Calorimeters in the Very Forward Region of ILC

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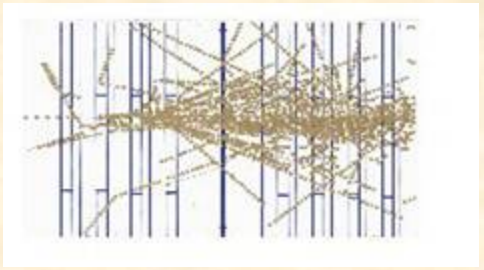
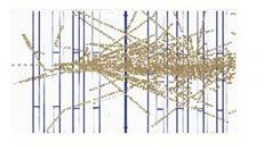
University of Colorado

XII International Conference on
Calorimetry in High Energy Physics
June 9, 2006

FCAL Collaboration
High precision design

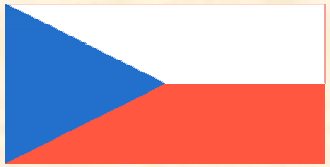




FCAL Collaboration

National Scientific and Educational Center of Particle and High Energy Physics, Belarus State University

Institute of Physics of the Academy of Sciences of the Czech Republic

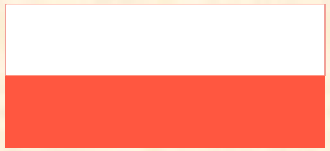


DESY Zeuthen

School of Physics and Astronomy,
Tel Aviv University

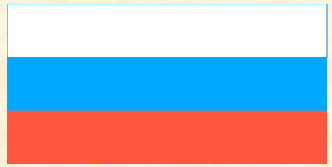
Faculty of Physics and Applied Computer Science,
AGH University of Science and Technology

Institute of Nuclear Physics of the Polish Academy of Sciences



JINR Dubna

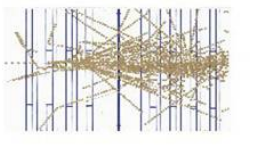
Institute of High Energy Physics Protvino



