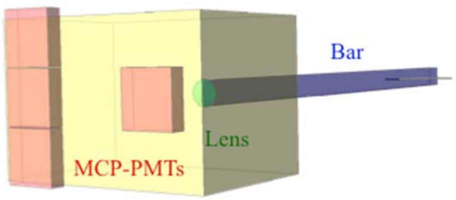
PANDA BARREL DIRC

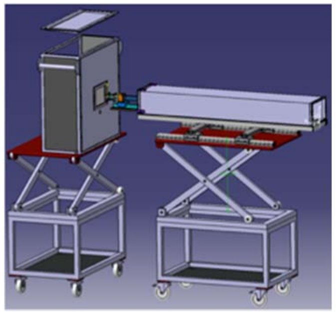
PROTOTYPE RESULTS

Jochen Schwiening

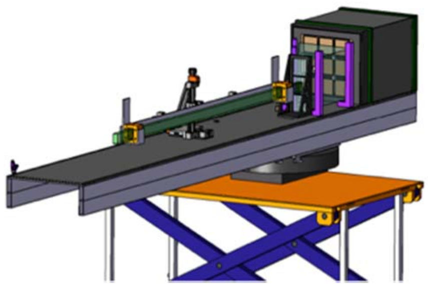
for the PANDA Cherenkov Group



2008, 2009: GSI

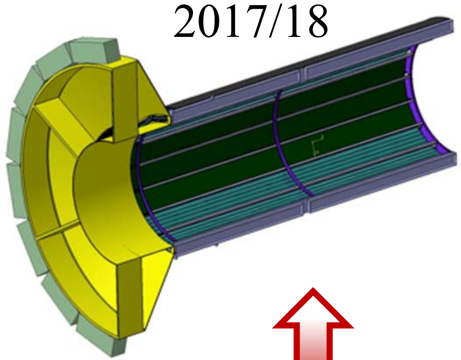


2011: GSI, CERN

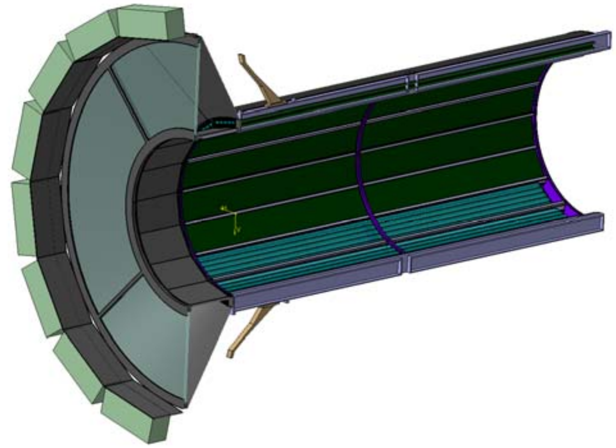


2012: CERN

2017/18



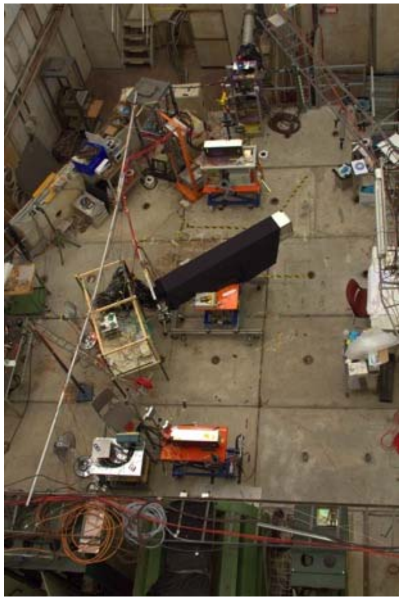
DIRC INTRODUCTION



PANDA BARREL DIRC OVERVIEW

PROTOTYPE COMPONENT LAB TESTS

RADIATORS, PHOTON DETECTORS



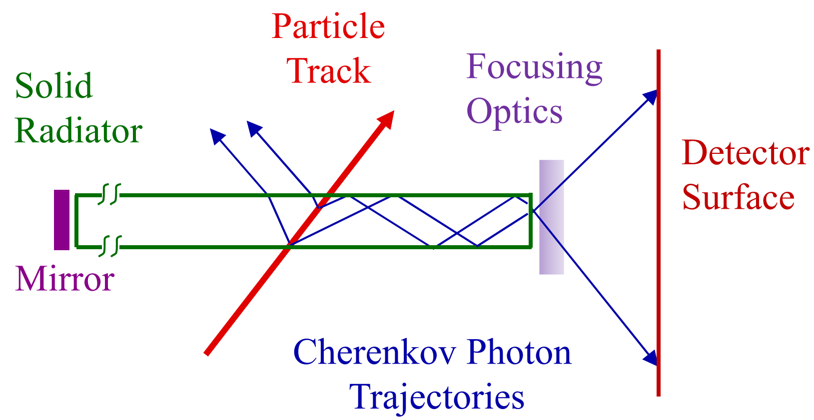
PROTOTYPE SYSTEMS IN PARTICLE BEAMS

2008/2009: GSI; 2011: GSI/CERN; 2012: CERN

Detection of Internally Reflected Cherenkov Light

- 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 $\beta\approx1$ tracks.



- Radiator and light guide: bar or plate made from Synthetic Fused Silica ("Quartz")

- Magnitude of Cherenkov angle conserved during internal reflections (provided optical surfaces are square, parallel, highly polished)

- Photons exit radiator via optional focusing optics into expansion region, detected on photon detector array → x, y, and time of Cherenkov photons.

- PID likelihood for observed pattern to come from $e/\mu/\pi/K/p$ plus background.

PANDA: rich program of QCD studies using anti-proton beam with unique intensity and precision.

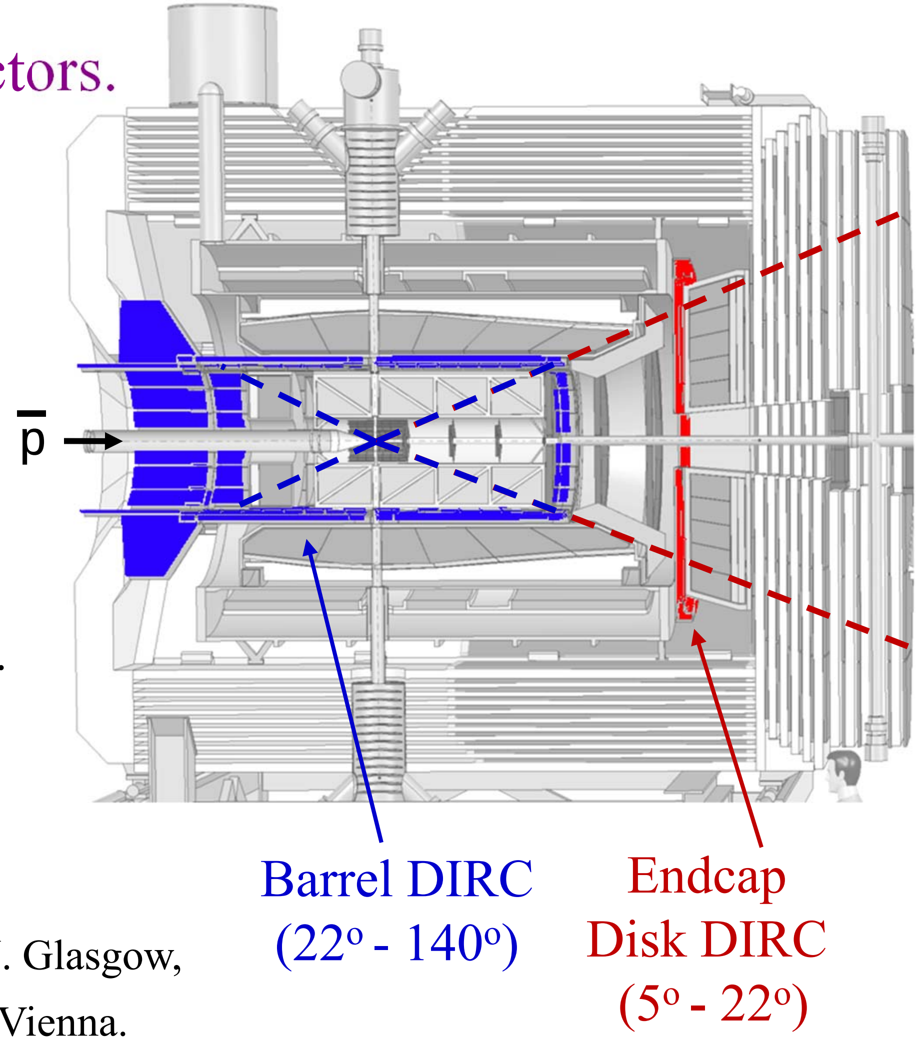
Hadronic Particle ID: two DIRC detectors.

- Barrel DIRC – similar to BABAR DIRC with several key improvements.

  Goal: 3σ π/K separation for p=0.5…3.5 GeV/c.

- Novel Endcap Disk DIRC

  Goal: 3σ π/K separation for p=0.5…4.0 GeV/c.

