Simulation of the Small Angle Pixel Telescope Luminosity Monitor

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- A brief overview of the proposed Luminosity Monitor

- Simulation Studies

Proposed CMS Luminosity Measurement Techniques

Real time Techniques

- HF
- Pixel Telescopes

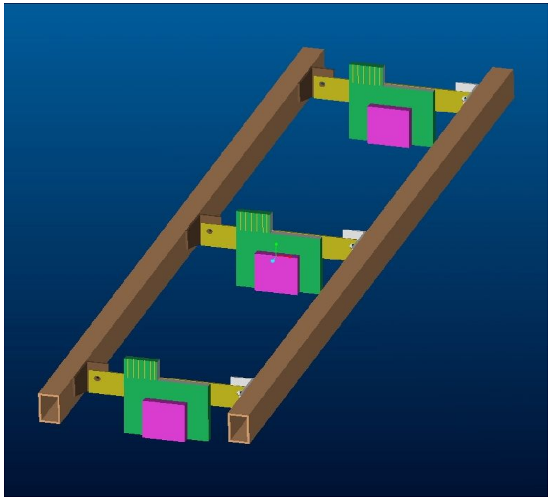
- Measure relative luminosity on bunch-by-bunch basis
    - bunch-to-bunch uniformity
    - fast feedback for beam tuning

- Absolute calibration form known cross sections (W,Z)

Pixel Luminosity Telescope (PLT)

Sensors in three fold coincidence looking at MB tracks from the interaction region.

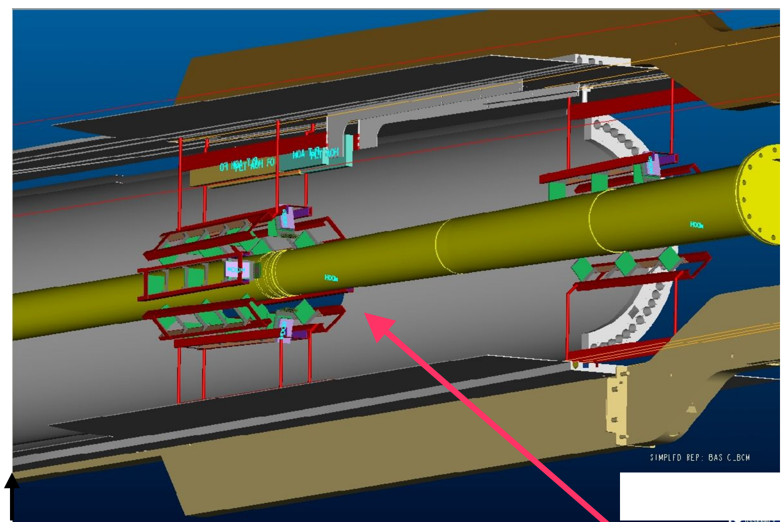
- Sensor size (8mm x 8 mm)
- Located ~170 in z from IP,~4cm from beam axis
- Total length 20 cm
- Eight arrays per side



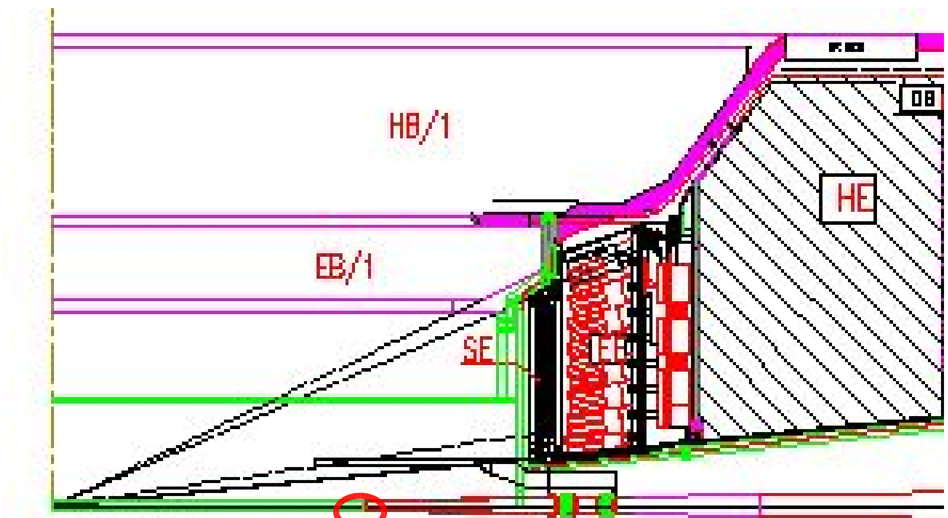
A pixel sensor array (one telescope)

Location

- Just outside of beam pipe (~ 4 cm from beam line)
- End of Be section of beam pipe (~ 1.7 m from IP)



IP

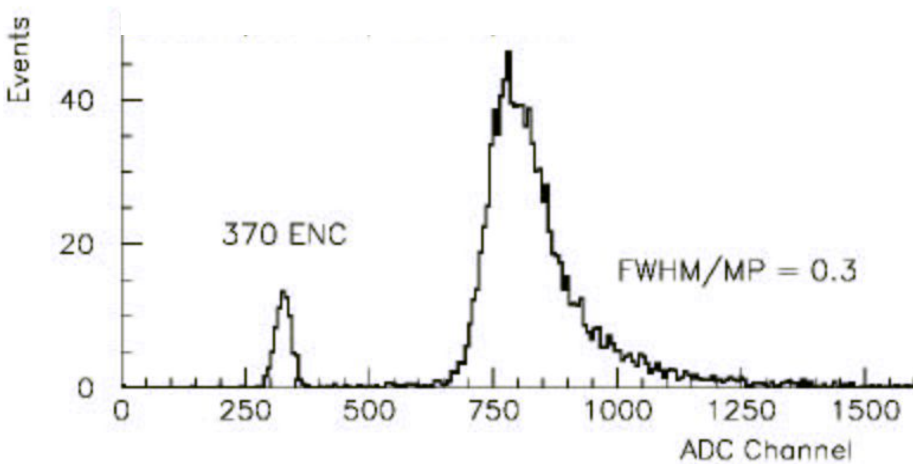


Luminosity telescopes

Sensor Material

Single crystal CVD diamond

- A new material
- Radiation hard
- Needs no cooling
- 18000 e for 500mm thick diamond
- Full charge collection @ 0.2V/mm



Read Out

Read out by CMS Pixel Readout Chips

pixels have lower capacitance   fast

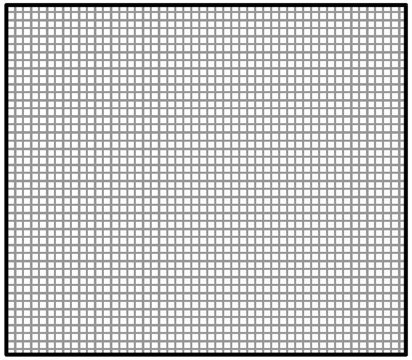
can use the same hardware developed for the pixels

CMS Pixel ROC:

- Active area: 8mmx8mm
- Individual pixel thresholds adjustable/masked
- regular pixel readout at L1
- A FAST OR output for every clock cycle (bunch crossing).

