Simulation of the forward region

Ronen Ingbir

Tel Aviv University
HEP Experimental Group

FCAL Collaboration
High precision design

Cambridge ILC software tools meeting

FCAL Collaboration

Goals : design and construction of

- **Luminosity detector**
- **Beam monitor**
- **Photons calorimeter**

"Vinča" Institute of Nuclear Sciences, **Belgrade**

AGH University, **Cracow**

Institute of Nuclear Physics, **Cracow**

Jagellonian University, **Cracow**

University of **Colorado**

DESY

Joint Institute Nuclear Research **Dubna**

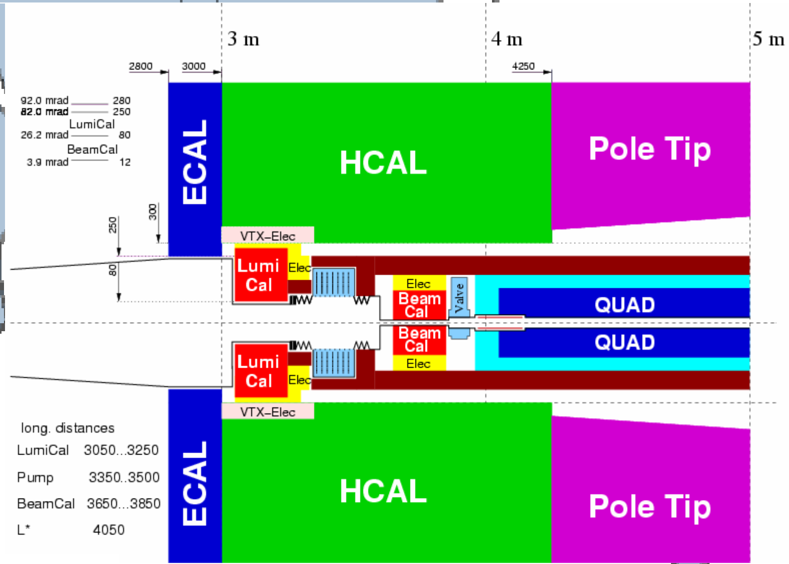
National Center of Particle & HEP **Minsk**

Brookhaven **NY**

Prague Acad. of Science

Institute HEP **Protvino**

Tel Aviv University



FCAL Collaboration *High precision design*

Tel Aviv University
HEP Experimental Group

Cambridge2006

FCAL simulation tools

Detector simulation: Geant-3, Geant-4 (and Mokka)
next step: G3/G4 comparison

Physics: BHWIDE, CIRCE, GUNIEA-PIG, WHIZARD

High statistics / Fast detector simulation

Electronics simulation: noise, dead cells, digitization
(Geant-3 + Fortran code)

BeamCal

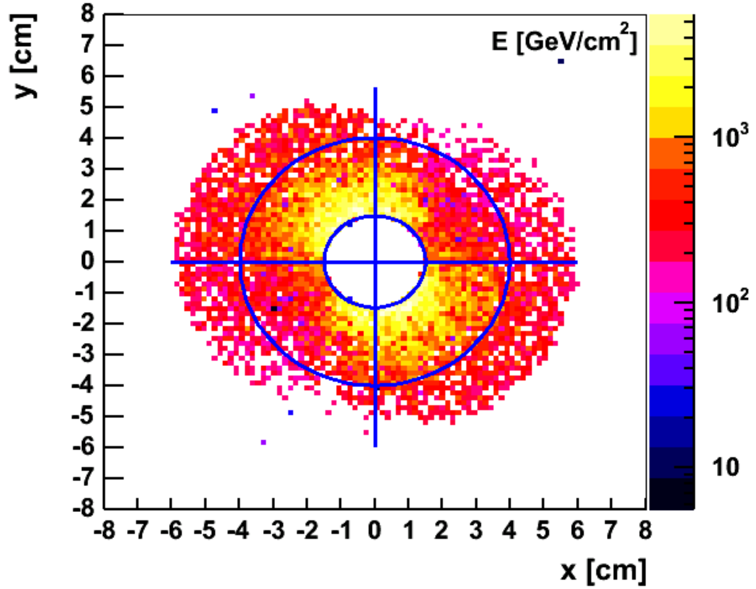
Detection of electrons/photons at low angle
Shielding the inner detector
Beam diagnostics from beamstrahlung
electrons/positron pairs.

Beam diagnostics : BS Pairs

- Observables (examples):
  - total energy
  - first radial moment
  - left/right, up/down,
  - forward/backward asymmetries

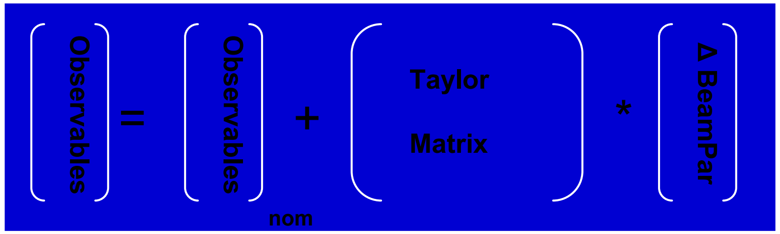
Christian Grah, DESY-Zuethen

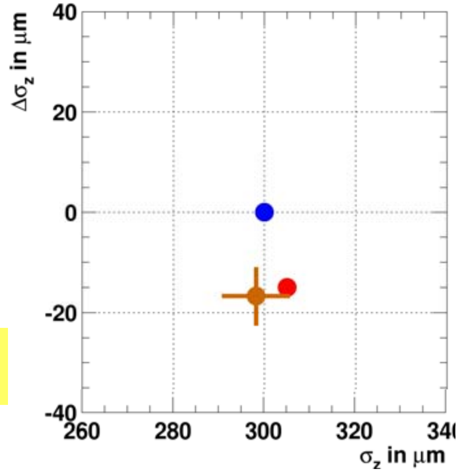
detector: realistic segmentation, ideal resolution, bunch by bunch resolution

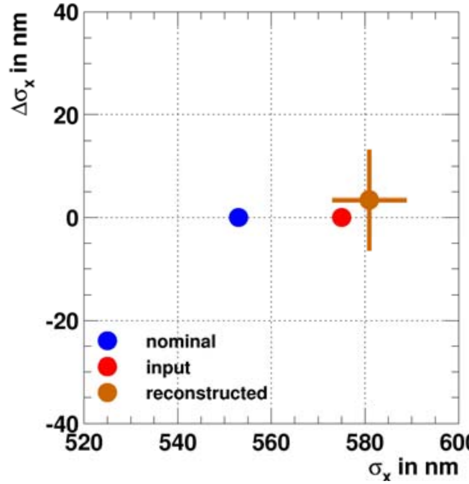


Solved by matrix inversion (Moore-Penrose Inverse)

1st order Taylor-Exp.

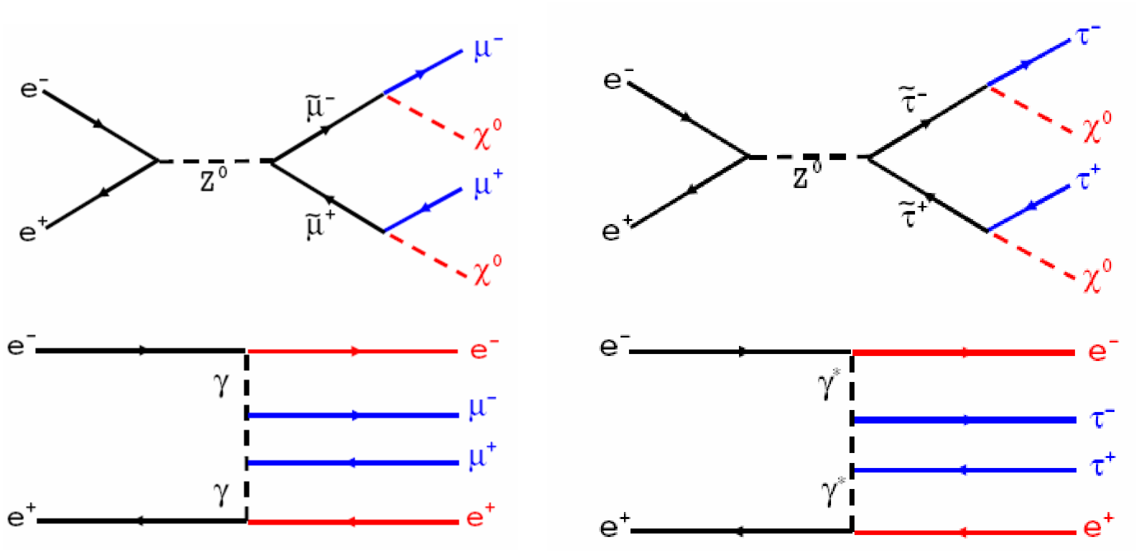






Being tested also for the 20mrad case

Particle identification in the BeamCal



SUSY analysis is done by Z.Zang(LAL)

The Physics:
SUSY particles production
Signature:
missing energy

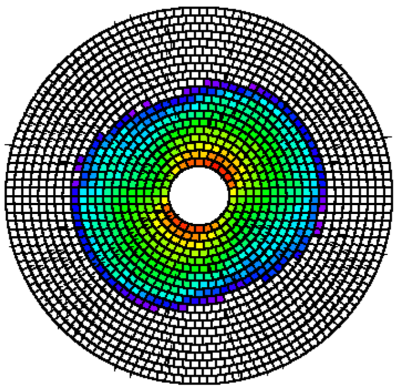
The Background:
two photons event
Signature:
missing energy
(if electrons are not tagged)

Excellent electron identification is needed down to as small angle as possible

Vladimir Drugakov NC PHEP, Minsk

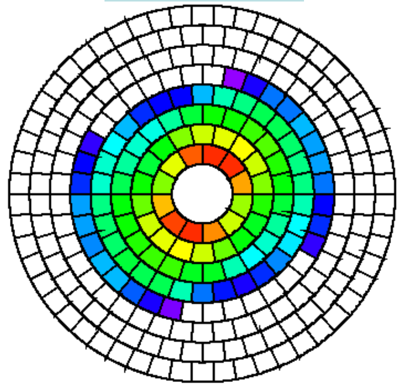
Electron detection in the BeamCal

4 mm



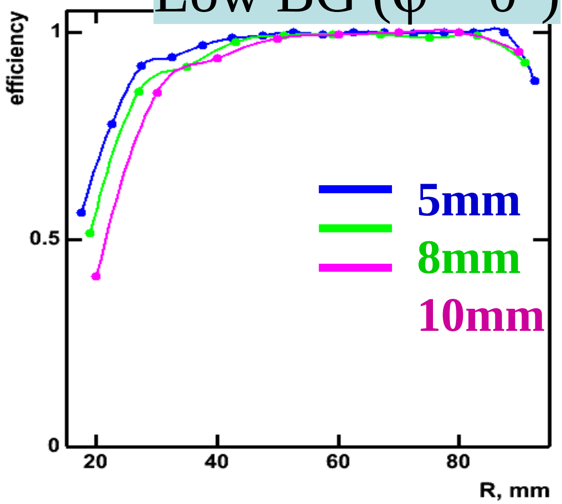
N_{rings}	20
N_{cells}	1660
$N_{channels}$	**49800**

10 mm



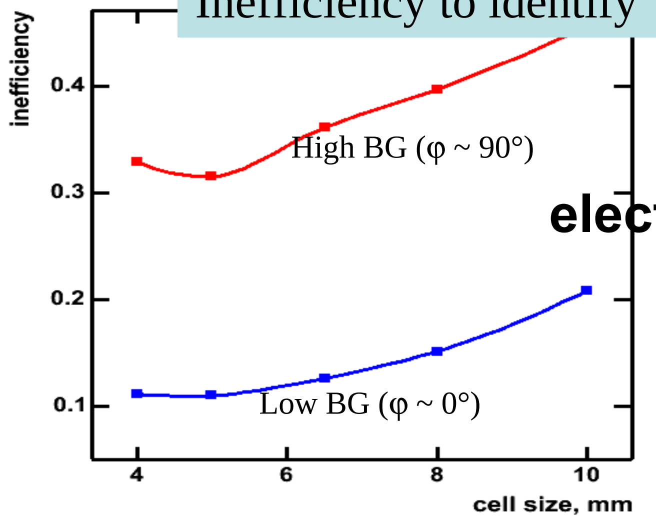
N_{rings}	8
N_{cells}	264
$N_{channels}$	**7 920**

