THE CBM RICH DETECTOR

Tariq Mahmoud

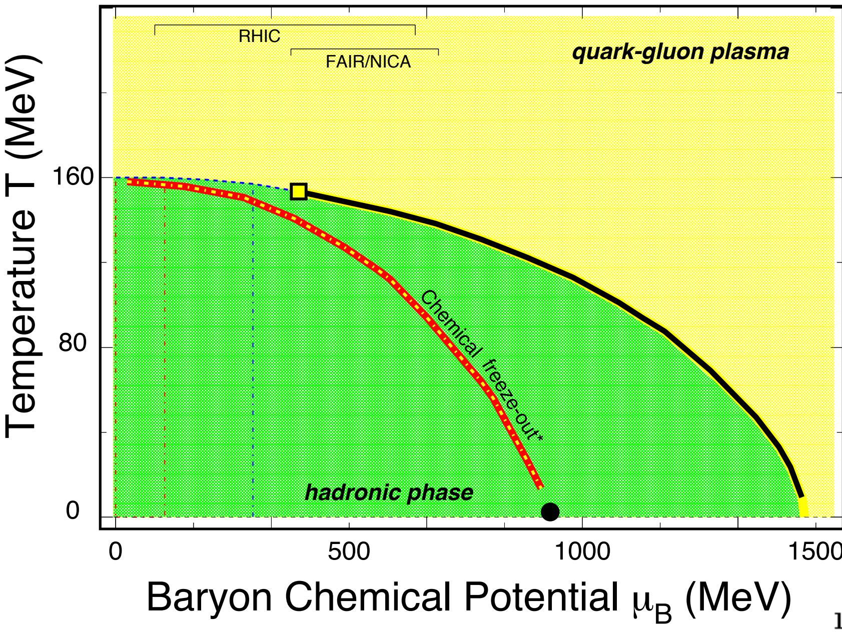
International Conference on Science and Technology for FAIR in Europe

13-17. Octobre • Worms • Germany

Outline

- Introduction
- The Concept of the RICH Detector
- R&D
  - Photon Detectors
  - Mirror System
- Laterally Scaled Prototype
  - Number of Hits per Ring
  - Ring Radius
  - Particle Identification
- Physics Potential
- Conclusion

Introduction



RHIC

$20 \leq \mu_B \leq 420$ MeV

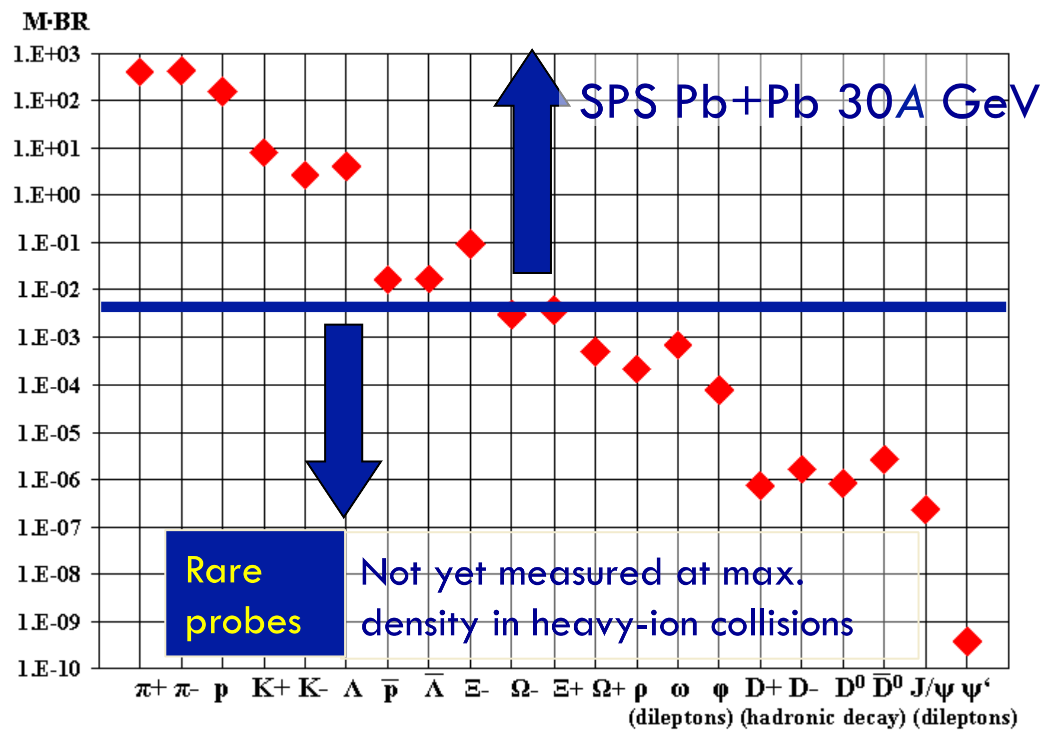
small temperature variation

CBM

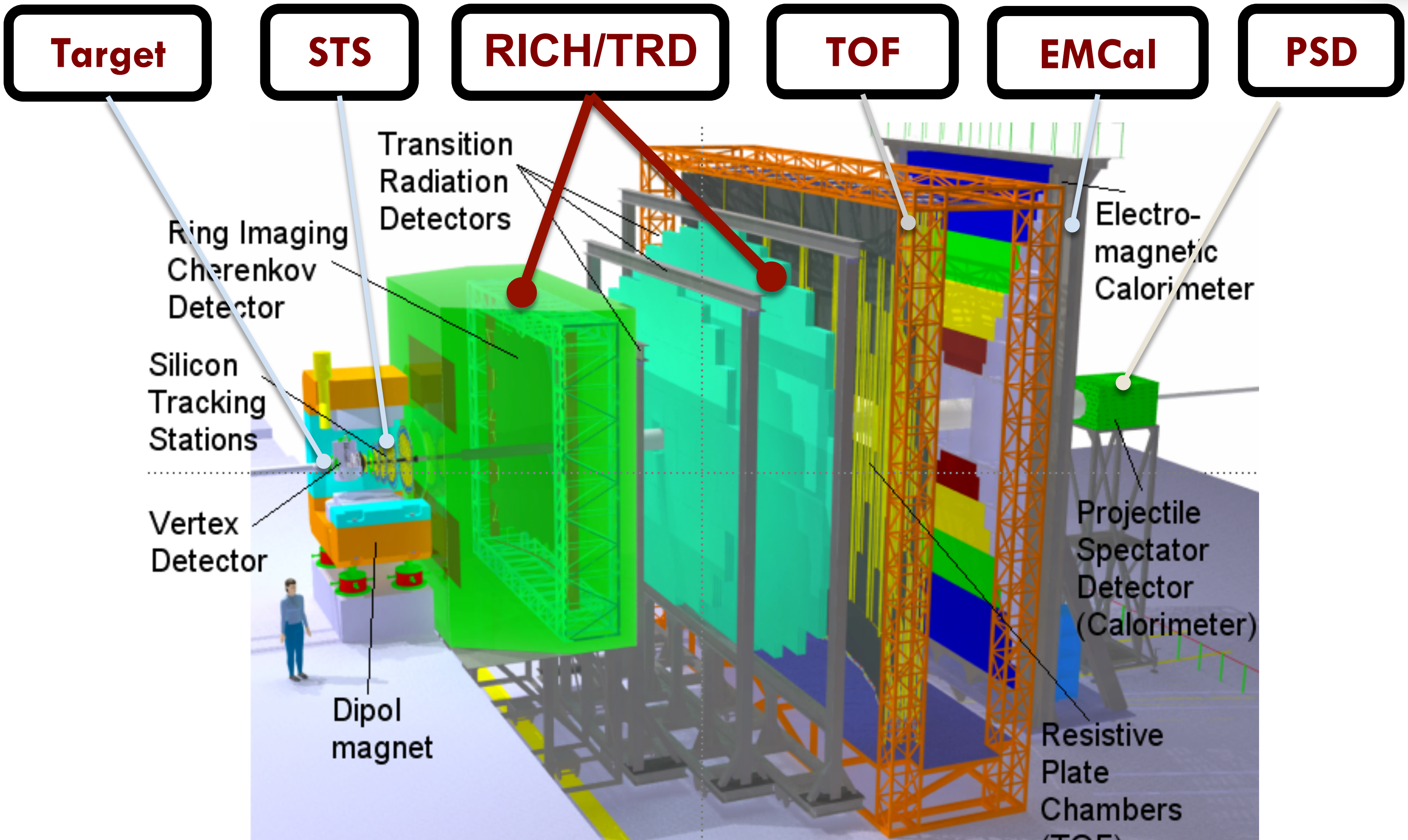
$400 \leq \mu_B \leq 750$ MeV

temperature changes dramatically!

- **Precision measurements** at high baryon density region for:
  - (i) high order baryon correlations
  - (ii) flavor productions (***s, c***);
  - (iii) dileptons (***e, μ***);
- In particular **rare probes** such as charm and low-mass vector mesons



THE CBM EXPERIMENT



MVD: investigate open charm production

STS: vertex reconstruction, tracking, momentum determination

ECAL: direct photons

TOF: hadron identification

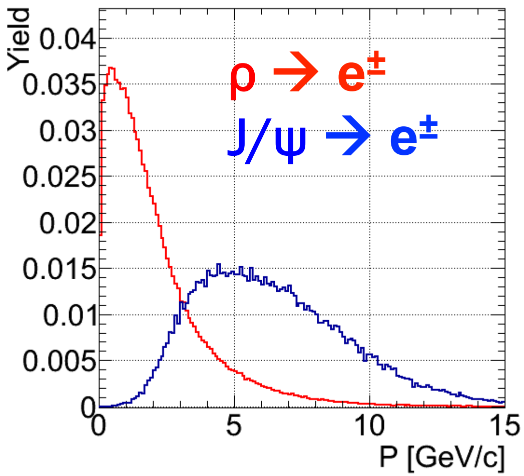
TRD: tracking

TRD: electron identification

RICH: electron identification

pion rejection factor of $\geq 10^4$

The CBM-RICH Detector: Mission To Concept



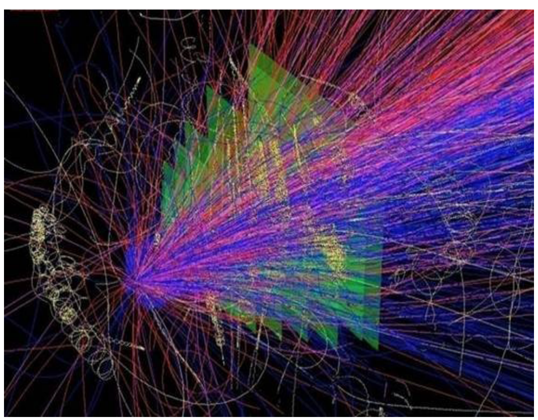
Mission

Efficient and clean electron identification with momenta below 8GeV/c

Philosophy

Build a stable, robust and fast focusing RICH detector relying to a large extend on components from industry.

Challenges

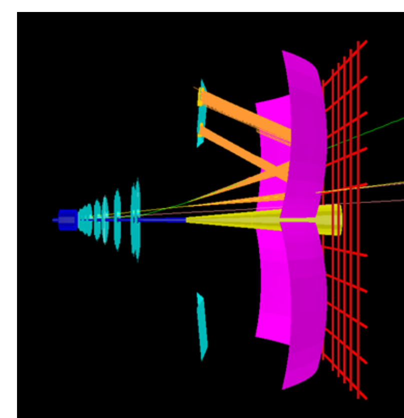


- Interaction rates up to 10 MHz → up to 700kHz/pixel
- RICH behind STS → secondary $e^{\pm}$ → high ring density
- High track densities → problem of ring-track mismatches
- Photon detector plane faces:
  - Energy density < 3krad/year
  - Neutron fluency < $3 \cdot 10^{11}$ n-eq/cm^2/year
  - Magnetic field ≈ 25 mT

  → causing gain deterioration

Concept

- Gaseous radiator.
- Multi-anode Photomultiplier Tubes (MAPMT).
- Focusing mirror system.



Radiator

	N_2	CO_2	C_4F_{10}	Aerogil	C_5F_{10}	Quartz
n-1 [10^{-4}]	2.98	4.3	14	300	2700	4700
$p_{th}(e)$ [GeV]	0.02	0.017	0.01	0.002	$7 \cdot 10^{-4}$	$5 \cdot 10^{-4}$
$p_{th}(\pi)$ [GeV]	5.72	4.76	2.64	0.57	0.19	0.14

- To separate electrons from pions we need a gas radiator!
- Nitrogen seems to be the best choice … but

	Radiator length	Full length	Mirror radius	Mirror size	Photo detector size	No. of channels
CO2	1.76m	2.1m	3m	11.8m^2	3.7m^2	55k
N2	2.5m	2.9m	4.5m	22.8m^2	9m^2	200k

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… due to costs and place reasons:

CO_2 is chosen

- CO_2; $\gamma_{th} = 33$
- $p_{\pi,th} = 4.76$ GeV/c
- $V \approx 30\ m^3$
- Length=1.7 m

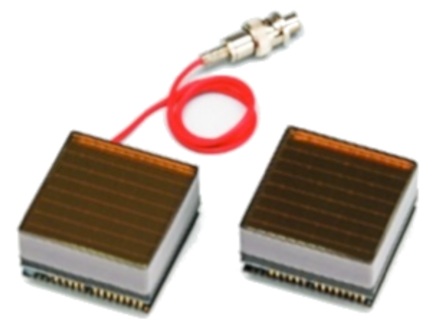
$p_{th} = \frac{m}{\sqrt{2\delta}}$, $\delta_{CO2} = 4.3 \times 10^{-4}$

e^- 17.4 MeV ✓ $K^{\pm}$ 17 GeV ✓

$\pi^{\pm}$ 4.6 GeV ✓ p 32 GeV ✓

Photon Detector

Four Main Properties:
- Quantum efficiency (QE)
- Single photon detection
- Crosstalk
- Tolerance of magnetic field



Hamamatsu: Multi-anode Photomultiplier Tubes (MAPMT);
- H8500: borosilicate glass and Bialkali cathode, 12-dynodes. (52x52 mm^2, 8x8 pixel)
- H10966: H8500 → Super-Bialkali cathode, 8-dynodes. (52x52 mm^2, 8x8 pixel)
- R11265: → Super-Bialkali cathode, 12-dynodes. (26x26 mm^2, 4x4 pixel)

- H12700: based on H8500, with dynode structure of R11265.

