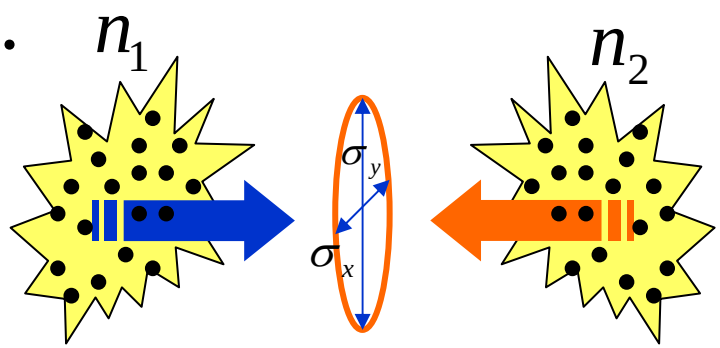
Luminosity Measurement

Tel Aviv University
HEP Experimental Group

LCWS2005

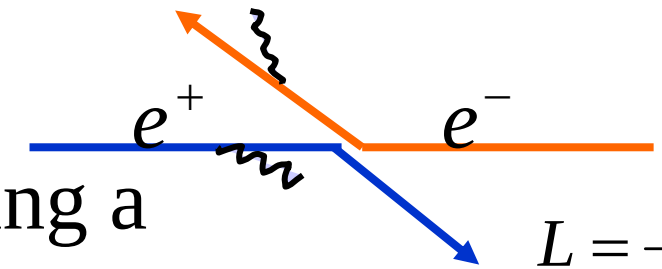
Luminosity Measurement

It is not only important to have a high luminosity machine, but it is as important to measure the luminosity with a high precision.



Event rate: $R = L\sigma_{\text{int}}$

Luminosity: $L = f\dfrac{n_1 n_2}{4\pi\sigma_x\sigma_y}$



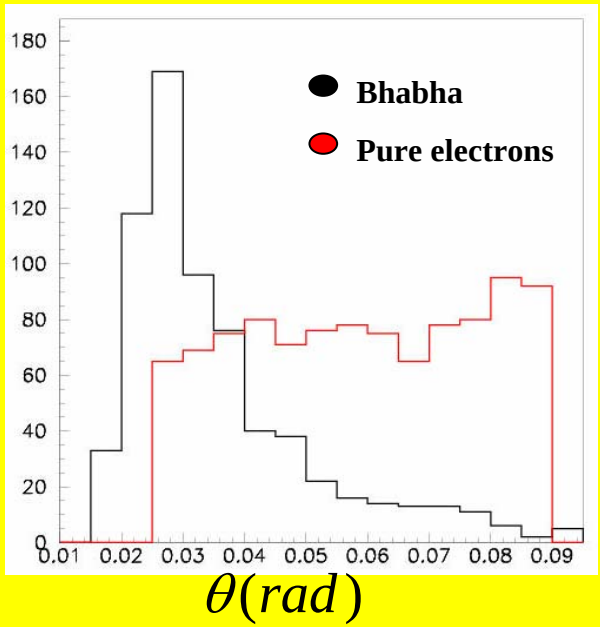
Measurement approach : taking a known process – **Bhabha scattering.**

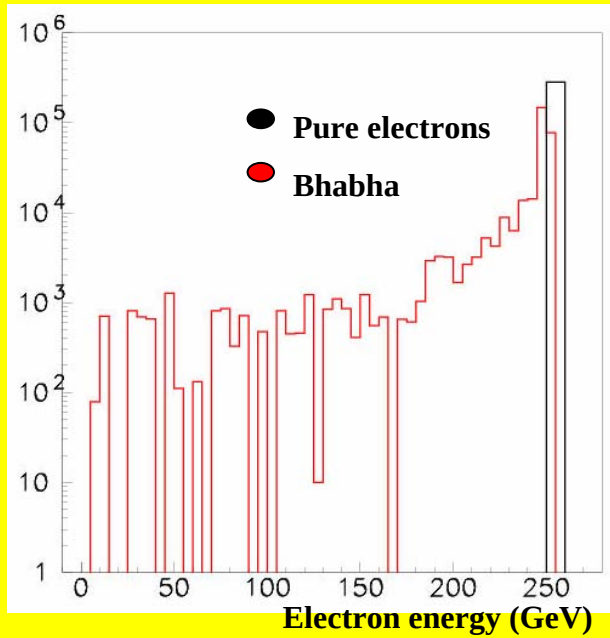
$$L = \frac{R}{\sigma_{Bhabha}}$$

Electrons/Bhabhas

Electrons/Positrons - Geant-3 integrated generator.

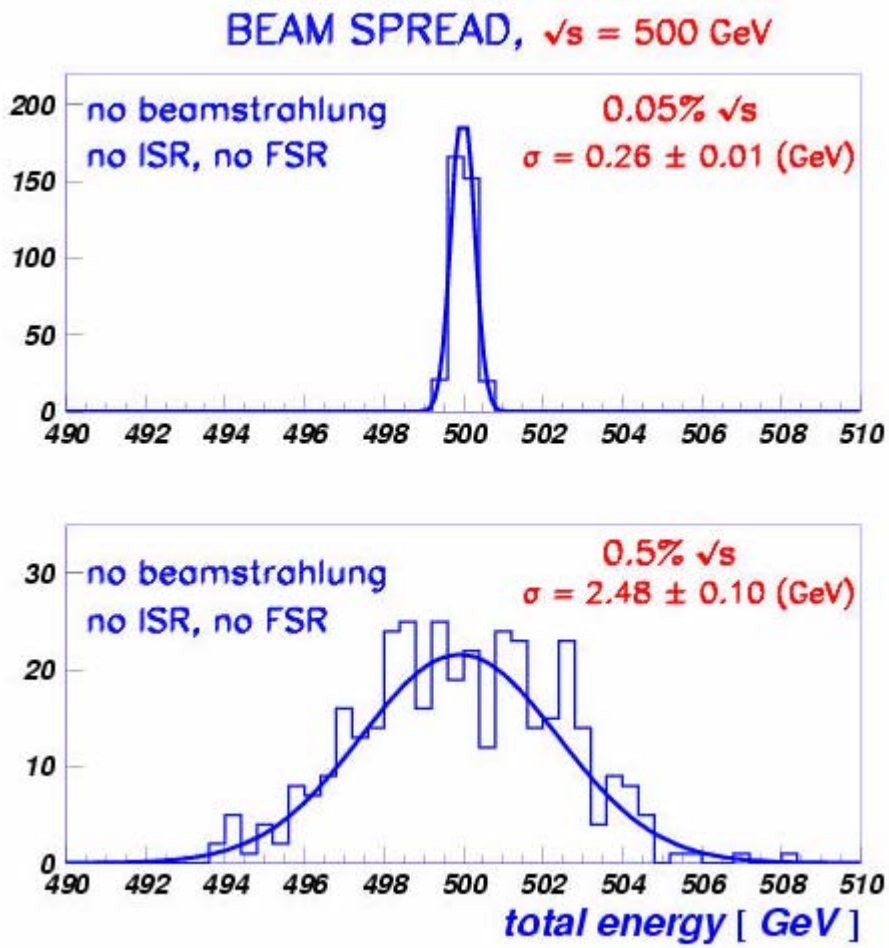
Bhabha scattering - BHWIDE generator.

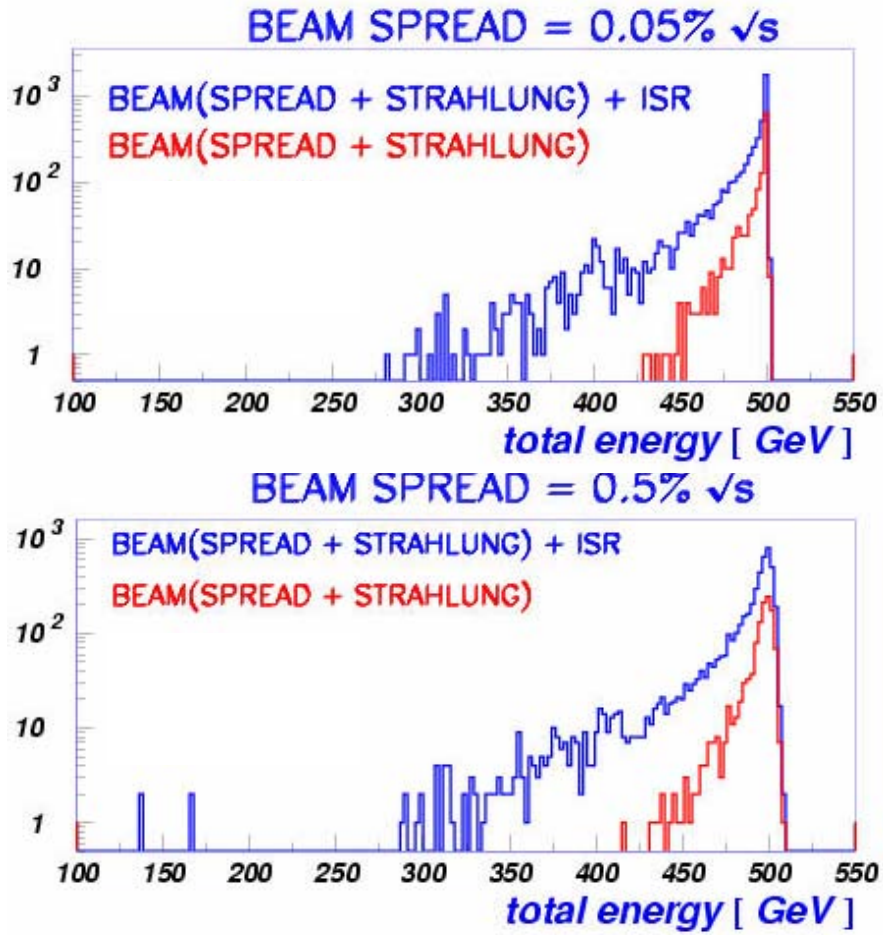




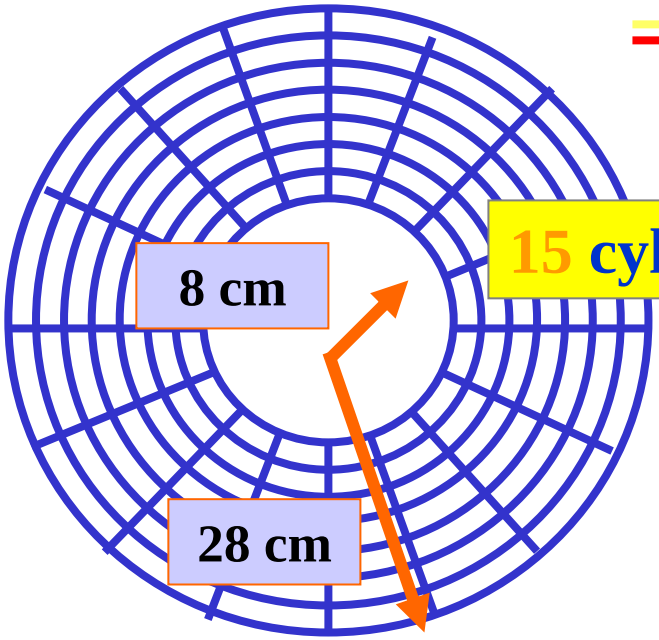
Beamstrahlung and Beam Spread

Beamstrahlung-Circe generator. Beam spread-Included separately.



