Novel Approach for Measuring ISR Photons at BESIII

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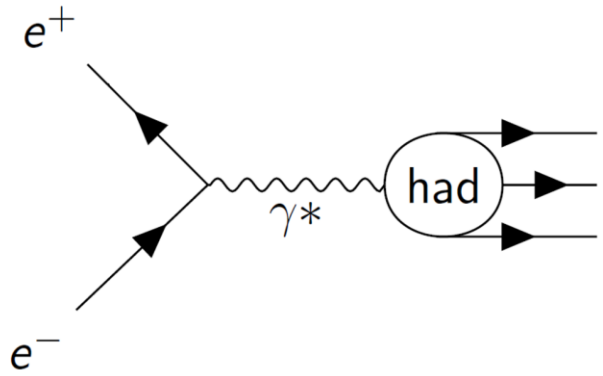
Meson 2026
18th International Workshop on Meson Physics

26.06.2026, Kraków Poland

Measuring Hadronic Cross-Sections at e^-e^+ - colliders

Energy Scans

- Measure at different beam energies
- Recalibration when changing beam parameters
- Range of energies depend on accelerator



Measuring Hadronic Cross-Sections at e^+e^- - colliders

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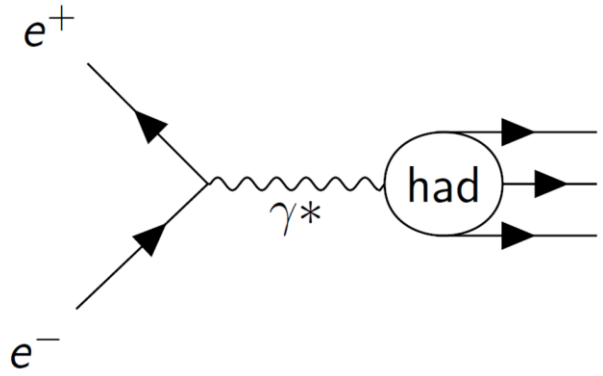
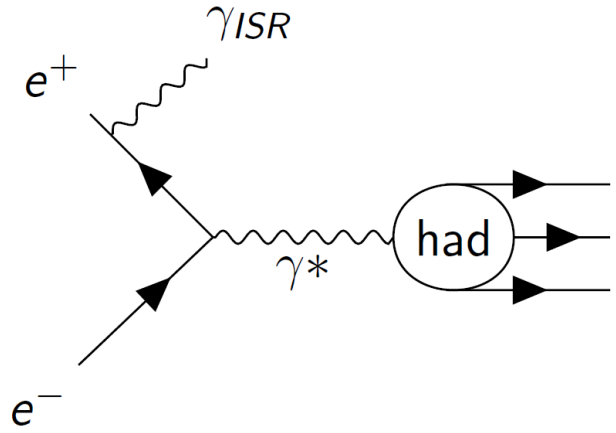
Initial State Radiation (ISR)

- ISR photon reduces effective center of mass energy
- Cover energy range: $2m_\pi < \sqrt{s'} < \sqrt{s}$
- Collect high statistics data set at one beam energy





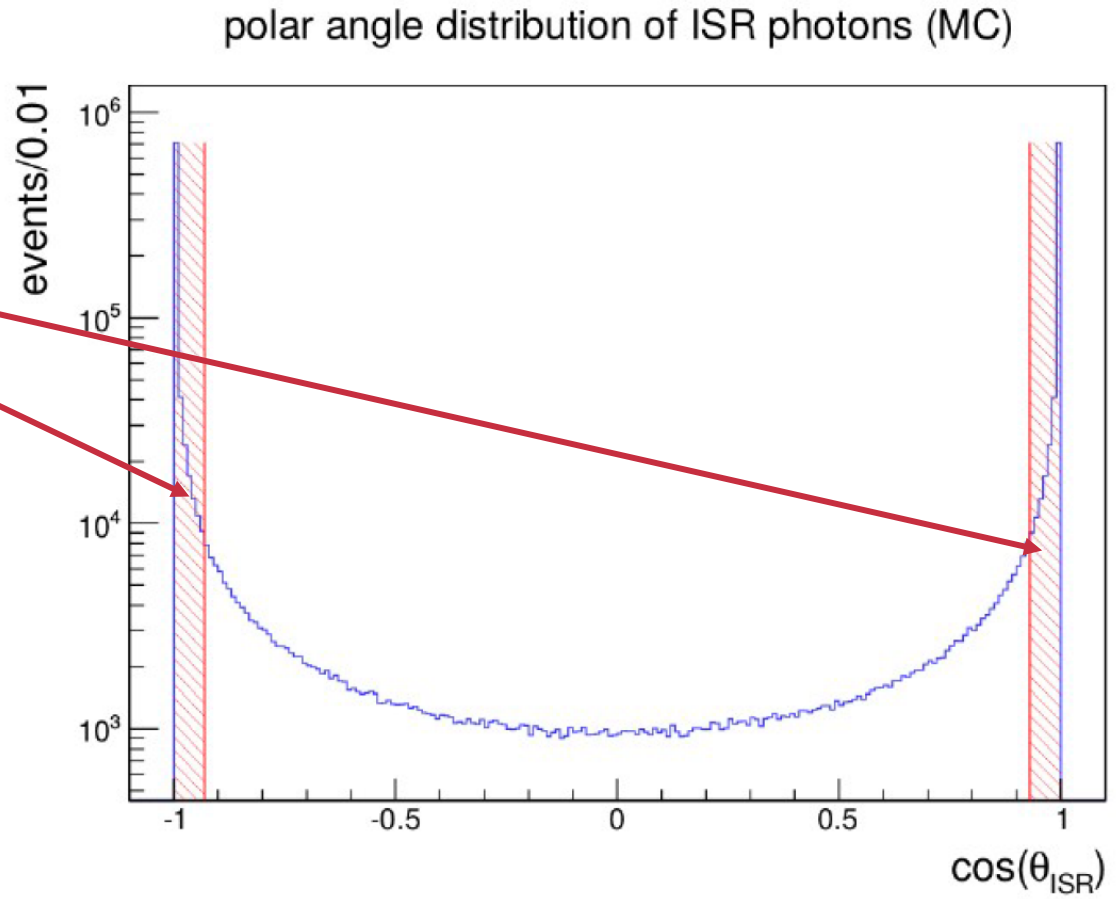
Initial State Radiation - Methods

Most ISR photons emitted at small angles

➔ Outside of typical detector acceptance

ISR Methods:

- Reconstruct photon from $E - \vec{p}$ conservation (untagged)
- Measure photon directly in EMC (tagged)



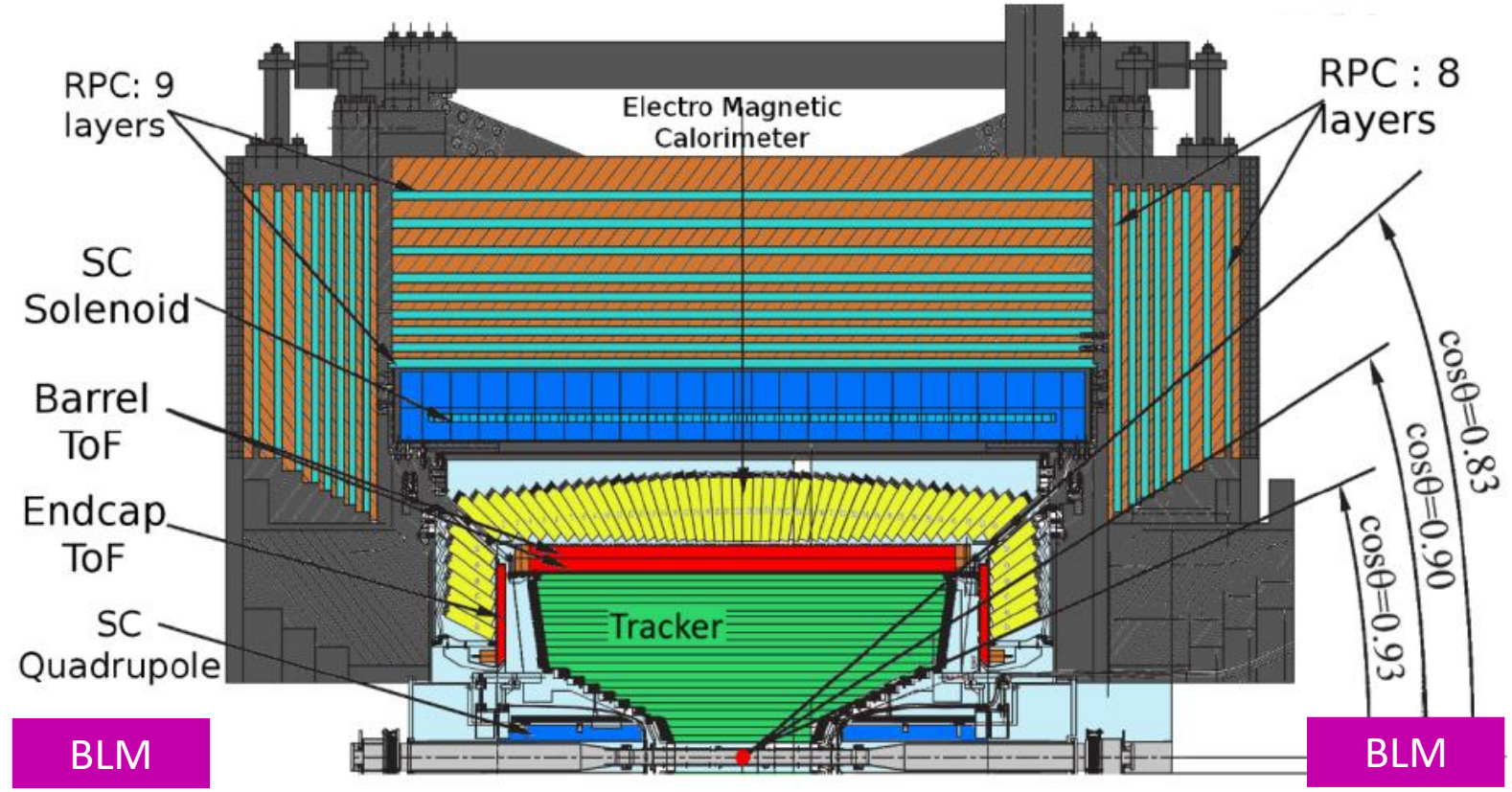
BEPCII – Beijing Electron-Positron Collider

- Design luminosity of 1.0×10^{33} $cm^{-2}s^{-1}$
- Center-of-mass-energy of 1.8 – 5.0 GeV

BESIII – Beijing Spectrometer III

- Design luminosity of 1.0×10^{33} cm^{-2}s^{-1}
- Center-of-mass-energy of 1.8 – 5.0 GeV
- Polar angle acceptance up to $|\cos(\theta)| < 0.93 \Rightarrow 21°$