Low BG (φ ~ 0°)



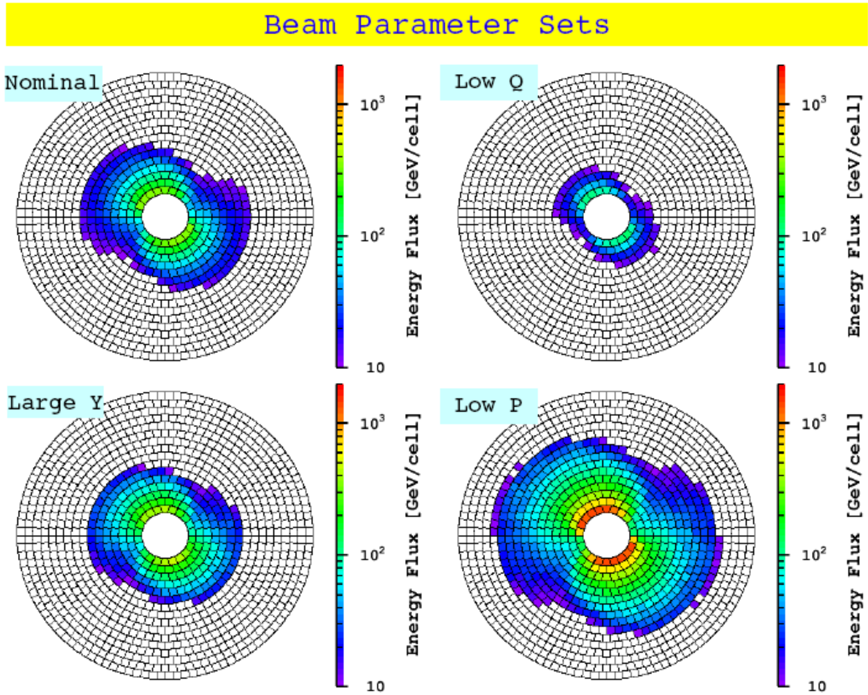
Lost particles for R < 55 mm

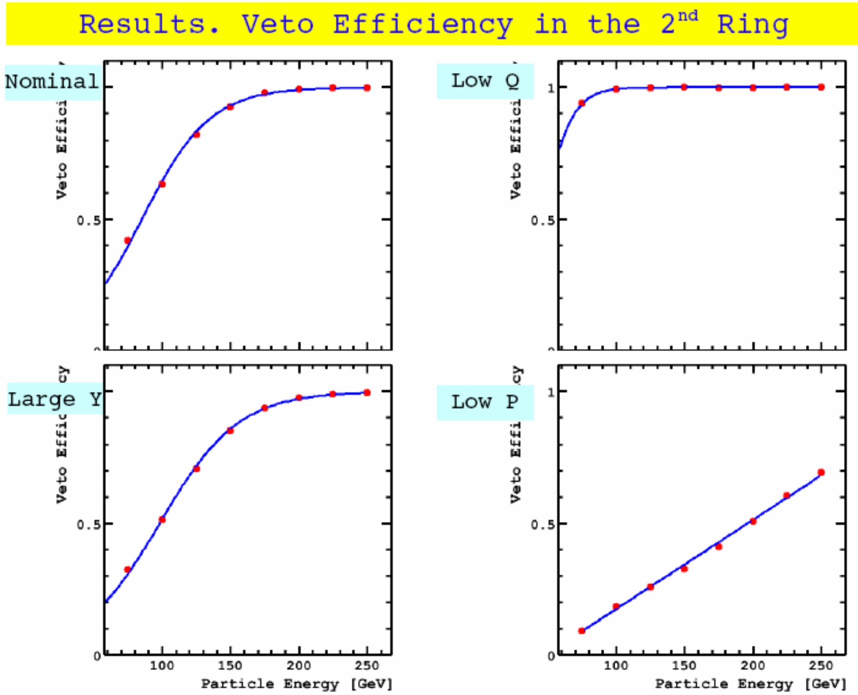
Inefficiency to identify



electrons 200 GeV

Electron detection for different beam parameters





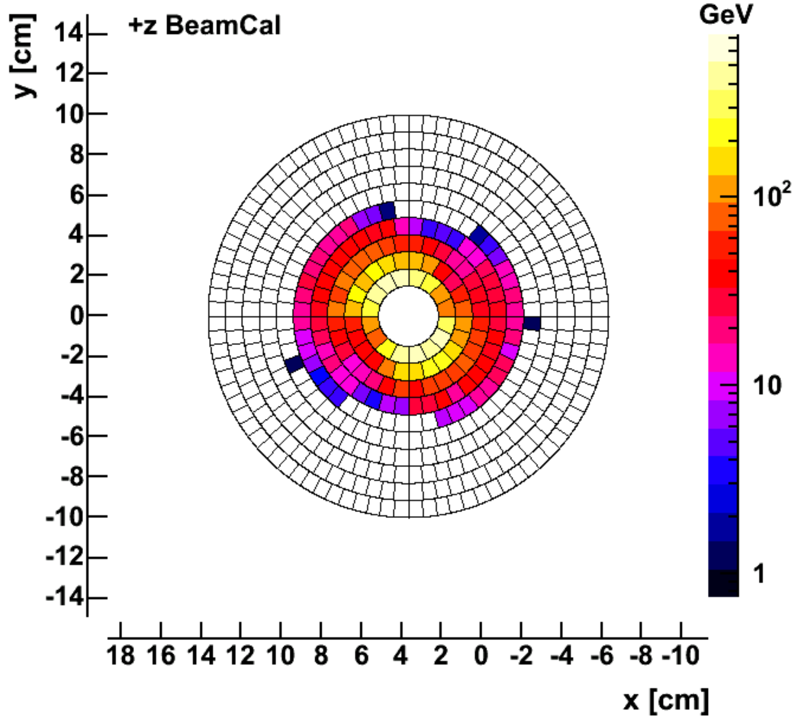
Nominal
Low Q – half Q, double Nb, shorter and smaller bunch
Large Y – longer, larger bunch
Low P – half Nb, shorter and smaller bunch

