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.**

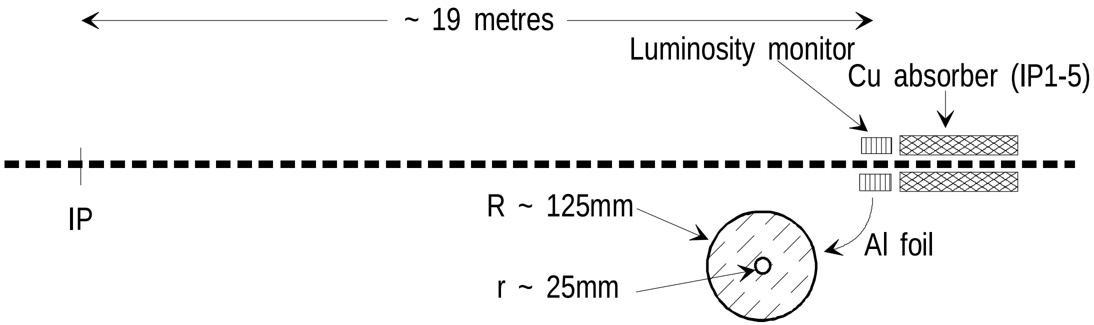
□ **Need for a monitor that covers 6 orders of magnitude:**

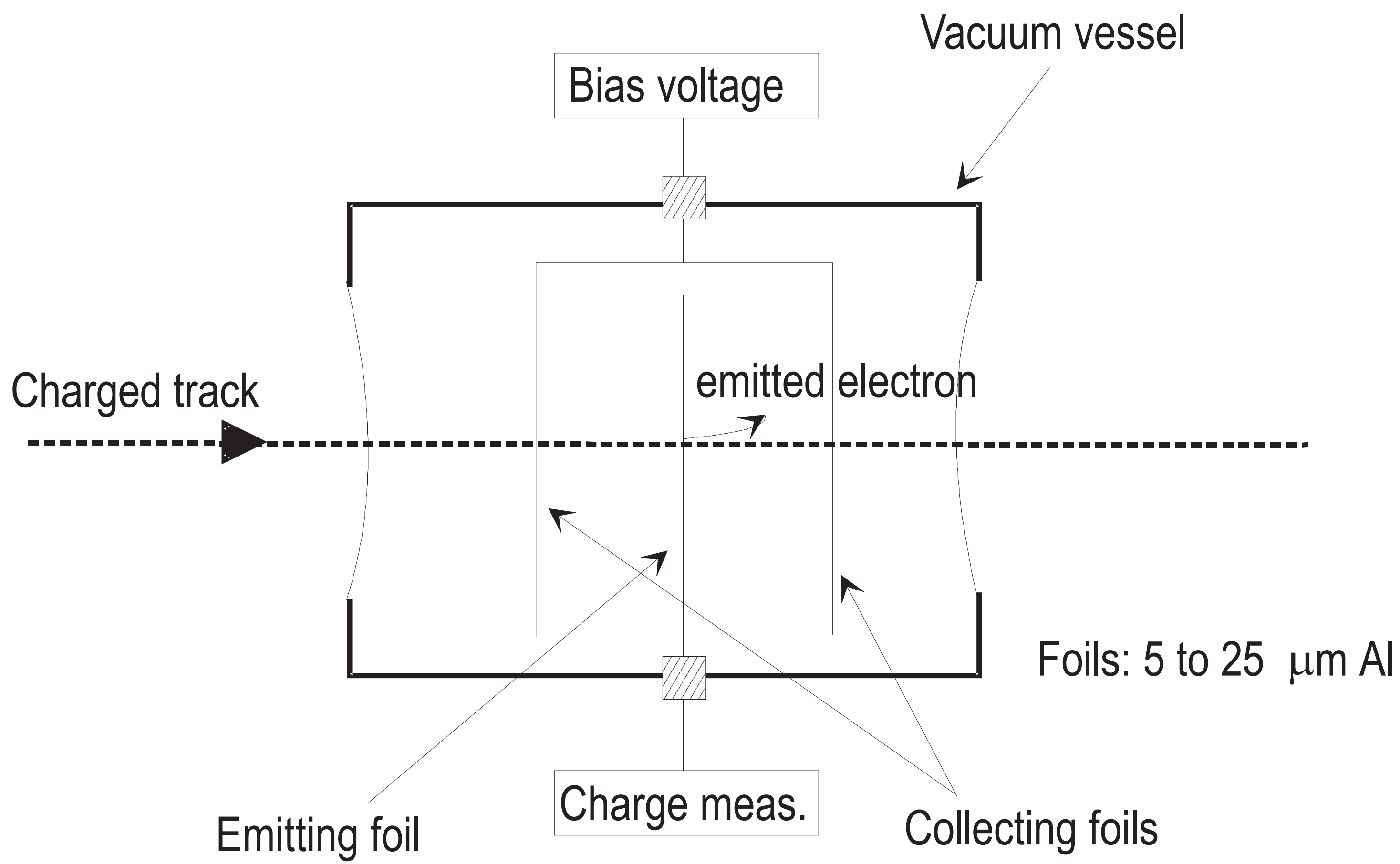
Propose to use a Secondary Emission Counter.

