Instantaneous luminosity and beam size measurements in PEP-II

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

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)

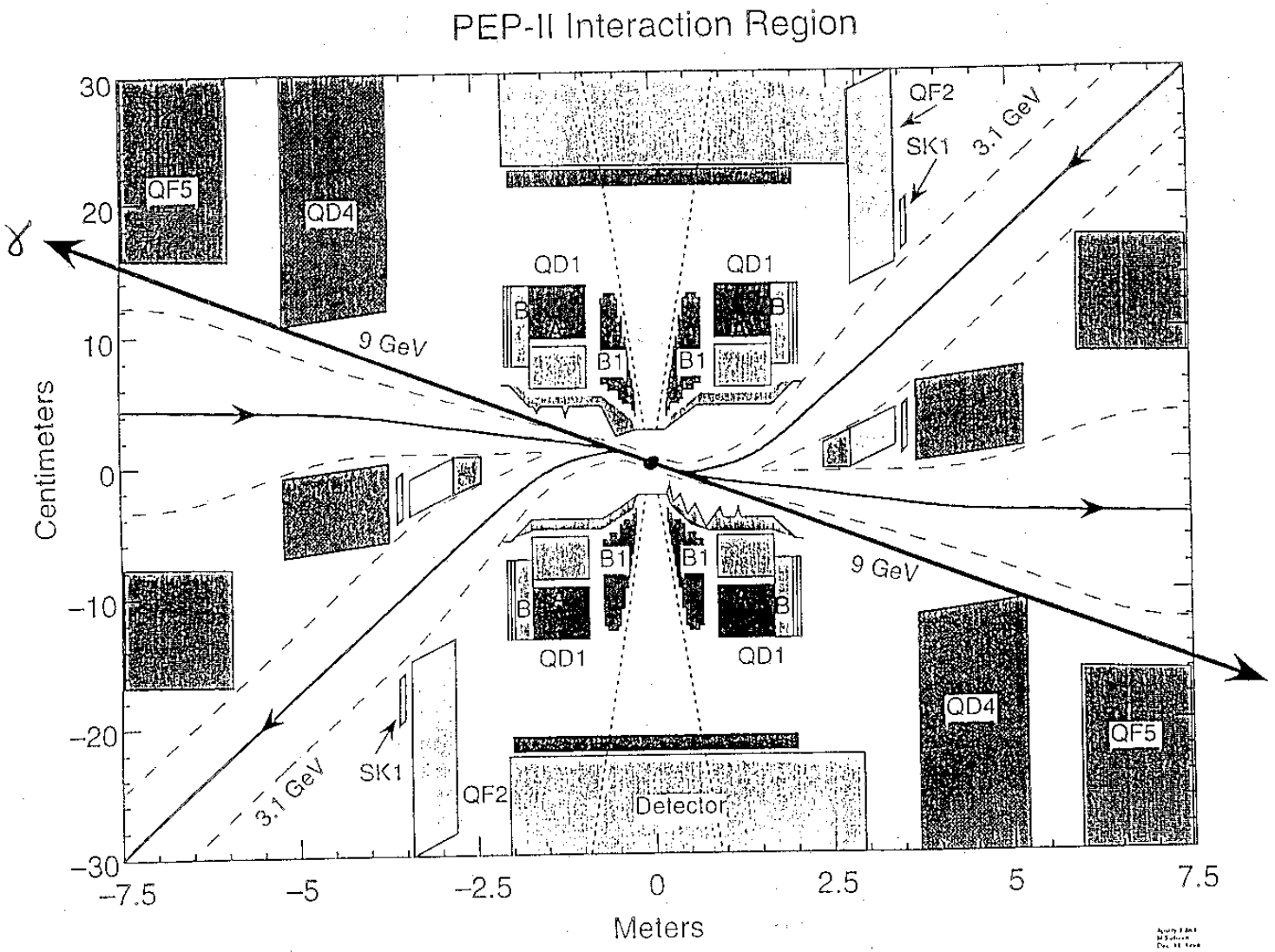
1. **Luminosity measured by radiative-Bhabha luminometer with beams in head-on collision**
   (<=> luminometer calibration & acceptance)

