HERA-B RICH

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4. Particle identification
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HERA-B RICH group

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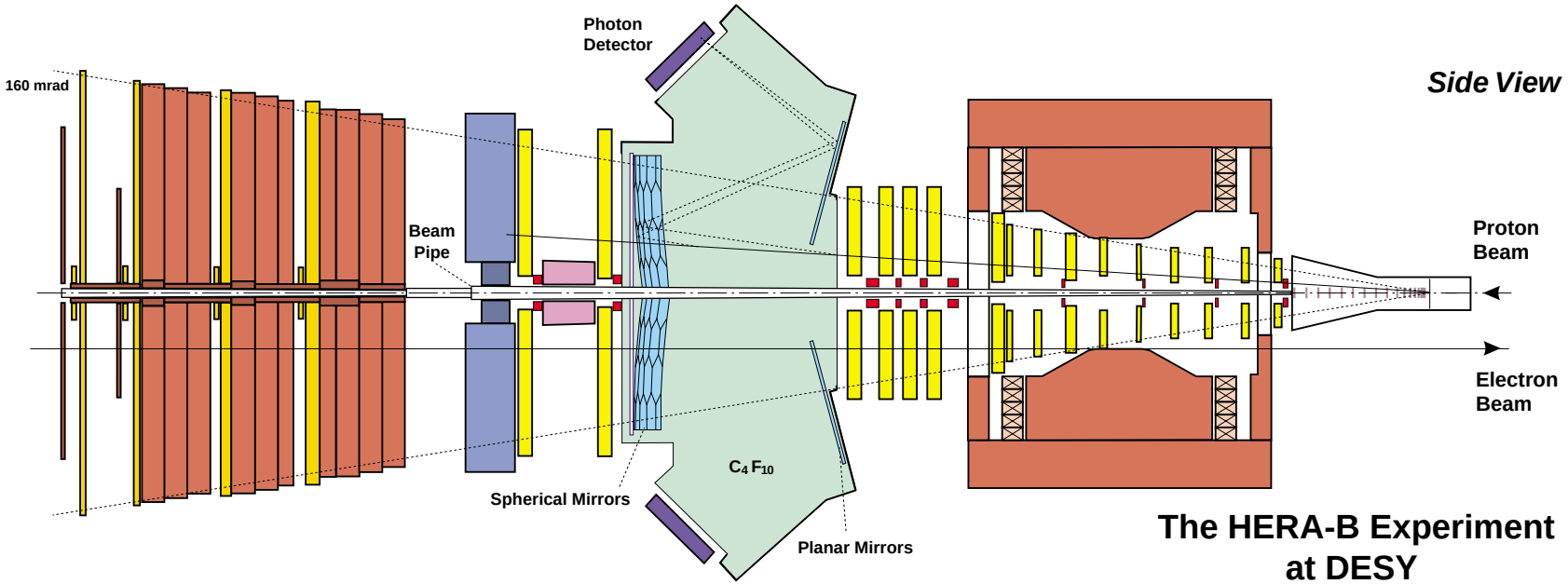
The HERA-B experiment

- Fixed target experiment at HERA proton beam
  - → Target(s) in the beam halo
  - → 10 to 20 MHz interaction rate
  - → High track multiplicities
- Purpose: study of B and D mesons, J/ψ production



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Particle Identification at HERA-B

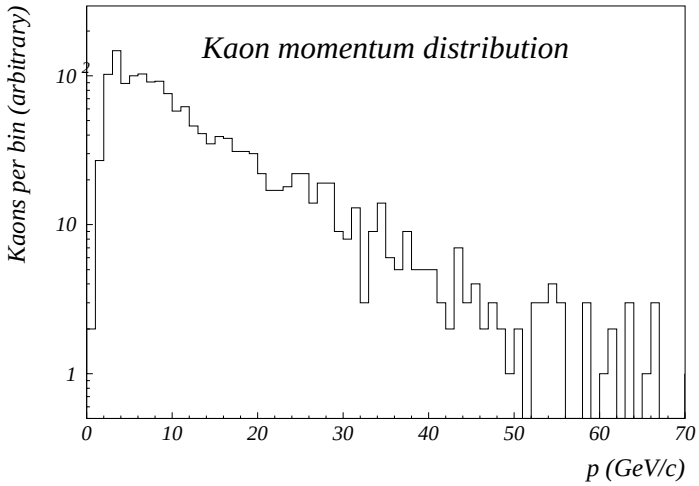
- ECAL and TRD: electrons
- MOUN: muons
- RICH: pions, kaons and protons

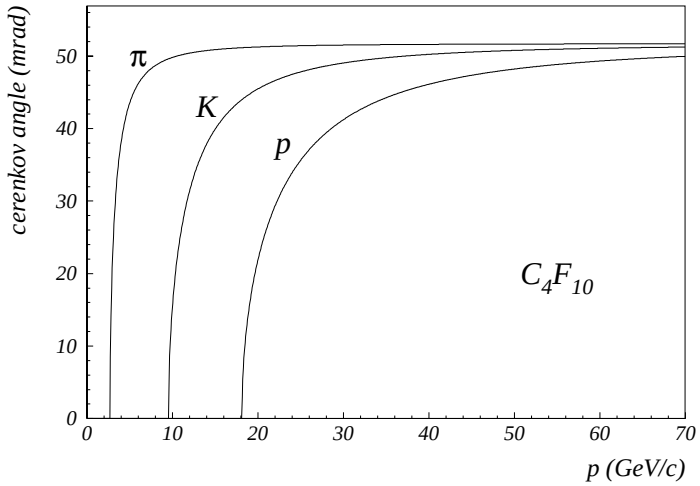
  $\rightarrow$ separation between kaons and pions, and protons and pions

The choice of Čerenkov radiator:

- K/π separation between $3GeV/c$ and $50-60GeV/c$

  $\rightarrow$ C_4F_{10} (gas), $n = 1.00137$, $\theta_{cer}^{max} = 52.4mrad$





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The choice of RICH geometry

- Radiator length: $2.8m$
  (more than 20 photons requires few meters of radiator)

- Focusing: spherical mirror(s), $f = 5.7m$
  (center of curvature at the interaction point, space left for the RICH)

