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SiD FCAL

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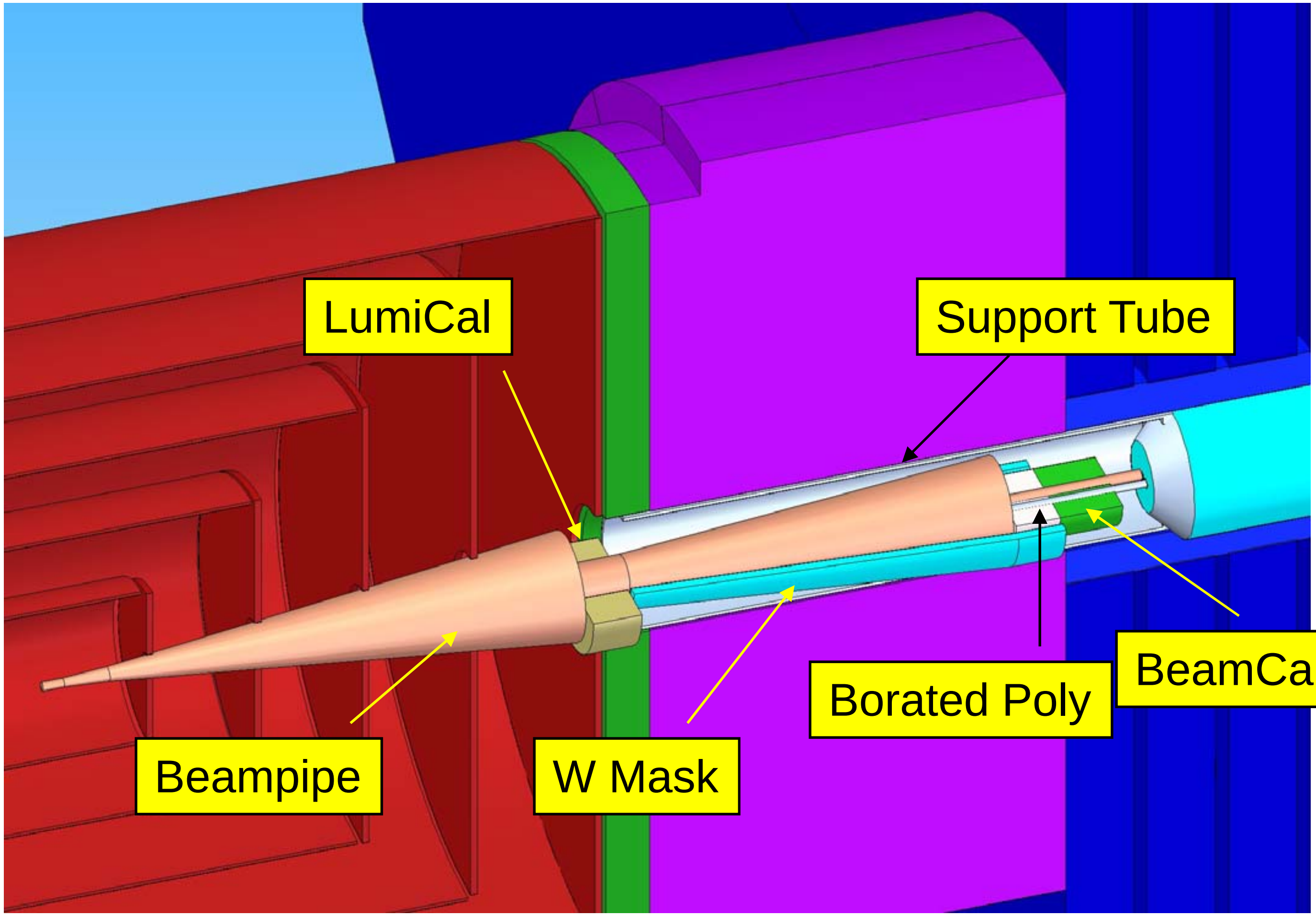
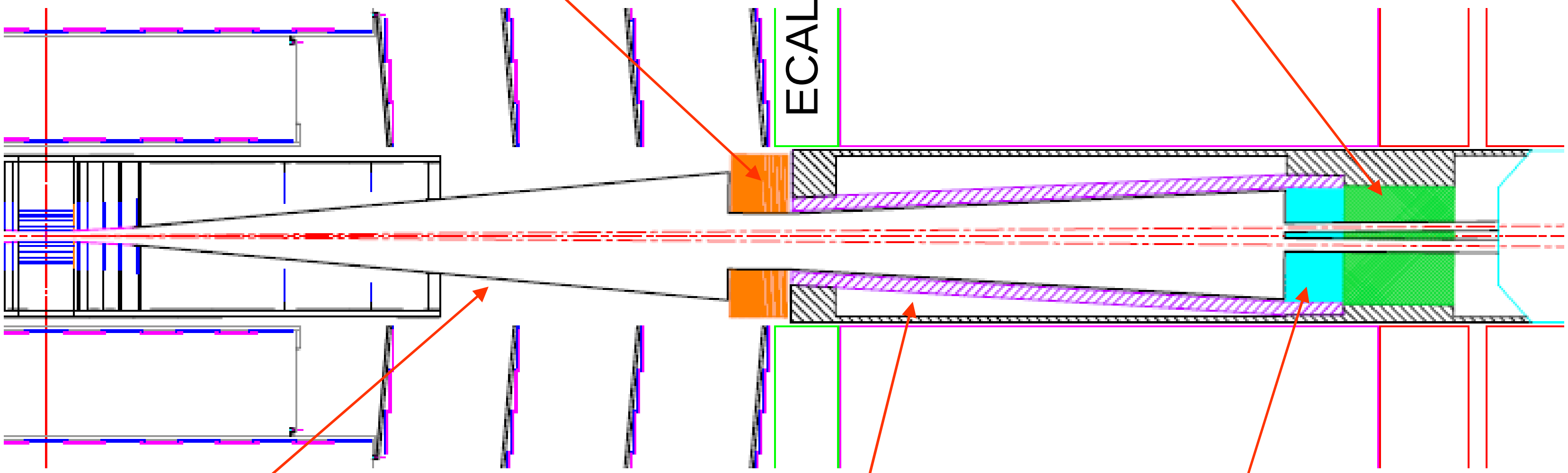
SiD Forward Region



