Forward Calorimeters for the Future Electron-Positron Linear Collider Detectors

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On behalf of FCAL Collaboration

Plan:

> Introduction

> Forward Region

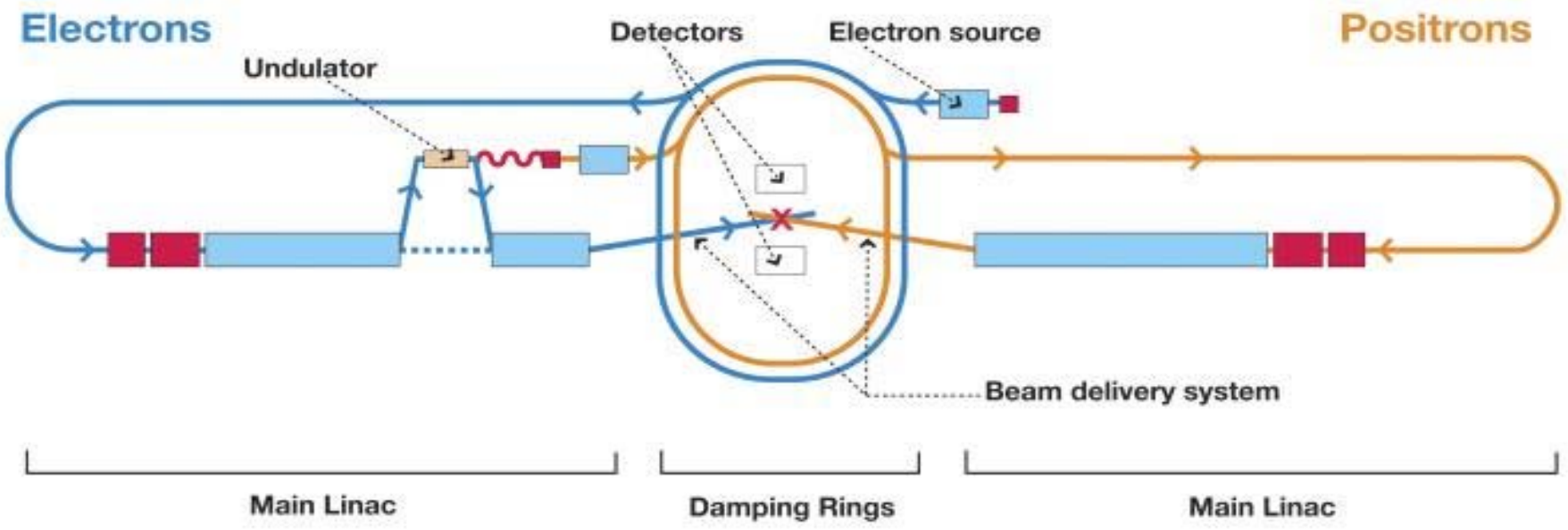
> Monte Carlo Simulations

> Sector Prototype for BeamCal

> Test Beam DESYII (Summer 2010)

> Conclusions

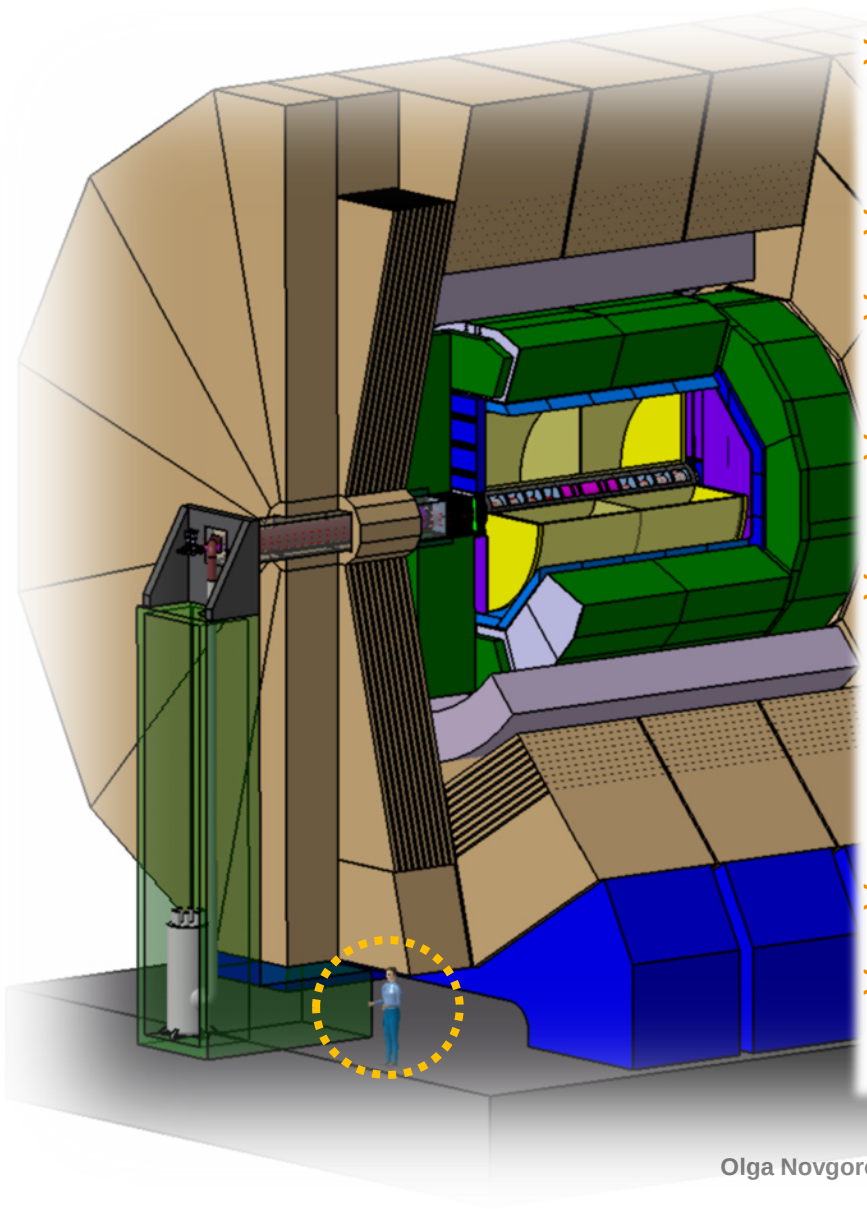
ILC and CLIC



- The International Linear Collider
- Electron-positron collisions → well defined initial state
- Energy from 200 GeV to 500 GeV

