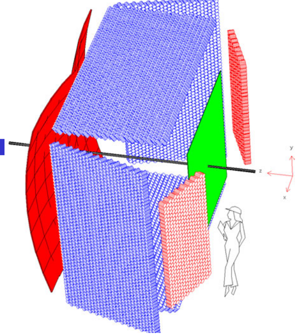
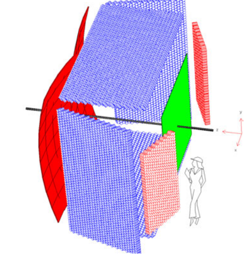


BTeV Ring Imaging Cherenkov Detector

Marina Artuso
For the BTeV RICH group



Introduction

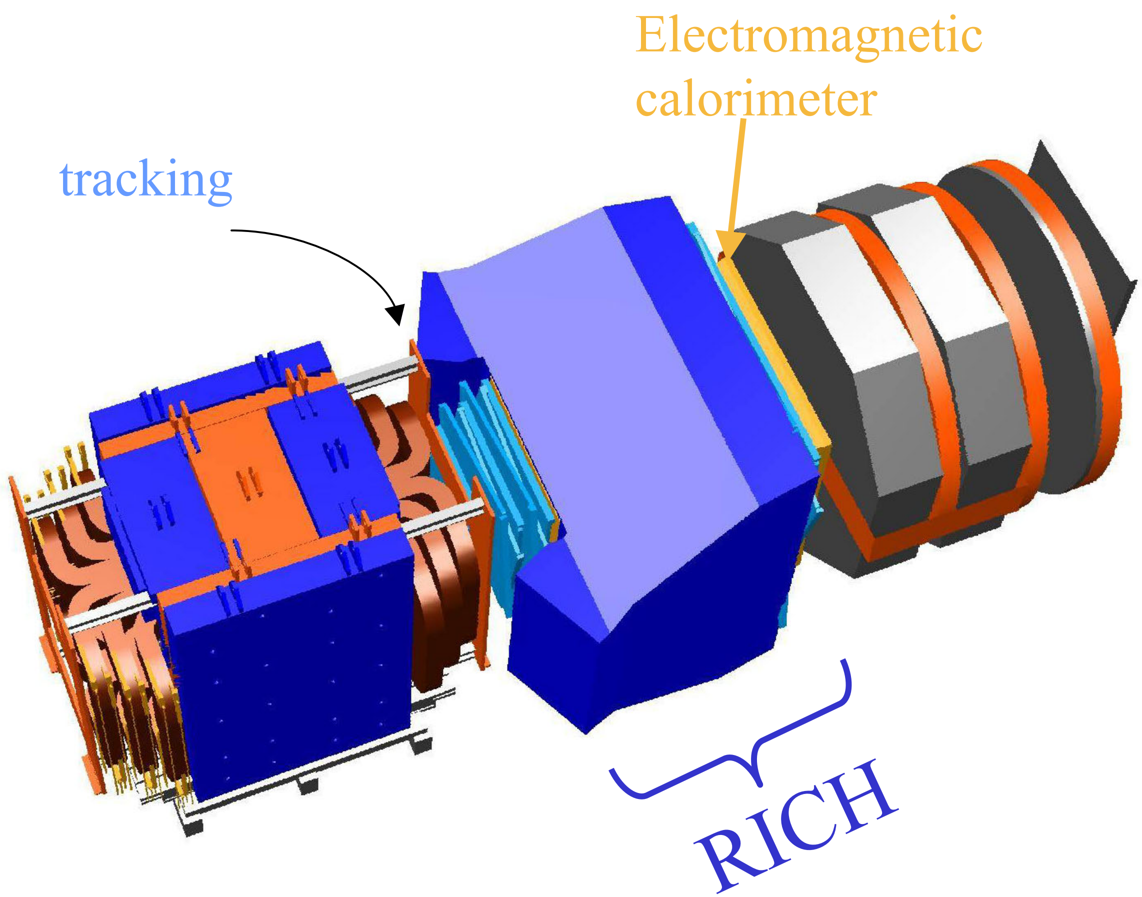
Requirements

- Physics requirements
  - At least 4σ separation for K, π, p in the momentum range 3-70 GeV/c $\Rightarrow$ average Cherenkov angle resolution per track better than 0.12 mrad.
- Geometrical Requirements:
  - full BTeV solid angle coverage (10-300 mrad).
  - Thickness $\leq$ 20% of a radiation length

Key features

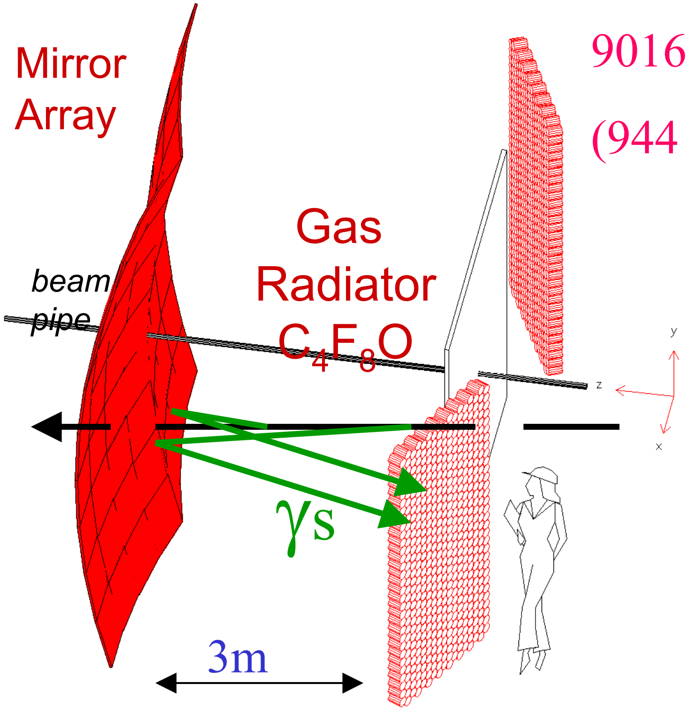
- Excellent hadron indentification in the the momentum range 3-70 GeV/c
- Lepton identification in the solid angle between 200 and 300 mrad (not covered by electron and muon ID systems)

