# The Barrel and Endcap Disc DIRC at PANDA

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for the
PANDA Cherenkov group

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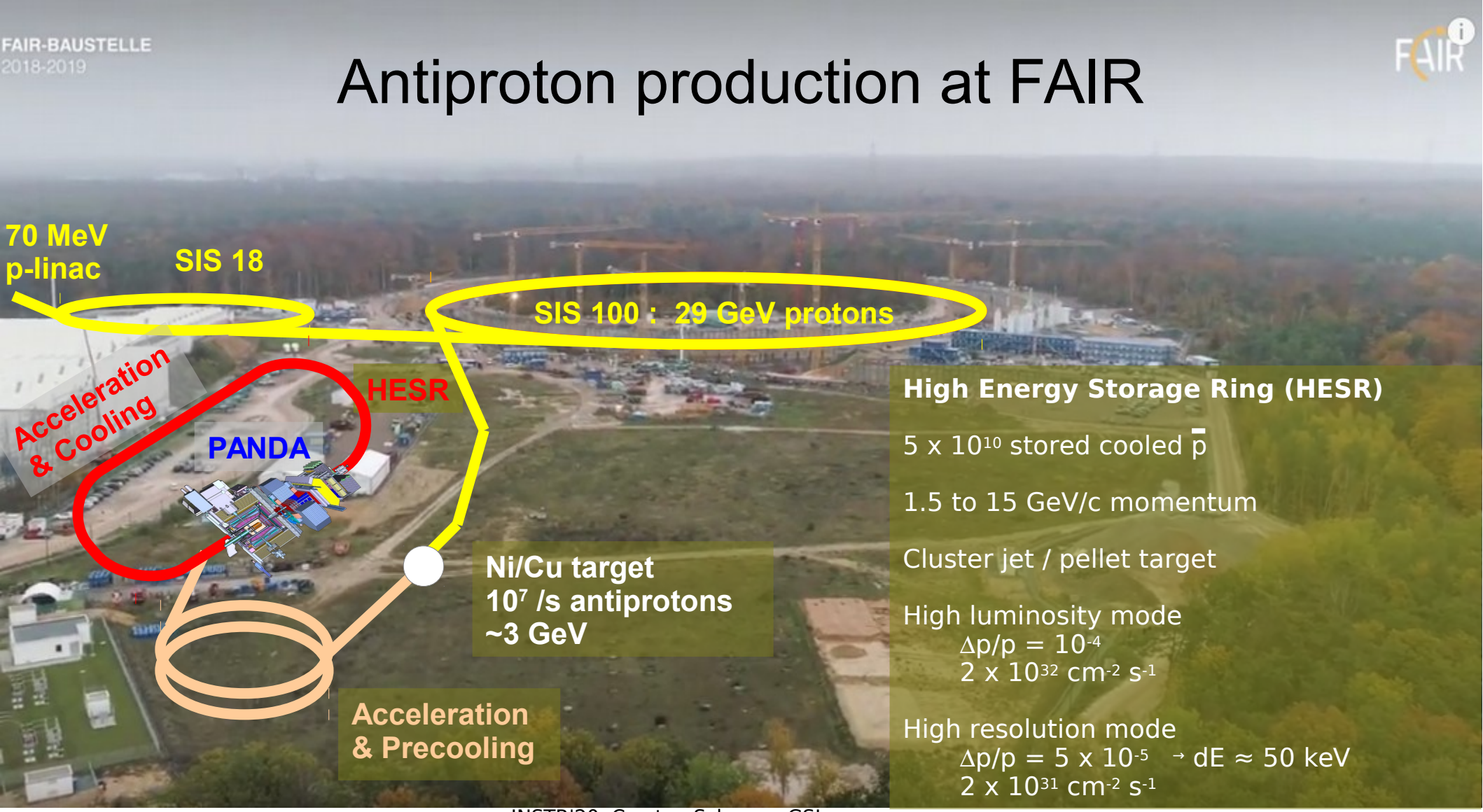
University of Erlangen
University of Giessen
University of Mainz
BINP Novosibirsk


- The PANDA detector
- The DIRC counters
- Barrel DIRC
- Endcap Disc DIRC

FAIR

panda

# Antiproton production at FAIR




**High Energy Storage Ring (HESR)**

5 x $10^{10}$ stored cooled $\bar{p}$

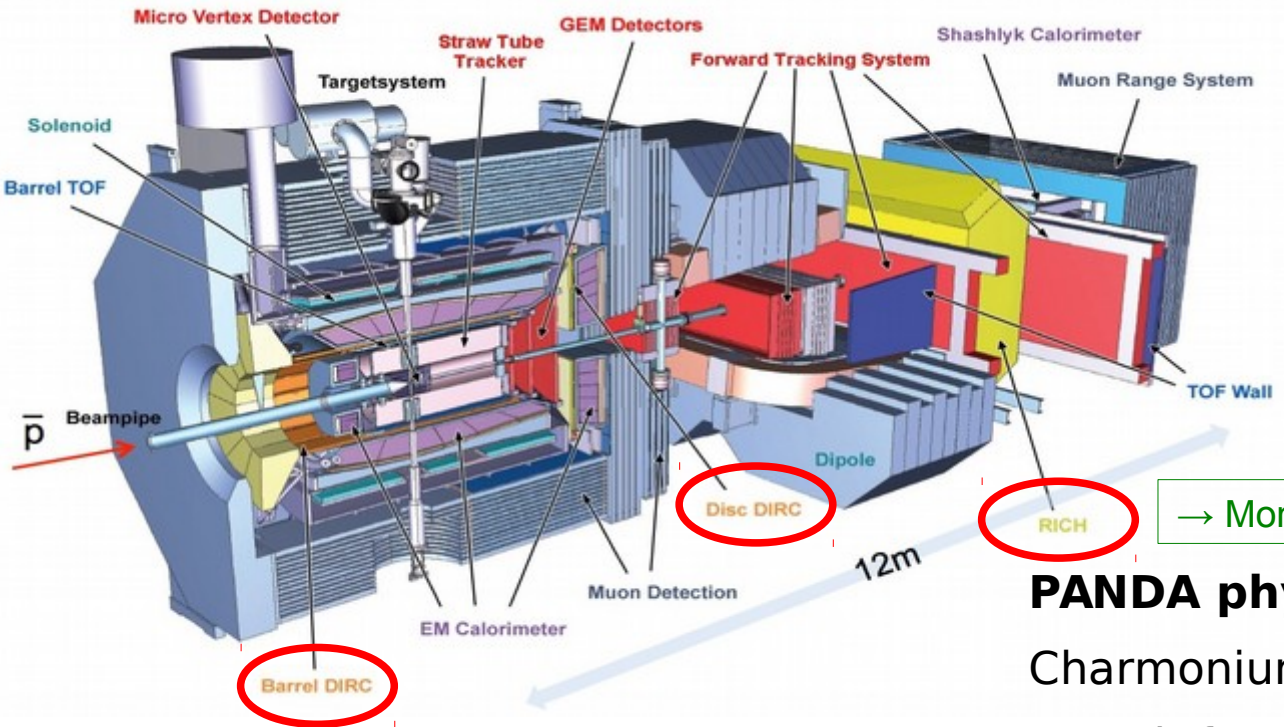
1.5 to 15 GeV/c momentum

Cluster jet / pellet target

High luminosity mode
$\Delta p/p = 10^{-4}$
2 x $10^{32}$ $cm^{-2}$ $s^{-1}$

High resolution mode
$\Delta p/p = 5 \times 10^{-5}$ → dE ≈ 50 keV
2 x $10^{31}$ $cm^{-2}$ $s^{-1}$

# PANDA experiment




→ Monday: Talk of Anastasios Belias

→ Monday: Talk of Sergey Kononov

**PANDA physics program**

Charmonium and open charm spectroscopy

Search for charmed hybrids and glueballs

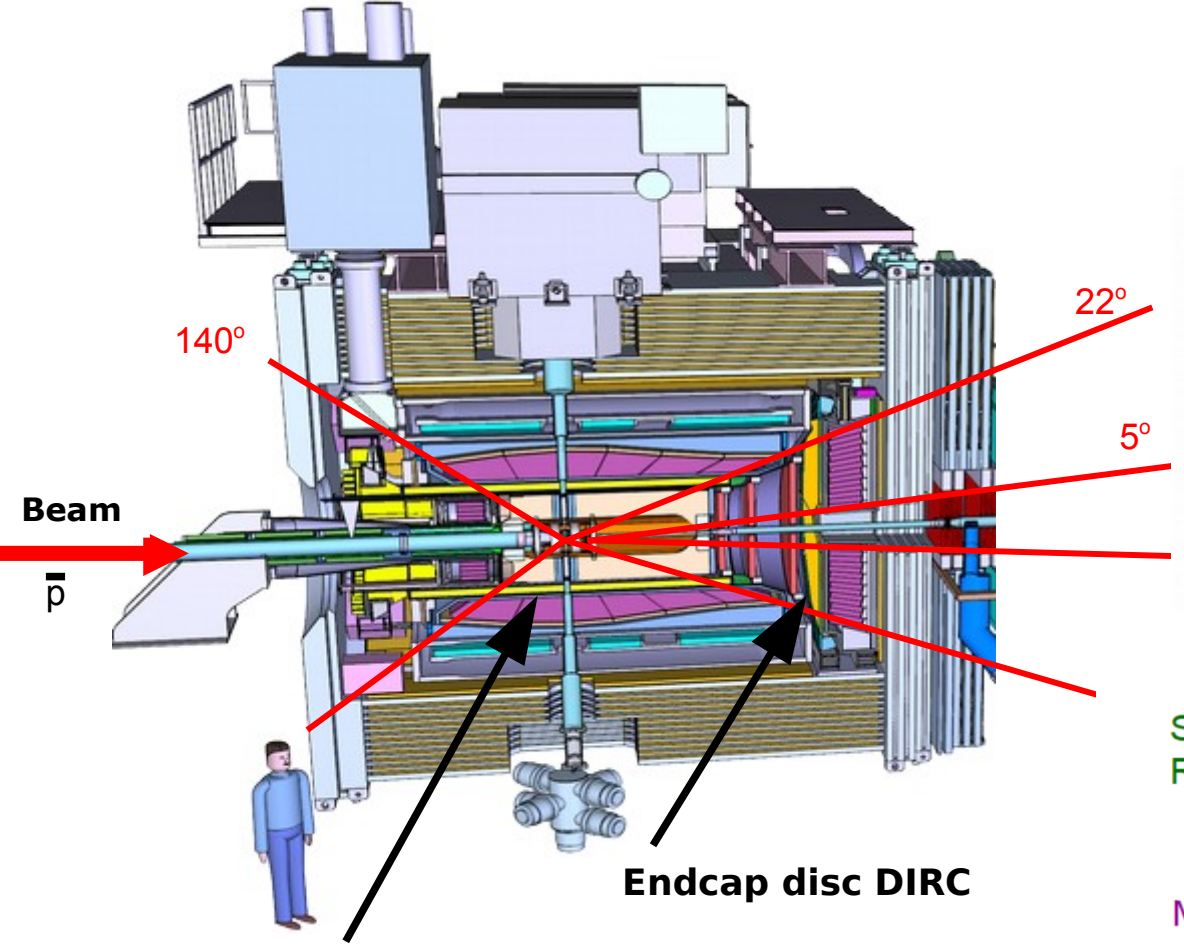
Modification of charmed mesons in nuclear matter