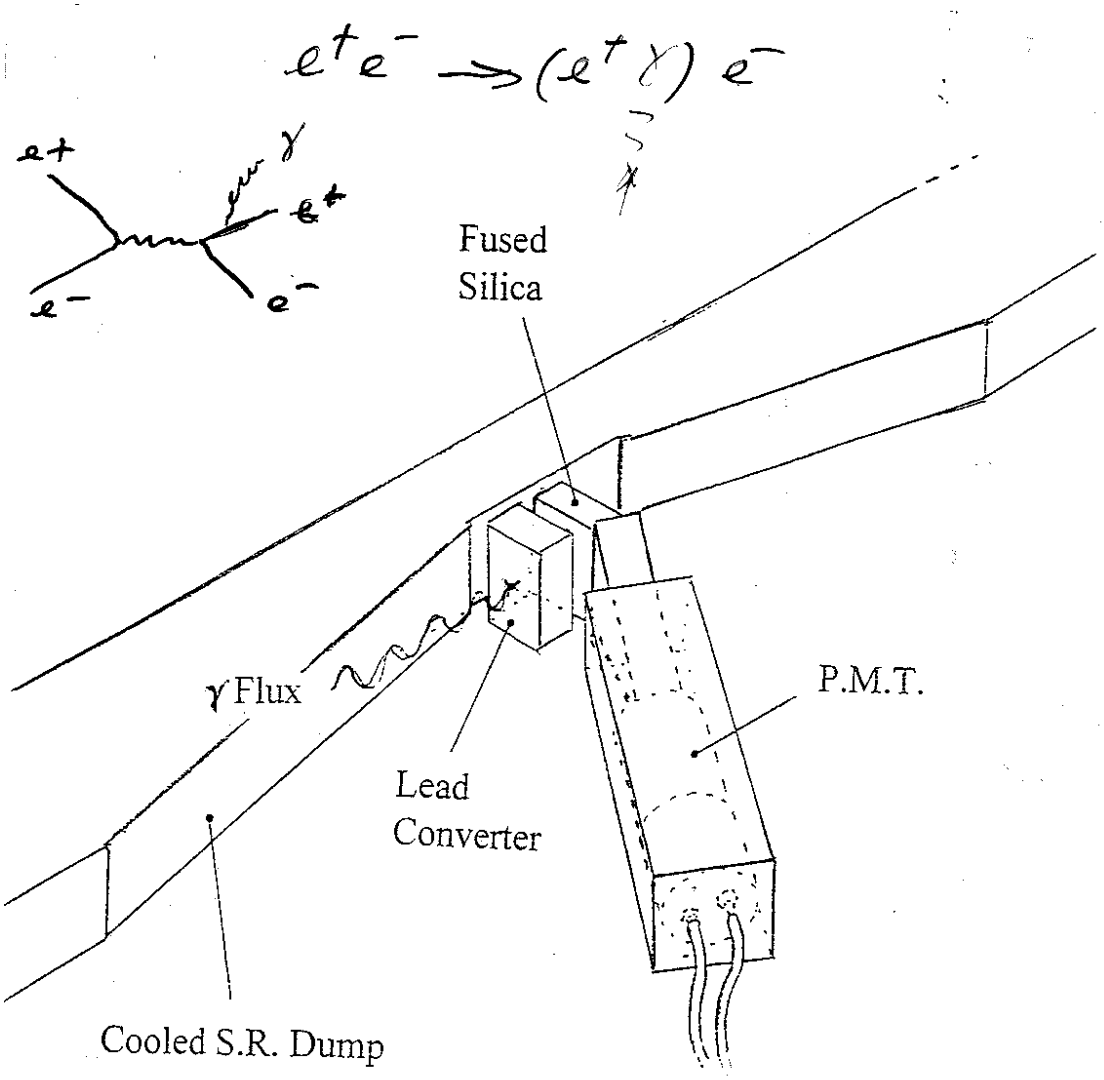
2. Luminosity from **measured beam currents & beam sizes**
   2.1 Sizes from luminosity scan
   2.2 Sizes from beam-beam deflection scan
   (<=> beam-beam blowup)

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^-
τ_E		2.8773	
$\varepsilon_{xo} \mid \varepsilon_{yo}$	π nm-rad	49.2 | 1.5	49.2 | 1.5
α_c		1.23×10^{-3}	2.41×10^{-3}
$\nu_x \mid \nu_y$		38.570 | 36.642	24.618 | 23.638
$\tau_x \mid \tau_y \mid \tau_s$	ms	61.5 | 60.3 | 29.9	36.9 | 37.1 | 18.6
$f_{rev} \mid T_{rev}$	kHz | μs	136.3113 | 7.336	
$\beta_x^* \mid \beta_y^*$	m	0.500 | 0.015	
$\sigma_{xo}^* \mid \sigma_{yo}^*$ $(\Sigma_{xo} \mid \Sigma_{yo})$	μm	156.8 | 4.7 (221.8 | 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 | 0.03	0.03 | 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
$\mathcal{L}_b$	$cm^{-2}s^{-1}$	1.81×10^{30}	
$\mathcal{L}$	$cm^{-2}s^{-1}$	3.00×10^{33}	