- Photon detector position: above and below the spherical mirror
  (out of the solid angle for charged particles)
  $\rightarrow$ spherical mirror divided into upper and lower, each one tilted by 9^0
  $\rightarrow$ additional plane mirrors required

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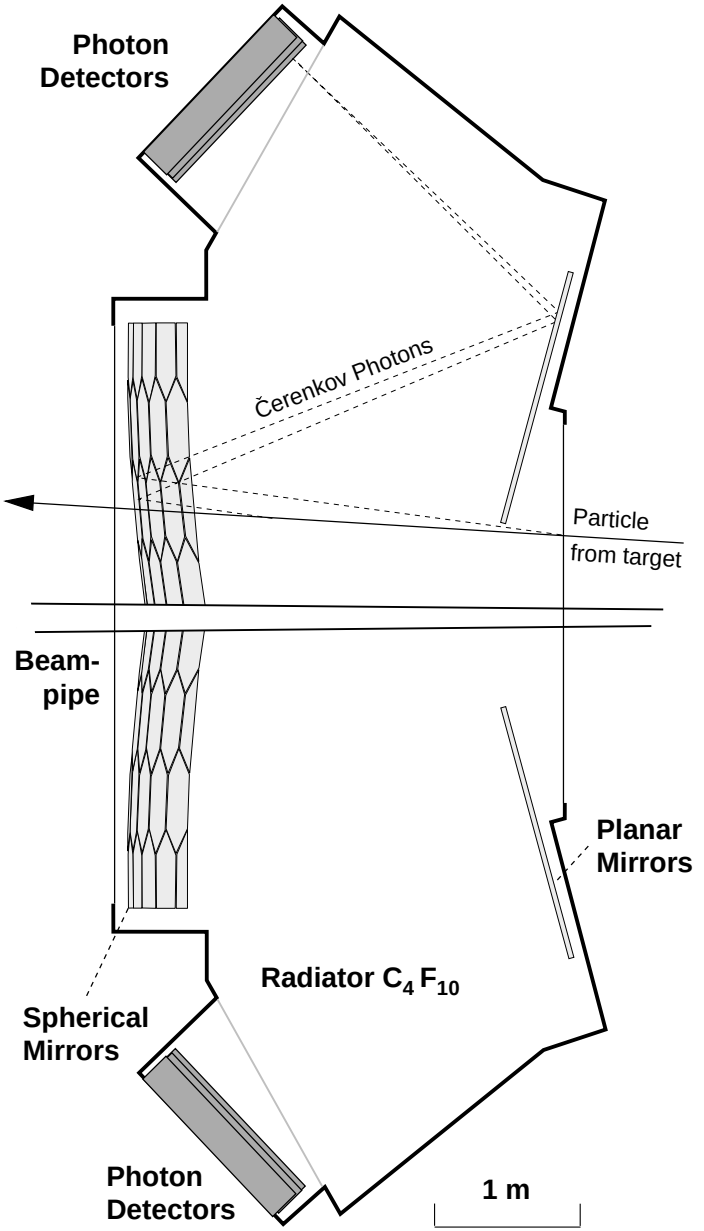
Scheme of the RICH

- $108m^3$ of C_4F_{10}
- Two spherical mirrors, tilted by 9^0, $f = 5.7m$
- Two planar mirrors
- Photon detector with Hamamatsu multi-anode PMT's



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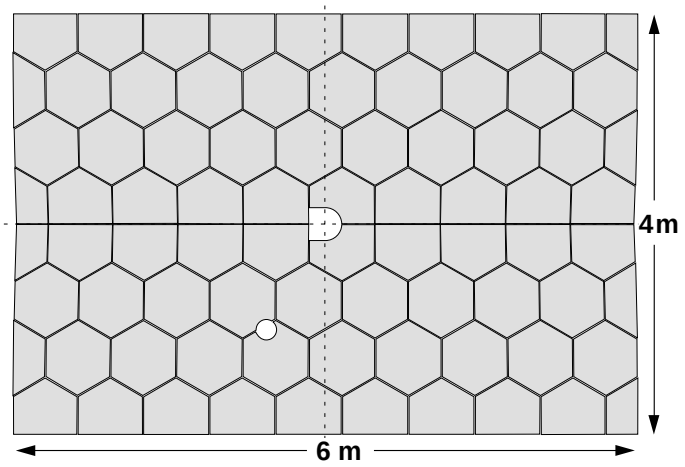
Mirrors

- Spherical mirror
  - consists of 80 full or partial hexagons
  - hexagons made from Pyrex glass, $7mm$ thick
  - coated with $200nm$ aluminum and $30nm MgF_2$
- Planar mirror
  - a set of two mirrors, 18 rectangular elements each
  - rectangular elements made of float glass, $8mm$ thick
  - coated with $200nm$ aluminum and $30nm MgF_2$
- Reflectivity better than 85% ($250nm$ - $600nm$)
- Each mirror piece adjustable by stepper motors from outside



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The RICH photon detector

! Photon fluxes up to few MHz/cm^2 !

Two wire chamber based photon detectors were initially considered:

- CsI photo cathode in a MWPC
  - chamber unstable even at few kHz/cm^2
  - couldn't be produced with sufficiently high quantum efficiency

  $\rightarrow$ abandoned
- TMAE detector with $10cm$ deep $8 \times 8mm^2$ unit cells
  - too fast decrease of avalanche gain due to aging effects

  $\rightarrow$ abandoned

Finally, the decision was:

- Hamamatsu R5900 multi-anode photo multiplier tubes
  - good single photon counting efficiency (large signals)
  - very high counting rates
  - sensitive in the visible light spectrum
  - 16 or 4 channels per PMT
  - outer dimension of $28 \times 28mm^2$, active area $18 \times 18mm^2$ (=40%)

