SiD Workshop, Boulder, September 18, 2008

LumiCal Optimization and Design

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LumiCal related issues

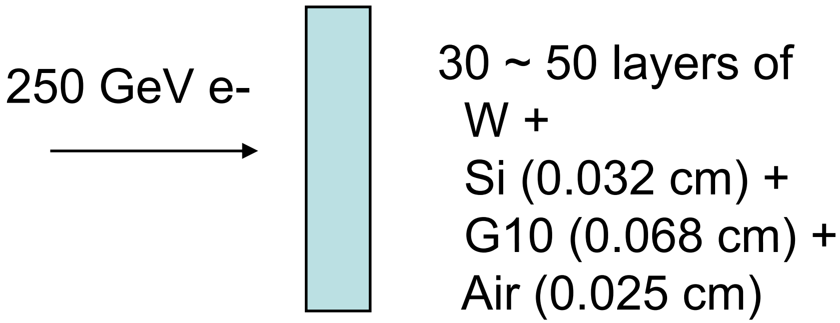
- Geometry
  - Location and angular acceptance
  - Centered on the outgoing beam or the solenoid axis
  - Beampipe
- Tungsten thickness and no. of layers
  - Default is ECAL 20 layers of 2.5 mm+10 layers of 5.0mm
- Segmentation
- Electronics dynamic range
  - MIP sensitivity
  - KPiX
- Occupancy
  - Bhabha event rate
  - Pairs, ee+had, ee$\mu\mu$
  - 4 buffer storage of KPiX
- Luminosity precision goal
- LHCAL
  - Do we need it?

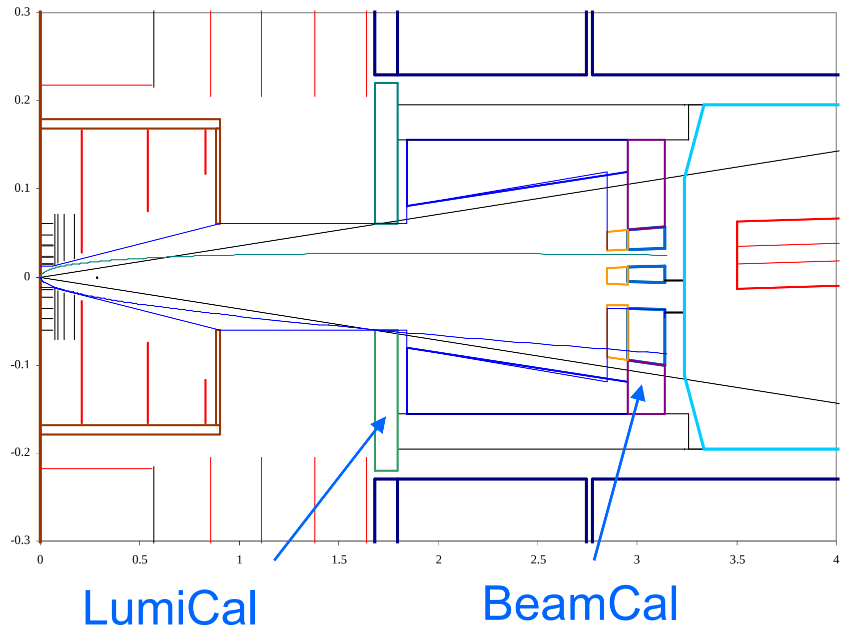
references

- Bill Morse: SiD LumiCal notes
- David Strom: all about luminosity measurement.
- FCAL collaboration

