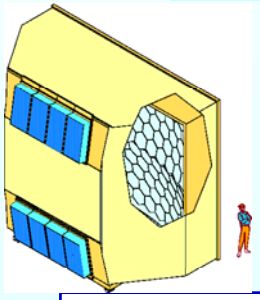
FAST PHOTON DETECTION FOR COMPASS RICH-1

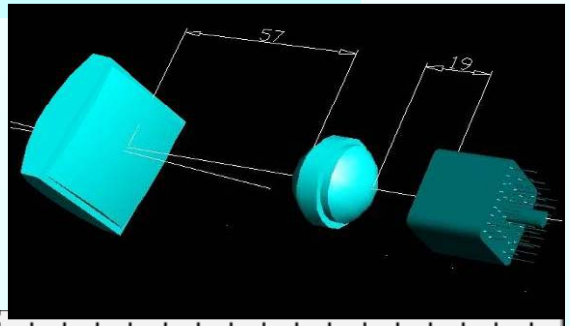
Fulvio Tessarotto

on behalf of the *COMPASS RICH Upgrade Group*

INFN Istituto Nazionale di Fisica Nucleare

Sezione di Trieste





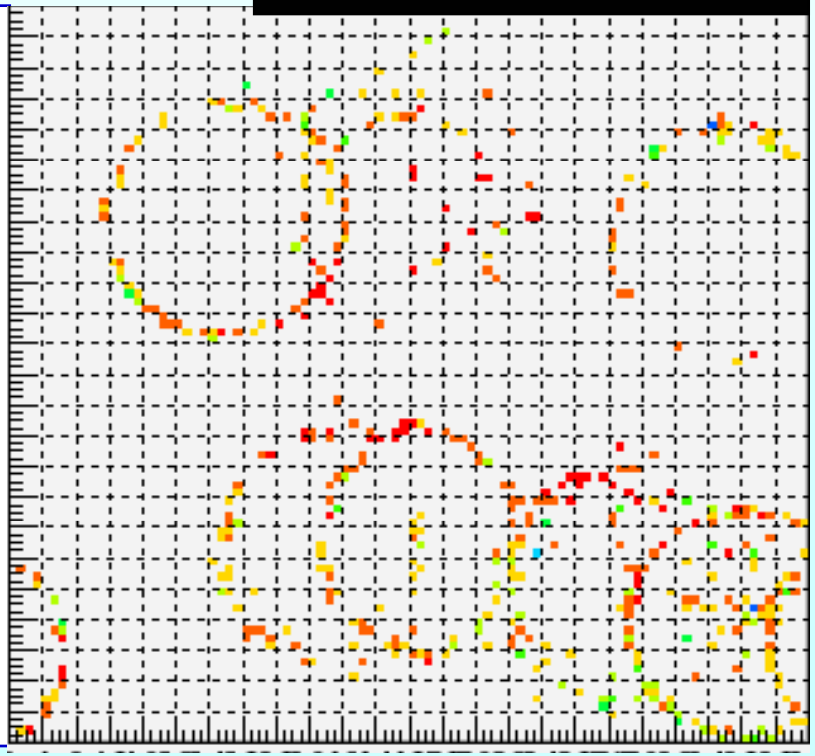
COMPASS RICH-1

The motivations for the upgrade

The project and the construction

Characteristics of lenses and MAPMT's

Preliminary performances



THE COMPASS SPECTROMETER

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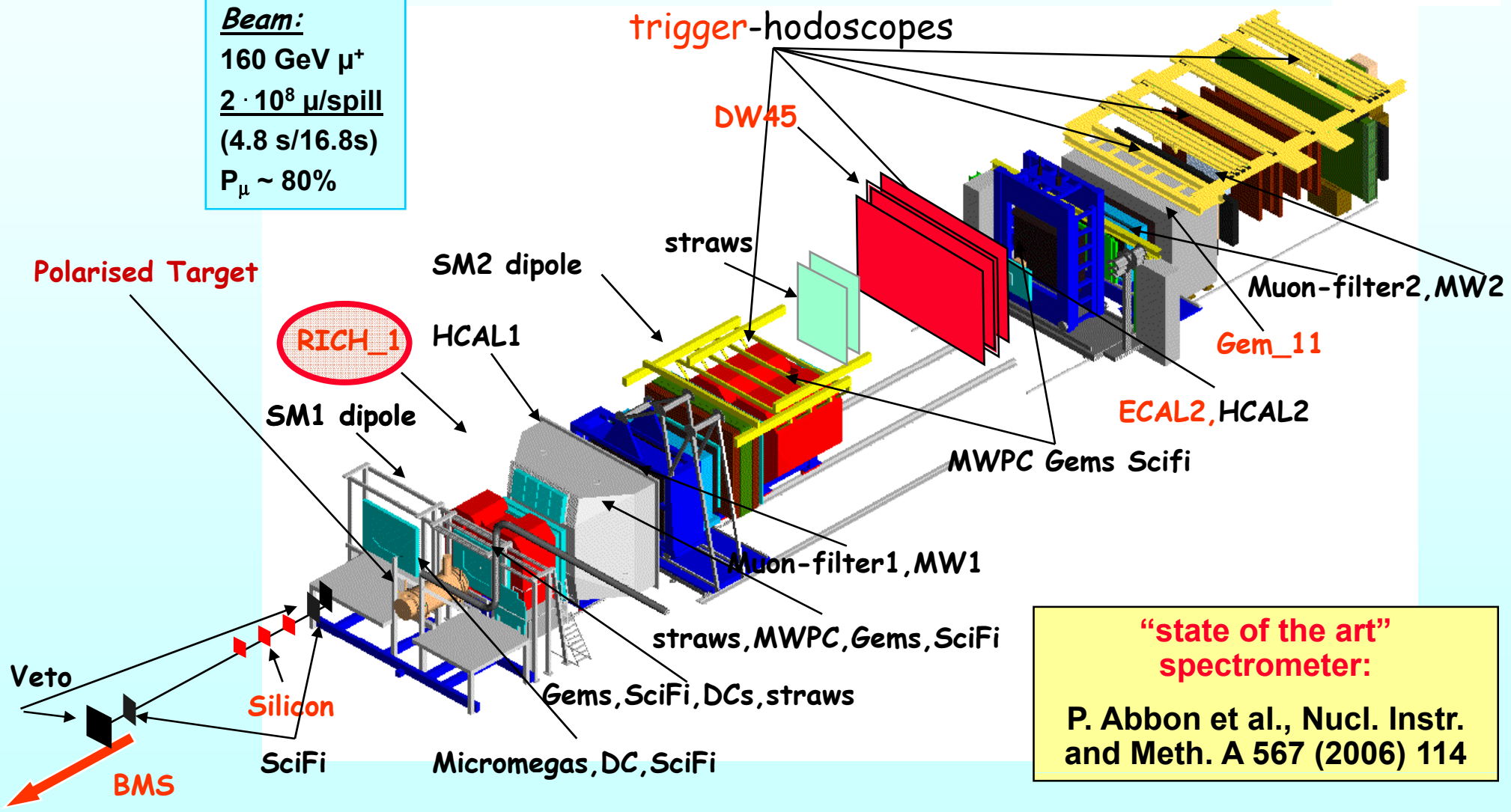
Beam:
160 GeV μ^+
$2 \cdot 10^8$ μ/spill
(4.8 s/16.8s)
$P_\mu \sim 80\%$



"state of the art" spectrometer:

P. Abbon et al., Nucl. Instr. and Meth. A 567 (2006) 114

COMPASS RICH-1

Trieste: INFN, Univ. & ICTP,
Turin: INFN and University,
Bielefeld University,
CERN technical support

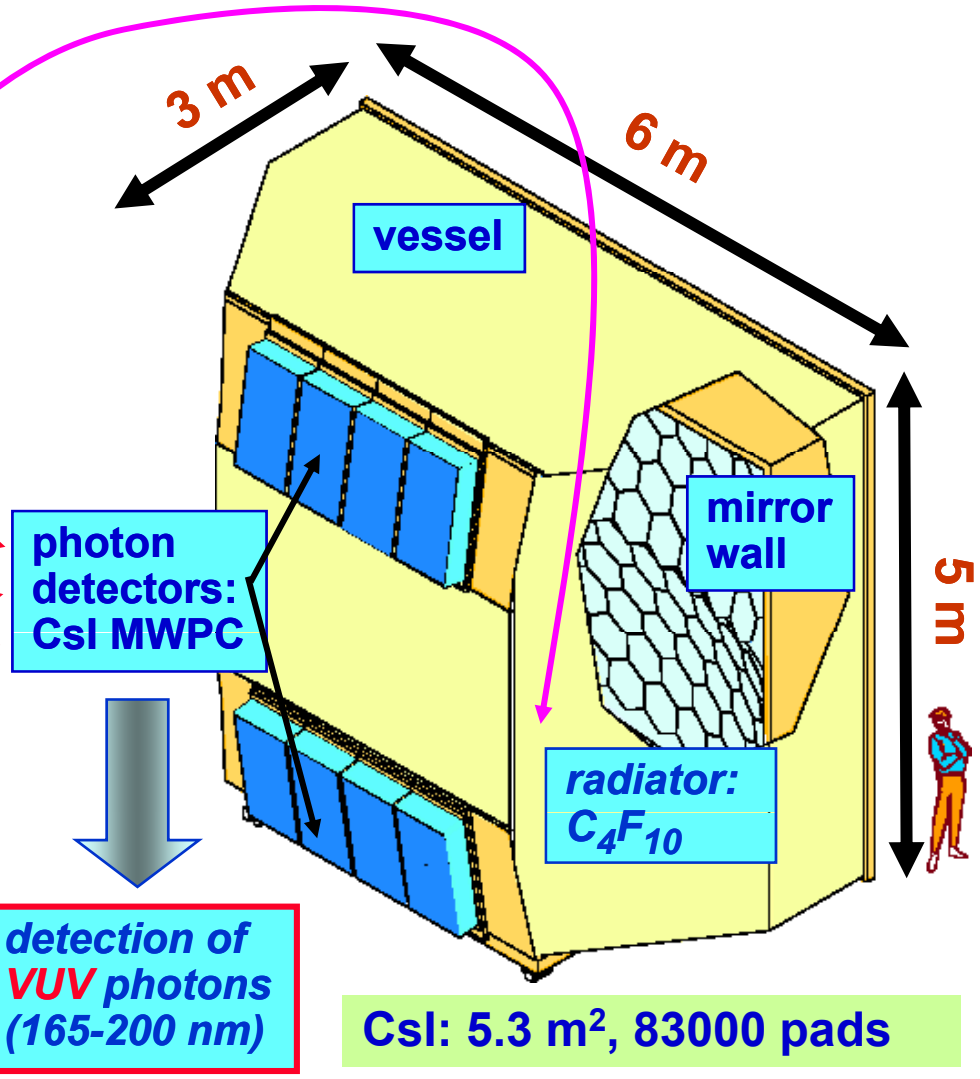
Fully described by Silvia Dalla Torre at RICH2004

requirements:

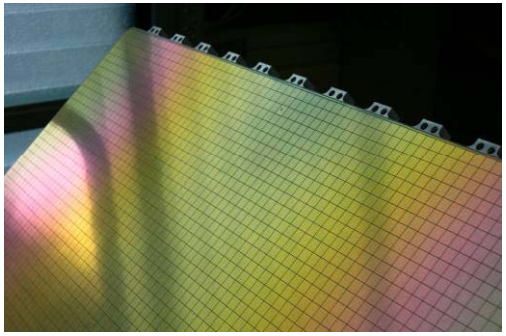
- hadron PID up to ~45 GeV/c
- LARGE acceptance (large size):
  - H: 500 mrad
  - V: 400 mrad
- able to stand trigger rates up to 20 KHz
- beam rates up to $4 \cdot 10^7$ Hz
- minimize material in the acceptance

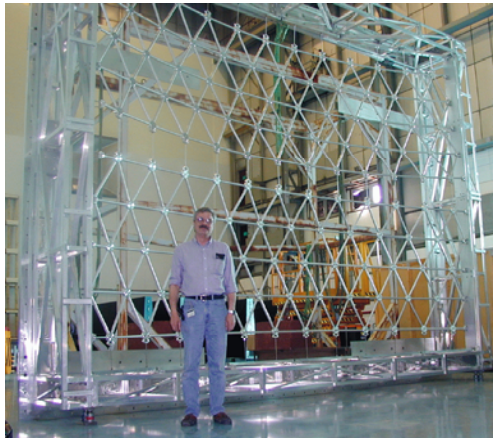
detector designed in 1996
in operation since 2002

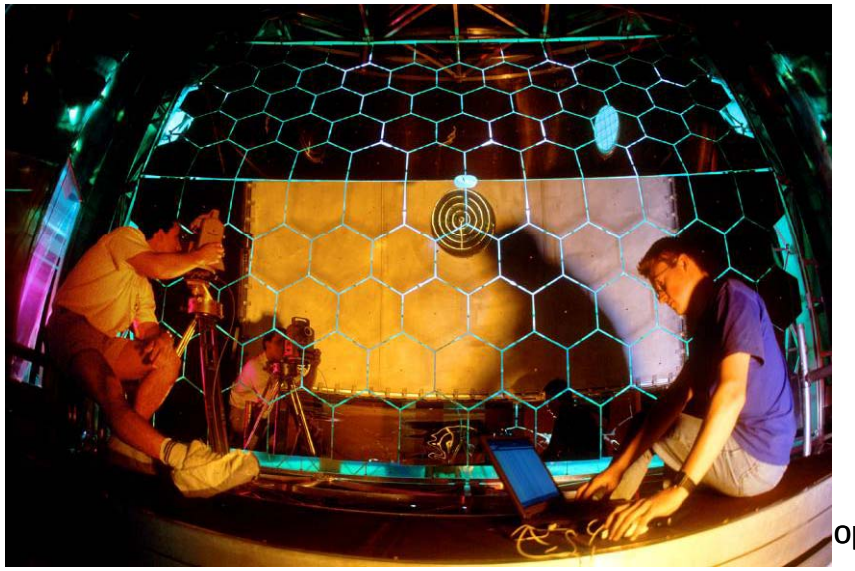
- PROJECT COST : ~ 3 M €



CsI: 5.3 m², 83000 pads







COMPASS RICH-1 performances before the upgrade

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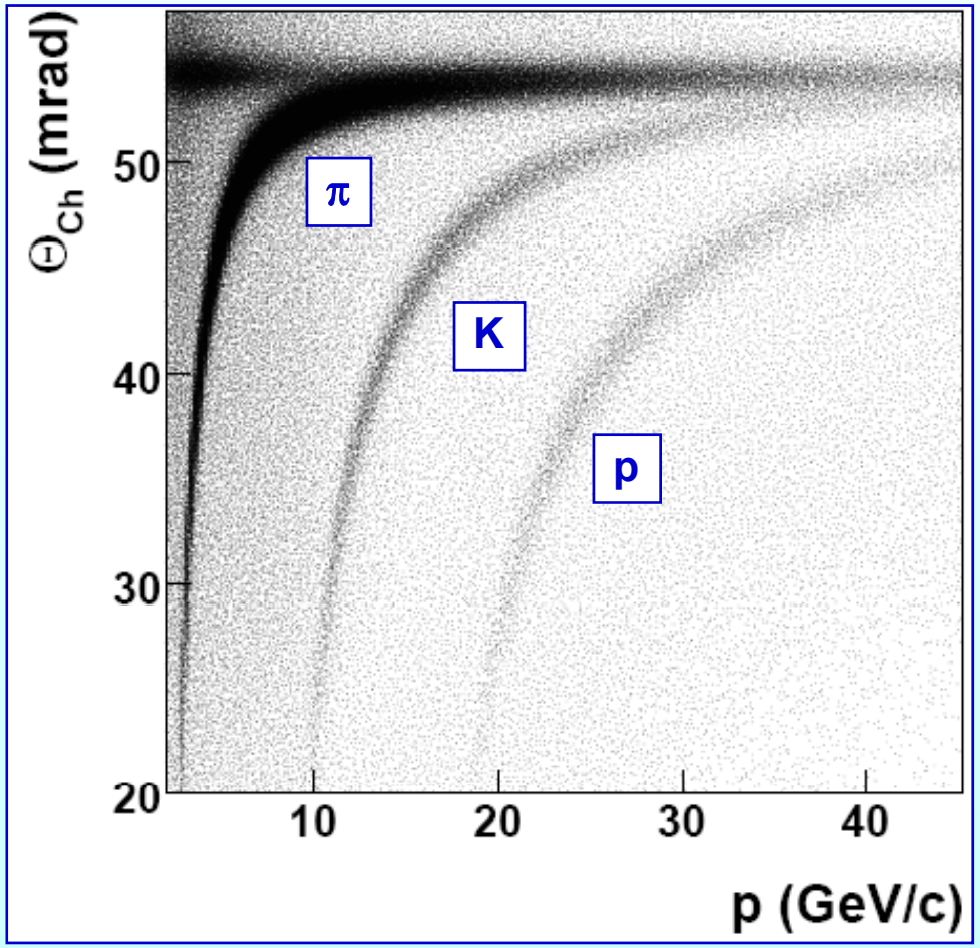

