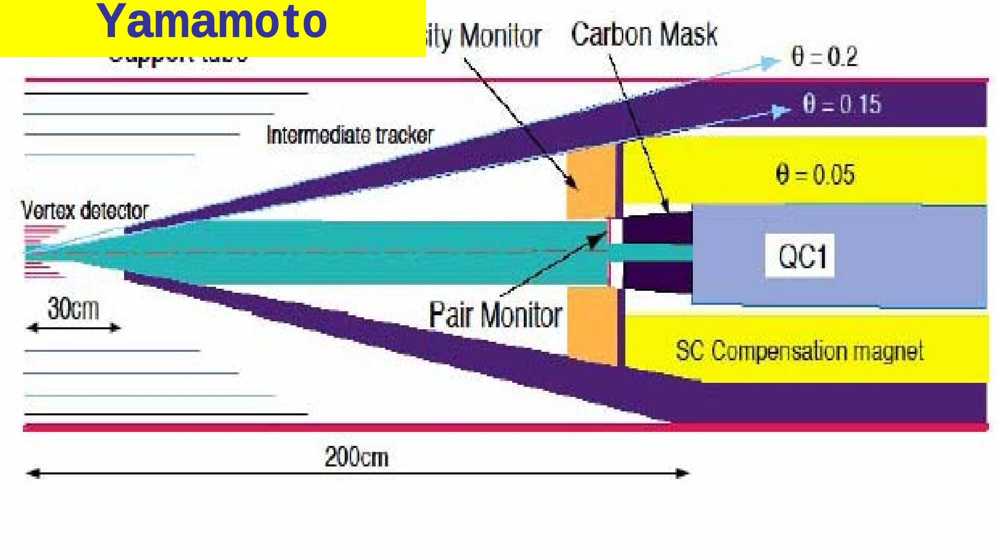
# Instrumentation of the Very Forward Region of a Linear Collider Detector

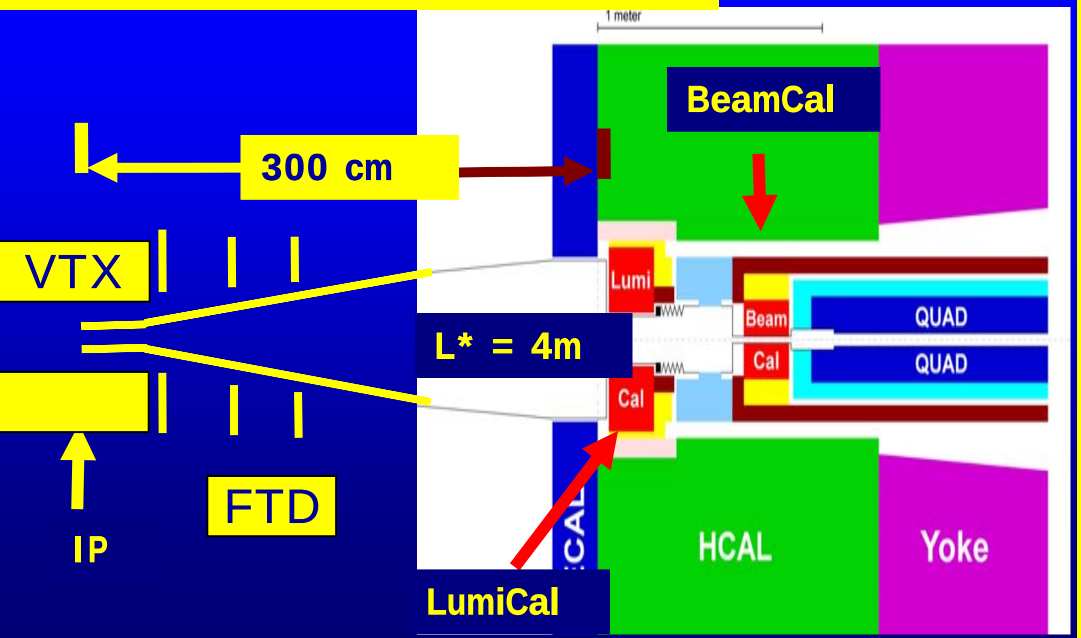
**Wolfgang Lohmann,**
**DESY**

**Used by H. Yamamoto**

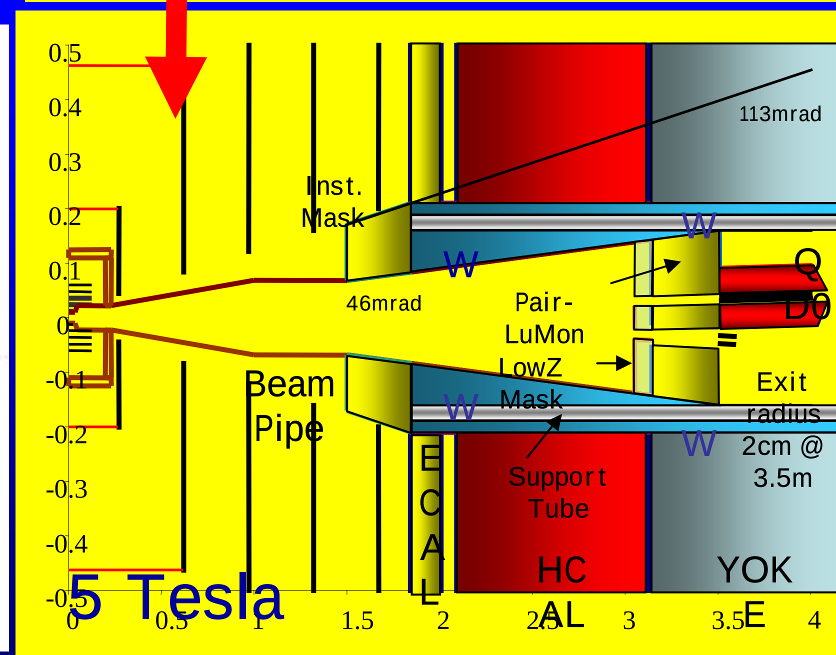



**Simulation studies on several designs**

**Design for 0-2 mrad crossing angle (FCAL design)**



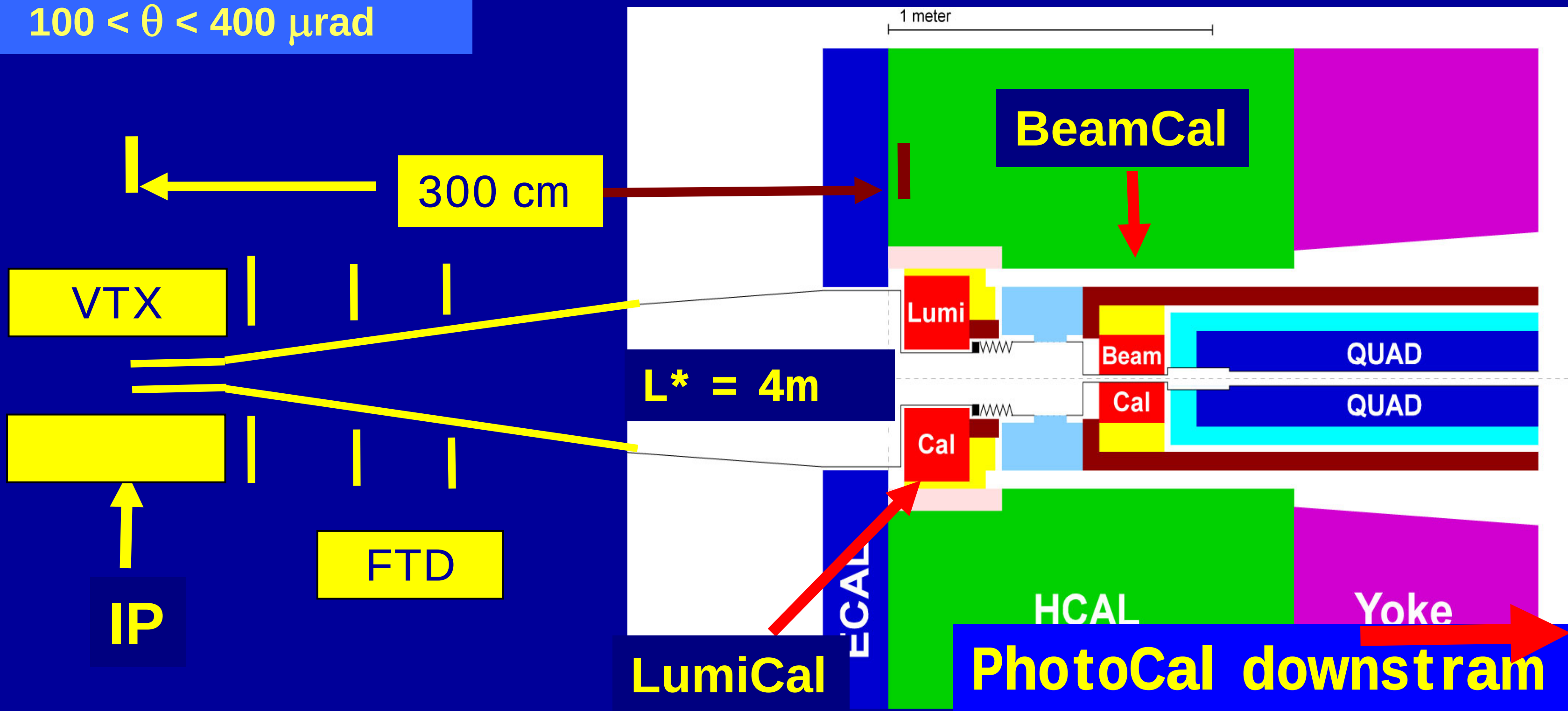

**SiD Forward Masking, Calorimetry & Tracking, 20 mrad crossing angle**



# Functions of the very Forward Detectors

- Measurement of the Luminosity with precision O(<$10^{-3}$) using Bhabha scattering (see talk by Halina)
- Fast Beam Diagnostics
- Detection of electrons and photons at small polar angles- important for searches (see talk by Philip&Vladimir)
- Shielding of the inner Detectors

LumiCal: $26 < \theta < 82$ mrad
BeamCal: $4 < \theta < 28$ mrad
PhotoCal: $100 < \theta < 400$ µrad



## • Measurement of the Luminosity (LumiCal)

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

Goal: $<10^{-3}$ Precision

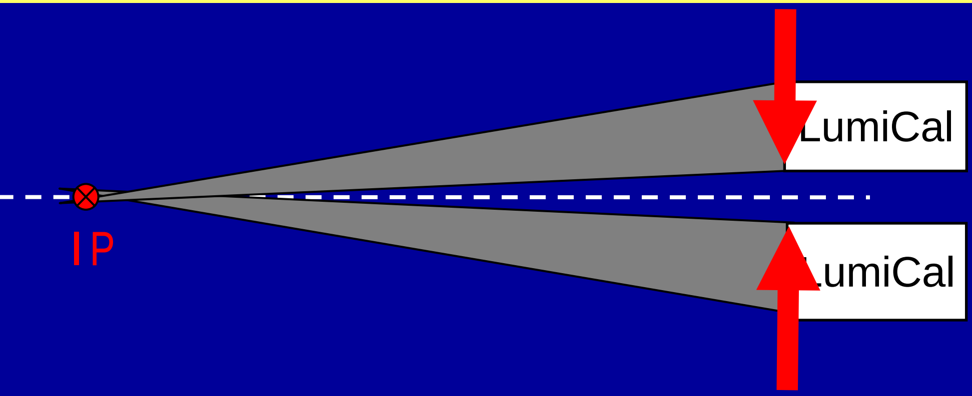
Physics Case: Giga-Z ,Two Fermion Cross Sections at High Energy, $e^+e^- \longrightarrow W^+W^-$

