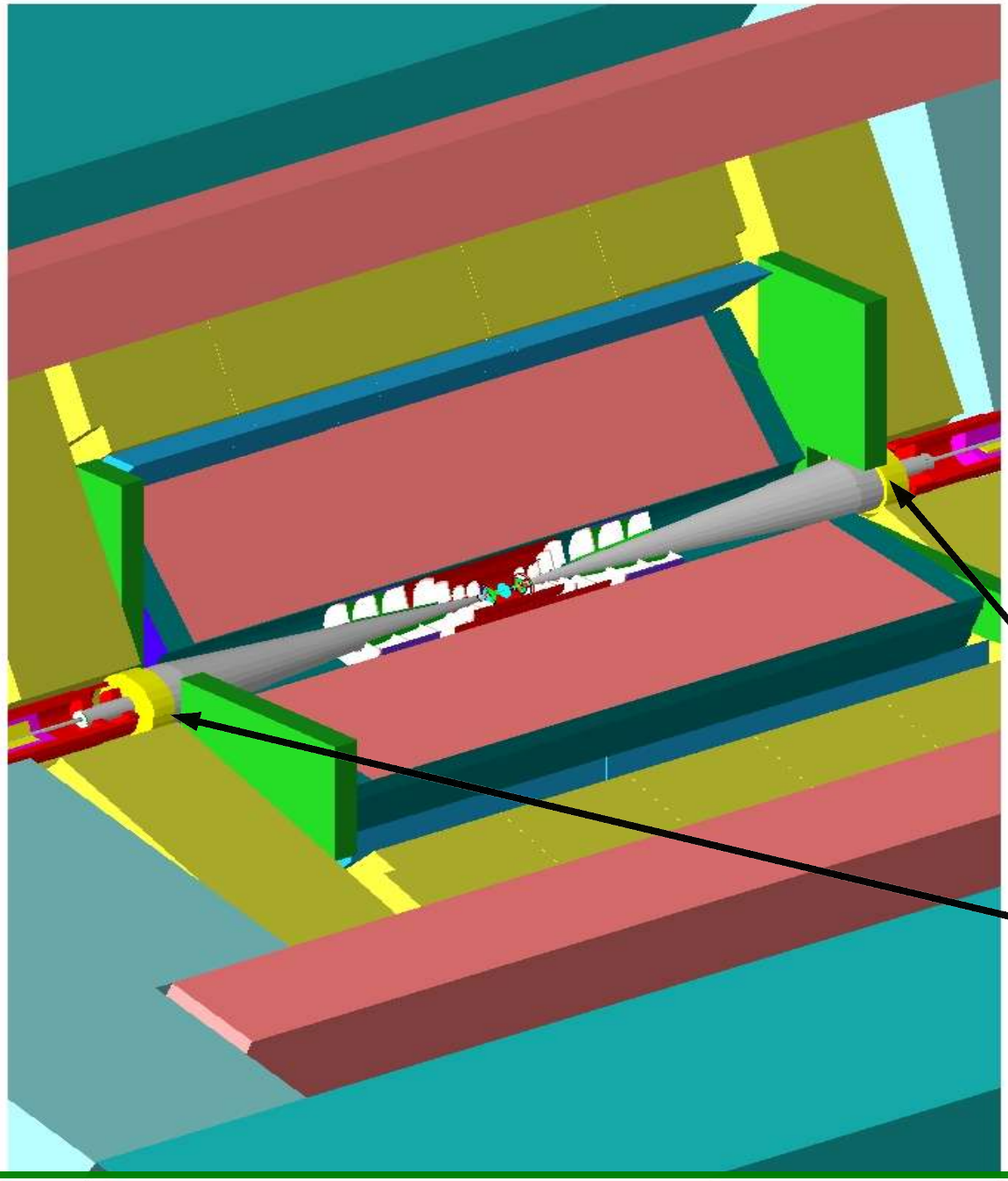
LumiCal Simulation

Bogdan Pawlik
INP PAS Krakow
Bogdan.Pawlik@ifj.edu.pl

ECFA ILC Workshop
Vienna 14-17 Nov 2005

LumiCal description

- LumiCal consists of 30 tungsten disks, thickness of 1X0 each (0.35 cm)
- Inner /outer radius of disk is respectively 8 cm/28cm
- Each disk has attached silicon strip detector (0.05 cm)
- Strip Design
  - Every second detector has either 120 radial strips (φ read-out) or 64 concentric strips (θ read-out only)
- Pad Design
  - each detector divided into 10/60 rings and 24 sectors