SiD Forward Region

LumiCal
20 layers of 2.5 mm W +
10 layers of 5.0 mm W

BeamCal
50 layers of 2.5 mm W



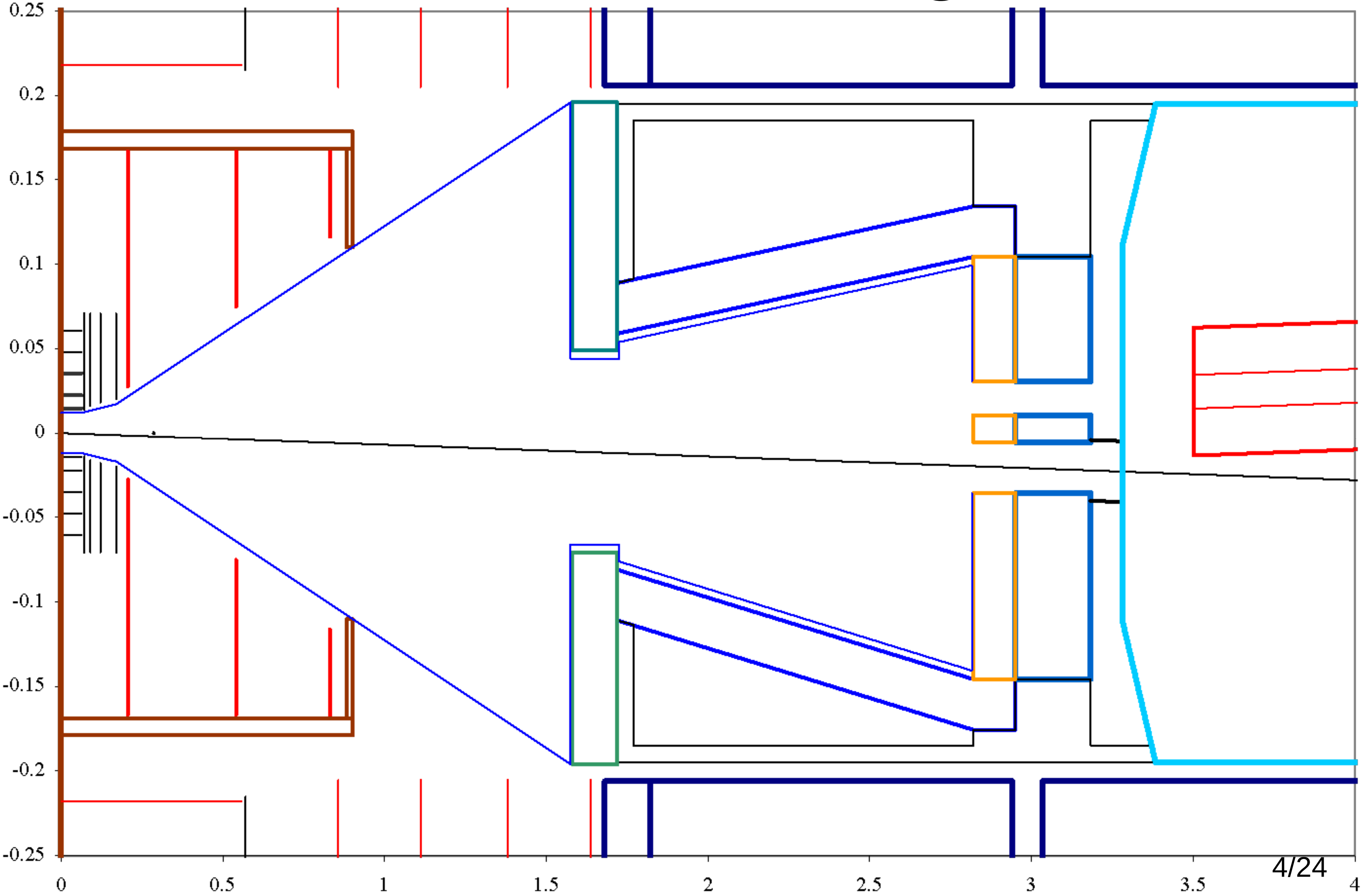
Beampipe
+/- 94 mrad (detector)
+101 mrad, -87mrad (ext. line)

3cm-thick Tungsten Mask

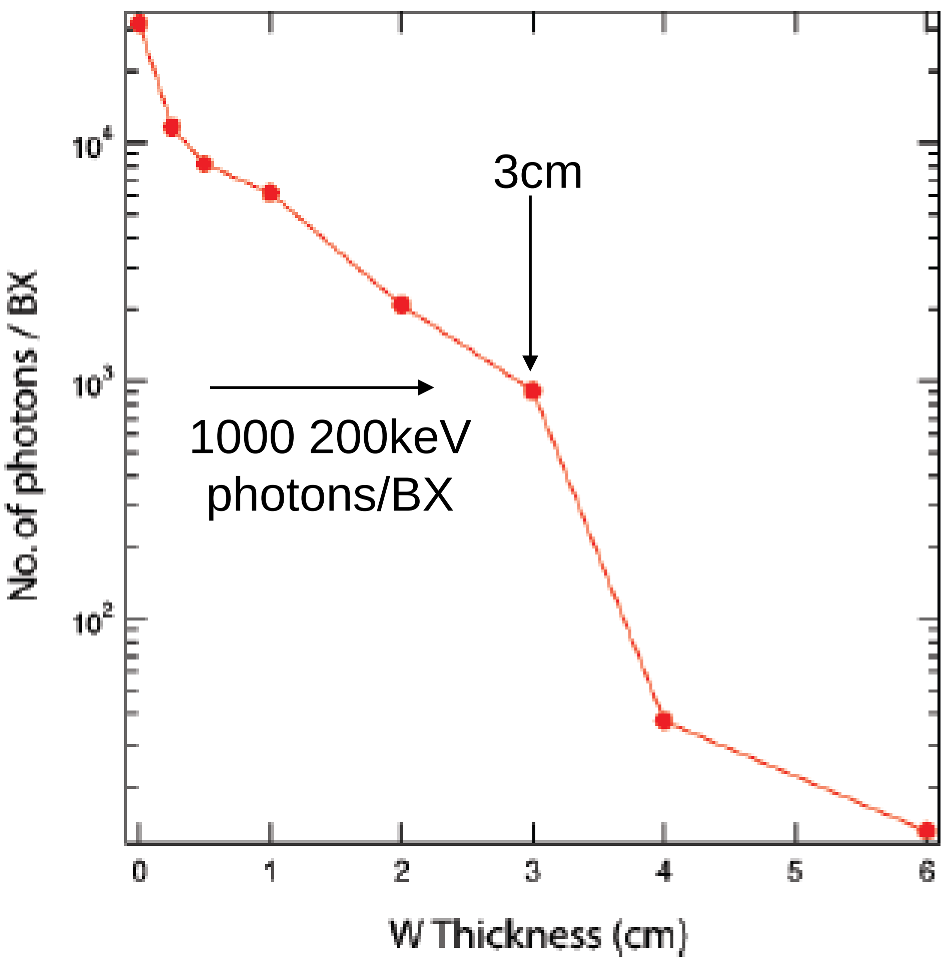
13cm-thick BoratedPoly

Centered on the outgoing beam line

SiD Forward Region



Tungsten Mask

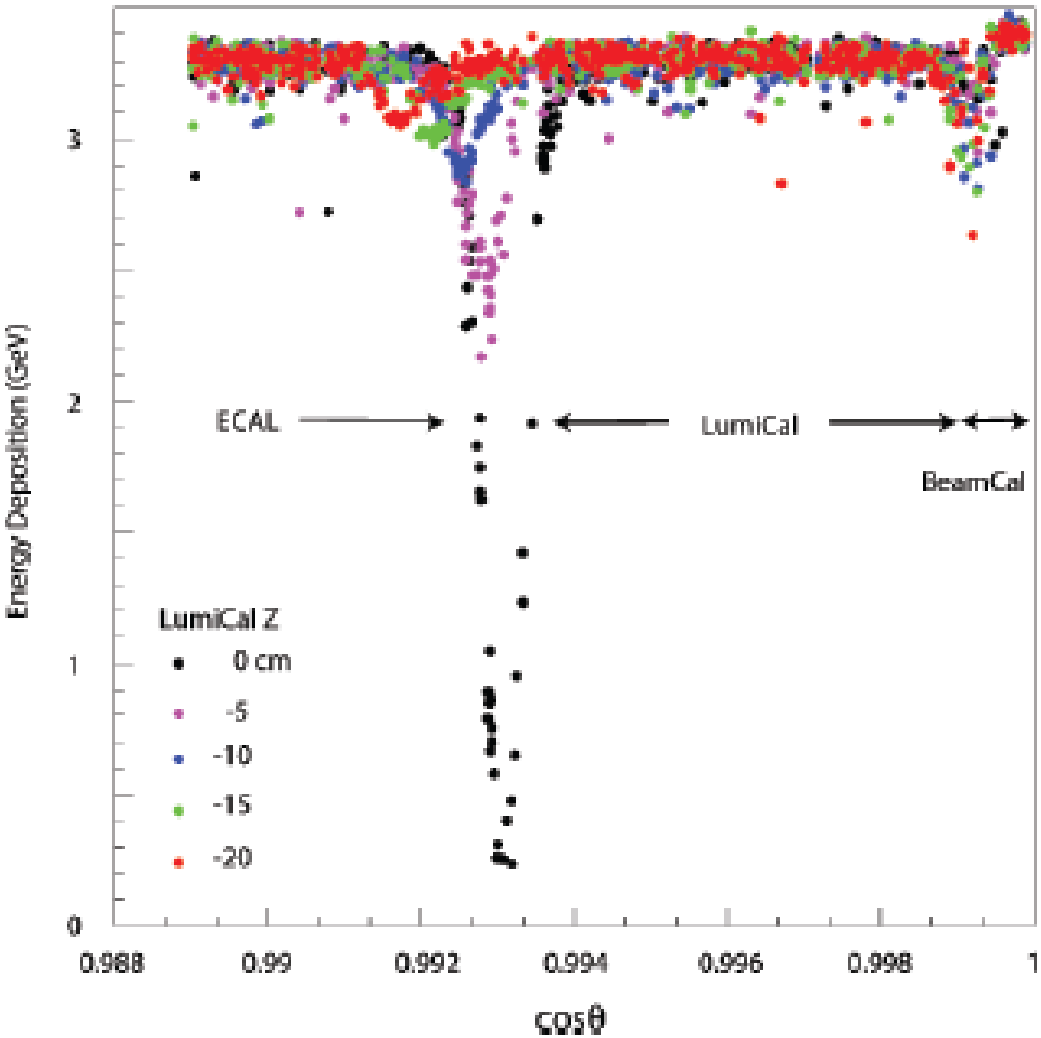


No "FHCAL" as only physics motivation is muon identification in this angular region, which is accomplished by identifying MIPs in LumiCal.