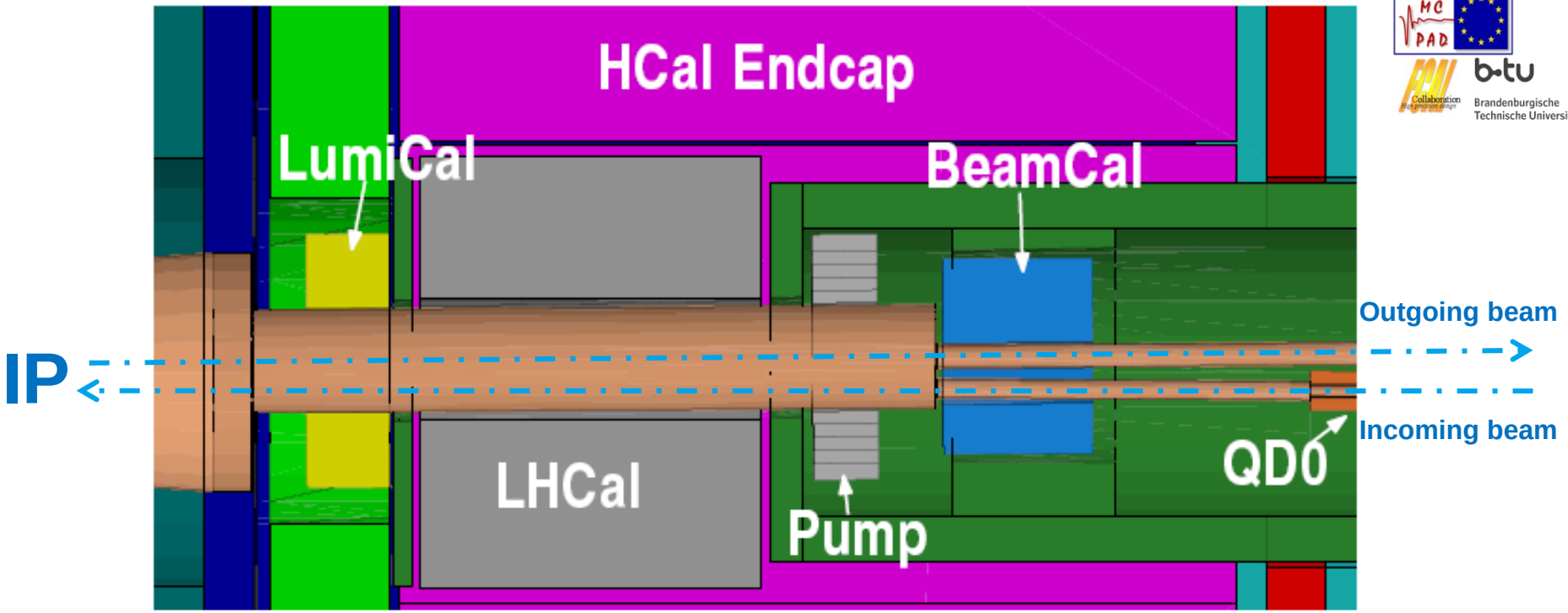
- The Compact Linear Collider
- Linear particle accelerator under design in CERN
- Energy from 500 GeV -> 3 TeV evolution options

ILD – The International Large Detector



- Multi-layer **pixel-vertex detector (VTX)**
- **Time projection chamber (TPC)**
- **Electromagnetic CALorimeter (ECAL) -** highly segmented
- **Hadronic CALorimeter (HCAL)** highly segmented
- **Forward region:**
  - **Luminosity CALorimeter (LumiCAL)**
  - **Beam Calorimeter (BeamCAL)**
- **Superconducting coil**
- **Iron yoke**

Forward Region



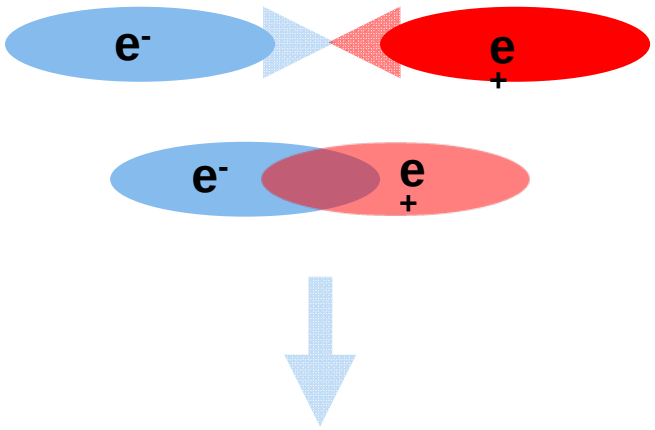
Precise luminosity measurement,

Hermeticity (electron detection at low polar angles),

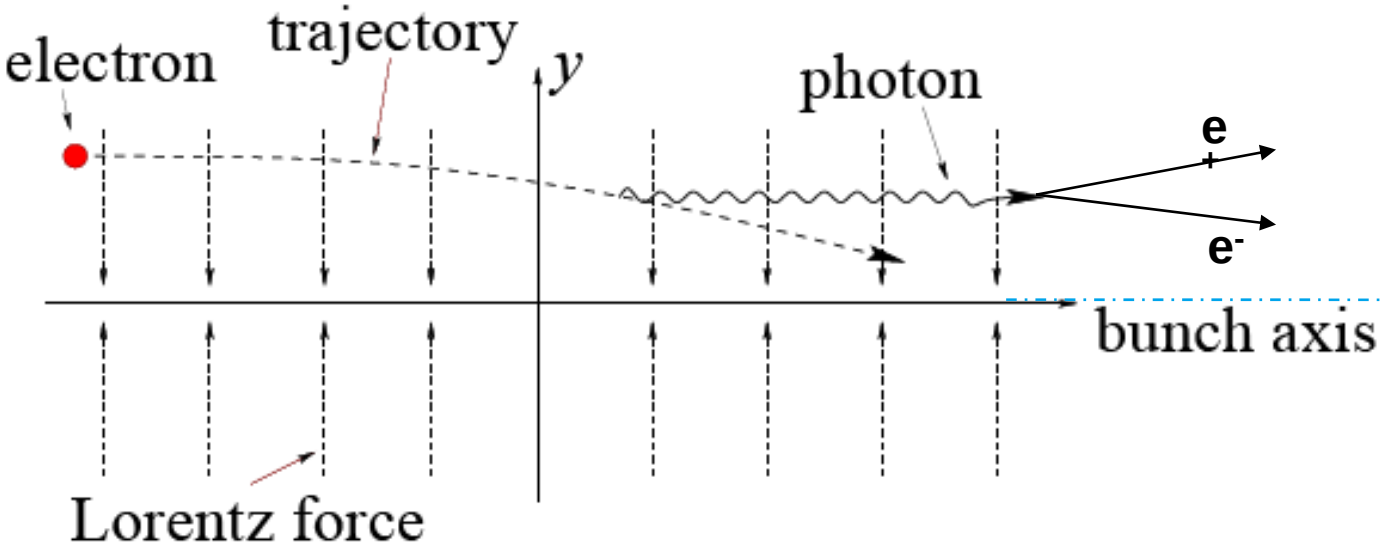
Assisting beam tuning (fast feedback of BeamCal data to machine)

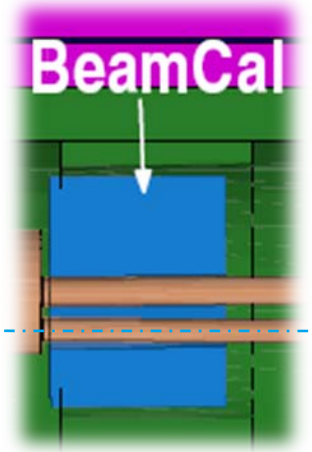
Challenges: radiation hardness (BeamCal), high precision (LumiCal) and fast readout (both)

Beamstrahlung Problem



- > Beamstrahlung - new phenomenon
- - Small bunches
- - High Luminosity
- > the bunch particles accelerated by the Lorentz force radiate photons, which are mostly collinear with the direction of the bunch motion
- > Photons are converted to e^+e^- pairs
- > e^+e^- pairs are deflected