Photonis: Micro Channel Plate (MCP)
- XP85012: quartz glass and Bialkali cathode. (59x59 mm^2, 8x8 pixel)

Photon Detector: Quantum Efficiency

Four Main Properties:

- Quantum efficiency (QE)
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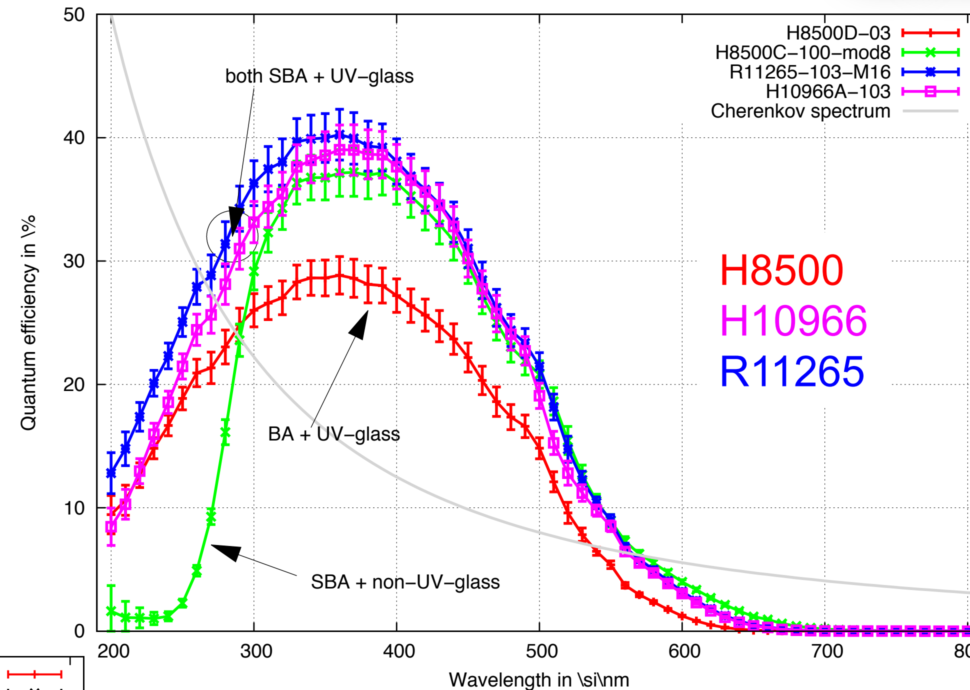
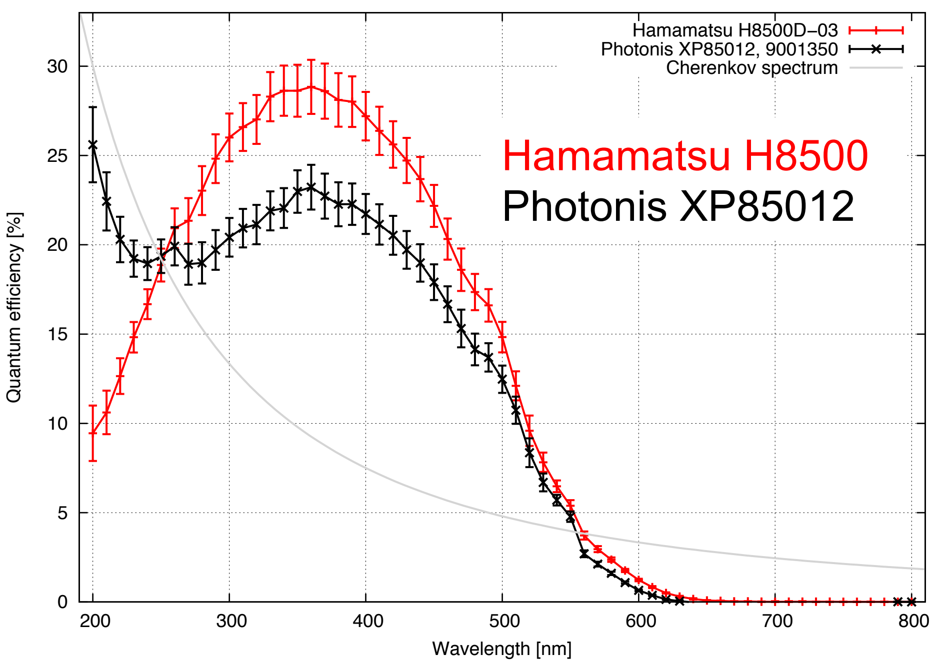


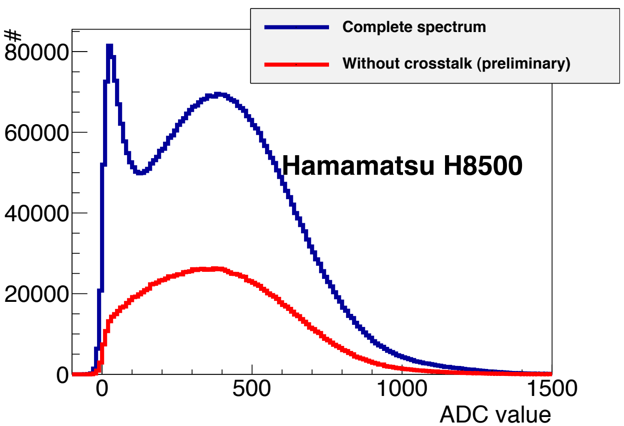


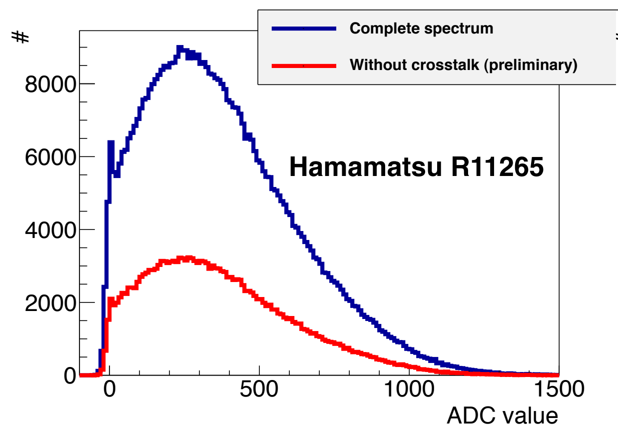
MCP shows a better QE especially at lower wavelength, where the most Cherenkov photons are emitted.

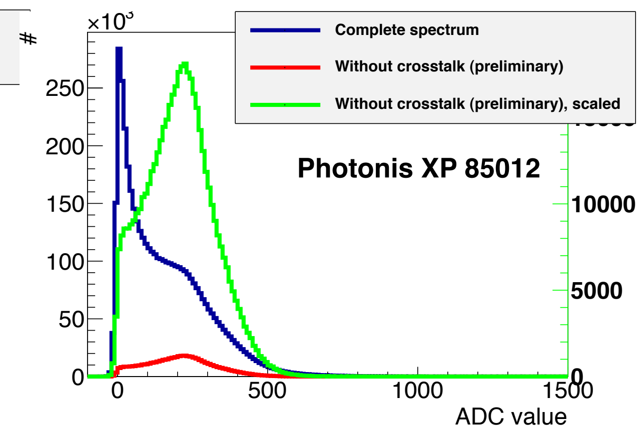
Photon Detector: Single Photon & Crosstalk

Four Main Properties:

- Quantum efficiency (QE)
- Single photon detection
- Crosstalk
- Tolerance of magnetic field





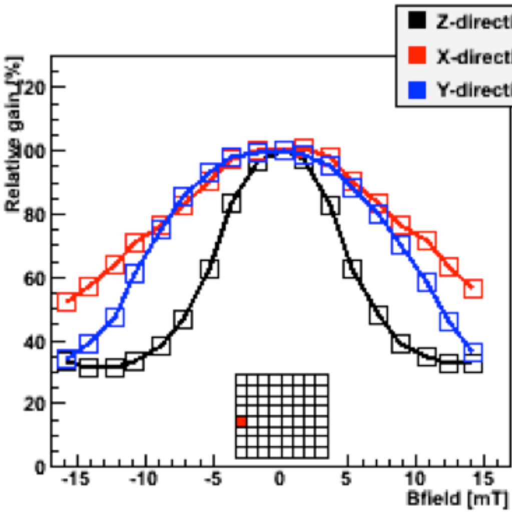


- Peak at 0 due to crosstalk
- Shape of R11265 spectra with and without crosstalk suppression almost Identical.
- Crosstalk in R11265 is less than H8500.
- XP85012 MCPs show significantly high crosstalk.

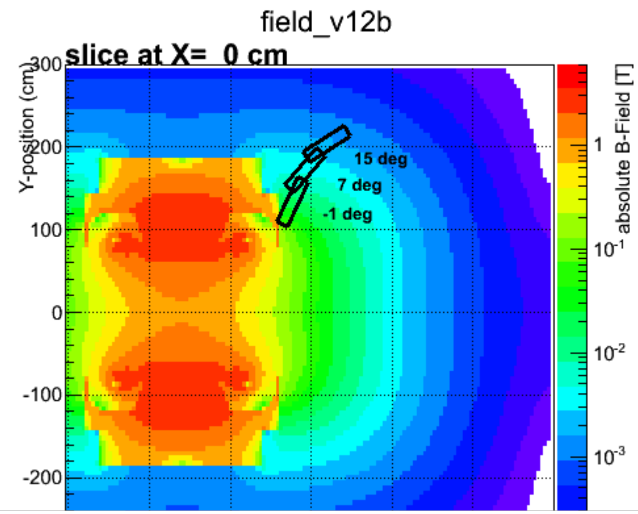
- MAPMTs of Hamamatsu show a better single photon detection capability.
- PMTs with SBA and 12 dynodes show almost no crosstalk.

Photon Detector: Magnetic Field Tolerance

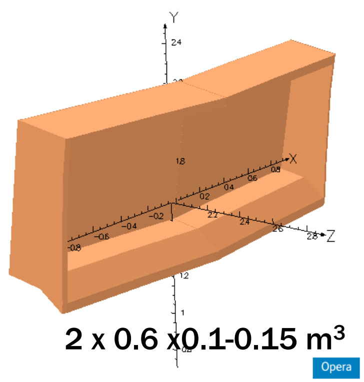
Hamamatsu: H8500, 12 stages, BA: Problems in magnetic field



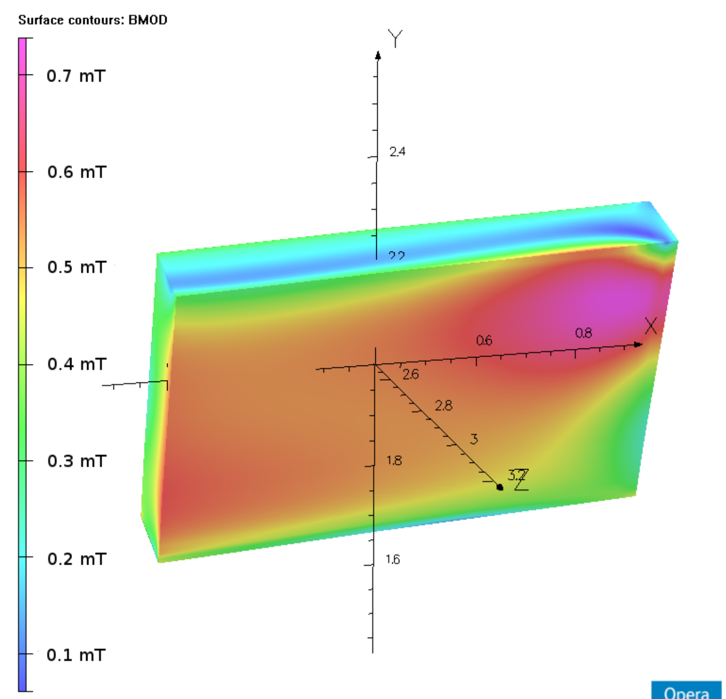
1. Rotation: $\alpha \geq 10$ deg.



