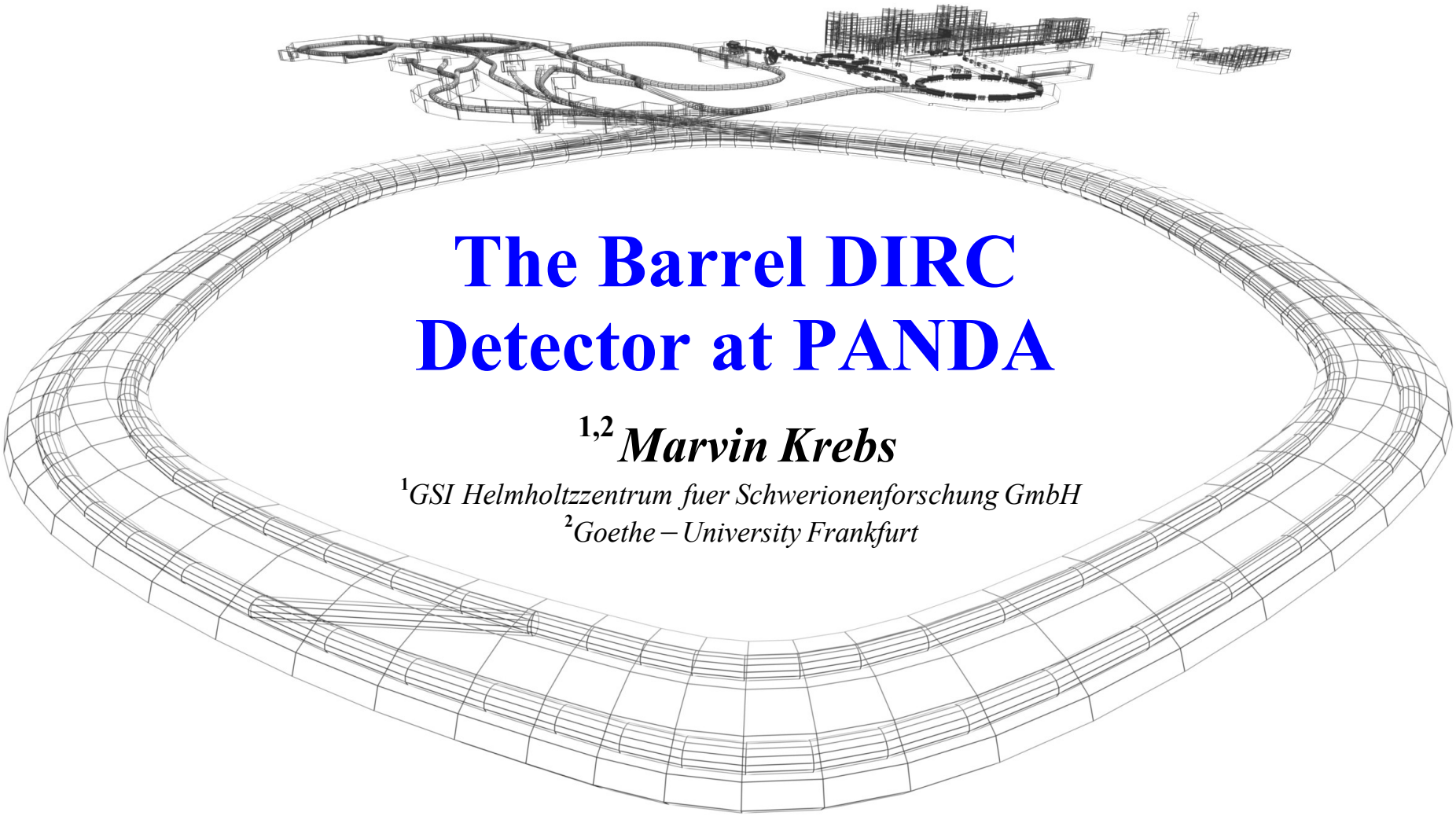


The Barrel DIRC Detector at PANDA

[1,2] *Marvin Krebs*

[1] *GSI Helmholtzzentrum fuer Schwerionenforschung GmbH*

[2] *Goethe – University Frankfurt*

Outline

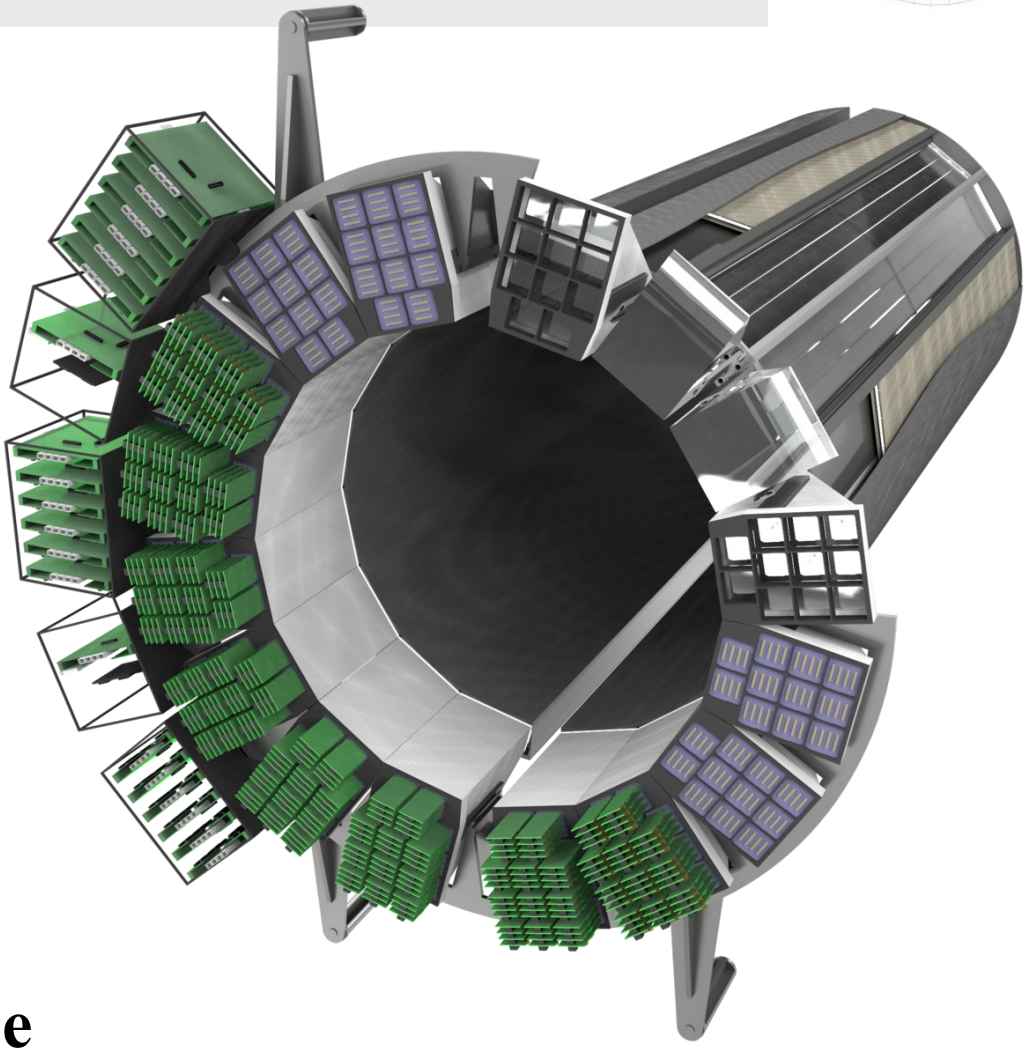
I. PANDA detector system

II. The Barrel DIRC detector

III. DIRC principle

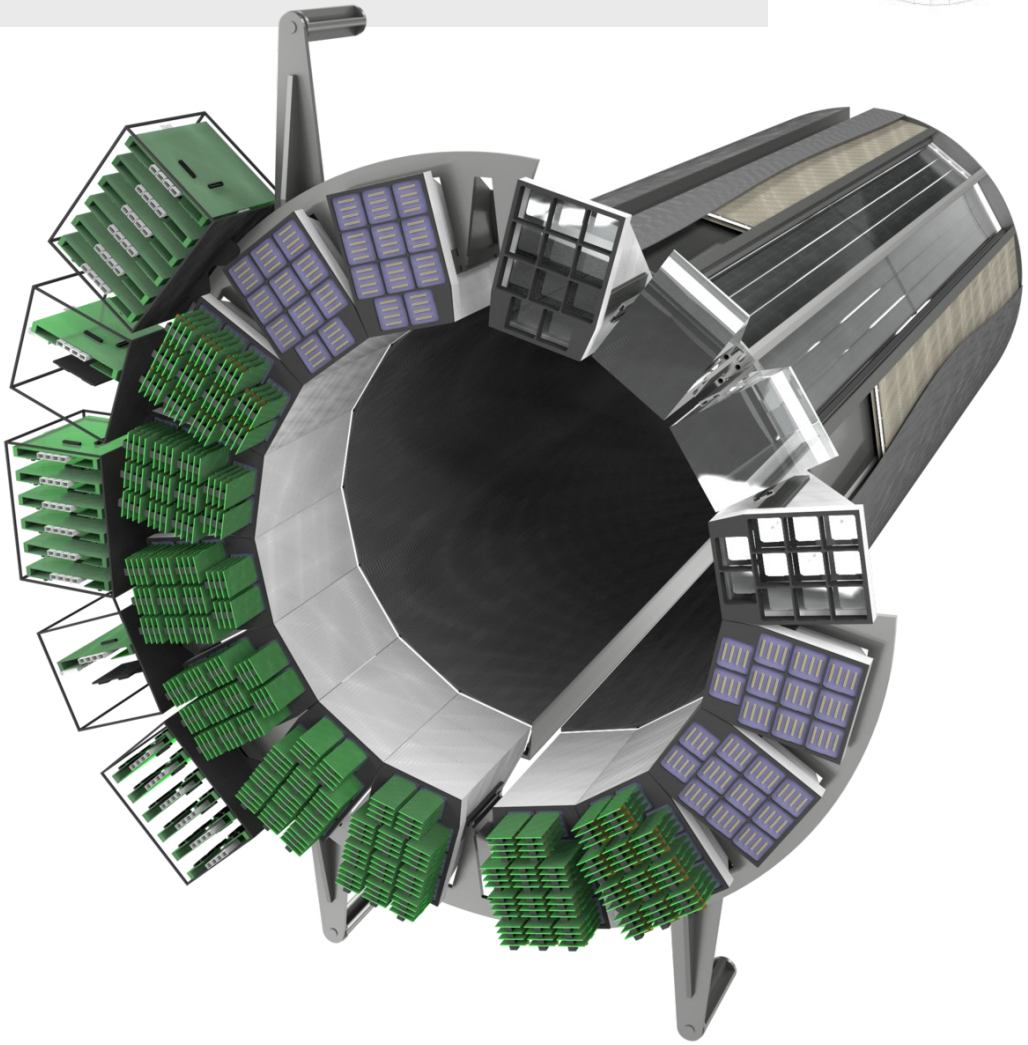
IV. Barrel DIRC optics

V. Prototype performance

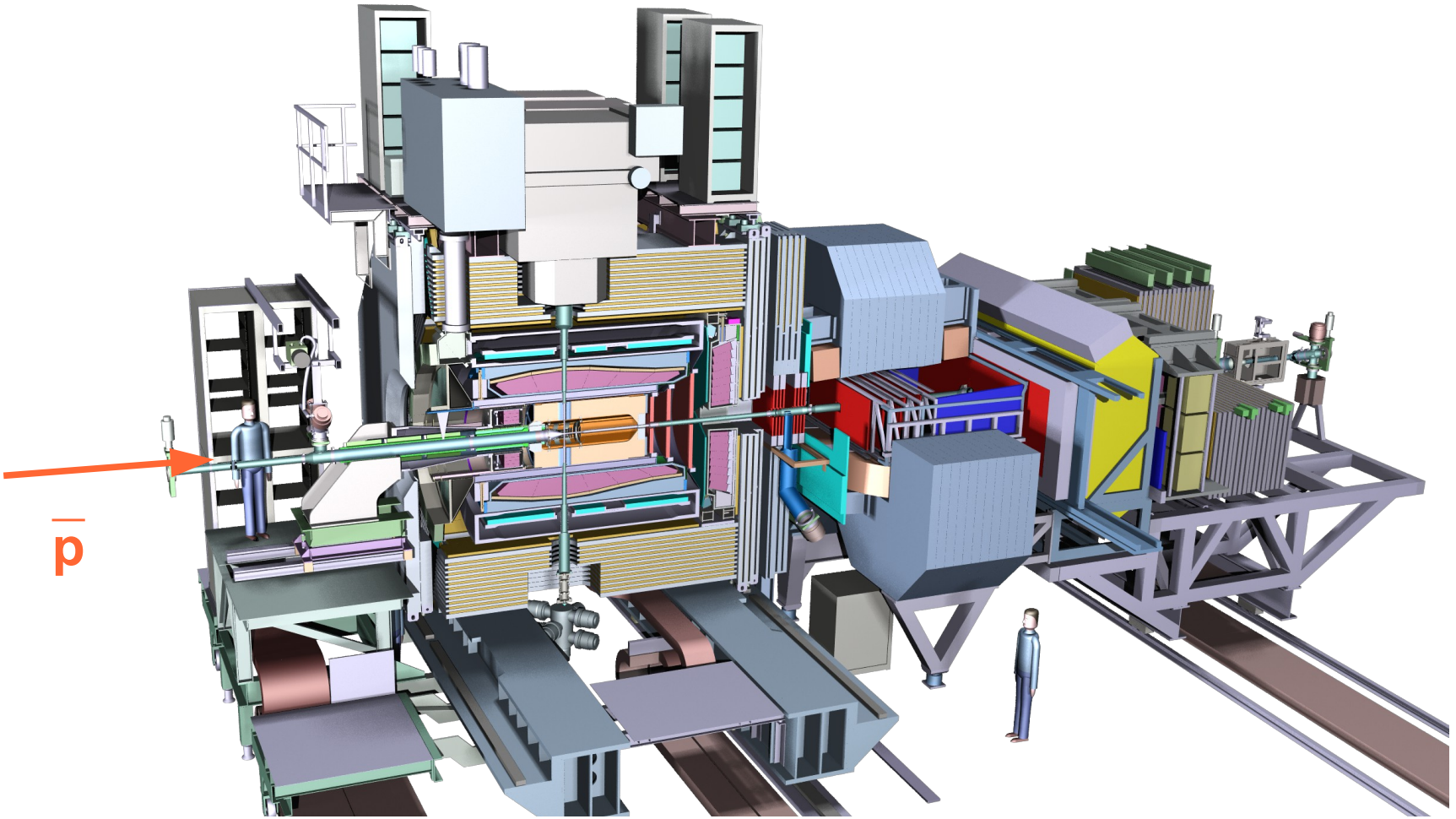


Outline

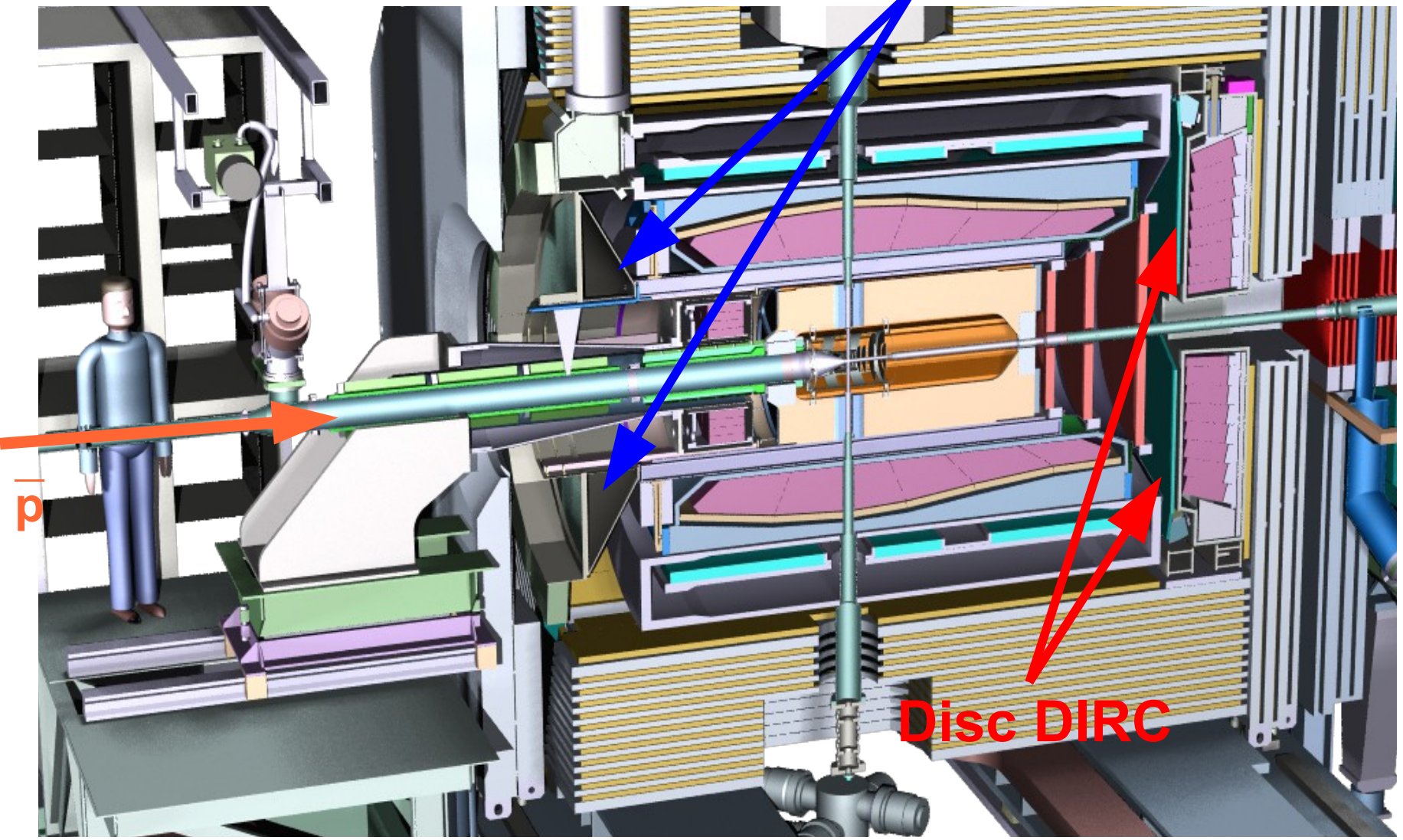
