WELCOME

1st LHC Machine-Experiments Joint Workshop on Luminosity Measurements at the LHC

Luminosity monitoring at the LHC

- Luminosity **L** is defined by:

$$N_{int} = L.\sigma$$

Where N_{int} is the Interaction rate for the process with cross-section σ

(Counting rate in a monitor is N_{int}.acceptance)

Luminosity in terms of machine parameters

$$L = \frac{N^2 . k_b . f . \gamma}{4 . \pi . \varepsilon_n . \beta^*} F$$

N = number of protons per bunch

k_b = circulating bunches

f = revolution frequency,

β^* is the betatron function at the collision point,

ε_n the normalised emittance

γ the Lorentz factor E/m_0c^2

F a reduction factor for crossing angle

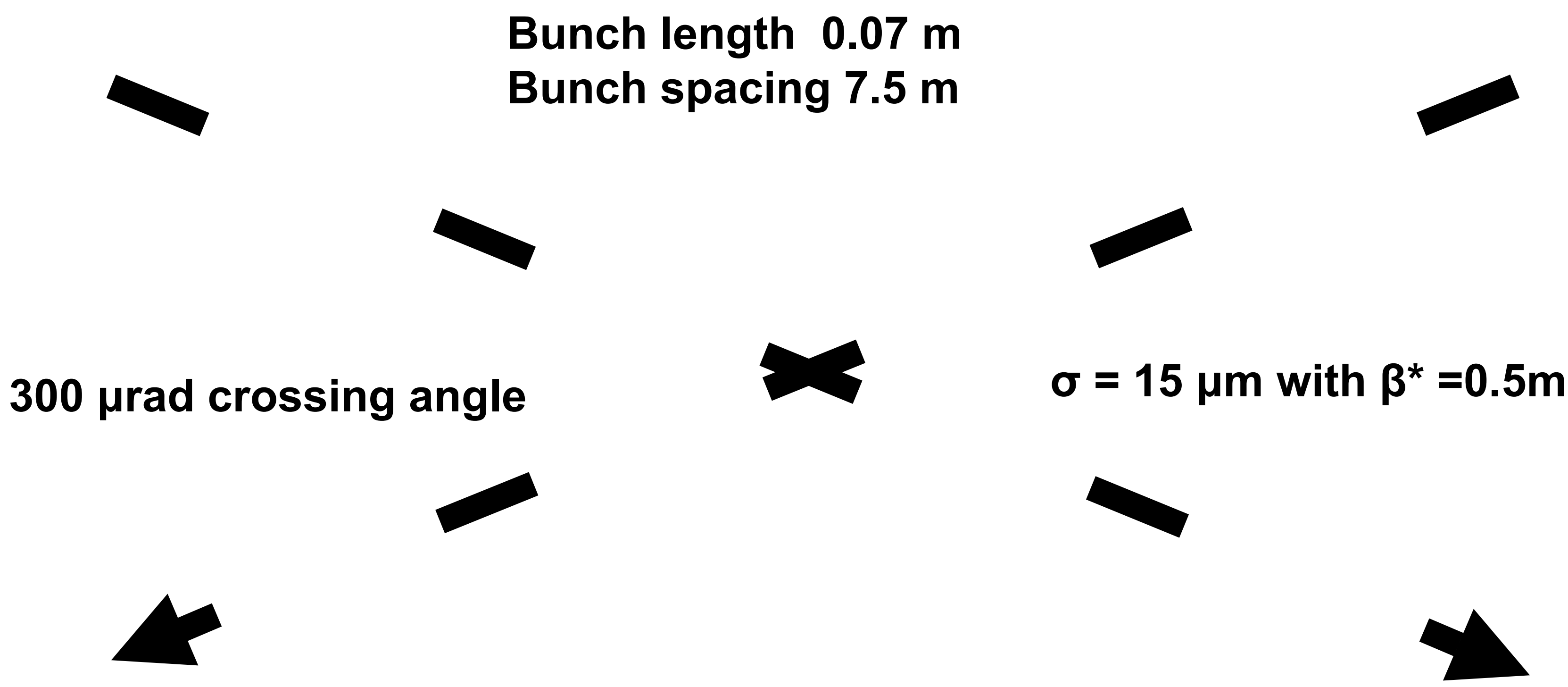
LHC has two magnetic rings

Two differing beams which do not collide

Luminosity proportional to $I^2.1/x_{eff}.1/y_{eff}$

Where $1/x_{eff}$ and $1/y_{eff}$ include not only the beam transverse sizes but also the overlap functions of the two beams.