The BTeV Detector



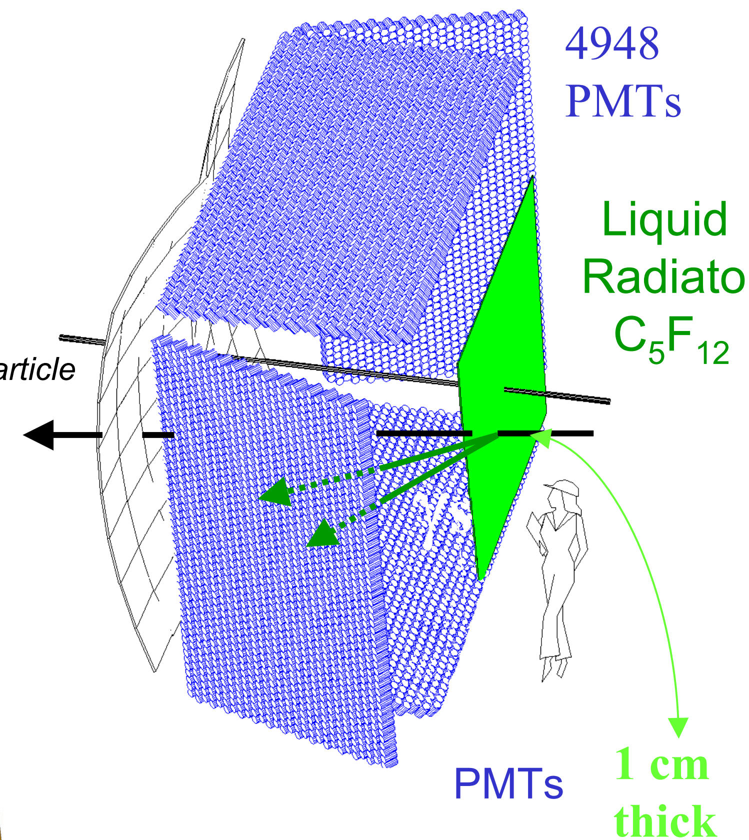
The BTeV RICH Components

Mirror Focused Gas Radiator RICH

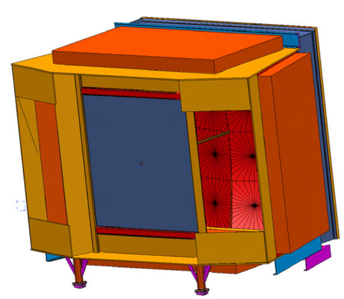


+

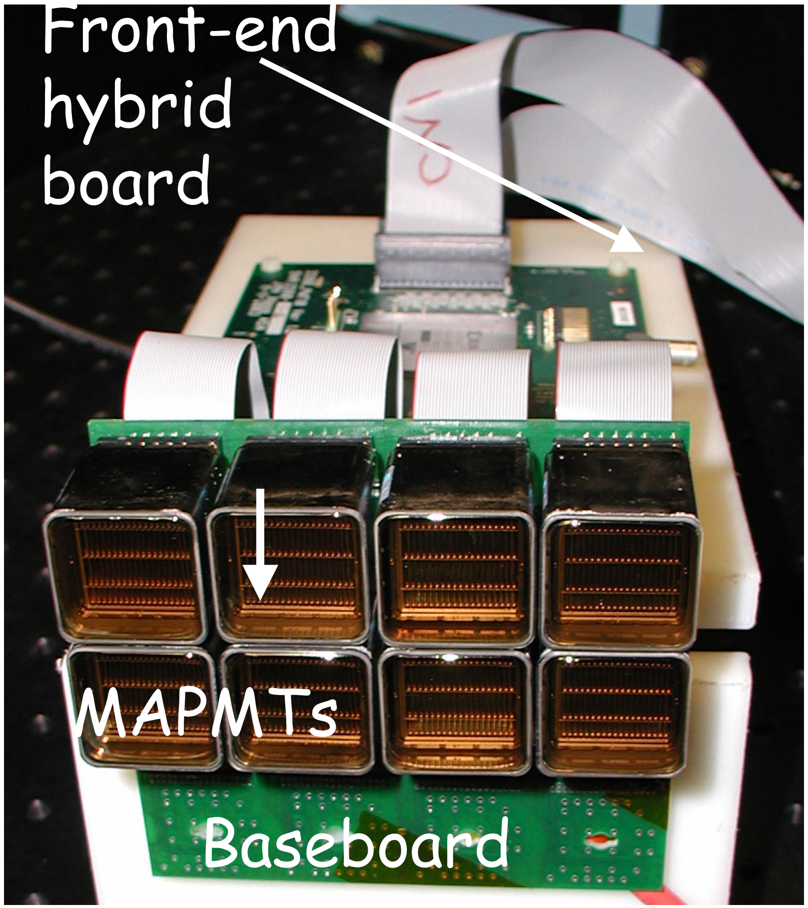
Proximity Focused Liquid RadiatorRICH



=



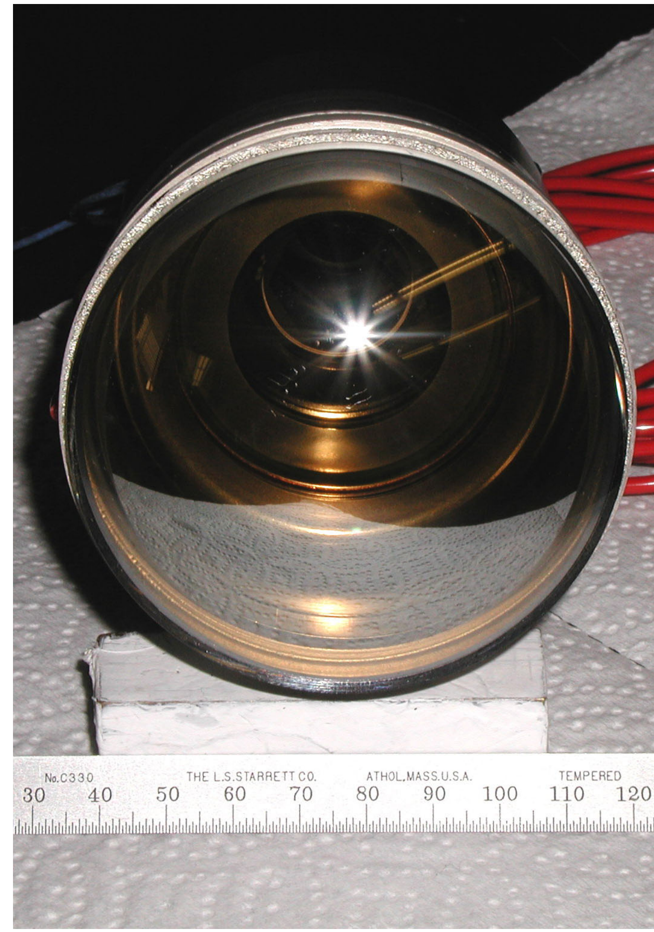
Gas Radiator Photon Detectors



- Baseline solution: 16 channel Hamamatsu R8900-00-M16 MaPMTs (9016 devices for 2 arrays)
- Main features:
  - **Predicted σ_{track} ~0.115 mr**
  - **Predicted N_{γ} ~52 detected**
  - QE*CE 13-15%
  - Active area: 85%
  - **6x6 mm pixel size well suited for BTeV**
  - Gain [1-4x10^6]
  - HV 600-900 V (negative)
  - Standing current in voltage divider 340 μA
- Alternative solution 163 pixel HPD from DEP

MAPMT vs HPD

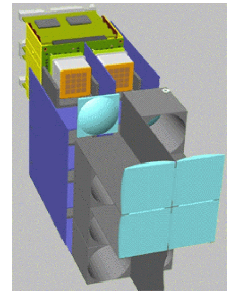
MAPMT: Hamamatsu R8900-M16

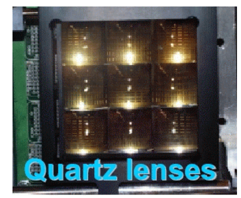


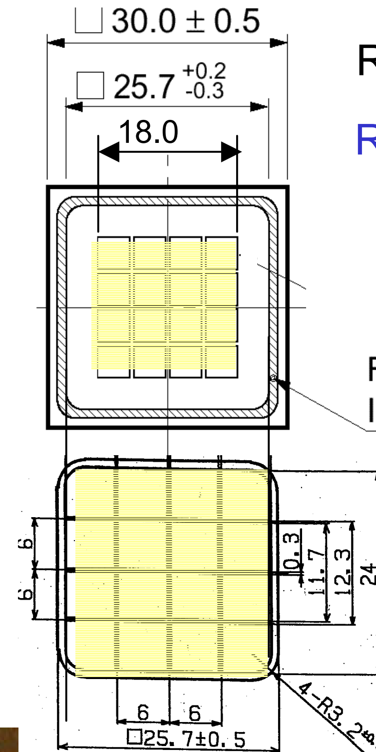
HPD: DEP PP0380AT

Development of MAPMT (Hamamatsu)

- First used in RICH detector by HERA-b (since 1998)
  - 1488 R5900-M16 + 752 R5900-M4
  - Active area: 36%
  - Double-lens focusing system
- Improved version with increased segmentation tested by LHC-b
  - R7600-M64
  - Active area: 48%
  - Single convex-plano lens system increases geometrical efficiency to 74%
- Redesigned focusing scheme on the first dynode
  - R8900-M16
  - Active area: 85%
  - No lens system needed!
  - **6x6 mm pixel size well suited for BTeV**
  - R8900-M25 developed for EUSO telescope







