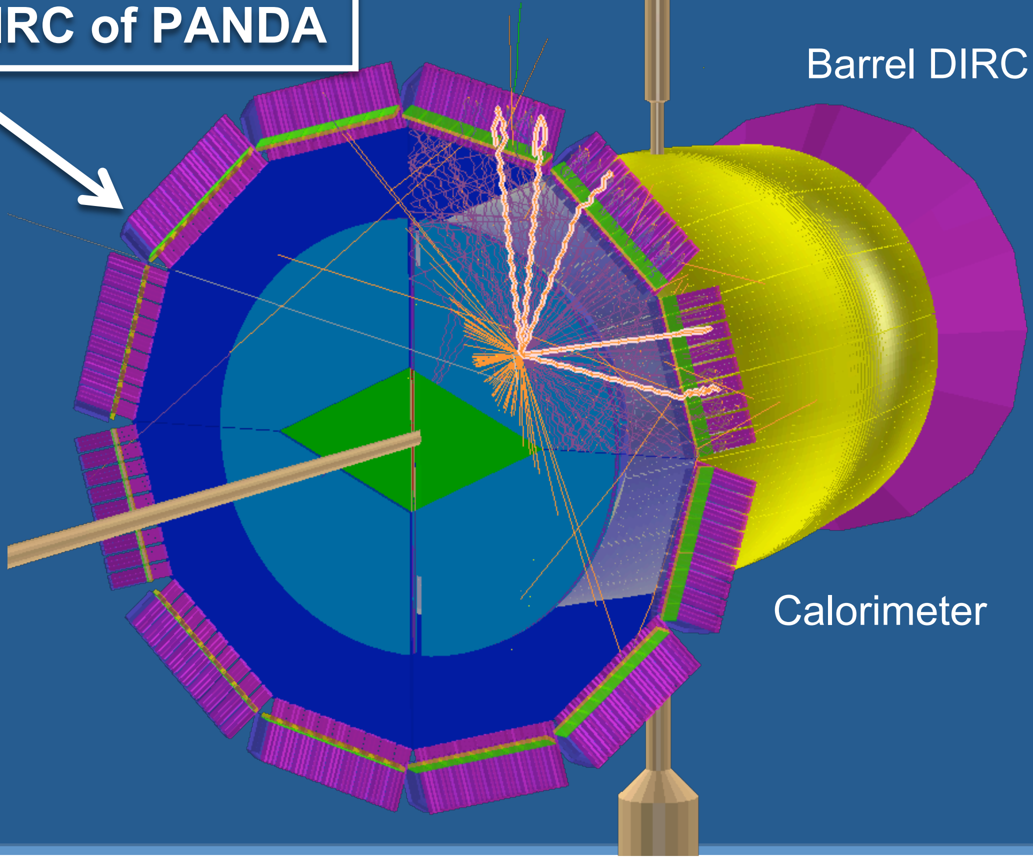
# The Endcap Disc DIRC of PANDA

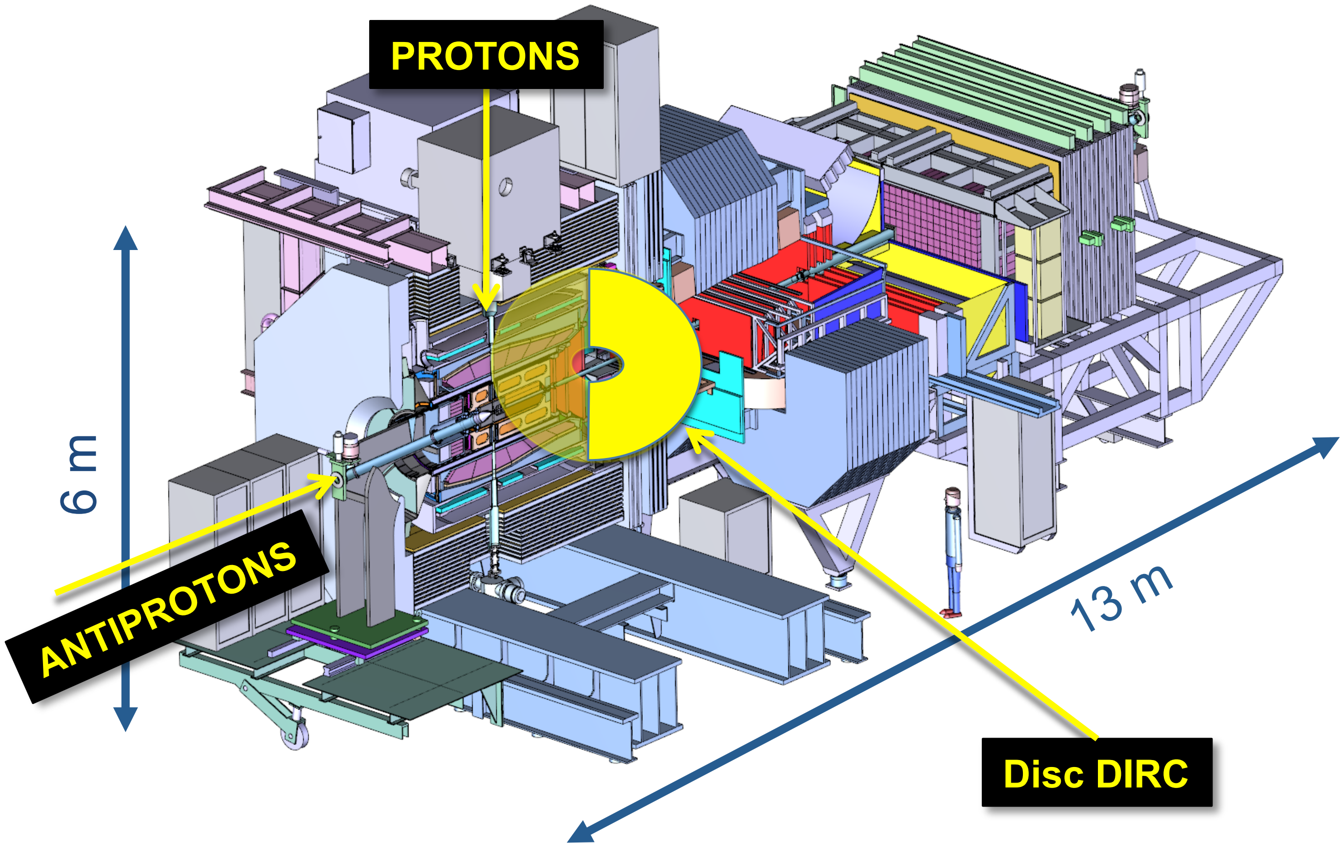



JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN


Michael Düren, E. Etzelmüller, K. Föhl, A. Hayrapetyan, K. Kreutzfeldt, J. Rieke, M. Schmidt - on behalf of the PANDA Cherenkov Group


PANDA


9th International Workshop on Ring Imaging Cherenkov Detectors (RICH 2016)
Lake Bled, Slovenia on September 5-9, 2016.




## Detector:

- fixed p-target
- antiproton beam:

$$p = 1.5 - 15\ \mathrm{GeV/c}$$

- momentum resolution

$$\frac{\Delta p}{p} = 4 \cdot 10^{-5}$$

- maximum luminosity

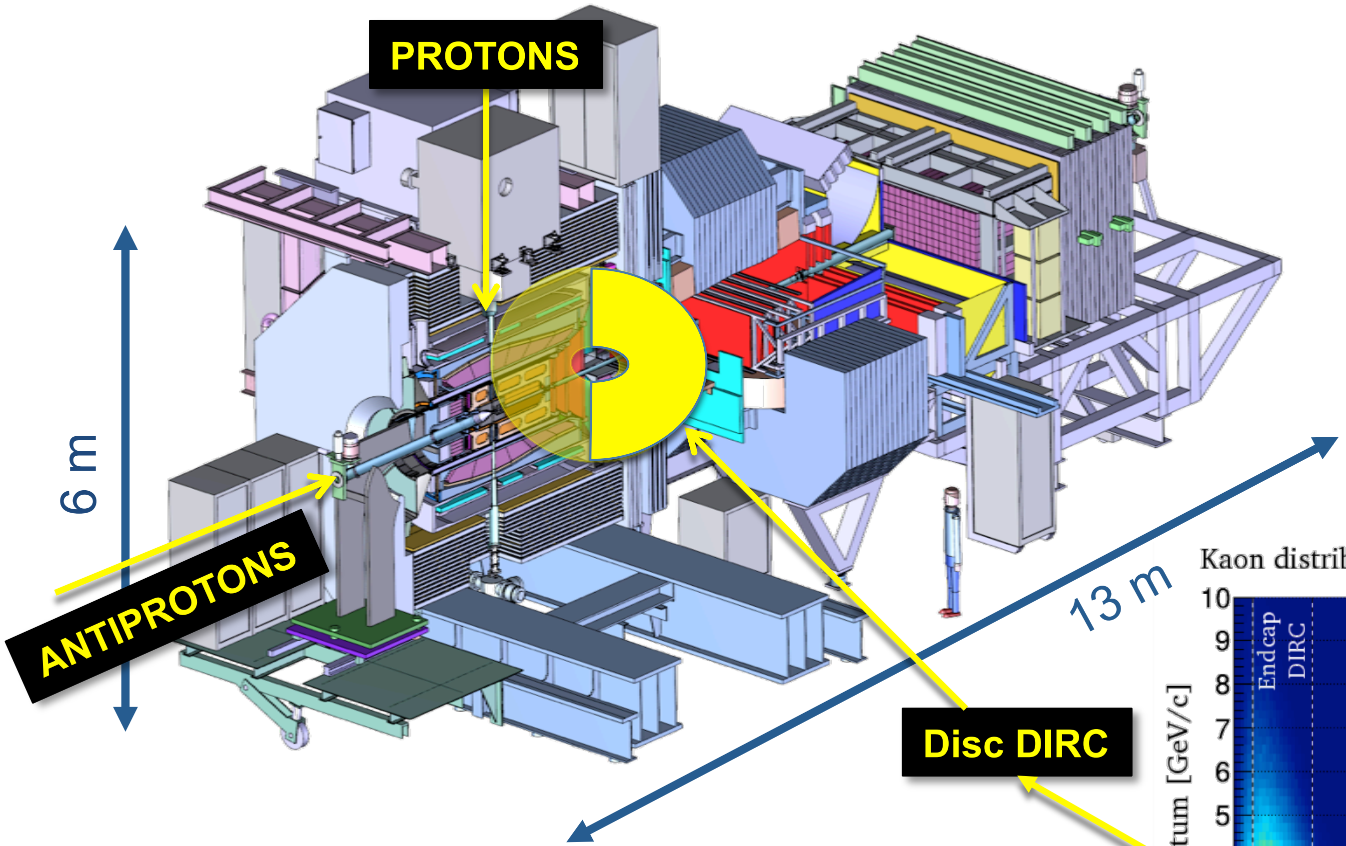
$$2 \cdot 10^{32} \frac{1}{cm^2 s}$$

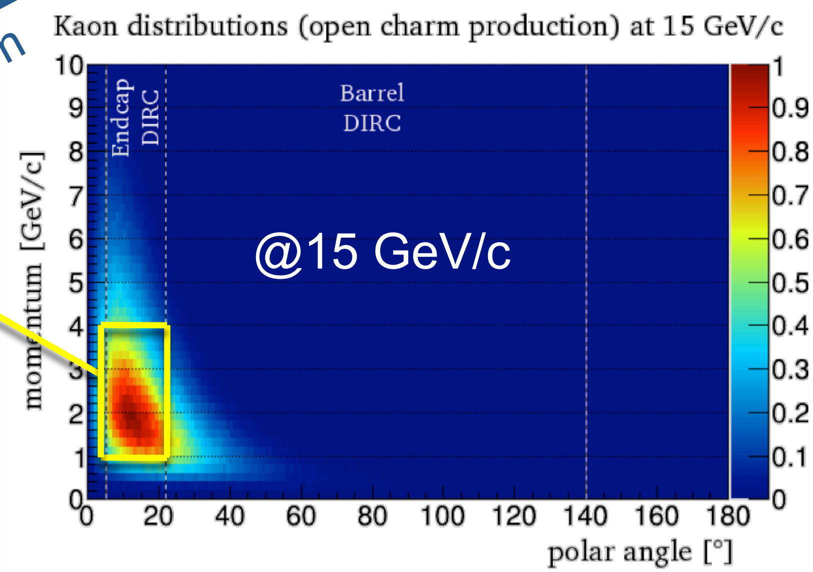
## Physics:

- hadron spectroscopy
- nucleon structure
- hadrons in matter
- hypernuclei

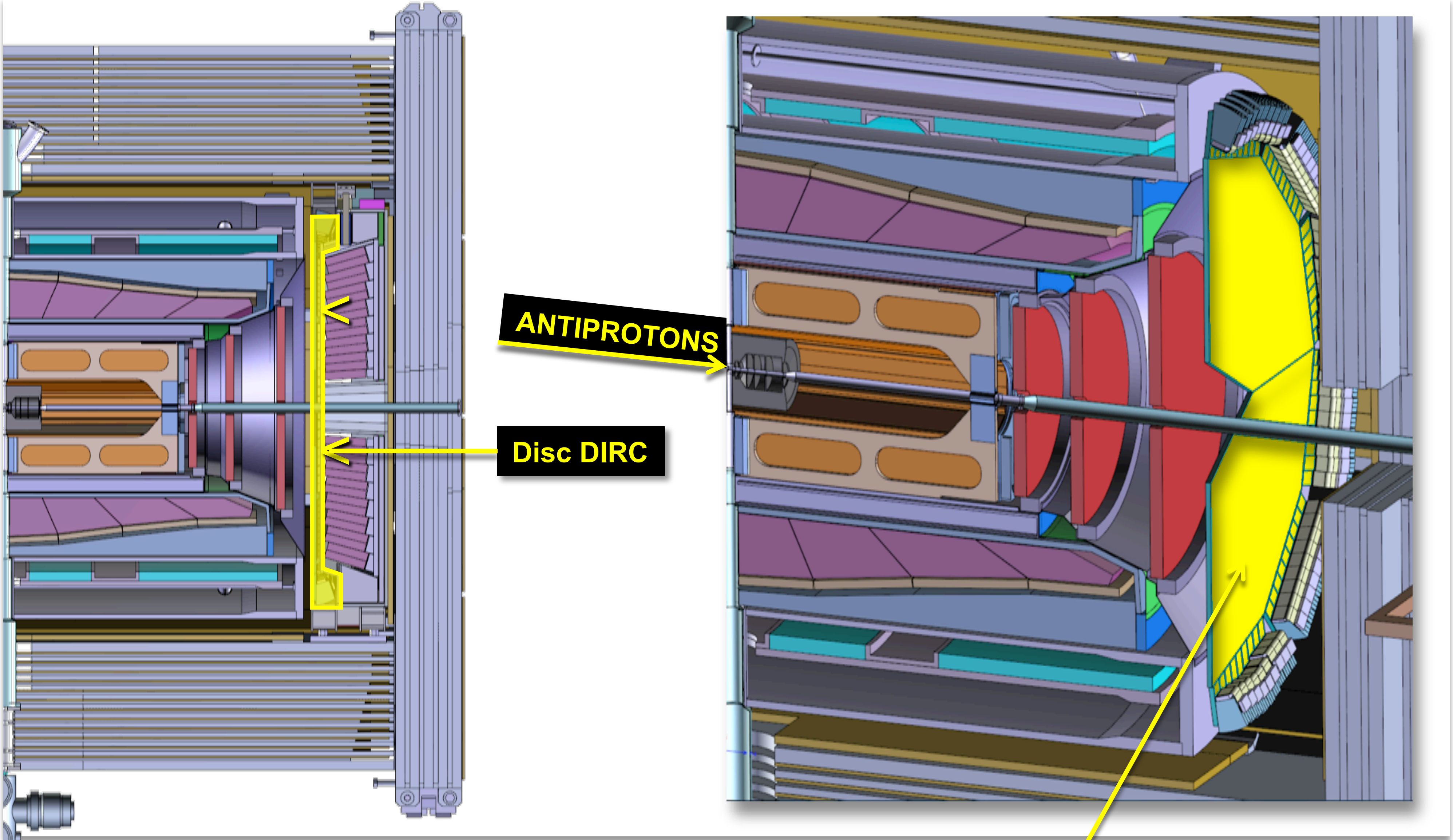
**PANDA @ RICH2016**
- Jochen Schwiening,
- Albert Lehmann,
- Sergey Kononov,
- Matthias Hoek, ...