Hypernuclei

Nucleon structure

Excellent PID needed

# PANDA DIRC counters

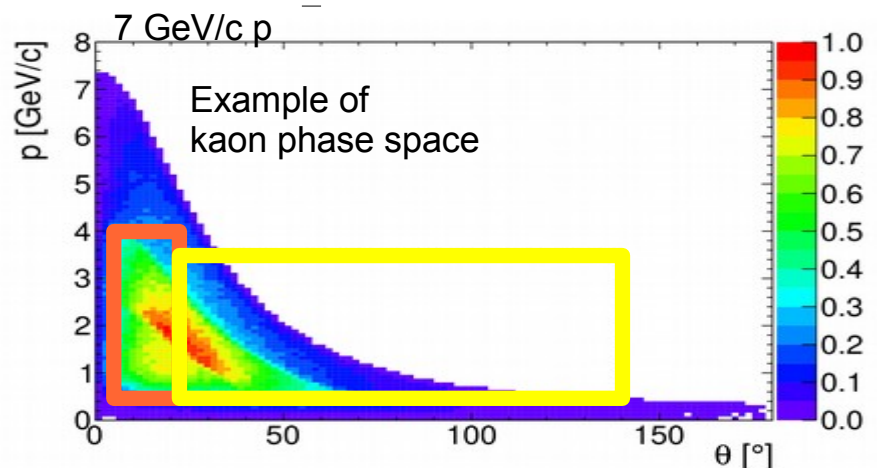


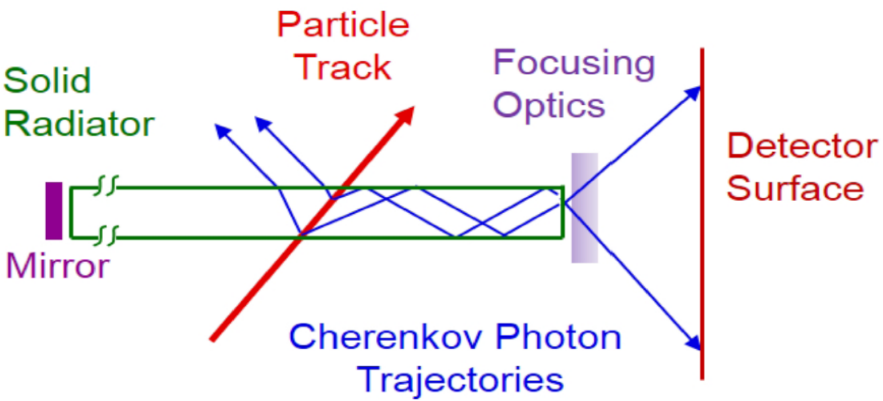

**Barrel DIRC**

Goal: 3 s.d. π/K separation
up to 3.5 GeV/c

**Endcap disc DIRC**

Goal: 3 s.d. π/K separation
up to 4 GeV/c




Magnitude of photon angles
in radiator preserved

# Barrel DIRC Design:

based on BABAR DIRC and SuperB FDIRC

with key improvements

- Barrel radius ~48 cm;

  expansion volume depth: 30 cm.

- 48 narrow radiator bars, synthetic fused silica

  17 mm (T) x 53 mm (W) x 2400 mm (L).

- Compact photon detector:

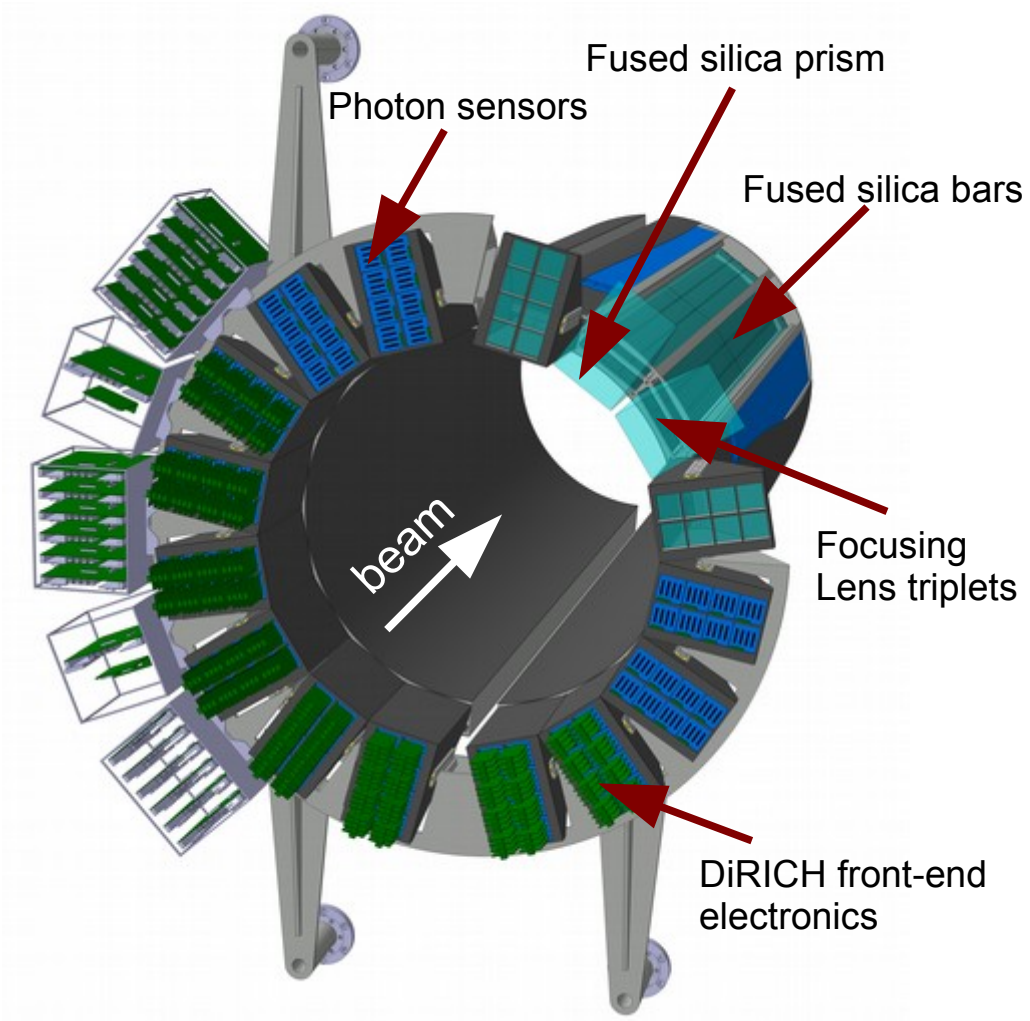
  30 cm fused silica expansion volume
  8192 channels of MCP-PMTs
  in ~1T B field

- Focusing optics: spherical lens system

- Fast photon detection:

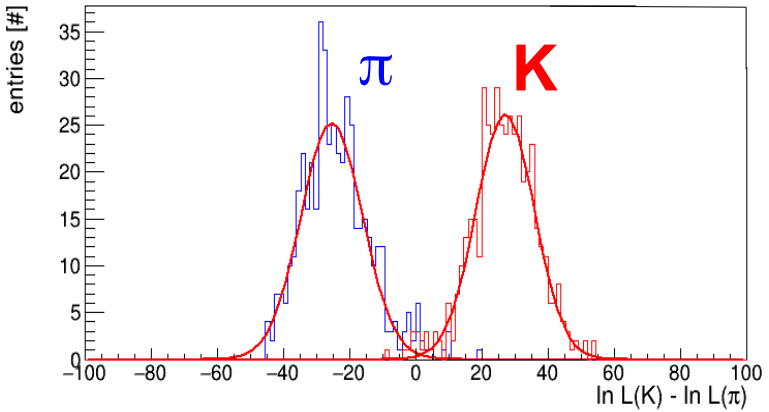
  fast TDC plus TOT electronics,

  → 100-200 ps timing



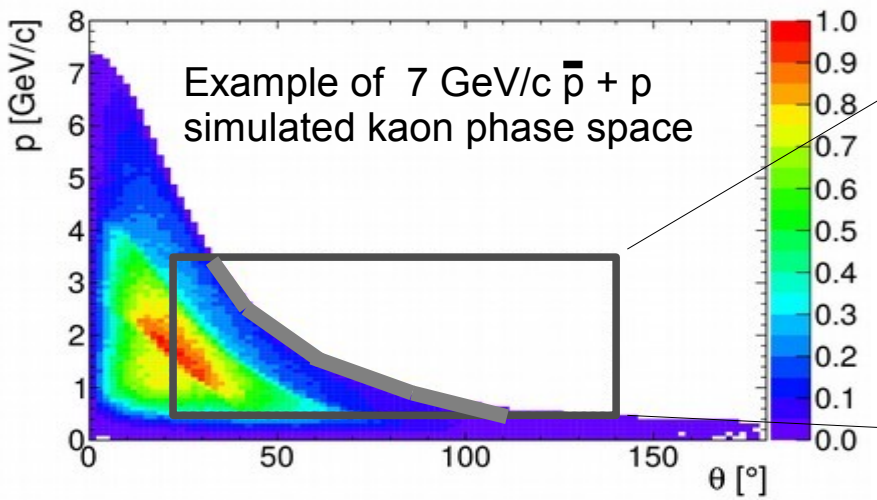
# Expected performance

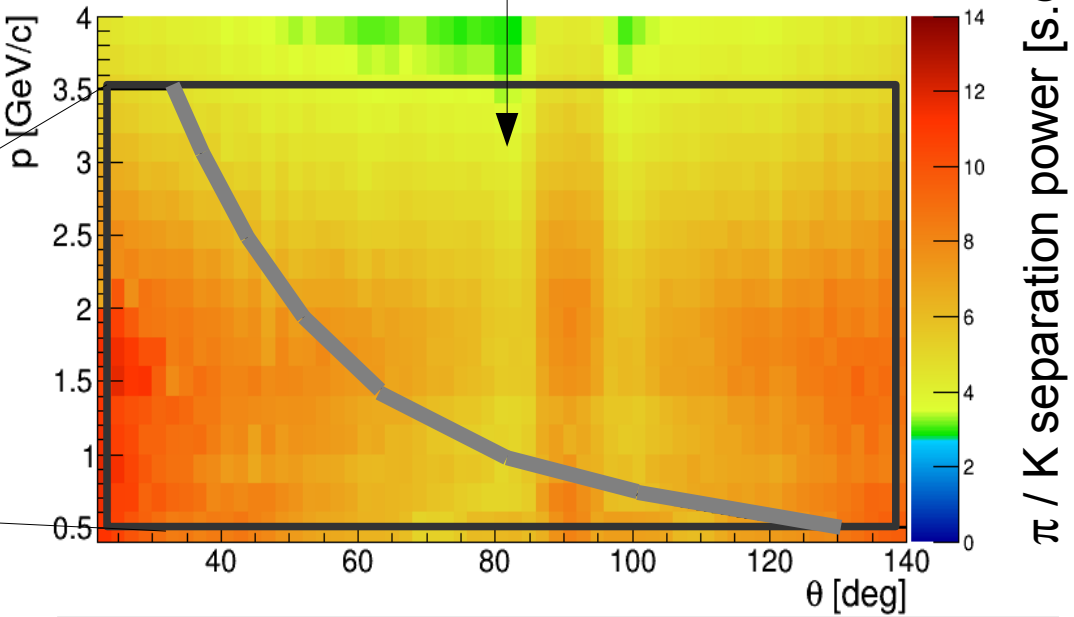
track-by-track max. likelihood fit




Time imaging reconstruction

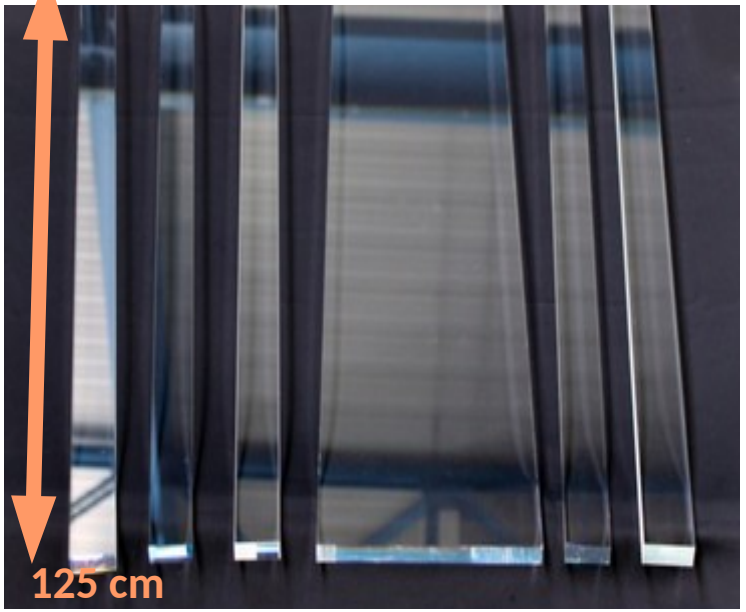
$$N_{sep} = \frac{|\mu_1 - \mu_2|}{\frac{1}{2}(\sigma_1 + \sigma_2)}$$

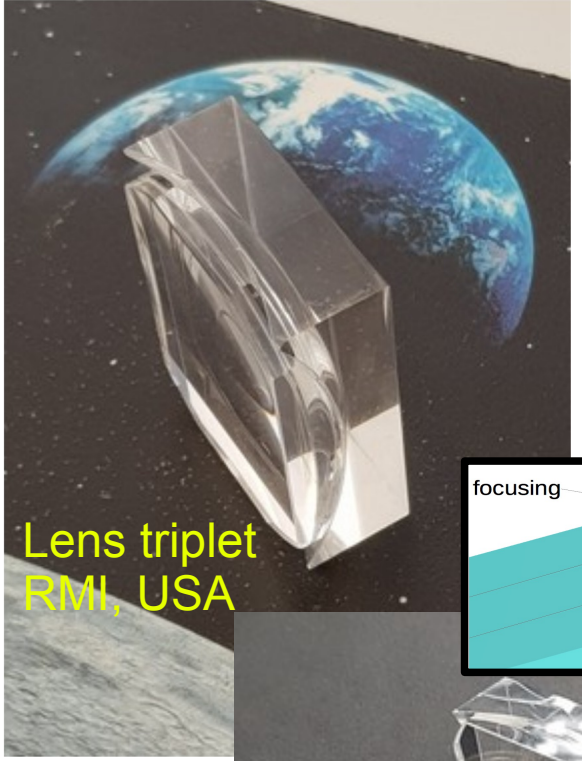


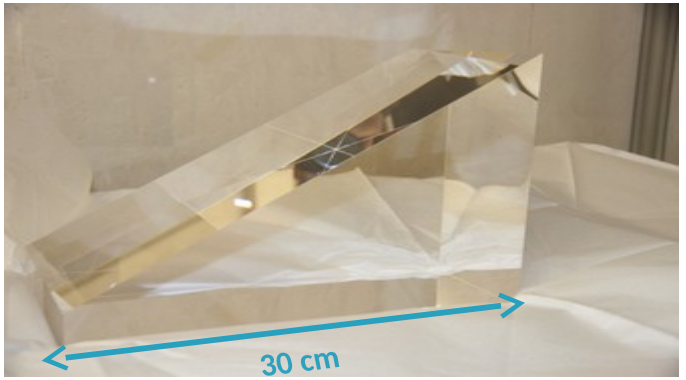



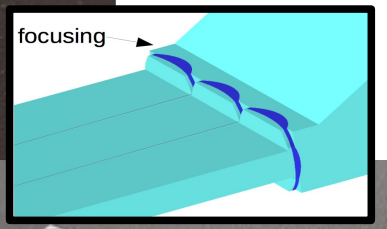

Design meets and exceeds PID requirements

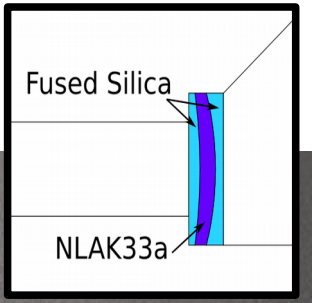
# Optical components



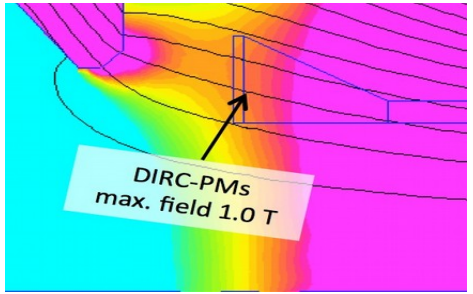




Bars from AOS/Okamoto, InSync, Nikon, Zeiss, Zygo; Heraeus, Lytkarino LZOS, Schott Lithotec.

Plates from InSync, Nikon

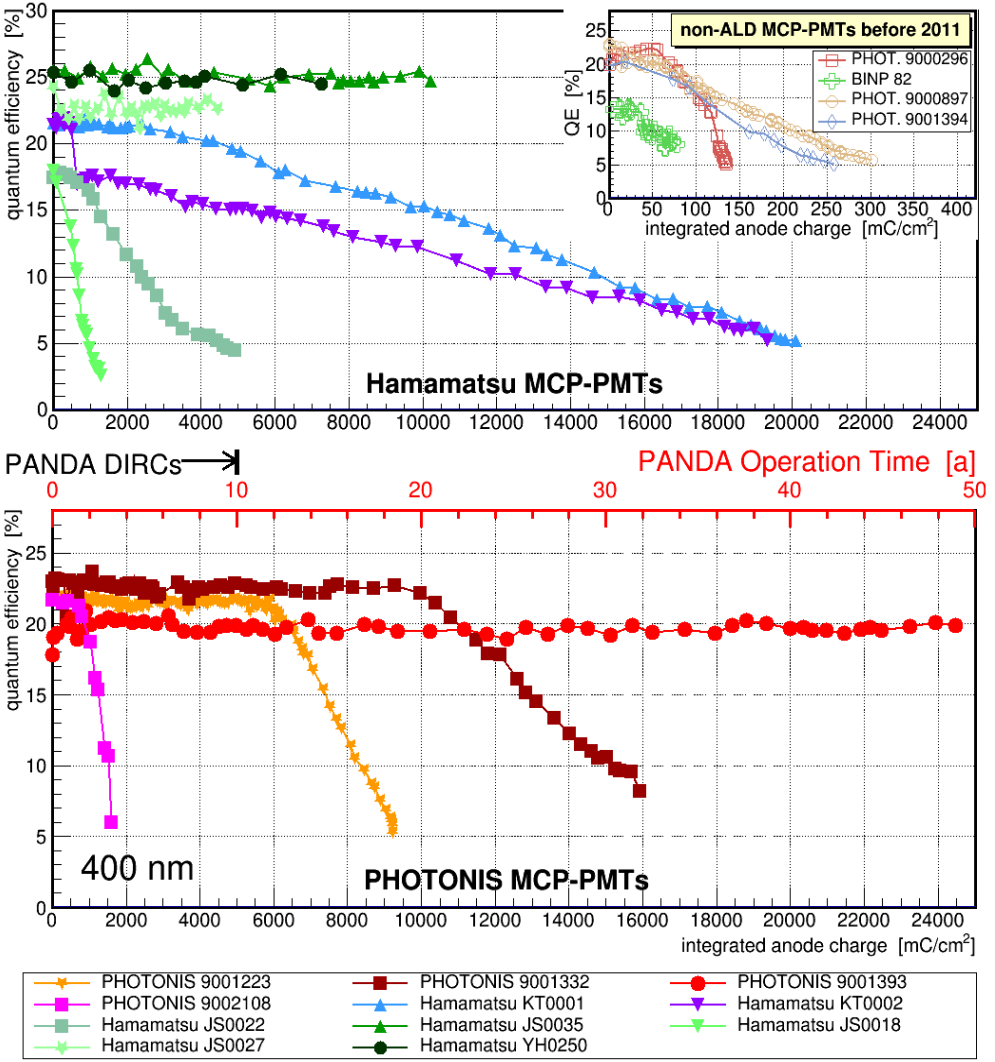
# Photon detector




Requirements:

- **few mm** spatial resolution
- **~100 ps** timing resolution

Sector:
**8 MCP-PMT**, each 8 x 8 pixels
(total 8 k readout channels)
with **pixel size 6 x 6 mm²**
work in **1T magnetic field**
survive **10 years** of PANDA (aging)

