The PANDA time-of-propagation DISC DIRC

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JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

Workshop on fast Cherenkov detectors
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panda

Structure of the Giessen Panda DIRC group

Simulation:
Peter Koch

Reconstruction:
Oliver Merle

Electronics and Readout:
Benno Kröck, Christof Kreutzfeldt

Optics:
Marko Zühlsdorf

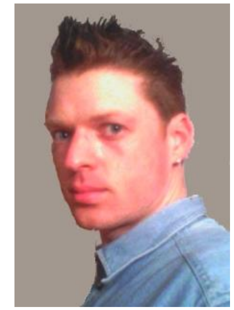
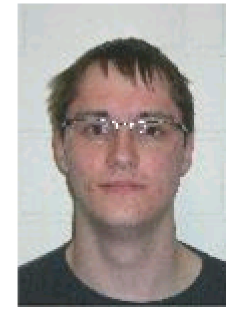
Test experiments:
all + Michael Sporleder

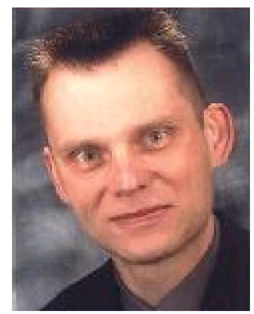
Physics simulation:
Irina Brodski

Mechanical Design:
Thomas Wasem

Advisory committee ☺:
Michael Düren, Klaus Föhl,
Avetik Hayrapetyan

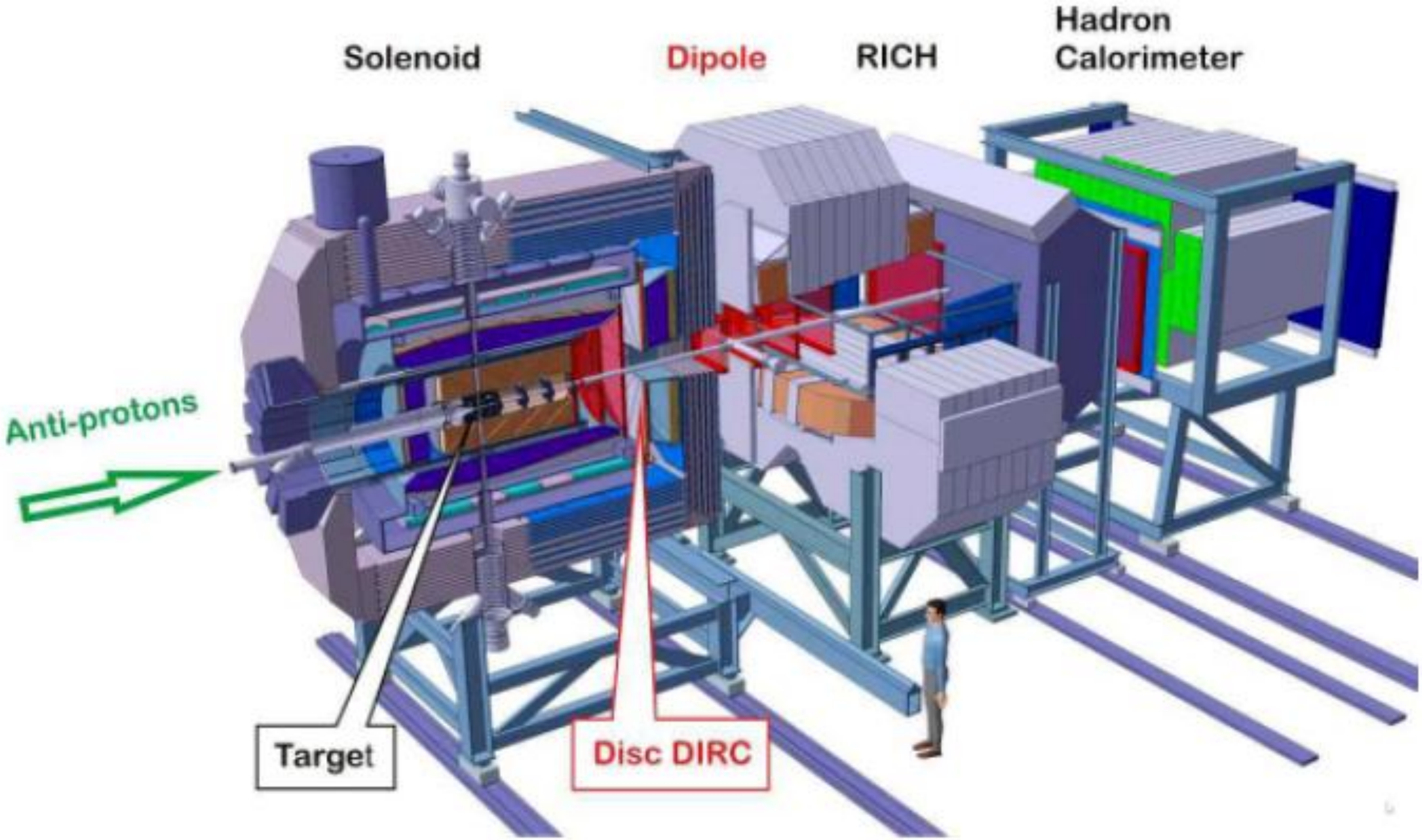


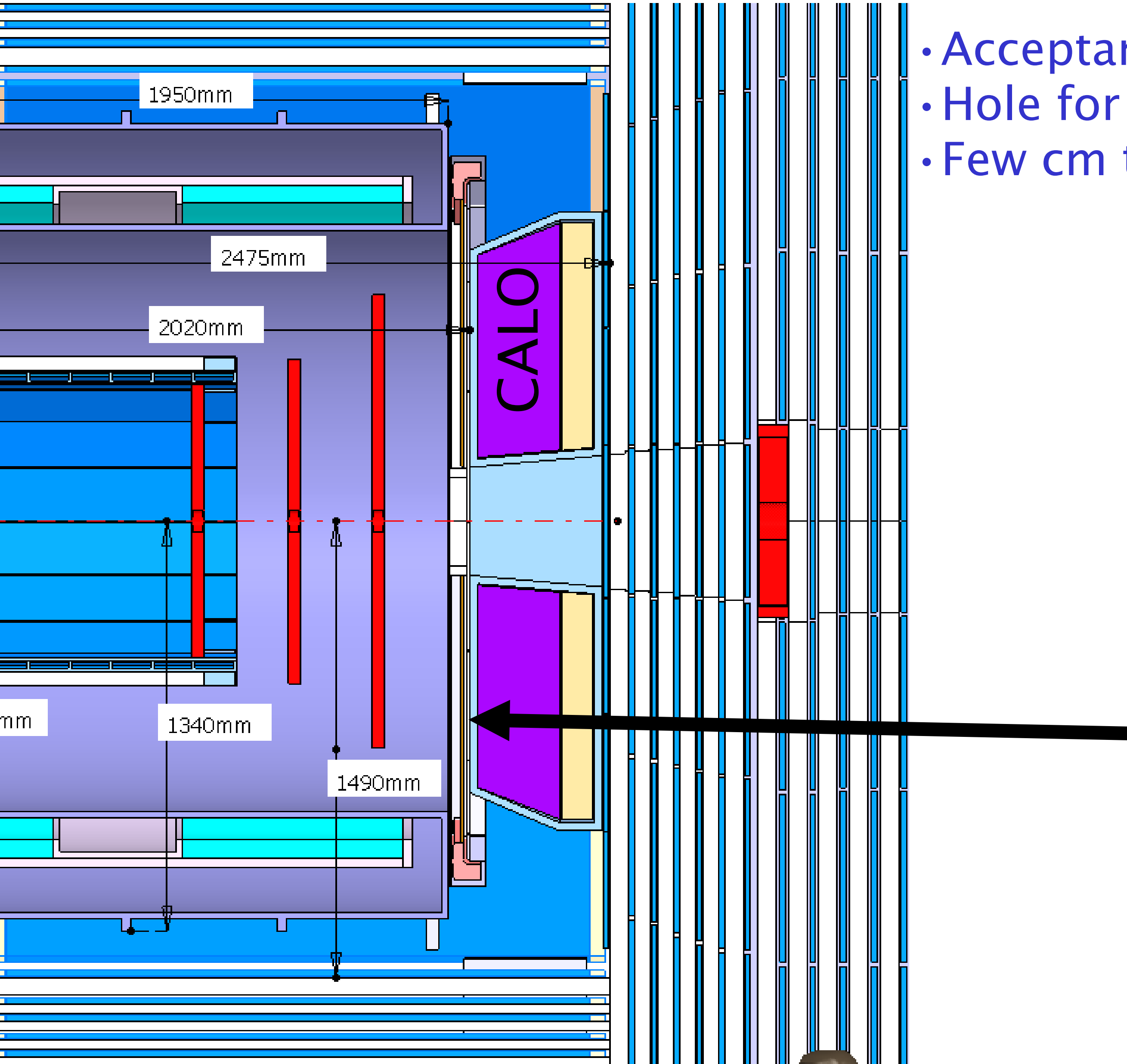




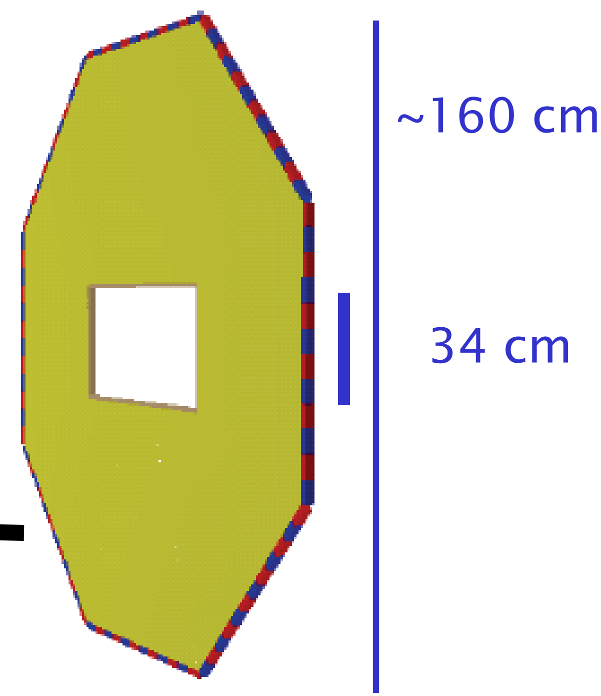

Disc DIRC: Geometry



DISC-DIRC: Geometry



- Acceptance: 5°–22°
- Hole for forward spectrometer
- Few cm thickness (2 cm plate)



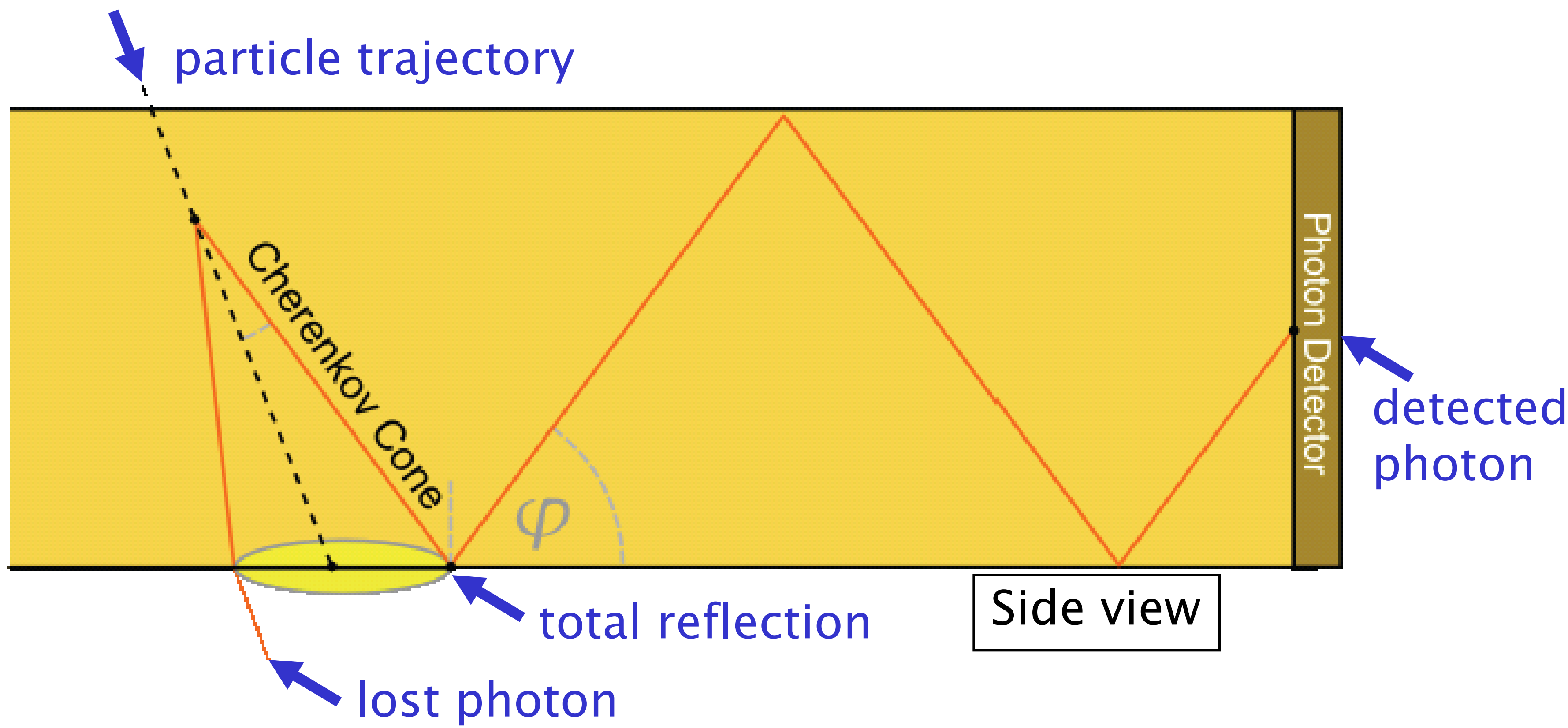
Disc DIRC: Requirements

- Pion–Kaon–(Proton) separation: ~ 1– 4 GeV
- Particle multiplicity in DISC: average ~ 1– 2.5
- Event rates: ~2–20 MHz (+background)
- Photons per track on rim: ~200 (+background)
- Photons on rim ~ $10^{13}/cm^2/yr$
- Radiation dose at disc center ~100krad
- Radiation dose at rim ?
- Magnetic field at rim ~0.5–1 T

Principle of a TOP-DIRC

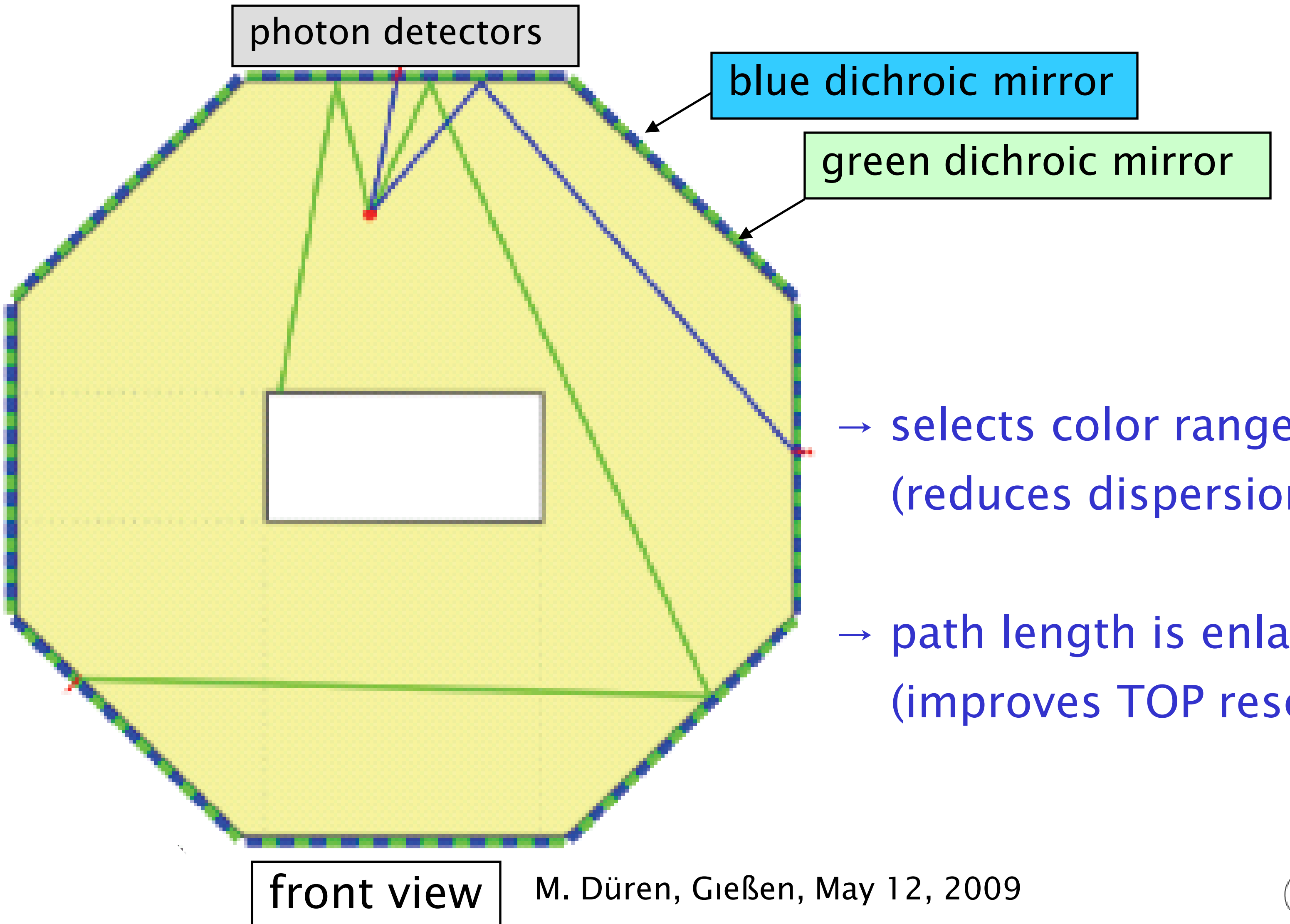
- Particle trajectory is known (position and angle)
- Photon path length depends on Cherenkov angle

→ time of propagation depends on particle type



Principle of the Giessen TOP-DIRC

- Dichroic mirrors at the rim in front of photon detectors

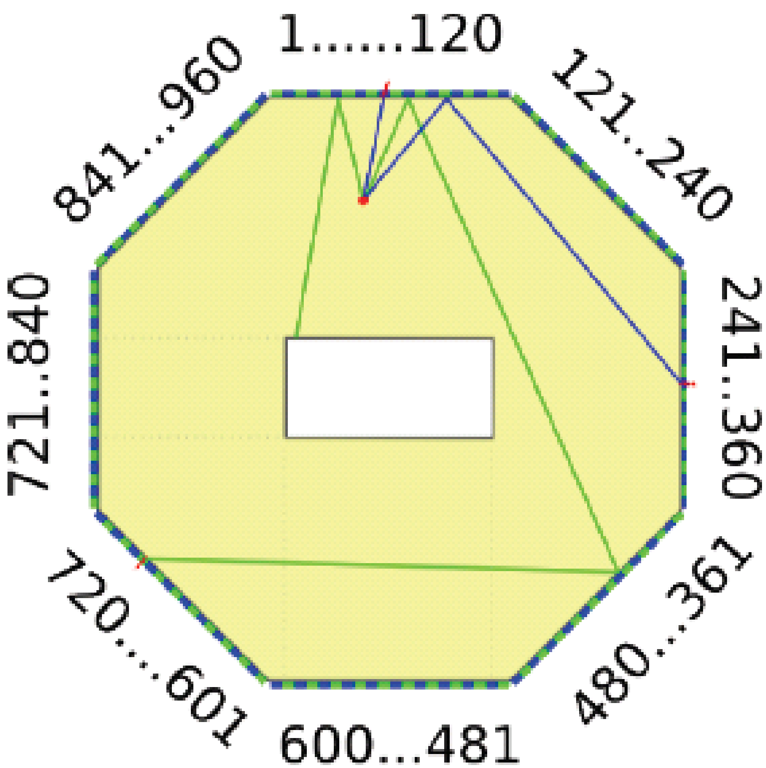


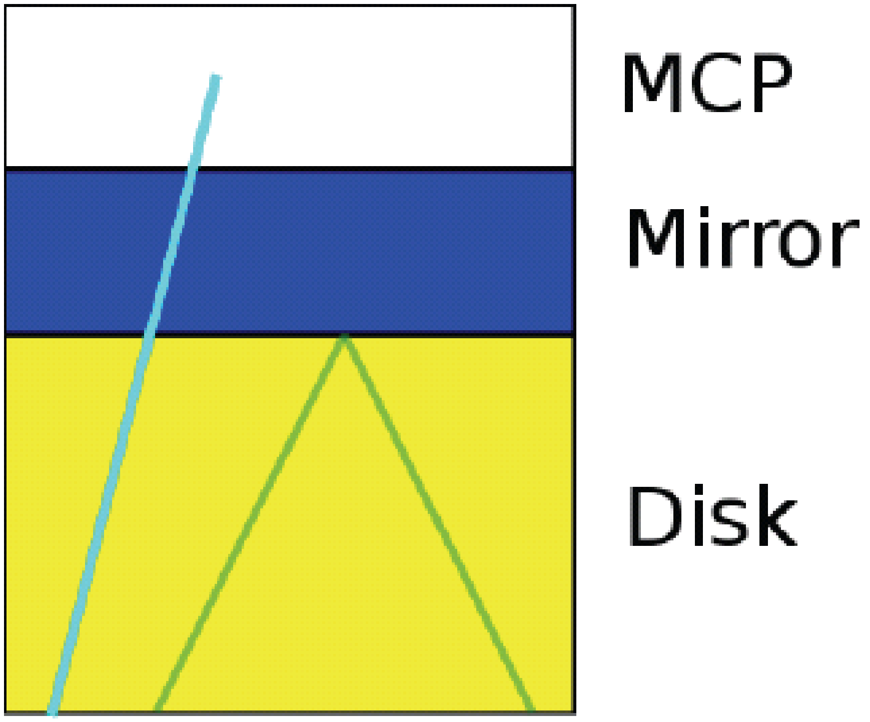
→ selects color ranges (reduces dispersion effects)