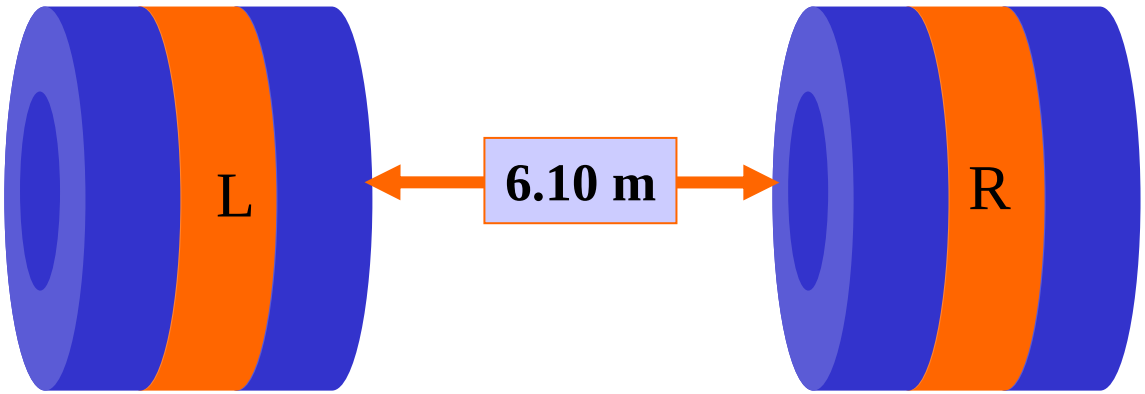


Pad Design



15 cylinders * 24 sectors * 30 rings = 10800 cells

0.34 cm	0.31 cm
Tungsten	Silicon



Cell Size

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

~1 Radiation Length

~1 Moliere Radius

Reconstruction Algorithm

We explored two reconstruction algorithms:

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

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

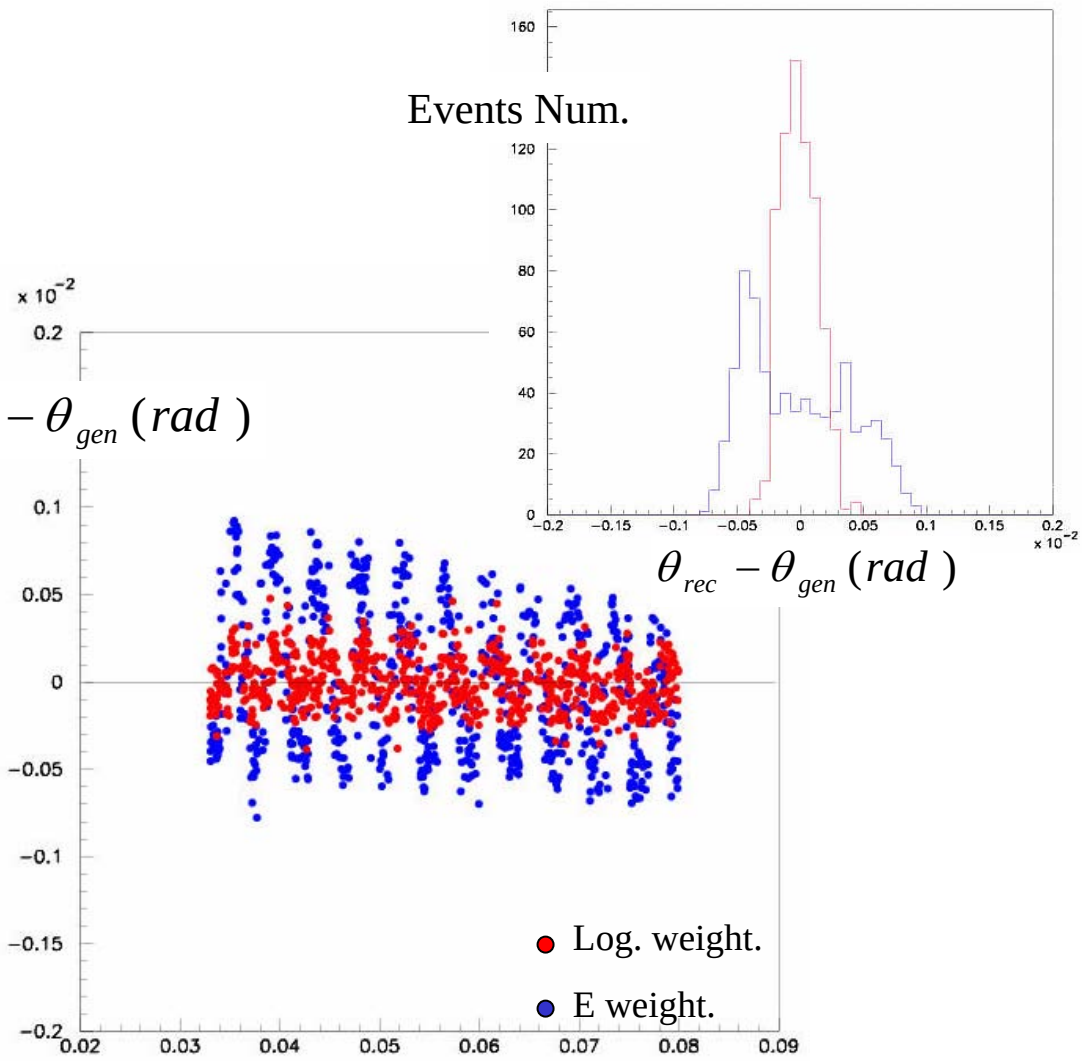
$$W_i = \max\{ 0, [const + \ln(\frac{E_i}{E_T})] \}$$

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

The log. weight fun. was designed to reduce steps in a granulated detector :

1. Selection of significant cells.

2. Log. smoothing.



Logarithmic Constant

After selecting:

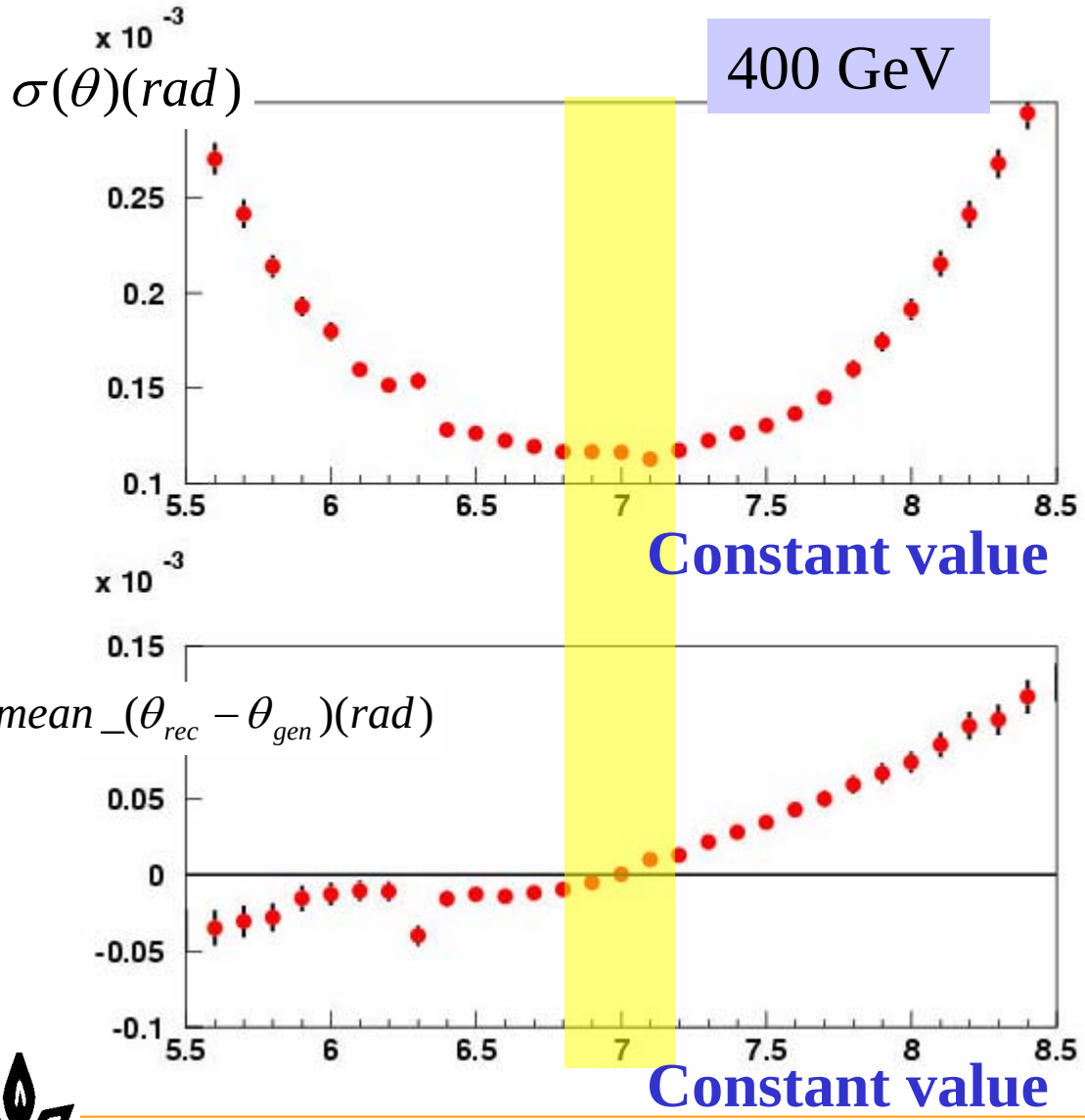
$$W_i = \max\{0, [const + \ln(\frac{E_i}{E_T})]\}$$

We explored a more systematic approach.

The first step is finding the best constant to use under two criteria:

1. Best resolution.

2. Minimum bias.

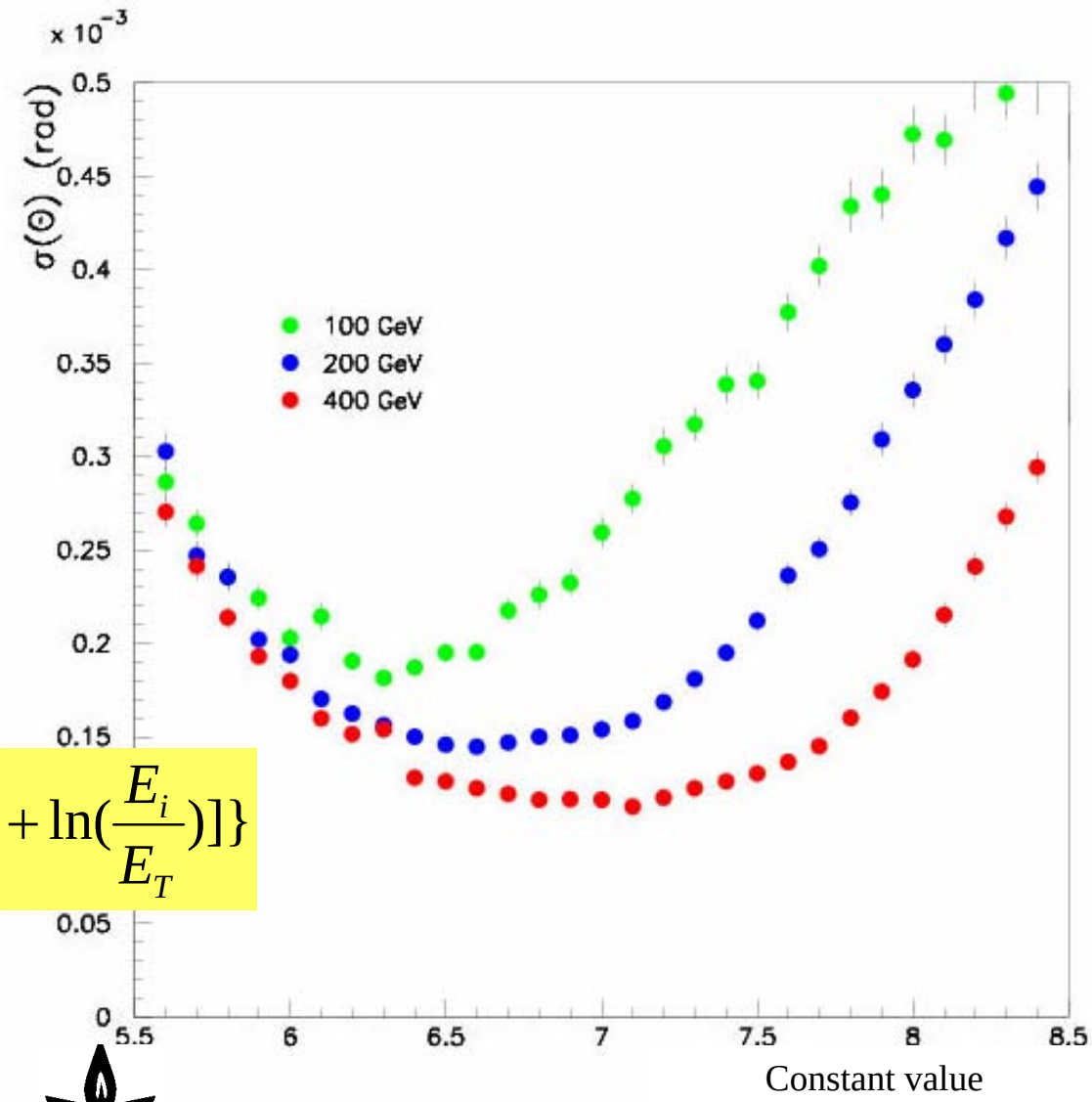


Energy Dependent Constant

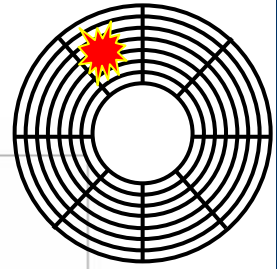
The goal is to find a global weight function.

Is the the log. weight constant really a constant ?

