Instrumentation of the Very Forward Region of a Linear Collider Detector

Univ. of Colorado, Boulder,
AGH Univ., INP & Jagiell.
Univ. Cracow,
JINR, Dubna,
NCPHEP, Minsk,
FZU, Prague,
IHEP, Protvino,
TAU, Tel Aviv,
DESY, Zeuthen

Wolfgang Lohmann

The Very Forward Calorimetry Collaboration

see: PRC R&D 01/02 (2002)

Functions of the very Forward Detectors

Measurement of the Luminosity with precision O(10^{-4})

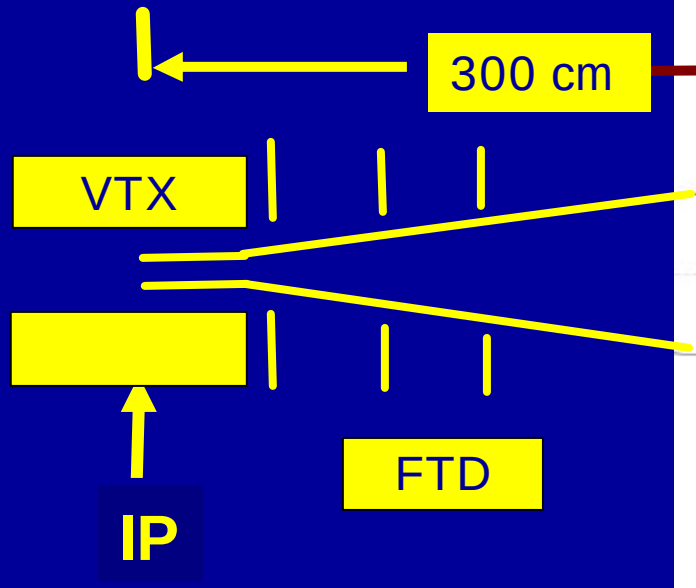
Fast Beam Diagnostics

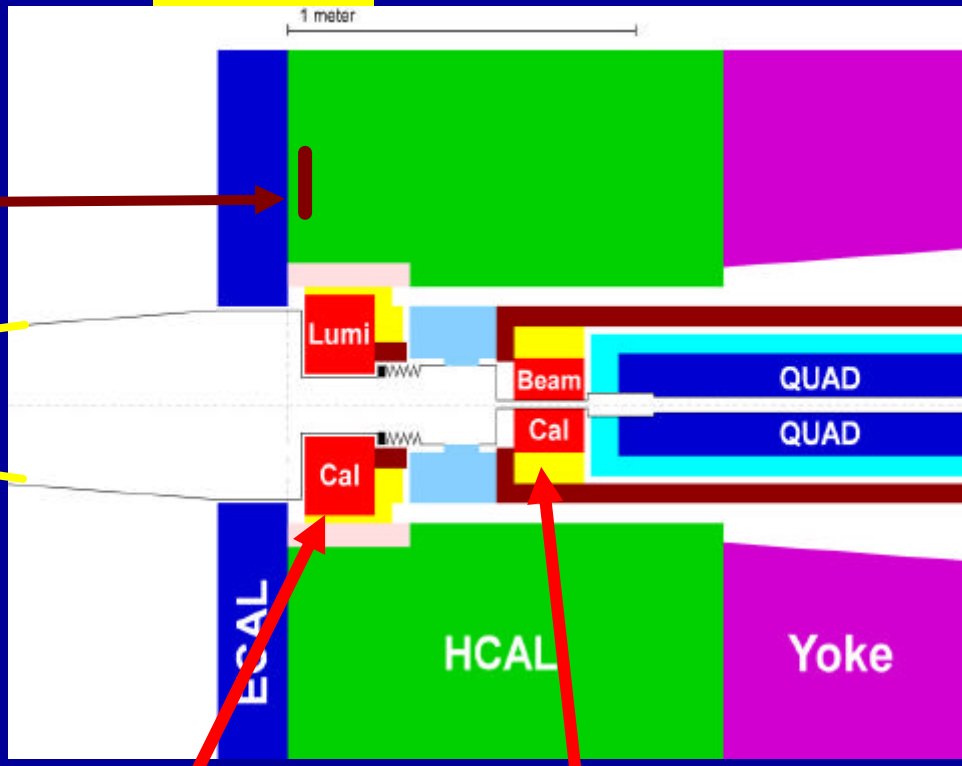
Shielding of the inner Detector

- **Detection of Electrons and Photons at very low angle – extend hermiticity**

(Important for Searches)

L* = 4m





umiCal: 26 < q < 82 mrad
eamCal: 4 < q < 28 mrad

LumiCal **BeamCal**

Measurement of the Luminosity

Gauge Process: $e^+e^- \longrightarrow e^+e^-(g)$

Goal: 10^{-4} Precision

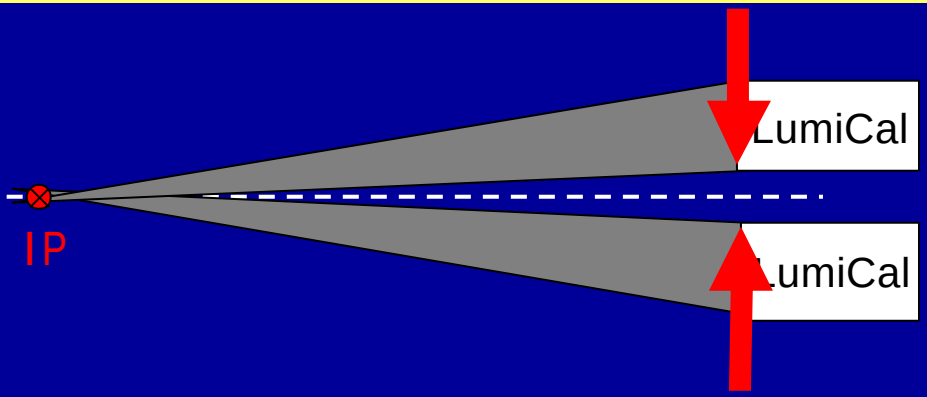
Physics Case: Giga-Z ,Two Fermion Cross Sections at High Energy, $e^+e^- \longrightarrow W^+W^-$

Technology: Si-W Sandwich Calorimeter

MC Simulations → Optimisation of Shape and Segmentation, Key Requirements on the Design

Close contacts to Theorists (Cracow, Katowice, DESY)

Requirements on the Mechanical Design

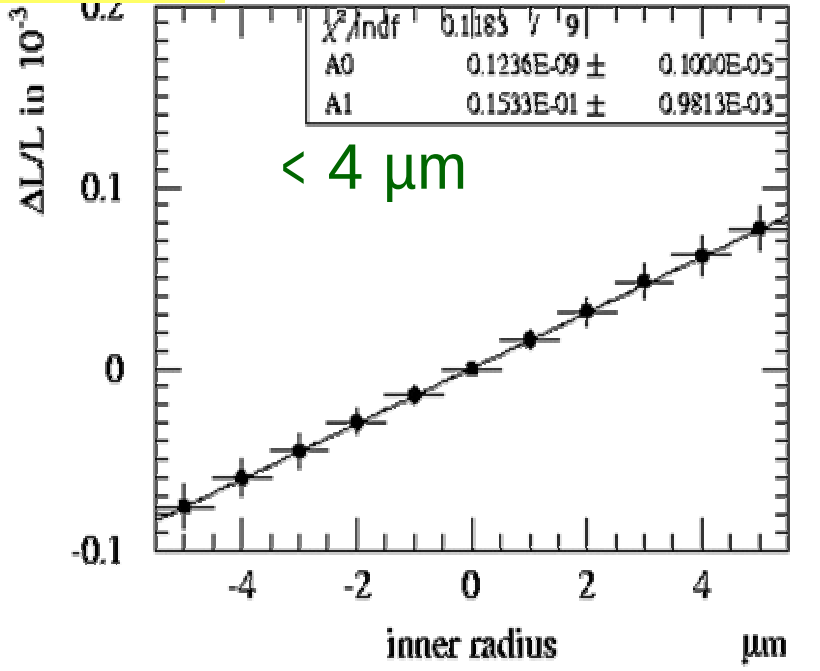


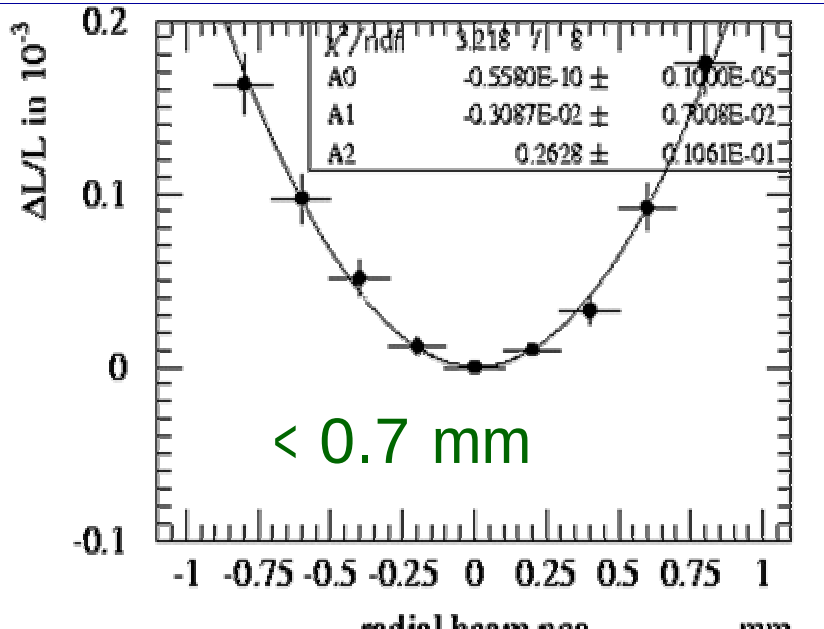
Requirements on
Alignment
and mechanical Precision
(rough Estimate)