→ path length is enlarged (improves TOP resolution)

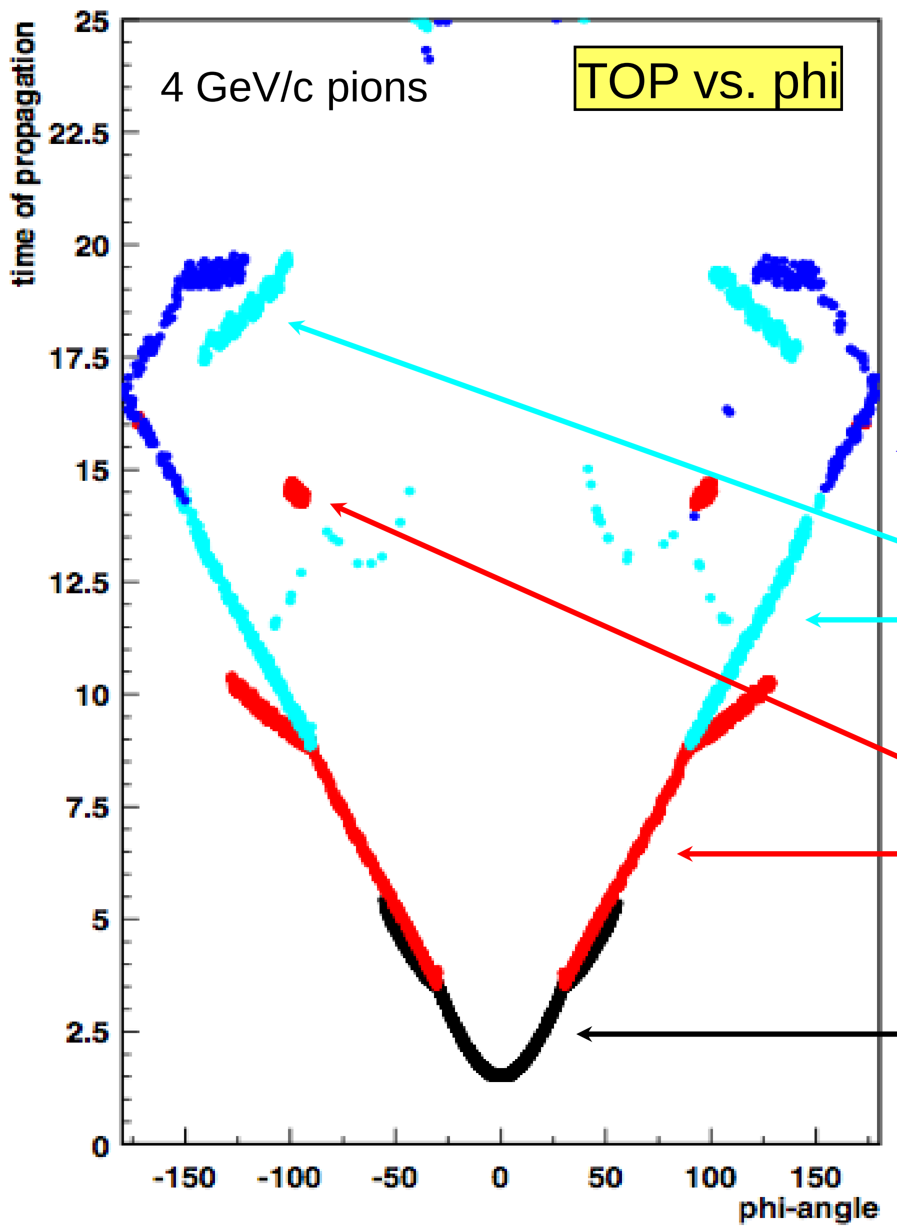
Hexagonal disc with dichroic mirrors

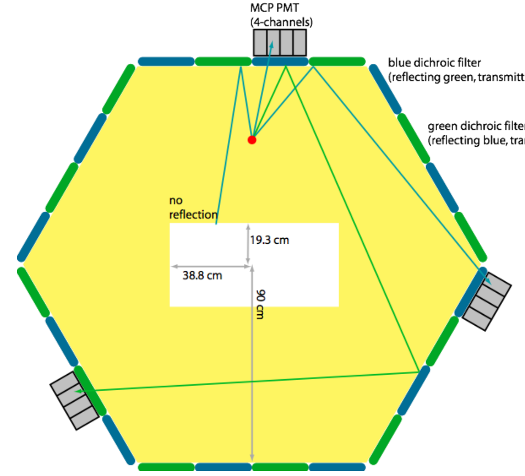
- Very simple mechanical setup!





2-D photon hit pattern





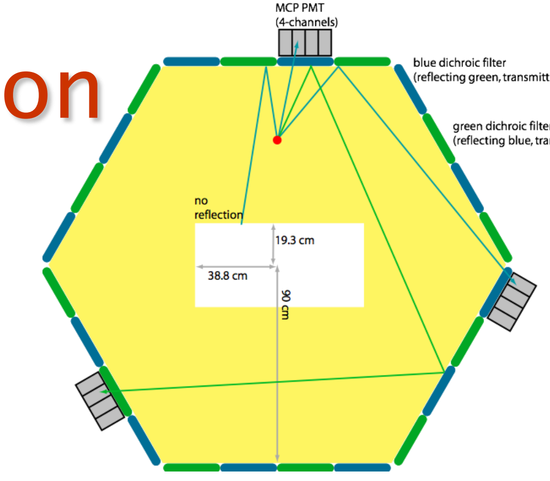
photons reflected three times

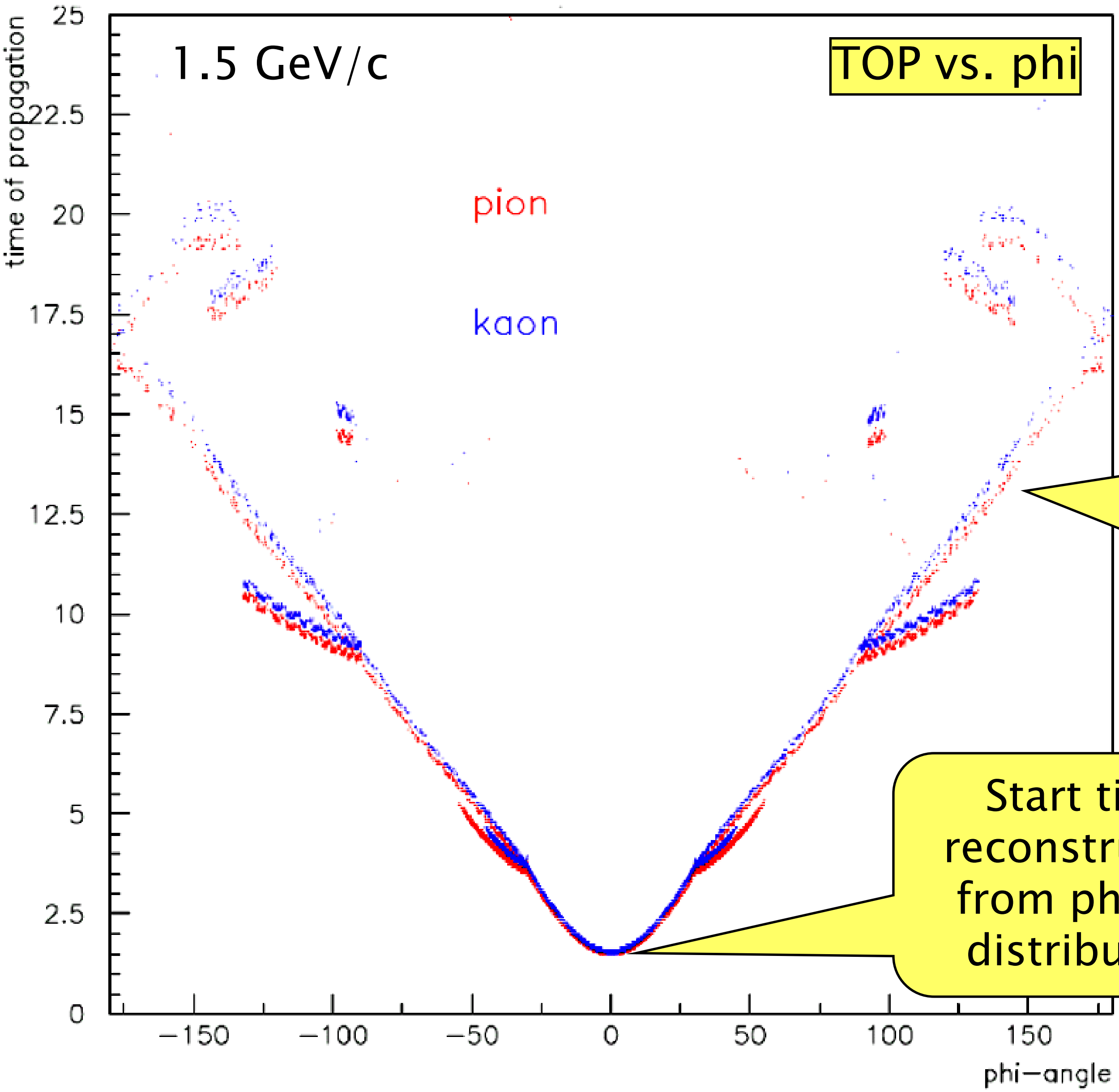
photons reflected two times

photons reflected one time

direct hits provide reference time

Principle of Pion–Kaon Separation



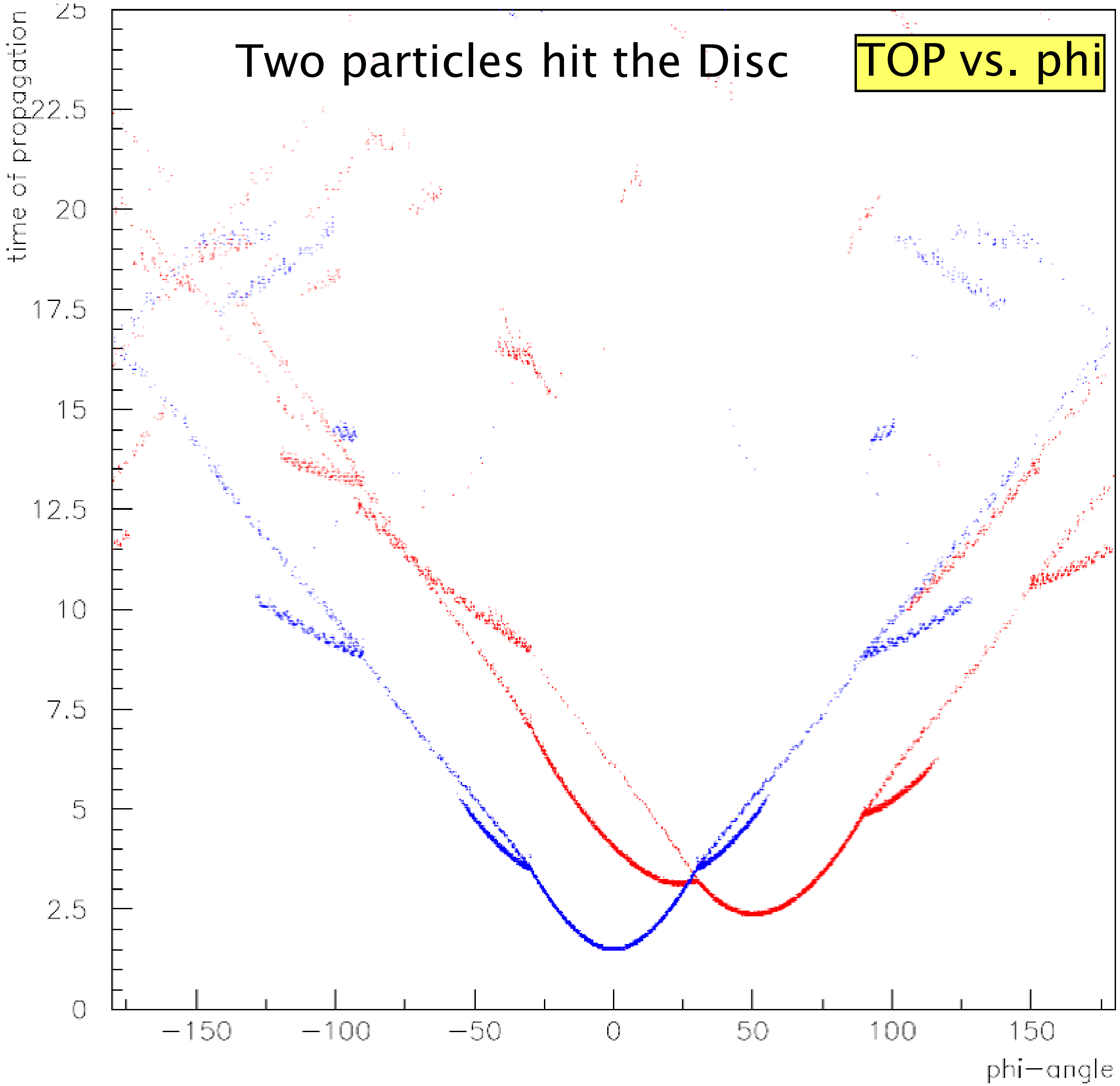


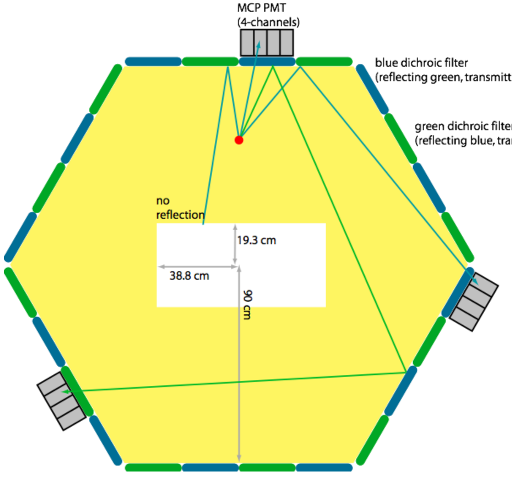
reconstruction software knows exactly where to expect the photons!

Start time reconstructed from photon distribution

Kaons and Pions are clearly separated at 1.5 GeV/c

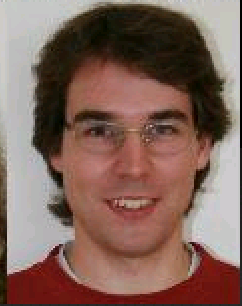
Multiple particle separation

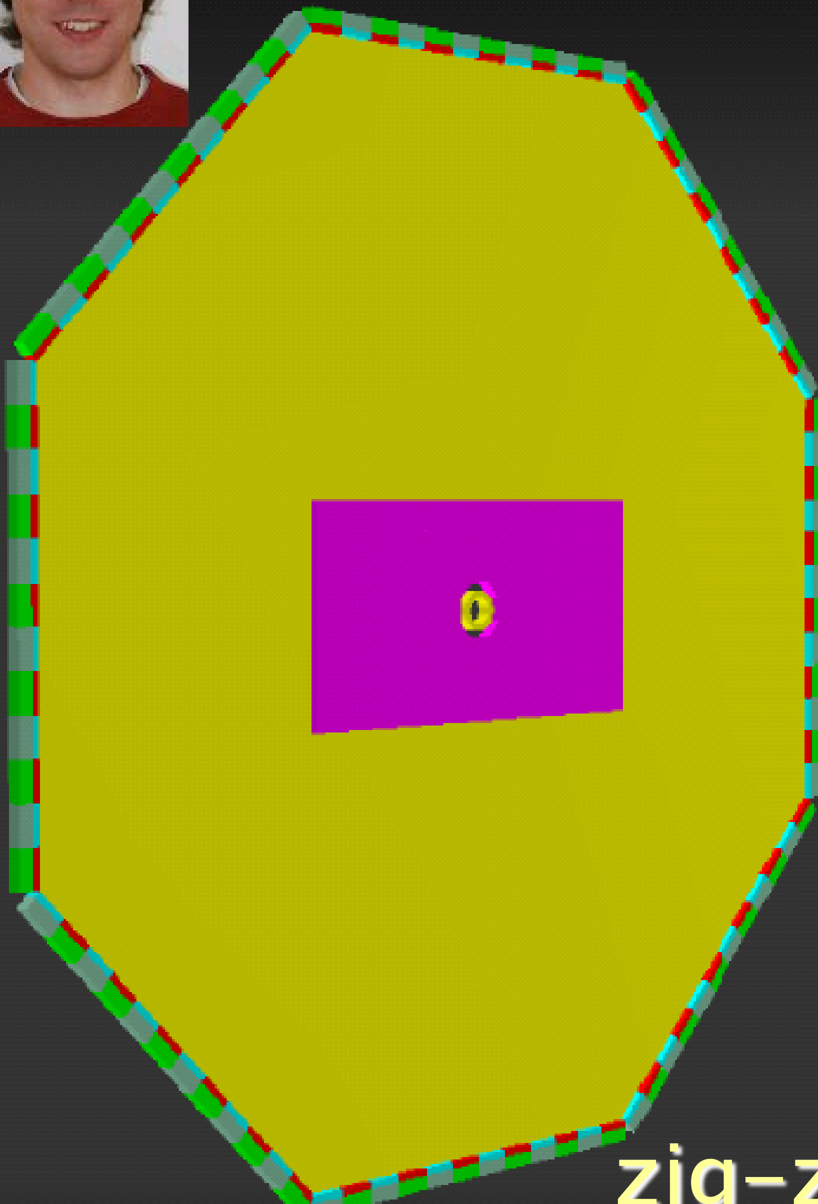


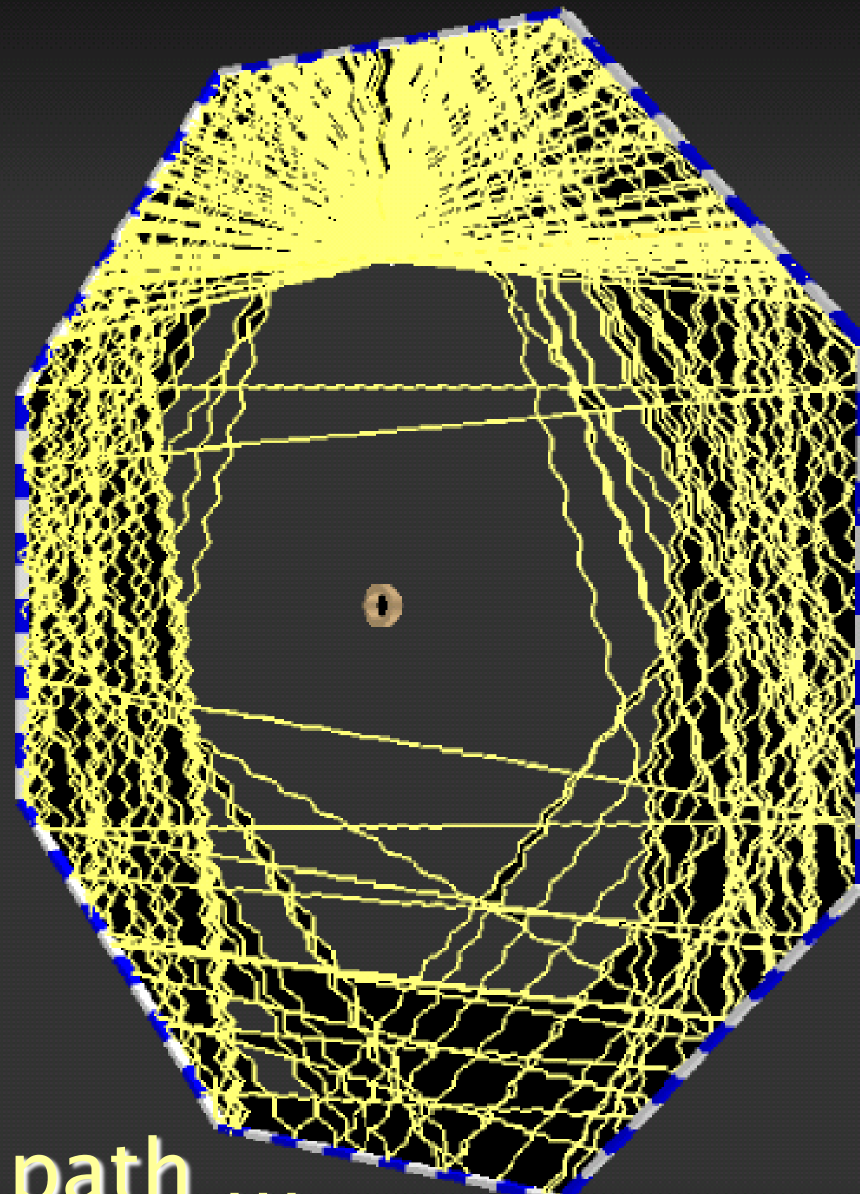


reconstruction software knows exactly where to expect the photons! (likelihood analysis will do PID)