## • Technology: Si-W Sandwich Calorimeter

• MC Simulations ⇒

**Optimisation of Shape and Segmentation, Key Requirements on the Design**

# Requirements on the Mechanical Design

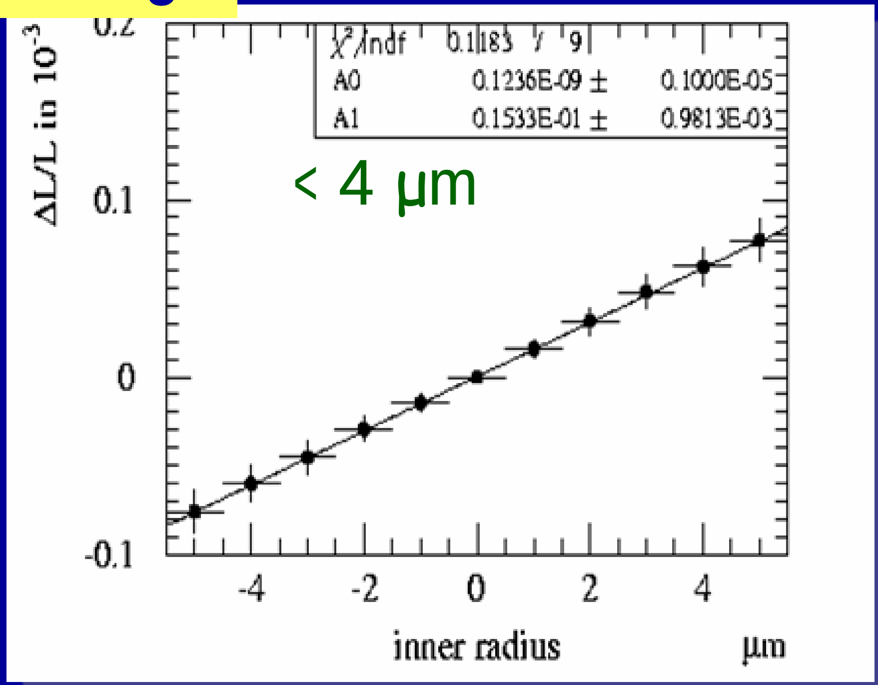


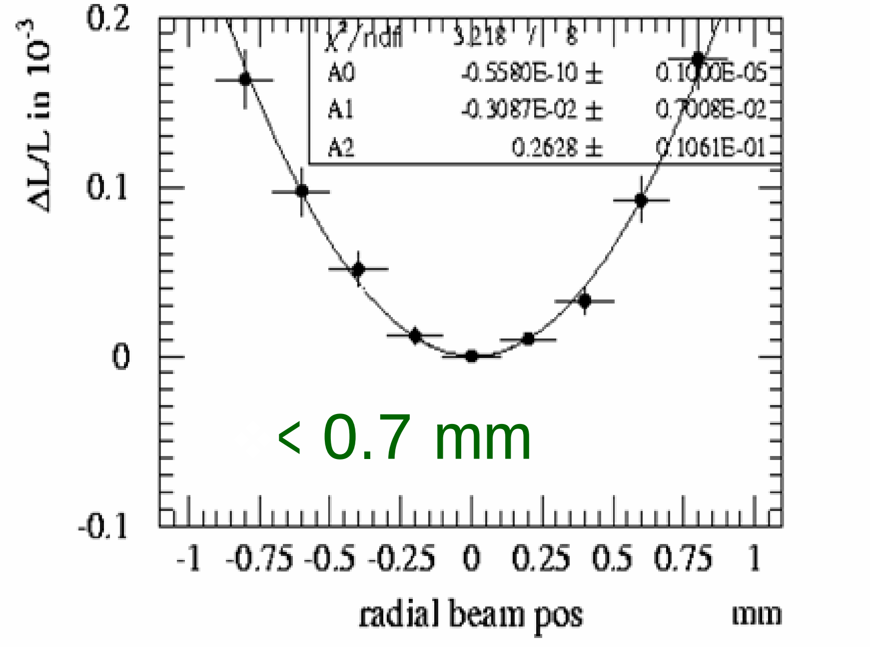

Requirements on Alignment and mechanical Precision (rough Estimate)

**Inner Radius of Cal.:** **< 1-4 µm**

**Distance between Cals.:** **< 60 µm**

**Radial beam position:** **< 0.7 mm**

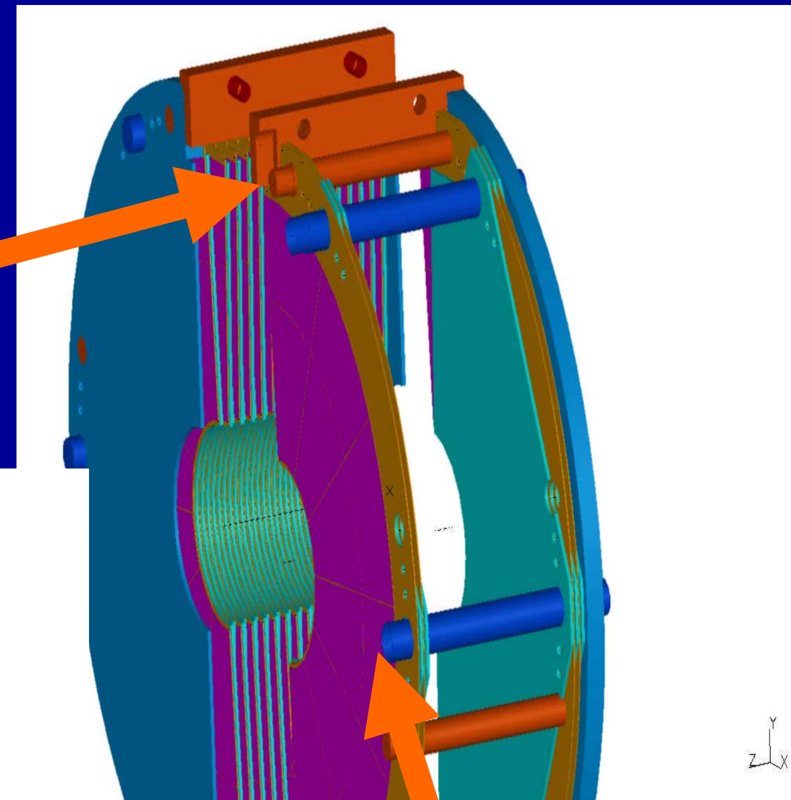


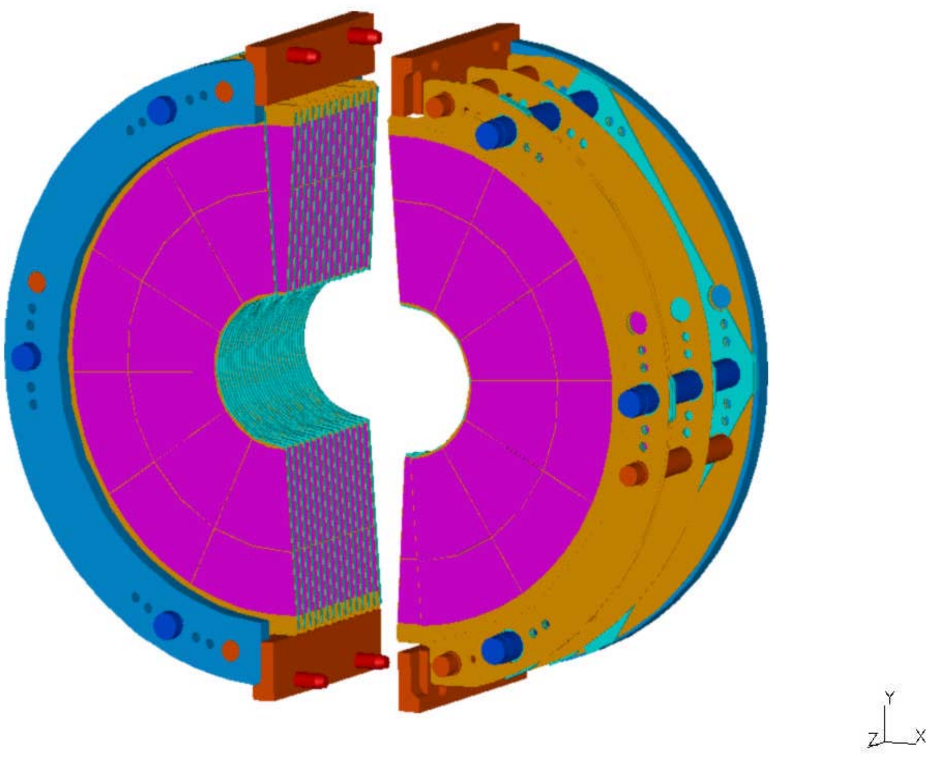



# Concept for the Mechanical Frame

**Decouple sensor frame from absorber frame**

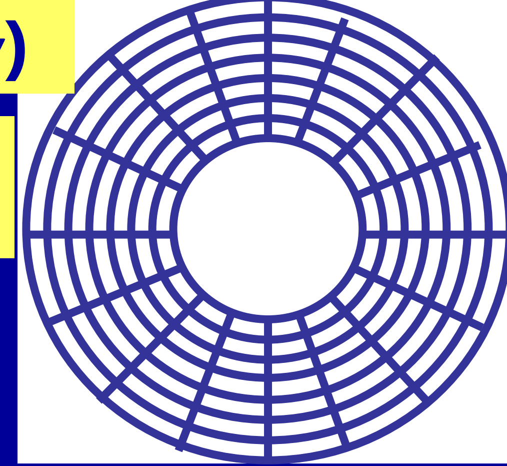
Sensor carriers





Absorber carriers

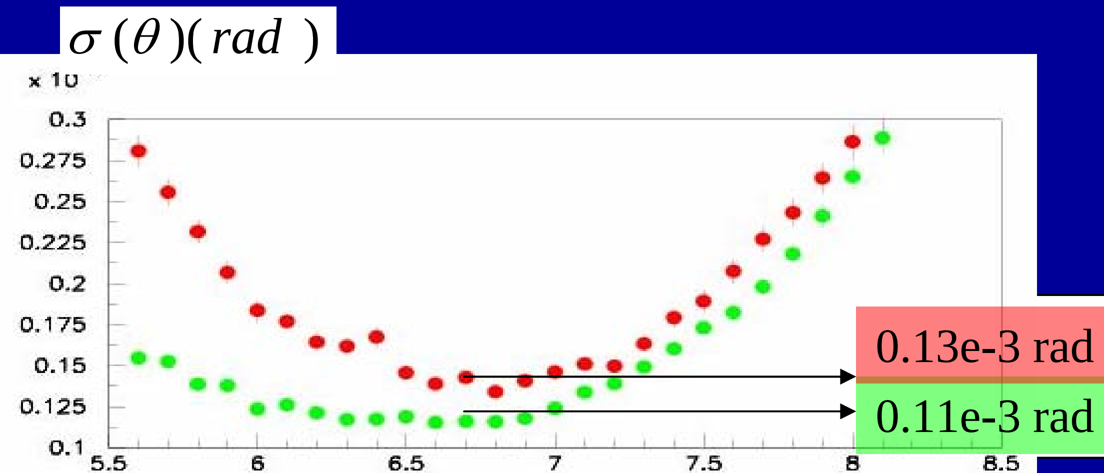
# Performance Simulations for $e^+e^- \longrightarrow e^+e^-(\gamma)$

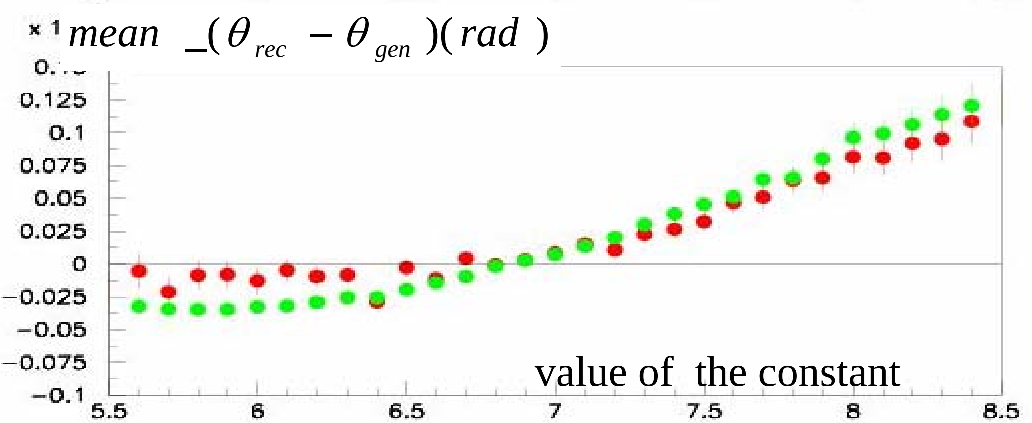


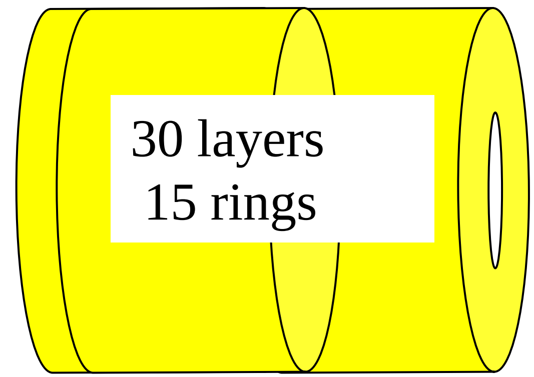
Simulation: Bhwide(Bhabha)+CIRCE(Beamstrahlung)+beamspread

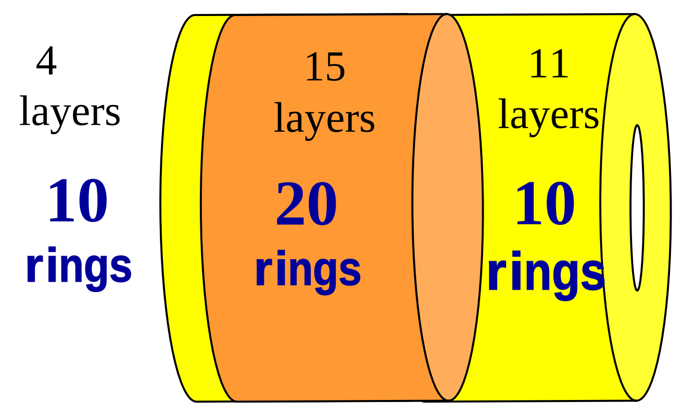
Event selection: acceptance, energy balance, azimuthal and angular symmetry.

