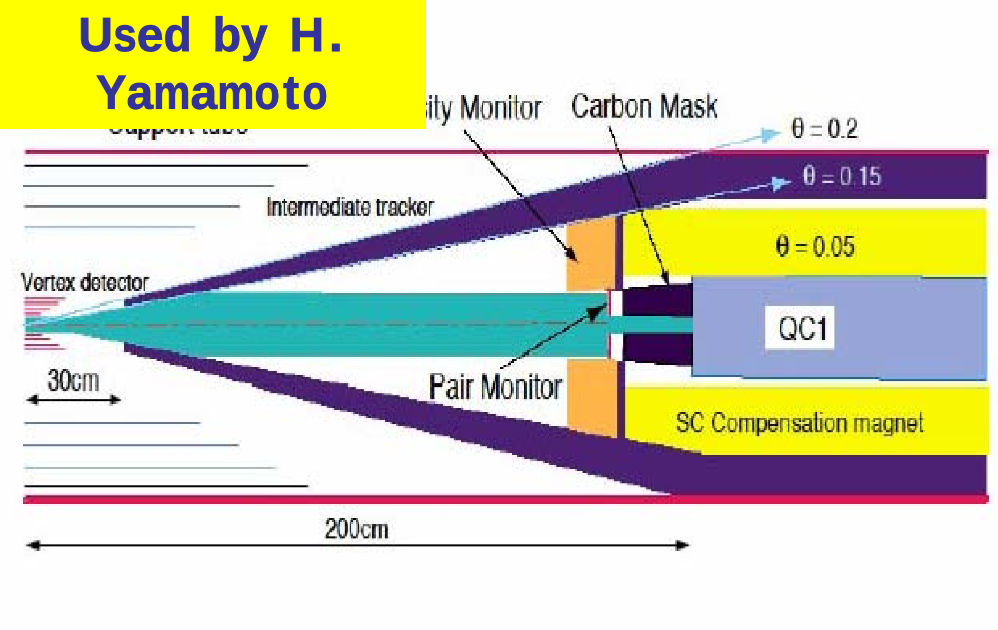
Instrumentation of the Very Forward Region of a Linear Collider Detector

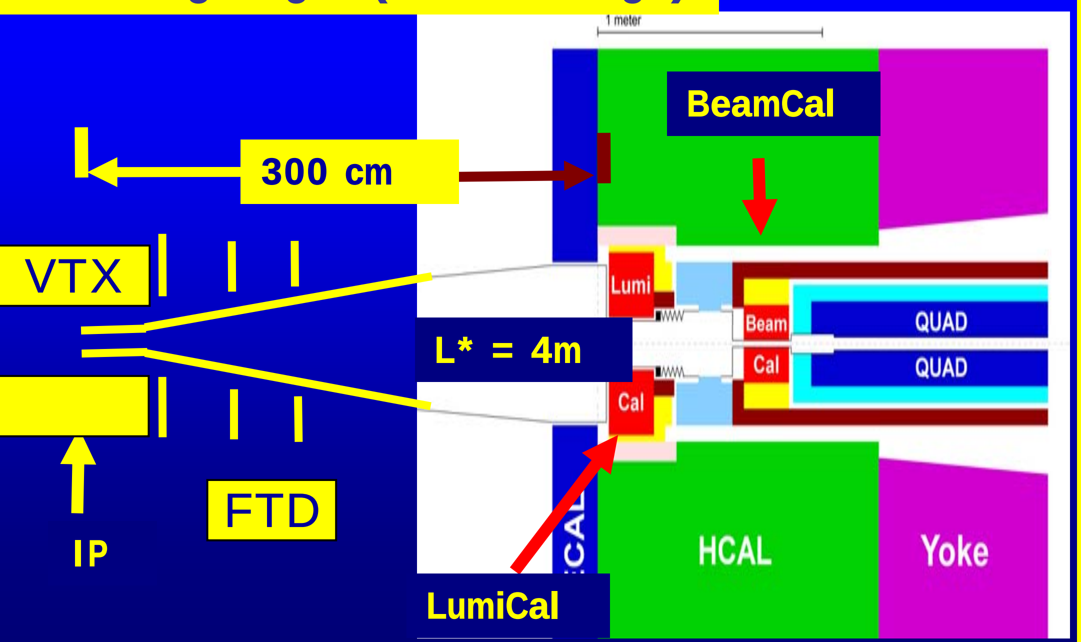
Wolfgang Lohmann,
DESY

Used by H. Yamamoto

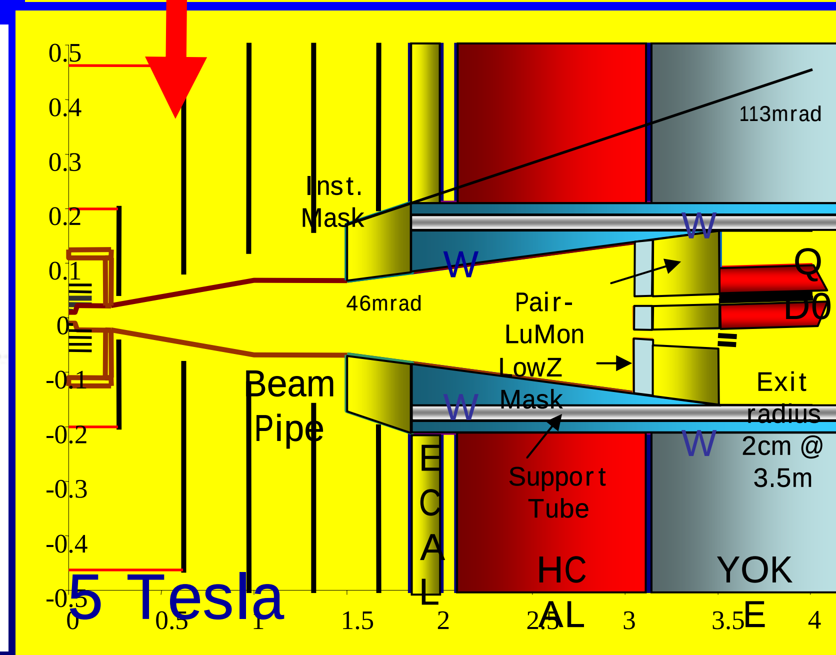


Simulation studies on several designs

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



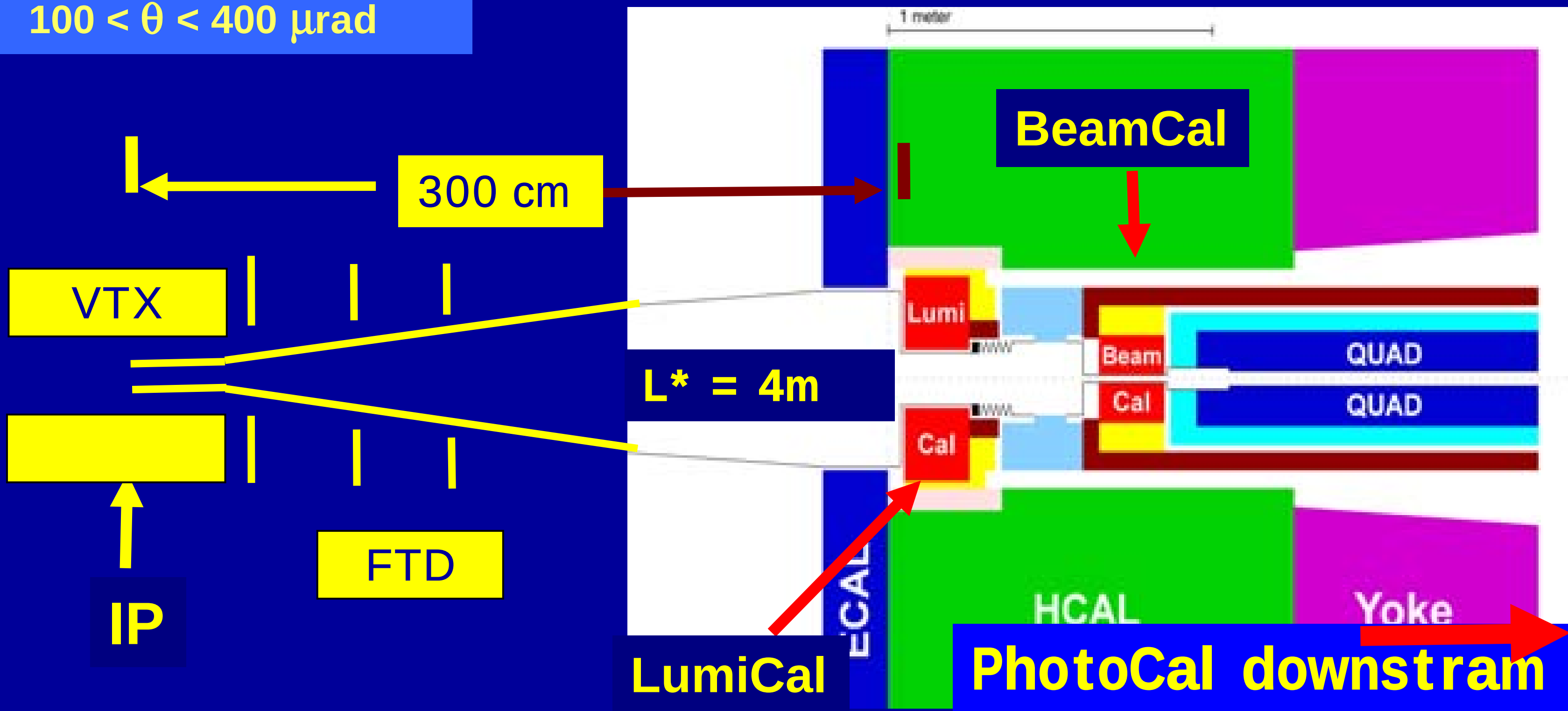
SiD Forward Masking, Calorimetry & Tracking, 20 mrad crossing angle



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**

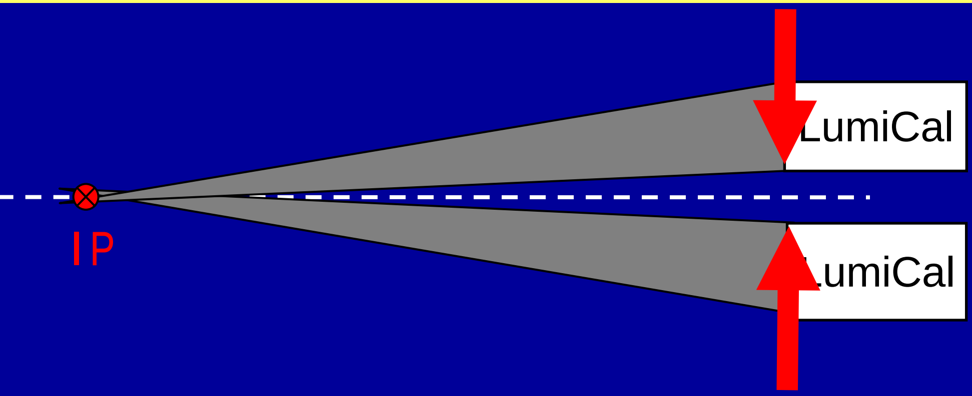
Physics Case: Giga-Z ,Two Fermion Cross Sections at High Energy, $e^+e^- \longrightarrow W^+W^-$

