The PANDA Endcap Disc DIRC

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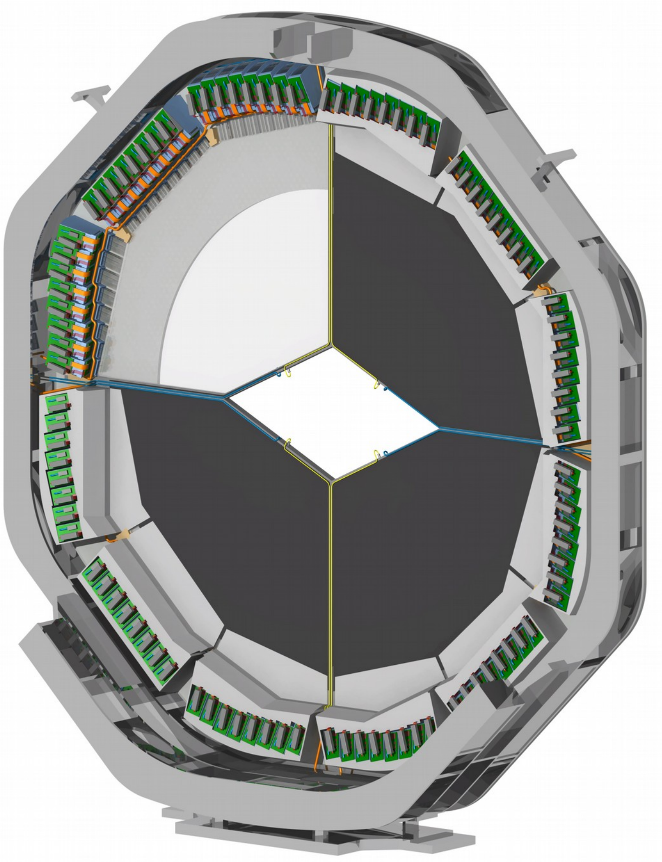


Rauischholzhausen
DIRC2017 workshop
8 August 2017

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

FAIR

HIC for FAIR
Helmholtz International Center

GSI

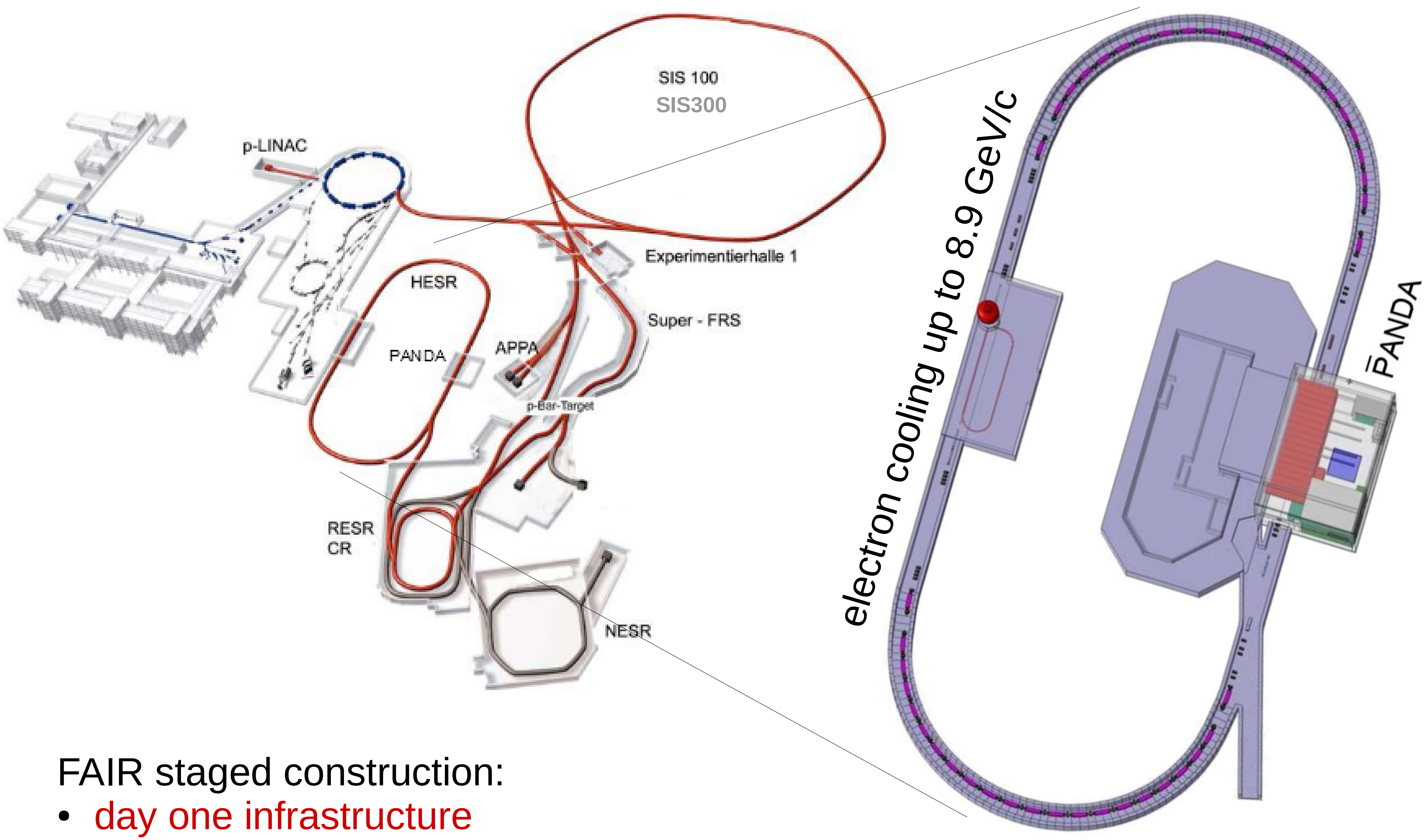
panda

Bundesministerium für Bildung und Forschung

Outline

- GSI and FAIR and HESR
- EDD requirements and design
- Quartz Optics
- MCP-PMT photon sensors
- TOFPET Electronics
- Test beam results

GSI and FAIR and HESR



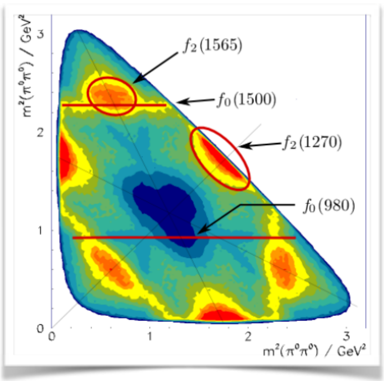
FAIR staged construction:

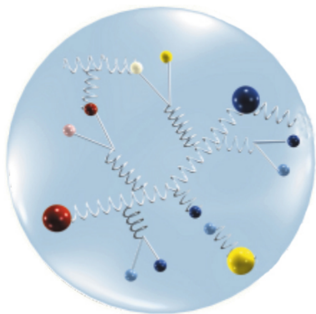
- day one infrastructure
- subsequent additions

High resolution mode: L=1E31cm-2s-1 dp/p=4E-5

High intensity mode: L=2E32cm-2s-1 rate=2E-7/s

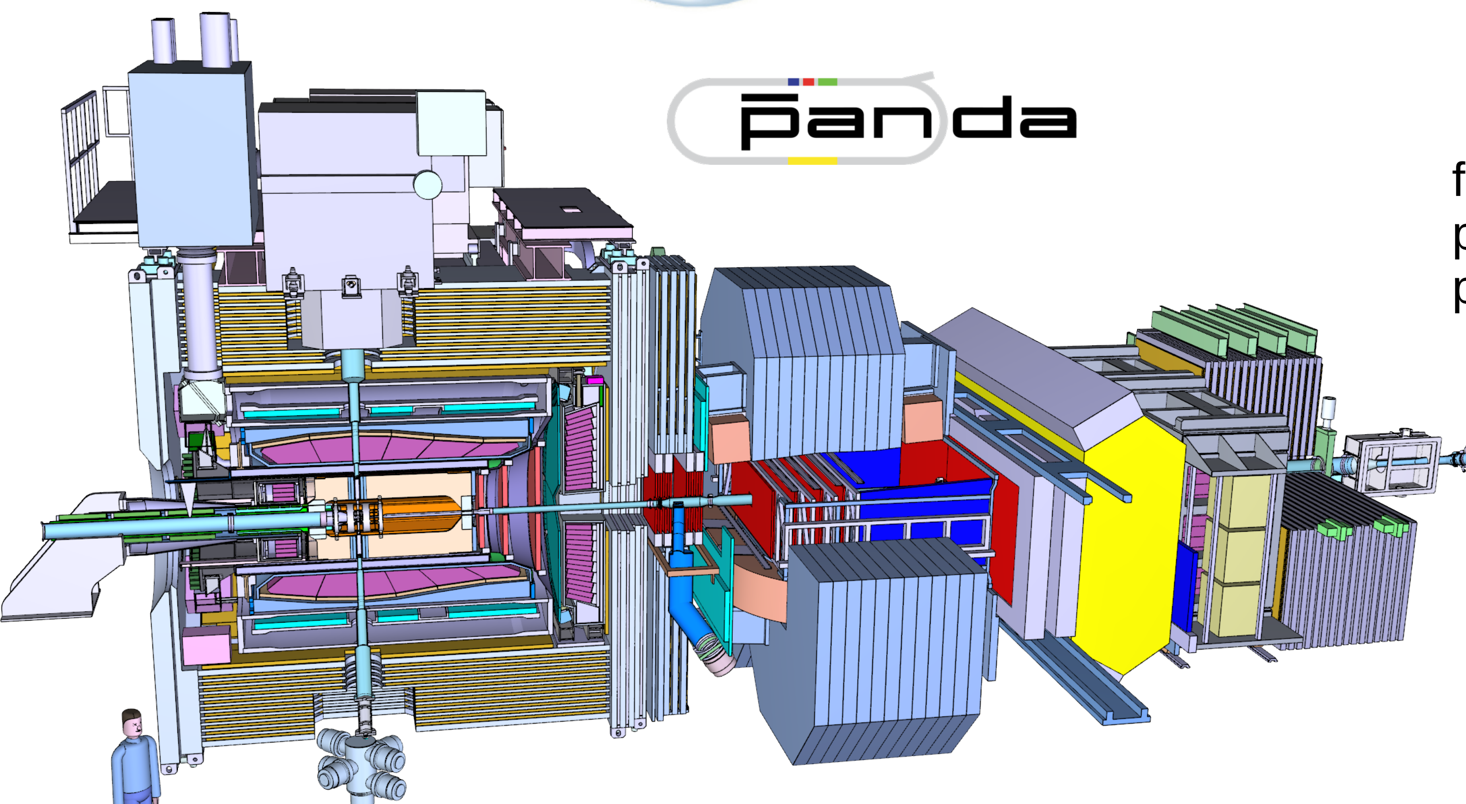
Endcap Disc DIRC in PANDA





PANDA physics:

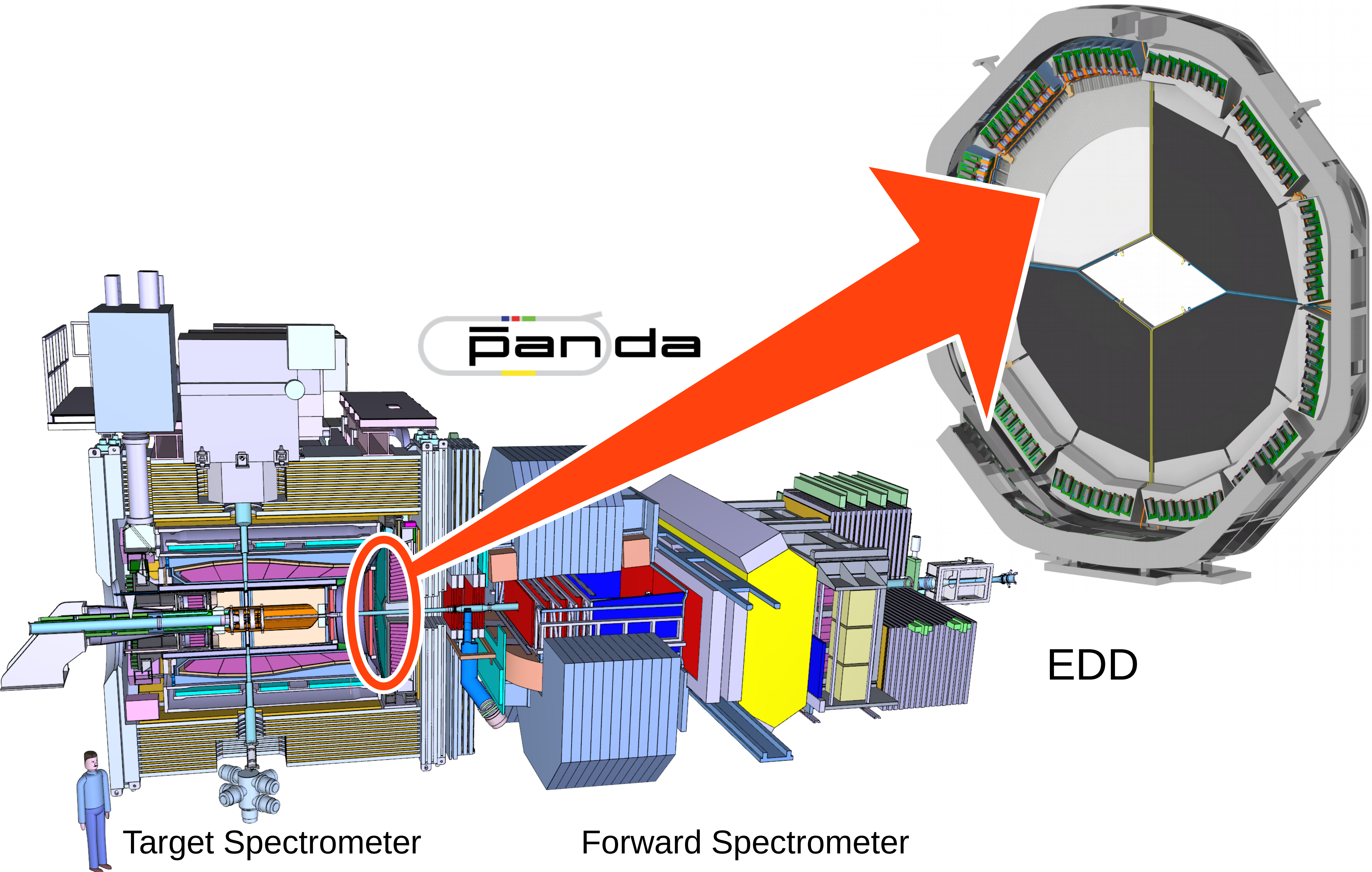
- hadron spectroscopy (c-quarks)
- nucleon structure
- hadrons in matter
- exotic nuclei



fixed-target experiment
p targets (and noble gases)
p from 1.5 to 15 GeV/c

Target Spectrometer Forward Spectrometer

Endcap Disc DIRC in PANDA



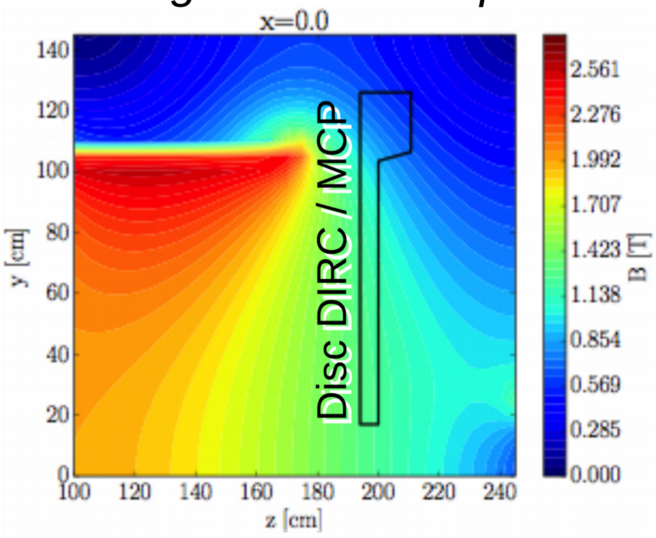
Constricted conditions

The EDD has to respect stringent boundary conditions:

