The PANDA Barrel DIRC

Carsten Schwarz, GSI

Introduction

Overview

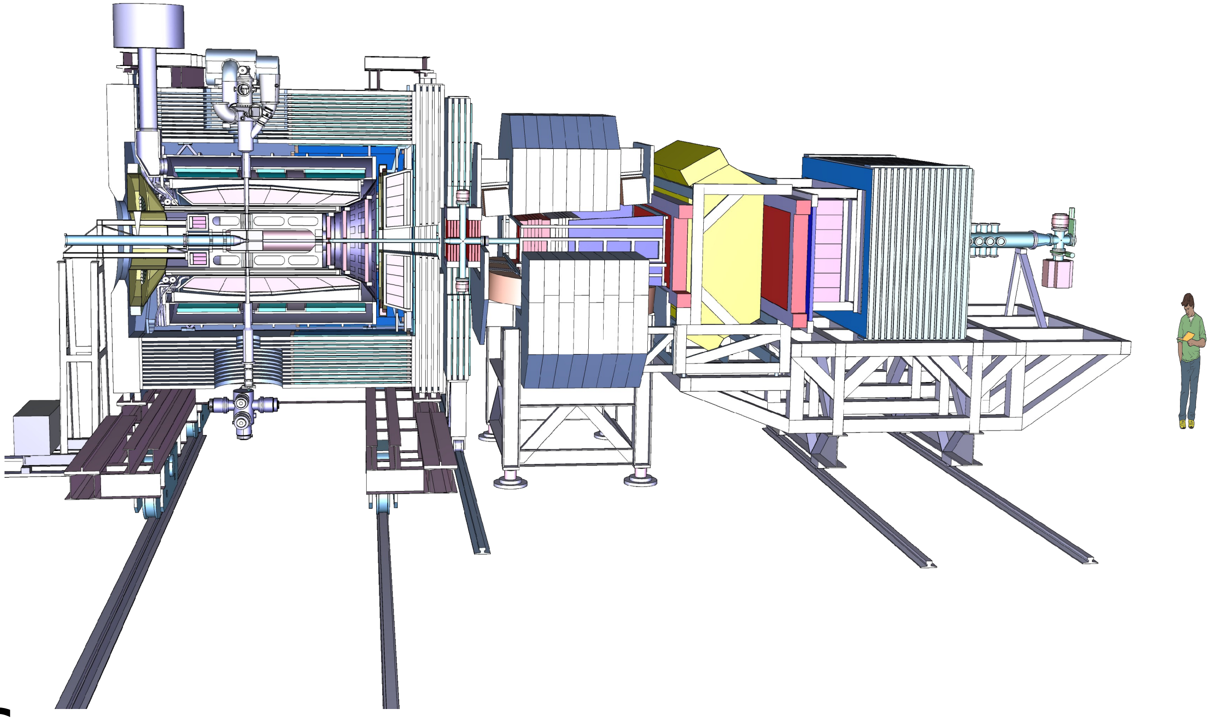
Focusing

Radiator

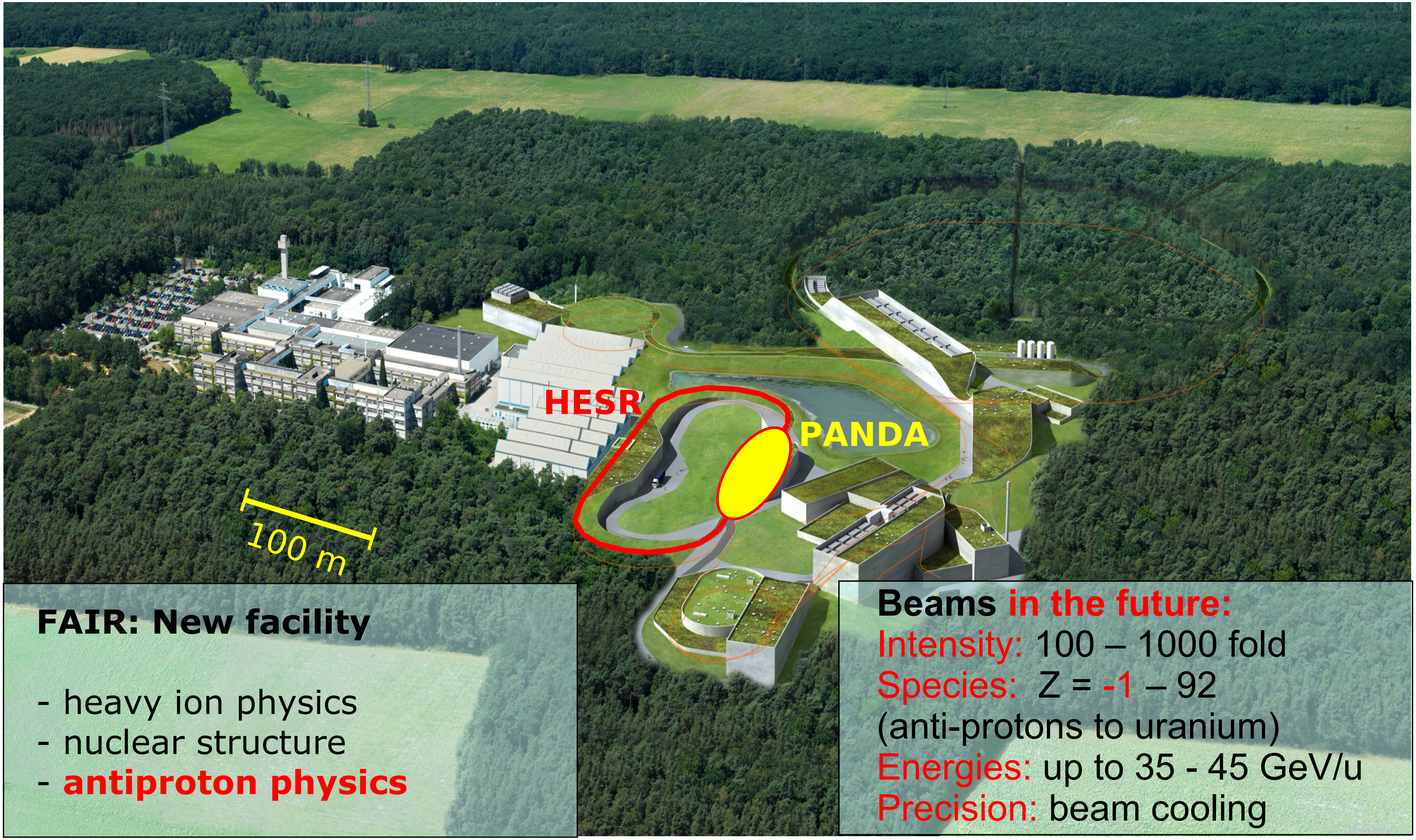
Photon detector

Test experiments

Readout



FAIR Facility for Antiproton and Ion Research



FAIR: New facility

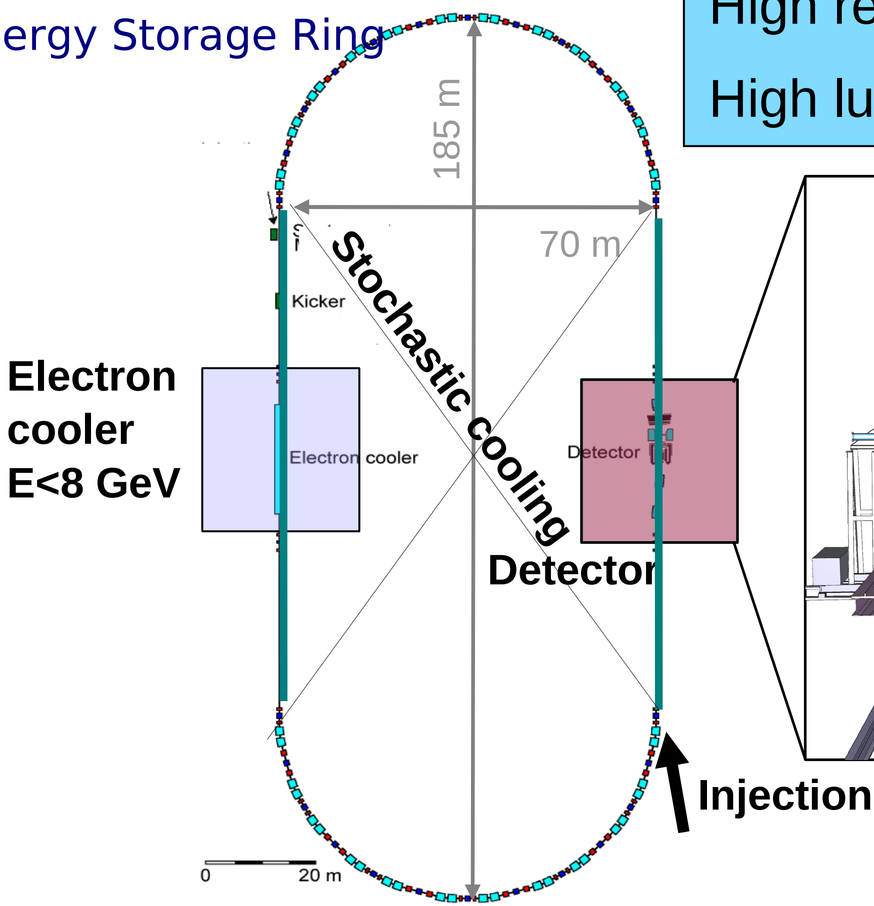
- heavy ion physics
- nuclear structure
- **antiproton physics**

Beams in the future:

Intensity: 100 – 1000 fold
Species: Z = -1 – 92
(anti-protons to uranium)
Energies: up to 35 - 45 GeV/u
Precision: beam cooling

HESR

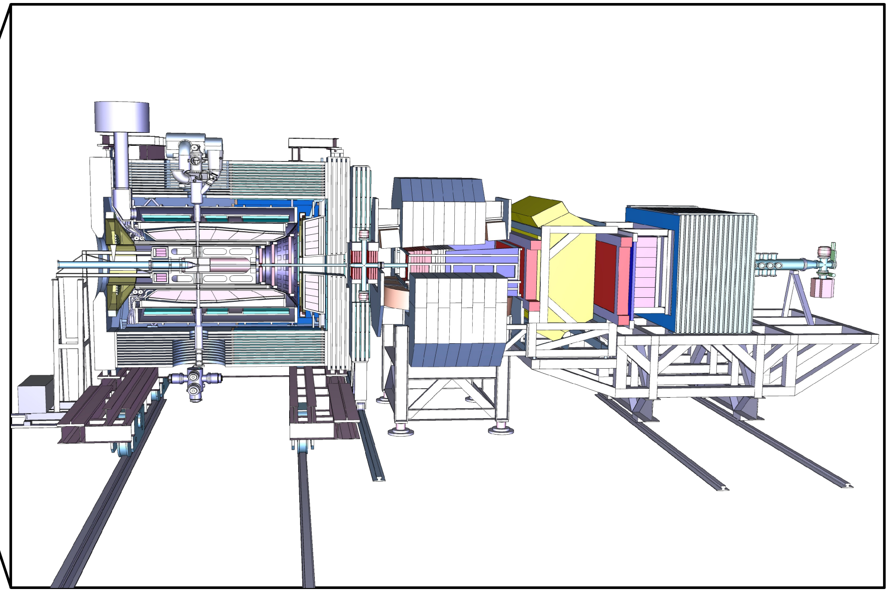
High Energy Storage Ring



Cooling: electron/stochastic

High resol. mode: $\mathcal{L} = 10^{31}\ cm^{-2}\ s^{-1}$ $\delta p/p \sim 10^{-5}$

High lum. mode: $\mathcal{L} = 2\cdot 10^{32}\ cm^{-2}\ s^{-1}$ $\delta p/p < 10^{-4}$



Characteristics

P_{max} = 15 GeV/c

$\mathcal{L}_{aver.}$ = $2\cdot 10^{32}\ cm^{-2}\ s^{-1}$

Ø < 100 µm

$\delta p/p < 10^{-5}$

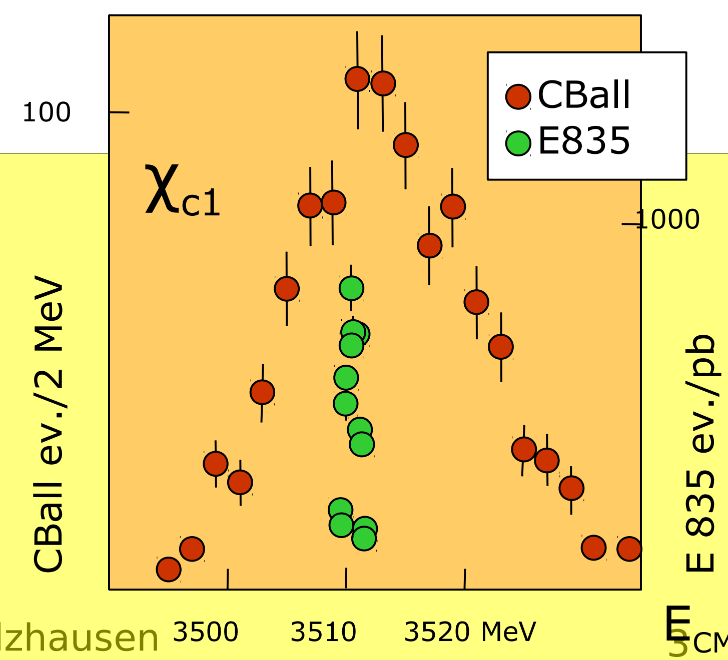
internal target

Resonance scan:

Energy resol. down to ~50 keV

Tune E_{CM} to probe resonance

Get precise mass and width



Physics topics

- Charmonium and open charm spectroscopy

  Confinement

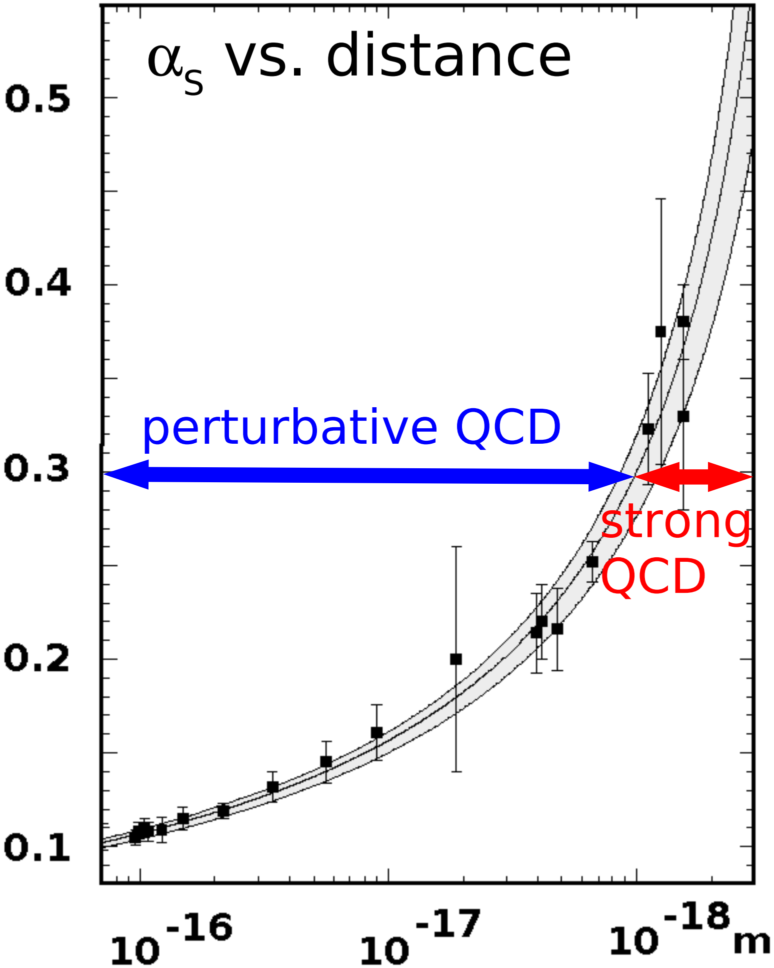
- Search for charmed hybrids and glueballs