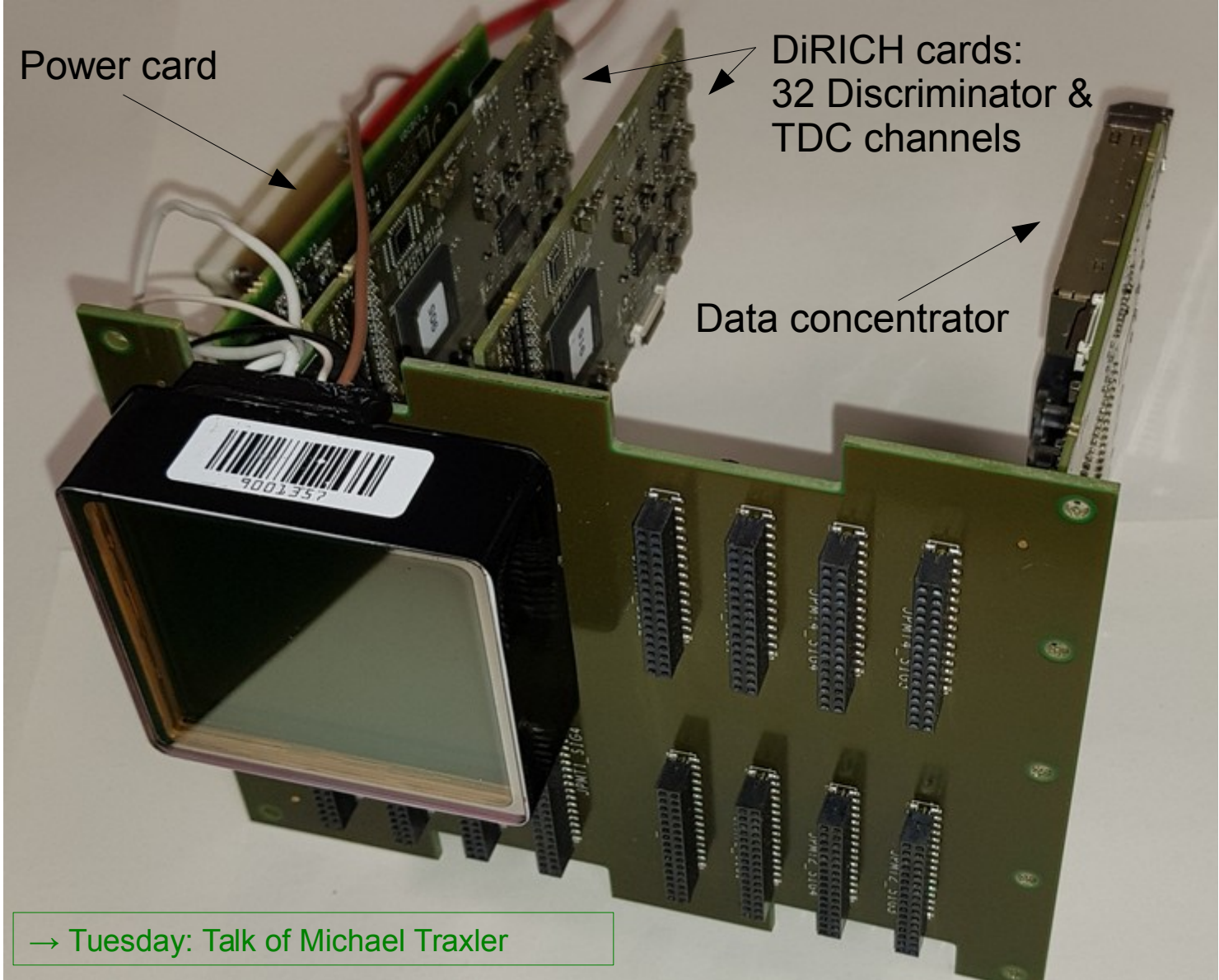



A.Lehmann, DIRC2019

Sensors with **ALD coated** MCPs have **lifetime > 5 C/cm²**

# Readout chain

DiRICH
Collaboration of
PANDA, CBM, HADES




Highly integrated
Low cost
~ 10 ps (discr. + TDC)
~ 50 mW / channel

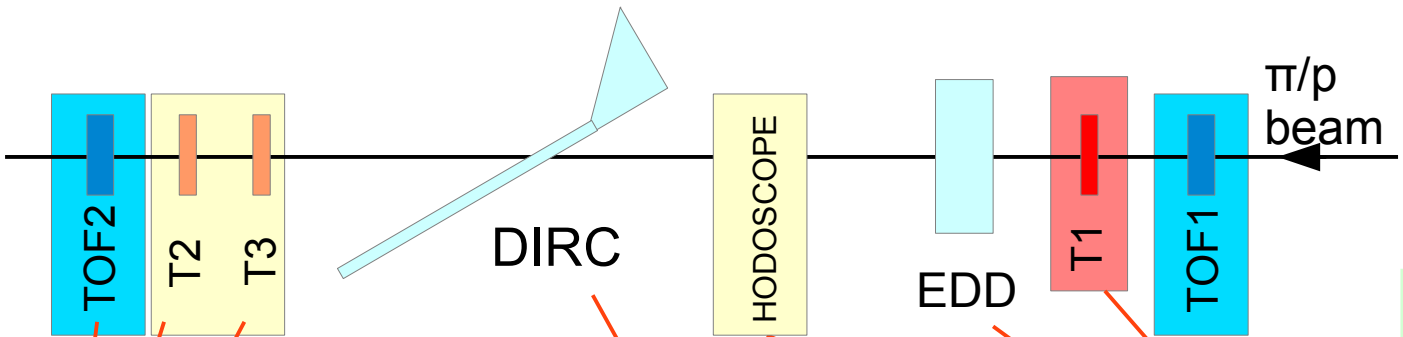
→ Tuesday: Talk of Michael Traxler

# Beam test at CERN 2018

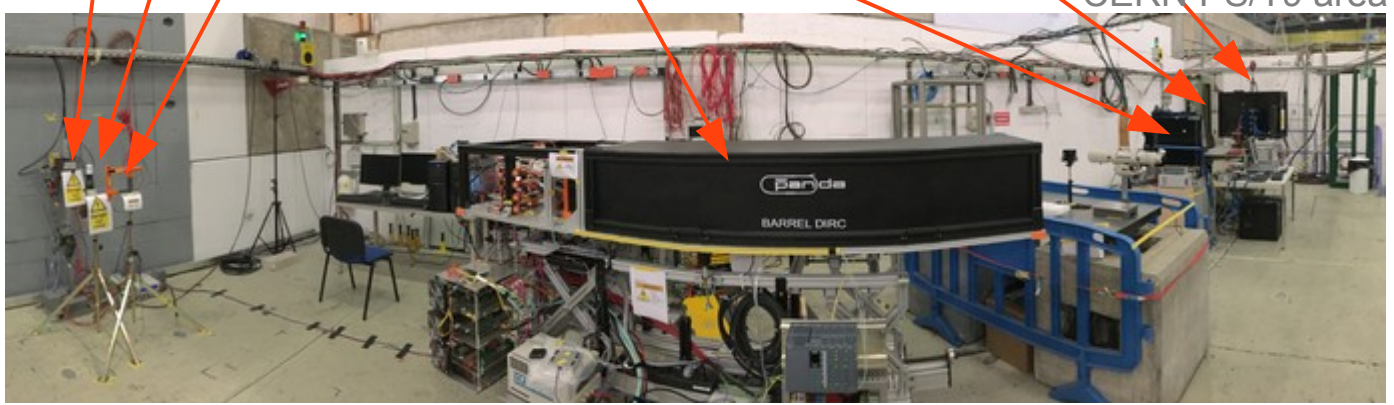
**TOF particle identification**

**Beam profiling**

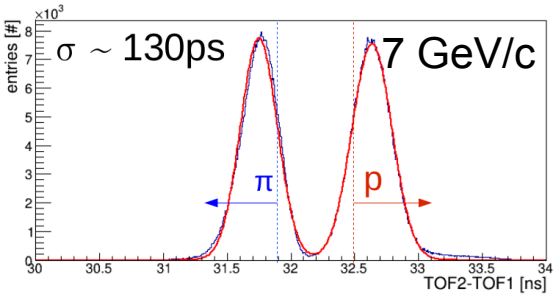
**Trigger**




CERN PS/T9 area

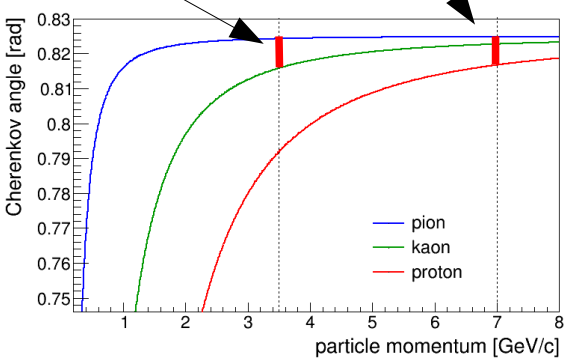



External TOF PID

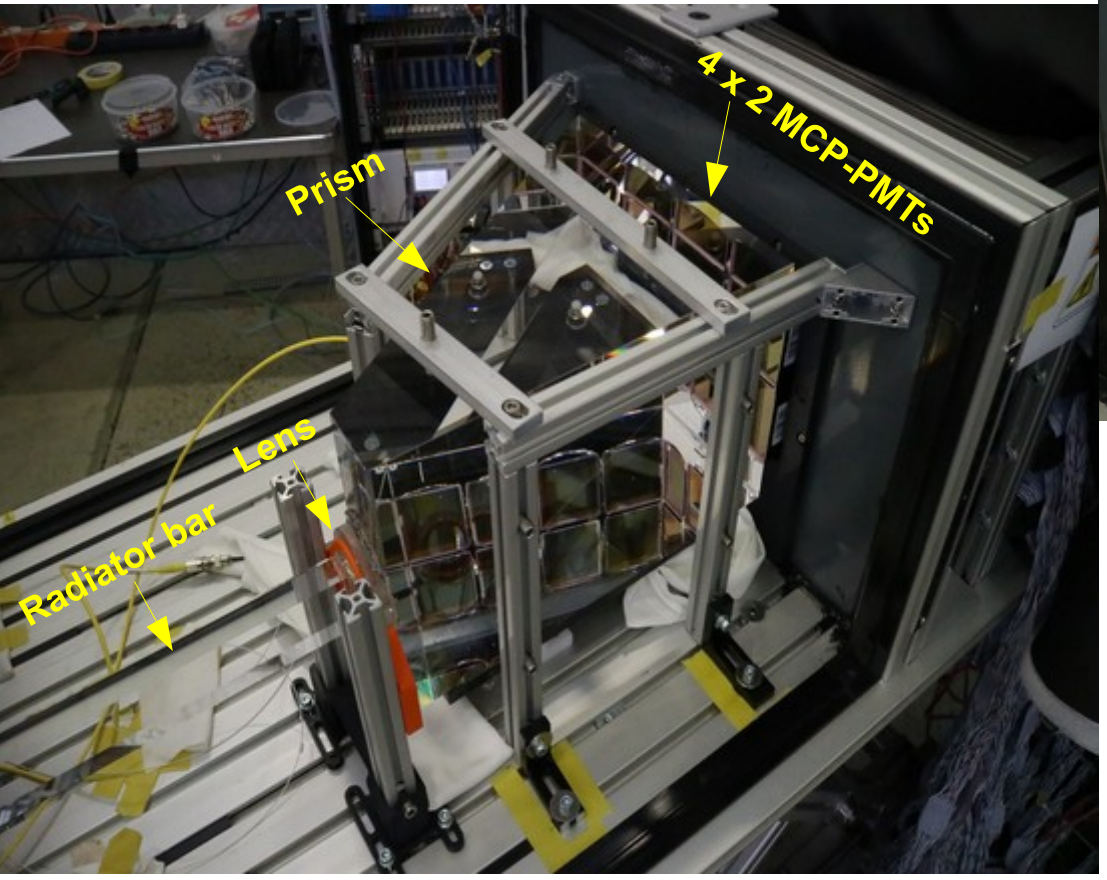


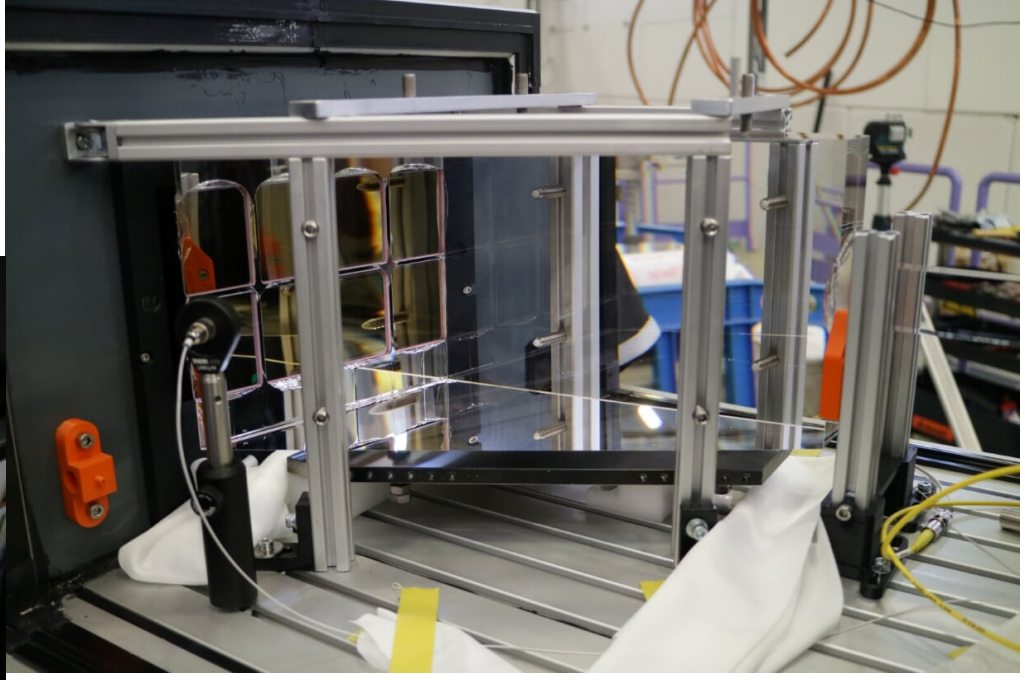

Most of the data taken at 7 GeV/c

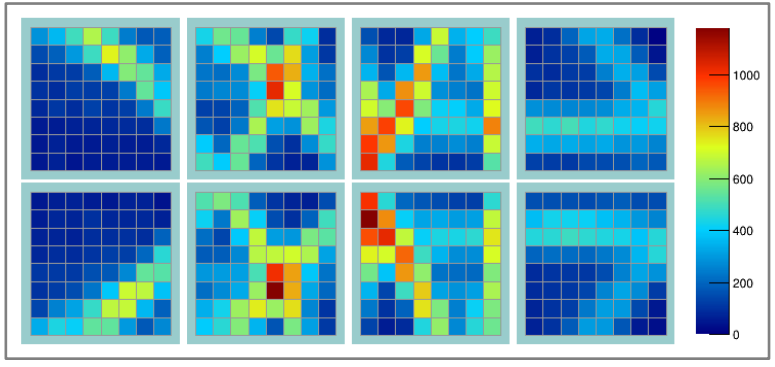