# PANDA @ FAIR: Particle Identification



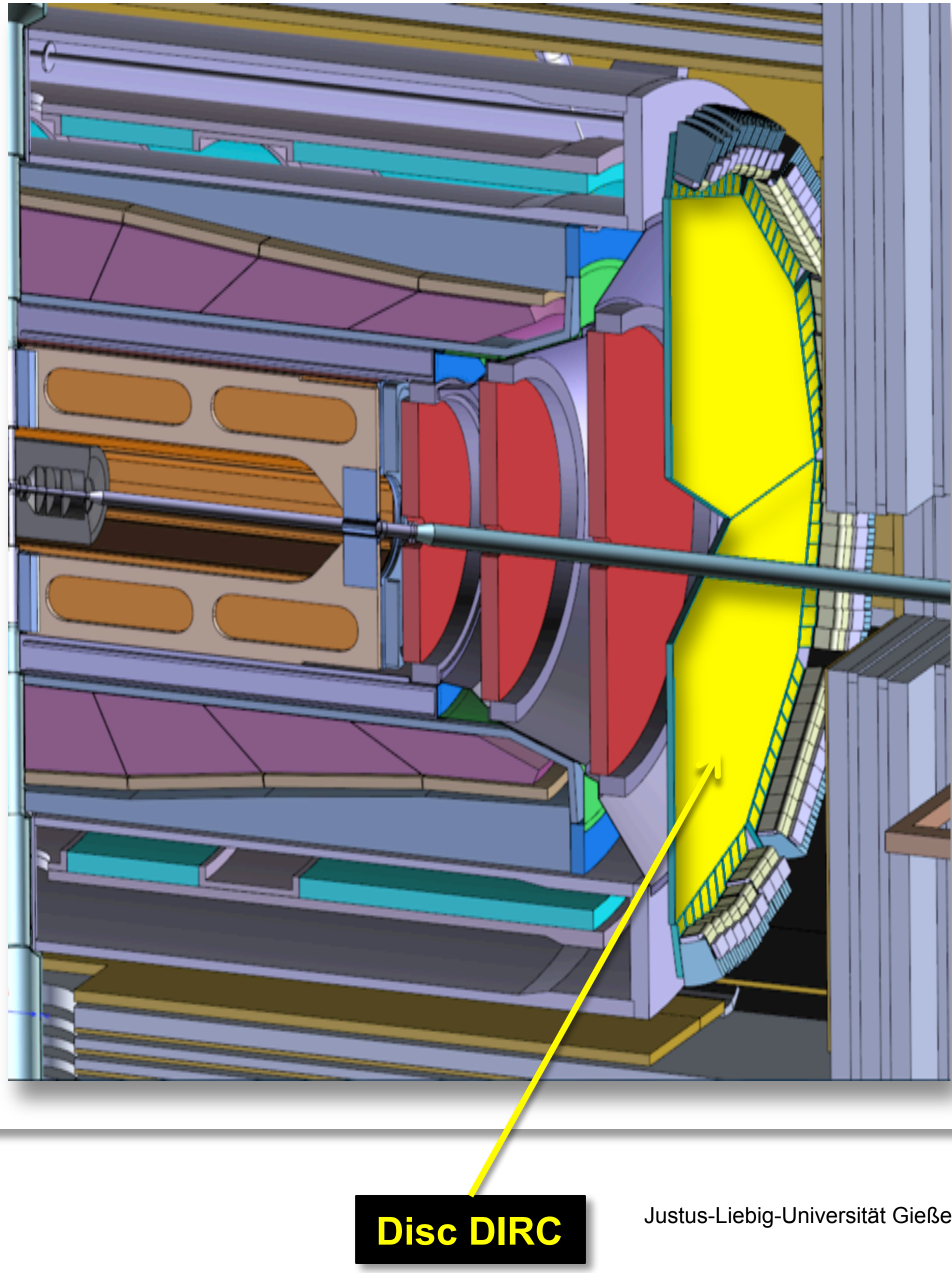
# The Disc DIRC: a compact forward PID detector (2 cm radiator plate)



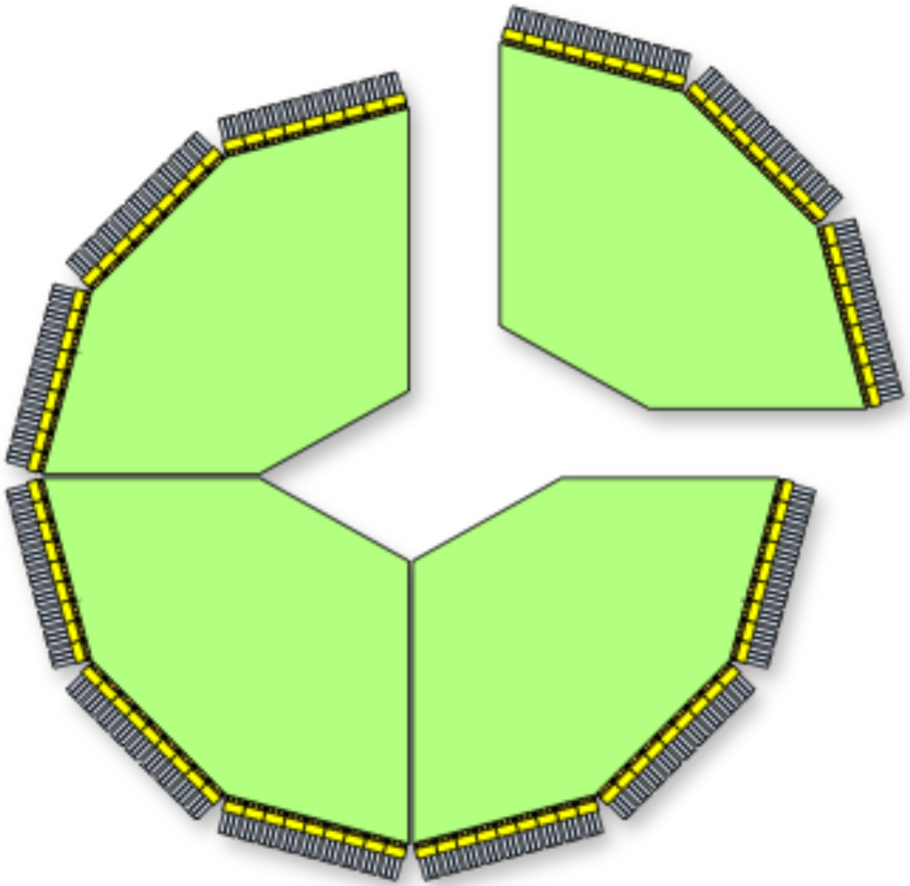
# Disc DIRC: Special  Panda Requirements



- 4σ π/K separation up to 4 GeV/c
- continuous beam with interaction rates up to 20 MHz
- strong magnetic field (~1 T)
- high radiation level and photon dose
- high-precision and large-area optics
- high time resolution (<100 ps) , high data rate and channel density
- very limited space



# Disc DIRC: Modularity

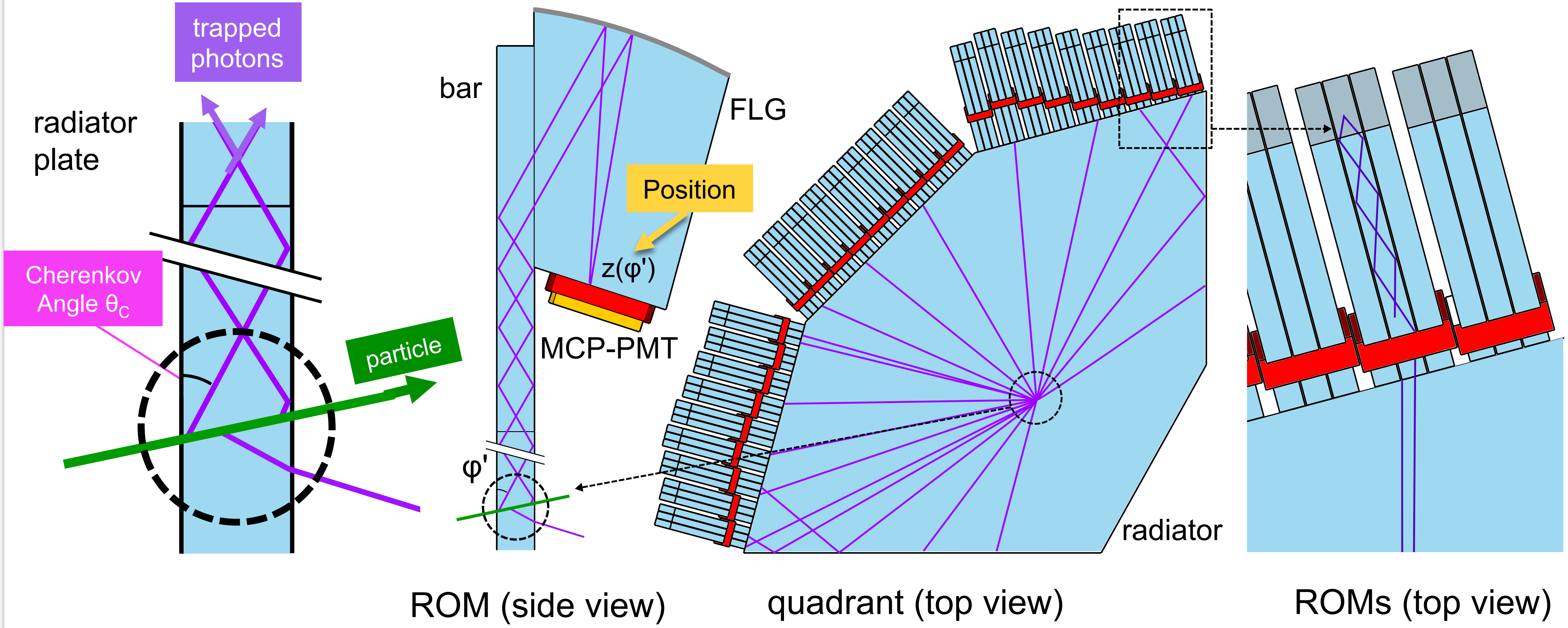


**Modularity:**
4 independent sub-detectors
4 identical fused silica plates

**Single Photon Detection:**
108 identical readout modules (ROM)
MCP-PMTs with ~3x100 customized anode strips
324 light focussing elements

**Fast Detector:**
32k readout channels @ <100 ps

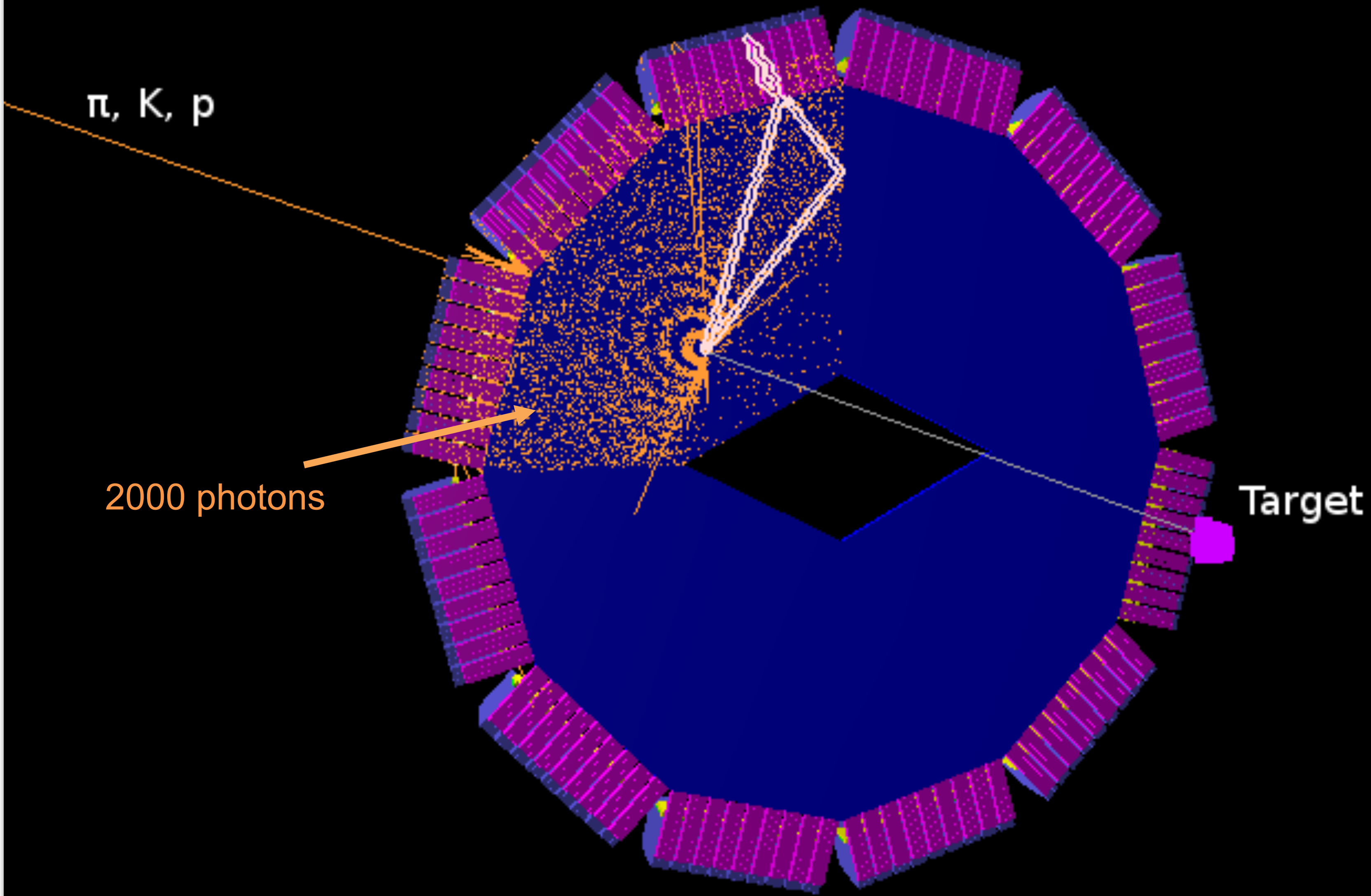
# Disc DIRC: Optical concept and analytic photon reconstruction




**Analytic reconstruction formula:**

$$z(\varphi') = z(\varphi, \alpha_{FEL}) = z\left(\arctan\left(\frac{\tan\varphi}{\cos\alpha_{FLG}}\right)\right)$$

# Disc DIRC: Optical concept and analytic photon reconstruction




$$z(\varphi') = z(\varphi, \alpha_{FEL}) = z\left(\arctan\left(\frac{\tan\varphi}{\cos\alpha_{FLG}}\right)\right)$$

# Reduction of dispersion vs. photon statistics

Cherenkov angle:

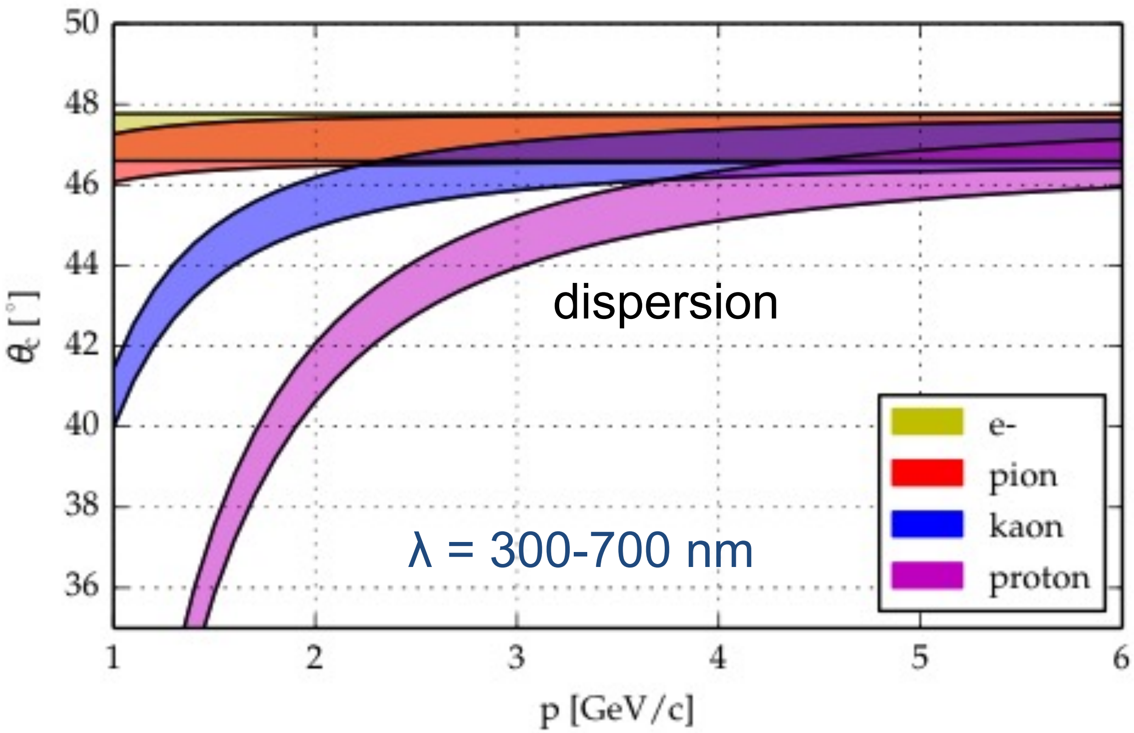
$$\cos\theta_C = \frac{1}{n\beta}$$

Photon statistics:

$$\frac{dN^2}{dkdx} = \alpha z^2 \sin^2\theta_C$$

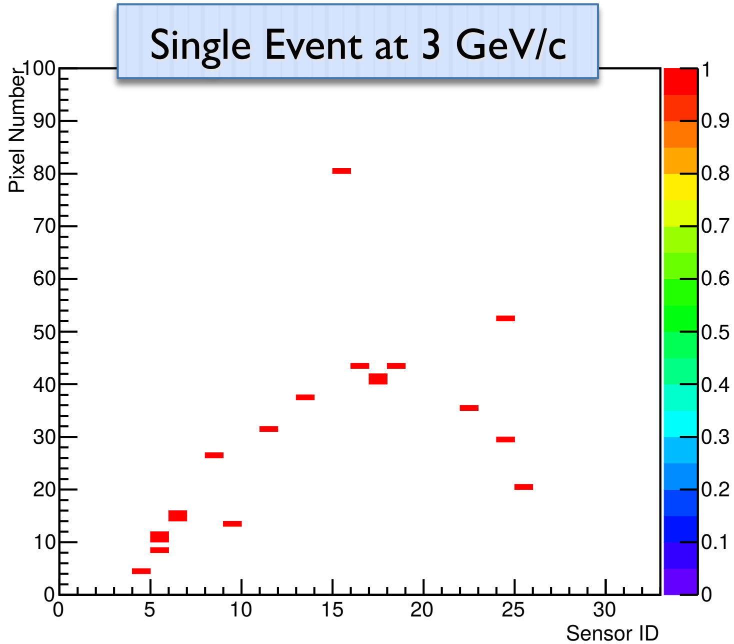
For every charged track
(2 cm fused silica):

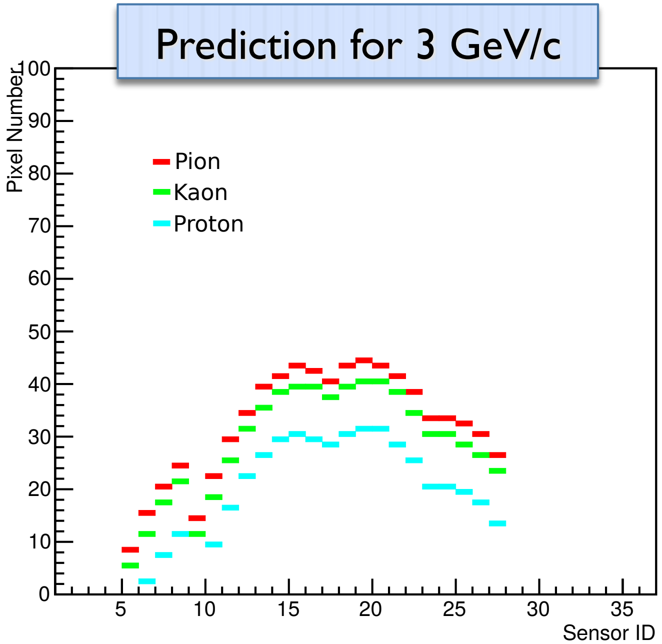
- ~2000 generated photons
- photons selected by bandwidth filter



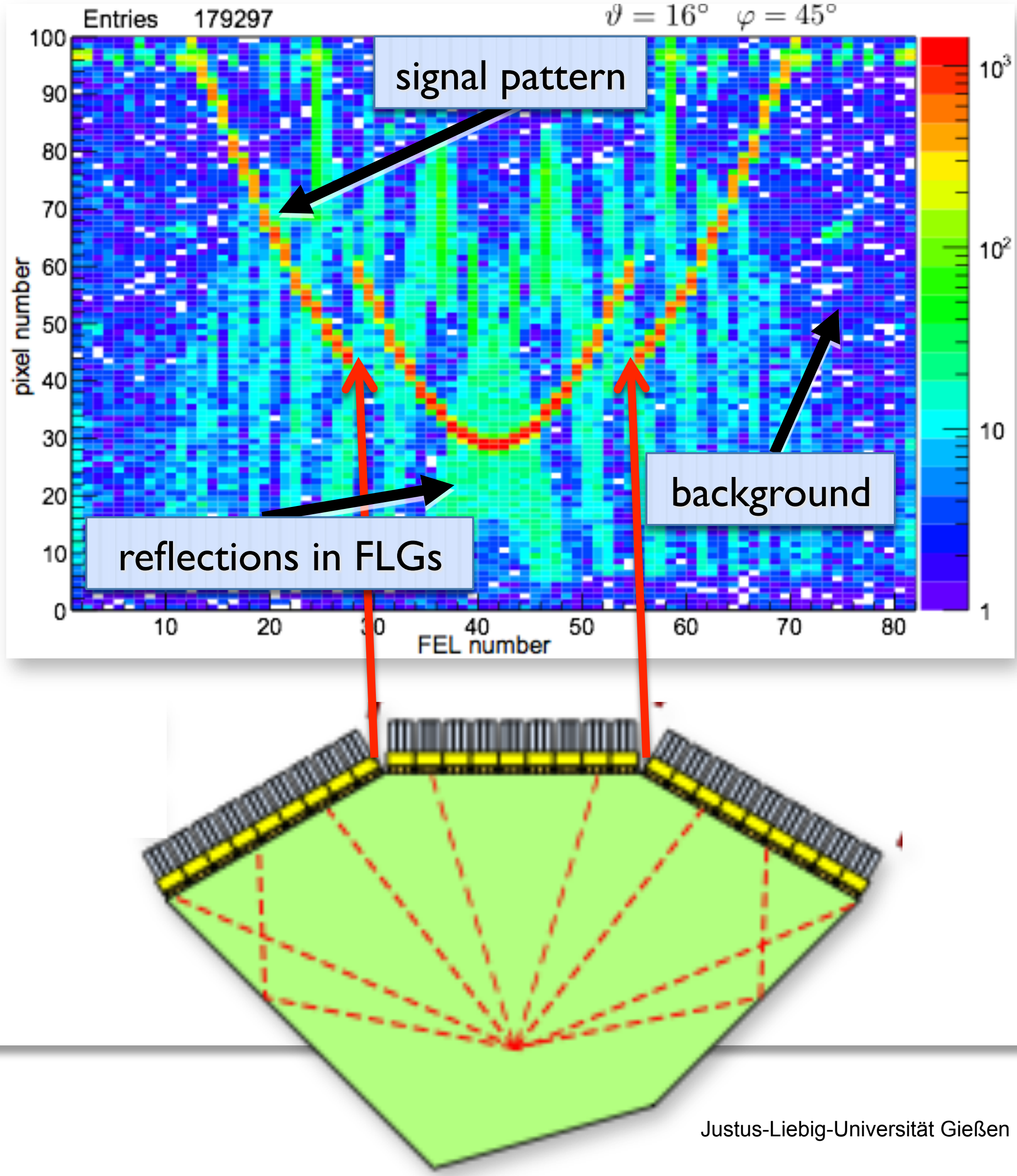

| Filter | Detected Photons $N_{ph.}$ | Performance $\sigma_{chrom.}/\sqrt{N_{ph.}}$ |
|---|---|---|
| > 300nm | 48 | 0,66 |
| 360-465 nm | 22 | 0.41 |

# Full time-ordered simulation and reconstruction (Panda-Root/ Geant4)
# Single and Accumulated hit pattern / Likelihood analysis for optimum PID

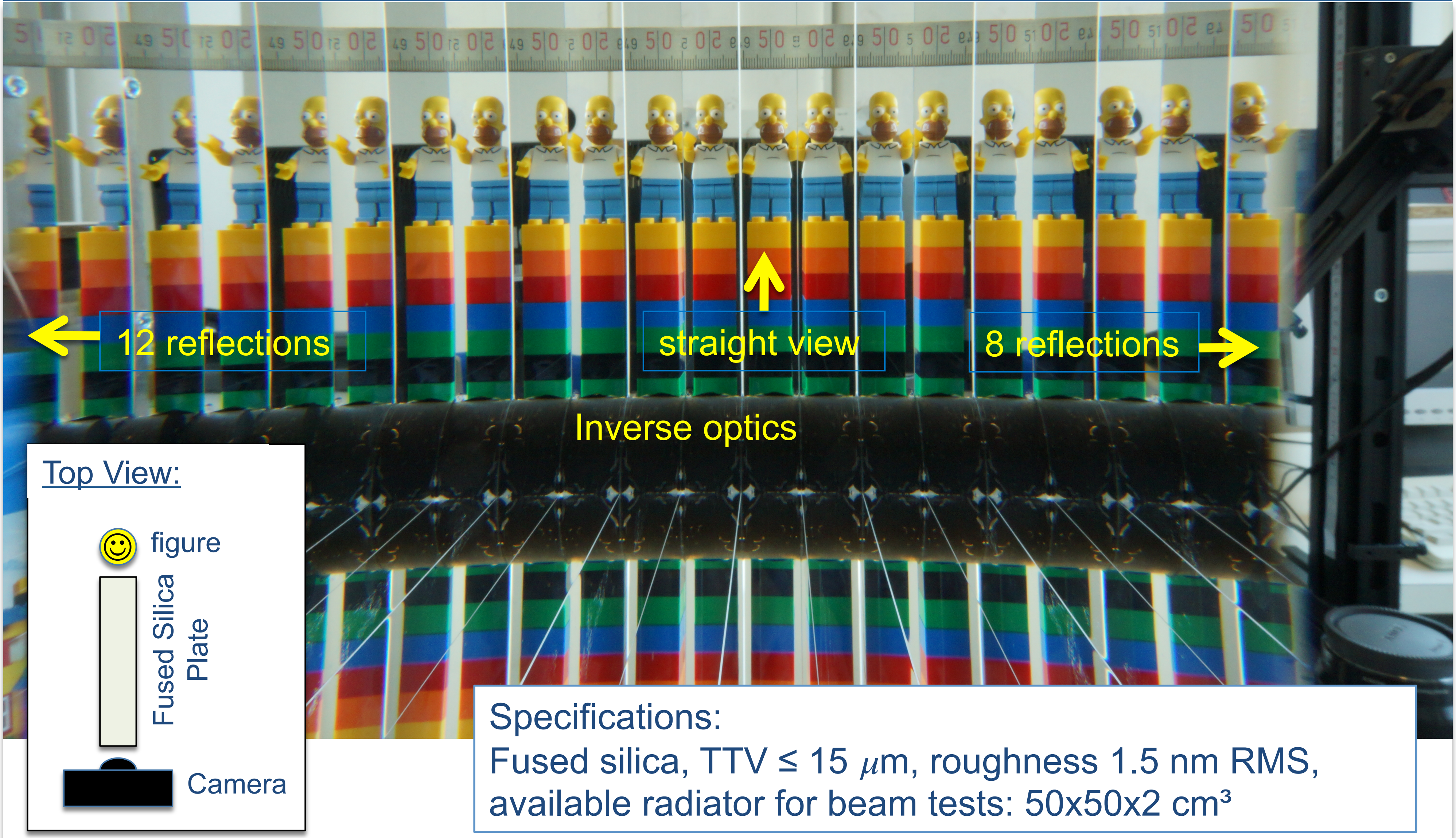



10k π-tracks at 4 GeV/c per histogram

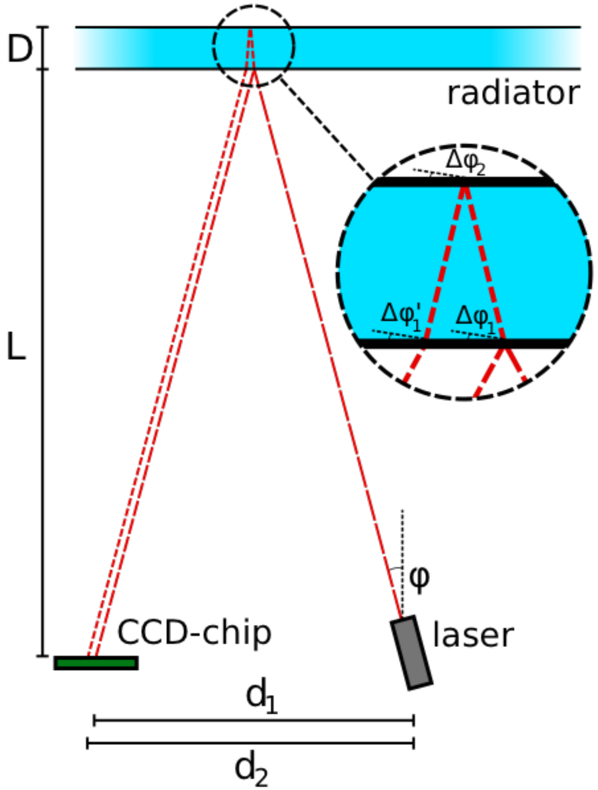


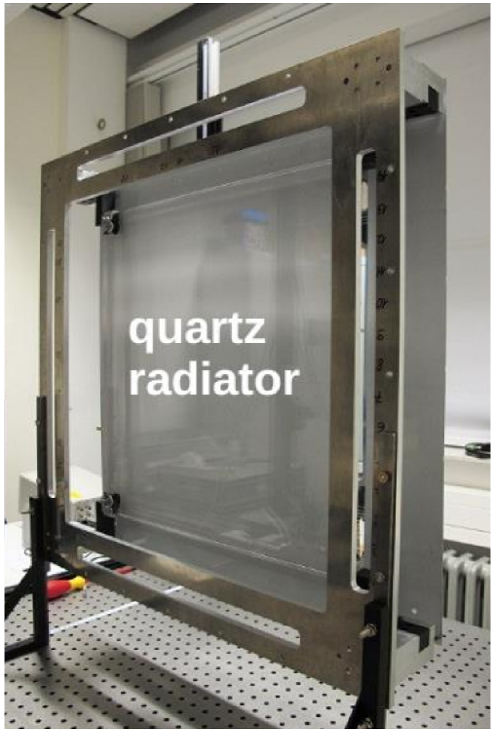
# From Simulation to Reality… : The Quartz Radiator