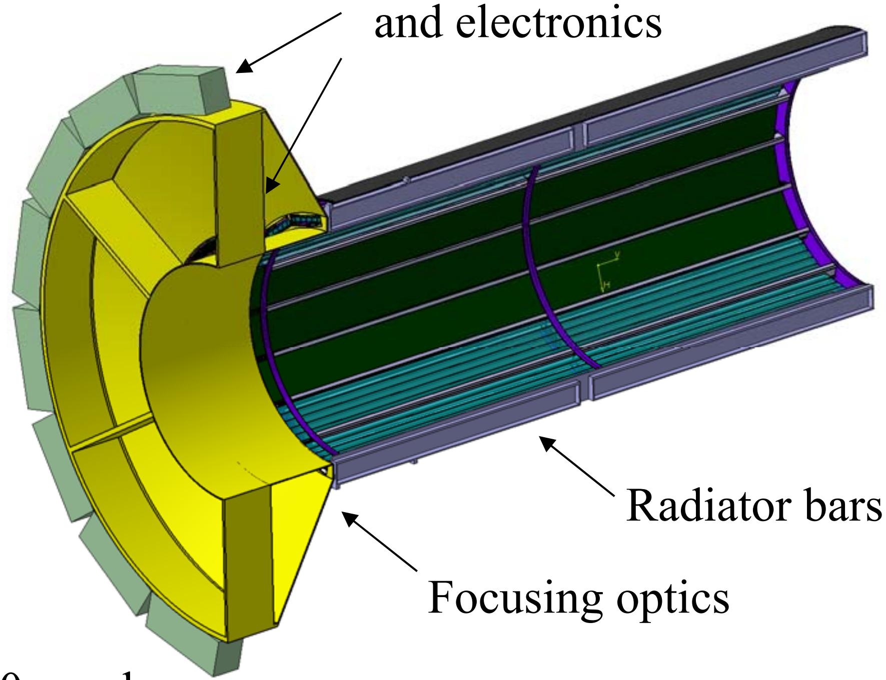


PANDA Cherenkov Group:

JINR Dubna, FAU Erlangen-Nürnberg, JLU Gießen, U. Glasgow, GSI Darmstadt, HIM Mainz, JGU Mainz, SMI OeAW Vienna.

PANDA Barrel DIRC design: based on BABAR DIRC with key improvements

- Barrel radius ~50 cm; expansion volume depth: 30 cm.
- 80 radiator bars, synthetic fused silica
  17mm (T) × 33mm (W) × 2500mm (L).
- Focusing optics: doublet lens system.
- Compact photon detector:
  30 cm oil-filled expansion volume
  10-15,000 channels of MCP-PMTs.
- Fast photon detection:
  fast TDC plus ADC (or ToT) electronics.
- Expected performance:
  Single photon Cherenkov angle resolution: 8-10 mrad.
  Number of photoelectrons for β≈1 track: at least 20.

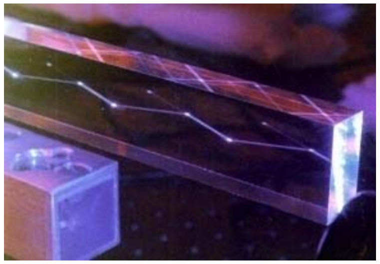


C. Schwartz et al.
2012 JINST 7 C02008

Still investigating several design options:

solid fused silica expansion prisms, thin bars, mirror focusing, radiator plates, photon detection outside magnetic field.

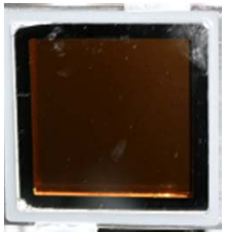
Radiator Challenges



- Production of large fused silica bars or plates challenging.
- Require mechanical tolerances on flatness, squareness, and parallelism with optical finish and long sharp edges.
  → difficult, potentially expensive, few qualified vendors worldwide.
- BABAR-DIRC used bars polished to 5 Å rms, non-squareness < 0.25 mrad; successfully done for BABAR, need to qualify/retrain vendors 10+ years later.

Working with potential vendors in Europe and USA, obtained/ordered prototype bars and plates from several companies, verifying surfaces and angles.

Photon Detector Challenges



- Compact multi-pixel sensor with single photon sensitivity in 1T magnetic field.
- Few mm position resolution with ~100ps timing.
- High rates up to 0.2 MHz/cm^2, long lifetime: 0.5 C/cm^2 per year at 10^6 gain.

No currently available sensor matches all criteria, working with industry to improve lifetime.

Goal: qualify vendors, quality assurance

Obtained prototype bars and plates from several vendors including actual BaBar DIRC bars.

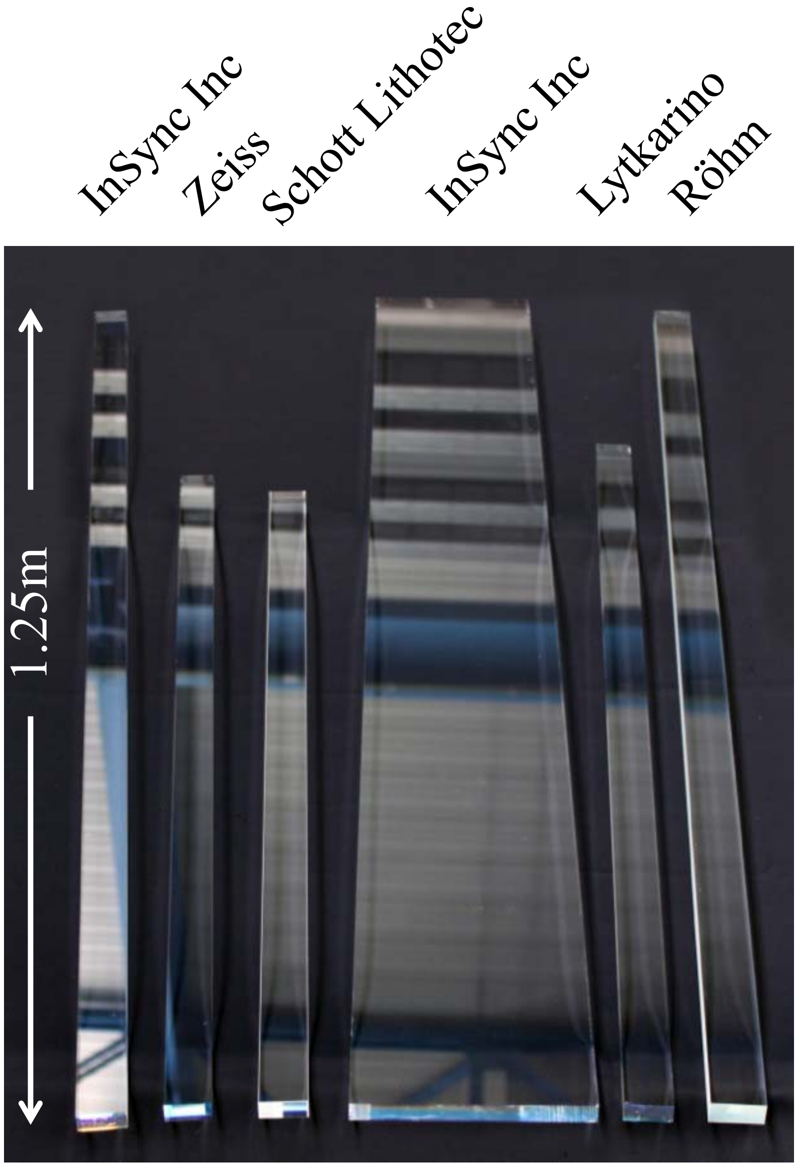
Current prototype production with Zygo Corp and Aperture Optical Sciences/Okamoto Optics.

Different fabrication processes and bulk materials.

One setup to measure internal angles user lasers, recently added autocollimator.

Another setup to measure bulk transmission and coefficient of total internal reflection using 4 lasers.

Sensitive to surface roughness and subsurface damage, indirect measurement of rms roughness with 1-2Å precision.



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G. Kalicy et al
Poster N14-156
this meeting

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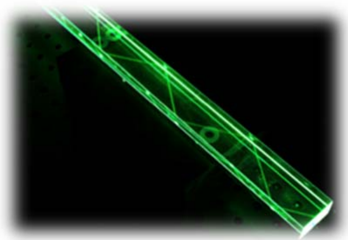

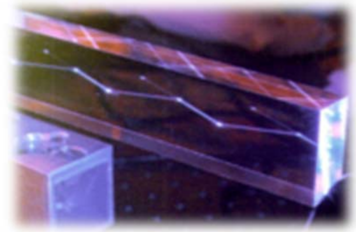

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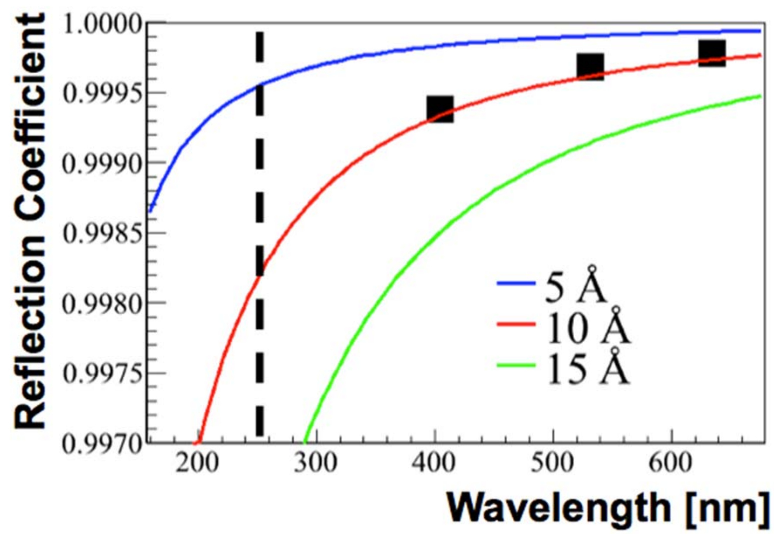
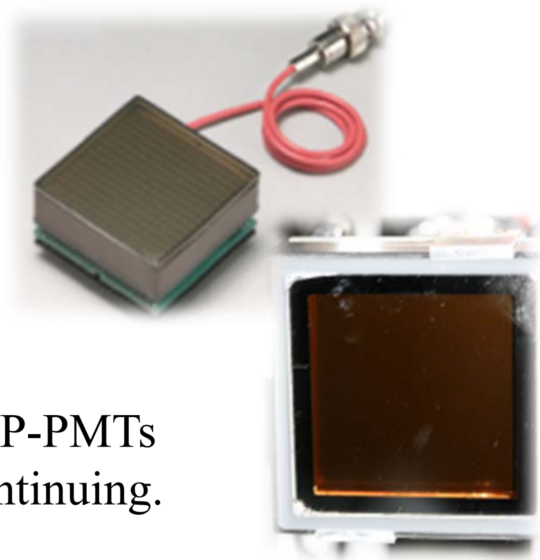


