Tools for Luminosity Optimisation in the LHC

2-day mini workshop held at CERN
on the 15th & 16th April 1999

Proceedings

Chairman: Hermann Schmickler (SL/BI)
Secretary: Rhodri Jones (SL/BI)

Contents:

Participants:

Chairman: Hermann Schmickler (SL/BI)

Secretary: Rhodri Jones (SL/BI)

- Jacques Bosser (PS/BD)
- Claude Bovet (SL)
- Philip Datte (LBL)
- Claude Fischer (SL/BI)
- Maurice Haguenauer (EP/HC)
- Georg von Holtey (SL/EA)
- J. Bernard Jeanneret (SL/AP)
- Roland Jung (SL/BI)
- Werner Kienzle (EP/DI)
- Jean-Pierre Koutchouk (SL/AP)
- Witold Kozanecki (CEA-Saclay)
- Mike Lamont (SL/OP)
- Pierre Lefevre (AC/DI)
- Pier F. Manfredi (LBL)
- Jaques Millaud (LBL)
- Tapio Niinikoski (EP/ATT-SC)
- Vittorio Palmieri (EP/N50)
- Anne-Laure Perrot (EST/LEA)
- Phil Pfund (Fermilab)
- Massimo Placidi (SL/BI)
- Keith Potter (EST/LEA)
- Rudiger Schmidt (LHC/ICP)
- Valeria Speziali (EP/Univ. of Pavia)
- Jim Strait (Fermilab)
- Stefan Tapprogge (EP/ATD)
- Tom Taylor (LHC/DLO)
- William Turner (LBL)
- Sylvain Weisz (EST/LEA)

Agenda:

1st Day:

Topic	Speaker	Time
Start of Workshop 10:00h		
Purpose of this workshop	H.Schmickler	10’
Absolute Luminosity Calibration (TOTEM) Principle, Running scenarios over the years,	W.Kienzle	15’
Procedures for initial collision steering, Procedures for L-optimisation, Expectations for L-Imbalance within the batches, expectations for L-Imbalance between IPs, Requirements for Instrumentation	B.Jeanneret	30’
Experience with L-Optimisation at the ISR	K.Potter	10’
Experience from PETRA, LEP and SPS	R.Schmidt	15’
Experience from PEP-II	W.Kozanecki	15’
Lunch Break until 14:00h		
Inventory of already planned LHC instruments (Emittance, BCT, BPMs) and their diagnostics potential	C.Bovet	30’
The proposed SEM L-monitor	S.Weisz	20’
The proposed TAS and TAN instrumentation	B.Turner	15’
Coffee break		
Hardware layout of TAS and TAN inst.	P.Datte	15’
Cold silicon detectors as technological alternative	V.Palmiery, T.Niinikoski	20’
Implication of the above proposals for the LHC layout	C.Fischer	15’

Agenda of 2nd day (discussions, conclusions) will be established during 1st day

Summary:

- Absolute Luminosity Measurements with $\delta L/L < 2\%$ is the task of the LHC experiments.

- Absolute Luminosity Measurements with $\delta L/L \sim 5\%$ for luminosities above 10^{30} $cm^{-2}s^{-1}$ via a machine L-monitor and occasional cross calibrations to the LHC experiments is the task of the machine community.

- Requirements for the Luminosity Monitor:

  1) Available in all 4 IPs.

  2) Sensitivity of Luminosity reading to variations of IP position ($x^*,y^* < 1mm$) and angle at IP ($x^{*\prime},y^{*\prime} < 10$ μrad ?) has to be lower than 1%.

  3) The dynamic range with "reasonable" acquisition times for 1% precision has to cover 10^{28} $cm^{-2}s^{-1}$ to 10^{34} $cm^{-2}s^{-1}$.

  4) In order to see structure along the batches, a minimum bandwidth of 132 kHz is required. For the lower 2 decades of the dynamic range the bandwidth can be much lower since the machine will operate using only 36 bunches.

- Concerning the two (three) presented proposals:

  1) The SEM monitor will be difficult to make operational in the requested dynamic range of 10^6. It is of no interest to the machine due to the severe bandwidth limitation (~ 1kHz). The technological alternative of cold silicon counters should be tried instead and studied rather rapidly.

  2) The proposal of a scintillator hodoscope needs much more study. However, if the studies on cold silicon counters prove to be promising, then the scintillator proposal should not be followed up.

  3) The LBL proposal with the comments below is supported by CERN and in particular by the SL beam instrumentation group. This means that the requested studies should be carried out, with beam tests performed over the next two years.

- Items to be reviewed on the LBL proposal:

  1) Simulations should be performed to investigate the collimation effect of D1 on the TAS and TAN detectors when the position of the IP changes.

  2) The position of the TAN should be reviewed with the aim of moving it 5m closer to IP. This would allow for the optimisation of the light path of Synchrotron Light Monitor.

3) Space should be reserved for instrumenting the TAS. The final decision of whether to go ahead will be taken in 2002. It should be noted that only by instrumenting both the TAN and TAS would it become possible to measure the absolute position of the IP.

4) The front-end electronics and acquisition system should be reviewed, taking into account the following points:

   - The detector should be made independent of external machine timing.

   - The requirement of a large dynamic range is more important than a high bandwidth. The possibility of using a lower bandwidth for the lower 2 decades of the dynamic range should be investigated, since the machine will operate at such luminosities using only 36 bunches.

   - The running scenario for the detector is up to 20 years without access in a highly radioactive zone. Any mechanical design, which weakens the detector, has to be avoided. Hence if operation at 40MHz is pursued then the subsequent design of the detector should not compromise its reliability.

The situation will be reviewed in spring 2002. By this time it is expected that the LBL group will have completed its prototype testing of the TAN monitor. At the same time the scintillator or cold silicon detector proposal will also be reviewed, allowing a final decision on the LHC luminosity monitor to be made.

Introduction

Hermann Schmickler (SL/BI)

Workshop on Tools for LHC Luminosity Optimisation

CERN 15/16 April 1999, H. Schmickler CERN

Aims of the Workshop:

- Specify requirements for Luminosity Tuning Tools
- Review "existing" beam instruments and their potential
- Specify requirements for a luminosity monitor
- Like: aperture, placement, time resolution, number of IPs …
- Discussion of LBL proposal for TAS and TAN instrumentation
- Why a presentation of TOTEM in this context?

  → an integral part of the TOTEM experiment is a L-monitor

  → can it do the above job?
- Presentation of alternative (cryogenic) technology

Absolute Luminosity Calibration (TOTEM)

Werner Kienzle (EP/DI)

See LHC Technical Proposal
CERN/LHCC 99-7

Luminosity Stability and Control at the LHC

Bernard Jeanneret (SL/AP)

Luminosity stability and control at LHC

15 April 1999

J.B. Jeanneret
CERN, Geneva, Switzerland

Outline

- Acceptable luminosity degradation
- Luminosity formula and variations
- Sensitivity to beam offset
- Beam-beam considerations
- Measuring beam motion at IP

This being a quick first order view of the subject.

Acceptable luminosity degradation

- We must justify a investment of 2 billion SF
- Get and keep nominal luminosity

$$\frac{\mathcal{L}}{\mathcal{L}_o} > 0.98 \tag{1}$$

(forgetting the decay with time)

Luminosity of two identical round gaussian beams

$$\mathcal{L}_o = k_b f_r N_{b1} N_{b2} \frac{1}{4\pi\sigma^4} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} e^{-\frac{x^2}{2\sigma^2} - \frac{y^2}{2\sigma^2}} \tag{2}$$

which integrates to

$$\mathcal{L}_o = \frac{k_b f_r N_{b1} N_{b2}}{4\pi\sigma^2} = \frac{k_b f_r N_{b1} N_{b2}}{4\pi\epsilon\beta} \tag{3}$$

with

- k_b the number of bunches
- f_r the revolution frequency
- N_b the nb of protons/bunch
- σ the beam size at the crossing point (IP)
- ϵ,β the emittance and the beta function at the IP

Intensity variations

- Bad for integrated luminosity => keep $\frac{\delta N_b}{N_b} < 2\%$
- Affects beam-beam tune shift

$$\xi_{head-on} = \frac{N_b r_o}{4\pi\epsilon_n} \qquad \xi_{long-range} = \frac{N_b r_o}{2\pi}\frac{\beta(s)}{\gamma d^2} \tag{4}$$

- $\xi_{long-range}$ dominant
- 10% variations of N_b acceptable beam-beam-wise
- Opposite IP1/IP5 ensures equal luminosity (N_i/N_j collide together at both locations)

Emittance variations vs. luminosity

For small beam size differences

$$\mathcal{L} \sim \frac{1}{\sqrt{\sigma_{x1}\sigma_{x2}\sigma_{y1}\sigma_{y2}}} \tag{5}$$

As most likely $\sigma_{x1,2} = \sigma_{y1,2}$ (residual coupling), we can write

$$\mathcal{L} \sim \frac{1}{(\epsilon_1\epsilon_2)^{1/4}} \tag{6}$$

Therefore

$$|\frac{\mathcal{L}}{\mathcal{L}_o}| < 2\% \quad <=> \quad \frac{\delta\epsilon_{1,2}}{\epsilon} < 4\% \quad \text{one beam} \tag{7}$$

$$|\frac{\mathcal{L}}{\mathcal{L}_o}| < 2\% \quad <=> \quad \frac{\delta\epsilon_{1,2}}{\epsilon} < 2\% \quad \text{both beams} \tag{8}$$

Beam-Beam:

Only $\xi_{head-on}$ depends on ϵ, so $\frac{\delta\epsilon}{\epsilon} \sim 10\%$ would be acceptable

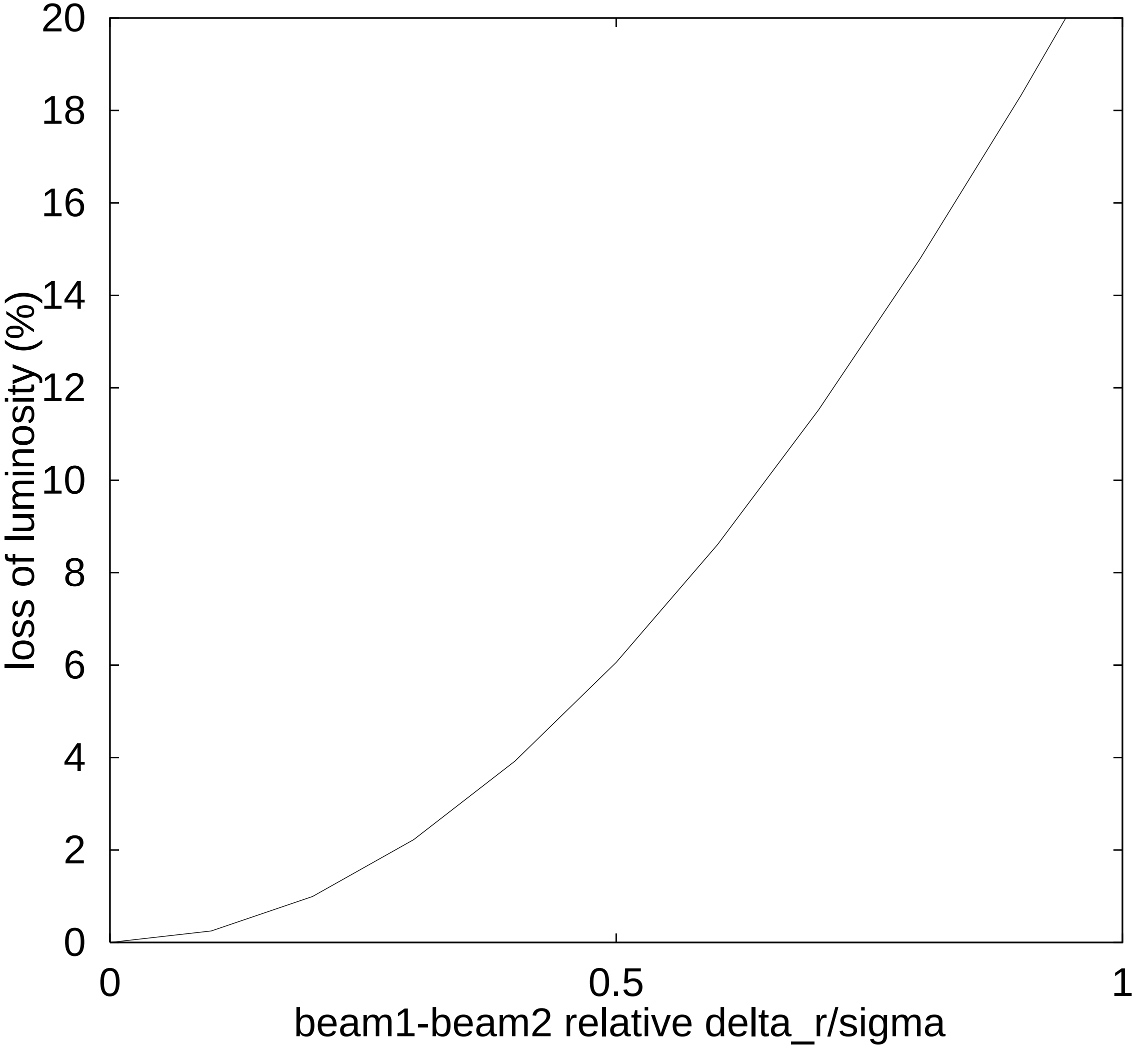
Luminosity loss with beam offset at IP

Apply a radial relative radial offset δ_r: in Eq. (2)

$x^2 + y^2 -> (x - \delta_r)^2 + y^2$

$$\frac{\mathcal{L}(\delta_r)}{\mathcal{L}_o} = \frac{1}{\pi\sigma^4} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} e^{-\frac{1}{\sigma^2}(x^2+y^2-x\delta_r+\delta_r^2/2)} \qquad (9)$$

no primitive, integrate numerically


20
18
16
14
12
10
8
6
4
2
0
loss of luminosity (%)
0
0.5
1
beam1-beam2 relative delta_r/sigma

Luminosity loss with beam offset at IP, continued

1D displacement relative to average orbit $\Delta_{x,y} = \delta_r/2\sqrt{2}$

With $\beta = 0.5$ m in collision $\sigma = 16\ \mu$m.

Then from the figure

$$\frac{\mathcal{L}(\delta_r)}{\mathcal{L}_o} = 2\% <=> \delta_r = 0.28\sigma <=> \delta_{x,y} \leq 0.1\sigma = 1.6\mu\mathrm{m} \tag{10}$$

$$\frac{\mathcal{L}(\delta_r)}{\mathcal{L}_o} = 5\% <=> \delta_r = 0.45\sigma <=> \delta_{x,y} \leq 0.1\sigma = 2.6\mu\mathrm{m} \tag{11}$$

The orbit default at the IP must be controlled to $\sim 1\mu$m

Beam offset and resonance excitation

- Whatever working point is used, the tune area will be crossed by 13th order resonances
- With head-on beams, this resonance is not excited (and marginally with large separations)
- Observed at the SPS collider with slight separation at IP
- It is wise to control the separation below $\approx 0.3\sigma$

Coherent bunch oscillations

This would induce luminosity losses, but in the abscence of damping would also kill the beam sooner or later (J.Gareyte). Therefore

- Either beam-beam does enough damping or
- The feedback must be used at high energy too
- => Not linked to luminosity or to luminosity controlled feed-back
- Therefore, no need of bunch by bunch luminosity measurement for this case

Intermediate Summary

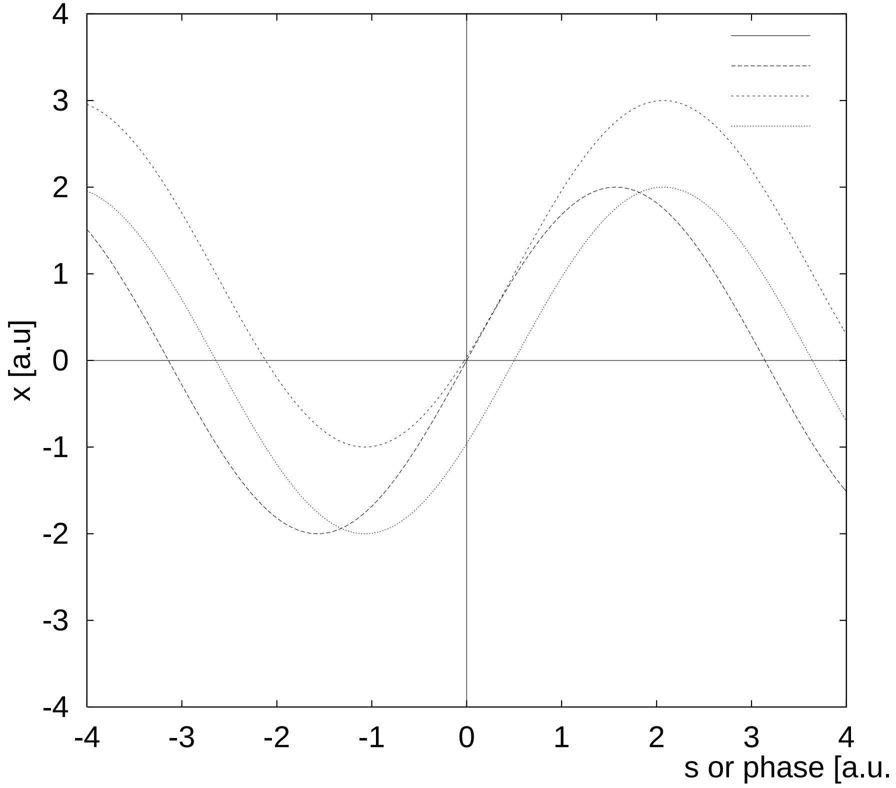
A specification might be:

Control and measure

- N_b to $\sim 2\%$ – Fast BCT's ?
- ϵ_n to $\sim 2\%$ – ?
- $\delta_{x,y}$ at IP to $\sim 1\ \mu$m – Local measurements

Measuring the beam position at the IP

- Need $\delta_{x,y} \approx 1\mu$m, but also $\delta'_{x,y} = \frac{\delta_{x,y}}{\beta} = \frac{10^{-6}}{0.5} \approx 2\mu$rad
- $\Delta x_{max} = \delta x \sqrt{\frac{\beta_{max}}{\beta_{ip}}} = 10 \times \sqrt{s\,\frac{4700}{0.5}} = 970$ mum $\approx 1\sigma_{max}$



Measuring the beam position at the IP - continued

- Most likely experiment might deliver the beam position every second to the requested relative precision of 1 micron
- If not, instrument the TAS?
- But of course, we shall first collide
- ’during the first days’, can we envisage to have a movable screen, next to the TAS? It would be used with pilot bunches or batches of adjusted intensity (see also next slide).

Measuring the beam angle at the IP - continued

- Use a detector in the TAN, located at 150m away from the IP
- Need a spatial resolution $\sigma_{TAN} = l_{TAN}\delta x'_{IP} = 1.5 \cdot 10^5 \times 2 \cdot 10^{-6} \approx 0.3$ mm
- The shower of the neutral spot in the TAN has a width of 10-20 mm
- With width fluctuations of $\sigma_{shower} \sim 10$ mm , integrating $n_{ev} = 10^6$, we get centroid fluctuations

$$\sigma(x, y) \approx \frac{\sigma_{shower}}{n_{ev}^{1/2}} \approx 0.01\text{mm} \tag{12}$$

- Therefore limited by the segmentation of the detector
- With segments of 3mm the resolution shall be 0.3mm – DOABLE
- This detector could be used when using screens too

Measuring the beam at the IP - continued

- The neutrals fly straight
- No disturbance because of triplet defaults
- BPM's in the triplet might be biased by radiation (aging, electrostatic) and by multipacting
- Knowing the beam position and angle might even help to understand the alignment (and therefore the aperture) of the triplet

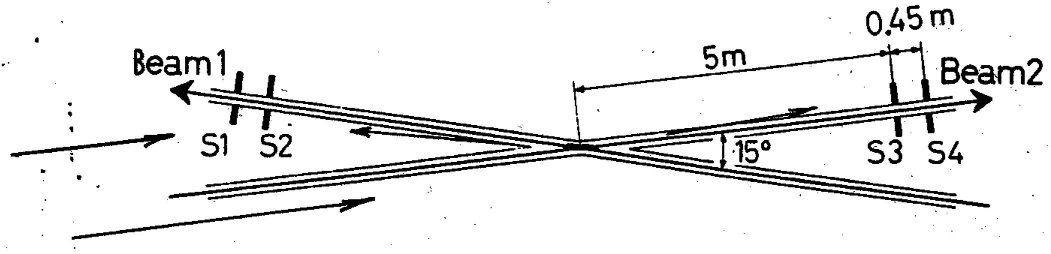
Summary

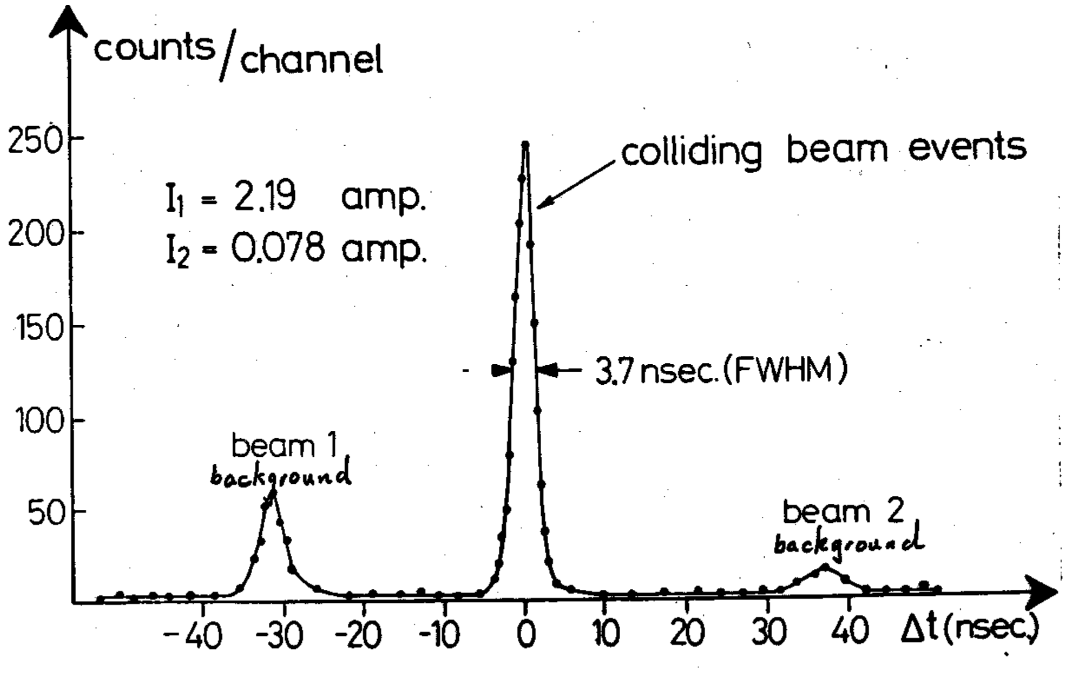
- The luminosity shall be measured/controlled to 1-2%
- The most critical parameter is the IP beam positions (x,x’,y,y’)
  need $\delta x = \delta y \approx 1$ μm and $\delta x' = \delta y' \approx 2$ μrad
- We propose to use a detector in the TAN to measure (x’,y’)
- We shall ask the experiments to provide x and y
- We see at present no need for luminosity measurement at the bunch level
  An exception might the understanding of PACMAN bunches - this would require a time resolution of $\sim$ 10 bunches or 250 ns.

Experience from the ISR

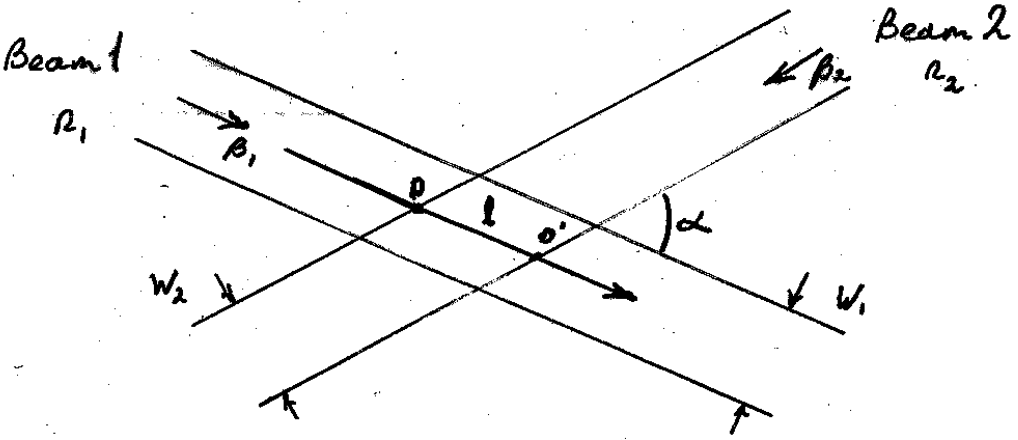
Keith Potter (EST/LEA)

Luminosity Optimisation at the ISR.

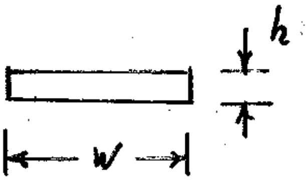




Coasting beams with crossing angle



$$\beta_{1,2} = \frac{V_{1,2}}{c}$$



Consider traversal of beam 2 by a single particle of beam 1

ISR luminosity depends only on circulating currents and h_{eff}.

eqn (26)

$$L = \frac{I_1 I_2}{c e^2 h_{eff} \tan\frac{\alpha}{2}}$$ is calculable

I_1 & I_2 measured

and $\frac{dR}{dt} = \sigma_M \cdot L$ allows σ_M to be found

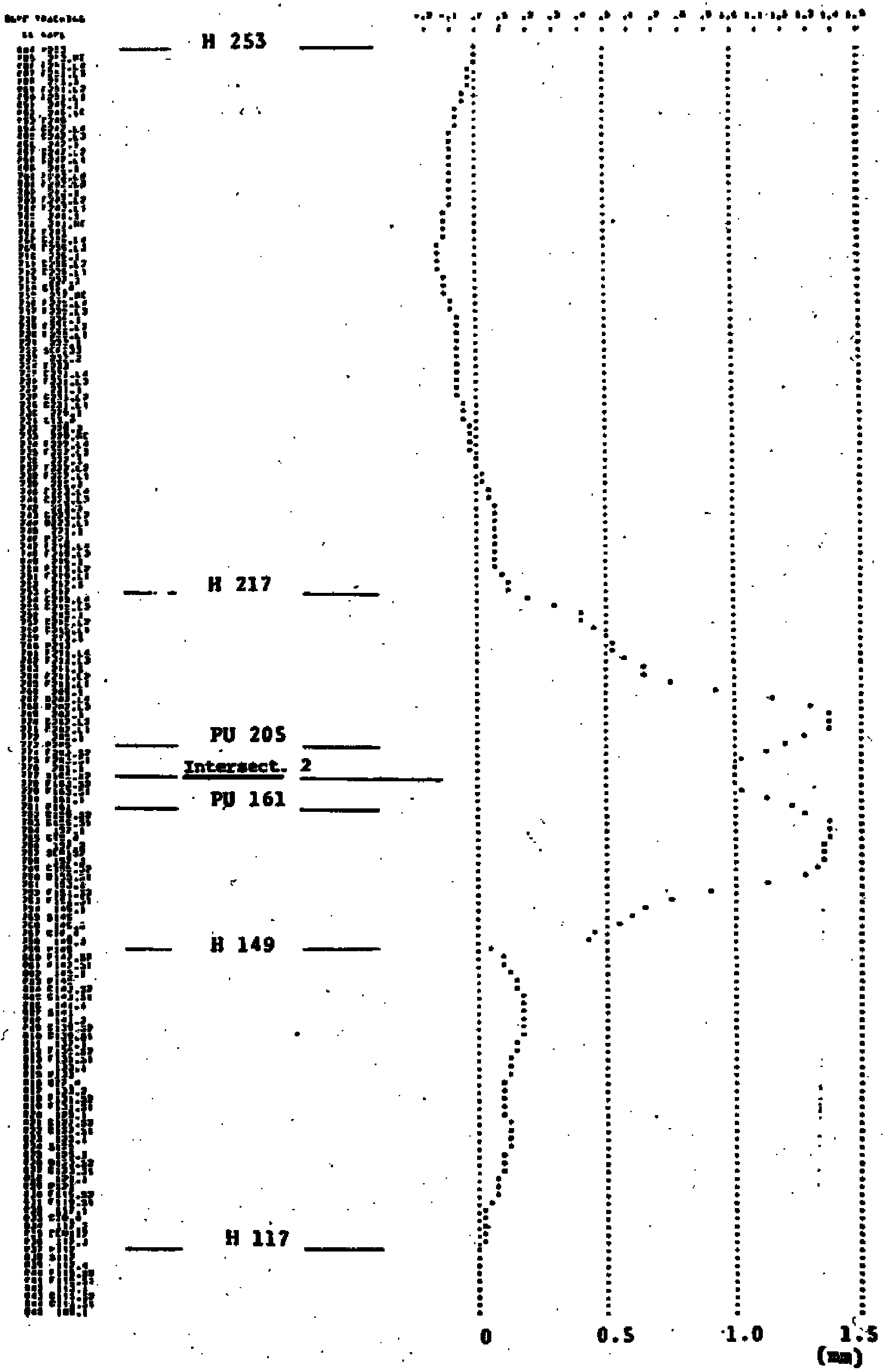
hence, now have a calibrated monitor.

Vertical Beam Displacements

Need accurate h scale

Horizontal field magnets $\frac{1}{4}\lambda$ before and after the crossing point for optimisation.

For completely local bumps with variable Q_v need correcting magnets in addition.



AGS tracking of 1 mm closed orbit bump

The Van der Meer method

$$h_{eff} = \frac{\int_{-\infty}^{\infty} \rho_1 \, dz \int_{-\infty}^{\infty} \rho_2 \, dz}{\int_{-\infty}^{\infty} \rho_1 \rho_2 \, dz} \qquad \text{equ (25)}$$

To maximise L need to minimise h_{eff} which requires zero separation between vertical beam centres.

Let the distance between vertical centres be h

The counting rate in a (background free) monitor will be

$$A \int \rho_1(z) \, \rho_2(z-h) \, dz \qquad (29)$$

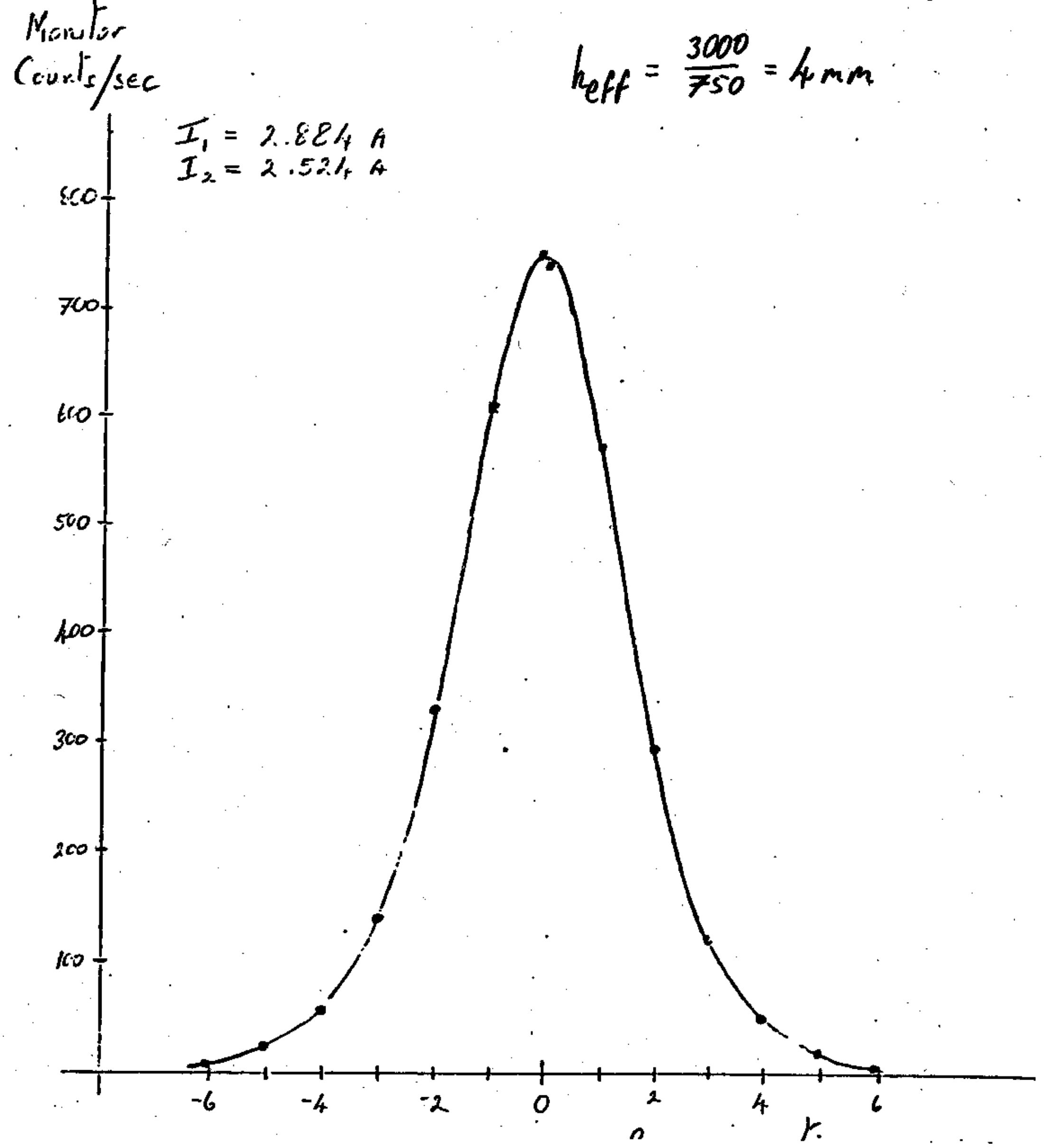
where A is an unknown constant depending on the acceptance of the monitor and σ_i.

If this counting rate is plotted as a function of h a distribution of the following kind will be obtained.

Area under curve = 3000 counts.mm

At $h=0$ rate = 750 counts/sec

$h_{eff} = \frac{3000}{750} = 4\,mm$



Experience from PETRA, LEP and the SPS

Rüdiger Schmidt (LHC/ICP)

Luminosity monitors for PETRA, SPS and LEP
…….a walk back in history

Rüdiger Schmidt, lumimon meeting 26 April 1999

- Some Requirements
- PETRA
- SPS
- LEP

Requirements

- Measure the relative luminosity integrated over all bunch collisions with an error of less than, say, 1% in one second
  - for optimising luminosity similar to the LEP luminosity scanning
- Acceptance and sensitivity of the monitors must be independent of the beam positions and beam angles at the IP over the whole range of possible displacements (citation UA1 Note 59, P.Gutierrez, A.Kernan)
- The acceptance and sensitivity of the monitors must be independent of the beam sizes and beam divergence at the IP
- A drastic change in the background should not change the counting rate in the monitors
- Measure the relative luminosity of individual bunch pairs with an error of less than, say, 1% in 50 seconds (matches error of above)
  - the measurement of individual bunch luminosity would allow simple interpretation of results (see beam-beam workshop)
  - such a measurement would be useful, also if it is much slower
  - would it be sufficient to integrate over 10 bunches?

