FCAL Collaboration

High precision design

The ILD Luminosity detector

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ILD2008

Challenges & Goals

The Forward CALorimeters system

- Extension of any ILC detector
- Independent system

Integrated **luminosity** measurement with high precision

($e^+e^- \rightarrow w^+w^-$ ~10^6 events/year, $e^+e^- \rightarrow f^+f^-$ ~10^6 events/year, GigaZ ~10^9 events/year)

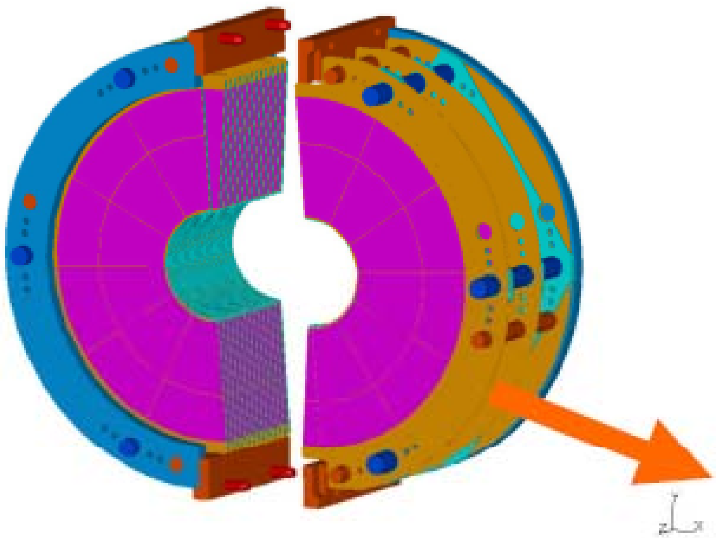
Challenges:

- High granularity and multi-channel detector
- High precision alignment
- High occupancy – machine and physics backgrounds
- High radiation environment
- Readout of every bunch (fast electronics, high volume storage)

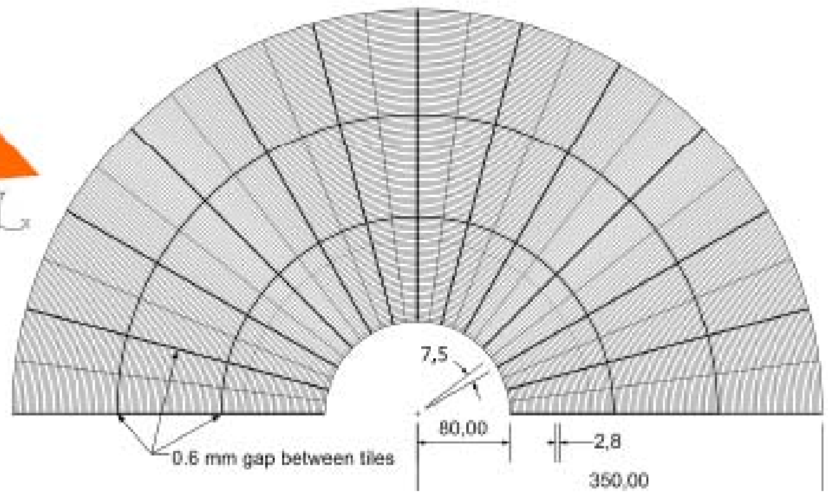
$\Delta L/L=10^{-4}$

Mechanical design

Si/W sandwich calorimeter,
2 half barrels, each 30 layers



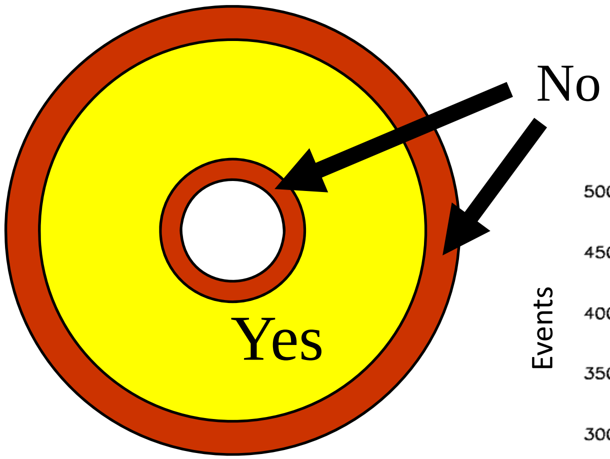
Single detector layer
48 azimuthal sectors,
Each sector ~ 64 radial pads

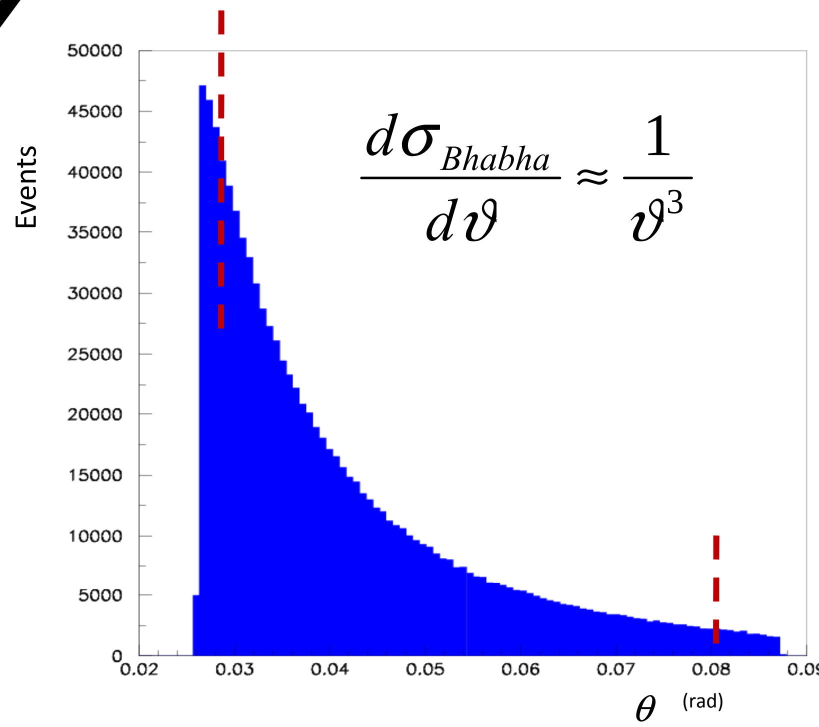


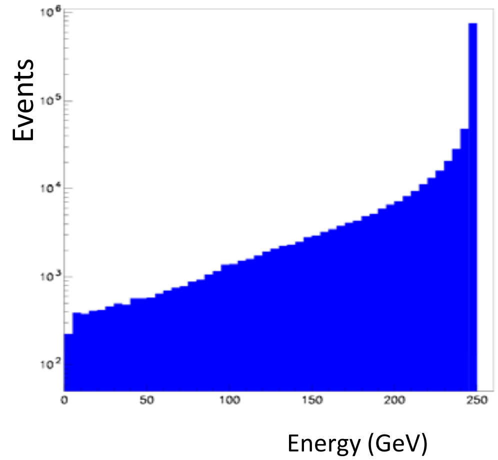
Each layer consists of
0.35cm thick tungsten
and 300µm thick Si sensor

Counting Bhabha Events

$$L = \frac{N_{Bh}}{\sigma_{Bh}}$$







Requires precision on the theoretical cross-section

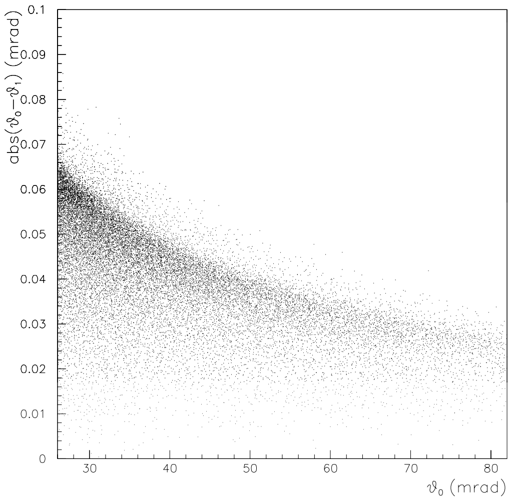
Polarised Bhabha

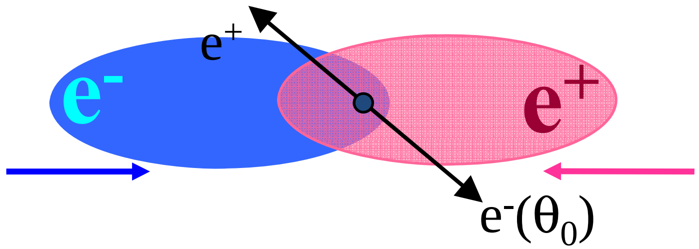
$$\sigma_{EW}^{LL}(P_-,P_+) = \frac{d\sigma_{EW}^{O}}{d\Omega}\left(1+\left(P_-{}^{L}-P_+{}^{L}\right)A_{LL}^{-}+P_-{}^{L}P_+{}^{L}A_{LL}^{-+}\right)$$

~2%

Bunch Charge Effect

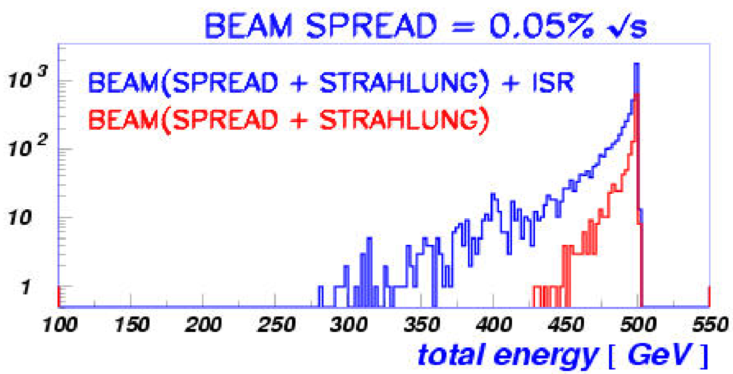
Deflection of Bhabhas due to the field of the opposite beam