"VINCA" Institute of Nuclear Science

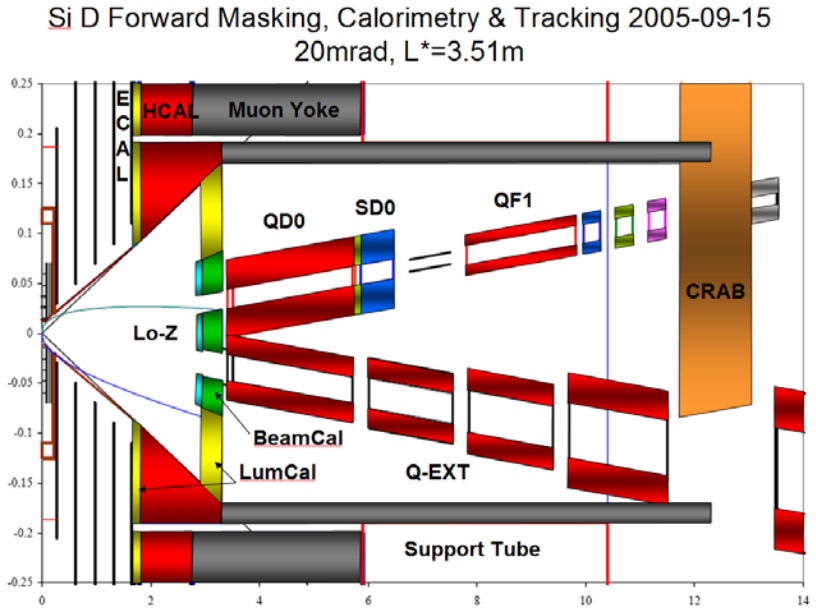
Royal Holloway University of London

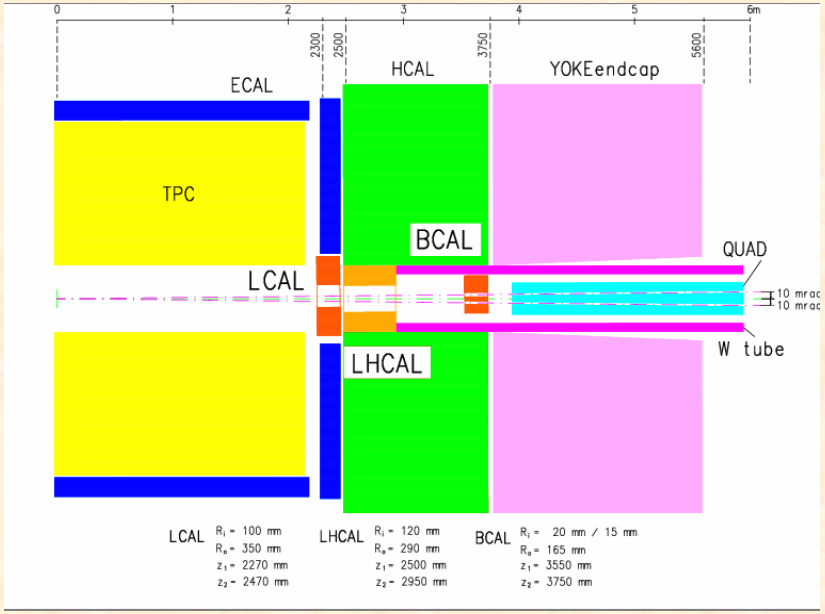
University of Colorado at Boulder



Very Forward Region

SiD ← 20mrad → LDC





5 < θ < 25 mrad

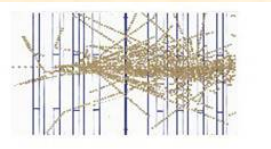
BeamCal

5 < θ < 45 mrad

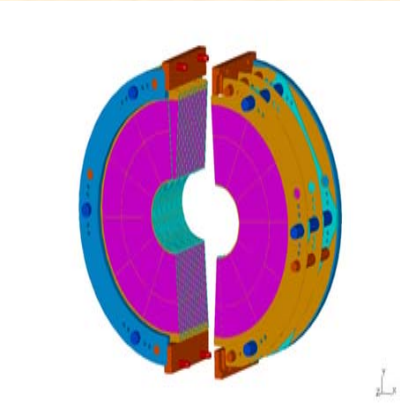
25 < θ < 113 mrad

LumiCal

44 < θ < 155 mrad



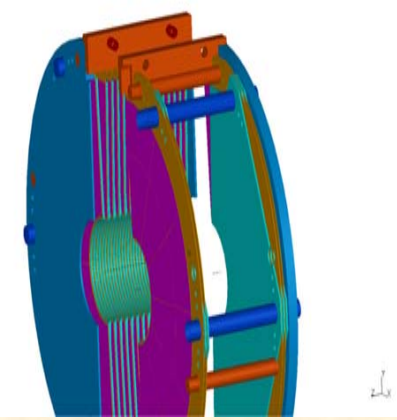
LumiCal



Measure the luminosity precisely

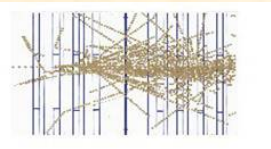
$$\frac{\Delta L}{L} \cong 10^{-4}$$

Extend the detector coverage



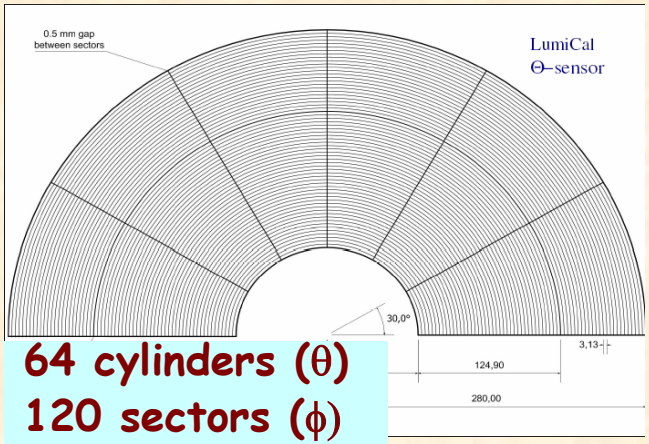
Silicon-tungsten sandwich geometry

	2mrad	20mrad
Absorber thickness (mm)	~3.5	~3.5
Sensor thickness (mm)	~0.5	~0.5
X/Y position (mm)	0/0	+23.70/0
Z_{min}-Z_{max} (mm)	± (2270-2470)	± (2270-2470)
Tilt angle (mrad)	0	10
R_{min} – R_{max} (mm)	60 – 350	100-350
Number of layers	30	30

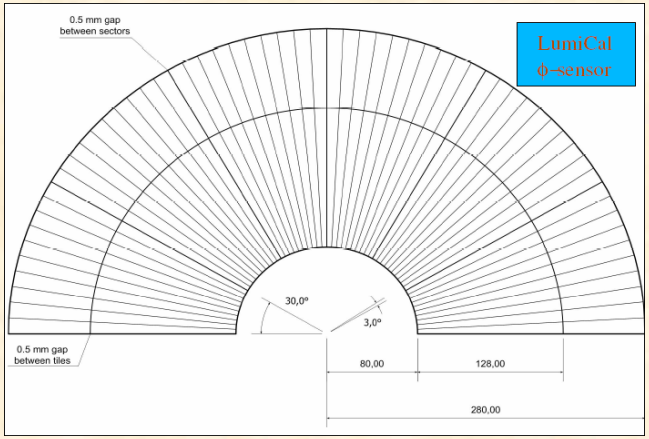


Two Designs

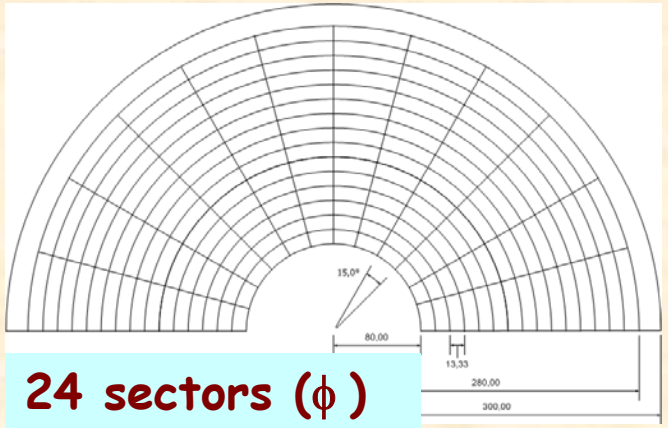
strip



64 cylinders (θ)
120 sectors (ϕ)
30 rings (Z)

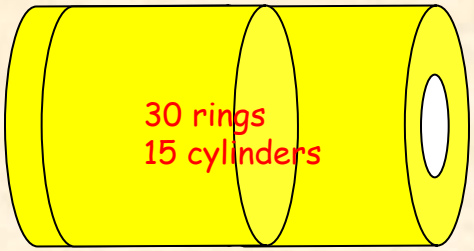


pad

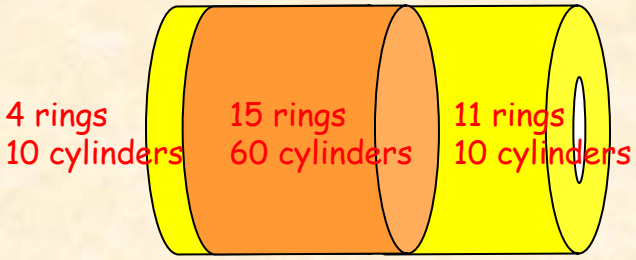


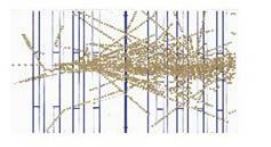
24 sectors (ϕ)
15 cylinders (r)