Full GEANT/PandaRoot simulation

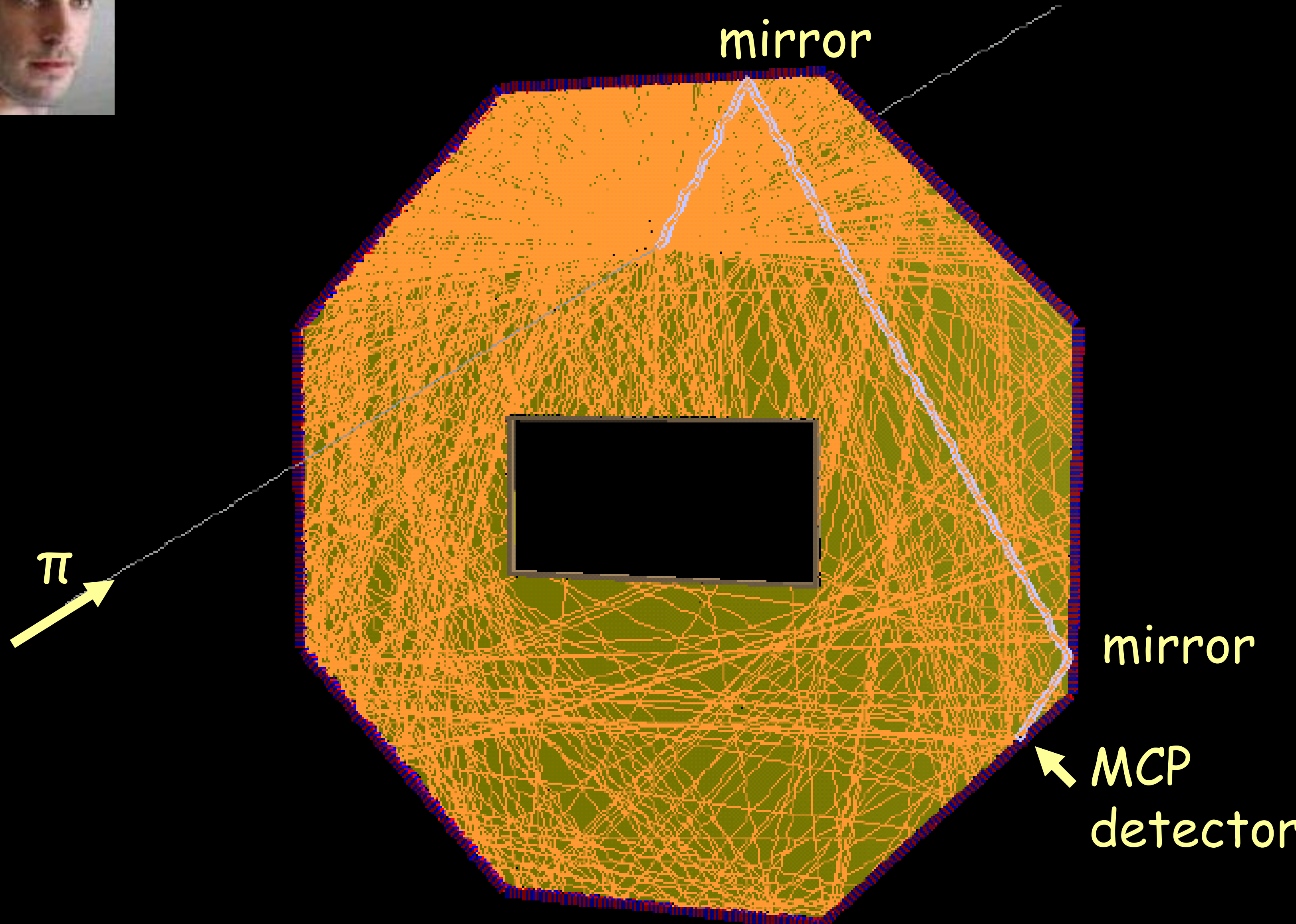






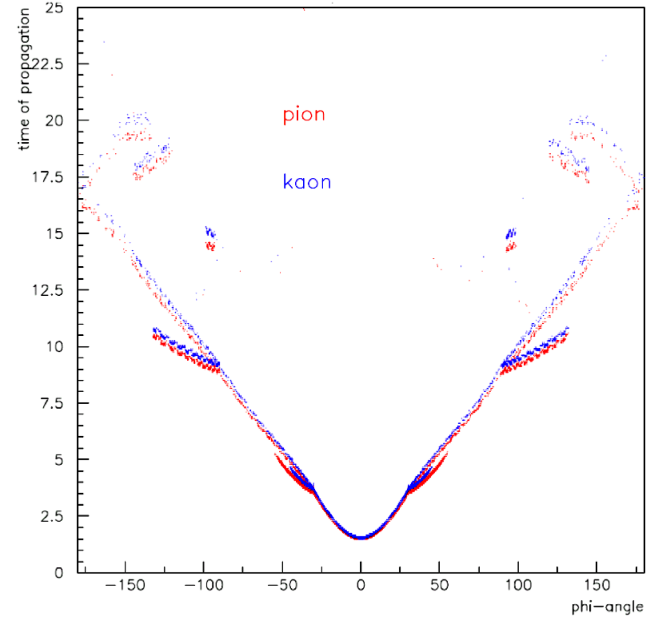
zig-zag path ...

Reconstruction software



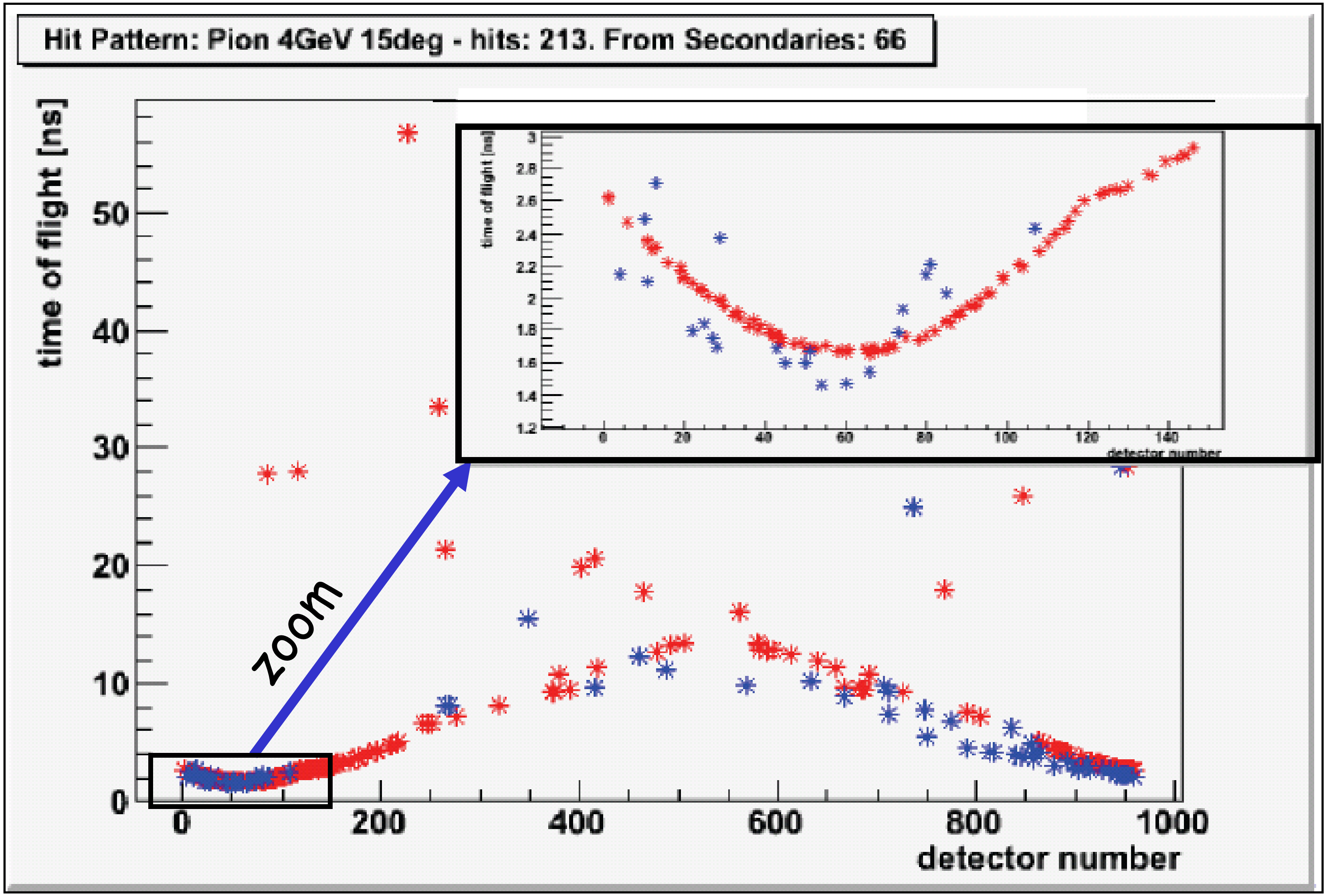
zig-zag path and projected path…

Reconstruction



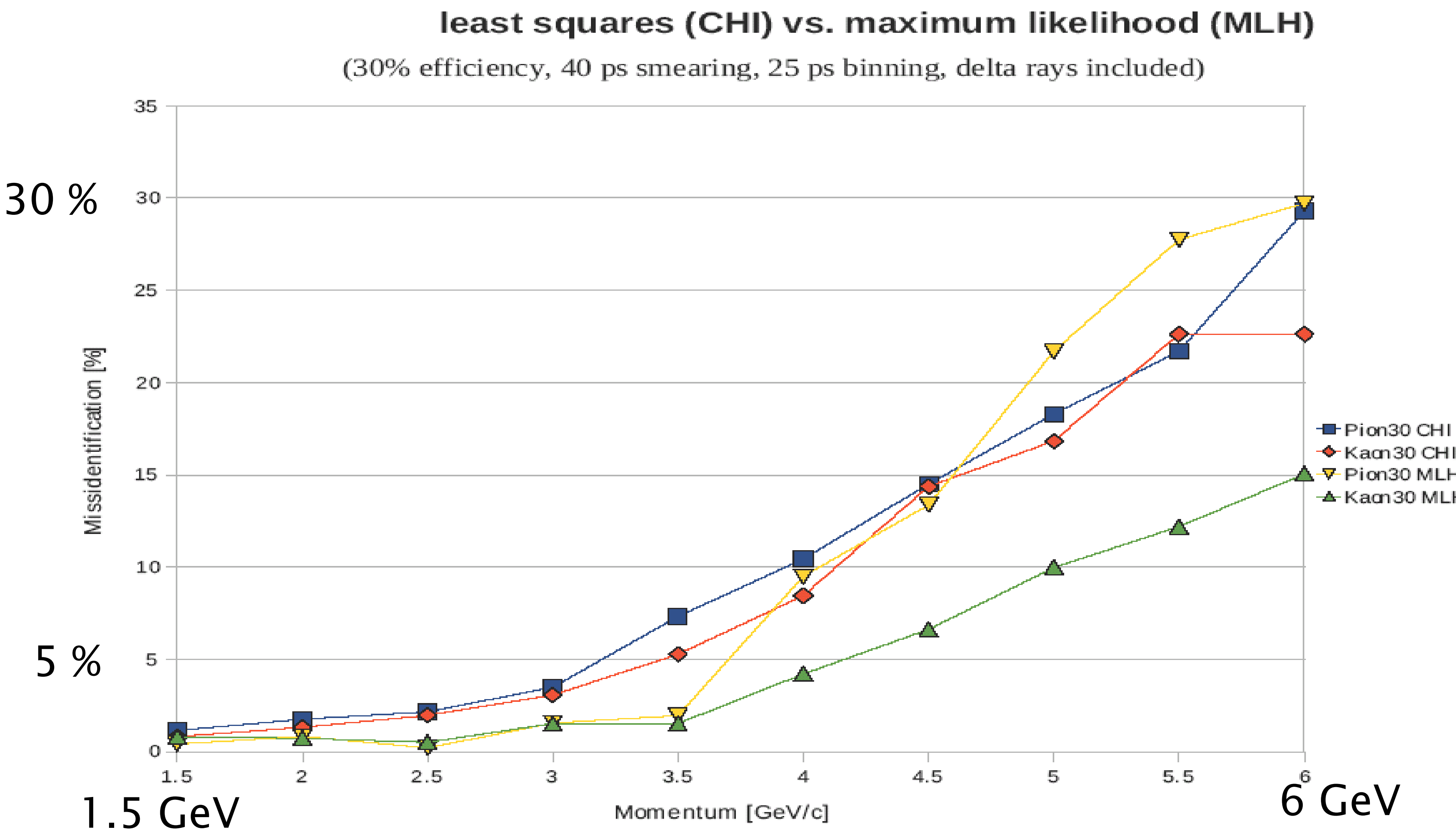
- See talk by Oliver Merle
- Principle: 1-dim pattern in 2-D plane
- Known pattern for pi and K
- Reconstruction of start time
- Large number of virtual ϕ-t pixels (~400,000 !)
- Likelihood method to decide which particle ID is more likely
- Distortions by geometry can be taken into account by calibration with large number of pion (kaon) patterns per second from experiment ! ?
- Challenges: rates, background, … (better than many other detectors in PANDA due to high time resolution)

Simulation and reconstruction with background!!!



Blue: Background from δ-electrons

Misidentification vs. momentum



Details in Oliver Merle's talk about DIRC reconstruction

Giessen TOP DIRC design

Features:

- Simple, compact & robust geometry, no complicated optics
- Dichroic mirrors
  - for wavelength separation
  - for path length enlargement
- Disc not round but octagonal
  (otherwise "trapping" of photons)
- Absorbing (or reflecting) beam hole (rectangular or elliptical)

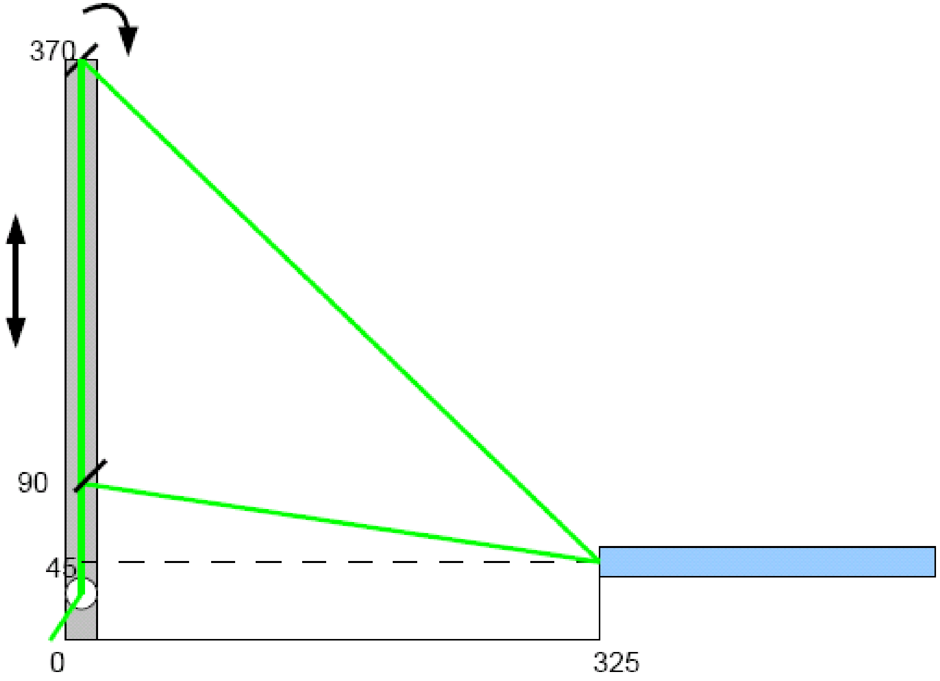
Difficulties:

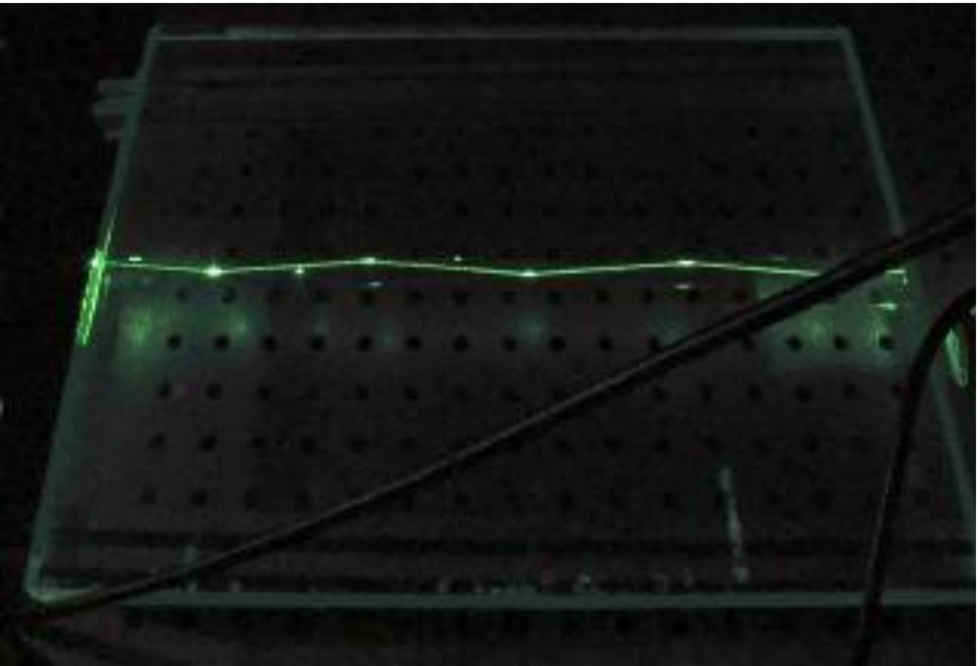
- ~50 ps time resolution needed
- Smearing due to uncertainty in point of emission (2 cm)
  (Partially compensated in TOP)
- Smearing due to dispersion effects
  (Fortunately, angular dispersion and group velocity dispersion cancel partially in TOP)

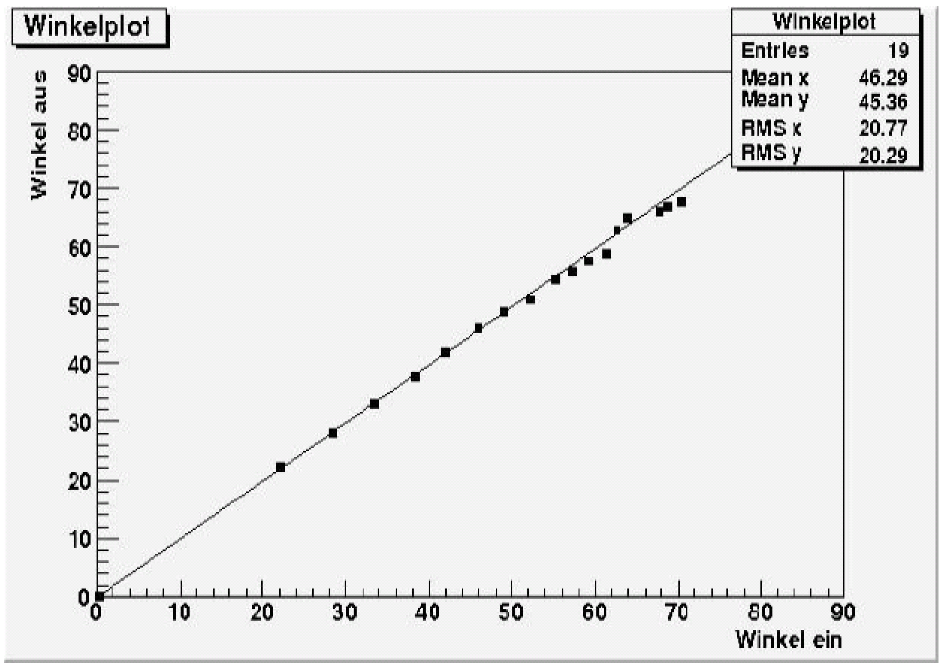
Optics tests

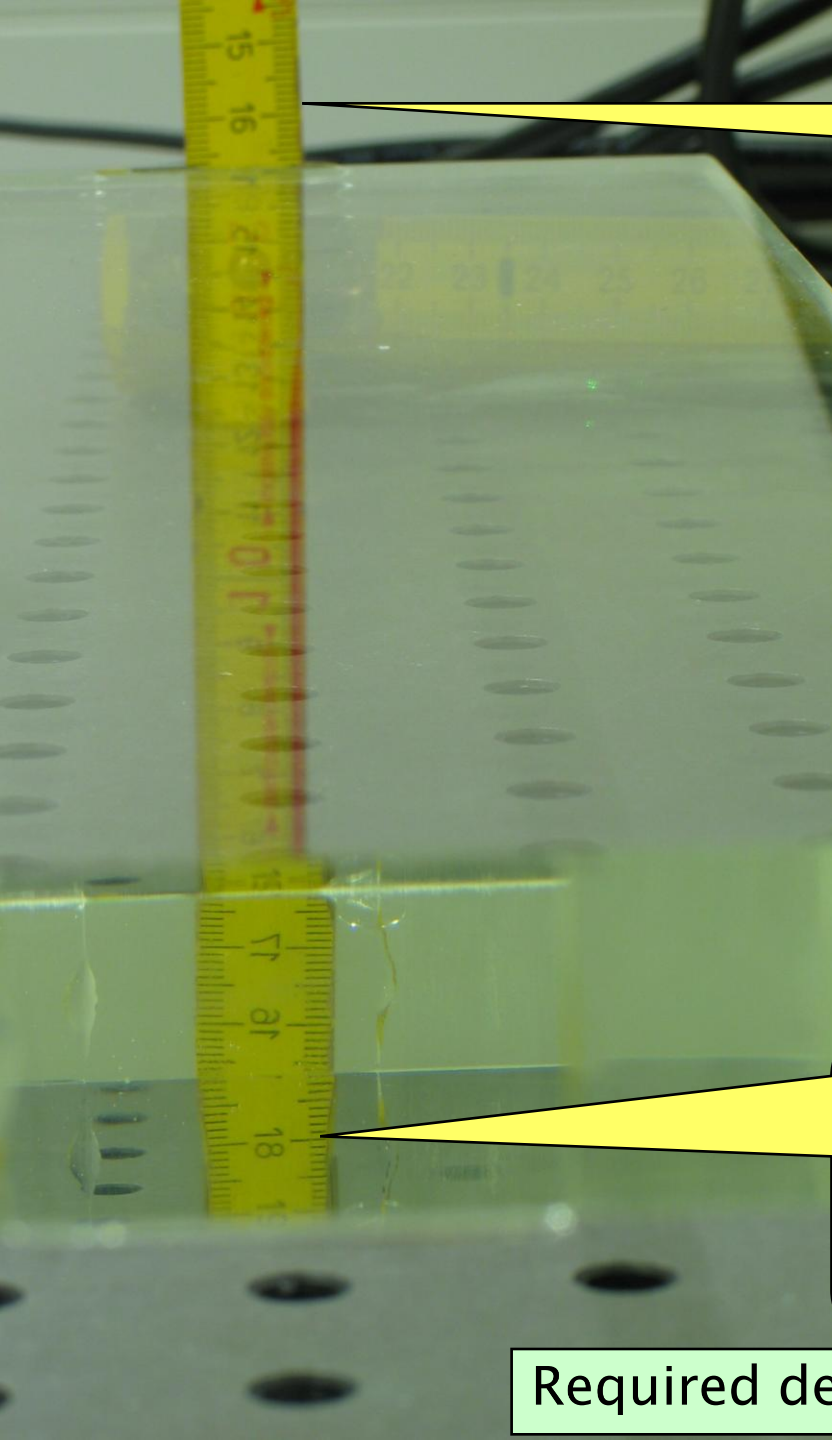
Marko Zühlsdorf

- Measure angle of light after many reflections in glass plate



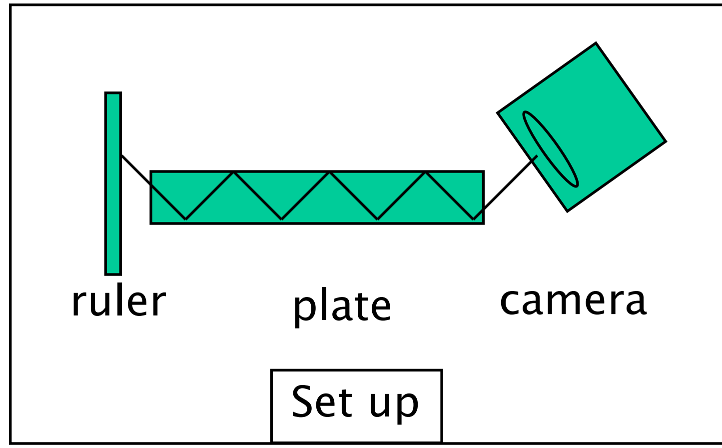






Ruler behind the glass plate

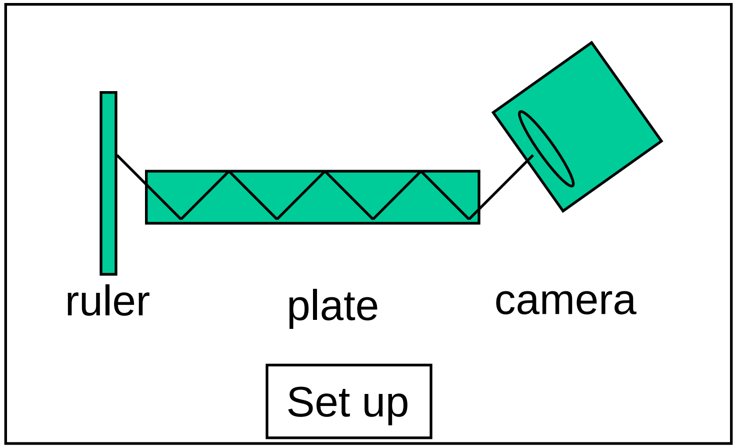
Optical resolution after multiple reflections (inverse approach)