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

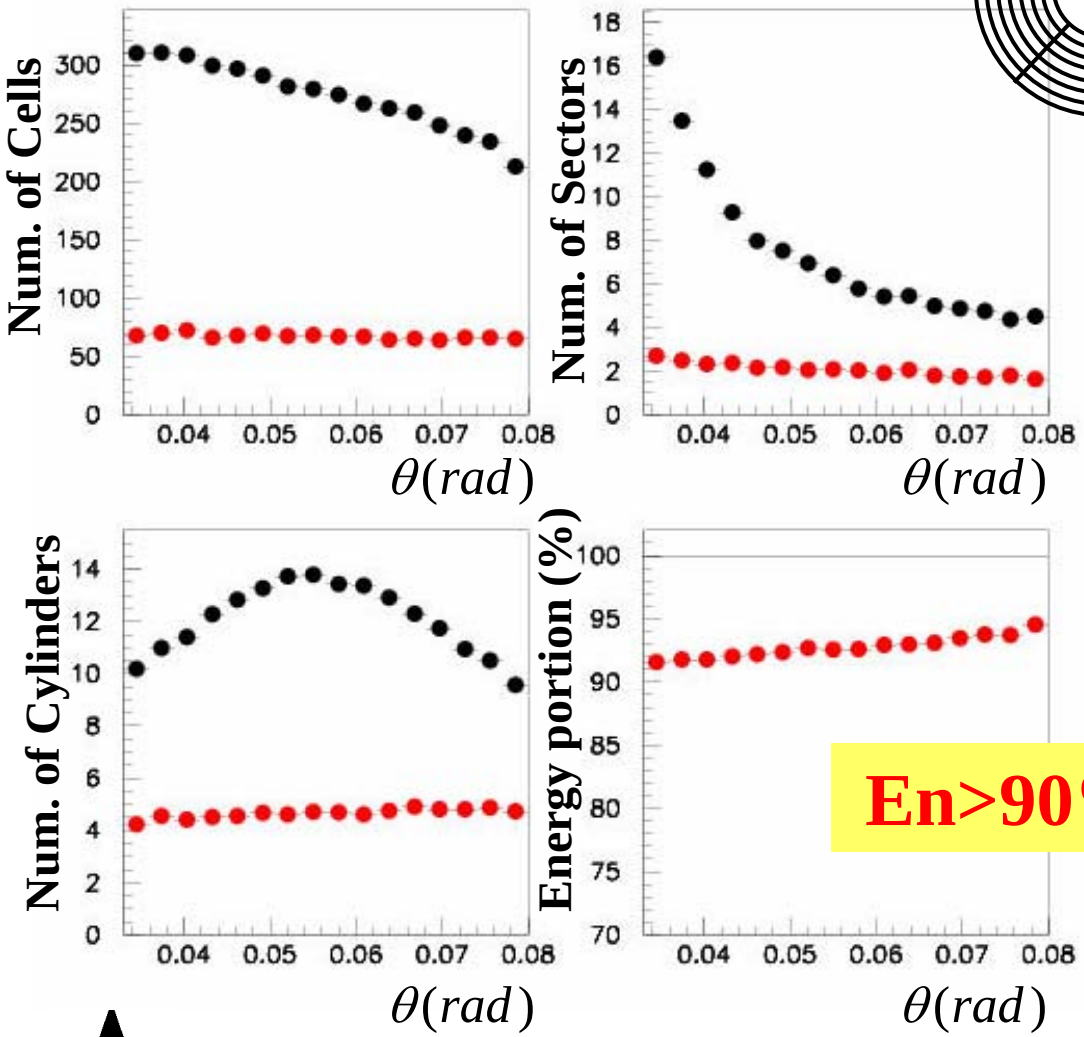


Shower Reconstruction



What happens when we select the best log. weight constant ?

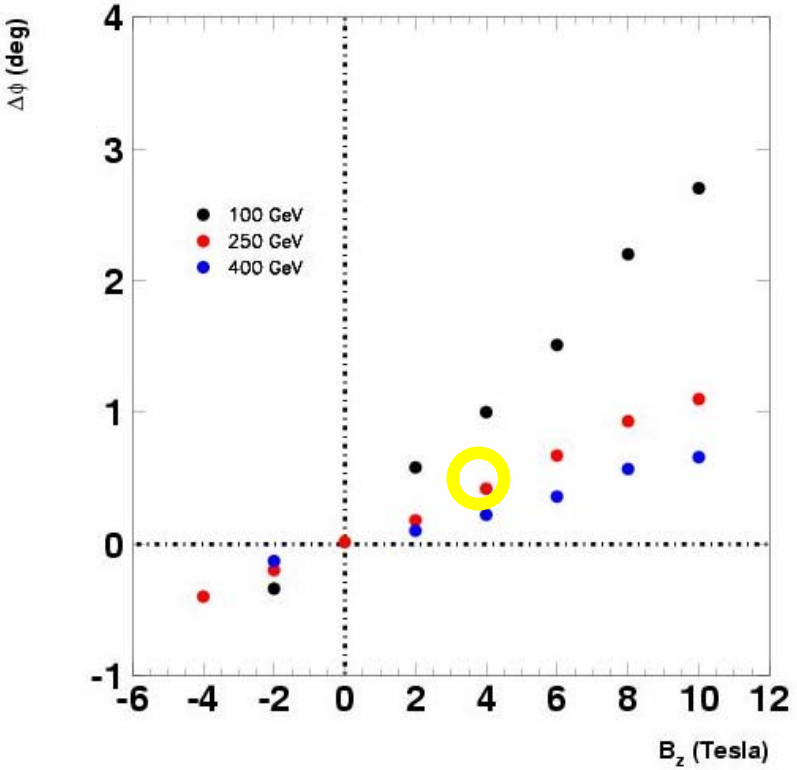
- **Shower size**
- **Log. Weight Selection**

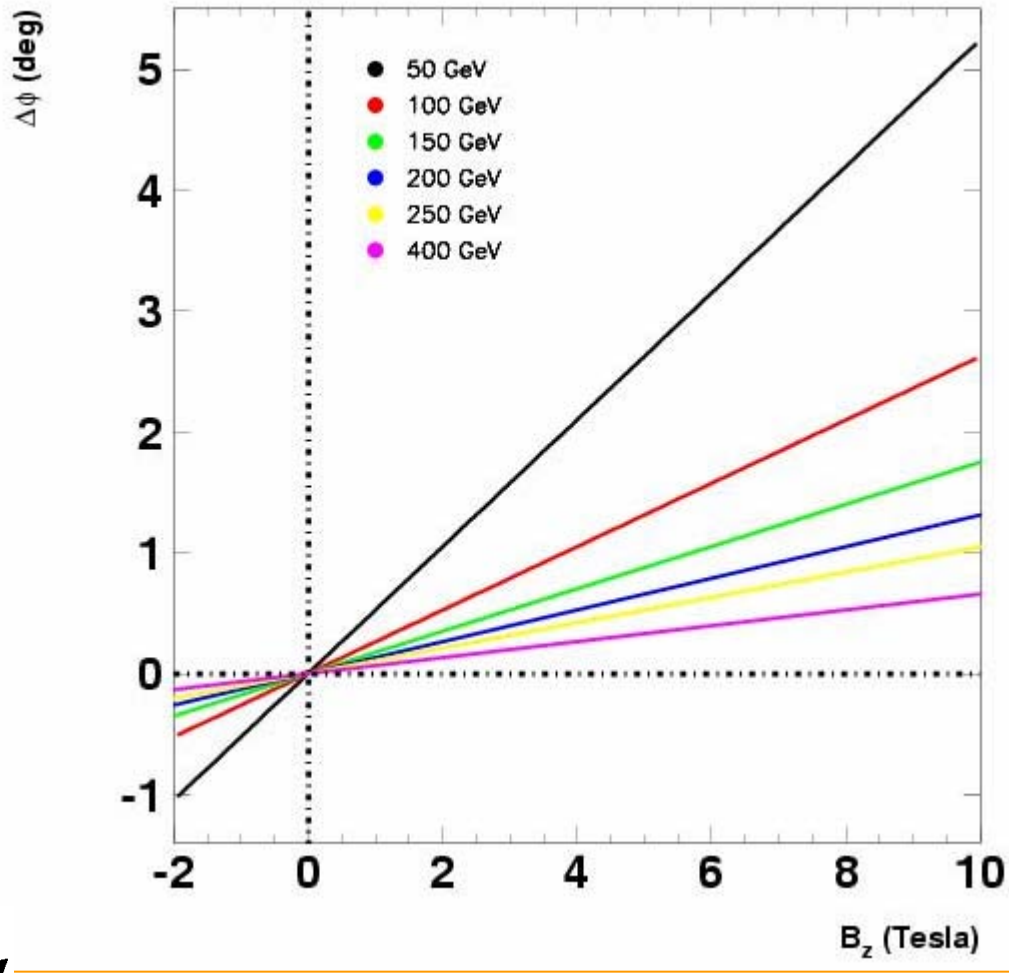


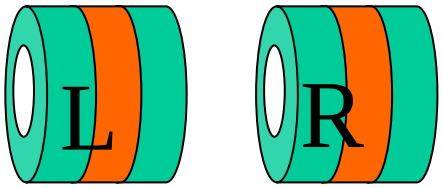
Most of the information is in the selected cells.

En>90%

Magnetic Field

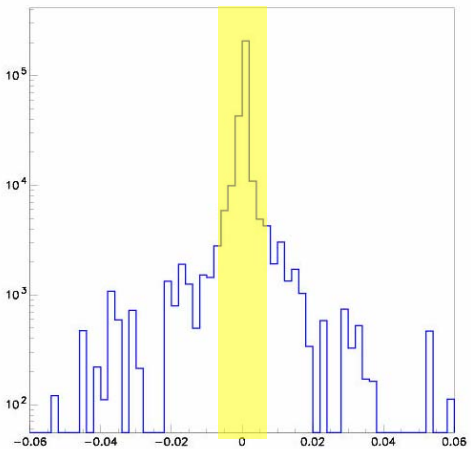


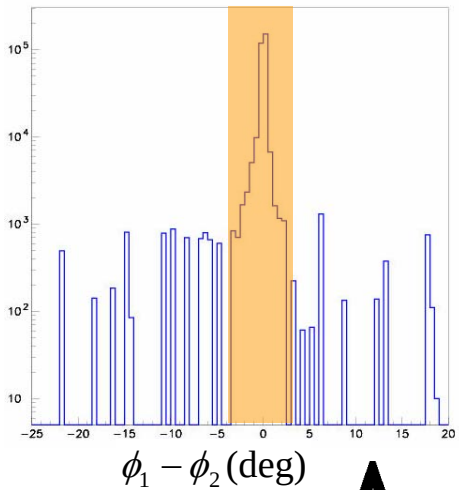


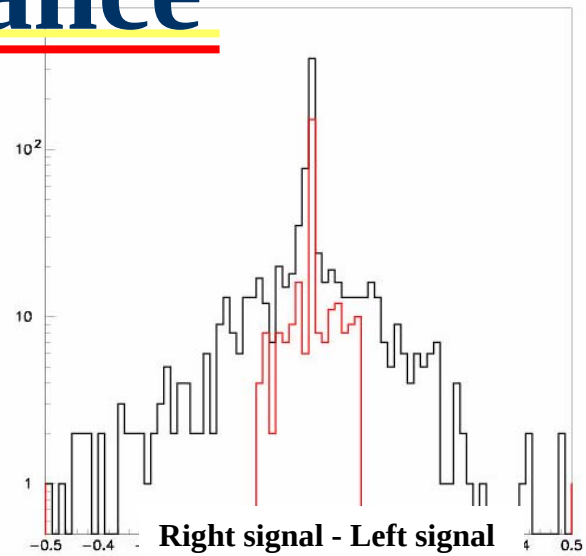


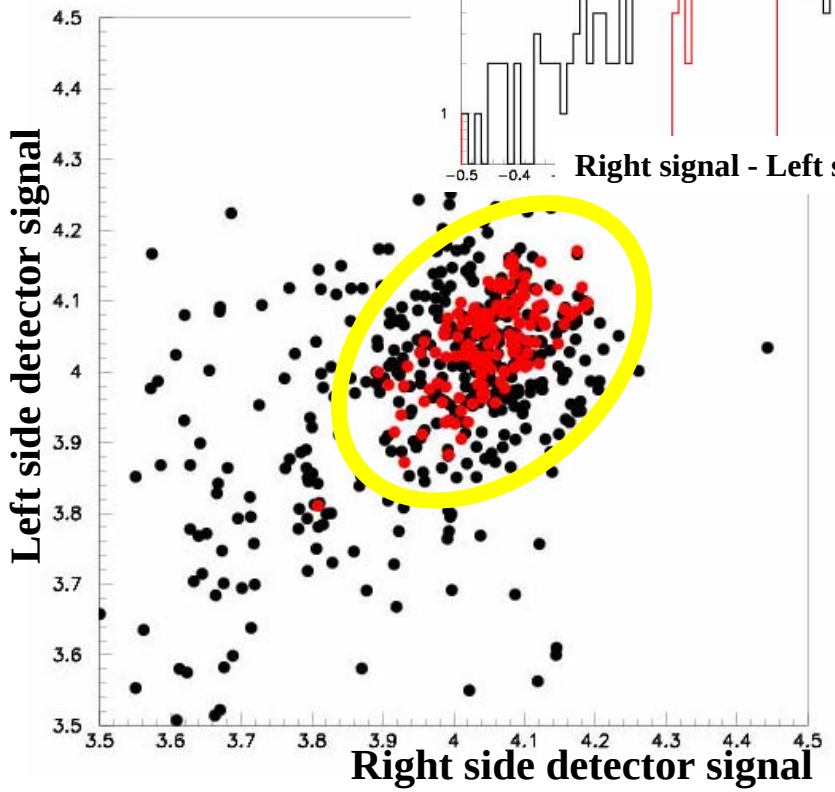
Left-Right Balance

- Simulation distribution
- Distribution after acceptance and energy balance selection



