THE CBM RICH detector

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for the CBM RICH group:
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ITEP Moscow, Pusan National University, JINR-LIT Dubna

Outline

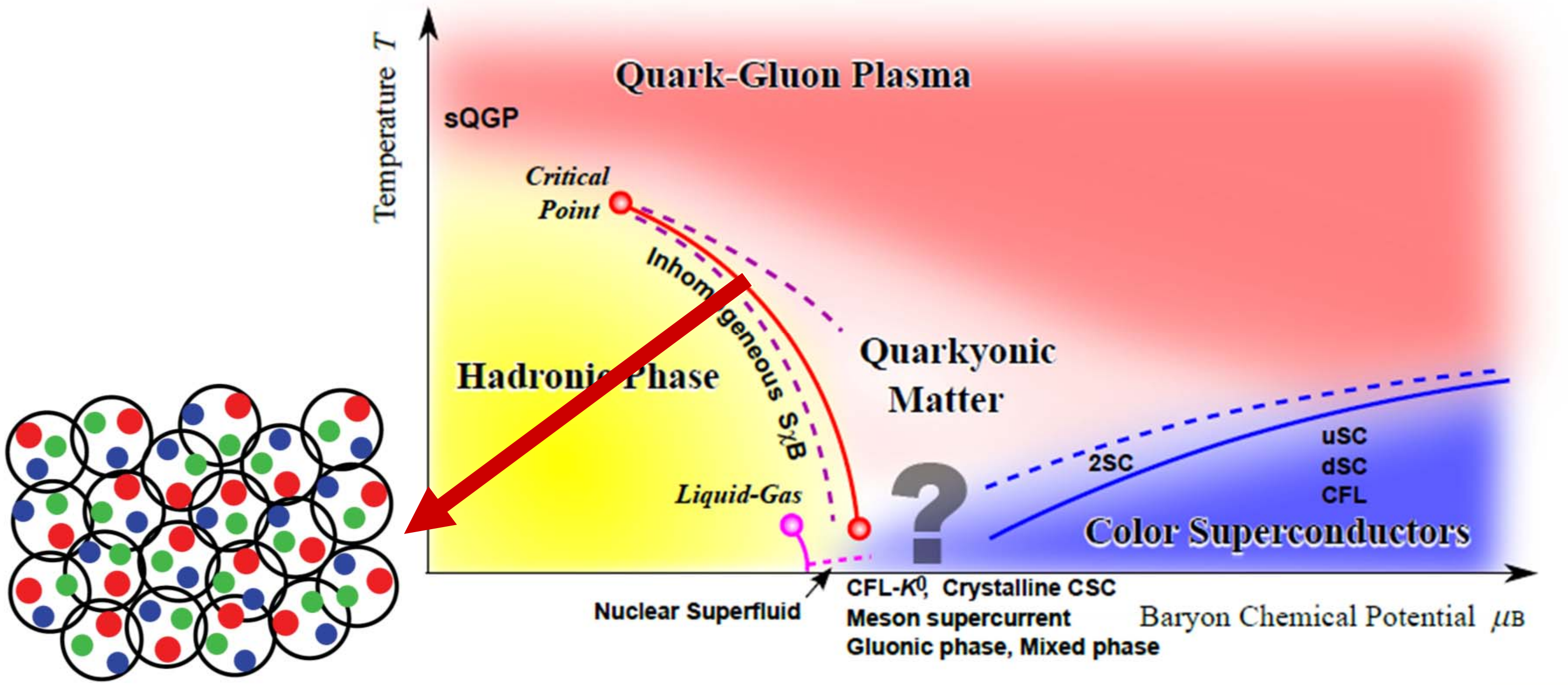
- The QCD phase diagram and the CBM experiment
- CBM RICH concept
- News on developments for the
  - Photondetector
  - Mirror
  - Readout electronics
  - RICH geometry
  - Mirror mount structure
- Real size prototye
- HADES RICH upgrade

CBM experiment @ FAIR – high μ_B, moderate T

phase diagram at high μ_B ?

- quarkyonic phase?
- phase transition(s)?
- critical point/ triple point?
- **need for high precision data including rare probes**

Electromagnetic probes!



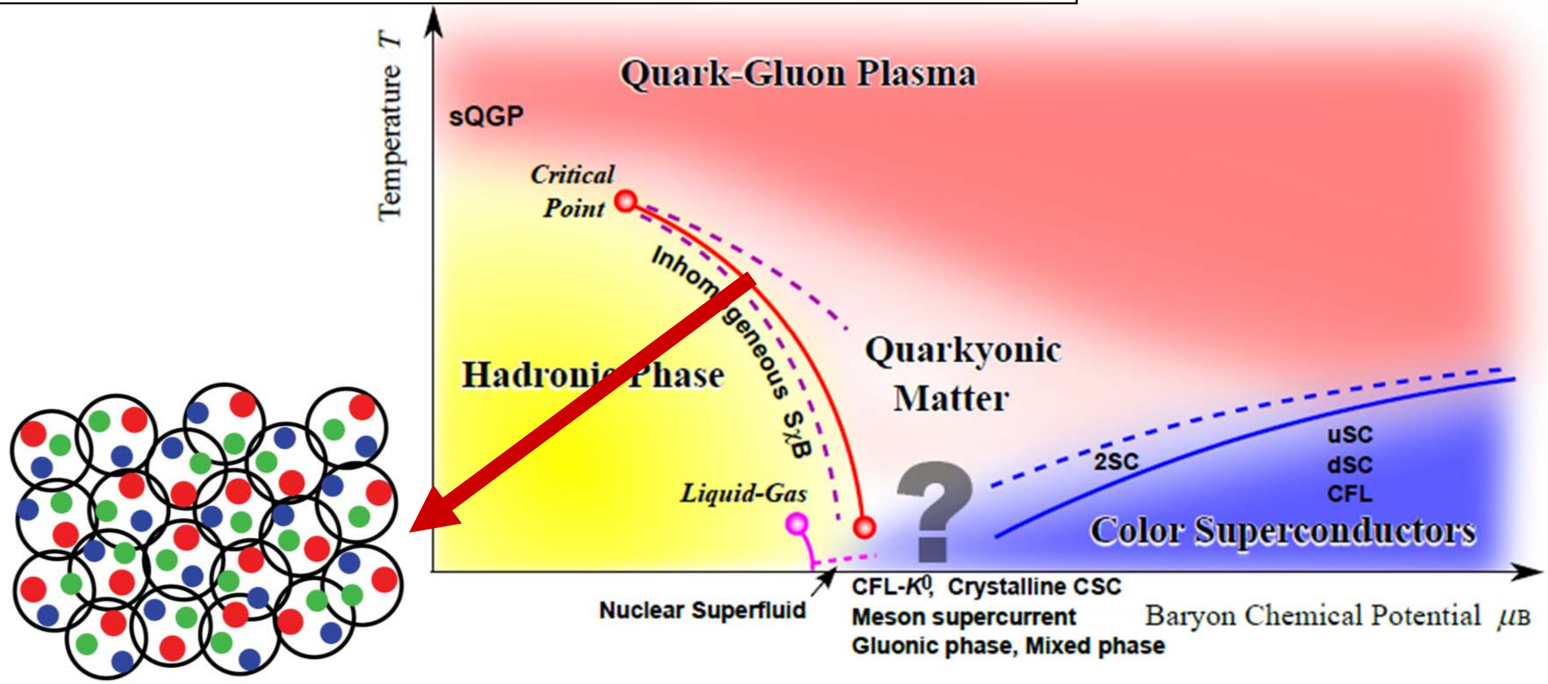
CBM experiment @ FAIR – high μ_B, moderate T

Electromagnetic probes!