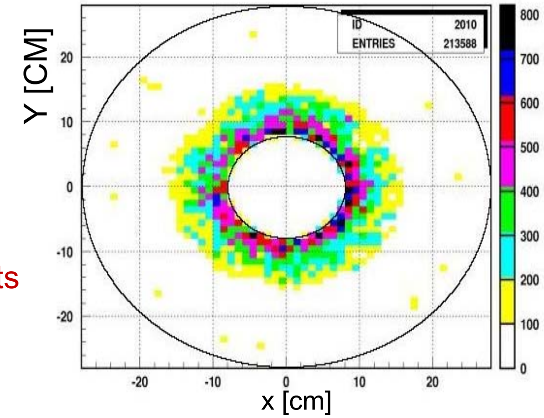
~0.5%

Machine and Physics Backgrounds

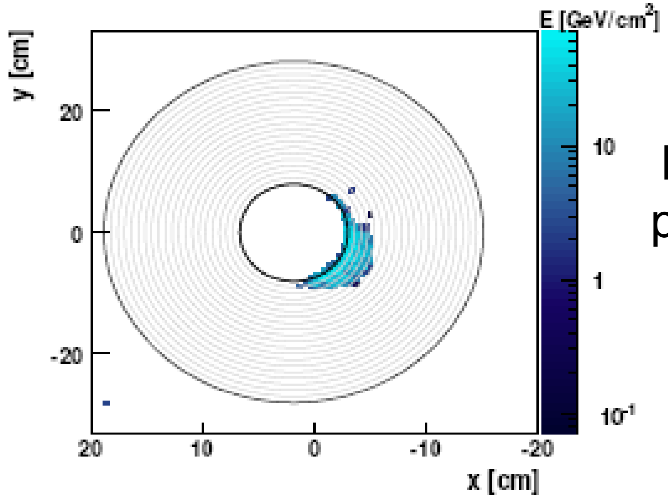


2 photon events are the main background. A set of cuts to reduce the background to the level of 10^{-4}

Before cuts

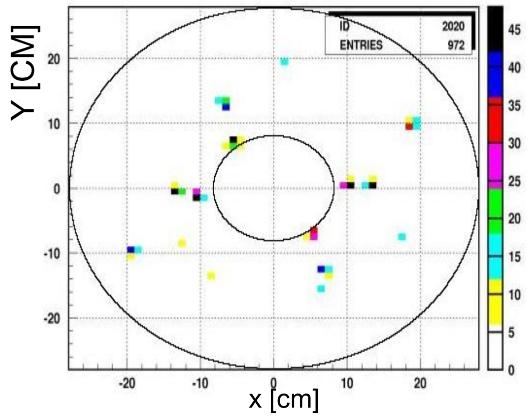


DID field



Beamstrahlung pair background

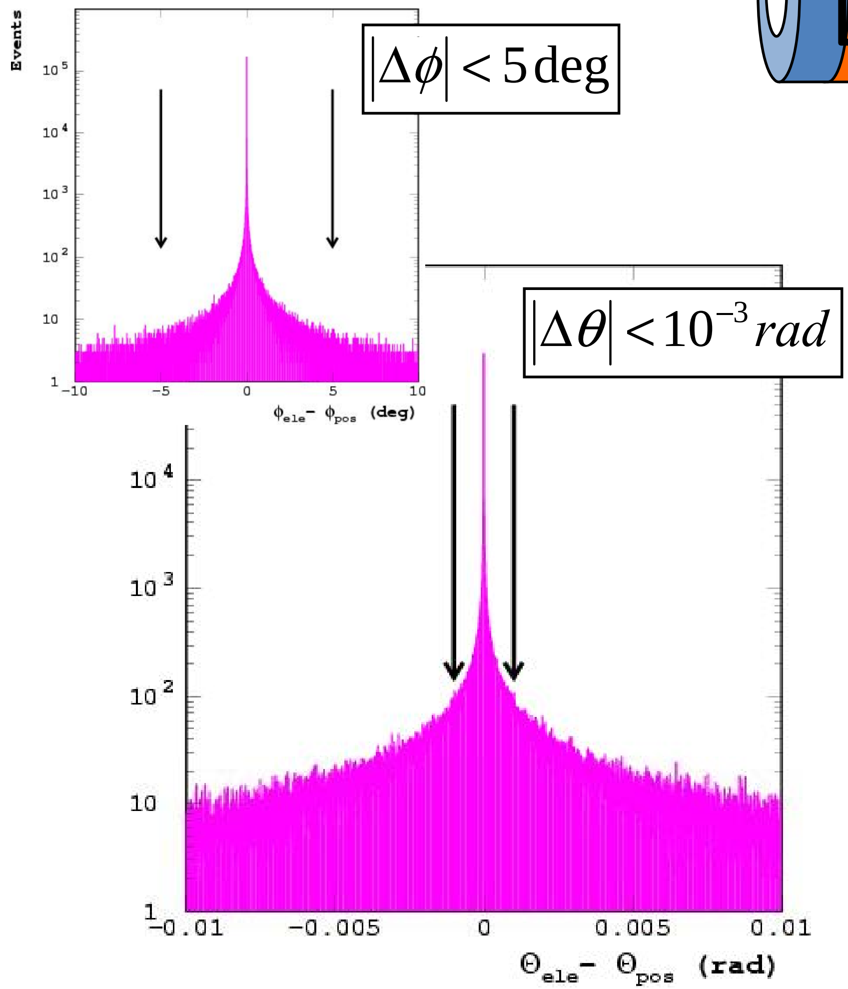
After cuts

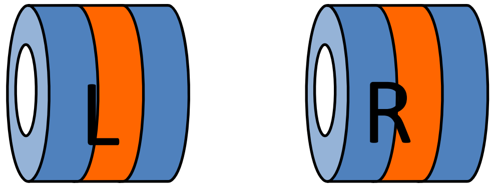


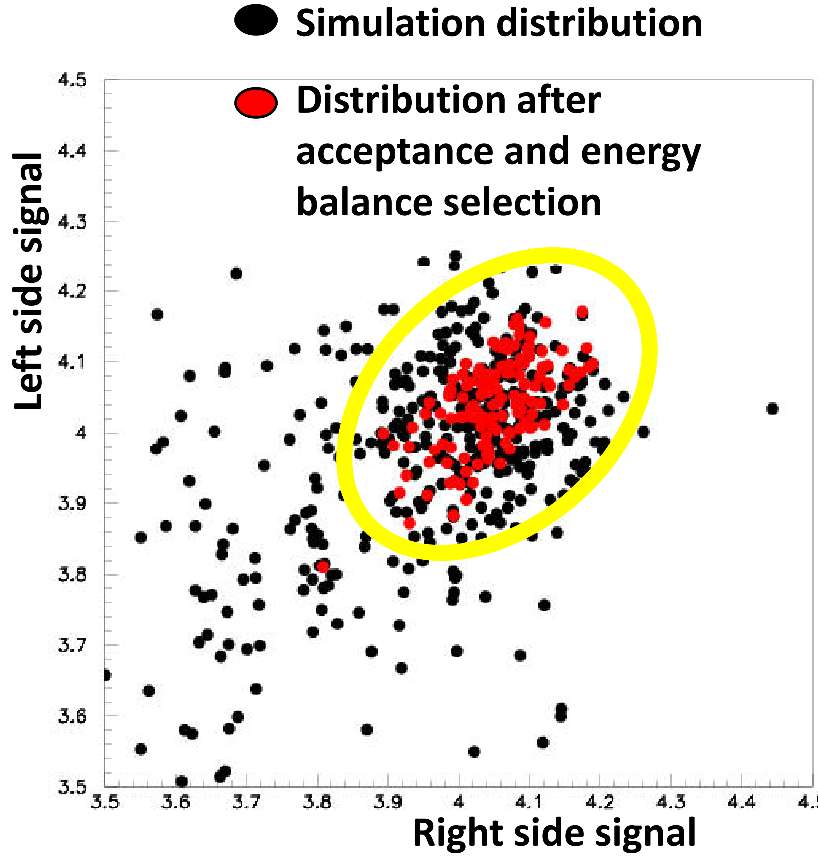
Simulation of $e^+e^- \rightarrow e^+e^-l^+l^-$ (l = e, μ, τ): **WHIZARD**

