Performance study of a compact LumiCal prototype in an electron beam.

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on behalf of the FCAL collaboration

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Taras Shevchenko National University of Kiyv, Ukraine
Tel Aviv University, Tel Aviv, Israel
Tohoku University, Sendai, Japan
University of California, Santa Cruz, USA
Vinca Institute of Nuclear Sciences, University of Belgrade, Serbia

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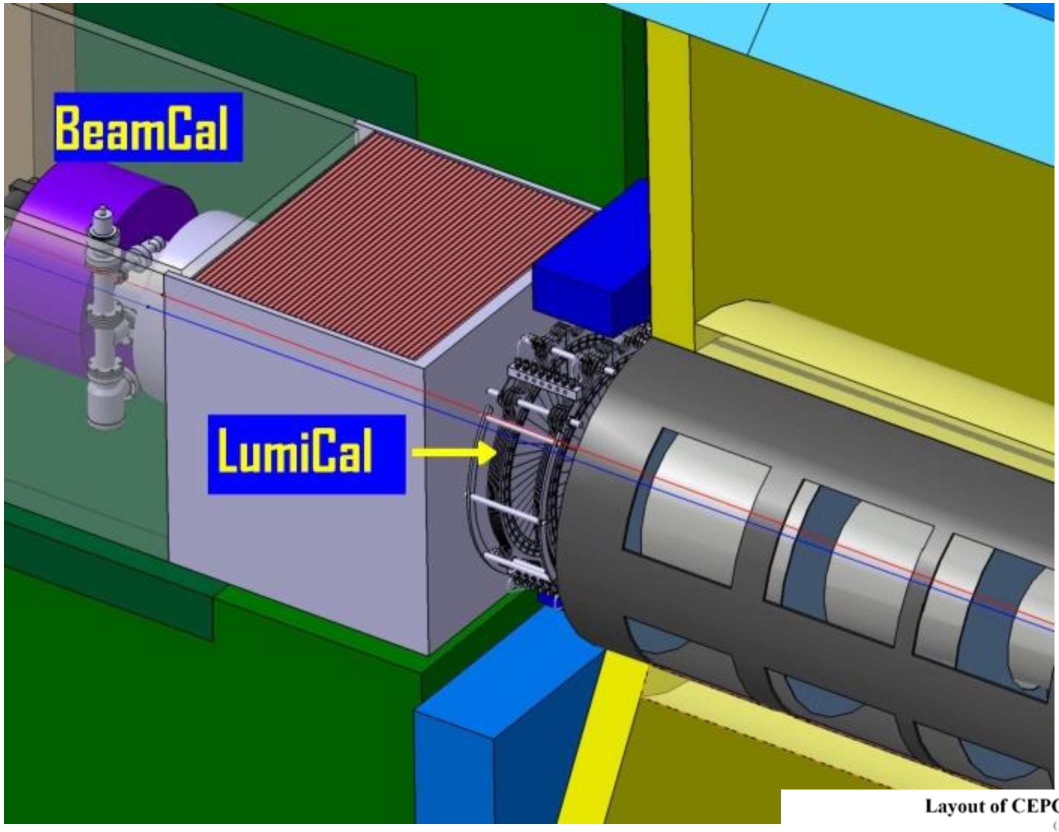
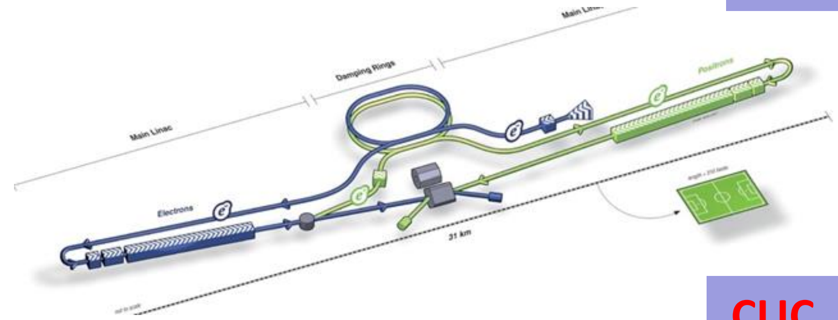
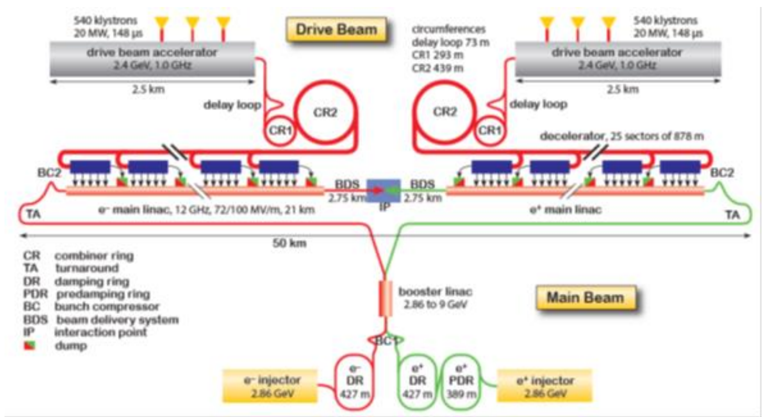
R&D for special calorimeters in the very forward region of future detectors at an e+e- collider.