- *photons / ring ($\beta \approx 1$, complete ring in acceptance) : **14***
- *$\sigma_{\theta\text{-}ph}$ ($\beta \approx 1$) : **1.2 mrad***
- *σ_{ring} ($\beta \approx 1$) : **0.6 mrad***
- *2σ π - K separation @ **43 GeV/c***
- *PID efficiency **> 95%** (θ_{Ch} > 30 mrad)*

except for the very forward region

E. Albrecht et al, Nucl. Instr. and Meth. A 502 (2003) 112

E. Albrecht et al, Nucl. Instr. and Meth. A 553 (2005) 215

RICH-1: experimental challenges

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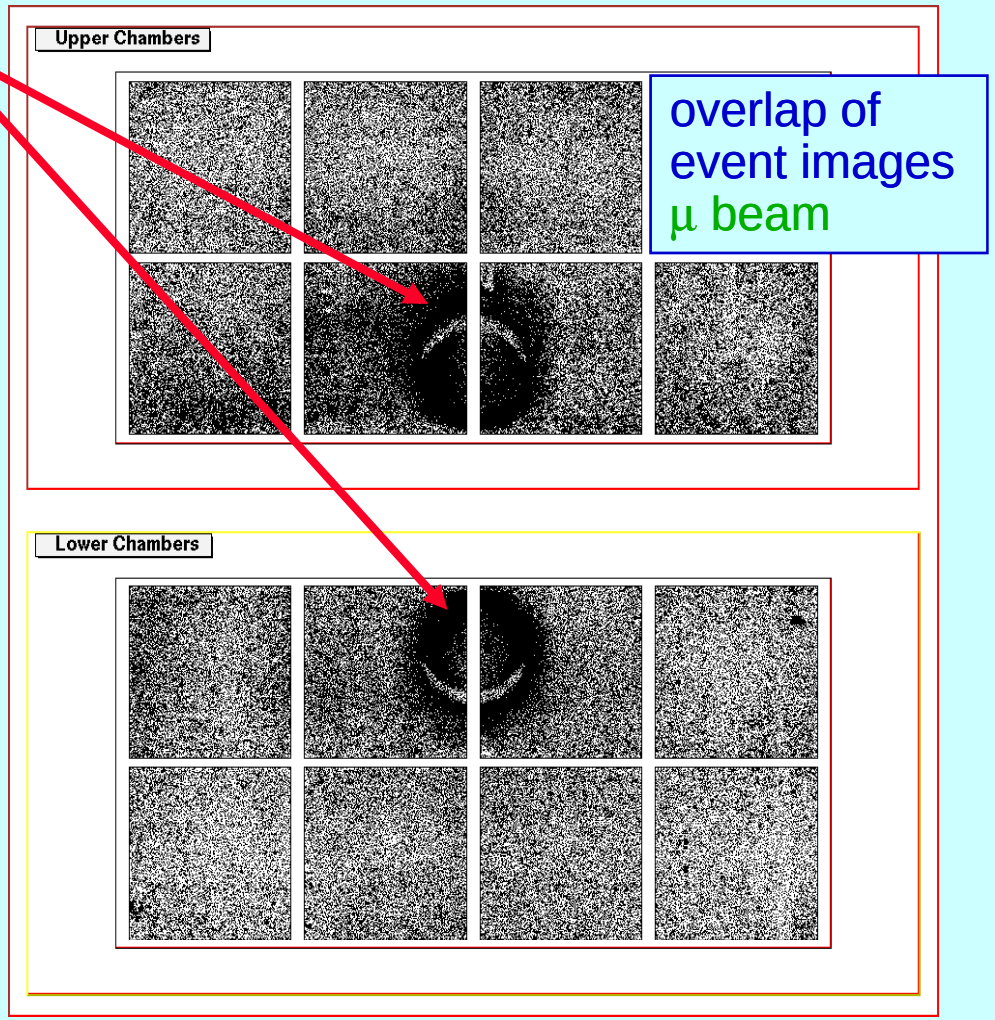
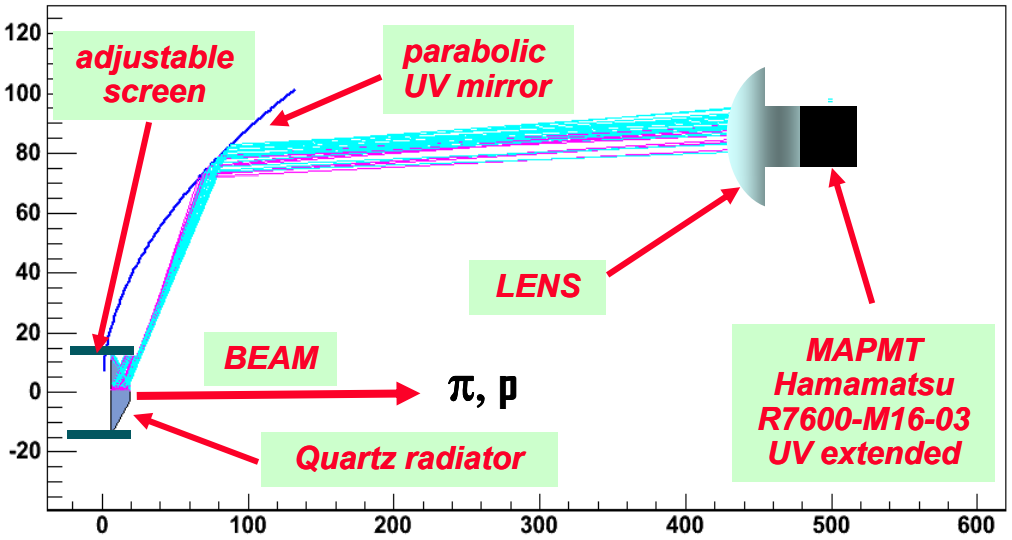
- **THE EXPERIMENTAL ENVIRONMENT**
  - huge uncorrelated background related to the memory of the MWPCs + read-out

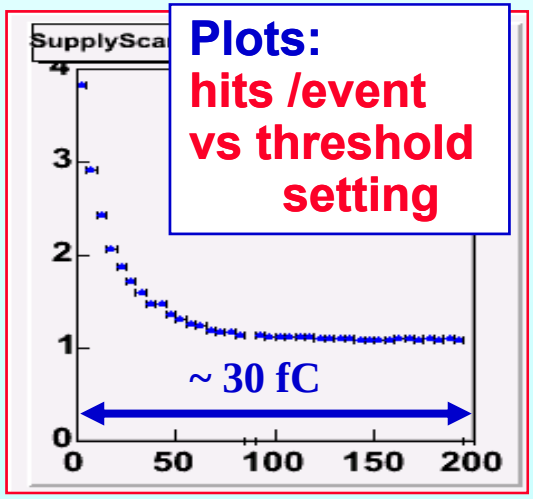
- **THE HIGH RATE OPERATION**
  - Increased beam intensity:
    - ultimate goal 100 MHz
    - presently: 40 MHz
  - Increased trigger rates
    - up to 100 KHz
    - presently: 20kHz
  - No dead time (Luminosity)

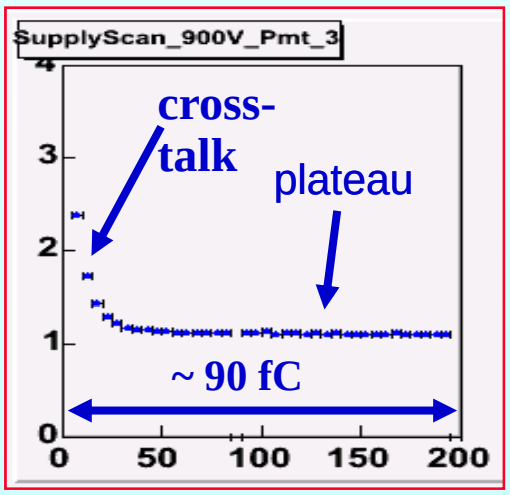


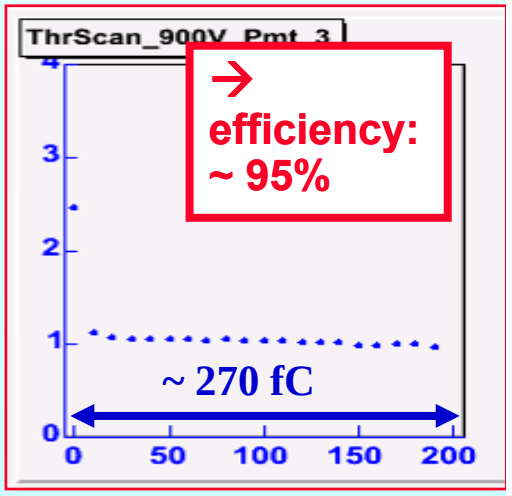
Studies for a fast RICH detector

Presented at RICH2004 by F. Tessarotto



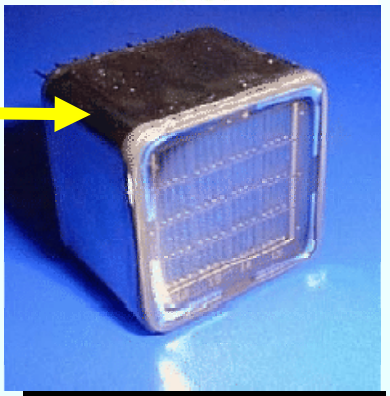






a flat region (no photon loss), good for safe threshold setting, is clearly identified between the cross-talk region and the region where detection loss starts (third plot)

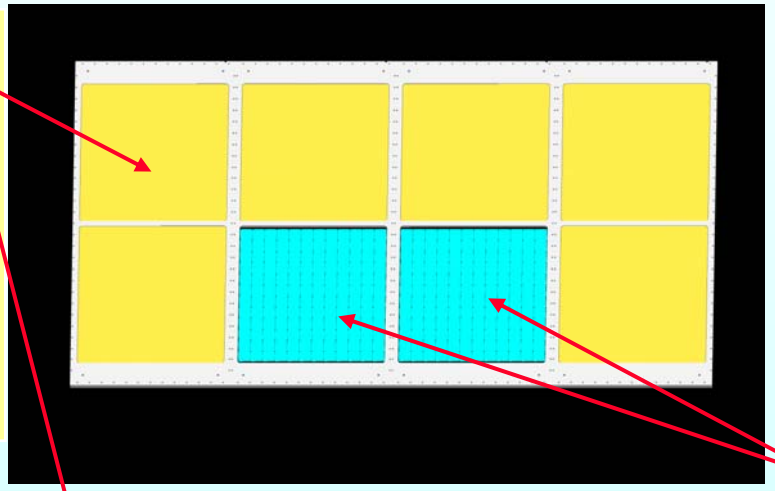
In October 2004 we proposed the upgrade of RICH-1 using MAPMT's

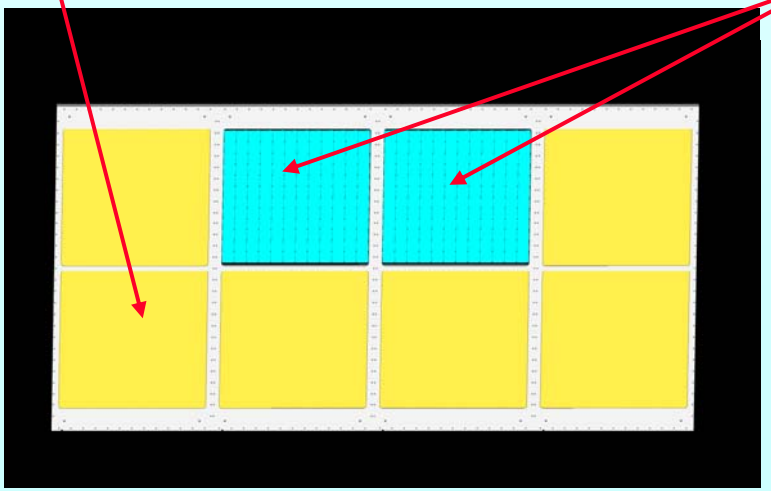


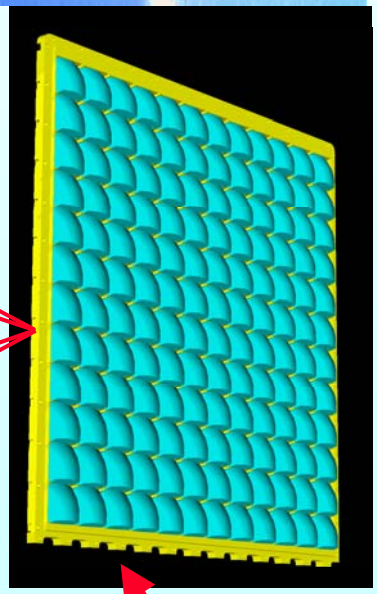
12 outer CsI cathodes: change electronics (use APV25-S1)

4 central CsI cathodes: remove and insert frames with MAPMTs and lense telescopes

keep mechanical compatibility







Same mechanics as CsI photo-cathode frame

Published articles on RICH-1 upgrade:

M. Alekseev et al., Nucl. Instr. and Meth. A 553 (2005) 53

P. Abbon et al., Czech. J. Phys., Suppl. F. 56 (2006) 307

P. Abbon et al., Czech. J. Phys., Suppl. F. 56 (2006) 315

P. Abbon et al., Czech. J. Phys., Suppl. F. 56 (2006) 323

P. Abbon et al., Nucl. Instr. and Meth. A 567 (2006) 114

P. Abbon et al., Nucl. Instr. and Meth. A 572 (2007) 419

P. Abbon et al., Nucl. Instr. and Meth. A 580 (2007) 906

The principle

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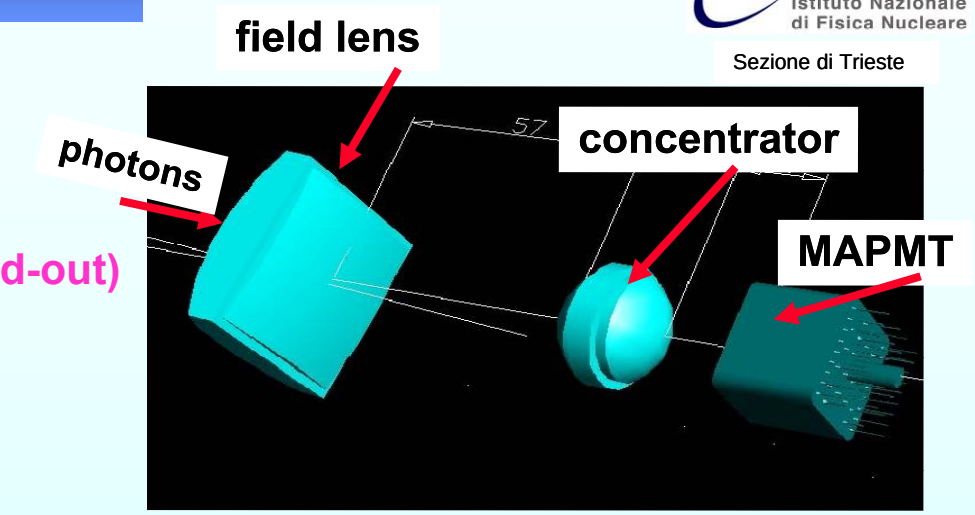
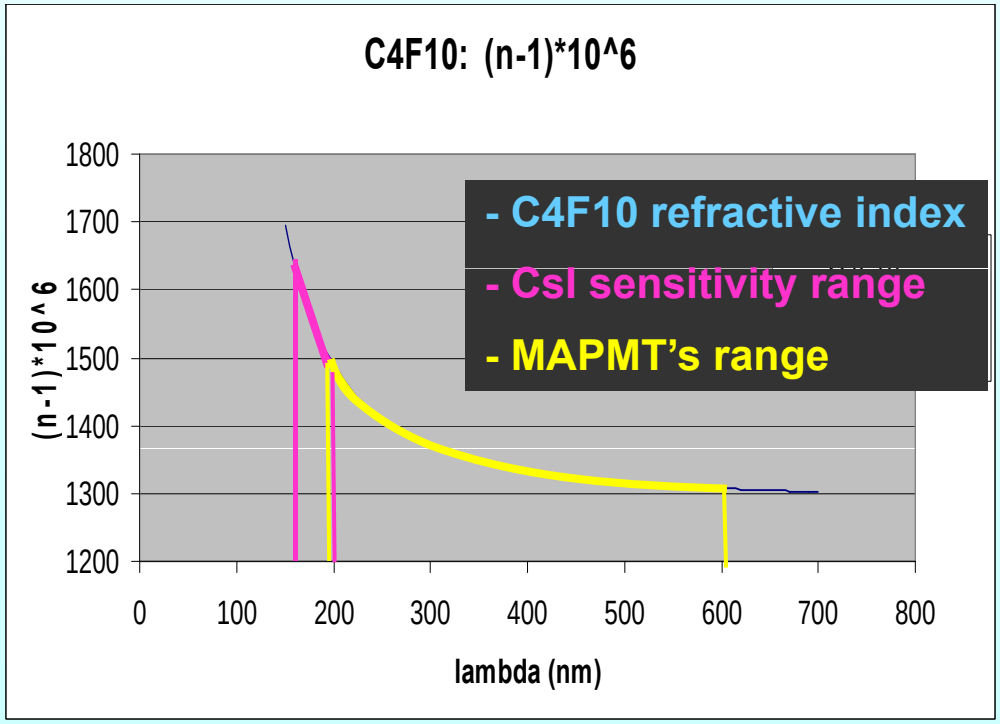
MAPMT's have:

- wide wavelength range
- time resolution < 1 nsec
- short detection system memory (MAPMT + read-out)
- adequate for high rate operation
- robustness
- high efficiency for single photon detection





challenges:

large ratio of the collection and photocathode areas with minimal image distortion

→ ratio = 7.3 ←→ critical LENS SYSTEM design

UV range ←→ fused silica LENSES

couple to a read-out system able to guarantee efficiency, high rate operation and to preserve time resolution

THE FUSED SILICA LENS TELESCOPE

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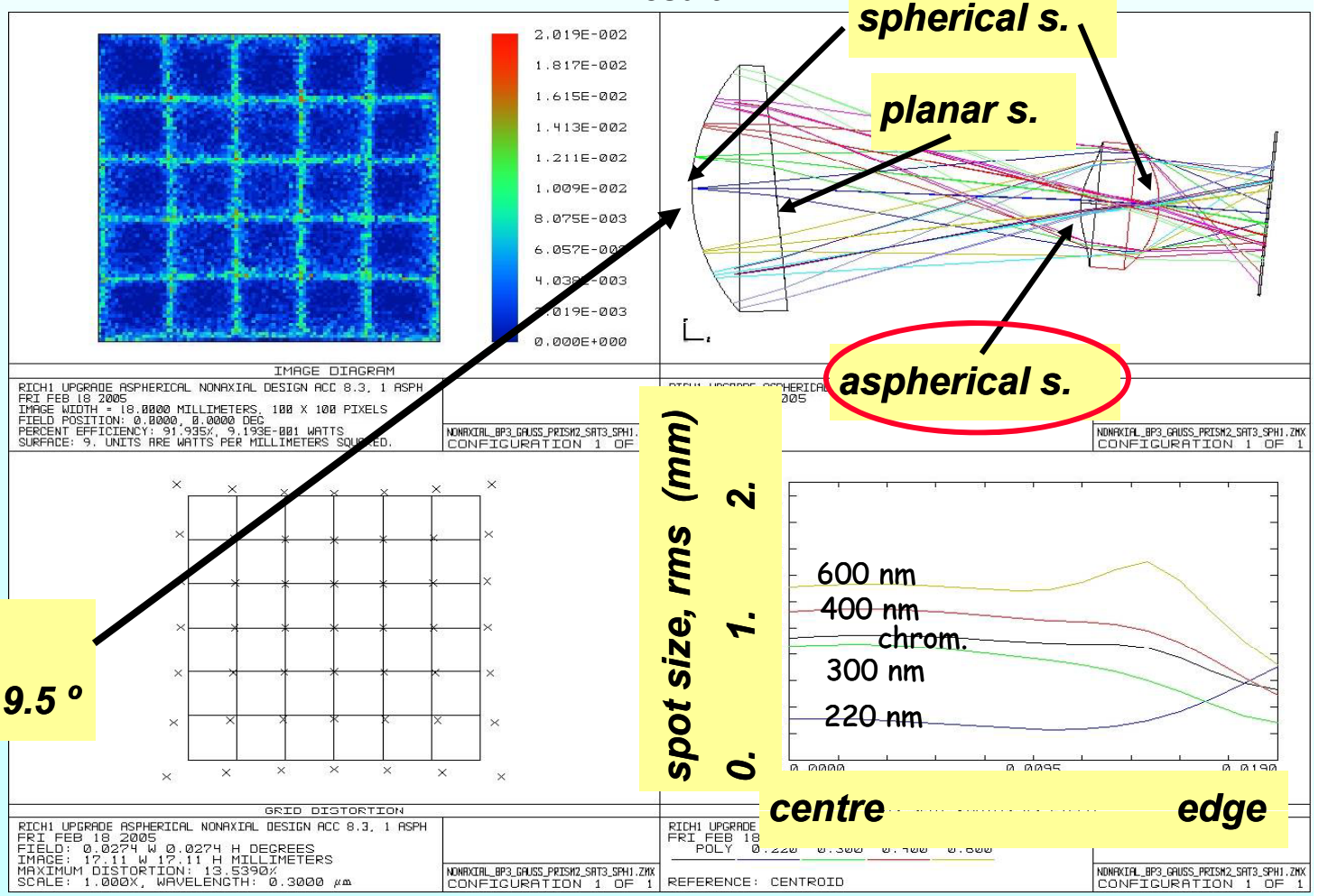
OPTIMISATION CRITERIA

limited image distortions
→ RICH resolution
(chromaticity is taken into account)
angular acceptance
of the telescope
mechanical constrains
manifacturing parameters
(feasibility, cost)

ZEMAX result:



AXIS TILT: 5 º

ANGULAR ACCEPTANCE: ± 9.5 º

THE LENSES

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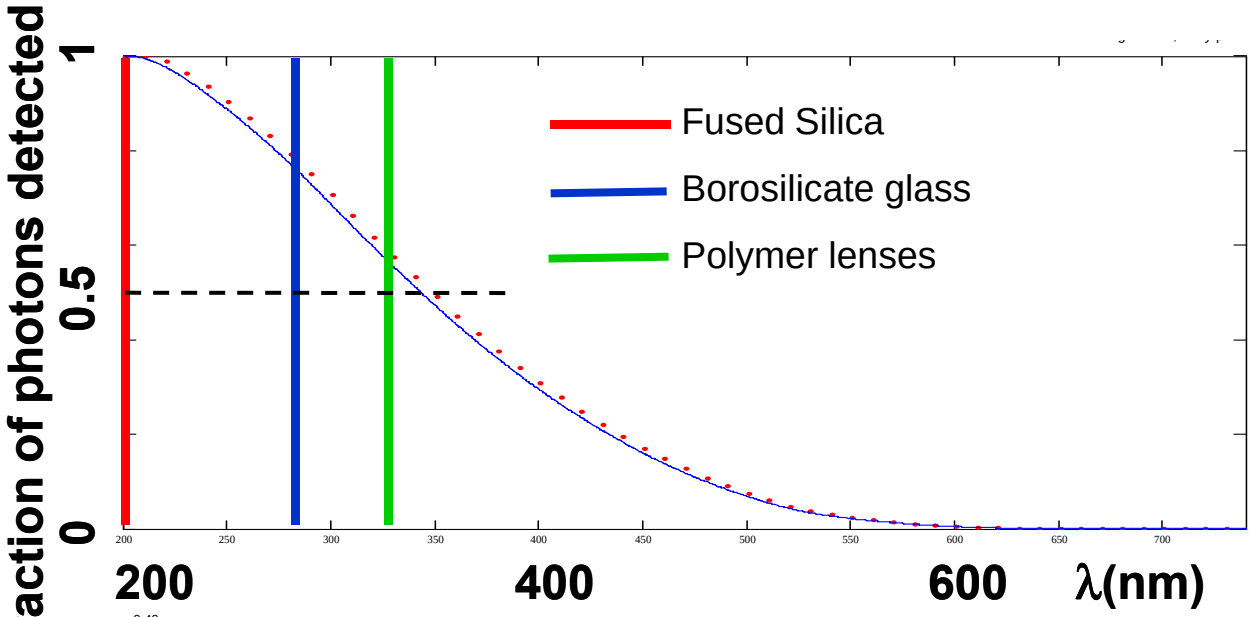
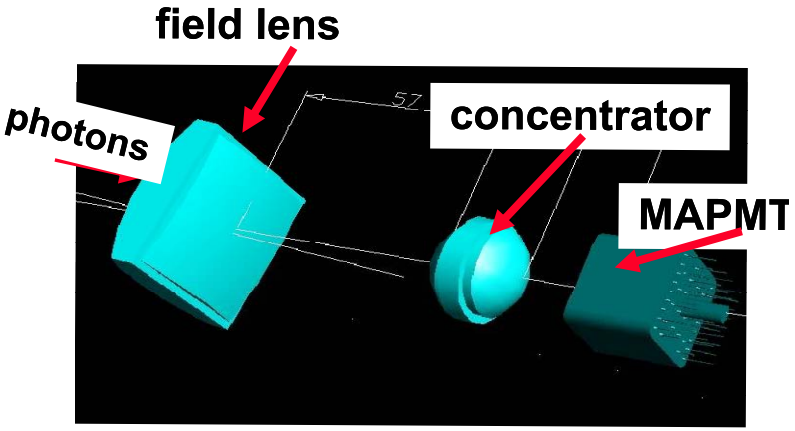
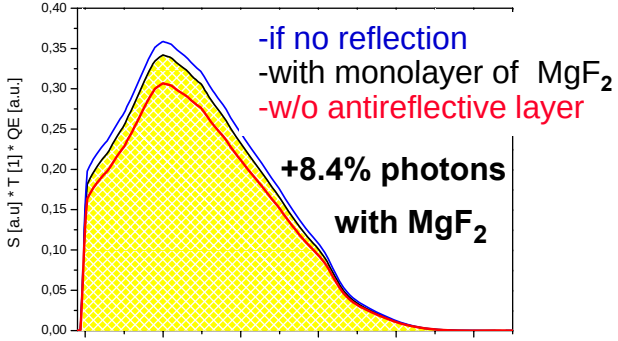
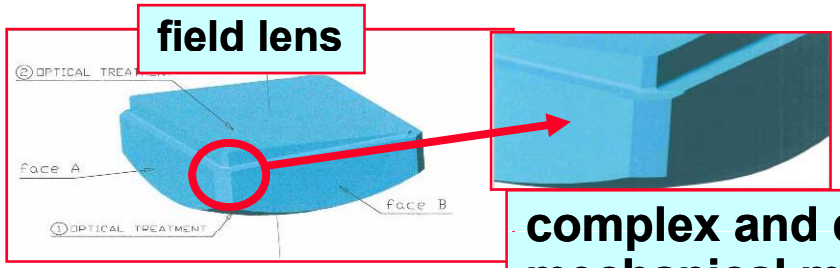
$$\int_{\lambda}^{800} QE\ (\lambda)\cdot S(\lambda)\cdot d\lambda \Big/ \int_{200}^{800} QE\ (\lambda)\cdot S(\lambda) d\lambda$$

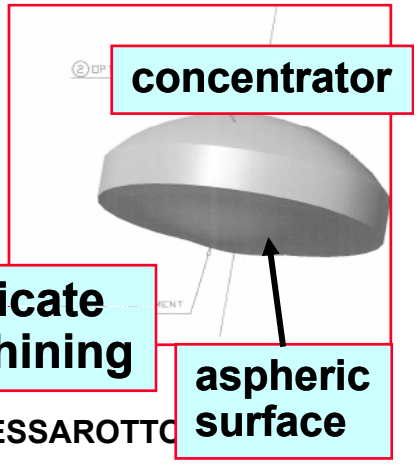
material:
fused silica, Corning 7980, standard grade F5





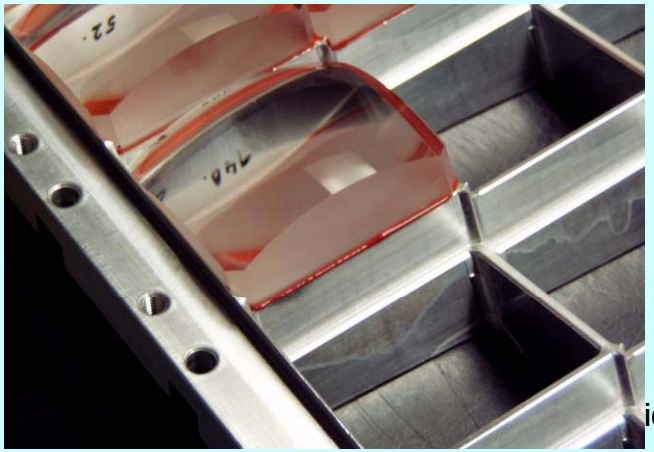
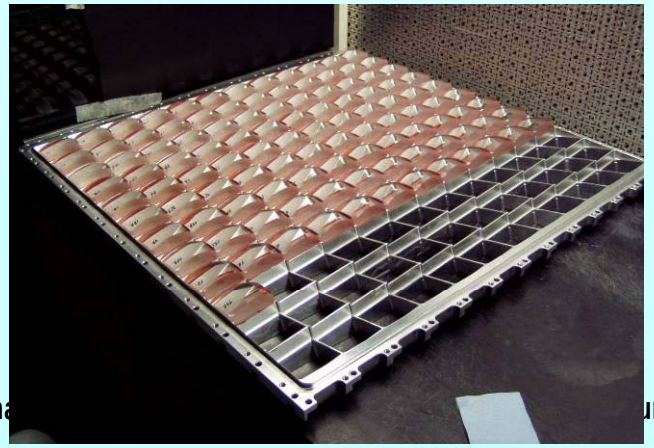
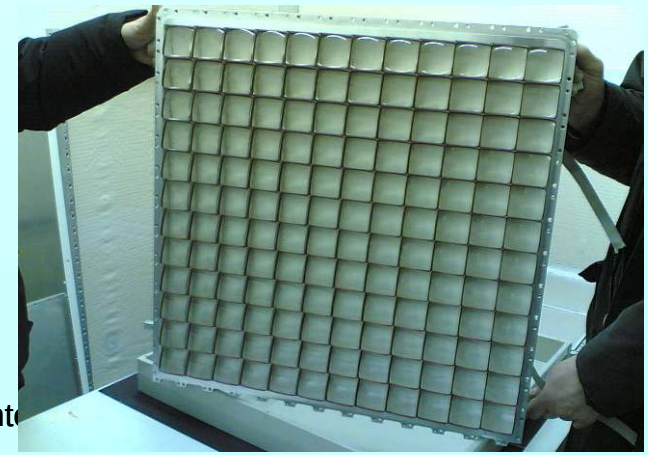






complex and delicate mechanical machining

Convolution of Cherenkov light and effective QE

OPTICS QUALITY CONTROL WITH THE HARTMANN METHOD

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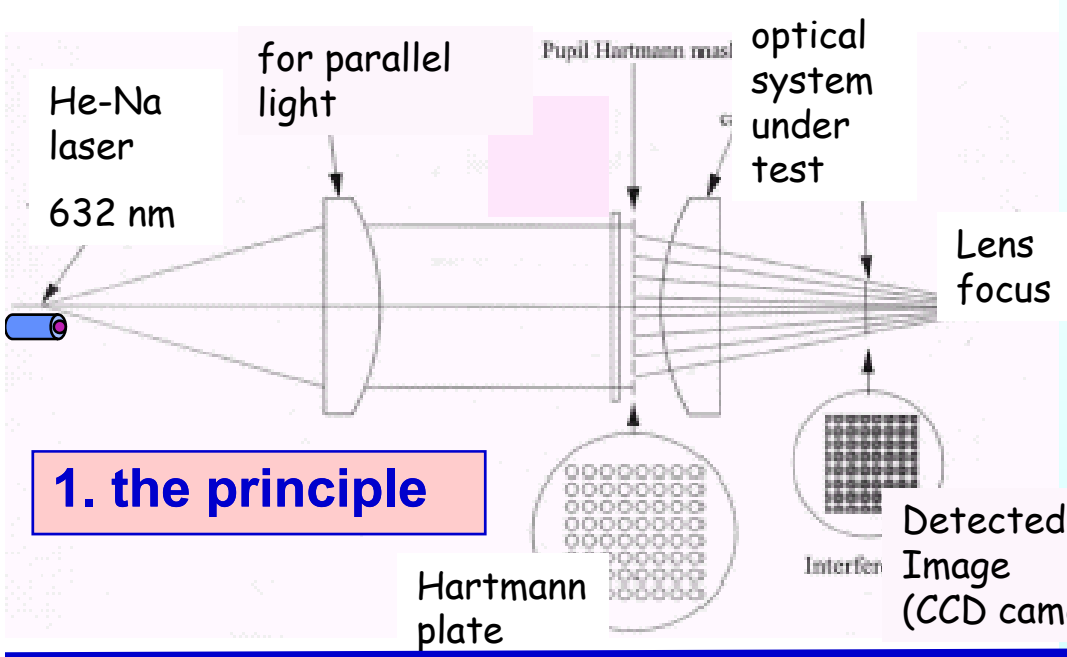
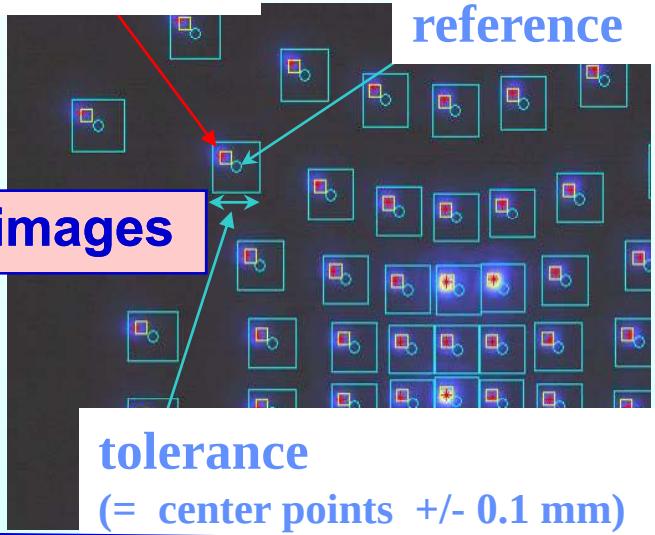
1. the principle