➔Most ISR photons are lost



Muon Chambers

Superconducting Solenoid

Electromagnetic Calorimeter

Time-of-Flight System

Tracker

NIM A614 (2010) 345

BESIII – Beijing Spectrometer III

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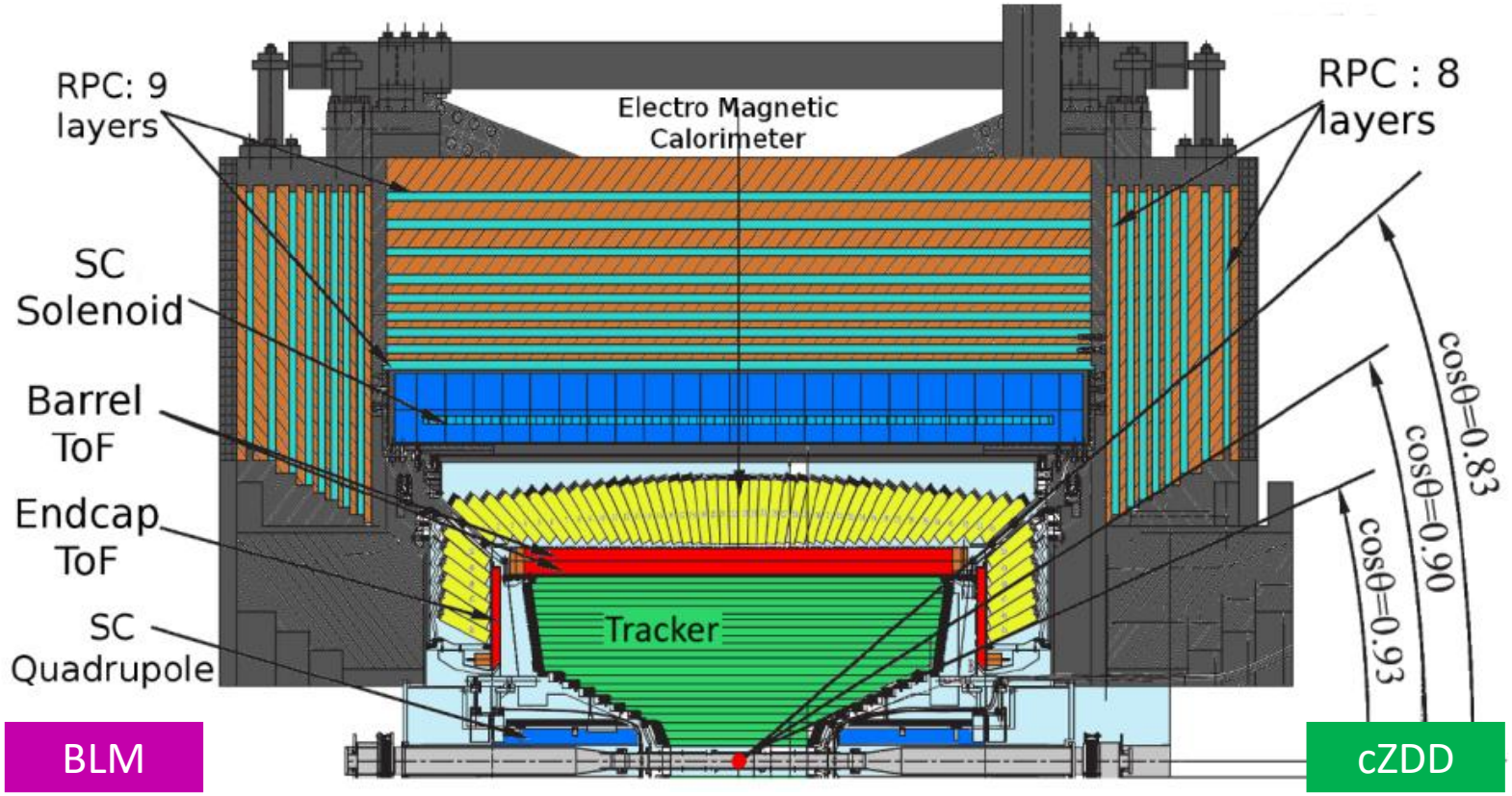
➔Most ISR photons are lost

➔Place crystal Zero Degree Detector (cZDD) at small angles



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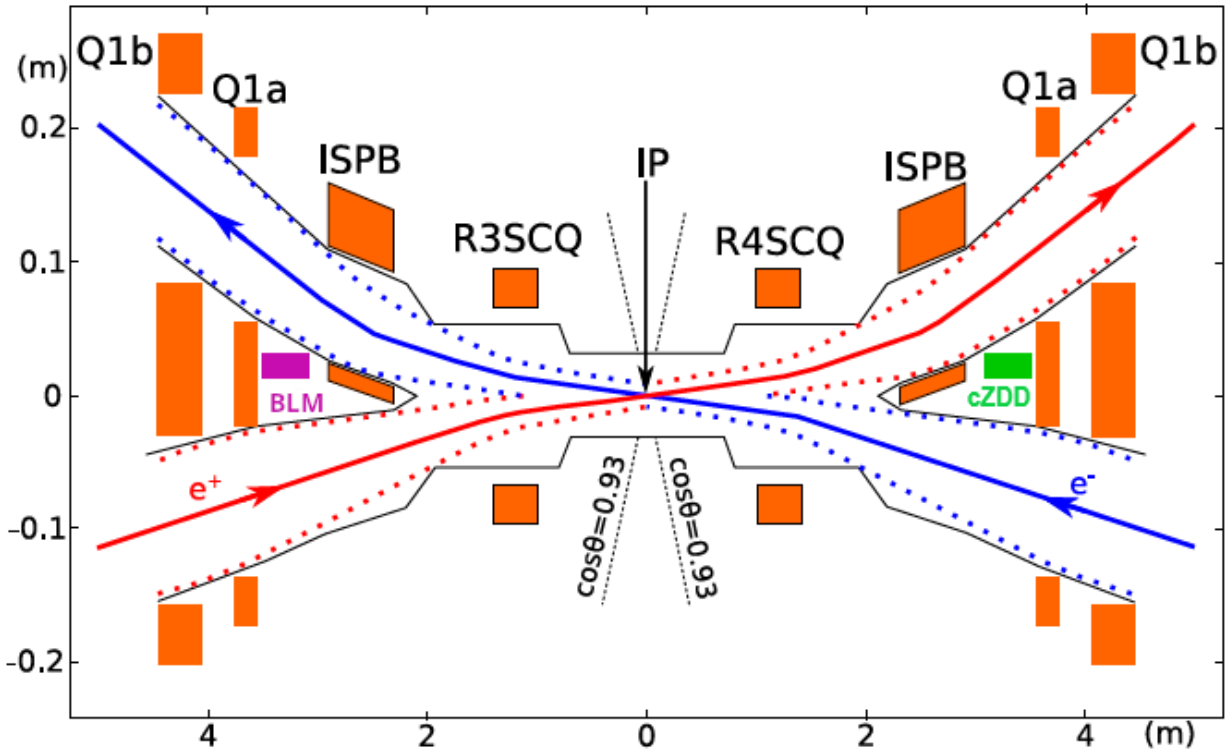
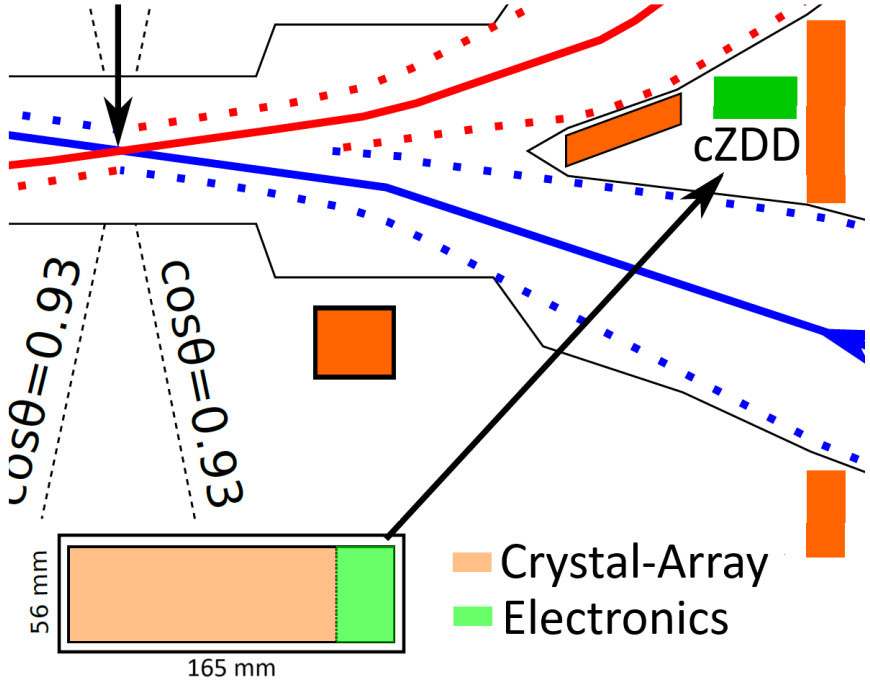
Location of cZDD