3cm is currently chosen thickness (507kg)

1000 of 35k backscattered photons penetrate mask and are spread uniformly across inner surface of endcap HCAL

Hermaticity



Effort made to minimize radius of FCAL package and to minimize gap between endcap ECAL and FCAL

LumiCal Outer Radius: 19.5cm

(to match QD0 cryostat radius)

Gap to endcap: 1.0 cm

To recover solid angle from IP, Lumical position 10cm closer to IP than from face of endcap ECAL

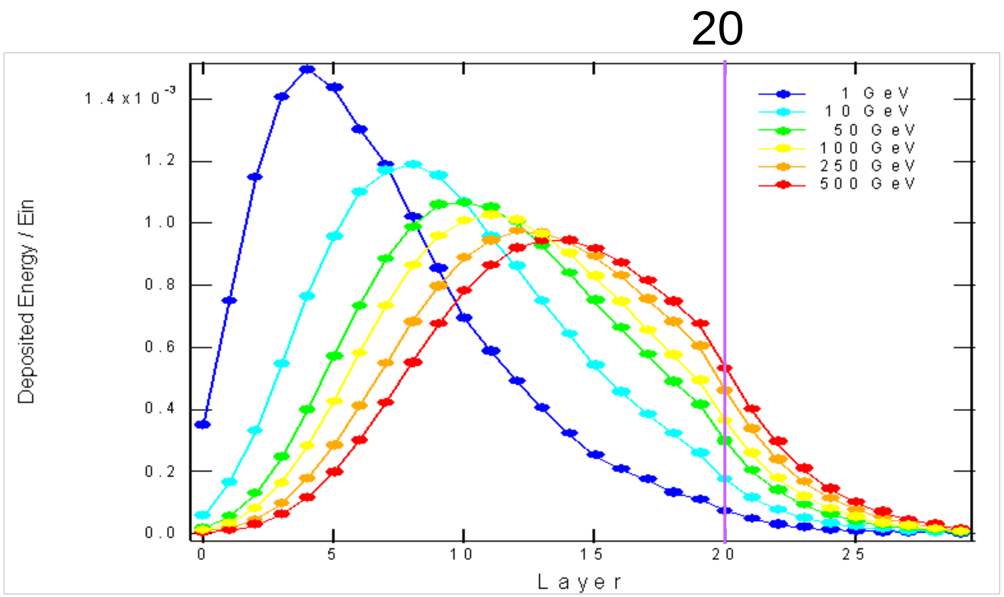
LumiCal

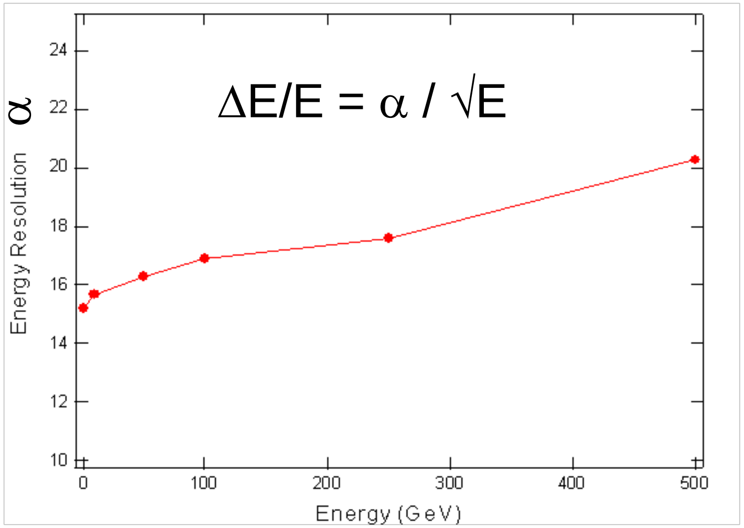
- Calorimeter coverage
  - $41 < \theta < 120$ mrad
  - 6cm inner hole, centered on extraction line
- Precision integrated luminosity measurement
  - Fiducial volume: $46 < \theta < 86$ mrad
- Luminosity spectrum dL/dE
  - $\sqrt{s}$ is not monochromatic due to beamstrahlung emission

Energy resolution

20 layers of 2.5mm W+
10 layers of 5.0mm W

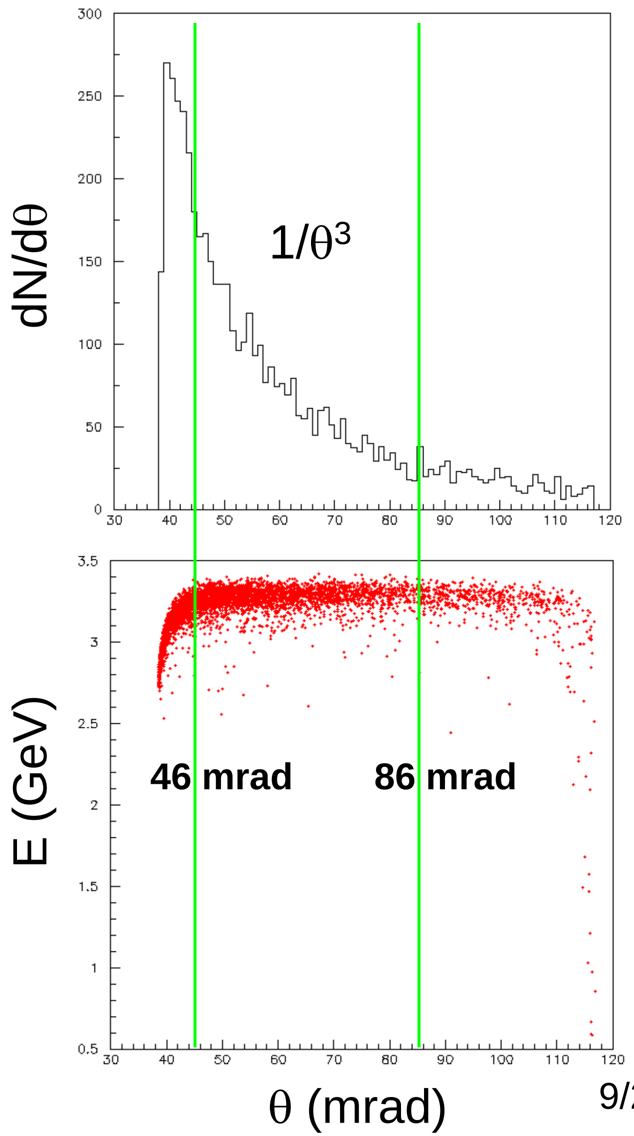
- Energy resolution parameter is dependent on energy
  - 15%/√E at low energy
  - 20%/ √E at high energy
- Energy leakage is small even at 500 GeV.





