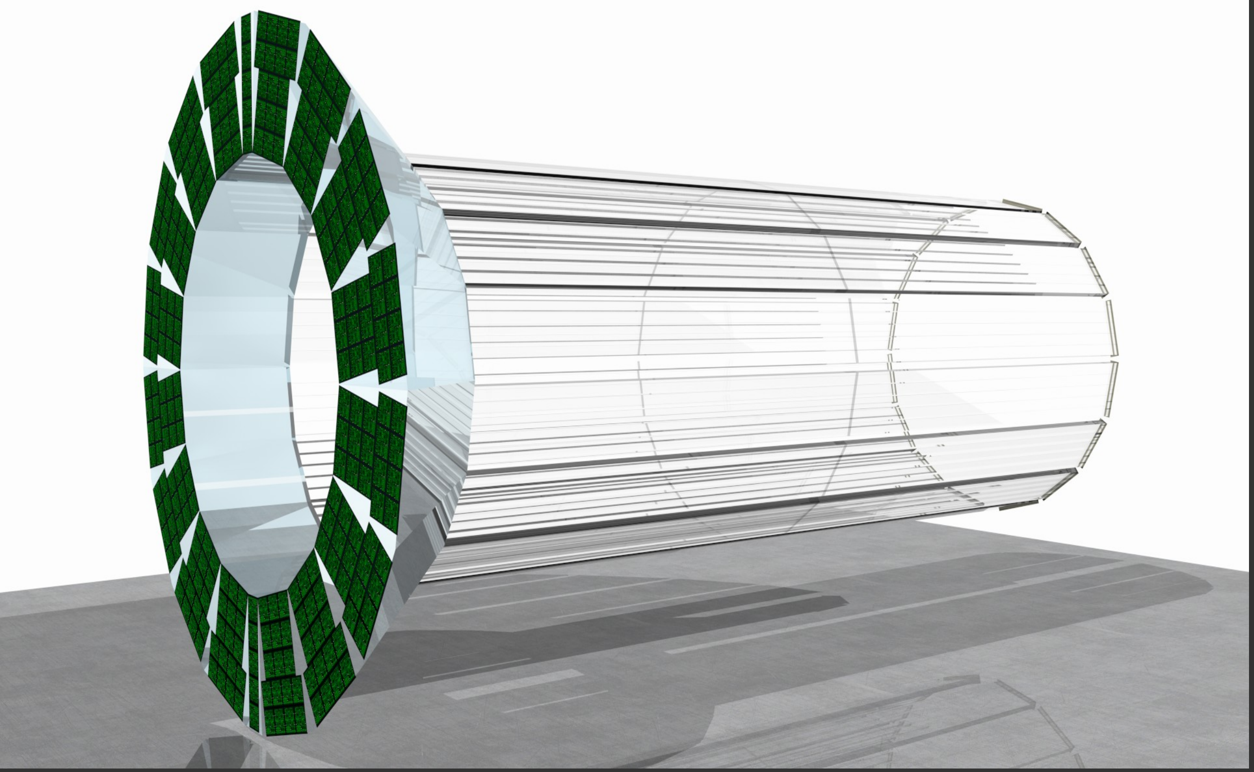


- PANDA @ FAIR
- PANDA Barrel DIRC design: baseline and options
- Simulation studies
- Overview of the test beams
- Summary and outlook

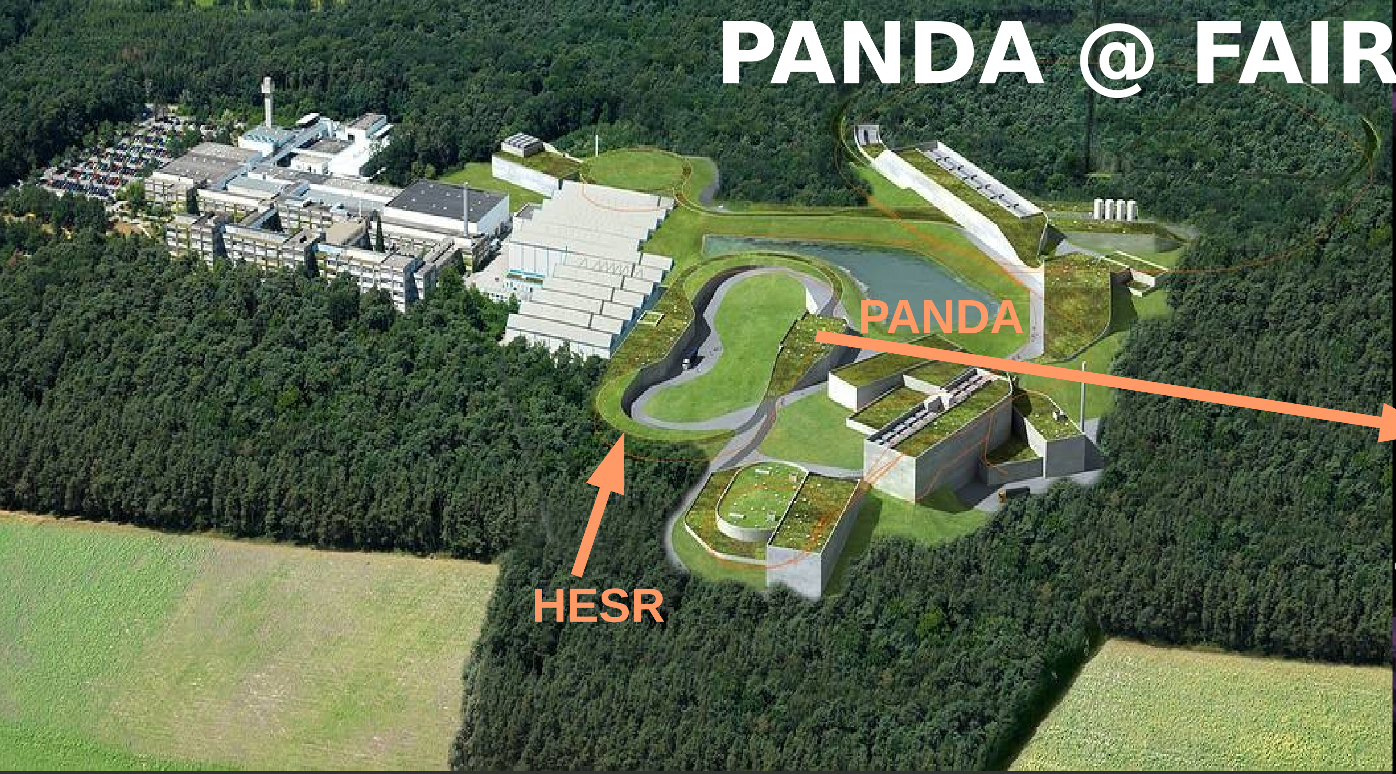
R & D for the PANDA Barrel DIRC

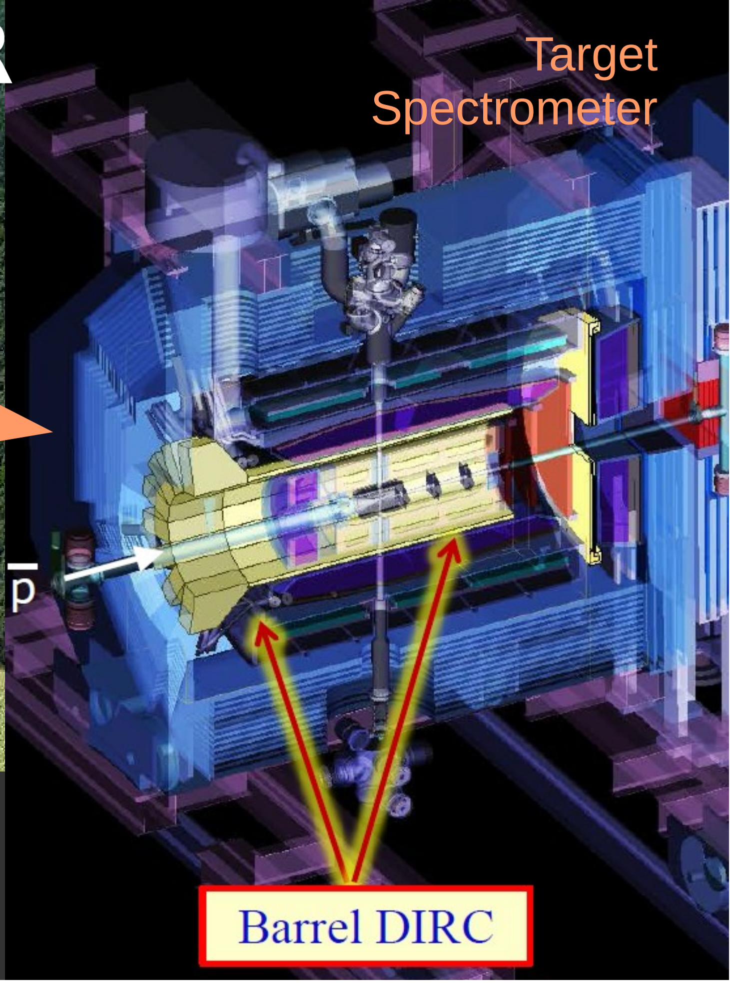
Maria Patsyuk

R. Dzhygadlo, K. Götzen, G. Kalicy, H. Kumawat, K. Peters, C. Schwarz, J. Schwiening, and M. Zühlsdorf

International Conference on Science and Technology for FAIR in Europe 2014, Worms, 13-17 October