Inner Radius of Cal.: < 1-4 µm

Distance between Cals.: < 60 µm

Radial beam position: < 0.7 mm

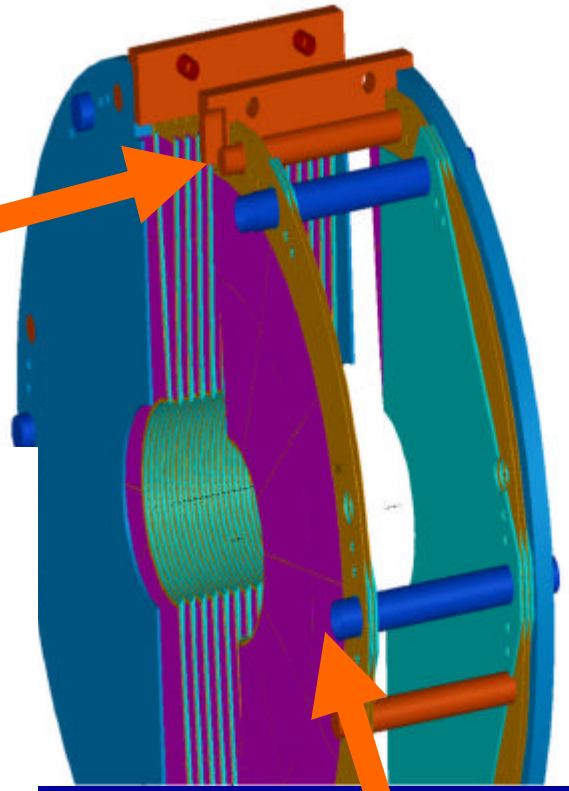


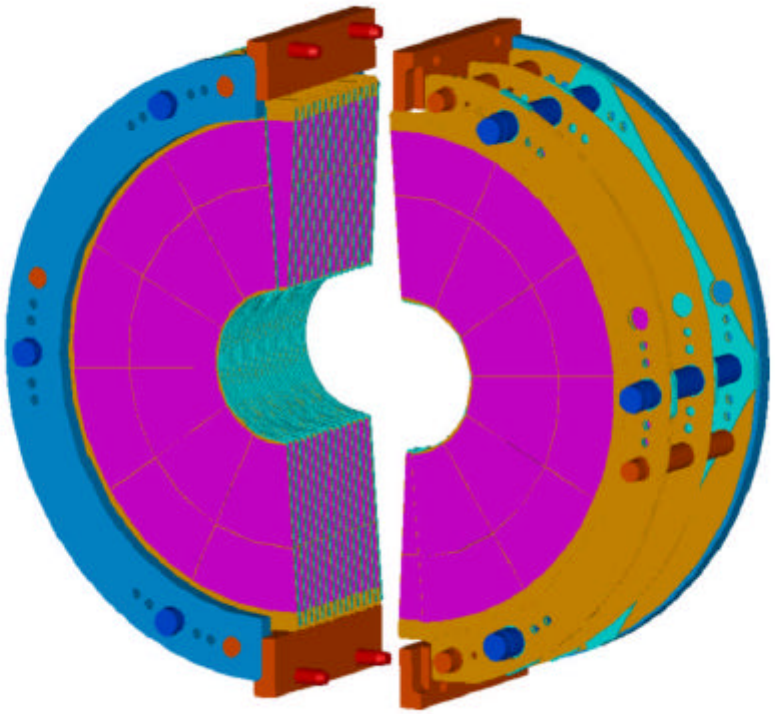


Concept for the Mechanical Frame

Decouple sensor frame from absorber frame

Sensor carriers





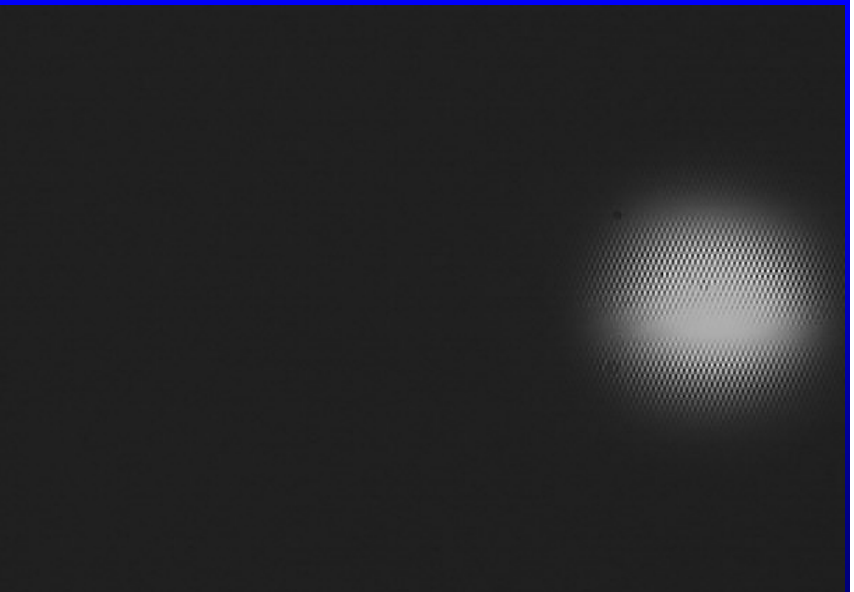
Absorber carriers

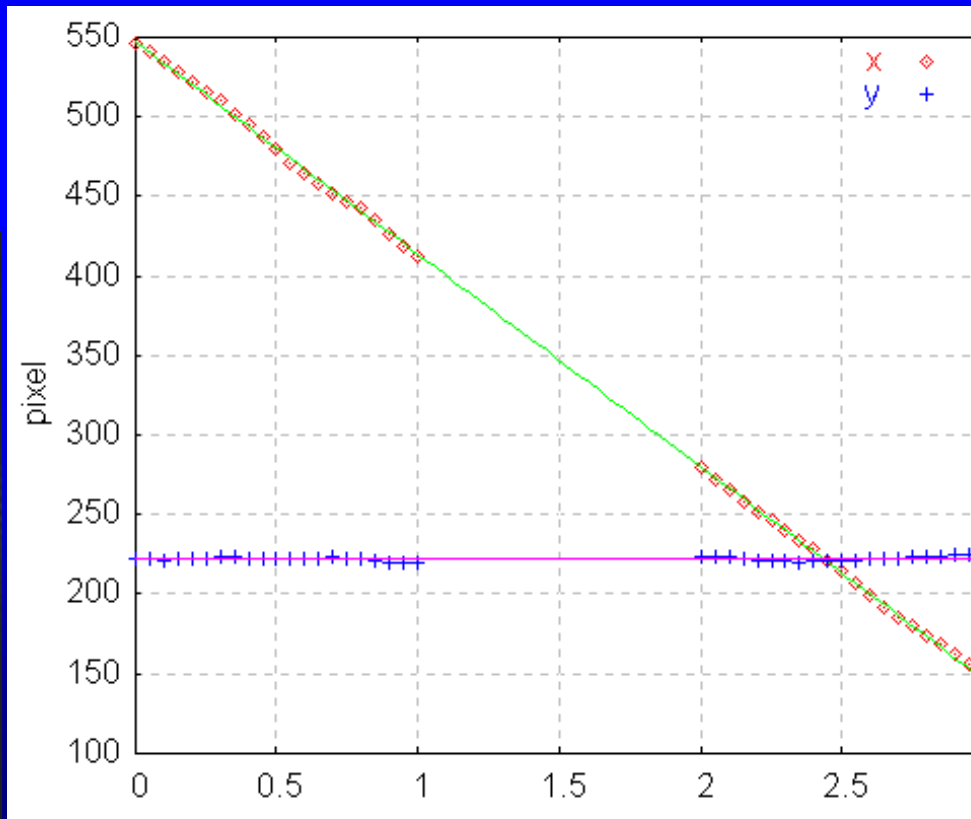
Laser Alignment Test

Jagiellonian Univ. Cracow
Photonics Group

- Simple CCD camera,
- He-Ne red laser,
- Laser translated in 50 mm steps

econstruction of
he laser spot (x,y) position
n CCD camera



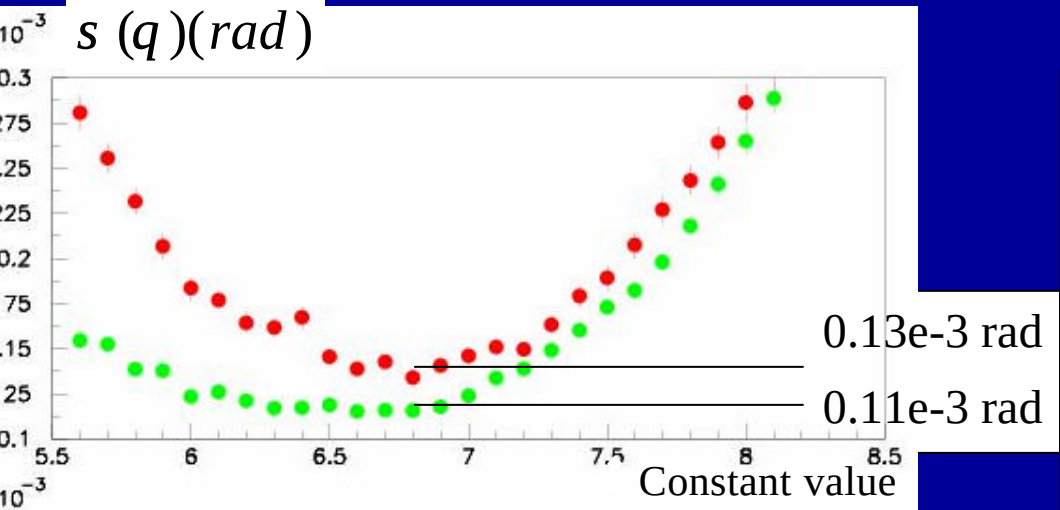


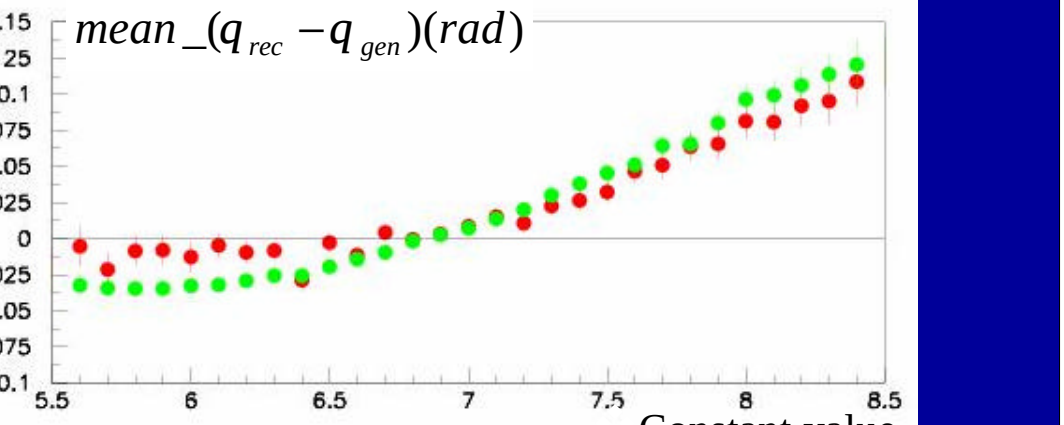
Performance Simulations for $e^+e^- \longrightarrow e^+e^-(g)$

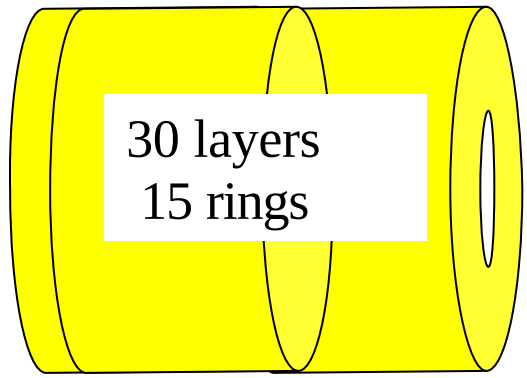
imulation: Bhwide(Bhabha)+CIRCE(Beamstrahlung)+beamspread

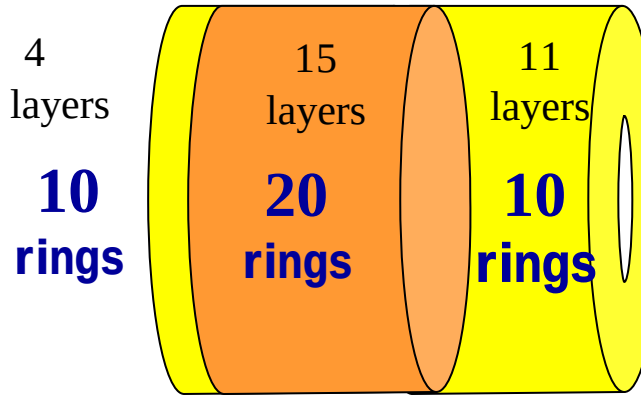
vent selection: acceptance, energy balance, azimuthal and angular symmetry.