• Technology: Si-W Sandwich Calorimeter

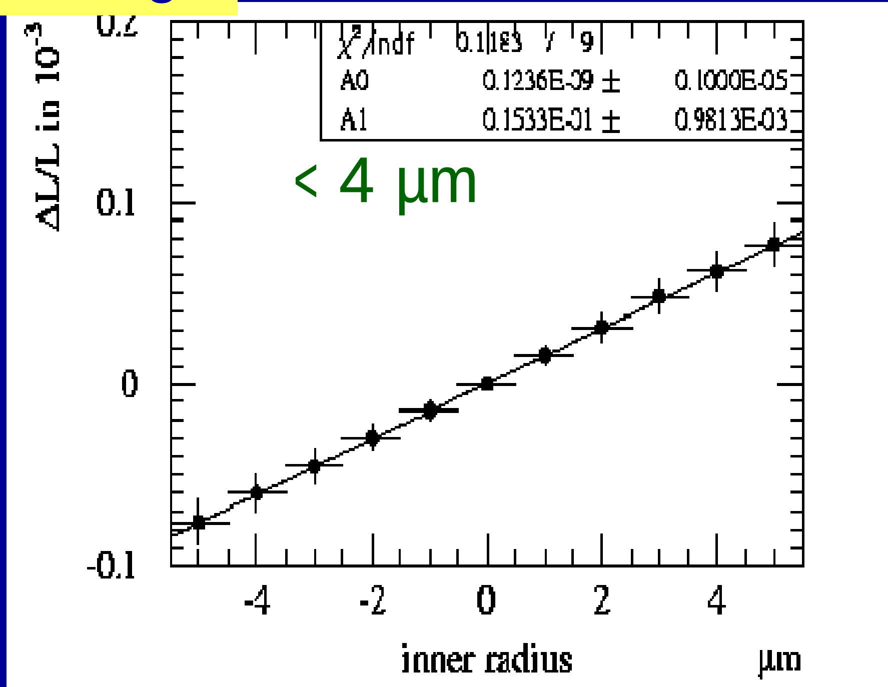
• MC Simulations

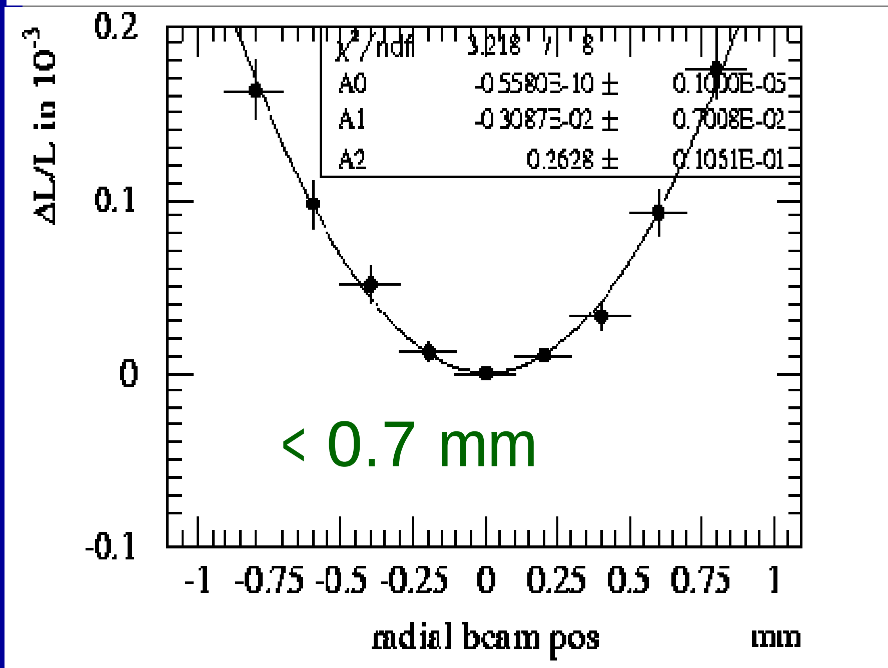
→ **Optimisation of Shape and Segmentation, Key Requirements on the Design**

Requirements on the Mechanical Design



Requirements on
Alignment
and mechanical Precision
(rough Estimate)

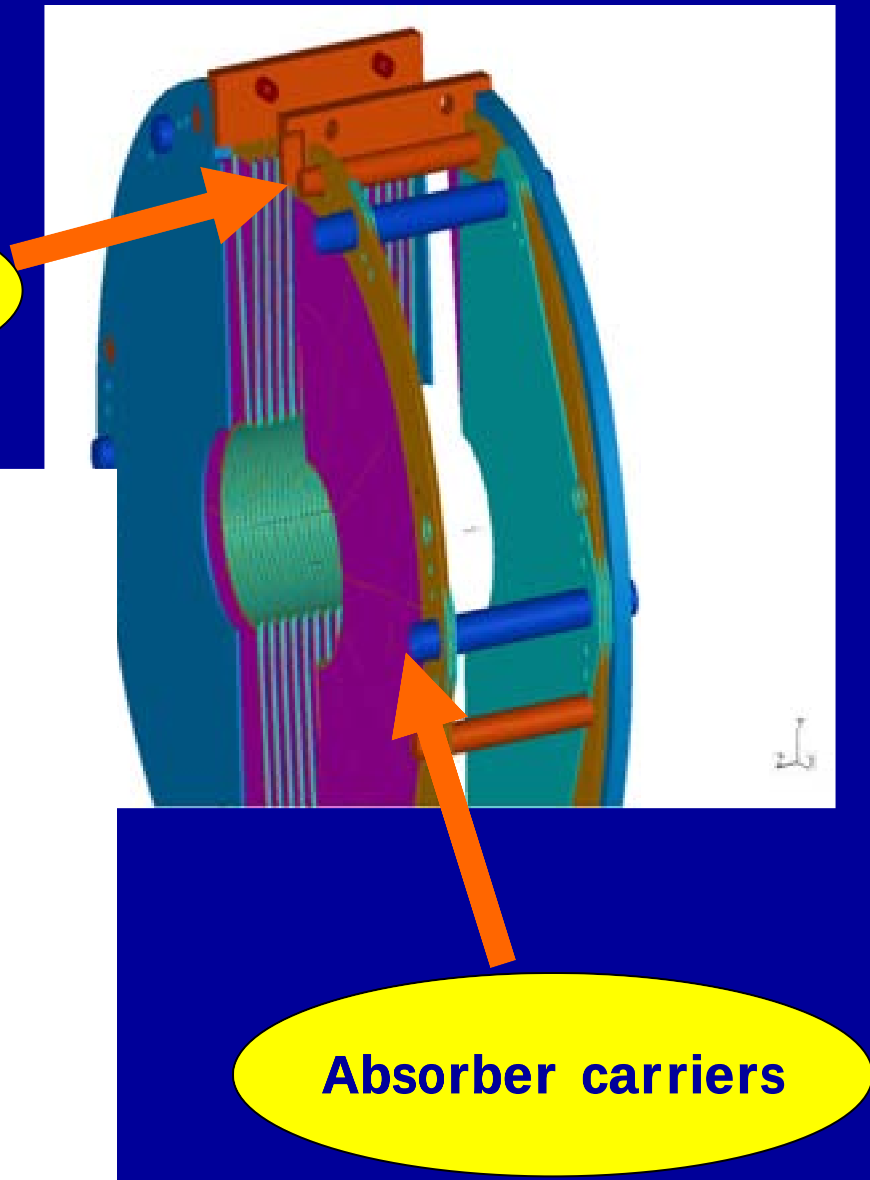


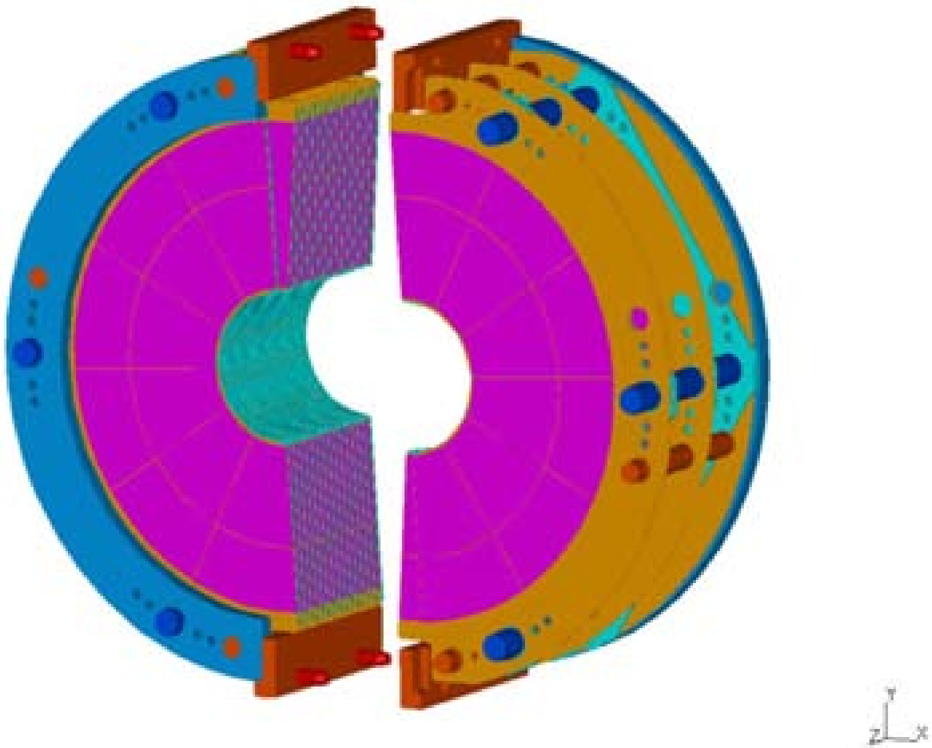


Inner Radius of Cal.:	**< 1-4 μm**
Distance between Cals.:	**< 60 μm**
Radial beam position:	**< 0.7 mm**

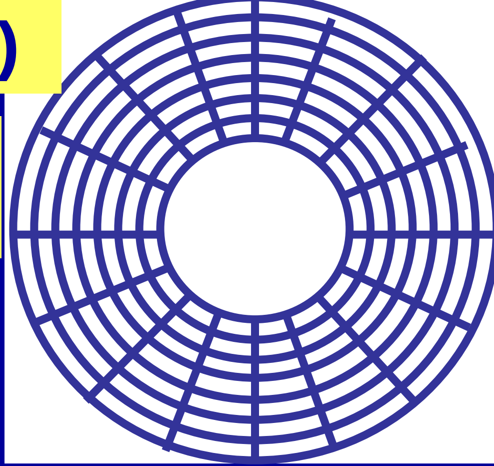
Concept for the Mechanical Frame

Decouple sensor frame from absorber frame





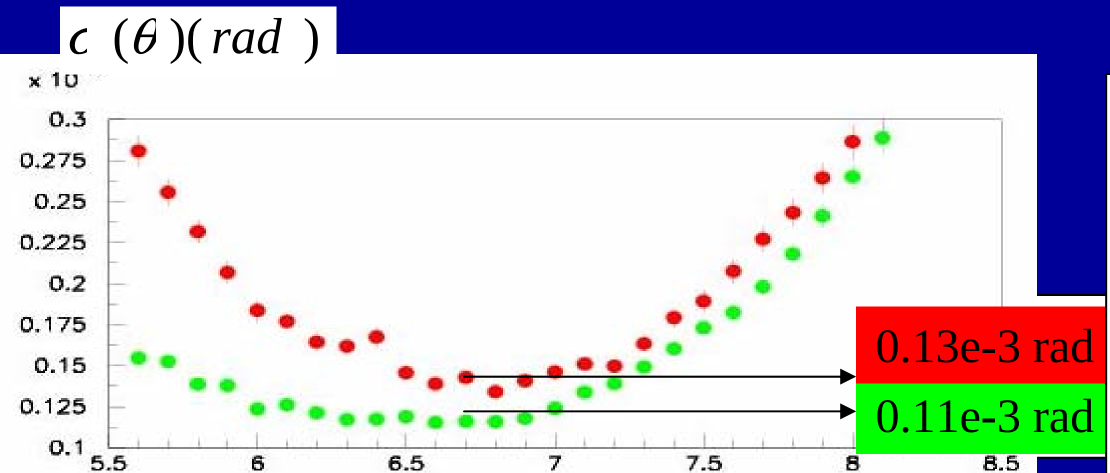
Performance Simulations for $e^+e^- \longrightarrow e^+e^-(\gamma)$

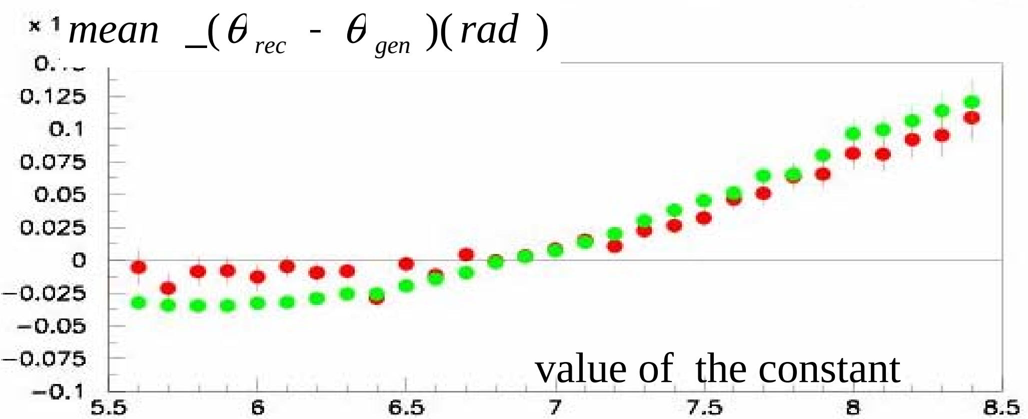


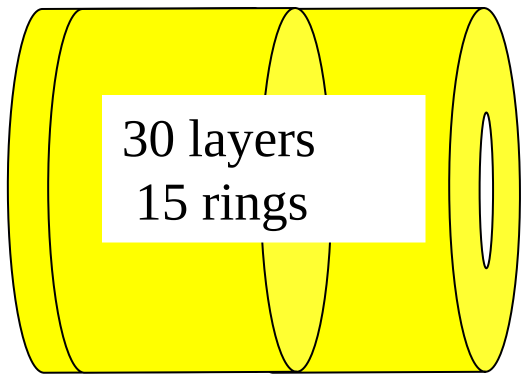
Simulation: Bhwide(Bhabha)+CIRCE(Beamstrahlung)+beamspread

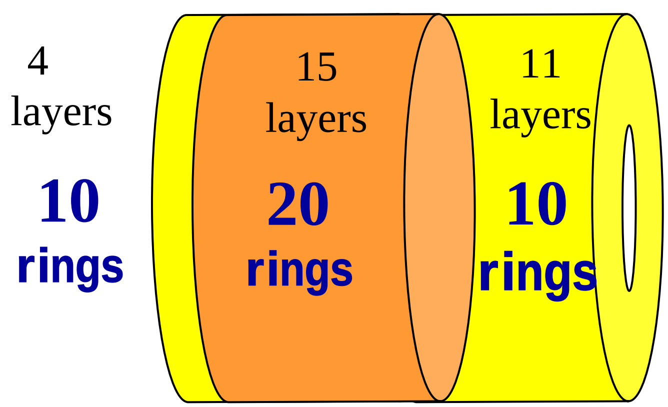
Event selection: acceptance, energy balance, azimuthal and angular symmetry.