PETRA

- Problem for e+e- colliders: event rate very low, for optimisation a high rate is required
  - Bhabha scattering in the order of some 10 Hz (at small angle, some mrad)
  - wide angle events in the order of 1 Hz
- Single Bremsstrahlung rate of some 100 kHz: lets use it
  - in 1/gamma cone with respect to beam axis
  - was measured using the Polarisation monitor
  - Problem A: very sensitive to beam parameters at IP (angle, divergence, and position)
  - Problem B: very sensitive to background from long straight section, changes in vacuum pressure, scraping of tails, ...

  - …turned out to be useless for any luminosity optimisation

SPS proton antiproton collider

- Both beams were separated along most of the circumference with electrostatic separators, therefore the luminosity had to be optimised
    - without optimising, the beams would not meet
- Luminosity monitors built by E.Rossa and G.von Holtey, later taken over by UA1 and UA2 (see slides)
    - fast, efficient and simple, outside vacuum chamber, between 23 mrad and 40 mrad (about)
- To measure luminosity at IP without detector, a “quick and dirty” detector was build and used to optimise the beam crossing in collision point without experiment (see slides)
- Such type of monitors, positioned correctly, are likely to fulfil the requirements for LHC luminosity monitoring
    - not too high rate in order not to damage them
    - high enough rate to get fast measurement (100 kHz - 1 MHz)
    - fast photomultipliers, or other light detectors

LEP small angle Bhabha detectors

- In order to have a sufficient rate for luminosity optimisation, a silicon strip calorimeter was developed and inserted inside collimators, and were positioned close to the beam (30 mm)
- The rate of Bhabha scattered particles was in the order of 40-80 Hz
- The background rate was in the order of up to some kHz after other collimators were driven close to the beam to minimise background
- Coincidences between 2 Monitors, right and left from the IP, were measured
- By subtracting the accidental coincidences the luminosity could be measured
- The detector was not 100% available, but the monitors of the LEP experiments could always used as back-up
- The spatial resolution of the detector was not used (until 1996)
  - the detector and the electronics could have been therefore much simpler
  - to keep the detector operating required at least one person full time

- This was the only way to get a high counting rate

Conclusion

- Comparing those three - my preferred monitor was the SPS luminosity monitor
  - fast luminosity detector at SPS was much simpler to build
  - worked very reliably, very little follow up from machine people
  - conceptually simple
  - matched requirements formulated previously
- Luminosity measurement at PETRA and LEP much more difficult
  - LEP: mainly due to complicated device and high background
  - PETRA: very sensitive to beam manipulations, for operation SPS like counters were used (H.C.Dehne)
- LHC: acceptance of monitors does not to be very high - counting rate of 100 kHz -1 MHz for maximum luminosity sufficient (less problems with radiation dose)
- Calibration between IP's possible since beam overlap can be measured in both planes (monitor constant can be established)
- Measurement of absolute luminosity is a task for the LHC experiments

Very fast luminosity monitor? …..why yes

- Main task of any luminosity monitor is to measure the integrated luminosity, in order to allow for an optimisation of the beam overlap - possibly the luminosity monitor response should be independent of beam parameters over the whole range of possible values
- Most arguments from yesterday and this morning (beam-beam workshop)
- The question is: do we need / prefer to measure the luminosity...
  - for each bunch
  - for sets of, say, 10 bunches (fast luminosity measurement, possibly any number in between)
- Into luminosity equation enter: N_{p1}, N_{p2}, σ_{xp1}, σ_{xp2}, σ_{yp1}, σ_{yp1}, δ_x, δ_y, $\alpha_{crossing}$
- Every bunch in the LHC is different - and bunches can be rather different from their direct neighbours (see J.Jowetts slide on bunch classes)
  - δ_x, δ_y in the order of 0.1-0.2 σ
  - in particular, δ_x and δ_y can be different for adjacent bunches, to calculate offsets is not trivial, but being developed (beam beam simulations) - does it matter? Not clear..
  - should be measured for individual bunches, in order to understand LHC accelerator physics. Such offsets could excite resonances, but it is likely that other effects will dominate.
  - measurement of offsets nontrivial (should be done with a resolution of 1-2 μm). To achieve such precision with BPMs some distance left and right, and then interpolate - not easy

.....why yes

- Van der Meer type of scan in x and y direction gives:
  - relative luminosity
  - δ_x
  - δ_y
  - overlap integral in x direction (can be calculated sigma for both bunches known)
  - overlap integral in y direction (can be calculated sigma for both bunches known)
- If bunch positions, currents, sizes are measured, the relative luminosity can be used a an independent consistency check (remember of the time spend at LEP for cross-calibrations of emittance measurement devices)
- My opinion: such “very fast” luminosity measurement is very desirable
  - We do not need to perform such very fast luminosity measurement in a short time (1 min or longer is sufficient)
- **The very fast luminosity monitor should not replace the capability of other instruments to measure bunch-by-bunch**
- It will take some time that all other instruments will be commissioned in order to give all information required (comment by J.Gareyte, 11:56 today)
- Finally: interest in measuring beam losses at collimators for individual bunches (a very few fast beam loss monitors)

Experience from PEP-II

Witold Kozanecki (CEA-Saclay)

Instantaneous luminosity and beam size measurements
in PEP-II

$L \sim k_B I_b^+ I_b^- / \Sigma_x \Sigma_y$ $\qquad\qquad$ $\Sigma_{x,y} = \sqrt{(\sigma^2_{x,y-} + \sigma^2_{x,y+})}$

Requirements

- fast (~ sec) measurement of **relative** luminosity
  - ⇒ **manual tuning**
  - ⇒ **luminosity feedback**

- measurement of absolute luminosity to understand quantitatively
  - ⇒ **beam sizes (consistency?)**
  - ⇒ beam-beam effects (abs. value of beam-beam parameter ξ, comparison with betatron tune changes, beam blowup limits, etc...

Several methods (and their dominant systematic)

1. **Luminosity measured by radiative-Bhabha luminometer with beams in head-on collision**
   (<=> luminometer calibration & acceptance)

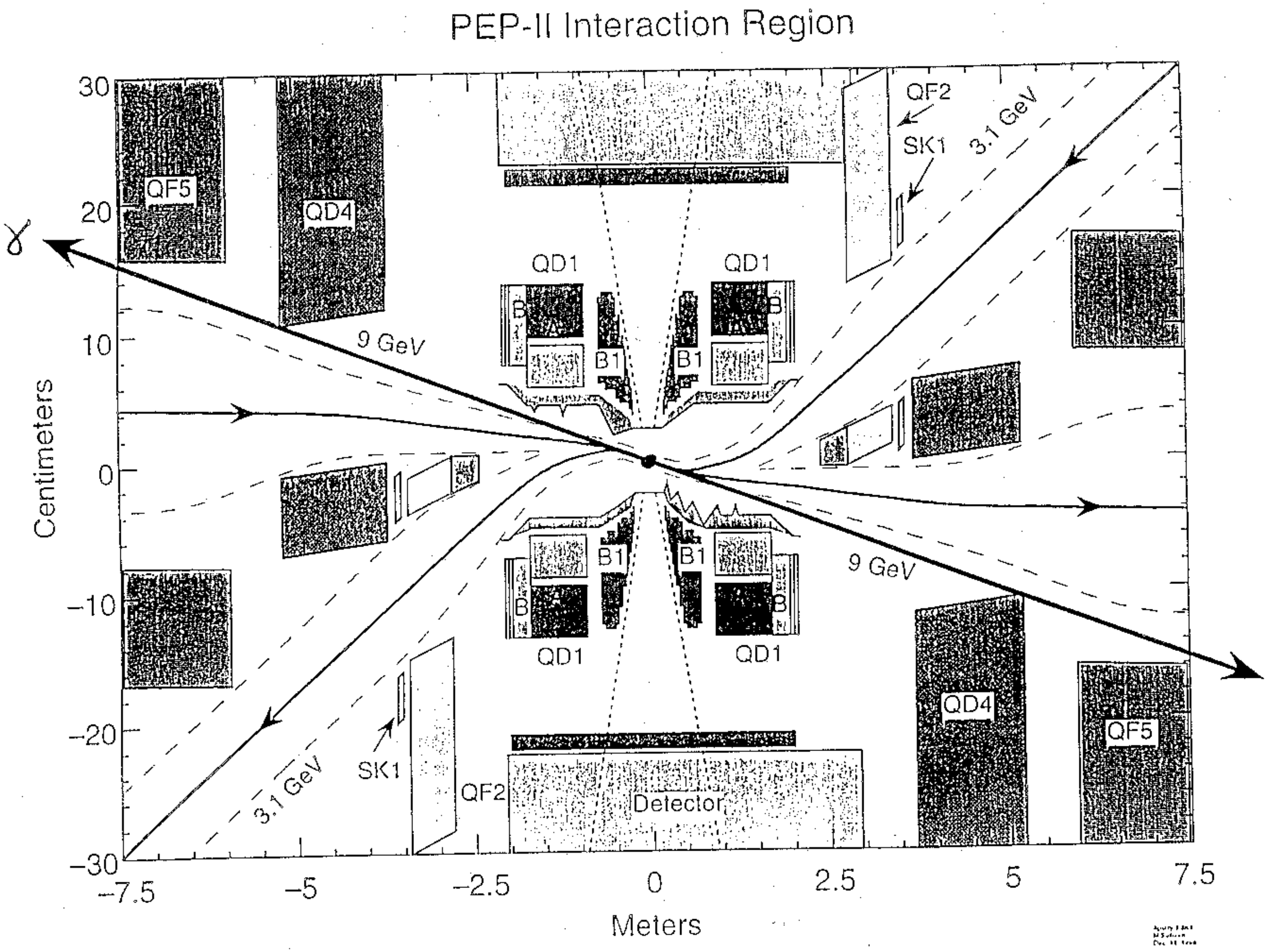
2. Luminosity from **measured beam currents & beam sizes**
   - **2.1 Sizes from luminosity scan**
   - **2.2 Sizes from beam-beam deflection scan**

   (<=> beam-beam blowup)

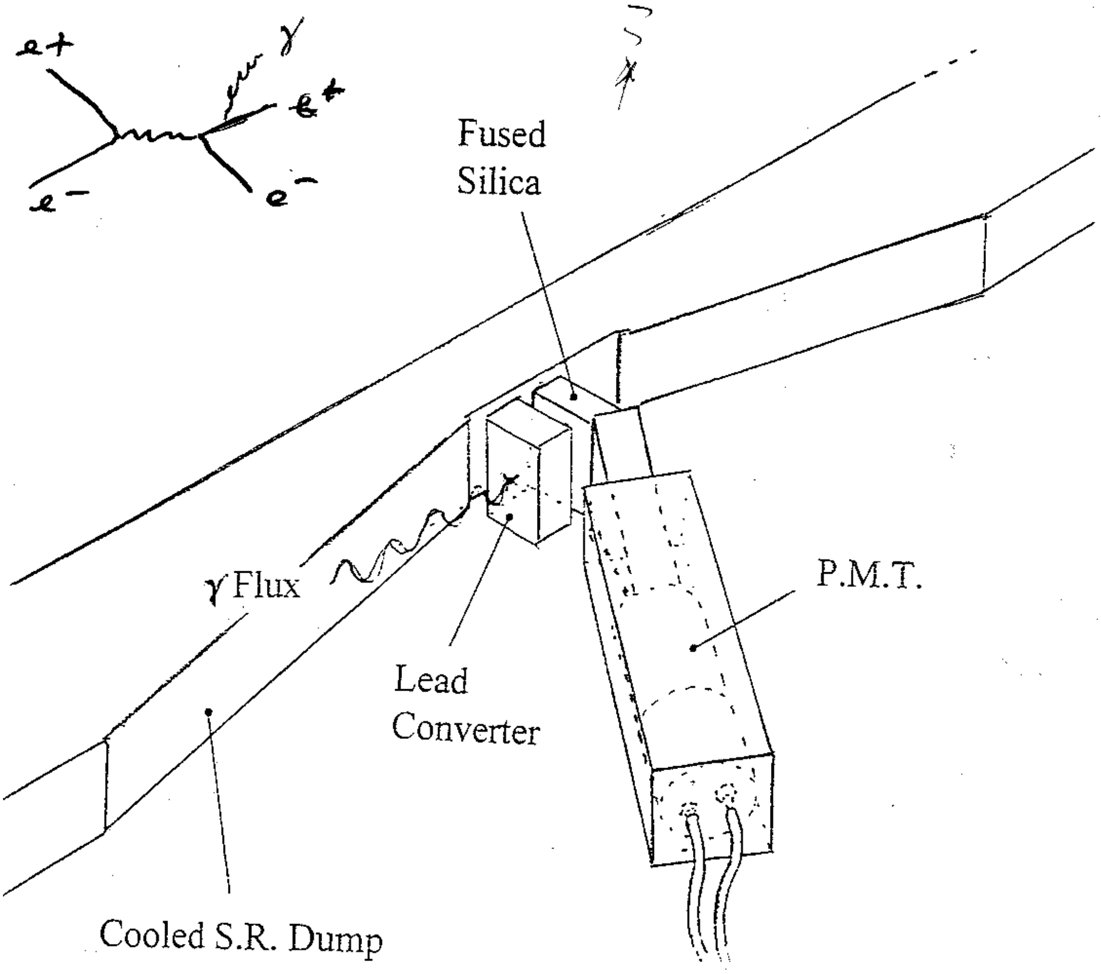
3. **Deflection slope in near-head-on collision ($S_y \sim \xi_y \sim L$)**
   (<=> magnet strengths, beam optics)

PEP-II Parameters relevant to the IR

Symbol	Units	LER	HER
E_{CM}	GeV	10.580	
E	GeV	3.1186 / e^+	8.9733 / e^-
r_E		2.8773	
$\varepsilon_{xo} \mid \varepsilon_{yo}$	π nm·rad	$49.2 \mid 1.5$	$49.2 \mid 1.5$
α_c		1.23×10^{-3}	2.41×10^{-3}
$\nu_x \mid \nu_y$		$38.570 \mid 36.642$	$24.618 \mid 23.638$
$\tau_x \mid \tau_y \mid \tau_s$	ms	$61.5 \mid 60.3 \mid 29.9$	$36.9 \mid 37.1 \mid 18.6$
$f_{rev} \mid T_{rev}$	$\text{kHz} \mid \mu\text{s}$	$136.3113 \mid 7.336$	
$\beta_x^* \mid \beta_y^*$	m	$0.500 \mid 0.015$	
$\sigma_{xo}^* \mid \sigma_{yo}^* \quad (\Sigma_{xo} \mid \Sigma_{yo})$	μm	$156.8 \mid 4.7 \quad (221.8 \mid 6.7)$	
$r = \sigma_{yo}^*/\sigma_{xo}^*$		0.03	0.03
$\kappa = \varepsilon_{yo}/\varepsilon_{xo}$		0.03	0.03
$r_\beta = \beta_y^*/\beta_x^*$		0.03	0.03
$\xi_x \mid \xi_y$		$0.03 \mid 0.03$	$0.03 \mid 0.03$
f_{RF}	MHz	475.99903	
λ_{RF}	m (ns)	0.630 (2.1)	
σ_E	MeV	2.4	5.5
δ_E		7.7×10^{-4}	6.1×10^{-4}
σ_{so}	mm (ps)	12.3 (40.3)	11.5 (38.2)
ν_s		0.0269	0.0448
$s_b \geq 2\lambda_{RF}$	m (ns)	1.26 (4.2)	
k_b		1658	1658
$I_b^+ \; I_b^-$	mA	1.300	0.452
$I^+ \; I^-$	A	2.155	0.750
$\mathcal{L}_b$	$\text{cm}^{-2}\text{s}^{-1}$	1.81×10^{30}	
$\mathcal{L}$	$\text{cm}^{-2}\text{s}^{-1}$	3.00×10^{33}	


PEP-II Interaction Region
Centimeters
Meters
30
20
10
0
−10
−20
−30
−7.5
−5
−2.5
0
2.5
5
7.5
QF5
QD4
QD1
B
B1
QF2
SK1
3.1 GeV
9 GeV
Detector
γ

$e^+e^- \to (e^+\gamma)\,e^-$



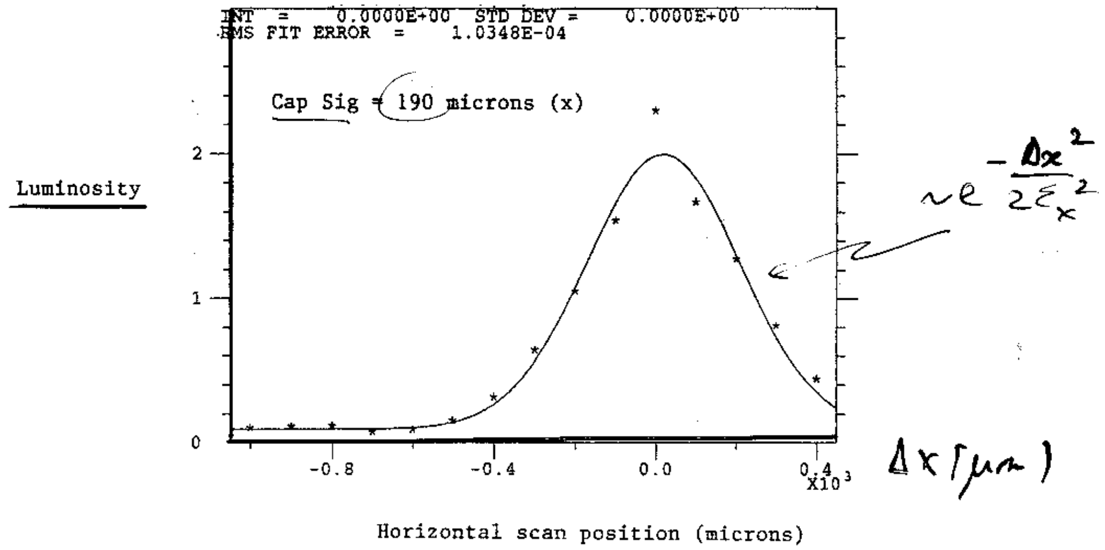
— Radiation Shielding Not Shown —

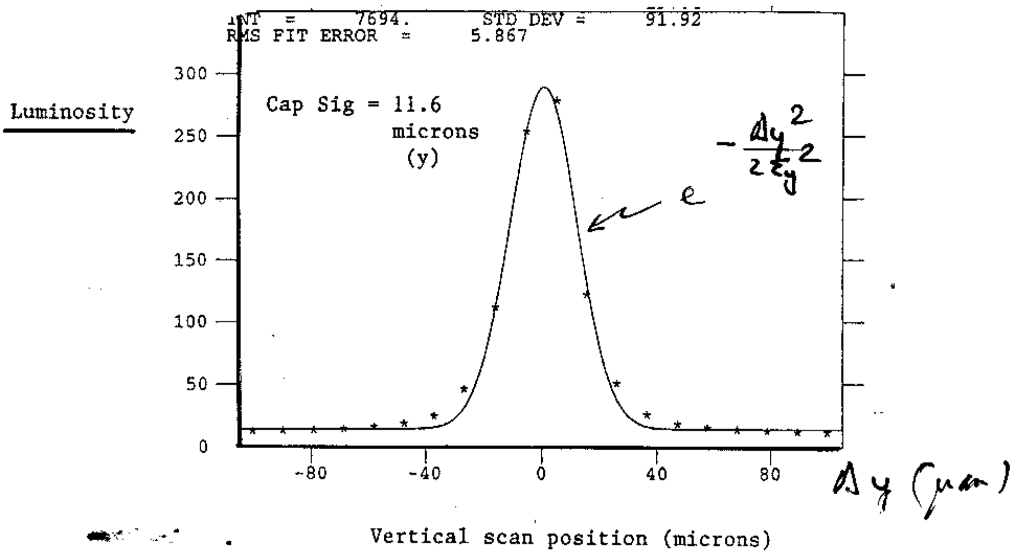
Rate : ~1γ/crossing at design $\mathcal{L}$ (238 MHz!)

Acceptance: ± 8 $\sigma^*_{y'}$

Background (beam-gas): ~%

PEP-II Horizontal and Vertical Beam-Beam Scans

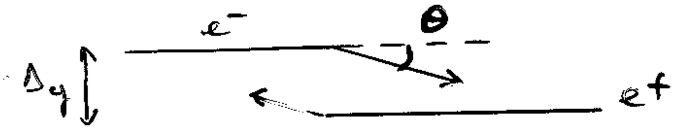




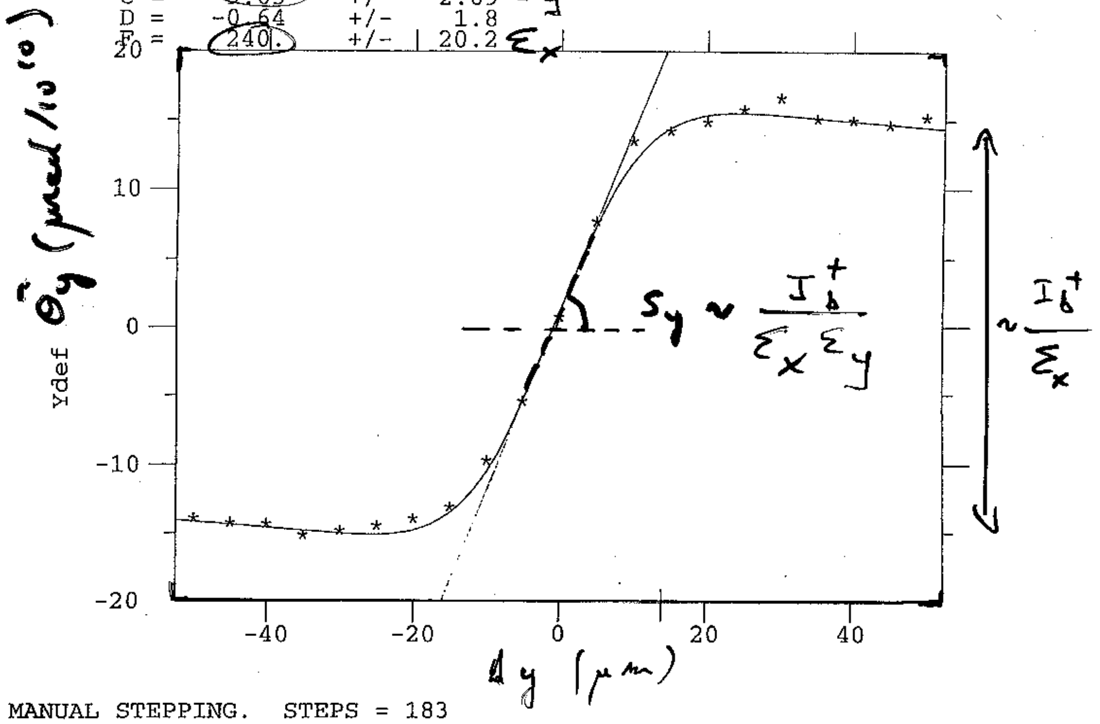
FULL SCAN (±5-10 σ)

- FOR DIAGNOSTIC PURPOSES ONLY (→ OPTICS) AT LOW BUNCH CURRENT

BEAM-BEAM DEFLECTIONS



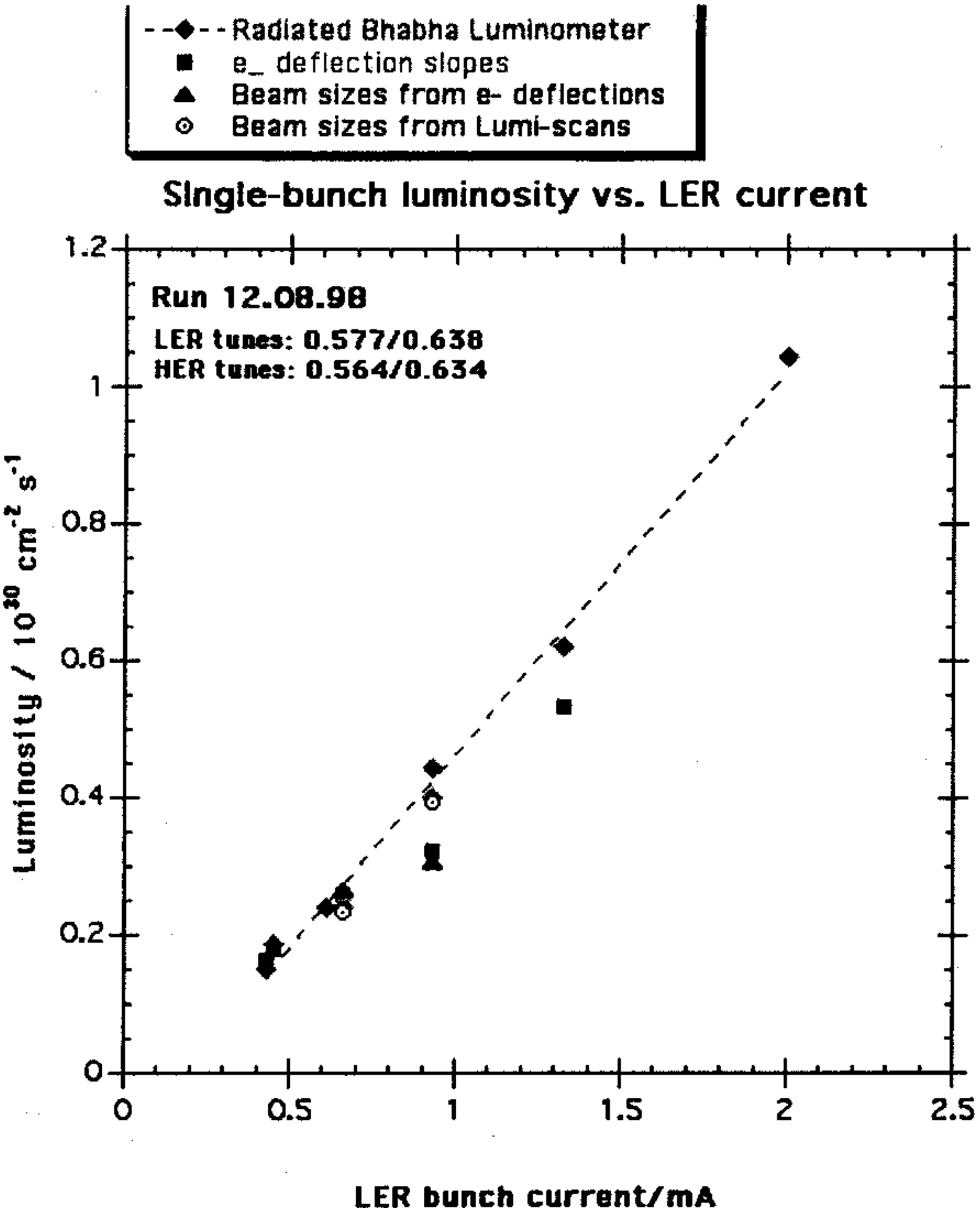
```
Y = A + B*Z*exp(Z*Z)*erf(Z,Z*F/C)/(X-D); Z = (X-D)/sqrt(2(F*F-C*C))
  A =     0.22     +/-    0.98          RMS ERROR   0.51
  B =   3210.                           CHISQ/DOF   0.37
  C =     9.65     +/-    2.69
  D =    -0.64     +/-    1.8
  F =    240.      +/-   20.2
```

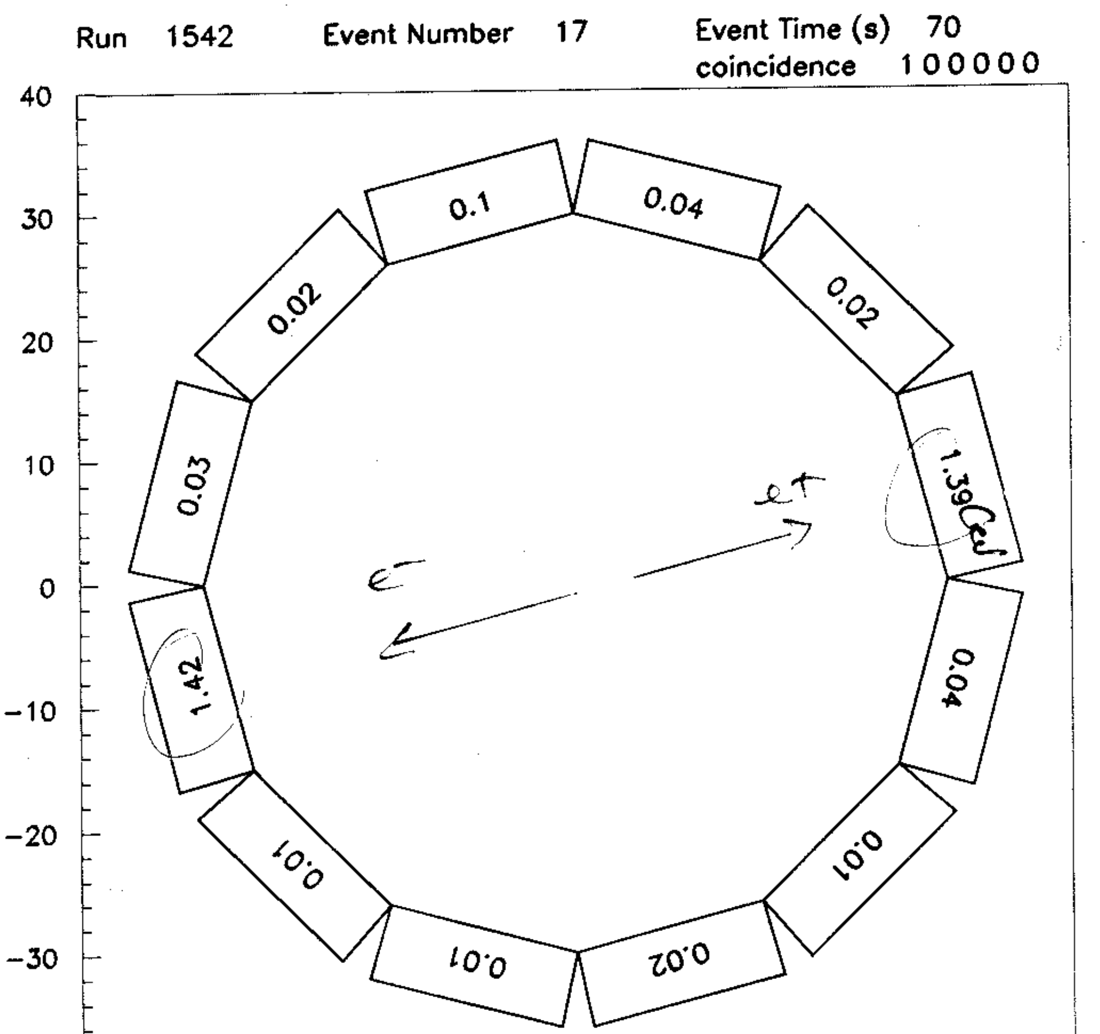


MANUAL STEPPING. STEPS = 183

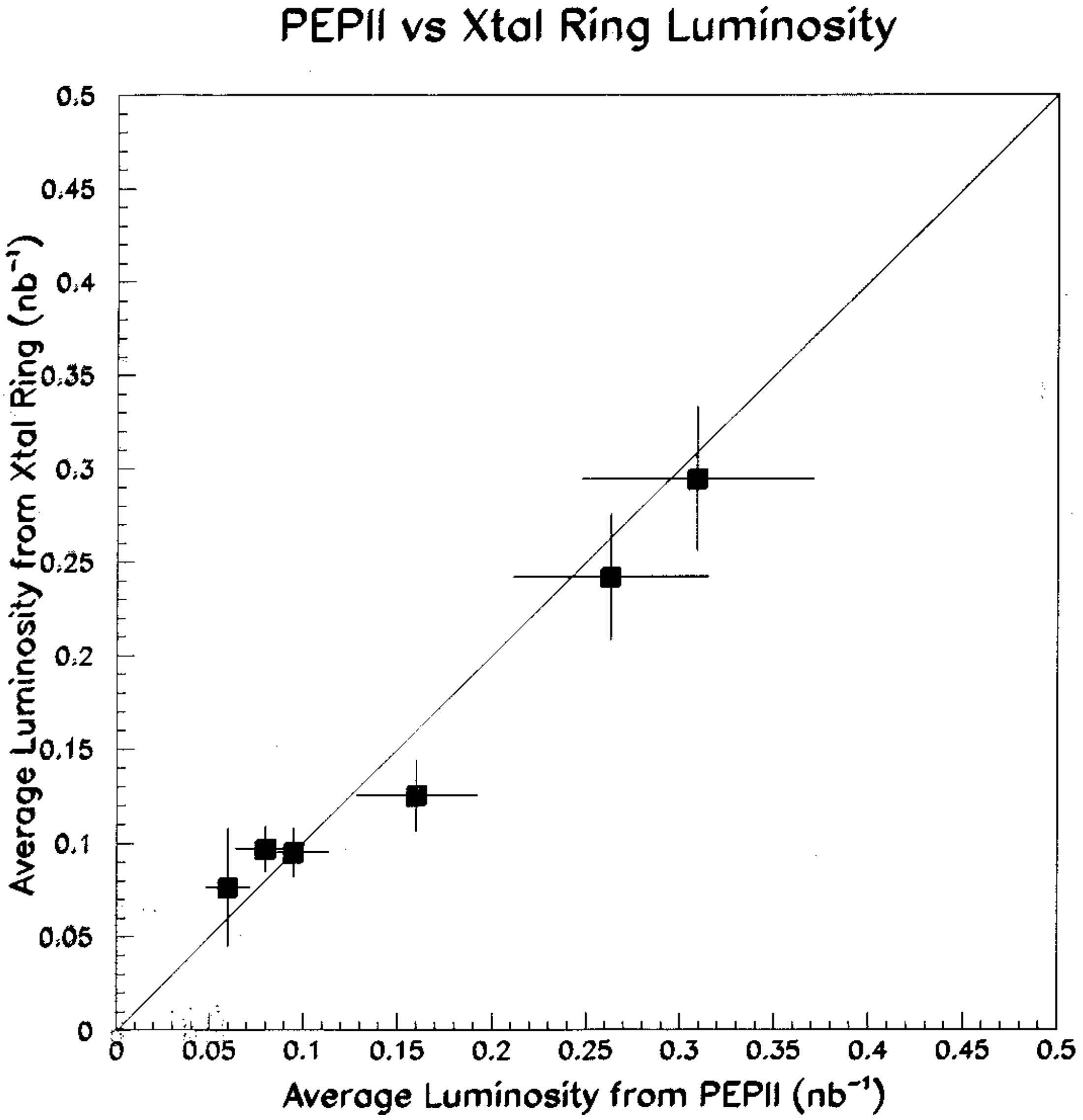
9-JAN-99 17:01:39

ele - defl - y - 6 - 8dec

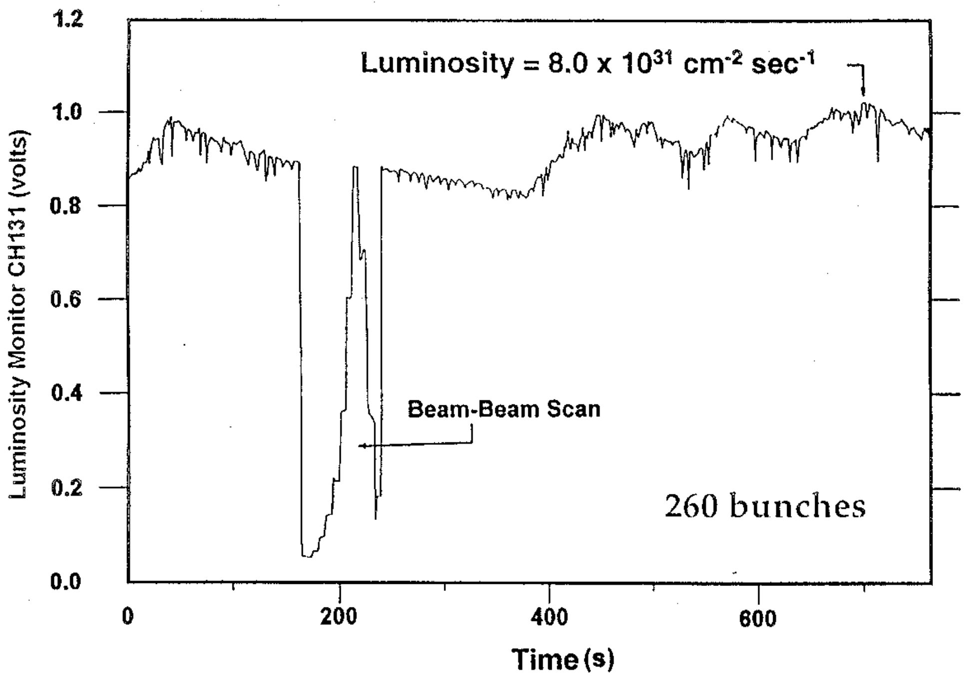

--◆--Radiated Bhabha Luminometer
■ e_ deflection slopes
▲ Beam sizes from e- deflections
⊙ Beam sizes from Lumi-scans
Single-bunch luminosity vs. LER current
Run 12.08.98
LER tunes: 0.577/0.638
HER tunes: 0.564/0.634
Luminosity / 10^{30} cm^{-2} s^{-1}
0
0.2
0.4
0.6
0.8
1
1.2
0
0.5
1
1.5
2
2.5
LER bunch current/mA



