Luminosity Detector for the ILC

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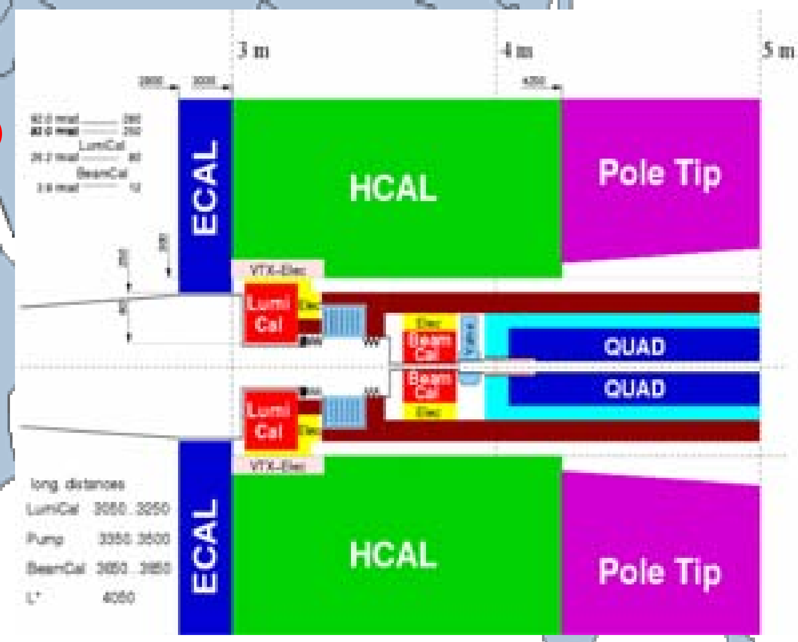
On behalf of the FCAL Collaboration

FCAL Collaboration

Goals : design and construction of
- **Luminosity detector**
- **Beam monitor**

Boulder, U. of Colorado
AGH, Cracow
INP, Cracow
Jagellonian U., Cracow
DESY
J I N R, Dubna
IHEP, Protvino
NCP & HEP Minsk
Acad. of Sc., Prague
Tel Aviv University



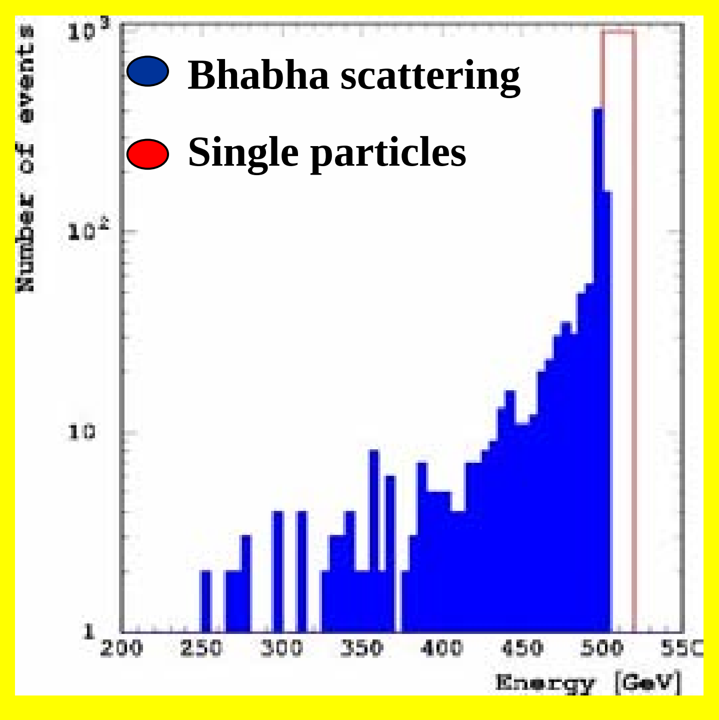
Cooperation with:
SLAC
Iowa State University
Wayne State University

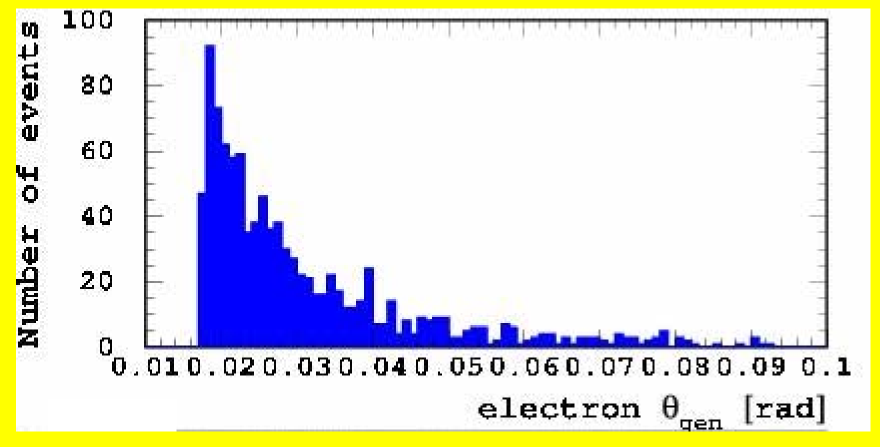
Electrons/Bhabhas

(for R. Ingbir)

Electrons/Positrons - Geant-3 integrated generator.

Bhabha scattering - BHWIDE generator.



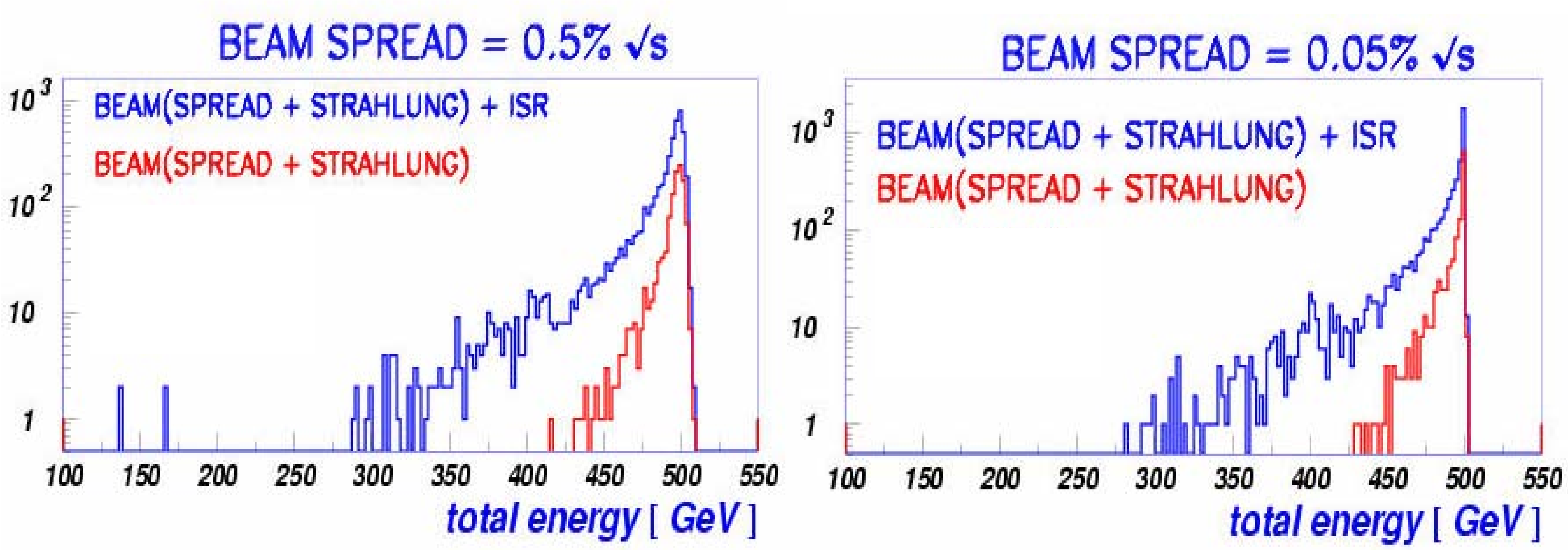


Beamstrahlung and Beam Spread

Bhabha scattering - BHWIDE generator.

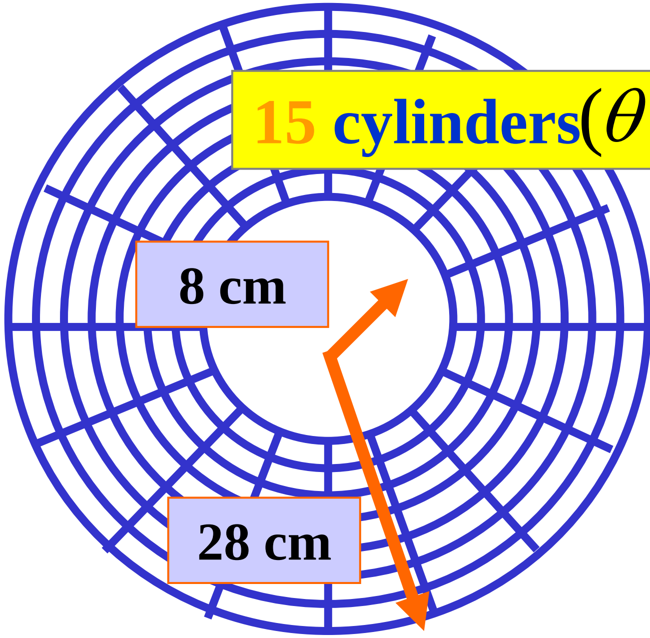
Beamstrahlung - Circe generator.

Beam spread - included separately.



Pad Design

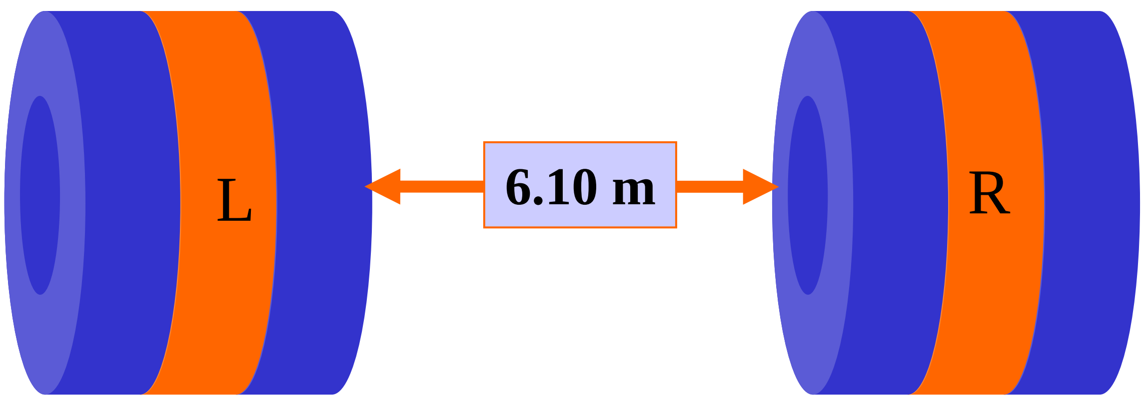
15 cylinders(θ)* 24 sectors(ϕ)* 30 rings(z)= 10800 cells