- Photons: access to early temperatures
- Low-mass vector mesons: in-medium properties of ρ-meson
- Intermediate range: acces to fireball radiation
- J/ψ: charm as a probe for dense baryonic matter

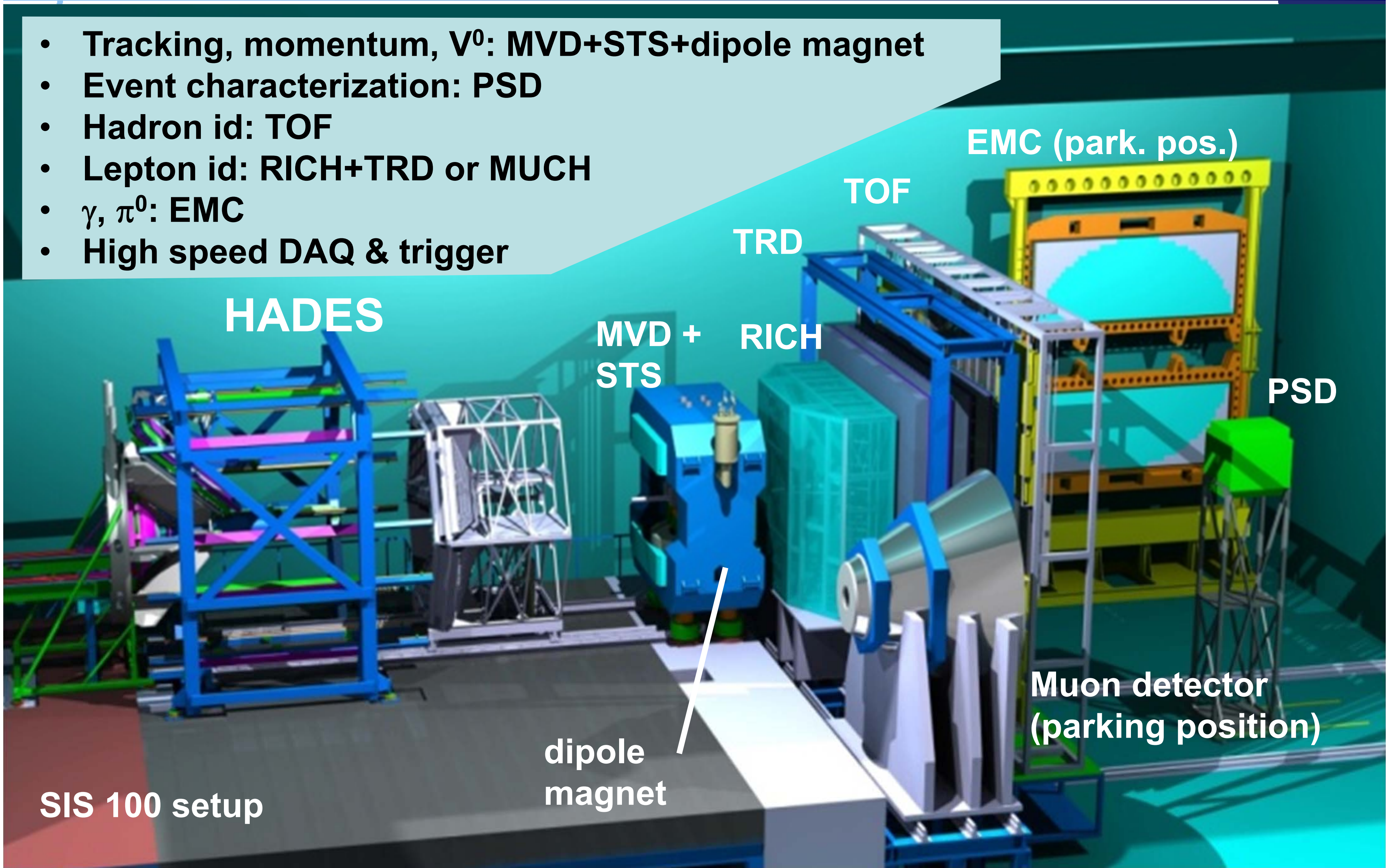
Field driven by experimental data!

need: ~ 2-40 AGeV beam energies at high intensities



The CBM experiment (SIS 100 setup)

- Tracking, momentum, V^0: MVD+STS+dipole magnet
- Event characterization: PSD
- Hadron id: TOF
- Lepton id: RICH+TRD or MUCH
- γ, π^0: EMC
- High speed DAQ & trigger



Concept of the CBM-RICH detector

aim: clean electron identification for momenta below 8 GeV/c
.... maybe use also for additional π-suppression in K-id at higher p

concept: RICH with gas radiator: stable, robust, fast
vertical splitting due to CBM dipole field

photodetector (2.4 m^2, 55k Ch.)

- photomultipliers (MAPMT: H12700 series)
- enhanced UV sensitivity using wavelength shifting films?
- fast self-triggered readout

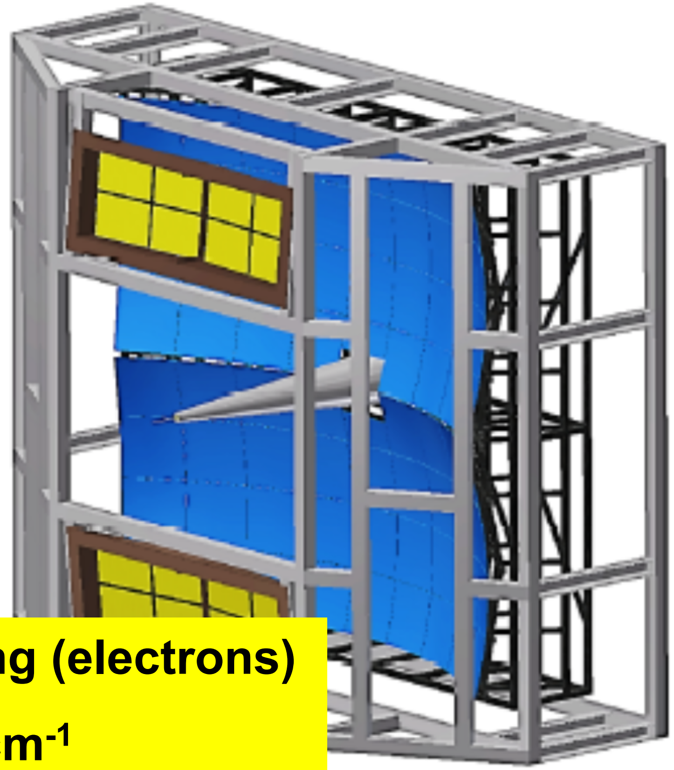
mirror (11.8 m^2)

- glass mirror: R=3m, ≤ 6mm thickness, $Al+MgF_2$ coverage

radiator

- CO_2: γ_{th}=33, $p_{\pi,th}$=4.65 GeV/c

→ Photons with $\lambda \geq$ 180 (200) nm



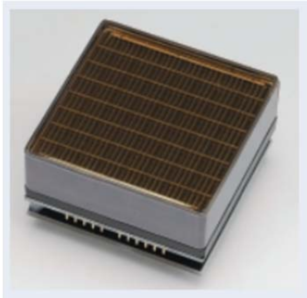
→ 26 $N_{p.e.}$/ring (electrons)

→ $N_0 \approx 170\ cm^{-1}$

Photodetector

Hamamatsu H12700 MAPMT (now H13708) has been selected after extensive R&D phase:

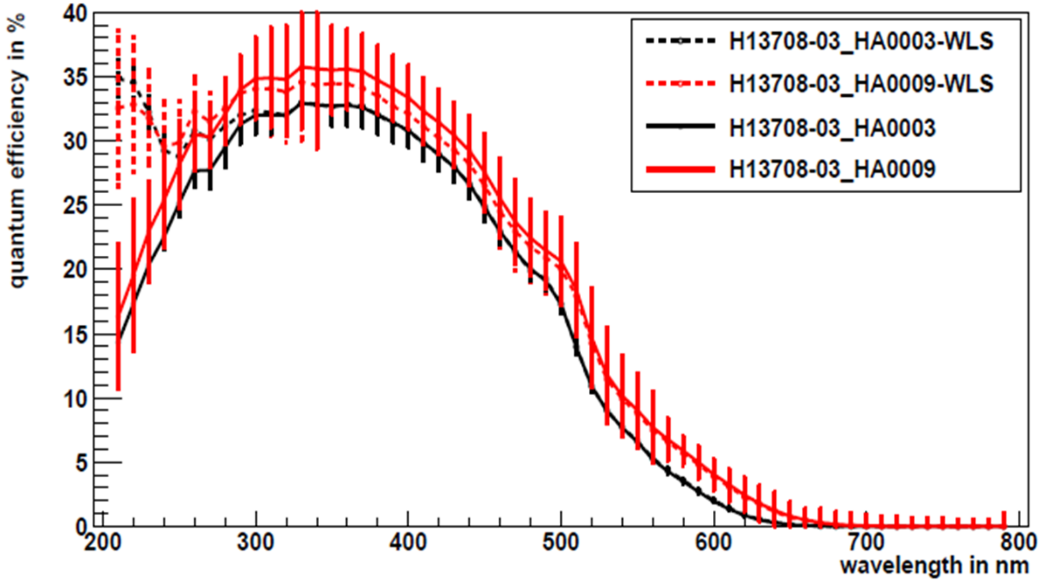
- Pixel resolution
- Single photon response
- Quantum efficiency
- Radiation hardness, activation
- Enhanced Q.E. with WLS coverage*
- Noise



H12700 MAPMT, Hamamatsu

H12700 combines the geometry of H8500 and the single photon response of R11265, blue shifted SBA photocathode (→ H13708)

Quantum efficiency with and without WLS coverage; the latter increases the final hit multiplicity by up to 20%



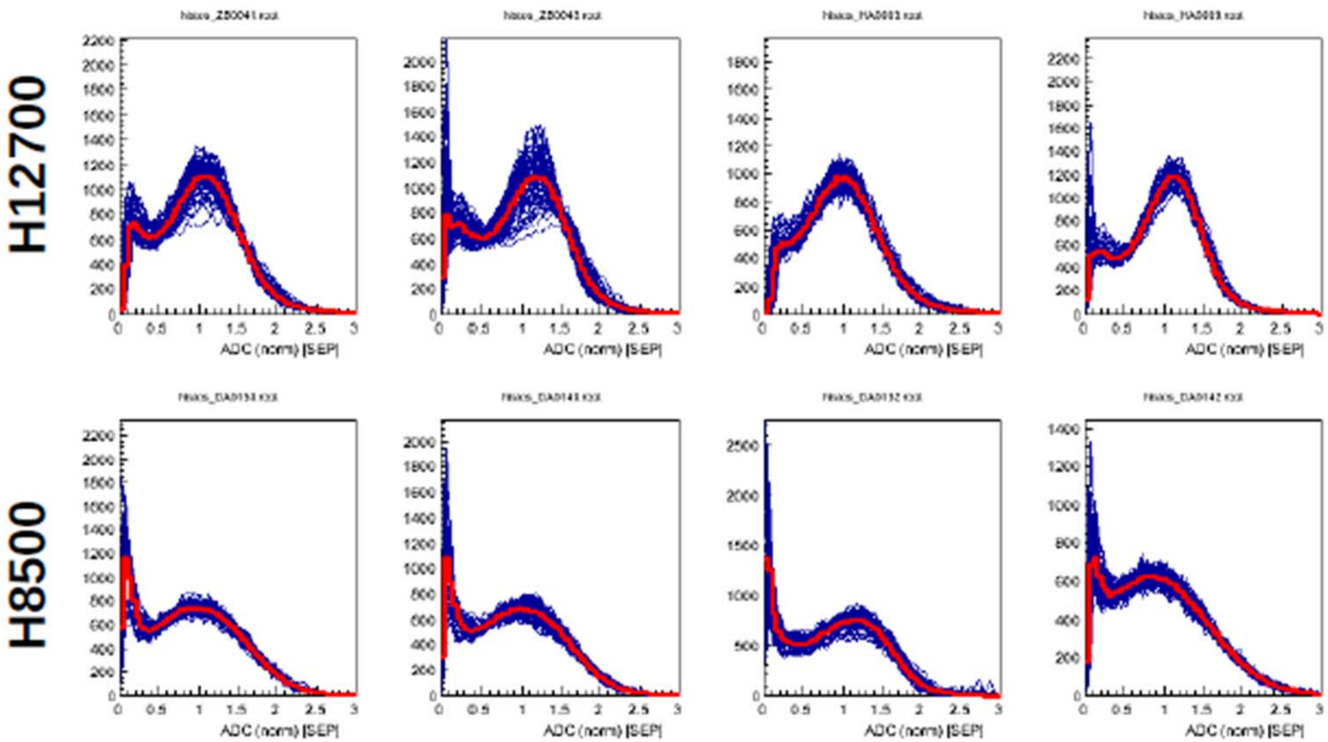
[* CBM-RICH group, Nucl. Instr. Meth. A783 (2015) 43.]

Photodetector

H12700 extensively tested in comparison to H8500:

- Good efficiency, surface homogeneity
- Less crosstalk compared to H8500
- Very nice single photon response

ADC single photon response



Photodetector

Radiation hardness, activation tested with thermal neutrons (TRIGA reactor, Ljubljana) and gammas (^{60}Co source, Gießen)

- Covar activation: $^{59}Co + n \rightarrow {}^{60}Co$
- Radiation hardness of transisitor: minor drift up to < 10^{13} n_{eq}/cm^2 (+100 Gy), breakdown at 1×10^{15} n_{eq}/cm^2 (+10 kGy)
- Radiation hardness of PMT window, cathodes, dynodes

H8500 MAPMT (very similar to H12700 MAPMT)
irradiated with **1.3×10^{11} n_{eq} / cm^2 thermal neutrons** (~ 15% CBM lifetime dose)

Gamma spectroscopy results measured 24hr after irradiation:

Radionuclide	Activity [Bq]	Half-life	Used in
Br-82	1.70×10^3 (± 3.4×10^2)	1.5 days	Voltage Divider PCB
Au-198	6.63×10^2 (± 1.4×10^2)	2.7 days	Gold-plated contacts
Na-24	2.46×10^2 (± 5.1×10^1)	15 hr	Glas window
Co-58	**3.03×10^1 (± 7.3×10^0)**	**71.3 days**	**Covar metal case**
Co-60	**7.13×10^1 (± 1.5×10^1)**	**5.3 years**	**Covar metal case**

Photodetector

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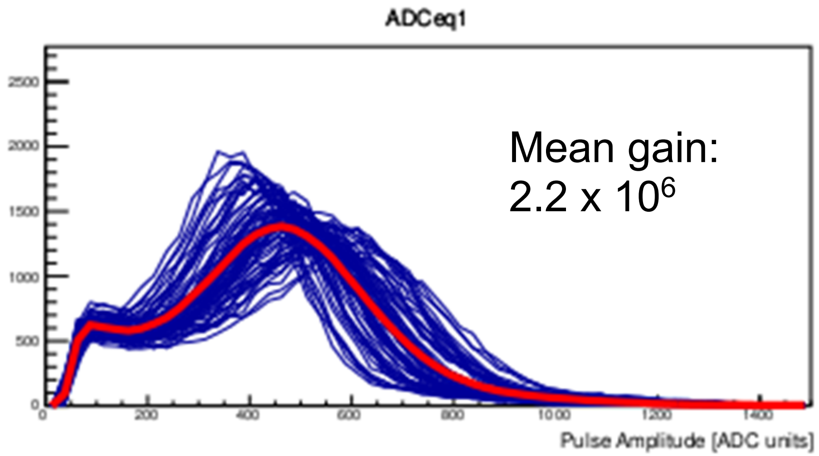
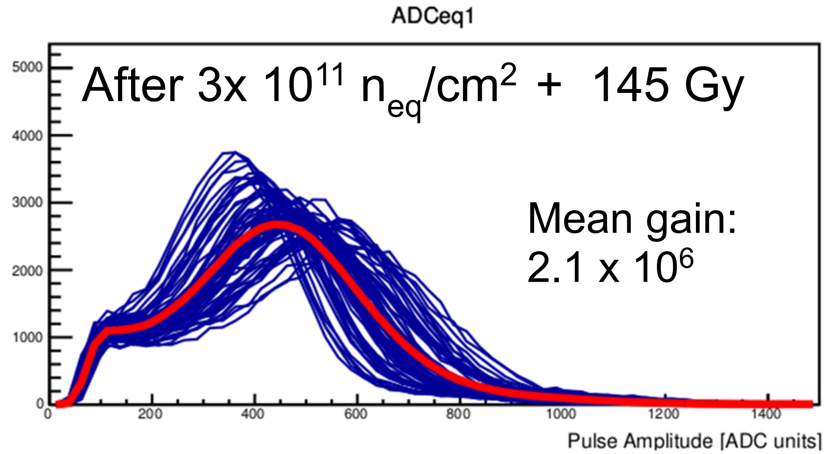
Gain normalized single photon spectra of all individual pixels before and after irradiation; Red line: average over all pixels
Sensors should survive: 1×10^{12} n_{eq}/cm^2 and 100 Gy (20 CBM years)