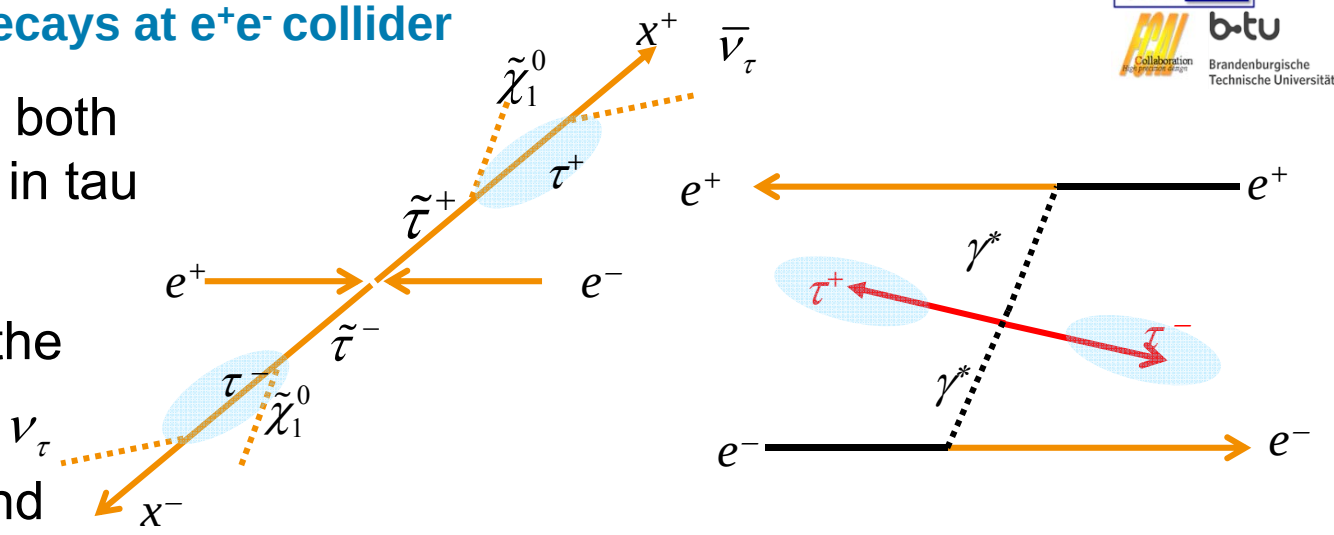




Why do we need hermeticity?

Stau production & Decays at e^+e^- collider

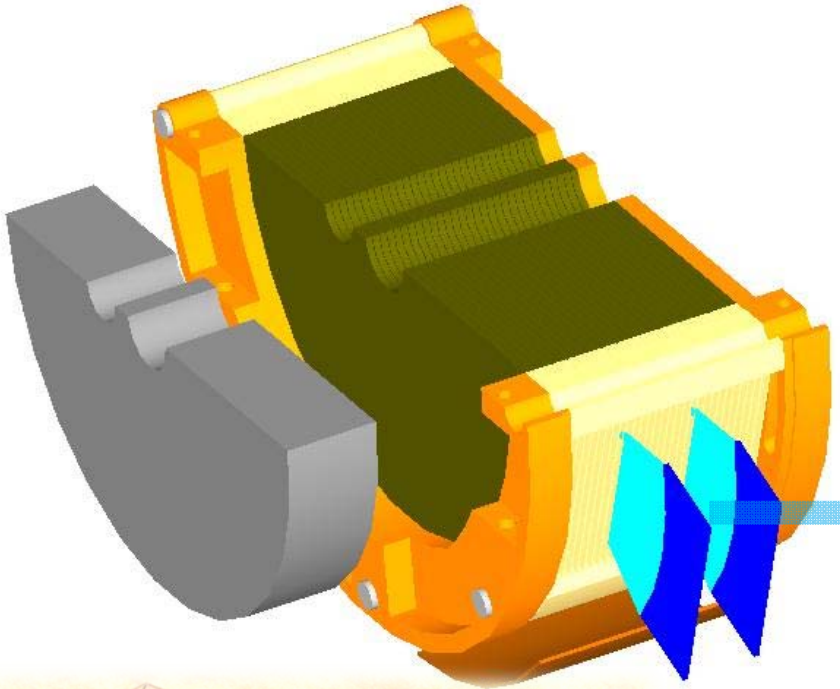
- Missing energy from both LSP and neutrino(s) in tau decay final state
- Only little activity in the center of detector
- Large SM background contributions



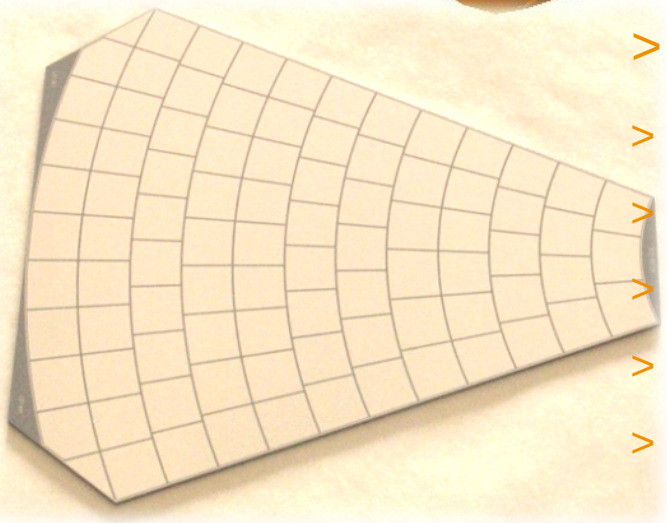
Algorithm of reconstruction:

- sHEe on top of BX search in respect to average of 10 BX
- Define a cluster:
  - Towers after 5-th layer with more then 10 consecutive cells
  - Two or more neighbors towers
- Reconstruction efficiency and fake rate calculations

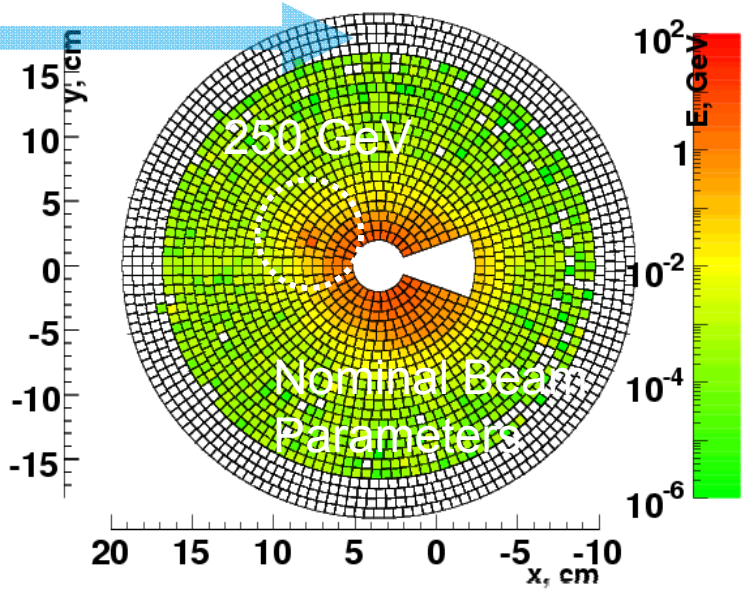
Beam Calorimeter



- Around Beam-pipe
- 30 Layers
  - Tungsten absorber:
  - Sensor layer GaAs or Di
- Radii 2…15 cm, depth ~12 cm
- Sensor segmentation 8x8 mm^2