R5900-M16

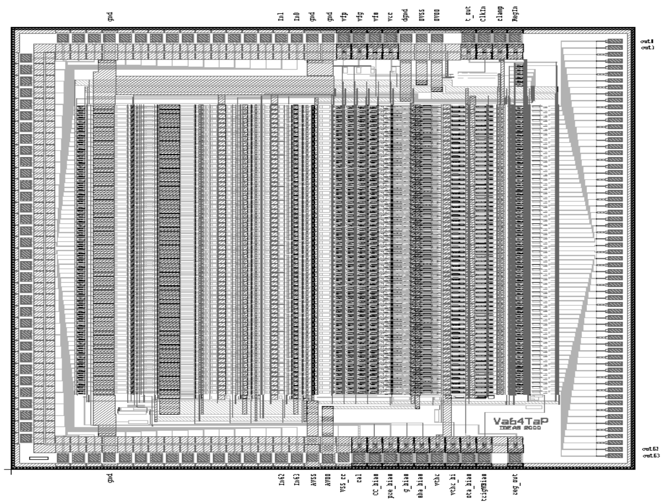
R7600-M64: no outer insulating layer

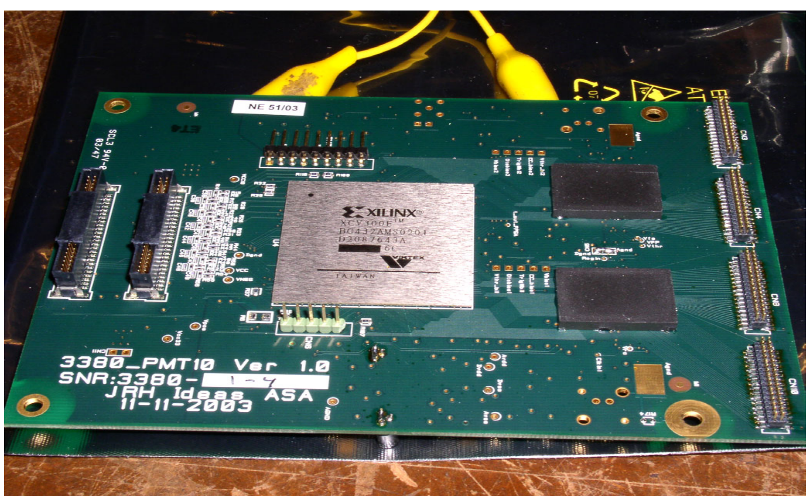
R8900-M16

R7600-M64

R8900-M16

Photon detector electronics





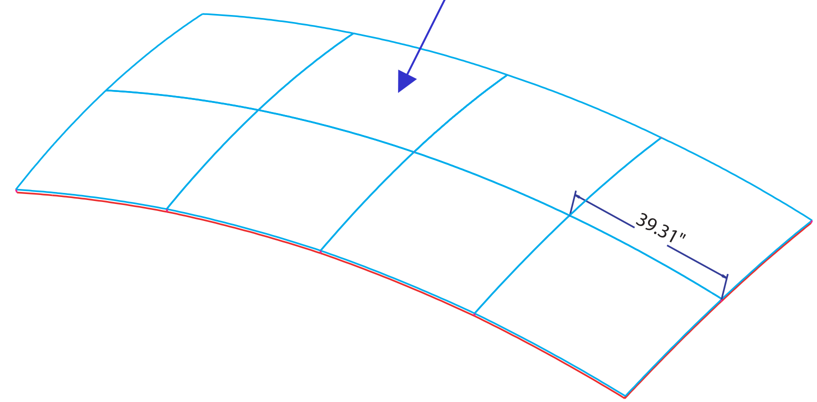
- FRONT END ASIC must feature:
  - Noise consistent with the minimum threshold giving us full counting efficiency [1/10 of average MaPMT gain]
  - On chip sparsification
  - High Dynamic range
  - Parallel digital readout to allow event synchronization
- PROTOTYPING STEPS implemented:
  - VA_BTeV1 [for HPD readout: low noise (500e$^-$ ENC), discriminator not optimized for high counting rates] & Va+BTeV1.1 [improved discriminator and 1 analog test channel]

  VA_MaPMT [for MAPMT, improved discriminator, 1 analog test channel]
  - In progress: optimization of dynamic range for MaPMT applications and of noise versus C_{in} for PMT applications

The RICH Mirror System

- Two large mirrors, each one has 200cm (width) and 400cm (height). They can be broken down to any number of mirrors of any shape, so that cost and performance are optimized.
- A half circle hole in the side for the beam pipe (~3 cm radius).
- Mean radius of curvature is fixed to 697cm.
- 1-2% radiation length
- CMA approach: each mirror made up of 8 square tiles

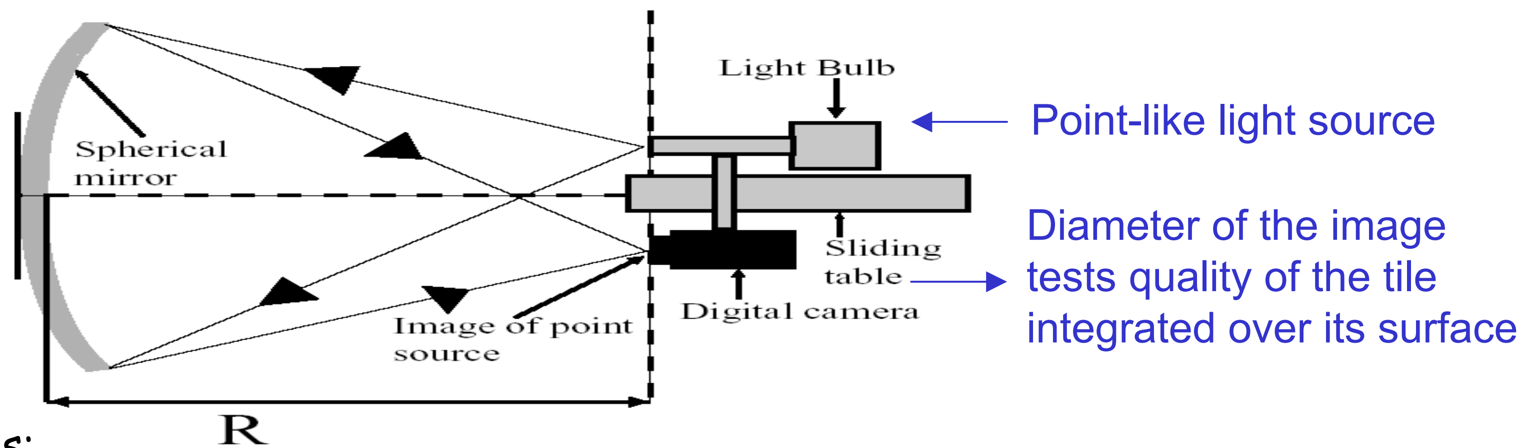
$\frac{1}{2}$ of RICH mirror based on CMA segment design



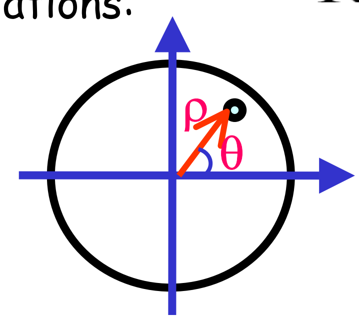
Mirror aberrations

- We have performed extensive simulations of possible mirror distortions and their effects on both Cherenkov angle resolution and simple mirror quality test:

Spot size measurement:

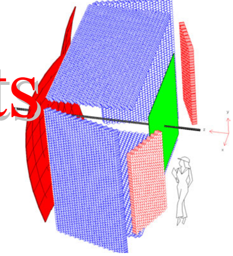


Simulations:

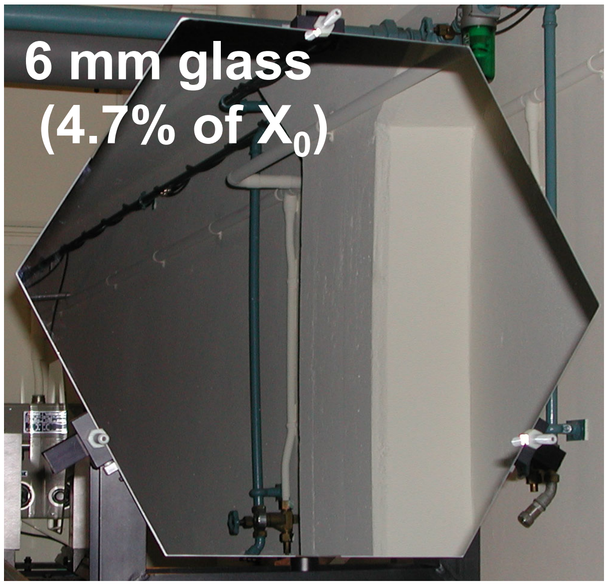


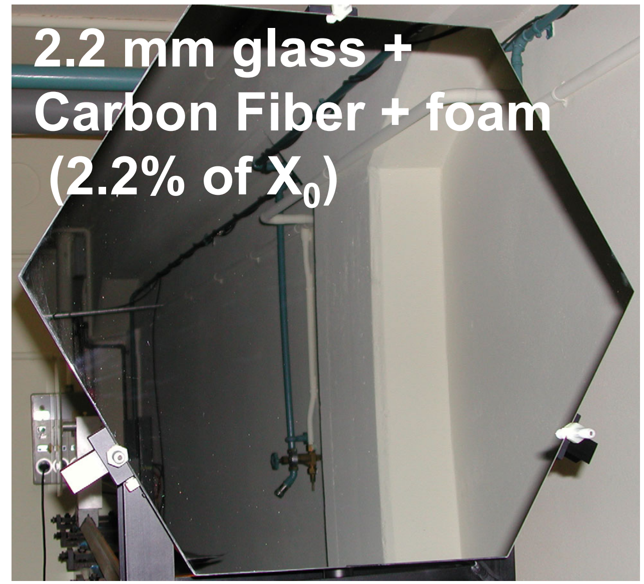
Surface deviations from the ideal spherical mirror parameterized in cylindrical coordinates of the mirror tile: $W(\rho,\theta)$