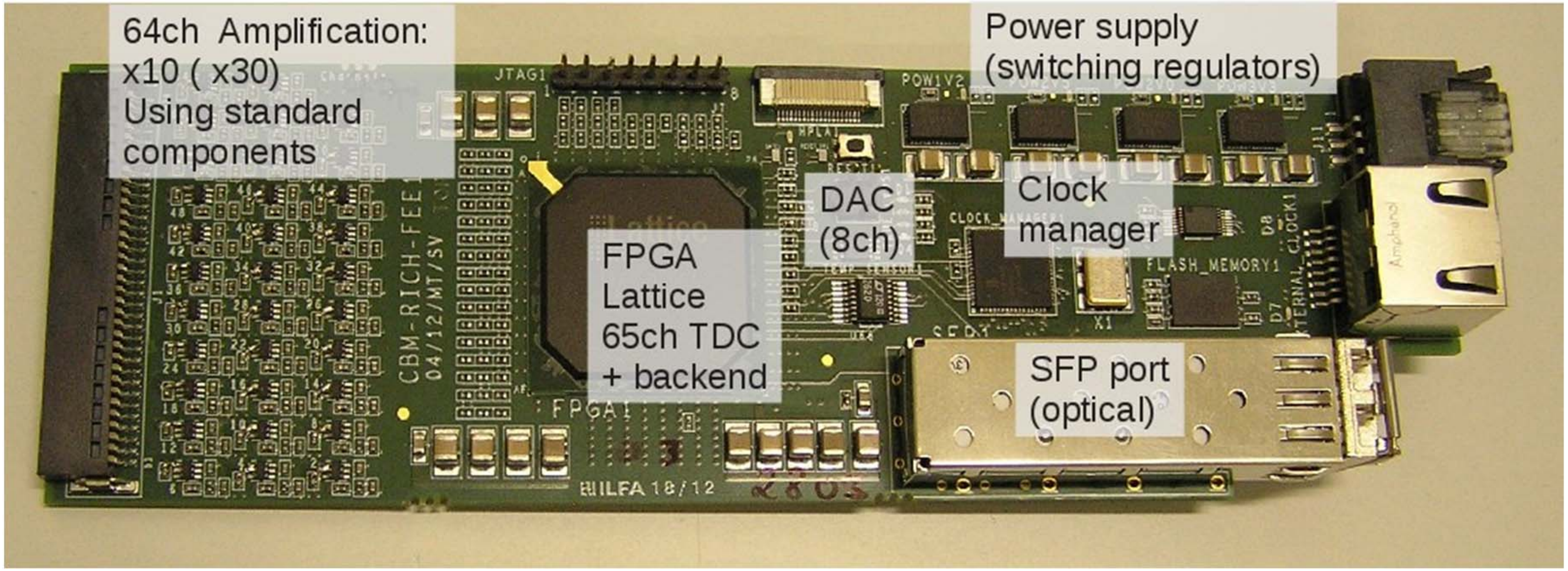
Photodetector

First batch (30 pieces) has been delivered!

Readout electronics

- Development of **DiRICH board**: combine PADIWA* functionality (discrimination) and TRB* (TDC, data handling) on a single board: joint development of PANDA-DIRC, CBM-RICH and HADES-RICH
  first boards expected early 2016
- make use of new Lattice ECP5-85F FPGA: 32 channels ToT, ~10ps precision TDC

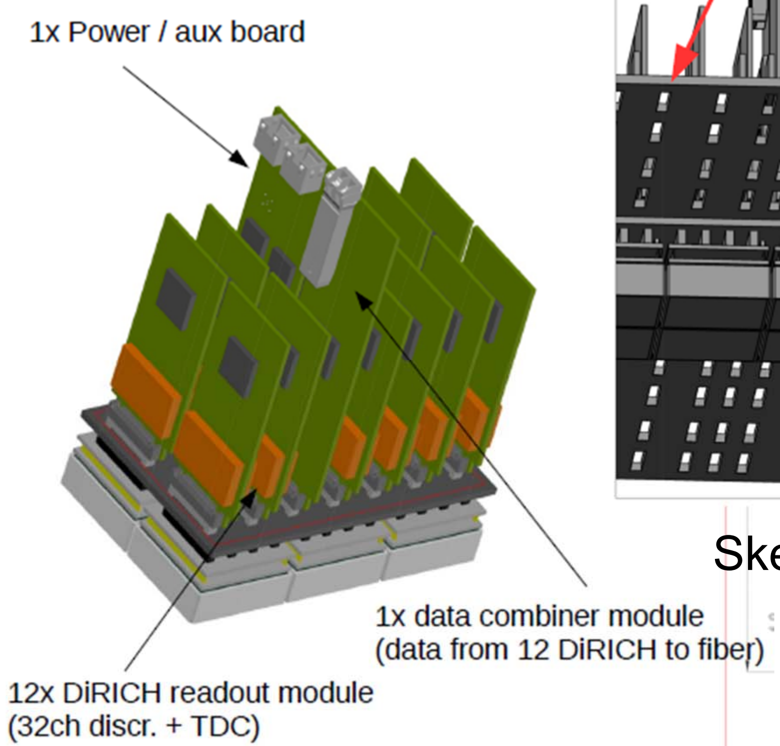
TRBRICH module, a predecessor of the DiRICH board

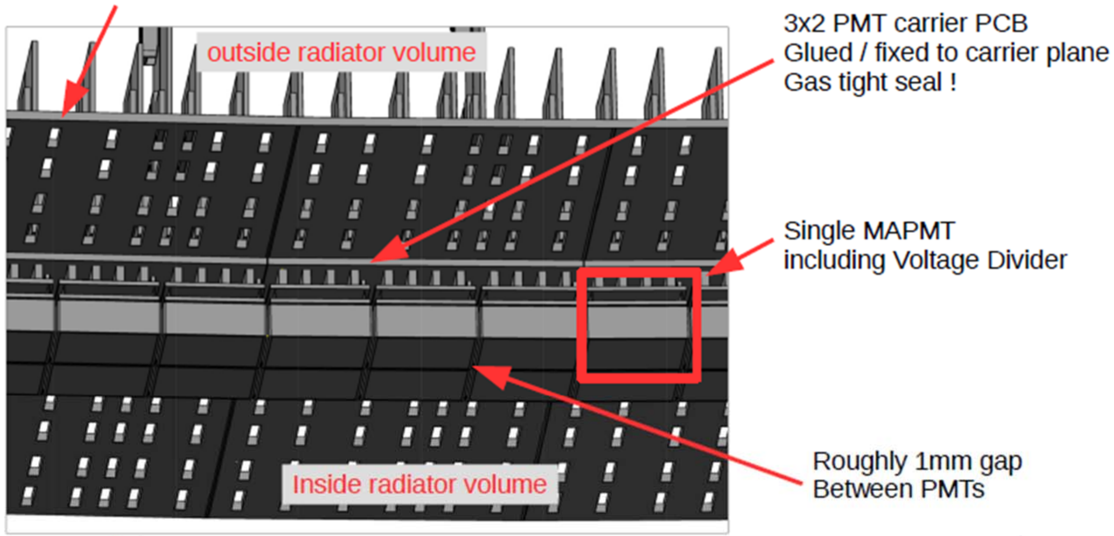


[* A. Neiser et al., JINST 8 (2013) C12043]