  $\rightarrow$ need light collection system to increase the fraction

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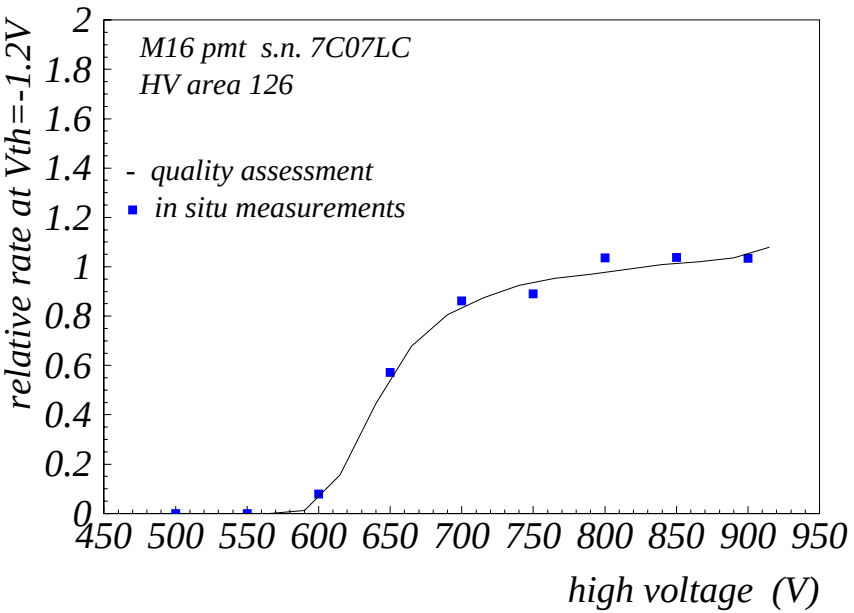
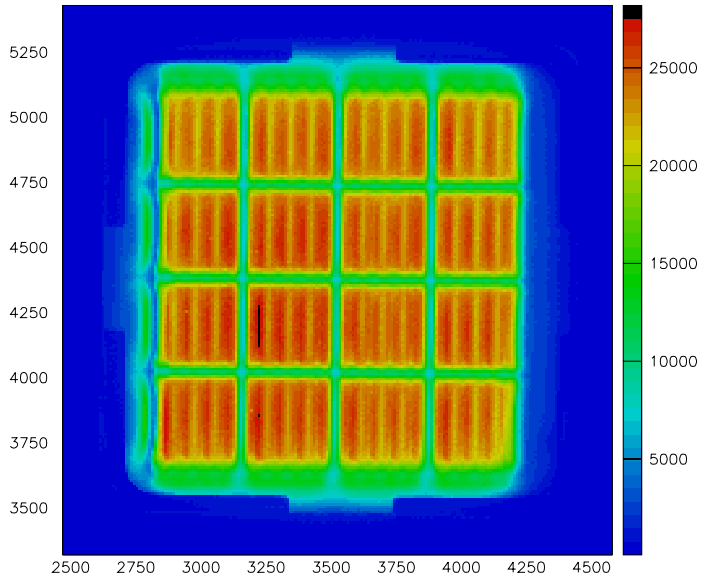
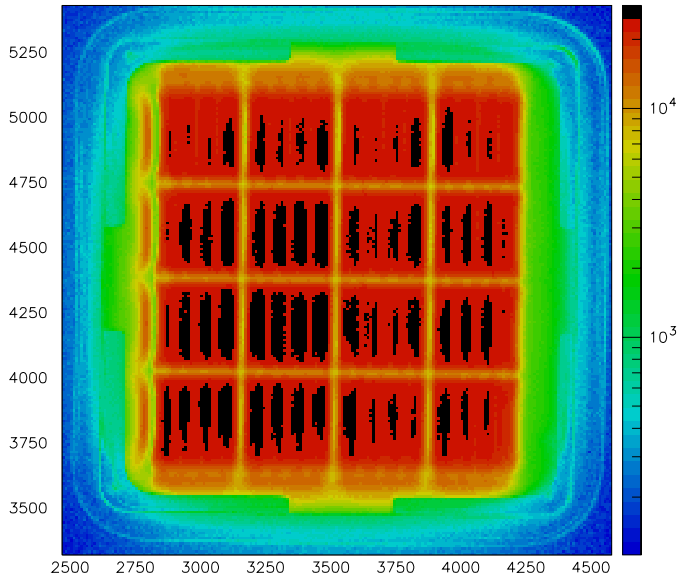
PMT tests

- The plateau curve for typical M16 tube, before and after instalation



- Relative counting rate as a function of a light beam position (beam diameter 30μm)





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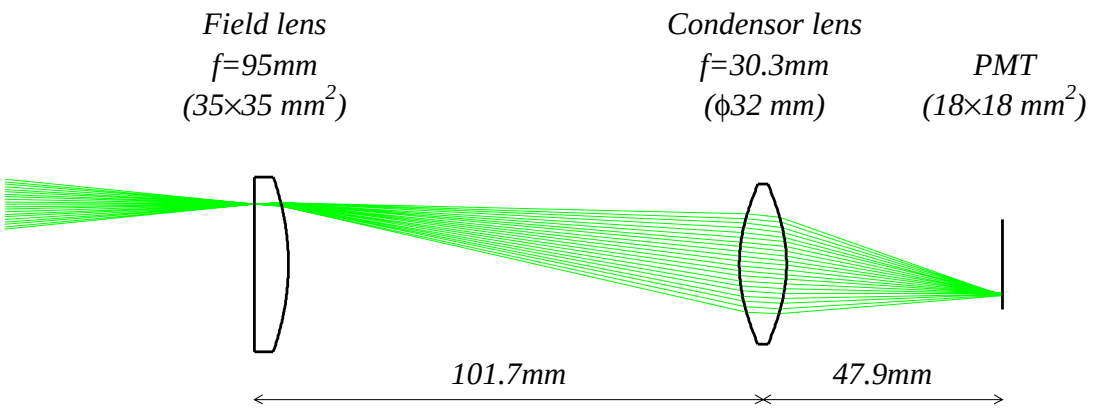
The light collection system