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



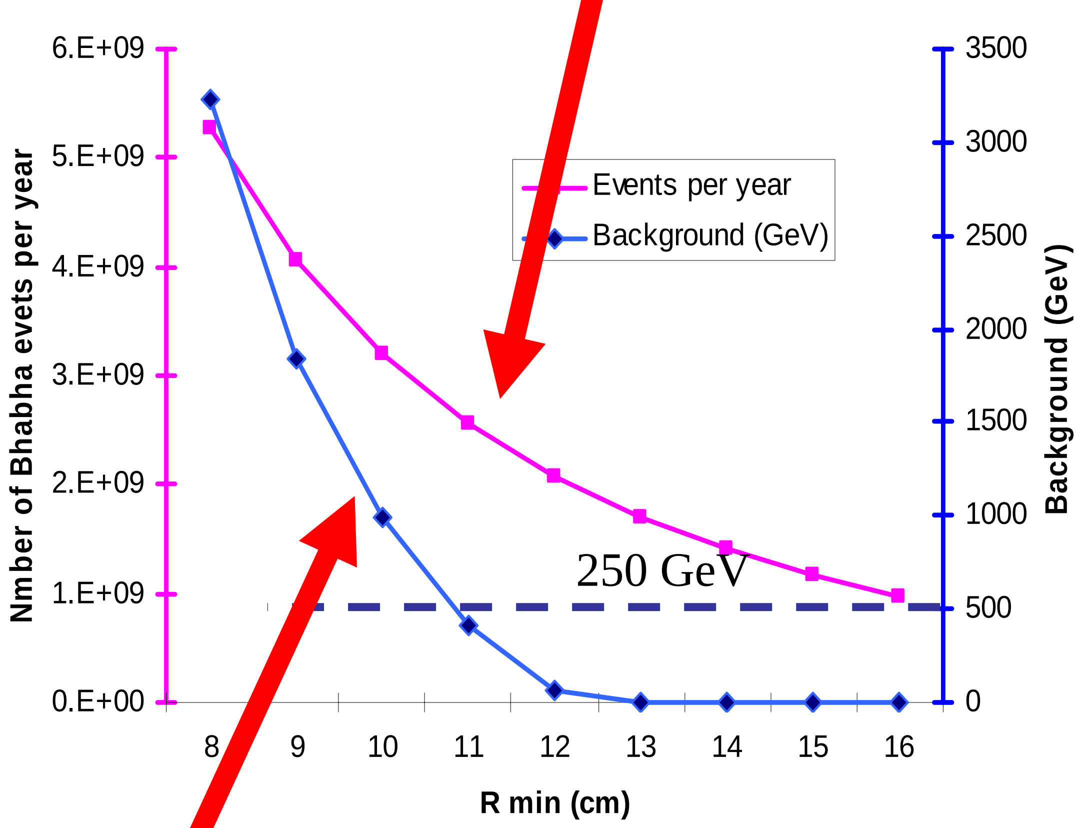



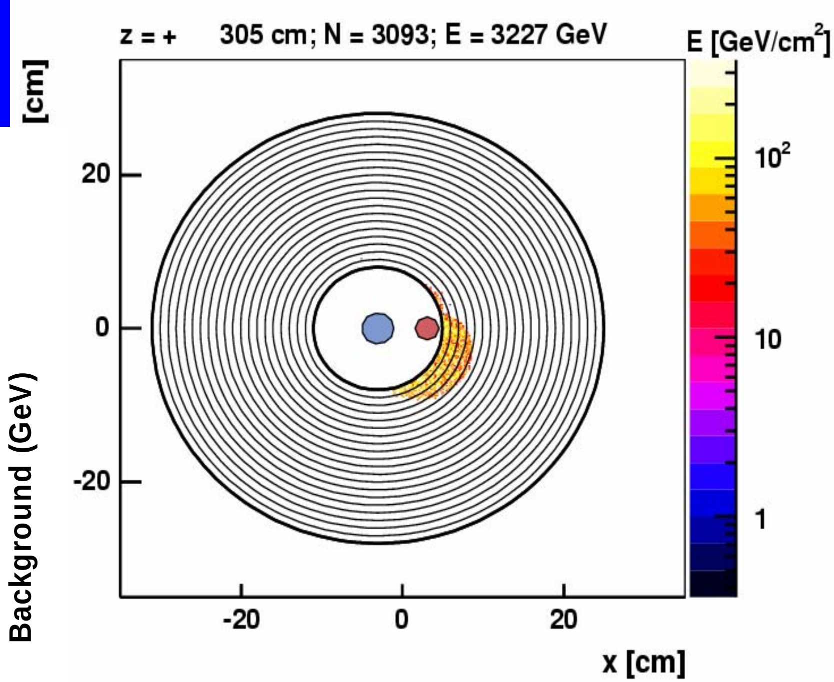

- More in the talks by Halina Abramowicz

# X- angle background

Number of Bhabha events as a function of the inner Radius of LumiCal

Beamstrahlung pair background using serpentine field

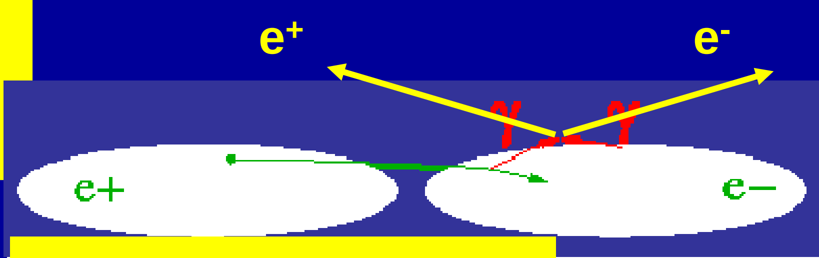



Background from beamstrahlung

Christian Grah,
DESY-Zuethen

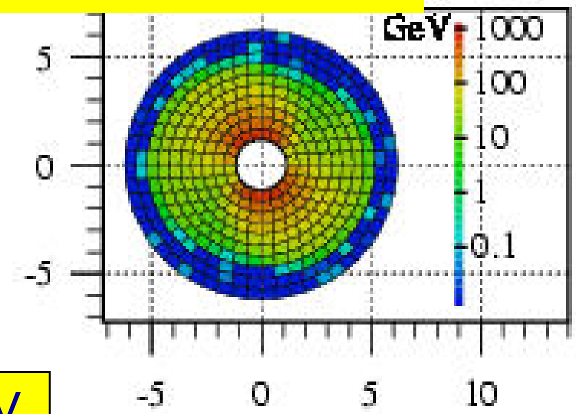
# •Fast Beam Diagnostics (BeamCal and PhotoCal)



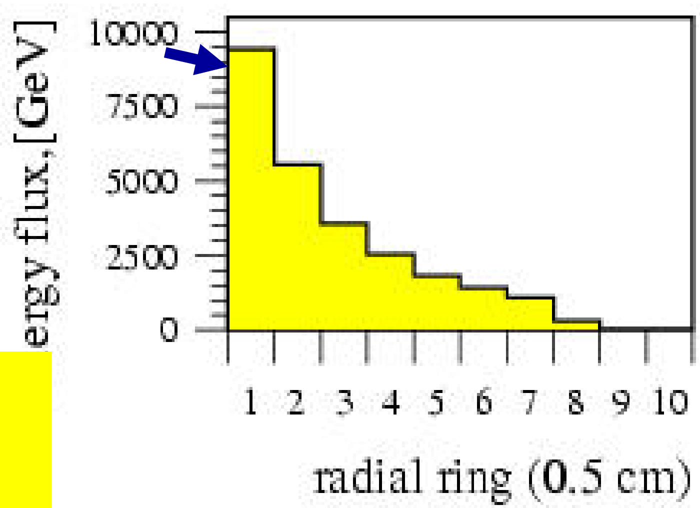

**Zero (or 2 mrad) crossing angle**

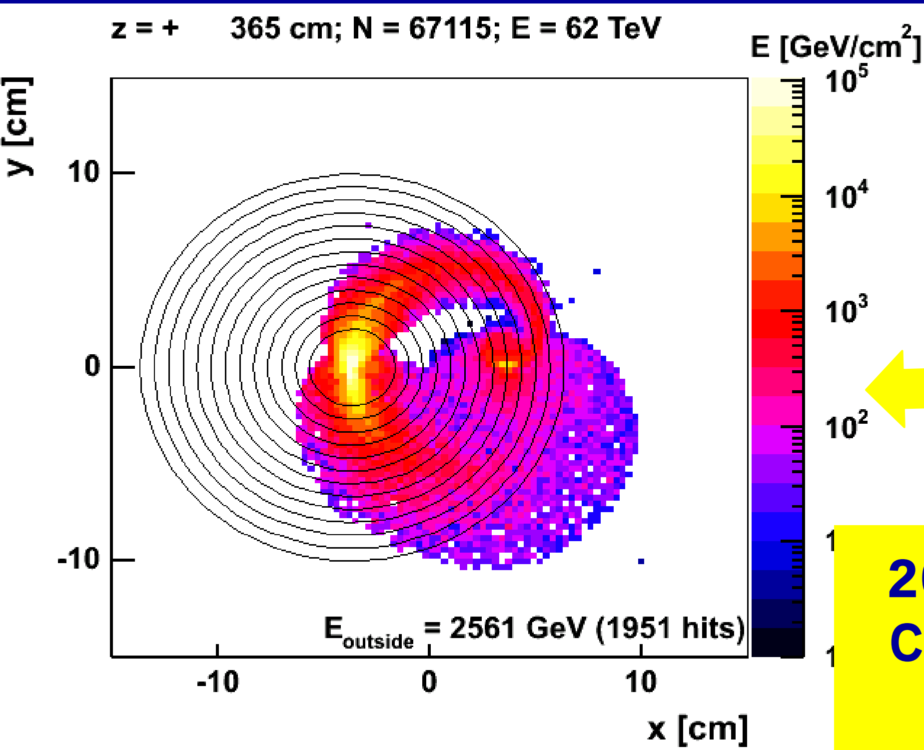
- $e^+e^-$ Pairs from Beamstrahlung are deflected into the BeamCal
- 15000 $e^+e^-$ per BX ⟶ 10 – 20 TeV

  (10 MGy per year)
- direct Photons for $\theta$ < 200 μrad




GeV



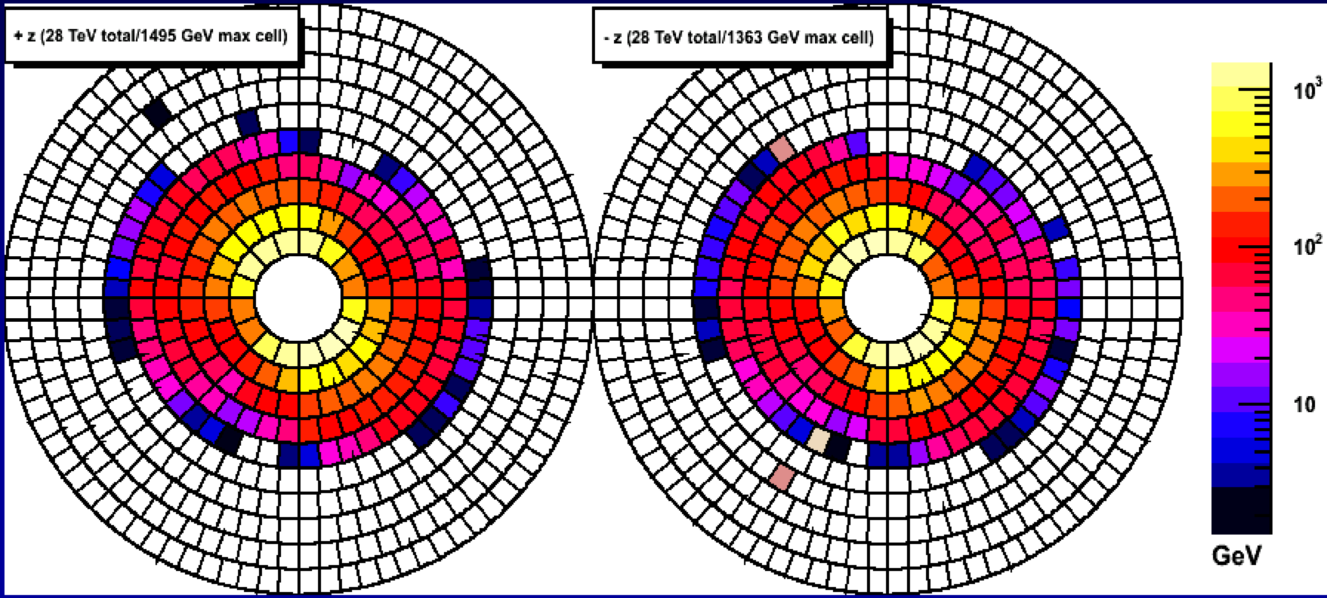




**20 mrad Crossing angle**

# Beam Parameter Determination with BeamCal

## Observables

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




| Quantity | Nominal Value | Precision |
|---|---|---|
| σx | 553 nm | 1.2 nm |
| σy | 5.0 nm | 0.1 nm |
| σz | 300 μm | 4.3 μm |
| Δy | 0 | 0.4 nm |

