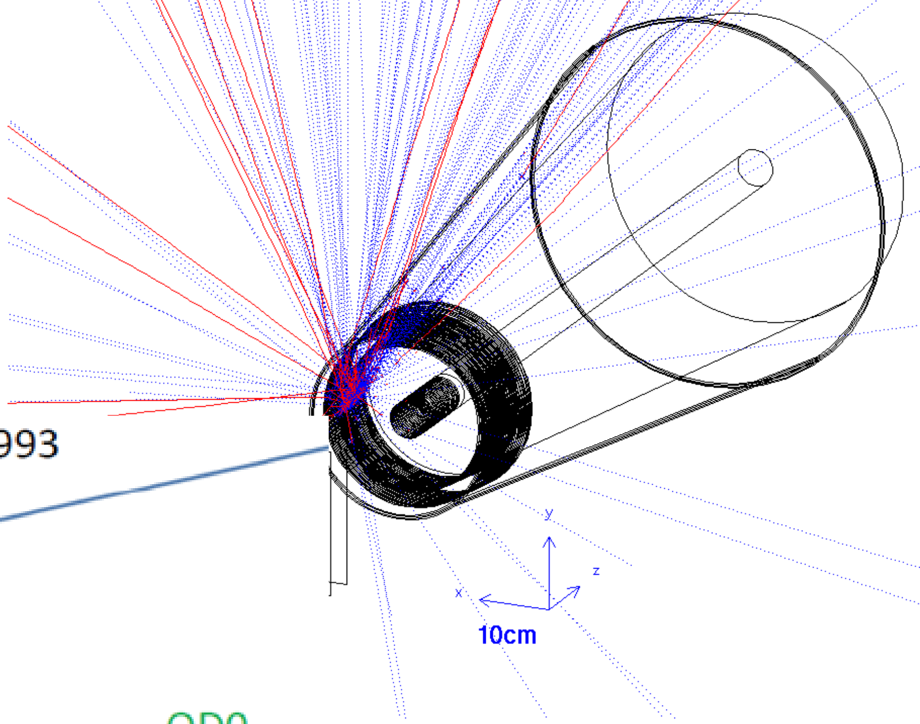
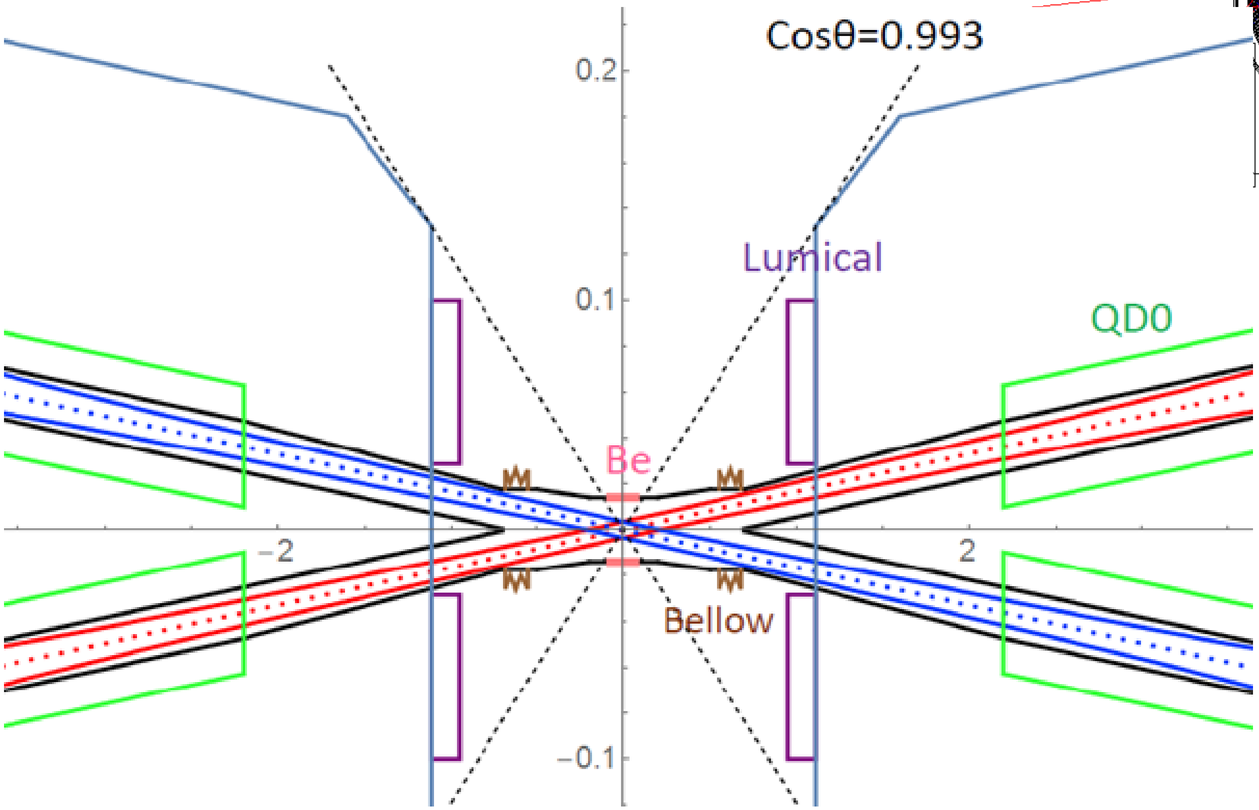
LumiCal at CEPC





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presented by
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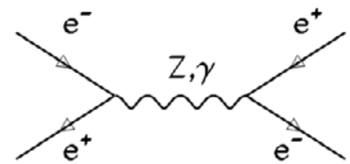
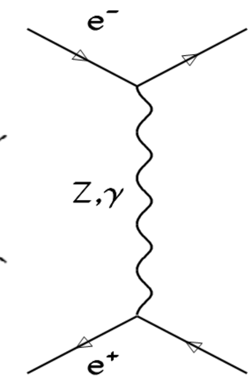
Luminosity measurement

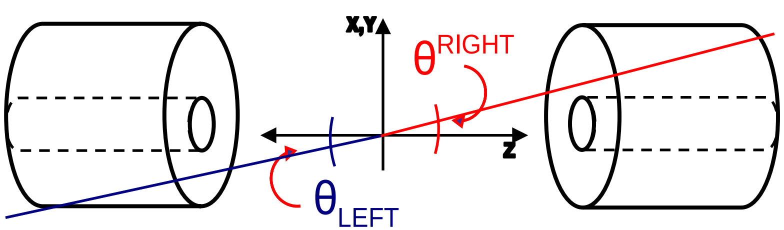
- Z lineshape, $e^+e^- \rightarrow Z \rightarrow q\bar{q}$ is dominant, ***σ = 41 nb***
- Luminosity is best provided by detecting\
  Bhabha, $e^+e^- \rightarrow e^+e^-$, elastics scattering
  - a pure QED process, theoretical MC to <*0.1%* precison
  - triggering on a pair of scattered e^+e^-