➔ **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.**

$\boldsymbol{L} = 10^{28}$ ➔ **~ 10^{4} charged tracks/second.**

$\boldsymbol{L} = 10^{34}$ ➔ **~ 10^{10} charged/s and ≤ 10^{8} charged/cm^{2} at the inner edge.**

➔ **≤ 10^{15} charged/cm^{2} after a year.**

(ageing effects starts at ~ 10^{17} charged/cm^{2})

Signal: efficiency (~7%) × Nb. foils (15?) = 1

$\boldsymbol{L} = 10^{34}$ ➔ **Q ~ 1.6×10^{-9} Coulomb/s**

$\boldsymbol{L} = 10^{28}$ ➔ **Q ~ 1.6×10^{-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.

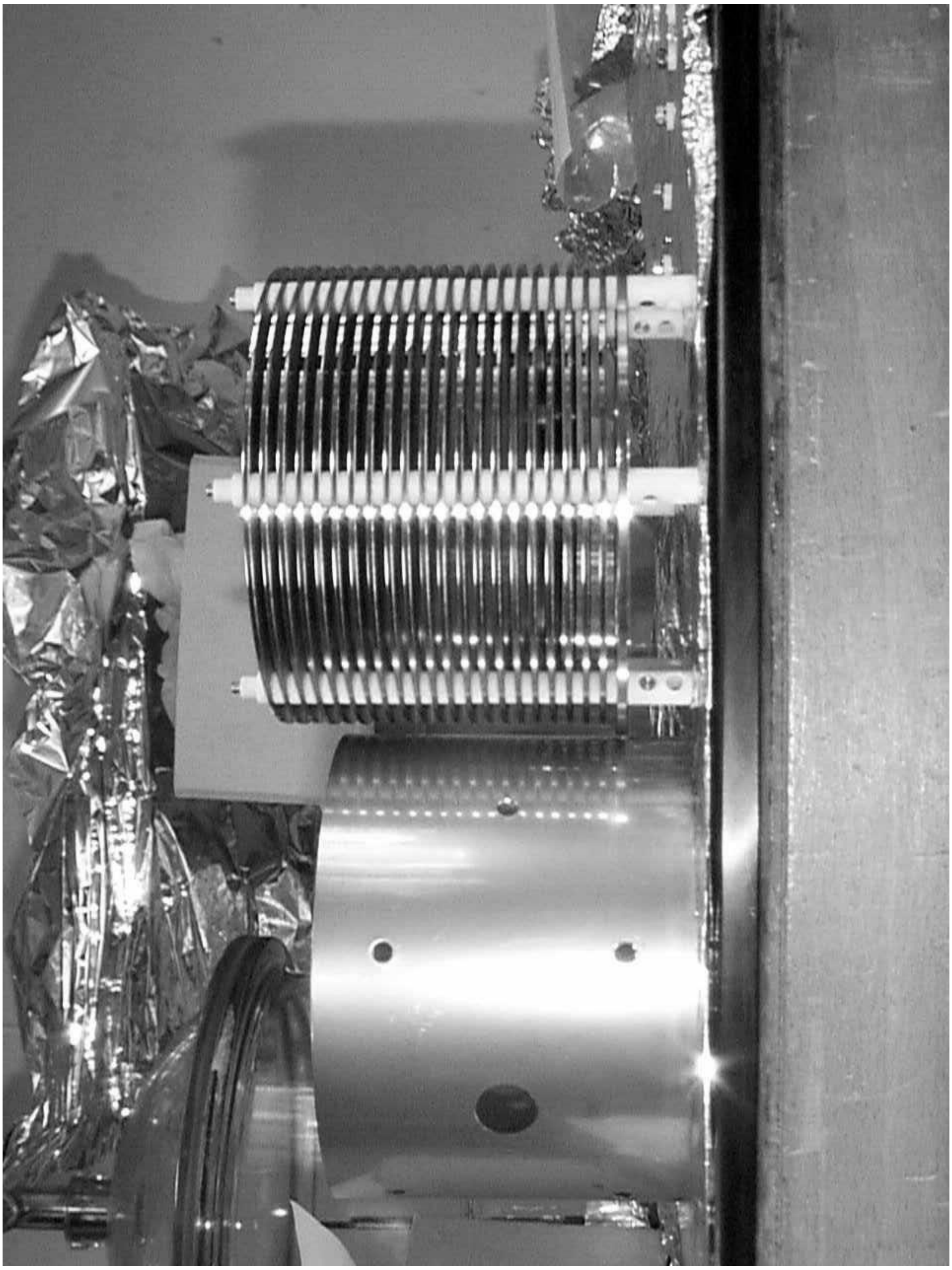
1) Relative measurement of Luminosity: Monitoring of Collision conditions.