Run 1542 Event Number 17 Event Time (s) 70
coincidence 1 0 0 0 0 0

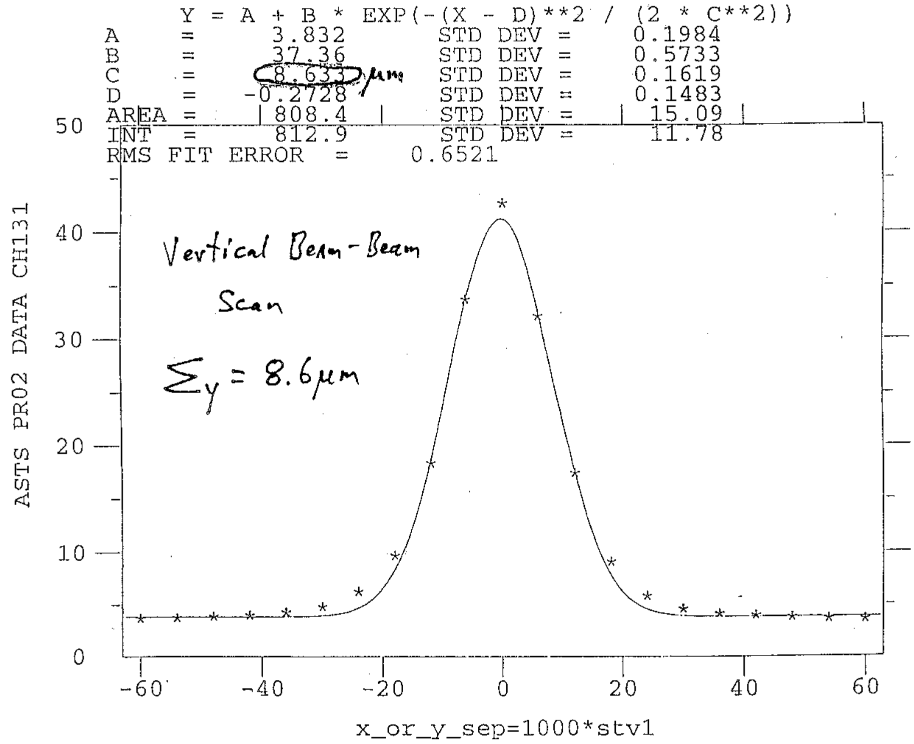

PEPII vs Xtal Ring Luminosity
Average Luminosity from Xtal Ring (nb^{-1})
Average Luminosity from PEPII (nb^{-1})
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

PEP-II Luminosity Record - Dec. 10, 1998



$\mathcal{L}_{measured} = 8.0 \times 10^{31}\ cm^{-2}\ sec^{-1}$ $I^+ = 260$ mA $\Sigma_y = 14$ um $\tau_+ = 24$ min

$I^- = 84$ mA $\Sigma_x = 320$ um $\tau_- = 470$ min

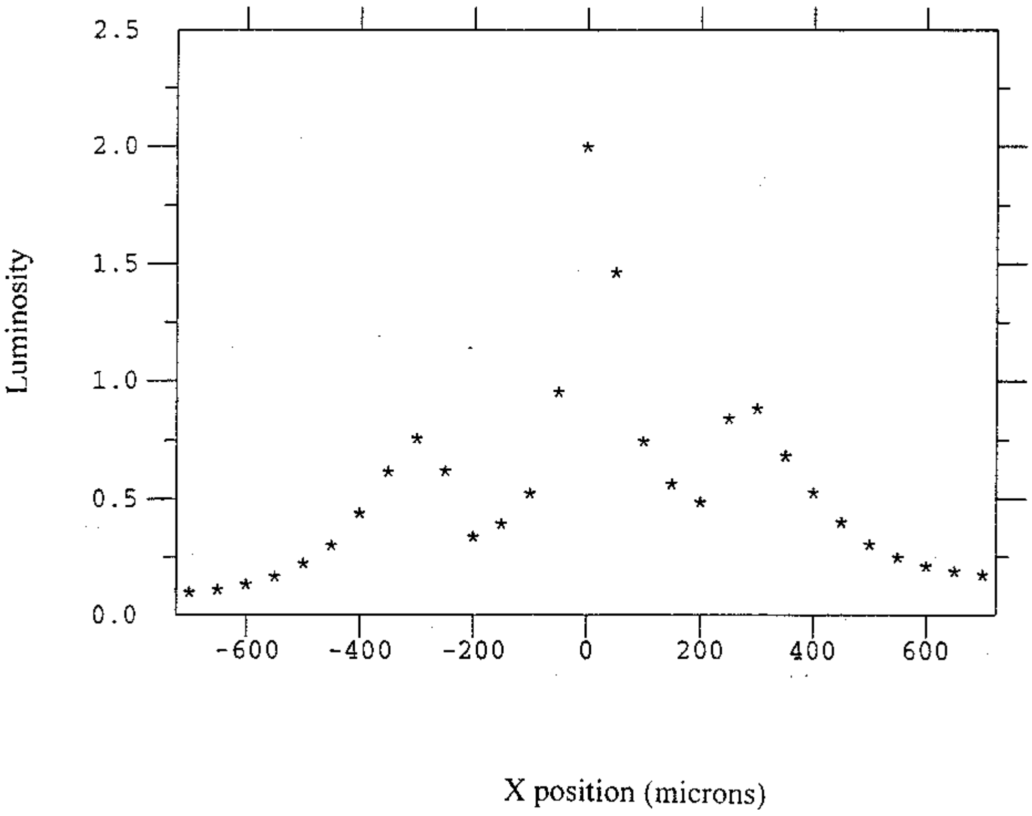


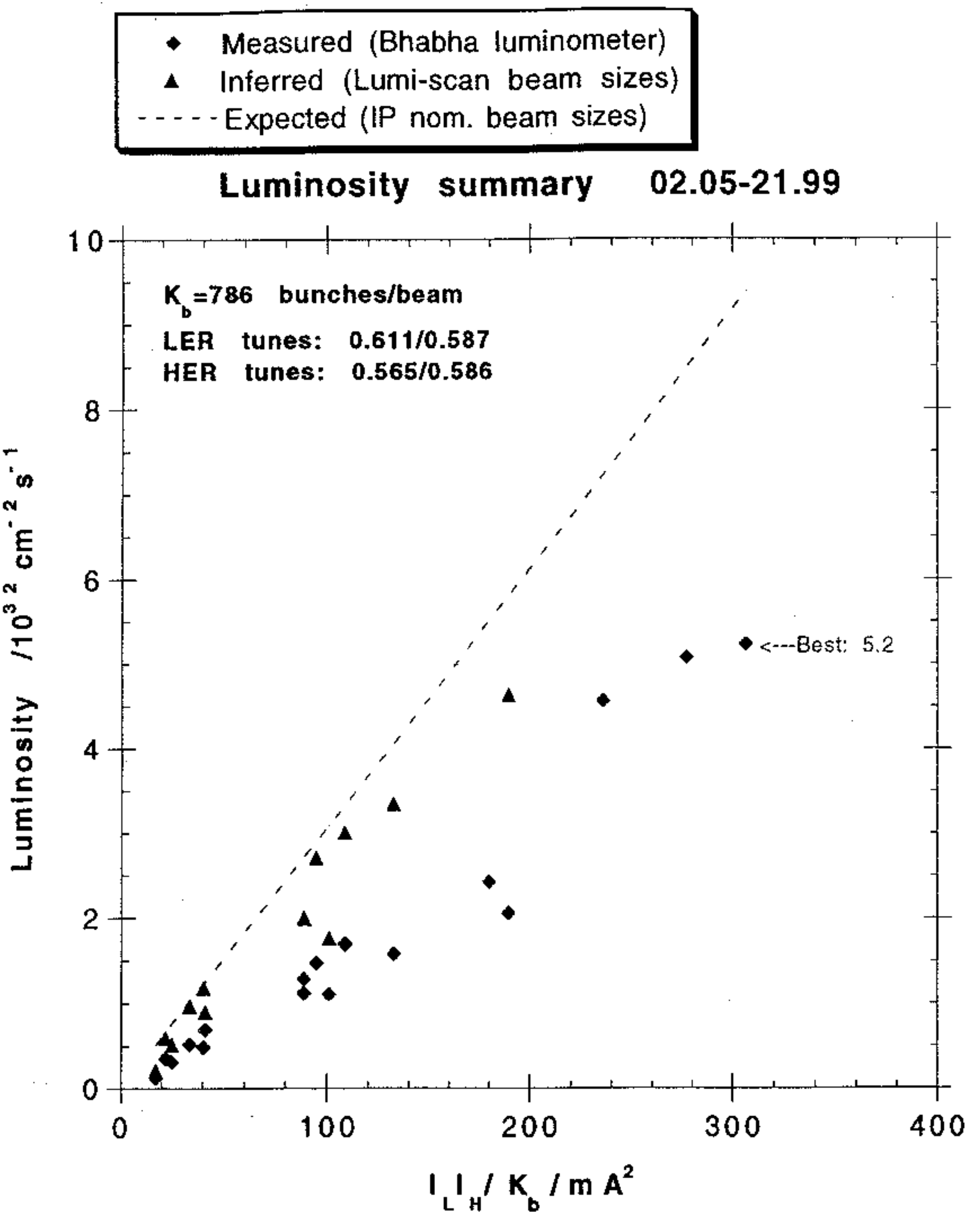
```
          Y = A + B * EXP(-(X - D)**2 / (2 * C**2))
A     =       3.832        STD DEV =     0.1984
B     =       37.36        STD DEV =     0.5733
C     =       8.633        STD DEV =     0.1619
D     =     -0.2728        STD DEV =     0.1483
AREA  =      808.4         STD DEV =     15.09
INT   =       812.9        STD DEV =     11.78
RMS FIT ERROR   =     0.6521
```

```
KNOB (COMMON$ROOT:[MKB]LERIP_Y.MKB.3)   STRT=-.0600 STEPS= 21 SIZE= 600-5
                                                21-FEB-99 05:02:25
```

PEP-II Horizontal Beam-Beam Scan at High Current

Note the distorted scan due to beam enlargement when the two beams are separated by about one sigma.




◆ Measured (Bhabha luminometer)
▲ Inferred (Lumi-scan beam sizes)
- - - - - Expected (IP nom. beam sizes)
Luminosity summary 02.05-21.99
K_b=786 bunches/beam
LER tunes: 0.611/0.587
HER tunes: 0.565/0.586
<---Best: 5.2
Luminosity /10^32 cm^-2 s^-1
I_L I_H / K_b / m A^2
0
2
4
6
8
10
0
100
200
300
400

SUMMARY

0. $\mathcal{L}$ monitor (fast!!) essential to rapid PEP-II progress

1. ORTHOGONAL x & y beam-beam scans PROVIDE FAST CENTERING TOOL.

2. $\mathcal{L}$ and/or BEAM-BEAM DEFLECTION SCANS OVER ± 6σ PROVIDE RELIABLE IP BEAM SIZE (σ_x^*, σ_y^*) MEASUREMENTS AT LOW BUNCH CURRENTS.

   AT BUNCH CURRENTS CLOSE TO OR HIGHER THAN NOMINAL, B-B BLOWUP DISTORTS THE BEAM SIZE MEASUREMENTS

   - $\mathcal{L}$ SCANS UNDERESTIMATE σ^*
   - DEFLECTION SCANS OVERESTIMATE σ^*
   - SUBSTANTIAL BEAM LOSS CAN OCCUR

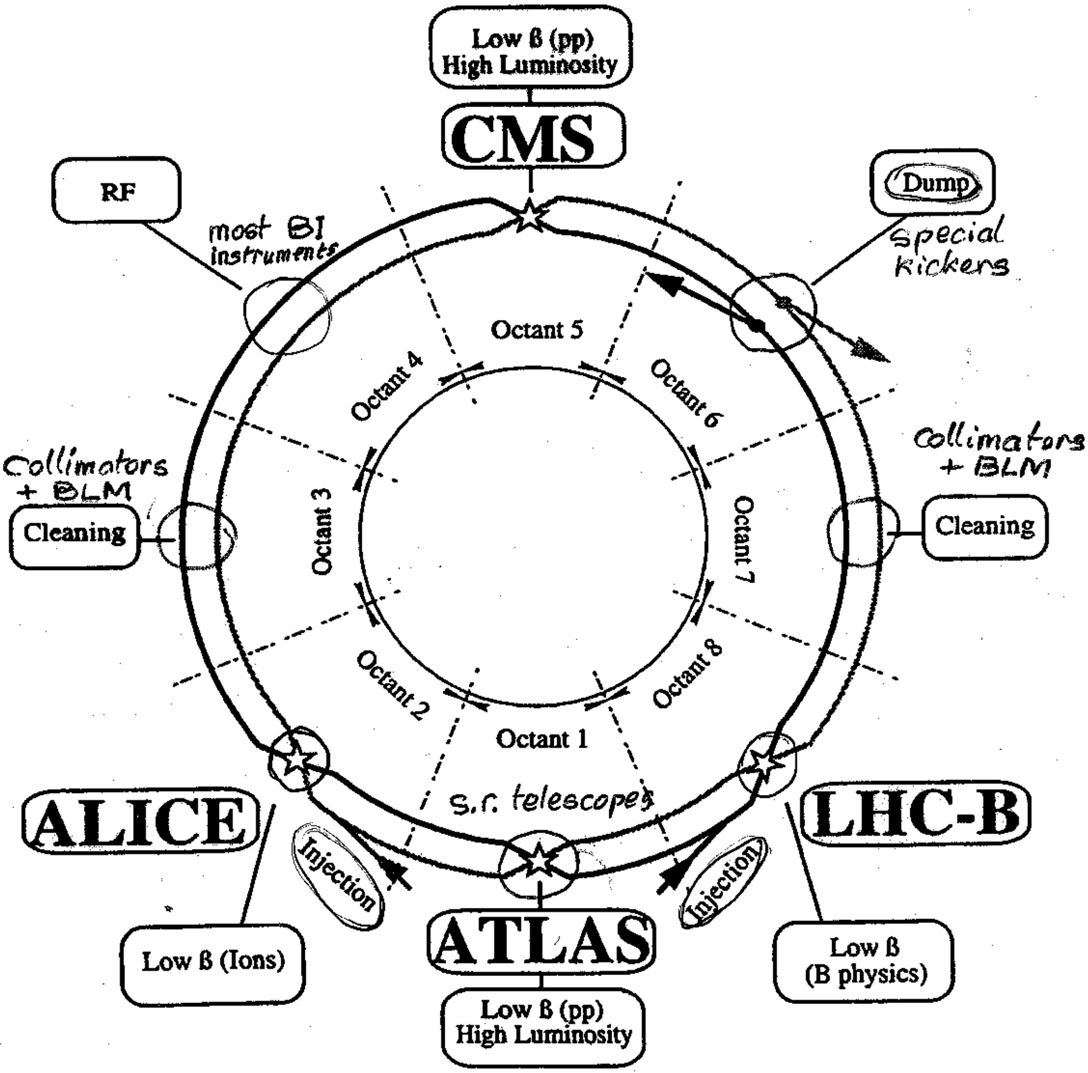
3. THE X & Y IP CENTERING KNOBS ARE USED ROUTINELY IN A SLOW (few) $\mathcal{L}$ FEEDBACK LOOP THAT PROVED ESSENTIAL TO MACHINE REPRODUCIBILITY.

4. THE ORTHOGONALITY OF THE CENTERING KNOB TURNED OUT TO BE VERY IMPORTANT

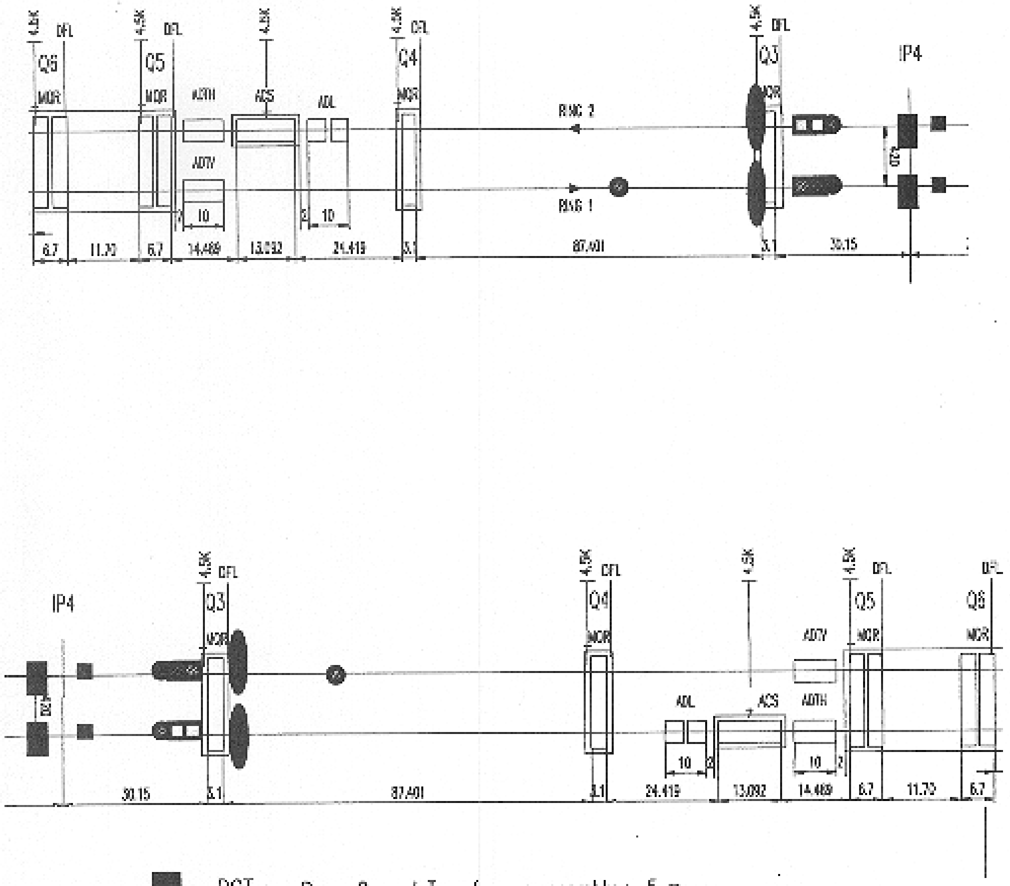
   → OPERATIONAL EFFICIENCY (≤ 2 iterations)
   → INTERPLAY WITH IP OPTICS ADJUSTMENTS

LHC Instruments

Claude Bovet (SL/BI)


Low ß (pp)
High Luminosity
CMS
RF
most BI instruments
Dump
special kickers
Octant 5
Octant 4
Octant 6
Collimators + BLM
Cleaning
Octant 3
Octant 7
Collimators + BLM
Cleaning
Octant 2
Octant 8
Octant 1
s.r. telescopes
ALICE
LHC-B
Injection
Injection
ATLAS
Low ß (Ions)
Low ß
(B physics)
Low ß (pp)
High Luminosity

Instruments in LSS4



■ BCT : Beam Current Transformer assembly : 5 m

■ BPHF : High Frequency Pick-up : 1 m

▬ BPSCH, BPBMH, BTVMH:H Schottky PU, Matching PU, Matching Screen : 3 m

▭ BPSCV, BPBMV, BTVMV:V Schottky PU, Matching PU, Matching Screen : 3 m

● BTV : First Turn Screen : 0.5 m

⬬ BRGH, BISH, BWSH : Profile Monitor Assembly H plane : 5 m

⬬ BRGV, BISV, BWSV : Profile Monitor Assembly V plane : 5 m

Figure 4: Layout of insertion region 4 with associated instruments.

LHC Project Note 144

1998-04-22

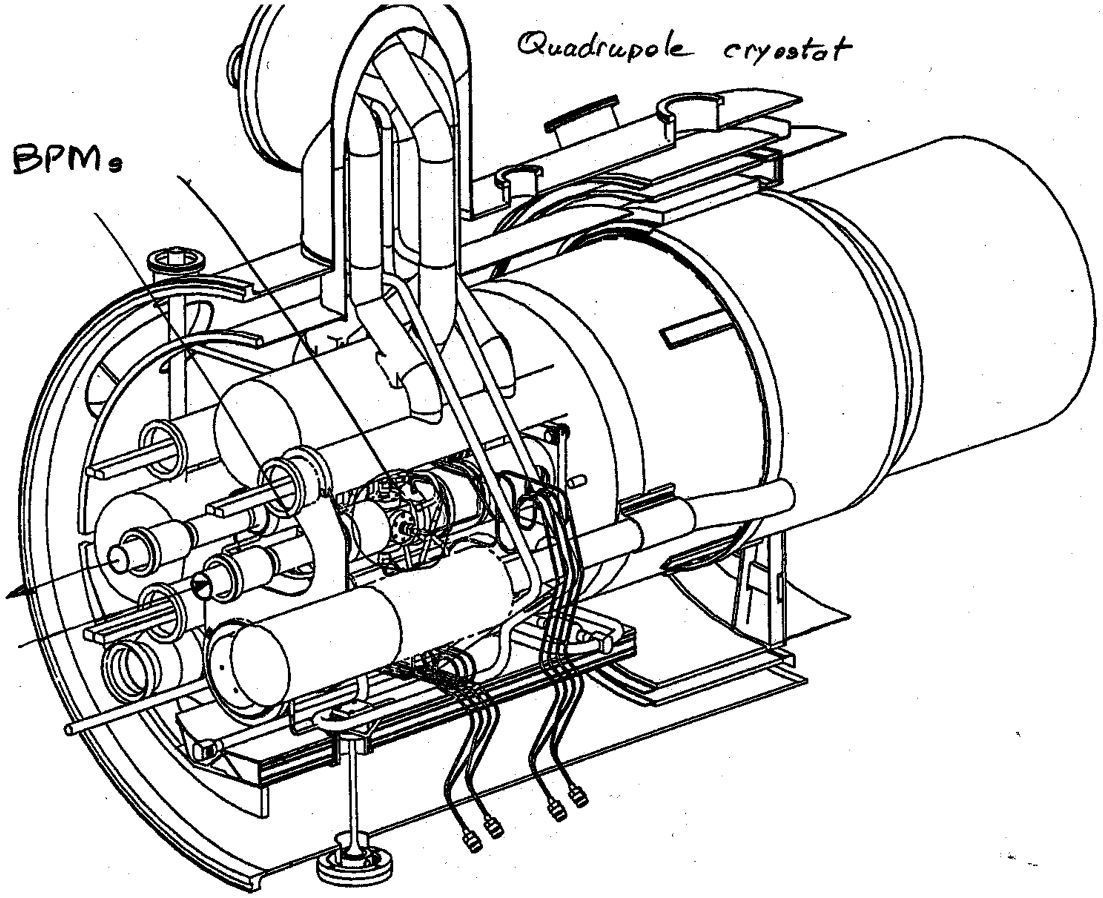
(Claude.Fischer@cern.ch)

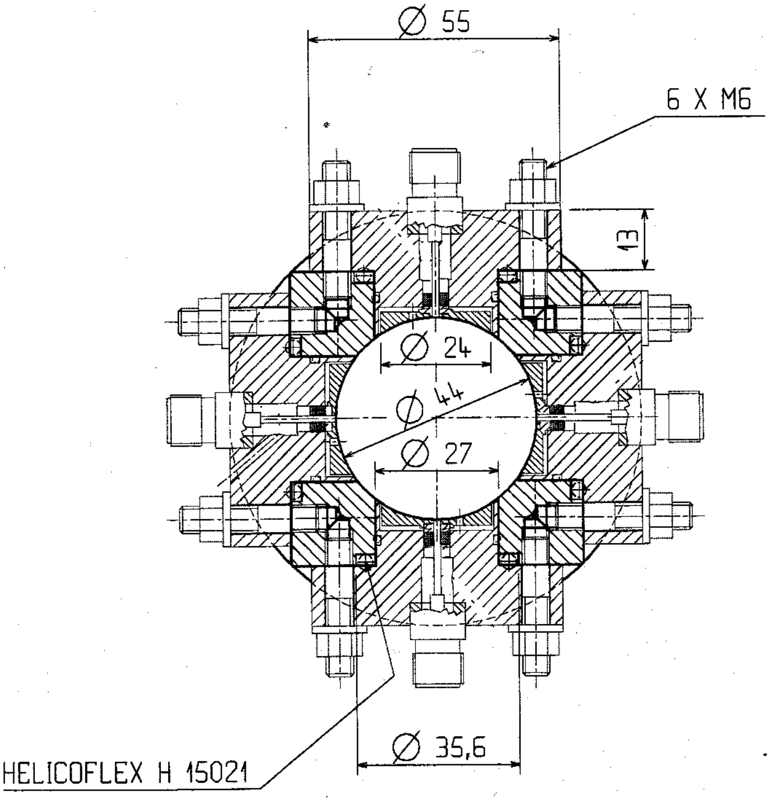
A Review of the LHC Beam Instrumentation

Table 1: LHC BPM Distribution

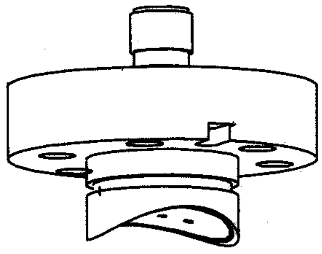
(button electrodes except in **Inner Triplets)**

	Adjacent Quadrupole (number/type)	Temperature (K)	Coil Aperture (mm)	Aperture #	BPM #
arcs	360 MQ	1.9	56	2	720
Dispersion Suppressors in all insertions:					
Q11	16 MQ	1.9	56	2	32
in insertions 3 / 7:					
Q10 / Q9 / Q8	12 MQL	1.9	56	2	24
in insertions 1/2/4/5/6/8:					
Q10 / Q9 / Q8	36 MQM or MQML	1.9	56	2	60+12 C C= combined [illegible]
Matching. Sections					
1/5 Q7	4 MQM	1.9	56	2	8
Q6	4 MQML	4.5	56	2	8
Q5	4 MQML	4.5	56	2	8
Q4	4 MQM	4.5	56	2	8
2/8 Q7	4 MQM	1.9	56	2	8
Q6	4 MQM	1.9	56	2	8
Q5	2 MQY / 2 MQM	4.5	70 / 56	2	4 / 4
Q4	2 MQY / 2 MQM	4.5	70 / 56	2	4 / 4
Inner Triplets 1/2/5/8					
Q2b	8 MQX	1.9	70	1	8
Q1	8 MQX	1.9	70	1	8 *bi-directional strips*
Cleaning Insertions 3/7					
Q7	4 MQ	1.9	56	2	8
Q6	4 MQW	warm	46	2	8
Q5	4 MQW	warm	46	2	8
Q4	4 MQW	warm	46	2	8
RF Insertion 4					
Q7	2MQM	1.9	56	2	4 C
Q6	2MQMLR	4.5	56	2	4
Q5	2MQMLR	4.5	56	2	4
Q4	2MQMR	4.5	56	2	4
Q3	2MQMR	4.5	56	2	4
Dump Insertion 6					
Q5	2 MQY	4.5	70	2	4
Q4	2 MQY	4.5	70	2	4





pick-ups made
of four buttons

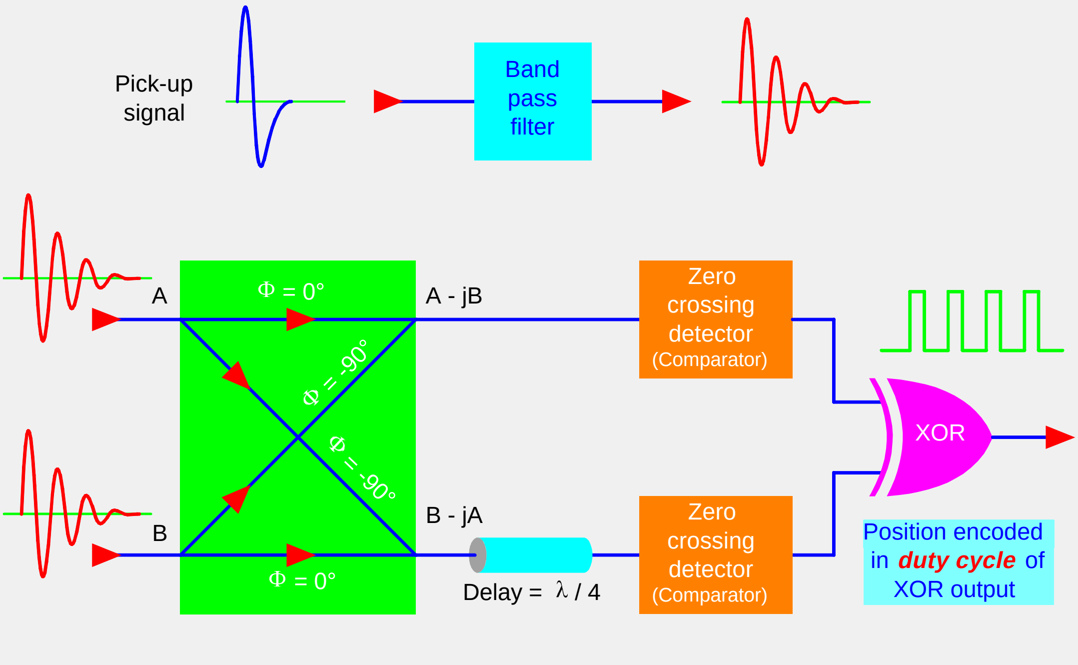


AXONOMETRIC VIEW

NARROW BAND NORMALISER

(LEP)

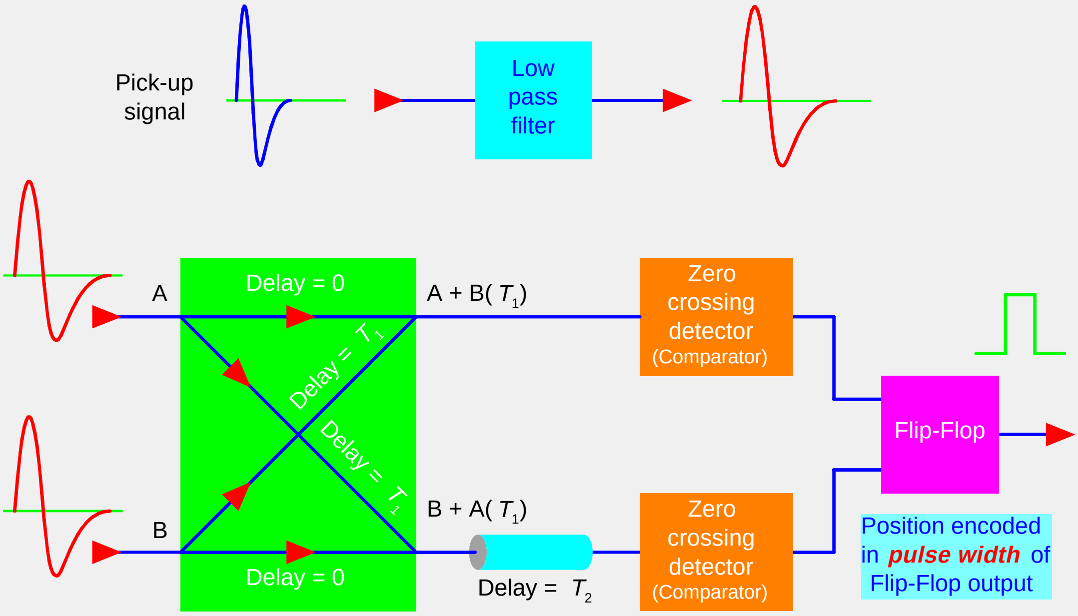
(PHASE PROCESSOR)