I. PANDA detector system



PANDA detector system

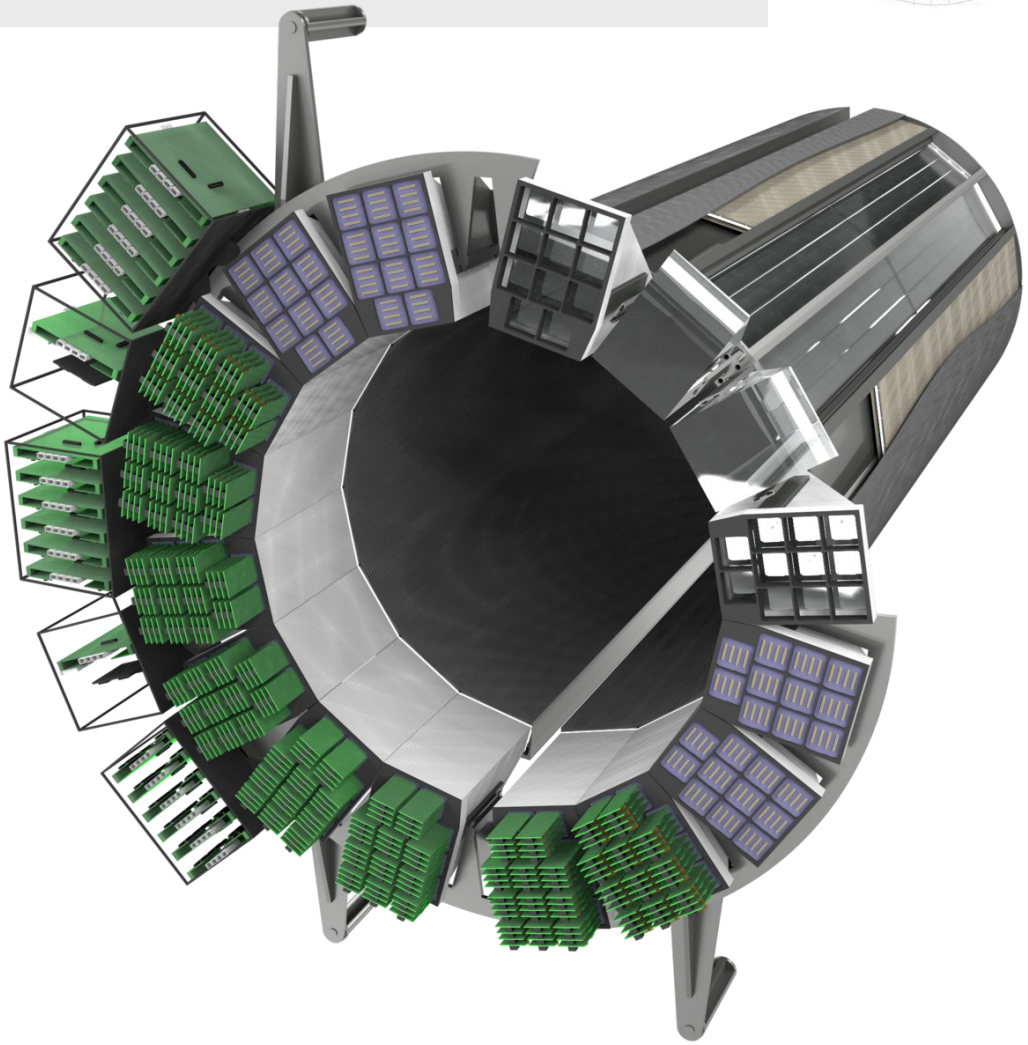


PANDA detector system



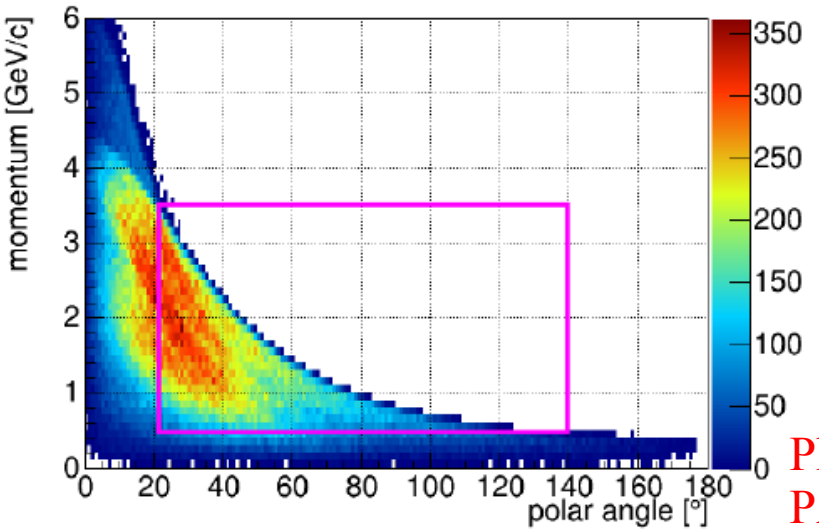
Outline

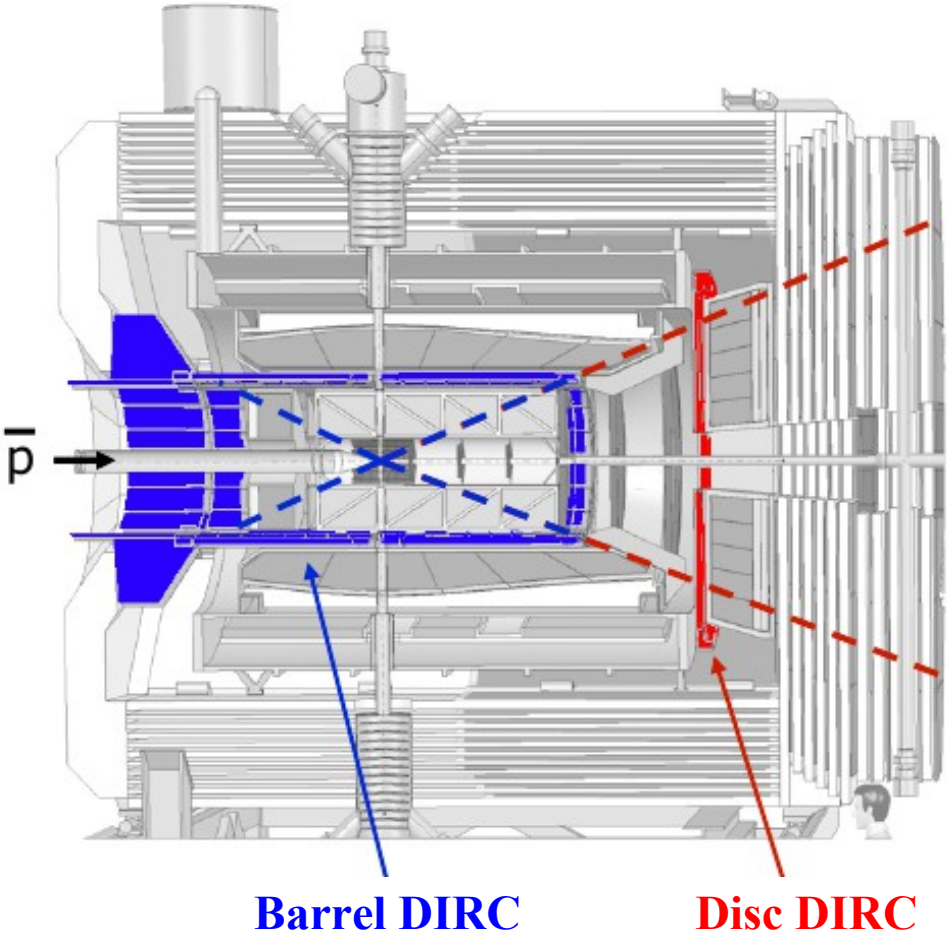
II. The Barrel DIRC detector



Target spectrometer

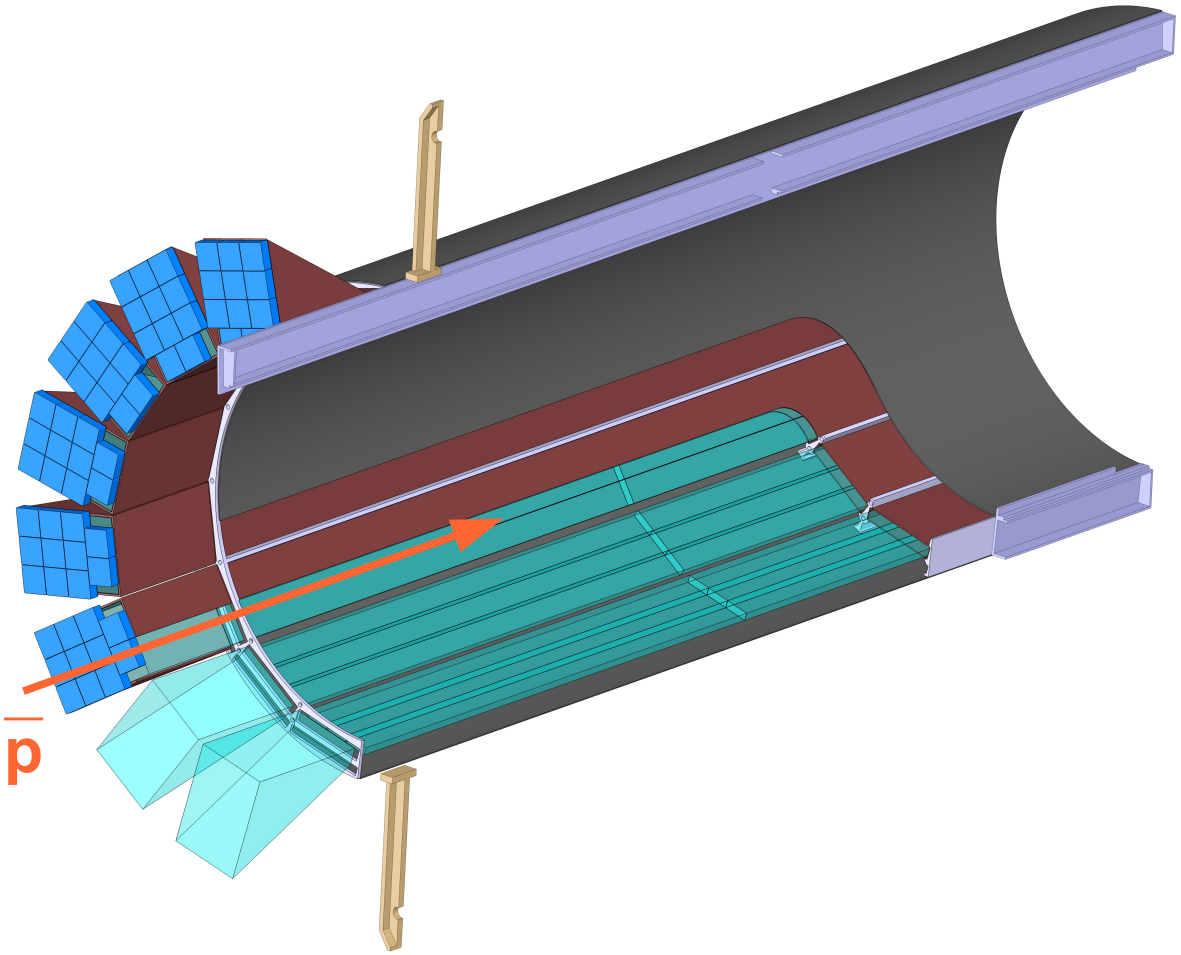
- **D**etection of **I**nternally **R**eflected **C**herenkov light
- PID of charged hadrons in the TS of PANDA
- Polar angle range from 22°-140°
- momentum range: 0.5 – 3.5 GeV/c