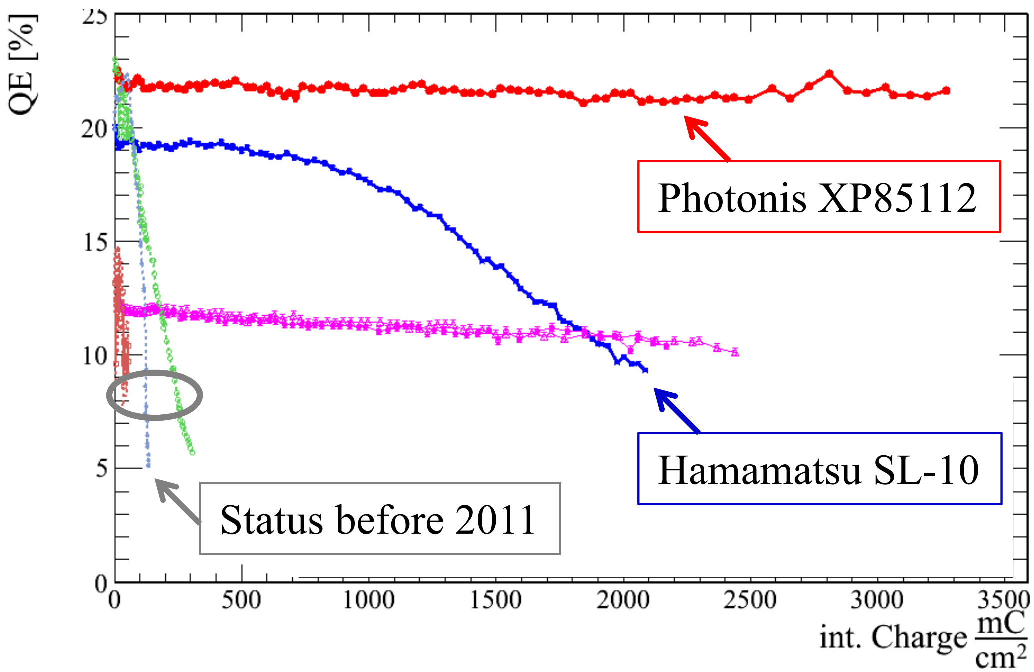
Goal: improve performance, quality assurance



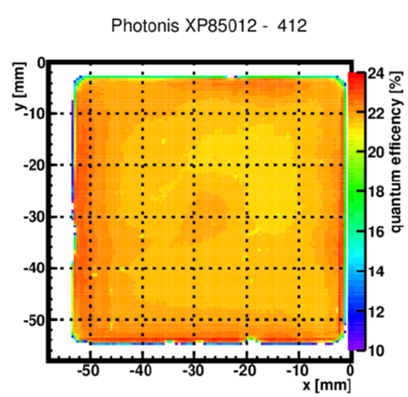
Obtained prototype multi-pixel sensors from Hamamatsu and Photonis.

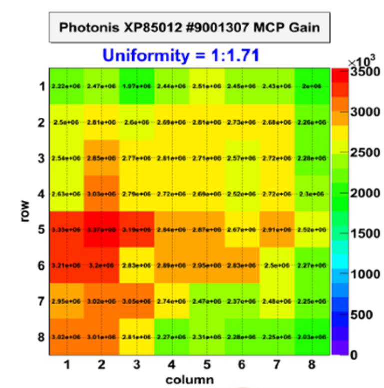
Setup to scan sensors for quantum efficiency and gain, measure rate tolerance and lifetime.

Recent significant improvement in lifetime of Photonis Planacon MCP-PMTs → no loss at 3.3 C/cm^2 yet, close to PANDA requirement, study continuing.



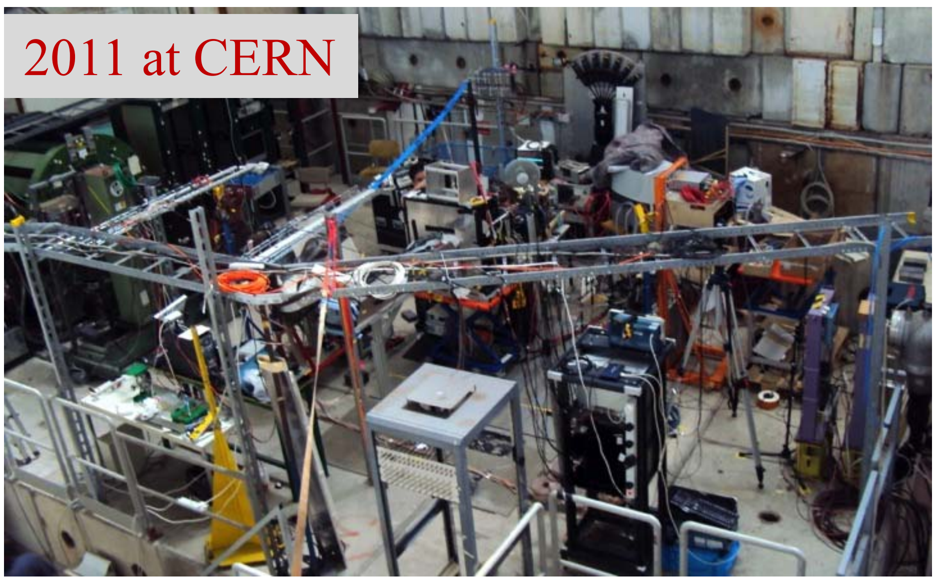
A. Lehmann et al
12th Pisa Meeting on
Advanced Detectors

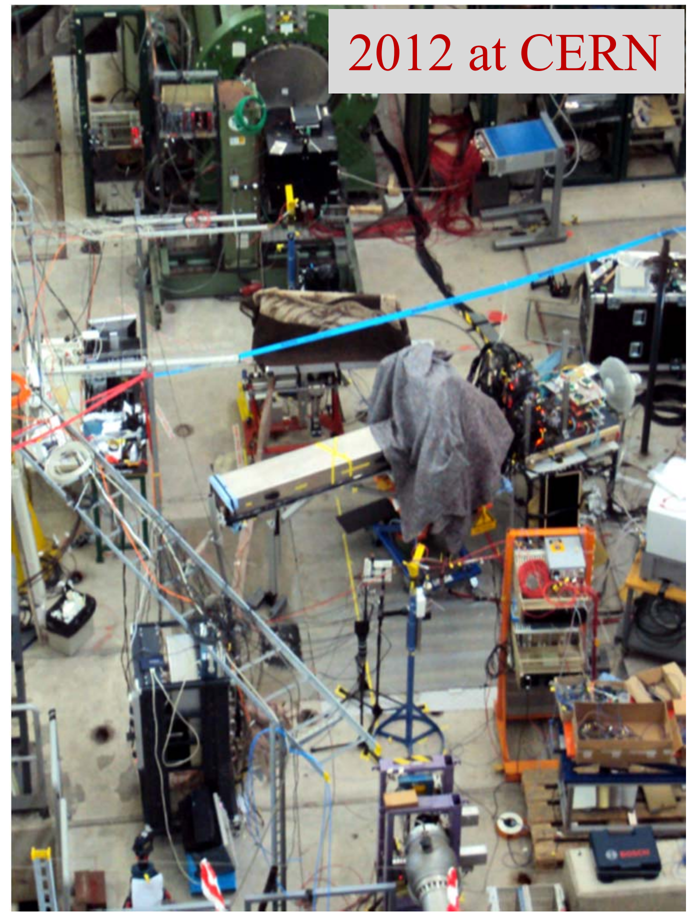




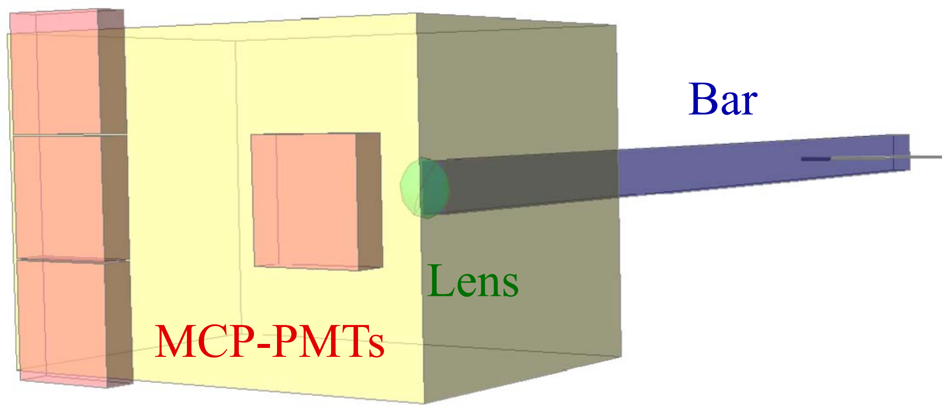
Barrel DIRC Prototype test beam campaigns