Tungsten	Silicon
0.34 cm	0.31 cm

X_0=0.65 cm

R_M =1.1 cm



Cell Size

1.3 cm * 2 cm >
1.3 cm * 6 cm <

~1 Radiation Length

~1 Moliere Radius

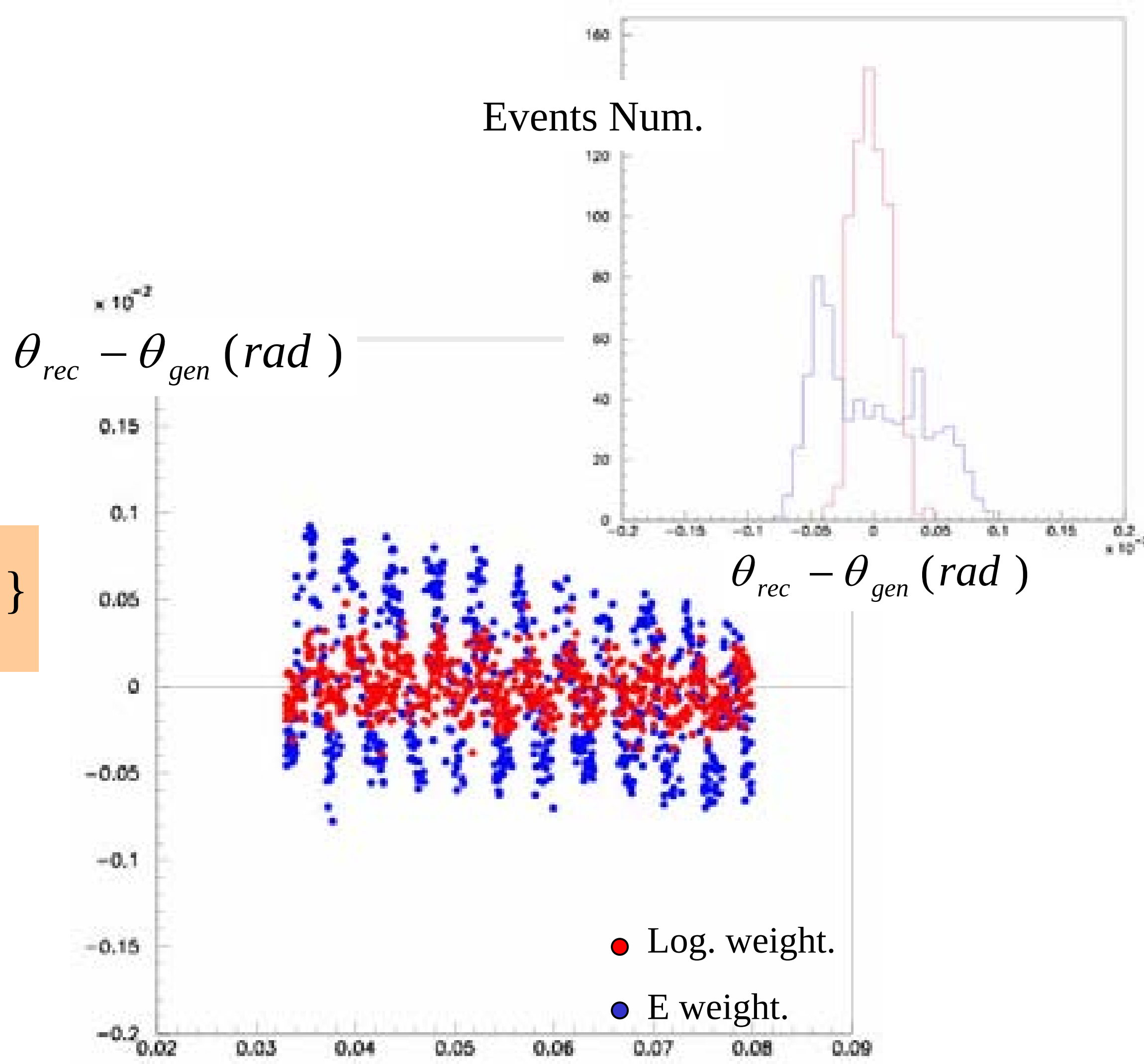
Reconstruction Algorithm

$$< X >= \frac{\sum X_i E_i}{\sum E_i}$$

$$< X >= \frac{\sum X_i W_i}{\sum W_i}$$

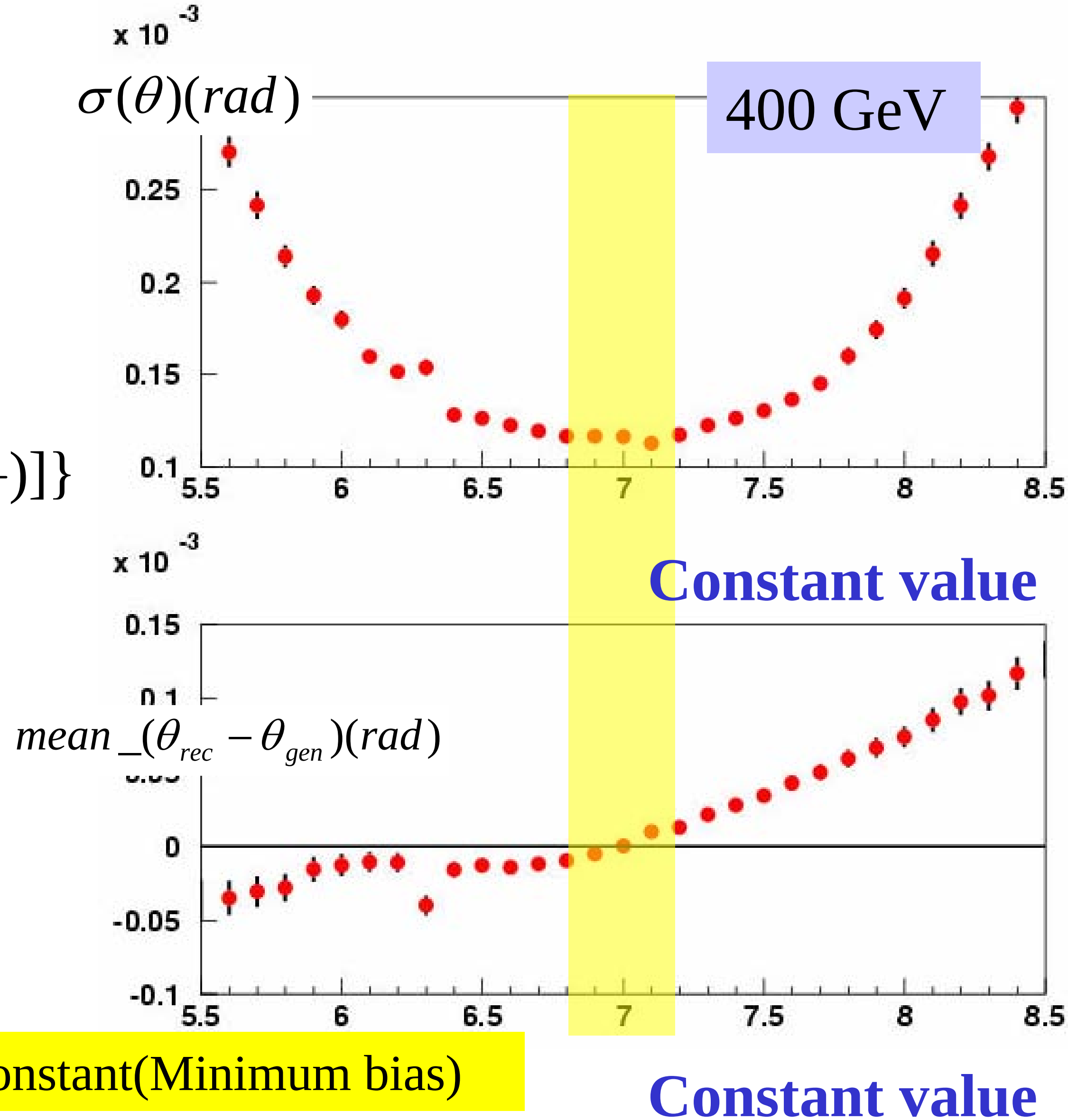
$$W_i = \max\{ 0, [const + \ln(\frac{E_i}{E_T})]\}$$

T.C Awes et al. Nucl. Inst. Meth. A311 (1992) 130.



Optimization of Log Weighting

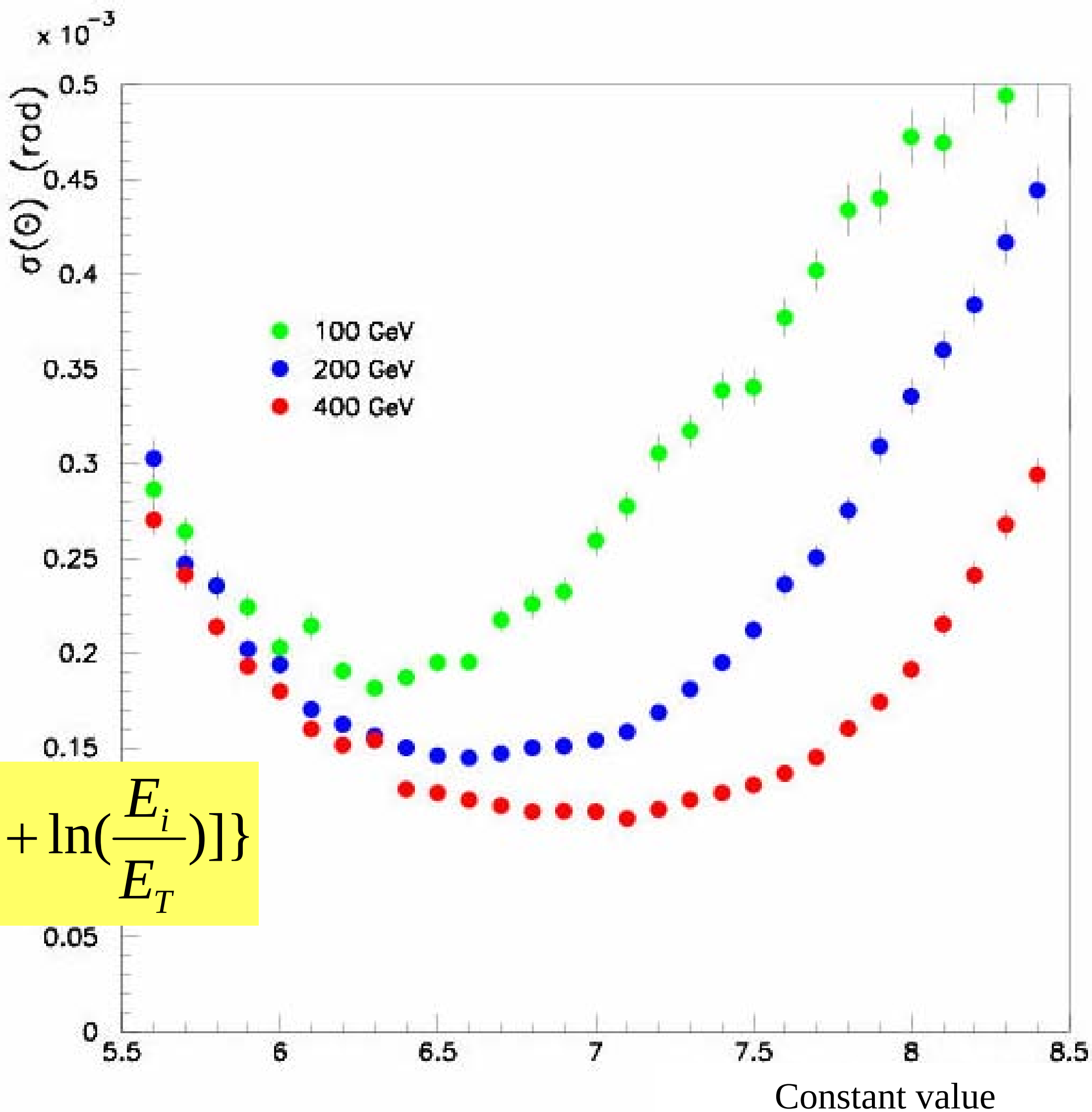
$$W_i = \max\{0, [\,\mathbf{Const} + \ln(\frac{E_i}{E_T})]\}$$



Constant (Best resolution) = Constant(Minimum bias)