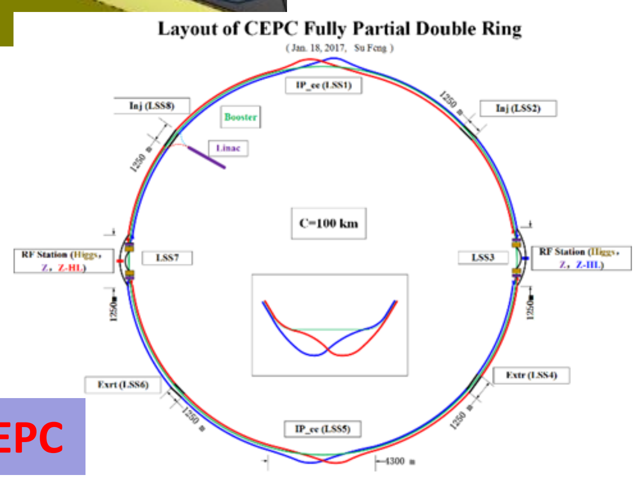
ILC



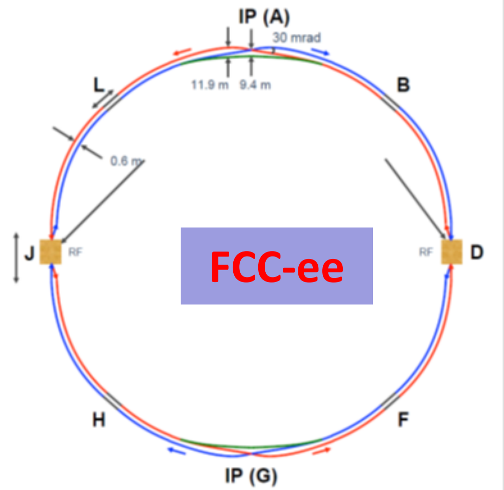
CLIC



- compact,
- precise shower position measurement
- read out very fast
- radiation hardness



CEPC



LumiCal and BeamCal in future e+e- accelerators

LumiCal provide:

- **precise determination of the integrated luminosity by measuring the rate of Bhabha events at low angles.**

BeamCal:

- **device for fast, bunch-by-bunch crossing luminosity using beamstrahlung. Radiation hardness is an issue.**

LumiCal and BeamCal:

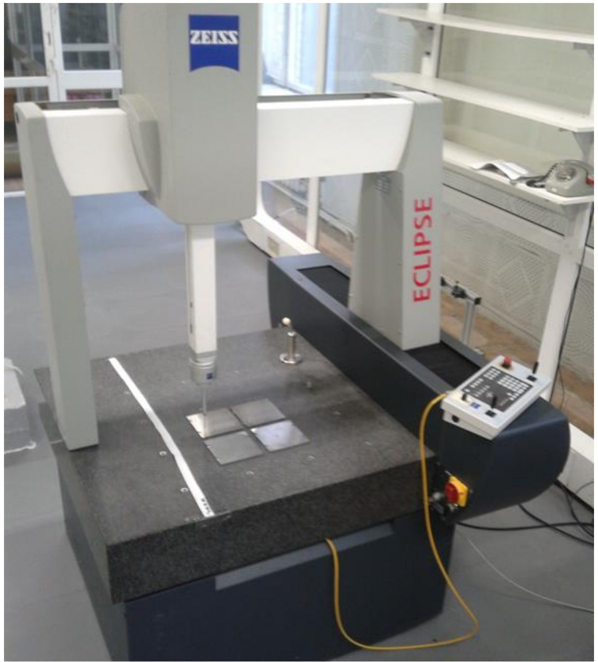
- **improving the hermeticity of the detector by providing electron and photon identification down to polar angles of a few mrad.**
- **to extend calorimetric coverage to small polar angles. Important for physics analysis.**

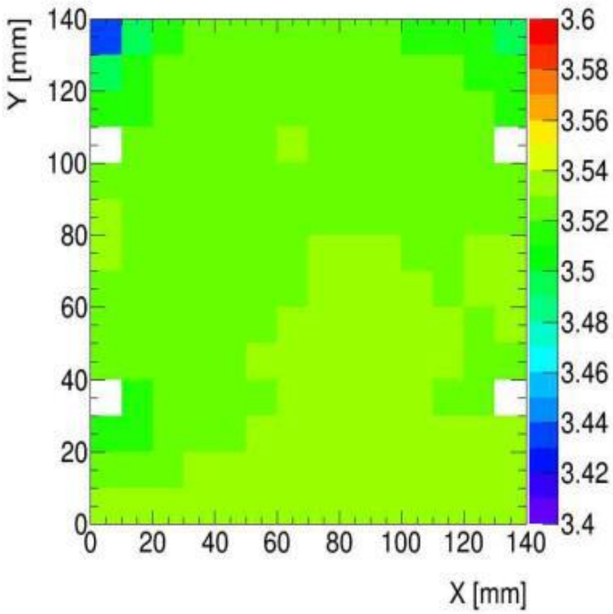
LumiCal and BeamCal – electromagnetic sampling calorimeters

- The technology of a Semiconductor-Tungsten sandwich calorimeter is under investigation:

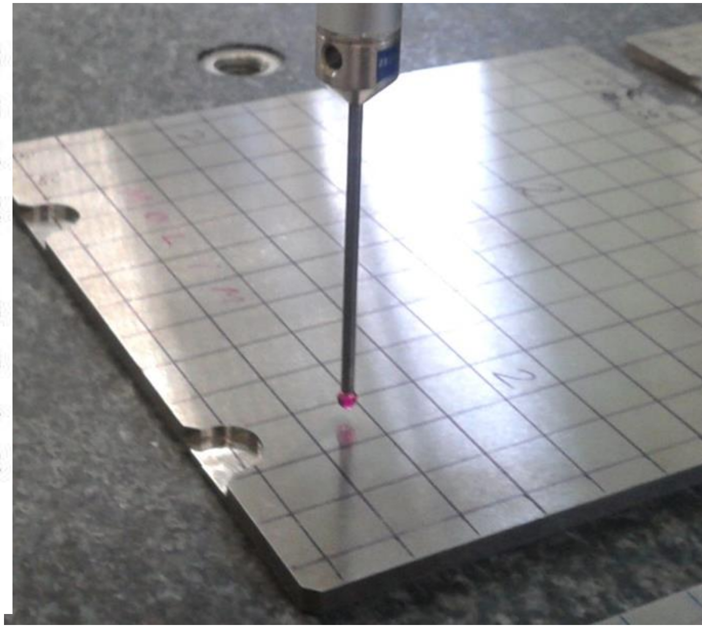
  Sensors for the LumiCal - Si; for the BeamCal GaAs or sapphire.
- layers of 140x140x3.5 mm (1 X_0) thick tungsten plates with 1 mm gap for silicon sensors (30 for ILC, 40 for CLIC)
- Good flatness ~30 μm were achieved

