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CBM

The CBM RICH project

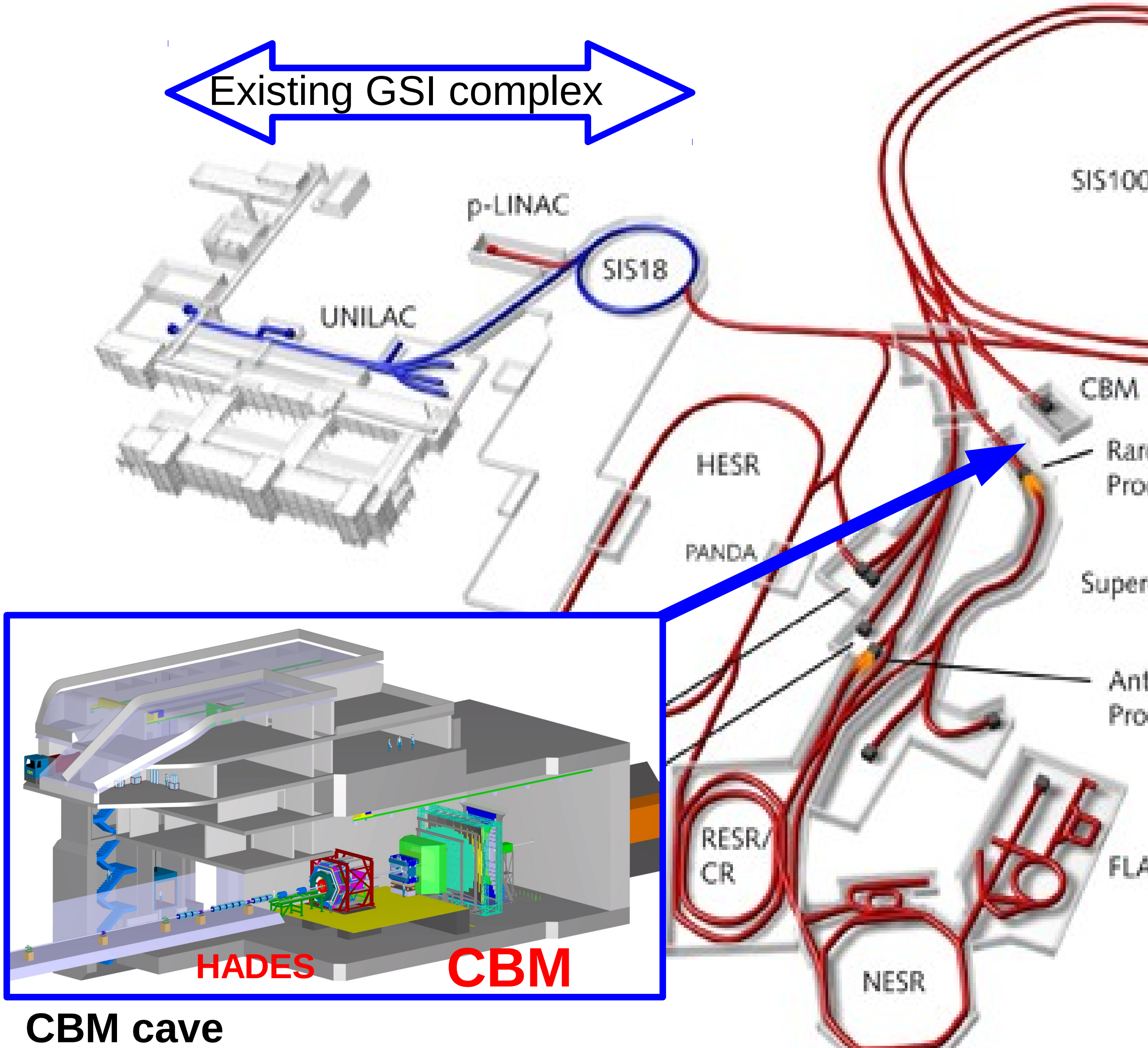
Christian Pauly, BU Wuppertal
for the CBM-RICH collaboration

CBM-RICH group:
Bergische Universität Wuppertal, Germany
Justus-Liebig-Universität Gießen, Germany
Petersburg Nuclear Physics Institute (PNPI), Gatchina, Russia
Pusan National University, Pusan, Korea

GSI
Bundesministerium für Bildung und Forschung
HIC for FAIR Helmholtz International Center
Study of Strongly Interacting Matter HadronPhysics

Overview

CBM @ FAIR –
Facility for Antiproton and Ion Research



CBM cave
already existing **HADES**- plus future **CBM** experiment

<u>C</u>ompressed <u>B</u>aryonic <u>M</u>atter:

Next generation Heavy-Ion experiment being set up at **FAIR** in Darmstadt, Germany

Accelerated proton / ion beams on fixed target:

SIS100 (**starting 2018**)
- 2 – 29 GeV (protons)
- 2 – 11 AGeV (Au)

SIS300 (second stage)
- 2 – 89 GeV (protons)
- 2 – 35 AGeV (Au)

Up to 10^9 ions/sec

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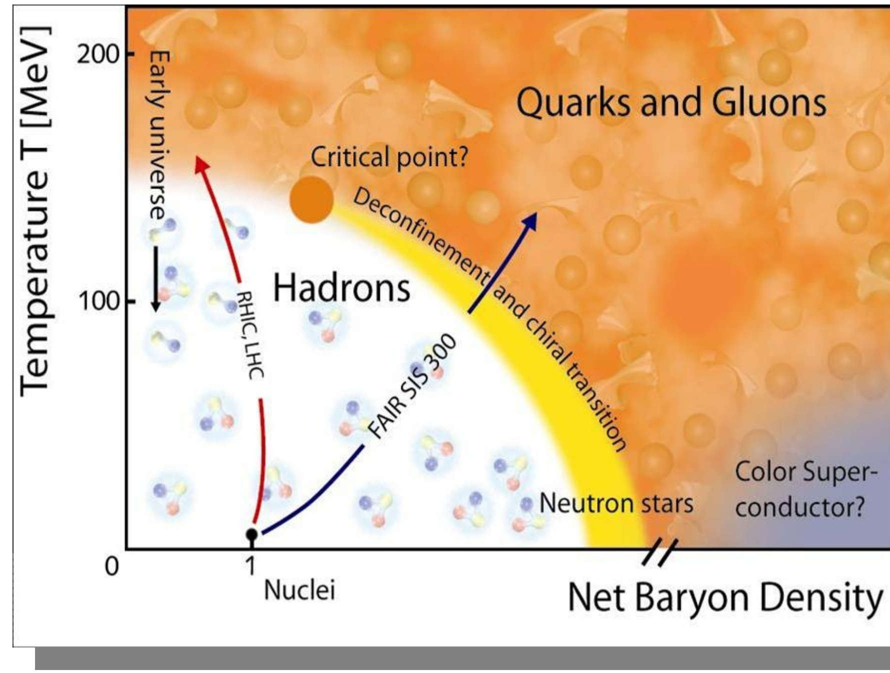
CBM physics motivation

CBM

Explore QCD phase diagram
- at **high net baryon density** and **moderate temperature**
- Study **different phases of matter**
- How does the phase transition look like ?
- Is there a critical point ?



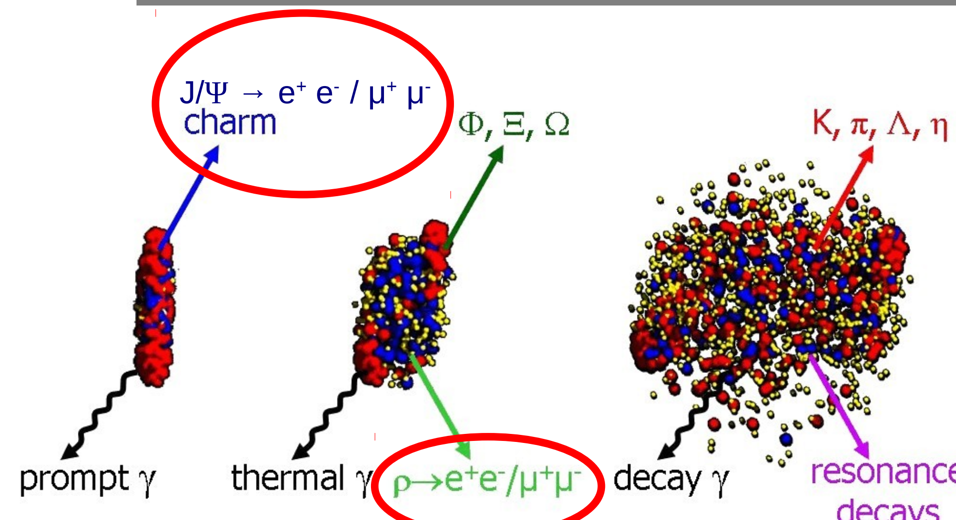
One of the main goals:
- Measure the **early, high density phase of the collision** using **penetrating dilepton probes**:

$\rho \rightarrow e^+ e^-$

$J/\psi \rightarrow e^+ e^-$

Challenges:
- very rare probes !
- Need **high statistics / interaction rates**
  (up to 10 MHz Au+Au for J/ψ)
- Immense background from bulk pions and kaons

Key capability:
- **Excellent particle ID – in particular e / π separation**



Ring Imaging Cherenkov Detector
CBM-RICH

CBM-RICH design considerations:

Main focus for CBM RICH:

- **Electron / pion separation up to ~10 GeV/c**
- Pion suppression > ~100
- Large charged particle multiplicity (scintillation!)

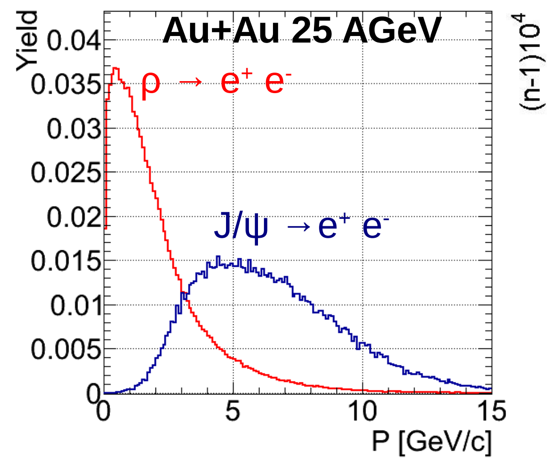
CO_2 gas radiator

normal pressure (+2 mbar)

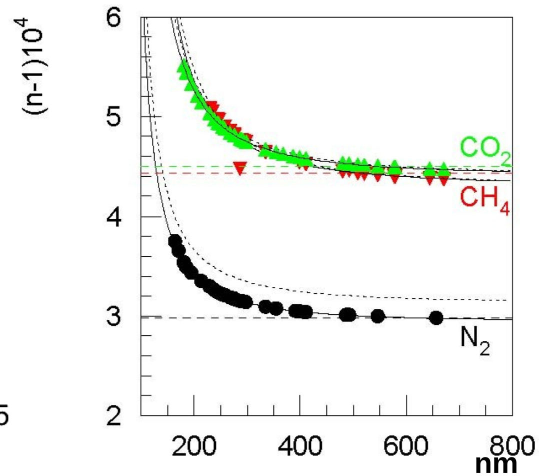
$\gamma_{threshold}$= 33.3, **θ_{max}=1.72°**

Pion threshold: 4.5 GeV/c

UV transmission cut off at 190nm



Electron momentum distribution from simulation



Refractive index for different gases

- CBM **interaction rates up 10 MHz**
- **Self-triggered readout concept** (→ dark noise !)
- Large ring-multiplicity per event
- Use industrial components as far as possible

Multianode Photomultiplier / MCP readout

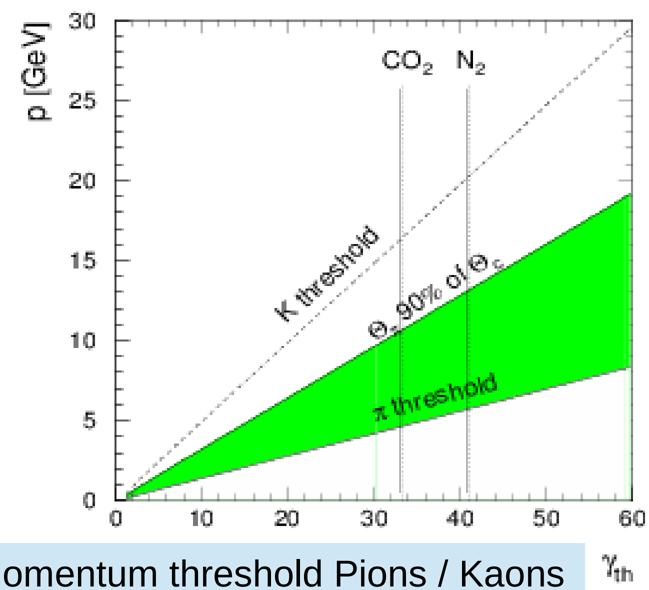
High rate capability

200nm – 600nm spectral range

Good timing (sub nano second)

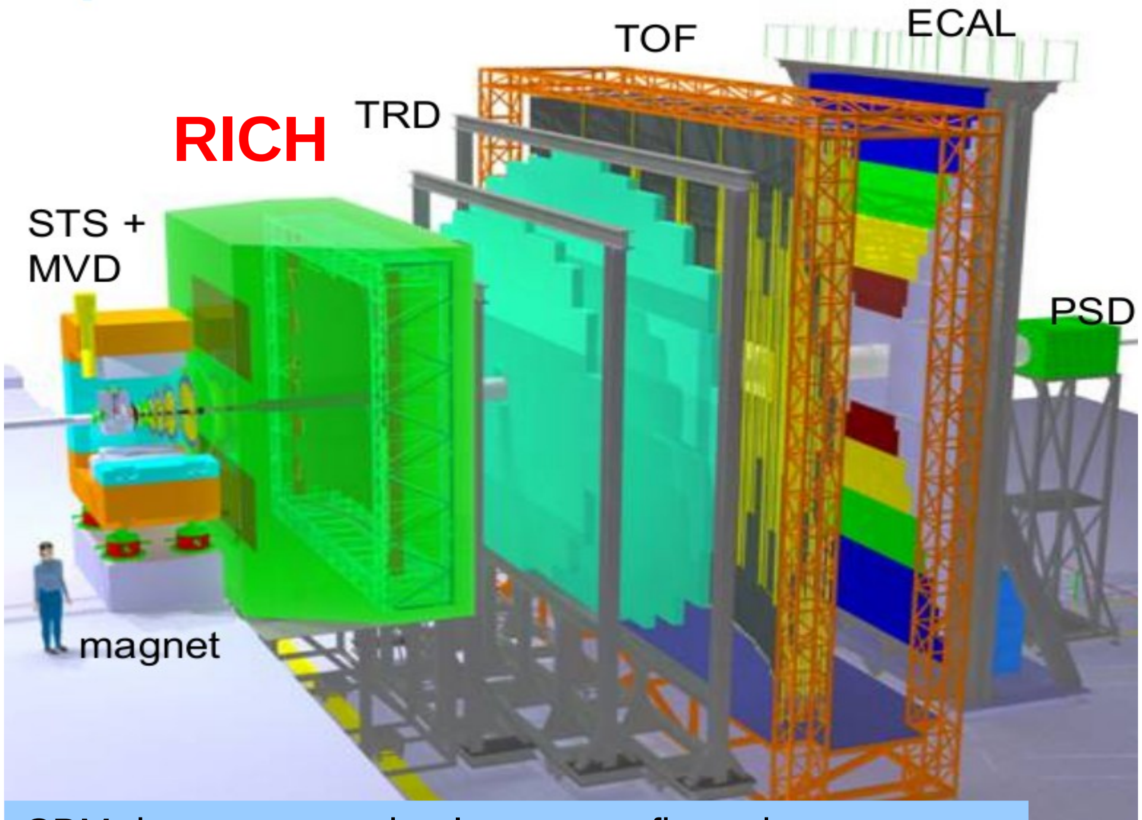
Commercially available product

Aluminum-coated glass mirror (Al+MgF_2)