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

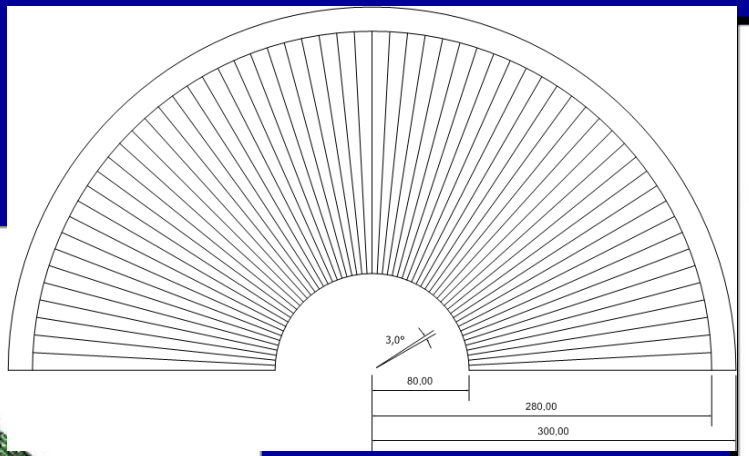


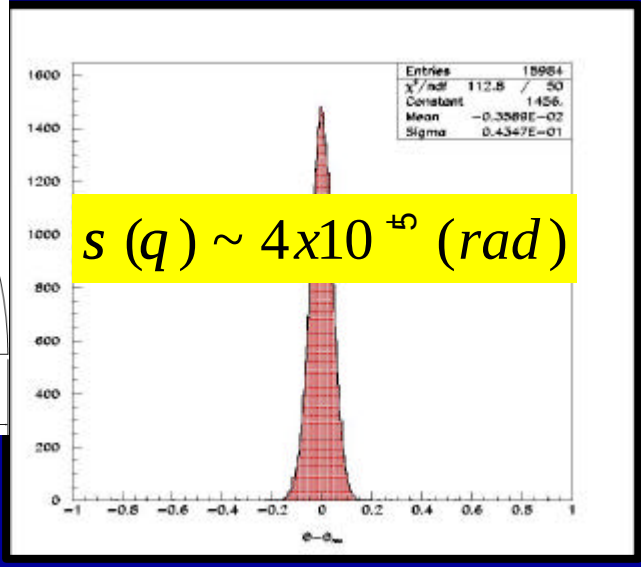




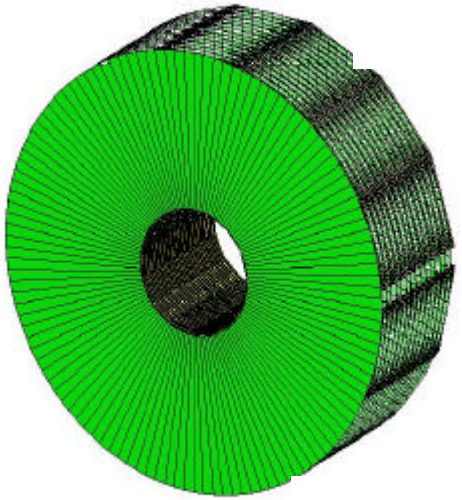


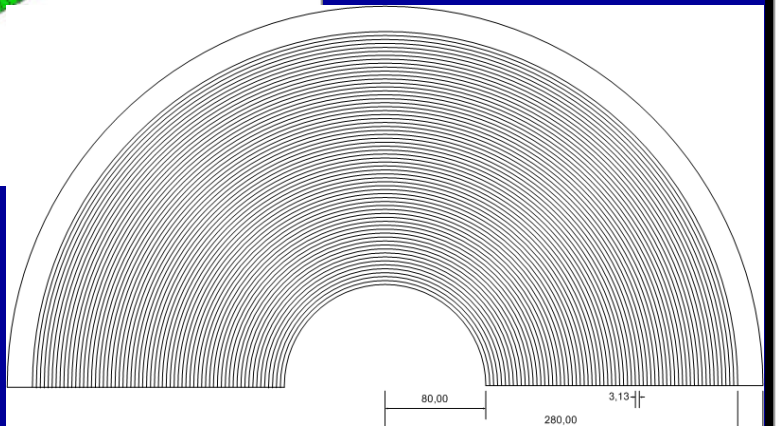
Determination of shower Coordinates
Strip version

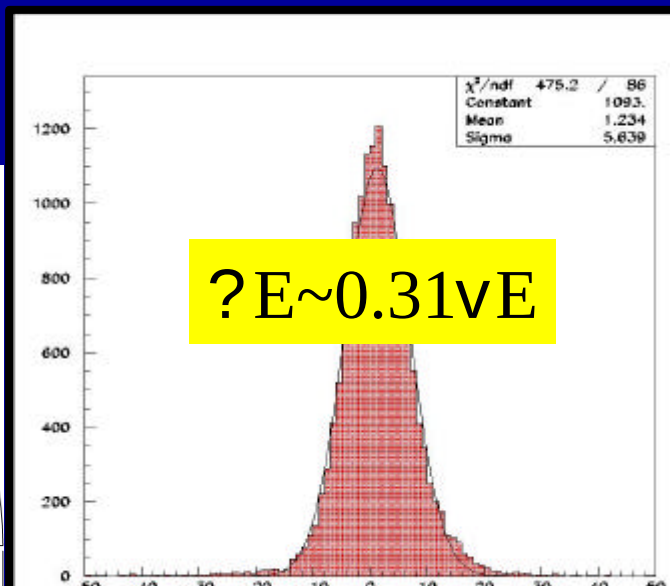




$$s(q) \sim 4x10^{-5}\ (rad)$$



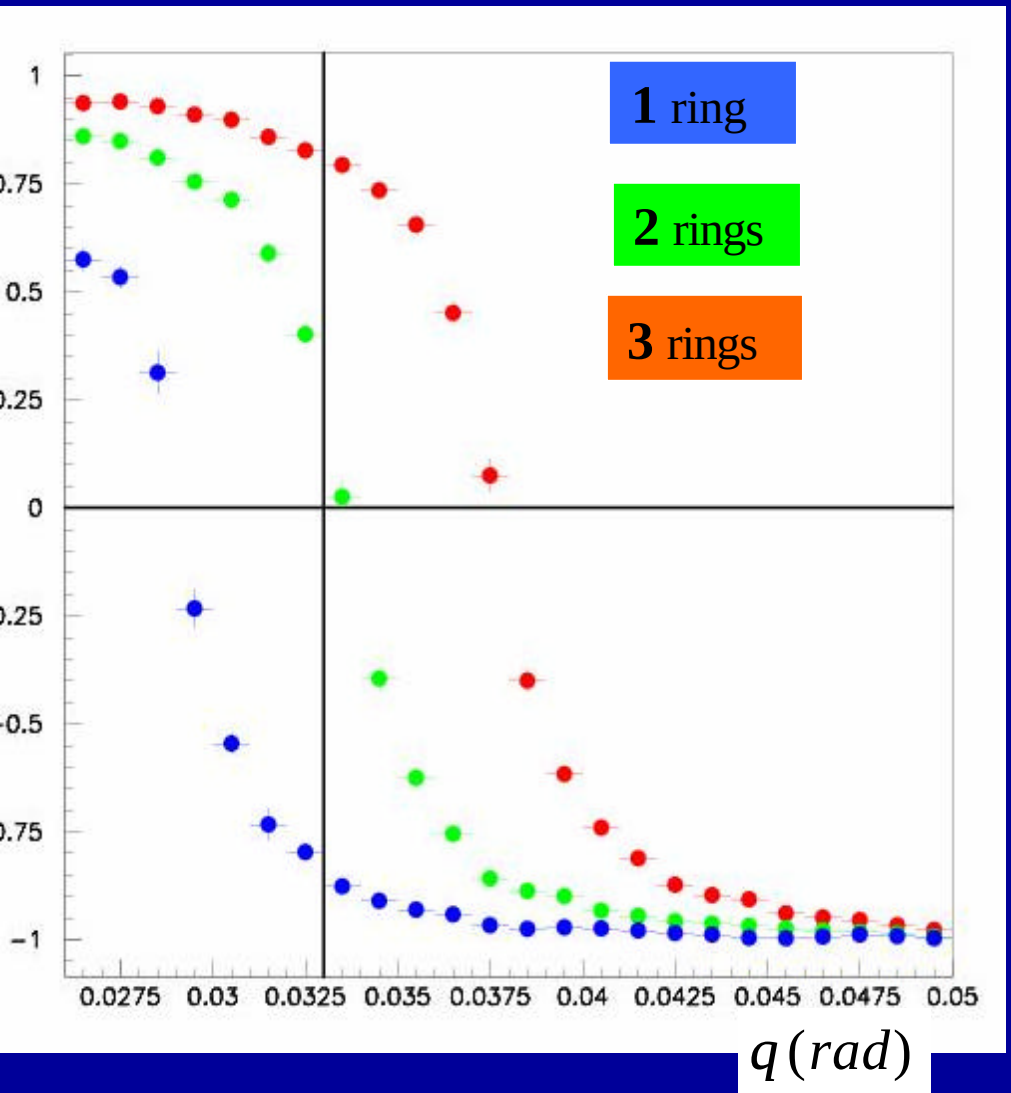


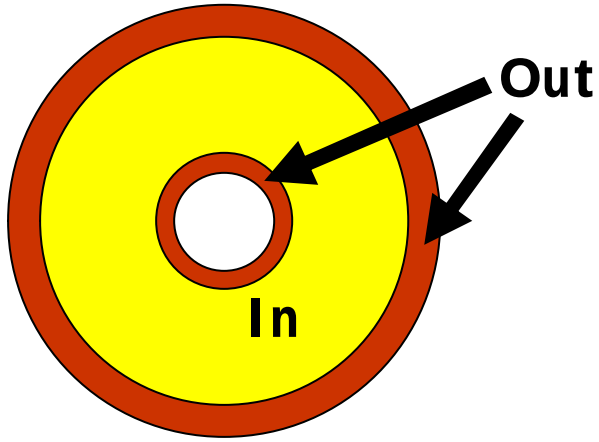


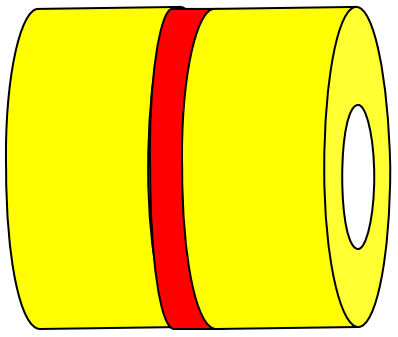
?E~0.31vE

Determination of the Acceptance Region

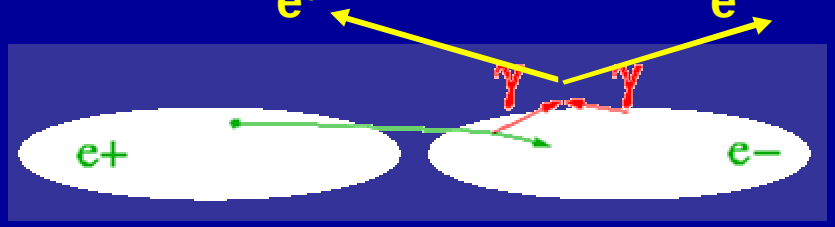
$$P = \frac{Eout\text{-}Ein}{Eout+Ein}$$