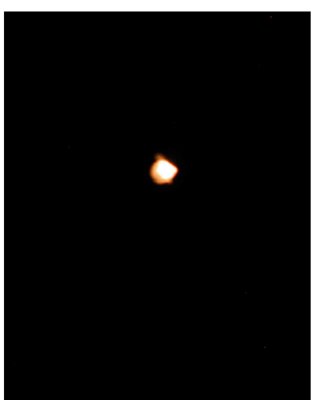
Examples of spot size measurements

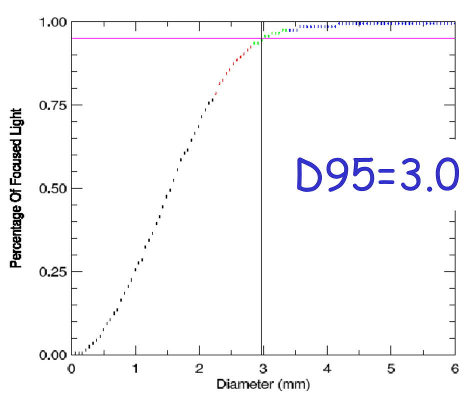


- Two prototype mirrors obtained from IMMA Compas, Turnov, Czech Republic (R~660 cm)

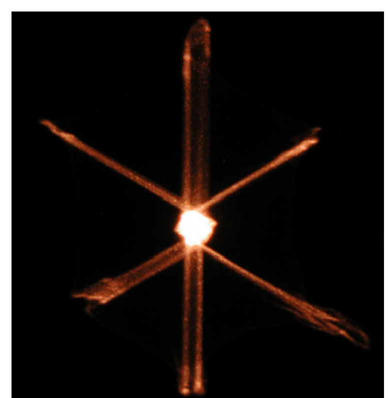






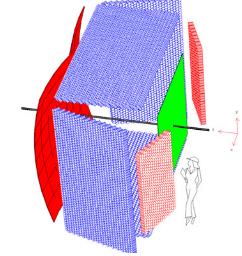


D95=3.0mm

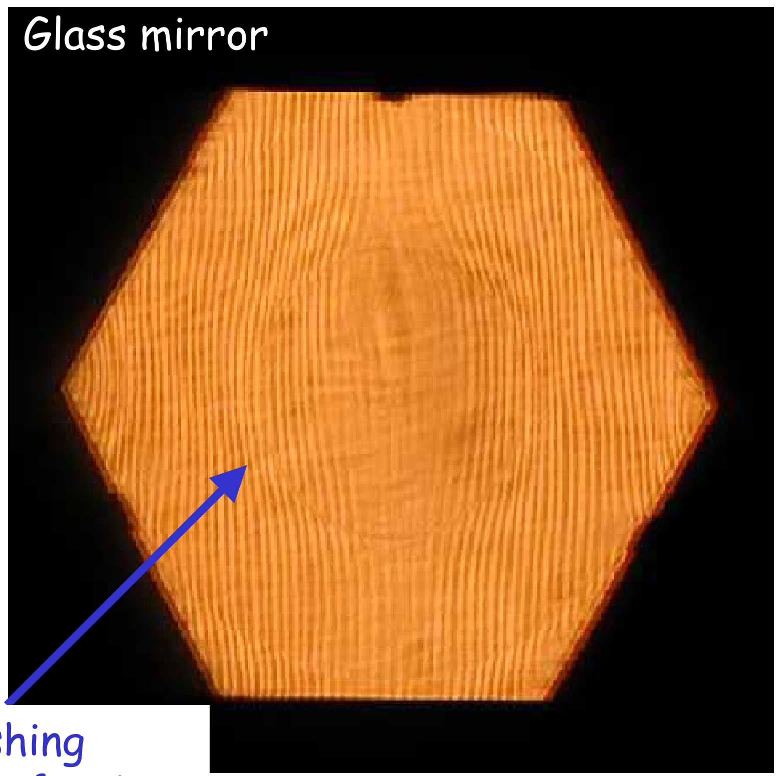


For the central part only: D95=4.1 mm

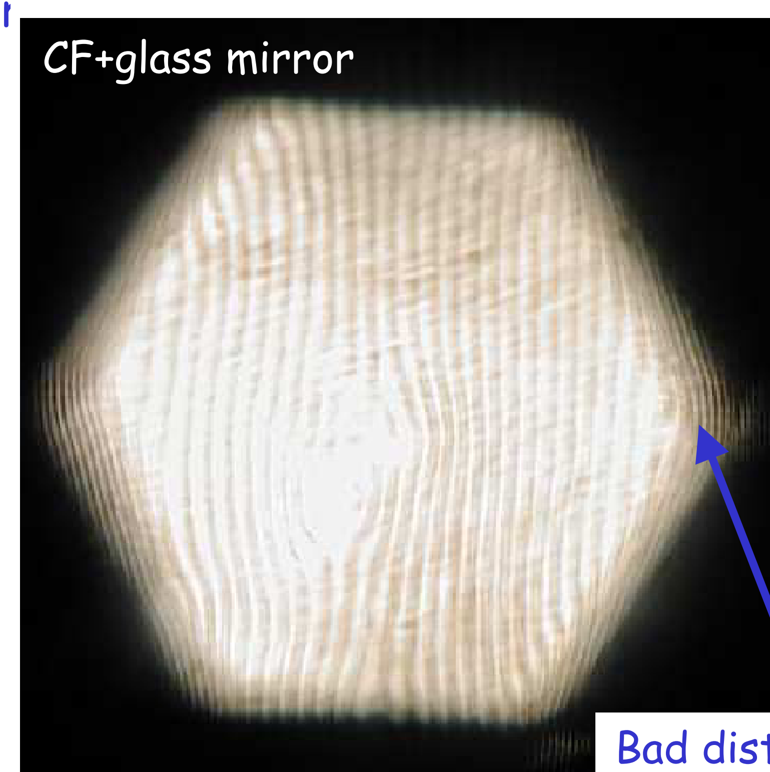
Mirror quality tests



- In addition to the spot size measurement we plan to perform Ronchi test
  - Gives qualitative information on type of mirror distortions

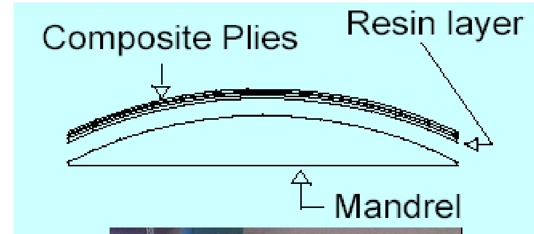


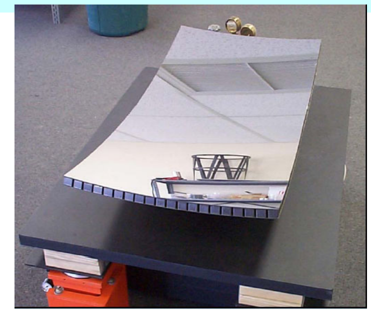
Polishing imperfections



Bad distortions at the edges

CMA mirrors



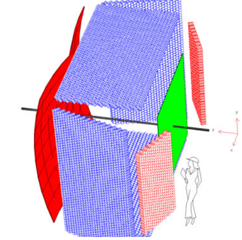


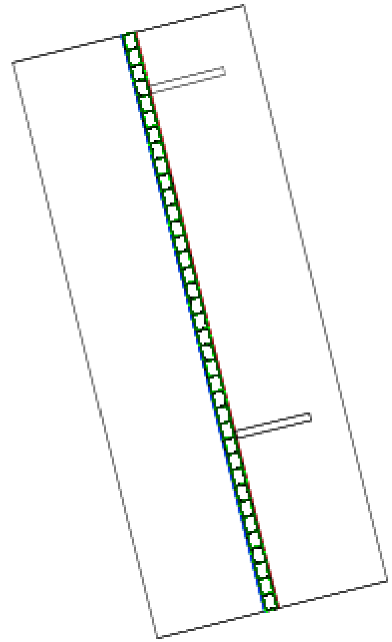
- CMA has developed a proprietary process which incorporates a very thin layer of pure resin at the surface. The resin layer imparts a super-smooth (RMS~7 angstroms) optical surface totally free from carbon fiber print-through.
- Unlike in traditional glass working, there is little or no distortion of the optical figure due to stress release at corners and edges. Can produce mirrors of non-traditional shape.
- Produces lightweight mirrors for space program telescopes.