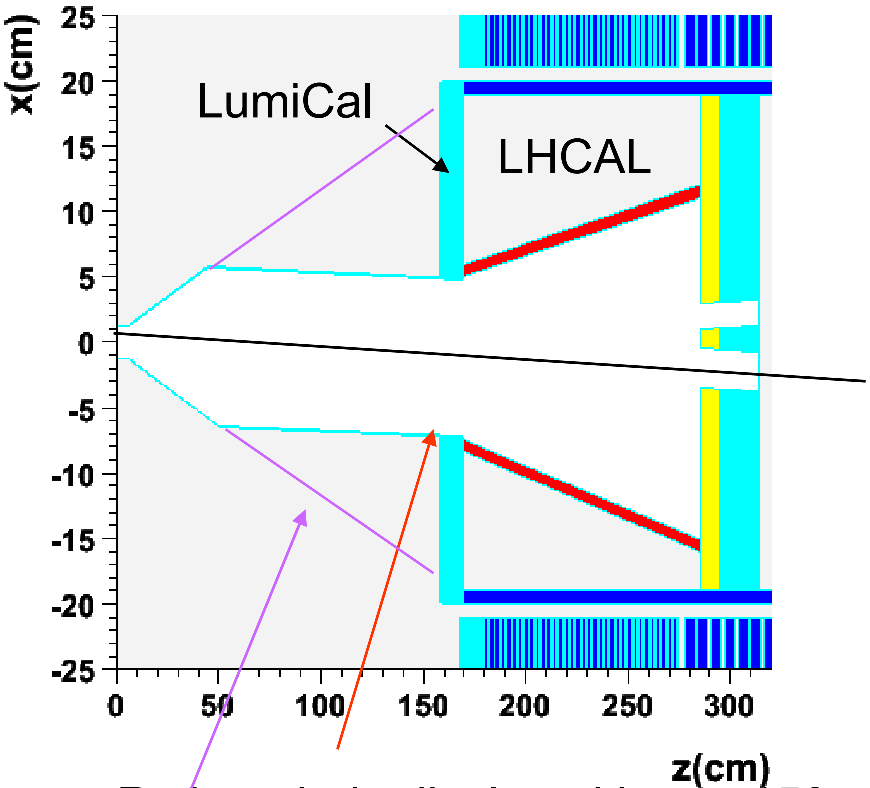
Simulations

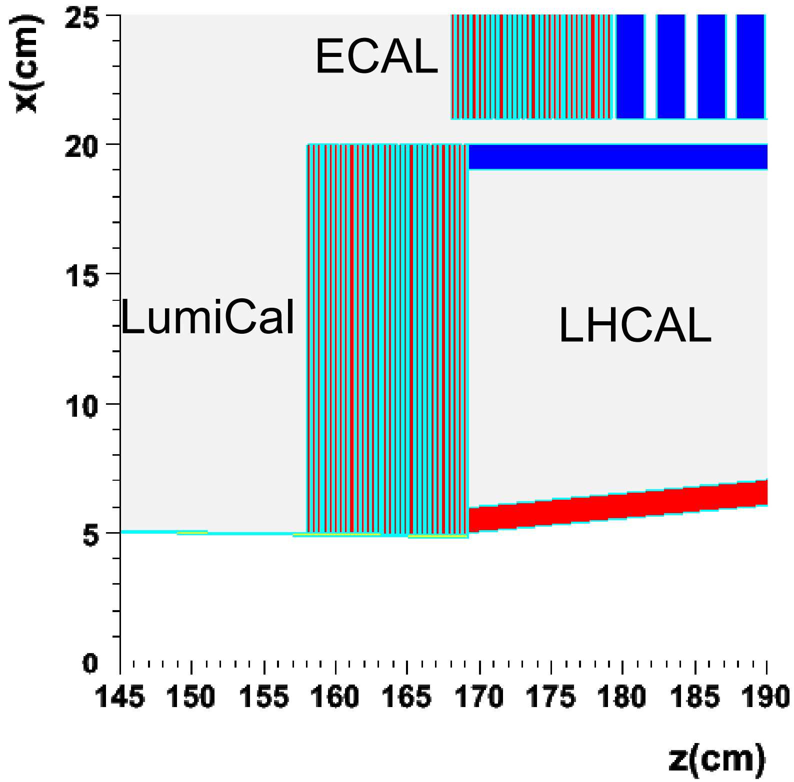
- EGS
  - Simple geometry
  - Study EM shower characteristics
- FLUKA
  - Forward region geometry
    - LumiCal/BeamCal centered on out beam
    - Include Endcap Cal
  - LumiCal simulation
    - OPAL r-ϕ segmentation
  - Study angular resolution





FLUKA Geometry

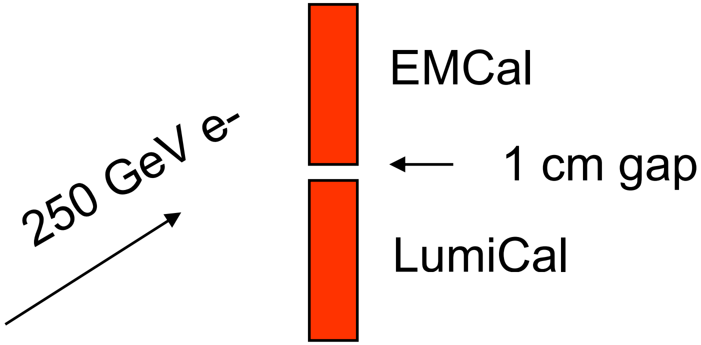




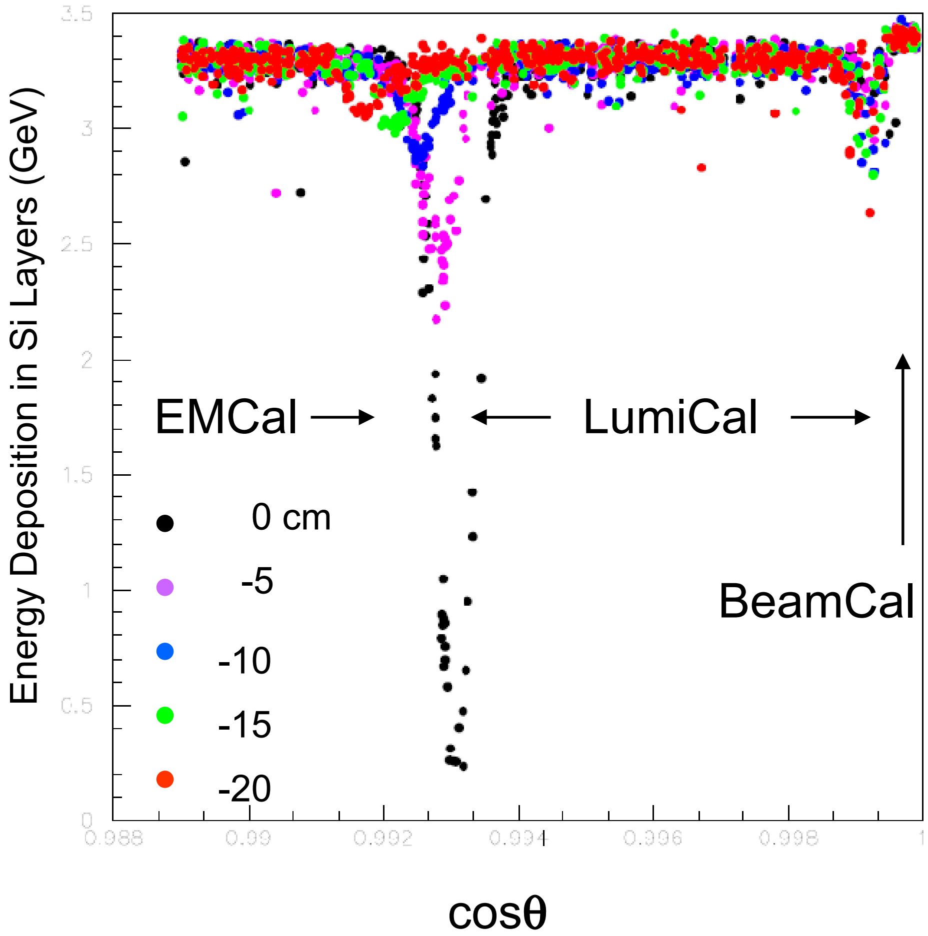
R=6 cm hole displaced by x=-158 cm * 0.007 and centered on out beam

