The PANDA DIRC detectors at FAIR

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for the
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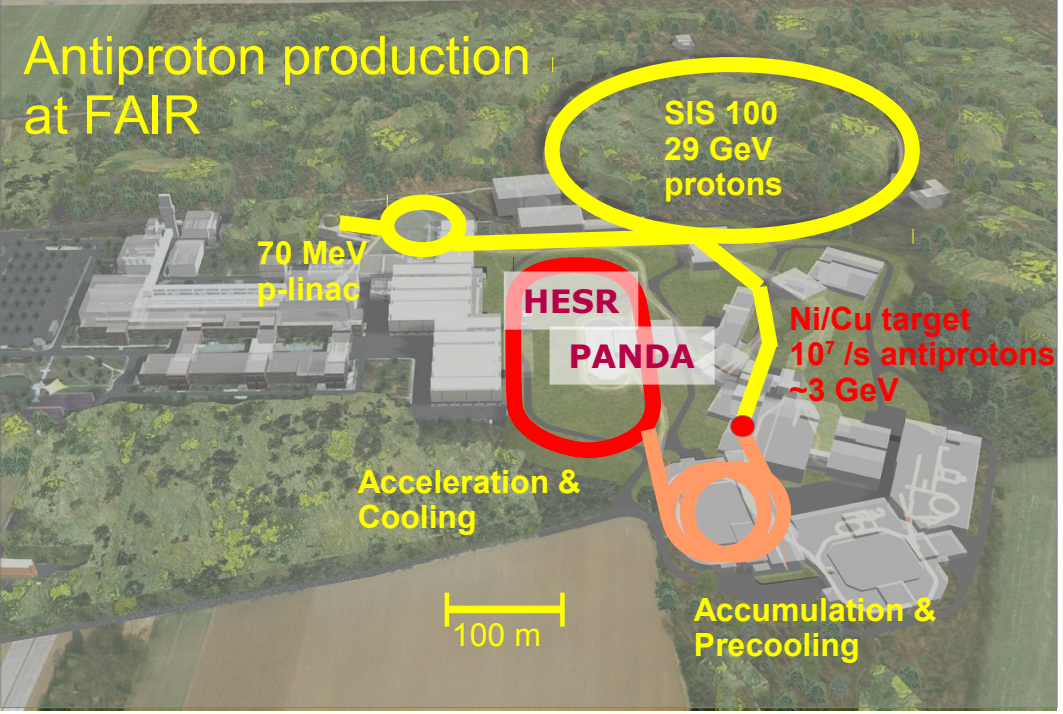
- PANDA at FAIR
- PID requirements
- Barrel DIRC
- Endcap Disc DIRC



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

High Energy Storage Ring

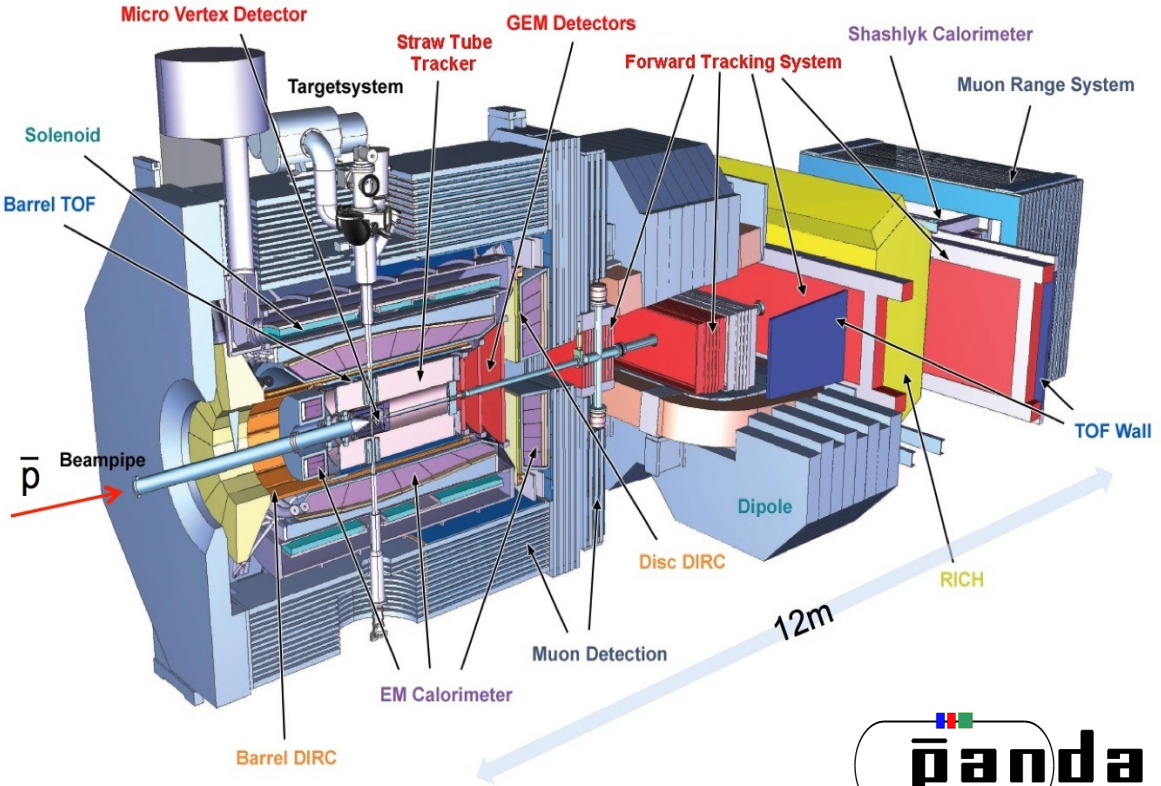
5 x 10^{10} stored cooled $\bar{p}$

1.5 to 15 GeV/c momentum

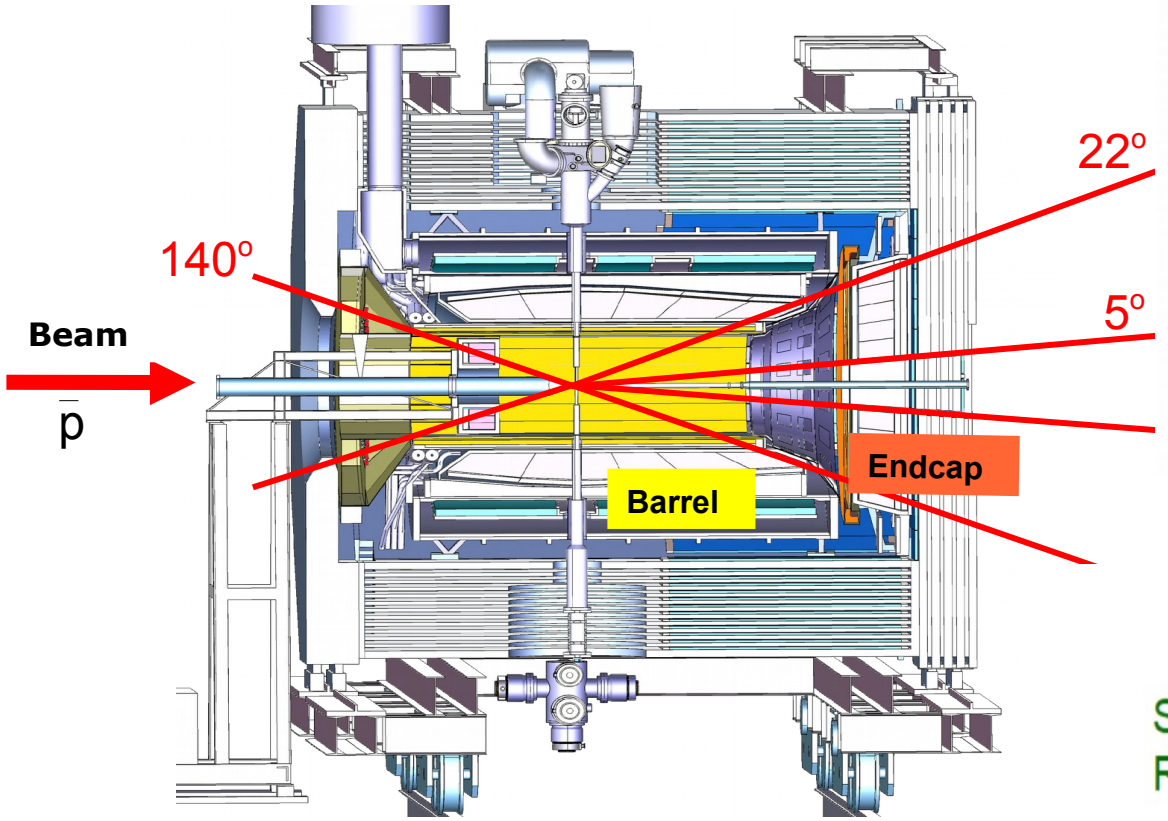
Cluster jet / pellet target

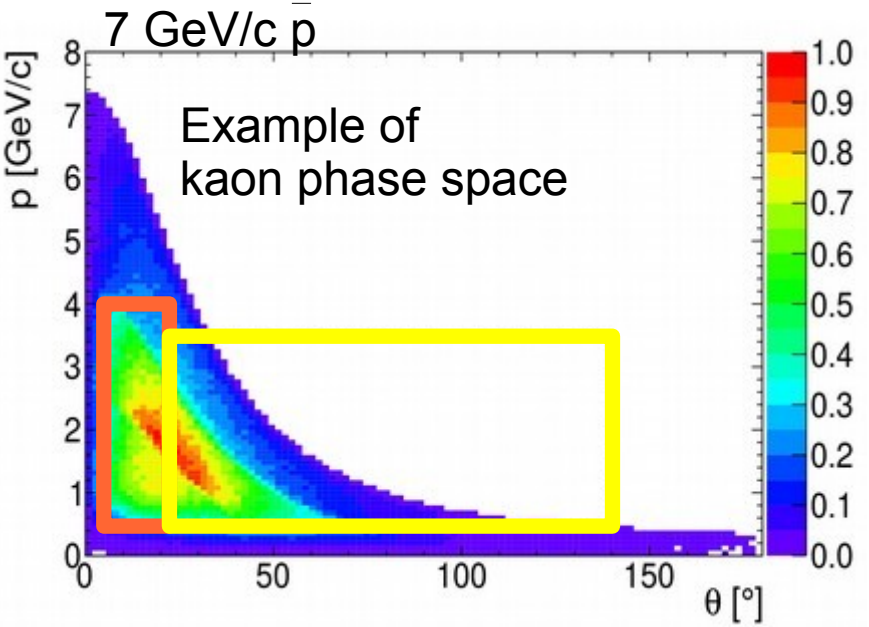
High luminosity mode
$\Delta p/p = 10^{-4}$
1.6 x 10^{32} cm^{-2} s^{-1}

High resolution mode
$\Delta p/p = 5 \times 10^{-5}$
1.6 x 10^{31} cm^{-2} s^{-1}