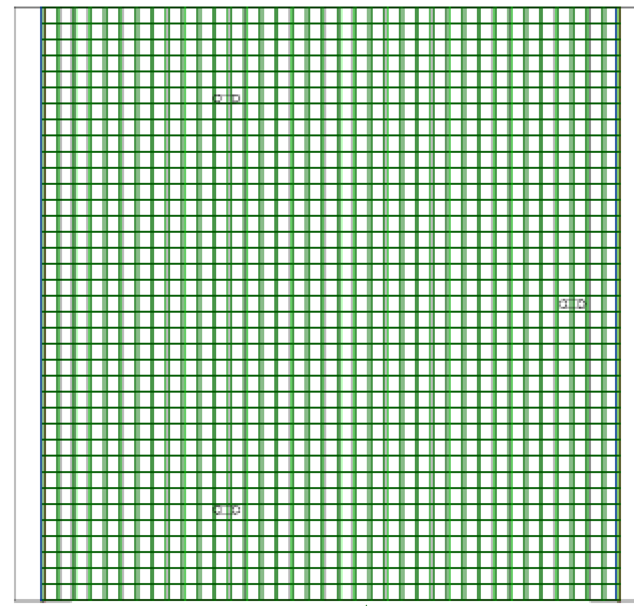
Prototype mirror from CMA

- CMA has made 11" x 11" mirror prototype for us with radius of curvature R=3.5m

Structure of the CMA mirror prototype







1.5mm CF sheets
(front Al-MgF_2 coating)

0.5mm CF reinforcement ribs
(creating 1"x1"x1" cells)

- Average radiation thickness 1.2% X_0 (+mounts 0.1% X_0)

Compatibility with C_4F_8O

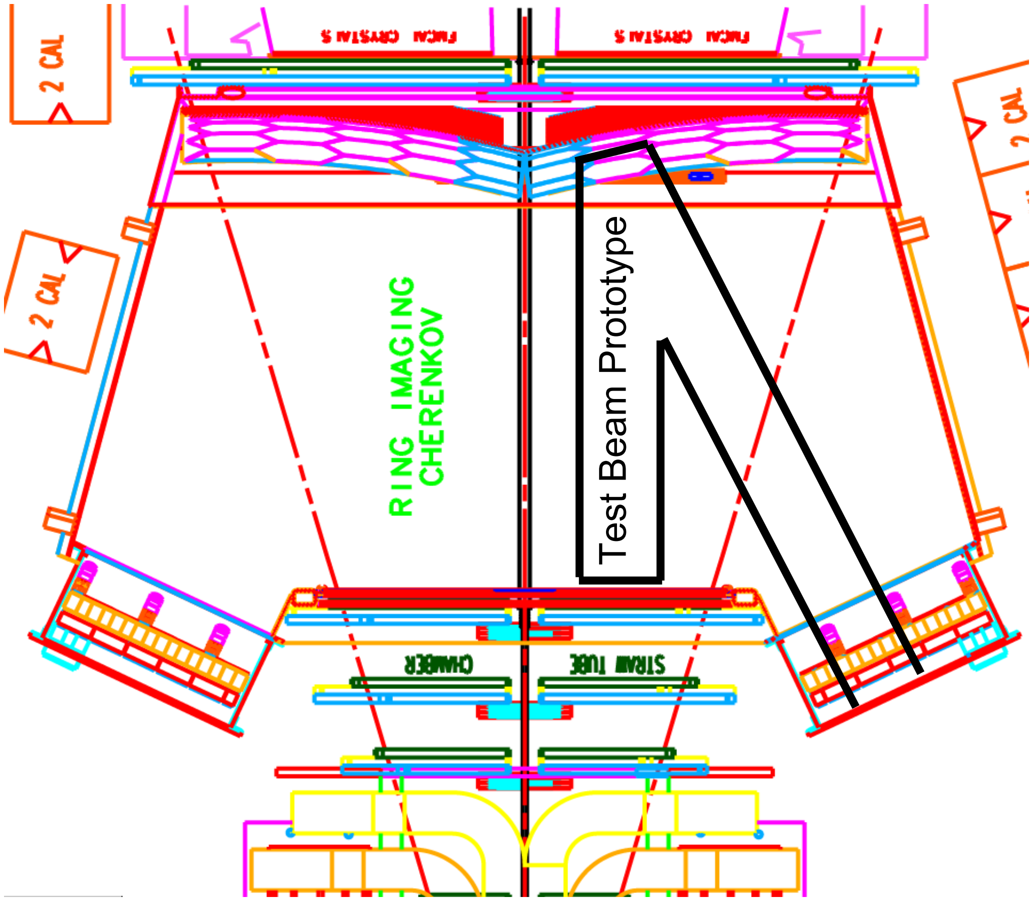
- CMA covers CF surfaces with protective glue layer
- Test compatibility of the CMA mirror prototype with C_4F_8O at Syracuse

CMA CF mirror inside transparent box with C_4F_8O.

Monitor mirror optical properties.

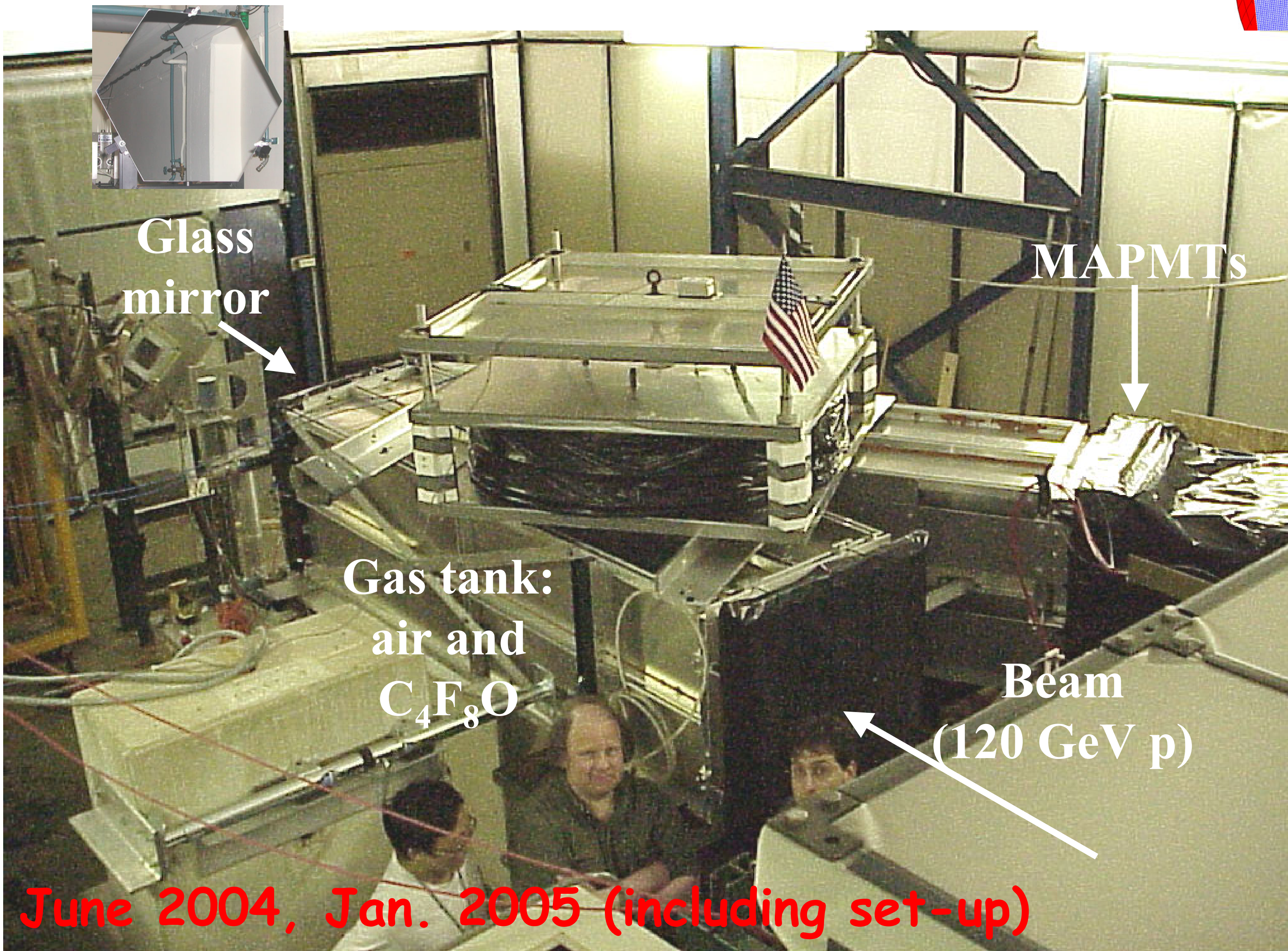
No change in mirror spot size and mean radius over more than 2 months