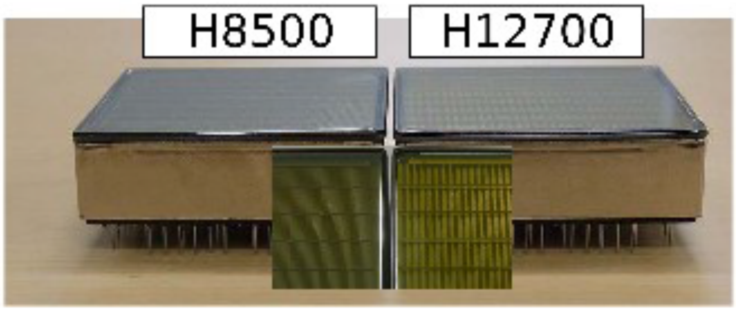
2. Shielding: Steal



2 x 0.6 x0.1-0.15 m³



3. Combine 1 & 2: Maximum stray field is 1mT



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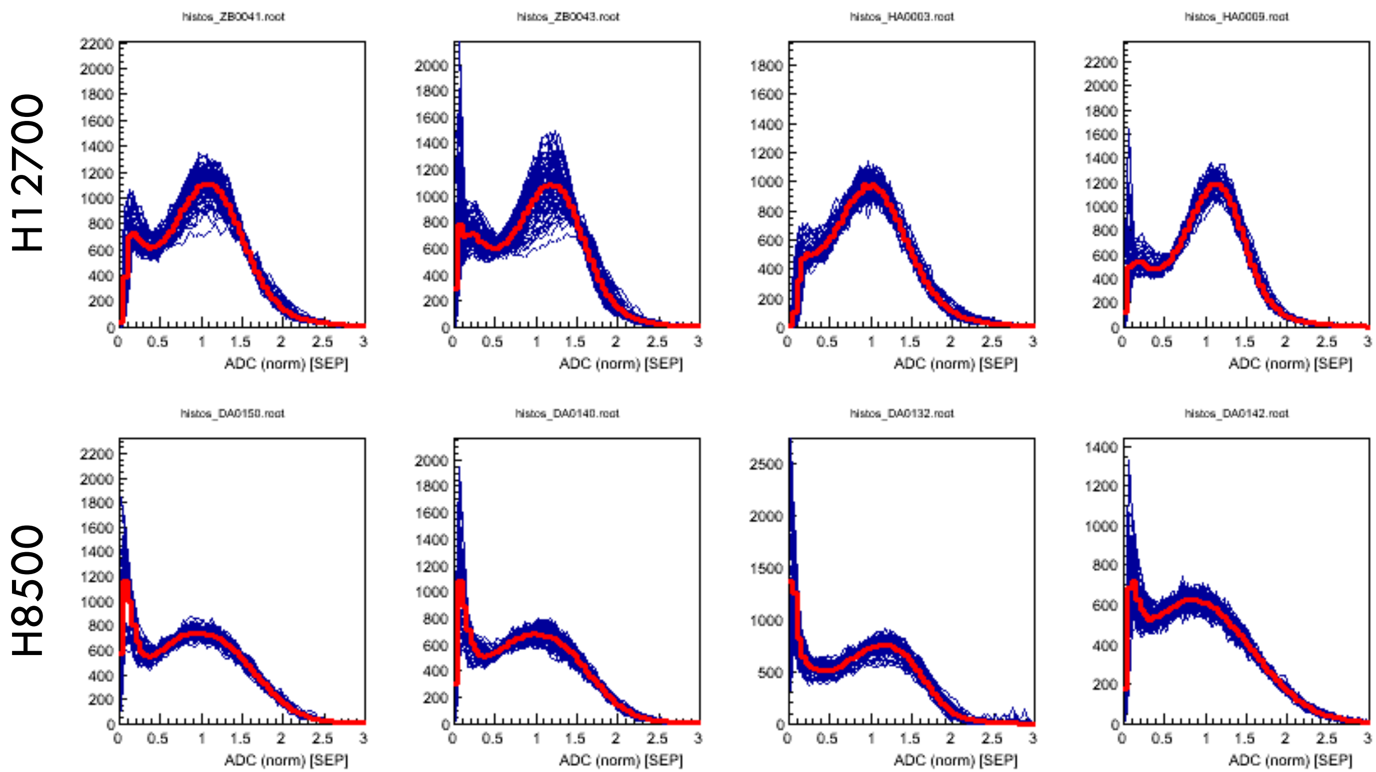
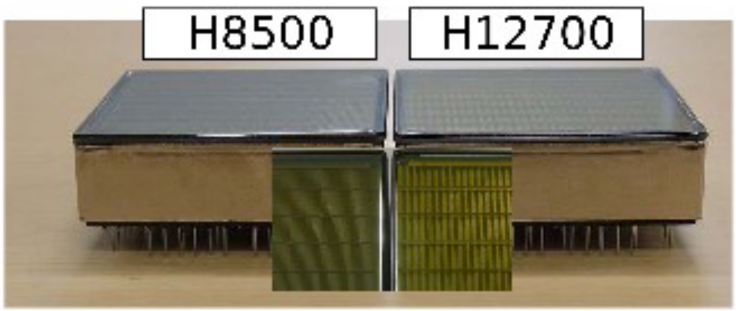
PROPERTIES:

- Significantly improved single photon spectrum.



Photon Detector: Hamamatsu's New Development



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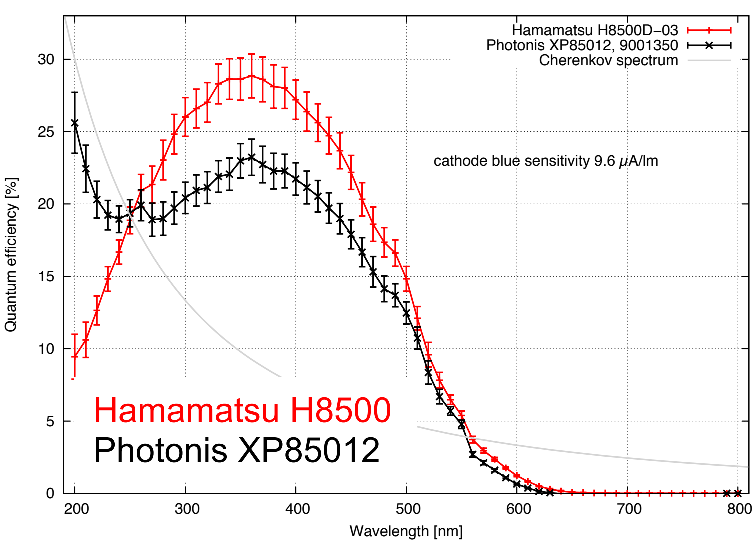
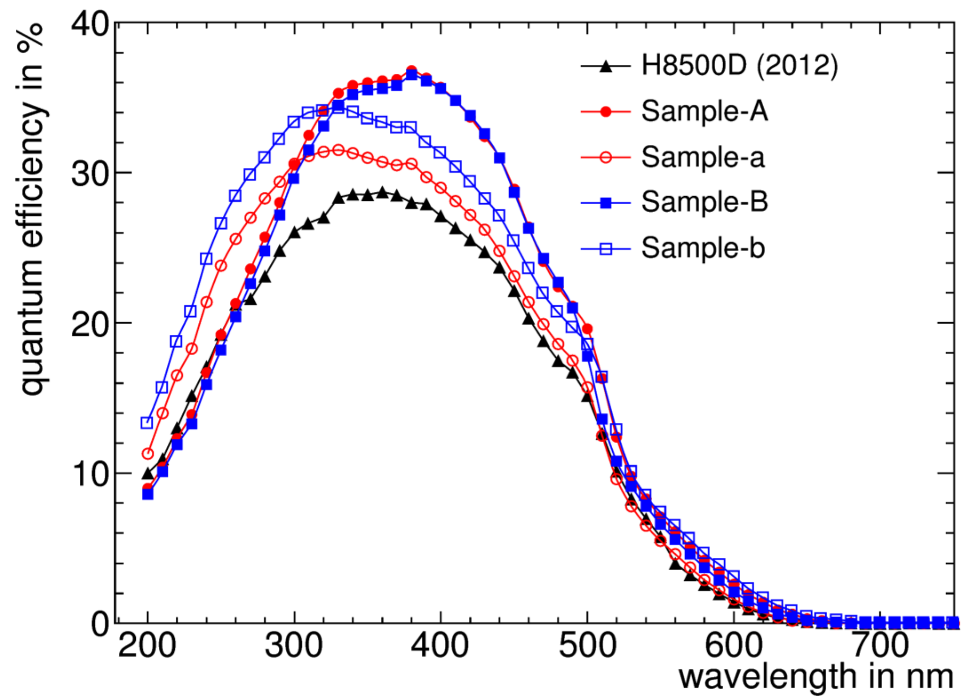
Properties:
- Significantly improved single photon spectrum.
- Higher quantum efficiency.





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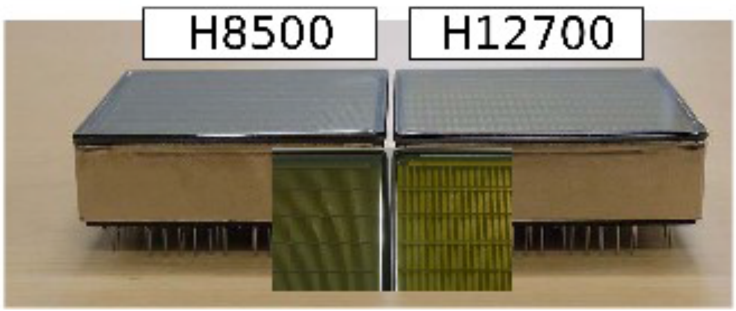

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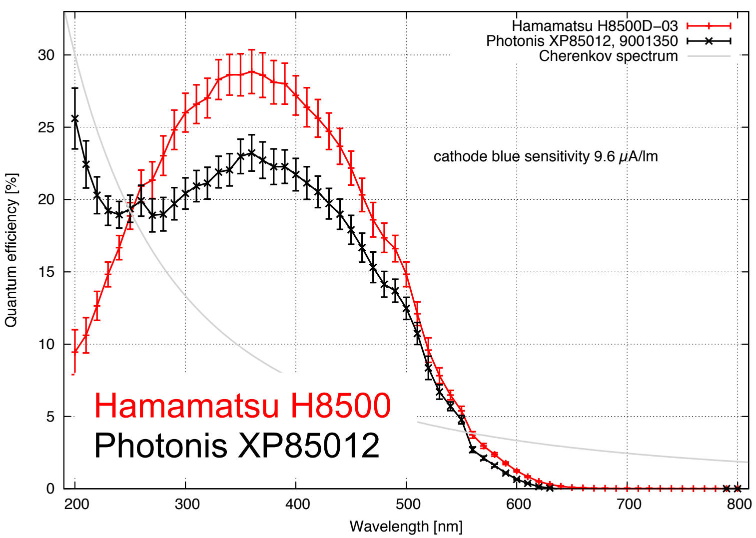
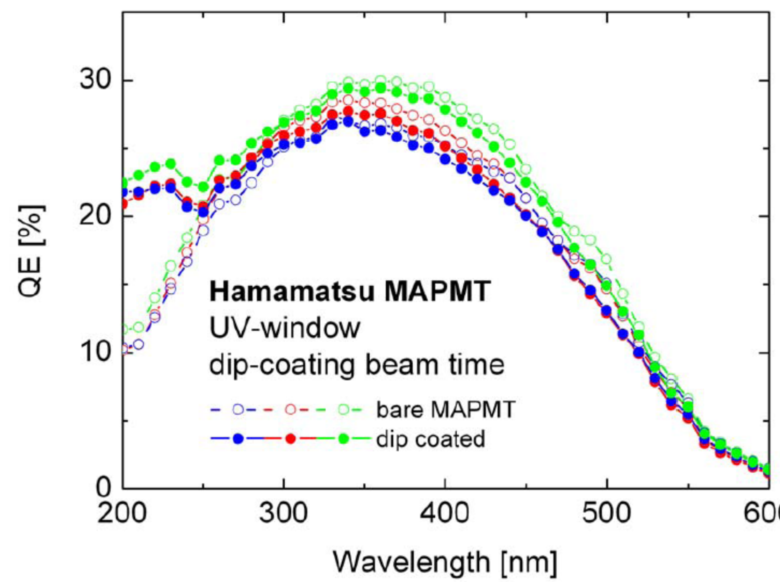
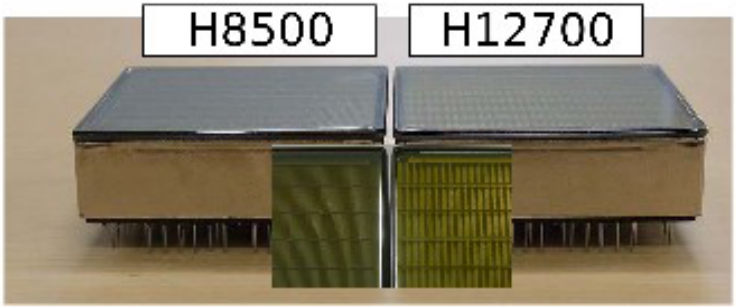




Wavelength Shifting Films: p-Terphenyl

Photon Detector: Hamamatsu's New Development



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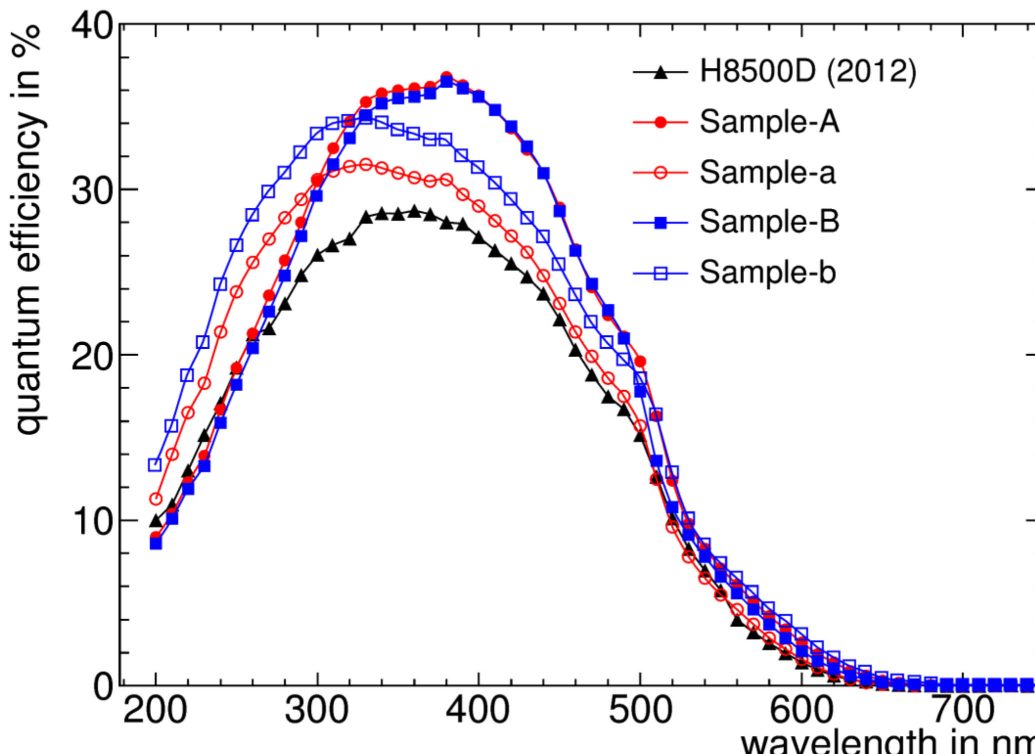
Properties:
- Significantly improved single photon spectrum.
- Higher quantum efficiency.
- Higher collection efficiency.