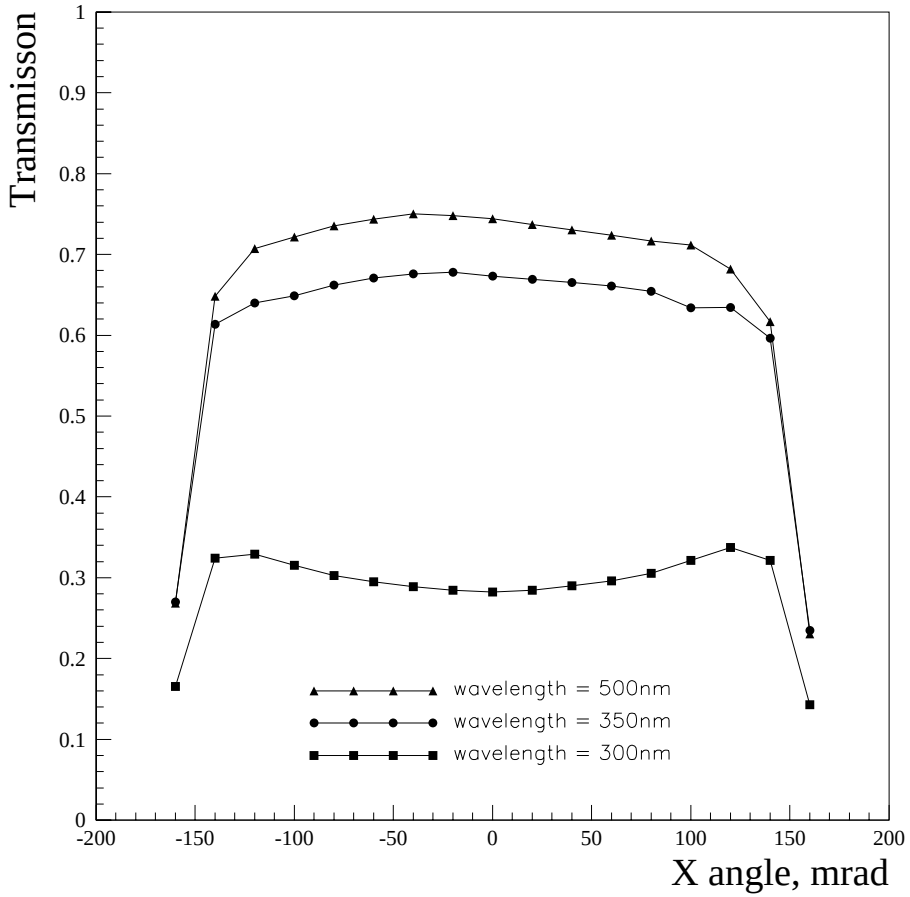
- PMT's are positioned on $36 \times 36mm^2$ grid
  $\rightarrow$ demagnification factor of 2 is needed
- The two lens light collection system has been designed
  $\rightarrow$ a spot on planar surface of field lens is imaged to a spot on the PMT



- Demagnification factor: -2
- Angular acceptance: 140 mrad
- Aspheric lenses, made of UVT perspex by injection molding

Lens system transmission

- Transmission of the lens system as a function of angle of incidence



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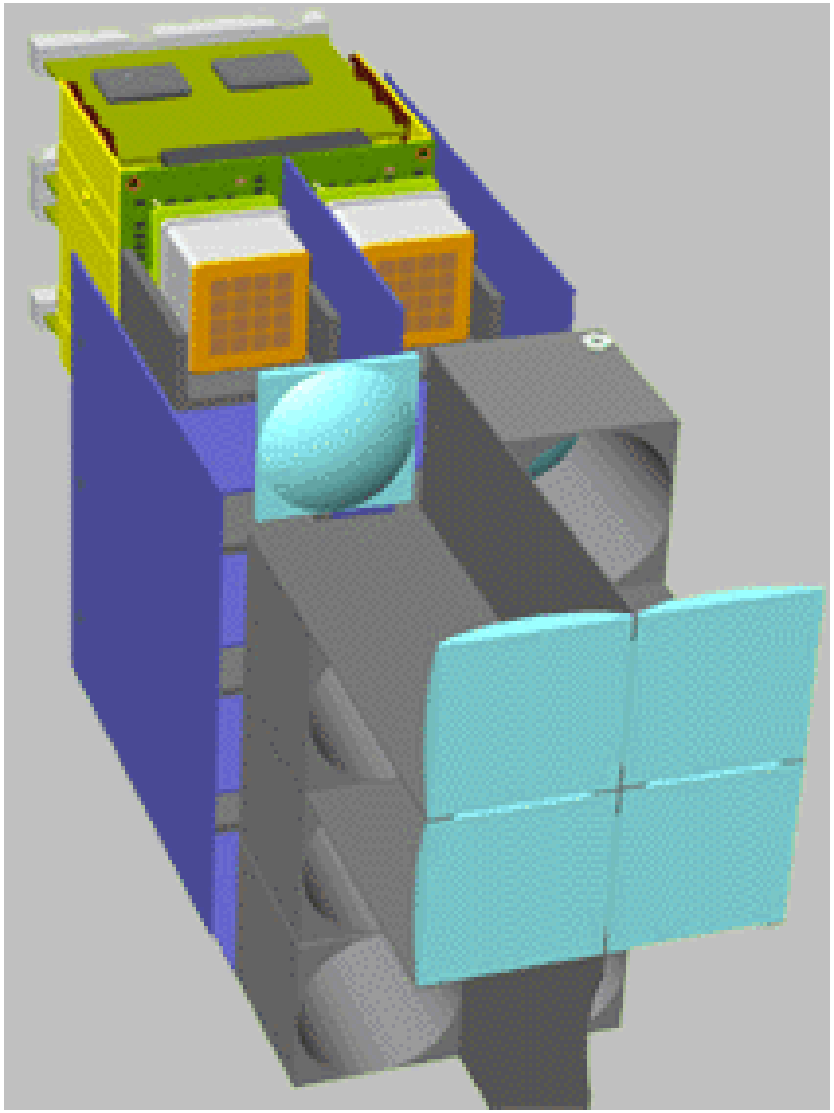
The RICH photon detector

Elementary building block:

- Holds 2 x 2 PMT's
- Distributes H.V. to dinodes
- Preamps connected at the back side
- Lens demagnifying system