Zeiss 3D coordinate measurement system





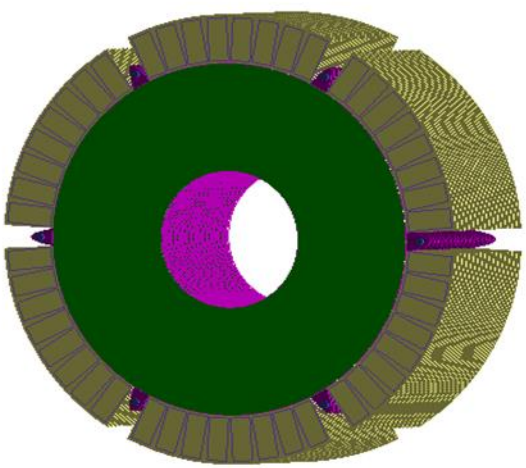
Precision 2.5 μm

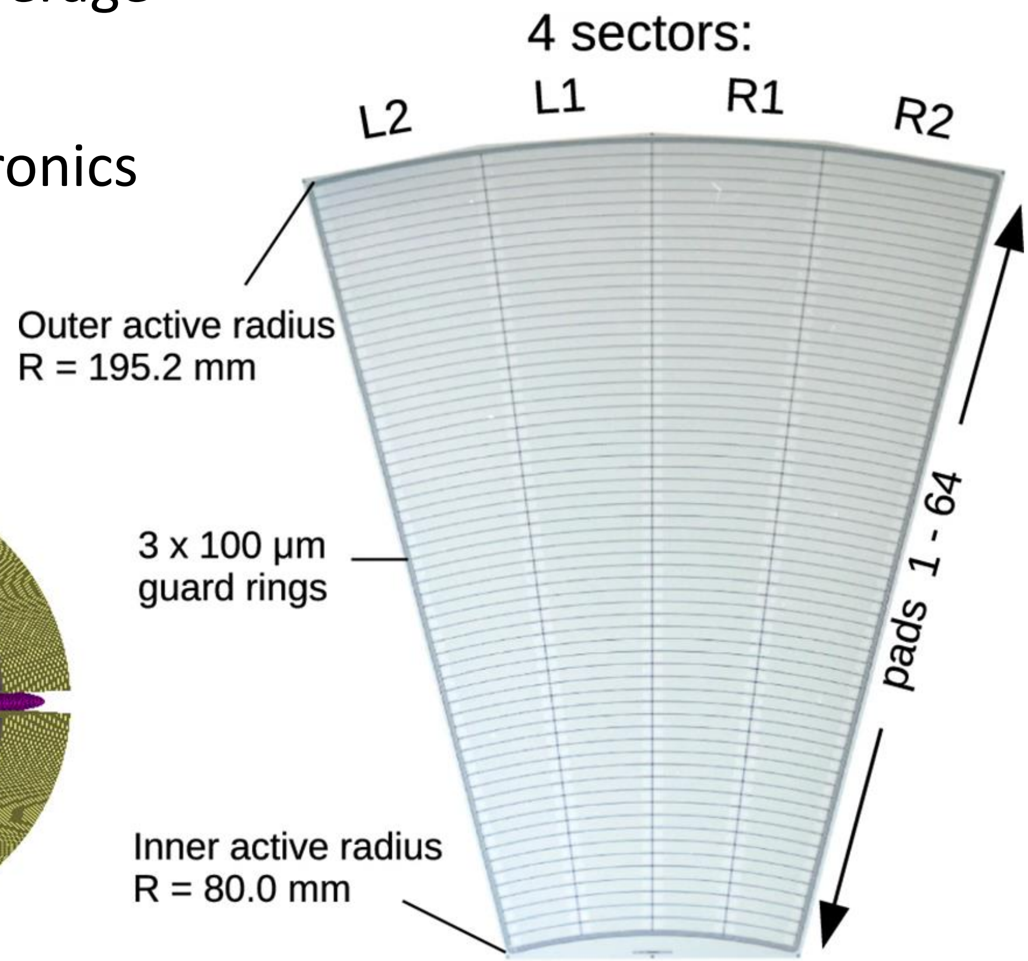


LumiCal sensor

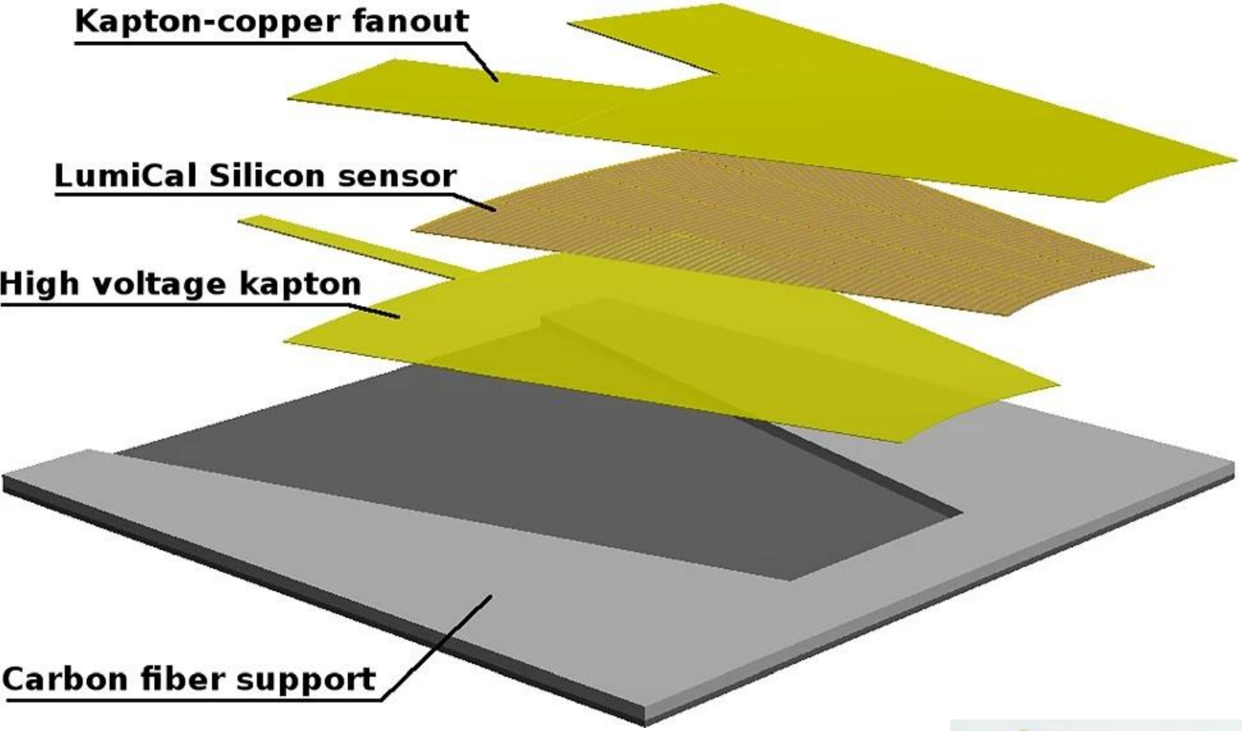
- Silicon sensor, 320 μm thickness
- 64 radial pads, pitch 1.8 mm
- 4 azimuthal sectors in one tile, each 7.5 degrees
- 12 tiles make full azimuthal coverage
- p+ implants in n-type bulk
- DC coupled with readout electronics
- 40 modules were produced