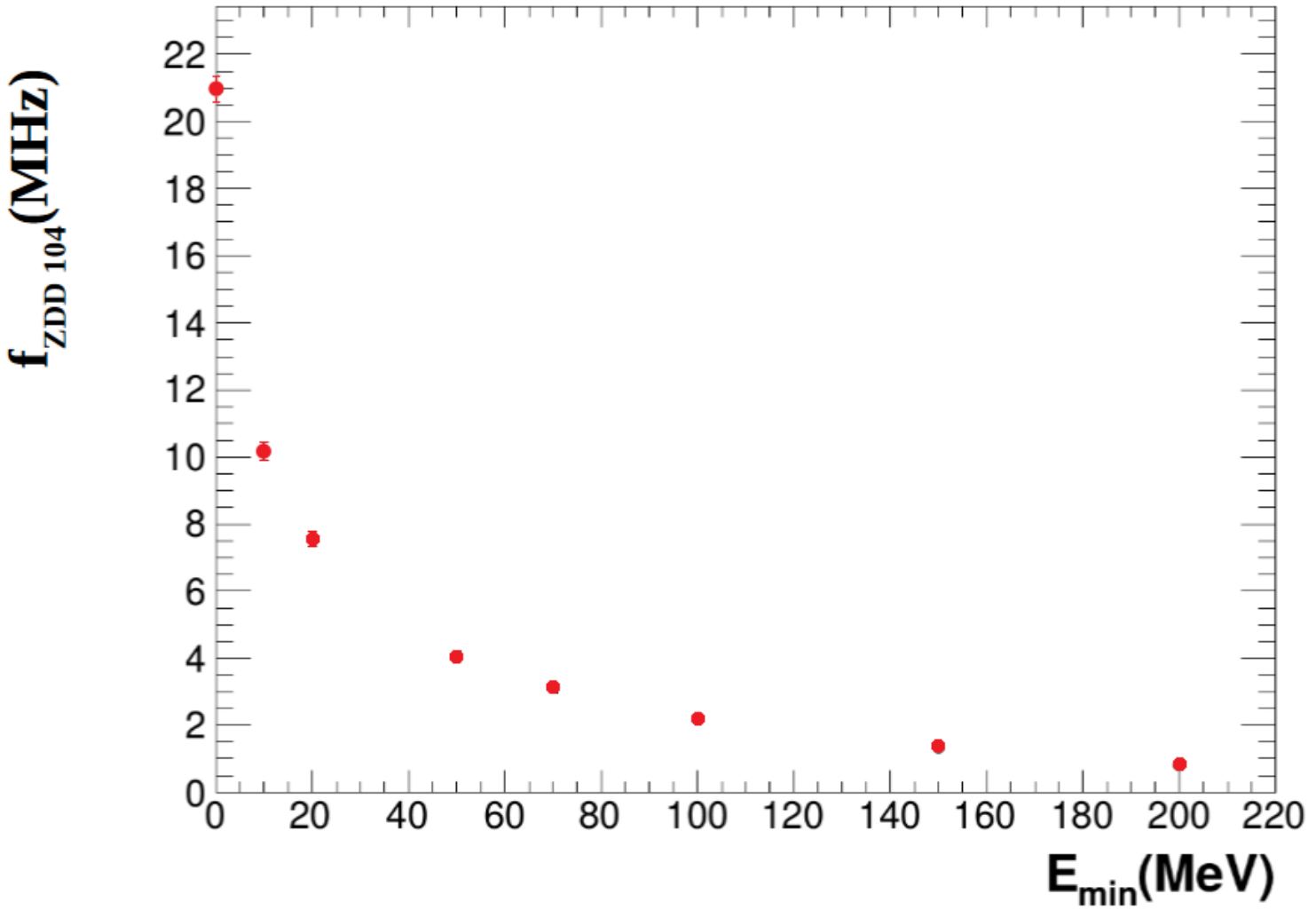


Challenges:

- Constrained space between beam pipes
- High background rates

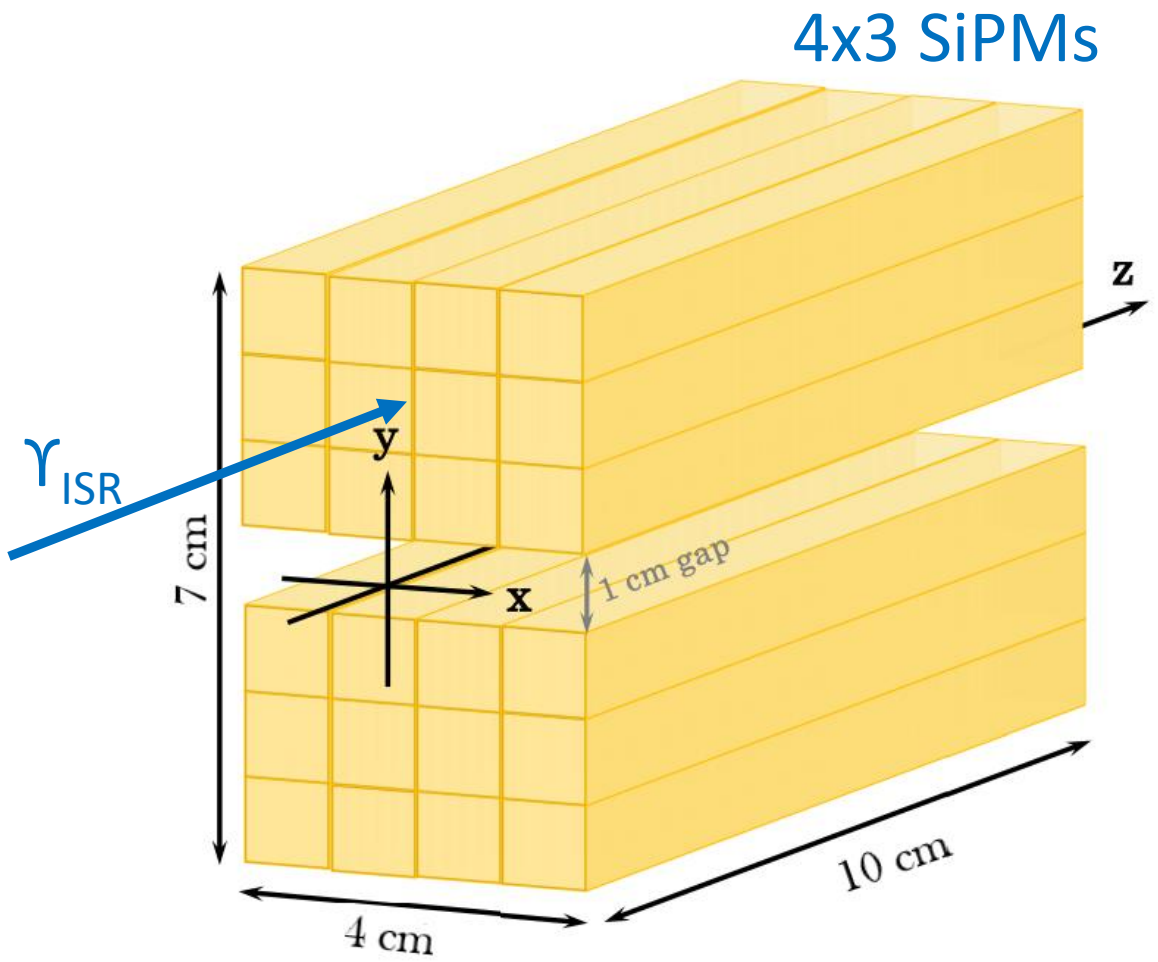
cZDD as Luminosity Monitor

- Correctly reconstruct low rate, high energy ISR photons over background
- Measure precise relative beam luminosity by detecting background spectrum



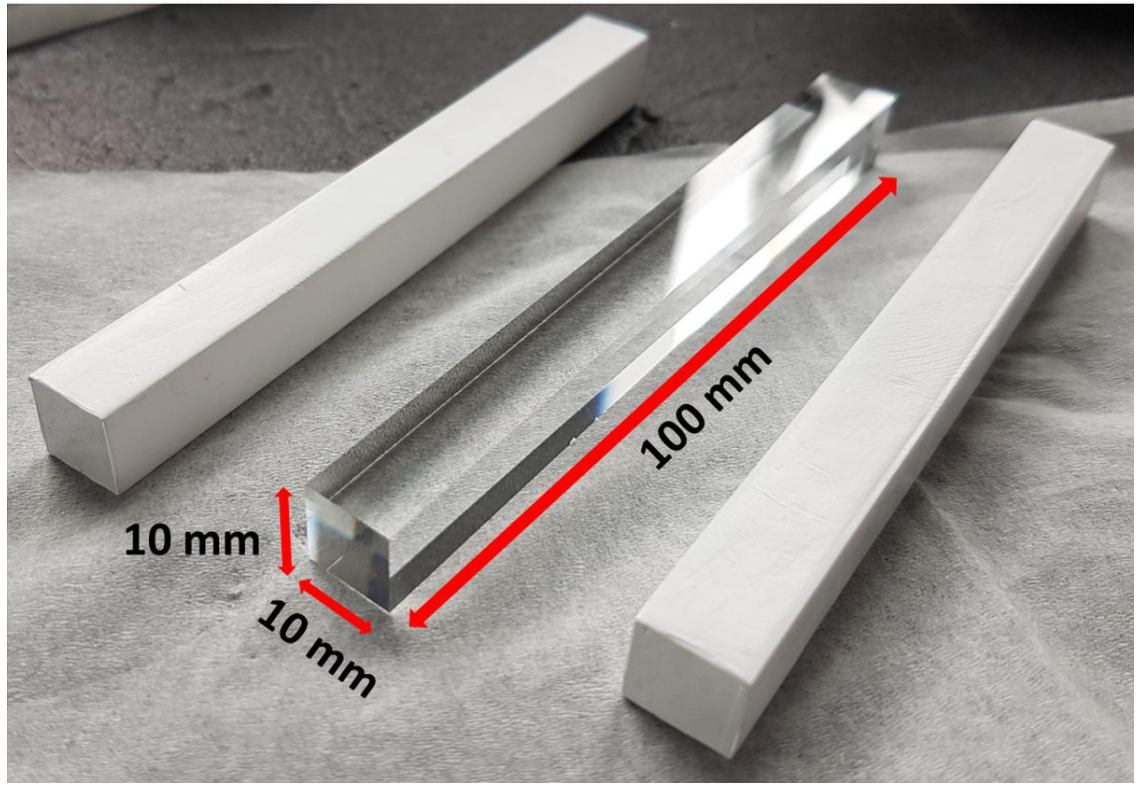
crystal Zero Degree Detector (cZDD)

- Two arrays of 4x3 crystals with polar angle acceptance of $0.1° < \theta < 0.7°$
- 1 cm gap due to Bremsstrahlung at small angles
- SiPMs collect light output
- cZDD signal sent to luminosity module and ISR online feature extraction module



Lutetium-yttrium oxyorthosilicate (LYSO) Crystals

- High density (≈ 7.2 g/cm^2)
- Molière radius (≈ 2.1 cm)
- Fast decay time (≈ 42 ns)
- Radiation hardness ($> 10^8$ rad)
- Maximal emission wavelength of 420 nm
- High light output

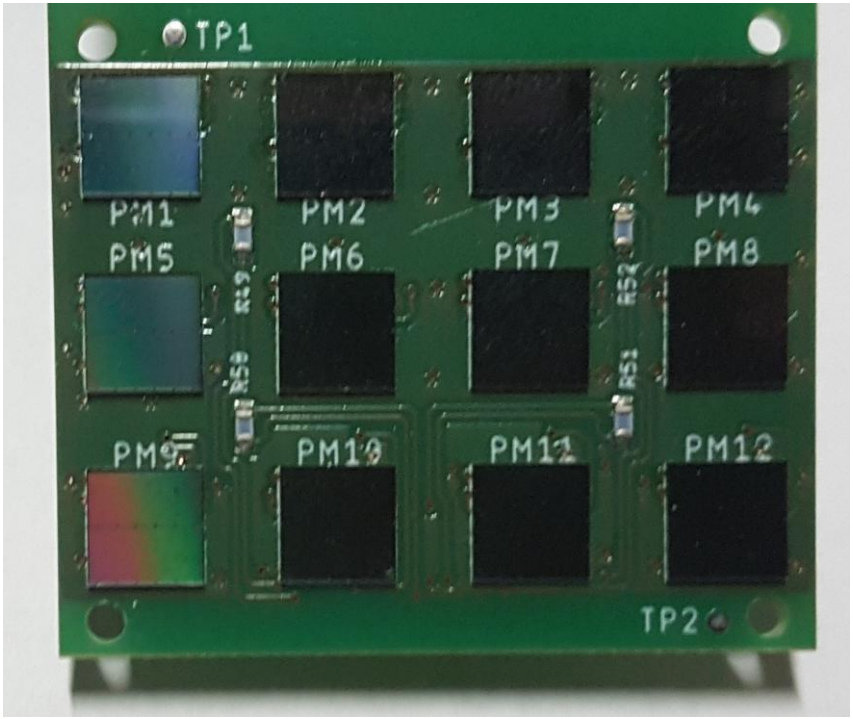


Epic-Crystal, "LYSO(ce)", http://www.epic-crystal.com/oxide-scintillators/lyso-ce-scintillator.html, 27.08.2021