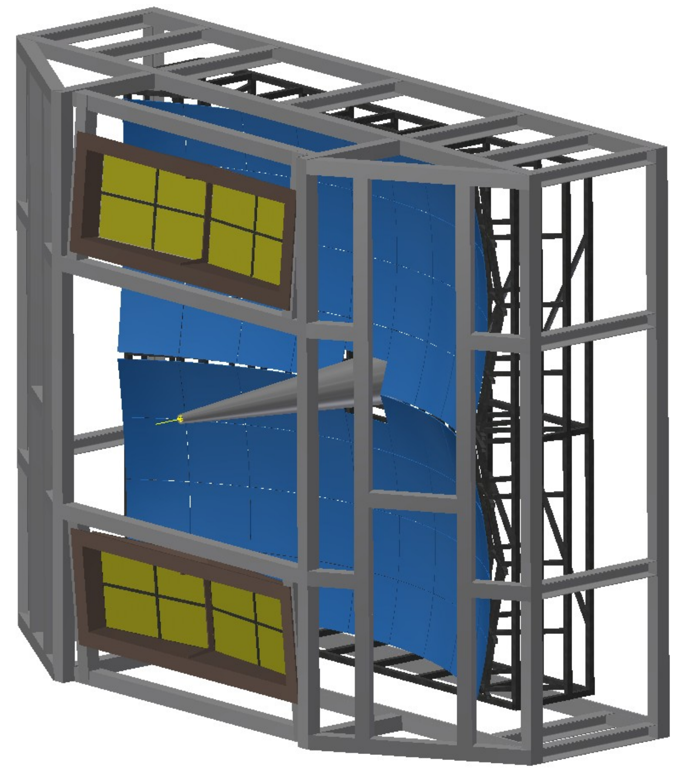


Momentum threshold Pions / Kaons for different gas radiators

The CBM RICH detector



CBM detector setup in electron configuration



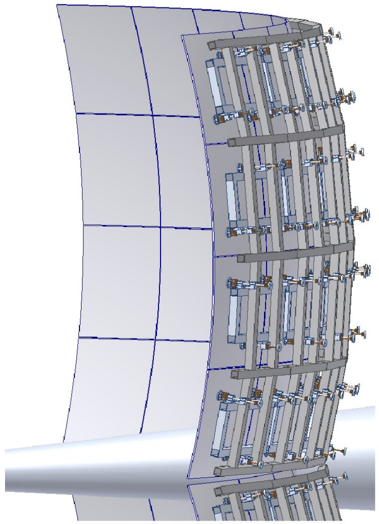
CBM RICH -
the ingenieurs view

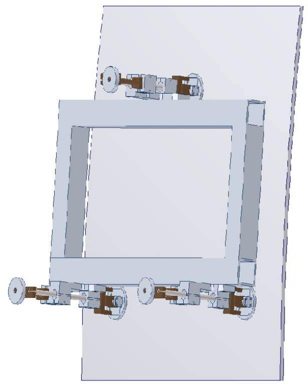
- Dimensions: 2m x 5.14m x 3.93m (length x height x width)
- Acceptance: 0-35° / 0-25° (horizontal / vertical)
- Close to CBM dipole magnet (stray field)
- Behind silicon tracking detector (→ many rings from secondary electrons)
- Movable by crane
- 35 m^3 radiator gas volume, 1.7m radiator length
- 13m^2 segmented glass mirror, 72 rectangular tiles 40x40 cm^2, focal length: 1.5m
- About 55k readout channels

Focussing mirror

Focussing mirror:

- 13m², two half-mirrors below / above beampipe
- 72 rectangular mirror tiles, **focal length: 1.5m**
- **glass substrate, 5-6mm**
- Aluminum+ MgF_2 protective coating (~110nm)
- **Aluminum support grid** (30x30 mm² / 40x40 mm² Al profiles)
- **Tripod mounting,** 3 actuators (electrical / mechanical)
- see **poster T. Mahmoud on required alignment precision**



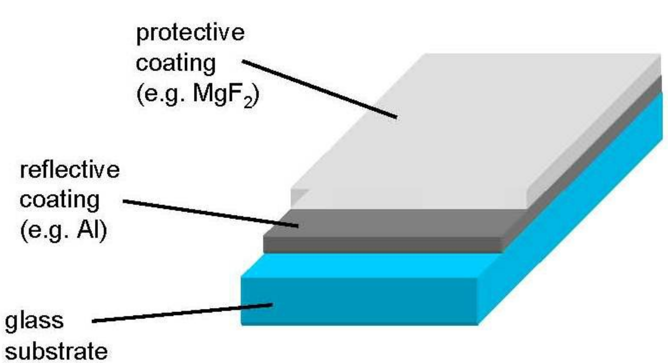


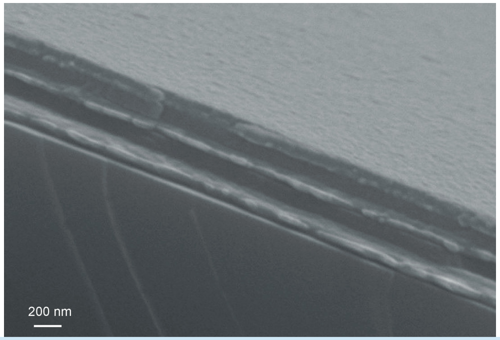
Three different manufacturers considered so far:

- **JLO Olomouc,** Czech Republic
- Compas, Czech Rebublic
- Flabeg GmbH, Germany

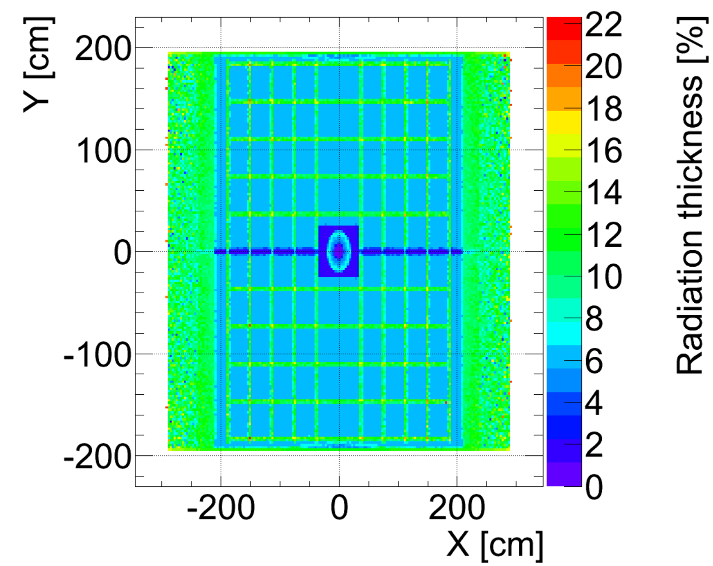
Sample tiles from all three were compared:

- Spectral reflectivity (→ Nr of photons per ring)
- Surface homogeneity (→ Ring finding / fitting)





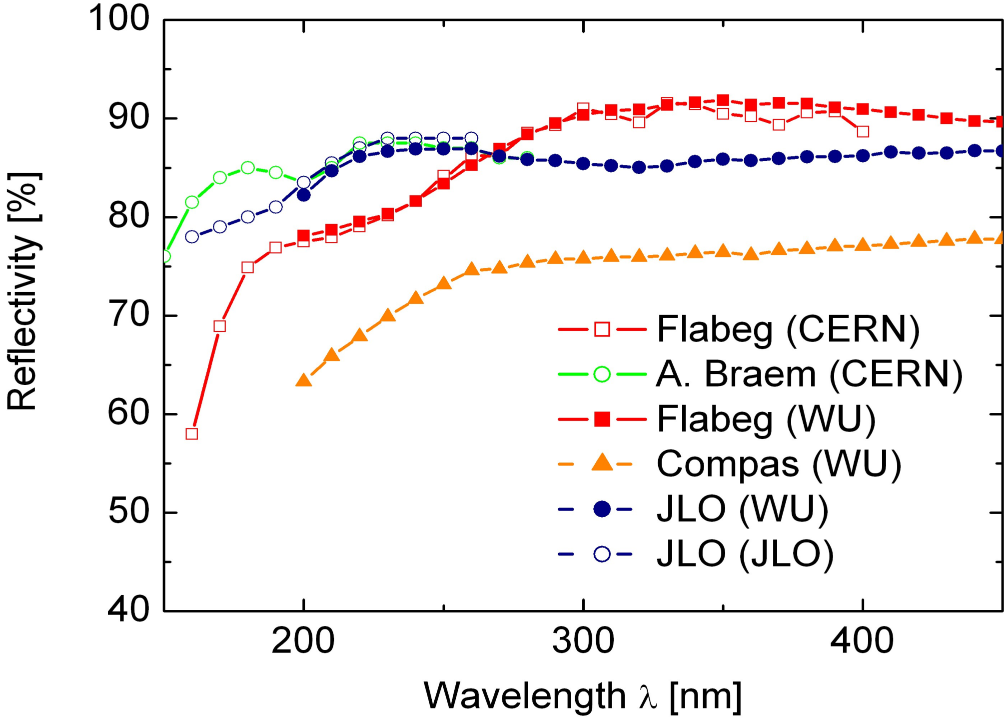
SEM image of layer structure



RICH total material thickness in terms of absorption length - mainly due to mirror

Mirror reflectivity

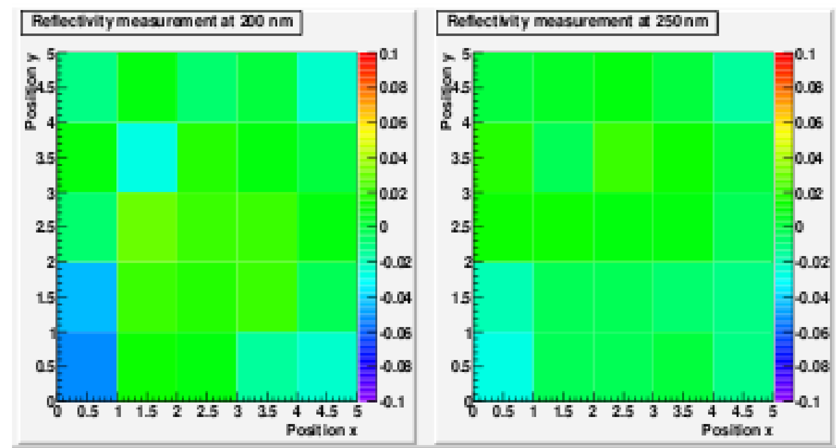
Spectral reflectivity for different mirror sample tiles



Mirror homogeneity: (spatially resolved reflectivity)
here: JLO Olomouc

250nm

300nm



color scale: +-10%

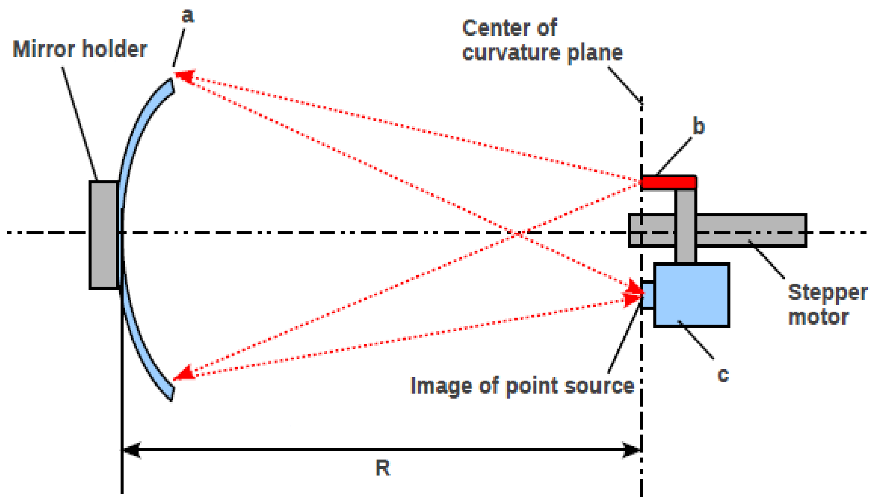
- **Large spread in absolute reflectivity:**
  JLO Olomouc: R>85% (visible), R>75% (UV)
  Flabeg: R>90% (visible), R>75% (UV)
  Much worse reflectivity for Compas mirror

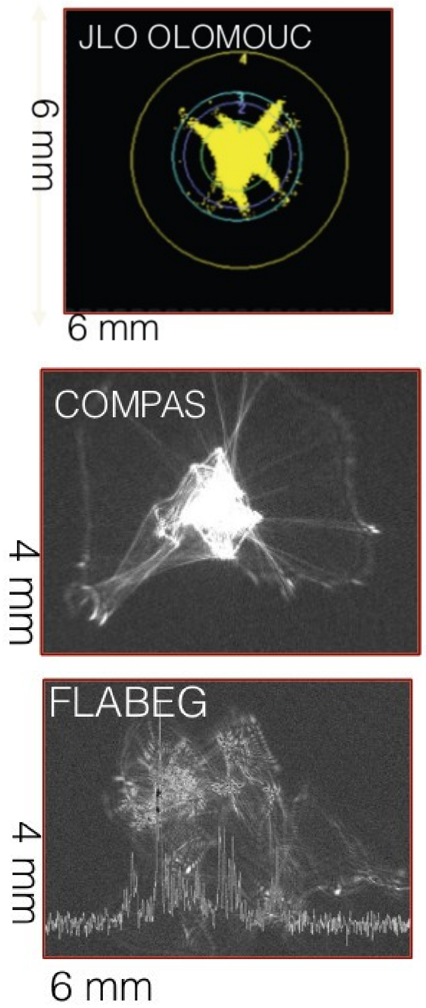
- **All mirrors show good coating homogeneity**
  Significant variations only in UV region (5 % level)
  (probably thickness variation of MgF_2 protective coating)

Mirror surface quality

Quality of mirror surface determined using D_0 test:

D_0: Diameter of focal image (circle containing 95% of total light) of spot light source positioned in focal point of spherical mirror.