Colliding beams at the LHC



Bringing the beams into collision

- The BPMS will not be sufficiently accurate
- A systematic scan in both transverse dimensions will be needed to maximise the collision rate

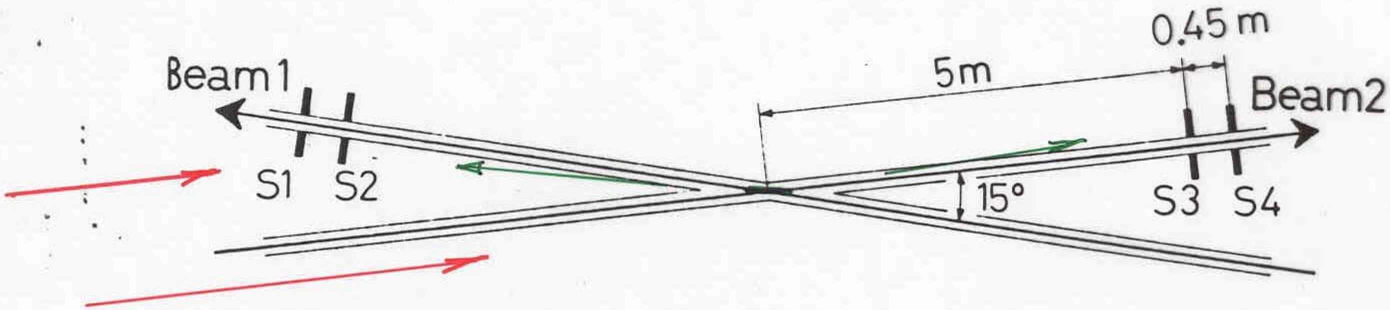
Primary use of the LHC luminometer

Keeping the beams in collision

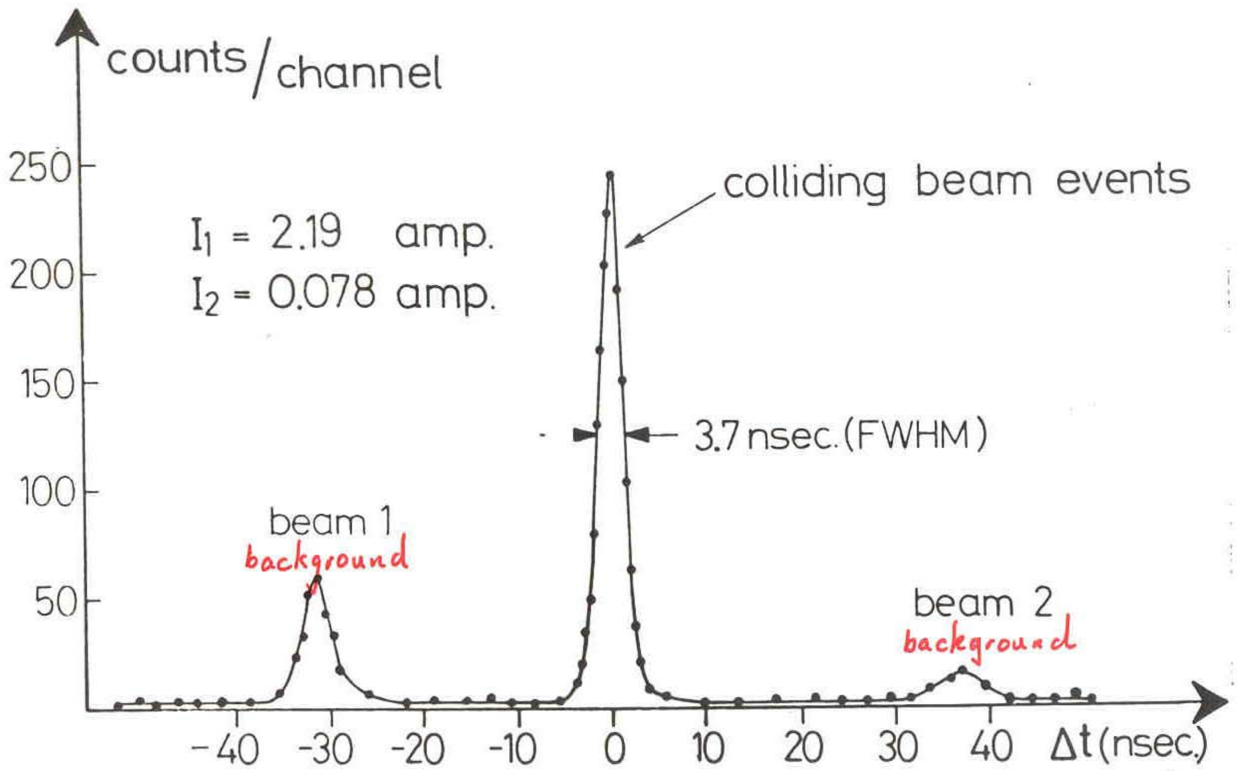
- With $\beta^* = 0.5$ m $\sigma = 15$ μm
- Orbit drifts during a run may reduce the integrated luminosity and need correcting
- Note that a 5 μm shift of Q1 relative to Q3 drops the collision rate by 20%

Rapid and background free

- In order to be able to bring beams into collision rapidly a high rate monitor is needed.
- which must be background free under a wide range of conditions.
- Bunch to bunch luminosity is needed to control ‘pacman’ bunches.
- A dynamic range of 1 to 25 interactions per bunch crossing (40 MHz) is required.