Bhabha scattering: **BHLUMI**

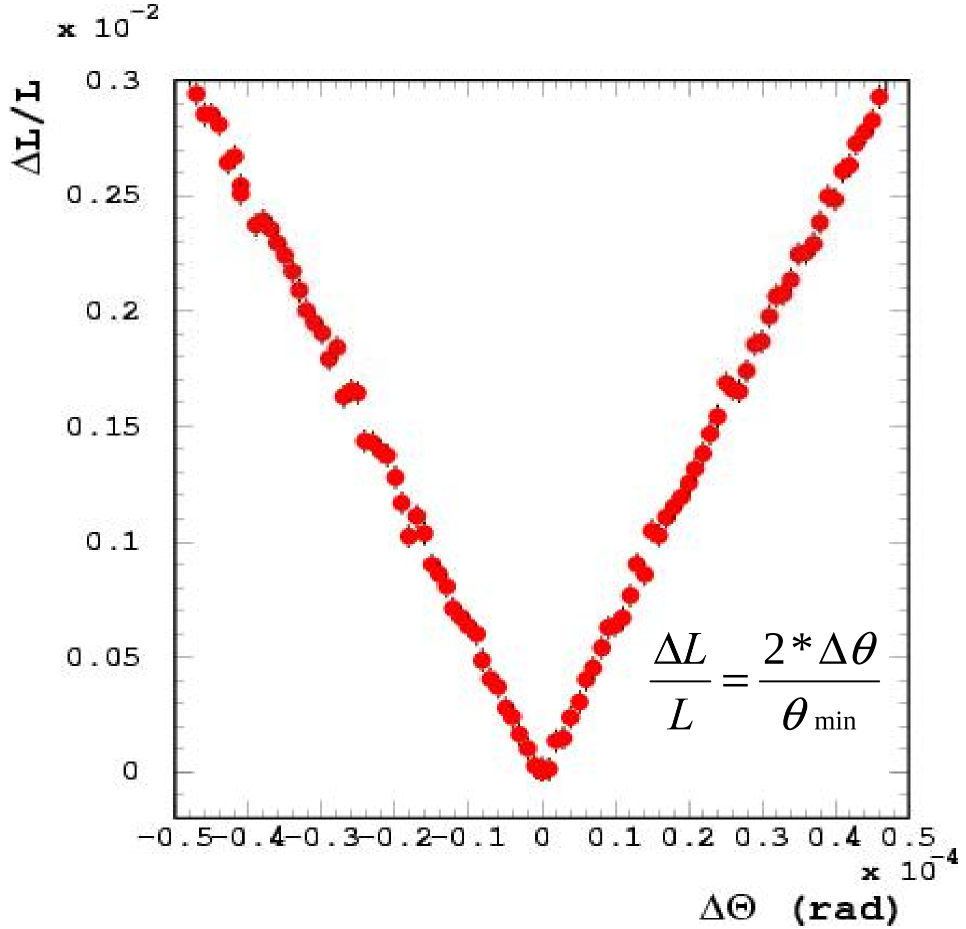
Selecting Bhabha Events

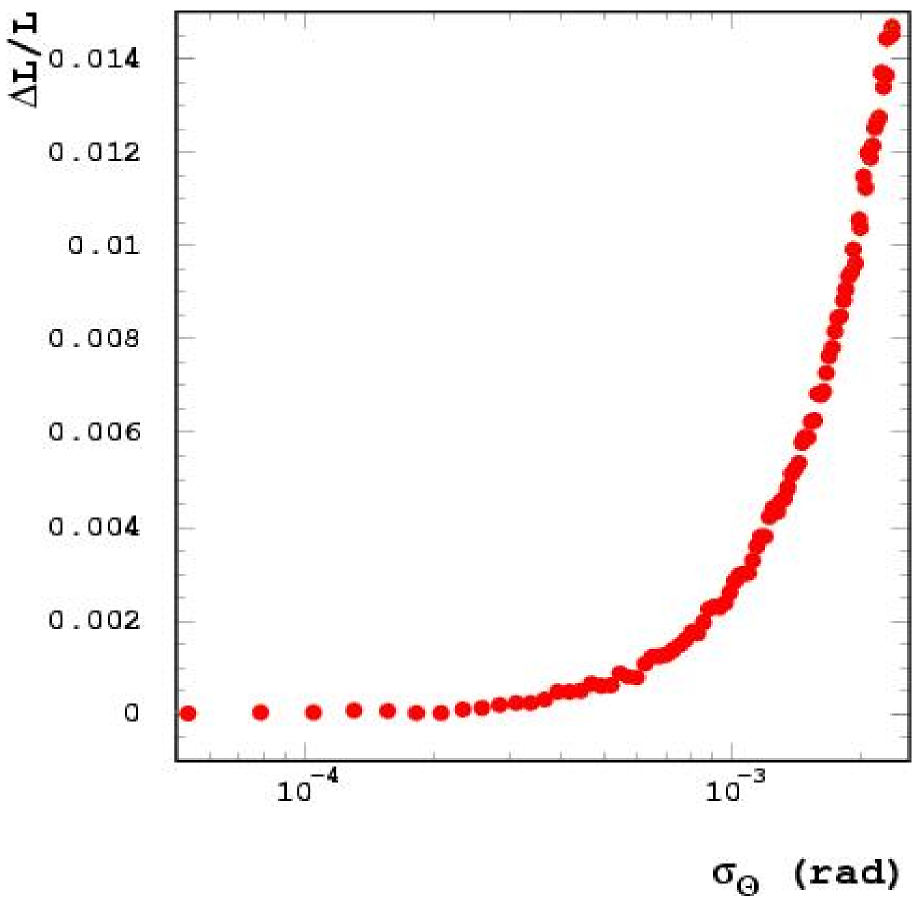




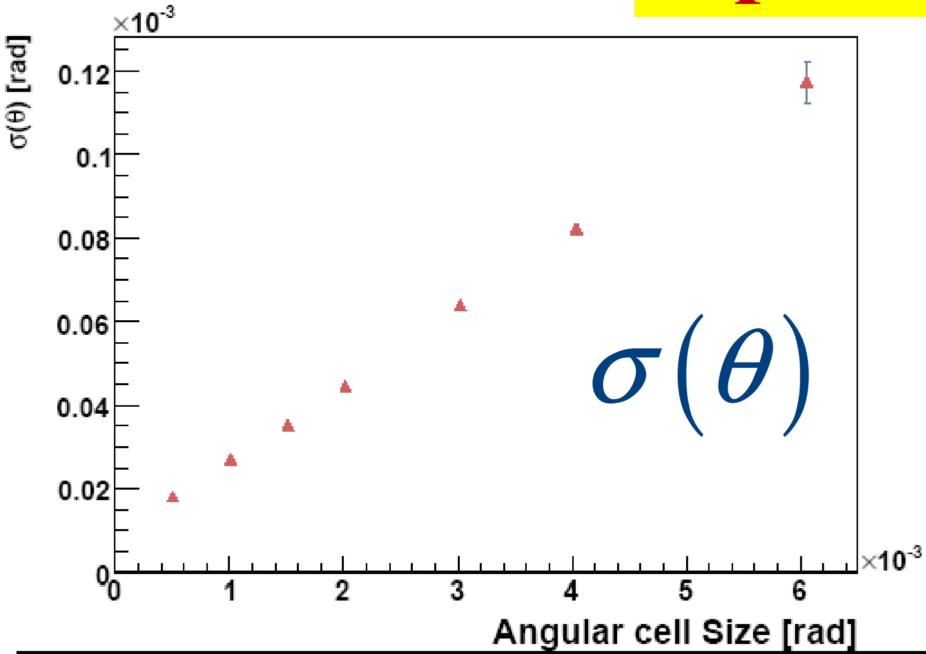


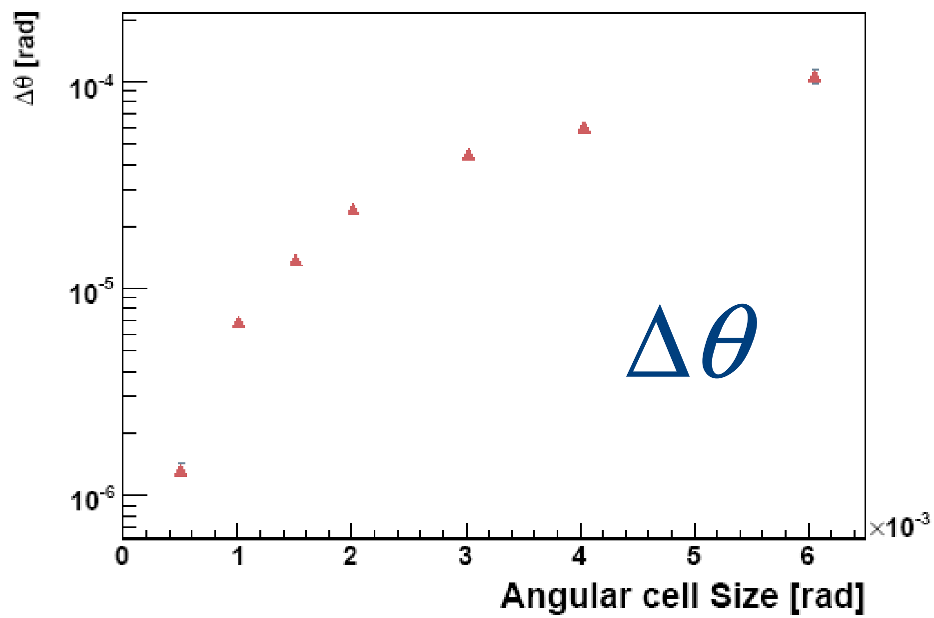
Fast Detector Simulation





Optimization





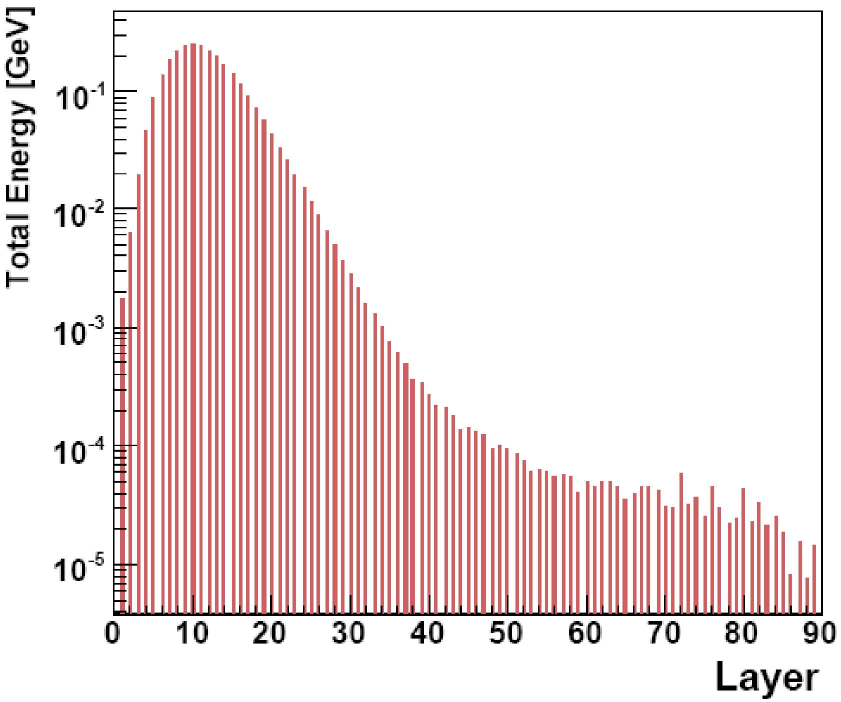
Cell size [mrad]	Cylinders	σ(θ) [mrad]	Δθ [mrad]	$2 \cdot \Delta\theta / \theta_{min}$
0.5	96	$1.8 \cdot 10^{-2}$	$1.3 \cdot 10^{-3}$	$0.6 \cdot 10^{-4}$
1	48	$2.7 \cdot 10^{-2}$	$6.9 \cdot 10^{-3}$	$3.1 \cdot 10^{-4}$
1.5	32	$3.5 \cdot 10^{-2}$	$13.7 \cdot 10^{-3}$	$6.2 \cdot 10^{-4}$
2	24	$4.4 \cdot 10^{-2}$	$24 \cdot 10^{-3}$	$10.9 \cdot 10^{-4}$