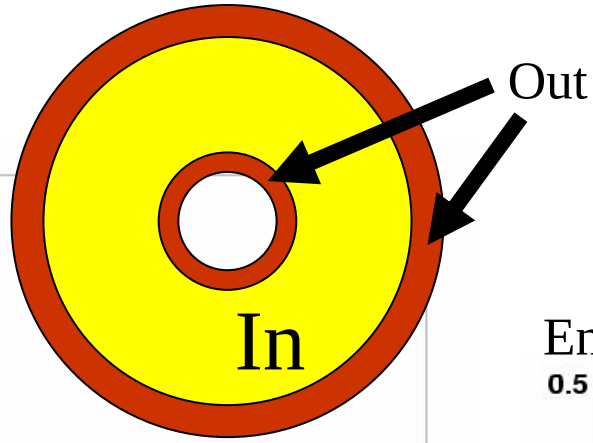


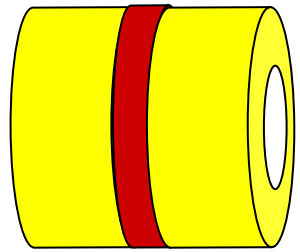


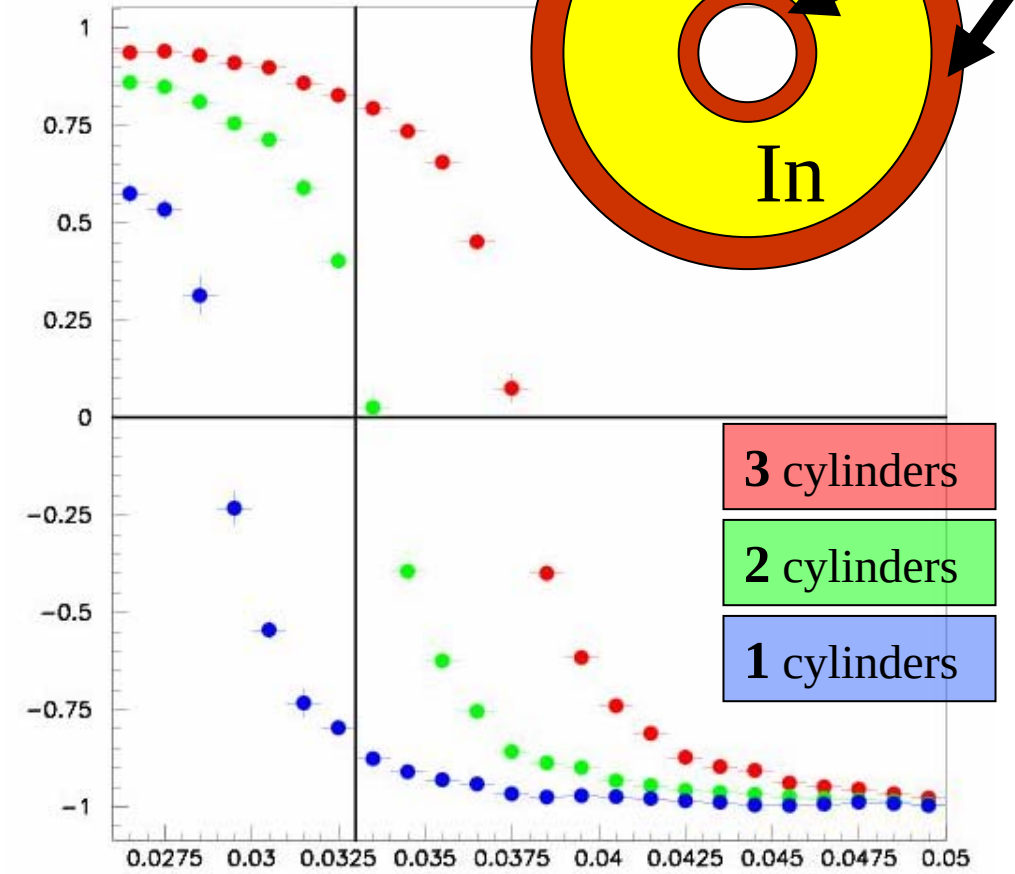


Geometric Acceptance

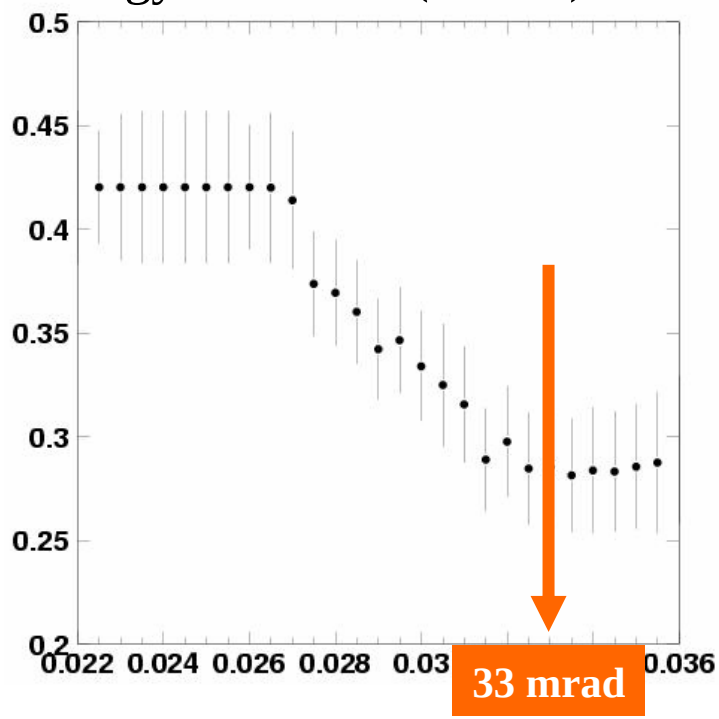
$$P = \frac{Eout-Ein}{Eout+Ein}$$





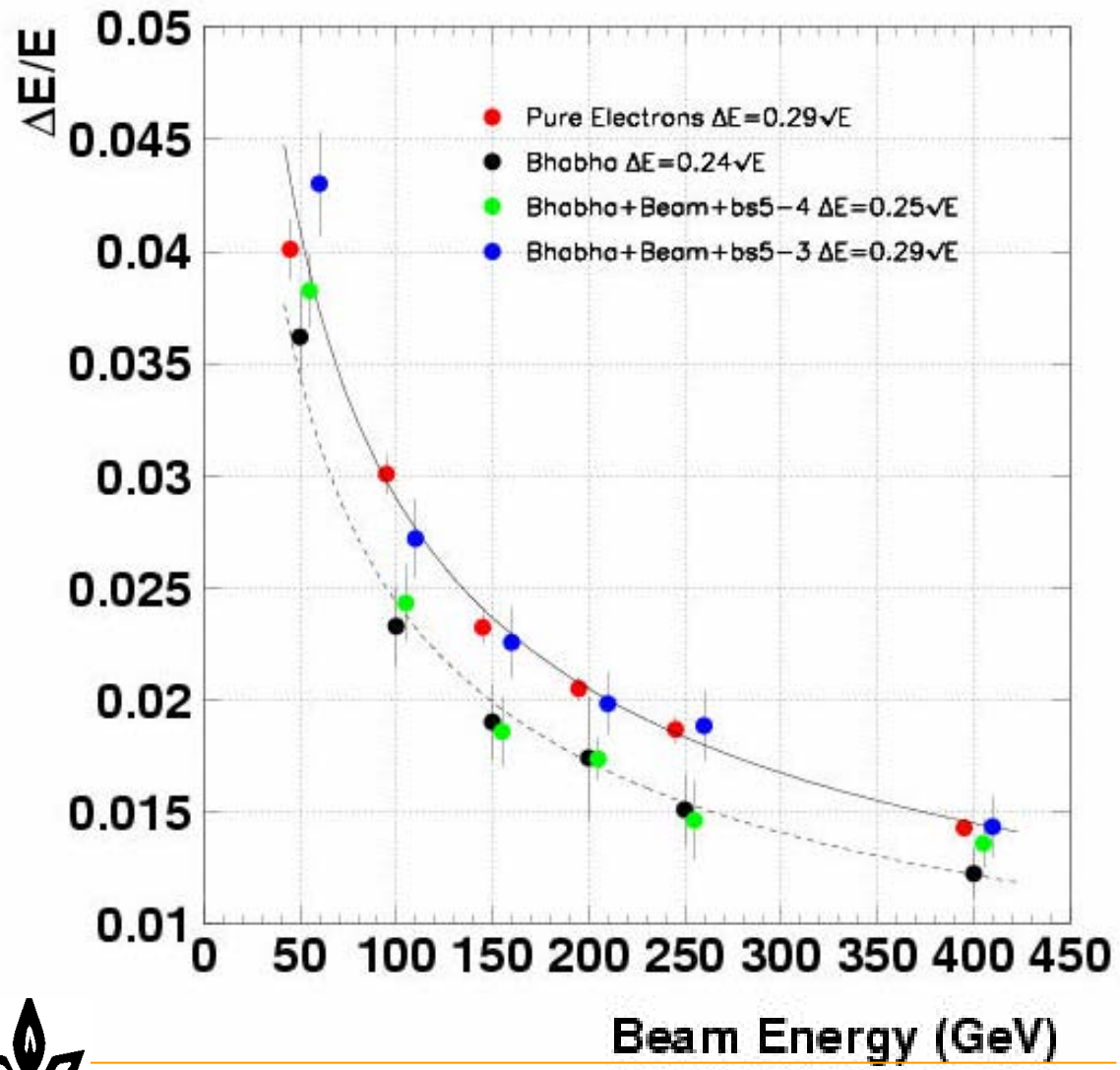


Energy Resolution $(\sqrt{GeV})$

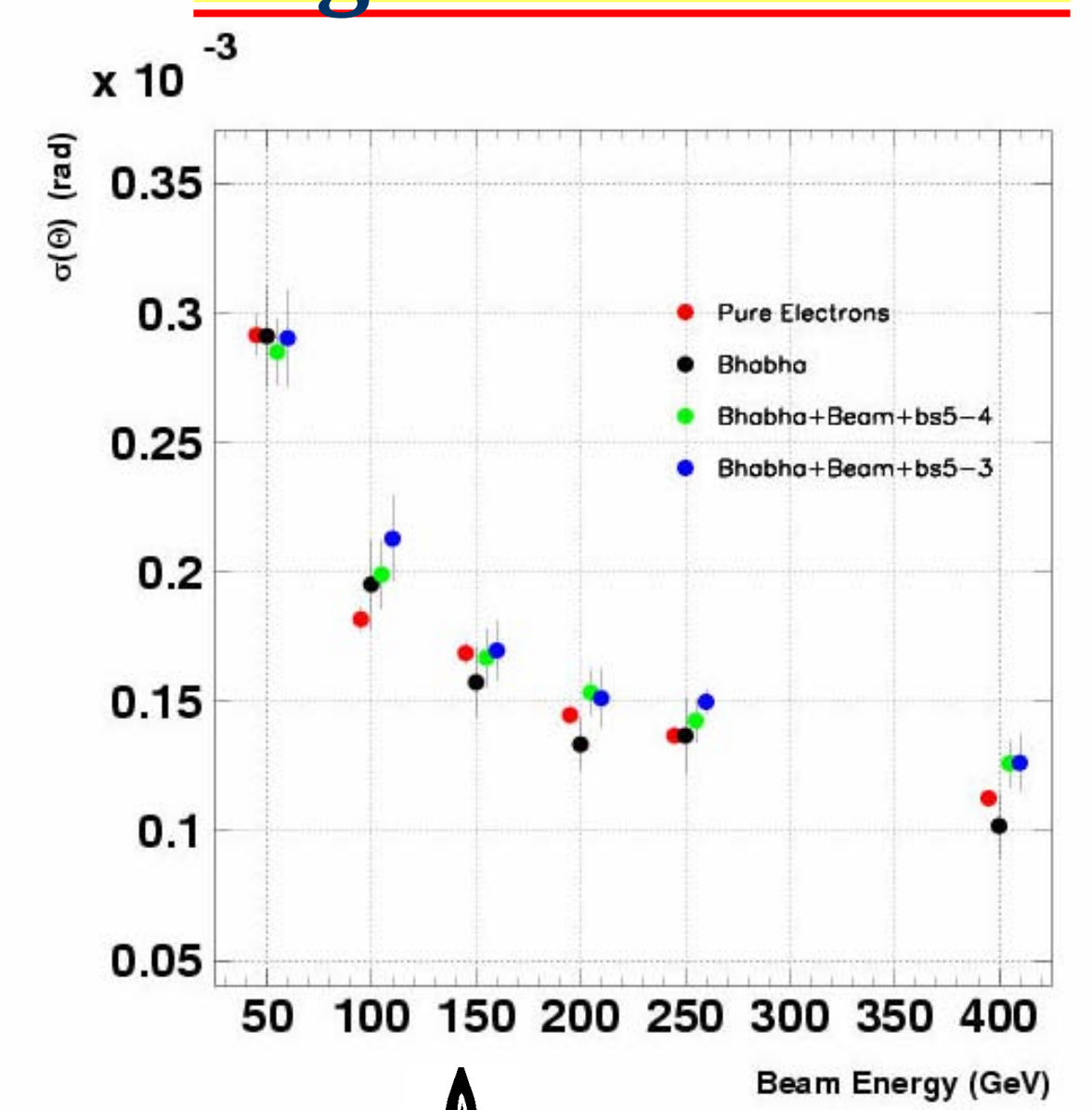


Energy Resolution

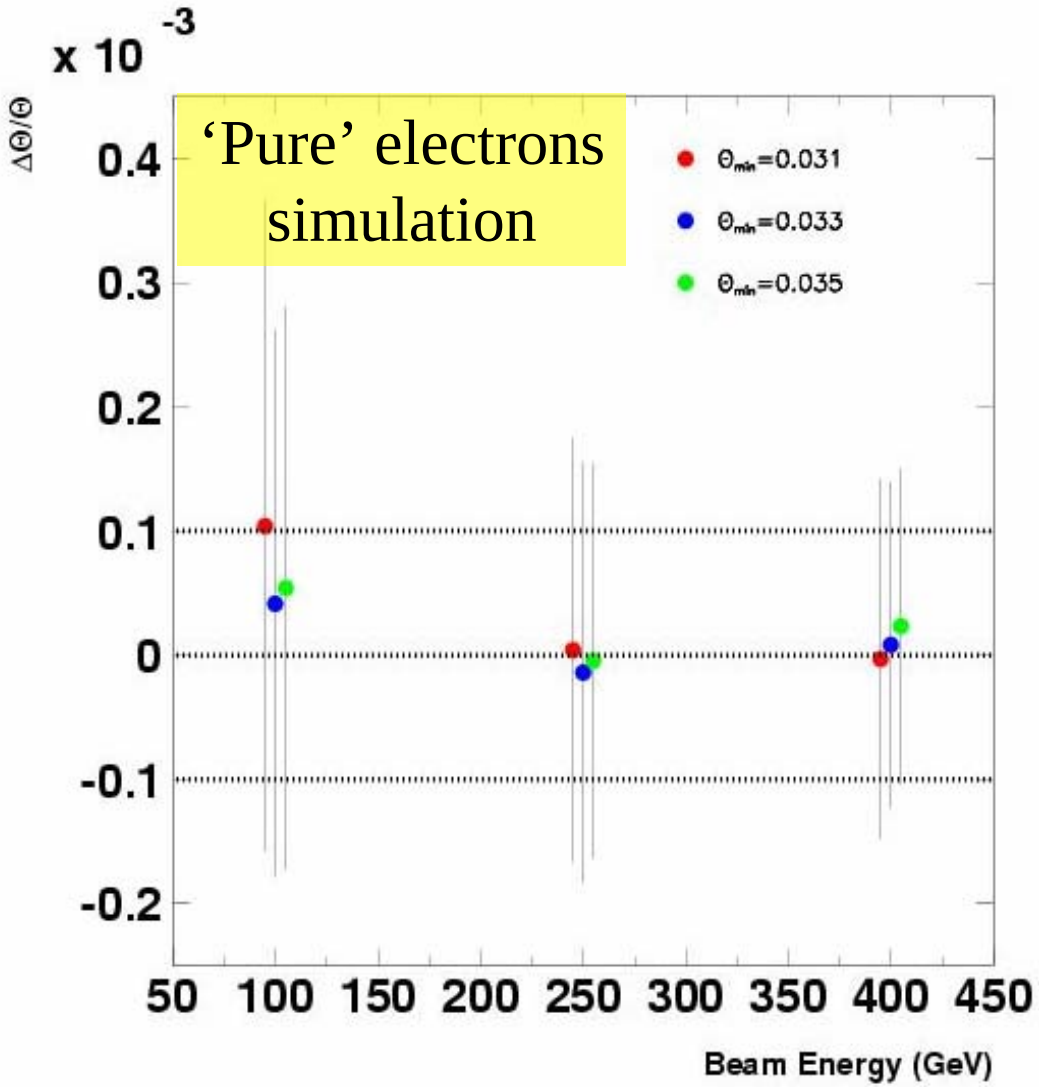
Ntuple	*No cuts*	*With cuts*
Pure electrons	**31%**	**29%**
Bhabha	**42%**	**24%**
Bhabha + Beamstrahlung	**45%**	**24%**
Bhabha + Beamstrahlung + Beam spread (0.05%)	**46%**	**25%**
Bhabha + Beamstrahlung + Beam spread (0.5%)	**49%**	**29%**



Angular Resolution

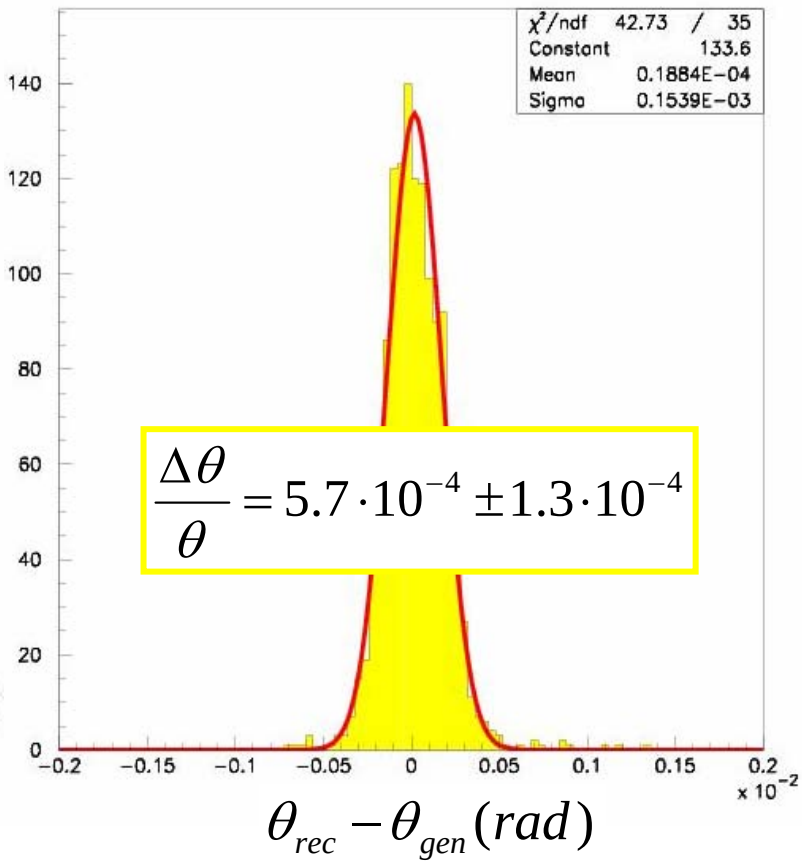


Bias Study



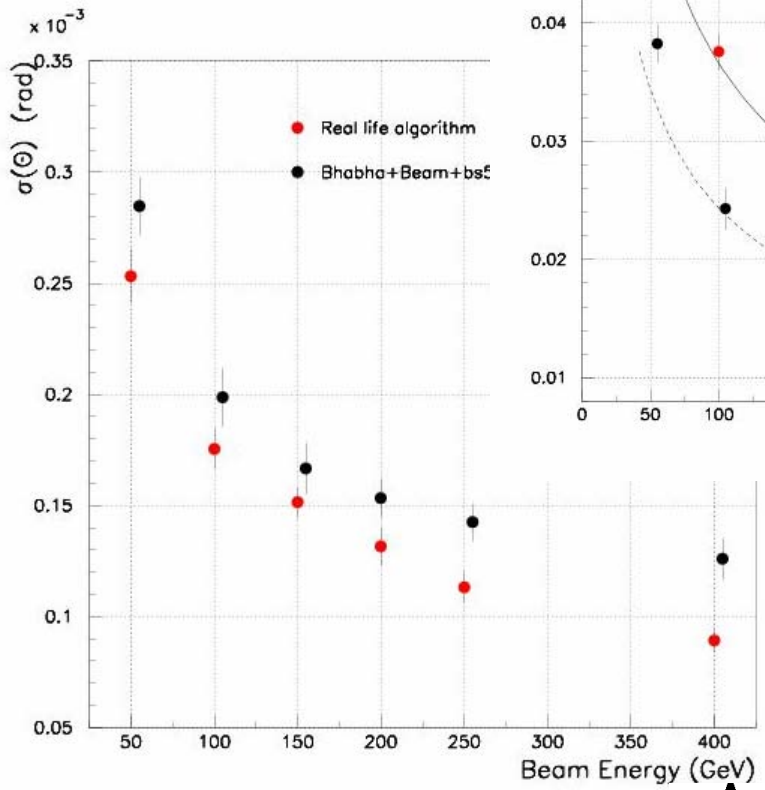
'Pure' electrons simulation

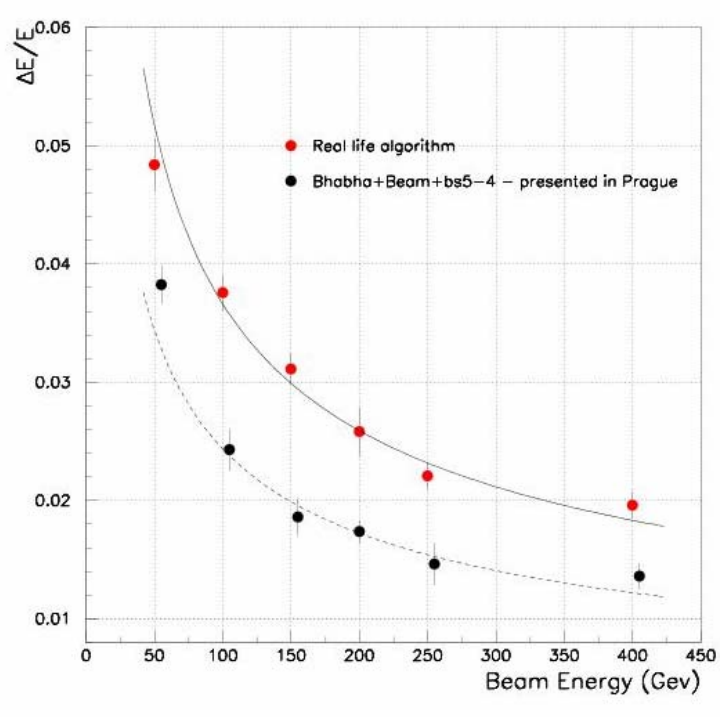
Bhabha+Beam+BS(5e-4)



$$\frac{\Delta\theta}{\theta} = 5.7 \cdot 10^{-4} \pm 1.3 \cdot 10^{-4}$$

Real Life Algorithm





Working with both sides of the detector and looking at the difference between the reconstructed properties:

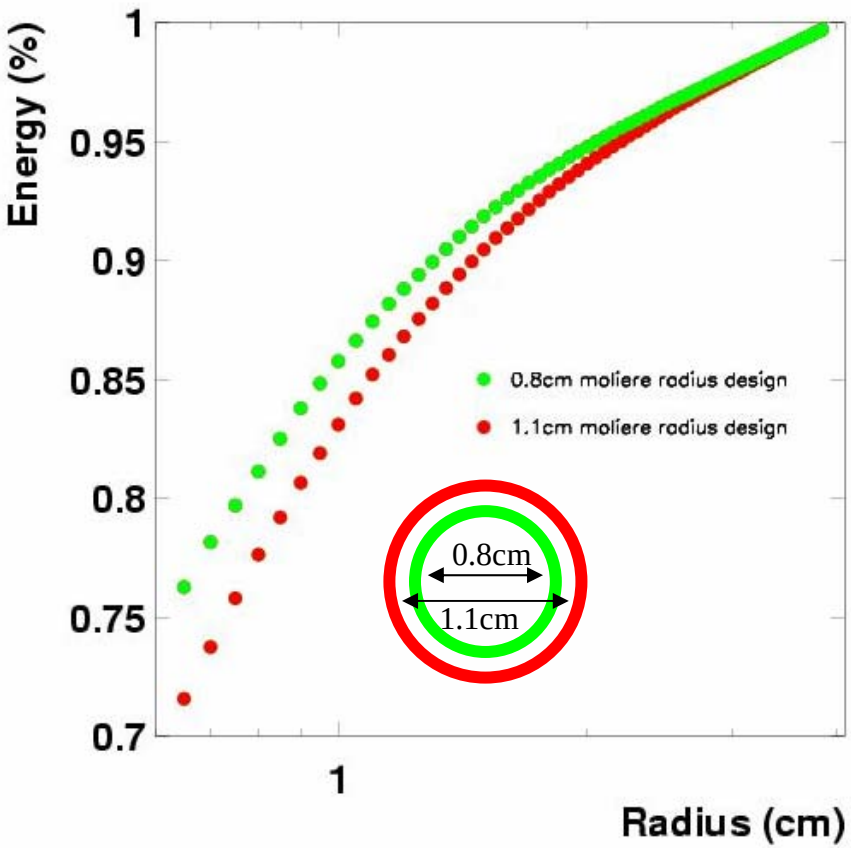
$$\sigma_{new} = \sqrt{2}\sigma$$

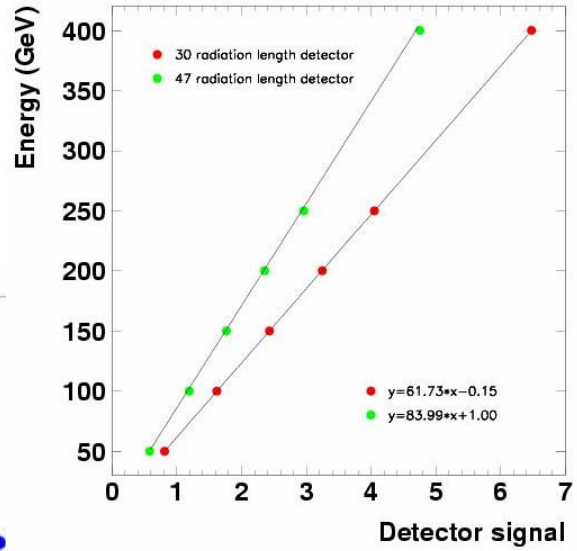
(In real life we don't have generated properties)