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

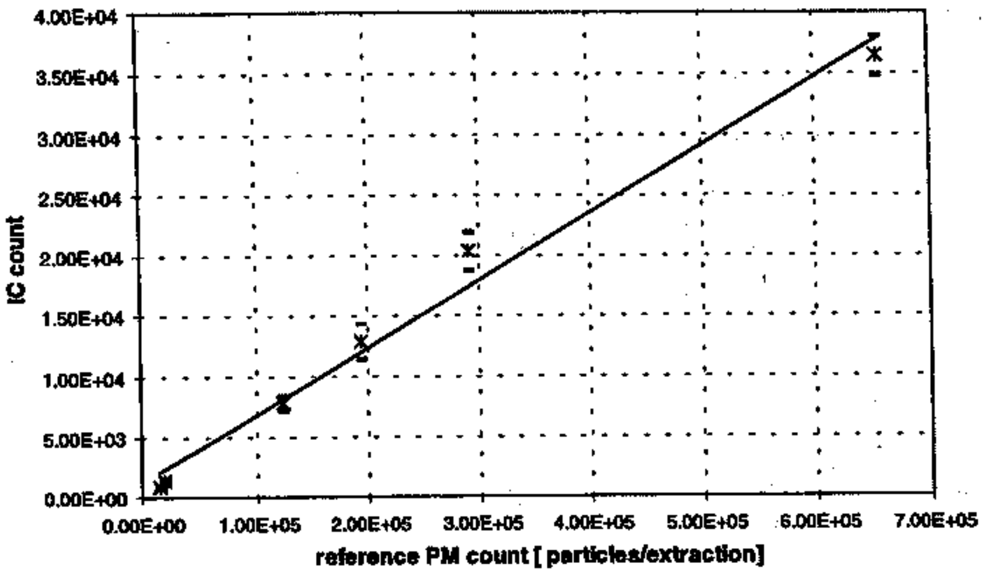
  ➔ Continuous measurement of beam-beam separation and possibility of feedback systems.

- **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.