$E(e^{\pm}) \sim E_{beam}$, Back-to-Back

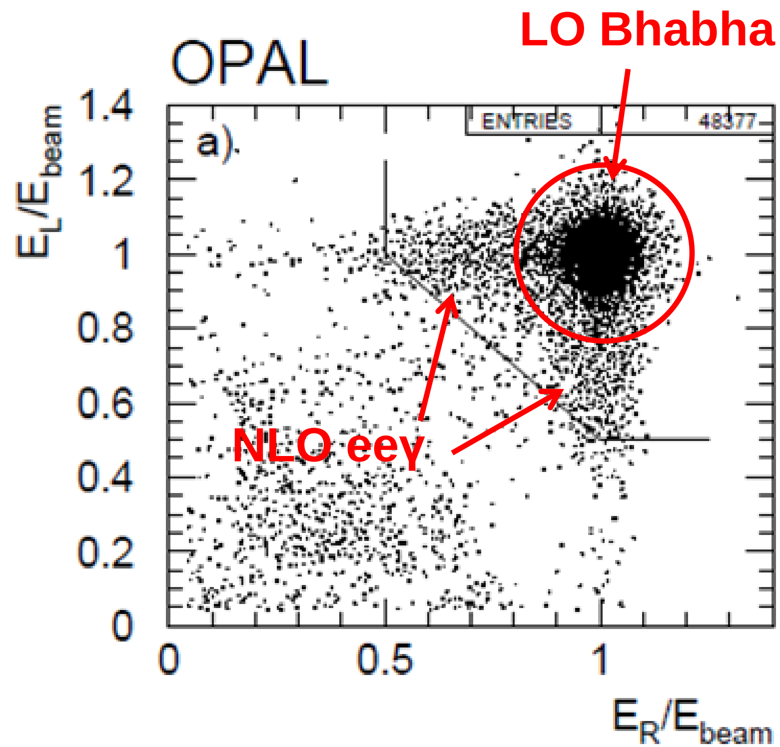




$$\sigma = \frac{16\pi\alpha^2}{s}\left(\frac{1}{\theta_{min}^2} - \frac{1}{\theta_{max}^2}\right)$$



$$\Delta\theta \equiv \theta_{RIGHT} - \theta_{LEFT}$$



LumiCal precision

Luminosity is by counting Bhabha events

In a fiducial θ region

$$\mathcal{L} = \frac{1}{\varepsilon}\frac{N_{\rm acc}}{\sigma^{\rm vis}} \qquad \sigma = \frac{16\pi\alpha^2}{s}\left(\frac{1}{\theta^2_{min}} - \frac{1}{\theta^2_{max}}\right)$$

Dominant systematic error

$\delta L/L \sim 2\, \delta\vartheta/\vartheta_{min}$

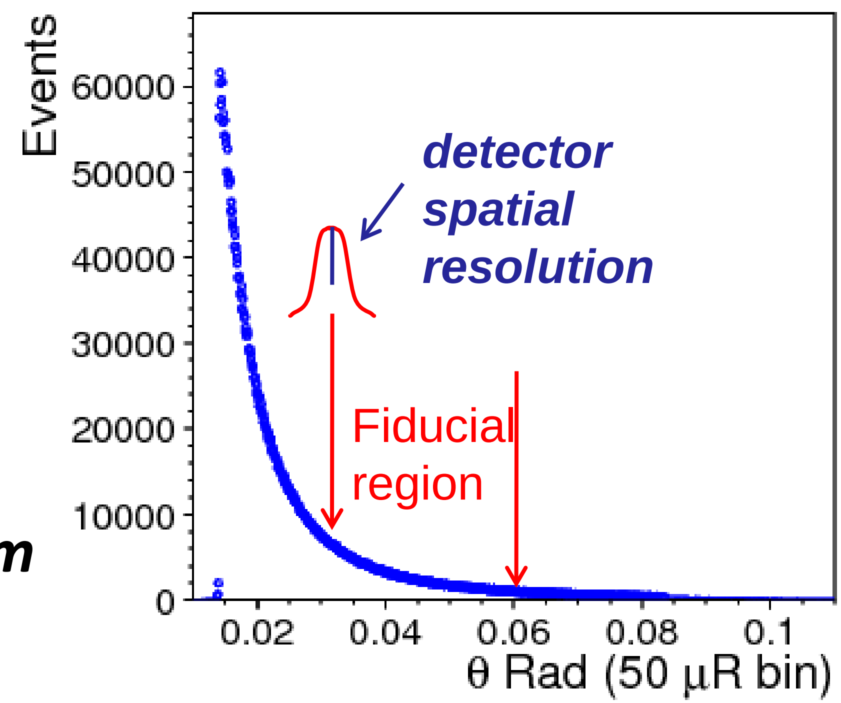
For a precision of $\delta L/L < 10^{-3}$

LumiCal at **z = ±1 m,** θ_{min} = 30 mRad

→ $\delta\vartheta$ = *15 μRad* or ***dr = 15 μm***

Error due to offset on Z

→ *0.1 mm on z* or *dr = δ Rx*ϑ ***= 3 μm***

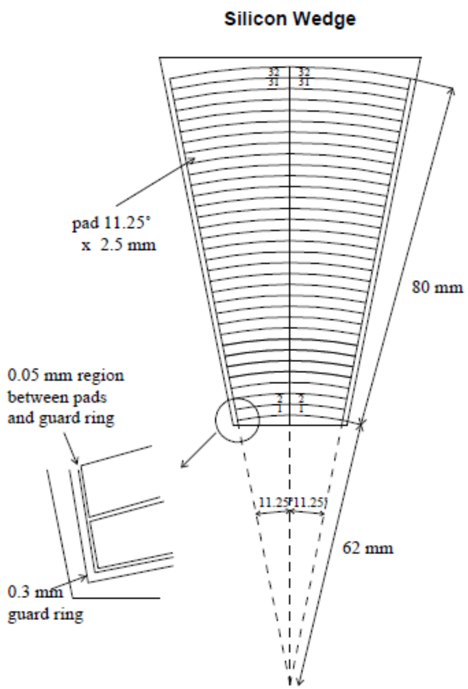


offset on the ***mean***
of spatial resolution = offset on θ_{min}
→ *dominant* ***LUMINOSITY error***

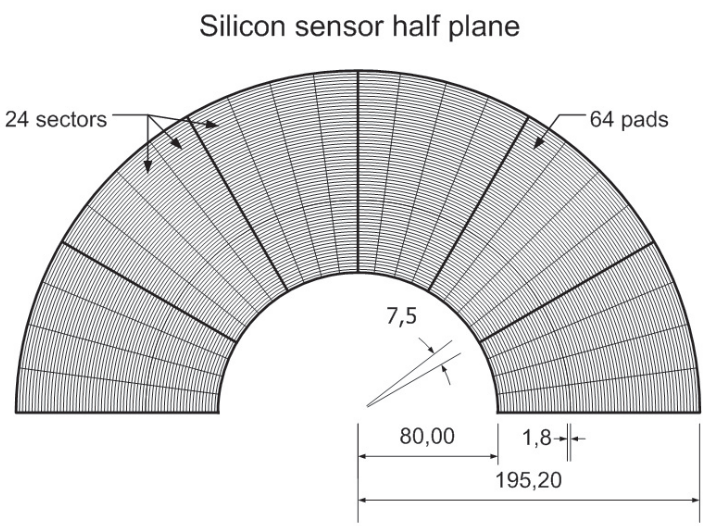
LumiCal vs LEP/ILD

	CEPC	OPAL	ILD
z to IP (m)	.95 ~ 1.11 m	2.5 m	2.5 m
radius (mm)	28 .5 ~ 100 mm	62 - 142 mm	80 – 195 mm
θ range	28.5 ~ 100 mRad	25 - 57 mRad	40 – 69 mRad
Si r-pitch	*Scale by Z to OPAL/ILD*	2.5 mm	1.8 mm
radius precision		4.4 μm	
Ref.		arXiv-0206074v1 EPJC 14 373	Procedia 37 258