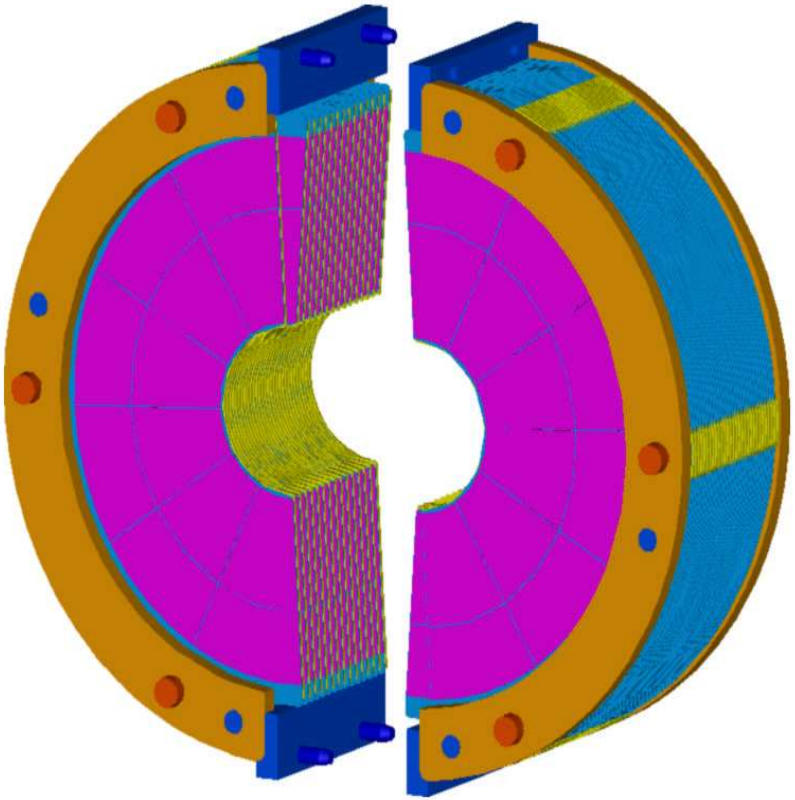


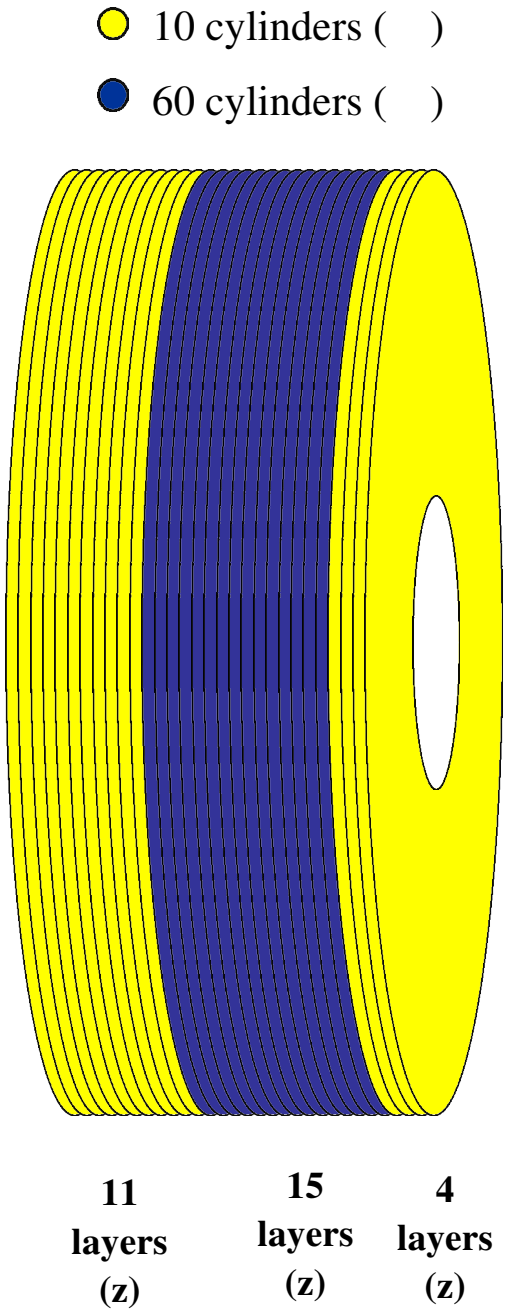
LCD Detector

LumiCal is to provide precise luminosity measurement based on Bhabha scattering events detection

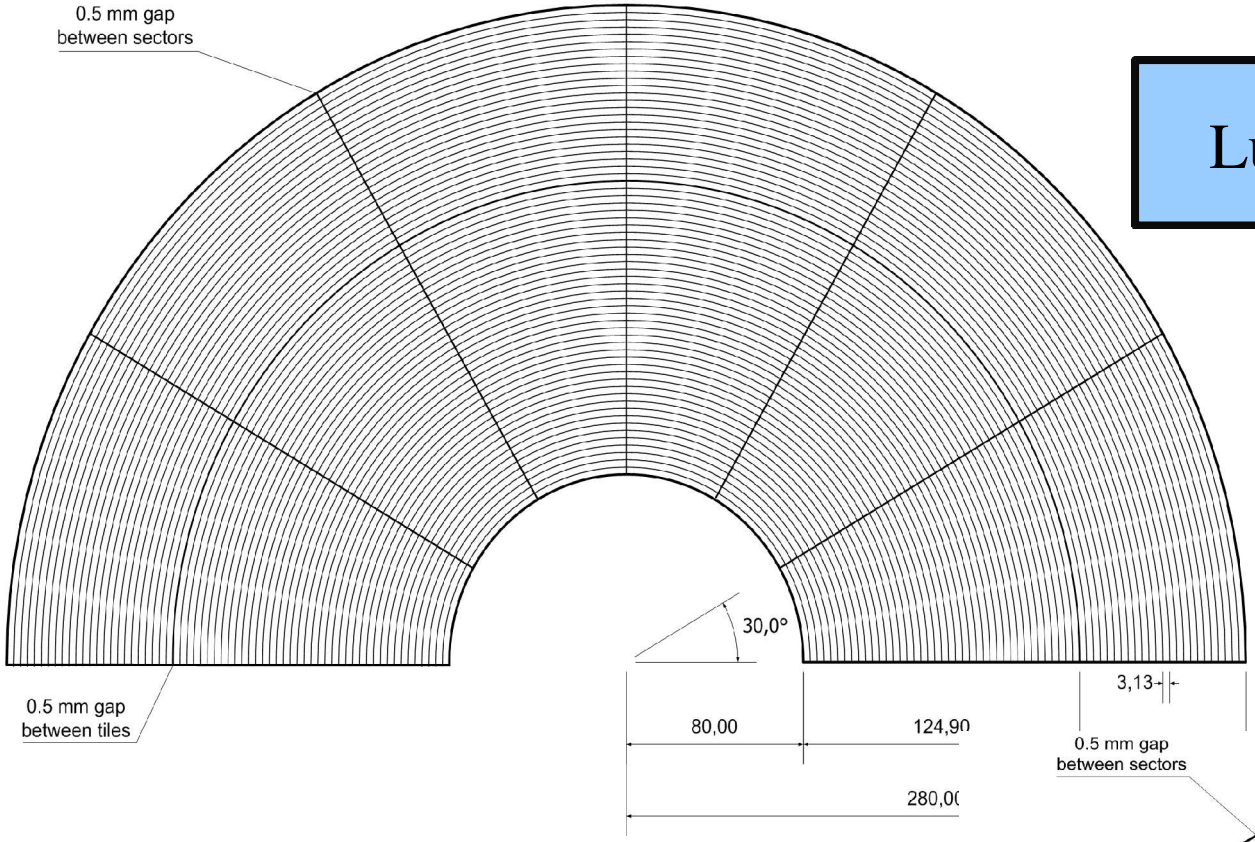
LumiCal

LumiCal (mech. design)