Luminosity measurement

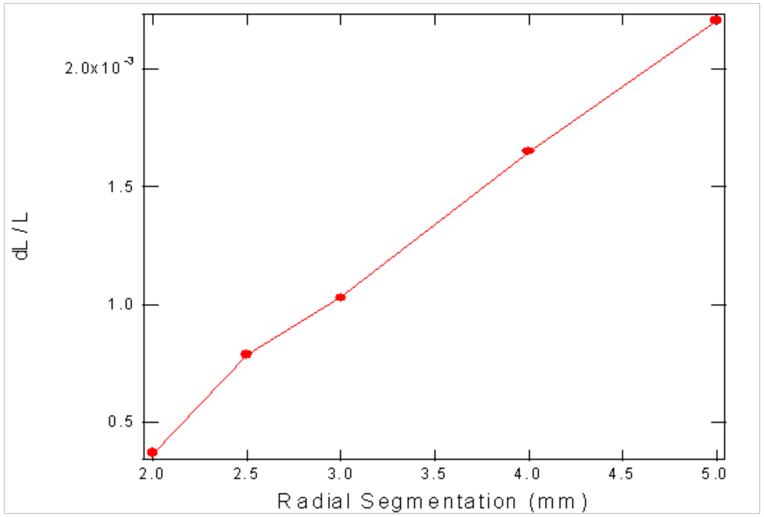
- Luminosity precision goal $\Delta L / L < 10^{-3}$
  - 10^6 W^+W^- events in 5 years (500 fb^{-1})
- $\Delta L/L=(N_{rec}-N_{gen})/N_{gen}$
  - Bhabha $d\sigma/d\theta \sim 1/\theta^3$
  - $\Delta L/L \sim 2\, \Delta\theta/\theta_{min}$, $\Delta\theta$ is a systematic error.
- $\Delta\theta$ must be less than ~20μrad to reach $\Delta L/L = 10^{-3}$.
  - Detector radial location must be know within 30μm.
- Bhabha event rate
  - N_{ev} / BX @ILC 500 Nominal=
    $5.9\, [1/\theta^2_{min} - 1/\theta^2_{max}]$ (θ in mrads)
  - 30 ev/sec for θ_{min}=46 mrad, θ_{max}=86 mrad



ΔL/L vs. segmentation

Radial segmentation $N\phi = 32$

Δr (mm)	Δθ (mrad)	σ(θ) (mrad)	ΔL/L
2.0	0.008	0.042	3.3×10^{-4}
2.5	0.017	0.046	7.9×10^{-4}
3.0	0.023	0.050	1.0×10^{-3}
4.0	0.036	0.058	1.7×10^{-3}
5.0	0.049	0.069	2.2×10^{-3}



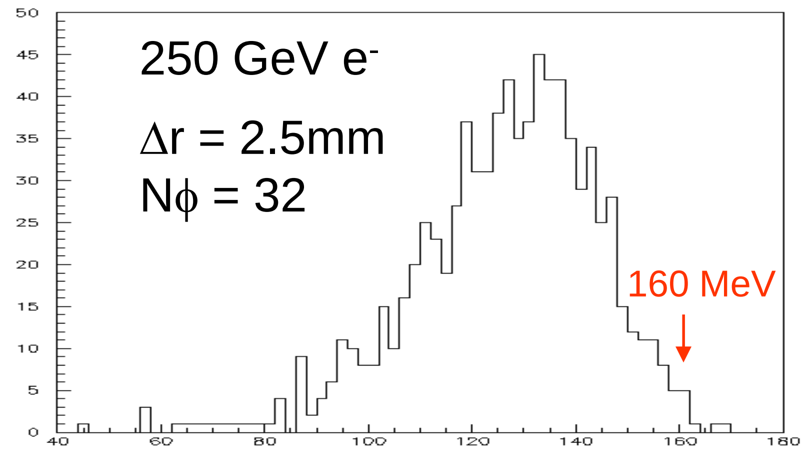
ϕ segmentation $\Delta r = 2.5$ mm

Nϕ	Δθ (mrad)	σ(θ) (mrad)	ΔL/L
16	0.017	0.046	7.7×10^{-4}
32	0.017	0.046	7.9×10^{-4}
48	0.017	0.045	7.6×10^{-4}
64	0.014	0.045	6.6×10^{-4}

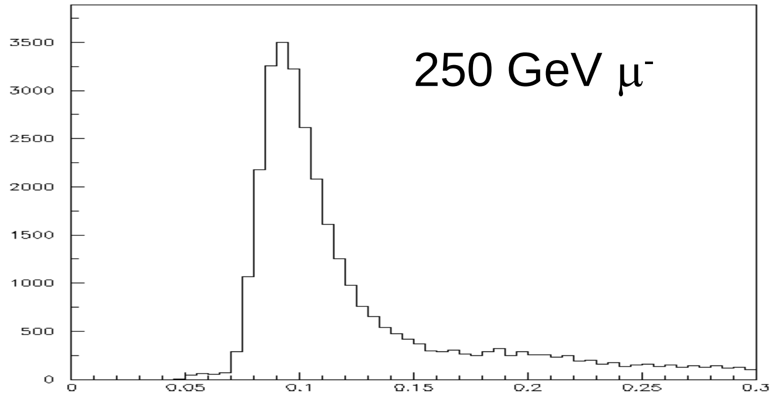
- $\Delta L / L < 10^{-3}$ can be reached by $\Delta r < 3$mm.
- Finer ϕ segmentation helps, but not much.
  - Finer ϕ segmentation will help shower separation.

Max Energy Deposition in Si channel

- Max energy deposition
  - 160 MeV (7010 fC*)
- MIP
  - MPV~0.0925 MeV (4.1 fC)
- Bhabha ~ 1710 MIP
- If we want S/N ~ 10 for MIP, we need 17,000 dynamic range.
  - 2 gains + 10 bit ADC



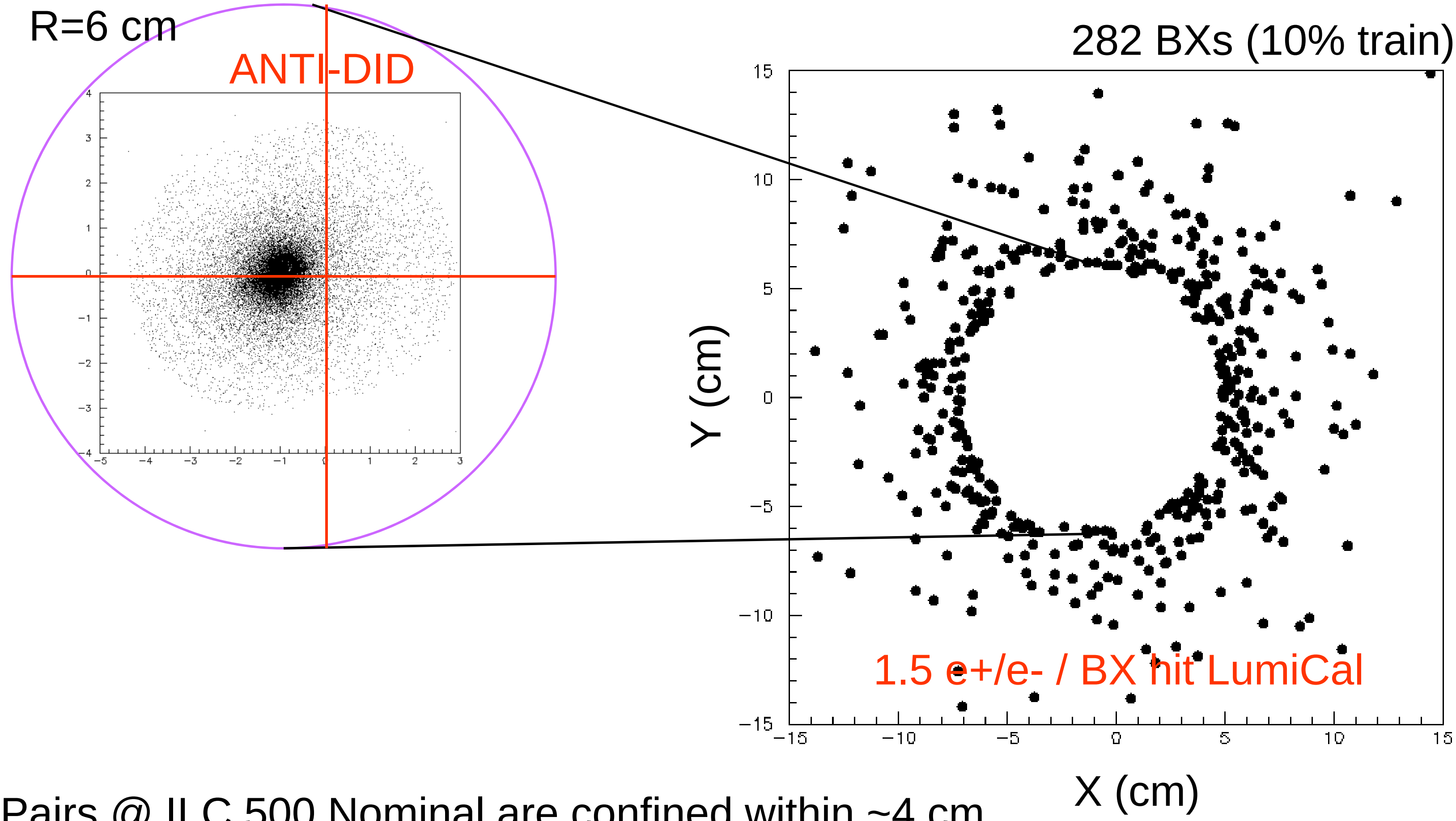
Max Energy Deposition (MeV)