8 mm

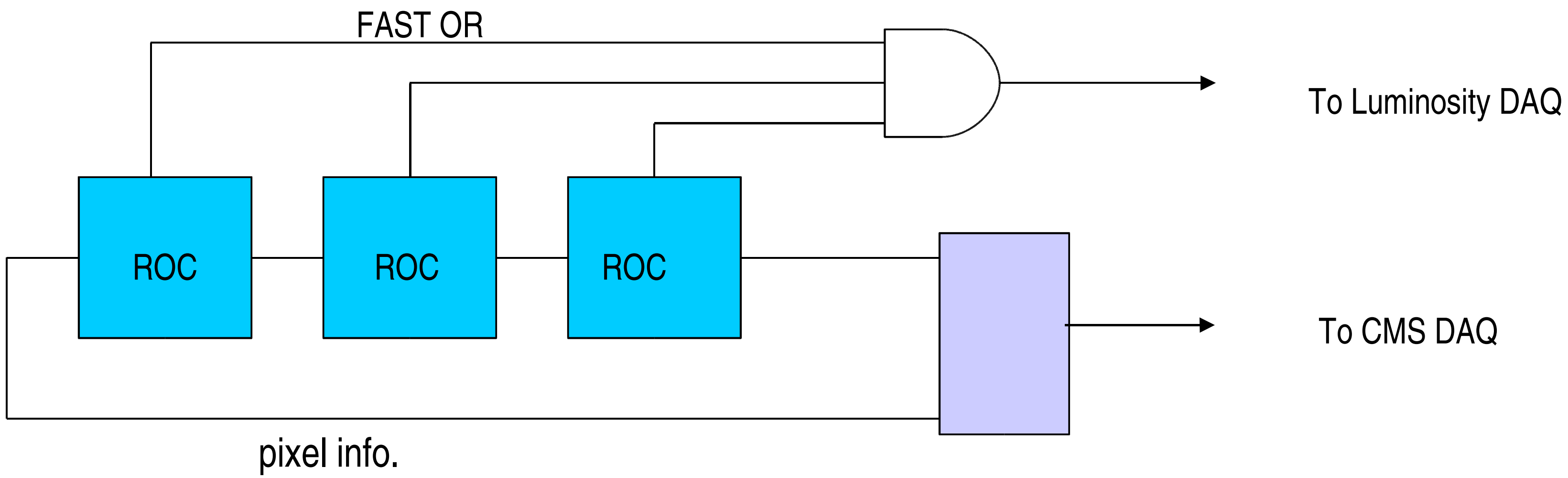
8 mm



80 x 53 pixels

100 µm x 150 µm

Read Out Scheme



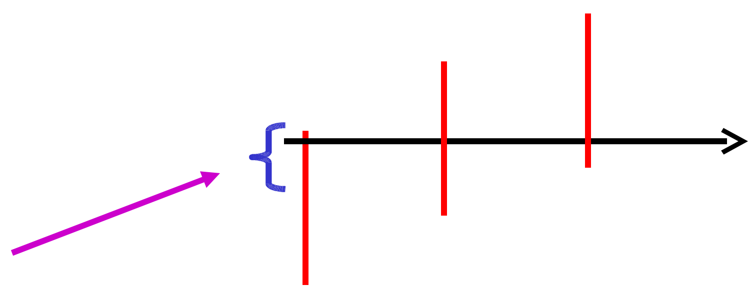
- FAST OR coincidence can be read for each bunch crossing.
- Track multiplicity for each bunch will be stored in a histogram

Pixel Readout

In addition it is possible to get full pixel readout at every L1 trigger

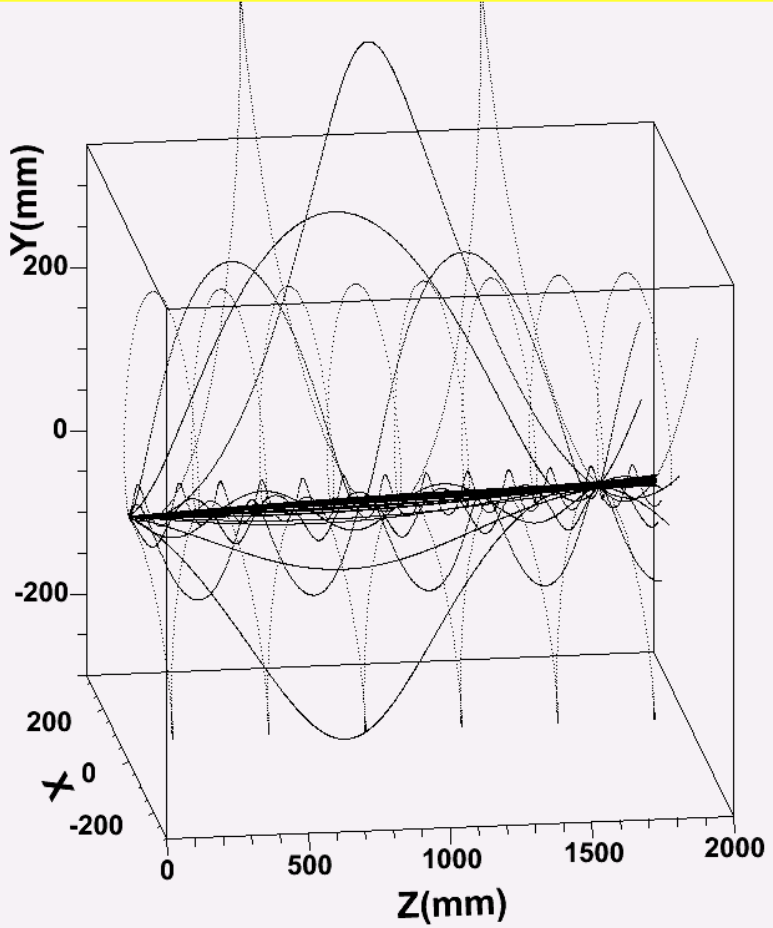
- pixel address and pulse height of each hit
  - determination of transverse track position at the IP better than 300mm
- distinguish particles from IP, scattering, beam halo