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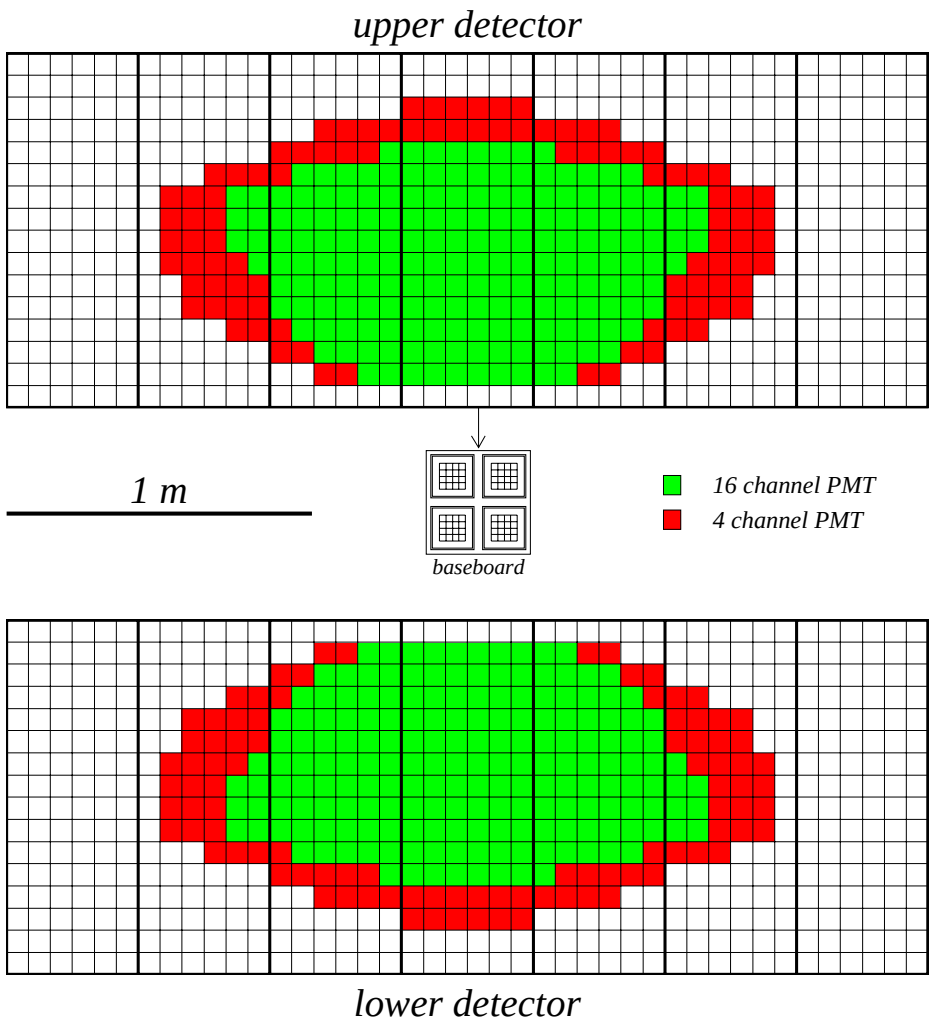
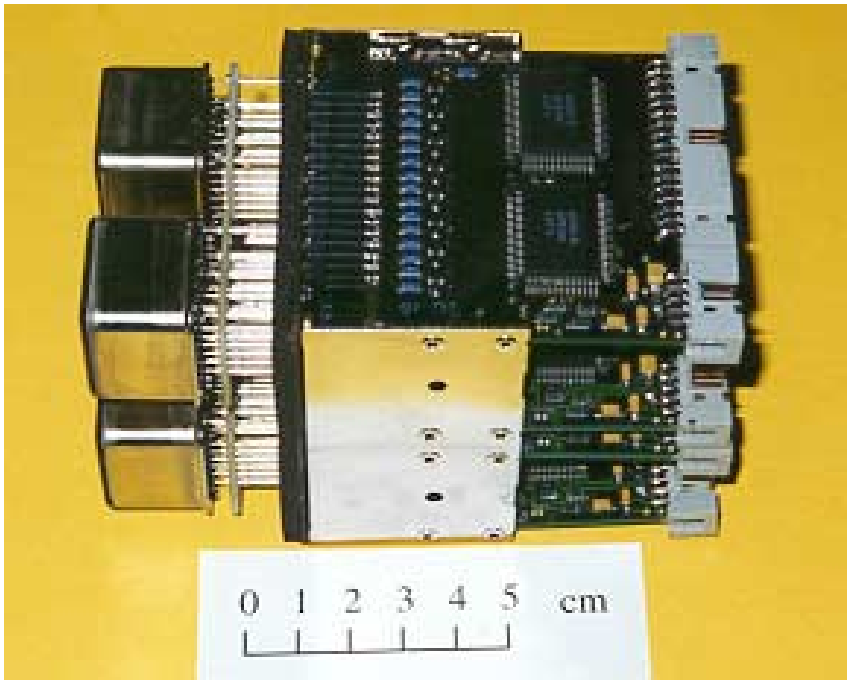
The RICH photon detector

- Upper and lower detector planes
- Subdivided into $7 + 7$ super-modules
- Hamamatsu R5900 photo multiplier tubes:
  1488 16-channel and 752 4-channel PMT's



The Front-end Electronics

- The same front-end electronics used as for MUON chambers
  - ASD8 preamplifier/shaper/discriminator cards (16 channel)
  - Front-end driver system with pipeline (128 depth, 1bit per channel)
  - ASD8 connected to Front-end driver via $7.5m$ long twisted pair flat cables
- Preamplifier too sensitive to signals from PMT
  $\rightarrow 1:10$ charge divider added in front of the preamp
- 26816 read-out channels, event size $4kb$