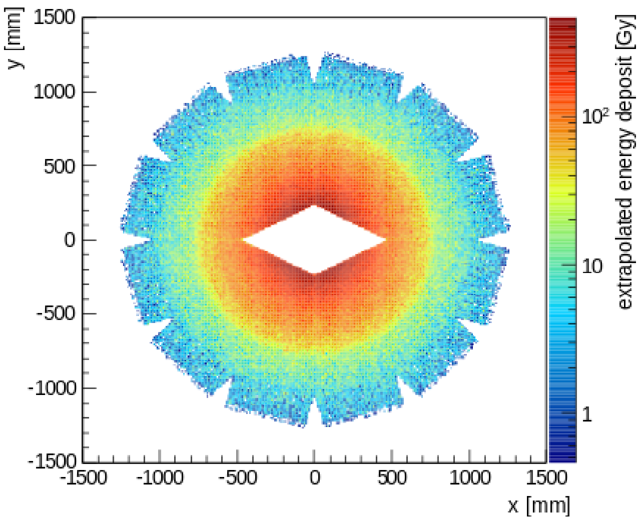
- Little available space
- Only thin layer allowed upstream of EMC
- Radiative environment
- MCP-PMT lifetime in anode charge
- High magnetic field

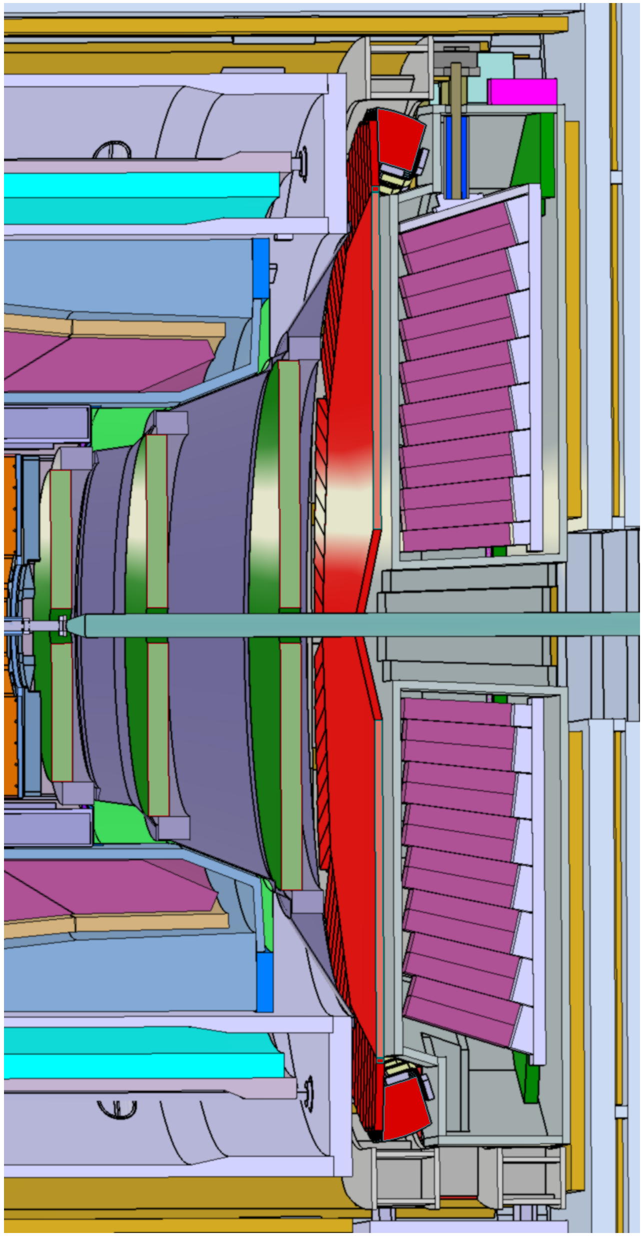
→ cf. talk by A. Lehmann

magnetic field map



radiation environment

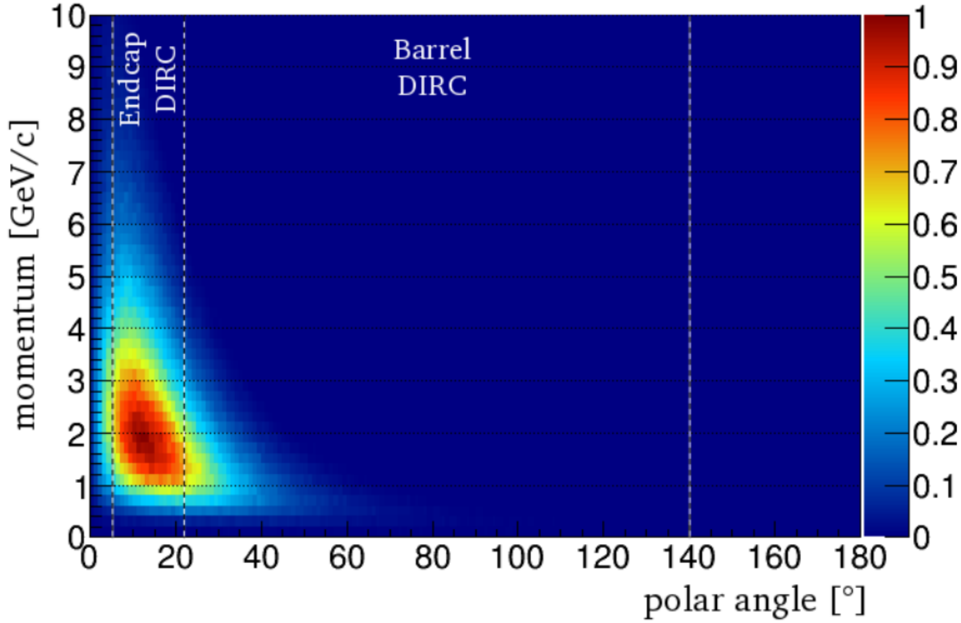


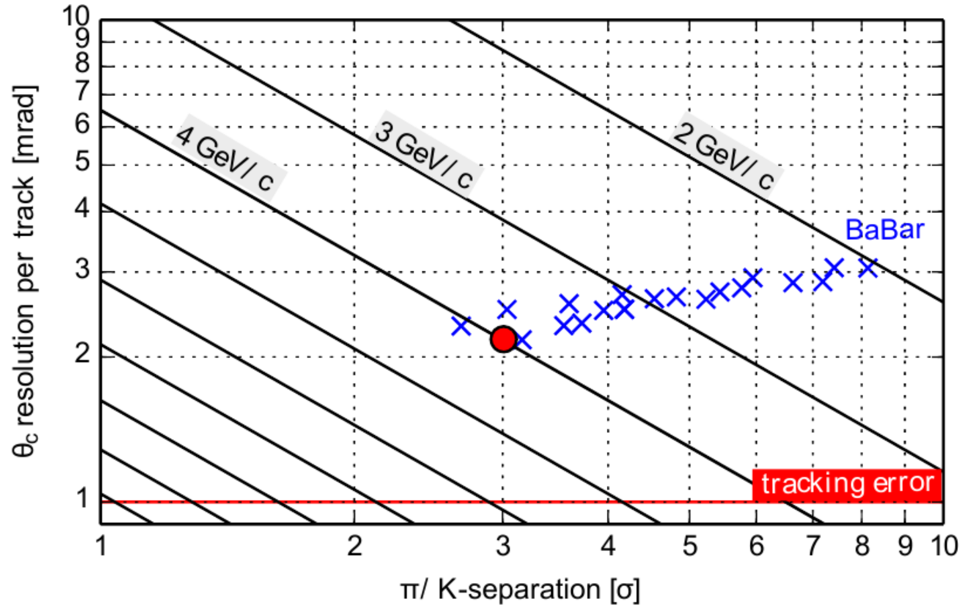


EDD located upstream of EMC

Performance requirements

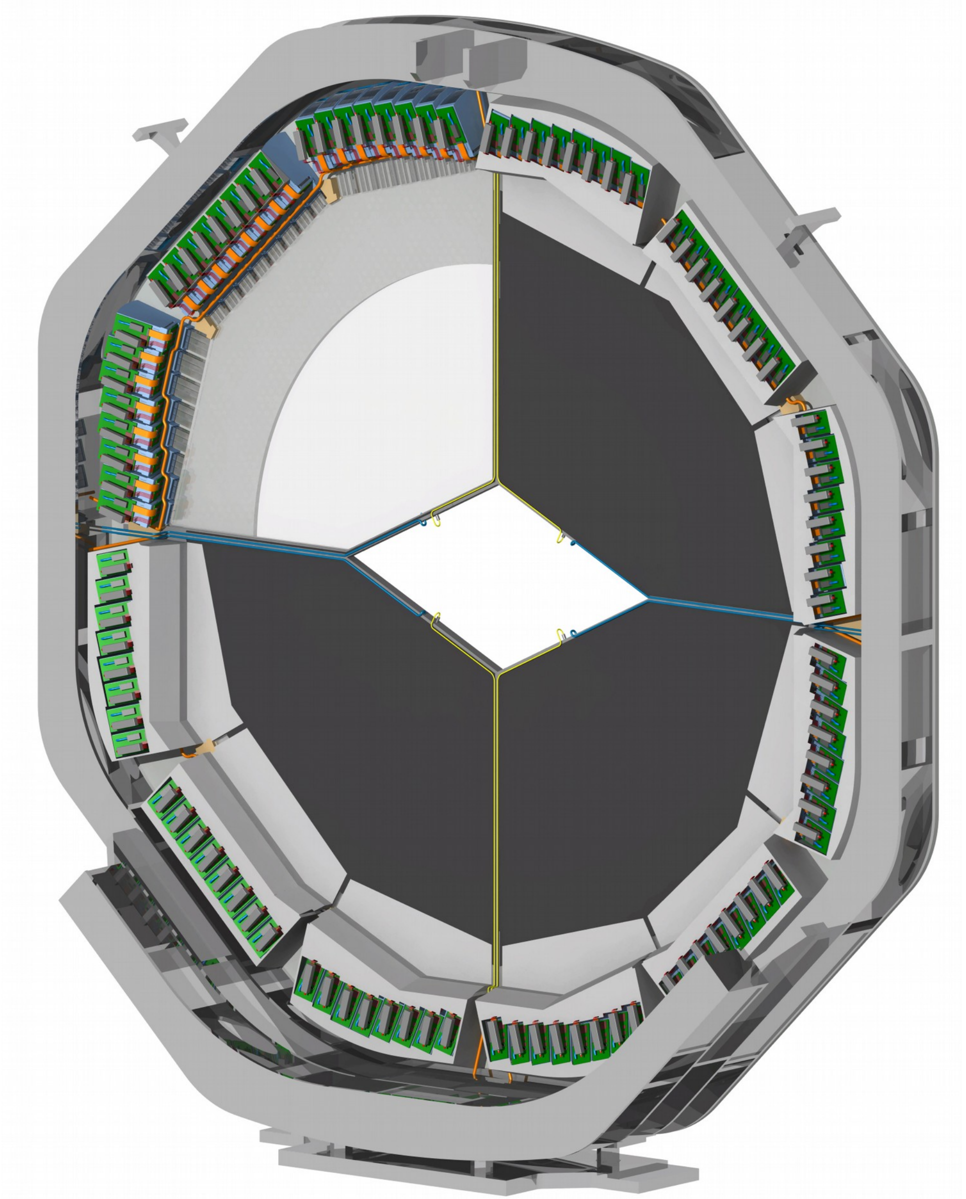
Kaon distributions (open charm production) at 15 GeV/c



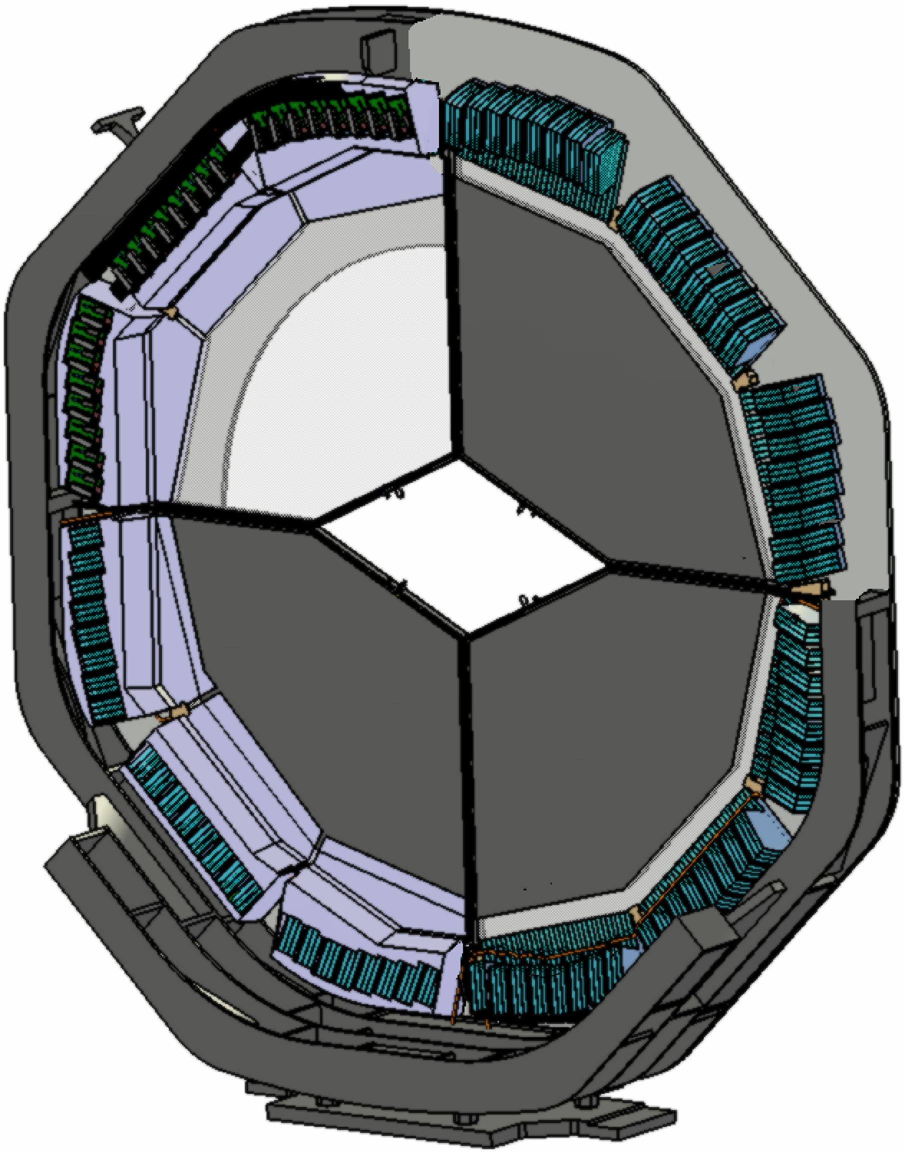


- Positive kaon identification
- Low multiplicity (one to few per module) but high interaction rate at IP
- Kaon-pion PID at 3σ (standard deviations, s.d.) for 4 GeV/c particles
- Contribution to Online Trigger desirable

Our proposed EDD



Some EDD parameters



- 2919 mm inscribing diameter
- 42 to 242 mm clearance in z direction
- ≈450 kg gross weight
- ≈85 kg weight per quadrant

- 4 quadrants
- 96 ROMs (4 x 3 x 8 Readout Modules)
- 96 MCP-PMTs 2” square
- 288 FELs (4 x 3 x 8 x 3 Focussing Elements)