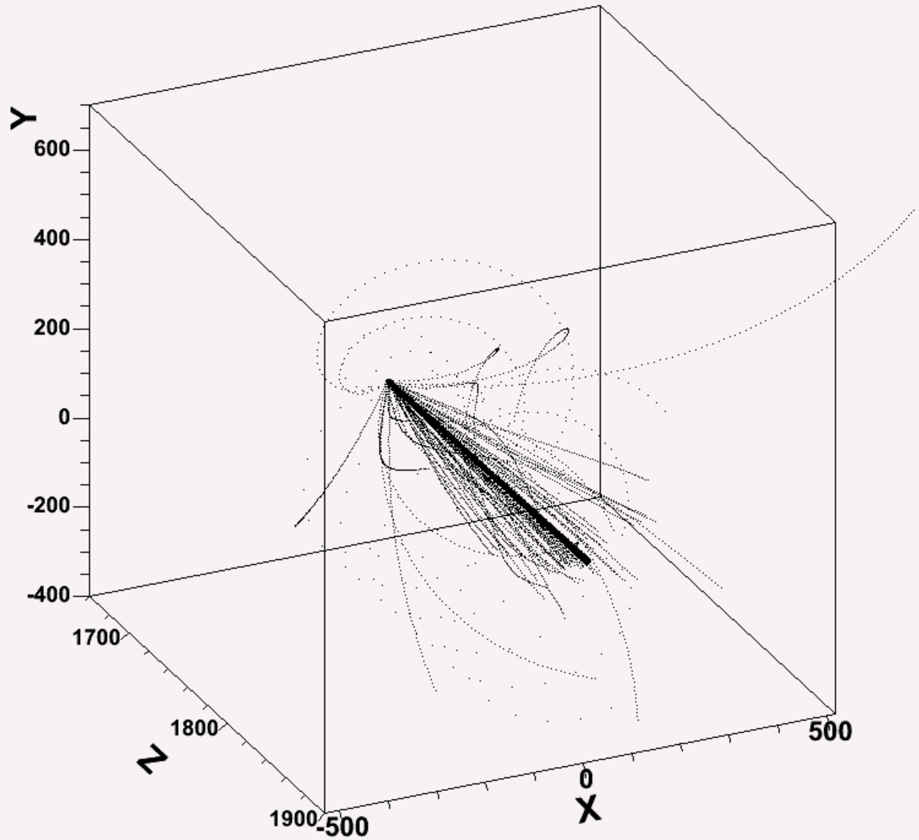
if background to luminosity measurement, mask pixels



Simulation Studies

- Minimum Bias events generated in CMKIN with PYTHIA 6.22 (with default parameters)
- Preliminary study:
  - NTUPLE generated by CMKIN was converted to root.
  - Using a root script particles in the events were propagated analytically in a 4T field.
- Full OSCAR simulation with CMS geometry and magnetic field





Hits per interaction (~20 interactions/bunch crossing @L=10^{34})

B field	senser1	sensor2	sensor3	Coincidences
0T	0.017	0.015	0.014	0.014
4T	0.020	0.018	0.165	0.013

Oscar Simulation

- Modified version of HCAL test beam simulation
  (TBHCal02 LumiMon)
- Full CMS geometry (Data/OSCARConfiguration.xml)
- CMS magnetic field (volume based)
- Eight telescope arrays per side (3x8x2= 48 sensors)
- Hits are stored as a CaloG4HitCollection
- Hits (E_{EM} ,E_{HAD} >0) and coincidences are counted

OSCARConfiguration.xml

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 <File name="CMS/CMSGeometry/beampipe.xml" url="."/>
 <File name="CMS/CMSGeometry/mgnt.xml" url="."/>
 <File name="Tracker/TrackerGeometry/trak.xml" url="."/>
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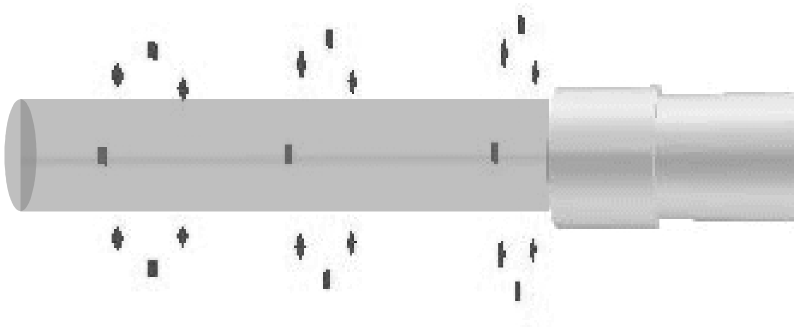


Numbering scheme/geometry

- Three sensors are place in a telescope (n=0,1,2)
- Eight telescopes are placed in a circular array to form a module (t=0-7)
- One modules each side (s=0,1)
- Hit position in each sensor is identified by pixel row and column numbers (r = 0-79, c=0,51)
- Hit id = 1E6*s + 5000(n*10 + t) + 100*c+r

Testing

- Charged particles were fired at telescopes using the particle gun
  - Saw hits in sensors when/where expected
- Repeated the same with a 2cm thick lead plate in front of the luminosity monitor with e,π^+,π^0
  - Saw showering (multiple hits)

- Comparisons with previous results

  Ran OSCAR simulation

    - without CMS detector or magnetic filed
    - without CMS detector with magnetic field
  - Good agreement with analytical results.

OSCAR Simulation Results

Hits in a telescope per MB interaction:

	senser1	sensor2	sensor3	Coincidences	
Location Z(m)/r(mm)	1.68/41	1.78/43.7	1.88/46.4		
• no CMS detector	0.017	0.015	0.014	0.014	or mag. filed
• no CMS detector	0.020	0.018	0.016	0.013	CMS magnetic field
• CMS Detector and	0.036	0.032	0.029	0.014	Magnetic field

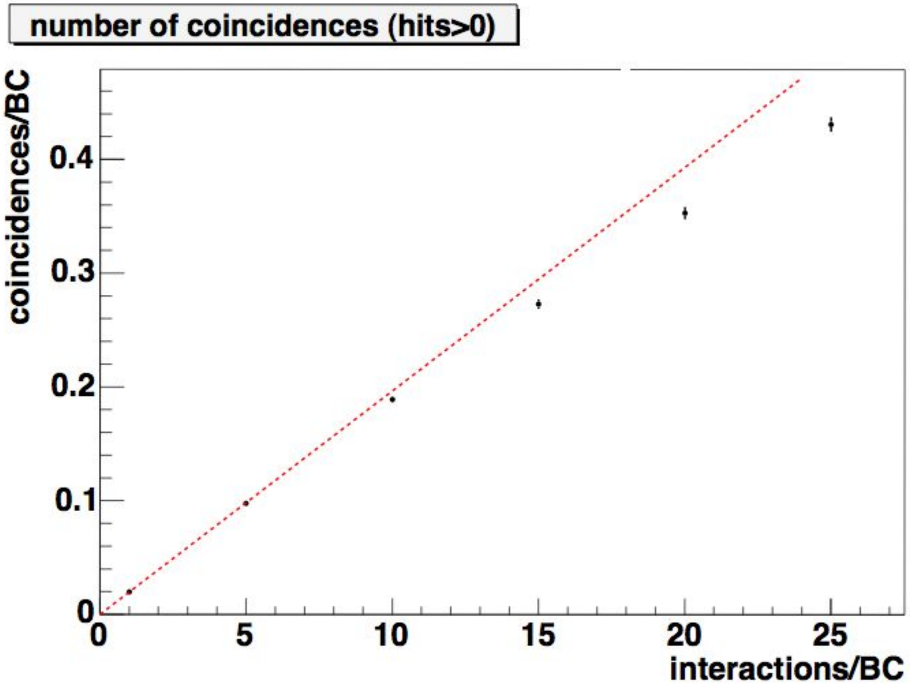
(errors ~ 2%)

~10% coincidences from backgrounds (γ ->e+ e-).