Readout electronics

- 3x2 MAPMT readout module with 2 DiRICH boards per MAPMT, data combiner module, Power board: small units for flexible photodetector setup
- Gas tight mounting on carrier plane (steel) resembling shape of focal plane



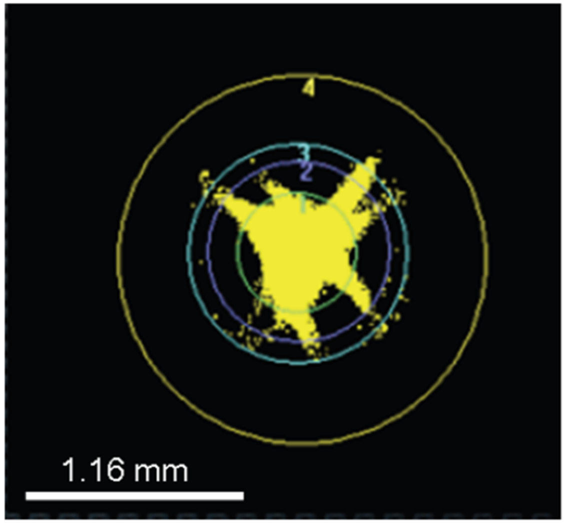


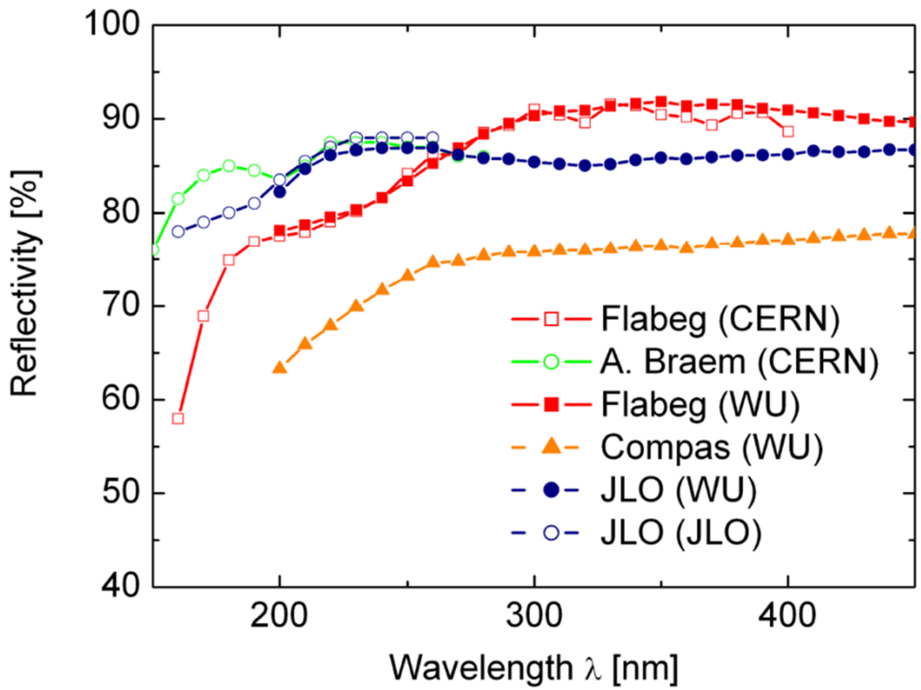
Sketch of later arrangement to PMT plane

Mirror

- SIMAX glass mirrors, tickness 6mm, R=3m, Al+MgF_2 coverage from JLO Olomouc

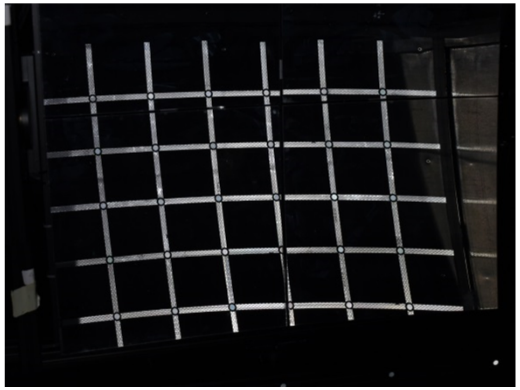
→ high reflectivity; very good surface homogeneity (D_0=2-3 mm: diameter of the reflected spot from a point source which contains 95% of the light intensity)
→ optimization of coating: Al+MgF_2 versus Al+MgF_2+HfO_2

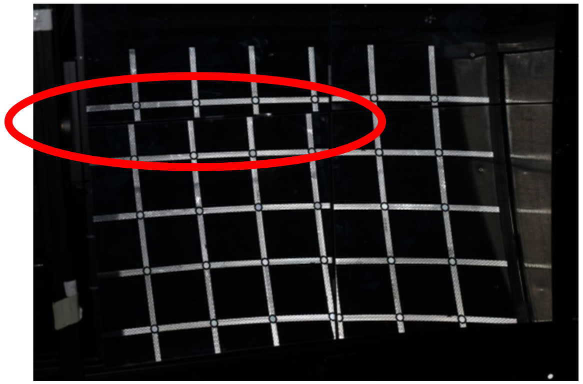


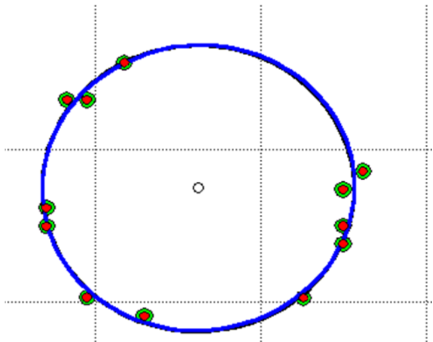


Mirror alignment control

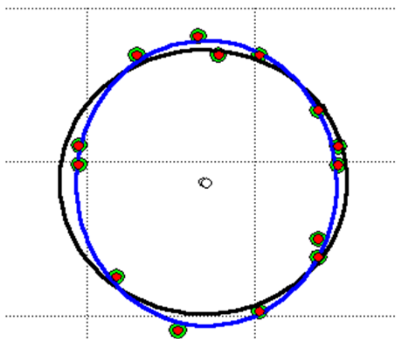
- Development of mirror alignment control system:
  - CLAM* method: retroreflective grid at entrance, illuminated by LED, reflection seen via mirror
  - Method based on online and offline data analysis comparing fitted and extrapolated ring center$







Test of CLAM method in prototype:
Mirror aligned → ring
… misaligned → ellipse



[* COMPASS experiment, Nucl. Instr. Meth. Phys. Res. A 553 (2005) 135]
[$ HERA experiment, Nucl. Instr. Meth. Phys. Res. A 433 (1999) 408]