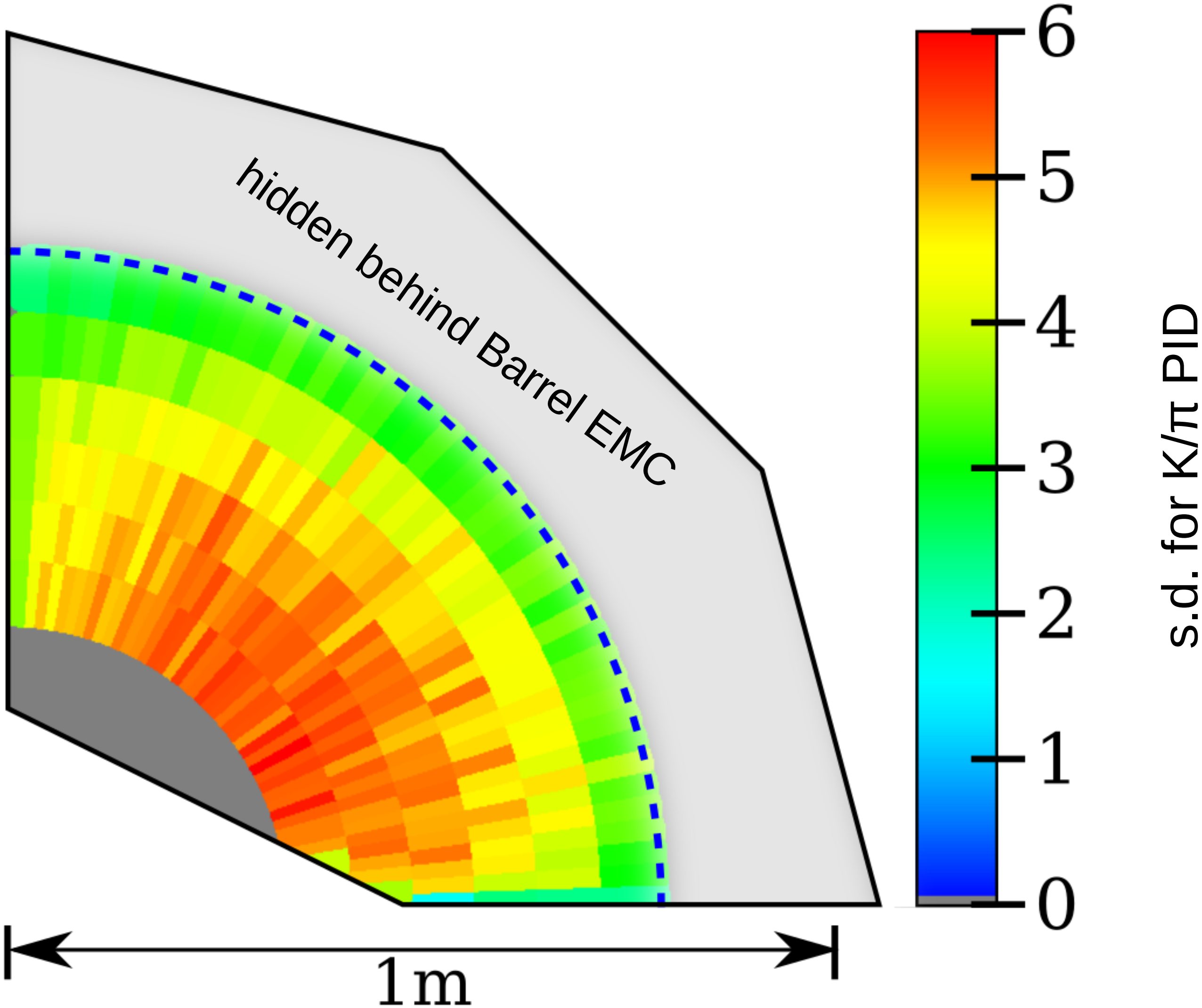
- 4 radiator discs 1050 x 1050 x 20 mm^3
- 100 x 3 / 128 x 6 MCP-PMT pixels
- 0.5 x 17 mm^2 pixel size
- 7 C/cm^2 integrated anode charge
- TOFPET ASIC-based read-out
- 75 kHz per pixel

- 22 detected Cherenkov photons per particle
- λ > 355 nm wavelength range (LP filter)
- $\theta = 6° - 22°$ polar angles
- 3.45 mrad best SPR (with Long Pass filter)
- >3 s.d. for 4 GeV/c K/π separation

Performance simulations (straight tracks)

→ cf. talk by M. Schmidt

22 degrees limit of required phase space coverage



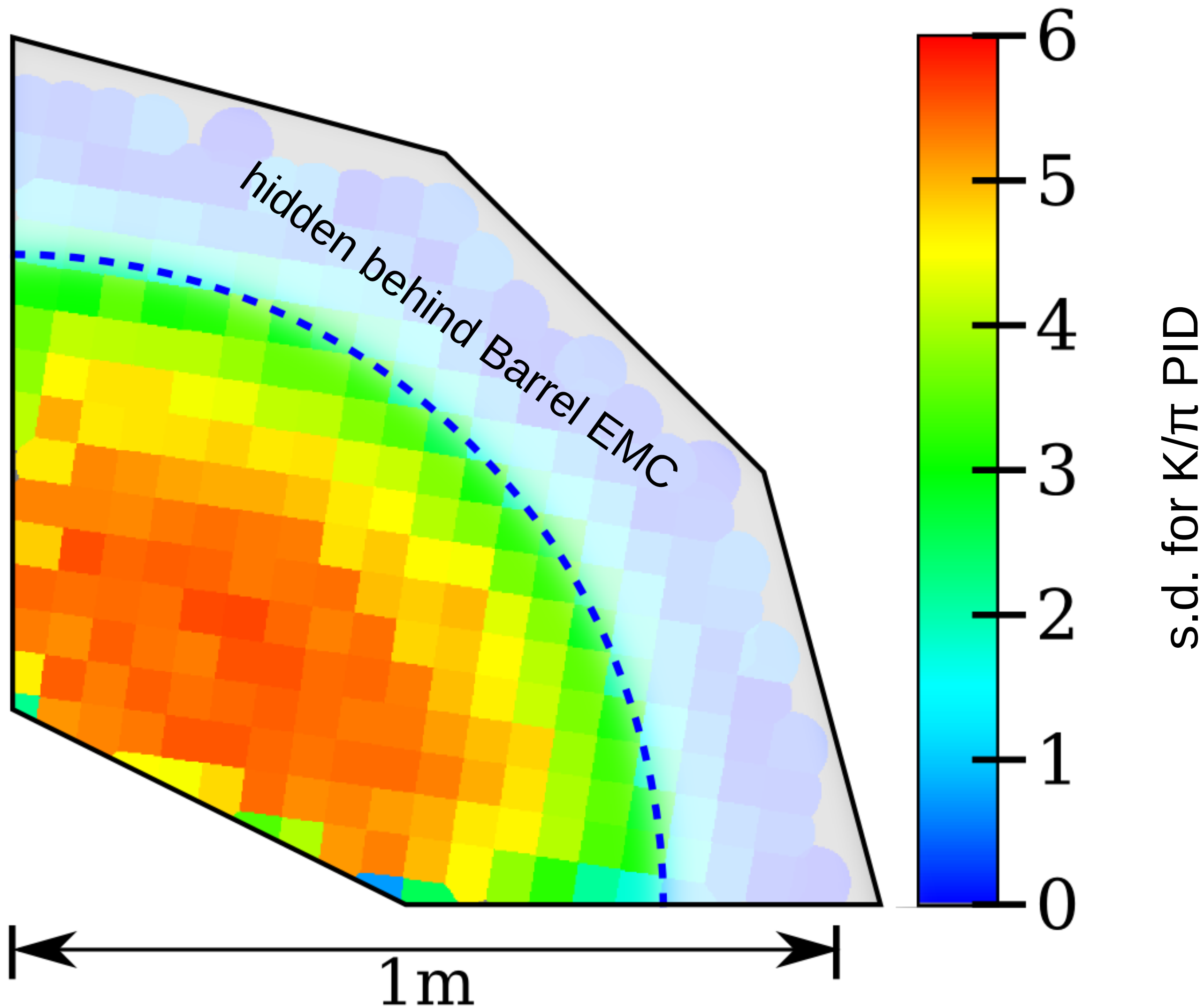
+4 GeV/c kaons and pions on "infinite momentum tracks" from the IP to the EDD

MCP-PMT blue sensitive photocathode plus dielectric LP λ > 355 nm edge filter

Performance simulations (PANDA B field)

→ cf. talk by M. Schmidt

22 degrees
limit of required
phase space
coverage

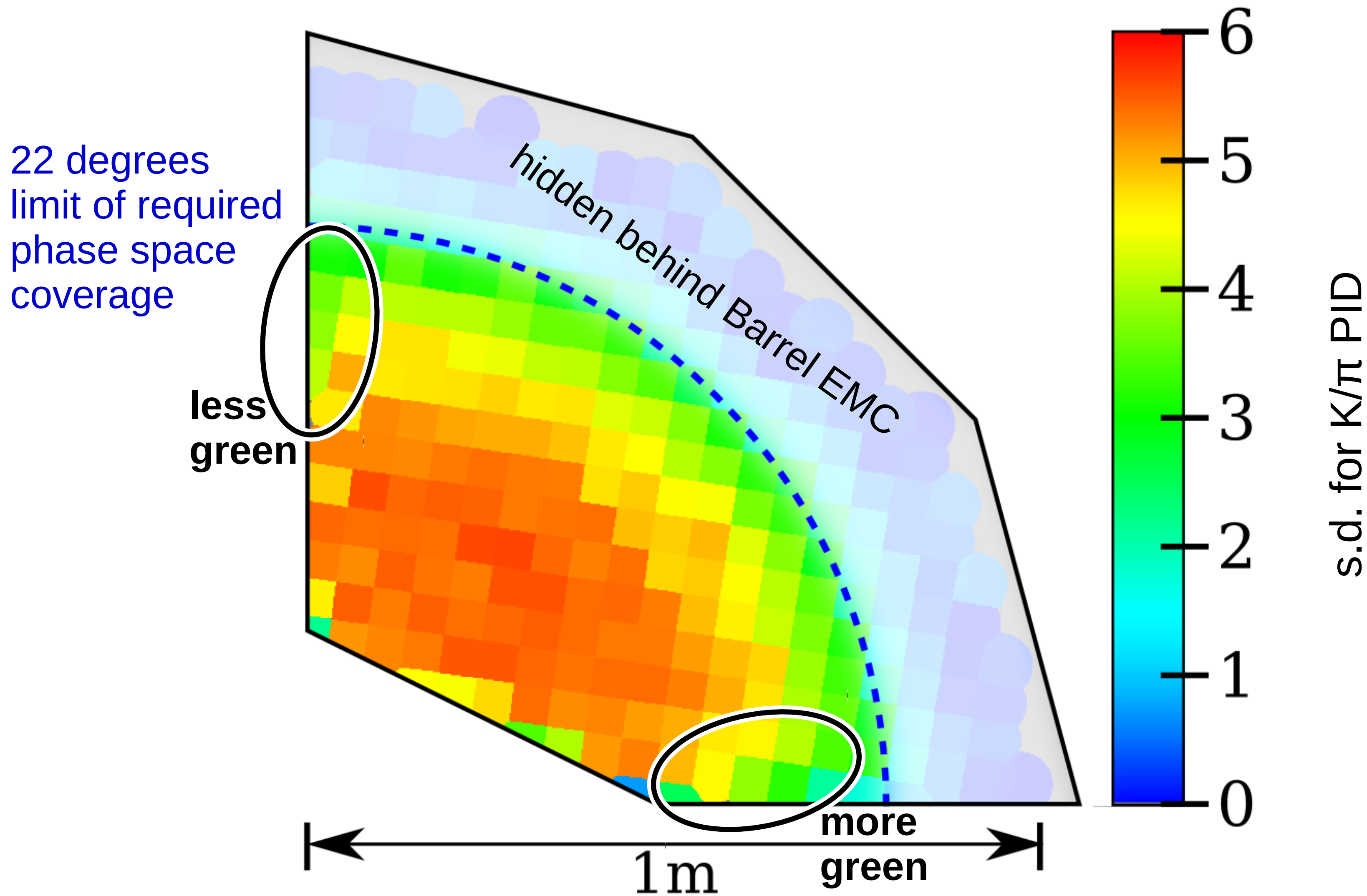


+4 GeV/c kaons and pions from the IP tracked through PANDA B-field to the EDD

MCP-PMT blue sensitive photocathode plus dielectric LP λ > 355 nm edge filter

Performance simulations (PANDA B field)

→ cf. talk by M. Schmidt



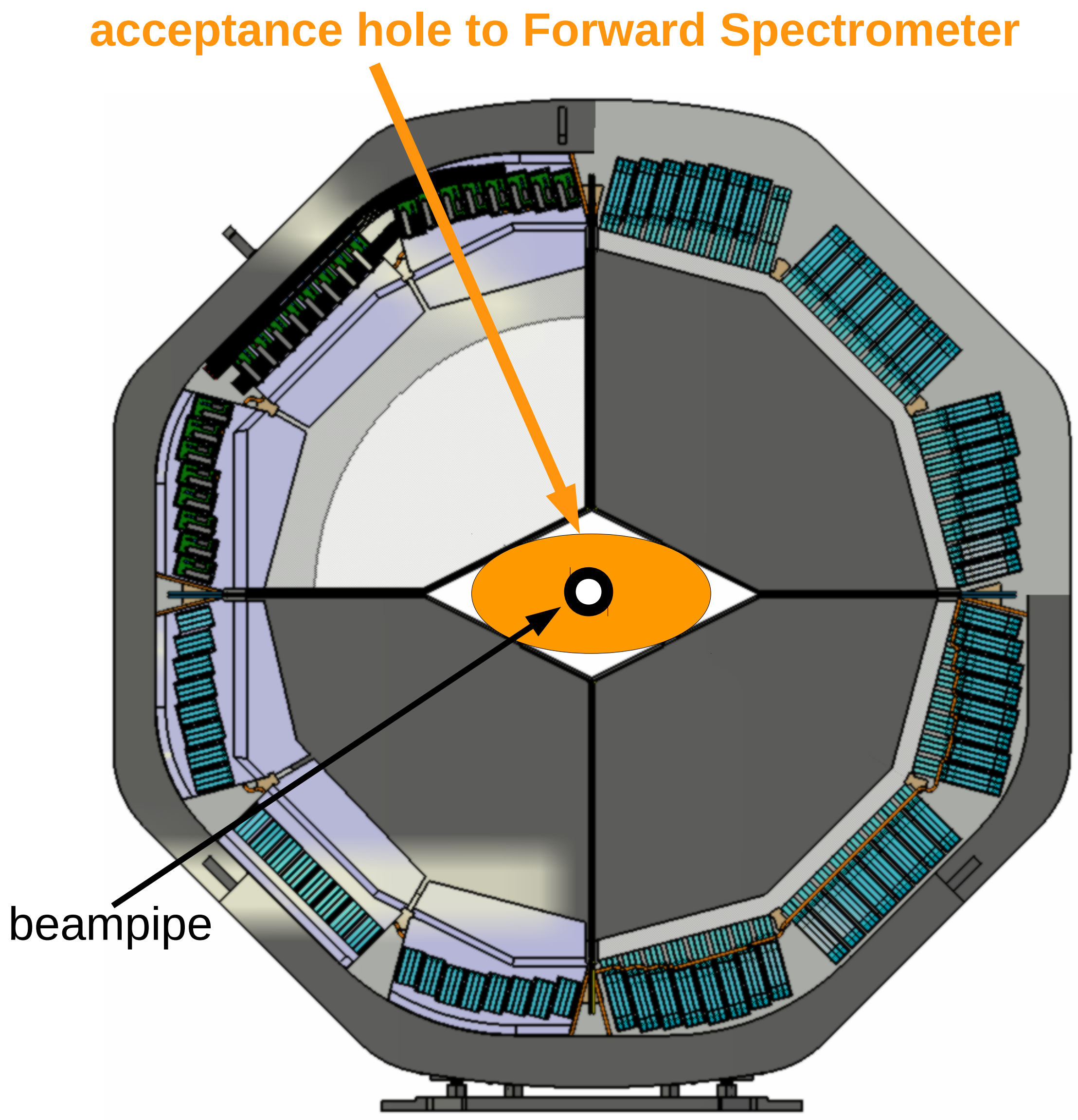
+4 GeV/c kaons and pions from the IP tracked through PANDA B-field to the EDD

MCP-PMT blue sensitive photocathode plus dielectric LP λ > 355 nm edge filter

Detector design

- Components
- Quartz optics
- MCP sensors
- Electronics
- Mechanics holding all together

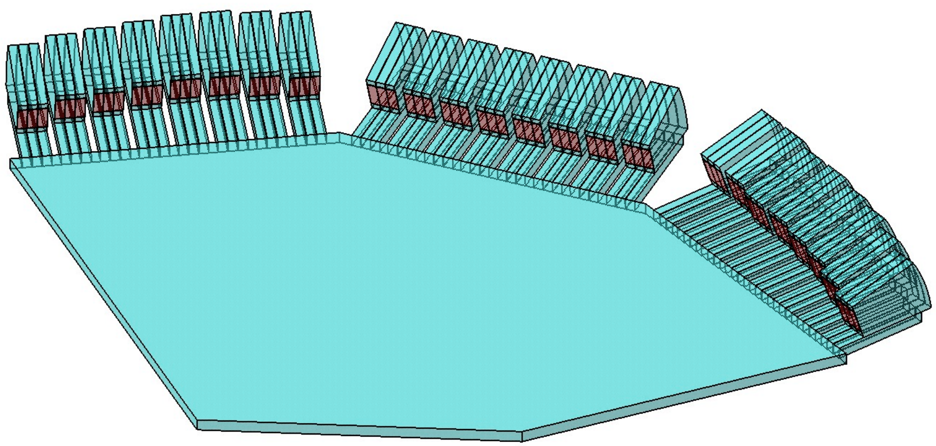
Detector geometry



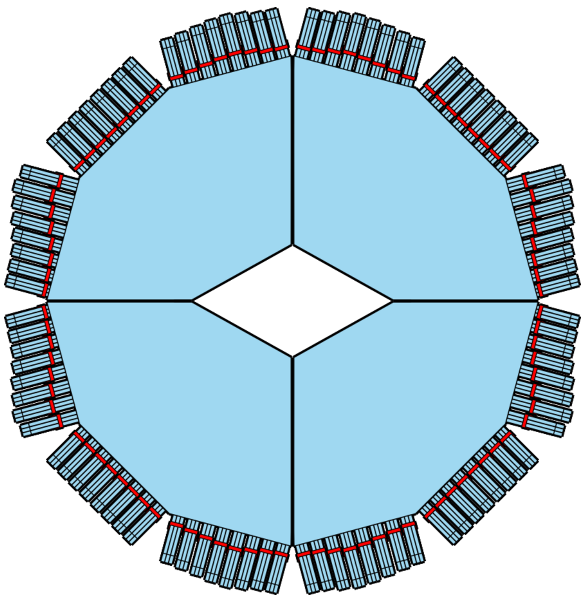
segmented ... because:
- radiator size limit
- mounting around beampipe
- handling
- risk mitigation