Our choice: **JLO Olomouc**
Further JLO mirrors also used in CBM-RICH prototype

	required	Compas	Flabeg	JLO Olomouc
D0	<3 mm	2.3 mm	bad !	2.3 mm
reflectivity	as good as possible	70% - 80%	>90% (>75% UV)	>85% (>80% UV)

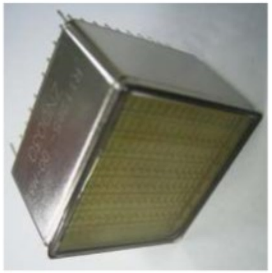
Photon camera sensor candidates

H8500 Multi-Anode PMT from Hamamatsu:

- **design baseline for CBM RICH**
- 52 x 52mm², **89% effective coverage**
- 64 channels, pixel size 5.8 x 5.8 mm²
- 12 dynodes (Bialkali, max 25% quantum efficiency.)
  8 dynodes (Super Bialkali, max 35% quantum efficiency)
- **Integrated active voltage divider**
- **Time resolution: ~400ps**, 0.8ns risetime
- **Non-optimal single-photon capabilities**

Hamamatsu R11265-103-M16:

- 26x26mm², **78% effective coverage**
- 16 channels, similar pixel size as H8500
- Similar signal characteristics as H8500, better timing
- **SBA-cathode, 35% max q.e.**
- **Optimized for single photon detection**
- **Nearly twice as expensive**
- **No integrated voltage divider**



Photonis XP85012/A1-Q Micro Channel Plate (MCP)

- 59x59mm², **80% effective coverage**
- 25 µm pore size
- No problems with magnetic field
- Life time / total accumulated charge

H12700 – a new MAPMT from Hamamatsu

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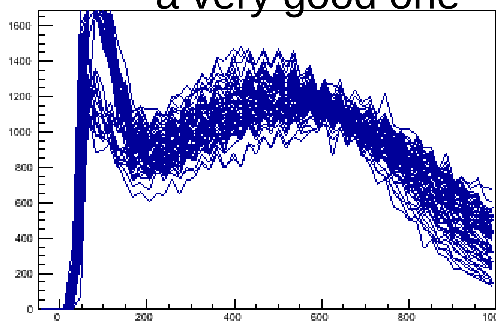
- Recently, Hamamatsu announced **a new MAPMT: H12700**
- Combining geometrical **benefits of large H8500**
  with single-photon optimized **dynode structure of R11265**
- **2x2" MAPMT, optimized for single photon detection**

- Sounds like perfect match - we tested a first sample:
  - ADC spectra
  - single photon scans

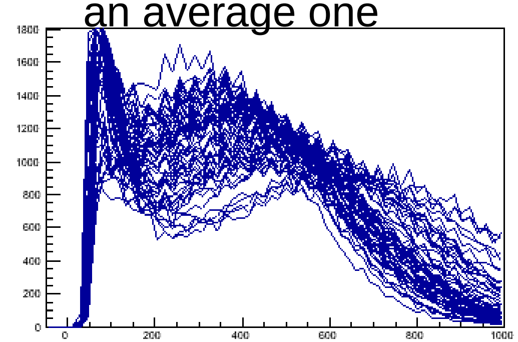
2 * H8500 | H12700

a very good one | an average one | our first sample

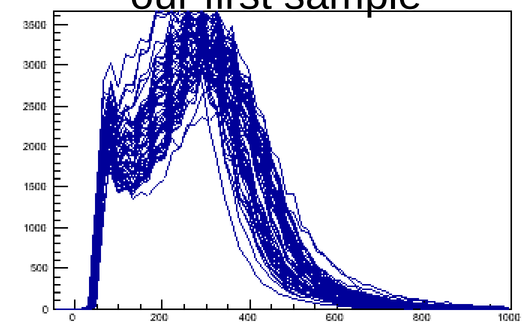
Raw spectra:
Overlay of all
64 channels
(in ADC counts)



Amplitude [ADC]

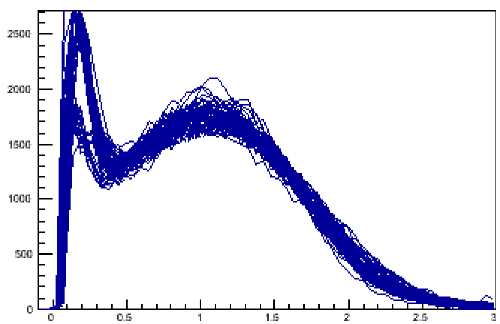


Amplitude [ADC]

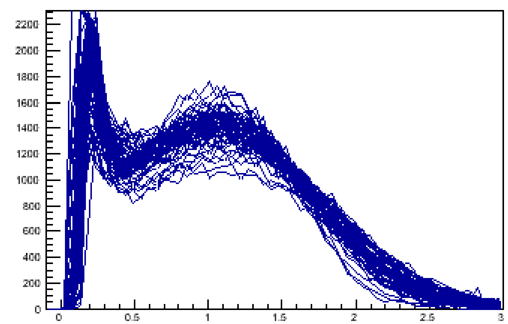


Amplitude [ADC]

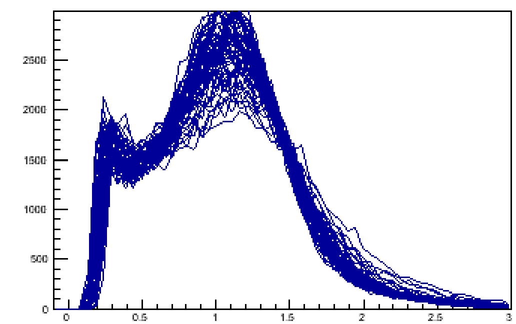
Gain normalized:
(in SPE units)



Amplitude [SPE units]



Amplitude [SPE units]



Amplitude [SPE units]

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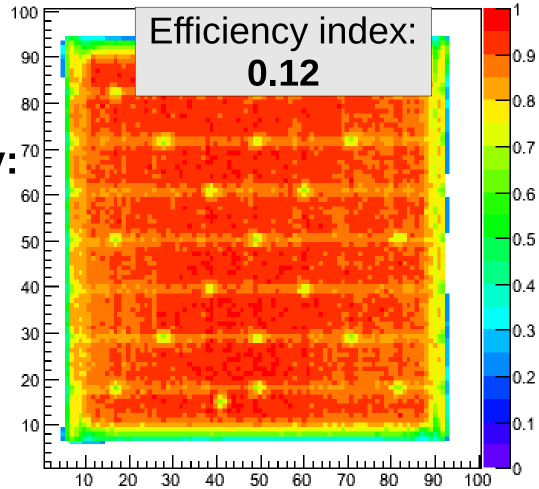
Single photon scans: H8500 vs R11265 vs R12700

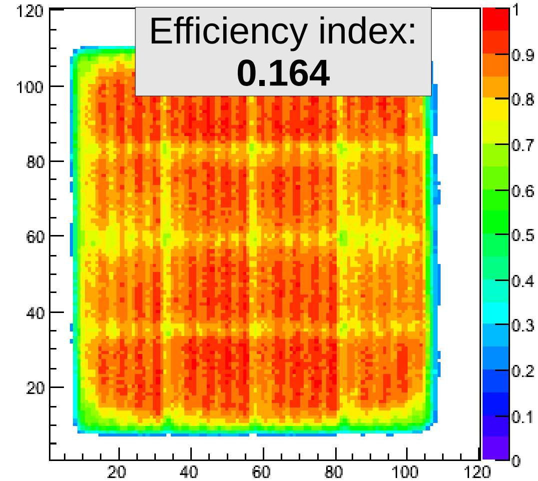
H8500 (2x2 inch”)
one of our best

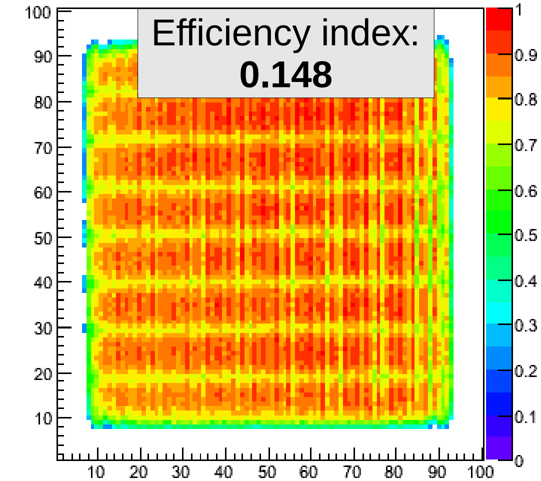
R11265 (1x1 inch²)

H12700 (2x2 inch²)
very first sampe

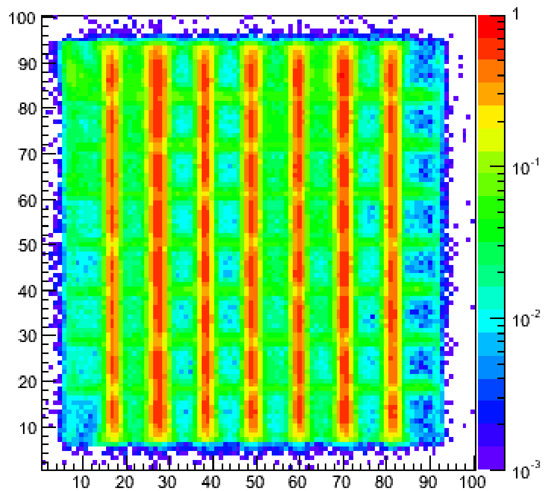
Detection efficiency:
>=1 hit
per detected photon

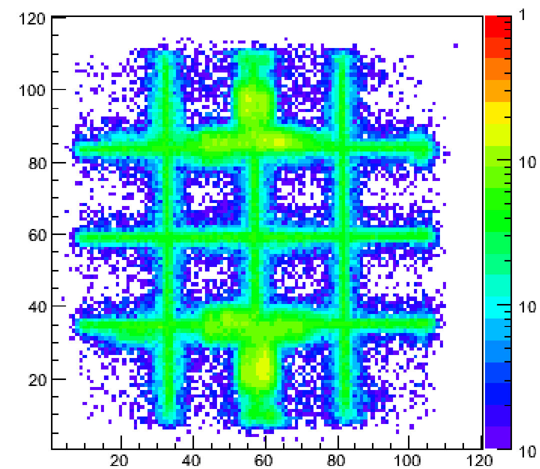


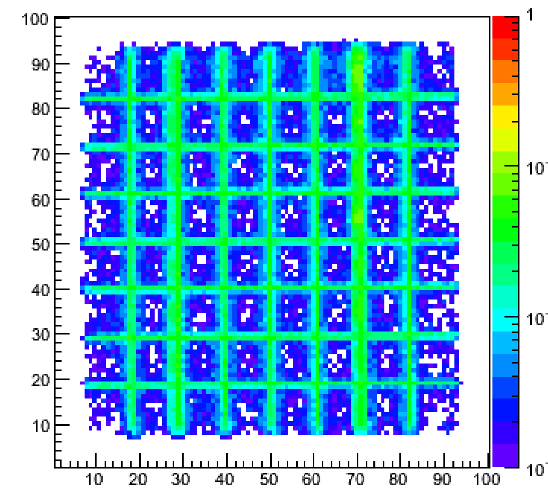




Cross talk:
>=2 hits
per detected photon







Spectral quantum efficiency
Specular cathode reflectivity (BA vs SBA)

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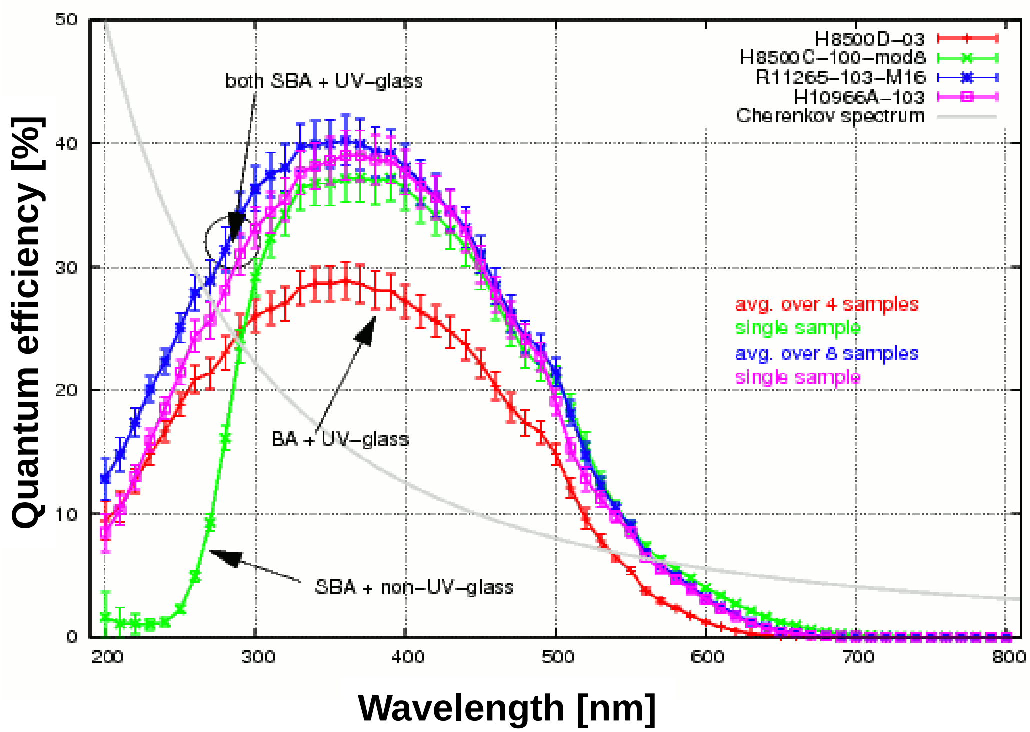
- Benefit of increased quantum efficiency for SBA cathodes (35% vs 25% q.e.) vanishes in UV range
- Can be qualitatively understood by increased reflectivity of SBA in UV region

H8500C-03
BA cathode
UV-glass

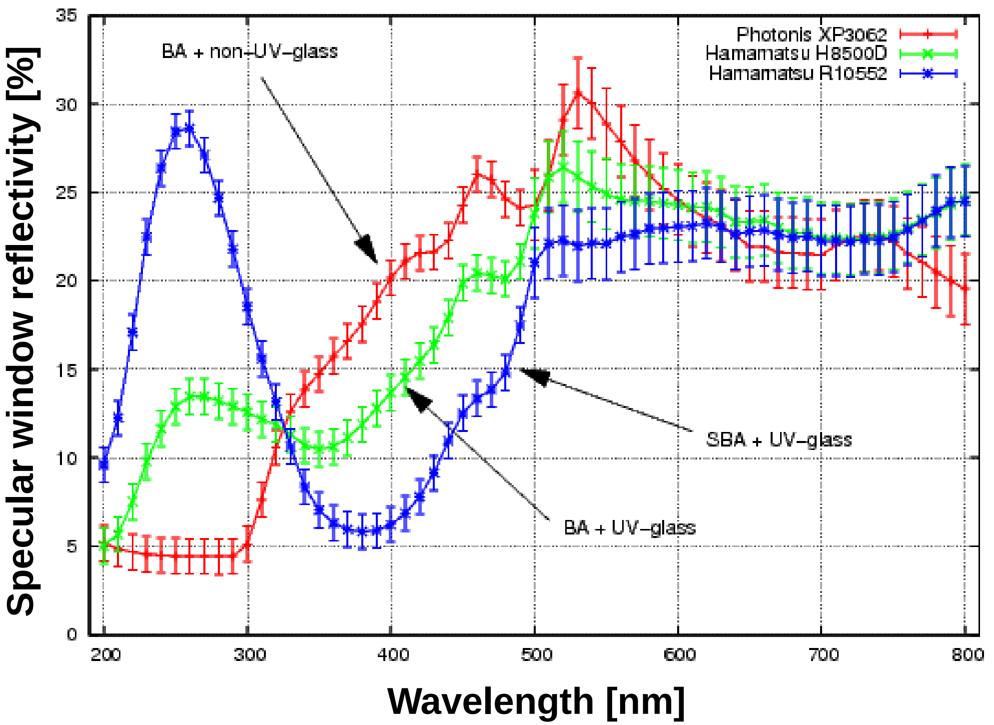
R11265-103
SBA cathode
UV-glass

H10966A-103
(like H8500, 8 dyn)
SBA cathode
UV-glass

Spectral quantum efficiency
for various MAPMTs with BA and SBA cathode



Specular cathode window reflectivity
for BA and SBA cathodes on UV glass



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Increase of photon detection efficiency by applying wavelength shifting coating

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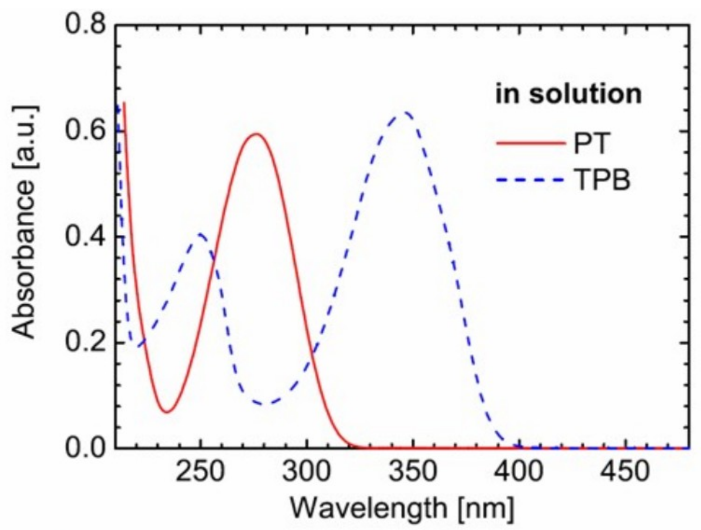
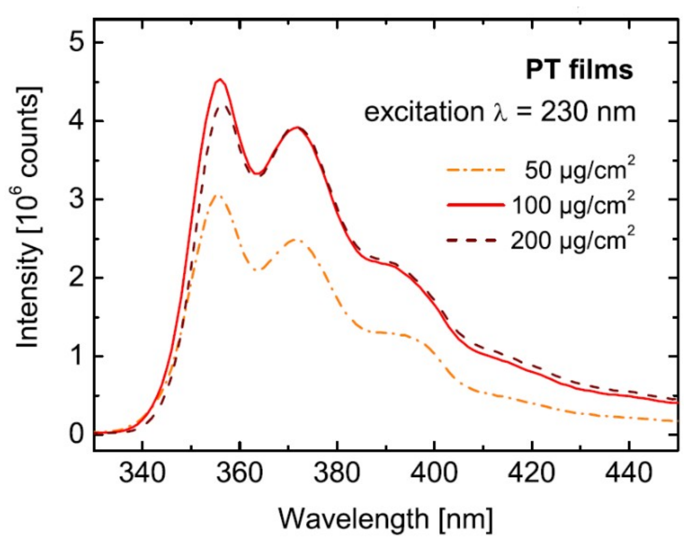
- In order to increase quantum efficiency in the UV region (below 300nm) we plan to apply a wavelength-shifting coating (WLS) on the MAPMT windows:

- **WLS coating:**
  - **absorption** of Cherenkov photons **in UV range**
  - **isotropic reemission** at larger wave length **close to peak quantum efficiency**
- **P-terphenyl (PT)** provides good match between absorption and reemission spectra





MAPMT half coated with WLS

- **Optimum layer thickness ~200nm** to minimize absorption in non-UV range
- **Dip coating process** for efficient coating of many PMTs
- **Up to 18% gain in Cherenkov photon efficiency**
- **Possible degradation of spatial resolution** due to isotropic reemission:
  - observable, but **small effect**, depending on window thickness
- **Time constant for re-emission process: ~1-2 ns** (only effecting UV photons !)