  by Hamamatsu



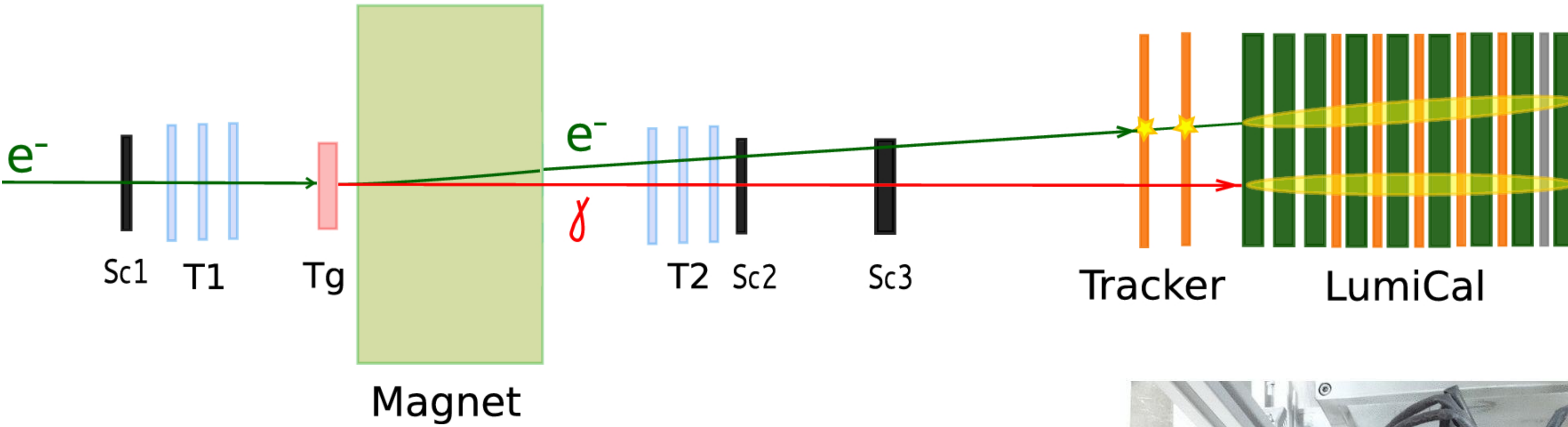


Detector plane assembly



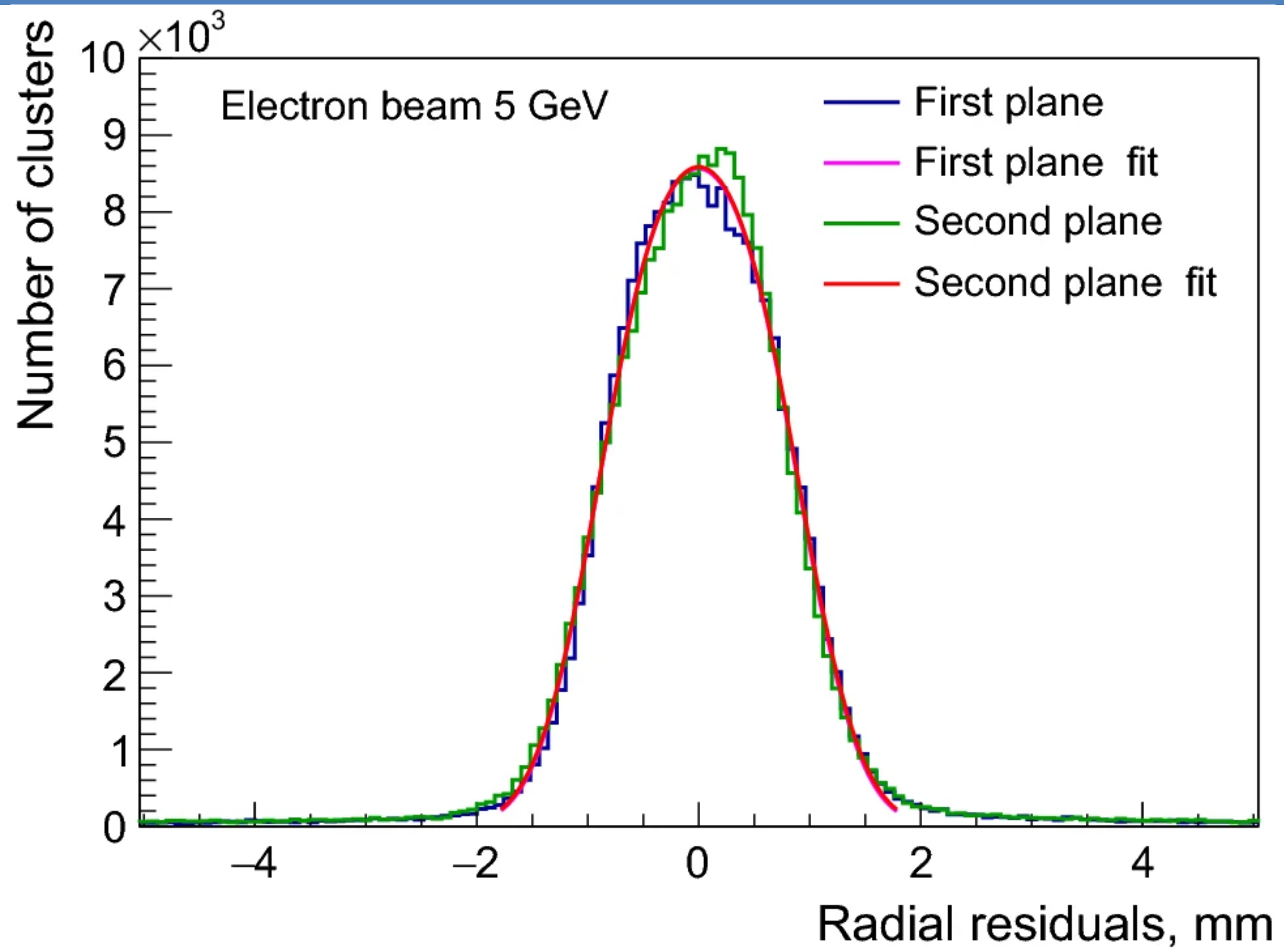
total thickness 650 μm

LumiCal test at DESY in 2016



- DESY-II Synchrotron electron beam 1-5 GeV (beam size 5x5 mm2)
- T1, T2 - Eudet telescopes each with 3 MIMOSA Si-pixel planes
- Sc1,2,3 - scintillator trigger
- Tg - copper target
- Dipole magnet –13 kGs for e/γ separation