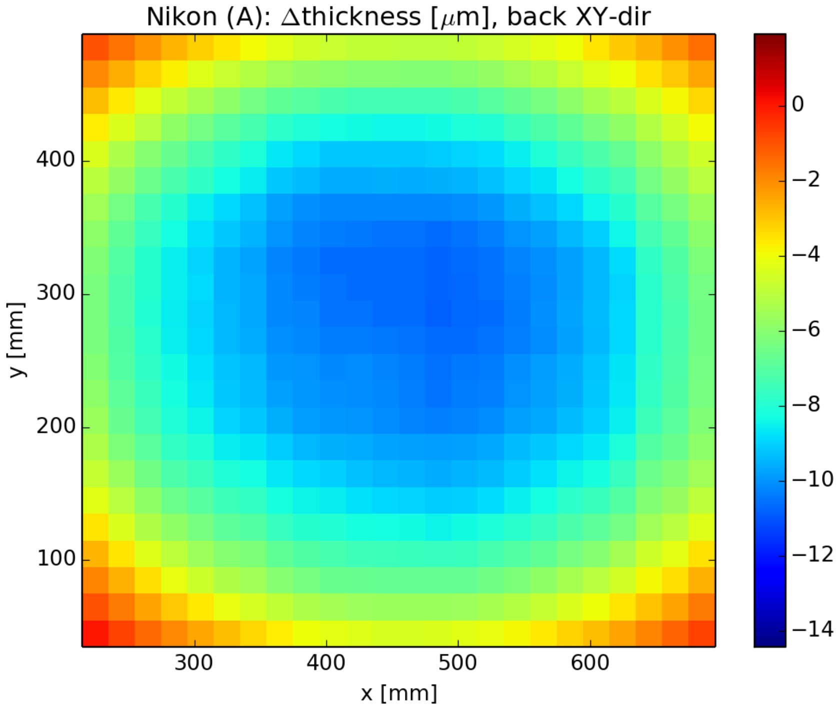



Specifications:
Fused silica, TTV ≤ 15 $\mu$m, roughness 1.5 nm RMS,
available radiator for beam tests: 50x50x2 cm³

# Optical quality of radiator plate



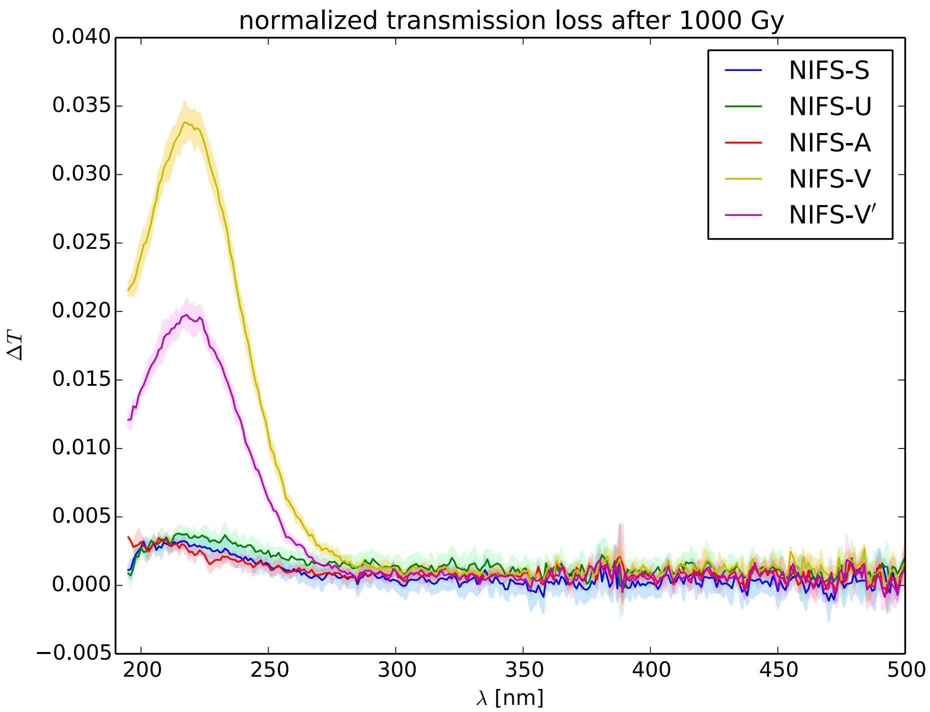



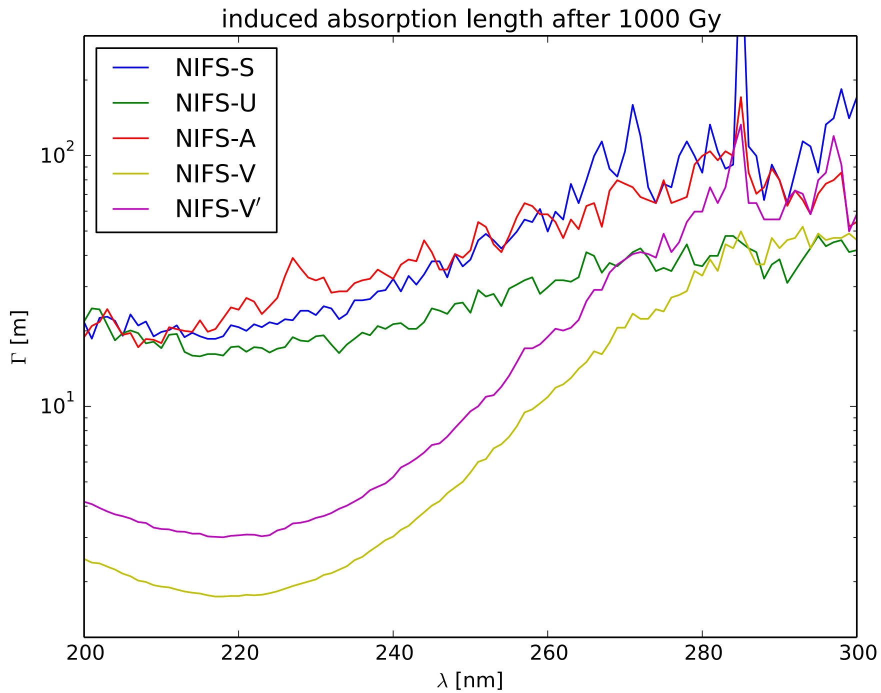




- Scan of thickness profiles for coplanar surfaces up to 1x1 m²
- Sub-$\mu$m precision for the profile and $\mu$rad precision for the slope

# Radiation hardness of fused silica (from Nikon)



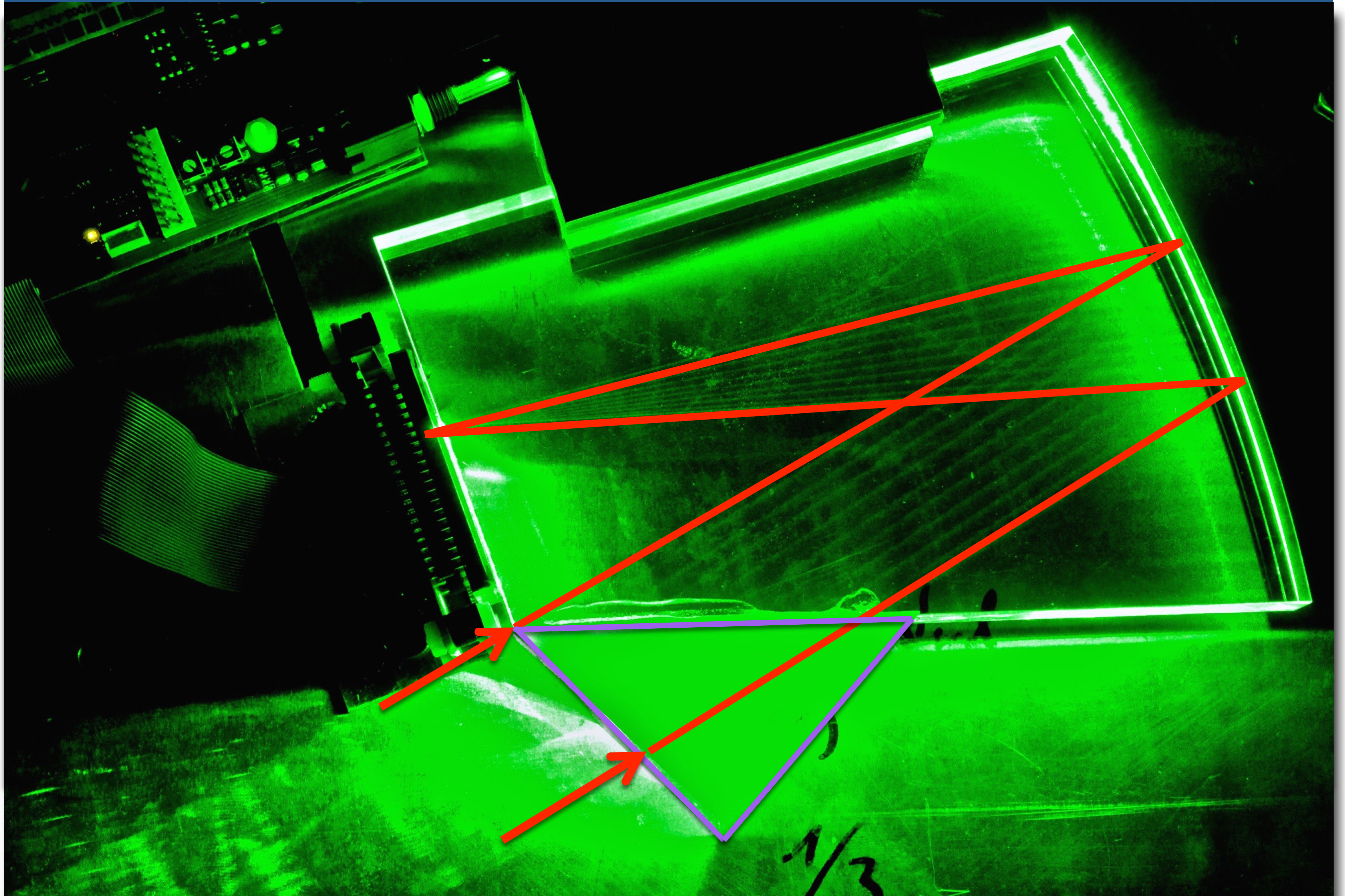



- Radiation hardness studies for different NIFS-types with a $^{60}$Co source @ 1000 Gy
- No degradation above 300 nm even for dry fused silica samples (NIFS-V)

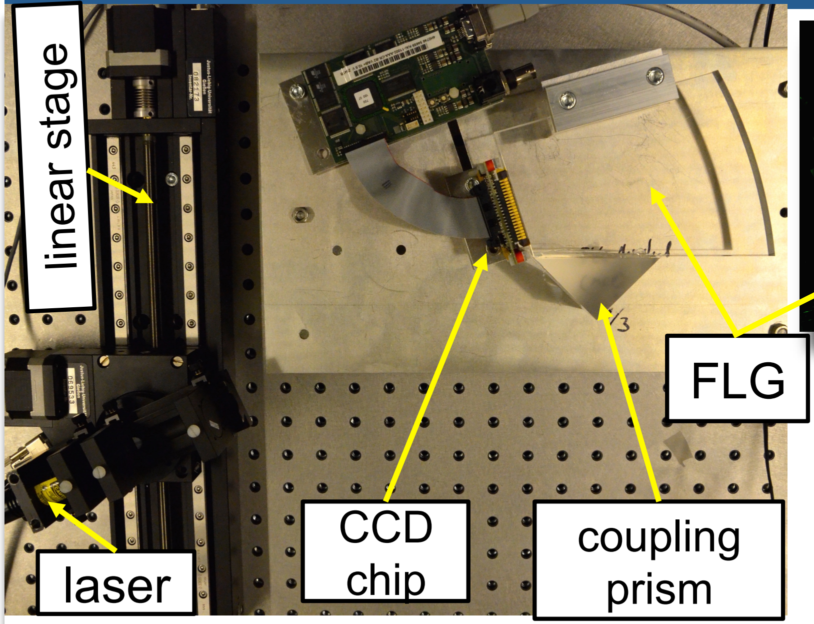
# Focussing light guide (FLG)

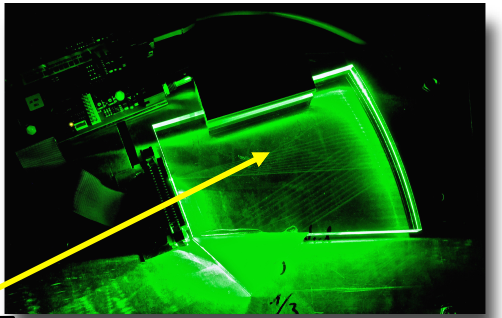


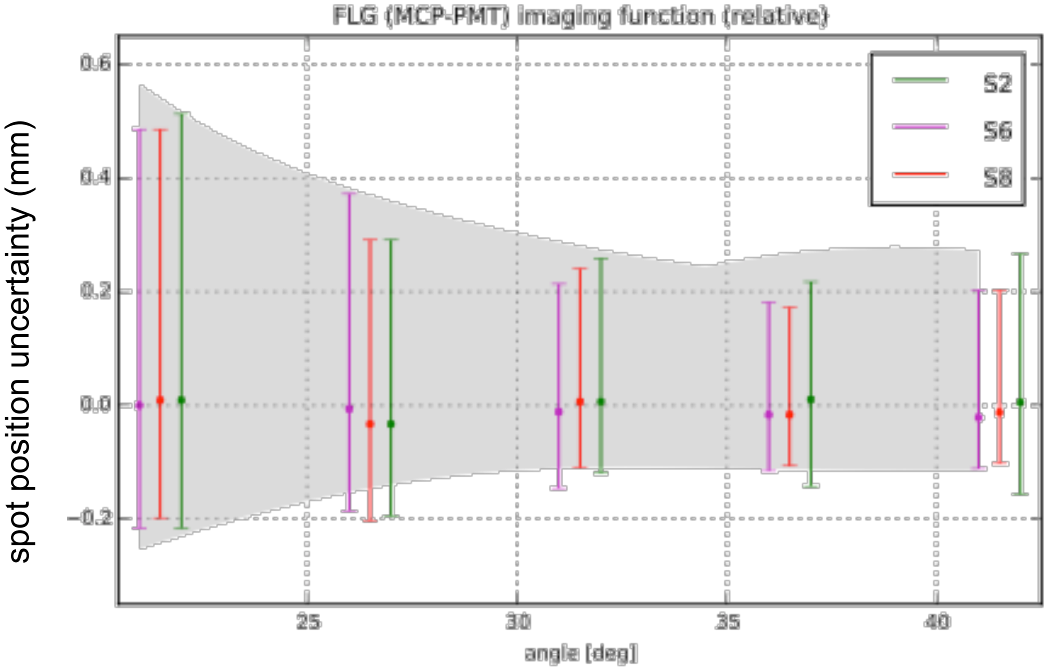


# Focussing light guide (FLG)





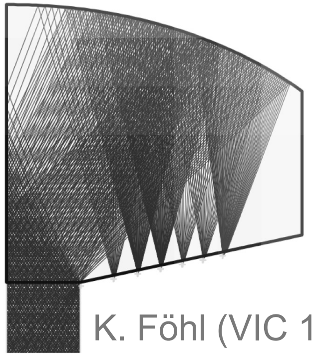






- FLGs can be produced according to our specifications
- 3 FLGs available; more are ordered