For details on WLS: → poster J. Kopfer

Magnetic stray field

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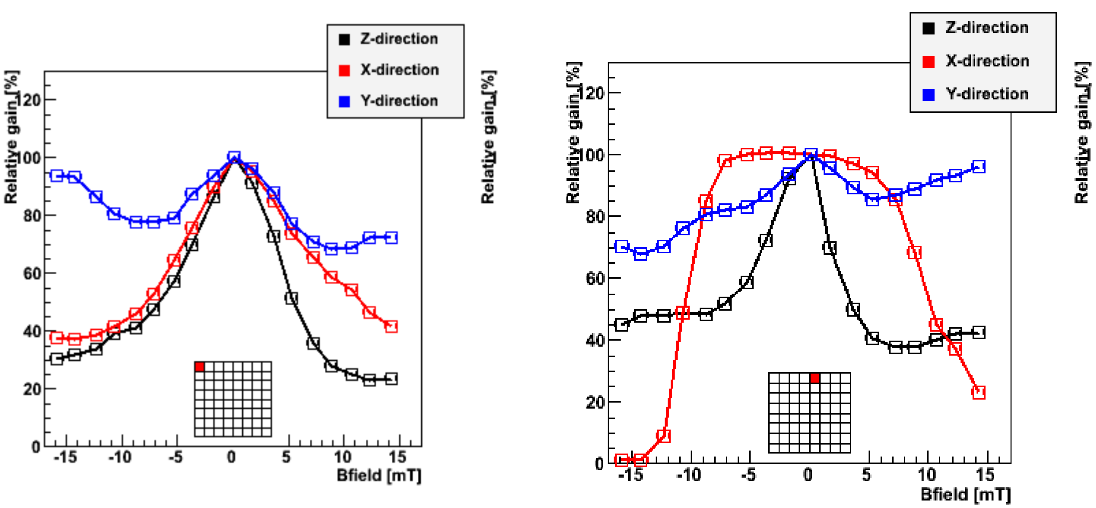
- Significant magnetic stray field in region of photon detector
- **Up to 30mT** depending on mirror tilt angle (and thus camera position)

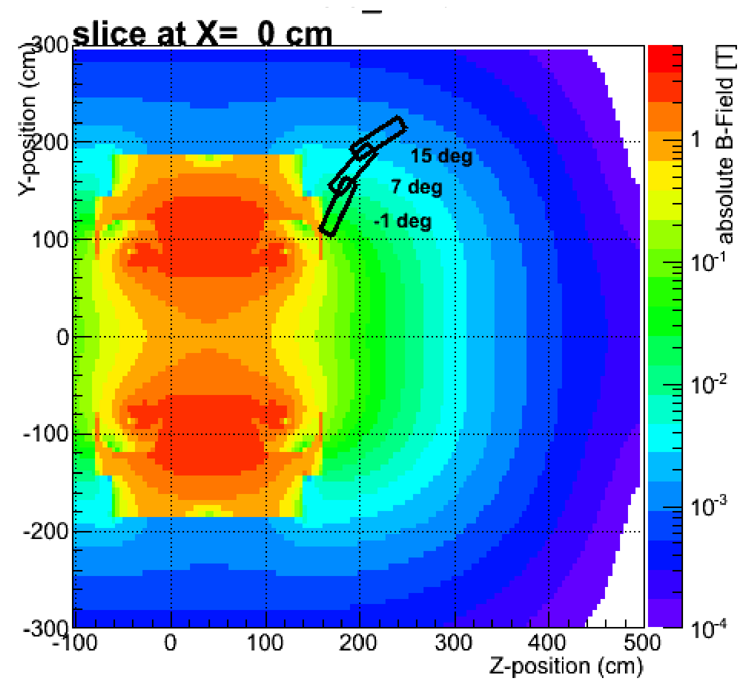
- H8500 MAPMTs: **performance degradation for B > ~1-2 mT**
  (new H12700 slightly better)

- **Our solution:**
  Put photon detector inside iron shielding box
  - Positive side effect: radiation shielding of PMTs
  - Limited space for electronics

- **Alternative:**
  Use MCPs instead of MAPMTs



effect of magnetic field on H8500 detection efficiency for two border / corner pixels

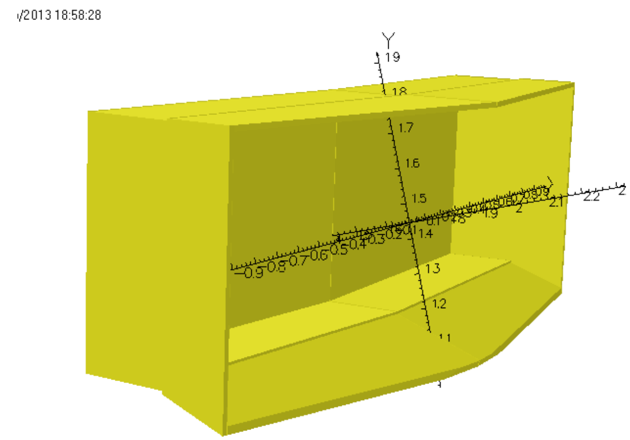


magnetic stray field simulation without additional shielding box in region of photon detector

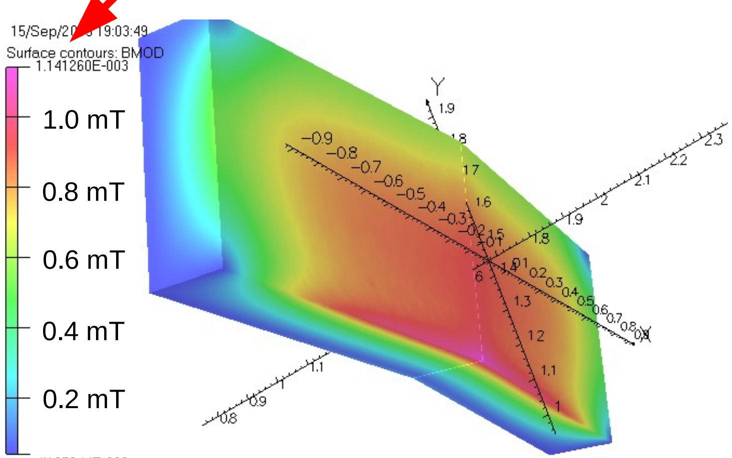
Field simulation with shielding box

- First tests with iron shielding box
- "Steel 08", 2.5cm – 5cm thick
- Each box: 2m x 0.6m (width x height)
- Weight: ~1 ton per box
- Remaining stray field according to present simulations:
  max 1.15 mT for mirror tilt angle 10°

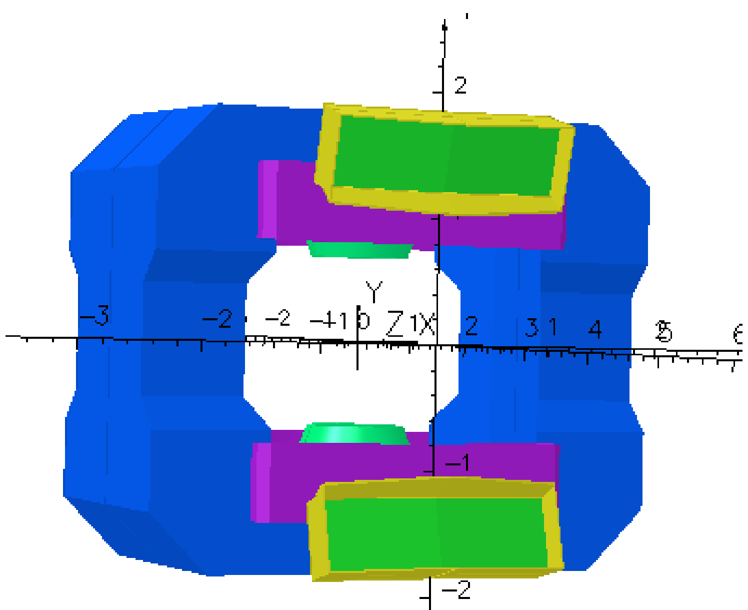
- Further optimization ongoing:
  - μ-metal sandwich ?
  - **Lower tilt angle preferable**



max. field 1.15 mT at PMT cathode !



Simulated stray field (OPERA) inside shielding box assuming 10° mirror tilt angle



CBM dipole magnet with field clamps (magenta) and shielding box (yellow)

Readout electronics

Our requirements:

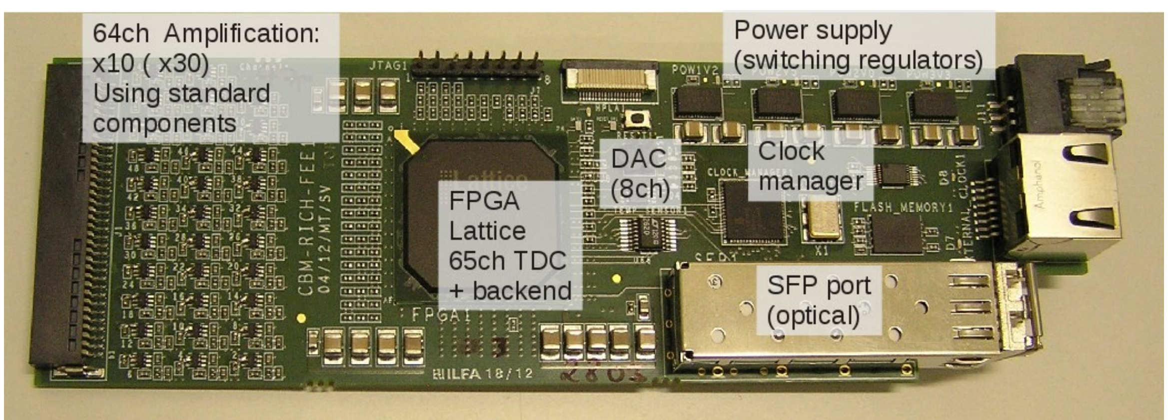
- About **55k readout channels**
- Time and amplitude information; sensors: ~500ps (MCP <100ps)
- Up to **700 kHz hit rate** per channel
- **Self triggered**, free streaming readout concept (CBMnet)
- Form factor matching camera channel density (64ch per 50x50 mm^2)
- Radiation tolerant front end (20 Gy / 10^{11} n_{eq}/cm^2)

HADES TRB3
5 FPGA multi purpose board

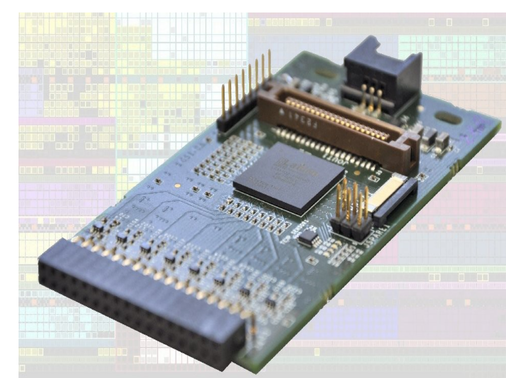
Foreseen solution:

- FPGA-TDC readout based on HADES TRB3 board
- Excellent time resolution: sensor is the limit
- Limited amplitude information via Time-over-Threshold
- Signal discrimination using FPGA differential line receivers

- First prototype tested during 2012 test beam at CERN (M. Traxler, GSI):



TRB-RICH 64 channel FPGA-TDC readout module prototype as tested 2012. Board is based on HADES TRB3 FPGA-TDC



PADIWA frontend board
16ch discrimination on FPGA
LVDS-output to TRB3

Expected RICH performance

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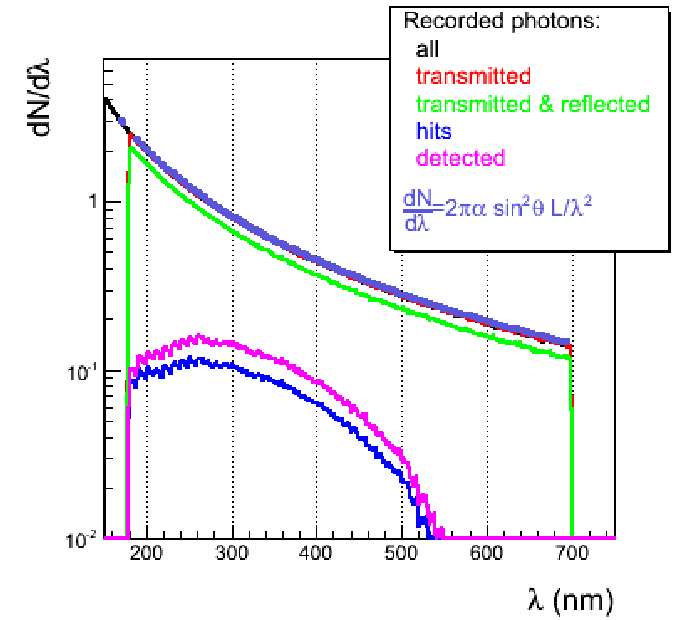
N=28 photons / electron ring (with WLS coating)

r_e = 4.56 cm
Θ_C = 1.72°
N_0 = 171 cm^{-1} $N = N_0 \; L \; \sin^2 \Theta_C$



Photons per wavelength interval

cherenkov angle resolution:

$$\sigma = \frac{\sqrt{\sigma^2_{mirror} + \sigma^2_{dispersion} + \sigma^2_{pixelsize} + \sigma^2_{MS} + \sigma^2_B}}{\sqrt{N}}$$

σ_{mirror} : Mirror distortion; negligible

$\sigma_{dispersion}$: Chromatic dispersion; **~1 mrad**

$\sigma_{pixelsize}$: Finite pixel size; **~1 mrad**

σ_{MS} : Multiple Scattering; = 0.847 MeV/c * 1/p

σ_B : B-field; = 55.1 MeV/Tm * L * B_T / p

P. Glässel,
Nucl. Instr. Methods A 433 17 (1999)

P [GeV]	0.4	1	8
σ_{MS}[mrad]	2.2	0.9	0.1
σ_B [mrad]	18	7.2	0.9

Ring distortion due to Multiple Scattering and B-field deflection as fnct. of momentum

σ (p=8 GeV, N=20) = 0.38 mrad

for σ = 0.572 mrad (resolution 2%):
5σ e/π separation up to 11 GeV/c

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The CBM RICH prototype

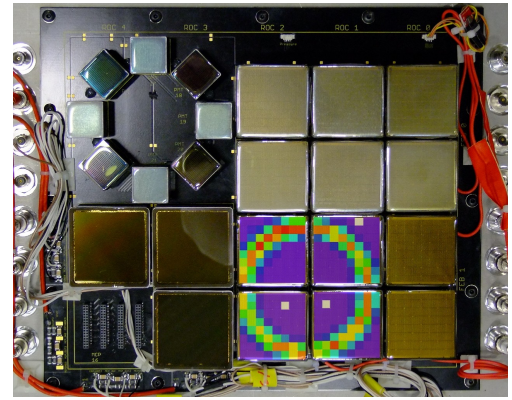
A CBM RICH prototype tested at CERN PS
(mixed e/π beam up to 10 GeV/c)