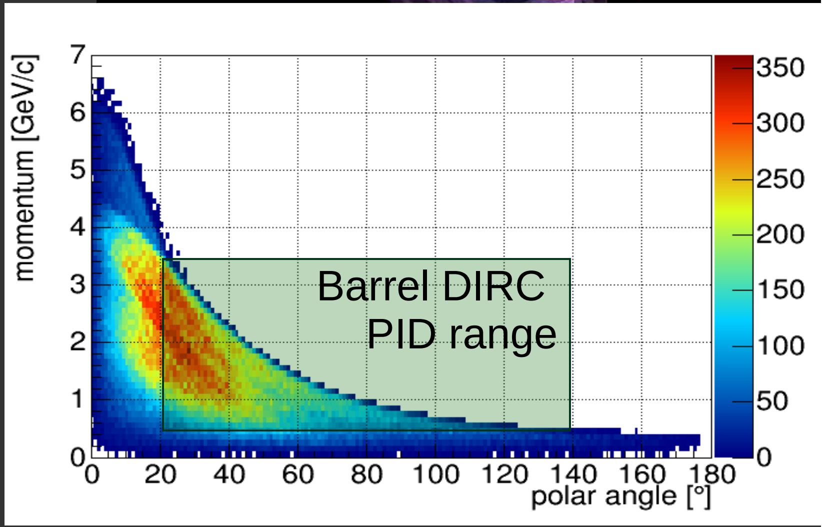
PANDA @ FAIR





- Uniquely thin and compact design
- Polar angle acceptance: 22-140 degrees
- PANDA PID requirement: **3σ K/π separation** in the momentum range **0.5 - 3.5 GeV/c**
- High efficiency and purity of identification
- High rate capability
- Based on BABAR DIRC

Simulated cumulative phase space distribution for the **final state kaons** for most of the PANDA benchmark channels



DIRC principle

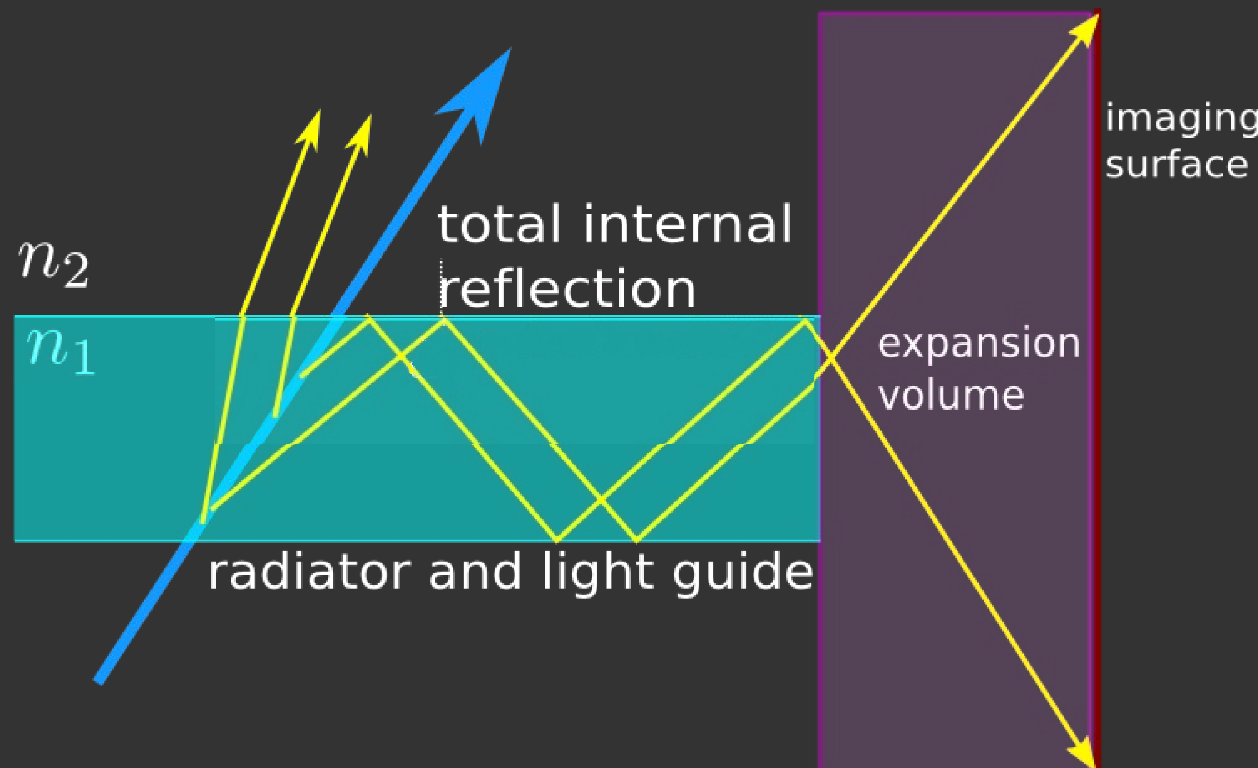
- **D**etection of **I**nternally **R**eflected **C**herenkov Light

Novel type of **R**ing **I**maging **CH**erenkov detector based on total internal reflection of Cherenkov light

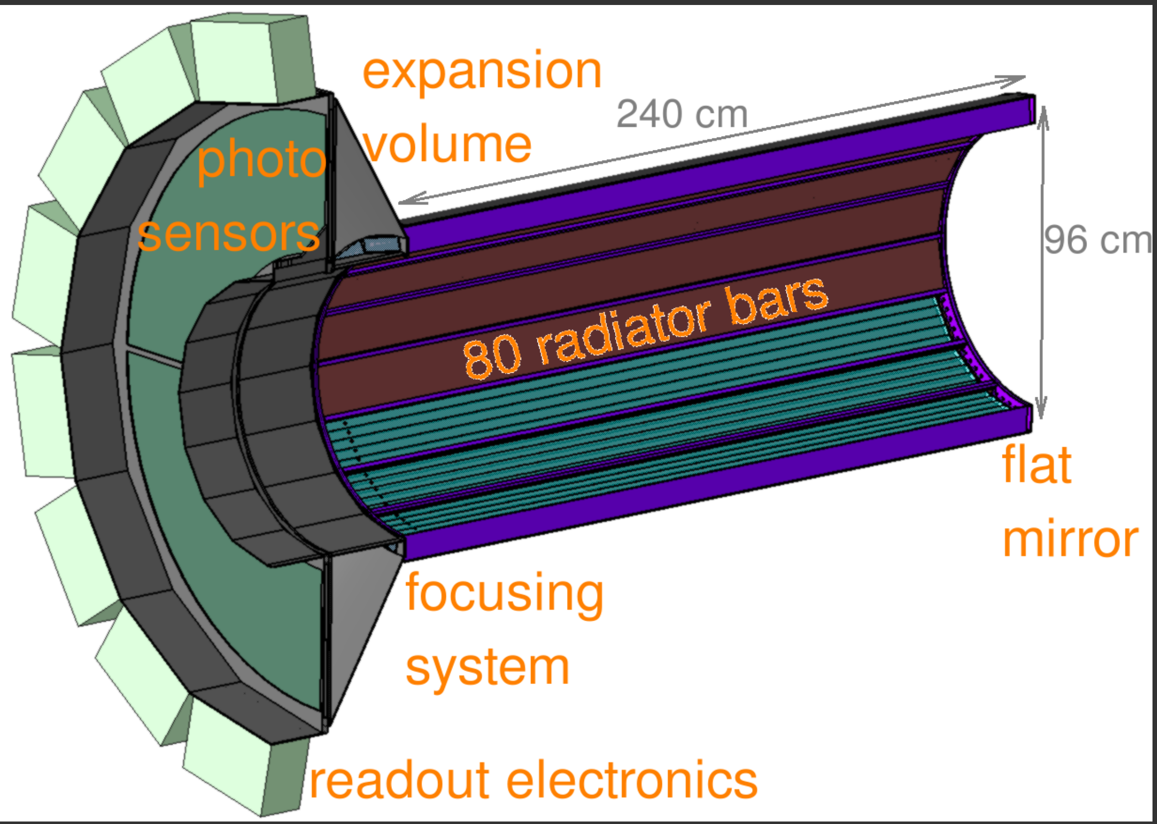
- Charged particle with $\beta = v/c > 1/n$ propagating in a medium with refractive index *n* emits Cherenkov photons on a cone with opening angle

$$\cos\theta_C = \frac{1}{\beta n(\lambda)}$$

Proven to work for BABAR DIRC and will be used for future experiments (PANDA Disc DIRC, Belle II, TORCH...)



Baseline design



Important improvements of the PANDA Barrel DIRC compared to the BABAR DIRC:

- compact expansion volume (EV)
- focusing (lens system)
- fast photon timing

Barrel radius ~ 48 cm

80 synthetic fused silica radiators 17 x 32 x 2400 mm^3 packed into 16 sectors

Focusing optics – lens system

30 cm deep expansion volume filled with mineral oil

10 000 - 15 000 channels of MCP-PMTs

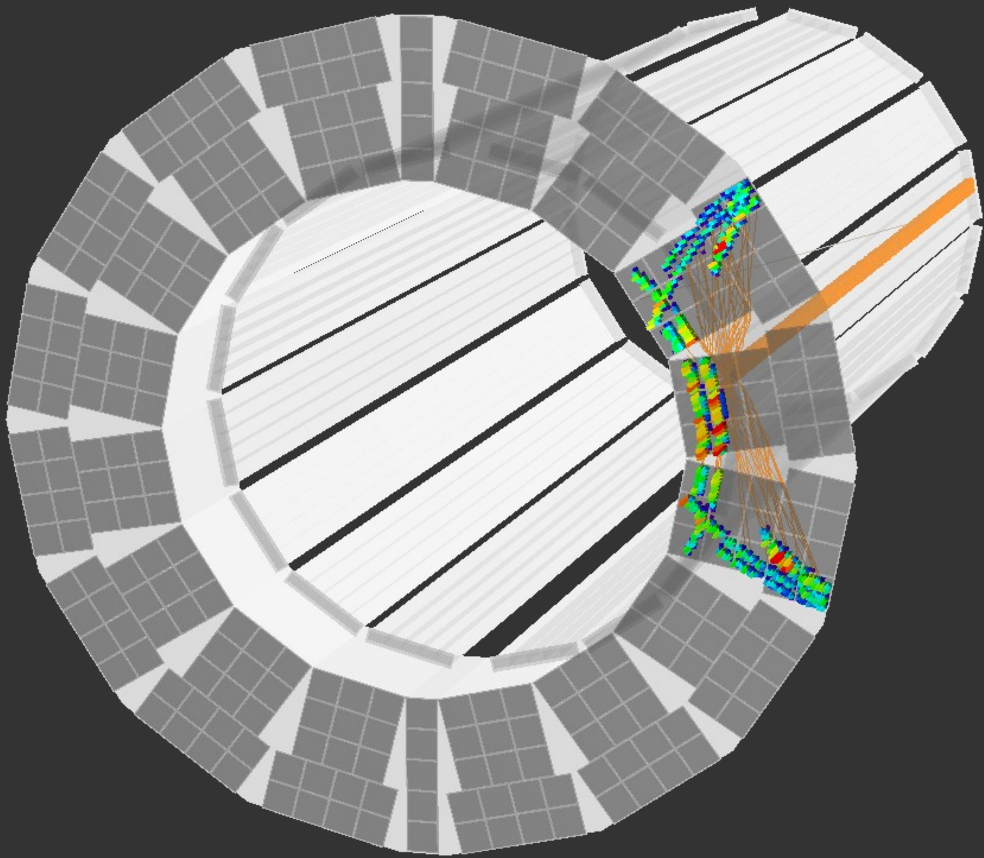
Expected performance:
at least 15 photons per track $(\beta \approx 1)$
single photon Cherenkov angle resolution ~ 10 mrad

<u>Main cost drivers:</u>

- fabrication of radiators (number of surfaces to be polished)

- sensor production (number of MCP-PMTs)

Detector simulation



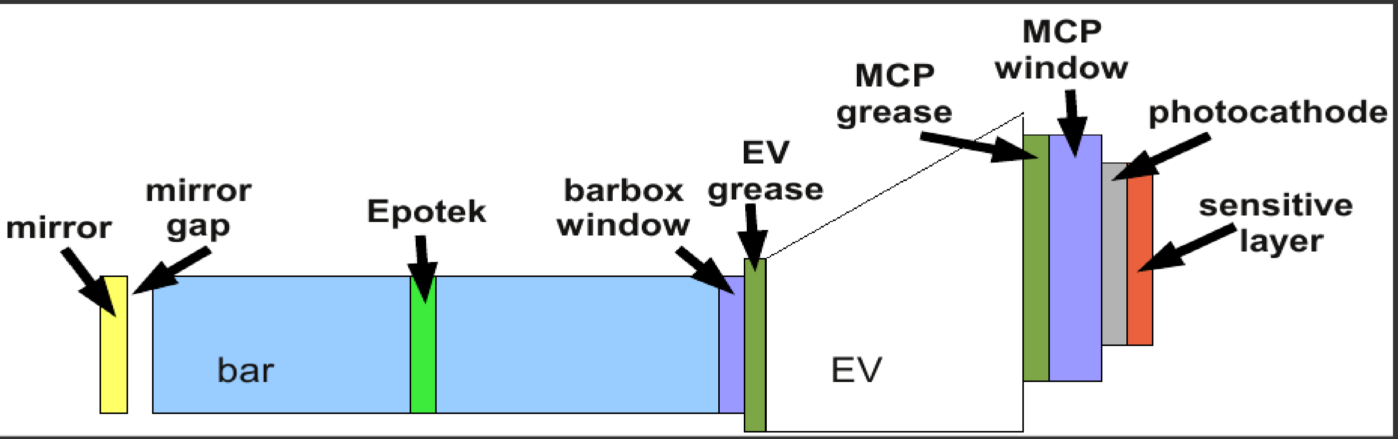
Geant-based

Complex geometry of the optical elements and photosensors is incorporated

Cherenkov photon propagation includes:

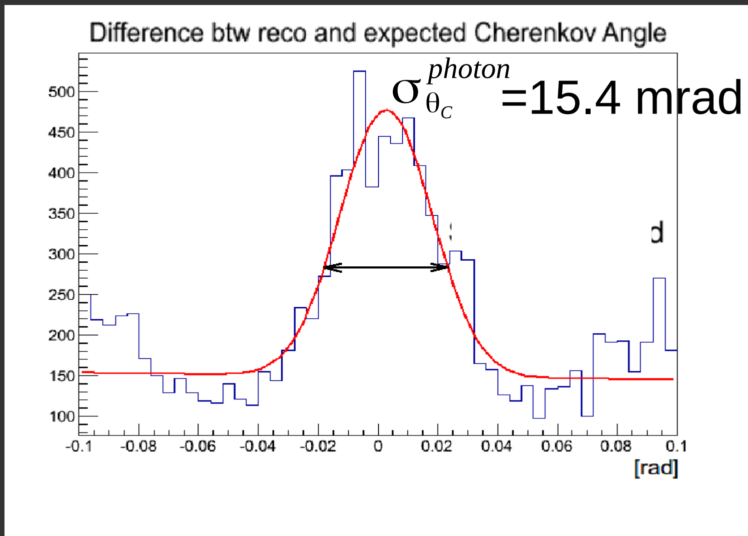
- total internal reflection effect
- surface roughness
- absorption inside materials
- mirror reflectivity
- reflection/refraction effects on the boundaries
- photon detection efficiency

Dark noise and charge sharing effects are included at digitization stage



Reconstruction of the hit pattern + timing info → performance evaluation

Performance of the baseline design



The resolution should lie in the green area to ensure 3σ K/π separation

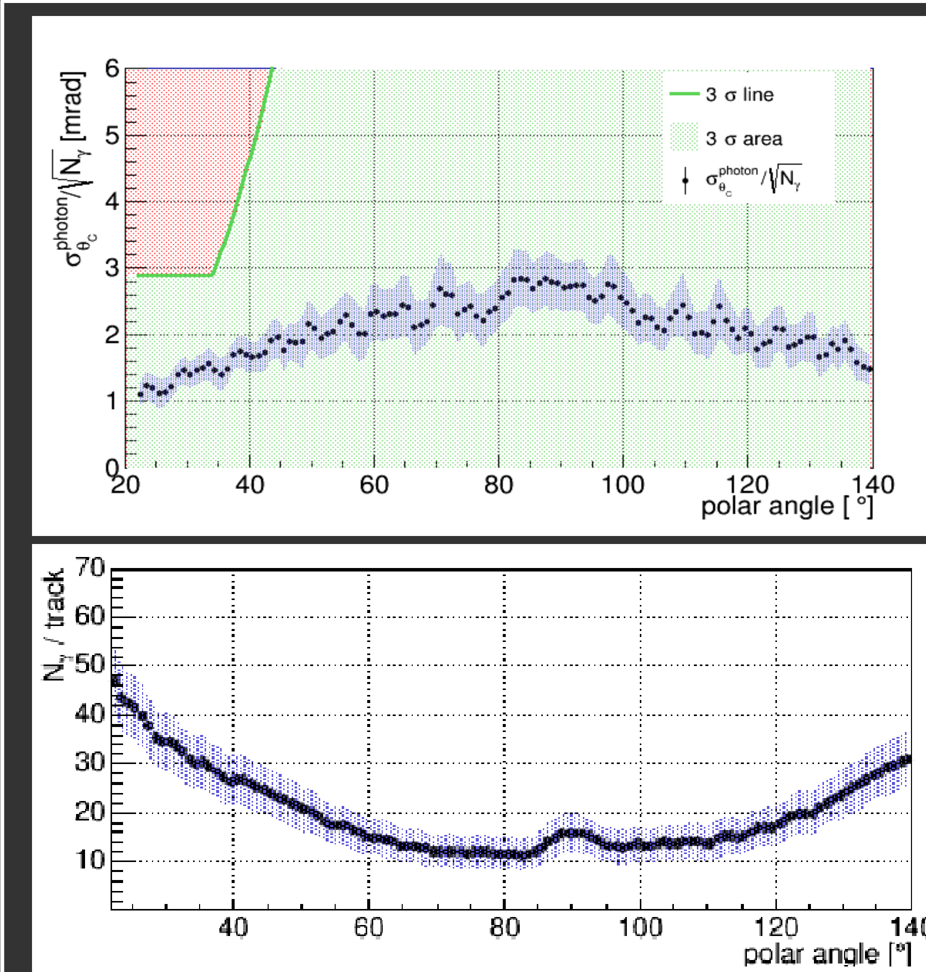


Figure of merit: resolution and photon yield

Geometric reconstruction algorithm:

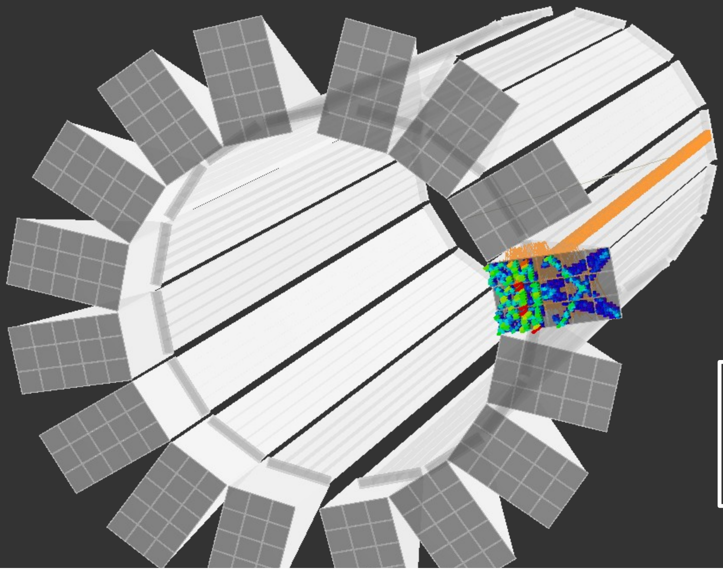
Cherenkov angle for each detected photon →

the width of resulting distribution – single photon Cherenkov angle resolution ($\sigma_{\theta_C}^{photon}$)

