# Status of the CBM-RICH detector

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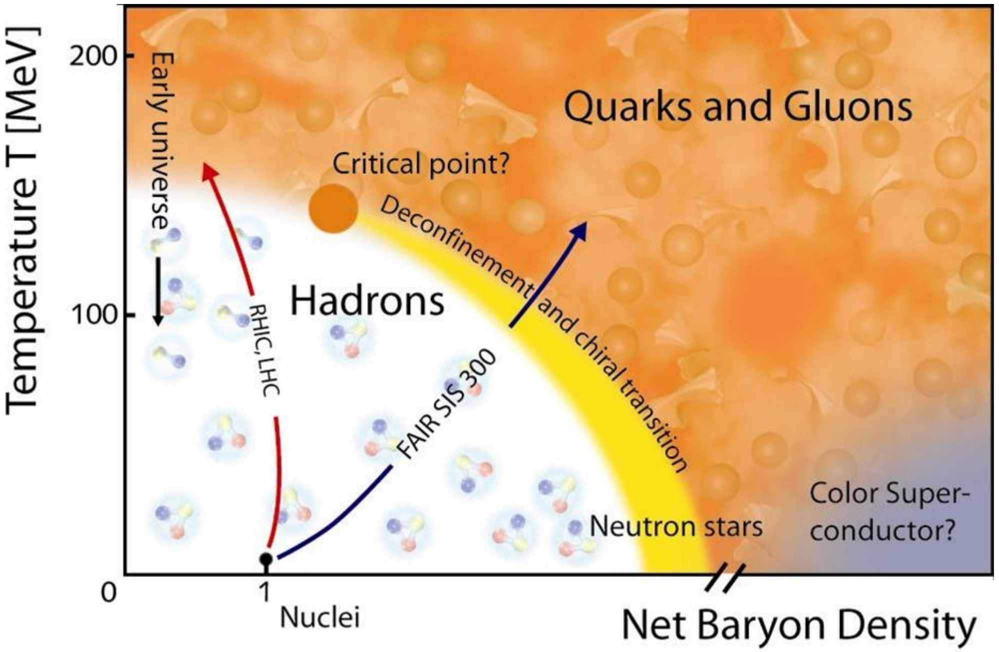
# Outline

- Introduction: CBM, PID with RICH
- Performance studies
- R&D on detector components
- Prototyping
- Next steps

# The CBM experiment

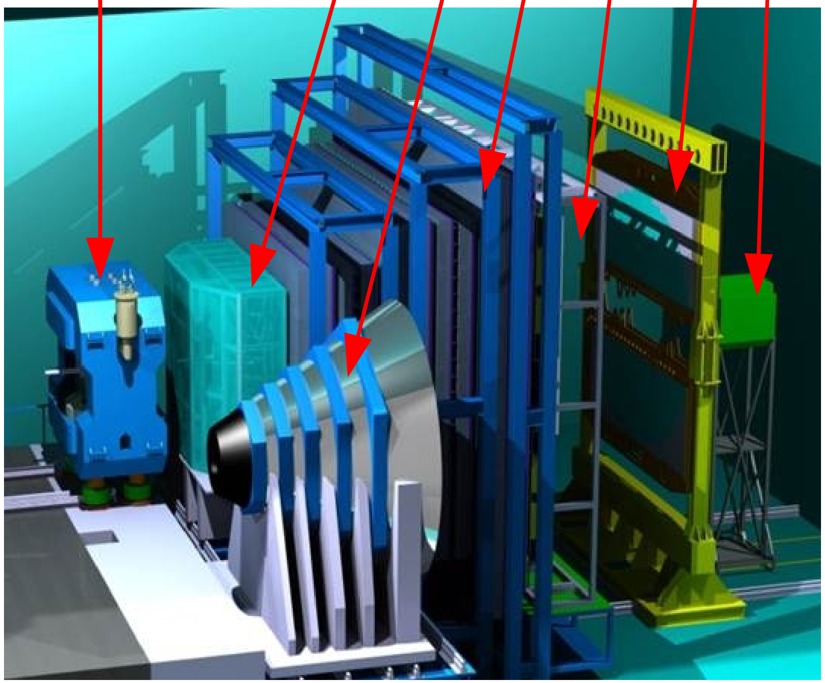
exploring the phase diagram of nuclear matter in the region of high net-baryon densities and moderate temperatures




**Questions to be addressed:**

- equation of state?
- deconfinement and chiral phase transitions?
- critical point?
- in-medium modifications of hadron properties?

MVD and STS in dipole magnet **RICH** MUCH TRD TOF ECAL PSD



**Approach:**

- nucleus-nucleus collision up to 45 AGeV
- measurement of bulk observables and rare probes

# The CBM experiment

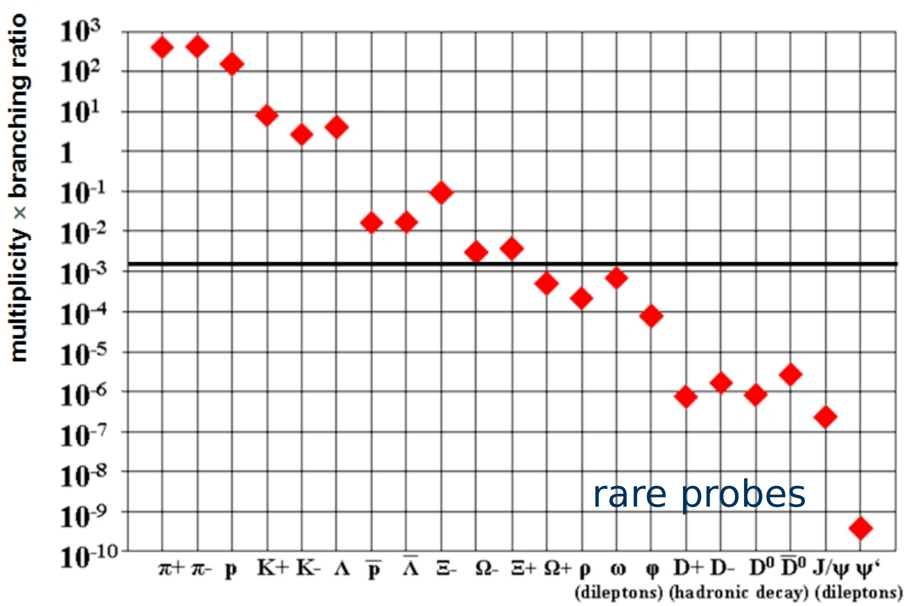
## Important CBM observables

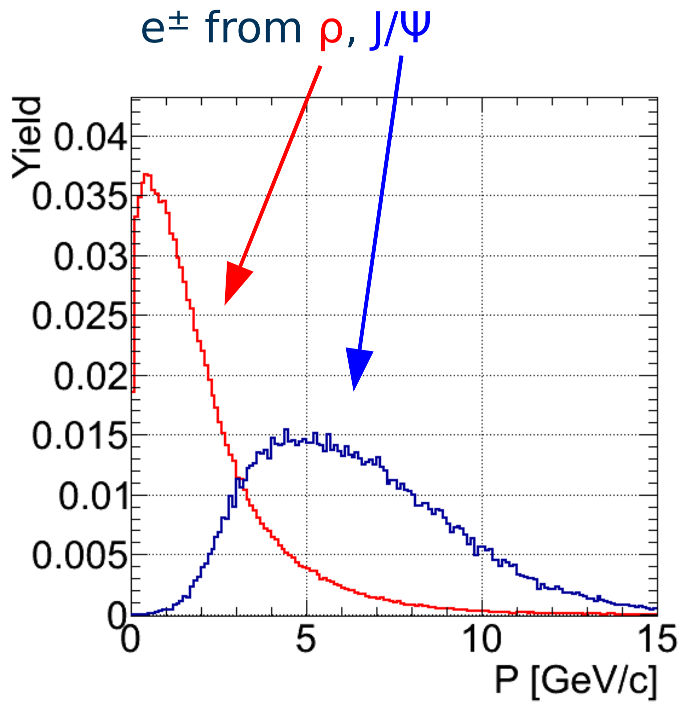
low mass vector mesons and charmonium in their leptonic decay channels:

ρ, ω, ϕ → $e^{\pm}$ and J/Ψ → $e^{\pm}$

no strong interaction of $e^{\pm}$ with the medium → penetrating probes

rare probes due to low BR



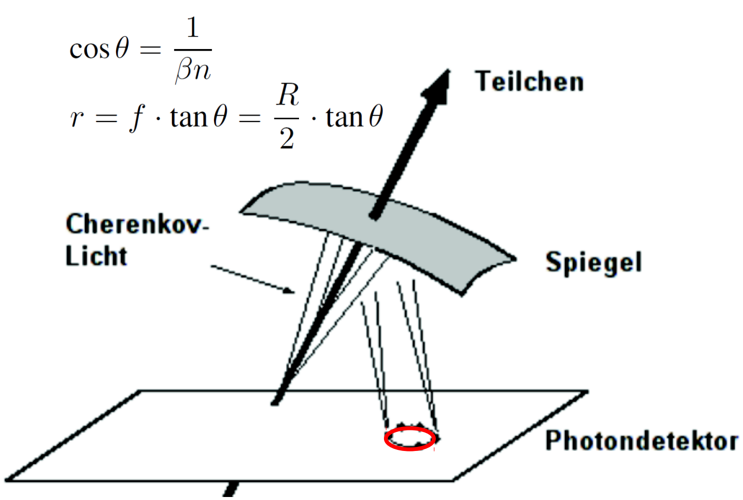



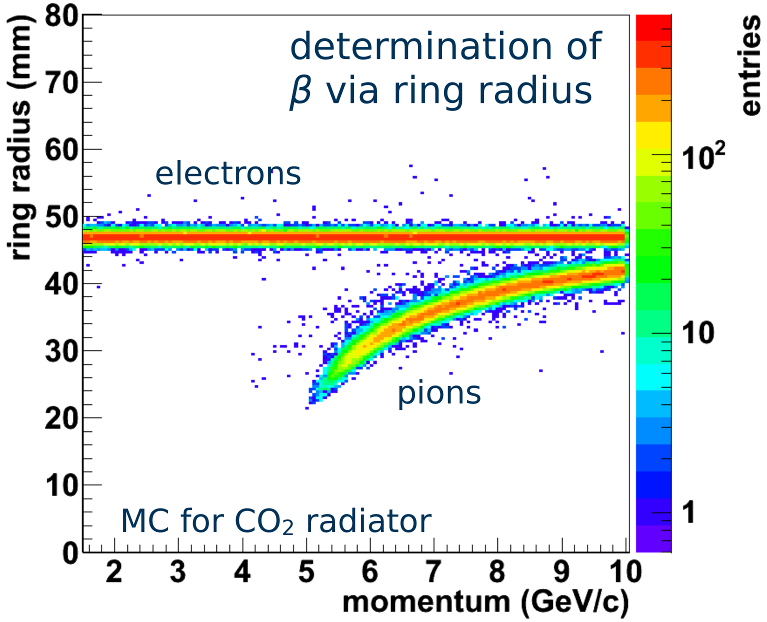

→ $e^{\pm}$ identification up to 10-15 GeV/c required

→ done with RICH (up to 10 GeV/c) and TRD

# Particle identification with RICH

A charged particle traversing transparent medium faster than the medium speed of light emits continuous electromagnetic radiation at visible and UV wavelengths. [P.A. Cherenkov, Phys. Rev. 52 (1937) 378]




➡ for separation of e and π gas radiator required

➡ $\beta$ from RICH, $p$ from silicon tracker => $m$

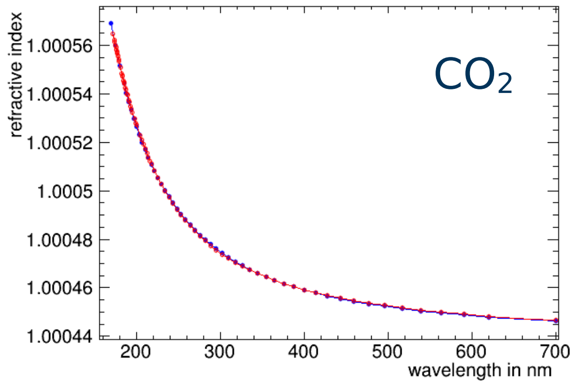
# The CBM-RICH detector

- <u>Radiator</u>

  $CO_2$ gas, length 1.7 m, 30 m³,

  n = 1.00045 at 600 nm,

  $\gamma_{thr}$ = 33.3, $p_{thr}$ =4.65 GeV/c




- <u>Mirror</u>

  surface 13 m²,

  trapezoidal tiles of 40x40 cm²

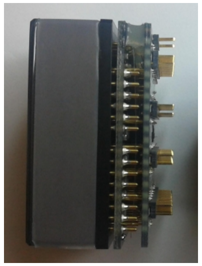
  6 mm glass substrate
  + Al + $Mg_2F$,