OPAL
SiW



ILD
LumiCal



LumiCal in MDI region

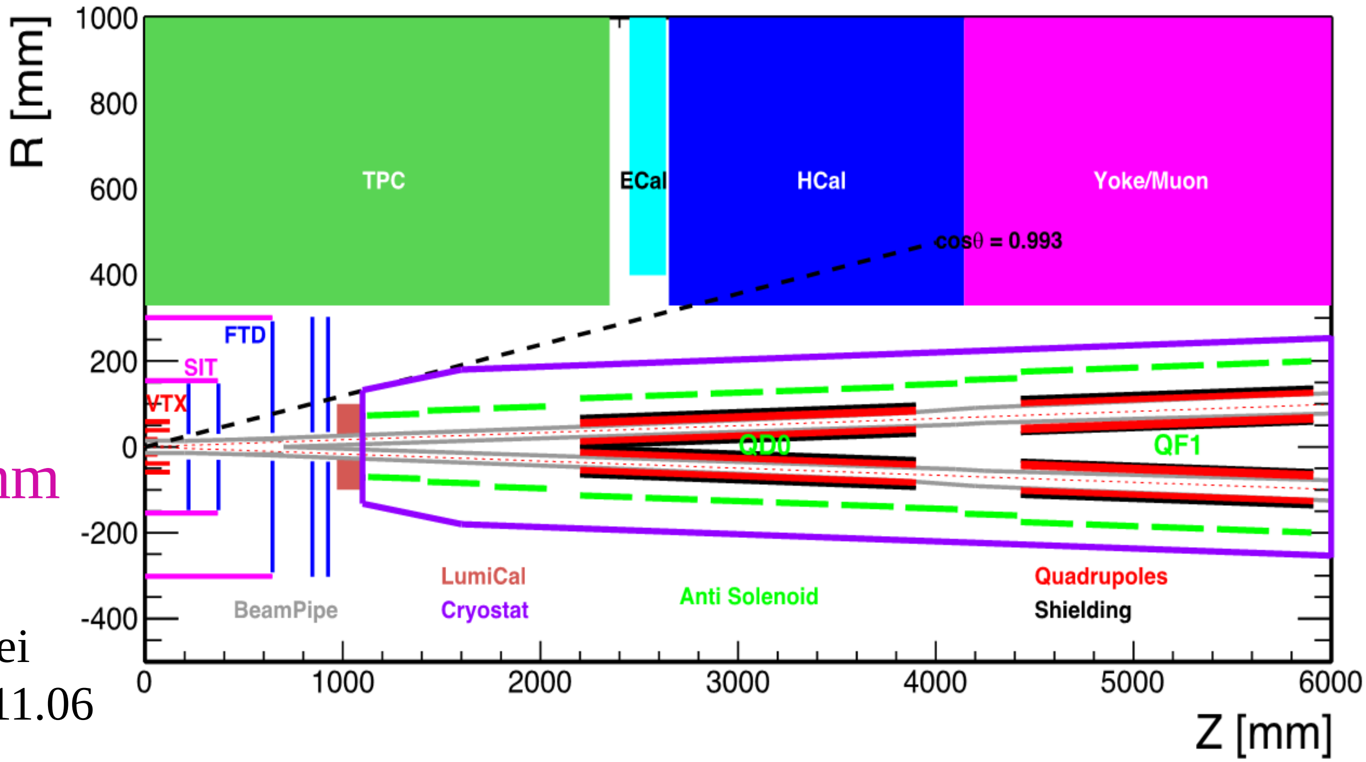
Mounted in front of Quadruple, front z ~ ±1 m

studies are conducted for

– **Beam crossing 33 mRad**

– **Electron shower leakage** in to TPC volume (z to ± 2 m)

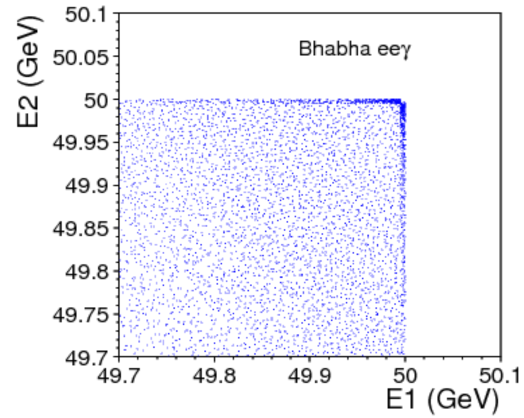
Be beampipe diameter ~ 28 mm



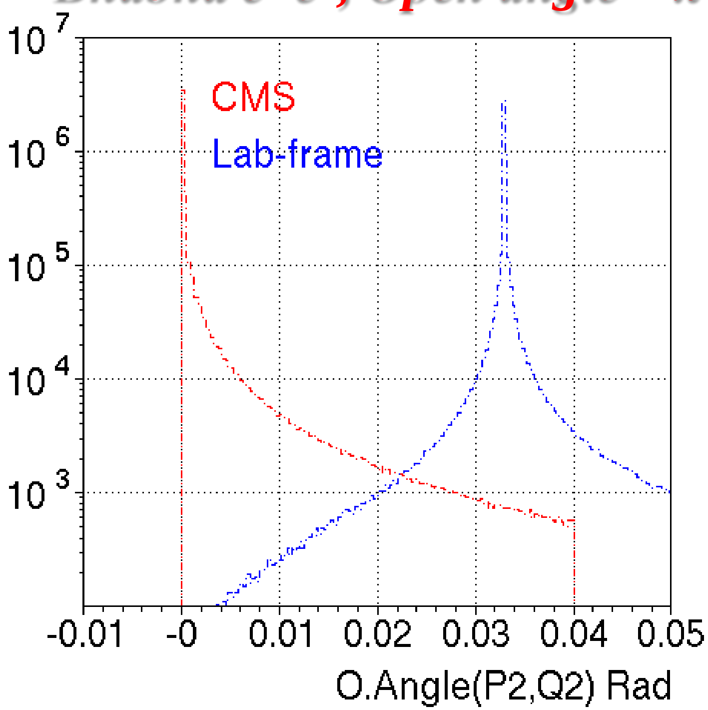
Sha Bei
2017.11.06

Boost by CEPC beam crossing angle

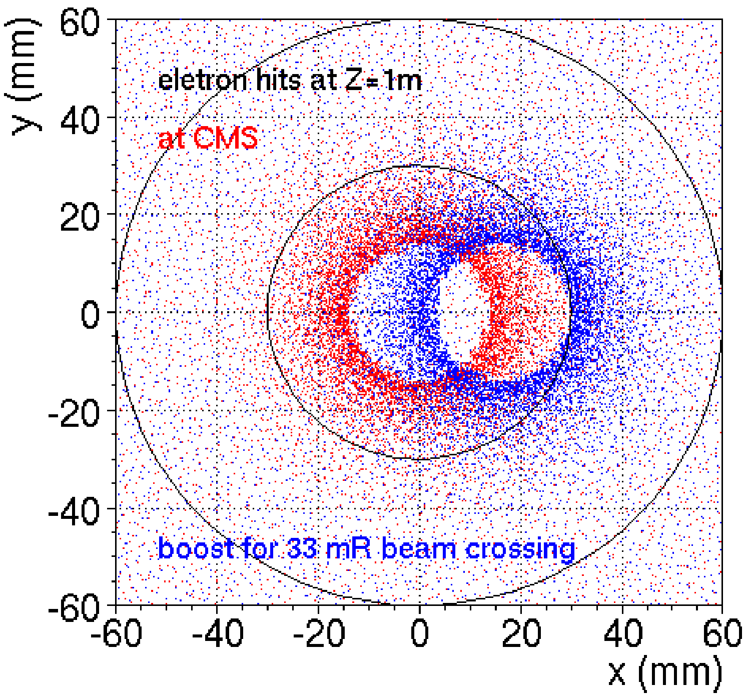
- ***BHlumi*** simulation, most are LO,
  $E(e^+)=E(e^-) = E_{beam}$, , OpenAng = π
- CMS(e^+e^-) boosted by beam crossing
- $e^\pm$ boosted *~16.5 mRad* off ring-center
  lost into beam-pipe



Bhabha e^+e^-, Open angle –π



Bhabha e^- @detector r-φ, z=1m



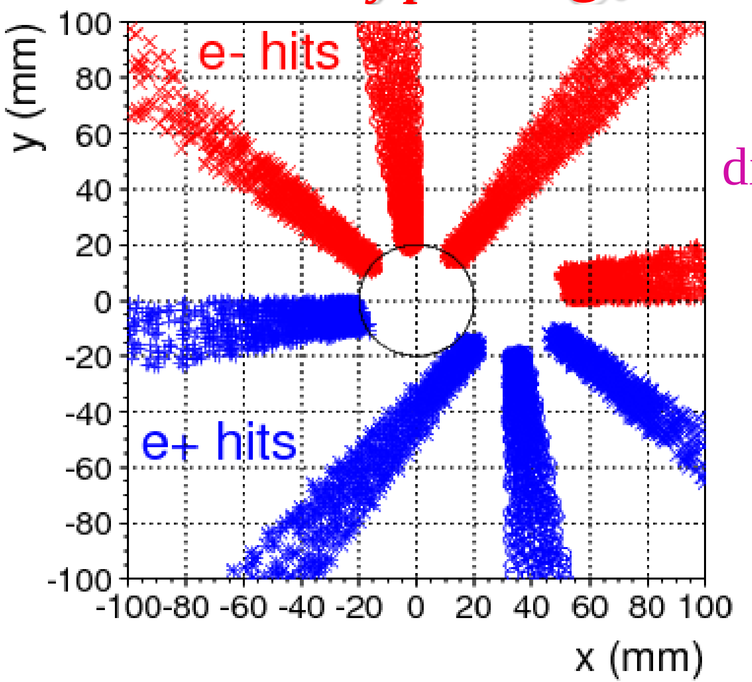
Boosted Bhabha

- Shift of LO Bhabha, (e^+e^-, no γ) on r-ϕ plane
- assuming e^+, e^- detected in ***fiducial of >20 mm***
- plotted in bands (every 45 deg in ϕ)
- event loss ***163 nb → 98 nb***