- 8 detector planes (6 -LumiCal, 2-tracker), 256 read-out channels
- 8 W absorber plates
- External electronics (ASD-based)

Shower position measurement



Resolution of (440±20) μm is found

$$f(x) = \frac{B}{p\sigma\sqrt{2\pi}} \int_{x_0-\frac{p}{2}}^{x_0+\frac{p}{2}} e^{-\frac{(x-z)^2}{2\sigma^2}}\,\mathrm{d}z,$$

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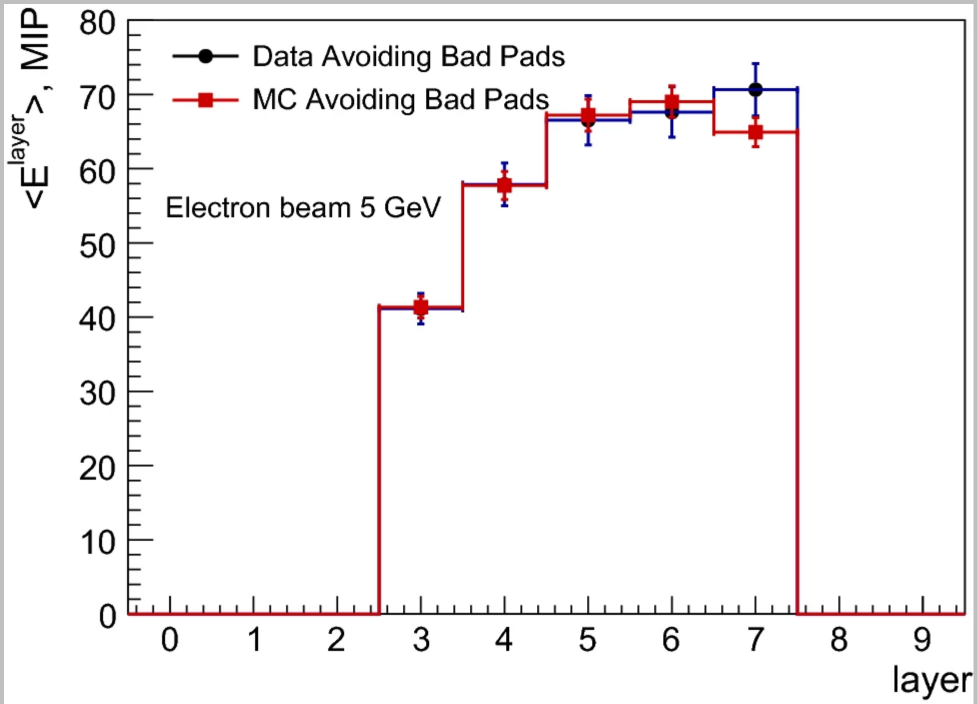
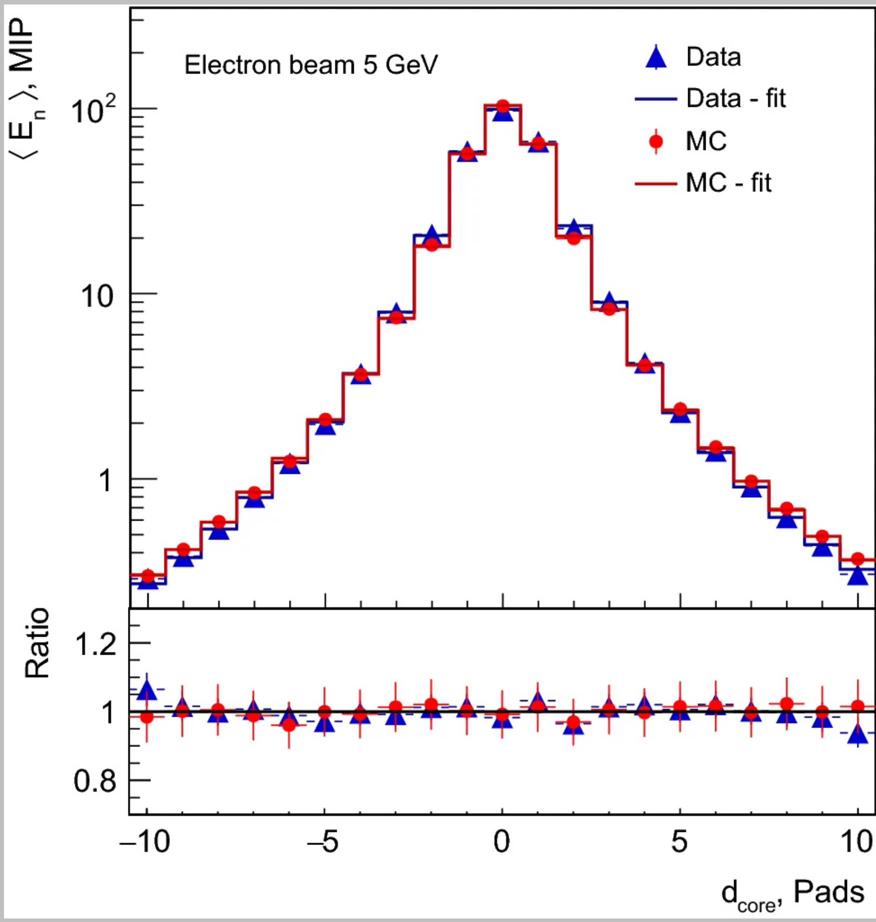
Shower development

