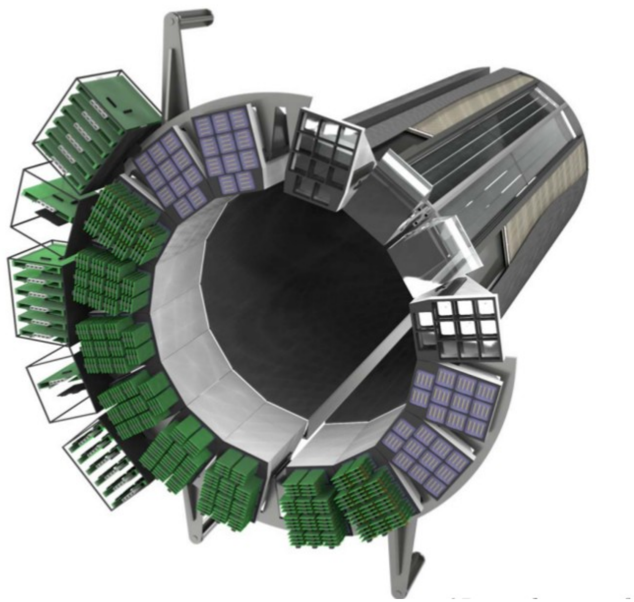
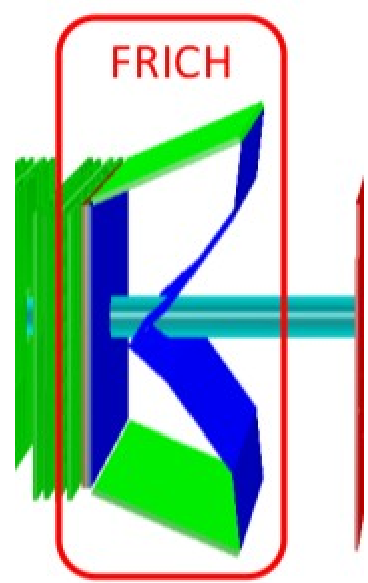
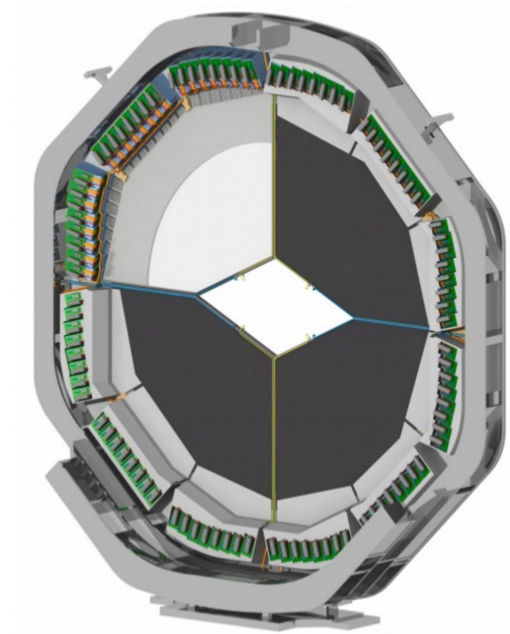
Particle identification at the PANDA/FAIR experiment using DIRC and RICH detectors







A. Hayrapetyan on behalf of the PANDA Cherenkov Group

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

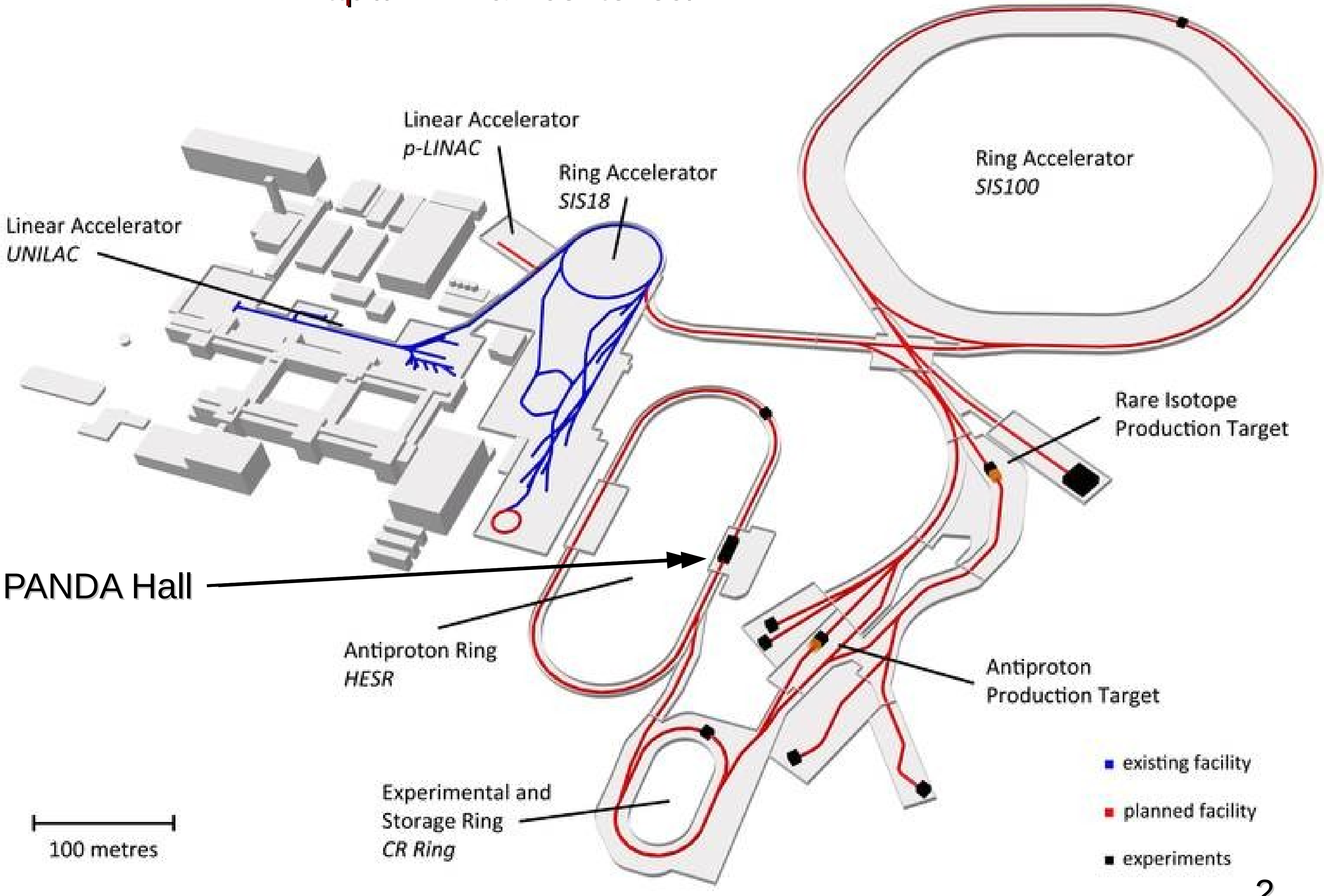
GSI

panda

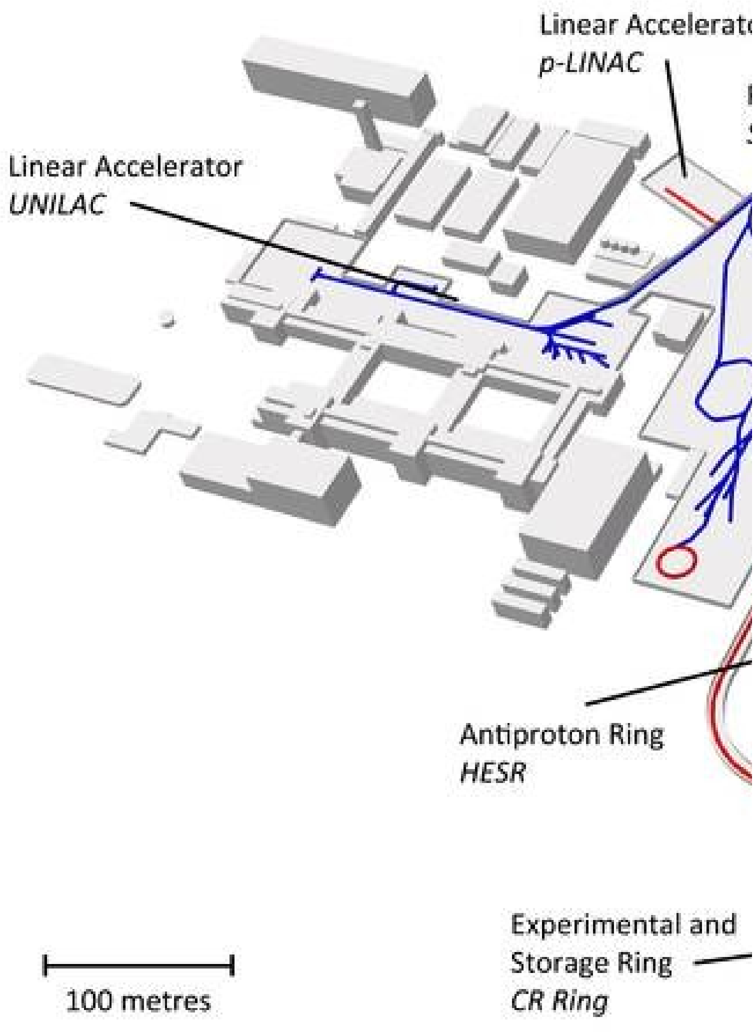
Bundesministerium für Bildung und Forschung

Facility for Antiproton and Ion Research
FAIR

http://www.fair-center.eu/



Facility for Antiproton and Ion Research
FAIR



High Energy Storage Ring

- Stochastic cooling
- Electron cooling

Beam momentum from 1.5 to 15 GeV/c

High luminosity mode

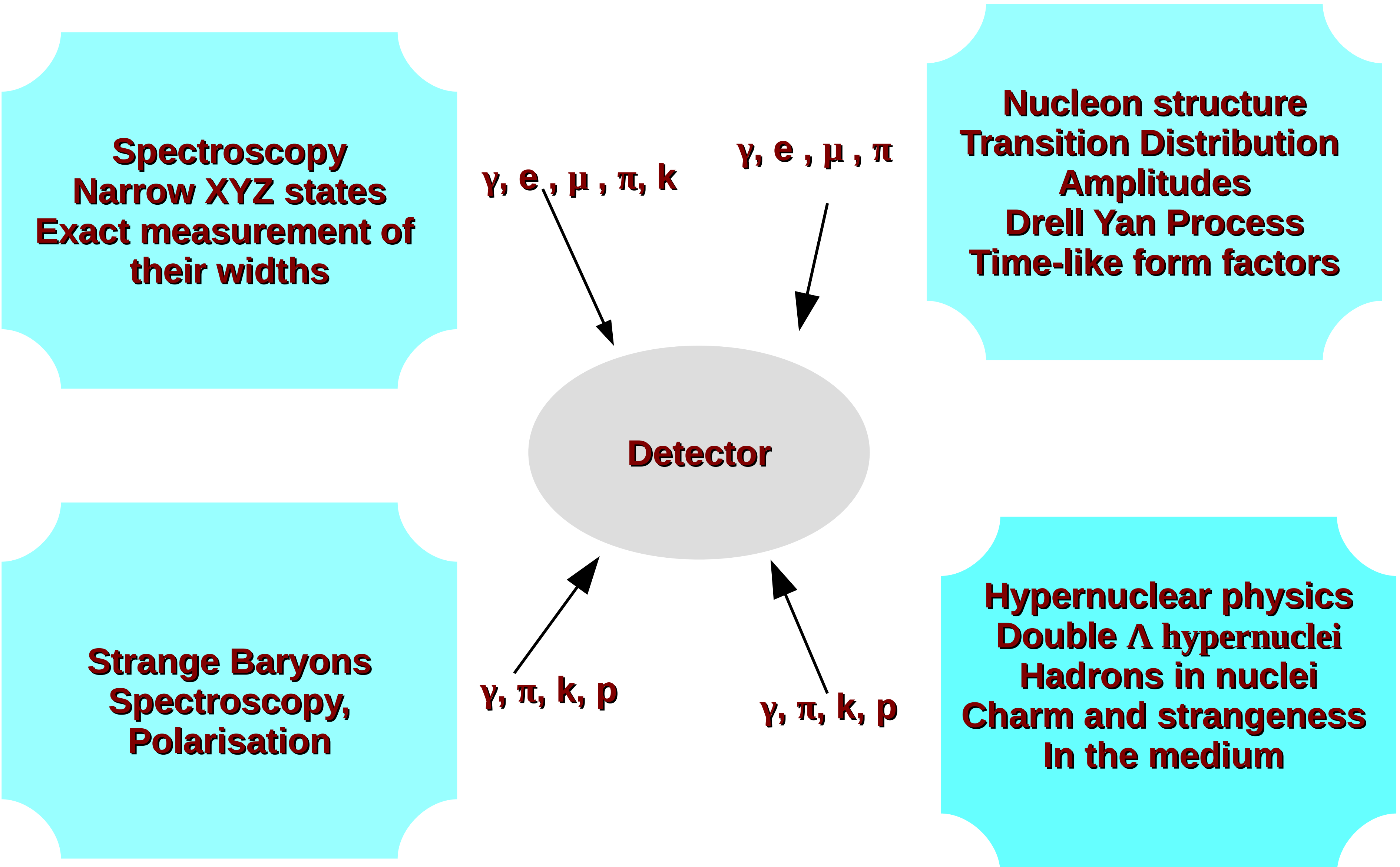
- $2 \cdot 10^{32} cm^{-2} s^{-1}$ (20 MHz)

High resolution mode

- $\Delta p/p = 4 \cdot 10^{-5}$ (2 MHz)

Cluster jet / pellet target

PANDA objectives



PANDA objectives

In all cases practically one needs to have PID

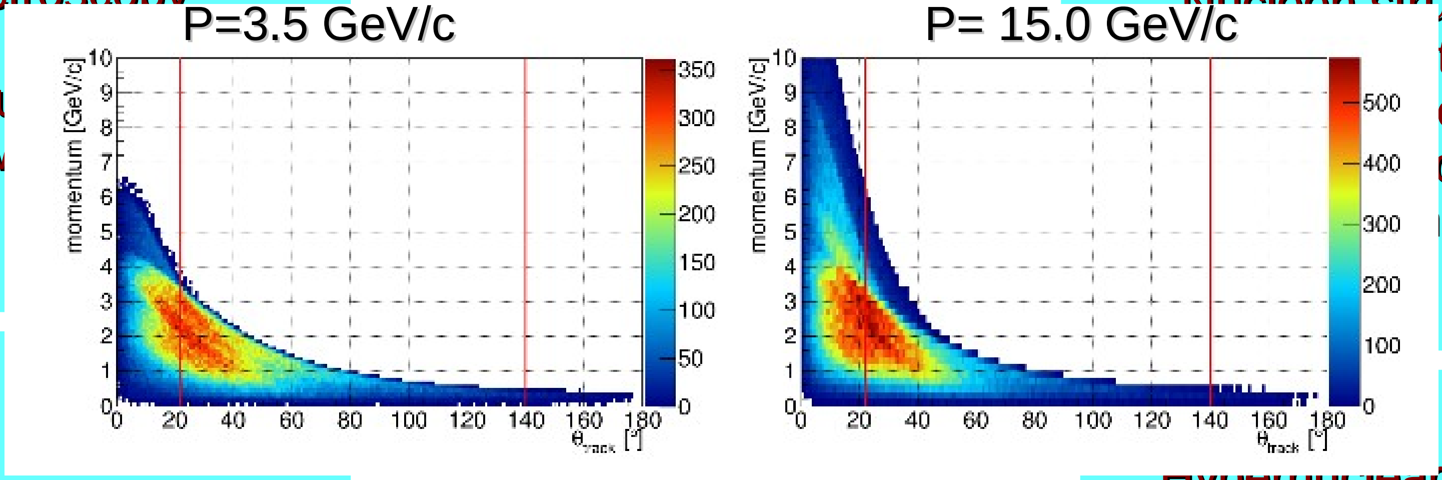
For all species (γ, e, μ, π, k, p)

As the kaon identification is the most challenging , here

their anticipated phase space

Spectroscopy
Narrow
Exact measu
w

Nucleon structure
tribution
es
ocess
factors



Strange Baryons
Spectroscopy,
Polarisation

Hypernuclear physics
Double Λ hypernuclei
Hadrons in nuclei
Charm and strangeness
In the medium