2009 at GSI


2011 at CERN


2012 at CERN

PROTOTYPES IN PARTICLE BEAMS

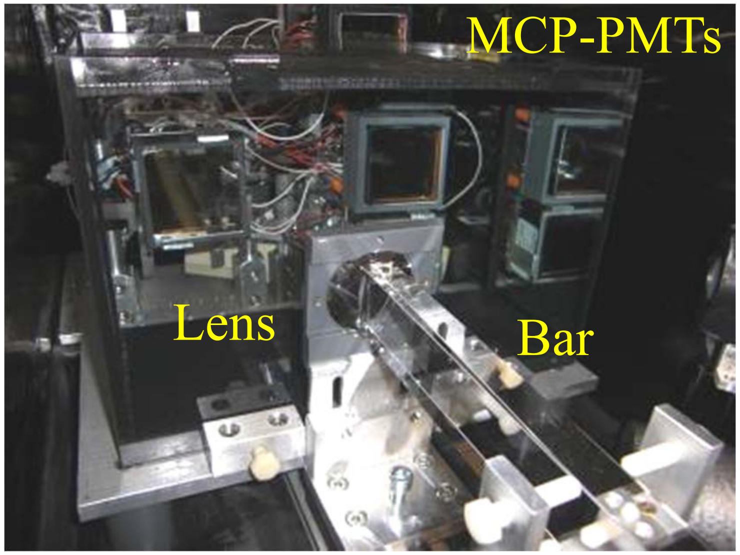


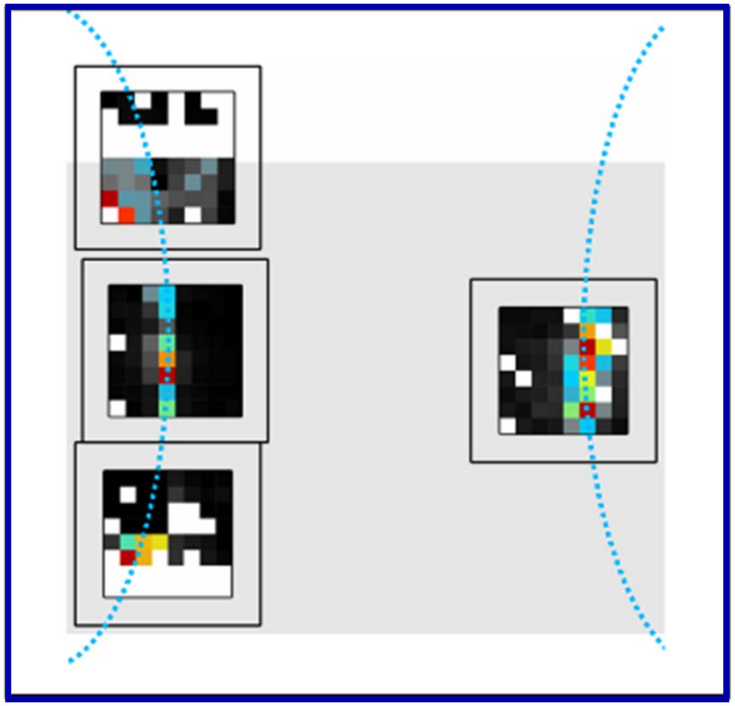
2008/2009

Schott Lithotec bar, spherical lens

Expansion volume: small oil tank

MCP-PMTs with pre-amplifiers





Observed Cherenkov ring segments

in GSI proton beam, location as expected

→ successful proof of principle test

PROTOTYPES IN PARTICLE BEAMS

2011: proton beam at GSI, π/p at CERN PS

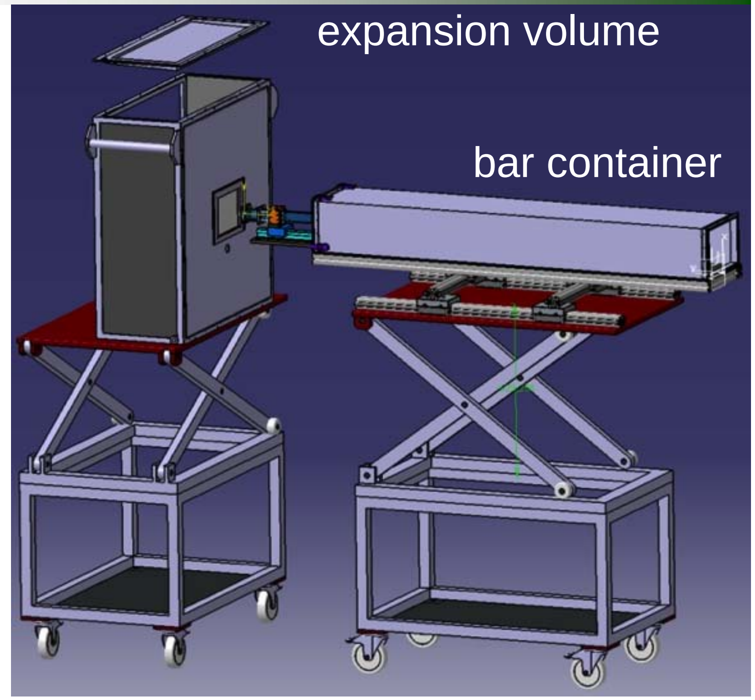
Larger, deeper expansion volume (mineral oil).

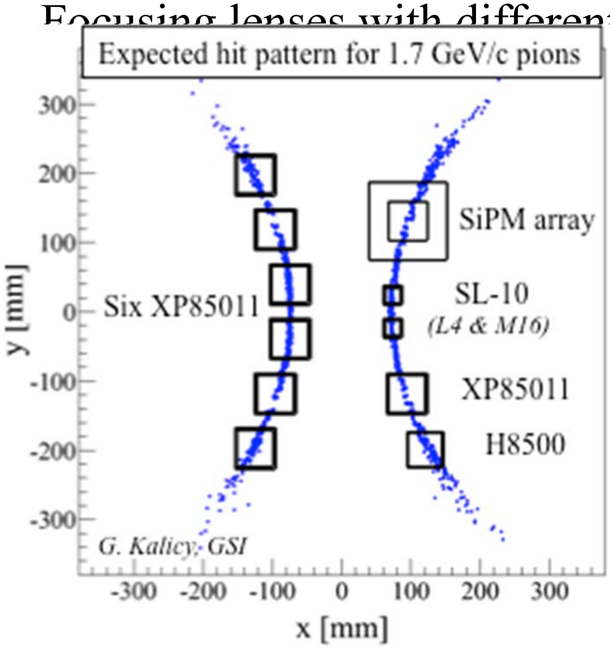
Capability to move and rotate bar wrt beam.

Larger detector plane, space for more sensors.
(MCP-PMTs, SiPM, MaPMT)

640 electronics channels (HADES TRB/NINO)
some optimized for use without amplifiers.

Focusing lenses with different AR coatings.