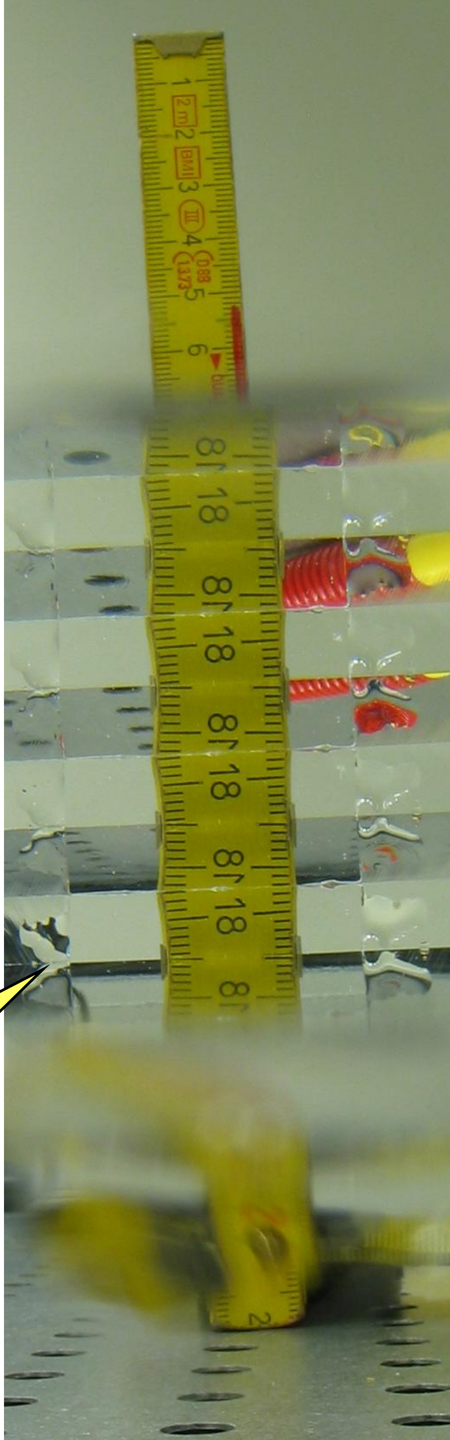
Mirror image of ruler is well readable: that means the light is transmitted through the surface and the 42 cm glass plate with a precision of better than about 1/10 mm

Required detector resolution of DIRC is ~3 mm only!