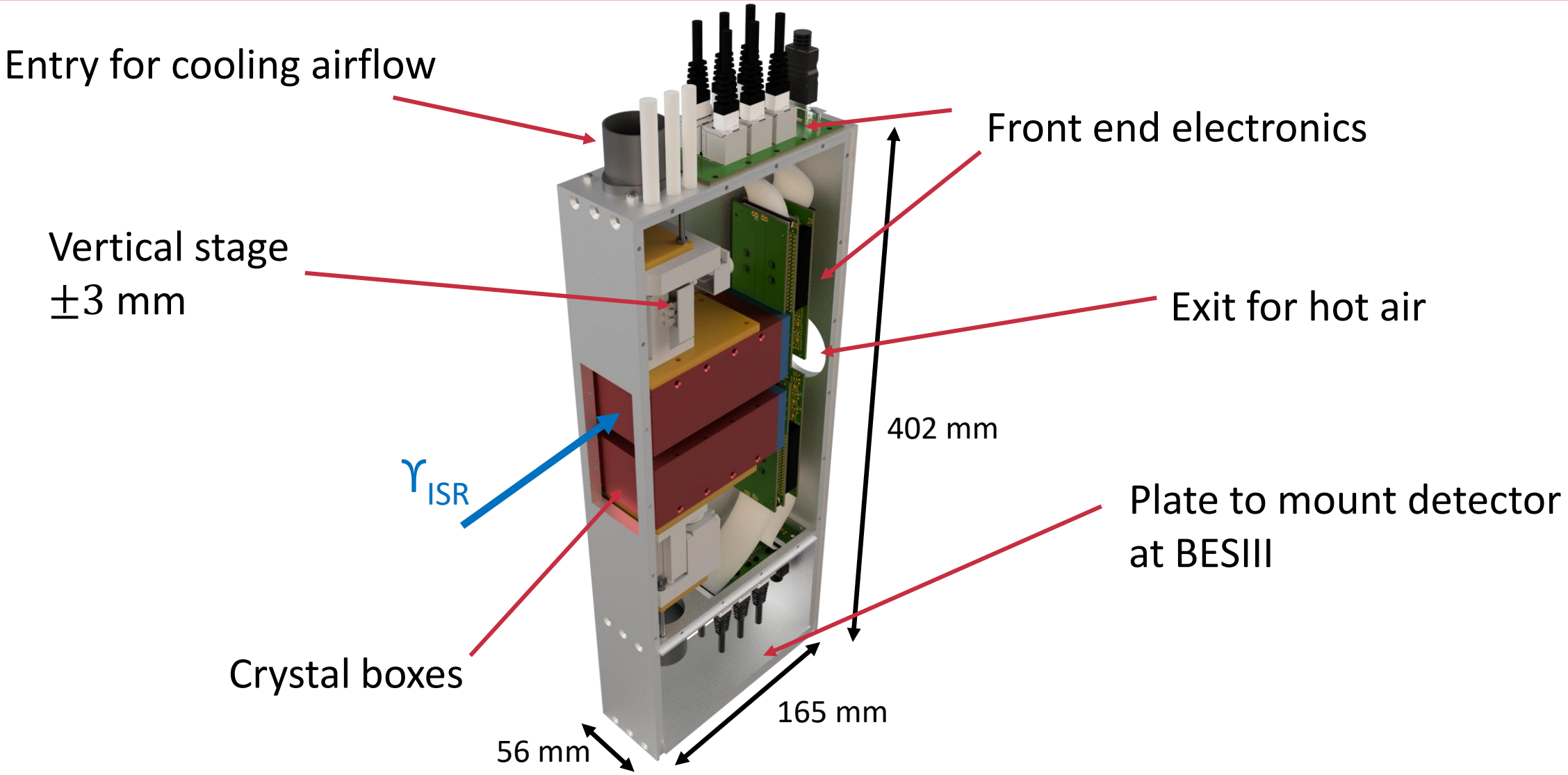
J-Series Silicon Photomultiplier

- Onsemi J-Series 60035
- Photon Detection Efficiency > 50 % at 420 nm
- RC charging time constant of 50 ns
- Total of 22,292 pixels on active area of (6 x 6) mm^2
- Dark count rate temperature dependent (~ MHz)

SensL, "J-Series: High PDE and Timing Resolution, TSV Package Datasheet"

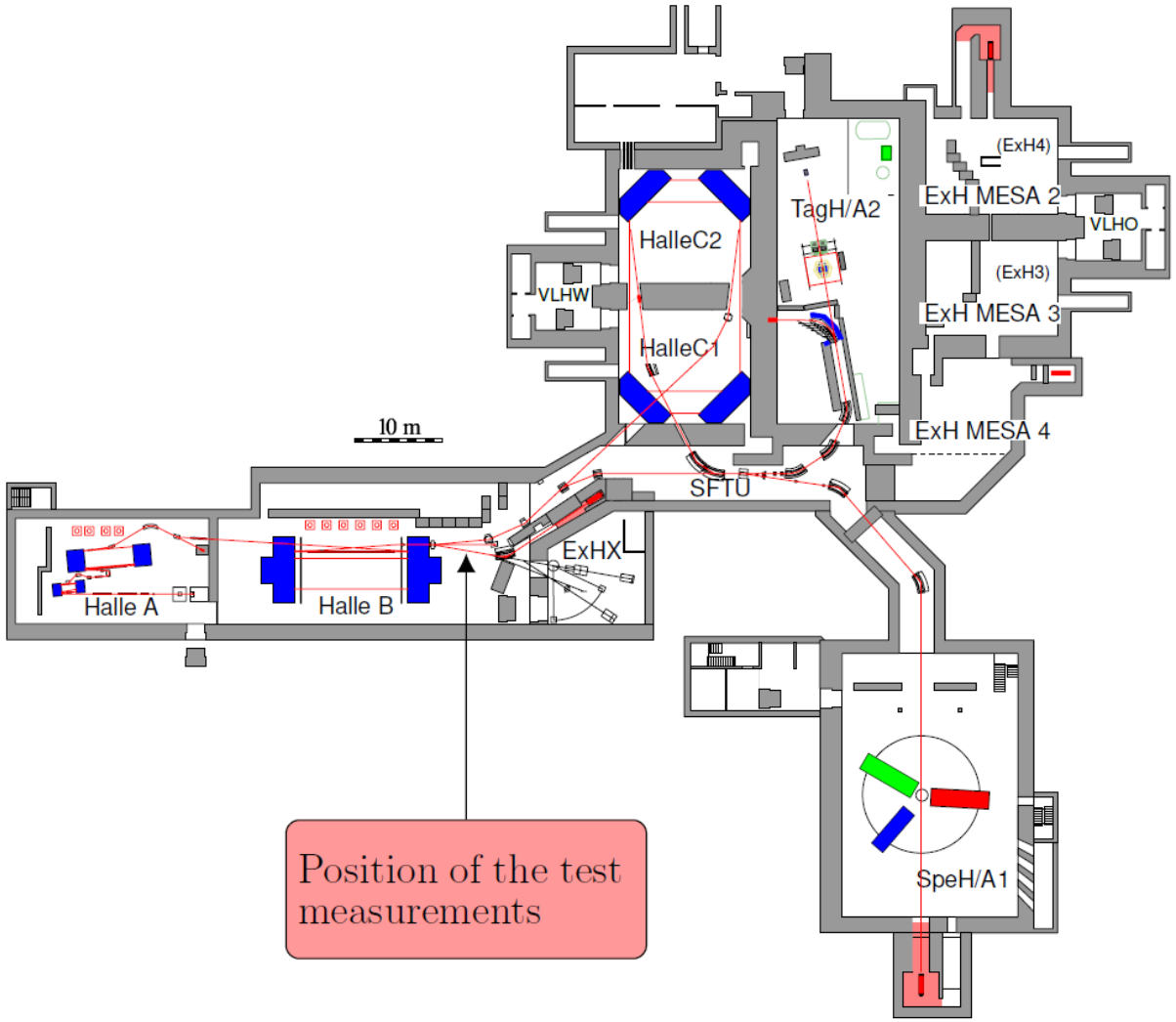


cZDD Mounting

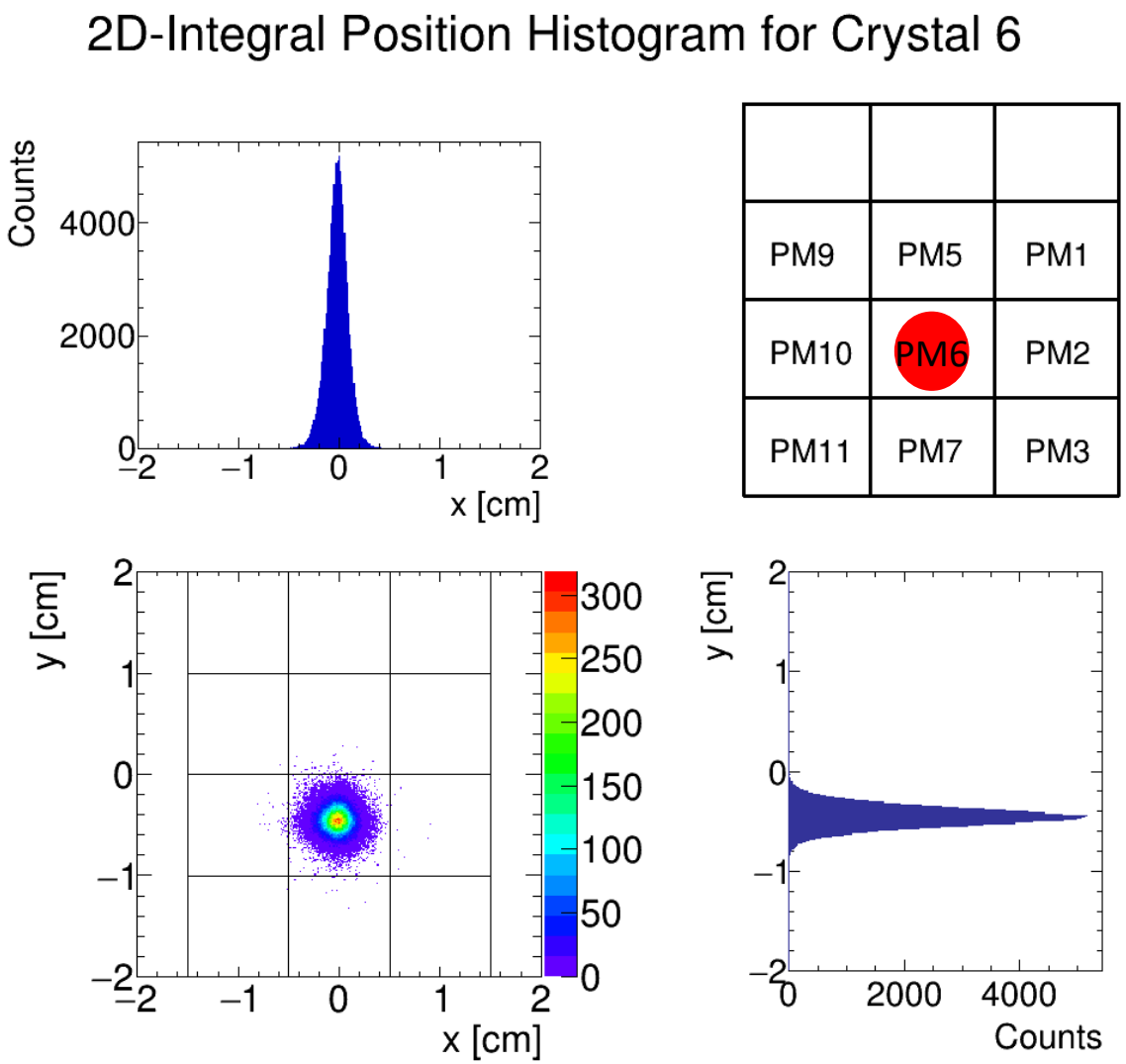


Testbeam at Mainz Mictroctron (MAMI)