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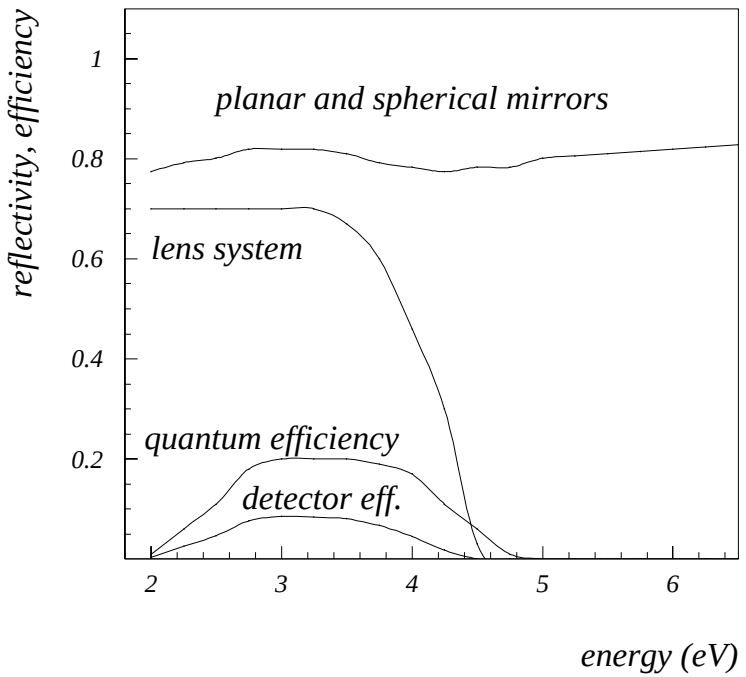
Expected parameters of the RICH

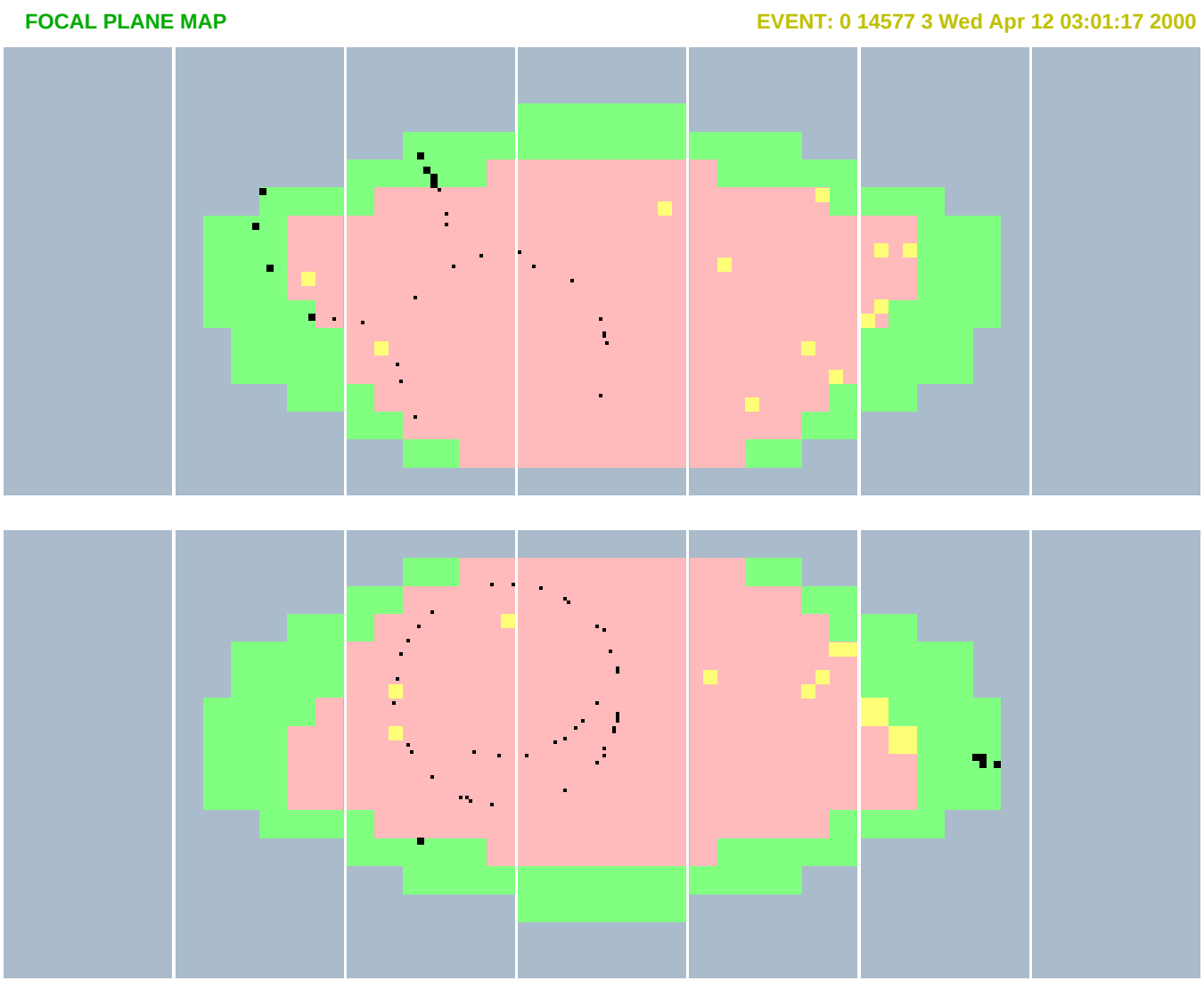
- Number of photons for $\beta = 1$ particle: 35
- Figure of merit N_0: $44cm^{-1}$