Phase space distribution for kaons from several PANDA benchmark channels

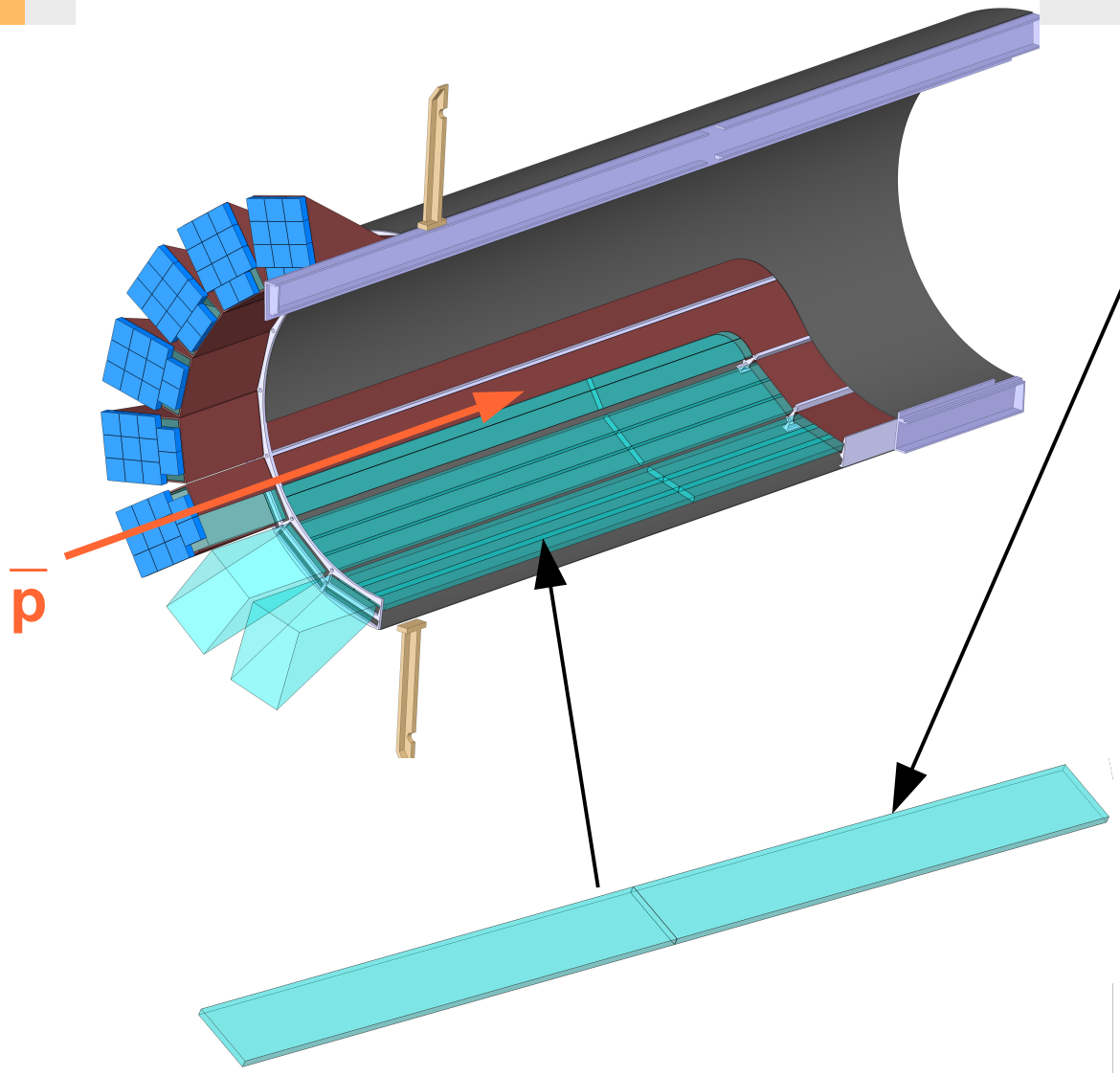
The Barrel DIRC detector



Baseline design:

- 16 segments (bar boxes), with 3 radiators each
- Radiators, synthetic fused silica, dimensions:
  2400 mm x 53 mm x 17 mm (L x W x T)
- Focusing optics for each radiator
- Synthetic fused silica prism, one per bar box
- 176 micro channel plate photomultiplier tubes (MCP-PMTs) in total

The Barrel DIRC detector

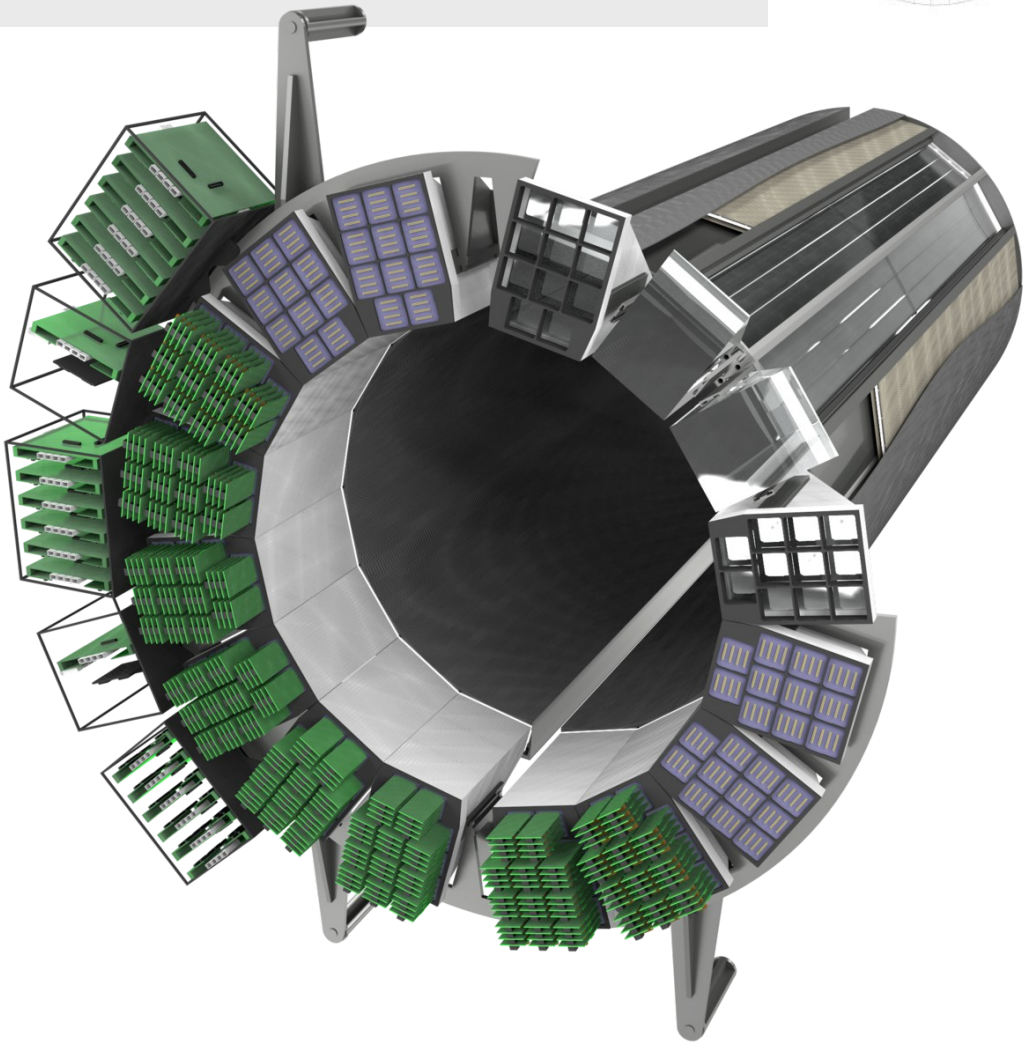


Cost-saving option:

- 16 segments (bar boxes), with 1 wide plate each
- Synthetic fused silica, dimensions:
  2400 mm x 160 mm x 17 mm (L x W x T)
- Focusing optics for each radiator
- Synthetic fused silica prism, one per bar box
- 176 micro channel plate photomultiplier tubes (MCP-PMTs) in total

Outline

III. DIRC principle



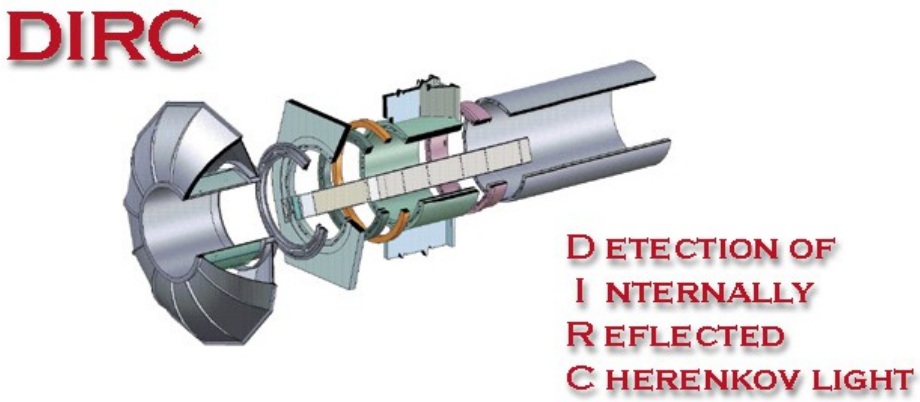
DIRC principle

Detection of Internally Reflected Cherenkov Light

Novel type of Ring Imaging CHerenkov detector *(first proposed in 1992[§])*
based on total internal reflection of Cherenkov light.

Used for the first time in BABAR (SLAC) for hadronic particle ID (1999-2008 in factory mode).

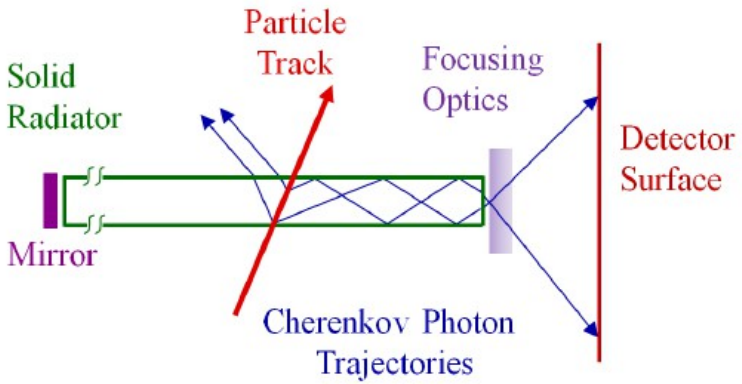
Success of BABAR DIRC prompted R&D for SuperB, Belle II, PANDA, LHCb, GlueX, EIC, ...



[§]*B.N. Ratcliff, SLAC-PUB-6047 (Jan. 1993)*

DIRC principle

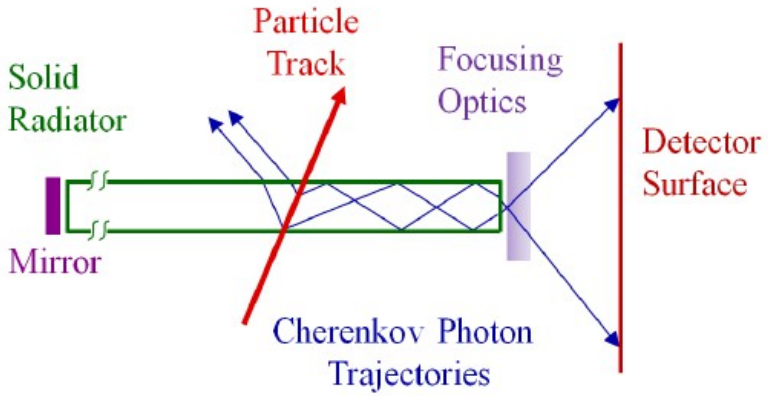
- Charged particle traversing radiator with refractive index n with $\beta = v/c > 1/n$ emits Cherenkov photons on cone with half opening angle $\cos \theta_c = 1/\beta n(\lambda)$.



- For $n>\sqrt{2}$ some photons are always totally internally reflected for $\beta \approx 1$ tracks.
- Radiator and light guide: bar, plate, or disk made from Synthetic Fused Silica ("Quartz") *(could be fused quartz or acrylic glass or ...)*
- Magnitude of Cherenkov angle conserved during internal reflections (provided optical surfaces are square, parallel, highly polished)
- Mirror attached to one bar end, reflects photon back to readout end.

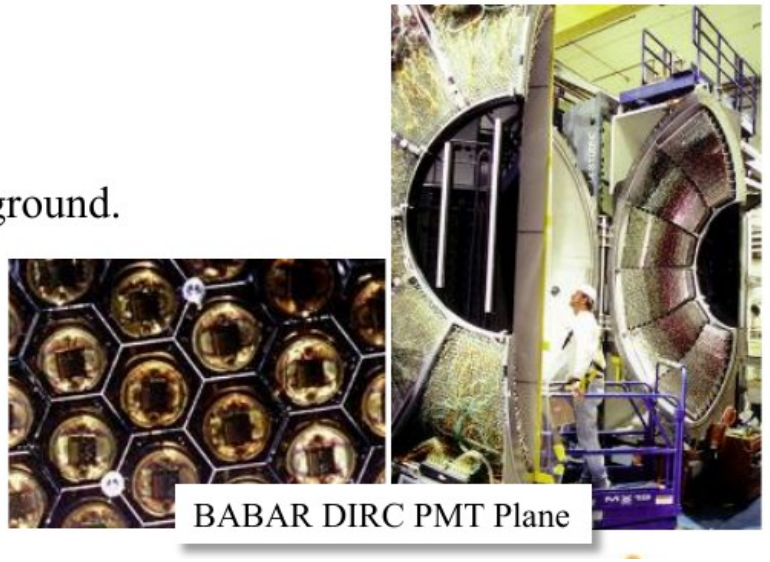
DIRC principle

- Photons exit radiator via optional focusing optics into expansion region, detected on photon detector array.



- DIRC is intrinsically a 3-D device, measuring: x, y, and time of Cherenkov photons, defining θ_c, ϕ_c, $t_{propagation}$.