  Formation of color neutral object

- Modification of charmed mesons in nuclear matter

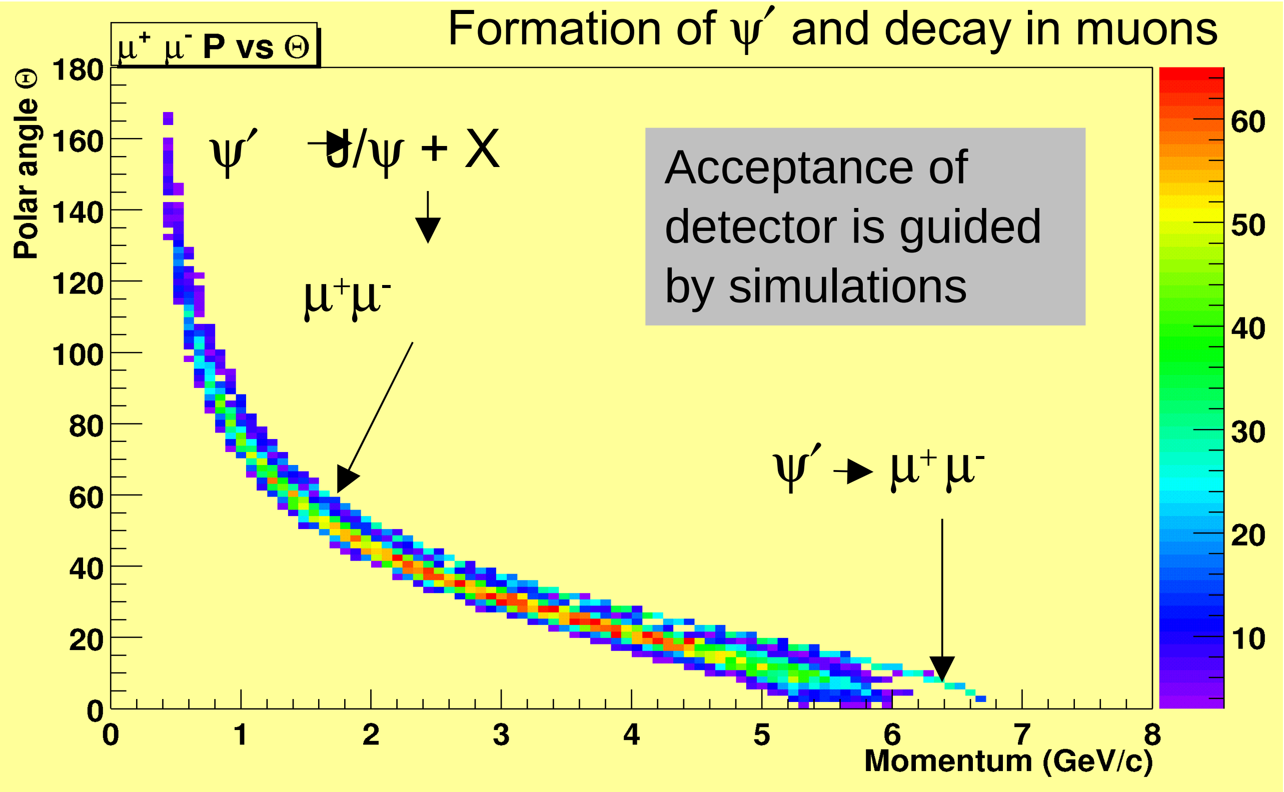
  Restoration of chiral symmetry

- Hypernuclei
- Nucleon structure

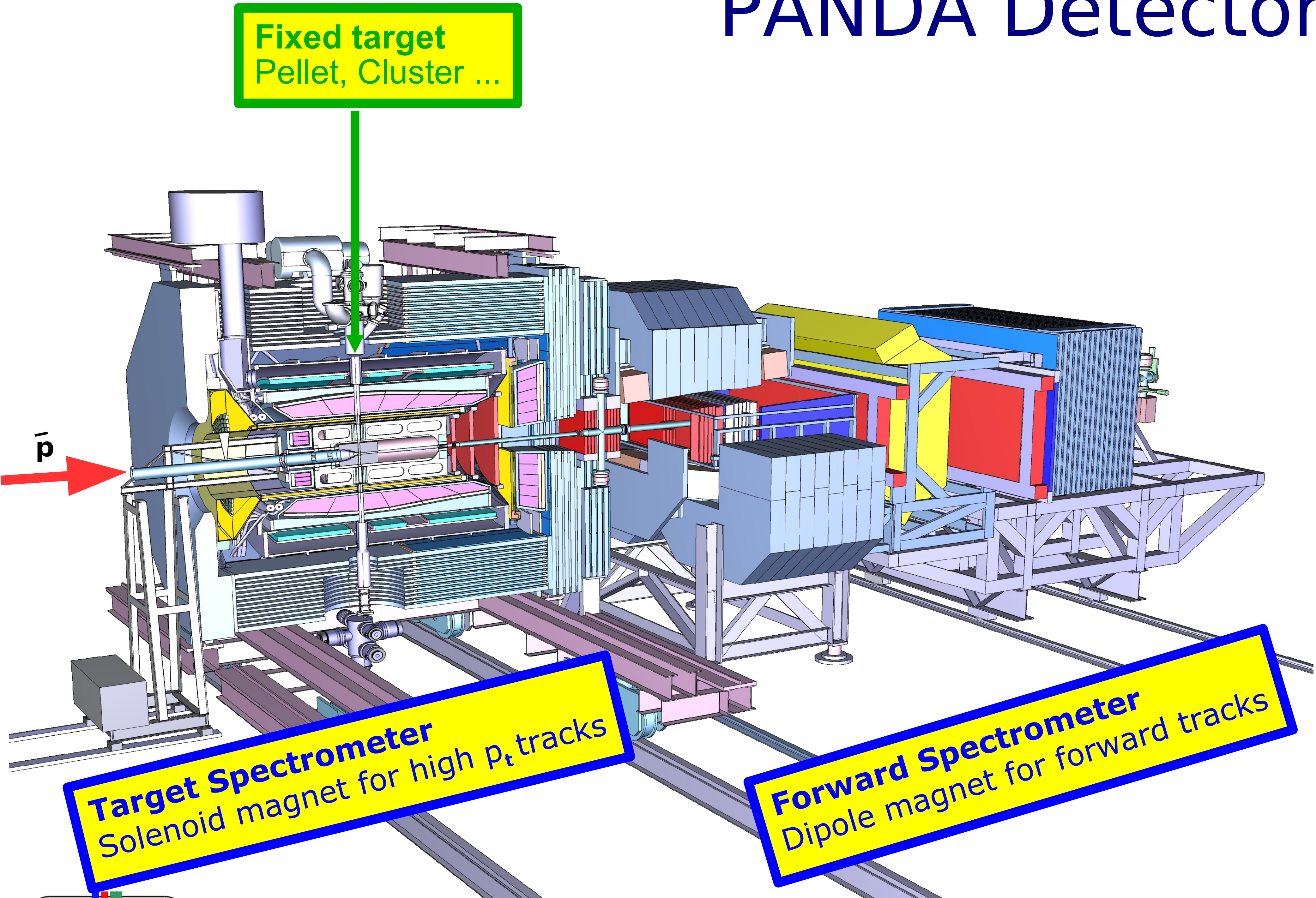


Detector Requirements

nearly 4π solid angle for PWA
high rate capability: $2\text{x}10^7\ s^{-1}$ interactions (average)
efficient event selection (triggerless DAQ)
momentum resolution ~1%
vertex info for D, K^0_S, Λ ($c\tau$ = 317 μm for $D^\pm$)
good PID (γ, e, μ, π, K, p)
photon detection 10 MeV – 15 GeV



PANDA Detector



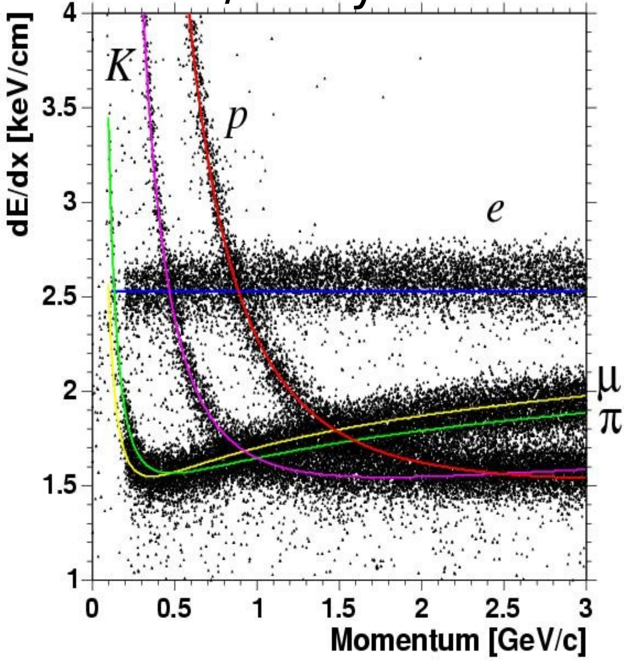
PANDA PID Requirements:

Particle identification essential for PANDA

Momentum range 200 MeV/c – 10 GeV/c

Several methodes for PID needed

dE/dX by TPC



PID Processes:

Cherenkov radiation:

Radiators: quartz

Energy loss: below Cherenkov threshold

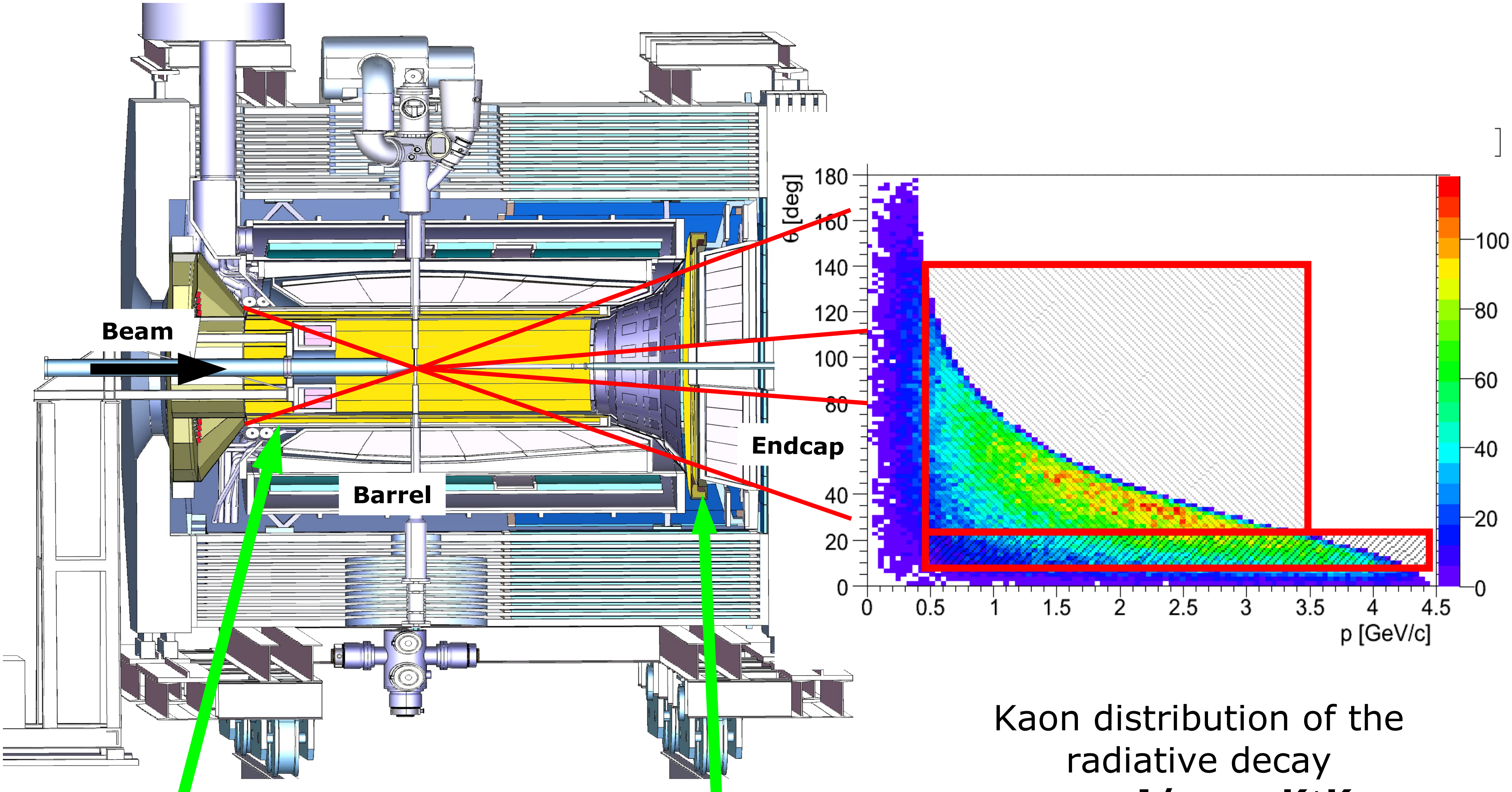
TPC or Straw Tubes

Time of flight

Challenge: no start detector, relative timing

Electromagnetic showers: EMC for e and γ

Cherenkov detectors



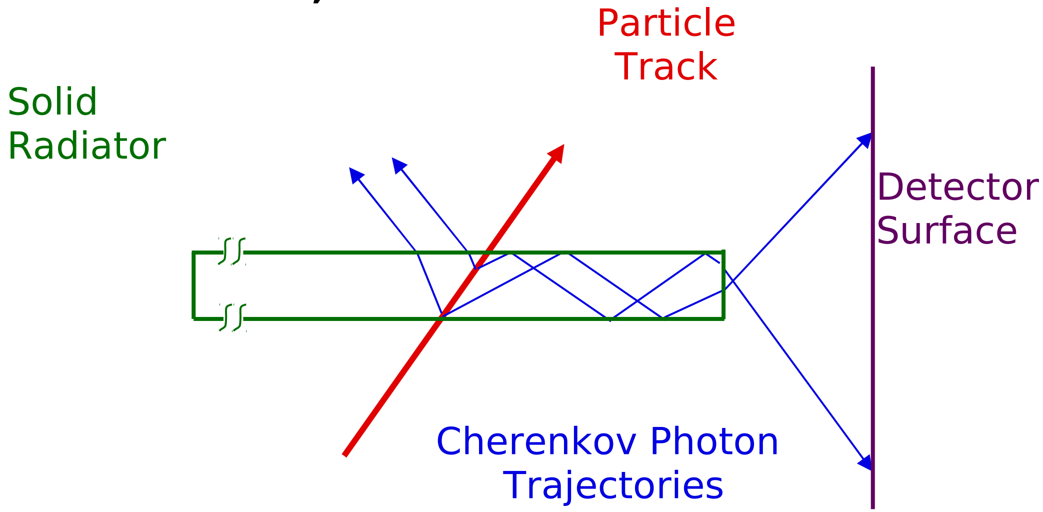
barrel DIRC **endcap disc DIRC**

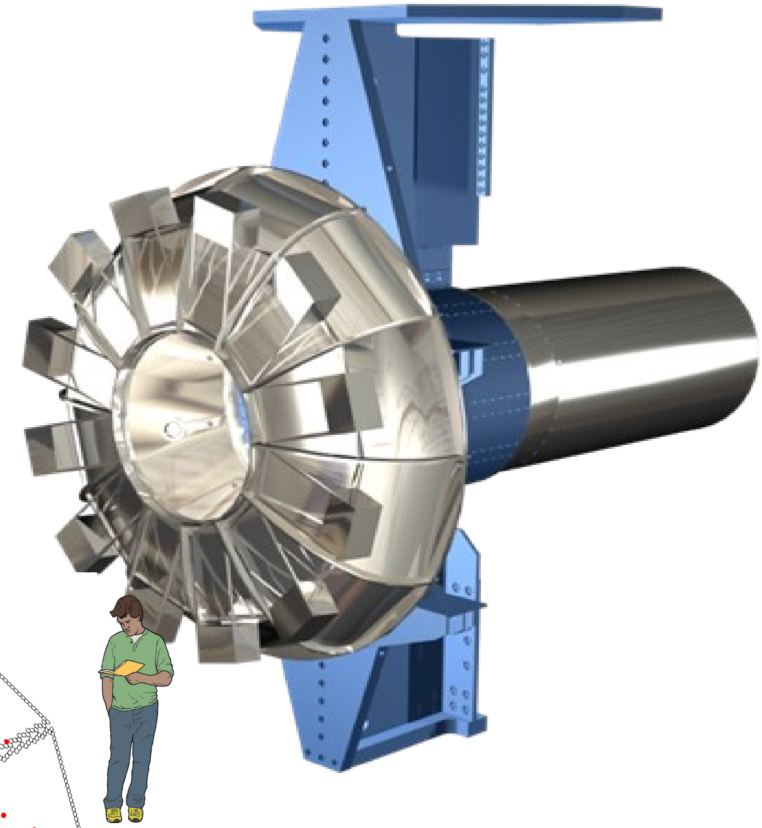
Kaon distribution of the radiative decay
$J/\psi \rightarrow K^+K^-\gamma$
(search of glue balls)

Barrel DIRC

Detection of **I**nternally **R**eflected **C**herenkov light

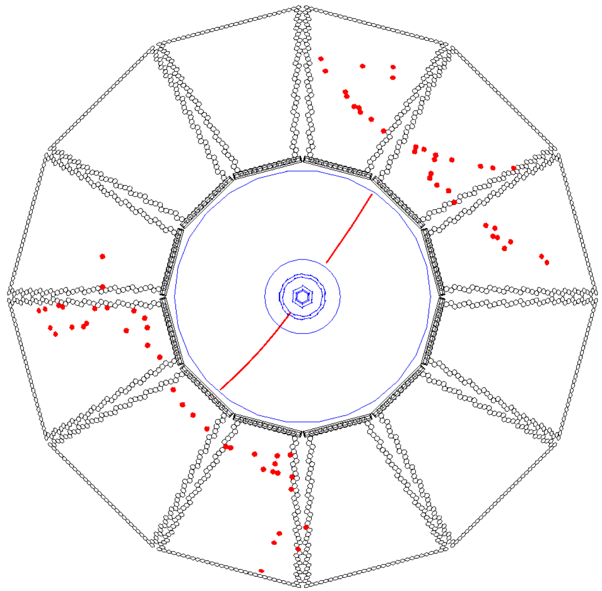
BaBar DIRC , SLAC

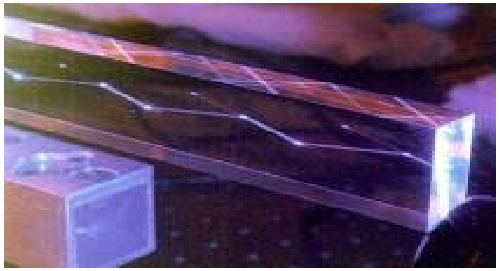




$$\cos(\theta) = \frac{1}{\beta n}$$

Magnitude of photon angles
in radiator preserved

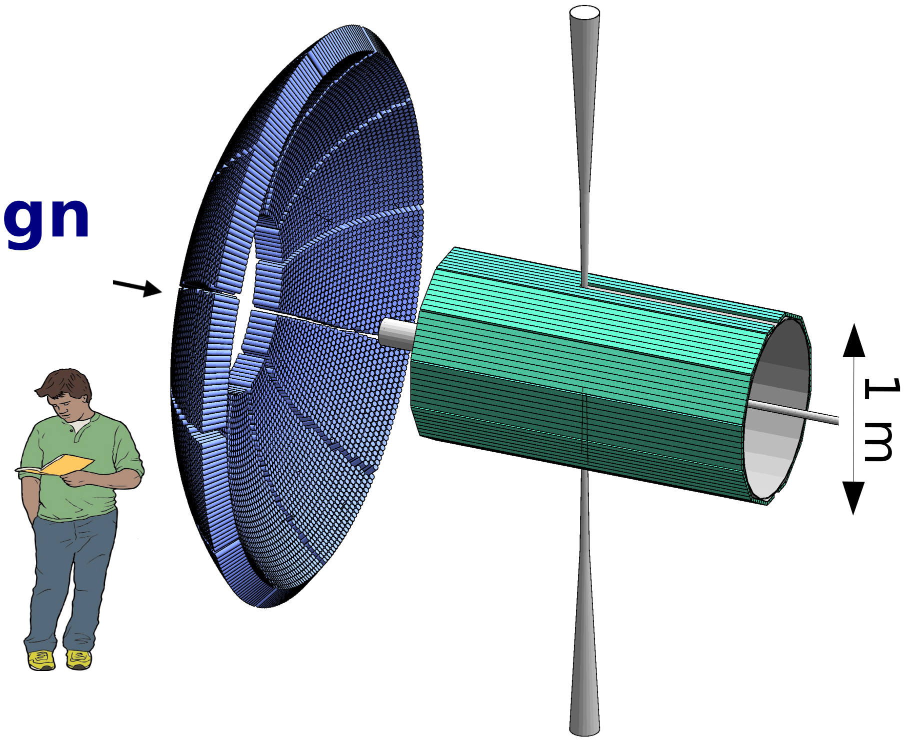


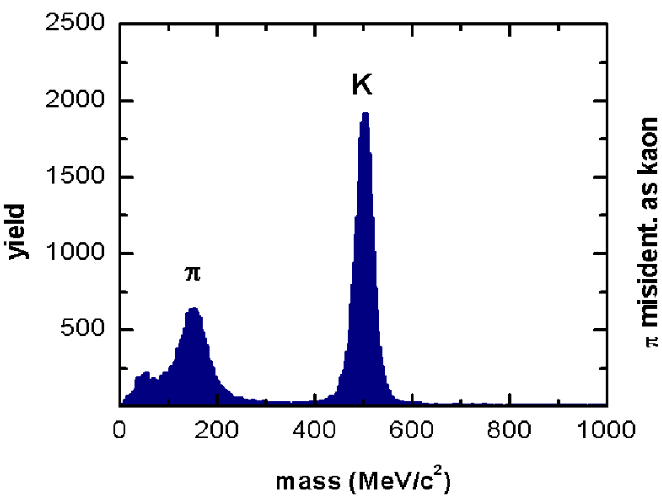


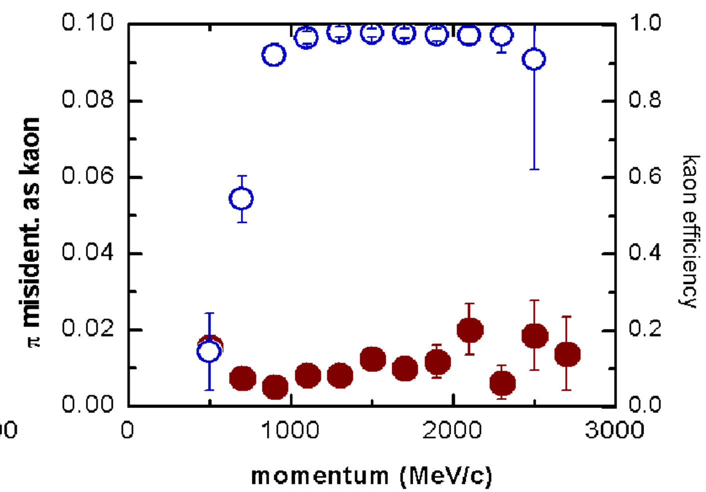
Barrel DIRC

PANDA Barrel DIRC, initial design similar to BaBar

96 Fused silica bars, 2.5m length
Scaled: Water tank & 7000 PMTs







98% kaon efficiency

2% pion miss id.