PANDA objectives

Details see here

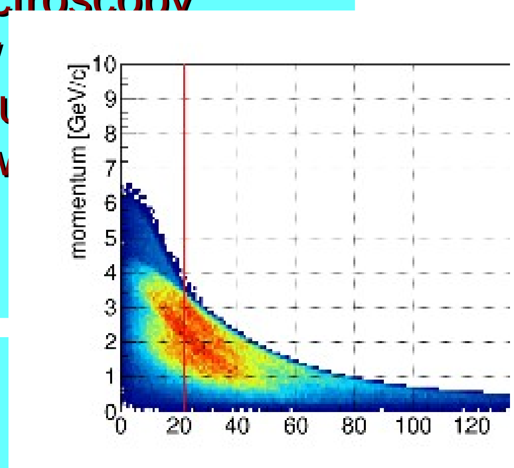
In all cases practically one needs to have PID

For all species (γ, e, μ, π, k, p)

As the kaon identificat

their anticipated phas

Spectroscopy
Narrow
Exact measu
w



Strange Baryons
Spectroscopy,
Polarisation

arXiv:0903.3905v1 [hep-ex]

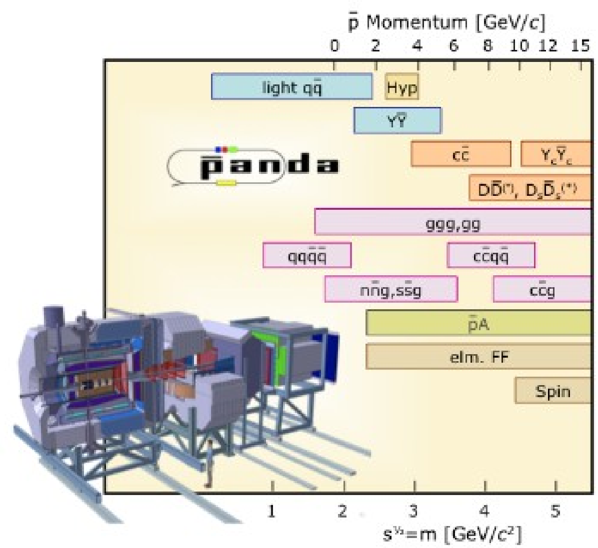
P̄ANDA

(AntiProton Annihilations at Darmstadt)

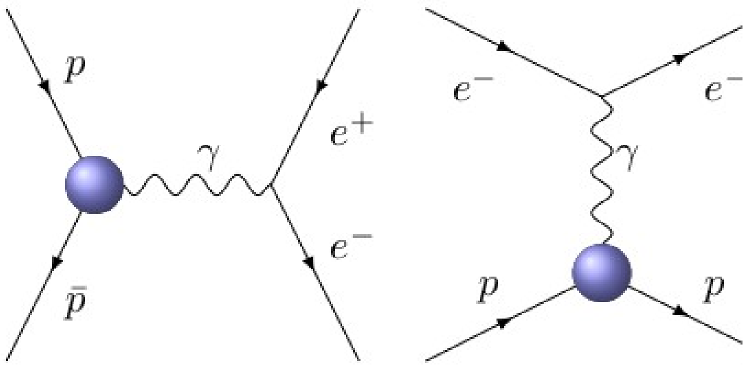
Strong Interaction Studies with Antiprotons

P̄ANDA Collaboration

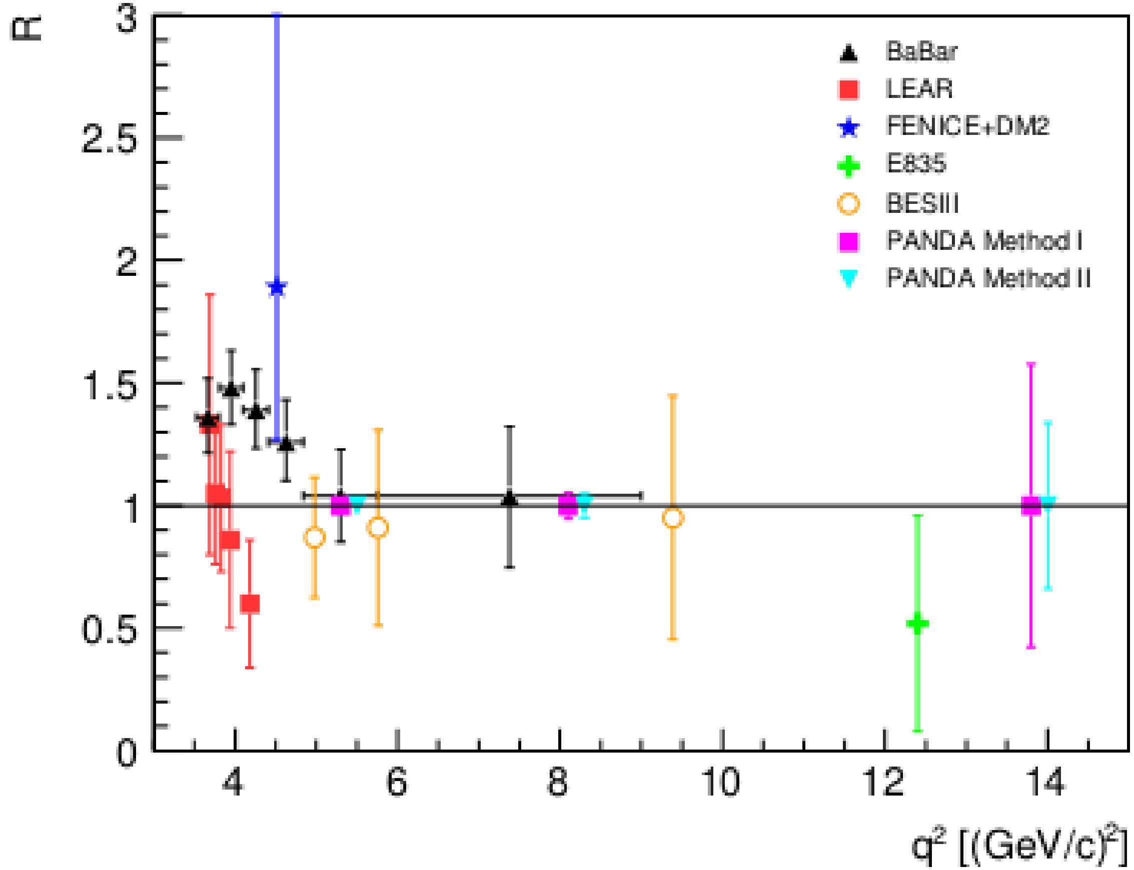
To study fundamental questions of hadron and nuclear physics in interactions of antiprotons with nucleons and nuclei, the universal P̄ANDA detector will be build. Gluonic excitations, the physics of strange and charm quarks and nucleon structure studies will be performed with unprecedented accuracy thereby allowing high-precision tests of the strong interaction. The proposed P̄ANDA detector is a state-of-the-art internal target detector at the HESR at FAIR allowing the detection and identification of neutral and charged particles generated within the relevant angular and energy range.
This report presents a summary of the physics accessible at P̄ANDA and what performance can be expected.



PANDA and this workshop
Time-like proton form factors



$R = |G_E|/|G_M|$

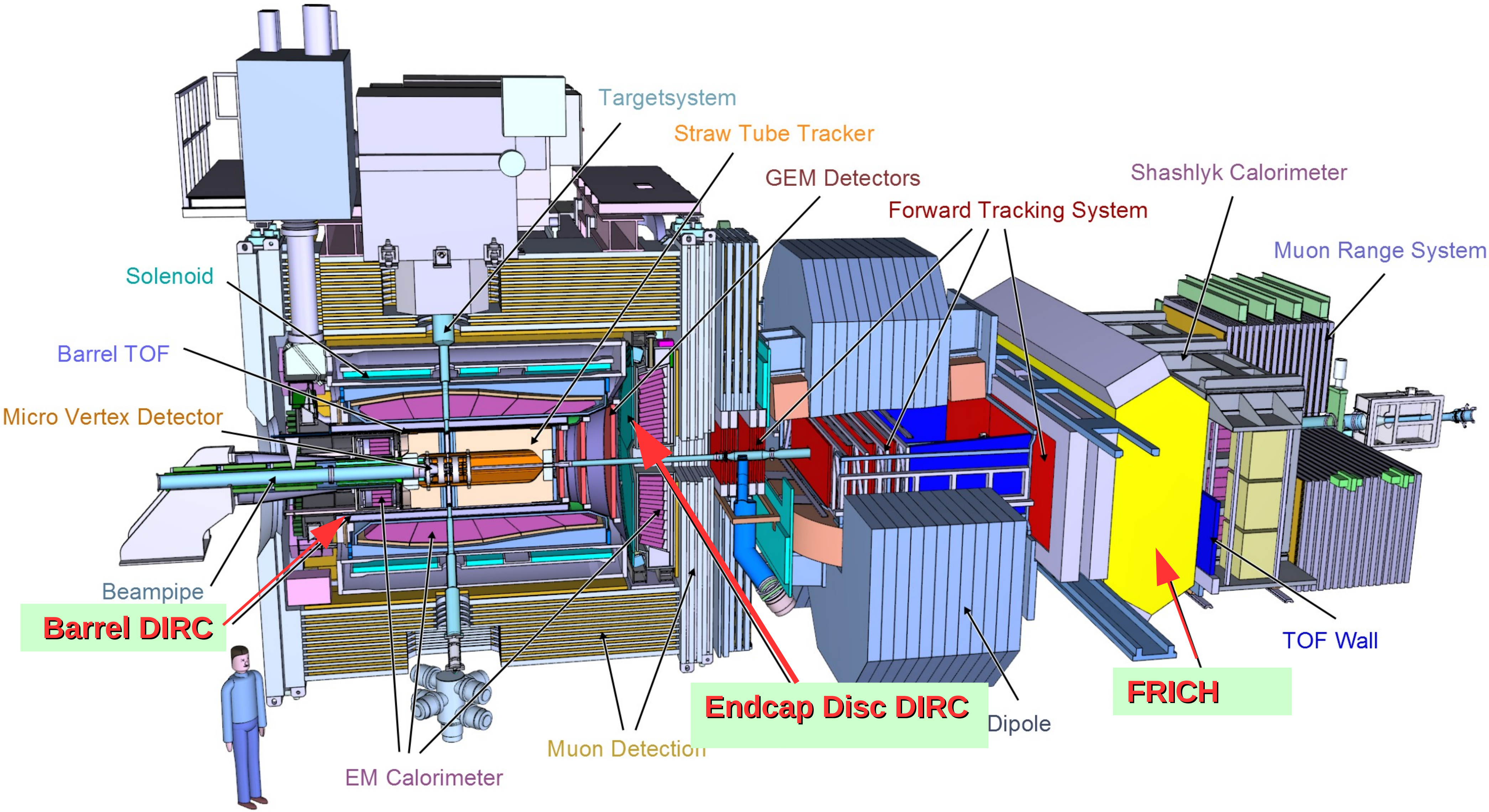


The PANDA experiment at FAIR will extend the knowledge of the TL electromagnetic proton FFs in a large kinematic range.

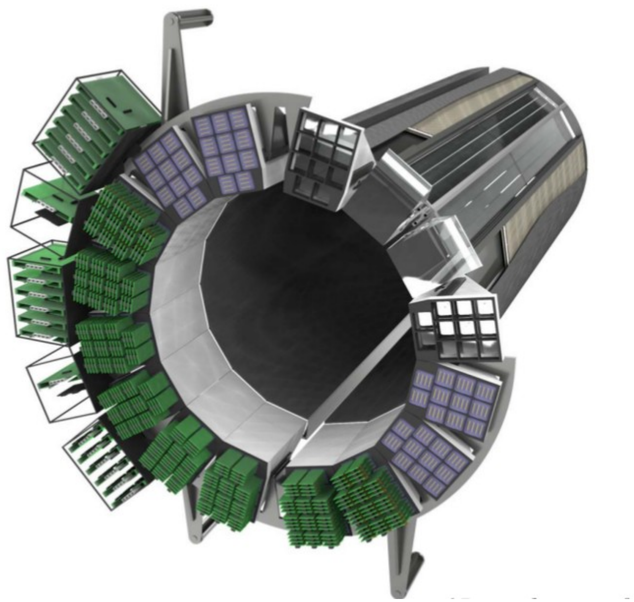
Eur.Phys.J. A52 (2016) no.10, 325

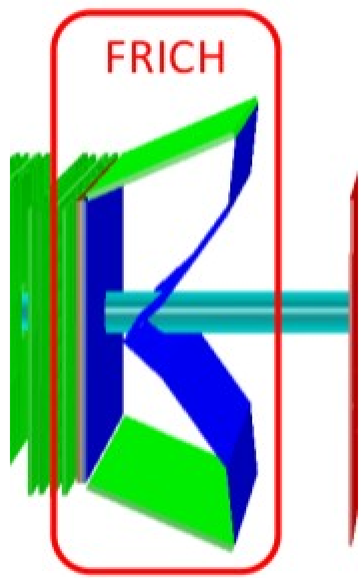
This is essential for a global analysis of the FFs in the SL and TL regions.

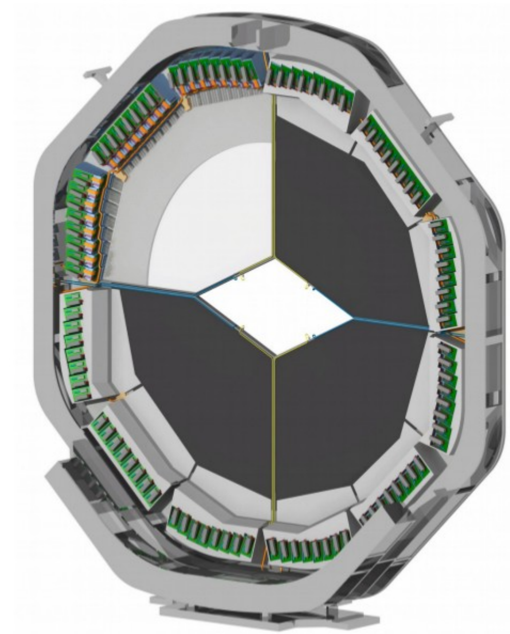
The PANDA detector



The PANDA Cherenkov Detectors







Barrel DIRC | **FRICH** | **Endcap Disc DIRC(EDD)**

Polar Angles

22-140 | **0-5(10)** | **5(10)-22 degree**

Goal

3 s.d. π/K separation Up to 3.5 GeV/C | **3 s.d.π/K 2÷10 GeV/c μ/π possible till ~2.0 GeV/C** | **3s.d. π/K up to 4.0 GeV/C**

The barrel DIRC

radius ~48 cm

48 narrow radiator bars, synthetic fused silica

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

Proved design:

similar to BaBar DIRC design,
Improved with focusing optics and expansion volume

to meet PANDA PID requirements

Focusing optics: 3-layer spherical lens

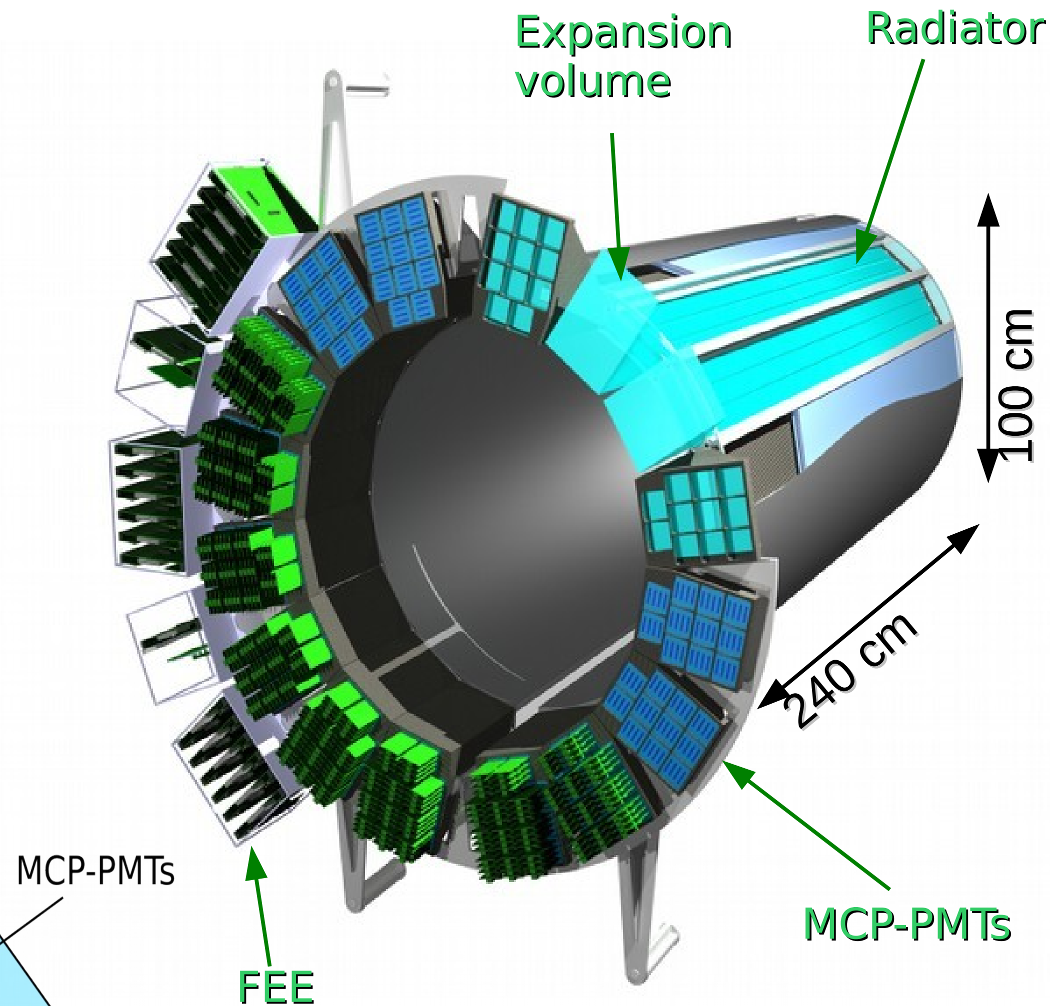
Compact expansion volume:

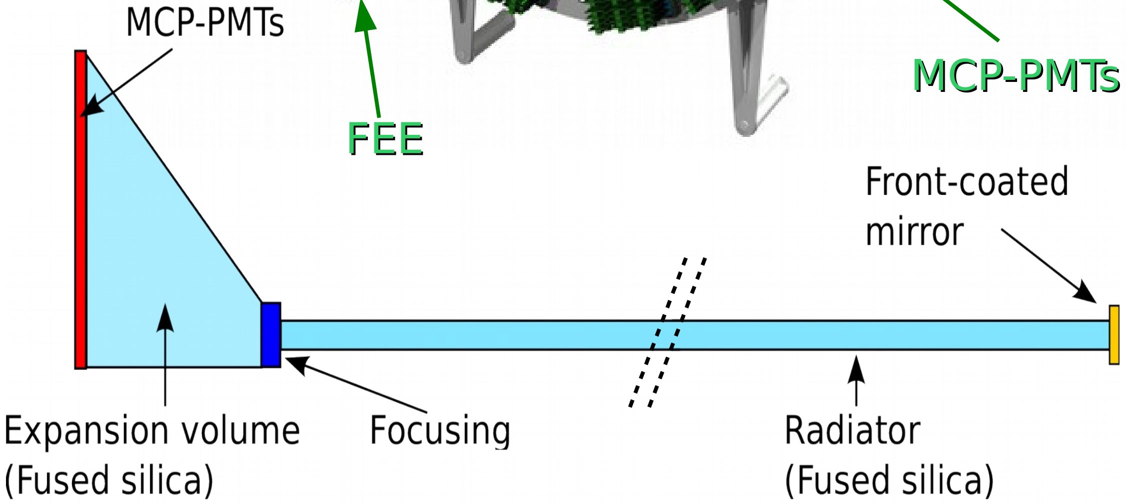
30 cm deep solid fused silica prisms

~11000 channels of MCP-PMTs

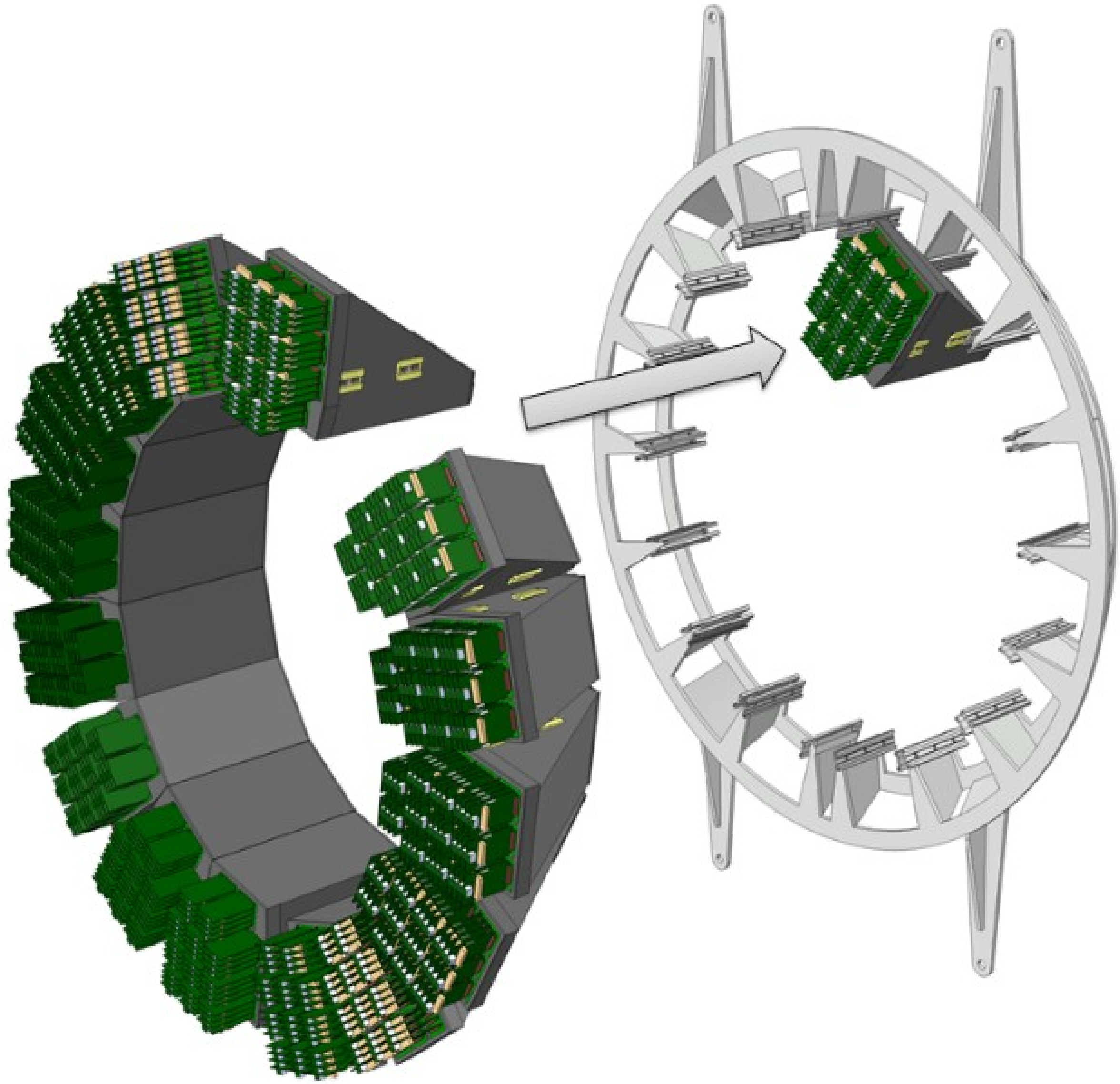
Fast FPGA based read out electronics:

~ 100 ps single photon timing resolution





Mechanical design



Light weight

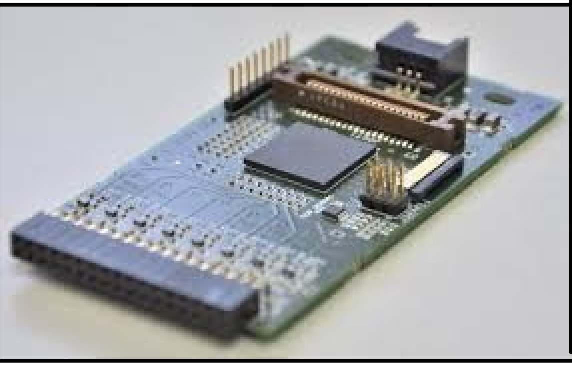
Made of carbon or aluminum alloy

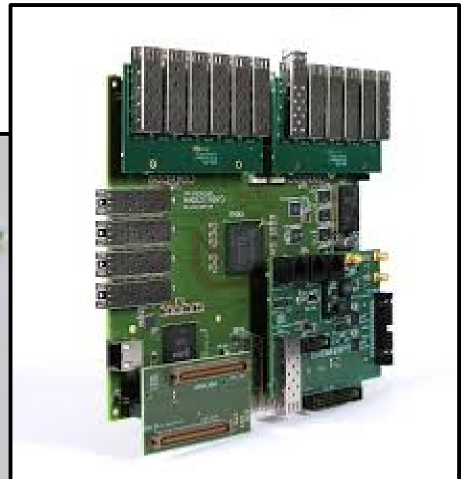
Each bar box can be built staged

Allows access to inner detectors easily

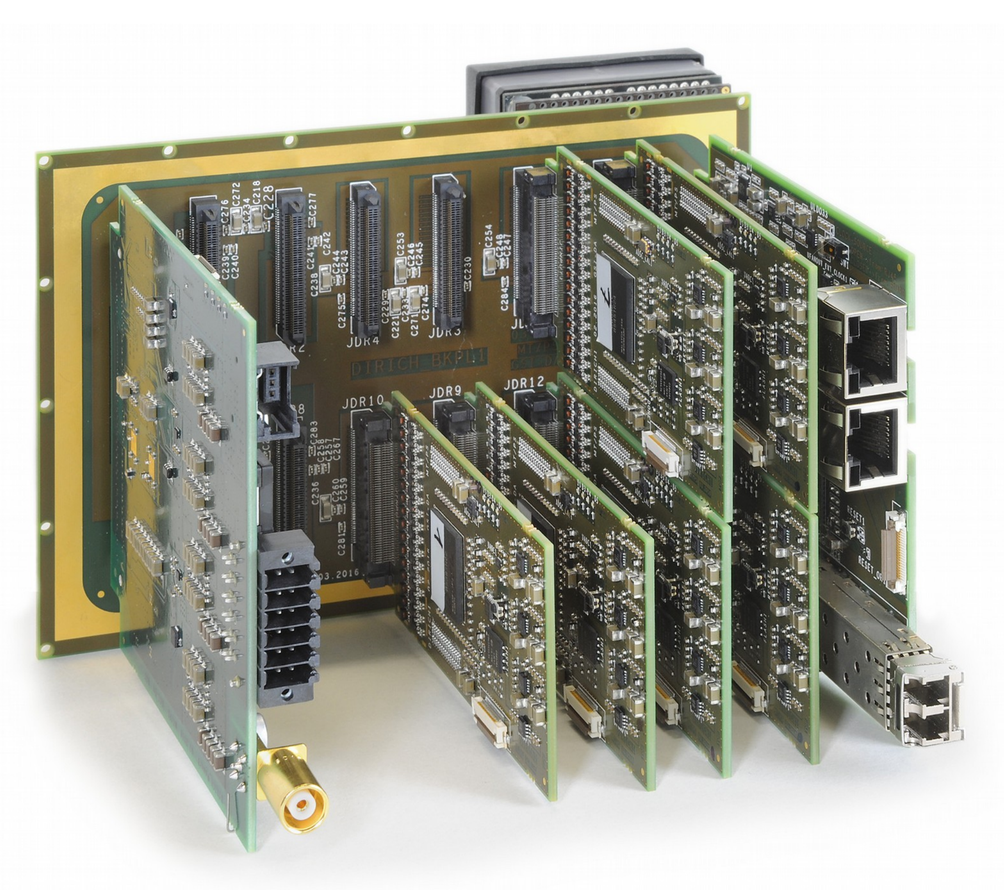
Readout chain

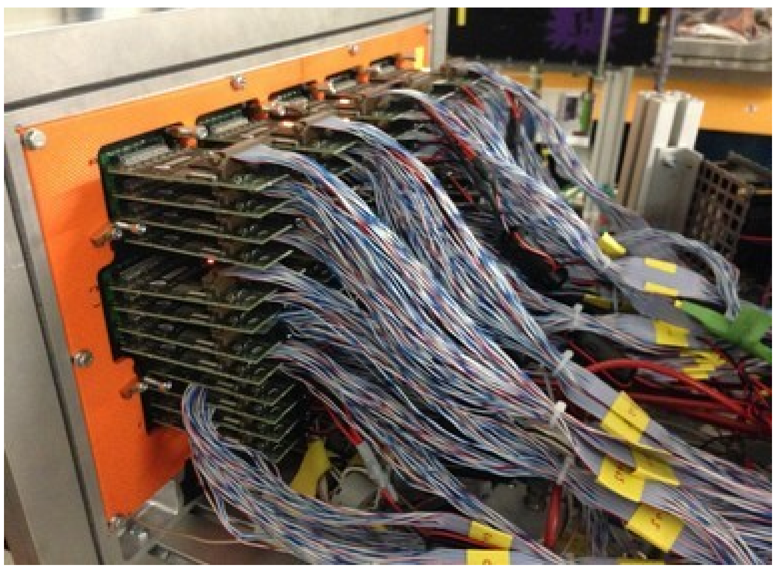
TRB3 for Prototype





DiRICH for final detector





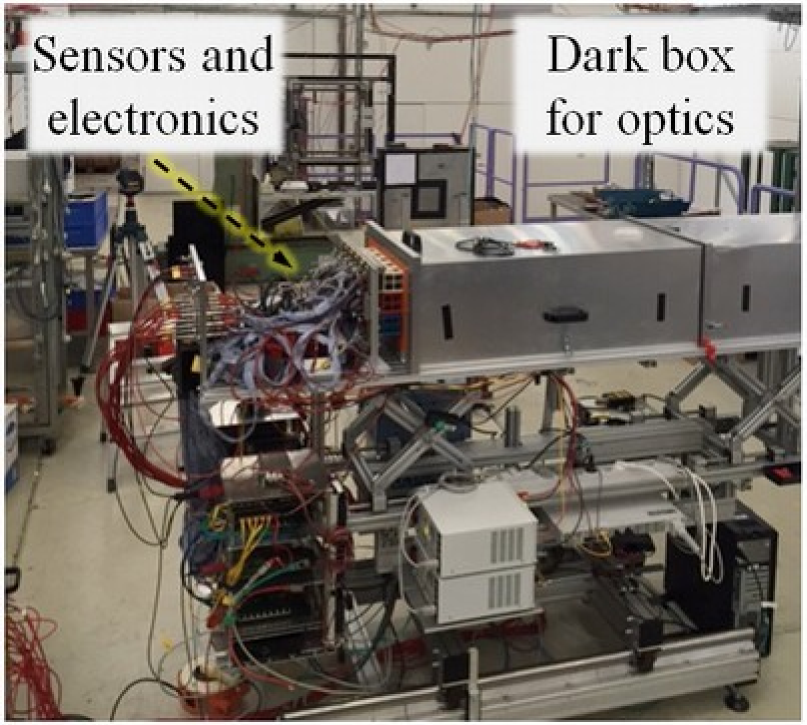
Common development with HADES/CBM RICH

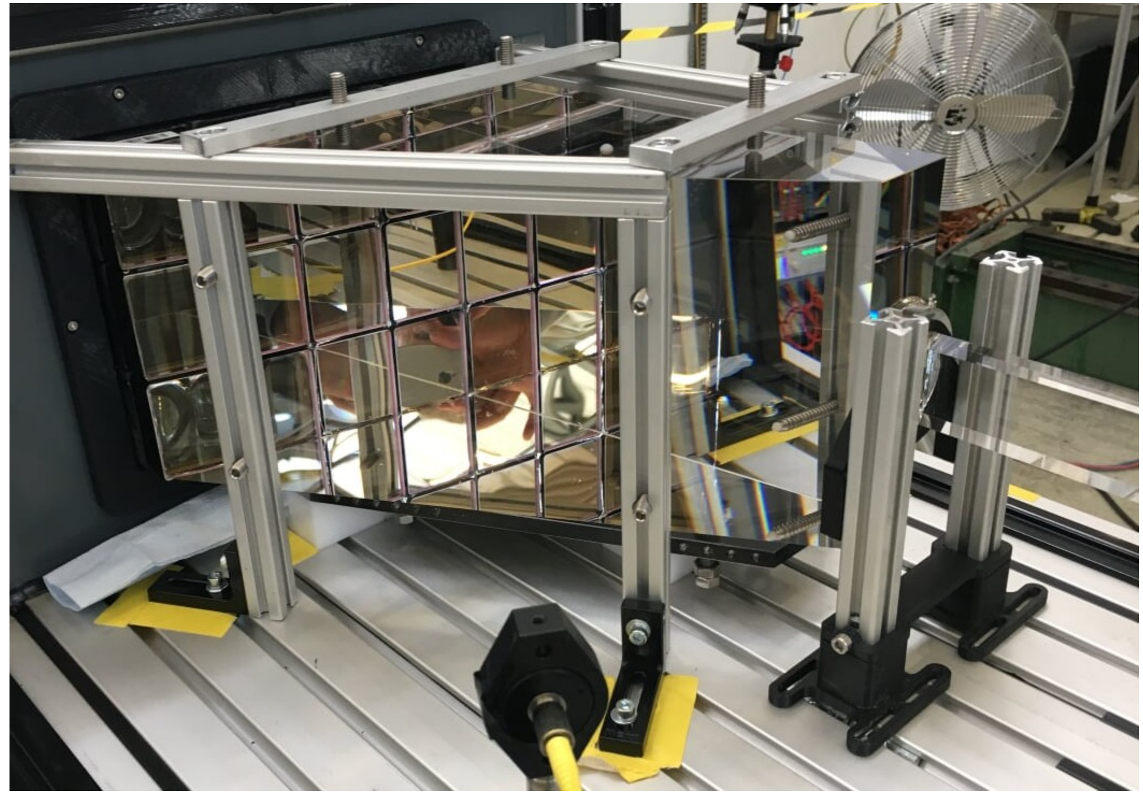
Low cost

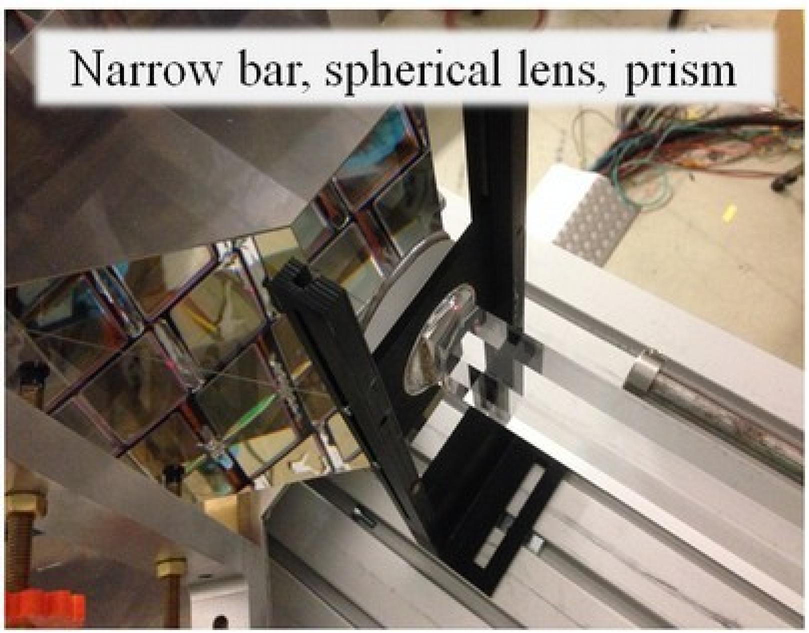
< 50 ps (discr. + TDC)

http://trb.gsi.de/

Prototyping, extensive testing one module







The prototypes were built with different options

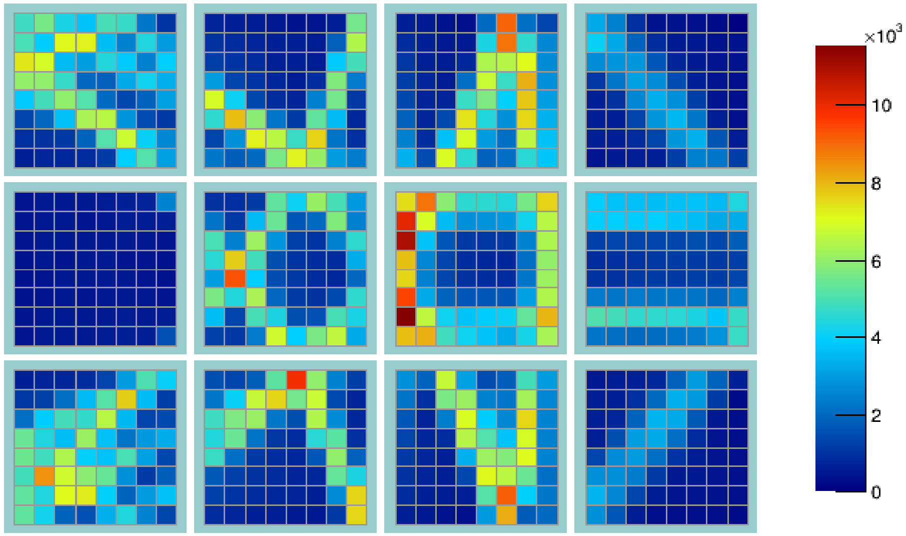
Narrow bar, wide plate,radiators, expansion volumes

Focusing elements…...

to test and validate the final design

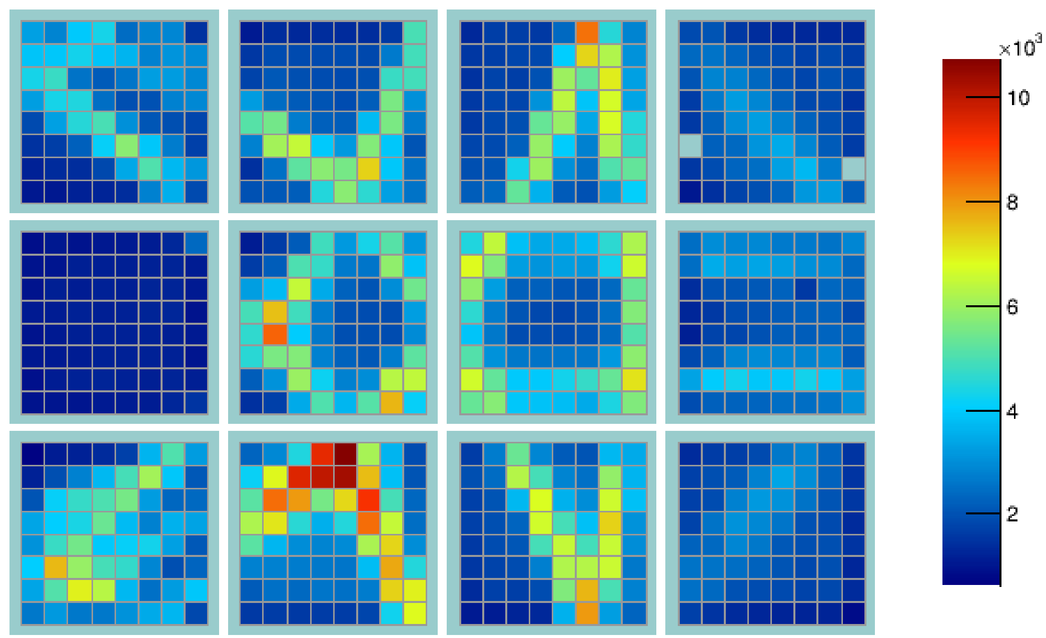
The beam tests done at CERN T9, hit patterns

In MC from Pions



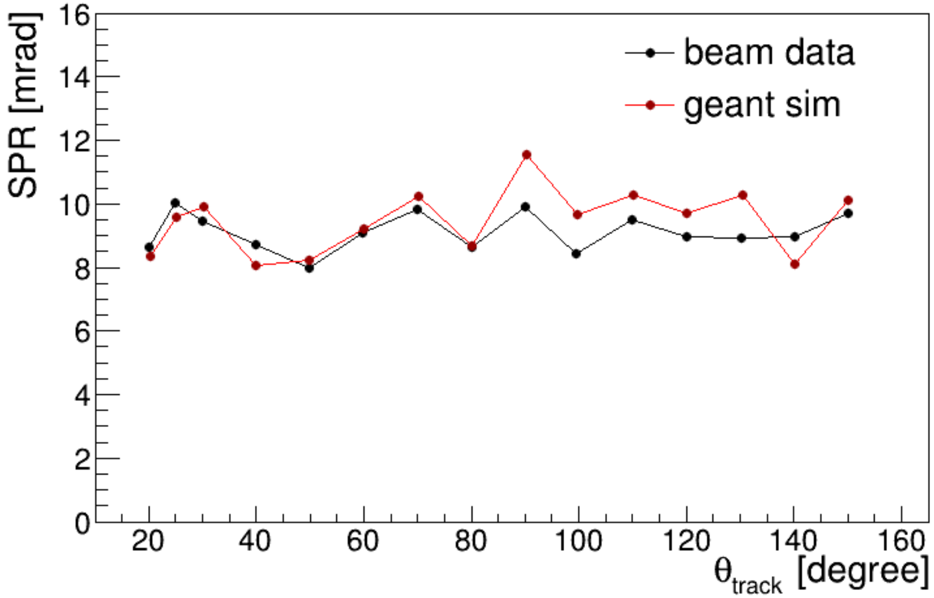
20 degree polar angle
Pions/protons at 7 GeV/c
Bar equipped with 3 layer spherical lens

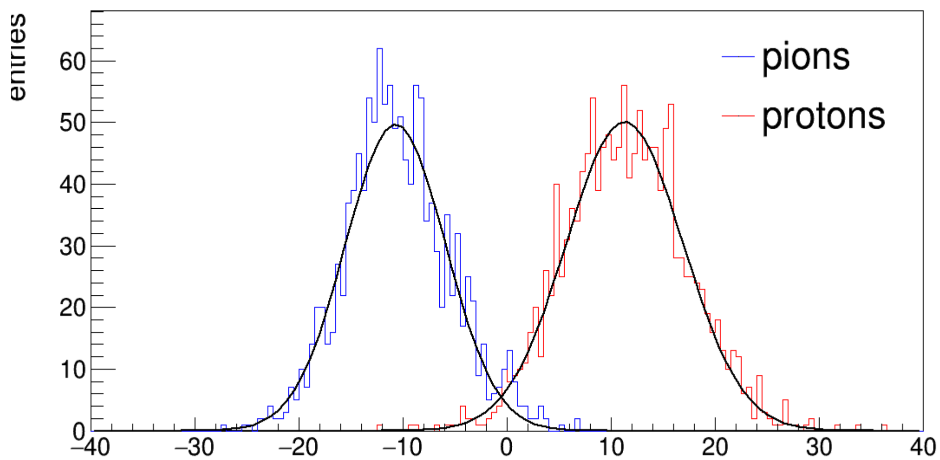
In test beam measurements

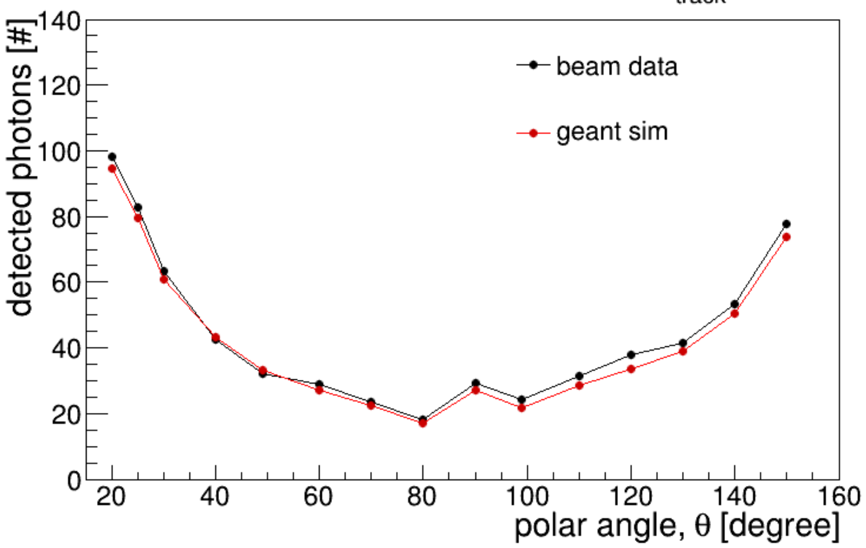


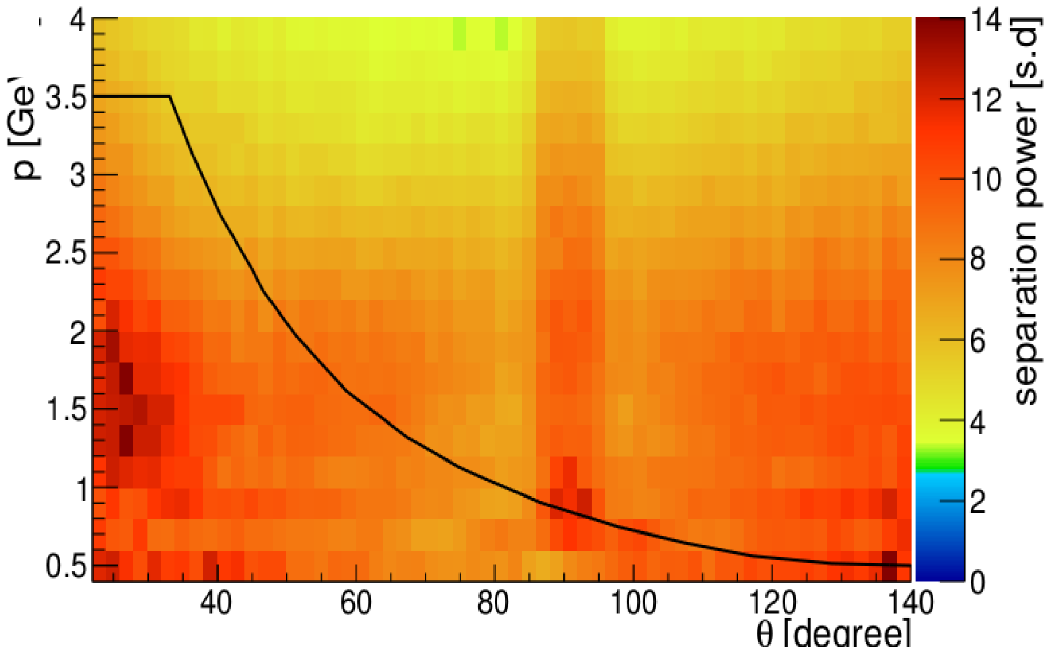
Intensive test beam campaigns
To verify and polish the design
to reach CDR level
The last test beam was in
July-Aug2018 (common with EDD)

Perfect agreement between MC and TB yields
PID probabilities, separation power







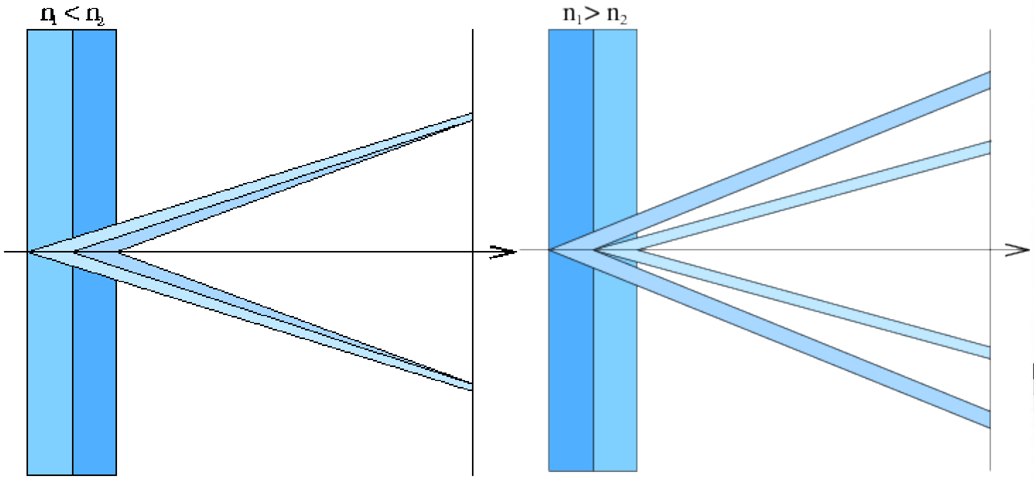


TDR approved(arXiv:1710.00684)