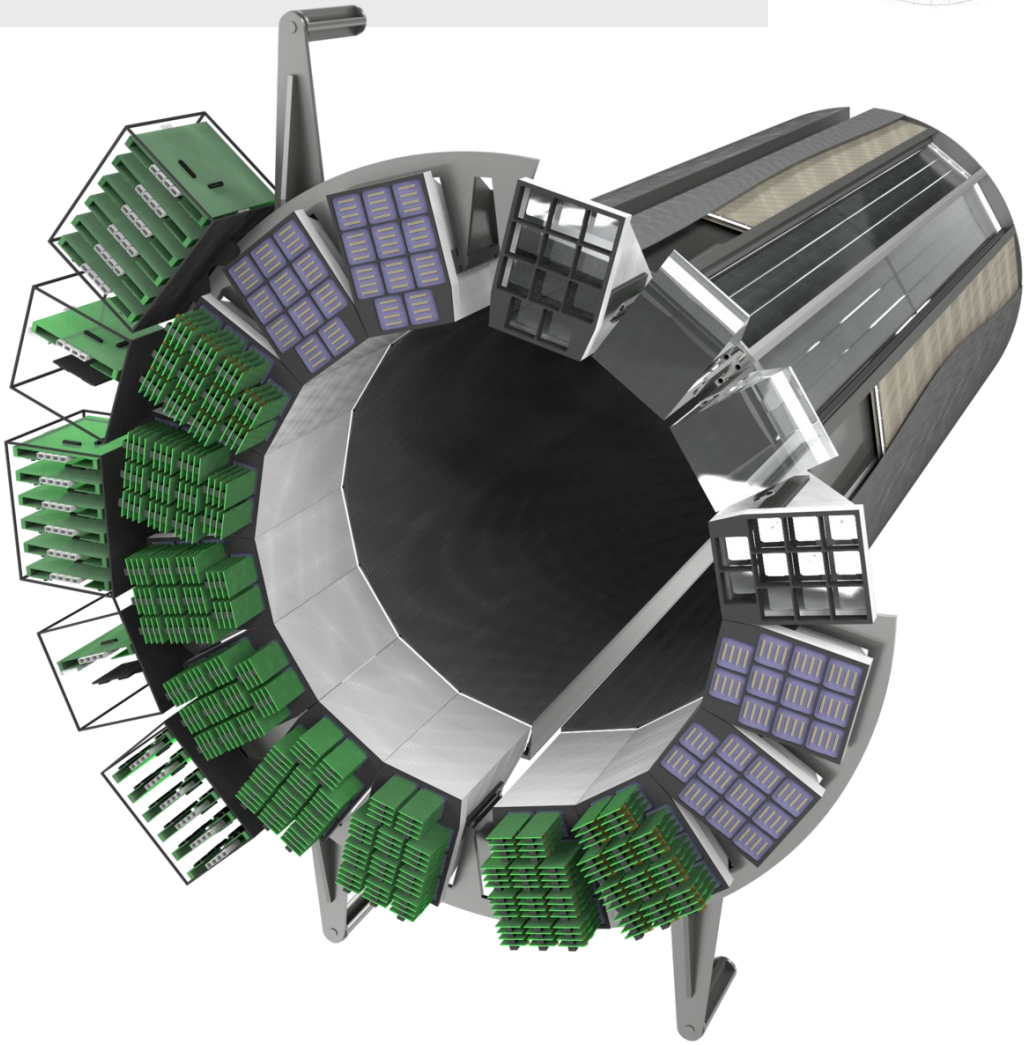
- Ultimate deliverable for DIRC: PID likelihoods.
  Calculate likelihood for observed hit pattern
  (in detector space or in Cherenkov space)
  to be produced by e/μ/π/K/p plus event/track background.


BABAR DIRC PMT Plane

Detailed review of the BABAR DIRC:
Nucl. Instr. Methods A 538 (2005) 281-357

Outline

IV. Barrel DIRC optics



Barrel DIRC optics

Optical components used in the Barrel DIRC

→ Radiator prototype program with industry partners in Europe, USA, Japan;

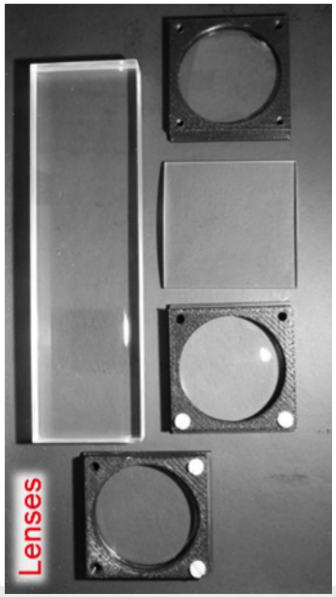
~30 bars/plates produced by 8 companies using different materials and techniques (pitch polishing, abrasive polishing, even new idea: extrusion and flame polishing).

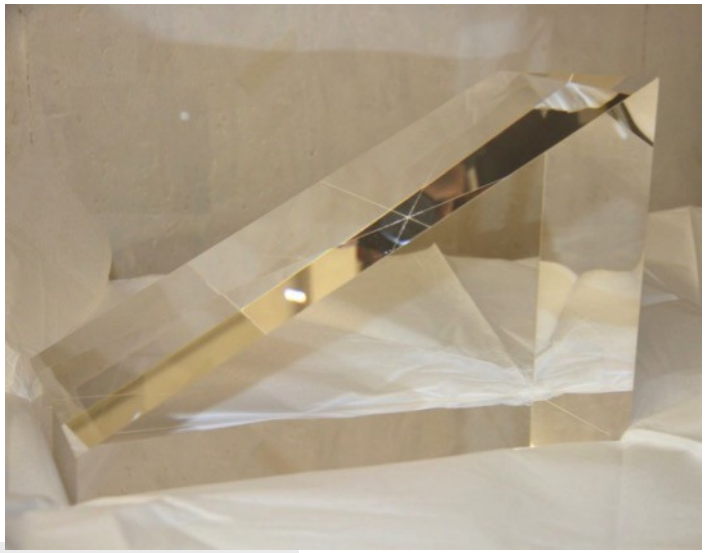
→ AOS/Okamoto, InSync, Nikon, Zeiss, Zygo; *Heraeus, Lytkarino LZOS, Schott Lithotec*.

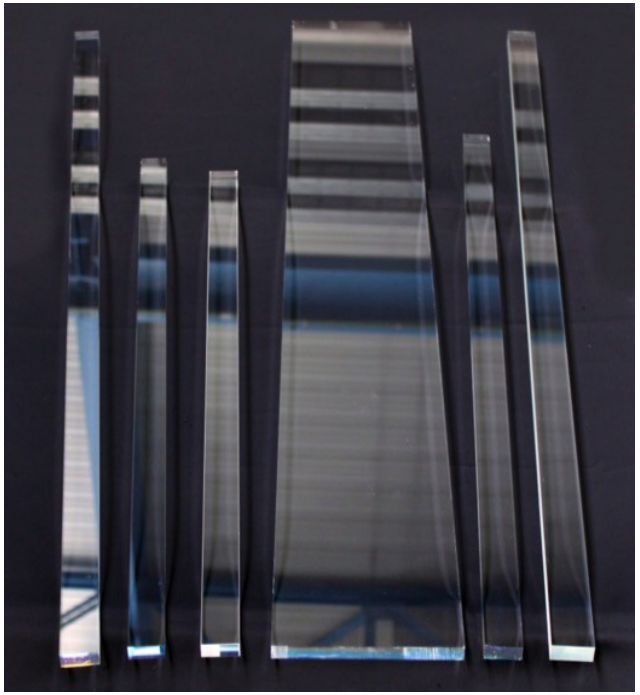
→ Two solid fused silica prism prototypes (30° and 45° top angle) built by industry.

→ Designed several spherical and cylindrical lenses,

with and without air gap, prototypes built by industry.







Barrel DIRC optics

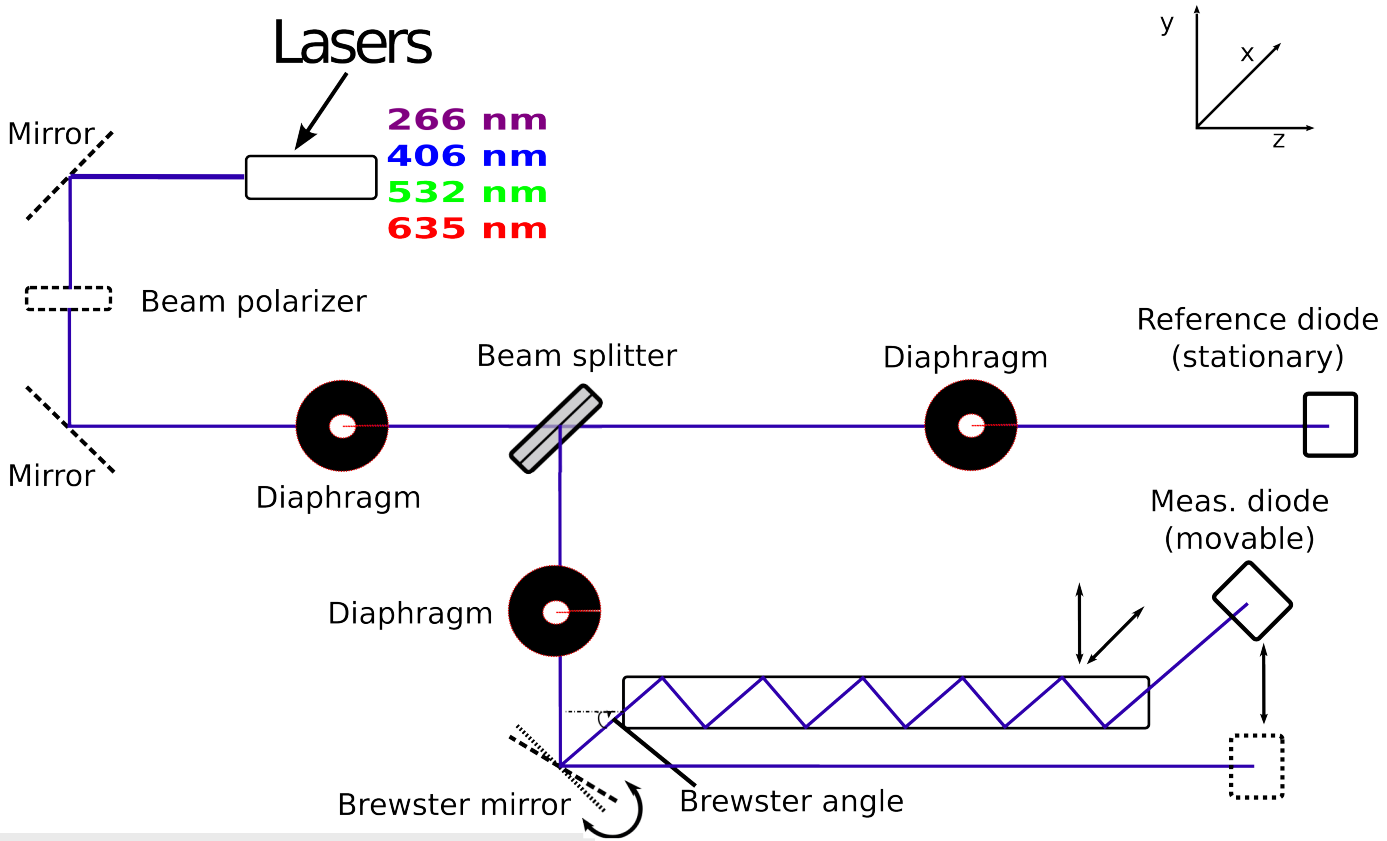
Quality assurance for prototype radiators

→ Measure the transparency of the material

→ Determine the attenuation length

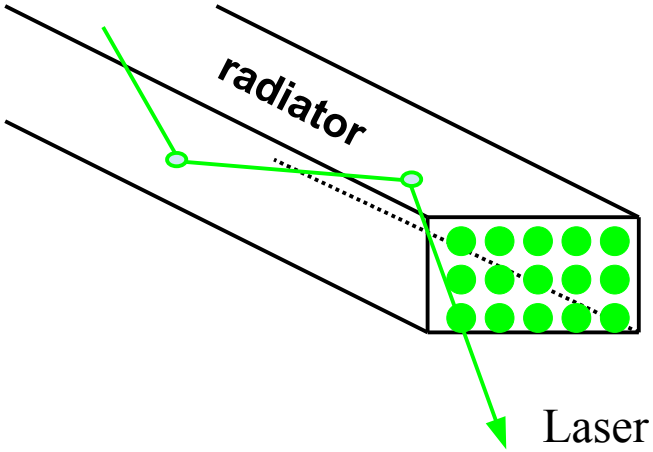
→ Measure reflection coefficient

→ Determine the surface roughness



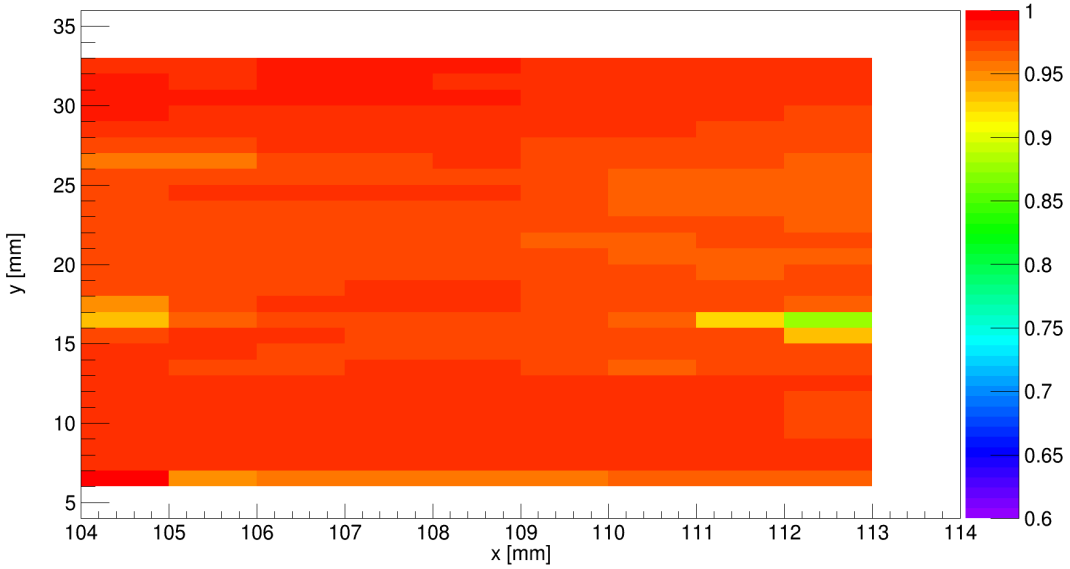
Barrel DIRC optics

Quality assurance for prototype radiators



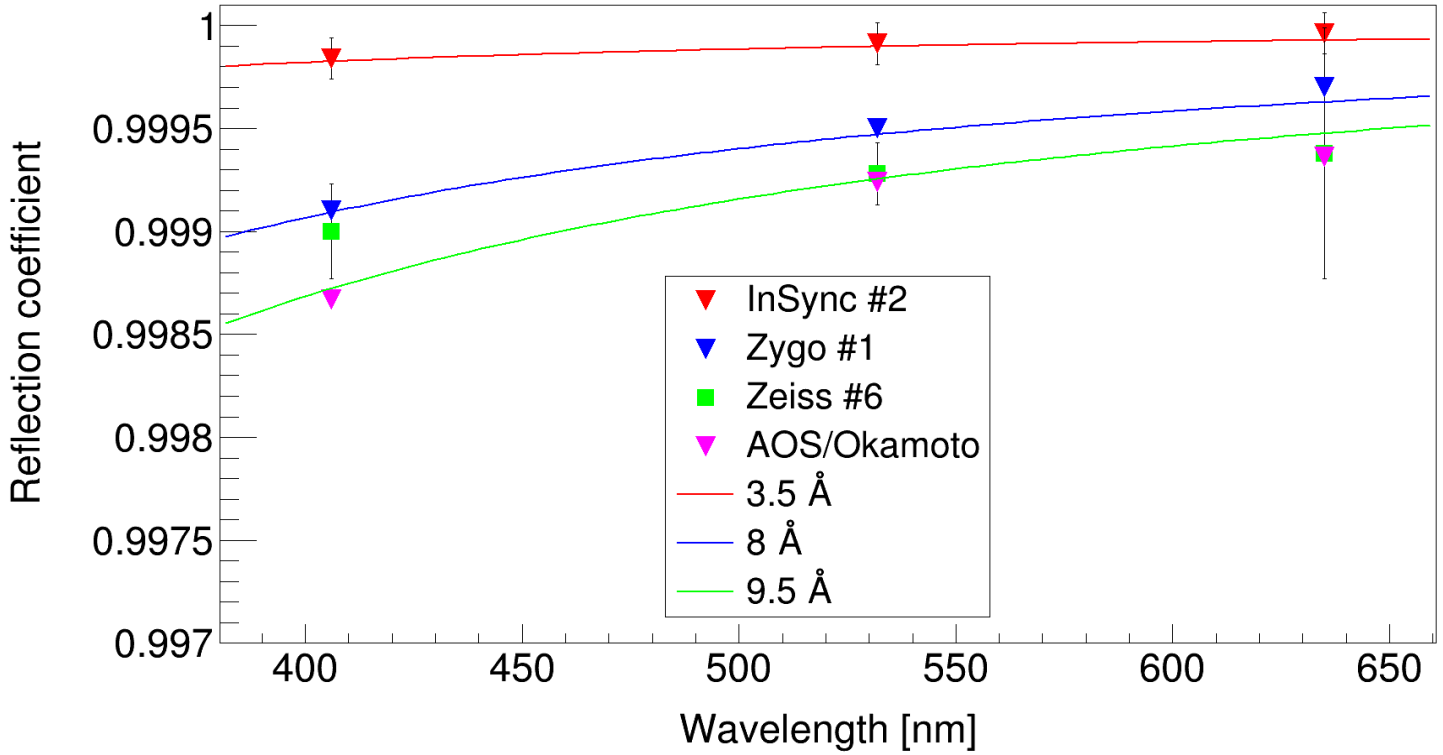
$$R = 1 - \left(\frac{4\pi \cdot \cos(\theta) \cdot n \cdot H}{\lambda} \right)^2$$