Longitudinal



transverse

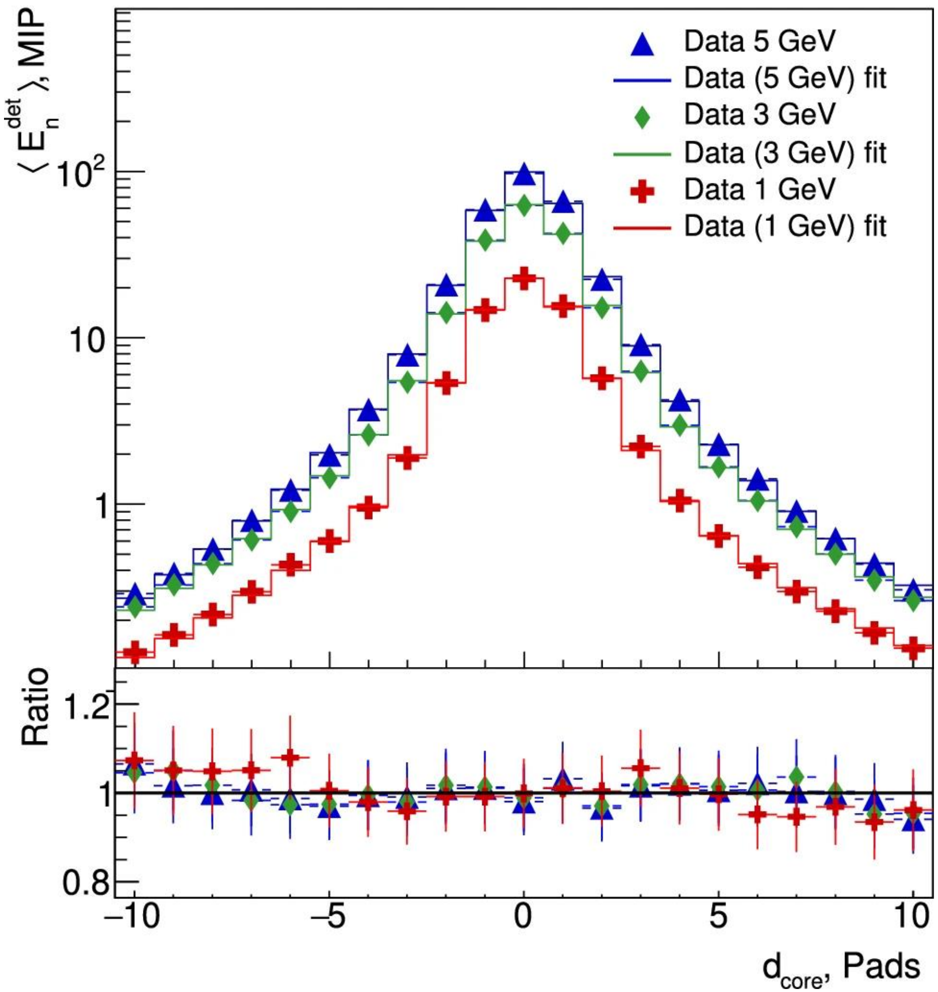


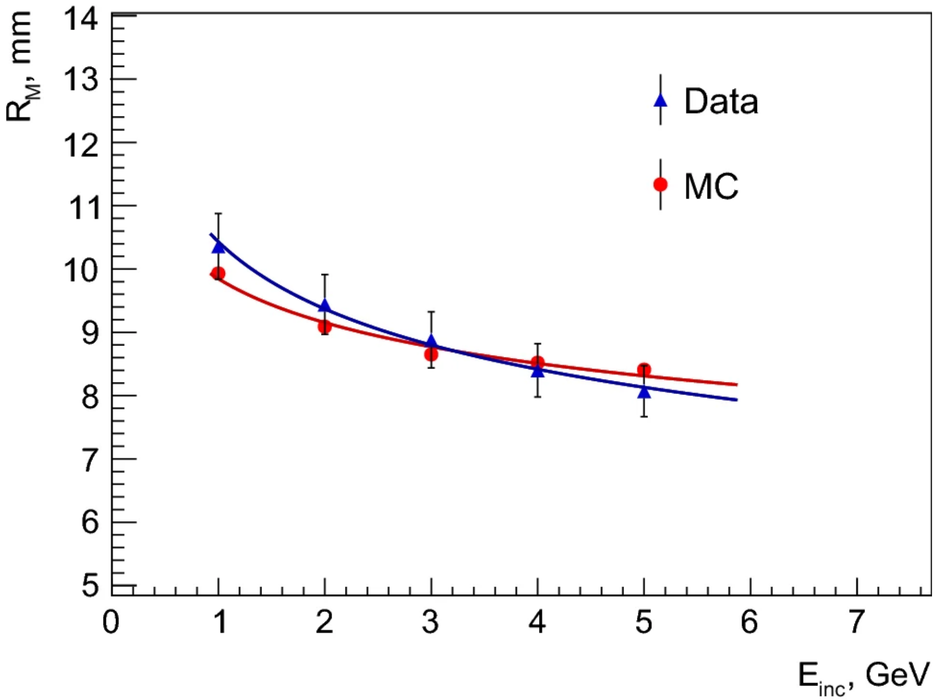
Good agreement between data and MC (within statistical uncertainties)