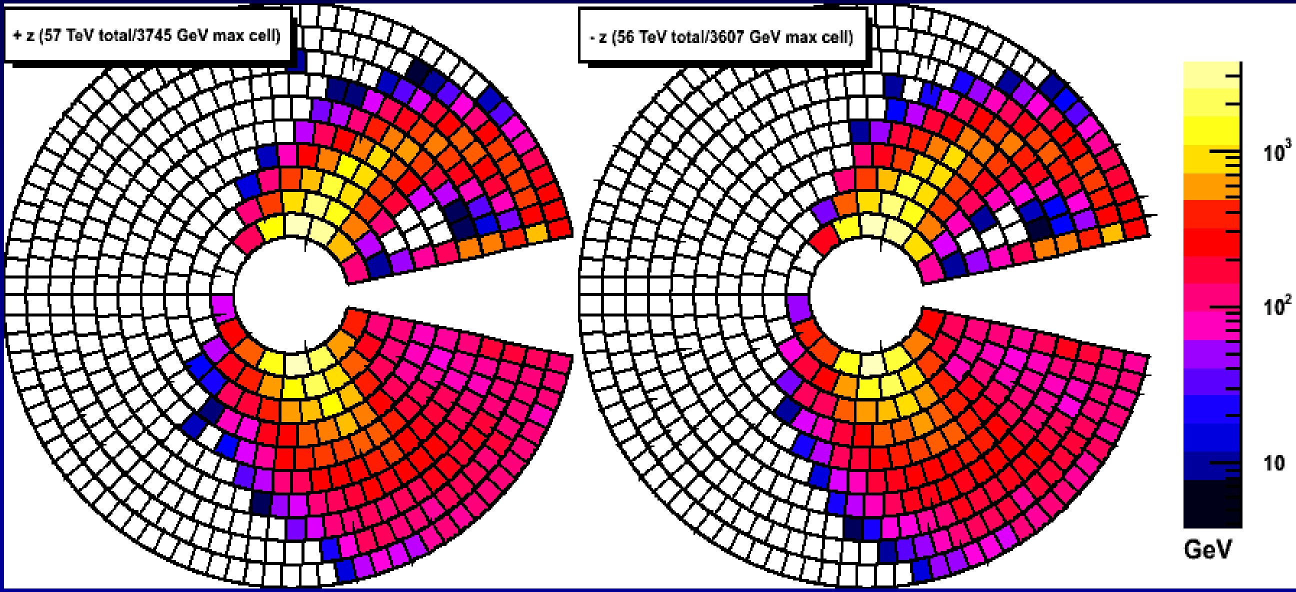
**√s = 500 GeV**

**zero or 2 mrad Crossing angle**

# Beam Parameter Determination with BeamCal

## Observables

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




| Quantity | Nominal Value | Precision |
|---|---|---|
| $\sigma x$ | 553 nm | 4.8nm |
| $\sigma y$ | 5.0 nm | 0.1 nm |
| $\sigma z$ | 300 $\mu$m | 11.5 $\mu$m |
| $\Delta y$ | 0 | 2.0nm |

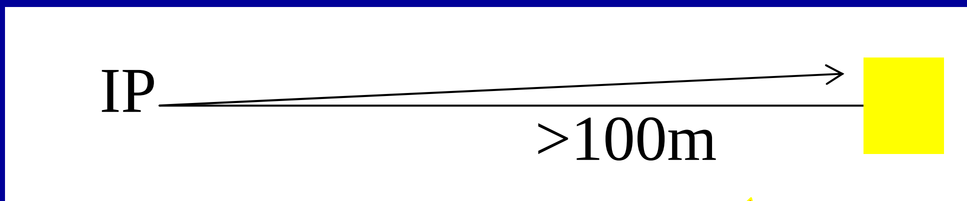
**20 mrad crossing angle**

**Also simultaneous determination of several beam parameter is feasible, but: Correlations! Analysis in preparation**

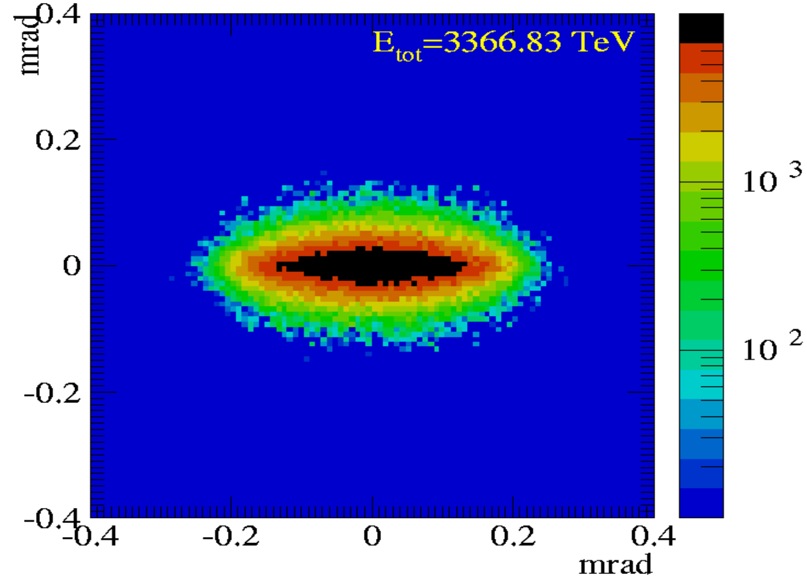
**PRELIMINARY!**

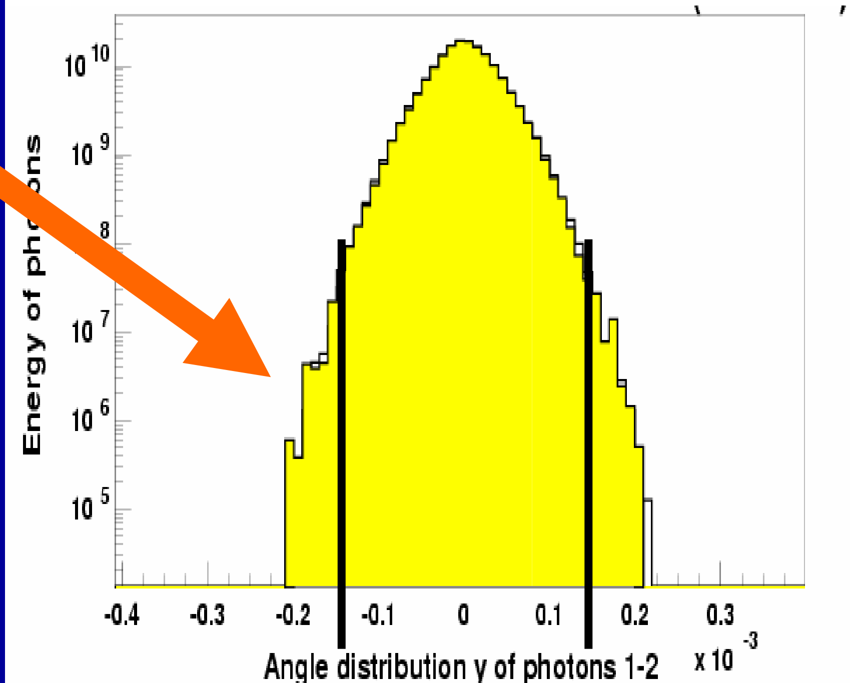
# and with PhotoCal

**Photons from Beamstrahlung**




**Heavy gas ionisation Calorimeter**



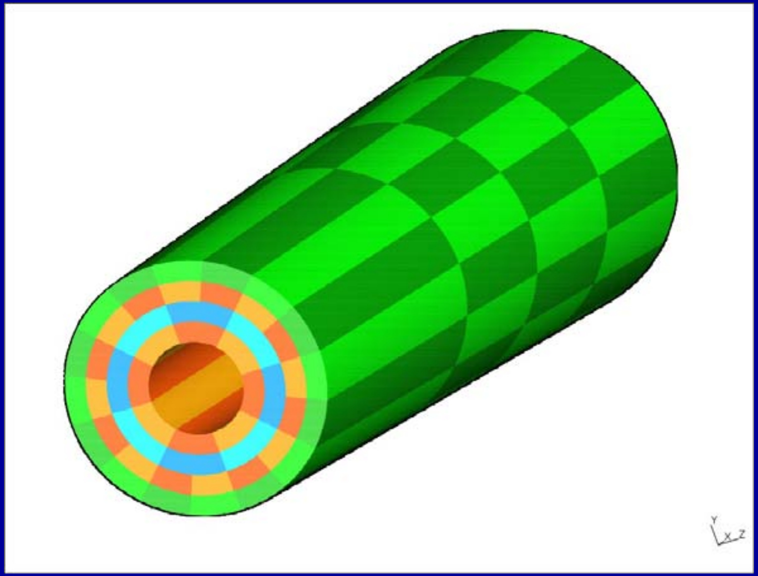

L/R, U/D F/B asymmetries of energy in the angular tails

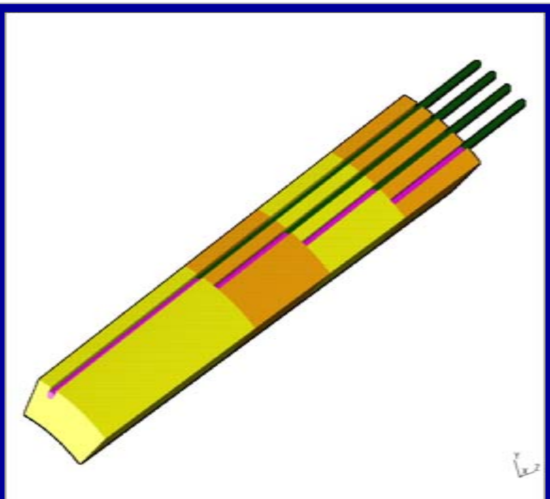
| Quantity | Nominal Value | Precision |
|---|---|---|
| $\sigma x$ | 553 nm | 4.2 nm |
| $\sigma z$ | 300 $\mu$m | 7.5 $\mu$m |
| $\Delta y$ | 0 | 0.2 nm |