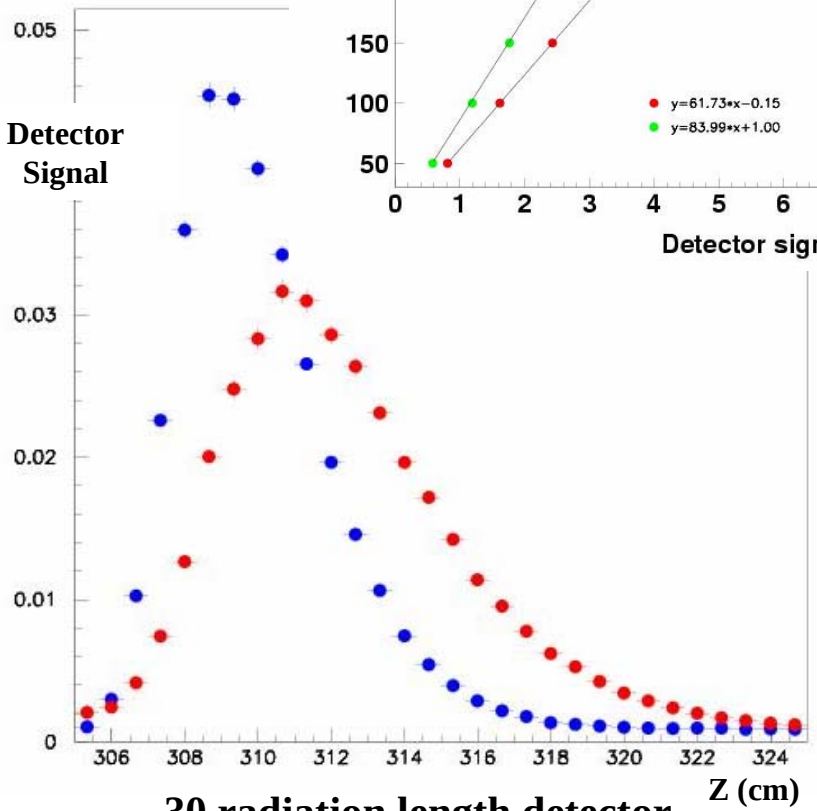
Dense Design

Moliere radius & Radiation length

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



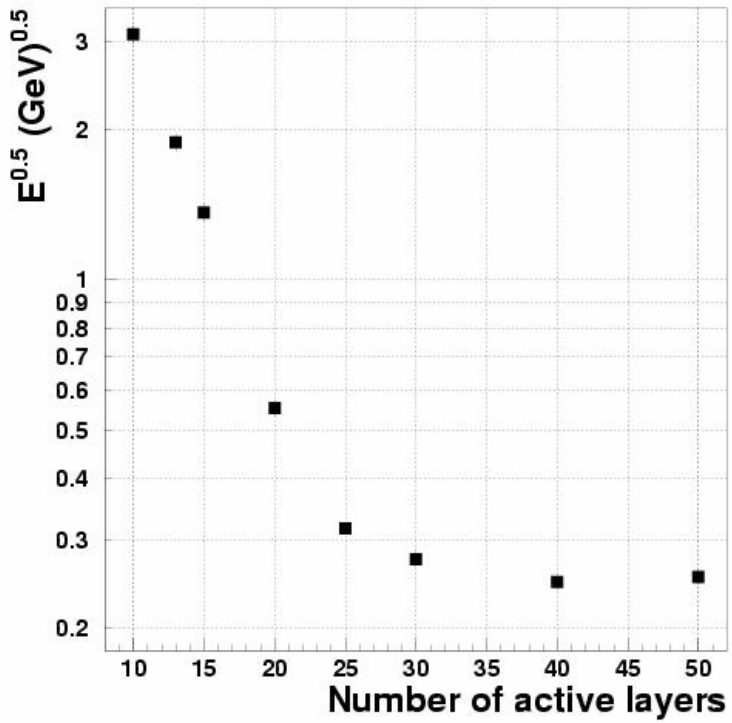


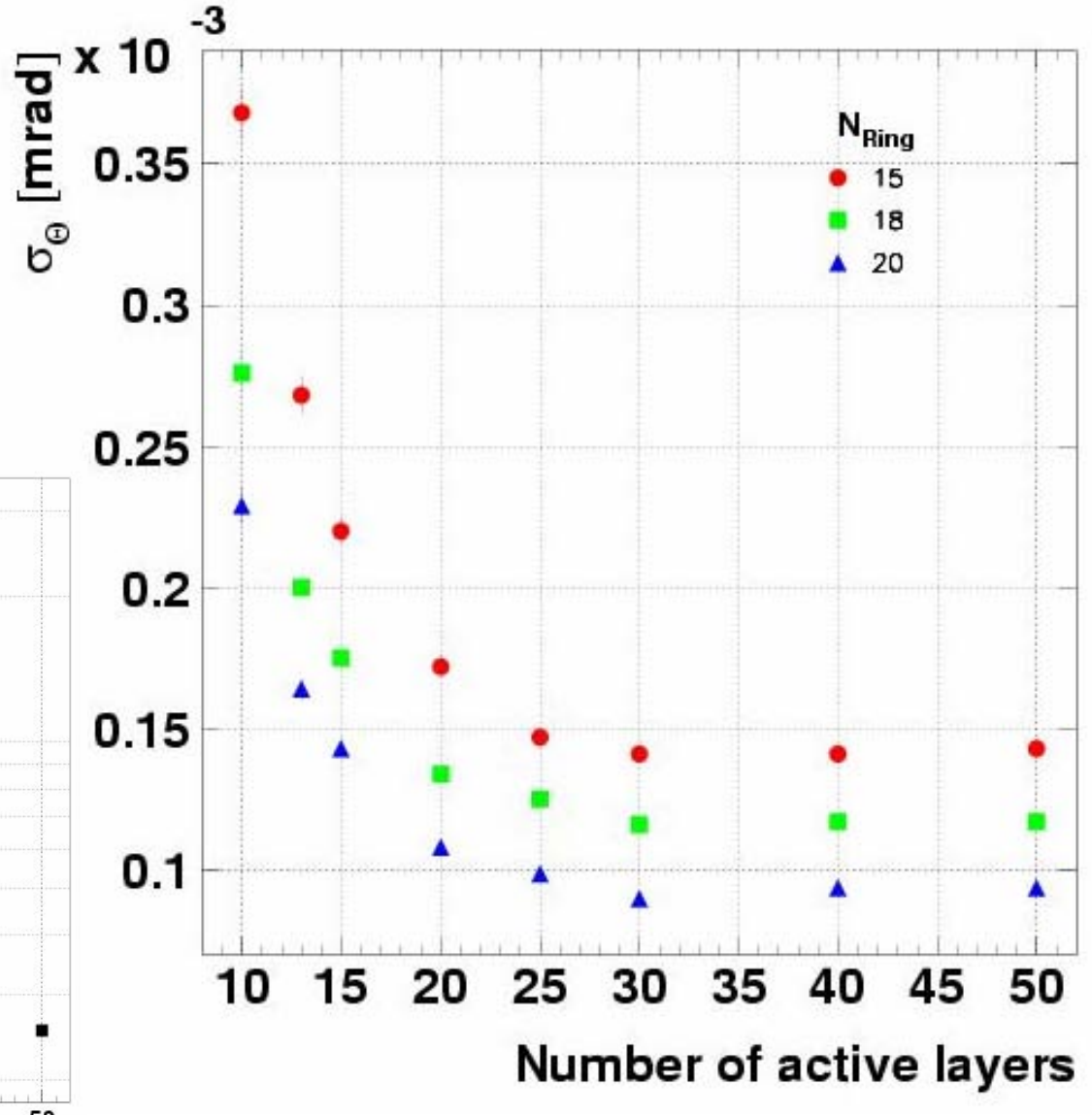


30 radiation length detector

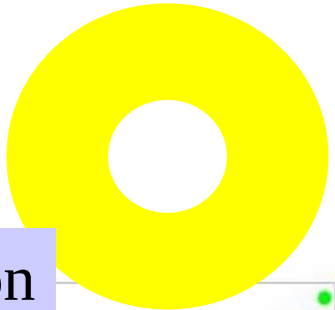
47 radiation length detector

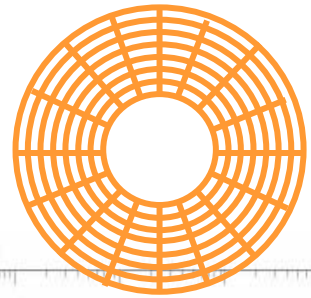
Optimization



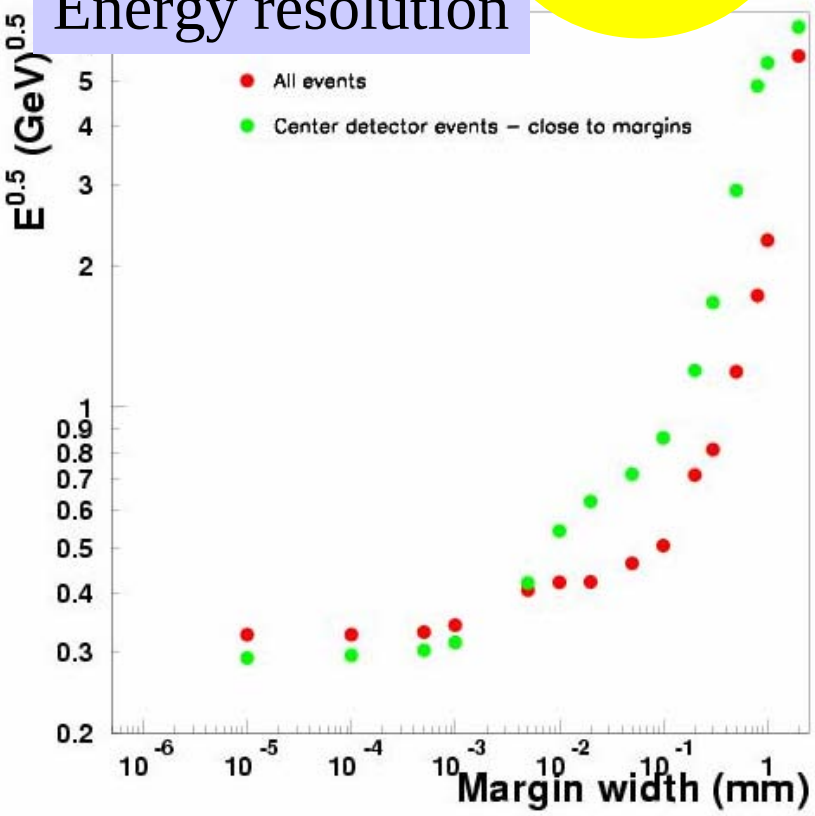


Margins in Between Cells

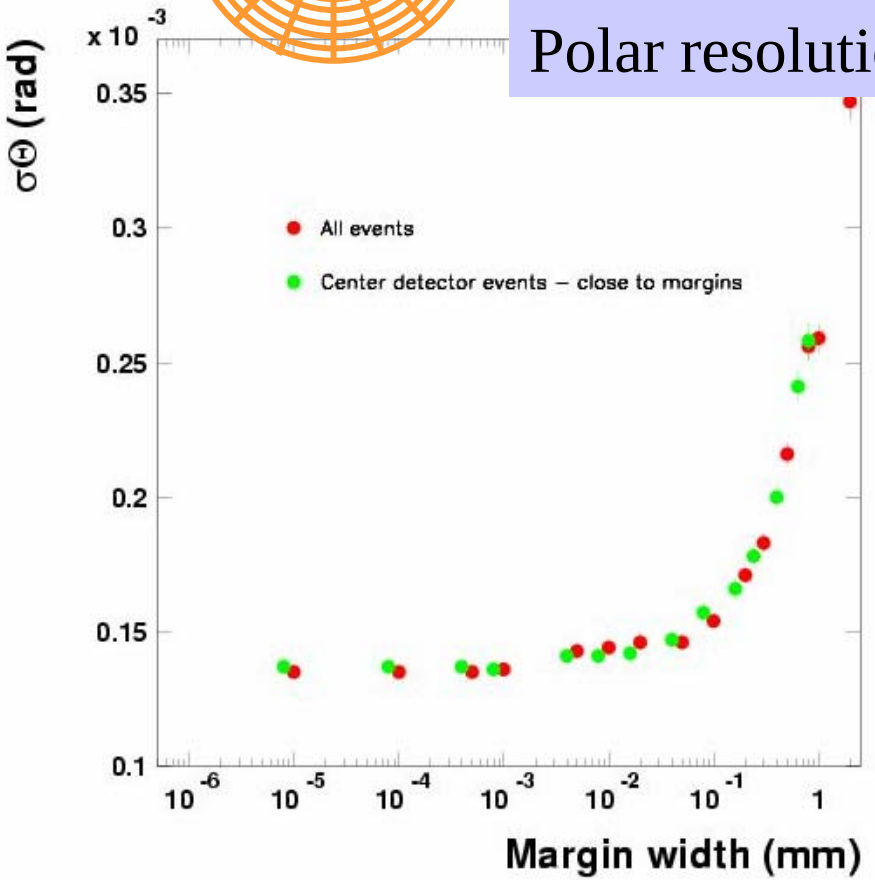




Energy resolution



Polar resolution

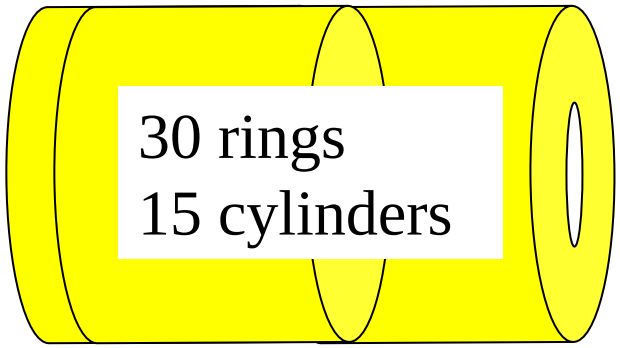


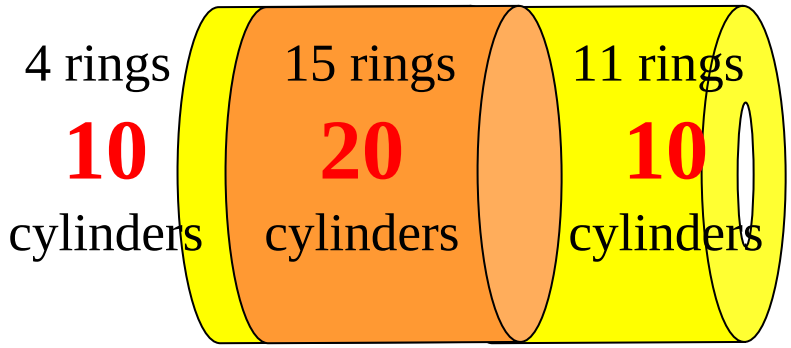
Maximum Peak Shower Design

Our basic detector is designed with

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

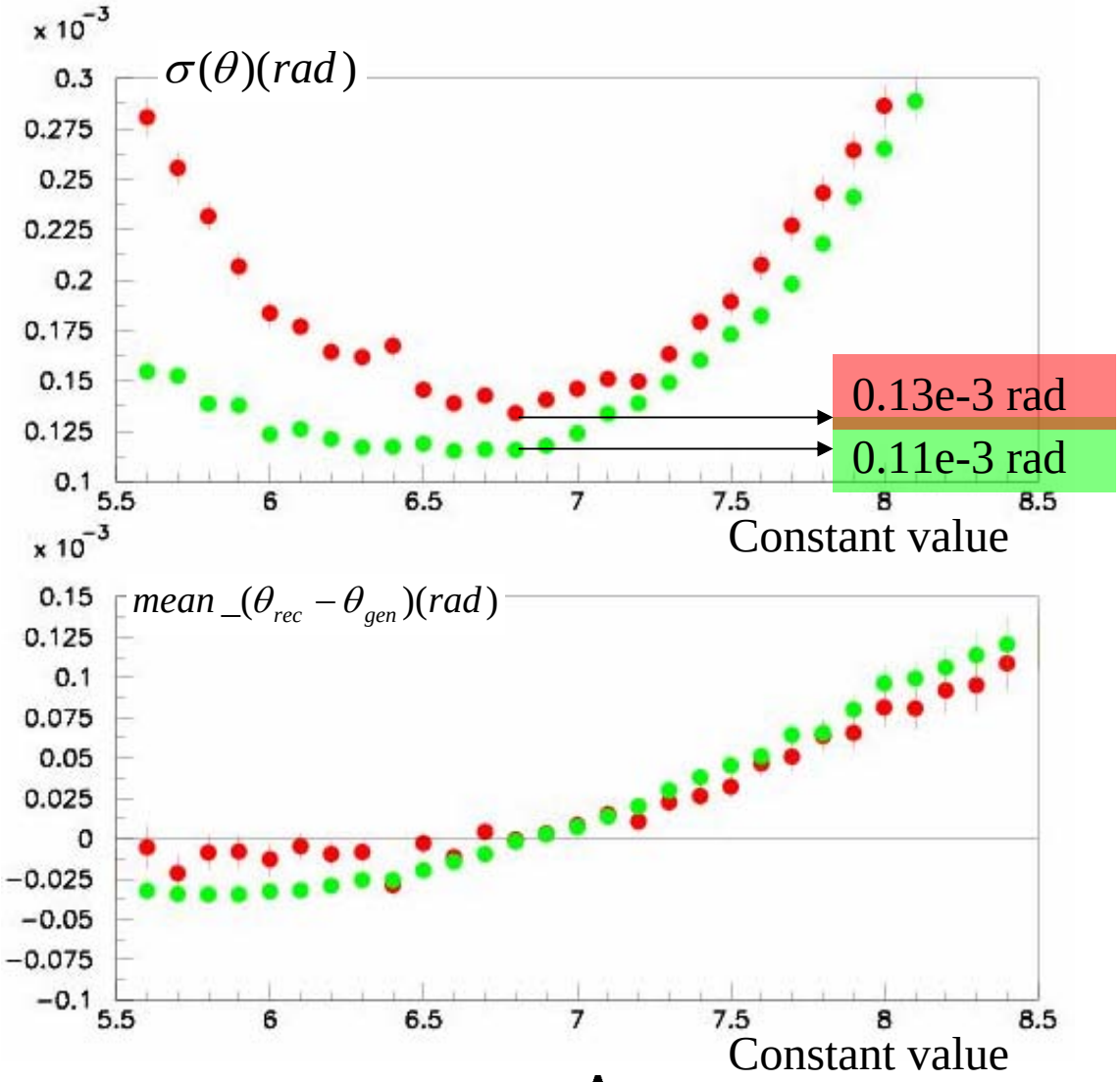
Do we use these channels in the most effective way ?