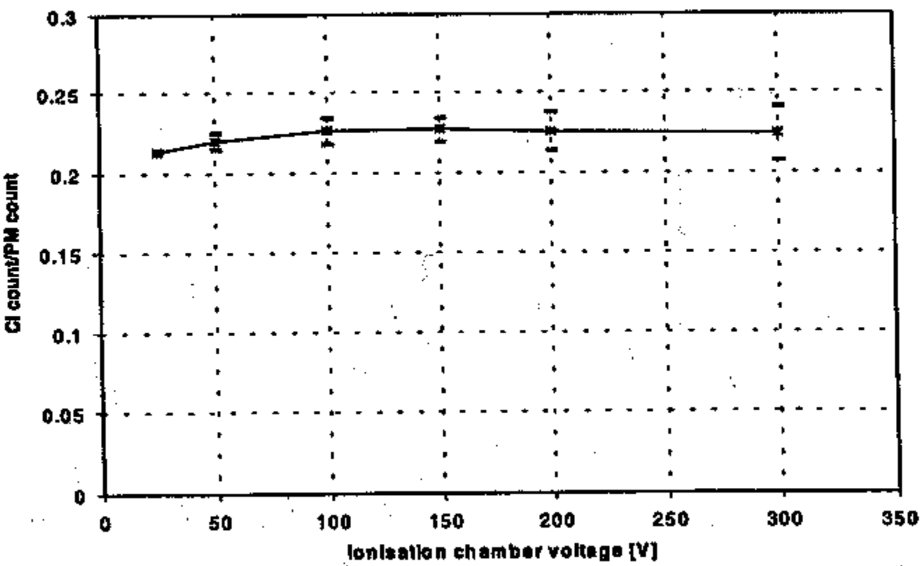


Ionisation chamber (IC) count as a function of the reference photomultipliers (PM) count



Linearity of the luminosity monitor in the ionisation mode.

Ionisation chamber (IC) count/Photomultipliers (PM) count as a function of the ionisation chamber voltage



High voltage curve of the luminosity monitor in ionisation mode.

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

- **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).

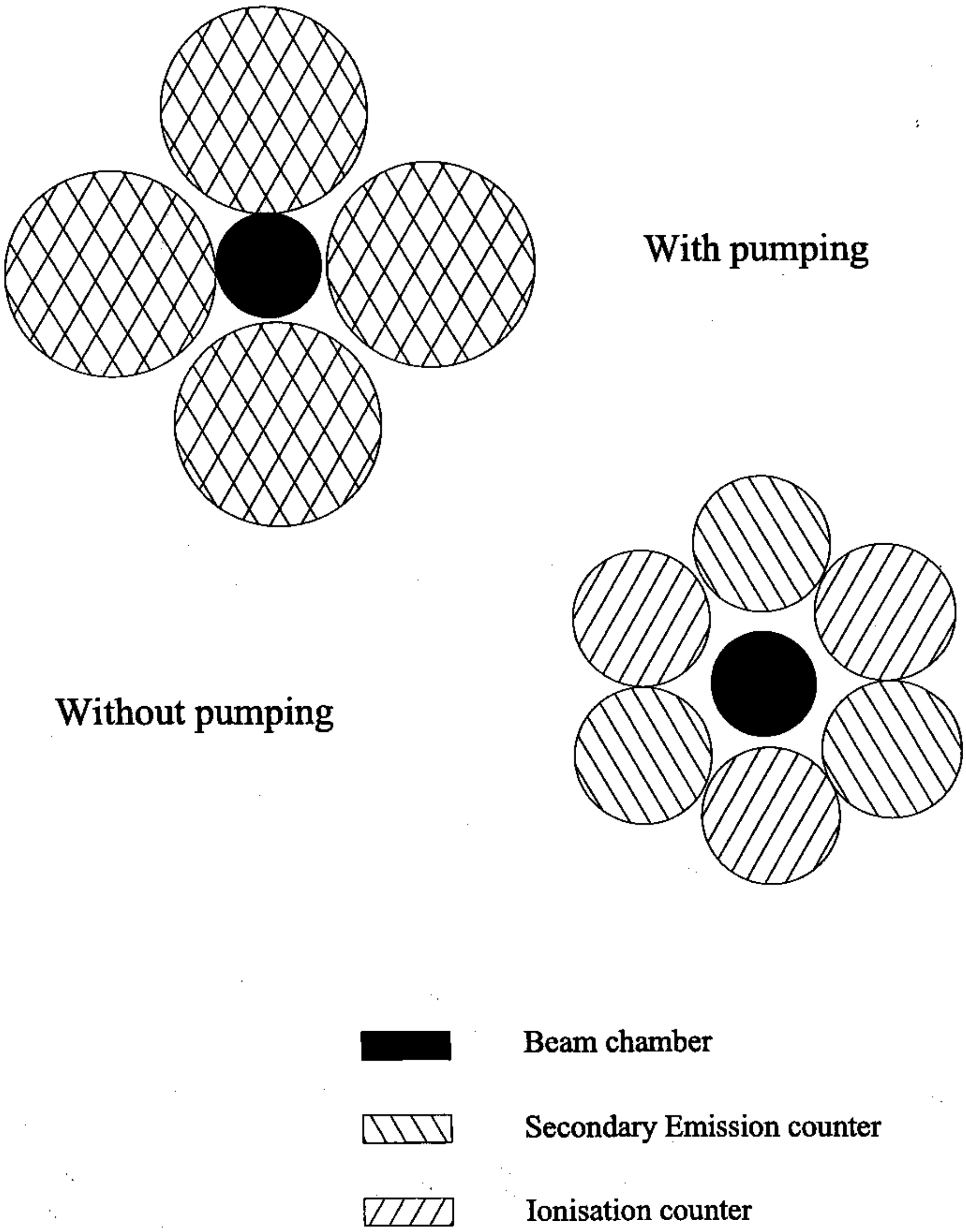
- **Install shielding cylinder to act as a Faraday cup and tri-axial cabling:**
  reduces background noise from pick-up and mass loops.