$$H_{Zc\,1_{532\,nm}} = 8\,A \pm 0.2\,A$$



Barrel DIRC optics

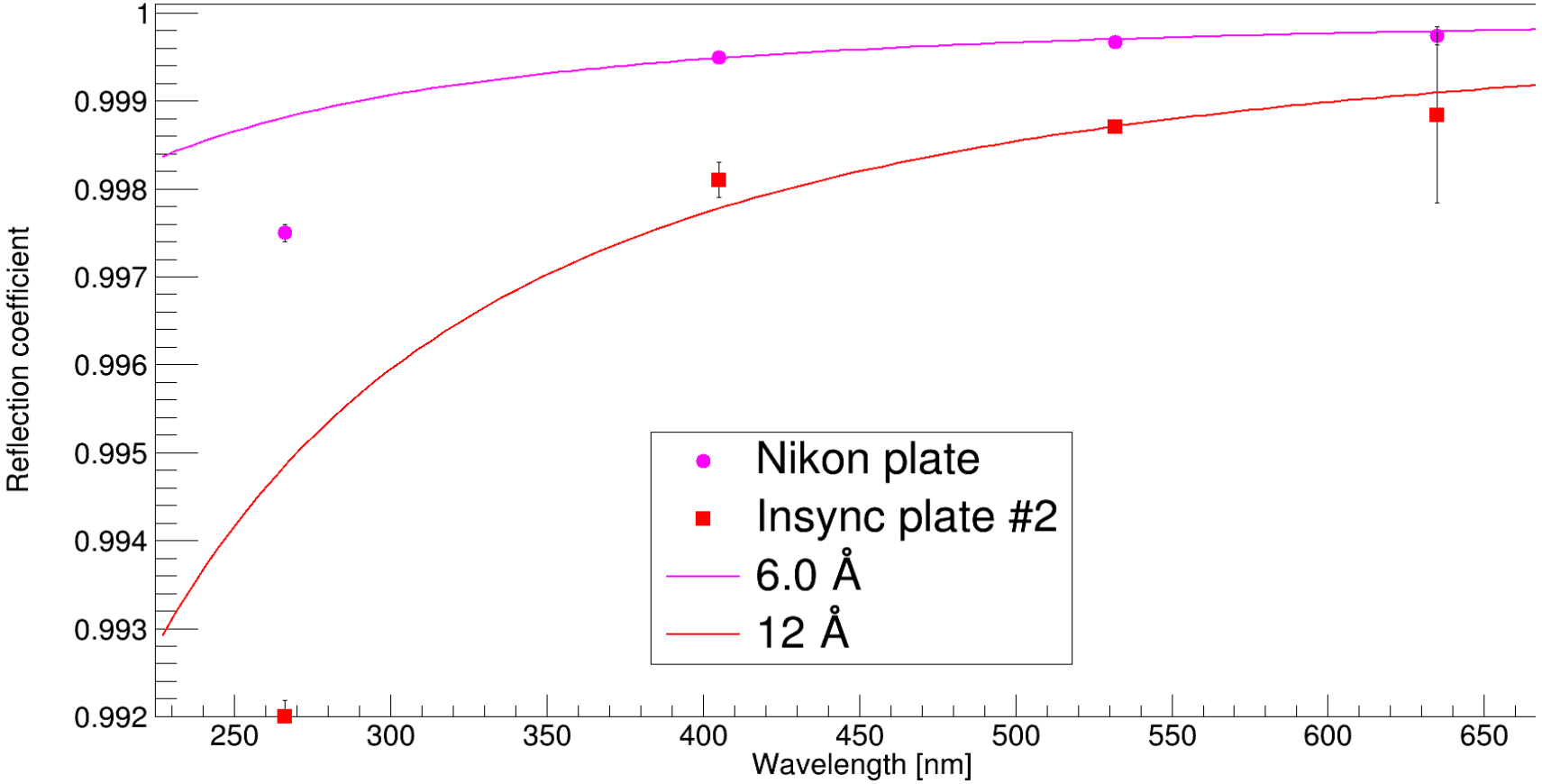
→ Results for InSync, Zygo, Zeiss and AOS/Okamoto



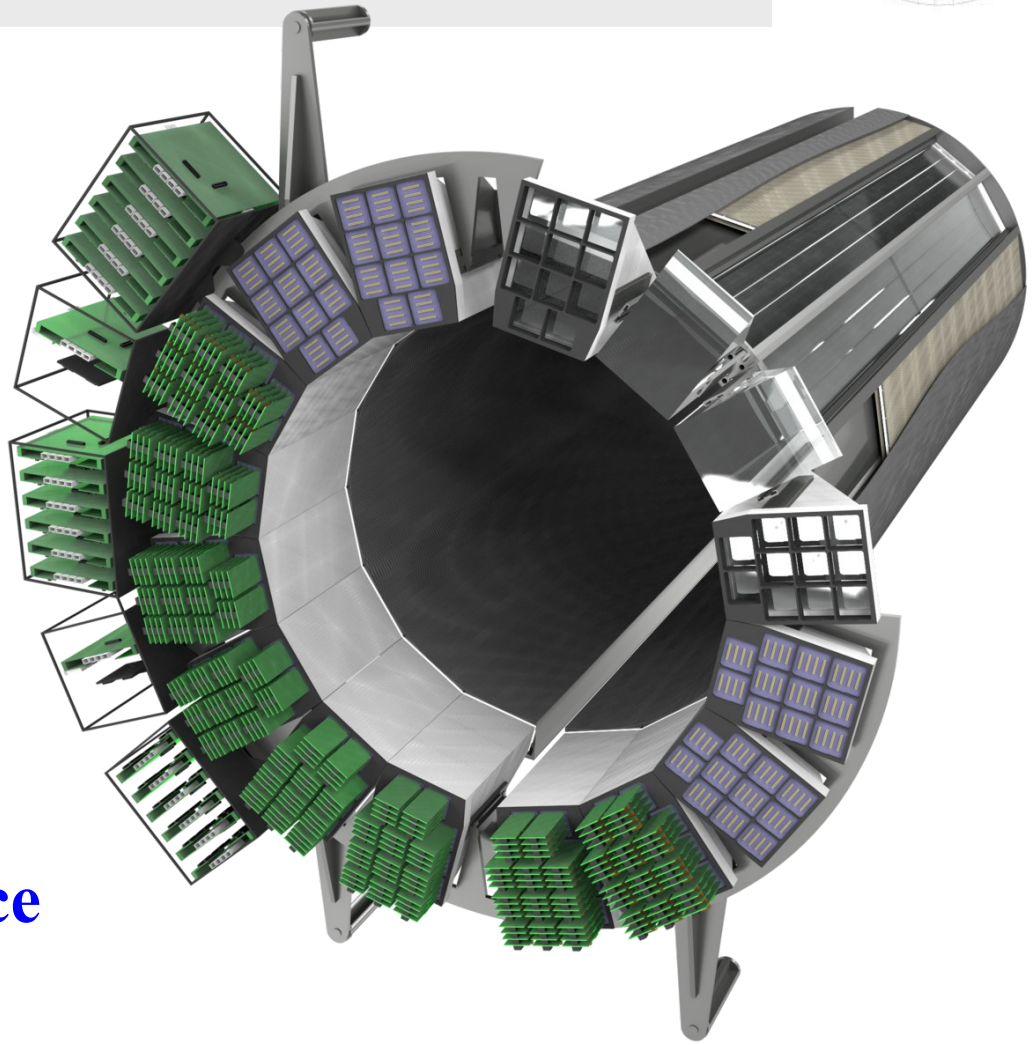
→ **No 266 nm laser at this point**

Barrel DIRC optics

→ Same measurements for two prototype plates



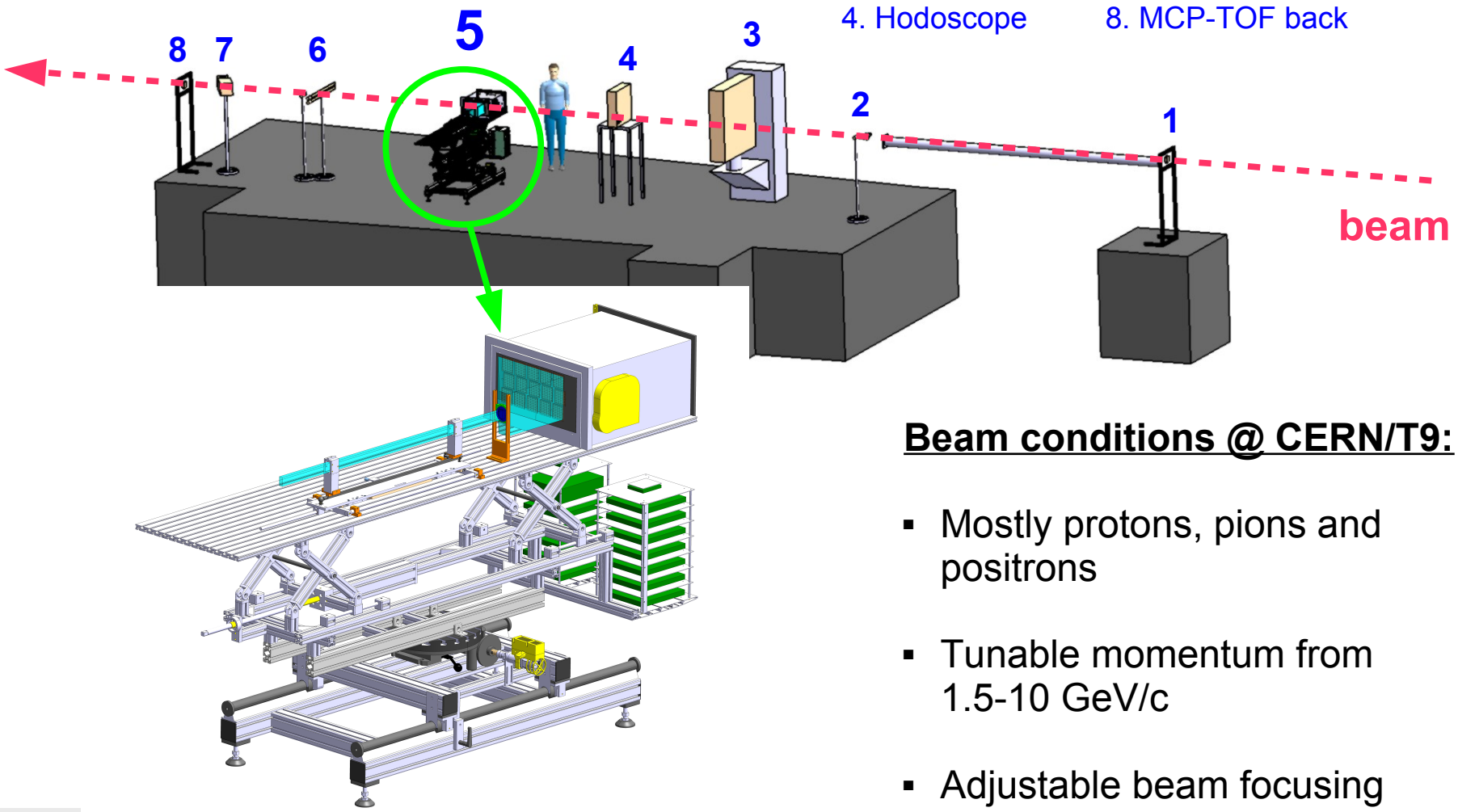
Outline



V. Prototype performance

Prototype setup & beam line

1. MCP-TOF front
2. Trigger1/Veto1
3. Disc DIRC
4. Hodoscope
5. **Barrel DIRC prototype**
6. Trigger2/Veto2
7. FLASH
8. MCP-TOF back



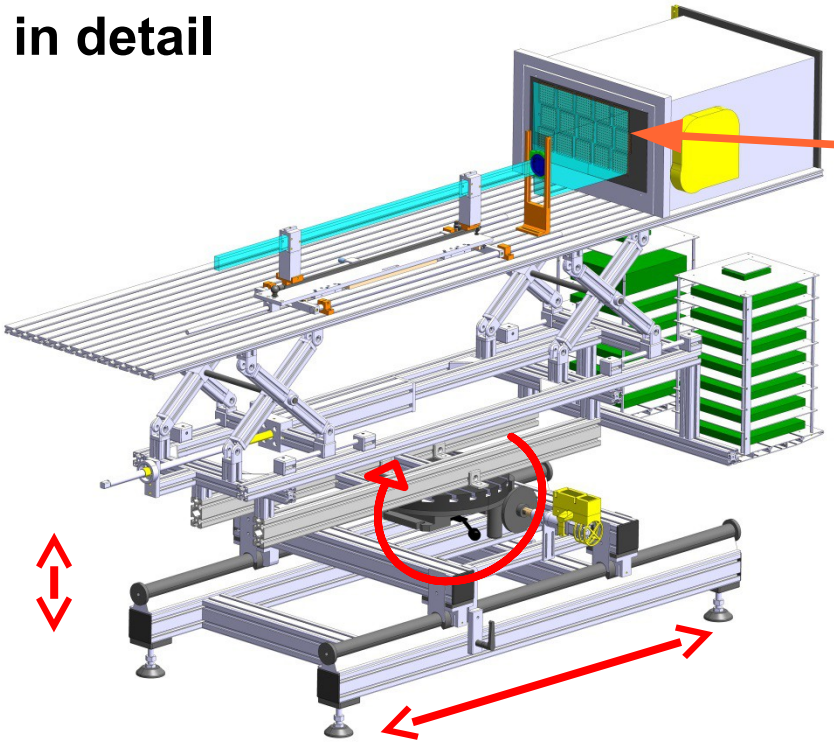
Beam conditions @ CERN/T9:

- Mostly protons, pions and positrons
- Tunable momentum from 1.5-10 GeV/c
- Adjustable beam focusing

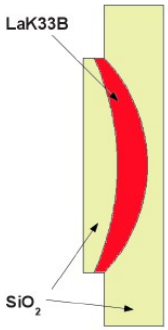
Prototype setup & beam line

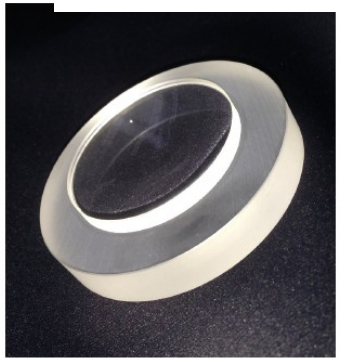
Prototype setup in detail

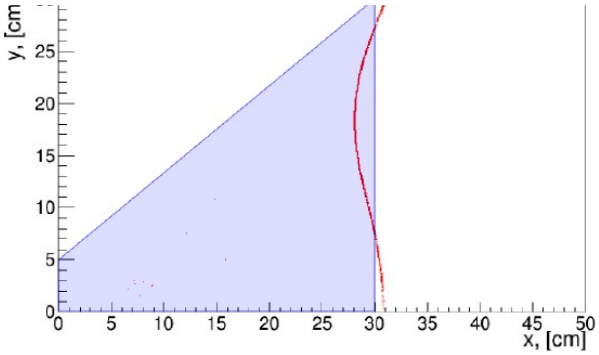
- Remotely moveable setup
- Bars/plates as radiators
- Focusing optics
- Fused silica prism



- Array of 15 MCP-PMTs
- 8x8 pixels, Photonis Planacon XP85012
- 60 PADIWA (FEE) cards
- Trigger and Readout Boards (TRBv3)
- Total of 960 pixels
- Total number of electronics channels in beam line: > 1.5k



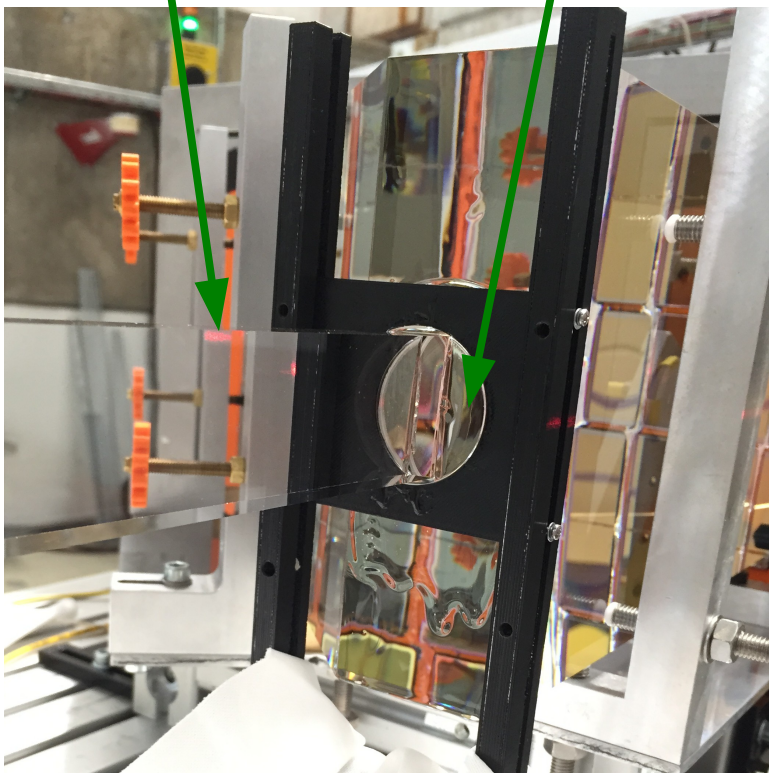




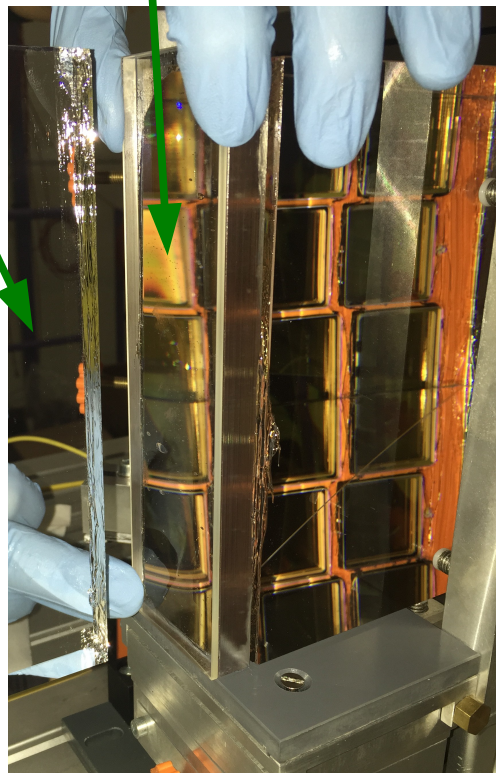
Prototype setup & beam line

Examples of prototype configurations

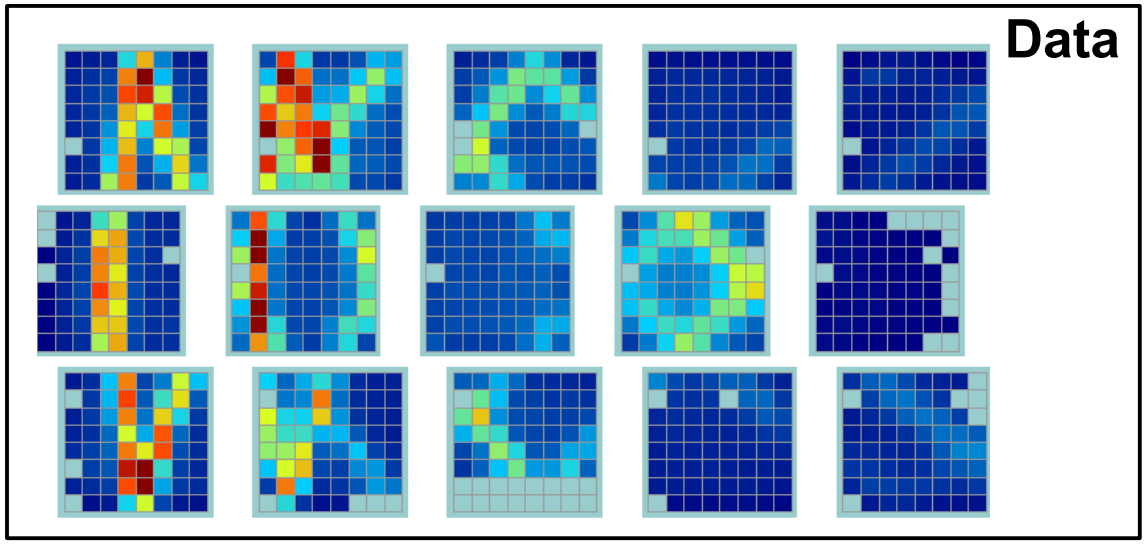
Narrow bar, 3-layer spherical lens

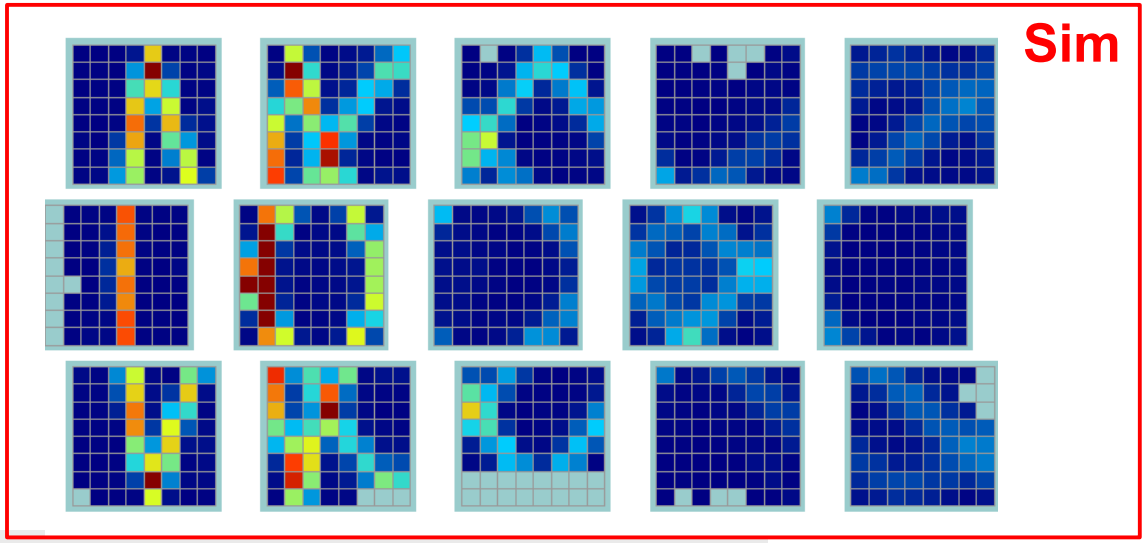


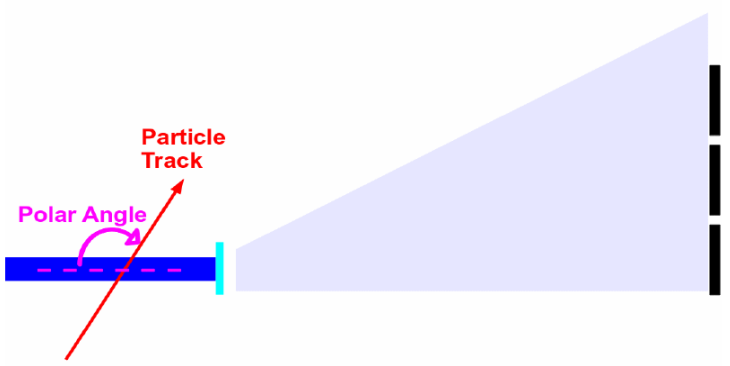
Wide plate, 2-layer cylindrical lens (attached)
(potential cost saver)



Prototype performance





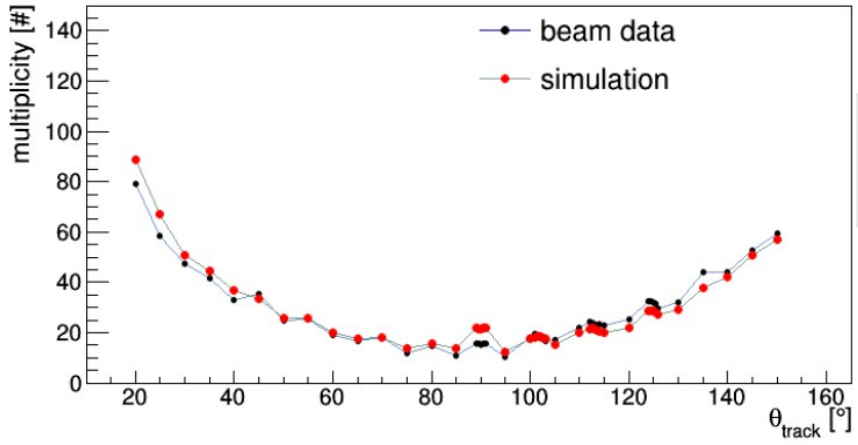


7 GeV/c, bar w 3-layer spherical lens, 125.5° polar angle

Standalone geant4 simulation includes:

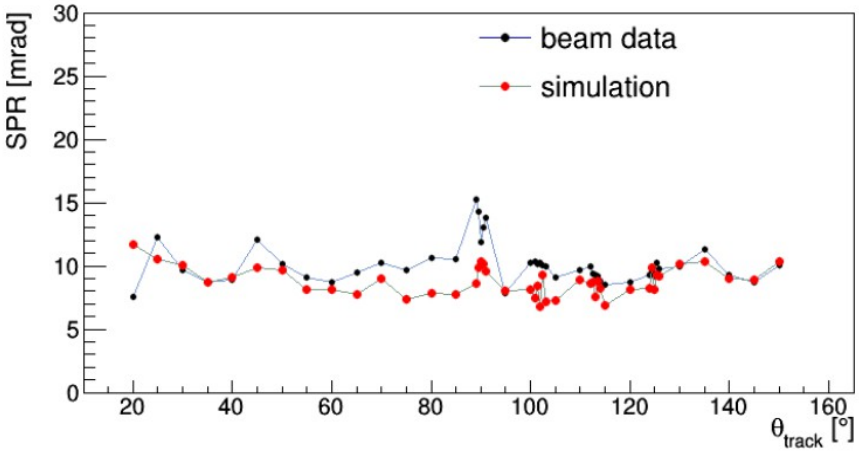
- Dead channels
- Quantum efficiency
- Charge sharing
- 200 ps time resolution

Prototype performance



- **Photon yield (beam data) between 16-80**
- PANDA PID requirement >15

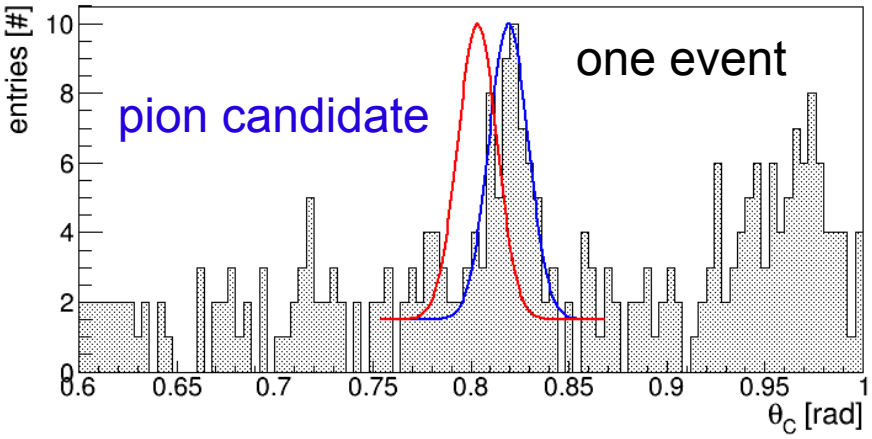
- bar with focusing
- 7 GeV/c beam momentum
- 125.5° polar angle