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





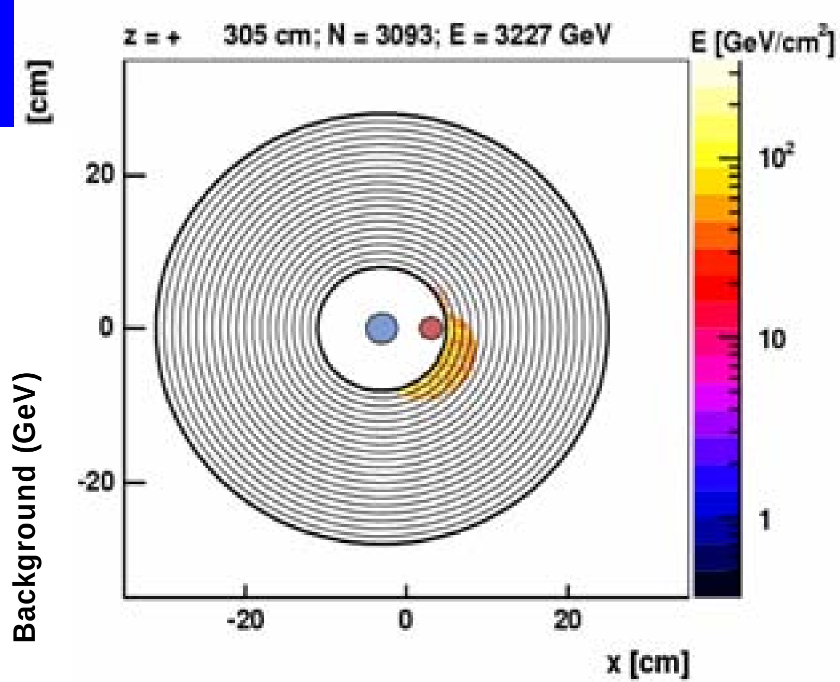




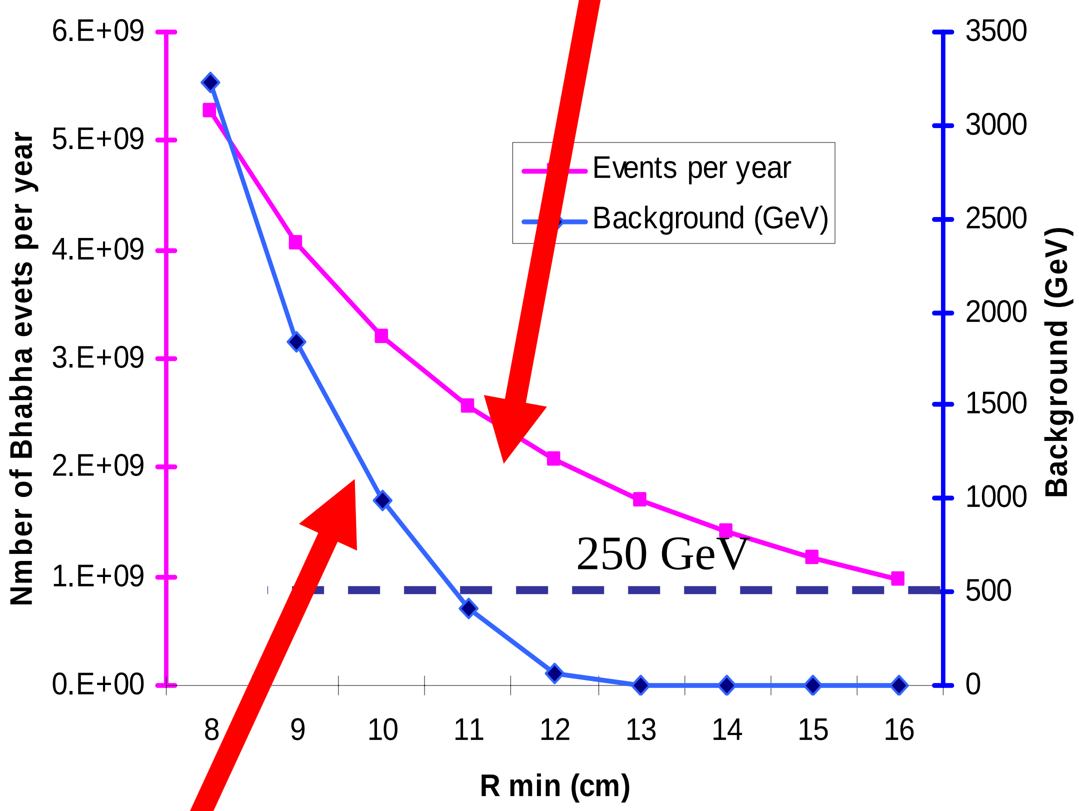
• More in the talks by Halina Abramowicz

X- angle background

Beamstrahlung pair background using serpentine field



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

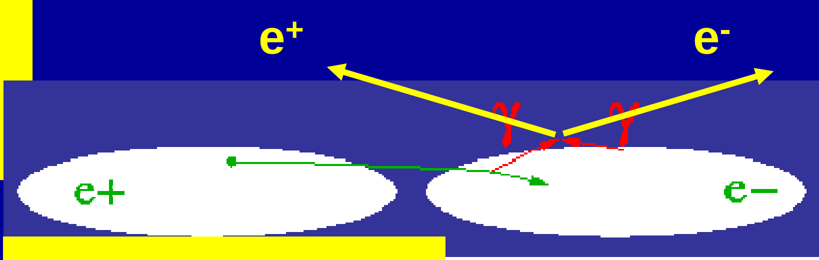


Background from beamstrahlung

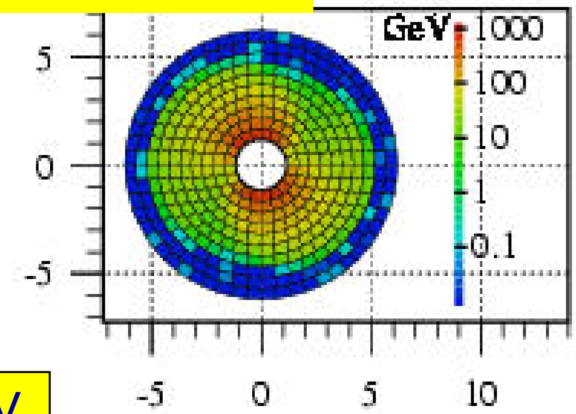
Christian Grah, DESY-Zuethen

•Fast Beam Diagnostics (BeamCal and PhotoCal)

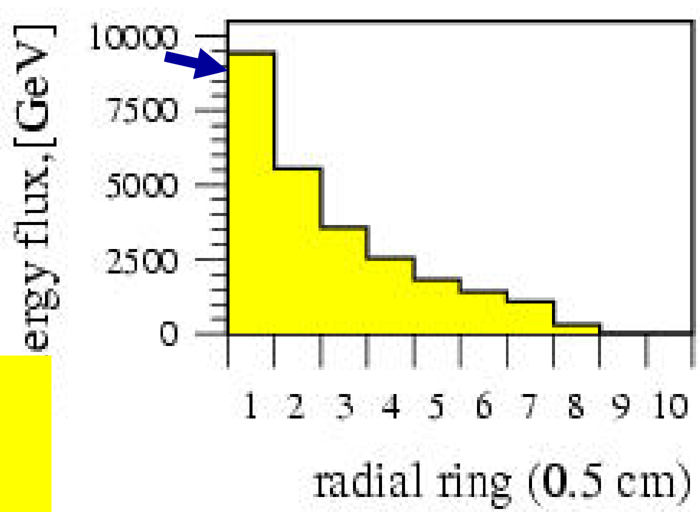
- e^+e^- Pairs from Beamstrahlung are deflected into the BeamCal
- 15000 e^+e^- per BX ⟶ 10 – 20 TeV (10 MGy per year)
- direct Photons for θ < 200 µrad