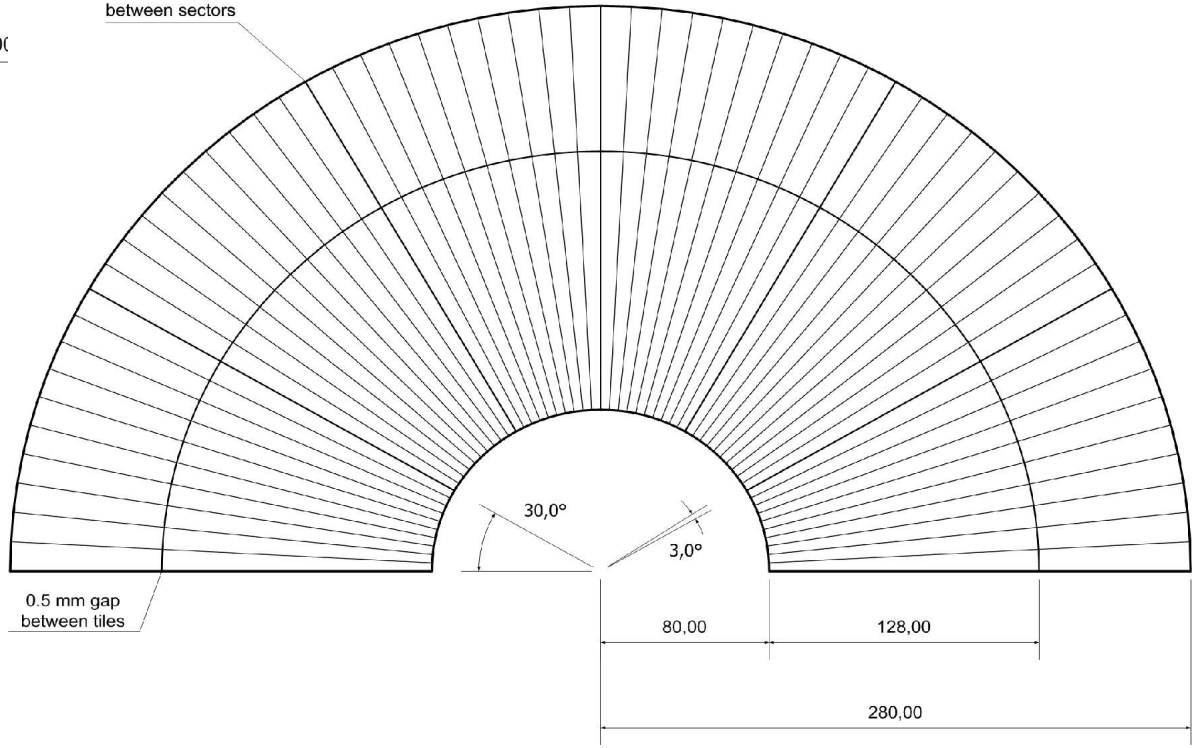




LumiCal θ-sensor



LumiCal φ-sensor



Data Sample

- Geant3 (cuts 100keV for gammas and 1Mev for electrons)
- Events generated with Bhlumi