PANDA DIRC counters



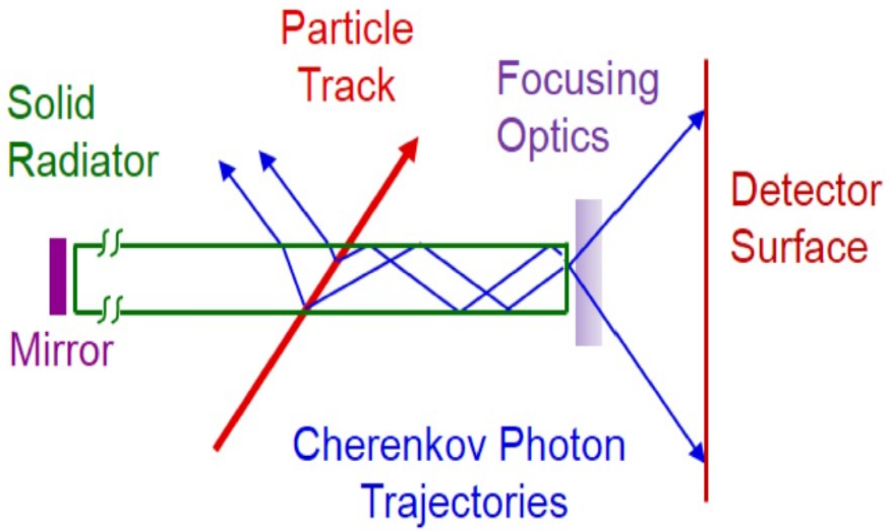


Barrel DIRC

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

Endcap disc DIRC

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

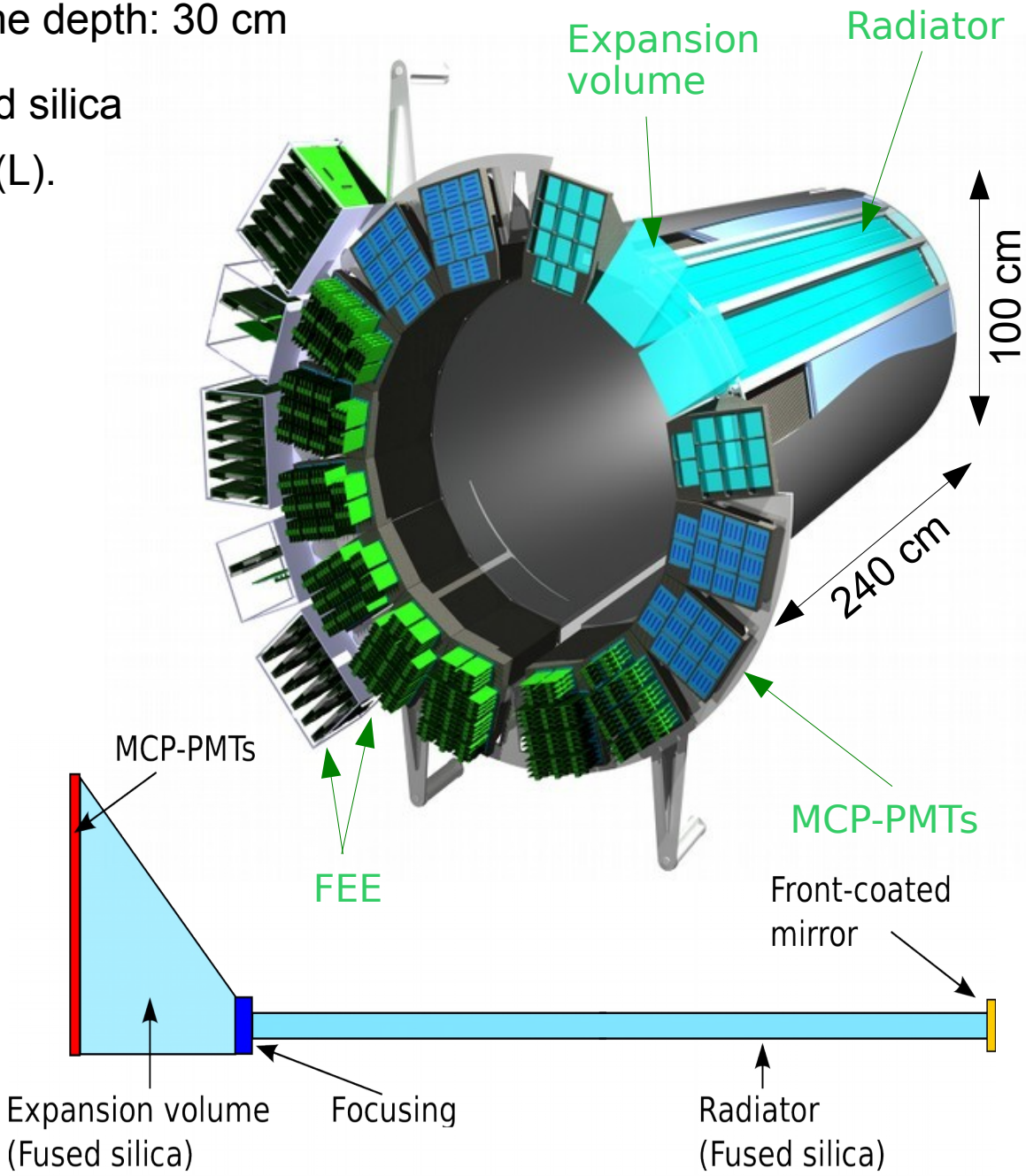


Magnitude of photon angles in radiator preserved

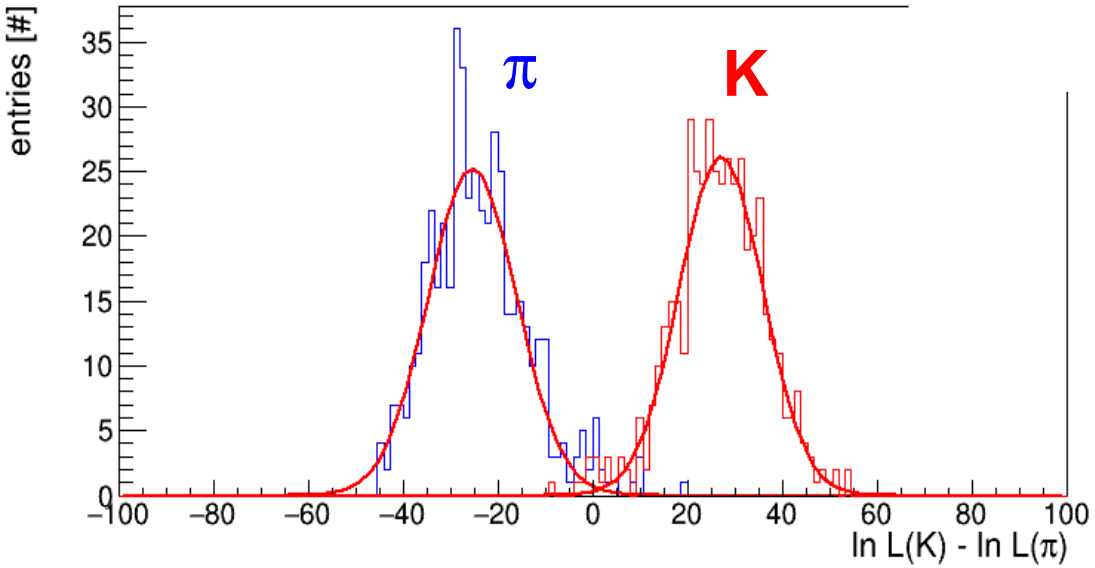
Baseline design: based on BABAR DIRC with key improvements

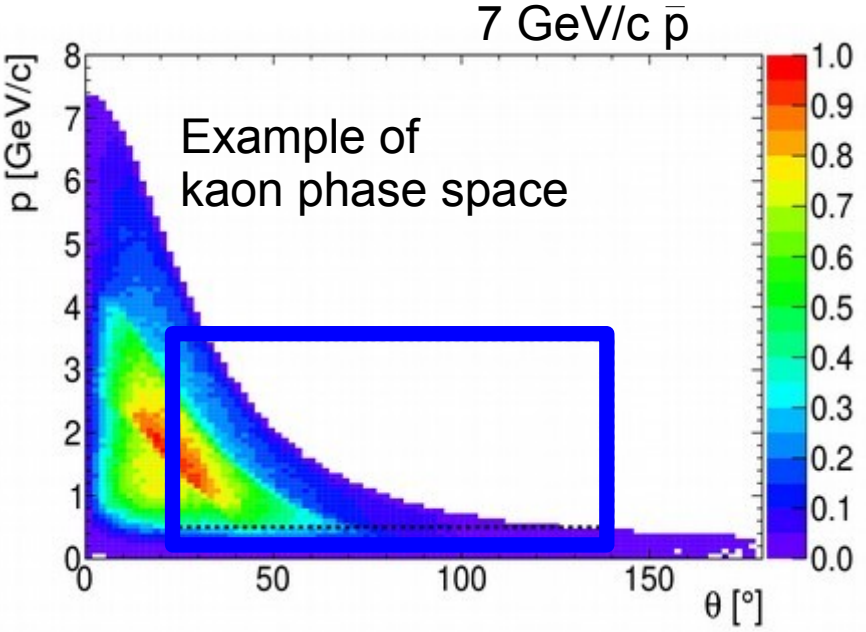
- Barrel radius ~48 cm; expansion volume depth: 30 cm
- 48 narrow radiator bars, synthetic fused silica
  17 mm (T) x 53 mm (W) x 2400 mm (L).

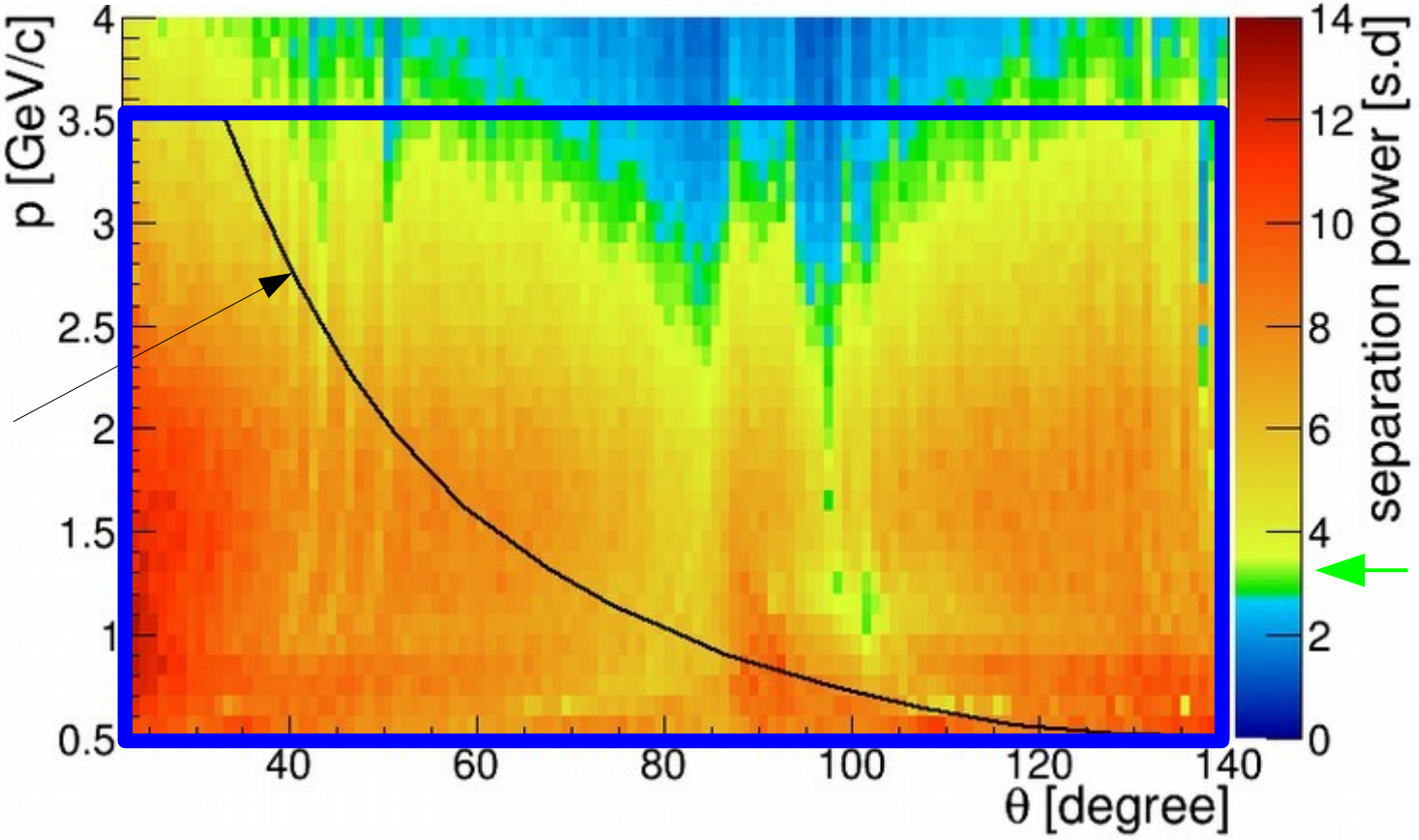
- Focusing optics:
  triplet spherical lens system
- Compact expansion volume:
  30 cm deep solid fused silica prisms
  ~11000 channels of MCP-PMTs
- Fast FPGA based read out electronics:
  ~ 100 ps per photon timing resolution
- Expected performance:
  better than 3 s.d. π/K separation
  for entire acceptance
- Conservative design:
  similar to proven BaBar DIRC design,
  which would meet PANDA
  PID requirements



Simulation results

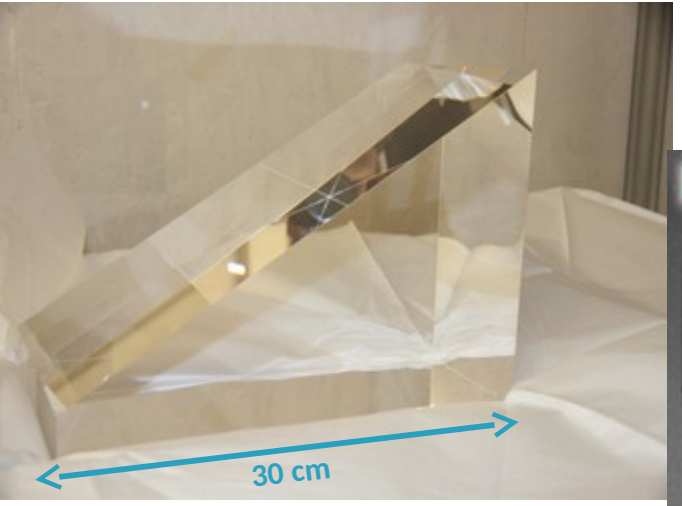


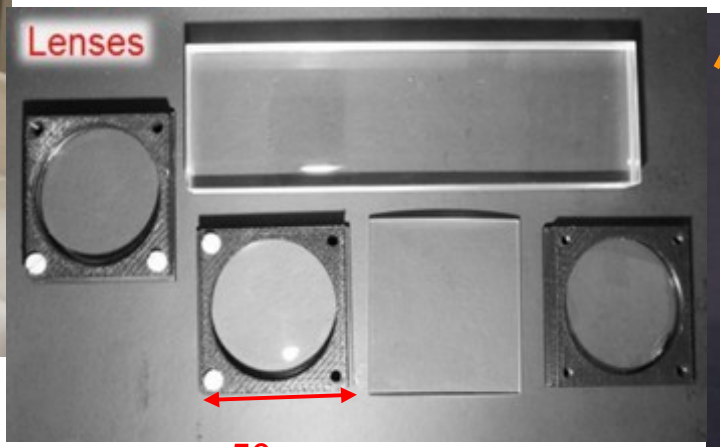


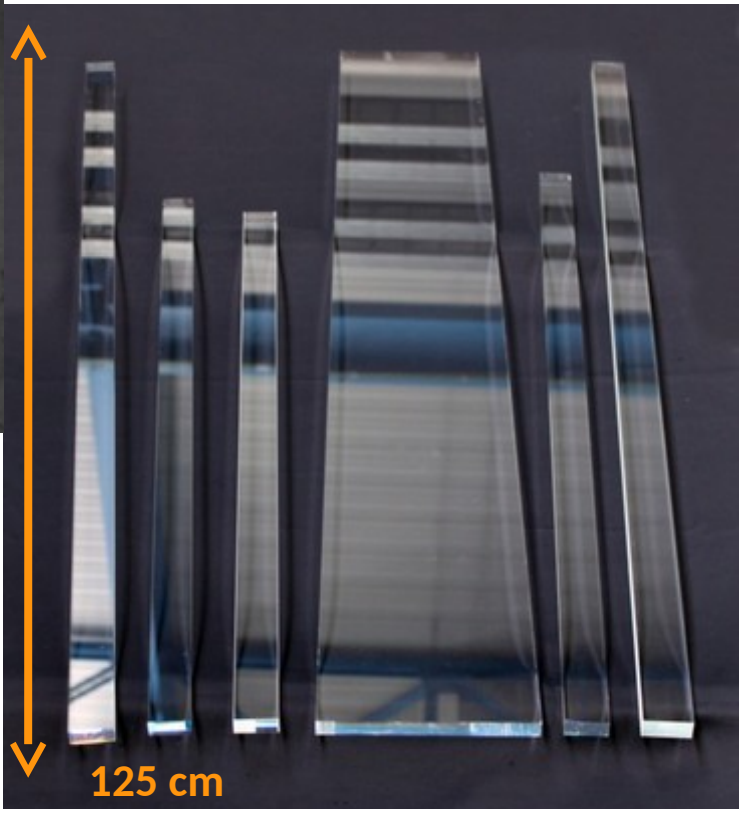


Barrel DIRC PID 3 s.d. goal
(from kaon phase space)