New Conical beampipe design

LumiCal Z-location



- Move LumiCal ~10 cm w.r.t. EMCal



Energy Deposition in Si Layers

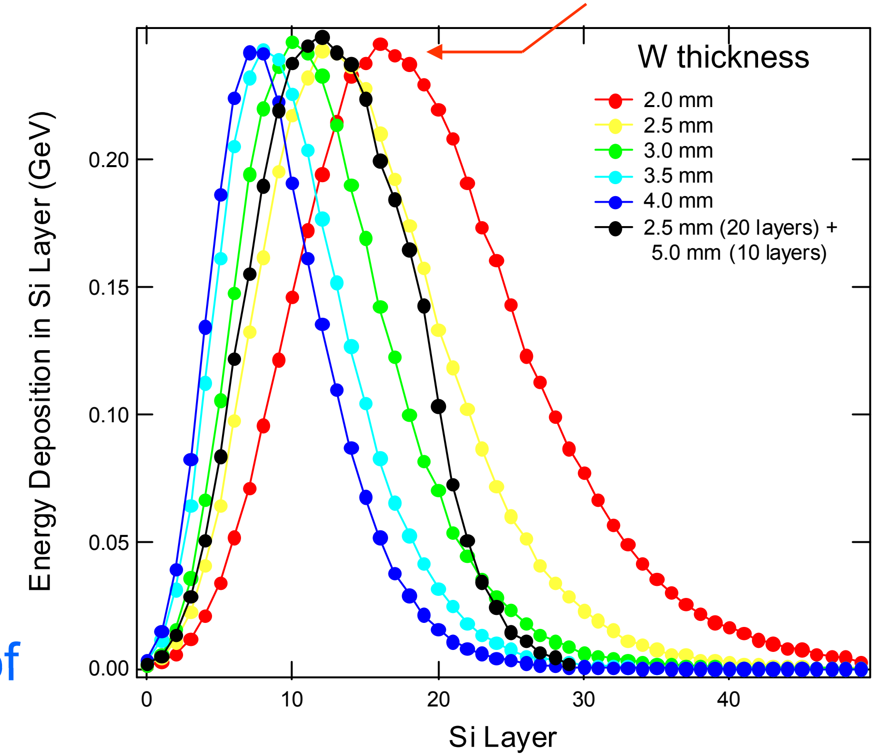
250 GeV e- normal incident

- Energy containment

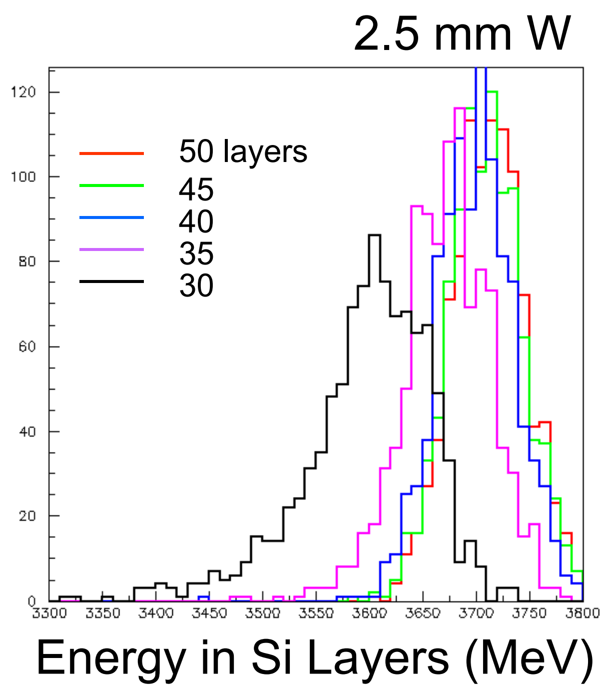
W Thickness (mm)	No Layers
2.0	50
2.5	40
3.0	35
3.5	30
4.0	25

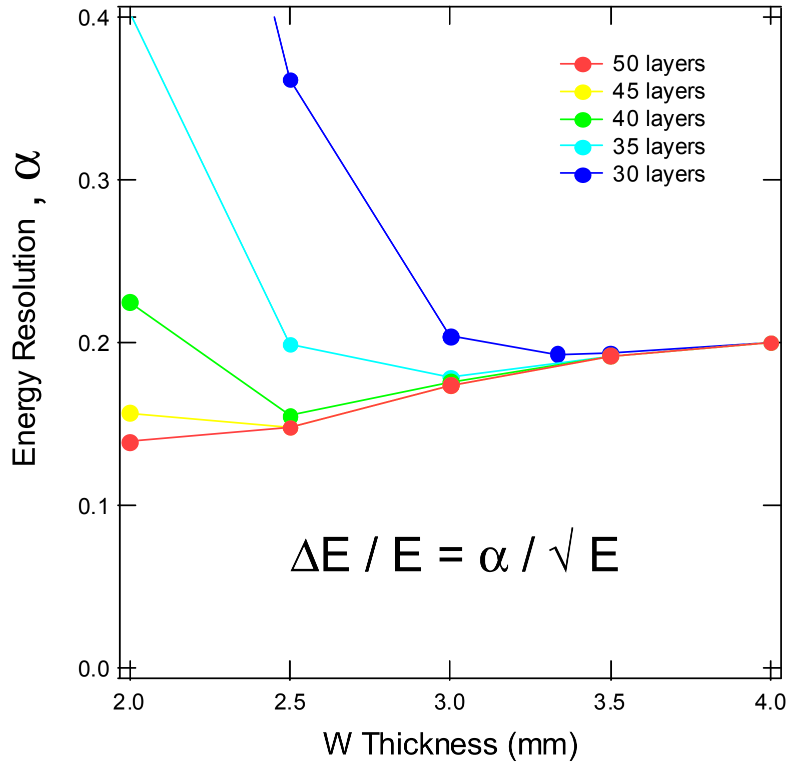
- 20 lyrs of 2.5mm + 10 lyrs of 5.0mm looks good.
- Shower max.
  - Layer #13 is shower max for 2.5 mm W