Basic



Maximum Peak Shower





Physics Simulation

- ★Bhabha scattering

  BHWIDE generator

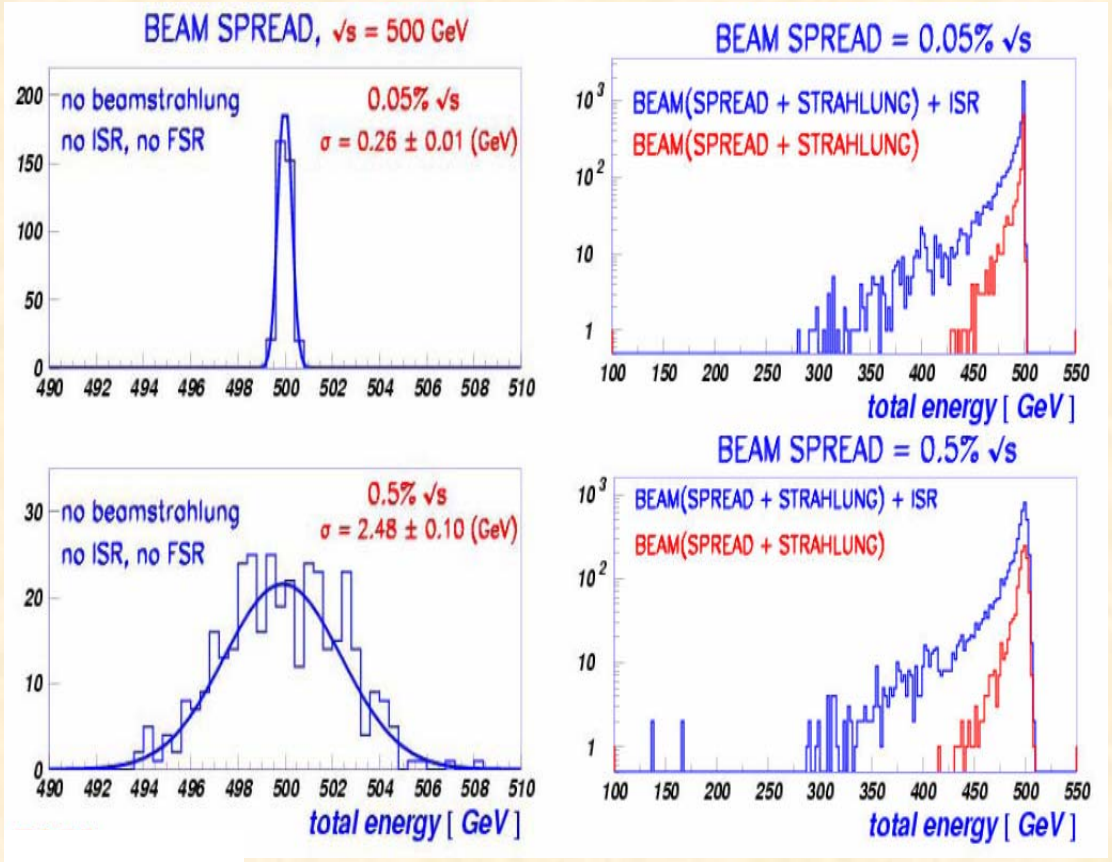
- ★Beam spread

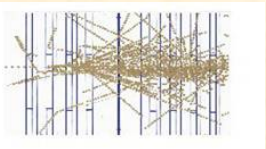
  $0.05\%\sqrt{S}$

  $0.5\%\sqrt{S}$

- ★Beamstrahlung

  CIRCE generator

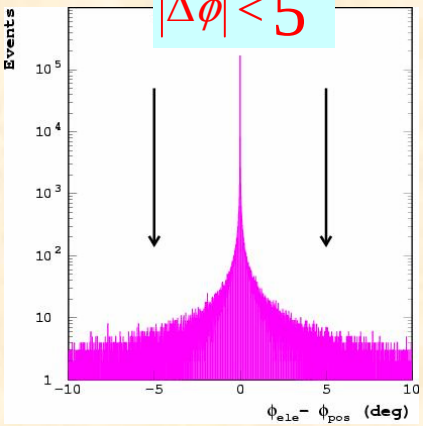




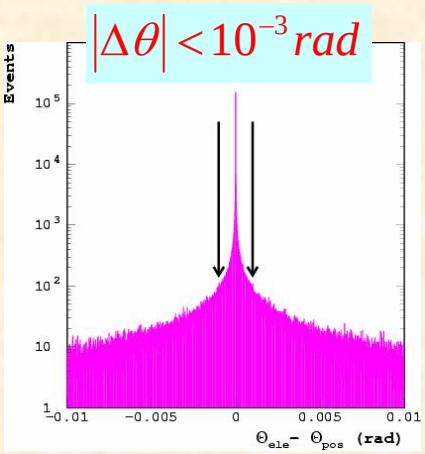
Event Selection

Symmetry cut

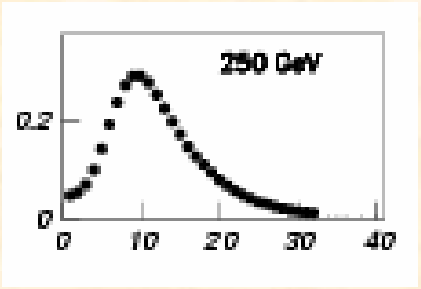
$|\Delta\phi| < 5^{\circ}$

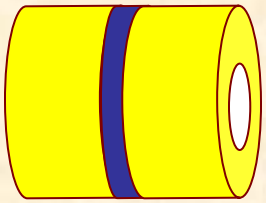


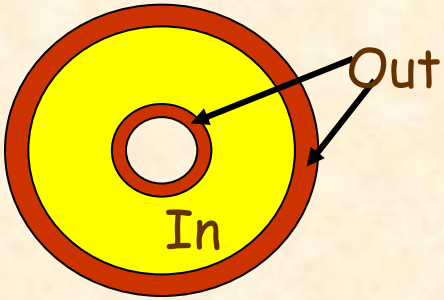
$|\Delta\theta| < 10^{-3} rad$



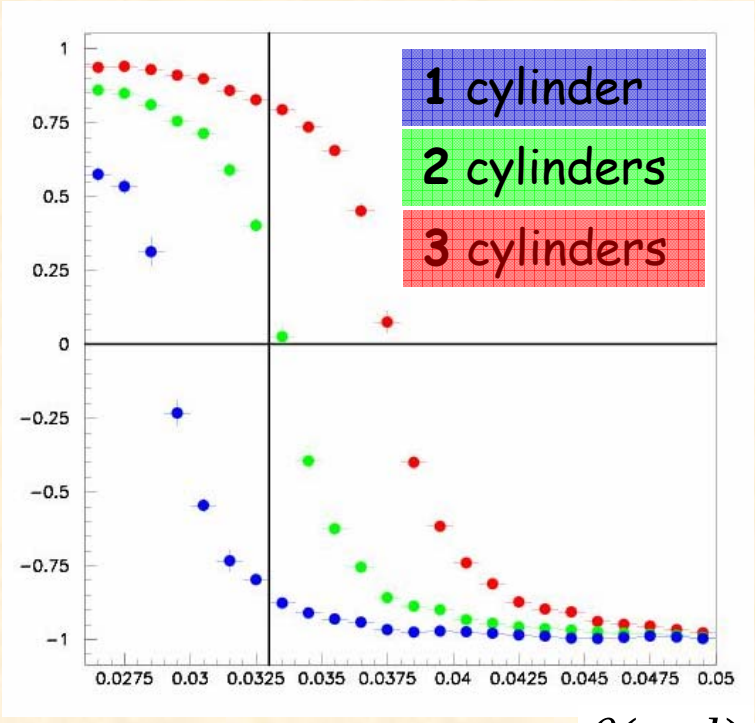
Geometric Acceptance

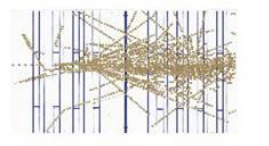






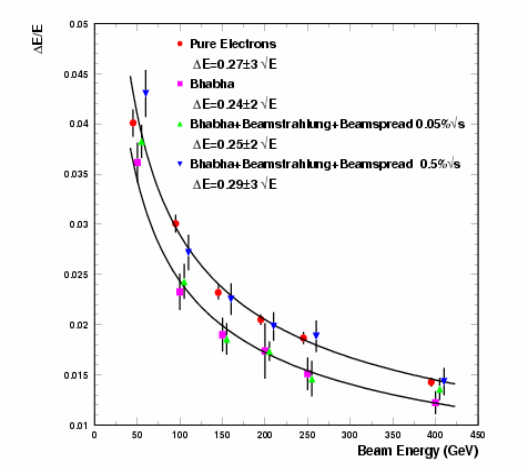
$$P = \frac{E_{out} - E_{in}}{E_{out} + E_{in}}$$