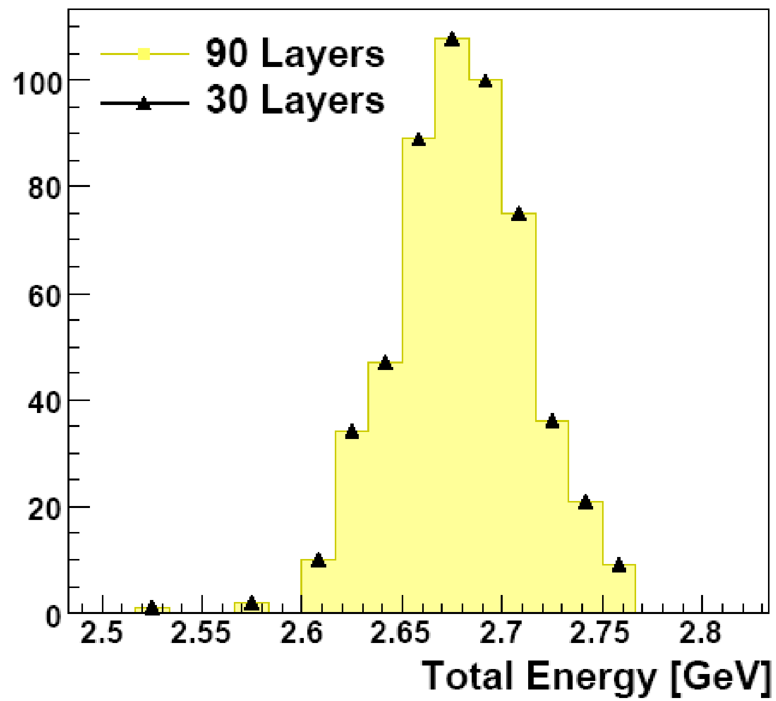
Calculated for:

Θ_{min} = 44 mrad

($R_{min} \rightarrow R_{max}$ = 80→190 mm)

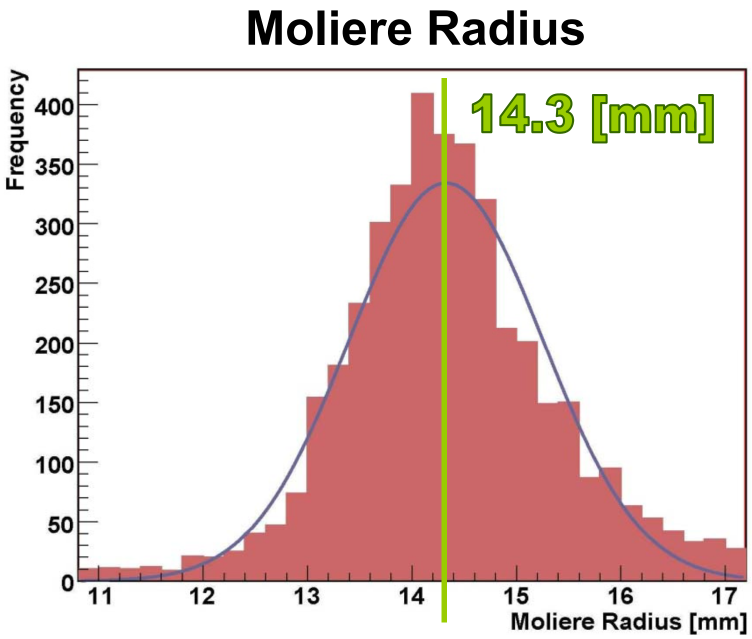
Optimization : Shower Containment

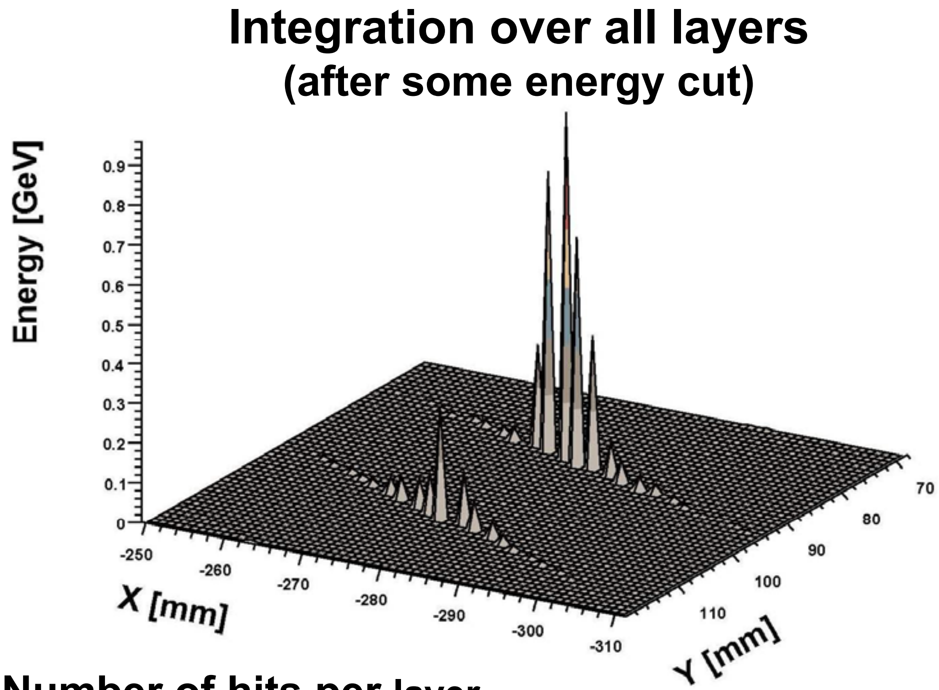


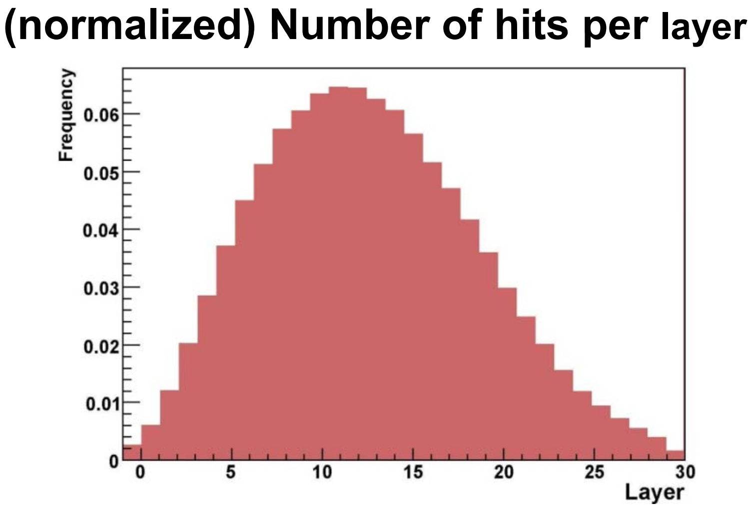


$$E_{res} \equiv \frac{\Delta E}{E}\sqrt{E_{beam}}\left[\sqrt{\text{GeV}}\right]$$