Luminosity Dependence

If we just count 3-fold coincidences
some non linearity due to multiple tracks

12% effect at 25 interactions per bunch crossing ($L = 10^{34}$ cm^{-2} s^{-1})



- Get number of tracks by measuring fast out level
- Get fraction of multi track coincidences from full pixel readout

and/or

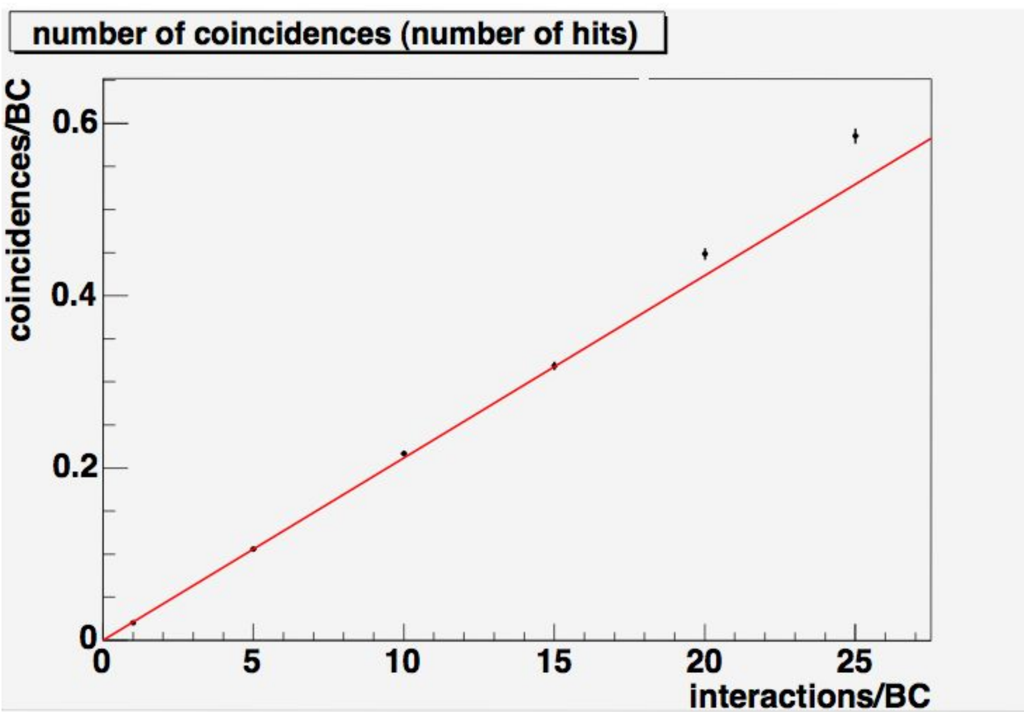
- Reduce fiducial area

Accidental Coincidences

Use fast out level to counts hits/plane

N_{tracks} = min ($hits_{plane1}$, $hits_{plane2}$, $hits_{plane3}$)

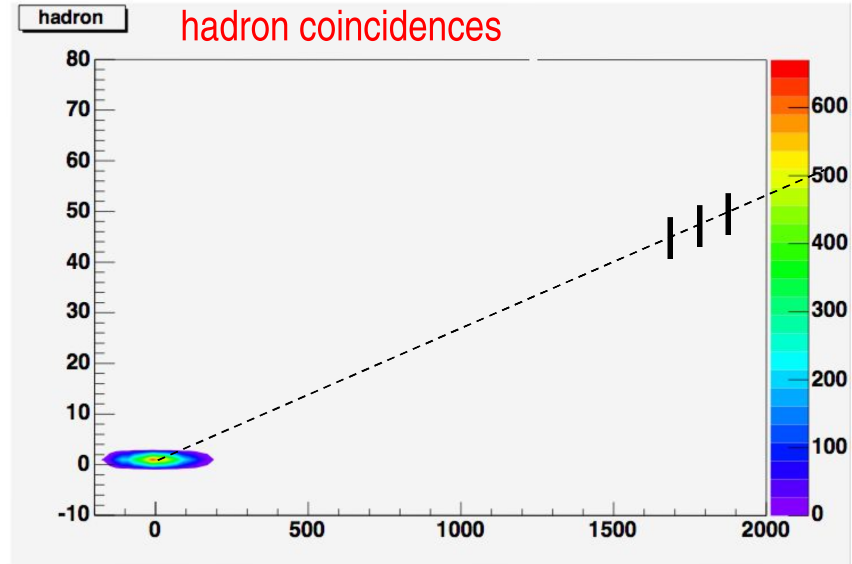
14% accidentals at 25 interactions per bunch crossing