Optical components





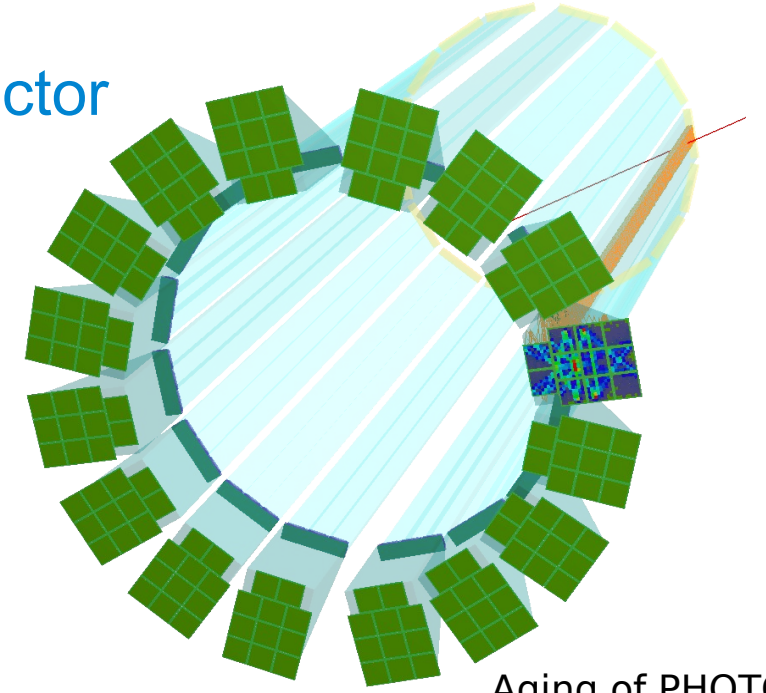


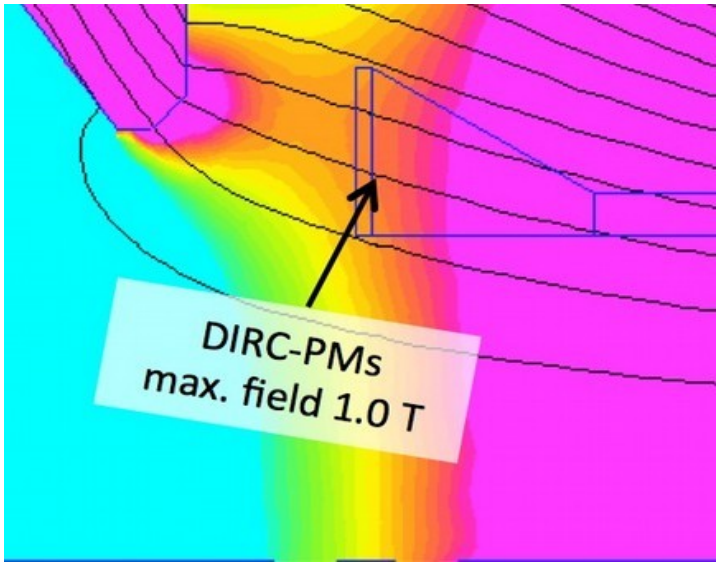
Quality assurance in optical laboratory at GSI and by producer

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

Plates from InSync, Nikon

Photon detector





Requirements:
few mm spatial resolution
~50 ps timing resolution

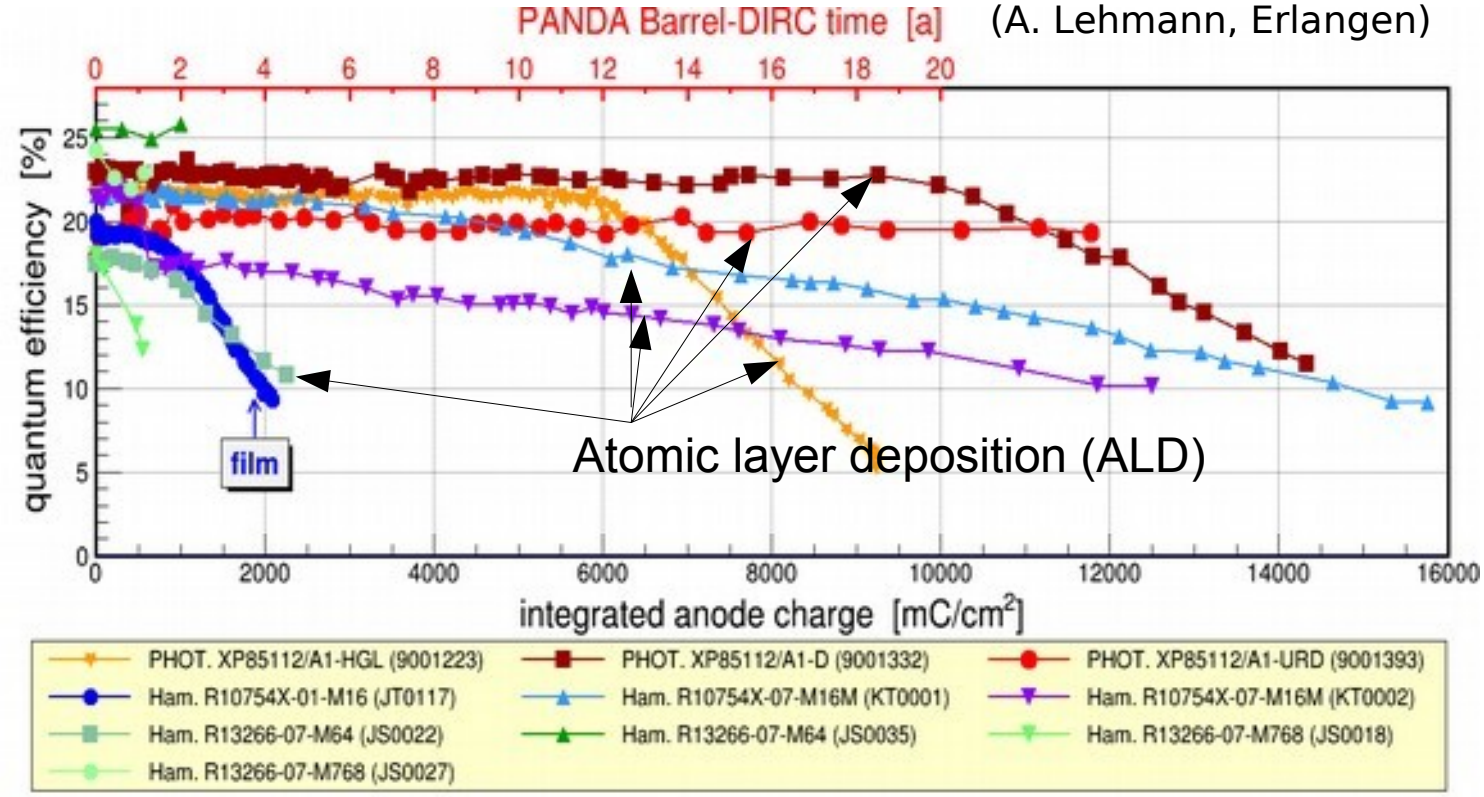
Bar-box:
3 x 3 + 2 MCP-PMT, 704 pixels
(total 11 k readout channels)

with **pixel size 6.5 x 6.5 mm²**

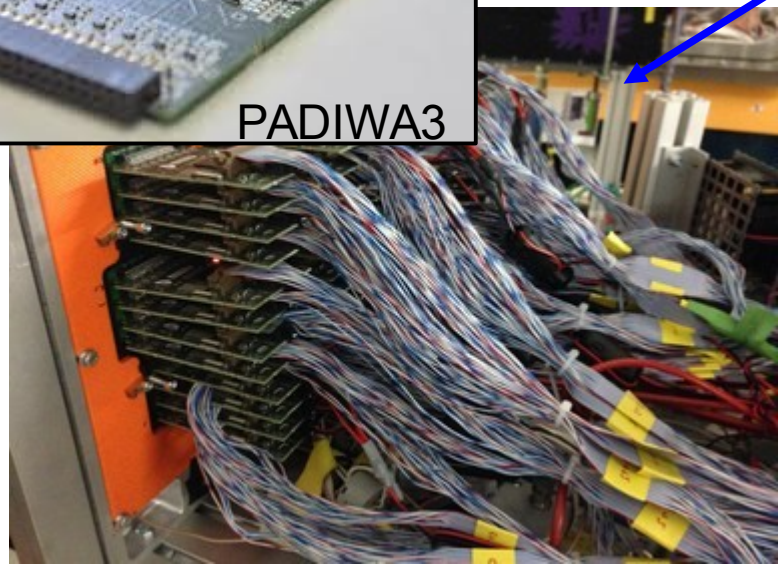
work in **1T magnetic field**

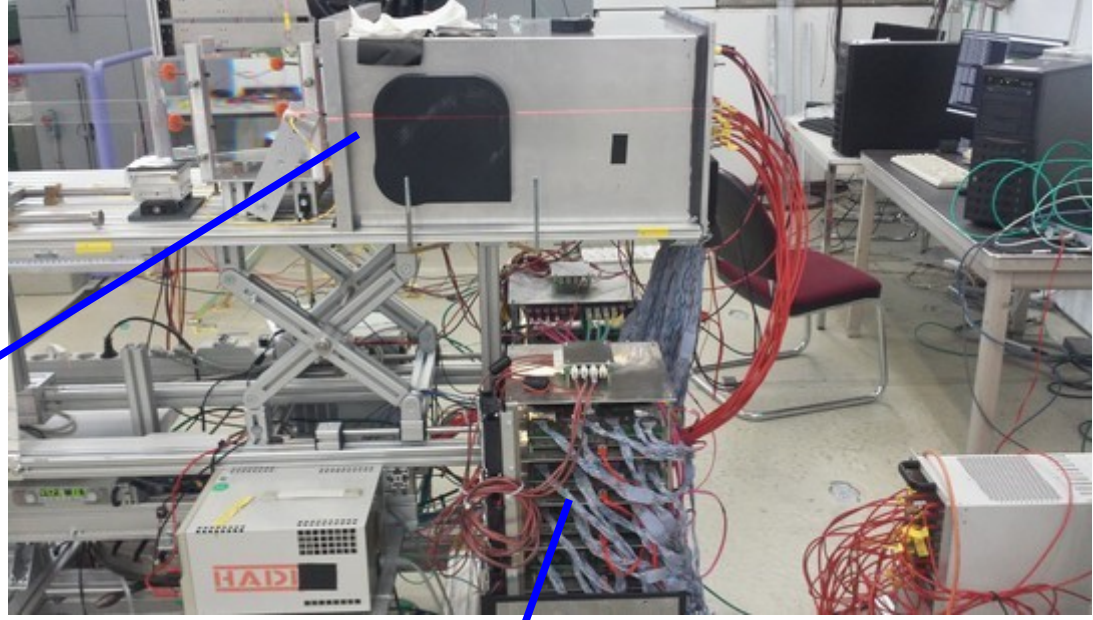
survive **10 years** of PANDA
(aging)

Aging of PHOTONIS (PHOT.) and Hamamatsu (Ham.) MCP-PMTs
(A. Lehmann, Erlangen)