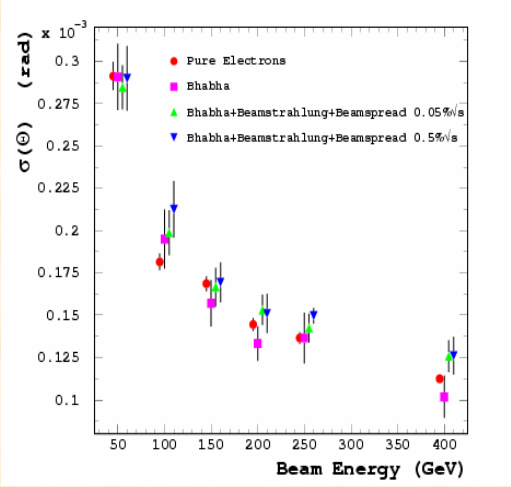


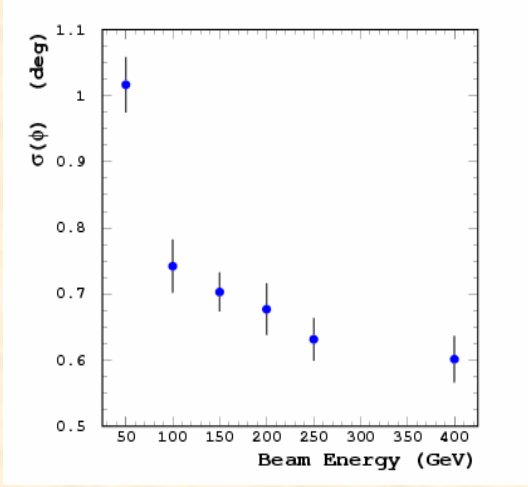


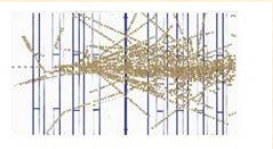
Resolution

Pad (Basic)







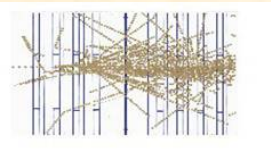


Performance

Maximum Peak Shower

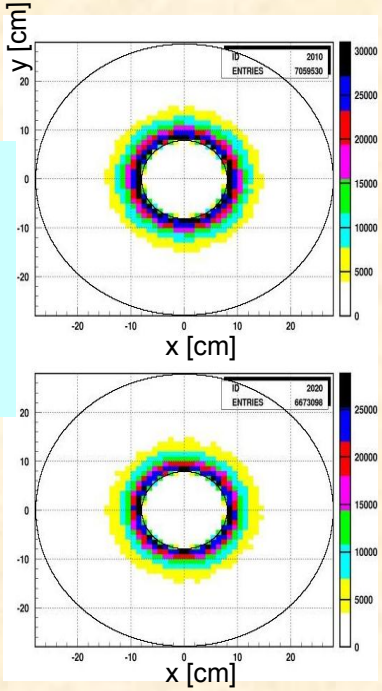
Parameter	Pad	Strip
Energy resolution	25%√E	25%√E
θ resolution (rad)	3.5×10^{-5}	2.1×10^{-5}
ϕ resolution (rad)	10^{-2}	10^{-3}
ΔΘ (rad)	~ 1.4×10^{-6}	~2.1×10^{-7}
Electronics channels	25,200	8000

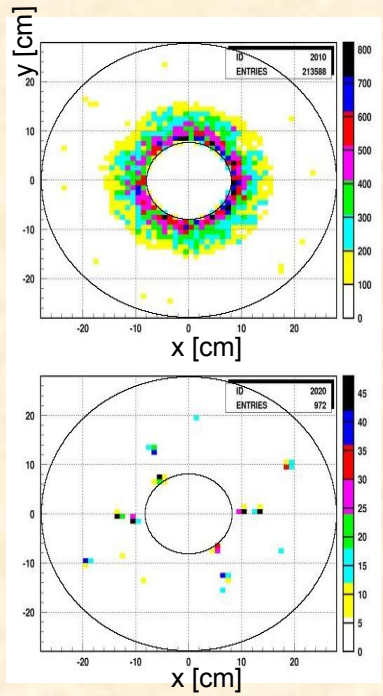
$$\frac{\Delta L}{L} < 10^{-4}$$

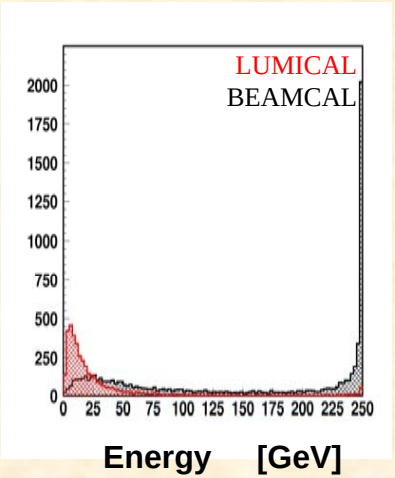


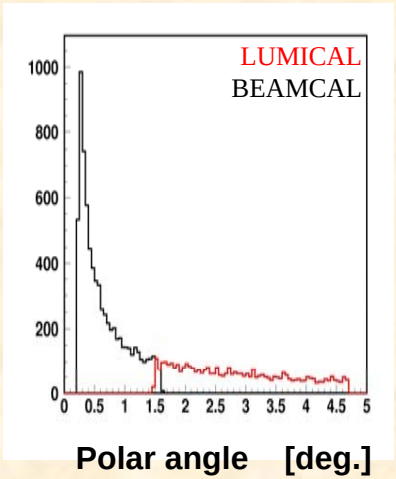
Background Suppression

- ★ Two-photon process as the main background
- ★ e+e- -> e+e-l+l- (l=e, μ, τ) simulated with WHIZARD