  + BeamStrahlung (GUINEA-PIG) at 250 GeV nominal beam energy

- Events were generated in the range

$$0.7*\theta\text{min} < \theta < 2*\theta\text{max}$$

- Cuts applied

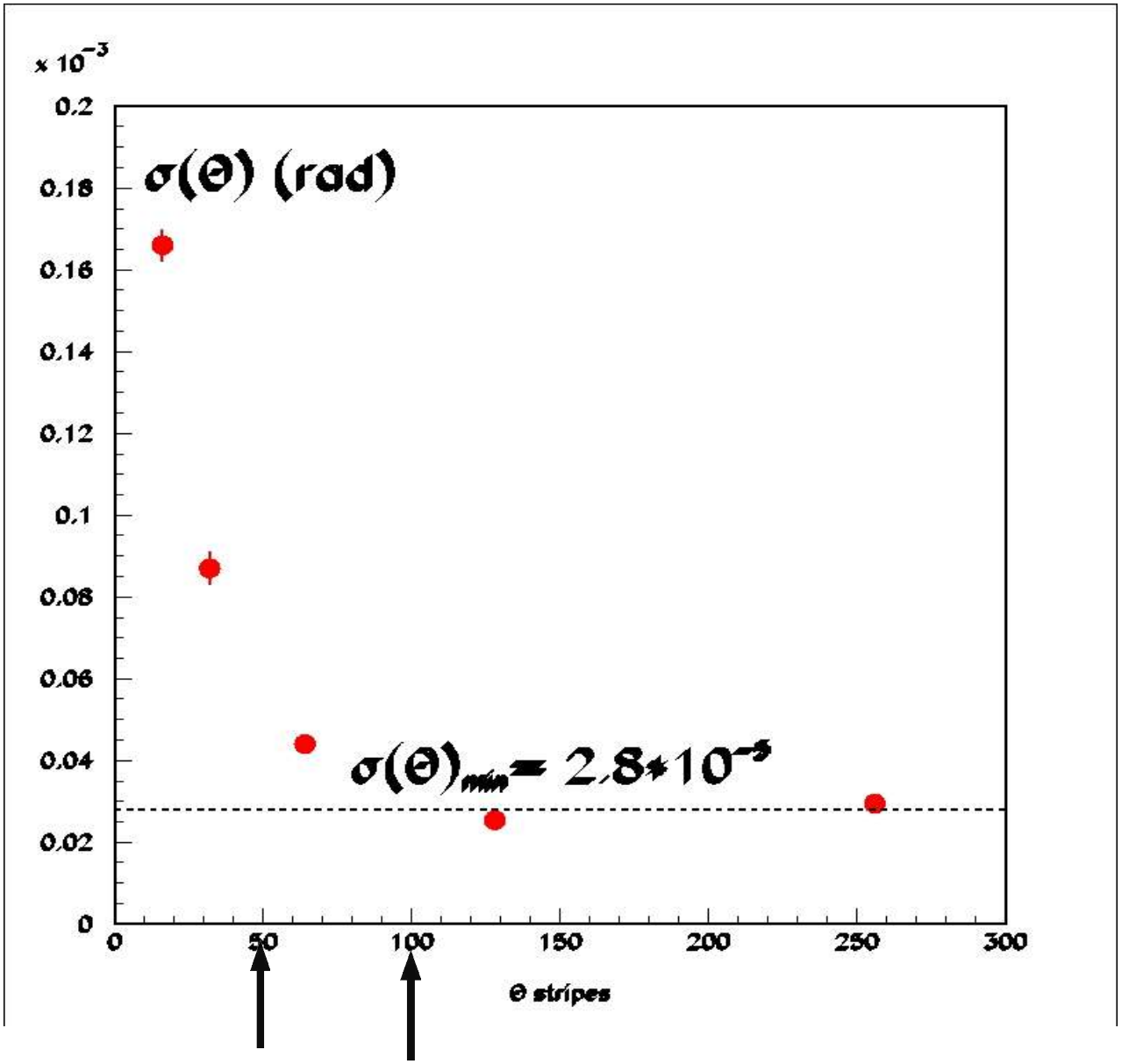
$$E_{cal} > 0.8 E_{beam}$$

$$0.028\ rad < \theta < 0.080\ rad$$

Reconstruction method

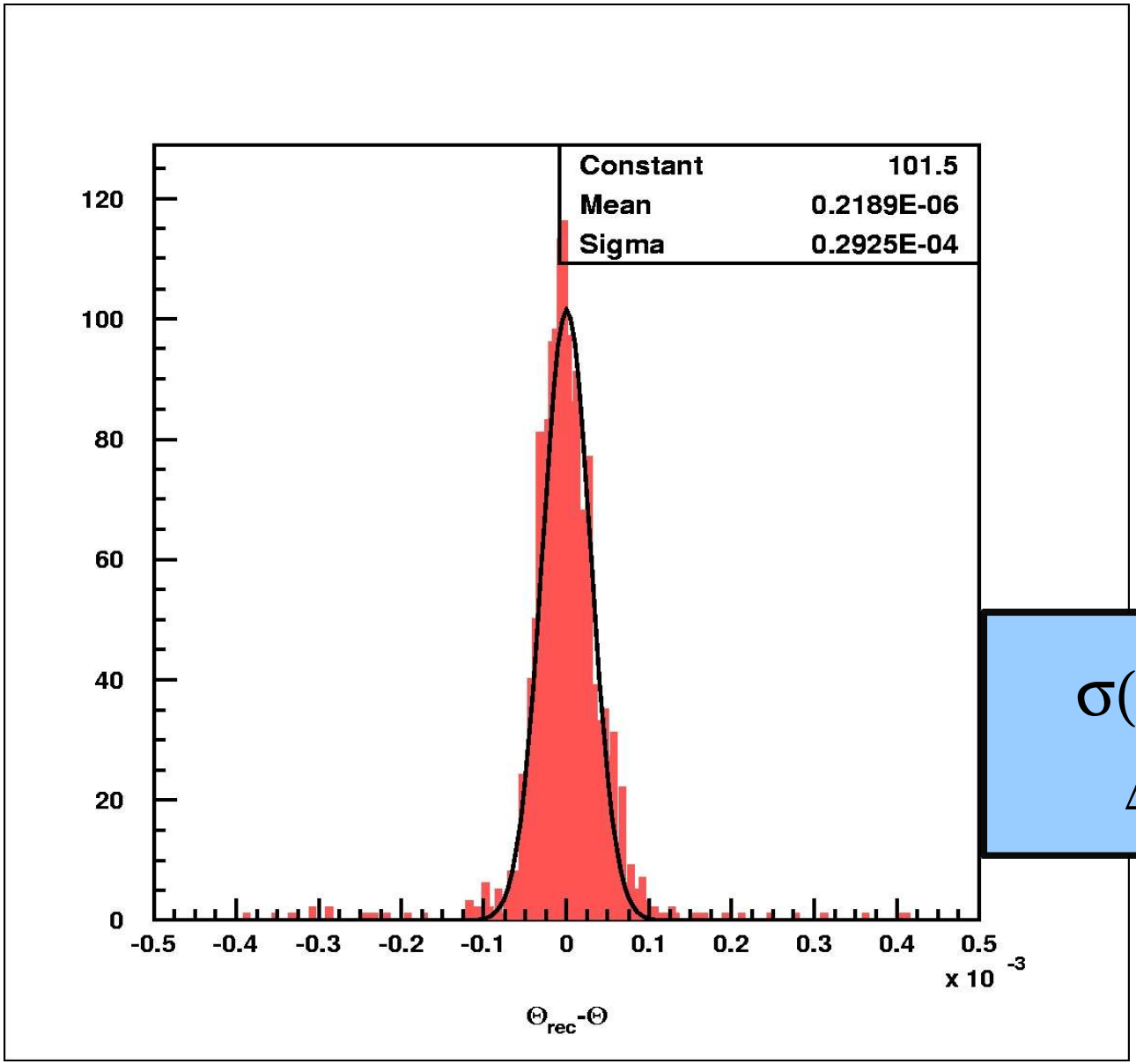
- For each LumiCal disk set of clusters (continuous chain of fired strips) is found.
- Their positions is estimated as weighted average of fired strip positions
- Weight of a strip is defined as $w_s = log(C*E_s/E_c)$ where constant $C \approx 8$ was tuned to minimize offset and $\sigma(\theta)$
- All clusters from all planes are combined to form "towers" - continuous chain clusters beginning at the first plane laying within radius R around position of the first cluster

Optimization of θ–cell size



*Resolution σ(θ) saturates at value ~3*10^{-5} for 100 strips (2 mm cell size along the radius)*