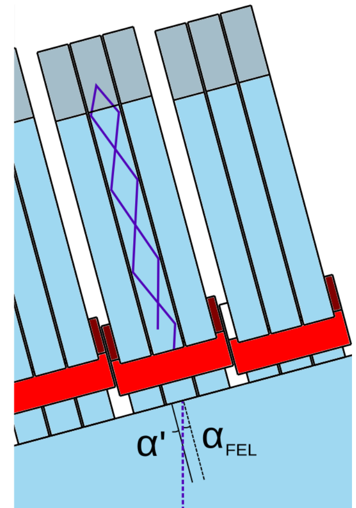
flat surfaces and convex shape:
- polishing reasons

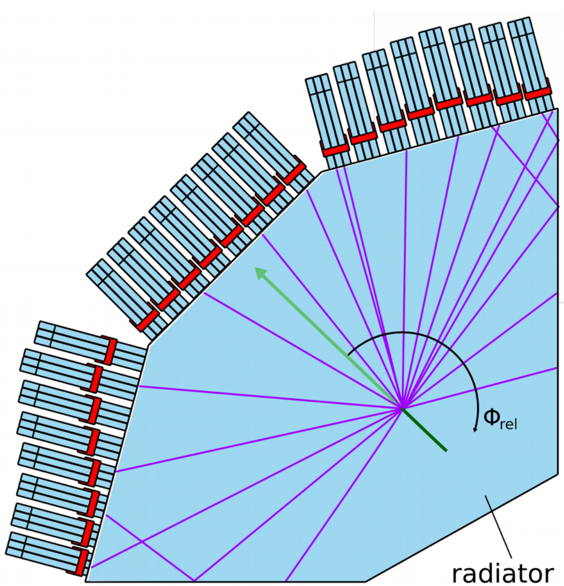
varying distances radiator-to-FEL due to constraints from the EMC

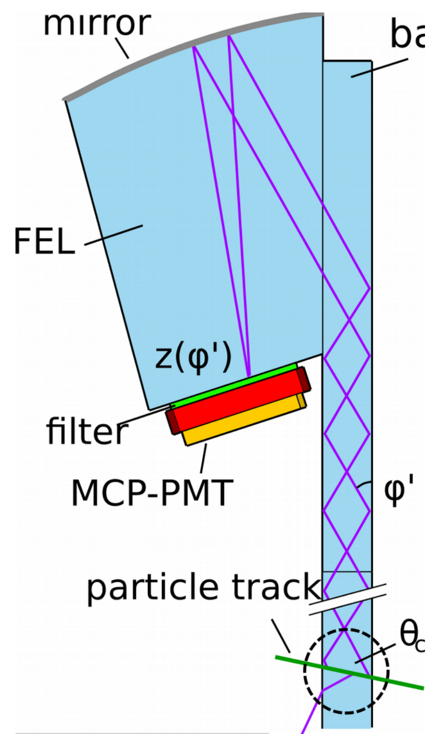


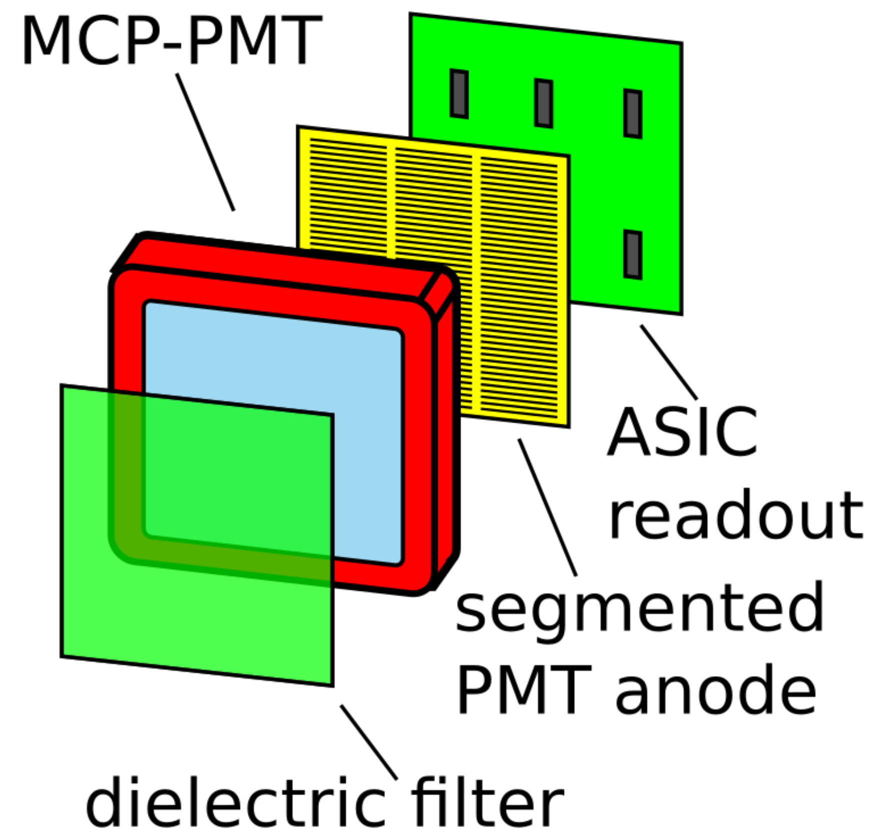
Optical components



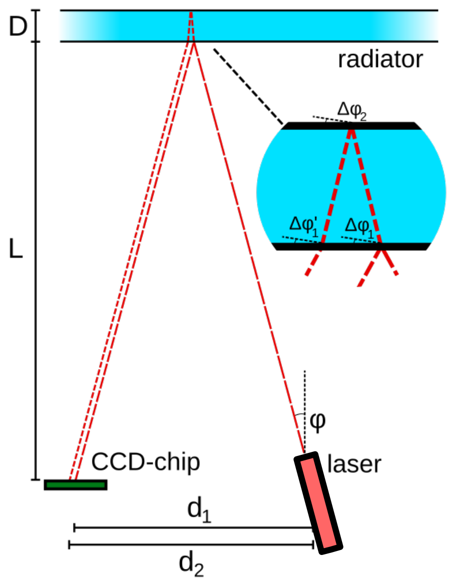




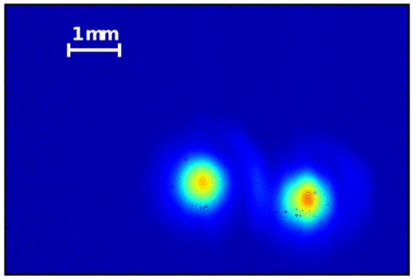


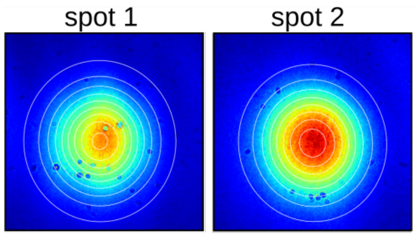


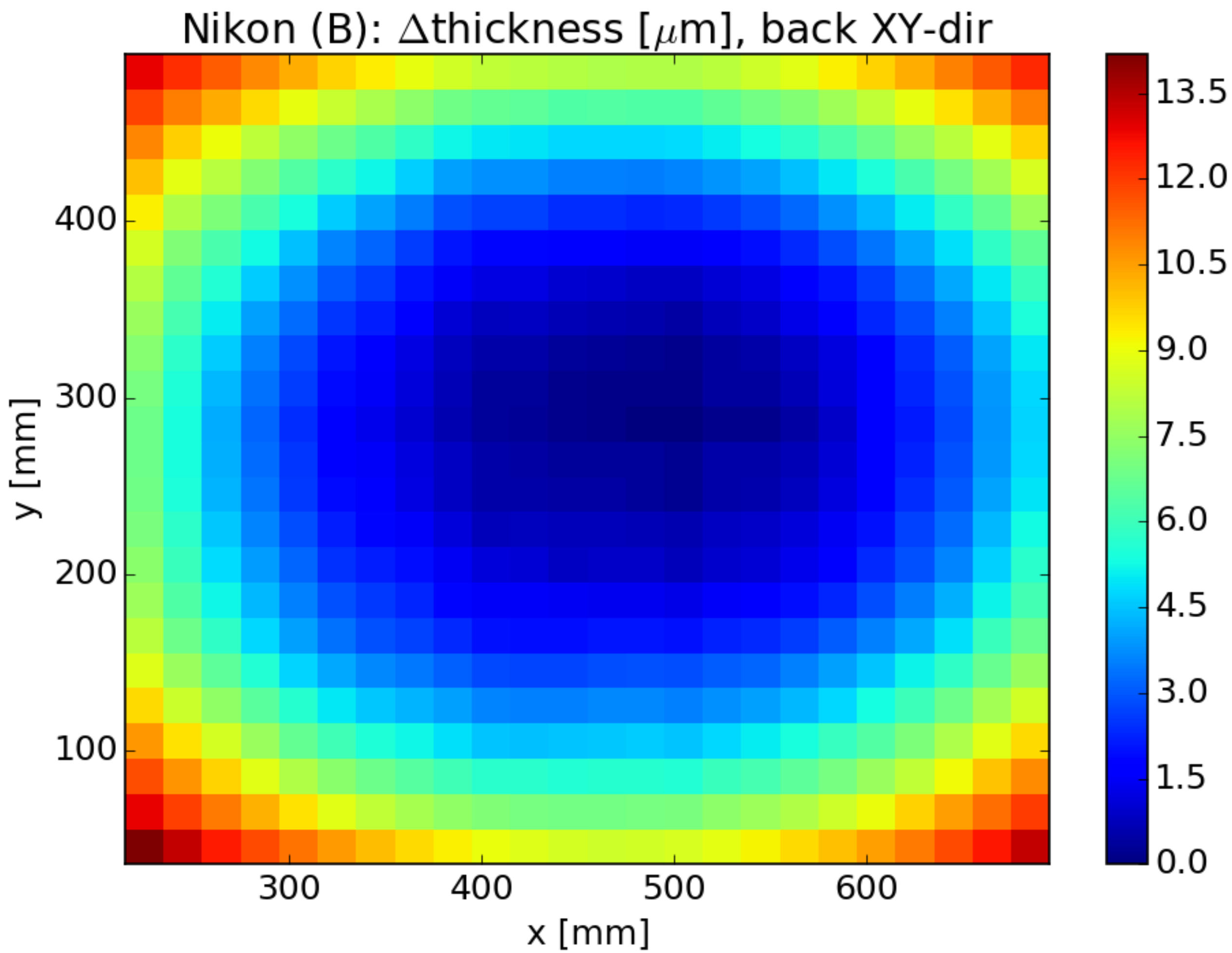
Optics component – Radiator plate QA



picture CCD-chip

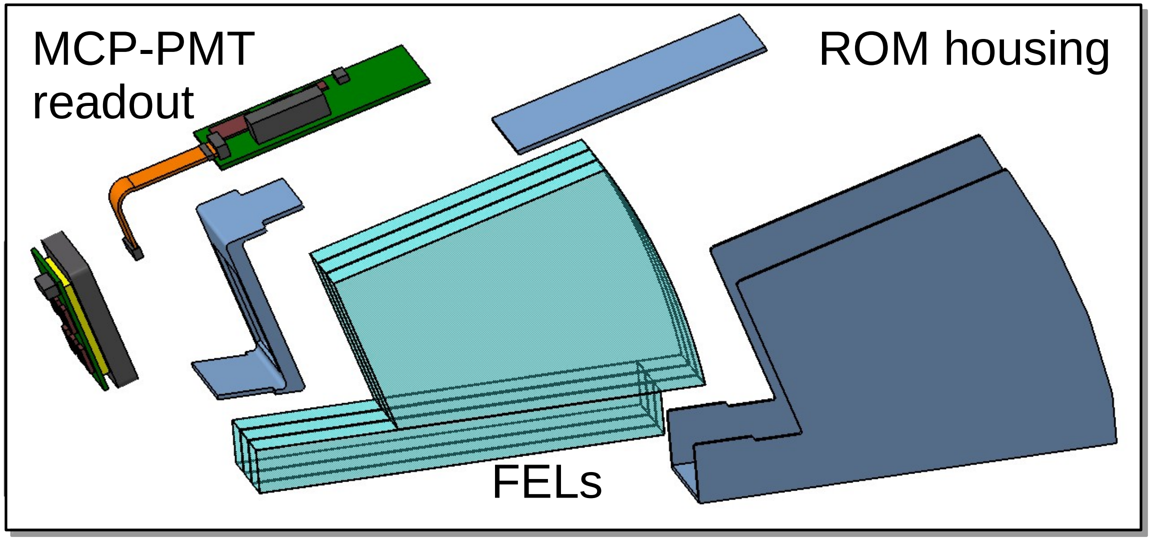


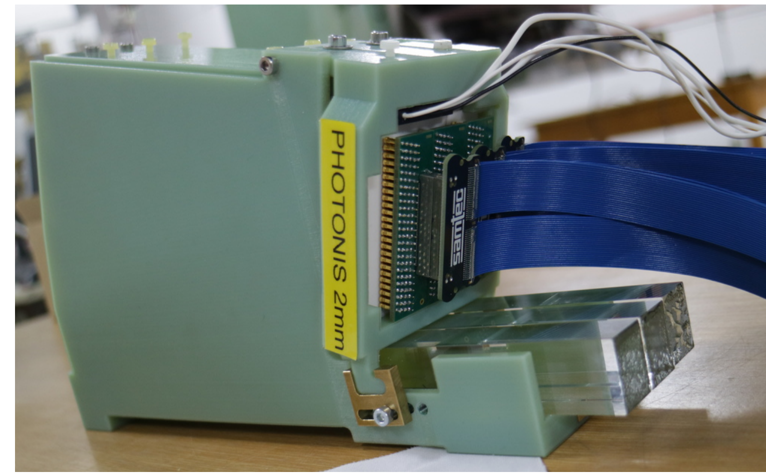


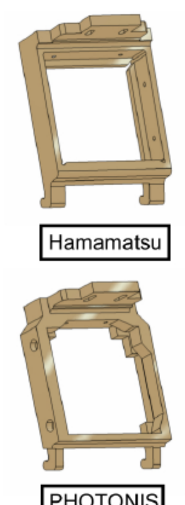


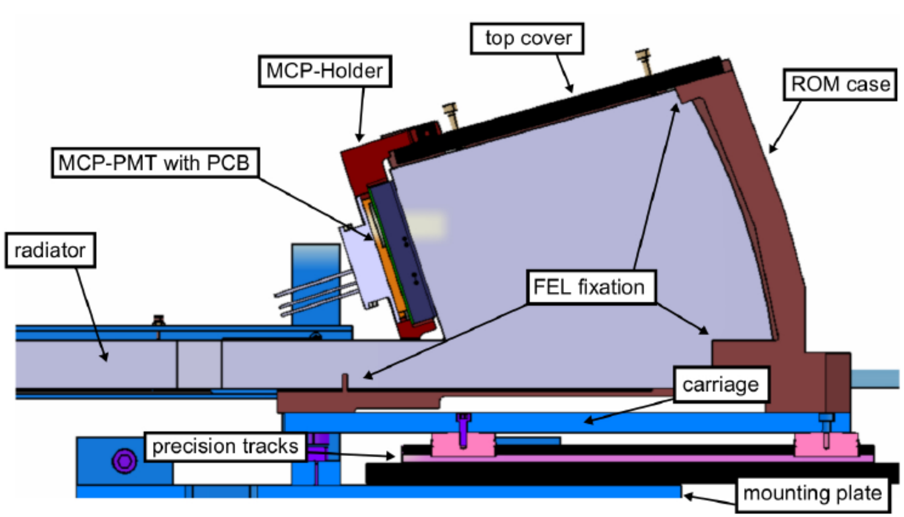
The radiator thickness determination is independent of several systematic errors.