2. the images

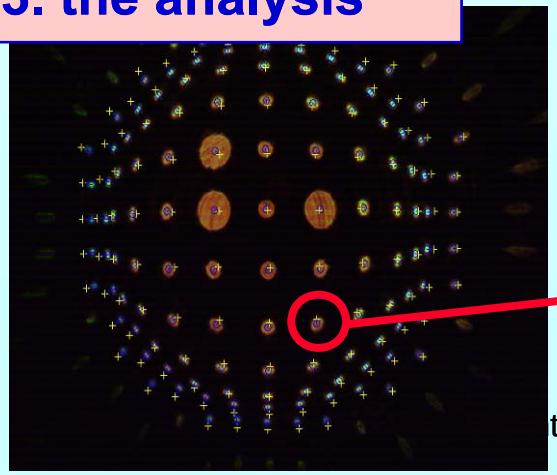
image centroide

Theoretical reference

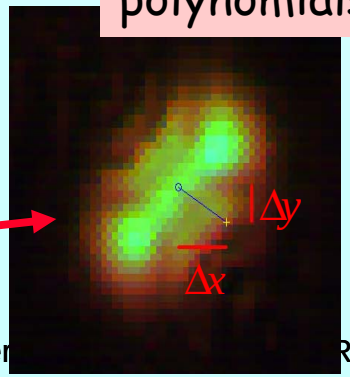


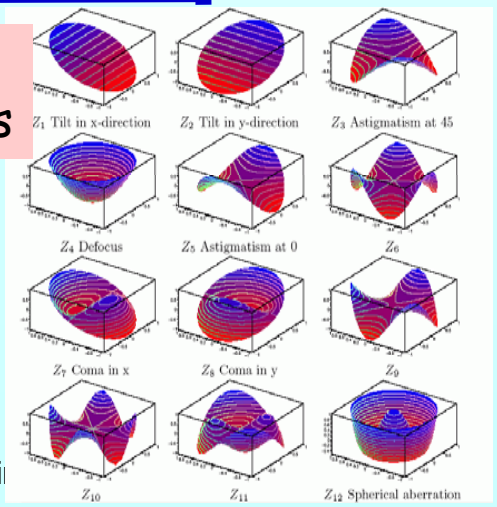
tolerance
(= center points +/- 0.1 mm)

3. the analysis

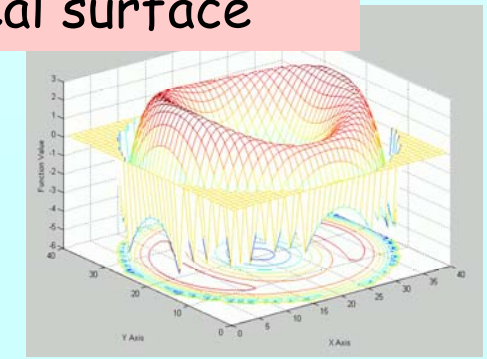


Zernike polynomials

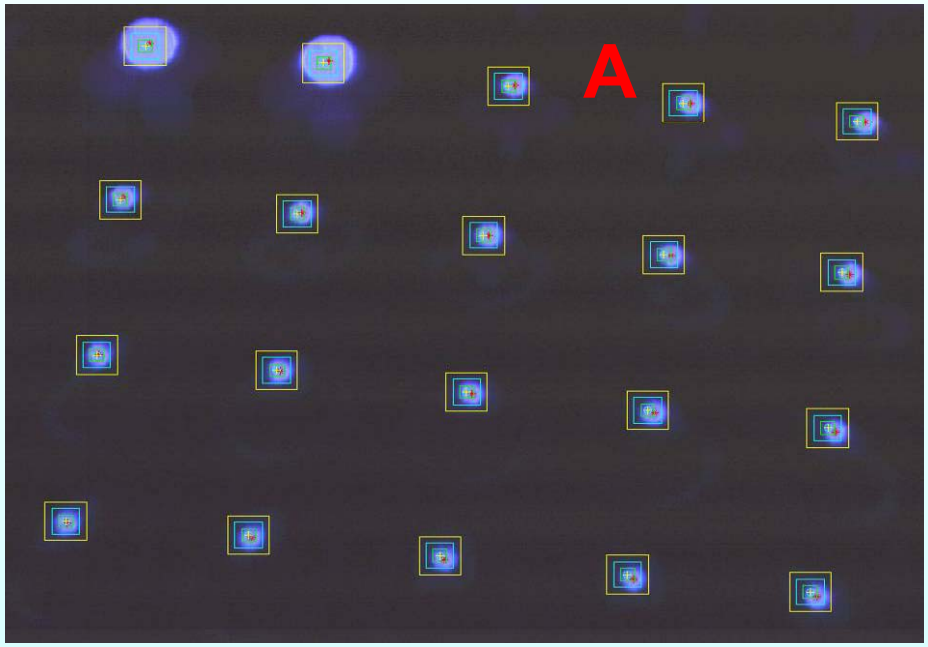


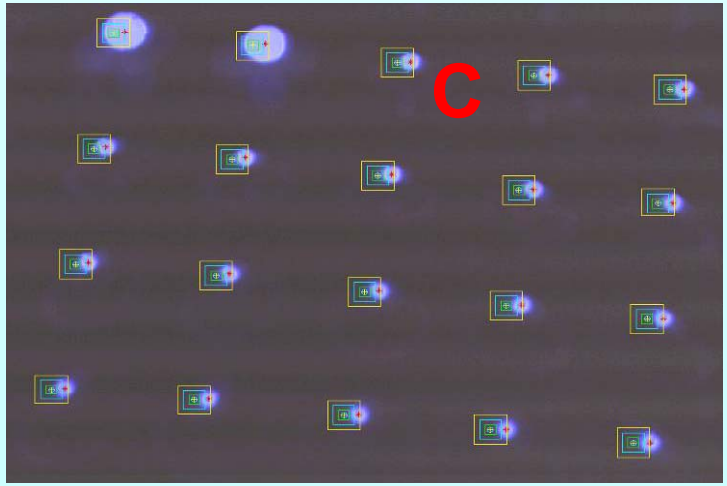


Deviations from ideal surface



OPTICS, THE ACHIEVEMENTS

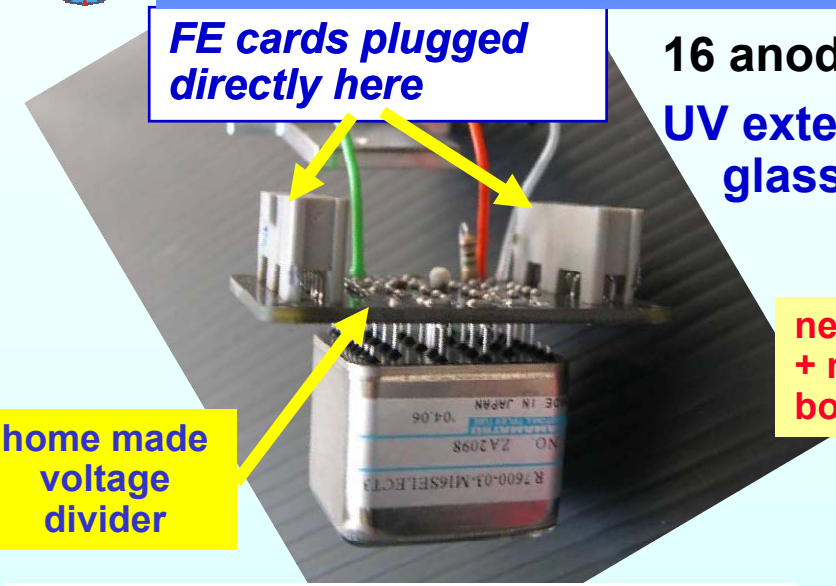




576 TELESCOPES:

A) ~70% within 50 μm tolerance
B) ~20% within 100 μm tolerance
C) ~10% within 150 μm tolerances

MAPMT: HAMAMATSU R7600-03-M16



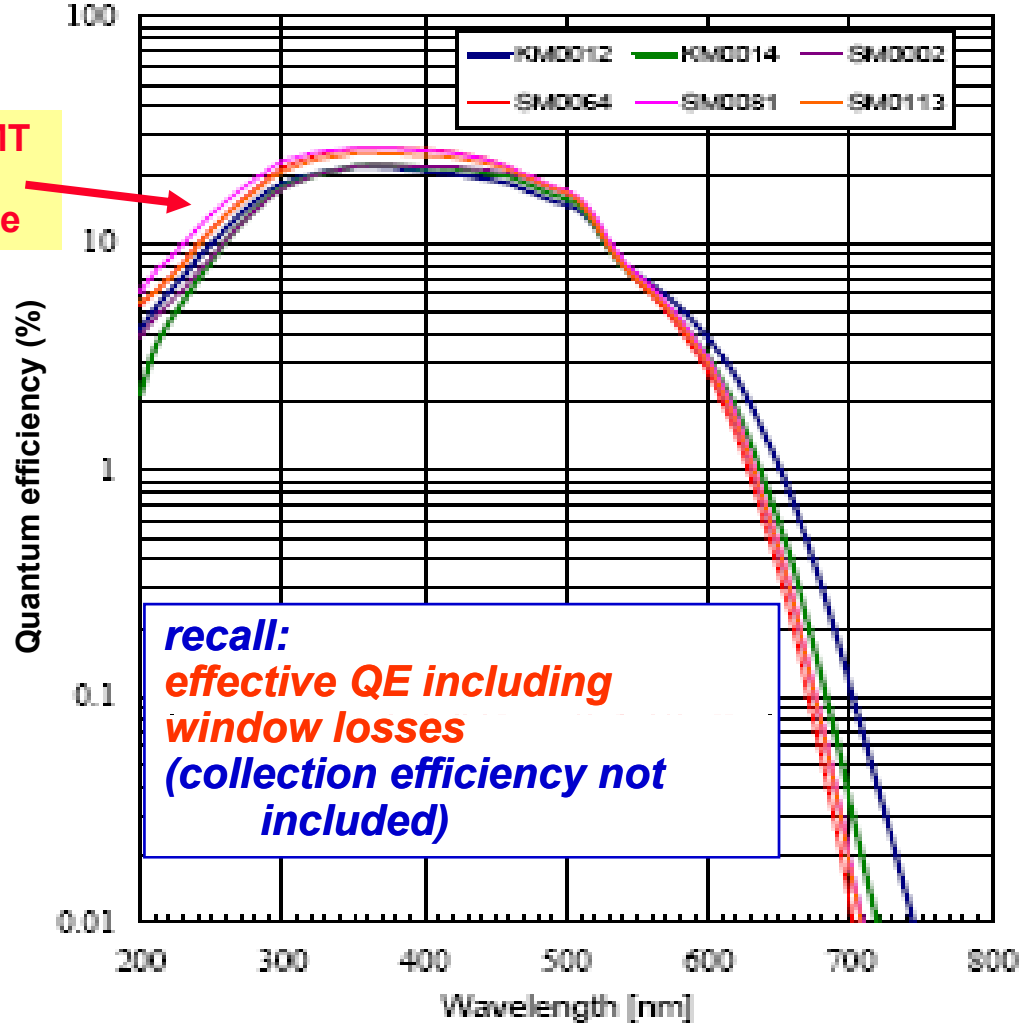
16 anodes

UV extended glass

new MAPMT + new UV borosilicate

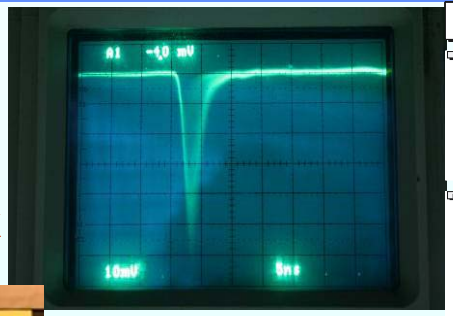
for more information see the poster by Andreas Teufel

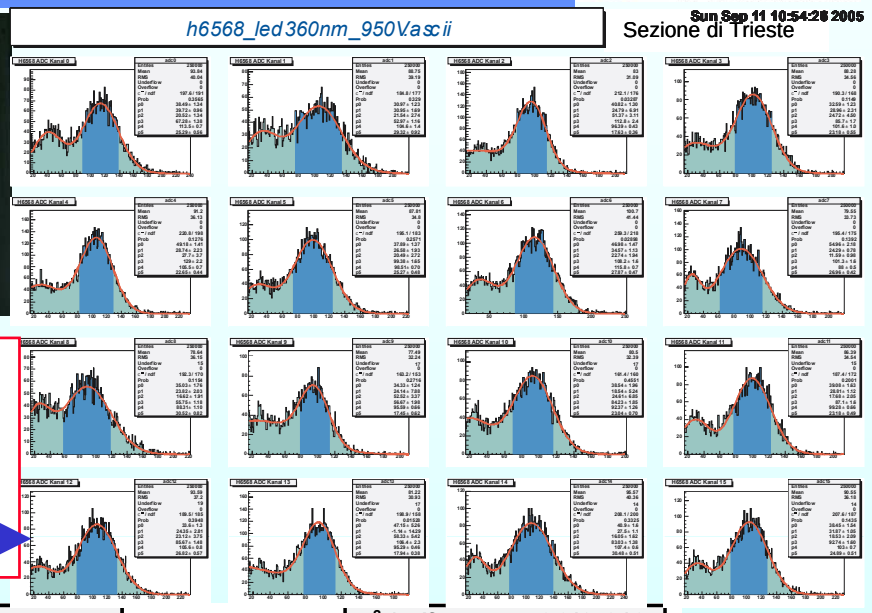
protects against B ≤ 200 G and guarantees good alignment



MAPMT Quality Control

out of 620 MAPMTs
less than 10 MAPMTs not fully satisfactory, mainly due to the dark current requirement:
I dark < 2 nA/ch after ½ h in dark

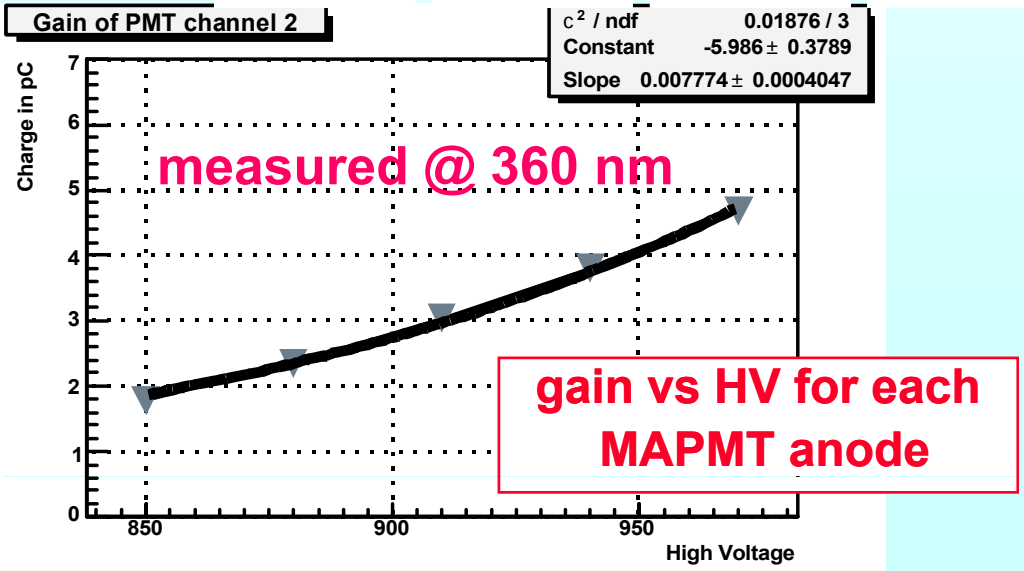




Individual ADC spectra for each channel, voltage, wavelenght

PROTOCOL – 2 h / MAPMT

- Visual Inspection (Pixel grid o.k.)
- Noise rates and dark current
- Scope Image stored
- Signal shape, uniformity, gain
  - measuring ADC distribution @ several Voltages
- Quantum efficiency
  - measurement with blue LED and UV LED