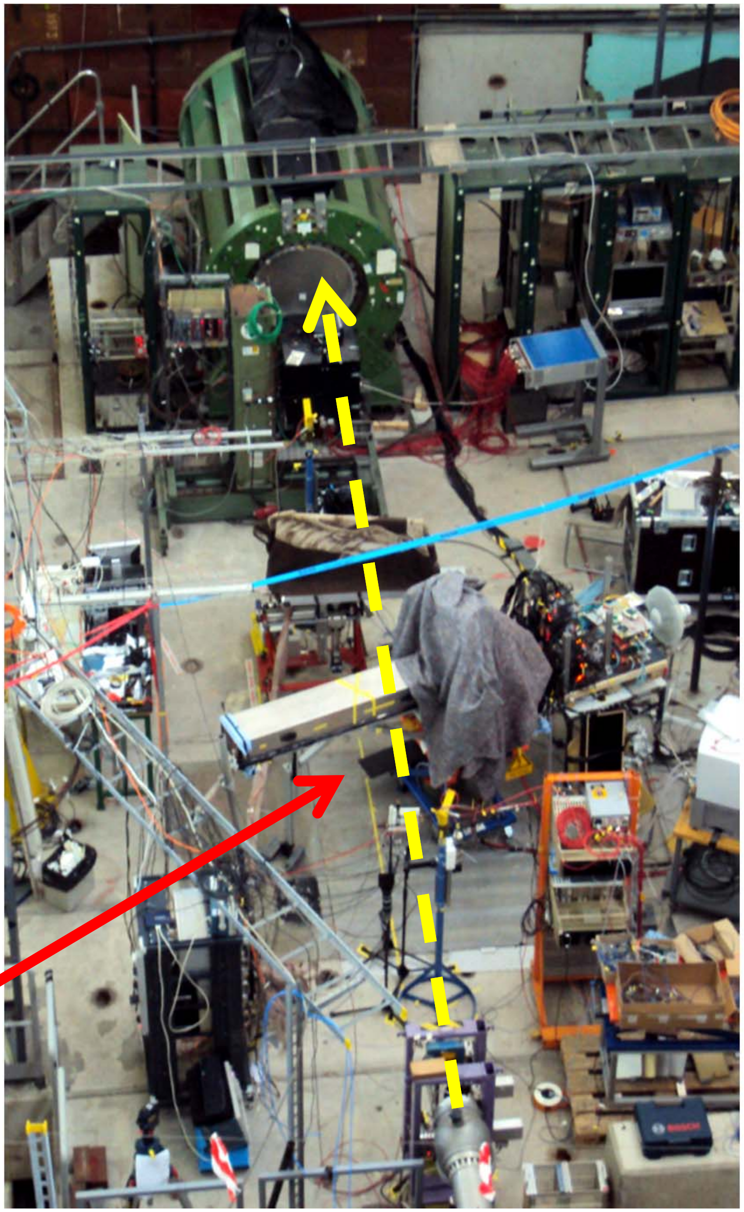


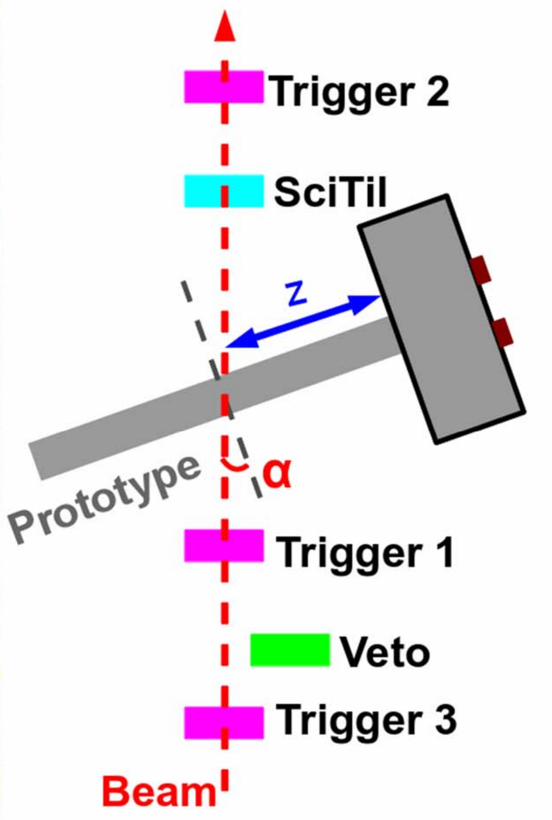
Test beams at GSI
and at CERN
Jun/Jul 2011

2011: CERN PS (T9)

- 1.5-10 GeV/c beam
- Improved event timing from Scintillating Tile det.
- Range of beam-bar angles and beam z positions
- 130M triggers recorded

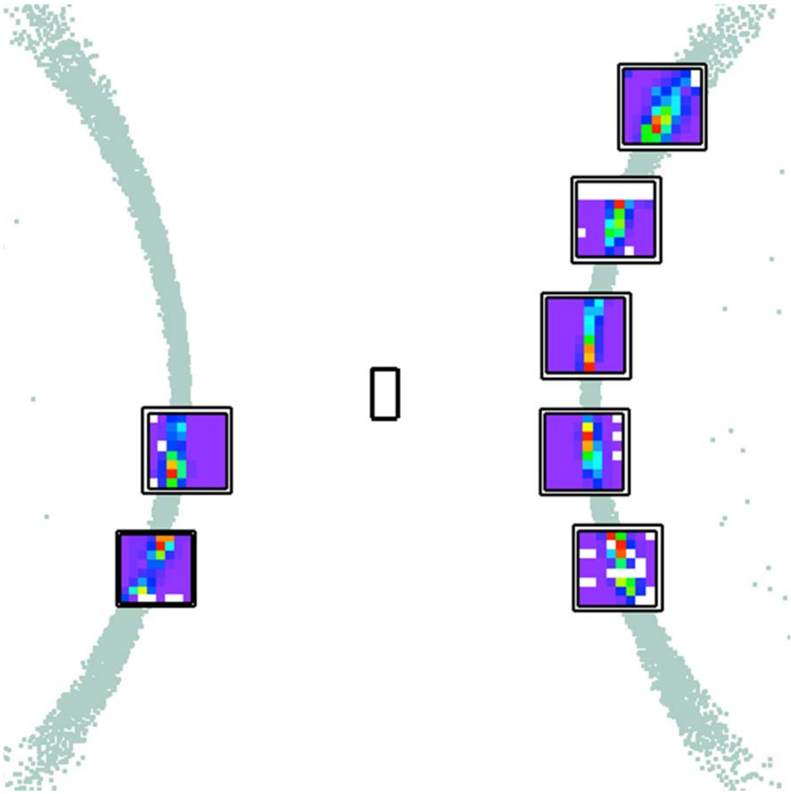
Barrel DIRC Prototype

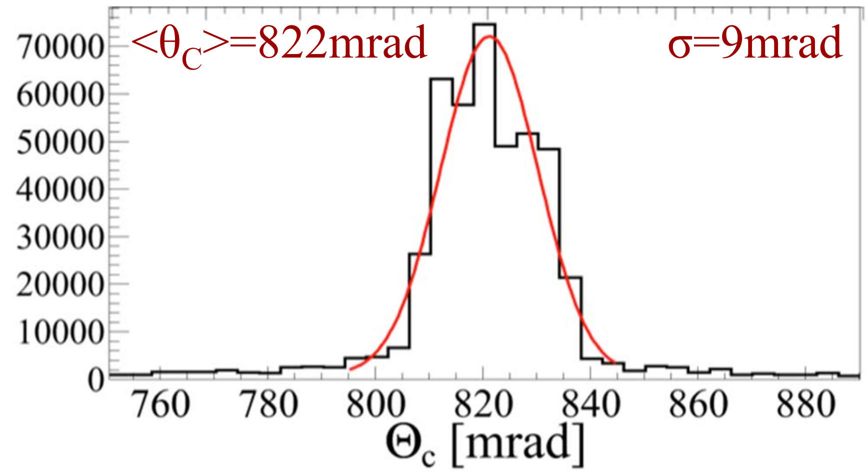




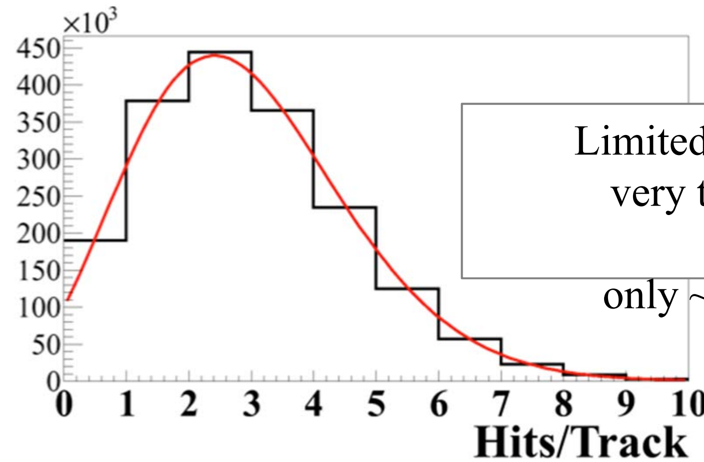
2011: CERN PS (T9)

Observed Cherenkov hit pattern
for CERN test beam configuration
(points are from simulation)





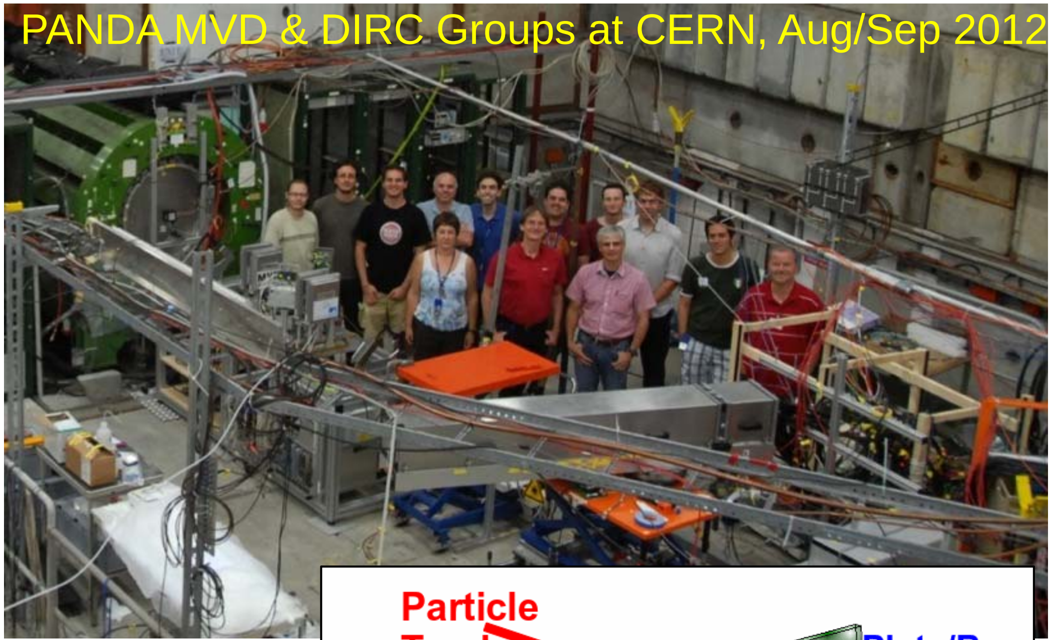
Reconstructed Cherenkov angle per photon