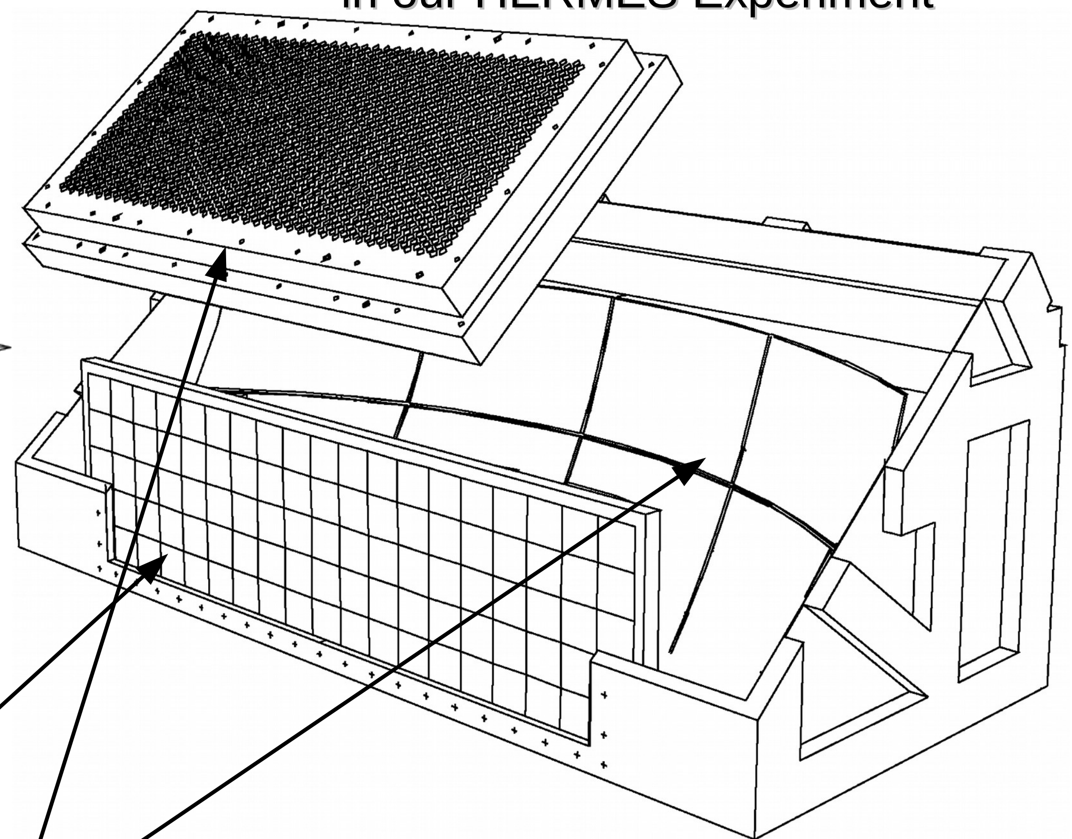
Will appear in
Journal of Physics G

The Forward RICH

The principle



as predecessor, 20 years ago
in our HERMES Experiment



T.Iijima et al., NIM A548 (2005)383
A.Yu.Barnyakov et al., NIM A553(2005)70

The HERMES RICH detector

NIMA v. 433. Issues 1-2 (1999) 98-103

A few layer of Aerogel, Mirrors and Photon detector area outside of acceptance
See Sergey Kononov talk at RICH2018

The prototype of FRICH tested at BINP and CERN

Aerogel produced at BIC SB RAS in cooperation with BINP Novosibirsk

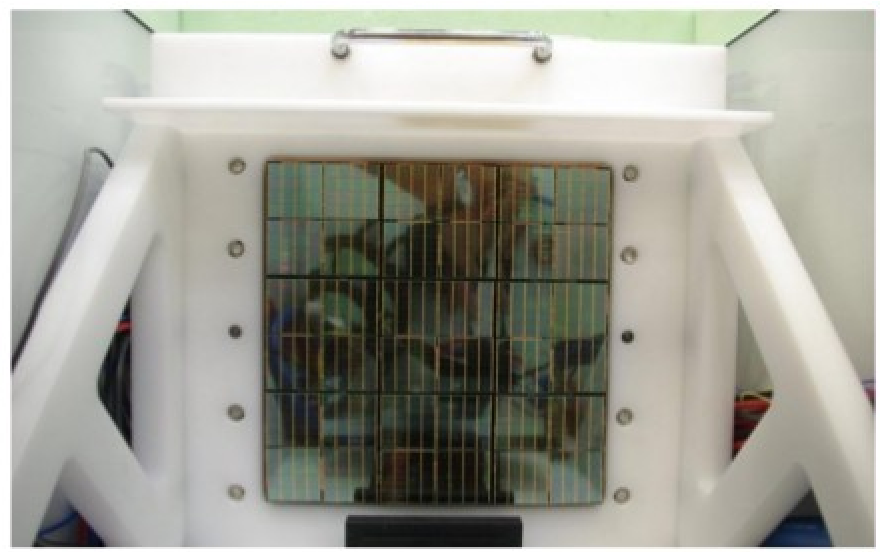
4-layer aerogel

- n_{max} = 1.046
- Thickness 37.5 mm
- Calculated focal distance 200 mm
- Hermetic container with plexiglass window to avoid moisture condensation on aerogel

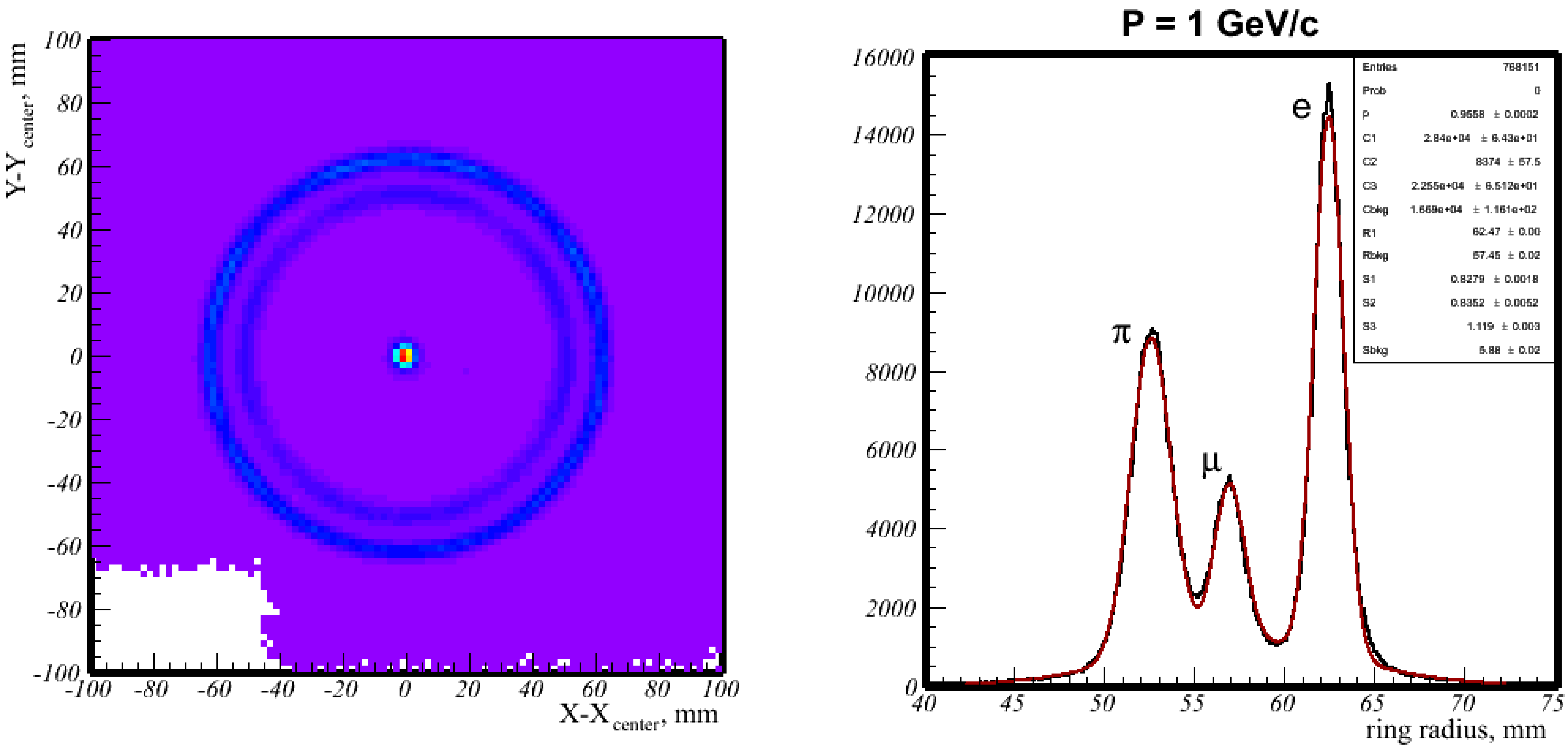
Photon detector , Philips Digital Photon Counting (PDPC)
https://www.digitalphotoncounting.com

Square matrix 20x20 cm^2

- Sensors: DPC3200-22-44
- 3x3 modules = 6x6 tiles = 24x24 dies = 48x48 pixels in total
- 576 time channels
- 2304 amplitude (position) channels
- 4 levels of FPGA readout: tiles, modules, bus boards, test board



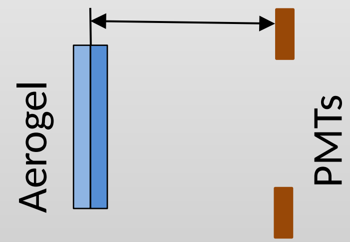
The FRICH prototype results

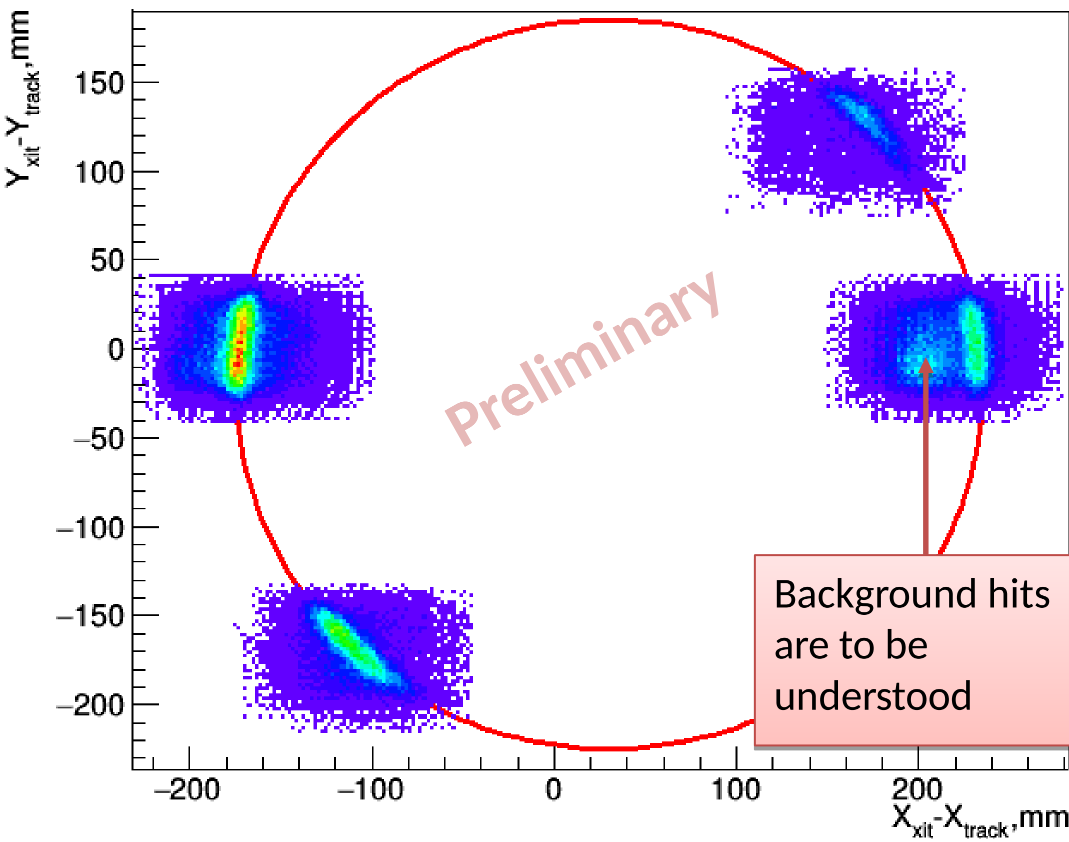


Ring 2D distribution for P=6 GeV/C(left) and ring radius distribution for P= 1 GeV/C Momentum beam measured by FRICH prototype at CERN T9 test beam

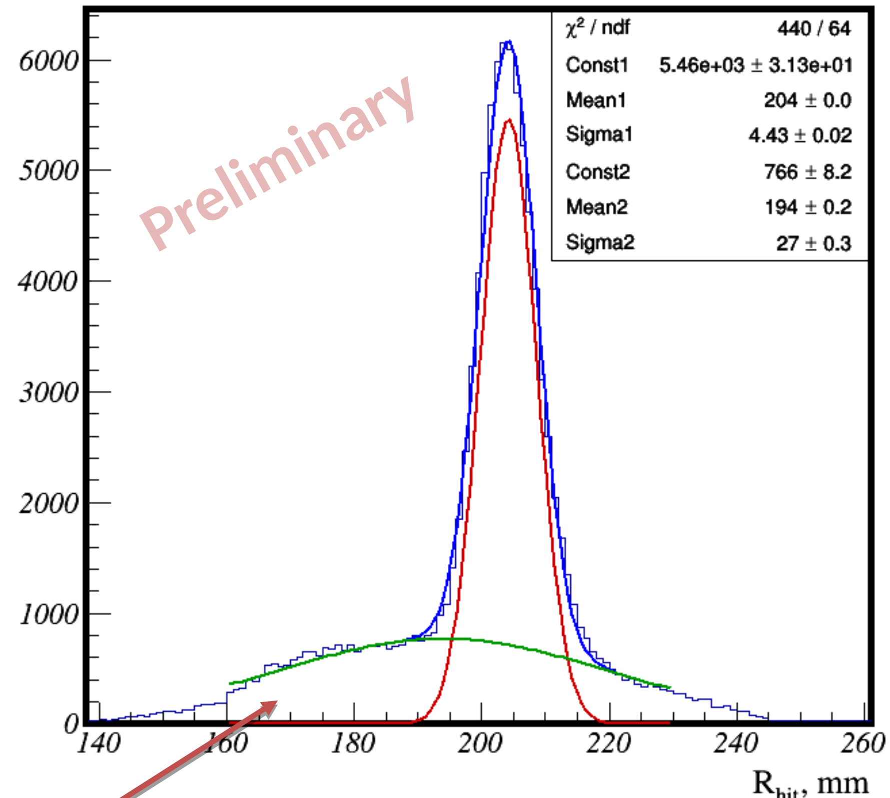
Continuous testing of FRICH Prototype in BINP testbeam 2018