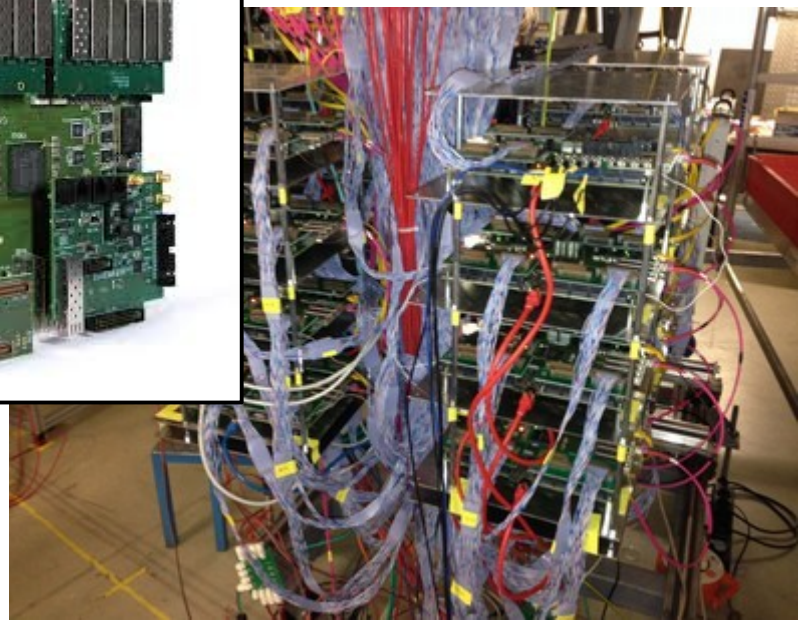


Readout chain





TRB3

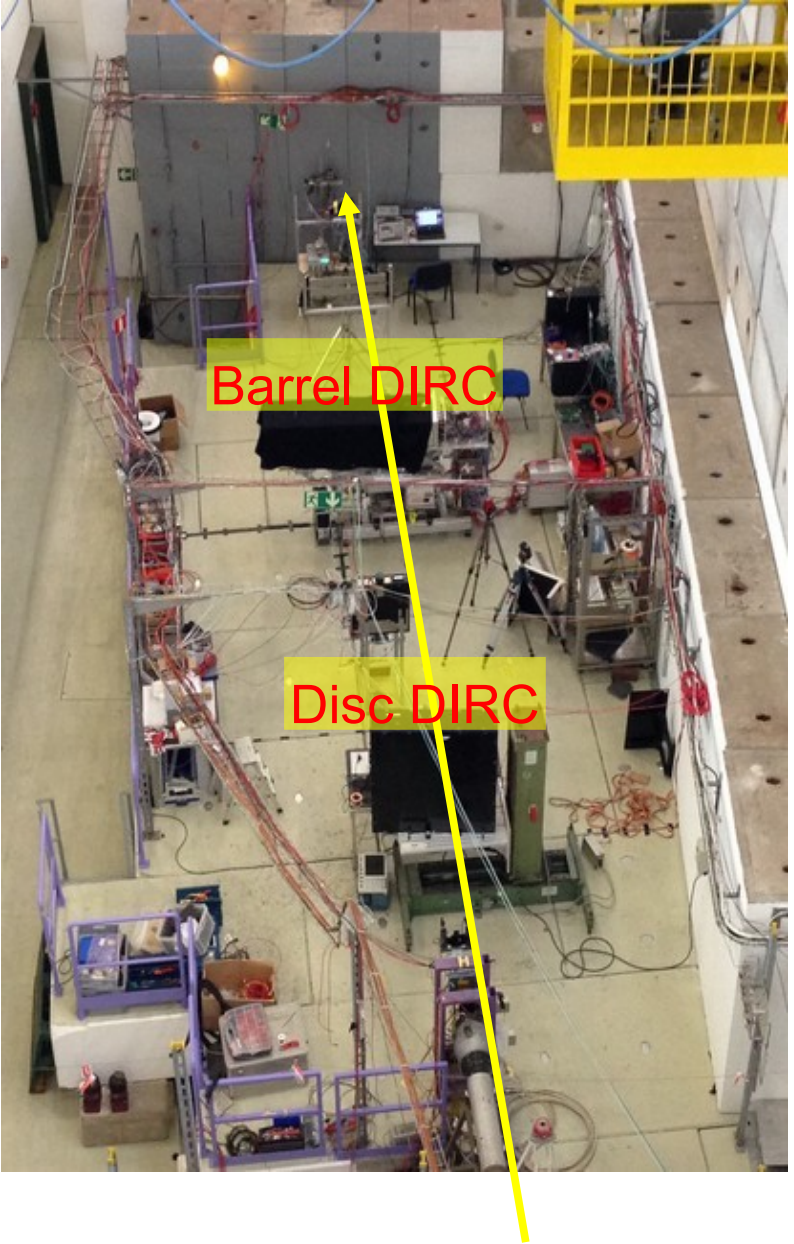


PADIWA3 discriminator

TRB3 TDC board
- Leading edge → timing
- Trailing edge → TOT → walk correction

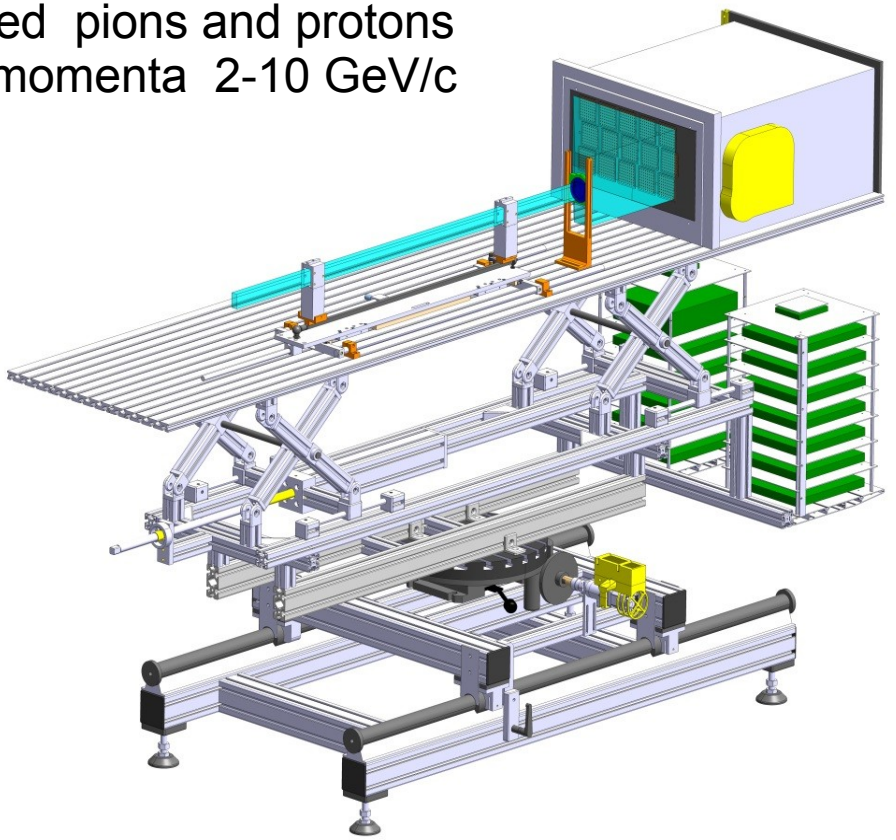
Highly integrated
Low cost
< 50 ps (discr. + TDC)

Experiments at CERN PS/T9 in 2015, 2016

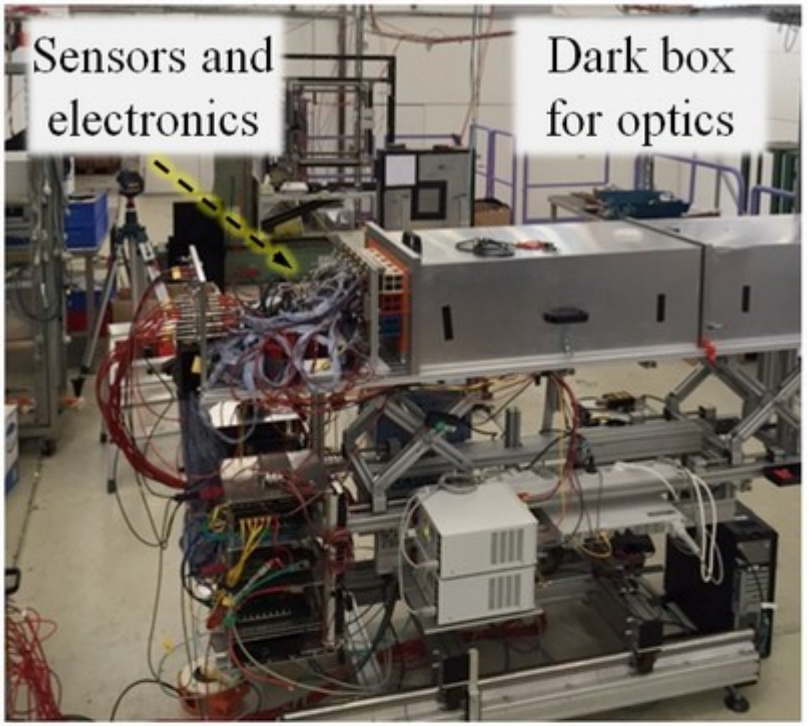


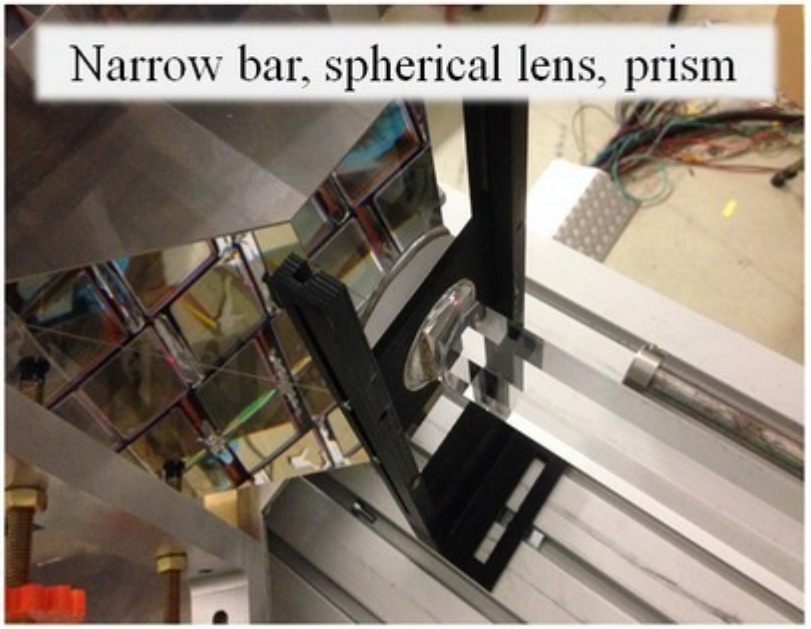
Joint effort of groups from
GSI, Uni Mainz, Uni Giessen, Uni Erlangen,
JLab, and Old Dominion University.