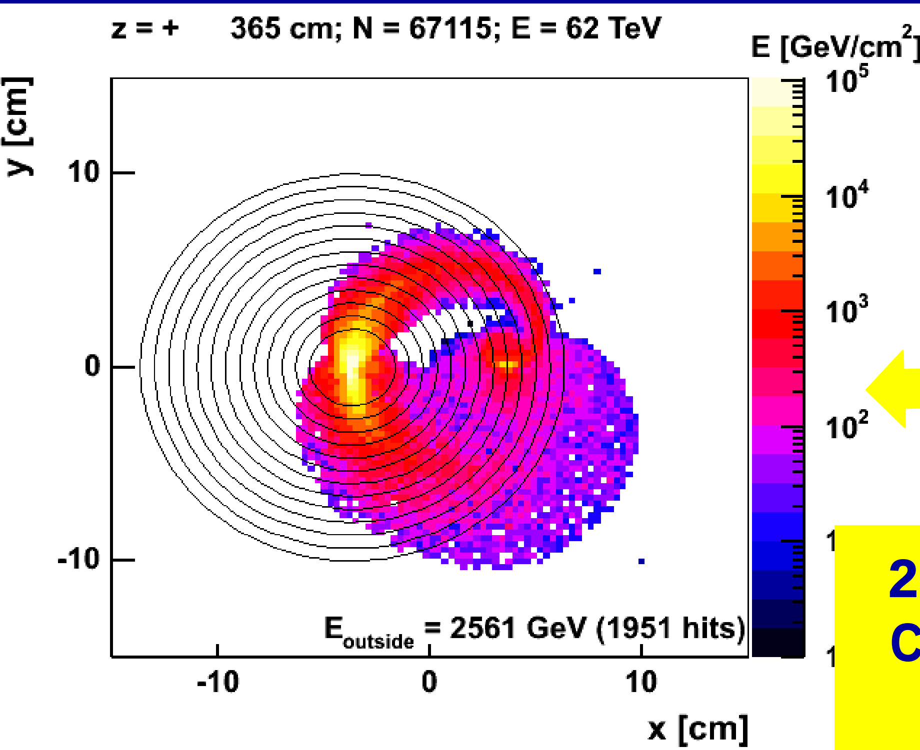


Zero crossing angle



GeV



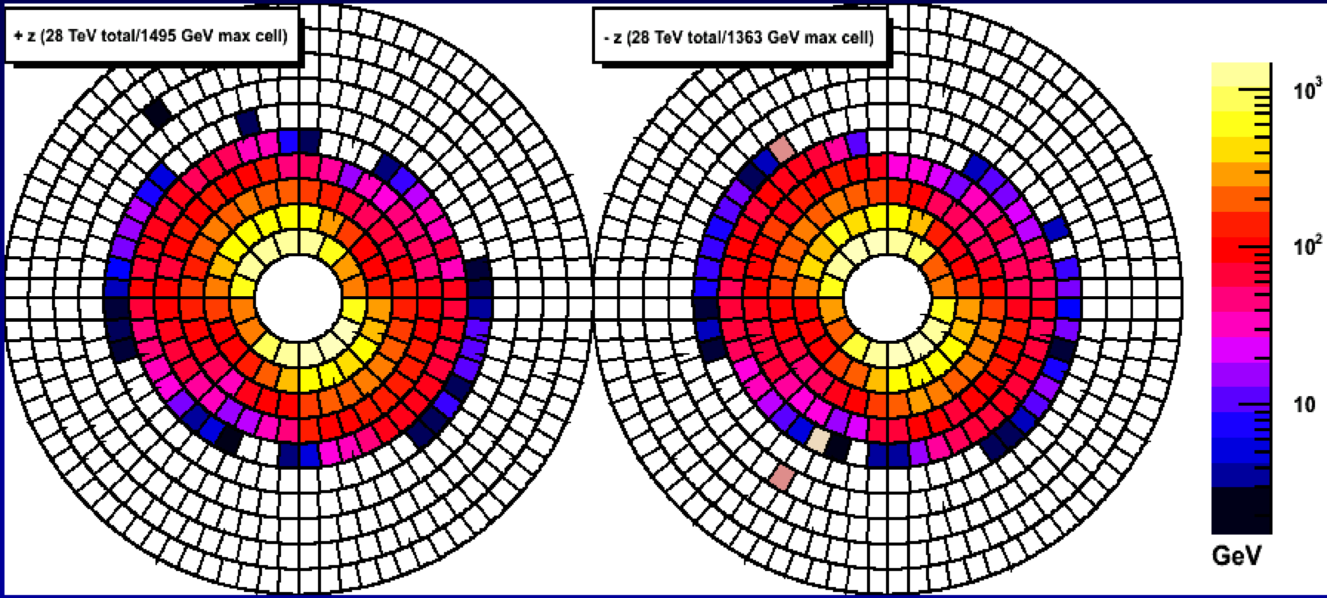


20 mrad Crossing angle

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

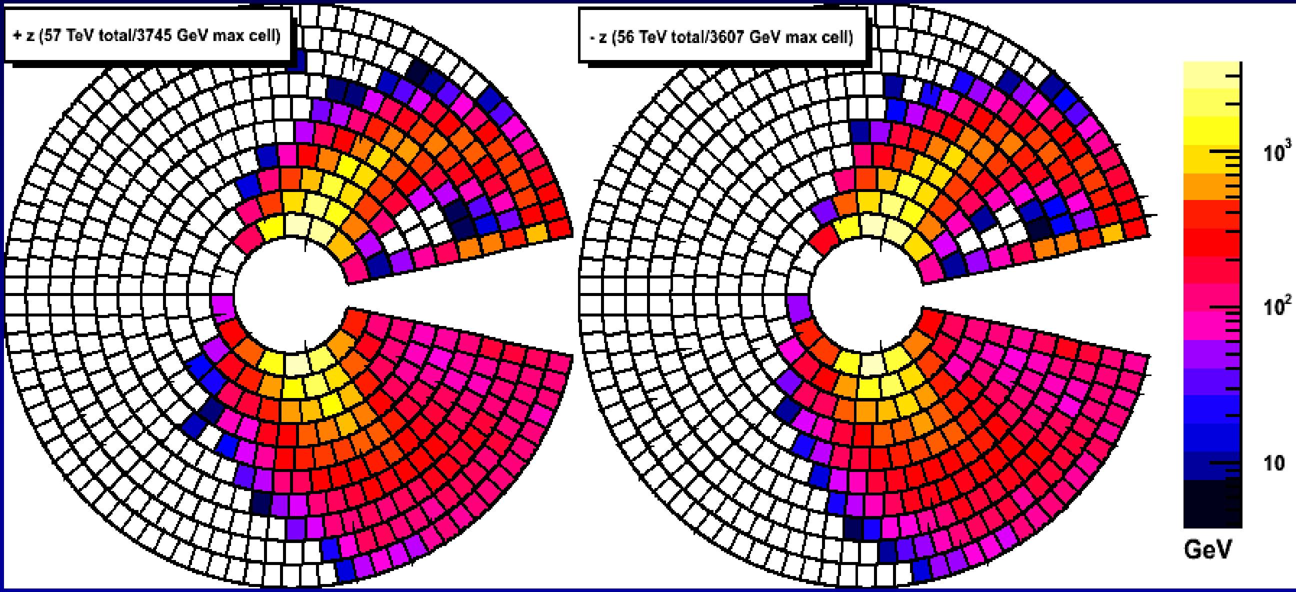
$\sqrt{s}$ = 500 GeV

Head-on or 2 mrad

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	4.8nm
σy	5.0 nm	0.1 nm
σz	300 μm	11.5 μm
Δy	0	2.0nm

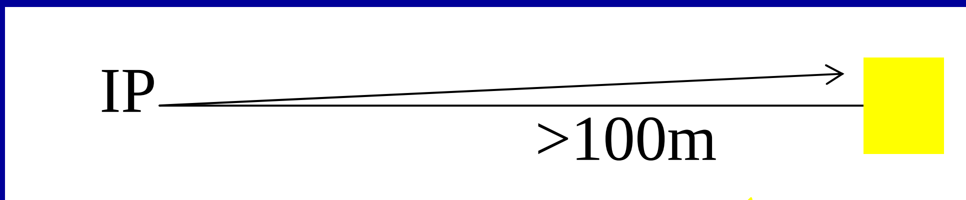
20 mrad crossing angle

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

PRELIMINARY!

and with PhotoCal

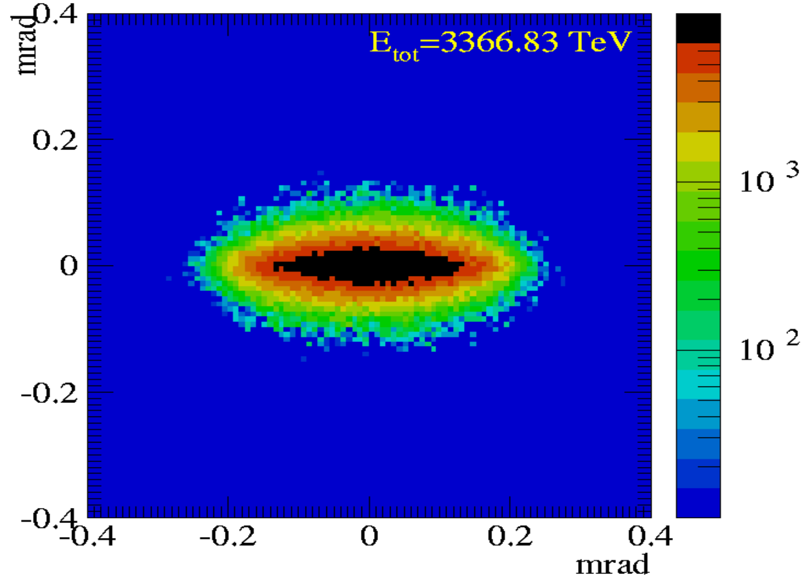
Photons from Beamstrahlung

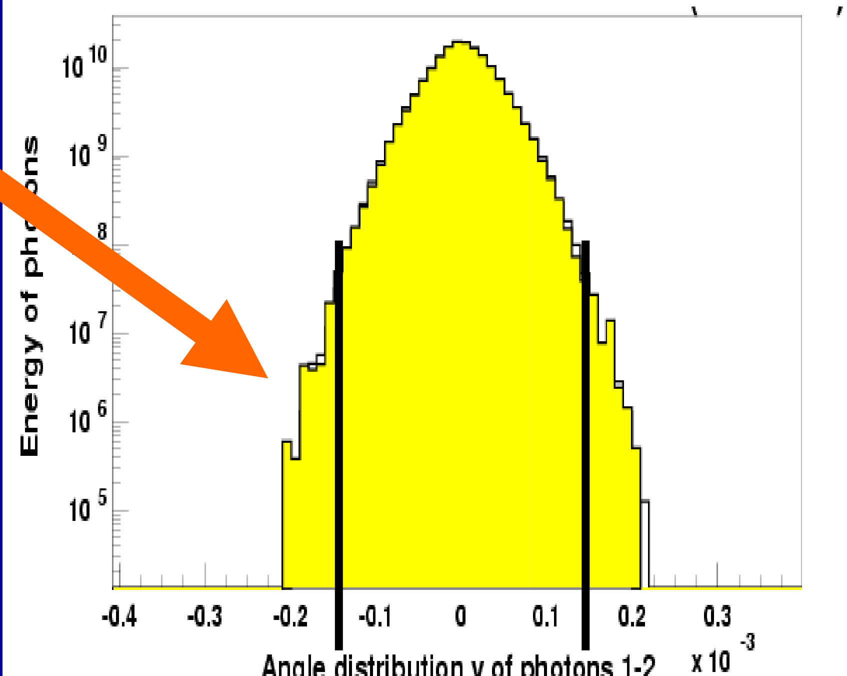


Heavy gas ionisation Calorimeter

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

Quantity	Nominal Value	Precision
σx	553 nm	4.2 nm
σz	300 µm	7.5 µm
Δy	0	0.2 nm

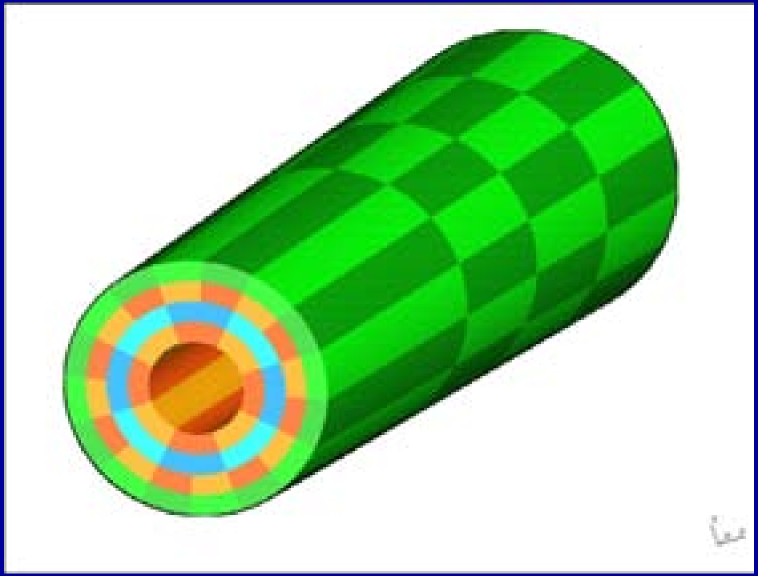


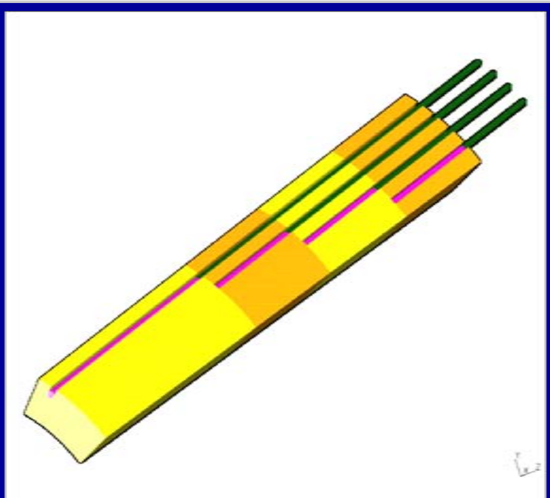


Technologies for the BeamCal:

- Radiation Hard
- Fast
- Compact

Heavy crystals

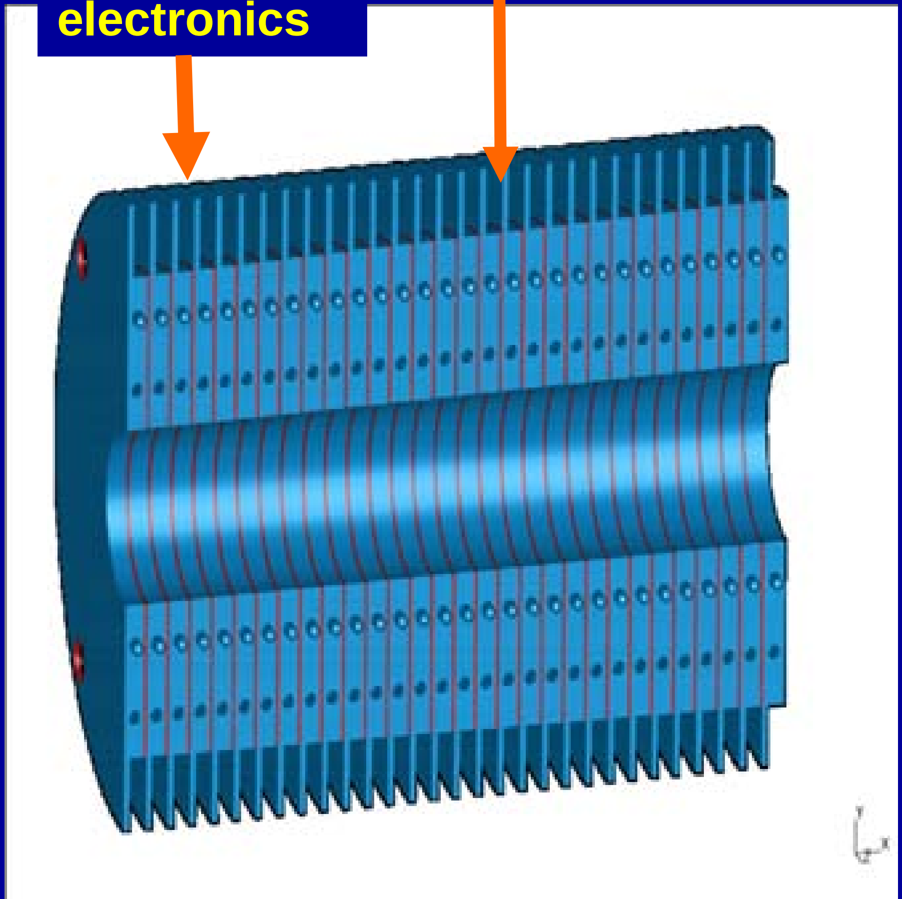




W-Diamond sandwich

Space for electronics

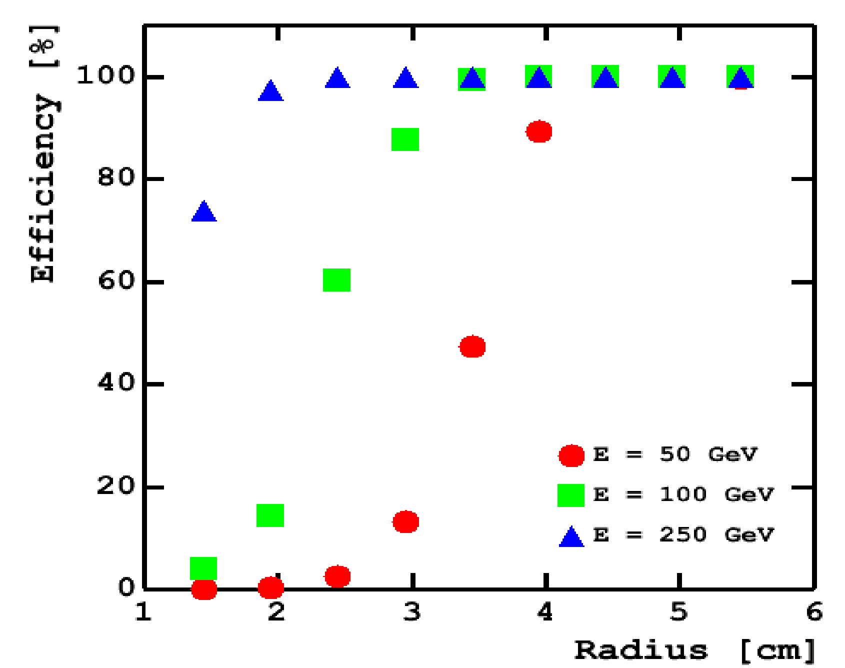
sensor



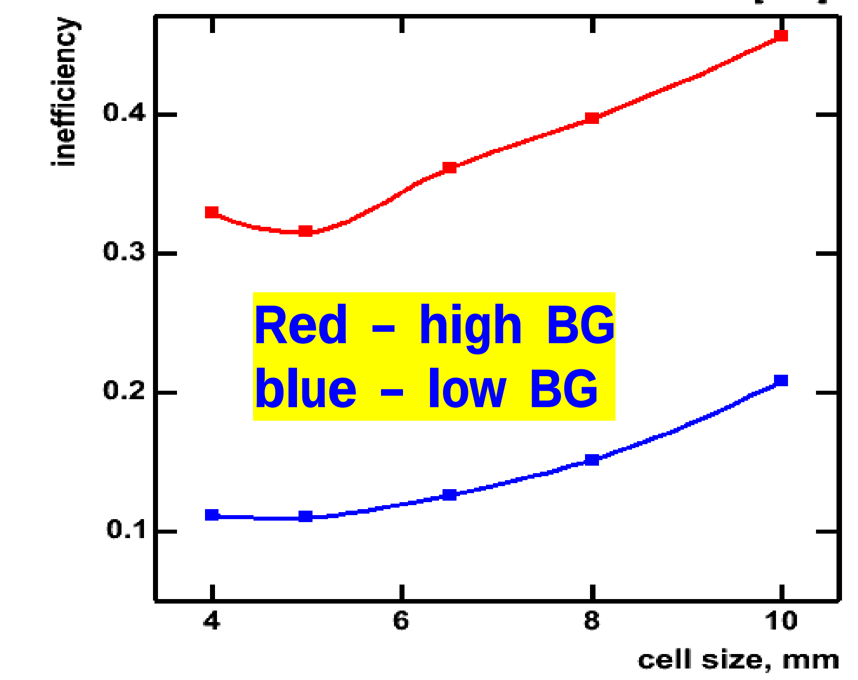
Detection of High Energy Electrons and Photons

$\sqrt{s}$ = 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)



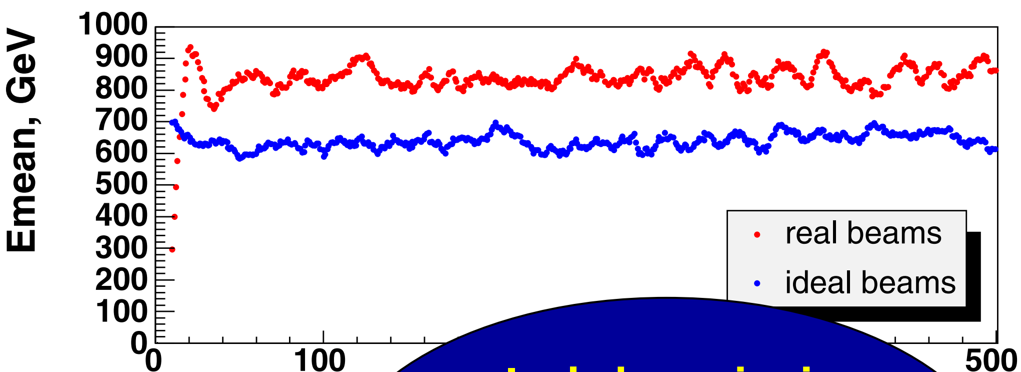
Message:
Electrons can be detected!

Detection of High Energy Electrons and Photons

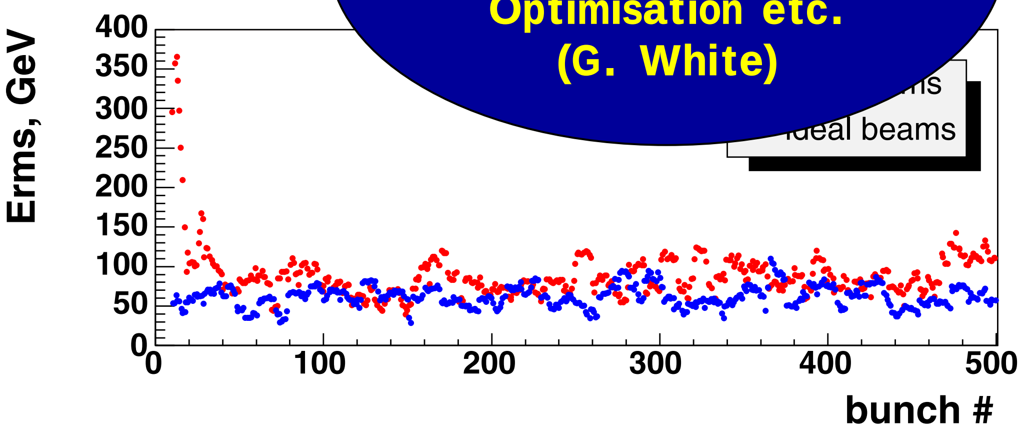
Realistic beam simulation
$\sqrt{s}$ = 500 GeV

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

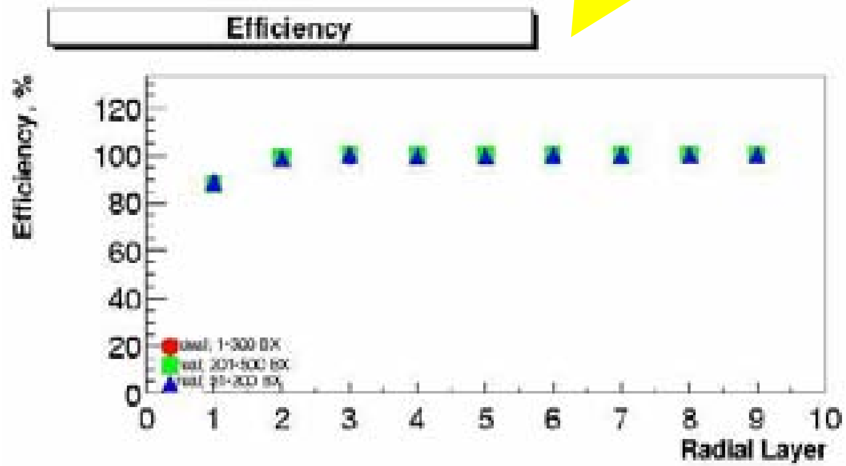
mean energy in particular cell (high BG near BP)

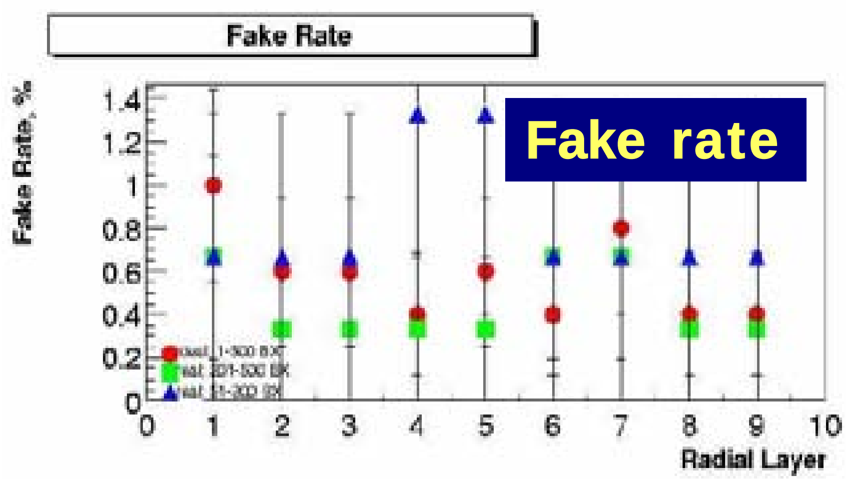


energy RMS in p



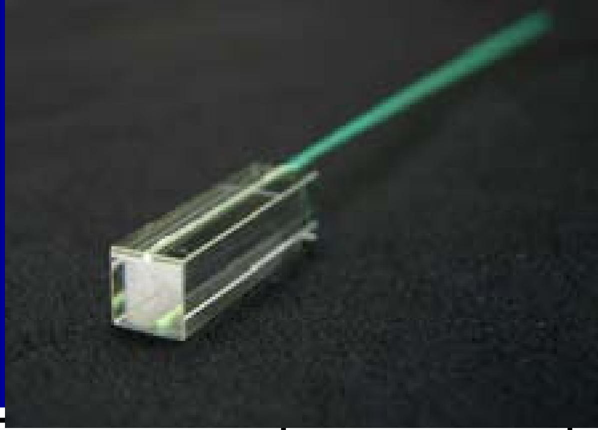
Includes seismic motions, Delay of Beam Feedback System, Lumi Optimisation etc.
(G. White)