Effective Moliere radius :

8.1 ± 0.1 (stat) ± 0.3 (syst) mm

Shower profiles and effective Moliere radius



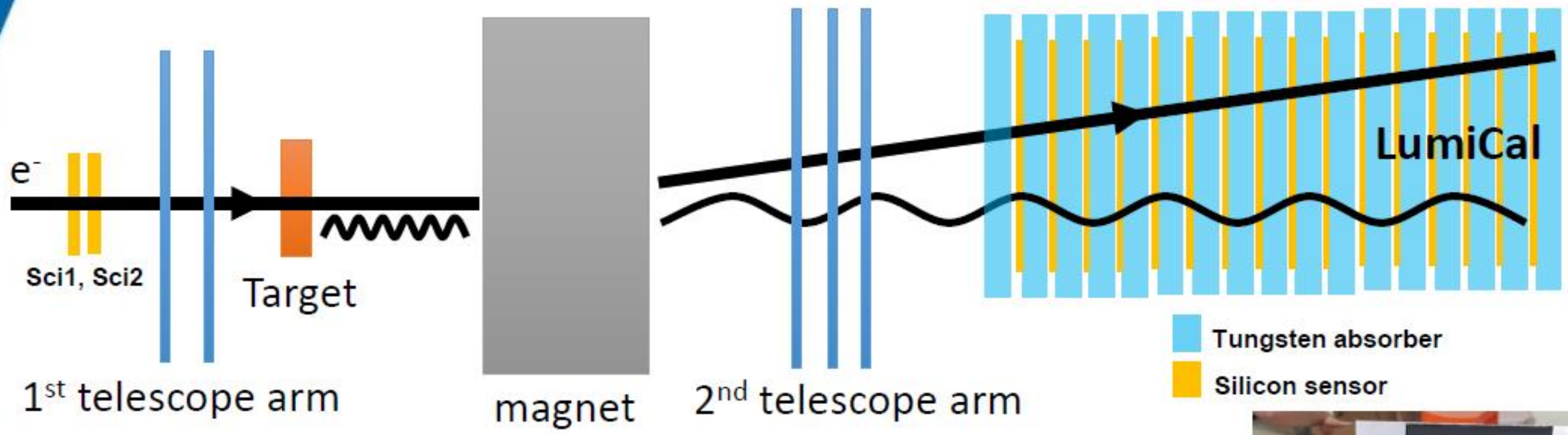


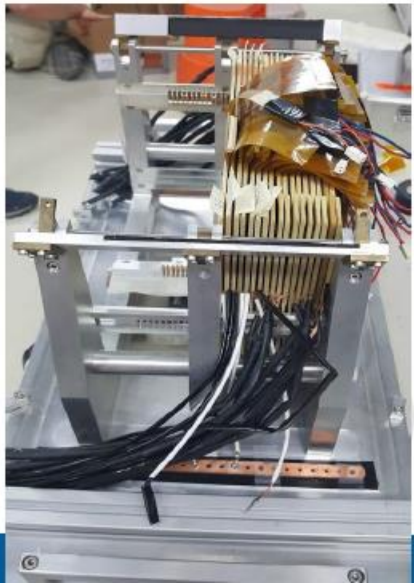
The Moliere radius is independent of the beam energy. Why we see an dependence is due to the limited fraction of the shower accessible in this analysis.

LumiCal test at DESY in 2019

Experimental set-up

- Test beam at DESY with 1 – 6 GeV electron beam
- ALPIDE telescope – 2 arms, 1st arm consists of 2 layers and 2nd arm consists of 3 layers;
- Target of tungsten with 90μm thickness;
- **Lumical** calorimeter consists of 16 Si sensors with one absorber layer placed in front of each active sensor layer;





Experimental set-up

The ALPIDE chip measures 15x30 mm and includes a matrix of 512x1024 pixel cells

LumiCal plane consist of 256 pads, during the test beam only 128pads were read-out using an APV-25 board