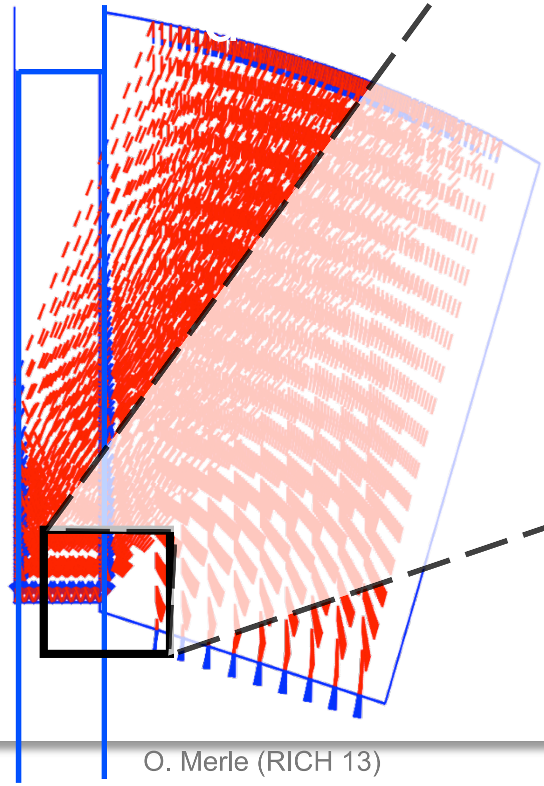
- optical precision matches pitch of the MCP-PMT anode

# Optical system: Non-adhesive bonding vs. glue



K. Föhl (VIC 12)

light-guides
are to scale

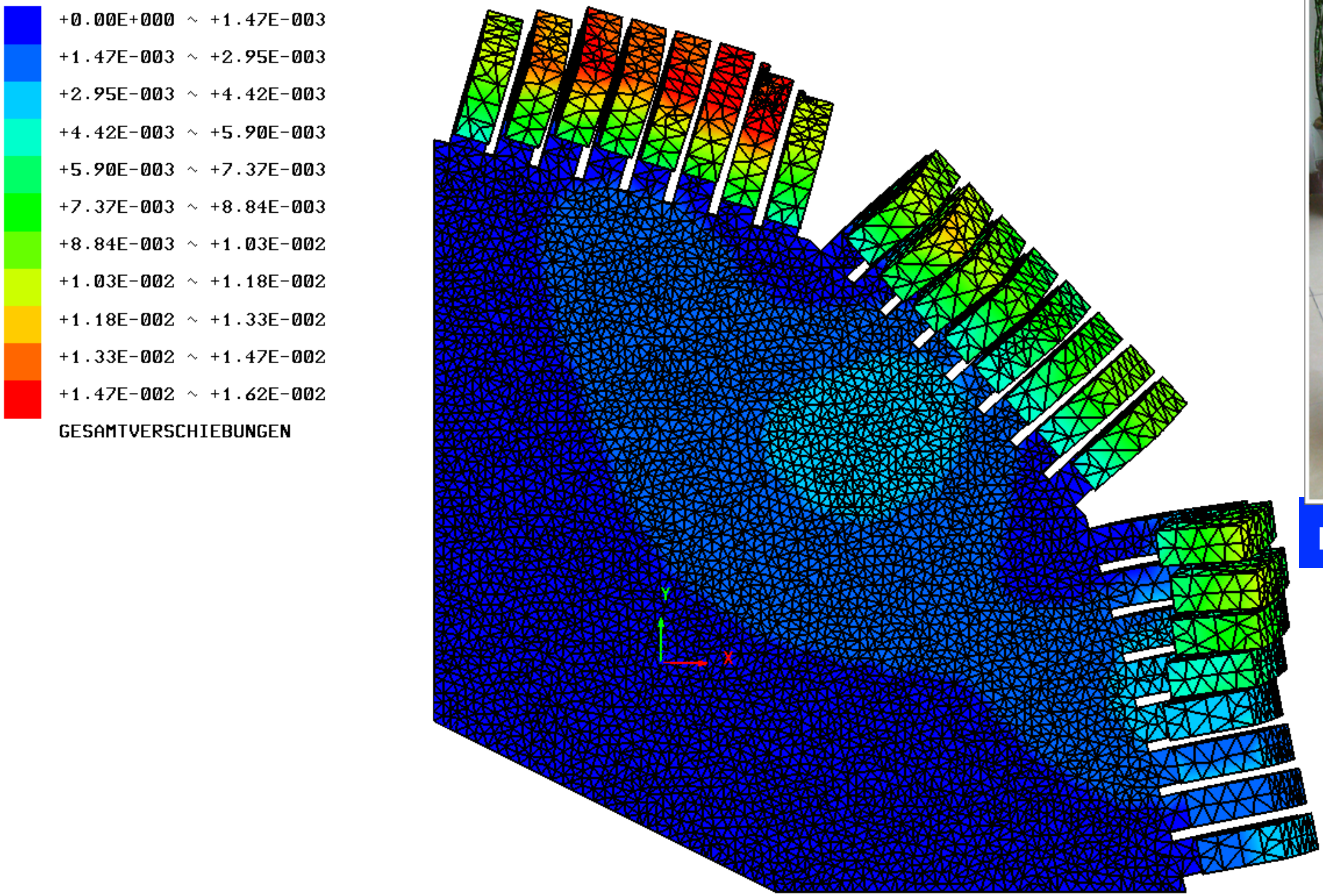


O. Merle (RICH 13)

- non-adhesive bonding of prism and FLG is perfect
- it prevents losses or defocusing of traversing photons

# FEA of Stress on Quartz Optical System (expanded scale)





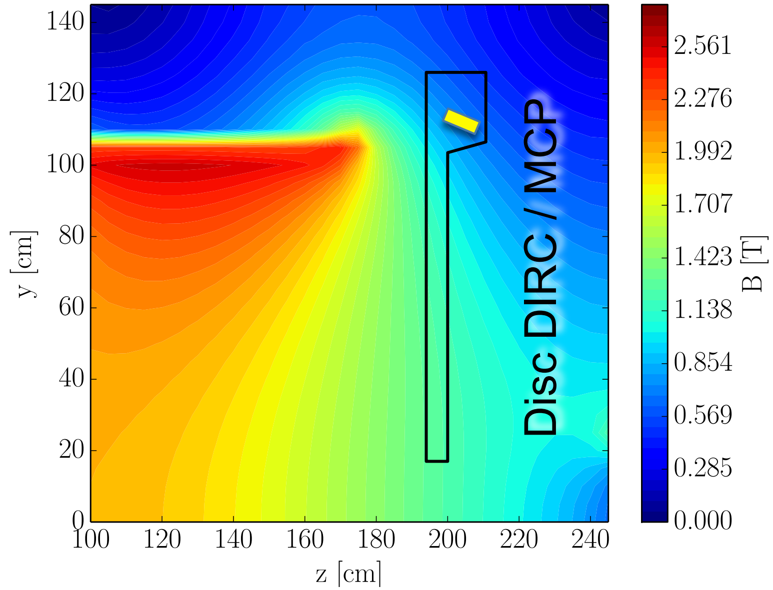

robustness

# Sensors: Custom made MCP-PMTs (Photonis and Hamamatsu)

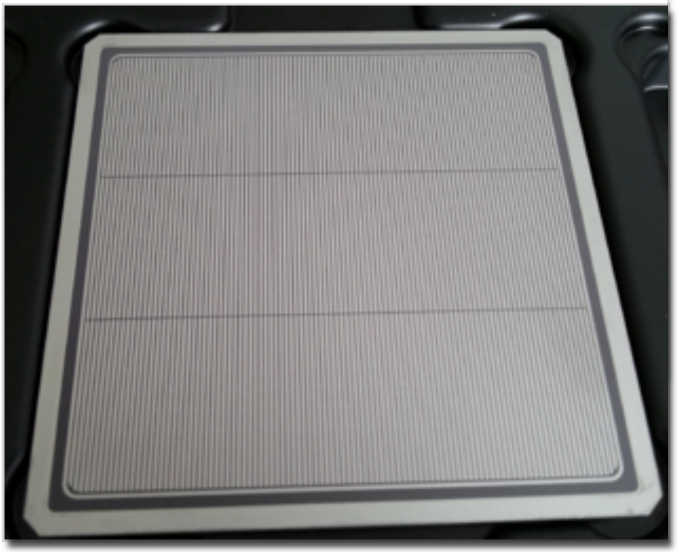
## Issues:

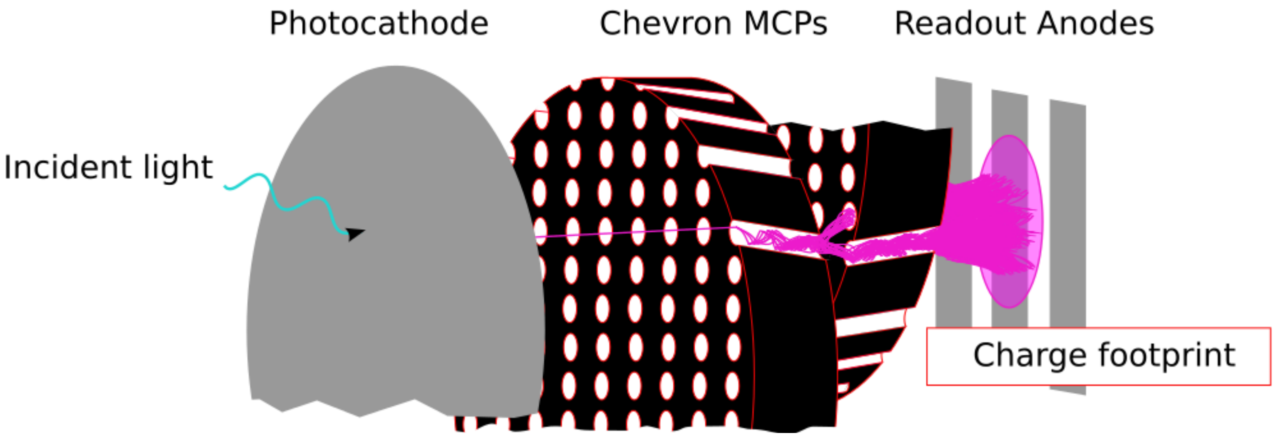
- radiation hardness
- enhanced lifetime
- restricted wavelengths by band pass filter 360-465 nm (reduced dispersion and enhanced tube lifetime)
- magnetic field strength and orientation
- anode 3x100 strips, 2 inch

PANDA magnetic field




Segmented Anode

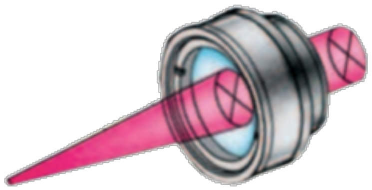


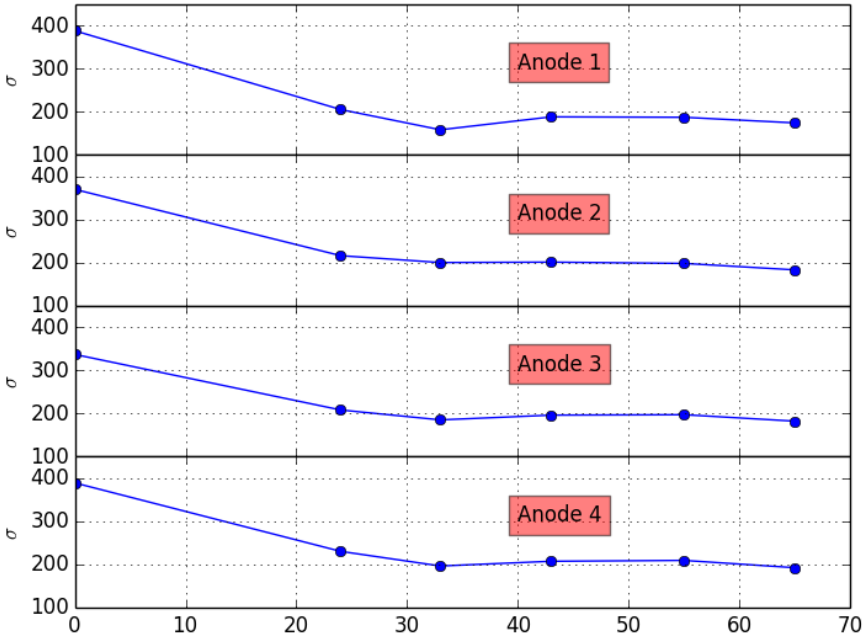



B-Field guides charge cloud and reduces charge sharing

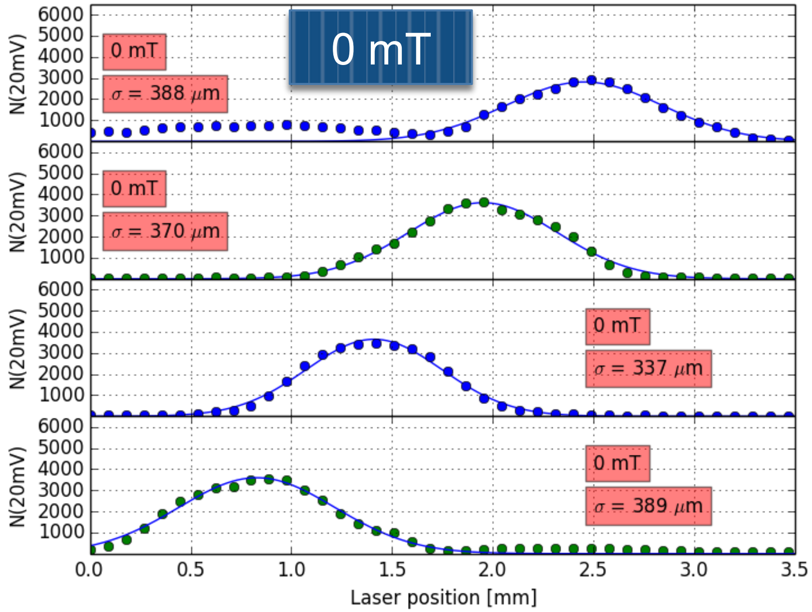
# Scan of laser spot on MCP-PMT



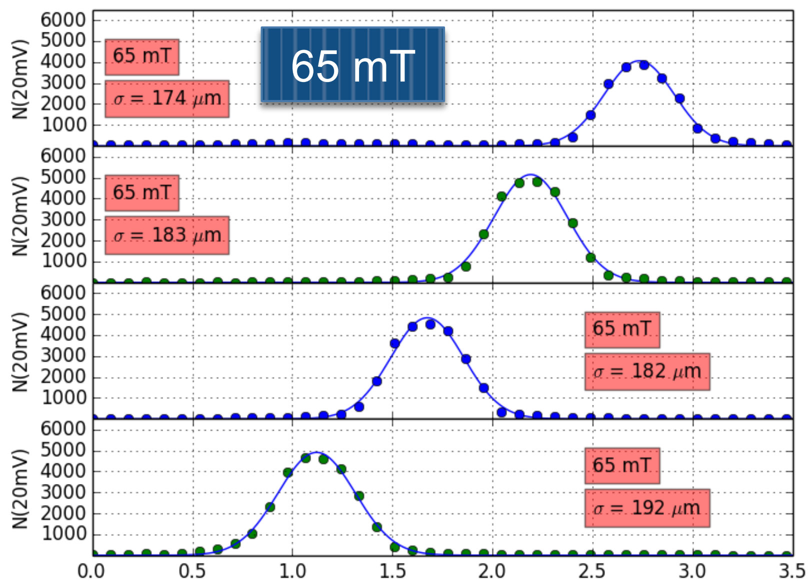





Magnetic Field (mT)