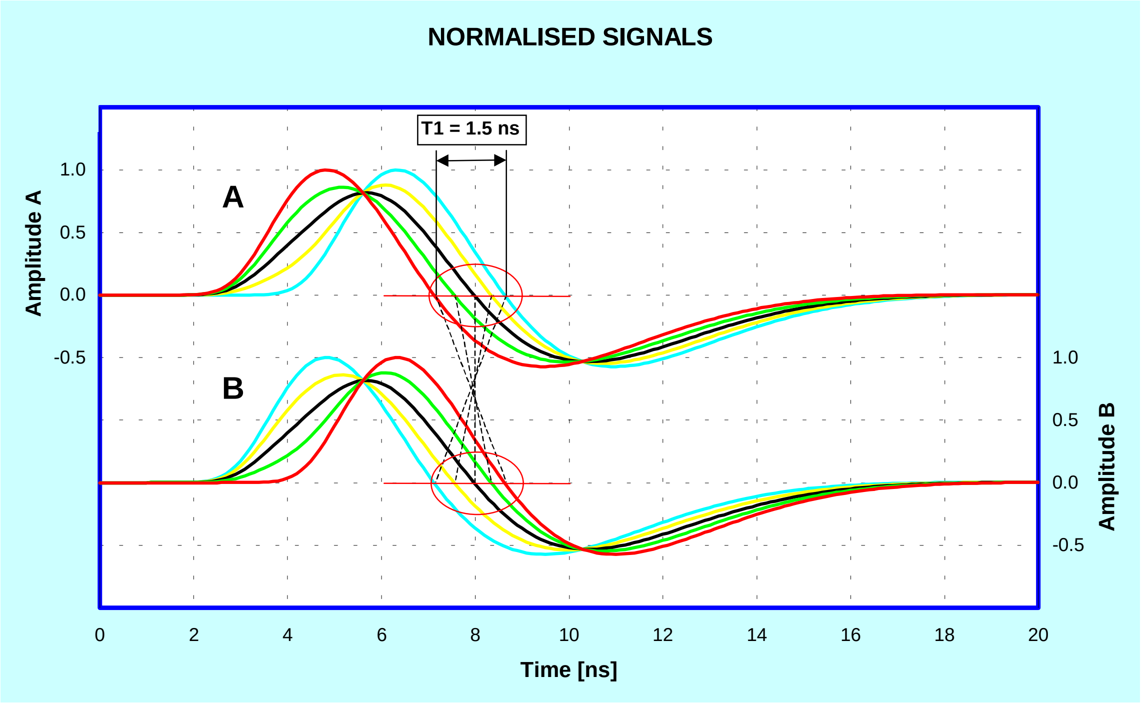
Position encoded in ***duty cycle*** of XOR output

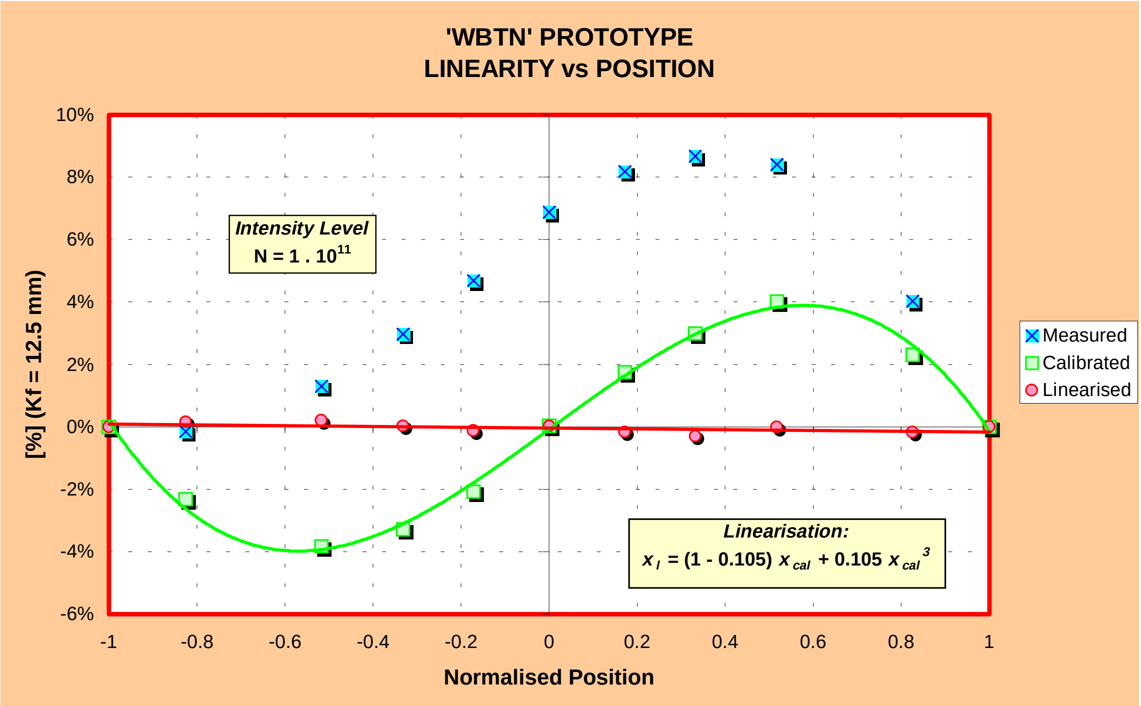
WIDE BAND NORMALISER

(TIME PROCESSOR)



Position encoded in ***pulse width*** of Flip-Flop output


NORMALISED SIGNALS
T1 = 1.5 ns
A
B
Amplitude A
1.0
0.5
0.0
-0.5
Amplitude B
1.0
0.5
0.0
-0.5
0
2
4
6
8
10
12
14
16
18
20
Time [ns]


'WBTN' PROTOTYPE
LINEARITY vs POSITION
Intensity Level
N = 1 . 10^{11}
Linearisation:
$x_l = (1 - 0.105)\, x_{cal} + 0.105\, x_{cal}^3$
Measured
Calibrated
Linearised
[%] (Kf = 12.5 mm)
10%
8%
6%
4%
2%
0%
-2%
-4%
-6%
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Normalised Position

Bunch position measurements

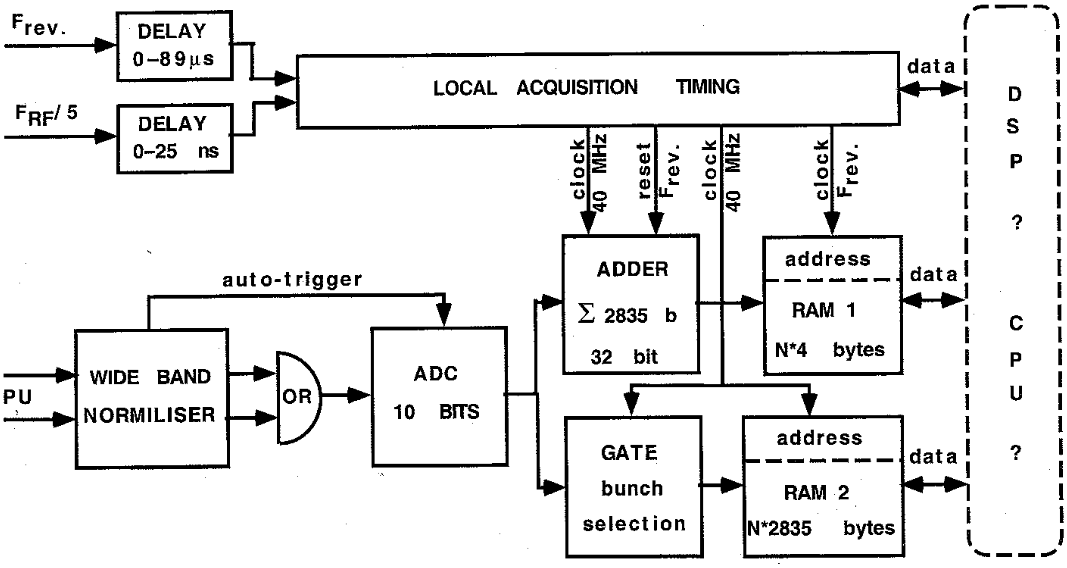
Bunch type	Pilot		Nominal	
Mode	Traj.	Orbit	Traj.	Orbit
Accuracy	1.5 mm	1 mm	150 µm	100 µm
Resolution	0.5 mm	0.2 mm	50 µm	5 µm

data taking at 40 MHz

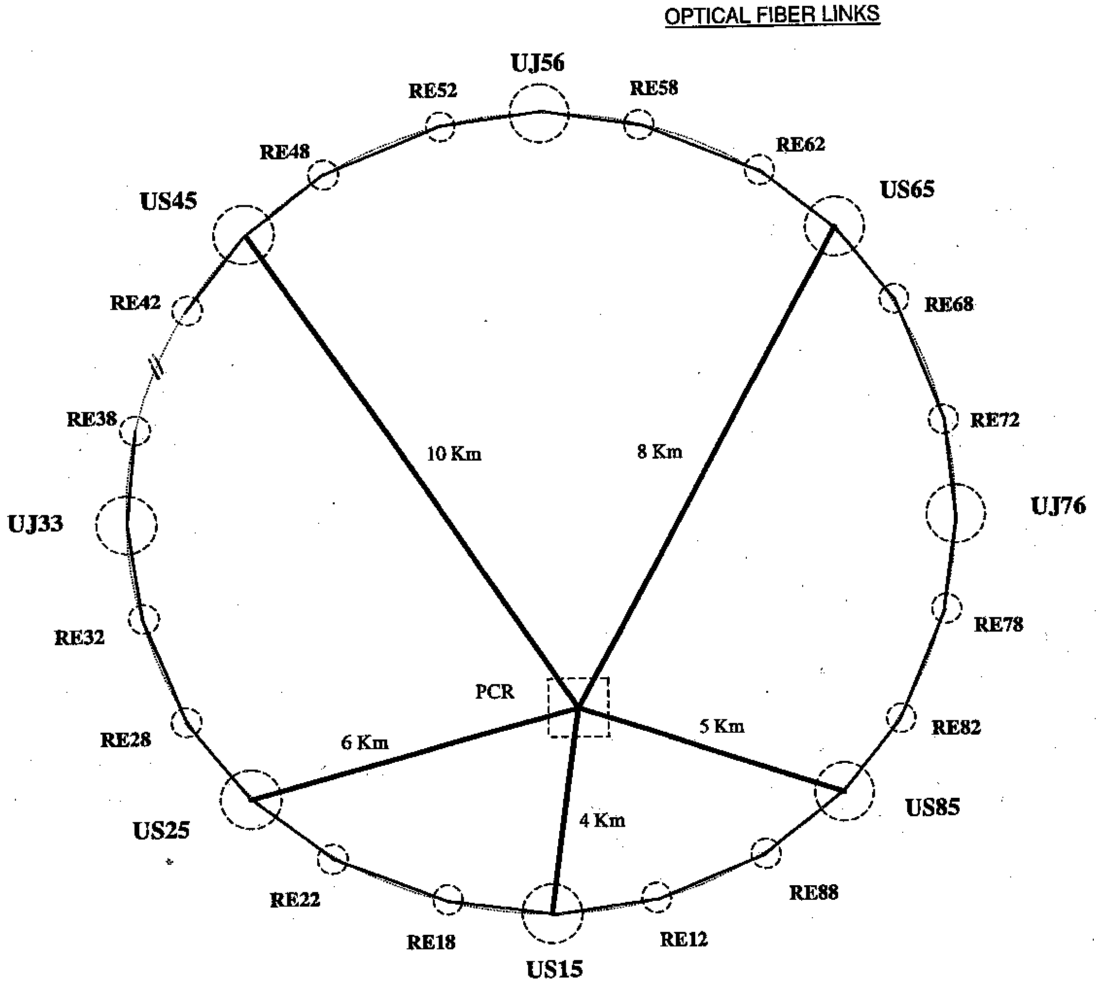
Diagnostics:

- Injection trajectories + closed orbits
- Harmonic analysis ⇒ machine optics
- Measurement of tranverse coupling
- Measurement of momentum dispersion
- Pacman bunch orbits
- Optimisation of luminosity/beam-beam deflection

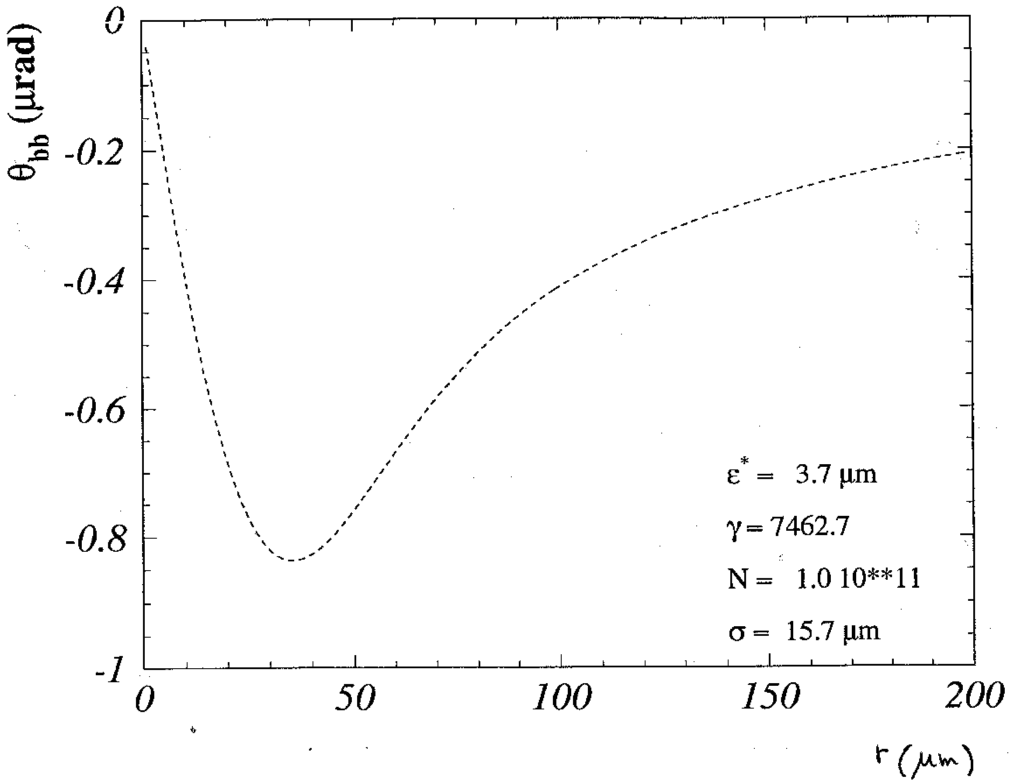
BPM ACQUISITION SYSTEM



Beam synchroneaus timing

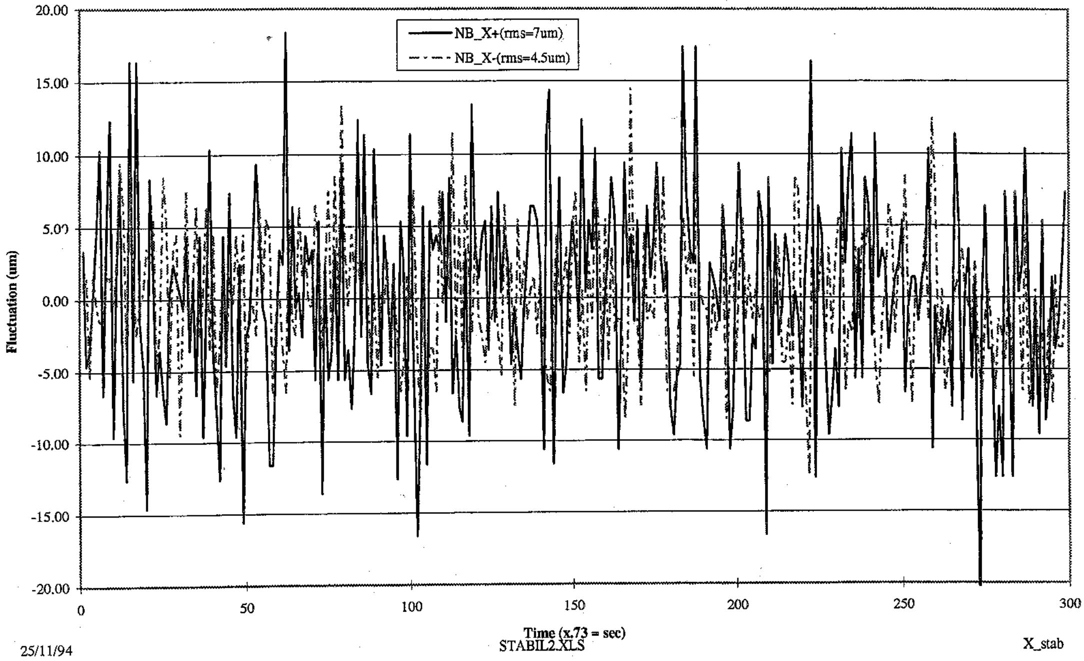


Kick at bunch crossing

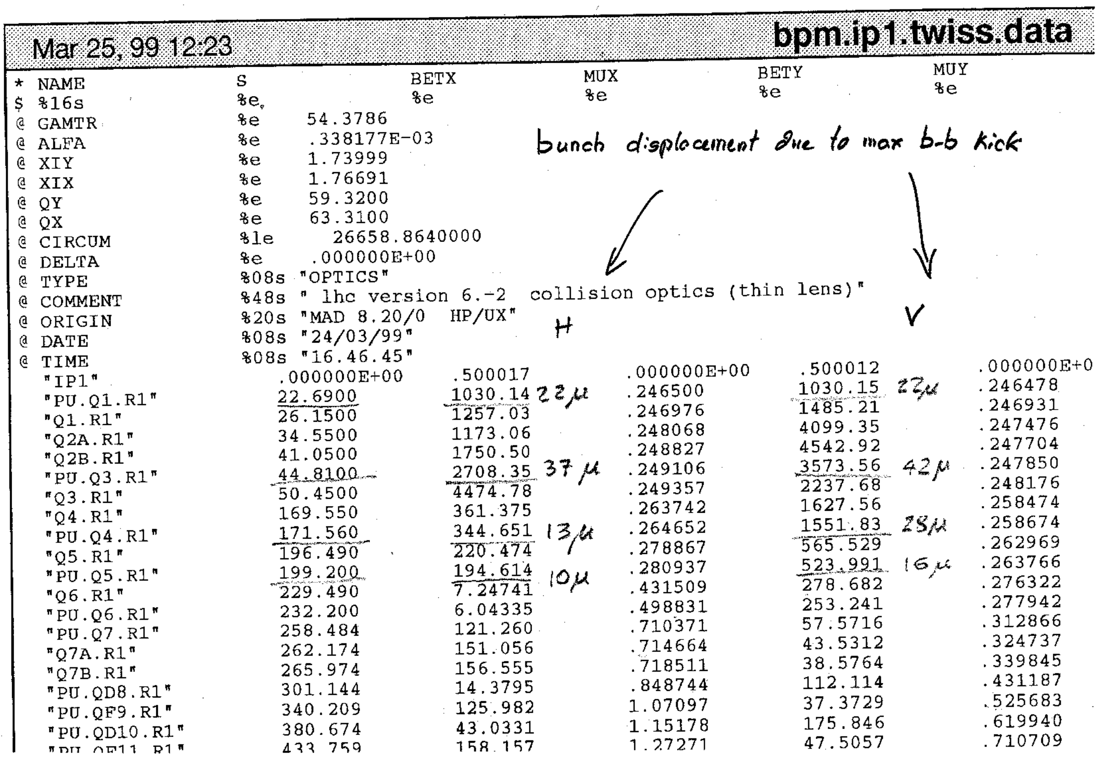


prepared by G. Vismara

X Stability *measured in LEP*

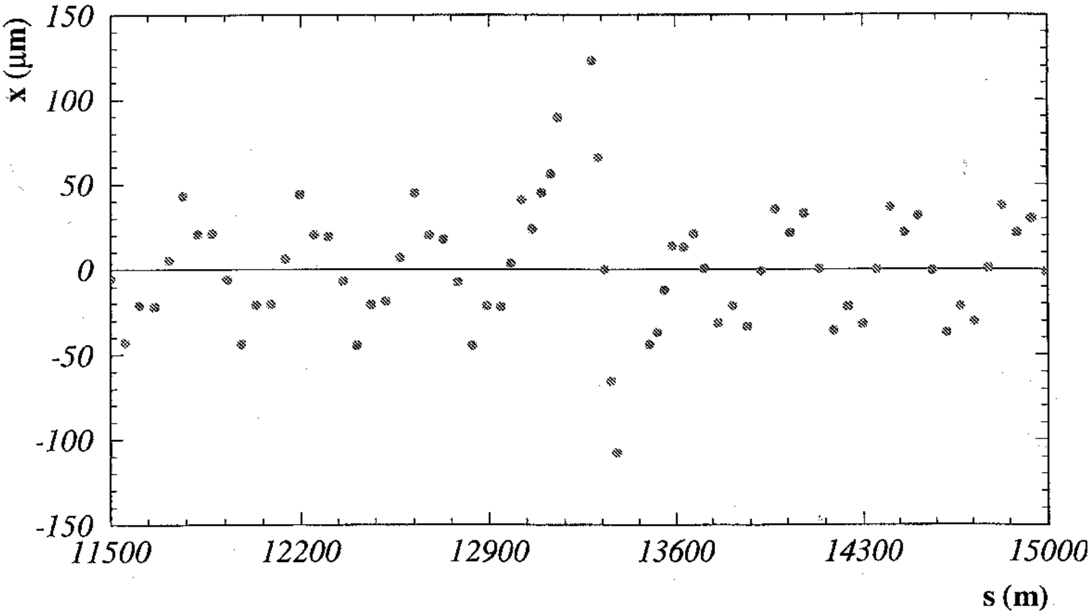


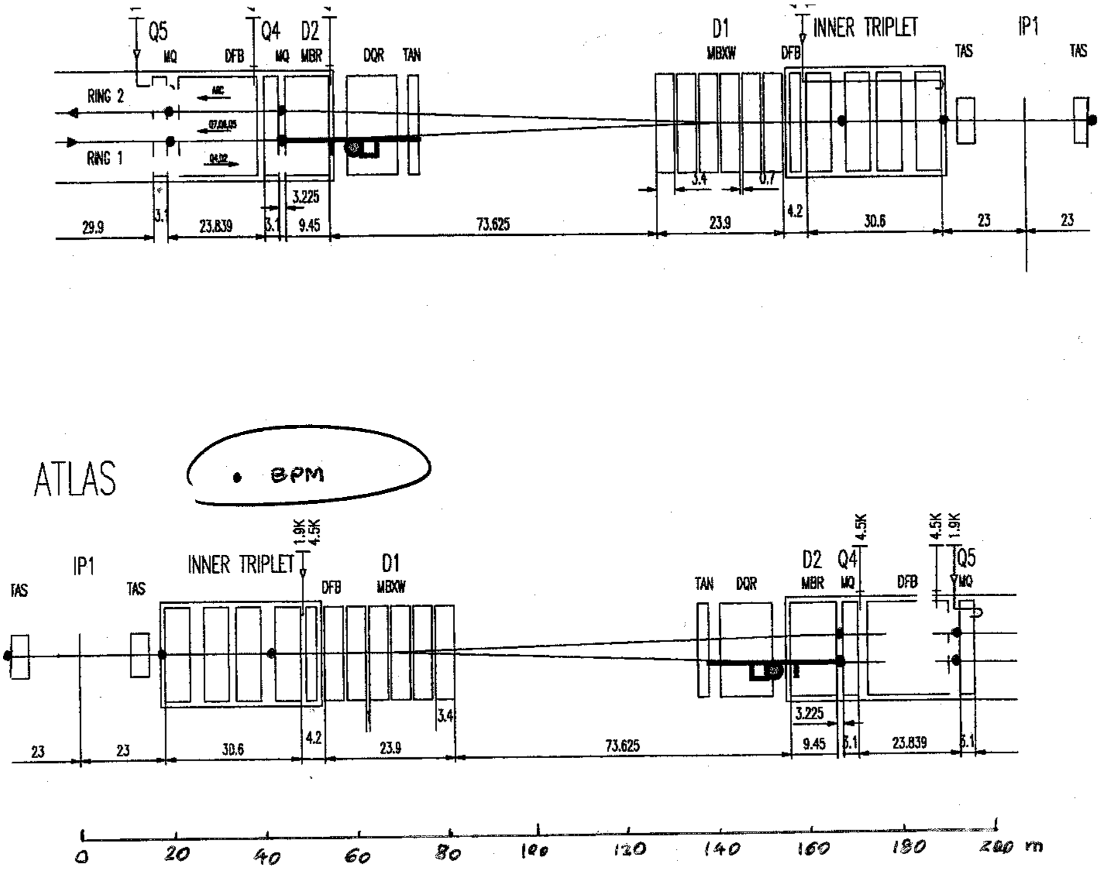
25/11/94 STABIL2.XLS X_stab



```
Mar 25, 99 12:23                                                    bpm.ip1.twiss.data
* NAME            S                BETX              MUX               BETY             MUY
$ %16s            %e               %e                %e                %e               %e
@ GAMTR           %e     54.3786
@ ALFA            %e     .338177E-03                bunch displacement due to max b-b kick
@ XIY             %e     1.73999
@ XIX             %e     1.76691
@ QY              %e     59.3200
@ QX              %e     63.3100
@ CIRCUM          %le       26658.8640000
@ DELTA           %e     .000000E+00
@ TYPE            %08s "OPTICS"
@ COMMENT         %48s " lhc version 6.-2  collision optics (thin lens)"
@ ORIGIN          %20s "MAD 8.20/0  HP/UX"    H                             V
@ DATE            %08s "24/03/99"
@ TIME            %08s "16.46.45"
  "IP1"              .000000E+00      .500017        .000000E+00      .500012          .000000E+0
  "PU.Q1.R1"         22.6900          1030.14 22μ    .246500          1030.15  22μ     .246478
  "Q1.R1"            26.1500          1257.03        .246976          1485.21          .246931
  "Q2A.R1"           34.5500          1173.06        .248068          4099.35          .247476
  "Q2B.R1"           41.0500          1750.50        .248827          4542.92          .247704
  "PU.Q3.R1"         44.8100          2708.35 37μ    .249106          3573.56  42μ     .247850
  "Q3.R1"            50.4500          4474.78        .249357          2237.68          .248176
  "Q4.R1"            169.550          361.375        .263742          1627.56          .258474
  "PU.Q4.R1"         171.560          344.651 13μ    .264652          1551.83  28μ     .258674
  "Q5.R1"            196.490          220.474        .278867          565.529          .262969
  "PU.Q5.R1"         199.200          194.614 10μ    .280937          523.991  16μ     .263766
  "Q6.R1"            229.490          7.24741        .431509          278.682          .276322
  "PU.Q6.R1"         232.200          6.04335        .498831          253.241          .277942
  "PU.Q7.R1"         258.484          121.260        .710371          57.5716          .312866
  "Q7A.R1"           262.174          151.056        .714664          43.5312          .324737
  "Q7B.R1"           265.974          156.555        .718511          38.5764          .339845
  "PU.QD8.R1"        301.144          14.3795        .848744          112.114          .431187
  "PU.QF9.R1"        340.209          125.982        1.07097          37.3729          .525683
  "PU.QD10.R1"       380.674          43.0331        1.15178          175.846          .619940
  "PU.QF11.R1"       433.759          158.157        1.27271          47.5057          .710709
```

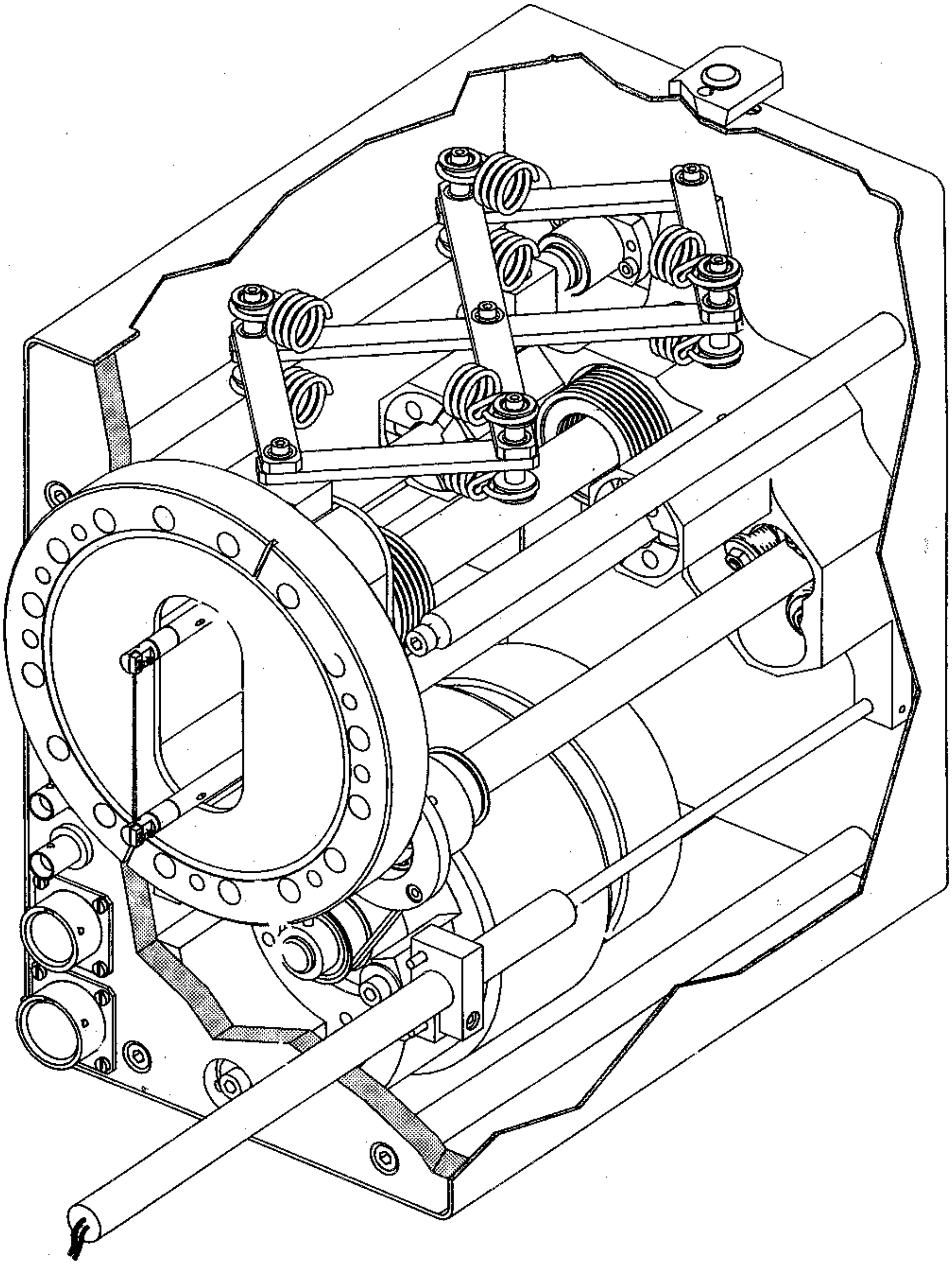
Beam separation around IP5





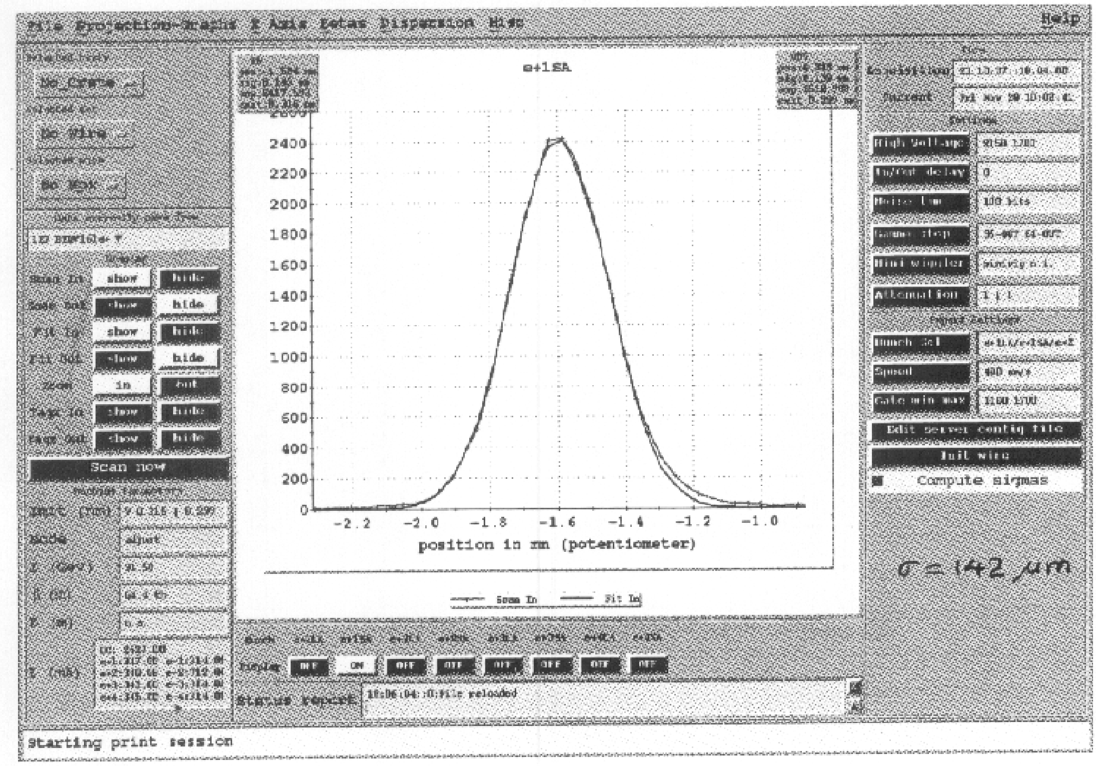
Emission Detector

BSRT : Synchrotron Radiation Monitor : 35 m



LEP wire scanner

Beam Size Measurements

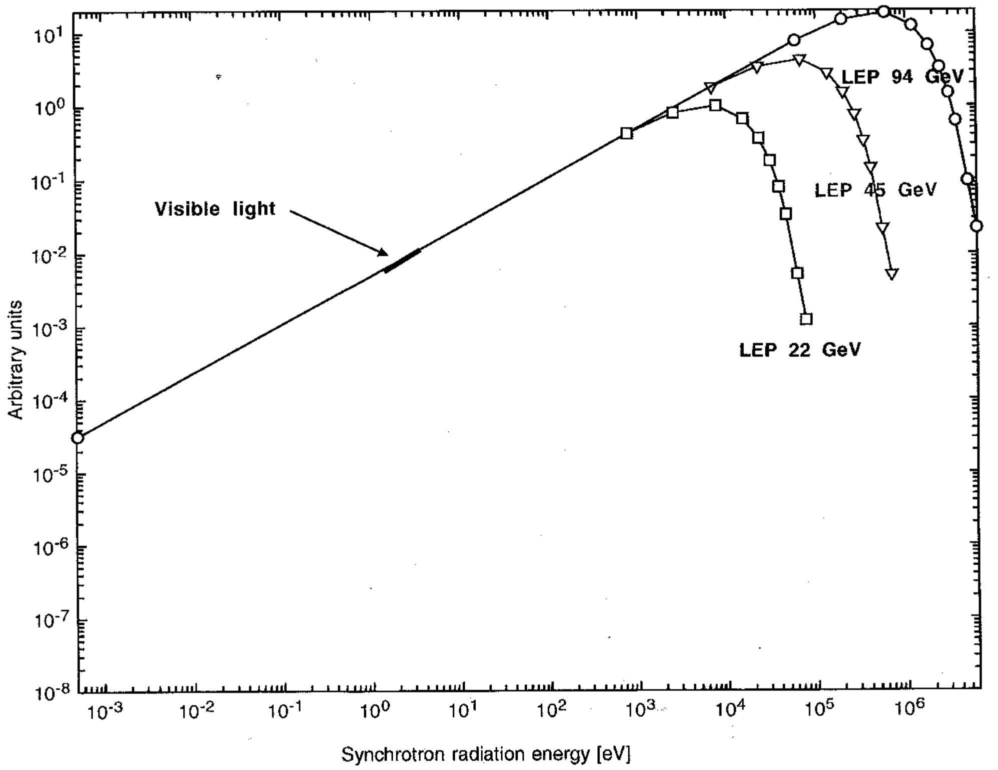


18:06:04::0:file reloaded

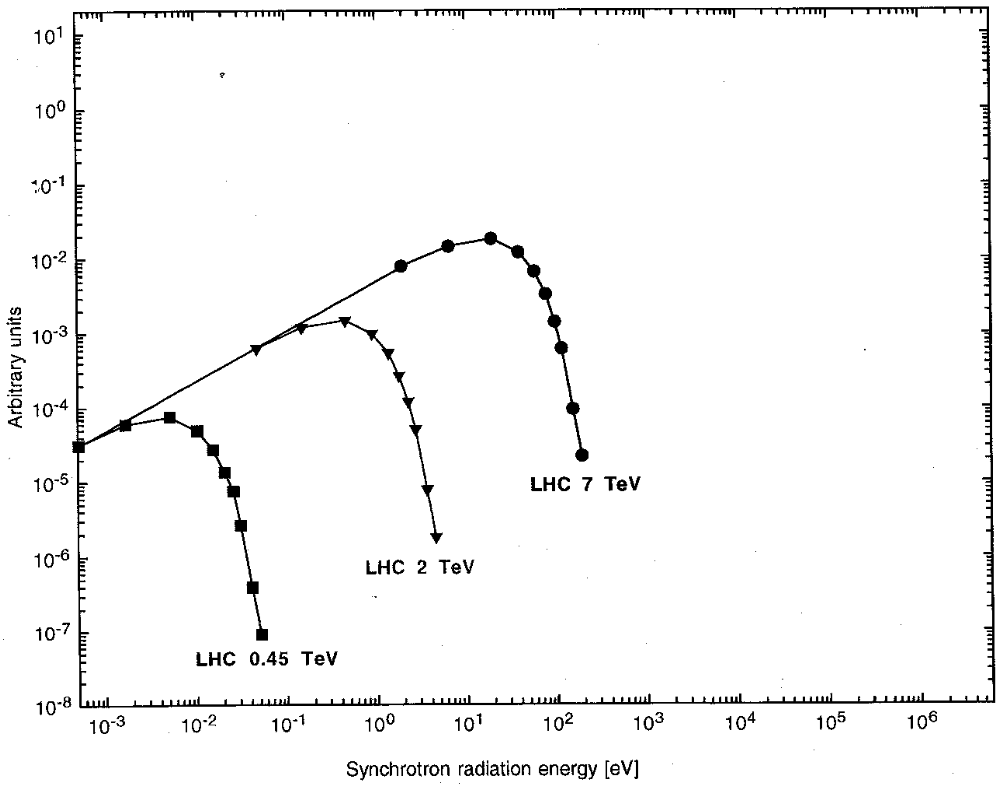
Starting print session

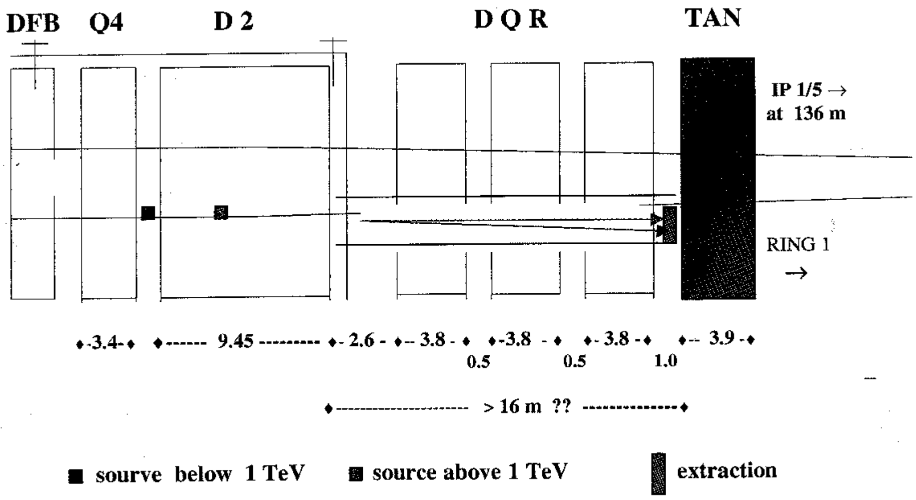
σ ≈ 142 μm

Production of synchrotron light in LEP dipoles



Production of synchrotron light in LHC D2 dipoles





Synchrotron Radiation Monitor Lay-out in IR1 or IR5

Number of photons emitted at one bunch passage

$B = 3.3\ T$

$E = 7\ TeV$ $\qquad \rho = \frac{10\ p\,[GeV/c]}{3\ B\,[T]} = \frac{7\ 10^4}{10} = 7000\ m$