# Technologies for the BeamCal:

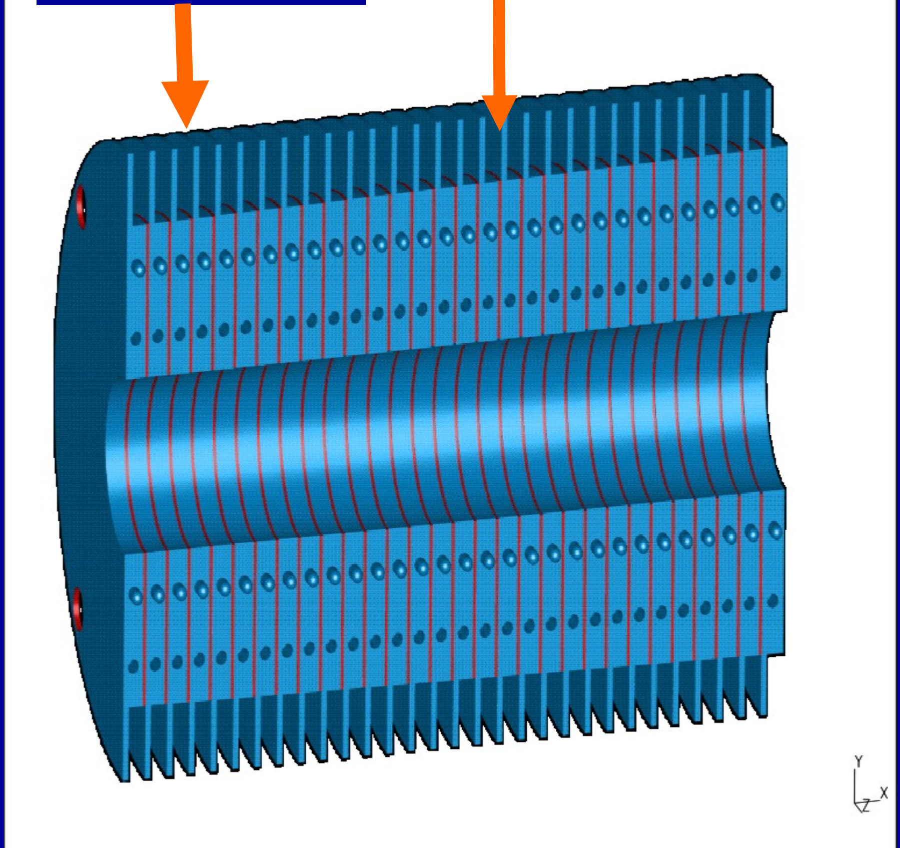
- Radiation Hard
- Fast
- Compact

Heavy crystals





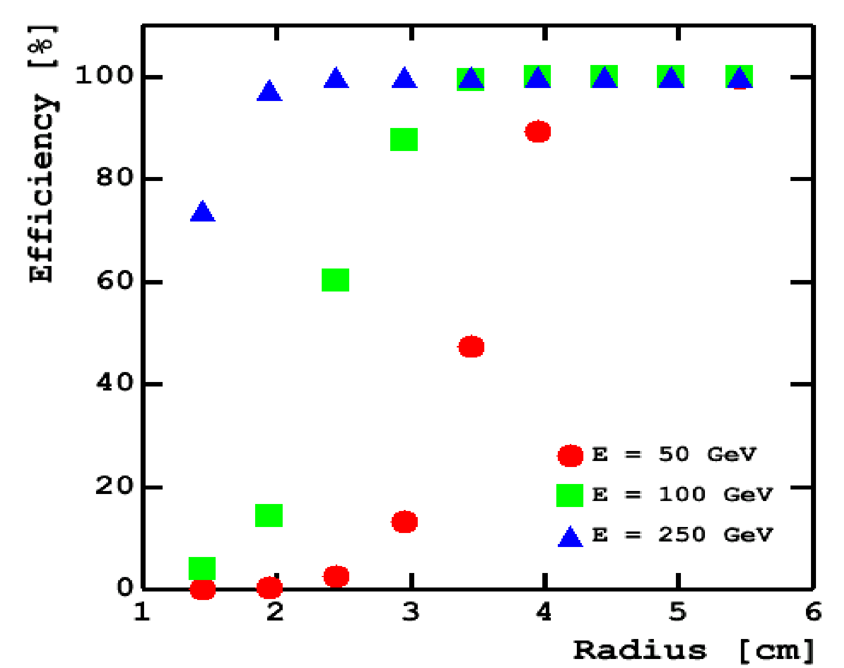
W-Diamond sandwich



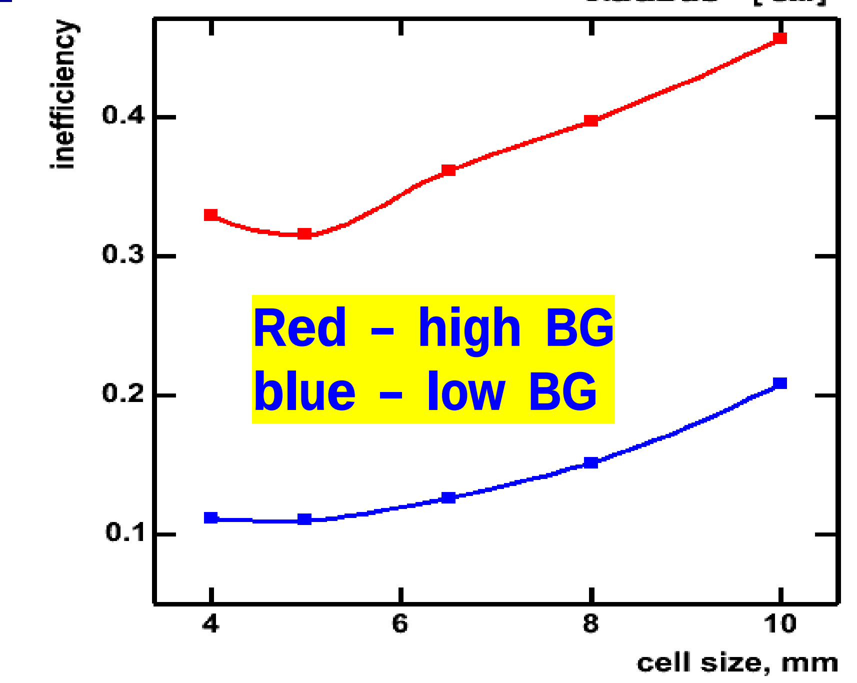
# Detection of High Energy Electrons and Photons

**$\sqrt{s}$ = 500 GeV**

**Single Electrons of 50, 100 and 250 GeV, detection efficiency as a function of R ('high background region')**
**(talk by V. Drugakov and P. Bambade)**




**Detection efficiency as a function of the pad-size**
**(Talk by A. Elagin)**



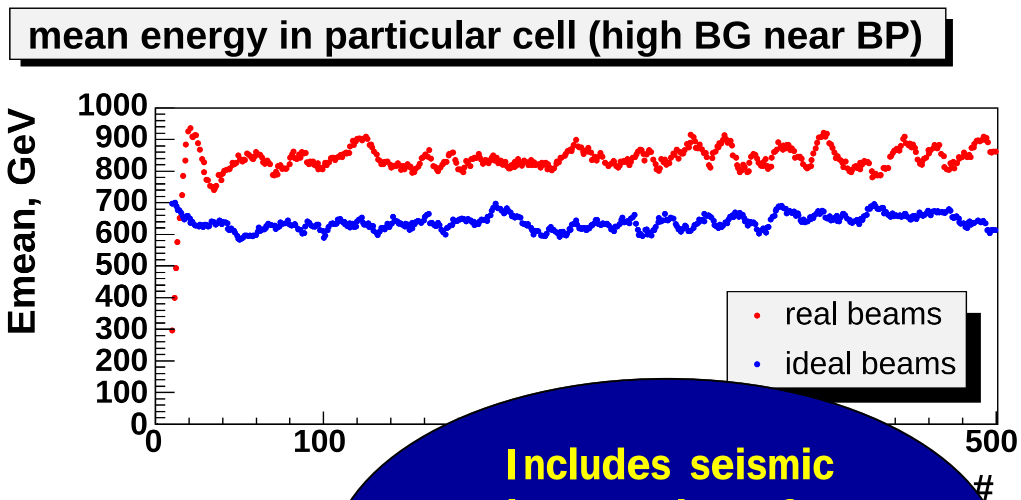

**Message:**
**Electrons can be detected!**

# Detection of High Energy Electrons and Photons

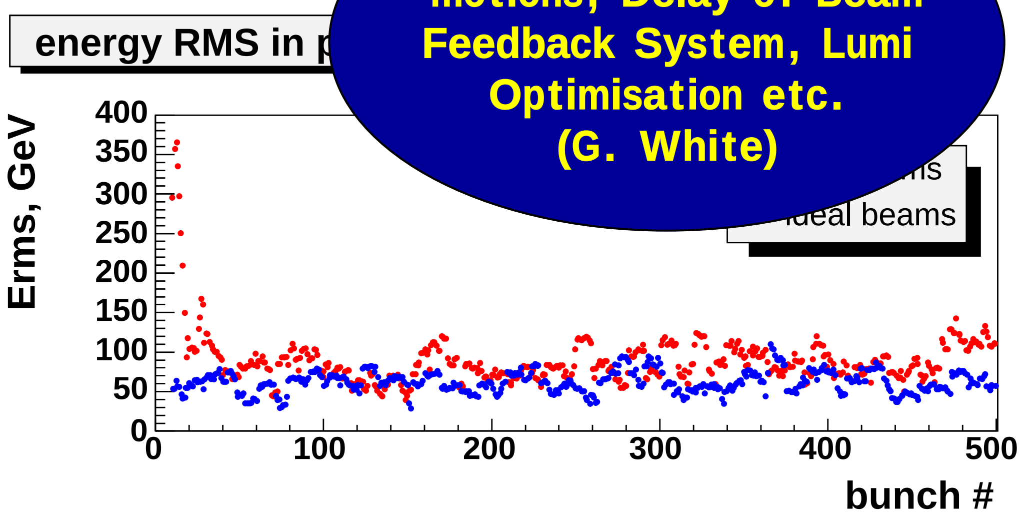
## Realistic beam simulation

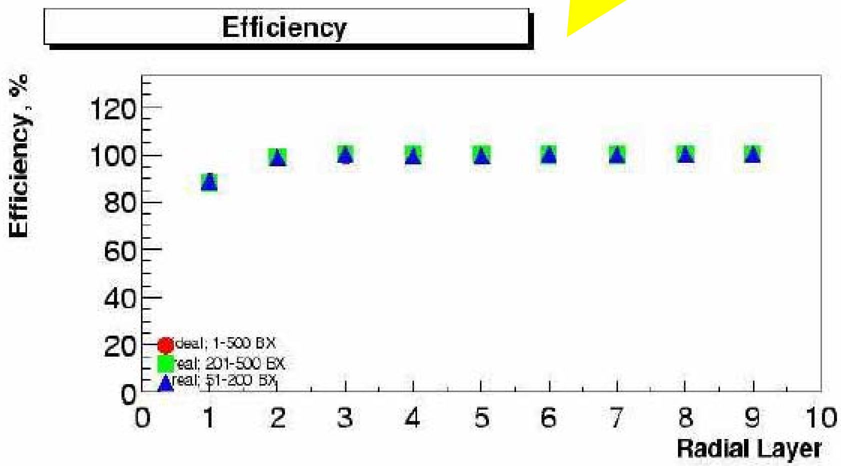
## $\sqrt{s}$ = 500 GeV

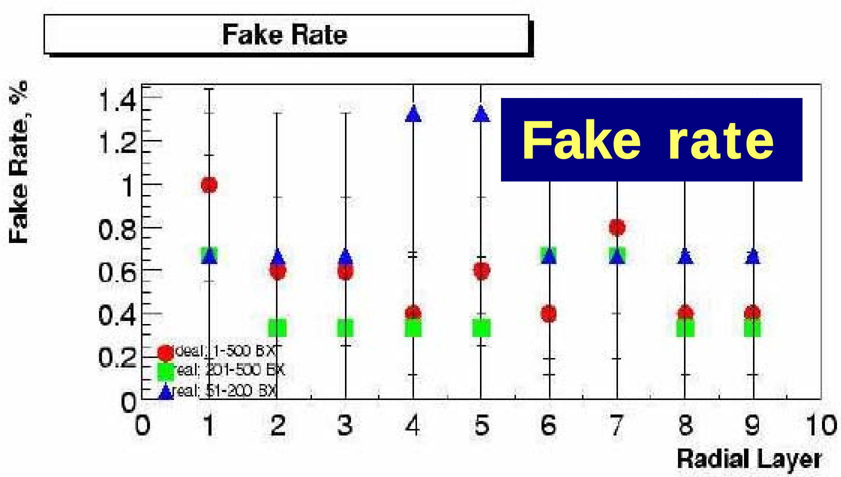
## Efficiency to identify energetic electrons and photons (E > 200 GeV)