Anode
1
2
3
4

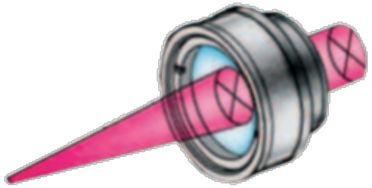


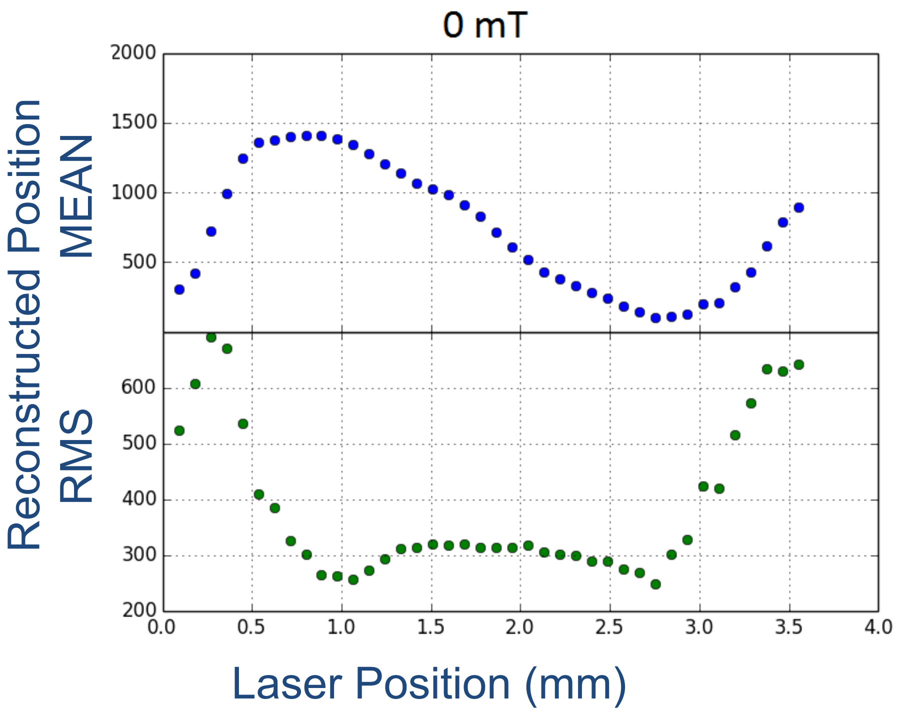

Anode
1
2
3
4

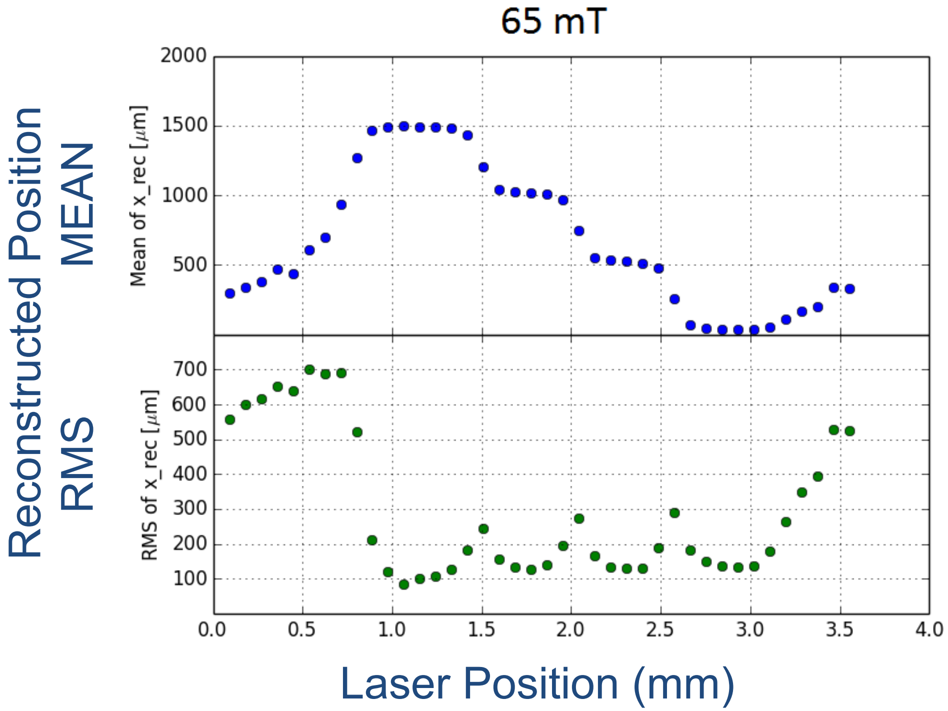
Laser Position (mm)

# Charge cloud vs. magnetic field

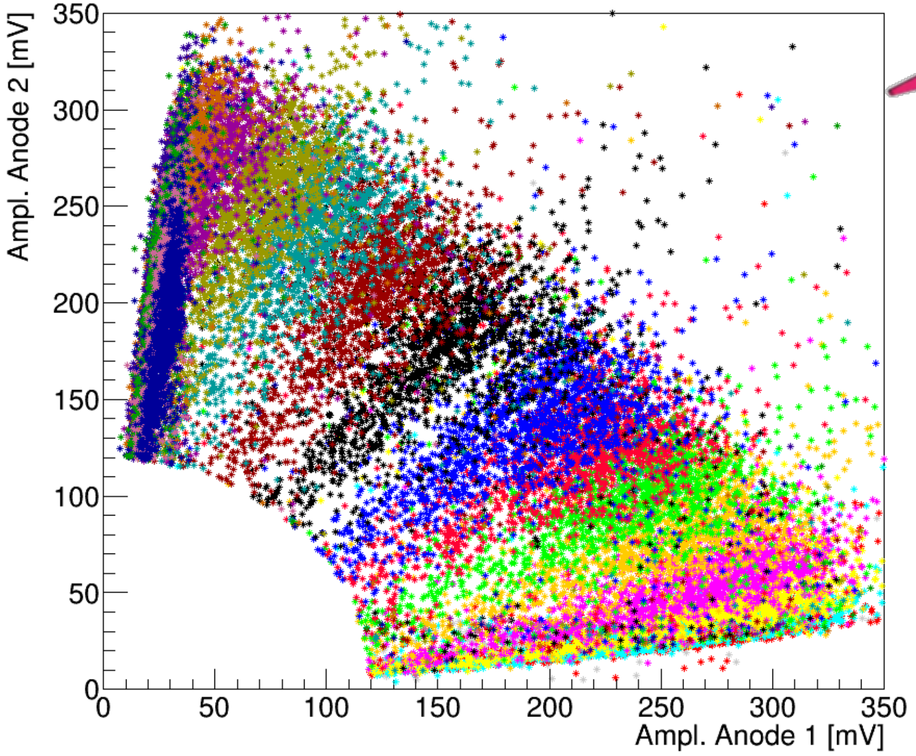
- PHOTONIS 3x100 2”
- 4 neighbouring anodes
- position reconstruction from measured charge ratio

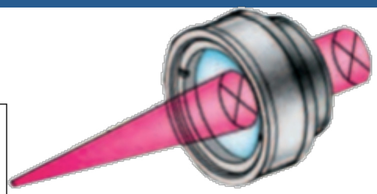


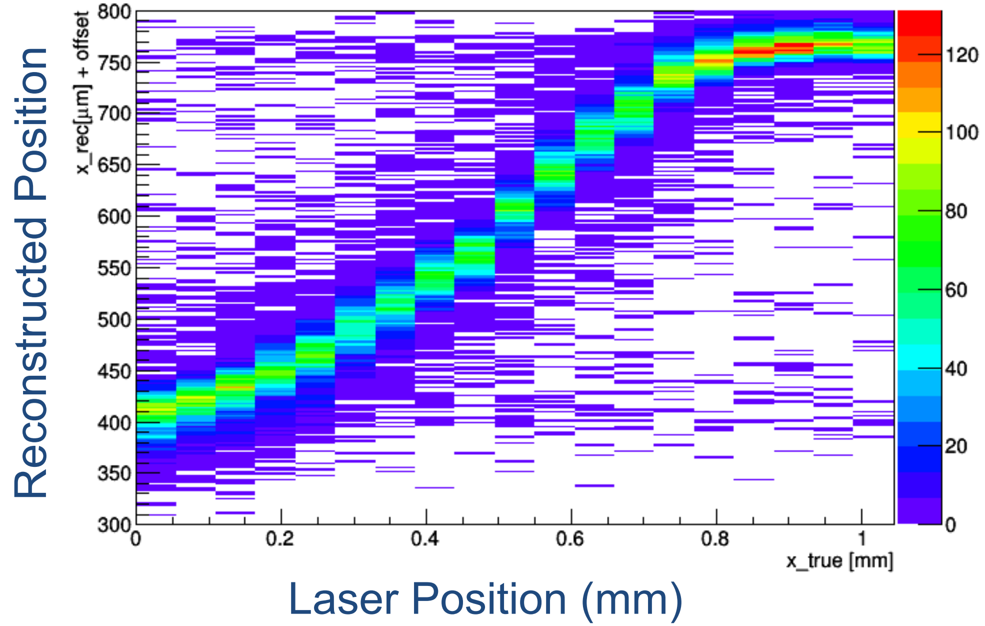


# MCP-PMT Position Resolution (Hamamatsu)





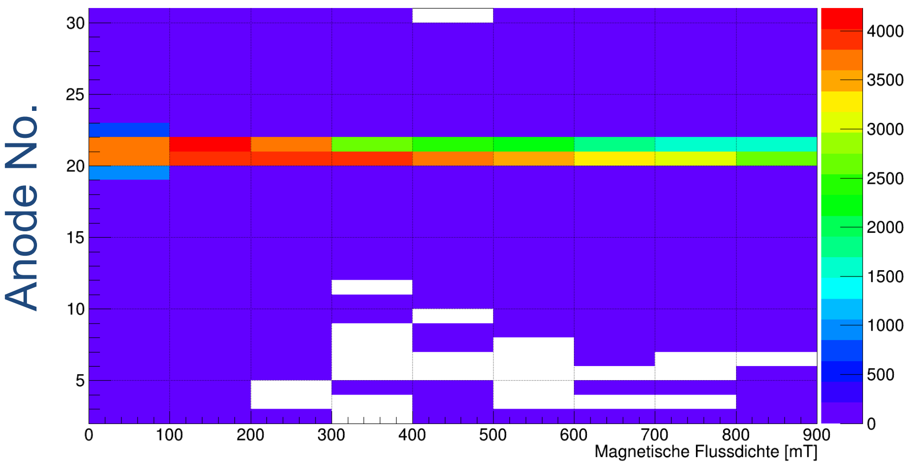

2 neighbouring anodes:
Anode 2 vs. Anode 1

Colour = Laser position

Reconstruction from measured charge ratio
Field=65mT
High position resolution

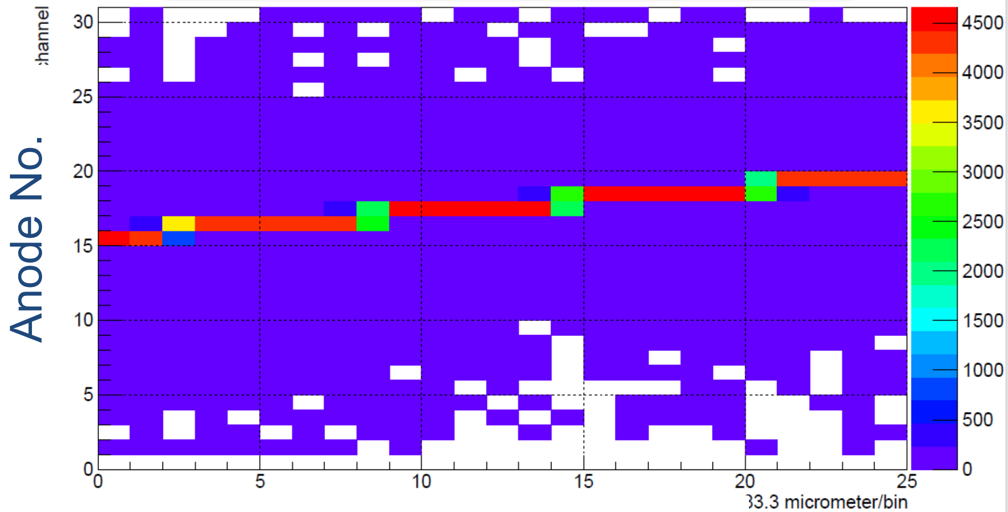
# Magnetic field dependence; TOFPET readout

Gain drops with field strength!