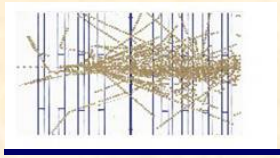




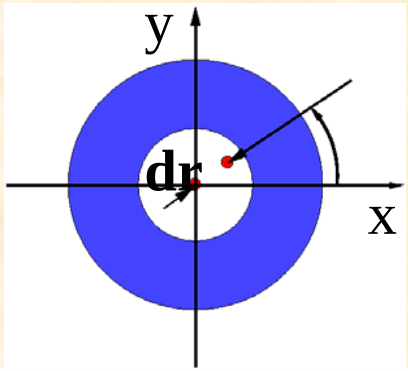




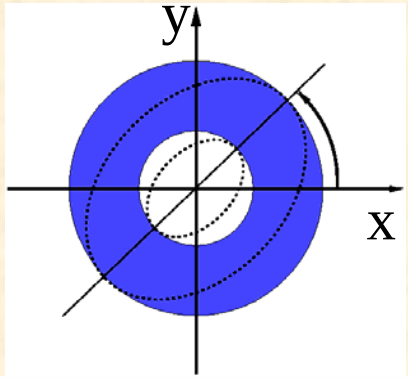
Signal efficiency	76.2%
Background rejection	99.6%

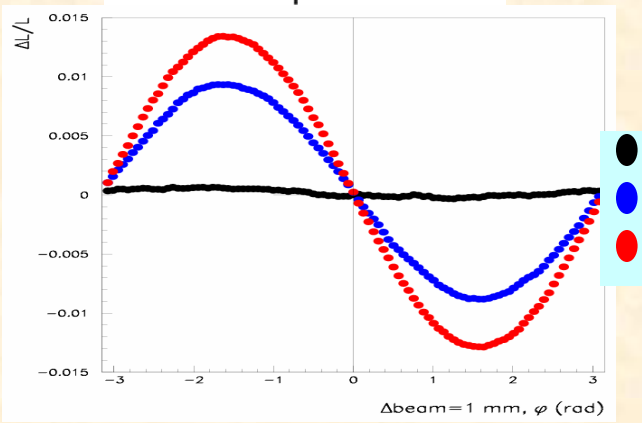


Beam Crossing Angle Effect

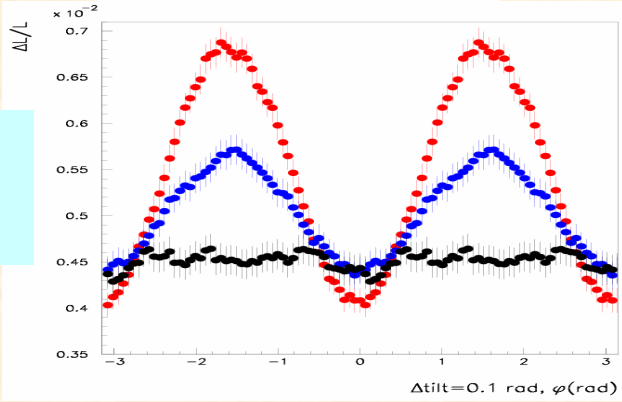


$$\frac{\Delta L}{L} = \frac{\Delta N}{N} = \frac{N_{\mathrm{rec}} - N_{gen}}{N_{gen}}$$





- Headon, 14,20 mrad outgoing beam
- 14 mrad detector axis
- 20 mrad detector axis



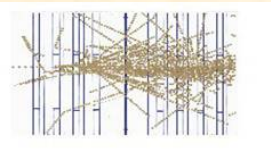
20mrad vs. 2mrad

Centered around the outgoing beam pipe

ΔL/L comparable

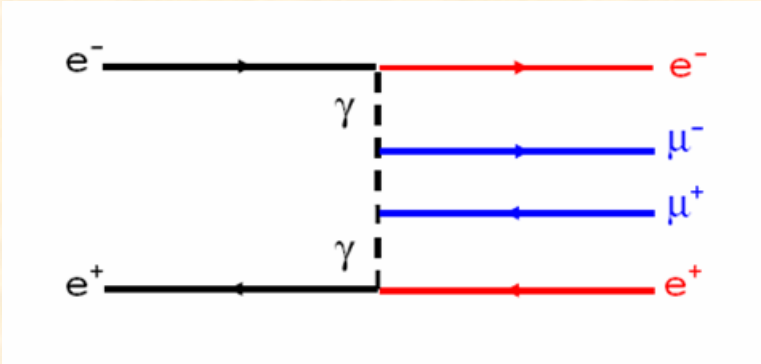
Centered around the detector axis

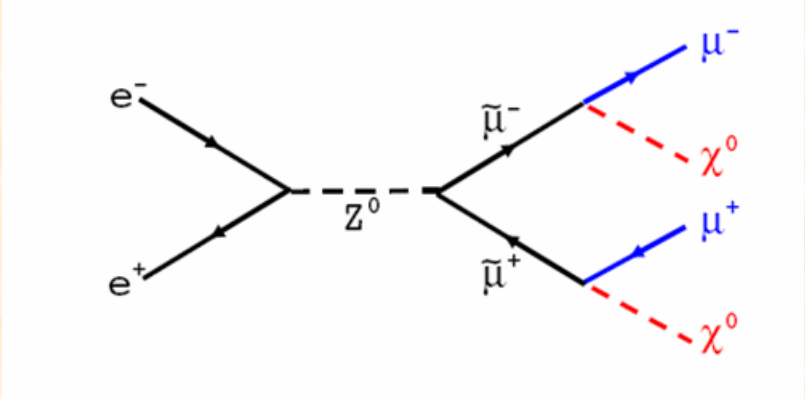
ΔL/L up to three orders of magnitude larger



BeamCal

- ★ Beam diagnostics
- ★ Reduction of backscattering to inner subdetectors
- ★ Detection of high energy electrons and photons