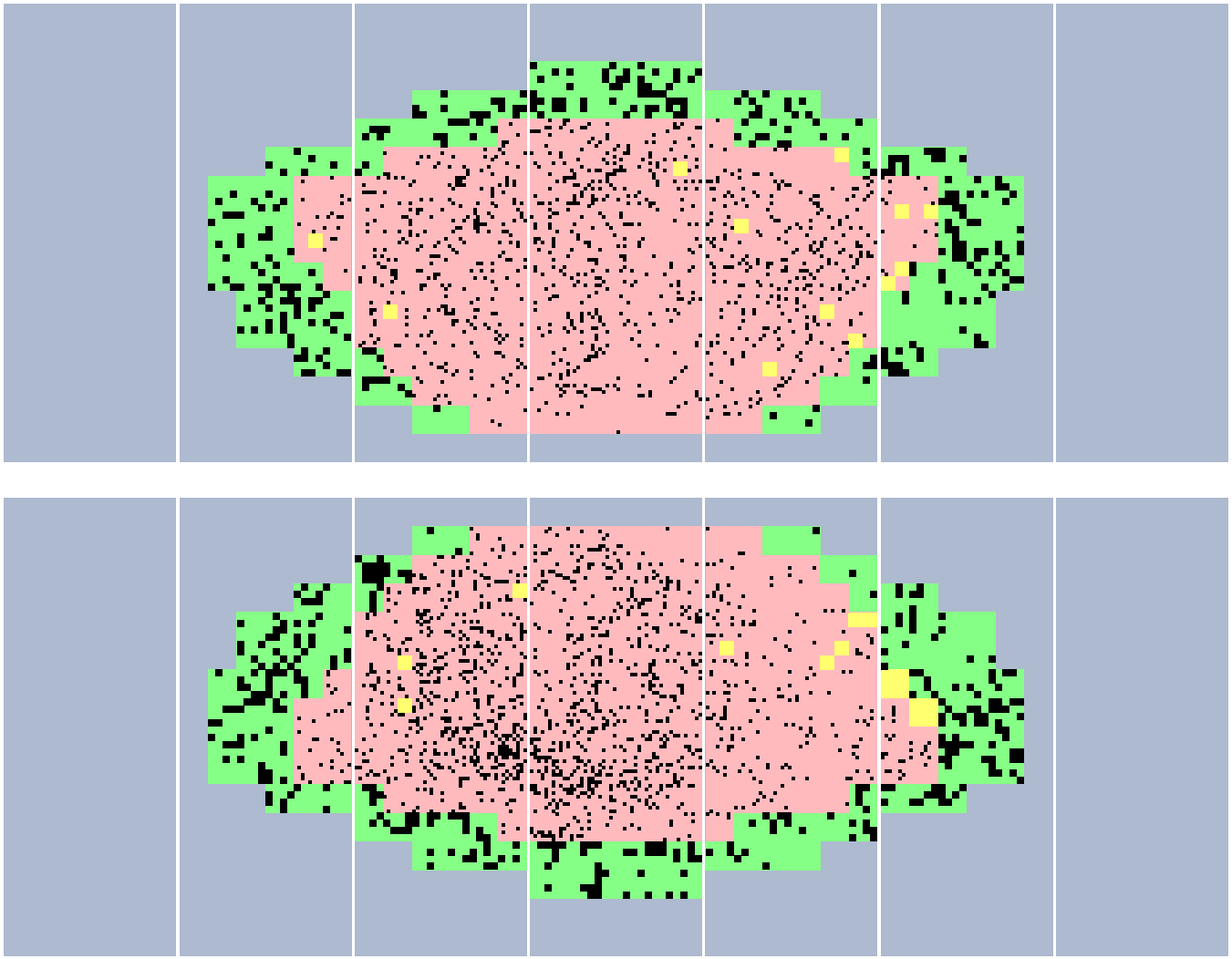
- Single photon resolution: $\sim 0.7mrad$

	M16 PMT	M4 PMT
granularity	0.50	0.93
dispersion	0.33	0.33
optics errors	0.25	0.25
multiple scattering	$3.5/p$	$3.5/p$
total	$0.65 \oplus 3.5/p$	$1.02 \oplus 3.5/p$