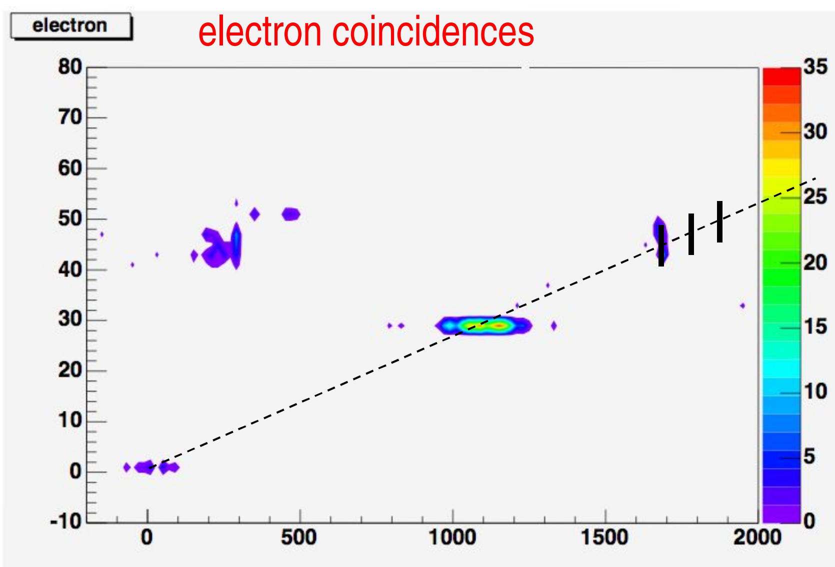


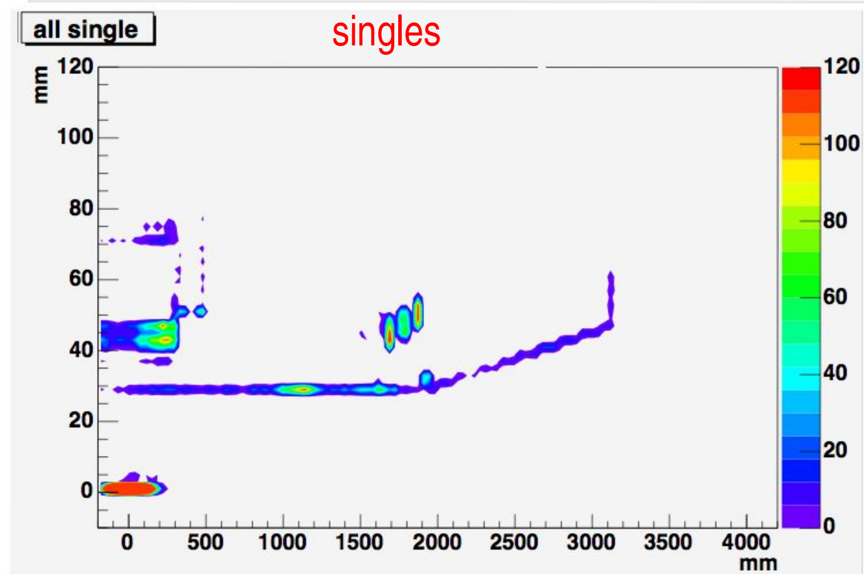
- Reduce fiducial area

Sources of Hits

- hadrons from physics (IP)
- electrons from physics (π^0 photon conversions in beam pipe)
- singles from IP, beam pipe, pixel detector, telescope planes







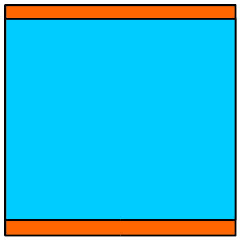
Acceptance Studies

Fast simulation: Find number of tracks by changing IP

the acceptance of the detector should be
flat to 1% over the region in which the
interaction point might wander

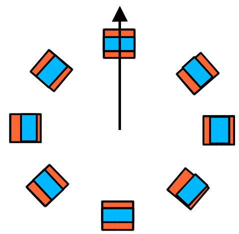
flatness can be maintained by cutting
(masking) 0.5 mm from top and bottom of
third plane (furthest from IP) in each telescope

makes the telescopes
less narrowly focused



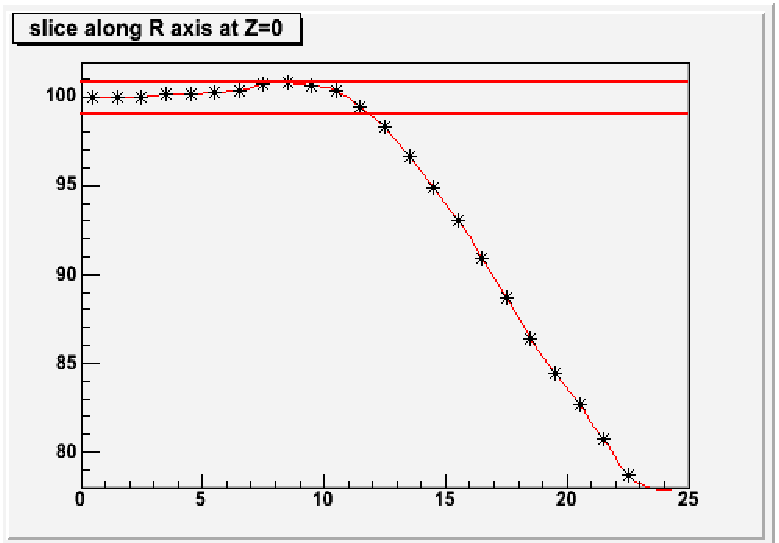
Acceptance Profiles

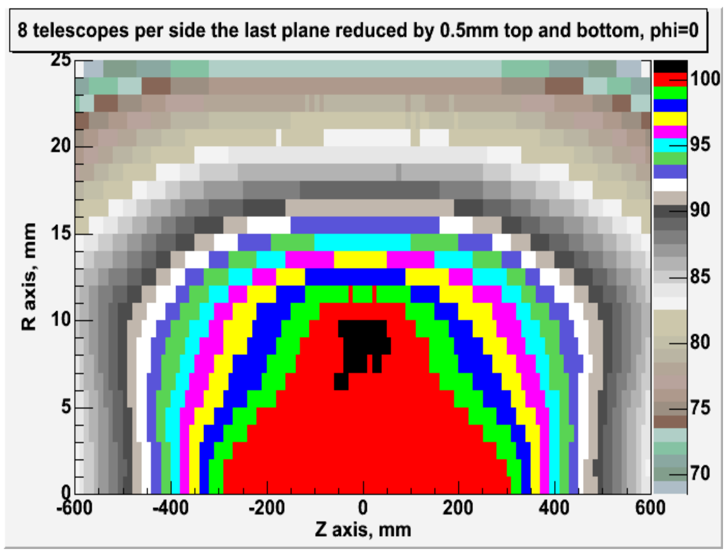
IP offset in radial direction of one telescope