Energy Deposition (MeV)

* 3.65 eV to generate e-h pair

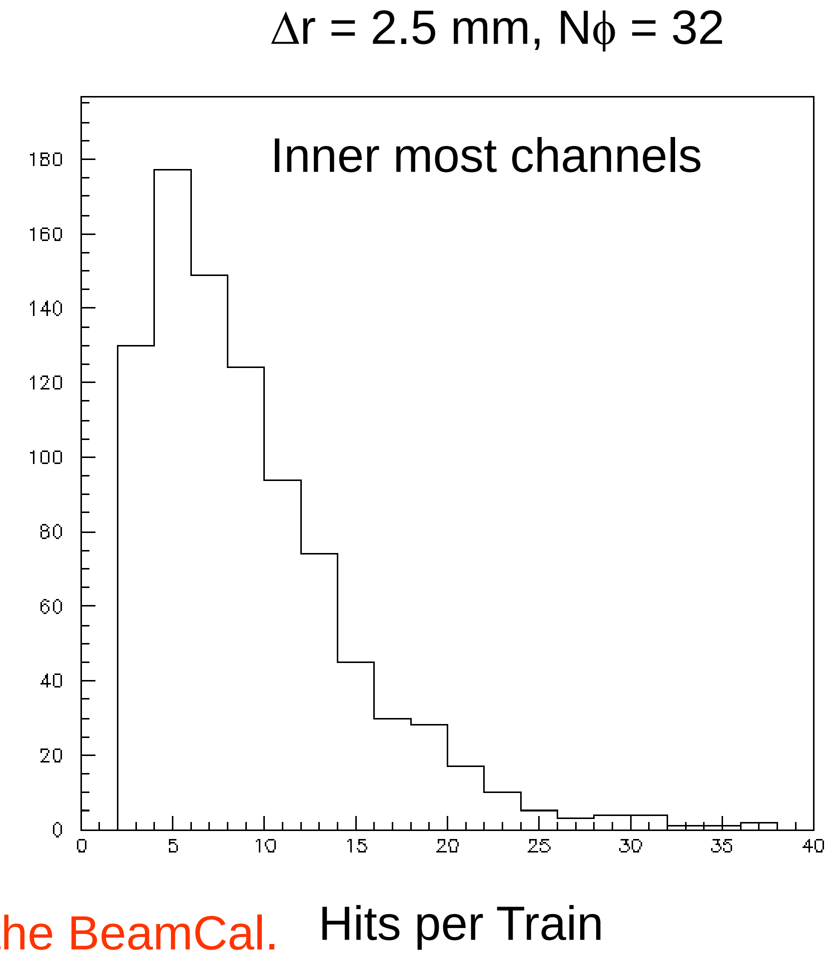
Pairs in LumiCal



Pairs @ ILC 500 Nominal are confined within ~4 cm.
However, there are pairs outside the ring of death,
and >4000 e+/e-/train hit the LumiCal.

Pair occupancy in LumiCal

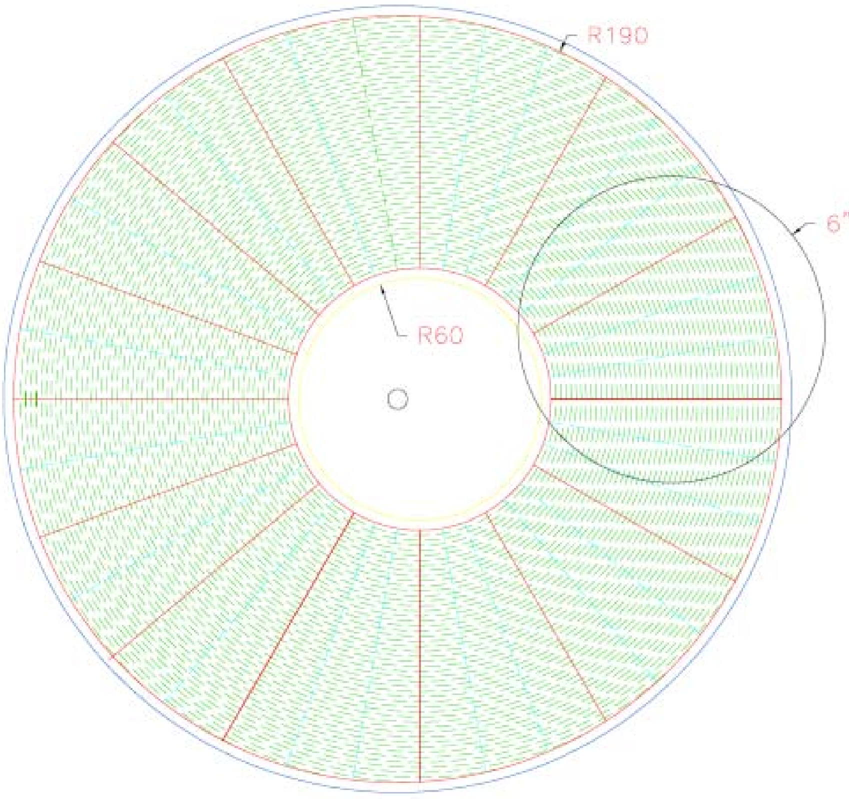
- 1.5 e+/e- / BX reaching LumiCal
- Hits are mostly in the front ~10 layers.
- Inner most channels have more than 4 hits.



KPiX has only 4 buffers.
Need a new chip being developed for the BeamCal.