Current design of Barrel DIRC

More compact, faster, focusing optics

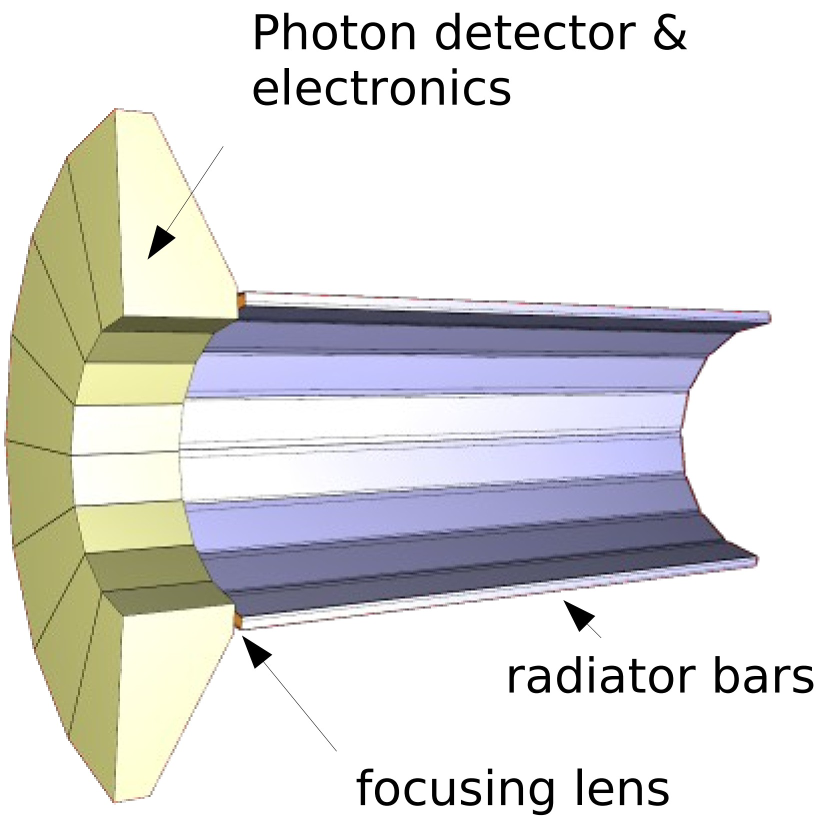
80 radiator bars, synthetic fused silica
17mm (T) × 33mm (W) × 2500mm (L)

Focusing optics: lens system

Compact photon detector: array of
Burle Planacon MCP-PMT
G-APD
total 7000-10000 channels.

Fast photon detection: MCP-PMT
fast TDC/Time Over Threshold electronics

→ 100-200 ps timing.



Still investigating several design options:

mirror focusing, radiator plates, photon detection outside magnetic field

BABAR-DIRC Cherenkov angle resolution: 9.6 mrad per photon → 2.4 mrad per track

Limited in BABAR by:

- size of bar image ~4.1 mrad
- size of PMT pixel ~5.5 mrad
- chromaticity ($n=n(\lambda)$) ~5.4 mrad

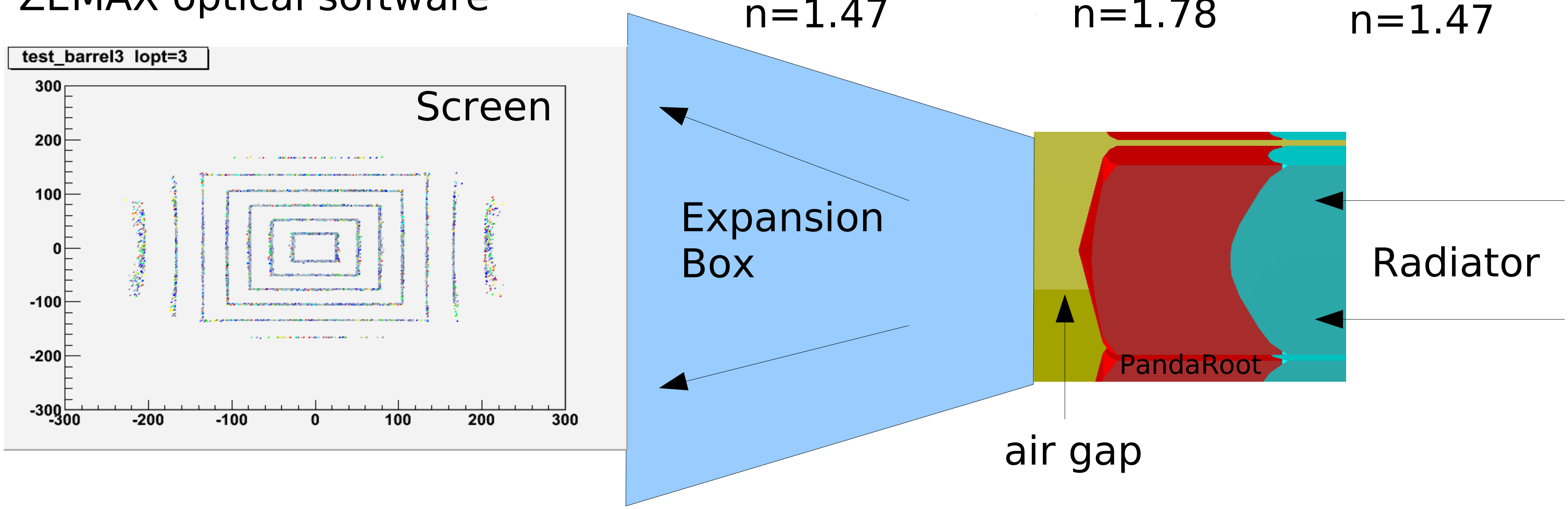
Could be improved for PANDA via:

- focusing optics
- smaller pixel size
- better time resolution

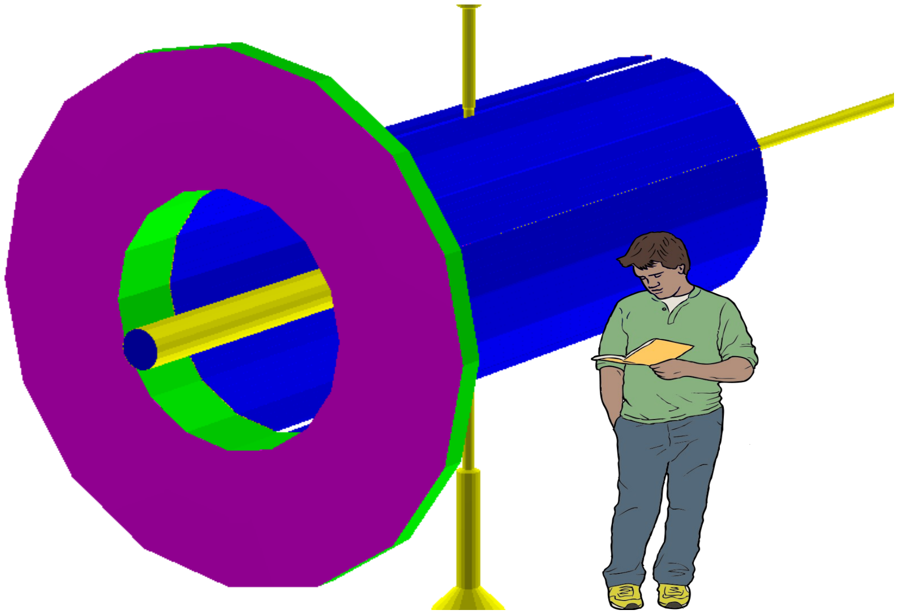
PANDA DIRC Design

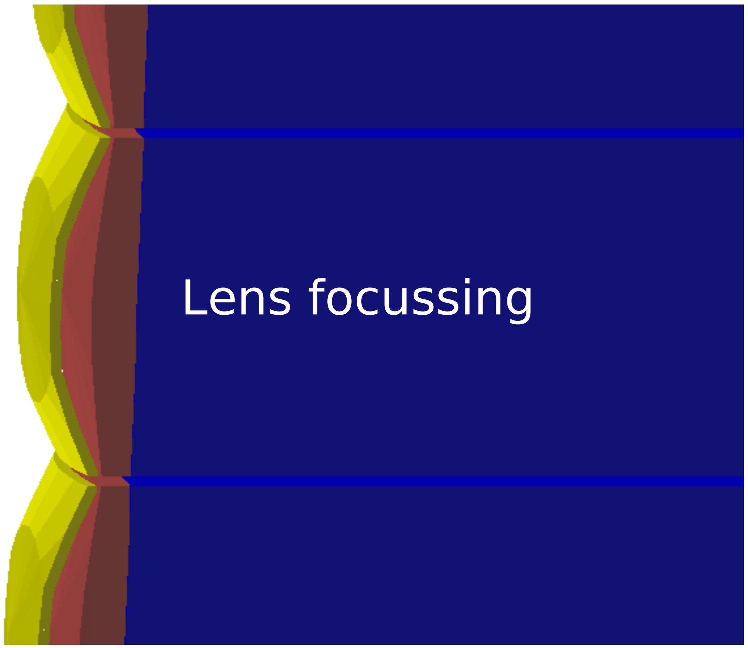
9.6 mrad → 4-5 mrad per photon → 1.5–2 mrad per track

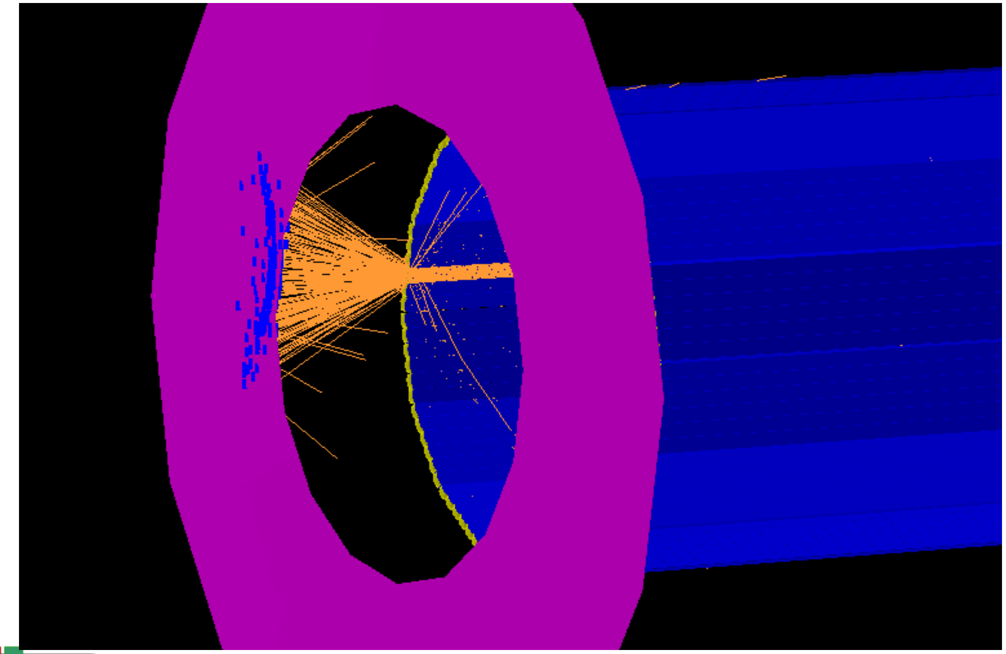
Lens design by ZEMAX optical software



Simulations in PandaRoot







Design is being optimized

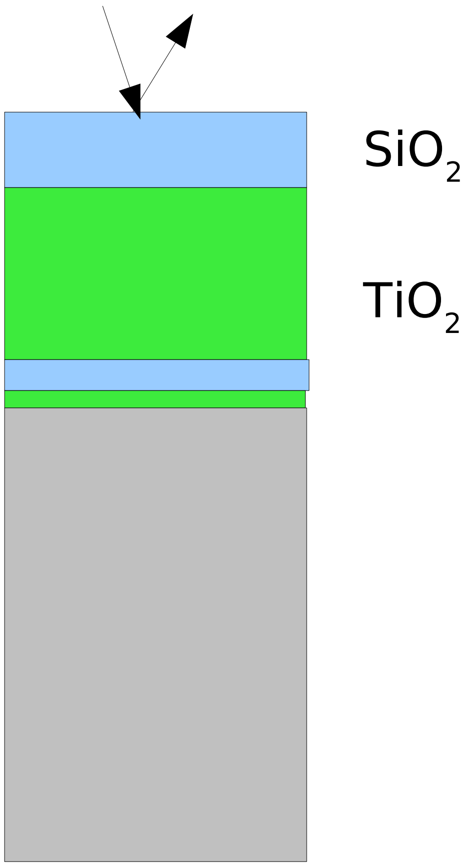
Fast reconstruction algorithm being developed

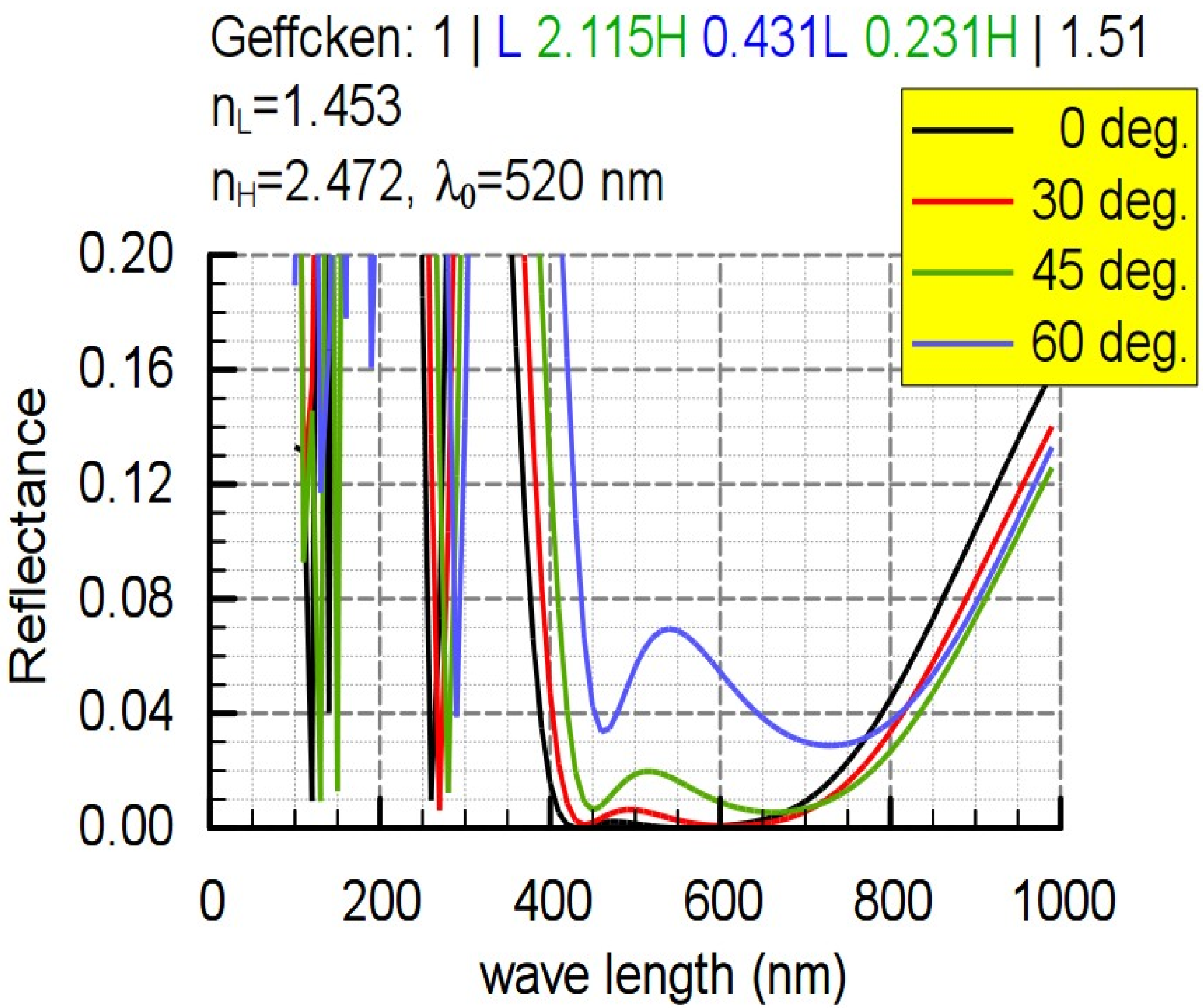
→ Maria Patsyuk, tomorrow

Lenses: Antireflex Coating

Example:

Walter Geffcken (1942)
German Patent 742.463

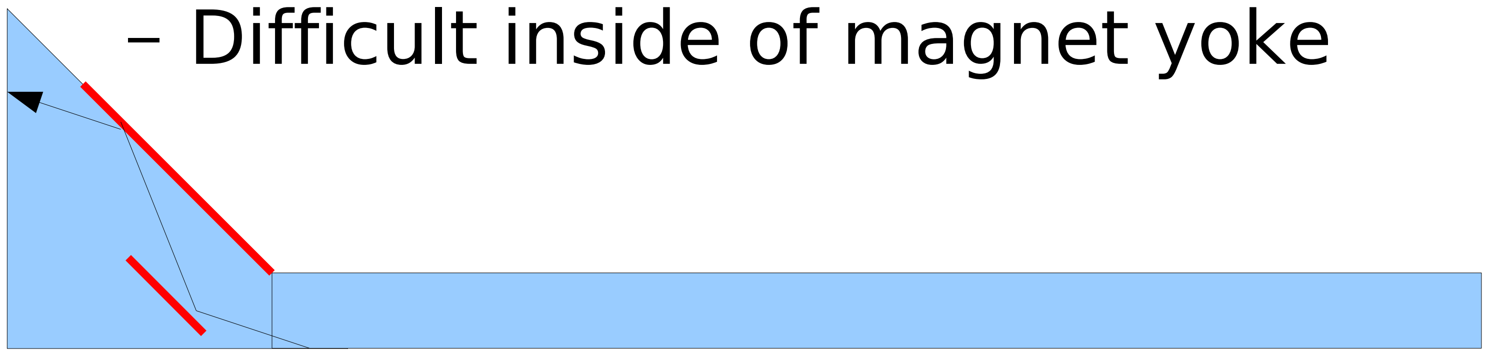




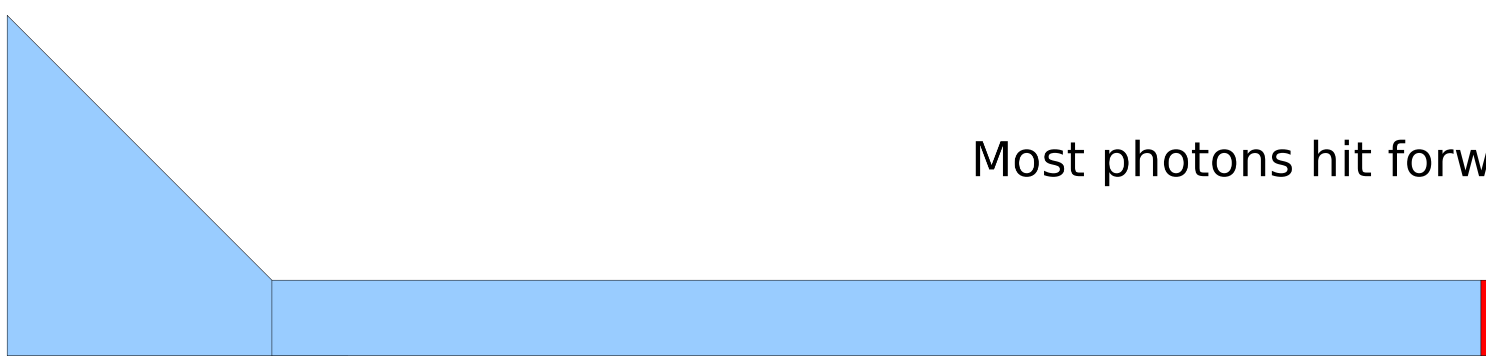
→ Needs R&D effort to find optimum for barrel DIRC