Fast Beam Diagnostics

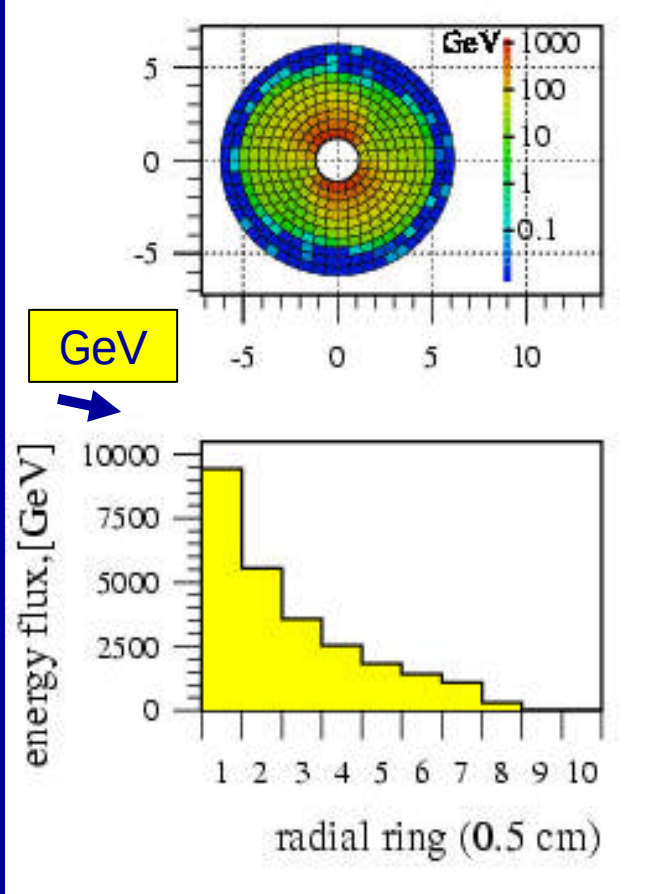


e^+e^- Pairs from Beamstrahlung are deflected into the BeamCal

15000 e^+e^- per BX ⟶ 10 – 20 TeV

10 MGy per year ⟶ Rad. hard sensors

direct Photons for $\theta < 200$ mrad



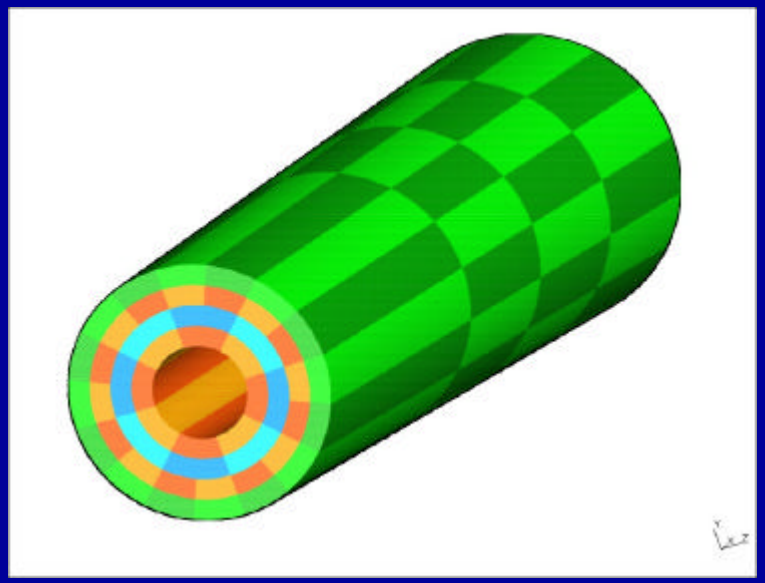
Technologies: Diamond-W Sandwich

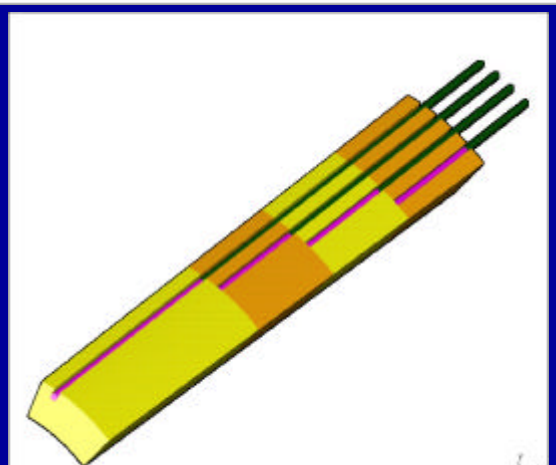
Scintillator Crystals

Gas Ionisation Chamber

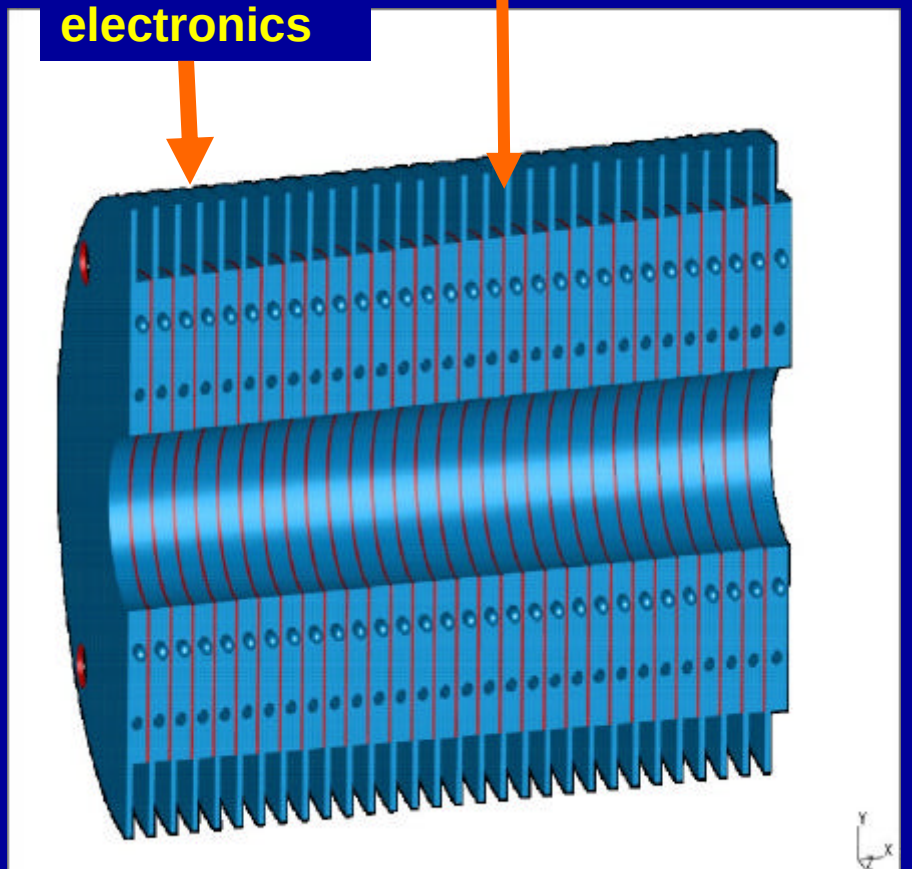
Schematic Views

Heavy crystals





W-Diamond sandwich



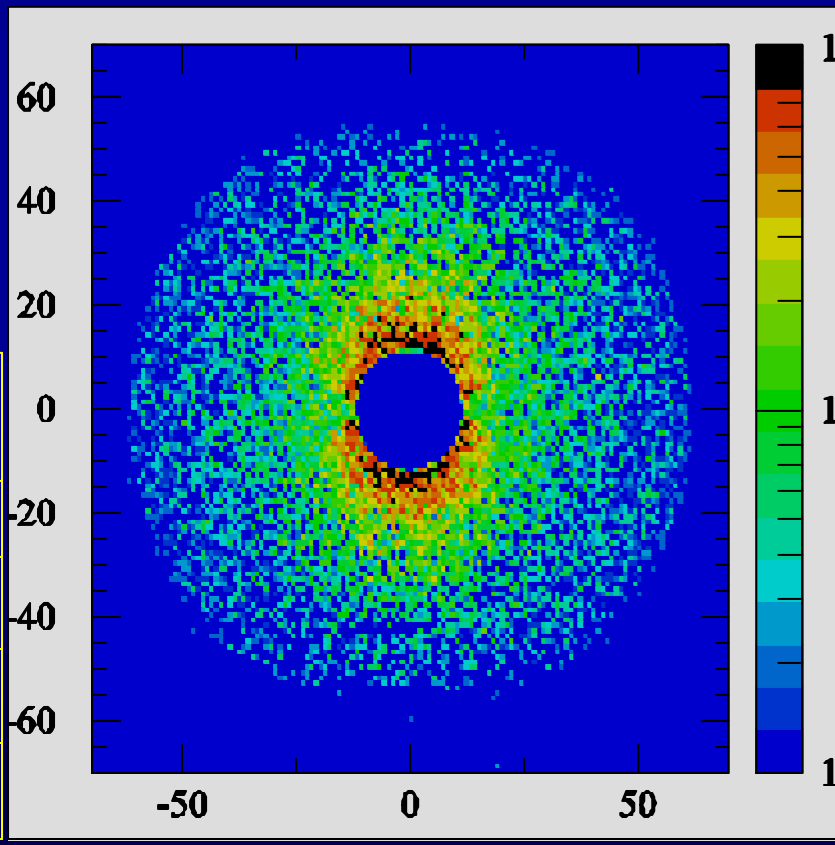
Beam Parameter Determination with BeamCal

Observables

detector: realistic segmentation, ideal resolution
single parameter analysis, bunch by bunch resolution

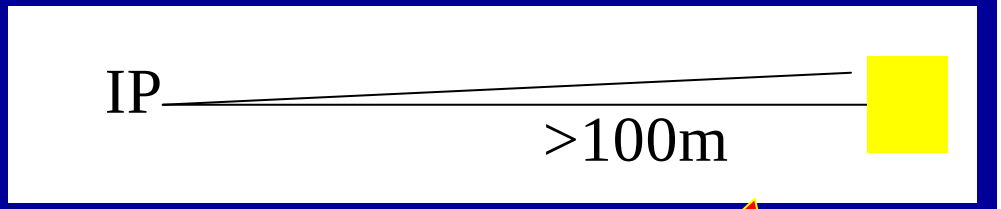
first radial moment
thrust value
total energy
angular spread
L/R, U/D F/B asymmetries

Quantity	Nominal Value	Precision
s_x	553 nm	1.2 nm
s_y	5.0 nm	0.1 nm
s_z	300 mm	4.3 mm
Dy	0	0.4 nm