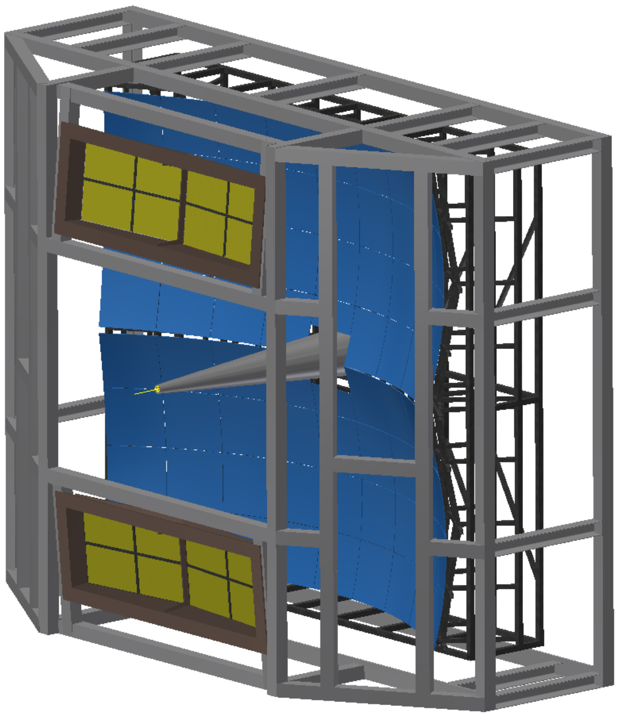
- <u>Camera</u>

  2.4 m² active area,

  55k channels,

  array of multianode (MAPMT) or
  microchannel plate (MCP) PMTs,





# Performance studies

# Event reconstruction

ca. 1000 charged particles per central Au+Au at 25 AGeV (mainly pions)

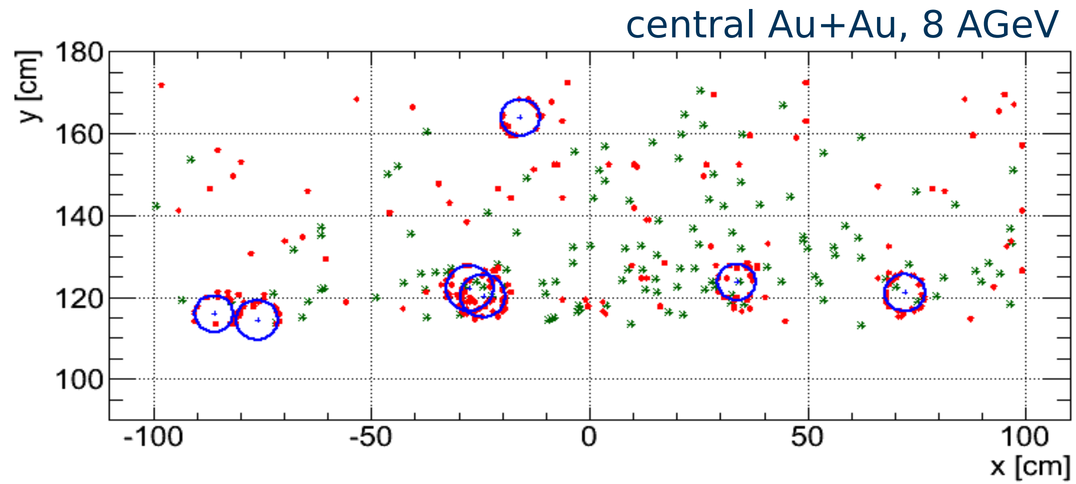
e± background from γ conversion and π Dalitz decays

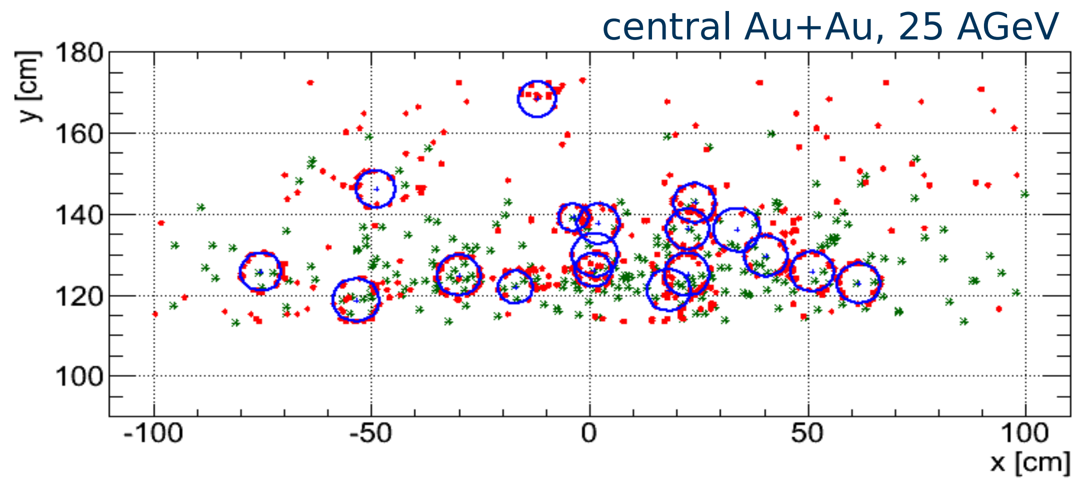
➡ make use of excellent tracking capability of CBM setup for ring reconstruction:

1) STS track extrapolation to photon detector plane

2) ring finding (Hough transform), ring fitting

3) ring – track matching



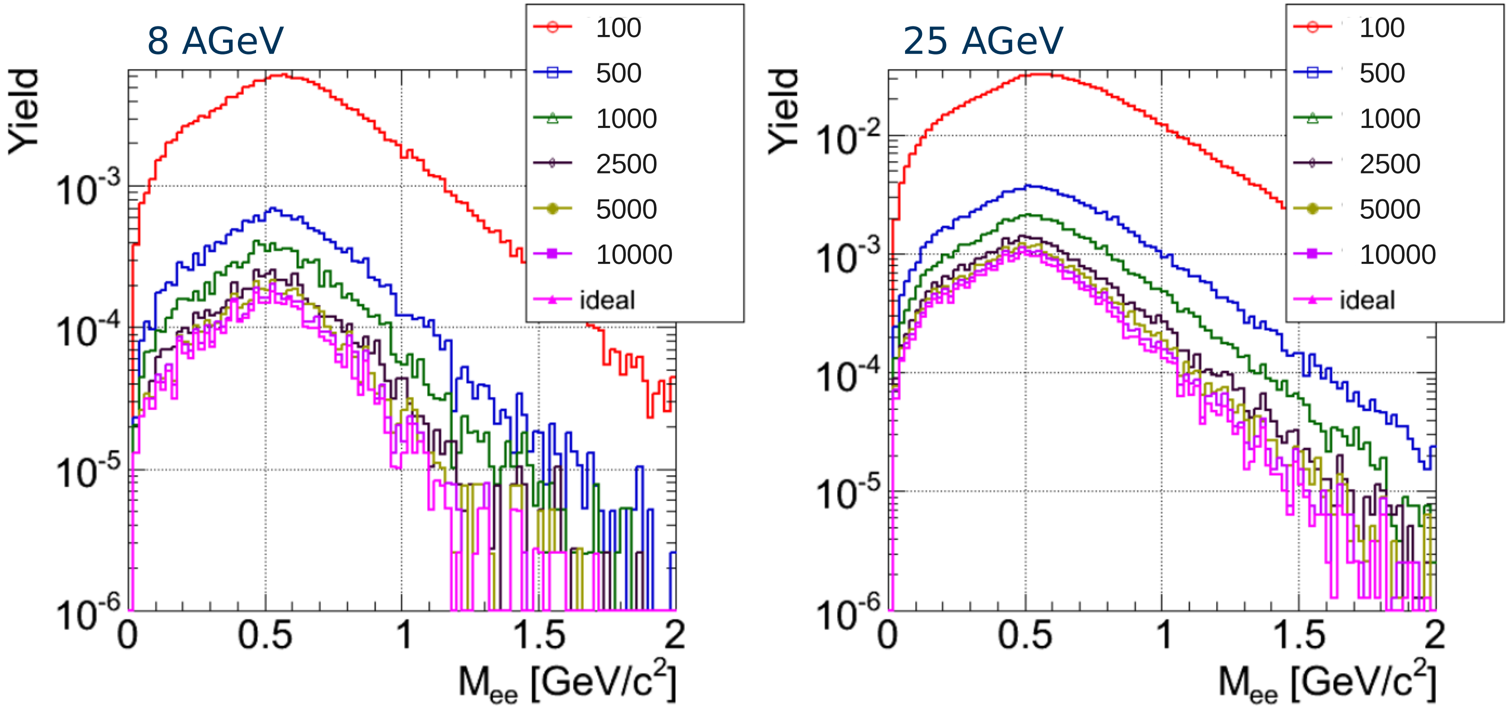




blue – reconstructed circles
red – RICH hits
green - track projections

# Background

e± pairs other than those stemming from leptonic low mass vector meson decays

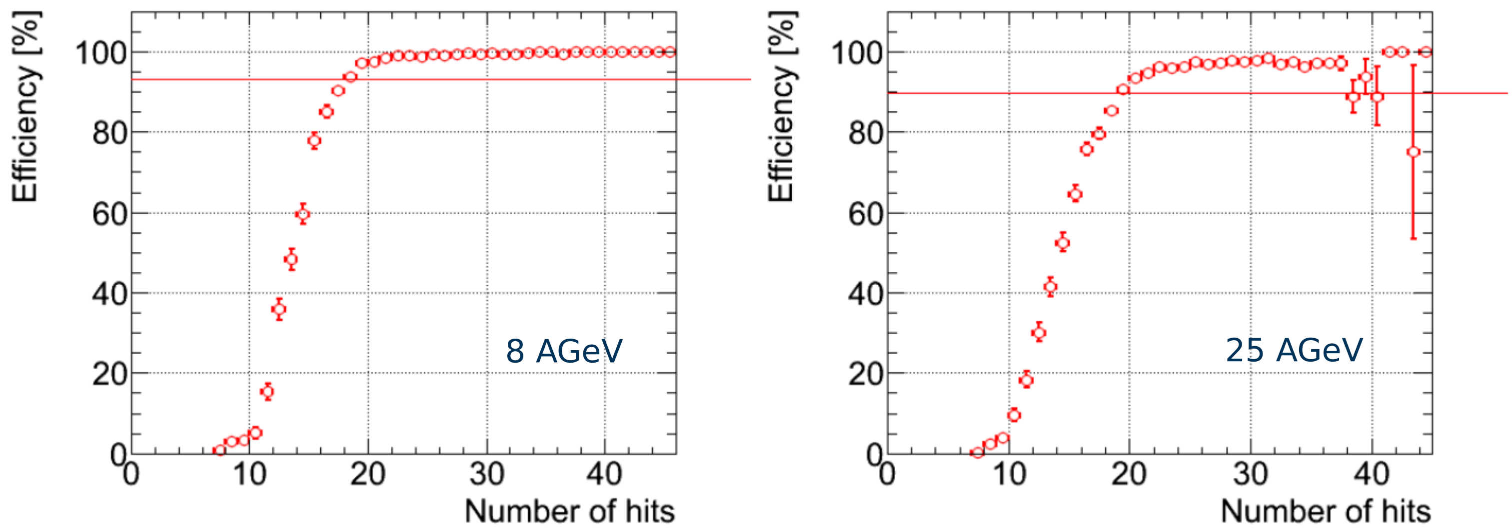
simulated combinatorial background in dependence of pion suppression