Other focusing options

- Focusing mirrors
  - Difficult inside of magnet yoke

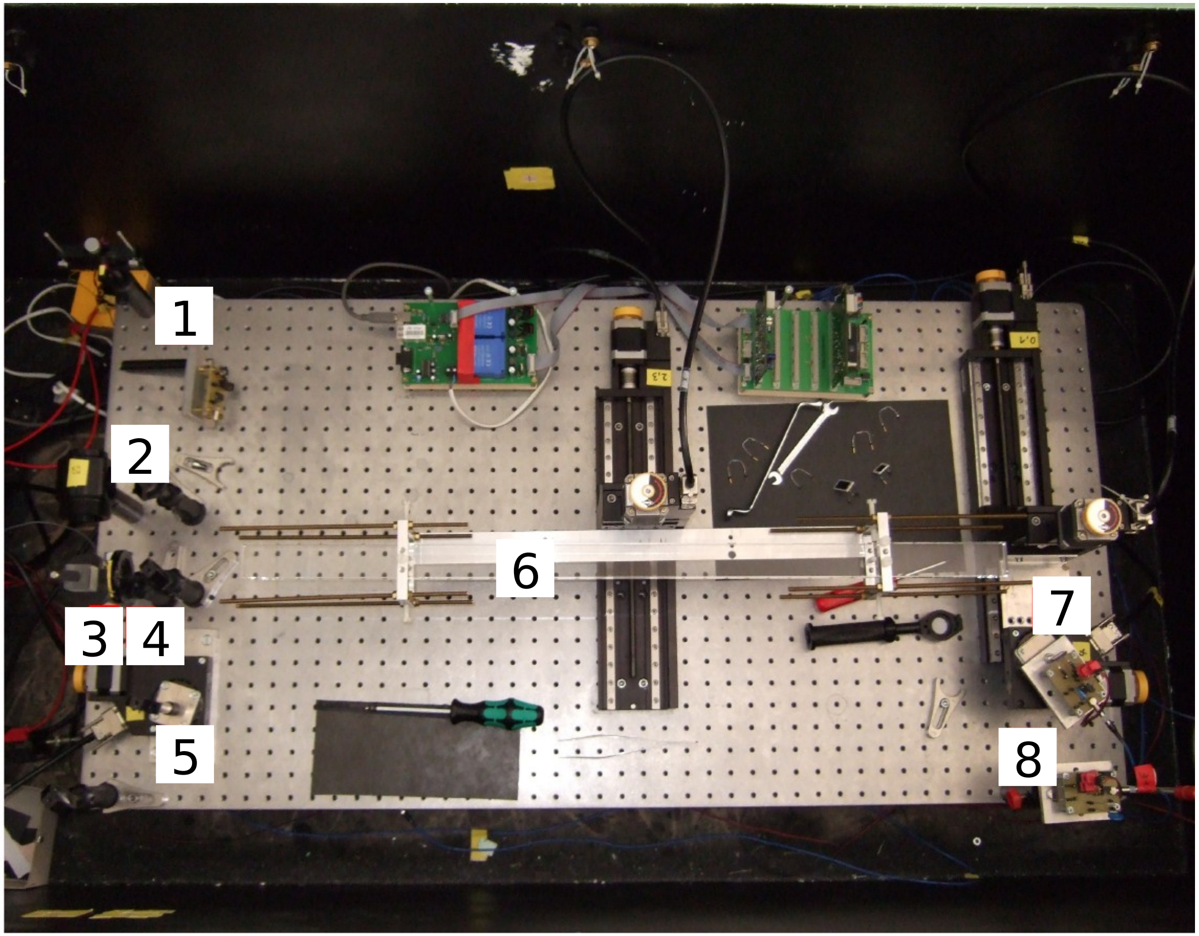


- Forward focusing mirror

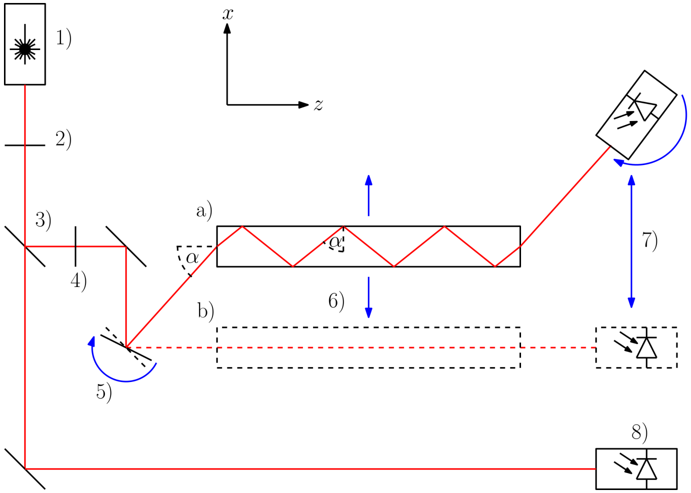


Most photons hit forward mirror

Radiator Quality Test
Motion-controlled scanning setup

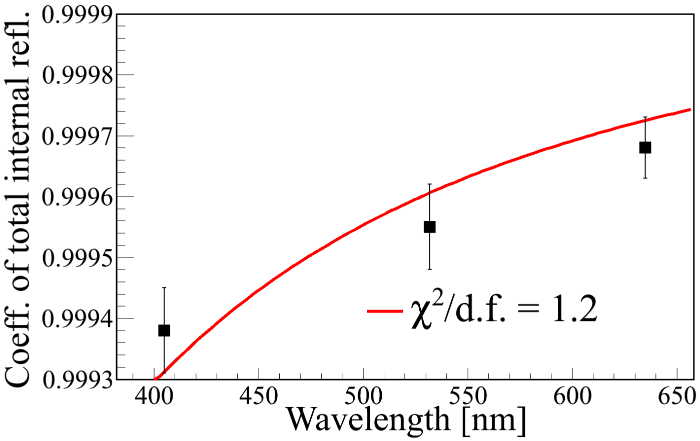


1) Laser (405, 532, 635 nm)
2) Polarizer
3) Beam splitter
4) Diaphragm
5) Brewster mirror
6) Bar on x, y stage
7) Value Diode
8) Reference Diode

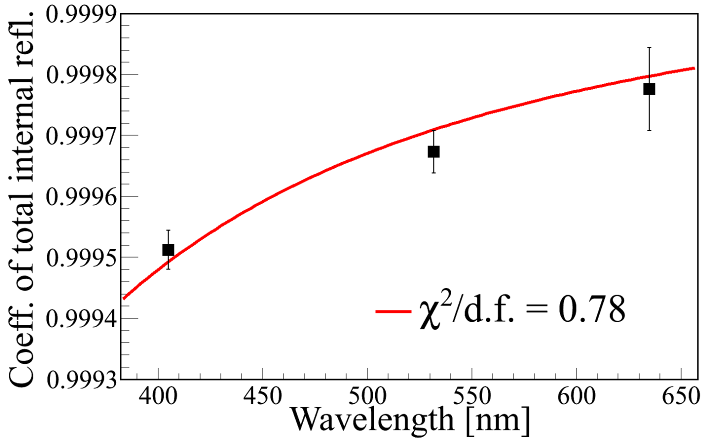


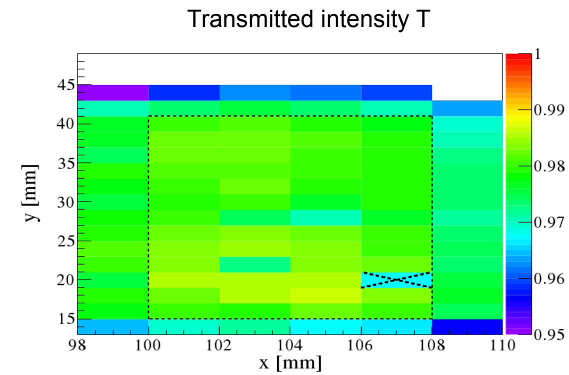
Radiator Quality Test Results: *Schott Lithotec, 80cm bar*

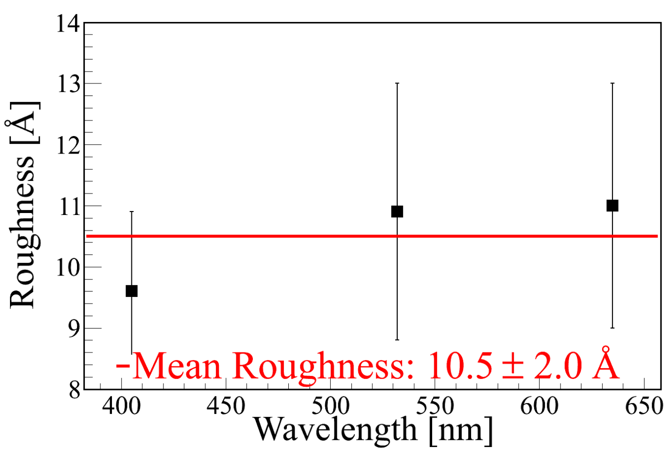
15 Reflections

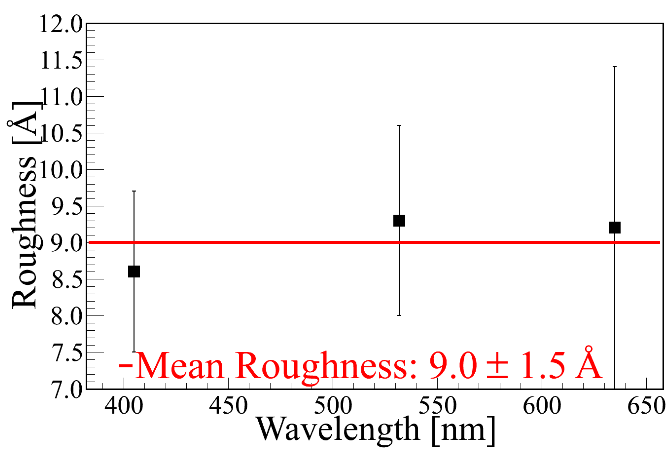


31 Reflections





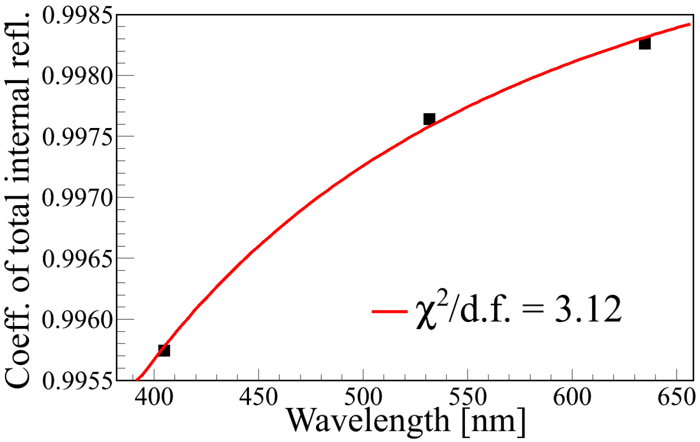




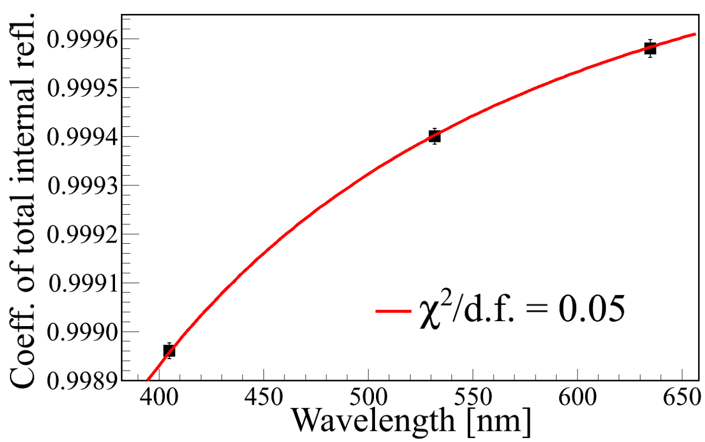
- Results consistent with the specifications.
- *Good agreement with scalar theory of scattering.*
- *Pitch polishing - similar to method used in BABAR is able to produce bars with very good surface polish.*
- *Not an option since Lithotec has shut down.*

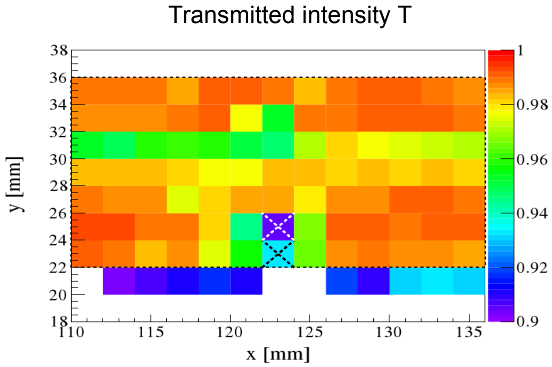
Radiator Quality Test Results: Lytkarino LZOS, *30cm bar*

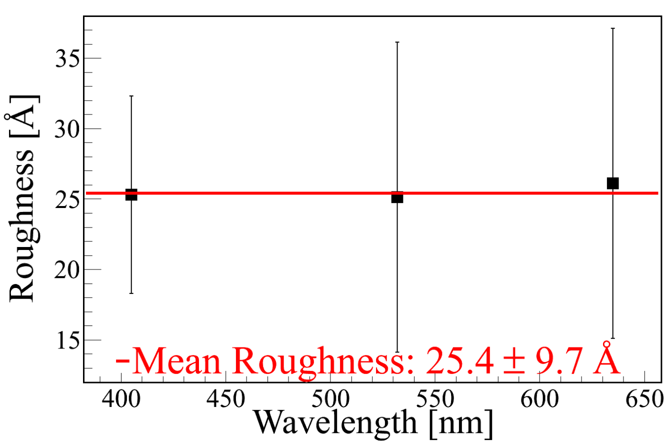
6 Reflections

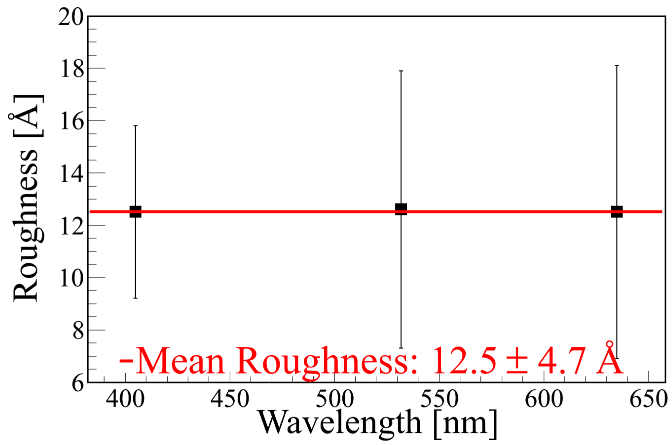


12 Reflections





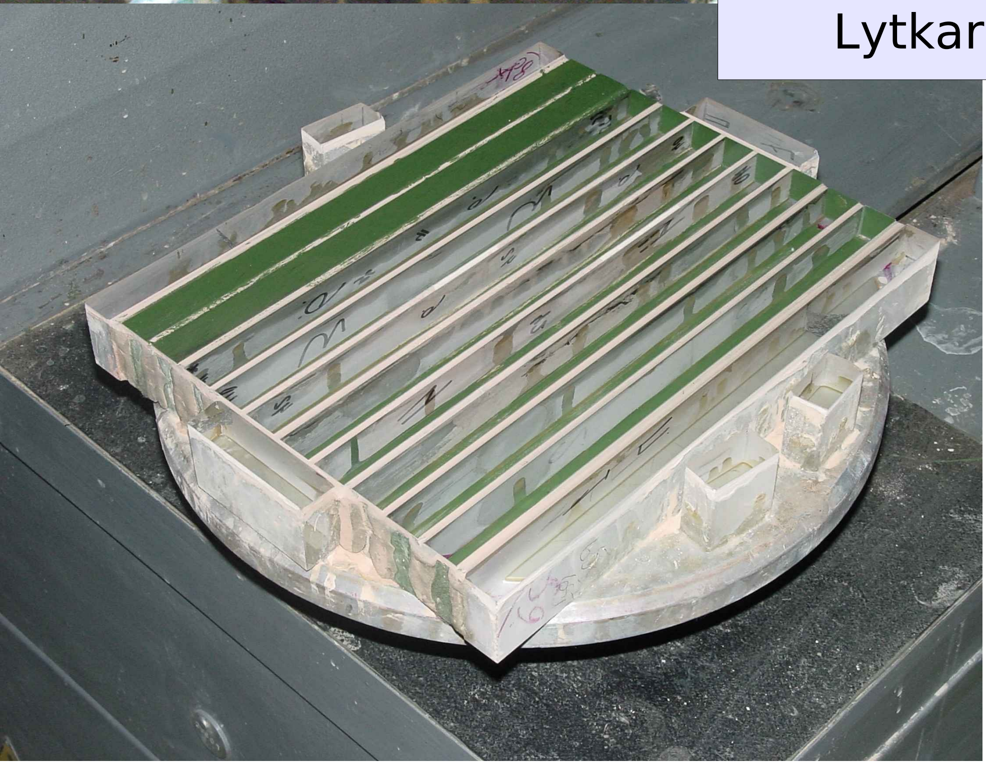


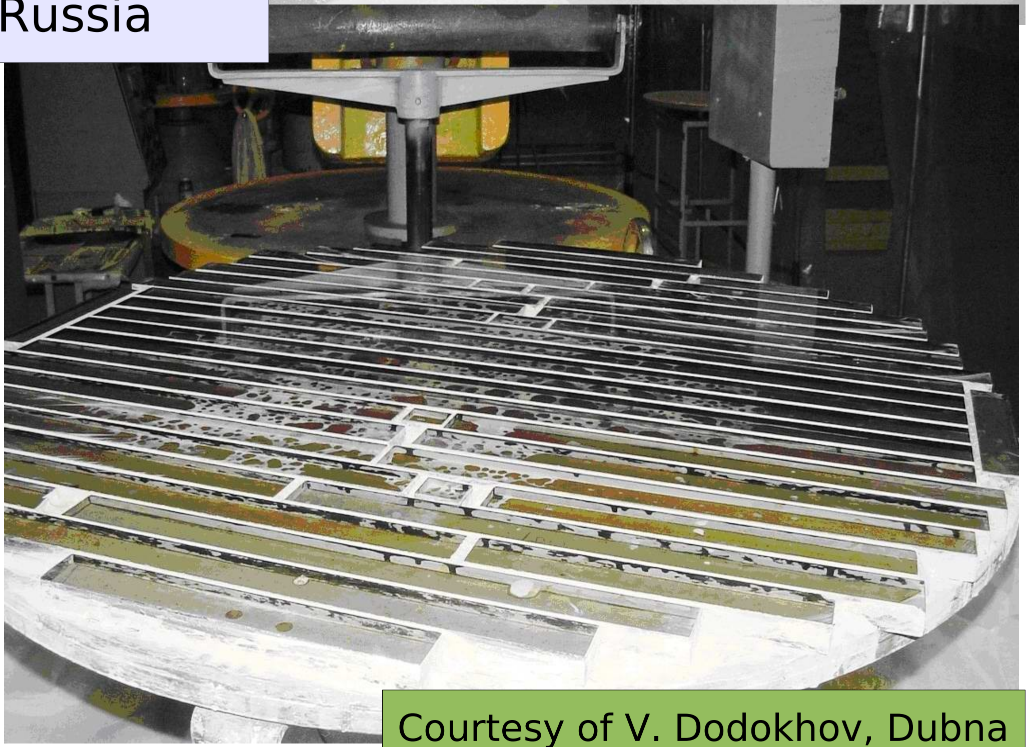


- Results consistent with the specifications.
- *Some bar defects.*
- *Short length of the bar.*
- *New 90cm length prototype bars from LZOS almost done (update on delivery and manufacturer's QA data at April DIRC workshop)*