- Electron beam energy of
  - ≈ 180 MeV to 855 MeV at RTM3
  - ≈ up to 1.6 GeV at HDSM
- Maximal cw current of ≈ 100 µA
- Small beam with high intensity



MAMI Testbeam – Position and Energy Resolution



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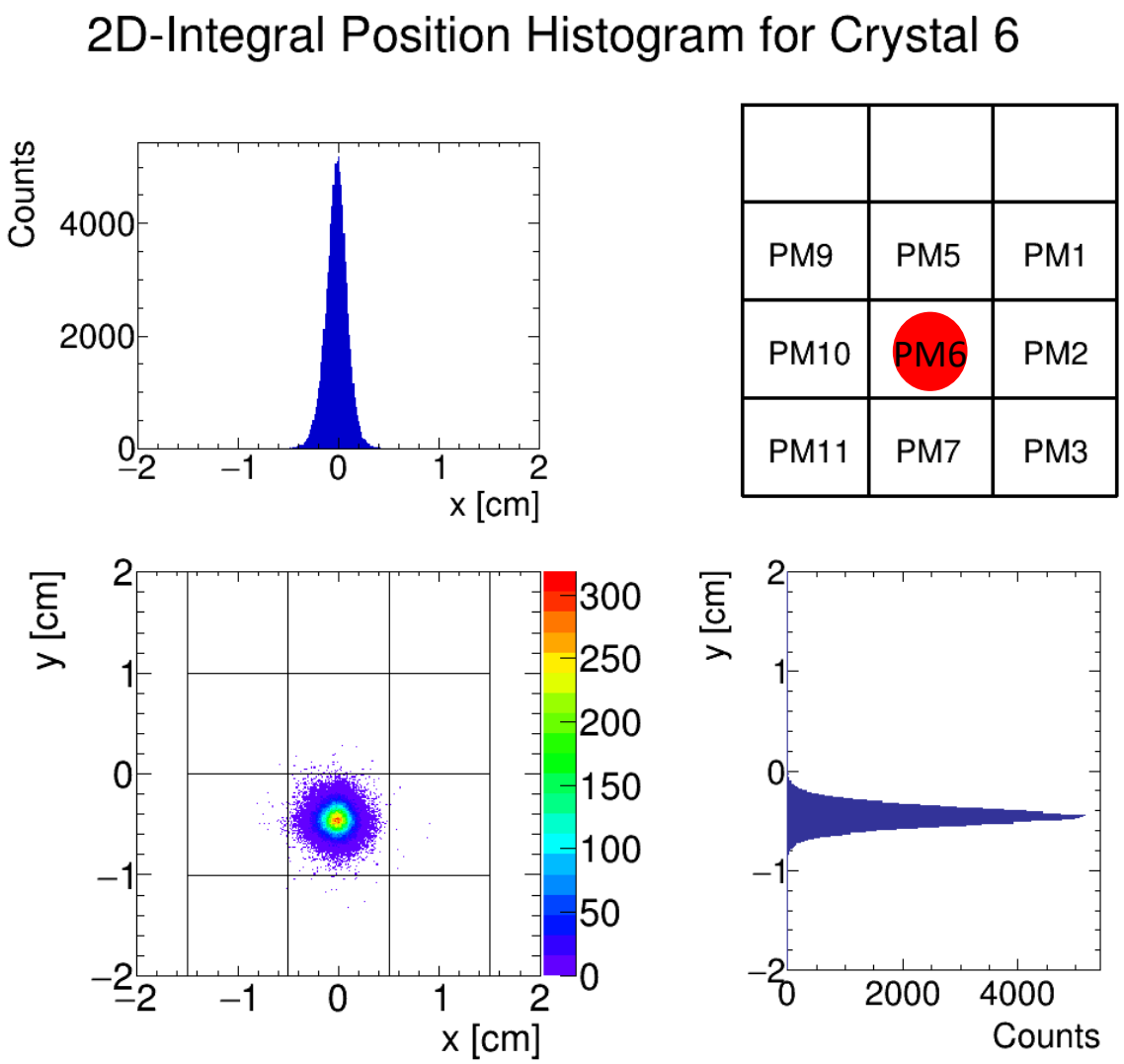
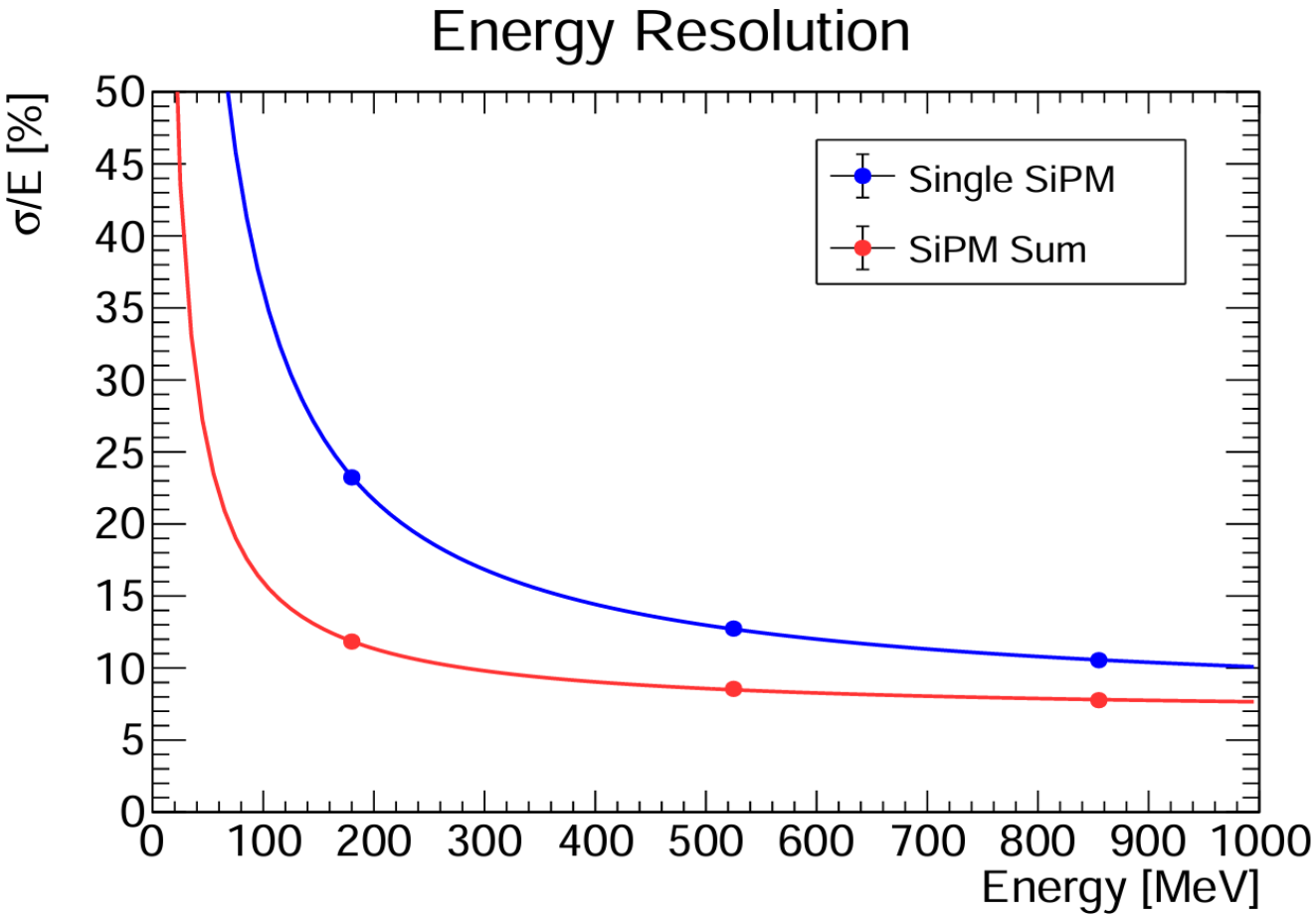
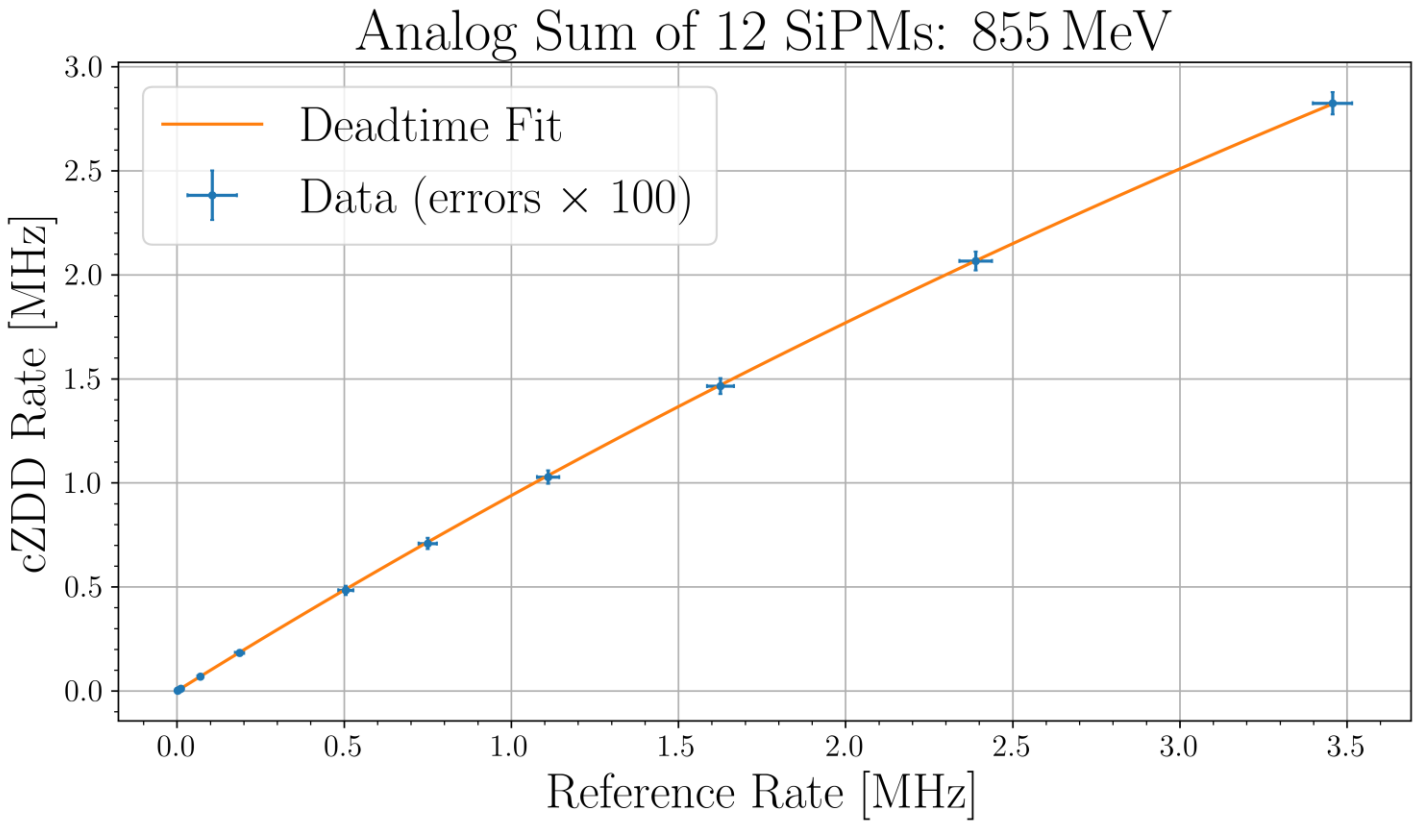