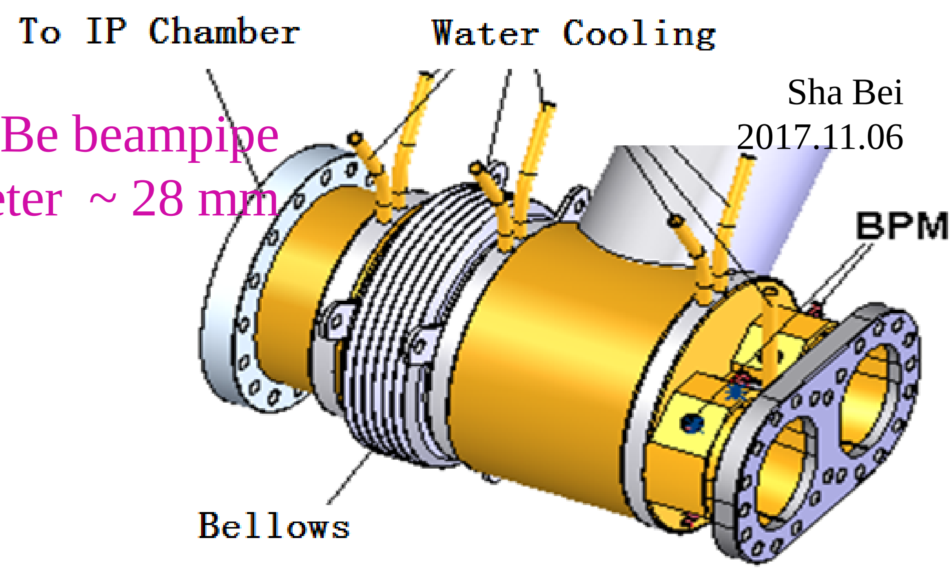
➔ *loss is SIGNIFICANT*

➔ *LumiCal wants a small inner r, in OVAL shape if feasible*

Hits on detector x-y planes @z=1m



Be beampipe
diameter ~ 28 mm



LumiCal
Inner R = 28.5 mm

LumiCal detector options

Luminosity precision **=** $e^{\pm}$ detection in ***r***, at inner radius of fiducial

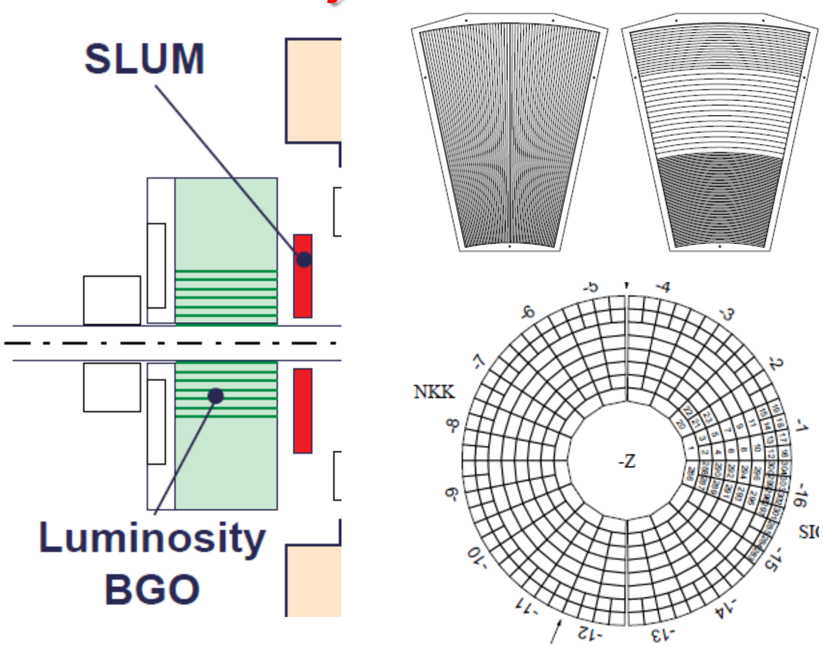
➔ **Silicon strip** is the choice!

➔ ***Alignment*** *CAN NOT reach 1 μm*

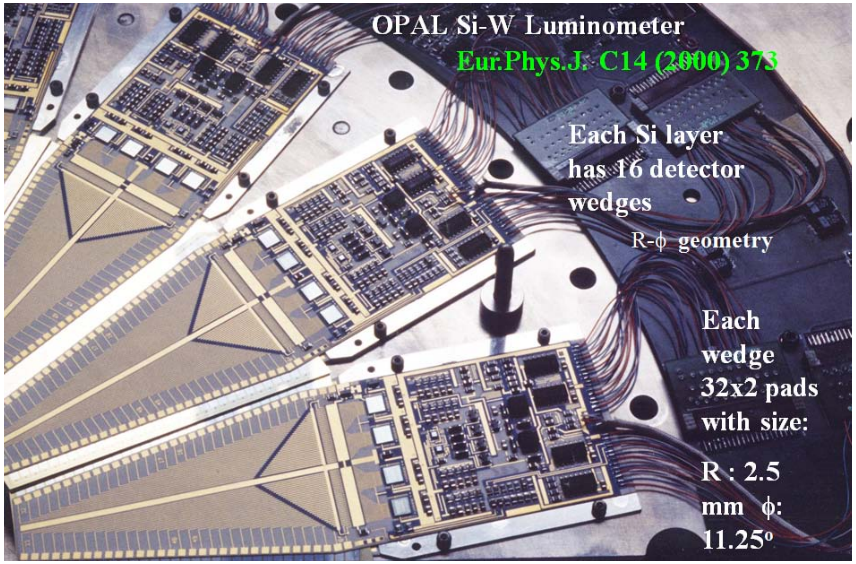
➔ ***wide strip*** *(~2mm) CAN NOT reach 10 μm resolution*