→ combined (using all subdetectors) pion suppression > 5000 required

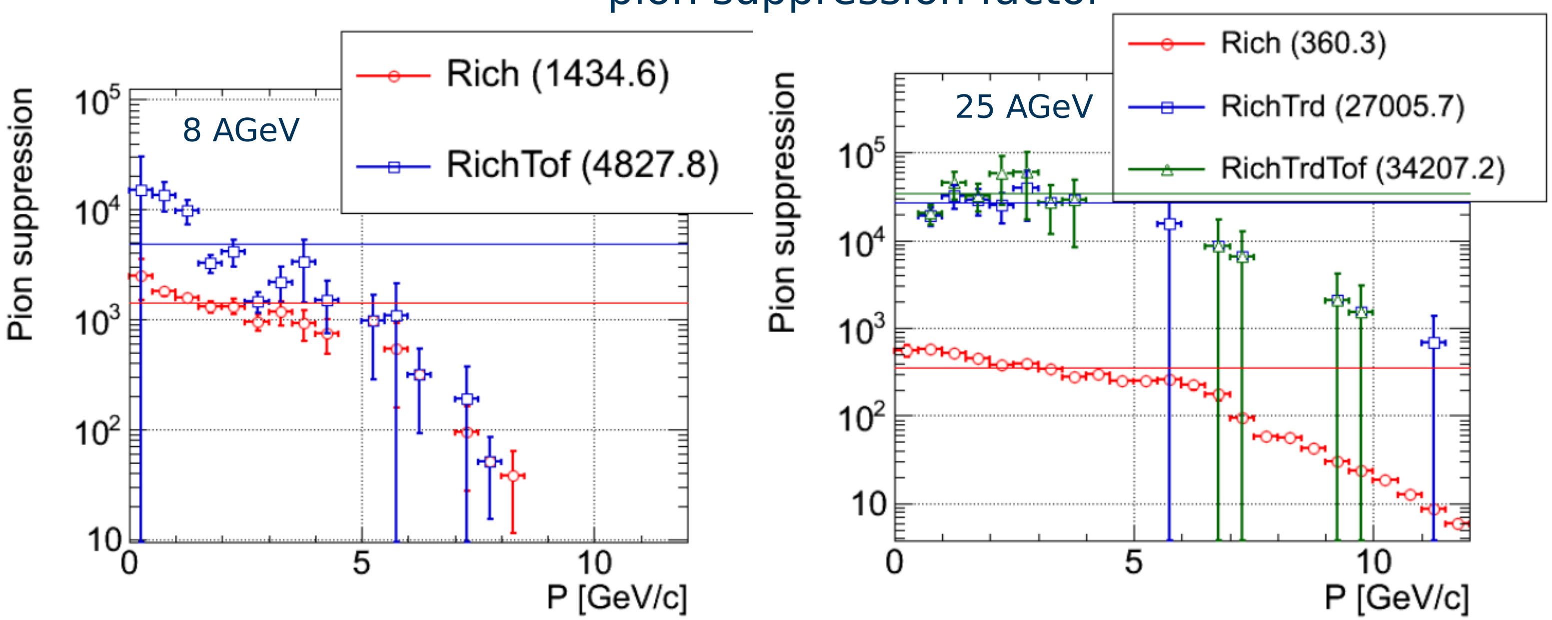
# Ring reconstruction and pion suppression

ring reconstruction efficiency for $e^{\pm}$ from the vertex




<u>ring reco eff.:</u>
no. of correctly found rings divided by no. of reconstructable rings

pion suppression factor

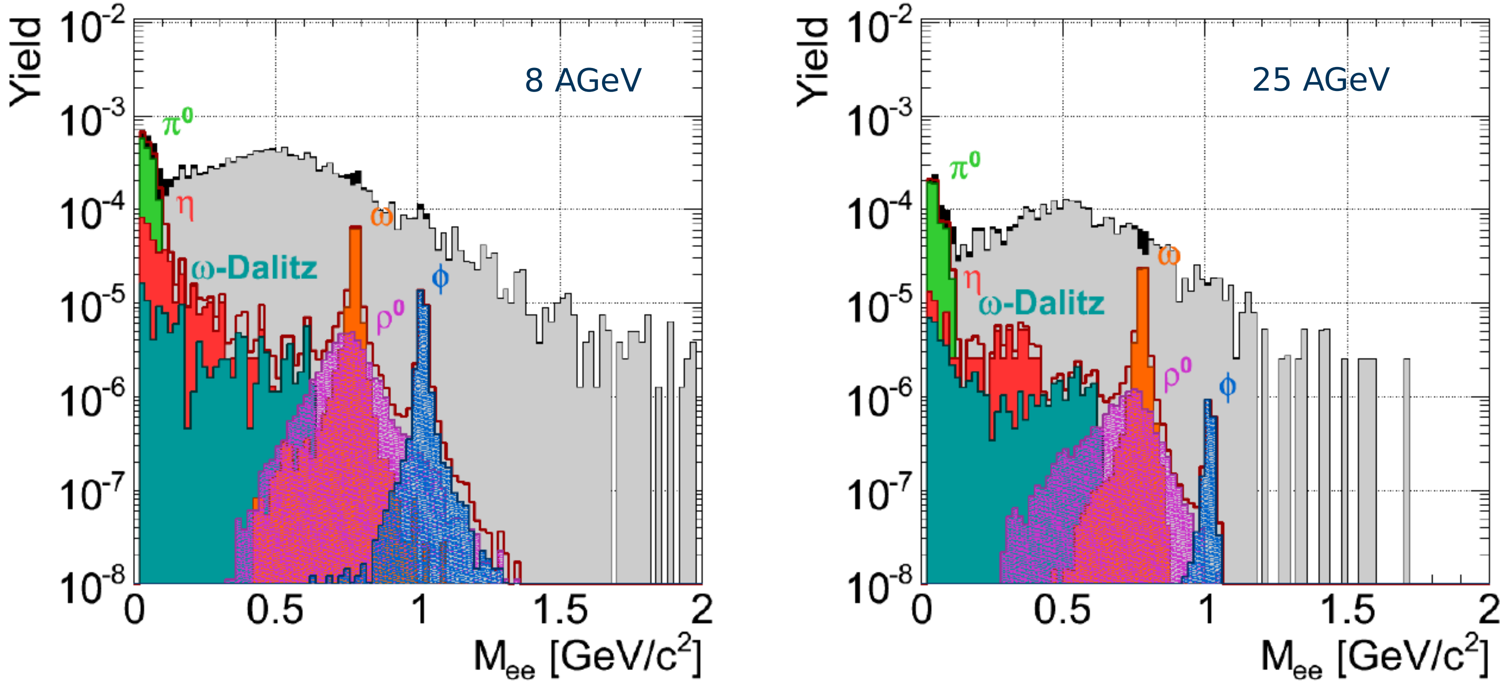



<u>pion suppr. factor:</u>
no. of pions reconstructed in STS with track projection in RICH acceptance divided by no. of misidentified pions

# Low-mass di-electron reconstruction

- central Au+Au collisions at 8 AgeV and 25 AGeV
- background: UrQMD events $e^{\pm}$ from γ-conversion, $\pi^0$, η-Dalitz decays
- ρ, ω, ω-Dalitz, ϕ decays (cocktail) generated by PLUTO

invariant mass spectrum of di-electrons




| | 8 AGeV beam energy | | 25 AGeV beam energy | |
|---|---|---|---|---|
| Mesons, | S/B | efficiency in % | S/B | efficiency in % |
| $\rho^0$ | – | 3.12 | – | 4.39 |
| $\omega$ | 0.65 | 4.10 | 0.31 | 5.53 |
| $\phi$ | 0.04 | 4.89 | 0.11 | 7.08 |

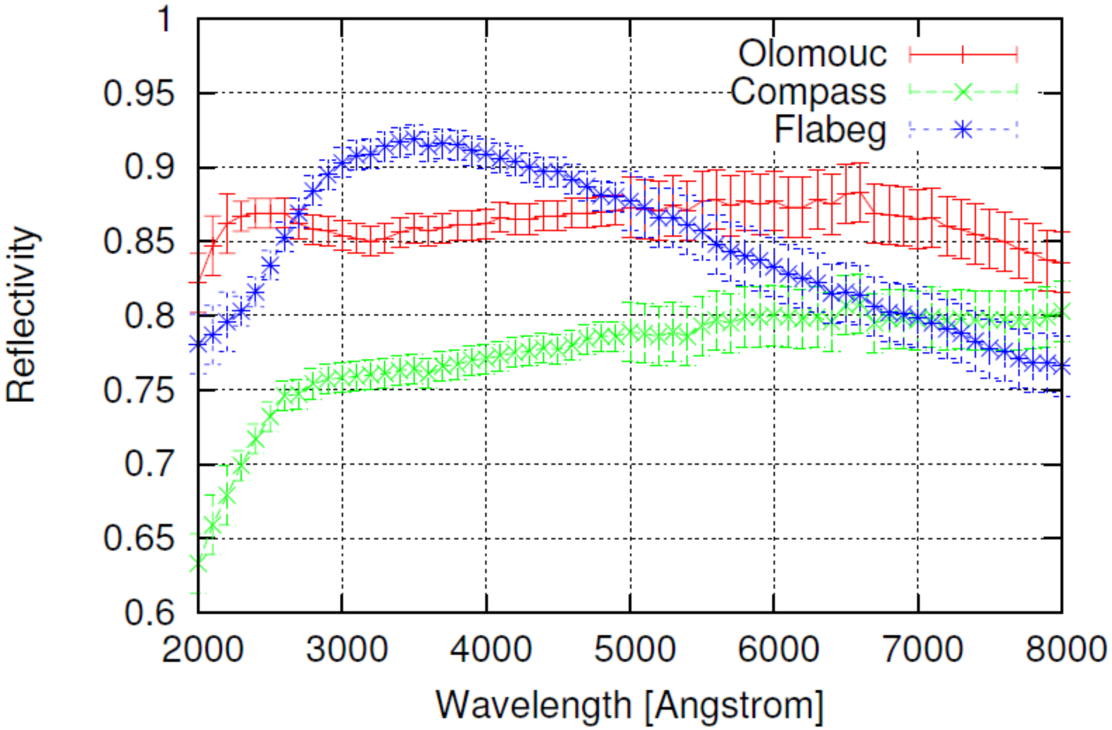
➡ good performance for anticipated measurements

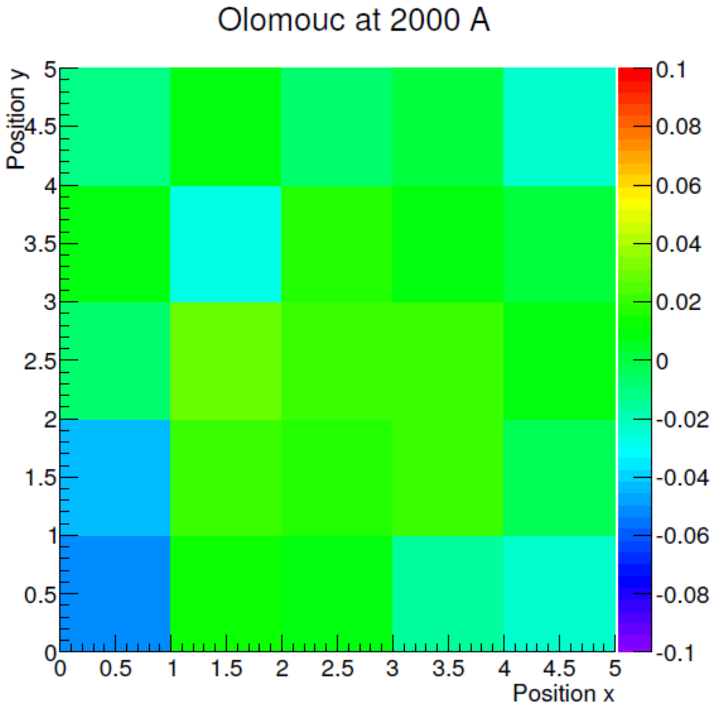
# R&D on detector components

# Mirror

evaluation of mirrors from 3 different manufacturers

reflectivity → Cherenkov photon yield



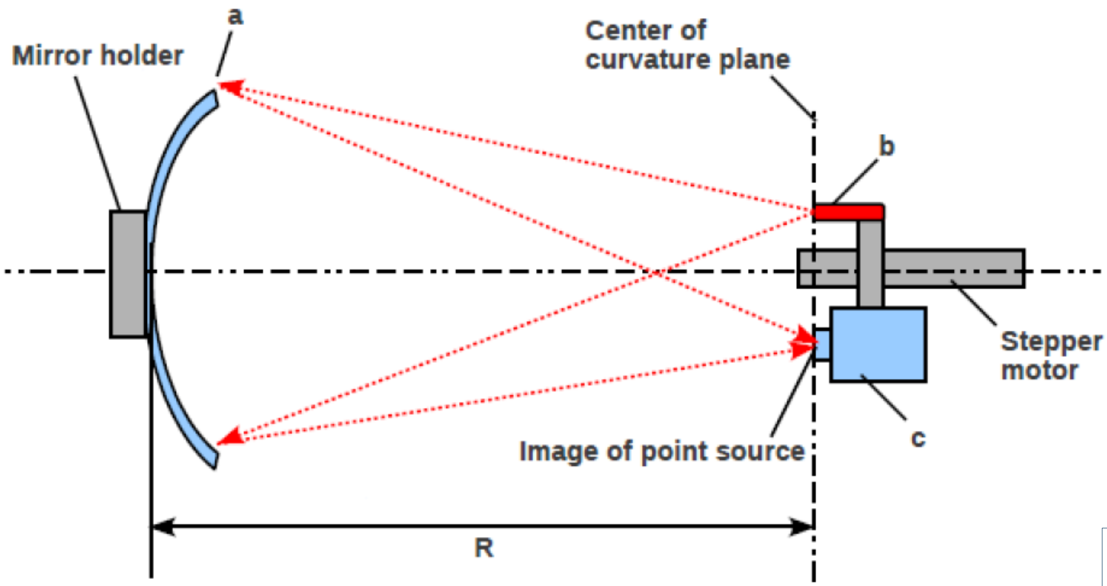



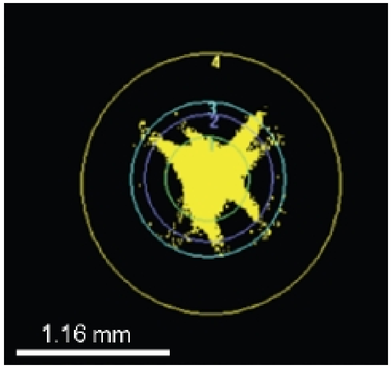
# Mirror

evaluation of mirrors from 3 different manufacturers

surface homogeneity → ring resolution

$D_0$ test
(diameter of circle with 95 % of light intensity)