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

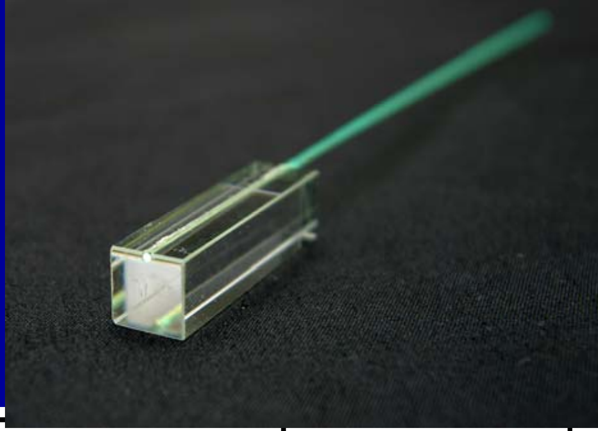


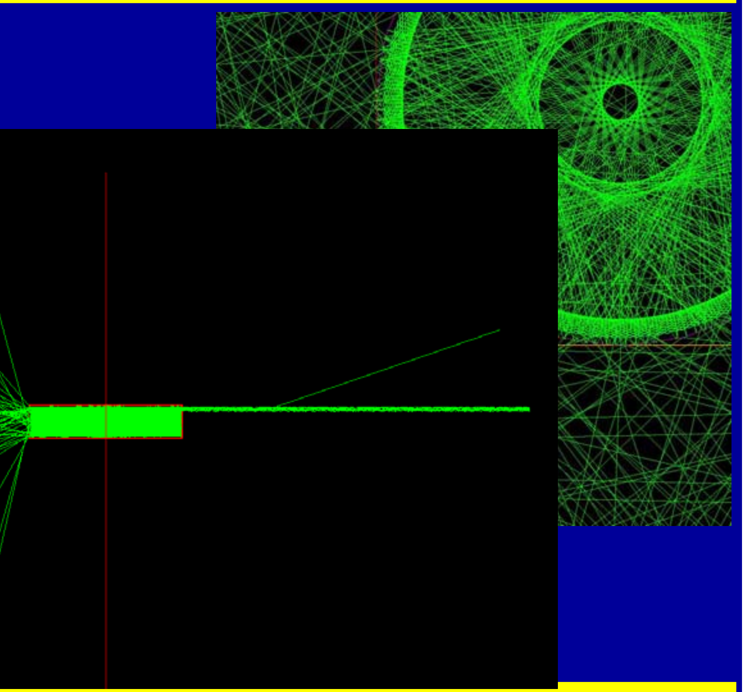

Fake rate

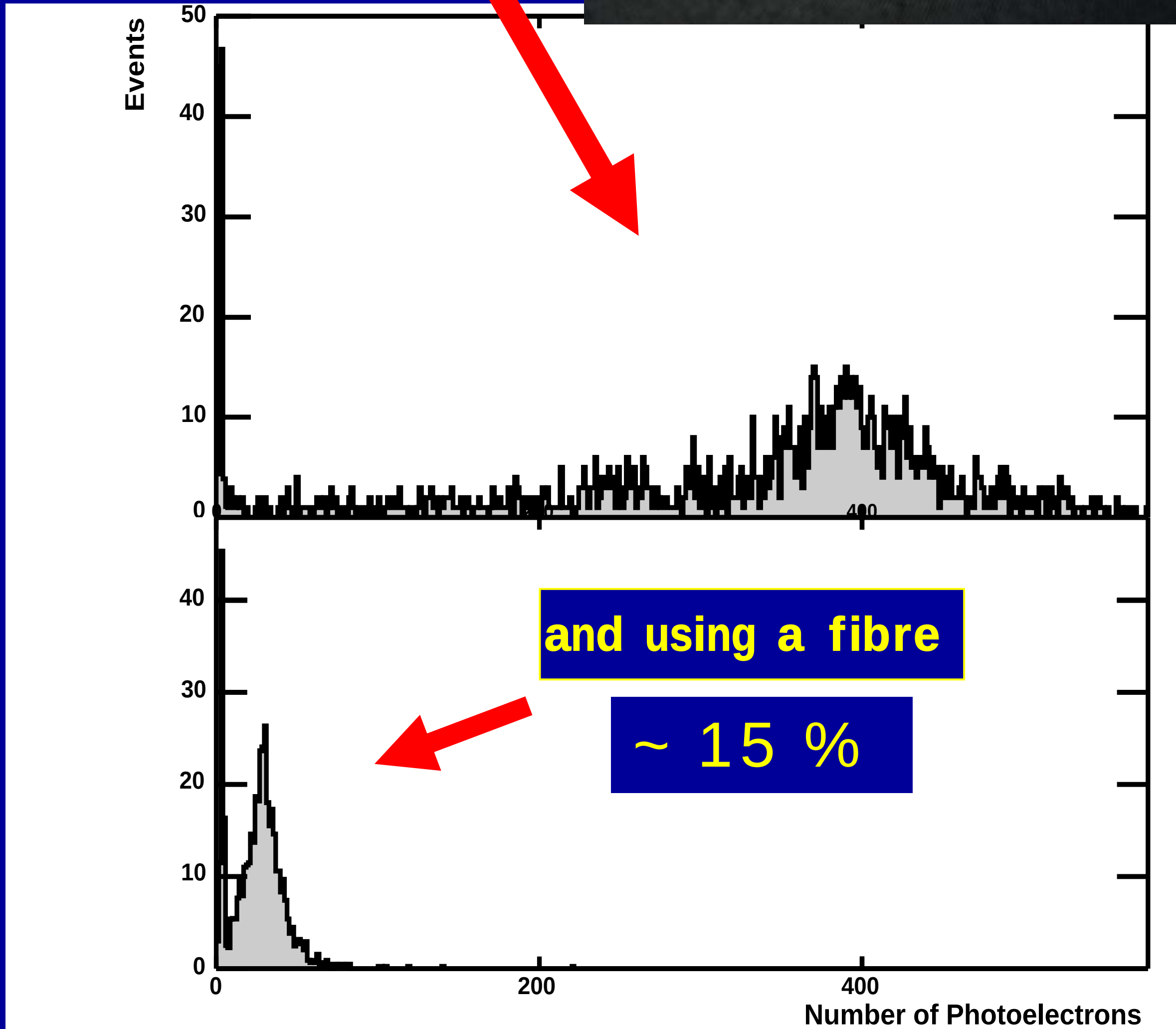
# Sensor prototyping, Crystals



Light Yield from direct coupling

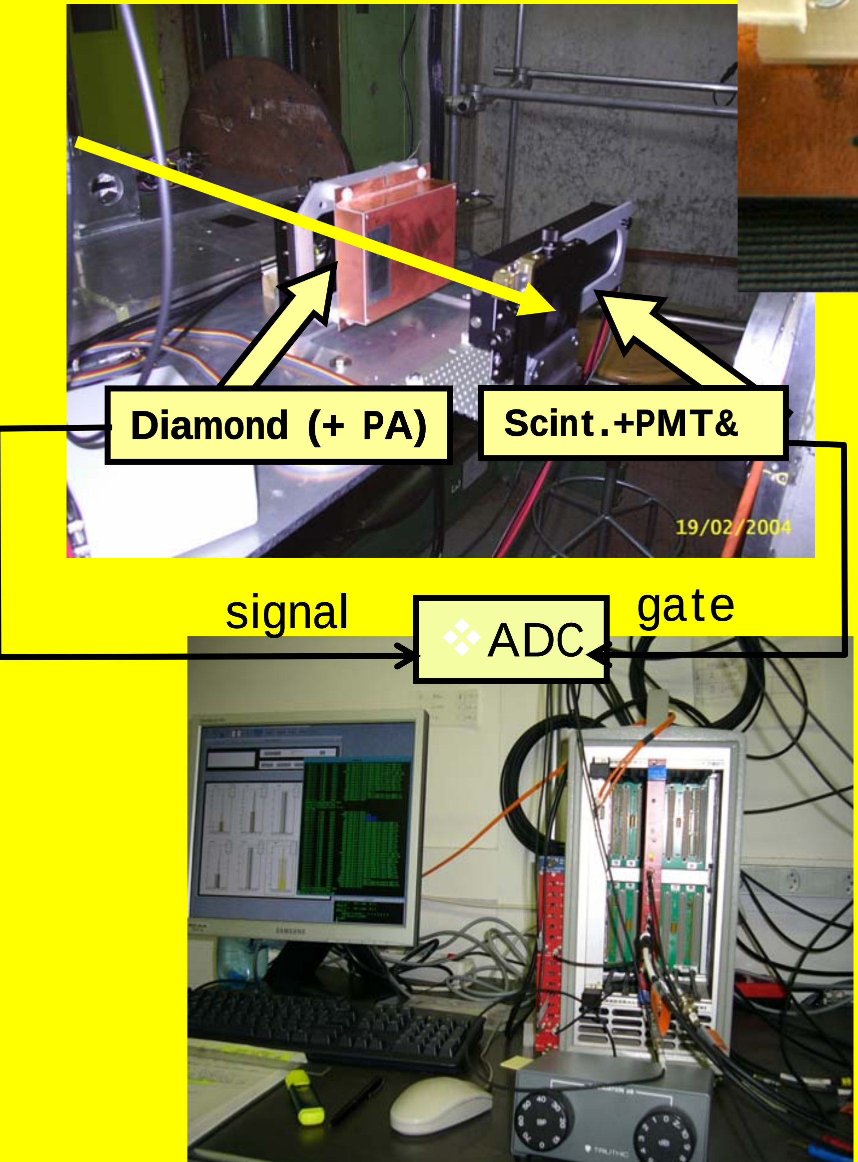
Compared with GEANT4 Simulation, good agreement

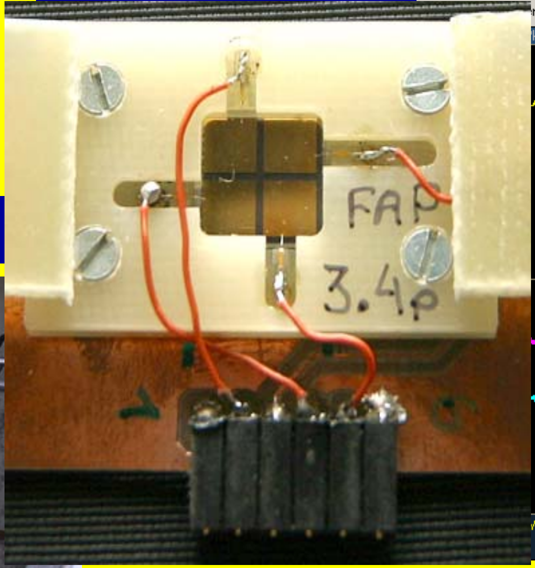


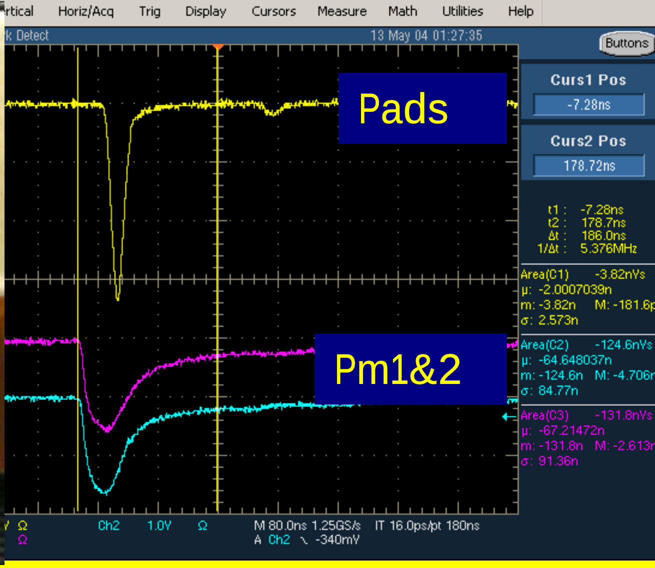



Similar results for lead glass Crystals (Cerenkov light !)

# Sensor prototyping, Diamonds




May,August/2004 test beams

CERN PS Hadron beam – 3,5 GeV

2 operation modes:

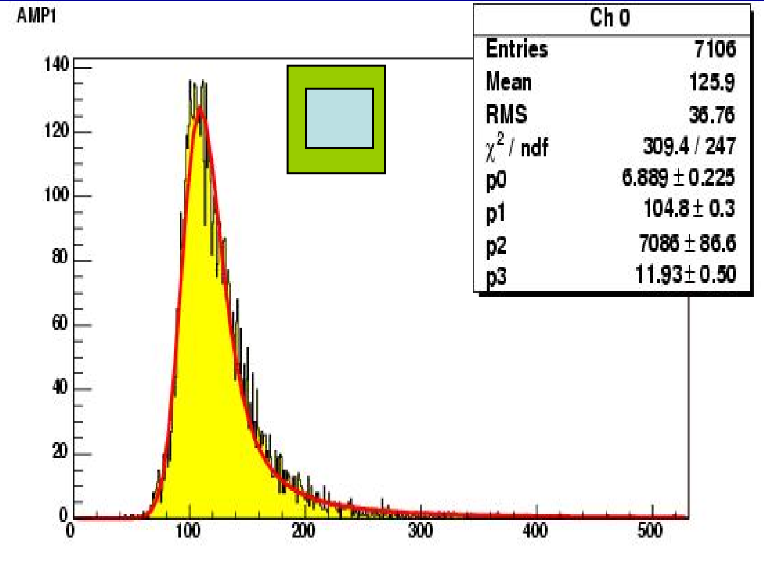
- Slow extraction ~$10^5$-$10^6$ / s
- fast extraction ~$10^5$-$10^7$ / ~10ns (Wide range intensities)

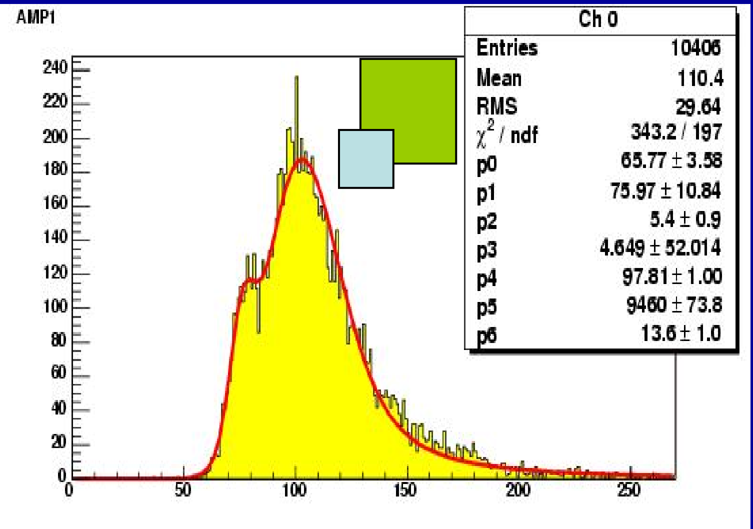
Diamond samples (CVD):

- Freiburg
- GPI (Moscow)
- Element6

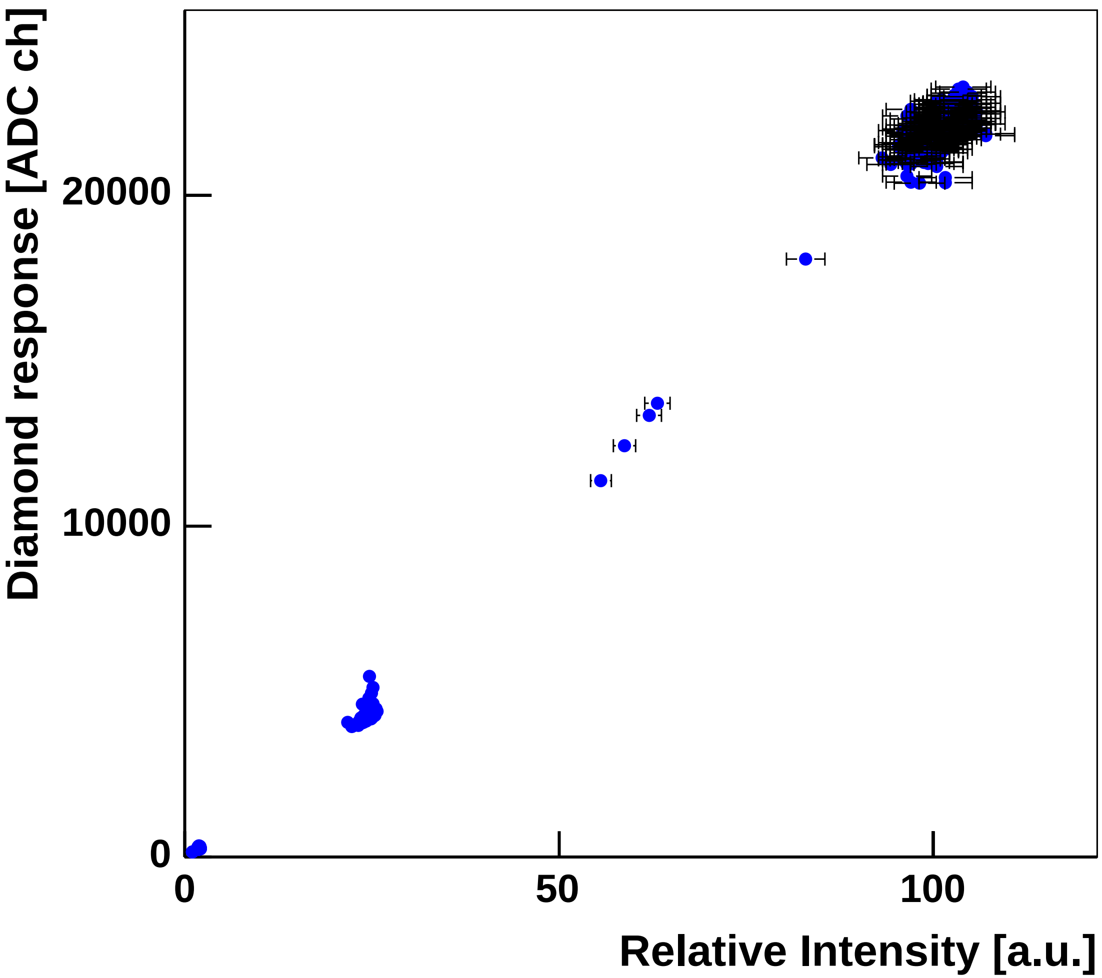
# Diamond Sensor Performance

## Response to mip




## Linearity Studies with High Intensities (PS fast beam extraction) $10^5$ particles/10 ns



FCAL Collaboration
High precision design

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

**Workshop on the Instrumentation of the Very Forward Region of the ILC Detector**
**Tel Aviv, Sept. 15.-20. 2005.**
**http//alzt.tau.ac.il/~fcal/**