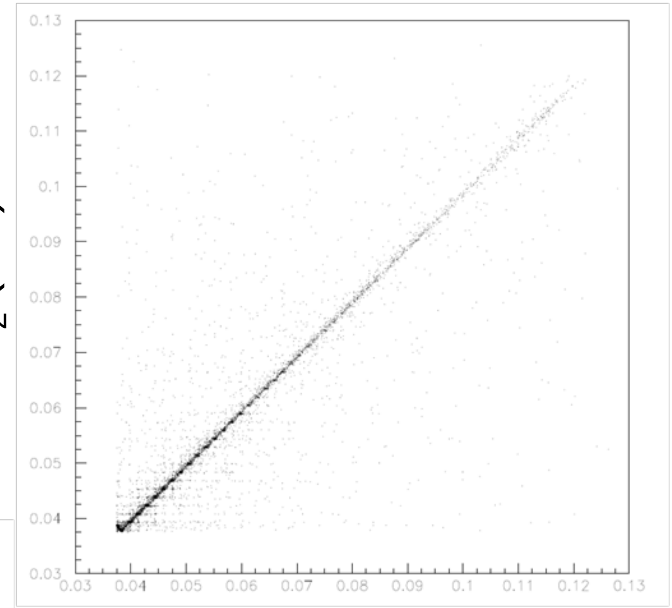
LumiCal sensor design

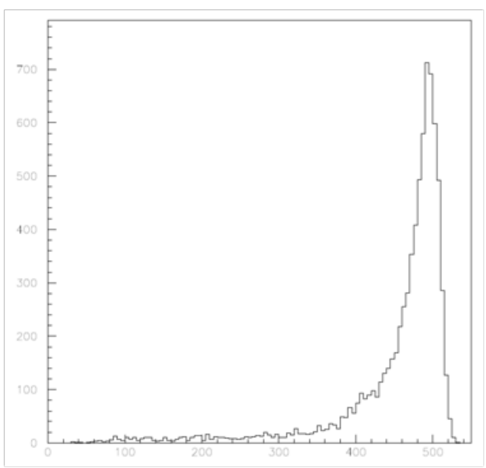
- Based on 6” wafer.
- The inner radius centered on the out-beam, while the outer radius on the detector.
- 14 petals are all different; need different Masks.
- $\Delta r = 2.5$ mm, $\Delta\phi = 10°$($N\phi$=36)
- Radial division varies from 46 to 54 channels.
- Non-projective geometry; same sensors in depth-wise.

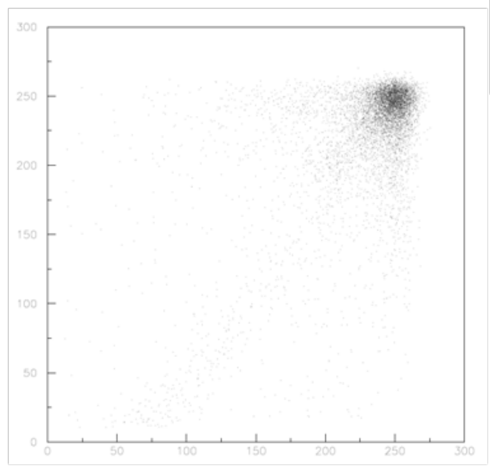


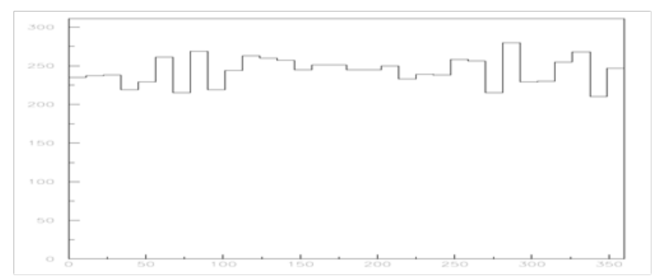
Bhabha events in LumiCal

- BHWIDE to generate Bhabha events
- Move to 14 mrad crossing angle system
- Simulate LumiCal response
- Reconstruct showers
- Move back to CM system
- Look at the distributions









BeamCal

- Extend calorimeter coverage to small angle
  - $7 < \theta < 44$ mrad
- High energy electron detection
  - Provide two-photon veto for new particle searches
- Instantaneous luminosity measurement using beamstrahlung pairs
  - Pair production is proportional to luminosity

$\gamma\gamma$ Veto in Pair Backgrounds

- Under SUSY dark matter scenarios, slepton & neutralino masses are nearly degenerate.

M. Battaglia et al. hep-ph/0306219

- Search & measure stau with Δm = 3 – 9 GeV

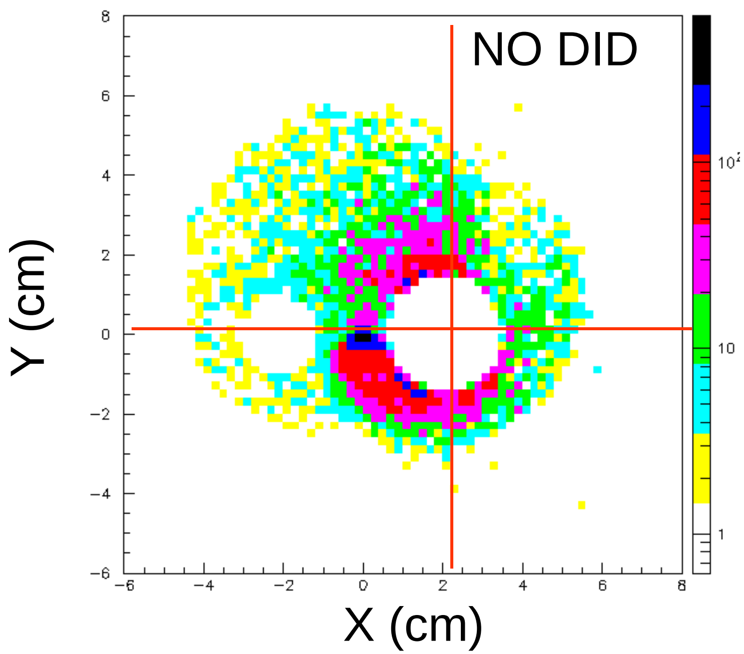
P. Bambade et al. hep-ph/0406010

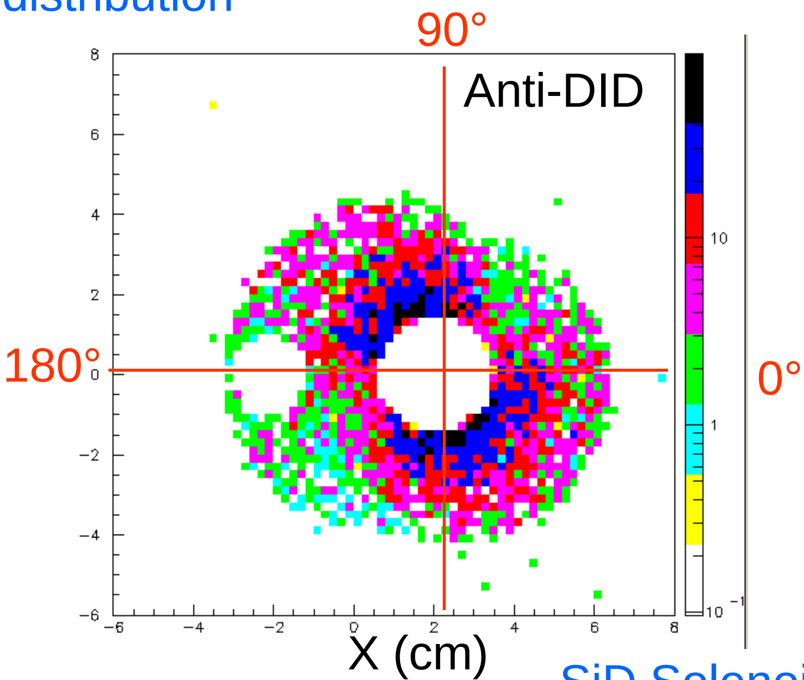
Signal	Major background
ee $\rightarrow \tau\chi\tau\chi$	ee$\rightarrow$(e)(e)$\tau\tau$
$\sigma \sim$ 10 fb	$\sigma \sim 10^6$ fb

- $\gamma\gamma$ veto is crucial.
  - High energy electron detection in beamstrahlung pair background

Detector-Integrated-Dipole

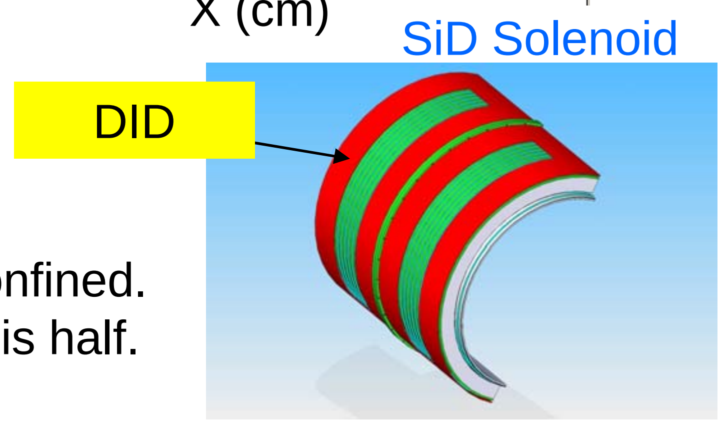
Pair energy distribution





We want Anti-DID.