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



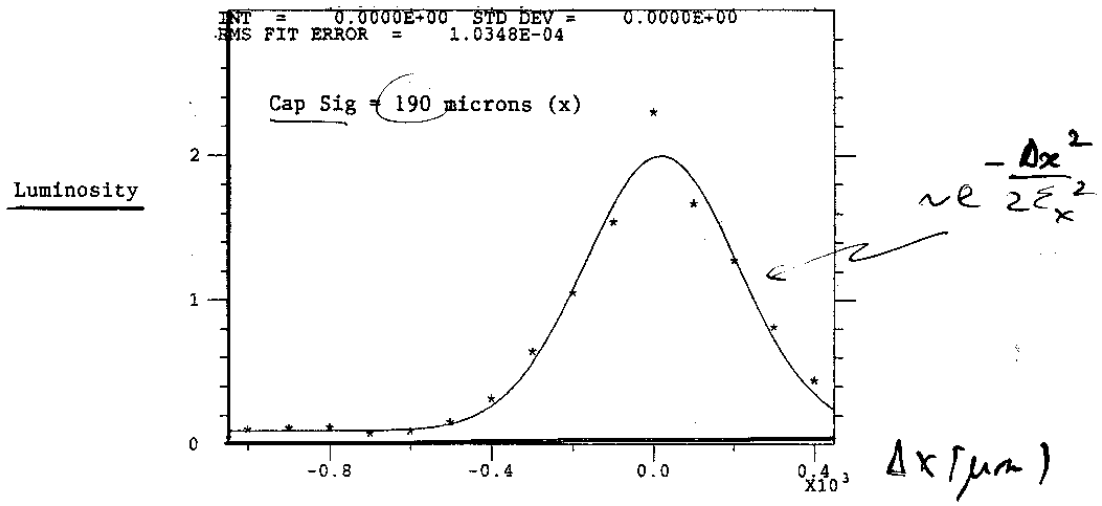
— Radiation Shielding Not Shown —

Rate : ~ 1 γ/crossing at design L (238 MHz!)

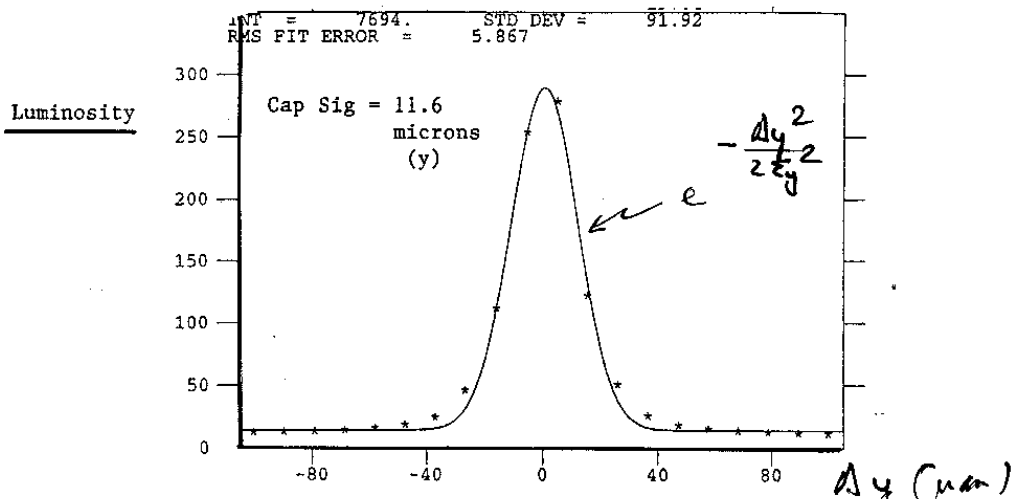
Acceptance : $\pm\ 8\ \sigma_y^*$

Background (beam-gas) : ~ %

PEP-II Horizontal and Vertical Beam-Beam Scans



Horizontal scan position (microns)

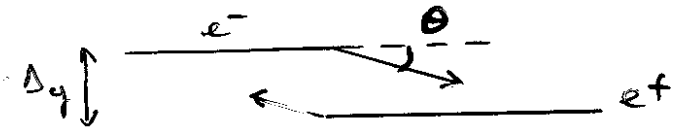


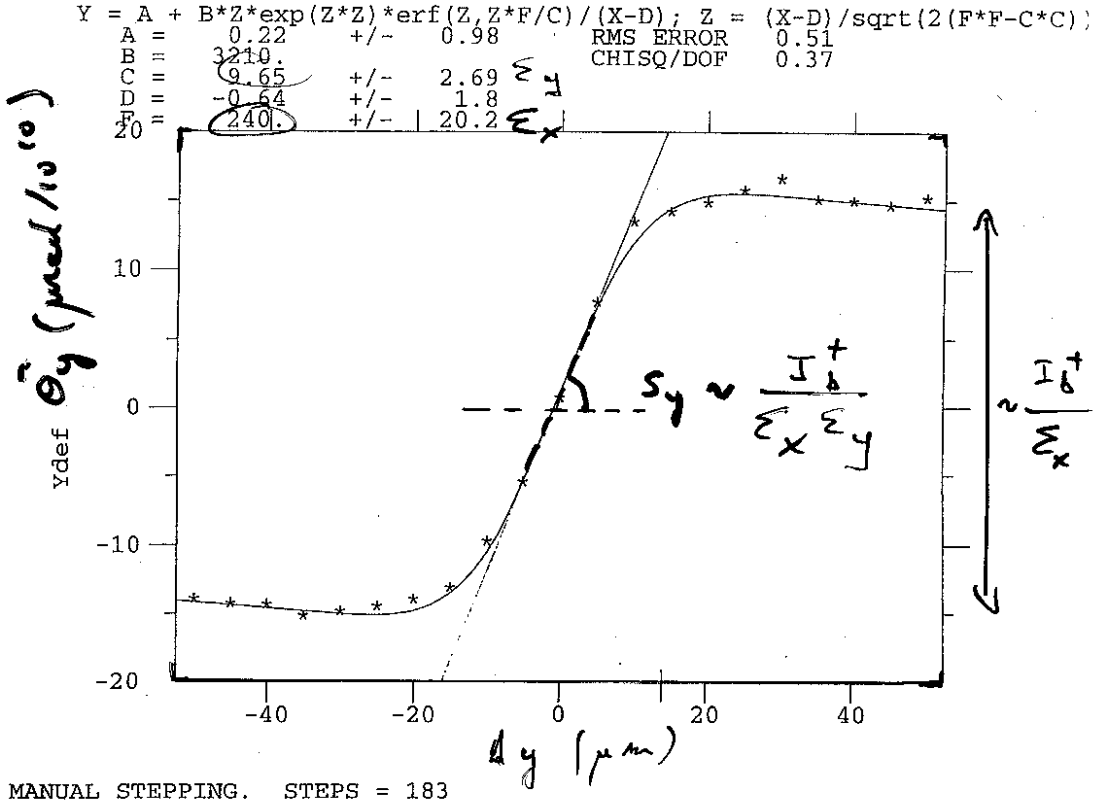
Vertical scan position (microns)