$\gamma = 7462$

$\lambda_c = \frac{4\pi\rho}{3\gamma^3} = 70\ nm$

$\lambda = 200\ nm$

$y = 70/200 = 0.35$

$k = \Delta\lambda/\lambda = 40/200 = 0.2$

$\Delta\varepsilon = k\,\varepsilon\,[eV] = \frac{k\ 124}{\lambda\,[nm]} = .12\ eV$

$N_{\Delta\varepsilon} = 10^{16}\ \gamma\ \lambda_c\ G_0(y)\ \Delta_E\ q\,[mC]\ \alpha\,[mrad]$

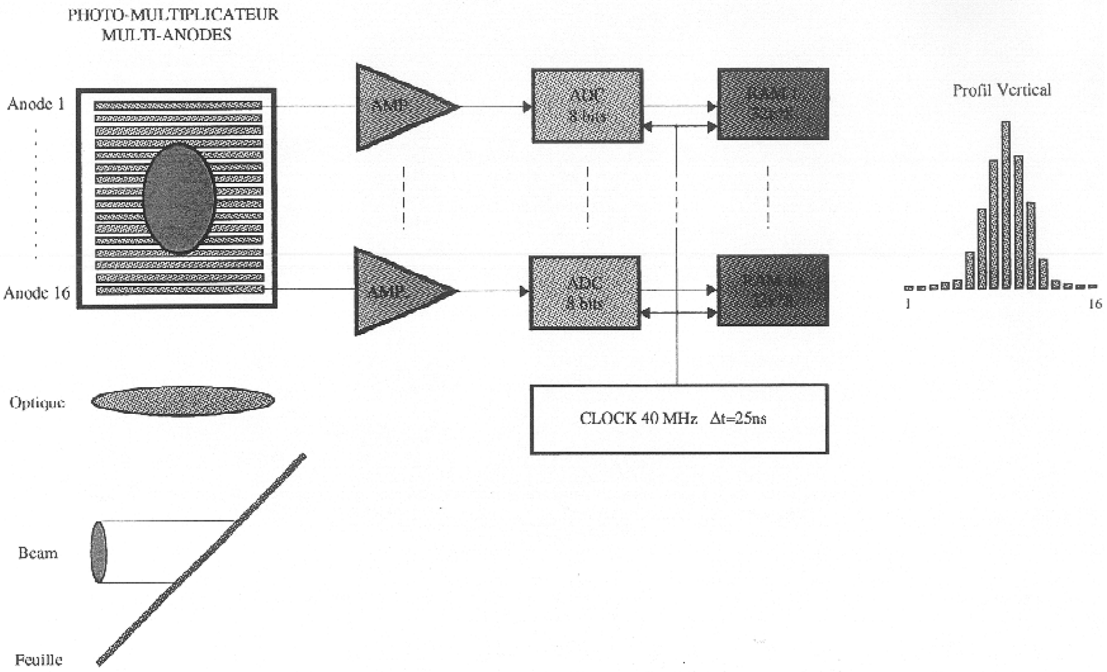
$q = 1.1 \times 10^{11} \times 1.6\ 10^{-19} = 1.8\ 10^{-8}\ C$

$\alpha = \frac{1\ m}{7000\ m} = .14\ mrad$

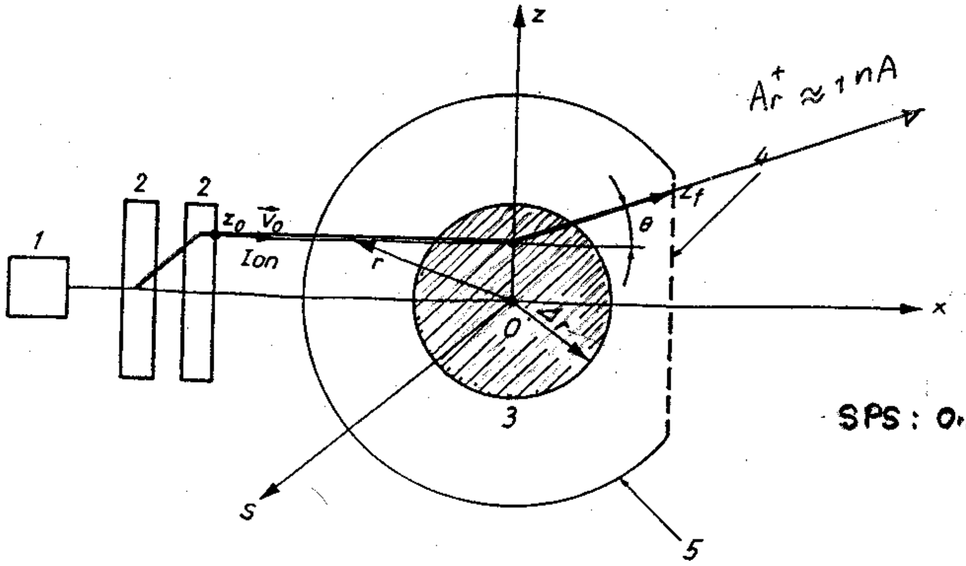
$G_0(0.35) = 2.6$

$$\boxed{N_\varphi = 10^{16}\ 7462\ \ 70\ 10^{-9}\ \ 2.6\ \ .12\ \ 1.8\ 10^{-5}\ \ .14 = 4\ 10^{6}}$$

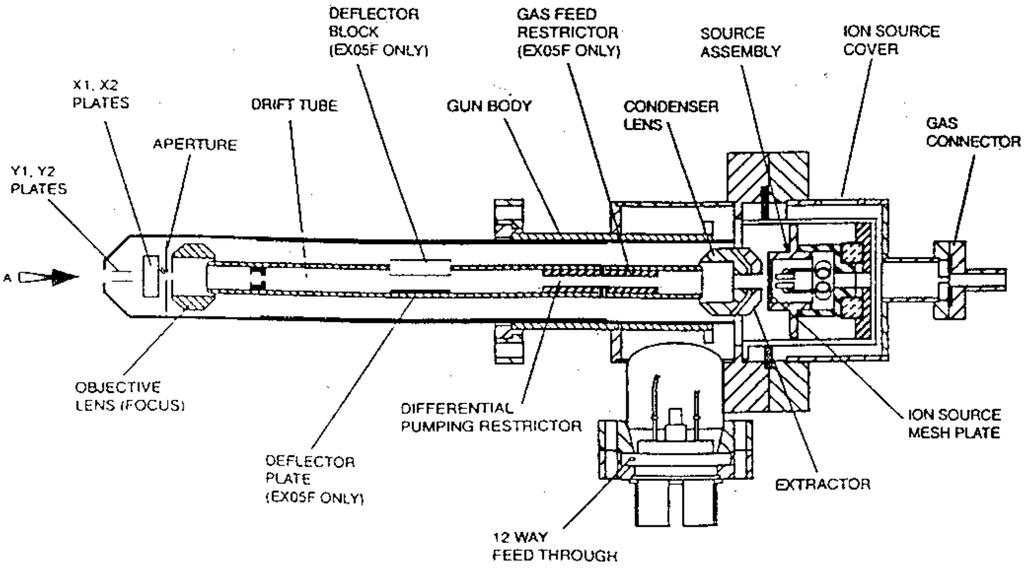
FAST MULTI-PROFILES



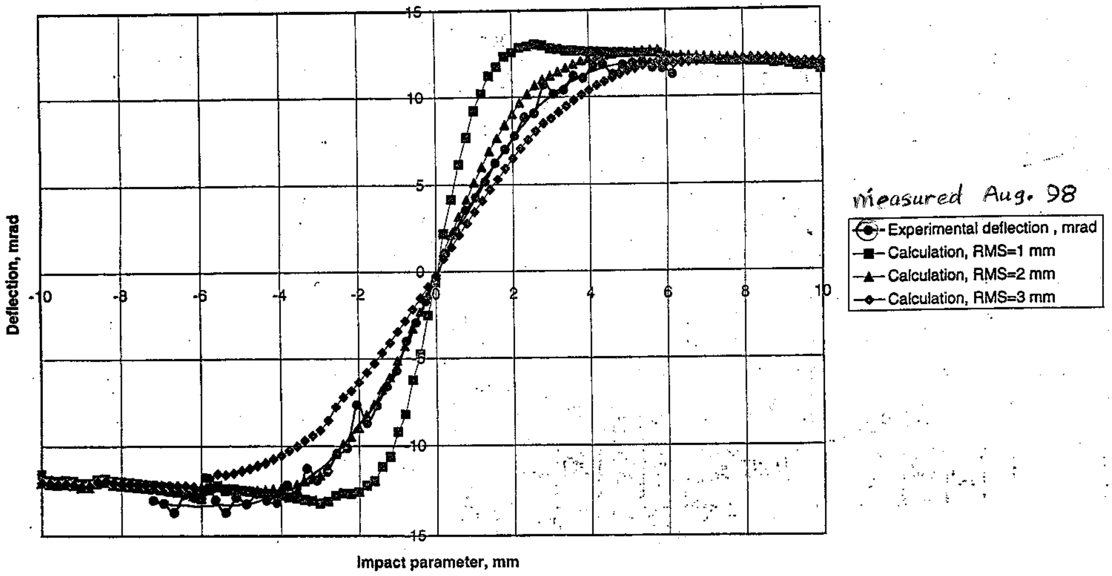
Profile measurement with transverse ion beam



SPS : 0.27 A

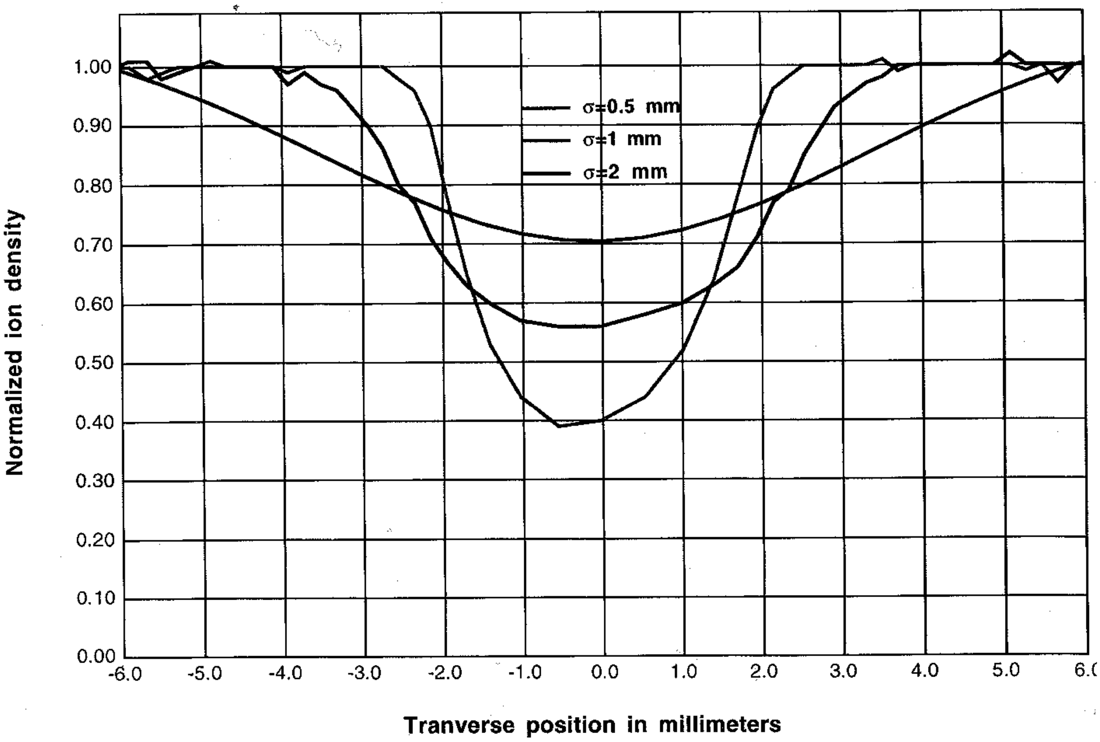


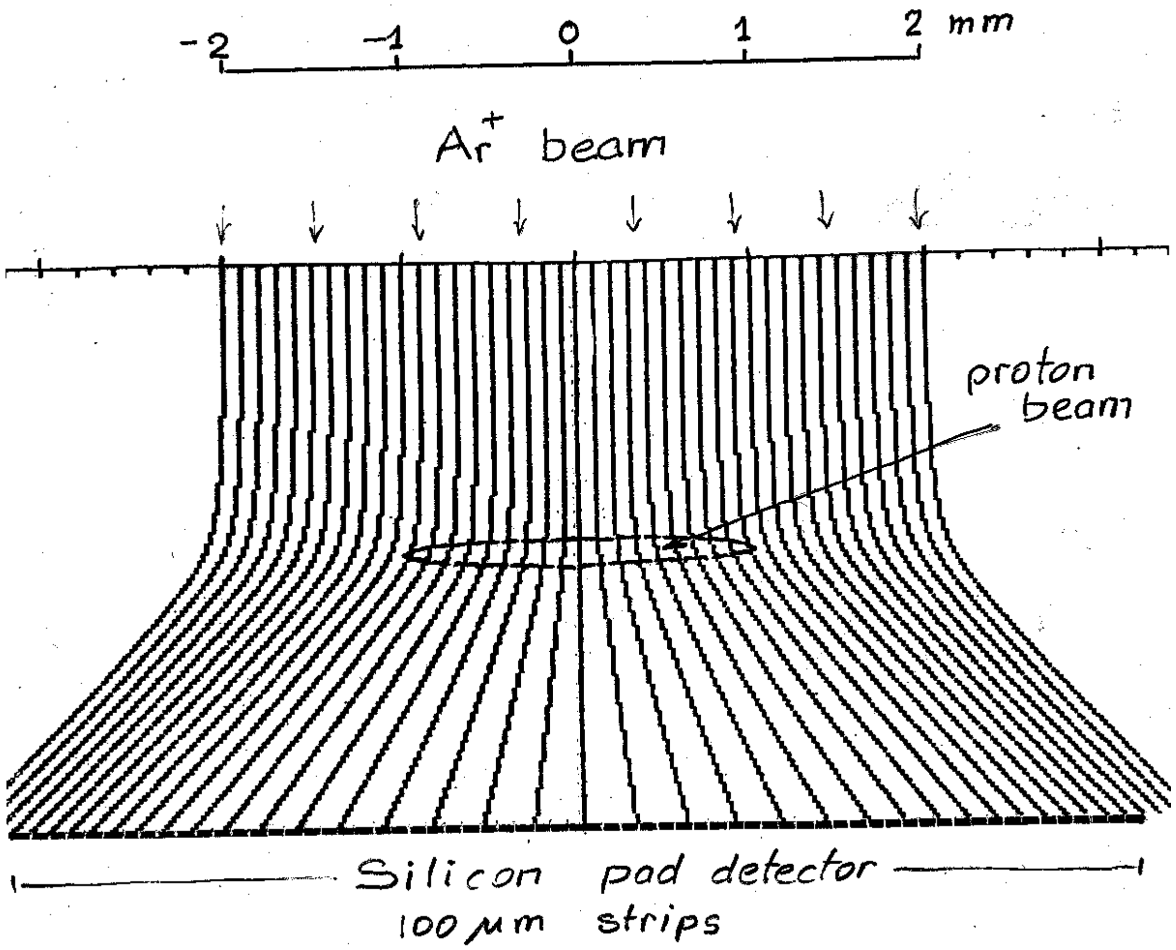
Deflection of 2 keV ions vs impact parameter (N=(3.7-3.8)*10^13 during the measurement and n=8.93*10^9 ppb for calculations, Ti=3200-4200 ms)

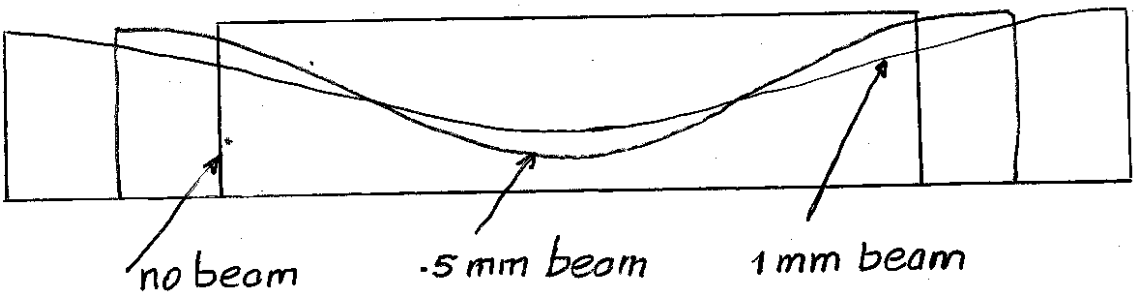


measured Aug. 98

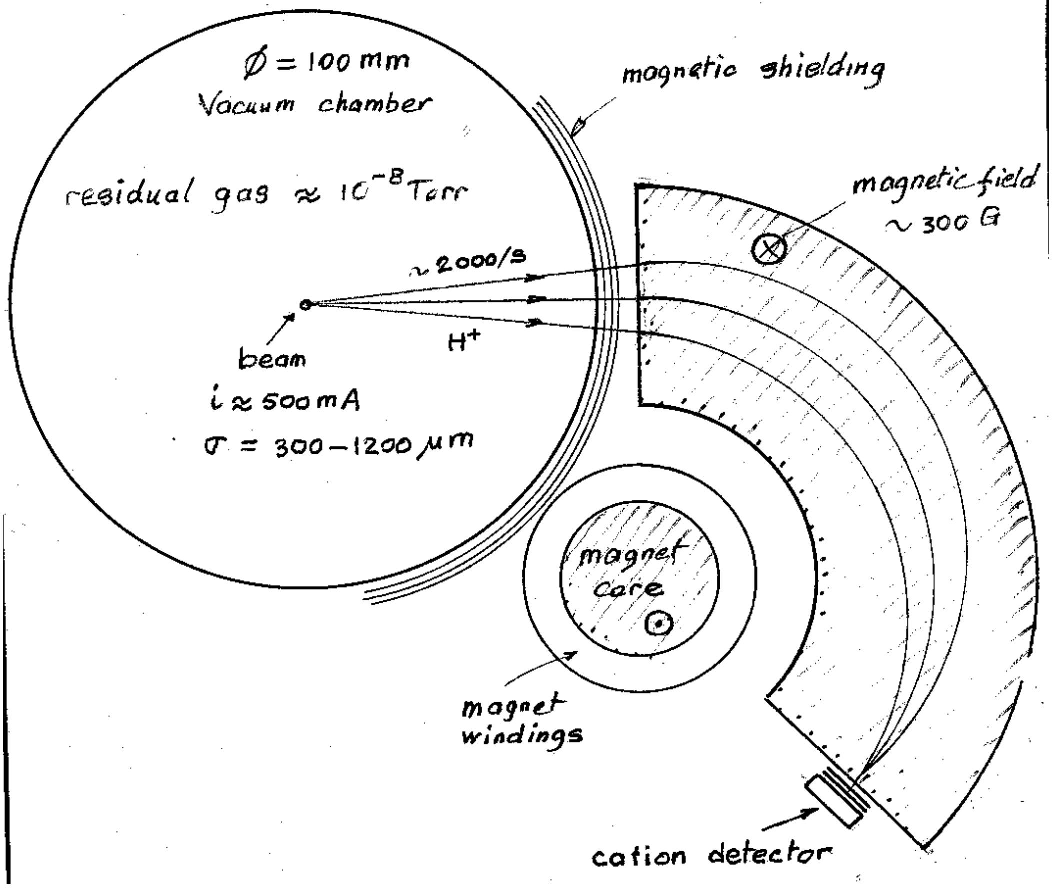
Ion (Xe) profile on detector

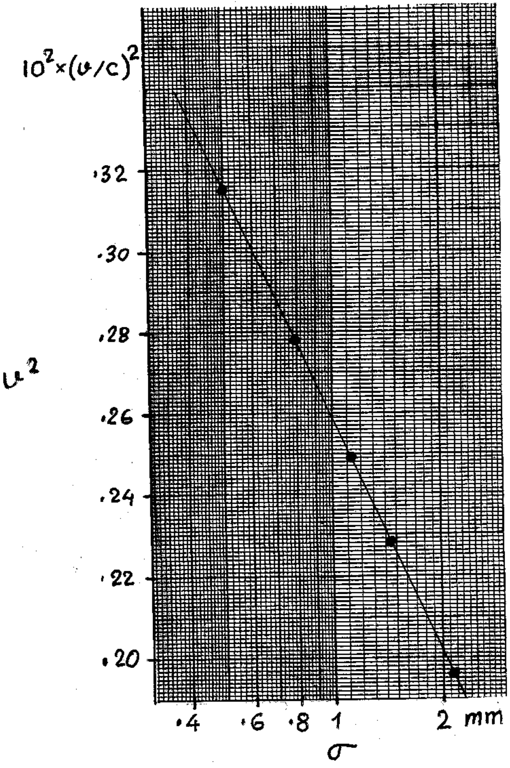



-2
-1
0
1
2 mm
Ar$^+$ beam
proton beam
Silicon pad detector
100 μm strips


no beam
.5 mm beam
1 mm beam

Beam size measurement device





For round beam 

$v^2 = A - \alpha \ln\sigma$

$v^2 = (.258 - .0816 \ln\sigma) \times 10^2$

For elliptical beam 

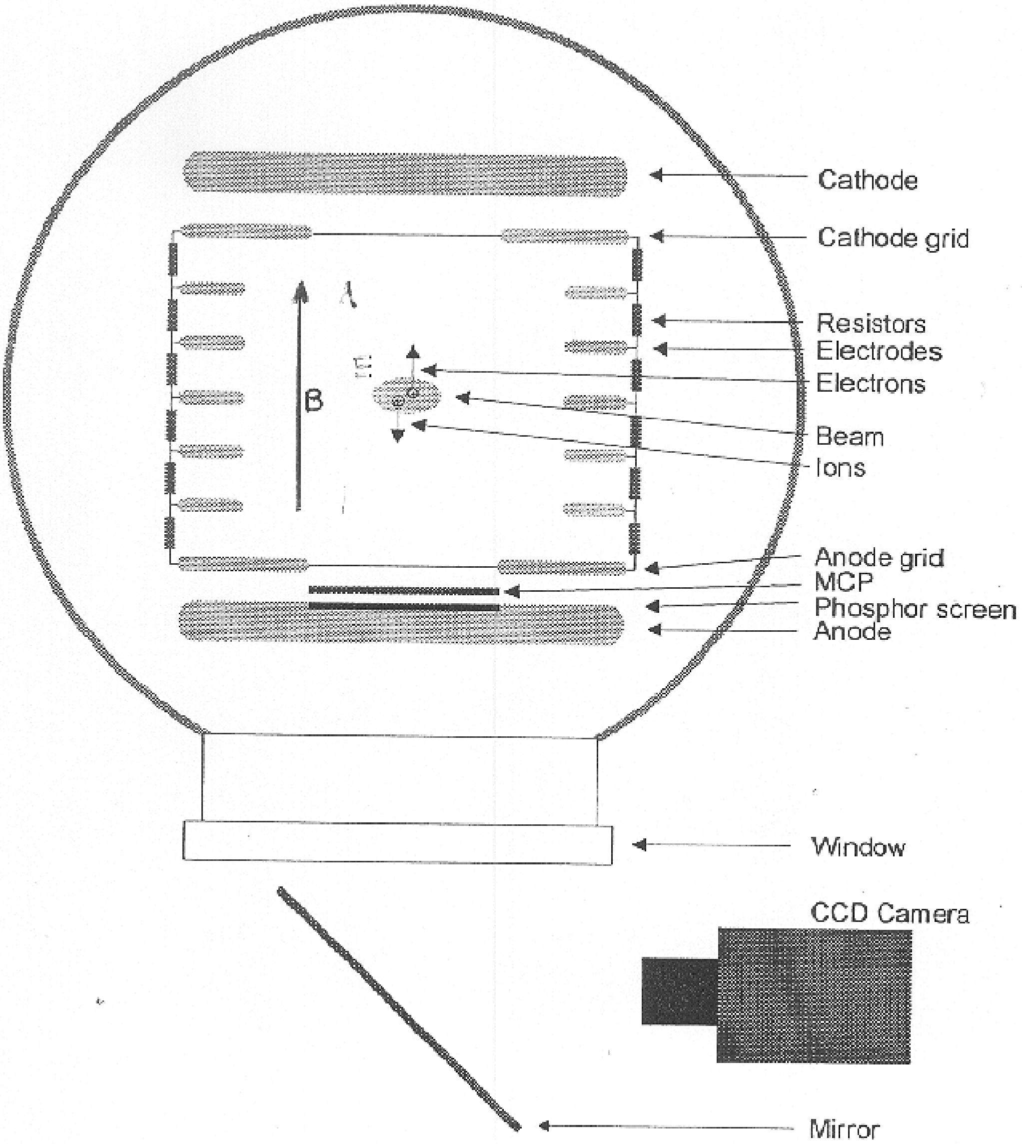
$v^2 = A - \alpha \ln\left(\frac{a+b}{2}\right)$

Sensitivity

$$\frac{d\sigma}{\sigma} = \underset{\uparrow}{\frac{2v^2}{\alpha}} \frac{dv}{v}$$

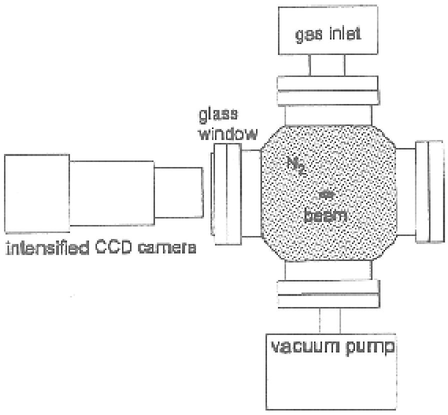
6.4 for $\sigma = 1$ mm

9.5 for $\sigma = 200\ \mu m$



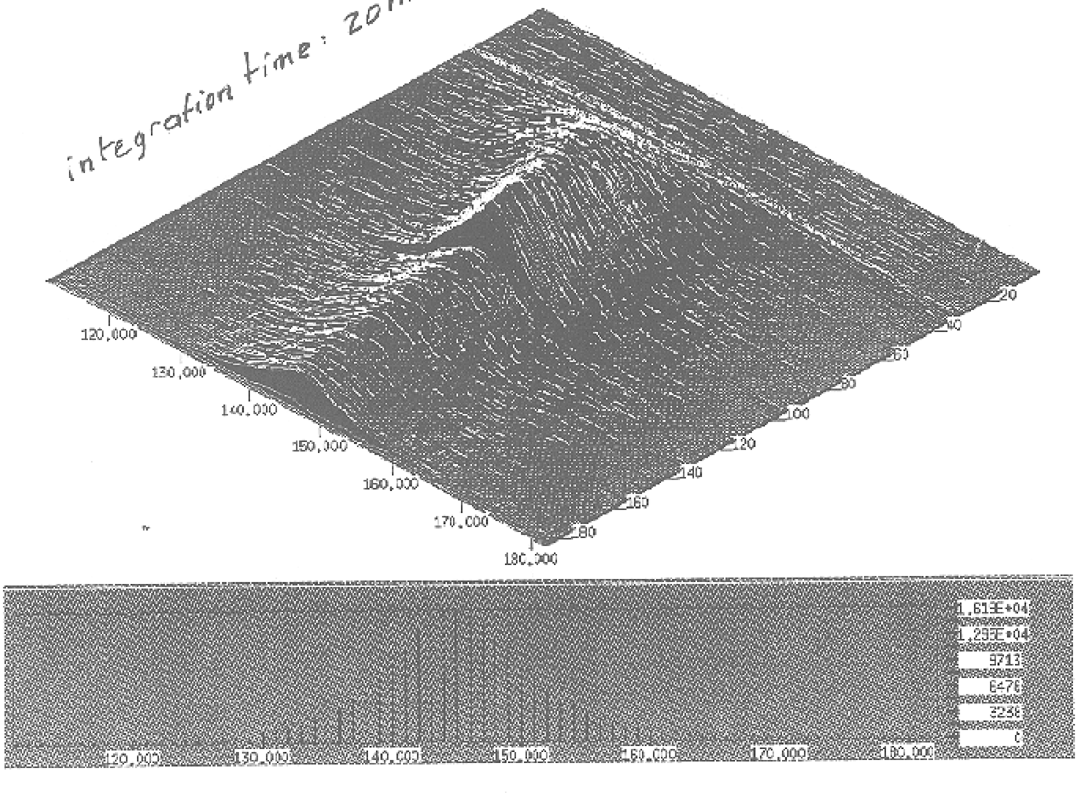
DESY Restgas Ionisation Profile Monitor used at CERN

LSS4 Luminescence Gas Test Monitor



$I_b = 2 \times 10^{13}$ p

integration time: 20ms



$\sigma = 860 \mu m$

Preliminary results with Nitrogen at 10^{-5} to 10^{-6} Torr

The proposed SEM Luminosity Monitor

Sylvain Weisz (EST/LEA)

S.Weisz-15/04/99

Luminosity Monitors at LHC.