θ angle resolution *(64 strips)*

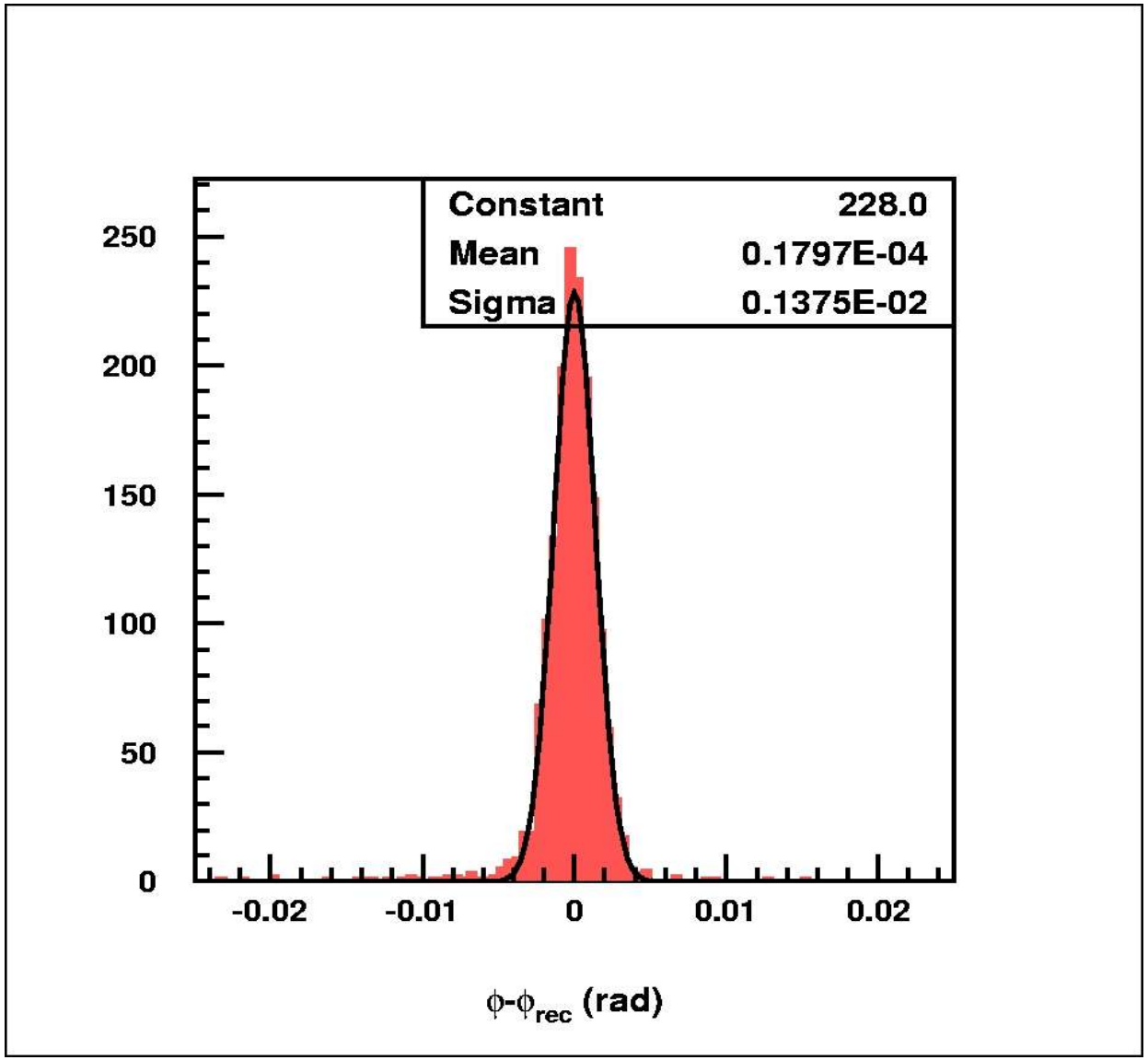


3 mm cell size

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

$\Delta\theta = 2.1 * 10^{-7}$ rad

φ angle resolution

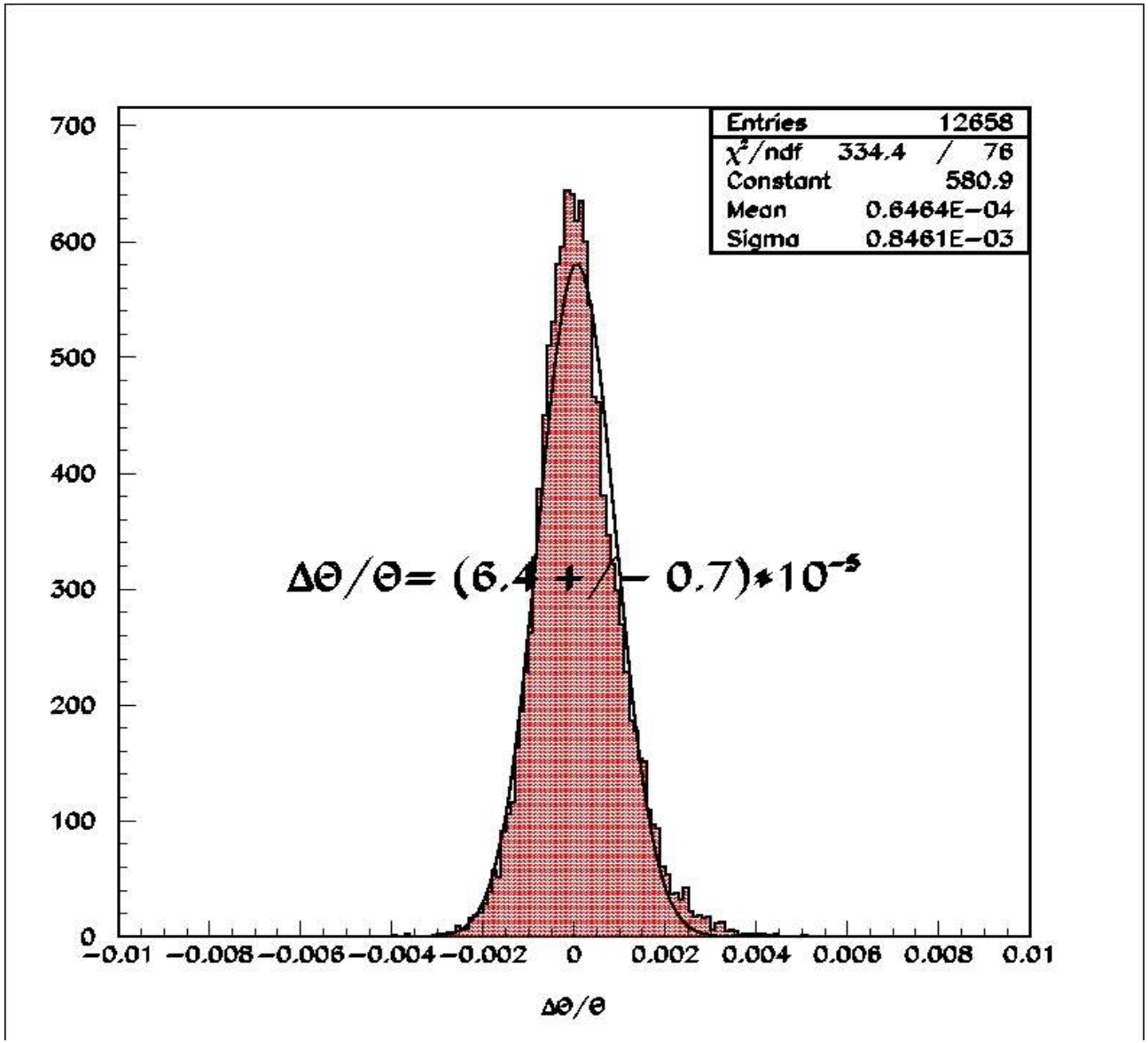


Cell size 3deg

$\sigma(\varphi) = 1.4*10^{-3}$ rad

$\Delta\varphi = 1.8*10^{-5}$ rad

Bias for polar angle Δθ



Average relative bias
for the simulated LumiCal

$$\Delta\theta/\theta = (6.4 \pm 0.7) * 10^{-5}$$

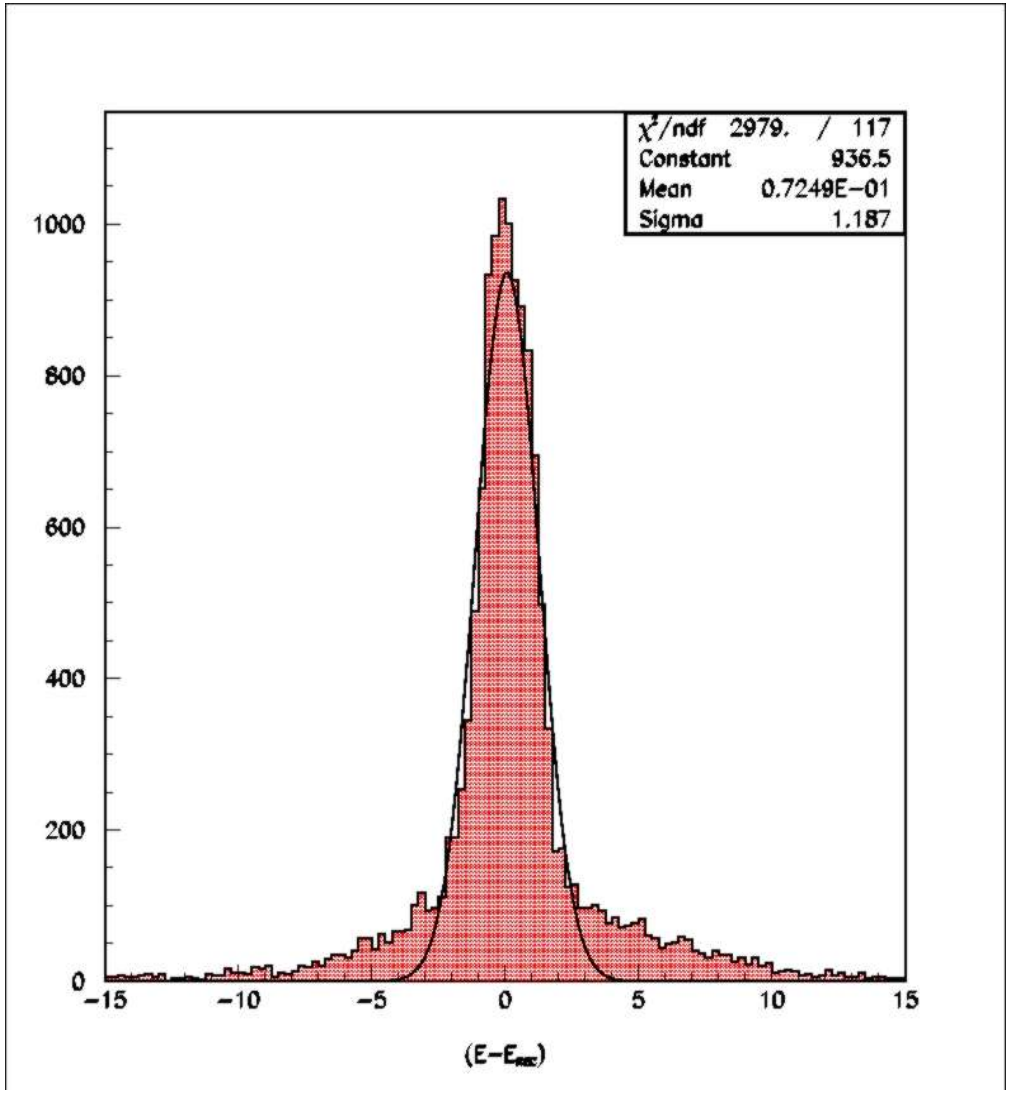