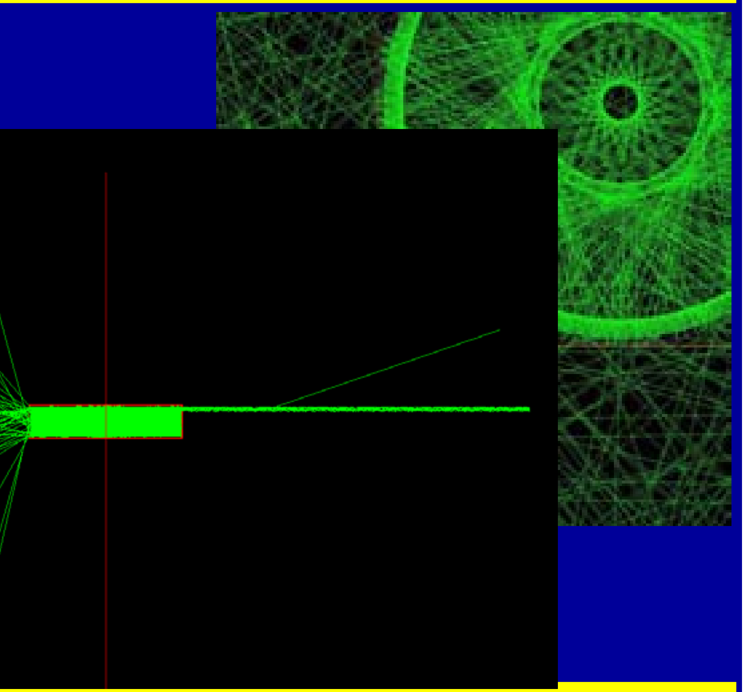


Sensor prototyping, Crystals

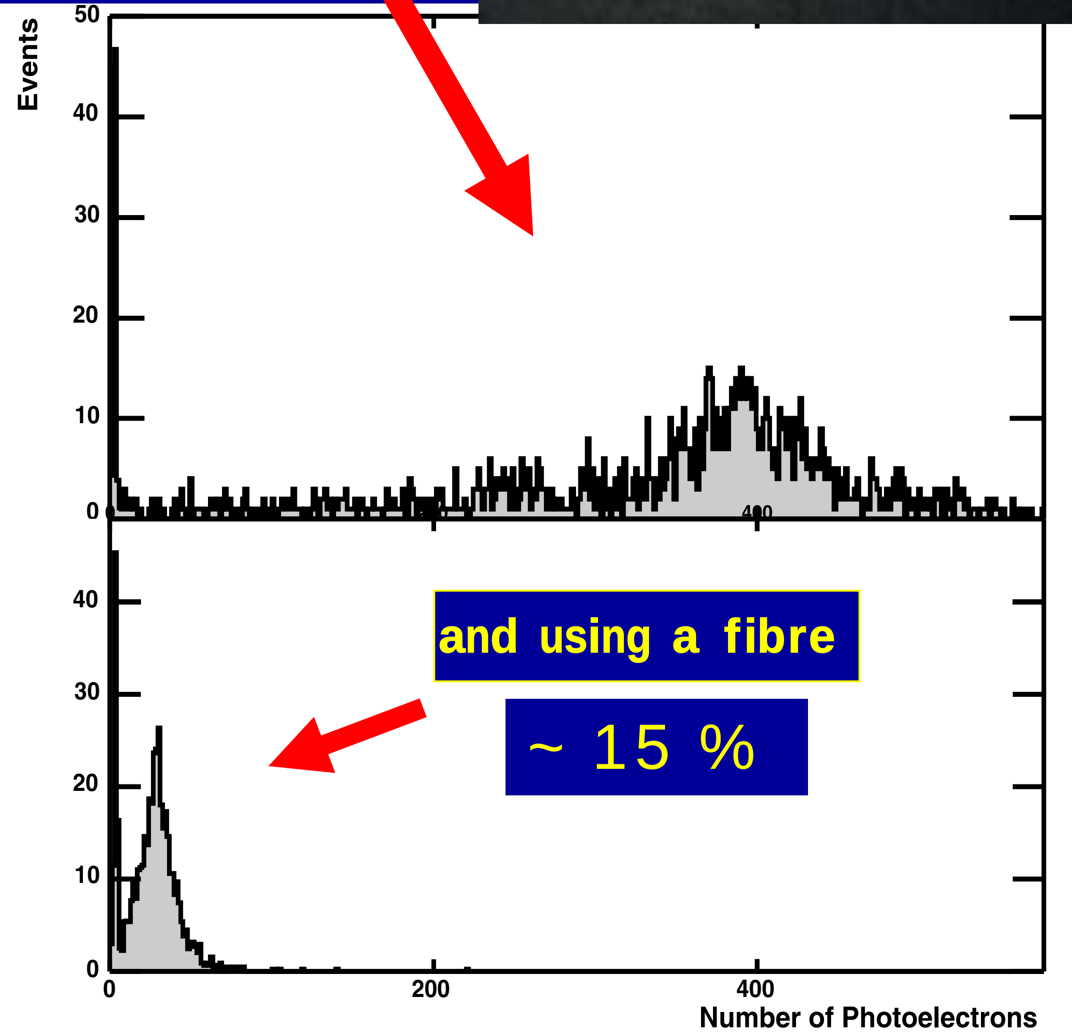
Light Yield from direct coupling



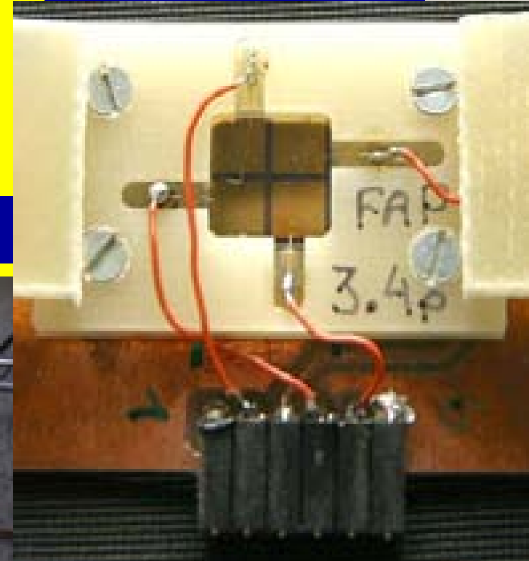
Compared with GEANT4 Simulation, good agreement

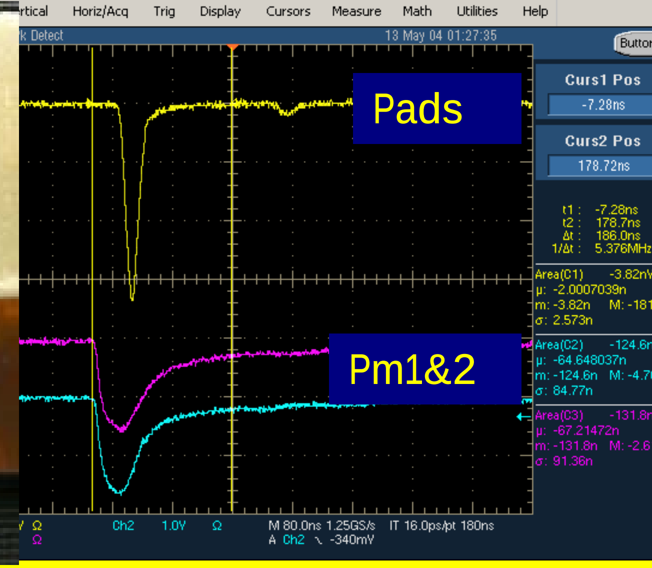


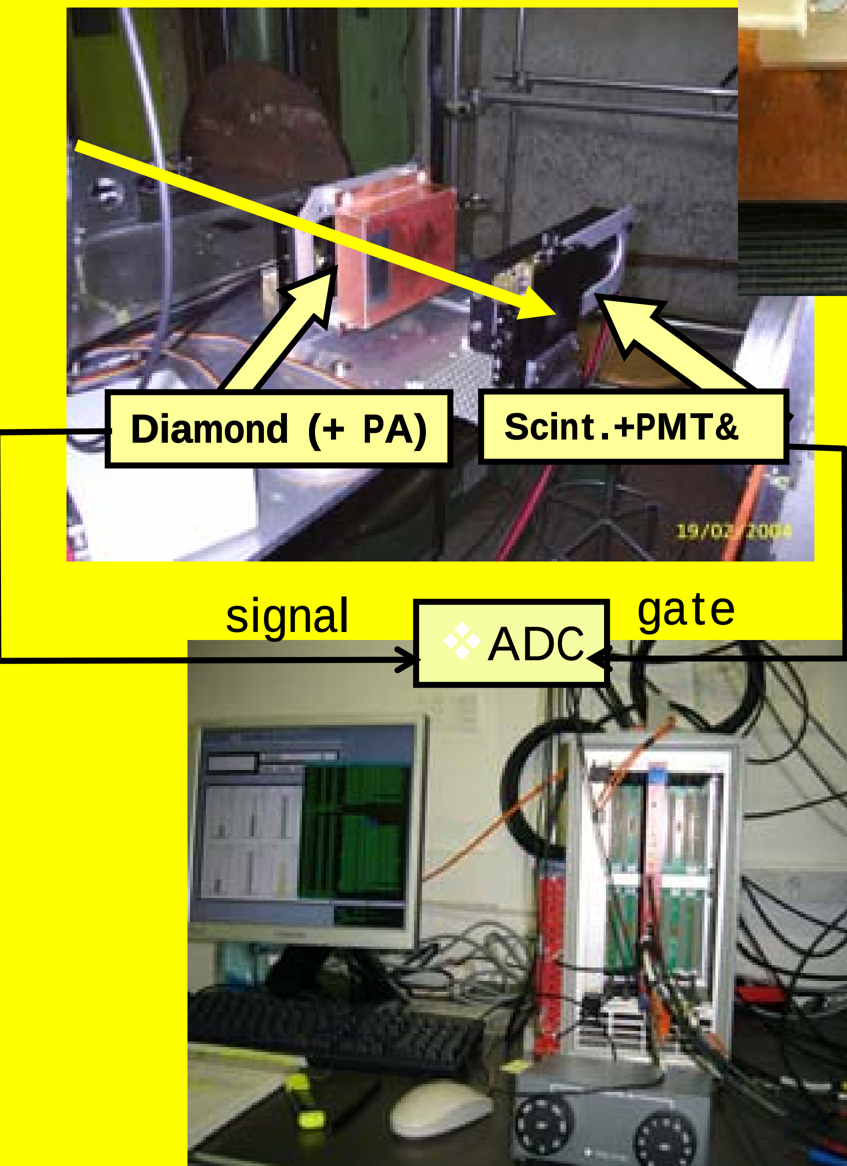
Similar results for lead glass Crystals (Cerenkov light !)



Sensor prototyping, Diamonds







May,August/2004 test beams

CERN PS Hadron beam – 3,5 GeV

2 operation modes:

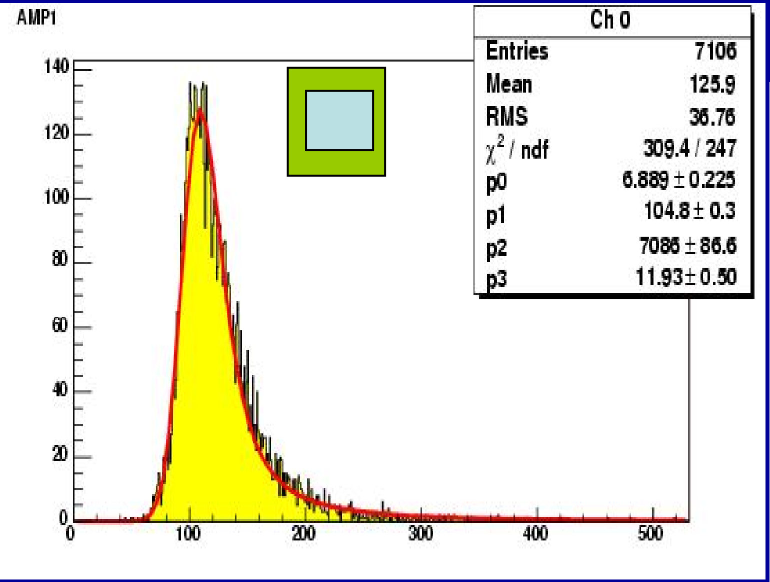
- Slow extraction ~10^5-10^6 / s
- fast extraction ~10^5-10^7 / ~10ns
  (Wide range intensities)

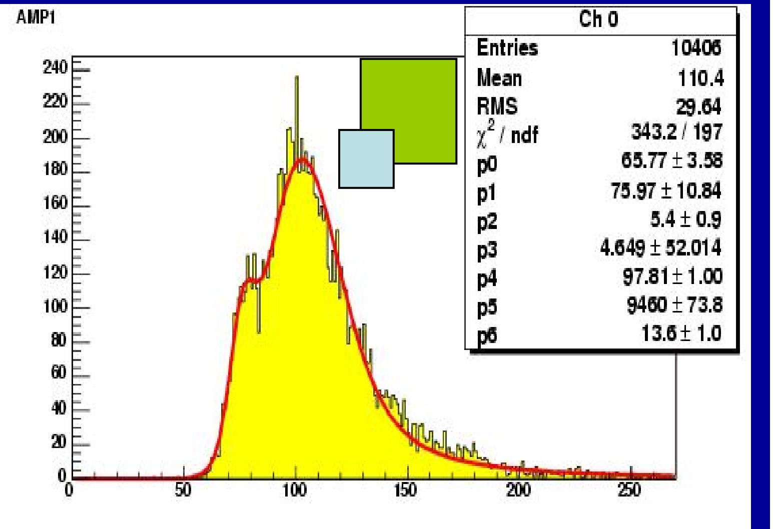
Diamond samples (CVD):