Grzegorz Kalicy, PANDA Collaboration Meeting, 14.03.2011

Polished by LZOS,
Lytkarino, Russia

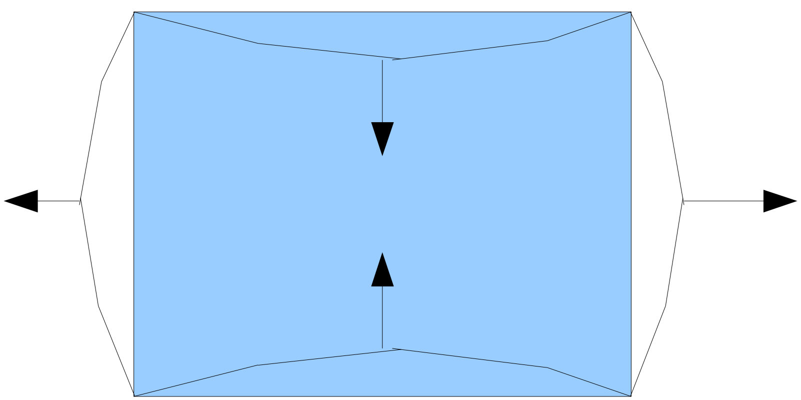


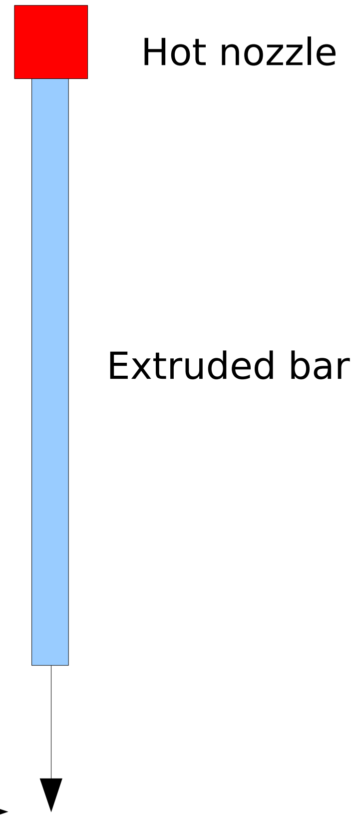


Courtesy of V. Dodokhov, Dubna

Radiator Quality Test Results: *Heraeus bars*

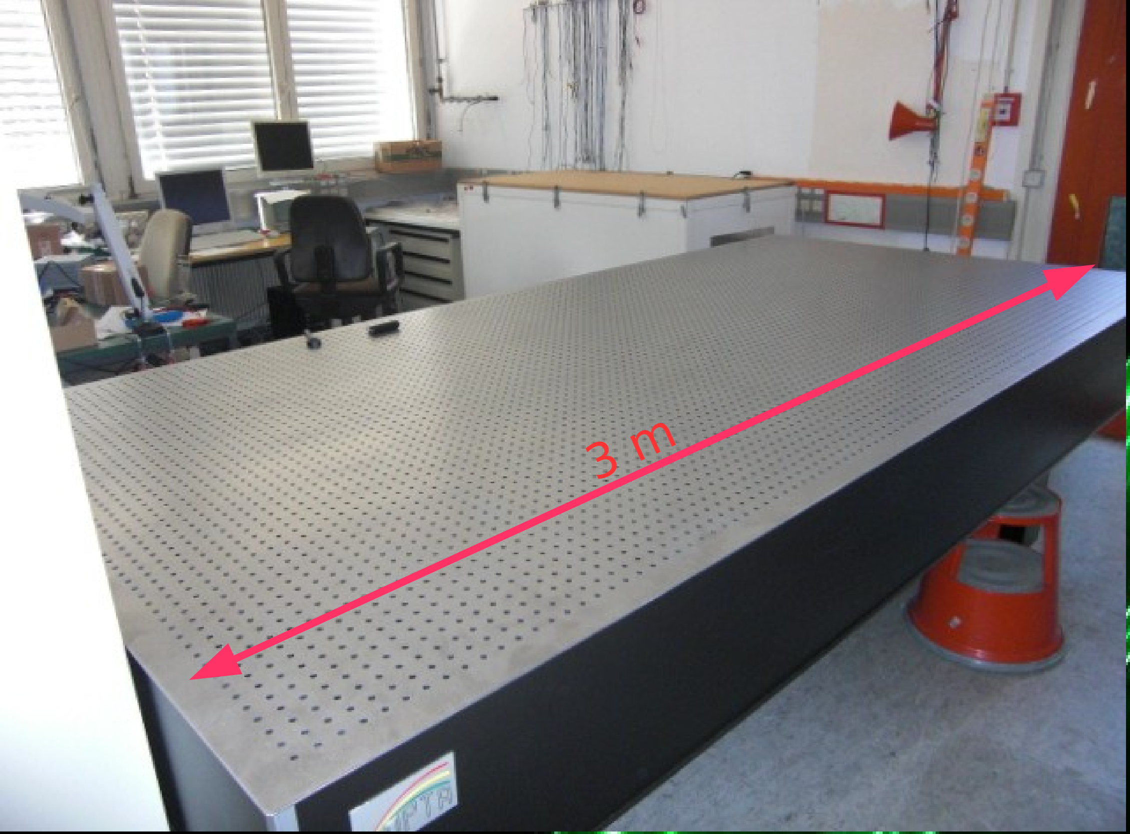
Bar cross section



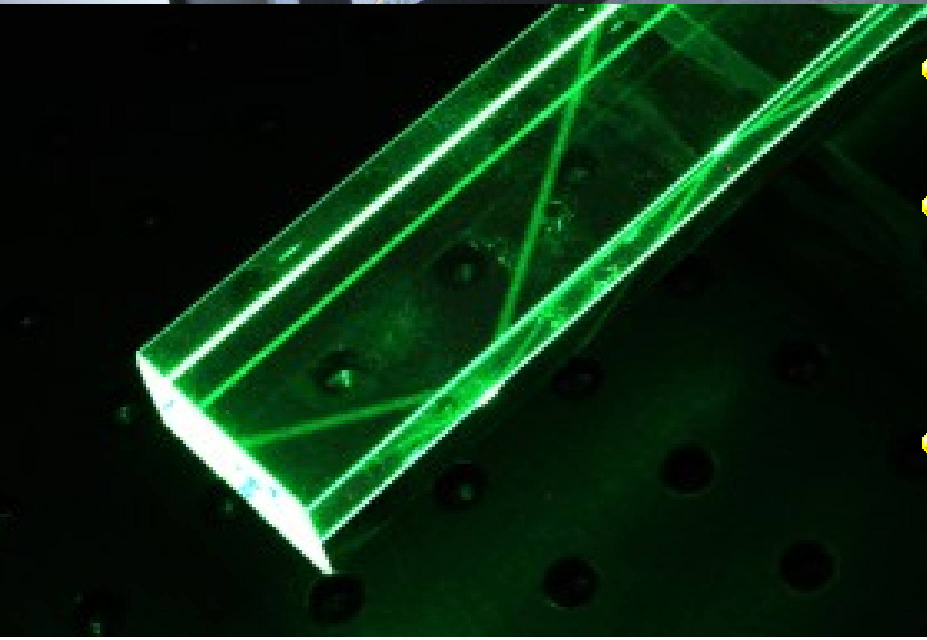


Tested inexpensive alternative production methods with Heraeus.

- *Production of the Heraeus bars using extrusion method - lateral sides of the bars are curved.*
- *Surface melting of ground bars – better, but surface roughness still not sufficient for PANDA DIRC.*
- *Several bars with different production parameters checked (temperature, feed-through speed).*
- *Heraeus production methods cannot reach so far requirements for optical properties of radiators (bar shape, surface roughness).*

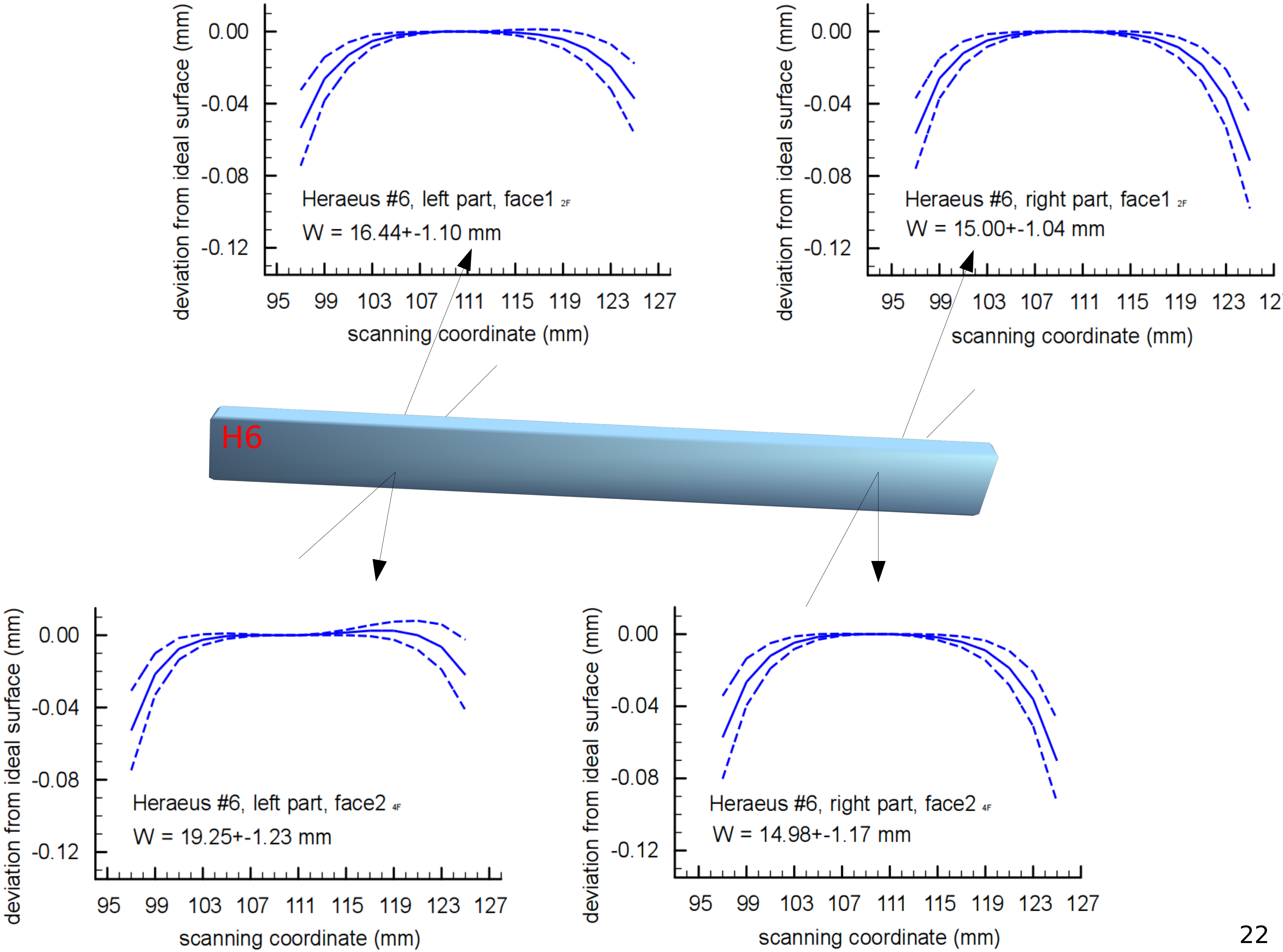


Radiator
next steps



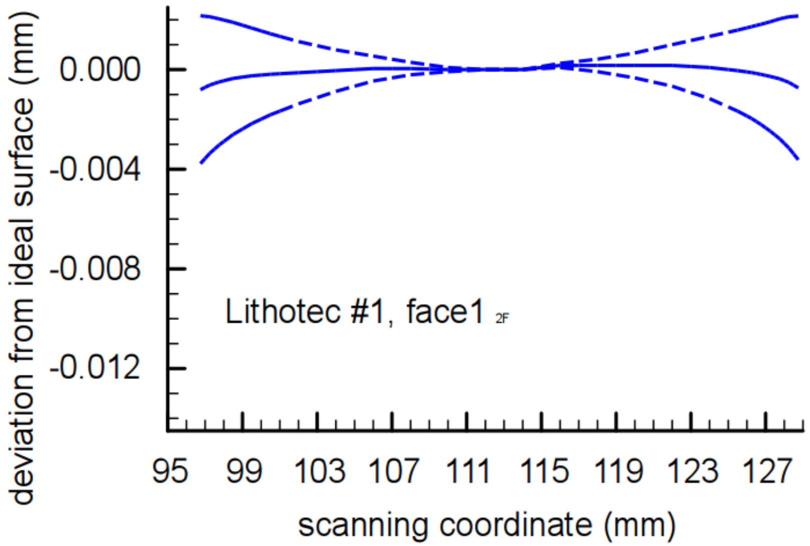
- Finish setup for long bars
- 1225mm bars from InSync (old BaBar bars)
- Production of Zeiss bars
  - HIM, JGU Mainz

Heraeus #6, faces



How a polished bar looks like?
Lithotec #1

Increased lever arm of Lasers L = 12m



no shape distortion visible

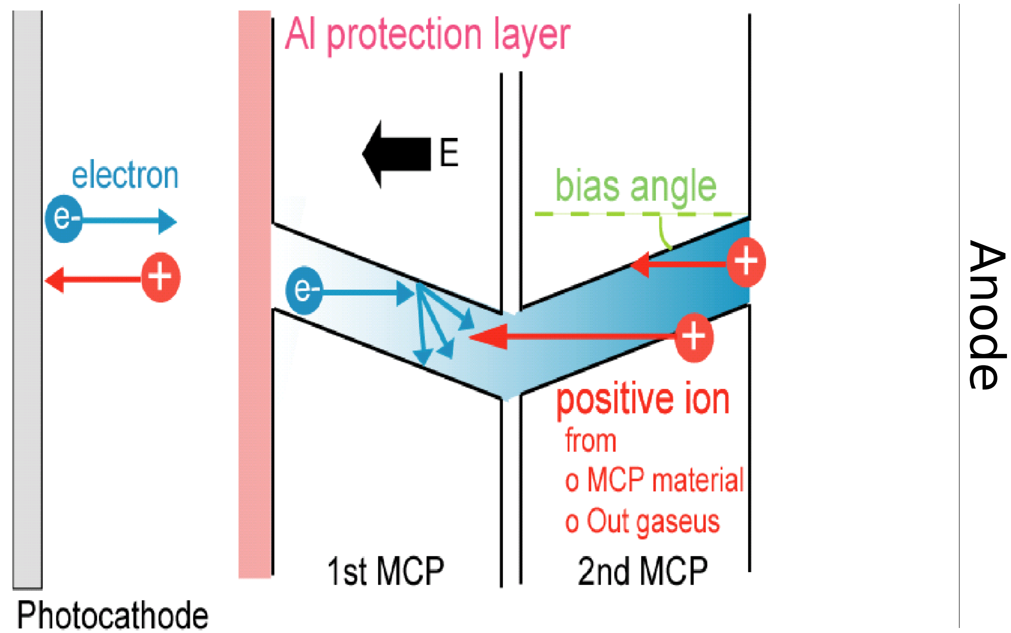
The surface molten bars show too large edge rounding.
Not an option for barrel DIRC bars.

Plates? Surface roughness: 40Å

Photon detector

K. Inami Fast timing workshop, Saclay 2007

Multi Channel Plate - PMT



200 V 2000 V 200 V

on anode!
gain ~ 10^6

Ageing: typically 1C/cm² -> 30% loss of QE

PANDA:

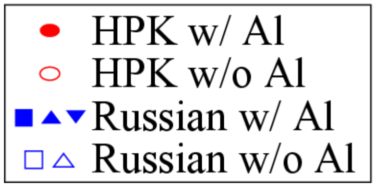
Barrel	0.8 C/cm²/y
Focussing	3.8C/cm²/y
TOP	9.6C/cm²/y

anti aging agents:

- protective layer (Hamamatsu/BINP)
- electron scrubbing of channels (Photonis)
- improved vacuum (Photonis)

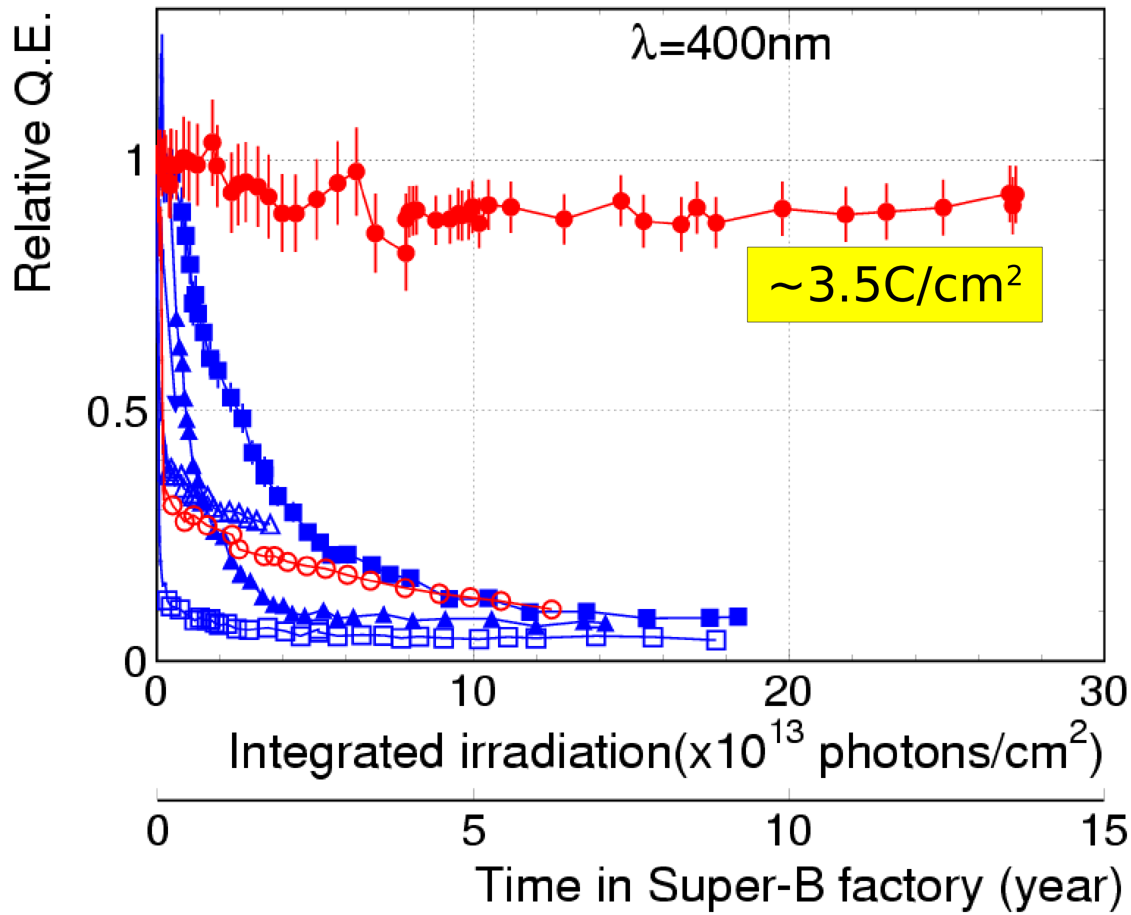
Protective layer on 1st MCP: CE 60% → 35%