~240 MeV/layer



Energy Resolution

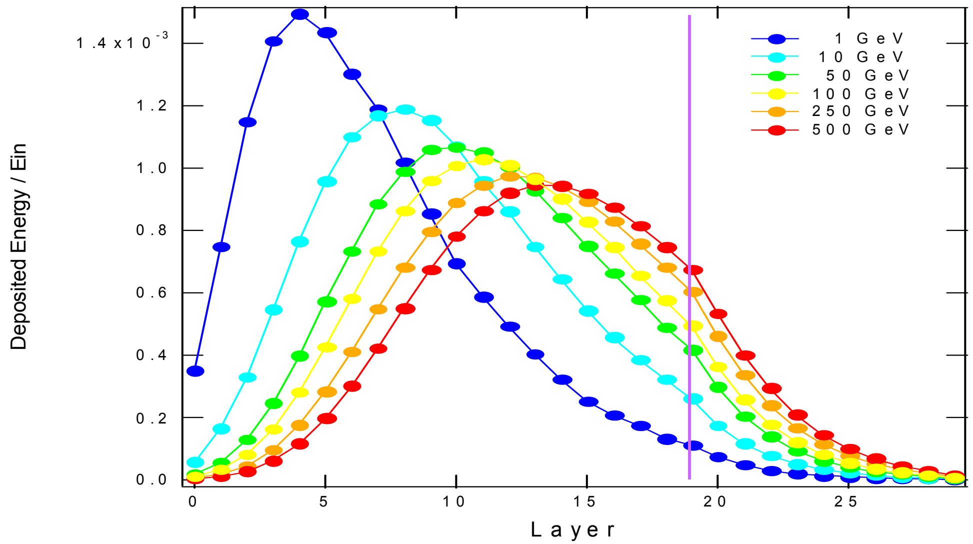


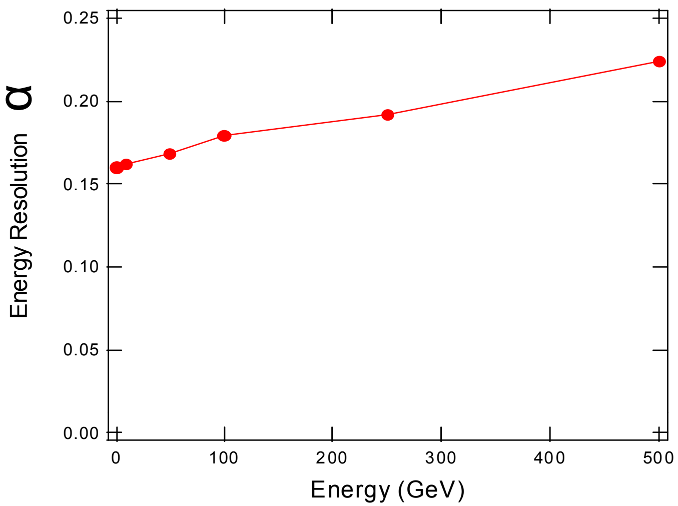


- **Energy resolution improves as W gets thinner.**
- **As long as the energy containment is satisfied.**
- **20 lyrs of 2.5mm + 10 lyrs of 5.0mm yields an optimum resolution for 30 layers.**

More on 20 lyrs (2.5mm)+10 lyrs (5.0mm)

- 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.





Good configuration for the LumiCal

Luminosity measurement

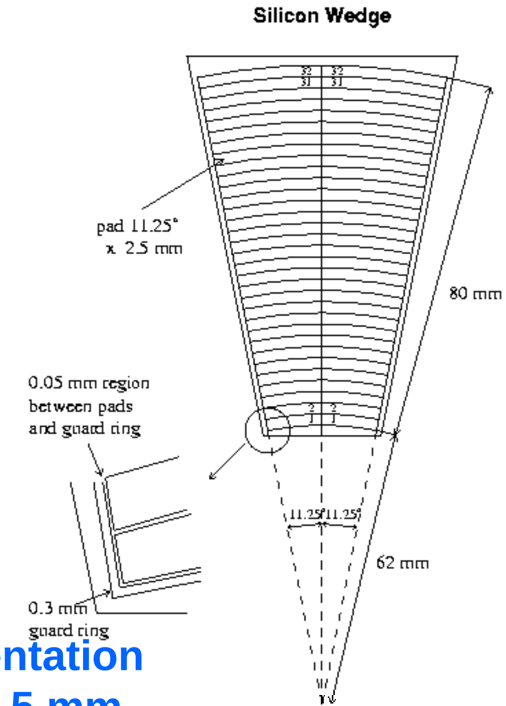
- Luminosity precision $\Delta L / L$:
  - 10^{-3} 10^{6} $W^{+}W^{-}$ events in 5 years (500 fb^{-1})
  - 10^{-4} GigaZ
- $\Delta L/L=(N_{rec} - N_{gen})/N_{gen}$
  - Bhabha $d\sigma/d\theta \sim 1/\theta^{3}$
  - $\Delta L/L \sim 2\, \Delta\theta/\theta_{min}$, $\Delta\theta$ is a systematic error.
- $\Delta\theta$ must be less than ~20μrad to reach $\Delta L/L = 10^{-3}$.
  - Detector radial location must be know within 30μm.