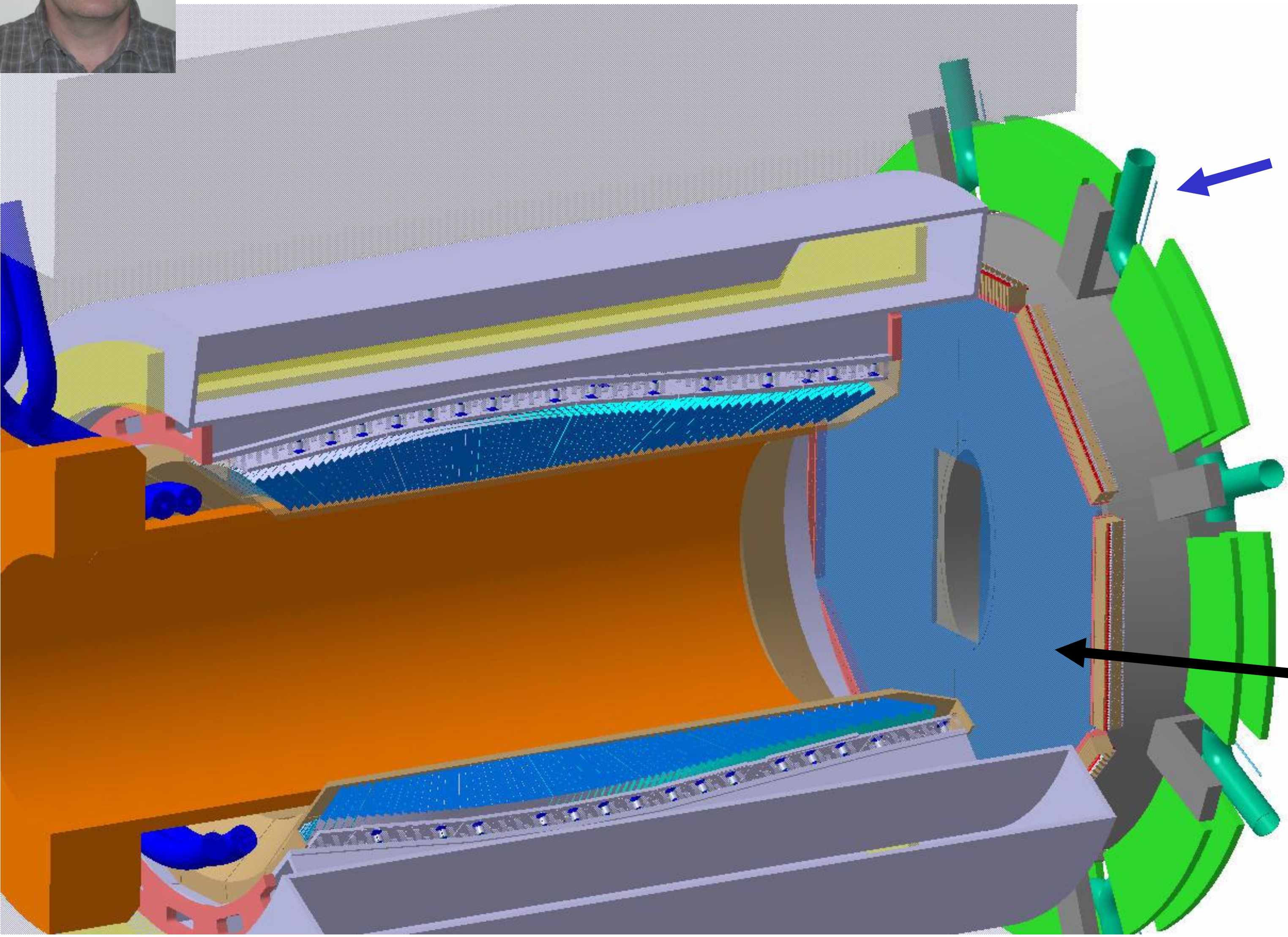
Resolution after multiple reflections



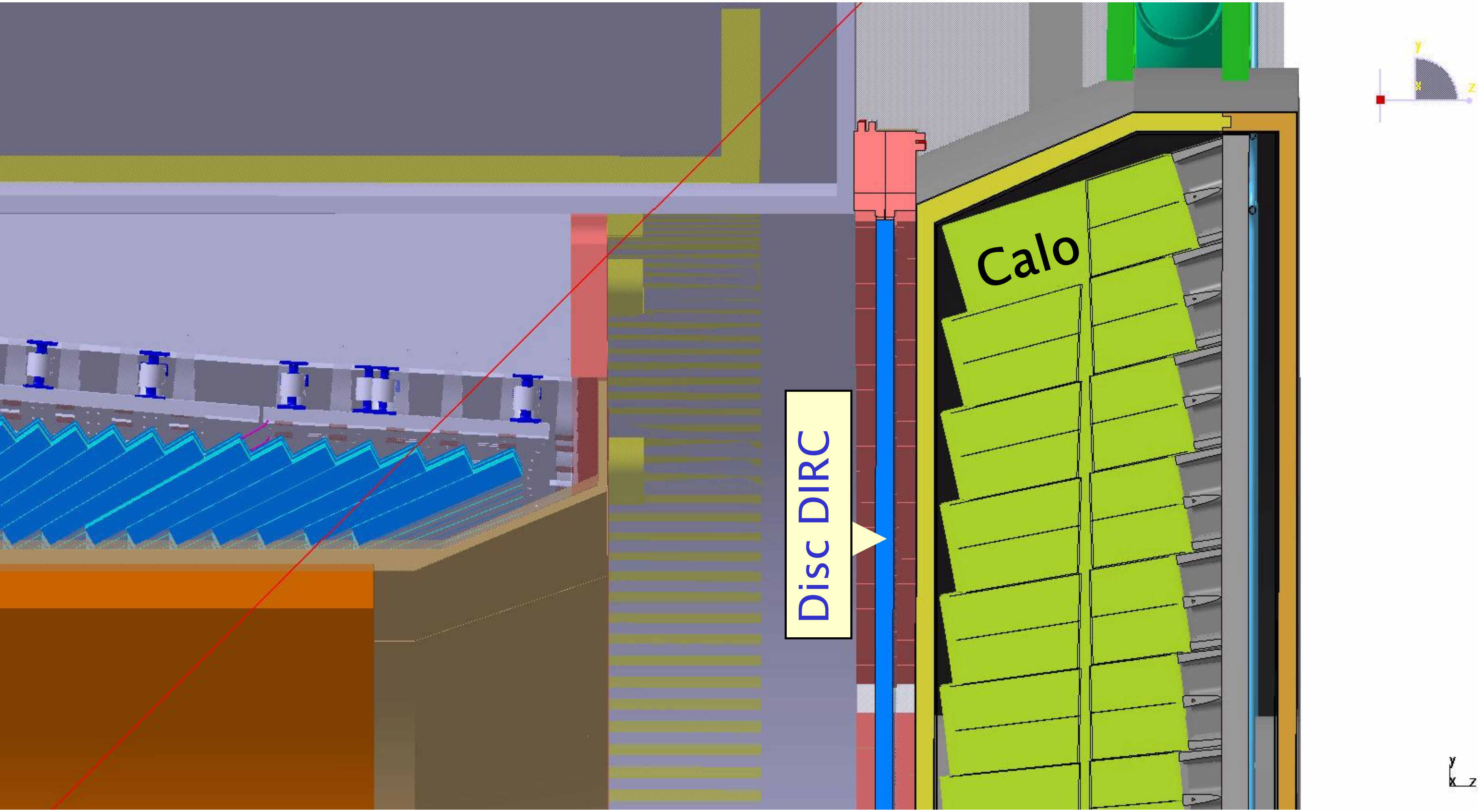
Same in 8 mm plexiglass plate



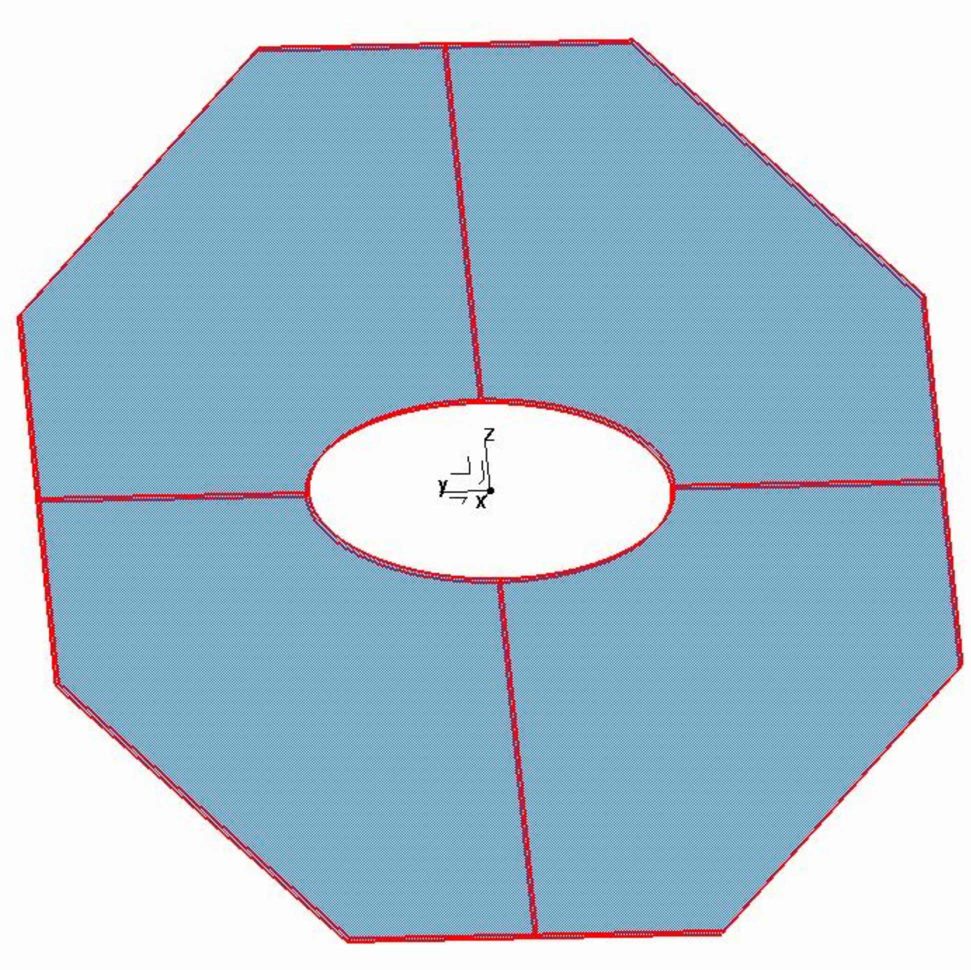
Disc DIRC attached to the calorimeter

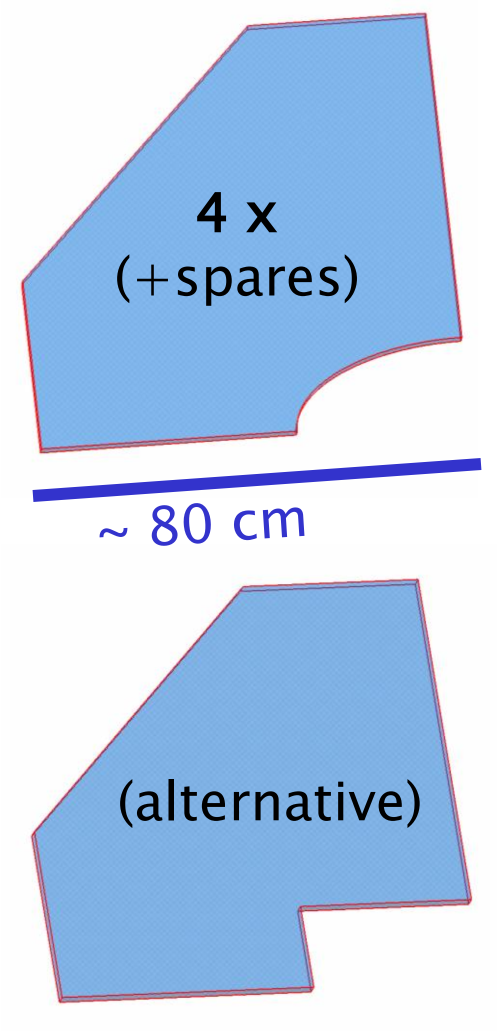


Disc DIRC attached to the calorimeter



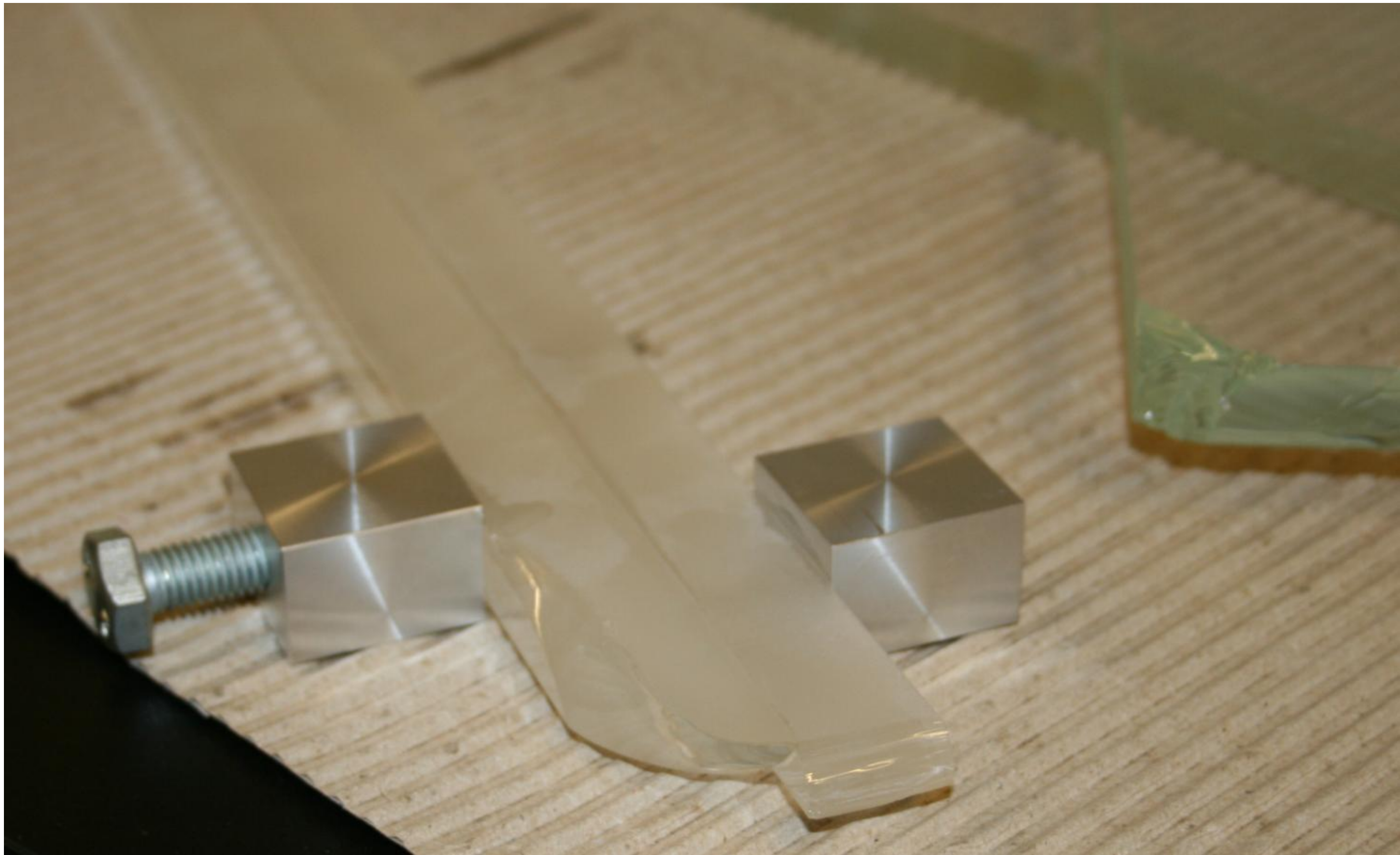
DIRC Disc made from 4 identical pieces





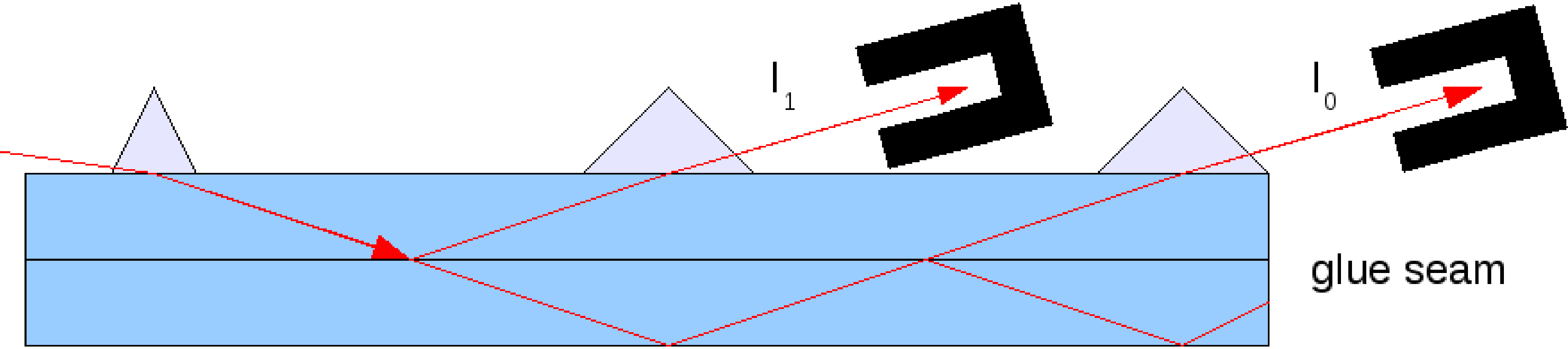
Gluing tests I: mechanical stability

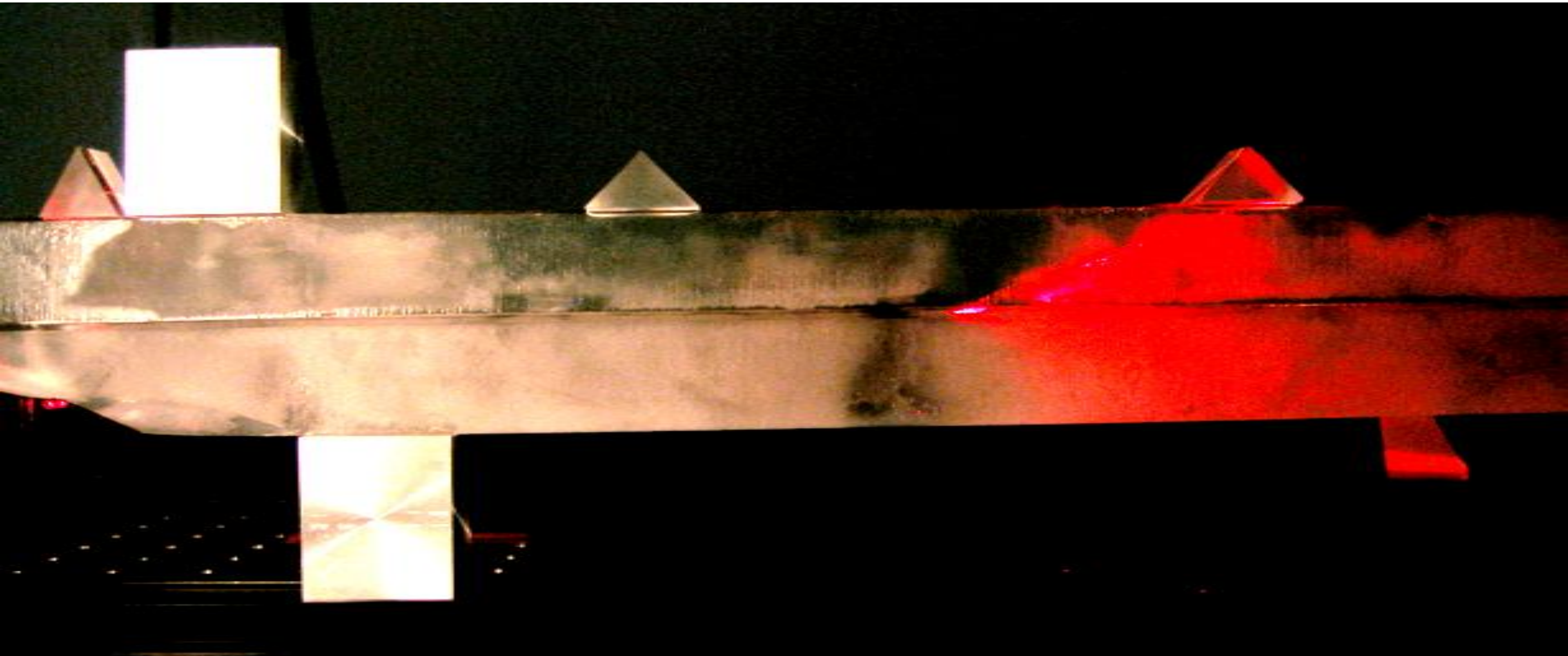
- Apply forces to find out if detector can be safely attached to mechanical frame by gluing it to aluminum blocks



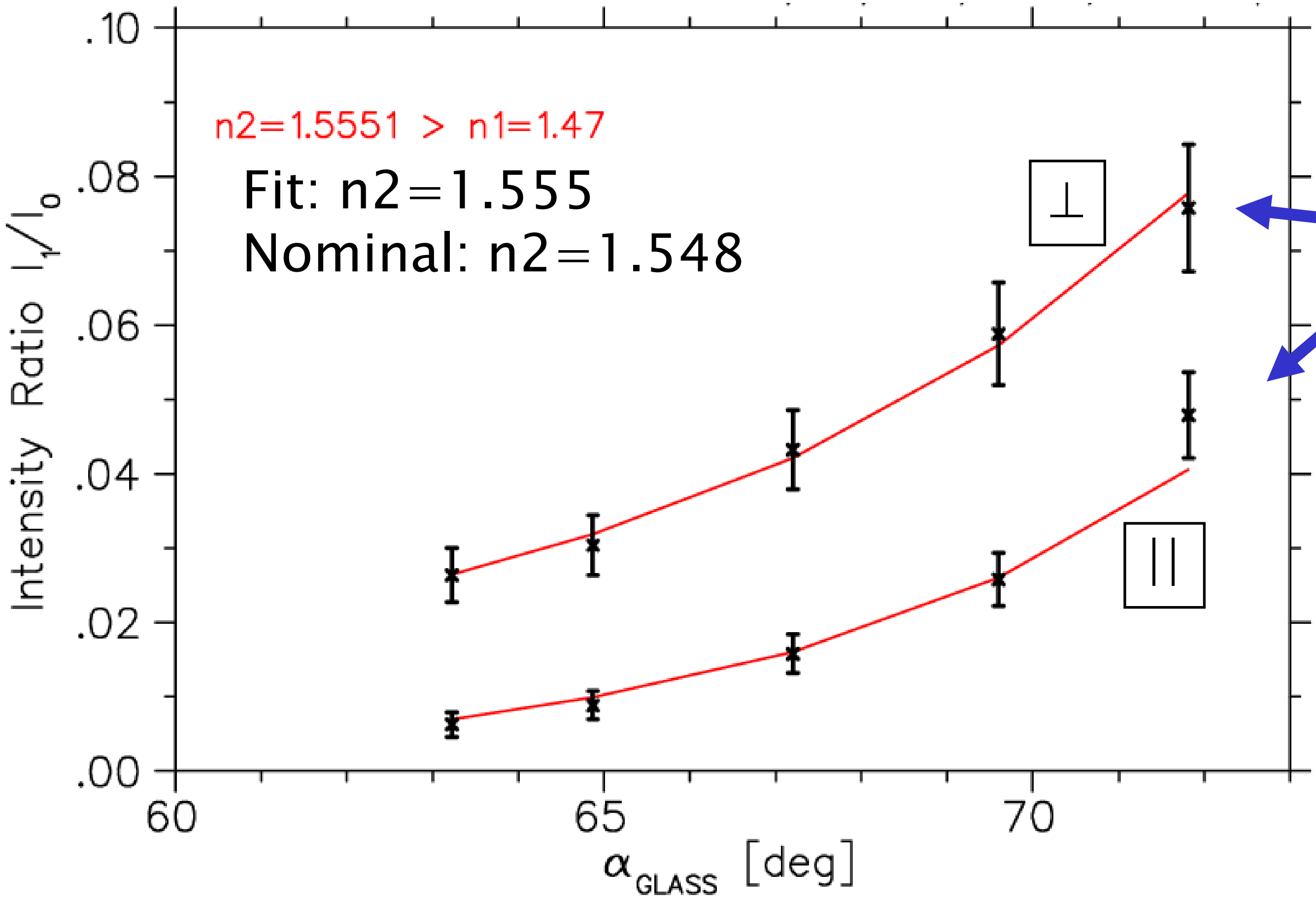
Weight of ~11 kg/3 cm² was no problem…

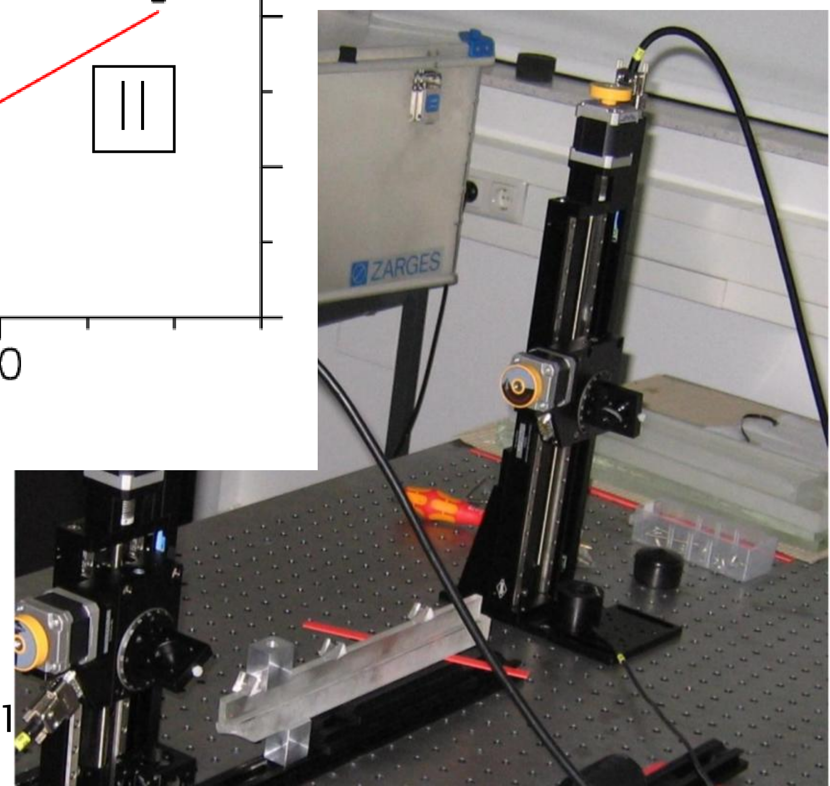
Gluing test II: Reflection on glue seam





Gluing test II: Reflection on glue seam



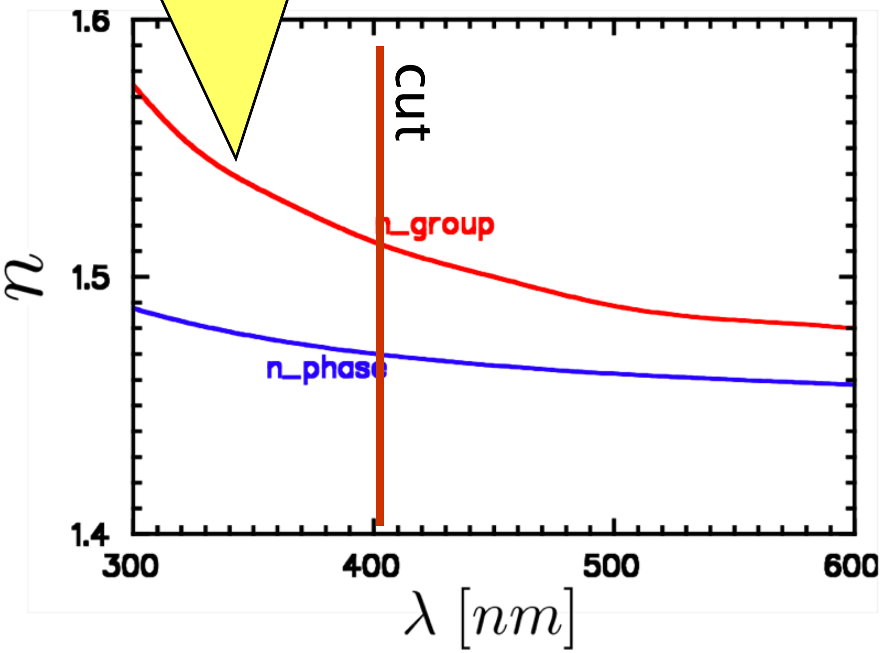


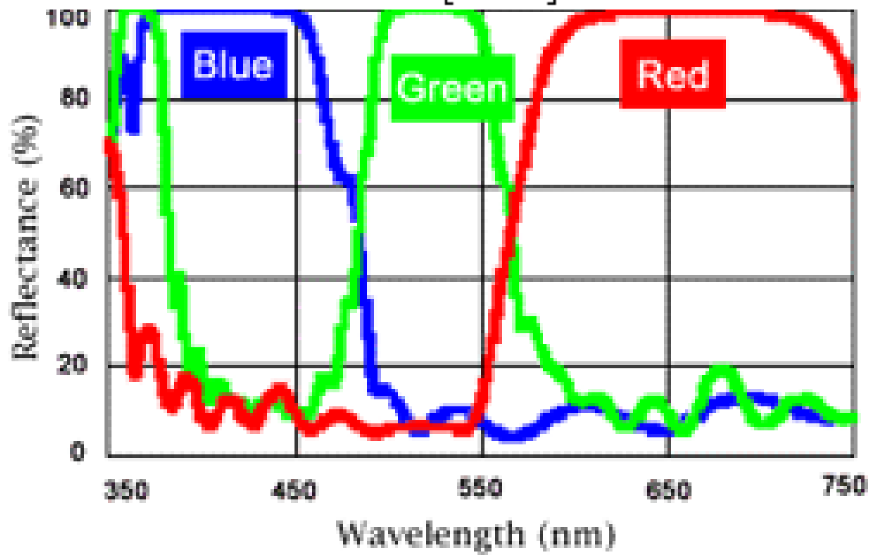
- Result agrees with Fresnel formulae
- Large loss at large angles (to be included in the detector simulation)

Dispersion correction

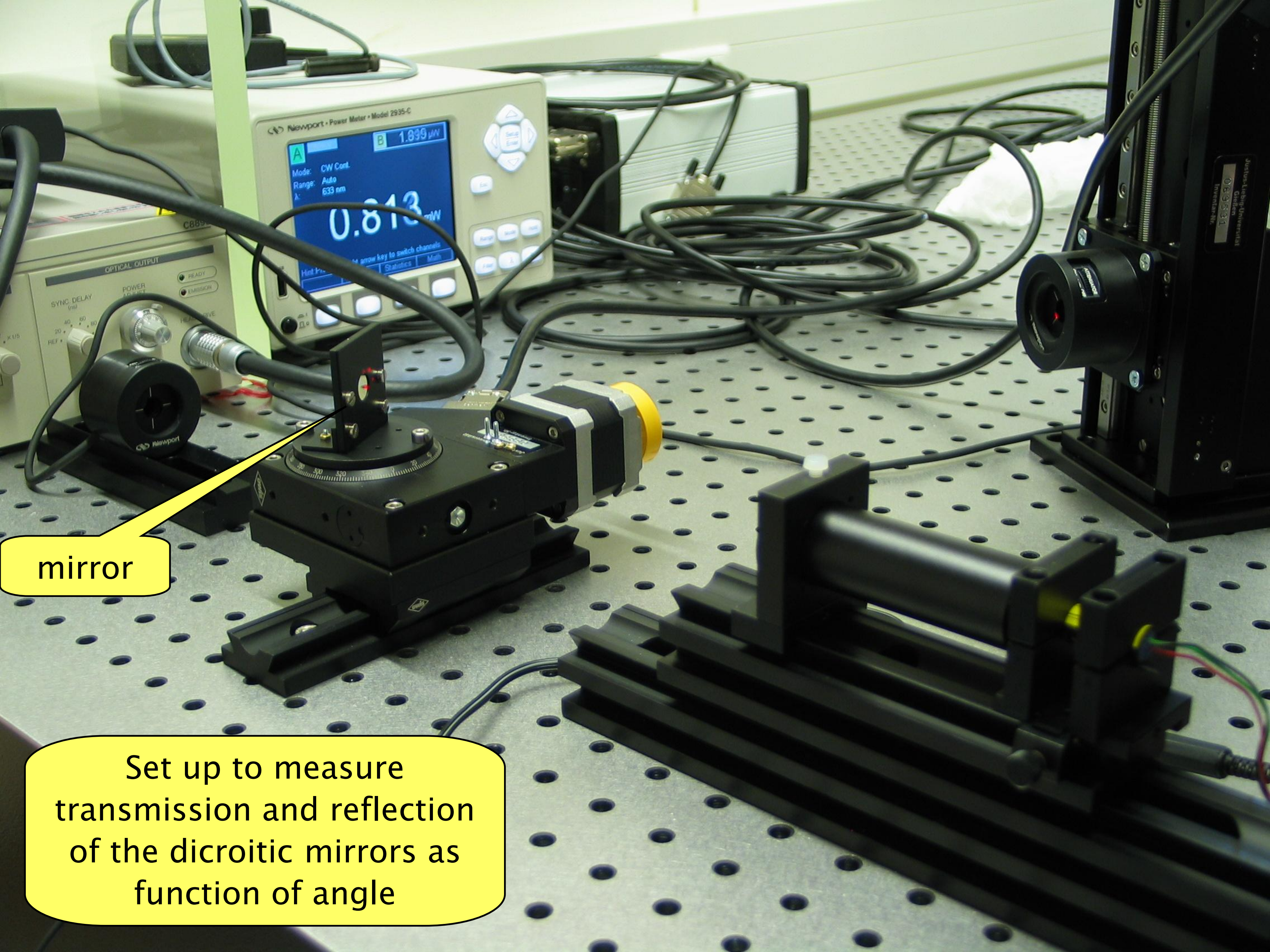
UV photons not useful for TOP!

- Dichroic mirrors split Cherenkov spectrum in two or three regions

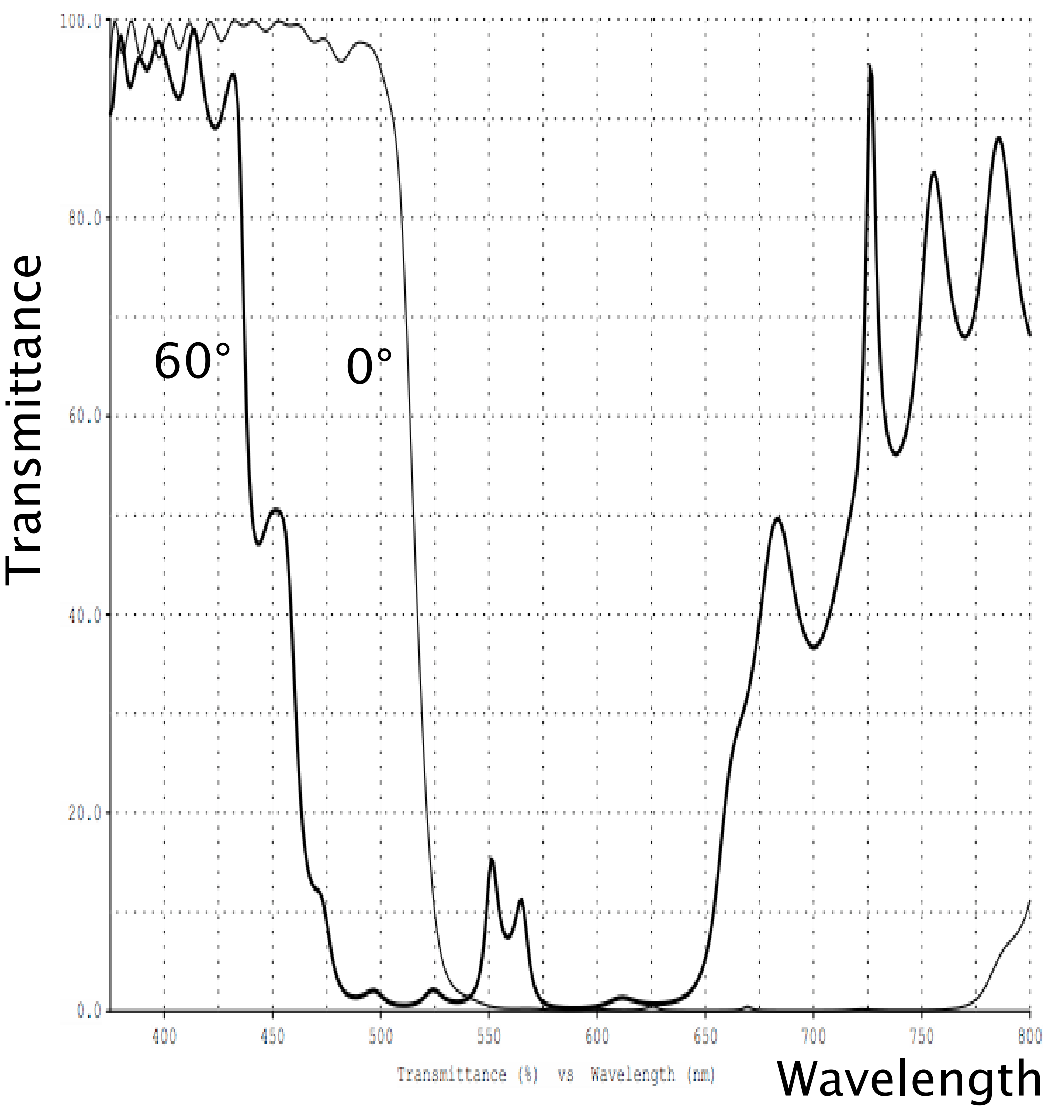


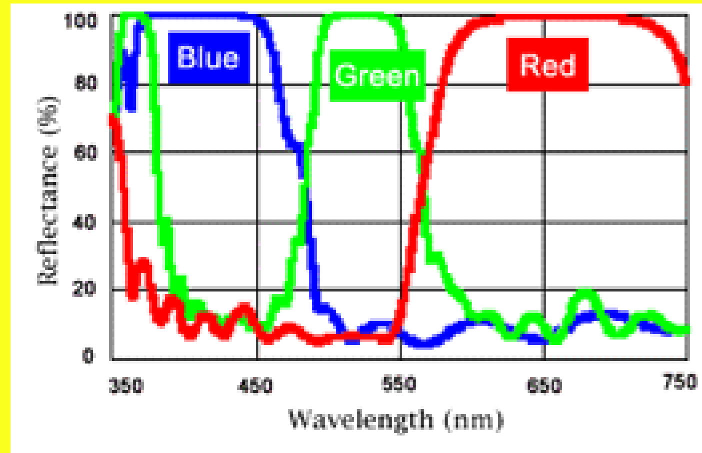


Disk must not be UV transparent; Any radiation hard glass sufficient

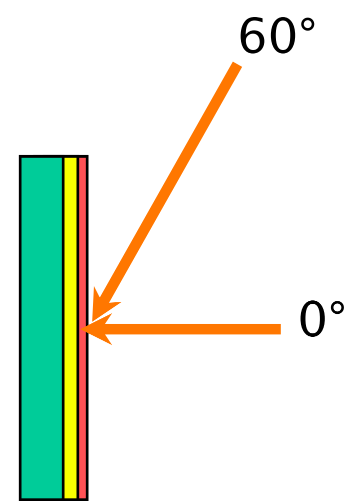

mirror
Set up to measure transmission and reflection of the dicroitic mirrors as function of angle

Reflectivity of dichroic mirrors vs. incident angle





Mirror currently optimized for 0° incident angle; custom made mirrors for almost any angle possible!