## Summary

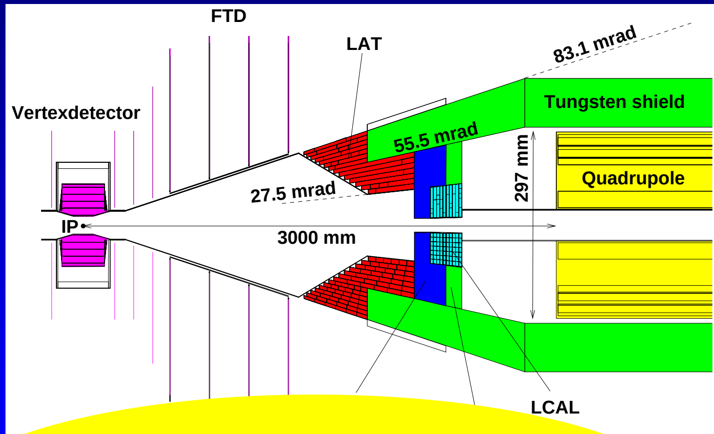
- Many (and promising) results in simulations/design studies
- Concept for a Luminometer for small crossing angle is advanced, 20 mrad needs a different design
- Mechanics design work ongoing
- calorimeters in the very forward region deliver very valuable information about beam parameters
- High energy electron detection down to small polar angles is feasible with compact and fine segmented calorimeters; easier for small crossing angle
- Studies with sensors started- needs more effort
- Prototype tests mandatory

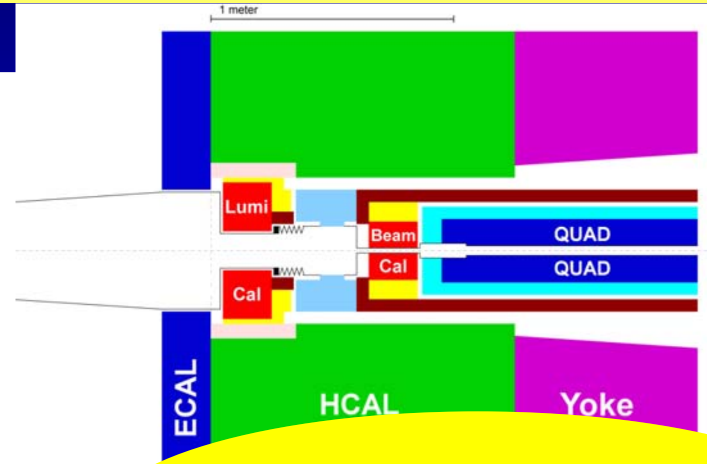
## Remarks

- The instrumentation of the forward region is relatively independent of the detector concept,

# Backup Slides

# Shower LEAKAGE in old (TDR) and new LumiCal design

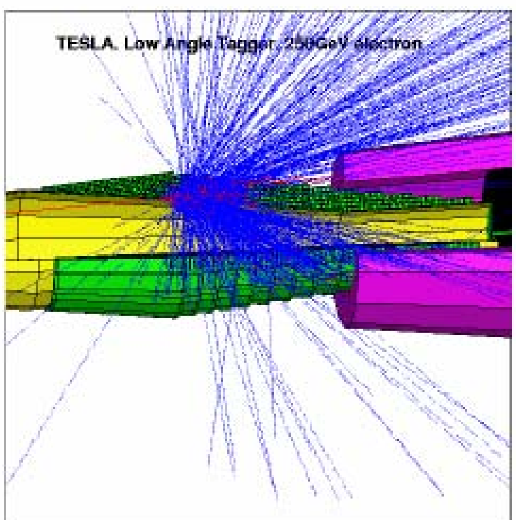



**Shower in LAT (TDR design)**

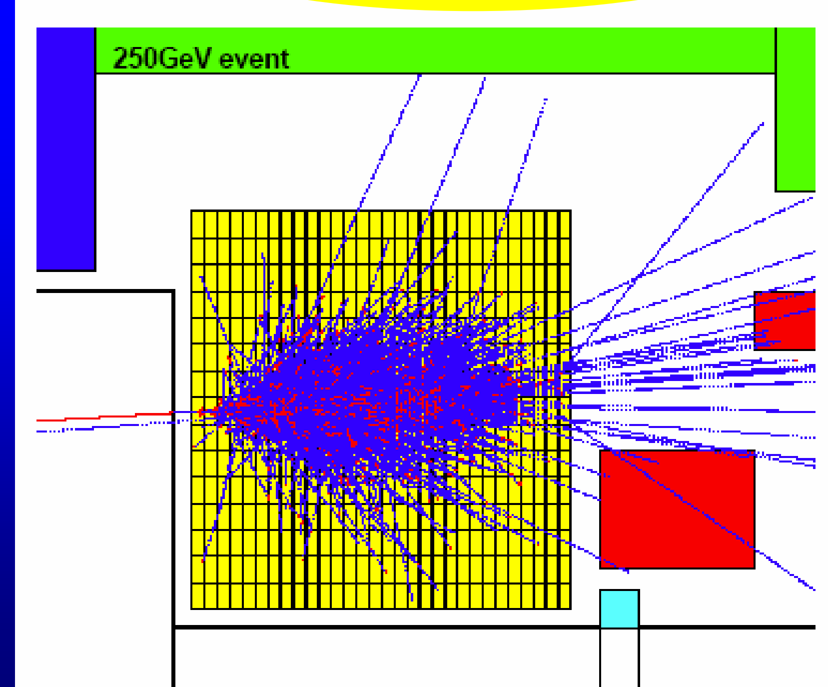
**Shower in LumiCal (new design)**

## LAT shower example

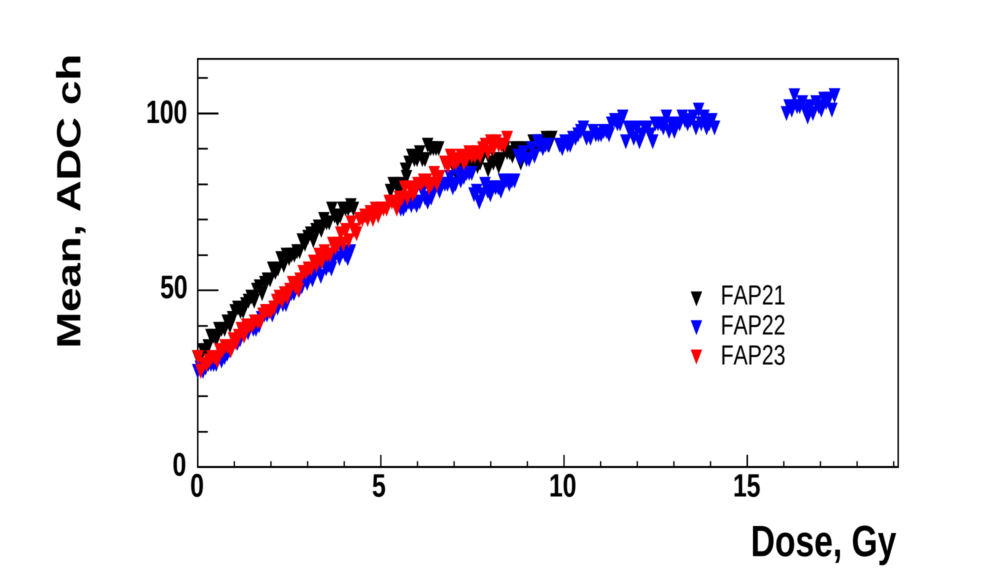



Only photons (blue) and electrons (red) over 5 MeV are displayed

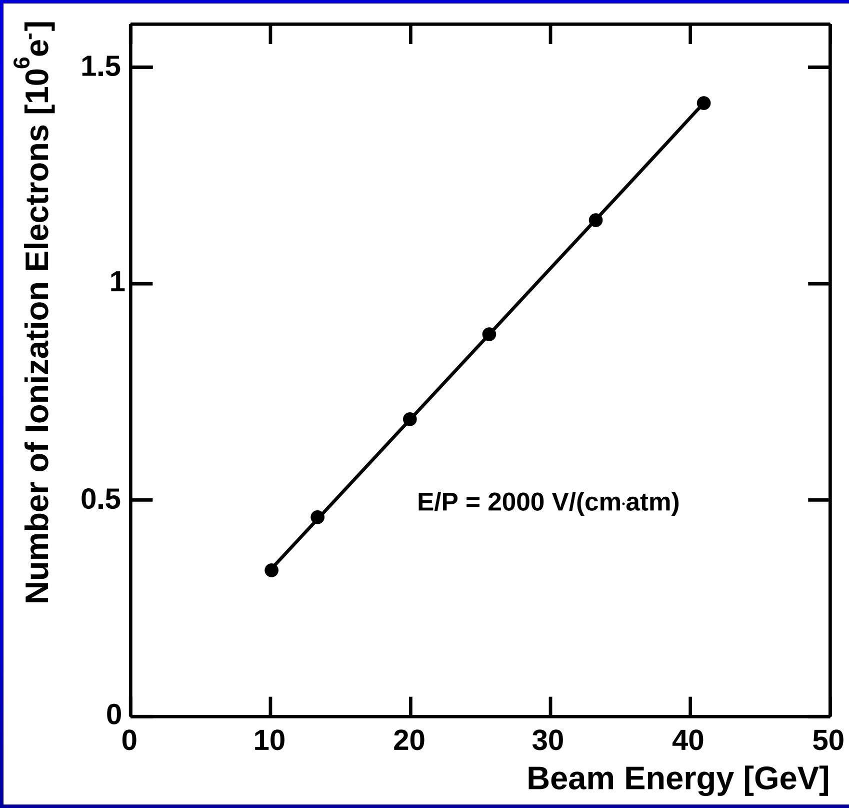
November 13, 2002 L.Suszycki: Luminosity...