LumiCal simulation

- Segment Si layer equally into Δr and $N\phi$, perfect alignment and no dead space.
- Non-projective geometry
  - Same detector in depth-wise
- Collect dE/dX in each channels.
- Output lyr, ir, iphi, edep.
- Reconstruct θ_{rec} and compare with θ_{gen}

OPAL Luminometer:

14 lyrs of 3.5mm + 4 lyrs of 7.0mm



R-ϕ segmentation

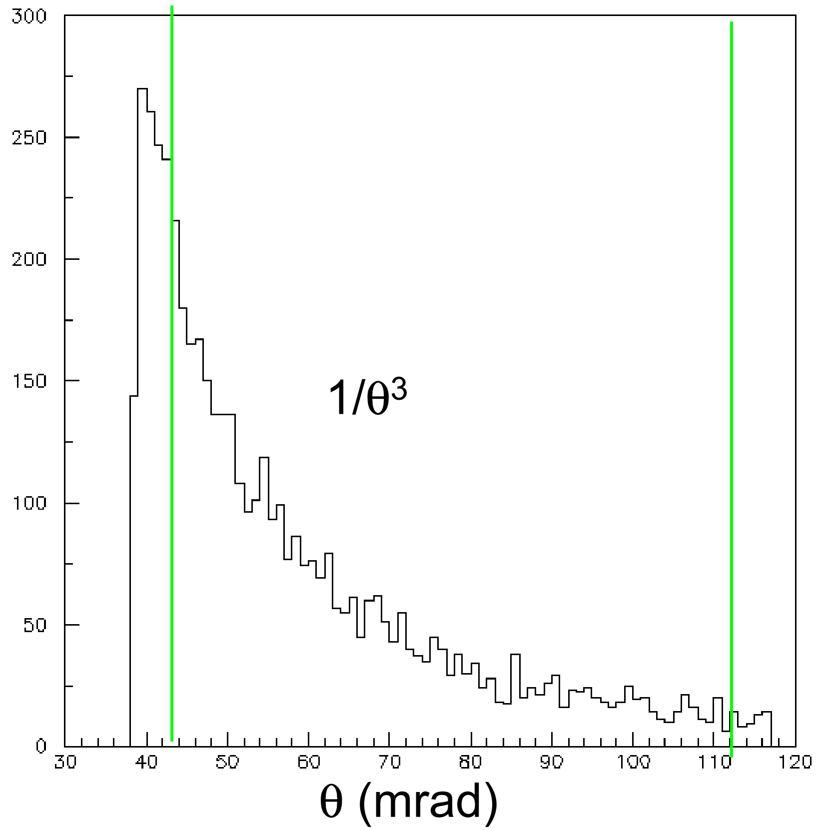
Δr = 2.5 mm

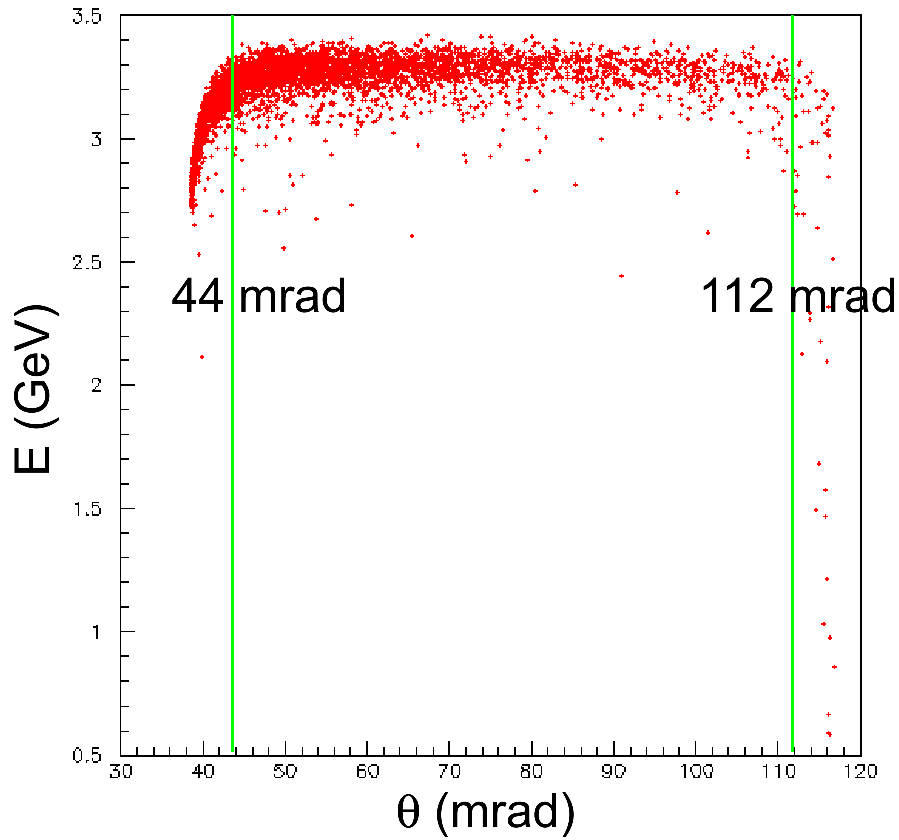
$\Delta\phi$ = 11.25° (=360°/32)