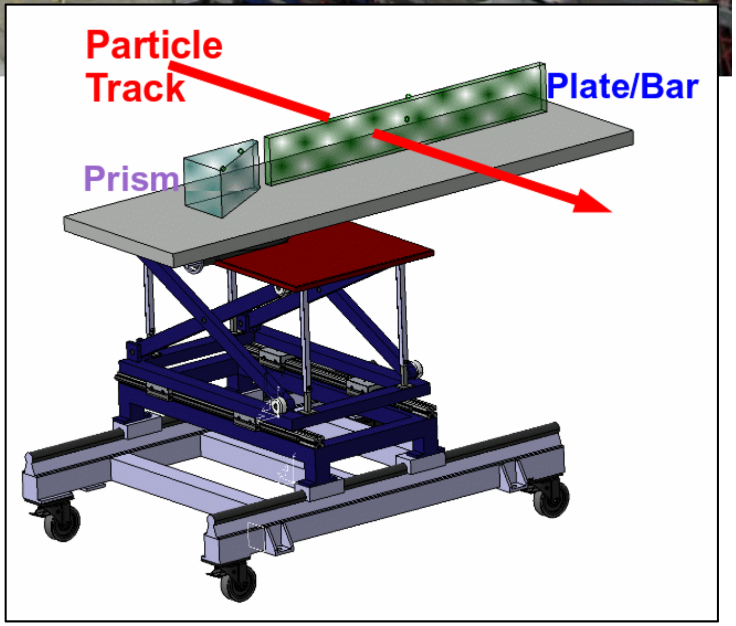


Limited sensor coverage,
very thick layer optical
grease
only ~3 photons/trigger

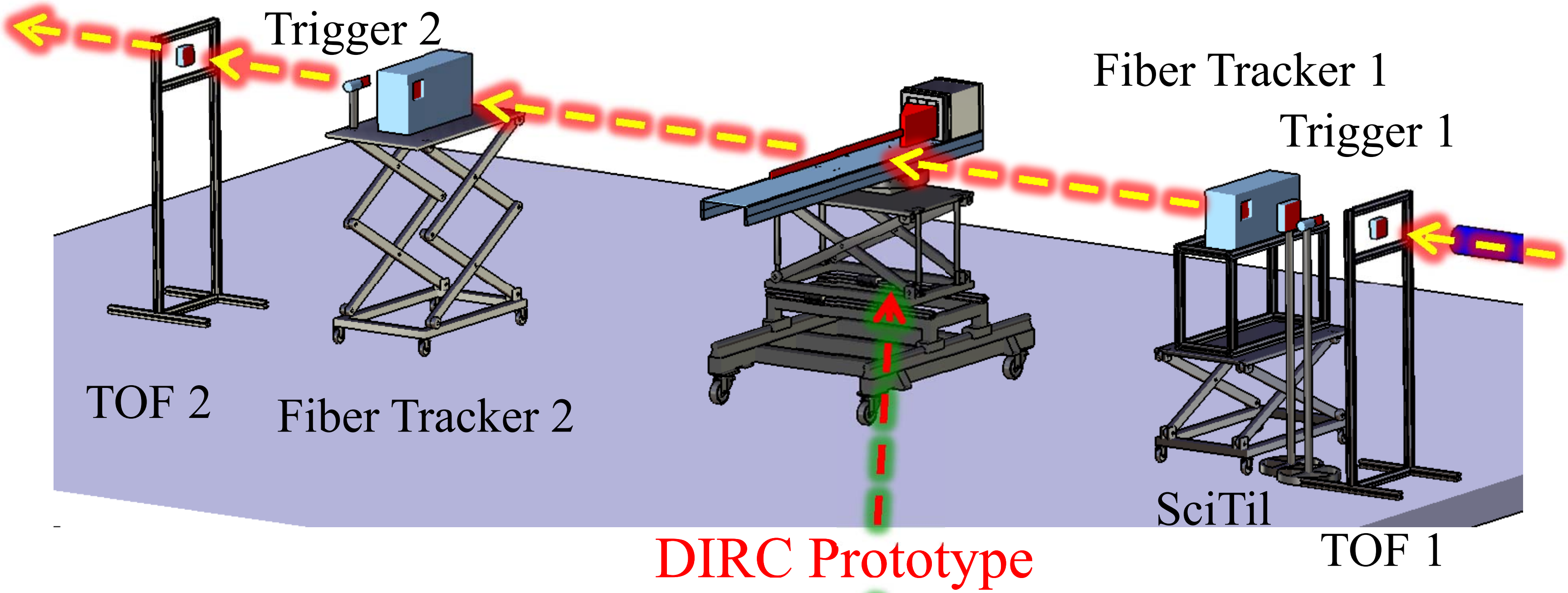
2012: π/p beam at CERN PS

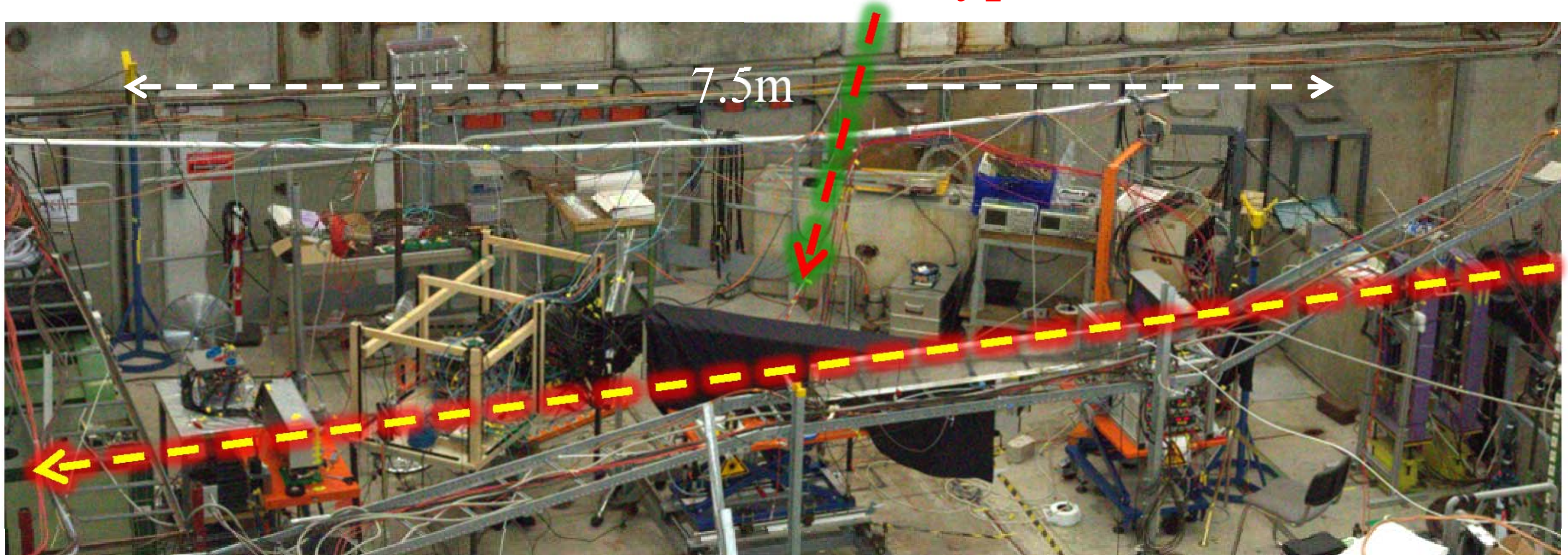
- Compact solid fused silica expansion volume (prism) instead of oil tank.
- Wide fused silica plate in addition to narrow bars.
- Focal plane almost fully covered by array of 3x3 Photonis Planacon MCP-PMTs, 896 channel DAQ.
- Capability to position, rotate, exchange bars/plates easily to compare radiator performance in beam.
- Different lenses w/ and w/o air gap, A/R coatings.
- Choice of coupling media between MCP/prism/radiator (matching liquid, optical grease, silicone sheet).
- Tracking stations to define track direction to ~1mrad.
- Time of flight system to enhance pion/proton sample.

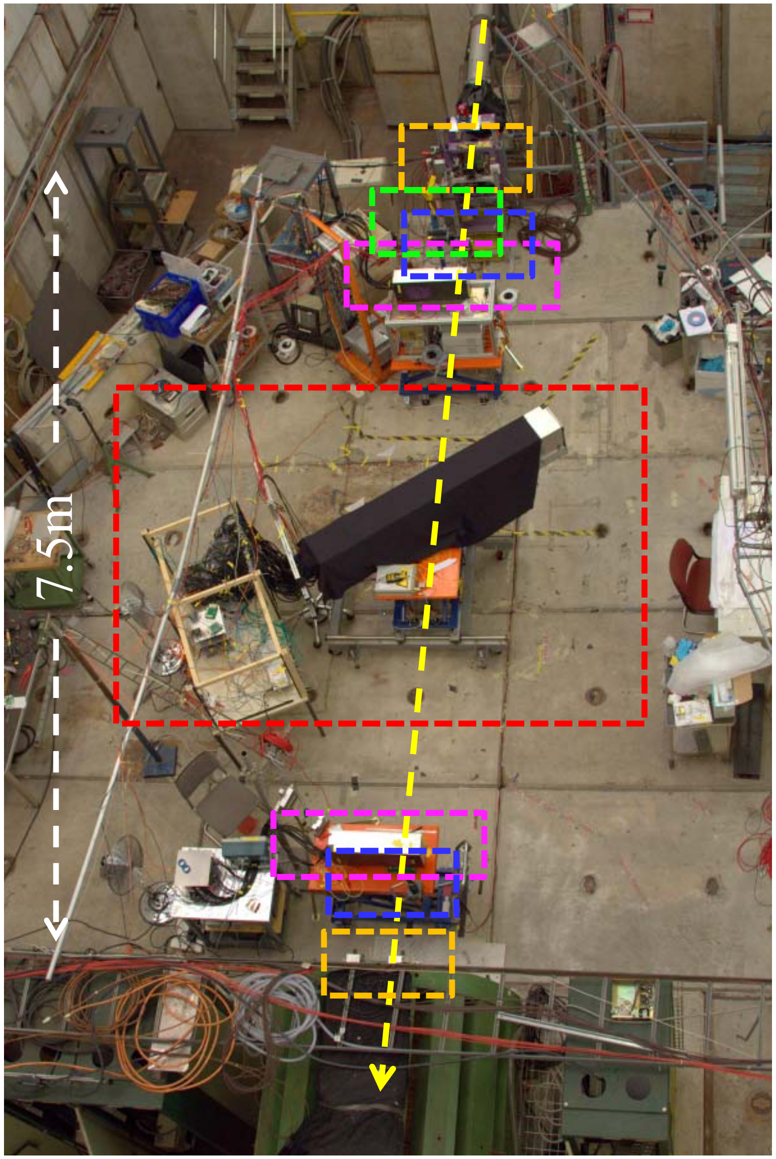




PROTOTYPES IN PARTICLE BEAMS







Cave layout on Aug 21.