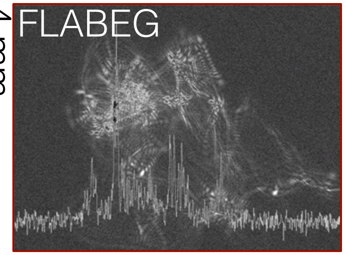


Planning to use H12700
- 2.4 m^2, 55k Ch.

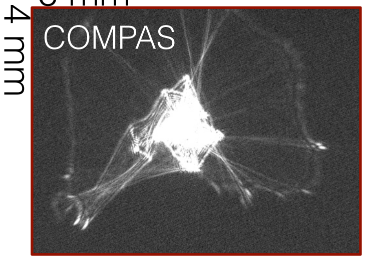
THE MIRROR SYSTEM

Homogeneity: Influences the photons distribution → ring fitting performance

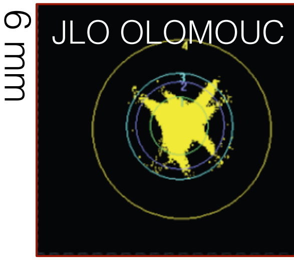
6 mm
4 mm



6 mm
4 mm



6 mm
6 mm

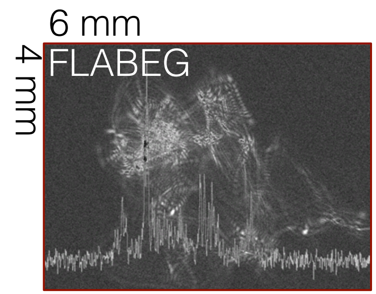


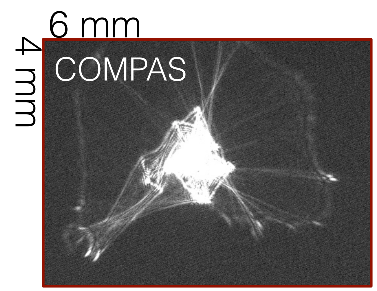
D_0 (mm)	Very bad	2.3	2.3

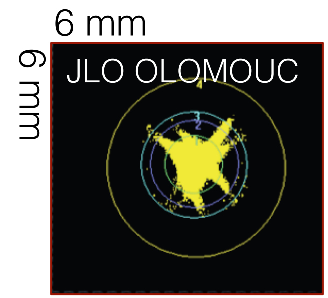
- D_0 is a measure of the mirror homogeneity.
- It is the diameter of a circle containing 95% of reflected light and being emitted through a point source.
- Required is a D_0<=3mm.

Homogeneity: Influences the photons distribution → ring fitting performance

Required is a D_0<=3mm.

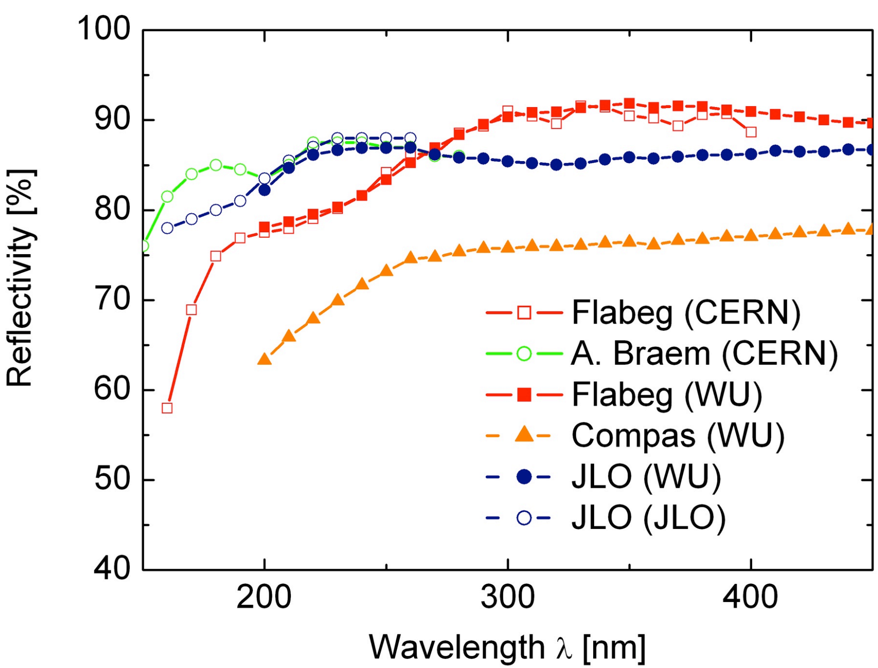






D_0 (mm)	Very bad	2.3	2.3

Reflectivity: Influences the number of photons → ring quality

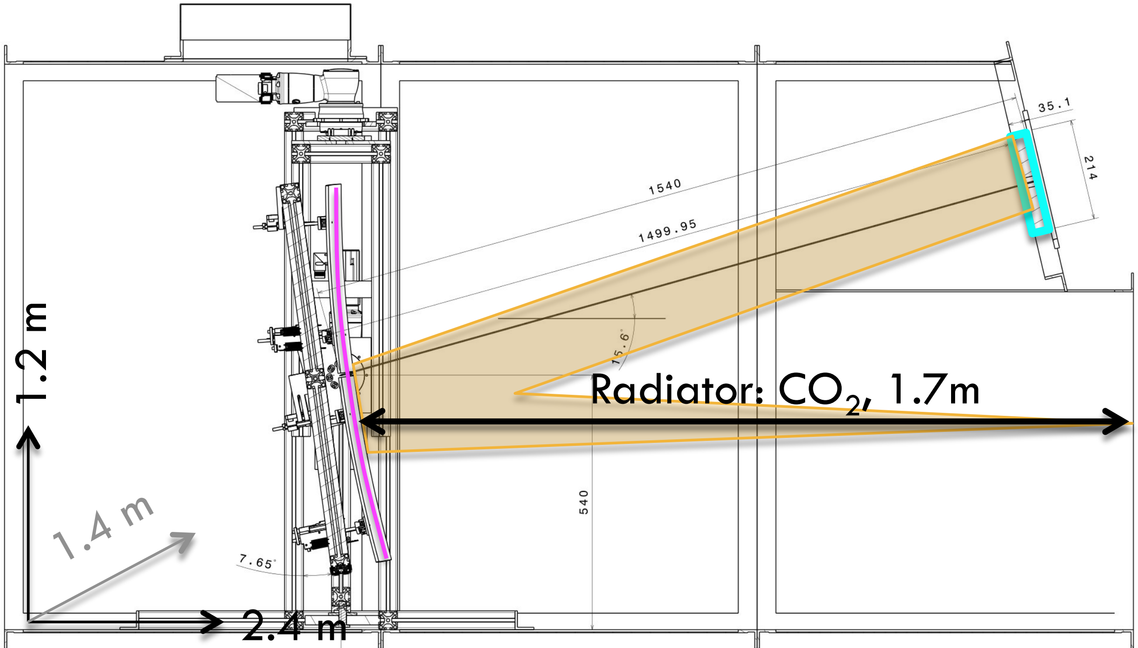


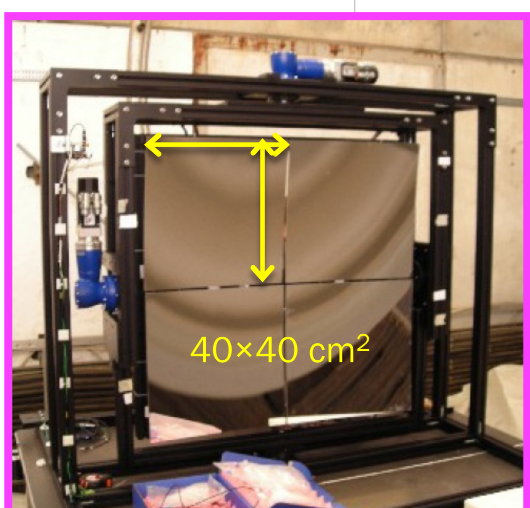
- Compas: <80%
- Flabeg: >90% (λ>270nm)
  ≈60% (λ=160nm)
- OLOMOUC: ≈85% (λ>200nm)
  ≈80% (λ≤200nm)

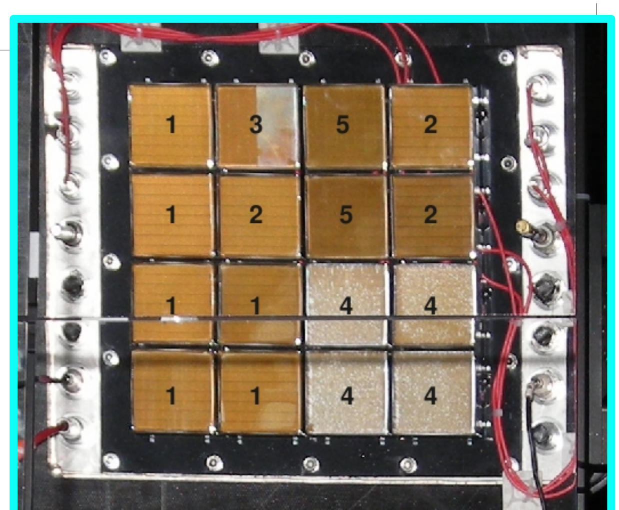
Mirrors from OLOMOUC are considered

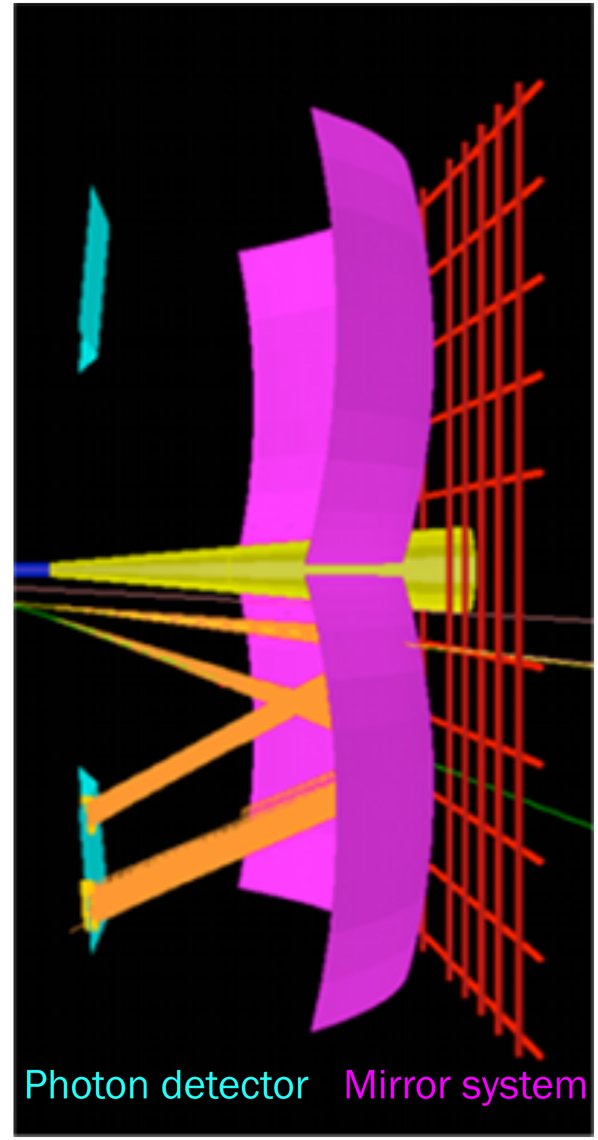
- SIMAX-glass, Al+MgF_2
- R = 3m, d ≤ 6mm
- 11.8 m^2
- Tiles of 40×40 cm^2