FITTING WITH 2 POLYA FUNCTIONS

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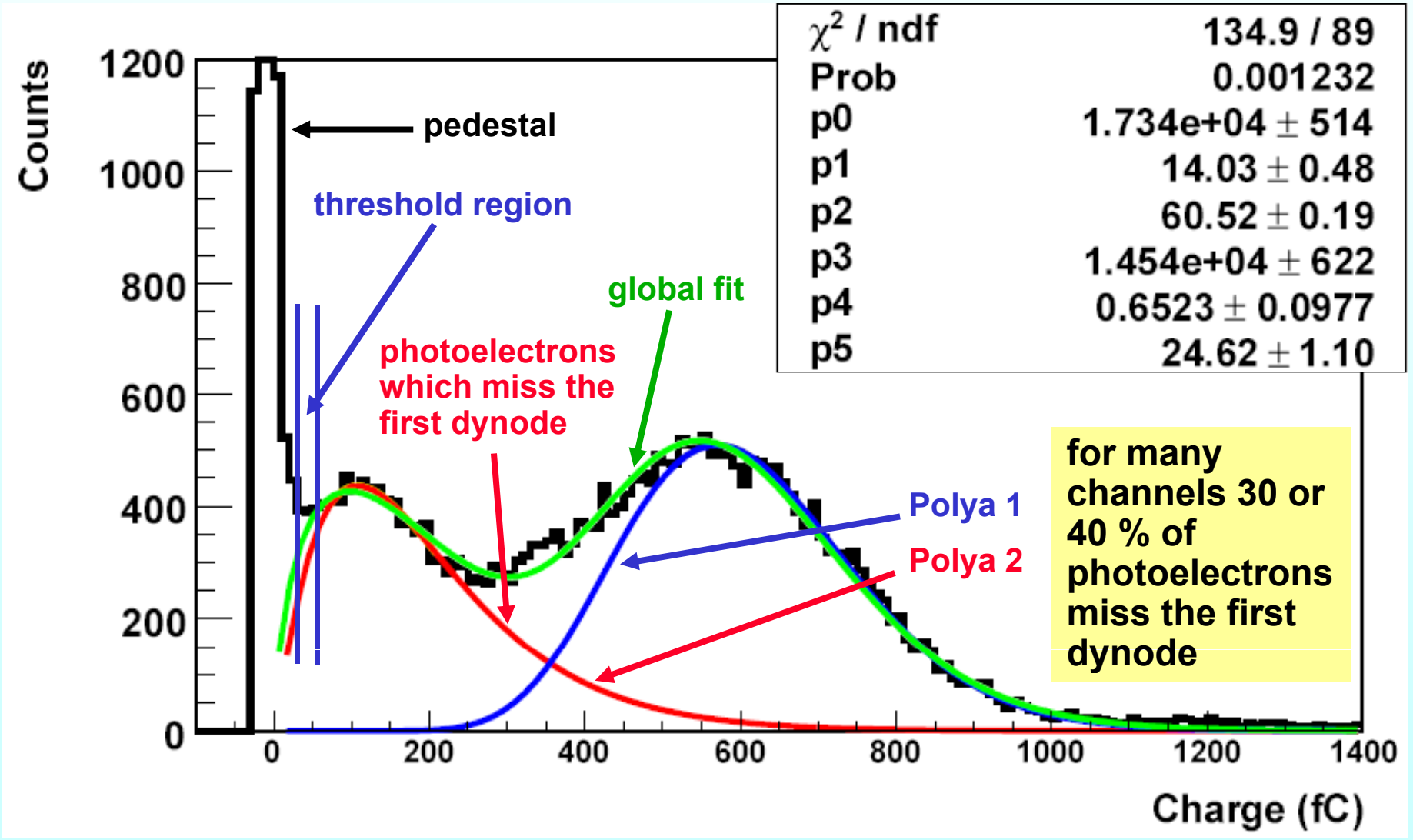

MAPMT GAIN AT HIGH RATE AND CROSS-TALK RATE

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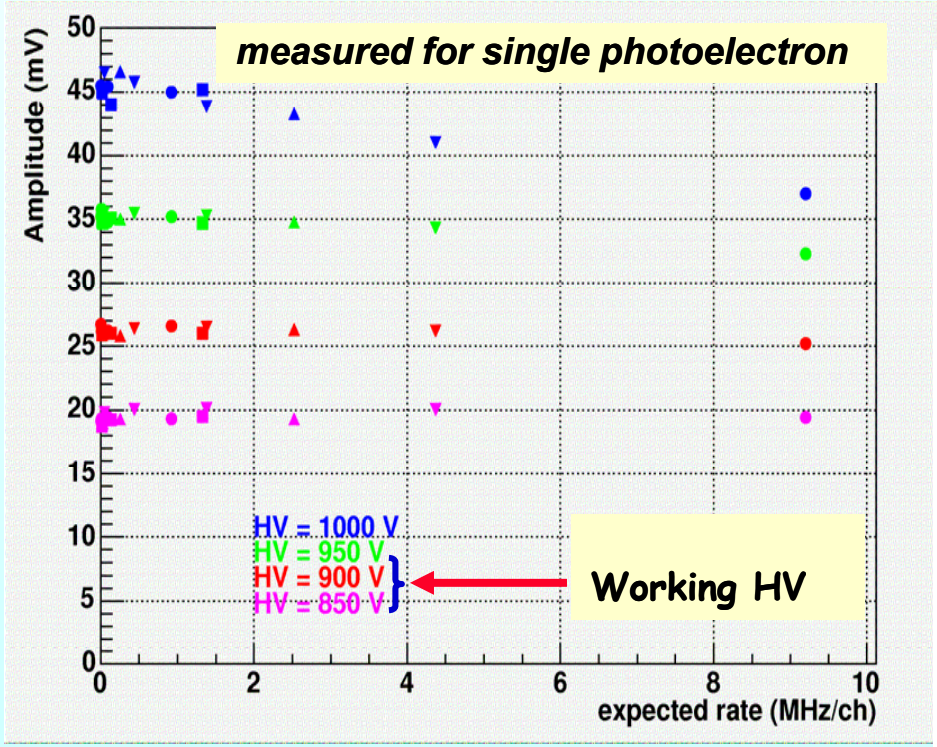
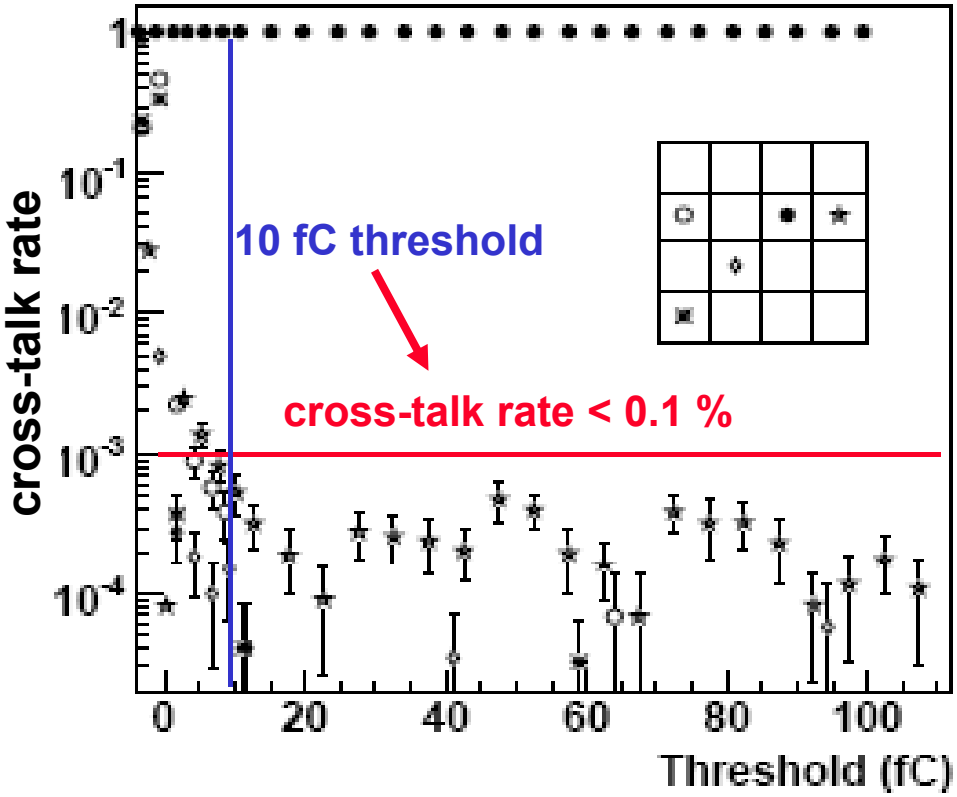
mean signal amplitude versus rate/pixel

pulsed light source synchronous to trigger + random background from lamp





for the future needs of COMPASS:
operate with single photoelectron rates up to 5MHz/pixel:
→ no rate limitation from MAPMT

time distribution for central and peripheral positions inside a pixel

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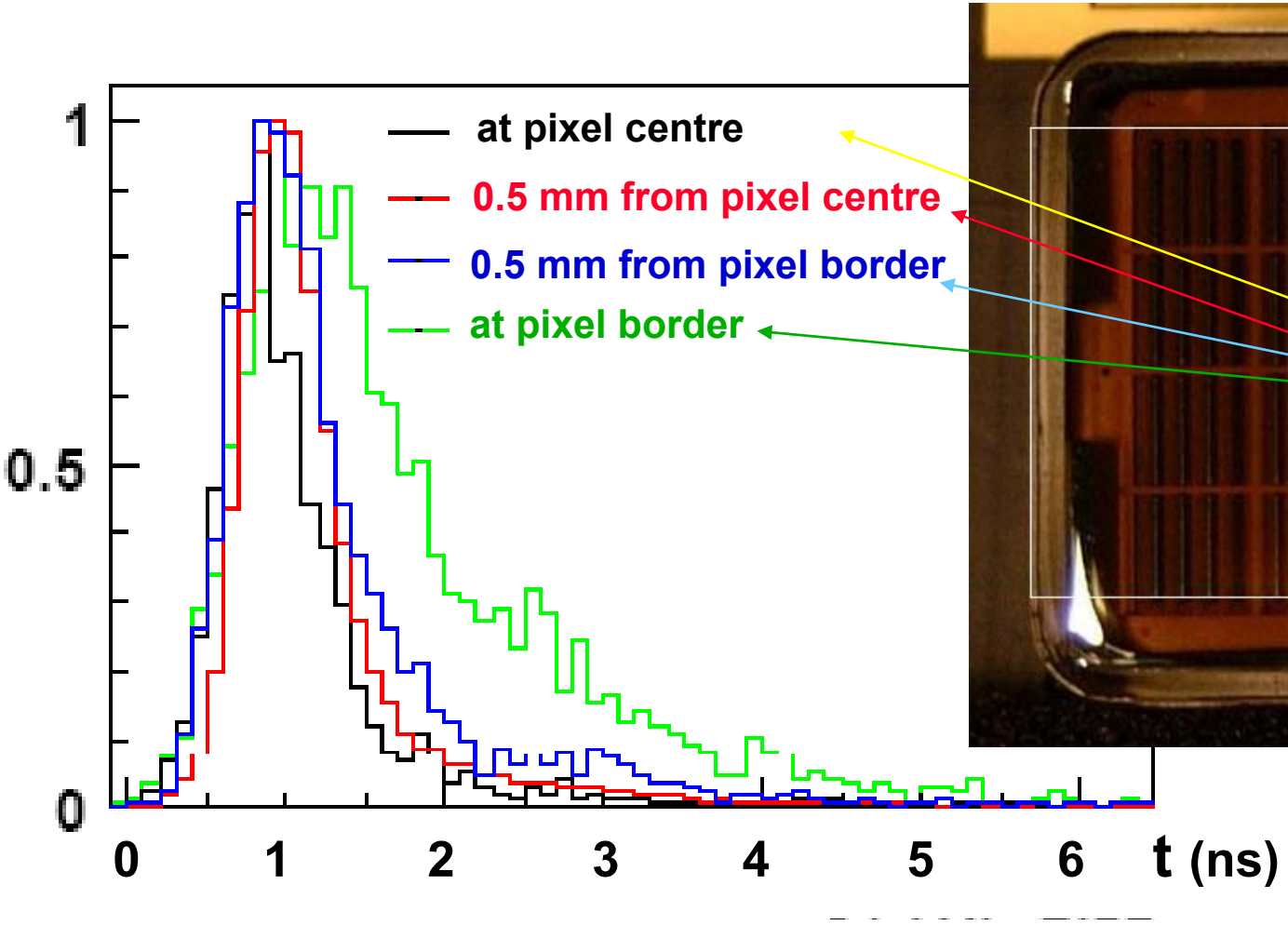

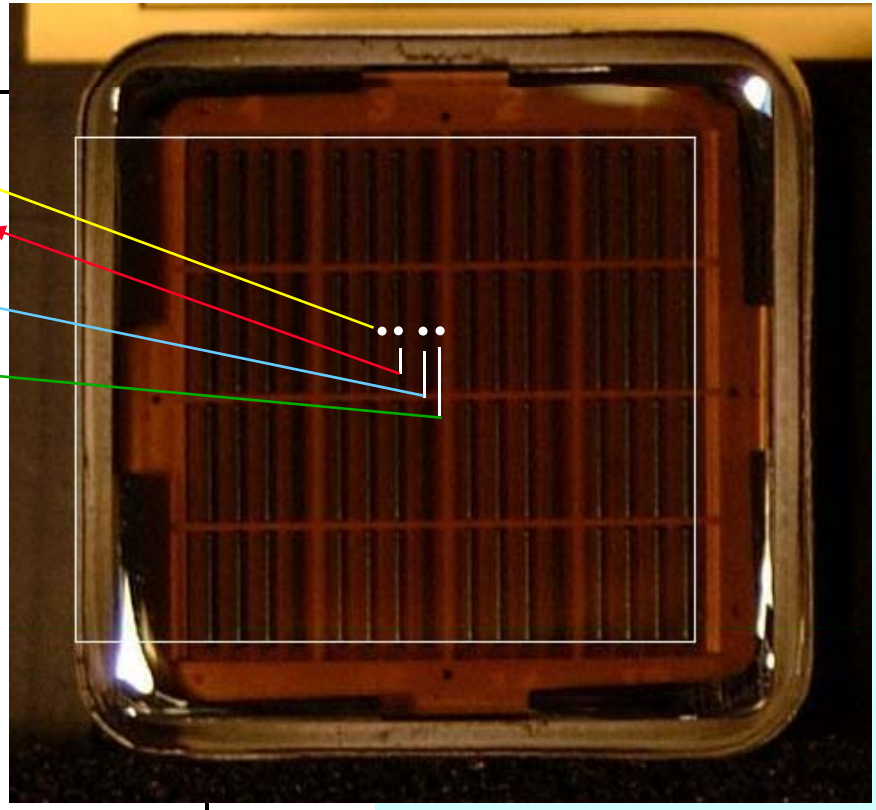

SCHEDULE OF ASSEMBLING

- Preliminary studies up to October 2004
- Project design November 2004 – March 2005
- Material procurement and constructions April 2005 - March 2006
- Assembly April-May 2006
- Ready for beam June 2006