Requirements of the DIRC Disk

- What is really needed?
  - No UV transparence needed (like glass, acrylic glass,…)
  - Moderate radiation hardness (disc is 20 cm away from beam)
  - Local smoothness of surface for high degree of total reflection (standard optical quality, less demanding than for UV)
  - Can long-range distortions of disk be corrected by software calibration? (As long as one does no focusing, the light path for reconstruction can basically be adjusted by the software; prototype test needed)
  - Rim surface does not need to be highly polished (we put index-matched glue on it)
  - Disk can be composed from several smaller pieces (polygons)
  - …

Photon Detectors (some entries to be discussed)

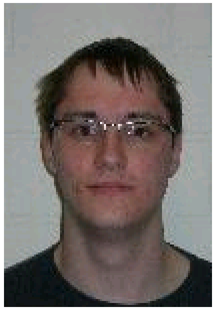
	Required (per pixel)	MCP PMTs	Geiger APD	Hybrid APD	Diamond PMTs
Time resolution	<50 ps				
Repetition rate	~ 1 MHz				
Dark rate	< 300 kHz				
Photon det. efficiency	>20 %				
Magnetic field	~ 0.5– 1 T				
Radiation hardness	~1.5 kRad				
Integrated light intensity	~ $2*10^{14}$ photons				
Spatial resolution	< 5 mm				

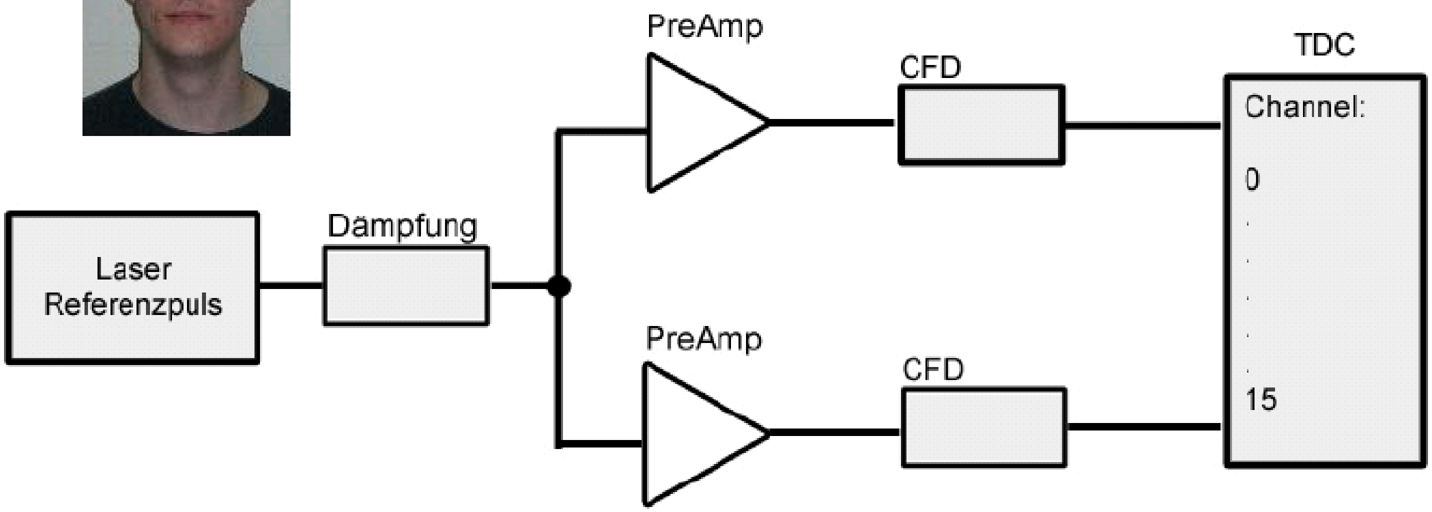
Photon Detectors (some entries to be discussed)

	Required (per pixel)	MCP PMTs	Geiger APD	Hybrid APD	Diamond PMTs
Time resolution	<50 ps	✓	(✓)	✓	?
Repetition rate	~ 1 MHz	✓	✓	✓	✓
Dark rate	< 300 kHz	✓	☠?	✓	✓
Photon det. efficiency	>20 %	?	✓	✓	?
Magnetic field	~ 0.5– 1 T	✓	✓	(✓)	?
Radiation hardness	~1.5 kRad	✓	?	?	✓
Integrated light intensity	~ $2*10^{14}$ photons	☠?	✓	?	?
Spatial resolution	< 5 mm	✓	✓	✓	✓

Electronics resolution studies

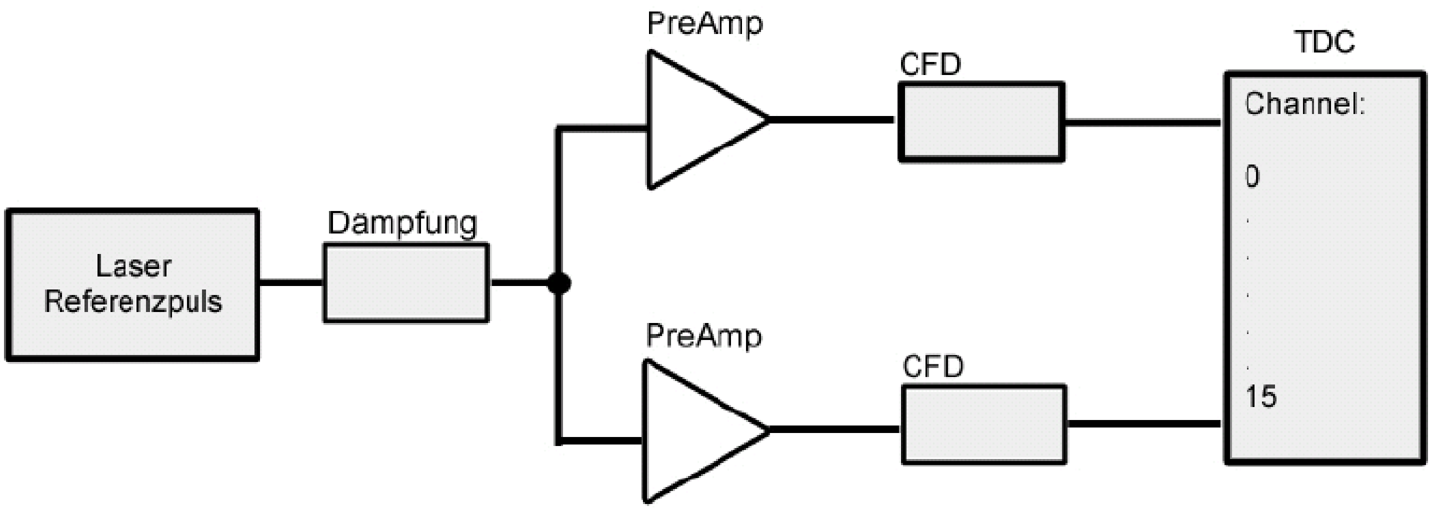
Kristof Kreutzfeldt





TDC 25 ps LSB

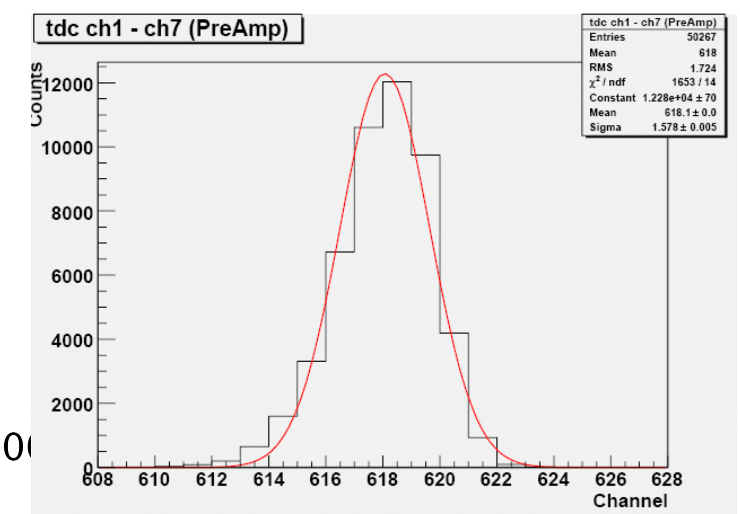
Electronics resolution studies



TDC 25 ps LSB (Least Significant Bit)

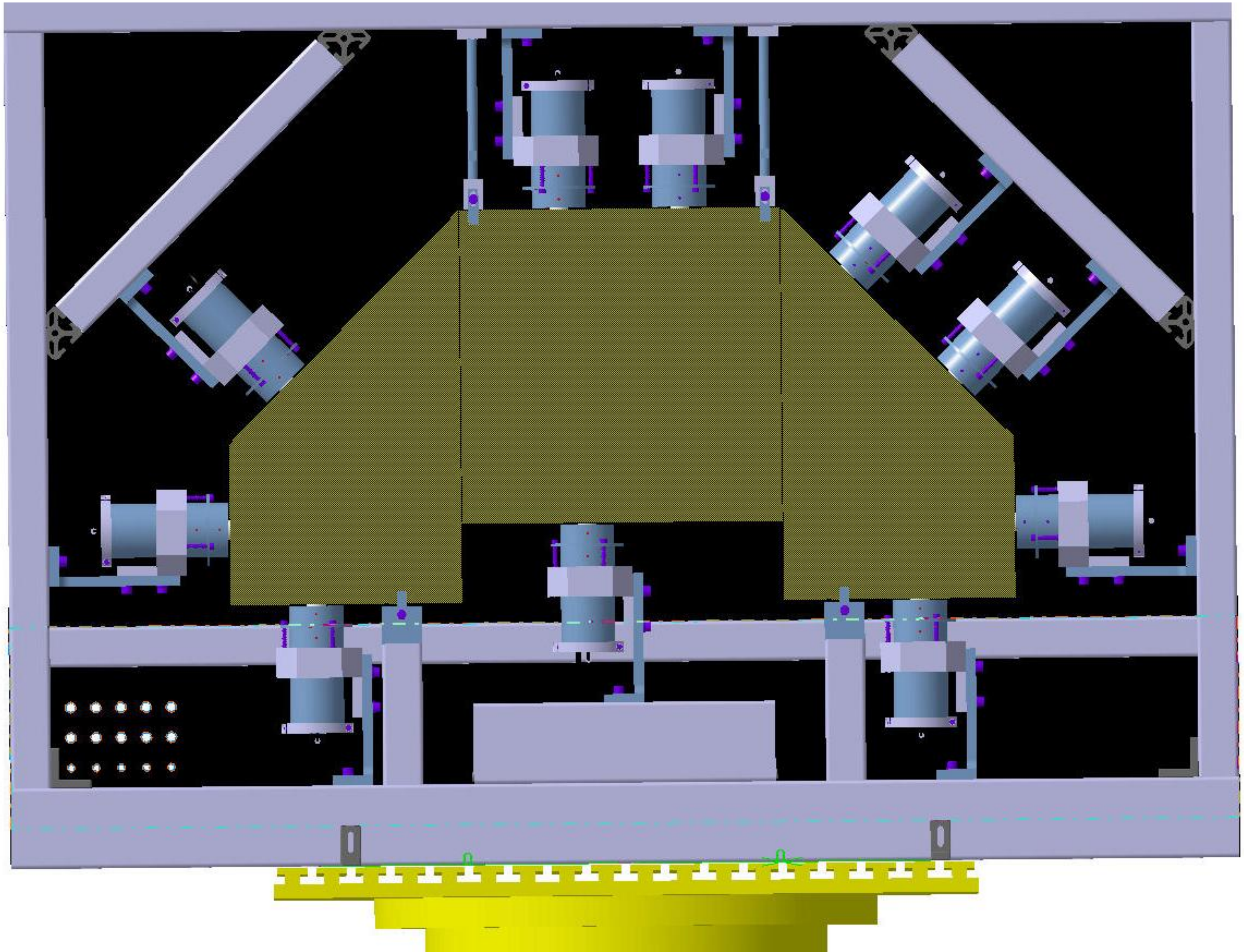
Measured resolution:

σ = 1.5 Channels = 38 ps




Work in progress…
Zutritt für
Unbefugte
verboten

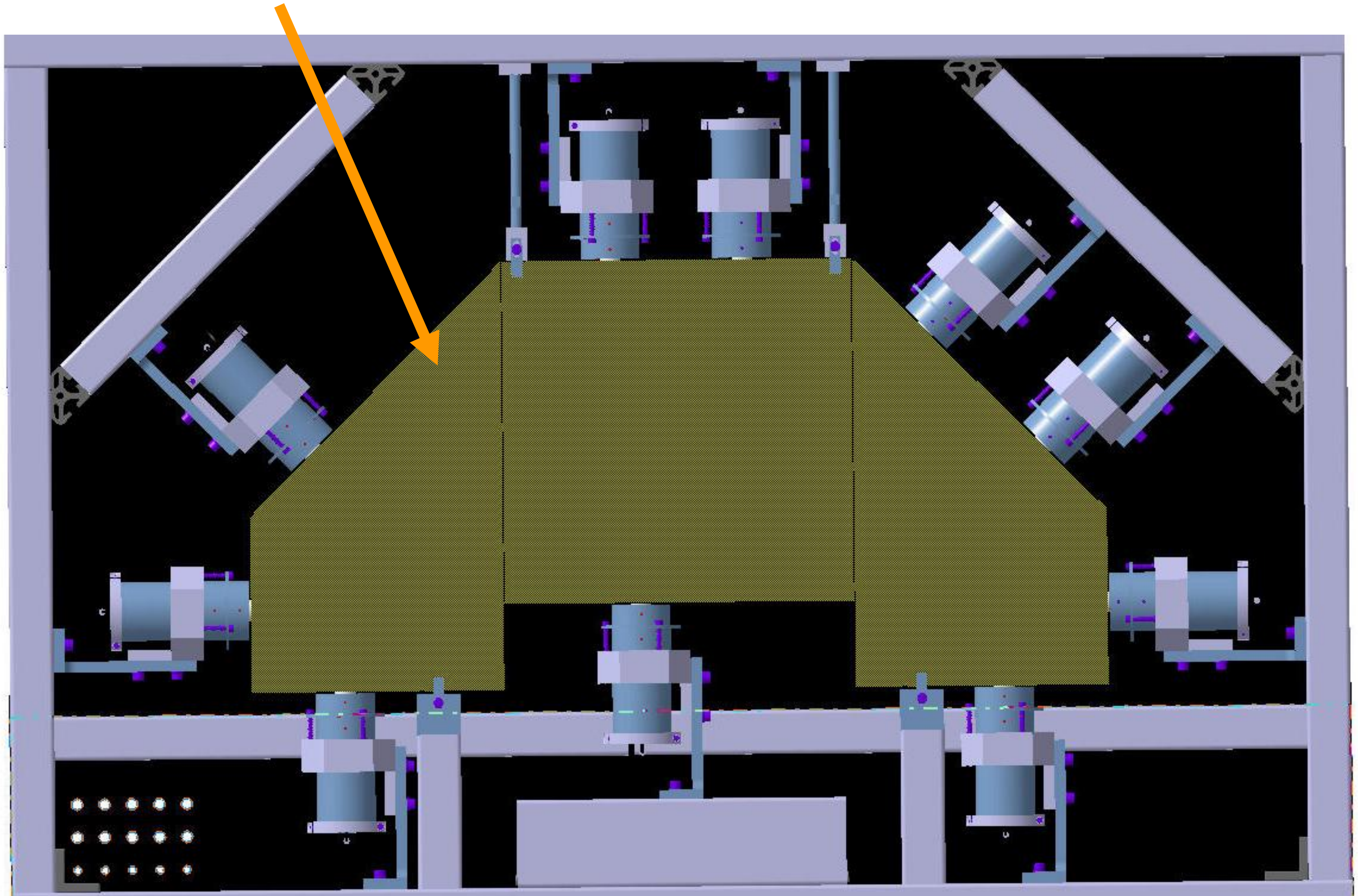
Test experiment at DESY



Test experiment at DESY

DIRC DISC Prototype:

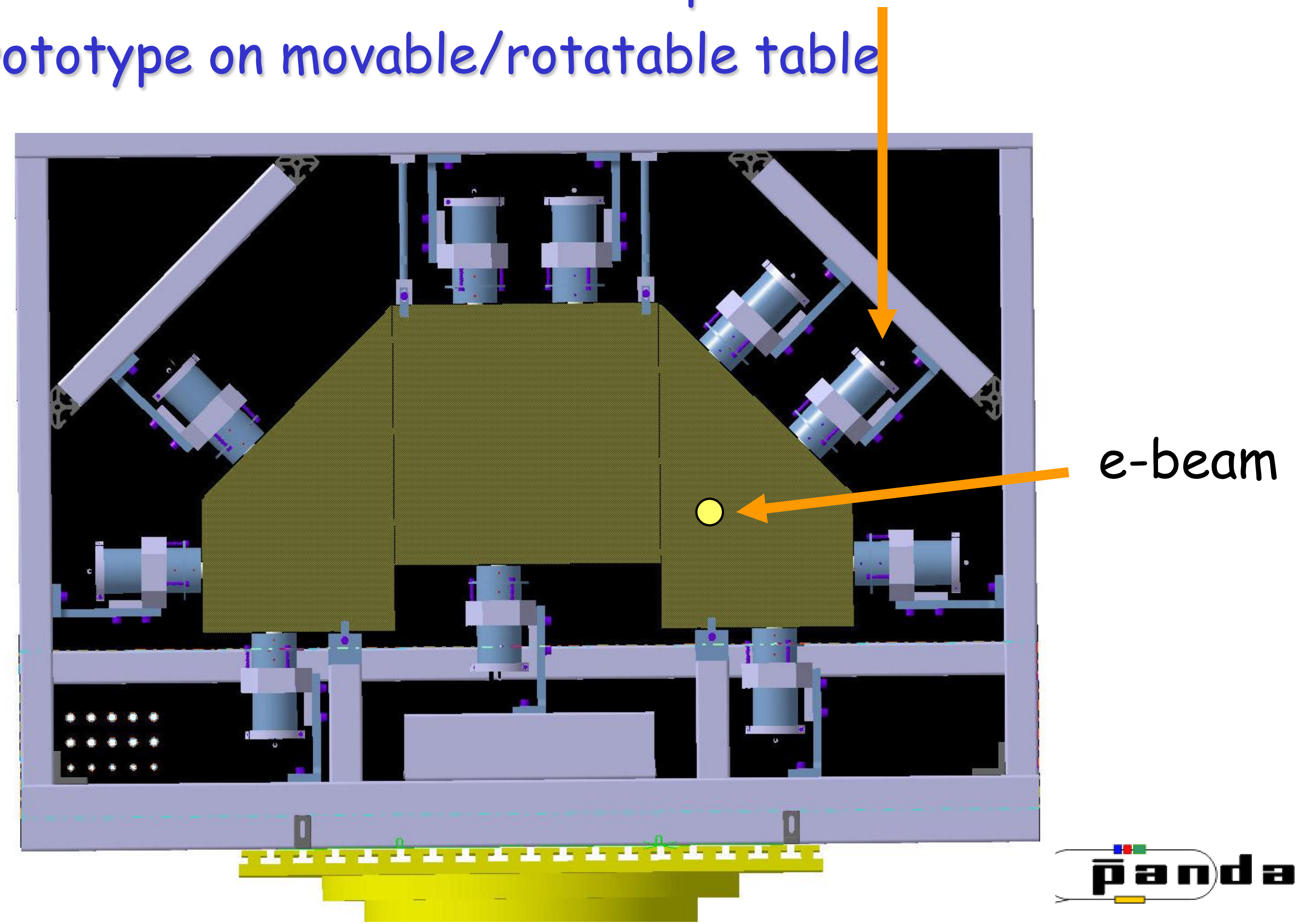
- Half size, upper half only, glass - not silica, glued from three pieces, polished edges