K. Inami Fast timing workshop, Saclay 2007



Hamamatsu

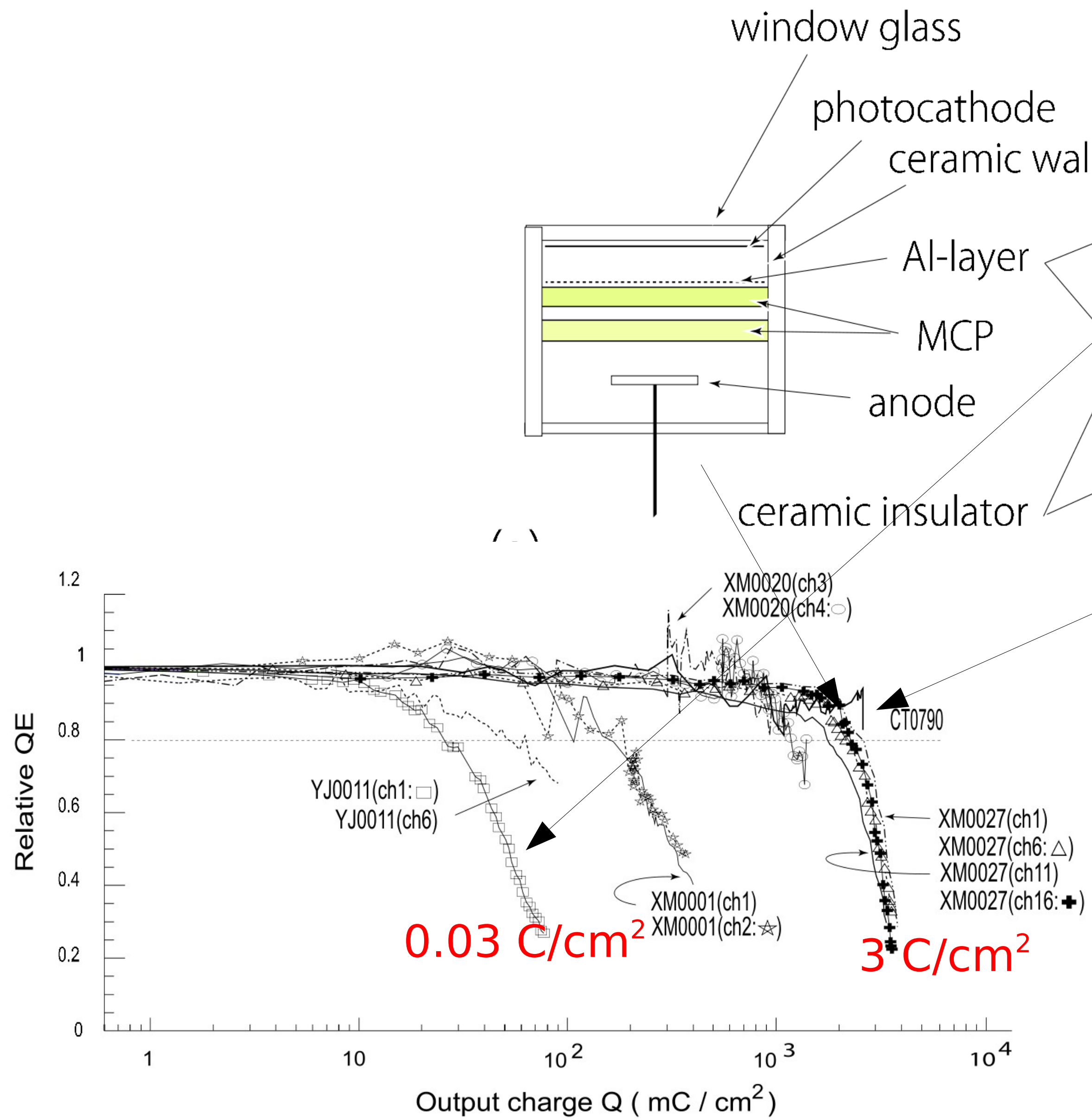
BINP

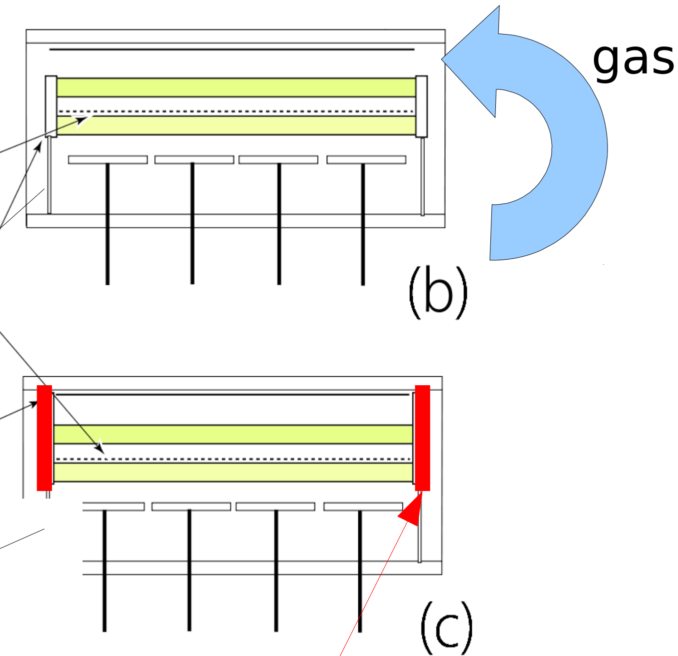


Long life times are in principle possible

T. Ninno et al., Lifetime-Extended MCP-PMT

Al protection layer on 2nd MCP
Regains CE~60%



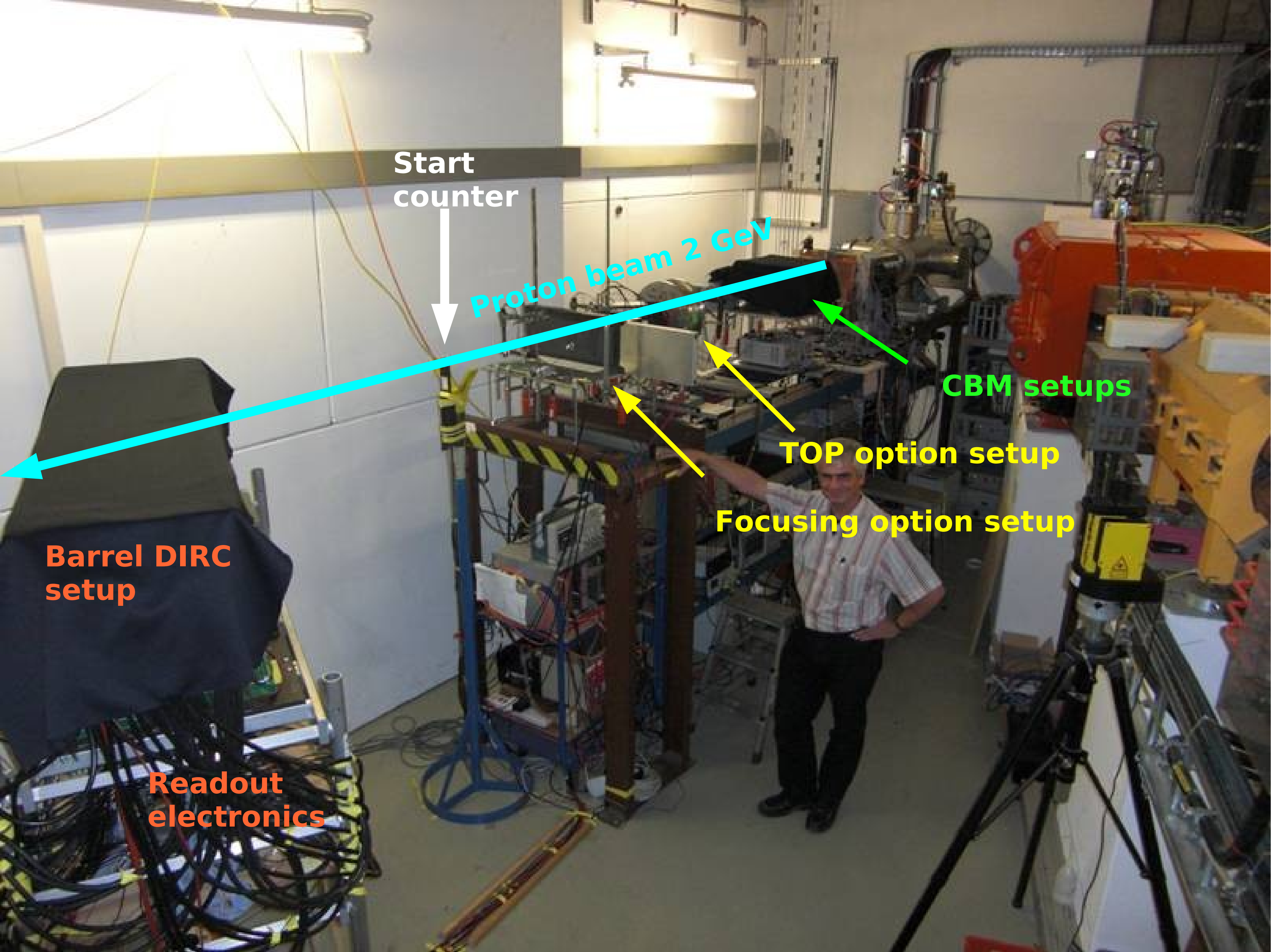


Gas barrier important anti aging agent against

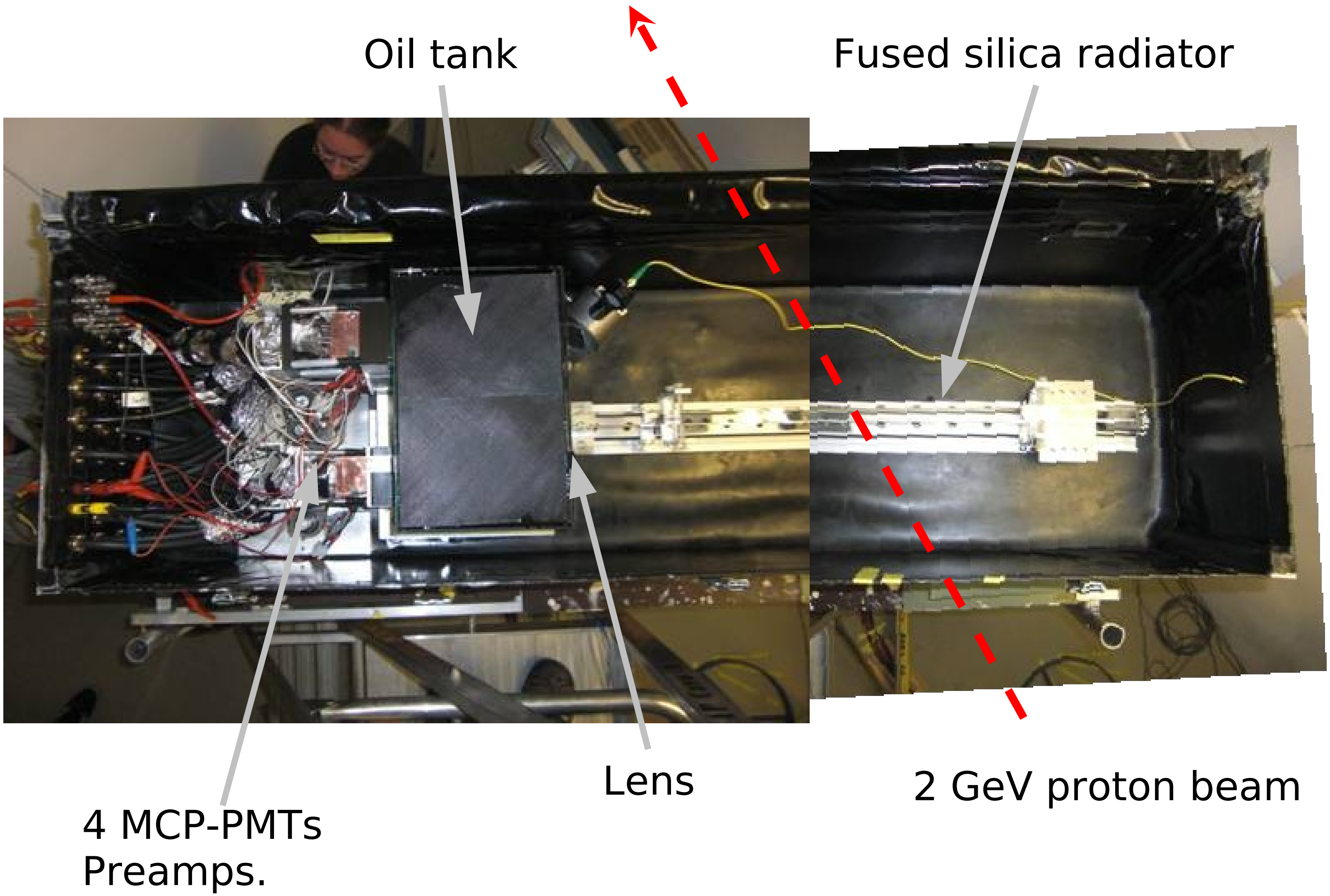
neutral CO_2 or O_2 (?)

Fig. 1: Relative QE vs. $\sum_Q$. Plotted are for R3809U-50-11X (CT0790) and SL10's (YJ0011, XM0001, XM0020 and XM0027).

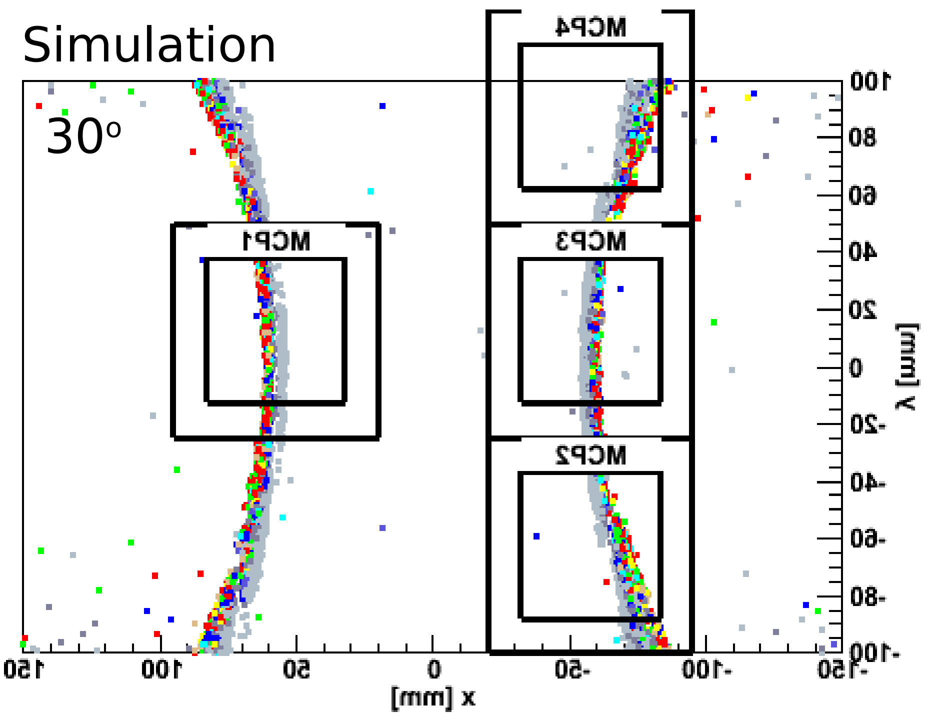
arXiv:1010.1057v1 [physics.ins-det] 6 Oct 2010

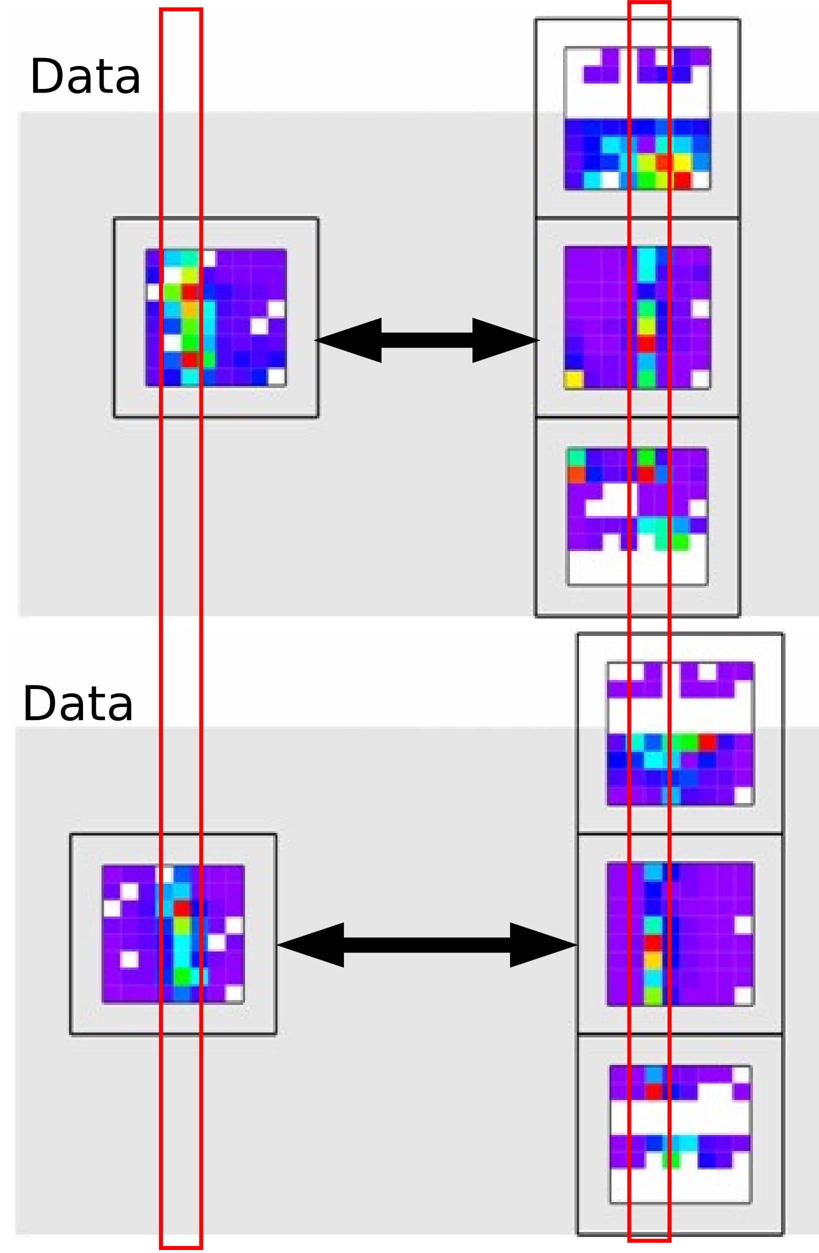

Start
counter
Proton beam 2 GeV
CBM setups
TOP option setup
Focusing option setup
Barrel DIRC
setup
Readout
electronics