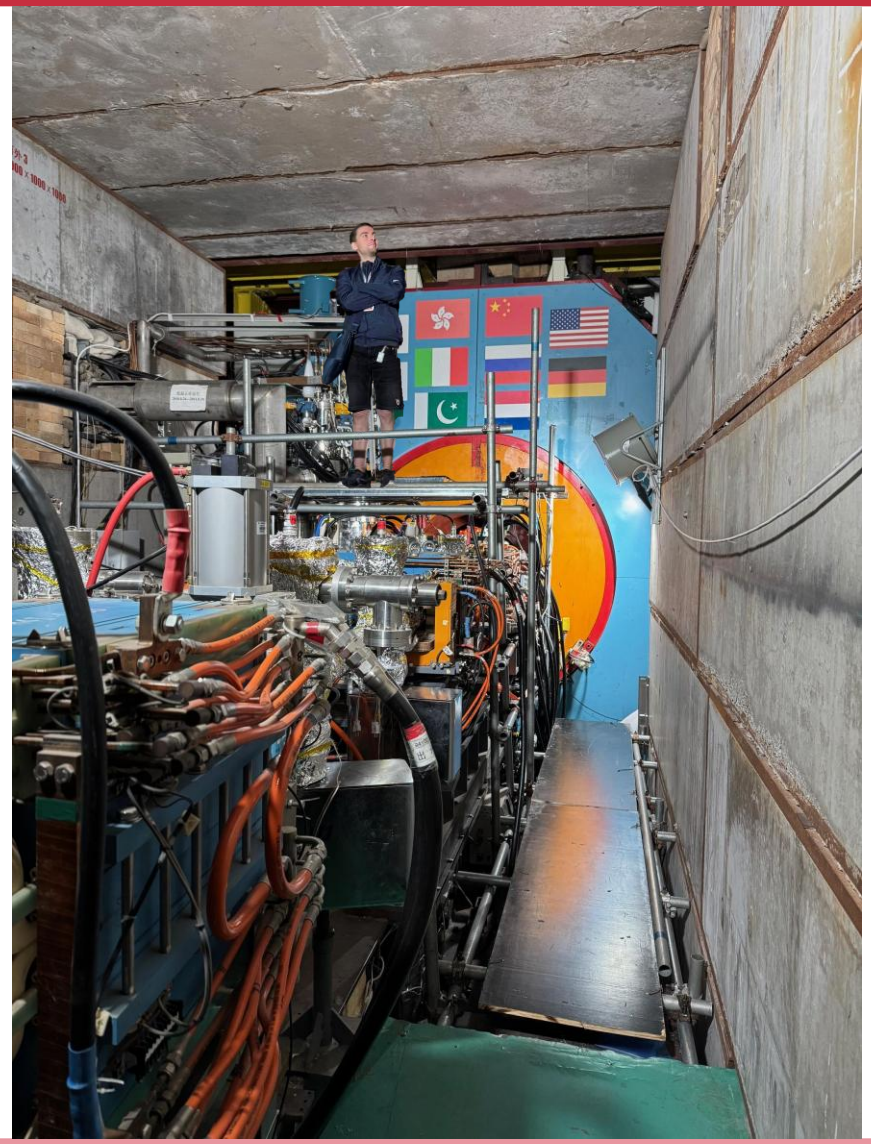


MAMI Testbeam – Deadtime

- cZDD compared to reference Cherenkov detector
- Deadtime correction:
  $\mathrm{R_{corr}} = \frac{R}{(1+R\cdot\tau)}$
- $\tau = 65.2 \pm 0.3$ ns



cZDD Installation at BESIII



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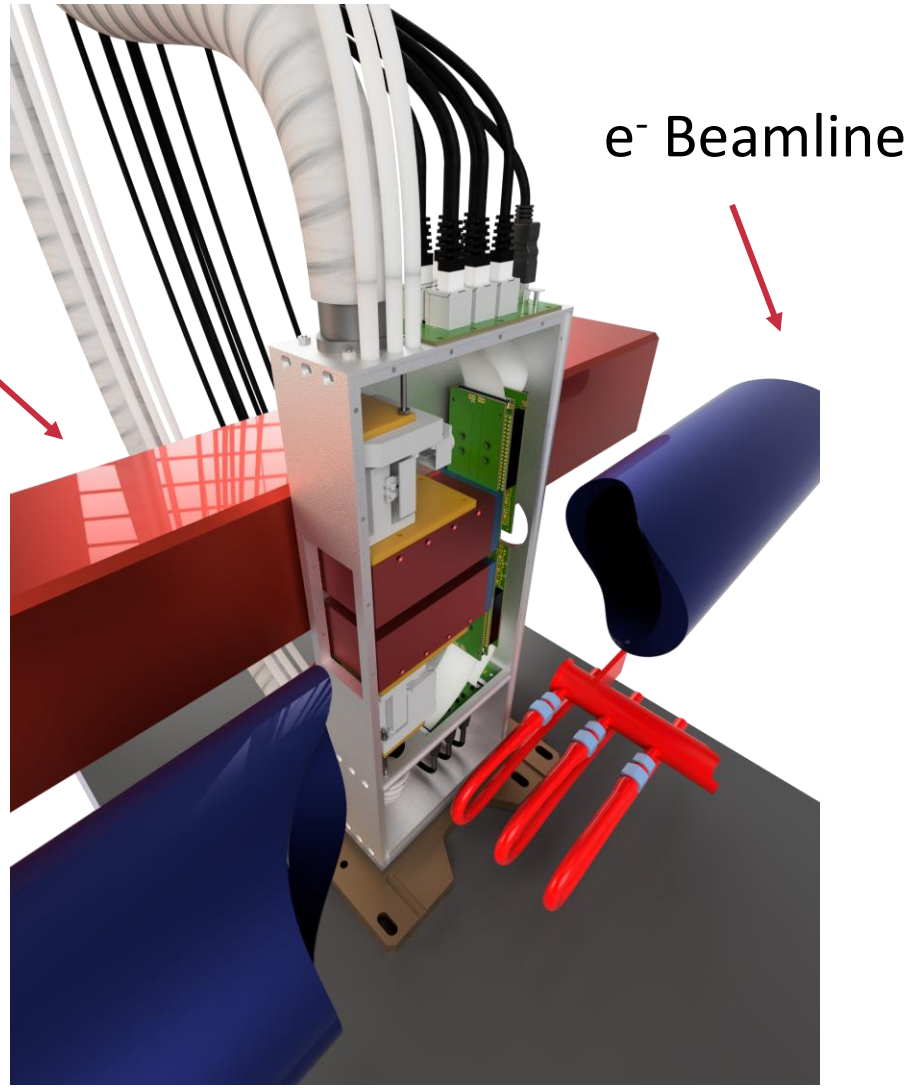
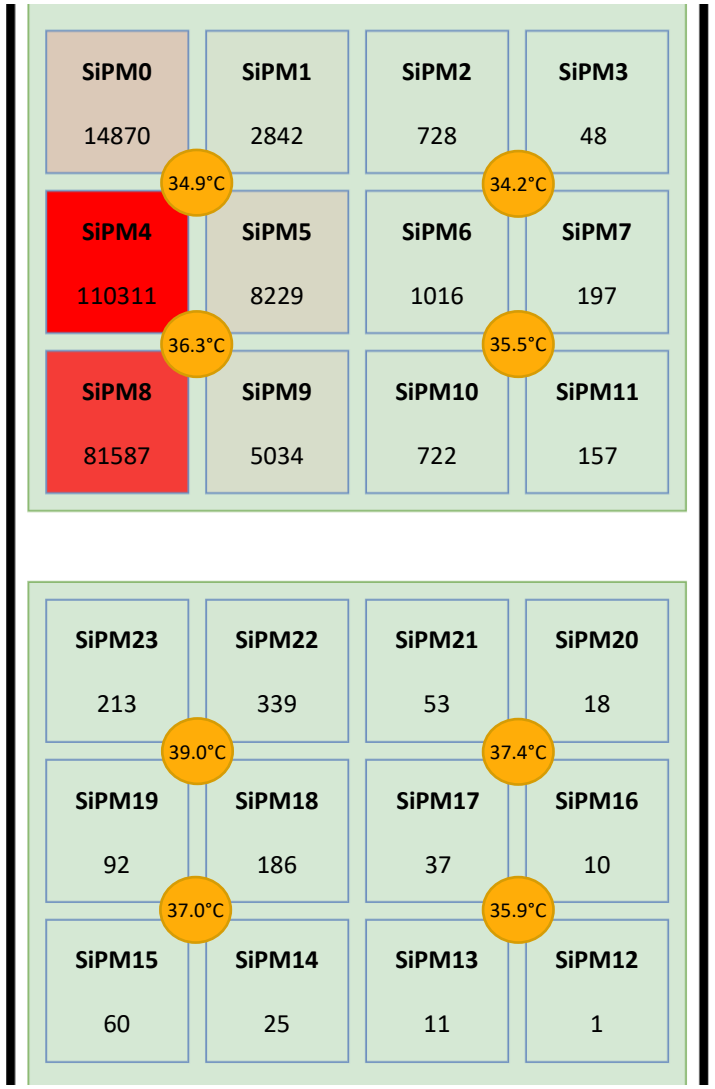
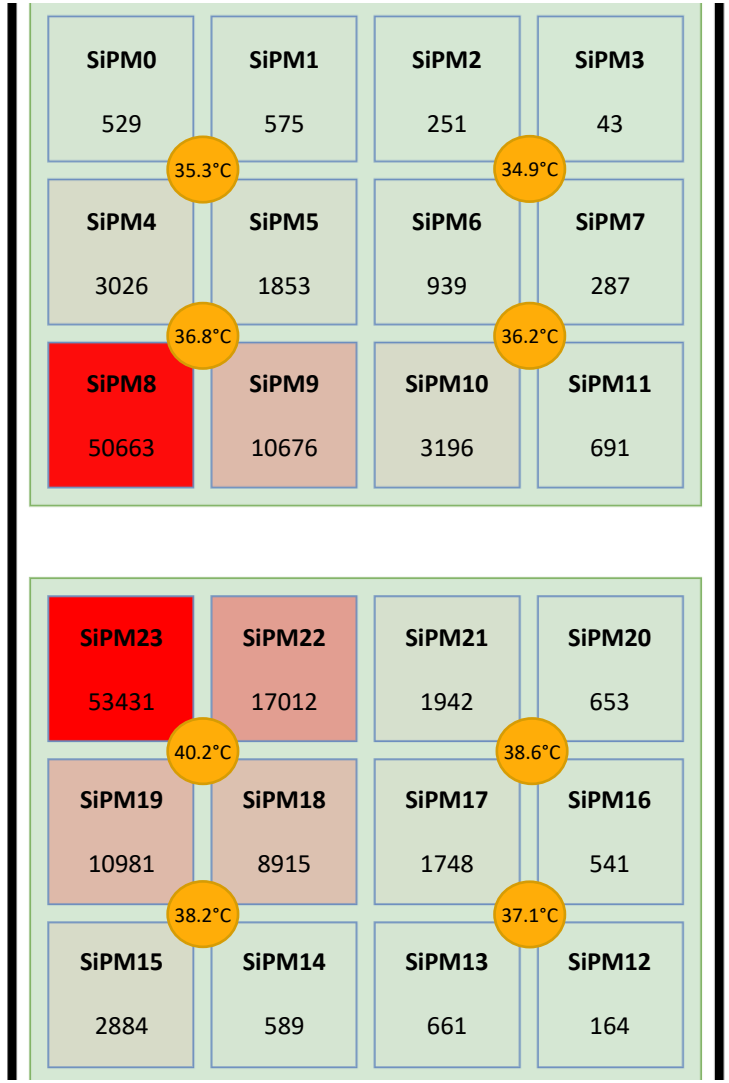