X-angle
&
magnetic field

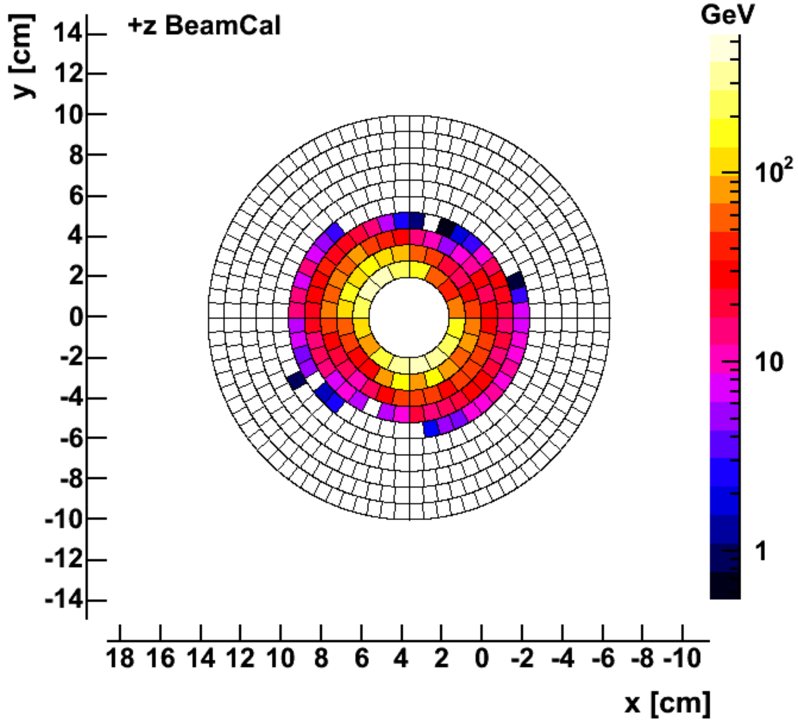
Distribution of BeamStrahlung pairs

Christian Grah,
DESY-Zuethen

Headon

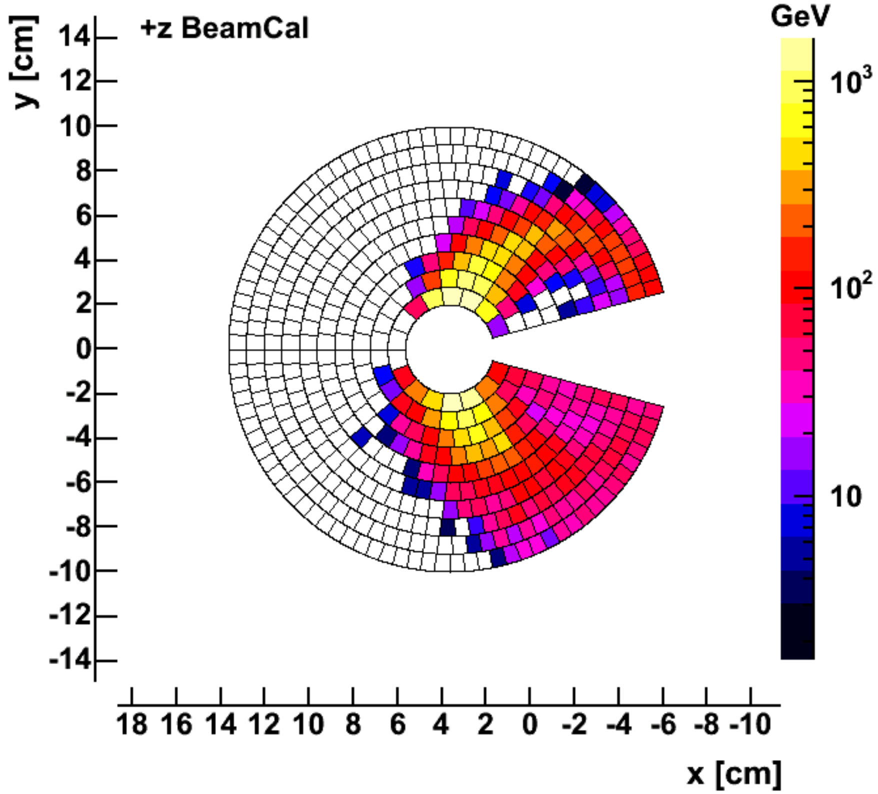


2 mrad

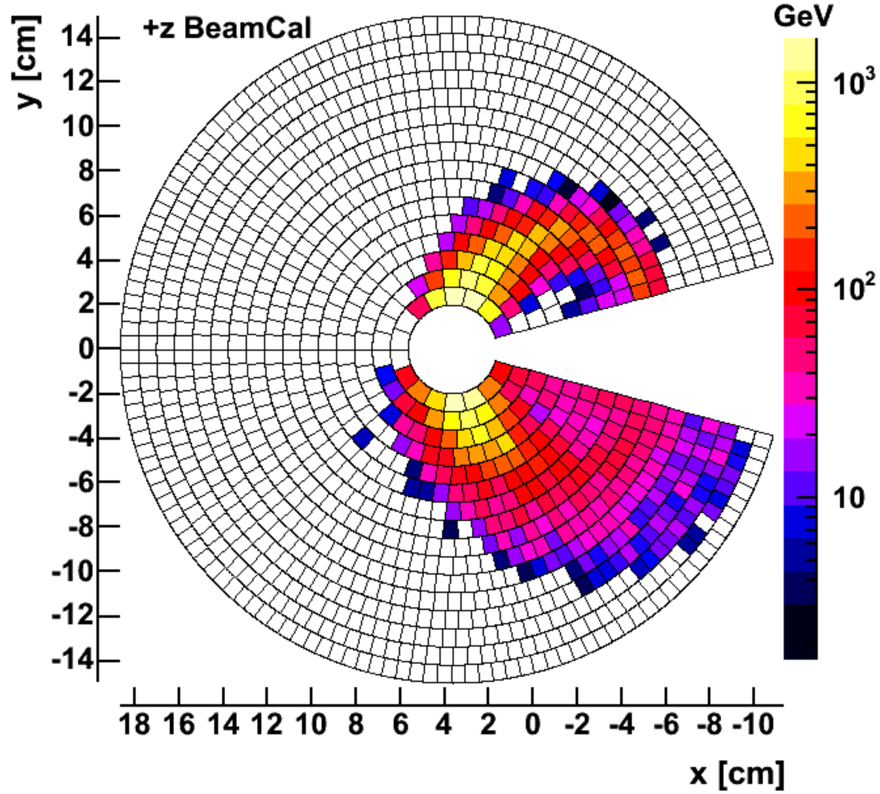


20mrad crossing angle and DID field

20 mrad, DID

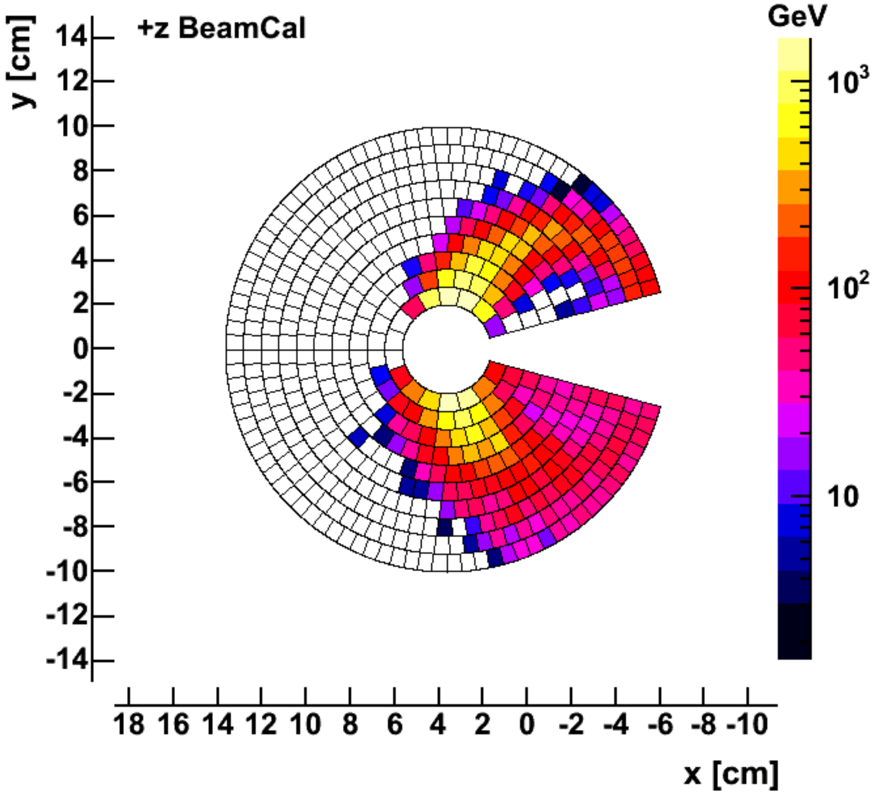


20 mrad, DID – extended Rmax

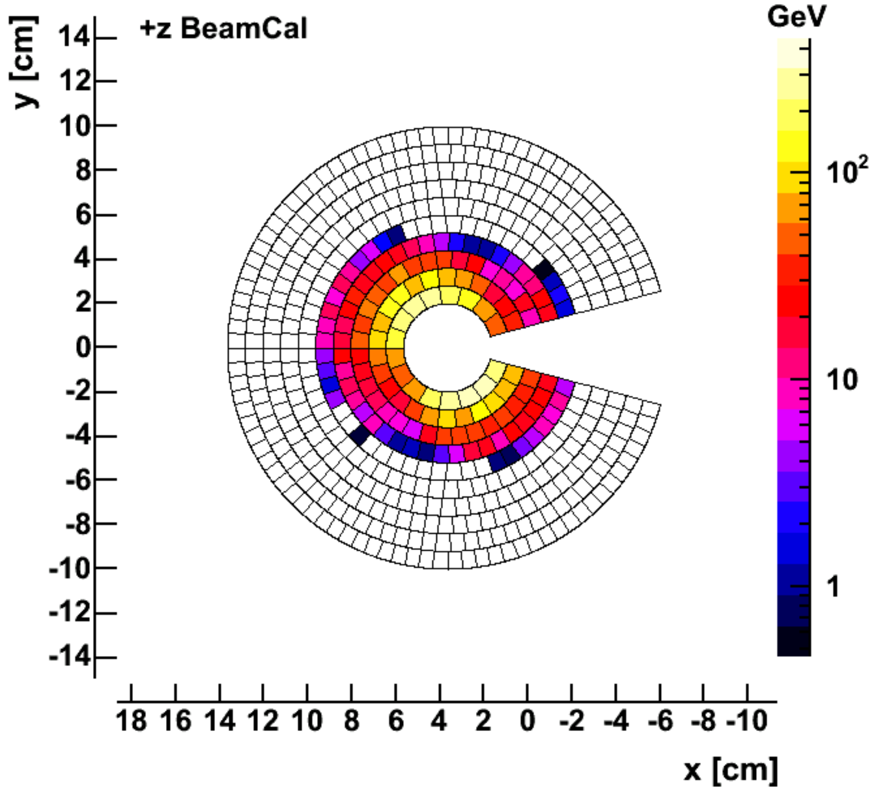


Anti DID

20 mrad, DID



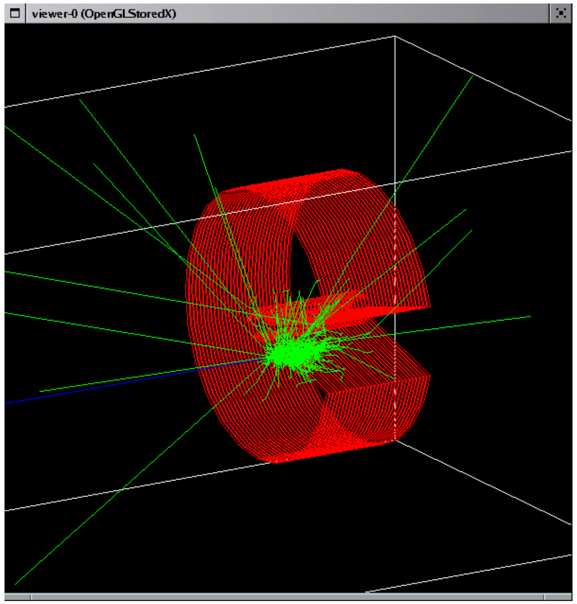
20 mrad, anti DID



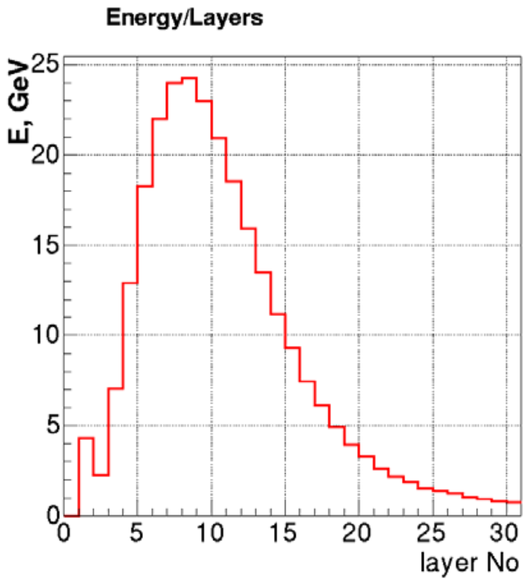
BeamCal Geant4 Simulation

- Need precise simulation for showering/realistic bfield map. Includes:
  - flexible geometry (beam crossing angle, layer thickness, variable segmentation, calorimeter tilt)
  - simplified DiD/antiDiD magnetic field
  - input – GP generated e+e- pairs
  - output – root tree with energy distribution in segments
  - 1 BX ~ 200min @ 2.4 GHz CPU

A.Sapronov



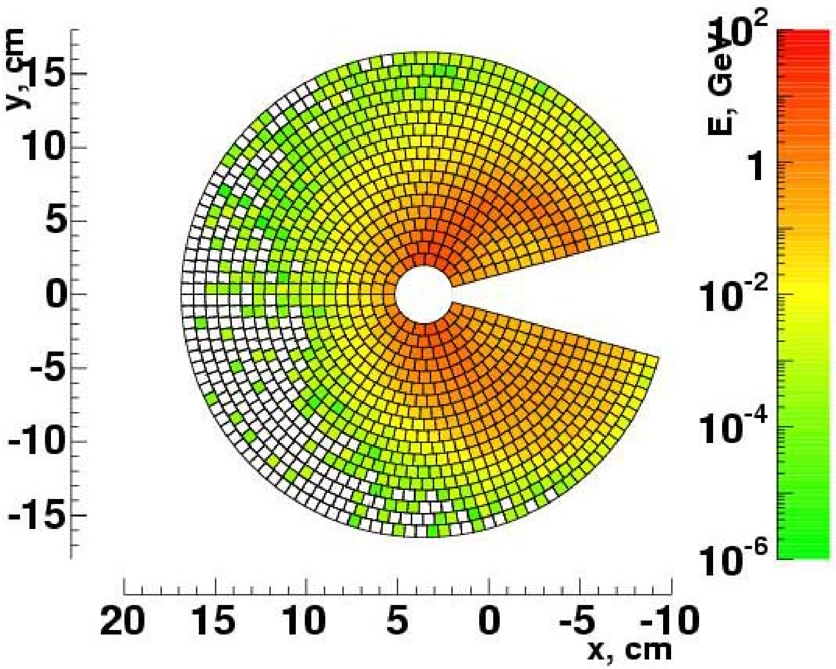
Shower visualization



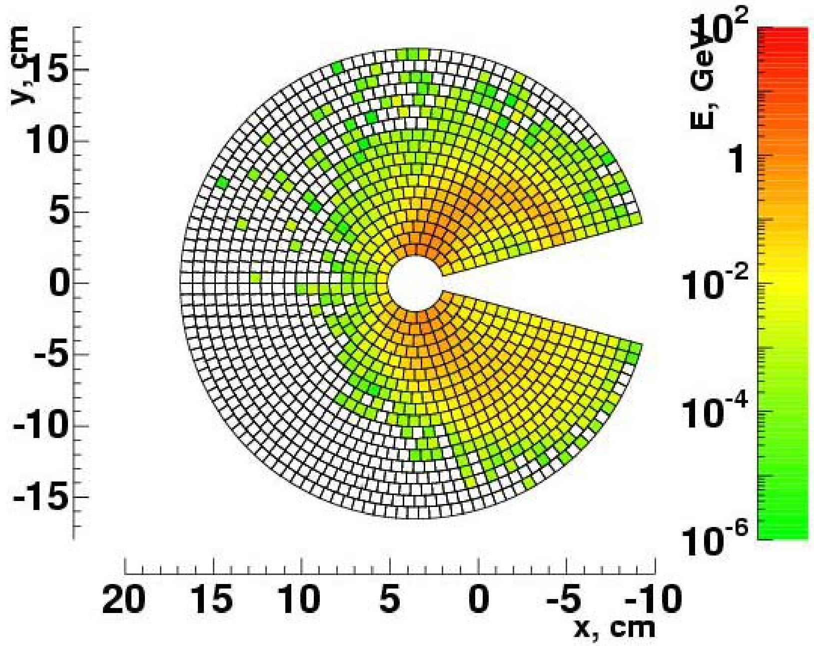
Energy/Layer distribution

B field Map

Energy deposited in the sensors of BeamCal.