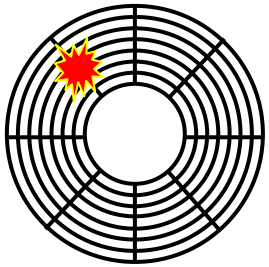
Energy Dependence

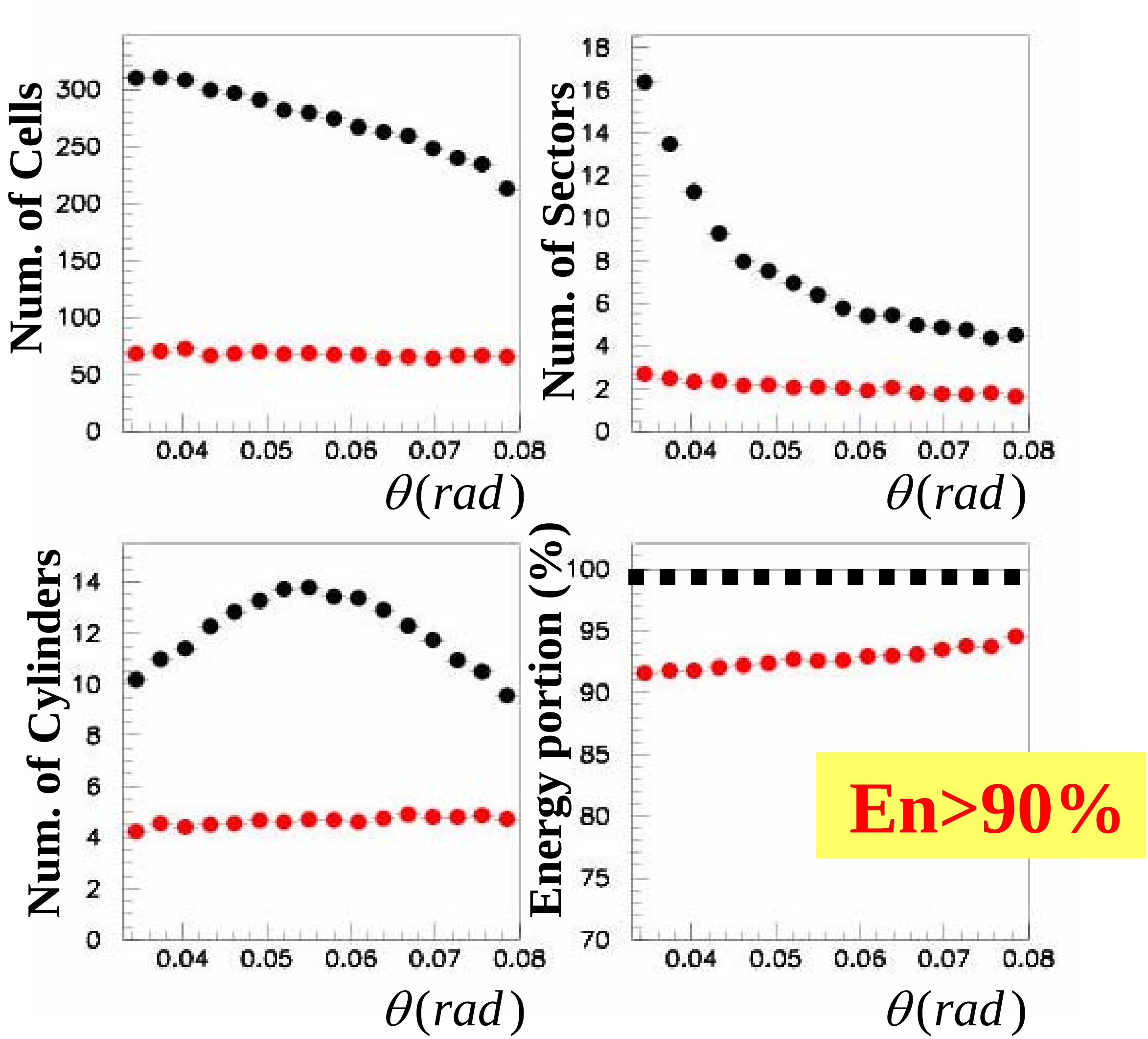
Energy dependence of the log weighting



$$W_i = \max\{0, [const(E_{beam}) + \ln(\frac{E_i}{E_T})]\}$$

Shower Information



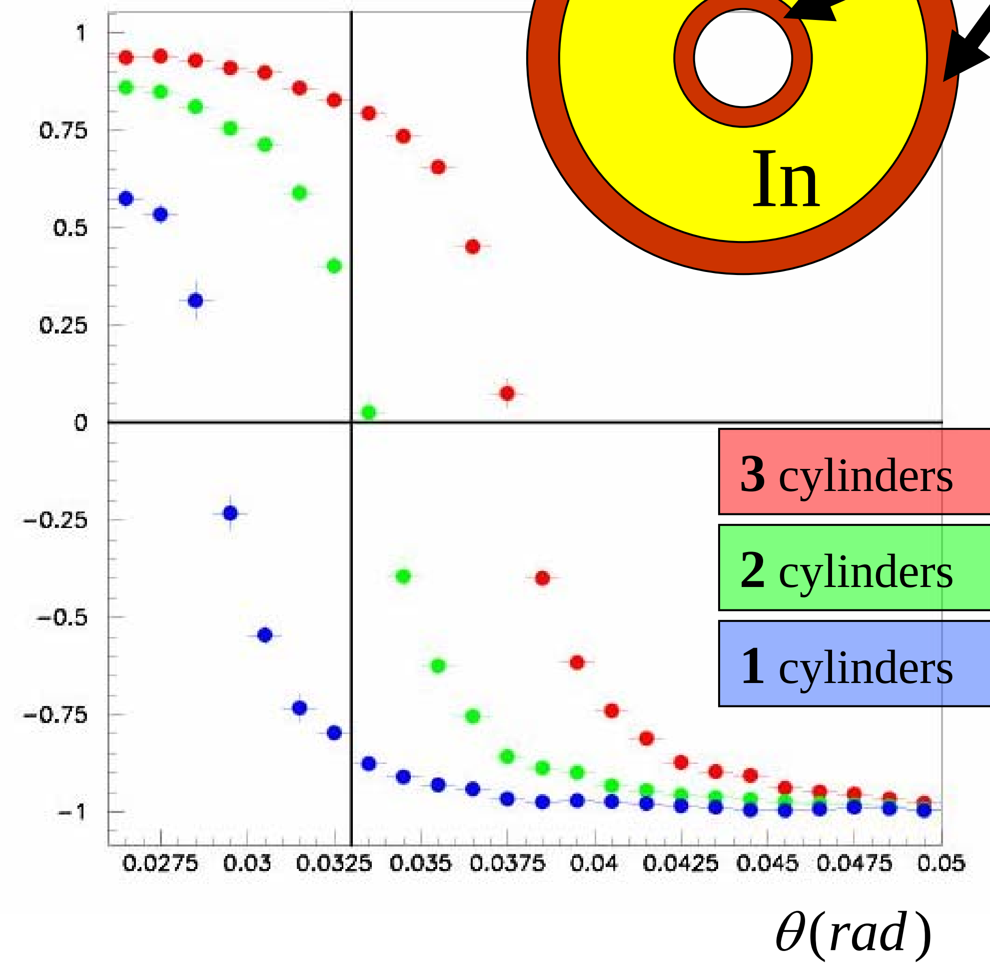


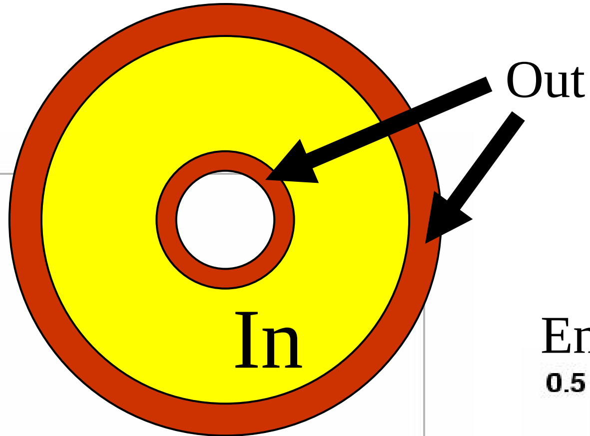
- Shower size
- Log. Weight Selection

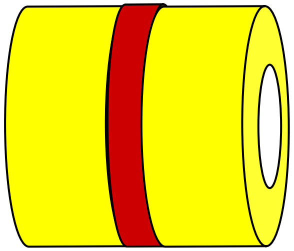
Most of the information is in the selected cells.

Geometric Acceptance

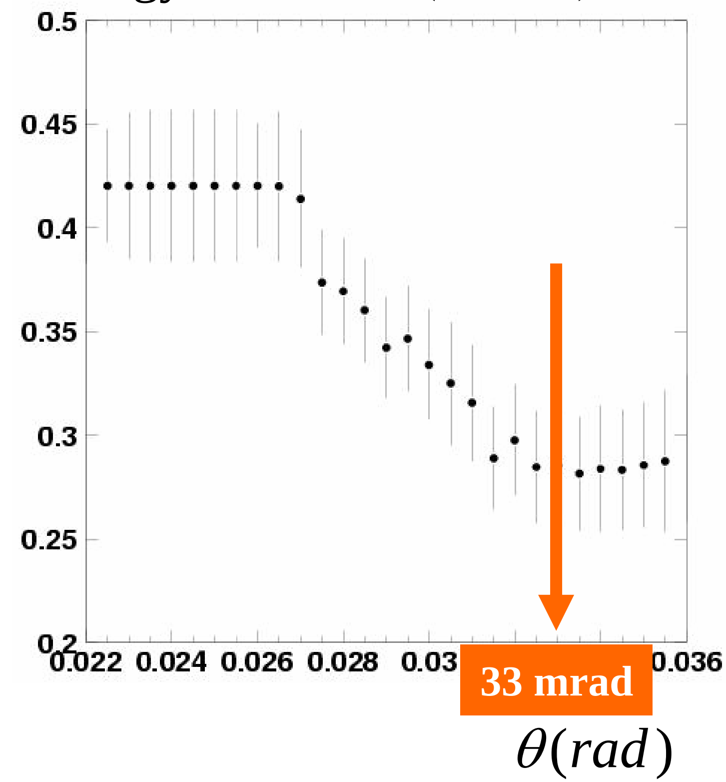
$$P = \frac{\text{Eout-Ein}}{\text{Eout+Ein}}$$



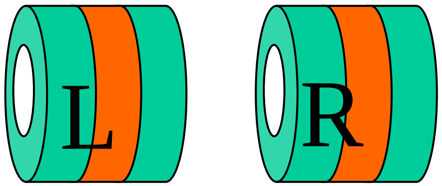


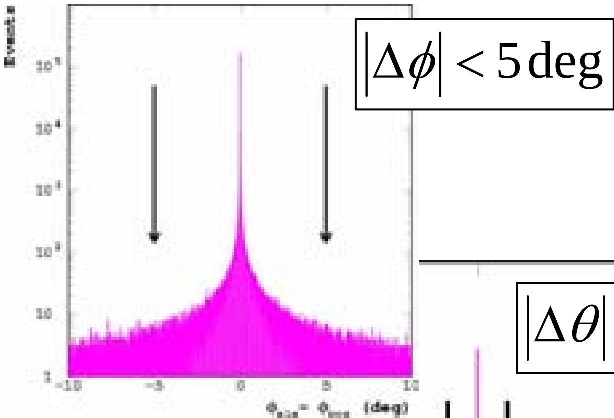


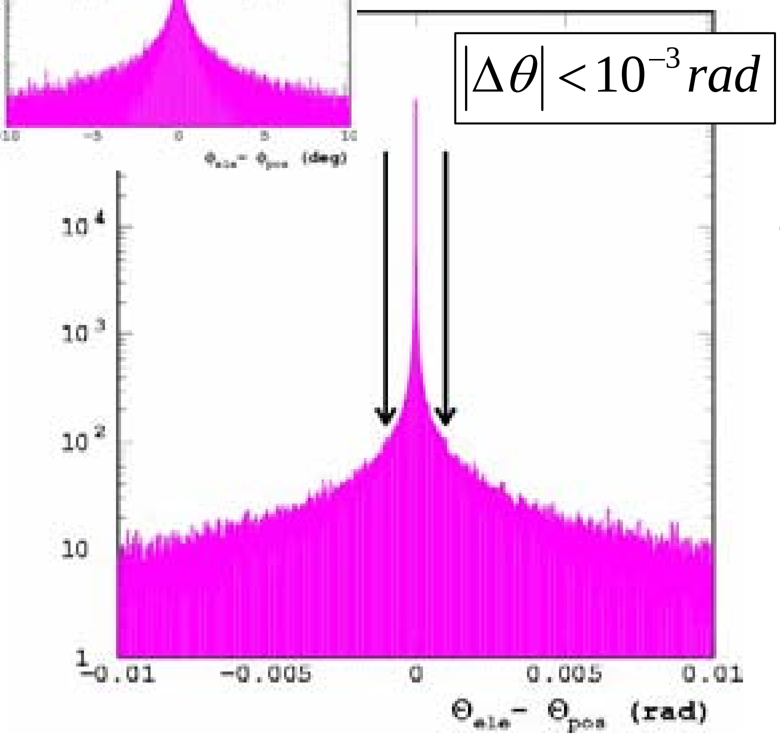
Energy Resolution($\sqrt{GeV}$)



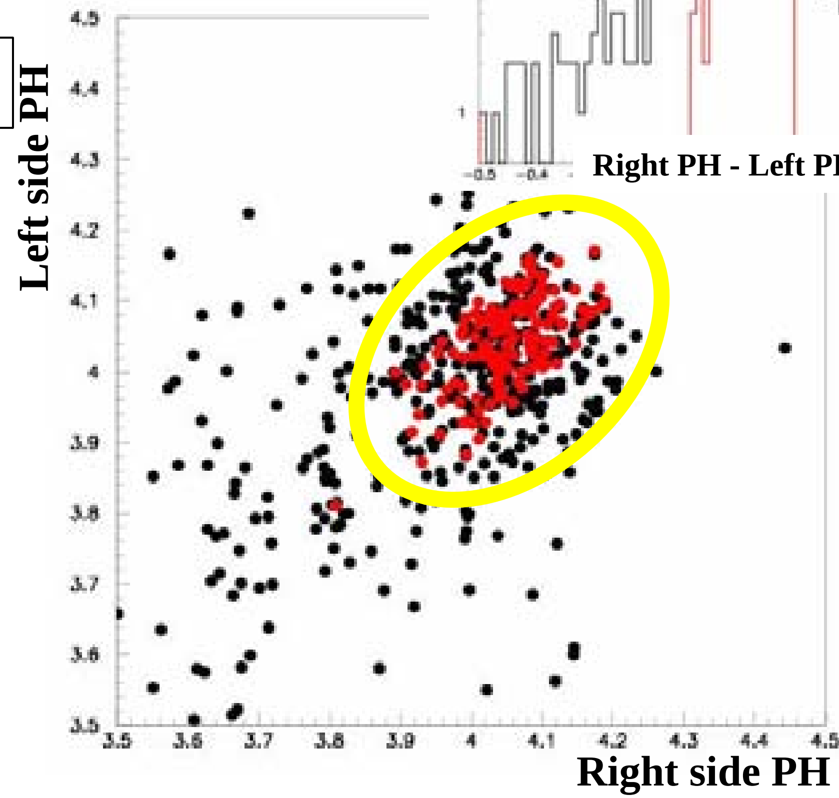
Forward-Backward Balance

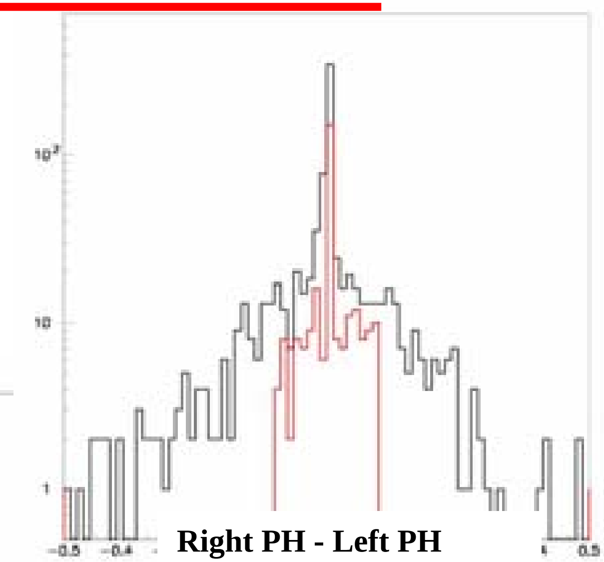






- Simulation distribution
- Distribution after acceptance and energy balance selection