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

Polar Reconstruction



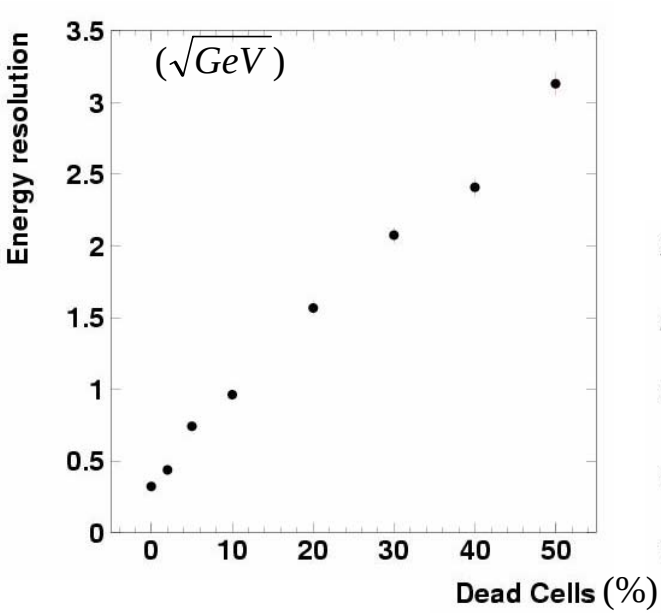
Maximum peak shower design

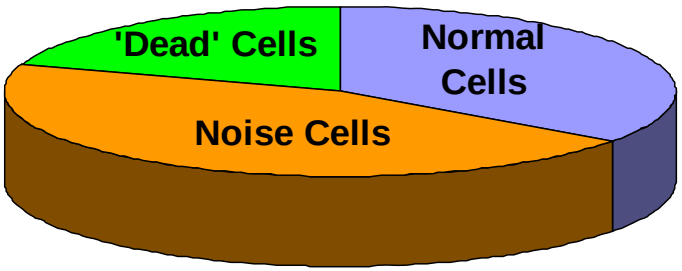
Basic Design

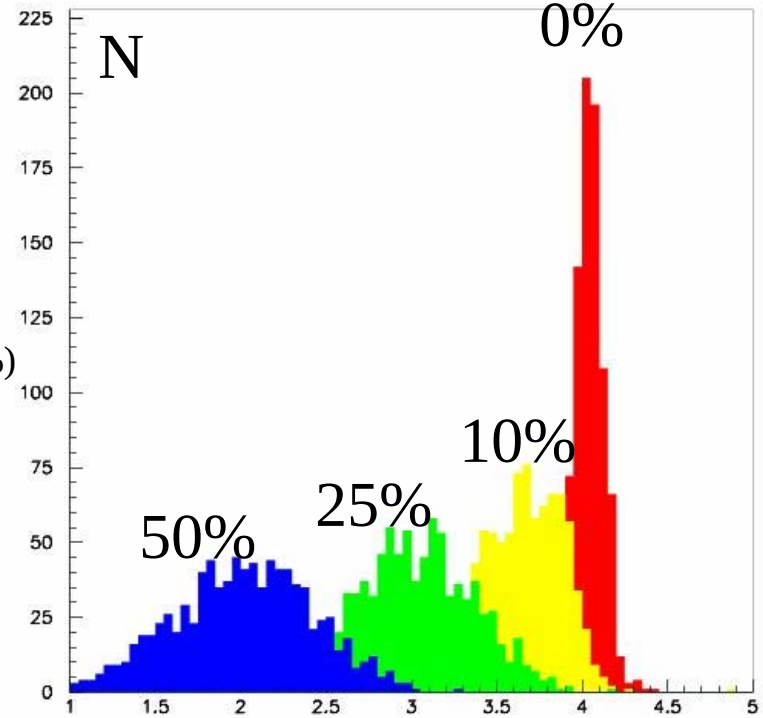
Angular resolution improvement without changing the number of channels

Other properties remain the same

Electronics Simulation







Signal (including Dead Cells)

Case Study: $\left\langle \frac{Total\_Signal}{Total\_Noise} \right\rangle \approx 5$

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)

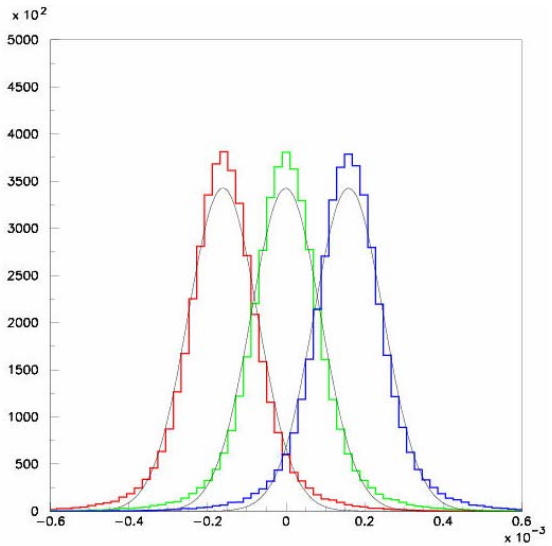
There is an analytic calculation (and approximation) : $\frac{\Delta L}{L} \approx \frac{2*\Delta\theta}{\theta}$

Is it a good approximation ? This calculation takes into account only the Bhabha angular distribution, how does other factors affect (backgrounds, detector design, electronics noise) ?