All layers

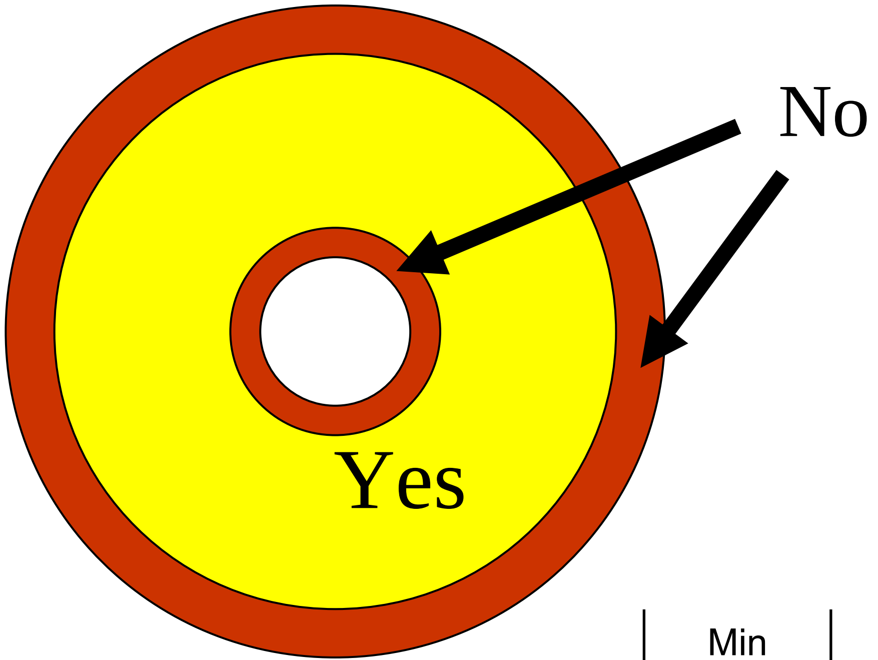


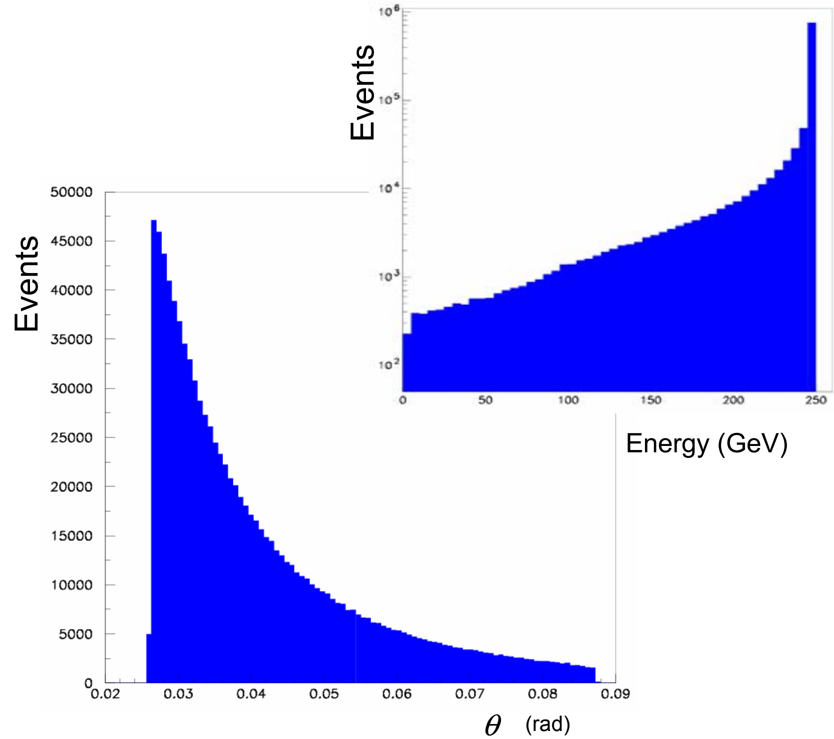
Layer 8

LumiCal

Precise measurement of the luminosity by using Bhabha events
Extend coverage of the ILC detector

Counting Bhabha events

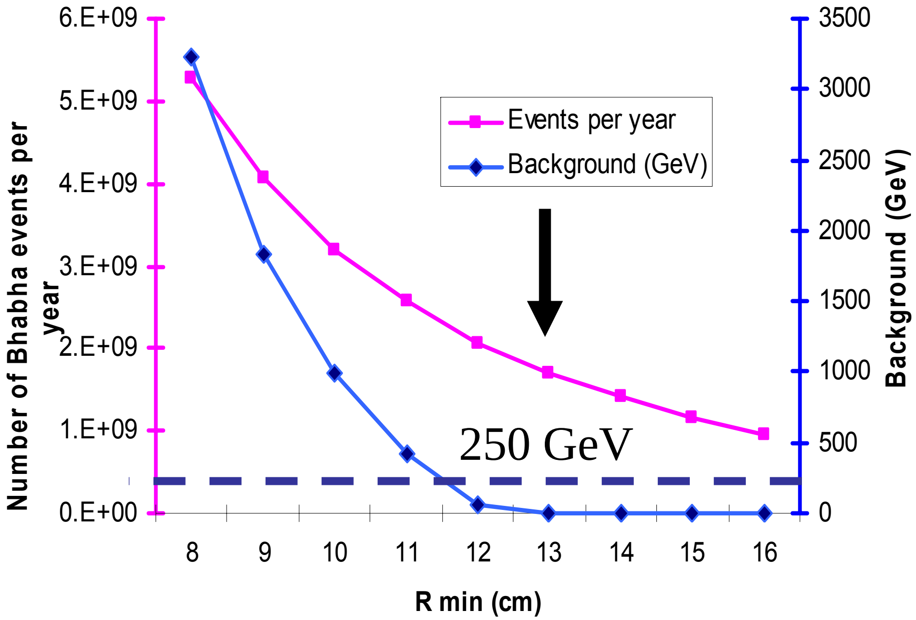


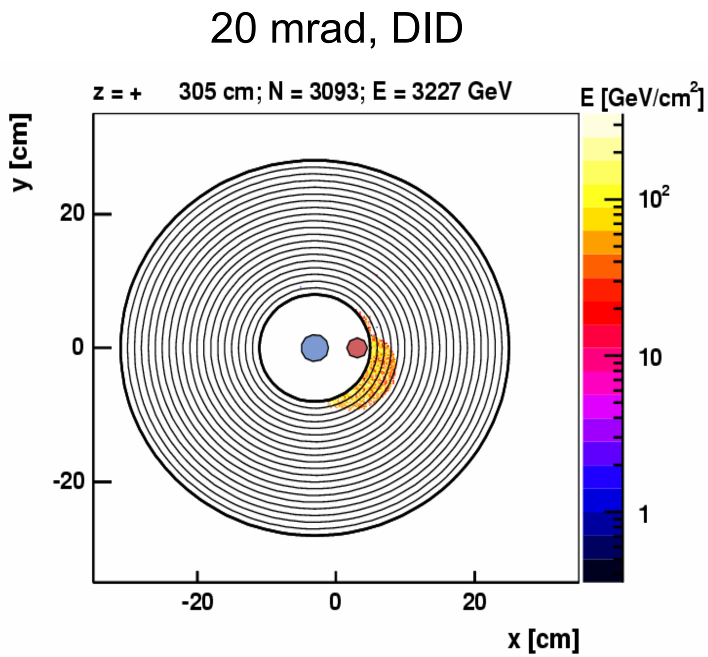


	Min	Max
R	~10 cm	~25 cm
θ	33 mrad	80 mrad

X- angle background

Beamstrahlung pair background





Christian Grah, DESY-Zuethen

Four-lepton processes

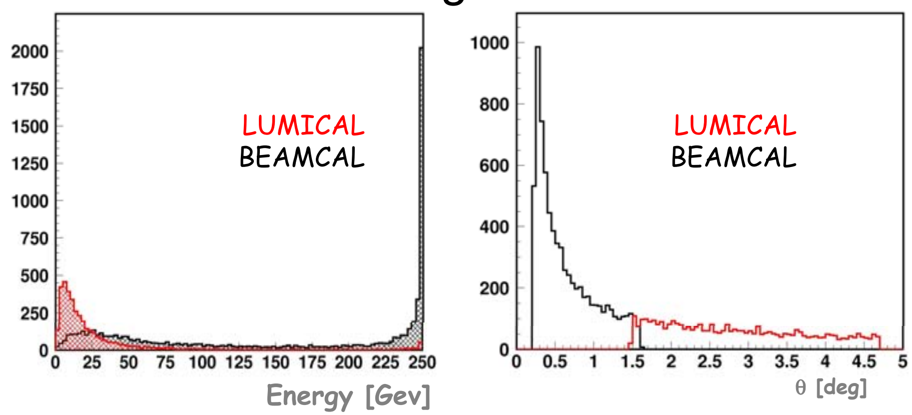
M.Pandurović / I. Božović-Jelisavčić, Belgrade

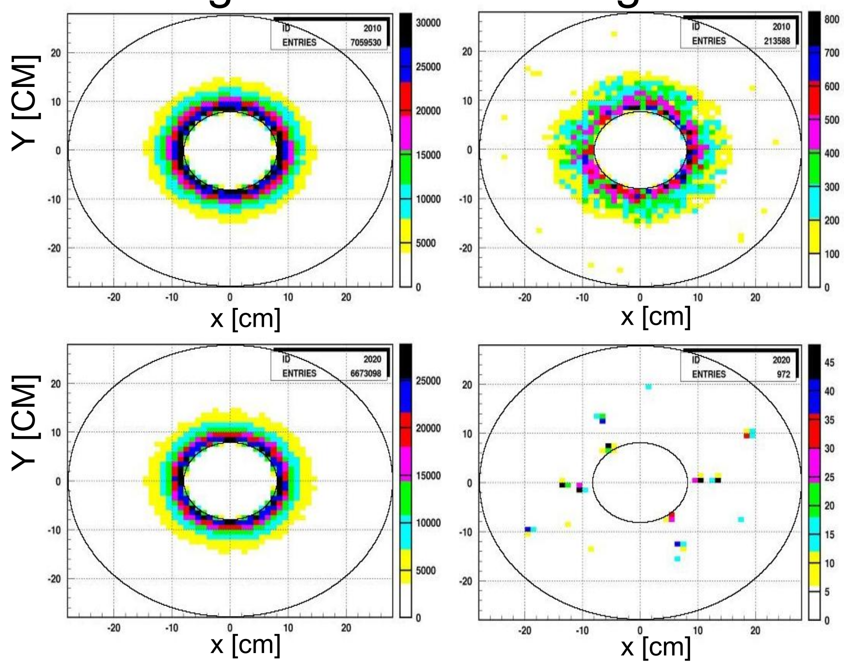
Simulation of $e^+e^- \rightarrow e^+e^- l^+l^-$ ($l = e, \mu, \tau$): **WHIZARD**