➔ *A* ***stand-alone LumiCal*** *CAN NOT calibrate its offsets to IP*

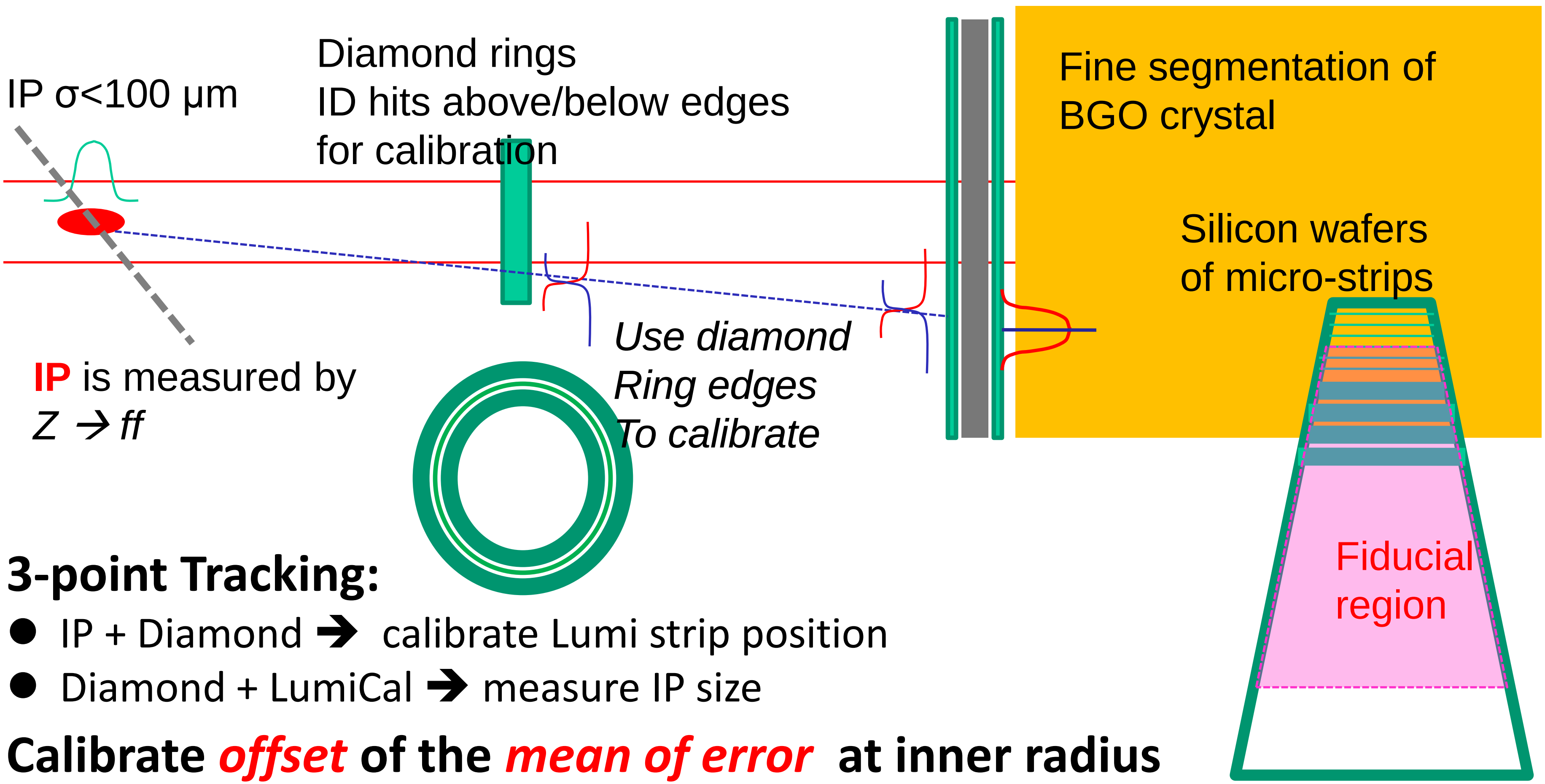
L3 Silicon layer + BGO



OPAL Si-W sandwich



LumiCal with a simple tracking ring



3-point Tracking:

- IP + Diamond ➔ calibrate Lumi strip position
- Diamond + LumiCal ➔ measure IP size

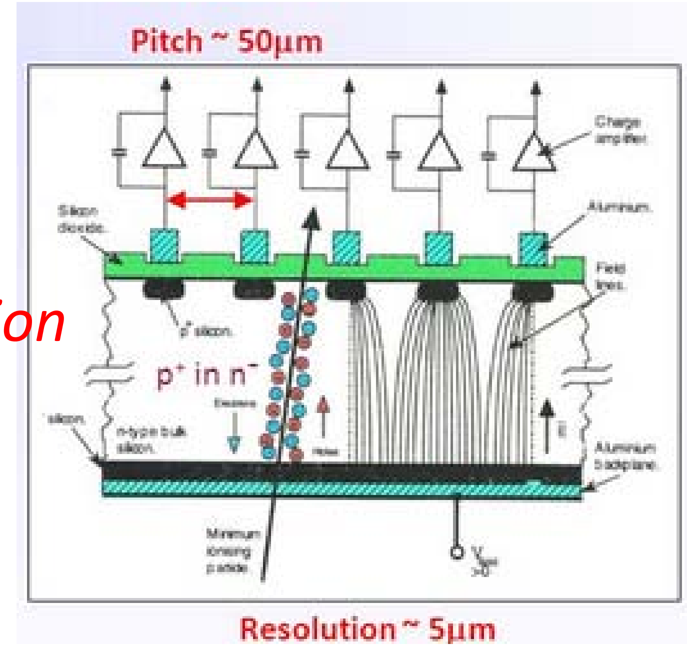
Calibrate *offset* of the *mean of error* at inner radius

*Silicon strip resolution **~ 5 um,***

error on mean is much smaller, ***CAN reach 1 μm, δL/L ~ 0.01 %***

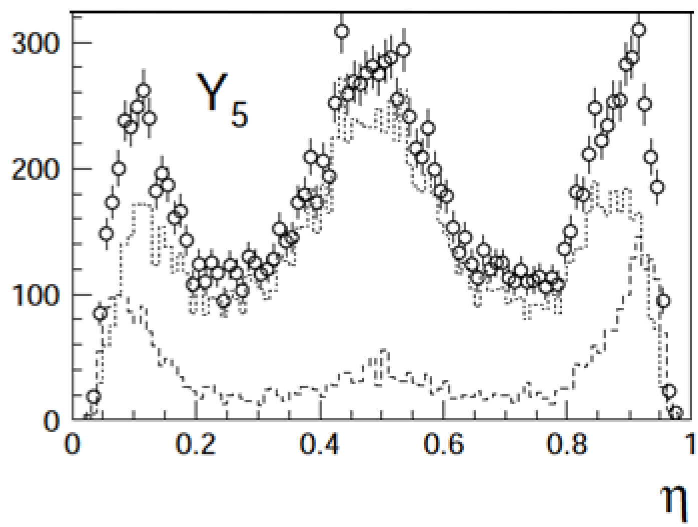
Si strips resolution

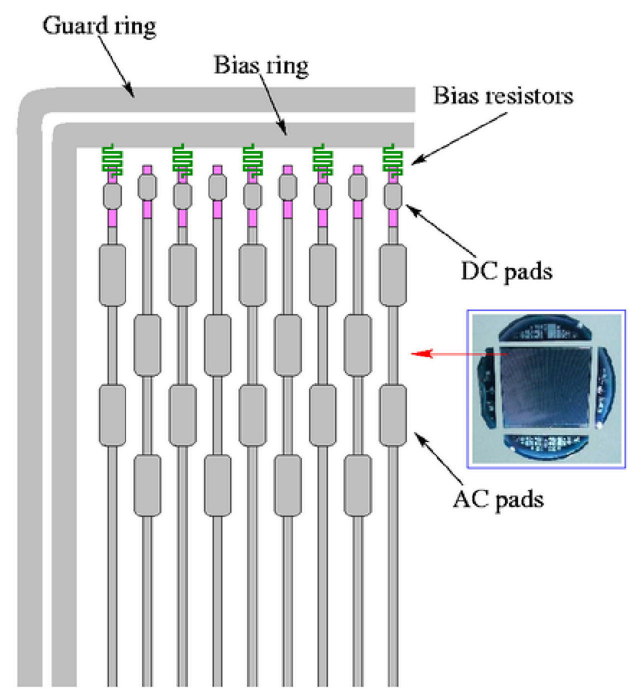
- Silicon strip of p-n on ~300 µm wafer
  - ionization e-h ~ 25k pairs in ~20 µm cone
- Readout pitch 50 µm ➔ *~5 µm resolution*
  - strip ~10 um, a floating p-implant
- Charge sharing of a MIP
  - to neighboring strips