THE RICH PROTOTYPE







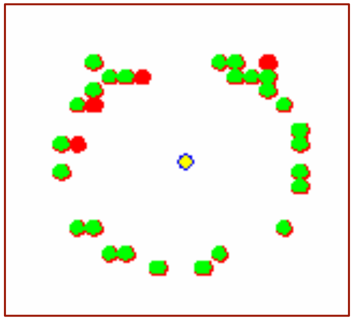


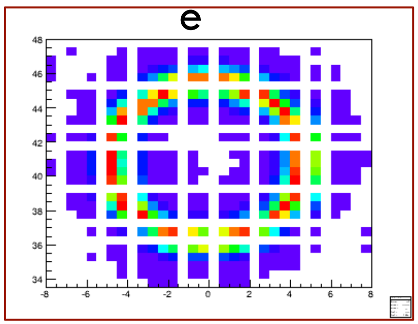
Laterally scaled prototype

The RICH Prototype

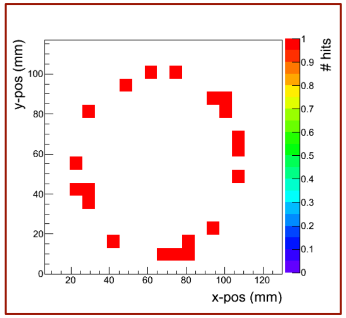
JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

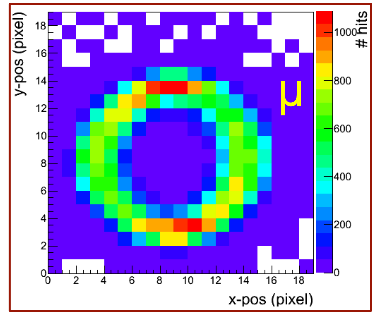
Simulation

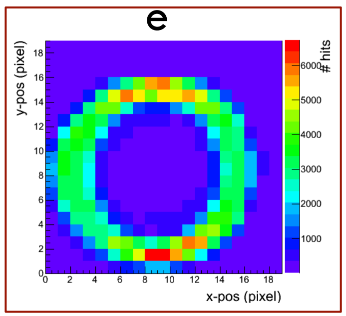


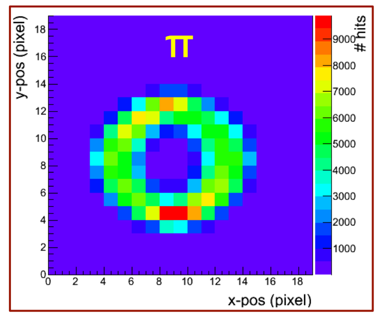


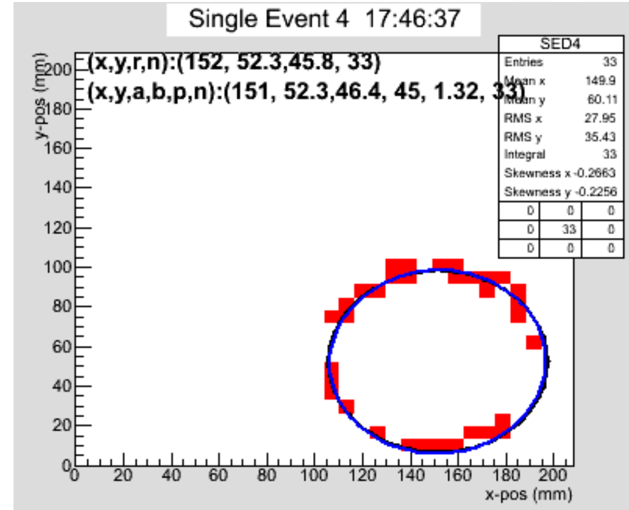
Data

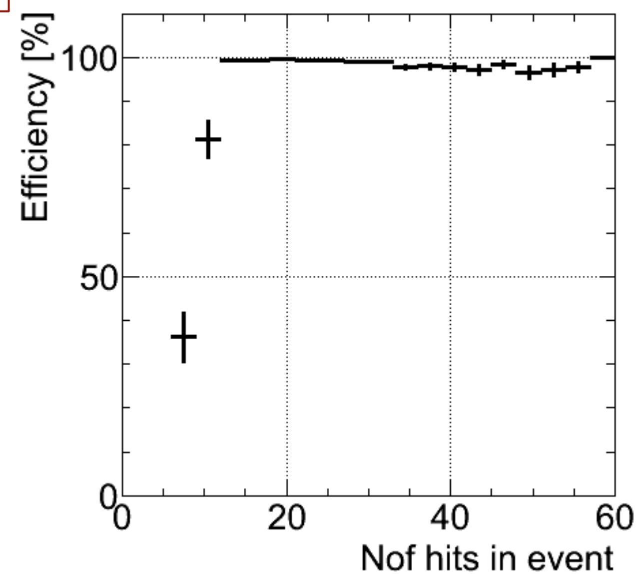








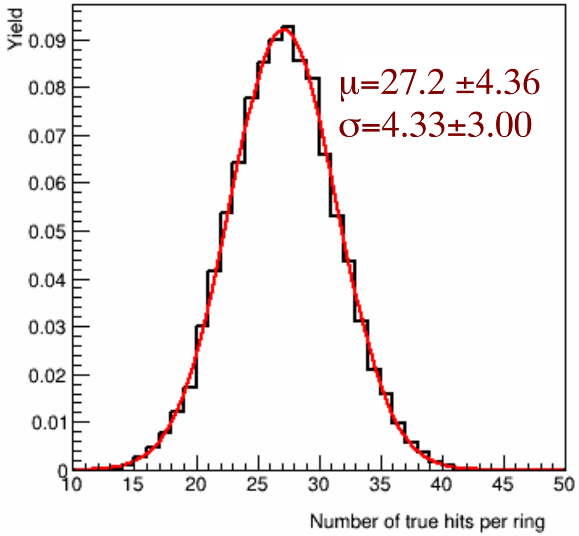




- Qualitative agreement between simulation and data.
- High performance of ring finding and fitting
  → 100% efficiency for number of hits above 6.
- Total "dark rate" ~5500 Hz from 1024 channels
  → Below 10 Hz/pixel in most of channels

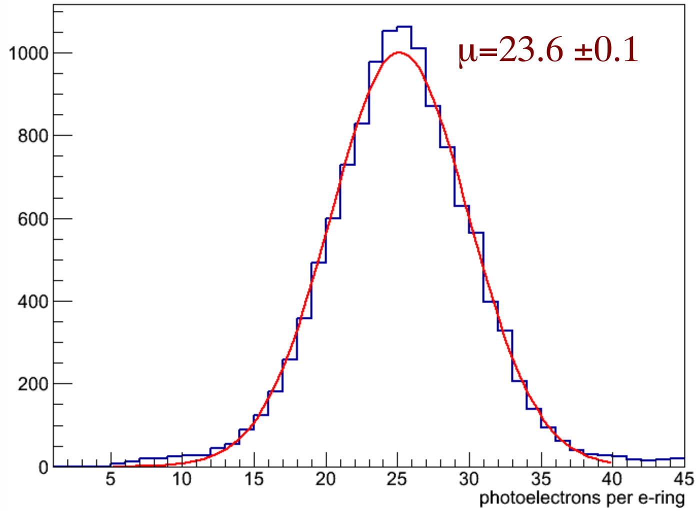
The RICH Prototype: N-Hits

Simulation



T=273 K, p=1 bar
Collection eff. =100%

Data



T=293 K, p=0.96 bar
Collection eff. =60%?

$$n(T,p) = 1 + (n_0 - 1) \bullet \frac{T_0}{p_0} \bullet \frac{p}{T}$$

Data = 0.867 • MC

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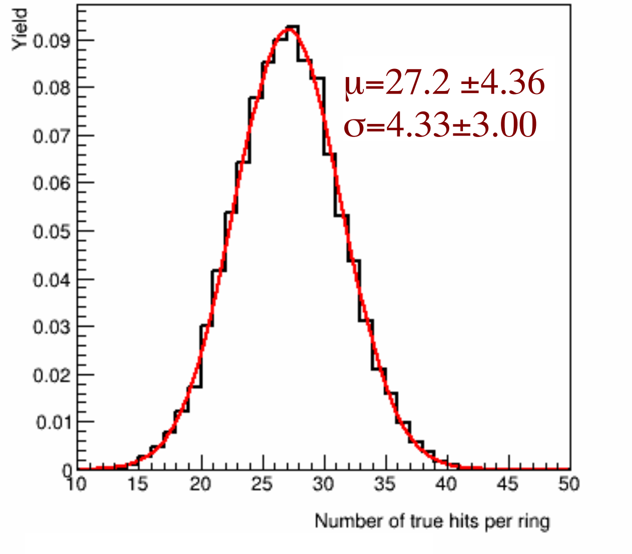

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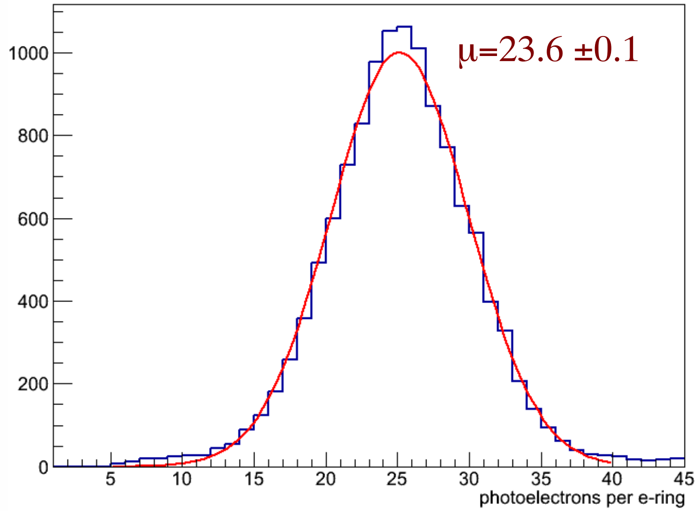

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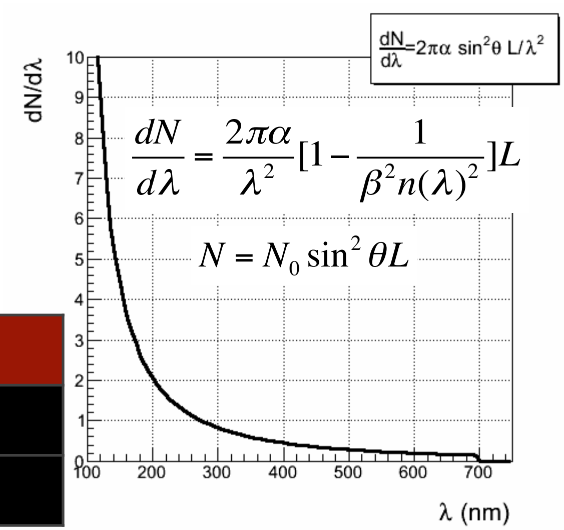
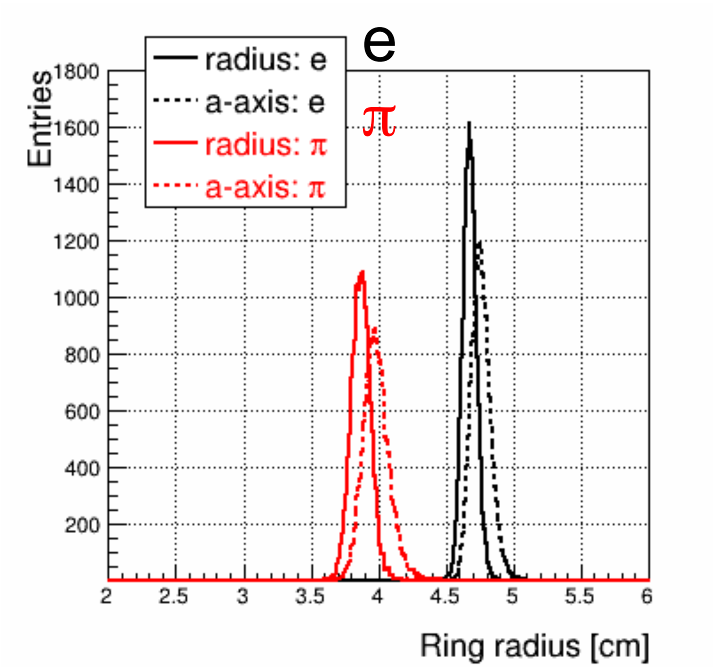


Wavelength Shifting Films: p-Terphenyl

WLS	Hit/ring MC	Gain	Hit/ring Data	Gain	Hit/ring MC/Data
no	27.2		23.6		-15.3%
yes	31.9	18.1%	28.0	18.6%	-13.9%

The RICH Prototype: Ring Radius

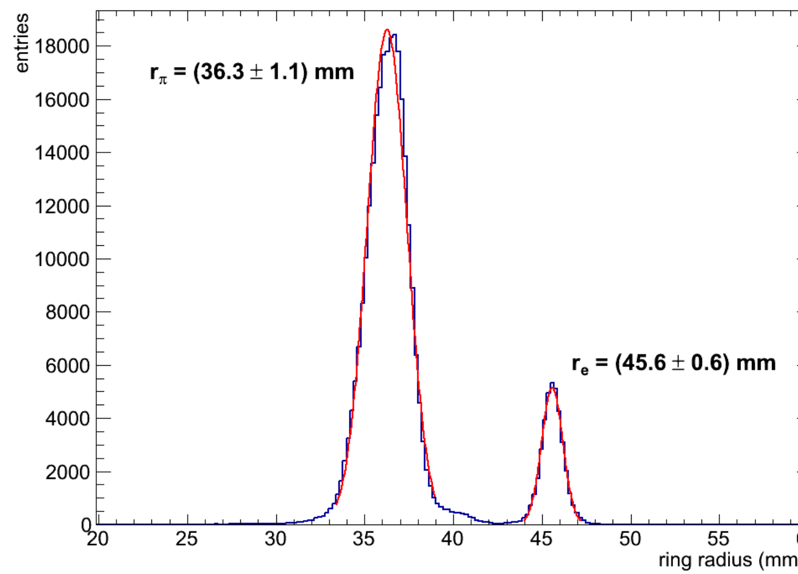
Simulation T=273 K, p=1 bar



r_e=4.68 cm

r_π=3.88 cm

Data T=293 K, p=0.96 bar



r_e= (4.56±0.6±0.11) cm

r_π= (3.63±1.1±0.09) cm

$d_{e\pi} > 7\sigma_\pi$

$$r(n) = L \bullet \tan\theta_c = L \bullet \tan\left(\arccos\frac{1}{\beta n}\right)$$