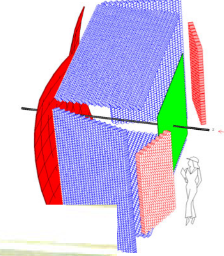
Gas RICH Test Beam Studies



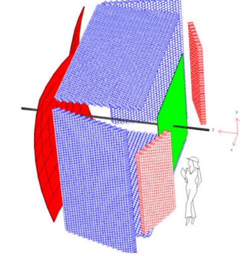
Details can be found in physics/0505110

In M-TEST area



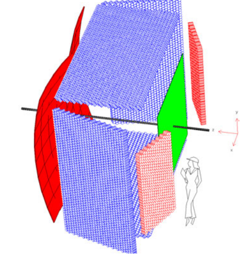


What are we testing?

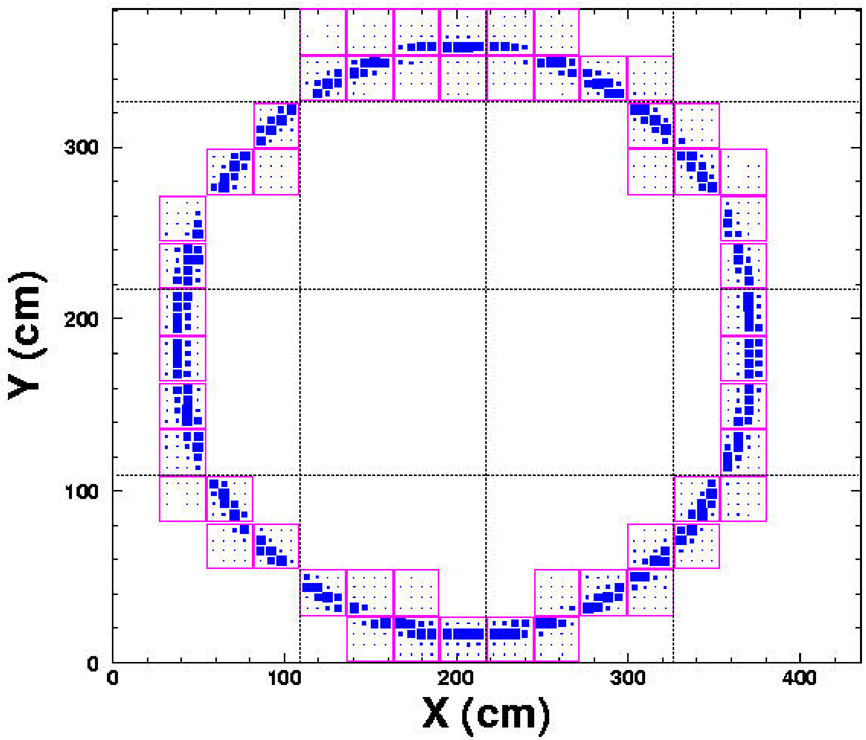


- First test beam of MAPMTs with large active area:
  - R5900 used in HERA-b RICH: active area: 36%
  - R7600 tested by LHC-b: active area: 48%
  - R8900 developed for BTeV and EUSO: active area: 85%
- First test beam of C_4F_8O gas radiator:
  - Production of C_4F_{10} discontinued (largest refractive index among RTP gases; used in many RICH detectors)
  - Optical measurements of **n** suggest that C_4F_8O is a good replacement
- Advanced prototype of FE readout board based on VA_BTEV MAPMT ASIC developed with IDE AS
- Prototype of MAPMT base(board)
- Prototype of mechanical support
- Validity of many components of RICH simulations used to design the detector and to predict its physics performance
- Step in system integration