3.5 GeV/c π/K ≈ 7 GeV/c π/p sep.



# Barrel DIRC setup inside the black box



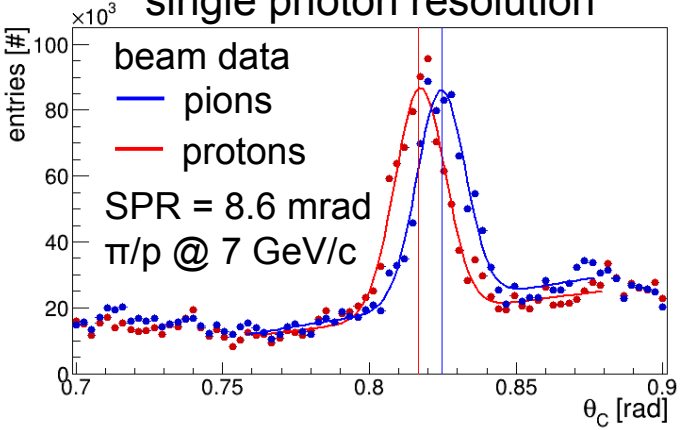



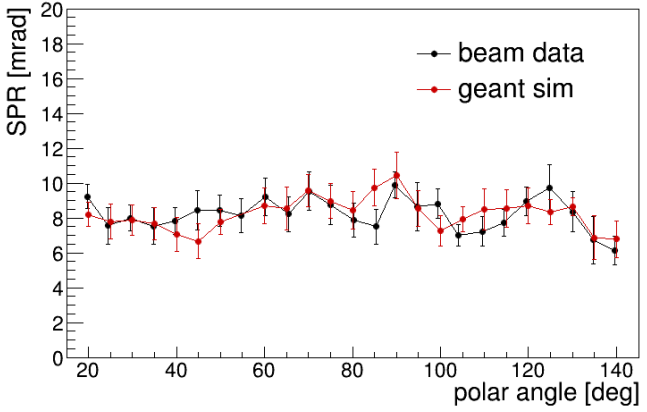



Barrel DIRC hit pattern at polar angle 20°

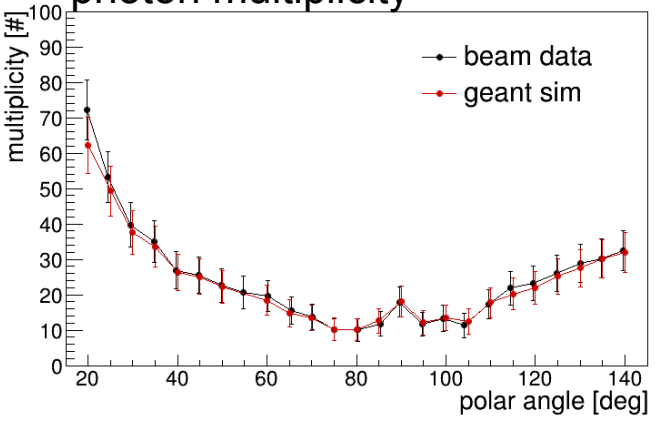
# Beam test at CERN 2018

single photon resolution

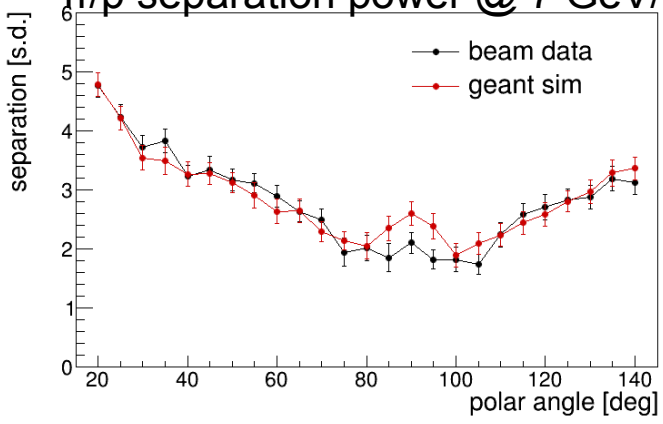



photon multiplicity




π/p separation power @ 7 GeV/c




Good performance

Good agreement with Geant simulations

→ Today: Poster of Ahmed Ali

The performance of the Barrel DIRC is validated.

The second DIRC in PANDA is the Endcap Disc DIRC (EDD)

# Endcap Disc DIRC (EDD)

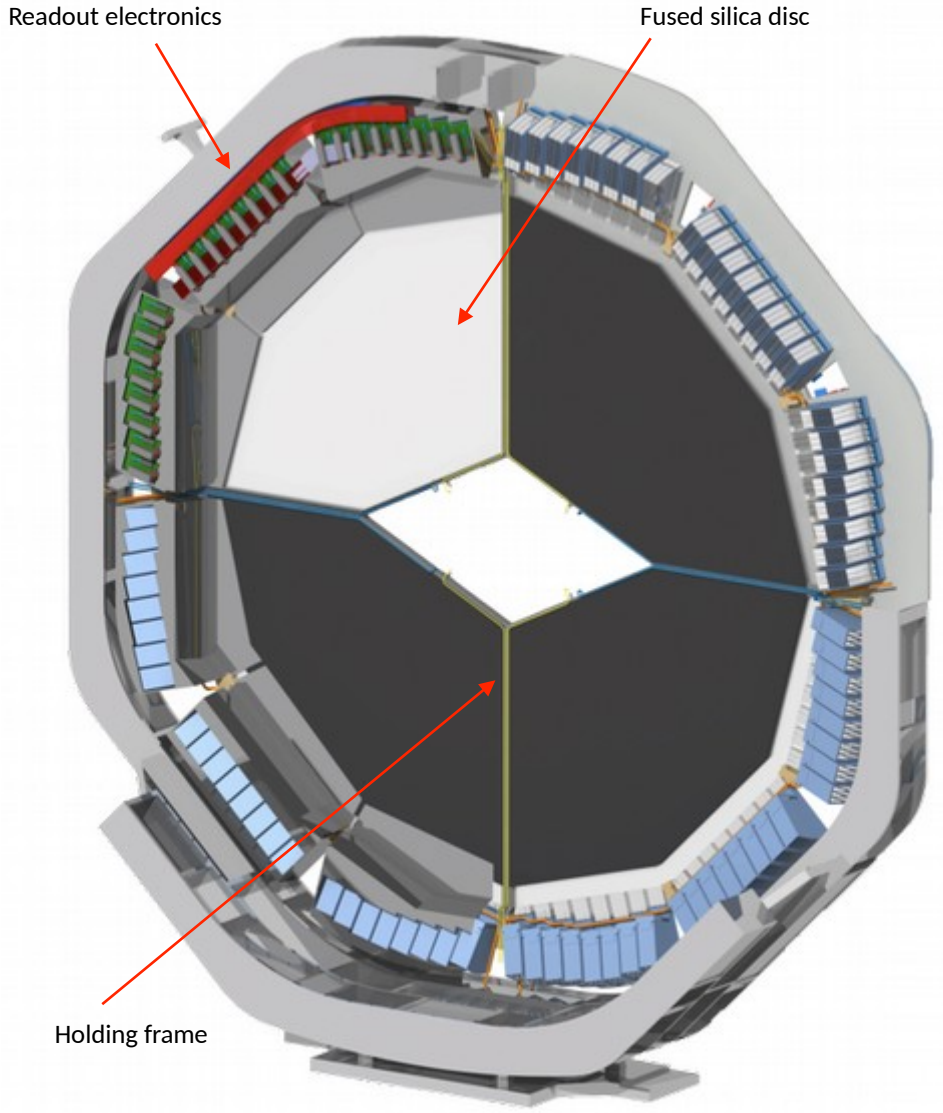
- Four independent quadrants
  highly polished synthetic fused silica (quartz),
  20 mm thickness, 1056 mm outer radius