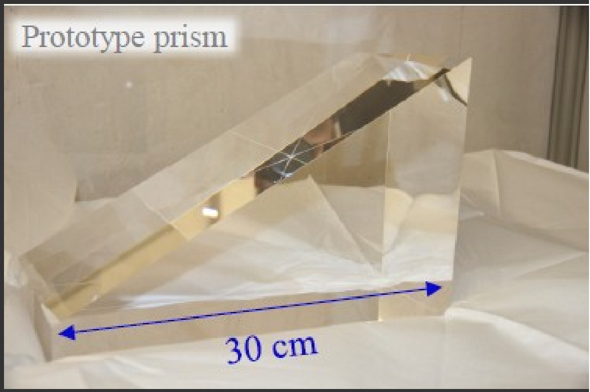
Baseline design meets the PANDA PID requirement

Detector cost optimization → simulation studies

Alternative EV: compact prism

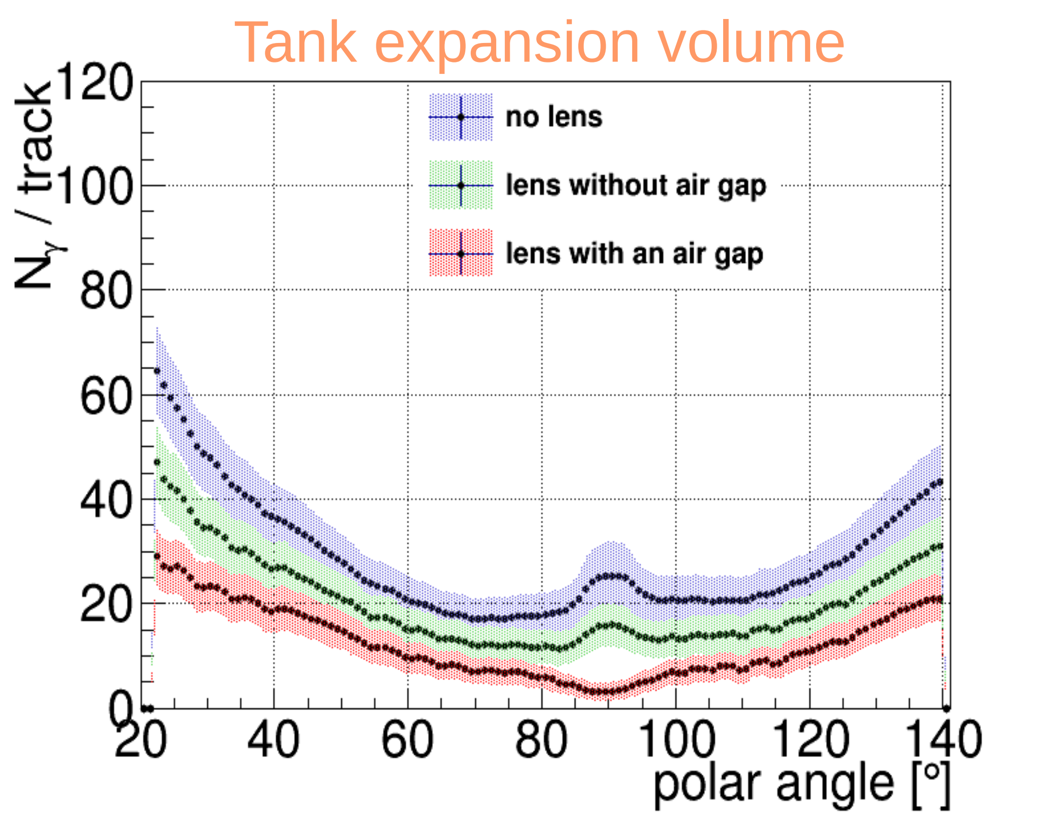


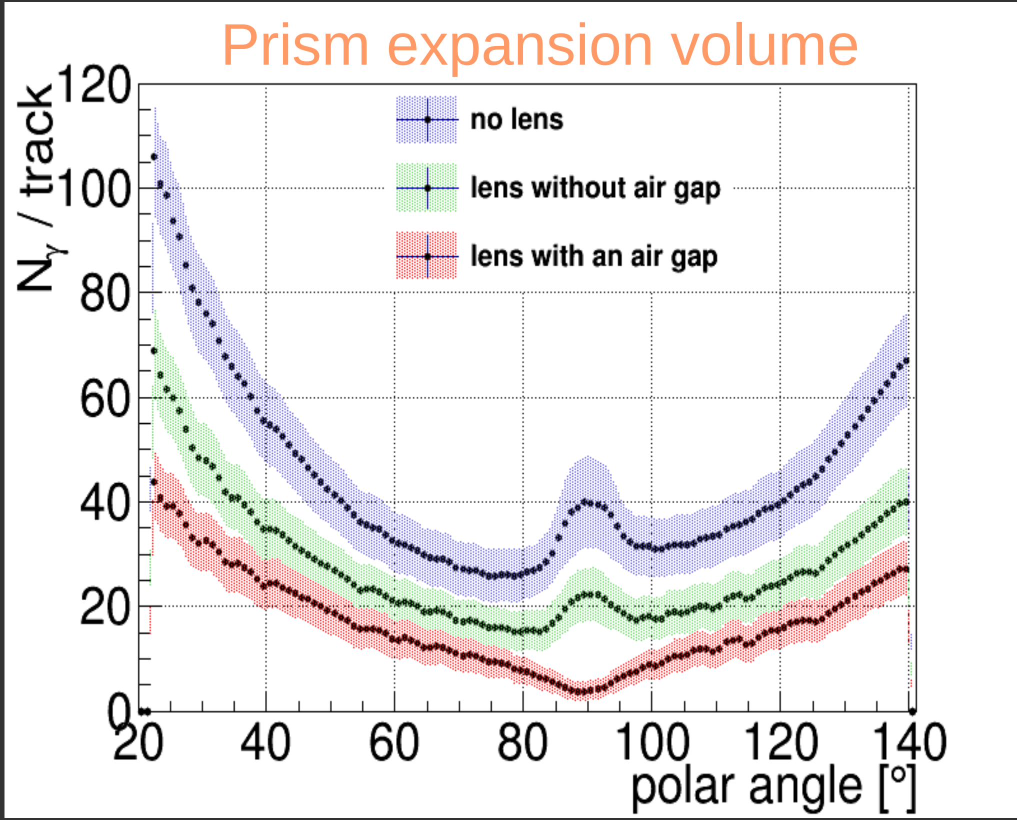
- higher photon yield
- more reflections – complicated hit pattern
- simpler assembly and maintenance