2012: CERN PS (T9)

- 1.5-10 GeV/c beam
- 4 weeks of beam time
- Improved track definition by adding fiber trackers and MCP-TOF system.
- Approx 100ps event timing from MCP-TOF system.
- Wide range of beam-bar angles and beam z positions, similar to PANDA phase space.
- First experience with prism expansion volume.
- First experience with plate geometry.
- First experience with lens w/o air gap.
- 220M triggers recorded.

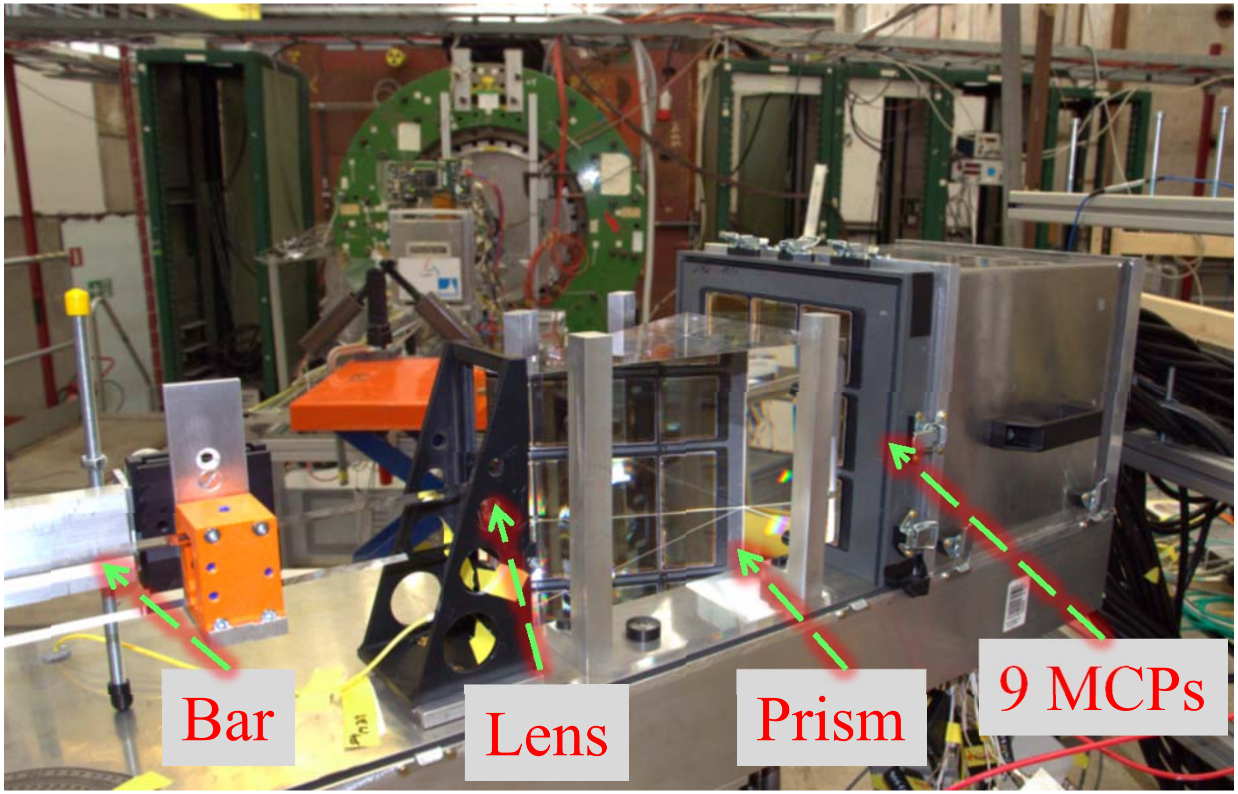
MCP-TOF station 1&2

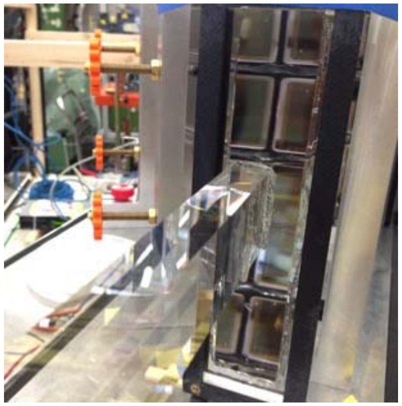
SciTil

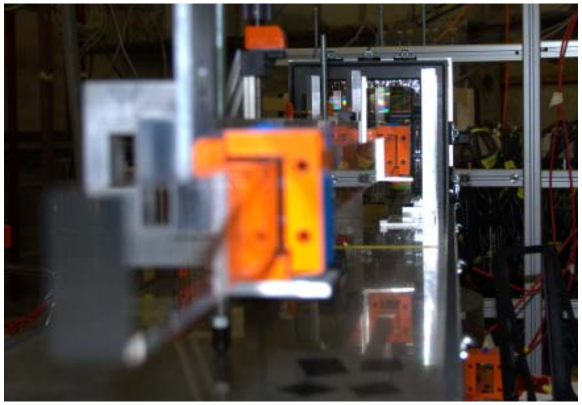
Fiber Tracker station 1&2

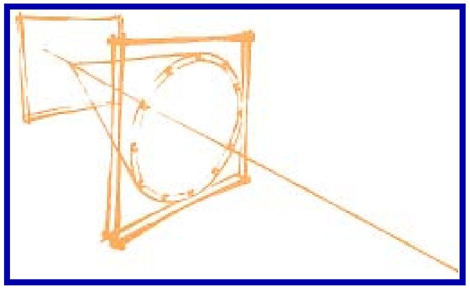
Barrel DIRC

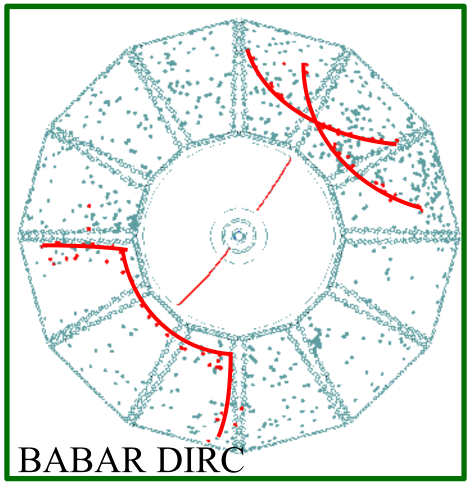
Trigger station 1 & 2

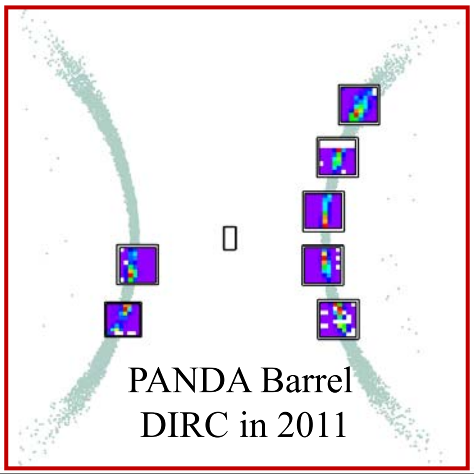

Bar
Lens
Prism
9 MCPs











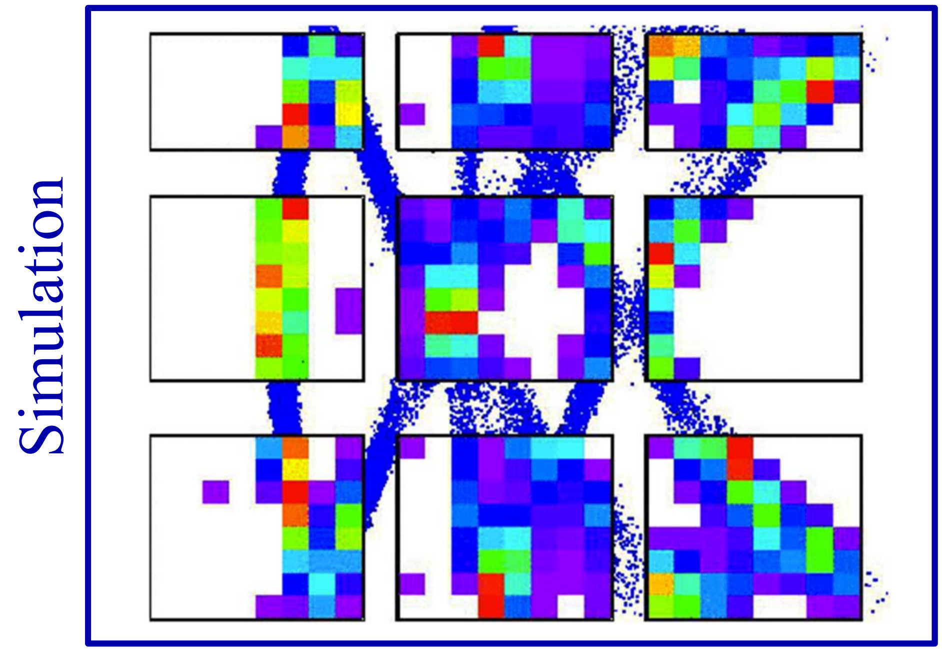
DIRC hit patterns do not look like your typical RICH detector