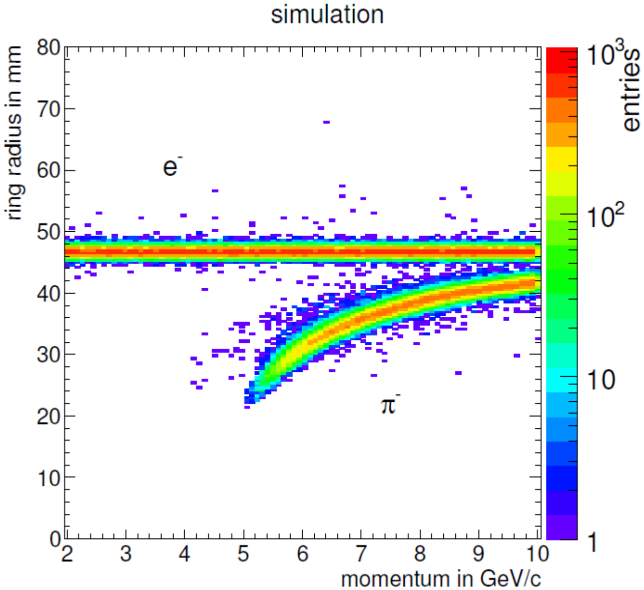
Pressure and temperature correction →

r_{MC}=1.04*r_{data}

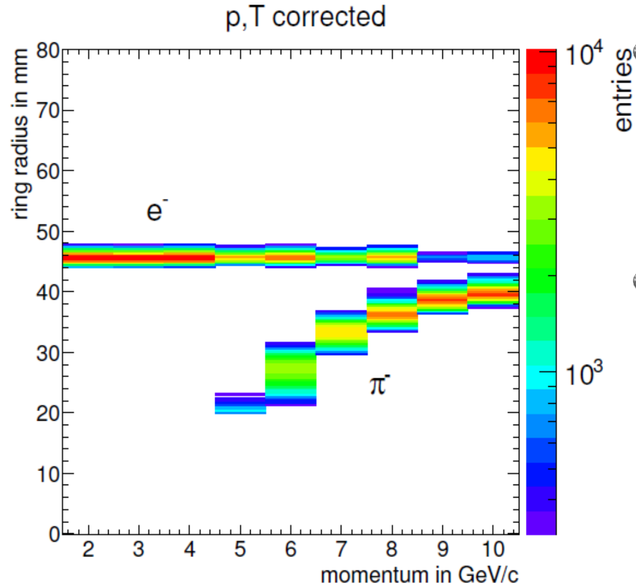
One finds: r_{MC}=1.05*r_{data}

The RICH Prototype: Pion Suppression Factor

Simulation



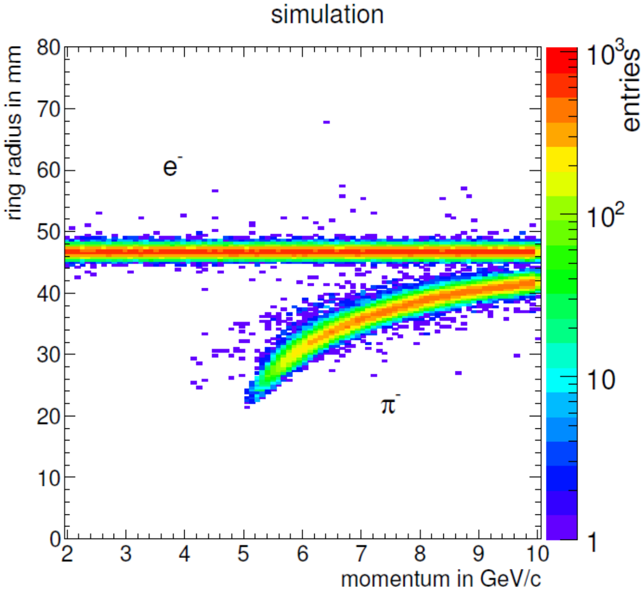
Data



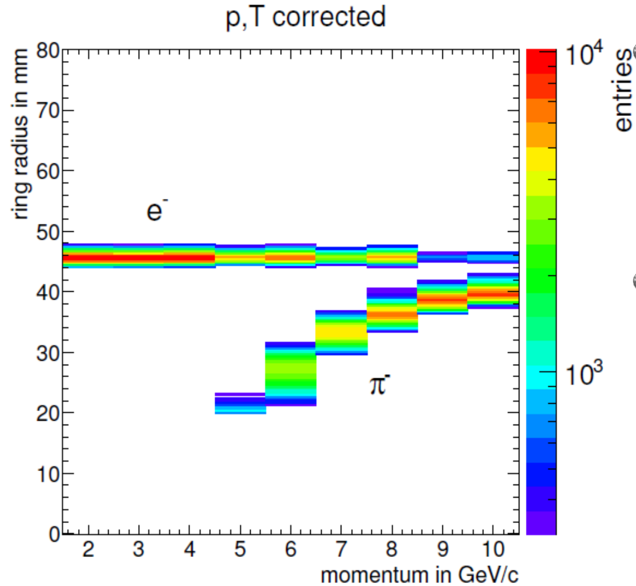
- Very good qualitative agreement between data and simulations is observed.
- Wider distribution in ring (y-) direction because of muons.

The RICH Prototype: Pion Suppression Factor

Simulation



Data



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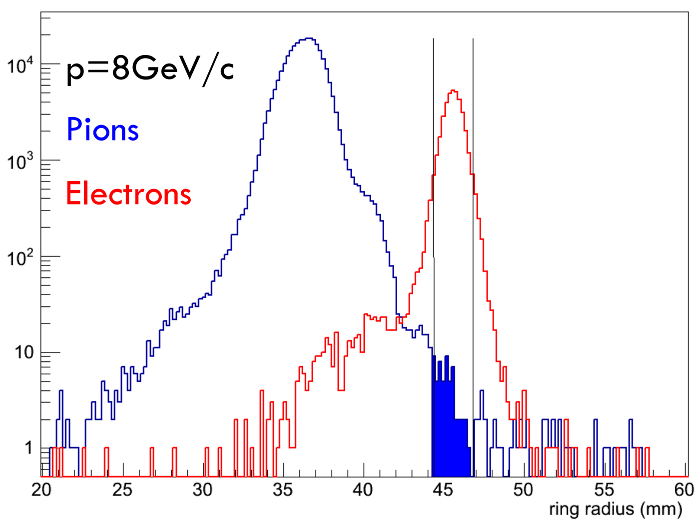
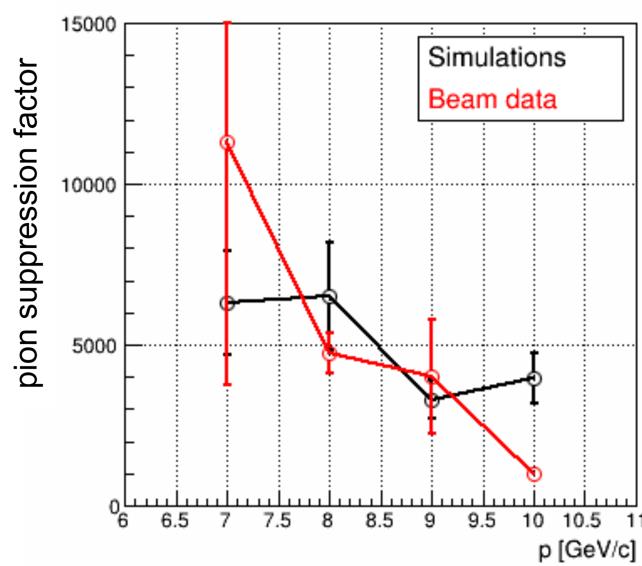




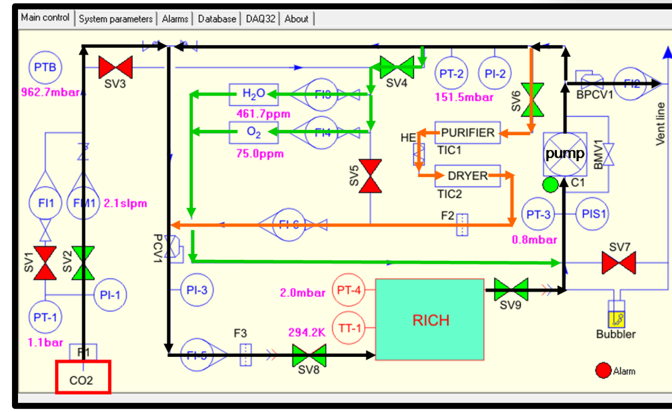
π_{SF} = 4760 @ 8GeV

The RICH Prototype: Other Tests

JUSTUS-LIEBIG-UNIVERSITÄT GIESSEN

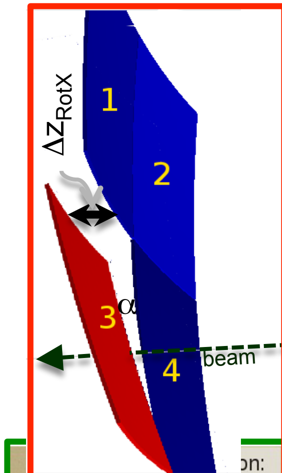
Gas system

- Provides pure CO_2 gas
- Constant over pressure of 2 mbar.
- Determine impurity tolerances



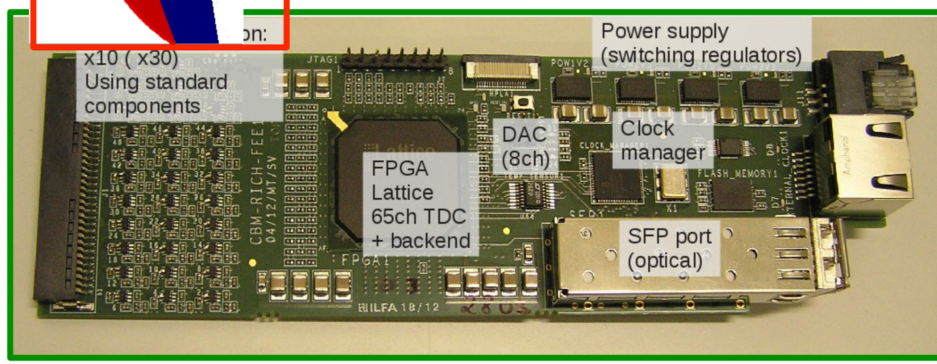
Mirror displacement

- Deteriorate the resolution of ring fit →
- Determine displacement tolerances



New electronics

- Compact with good time resolution

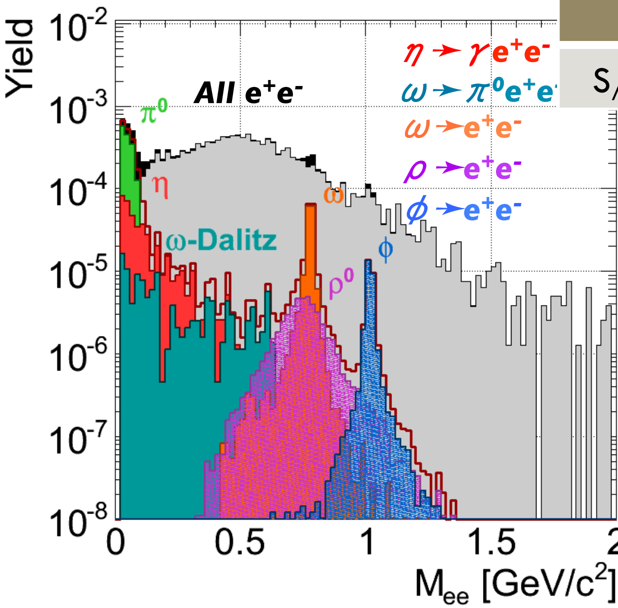


Next Beam Time (Nov14)

- Test new PMTs
- Test updated new electronics
- Test mirror alignment system

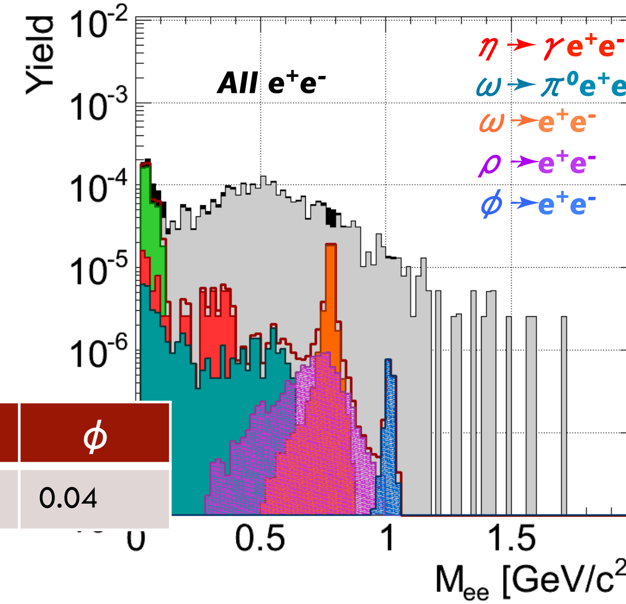
Physics Performance

25 AGeV: 200k events ~8 sek of beamtime



	ρ	ω	ϕ
S/BG	-	0.31	0.11

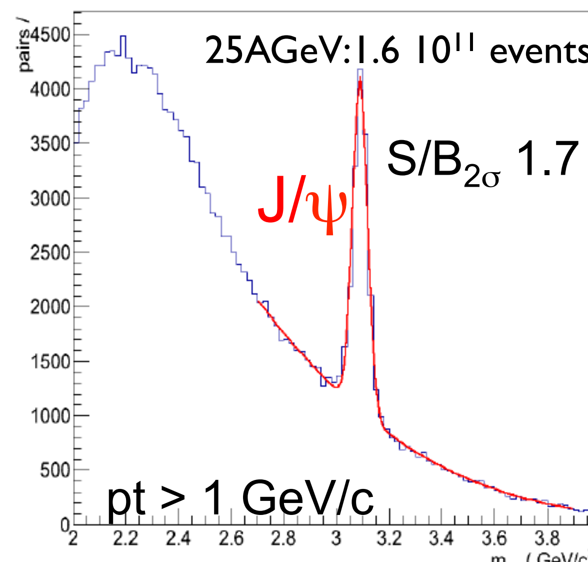
8 AGeV: 100k events ~4 sek of beamtime



	ρ	ω	ϕ
S/BG	-	0.64	0.04

25 AGeV:

- Mass resolution: 13.6 MeV (ω) and 44 MeV (J/ψ)
- LMVM spectra for SIS100 show similar quality
- J/ψ in central pAu at 30GeV with S/B=1.25 („thick“ 1% int. length target)



Conclusion

- RICH is essential for the CBM experiment at SIS100 & SIS300.
- A concept has been established to cope with the CBM (FAIR) environment.
- Individual components tested and chosen.
- Concept verified through a real dimension prototype.
- Simulation under realistic conditions show very promising physics performance.
- TDR is approved.
- Next:
  - Clarify some open issues: readout electronics, geometry optimisation, mirror alignment controlling system.
  - Start building the detector.