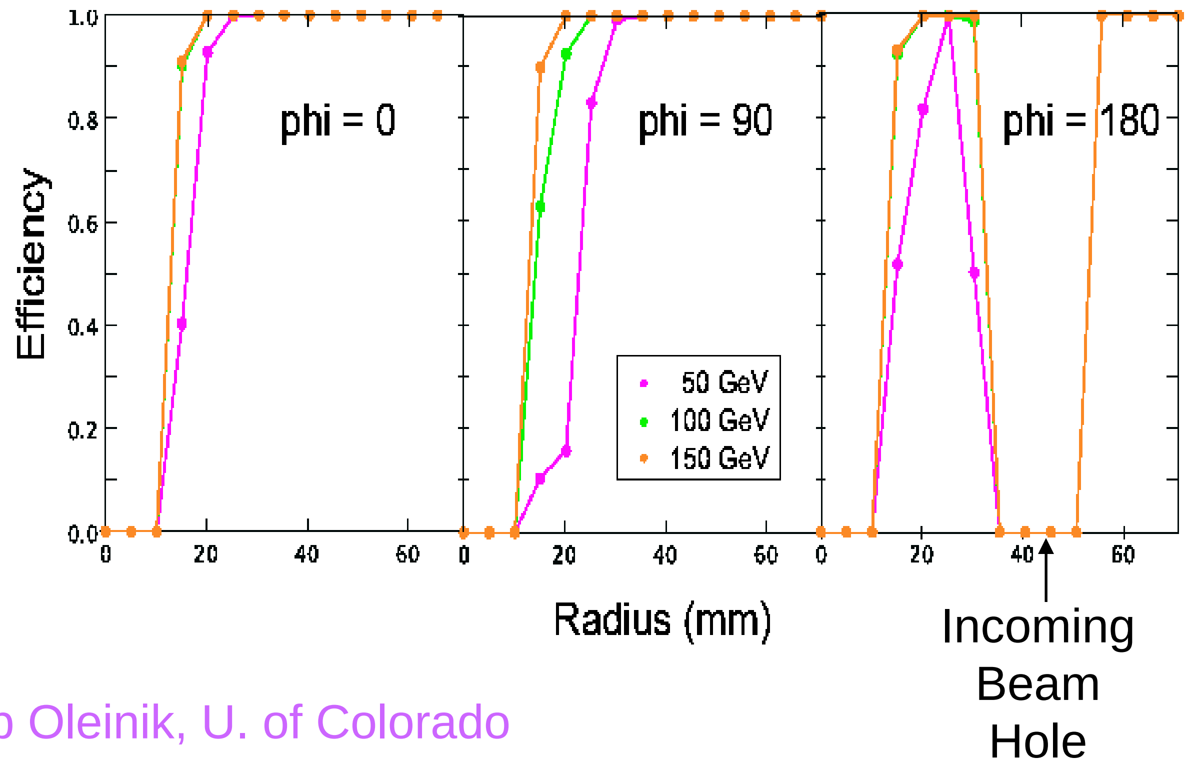
- Total pair energy into BeamCal is half.
  - 10 TeV/BX vs. 20 TeV/BX with NO-DID.
- Pair distribution is symmetric and more confined.
- No. photons backscattering to the tracker is half.



High energy electron detection

- **A lookup table to correlate energy deposition and incident energy.**
  - **θ , ϕ dependence**
  - **Geometry dependence**
- **Overlay high energy electron shower and one bunch crossing of beamstrahlung background.**
- **Subtract average beamstrahlung energy.**
- **Cluster algorithm favoring layers >3cm to find high energy electron.**

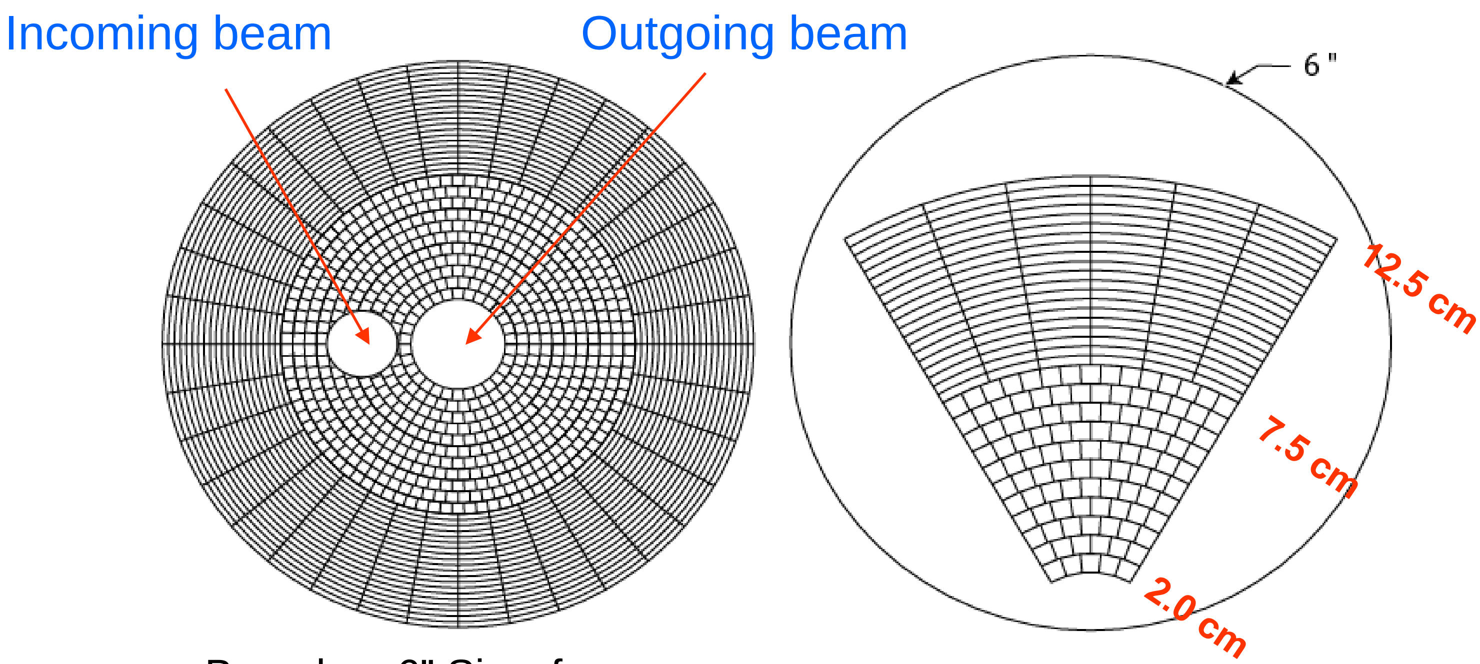
Detection efficiency



Analysis by Jack Gill and Gleb Oleinik, U. of Colorado

http://hep-www.colorado.edu/~uriel/Beamstrahl_TwoPhoton-Process/grp_results.html

BeamCal Sensor



- Based on 6” Si wafer
- Centered on the outgoing beam line
- Two regions
  - R=2.0 - 7.5 cm (7 mrad – 25 mrad)
    BeamCal where beamstrahlung pairs hit.
    5mm x 5mm Rϕ segmentation
  - R=7.5 - 12.5 cm (25 – 42 mrad)
    LumiCal extension, no beamstrahlung pairs
    ΔR=2.5mm, $\Delta \phi$ =10°