Tagged pions and protons
with momenta 2-10 GeV/c

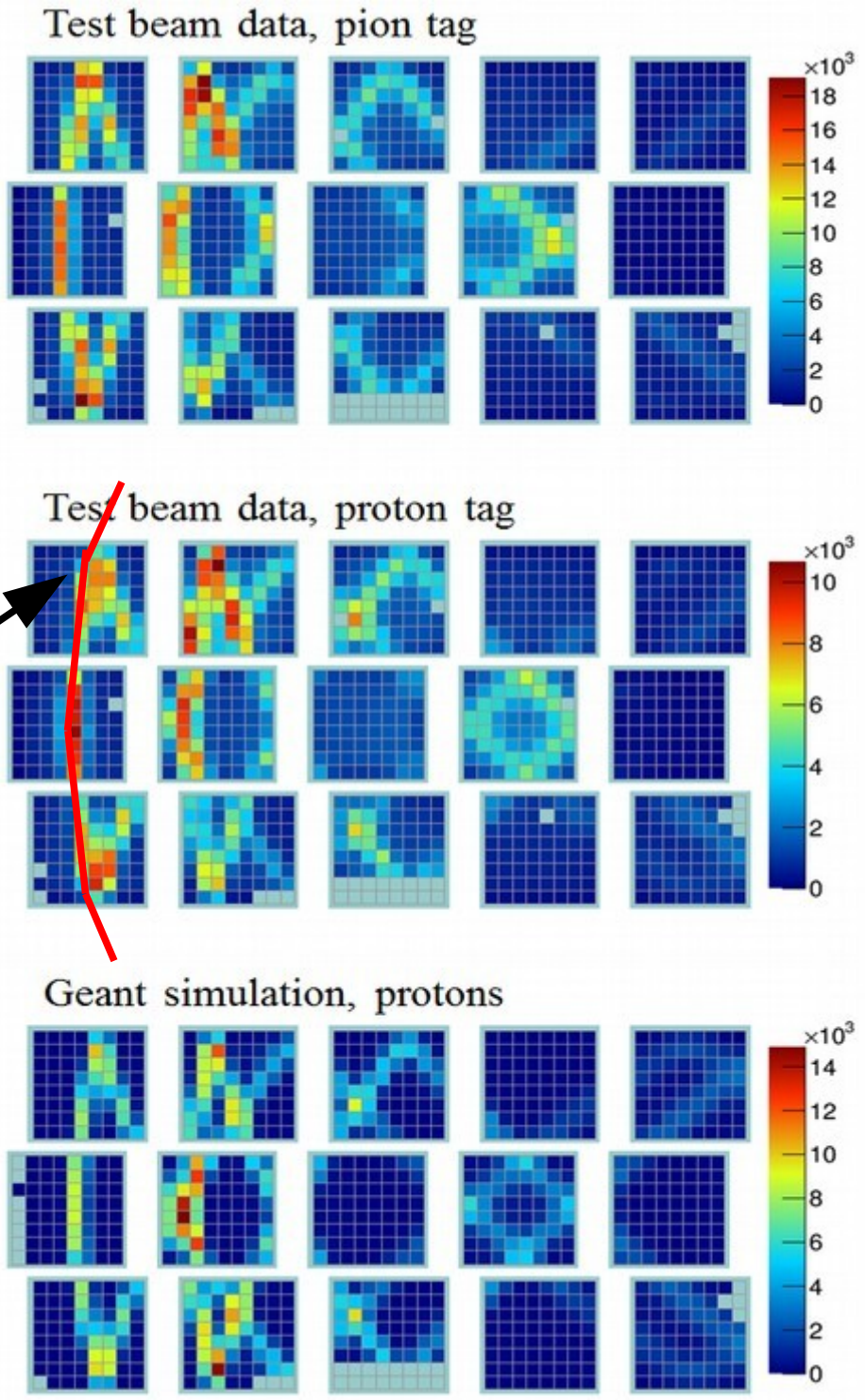


Measured resolution and PID performance for entire PANDA Barrel DIRC phase space





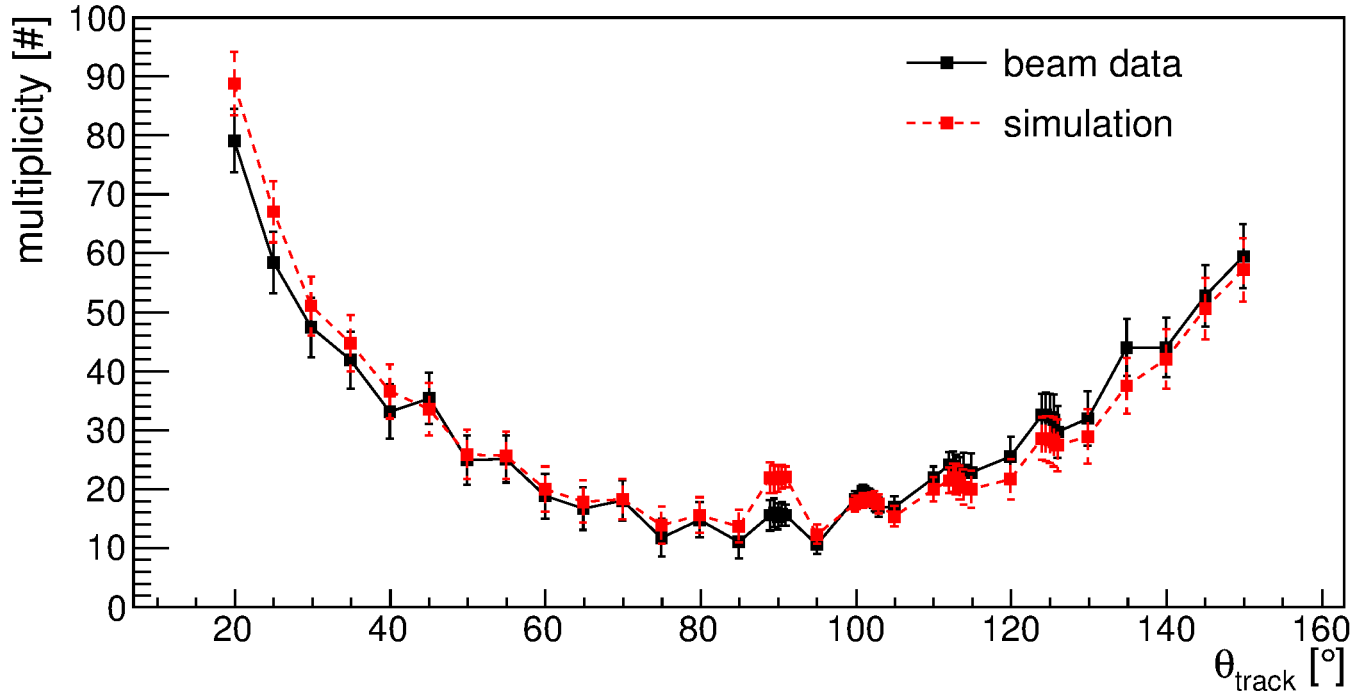
Cherenkov pattern is folded

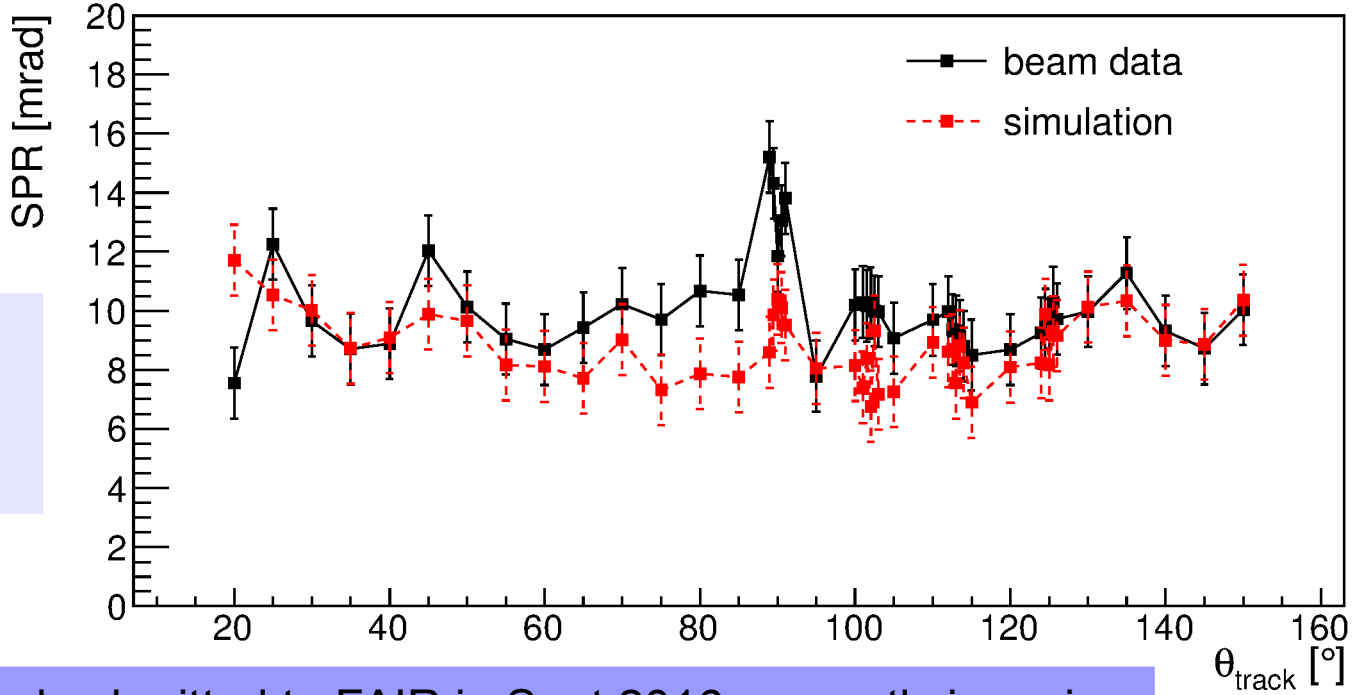


Good agreement between data and simulation

Validation of the simulation

7 GeV/c
3 component lens

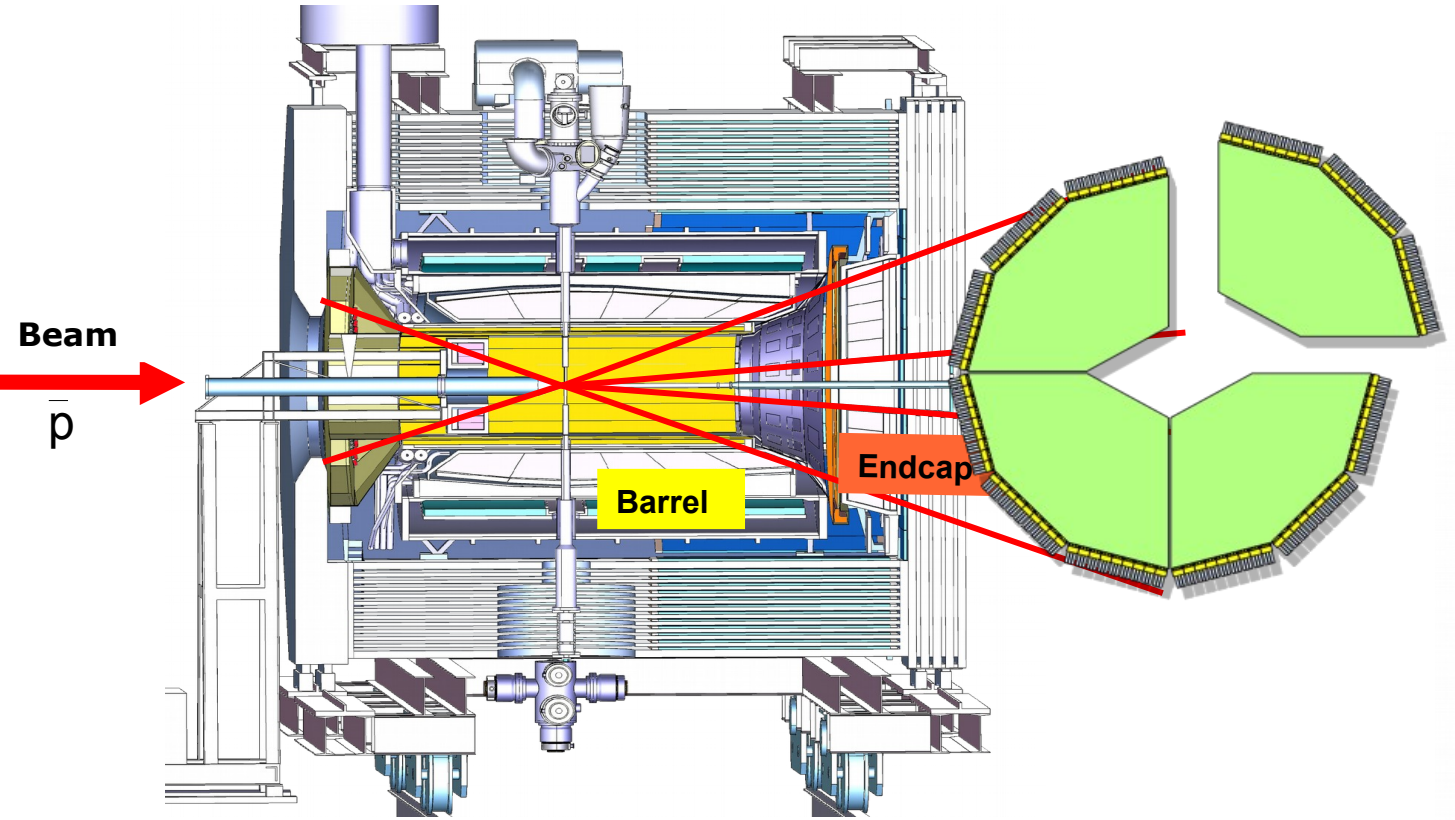


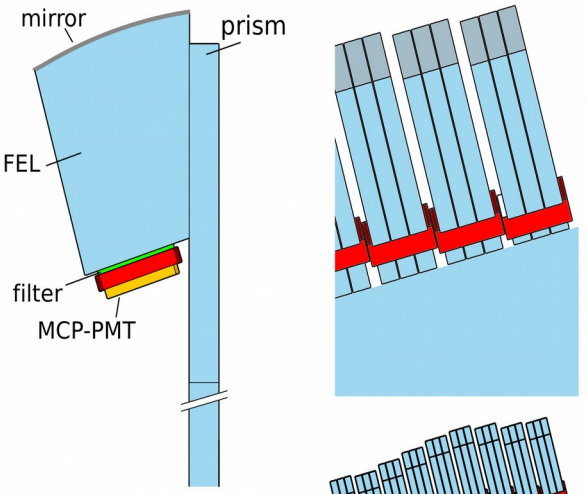


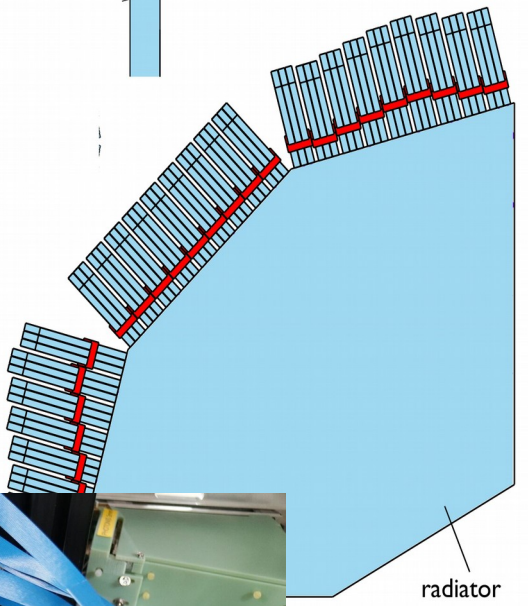
Agrees reasonably well, especially in most demanding (forward) region

TDR completed and submitted to FAIR in Sept 2016, currently in review

Endcap Disc DIRC



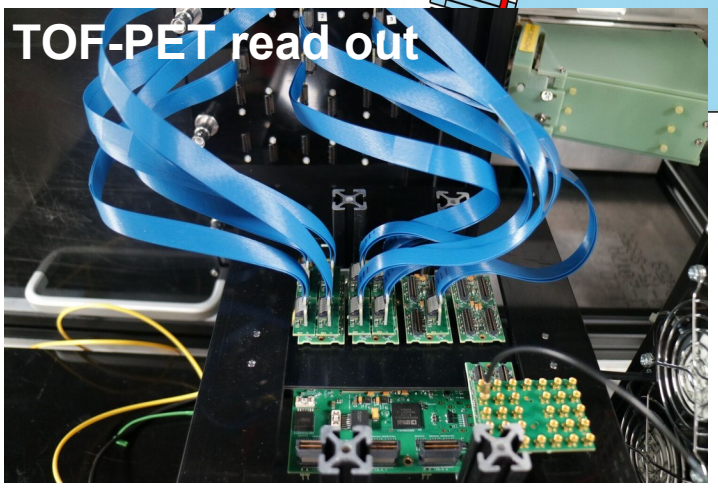




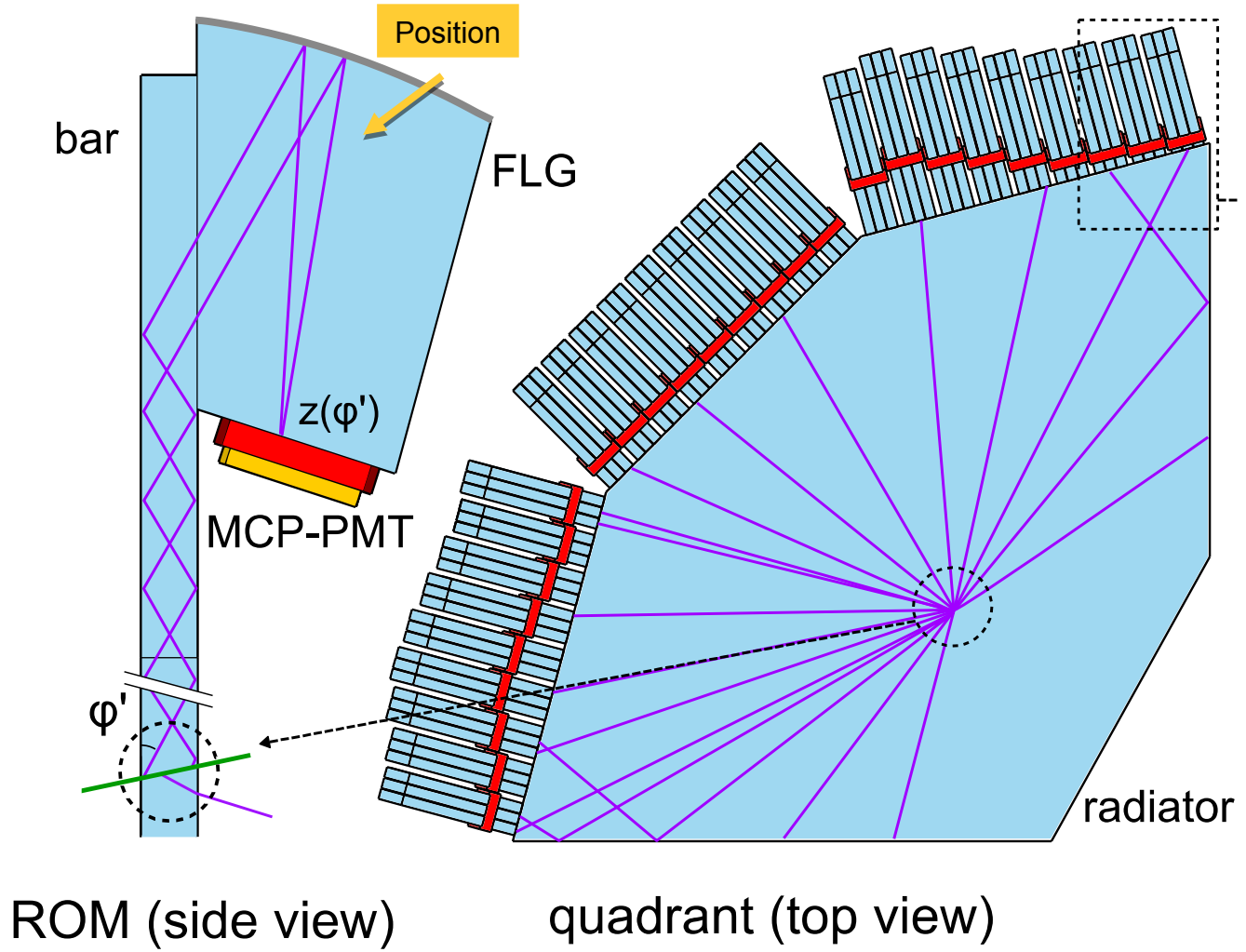
Modularity:
4 independent sub-detectors
4 identical fused silica plates