according to formula

$$\Delta L / L \approx 2 * \Delta\theta/\theta$$

one may expect

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

Calibrated Energy Resolution σ(E)



- Calibrated energy

$$E_{CAL} = E_{DEP} * f_C$$

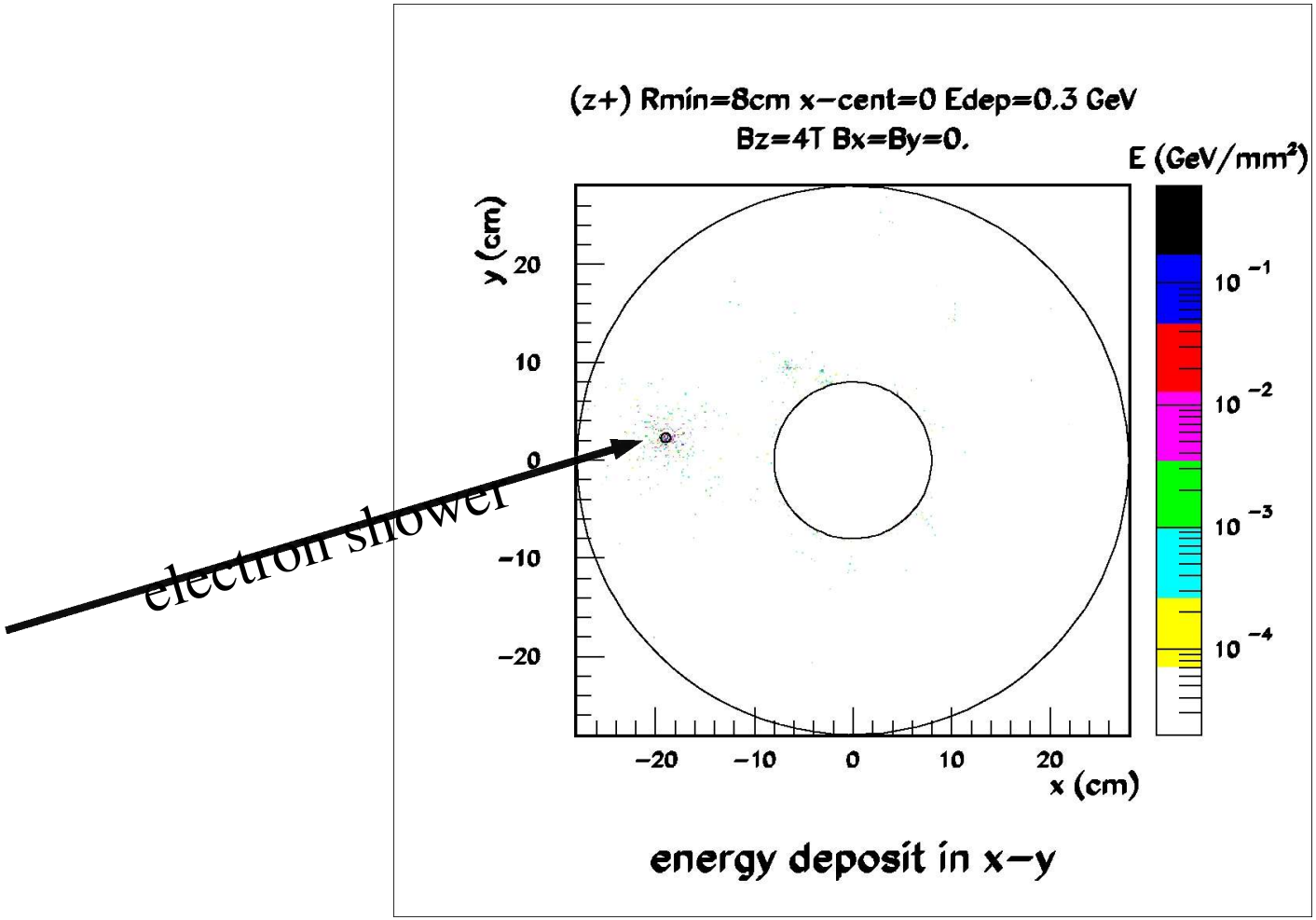
- Distribution is not Gaussian fitted σ= 1.2 GeV
- RMS however is 2.5
- This gives an estimate

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

at 250GeV

Energy deposit in Lumical xangle=0mr

Rmin=8cm, N=129 000



σ = 5.8 nb (seen)