nd with PhotoCal

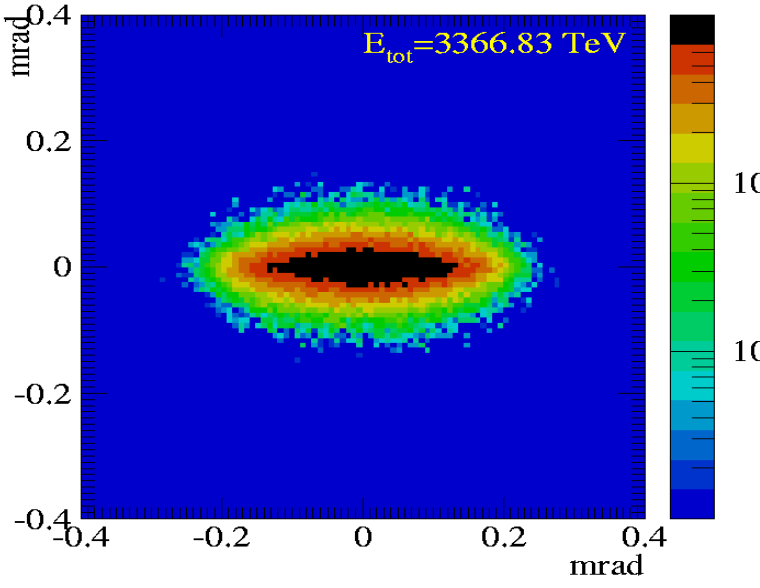
hotons from Beamstrahlung

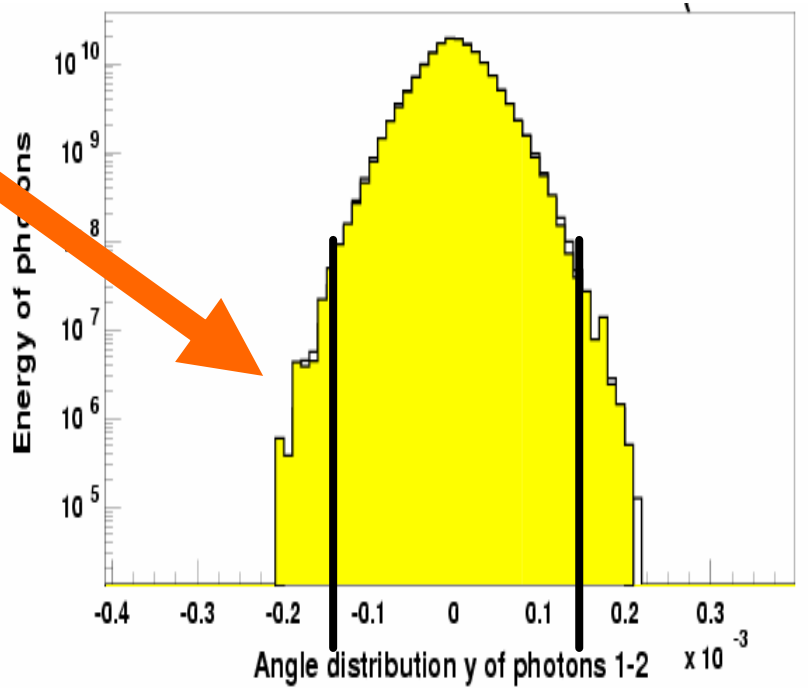


Heavy gas ionisation Calorimeter

L/R, U/D F/B asymmetries of energy in the angular tails

Quantity	Nominal Value	Precision
s x	553 nm	4.2 nm
s z	300 mm	7.5 mm
Dy	0	0.2 nm

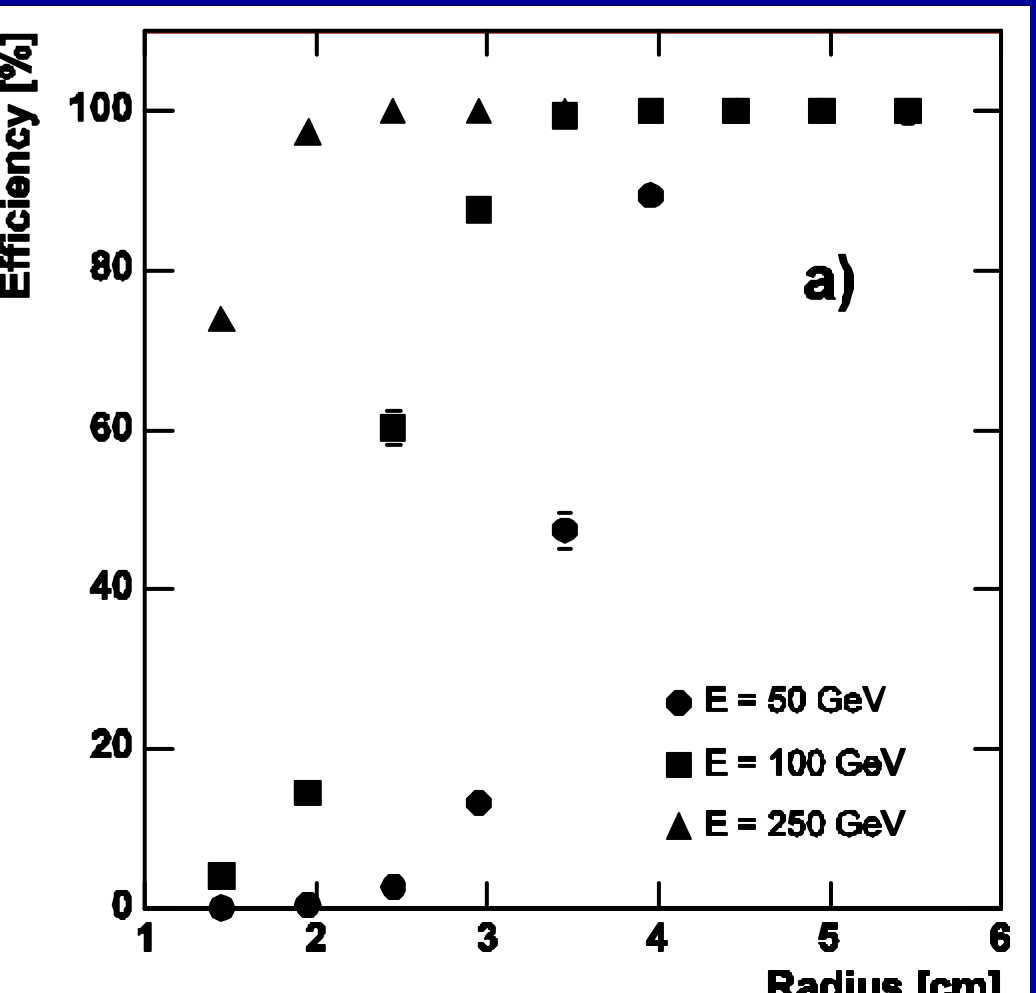


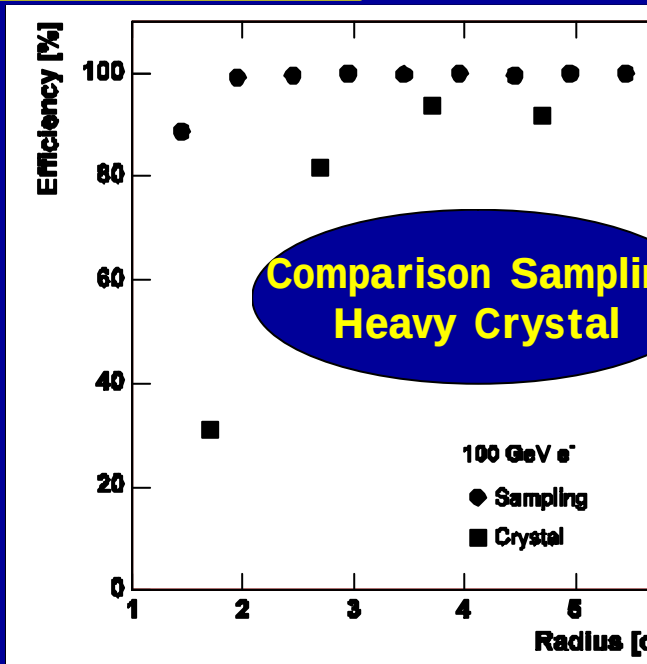


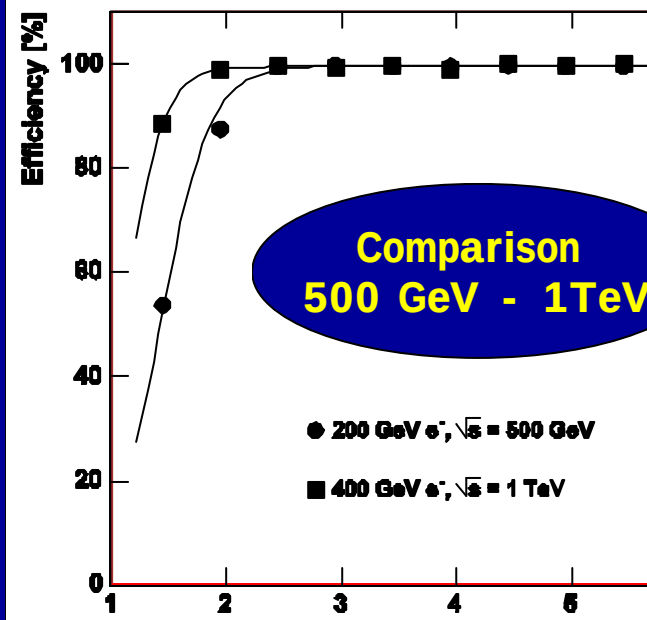
Detection of High Energy Electrons and Photons

s = 500 GeV

Single Electrons of 50, 100 and 250 GeV



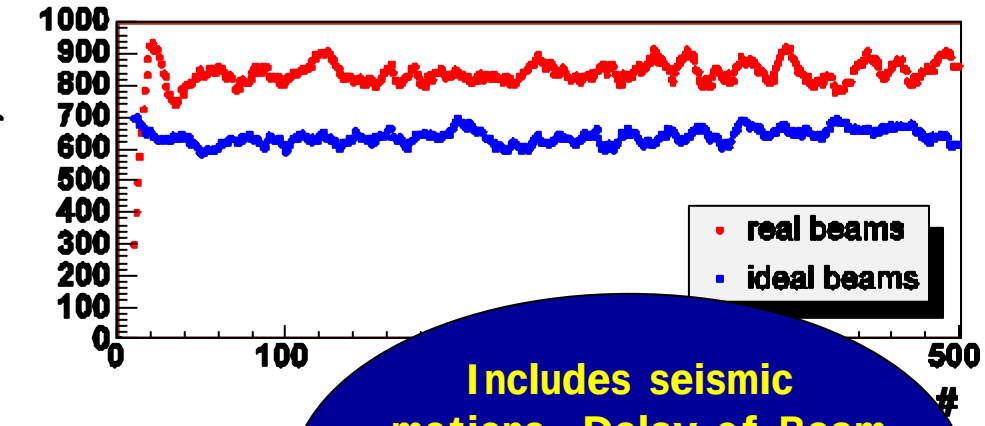




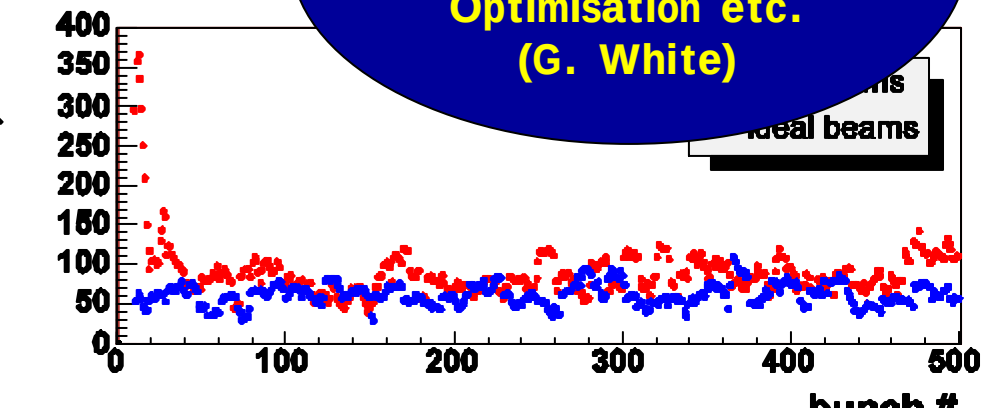
Realistic beam simulation

√s = 500 GeV

mean energy in particular cell (high BG near BP)