  ➔ **Sensitivity limited by leakage current between Al foils: $I \sim 10^{-13}$ A.**

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

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

Possible monitor layout



Summary

Luminosity range	Collision Points	Reading Frequency	Bunch to bunch Luminosity
10^{28} to $\geq 10^{34}$ $cm^{-2}s^{-1}$	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.

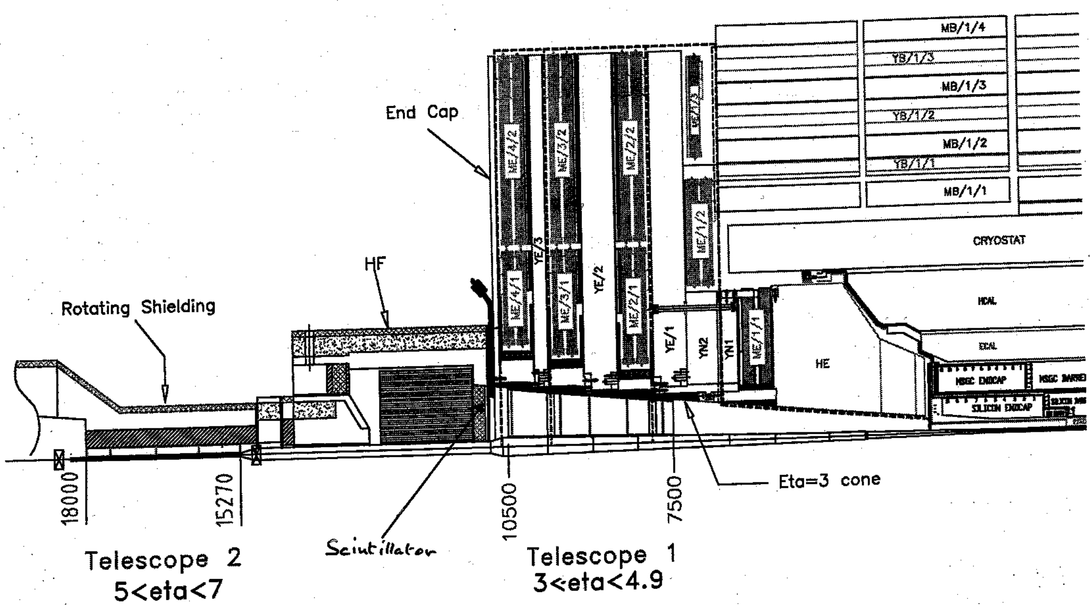
We have $dn/d\eta \sim 8$ tracks/events at $\eta=3$: a $10\times10\ cm^2$ scintillator placed at the end of the CMS solenoid would then count ~ 1% of the inelastic events.