EM-Shower Properties







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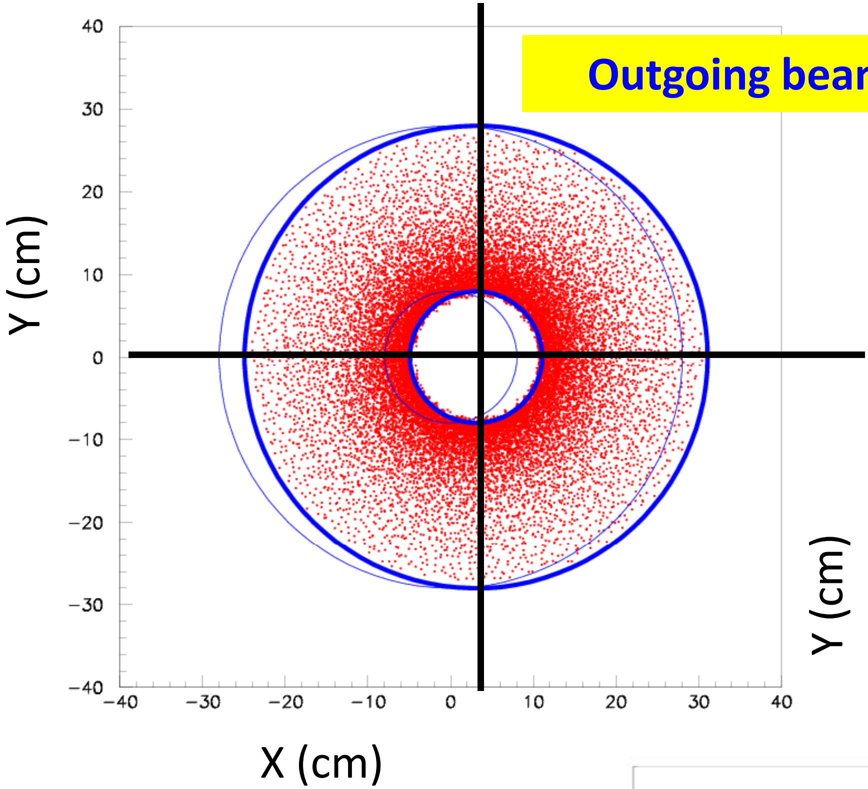
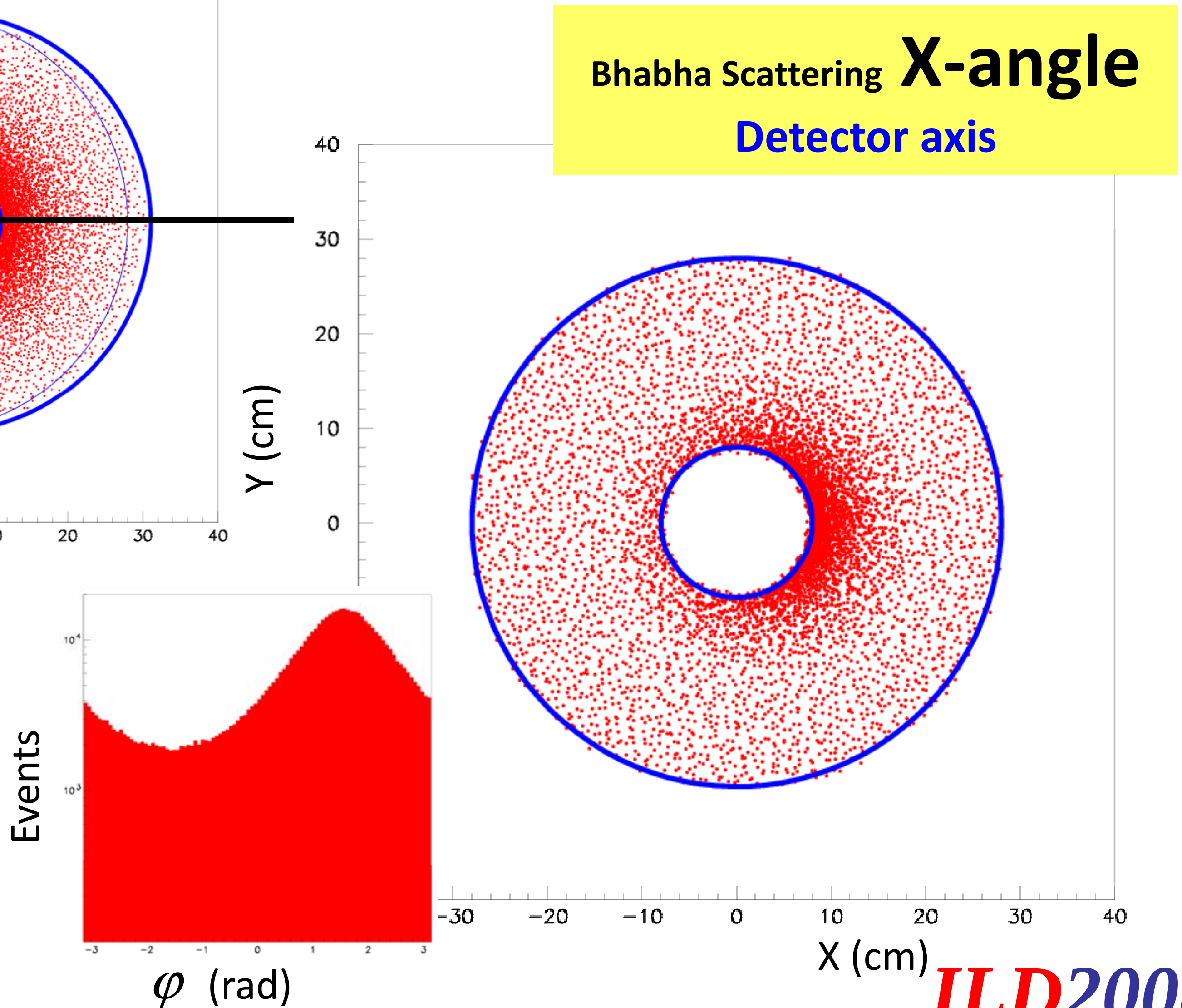
Detector Position





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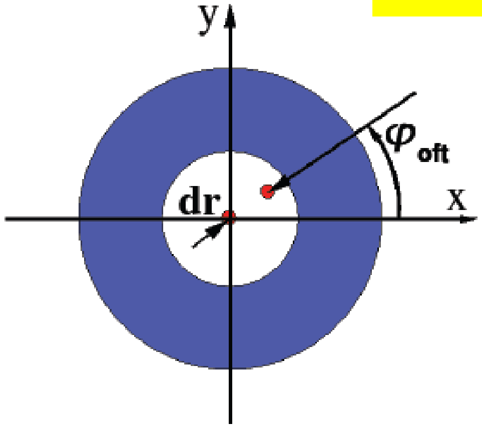
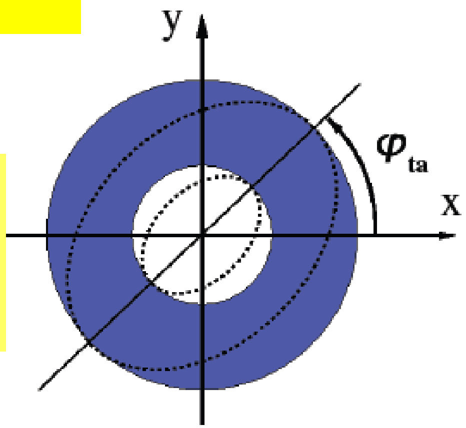
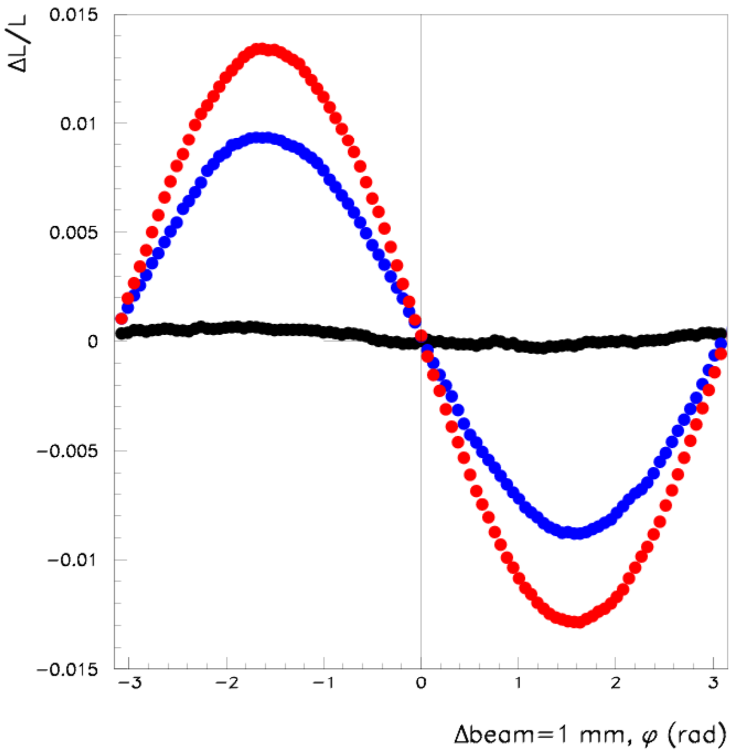
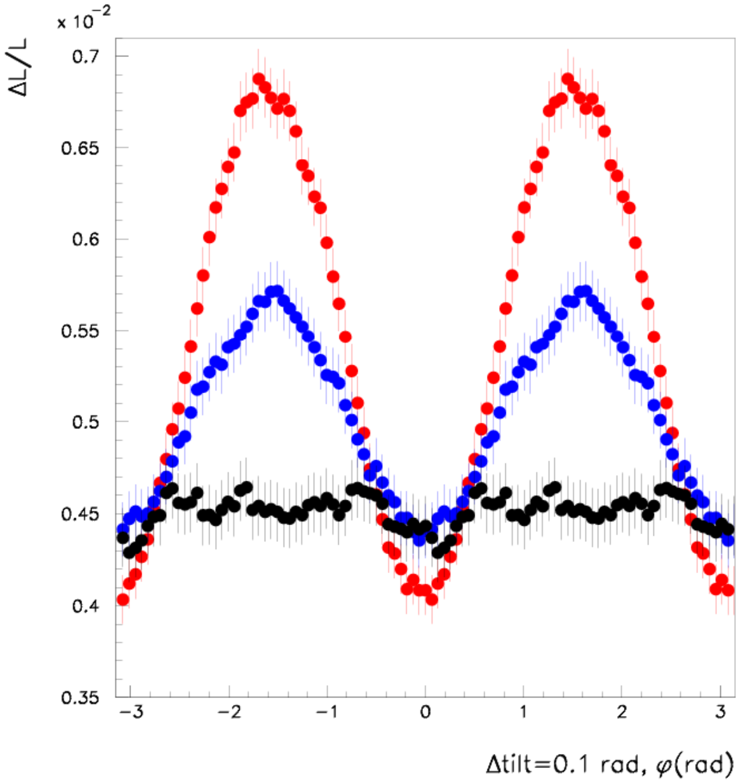
X-angle Versions



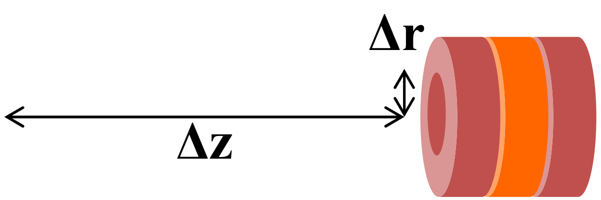
- Headon, 14,20 mrad X-angle outgoing beam
- 14 mrad X-angle detector axis
- 20 mrad X-angle detector axis