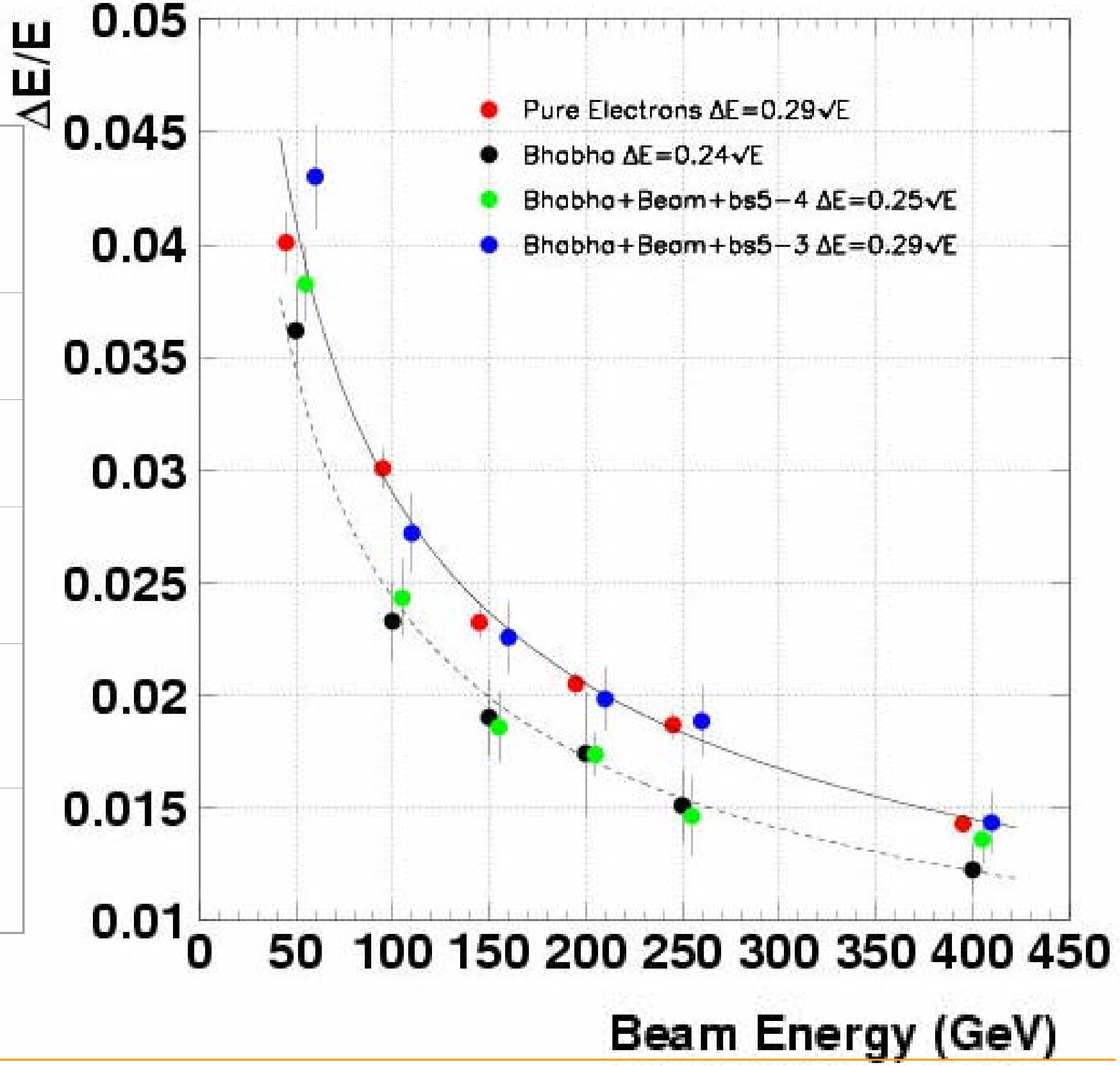




Energy Resolution

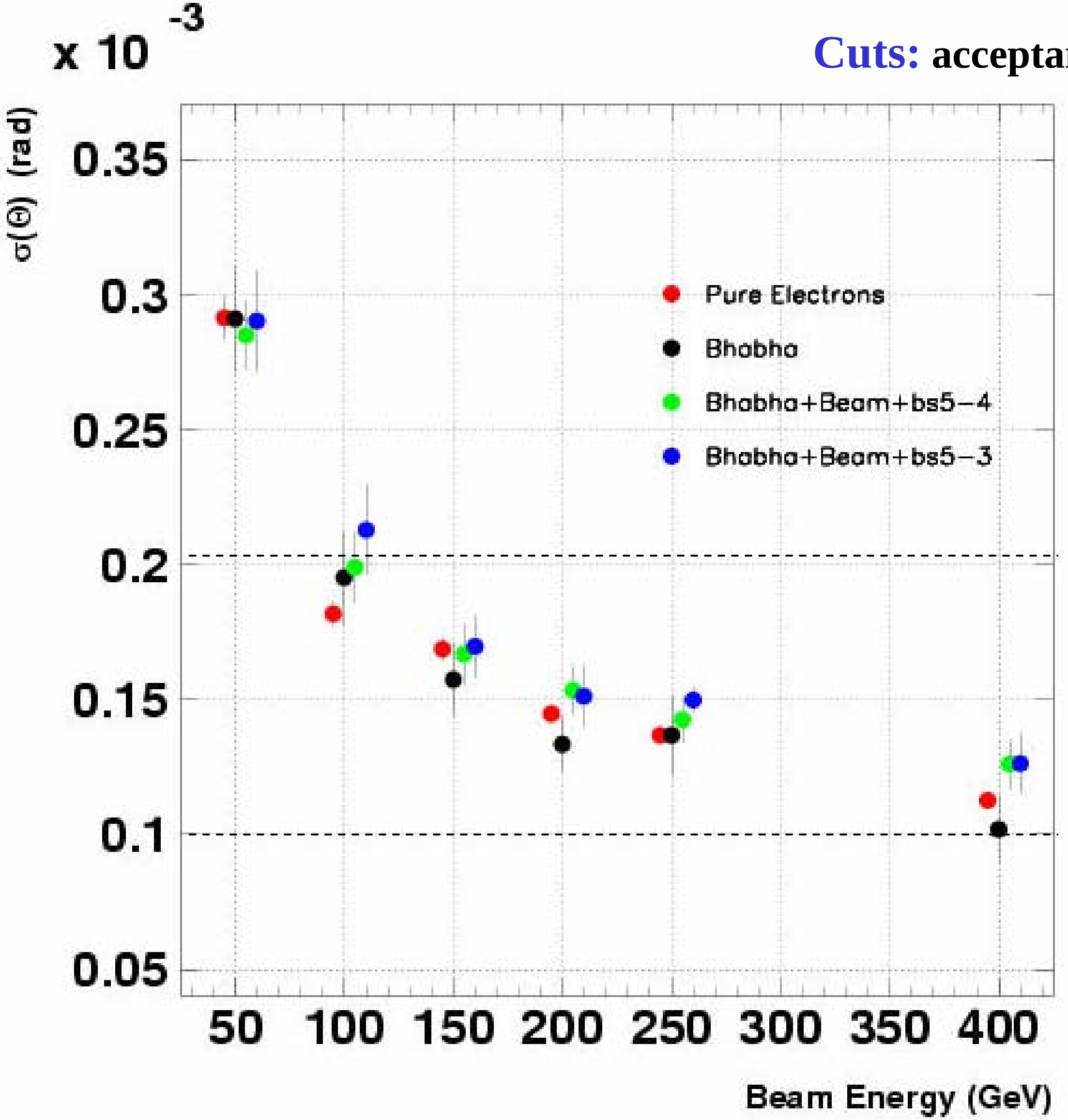
Cuts: **acceptance and back-to-back**

Ntuple	*No cuts*	*With cuts*
Pure electrons	**31%**	**29±3%**
Bhabha	**42%**	**24±2%**
Bhabha + Beamstrahlung	**45%**	**24±2%**
Bhabha + Beamstrahlung + Beam spread (0.05%)	**46%**	**25±2%**
Bhabha + Beamstrahlung + Beam spread (0.5%)	**49%**	**29±3%**