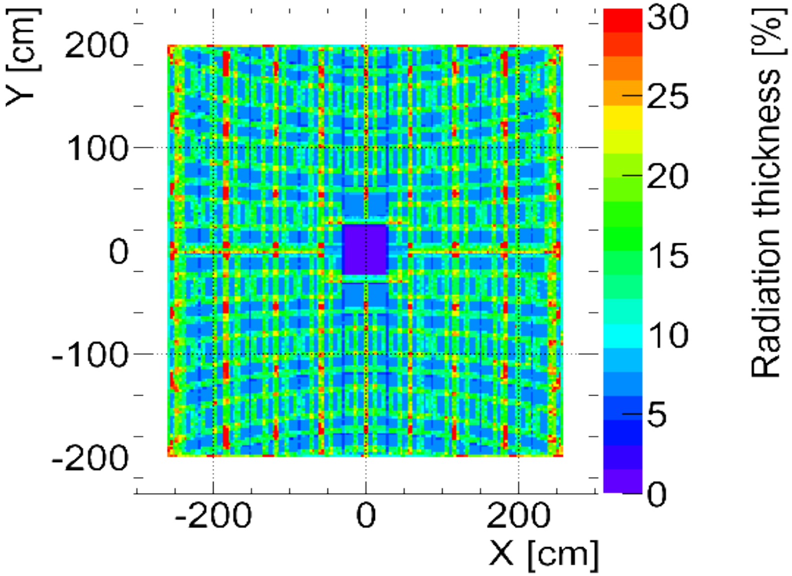




| Mirror | $D_{0,min}$ [mm] |
|---|---|
| SP01 | 1.16 |
| SP02 | 1.42 |
| SP03 | 0.88 |
| SP04 | 1.3 |
| Mounted | 0.98 |

→ both test reveal Olomouc to be the best choice

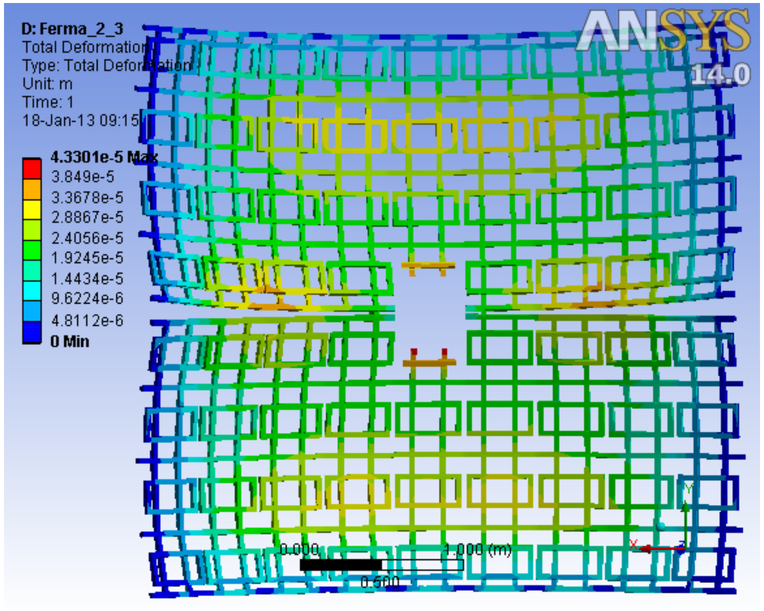
Ronchi test in process...

# Prototype for mirror support structure




requirements:

- minimum material budget
- stability




4x3 supporting frame

goals of prototype studies:
- select type of connections
- identify possible problems
- test trength
- test mechanical response to shaking, acceleration
- test behaviour in time

# Photon sensors

demands:

- quantum efficiency
- spatial resolution (5 mm)
- hit rate capability (>100 kHz/ch)
- dark count rate
- time resolution (ns)
- magnetic field resistance
- life time
- radiation hardness

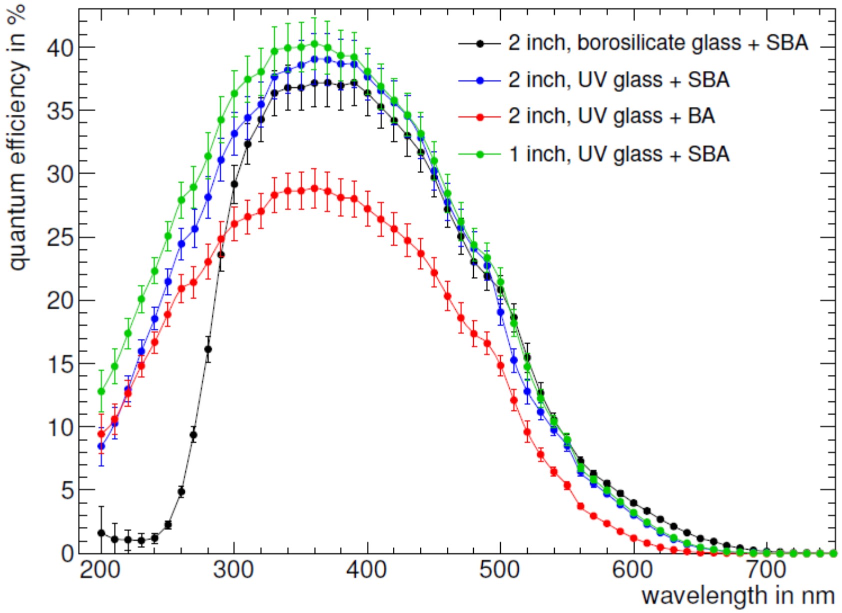
MAPMTs preferred photon sensor

(because magnetic field can be shielded)

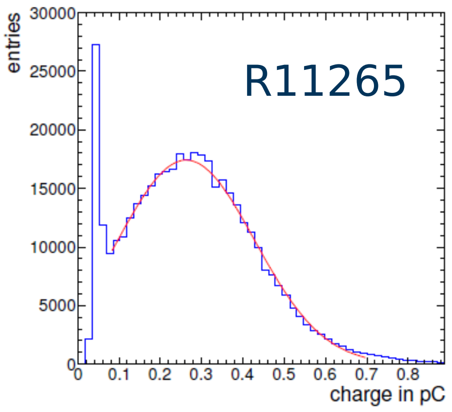
3 Hamamatsu MAPMT types tested:

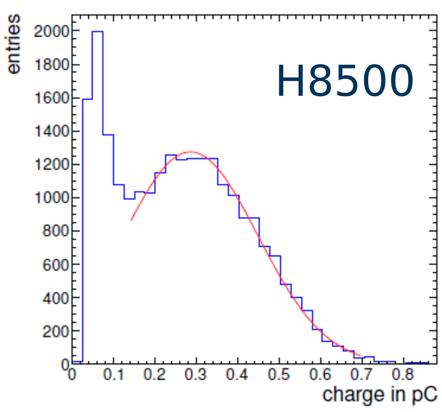
- R11265-103-M16
- H8500C/D-03
- H10966A-103

quantum efficiency




single photon spectra

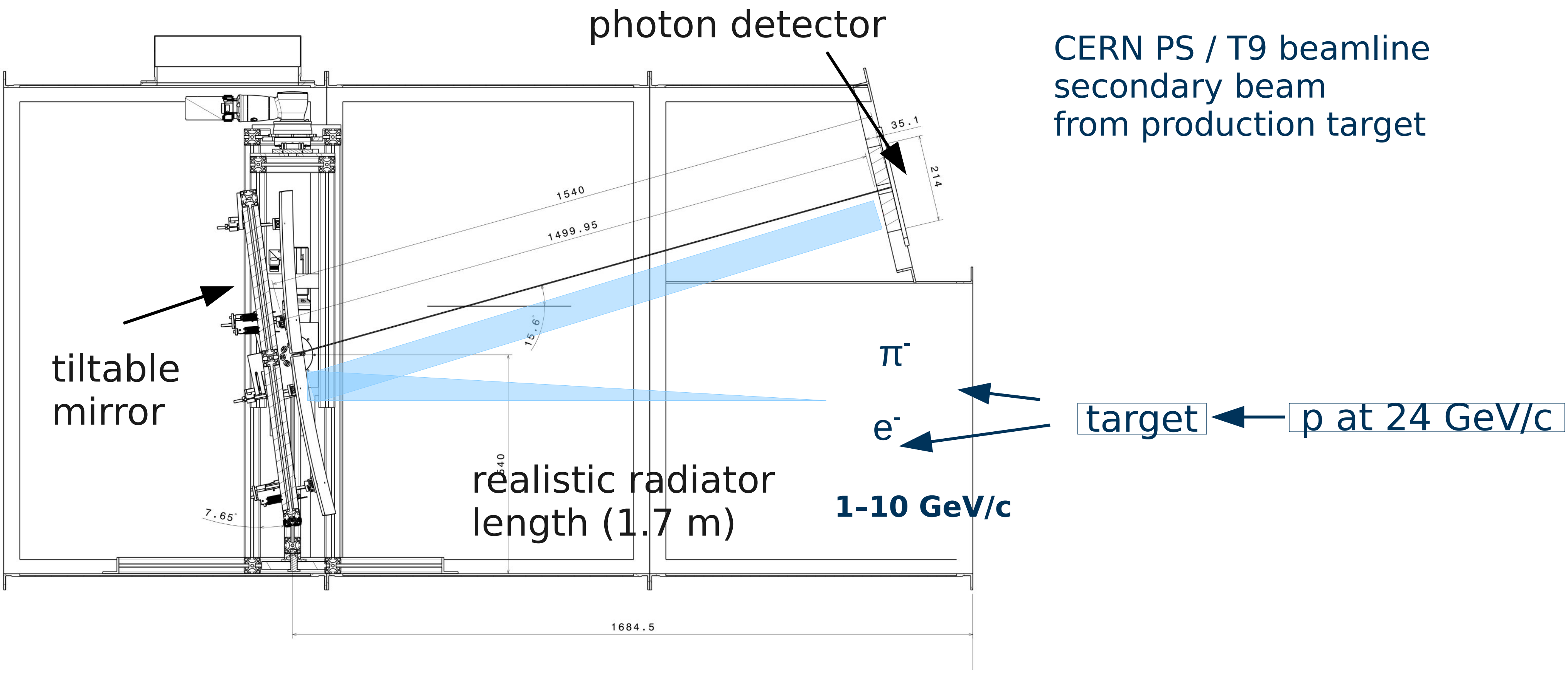


# Prototyping

# Real-size prototype

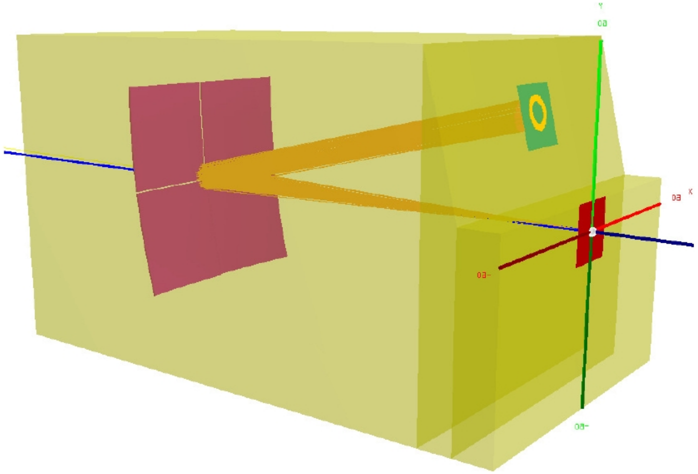
tested in beam 2011 and 2012 at CERN PS/T9