- fewer MCPs required
- more expensive than the oil tank

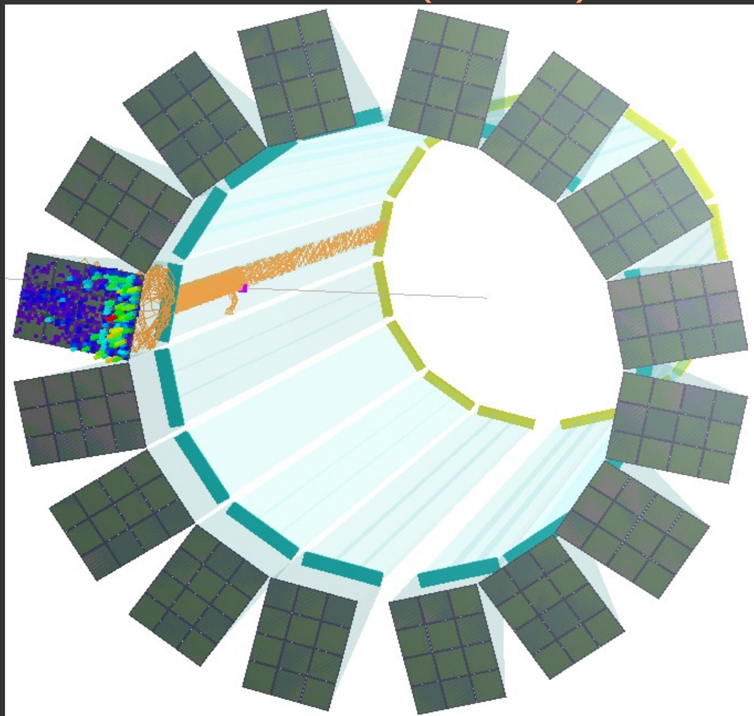
→ lower total cost



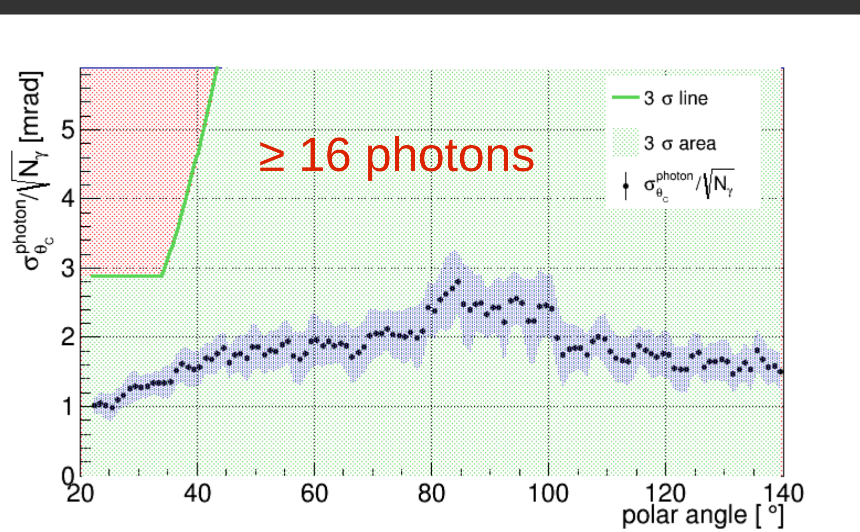


Alternative radiator shapes

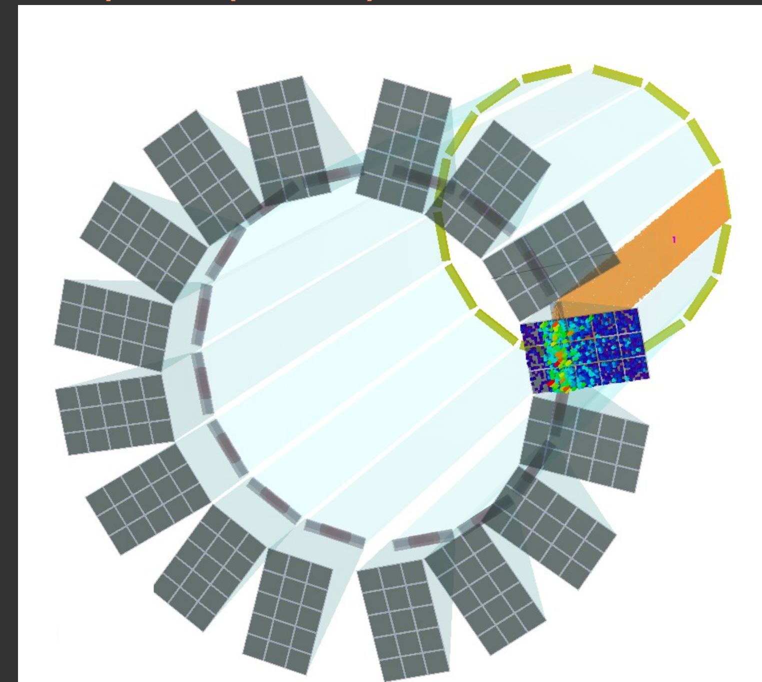
3 wider bars (5.3 cm)



Geometric reconstruction

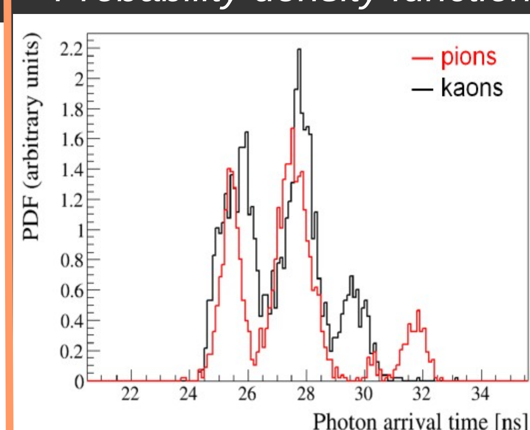


Wide plate (16 cm)

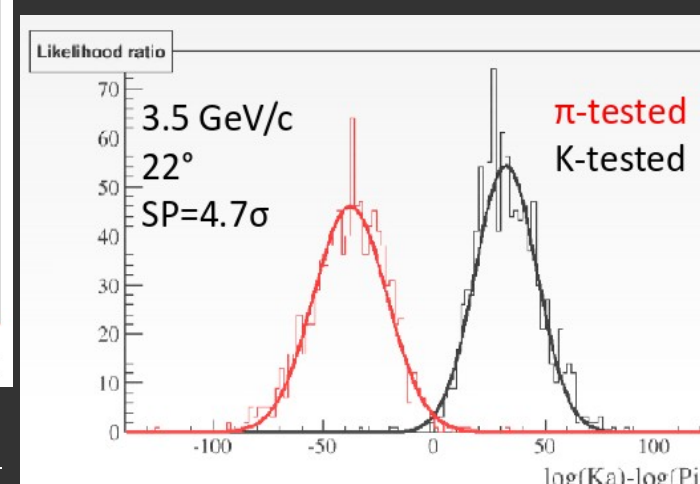


Time likelihood reconstruction

Probability density function

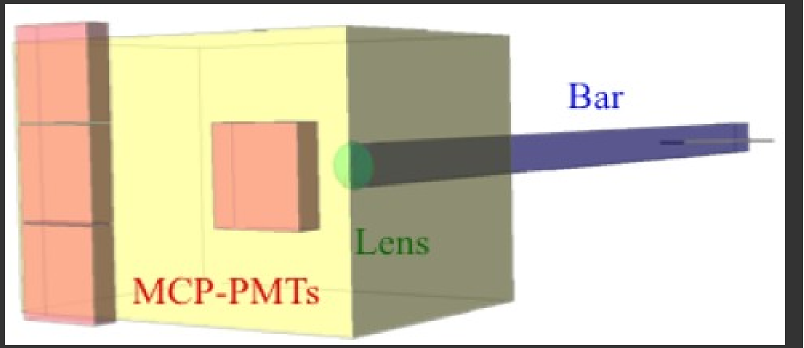


$$SP = \frac{|\mu_1 - \mu_2|}{(\sigma_1 + \sigma_2)/2}$$

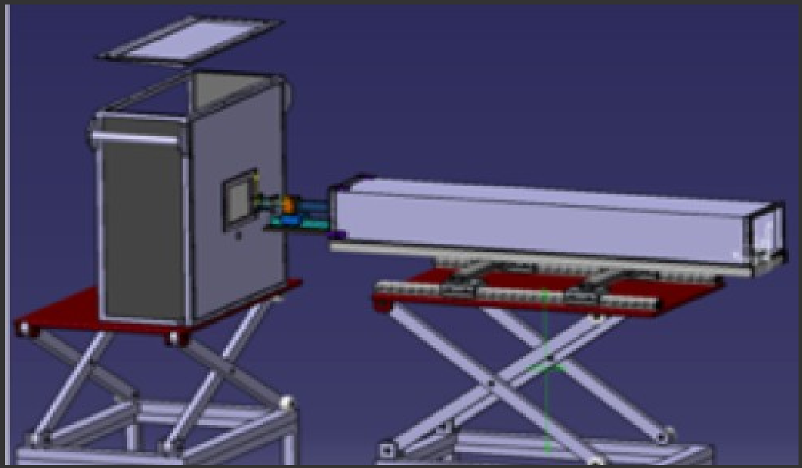


Test beams 2008-2012

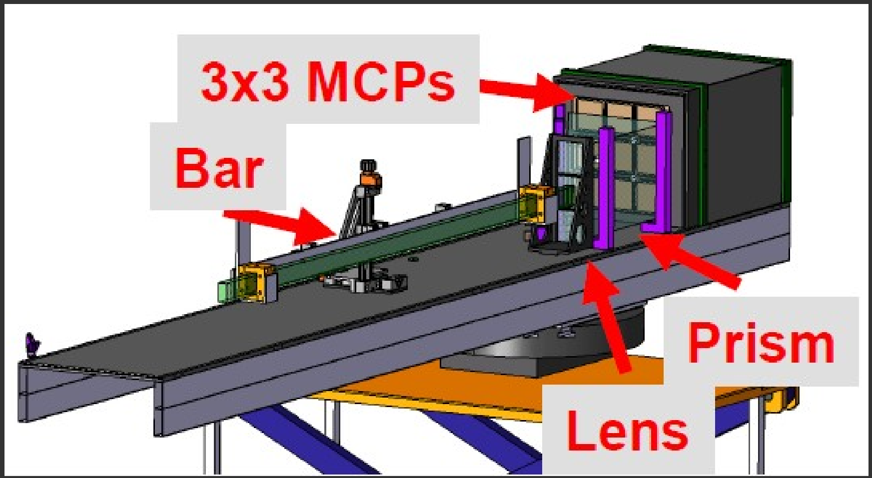
2008, 2009 – GSI
- Small oil-filled EV, 4 MCPs
- First clear Cherenkov ring observed



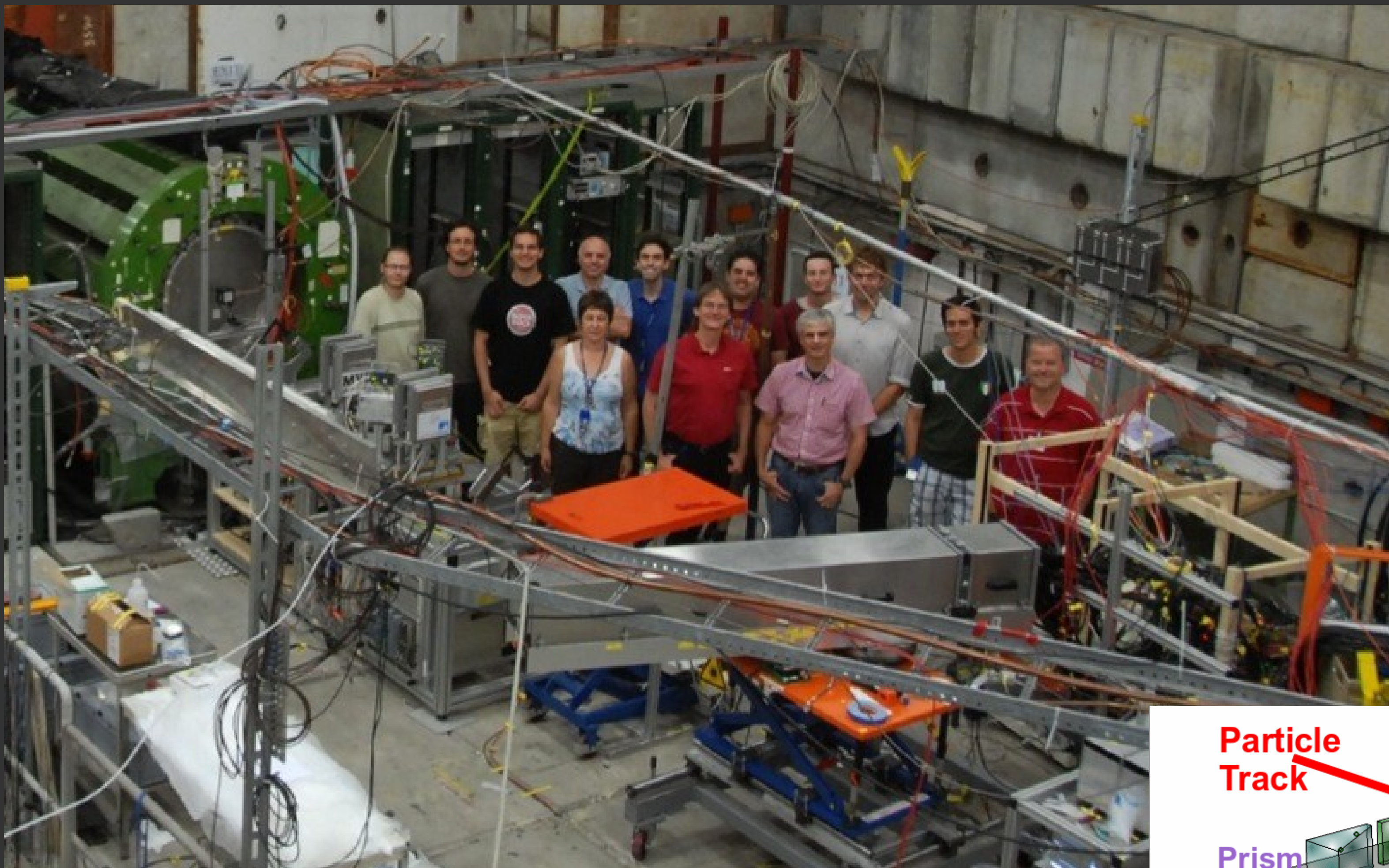
2011 – GSI, CERN
- Large oil-filled EV, lenses, different photon sensors, radiator bars
- First determination of angle resolution and photon yield