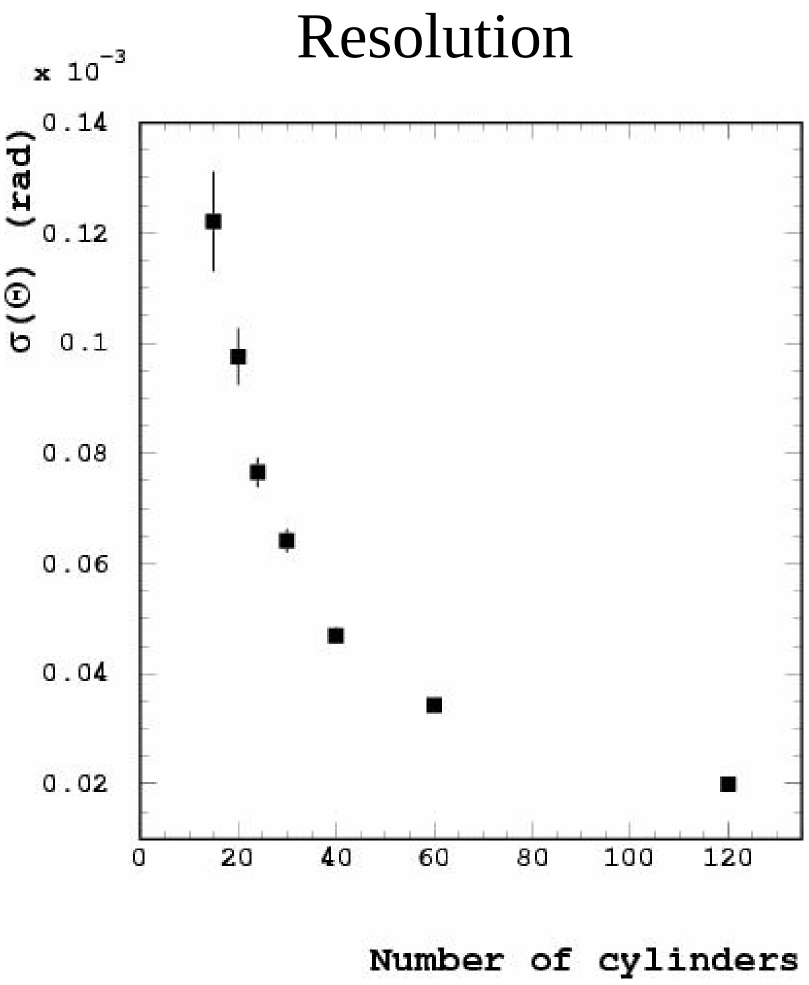


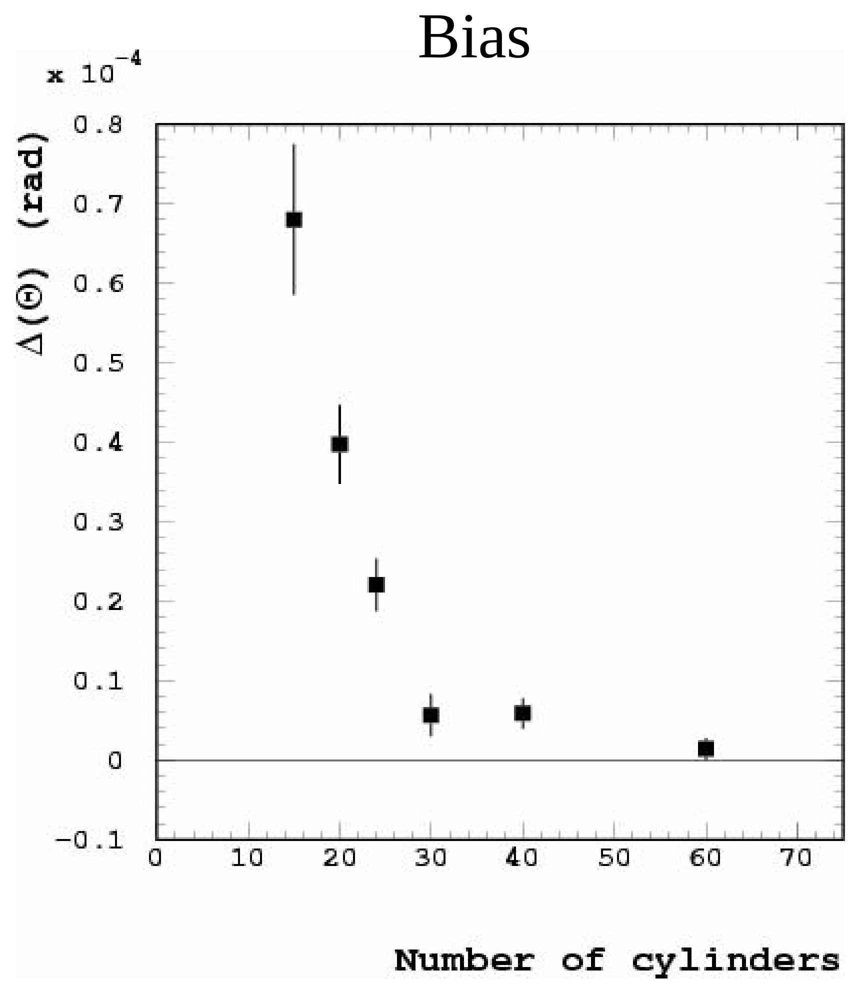
Angular Resolution

Cuts: **acceptance and back-to-back**



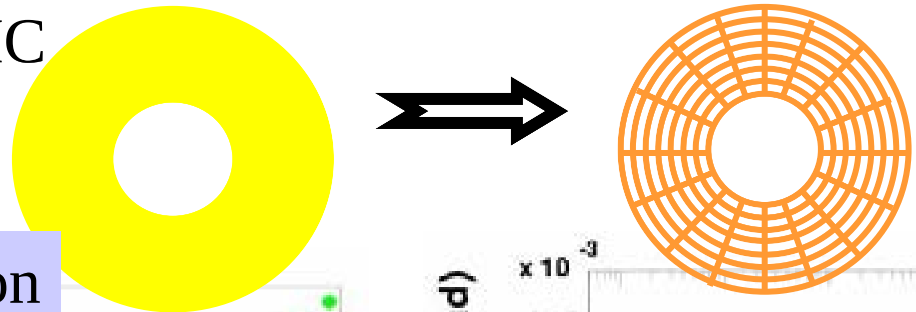
Granularity in θ



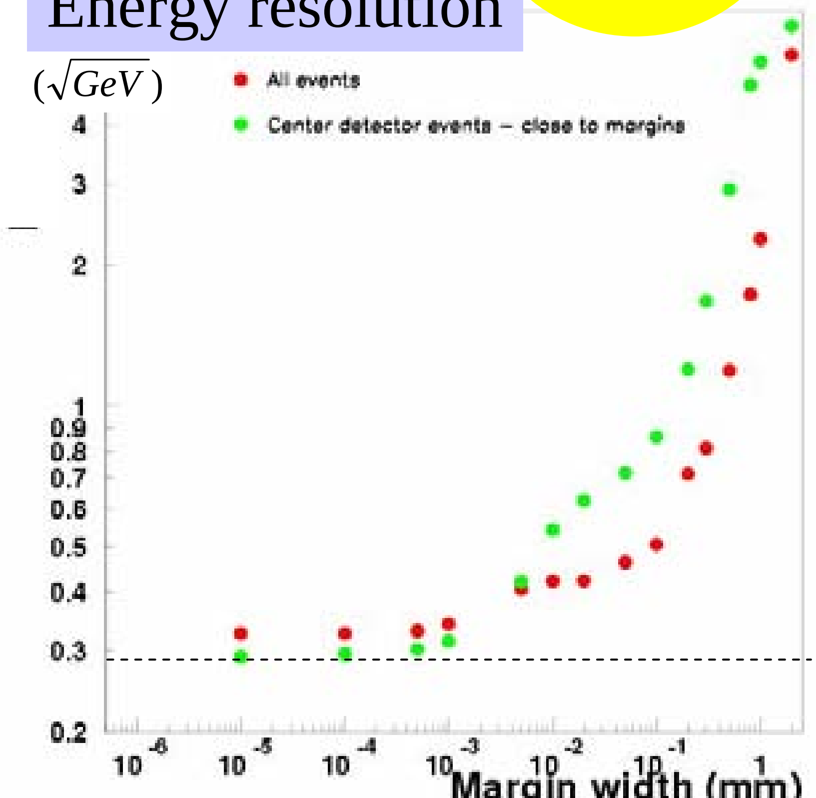


Margins in-between Cells

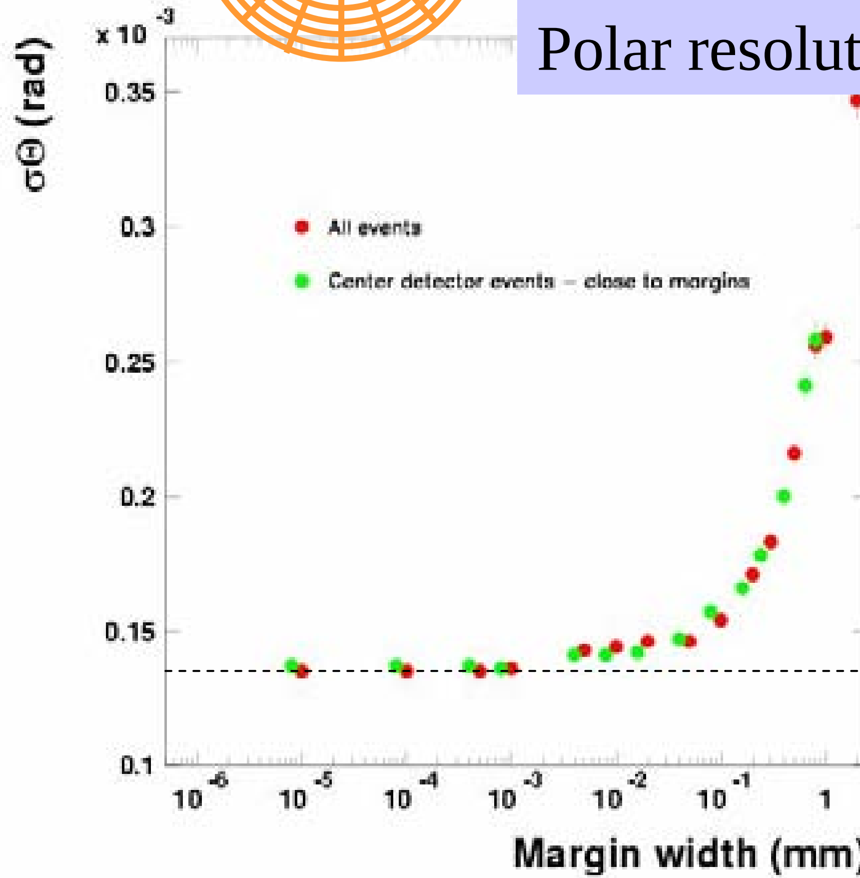
Single electrons MC



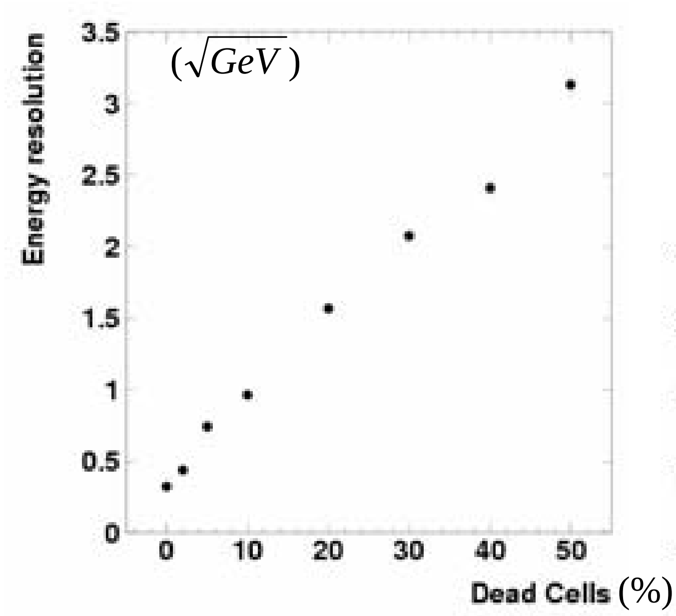
Energy resolution

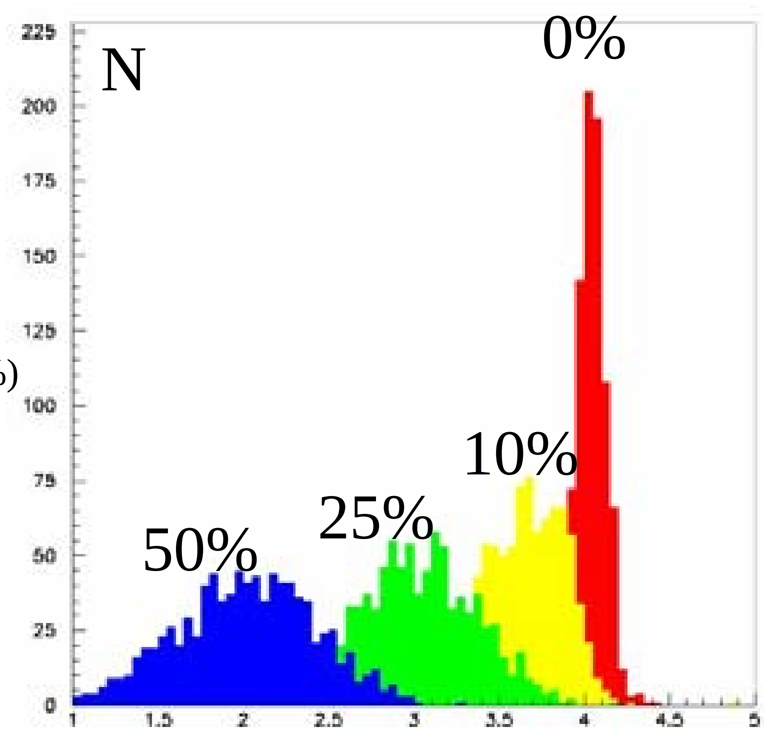


Polar resolution



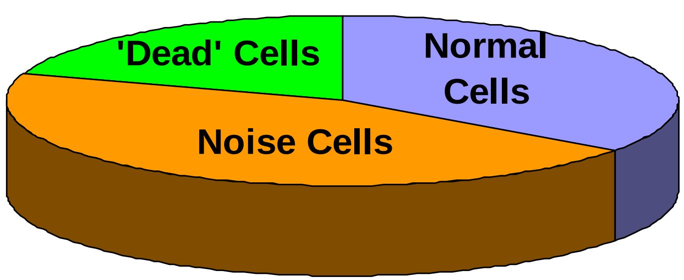
Electronics Simulation



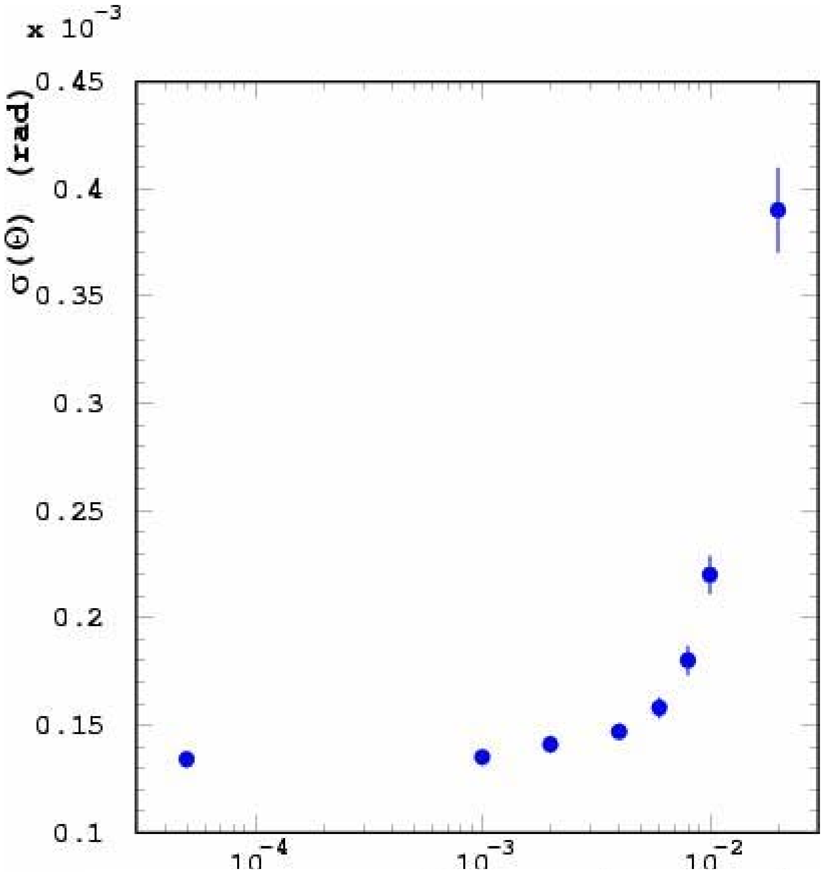


Signal (including only Dead Cells)

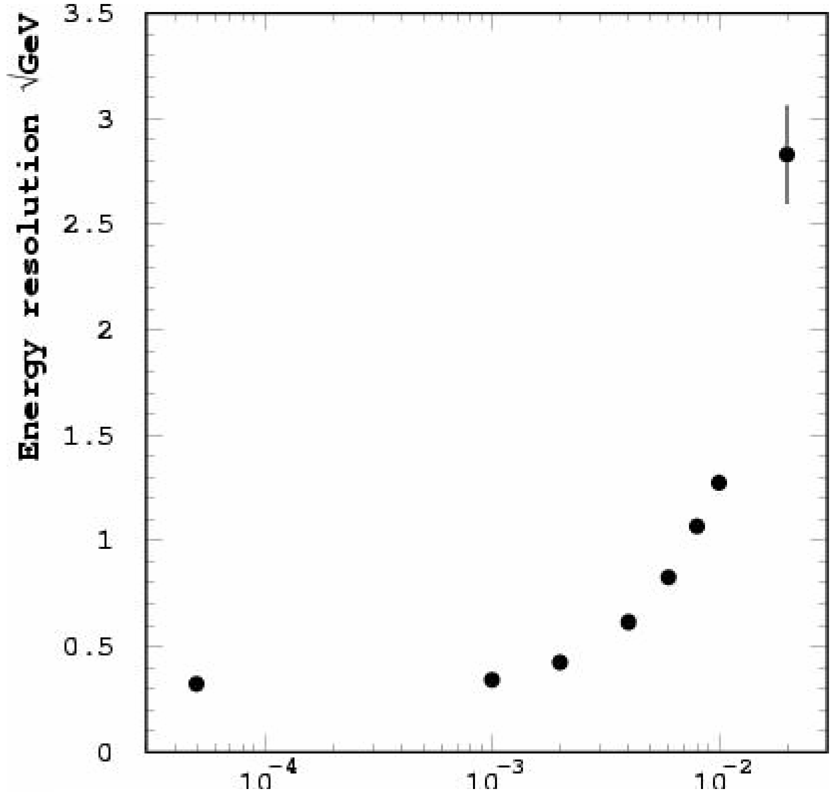
Electronics model:



Electronics noise



σ noise fraction relative to the average signal cell



σ noise fraction relative to the average signal cell

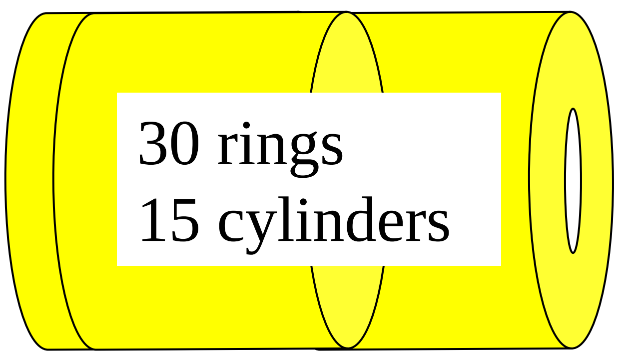
100% of the cells have noise, without any dead cells

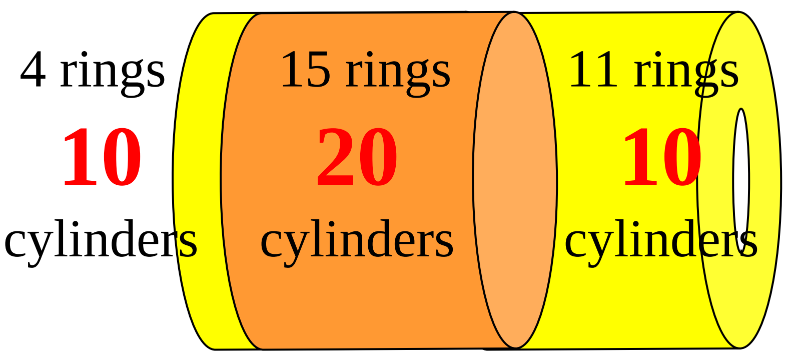
Maximum Peak Shower Design

Our basic detector is designed with

30 rings * **24** sectors * **15** cylinders = **10,800** channels

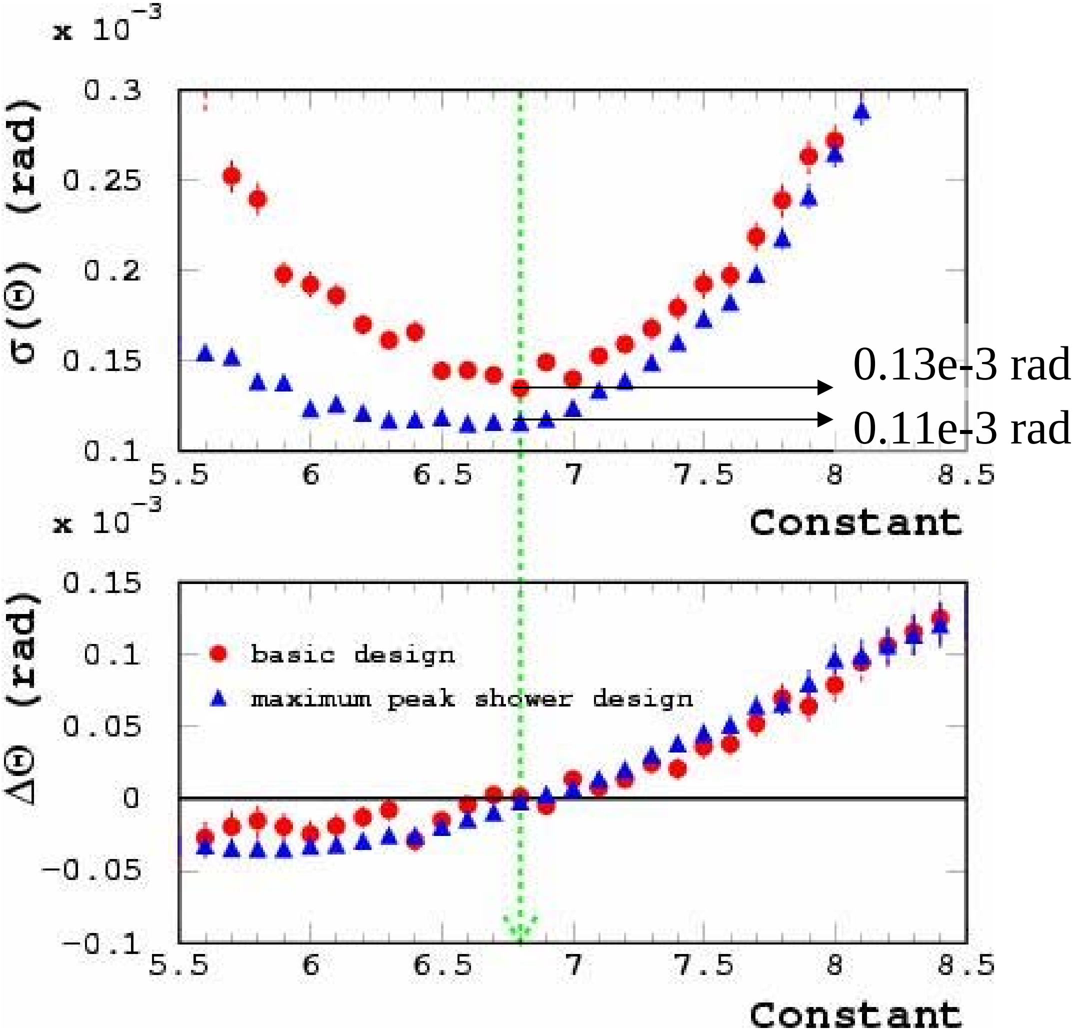
Do we use these channels in the most effective way ?





24 sectors * **15** rings * (10 cylinders + 20 cylinders) = **10,800** channels

Polar Reconstruction



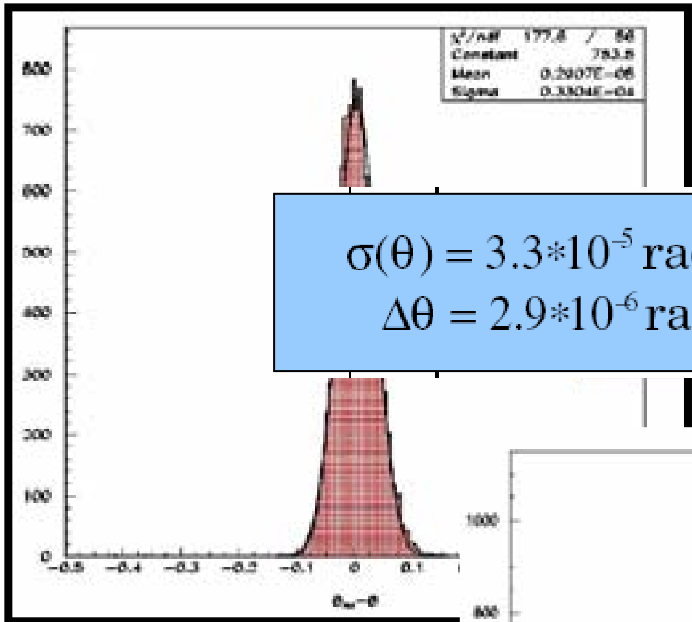
Maximum peak shower design

Basic Design

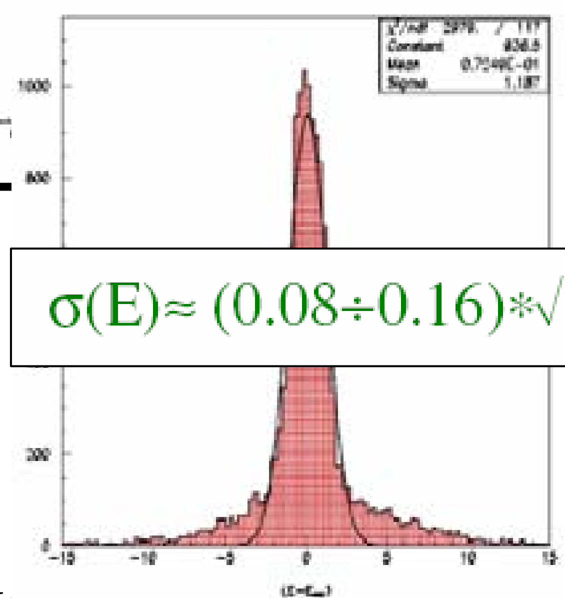
Angular resolution improvement without changing the number of channels

Other properties remain the same

Strip design

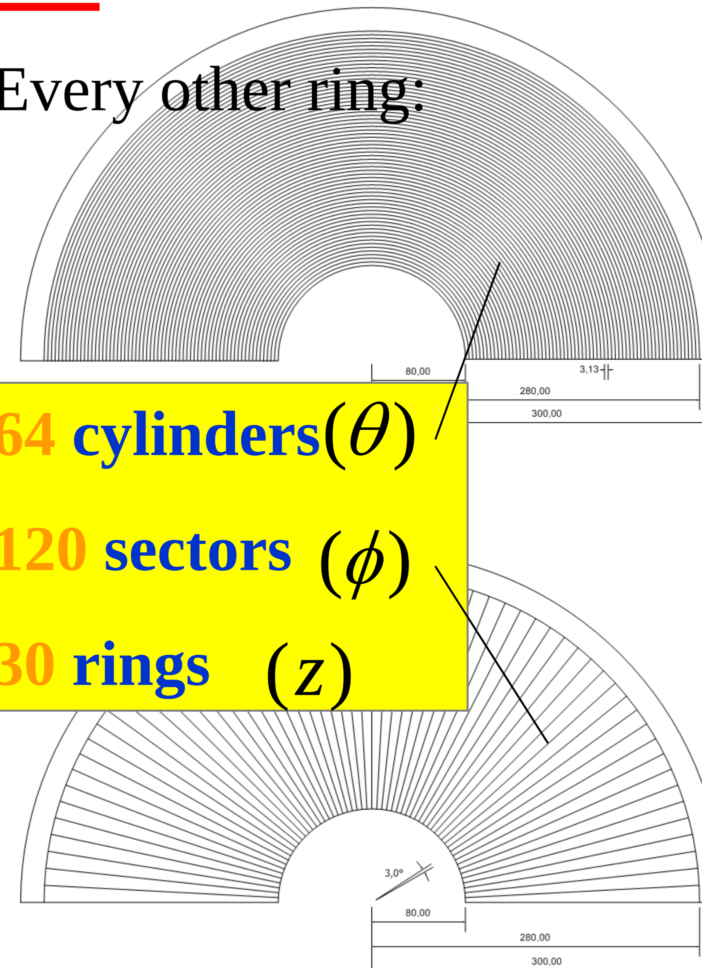


$$\sigma(\theta) = 3.3*10^{-5}\ \text{rad}$$
$$\Delta\theta = 2.9*10^{-6}\ \text{rad}$$



$\sigma(E) \approx (0.08 \div 0.16) * \sqrt{E}$

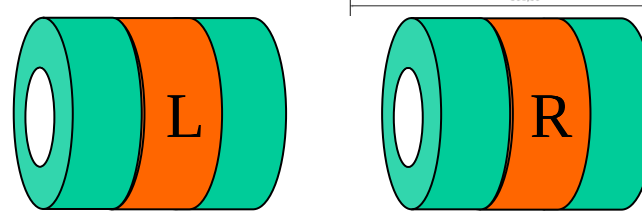
Every other ring:



64 cylinders (θ)

120 sectors (ϕ)

30 rings (z)



Bogdan Pawlik,
INS PAS Cracow

Fast Detector Simulation

Motivation :

High statistics is required to notice precision of : $\frac{\Delta L}{L} \cong 10^{-4}$
(Which is the precision goal of the ILC)

There is an analytic calculation (and approximation) : $\frac{\Delta L}{L} \approx \frac{2 * \Delta\theta}{\theta}$