Bhabha scattering: **BHLUMI**

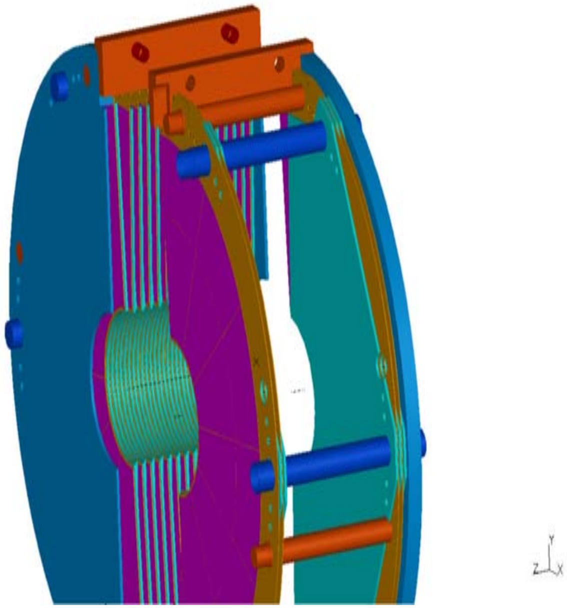
Detector: **Geant-3**

Background



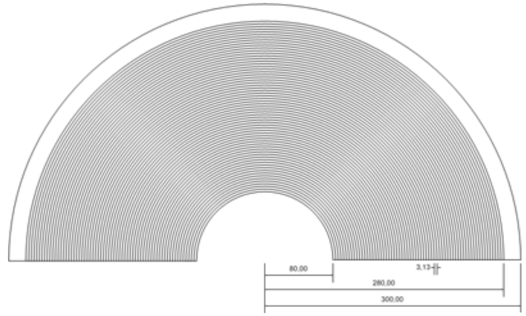


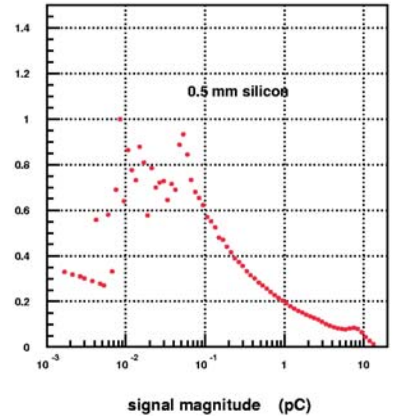
Strip design - signal digitization



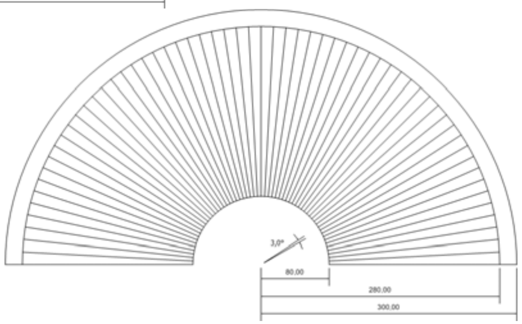
Bogdan Pawlik, Cracow

Geant-3 + Fortran code





	analog	*8-bit ADC*
σ(θ) [rad]	$(3.11\pm0.01)\times10^{-5}$	$(3.07\pm0.01)\times10^{-5}$
Δθ/θ	$(2.1\pm0.3)\times10^{-5}$	$(2.3\pm0.3)\times10^{-5}$
σ(φ) [rad]	$(1.4\pm0.1)\times10^{-3}$	$(1.4\pm0.1)\times10^{-3}$



Fast
Simulation

Luminosity precision determination

Based on BHWIDE

N_1 : Reconstructed and generated in acceptance region.

N_2 : Generated in acceptance region but reconstructed outside.

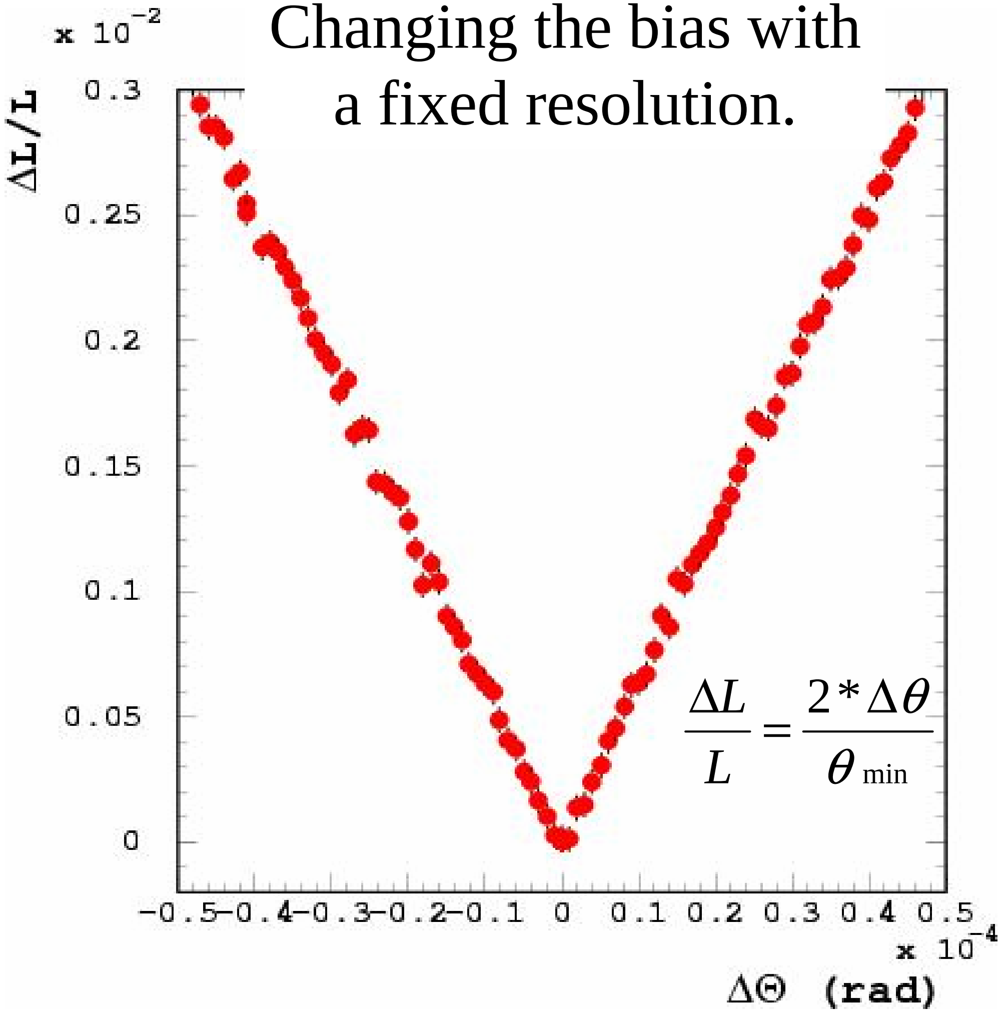
N_3 : Generated outside acceptance region but reconstructed inside.

$$\frac{\Delta L}{L} = \frac{\Delta N}{N} = \frac{N_{\mathrm{rec}} - N_{gen}}{N_{gen}} = \frac{N_3 - N_2}{N_1 + N_2}$$

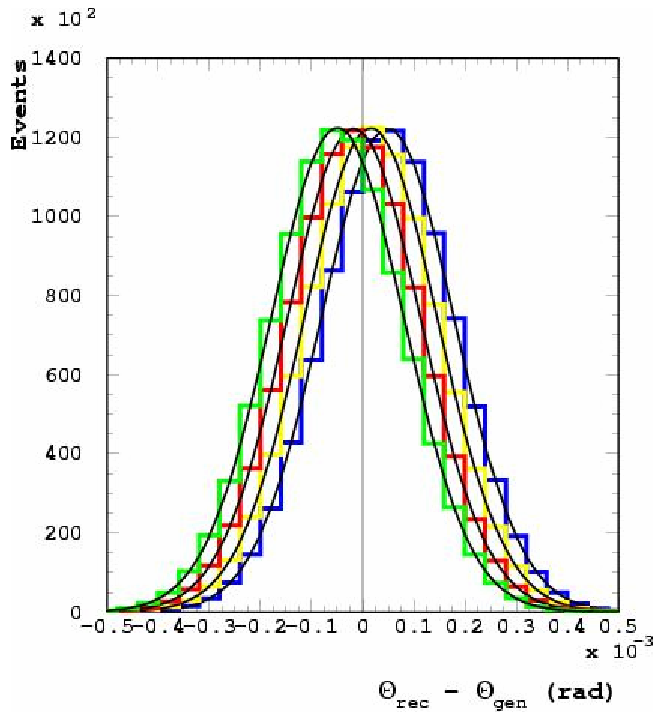
$$\delta\left(\frac{\Delta L}{L}\right) = \frac{\sqrt{(N_3 - N_2)^2 \sigma_{N_1}^2 + (N_1 + N_3)^2 \sigma_{N_2}^2 + (N_1 + N_2)^2 \sigma_{N_3}^2}}{(N_1 + N_2)^2}$$

Fast detector simulation – bias

Changing the bias with
a fixed resolution.

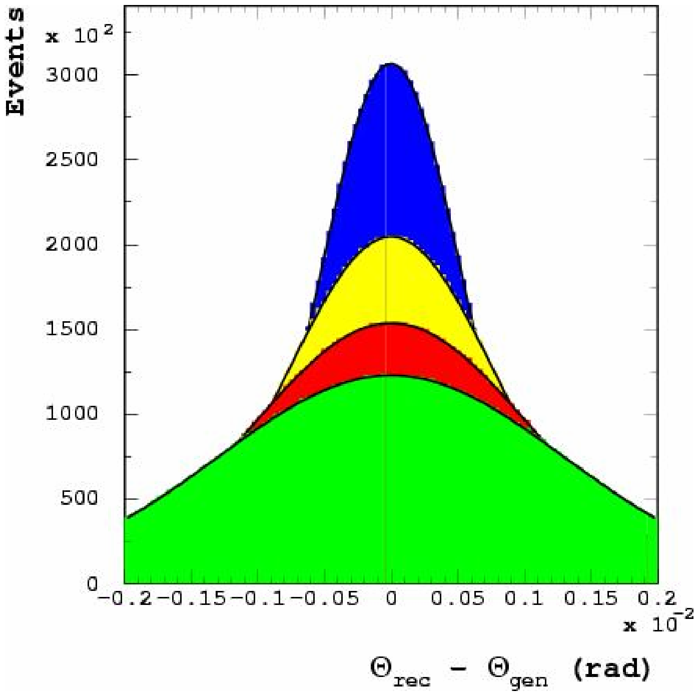


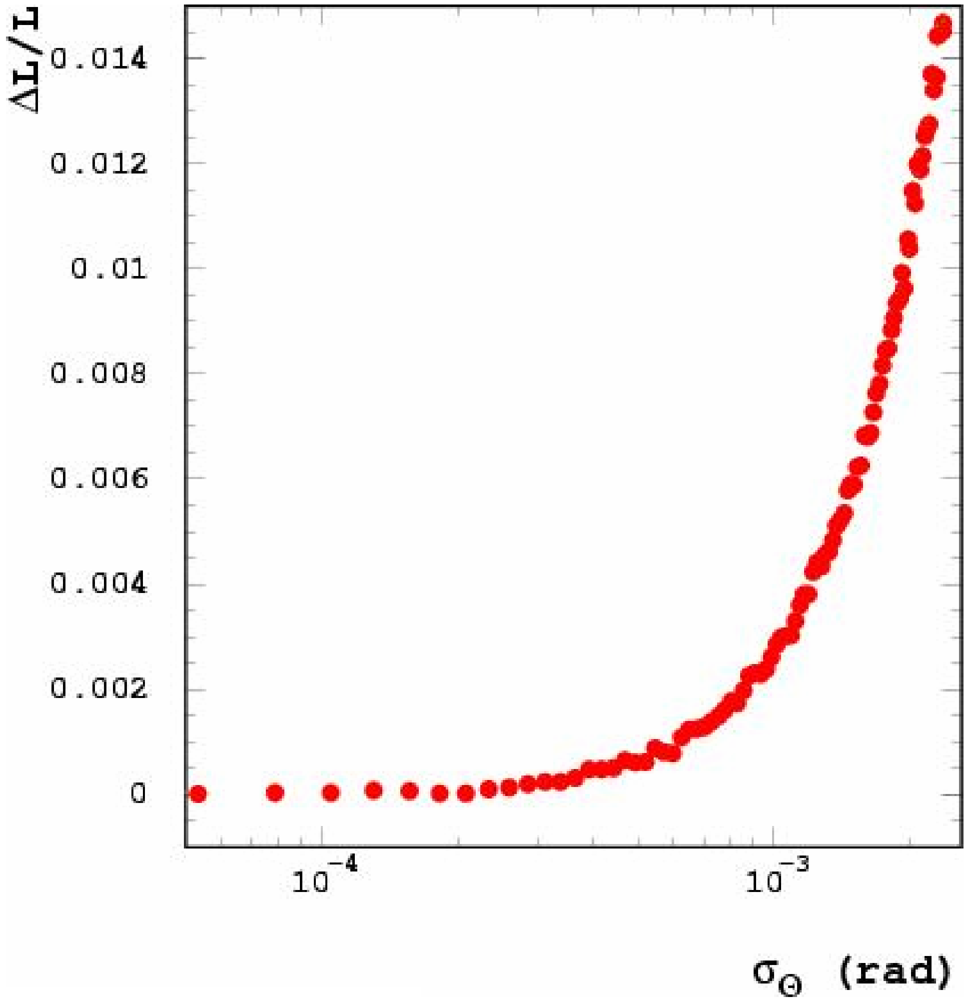
$$\frac{\Delta L}{L} = \frac{2 * \Delta\theta}{\theta_{\min}}$$