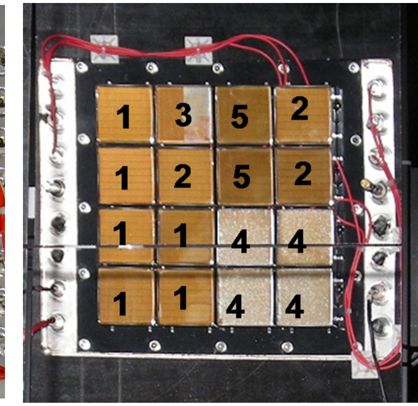
Realistic dimensions:

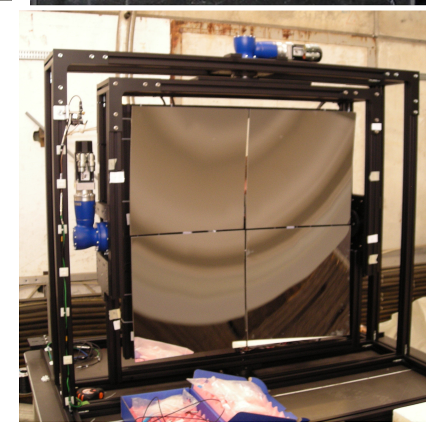
- Radiator length: 1.7m
- Segmented mirror, 40x40 cm² tiles (remote tilt control)
- Focal length 1.5m
- Photon detector (different sensors)

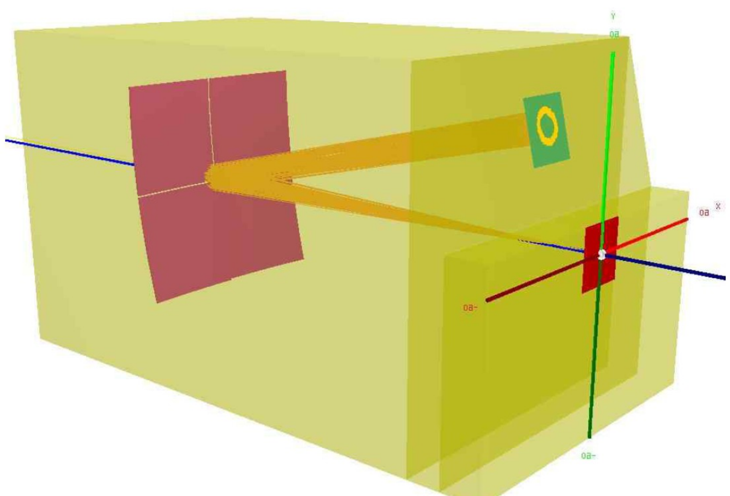
Goals: test and validate the RICH design

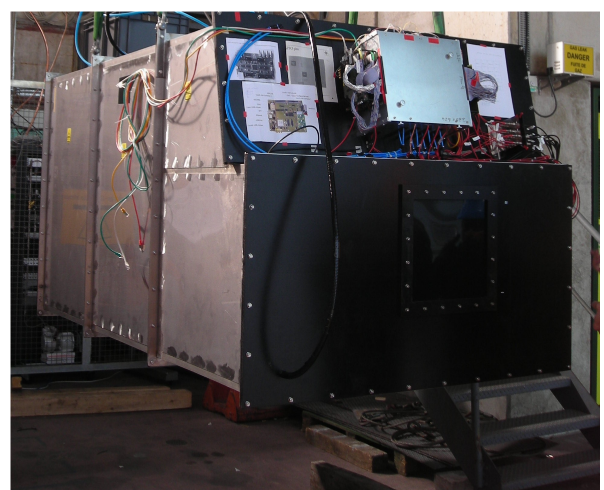
- Photon multiplicity
- Ring reconstruction **→ talk by S. Lebedev**
- e / π separation
- Study photon detector performance (and WLS)
- Study effects due to mirror displacement **→ poster by T. Mahmoud**

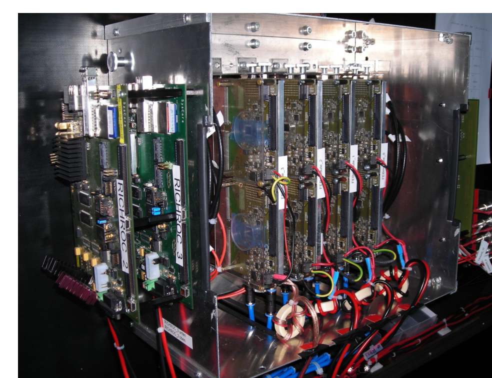












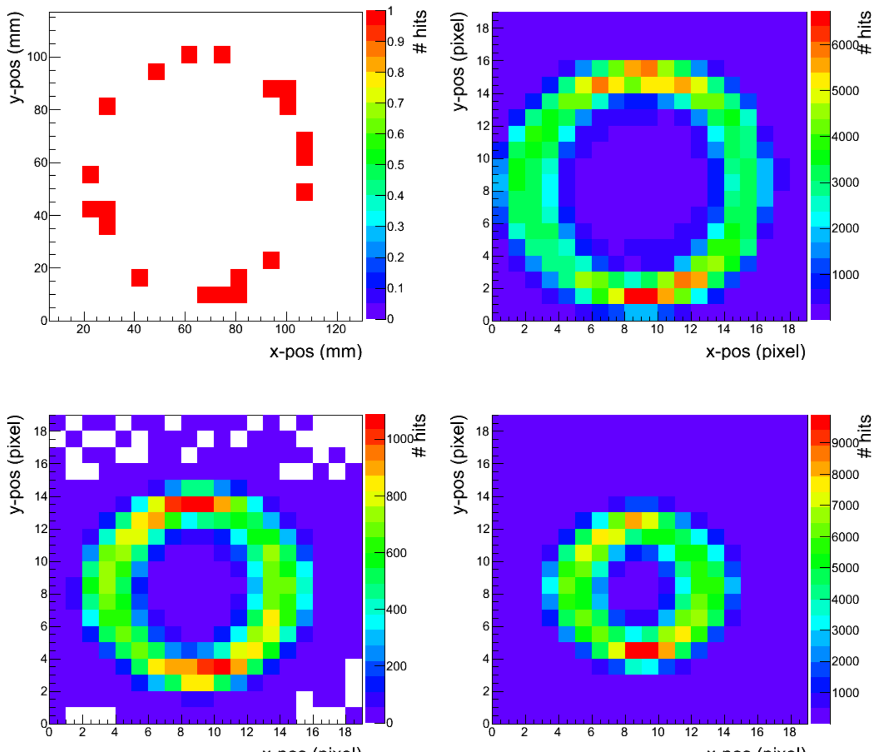
Cherenkov photon multiplicity

Clear single event Cherenkov rings observed (hardly any noise)
Hit multiplicity hits/ring: **~22-23 (no WLS) / 26-27 (WLS)**

Comparison to Monte Carlo:

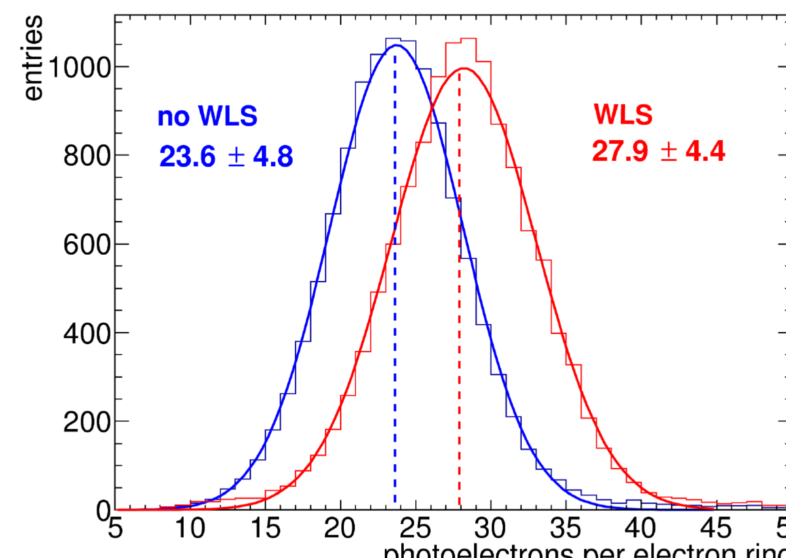
10-15% more hits in Monte Carlo compared to data
(after temperature and pressure correction)
But: **assuming 100% PMT collection efficiency**

$$N(T,p) = 1 + (N_0 - 1)\,\frac{T_0}{p_0}\,\frac{p}{T}$$



Single event e⁻ ring, integrated rings for selected electrons, muons and pions

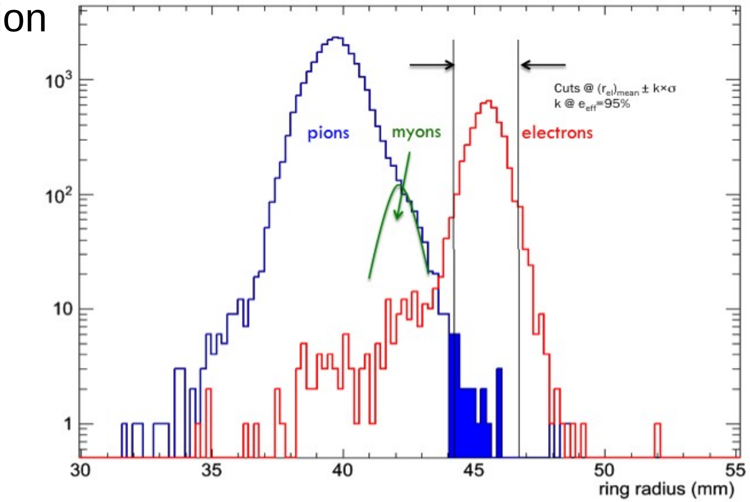
T~293 K, p=0.96 bar (CERN)



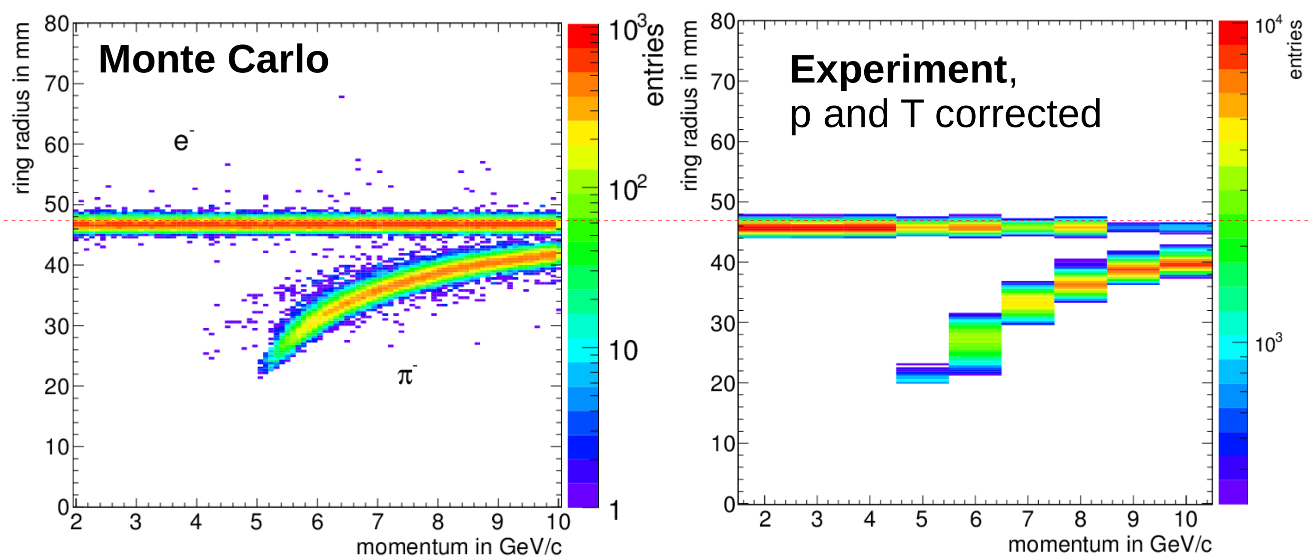
Measured e- ring hit multiplicitiy for H8500 MAPMTs with and without WLS coating

Selected prototype results

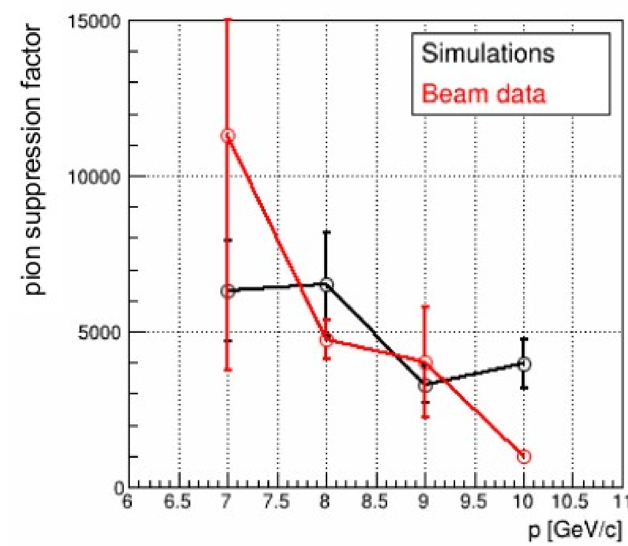
- Ring finding and fitting using Localized Hough-Transformation
  → more details: talk S. Lebedev, Thu 18.05h
- Good agreement of ring radii vs momentum (after correction for T and p)
- Pion suppression factor π_{sup} :
  Relative amount of pions identified as electron for given electron acceptance 95%
- $\boldsymbol{\pi_{sup}}$ **= ~4500 at 8 GeV/c**
  In agreement with Monte Carlo expectation



Fitted ring radii for momentum p=10 GeV/c



Ring radii vs momentum for electrons and pions, p=2..10 GeV/c



Pion suppression factor, data vs MC

Cherenkov ring hit multiplicity for different sensor candidates

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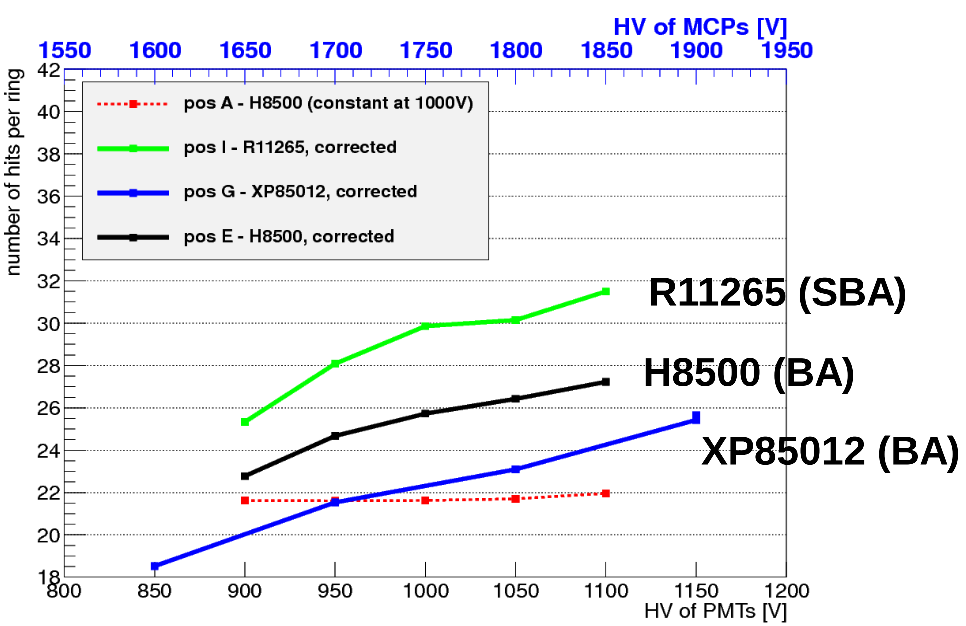
- In 2012, the prototype camera included 3 different sensor candidates
  - 12* H8500
  - 8* R11265
  - 3* XP85012 MCP

- Cherenkov ring could be positioned on different camera regions
- All results after subtracting individual cross talk contribution !