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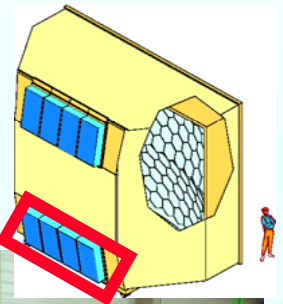
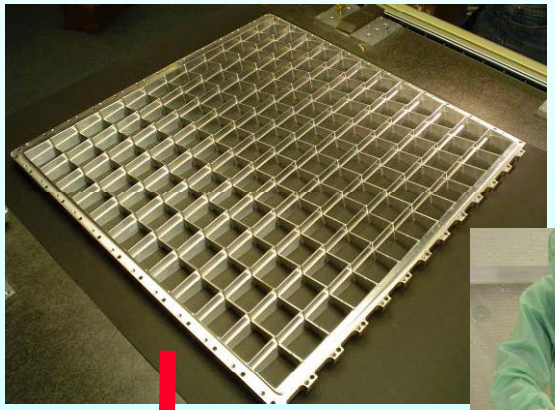
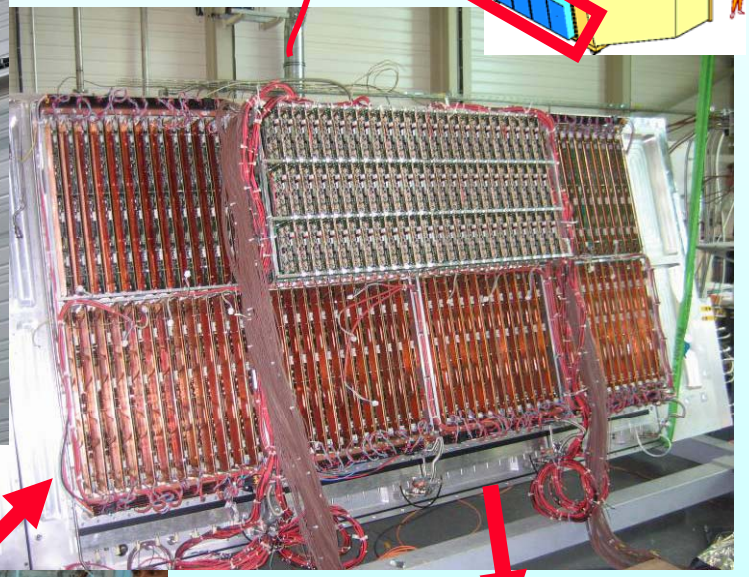
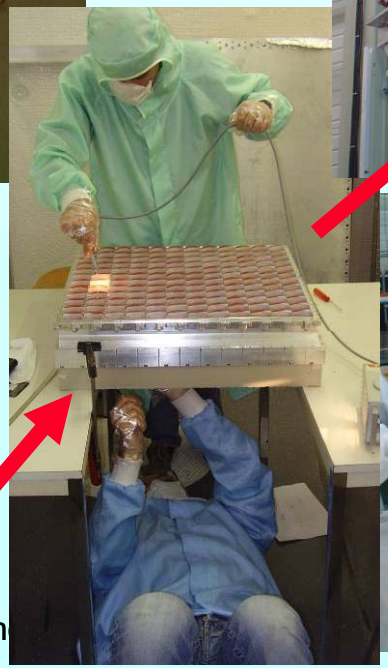
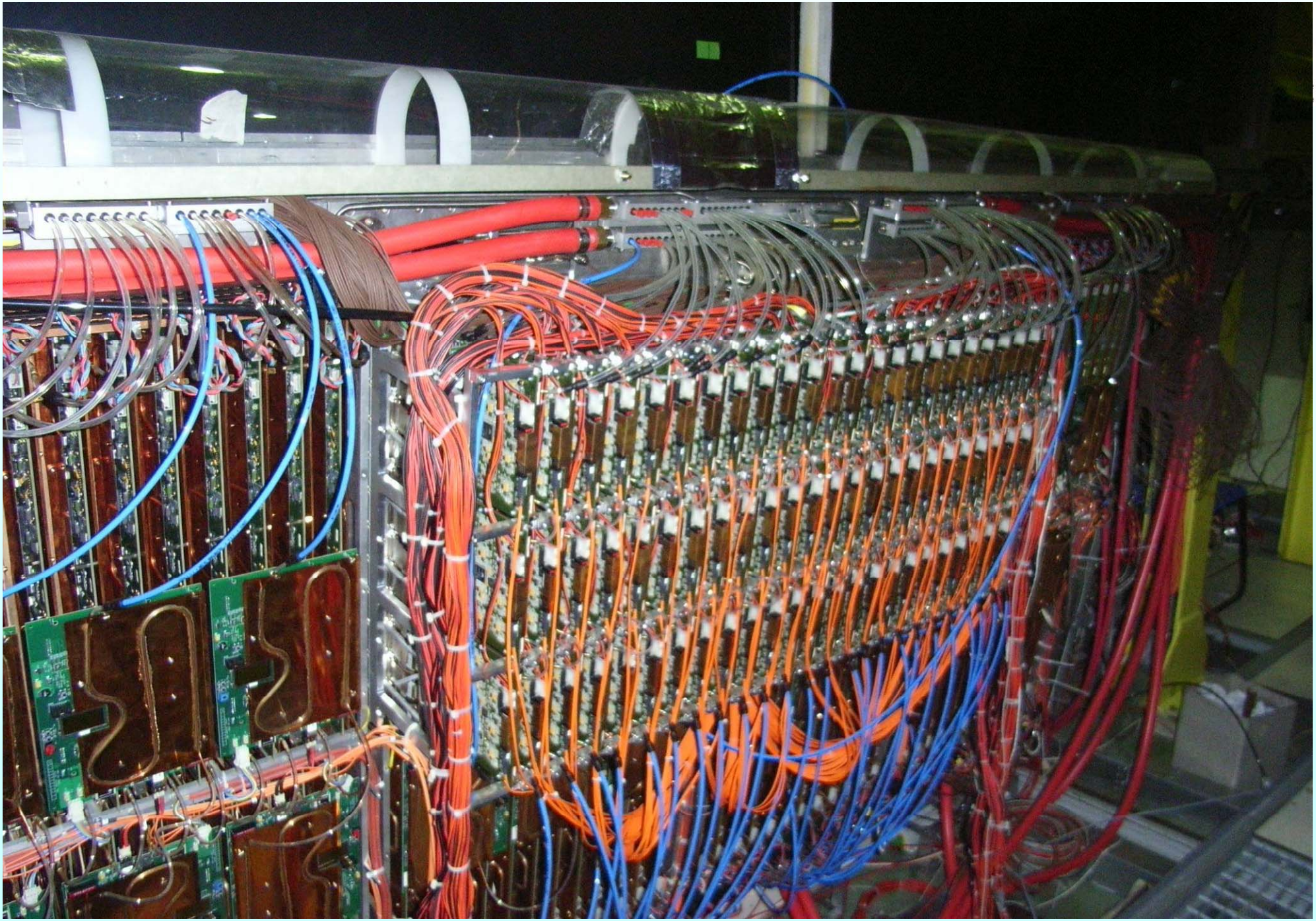


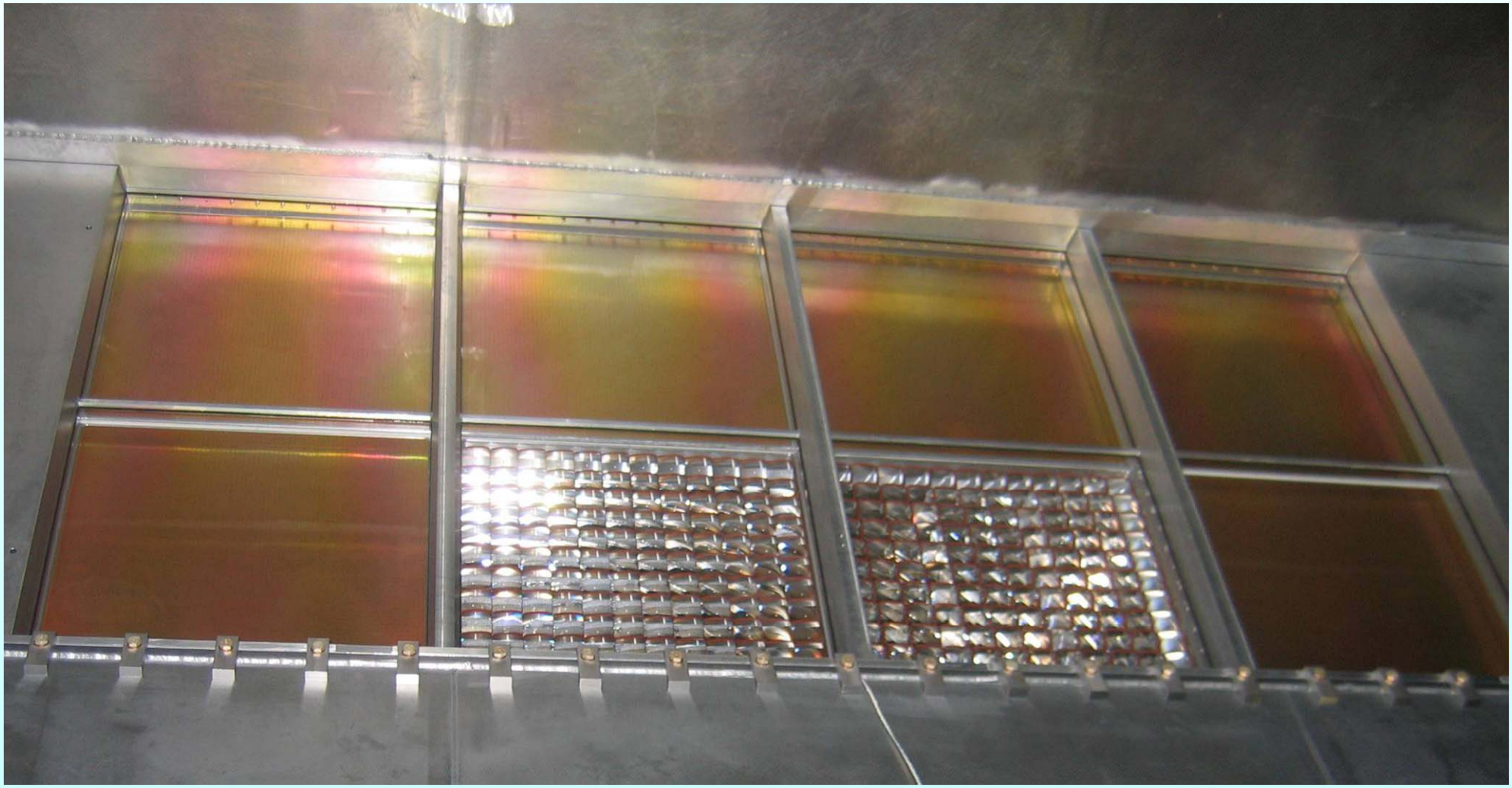








The Upper Detector from inside



The central part of the lower detector

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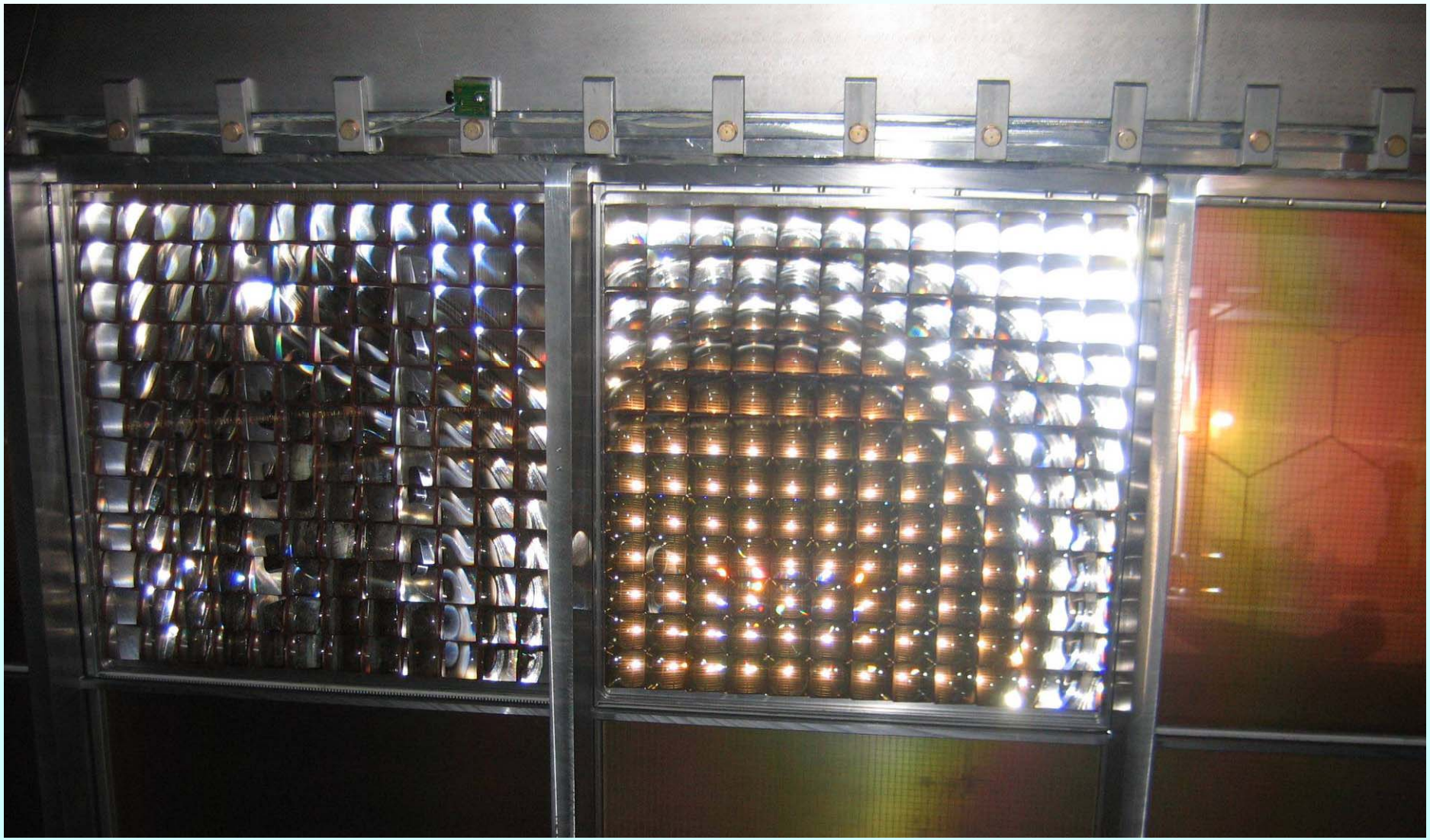
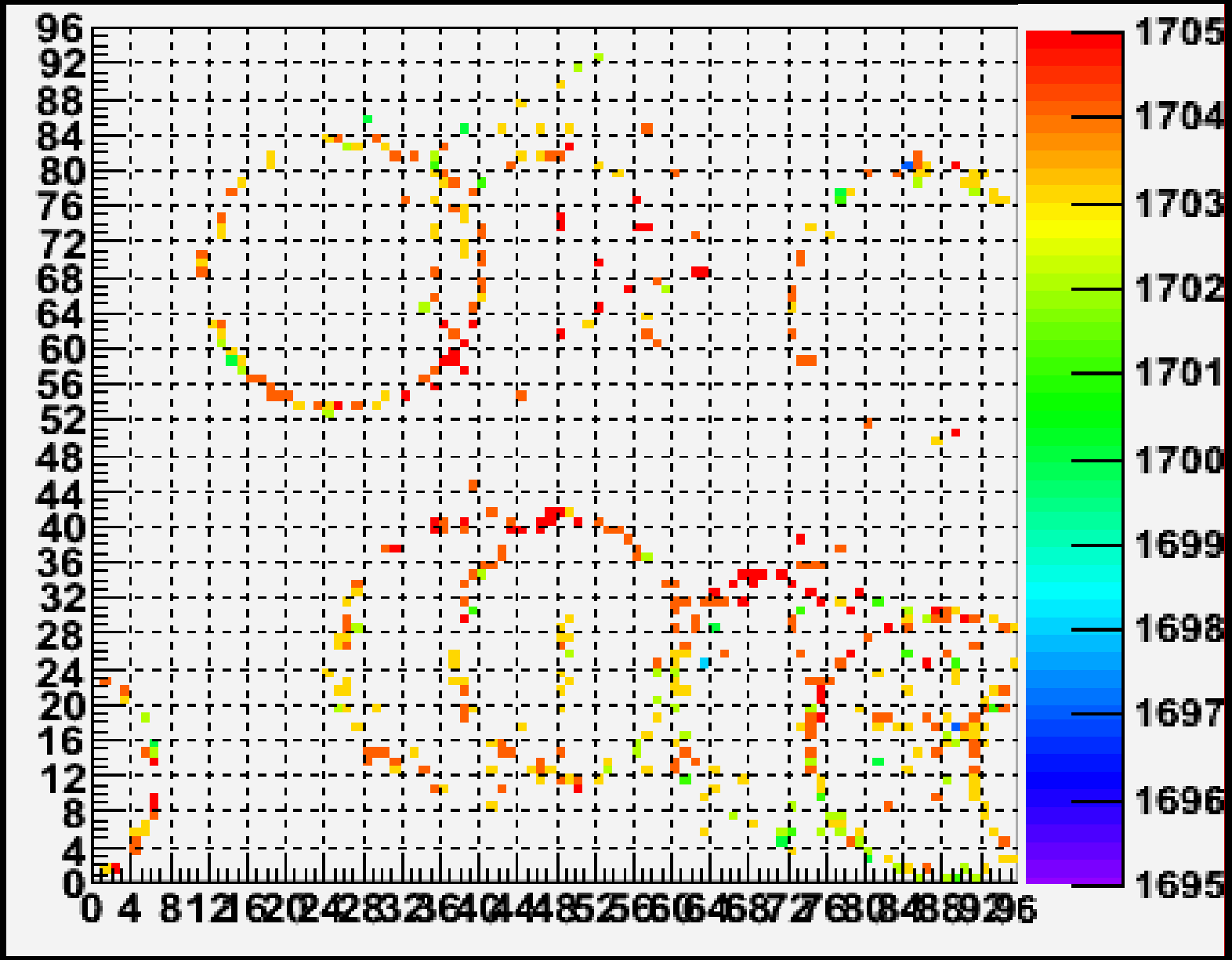
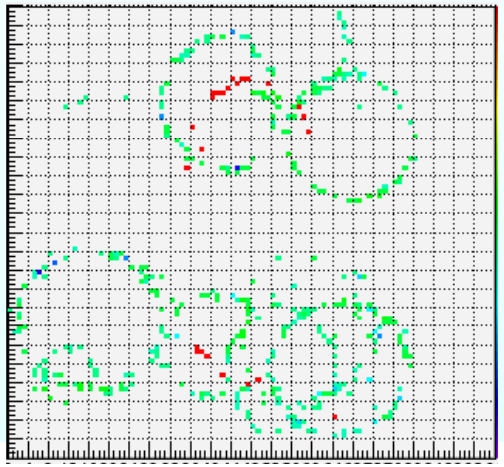