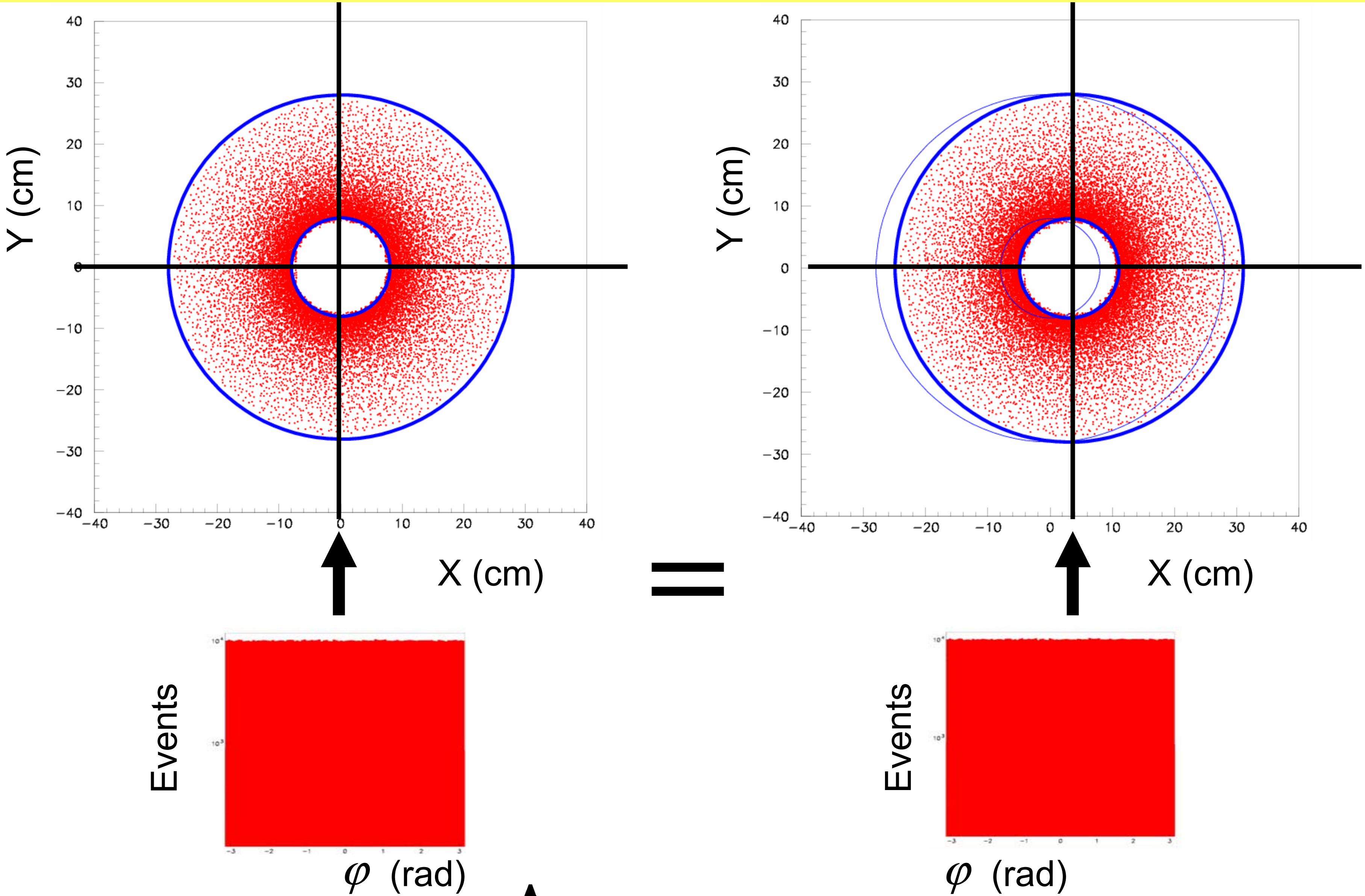
Fast detector simulation – resolution

Changing the detector resolution with no bias

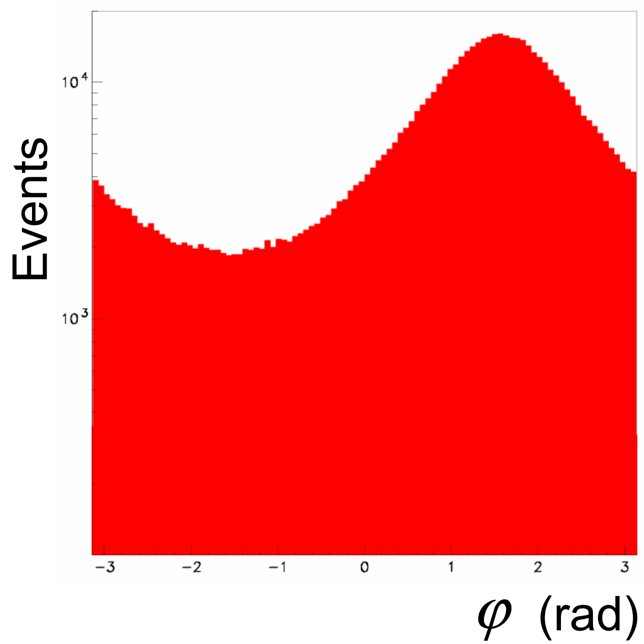


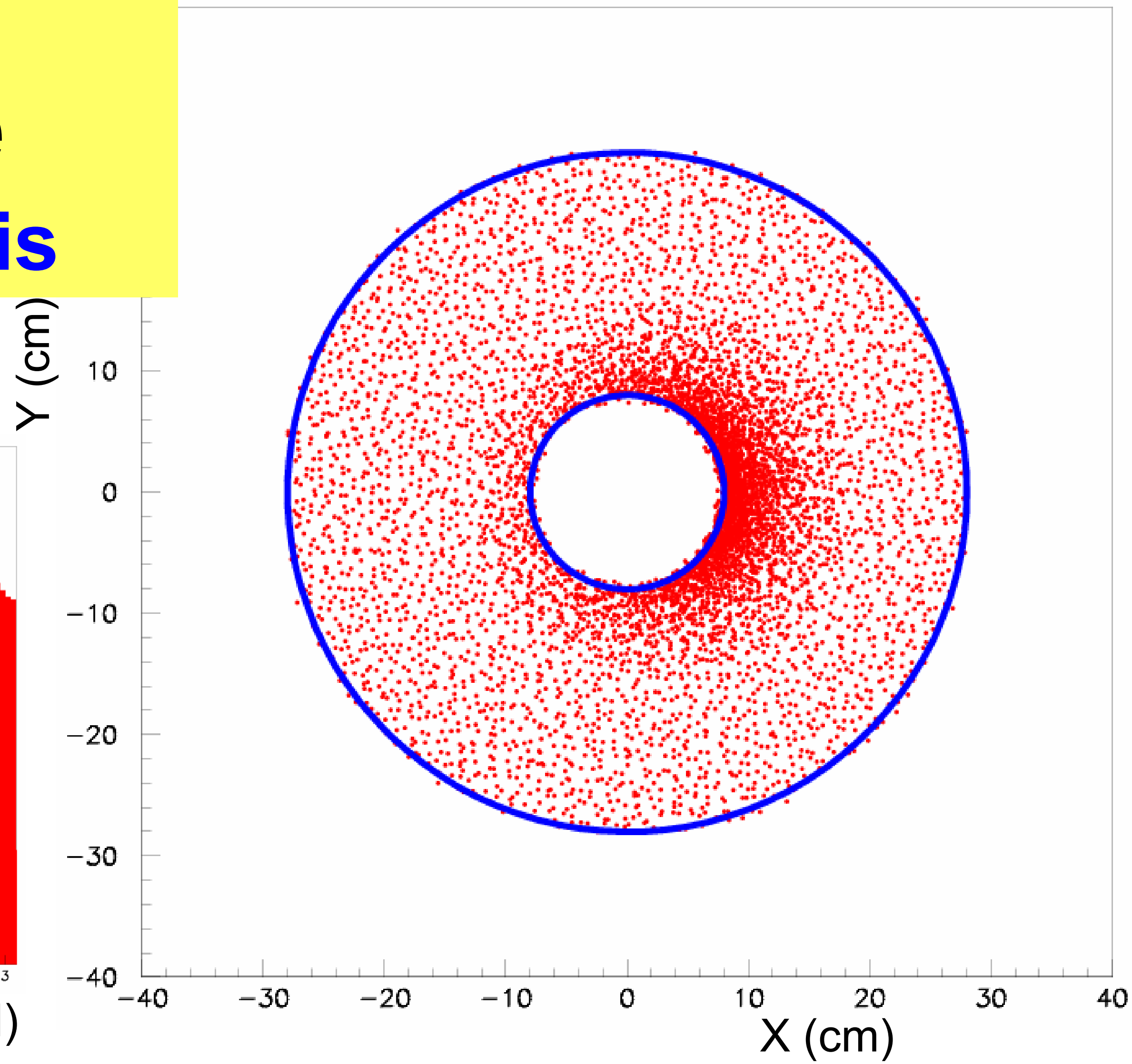


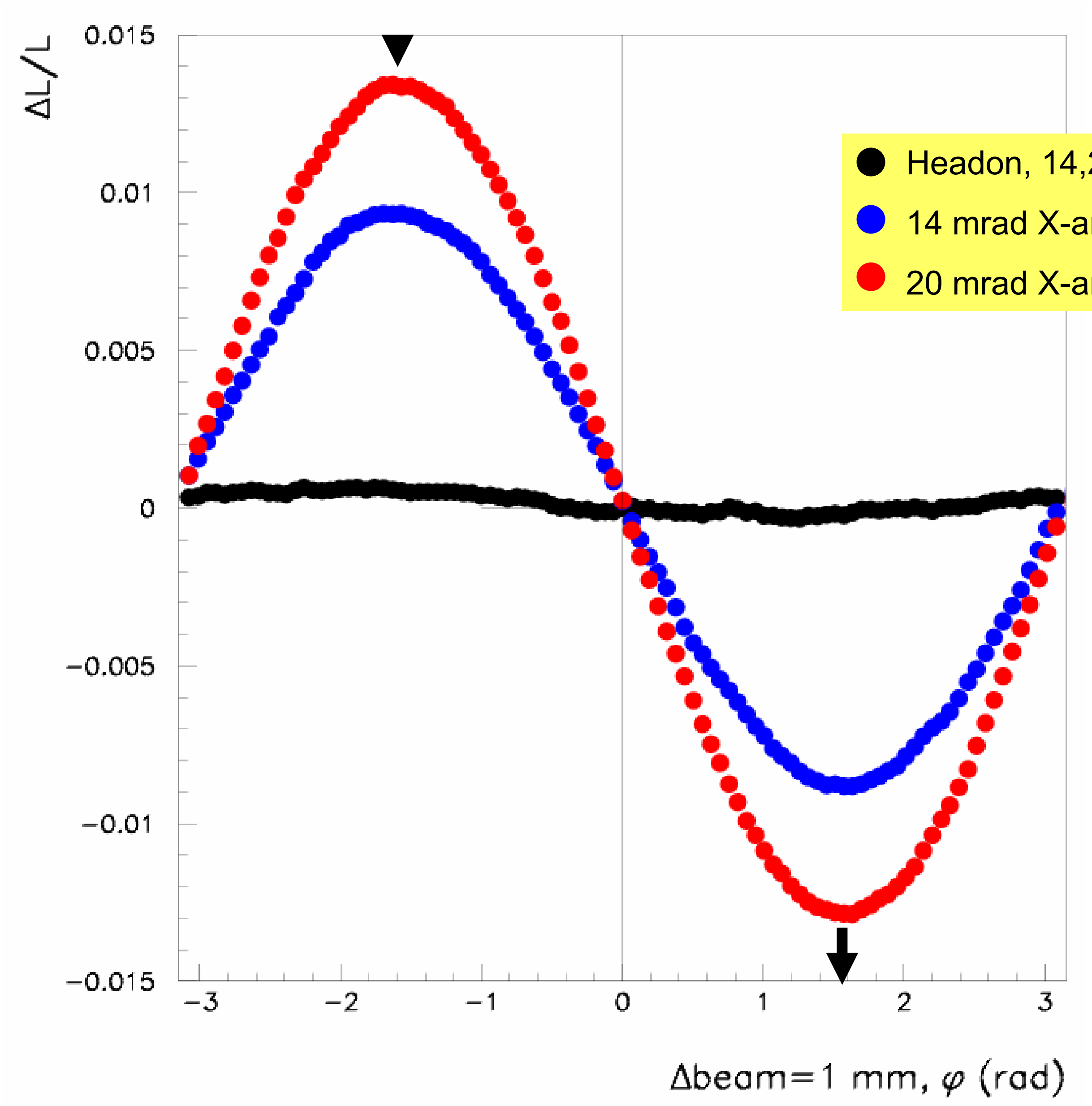
Outgoing beam → flat azimuthal distribution