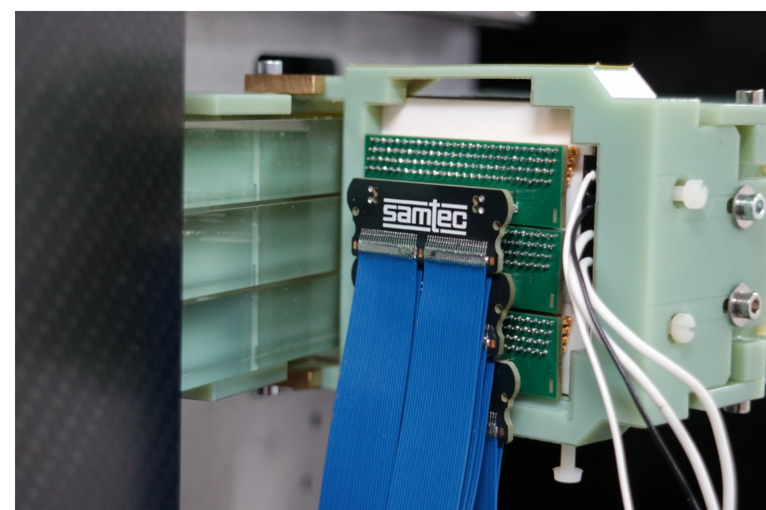
Optics – Focussing components





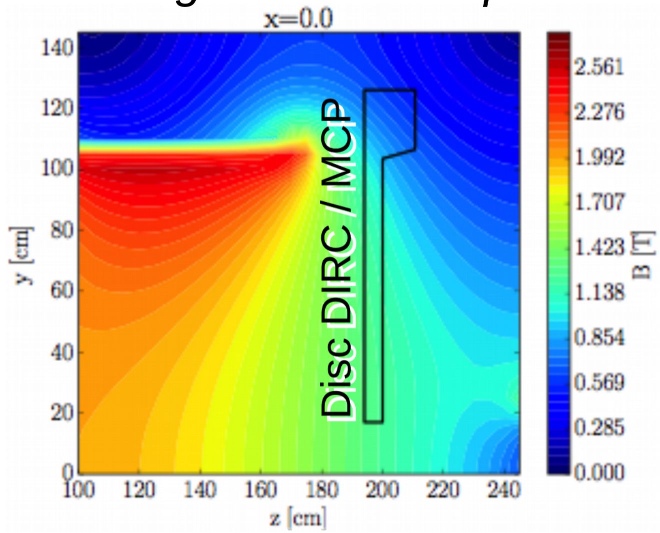




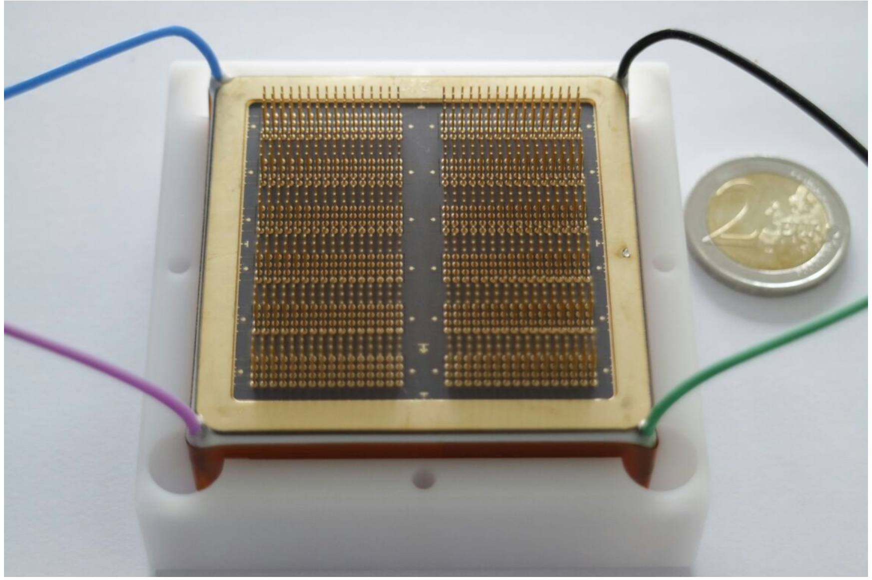


MCP-PMT sensors

magnetic field map



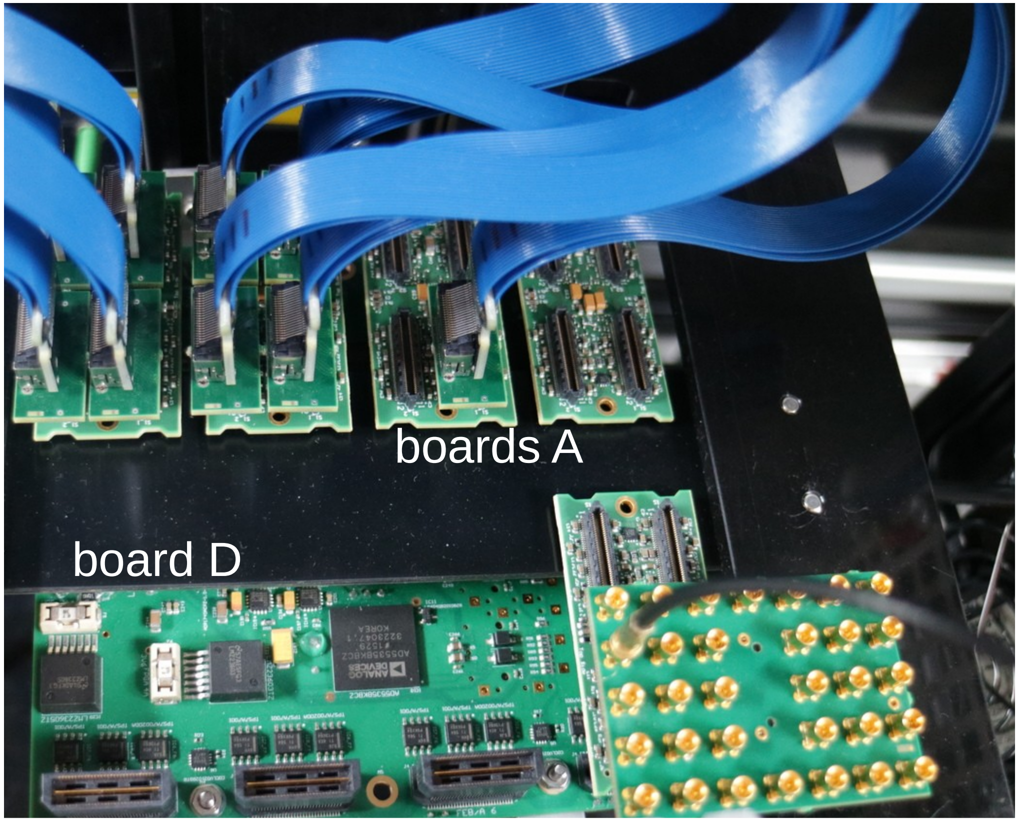
Hamamatsu MCP-PMT



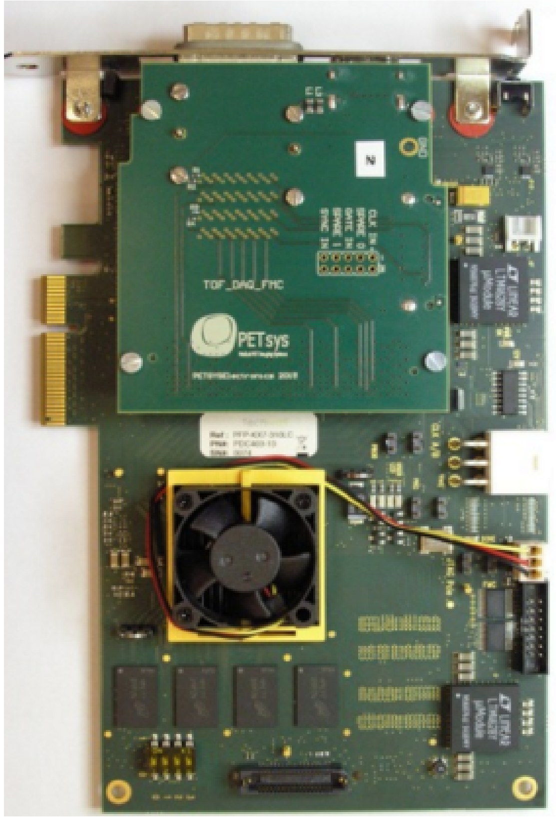
Challenges:

- Enhanced lifetime (7 C/cm² required)
- Wavelengths bandwidth-filtered >355 nm LP
  (reduced dispersion and enhanced tube lifetime)
- Magnetic field strength (≈1 T) and orientation
- Sensor 2 x 2 inch, pitch size < 0.5 mm
- Anode 3 x 100 strips or 6 x 128 strips

TOFPET readout for DAQ



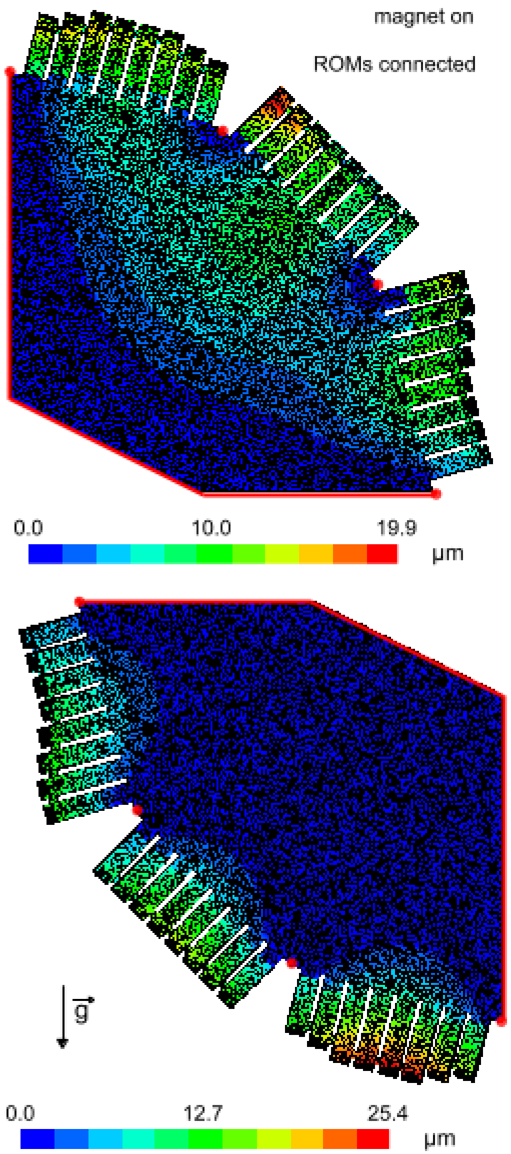
small TOFPET boards A, motherboard D, adapter boards



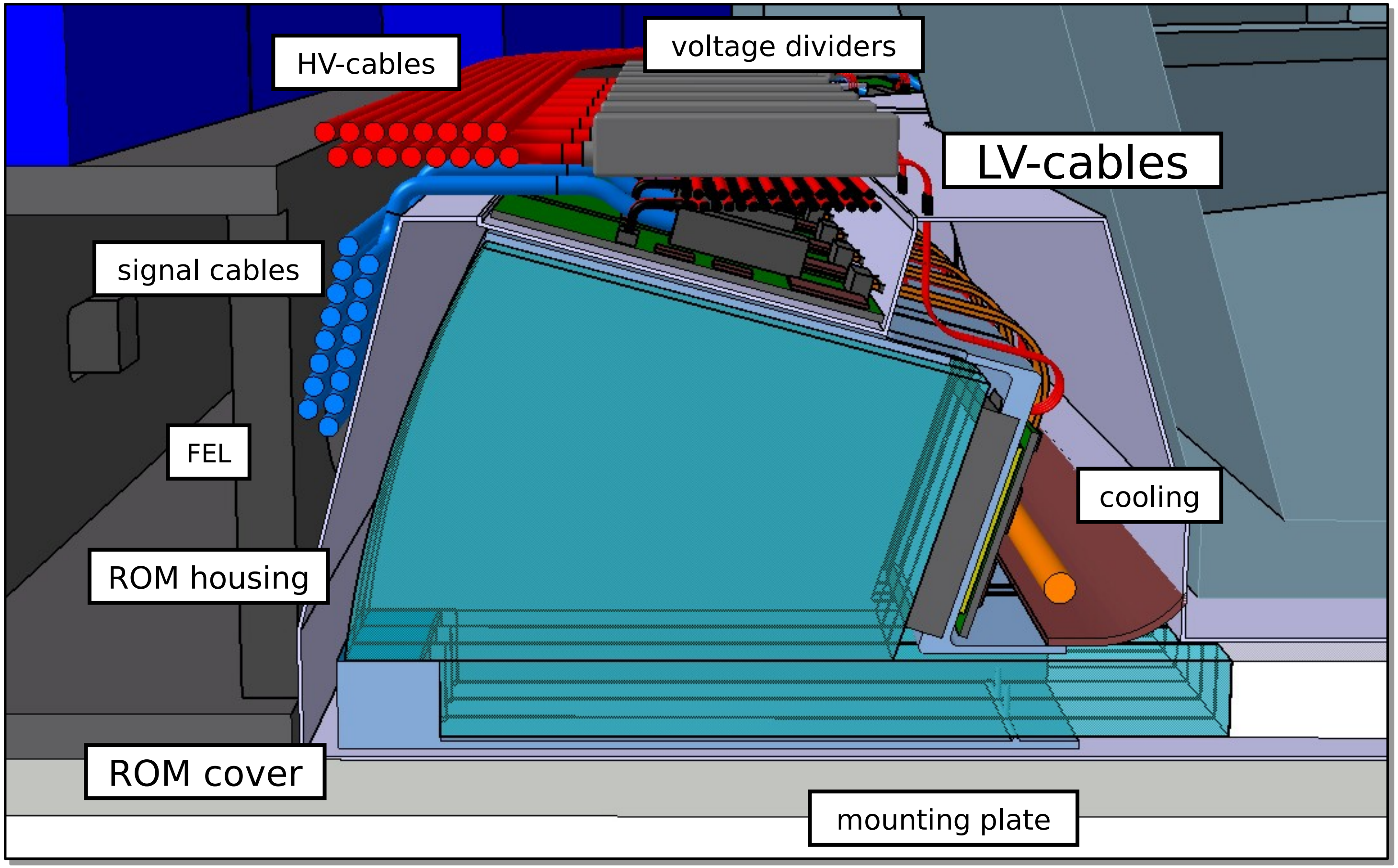
TOFPET DAQ board

- TOFPET ASIC (from PETSYS) holds discriminators and digitisation
- Free-running TDC system with time-over-threshold capability
- 128 channels per board A, 1024 channels per board D
- High density coaxial cables, adapter PCBs