Test experiment at DESY

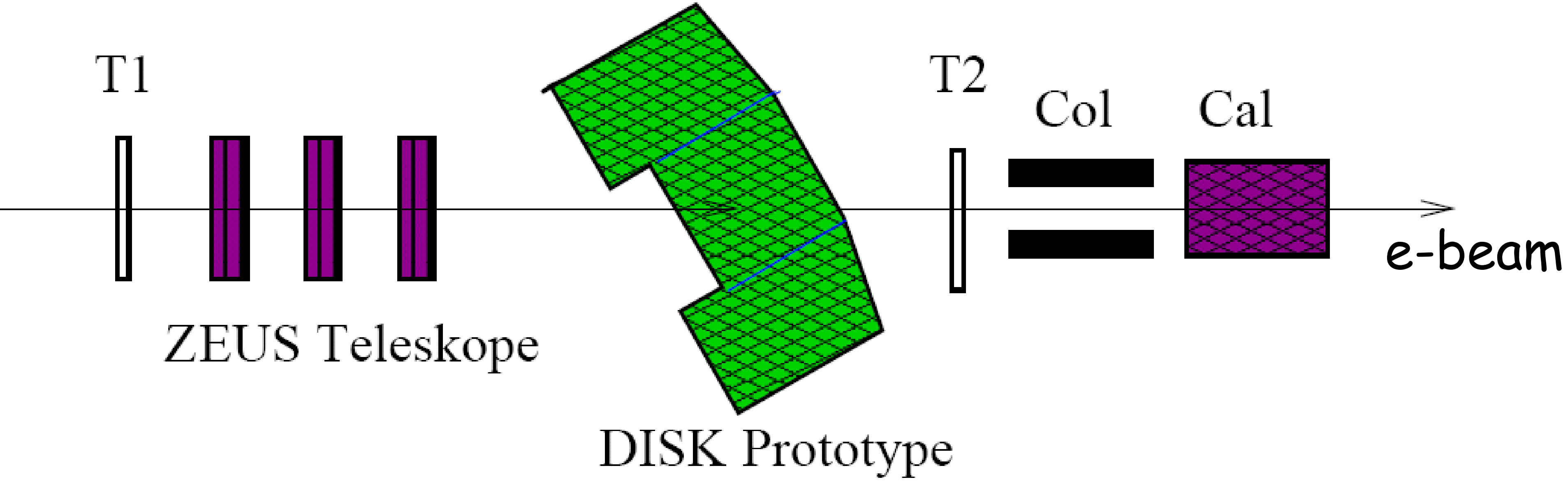
DIRC DISC Prototype:

- 10 MCP detectors at variable positions
- Prototype on movable/rotatable table

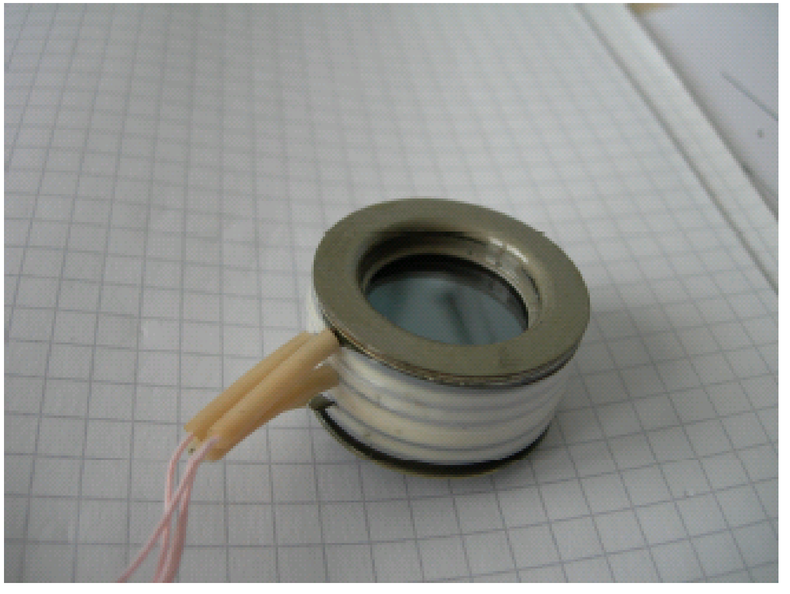


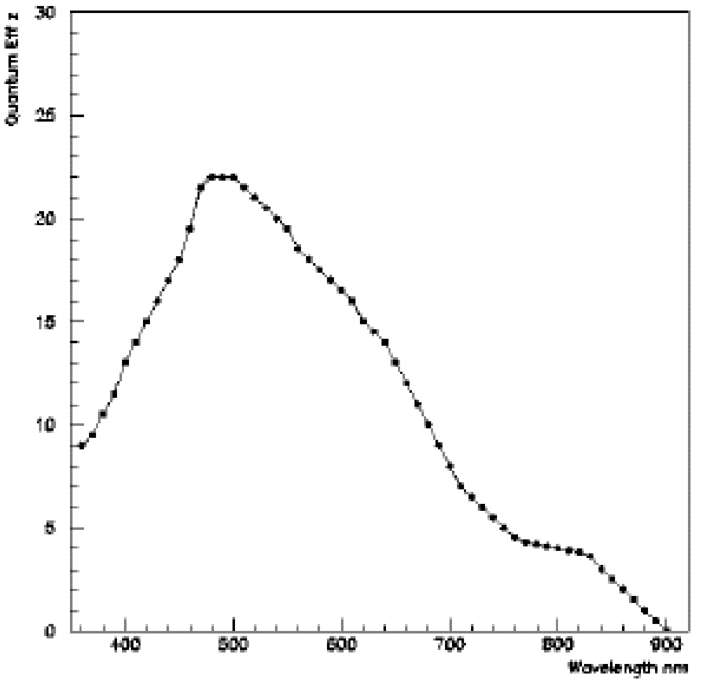
Test experiment at DESY

- Beam line set-up:
  DIRC prototype between tracking telescope and calorimeter (to suppress bremsstrahlung and shower events)



Micro Channel Plate (MCP)

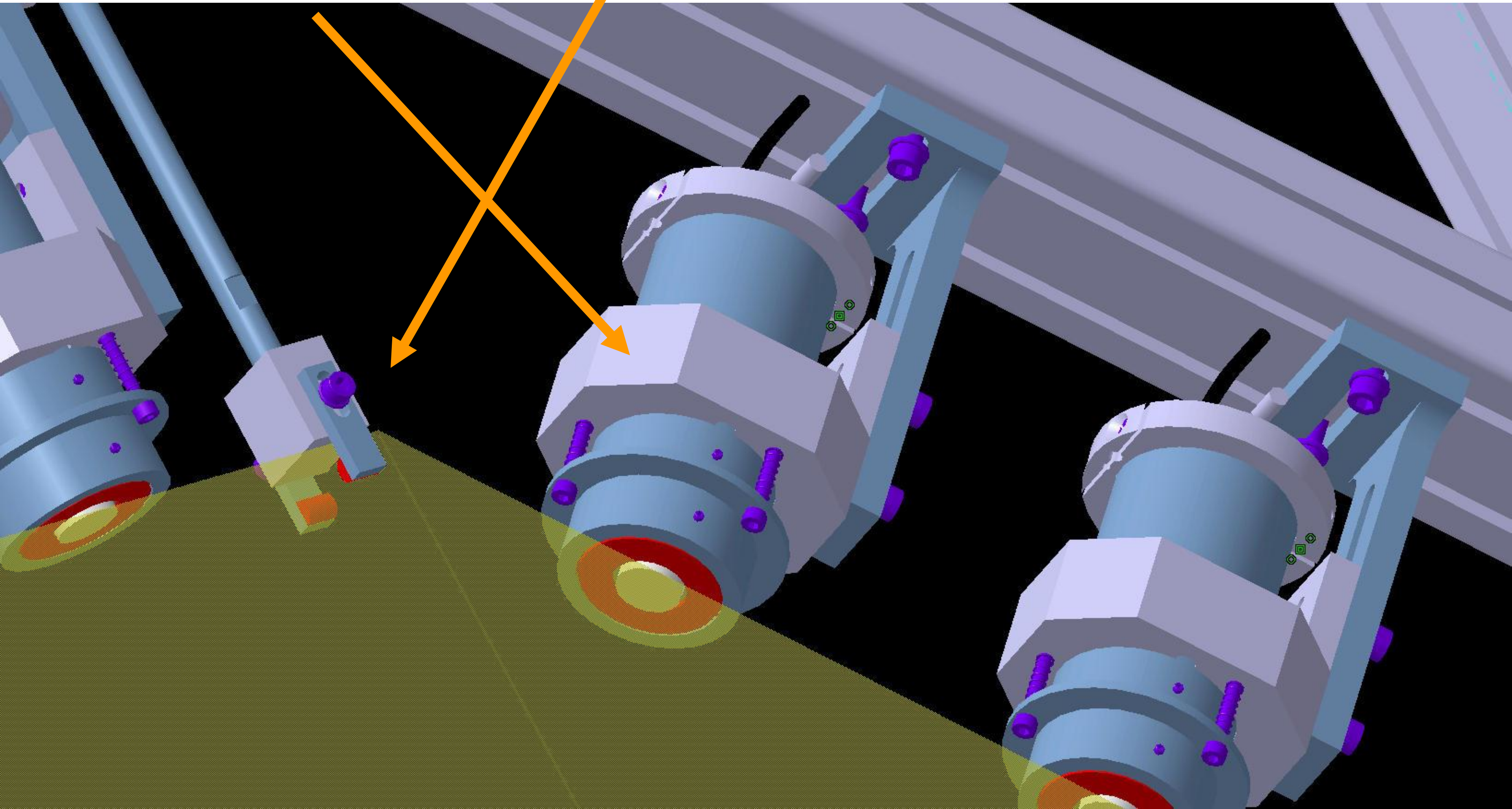




- Time resolution: $\sim$ 45ps
- Quantum Efficiency: approx 15%

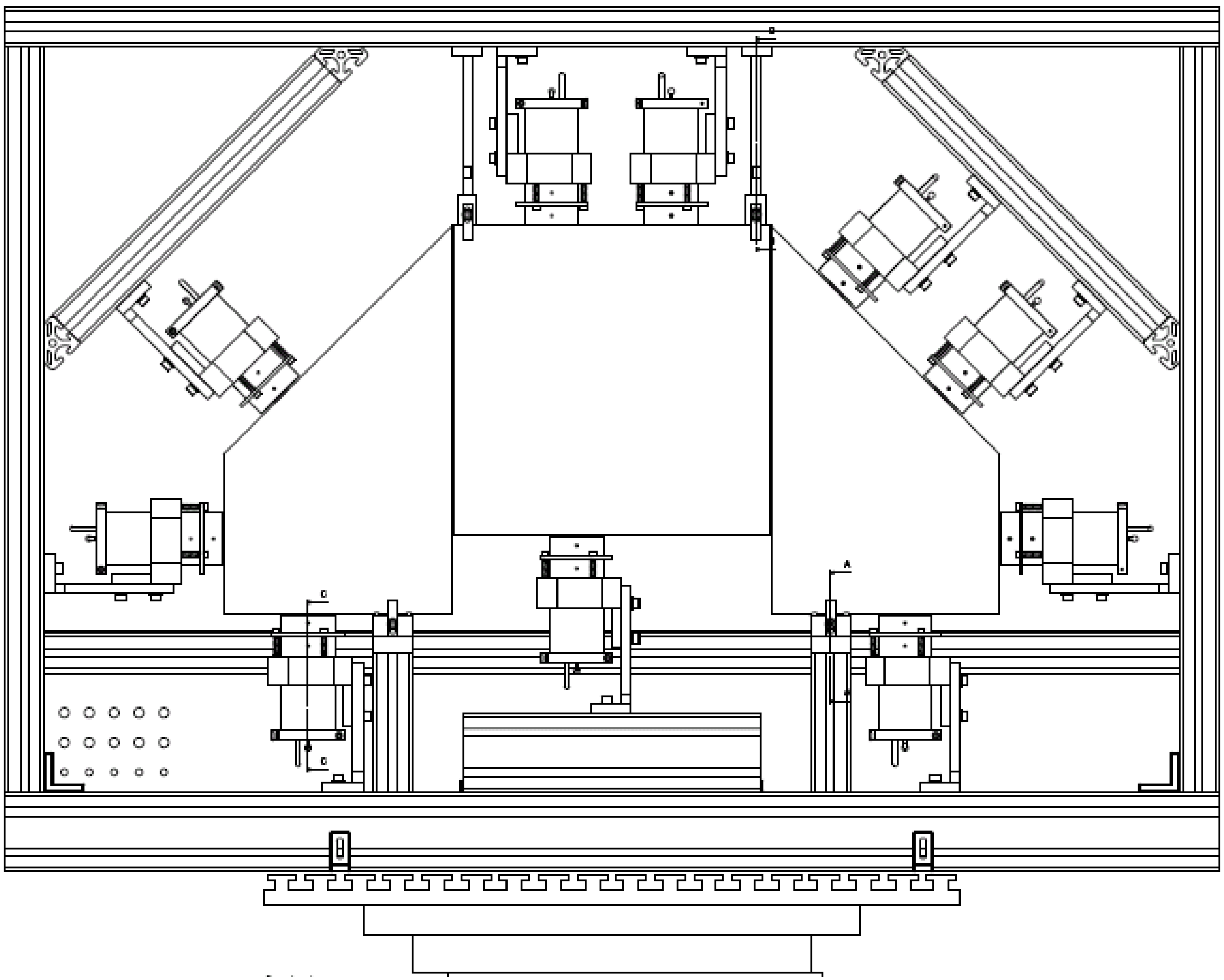
Test experiment at DESY

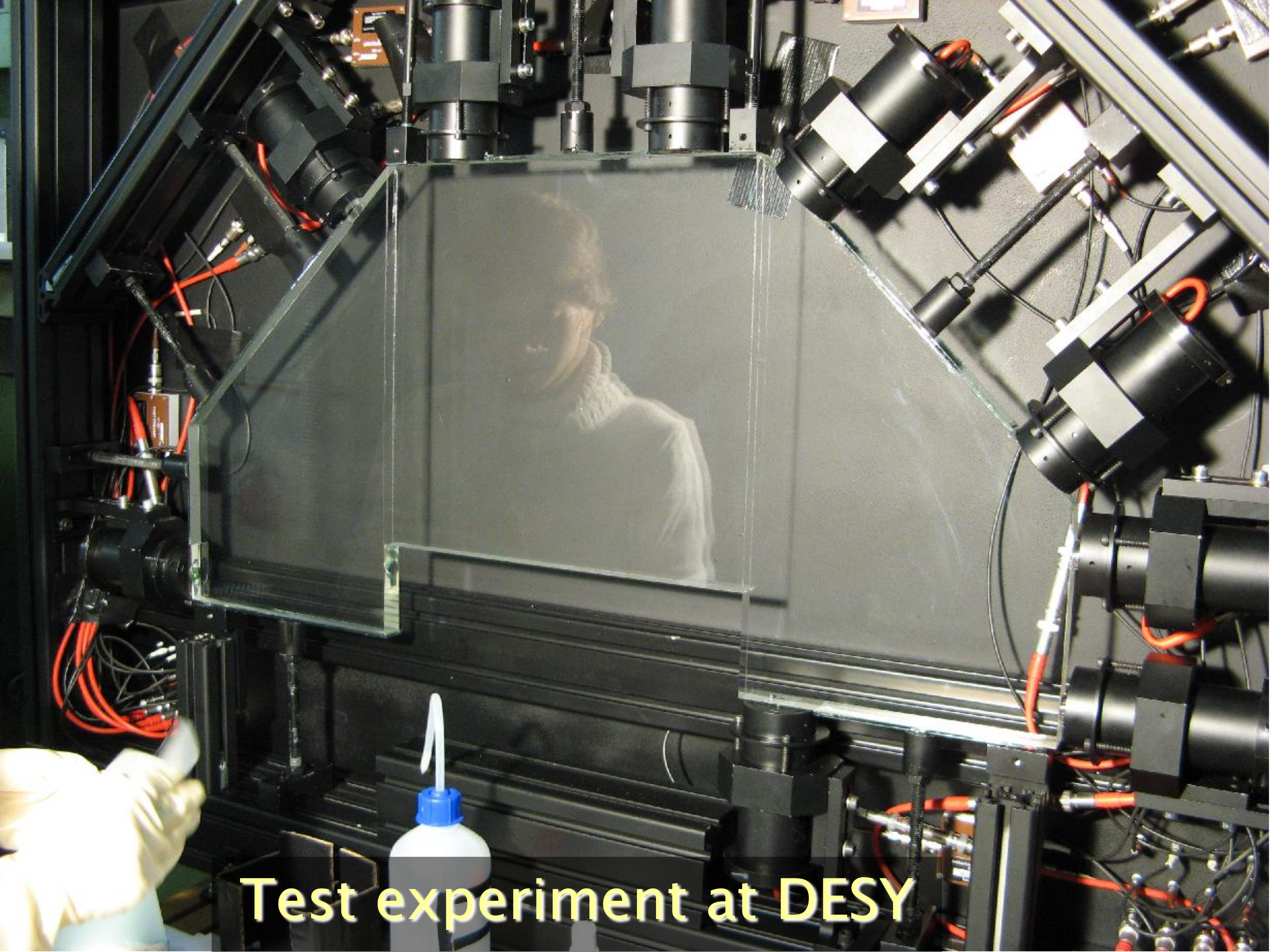
- Glass plate glued or clamped to frame
- MCP boxes



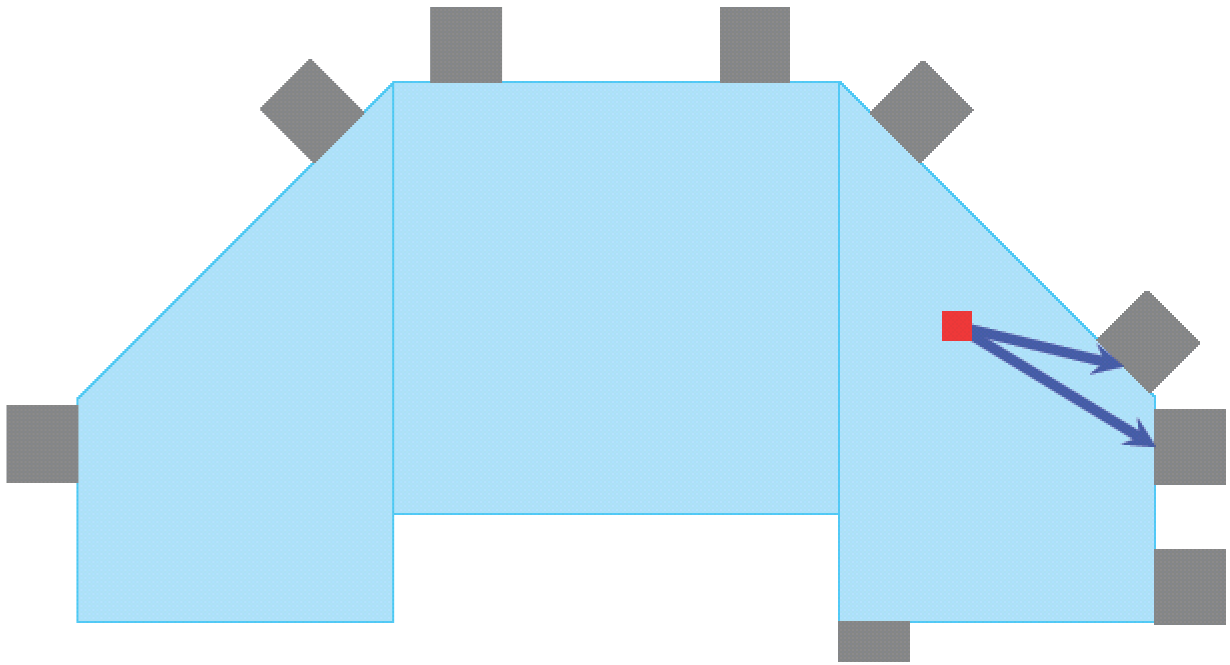
Test experiment at DESY

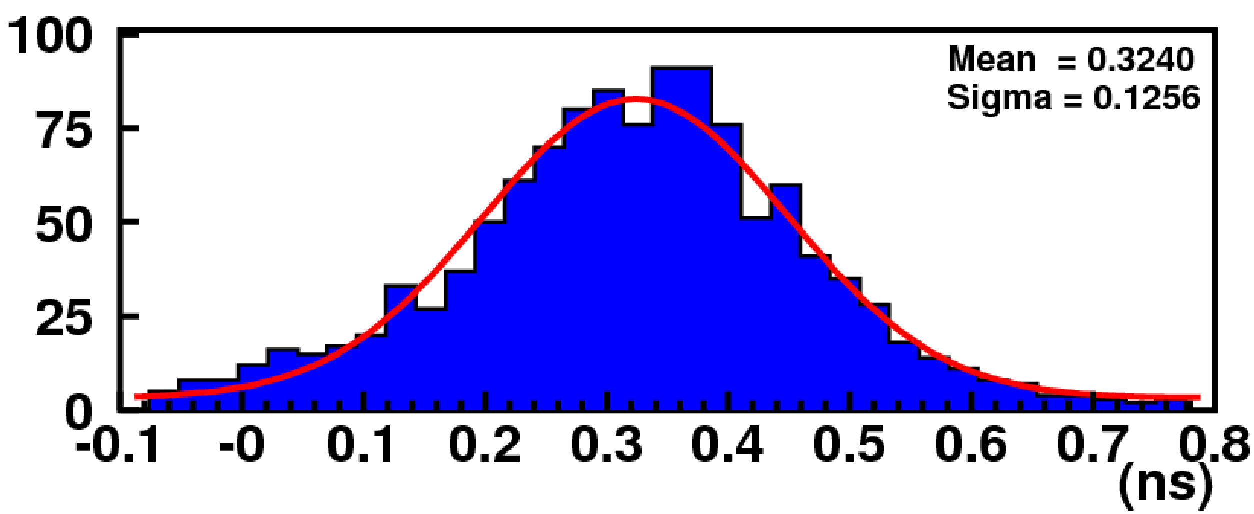
- Technical drawing (Thomas Wasem)