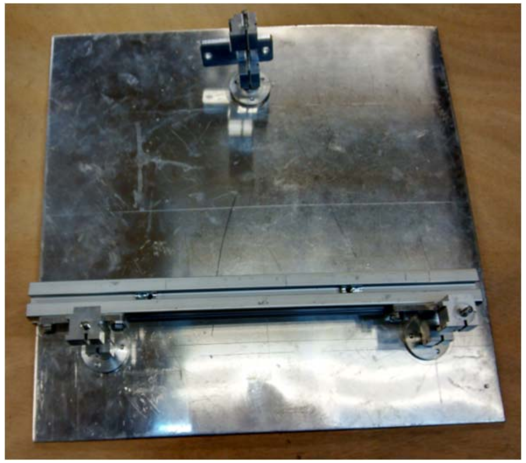
RICH mirror mount structure

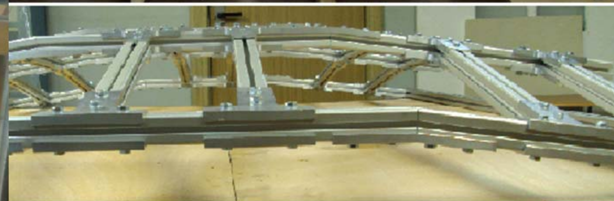
- Optimize mirror mounting structure to reduce the material budget in the detector volume while keeping high mechanical stability and alignment precision (< 1mrad): prototypes built, measured deviations are a few µm only

Prototype of mirror wall with mirror mounting scheme

use three point mount for mirror tiles in order to reduce material budget

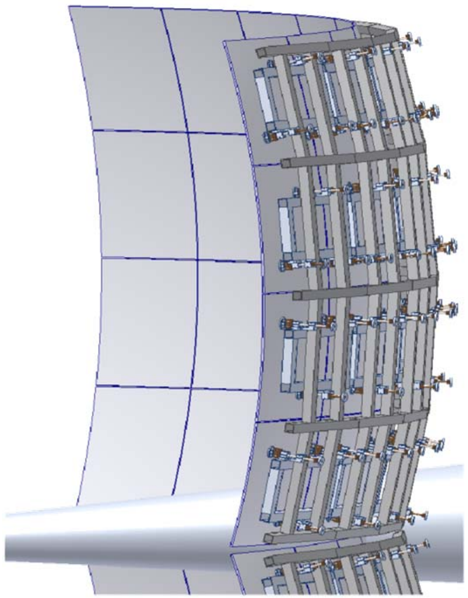
actuators allow for full alignment flexibility





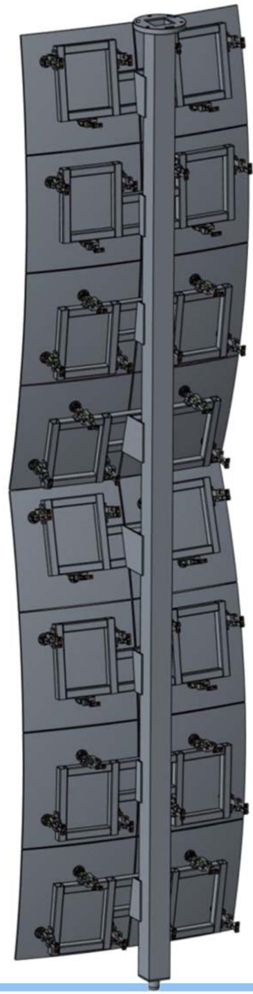
RICH mirror mount structure

- Optimize mirror mounting structure to reduce the material budget in the detector volume while keeping high mechanical stability: prototypes built, measured deviations are a few μm only



30% less material budget

Even more if pillars made from carbon fibre

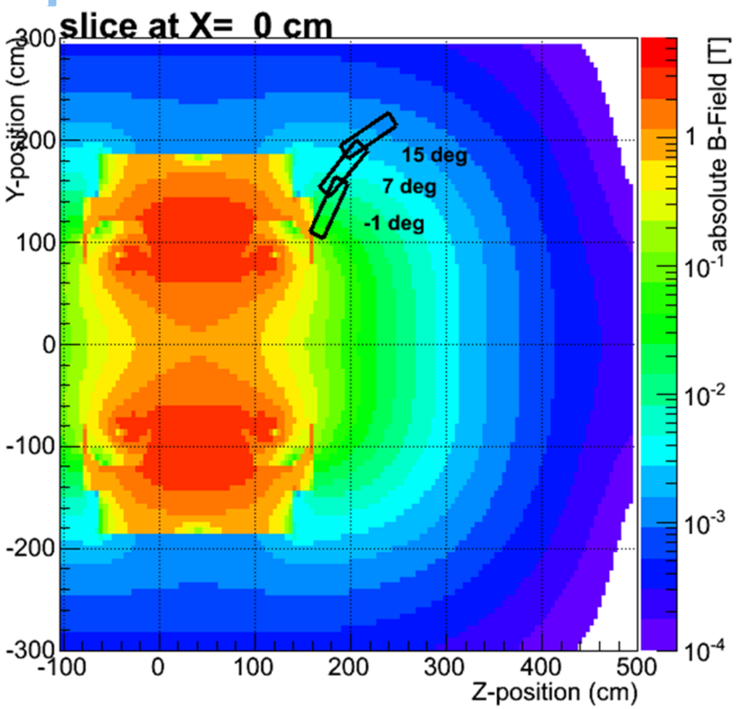


Alternative solution with mount structure made from large Rohacell like structure under consideration

Start of R&D project depends on outcome of detailed simulations

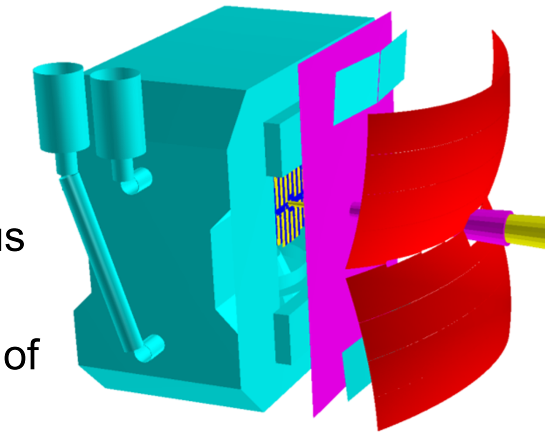
RICH geometry optimization

- Tilt mirrors by 10° in order to move photodetector outwards of magnetic stray field of CBM dipole magnet (and into less radiation hard environment): optimization of position and segmentation of photodetector plane
- Still need to add shielding boxes in order to reduce the field to 1 mT in the photocathode plane