Two photon background

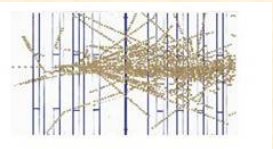
$\mu^+ \mu^-$ + missing energy

$\sigma \sim 10^6$ fb

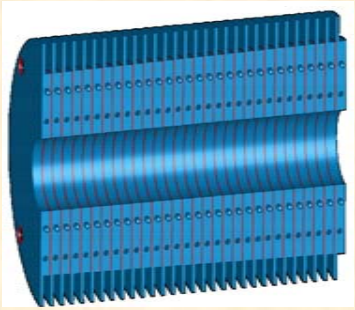
SUSY physics

$\mu^+ \mu^-$ + missing energy

$\sigma \sim 10^2$ fb

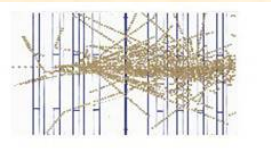


Geometry

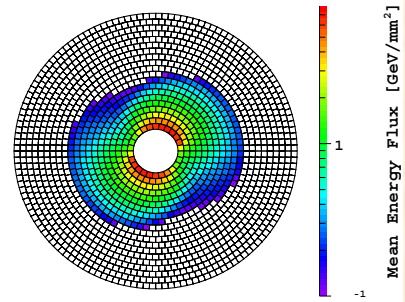


Sensor: diamond
Absorber: tungsten

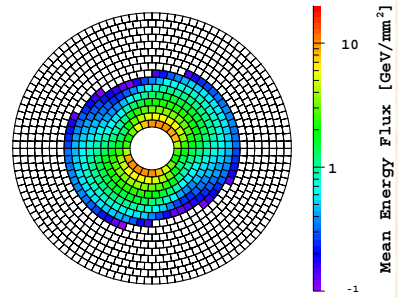
	Head-on	2mrad	20mrad
Absorber thickness (mm)	3.5	3.5	3.5
Sensor thickness (mm)	0.3	0.3	0.3
X/Y position (mm)	0/0	0/0	+36.5/0
Z position (mm)	±3650	± 3650	± 3650
Tilt angle (mrad)	0	0	10
$R_{min} - R_{max}$ (mm)	15 – 100	20 – 100	20 – 165
$\theta_{in} - \theta_{out}$ (mrad)	4– 28	5 – 28	5-45
Number of layers	30	30	30



Segmentation



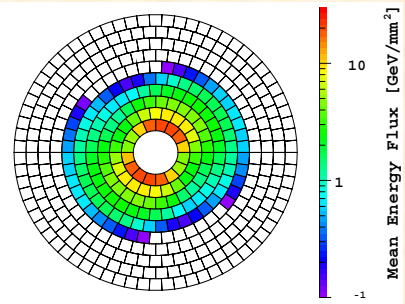
Optimization with fixed cell size



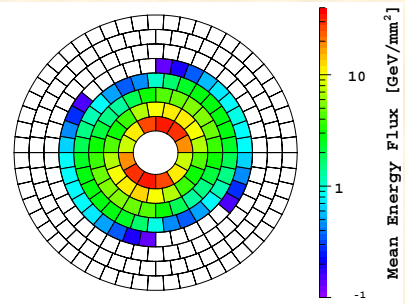
Head-on

	4 mm	5 mm	8 mm	10 mm
Ring	20	16	10	8
Cell	1660	1072	430	264
Channel	49800	32160	12900	7920

Head-on



Optimization for electron identification



Electron Identification

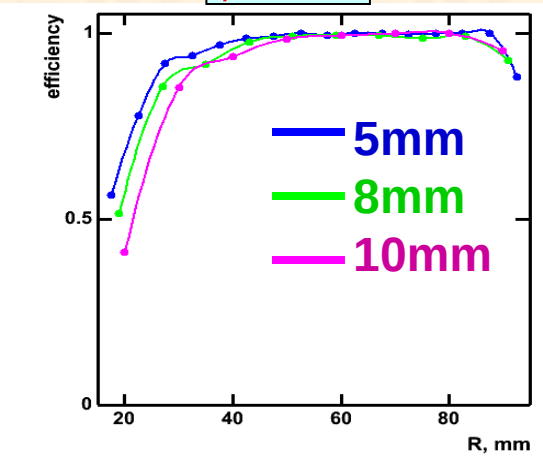
- ★ Use 10 bunches to define $\langle E_{bg} \rangle$ and RMS_{Ebg} for each pad;
- ★ Subtract $\langle E_{bg} \rangle$ from E_{dep} for each pad for a signal event;
- ★ Keep pads with remaining E_{dep} larger than $5 \cdot RMS_{Ebg}$;
- ★ Build clusters:
  more than **7** pads in the segment and
  more than **4** pads in at least one neighbor segment.

- ★ $|E_{rec} - E_{fit}| < 3\sigma_{fit}$
- ★ $|R_{rec} - R_{sim}| <$ CellSize/2
- ★ $|\varphi_{rec} \cdot R_{rec} - \varphi_{sim} \cdot R_{sim}| <$ CellSize/2