Requirements:
sub-mm spatial resolution
<100 ps timing resolution

Single Photon Detection:
108 identical readout modules (ROM)
324 light focussing elements



Endcap Disc DIRC



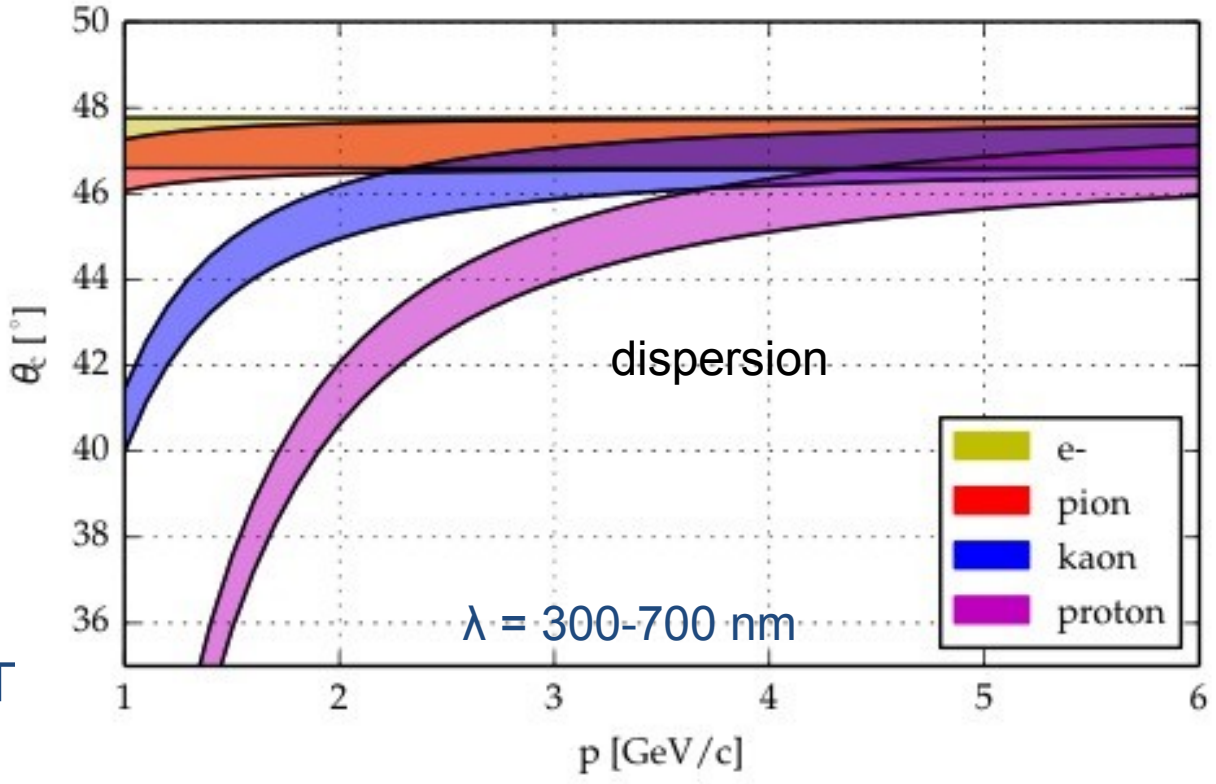
ROM (side view) quadrant (top view)

Measured: 2d pattern + timing

Dispersion mitigation vs. photon statistics

For every charged track (2 cm fused silica):

- ~400 photons generated in 300-700 nm range
- photons selected by bandwidth filter
  - reduced dispersion
  - reduced aging of MCP-PMT



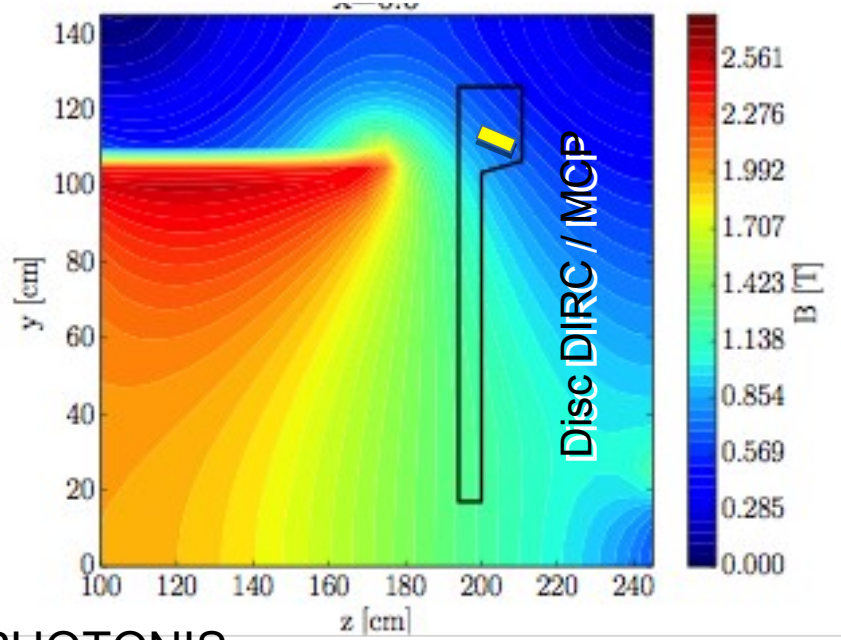
Filter	Detected photons $N_{ph.p}$	Chrom. effect $\sigma_{chrom.}/\sqrt{N_{ph.}}$
> 300nm	48	0.66
360-465 nm	22	0.41

Sensors: MCP-PMTs (PHOTONIS and Hamamatsu)

Issues:

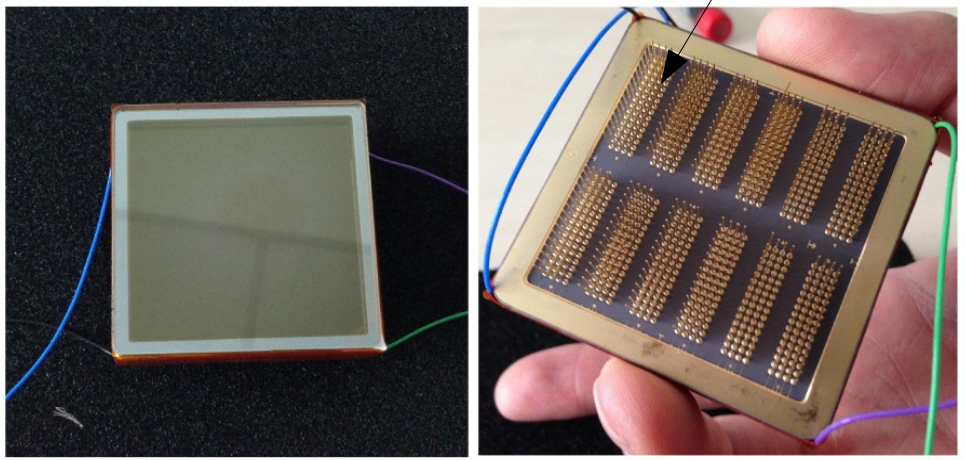
- enhanced lifetime
- restricted wavelengths by band pass filter 360-465 nm (reduced dispersion and enhanced tube lifetime)
- magnetic field strength and orientation
- 2 x 2 inch, pitch size < 0.5 mm, anode 3x100 strips or 6 x 128 strips