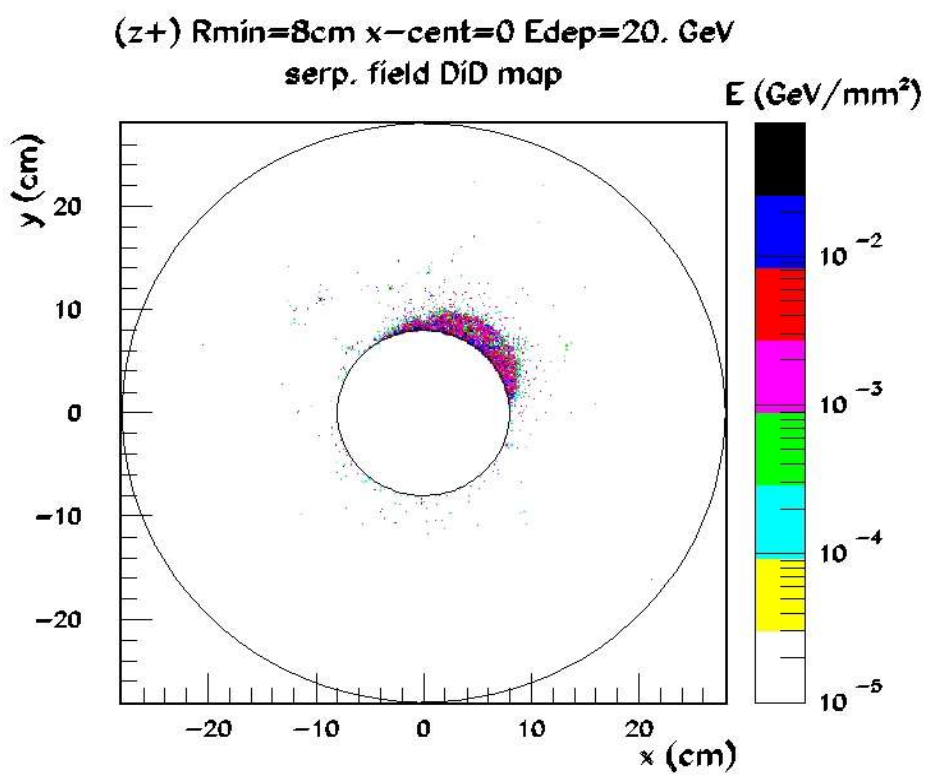
Summary *(0/2 mrad crossing angle)*

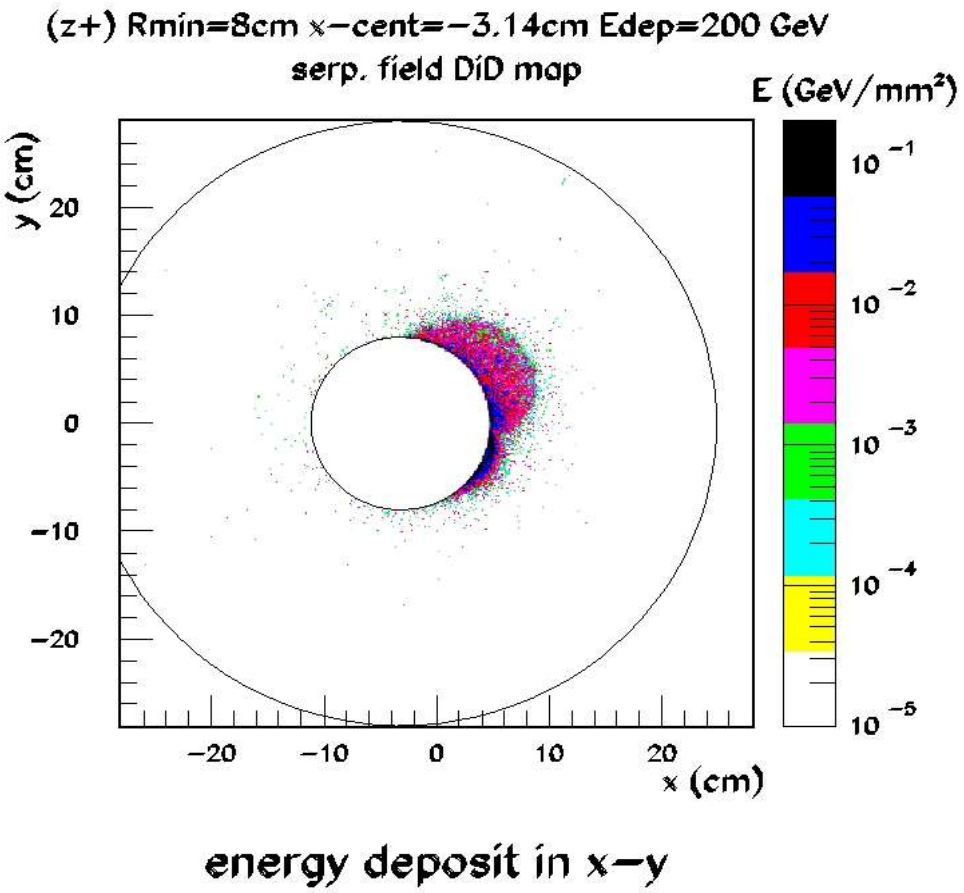
- Stripped LumiCal with 4000 read-out channels can achieve resolution in polar angle θ order of $3x10^{-5}$ radian and offset $\Delta\theta/\theta \approx 6x10^{-5}$ which results in $\Delta L/L \approx 10^{-4}$
- Measurement of electron energy can be done with accuracy $\sigma(E) \sim (0.08 \div 0.16)\sqrt{E}$ at 250GeV
- No need to increase segmentation of θ-planes as the resolution saturates at a level $3*10^{-5}$ for about 100 strips
- Impact of beamstrahlung negligible

Implications of 20mr crossing angle

- need serpentine field and Lorentz boost
- Lab Frame is no longer CMS, no simple “back to back” Bhabha event tag
- products of beam-strahlung get into LumiCal acceptance
- θ and φ offsets become correlated due to serpentine field

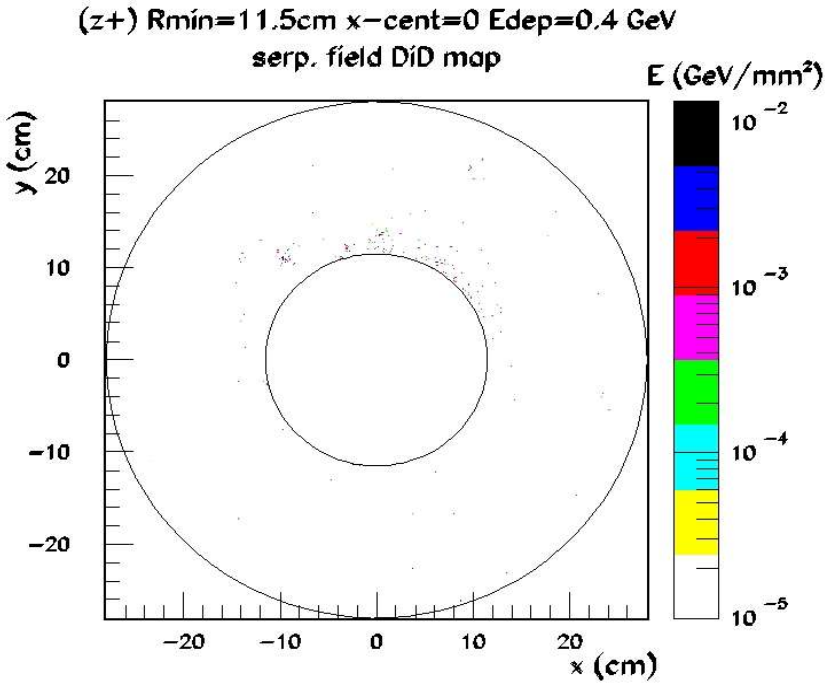
Energy deposit in Lumical xangle=20mr
Rmin=8cm, DiD field, N=129 000





- keeping LumiCal aligned with axis of the detector (xc=0) makes the measured distributions of Bhabha scattering asymmetric
- aligning LumiCal with outgoing beam pipes (xc=-3.14 cm for 20mr crossing angle, increases background energy deposit by factor of 10.
- in order to reduce background energy seen in LumiCal, inner radius of sensors can be increased from 8cm to 11.5cm and 13.5 cm for xc=0 and xc = -3.14 respectively.
- this procedure reduces background to harmless level of 0.3-0.4 GeV per bunch crossing as we had for 0mr crossing angle
- reconstruction accuracy remains the same as for 0mr setup, but seen cross-section drops from 5.8 nb to 1.8/1.5 nb for xc = 0.
  and xc = -3.14 cm respectively.