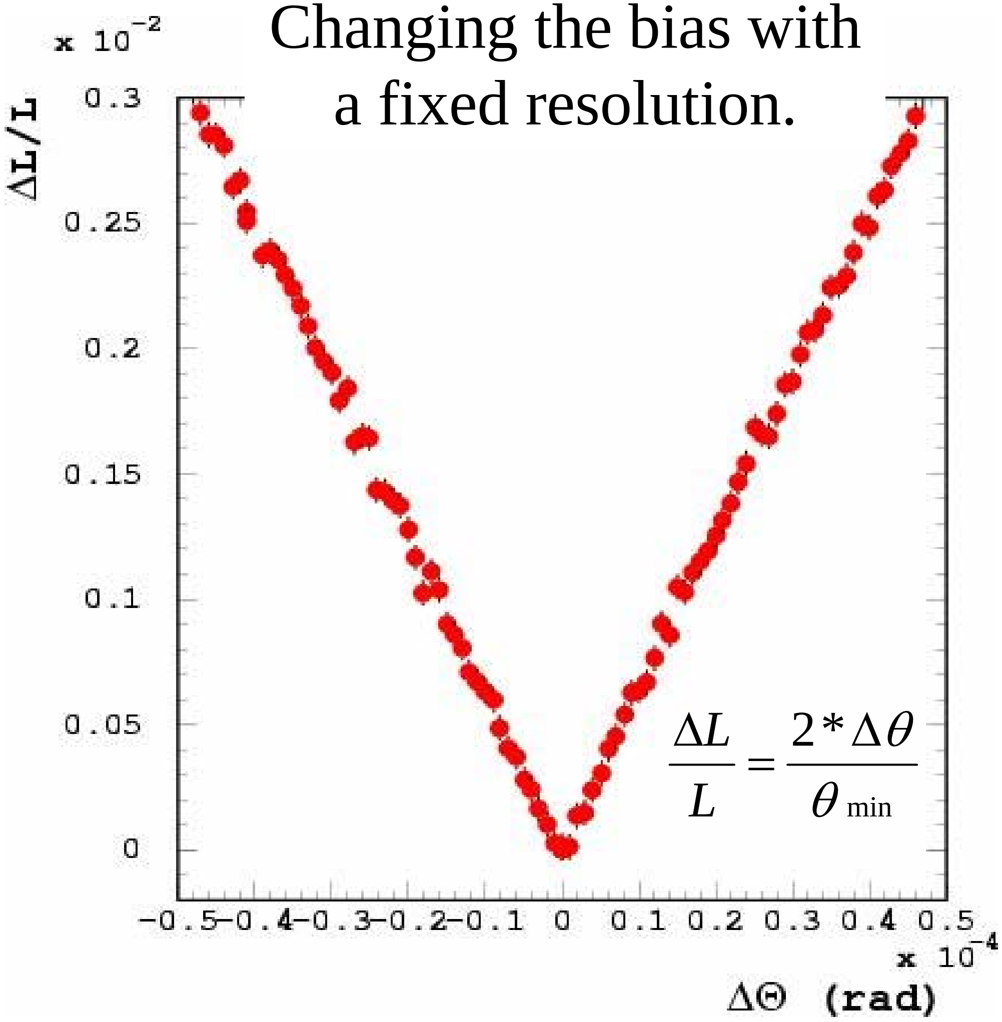
Luminosity precision determination : $\frac{\Delta L}{L} = \frac{N_3 - N_2}{N_1 + N_2}$

N_1 : Reconstructed and generated in acceptance region.

N_2 : Generated in acceptance region but reconstructed outside.

N_3 : Generated outside acceptance region but reconstructed inside.

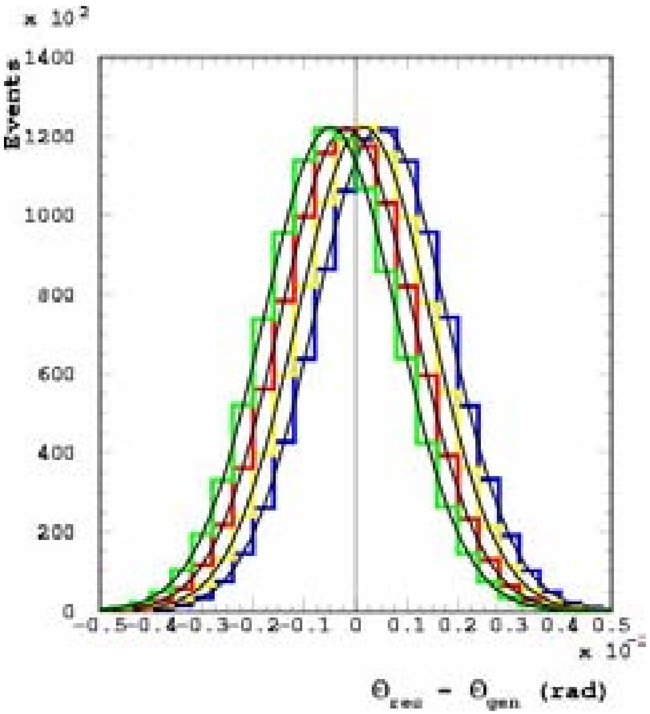
High Statistics Simulation



Changing the bias with a fixed resolution.

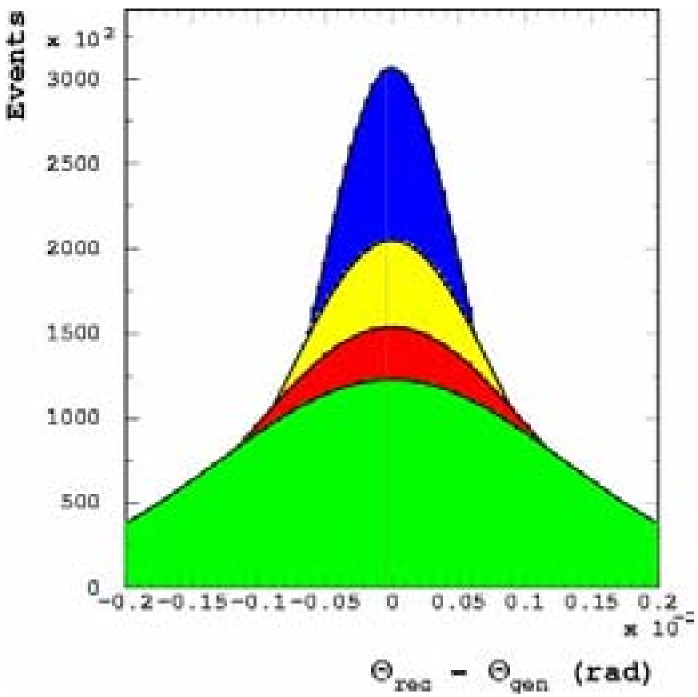
$$\frac{\Delta L}{L} = \frac{2 * \Delta\theta}{\theta_{\min}}$$

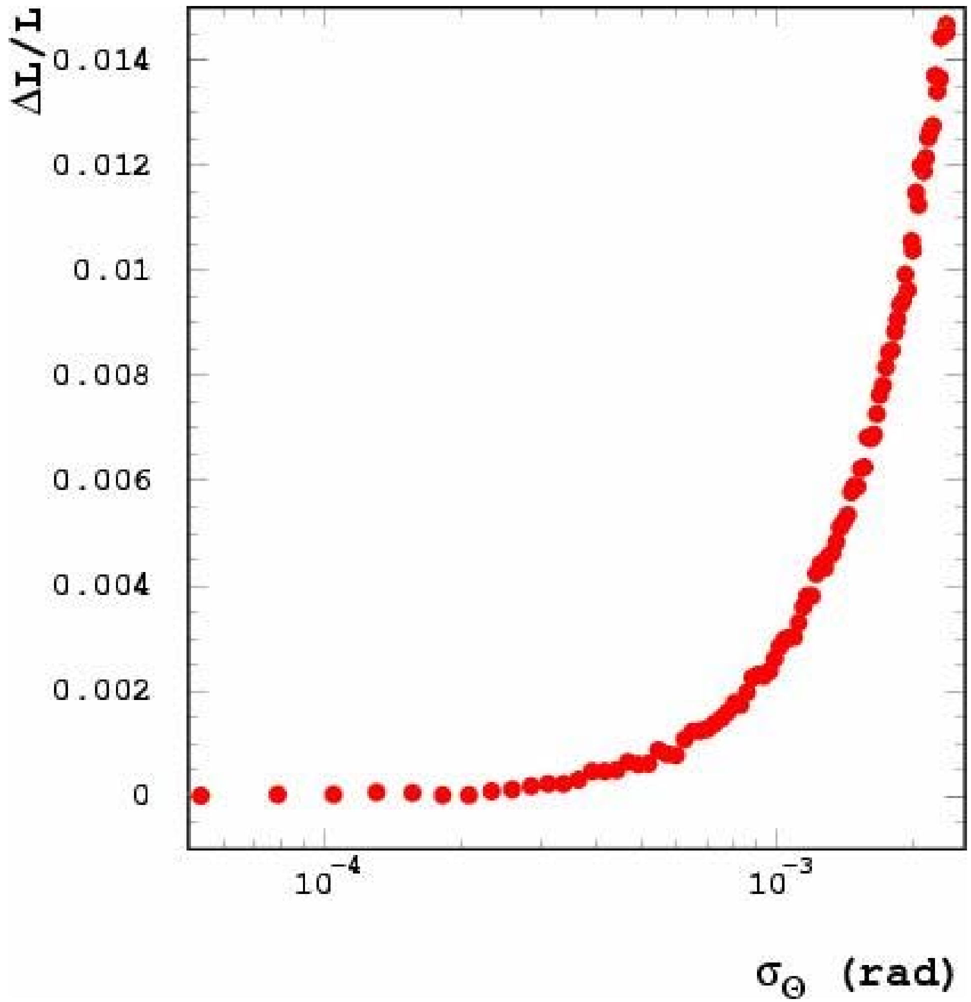
BHWIDE generated properties + smearing to simulate detector



High Statistics Simulation

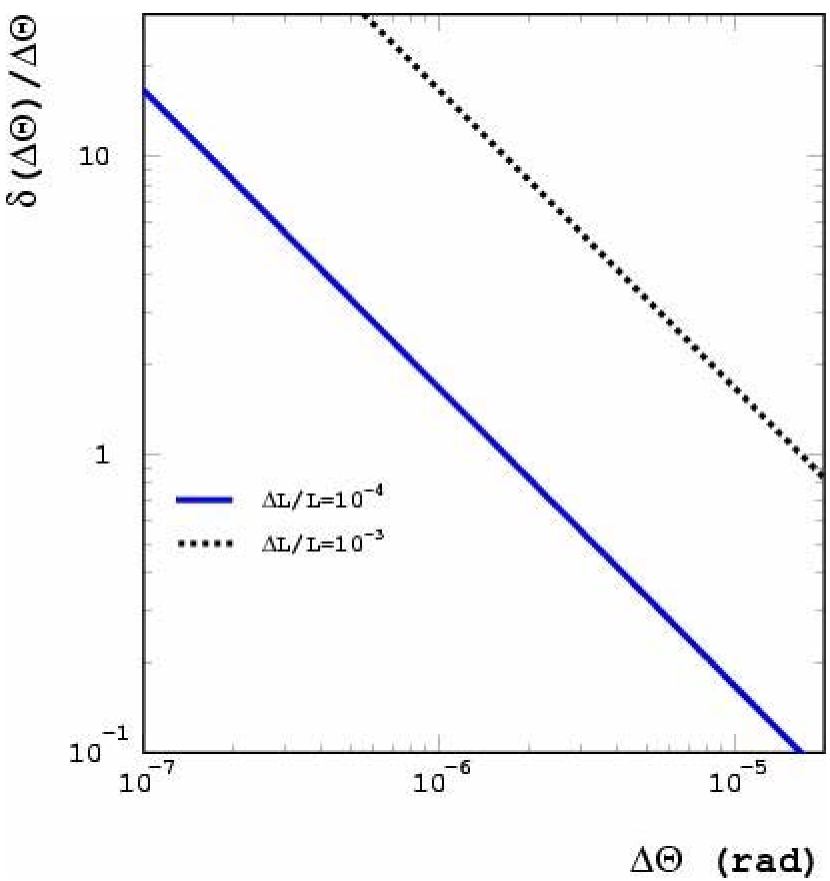
Changing the detector resolution with no bias

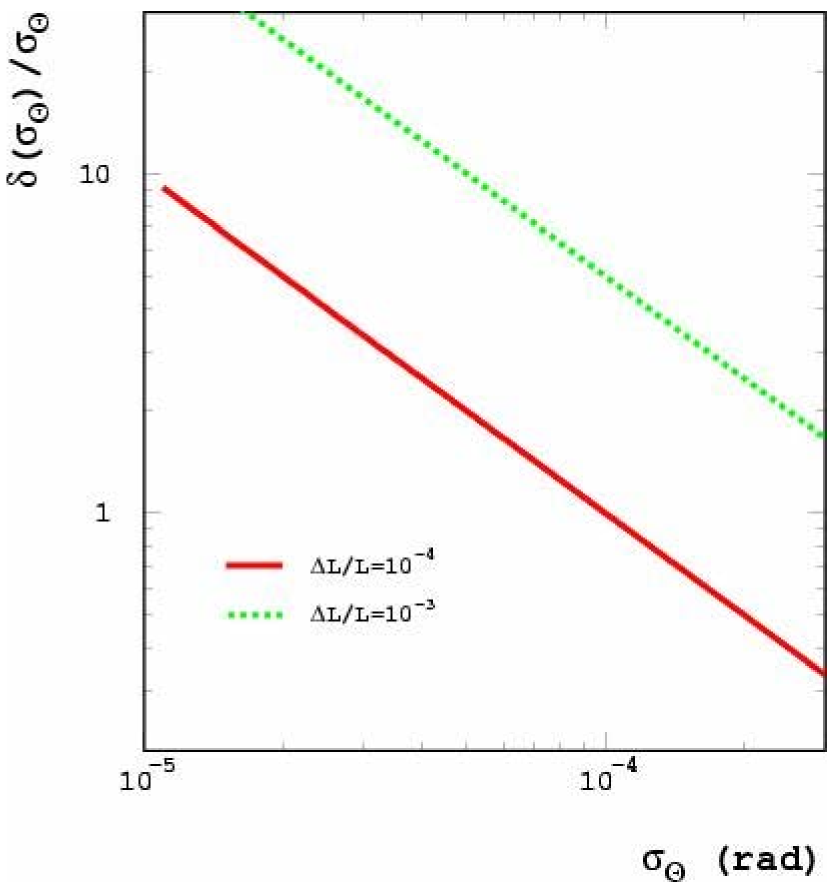




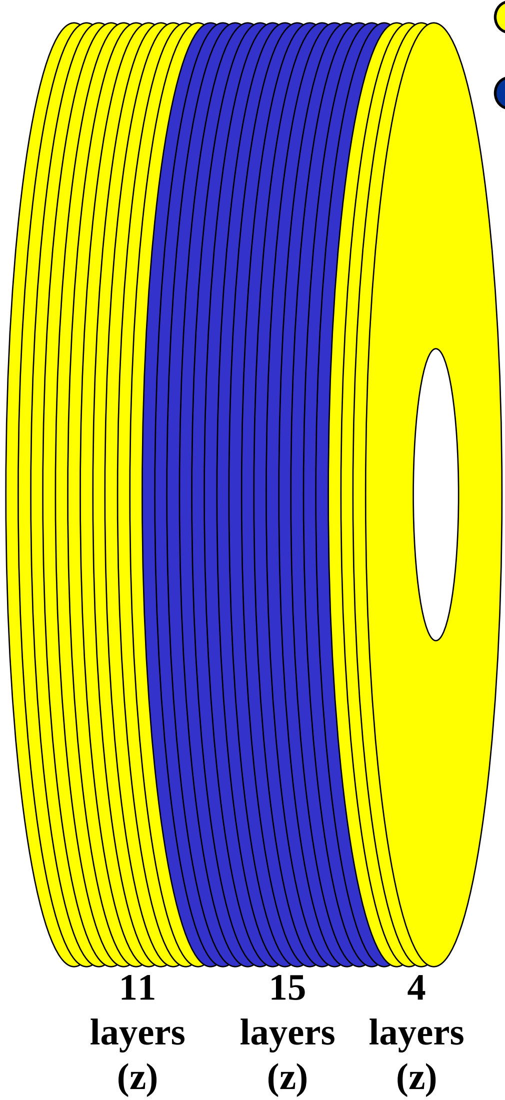
Data and MC

In real life we can include the detector performance (which is measured in test beam) into MC. The only question is: **How well should we know the detector performance ?**