Configuration 1
Aerogel-PMT distance: 600 mm





Background hits are to be understood

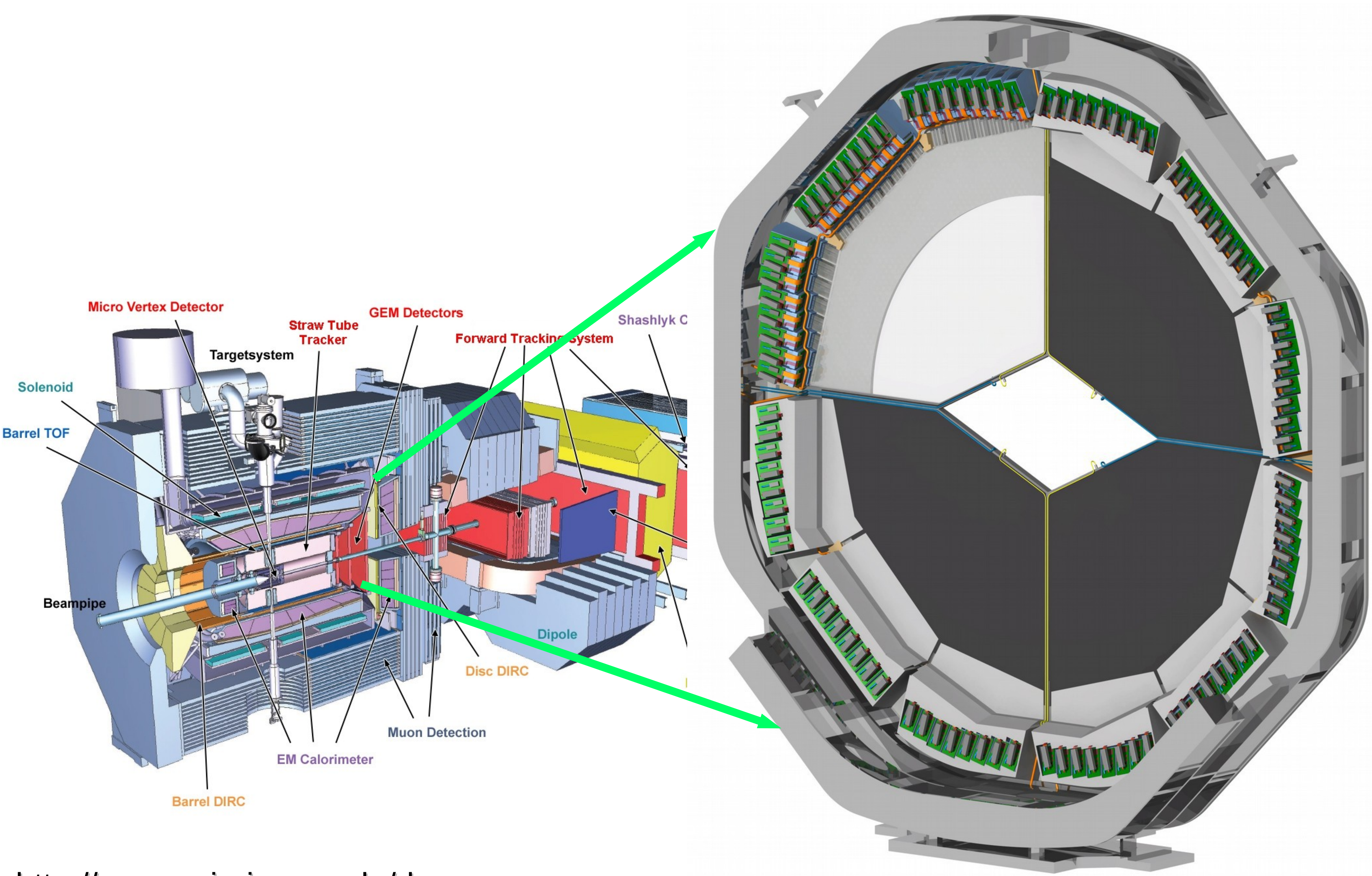


Preliminary results:

R = 204 mm

σ_{R1} = 4.4 mm (6.6 mrad)

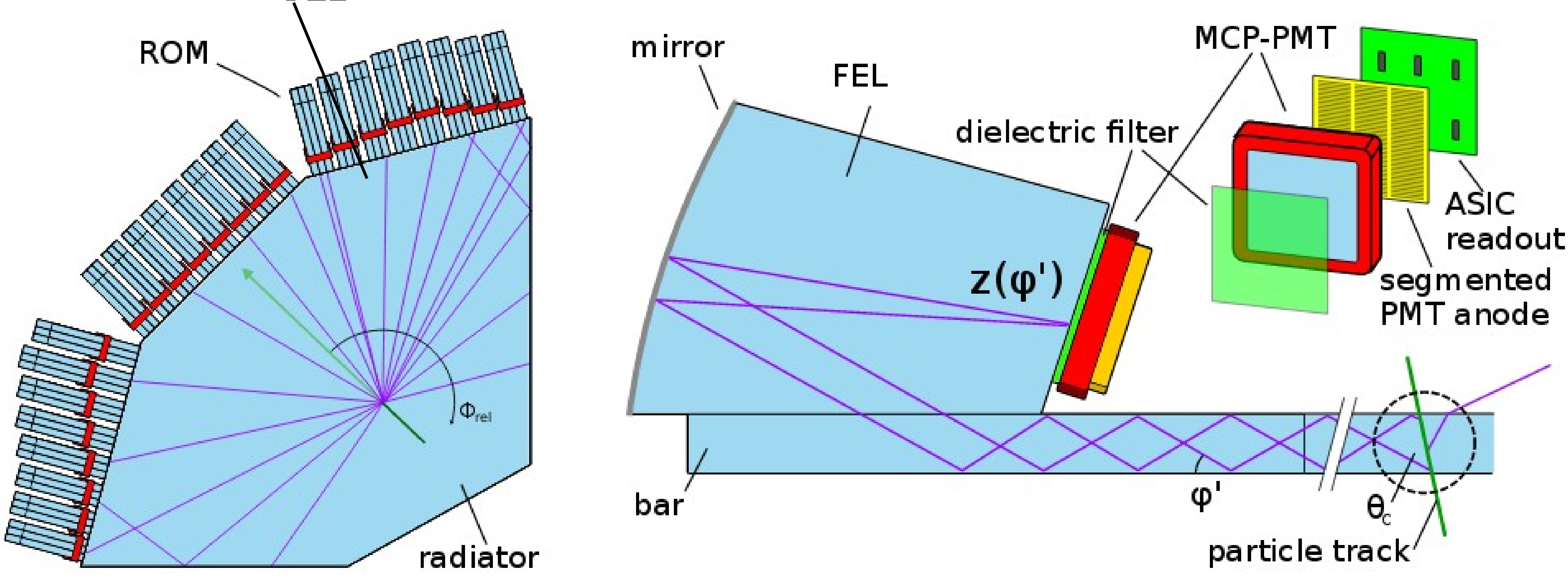
Novel Endcap Disc DIRC(EDD) will be built by Giessen



http://www.uni-giessen.de/dueren

The working principle

$$\tan\varphi' = \frac{\tan\varphi}{\cos\alpha_{\mathrm{FEL}}}$$

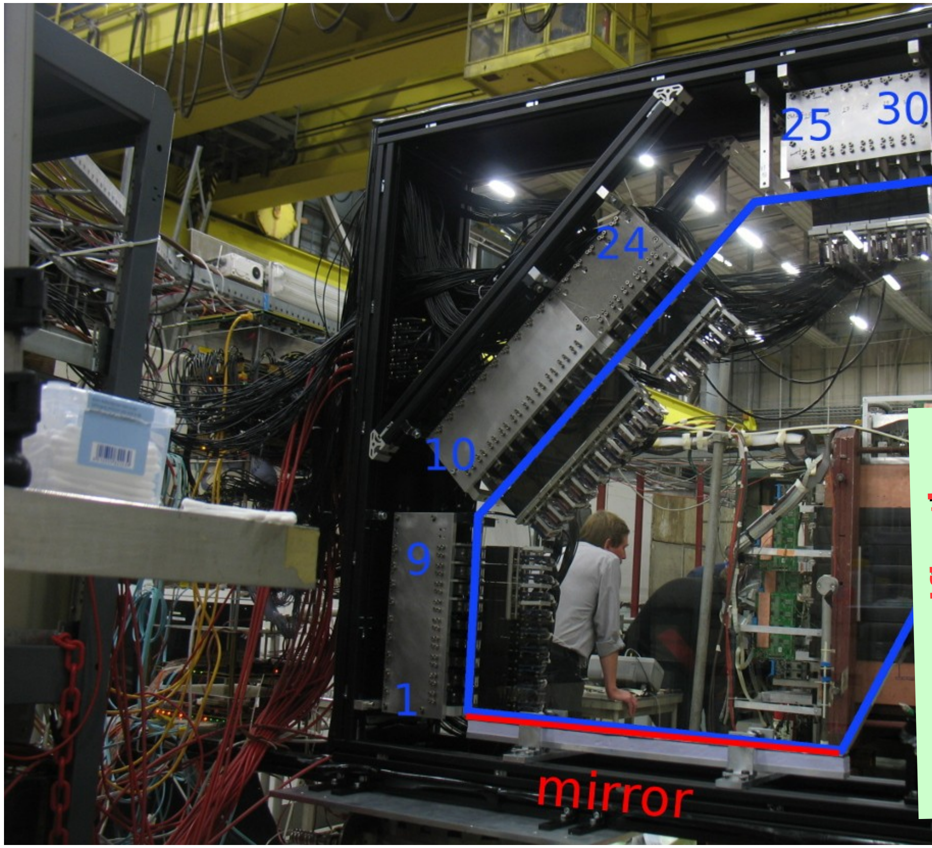


$$\theta_c = \arccos\left(\sin\theta_p \cos\phi_{\mathrm{rel}} \cos\varphi + \cos\theta_p \sin\varphi\right)$$

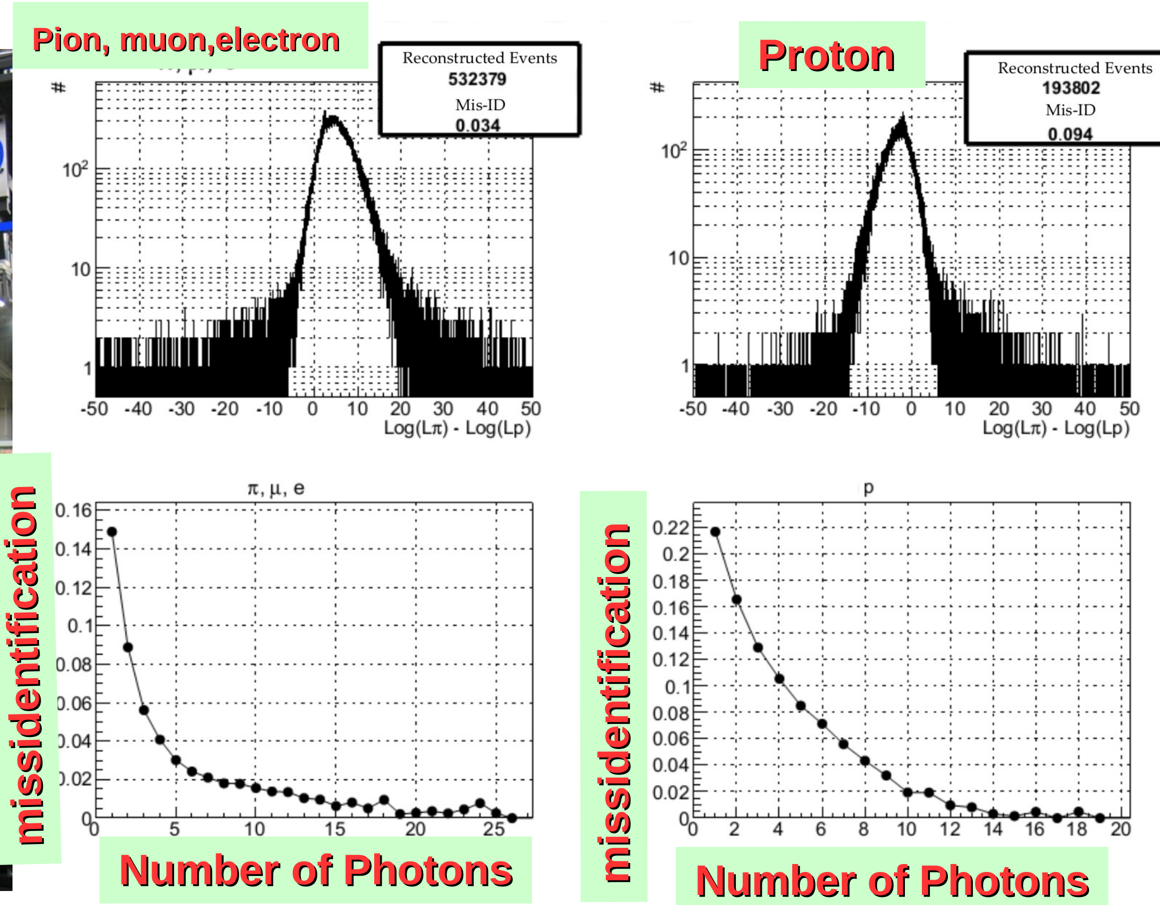
One can calculate the Cherenkov angle analytically, hence EDD could be a part of online trigger at any level

The first full size EDD

prototype at CERN T9(2012)



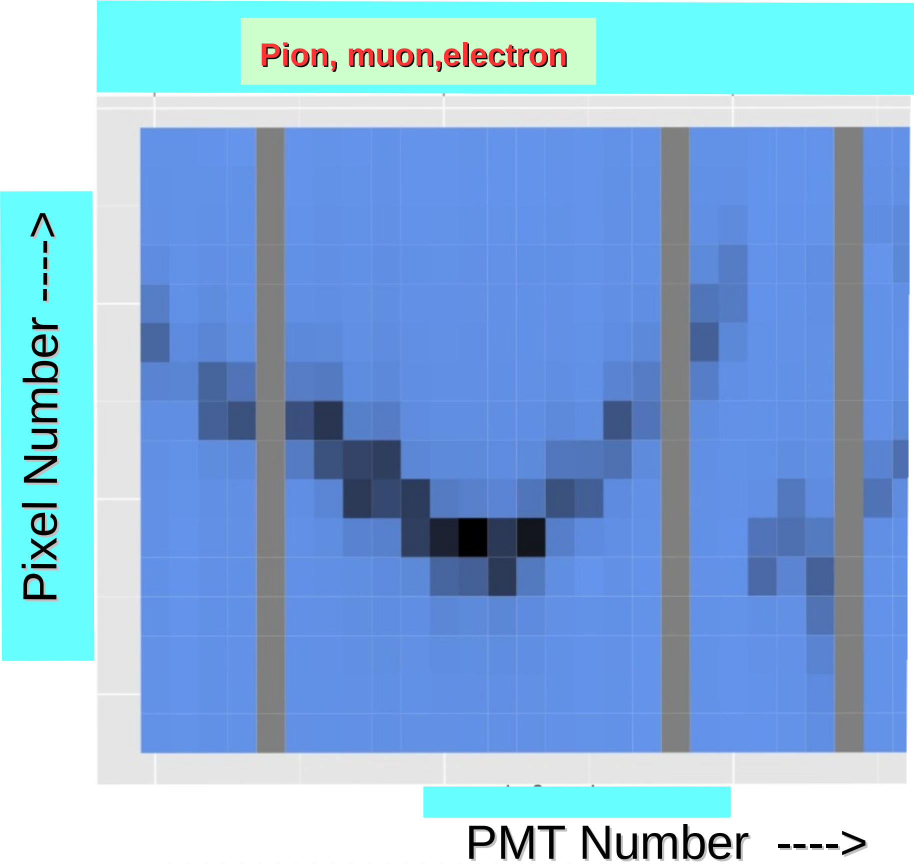
PID probabilities

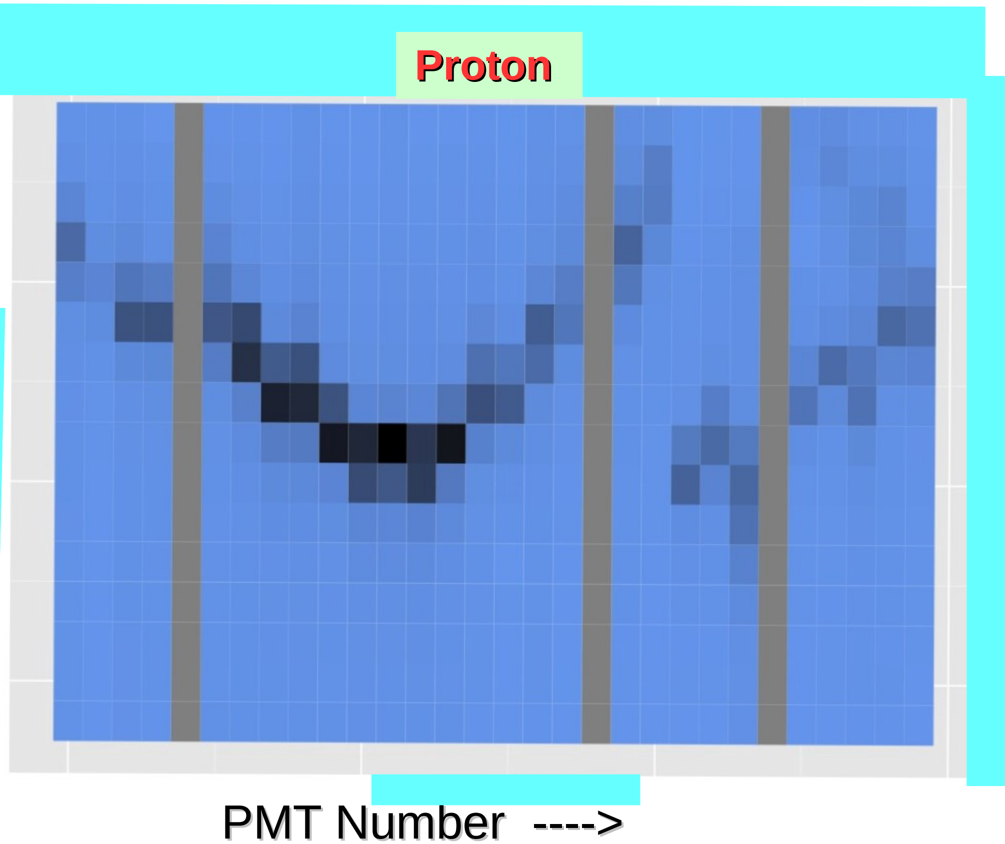


- radiator made of float glass
- FELs made of acrylic glass
- photo sensors: MA-PMT with 16 strips
- mixed hadron beam at CERN