- Holding frame
  stabilizating cross for all four quadrants

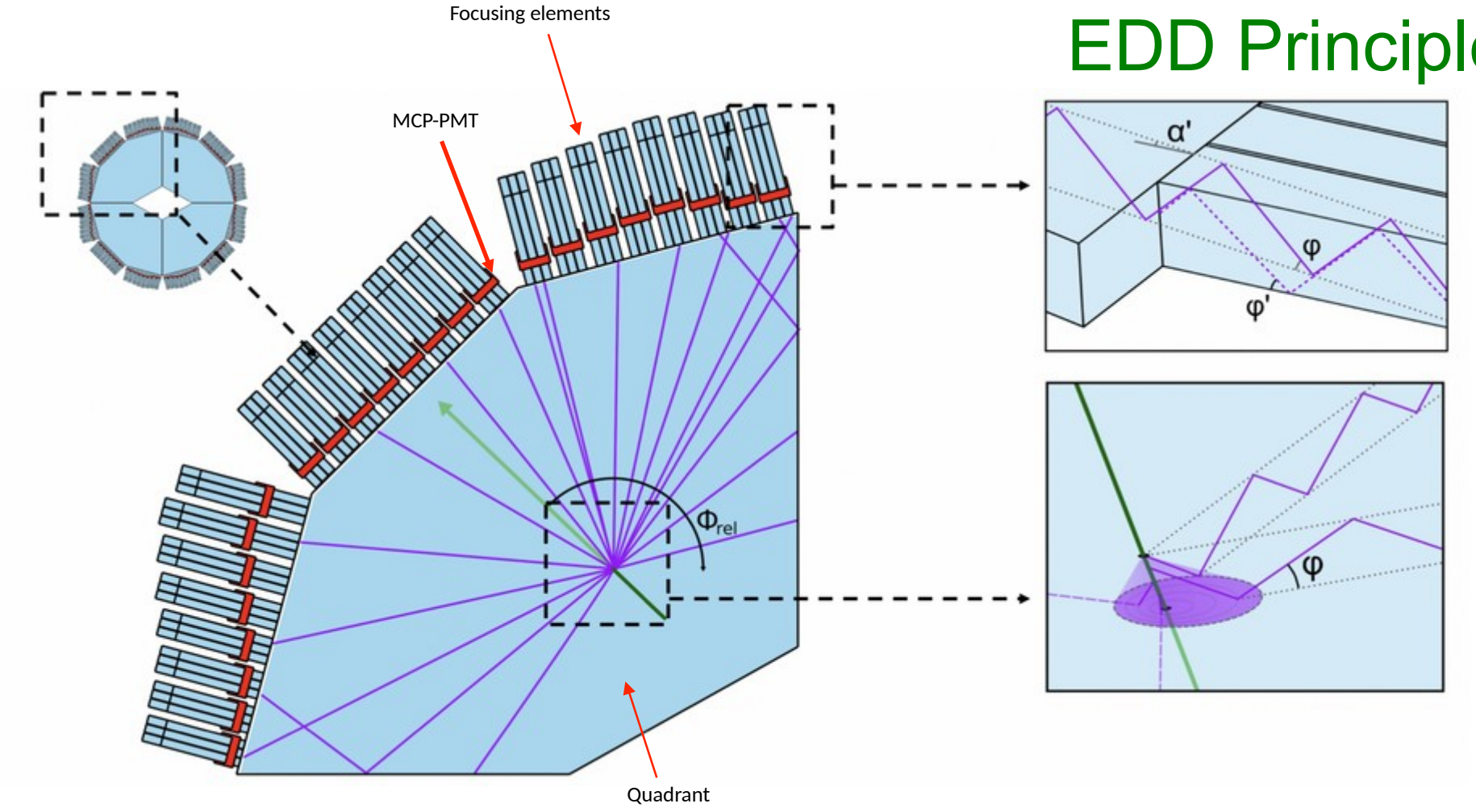
- Focusing optics
  Expansion volume with focusing elements
  convert angle to position information

- Sensors
  96 MCP-PMT sensors with
  highly segmented anode (3 x 100 pixels)

- Readout
  TofPET2 ASIC, 64 channels
  1 ROM: 5 ASICs for 1MCP-PMT,
  24 ROMs per quadrant,
  in total ~ 28800 pixels



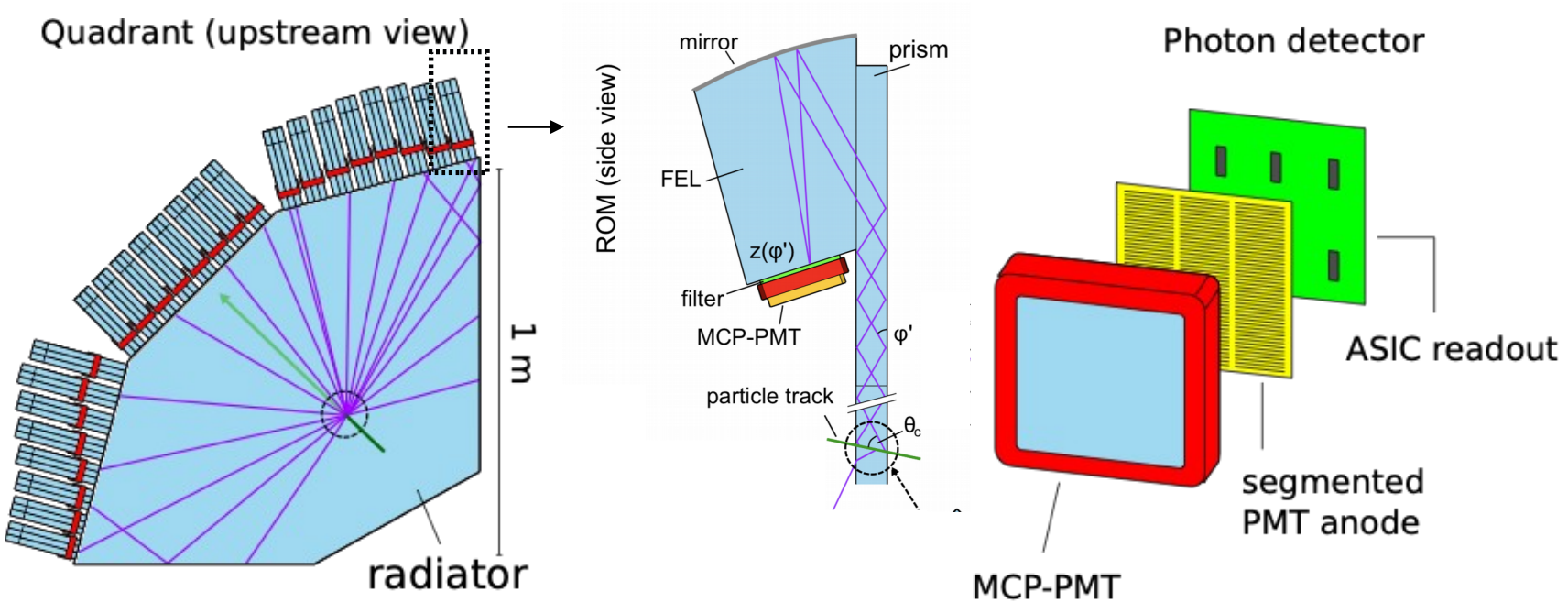
# EDD Principle




$$\theta_c = \arccos\left(\sin\theta_p \cos\phi_{\mathrm{rel}} \cos\varphi + \cos\theta_p \sin\varphi\right)$$