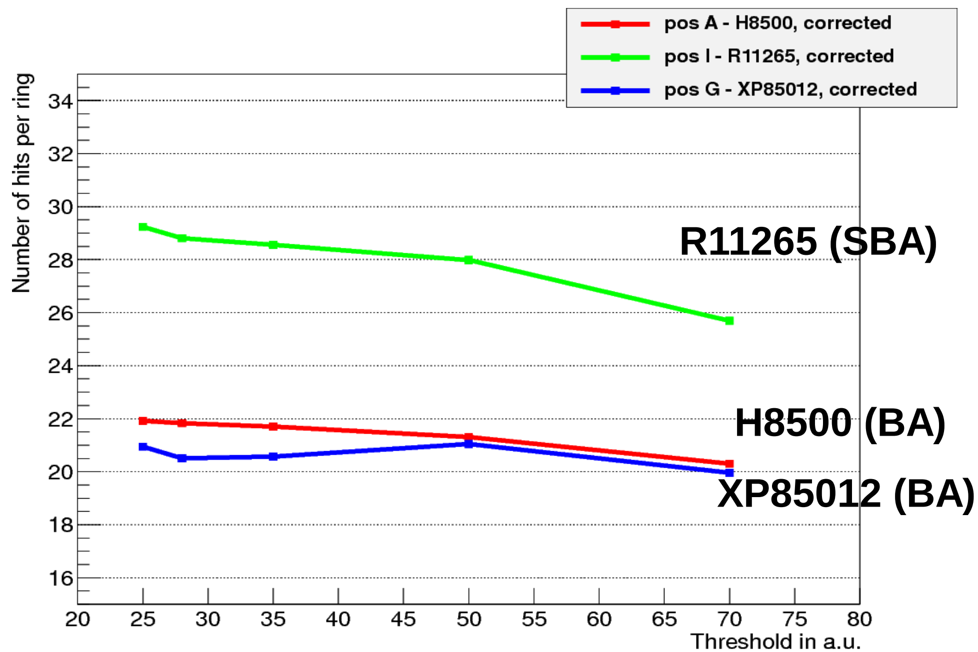
Prototype camera in 2012 beam test

Results:

- **R11265 : ca 25% more photons** compared to H8500 / XP85012
- **XP85012 and H8500 show similar detection efficiency**



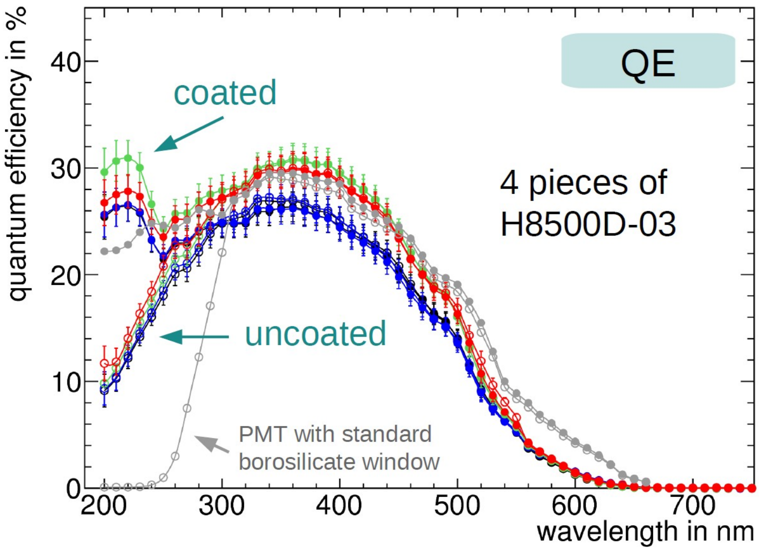
Hits / ring : High voltage scan



Hits / ring : Threshold scan

Quantitative study of WLS performance

- During 2012 prototype beam test, several PMT were dip-coated with optimized WLS layers
- Shifting ring position back and forth on WLS-coated regions allowed for **precise quantitative determination of WLS gain**
- **Latest WLS coatings increase Cherenkov photon detection efficiency by up to 18%**
- **In good agreement with expected yield** (based on measured spectral quantum efficiency)
- Gain depending on cathode material and window thickness



Spectral quantum efficiency for several multianode PMTs with and without WLS coating (BA cathode, UV-window)

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

for detail on WLS coating see poster J. Kopfer

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Summary and Outlook

- **New gas RICH** detector being developed **for the CBM experiment at FAIR**
- Focus: **e / π separation up to 8 GeV/c**, high rates, high ring multiplicity (secondary e-)
- Design concept established, **Technical Design Report submitted this summer**

- **Full-scale prototype** has been built and successfully **tested at CERN-PS**
- Results prove a **sound understanding of the prototype performance**
- Further results on:
  - Mirror (miss-)alignment
  - Photon sensor comparison and electronics
  - WLS efficiency
  - Ring reconstruction routines
  - Full system test: gas system, slow control, ...

- Lab tests of brand **new Multianode PMT H12700: very promising results...**

More work needed on:

- **Shielding of magnetic stray fields** from CBM dipole
- **Final choice of photon sensor**
- Development of **FPGA-TDC based readout** electronics
- **WLS behavior under neutron irradiation**, aging

Another prototype currently being developed and tested at Pusan National University, PNU

- Test different radiator gases
- Test high rate conditions

Timeline: first beam end of 2018 !

Additional information:

talk S. Lebedev:	Ring finding (**Thu. 18.05h**)
poster T. Mahmoud:	mirror, gas system
poster J. Kopfer:	WLS studies

The CBM collaboration

China:
Tsinghua Univ., Beijing
CCNU Wuhan
USTC Hefei

Croatia:
University of Split
RBI, Zagreb

Cyprus:
Nikosia Univ.

Czech Republic:
CAS, Rez
Techn. Univ. Prague

France:
IPHC Strasbourg

Germany:
Univ. Gießen
Univ. Heidelberg, Phys. Inst.
Univ. HD, Kirchhoff Inst.
Univ. Frankfurt
Univ. Mannheim
Univ. Münster
FZ Rossendorf
GSI Darmstadt
Univ. Tübingen
Univ. Wuppertal

Hungaria:
KFKI Budapest
Eötvös Univ. Budapest

India:
Aligarh Muslim Univ., Aligarh
IOP Bhubaneswar
Panjab Univ., Chandigarh
Gauhati Univ., Guwahati
Univ. Rajasthan, Jaipur
Univ. Jammu, Jammu
IIT Kharagpur
SAHA Kolkata
Univ Calcutta, Kolkata
VECC Kolkata
Univ. Kashmir, Srinagar
Banaras Hindu Univ., Varanasi

Korea:
Korea Univ. Seoul
Pusan National Univ.

Norway:
Univ. Bergen

Poland:
Krakow Univ.
Warsaw Univ.
Silesia Univ. Katowice
Nucl. Phys. Inst. Krakow

Portugal:
LIP Coimbra

Romania:
NIPNE Bucharest
Bucharest University

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

Ukraine:
INR, Kiev
Shevchenko Univ. , Kiev

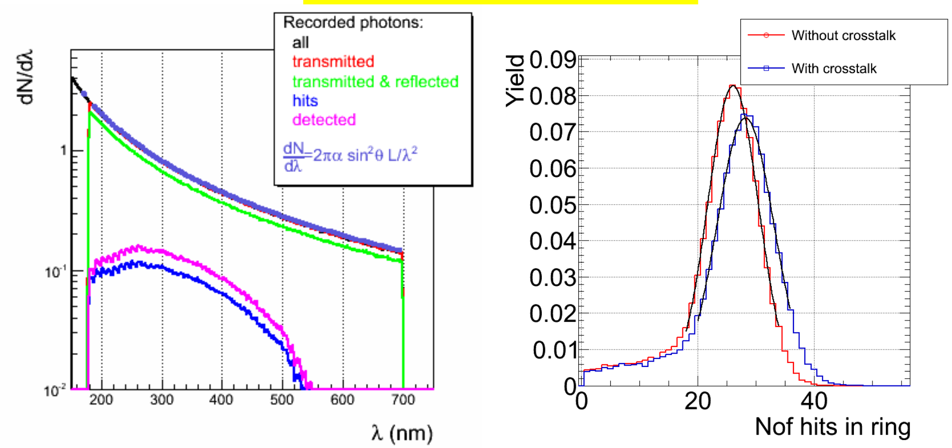
56 institutions, 450 members

backups

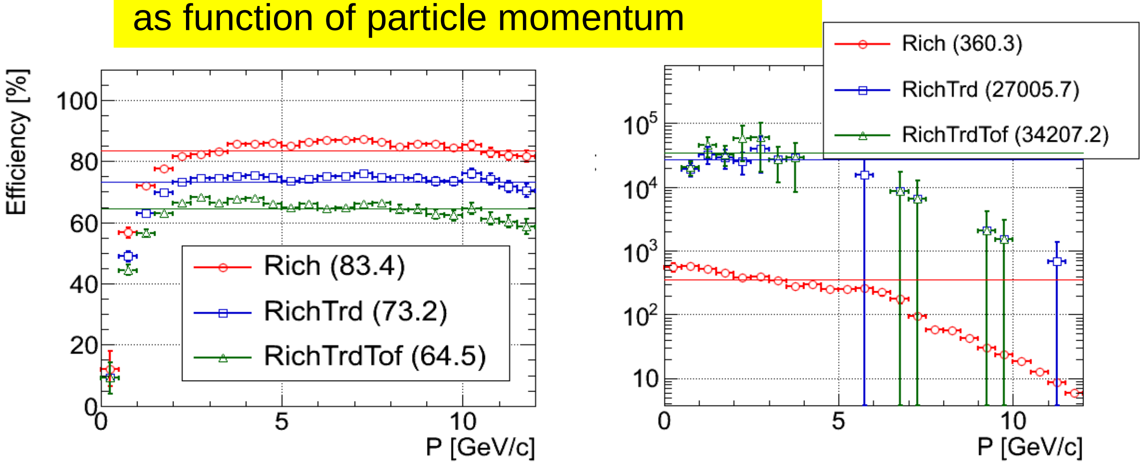
CBM RICH performance (according to simulation)

- 26 photons per electron ring (w/o WLS)
- $N_0 = 171\ cm^{-1}$
- electron reconstruction efficiency
  RICH alone : 80% - 90%
- Pion suppression as expected

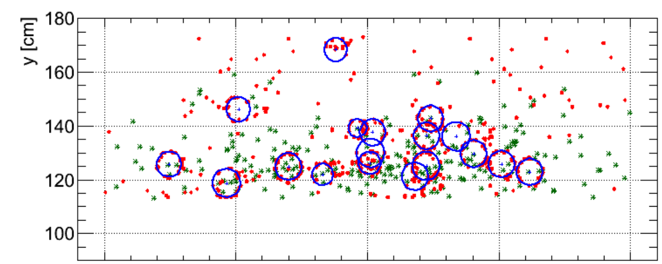
N_{ph} per electron ring



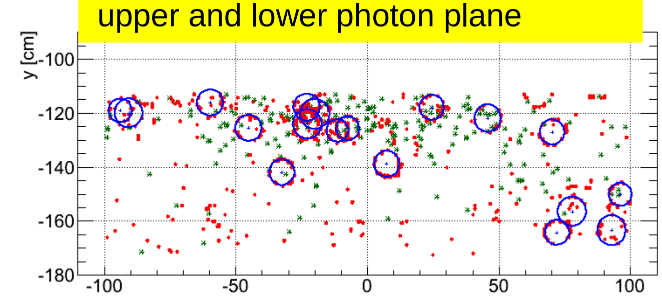
Electron efficiency and pion suppression as function of particle momentum



Au+Au at 25 AGeV



Au+Au central collision at 25 AgeV
upper and lower photon plane



Green points: projected charged track coordinates

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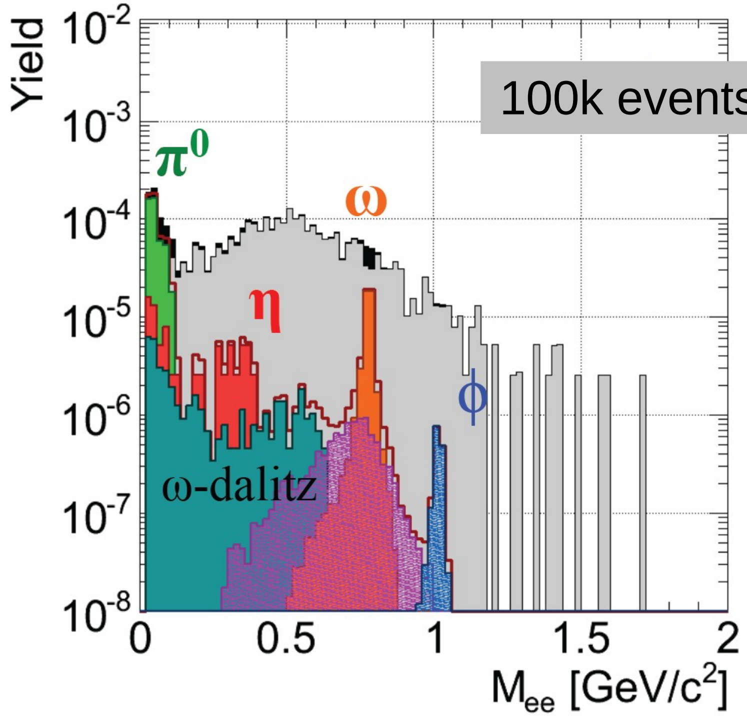
CBM performance (ii): di-electron decays of vector mesons