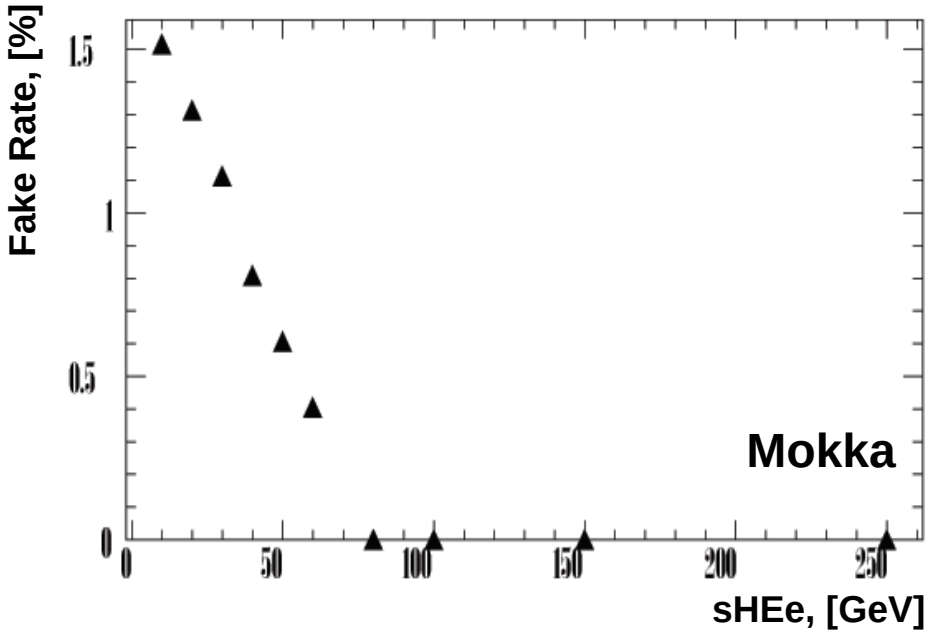


- Prototype
- GaAs plate
- Al metallization
- Thickness 500 μm
- Segmentation ~5x5 mm^2
- Radii 2…8.5 cm

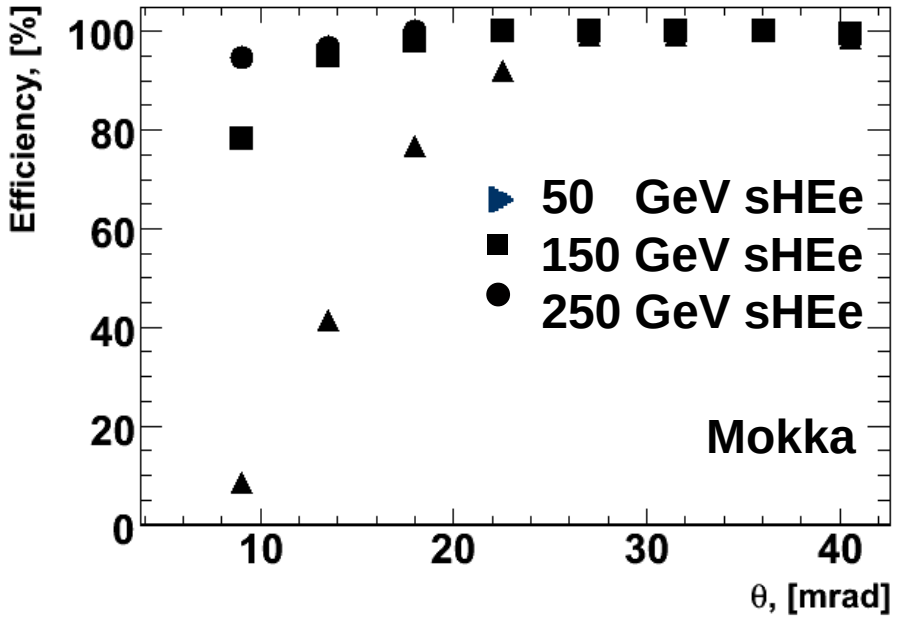


Segmentation of sensor layer

Efficiency of Electron Reconstruction



Fake Rate calculated for 1000 bunch crossings with applying an reconstruction algorithm for sHEe.



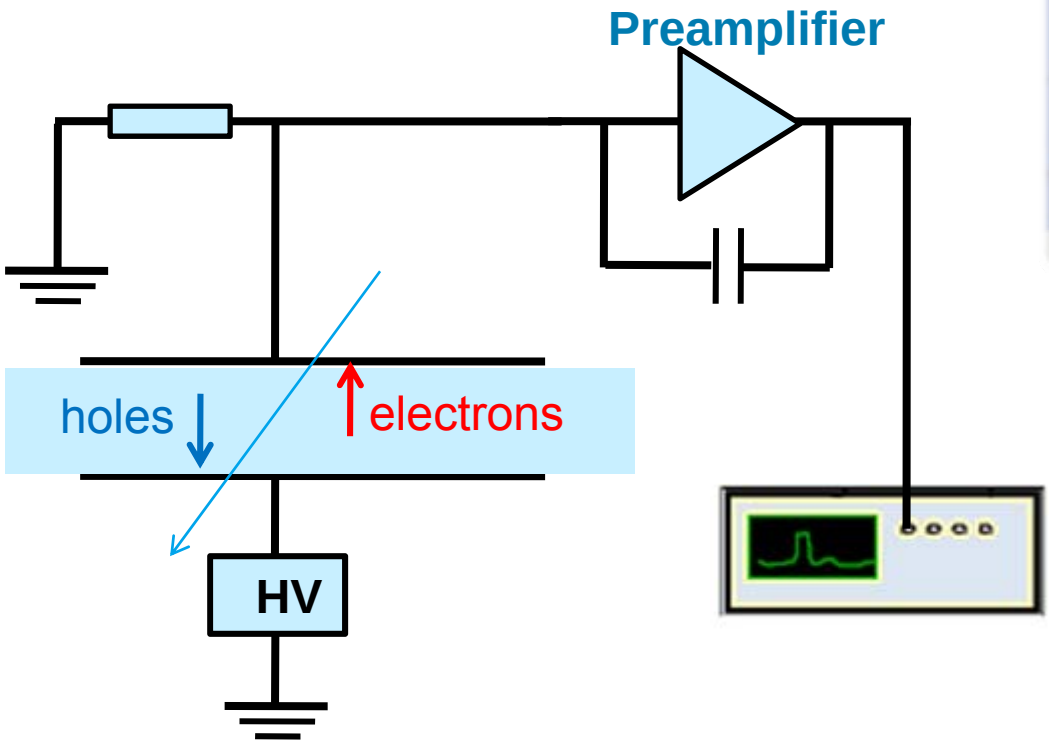
Reconstruction efficiency as a function of Radius (start from beam-pipe) for 50, 150, 250 GeV sHEe with nominal beam parameters.

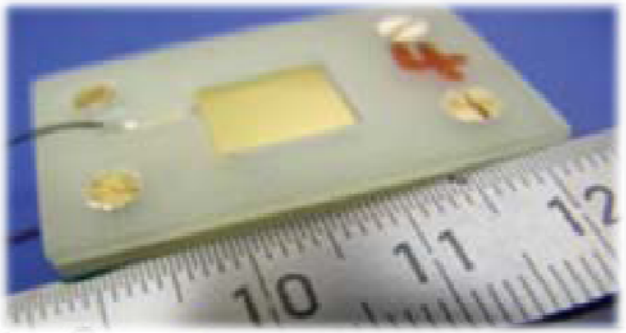
sHEe - single high energy particle

Mokka - GEANT4 based full Monte Carlo for an ILC large detector

Radiation Hard Detectors

- Materials: Diamond, Sapphire, GaAs
- How are they operated:

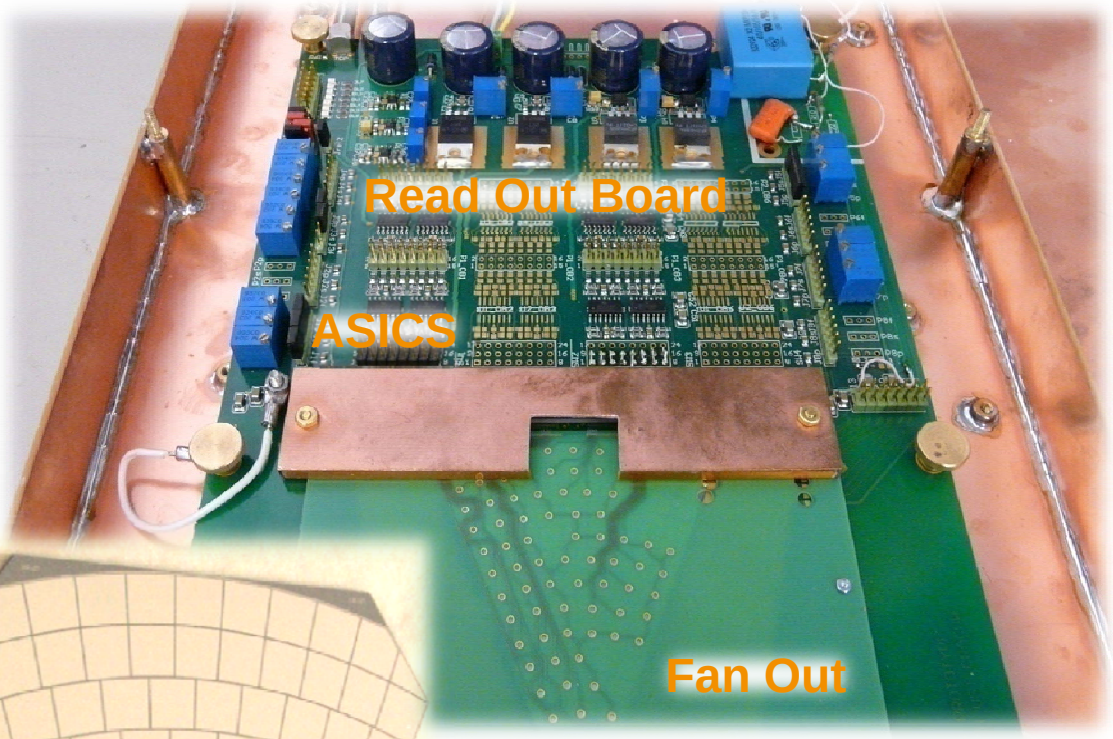


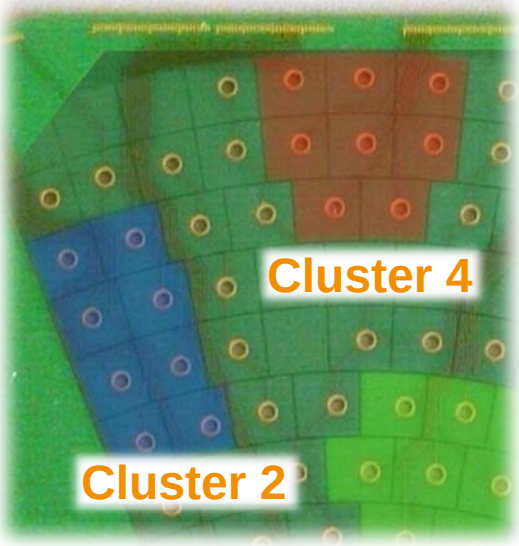


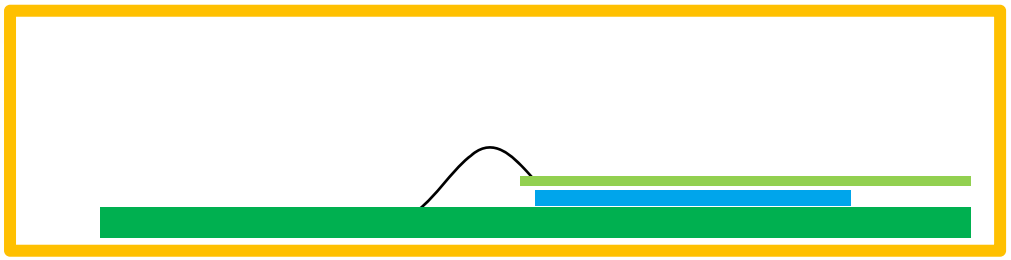
Radiation Hard Materials

	Diamond	GaAs	Sapphire
	Insulator	Semiconductor	Wide band-gap insulator
Leakage Current	few pA at 500V	~300 nA at 50V	~ 1 pA
CCE before irradiation	~100% For single crystals	~ 50 %	~ 2 %
Radiation hardness	tested up to 10 MGy with e-	1 MGy	12 MGy
CCE relative drop after irradiation	Up to 10 %	Up to 10%	Up to 30%