OPAL achieved $\Delta L/L = 3.4 \times 10^{-4}$

250 GeV Pseudo-Bhabha events

- Although good Bhabha generator is available, real Bhabha events obscure the angular resolution issue.
  - Bhabhas need to be separated from radiative Bhabhas.
  - Shower finder needs to be optimized for different segmentation.
- Genetate 250 GeV e- with $1/\theta^3$ distribution





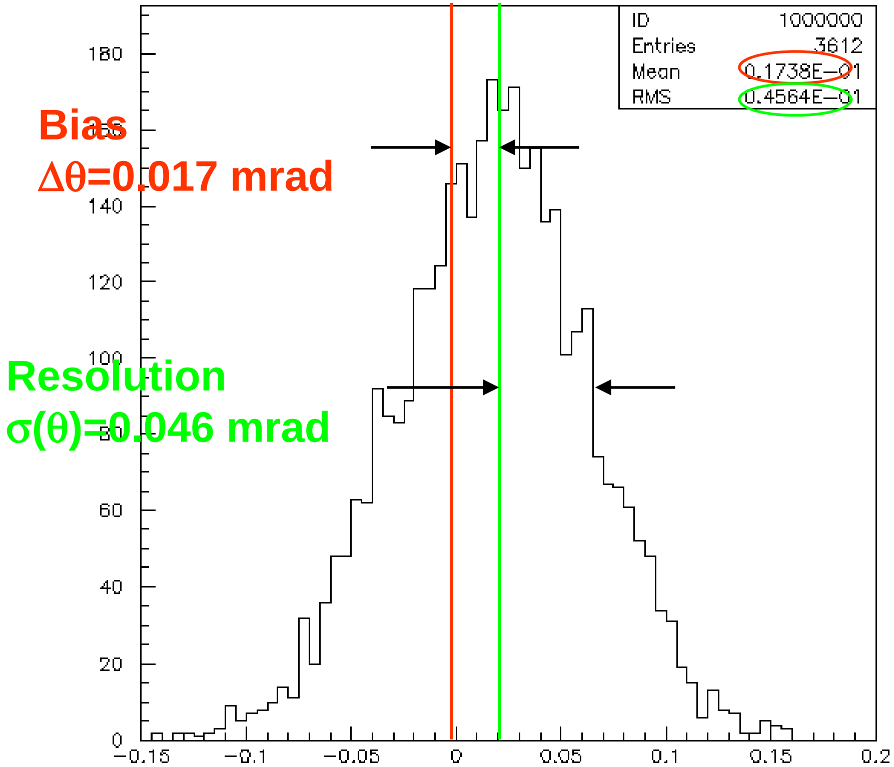
Angular resolution and bias

$$\theta = \frac{\sum w_i \theta_i}{\sum w_i}$$

W_i = Log energy weight*

Max{0, const.+ln(E_i/E_{tot})}

Δr=2.5mm, Nϕ=32



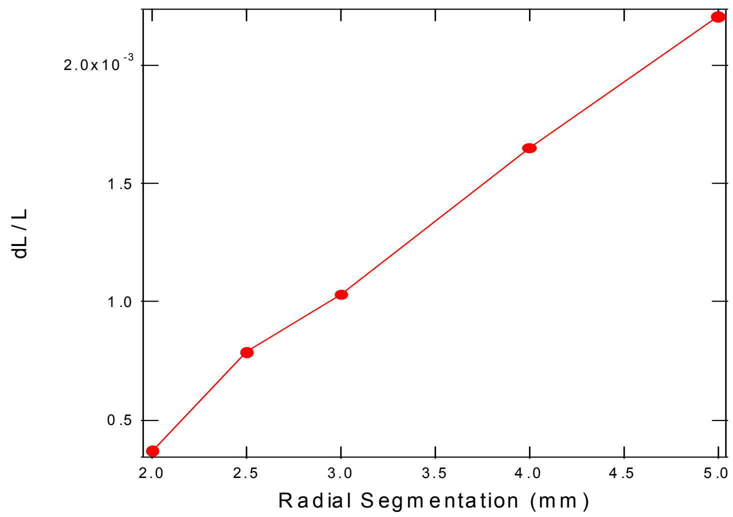
θ(rec) – θ(gen) (mrad)

* Linear energy weight is much worse.
Awes et al, NIM A311, 130 (1992)

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   Δr = 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.

Radial segmentation

- When misalignment and dead space are considered, Δr = 2 mm is probably required.
  - D. Strom: All biases in the radial coordinate must be measured in a test beam and not calculated from Monte Carlo.

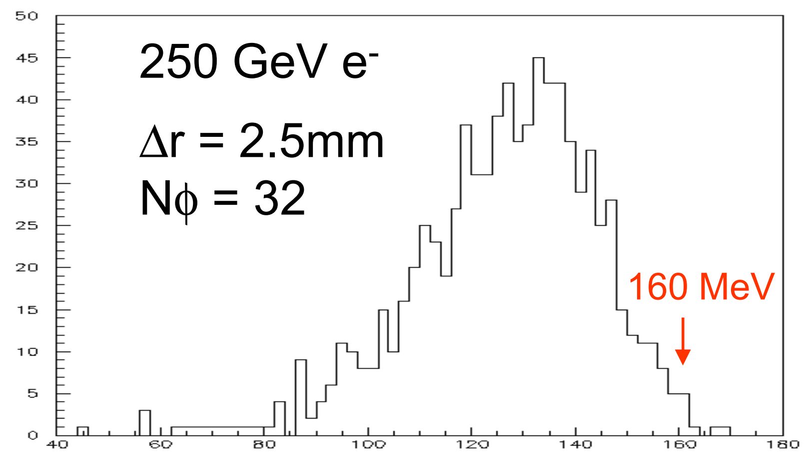
- A tracking detector like MAPS in front of the LumiCal
  - Precise polar angle measurement
  - Fine LumiCal segmentation is not necessary