FULL SCAN (±5-10 σ)

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

BEAM-BEAM DEFLECTIONS

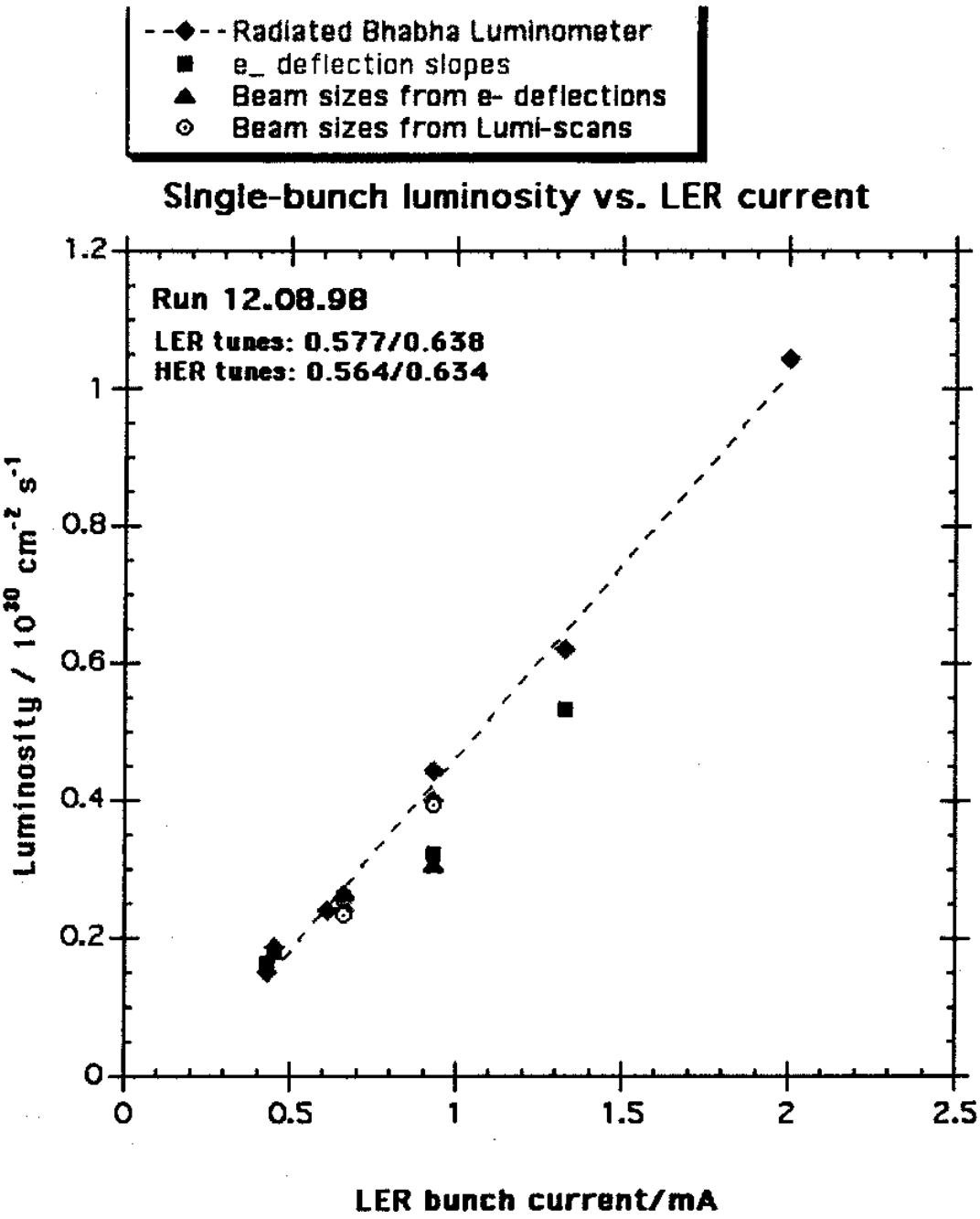