Beam1
S1
S2
5m
0.45 m
Beam2
S3
S4
15°


counts/channel
250
200
150
100
50
I1 = 2.19 amp.
I2 = 0.078 amp.
colliding beam events
3.7 nsec. (FWHM)
beam 1
background
beam 2
background
-40
-30
-20
-10
0
10
20
30
40
Δt (nsec.)
(22)

Experiments require absolute luminosity $cm^{-2}.s^{-1}$

- Use a calculable and identifiable process ?
- TOTEM will measure the total cross-section with the luminosity independent method and hence can calibrate interaction rate monitors in IR5 at $L = 10^{28}.cm^{-2}.s^{-1}$.

  What application to other experiments?
- Use the Van der Meer method ?

The Van der Meer method

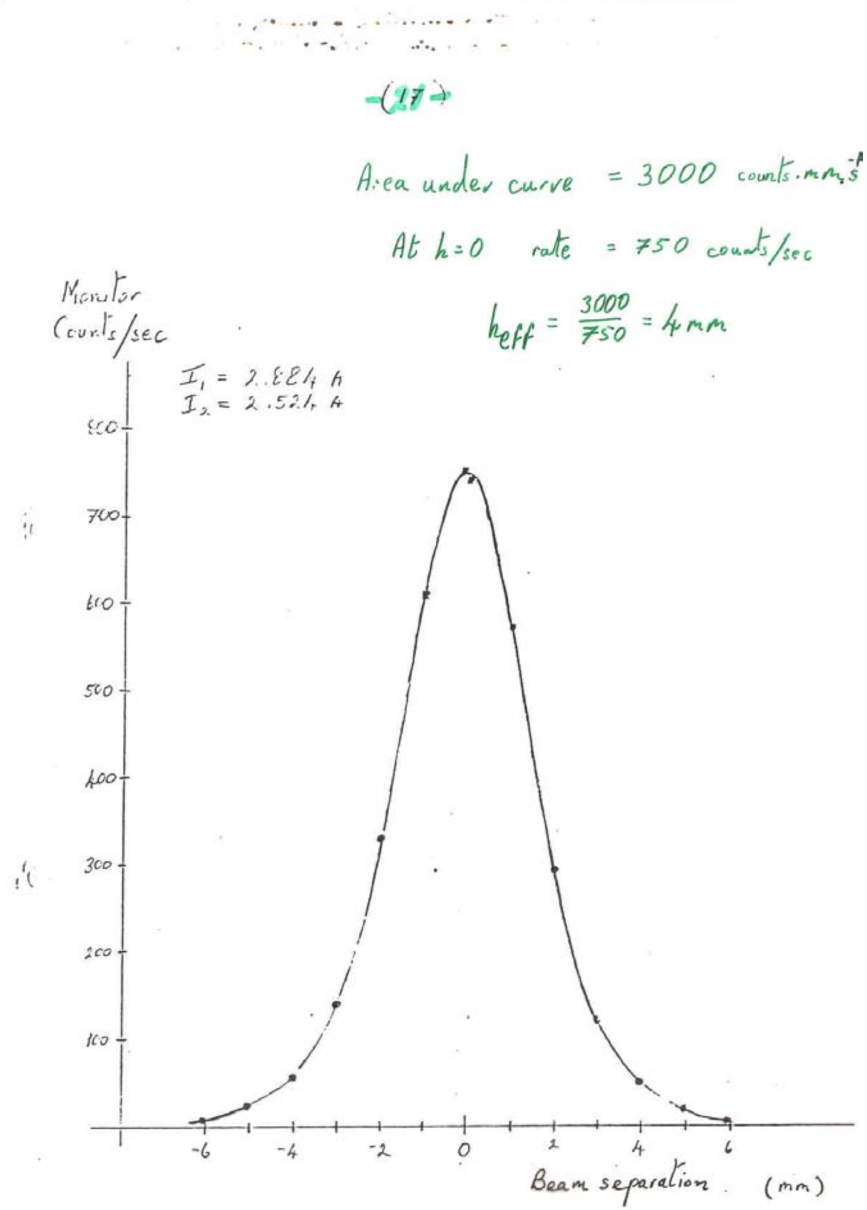
- Interaction rate as a function of beam separation

$$h_{eff} = \frac{\text{Area under the distribution}}{\text{counting rate}}$$

- At the ISR a single scan determined the absolute luminosity to 1%

- The LHC needs two orthogonal scans (X_{eff},Y_{eff})

- What precision is possible under what conditions?


-(17)-
Area under curve = 3000 counts.mm.s⁻¹
At h=0 rate = 750 counts/sec
h_eff = 3000/750 = 4mm
Monitor Counts/sec
I₁ = 2.884 A
I₂ = 2.524 A
800
700
600
500
400
300
200
100
-6
-4
-2
0
2
4
6
Beam separation (mm)

Conclusion

- The best interaction rate monitor for efficient machine operation is unlikely to provide the best absolute luminosity monitor
- The machine and experiments need to work together
- There is still plenty of work to do