$$\eta = \frac{Q_r}{Q_r + Q_l},$$

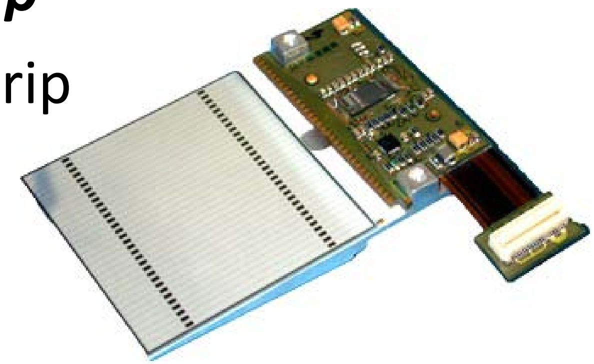
➔A flat η gives better resolution



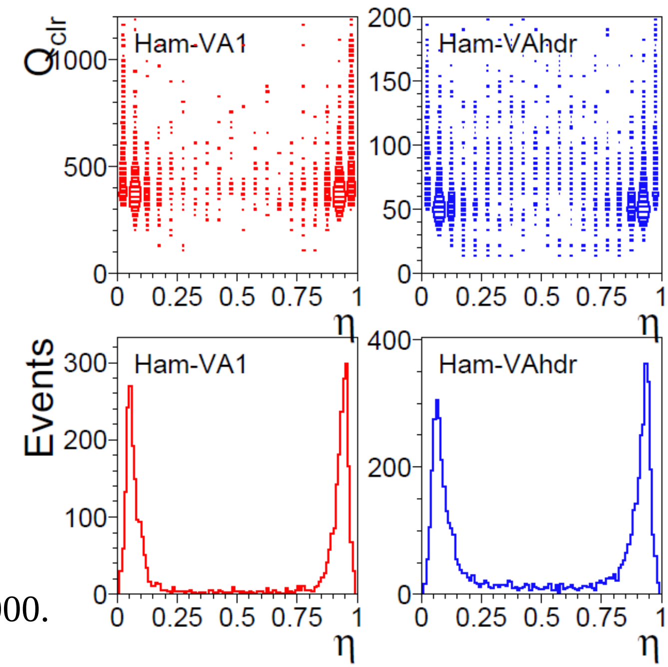


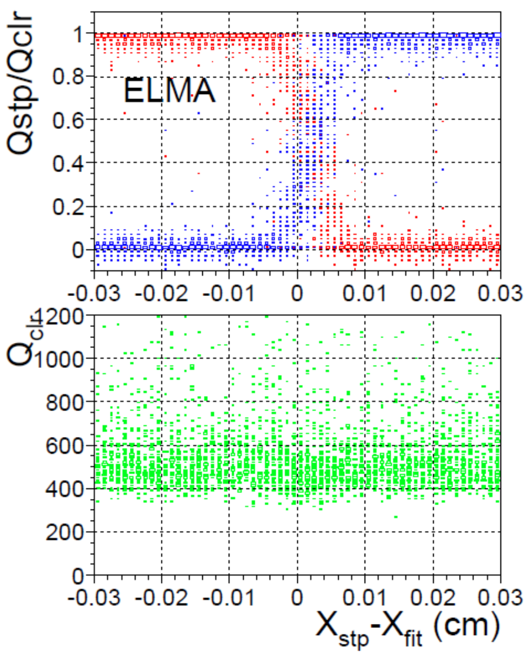
Spatial resolution of a wide Si strip

- CMS preshower prototype strips*
  380 μm thick, 1810 μm pitch, ***50, 160 μm gap***
- charge of A MIP is collected mostly in one strip
- a MIP in gap between two Si strips
  charge tend to drift to the nearest strip
  collection efficiency ~100%
  spatial resolution > 20 μm, the mean on error ??



$$\eta = \frac{Q_r}{Q_r + Q_l}$$





*CMS note 2000/042, 1 July, 2000.

LumiCal shower leakage

- **GEANT3 of a lateral shower testbeam***

  agree on charged multiplicity, lateral dist.

- **Si-W sandwich**

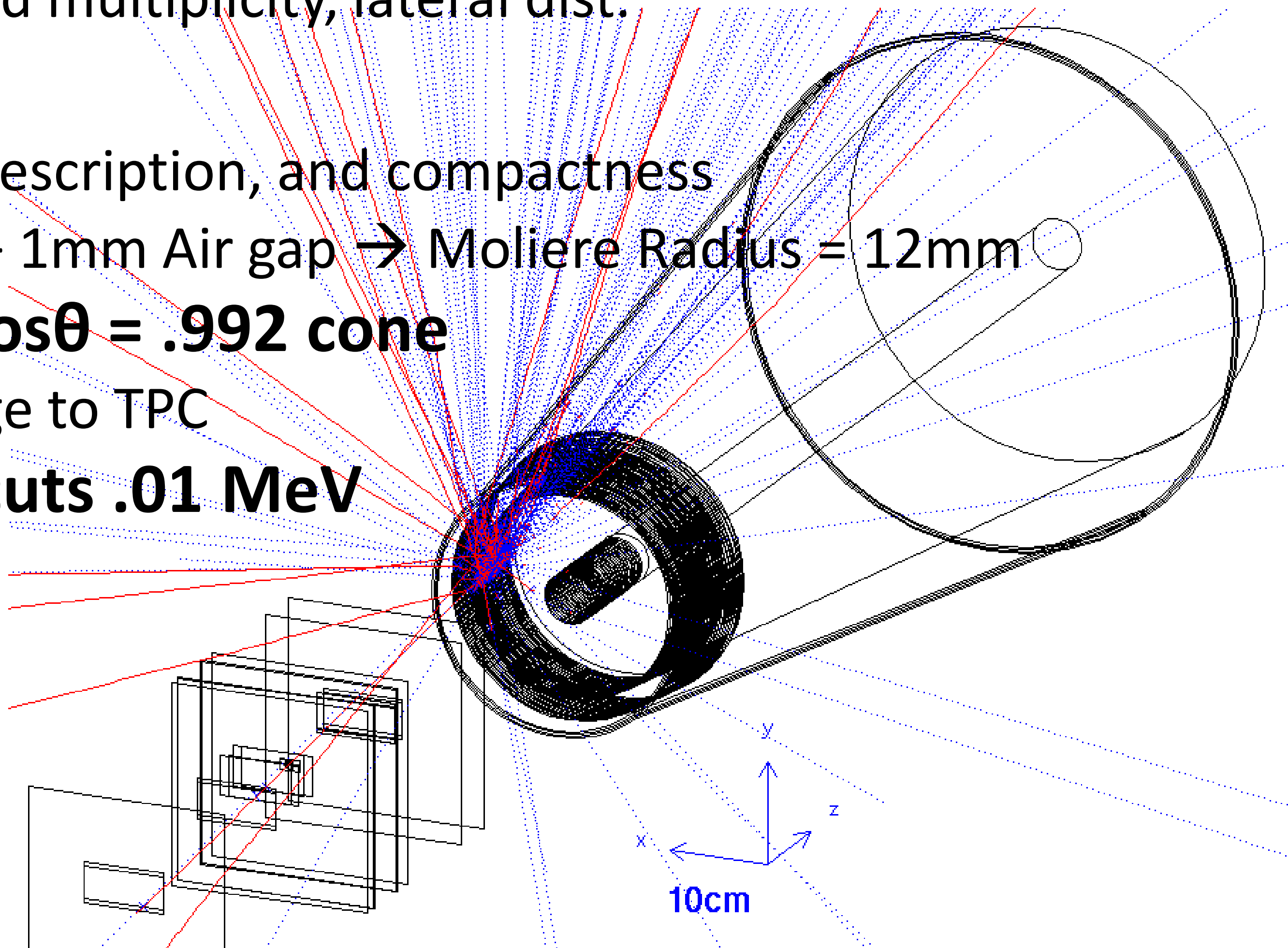
  better shower description, and compactness

  W $1X_0$(3.5mm) + 1mm Air gap → Moliere Radius = 12mm

- **Mockup of a cosθ = .992 cone**

  detecting leakage to TPC

- **Mininum e/γ cuts .01 MeV**

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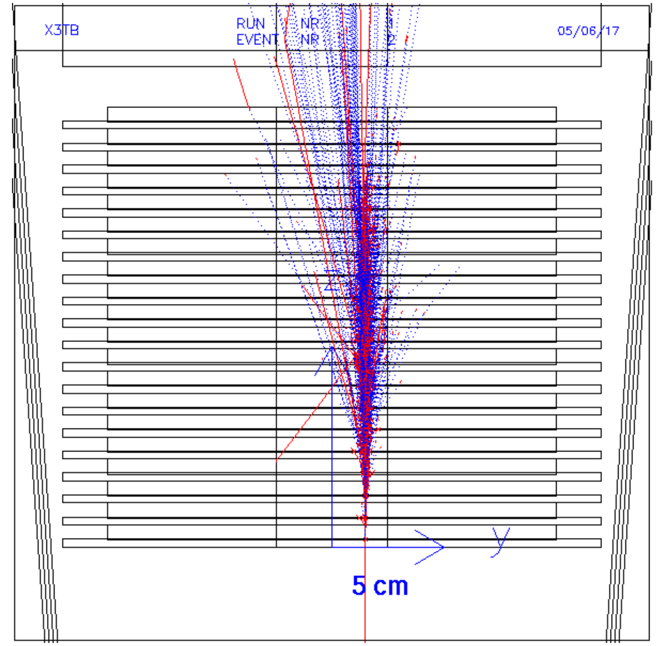
* NIM A 388 (1997) 135.