Max Energy Deposition in Si channel

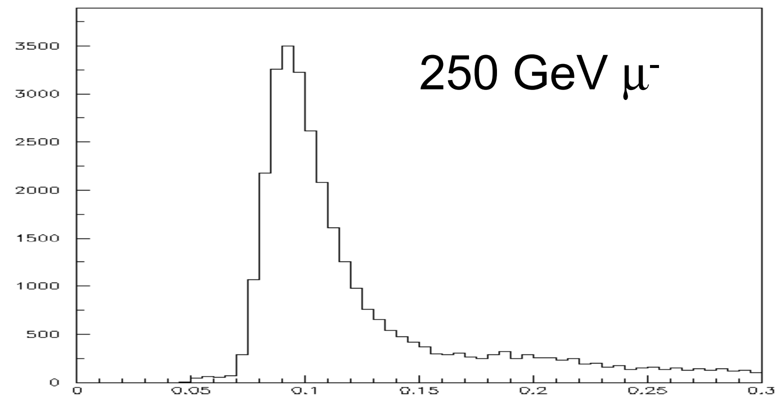
- Max energy deposition
  - 160 MeV (7010 fC*)
- MIP
  - MPV~0.0925 MeV (4.1 fC)
- Bhabha ~ 1710 MIP
- If we want S/N ~ 10 for MIP, we need 17,000 dynamic range.
  - 2 gains + 10 bit ADC

KPiX (2 gains + 13 bits) can handle it.

* 3.65 eV to generate e-h pair



Max Energy Deposition (MeV)



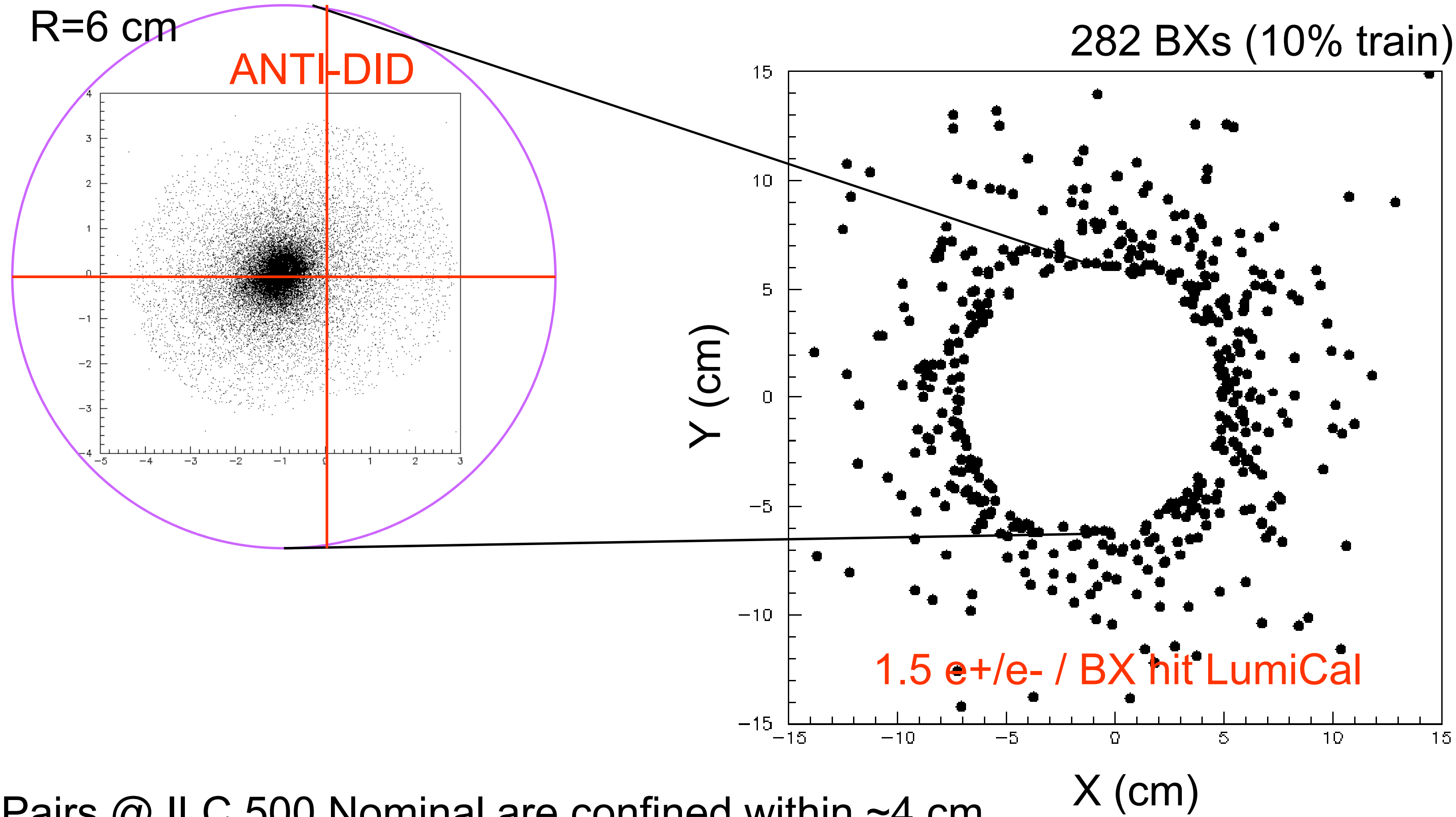
Energy Deposition (MeV)