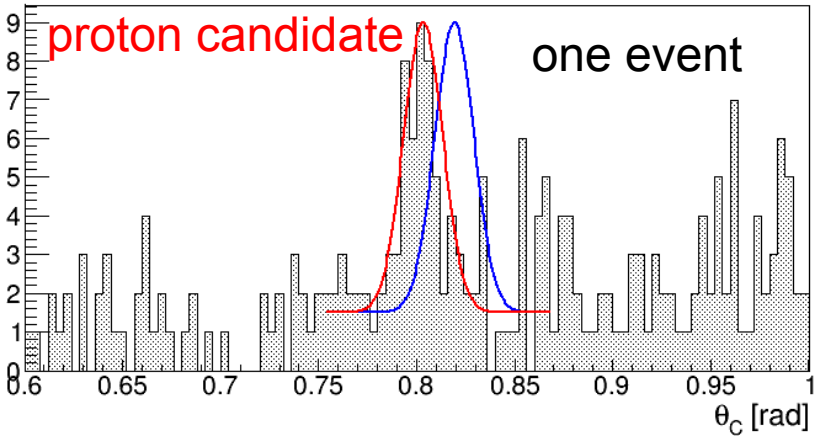


- **Single photon Cherenkov angle resolution (SPR) 10 mrad mostly for data**
- PANDA PID requirement 8-10 mrad

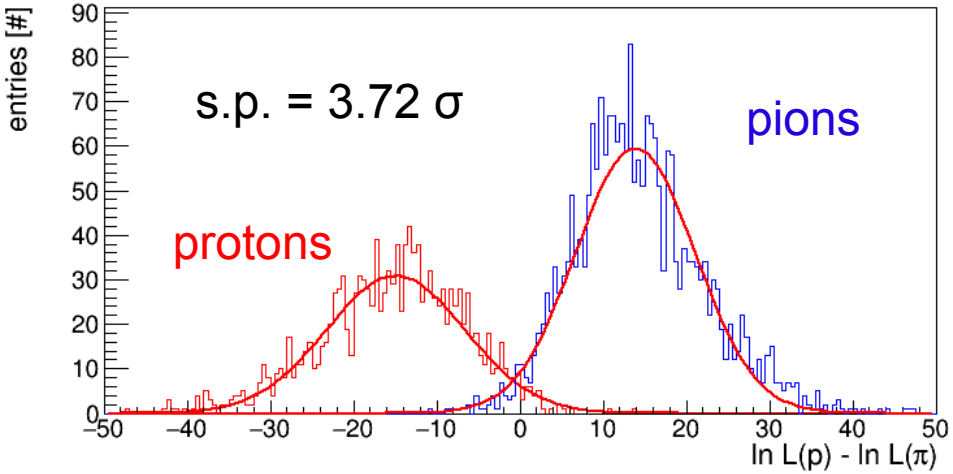
Prototype performance

Narrow bar, 3-layer spherical lens, 5 GeV/c beam momentum, 125.5° polar track angle





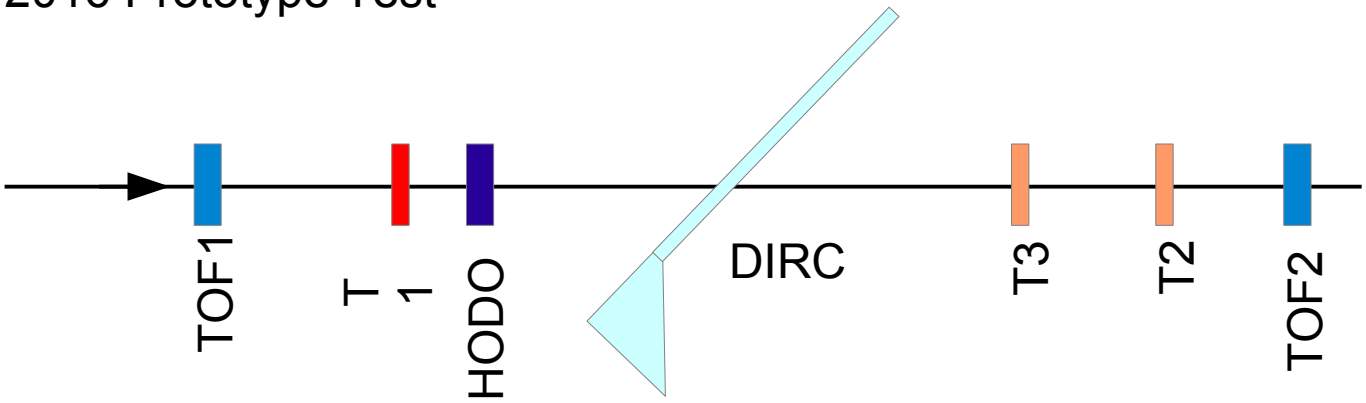
preliminary



Color lines represent particle tagging from the TOF system

Prototype performance

CERN 2016 Prototype Test



- main goal: validate the PID performance of the plate design

- CERN T9 area
- beam type: protons and pions
- beam momentum: 8, **7**, 6, 5, 4, 3 GeV/c
- TOF PID

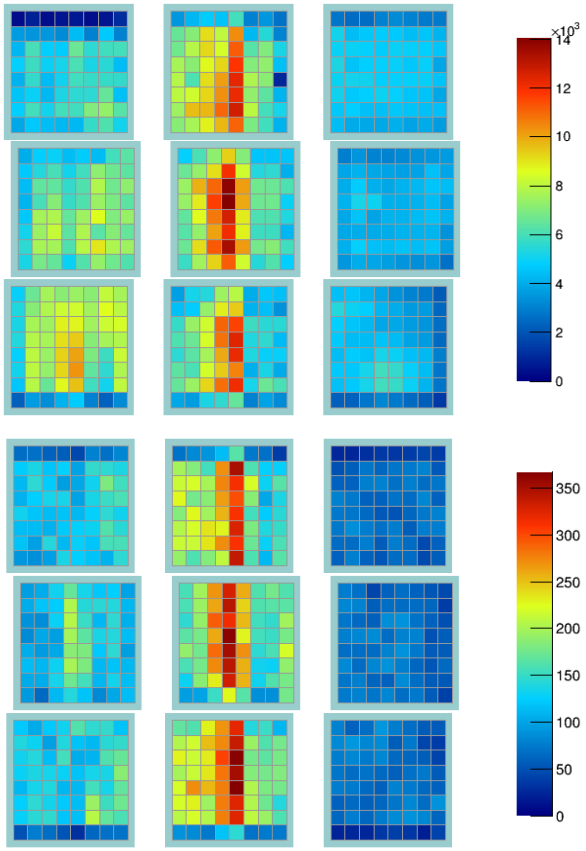
- 30 degree prism as expansion volume => 9 MCP-PMTs (vs 15 last year)
- different configurations of the DIRC prototype (most of the data are with plate)
- different DIRC prototype angles

Prototype performance

Mostly used configuration:
Wide plate radiator, (2-layer cylindrical) or no lens, 30 deg prism, 3x3 array MCP-PMTs

Prototype performance

Hit Patterns: Plate with cylindrical lens



25 degree polar angle
7 GeV/c

← Beam data for pion tag

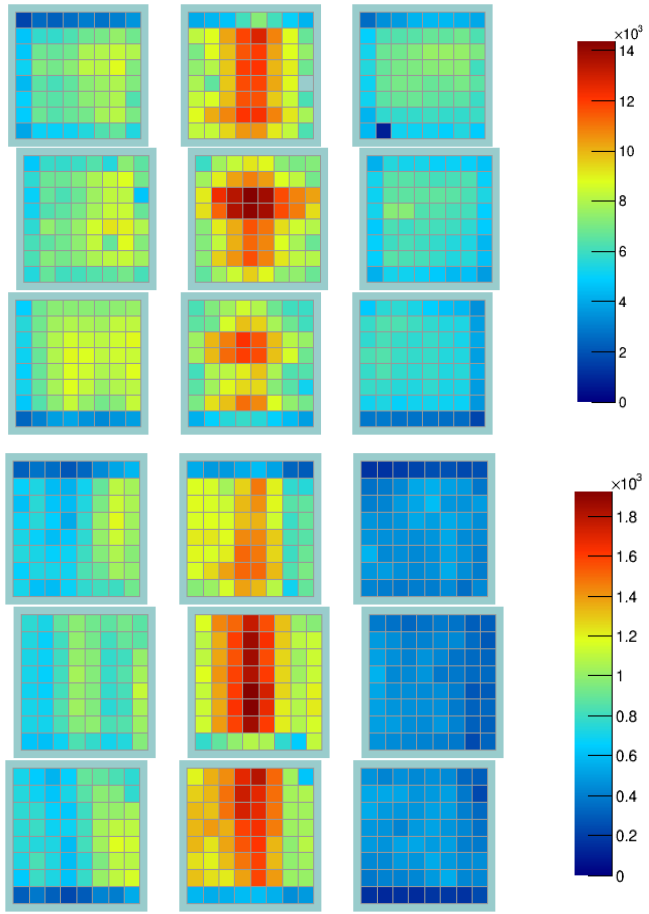
← Simulation for pions

Standalone geant4 simulation includes:

- dead channels
- quantum/collection efficiency
- charge sharing
- 190 ps time resolution

Prototype performance

Hit Patterns: Plate without lens



25 degree polar angle
7 GeV/c

← Beam data for pion tag

← Simulation for pions

Prototype performance

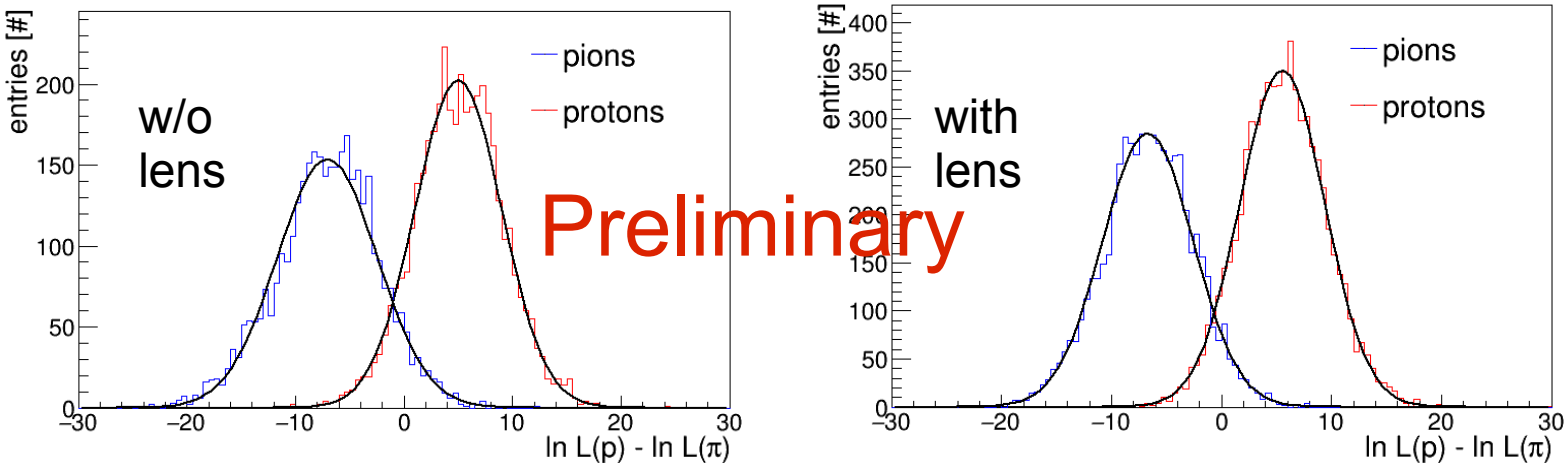
Time Imaging Reconstruction

beam data with plate @ 7 GeV/c @ 25 degree

$$N_{\mathrm{sep}} = \frac{|\mu_1 - \mu_2|}{0.5(\sigma_1 + \sigma_2)}$$

s.p. = 2.81 +/- 0.02

s.p. = 3.08 +/- 0.02



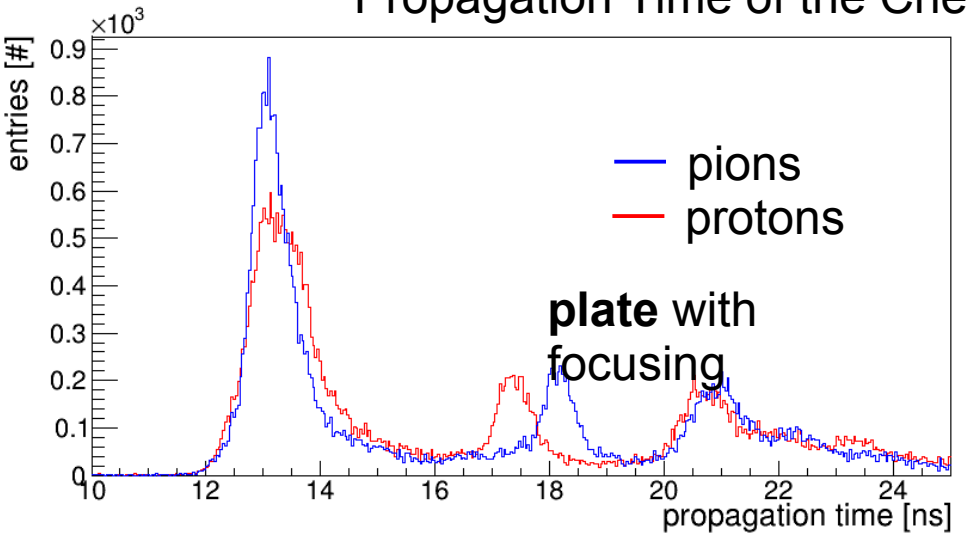
Summary and outlook

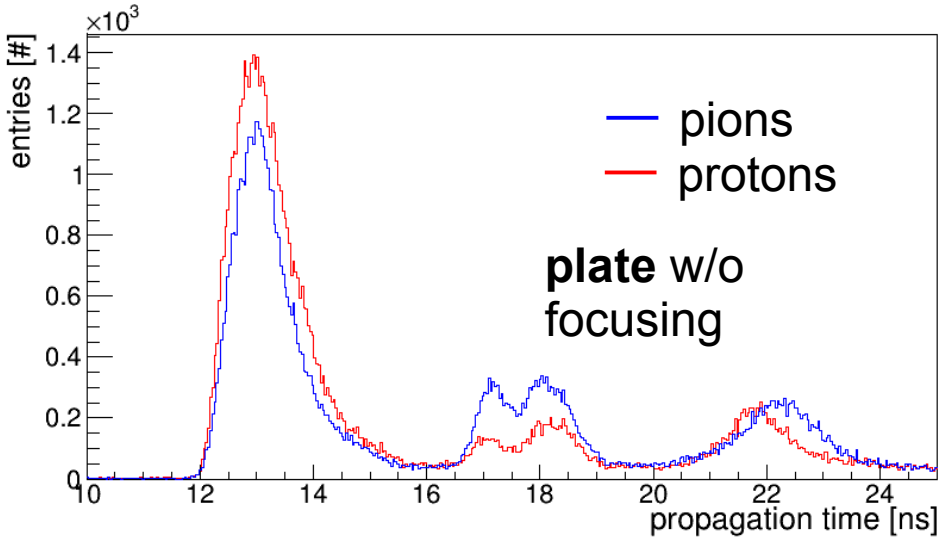
- Baseline design's performance meets PANDA PID requirements
- Simulation and test beam data agree nicely
- Cost saving option (wide plate) is still under investigation
- Another test beam time at CERN is foreseen for Aug 23rd-Sep. 13th 2017
- Wide plate design shall be finally evaluated
- ***TDR was submitted to the FAIR ECE in fall 2016***


Thanks
for your attention

Backup slides

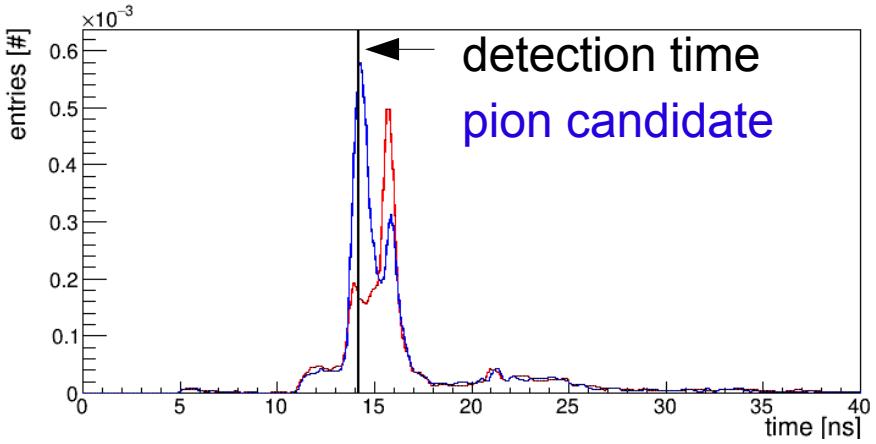
Propagation Time of the Cherenkov Ph.