@SIS100: **8 AGeV**

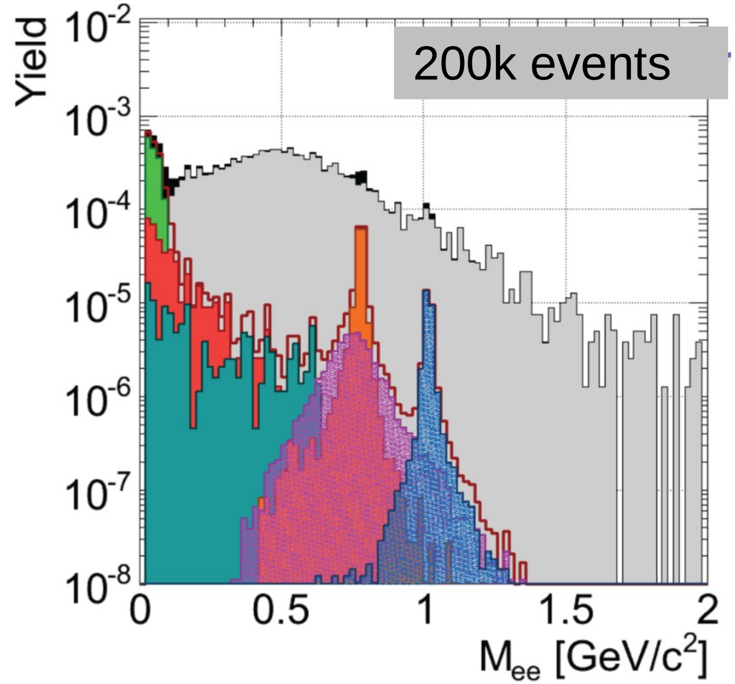
Using STS, RICH and TOF



	ρ	ω	φ
eff. [%]	3.12	4.11	4.89
S/BG	-	0.64	0.04

@SIS300: **25 AGeV**

Using STS, RICH, TRD and TOF



	ρ	ω	φ
eff. [%]	4.39	5.53	7.08
S/BG	-	0.31	0.11

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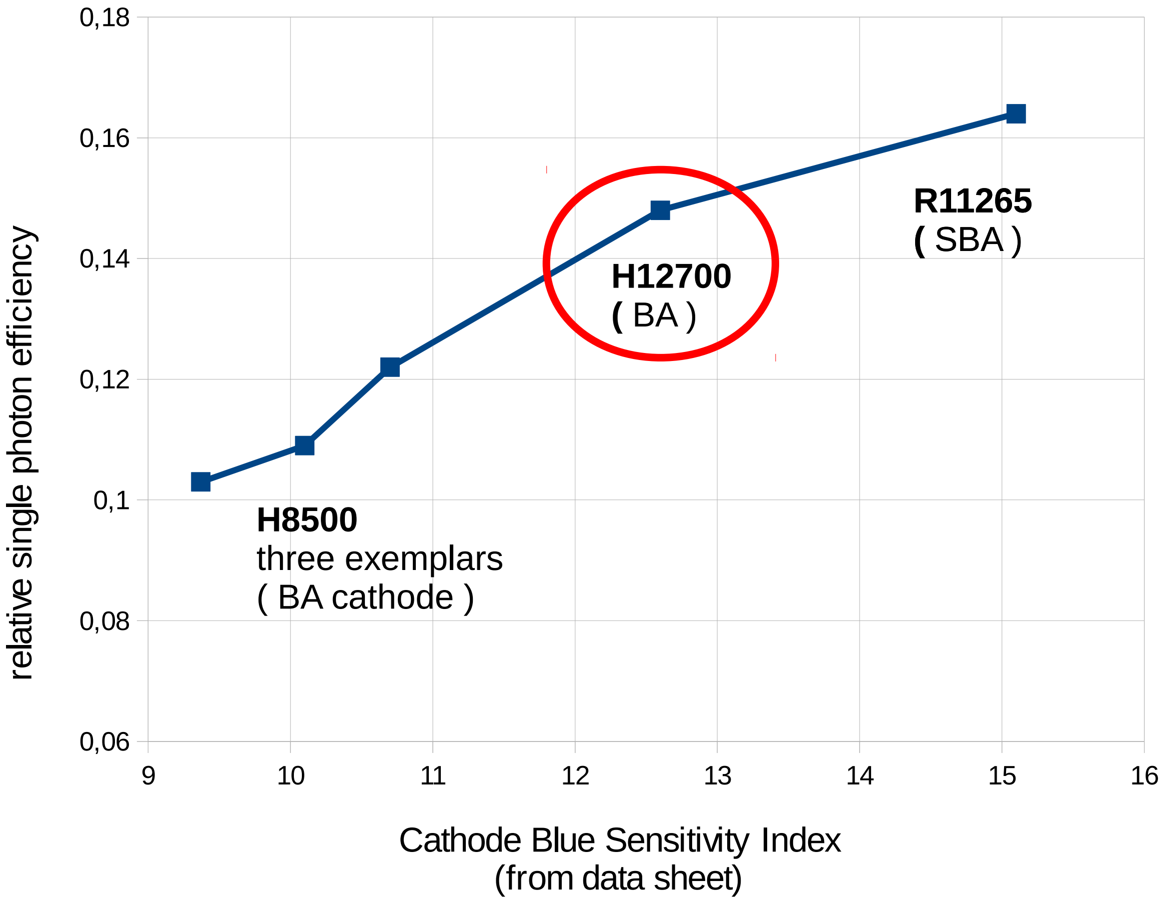
New H12700 MAPMT

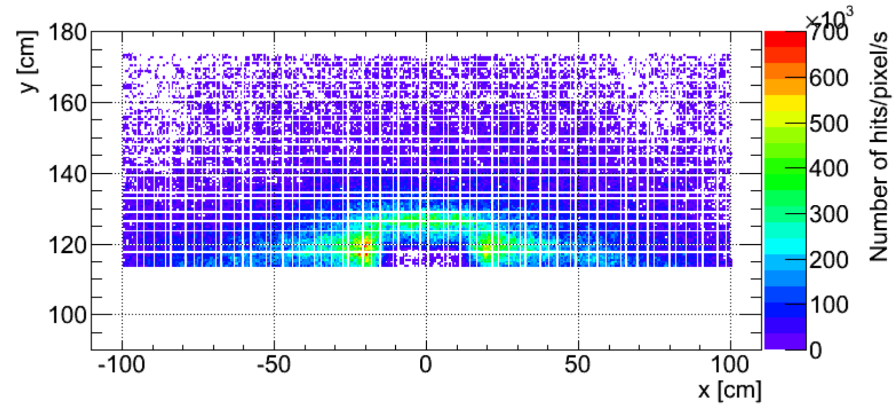
- First test of very first sample H12700 look very promising
- Significant better Single photon peak distribution (similar R11265)
- Much better channel separation (similar R11265)
- First sampe: very high overall efficiecy, half-way to SBA cathodes

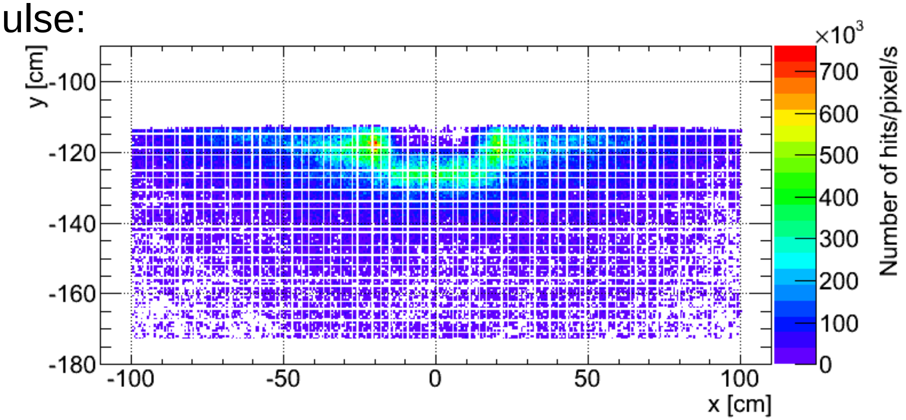


sensor requirements: rate / lifetime

- CBM is particularly designed for high interaction rates: up to 10 MHz Au+Au @ 35 AGeV
- single photon hit rates RICH:
  - **up to 2 MHz / cm²**
  - **up to 700 kHz/pixel** (assuming 6x6 mm² pixels)
  - in limited regions, inhomogeneous distribution
- assuming $1x10^6$ sensor gain, 150fC per single photon pulse:
  → anode current: **max 0.1 µA/pixel**,
  → ~ 5 µA total, assuming 64pixel sensors

  → **well within typical PMT limits**





expected **hit rates per pixel**
Au + Au @ 35 AGeV
10 MHz interaction rate

life time requirement:

- based on total collected anode charge

  → **2 C/cm²** for 2 months Au+Au @35 AGeV, maximum rate
  → **20 C/cm²** for 10yr CBM lifetime

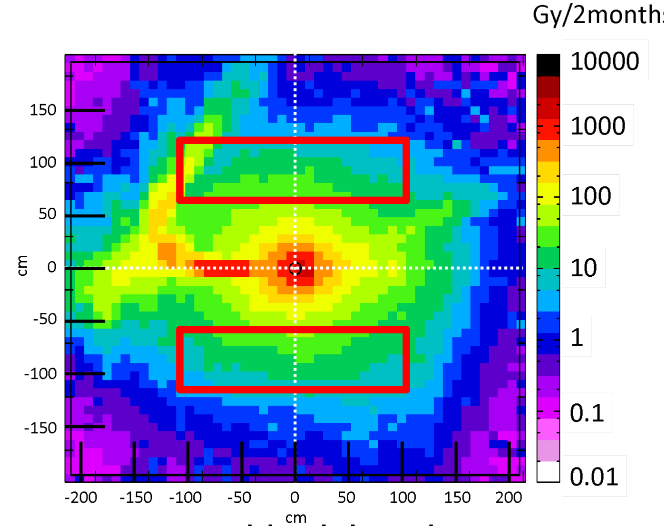
  → **within typical PMT limits**

sensor requirements: radiation hardness

- the photon detector will be exposed to significant radiation dose during its life time
- according to FLUKA simulations, **assuming 2 months at maximum rate, Au+Au@35 AGeV:**

  → **ionizing dose:** **20 Gy** (100 Gy in selected regions)
  → **non-ionizing dose :** **10^{11} n_{eq}/cm²/2 months**

- for PMTs, we expect the glass window to be most sensitive
- **UV-extended borosilicate glass** ("UV-glass") provides enough safety margin (x10 – x100)
  (information based on Hamamatsu PMT handbook)
- dedicated **irradiation tests of PMTs and windows** with neutrons (fission) **planned for autumn 2013** (at FRM II in munich)



expected ionizing dose for 2 months at full rate, Au+Au@35 AGeV

expected radiation dose without additional shielding

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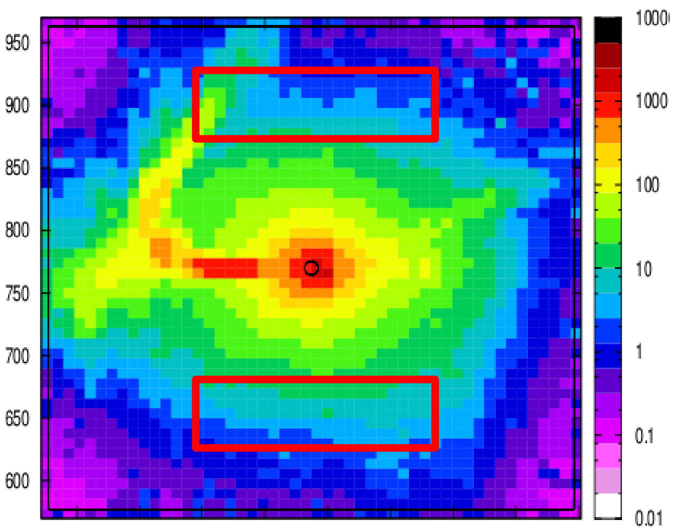
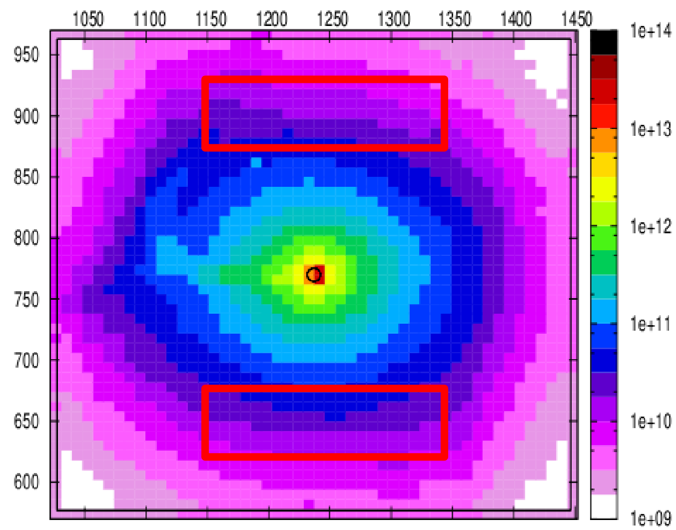
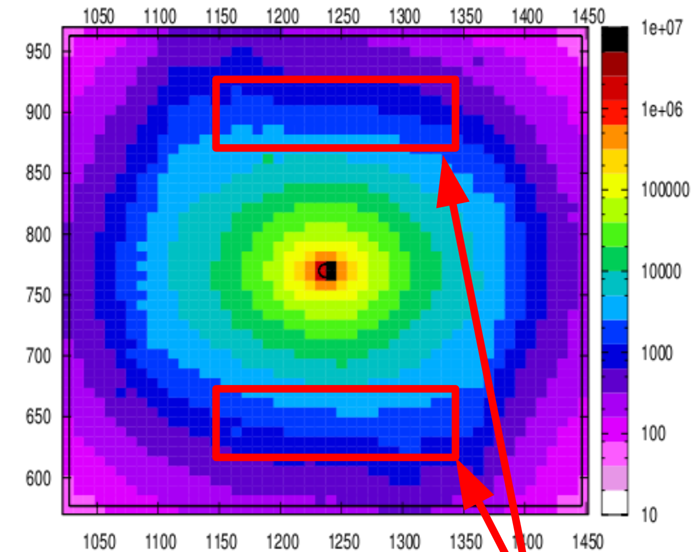
Dose rate (Gy / year)	**Non-Ionizing Energy Loss** (n_{eq} / cm^2 / year)	**High-Energy Hadron Fluence** (1 / cm^2 / s)







camera position

- latest FLUKA simulations by Anna Senger, CBM-Coll meeting Bejing
- assuming standard run conditions, 5×10^{15} beam particles

- **maximum Dose rate : < 20 Gy/year, 2krad / year** (100 Gy in localized area ?)
  maximum NIEL : < 3×10^{10} n_{eq} /cm^2 / year
  high-Energy Hadron Flux : < 10^4 1/cm^2/s

First test of TRB-RICH CERN 2012: mixed readout nXYTER ↔ TRBRICH

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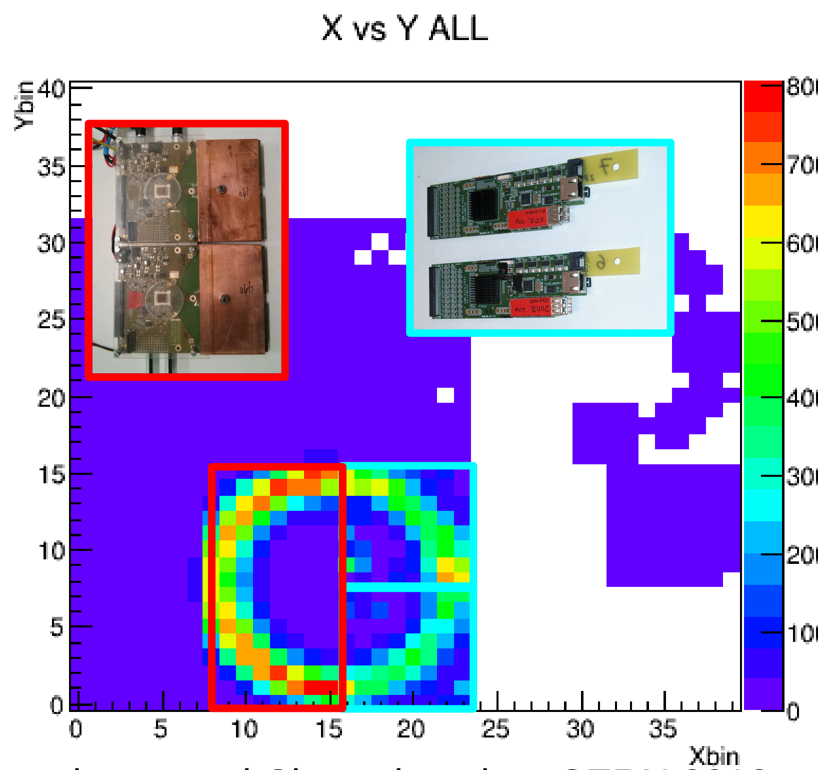
- **First prototype successfully tested at CERN 2012**
  → parallel readout of Cherenkov ring with nXYter and TRB-RICH
  → direct comparison to nXYter "benchmark"
  → Time-over-Threshold not yet available at that time

- successful Cherenkov photon reconstruction
  → **General concept seems to work**
- some minor issues discovered (and understood)

- more detailed lab tests ongoing...