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



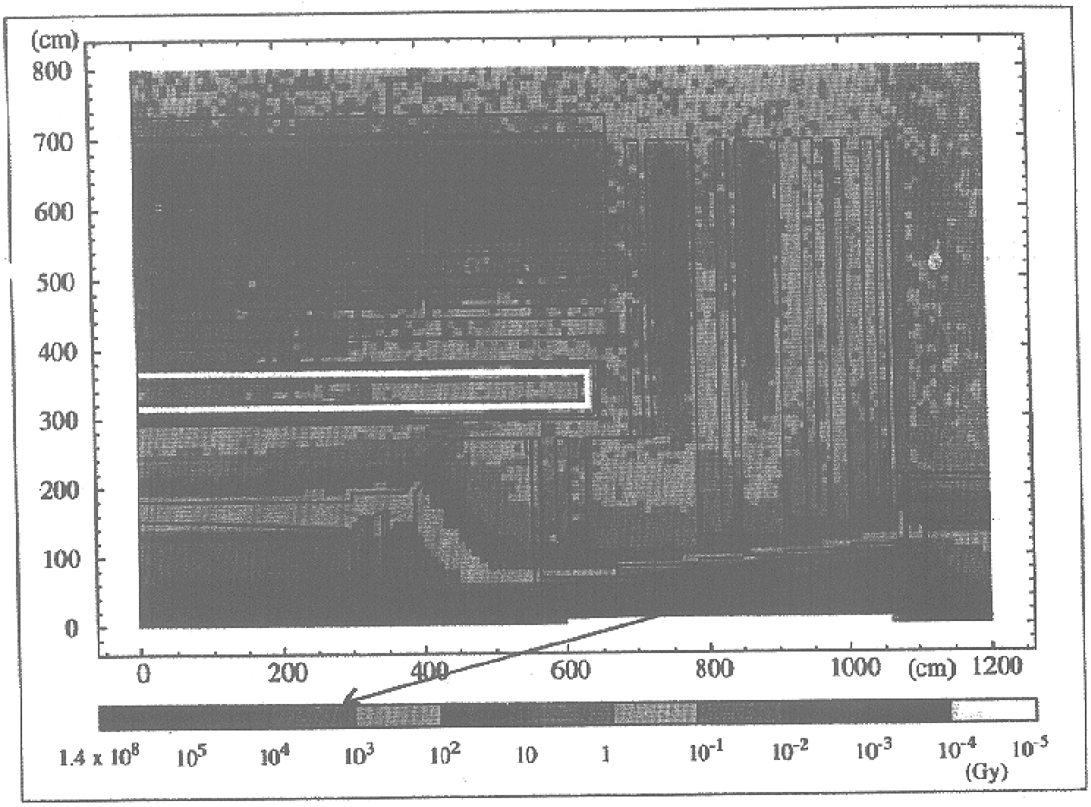
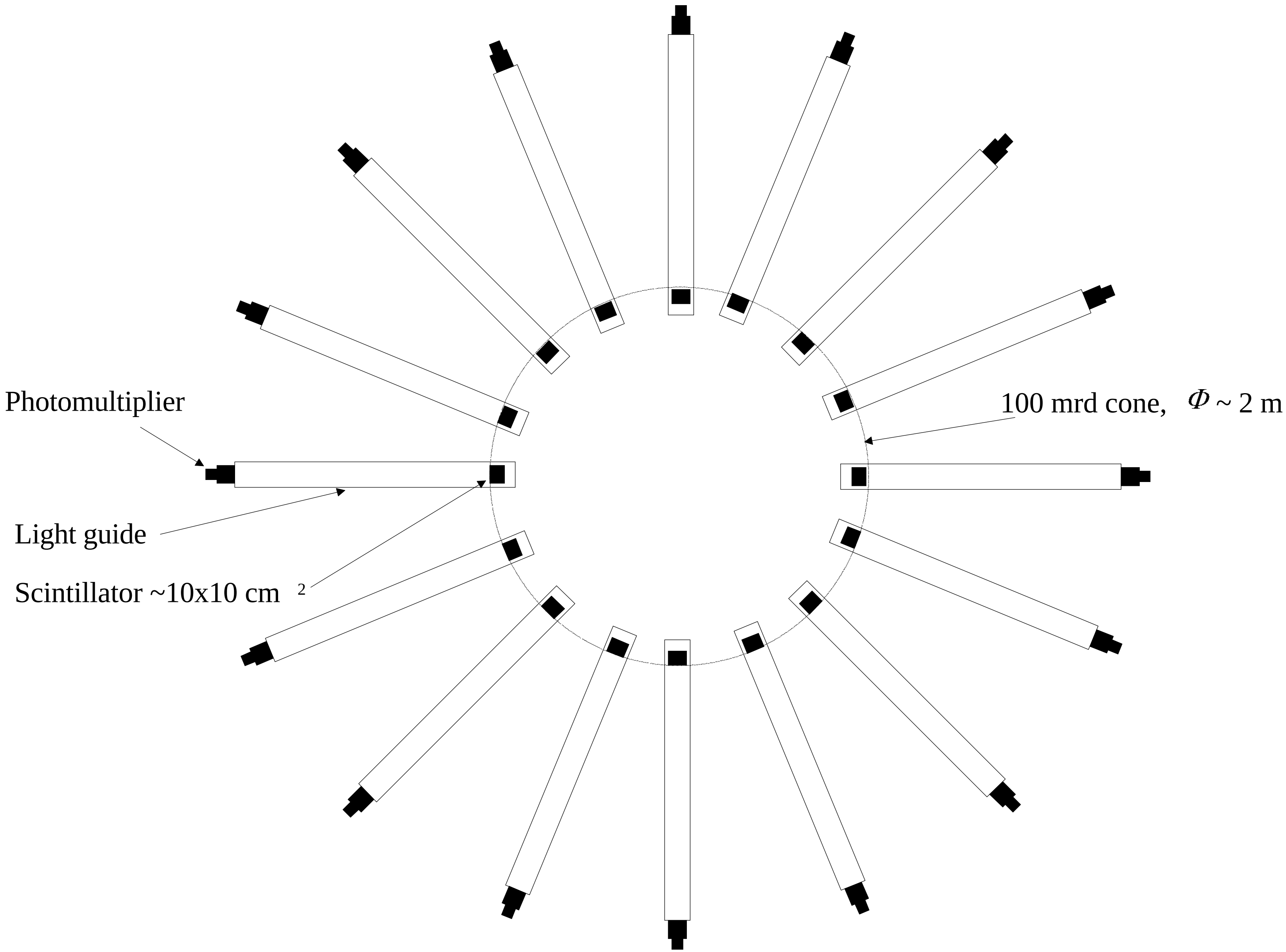
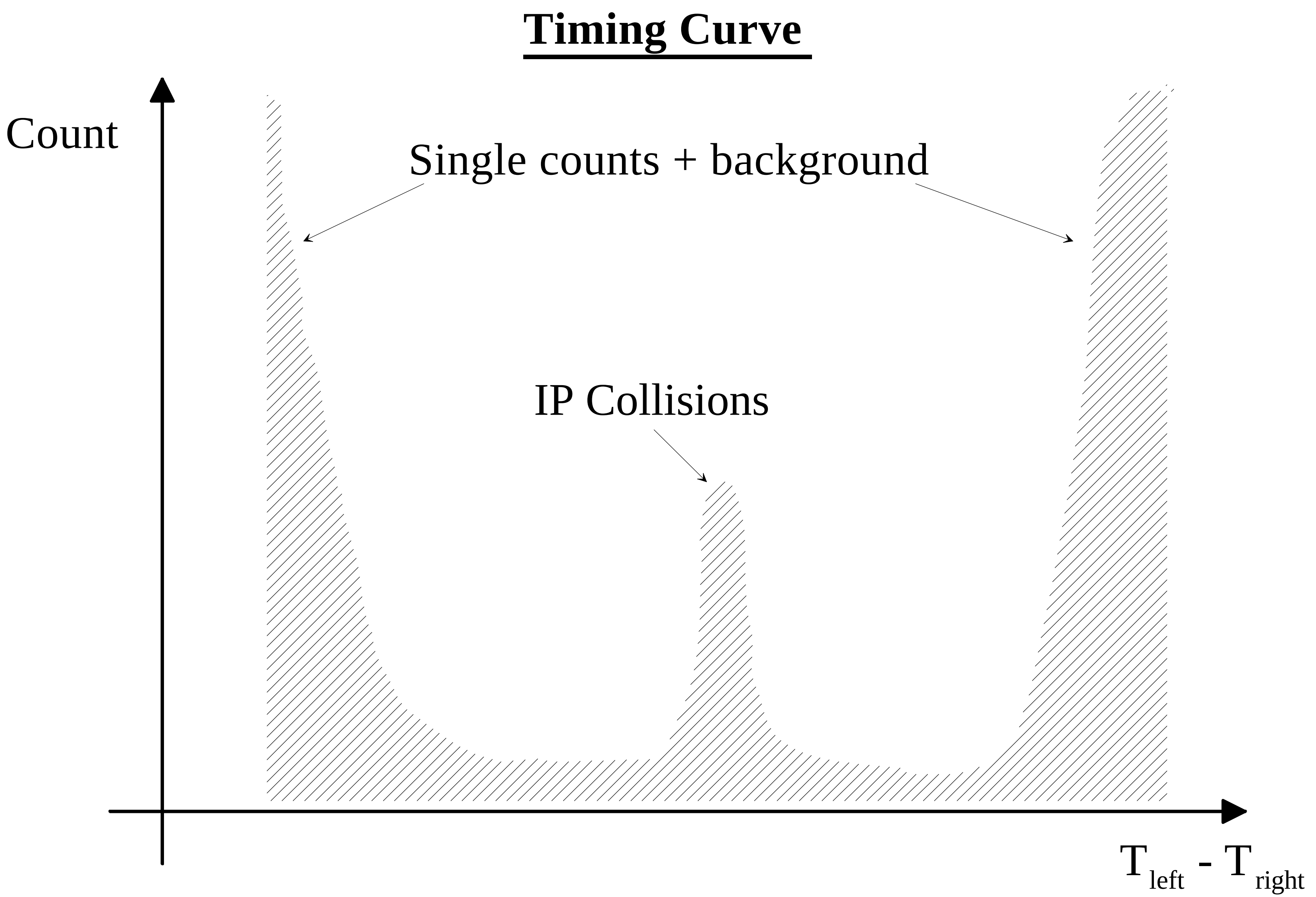


Fig. 10.8.1(color): Absorbed dose (in Gy) in the CMS detector. The values correspond to an integrated luminosity of 5×10^5 pb^{-1}, as expected to be accumulated during the first ten years of LHC operation.


Photomultiplier
100 mrd cone, $\Phi \sim 2$ m
Light guide
Scintillator ~10x10 cm ^{2}


Timing Curve
Count
Single counts + background
IP Collisions
T_{left} - T_{right}

Longitudinal versus transverse scan in crossing plane.

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

Momentum compaction factor at LHC: $\alpha = \frac{\overline{\mathbf{D}}}{\mathbf{R}} = 3.473 \times 10^{-4}$.

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

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.