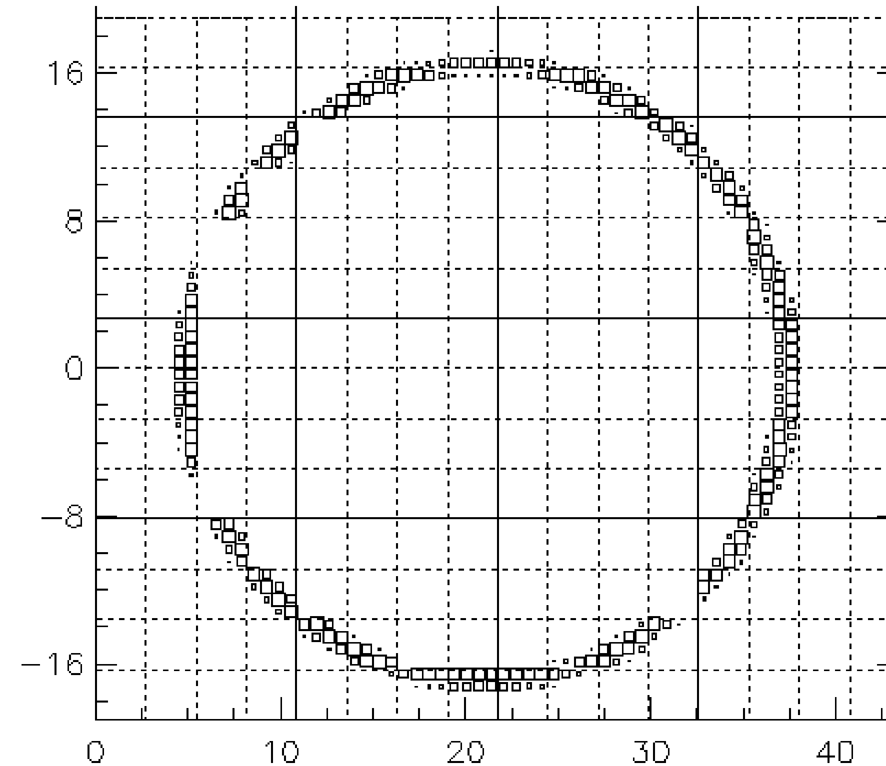
Data vs MC



BTeV RICH Beamtest
(01/10/05-01/31/05)
Run 01112 Nevent 012757



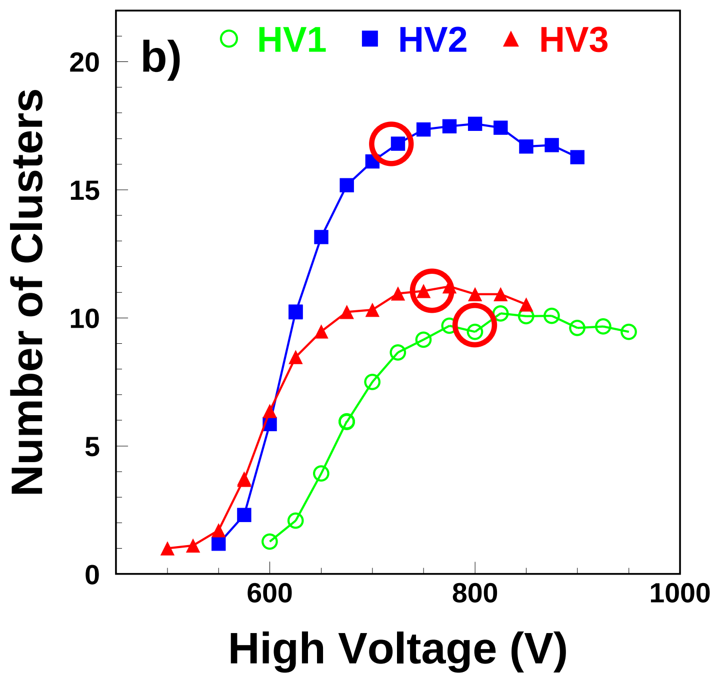
MC after minimazation

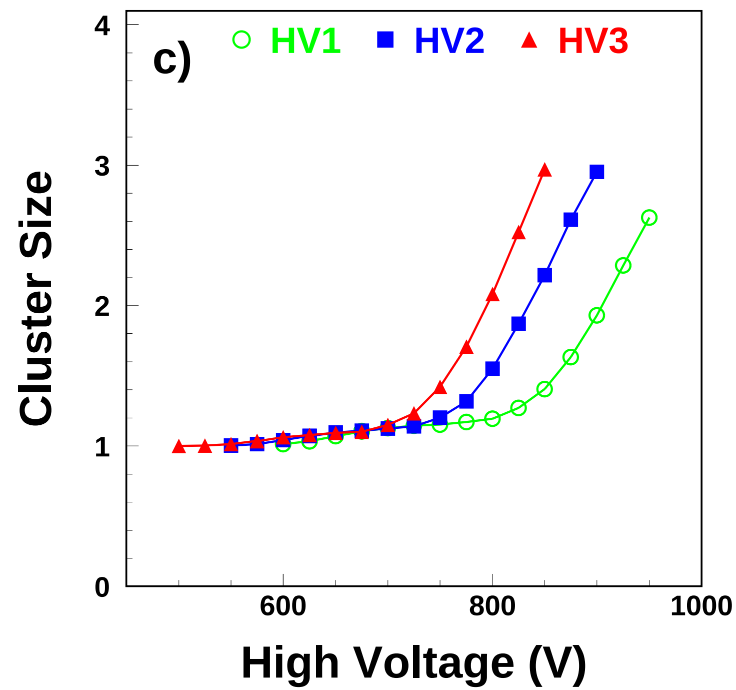


Ring intensity pattern well reproduced in MC

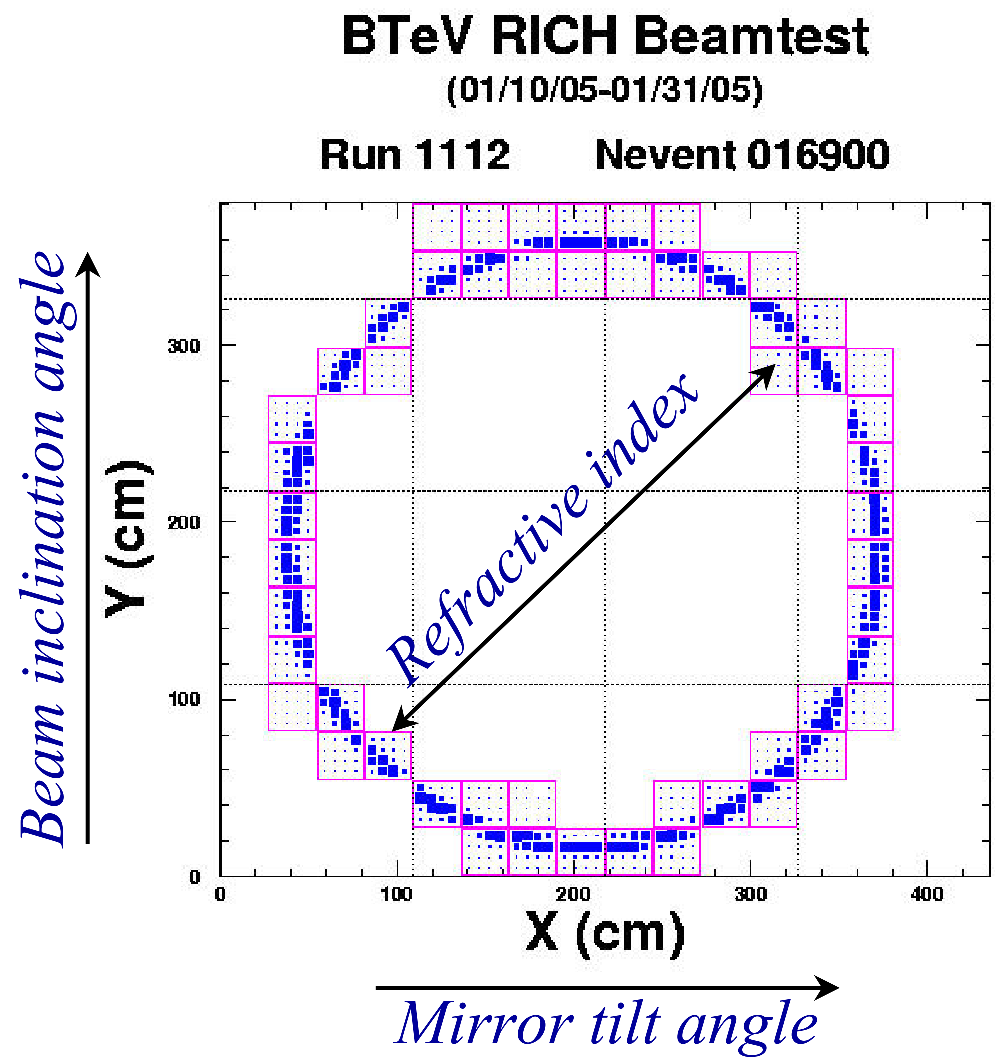
HV SCAN

- HV1,2,3 = the three groups of gain-equalized MAPMTs
- Operating point: 800/750/700 for most of data-taking





Parameter Determination

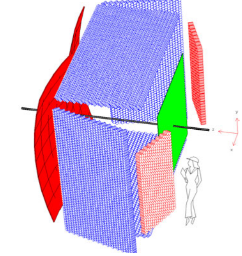


Fit these 3 parameters by minimizing:

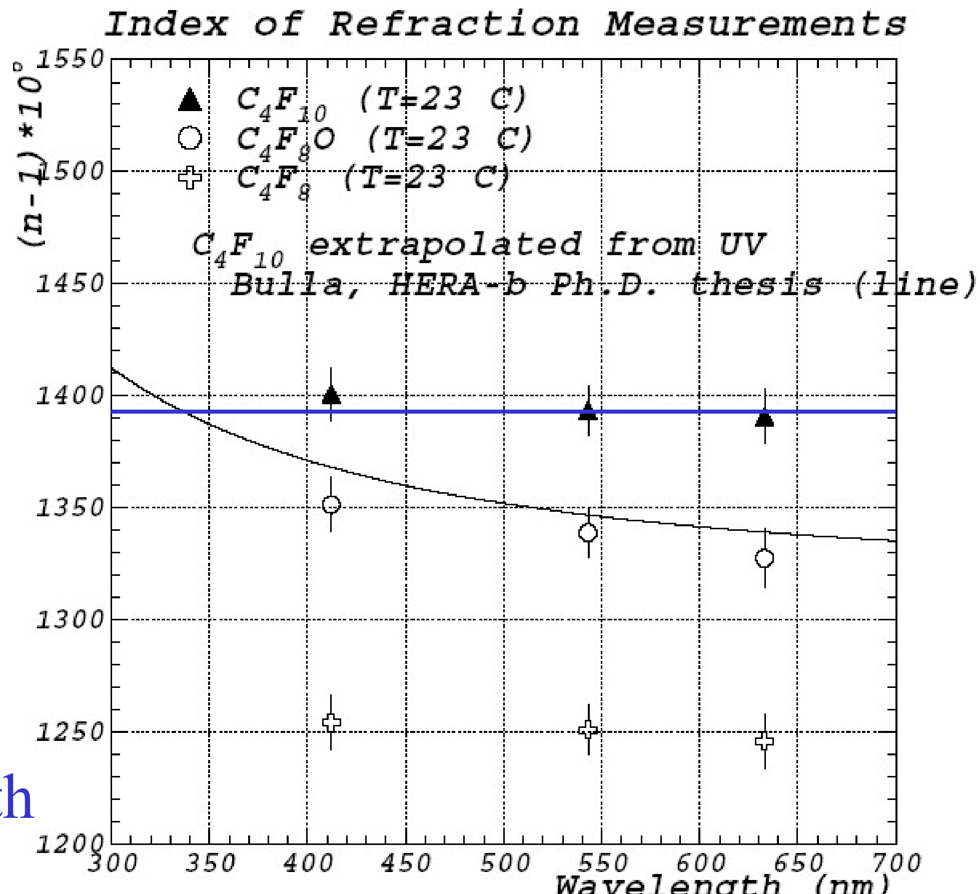
$$\chi^2 \equiv \sum_{i(pixels)} (I_i^{data} - I_i^{MC})^2$$