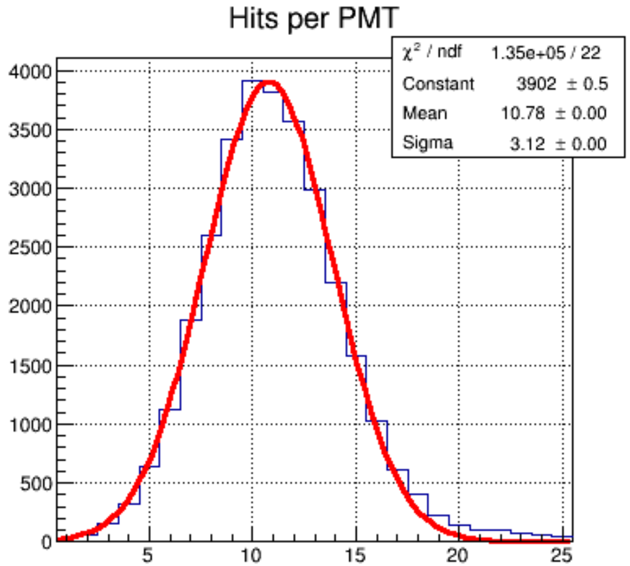
BACKUP

Tariq Mahmoud

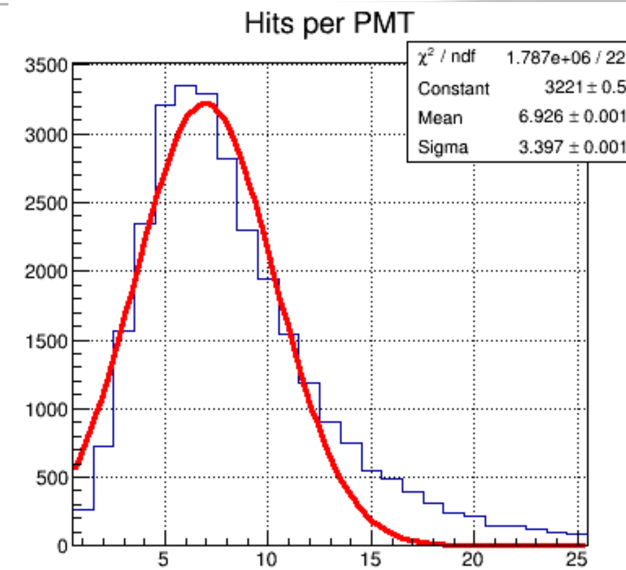
International Conference on Science and Technology for FAIR in Europe

13-17. Octobre • Worms • Germany

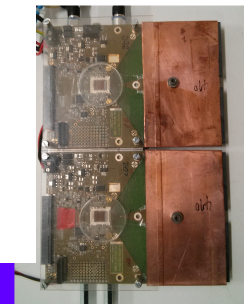
New Electronics

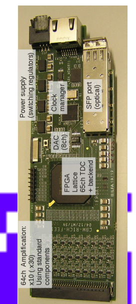


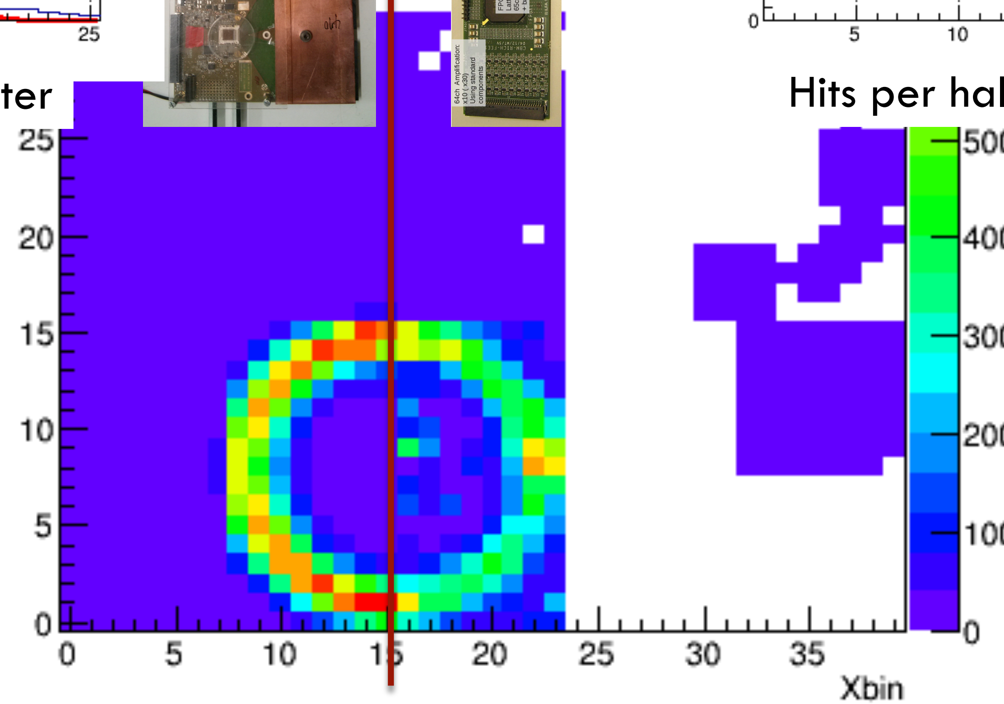
Hits per half ring: nXYter



Hits per half ring: TRBRICH





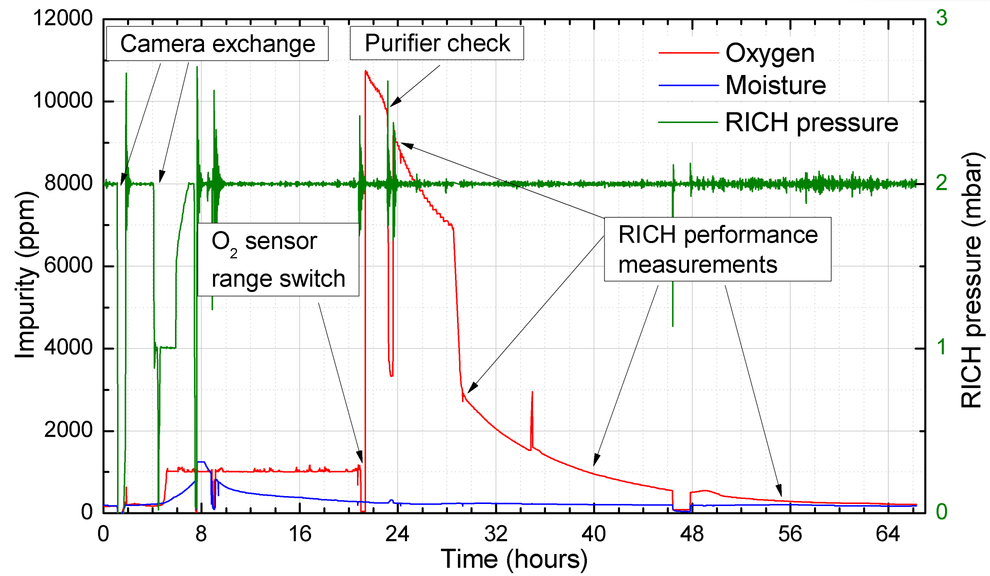


Integrated Cherencov ring: left half nXYter, right half TRBRICH

GAS SYSTEM

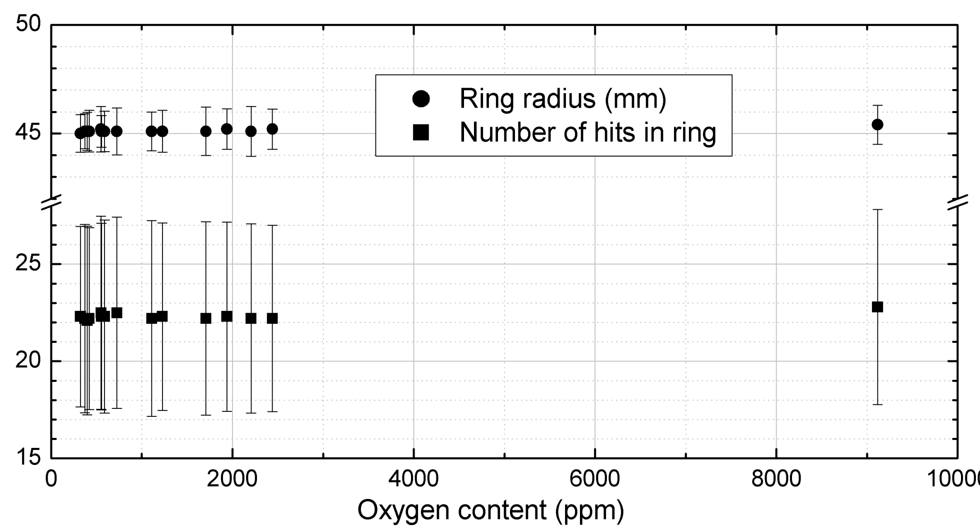
Normal operation:

- Constant differential pressure of 2 mbar ± 1%
- O_2 (H_2O) impurity about 80 (250) ppm



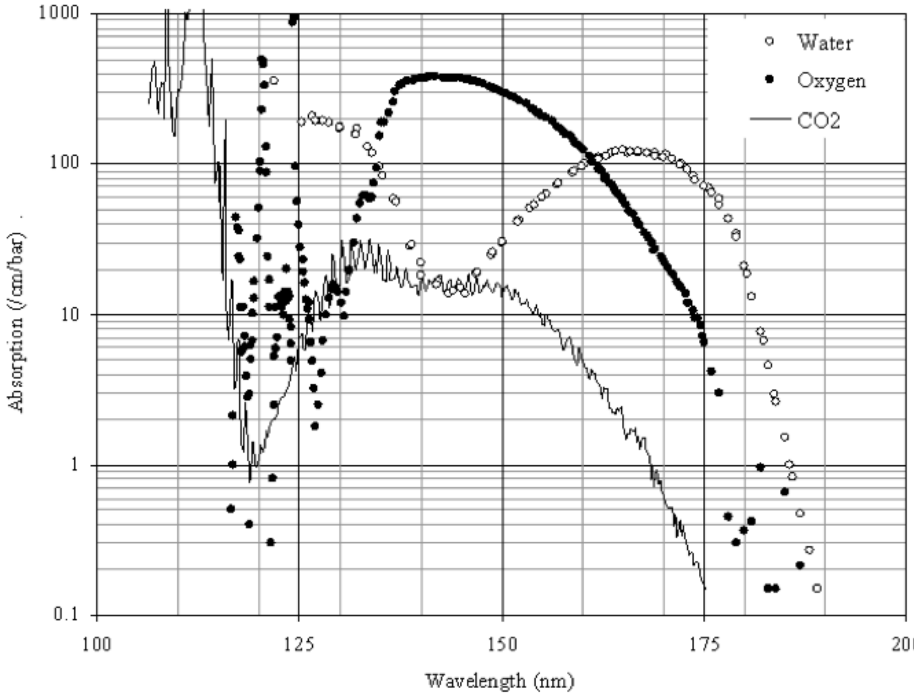
Tested up to:

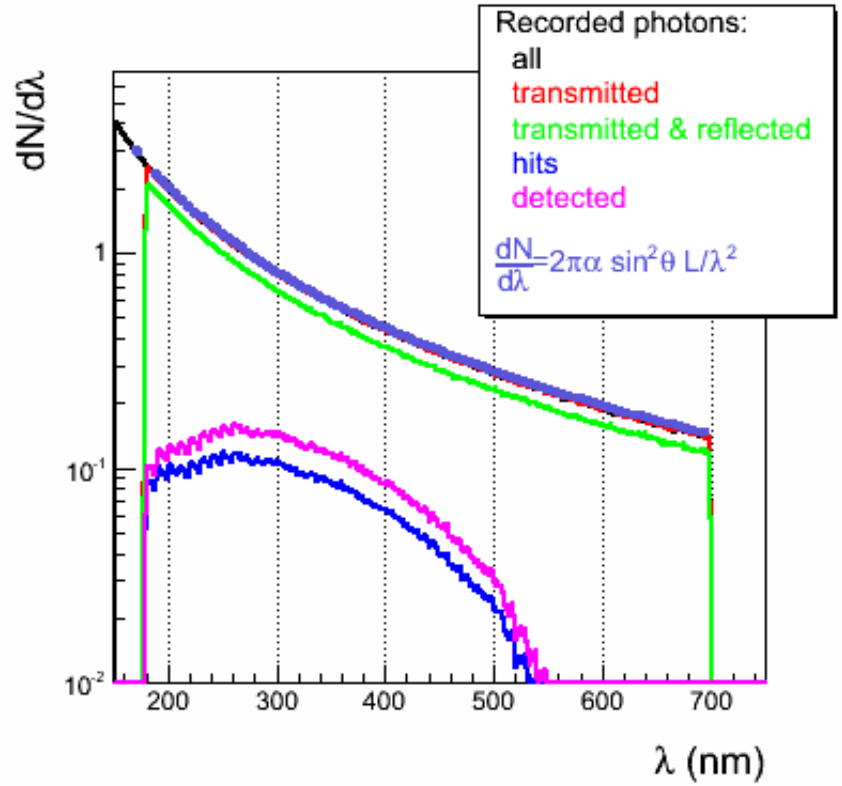
- O_2 impurity of 10000 ppm
- H_2O impurity of 1100 ppm



THE RADIATOR

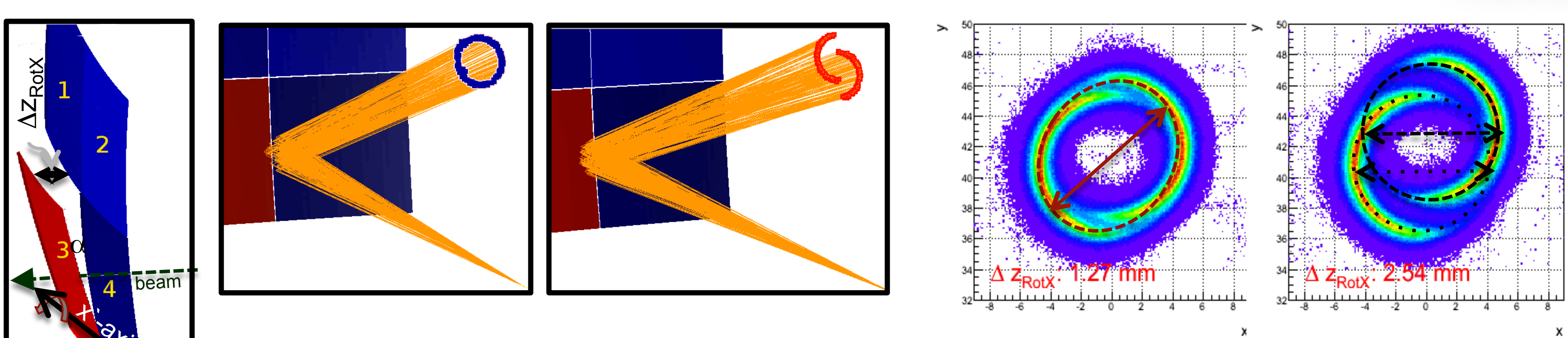
	n-1 [10^{-4}]	γ_{th}	λ_{th} [nm]	$p_{th}(e)$ [GeV]	$P_{th}(\pi)$ [GeV]
CO_2	4.3	33.3	~180	0.017	4.76

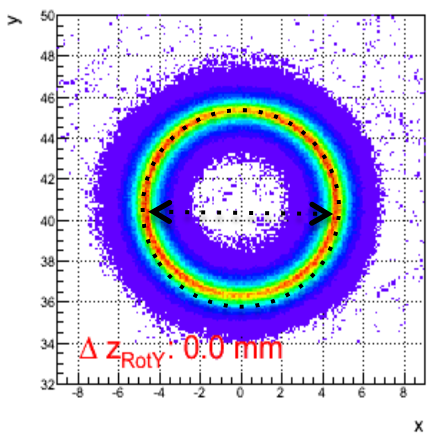




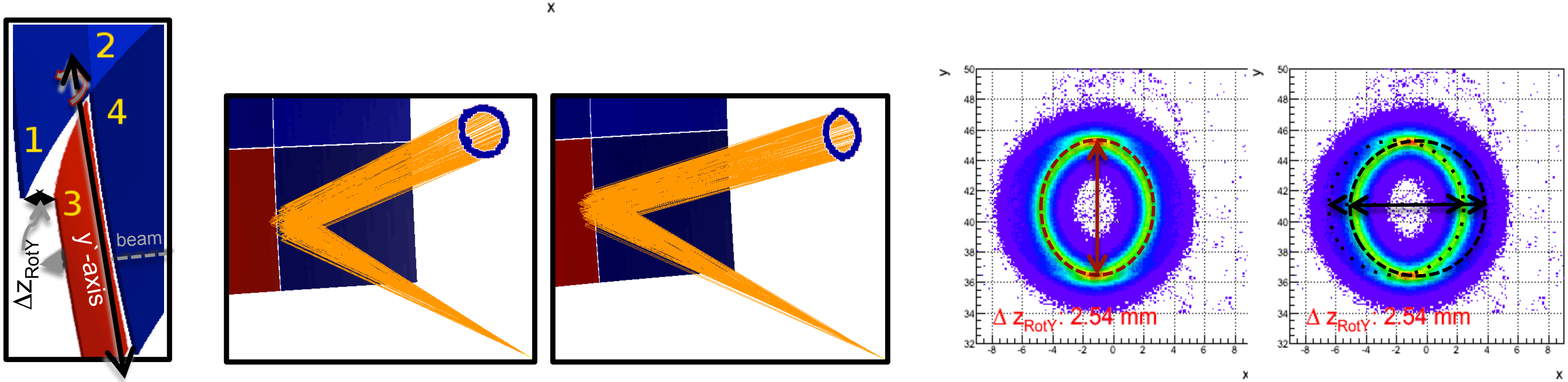
	Radiator length [m]	Full length [m]	Mirror radius [m]	Mirror size [m^2]	Photon detector plane [m^2]	# of channels
CO_2	1.7	2.1	3	11.8	3.7	55k

Mirror Displacement





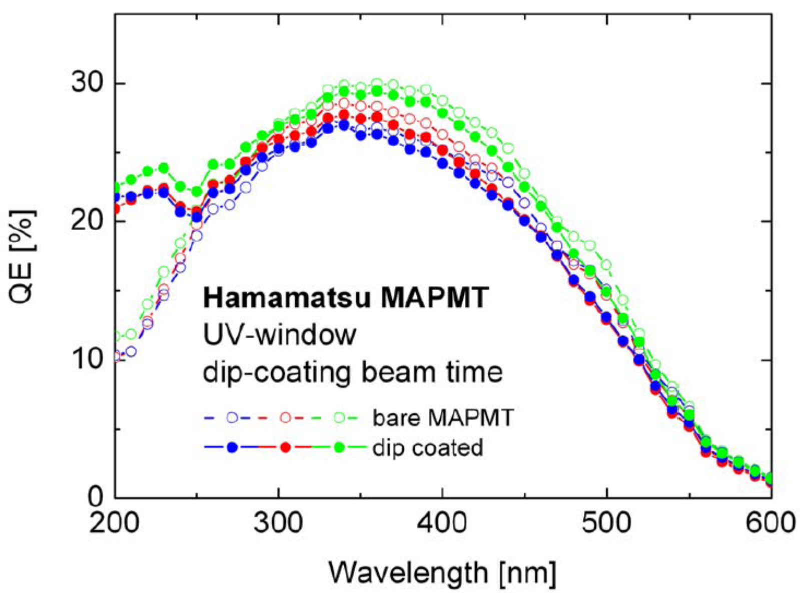
$\Delta Z_{RotX\,(Y)} \leq 0.35$ mm ($\alpha_{X(Y)} \leq 1$ mrad) is tolerable



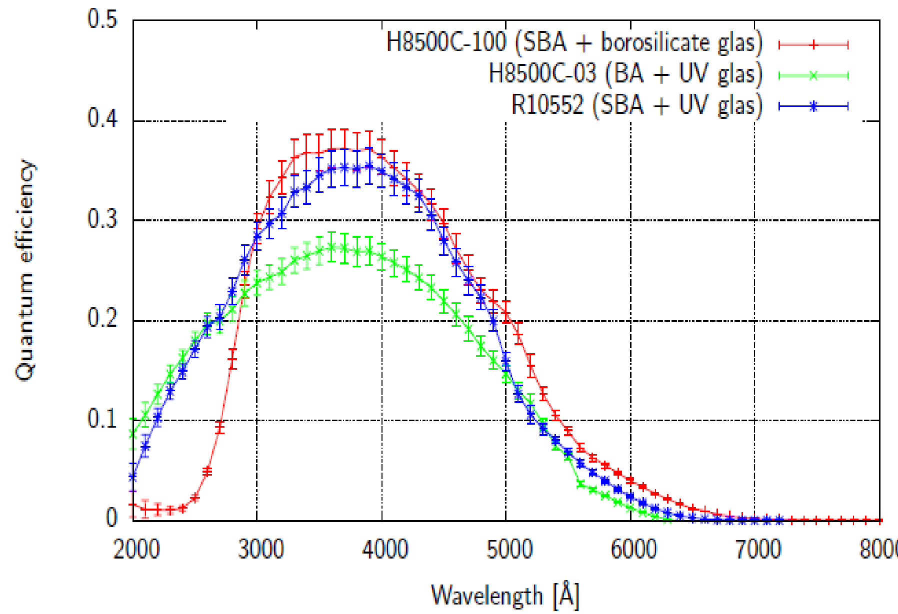
The Radiator

WLS COATING – SBA PHOTOCATHODE

MAPMTs for beam time – QE



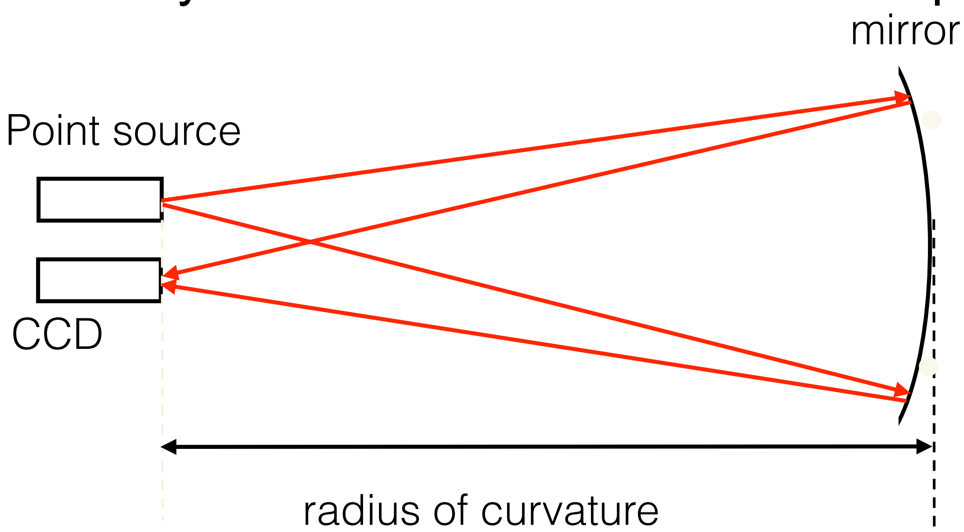
SBA photocathode: 35% eff. max

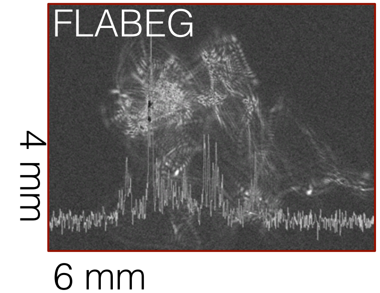


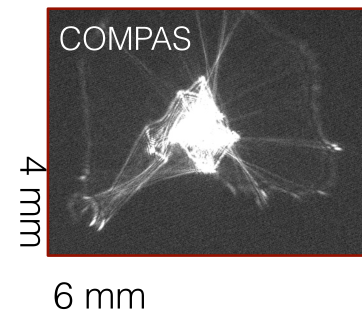
expectation: 17% more hits with WLS coating

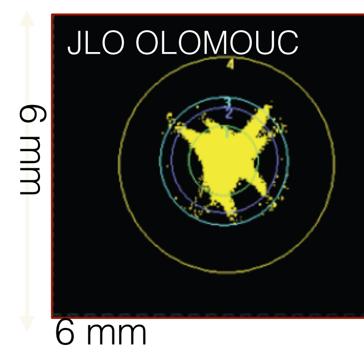
The RICH Concept: Mirror

Homogeneity: Influences the photons distribution → ring fitting performance
Reflectivity: Influences the number of photons → ring quality









Homogeneity:

- D_0 as a measure of the mirror homogeneity.
- Reflect a point-like source on the mirror and record its image.
- Ideally the image is also point-like. In Reality, inhomogeneity causes a non-homogenous spot (picture).
- D_0 is the diameter, of a circle, which contains 95% of the reflected light

	required	FLABEG	COMPAS	JLO OLOMOUC
D_0 (mm)	≤3	Very bad	2.3	2.3