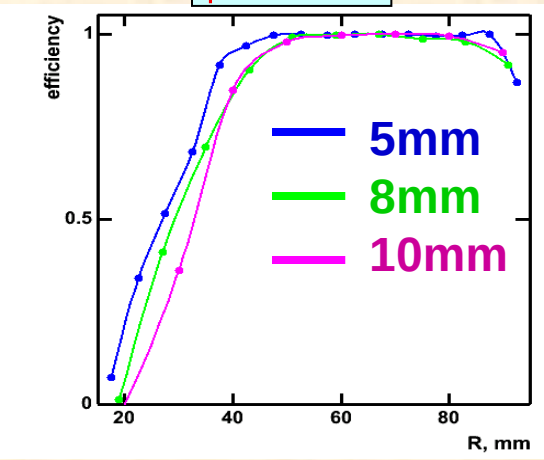
Head-on

Head-on

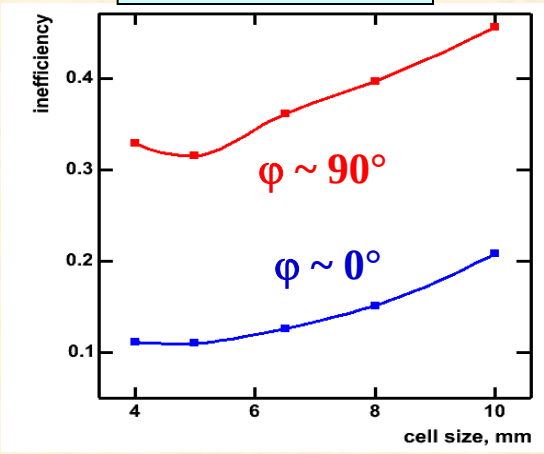
$\varphi \sim 0°$

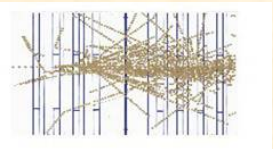


$\varphi \sim 90°$



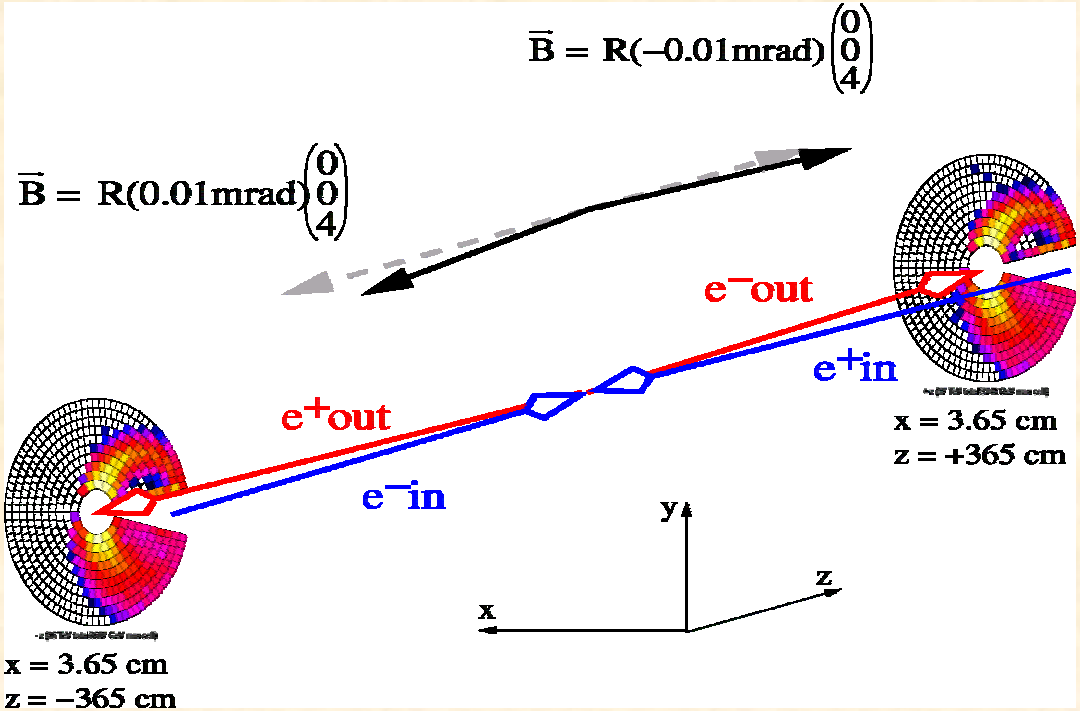
Inefficiency





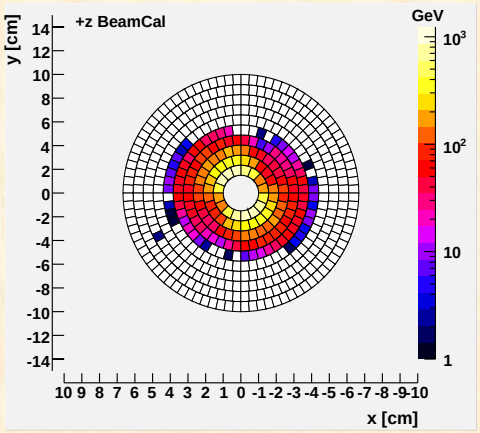
20mrad crossing angle & DID

★Detector mounted on the outgoing beam
★Blind area for the incoming beam
★Simplified implementation (or B map) of DID

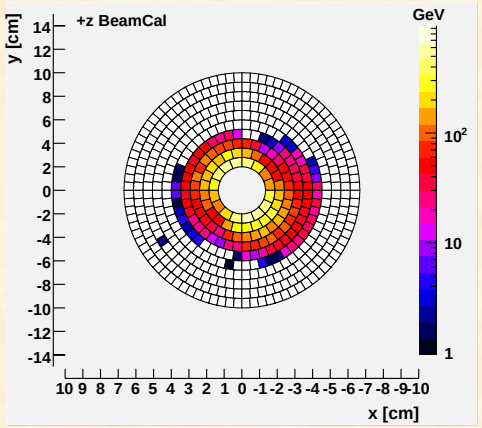


Background

Head on

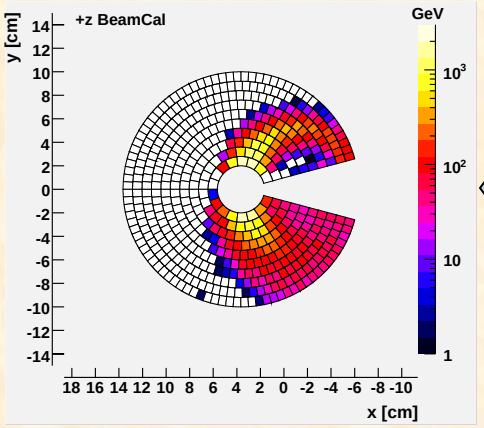


2 mrad



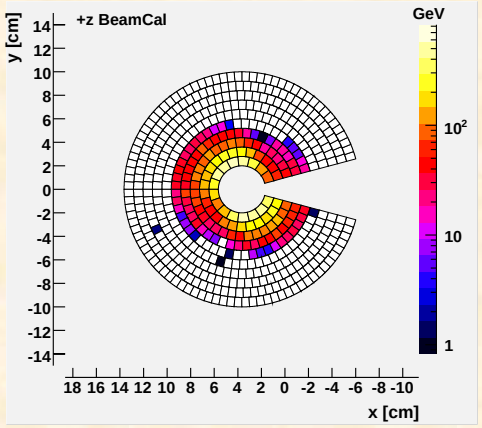
One bunch crossing (500GeV)