Occupancy

- Bhabha event rate
  - N_{ev} per BX @ILC 500 Nominal=

    $5.9\,[1/\theta^2_{min} - 1/\theta^2_{max}]$ (θ in mrads)
  - 7 ev/train for θ_{min}=44 mrad, θ_{max}=112 mrad
- Backgrounds
  - Pairs
  - $\gamma\gamma \rightarrow$hadrons
  - $\gamma\gamma \rightarrow \mu\mu$

Pairs in LumiCal

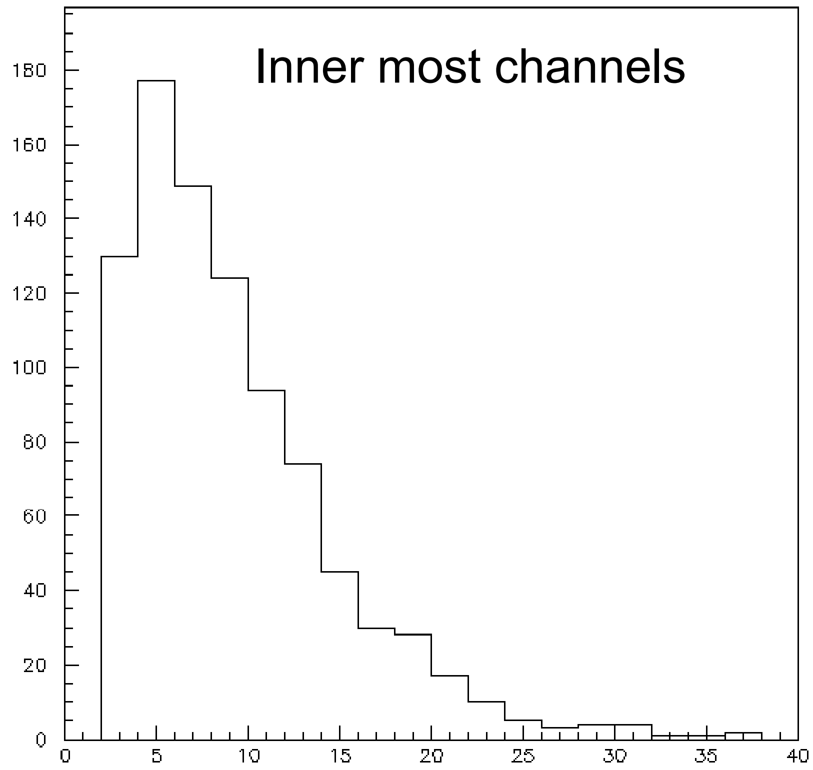


Pairs @ ILC 500 Nominal are confined within ~4 cm.
However, there are pairs outside the ring of death,
and >4000 e+/e-/train hit the LumiCal.

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.

Δr = 2.5 mm, Nϕ = 32



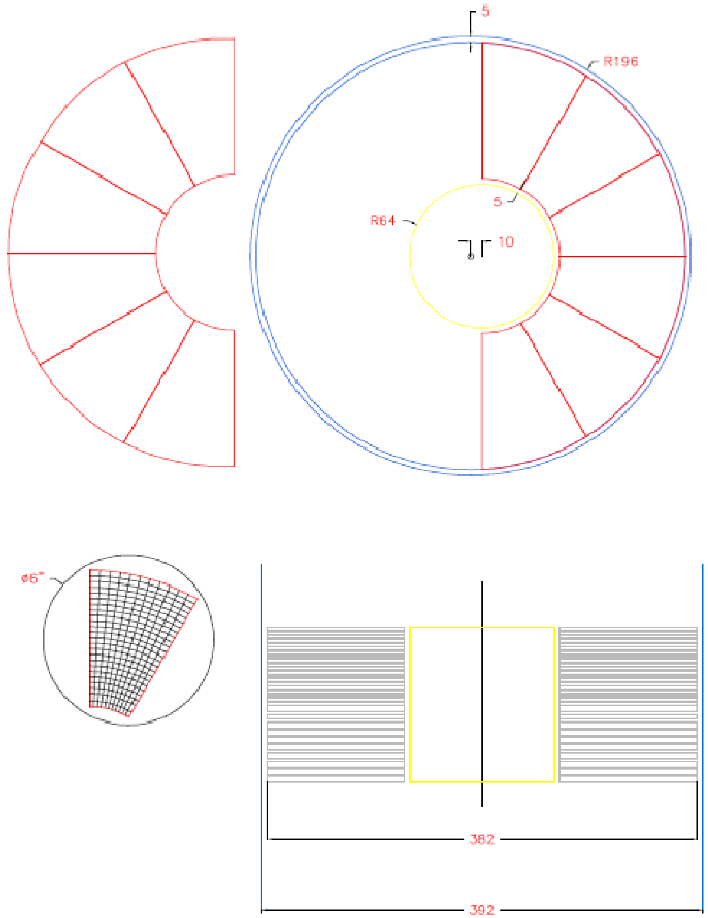
Hits per Train

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

Possible LumiCal design

Oriunno

- 6” wafer can be used if $R^{out} < 20$ cm
- 12 petals are all different; need different Masks.
- Non-projective geometry; same detector in depth-wise.
- Each petal is held by four alignment pins at the corners.



LHCAL

- Original SiD did not have LHCAL.
- LDC introduced LHCAL.
  - Hermiticity
  - Veto capability of ee+had, eeμμ
- The solid angle coverage of LHCAL is miniscule, $\sim 2\times 10^{-3}$.
- As long as the LumiCal has 100% MIP sensitivity, LHCAL is not needed.