Finding Best Position for cZDD

SiPM
Rate [Hz]



Raising cZDD by 30mm

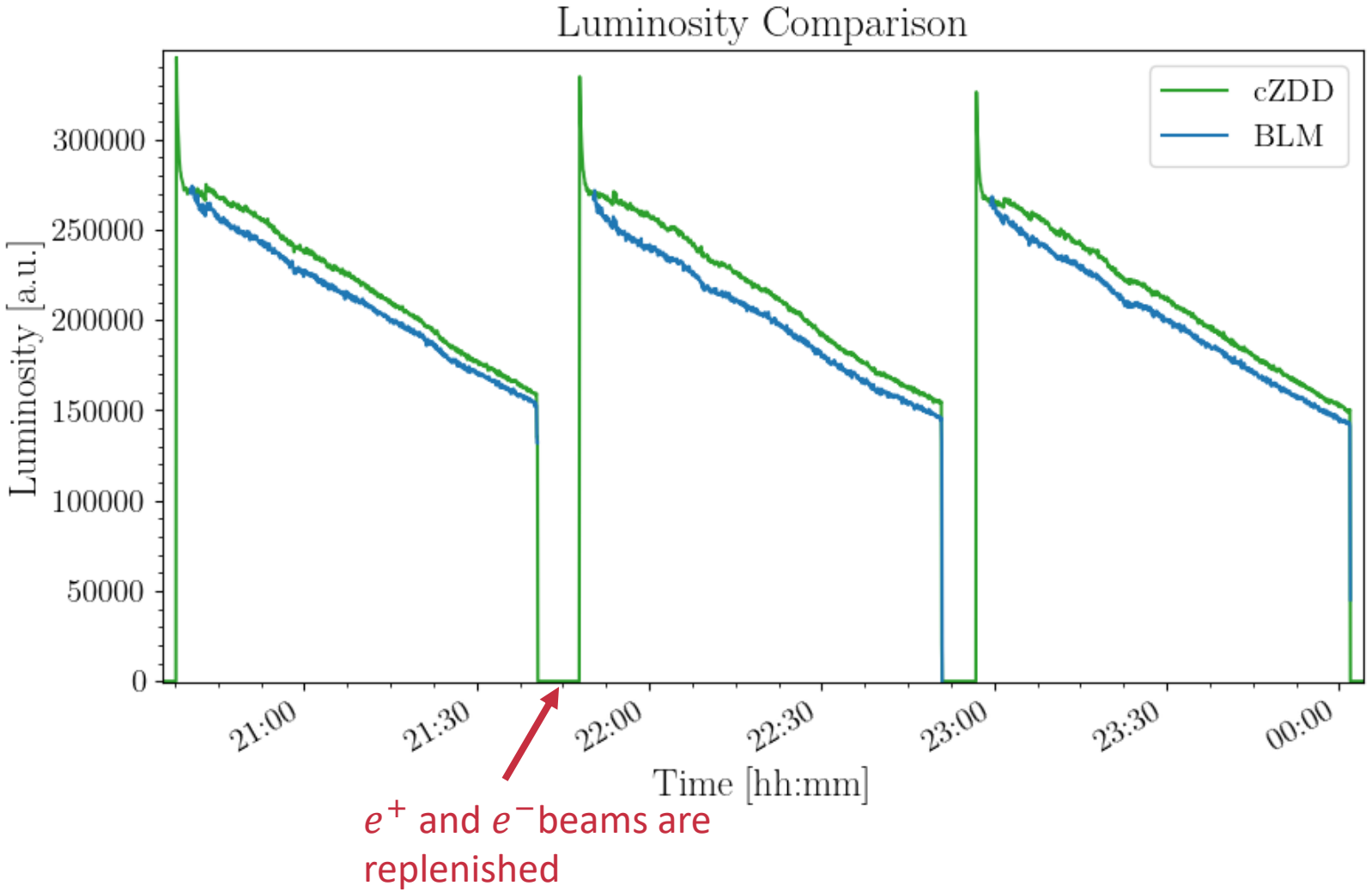


Commissioning

- Luminosity monitor
- Competitive with BLM performance on west side
- SiPMs turned off during beam preparation

➔Cause temperature difference of 10 degrees

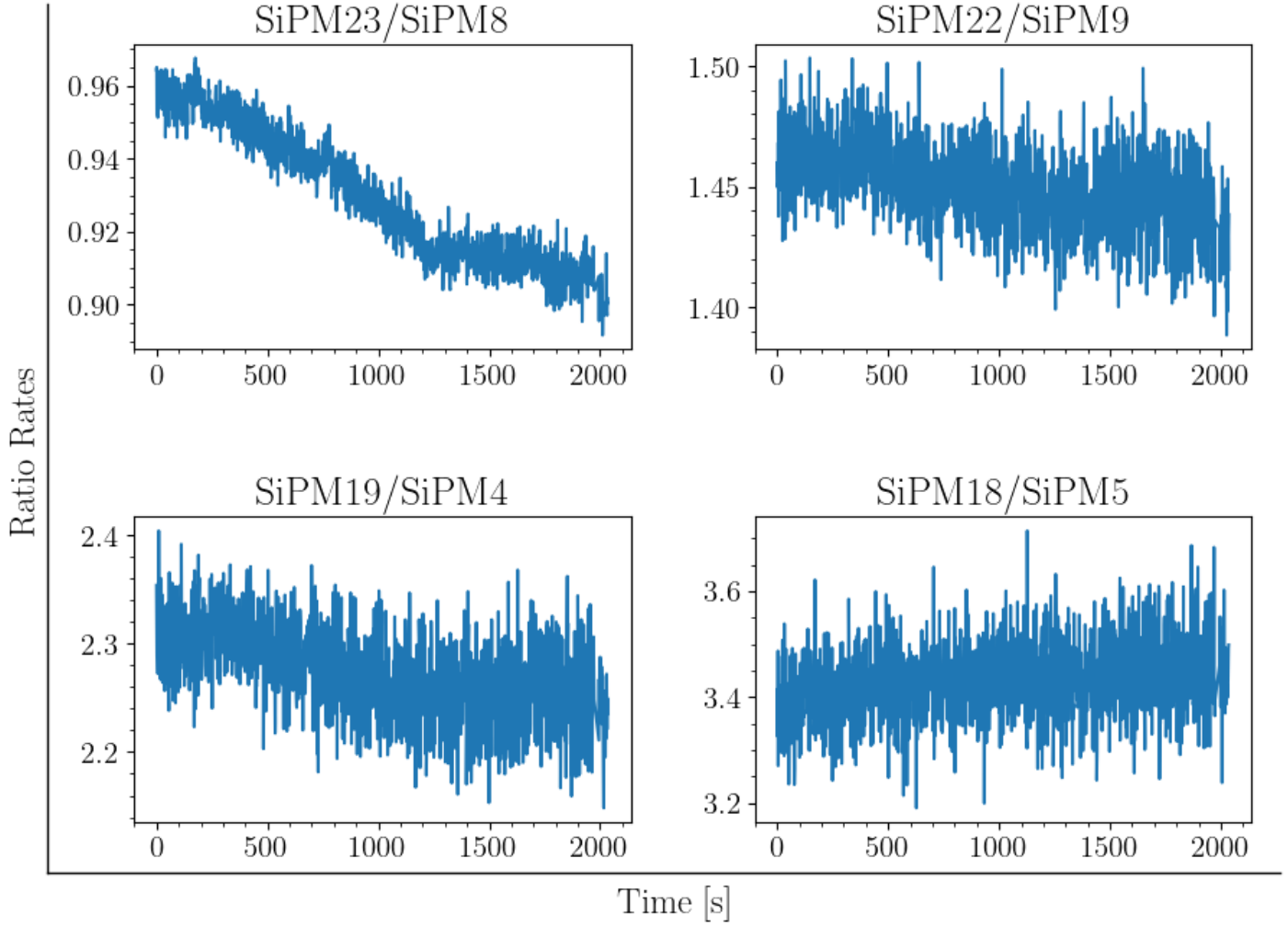
➔Stable operation in thermal equilibrium after three minutes