- Angles check alignment
- Index of refraction compared with optical measurements

Index of refraction data



Measurements with Michelson-Morley interferometer



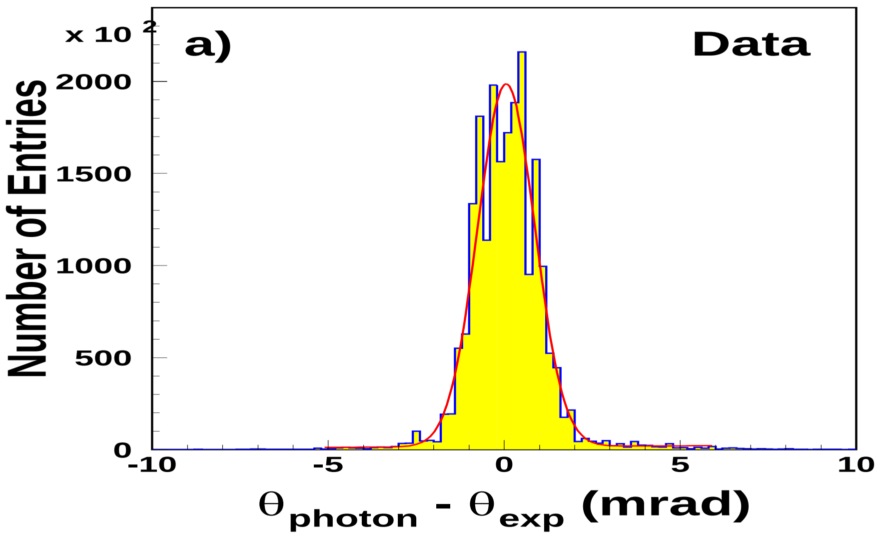
Average n-1 from the fit

1389±24

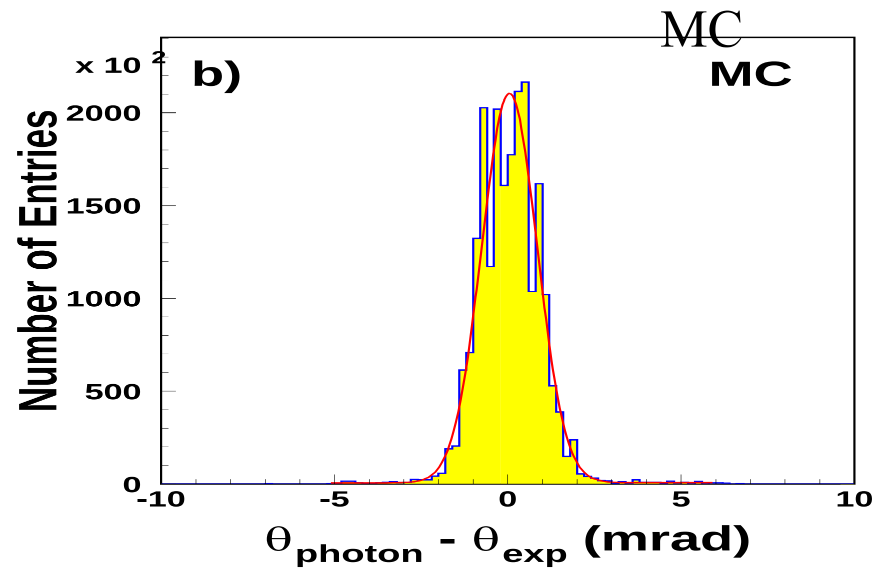
(averaged with the $1/\lambda^2$ weight within the gas RICH bandwidth 280-600 nm)

Single Photon Cherenkov Angle Resolution

$\sigma \sim 0.79$ mrad

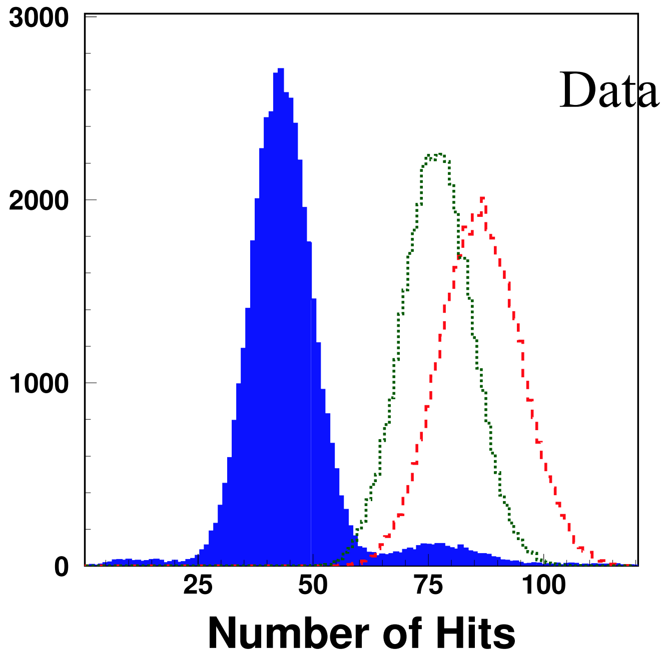


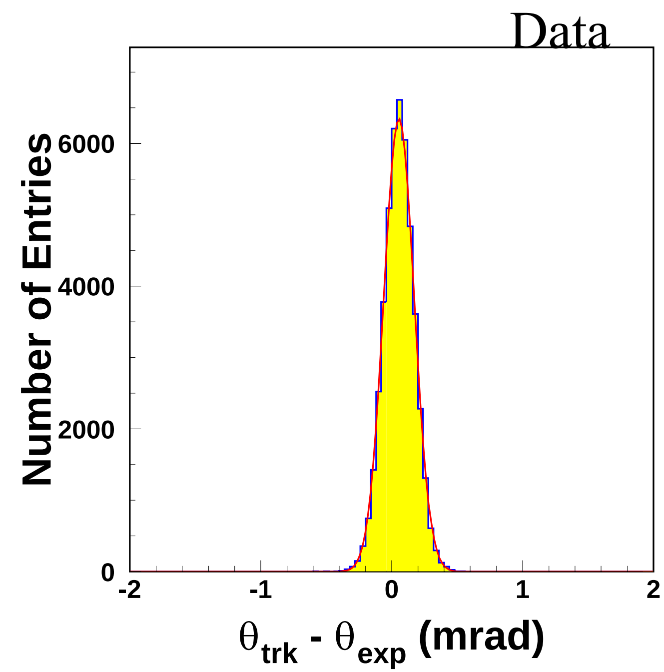
$\sigma \sim 0.75$ mrad



- This is a single run with nominal setting.
- Cross talk contributes to the resolution in real data.

Track Cherenkov Angle Resolution





Single track peak

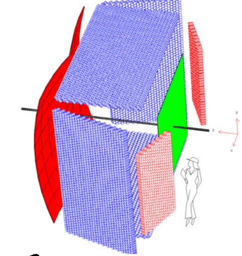
$\langle N\rangle_{Data} = 43.1$

$\langle N\rangle_{MC} = 40.5$

The difference is about 5%, which is the same as cross talk effect.

$\sigma_{Data} = 0.1164$ mrad

$\sigma_{MC} = 0.112$ mrad



Conclusions

- BTeV gas RICH detector performance was validated by extensive test beam studies:
  - R8900 MAPMTs + Front End deliver anticipated Cherenkov photon yield
  - C_4F_8O proved suitable Cherenkov radiator
  - Biasing scheme for the R8900 worked well
- New iteration of electronics is being studied that should eliminate residual cross talk problem
- BTeV terminated in the president's budget 2006: we hope that some of this techology will be transferred to other applications