Barrel DIRC: Ring Imaging



Simulation

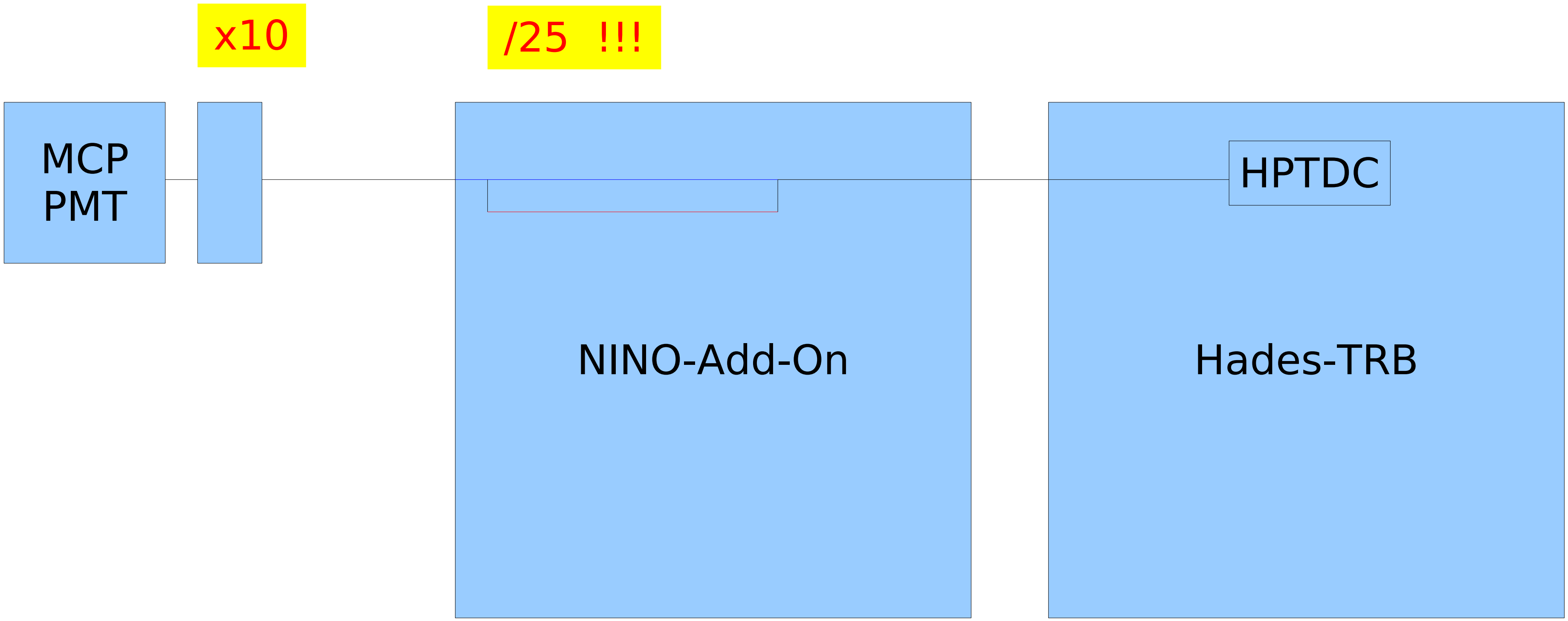


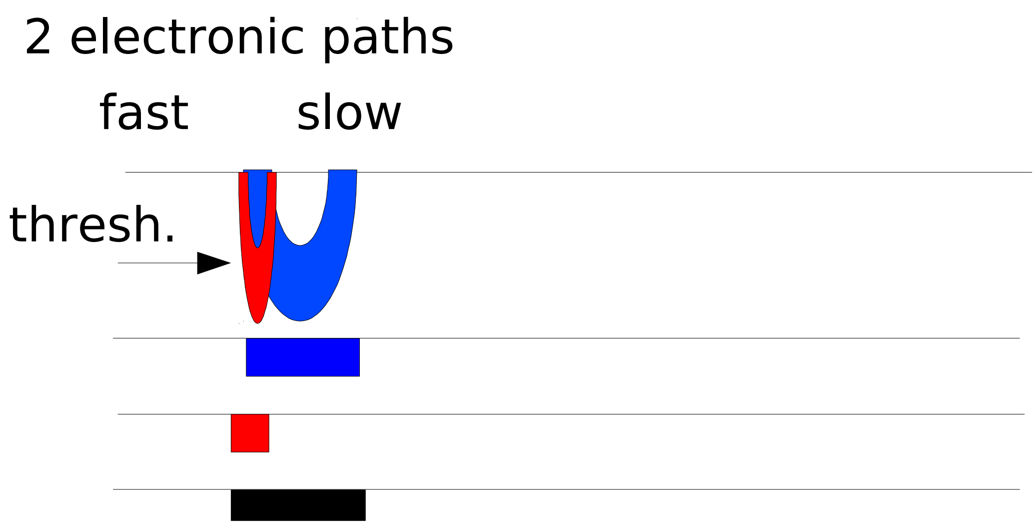


move MCP PMTs by 15mm each
→ does the ring stay in place?
(in box coordinates)

It does.

Read out

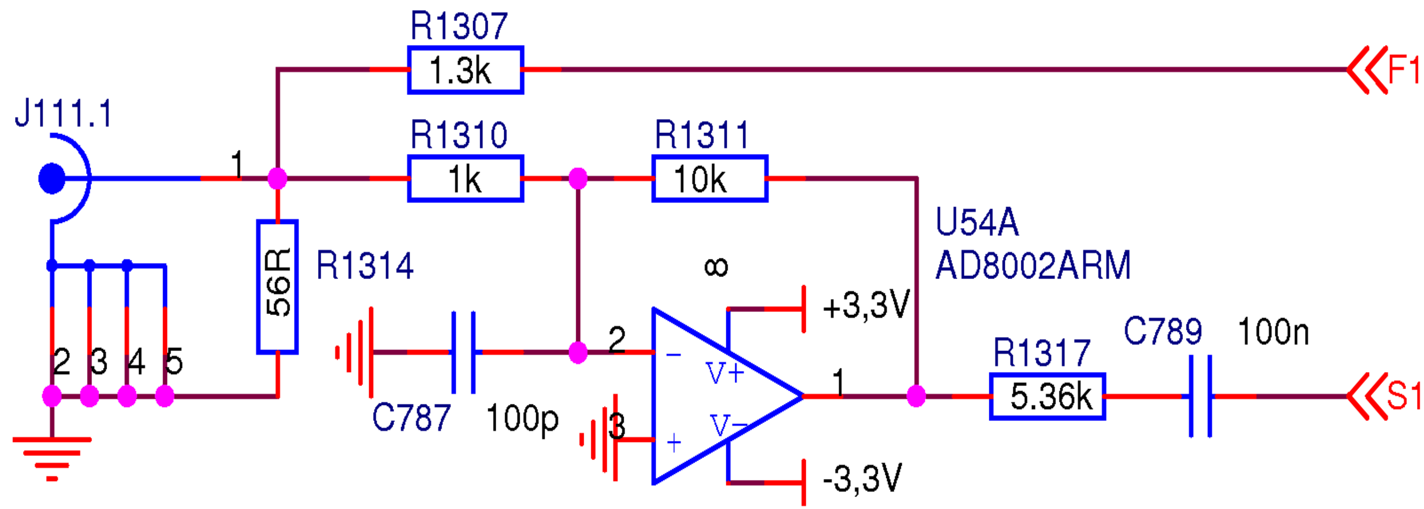

x10
/25 !!!
MCP
PMT
HPTDC
NINO-Add-On
Hades-TRB

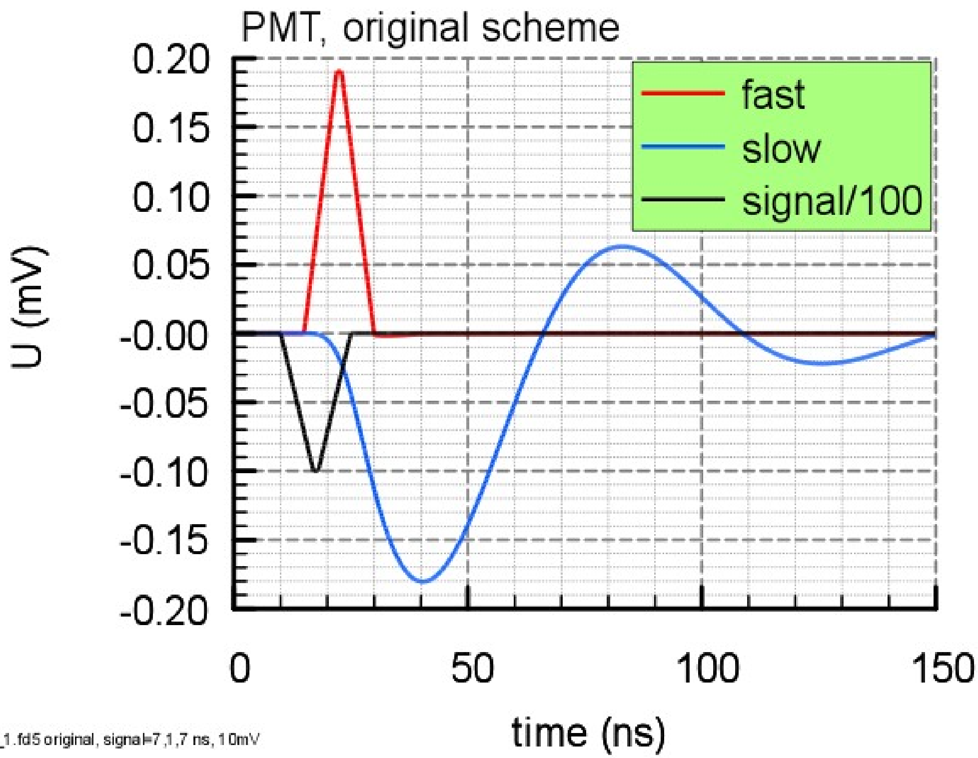

2 electronic paths
fast
slow
thresh.

Q2W

Read out

Original design





nino_1.fd5 original, signal=7,1,7 ns, 10mV

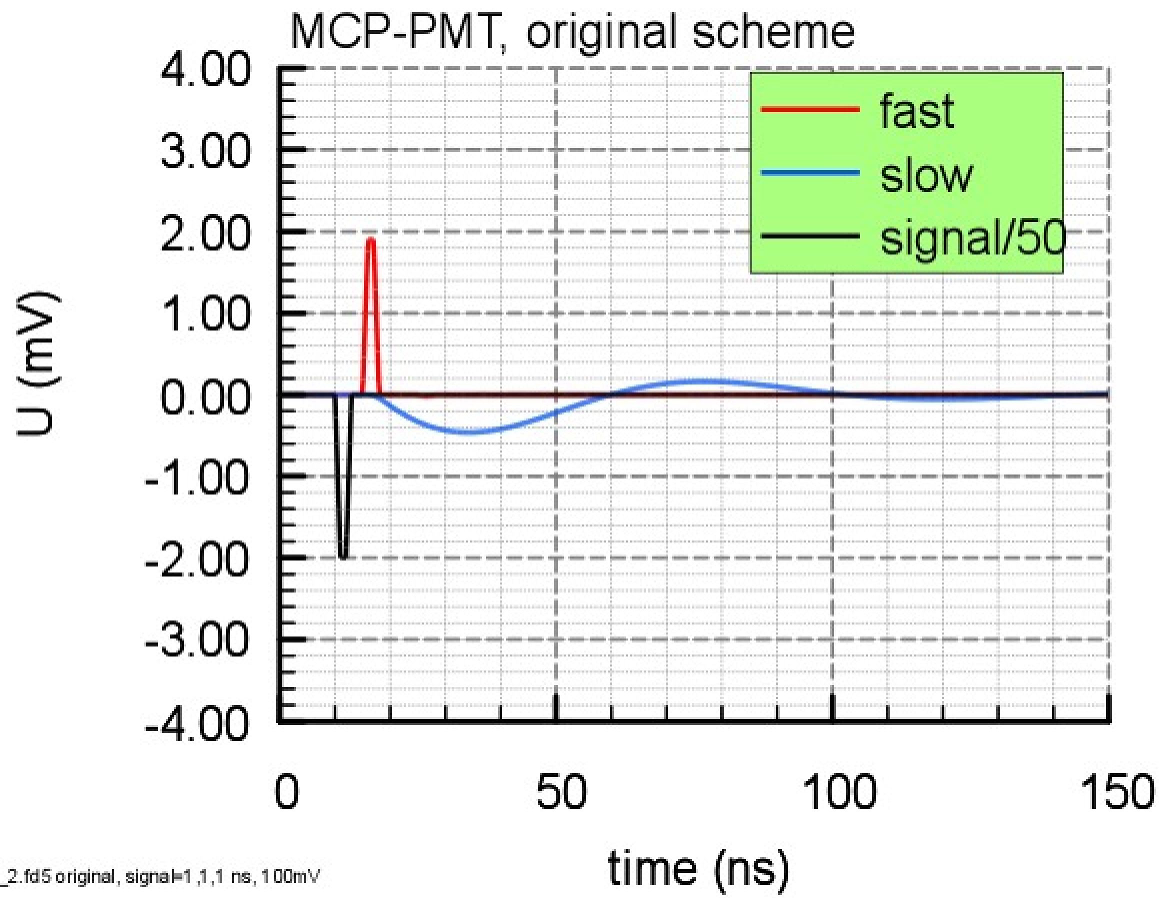
“slow” PMT signal

gEDA/ng-spice simulation:

fast and slow have same amplitudes

fast MCP-PMT signal

after preamp 100mV signal



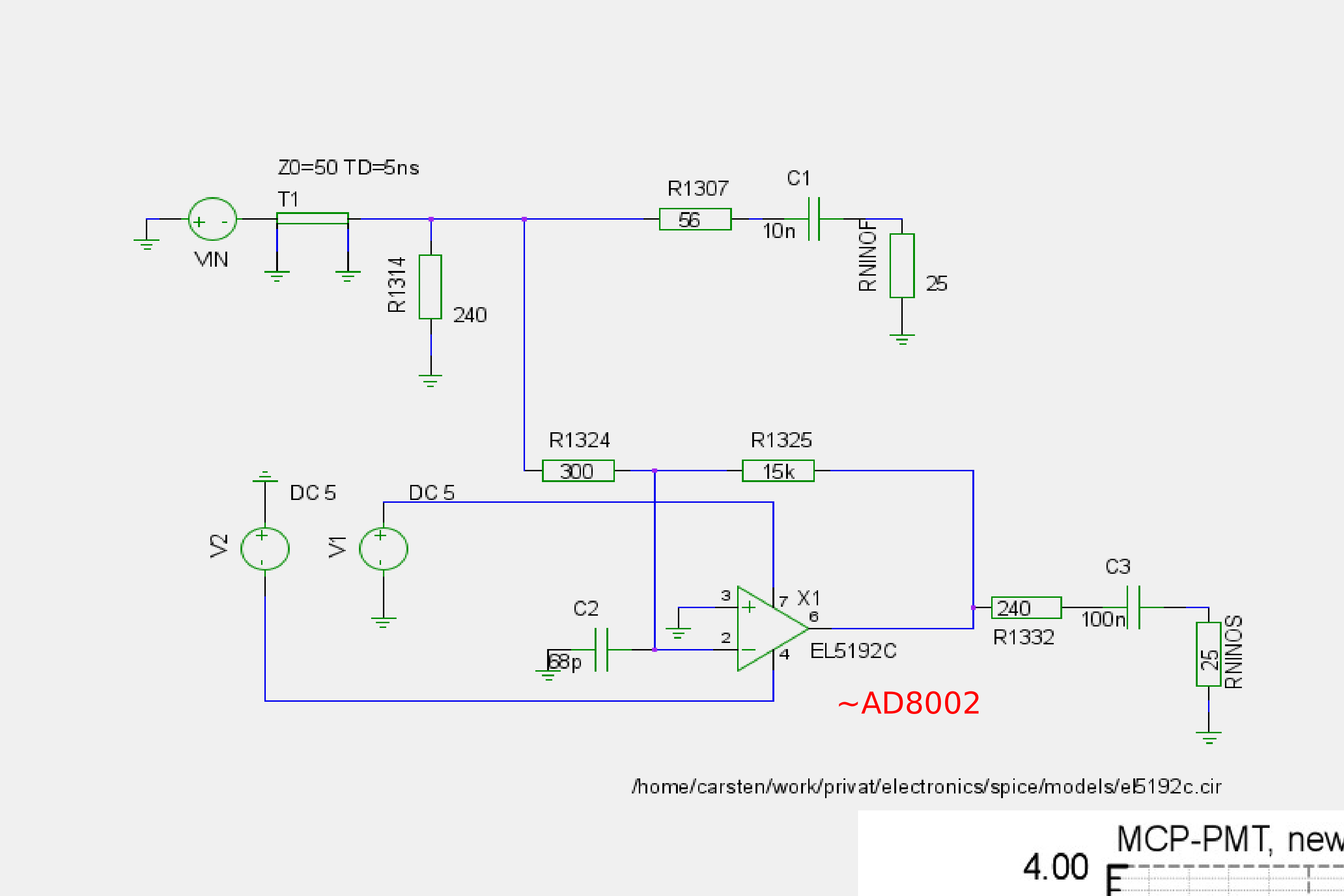
nino_2.fd5 original, signal=1,1,1 ns, 100mV