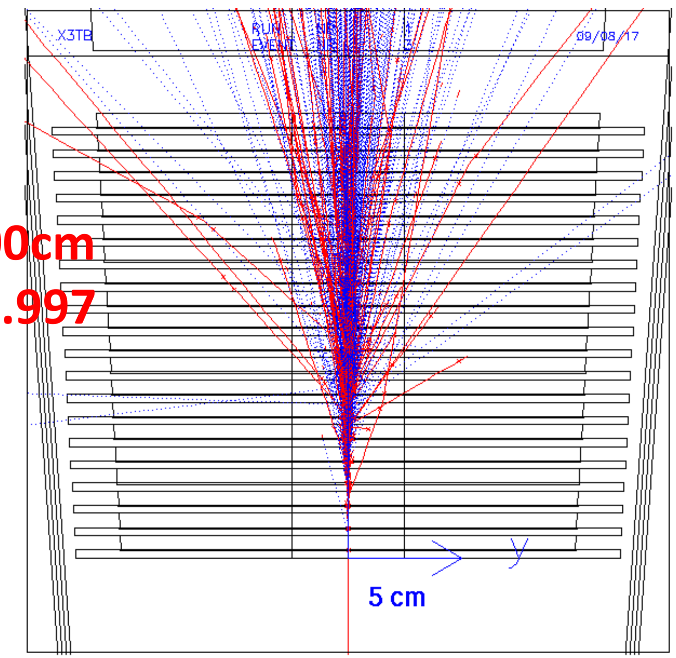
LumiCal simulation

- **TPC cone**: θ=126.6 mRad (cosθ=.992)
  Fe 0.5 cm
  scintillators on surfaces detecting charged hits
- **DQ0 support**: Fe=100 cm tube, behind LumiCal

- **TUBE SiW**: 20 decks of tubes
  W: 0.35 cm $(1X_0)$, **r = 2.5 - 10 cm**
  Airgap: 0.2 cm
  Si: 0.03 cm thick, r = 2.5 - 10 cm

- **CONE SiW**: 20 decks of **cones**
  W: 0.35 cm $(1X_0)$, front **r = 2.5 - 10 cm @z=100cm**
  Airgap: 0.2 cm **outer edge radially to IP, θ=.997**
  Si: 0.03 cm thick, front r = 2.5 - 10 cm