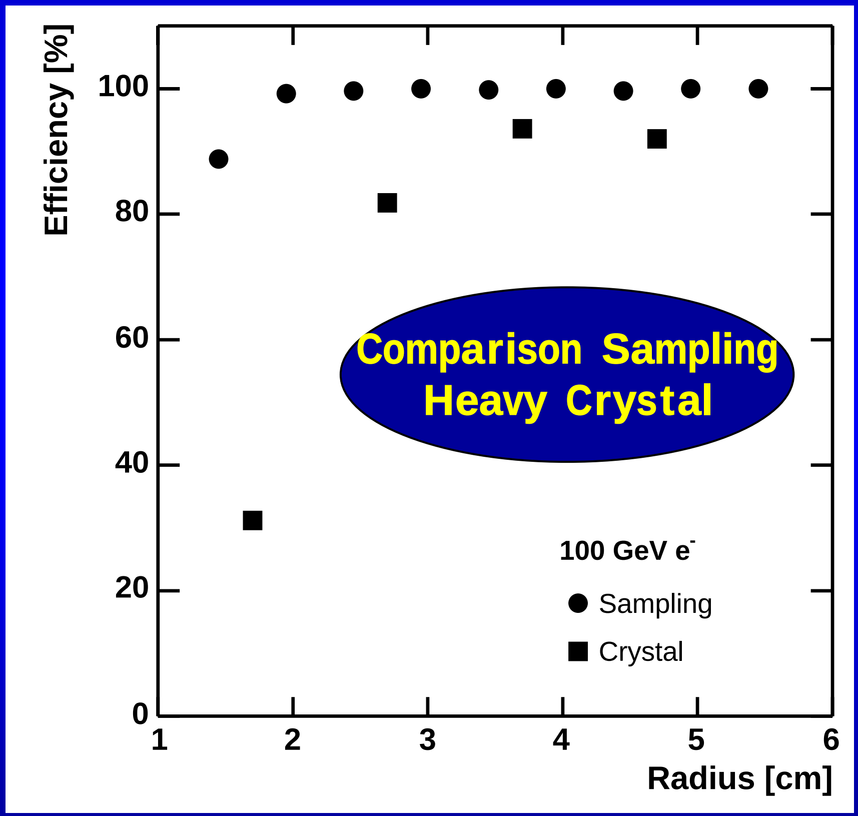


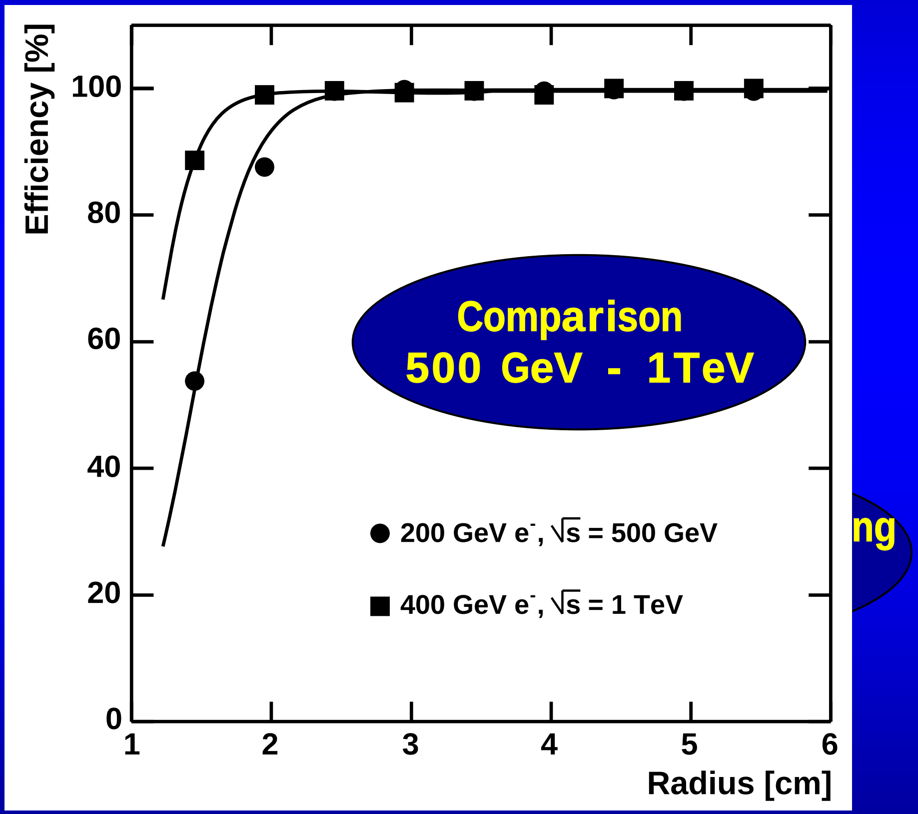
## Diamond performance as function of the absorbed dose

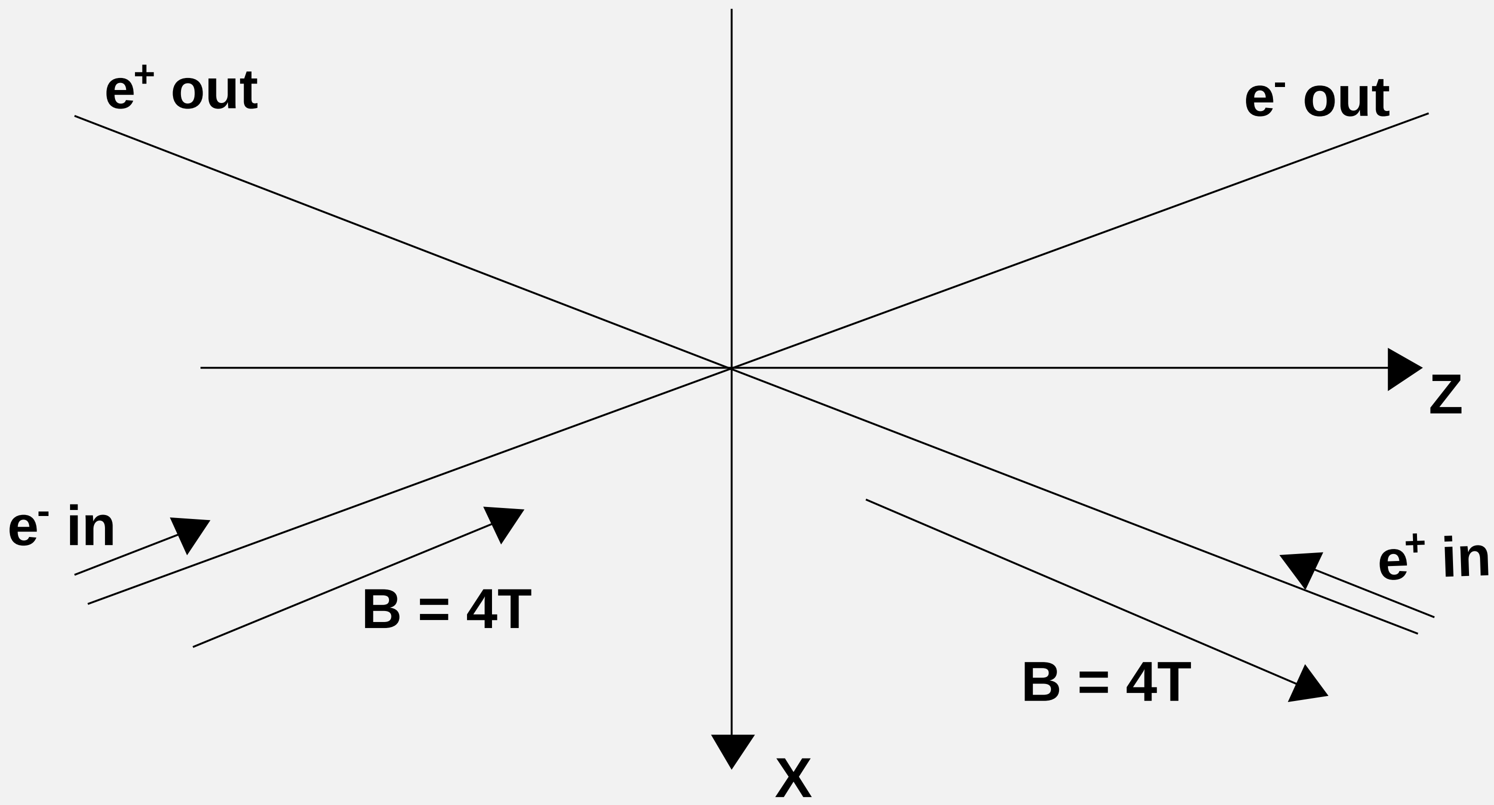



## Linearity of a heavy gas calorimeter (IHEP testbeam)



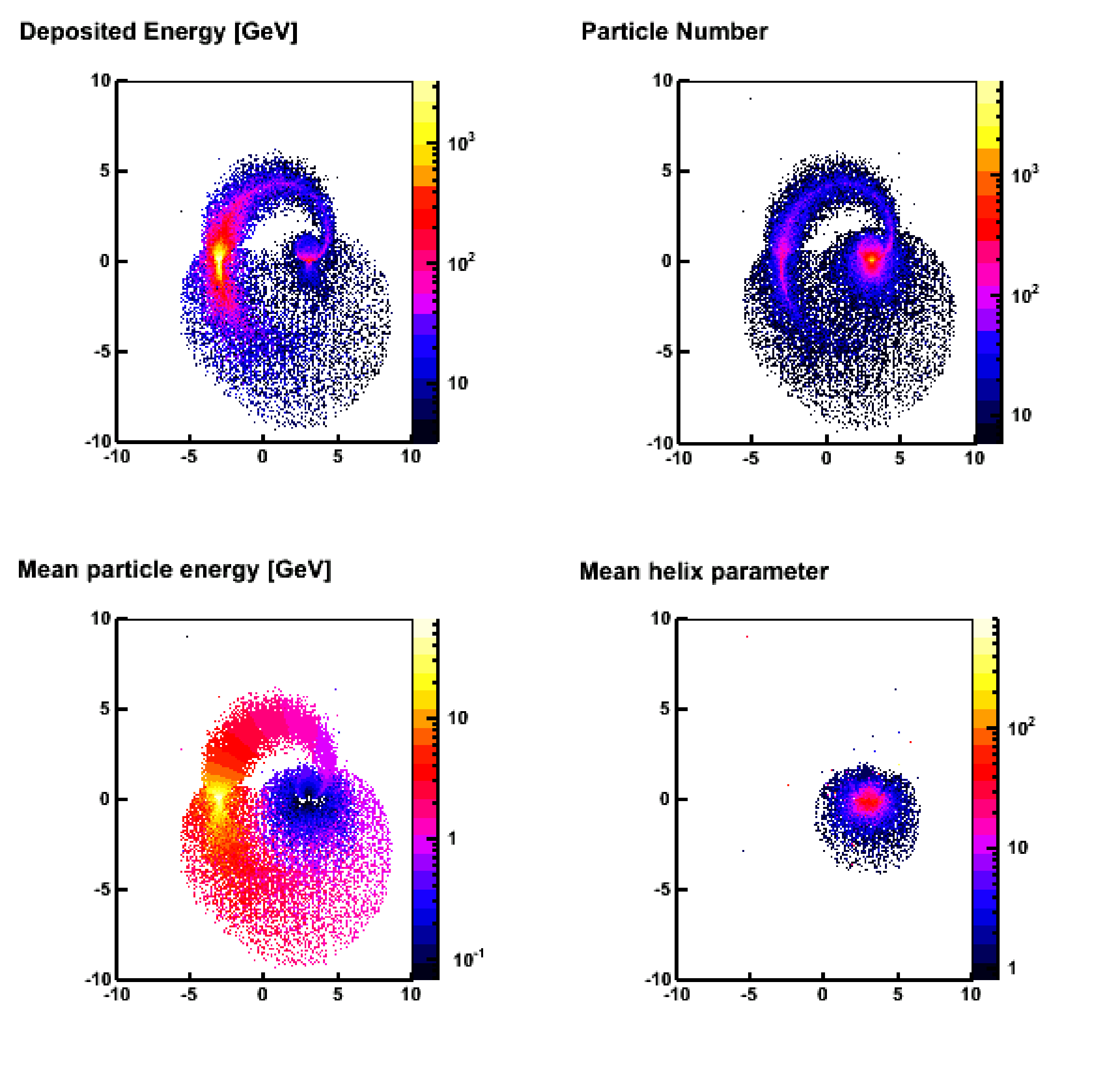

Efficiency [%]
100
80
60
40
20
0
1
2
3
4
5
6
Radius [cm]
Comparison Sampling
Heavy Crystal
100 GeV e-
Sampling
Crystal


Efficiency [%]
100
80
60
40
20
0
1
2
3
4
5
6
Radius [cm]
Comparison
500 GeV - 1TeV
200 GeV e-, √s = 500 GeV
400 GeV e-, √s = 1 TeV



e+ out
e- out
Z
e- in
B = 4T
e+ in
B = 4T
X

# Depositions on the calorimter frontface



| | Headon | 20mrad | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BeamPar | MPI resolution | MPI resolution | σx | σx’ | σy | σy’ | σz | σz’ | off x | off y | w y | N |
| σx (ave) | 26.789 | 20.471 | 1 | | | | | | | | | |
| σx (diff) | 11.201 | 16.615 | 0.720 | 1 | | | | | | | | |
| σy (ave) | 0.893 | 2.196 | -0.182 | -0.271 | 1 | | | | | | | |
| σy (diff) | 1.648 | 1.839 | -0.520 | -0.369 | 0.700 | 1 | | | | | | |
| σz (ave) | 13.018 | 17.781 | 0.290 | 0.101 | 0.852 | 0.441 | 1 | | | | | |
| σz (diff) | 18.780 | 14.747 | -0.032 | -0.527 | 0.080 | -0.143 | -0.101 | 1 | | | | |
| Beam offset x | 5.918 | 6.652 | 0.004 | -0.488 | 0.127 | -0.125 | -0.036 | 0.887 | 1 | | | |
| Beam offset y | 0.536 | 6.767 | 0.414 | 0.237 | -0.803 | -0.927 | -0.577 | 0.168 | 0.144 | 1 | | |
| Vertical waist shift | 327.312 | 159.172 | -0.496 | 0.434 | 0.901 | 0.713 | 0.623 | 0.017 | -0.016 | -0.748 | 1 | |
| N per Bunch (ave) | 0.109 | 0.080 | 0.581 | 0.316 | 0.619 | 0.016 | 0.869 | 0.039 | 0.056 | -0.161 | 0.395 | 1 |
| N per Bunch (diff) | 0.043 | 0.054 | 0.481 | 0.631 | -0.048 | -0.119 | 0.066 | 0.149 | 0.018 | 0.030 | -0.209 | 0.275 |