1) Absolute measurement of Luminosity:

□ **TOTEM (and ATLAS):**

Simultaneous measurement of elastic and inelastic rates + Optical theorem

➔ **Absolute σ_{tot} (⇔ Luminosity) with 1-2% precision (at L ~ 10^{28} $cm^{-2}s^{-1}$).**

➔ **Calibration of a dedicated Luminosity counter.**

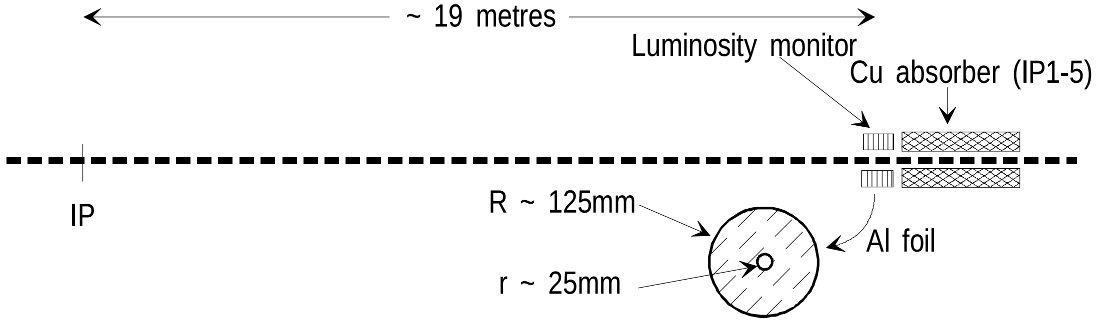
□ **Need for a monitor that covers 6 orders of magnitude:**

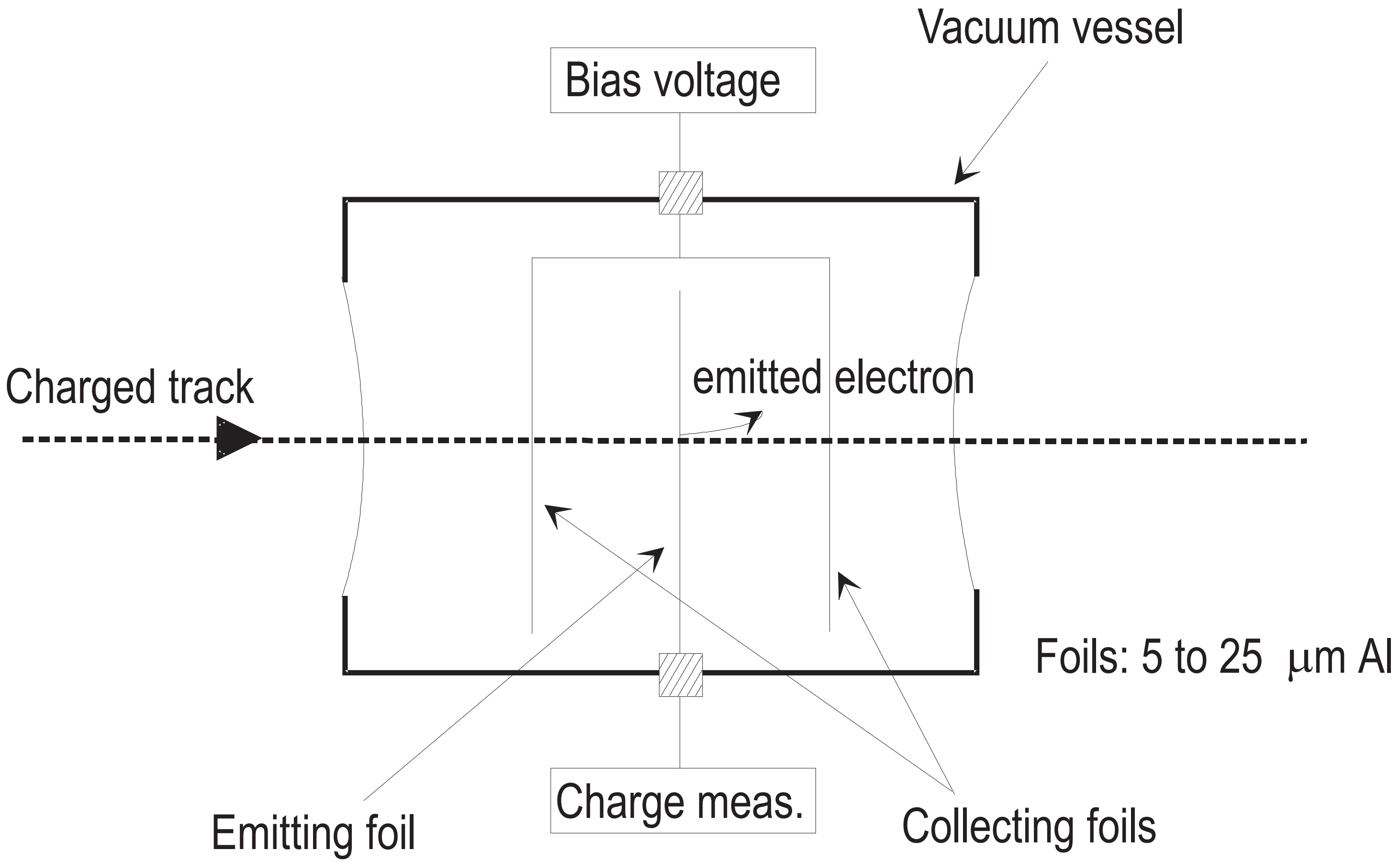
Propose to use a Secondary Emission Counter.

➔ **Very simple and robust**

➔ **Radiation hard**

➔ **Lots of experience at CERN**




Vacuum vessel
Bias voltage
Charged track
emitted electron
Foils: 5 to 25 μm Al
Emitting foil
Charge meas.
Collecting foils

☐ **Specifications.**

$\eta \in [\sim 6, \sim 7]$ ➔ ~ 8 **charged tracks/inelastic events.**
$L = 10^{28}$ ➔ ~ 10^{4} **charged tracks/second.**
$L = 10^{34}$ ➔ ~ 10^{10} **charged/s and** $\leq 10^{8}$ **charged/cm**^{2} **at the inner edge.**
➔ $\leq 10^{15}$ **charged/cm**^{2} **after a year.**
(ageing effects starts at ~ 10^{17} **charged/cm**^{2}**)**

Signal: efficiency (~7%) × Nb. foils (15?) = 1
$L = 10^{34}$ ➔ $Q \sim 1.6 \times 10^{-9}$ **Coulomb/s**
$L = 10^{28}$ ➔ $Q \sim 1.6 \times 10^{-15}$ **Coulomb/s (Challenging!)**

☐ **Possibility to switch to an ionisation chamber:**
Fill the SEC with Argon
➔ **Gain ~** 5×10^{2} **on the signal.**

➔ **Become much more sensitive to background.**
Ex: Low energy/highly ionising particles at large angle from activation of the surrounding material.

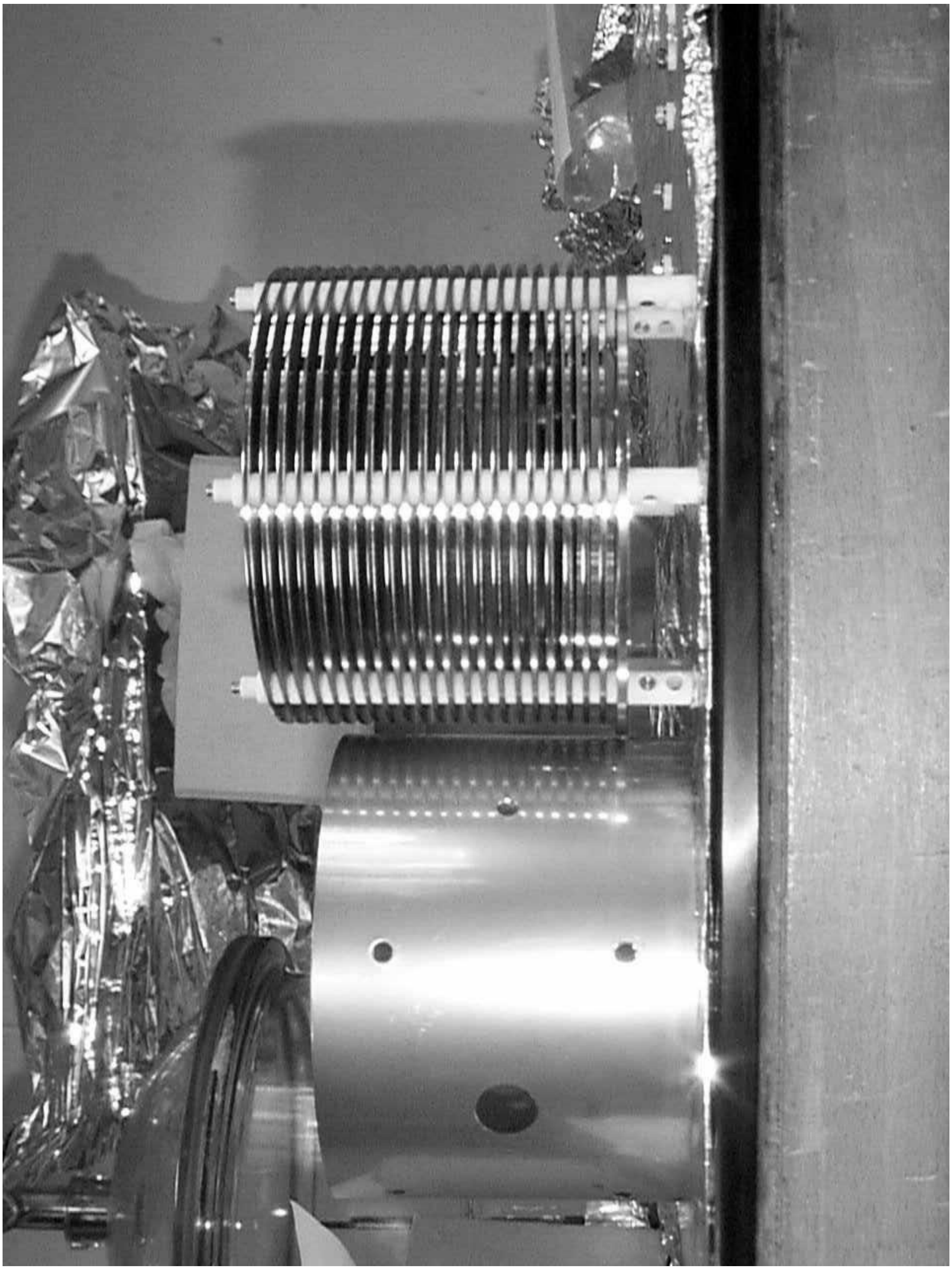
1) Relative measurement of Luminosity: Monitoring of Collision conditions.

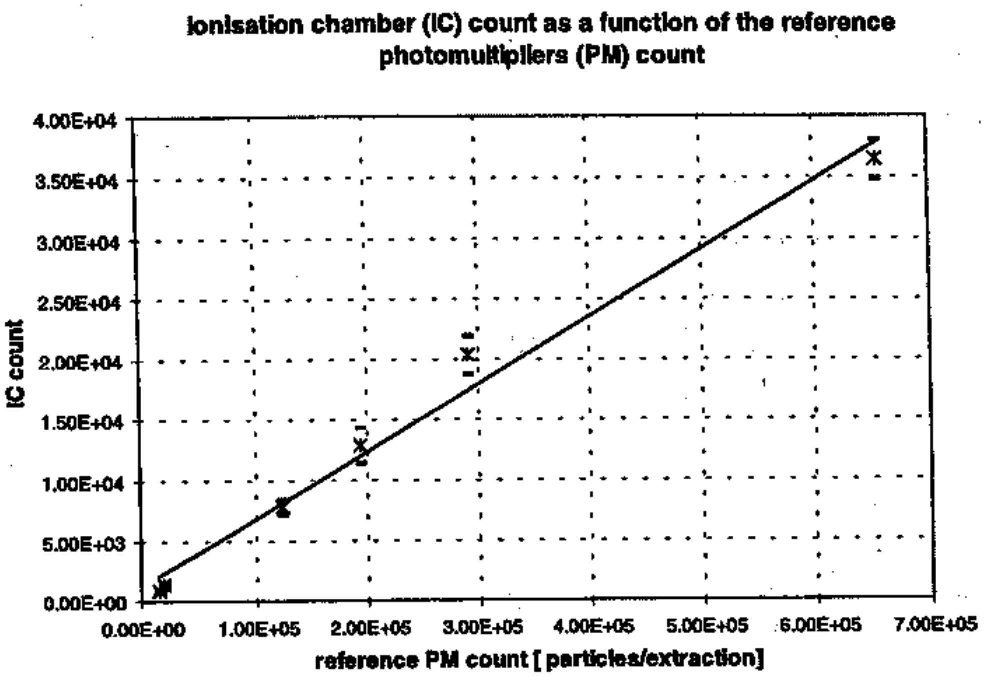
- **Detector reading is fast:**
  Existing SEC electronic can cycle at a few kHz.
  (Precision increases with signal strength)

  ➔ Continuous measurement of beam-beam separation and possibility of feedback systems.

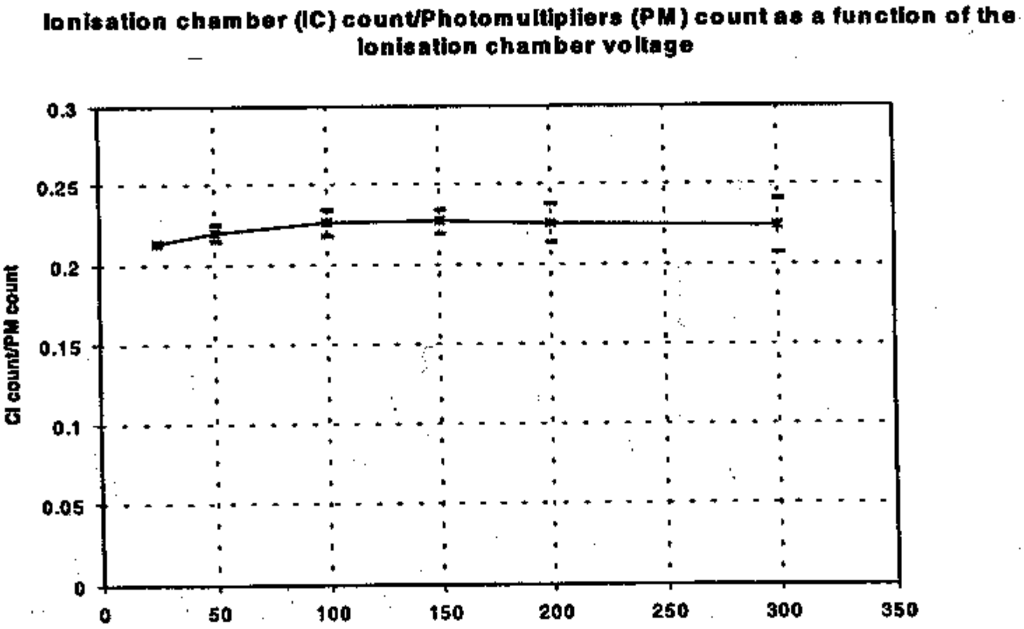
- **Monitors can be installed in all 4 experimental areas:**
  Un-calibrated detector: Optimisation and control of the beam crossings.

  Calibrated detector: Control of the absolute Luminosity.





Linearity of the luminosity monitor in the ionisation mode.



High voltage curve of the luminosity monitor in ionisation mode.

3) Development of a high sensitivity Secondary Emission Counter (J. Bosser, G. Molinari and A.L. Perrot).

- **Modify SEC used on PS extracted beam:**
  10 μm Al (99% purity) foils, 5 mm spacing, 120 mm in ∅,
  IVC 102 amplifier (Burr Brown) + AD 650 voltage to frequency converter (Analog Device).

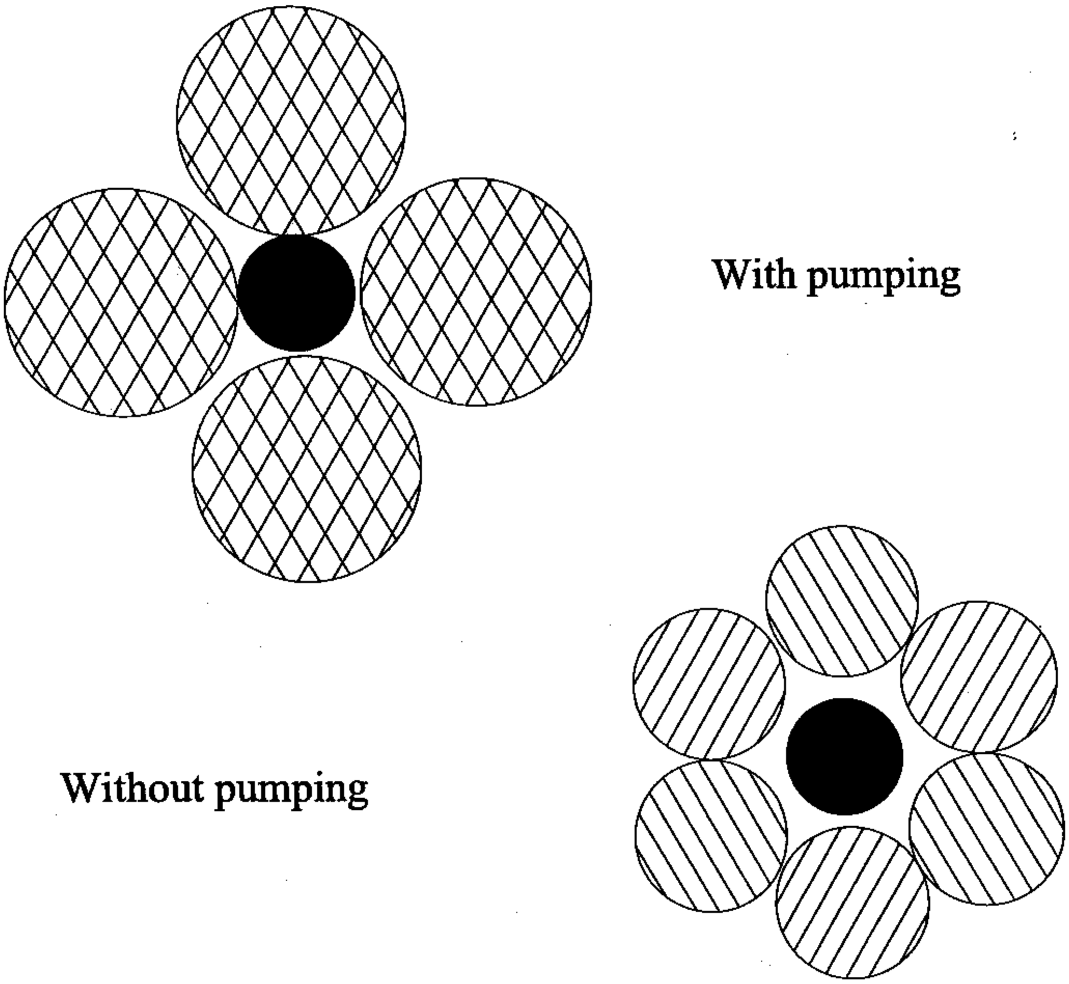
- **Install shielding cylinder to act as a Faraday cup and tri-axial cabling:**
  reduces background noise from pick-up and mass loops.

  ➔ Sensitivity limited by leakage current between Al foils: I~10^{-13} A.

- **Fill chamber with Argon to run in ionisation mode:**
  first beam tests occurred in 98: study luminosity and voltage curve.

- **2 SPS "high intensity" shifts and 4×2 days periods at the PS (T11, <5 10^{5} pps) expected in 99**
  + new prototype with increased isolation between foils.

Possible monitor layout



■ Beam chamber

▧ Secondary Emission counter

▨ Ionisation counter

Summary

Luminosity range	Collision Points	Reading Frequency	Bunch to bunch Luminosity
10^{28} to ≥ 10^{34} $cm^{-2}s^{-1}$	IR5 (&1-2-8)	KHz range	No

➔ **Provides absolute luminosity to experiments once calibrated with TOTEM.**

➔ **Stand alone detector able to run at any time.**

➔ **Available to monitor the beam crossing conditions and to optimise the luminosity.**

Scintillator counters to monitor beam crossing conditions.

Ionisation or SEC chambers are non directional, cannot be gated or used in coincidence, and they will be sensitive to any kind of background.

Scintillator counters can be gated and would allow to increase the signal/background ratio.

However, scintillators deteriorate in a high radiation environment: rad. hard scintillators (co-polymer type) can stand up to $\sim 4\times10^4$ Gray.

Energy deposition simulation (DPMJET II + FLUKA, M. Huhtinen): absorbed dose along the cone $\eta=3$ (100 mrd), at the end of the CMS solenoid (~10 m from IP), is in the range 10^3-10^4 Gray.

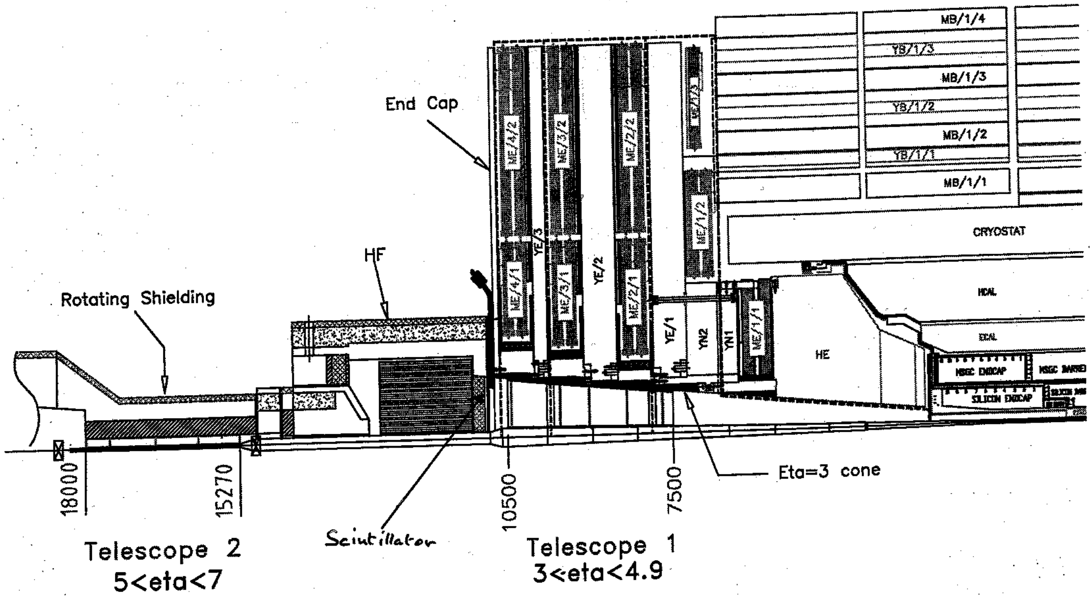
We have $dn/d\eta \sim 8$ tracks/events at $\eta=3$: a 10×10 cm^2 scintillator placed at the end of the CMS solenoid would then count ~ 1% of the inelastic events.

Consider crowns of 16 scintillators on both sides of the IP:

- $OR_{left,}$, OR_{right} count 16% of inelastic events: ~ 100 Hz at $L=10^{28}$ cm^{-2}s^{-1}.
- $(OR_{left})AND(OR_{right})$ counts 2.5% of inelastic events: ~ 15 Hz at $L=10^{28}$ cm^{-2}s^{-1}.

Single rates reach $\sim 6\times10^6$ Hz at $L=10^{34}$ cm^{-2}s^{-1}: still ok, but pile-up effects must be carefully corrected off-line.

CMS case



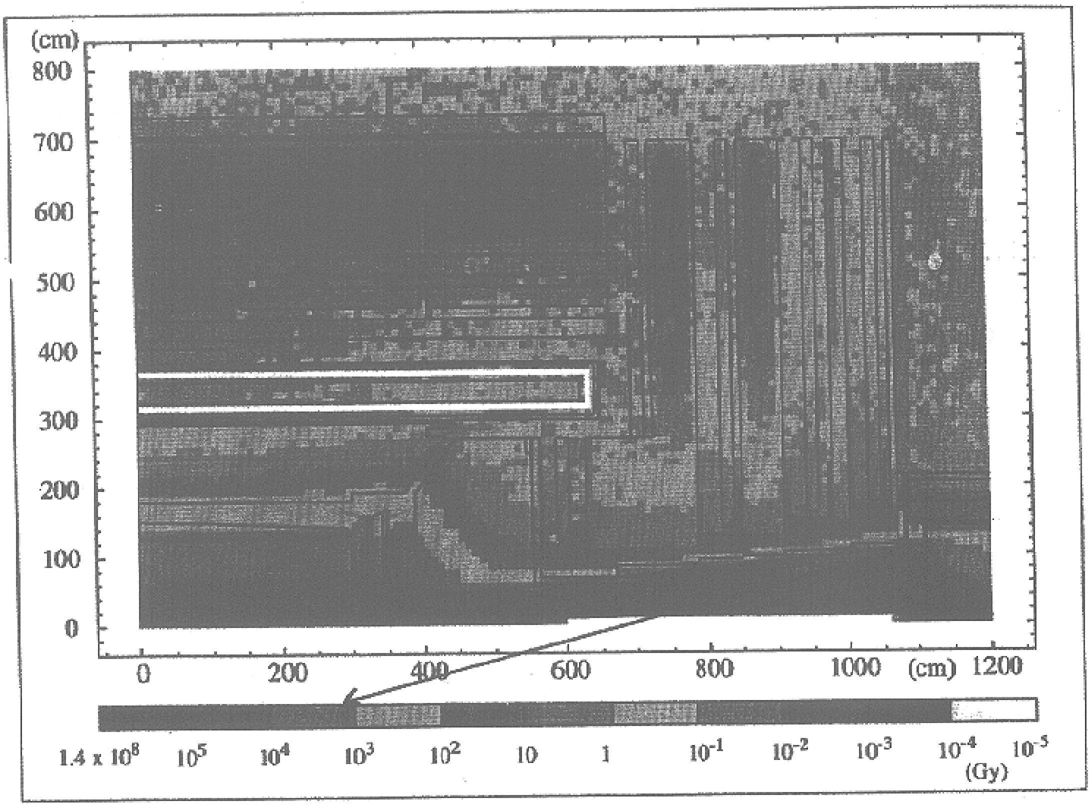
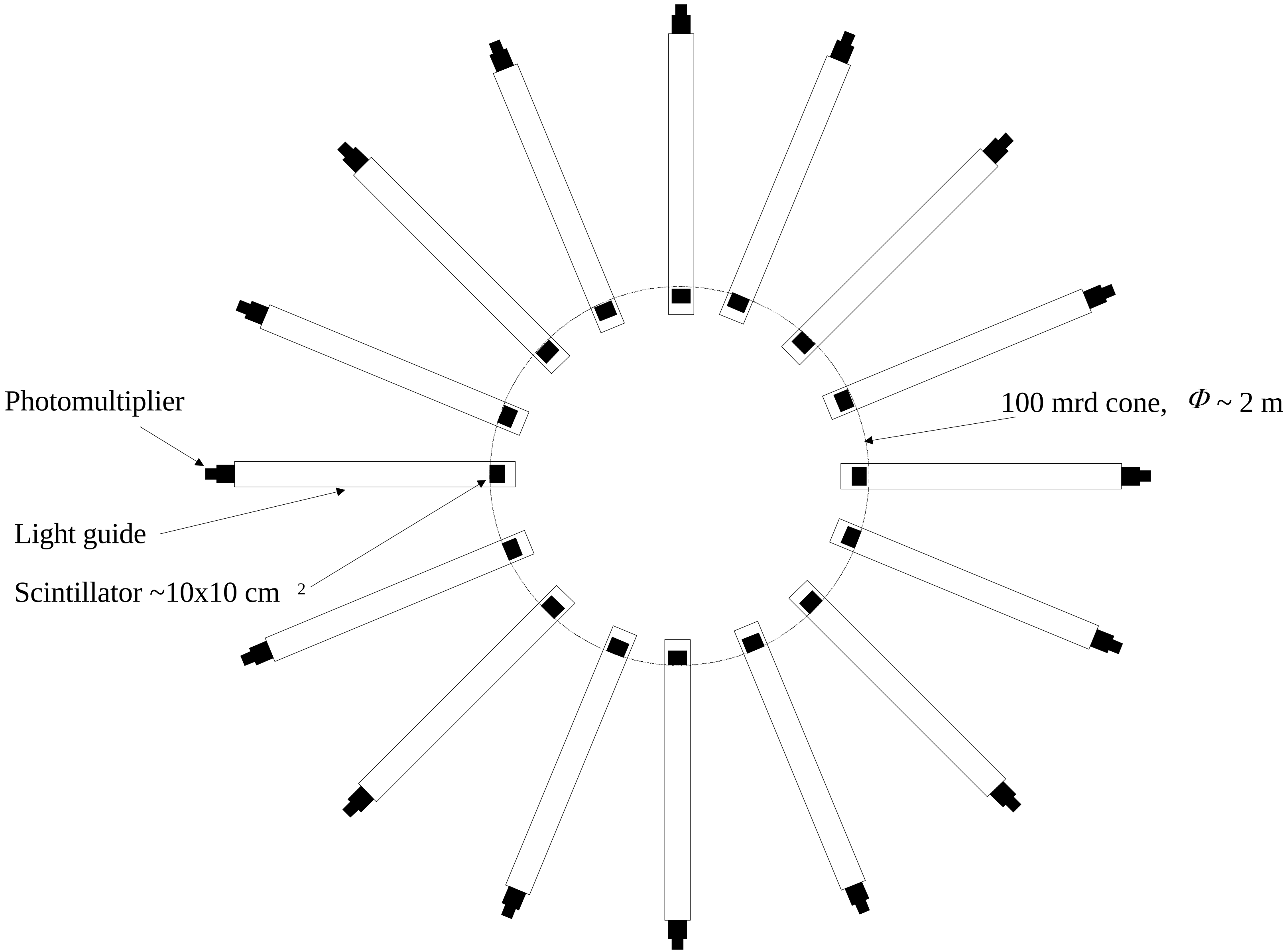
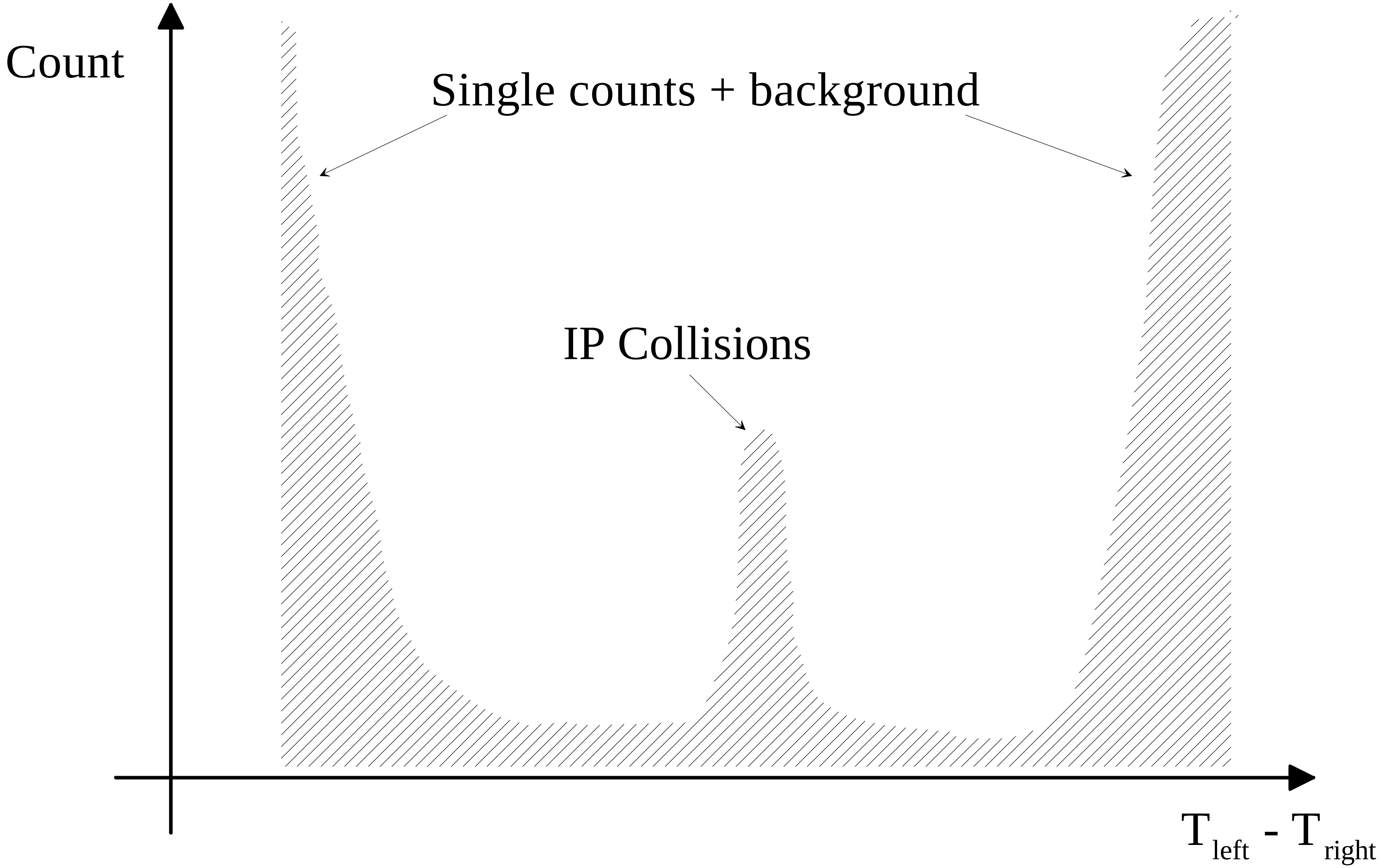


Fig. 10.8.1(color): Absorbed dose (in Gy) in the CMS detector. The values correspond to an integrated luminosity of 5×10^5 pb^{-1}, as expected to be accumulated during the first ten years of LHC operation.


Photomultiplier
Light guide
Scintillator ~10x10 cm 2
100 mrd cone, Φ ~ 2 m

Timing Curve



Longitudinal versus transverse scan in crossing plane.

Longitudinal adjustment of crossing point with independent RF for the 2 rings:

Momentum compaction factor at LHC: $\alpha = \frac{\overline{\mathbf{D}}}{\mathbf{R}} = 3.473\times10^{-4}$.

The length of the closed orbit varies as: $\frac{\mathbf{\Delta L}}{\mathbf{L}} = \alpha \times \frac{\mathbf{\Delta P}}{\mathbf{P}}$.

For $\Delta P/P = 10^{-4}$ (well within aperture), we get $\Delta L = 9.26 \times 10^{-4}$ m per turn.

~ 1.1×10^{4} turns/second ➔ longitudinal bunch de-phasing of ~ 10 m/second.

Consider a swinging “RF scan” of amplitude 7.5 m (inter-bunch distance) at a rate of 1Hz:

Bunches are bound to collide in the crossing plane.

One is left with a transverse scan in the direction orthogonal to the crossing plane.
➔ similar situation to the ISR case with continuous beams.

With a bunch length of 7.5 cm, we will count ~1% of the coincidences expected when the beam crossing conditions are optimal: 1500 to 150K counts/sec. for final luminosity of 10^{32} to 10^{34} $cm^{-2}s^{-1}$.

The final adjustment of the collision point in the crossing plane is obtained when the T_{left}-T_{right} signal is centered.

The proposed TAS and TAN Instrumentation

Bill Turner (LBL)

US LHC ACCELERATOR PROJECT

brookhaven - fermilab - berkeley

Concepts for IR Absorber Luminosity Instrumentation

W.C. Turner
LBNL

Presented at the CERN Tools for Luminosity Optimization mini-Workshop
15-16 Apr. 1999

Why instrument the IR absorbers ?