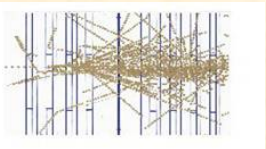
20 mrad old DID



Hard to identify electron

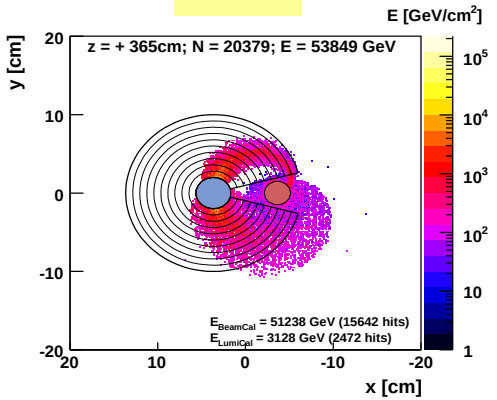
20 mrad old antiDID



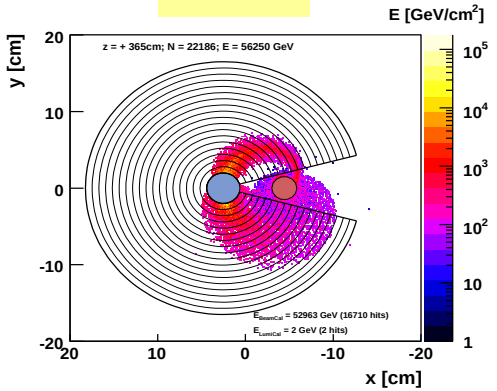


Problem & Possible Solution

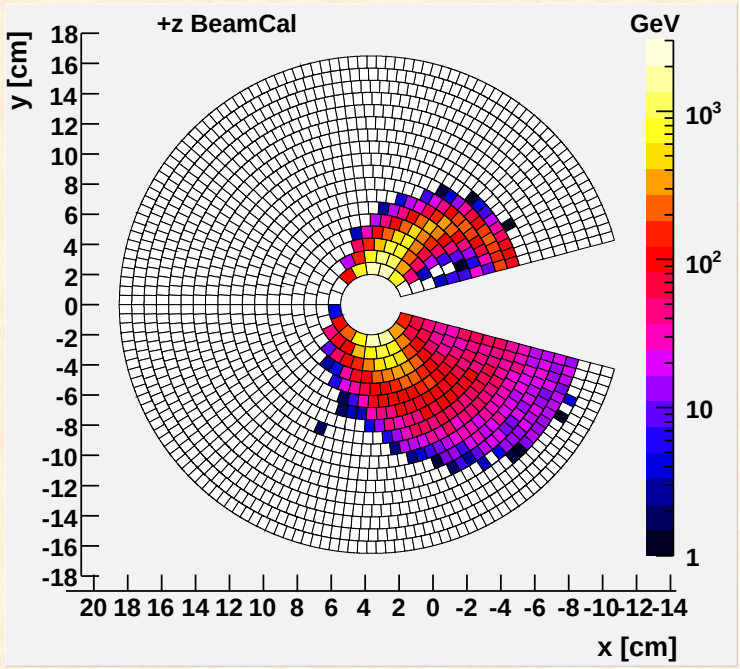
old



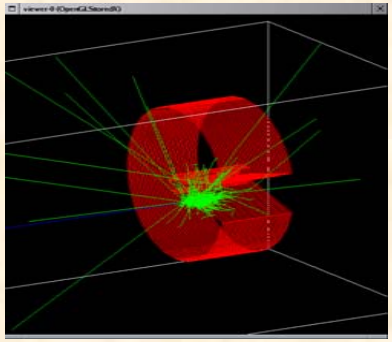
new



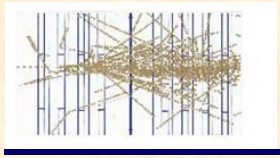
20 mrad new DID



Segmentation with less channels



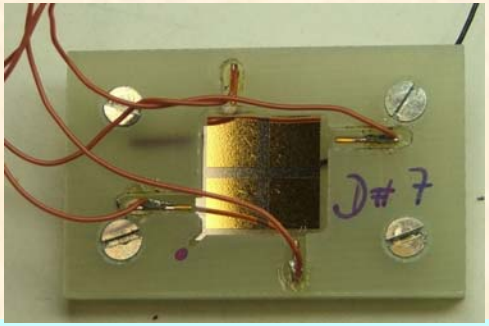
	Head-on	2mrad	20mrad
Rings	10	10	18
ΔR (mm)	8.5	8.0	8.06
N_{seg} in 1st ring	16	16	16
ΔN_{seg} per ring	8	8	8
N_{seg} per layer	520	520	1512
Blind area	0	0	±15°



Diamond sensor

Diamond samples (CVD)

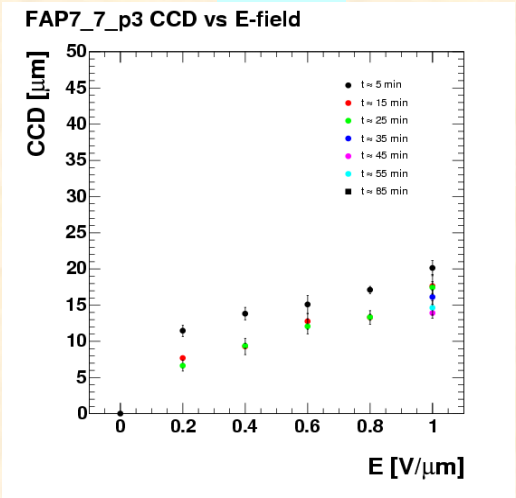
- FAP (Freiburg)
- GPI (Moscow)
- Element6 (De Beers)



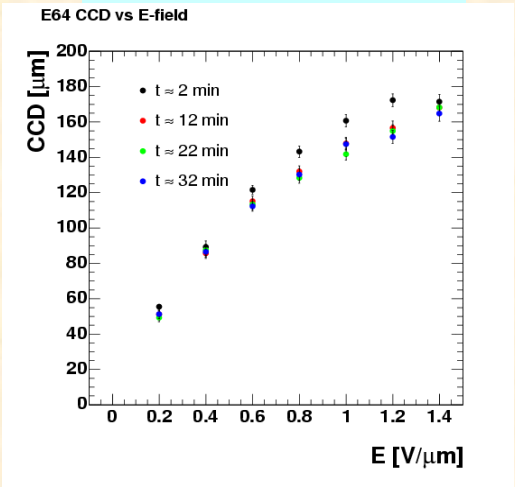
IV behavior
CCD performance
MIP signal
Irradiation
… …

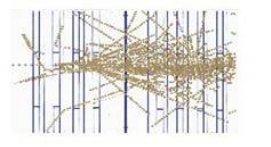
★Some sensors show microcracks (and leakage)
★CCDs are between 0 and 150 μm
★Some sensors are not stable under irradiation

FAP



Element 6





Summary

- ★ LumiCal
  - ➢ Detetor design and performance study with detailed simulation
  - ➢ Background suppression
  - ➢ Systematics from geometric distorsion effects
  - × Mechaincs and alignment
  - × Sensor and Readout system
  - ➢ Achievable $\Delta L/L \approx 10^{-4}$
- ★ BeamCal
  - ➢ Detector Design and performance study with different level simulations
  - × Beam diagnostics to provide many beam parameters
  - ➢ Different instrumentations
  - ➢ Sensor testing
  - × Electronics design
- ✓ Good progresses by FCAL collaboration. Further optimization is needed. 14 mrad crossing angle ?