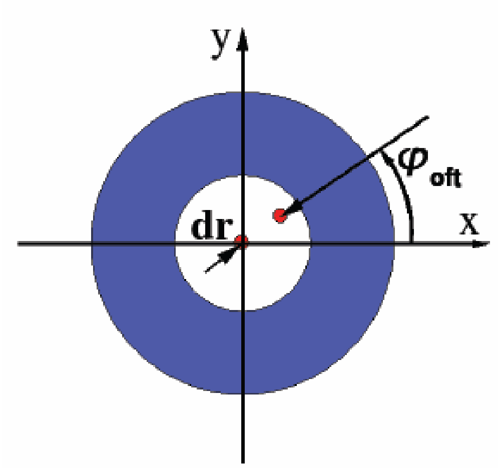


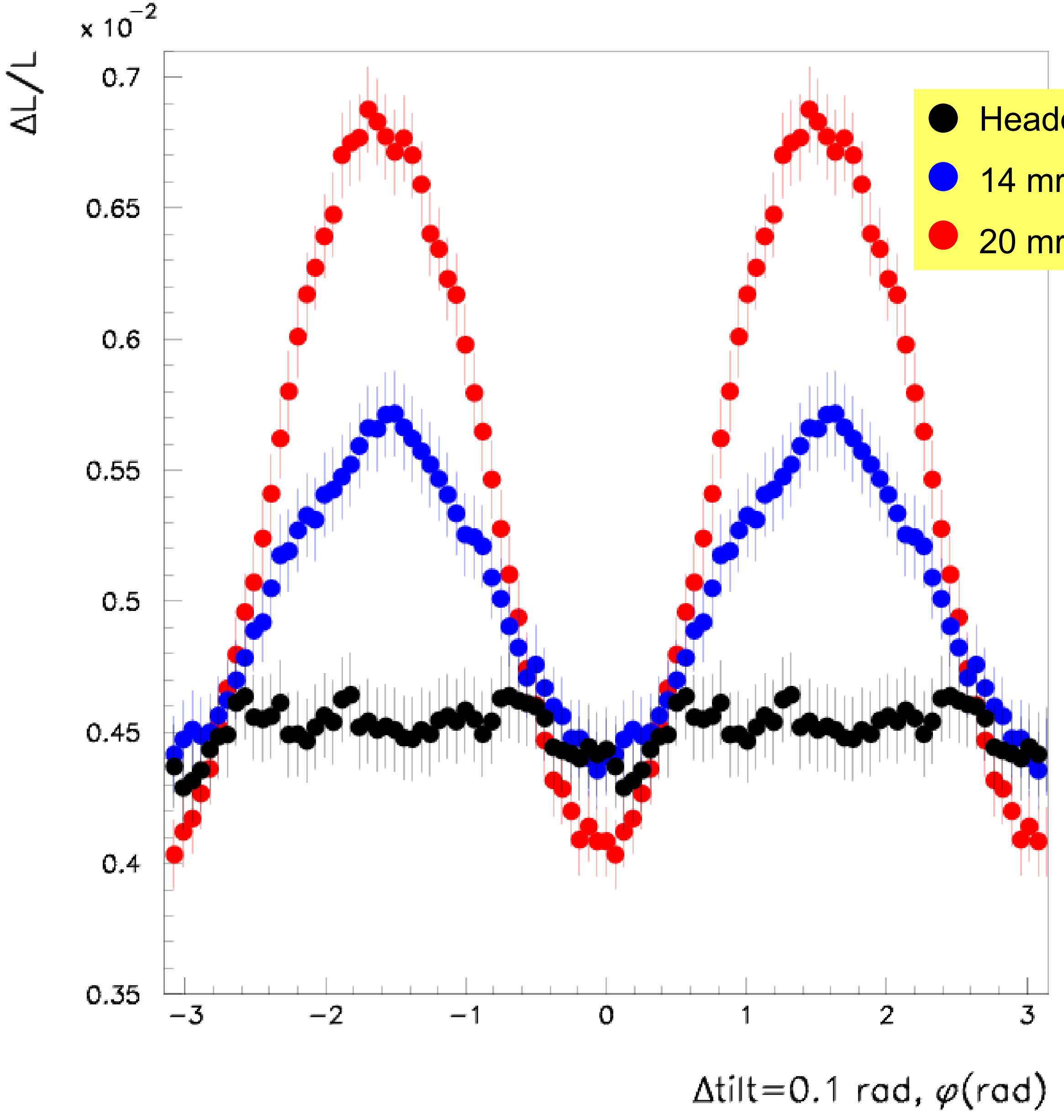
Bhabha Scattering
20mrad X-angle
Detector axis

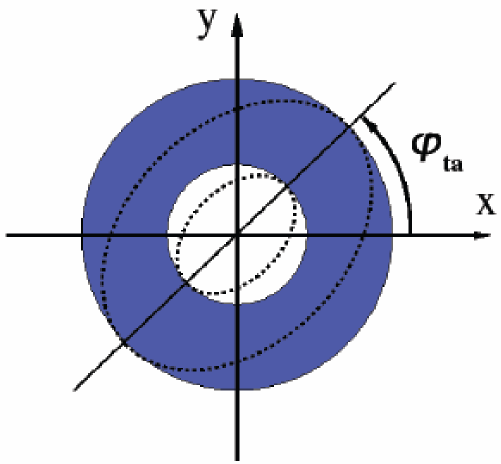





ΔL/L
0.015
0.01
0.005
0
−0.005
−0.01
−0.015
−3
−2
−1
0
1
2
3
Δbeam=1 mm, φ (rad)
Headon, 14,20 mrad X-angle outgoing beam
14 mrad X-angle detector axis
20 mrad X-angle detector axis