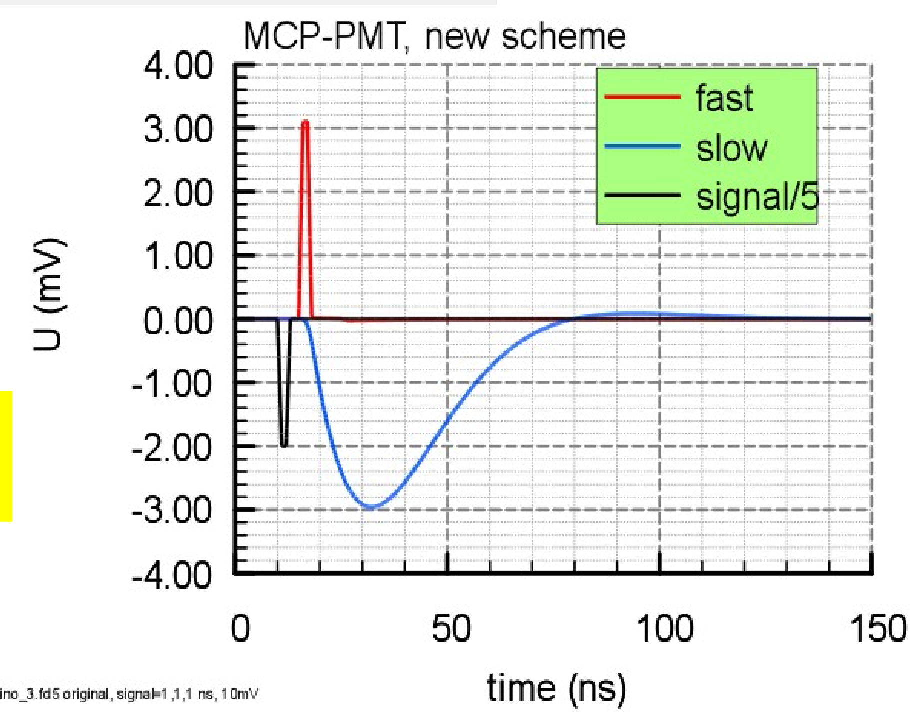
mismatch in amplitudes
for fast/slow

possible problem for
time over threshold

New design

Simulation

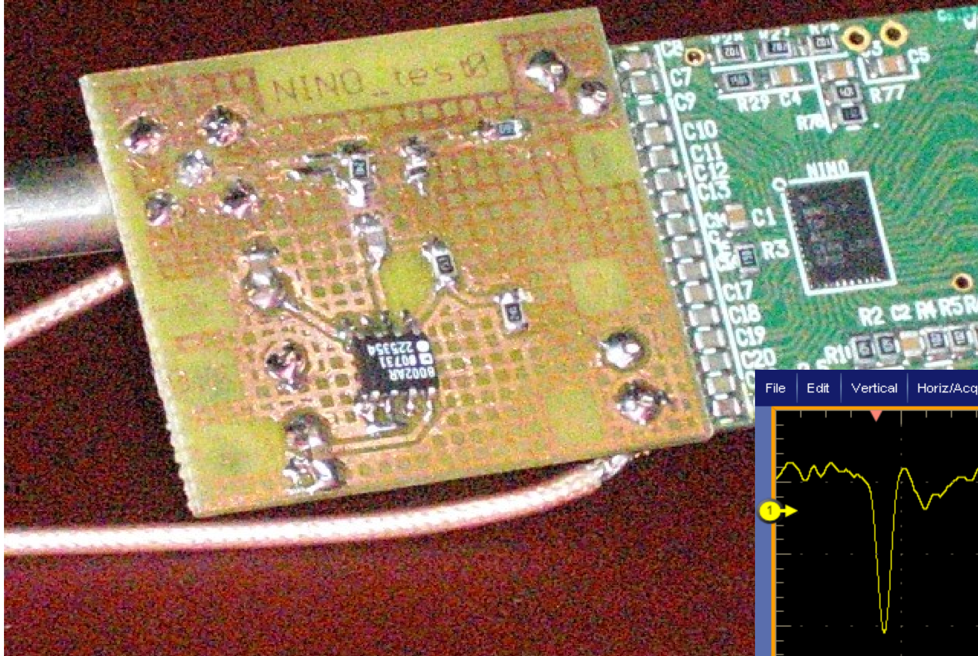




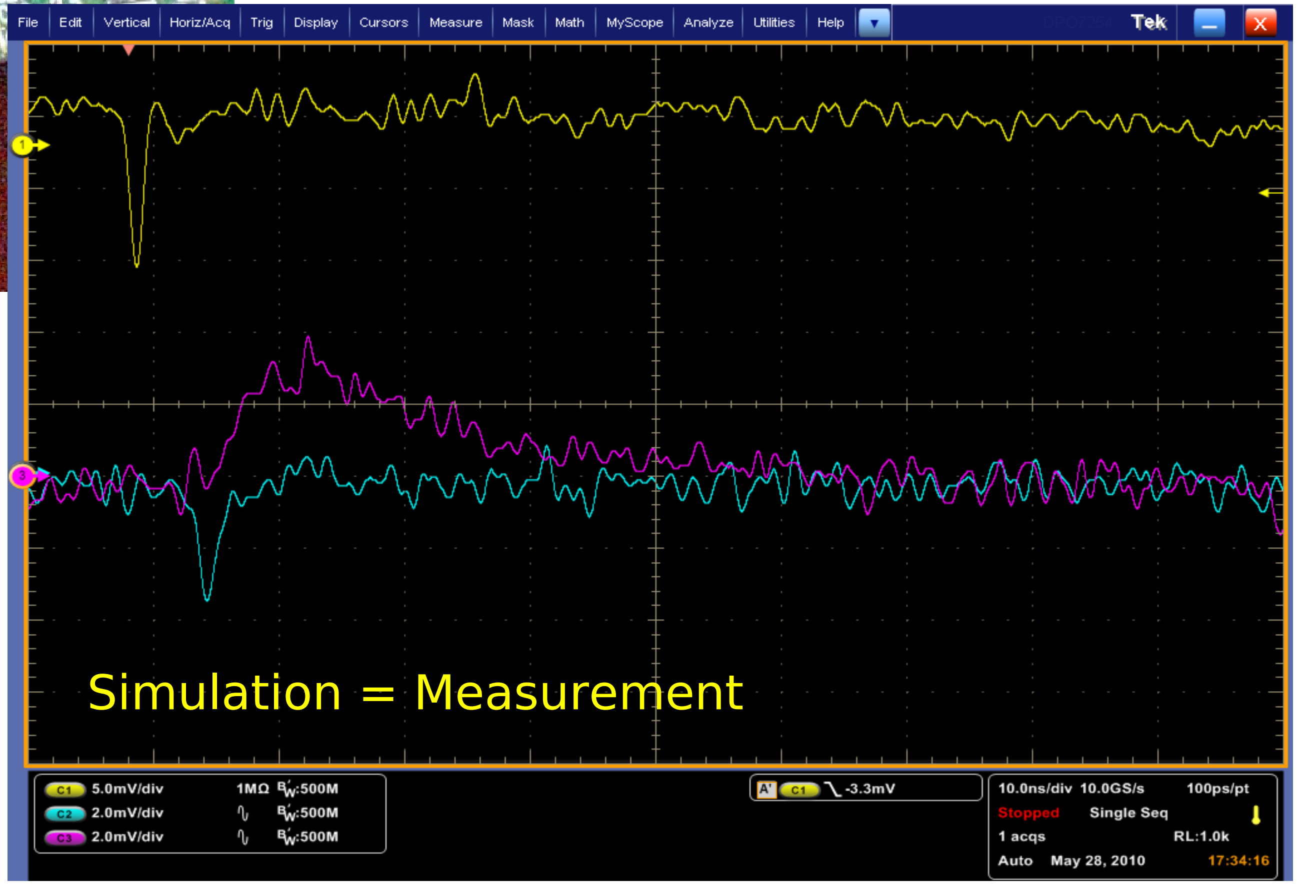
6 parts are changed

Higher gain of x16 for both channels, amplifier x10 can be skipped

Read out New design



Test board



Three boards
(3 x 128#)
produced

We are currently investigating the new add-on boards.

2011 test beam opportunities for PANDA DIRCs

Barrel DIRC plans to participate in both.
Focus on technical aspects at GSI beam, commissioning of new prototype and DAQ.
Focus on imaging, timing, and sensor tests at CERN.

Glasgow disc plans to participate in beam at CERN.

Any other takers?

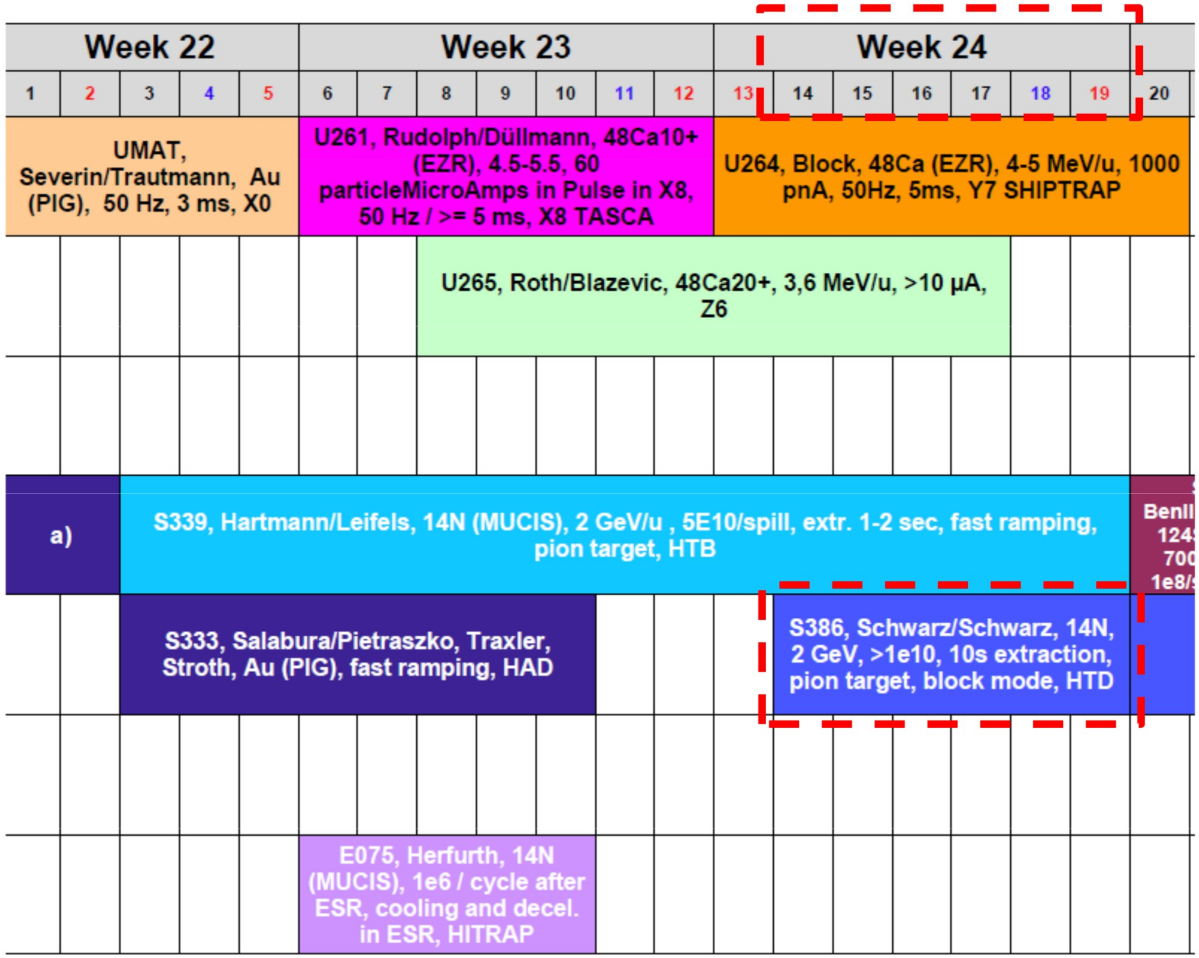
GSI test beam 2011

June 14-19
(following long Pentecost weekend)
Same cave as 2009

Pion beam from secondary target
(nitrogen primary beam),

p=1.7 GeV/c, 10^4-10^5 particles per spill,

2-10 second extraction



CERN test beam 2011

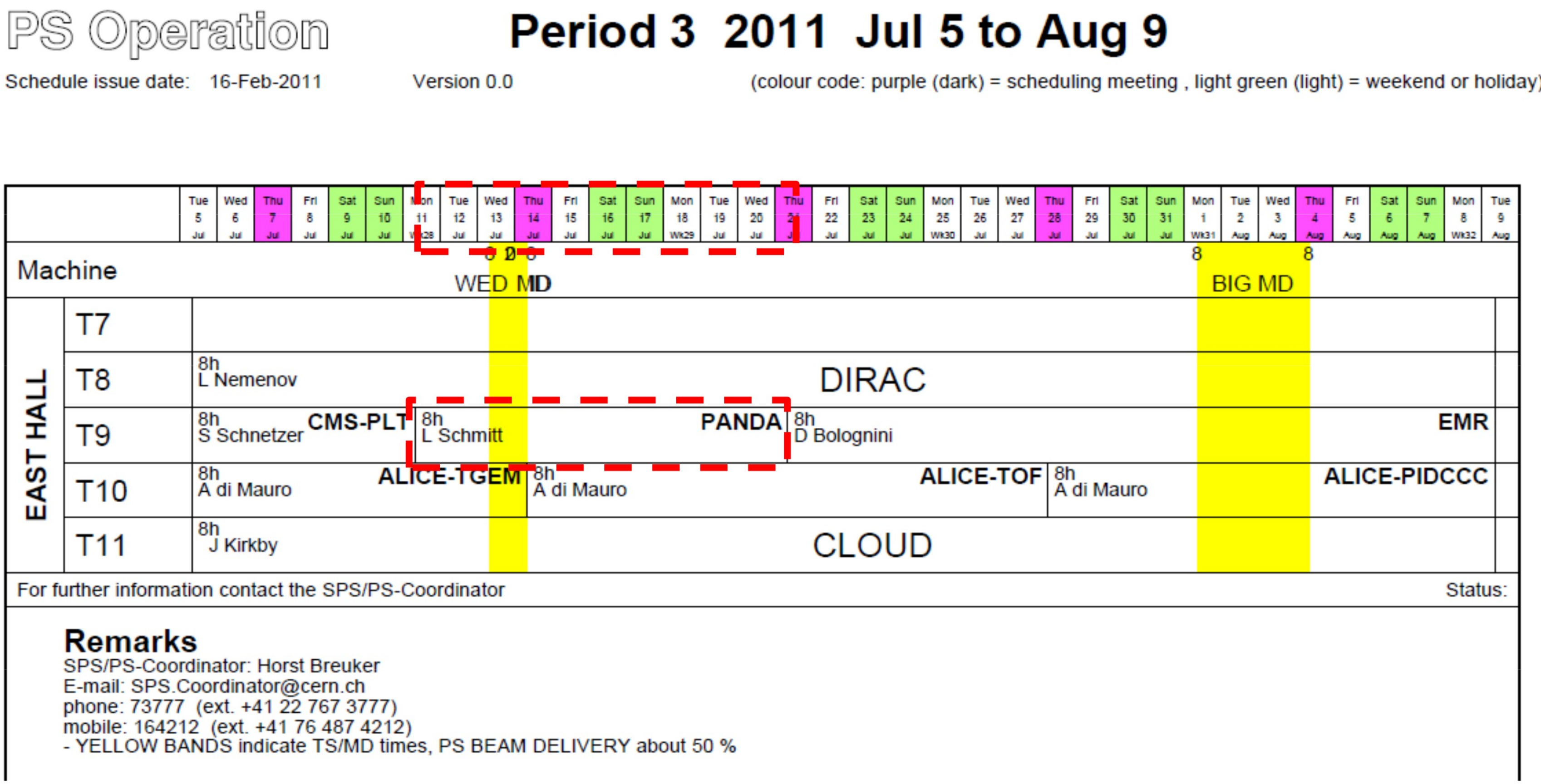
July 11-21
T9 beam line, PS (East Hall)

Hadron beam, p=1-15 GeV/c π and K.

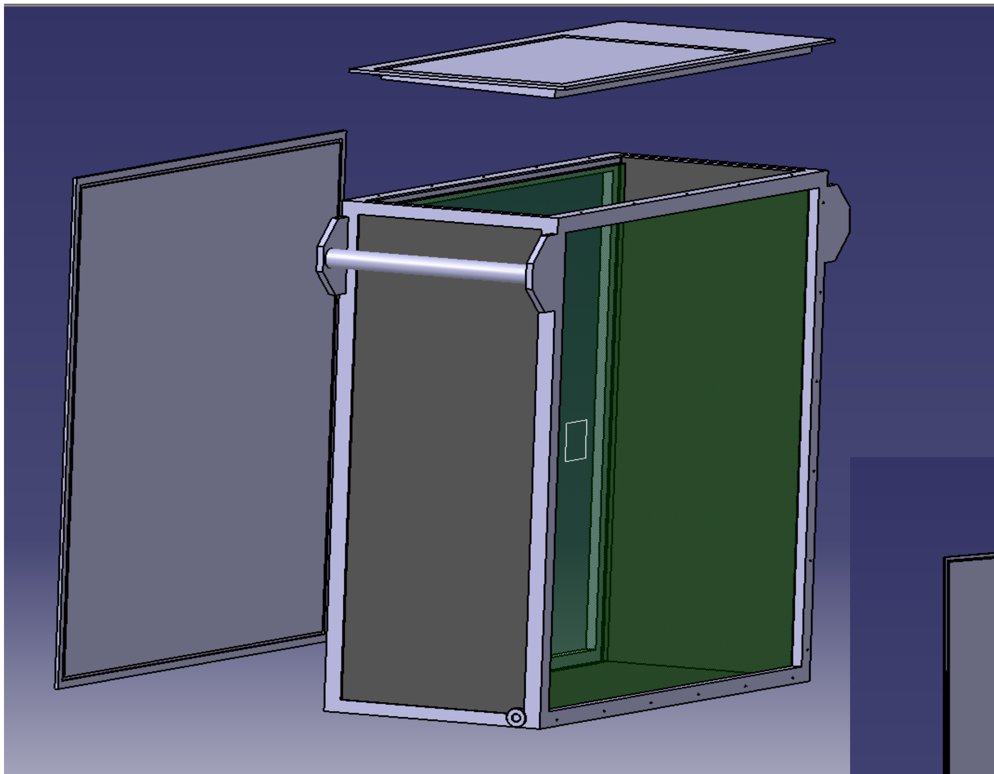
Beam instrumentation available. (Fast start time?)

10 days include time for setup and removal and one day for machine development.

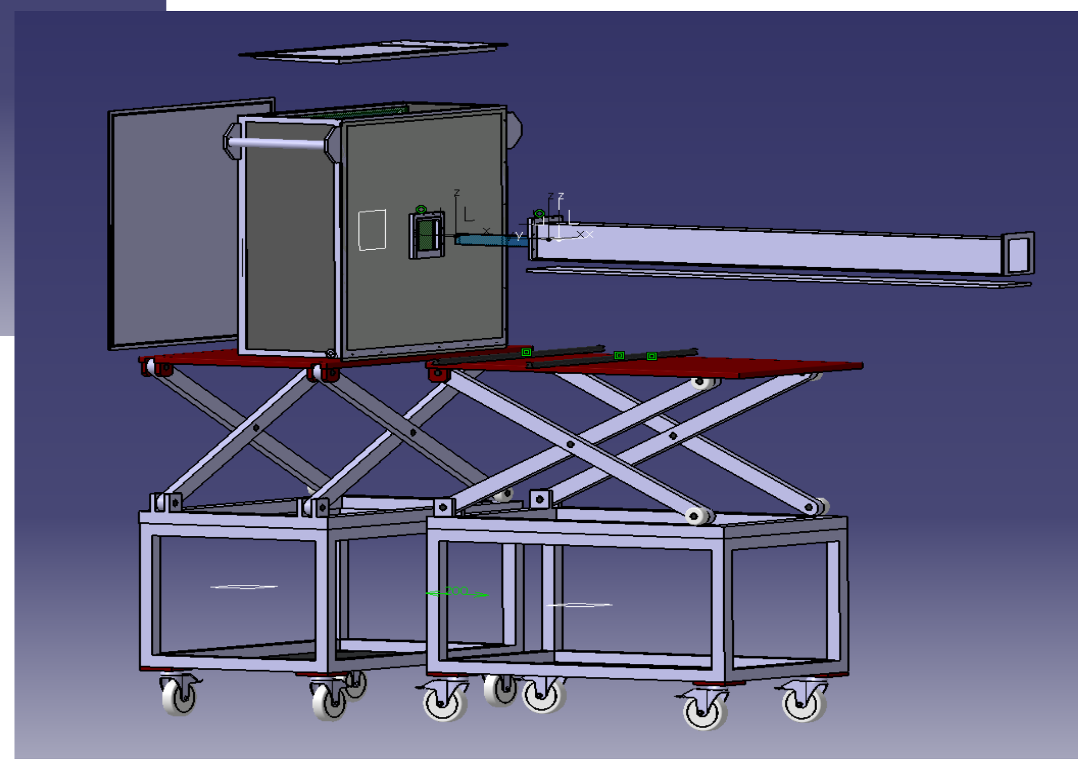
We need to factor in one weekday for paperwork to get accounts, access card, rad training, etc.



Prototyp 2



Doro Lehmann, GSI



Summary

- PANDA includes two DIRCs for PID
  - Barrel DIRC similar to BaBar DIRC
  - Endcap Disk DIRC
- R&D activities
  - radiator quality, focusing optics
  - photon detectors, readout electronics
  - simulation, reconstruction... → Talk by Maria Patsyuk tomorrow
- Test experiments for small scale prototypes