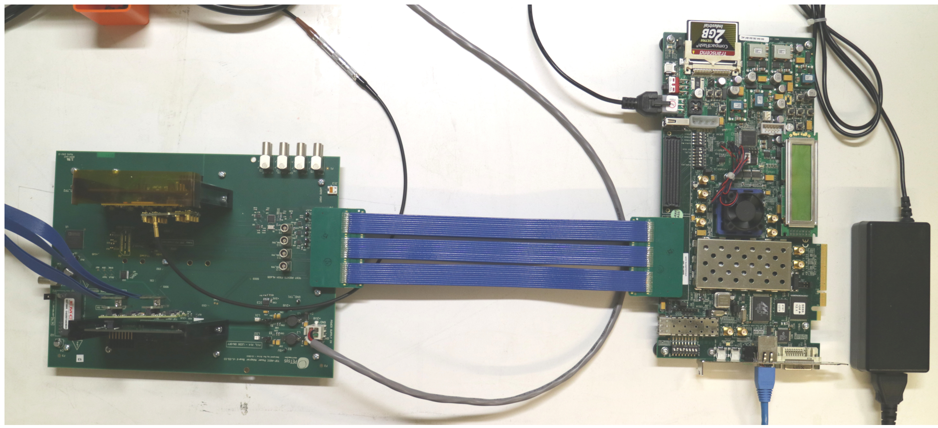


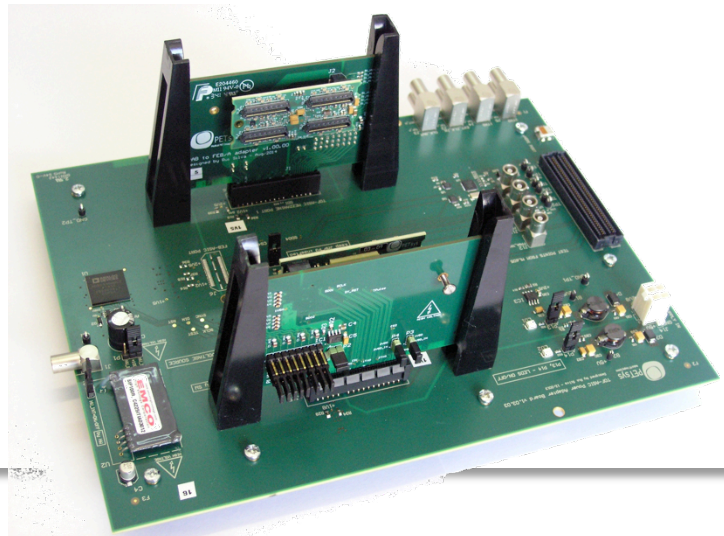

Magnetic Field (mT)

charge cloud << pitch @ 800 mT




Laser Position (mm)

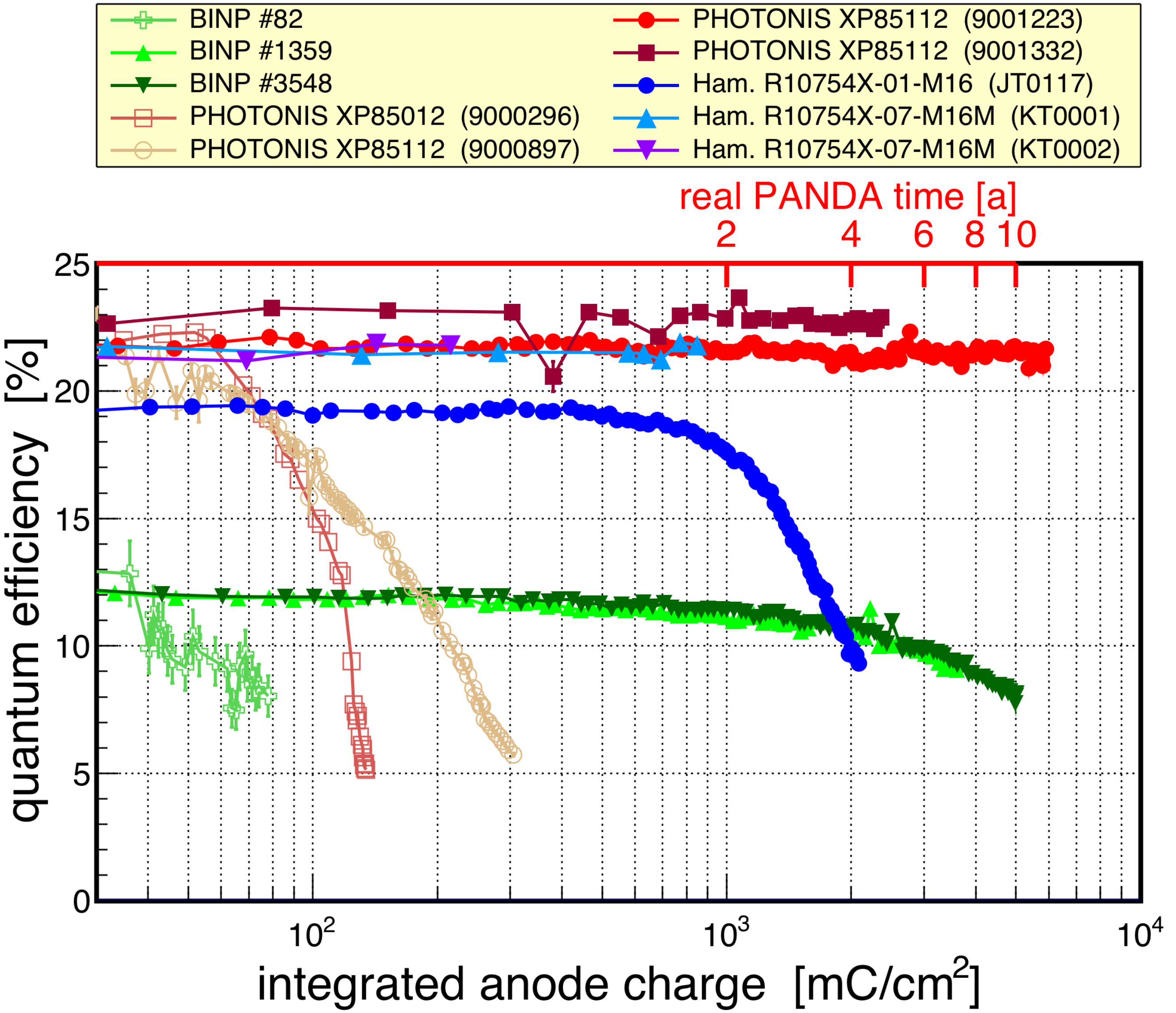




TOFPET Readout

# Lifetime studies and rate capabilities … (Talk by Albert Lehmann)

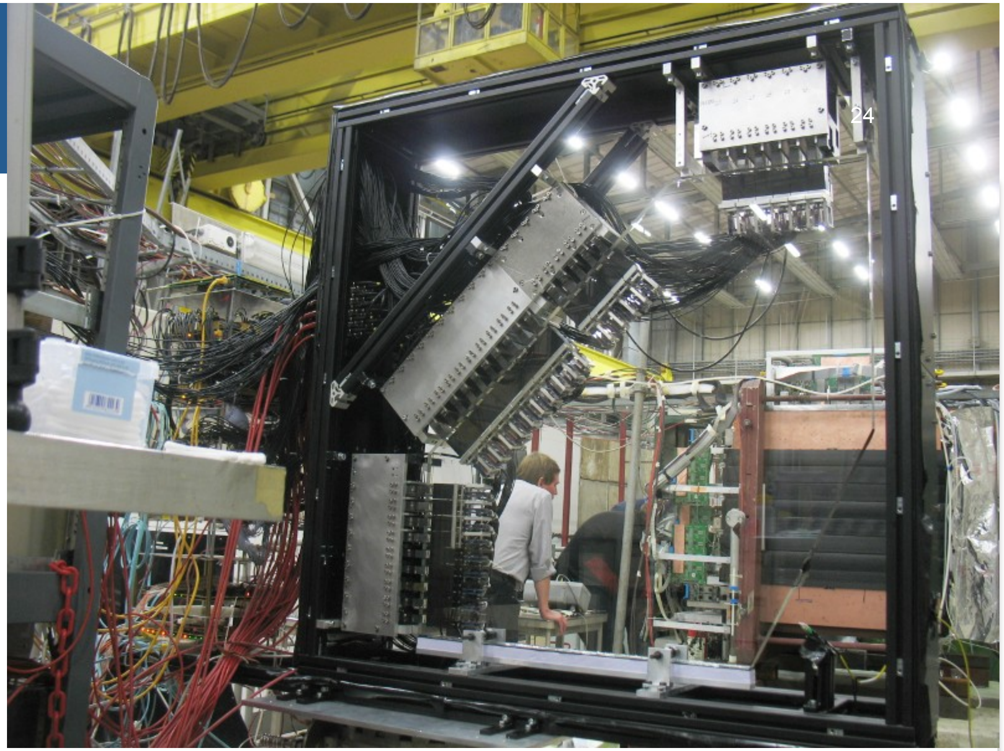


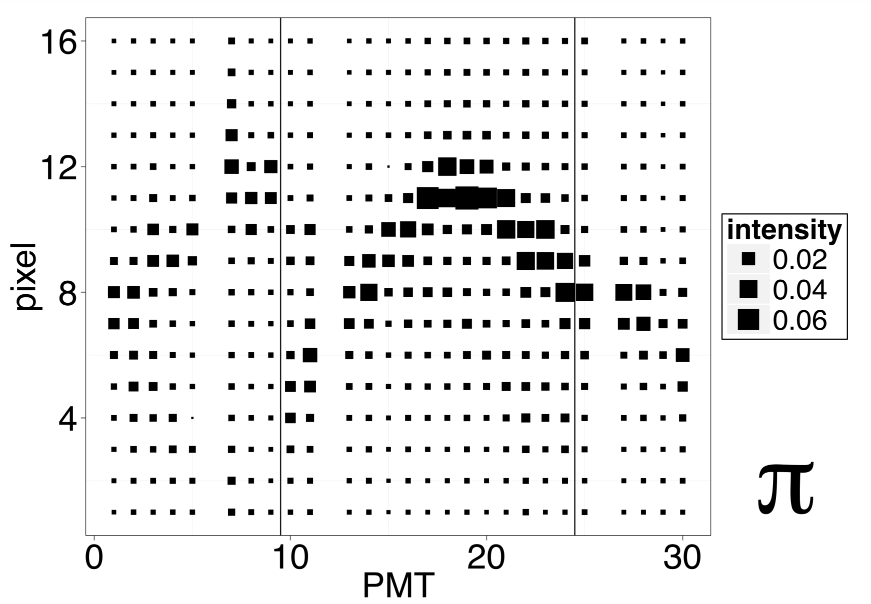


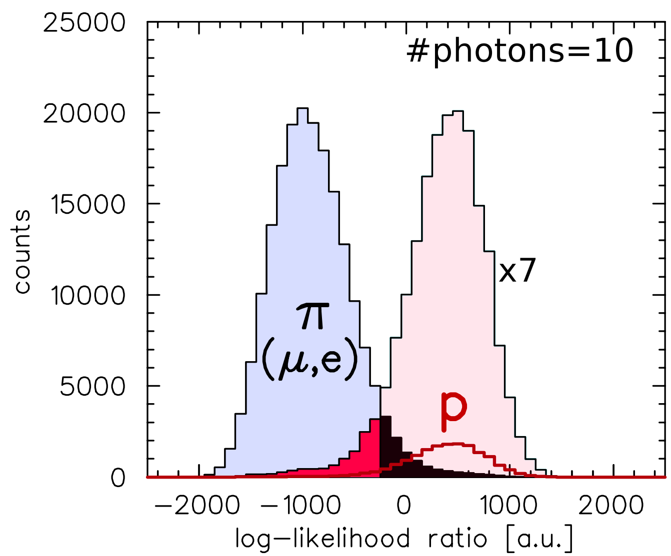
# Test Beam CERN 2012: First PID results

Radiator: float glass
FLGs: acrylic glas

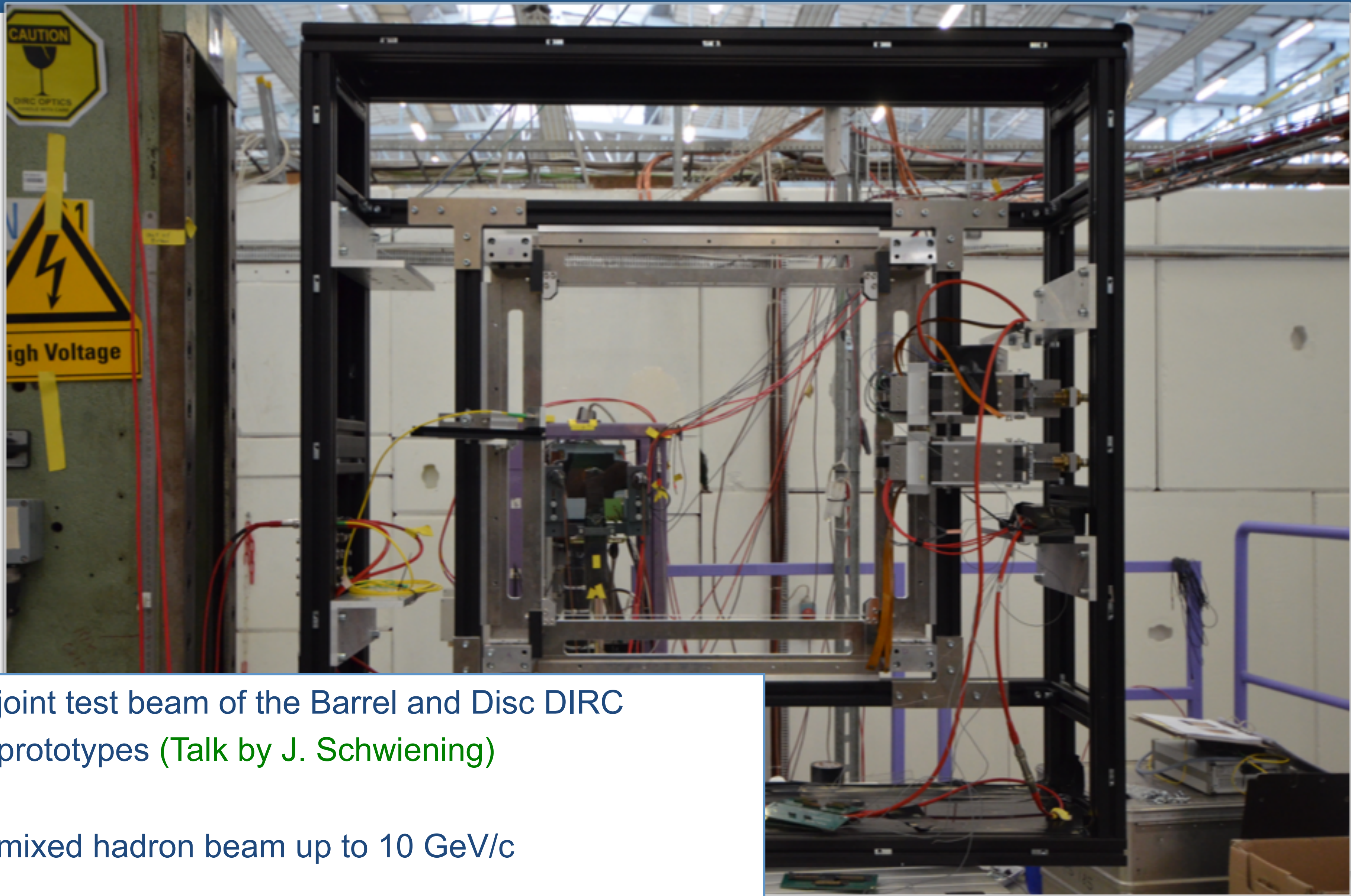
30x 16-channel MA-PMTs
480x readout channels