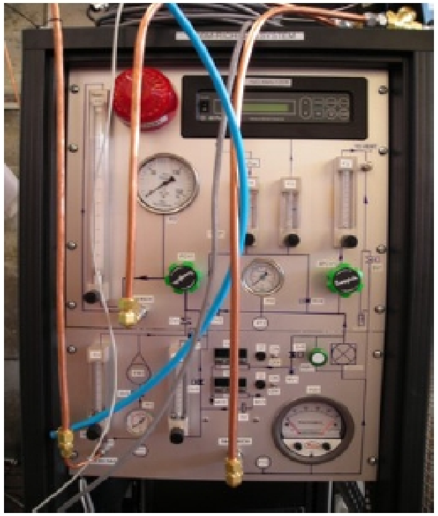


# Real-size prototype

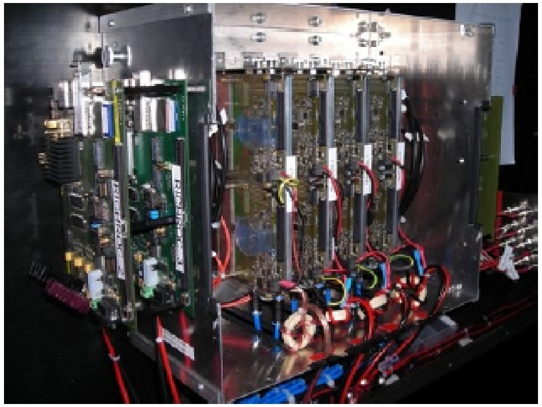
tested in beam 2011 and 2012 at CERN PS/T9


photon detector with 3 different sensor types: MAPMTs and MCPs

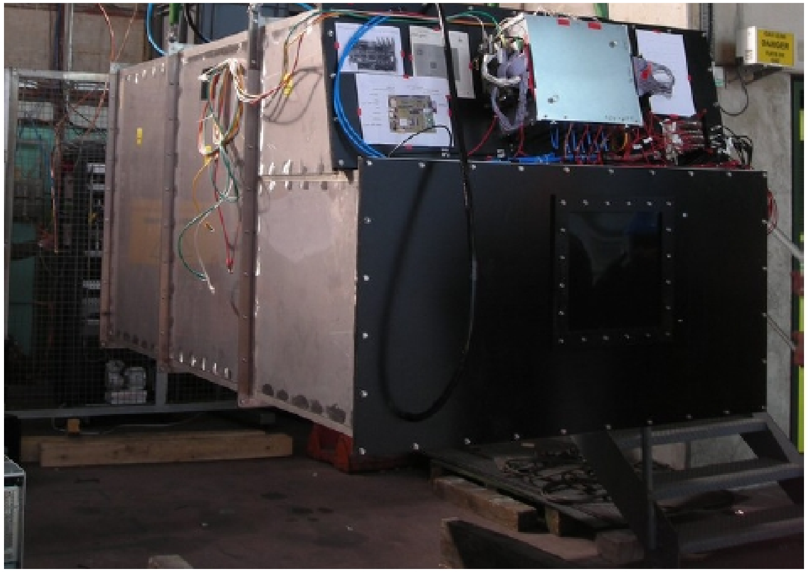




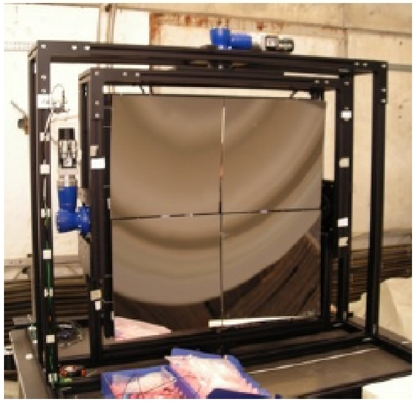
$CO_2$ gas circulation system with $O_2$ and $H_2O$ purification



self-triggered readout based on n-xyter ASIC



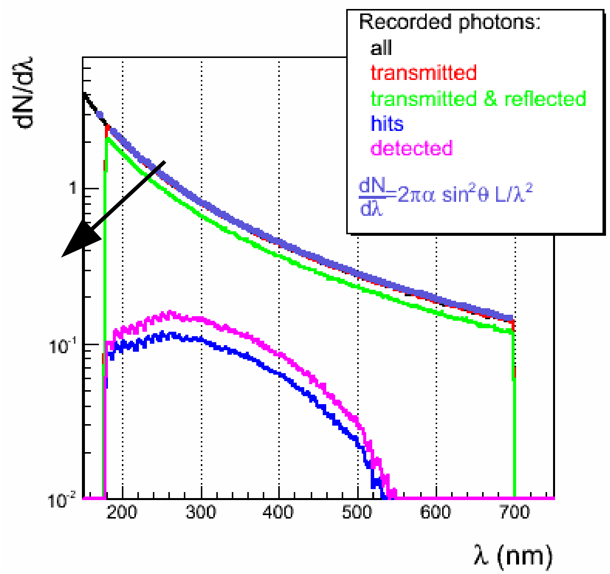
CBM-RICH prototype at PS/T9 realistic radiator length

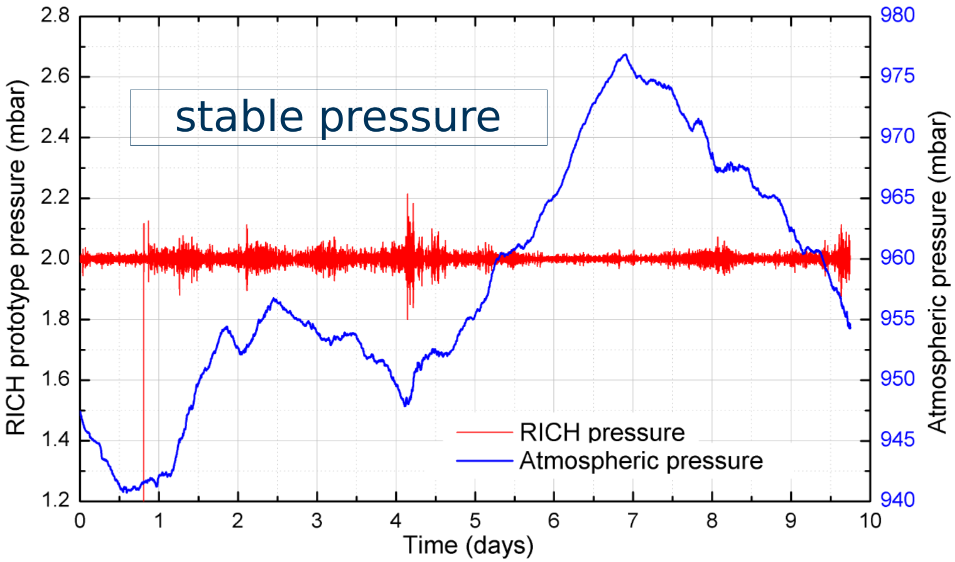


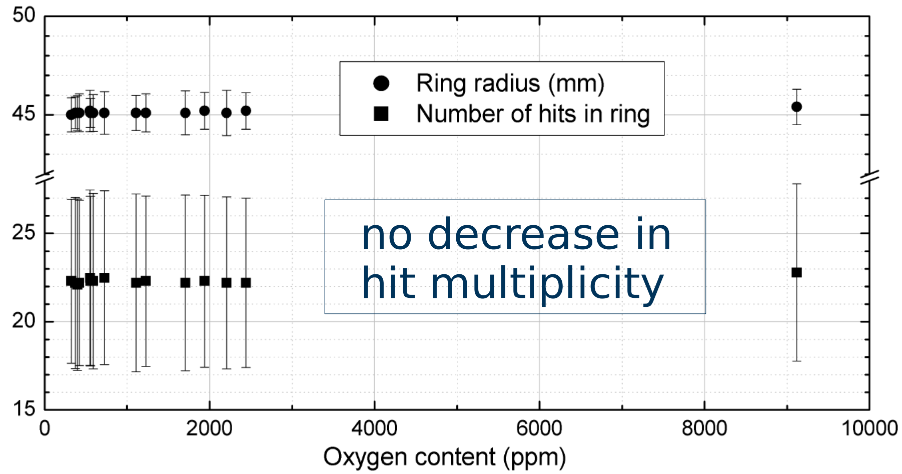
remote controlled tiltable mirror, mirror alignment with individual actuators

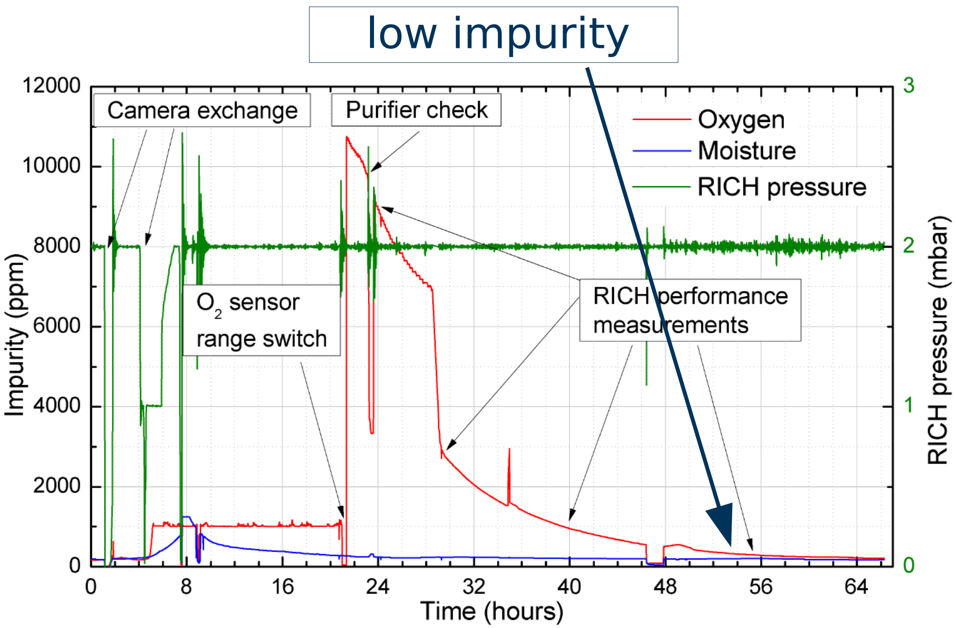
# Gas system performance

- pure $CO_2$ at constant pressure
- $O_2$ and $H_2O$ absorb UV photons
- excellent performance in beam tests



