# The RICH detector for the CBM experiment at FAIR

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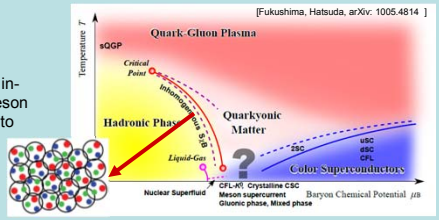
## Compressed Baryonic Matter @ FAIR – high $\mu_B$, moderate T

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

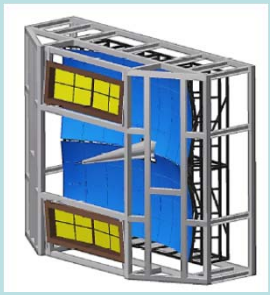
Field driven by experimental data!
need: ~ 2-40 AGeV beam energies at high intensities

**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




## Concept of the CBM RICH detector

**R**ing **I**maging **CH**erenkov detector for electron identification (p<8GeV/c):
- Gaseous RICH detector for electron identification
- $CO_2$ as radiator gas ($p_{\pi,th}$=4.65 GeV/c)
- 2 photodetector planes (MAPMTs, Hamamatsu H12700) with approx. 55.000 channels
- 2 large spherical mirrors (R=3m) as focussing optics, Al+$MgF_2$ reflective coating
- Vertical splitting of RICH geometry because CBM dipole magnet is located in front of the RICH (photodetector planes shielded by magnet yoke; particle tracks horizontally spreadened

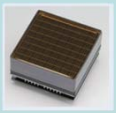


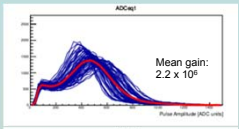
**CBM-RICH collaboration:**
University Giessen, University Wuppertal, GSI, PNPI Gatchina St. Petersburg, ITEP Moscow, Pusan National University, JINR-LIT Dubna

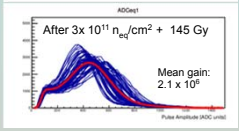
## Photodetector

- Hamamatsu H12700 MAPMT 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

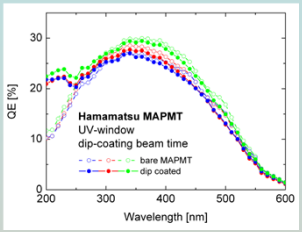





Gain normalized single photon spectra of all individual pixels before and after irradiation; Red line: average over all pixels

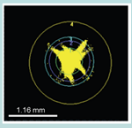
Quantum efficiency with and without WLS coverage; the latter increases the final hit multiplicity by up to 20%

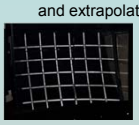


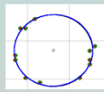

[* CBM-RICH group, Nucl. Instr. Meth. A783 (2015) 43.]

## Mirror and mirror alignment control

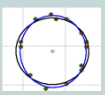
- SIMAX glass mirrors, tickness 6mm, R=3m, Al+$MgF_2$ coverage from JLO Olomouc
→ high reflectivity; very good surface homogeneity ($D_0$=2-3 mm: diameter of the reflected spot from a point source which contains 95% of the light intensity)
- Development of mirror alignment control system:
  - CLAM* method: 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$

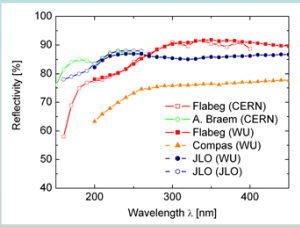




Test of CLAM method in prototype:
Mirror aligned → ring
… misaligned → ellipse

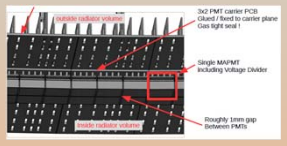




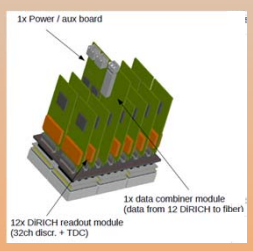

[* COMPASS experiment, Nucl. Instr. Meth. Phys. Res. A 553 (2005) 135]
[$ HERA experiment, Nucl. Instr. Meth. Phys. Res. A 433 (1999) 408]

## Readout electronics

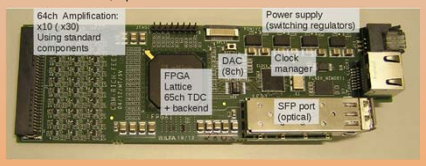
- Development of **DiRICH board**: combine PADIWA* functionality (discrimination) and TRB* (TDC, data handling) on a single board: joint development of PANDA-DIRC, CBM-RICH and HADES-RICH
- make use of new Lattice ECP5-85F FPGA: 32 channels ToT, ~10ps precision TDC
- 3x2 MAPMT readout module with 2 DiRICH 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



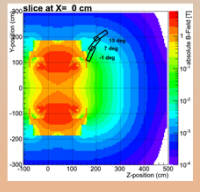

TRBRICH module, a predecessor of the DiRICH board

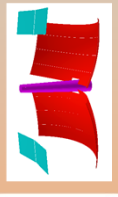



[* A. Neiser et al., JINST 8 (2013) C12043]

## RICH geometry optimization and technical design

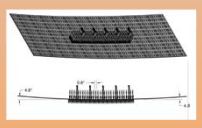
- Tilt mirrors by 10° in order to move photodetector outwards of magnetic stray field of CBM dipole magnet (and into less radiation hard environment): optimization of position and segmentation of photodetector plane
- Still need to add shielding boxes in order to reduce the field to 1 mT in the photocathode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

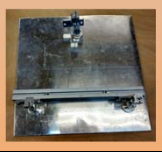


Prototype of mirror wall with mirror mounting scheme
use three point mount for mirror tiles in order to reduce material budget
actuators allow for full alignment flexibility

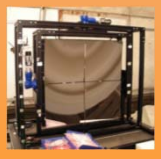
CBM dipole field with various PMT positions
RICH geometry with 10° tilt of mirrors
Possible realization of curved PMT plane with readout board concept shown on the left

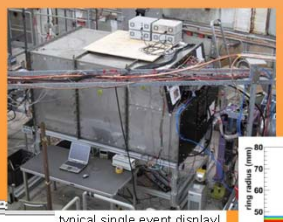


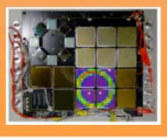


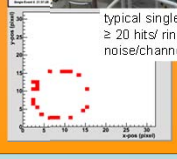
## CBM RICH prototype tests

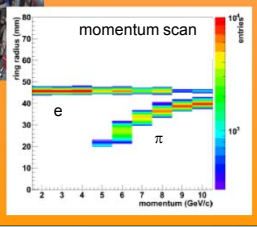
- Real dimension prototype succesfully tested in mixed e-µ-π testbeam at CERN PS from 2-10 GeV, autumn 2011, 2012, 2014
- Investigate various photosensors, WLS coverage, electronics developments, gas system and required gas purity, mirror misalignment limits, mirror alignment controls







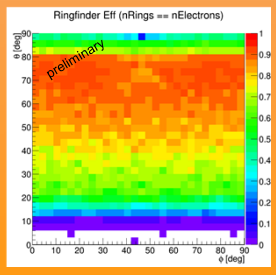




## Upgrade of HADES RICH detector

- 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

Pair finding efficiency in one quadrant for the MAMPT geometry shown above 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)]