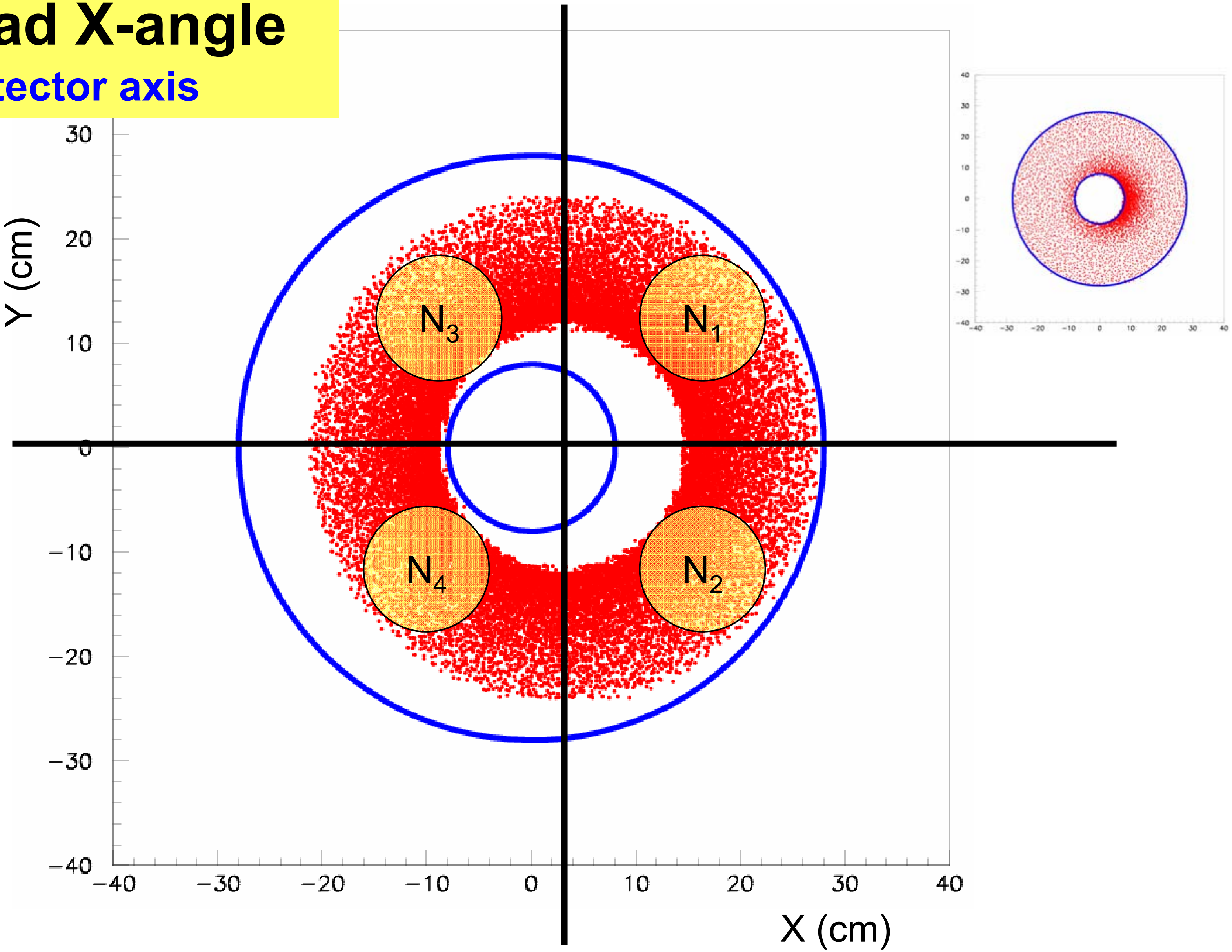

y
x
dr
φ_{oft}

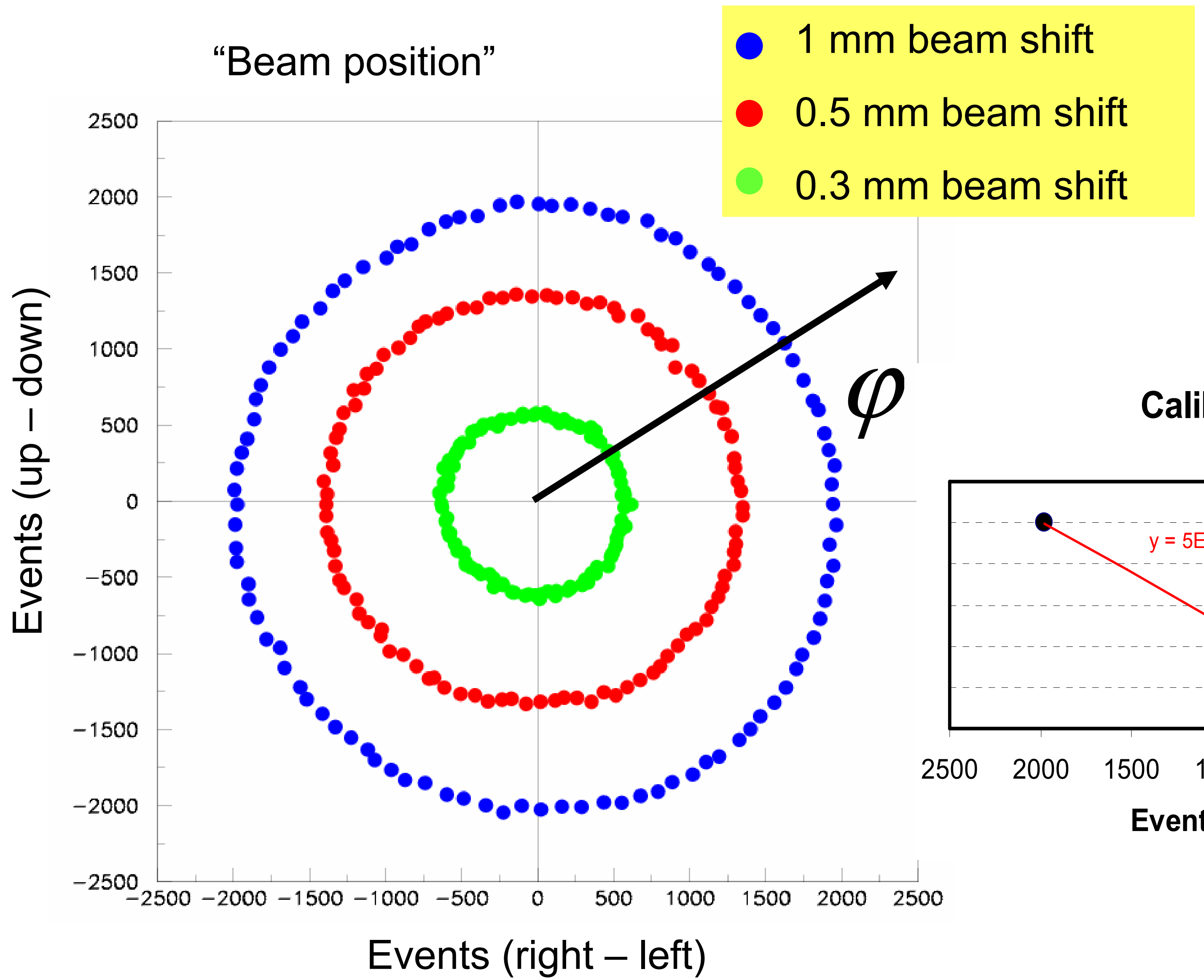

x 10^{-2}
ΔL/L
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
−3
−2
−1
0
1
2
3
Δtilt=0.1 rad, φ(rad)
Headon, 14,20 mrad X-angle outgoing beam
14 mrad X-angle detector axis
20 mrad X-angle detector axis

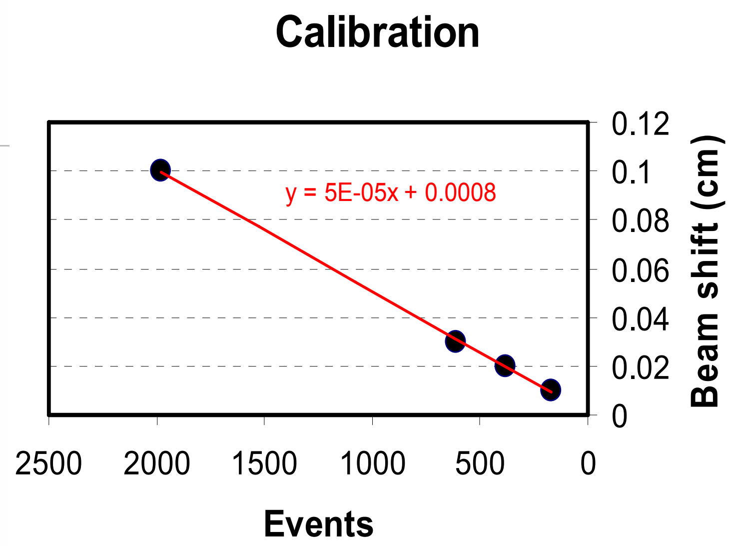

y
x
φ_{ta}

20mrad X-angle

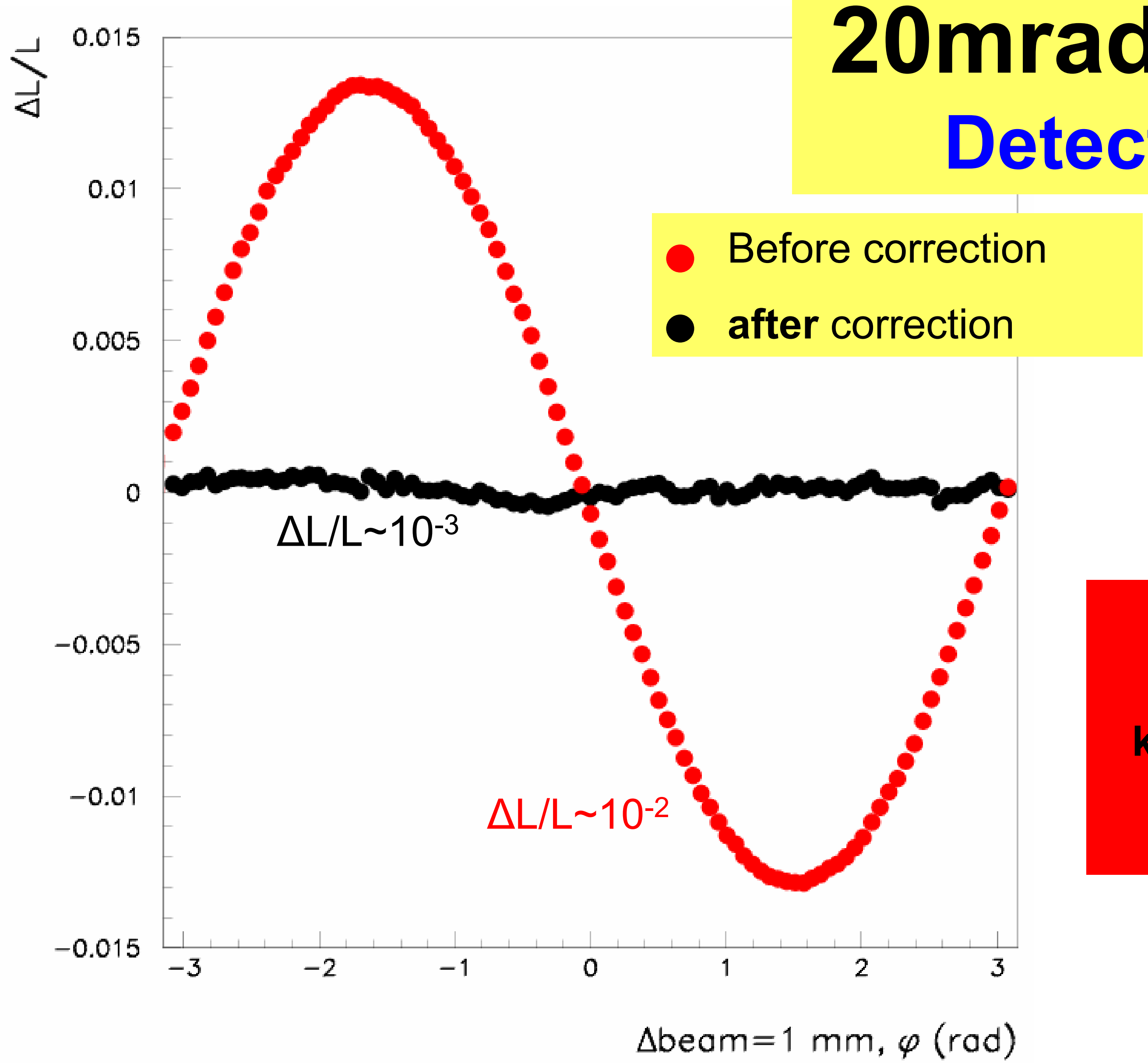
Detector axis




"Beam position"
1 mm beam shift
0.5 mm beam shift
0.3 mm beam shift
φ
Events (up – down)
Events (right – left)
2500
2000
1500
1000
500
0
−500
−1000
−1500
−2000
−2500


Calibration
y = 5E-05x + 0.0008
Beam shift (cm)
0.12
0.1
0.08
0.06
0.04
0.02
0
2500
2000
1500
1000
500
0
Events

20mrad X-angle
Detector axis



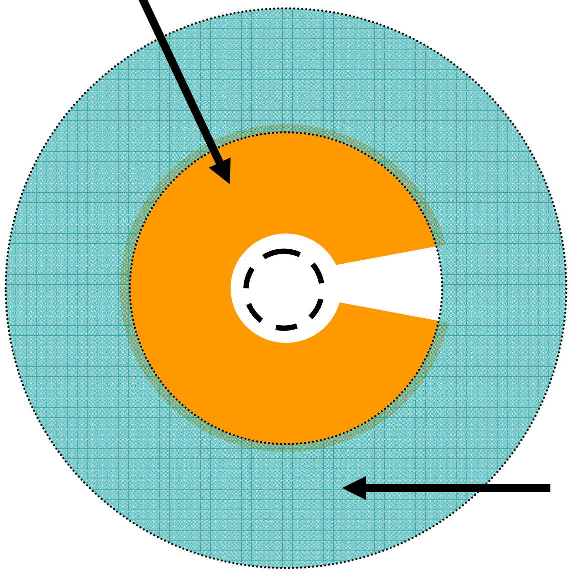
But !!!!!!

This is assuming knowing in perfect precision many parameters

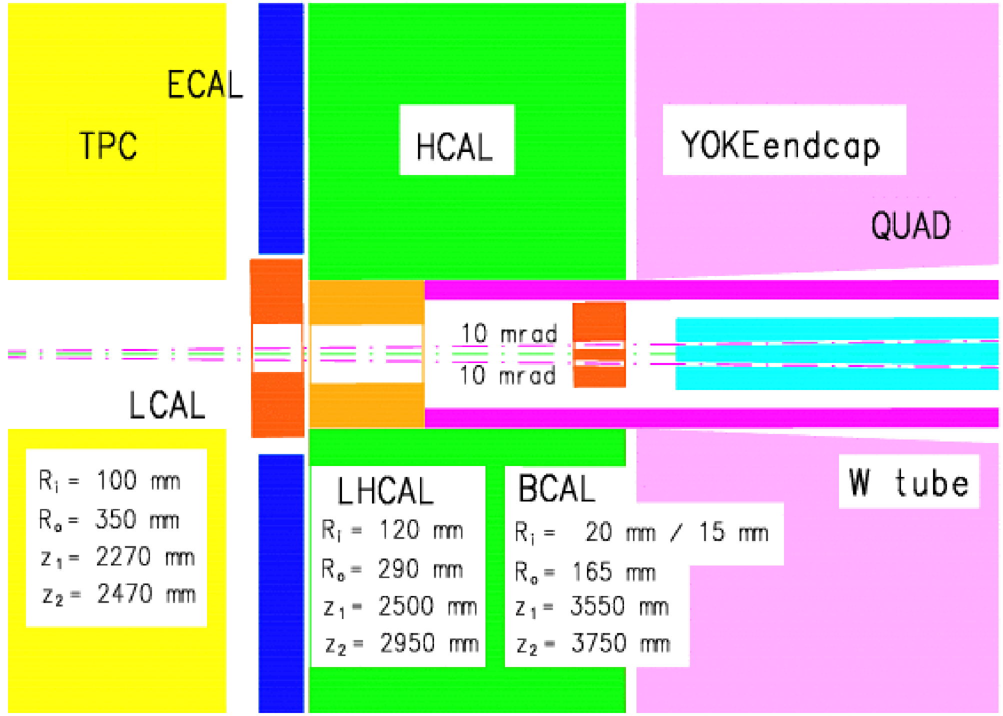
Present Understanding

20 mrad LDC

BeamCal (bigger outer radius)



LumiCal (bigger inner radius)



Detailed detector design recommendation