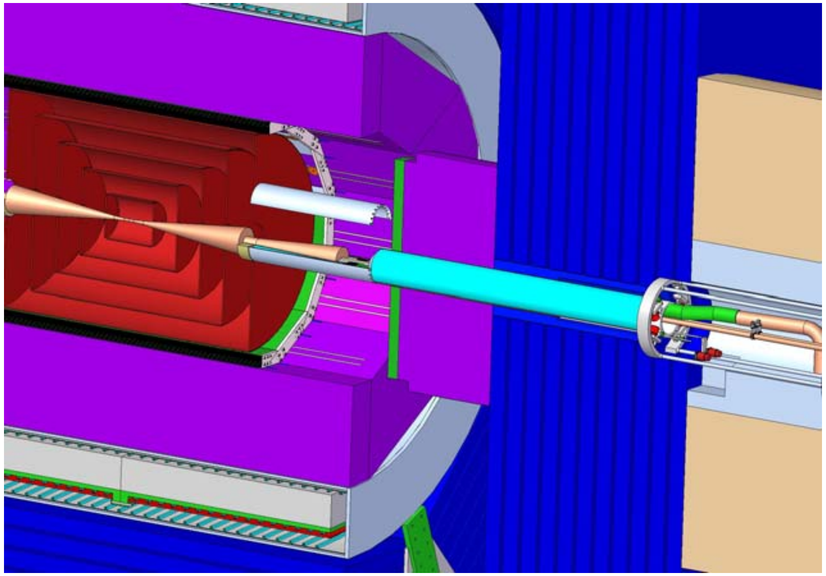
High occupancy and high radiation

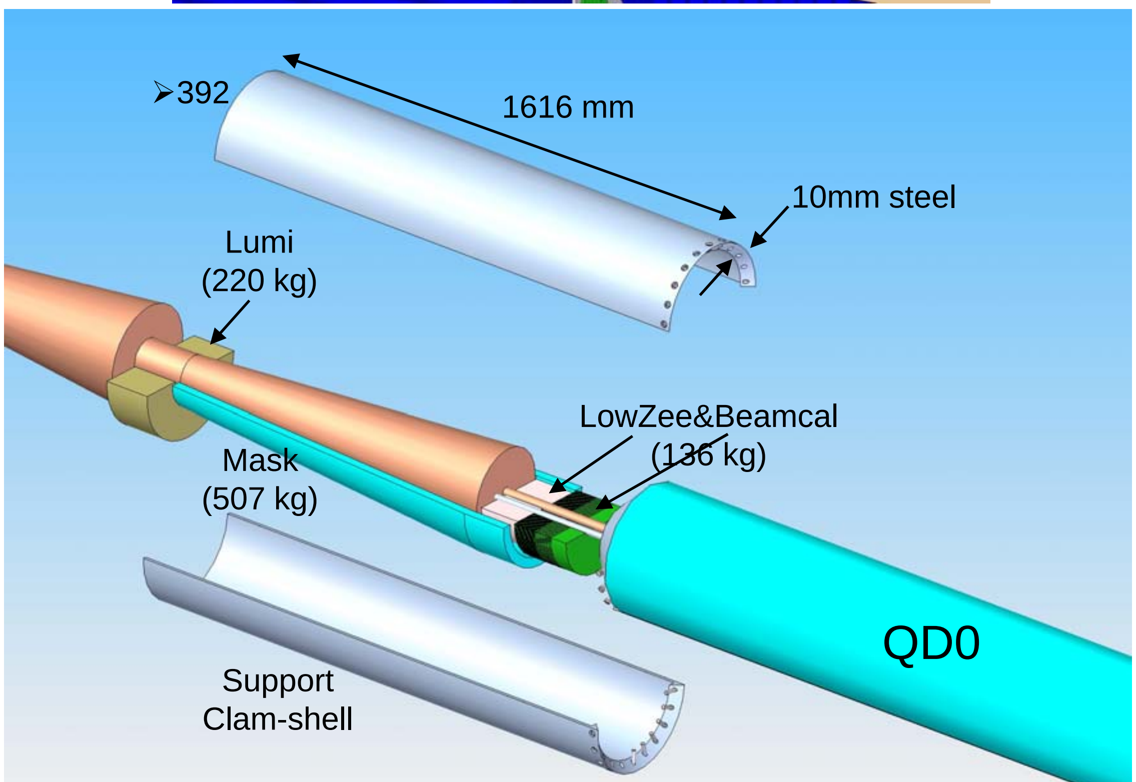
- 100% occupancy R < 5 cm.
  - Need a new chip to store every bunch crossing.
  - KPIX with 1024 channels & 4 buffers for ECAL
  - New FCAL chip with 64 channels, 2820 buffers $\rightarrow$ R&D
- Highest radiation dose ~100 MRad/year.
- Neutron fluence 5×10^{13} $n_s/cm^2/year$
  - Need radiation hard sensors. $\rightarrow$ R&D

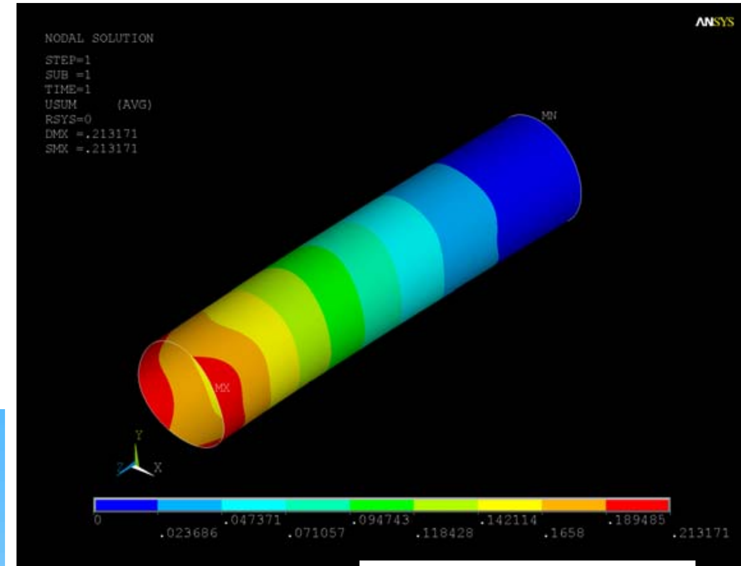
Unresolved Issues

- LumiCal
  - Readout design
  - Petal-to-Petal dead space
  - Reproducible alignment to $<$ 30 um and verification
- BeamCal
  - Choice of sensor
  - Readout design
  - Petal-to-Petal dead space
  - Electronics cooling
- BeamPipe
  - HOM heating, cooling & wakefields due to abrupt radial transitions
- Global FCAL
  - Integration
  - Installation and servicing

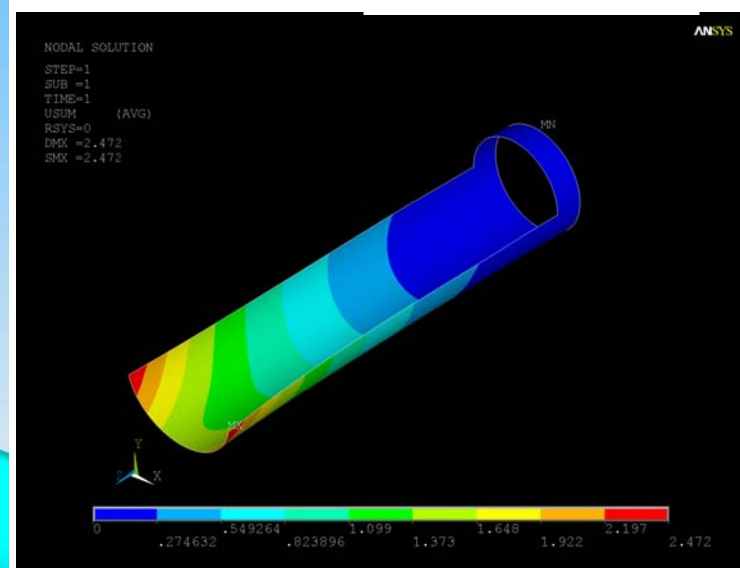
Forward Integration







Deformations in mm



Summary

- Good enough progress has been made to write the LoI.
- We still have to resolve many issues before we can write TDR.