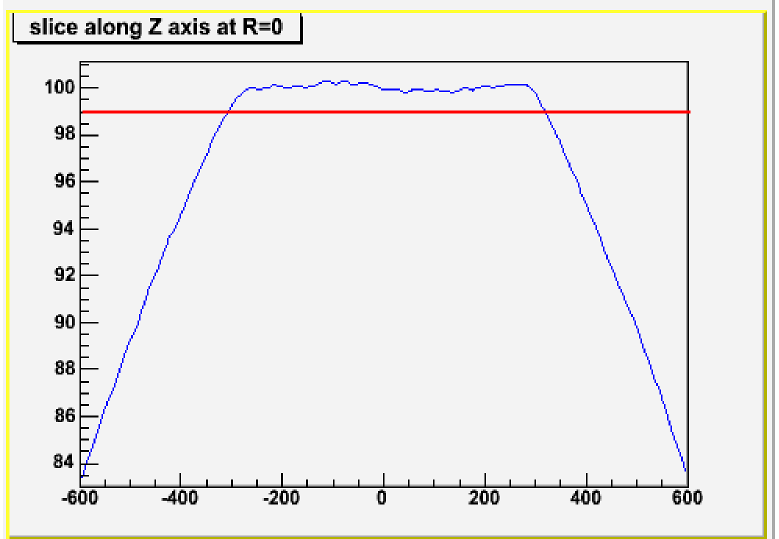


1% flat in r to 12 mm @ z=0

1% flat in z to ±320 mm @ r=0

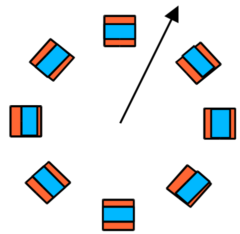






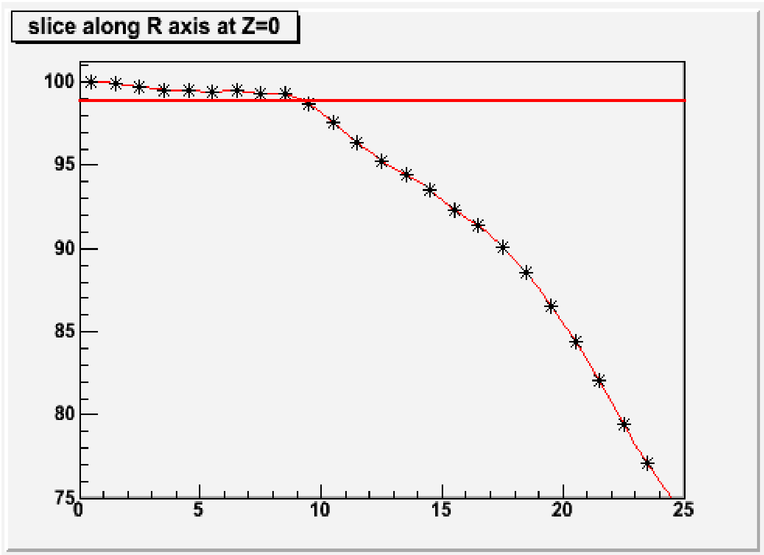
Acceptance Profiles

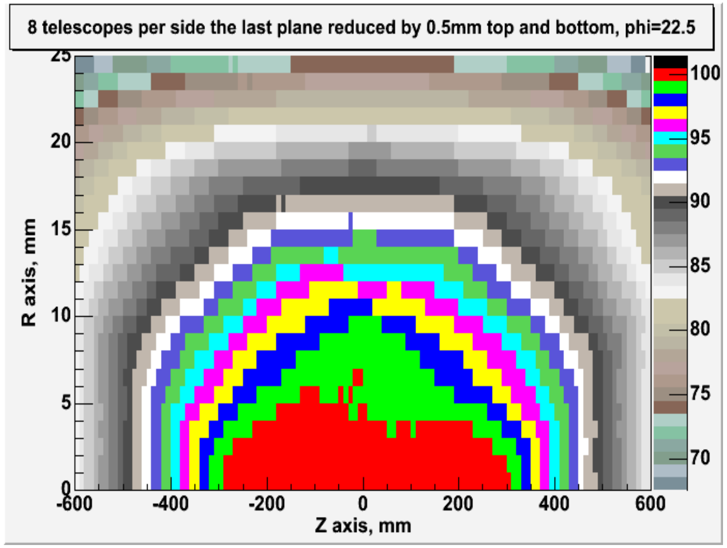
IP offset in radial direction between two telescopes