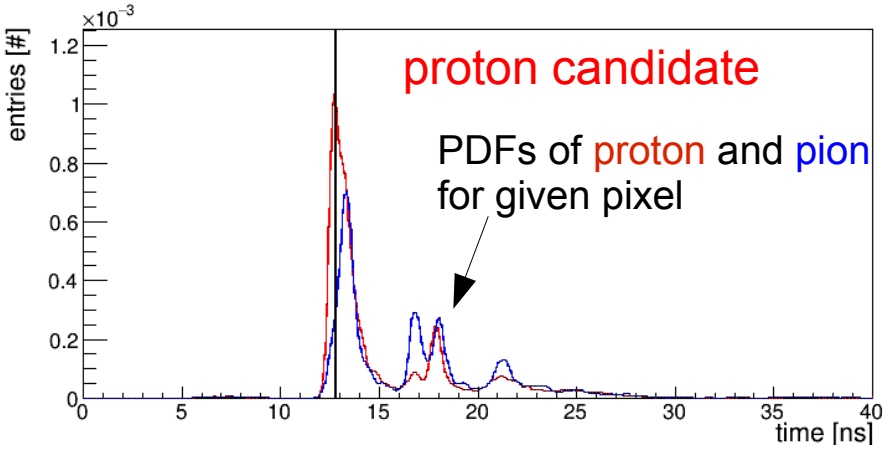


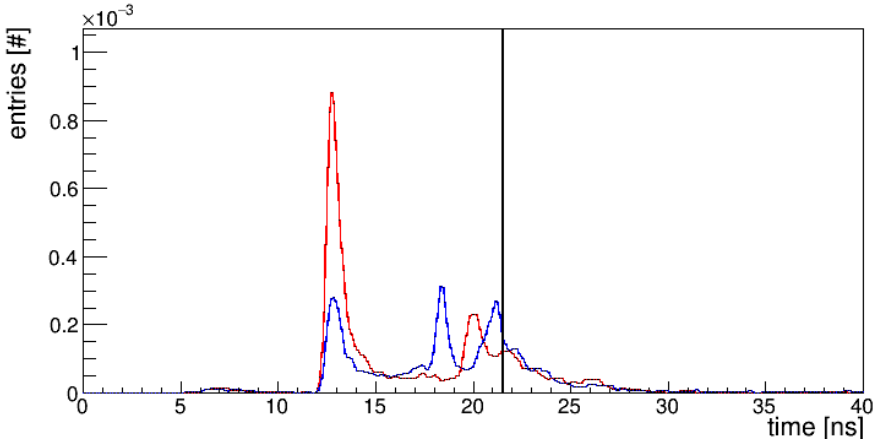


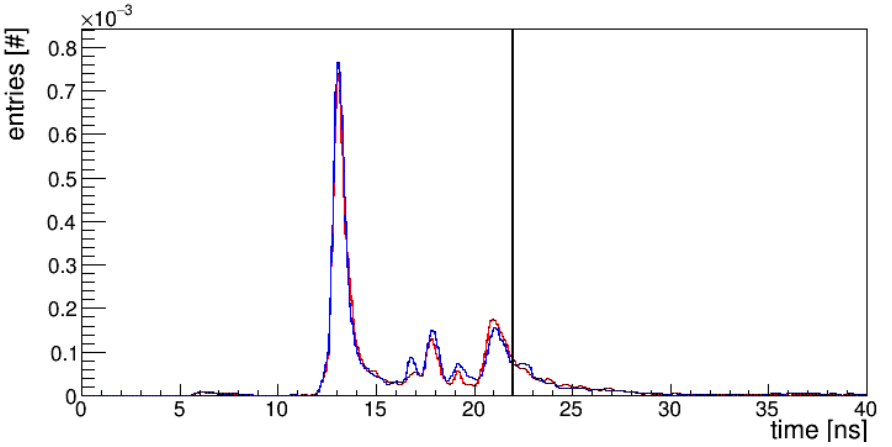
beam data
@ 7 GeV/c
@ 25 degree
ch 363

beam data with plate @ 7 GeV/c @ 25 degree

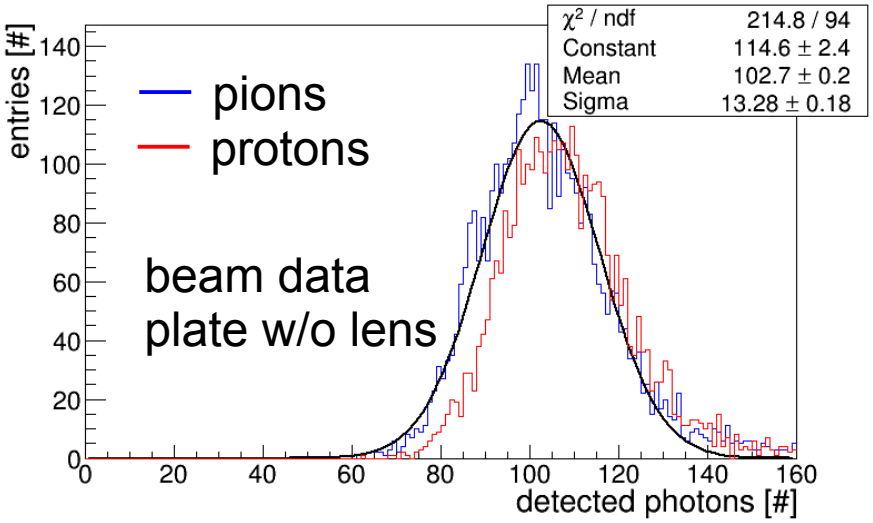


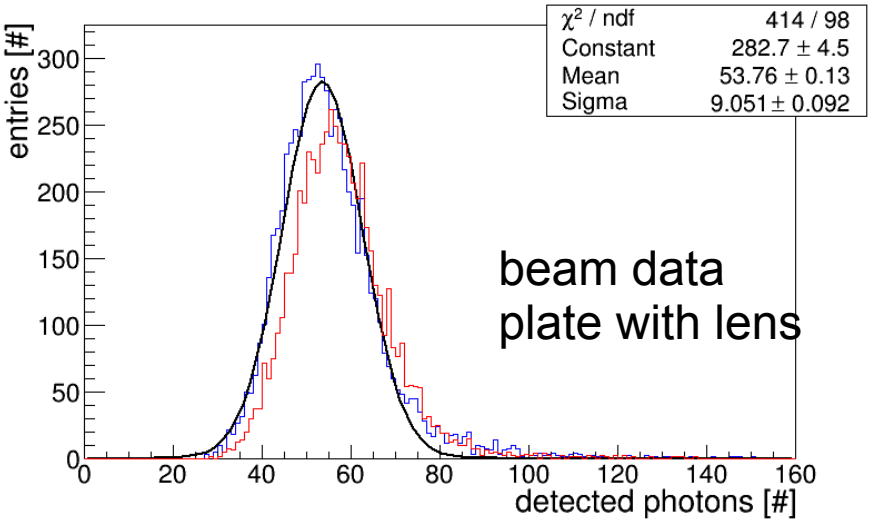


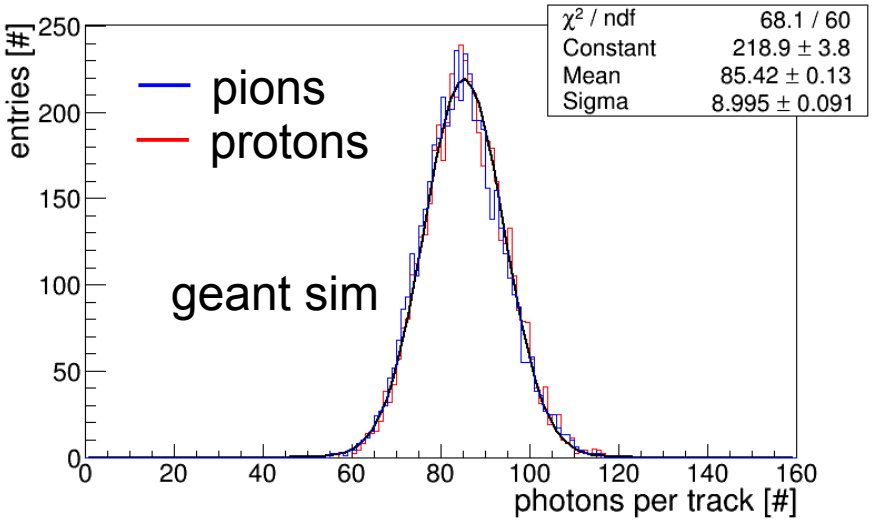


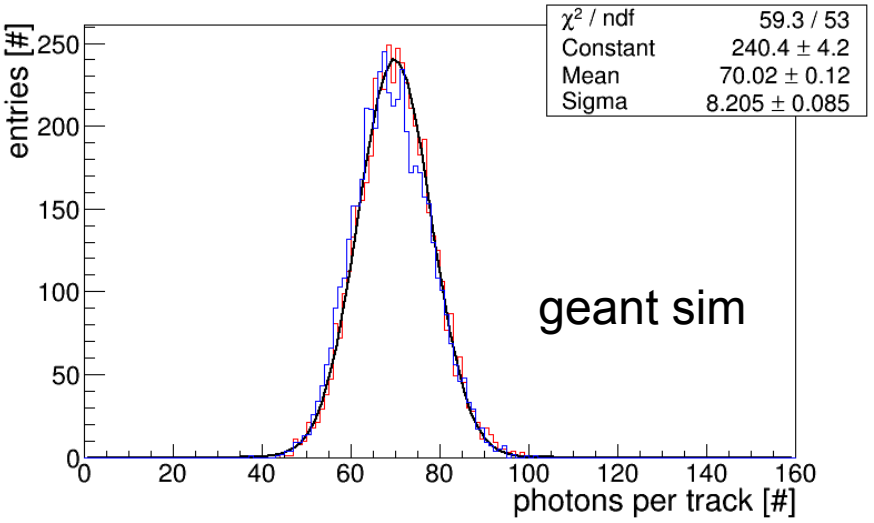


Detected Photon Yield



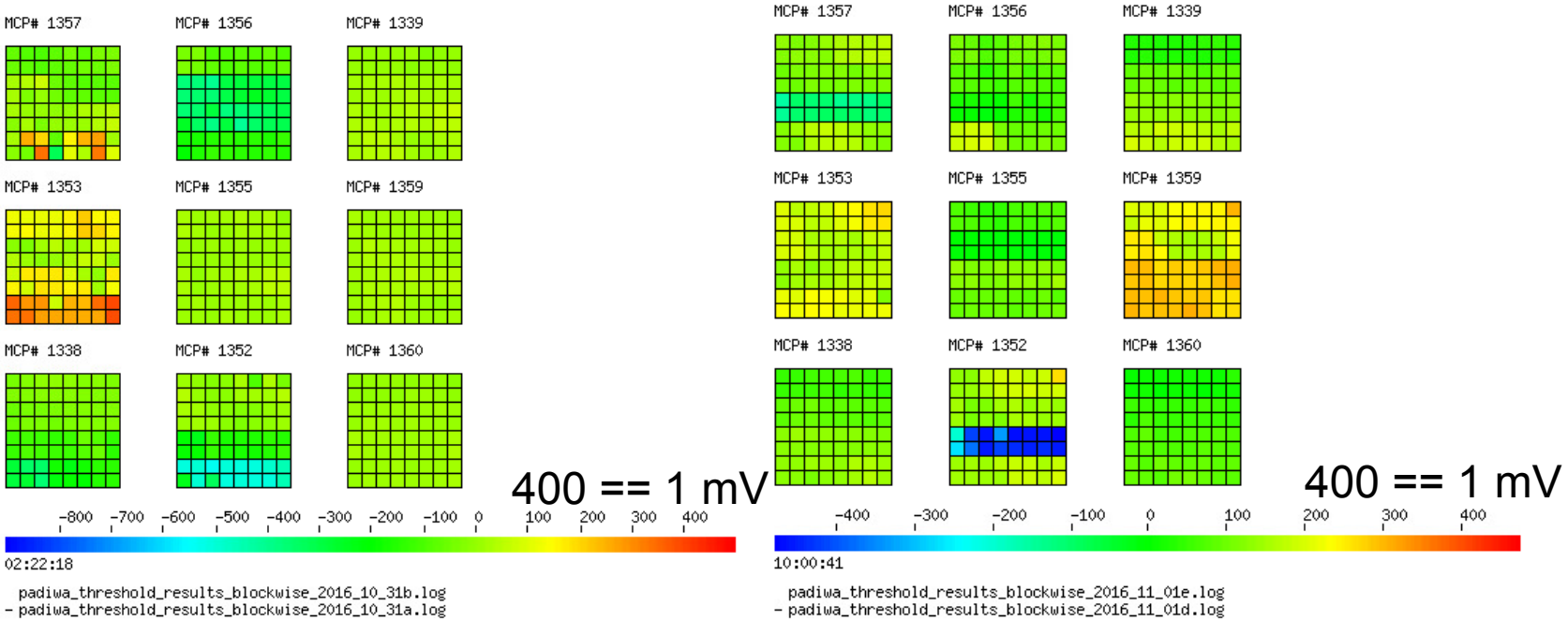






Threshold Floating

Threshold difference after few hours of data taking:



- floating in the range of [-1,+1] mV
- the data were taken with 1-2 mV offset to the threshold value due to low amplitude signals

➡ Significant impact on recorded hit multiplicity