- Freiburg
- GPI (Moscow)
- Element6

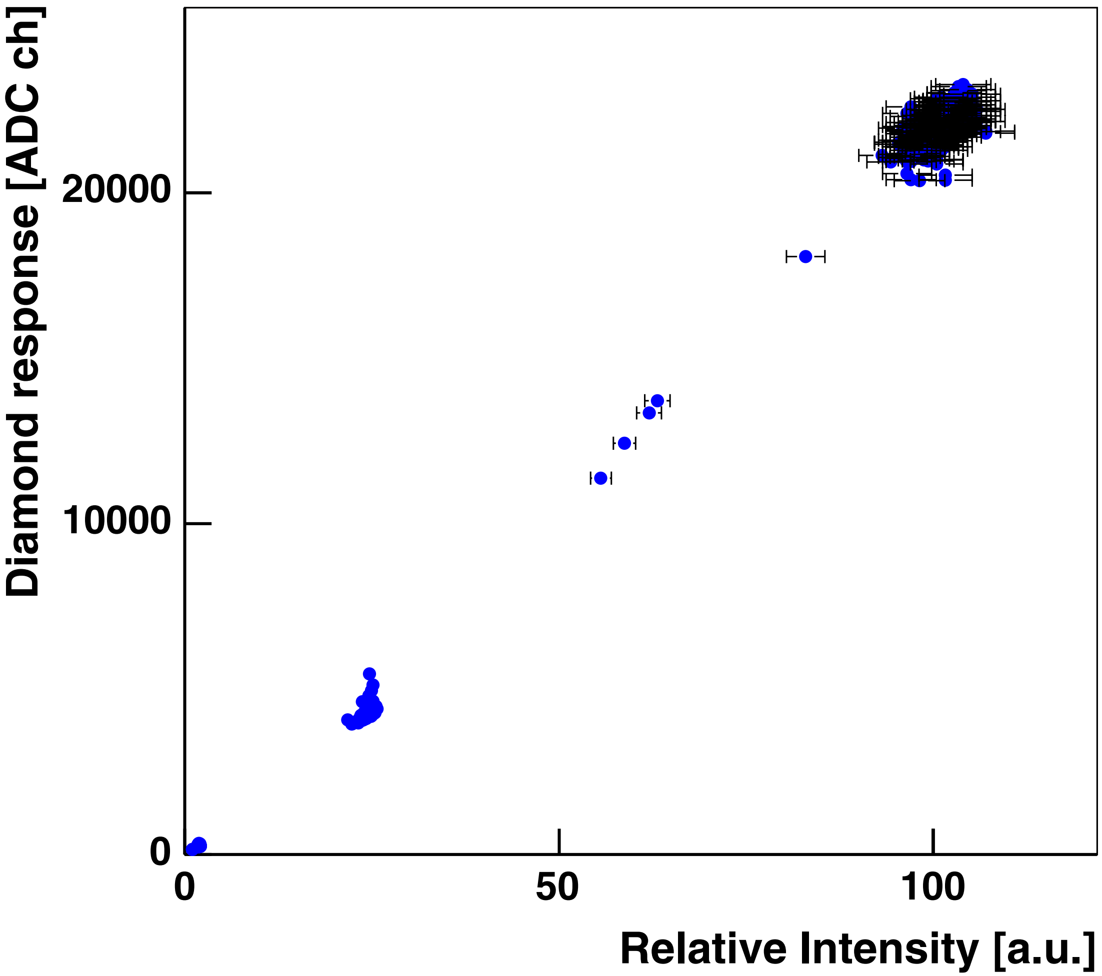
Diamond Sensor Performance

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

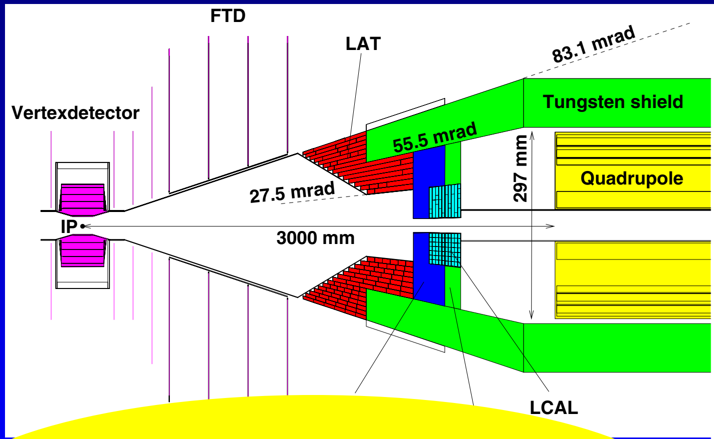
- Many (and promising) results in simulations/design studies
- Concept for a Luminometer for small crossing angle is advanced, 20 mrad needs a different design
- Mechanics design work ongoing
- calorimeters in the very forward region deliver very valuable information about beam parameters
- High energy 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

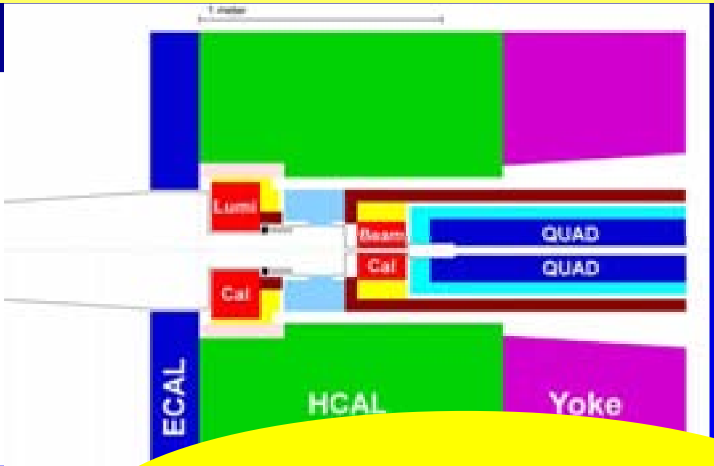
Remarks

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

Backup Slides

Shower LEAKAGE in old (TDR) and new LumiCal design

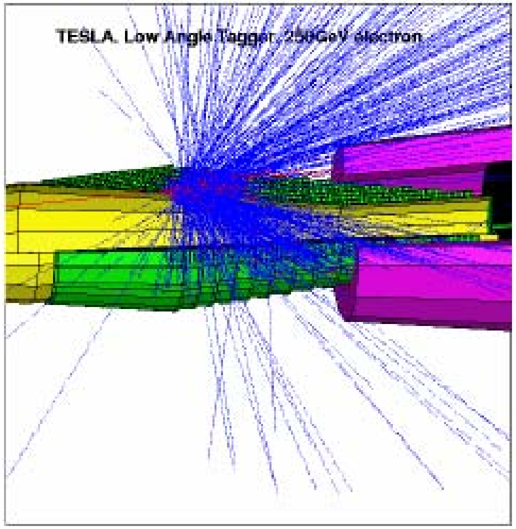




Shower in LAT (TDR design)

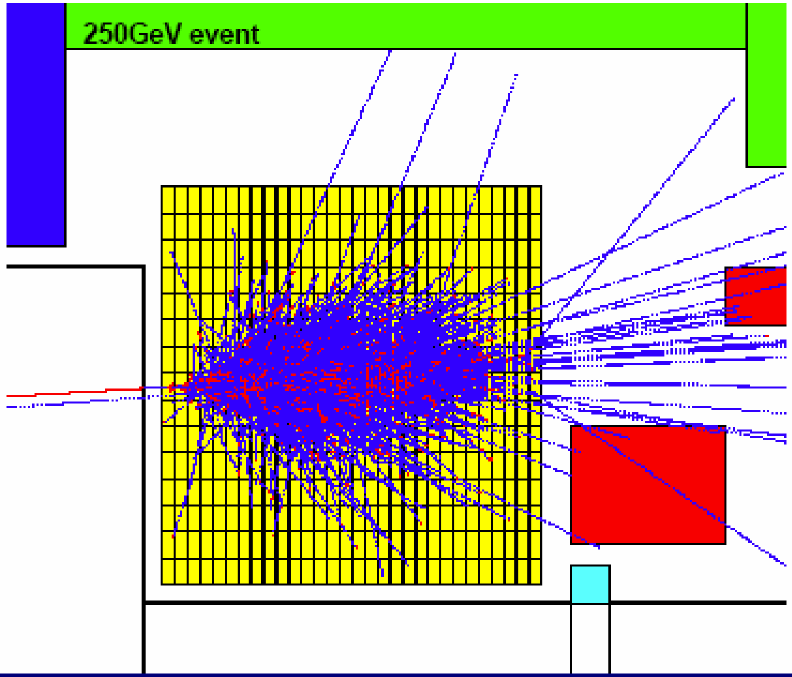
Shower in LumiCal (new design)

LAT shower example

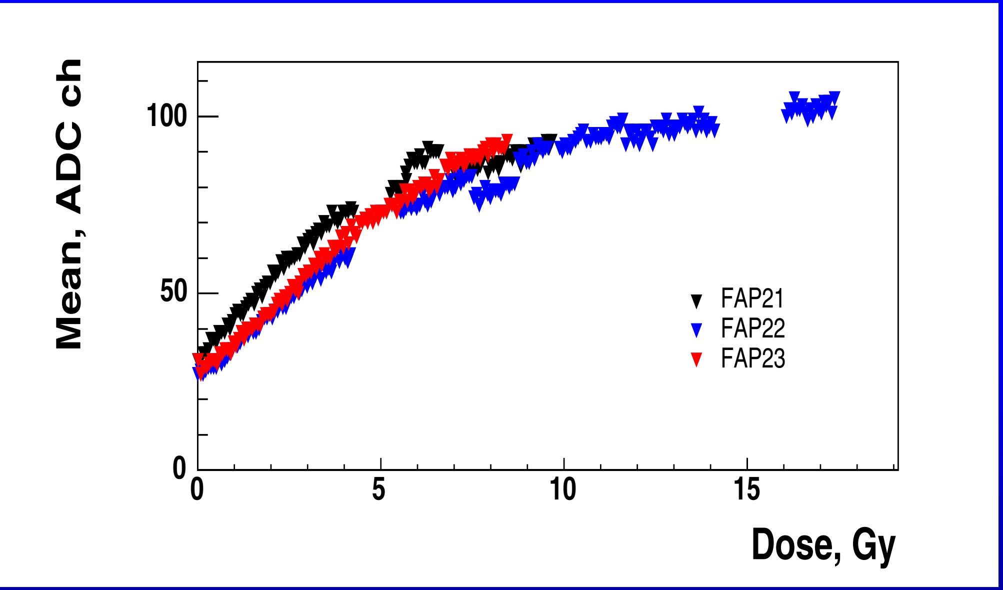


Only photons (blue) and electrons (red) over 5 MeV are displayed

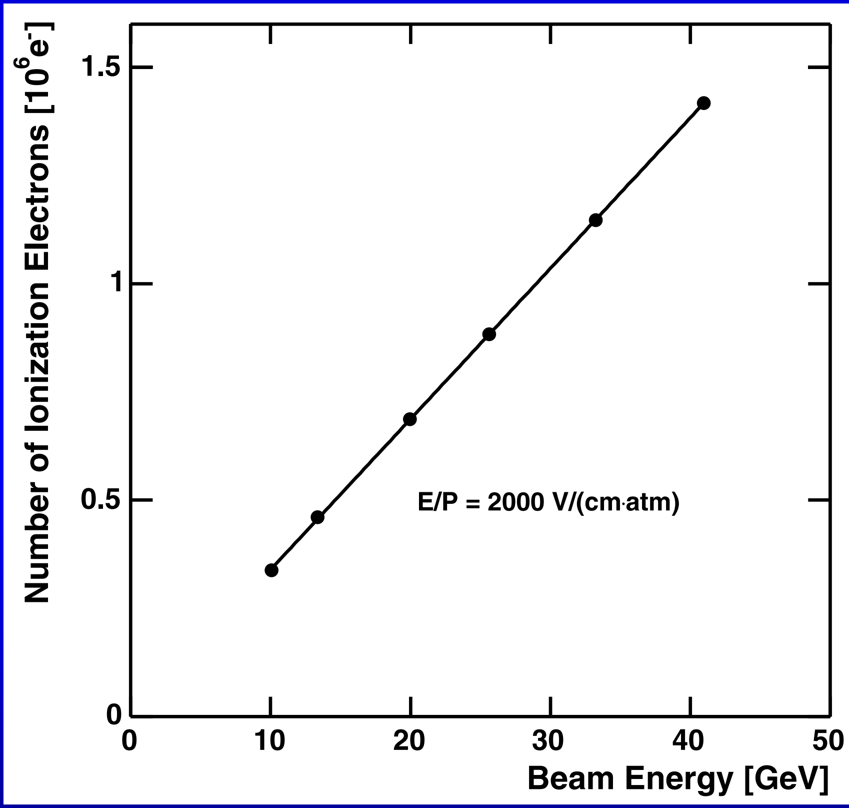
November 13, 2002 L.Suszycki: Luminosity...