Mechanical integration



FEM strain studies

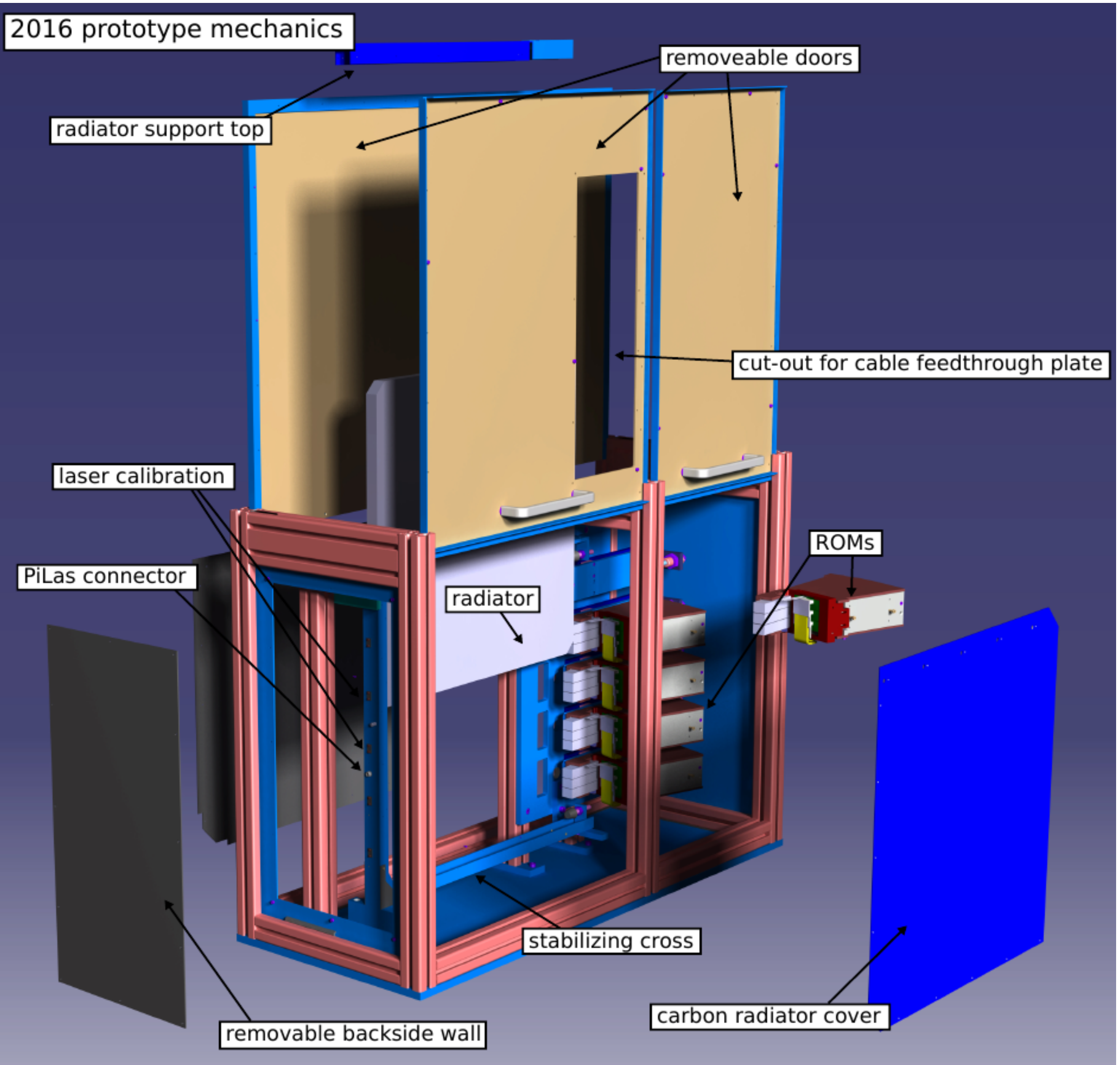


cutaway view from EDD CAD model

Test Beam at DESY T24 in October 2016

EDD Prototype

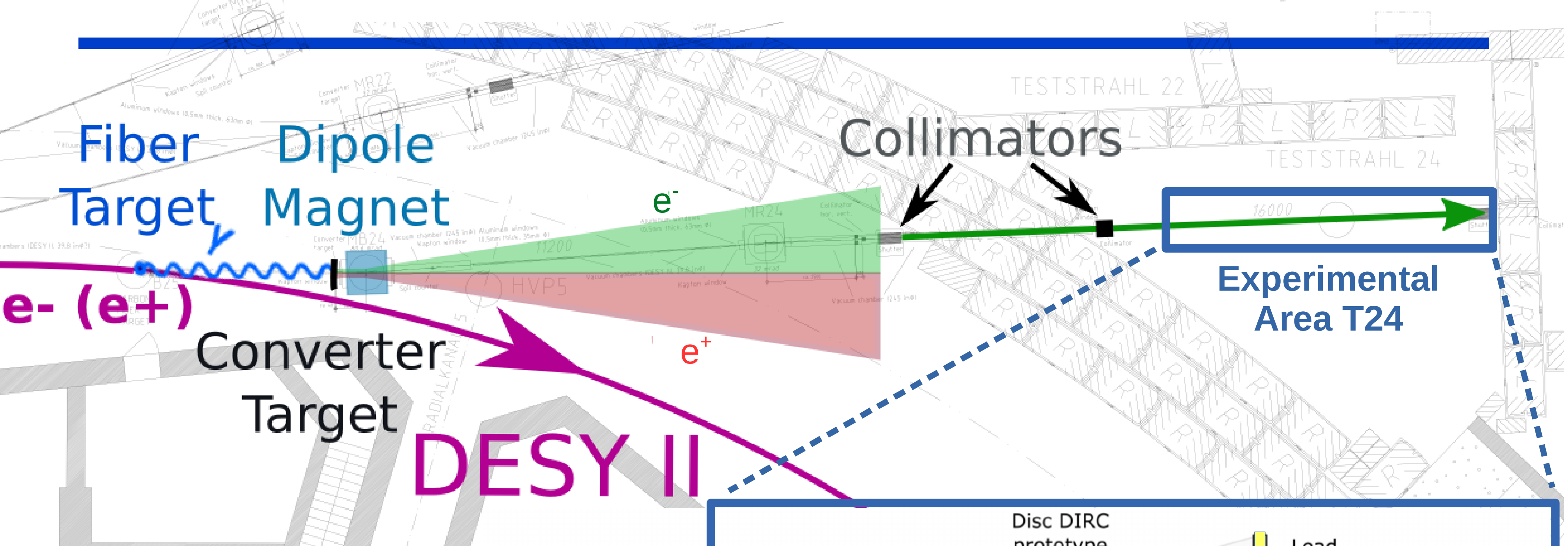
EDD 2016 prototype CAD 3D rendering



Prototype partially assembled.
View from ROM assembly side,
upstream side in DESY 2016 test.

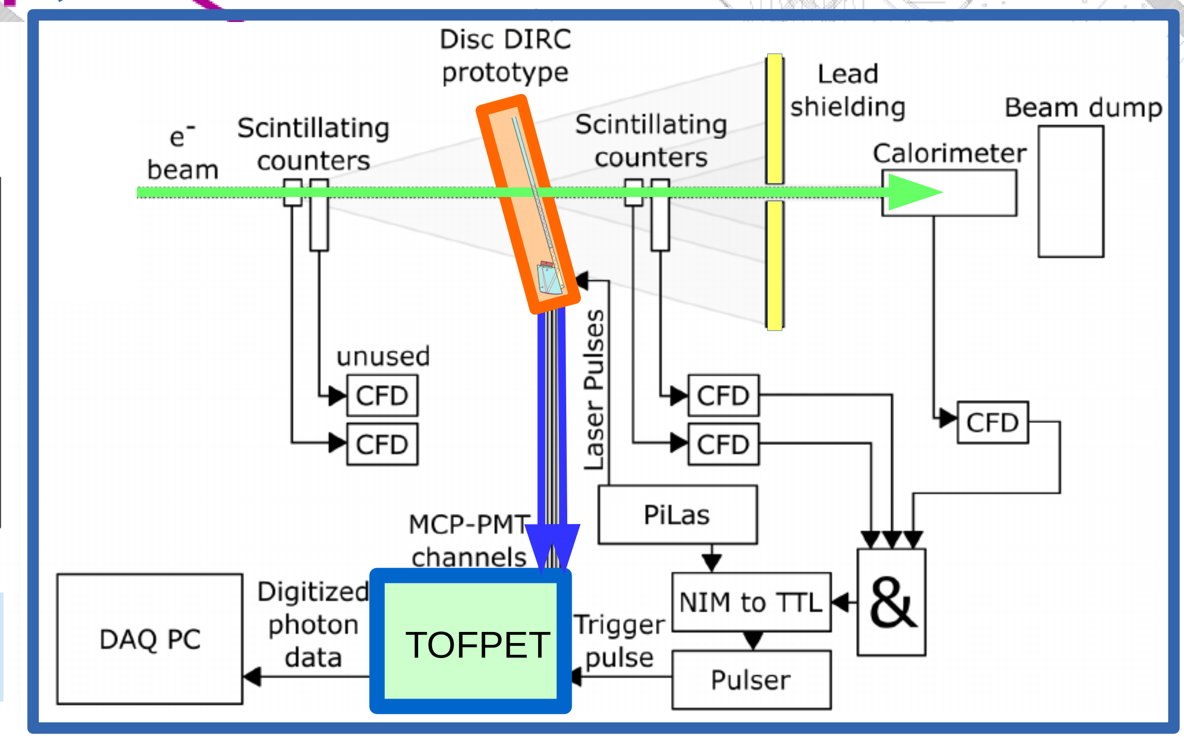
ROM with MCP in contact with quartz

Testbeam set-up at DESY



Beam characteristics

Spatial uncertainty of e^- on radiator	$\approx 5\,\mathrm{mm}$
Angular uncertainty of e^-	$\approx 1\,\mathrm{mrad}$
Beam momentum	$3\,\mathrm{GeV/c}$
Size of primary collimator	$5{\times}5\,\mathrm{mm}$
Size of secondary collimator	$15{\times}15\,\mathrm{mm}$

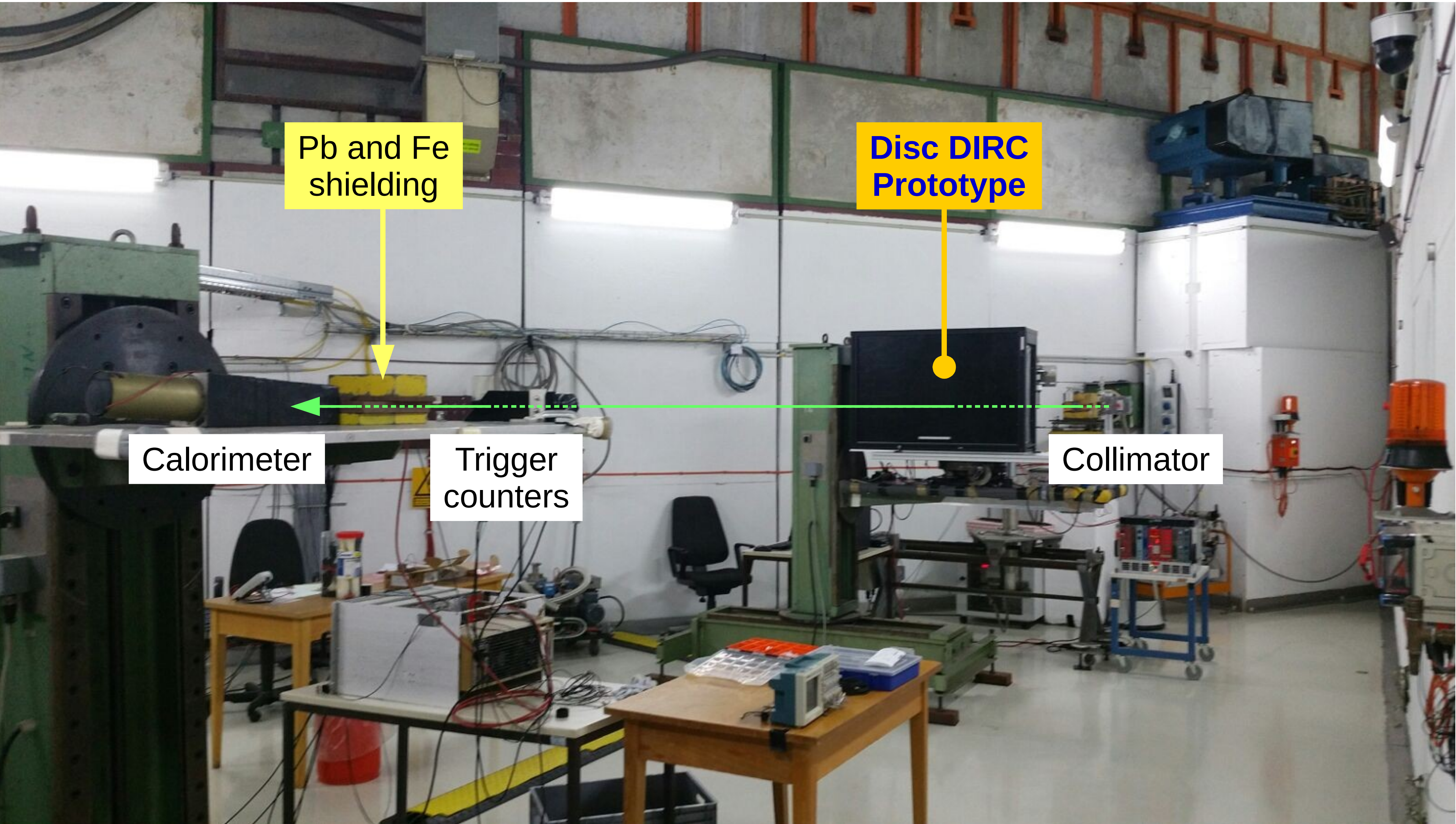


Thank you to DESY for the test beam possibility and the DESY colleagues for their kind support.