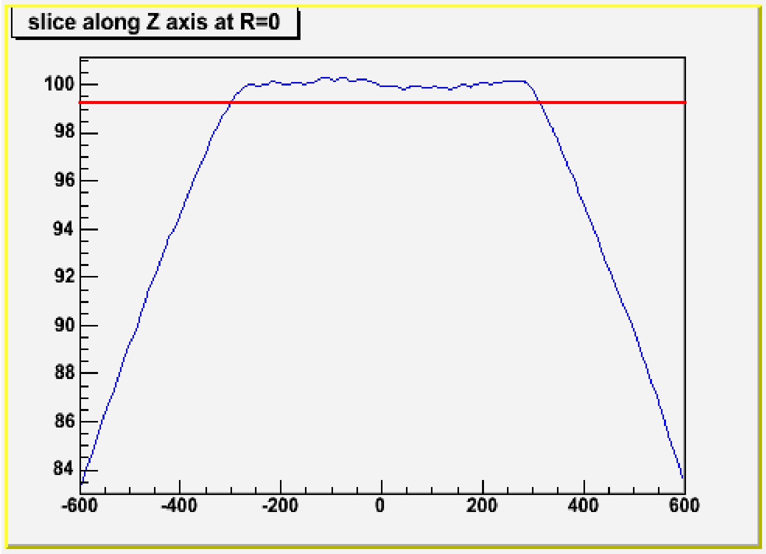


1% flat in r to 9 mm @ z=0

1% flat in z to ±320 mm @ r=0







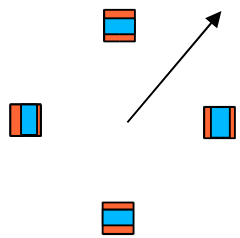
Acceptance with Four Telescopes

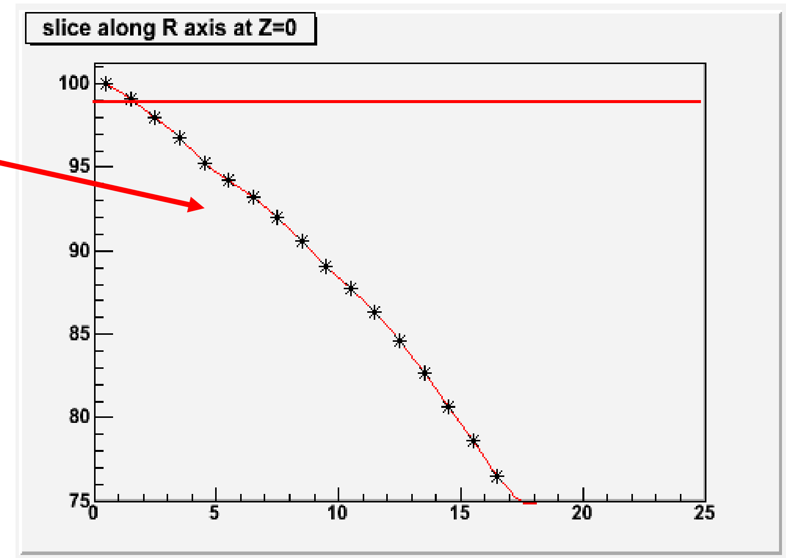
Four telescopes per side

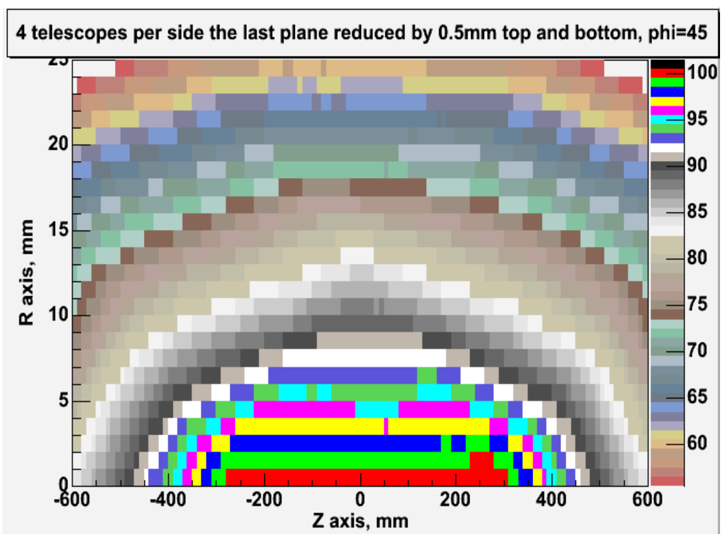
no flat region in r

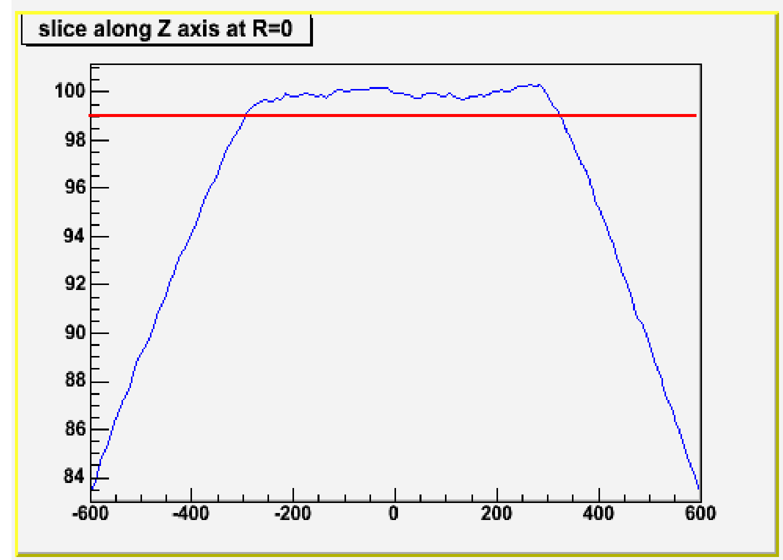
Need 8 telescopes per side

IP offset in radial direction between two telescopes





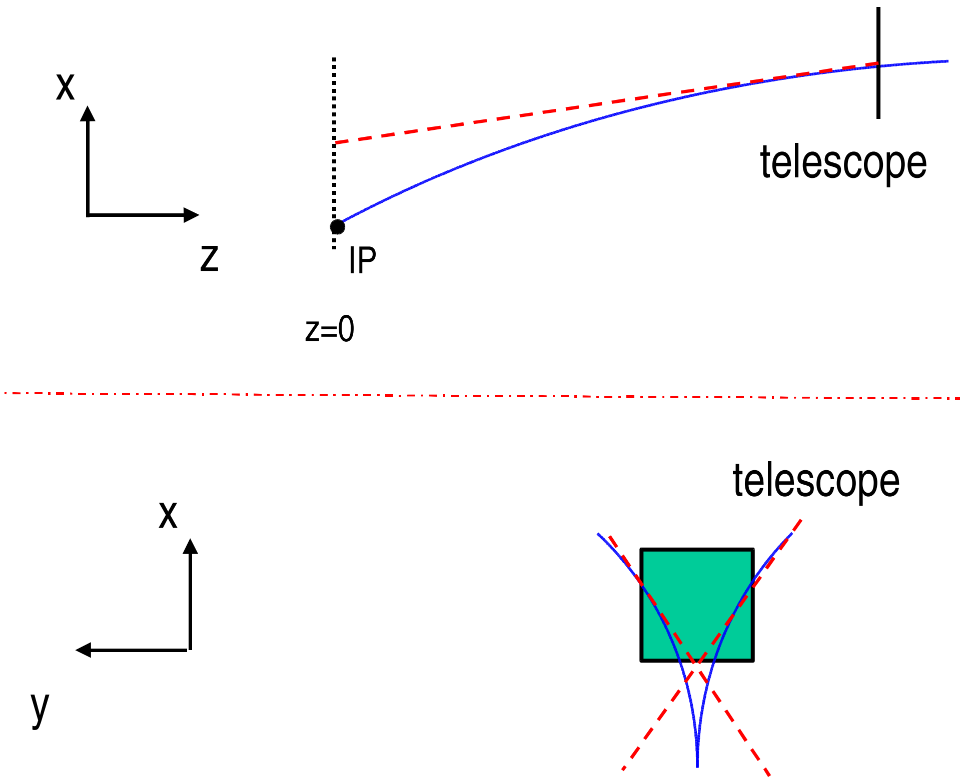




Track Curvature

Smearing in linear extrapolation of x/y position at z=0

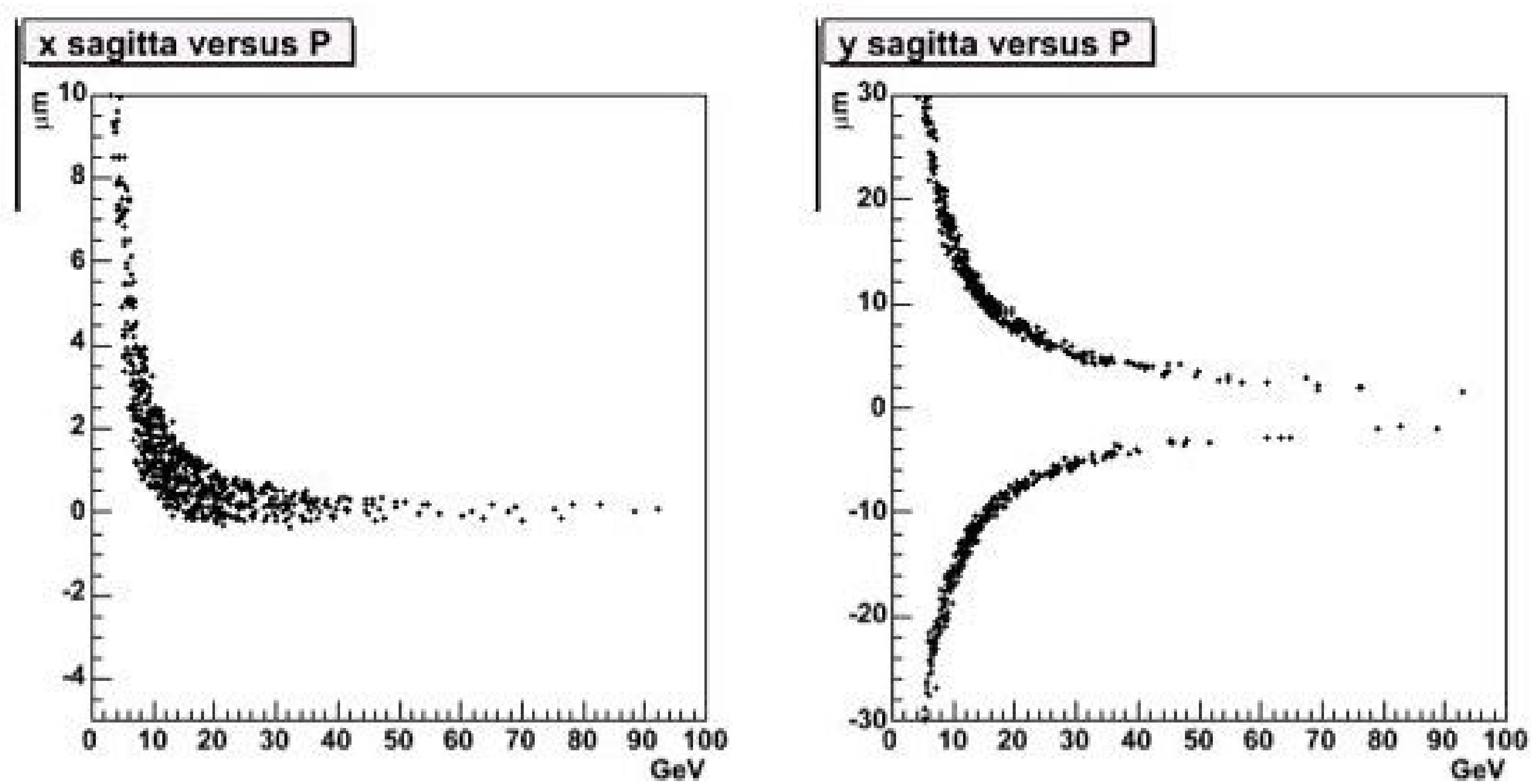
- curvature of track
  - momentum dependent
- longitudinal beam spread
  - source not at z=0
- effect greater in y than in x direction



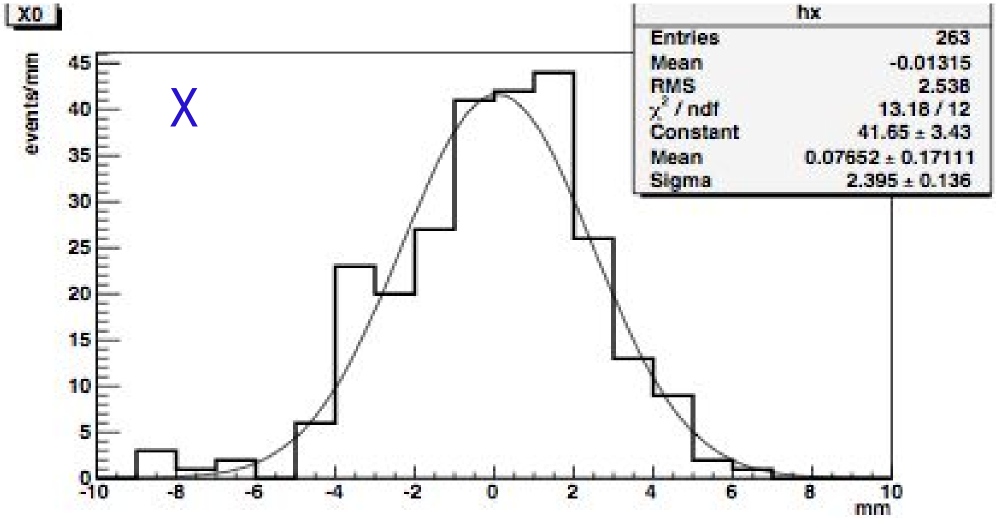
Sagitta