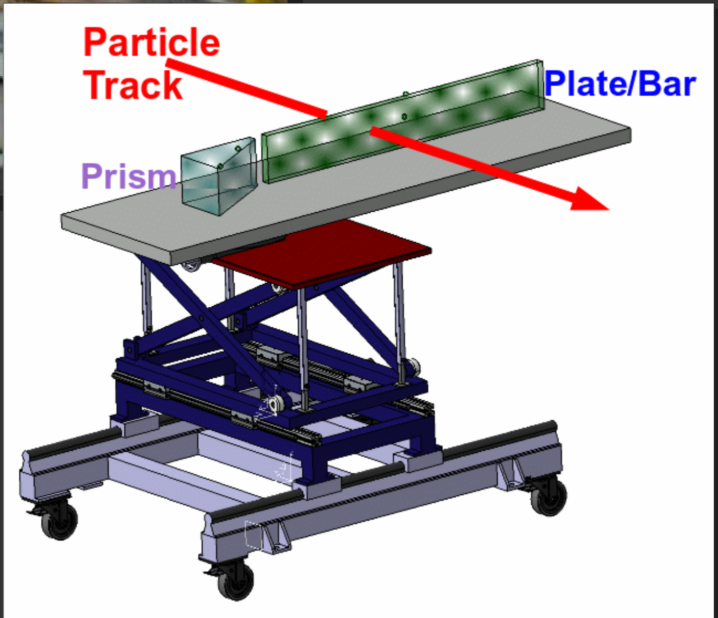
2012 – CERN
- Prism EV, radiator bars and plate, different lens systems, 9 MCP-PMTs
- Determination of Cherenkov angle for setups with different prototype bars and wide range of polar angles. Estimation of photon yield. First test of radiator plate



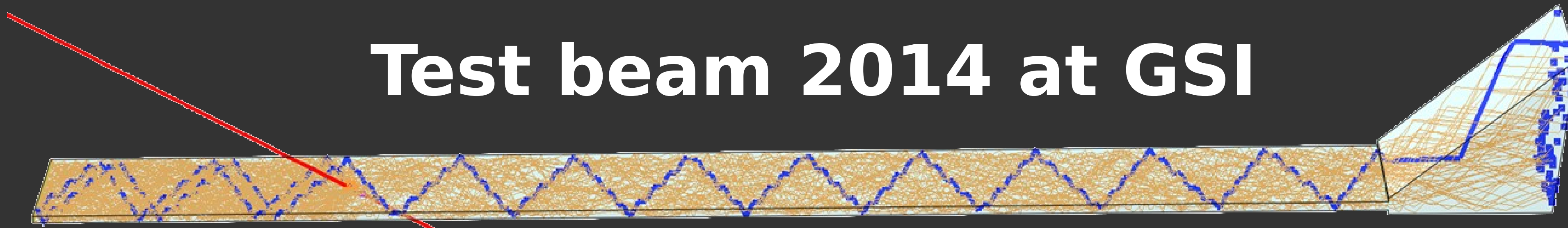
Test beam 2012



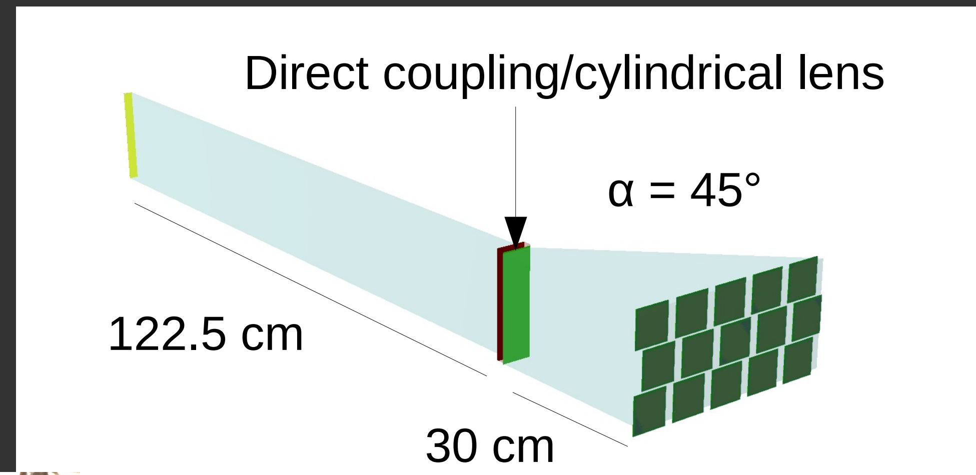
PANDA MVD & DIRC Groups at CERN, Aug/Sep 2012

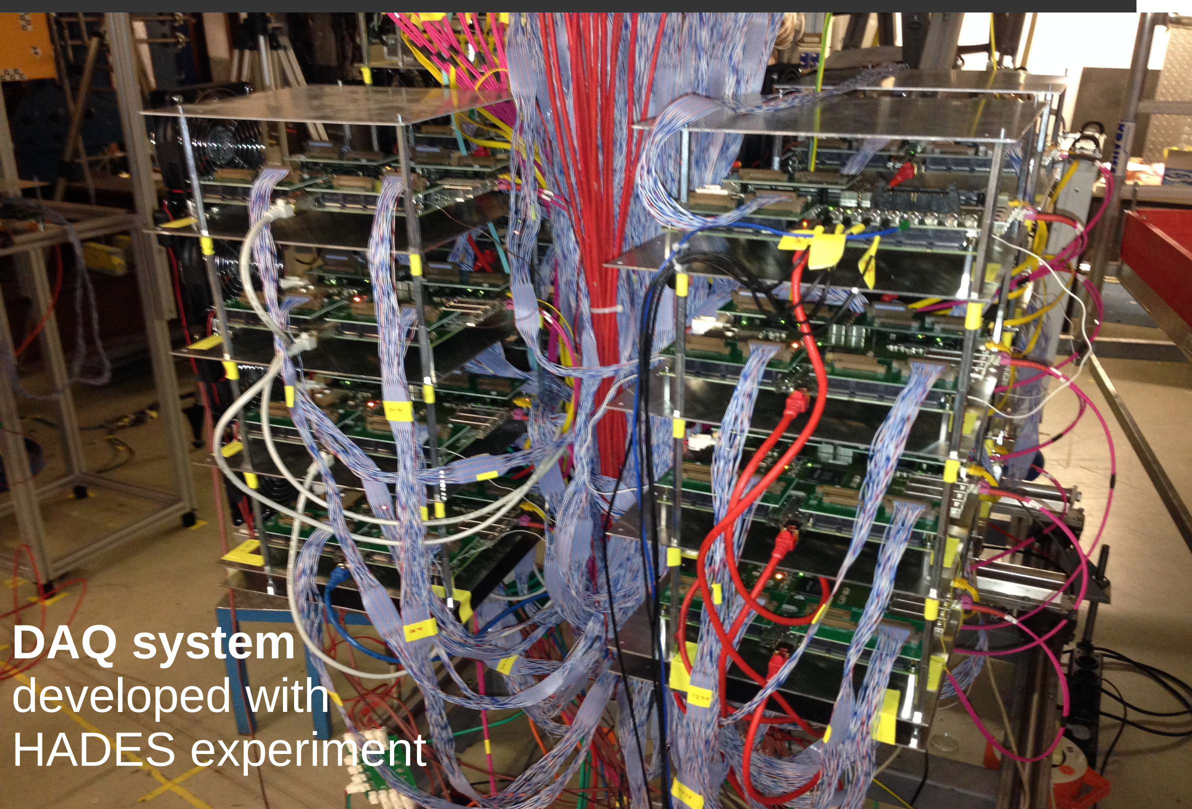


Test beam 2014 at GSI



- July – September 2014
- Prism EV,
  radiator plate + focusing,
  radiator bar + new compound lens
- Timing resolution,
  hit patterns with plate,
  test of the new lens with the radiator bar