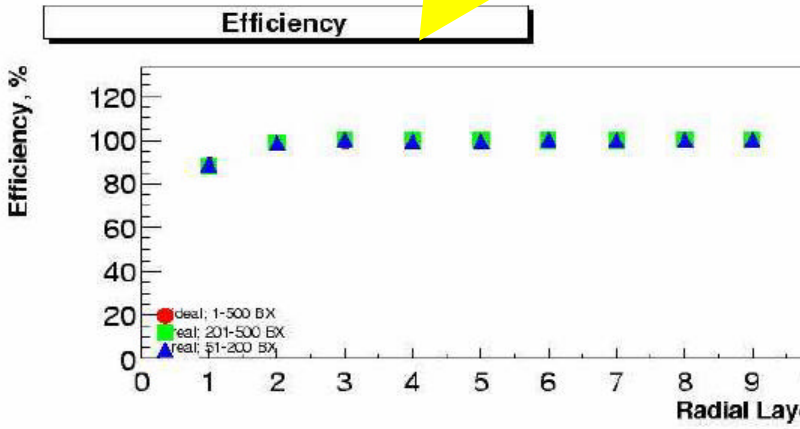


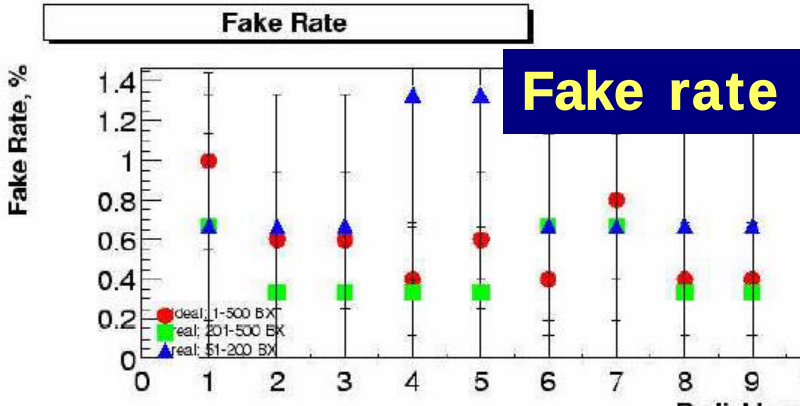
energy RMS in p



Includes seismic motions, Delay of Beam Feedback System, Lumi Optimisation etc. (G. White)

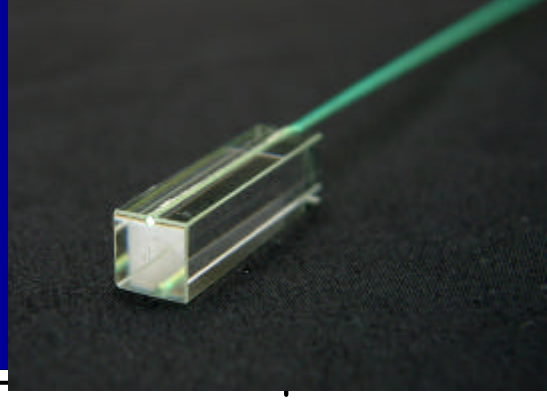
Efficiency to identify energeti electrons and photons (E > 200 GeV)





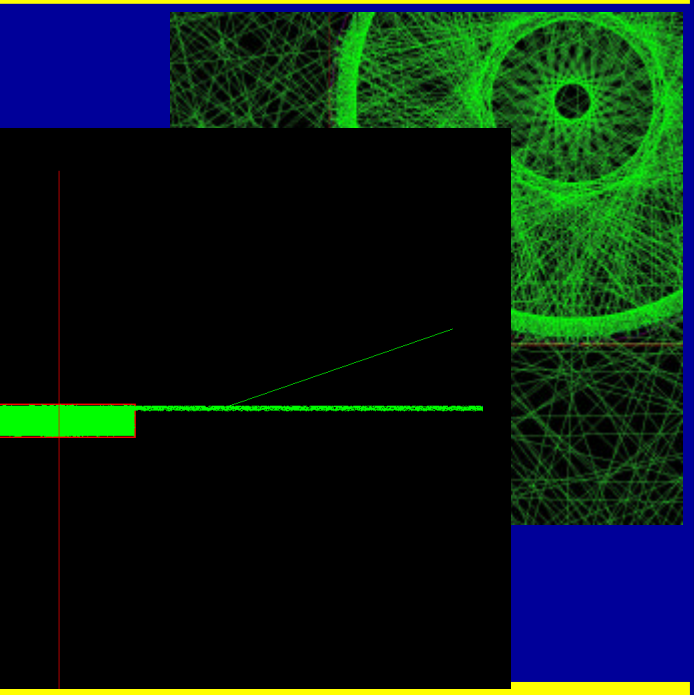
Fake rate

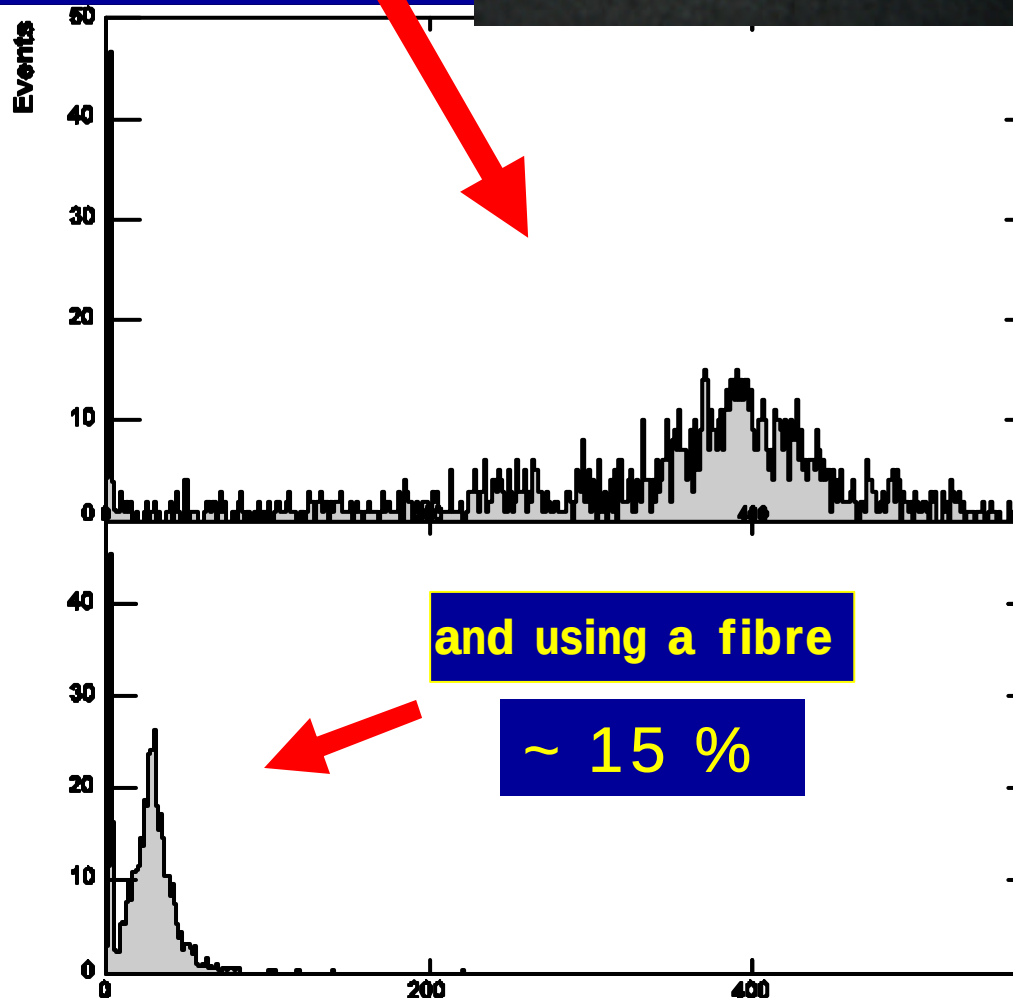
Sensor prototyping, Crystals



Light Yield from direct coupling

Compared with GEANT4 Simulation, good agreement



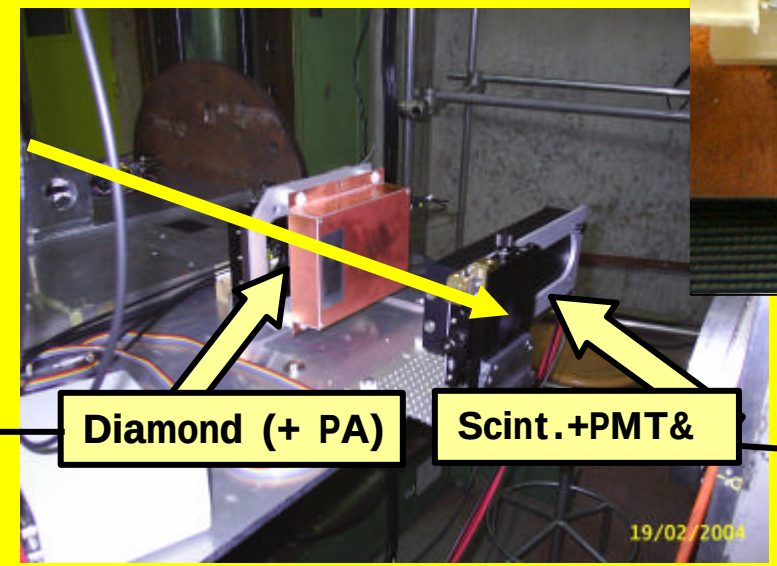


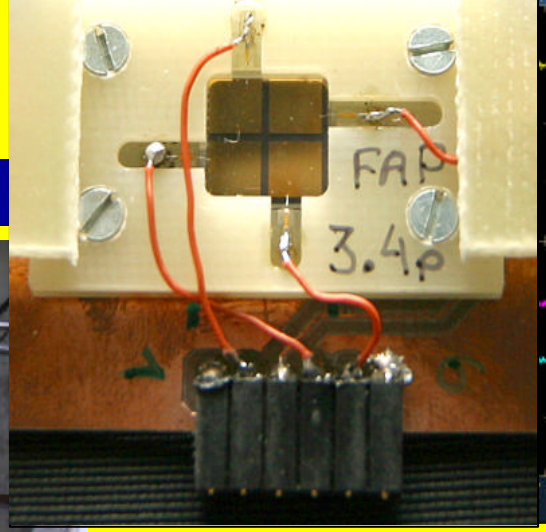
and using a fibre

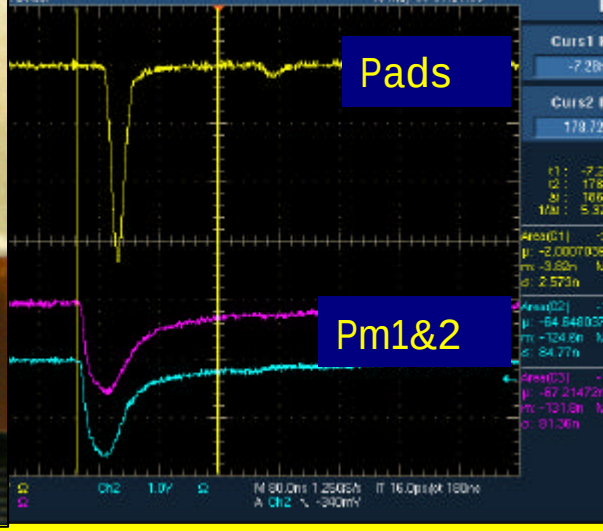
~ 15 %

similar results for lead glass Crystals (Cerenkov light !)