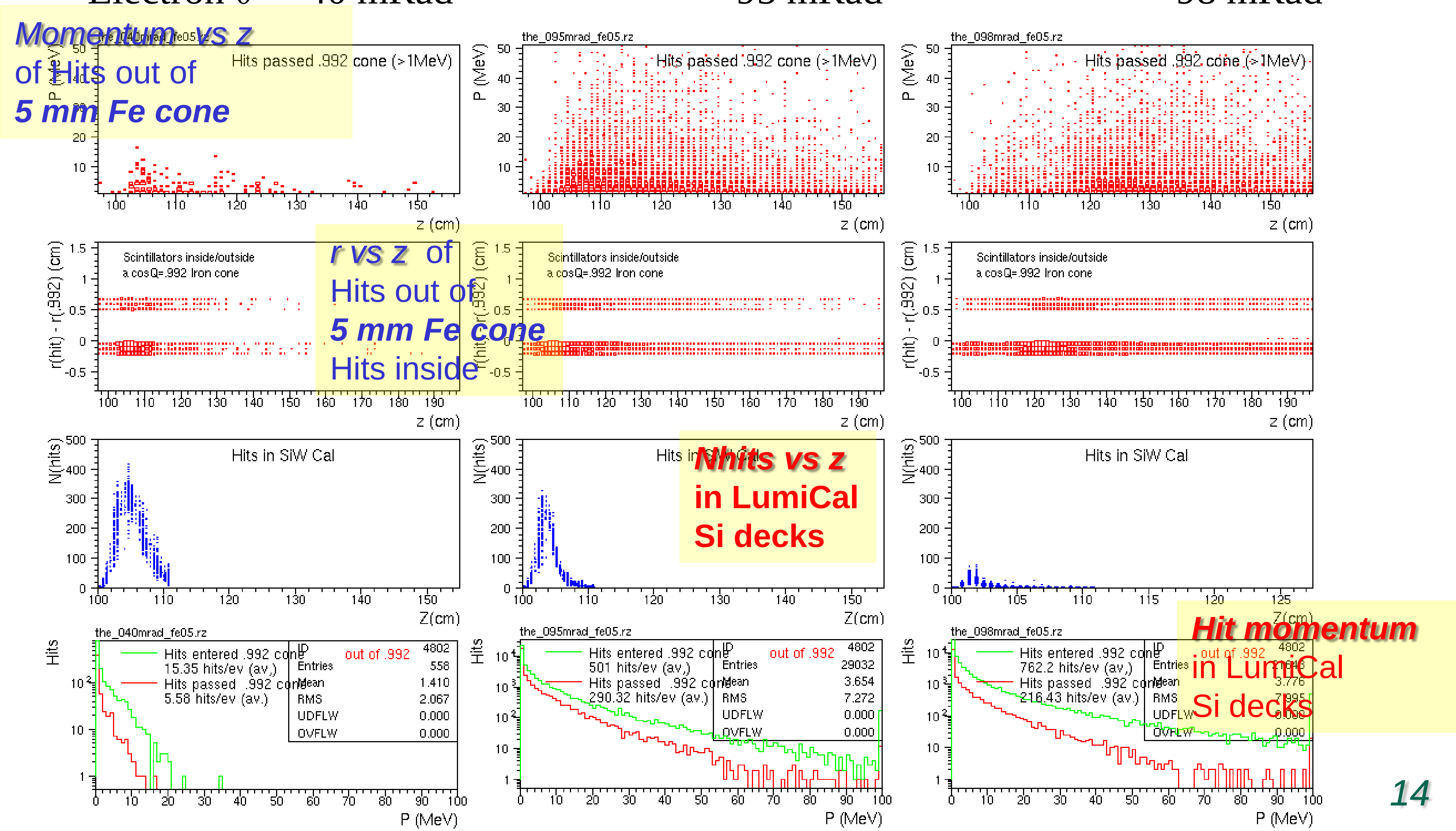




"TUBE" LumiCal shower leak distribution

50 GeV electron shower, reaching the outer Fe cone (5mm) at θ=.992

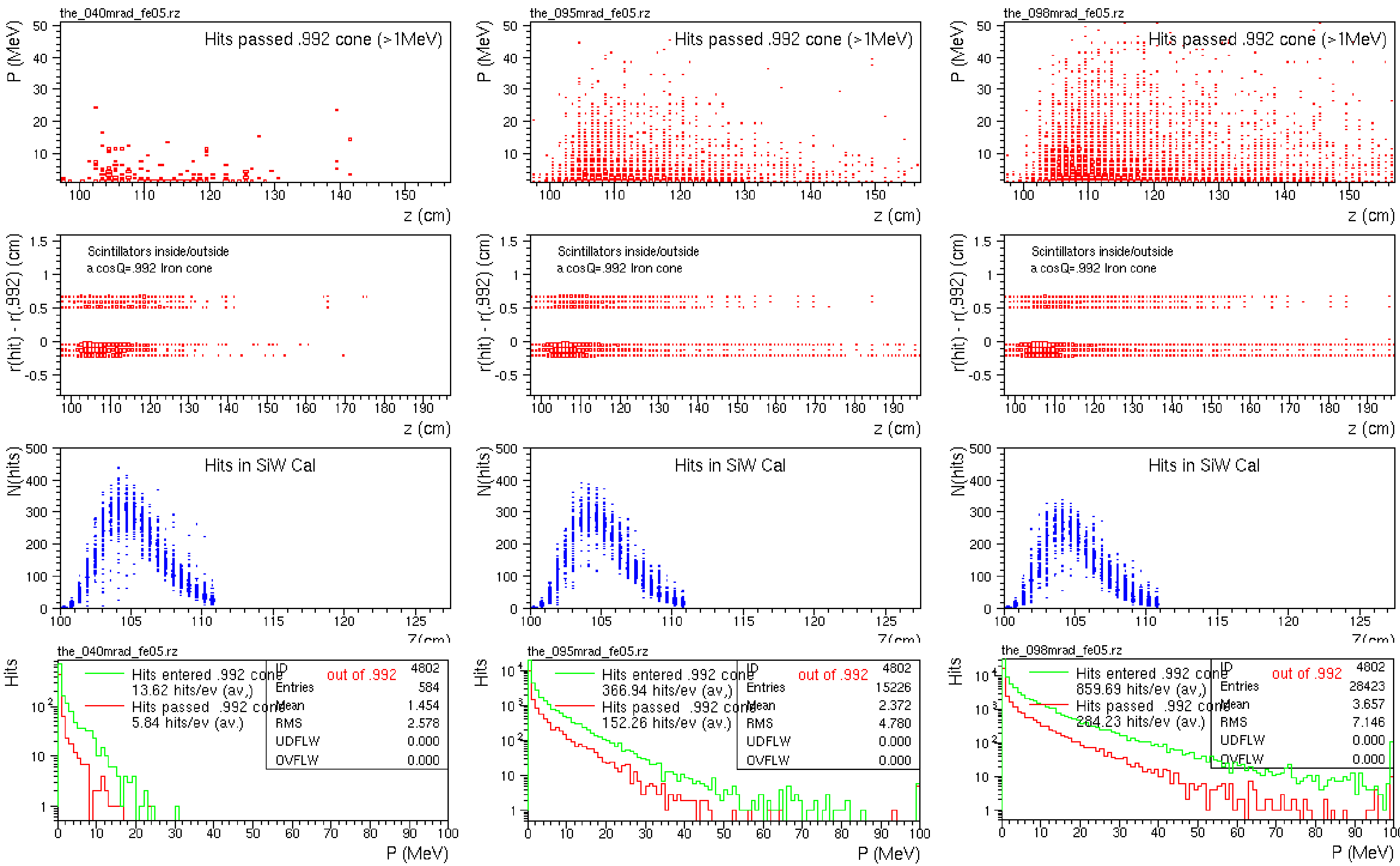
Electron θ= 40 mRad 95 mRad 98 mRad



“CONE” LumiCal shower leak distribution

50 GeV electron shower, particles off Calo to outer cone at θ=.992

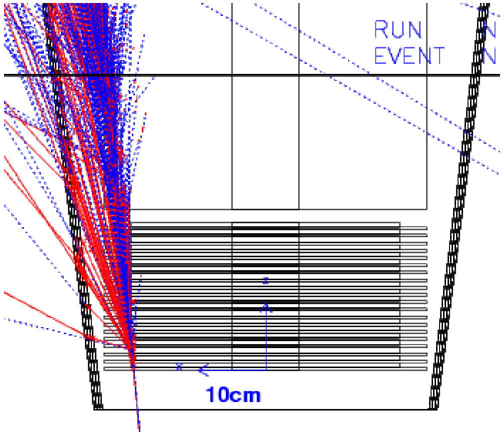
Electron θ= 40 mRad — 95 mRad — 98 mRad

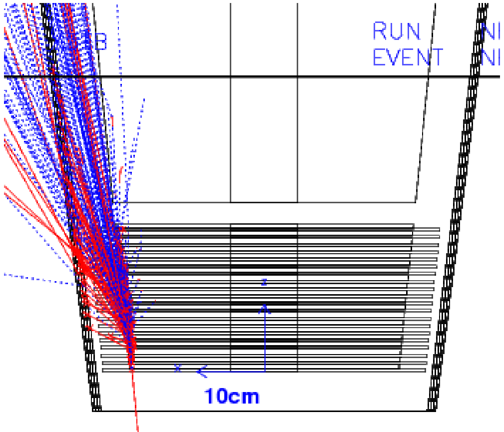


50GeV electron shower leak vs theta

Simulate 50 GeV electron from IP at fixed theta
Shower leakage are mostly low energy < 100 MeV particles

50 GeV electron	average events enter/pass 5 mm Fe cone at 0.992 Rad	
electron θ (mRad)	TUBE LumiCal N(enter) /N(pass)	CONE LumiCal N(enter) /N(pass)
40	15.4 / 5.6	13.6 / 5.8
90	392 / 155	173 / 76
95	501 / 290	367 / 152
98	762 / 216	860 / 284
99	553 / 140	1331 / 367

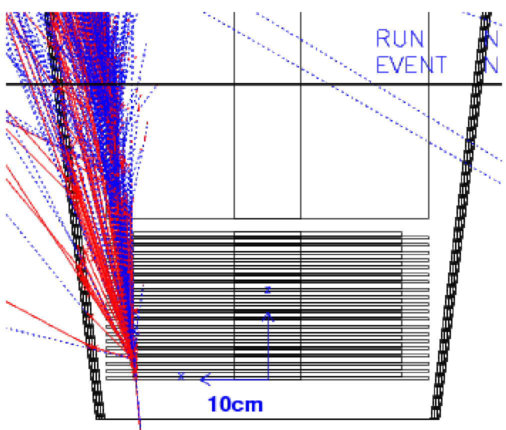


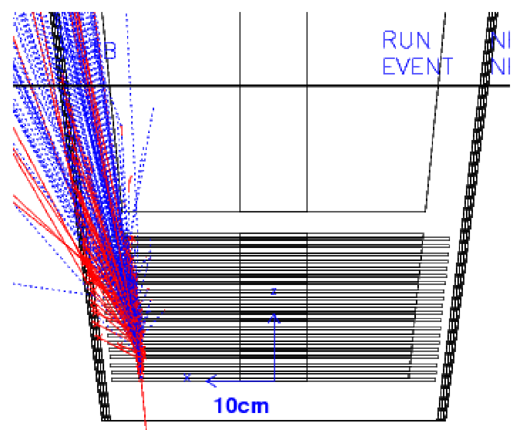


125GeV electron shower leak vs theta

Simulate 125 GeV electron from IP at fixed theta
Shower leakage are mostly low energy < 100 MeV particles

125 GeV electron	**average events enter/pass 5 mm Fe cone at 0.992 Rad**	
electron θ (mRad)	TUBE LumiCal N(enter) /N(pass)	CONE LumiCal N(enter) /N(pass)
40	38.0 / 16.0	35.8 / 14.7
90	1028 / 399	434 / 19 7
95	2389 / 720	937 / 382
98	1718 / 473	2176 / 725
99	1102 / 273	3306 / 915





Summary

1. Luminosity of Bhabha counting is demanded to $\delta L/L$ ~ ***0.1%*** wtih Si Strip to reach r_{inner} to resolution ***<10 μm***

   A "floating LumiCal" has unknown systematics on r_{inner}

   By adding electron tracking to calibrate "mean of r_{inner}" to ***1 μm*** → ***to reach*** $\delta L/L$ ~ ***0.01%***

2. Beam crossing boosts electrons and → loss of event requiring both e^+, e^- detected by LumiCal → smaller r_{inner} ***of LumiCal*** is demanded for ***σ> 50 nb***

3. Shower leakage is ***~ 1k*** secondaries, mostly <*100 MeV* to TPC