First Prototype for GaAs

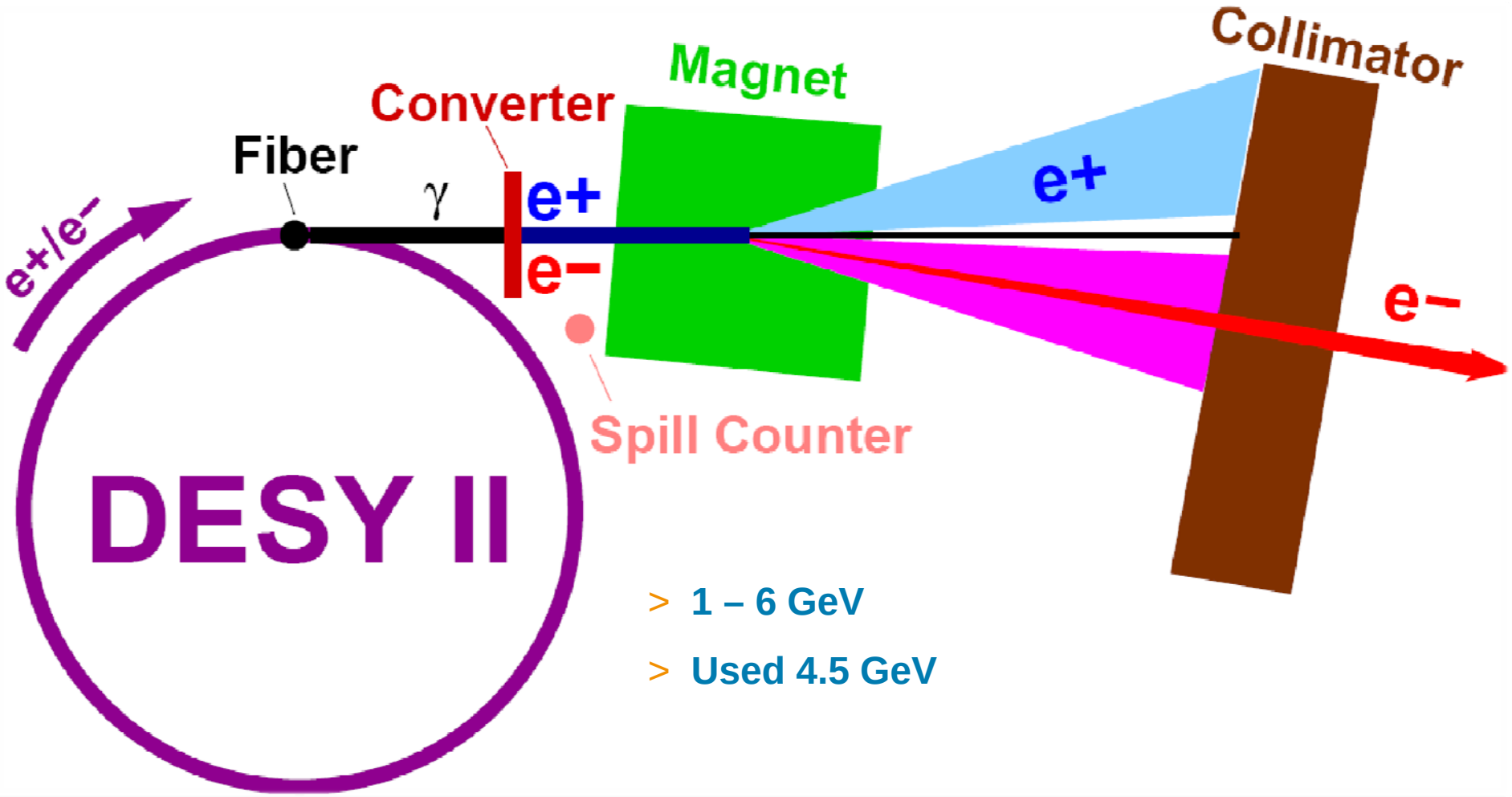






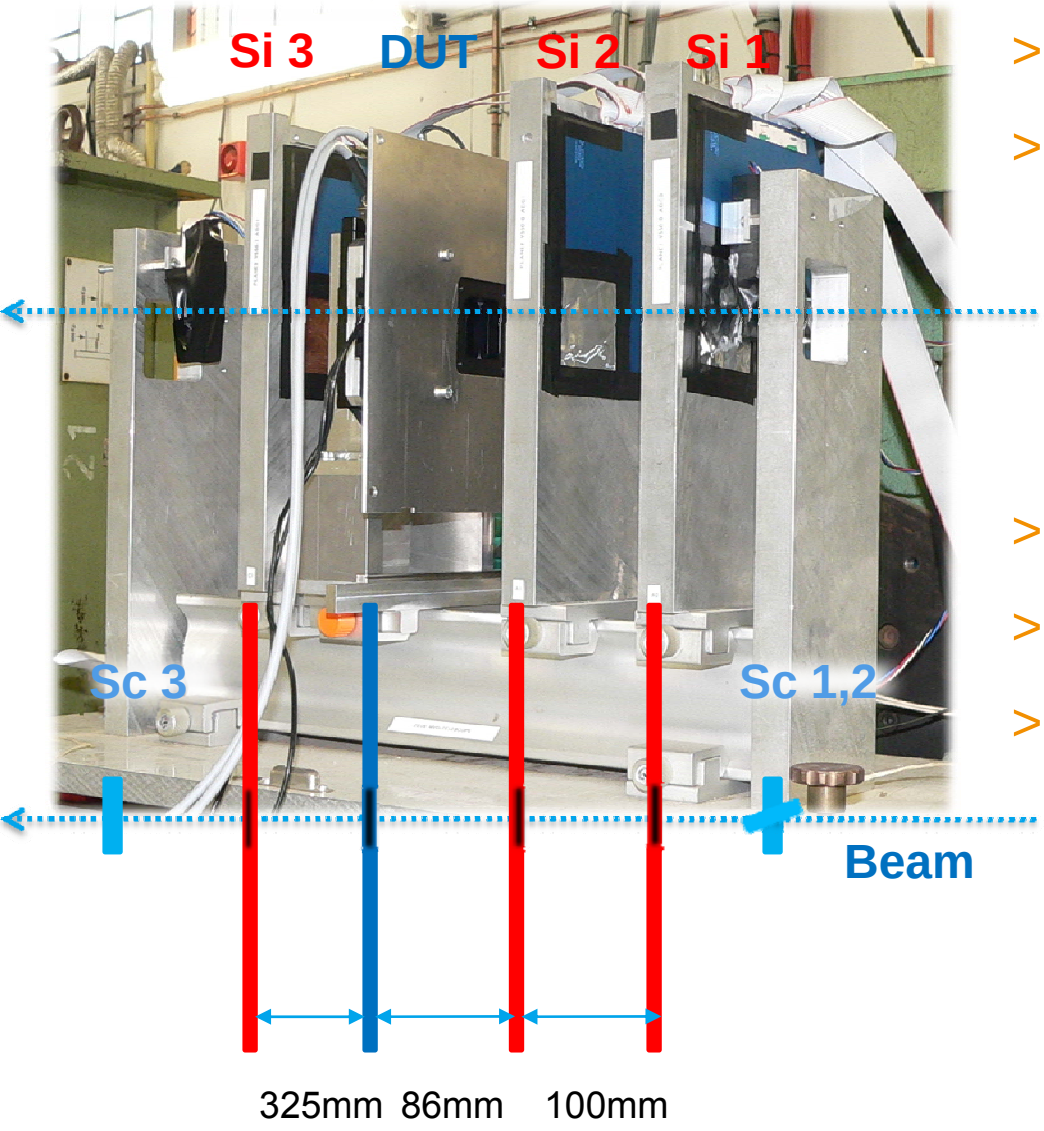
Al window
Fan Out
Sensor
R/O Board
Al window