We need a mechanism to actually count events, as if it was real life.

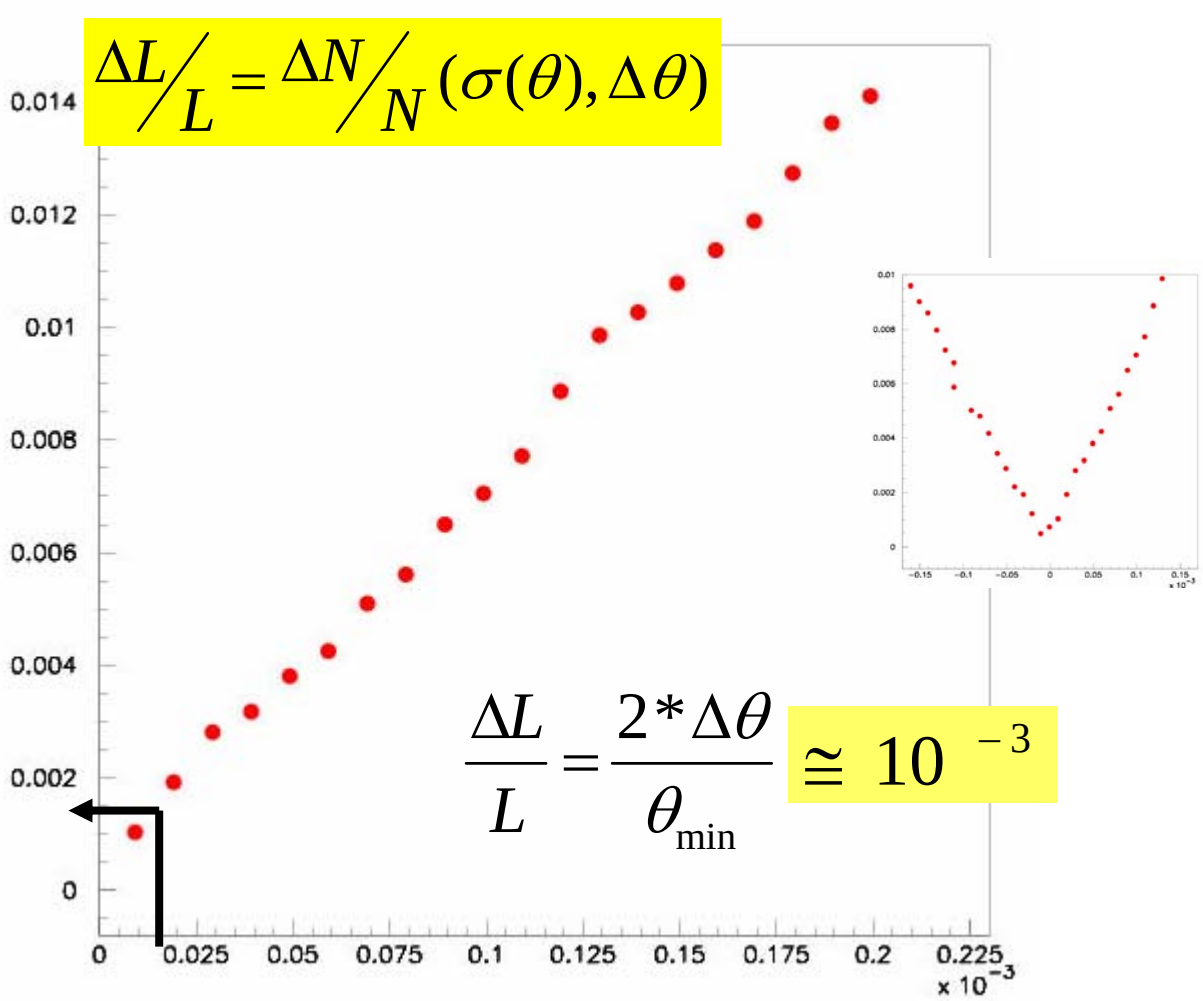
High Statistics MC

BHWIDE + fast detector simulation



θ (*rad*)

$$\Delta L/L = \Delta N/N\,(\sigma(\theta), \Delta\theta)$$

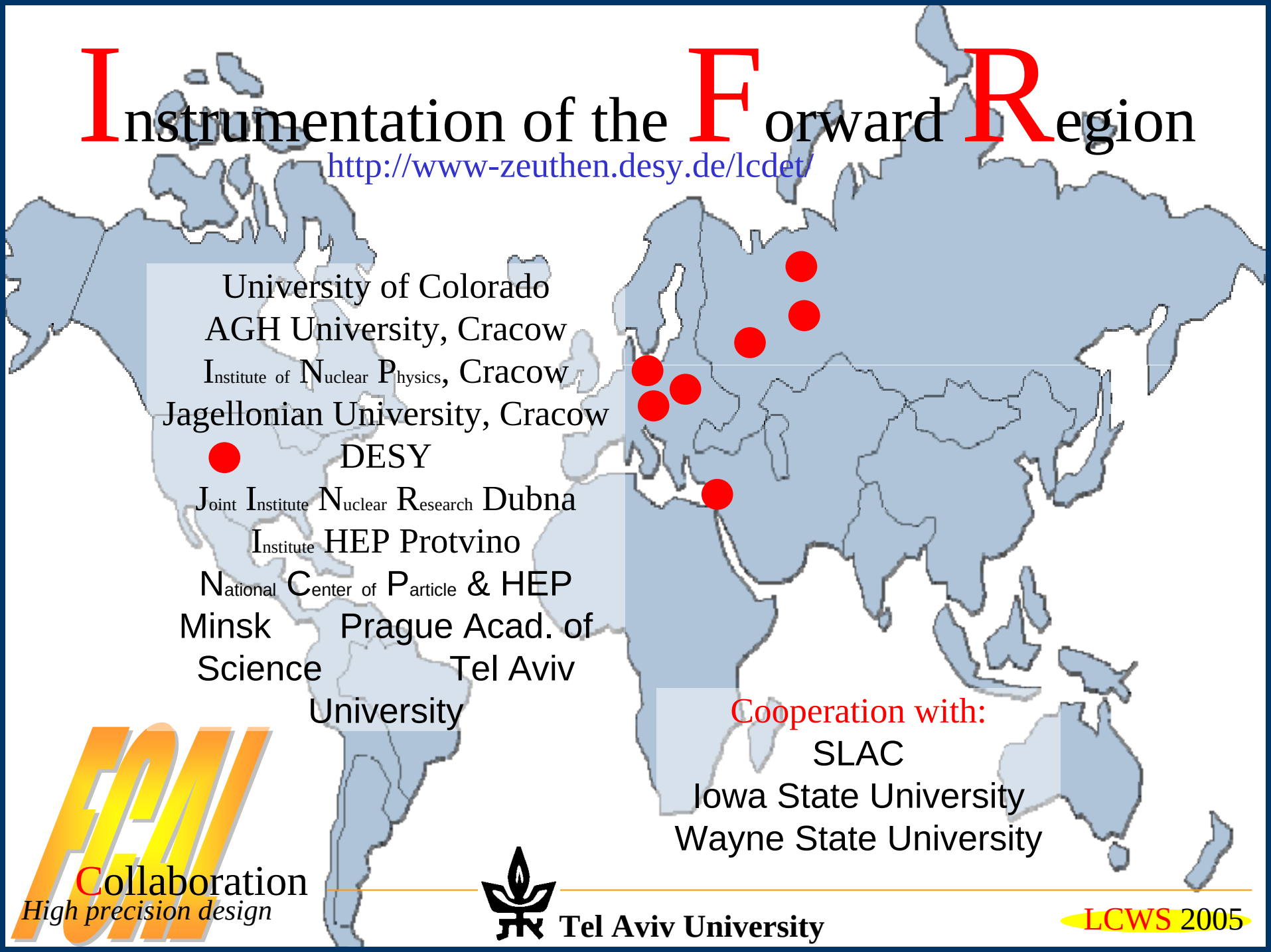


$$\frac{\Delta L}{L} = \frac{2*\Delta\theta}{\theta_{\min}} \cong 10^{-3}$$

$\Delta\theta(rad)$

Instrumentation of the Forward Region

http://www-zeuthen.desy.de/lcdet/



University of Colorado
AGH University, Cracow
Institute of Nuclear Physics, Cracow
Jagellonian University, Cracow
DESY
Joint Institute Nuclear Research Dubna
Institute HEP Protvino
National Center of Particle & HEP
Minsk
Prague Acad. of Science
Tel Aviv University

Cooperation with:
SLAC
Iowa State University
Wayne State University

FCAL Collaboration
High precision design

Tel Aviv University

LCWS 2005

FCAL Collaboration

Goals : design and construction of

- **Luminosity detector**
- **Beam monitor**

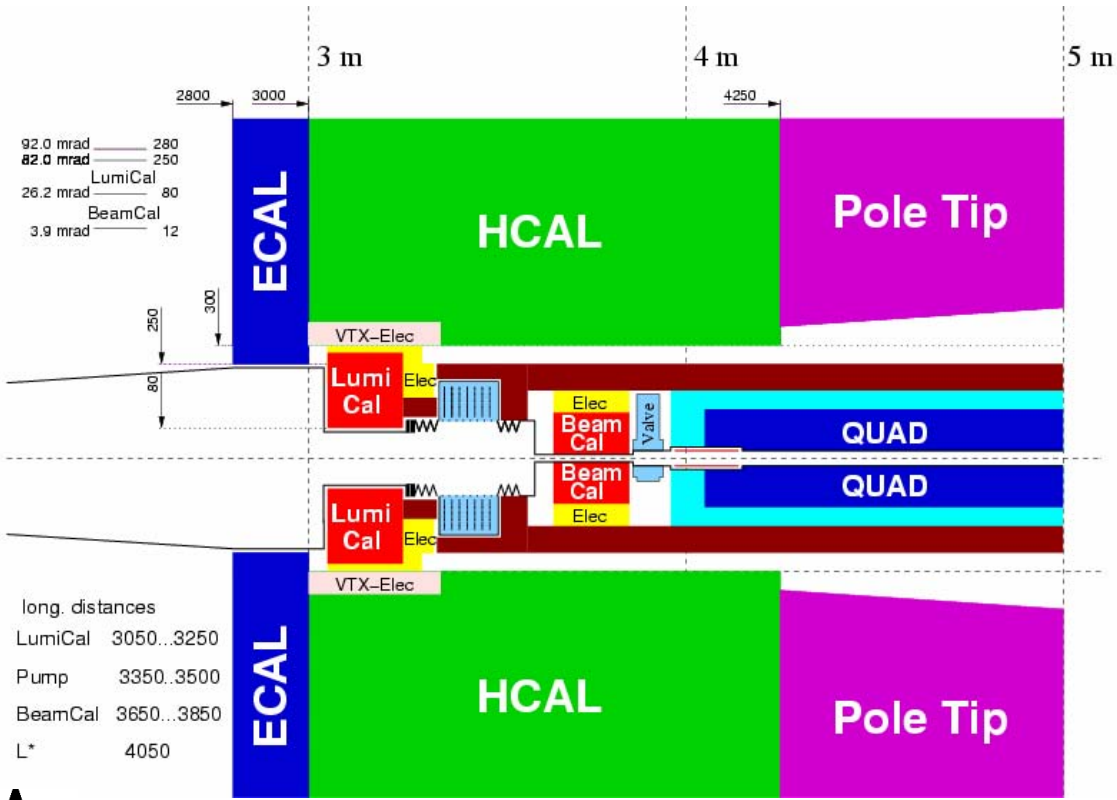
Detectors and physics simulations

Electronics design

Sensors tests

Engineering design

Prototypes design & tests



Luminosity R&D Status

Pure electron MC

Reconstruction Algorithms

Detector properties

'Real physics' MC

Bhabha + Beamstrahlung + Beamspread

Events selection

Design optimization (Dense design, Margins in between cells, Maximum peak shower design)

Electronics noise and 'Dead' Cells

$$\Delta L/L = \Delta N/N\,(\sigma(\theta), \Delta\theta, E, \sigma(E))$$

$$\Delta N/N \approx 10^{-4}$$

High statistics MC

Luminosity Future Steps

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

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

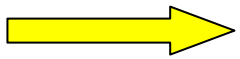
Luminosity with polarised beams (Gideon Alexander)

Luminosity with a crossing angle

Sensors design & tests

Electronics design

Prototype



Final Design

Tel Aviv University

Collaboration

High precision design

LCWS 2005

Thank You !