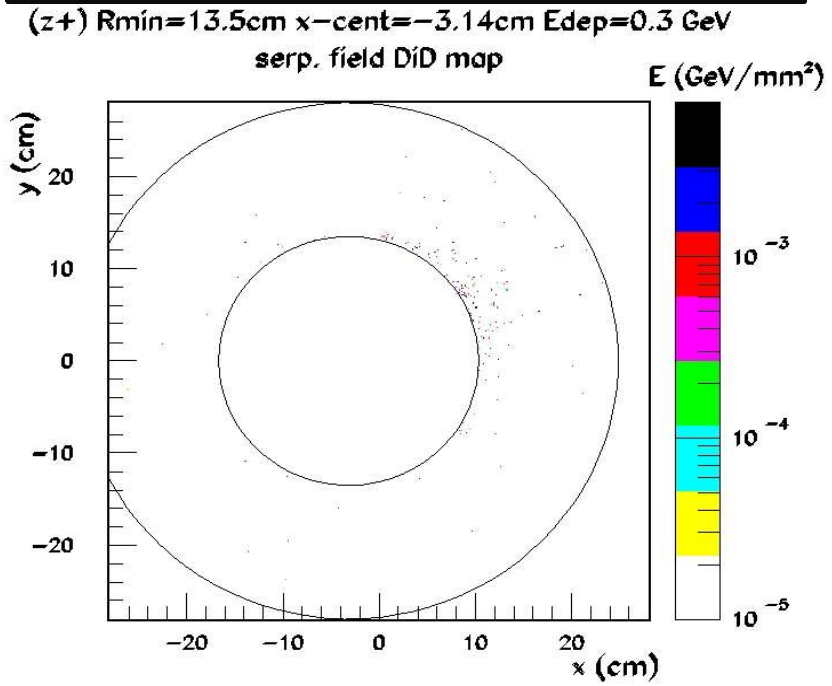
Energy deposit in Lumical xangle=20mr enlarged Rmin, DiD field, N=129 000



θ = 38-86 mr

σ = 1.8 nb

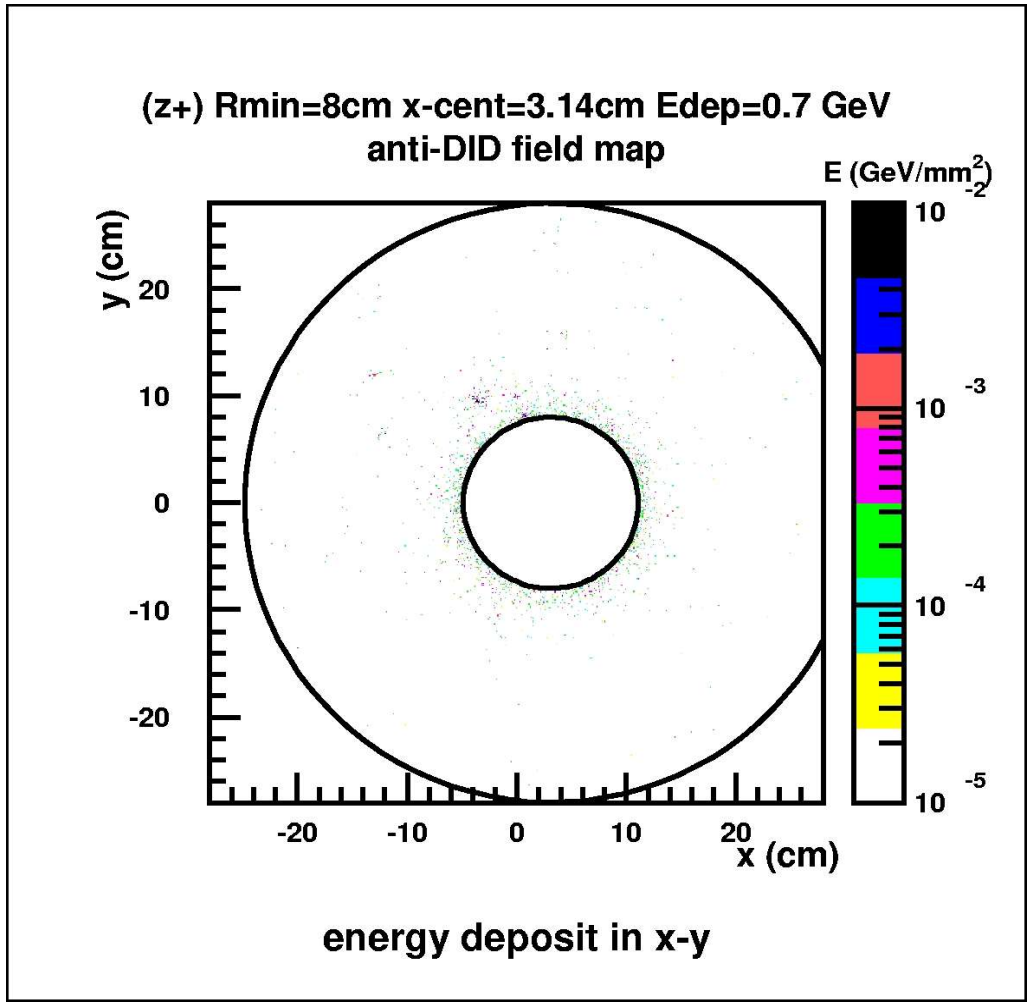
Preffered option with DiD



θ = 44-86 mr

σ = 1.5 nb

20 mr crossing angle, anti-DID field



nominal Rmin = 8 cm

LumiCal aligned with out-beam

xc = 3.14 cm

harmless background

performance as for 0/2 mr

Summary *(20mr crossing angle)*

To maintain same as for 0/2mr performance we need to move LumiCal to be aligned with outgoing beam and

- with DID field
  - inner radius must be enlarged to 13 cm (measured cross-section drops by factor of 4)
- with anti-DID field
  - no need to change dimensions

Performance of present configurations

Parameter	Pad Performance	Strip Performance
Energy resolution	$25\% \ (\sqrt{GeV})$	$8{:}16\% \ (\sqrt{GeV})$
θ resolution	$3.5 * 10^{-5}$ rad	$2.9 * 10^{-5}$ rad
φ resolution	10^{-2} rad	10^{-3} rad
$\Delta\theta$	~ $1.5 * 10^{-6}$ rad	~$2.1* 10^{-6}$ rad
Electronics channels	25,200	3720 (with bonding sectors) 13,320 (without bonding)

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

Simulated signal size in electron charge units for LumiCal