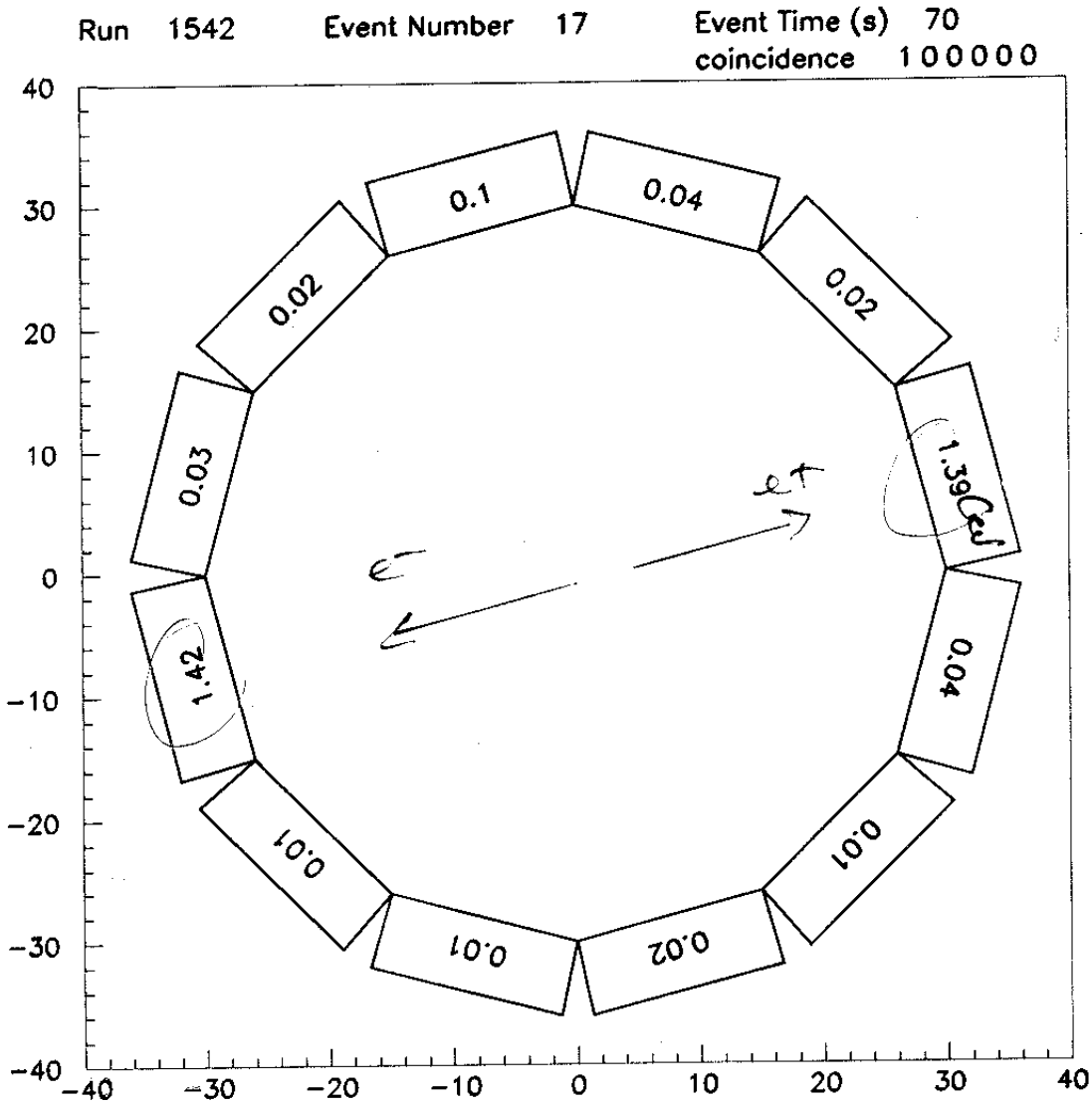


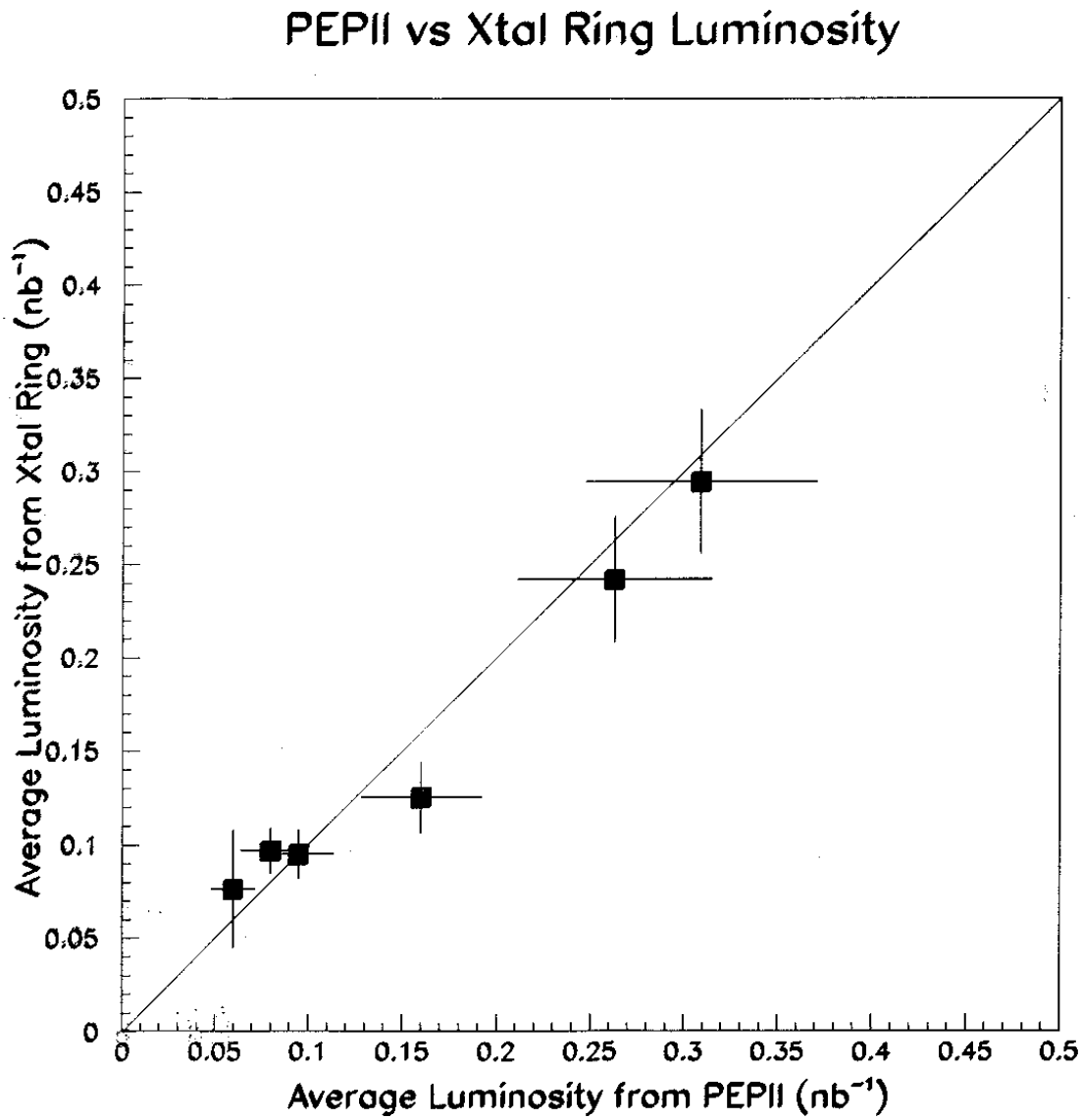
MANUAL STEPPING. STEPS = 183

9-JAN-99 17:01:39

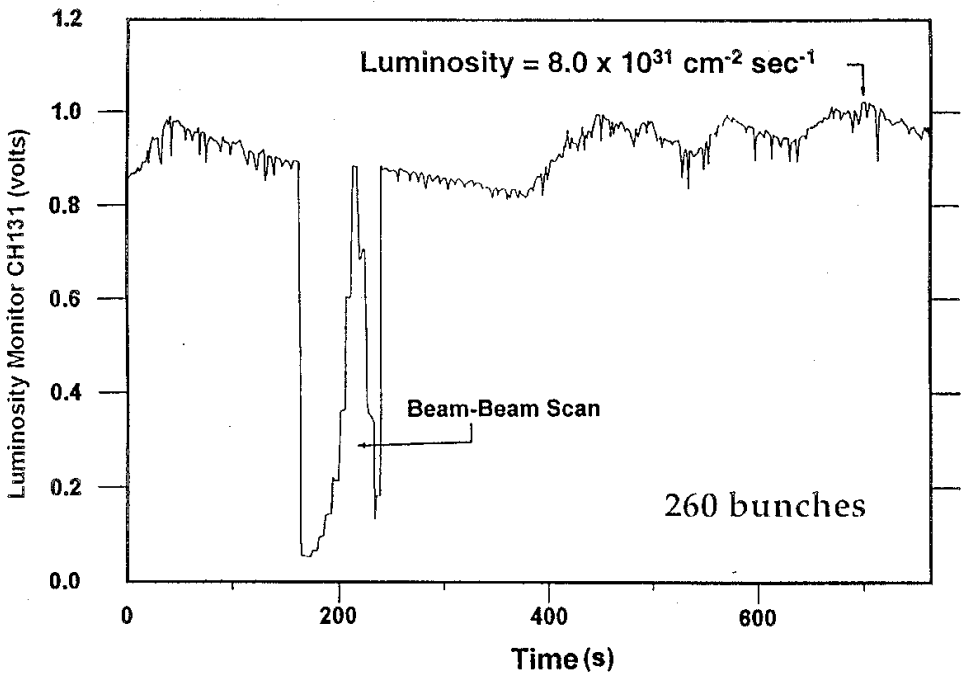
ele - deff - y - 6 - 98dec


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
LER bunch current/mA
0
0.2
0.4
0.6
0.8
1
1.2
0.5
1.5
2
2.5