Test experiment at DESY

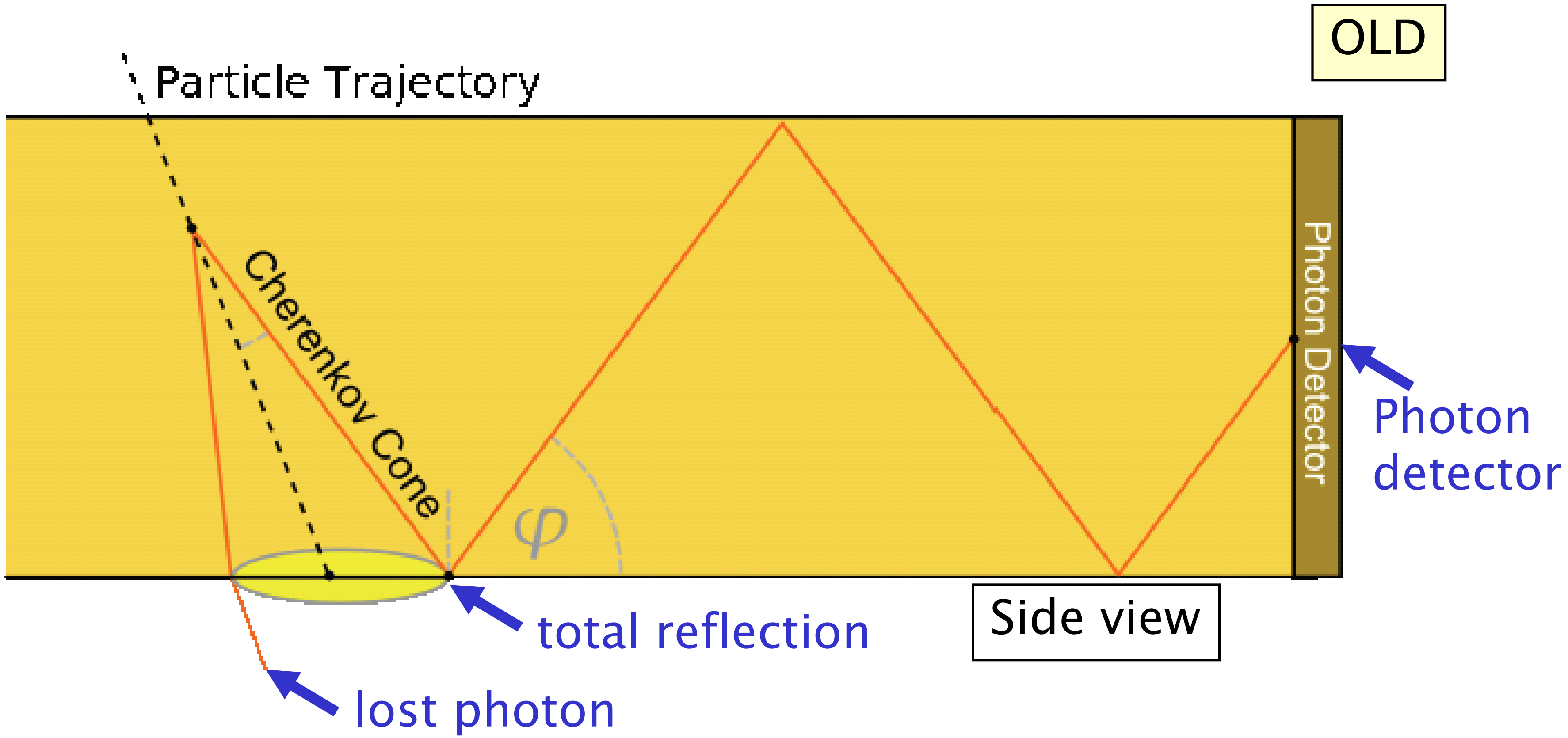
Cosmics results





Resolution
$= 0.126$ ns$/\sqrt{2}$
$= 89$ ps
(includes angular smearing etc.)

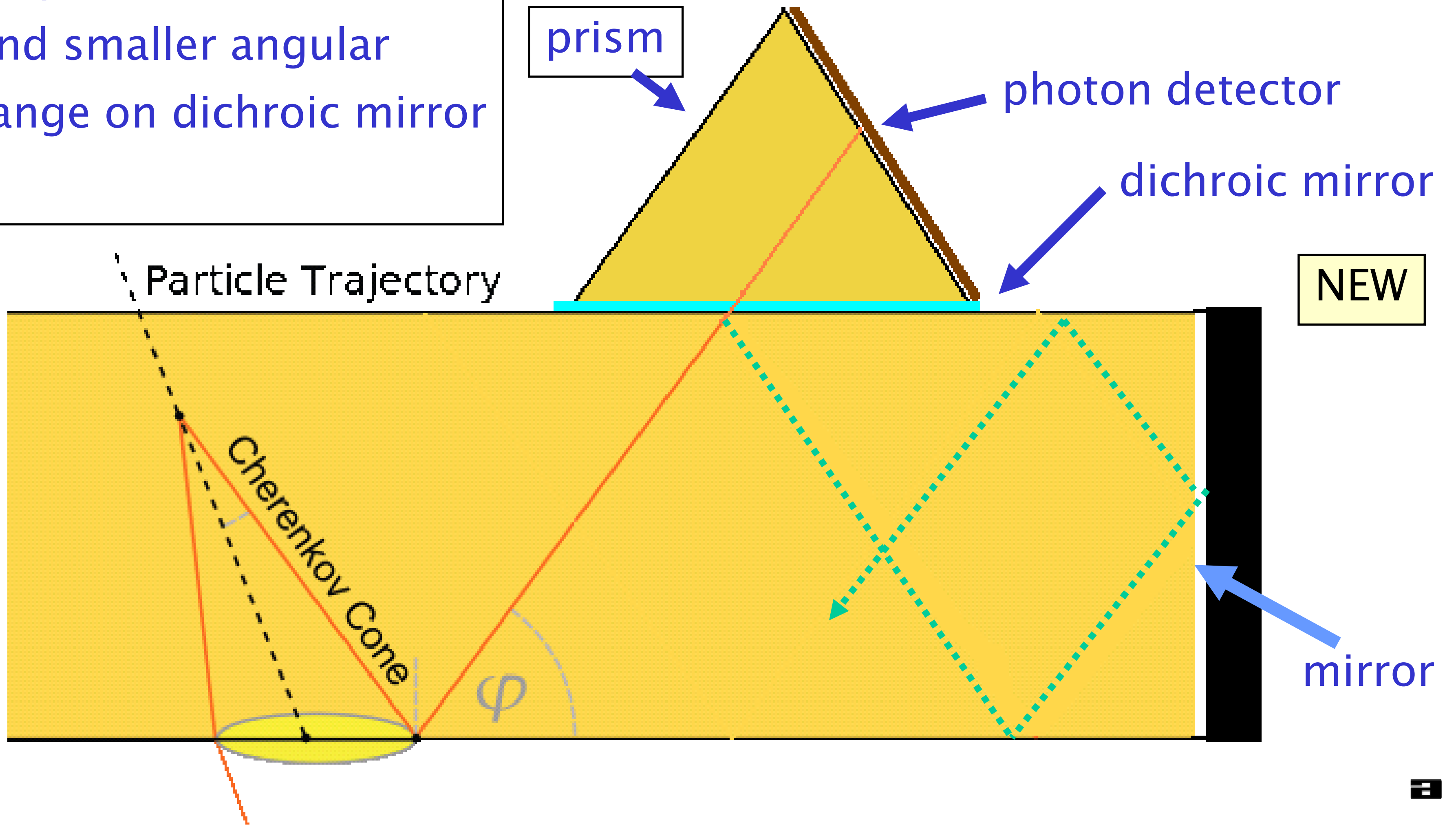
Design variations: Standard below



New idea: photon detection from the side

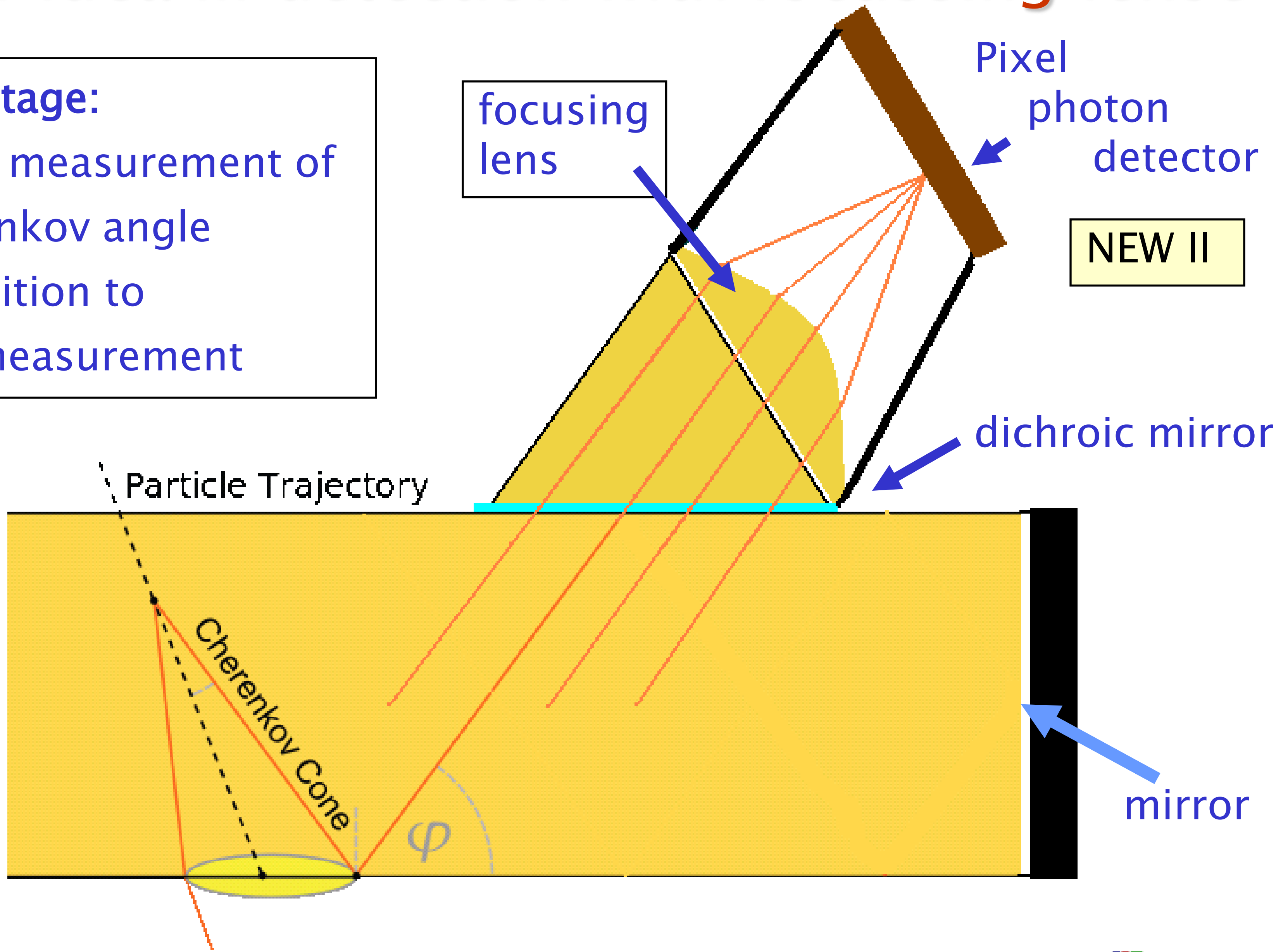
Advantages:

steeper incident angle on photon detector and smaller angular range on dichroic mirror

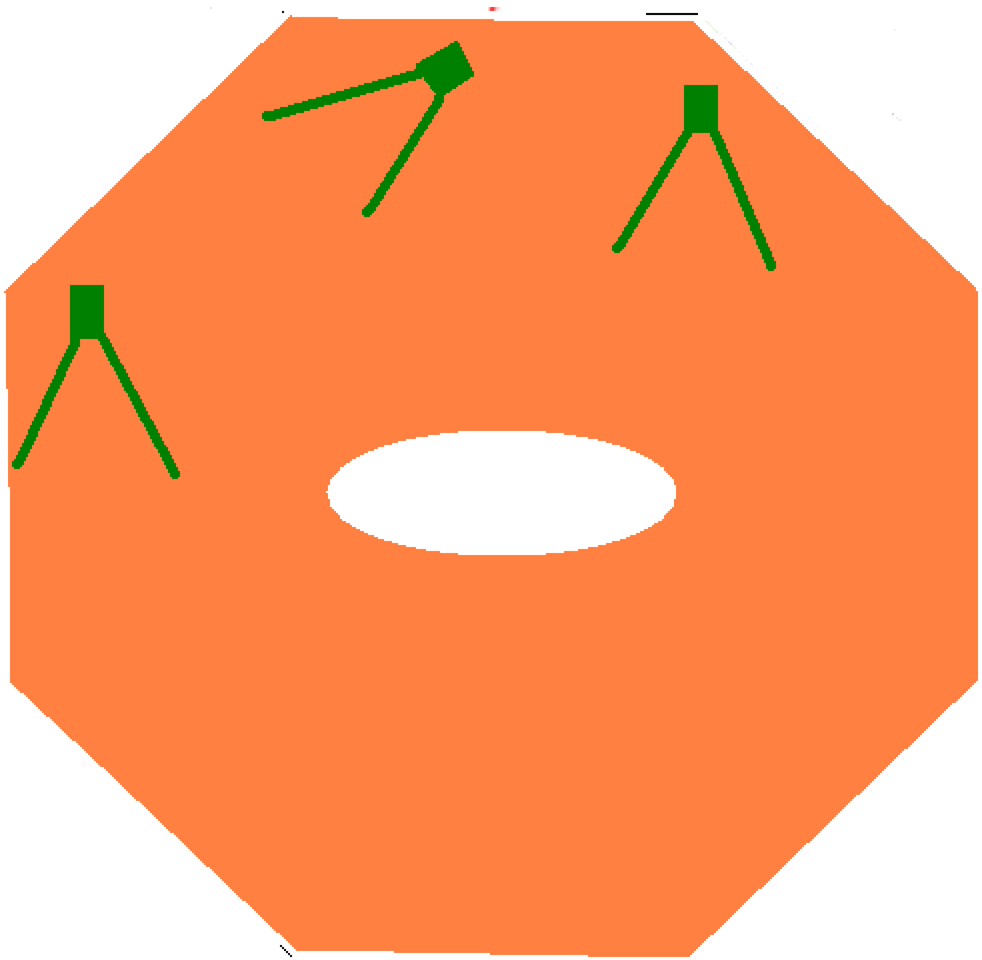


New idea II: detection with focussing lense

Advantage:
Direct measurement of Cherenkov angle in addition to TOP measurement



Top view

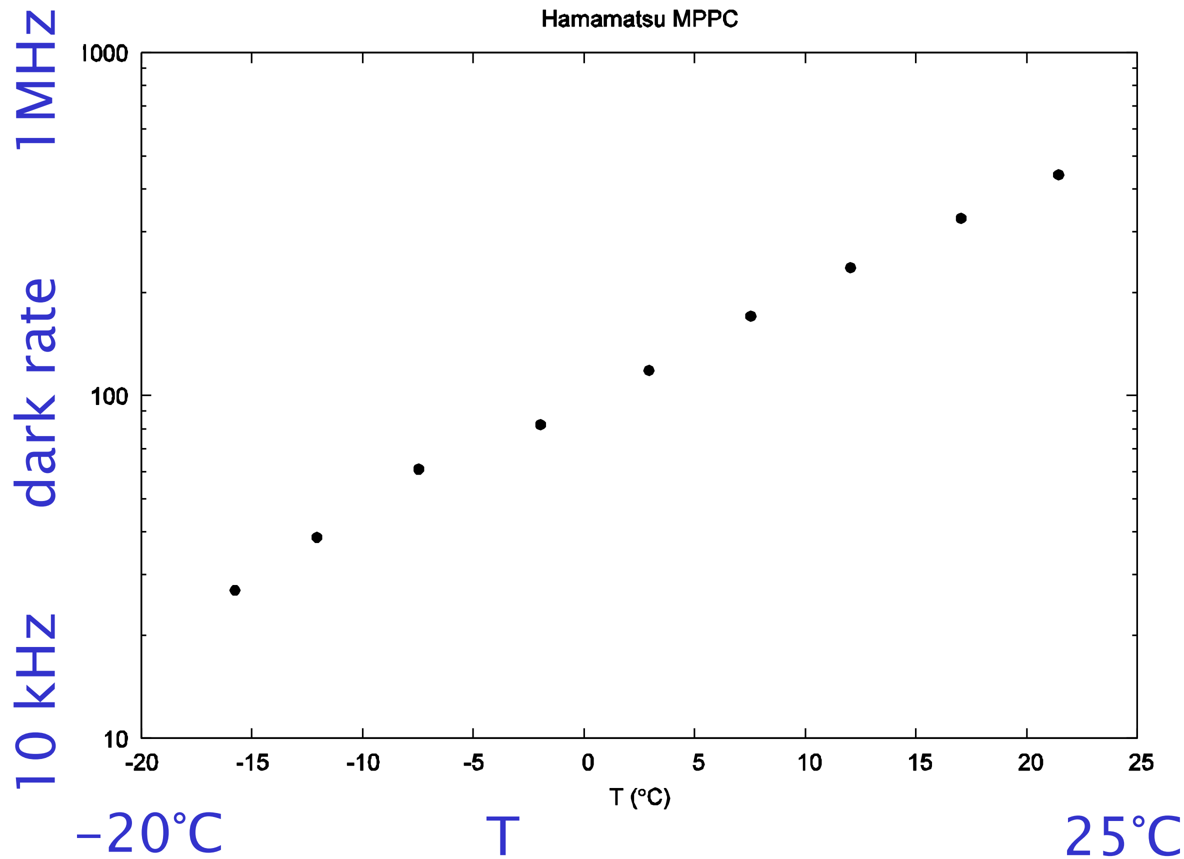


New ideas II

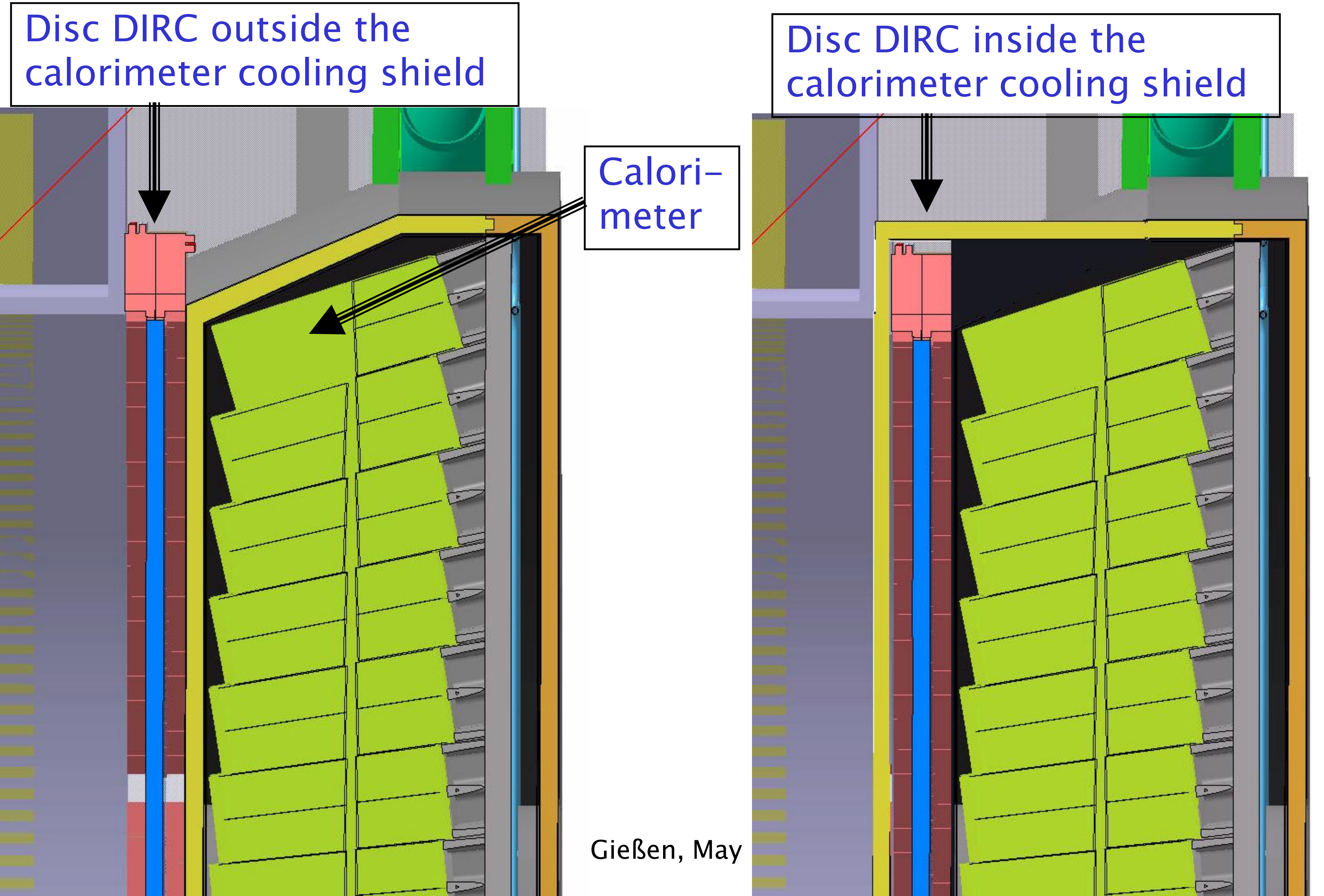
Detection from the side with prisms and lenses:

- additional direct information on Cherenkov angle
- Selected angular acceptance on detector
- Low overall photon detection efficiency (less aging)
- Additional path enlargement
- Small pixel detectors needed: G-APDs!
- Cooling of G-APDs by attaching the DIRC Disc to the calorimeter

Cooling of APDs reduces dark count rate



Disc DIRC attached to the calorimeter



Conclusions

Work in progress for TOP Disc DIRC

- Several design options
- Radiator quality to be refined
- Type of Photon detector to be selected
- Readout to select

- No show stoppers yet
- Interesting R&D project …