Ring image gets folded due to propagation in bar/plate

Part of the ring escapes, not totally internally reflected

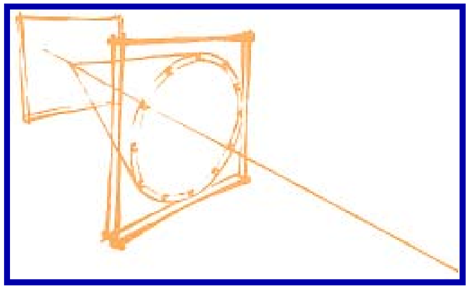
→ broken rings, complex, disjoint images

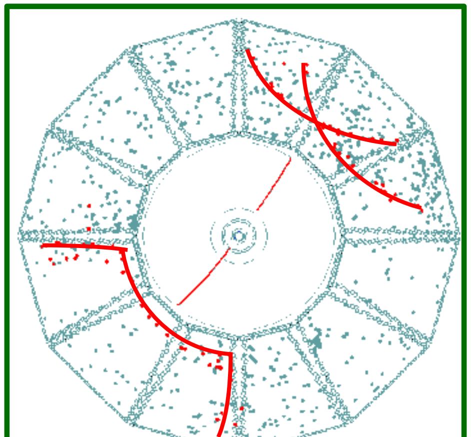
What do we expect to see in 2012 with the prism?



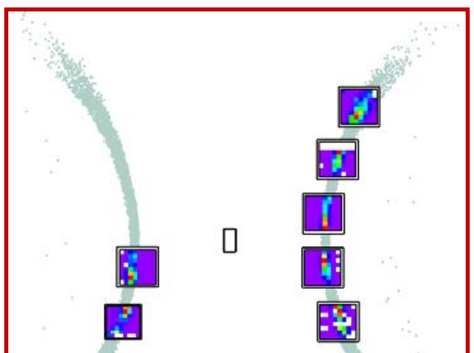
Simulation: track polar angle 58 deg; dots: true hit position

PROTOTYPES IN PARTICLE BEAMS





BABAR DIRC



PANDA Barrel DIRC in 2011

DIRC hit patterns do not look like your typical RICH detector

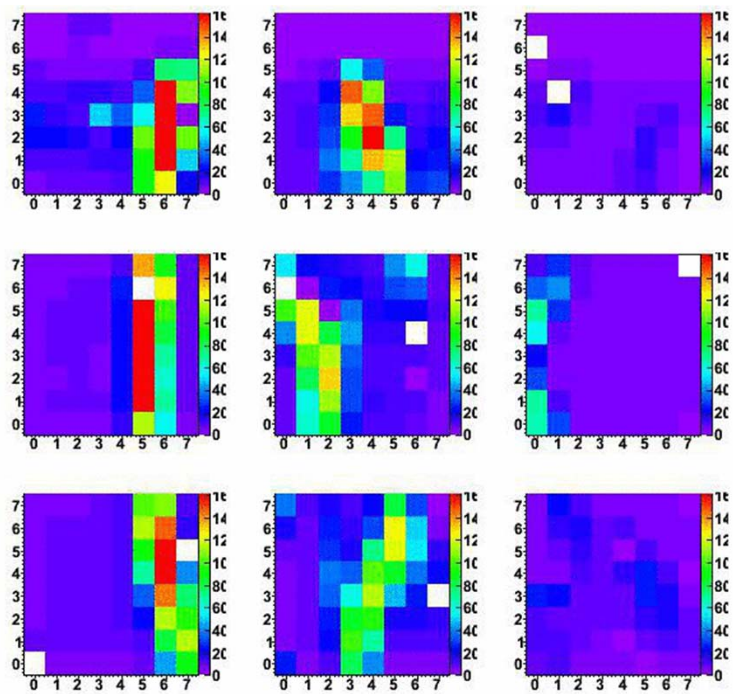
Ring image gets folded due to propagation in bar/plate

Part of the ring escapes, not totally internally reflected

→ broken rings, complex, disjoint images

What do we actually see in 2012 with the prism?

2012 data



2012 data: track polar angle range 55-57 deg

2012 beam test concluded in early September.

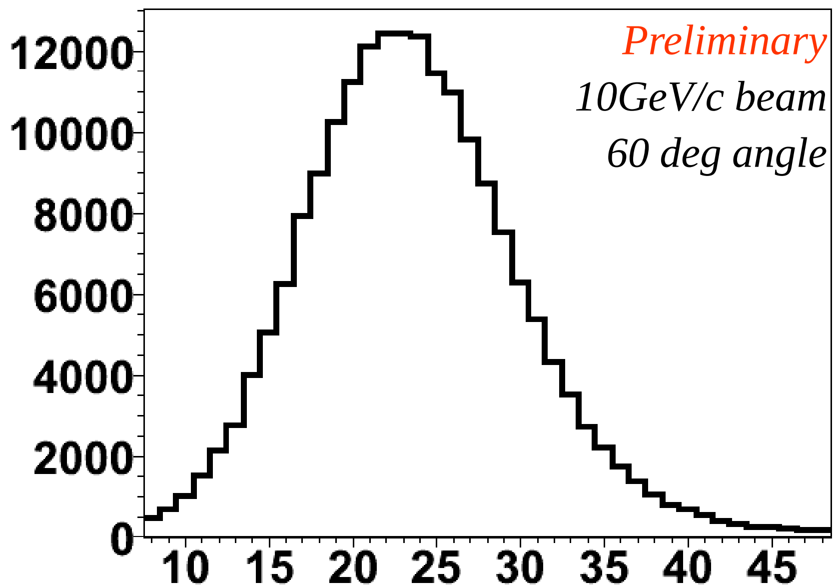
Only just starting detailed analysis, no 3D tracking, no full timing/position calibration yet.

Today only one *preliminary* performance example:

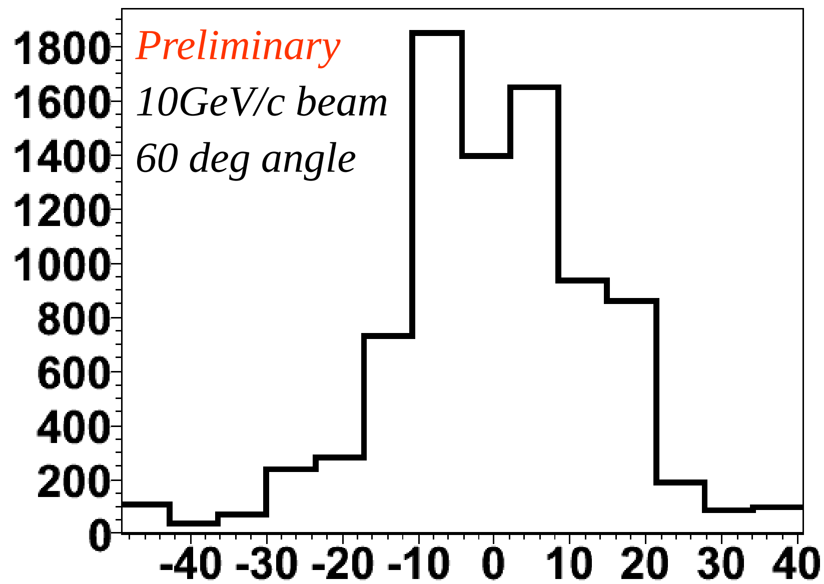
InSync bar, spherical lens with UV A/R coating and 2.2mm air gap.

→ Clear Cherenkov signal with reasonable single photon resolution.

→ Significant improvement in number of photons per trigger (no charge sharing correction yet).



Number of detected photons per trigger



θ_C per photon – average θ_C [mrad]

PANDA BARREL DIRC SUMMARY

Hadronic PID for PANDA target spectrometer provided by two DIRC counters.

Design of Barrel DIRC inspired by BABAR DIRC with key improvements:

fast timing, focusing optics, compact expansion volume.

Key challenges:

- Pico-second timing with single photons in environment with 1 C/cm^2/yr and 1T.
  - → Discussing solutions with industry, testing prototypes in lab, rapid improvement.
- Cherenkov radiator (bars, plates) production and assembly.
  - → In contact with vendors in Germany, Russia, USA, testing prototype pieces.
- Design of detector optics and reconstruction software.
  - → Developing simulation framework (Geant and ray-tracing).

Progression of increasingly complex system prototypes

to validate technology and design choices using particle beams.

FAIR construction started Nov. 2011, PANDA installation 2017, beams 2018.