One can see that by enough hits
the misidentification is then negligible

The hit pattern shows what we call "SMILE"



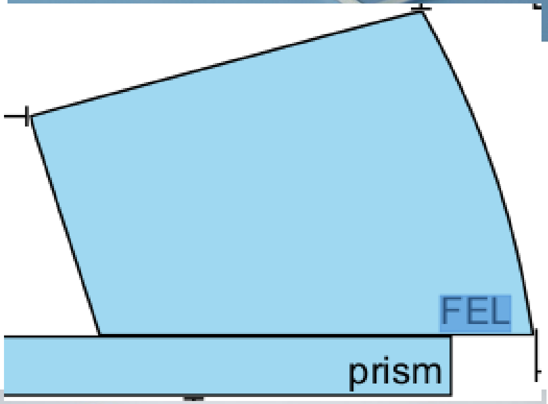


One sees that Protons are more happy than Pions&Co

Moving in EDD final design direction

Radiator

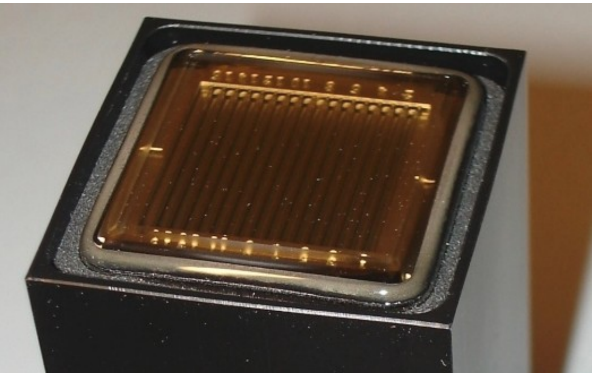
Borofloat Glass ---- fused Silica

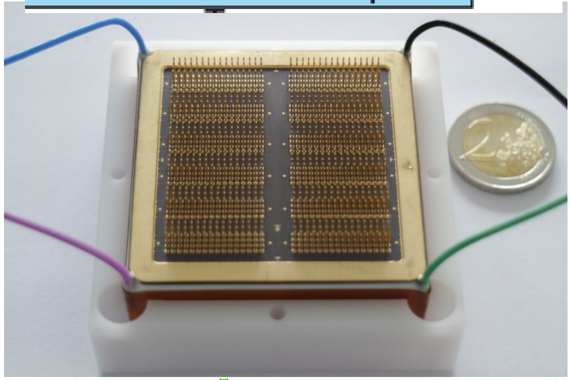


FEL

Plexiglas

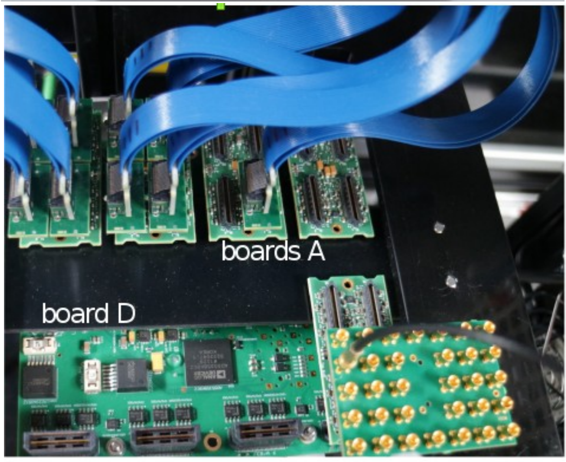
Quartz with prism
With optic bonding





Photon Detector

MaPMT(16 channels)---MCP-PMT
(>=300 channels)



Readout FEE

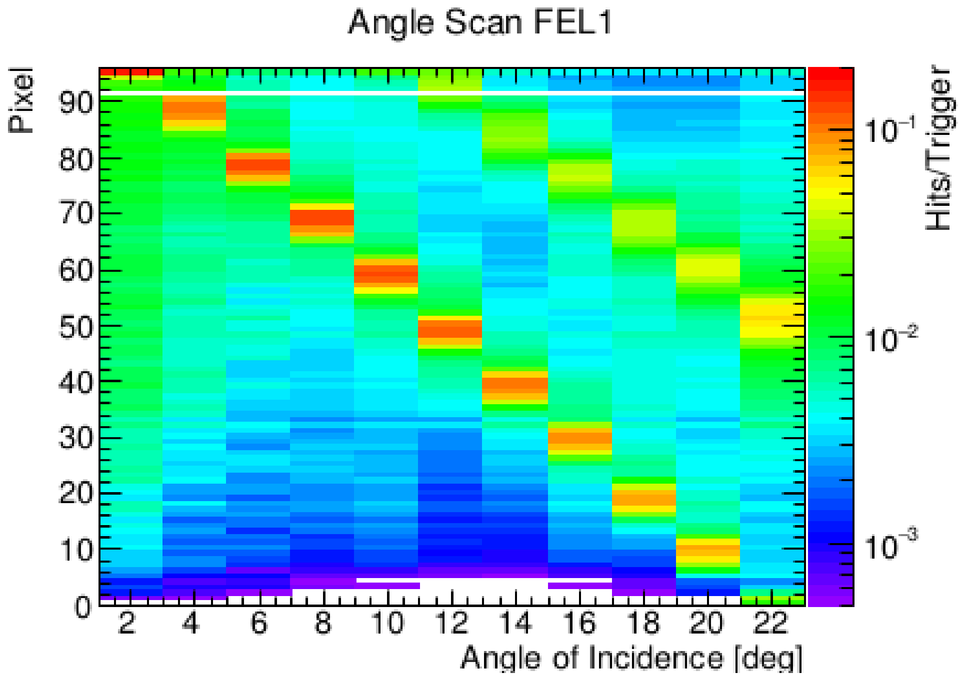
FPGA based
channels (256 single edge,
192 with ToT)
TRB3

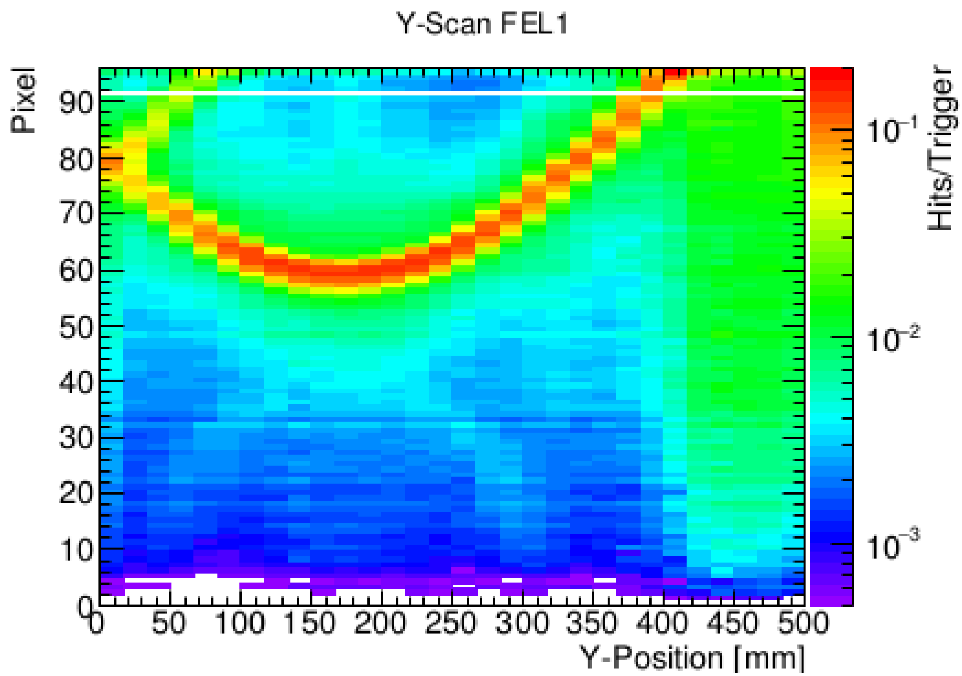
TOFPET ASIC compact
design
8X128=1024 channels

New prototype, new tests(2016)

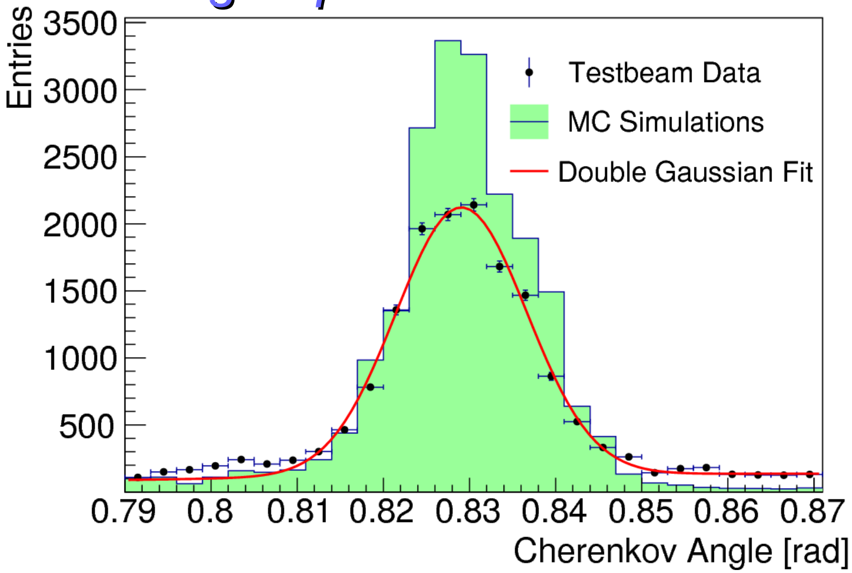
finer scaling

new “SMILE”