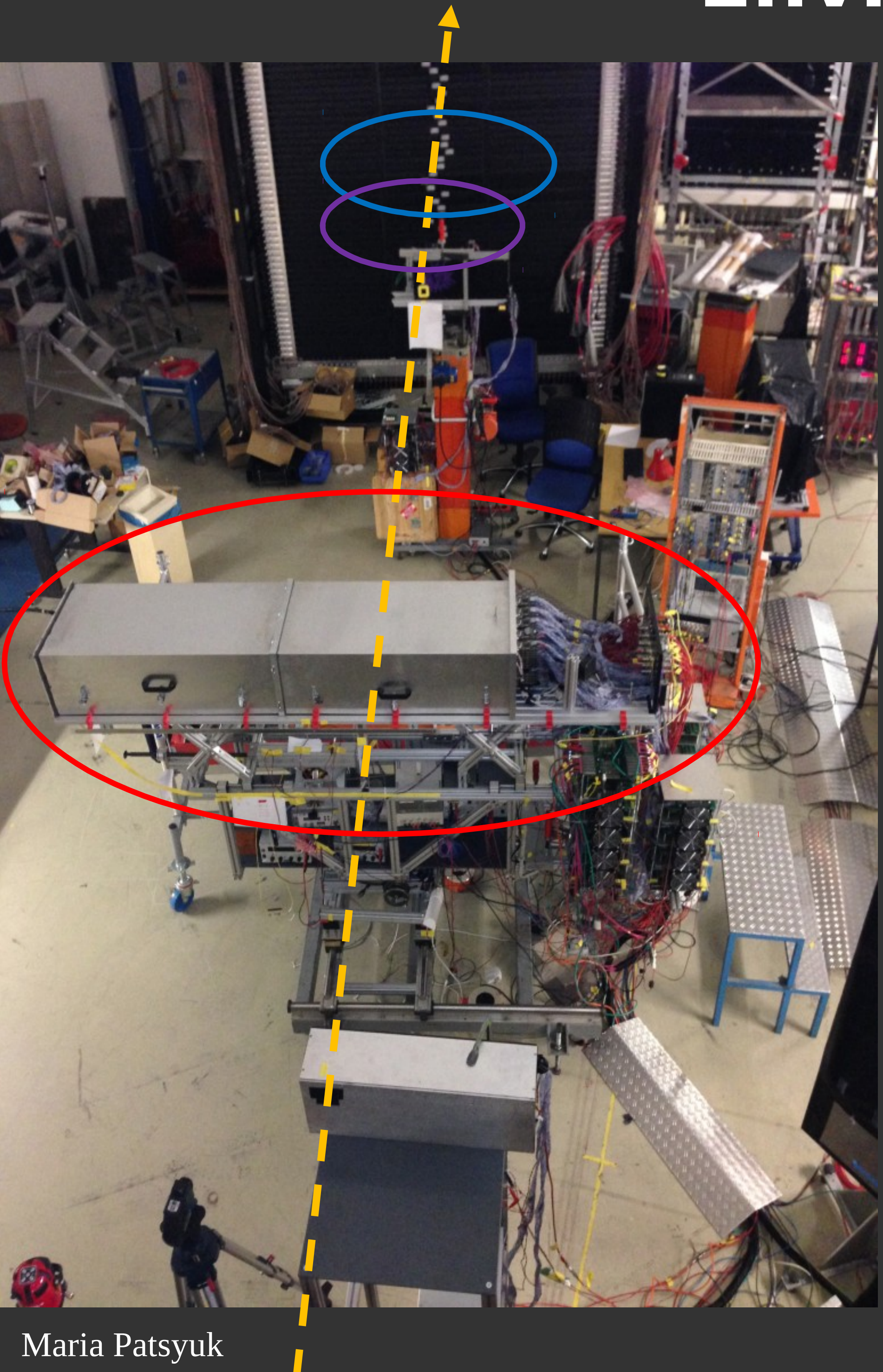




DAQ system
developed with
HADES experiment

Array of 15 Planacon MCP-PMTs
coupled to prism with optical grease

Environment



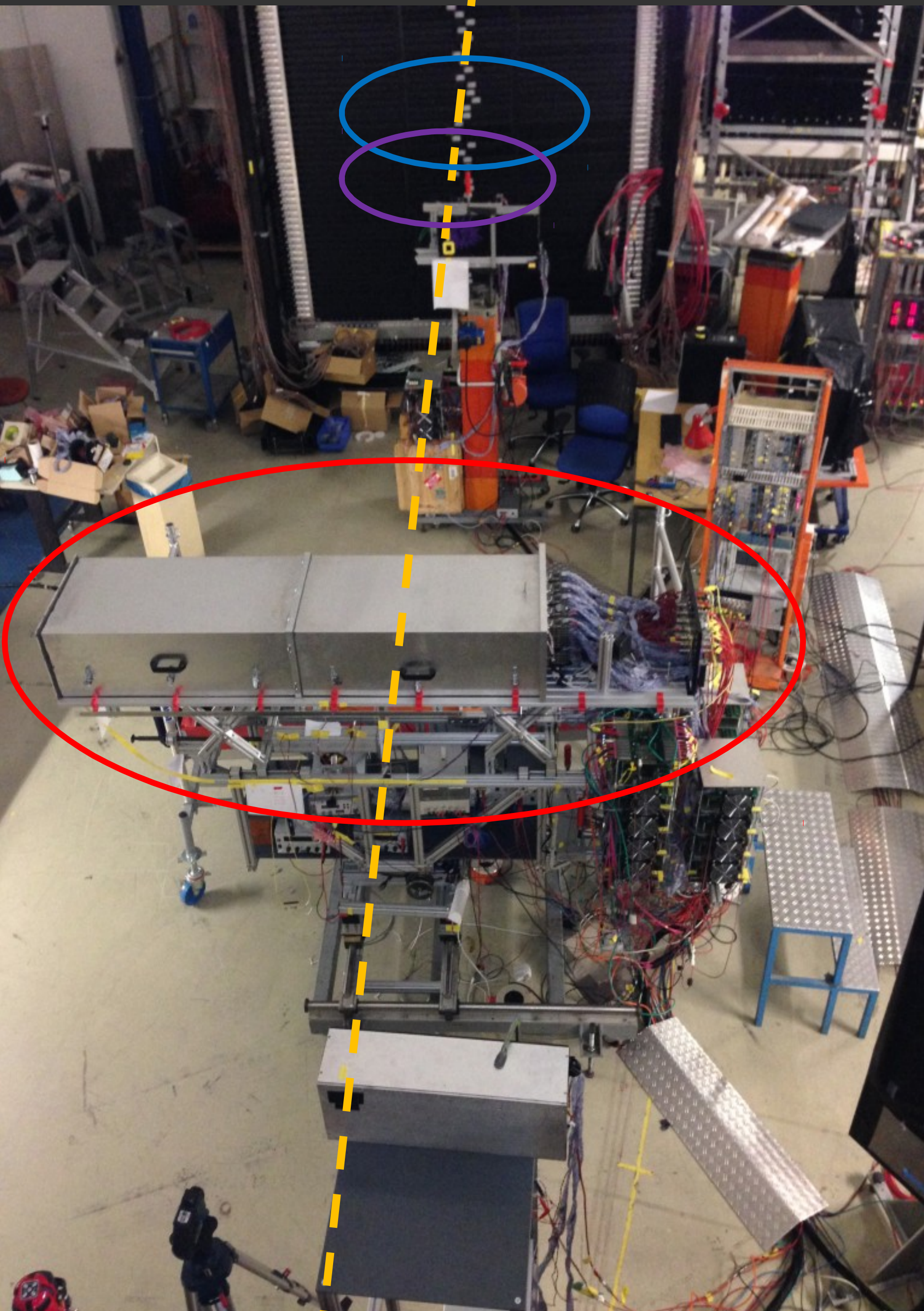
Downstream Trigger Counter

Downstream MCP-TOF Counters

~1000 particles/spill
1.7 GeV/c pions

Barrel DIRC Prototype

Environment



Downstream Trigger Counter

Downstream MCP-TOF Counters

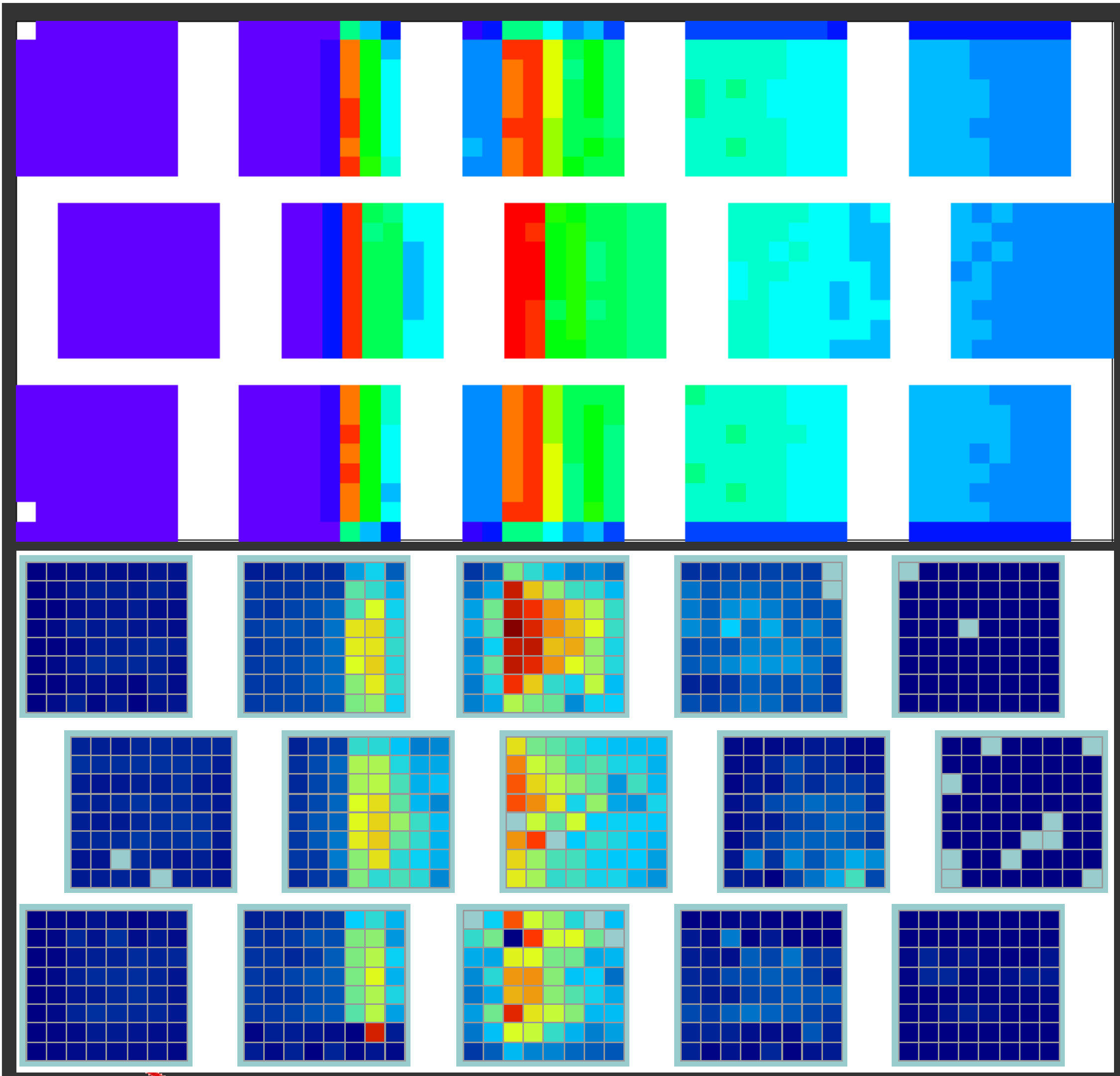
~1000 particles/spill
1.7 GeV/c pions

Barrel DIRC Prototype

Test beam just ended in September

Today first preliminary results will be shown

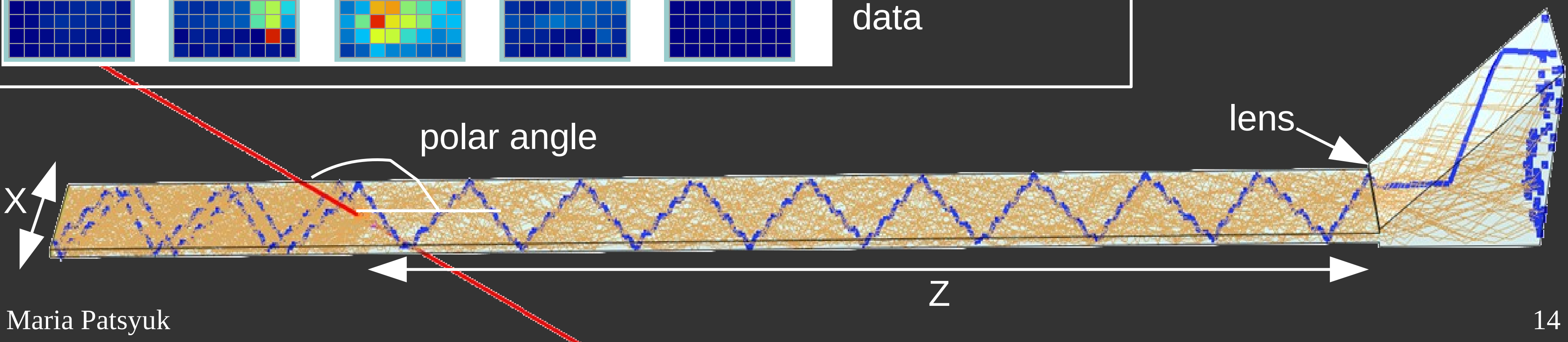
Measurements: radiator plate



With lens, polar angle of pions = 69 °

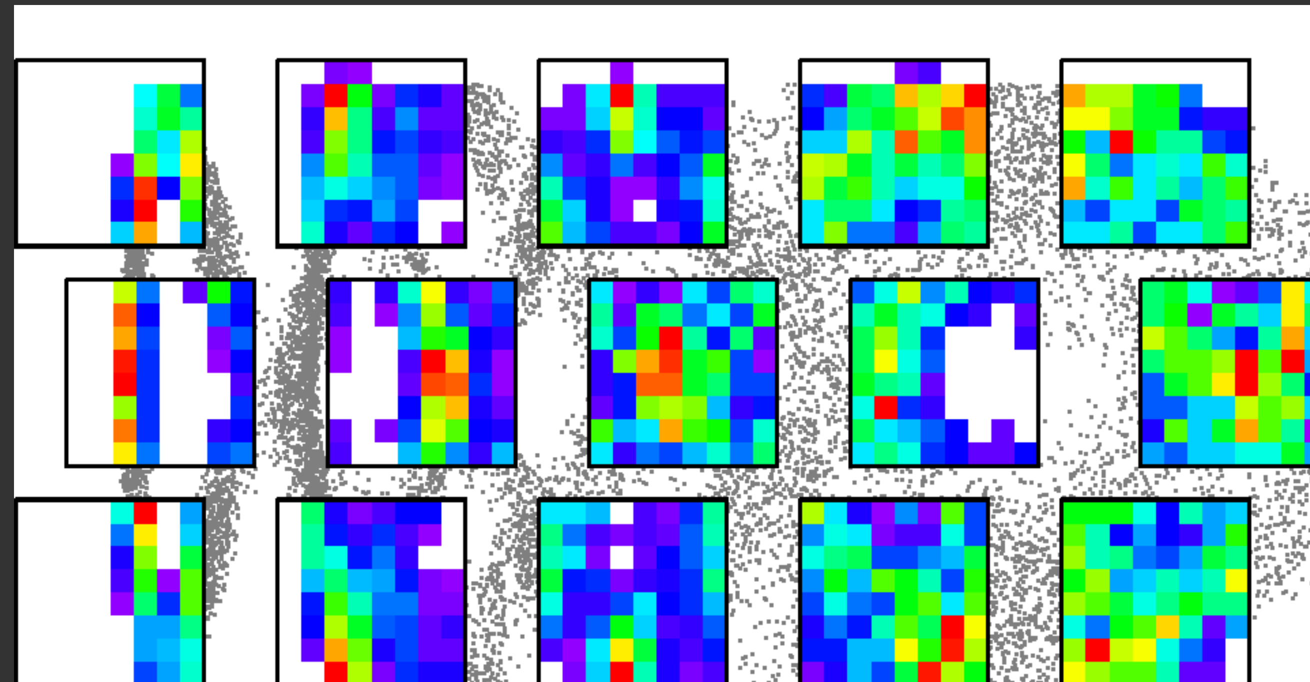
Data taken:

with(out) lens
polar angle scan