Run 1542 Event Number 17 Event Time (s) 70
coincidence 1 0 0 0 0 0
0.1
0.04
0.02
1.39 Cu
0.04
0.01
0.02
0.01
0.01
1.42
0.03
0.02
e+
e-
40
30
20
10
0
−10
−20
−30
−40
−40 −30 −20 −10 0 10 20 30 40

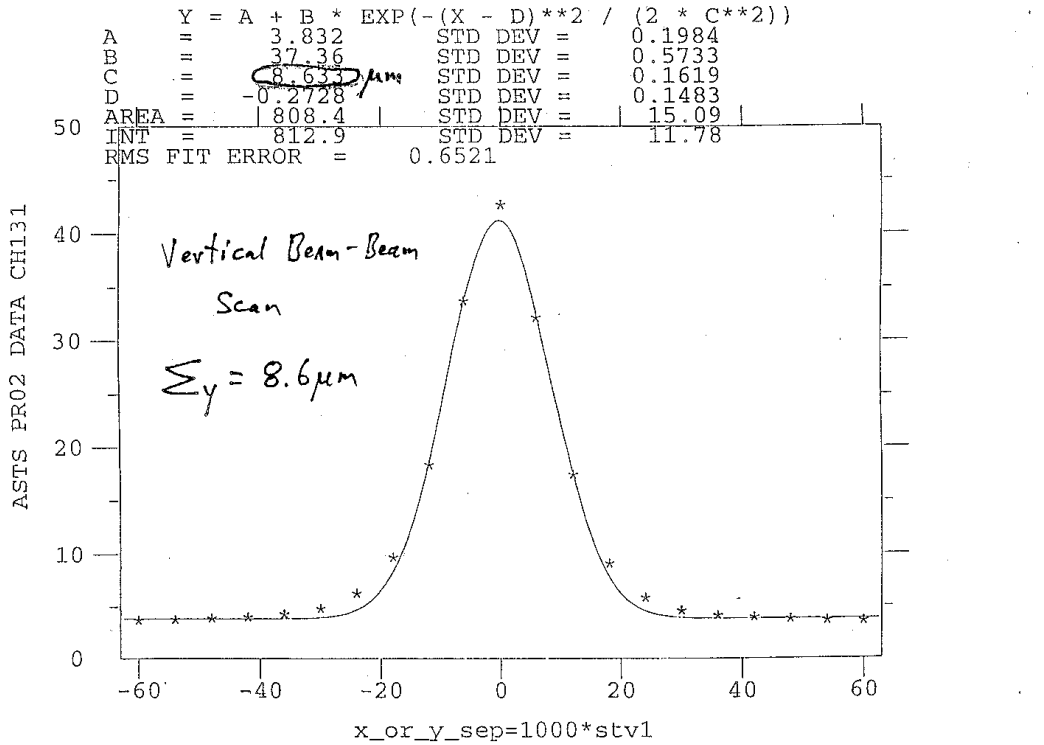

PEPII vs Xtal Ring Luminosity
Average Luminosity from Xtal Ring (nb^{-1})
Average Luminosity from PEPII (nb^{-1})
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