Present Understanding (pad option)



- 10 cylinders (θ)
- 60 cylinders (θ)

Based on optimizing theta measurement

Parameter	Opal	LumiCal
Distance from the IP	±2.5 m	±3.05 m
Sampling layers	19	30
Cylinders	32	60 (middle layers), 10 (first and last layers)
Sectors	32	24
Pitch in r (mm)	2.5	3.3 (middle layers), 20 (first and last layers)
Pitch in θ (rad)	0.001	0.001 (middle layers), 0.006 (first and last layers)
Pitch in ϕ (deg)	11.25	15
Pitch in z	1 X_0 2 X_0 (last 4 layers)	1 X_0
r_{min} (mm)	62	80
r_{max} (mm)	142	280
θ_{min} (mrad)	25	26
θ_{max} (mrad)	57	91
$Z_{max} - Z_{min}$ (cm)	14	20
Electronics channels in one detector arm	19,456	25,200

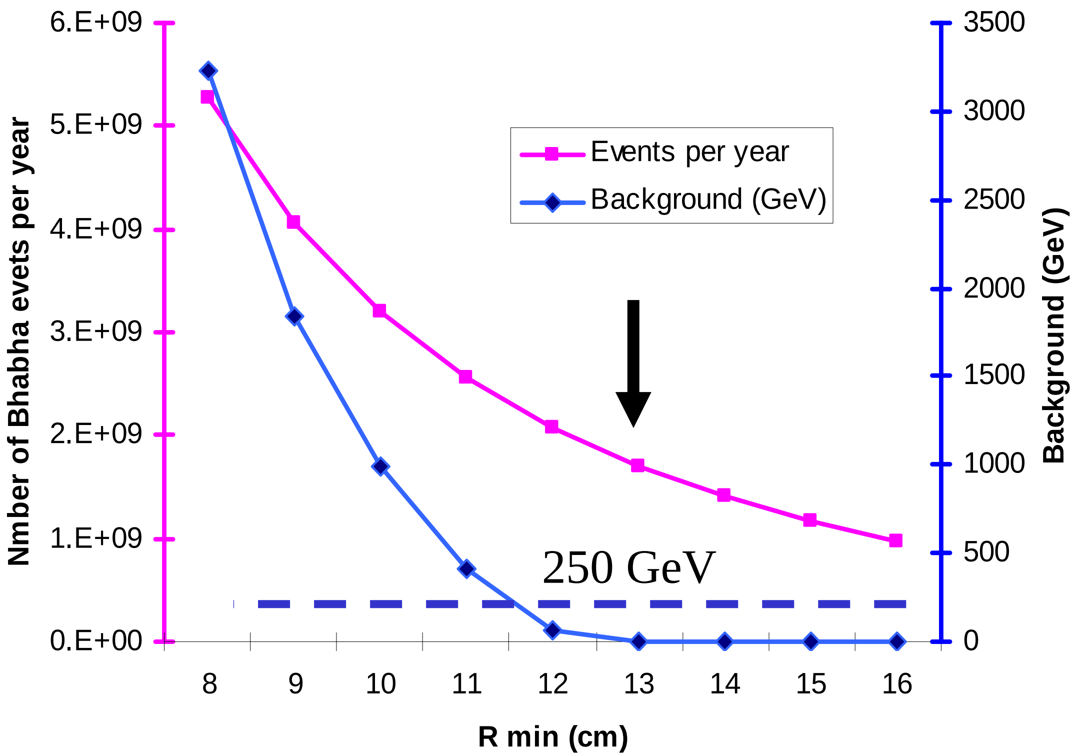
Performance of present configuration

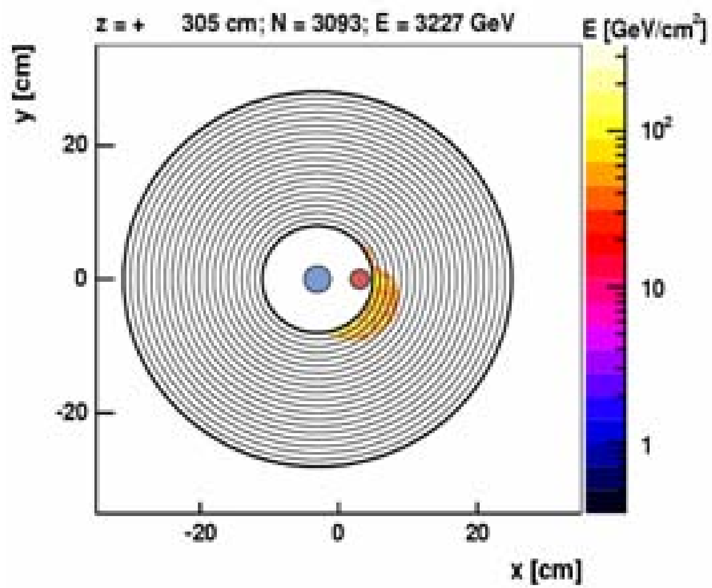
Parameter	Pad Performance	Strip Performance
Energy resolution	25% $(\sqrt{GeV})$	8:16% $(\sqrt{GeV})$
θ resolution	3.5 * 10^{-5} rad	3.3 * 10^{-5} rad
ϕ resolution	0.63 deg	
$\Delta\theta$	~ 1.5 * 10^{-6} rad	~2.9* 10^{-6} rad
Electronics channels	25,200	3720 (with bonding sectors) 13,320 (without bonding)

With this performance the $\Delta L / L = 10^{-4}$ goal can be reached.

X- angle background

Beamstrahlung pair background





Christian Grah,
DESY-Zuethen

Future R&D plans

Additional hardware design constrains and electronics simulation (digitisation, reality noise parameters, silicon production constrains)

Additional background studies (two photon events, beamstrahlung hitting the detector)

Luminosity with polarised beams

Luminosity with a crossing angle

Sensors design & tests

Electronics design

Prototype

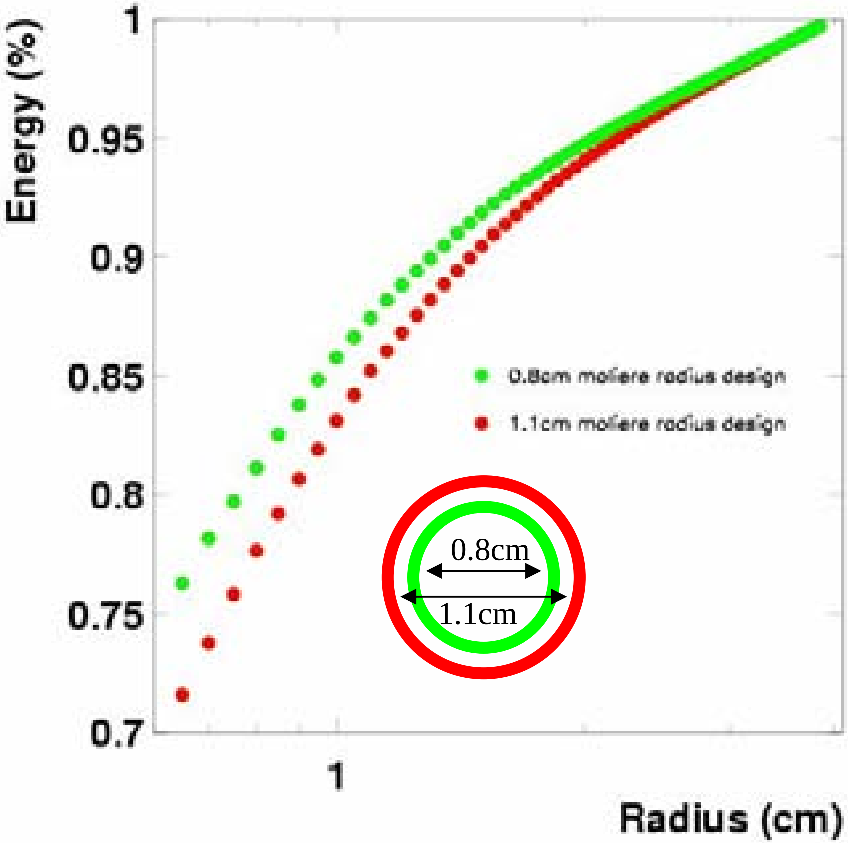
→ Final Design

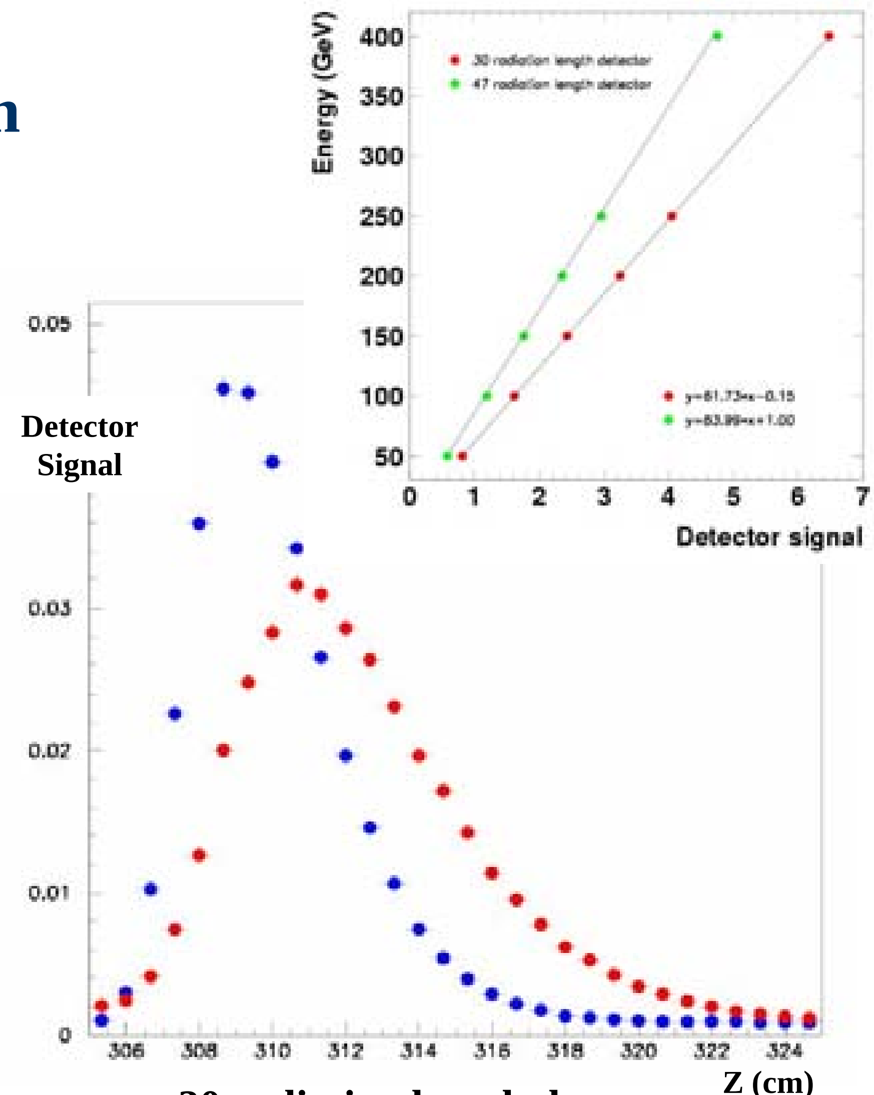
The End

Density Design

Moliere radius & Radiation length

0.55 cm Tungsten	0. 1 cm Silicon	0.34 cm Tungsten	0.31 cm Silicon





30 radiation length detector

47 radiation length detector

FCAL Collaboration

High precision design

Snowmass 05

Dense Design Optimization