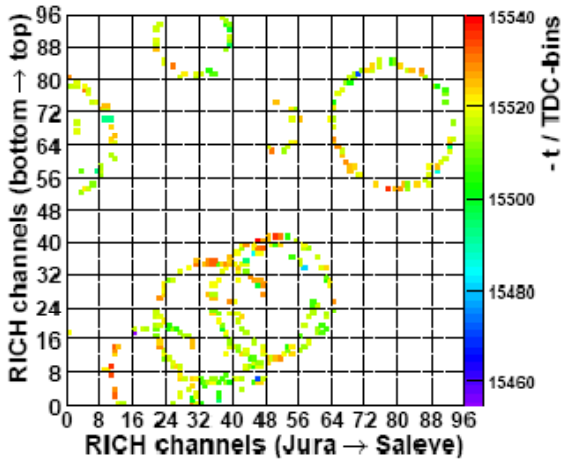
ON LINE EVENT DISPLAY FOR THE CENTRAL AREA

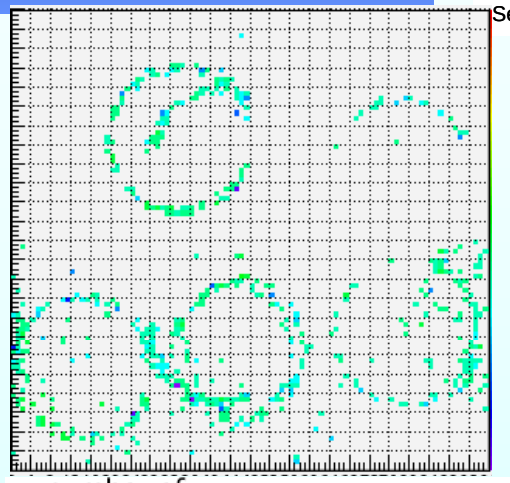


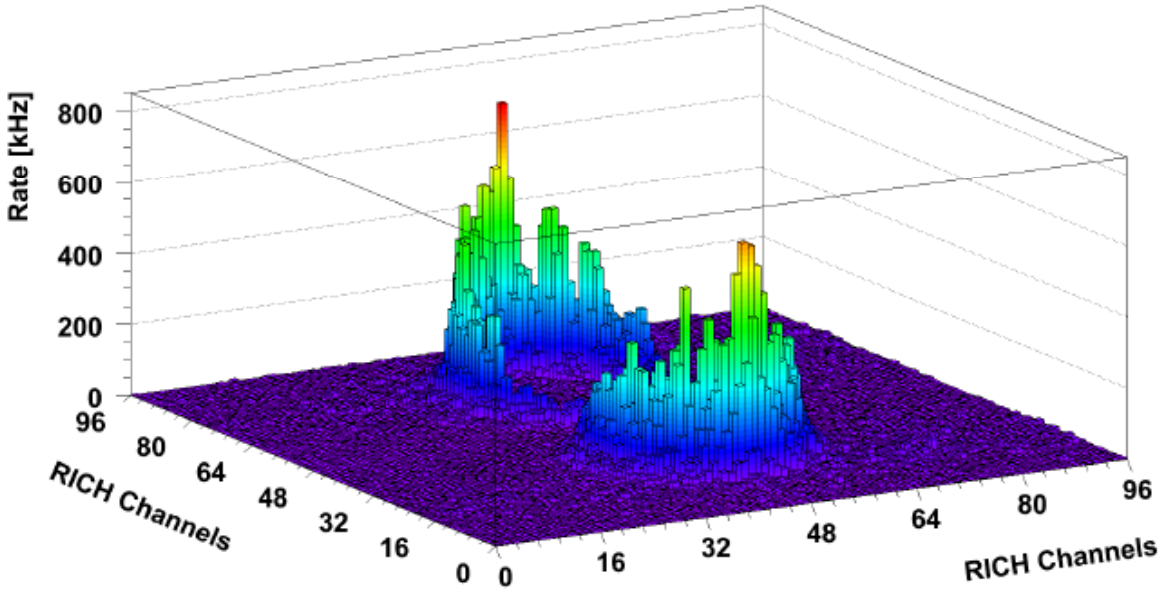
10 ns time window

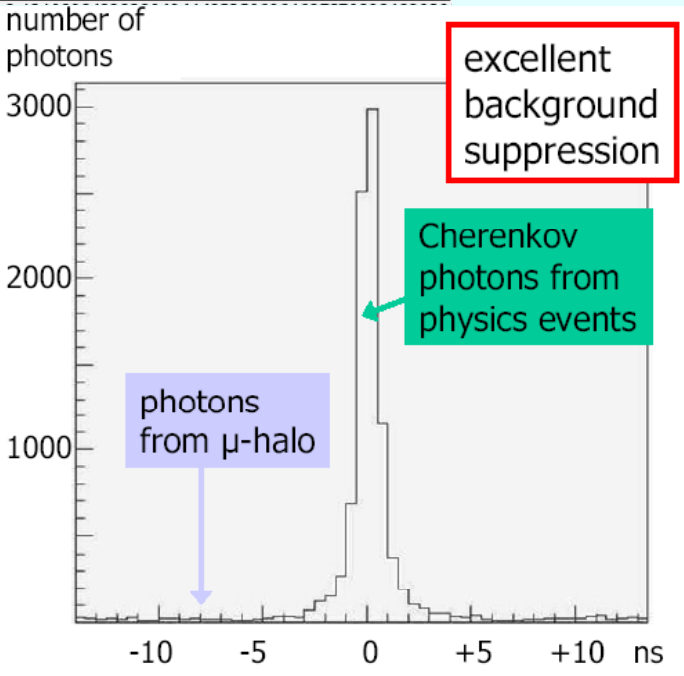
events, rate and time peak



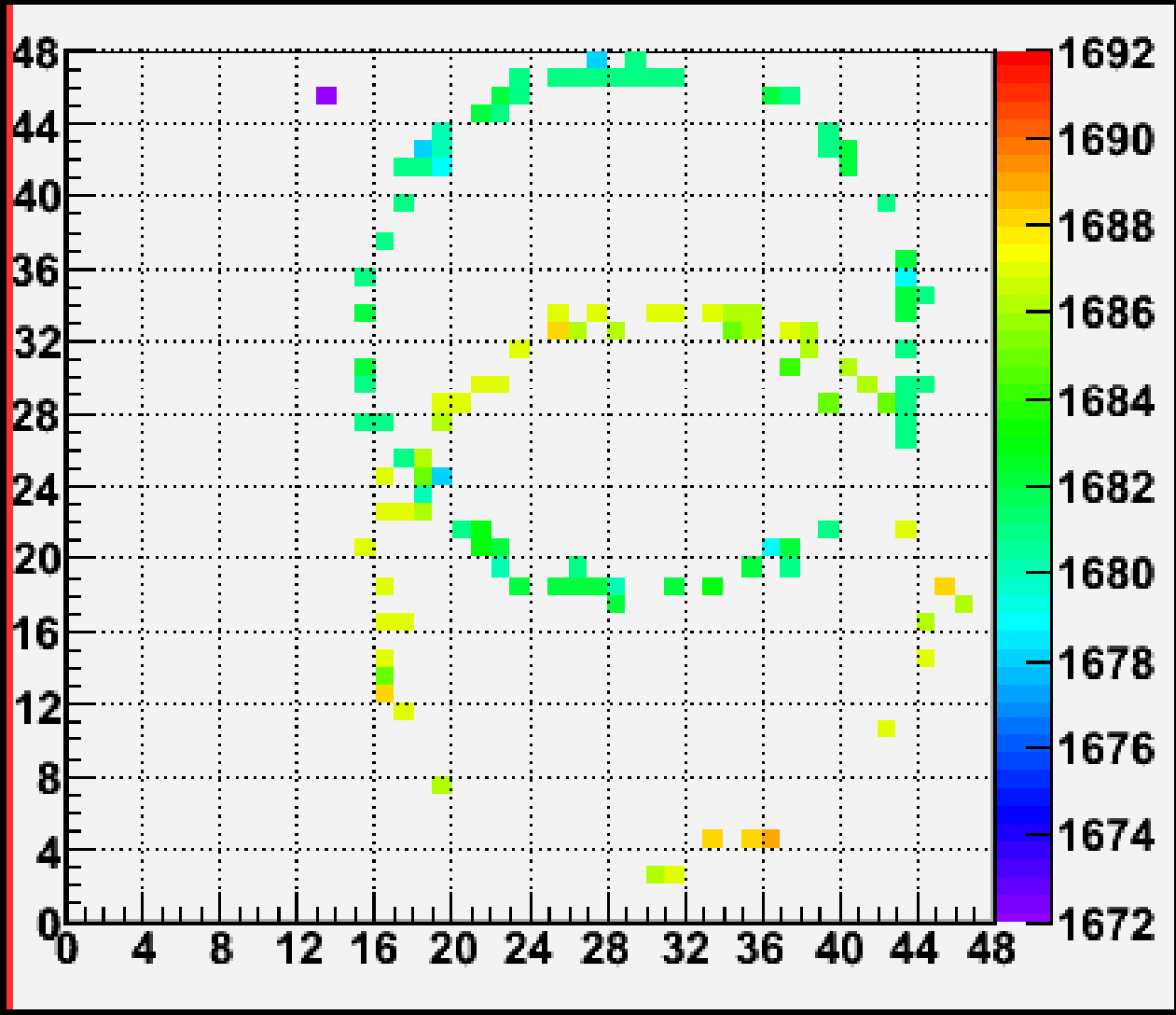








time resolution is useful for correctly assigning hits to rings



for detailed description of the r/o electronics and more information on the measured time resolution: see the talk by Christian Schill

Number of detected photons

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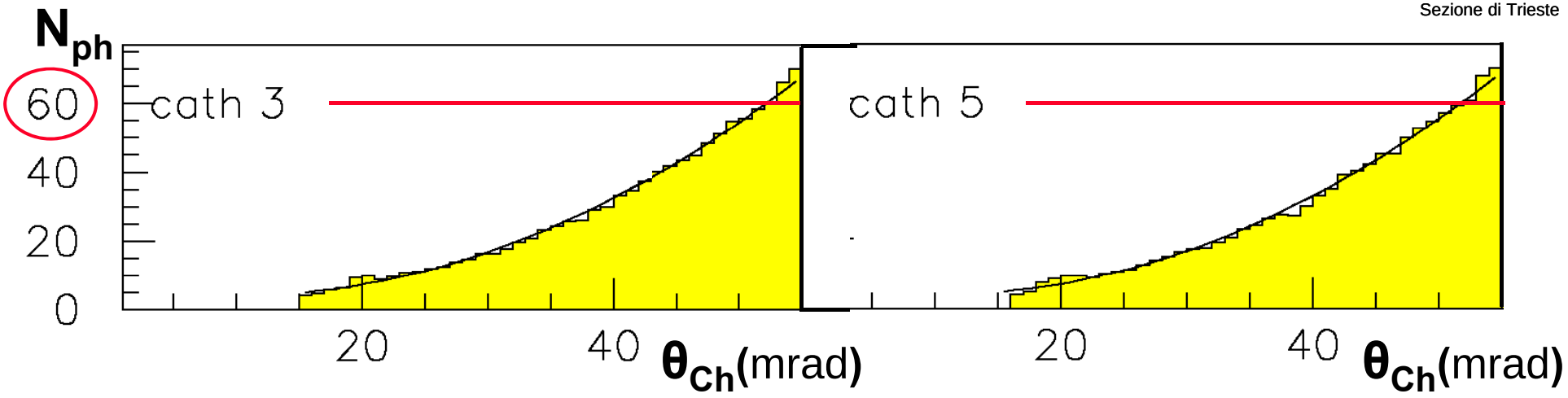
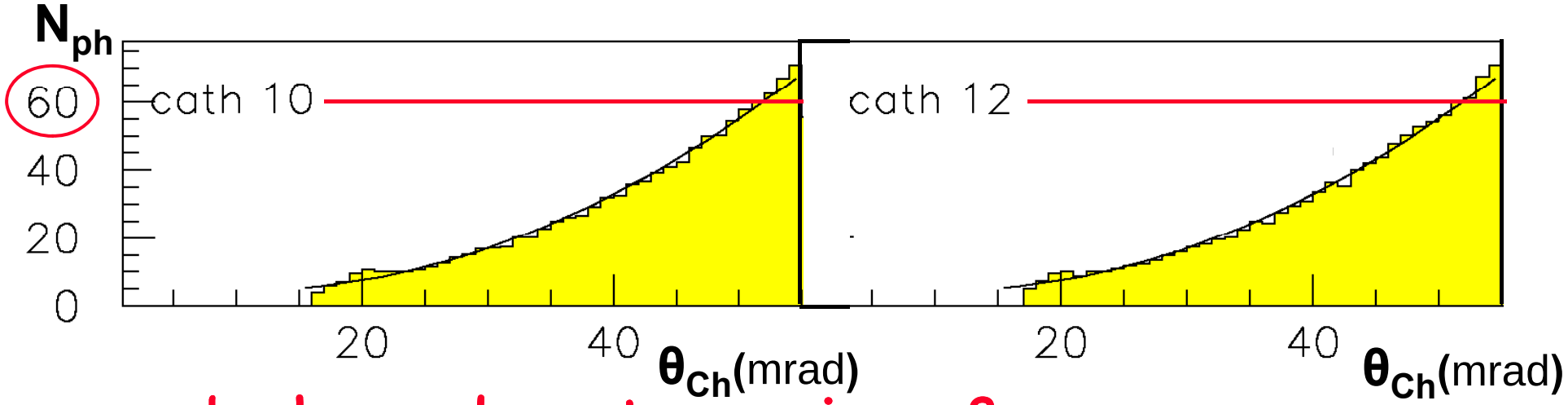


in the four quarters of the central area



mean background counts per ring ~ 8

UPGRADED RICH PERFORMANCES

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much more information in the talk by Federica Sozzi

→ **N_{ph} / ring: almost 60** *($\beta \approx 1$)* *IN THE CENTRAL REGION*

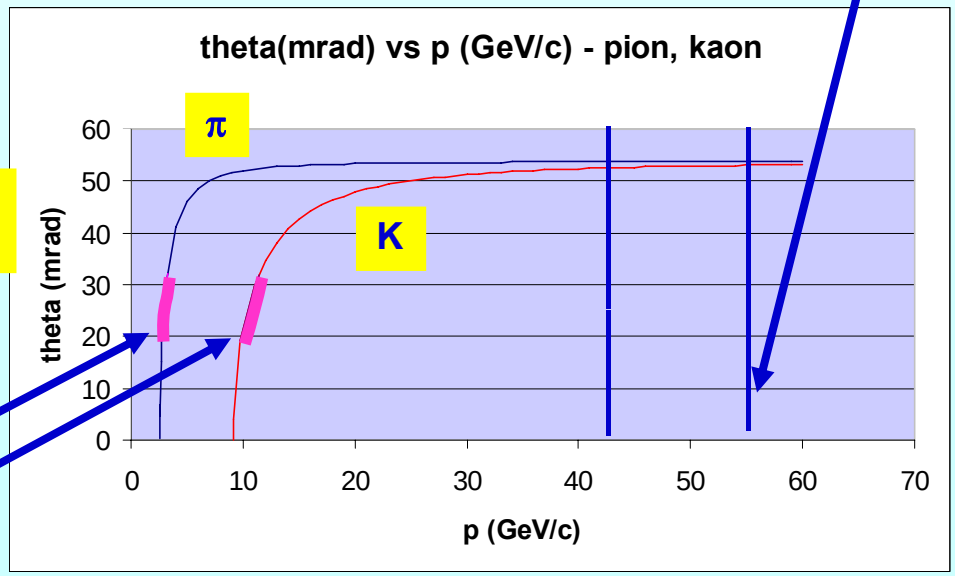
→ **σ_{ring} ~ 0.3 mrad** *($\beta \approx 1$)* (2004: **σ_{ring} = 0.6 mrad**)

→ **2 σ π/K separation up to p > 55 GeV/c** (2004: **2 σ π/K p=43 GeV/c**)