PEP-II Luminosity Record - Dec. 10, 1998



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

I^- = 84 mA Σ_x = 320 um τ_- = 470 min

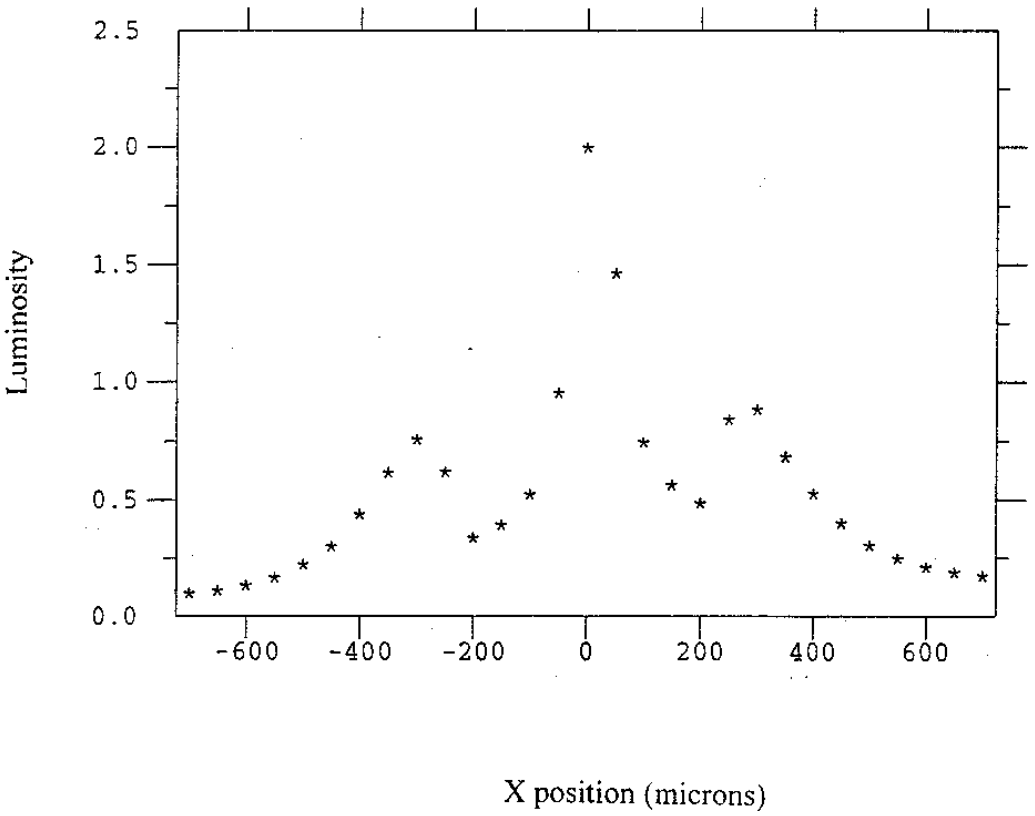


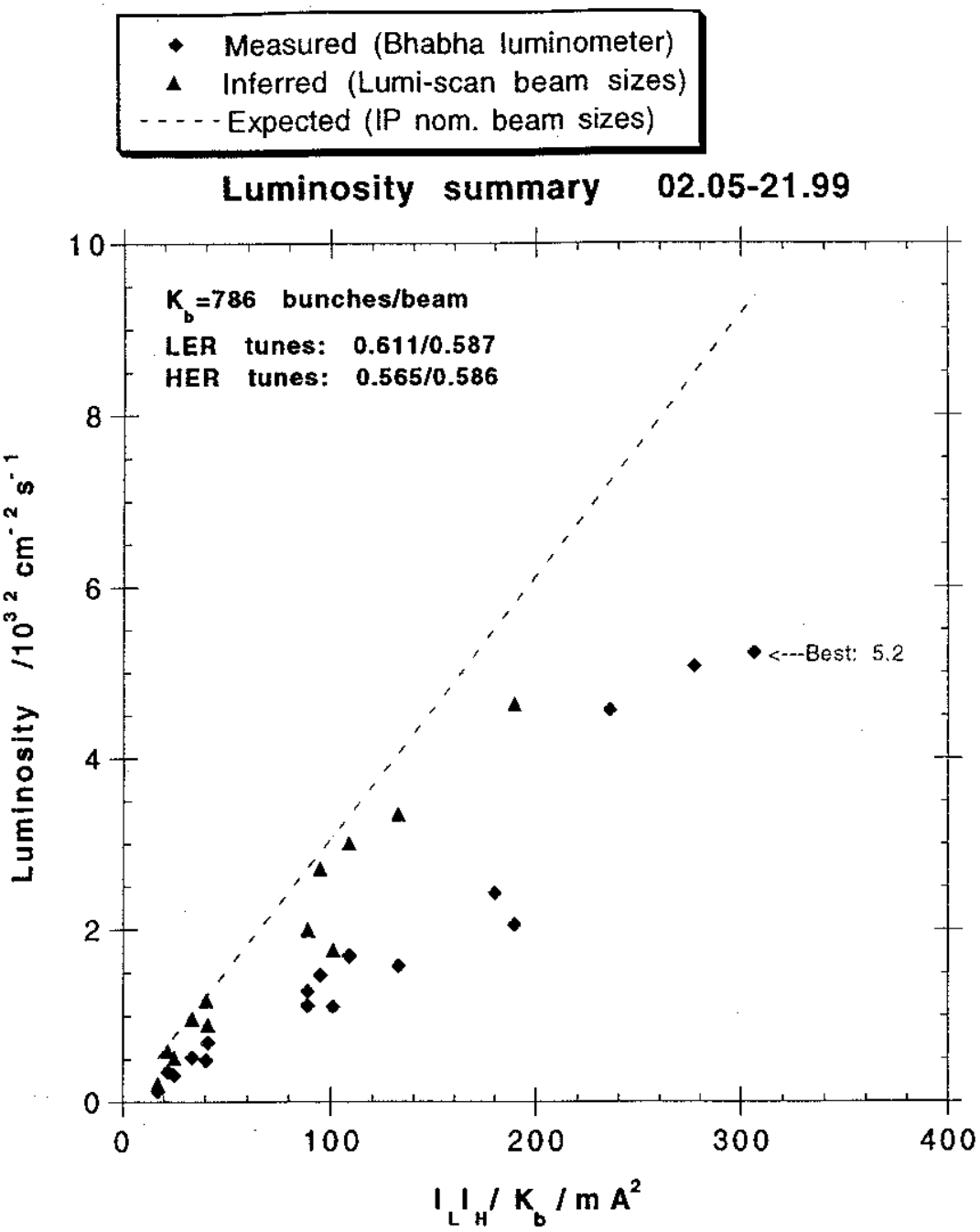
KNOB (COMMON$ROOT:[MKB]LERIP_Y.MKB.3) STRT=-.0600 STEPS= 21 SIZE= 600-5

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!!) [crucial] to rapid IP-I improvement

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

2. $\mathcal{L}$ and/or BEAM-BEAM DEFLECTION SCANS OVER $\pm 6\sigma$ 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 XKY IP CENTERING KNOBS ARE USED ROUTINELY IN A SLOW (Hz) $\mathcal{L}$ 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