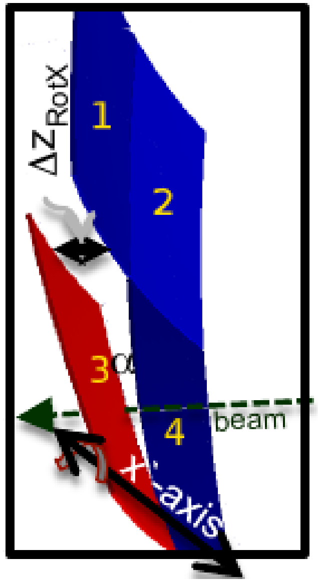



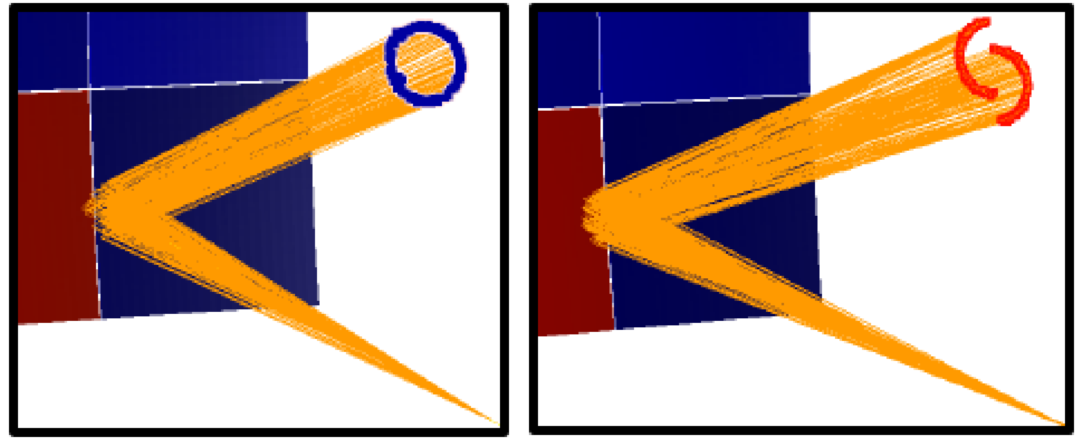



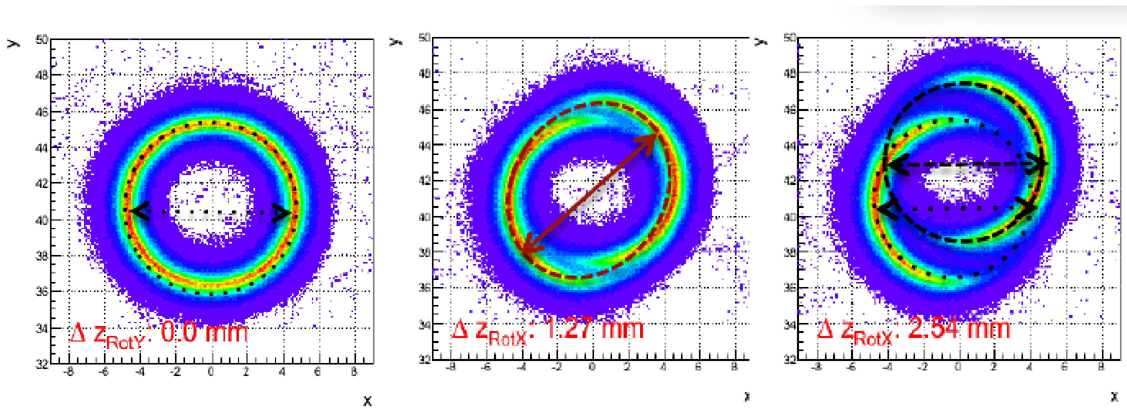

$O_2$ 80 ppm
$H_2O$ 250 ppm

# Tolerances for mirror alignment



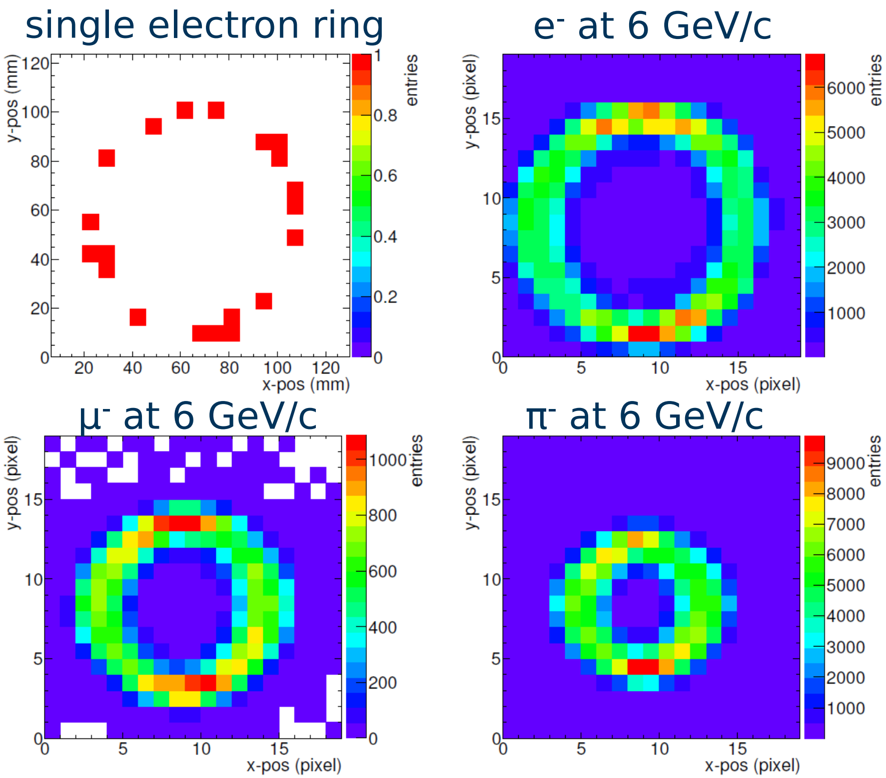



mirror back side:
3 actuators
per mirror tile

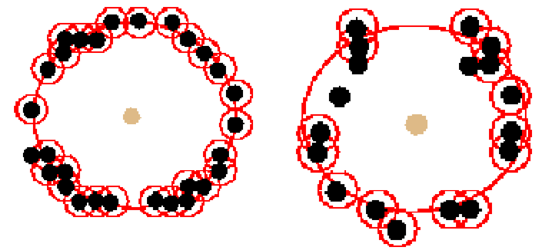


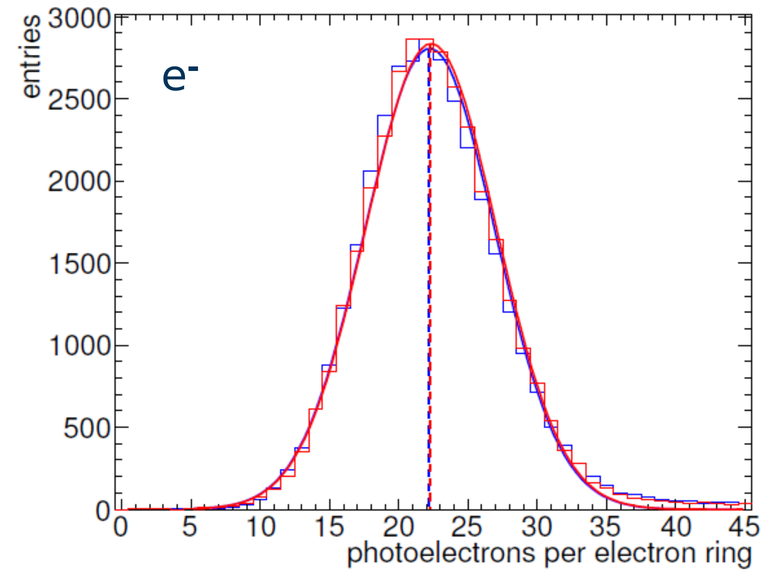

➡ $\Delta Z < 0.35$ mm ($\alpha < 1$ mrad) is tolerable

# Prototype performance




large hit multiplicity
→ efficiency of ring finding
→ quality of ring fitting





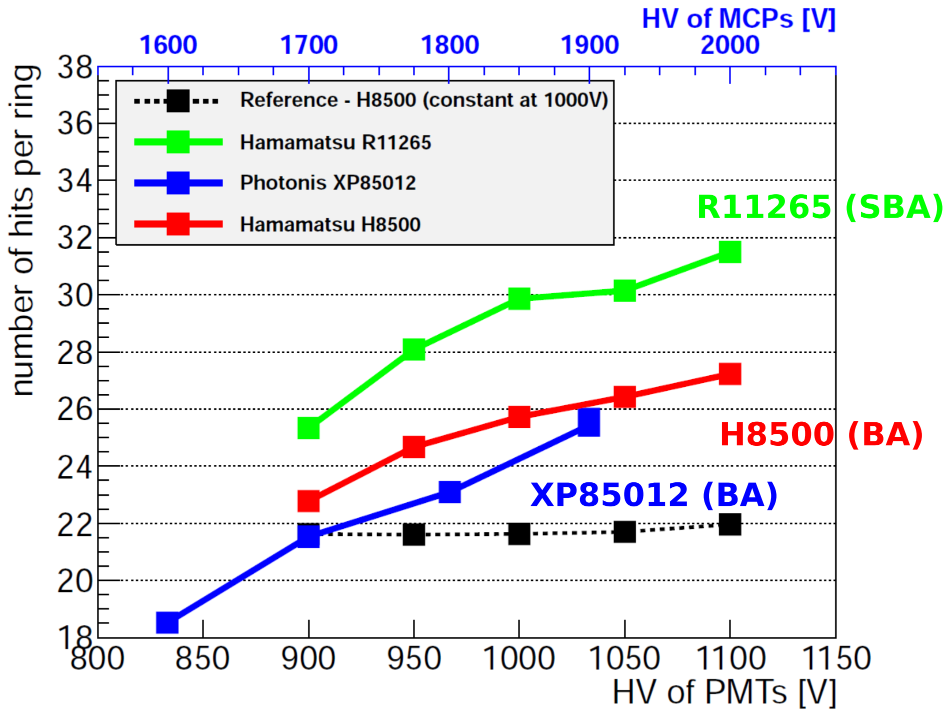

➡ clear Cherenkov rings

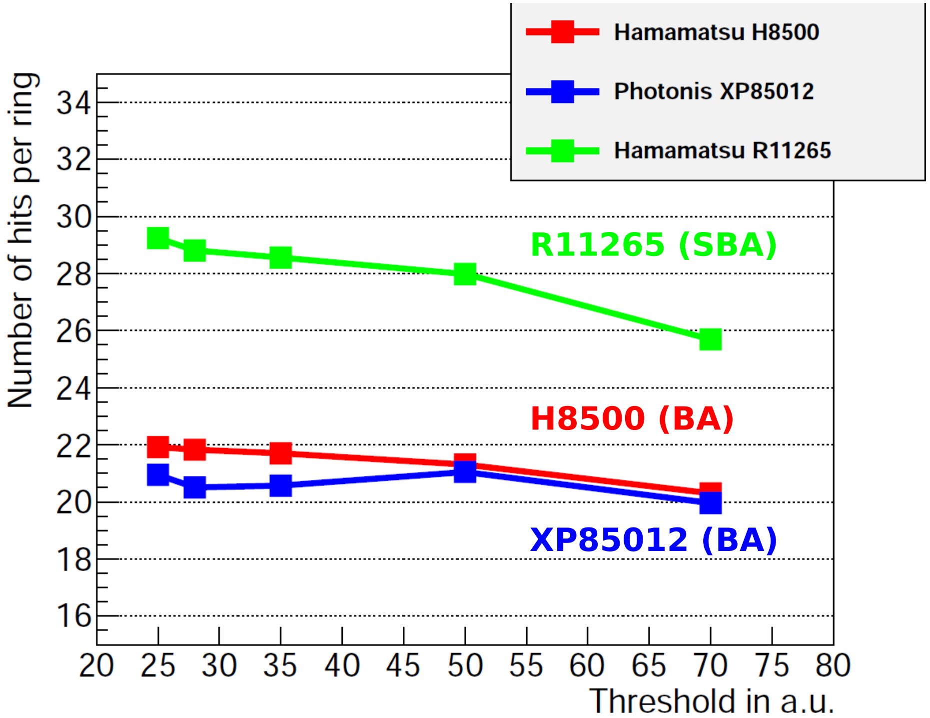
low noise rate (10 Hz per channel)

22 photoelectrons per e-ring
at 20°C, 960 mbar in agreement with MC

# Photon sensors

- comparison of different sensor candidates using tiltable mirror
- all results after subtracting individual cross talk contribution

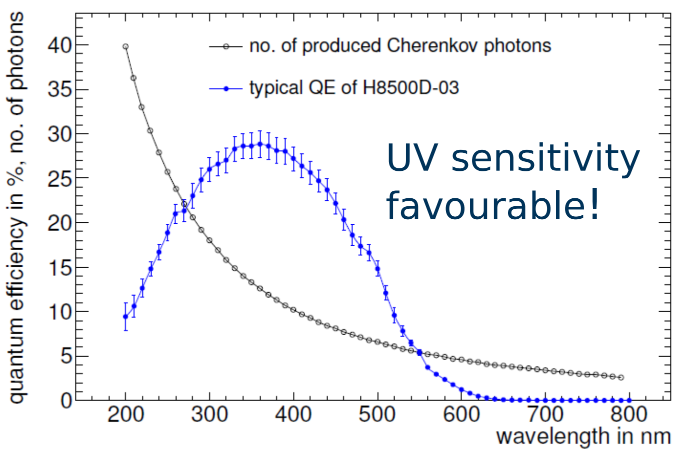



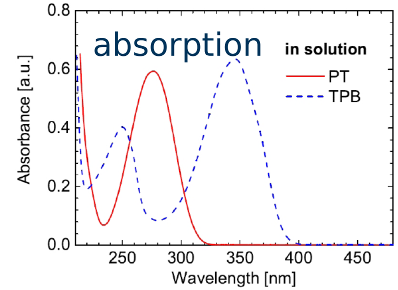



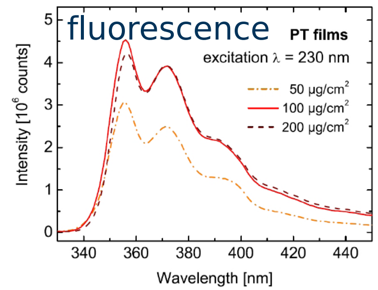

➡ R11265: ca 25 % more photons compared to H8500 / XP85012

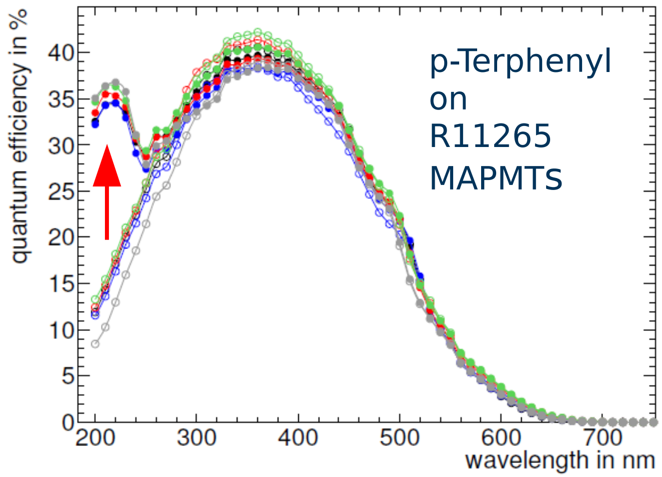
XP85012 and H8500: similar detection efficiency