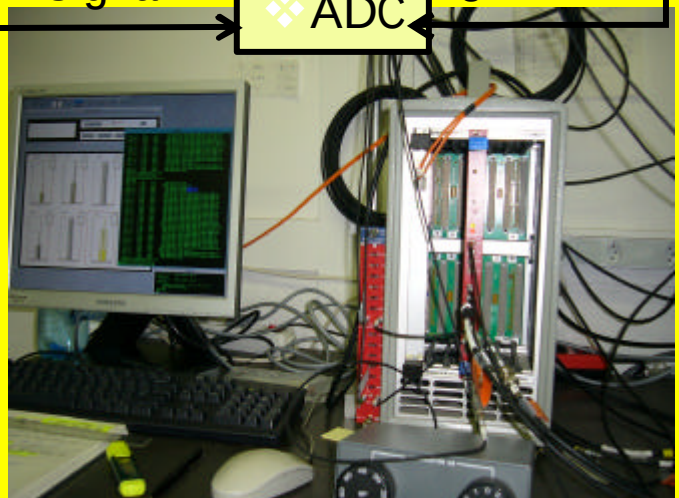
Sensor prototyping, Diamonds







signal ADC gate



May,August/2004 test beams

CERN PS Hadron beam – 3,5 GeV

2 operation modes:

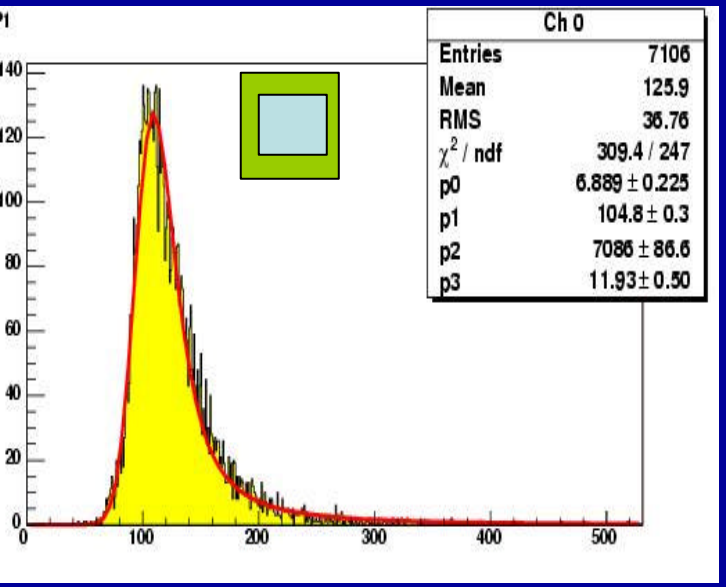
- Slow extraction ~10^{5}-10^{6} / s
- fast extraction ~10^{5}-10^{7} / ~10ns (Wide range intensities)

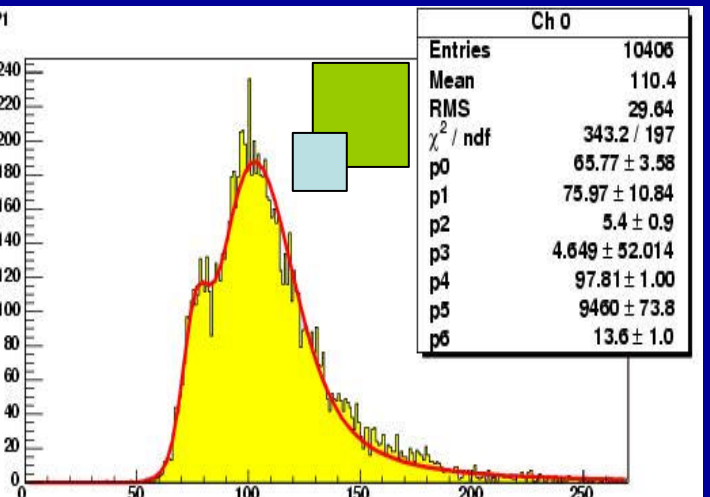
Diamond samples (CVD):

- Freiburg
- GPI (Moscow)
- Element6

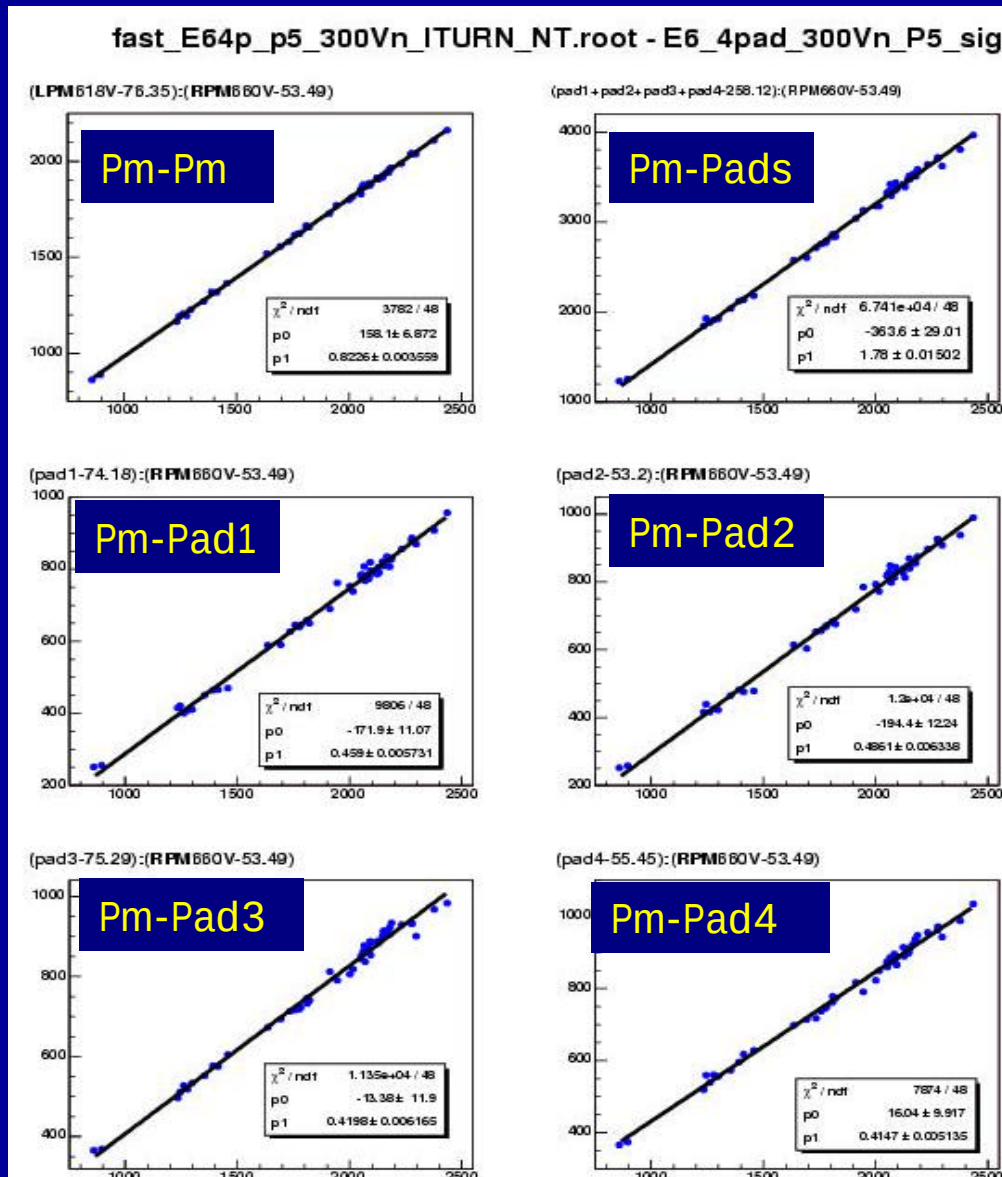
Diamond Sensor Performance

Response to mip

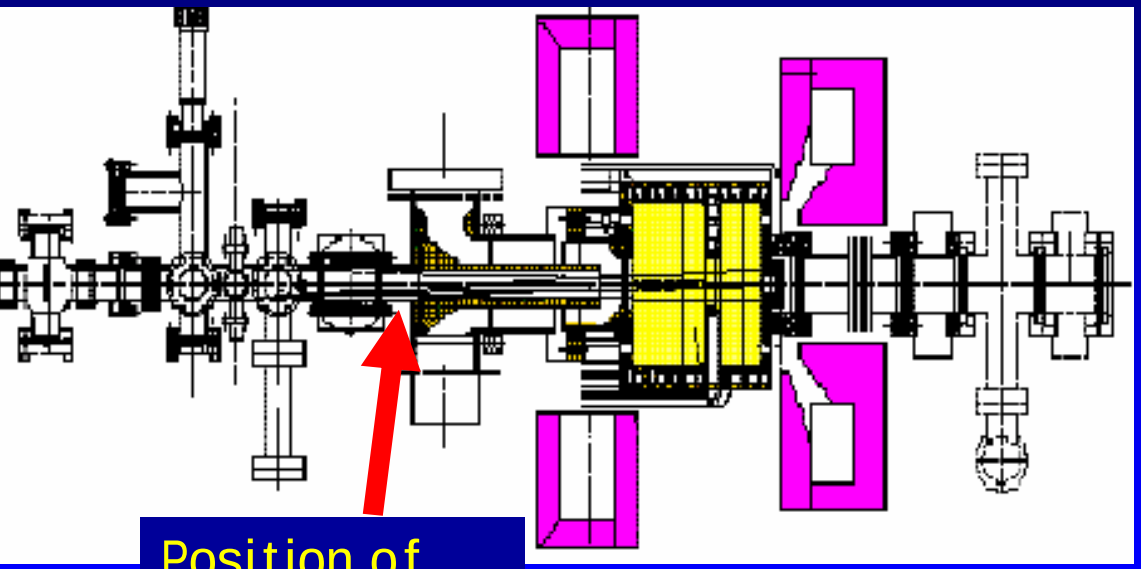




Linearity Studies with High Intensities



Application as beam halo monitor



PITZ Facility at Zeuthen

Position of the Diamond

Laser Reference Pulse

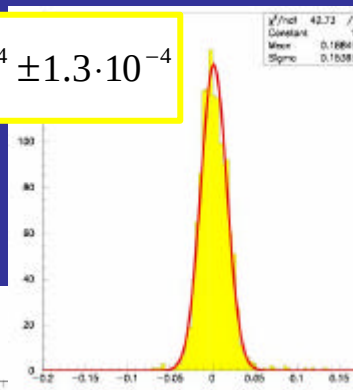
Diamond Response (on top of dark current)