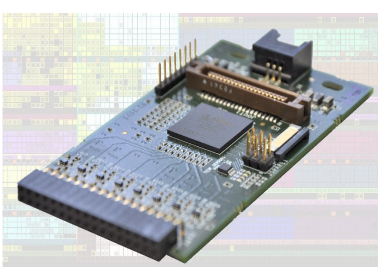


integrated Cherenkov ring, CERN 2012

left half: **nXYter** ↔ right half: **TRBRICH**

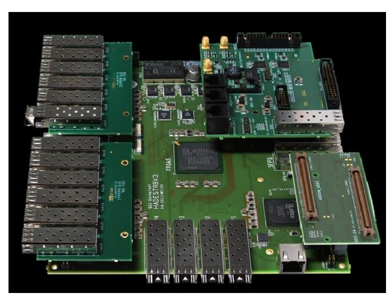
Possible variant: PADIWA+TRB3

- split signal discrimination from TDC
- use standard TRB3 for TDC
- (flat) cable differential connection in-between
- under investigation now
- parallel development for PANDA



PADIWA front end discrimination board

\+



Standard HADES TRB3 for TDC

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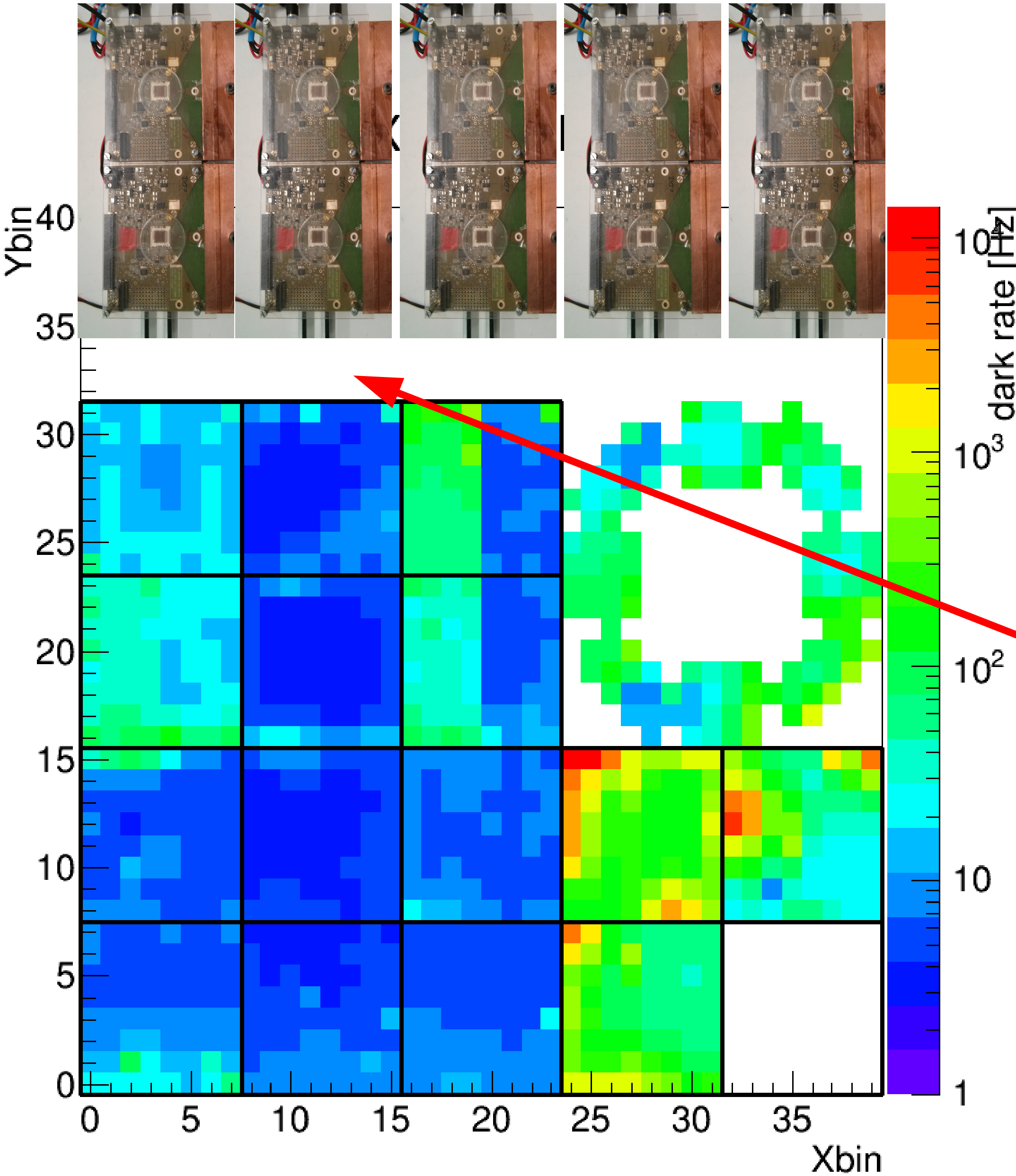
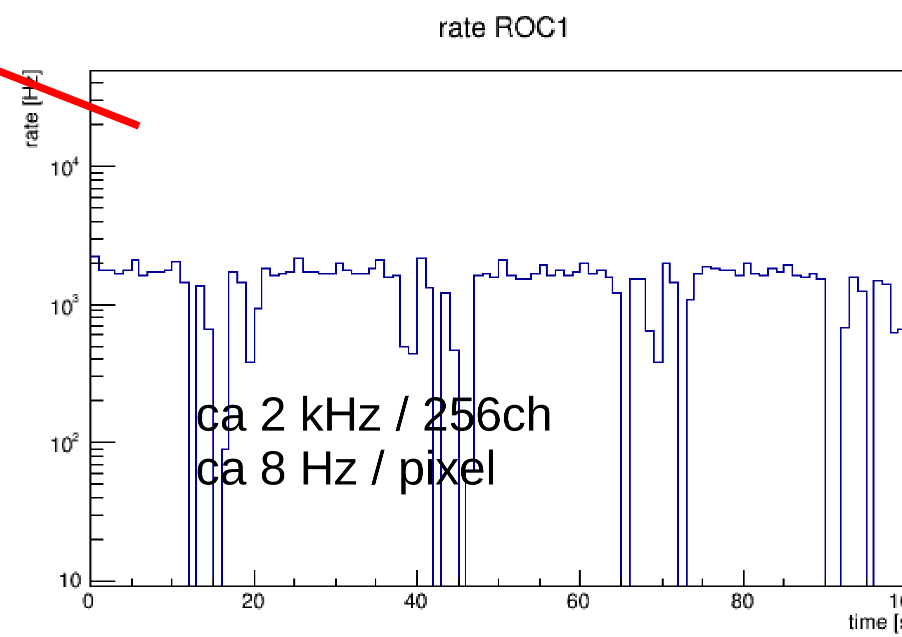
total dark noise 2012, nXYTER reference



reference run 197
ring on pos A, but 4 GeV/c

“standard” HV settings
“standard, low” threshold for nXYters

beam spill events excluded !!!



The CBM detector setup

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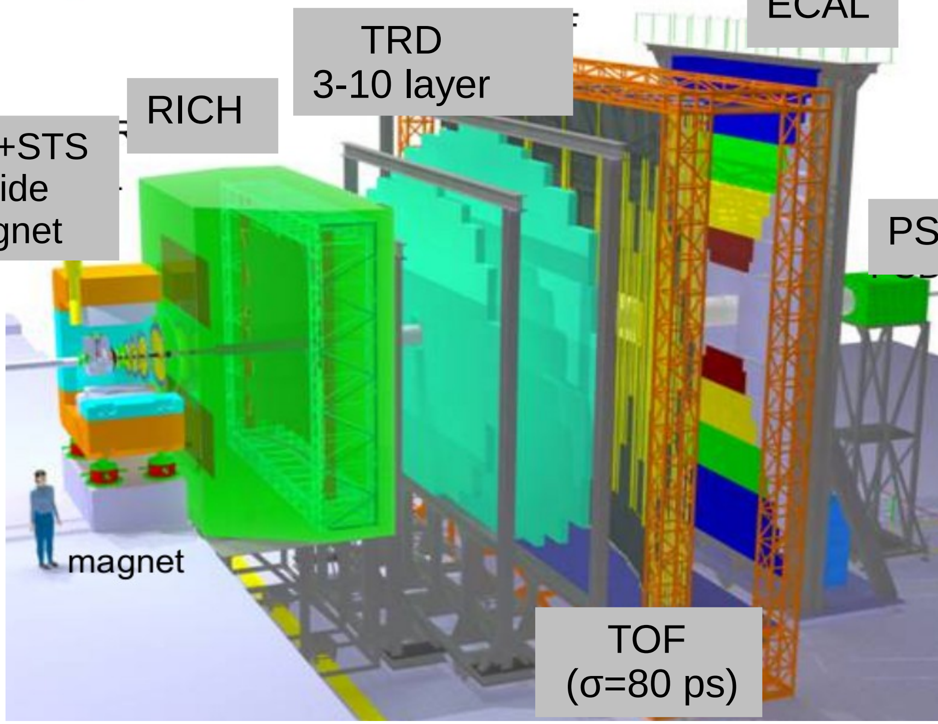
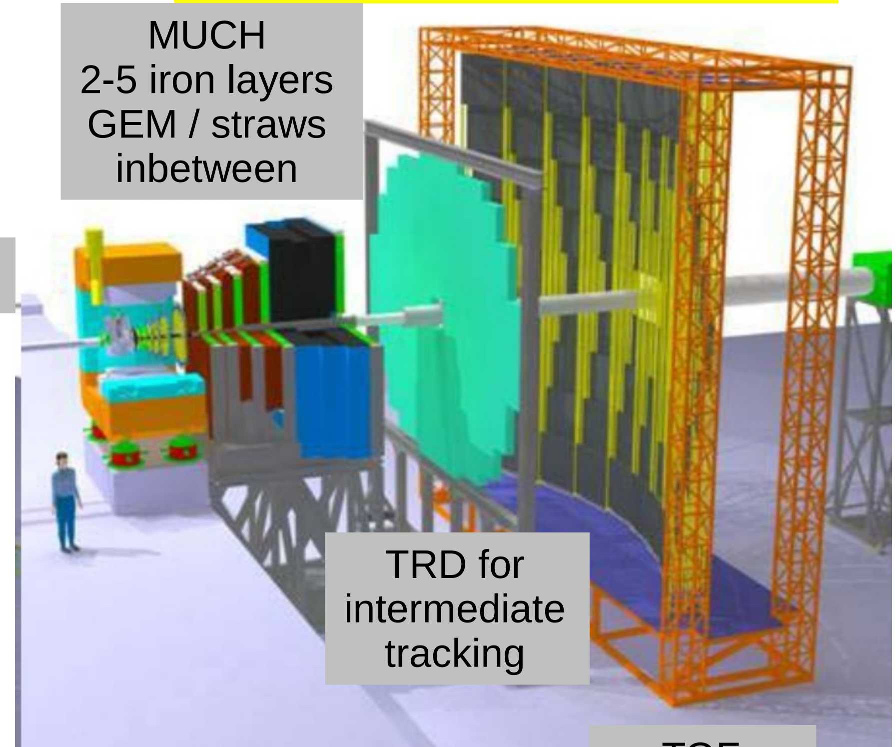
Electron setup

RICH and TRD for electron-ID
pion suppression >10^4



Muon setup

instrumented iron absorber

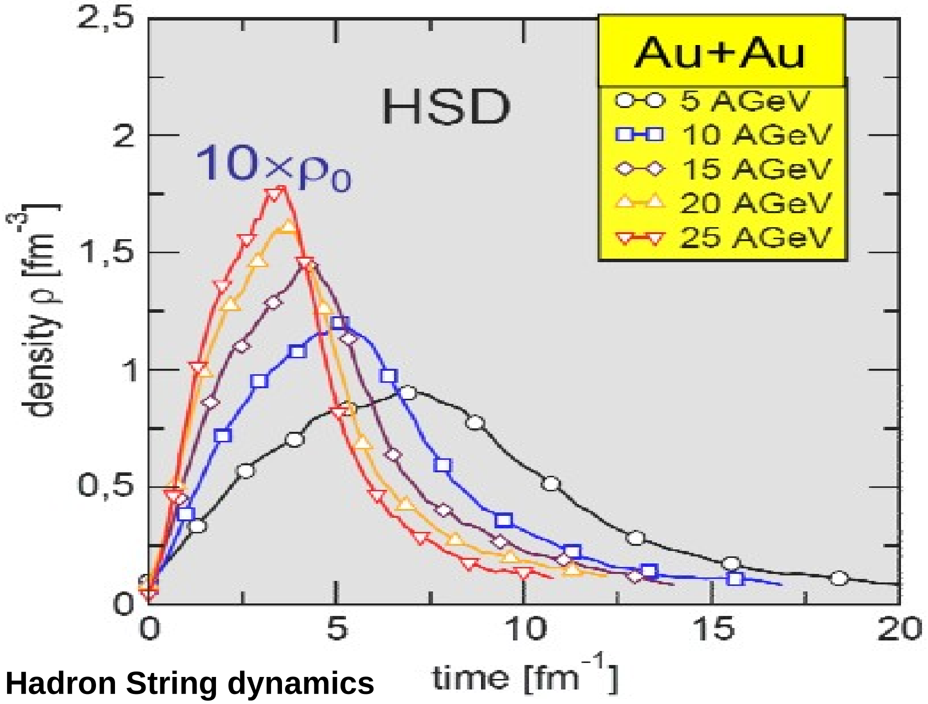


- **Exceptional high rate** capability (up to 10 MHz for J/Ψ)
- Hadron- and lepton reconstruction/ID with **large acceptance**
- **Displaced vertex reconstruction** (open charm, strangeness)
- Fully **self-triggered readout**, no hardware triggering
- Online event reconstruction and selection
- **excellent fast tracking** inside 1Tm superconducting magnet

How to produce dense matter in the lab ?

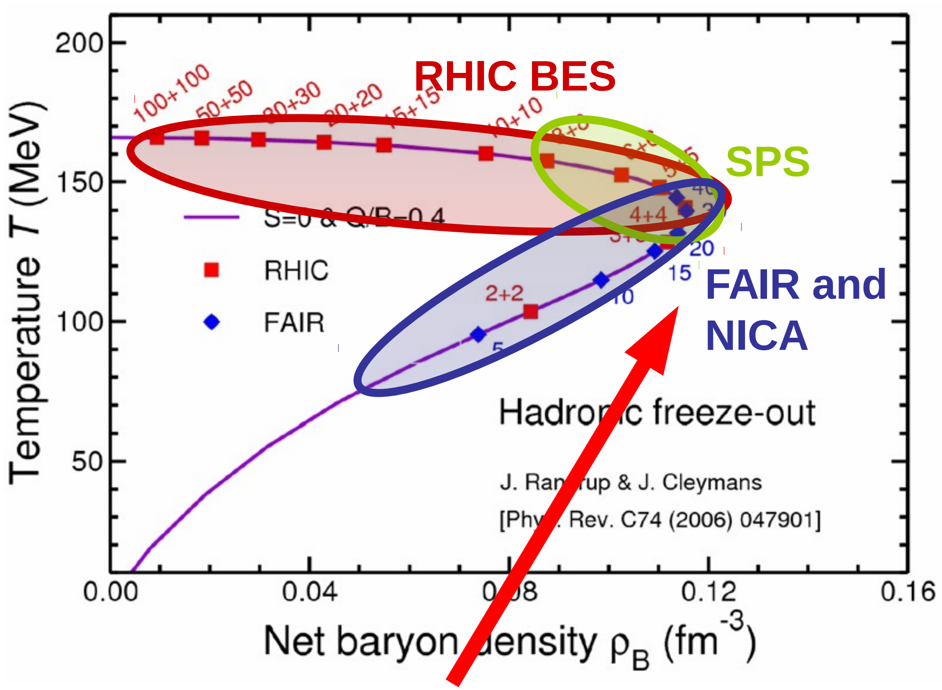
At FAIR / CBM: **Au+Au** collisions at **medium energies**, fixed target
SIS 100: Ekin 2.0 – 11 AGeV, $\sqrt{S_{NN}}$ = 2.7 – 4.7 GeV
SIS 300: Ekin 2.0 – 35 AGeV, $\sqrt{S_{NN}}$ = 2.7 – 8.3 GeV
contrary to "high T" physics at LHC: Pb+Pb collisions at highest energy

density as function of time according to transport calculations



Hadron String dynamics
W. Ehehalt, W. Cassing
Nucl. Phys. A 602(1996) 449

density and **temperature at freezeout** for different beam conditions



Maximum freezeout density reached at 30 AGeV, well within SIS300 range

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Experimental challenge (i)

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Particle multiplicity x Branching ratio
for min bias Au+Au collisions at 25 A GeV (from HSD and thermal model)