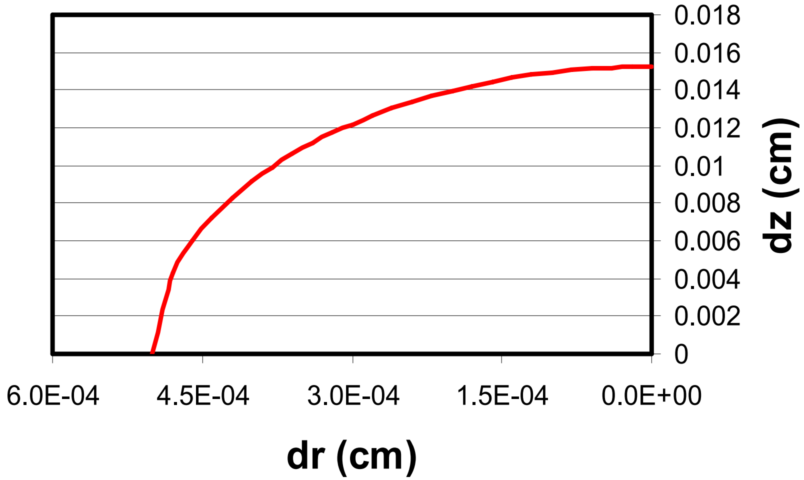


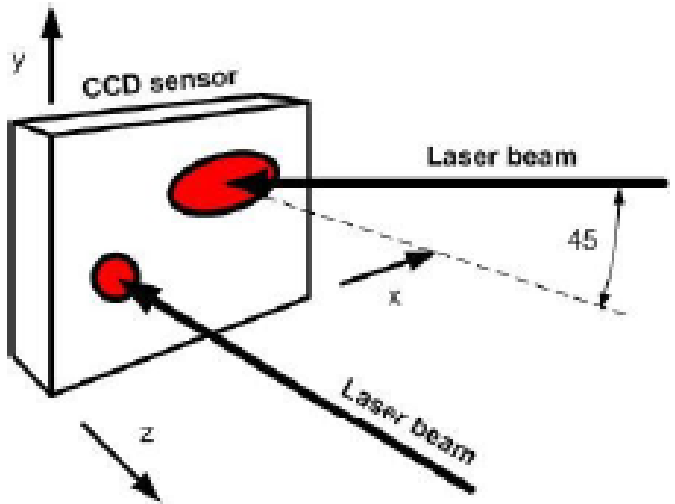


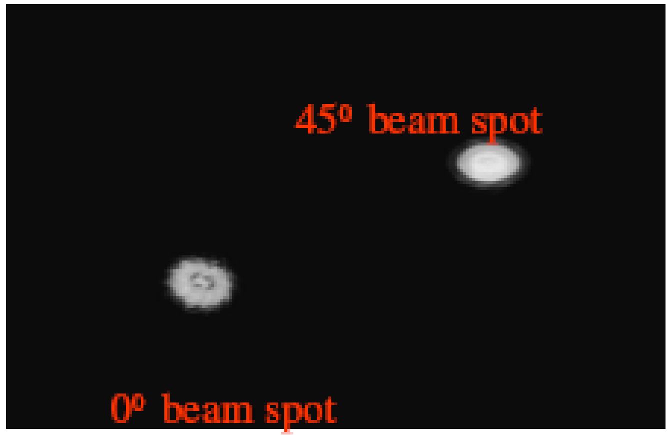
Laser Alignment System



$\Delta L/L=10^{-4}$





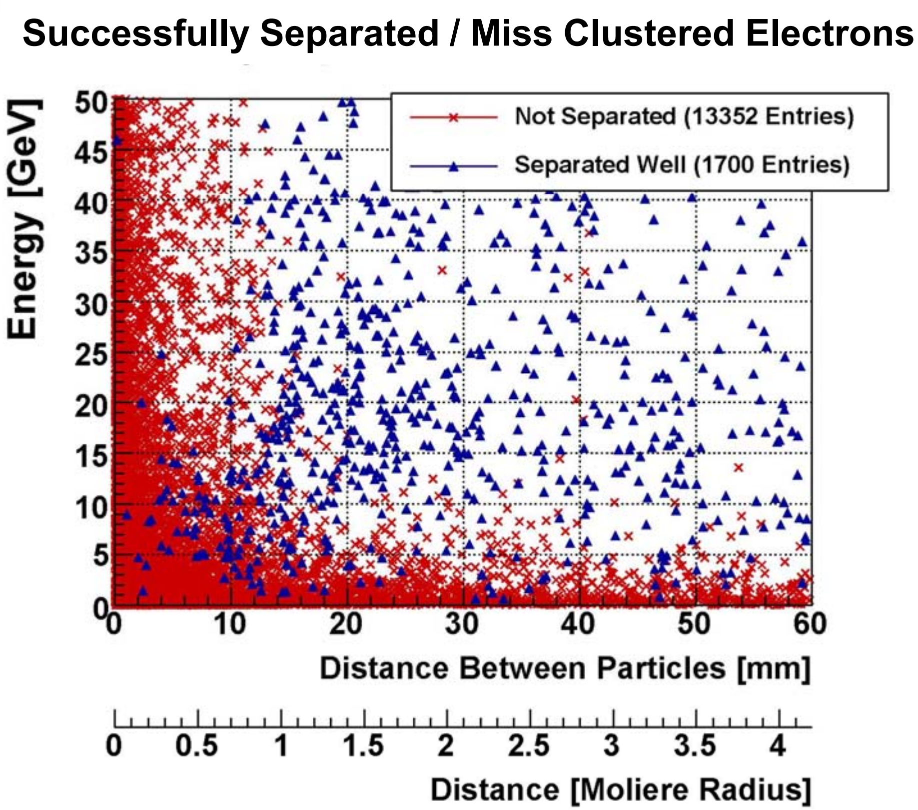


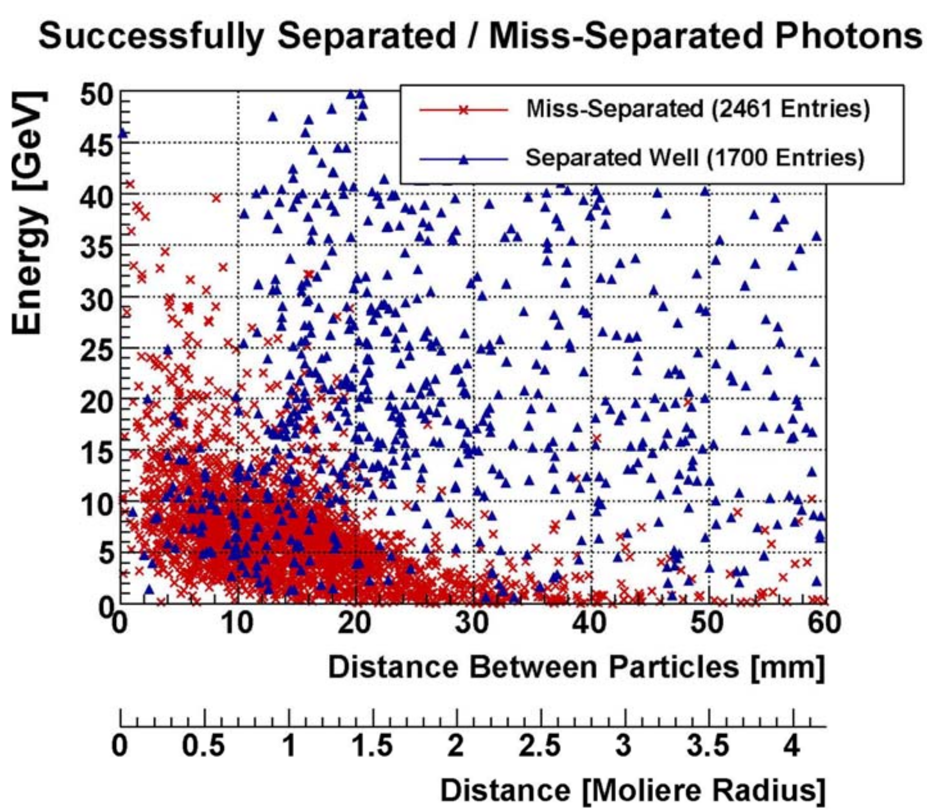
Clustering Algorithm

1. Perform initial 2D clustering in shower-peak layers.
2. Extrapolate “virtual cluster” CMs in non shower-peak layers, and build real clusters accordingly.
3. Build (global) 3D “super clusters” from all 2D layer clusters.
4. Check cluster properties, and (try to) re-cluster if needed.

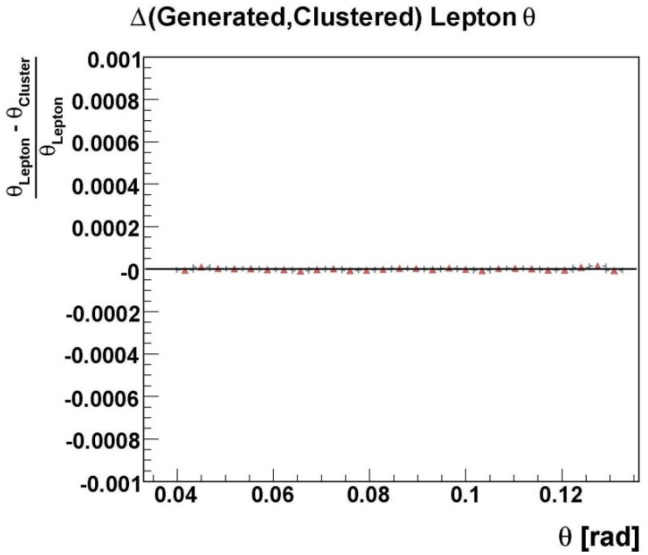
- Events were generated with **BHWIDE** (1.04) and simulated by **Mokka**(v06-03-p01) using **Geant4**(v4.8.1.p02). The super-driver LumiCalX of the LDC(00-03Rp) model was used to build LumiCal in Mokka.
- The clustering algorithm was written as a **Marlin** processor, using Marlin(v00-09-08).