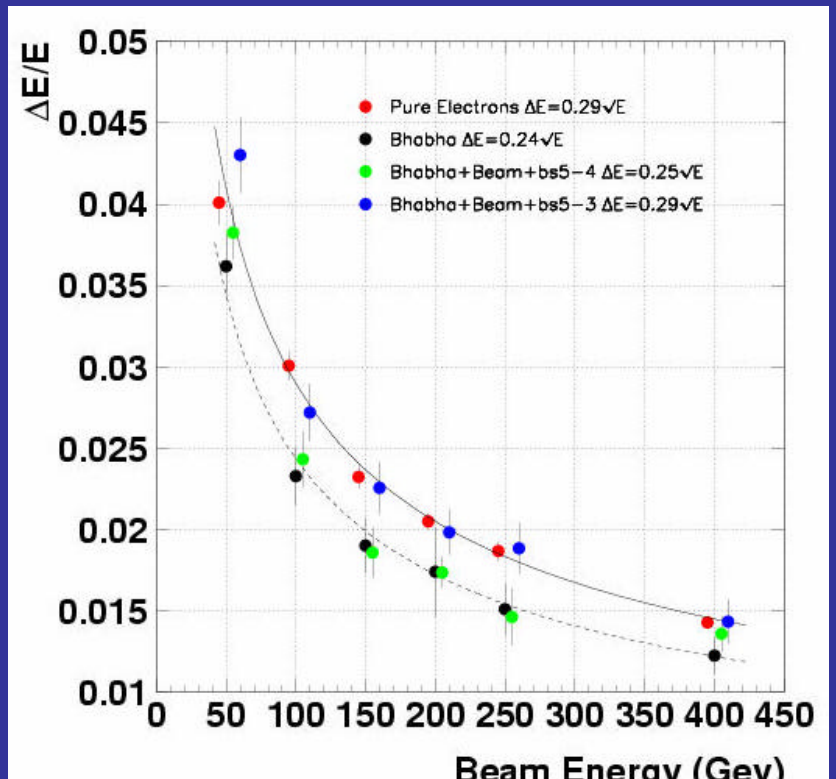
Summary

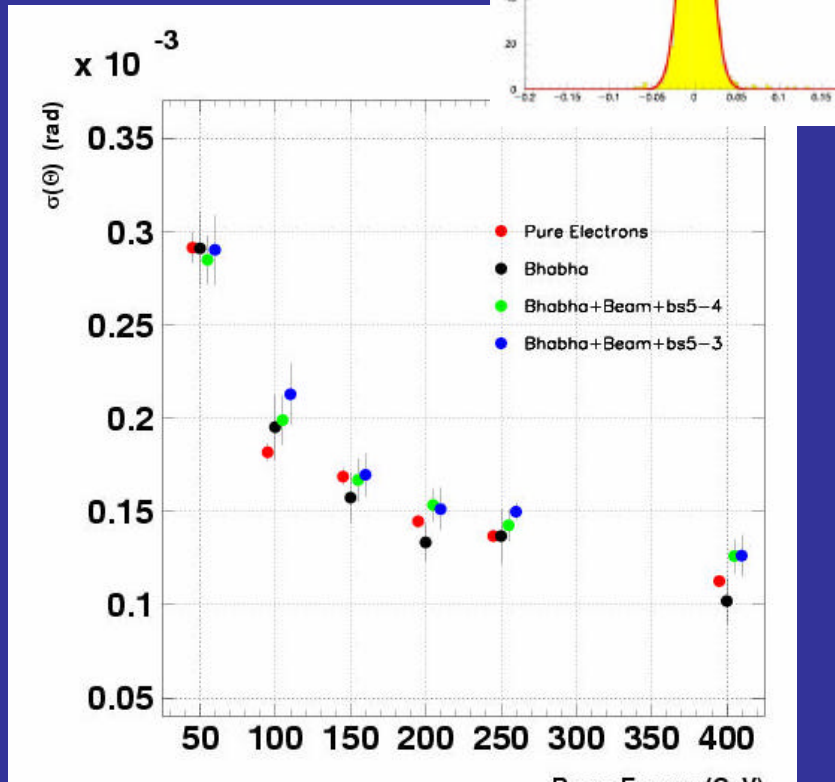
- We learned a lot ……
- We are motivated to continue
- LumiCal: More detailed Monte Carlo Studies on the bias in q, Acceptance boundaries, two photon background;
  Mechanics Support, Laser Alignment, Sensors
  → Prototype in 3 years.
- BeamCal: MC to reduce segmentation, not performance, beam diagnostics;
  Feasibility Study for Large Area Diamond Sensors (Coll. with IAF) → Preparation of a Prototype
- PhotoCal: We are just at the beginning….

nergy and polar angle resolution, pad ersion

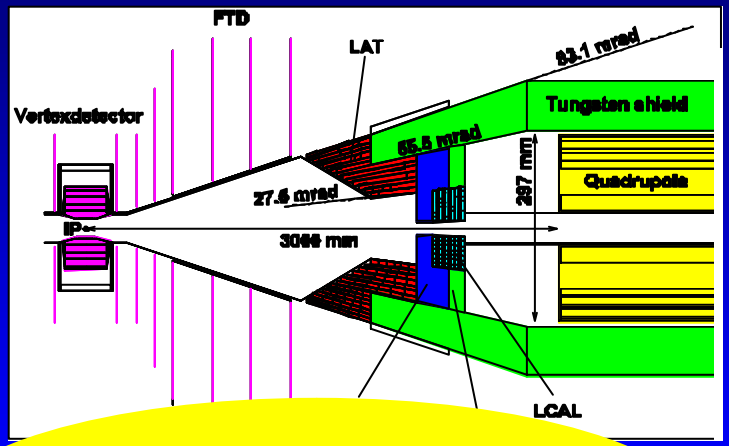
$$\frac{\Delta q}{q} = 5.7 \cdot 10^{-4} \pm 1.3 \cdot 10^{-4}$$



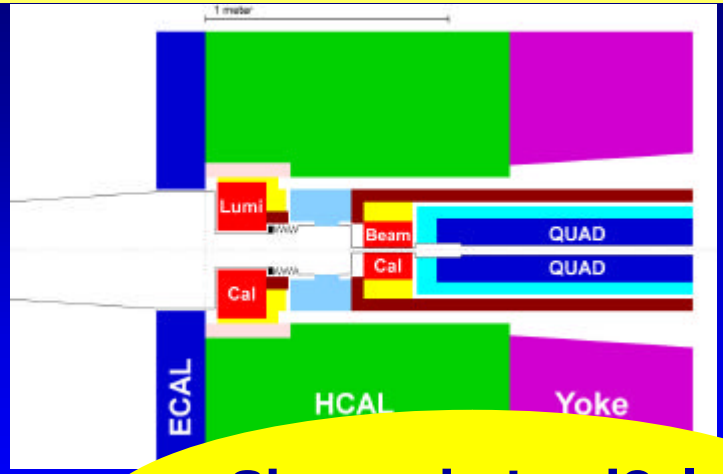




Shower LEAKAGE in old (TDR) and new LumiCal design

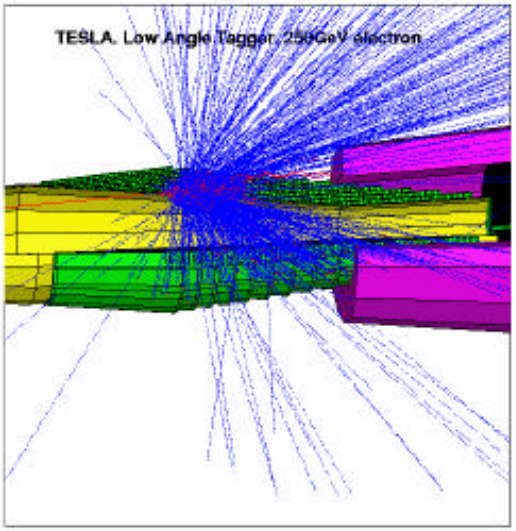


Shower in LAT (TDR design)

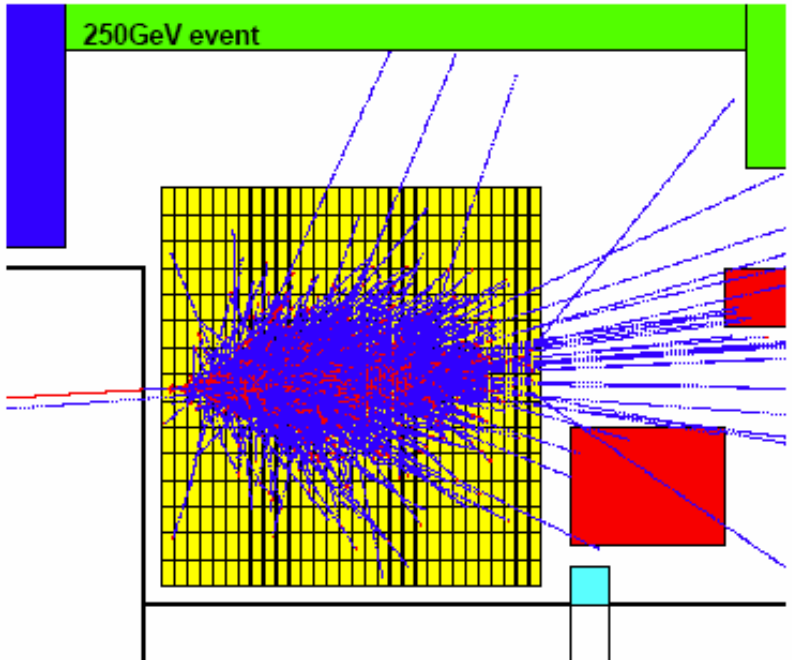


Shower in LumiCal (new design)

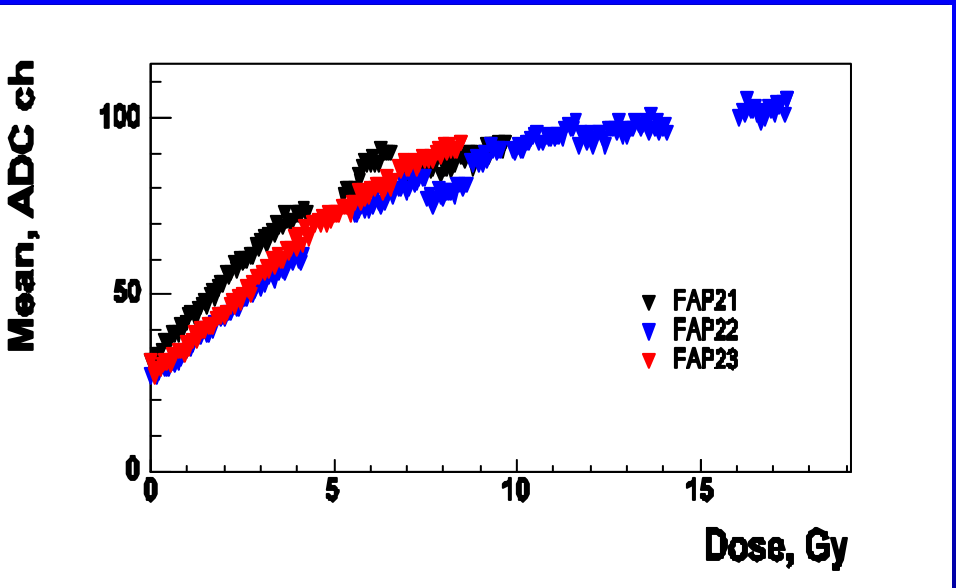
LAT shower example



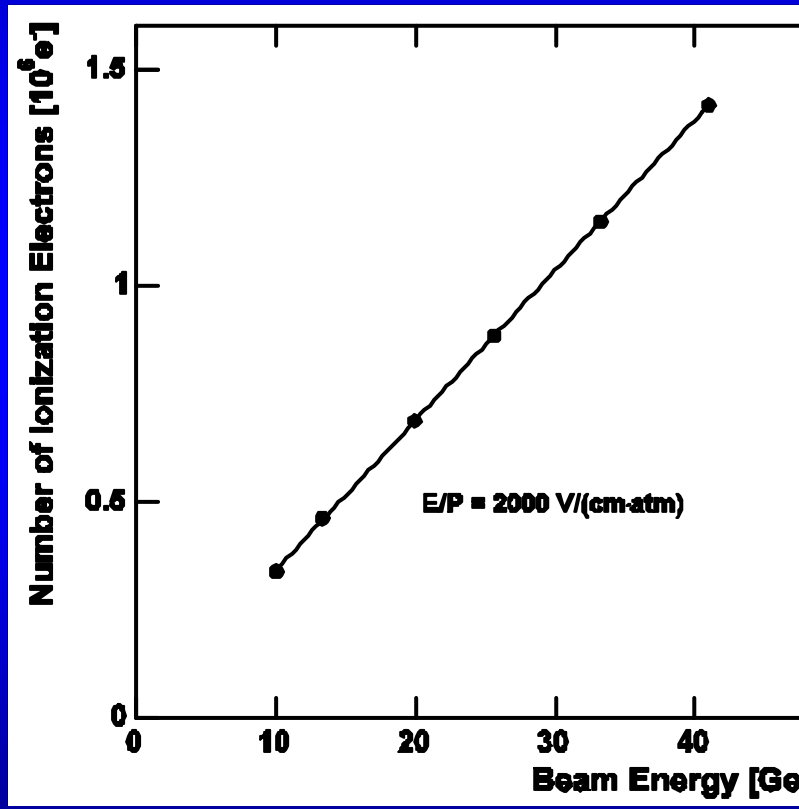
Only photons (blue) and electrons (red) over 5 MeV are displayed



Diamond performance as function of the absorbed dose



Linearity of a heavy gas calorimeter (IHEP testbeam



ile up effects

200 GeV Electrons Efficiency less then 90%