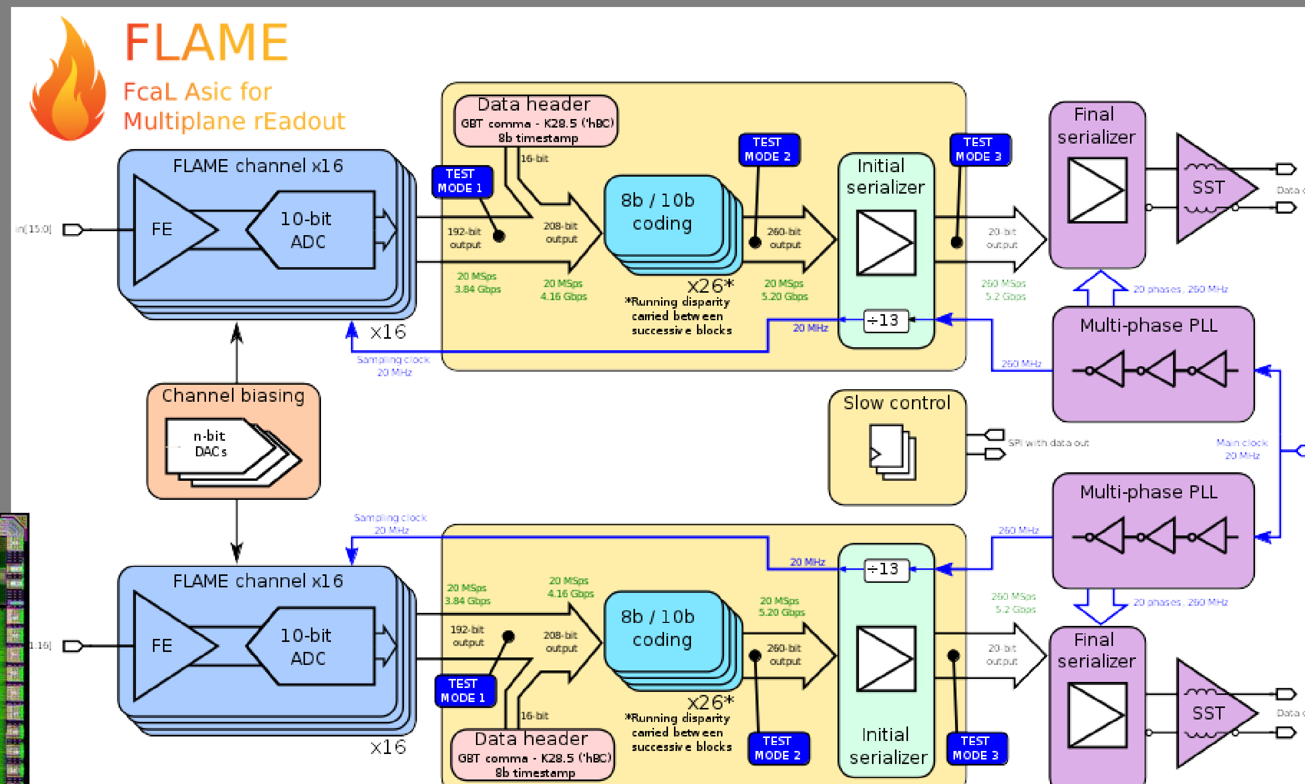
3 million events acquired in LumiCal

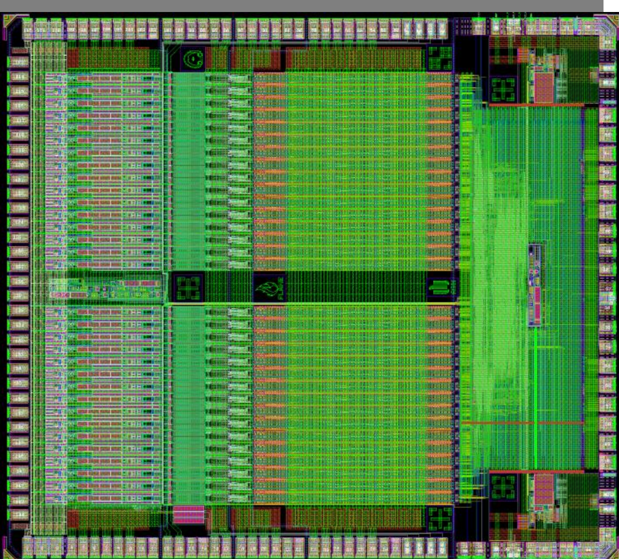
Work is ongoing on analysing November 2019 test beam data

New readout FLAME

JINST 10 (2015) P11012
JINST 10 (2015) P12015

FLAME: project of 32-channel readout ASIC in CMOS 130nm, front-end&ADC in each channel, fast serialization and data transmission, all functionalities in a single ASIC





Chip and front end board produced.
Will equip the 2020 test beam.

Conclusion

- A prototype of a compact calorimeter is studied in electron beams.
- The measurement of the longitudinal and transverse shower size is in very good agreement with simulations.
- The effective Moliere radius is obtained to be 8.1 ± 0.1 (stat) ± 0.3 (syst) mm and the resolution of the shower position reconstruction (440±20) μm.
- This is indeed a 'highly compact' calorimeter, with the Moliere radius at the feasible limit.

- March 2020:

  LumiCal test beam with 20 assembled layers

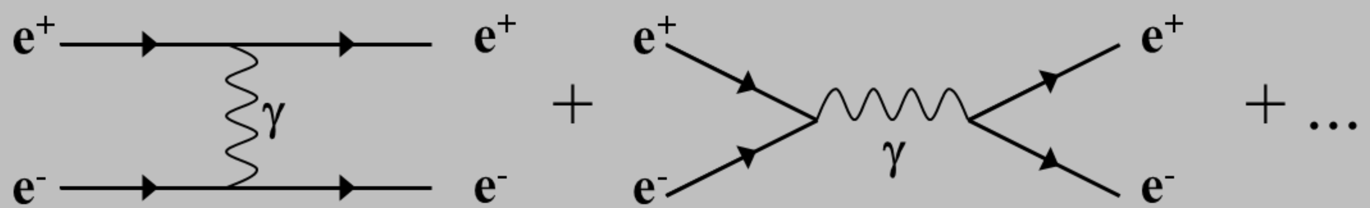
  Close to final front end electronics + readout and DAQ, based on FPGA.

Backup

Luminosity at e^+e^- collider

Bhabha scattering at low polar angles is used

$$e^+e^- \longrightarrow e^+e^- (\gamma)$$



$$\mathcal{L} = N / \sigma$$

Count Bhabha events

From theory

$$\frac{d\sigma_B}{d\theta} = \frac{2\pi\alpha_{em}^2}{s}\frac{\sin\theta}{\sin^4(\theta/2)} \approx \frac{32\pi\alpha_{em}^2}{s}\frac{1}{\theta^3}$$

$$\left(\frac{\Delta L}{L}\right)_{rec} \approx 2\frac{\Delta\theta}{\theta_{min}}.$$