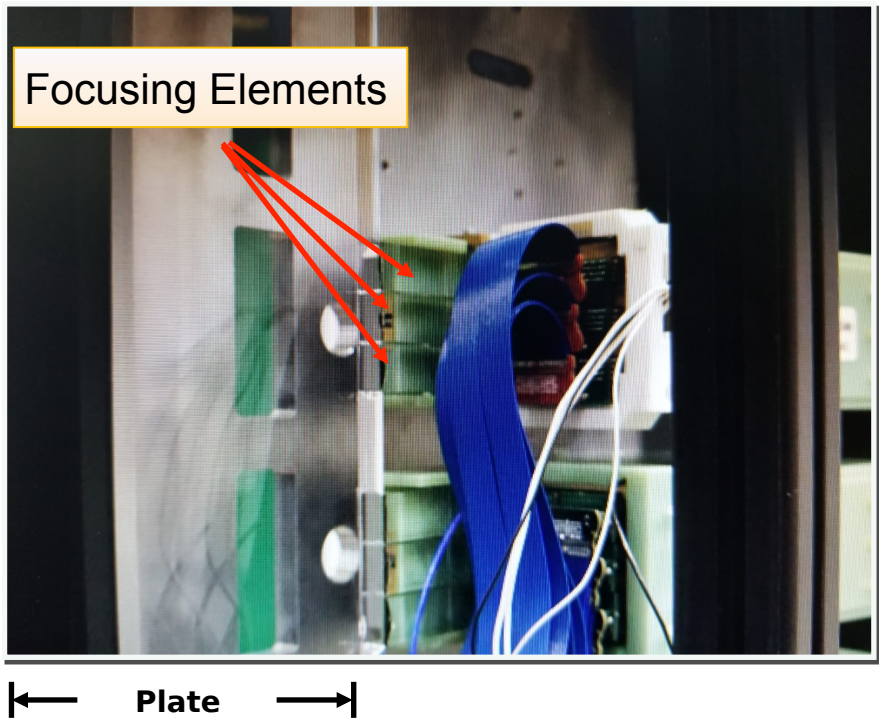
# EDD Design

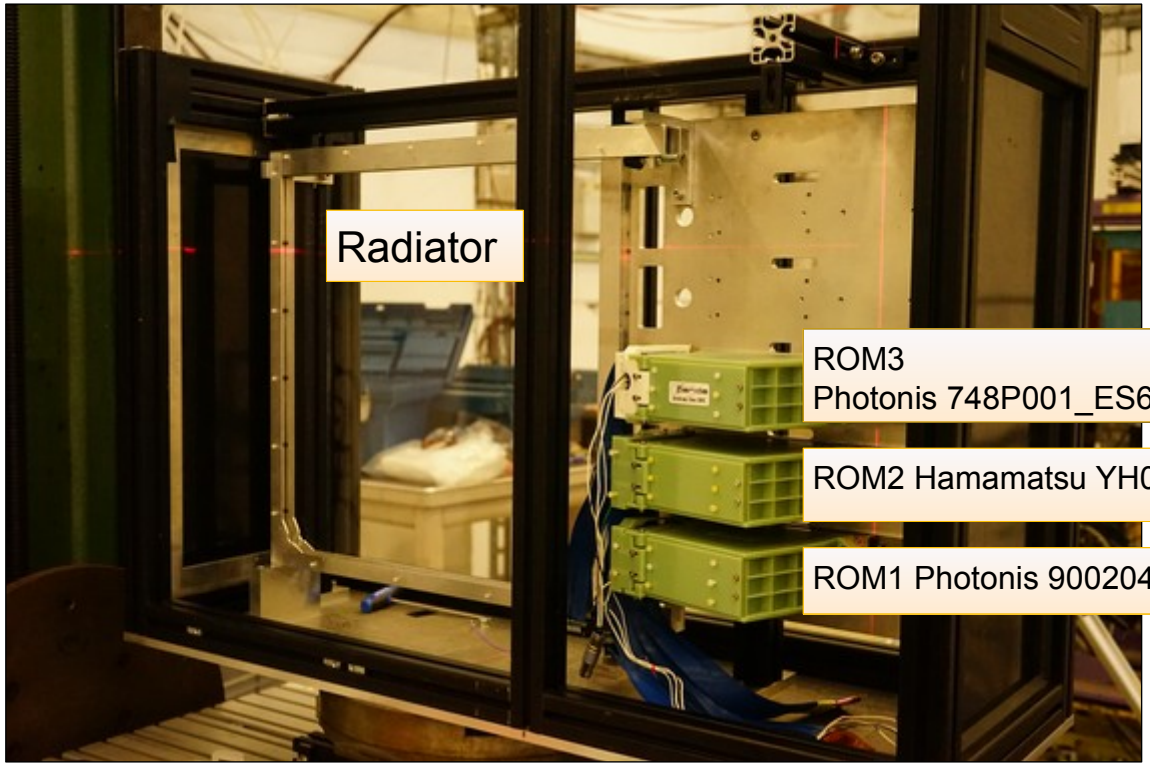
Optics made of synthetic fused silica




3 x 100 pixels
3 x 128 pixels

# EDD Prototype from Test Beam 2018

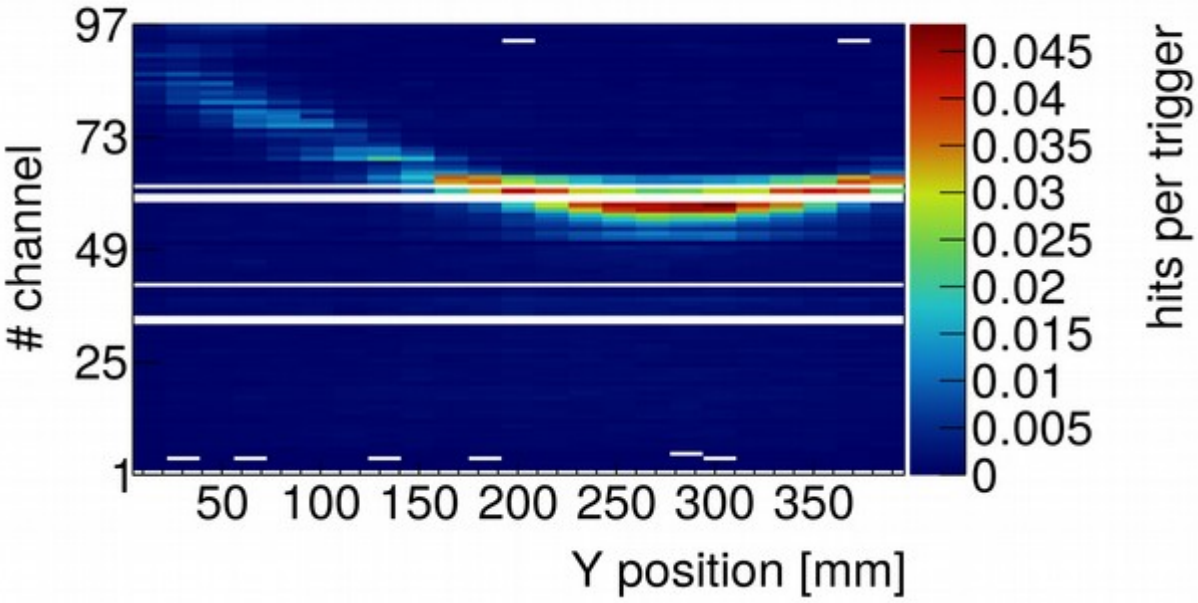


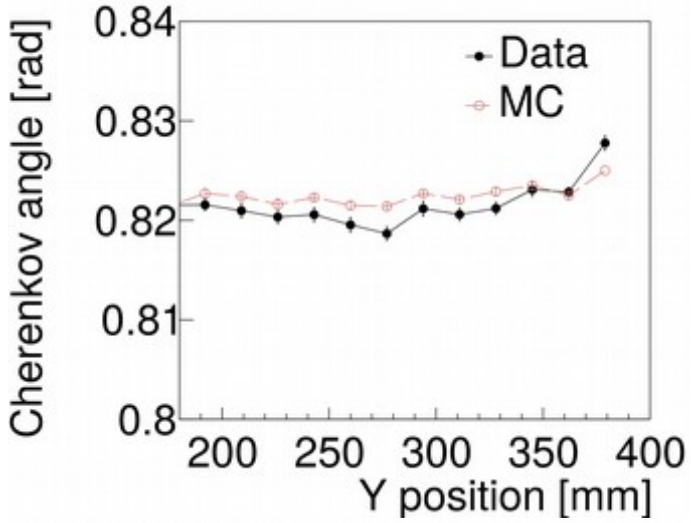



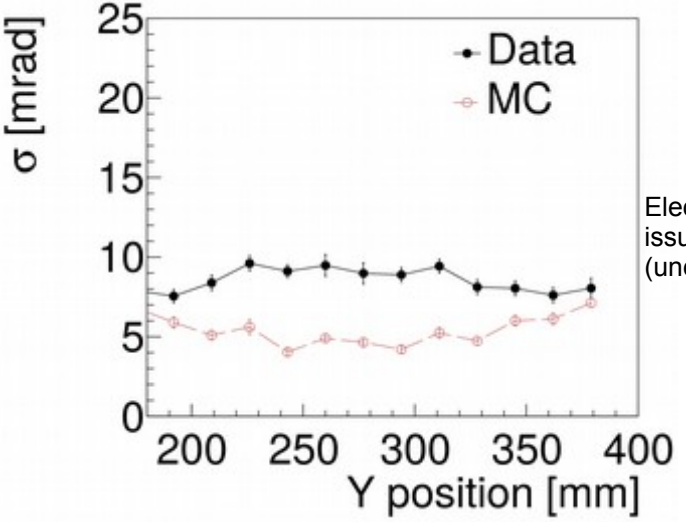

Radiator: Fused silica, 500 x 500 x 20 $mm^3$
9 focusing elements (FELs),
3 readout modules (ROM),
3 photon sensors (MCP-PMTs)

# Selected test-beam results for the EDD prototype: 2018

Y-scan @ 10 GeV/c



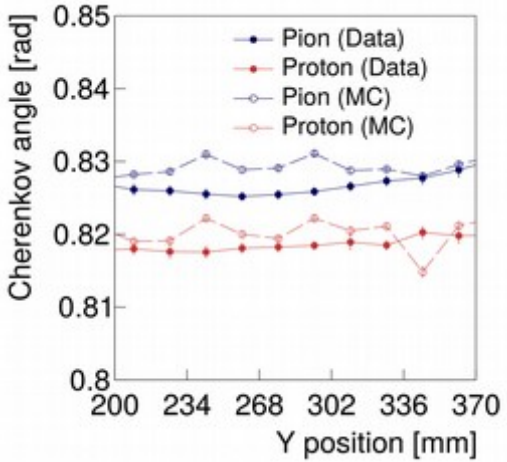

Electronic issue (understood)

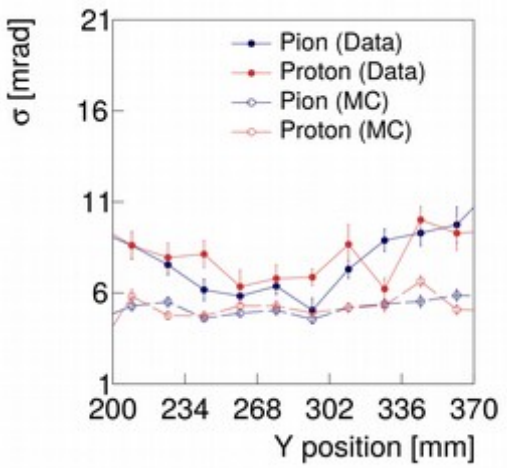
# Selected test-beam results for the EDD prototype: 2018

Cherenkov angle (rad)

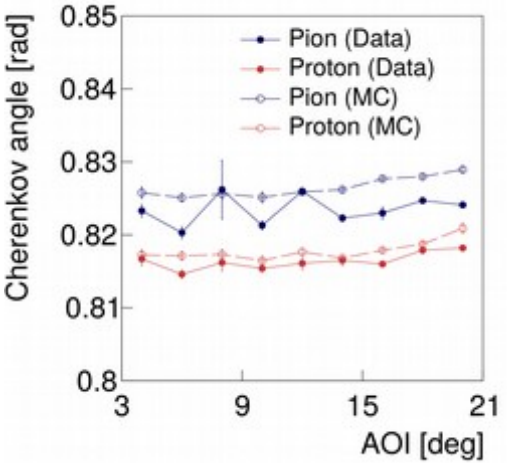
Single photon resolution (mrad)

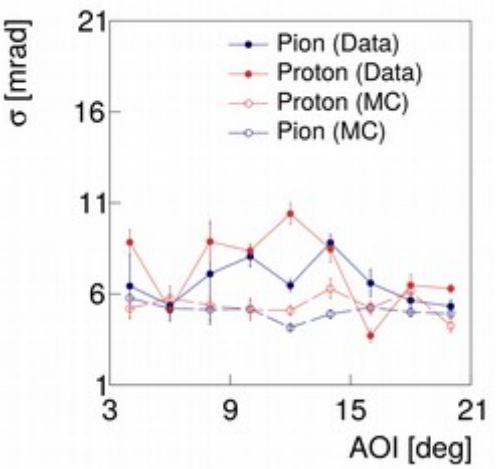
Y-scan




Angle-scan angle of incident (AOI)