An event with a few rings

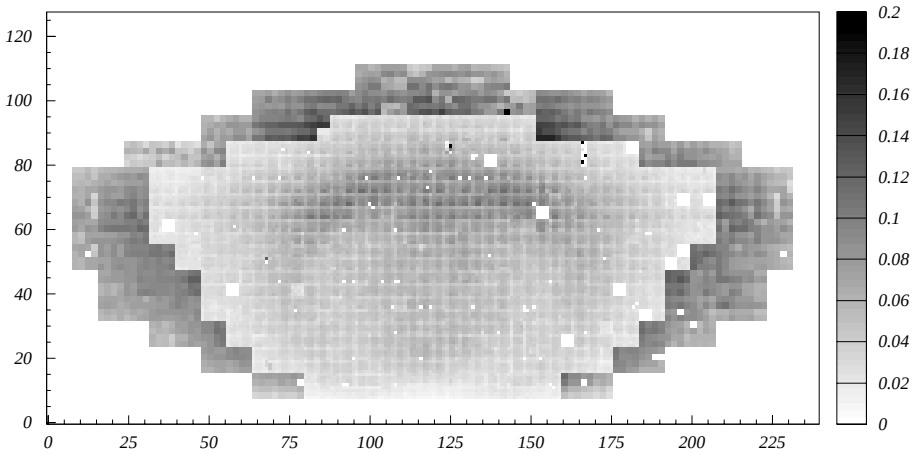


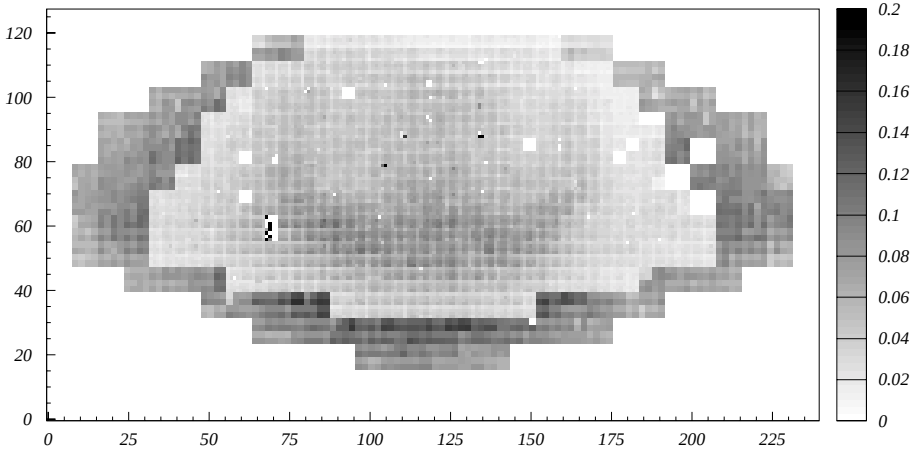
A typical event



Occupancy plot

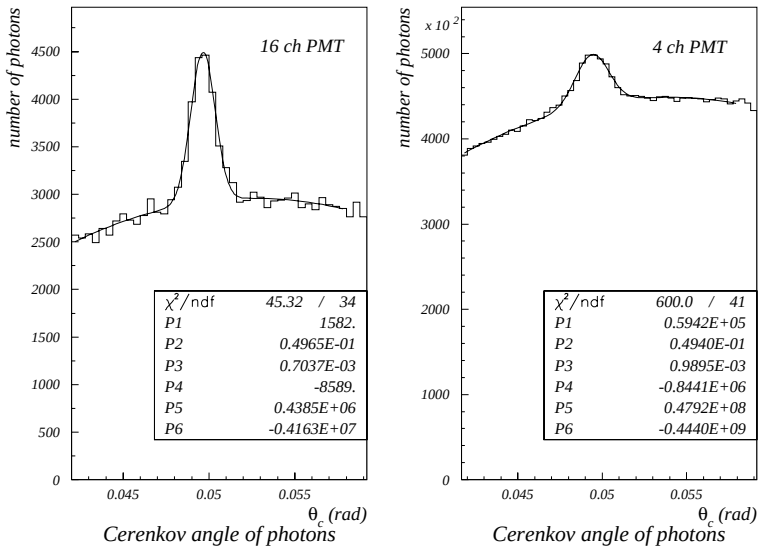
- Channel occupancies up to 20%
- 0.3% of hot (noisy) channels
- 1.5% of dead channels
- 32 PMT's are dead or not installed

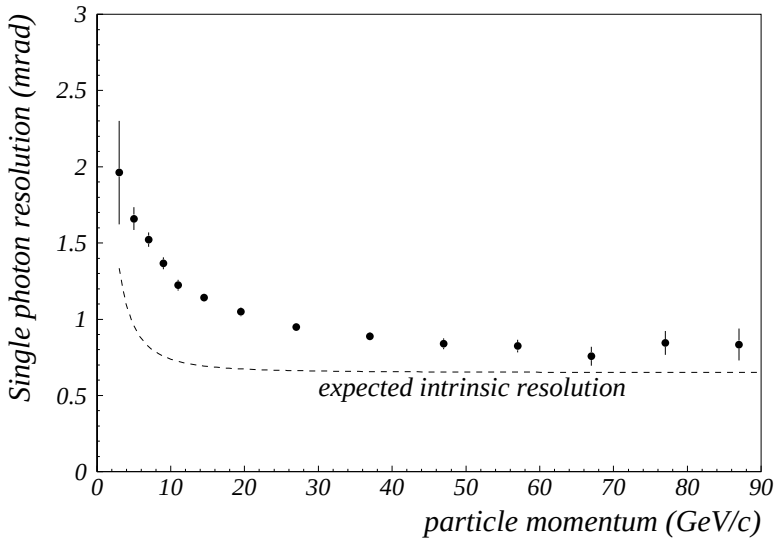




Measured parameters of the RICH

- Čerenkov angle for $\beta = 1$ particle: 52 mrad
- Single photon angular resolution:
  - $\rightarrow$ 16 channel PMT region: 0.7 mrad
  - $\rightarrow$ 4 channel PMT region: 1.0 mrad
  - $\rightarrow$ including track error: 1.2 mrad (mean)
- Number of hits per $\beta = 1$ particle: 32
- Figure of merit N_0: $42cm^{-1}$





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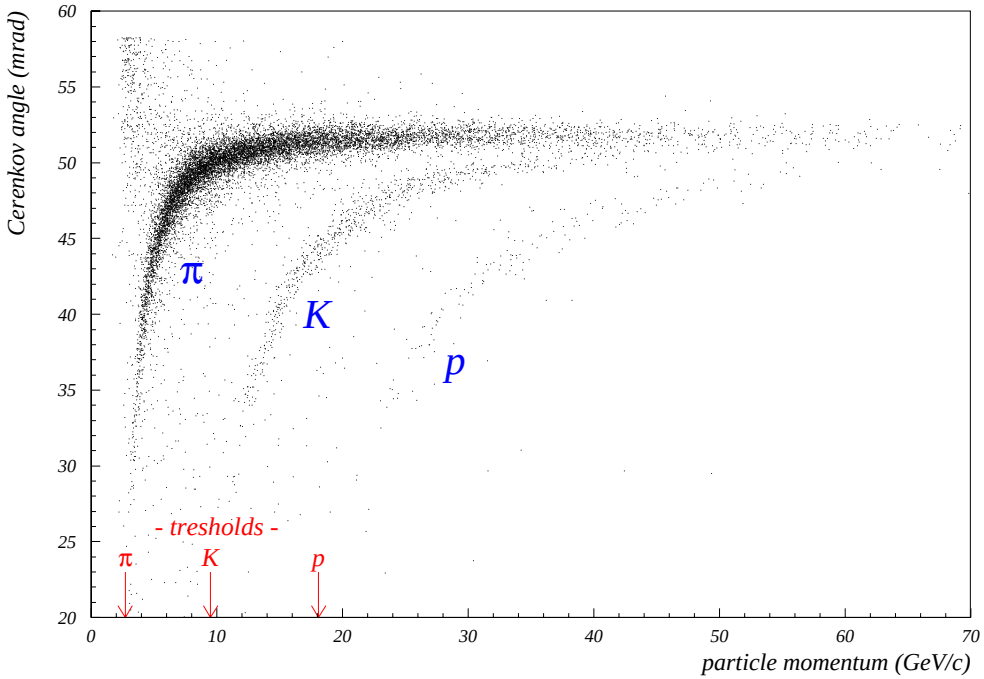
Particle identification: first impression

Reconstructed Čerenkov angle versus particle momentum:
→ likelihood fit of Čerenkov histograms of individual tracks



For final PID an extended likelihood method is used.
→ talk by M. Starič on Sunday

Conclusions

- The design and performance of the Ring Imaging Čerenkov detector of HERA-B has been presented:
  - C_4F_{10} is used as the radiator gas.
  - The photons are focused by a spherical mirrors of focal length of $5.7m$ into the photon detectors
  - The photon detectors consists of an array of 2240 multi-anode PMT's with a light collection system made of two lenses in front of each PMT.
- The number of photons per particle approaching the speed of light is 32 and the figure of merit factor of the RICH (N_0) is $42cm^{-1}$.
- It has been shown, that the RICH is capable for efficient particle identification at high track densities and high interaction rates of the HERA-B experiment.
- The RICH detector is in operation since 1998. No degradation of performance has been observed so far.

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