→ **effective Cherenkov threshold:**

PID capability extended with the upgrade

"ring reconstruction" only after the upgrade



→ **Time resolution < 1 ns**
(see talk by Christian Schill)

improved efficiency

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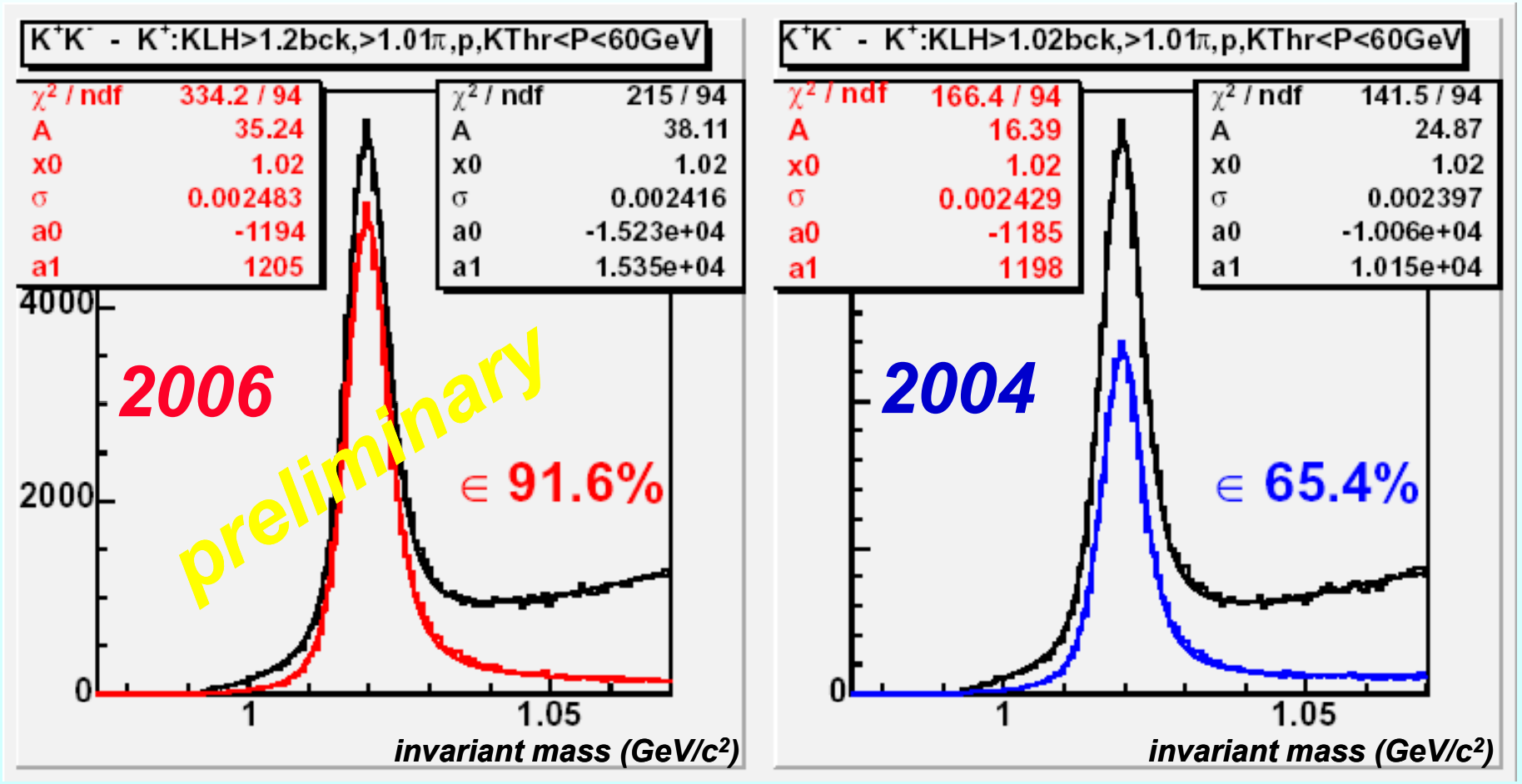

Probability of correclty identify a kaon in the most delicate kinematic region is estimated using kaons from decay of exclusively produced φ(1020) mesons

improved purity

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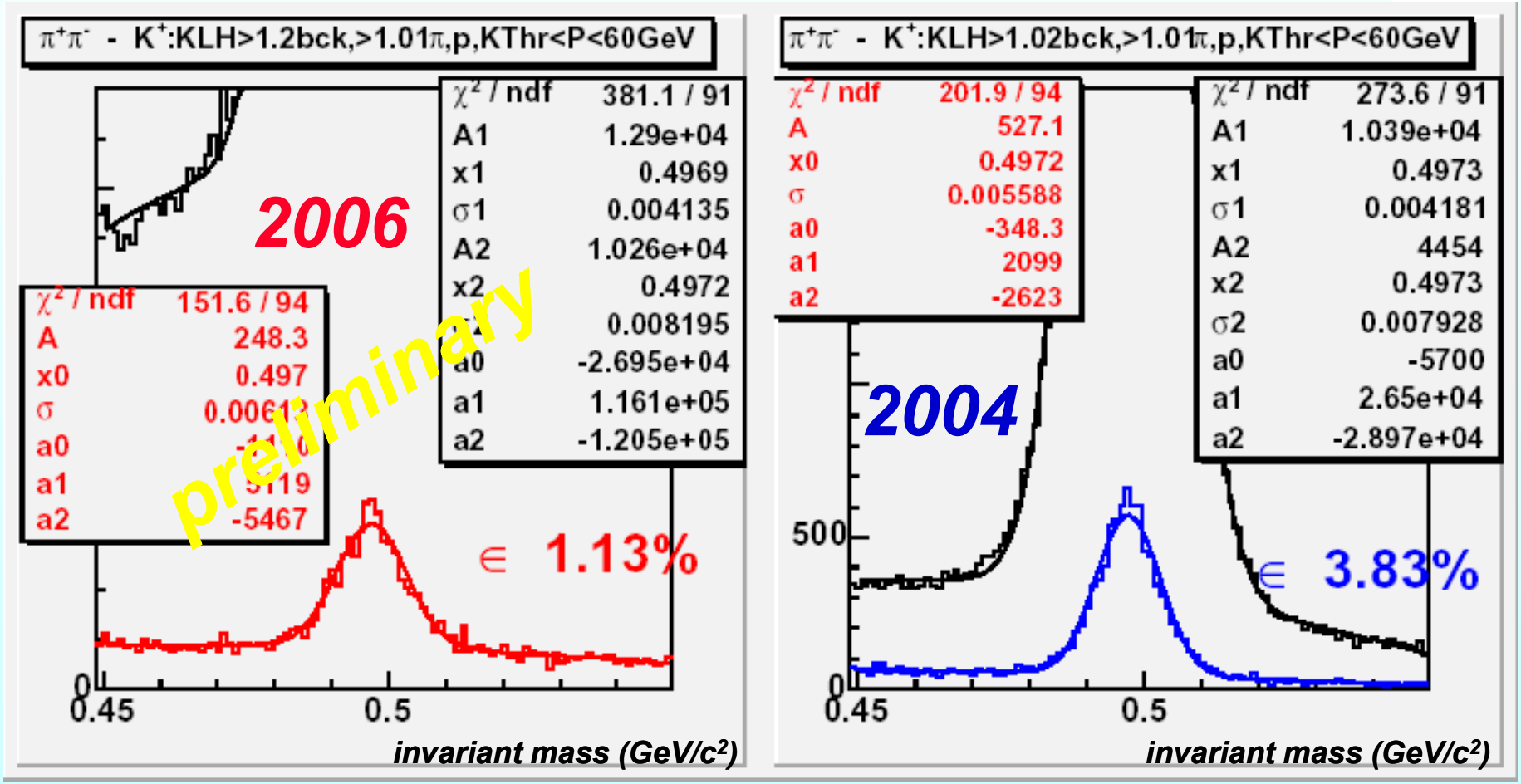
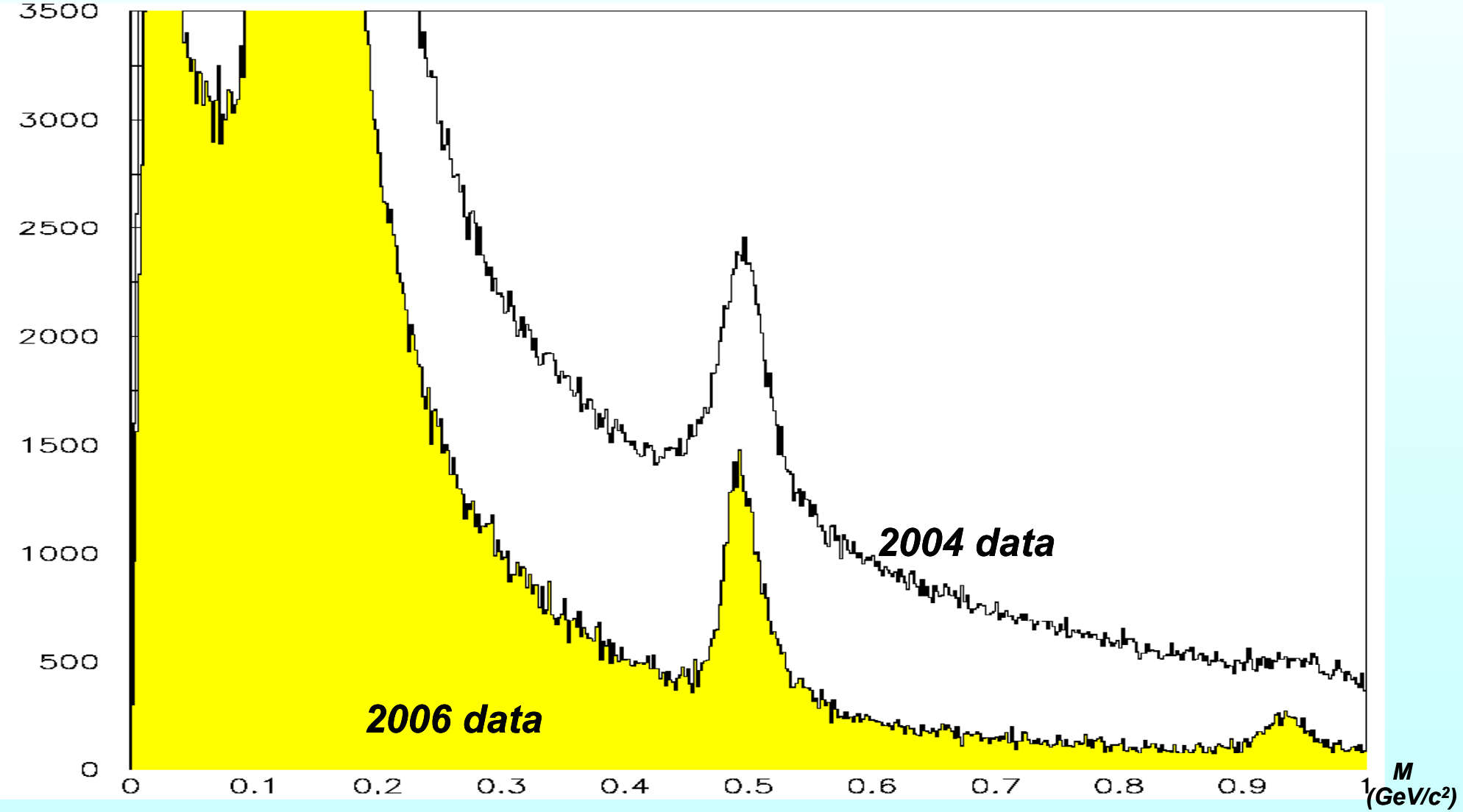


Probability of misidentification of a true pion as a kaon in the most delicate kinematic region is estimated using pions from decay of exclusively produced K_s

Improved PID performances



Conclusions

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COMPASS RICH-1 has undergone a major upgrade, implementing a fast photon detection system based on MAPMTs in the central area

The design and construction took 1.5 y: November 2004 – May 2006
576 MAPMT's + fused silica lenses telescopes and r/o were installed

The upgraded RICH-1 has almost 60 detected photons per ring,
$N_0 \sim 70$, $\sigma_{\theta_C} \sim 0.3$ mrad, $\sigma_t < 1$ ns.

It can stand high trigger rates, it has high efficiency and purity and 2σ π-K separation at 55 GeV/c

COMPASS RICH-1 has now really outstanding performances

Outlook

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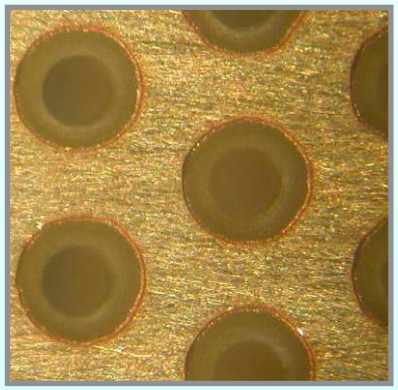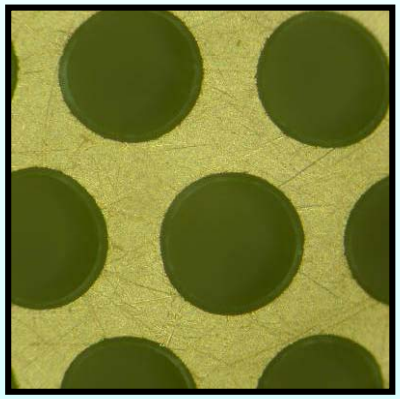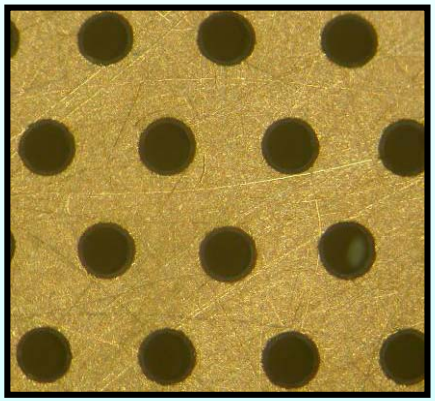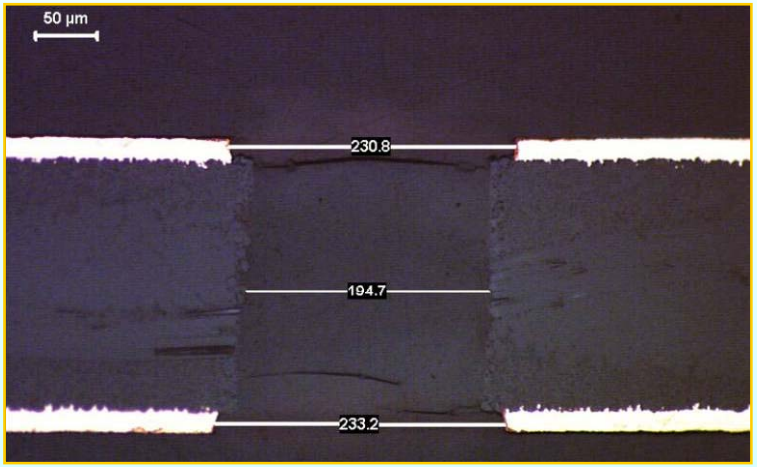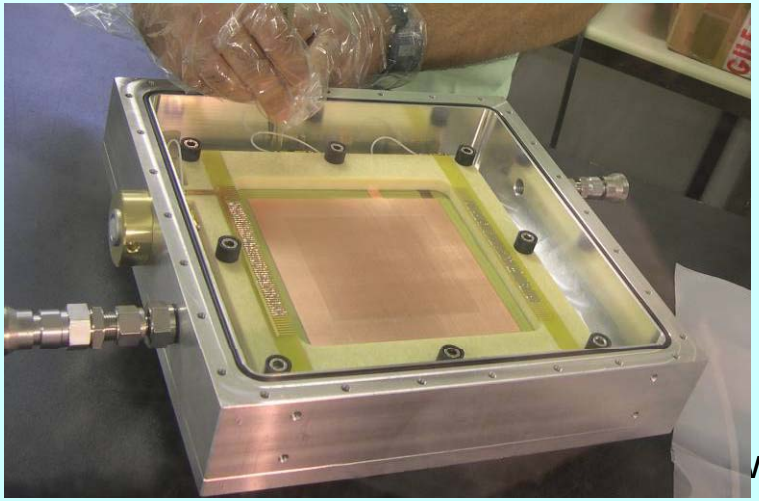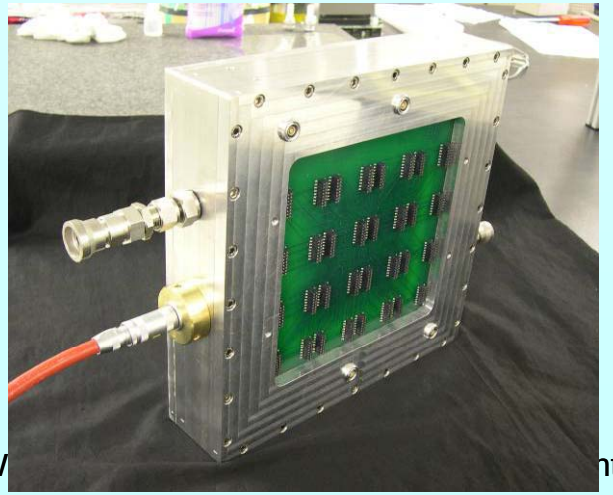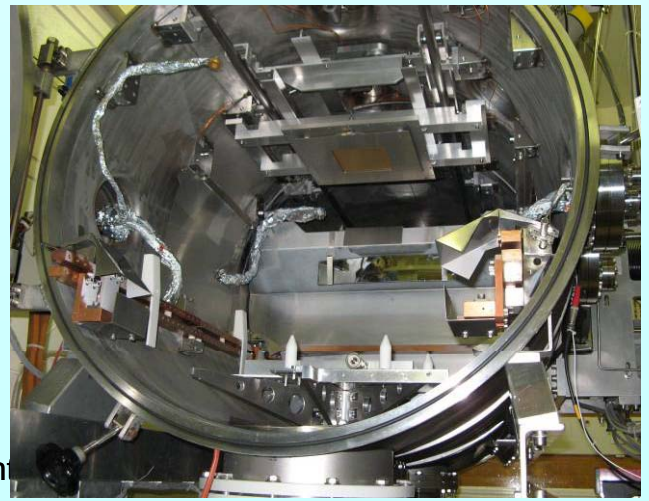
for the external part of RICH-1 a possibility of further increase in the performances could come from usage of a new technology: THGEM + CsI. We are presently exploring and testing this option