Commissioning – Beam Stability

- Sensitive to minor changes in beam position
- Important information for accelerator team

SiPM 0	SiPM 1	SiPM 2	SiPM 3
SiPM 4	SiPM 5	SiPM 6	SiPM 7
SiPM 8	SiPM 9	SiPM 10	SiPM 11
SiPM 23	SiPM 22	SiPM 21	SiPM 20
SiPM 19	SiPM 18	SiPM 17	SiPM 16
SiPM 15	SiPM 14	SiPM 13	SiPM 12



Summary

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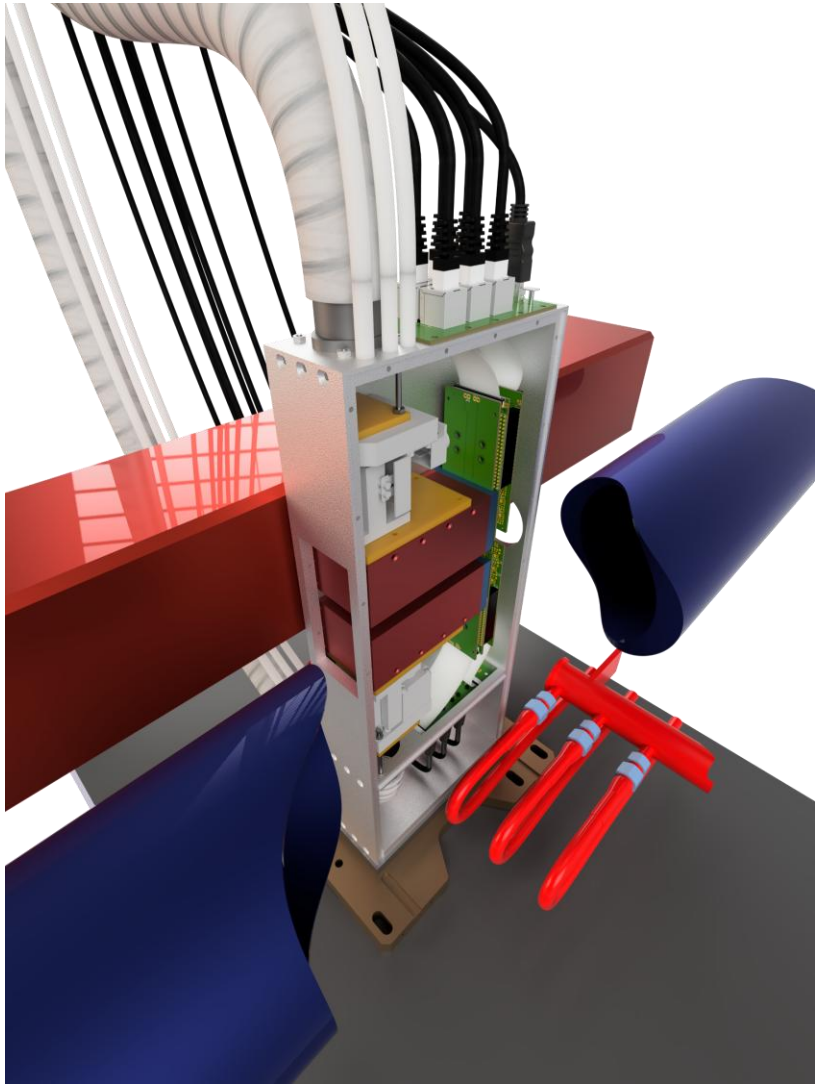
- cZDD as additional detector for BESIII at small angles
- Detect ISR photons and measure luminosity for beam tuning
- Installation at BESIII and first data taken

Outlook

- Improvement of detector electronics ➔ Radiation hardness
- Development of an online feature extraction for ISR measurement



Summary - Thank you for your attention

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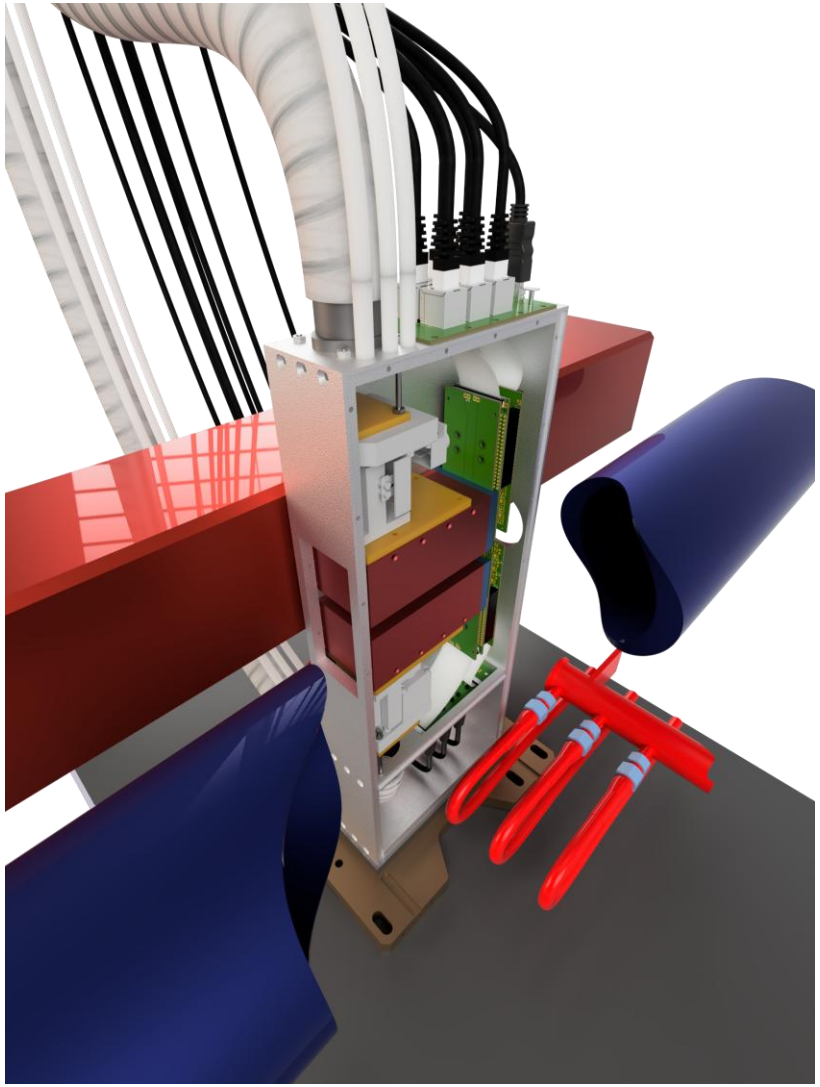


Appendix

Data Acquisition – Luminosity and Slow Control

- Slow control for configuring SiPM voltages and thresholds
- Temperature monitoring
- Preparation of the luminosity signal

  ➔Using sum over signals of both SiPM arrays
- Implementation of luminosity measurement planned for this summer

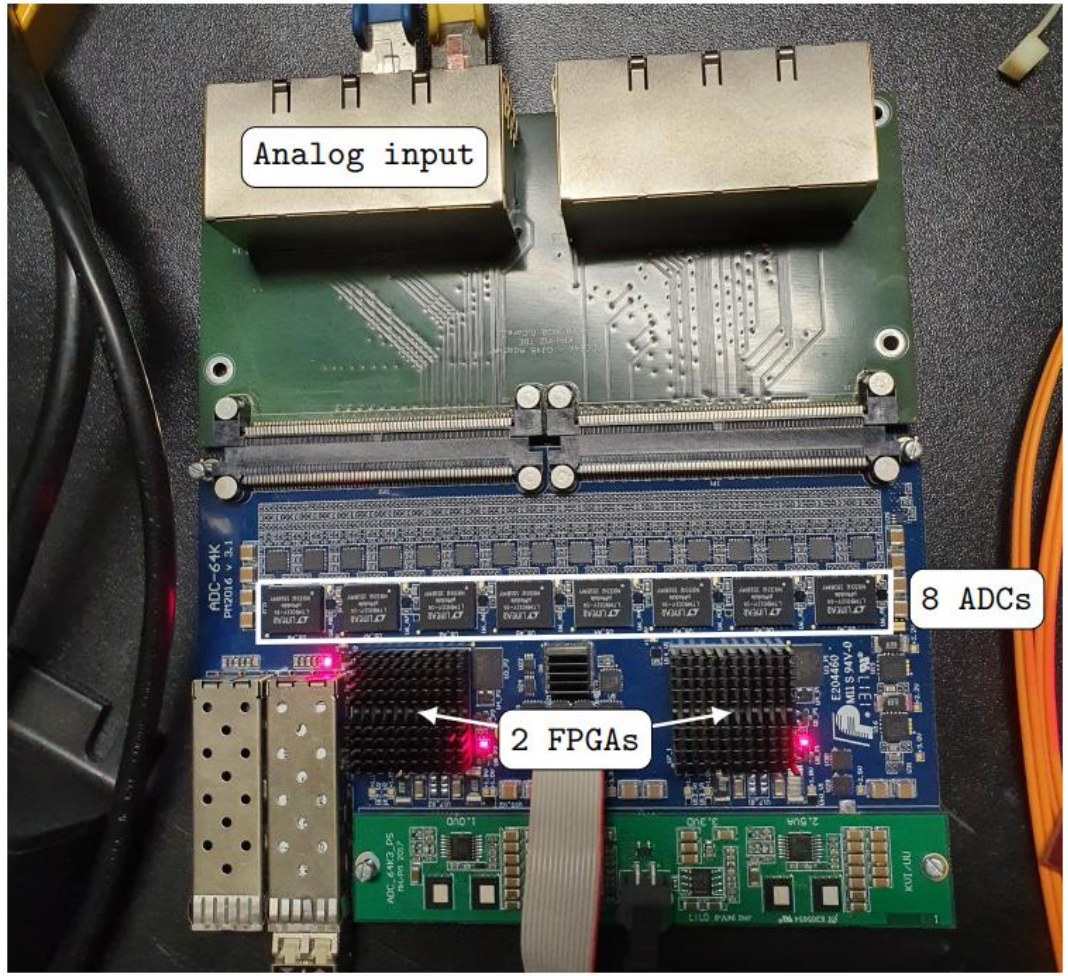
Data Acquisition – SADC

Luminosity and Slow Control Unit

- Adjust SiPM voltages and thresholds
- Temperature monitoring
- Preparation of the luminosity signal

SADC Board – Online Feature Extraction

- Digitizes analog signal
- Sampling rate of 125 MHz
- 14 bit resolution
- Two FPGAs for online feature extraction



Radiation Damage

- SiPMs and electronics stopped working after few weeks of operation
- Measurement of background radiation dose using gamma dosimeter
- Measurement period: 1 week

➔Place frontend electronics in safe location

➔Transport light using light-guides