Z scan
X scan

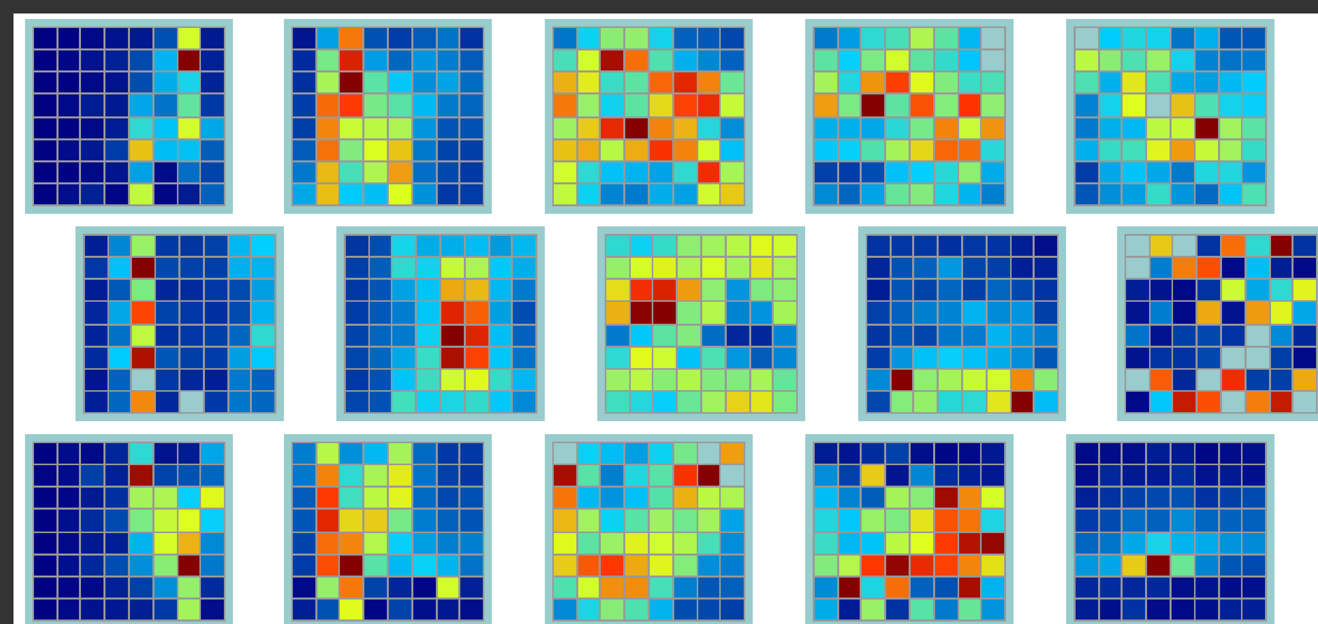


Measurements: radiator bar

simulation



Test of a new 3-component high refractive lens, polar angle of pions = 125 °



data

Summary & Outlook

- The Barrel DIRC is a key component of the PANDA particle identification system

- The baseline design with narrow bars and a 3-component lens meets the PANDA PID goal

- Simulation studies revealed several ways to reduce the total detector cost with no loss in performance

- The main design alternatives:
  - Prism-shaped EV + wide radiator plates
  - Prism-shaped EV + three wider bars

- The simulation results are being validated with prototypes in particle beams

- One more test beam campaign in 2015 will define the design and expected performance for the TDR