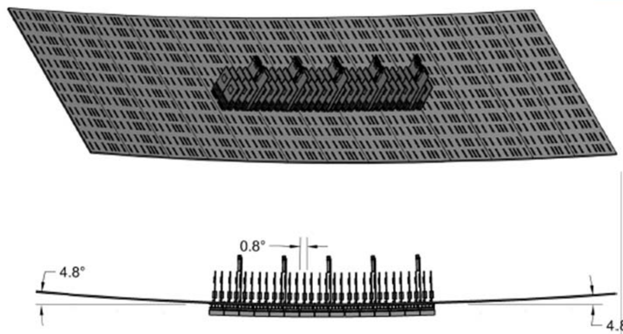


CBM dipole field with various PMT positions

RICH geometry with 10° tilt of mirrors



Possible realization of curved PMT plane with readout board concept

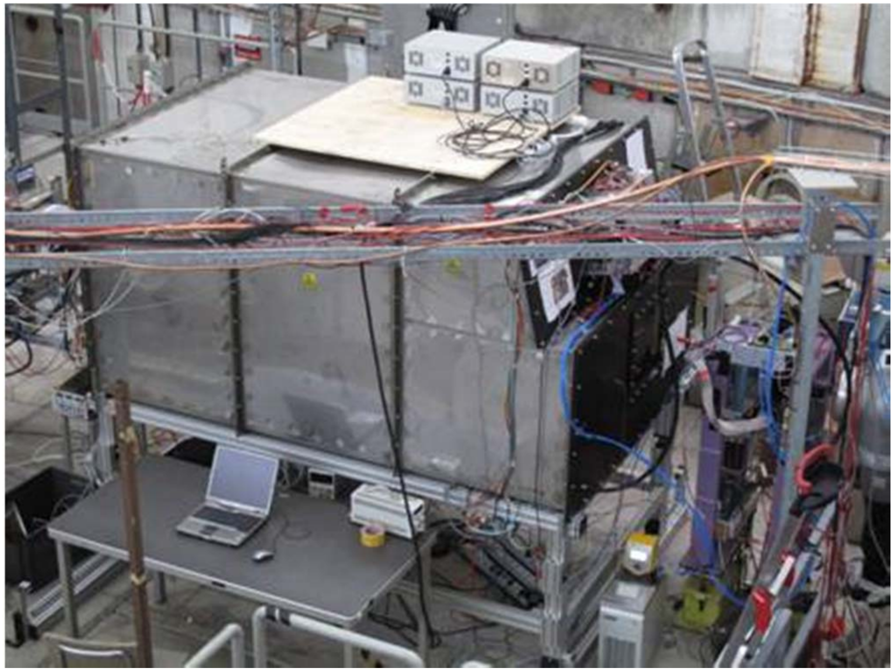


Prototype tests

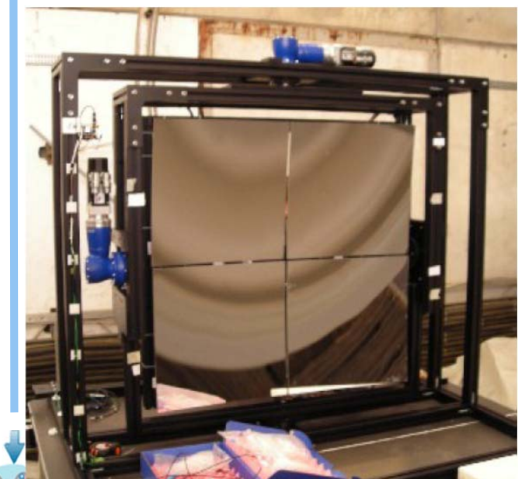
RICH radiator box filled with CO_2

elaborated gas system

test with mixed e-π beam from 2-10 GeV/c

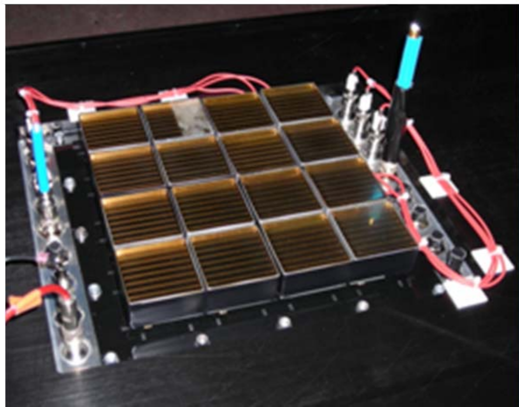


real dimension prototype in test beam at CERN, October 2011, 2012, 2014

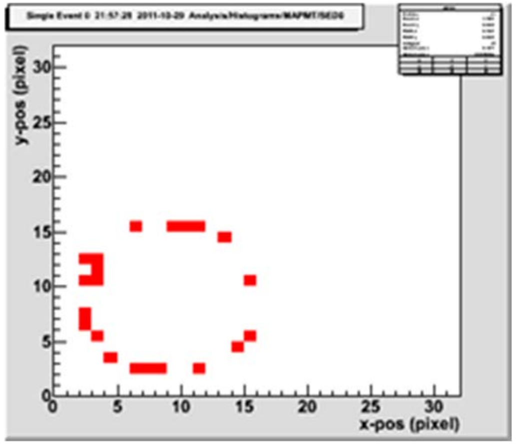


photocamera with various MAPMTs (H8500-03, H10966-103, R11265-103-M16, H12700)/ MCPs (XP85012);
selftriggered n-XYter readout; FPGA based readout
w & w/o WLS coating

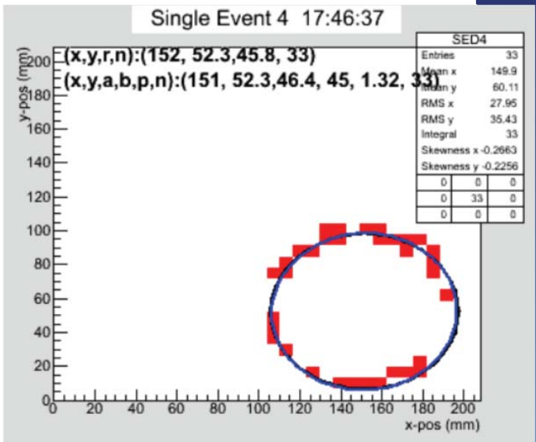
2x2 mirror array
scan of RICH camera
with movable mirror frames

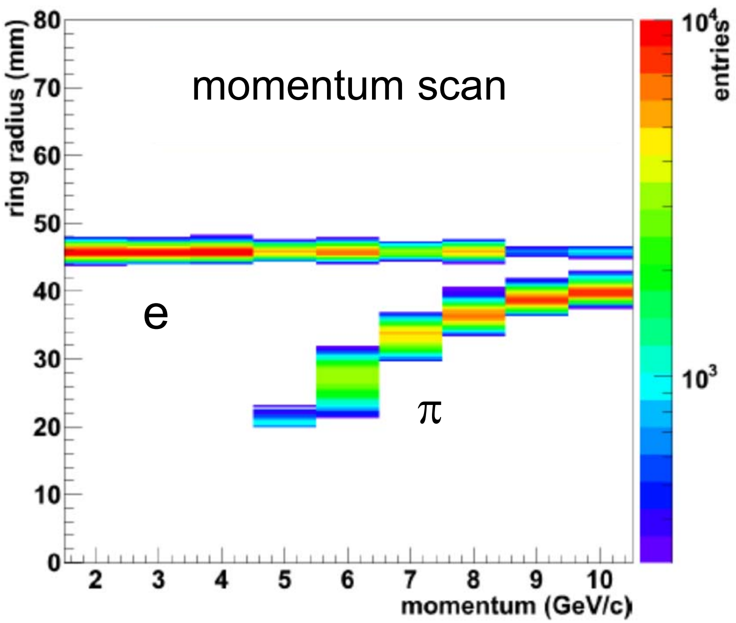


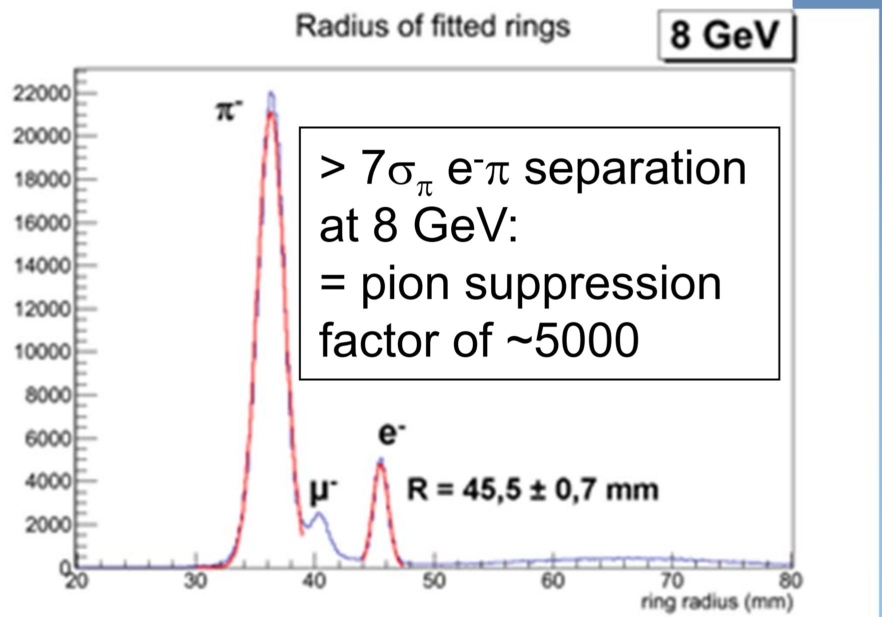
Prototype tests



typical single event display!
≥ 20 hits/ ring
noise/channel ~10Hz
online ring fit
WLS: increase number of hits by 14-18%