TestBeam DESY II



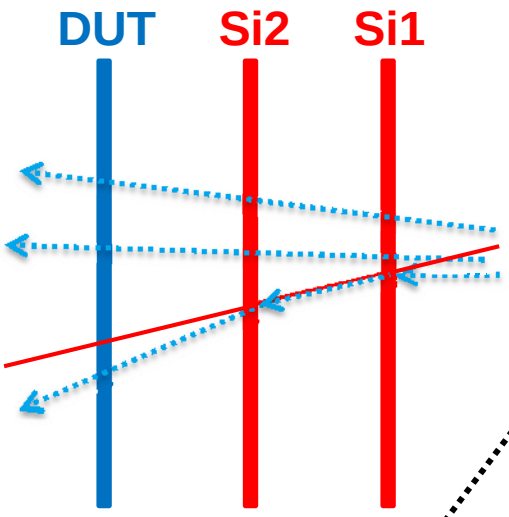
- 1 – 6 GeV
- Used 4.5 GeV

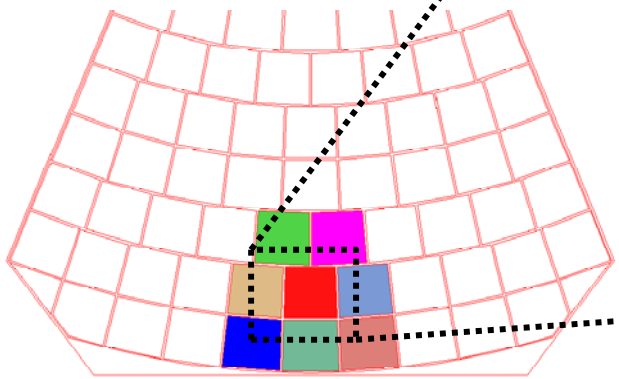
Test Beam Set Up



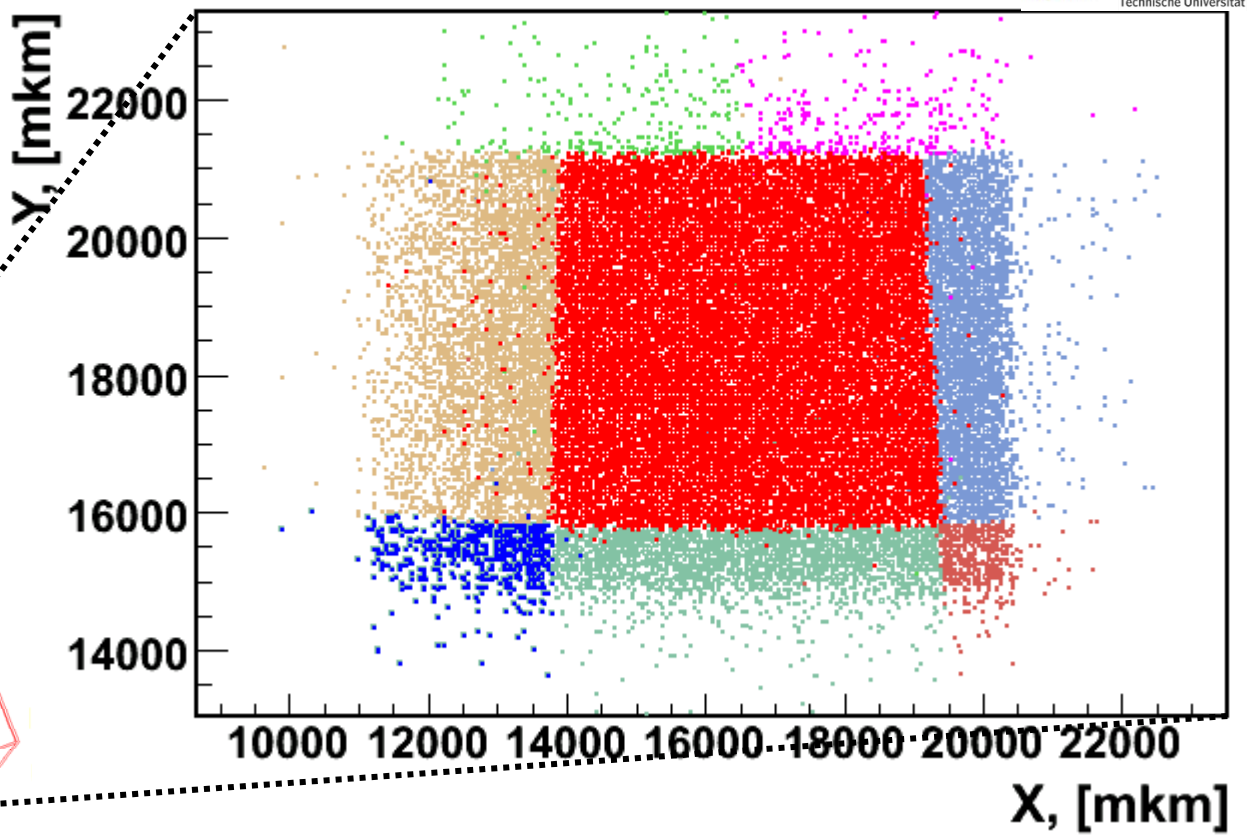
- 7mm scintillator fingers
- Zeus Telescope
  - 3 Si planes
  - Double perpendicular layers
  - 640 strip channels (50µm)
- Precise XY Table
- Sensor Box
- 2 DAQ (Telescope and Sbox)

Tracking



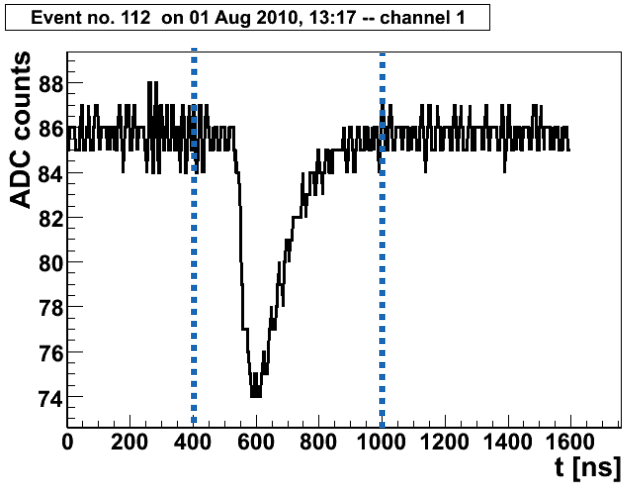


Region 4



Reconstruction of position in the Sensor Box

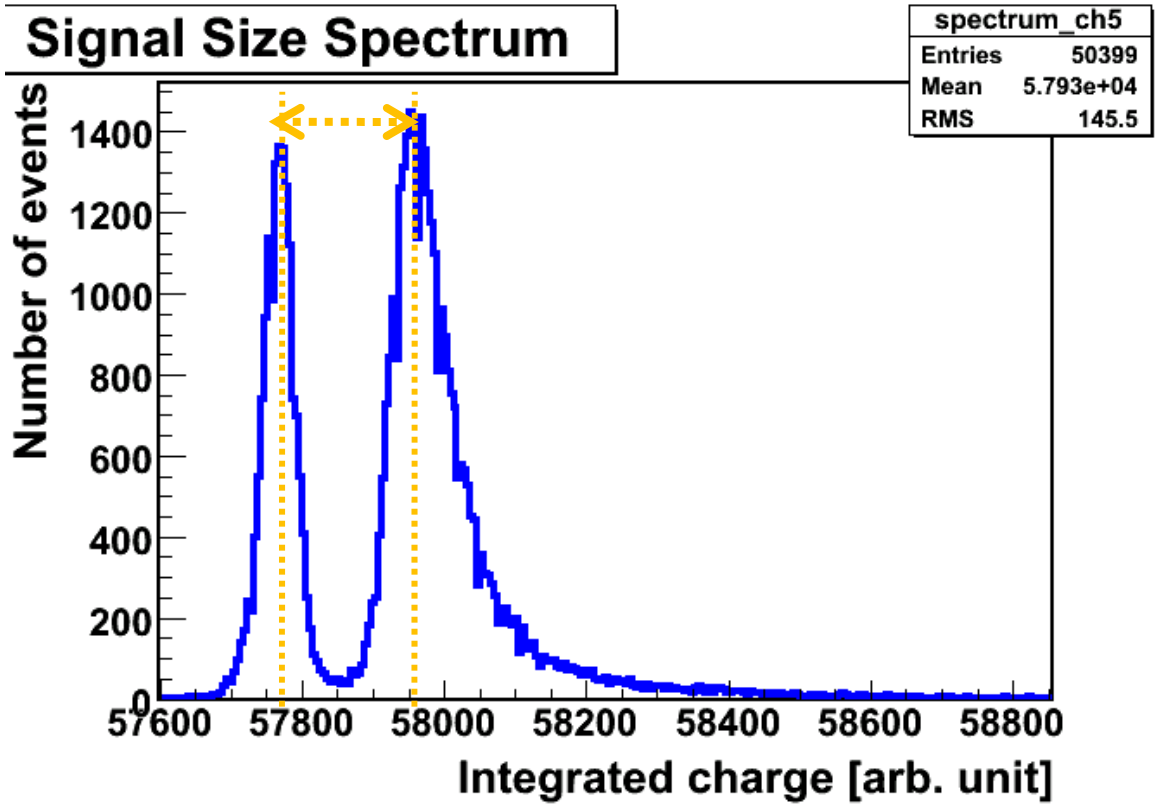
Charge Collection Efficiency (CCE)



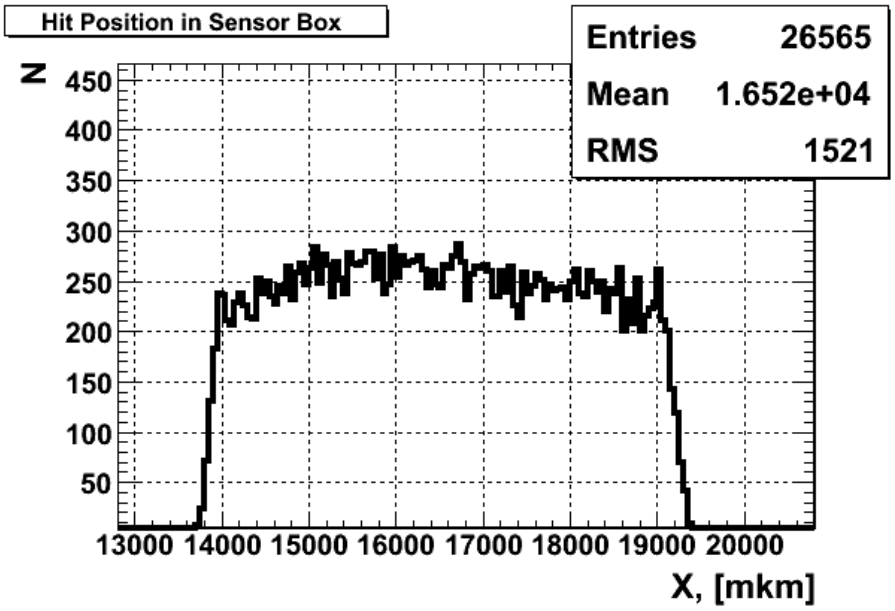
$$CCE = \frac{Q_{collected}}{Q_{induced}}$$