Barrel DIRC and Endcap Disc DIRC performance validated in test beams,

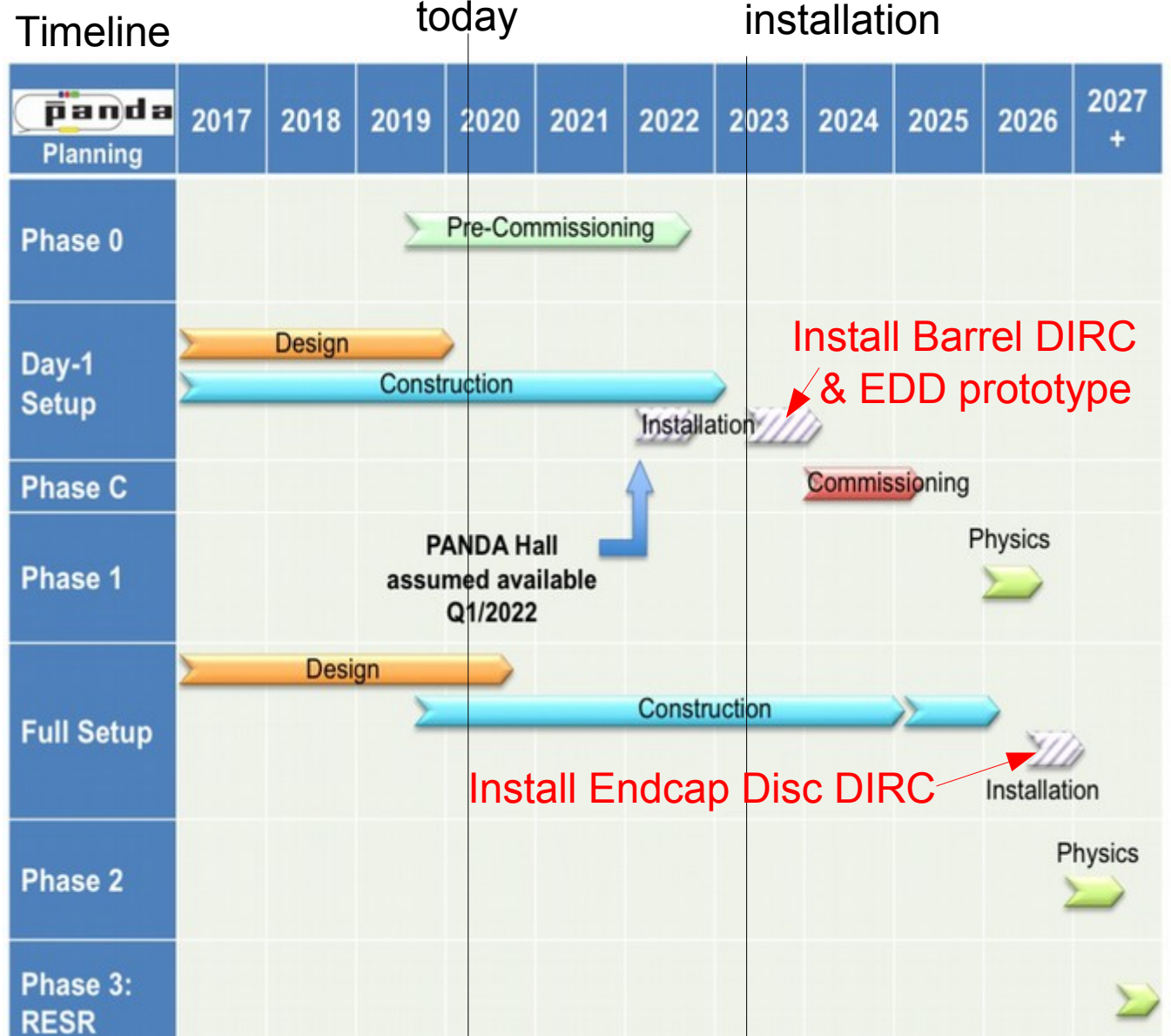
Both TDRs are completed

→ next steps ?

# Next steps

- 2020-2022: Industrial fabrication of Barrel DIRC main components (sensors, bars, lenses, prisms), Production and QA of readout electronics.
- 2021-2022: Industrial fabrication of Barrel DIRC bar boxes and mechanical support frame; QA of all components; gluing of long bars, assembly of complete sectors.
- 2023/2024: Installation in PANDA, commissioning.

- 2021-2024: Industrial fabrication of 4 independent Endcap Disc Dirc quadrants and mechanical support frame, gluing of focusing elements/plates, detailed scans of all sensors assembly of readout units.
- 2023/2024: Installing prototype in phase 1: One quadrant with 3 ROMs.
- 2025: Completing the quality assurance of components.
- 2026/2027: Installation of the Endcap Disc DIRC into the PANDA detector and commissioning.




Experiments with PANDA detectors and software at HADES, MAMI, and GlueX

Construction of Phase 1 systems

Two Phase 1 installation periods
1. Solenoid, dipole, supports
2. All Phase 1 detectors

Commissioning with cosmics and beam (protons / antiprotons)

Physics with antiprotons

Construction of Phase 2 systems

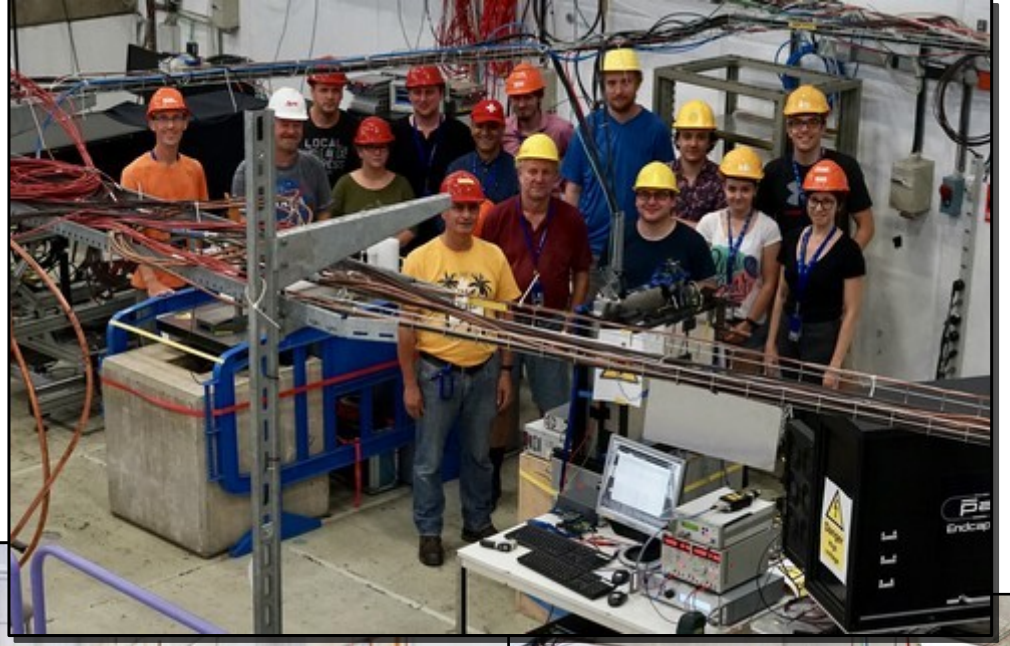
Installation period for remaining Phase 2 detectors

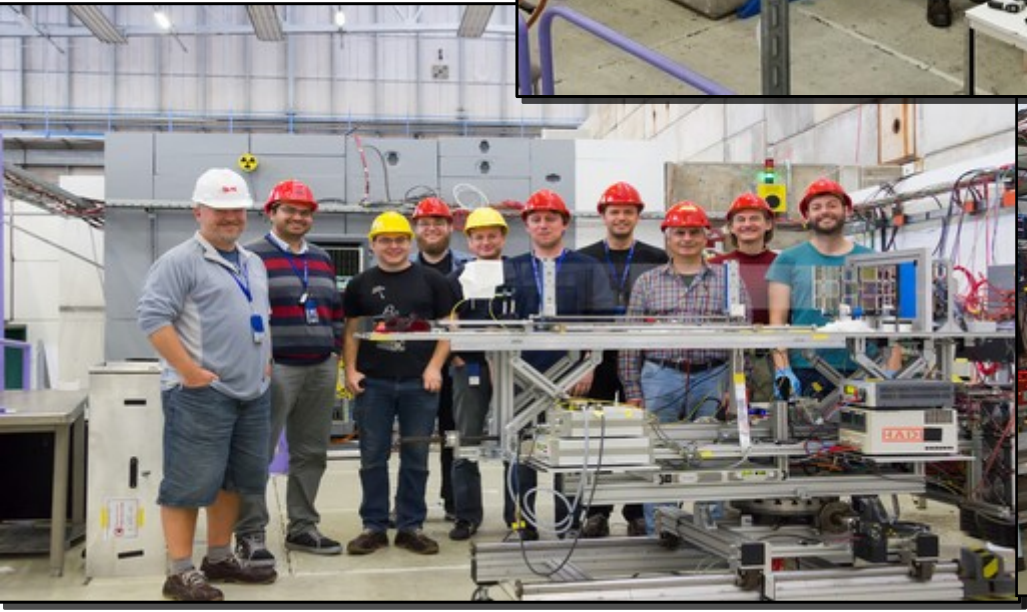
Physics with antiprotons

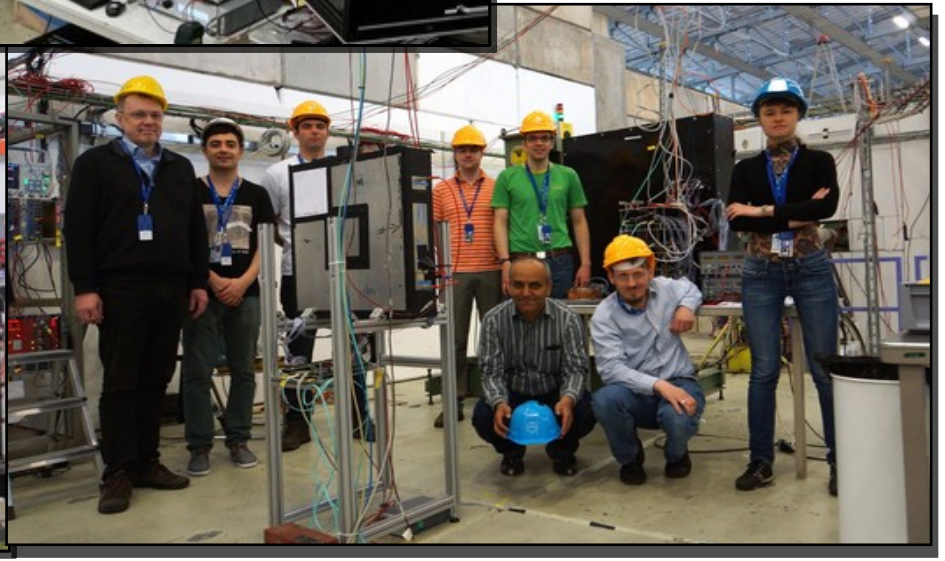
# Summary

- The Barrel DIRC design with narrow bars, 3-layer spherical lens, and compact prisms meets or exceeds the PANDA PID requirements.
- The mass production has started. First 4 bars are shipped this week by Nikon.
- Final state of MCP tendering.

- The Endcap Disc DIRC with 4 independent quadrants and focusing optics is a key component of the PANDA PID system.
- The Endcap Disc DIRC PID performance is successfully validated in particle beams.







**Thank You**