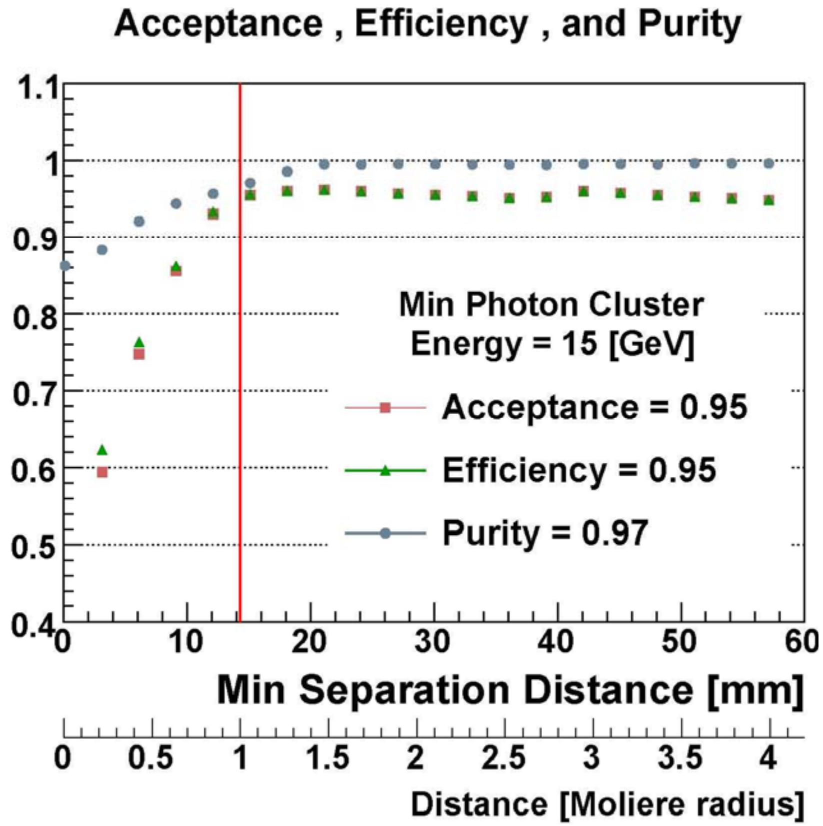
Results of the Algorithm

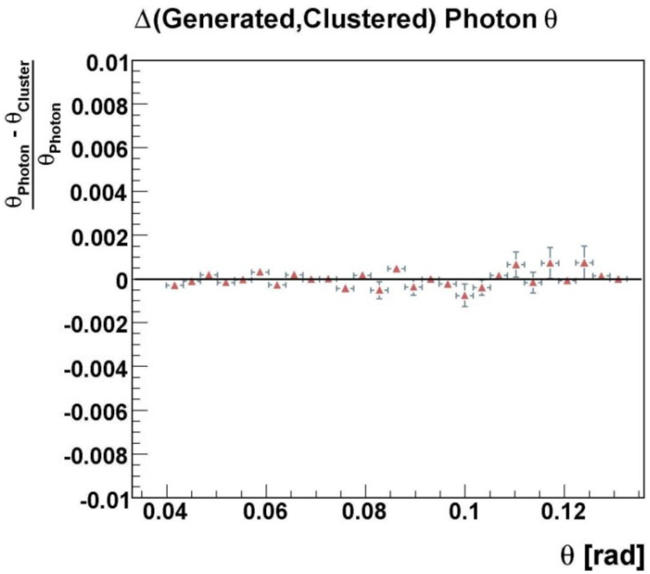




Results of the Algorithm



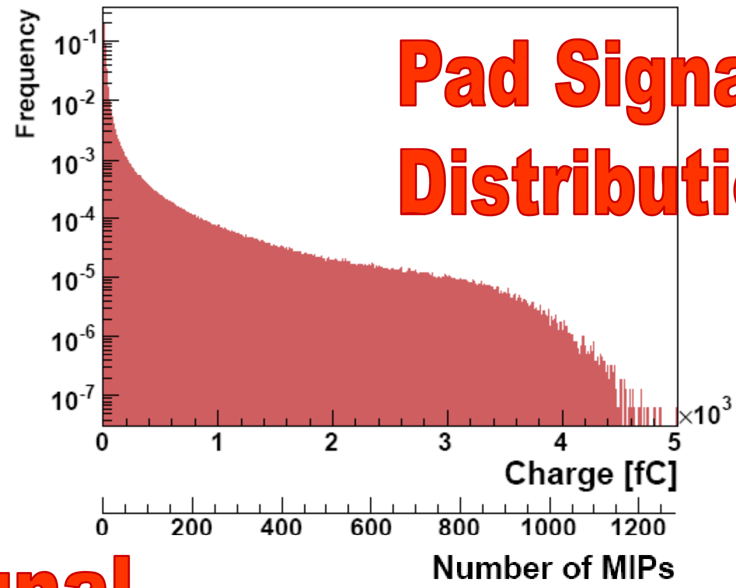




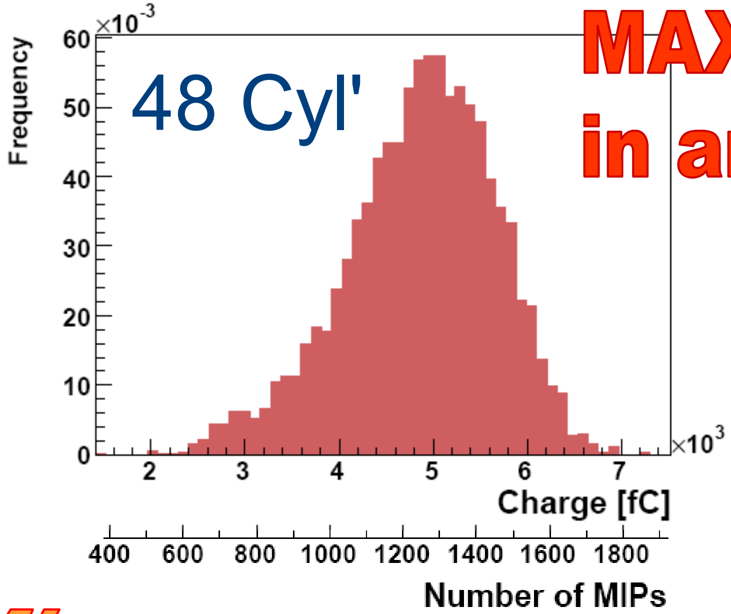
Inputs for Elec. Design (250 GeV Electrons)

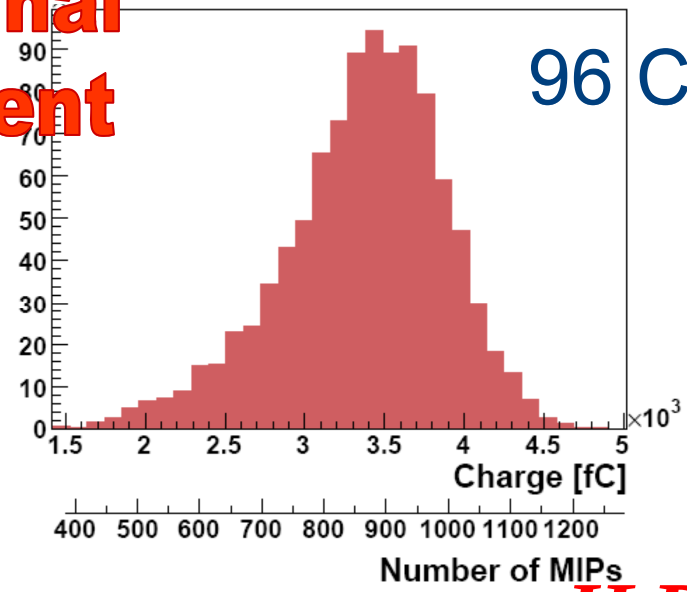
- The max induced charge in an event sets the upper bound on the charge that is read out by the electronics.

Pad Signal Distribution



MAX signal in an event





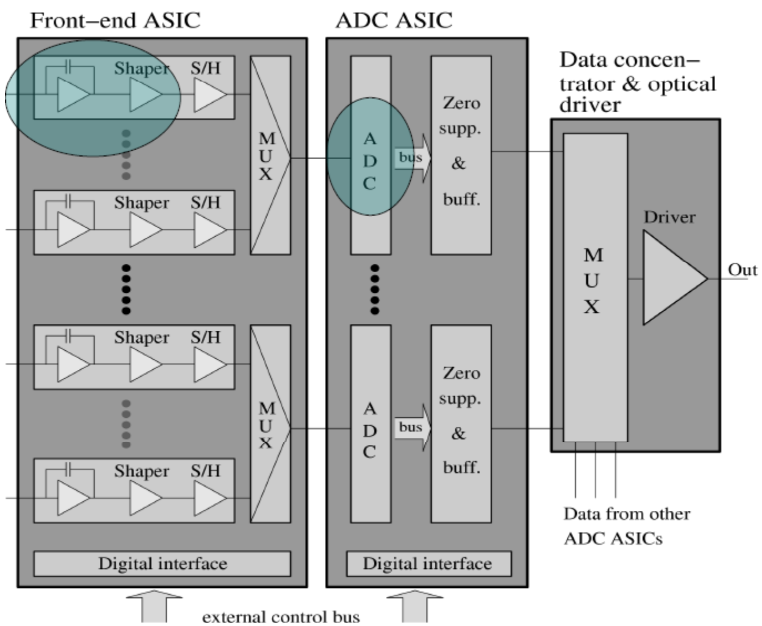
Sensors and Electronics Design

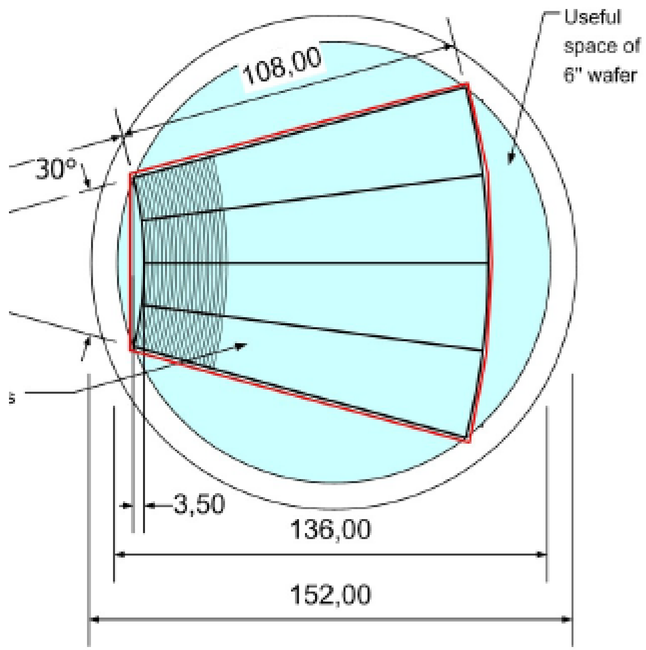
Frontend ASIC will
contain 3264 dual gain channels