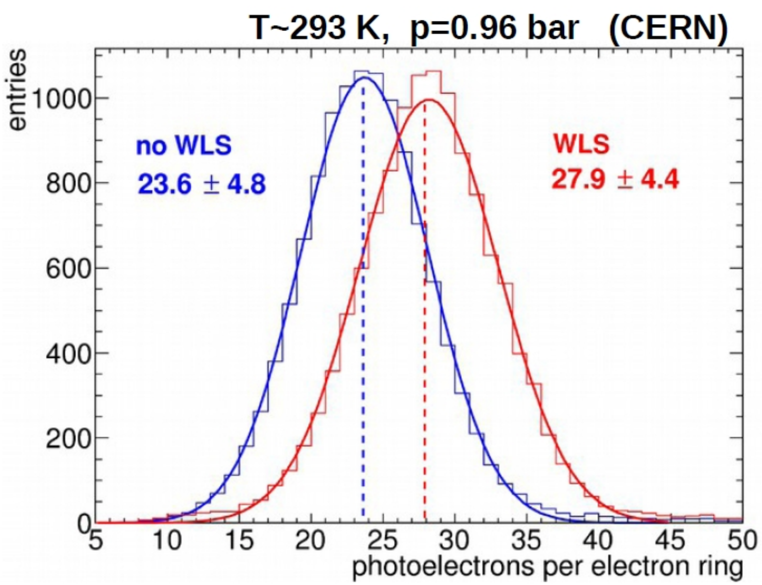
# Wavelength shifting films



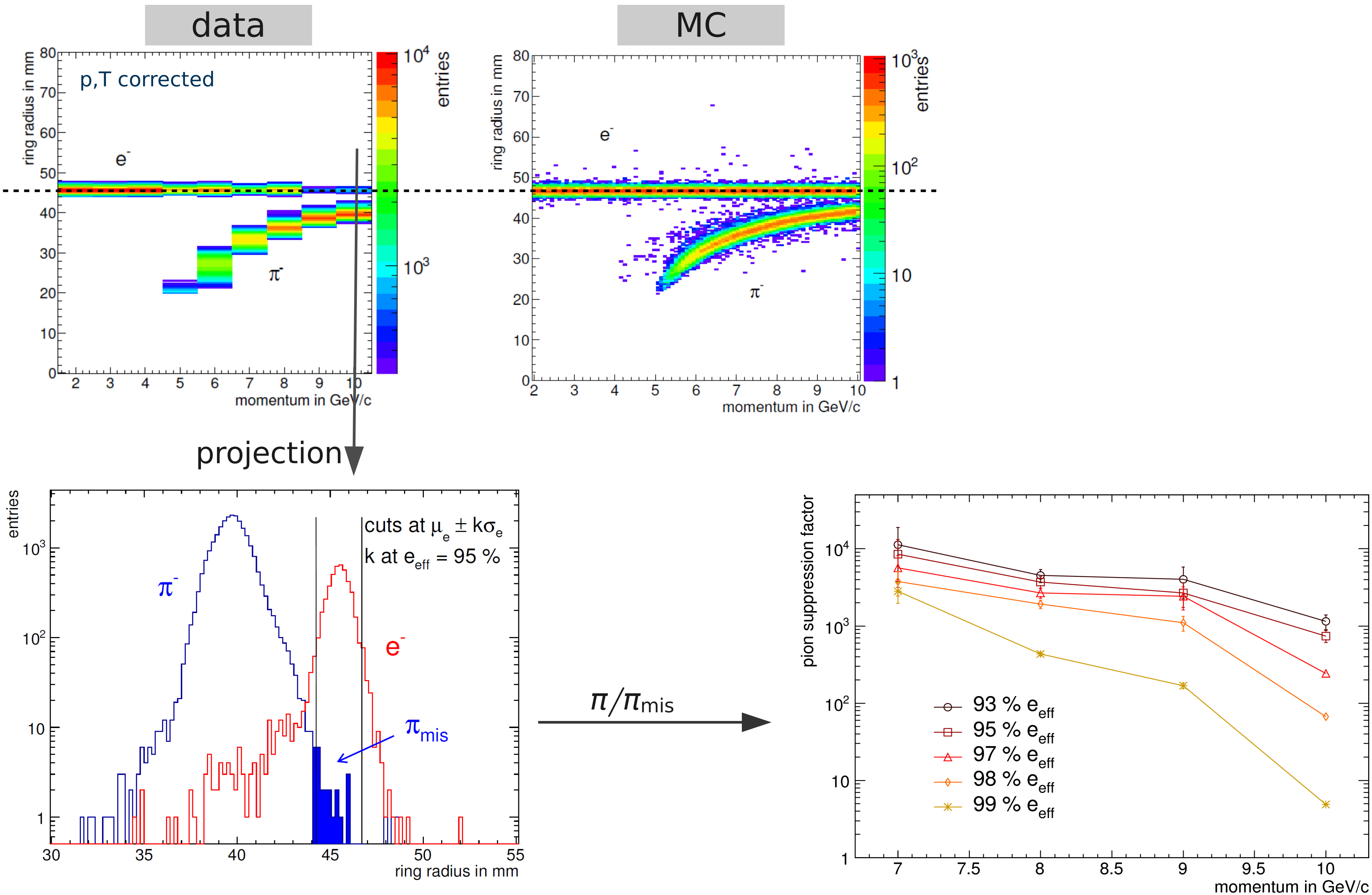




| MAPMT type | film thickness | hit multiplicity gain data | hit multiplicity gain MC |
|---|---|---|---|
| H10966A-103 | ≈ 200 nm | (21.2 ± 1.4) % | (23.1 ± 4.3) % |
| H8500D-03 | ≈ 200 nm | (18.2 ± 1.5) % | (18.3 ± 4.7) % |
| H8500D-03 | 50 nm to 100 nm | (12.2 ± 1.7) % | (10.9 ± 4.6) % |
| R11265-103-M16 | ≈ 200 nm | (18.0 ± 1.4) % | (14.8 ± 3.9) % |

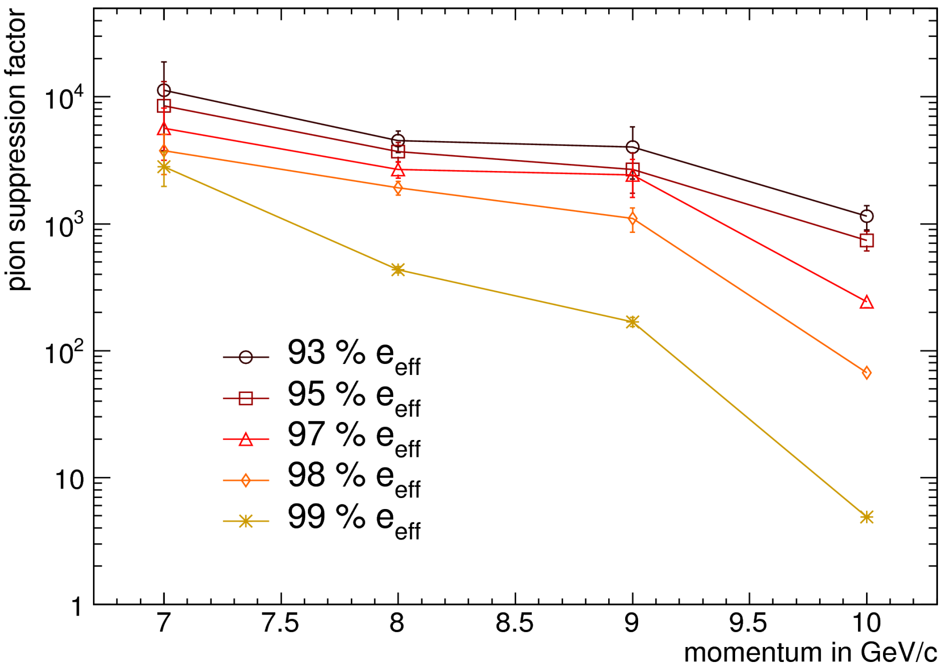
➡ + 18-21 % detected photons per ring, dependent on photocathode and window material

no significant effect on ring resolution

# Electron pion separation

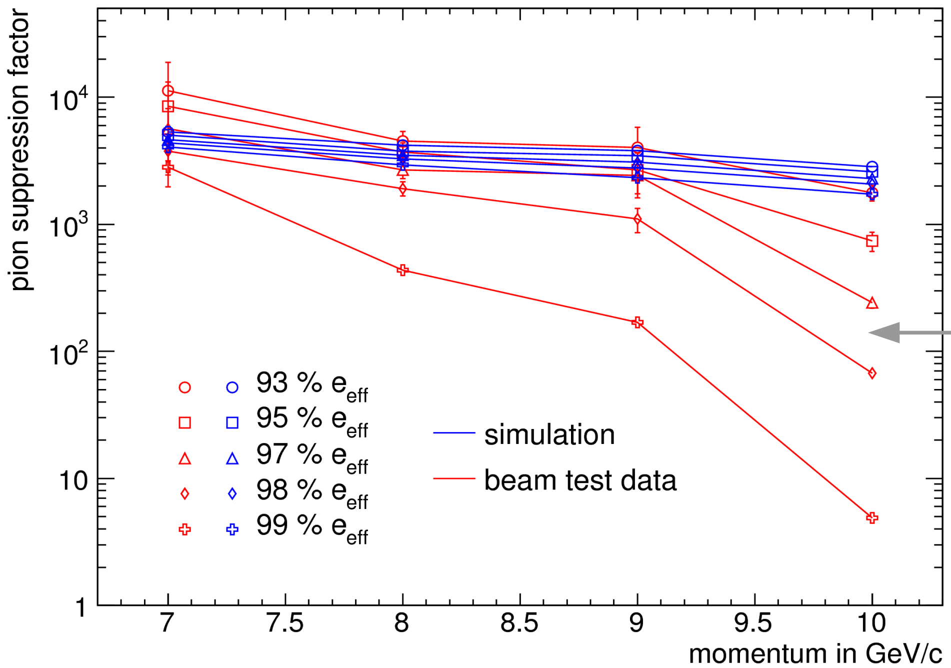


# Electron pion separation



# Electron pion separation

agreement between MC and data up to 9 GeV/c and $e_{eff}$ < 98 %




discrepancy due to muons in pion sample

→ verification of detector simulations

# Technical Design Report


submitted in June 2013 and
approved by FAIR in February 2014

# Next steps

# Next steps

- Readout electronics
  - successful beam test with n-xyter, but no option for CBM-RICH
  - first beam test with FPGA-based TDC promising
  - time information sufficient or amplitude information required?