PANDA magnetic field



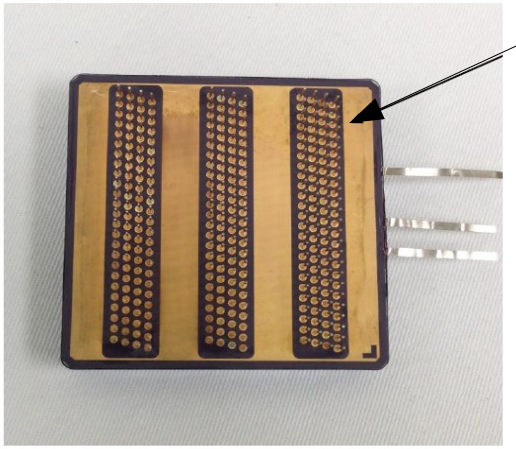
Hamamatsu 6 x 128
R13266-07-M768

6 x 128 strips

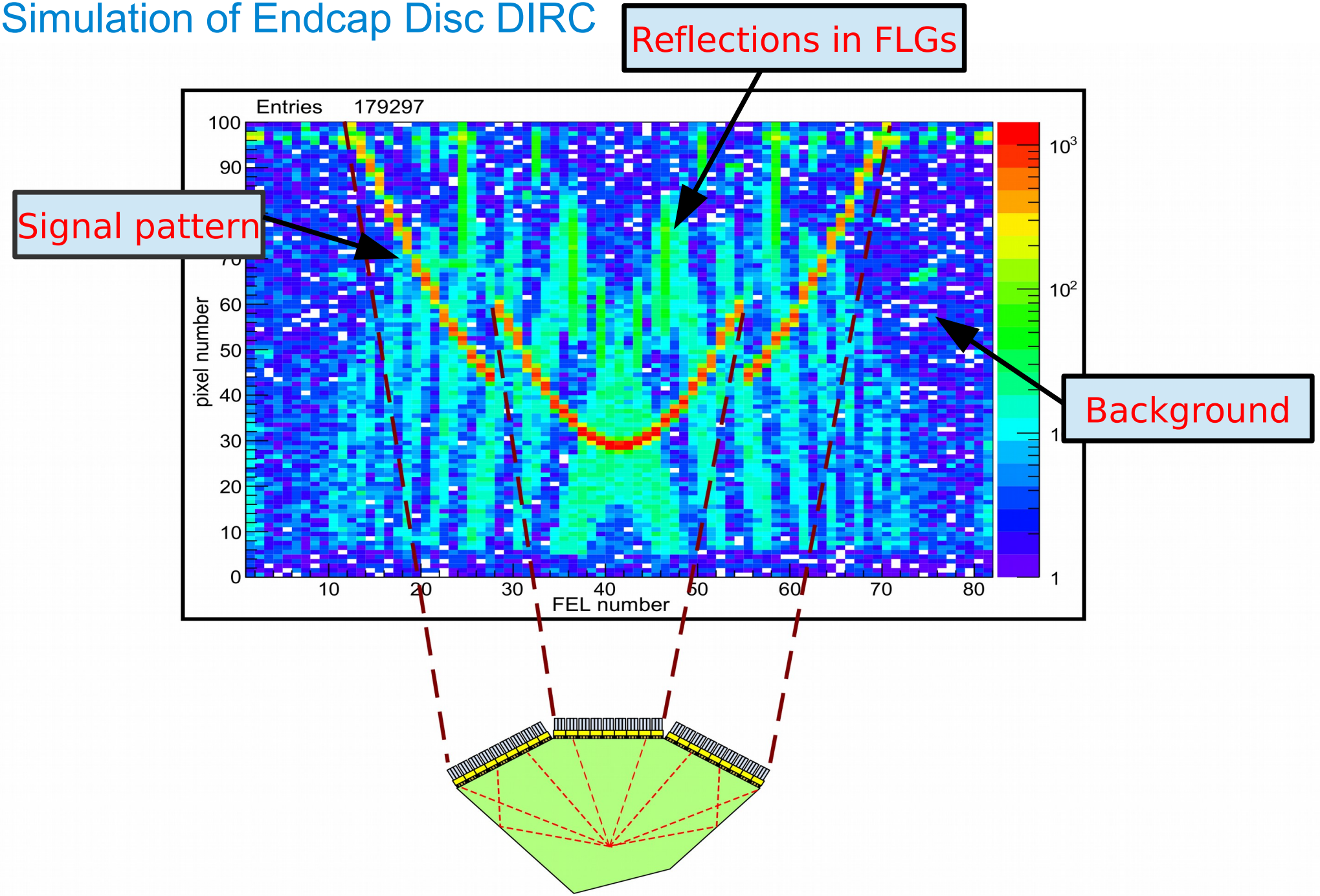


PHOTONIS,
XP85132-S-MD3

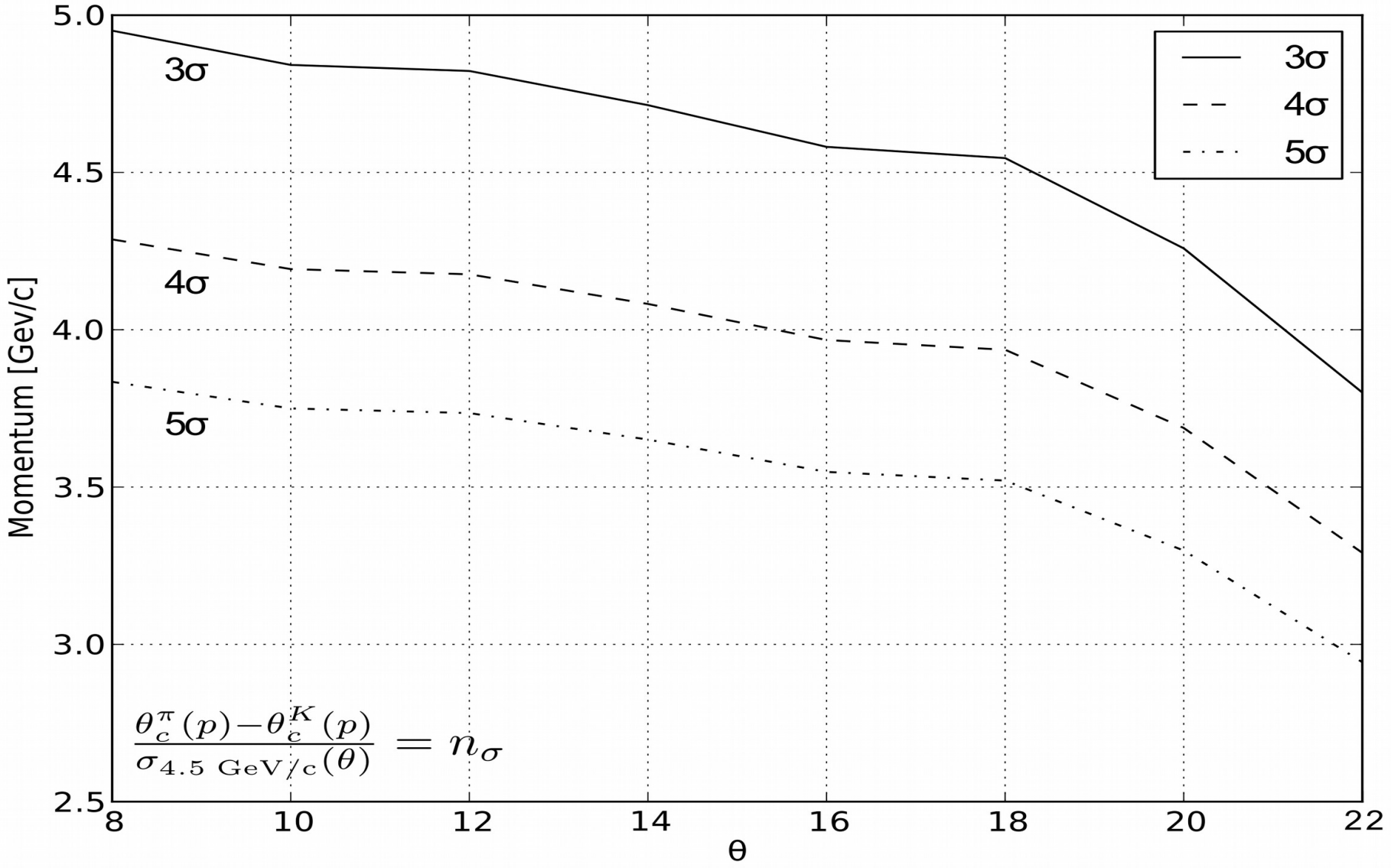
3 x 100 strips



Simulation of Endcap Disc DIRC

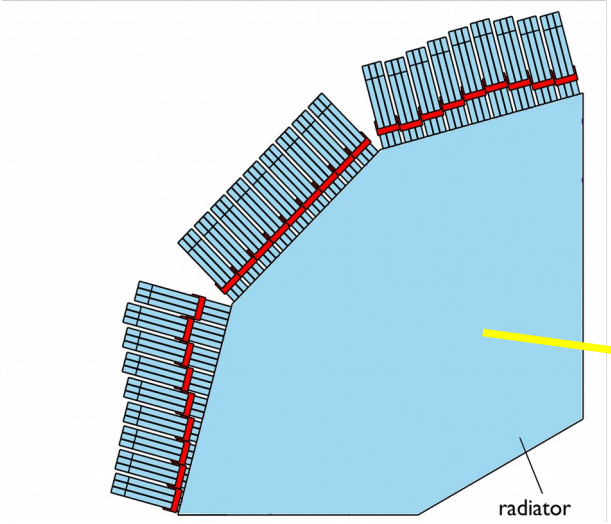


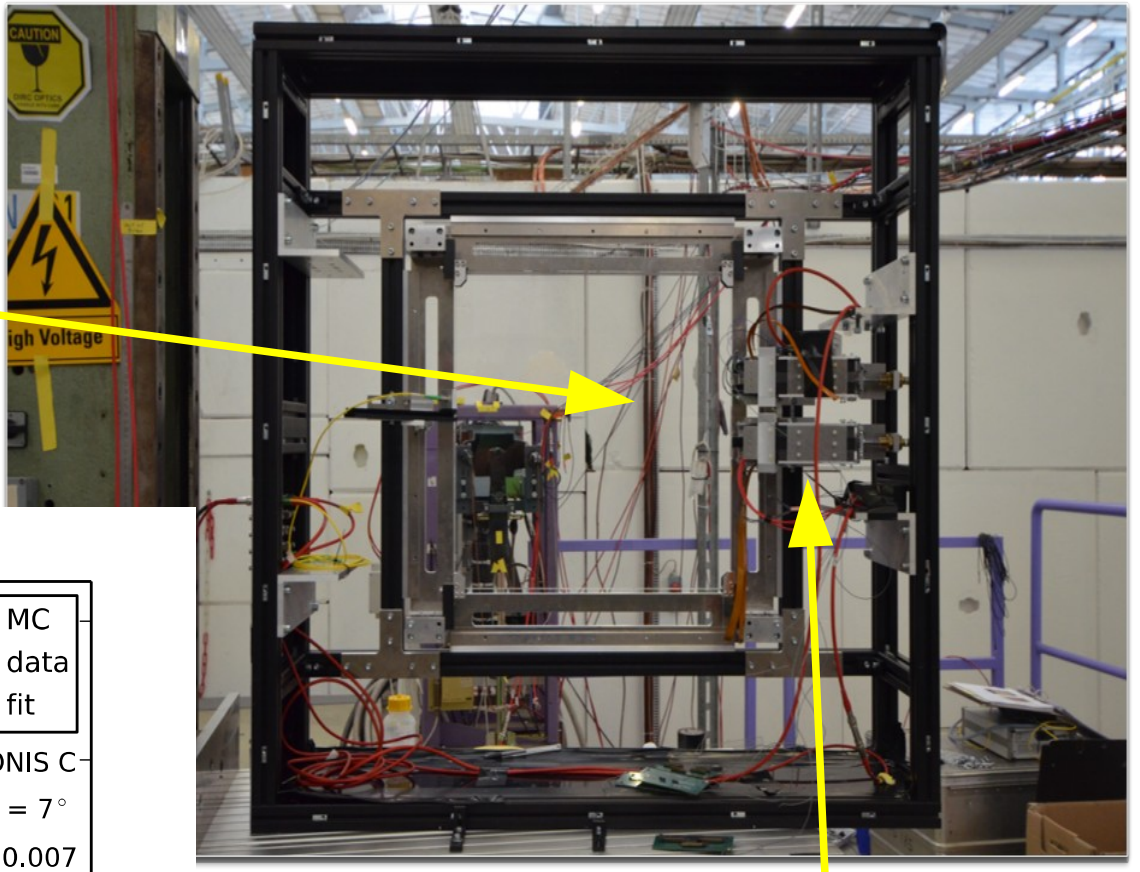
Simulation of Endcap Disc DIRC



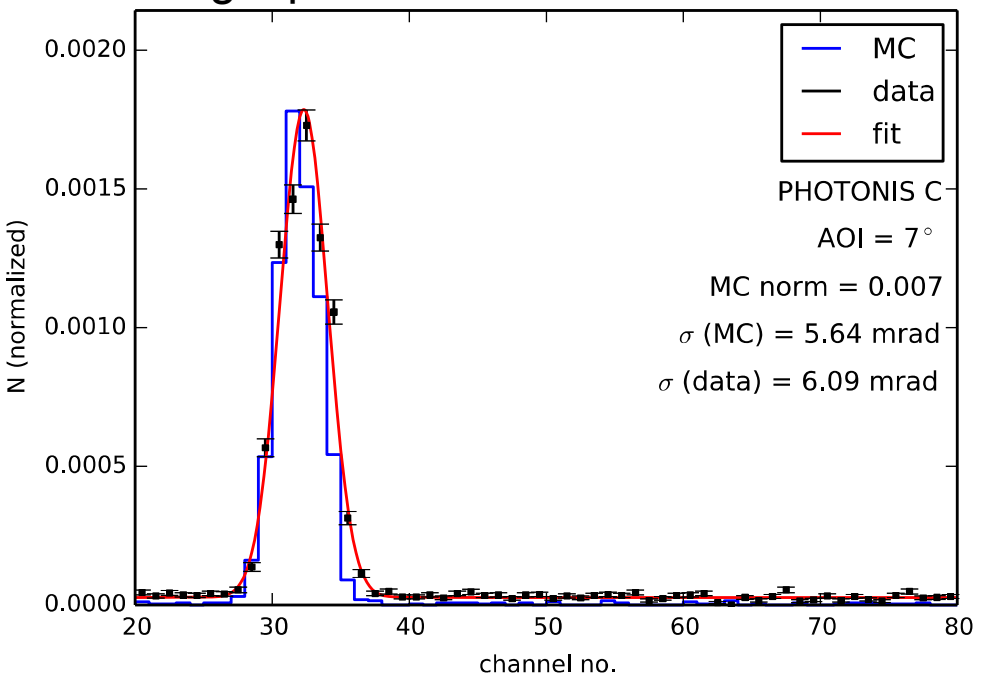
4 σ π-K separation power @ 4GeV/c up to 18 degree.
3 σ π-K separation power @ 4GeV/c for full disc.

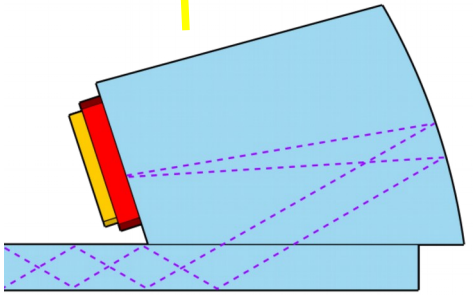
Test Beam CERN 2015/16:





Single photon resolution studies





Read out module

Simulation agrees well with data

Barrel DIRC

Time line

2018 Start of components production, QA

2019-21 Assembly of mechanical support structure, then expansion volume and bar boxes

2022 Installation

2023 Comissioning with cosmics and beams

Endcap Disc DIRC

Close to final R&D

2018-2020 production of a full scale prototype of one quadrant

production of remaining quadrants as soon as funding is available

Summary

The PANDA **Barrel DIRC** is a key component of the PANDA PID system. A completed Technical Design Report is currently in review.

Baseline design with narrow bars, 3-layer spherical lens, and compact prisms **meets or exceeds the PANDA PID requirements.**

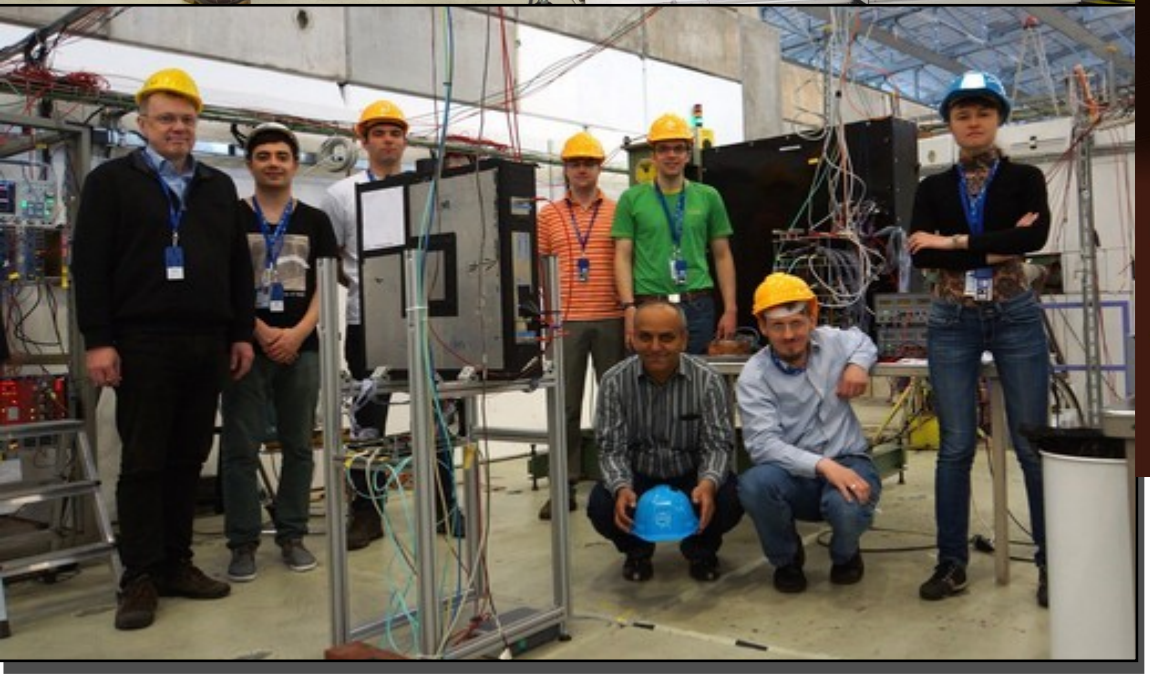
The design is robust in terms of background and timing resolution.

Simulation and **PID performance validated with particle beams.**

The **Endcap Disc DIRC** is a compact, modular forward PID detector.