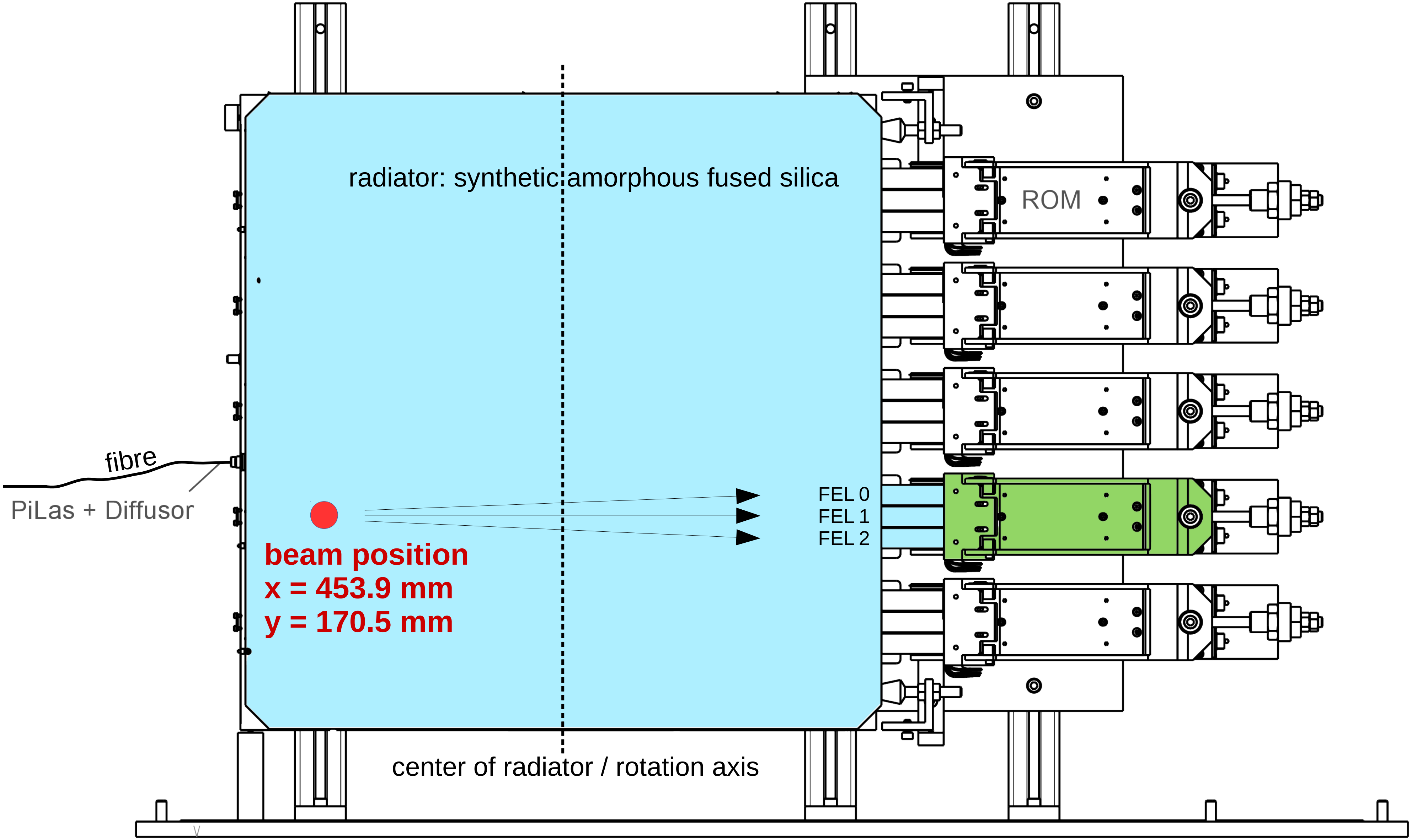
Testbeam at DESY – Teststrahl 24

Testbeam at DESY – Teststrahl 24

Area

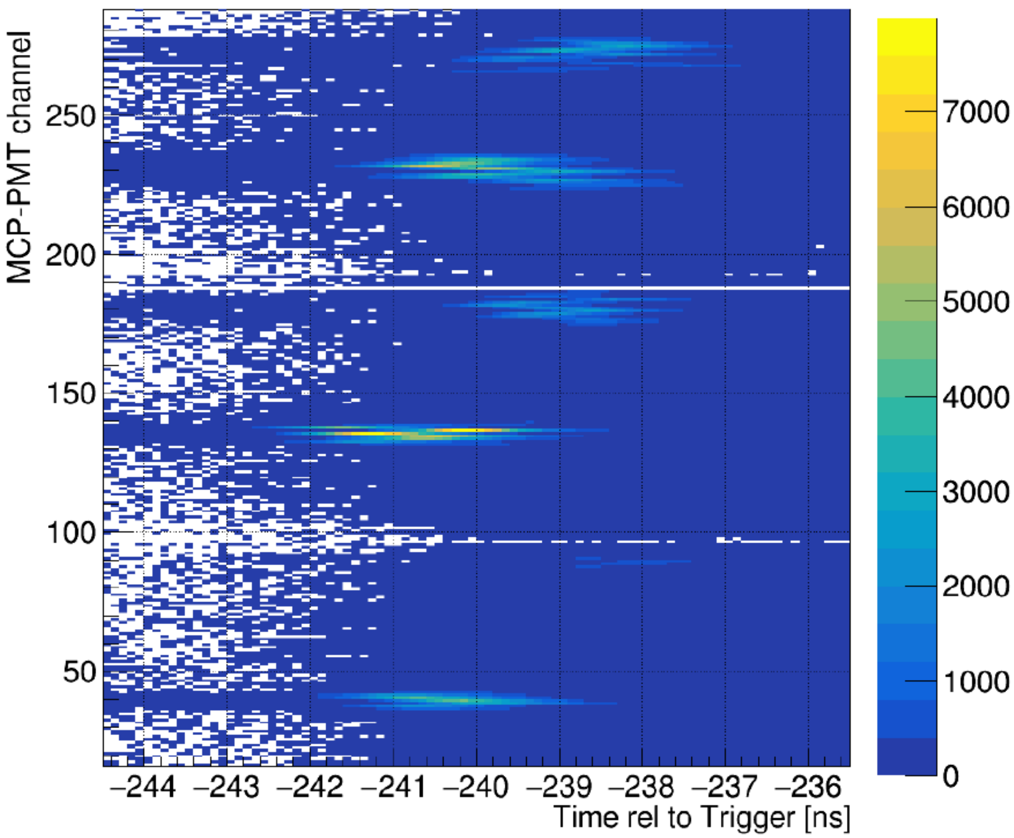


Beam positioning on radiator

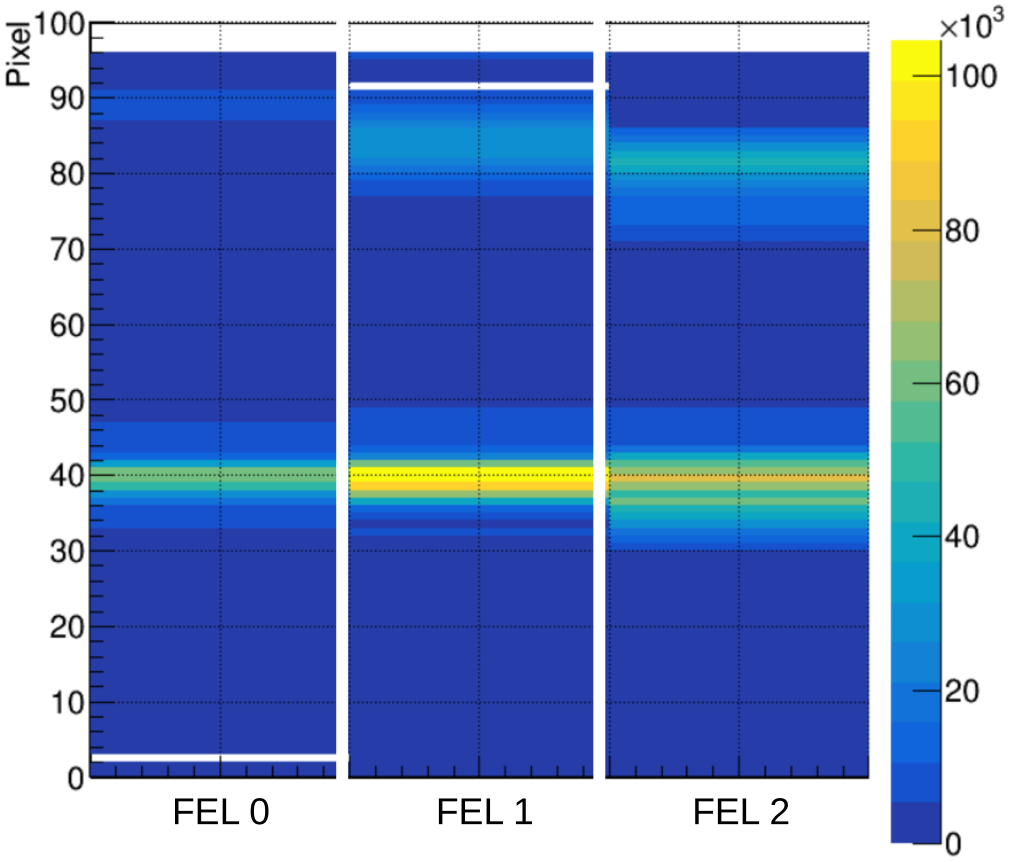


Raw time and position hit-patterns

Time (default time calibration used)

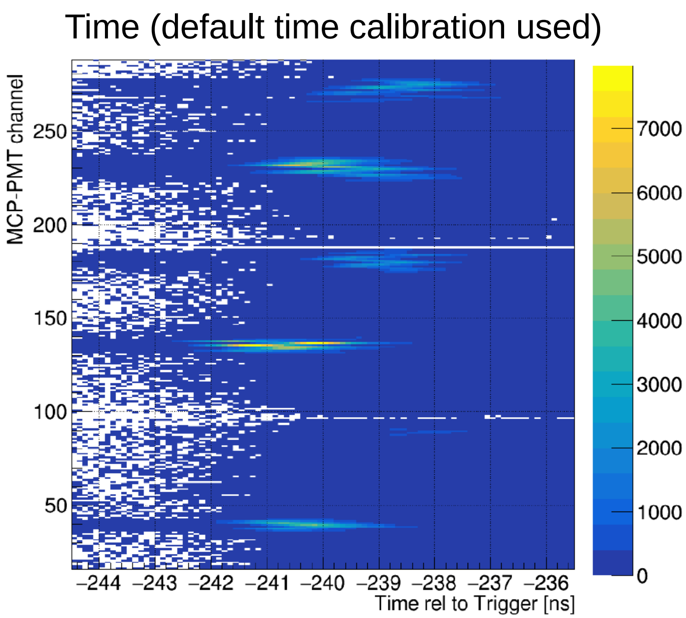


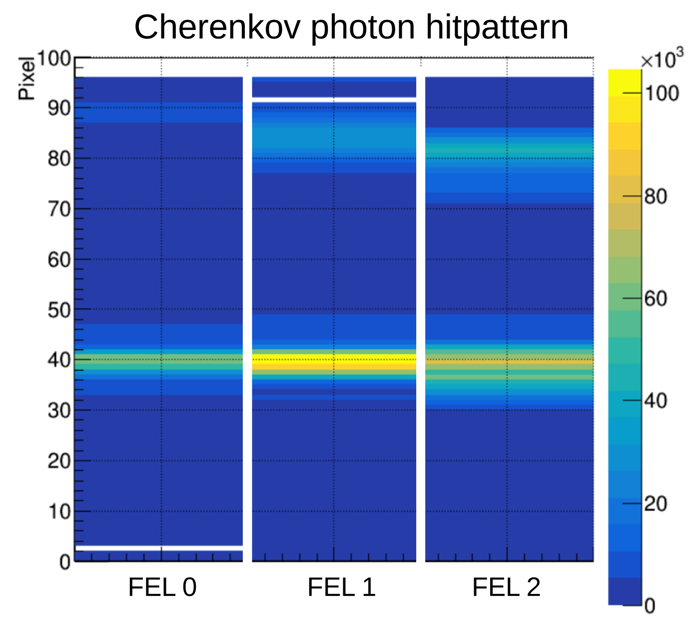
Cherenkov photon hit-pattern

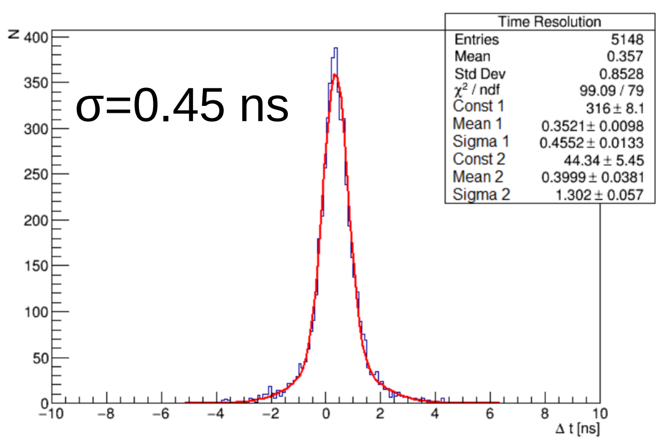


- radiator rotation θ = 14°
- > 1,000,000 triggers in 600 seconds

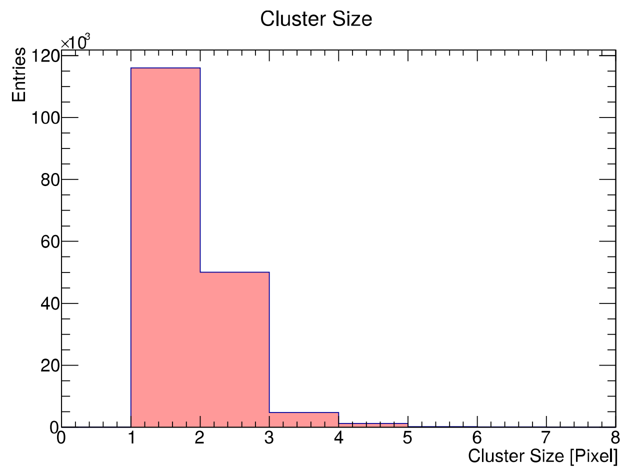
Checks on the raw data



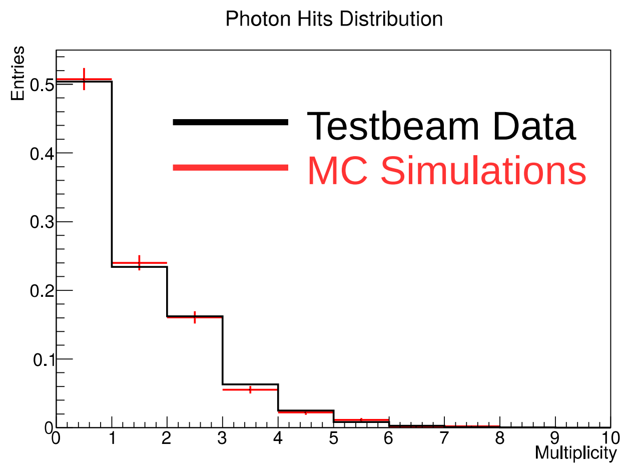




time difference choosing two non-adjacent pixels

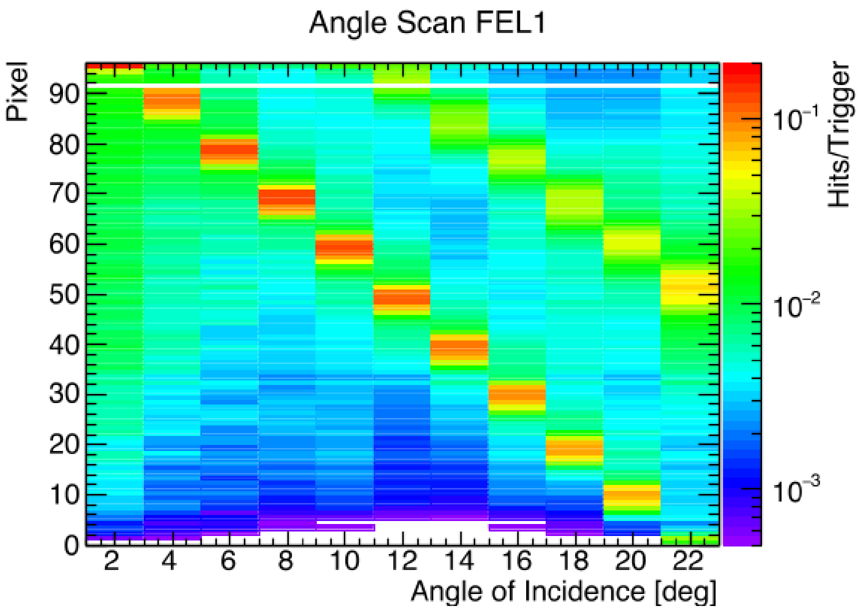


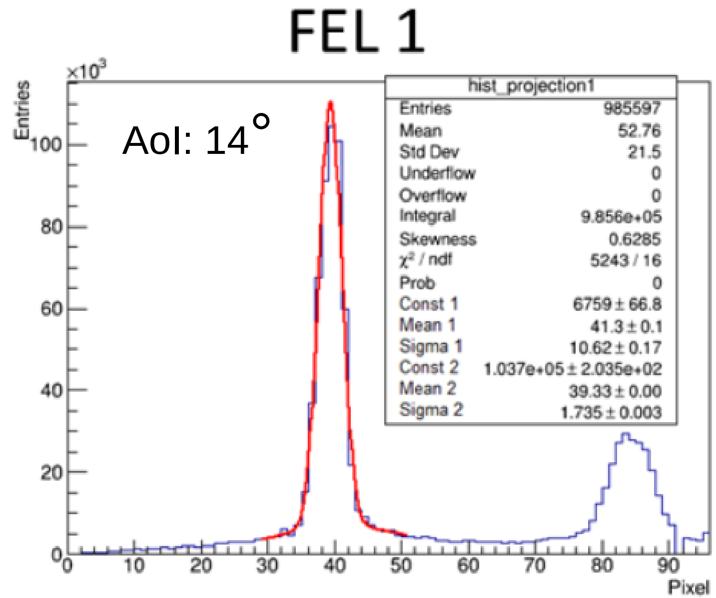
pixel cluster size histogram



pixel multiplicity histogram

Angle scan and resolution

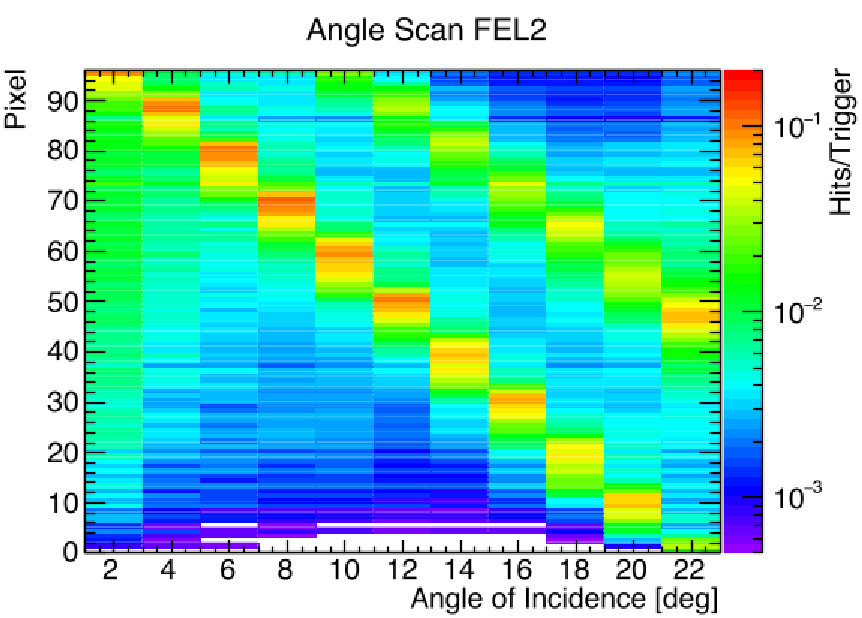


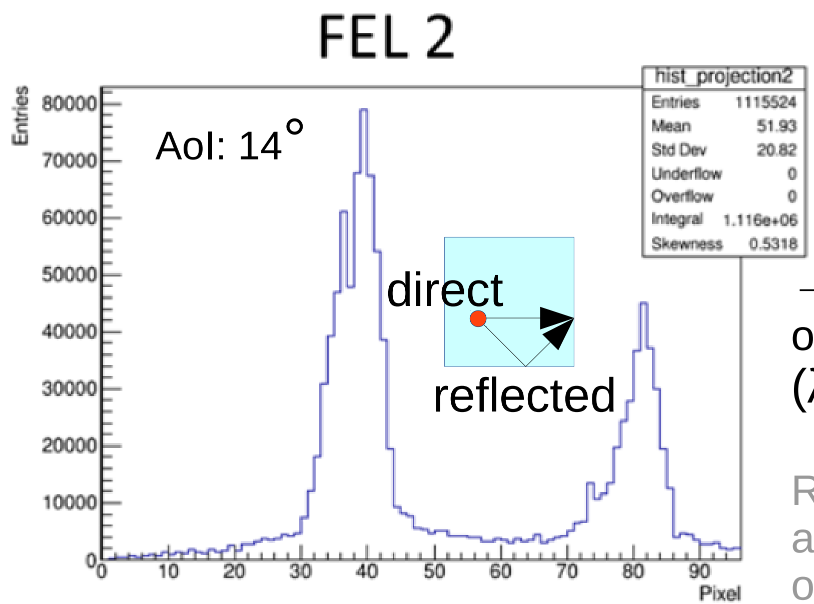


Epoxy glue seam edge filter effect (λ > 295 nm)