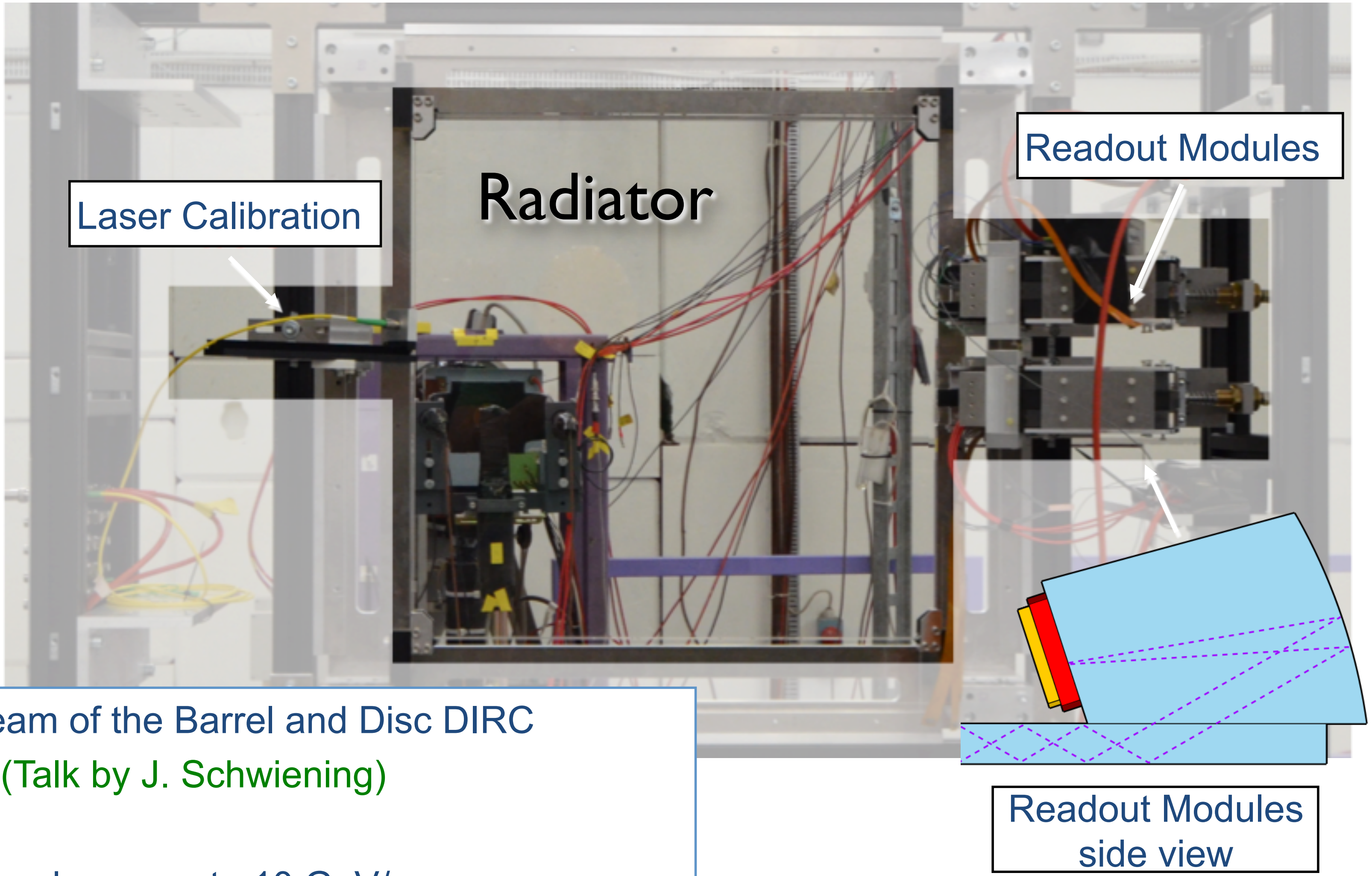



# Fused Silica Prototype: Test Beam CERN 2015: Resolution Studies




- joint test beam of the Barrel and Disc DIRC prototypes (Talk by J. Schwiening)
- mixed hadron beam up to 10 GeV/c
- common system for data taking (TRBv3)

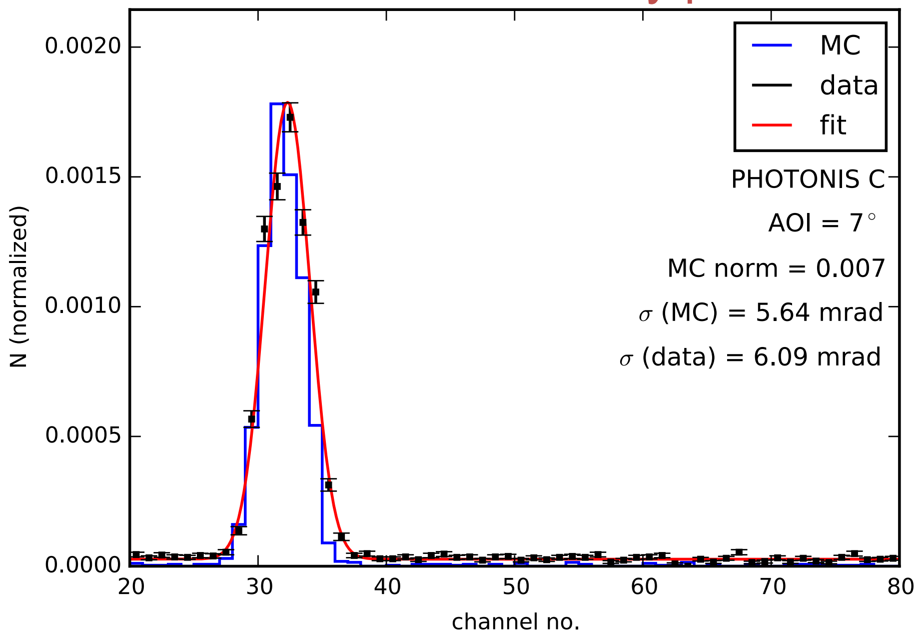
# Fused Silica Prototype: Test Beam CERN 2015: Resolution Studies

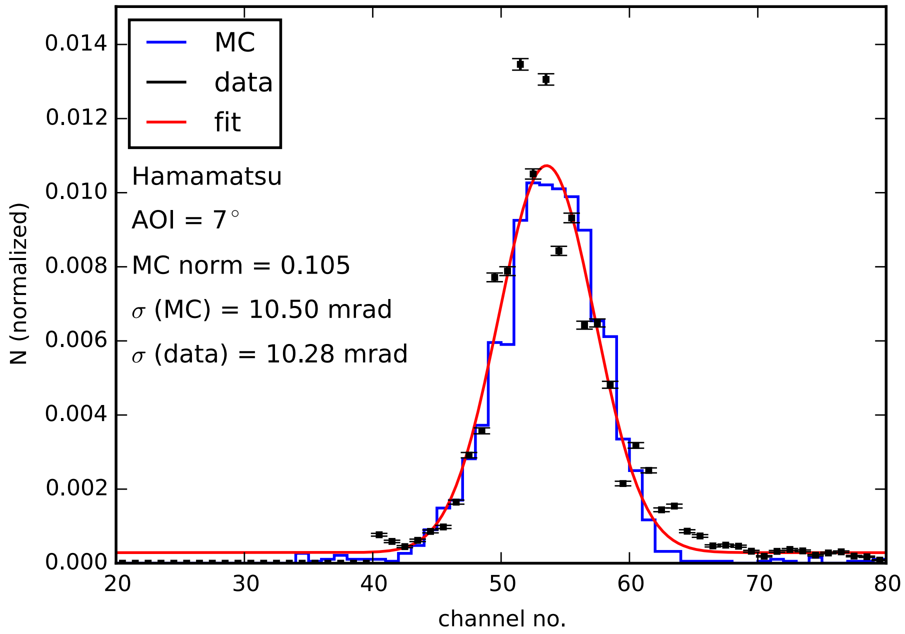


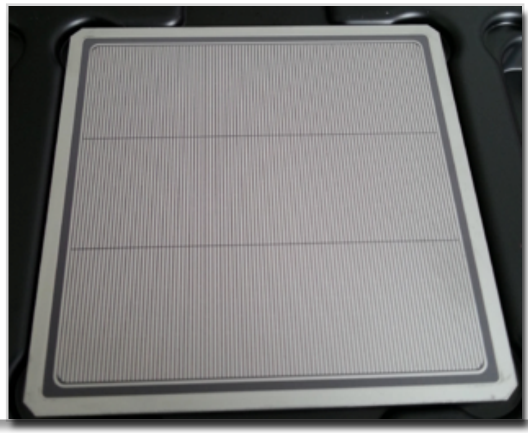

- joint test beam of the Barrel and Disc DIRC prototypes (Talk by J. Schwiening)
- mixed hadron beam up to 10 GeV/c
- common system for data taking (TRBv3)

# Fused Silica Prototype: Results of Resolution Studies

## Resolution limited by position and resolution of beam

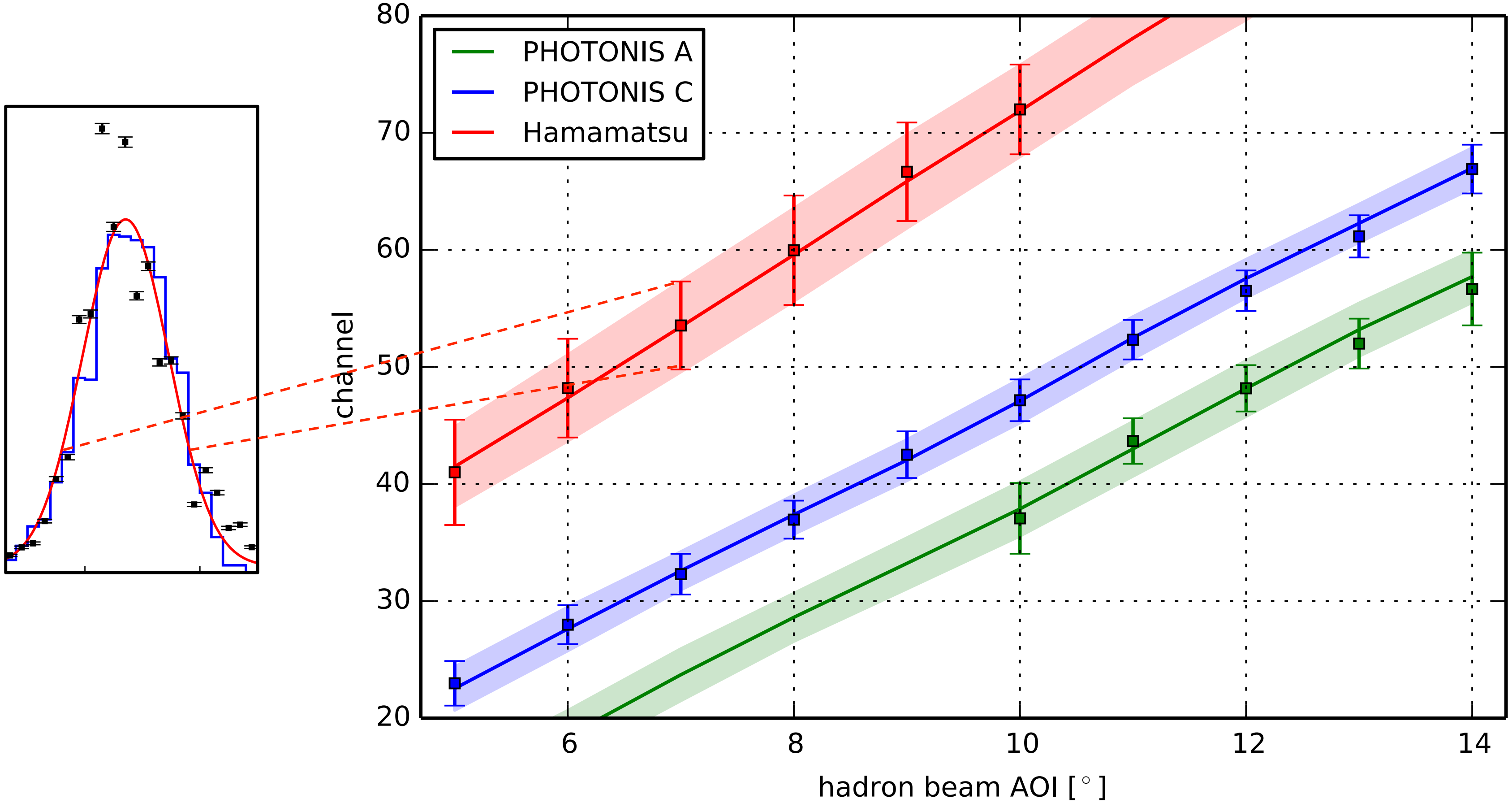


- 10 GeV/c mixed hadron beam
- 7° angle of incidence
- Single-photon resolution confirmed

# Fused Silica Prototype: Test Beam CERN 2015: Resolution Studies

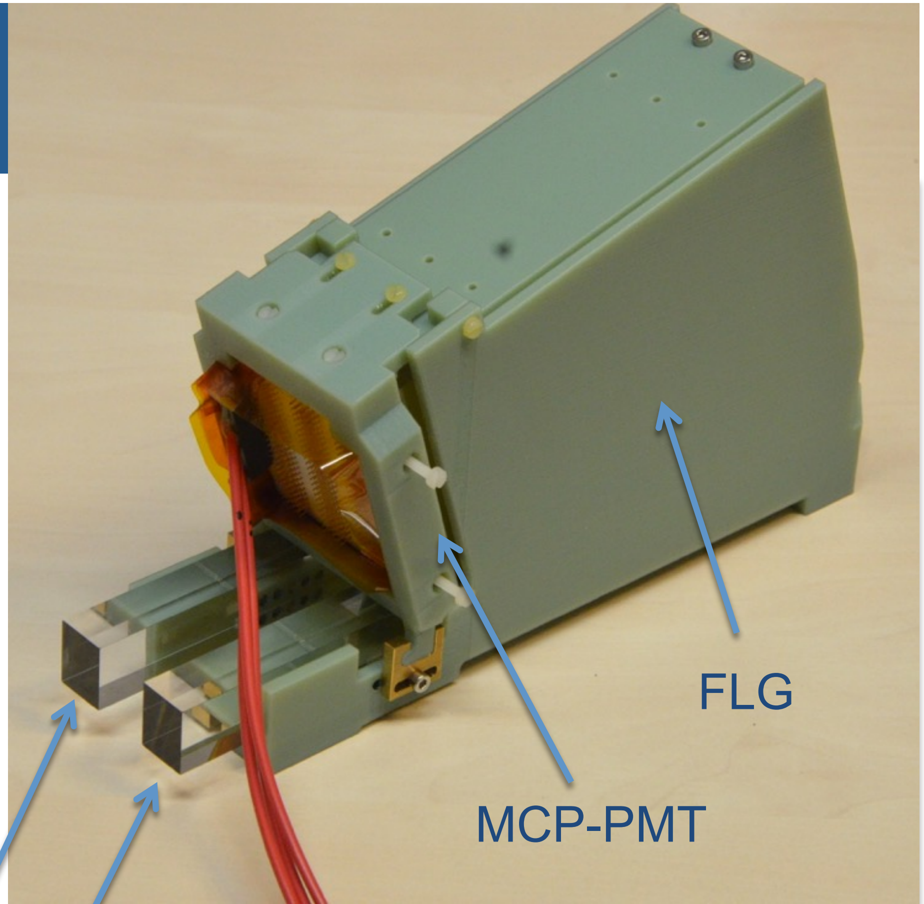



* Mean and single photon resolution for different hadron angles @10 GeV/c

* Position and resolution agree with simulation

# Outlook: Test Beam DESY Oct. 2016

- 3D printed readout modules
- quartz optics (50x50 cm$^2$ plate)
- precise electron beam (position & angle)
- TOFPET readout system




Aim:

Measure single photon resolution and photon yield

# Summary and Outlook

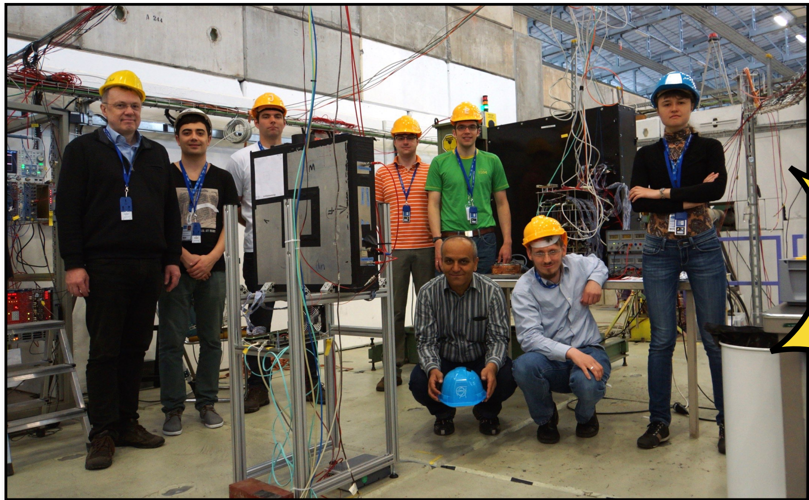


- fused silica prototype has been constructed and tested
- emission angles of individual Cherenkov photons have been measured with a precision of 6-12 mrad (They are limited by test beam setup)
- a new prototype is under construction and will be tested in Oct. 2016

Acknowledgements:

Work was mainly done by our students!

Thanks to the organizers of RICH2016 in Slovenia!



thank you for your attention