- The objective for instrumentation of the IR absorbers is to provide LHC machine operations with a simple, reliable, dedicated device for maximizing luminosity for all operating scenarios

A team has been assembled to address IR absorber instrumentation issues:

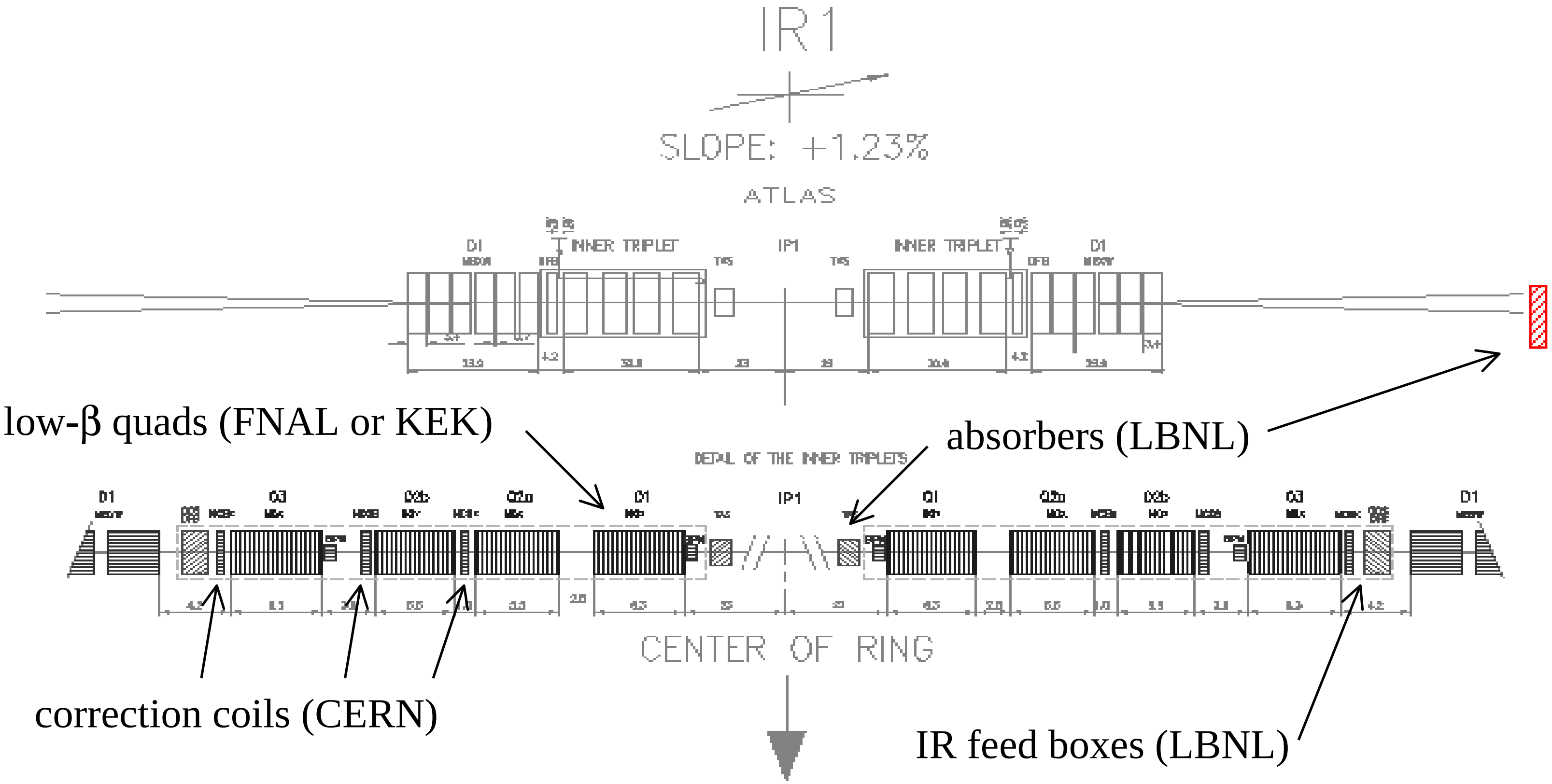
- application to storage ring operation
- beam-beam interaction
- detector physics
- radiation effects
- signal processing and data acquisition
- hardware design

P. Datte
S. Krishnagopal (CAT, India)
E. Hoyer
P.F. Manfredi
N. Mokhov (FNAL)

J. Millaud
D. Nygren
D. Plate
W. Turner

Schematic of components in IP1(5), v6.0

- Luminosity instrumentation would be located in the front quadrupole (TAS) and neutral particle (TAN) absorbers



low-β quads (FNAL or KEK)

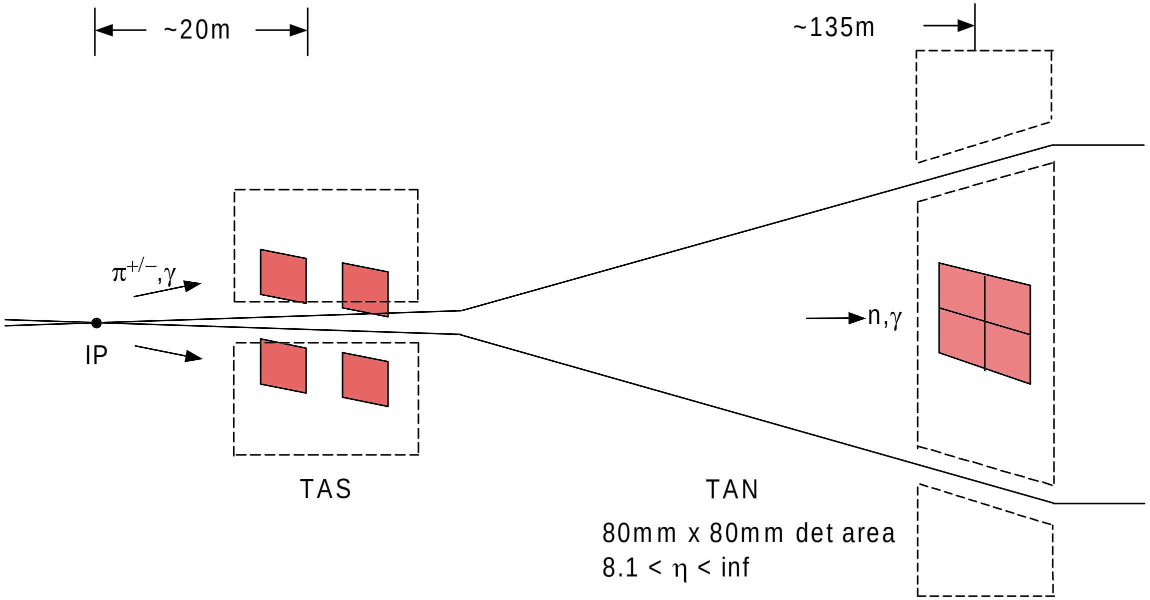
absorbers (LBNL)

correction coils (CERN)

IR feed boxes (LBNL)

Schematic of TAN and TAS instrumentation

- Fast gas ionization sampling chambers are located near the shower maxima inside the absorbers to take advantage of ;
  - multiplication of the collected charge due to shower production and gas ionization
  - increased sensitivity to the most energetic IP collision fragments, shielding from soft particles
  - negligible impact on lattice space



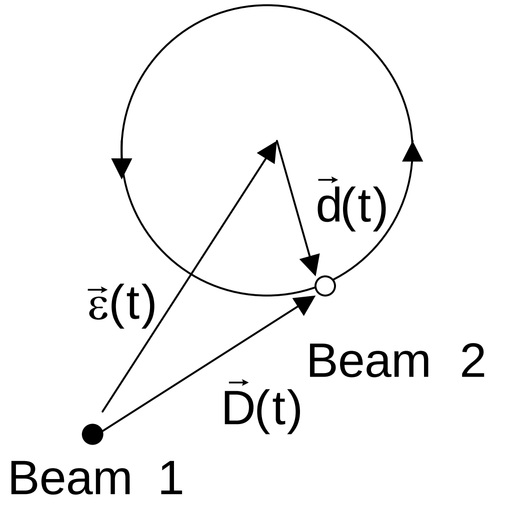
What can be measured with absorber instrumentation?

1. Luminosity
2. Beam-beam separation
3. RMS beam size
4. Beam-beam crossing angle
5. Transverse position of the IP

- Bunch by bunch measurements are feasible
- Measurement of beam-beam separation can be used in feed-back to bring the beams into collision and optimize L
- Items 1. to 3. can be accomplished with TAN only single element detectors
- Items 4. and 5. require segmenting the detectors into quadrants and instrumenting the TAS and TAN

- An intentional transverse sweep of one beam introduces a time dependent modulation of luminosity
  - $\boldsymbol{\varepsilon}$ = error offset amplitude
  - d = intentional sweep amplitude

$$L \approx L_0 - L_0 \frac{\varepsilon d}{2\sigma_*^2}\cos(\omega t - \varphi);\ \varepsilon, d << \sigma_*$$



- Define the detector current

$$I(t) = e\alpha\varepsilon_{\det} m\sigma_{inel} L$$

- Integrate to obtain the luminosity and error offset, 0 < *t* < *T*, $T = n\frac{2\pi}{\omega}$

$$L_0 = \frac{\int_0^T I(t)dt}{e\alpha\varepsilon_{det} m\sigma_{inel} T};\qquad \vec{\varepsilon} = -\frac{\hat{e}_x \int_0^T \cos(\omega t) I(t)dt + \hat{e}_y \int_0^T \sin(\omega t) I(t)dt}{\left(\frac{d}{4\sigma_*^2}\right) e\alpha\varepsilon_{\det} m\sigma_{inel} T}$$

- Integration times are sufficiently short to be practical even for the lowest luminosity envisioned (TOTEM)
  - Bunch by bunch measurements increase the integration times by the number of bunches (x2835 for L = 10^{34}, x236 for TOTEM)
  - The practical sweep frequency needed for beam-beam separation measurements (1 Hz ?) will determine the integration time at the highest luminosity

		Integration time(sec/turns)		
L $cm^{-2}s^{-1}$	$\frac{\sigma_L}{L} = 0.01$	$\sigma_\varepsilon = 0.1\sigma_*$	$\sigma_\psi = 1\mu rad$	$\sigma_{a_X^*} = \sigma_*$
10^{34}	$6.2\text{x}10^{-5}$/ 0.7	$1.0\text{x}10^{-3}$/ 11	$2.55\text{x}10^{-4}$/ 2.9	$3.8\text{x}10^{-3}$/ 42.6
10^{28}	62/ $7.0\text{x}10^{5}$	$1.0\text{x}10^{3}$/ $1.1\text{x}10^{7}$	$2.55\text{x}10^{2}$/ $2.9\text{x}10^{6}$	$3.8\text{x}10^{3}$/ $4.26\text{x}10^{7}$

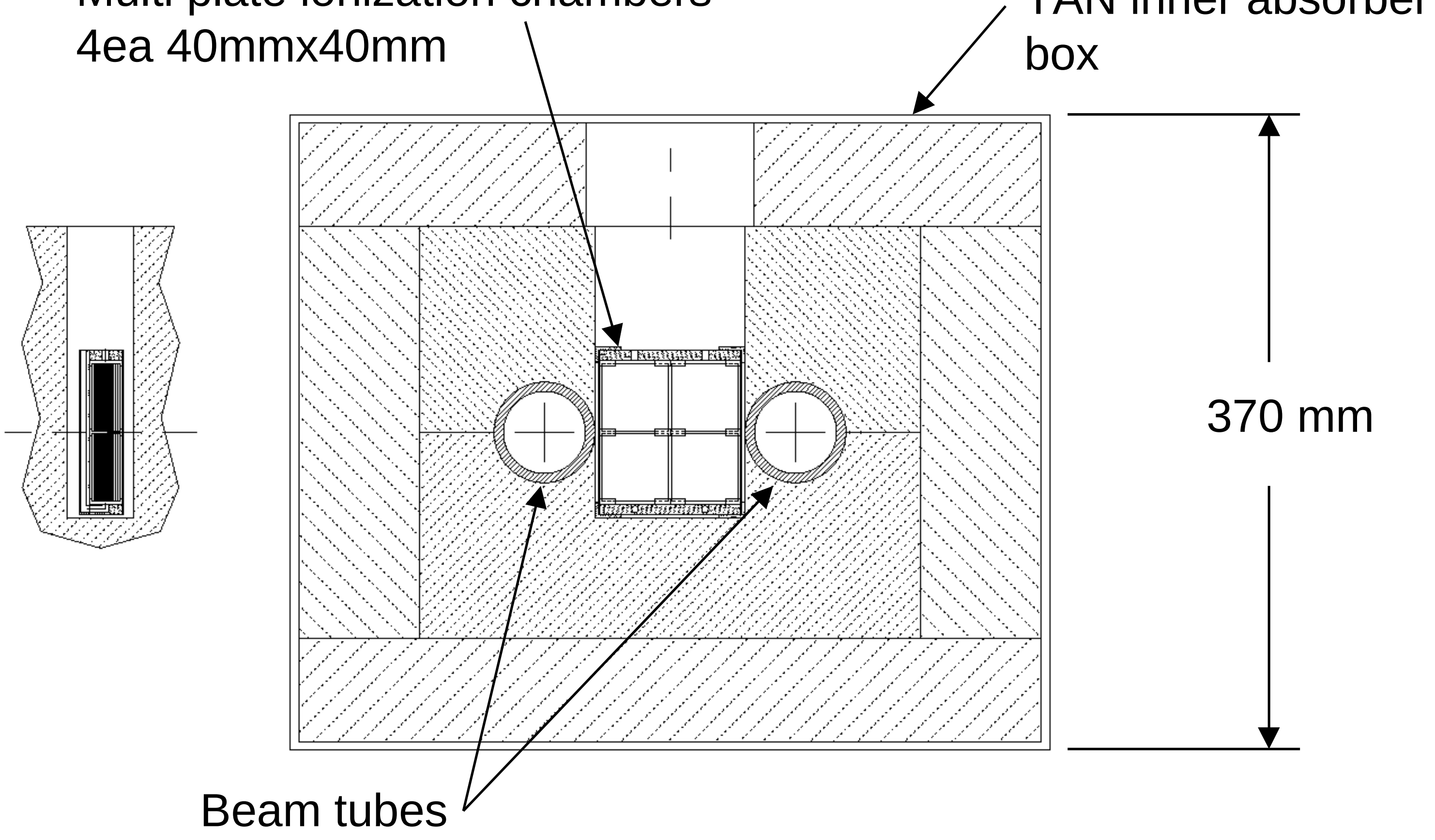
Bringing the beams into initial collision

- One approach - start with a coarse grid map with successively finer mesh followed by application of the beam sweeping method with successively smaller radii
- An extreme example - TOTEM, L = $10^{28}\text{cm}^{-2}\text{s}^{-1}$

Domain	Grid size	$\delta L/L$	Integration time (sec)
$\pm 4\sigma \times \pm 4\sigma$	2σ	10%	15.5
$\pm 2\sigma \times \pm 2\sigma$	1σ	5%	62.5
Sweep radius		σ_ε	
1σ	NA	1σ	10
$.5\sigma$	NA	$.5\sigma$	40
$.2\sigma$	NA	$.2\sigma$	250
$.1\sigma$	NA	$.1\sigma$	1000

- Total integration time allowing for two iterations of each beam sweep = approximately 45 min

Layout of TAN ionization chamber



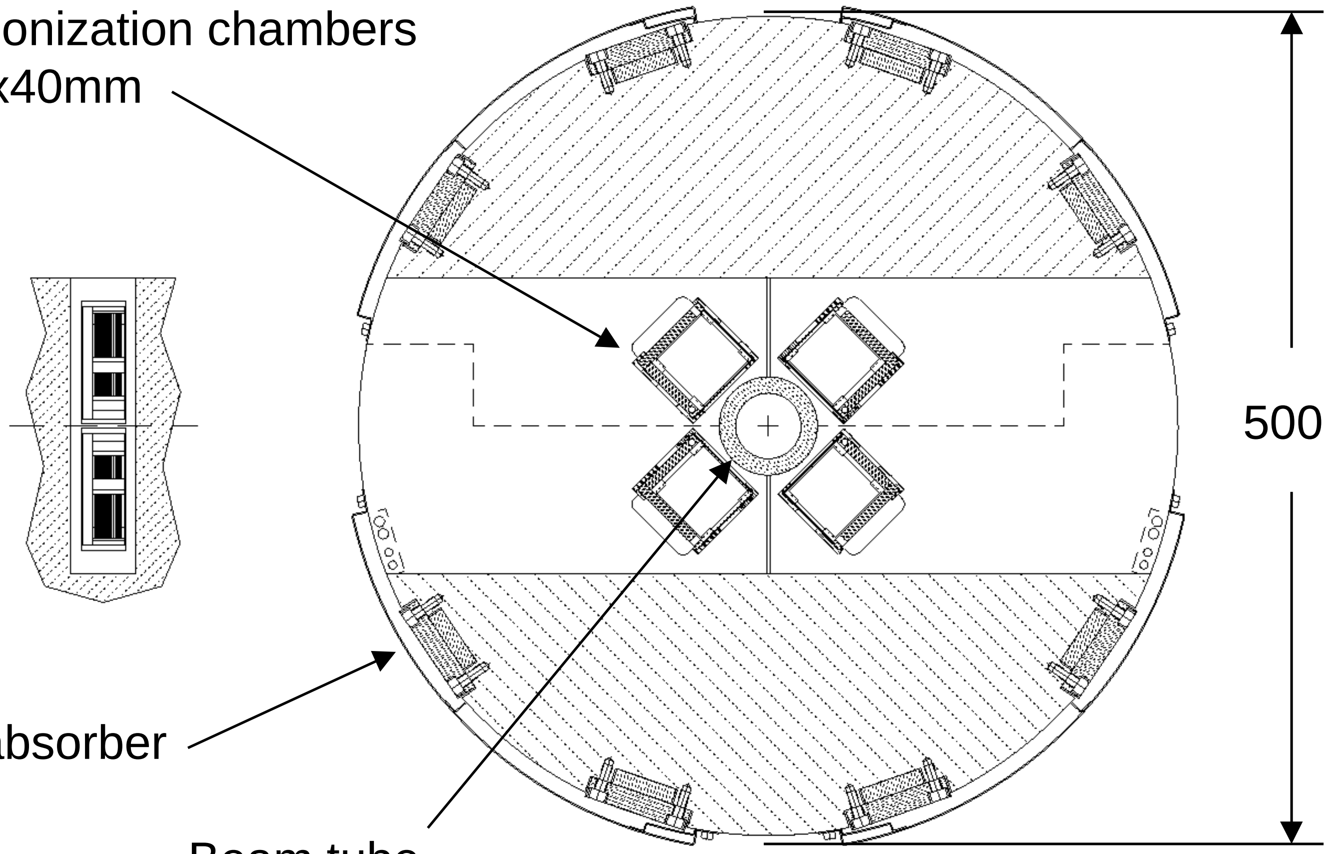
Multi plate ionization chambers
4ea 40mmx40mm

TAN inner absorber box

370 mm

Beam tubes

Layout of TAS ionization chamber



Multi plate ionization chambers
4ea 40mmx40mm

500 mm

TAS absorber

Beam tube

Parameters for an ionization chamber module:

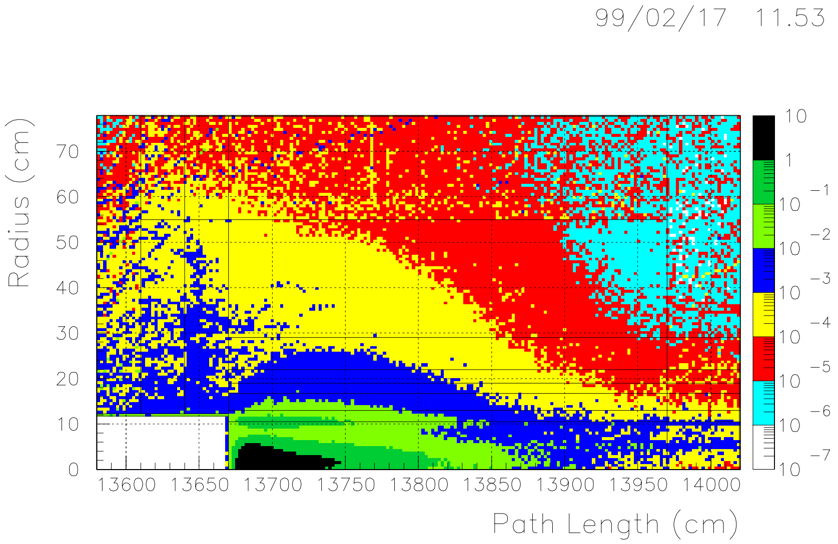
Active area(1 quadrant)	40mm x 40mm	
Plate gap	0.5 mm	
No. of gaps	12	
Capacitance/gap	28.3 pF	
Gas	Ar+N_2(1%), 760 Torr	
Elec gap transit time	21.7 nsec	
Bunch freq/Rev freq	40.079 MHz/11.2455 kHz	
Bunch structure	12x(3x81+2x8+38) = 3,564	
Inel pp int/bunch xing@10^{34}	20	
mip per pp int	268	
mip per bunch xing@10^{34}	5.35×10^3	
Electron/ion pairs/cm-mip	97	
Ioniz e^-/pp int	1.3×10^3(1 gap)	1.56×10^4(12 gaps)
Ioniz e^-/bunch xing@ 10^{34}	2.6×10^4(1 gap)	3.1×10^5(12 gaps)

Dynamic range

- The magnitude of charge collected in a single pp interaction is adequate for pulse shaping, digitizing and acquisition (see companion presentation by Datte and Manfredi)
- If the data are accumulated bunch by bunch, the dynamic range needed for front end electronics is a factor of ~ 40 to cover luminosity from an arbitrarily low value up to 10^{34} cm^2sec^{-1} bb
- The dynamic range increases linearly with the bunch accumulation factor

- Radiation deposition and activation have been studied in great detail with the MARS code
  - power density ~ 3 W/kgm at ionization chambers
  - power density < 10^{-5} W/kgm at front end electronics located on the outer radius and at the back of the TAN
- Although the ionization chambers become activated there do not seem to be difficulties with induced radiation background or radiation damage to sensitive electronics

TAN power deposition (mW/gm)



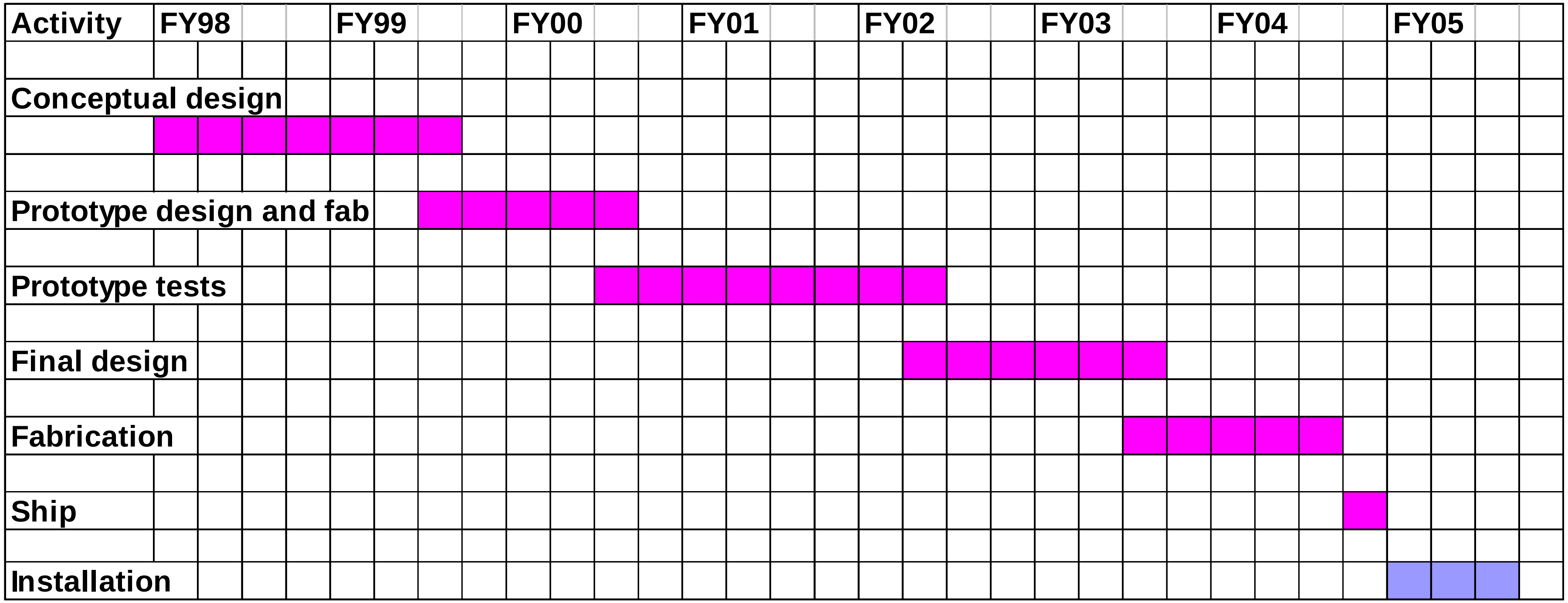
Backgrounds

- Backgrounds and systematic effects have been examined due to
  1. beam gas collisions
  2. beam-halo scraping
  3. drift of the IP position
  4. drift of crossing angle
  5. ac modulation of the crossing angle at the beam sweeping frequency
  6. activation of the Cu absorber and ionization chamber gas
  7. electronic noise
- Items 4. and 5. contributed the largest backgrounds (to luminosity and beam-beam separation respectively)
- In all cases the backgrounds have been estimated to be small compared to the expected signals

Estimated luminosity background rates are small compared to the pp inelastic collision rate

Process	Scaling	Rate(sec-1)
pp inel. collisions	~L	8×10^8
beam gas collisions (10^{-10}Torr)	~$L^{1/2}$	3.5×10^4
beam halo scraping (1:6,500 cleaning eff)	~L	8×10^4
1μm slow drift of IP	~L	8×10^3
1μrad slow drift of xing angle	~L	1.2×10^6

Preliminary schedule



Activity	FY98				FY99				FY00				FY01				FY02				FY03				FY04				FY05			
Conceptual design																																
	🟪	🟪	🟪	🟪	🟪	🟪	🟪																									
Prototype design and fab							🟪	🟪	🟪	🟪	🟪																					
Prototype tests											🟪	🟪	🟪	🟪	🟪	🟪	🟪	🟪														
Final design																		🟪	🟪	🟪	🟪	🟪	🟪									
Fabrication																							🟪	🟪	🟪	🟪	🟪					
Ship																												🟪				
Installation																													🟦	🟦	🟦	

Options for IR absorber instrumentation

- Instrument TAN only or TAN + TAS
- Instrument IPs 1 and 5 or IPs 1,2,5 and 8
- Single bunch (40 MHz) or multi-bunch bandwidth (~4 MHz)
- Quadrant or single element ionization chambers

Summary

- Instrumentation of the IR absorbers is a potentially useful beam operations tool for optimizing luminosity
- Gas ionization chambers are practical radiation hard devices that can be engineered for high reliability
- Operational characteristics can be validated under LHC like conditions in an SPS test beam with 25 nsec bunched protons (H4 beamline)

Cold Silicon Detectors

Vittorio Palmiery (EP/N50)
Tapio Niinikoski (EP/ATT-SC)

Cold Silicon detectors as Technological Alternative

Vittorio Palmieri and Tapio Niinikoski
CERN EP Division 1211 Geneva 23

on behalf of the

CERN-RD39 Collaboration
http://www.cern.ch/RD39

The CERN-RD39 Collaboration

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B. Dezillie[11], Z. Dimcovski[8], V. Eremin[12], A. Esposito[13], V. Granata[9,14], E. Grigoriev[3,8],
F. Hauler[3], E. Heijne[14], S. Heising[3], S. Janos[5], L. Jungermann[3], I. Konorov[13], Z. Li[11],
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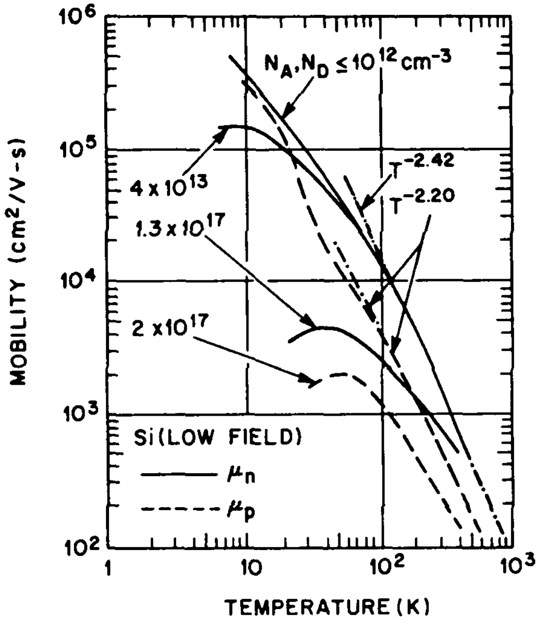
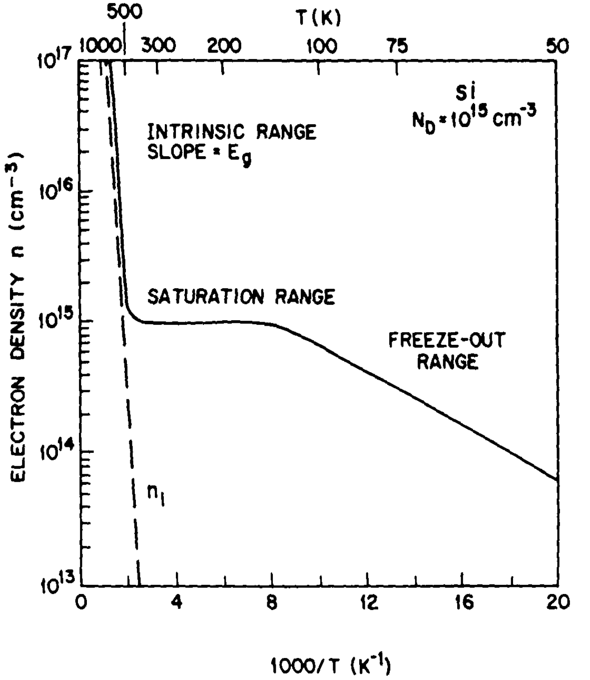
Outline

- Properties of Si at cryogenic temperatures
- CCE of heavily irradiated Si detectors at cryogenic temperatures (up to $2 \cdot 10^{15}$ n/cm$^{2)}$
- Neutralization of induced defects: the Lazarus effect
- Tracking efficiency and position resolution of an irradiated DELPHI module ($4*10^{14}$ n/cm^2)
- Beam monitoring and diagnostic
- Cold silicon for luminosity measurements

Properties of Silicon at Cryogenic Temperatures





Why is the present technology not sufficient ?

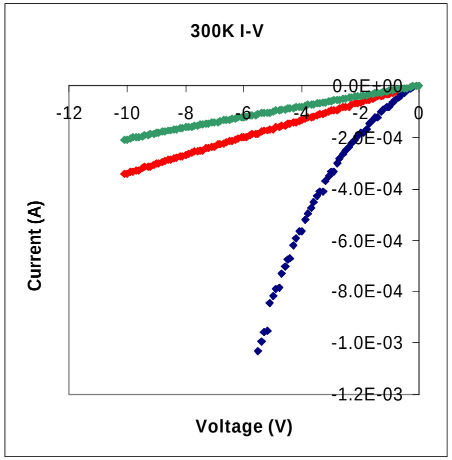
… and how can we improve it ?