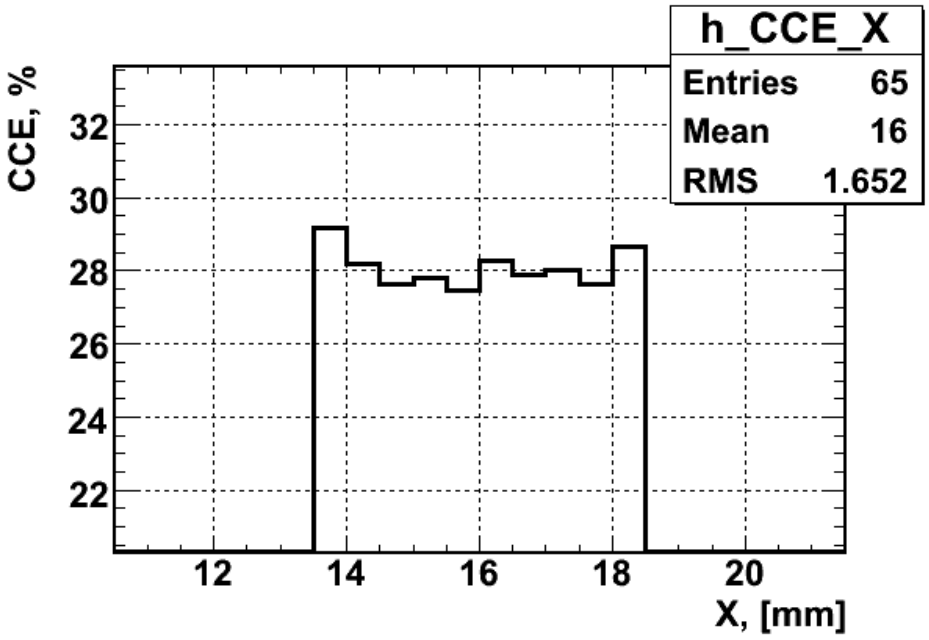
$$CCD = CCE\ d_{thikness}$$

CCE ~ 30%, HV 60V



CCE vs Position





> Number of hits as a function of reconstructed x position in sensor box.

> CCE as a function of reconstructed x position in sensor box.

Conclusions

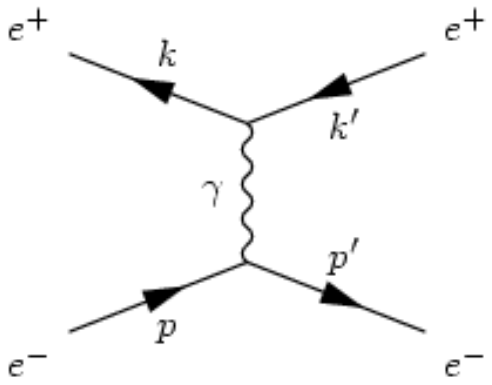
- In the summer 2010 a first measurement combining a sensor with a front-end ASIC was made on the TestBeam DESYII (Hamburg).
- The next step will be to add the ADC ASIC.
- After this will be successful, a prototype calorimeter will be the next step.
- Lab measurements continue for sensor investigations.
- Simulation and optimization work for BeamCal are on the way.

Back Up Slides

>Thank You for Your Attention!

How to measure Luminosity

> Bhabha scattering process



- N_B – number of selected events
- N_{bgr}– number of estimated background events
- ε - for acceptance and steering corrections
- σ_B – Bhabha scattering cross section

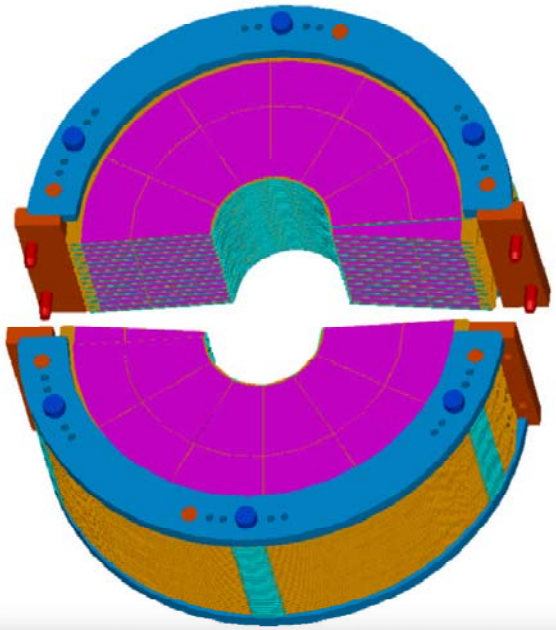
$$L = \frac{N_B - N_{bgr}}{\varepsilon \cdot \sigma_B}$$

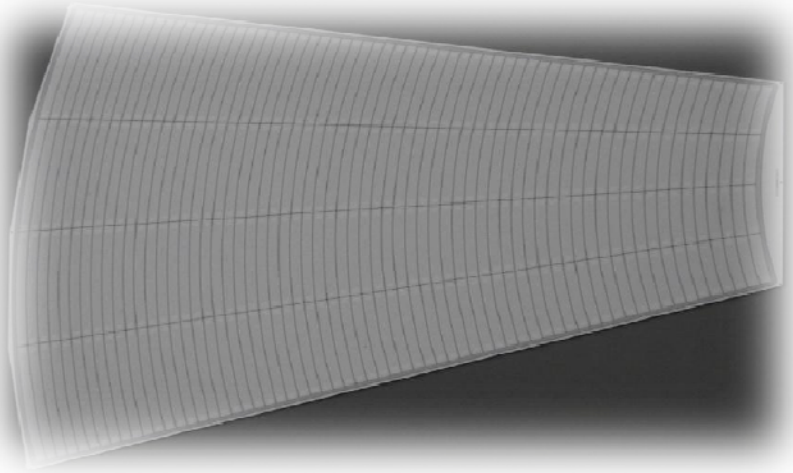
> Cross section is known from theory:

> Using LumiCal and BeamCal, we measure N_B to calculate Luminosity

> Luminosity is then used to calculate the cross sections of other processes

Luminosity Calorimeter





- 30 Layers
  - Tungsten absorber:
  - Sensor layer Si
- Outer radius 19.5 cm
- Inner radius 8 cm
- Prototype
  - High resistivity n-type Si 1,7mm p+ - strips with an Al-metallization
  - Backplane: n+ implant and an Al-metallization
  - 3 Guard rings
  - x-Size = 10,8cm
  - y-Size = 4…12cm

Abstract

- In future electron-positron colliders special calorimeters are needed at small polar angles for a precise and fast luminosity measurement. In addition, the hermeticity of the detector will be improved, particularly important to tag single high energy electrons. The latter will be a challenge, since a large amount of beamstrahlung electron-positron pairs will create widely spread depositions in the innermost calorimeter. Within the FCAL collaboration the technologies for these calorimeters are developed. A report is given on requirements from physics, Monte Carlo simulations to optimize the design, sensor studies and prototype component developments.