An ADC will serve ~8(1?)
frontend channels

8-10 Bit ADC

Standard silicon
No radiation problem (To be verified)
Possible candidate (Hamamatsu)
Si wafer thickness ~ 320 μm
Dark current ~ 10 nA/cm2 @ 200 V





Present Understanding (LDC V.5)

1. Overall design:

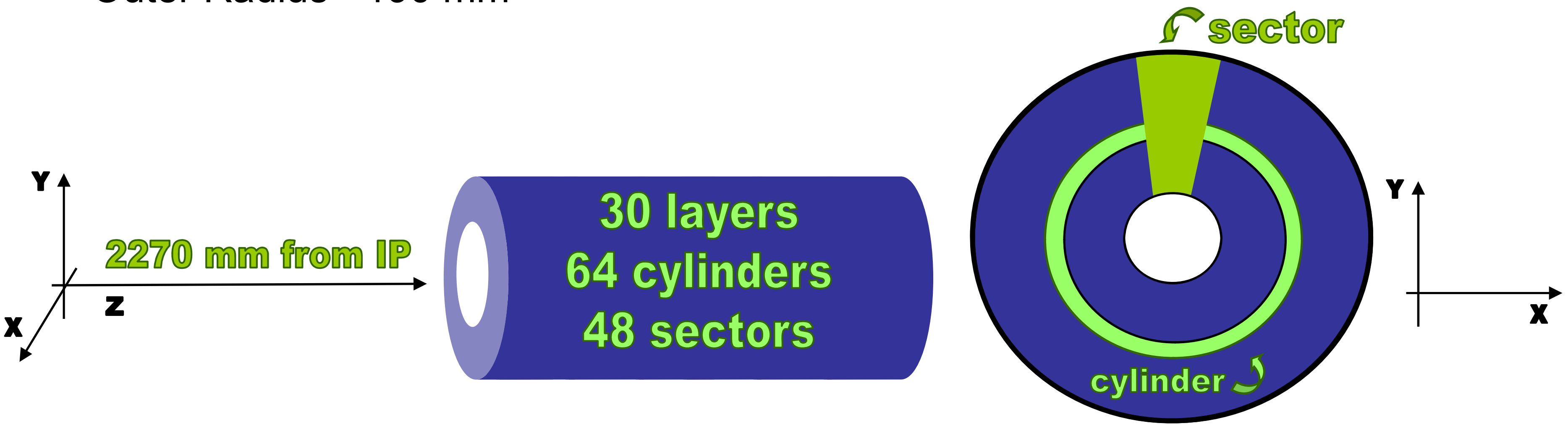
- Tungsten Thickness - 3.5 mm
- Silicon Thickness - 0.3 mm
- Elec. Space - 0.1 mm
- Support Thickness - 0.6 mm
- Inner Radius - 80 mm
- Outer Radius - 190 mm

2. Internal segmentation:

- 48 sectors → Phi Cell Size - 131 mrad
- 64 cylinders → Theta Cell Size – 0.75 mrad
- 30 layers

3. Placement:

- 2270 mm from the IP



Expected Luminosity Precision

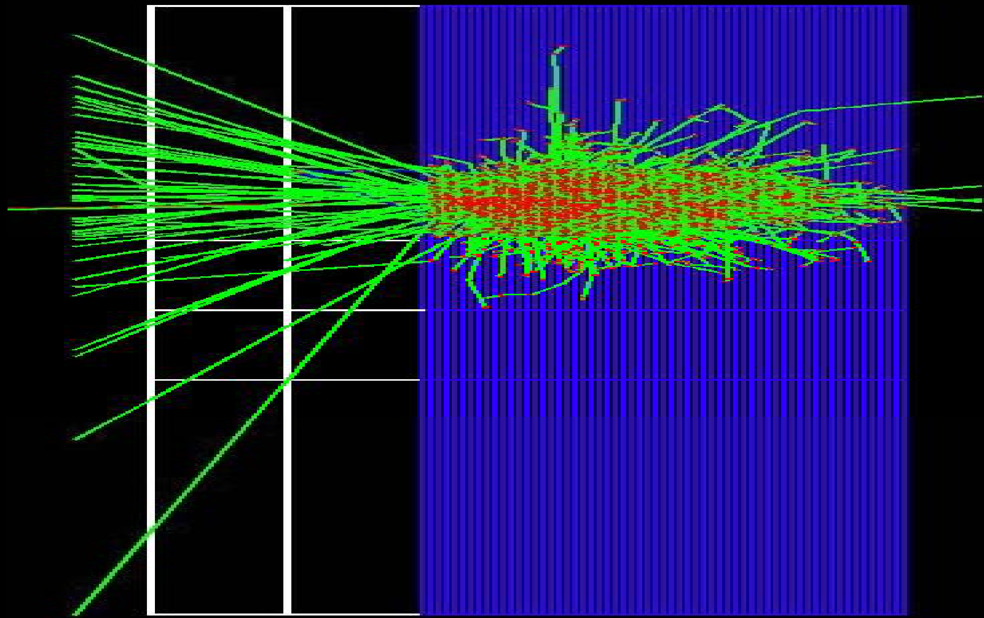
$R_{min} \rightarrow R_{max}$ [mm]	Fiducial volume		σ_{Bhabha} [pb]	Relative Error	
	θ_{min} [mrad]	θ_{max} [mrad]		Stat.	Systematic $(2 \cdot \Delta\theta / \theta_{min})$
$60 \rightarrow 170$	33	59	2577	$2.8 \cdot 10^{-5}$	$8.1 \cdot 10^{-5}$
$70 \rightarrow 180$	37	64	1987	$3.2 \cdot 10^{-5}$	$7.2 \cdot 10^{-5}$
$80 \rightarrow 190$	44	69	1229	$4 \cdot 10^{-5}$	$6 \cdot 10^{-5}$
$90 \rightarrow 200$	50	74	863	$4.8 \cdot 10^{-5}$	$5.3 \cdot 10^{-5}$

- $\sqrt{s} = 500$ GeV, $L = 500$ fb^{-1} , $L = \frac{N}{\sigma_{Bhabha}}$
- For $R_{min} \geq 70$ mm , the amount of backscattering in other parts of the detector is manageable.

New Ideas

Calorimeter + Tracker:

- 2 silicon layers
- gap between layers: 5 cm
- silicon thickness 300 µm
- inner radius: 80 mm
- outer radius: 350 mm
- 1000 sectors
- 3576 cylinder



Reconstruction Algorithm

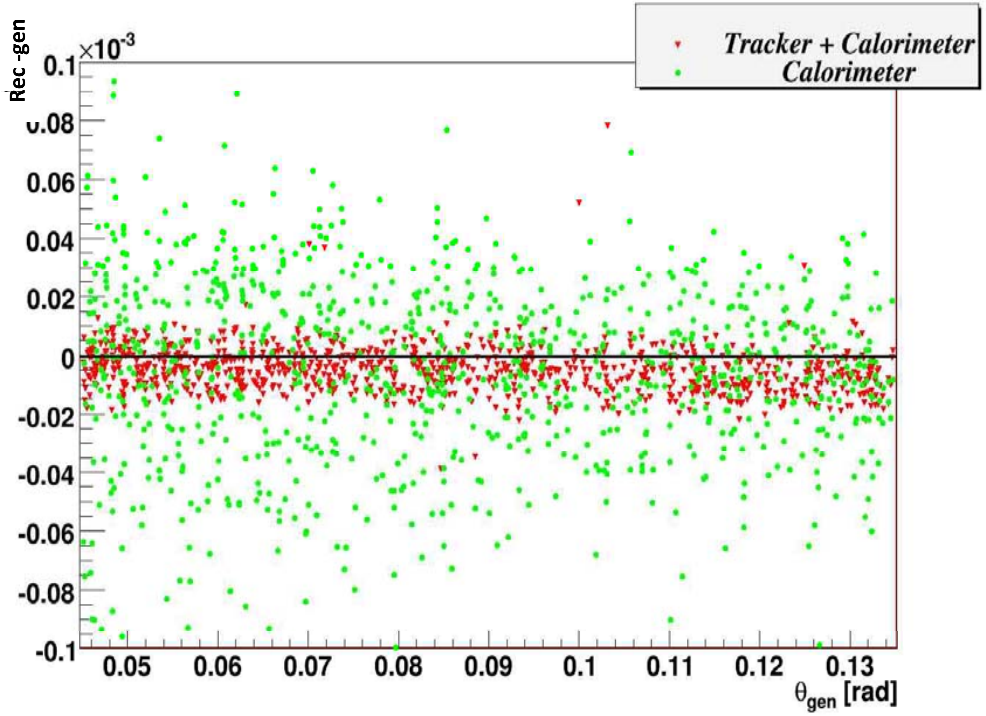
- Reconstruction is done first for the calorimeter

$$\theta_{calor} = \frac{\sum \Theta_i W_i}{\sum W_i} \qquad \varphi_{calor} = \frac{\sum \varphi_i W_i}{\sum W_i} \qquad W_i = max\left[0, \left(const + \ln \frac{E_i}{E_{tot}}\right)\right]$$

- Use hit pads in each tracker layer which are in a cone relative to calorimeter.
- Information from the tracker is used to correct the calorimeter reconstruction

$$\varphi_{\text{tracker}} = \sum_{i \in pad} \varphi_i \omega_i \Big/ \sum_{i \in pad} \omega_i$$

$$\tan(\theta_{\text{tracker}}) = \frac{\sum_{i \in layer} \frac{R_i Z_i}{\sigma_i^2}}{\sum_{i \in layer} \frac{Z_i^2}{\sigma_i^2}}$$



Summary & Outlook

Main Simulation results:
Position and granulation of the detector
Event selection and reconstruction algorithm
Inputs for sensors and electronics design

Once the ILD dimensions & design will be fixed an optimization phase will begin to scale the luminosity detector to the new environment.

The FCAL collaboration and the luminosity studies are changing course From simulations to more extensive hardware studies with a goal to produce a small scale prototype by 2010.

Mechanical design, laser positioning system, electronics design and sensors research & production is ongoing.