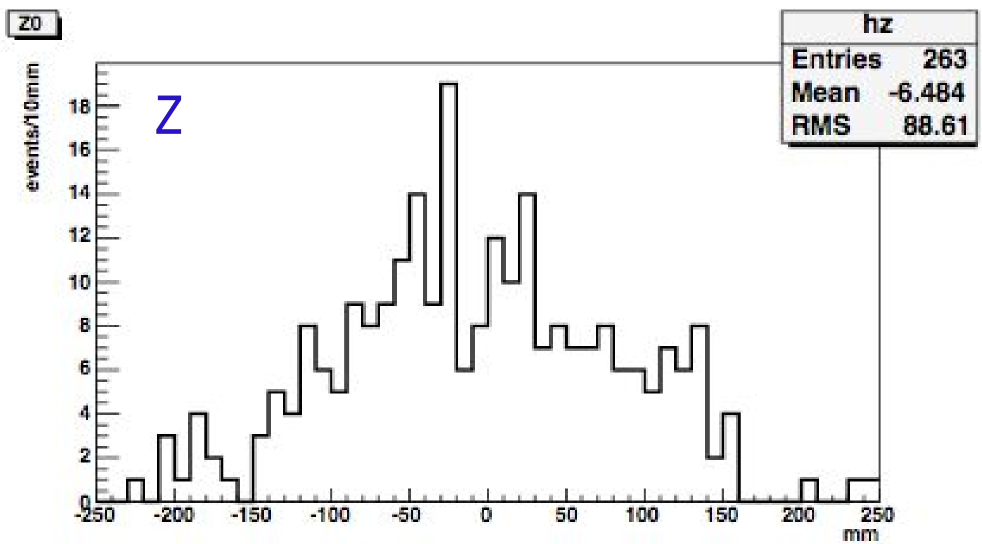
Sagitta is too small to measure

spatial resolution 30 μm (43 μm)
for 100 μm x 150 μm pixels



IP Distributions





σ_x = 2.4 mm (0.63 mm)

no longitudinal beam spread

σ_z = 89 mm (19 mm)

Location of IP Centroid

Relative location of IP

- $L = 10^{33}\ cm^{-2}\ s^{-1}$
- assume readout rate of 30 kHz
  ~ 1200 tracks per telescope per s
- σ_x = 2.4 mm
- σ_z = 90 mm
- 4 telescopes involved in x/y measurement
- 16 telescopes involved in z measurement

@ $L = 10^{33}\ cm^{-2}\ s^{-1}$ in 1 s

35 μm centroid precision in x/y

700 μm centroid precision in z (statistical)

Summary

- A full simulation of the luminosity monitor was done.
- Performance of the proposed luminosity monitor (PLT) meets the requirments.
- More studies/tuning underway

Thanks LPC, Daniel, Stefan …