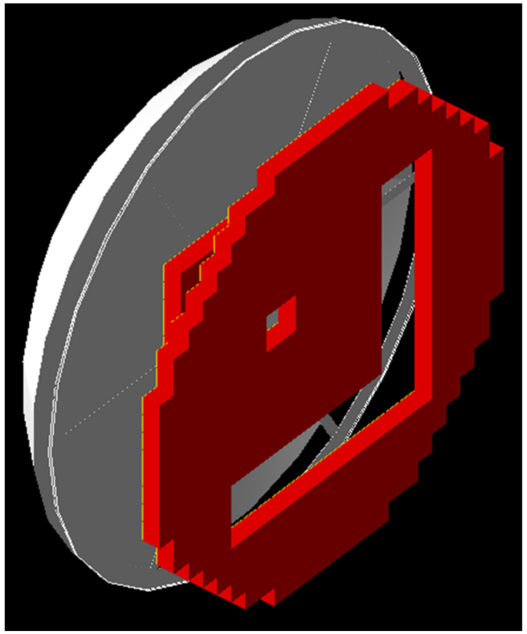


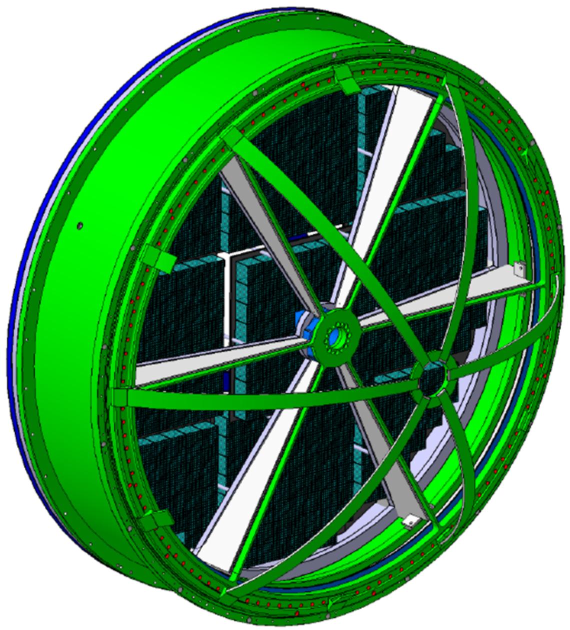
> $7\sigma_\pi$ $e^-\pi$ separation at 8 GeV:
= pion suppression factor of ~5000

HADES RICH upgrade

- HADES RICH successfully in operation since more than 10 years
- In cooperation with TU Munich: Replace existing CsI photocathode with MAPMTs from CBM in order to significantly enhance the e+/e- identification capability
- Be ready asap for next HADES π+A, A+A beamtime at GSI

→ Data taking and physics analysis: checks performance of MAPMTs, electronics, ring finding and calibration routines for CBM





[simulation, technical drawings: Mike Faul (GSI), Jürgen Friese und Tobias Kunz (TU München)]

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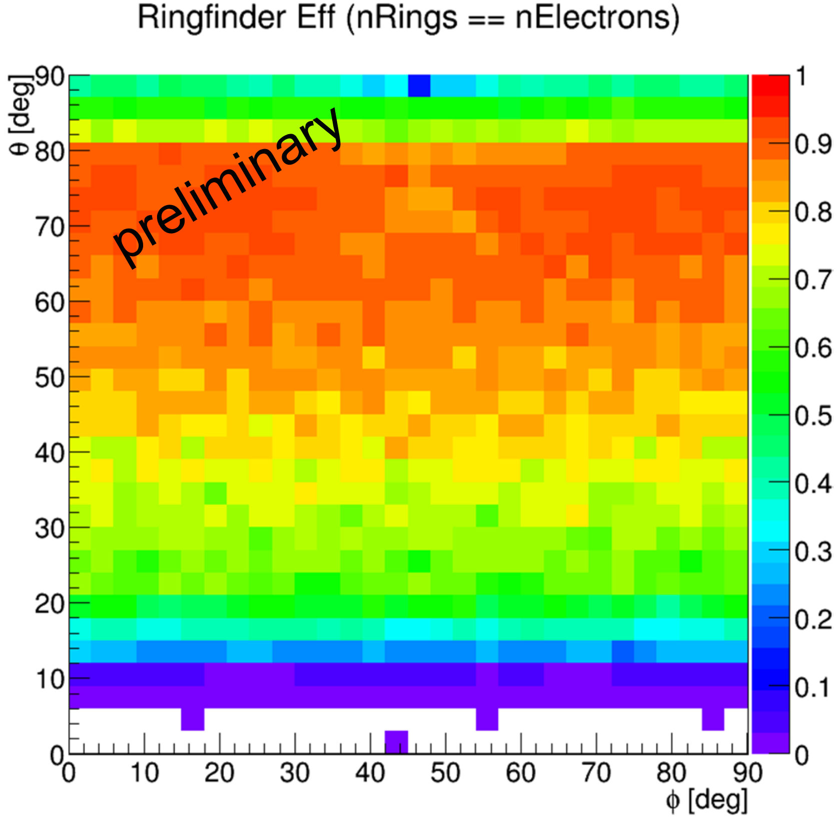

Pair finding efficiency in one quadrant for the MAMPT geometry for e^+e^--pairs with opening angles of 9° and pessimistic photon detection scenario

[simulation, technical drawings: Mike Faul (GSI), Jürgen Friese und Tobias Kunz (TU München)]

Summary

- **RICH detector development well on track for CBM**
  - Photodetector ordered (H12700 MAPMT, Hamamatsu)
  - Readout electronics in development, joint project with HADES and PANDA
  - Mirrors selected; minor R&D on optimization of coating
  - New lightweight concepts for mirror mount structure under development
  - Mirror alignment control system in preparation

- **HADES RICH upgrade project**
  - Use CBM MAPMTs and electronics prior to start of CBM
  - Improve pair finding efficiency for dilepton pairs in HADES dramatically
  - Data taking and physics analysis

- **(not shown): continuosly ongoing software development, detailed physics feasibility studies**

CBM collaboration

China:
Tsinghua Univ., Beijing
CCNU Wuhan
USTC Hefei

Croatia:
University of Split

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

Hungaria:
Wigner IPNP, Budapest
Eötvös Univ. Budapest

Germany:
TU Darmstadt
Univ. Gießen
Univ. Heidelberg, Phys. Inst.
Univ. Heidelberg, ZITI
KIT Karlsruhe
Univ. Frankfurt, IKP + IRI
FIAS Frankfurt
Univ. Münster
FZ Rossendorf
GSI Darmstadt
FAIR Darmstadt
Univ. Tübingen
Univ. Wuppertal

India:
Aligarh Muslim Univ., Aligarh
IOP Bhubaneswar
Panjab Univ., Chandigarh
Gauhati Univ., Guwahati
Univ. Rajasthan, Jaipur
Univ. Jammu, Jammu
IIT Kharagpur
Bose Institute
Univ Calcutta, Kolkata
VECC Kolkata
Univ. Kashmir, Srinagar
Banaras Hindu Univ., Varanasi
Inst. of Tech., Indore, India

Korea:
Pusan National Univ.

Poland:
AGH, Krakow
Warsaw Univ.
Warsaw Univ. of Tech.
Univ. of Silesia,Katowice
Jagiellonian Univ. Krakow

Romania:
NIPNE Bucharest
Bucharest University

Russia:
IHEP Protvino
INR Moscow
ITEP Moscow
KRI, St. Petersburg
Kurchatov Inst. Moscow
VBLHEP, JINR Dubna
LIT, JINR Dubna
MEPHI Moscow
Obninsk State Univ.
PNPI Gatchina
SINP, Moscow State Univ.
St. Petersburg Polytec. U.
Ioffe Inst., St. Petersburg

Ukraine:
KINR, Kiev
Shevchenko Univ. , Kiev

56 institutions, > 400 members