Band pass filters reduce the photon dispersion and enhance the life time of the MCP-MPTs.

A fused silica **prototype has been constructed** and tested, **emission angles** of individual Cherenkov photons have been measured and **agree with simulations.**



DIRC 2017

International Workshop on Fast Cherenkov Detectors

Photon detection, DIRC design and DAQ

August 7-9, 2017

Castle Rauischholzhausen

Justus-Liebig-Universität Gießen

DIRC design — Novel developments and progress in the detection of internally reflected Cherenkov photons.

ps timing — Readout electronics with time resolution in the 10 - 100 ps regime.

fast DAQ — Data acquisition for Cherenkov detectors with interaction rates in the 10 MHz region.

single photon detection — Fast photodetectors for the detection of single photons. Influence of strong magnetic fields and lifetime issues.

For more information and registration, visit:

www.uni-giessen.de/dirc17

HIC for FAIR
Helmholtz International Center

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Local organizers:

Simon Bodenschatz, Michael Düren, Erik Etzelmüller, Klaus Föhl, Avetik Hayrapetyan, Christian Heinz, Daniela Museaus, Julian Rieke, Mustafa Schmidt, Hasko Stenzel

Sponsored by HIC for FAIR (Helmholtz International Center for FAIR)

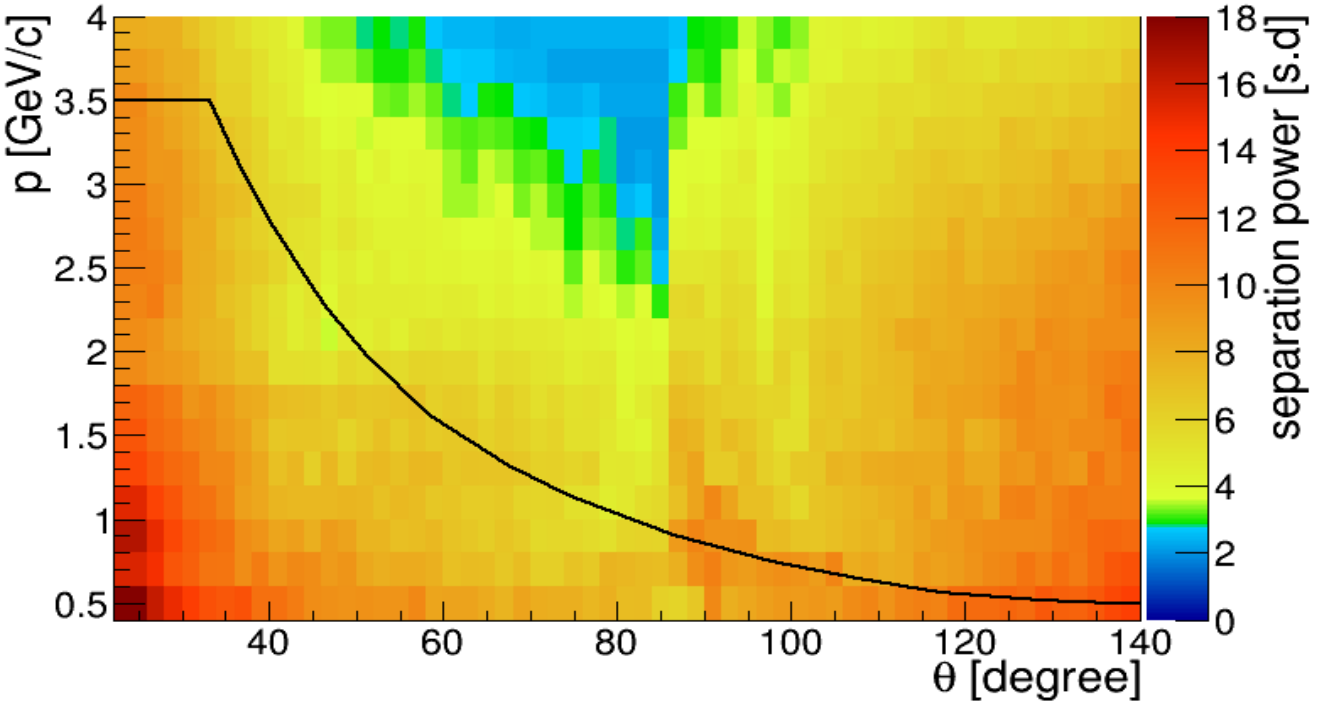
Thank You

Extra slides

Cost-saving option, 1 plate per bar box, cylindrical lens

π/K separation power from time-based imaging
(Belle II-like algorithm, PDFs from simulation).

Wide plate with focusing exceeds PID requirements for entire acceptance range.
Performance even superior to narrow bar
(possibly due to limitation of geometrical reco).

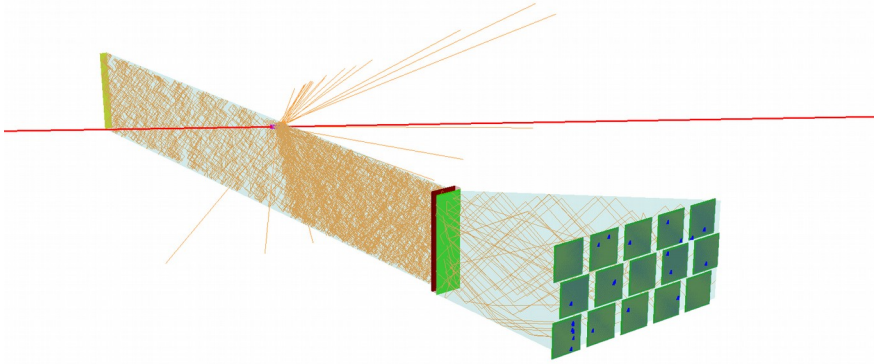


Needs PID performance validation from prototype using particle beams.

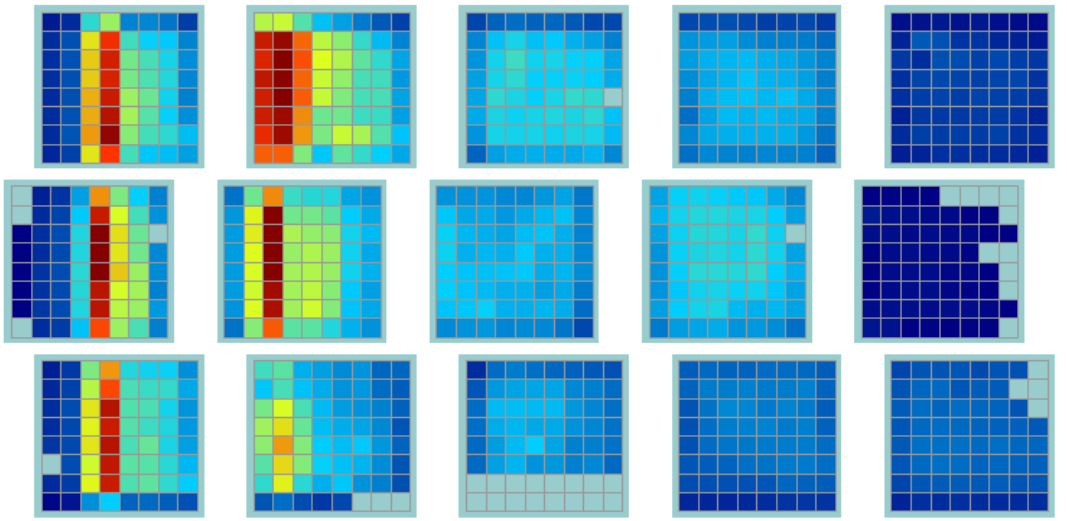
Plate prototype in beam 2015

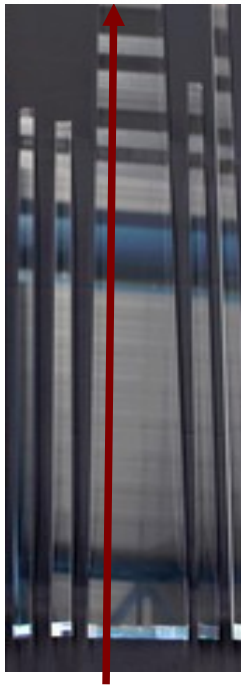
Test of wide plate

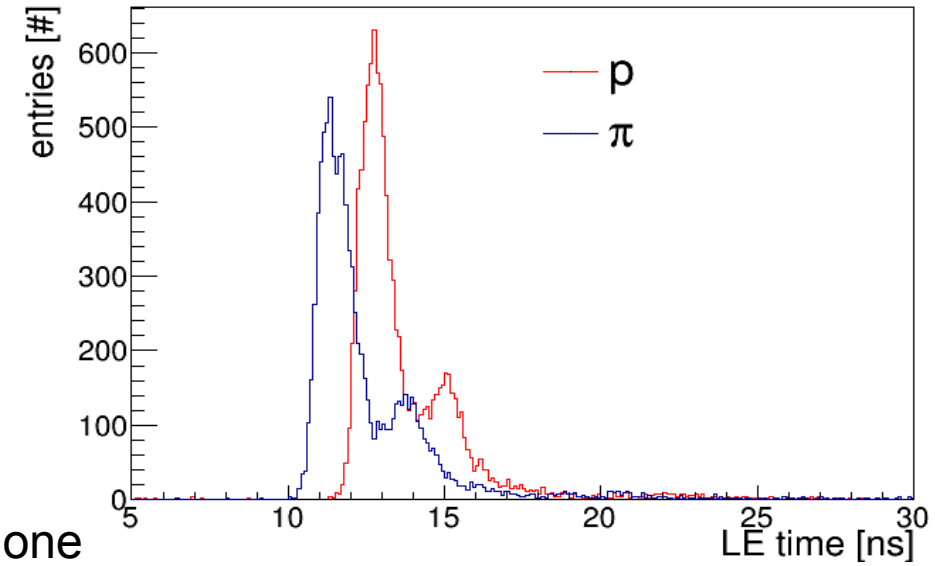
7 GeV/c, polar angle 55°, cyl. Lens



Data

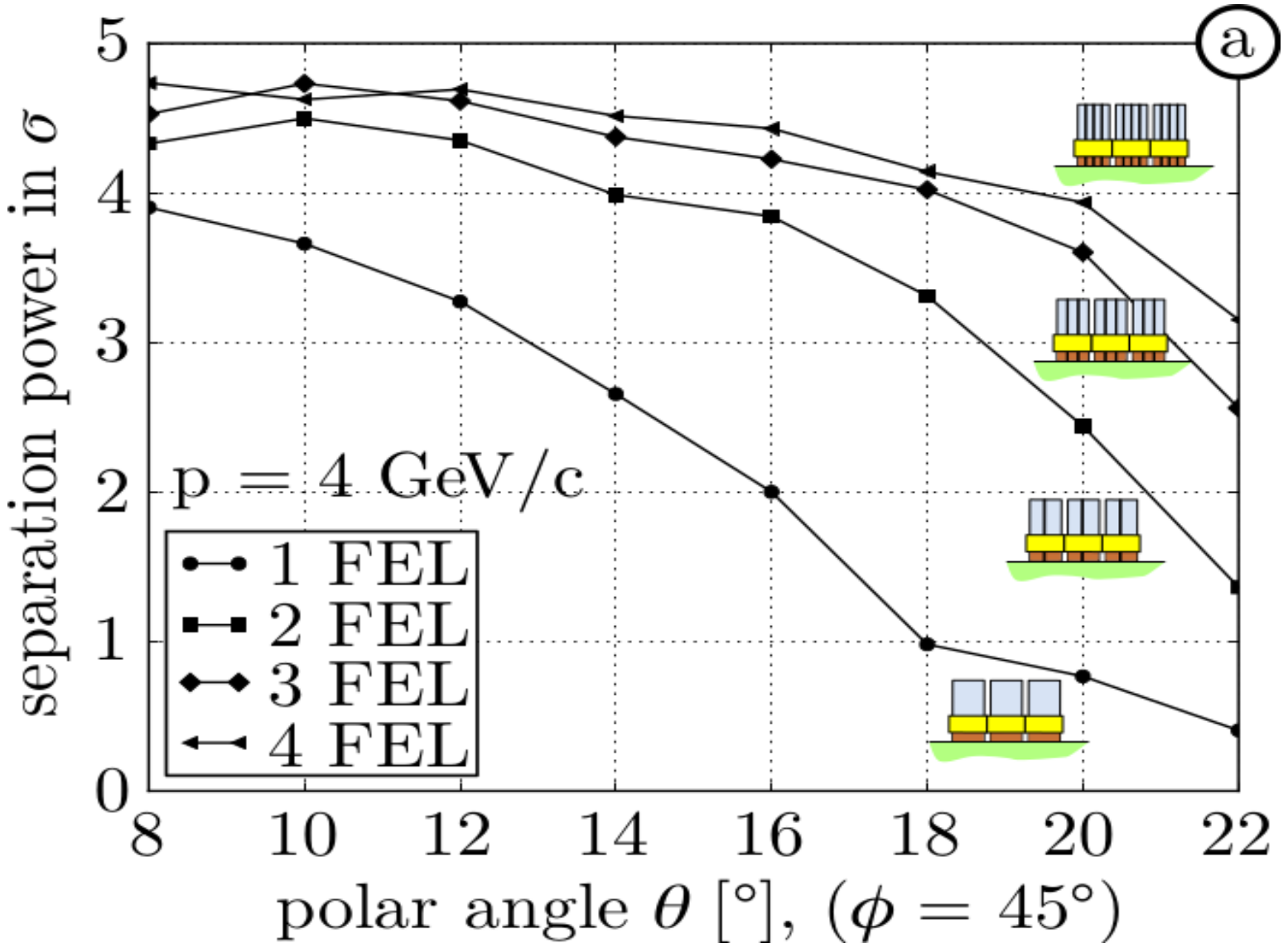






Time difference clearly visible

Reconstruction remains to be done


a
separation power in σ
0
1
2
3
4
5
8
10
12
14
16
18
20
22
polar angle θ [°], ($\phi = 45°$)
p = 4 GeV/c
1 FEL
2 FEL
3 FEL
4 FEL