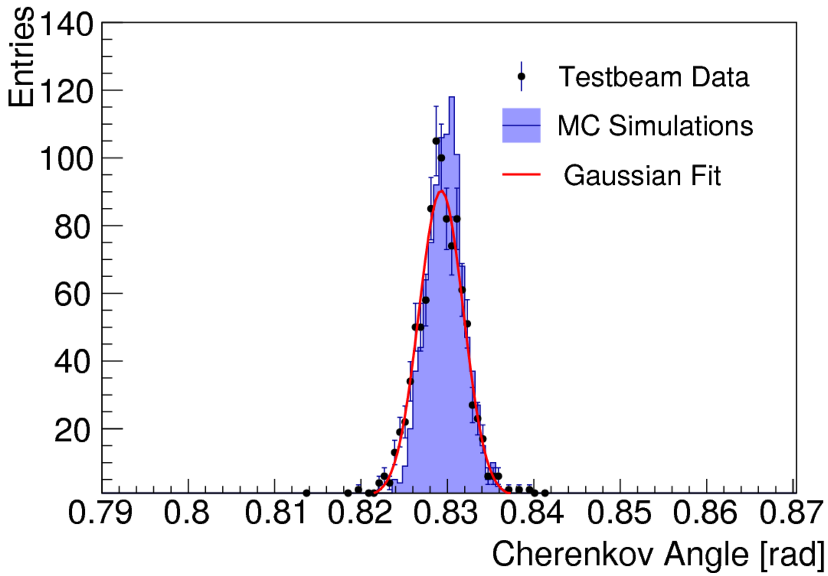




Single γ resolution

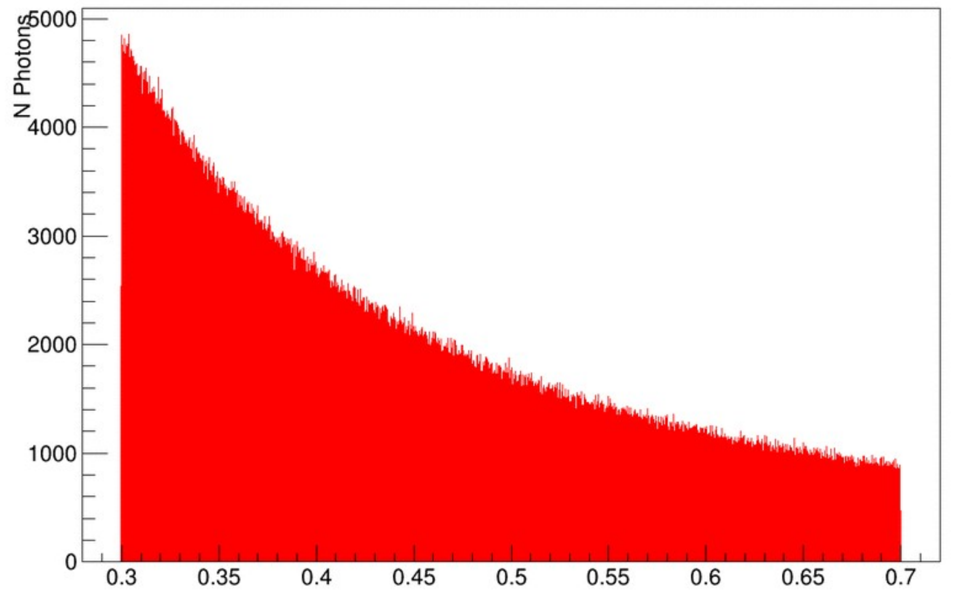


“mimicking” full prototype



The importance of the filter

In Silica produced Cherenkov Photons Number Against wavelength –>

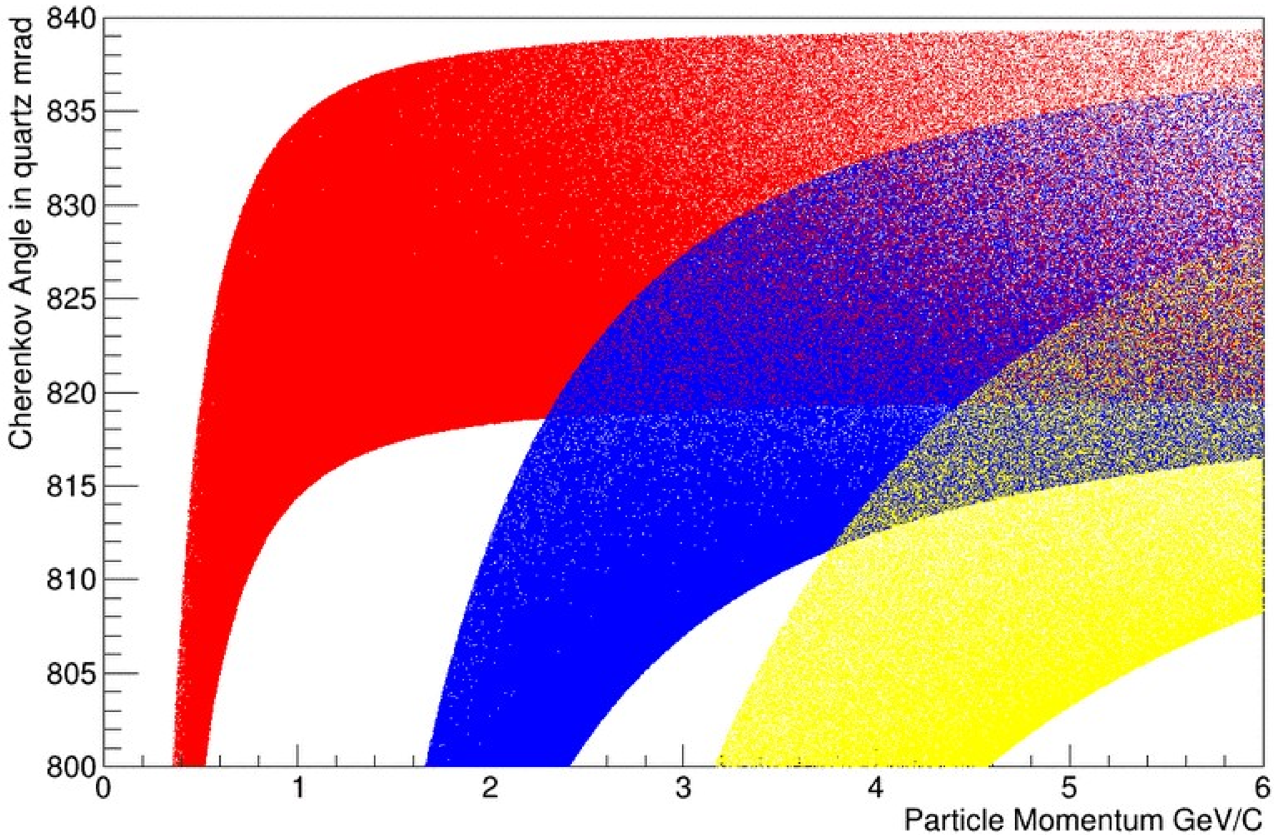


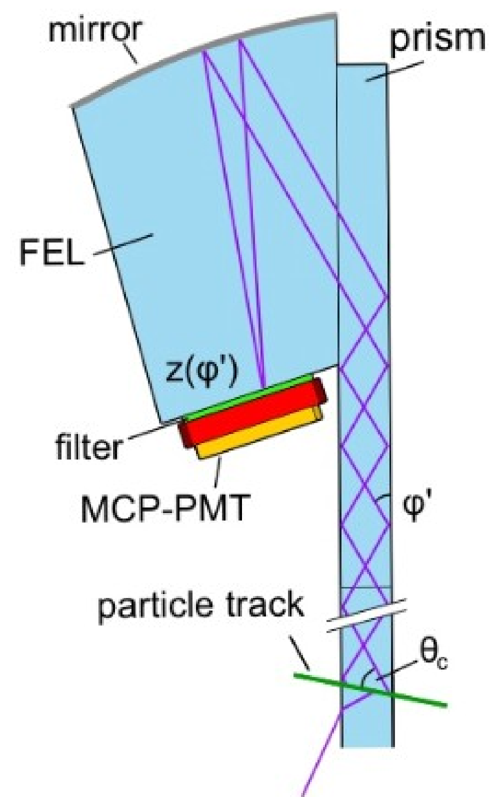
Pions

Kaons

Protons

Cherenkov angle against momentum



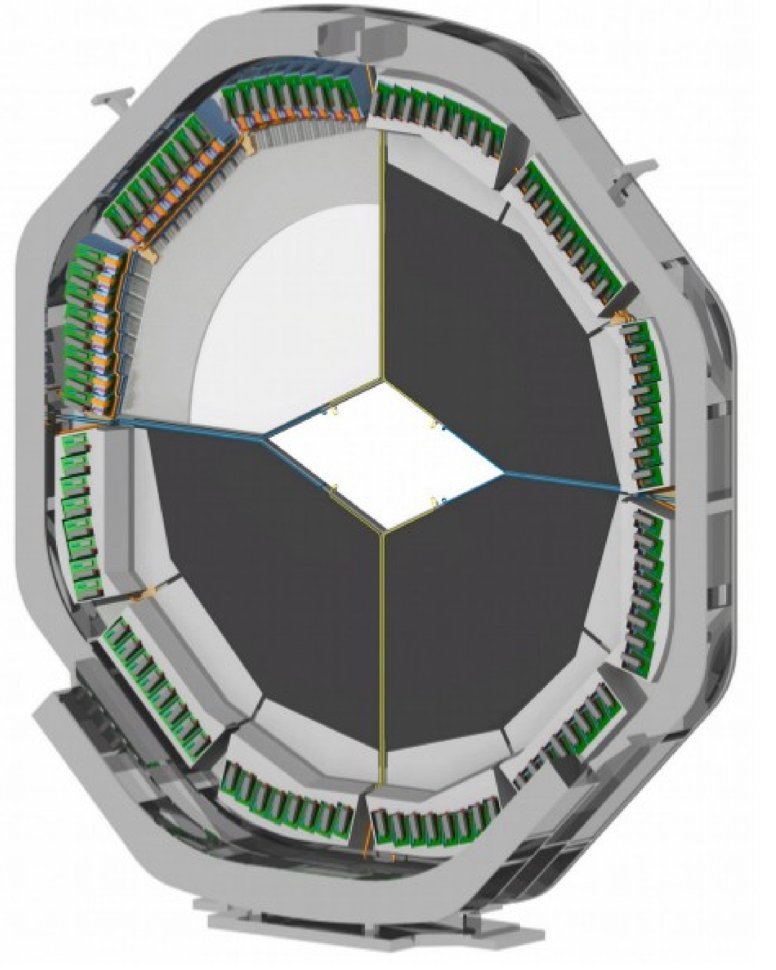


The Endcap Disc DIRC design

Full Weight ~ 450 kg
For 1 Quadrant ~ 85 kg

Quadrants 4
ROMs 96 = 4x3x8
(Readout Modul)
Photon detection area ~600cm^2
FELs 288 = 4x3x8x3
(Focusing Element)
Readout Channels ~30k
free running readout system
Wavelength Filters ~ 100 or
New “green” photocatode MCP

We expect ~22 detected hits
(per track)
We promise >3 s.d. for π/K separation
up to 4 GeV/c momentum



The time-lines

Barrel DIRC

2018 component procurement

2019-2021 bar box and readout module assembly

2022-2023 installation in PANDA hall

2023-2024 commissioning with cosmic and beam

EDD

2018 R&D fine tuning

2018-2021 1st Quadrant production

2022-2023 Installation of First Quadrant

2023-2024 commissioning

2025 completion of remaining 3 Quadrants

PANDA Phase 1

FRICH

Mirror layout optimization in 2D

Aerogel Optimization

Photon detector investigation

2019 TDR expected

PANDA Phase 2, 2025

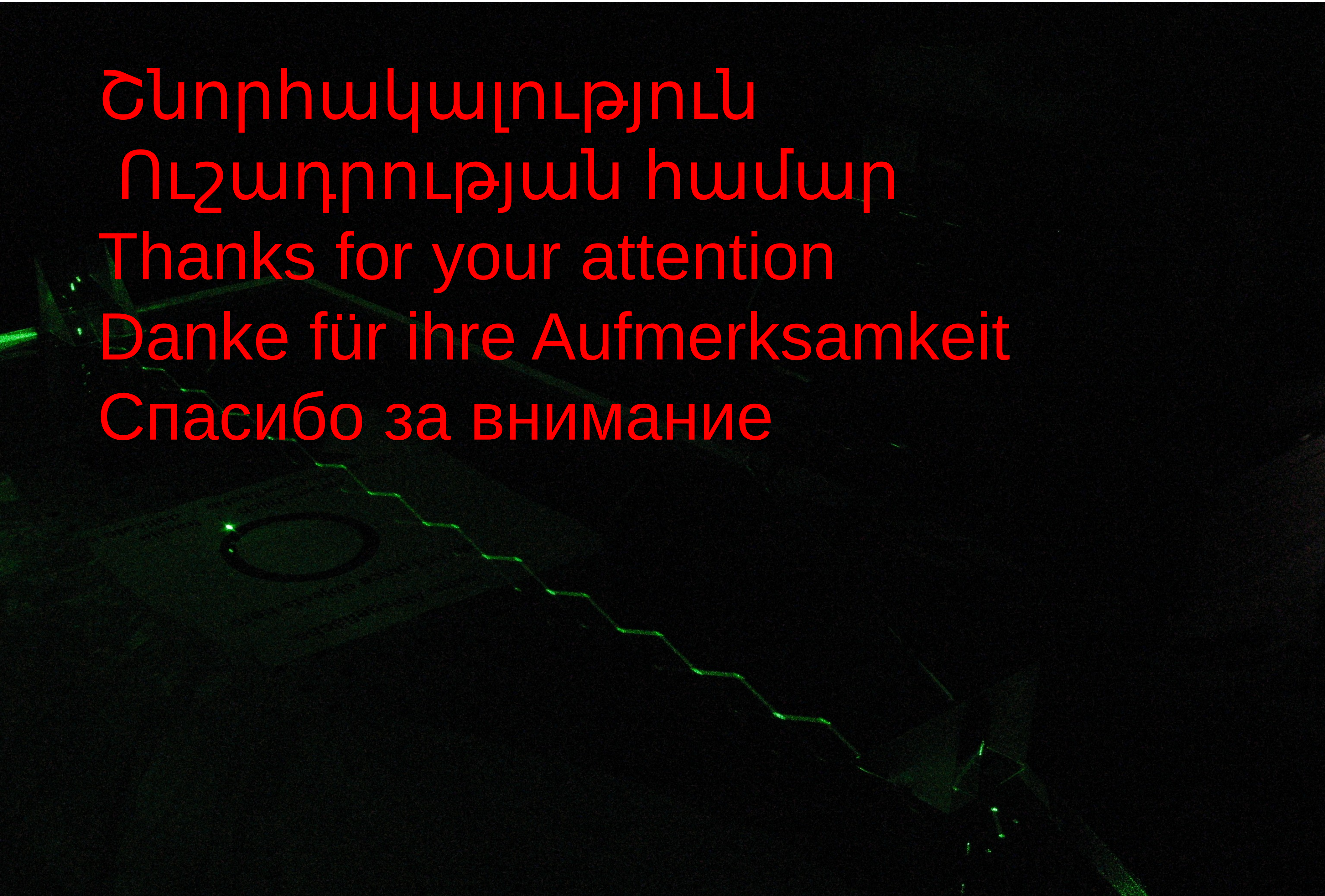
Շնորհակալություն

Ուշադրության համար

Thanks for your attention

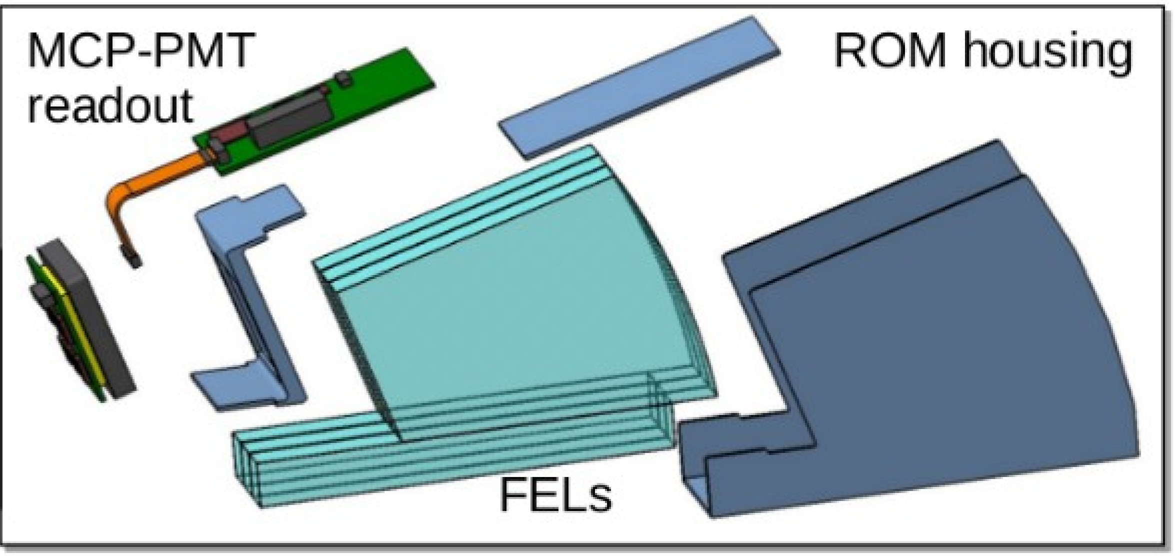
Danke für ihre Aufmerksamkeit

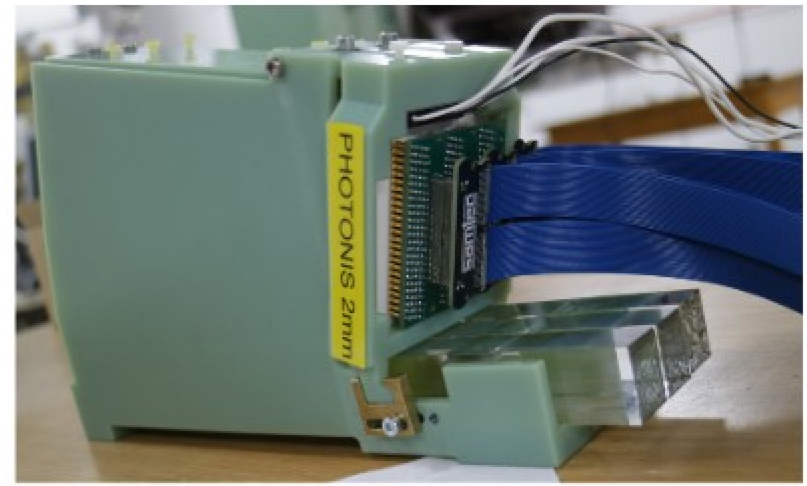
Спасибо за внимание

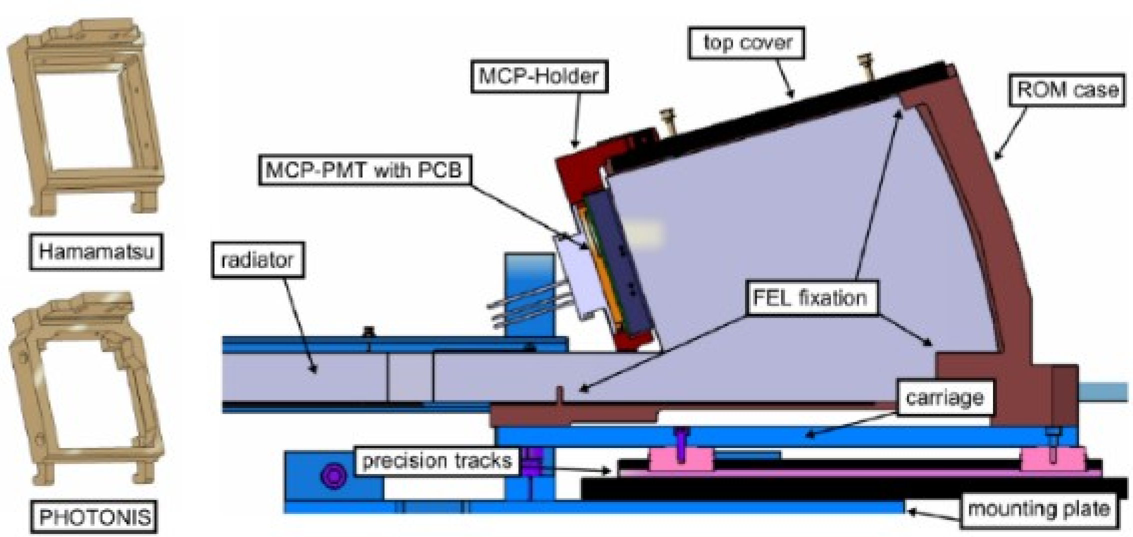


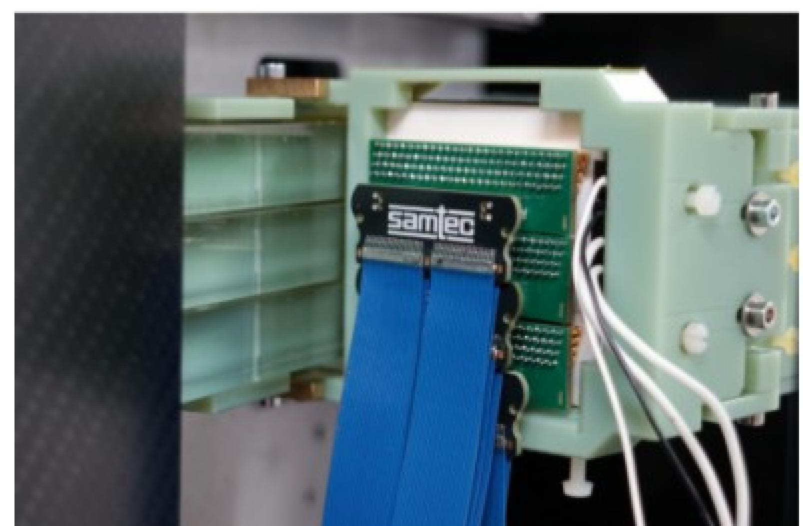
The EDD Read Out Module

In design or in Prototype(in 3d printed housing)









EDD final design

Finalizing the specifications , algorithms, TDR for a EDD Quadrant readiness for Phase1, 2018 new Testbeam at T9

The complete design in CAD