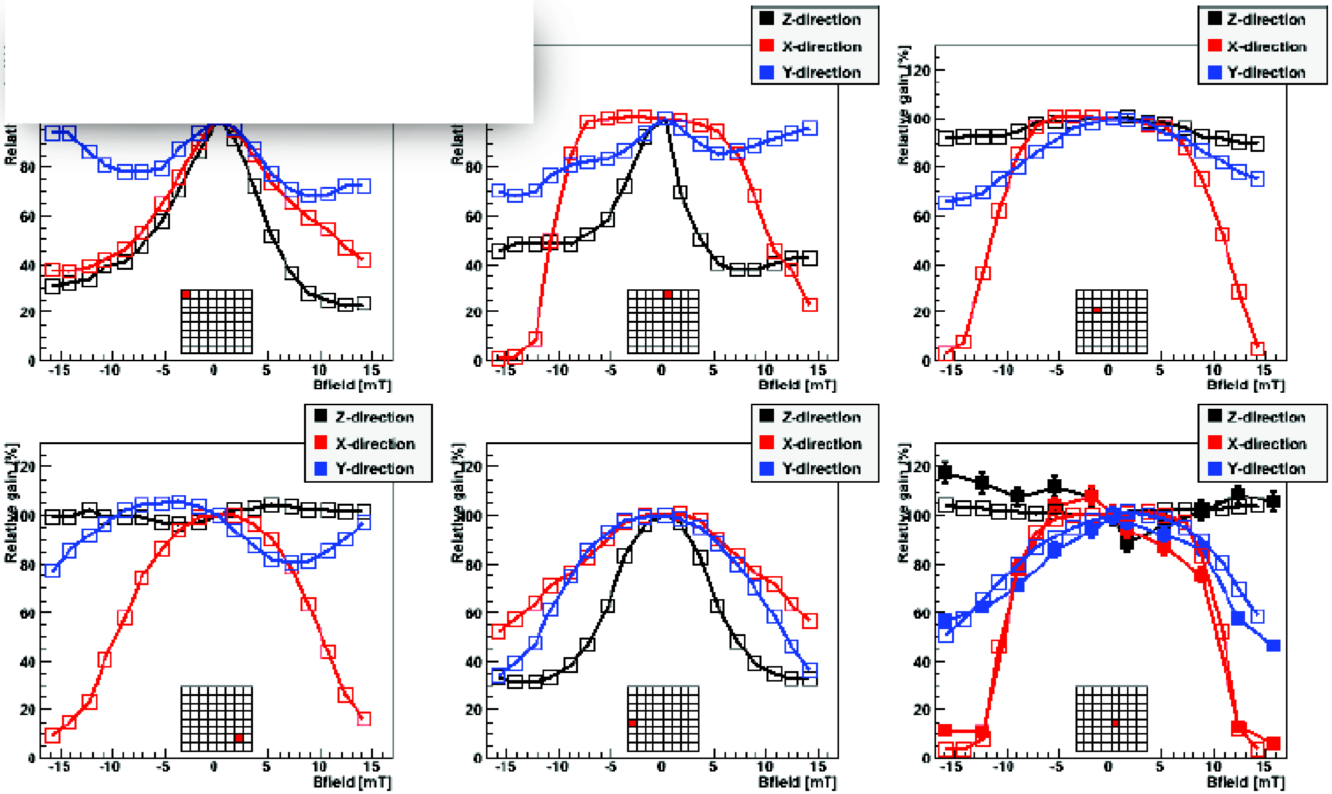
- update of magnetic field simulations with new CBM dipole magnet design (slightly less stray field in camera region expected)

- choice of sensor type

# Summary

- CBM-RICH concept validated in beam test with real-size prototype
- Detector simulation verified through comparison with beam test data
- Technical Design Report approved by FAIR
- … still work to do

# Magnetic field



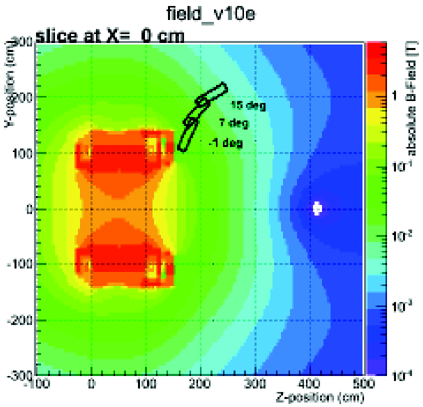

## PROBLEM:

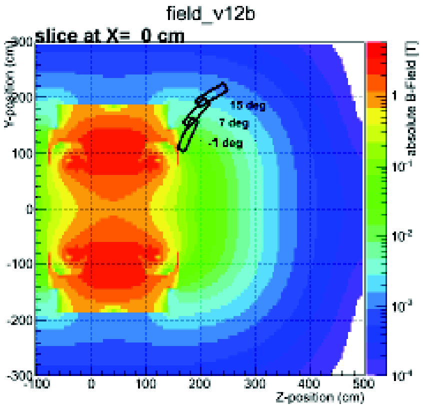
- B (10-100mT) influences the overall gain and the single-photon detection efficiency
- Strongest effect along the PMT axis (z) and at the PMT edges.
- Tolerable fields below 2mT

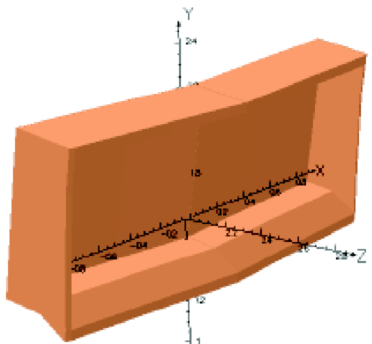
## SOLUTION ANSATZ:

- <u>Shielding</u>:
- Steal 08: 2.5-5cm thick → 1000kg
- Maximum stray field is 1mT

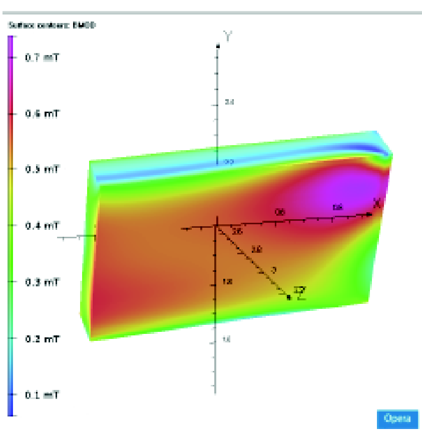
*<u>Rotation</u>:* $\alpha \geq 10$ *degrees*



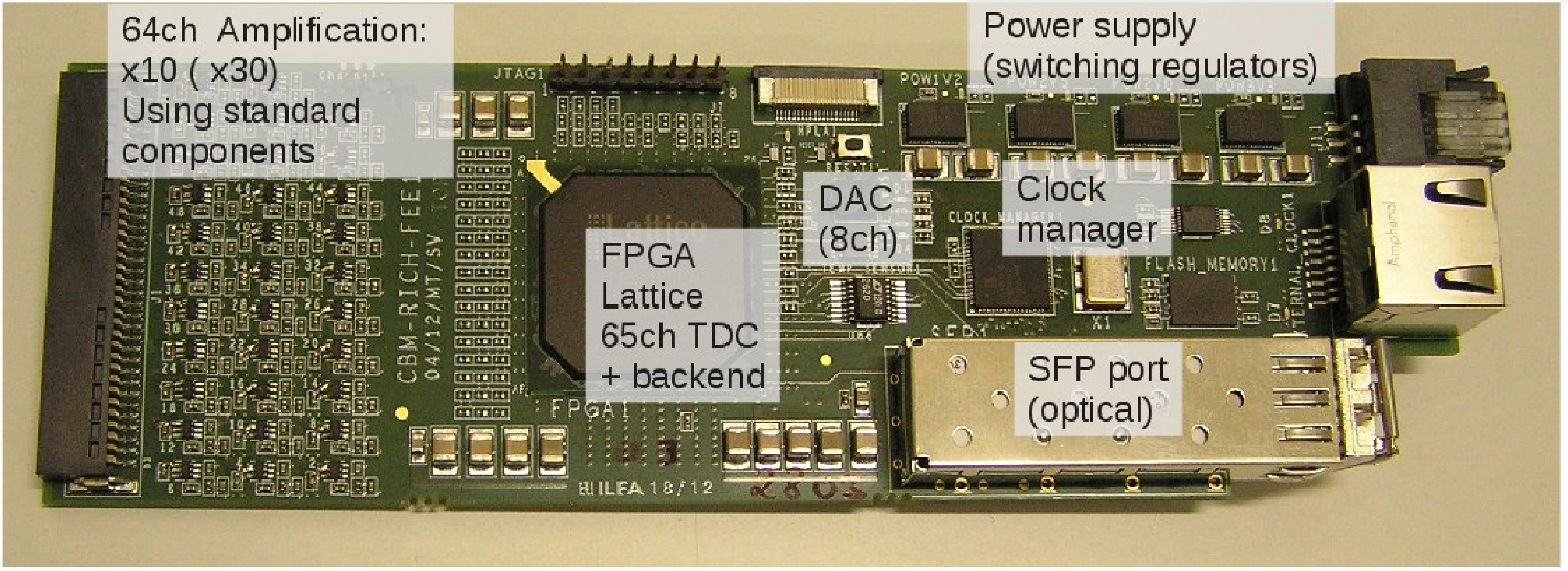



2 x 0.6 x0.1-0.15 m³

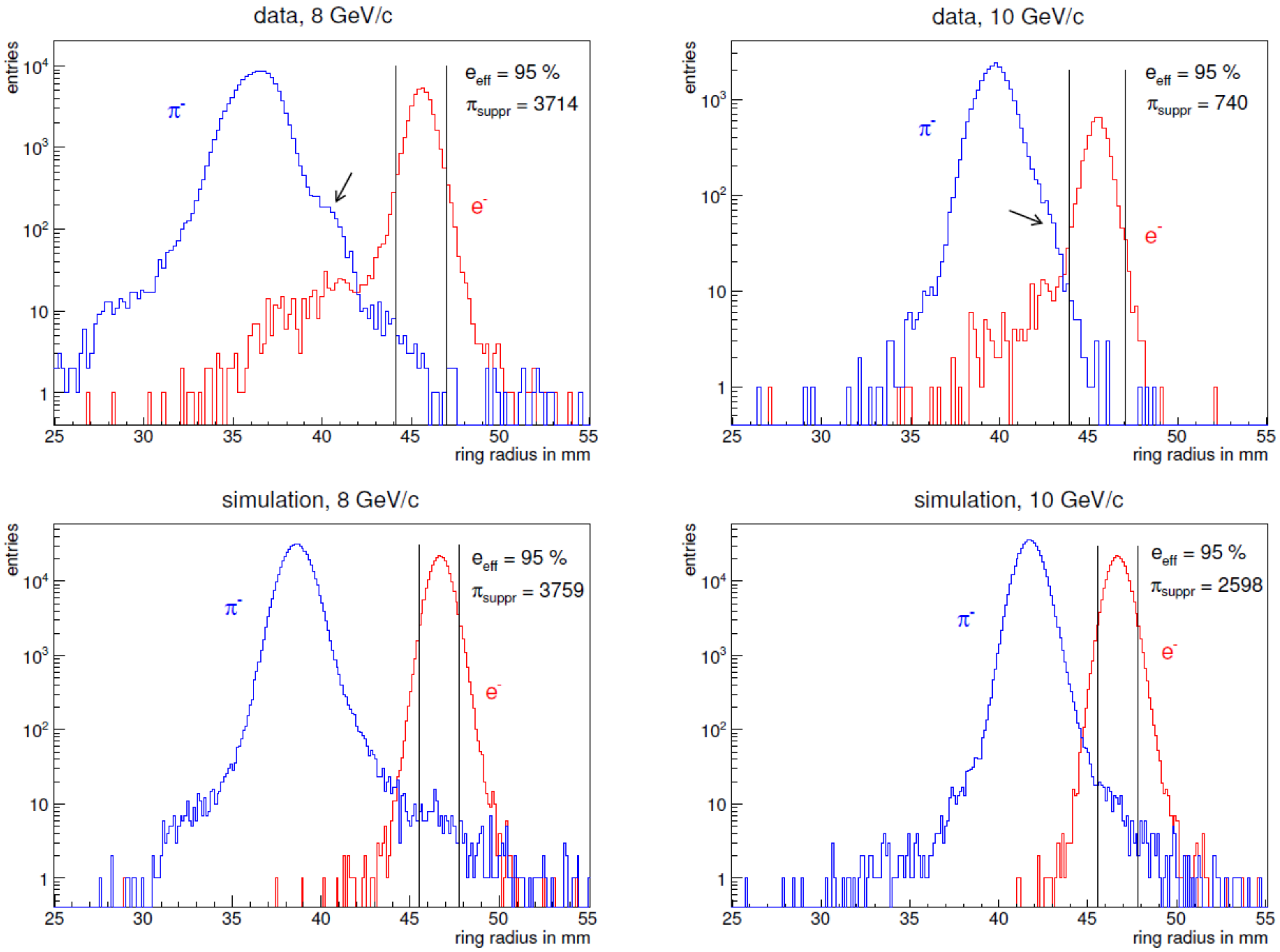


# New FPGA-TDC read-out electronics




- FPGA-TDC 64 channels/board.
- Signal discrimination using LVDS receivers on FPGA.
- Digital backend included on FPGA.
- Highly integrated and inexpensive approach.
- Only time information, no amplitude measurement → to be evaluated.
- Limited amplitude information could be gained via Time–over-Threshold (ToT).
- Development started Feb. 2012, first prototype already tested in beam Oct. 2012!
- Fruitful collaboration with GSI Experiment-Elektronik division (M. Traxler et al.)

# Electron pion separation




muons in
data sample!