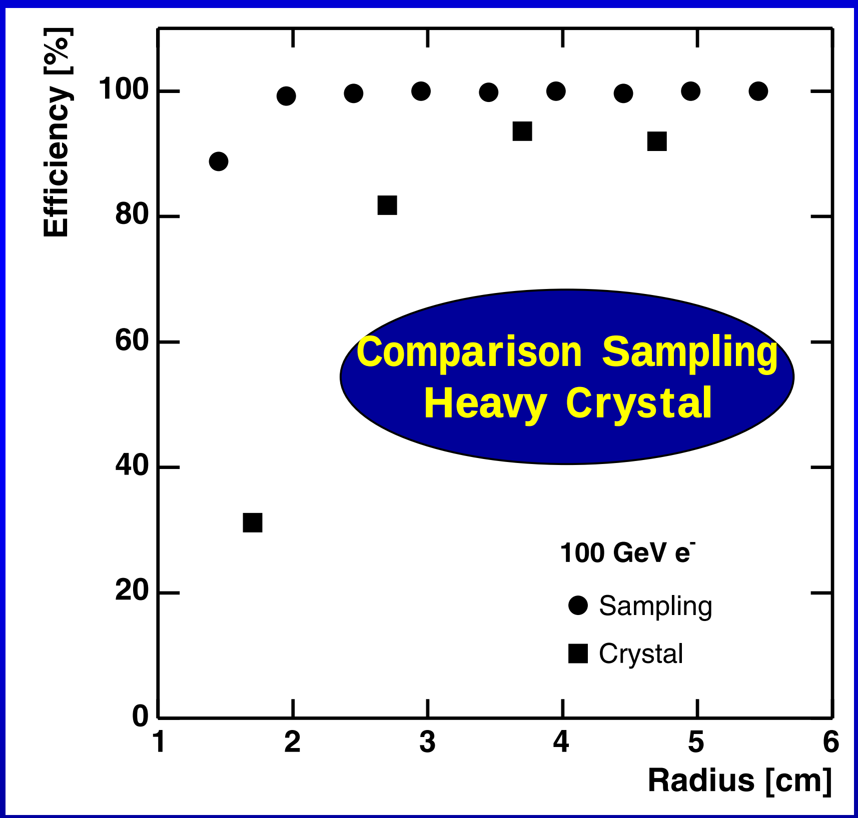


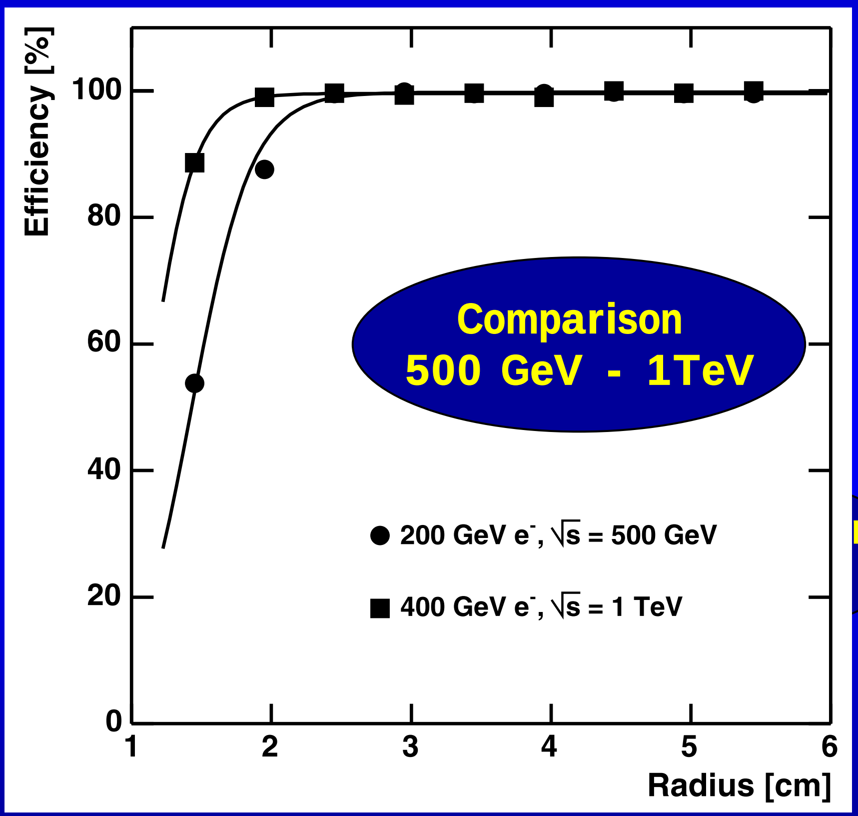
Diamond performance as function of the absorbed dose

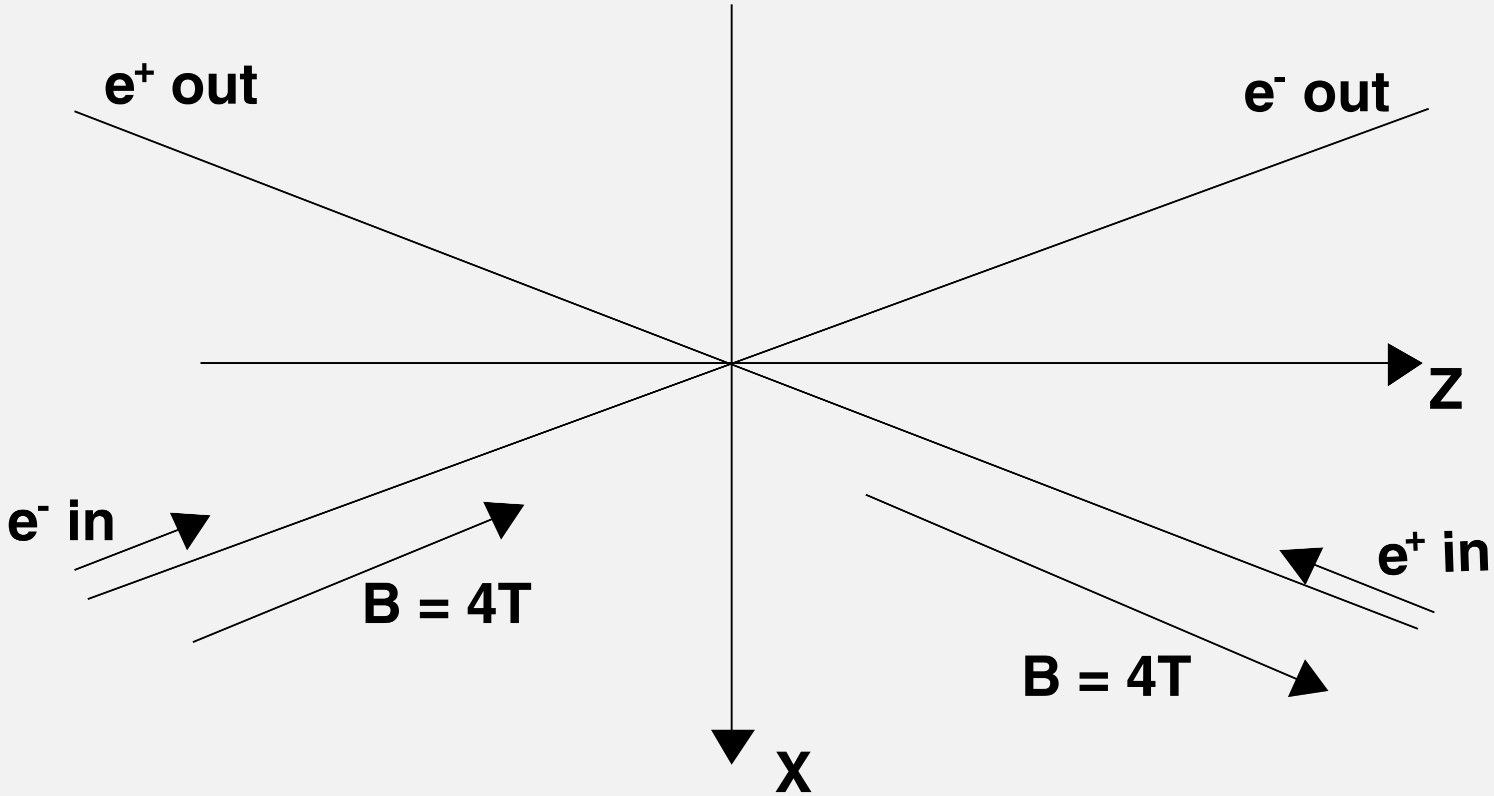


Linearity of a heavy gas calorimeter (IHEP testbeam)



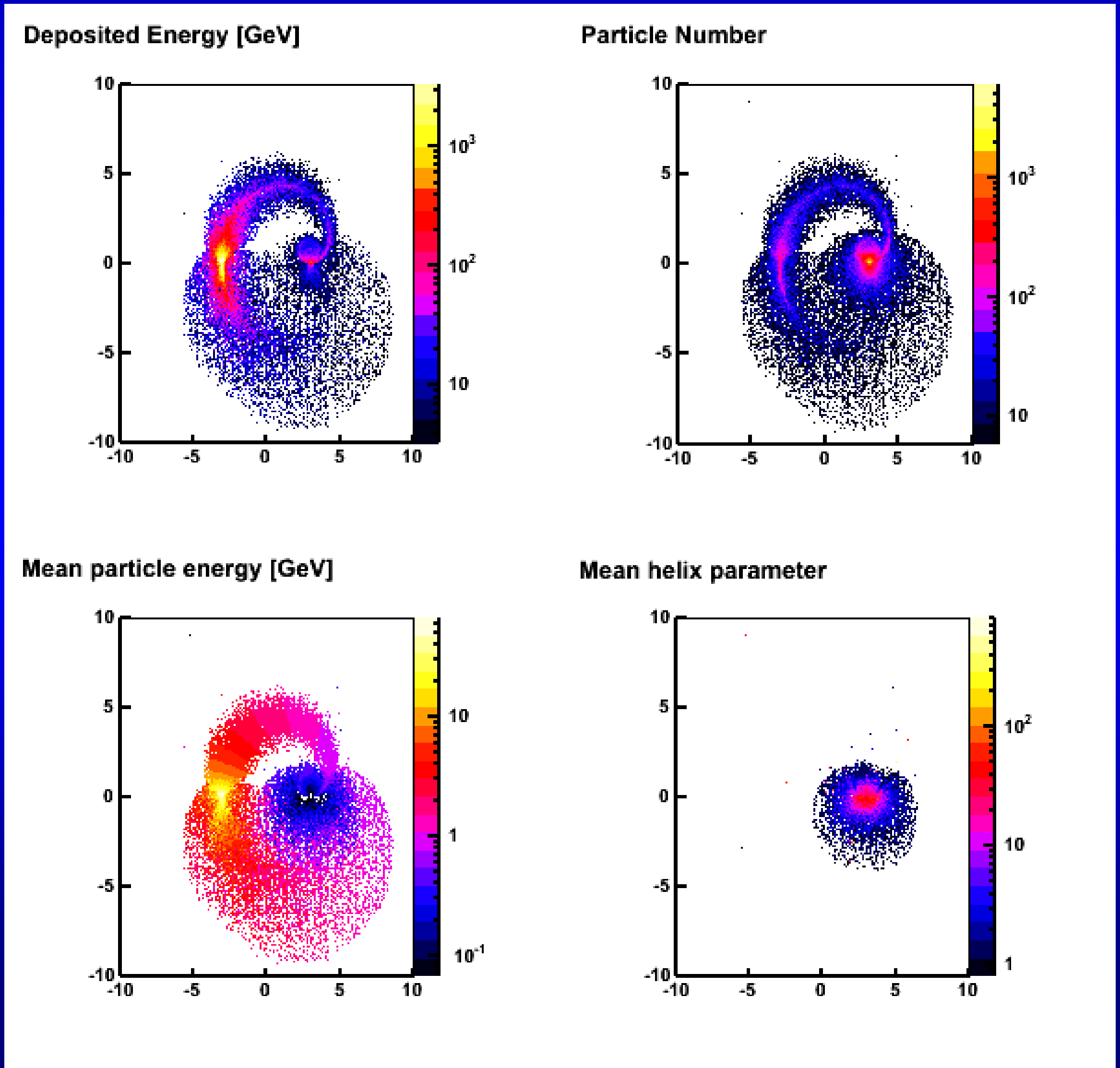

Efficiency [%]
100
80
60
40
20
0
1
2
3
4
5
6
Radius [cm]
Comparison Sampling
Heavy Crystal
100 GeV e-
Sampling
Crystal


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