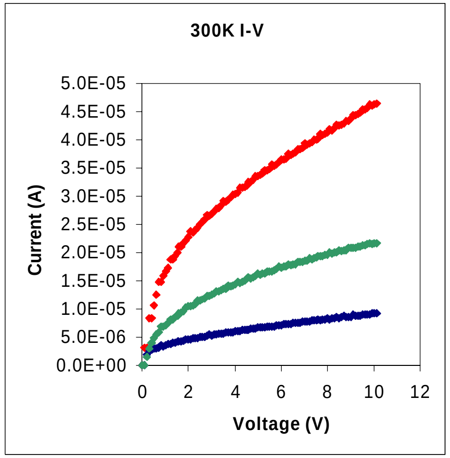
Irradiated Si Detectors

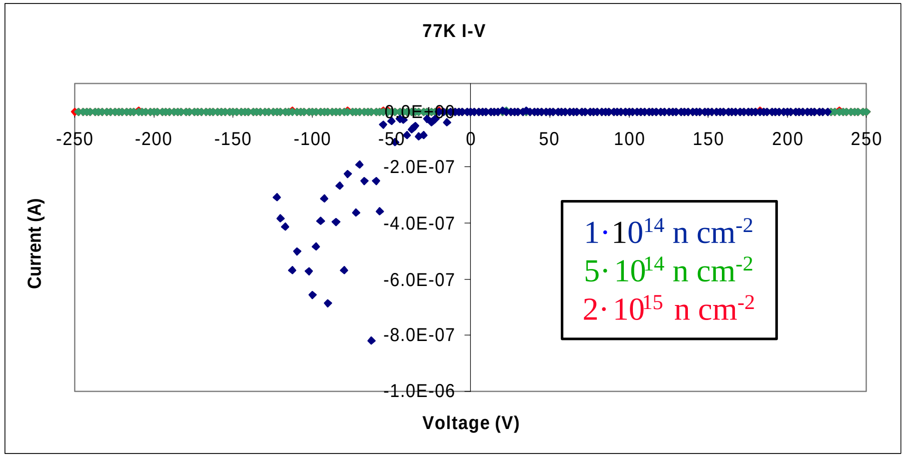
- Irradiated at room temperature at TRIGA neutron reactor, JSI Slovenia
- Stored at room temperature and subjected to thermal cycles, therefore strongly reverse annealed (RA)
- Different materials and processes:
  - Al/n+/n/p+/Al 1.8 kΩ cm
  - Al/n+/n/p+/Al 2.7 kΩ cm
  - Al/n+/n/p+/Al 4 kΩ cm

Preliminary

Current-Voltage Characteristics

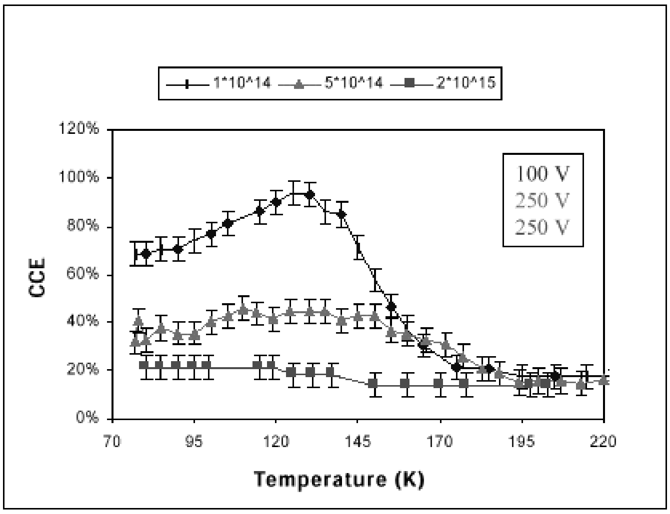






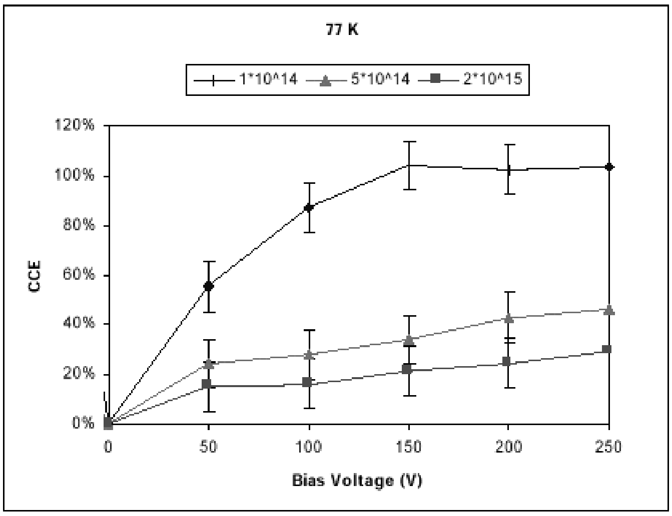
Preliminary

Temperature Dependence of CCE



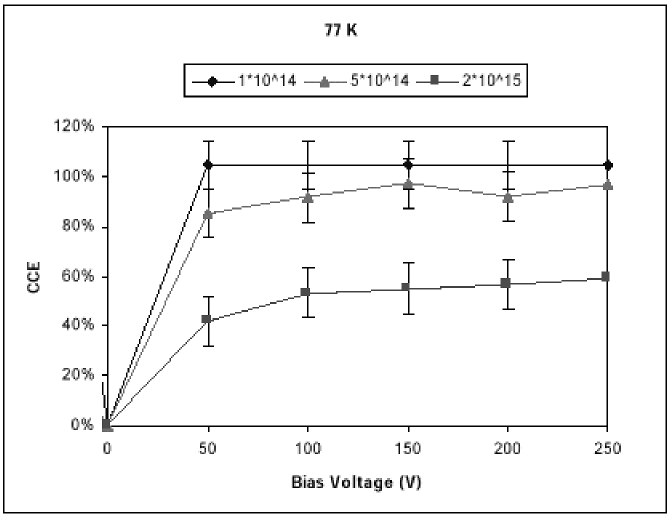
Preliminary

Voltage Dependence of CCE



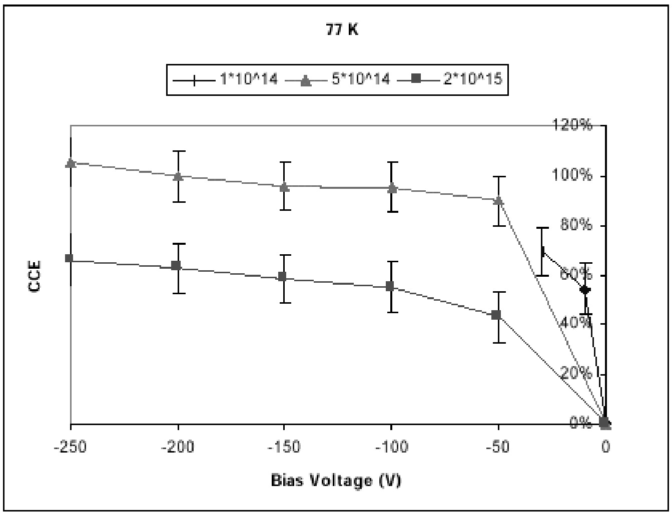
Preliminary

Voltage Dependence of CCE "pumped"



Preliminary

Voltage Dependence of CCE "forward bias"



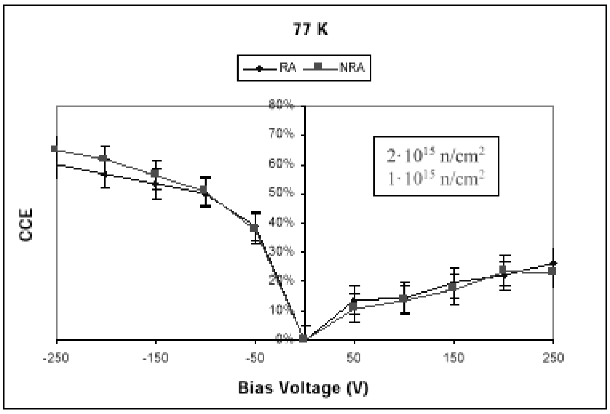
How do we explain all this ?

The Lazarus Effect

What is the role of long term annealing?

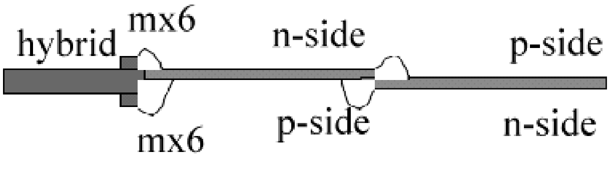
Preliminary

Annealing Effects ...



The charge is back, but what about position resolution ?

The DELPHI Module



V. Chabaud et al., CERN-PPE/95-86, 1995

Detectors:

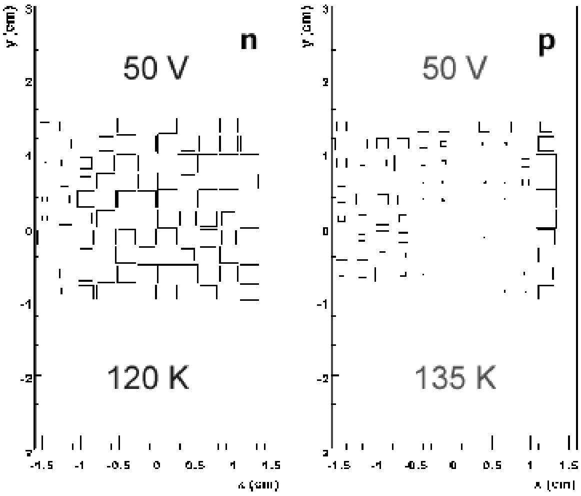
2x Hamamatzu
320 μm 5.75 x 3.2 cm^2 3-6 Kohm cm
p-side 640 strips
  strip pitch 25 μm
  r-o pitch 50 μm
n-side 640 strips (p-stops)
  strip pitch 42 μm
  r-o pitch 42 μm

Electronics:

10x Mx6
128 input channels
CMOS technology
2.5 MHz speed
1.5 μs peaking time
"radiation soft"

Preliminary

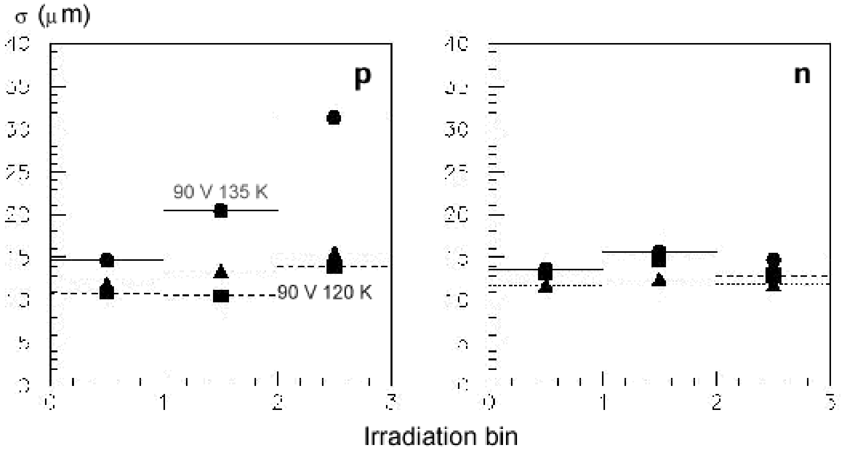
Back from the Dead ...



L. Casagrande et al., CERN-EP/98-207, 1995

Preliminary

Position Resolution



RD39 15.4.1999 T. NIINIKOSKI

COLD Si DETECTOR AS LUMINOSITY MONITOR

① RADIATION HARDNESS

OPERATION POSSIBLE UP TO

$$\Phi_{max} = 2 \cdot 10^{15}\ n/cm^2$$

RATE AT 16 m FROM IP,
20 mm FROM BEAM

$$\dot{\Phi} = 10^{8}\ cm^{-2}s^{-1} \qquad \text{(TOTEM Prop.)}$$

$$@\ \mathcal{L} = 2 \cdot 10^{34}\ cm^{-2}s^{-1}$$

⇒ LIFETIME

$$t_{exp} = \frac{\Phi_{max}}{\dot{\Phi}} = 2 \cdot 10^{7}\ s = 231\ d$$

② LINEARITY

CALIBRATION AT $\mathcal{L} = 10^{28}\ cm^{-2}s^{-1}$

OPERATION AT $\mathcal{L} \leq 2 \cdot 10^{34}\ cm^{-2}s^{-1}$

⇒ DYNAMIC RANGE OF 6 ORDERS OF MAGNITUDE REQUIRED

- LINEARITY OVER 10^6 HAS BEEN TESTED USING Pb BEAM AT SPS (ALSO WITH p)
- PROTON TEST WILL TAKE PLACE IN MAY 1999

③ TIME AND POSITION RESOLUTION

MOBILITY INCREASES AT LOW TEMPERATURE

⇒ SIGNAL PEAKING TIME BELOW 5 ns IS POSSIBLE

⇒ BUNCH-BY-BUNCH MEASUREMENT OF $\mathcal{L}$ IS POSSIBLE

SEGMENTED DEVICES HAVE BEEN TESTED AT 80 K

⇒ MICROSTRIP DETECTOR POSITION RESOLUTION <u>CAN</u> BE PRESERVED

⇒ PIXEL DETECTORS OPERATED AT TEMPERATURE OF 80 K

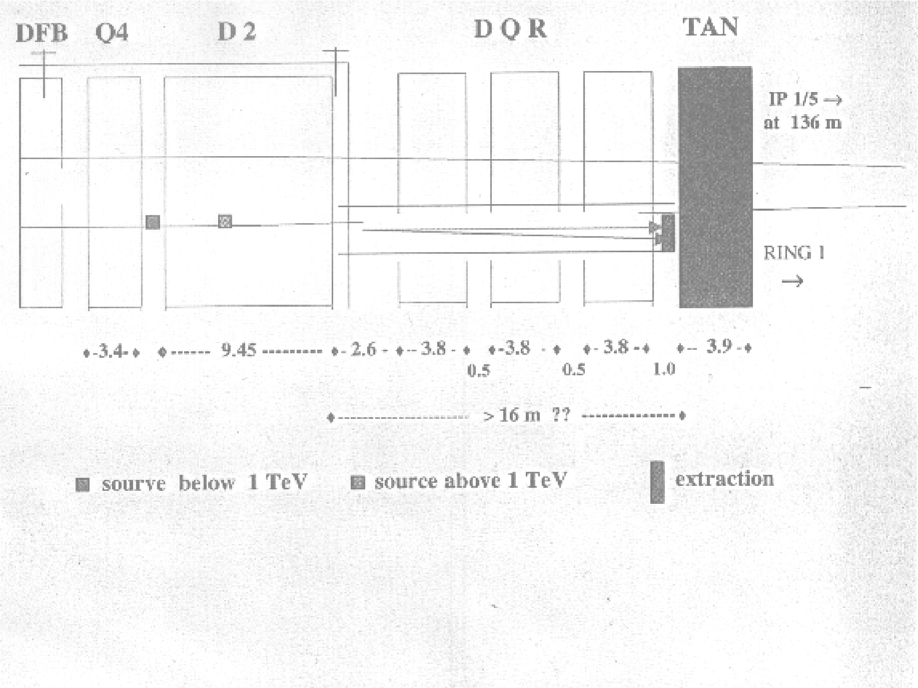
④ SENSITIVITY TO FIELD, TEMPERATURE, LIGHT etc.

LOW MAGNETIC FIELDS : OK
TEMPERATURE : STABILIZED, LOW SENS.
LIGHT : CANNOT OPERATE IN BEAM PIPE

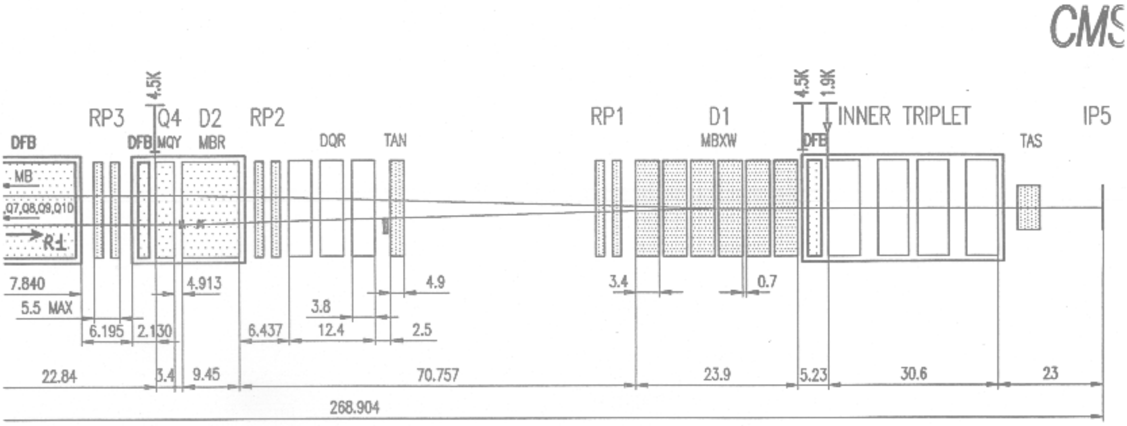
Implications of the TAN
for the LHC Layout

Claude Fischer (SL/BI)

Synchrotron Light Monitor Considerations



Synchrotron Radiation Monitor Lay-out
in IR1 or IR5



Synchrotron Radiation Monitors

----[1]----

- *Proposal is to use the following light sources:*

  from 450 GeV up to 1 TeV: D2 stray field (upstream)

  from 1 TeV onwards: D2 dipole field (≅ 3m inside D2)

- *and to* **extract** *the light* **25 m downstream D2 (upstream TAN)**, *where the beam is deflected and where there is* **no cryostat.**

- **IR1/5 more favourable than IR2/8** *as beam optics makes beam dimensions larger* ($\sqrt{2}$) *which reduces the relative influence of* **parasitic effects:**

$\varepsilon_n = 3.75\ \mu$rad

	Injection optics v5		Collision optics v5
E (TeV)	.45	7	7
Source	**Stray-field**	**dipolar field**	**dipolar field**
$\beta_{H,V}$ (m)	**224 , 110**	**215, 107**	**1588, 467**
$\sigma_{H,V}$ (mm)	**1.322, 0.926**	**0.328, 0.232** *most critical*	**0.893, 0.484**

Extraction upstream TAN (mirror location):

$\beta_{H,V}$ (m)	**125, 87**	**125, 87**	**1650, 1500**
$\sigma_{H,V}$ (mm)	**0.988, 0.824**	**0.251, 0.209**	**0.911, 0.868**

C. Fischer, LHC Luminosity Workshop,15 April 1999.

Bump Separation Scheme

☐ *Bump shape not frozen yet; but* **angle and separation** *are specified and with present* **bump configuration** *the region of interest for the S.R. monitor can be investigated.*

☐ **two nominal bumps** *as proposed* **in IP1/5** *considered*.

☐ *The* **radial plane** *is more important as* **D2** *acts in this plane.*

☐ **BUMP #1:**

H angle (± 150 µrad):	**kept in collision**
V separation (± 2.5 mm):	**suppressed in collision**

☐ **BUMP #2:**

H separation (± 2.5 mm):	**suppressed in collision**
V angle (± 150 µrad):	**kept in collision**

Polarity can be inverted ?

C. Fischer, LHC Luminosity Workshop,15 April 1999.

BUMP #1

- ☐ *Its impact on the beam trajectory for the two polarities.*
- ☐ **Three light sources considered** *namely*:
  - a): *located at the bump extremum upstream D2 (second dipole bumper); it gives the direction of the* **background light** *generated upstream our sources* **(dipoles & Q4).**
  - **b):** *gives the direction of the light generated by the* **fringe field of D2** *(up to 1 TeV).*
  - c): *for the light emitted* **3 m inside D2** *(beyond 1 TeV).*
- ☐ **Extraction mirror** *at* **20 m** *from* **D2 exit** *end with* **TAN** *starting* **1.3 m downstream***)*

H angle > 0:

at the mirror, ● **b)** ***is separated from*** **a)** ***by*** **11.3 mm**
● **c)** ***is separated from*** **a)** ***by*** **20.5 mm**

● **beam axis** *at* **18 mm** *from* **non tilted machine axis**
⇒ **to maintain a clearance of :**

$$\boxed{12\,\sigma_H + \underset{\overset{\uparrow}{\textbf{tolerance}}}{1\text{ mm}} + \underset{\overset{\uparrow}{\textbf{closed orbit}}}{4\text{ mm}} = 16 \text{ to } 17\text{ mm}}$$

the top of the mirror must stay within +1 mm
⇒ **at the axis of shower c)**

⇒ **shower is cut at its maximum**
⇒ **signal reduction**
⇒ **relatively higher diffraction effects**

Solution is to push the mirror further

H angle < 0:

at the mirror,

- b) *is separated from* a) *by* 11.3 mm
- c) (operational source) *is separated from* a) (background) *by* only 2 mm ⇒ bad conditions
- beam axis *at* 34 mm *from* non tilted machine axis
  ⇒ to maintain a clearance of :

$12\,\sigma_H + 1\text{ mm} + 4\text{ mm} \doteq 16\text{ to }17\text{ mm}$

↑ ↑

tolerance closed orbit

the top of the mirror must stay within +17 mm
⇒ again at the axis of shower c)

By increasing the distance of the light extraction from 20m to ≥ 25 m from D2, situation is much better:

- H angle < 0: is not convenient due to previous point

but

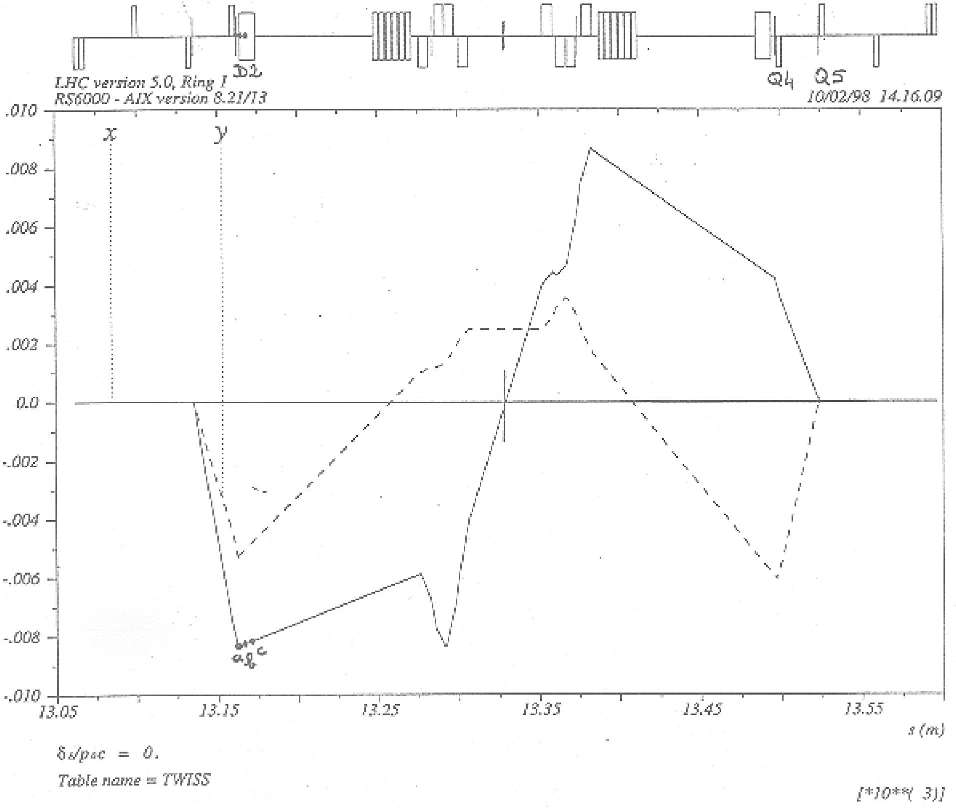
- H angle > 0: beam axis is then at 24 mm

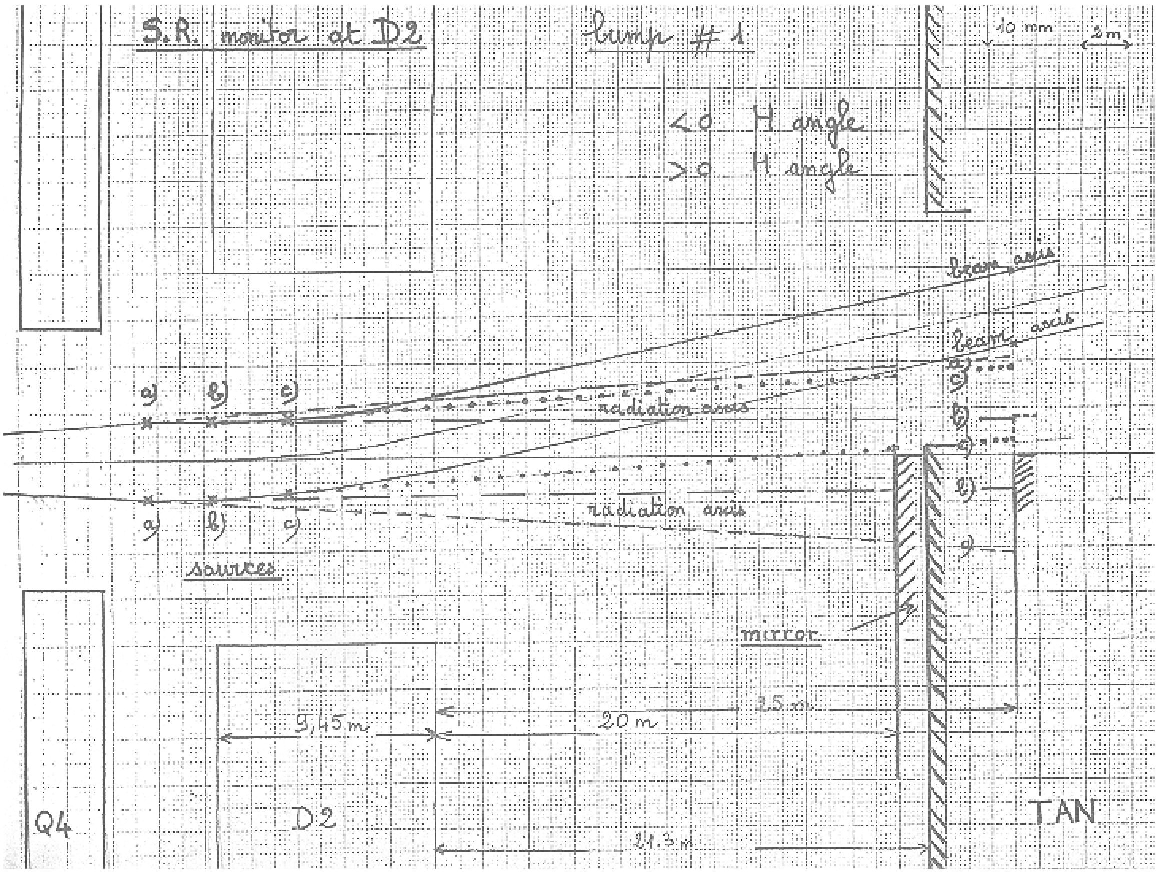
mirror can be set up to + 7 mm while maintaining the clearance, i.e.

4 mm (1 σ_{ph}) beyond c) shower axis

---

bump # 1


Q5 Q4
D2
D2
Q4 Q5
LHC version 5.0, Ring 1
RS6000 - AIX version 8.21/13
10/02/98 14.16.09
x (m), y (m)
x
y
.010
.008
.006
.004
.002
0.0
-.002
-.004
-.006
-.008
-.010
a b c
13.05
13.15
13.25
13.35
13.45
13.55
s (m)
δs/p₀c = 0.
Table name = TWISS
[*10**(3)]


S.R. monitor at D2
bump # 1
10 mm
2 m
<0 H angle
>0 H angle
beam axis
beam axis
a)
b)
c)
a)
b)
c)
radiation axis
radiation axis
a)
b)
c)
a)
b)
c)
sources
mirror
9,45 m
20 m
25 m
21,3 m
Q4
D2
TAN

BUMP #2

H separation > 0:

at the mirror,
- **b)** ***is separated from*** **a)** ***by*** **9.7 mm**
- **c)** ***is separated from*** **a)** ***by*** **19.1 mm**

1.5 mm less than with bump #1

- **beam axis** ***at*** **22 mm** ***from*** **non tilted machine axis**

⇒ to maintain a clearance of :

$$\boxed{12\,\sigma_H + \underset{\substack{\uparrow \\ \text{tolerance}}}{1\text{ mm}} + \underset{\substack{\uparrow \\ \text{closed orbit}}}{4\text{ mm}} = 16\text{ to }17\text{ mm}}$$

the top of the mirror must stay within +5 mm

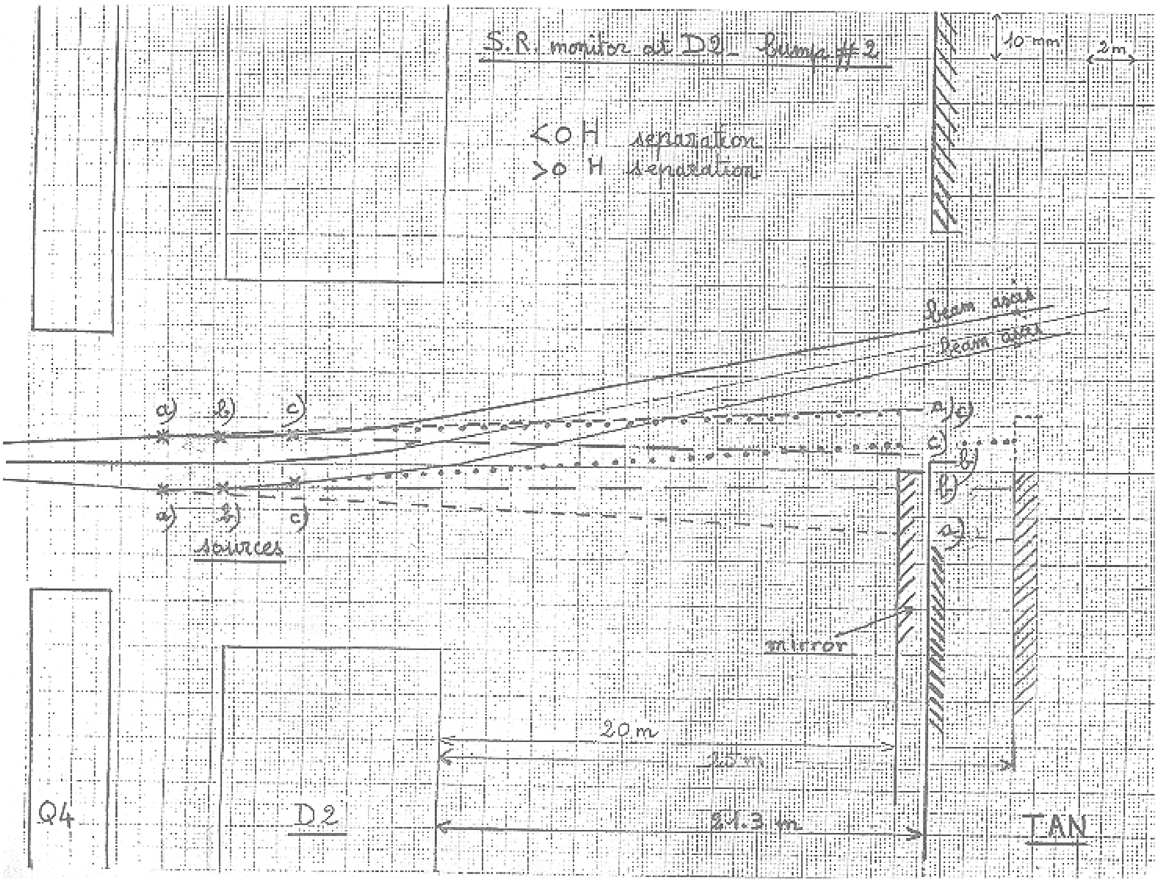
⇒ again at the axis of shower c)

H separation < 0: (mandatory in one ring)

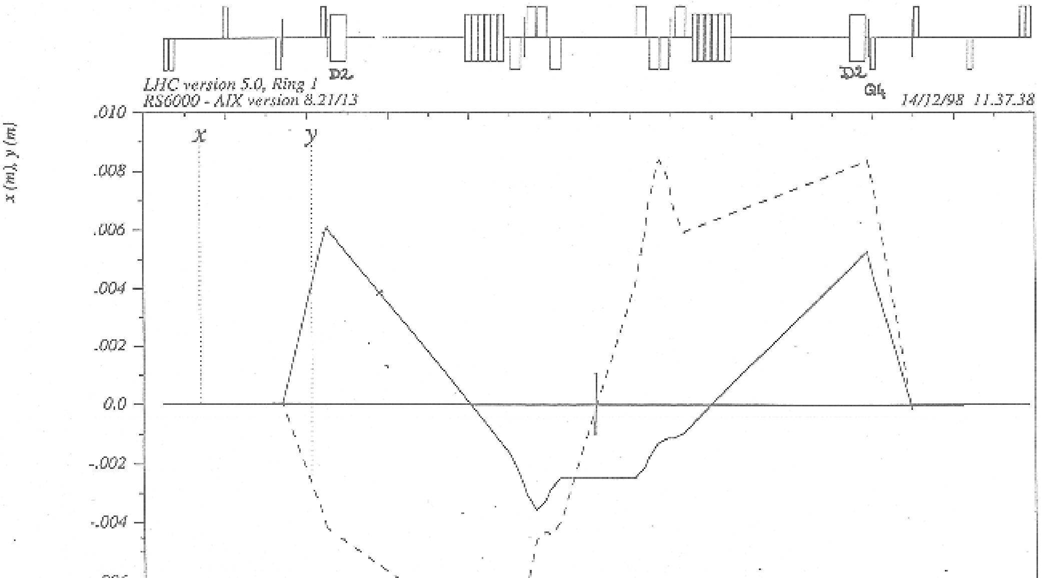
at the mirror,
- **b)** ***is separated from*** **a)** ***by*** **9.7 mm**
- **c)** ***coincides with*** **a)**

- **again limitation at the axis of shower c)**

compared to **bump #1:**
- less clearance w.r.t. a)
- **anti-symmetrical** situation between the rings and one ring in a **bad shape**
- conditions **not stable:** H separation **removed** in collision


S.R. monitor at D2 - bump #2
10 mm
2 m
<0 H separation
>0 H separation
beam axis
beam axis
a)
b)
c)
a) c)
c)
b)
b)
a)
a)
b)
c)
sources
mirror
20 m
25 m
21.3 m
Q4
D2
TAN

bump #2


Q4
D2
D2
Q4
LHC version 5.0, Ring 1
RS6000 - AIX version 8.21/13
14/12/98 11.37.38
x (m), y (m)
x
y
.010
.008
.006
.004
.002
0.0
-.002
-.004
-.006
-.008
-.010
13.05
13.15
13.25
13.35
13.45
13.55
s (m)
δE/p₀c = 0.
Table name = TWISS
[*10**(3)]

⇒ **BUMP #1**

with :

- **H angle > 0 in Ring 1 & < 0 in Ring 2 (symmetry w.r.t. IP)**
- **Mirror at ≥ 25 m from D2 exit end**

is the most convenient.

further advantage

- **conditions stable as H angle is maintained in collision**

Summing Up

Hermann Schmickler (SL/BI)

Luminosity Related Measurements

Measured Quantity	*Measurement Principle*	*Comments*
Bunch Current	Bunch Current Transformer	δ I/I < 2% possible Error on total current from DCCT < 1%
Emittance at 7TeV	Wire scanner for I = 10% of I_{nom} Synchrontron light monitor	δ σ /σ < 2% between bunches not realistic; most likely 5% ok. For absolute calibration ε proportional β Tail studies require dynamic range > 10^5
β *	k-modulation of insertion quadrupoles – measure change in tune	Evaluation of obtainable precision required
Beam-beam deflection → ε	With BPMs	Range of possible beam separation depends on beam current. Orbit difference for maximum kick (2.2σ) > 20μ m in BPMs. Expected resolution: few μ m Study possibility of zoom.
Miscrossing of individual bunch pairs	With LBL monitor? BPMs ?	Require relative resolution between bunches of 2μ m (& 4μ rad)
Beam Loss	BLMs in cleaning section	40 MHz bandwidth; tail studies

The Luminosity Monitor

- Absolute Luminosity Measurements with $\delta L/L < 2\%$ is the task of the LHC experiments

- Absolute Luminosity Measurements with $\delta L/L \sim 5\%$ for luminosities above 10^30 via a machine L-monitor and occasional cross calibrations to the LHC experiments is the task of the machine community.

- Requirements for the Luminosity Monitor:

  1) Available in all 4 Ips

  2) Sensitivity of Luminosity reading to variations of IP position ($x^*, y^* < 1$mm) and angle at IP ($x^{*\prime}, y^{*\prime} < 10\ \mu$ rad ?) has to be lower than 1%.

  3) The dynamic range with "reasonable" acquisition times for 1% precision has to cover 10^28 to 10^34. For the lower 2 decades of the dynamic range only a much reduced bandwidth is required, as this will be produced with few bunches.

  4) The minimum bandwidth is 132 kHz to see a structure along the batches, a few MHz seems adequate.

- Concerning the two (three) presented proposals:

  1) The SEM monitor will be difficult to make operational in the requested dynamic range of 10^6. It is of no interest to the machine due to the severe bandwidth limitation. The technological alternative of cold silicon counters should be tried instead and studied rather rapidly.

  2) The presented scintillator hodoscope needs much more studies. In case the studies on cold silicon counters are promising, the scintillator proposal should not be followed.

  3) The LBL proposal with the comments below is supported by CERN and in particular by the SL beam instrumentation group.
  This means that the requested studies should be carried out, beam tests should be done in the following two years.
  The situation will be reviewed in spring 2002, after the expected completion of the prototype tests
  At that time also the scintillator proposal or the cold silicon detector will be reviewed.

- Items to be reviewed on the LBL proposal:

  1) Cleaning efficiency of the machine and related background due to charged particles scraping the internal TAS & collimation effect of D1.

  2) Position of the TAN 5m towards the IP (→ optimisation of light path of Synchrotron Light Monitor)

  3) The running scenario for the detector is up to 20 years without access in a highly radioactive zone. Any mechanical design, which weakens the detector, has to be avoided.
     Review plate thickness and distance (0.5 mm) versus bandwidth requirement.

  4) Do we have to instrument the TAS? Can this decision wait until 2002?

  5) Review front end electronics and acquisition system. Make it independent of external machine timing. In case a compromise is needed, the requirement on large dynamic range counts more than high bandwidth.