σ = 1.73 pixel
σ = 0.86 mm
σ = 6.1 mrad

chromatic dispersion rules angle resolution

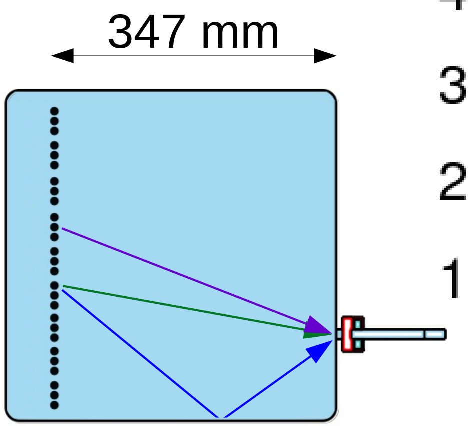


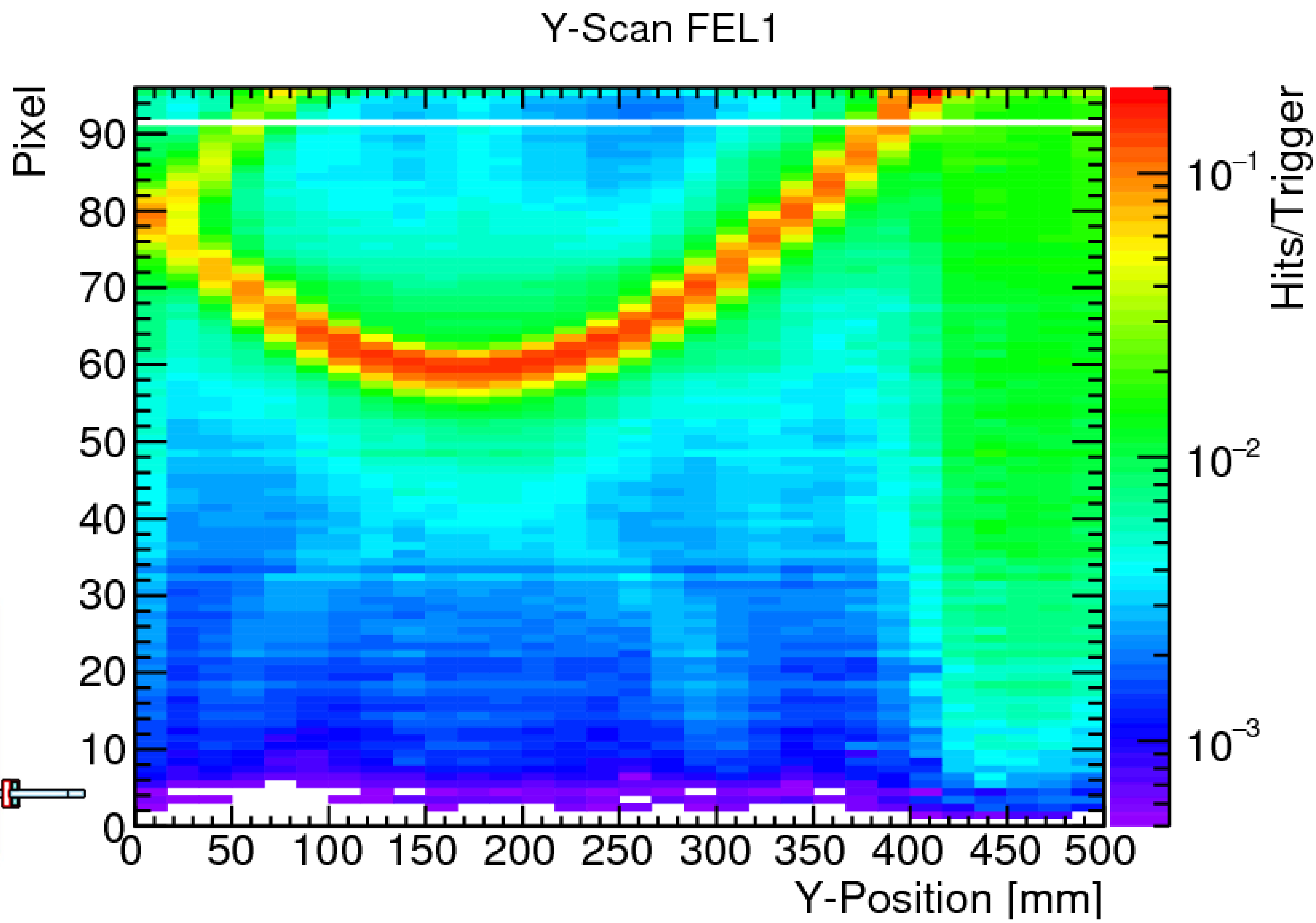


Optical contact bonding between prism and FEL
→full transmission of quartz & grease (λ > 220 nm)

Radiator-Prism angle mismatch of 1.5 mrad

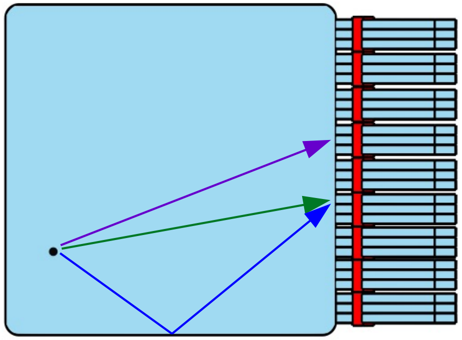
Vertical scan for one FEL

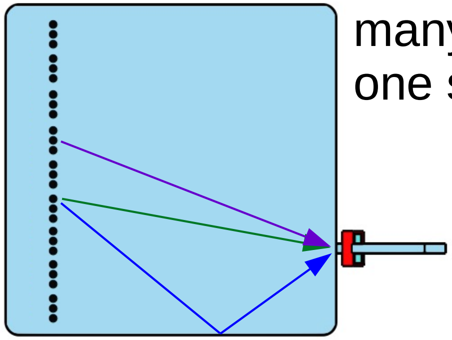




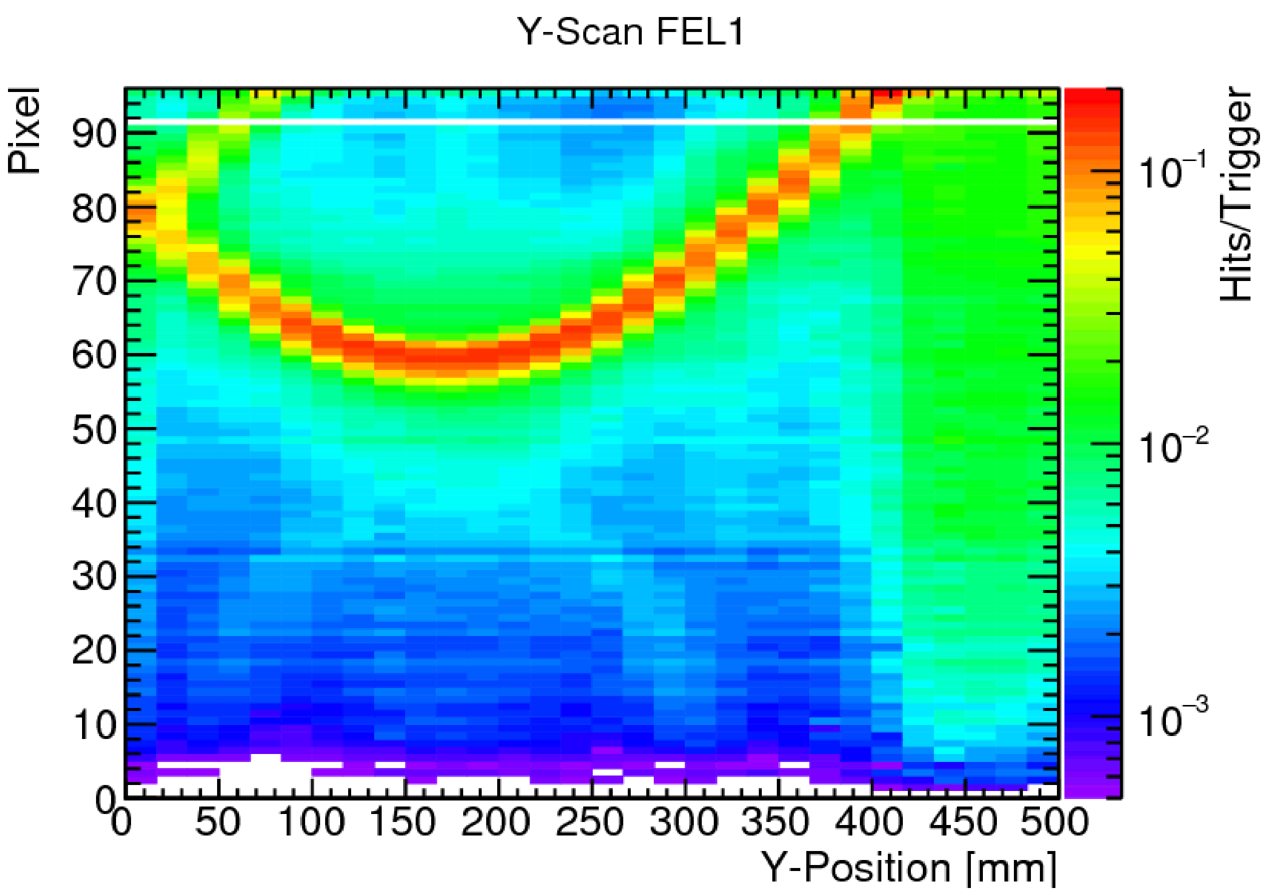
Combined events

one particle position
many ROM systems



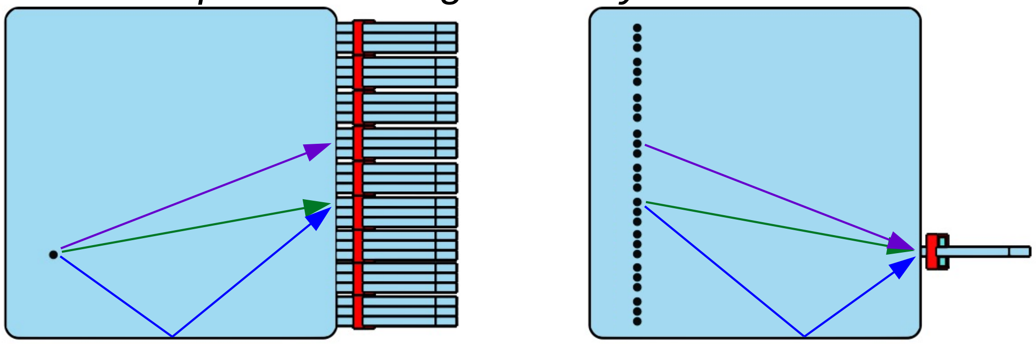


many particle positions
one single ROM system



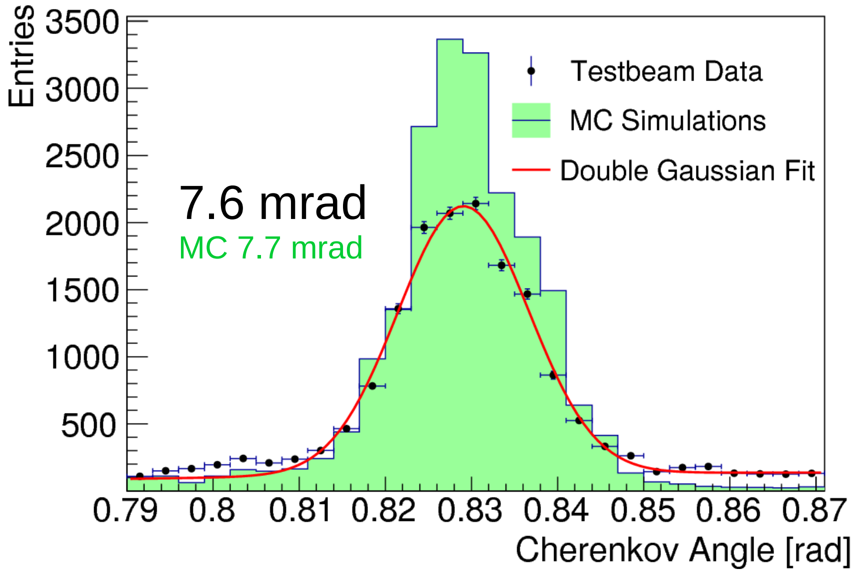
Combined events

obtain experimental signature by vertical scan



	from data	***MC sample***
• Photon hit multiplicity:	**24**	26
• Single photon resolution:	**7.57** mrad	7.66 mrad

(determined from pixel hit distribution)

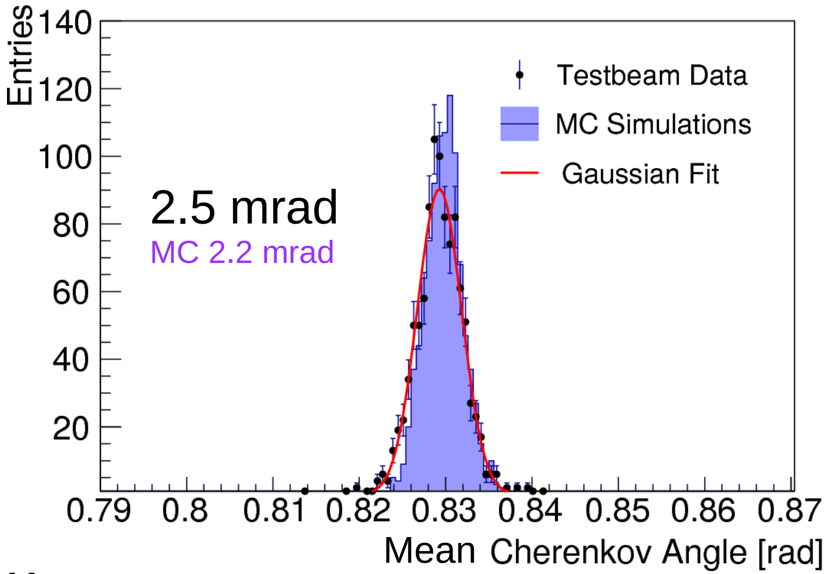


N.B. Cherenkov angle determined from pixel hit positon

- Combining events from different runs of scan creates a data sample which simulates the performance of a fully equipped prototype

- Truncating method selecting hits in ±3σ interval

	from data	***MC sample***
• #Selected hits (average):	13	18
• Single photon resolution:	**2.52** mrad	2.16 mrad



Summary

- PANDA Endcap Disc DIRC Design
  - Large area quartz, custom MCP-PMTs, small volume electronics
- Prototype for PANDA Endcap Disc DIRC
  - Dedicated quartz optical elements
  - High spatial resolution MCP-PMTs (Photonis, Hamamatsu)
  - DAQ system based on TOFPET ASIC (PETSYS)
  - Optimised mechanical set-up
- Test beam (electrons) at DESY in October 2016
  - Cherenkov angle resolution $\sigma = 6.1$ mrad
    - dominated by chromatic dispersion
    - Full apparatus wavelength range $\lambda > 295$ nm (no discrete filter used)
- Test beam results agree with MC-Simulations

→ cf. talk by M. Schmidt this afternoon


THANK YOU