The COMPASS RICH detector upgrade

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Universität Freiburg, Physikalisches Institut

on behalf of the
COMPASS RICH Upgrade Group

Outline:

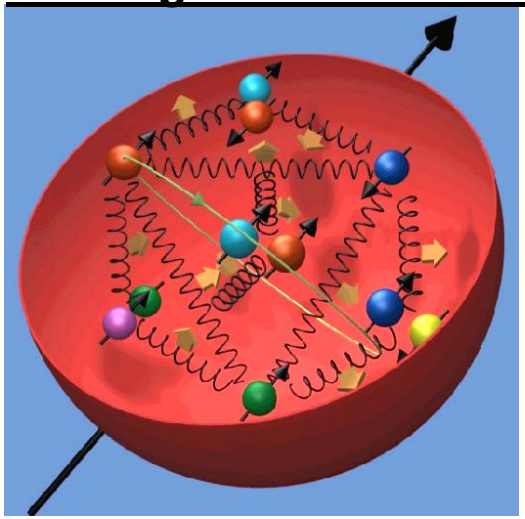
- **Introduction**
- **Motivation of the upgrade project**
- **Constructions & realisation:**
  - **MAPMTs, optics**
  - **read-out electronics**
  - **mechanics, installations**
  - **monitoring**
- **Performances based on 2006 data**

bmb+f - Förderschwerpunkt
COMPASS
Großgeräte der physikalischen Grundlagenforschung

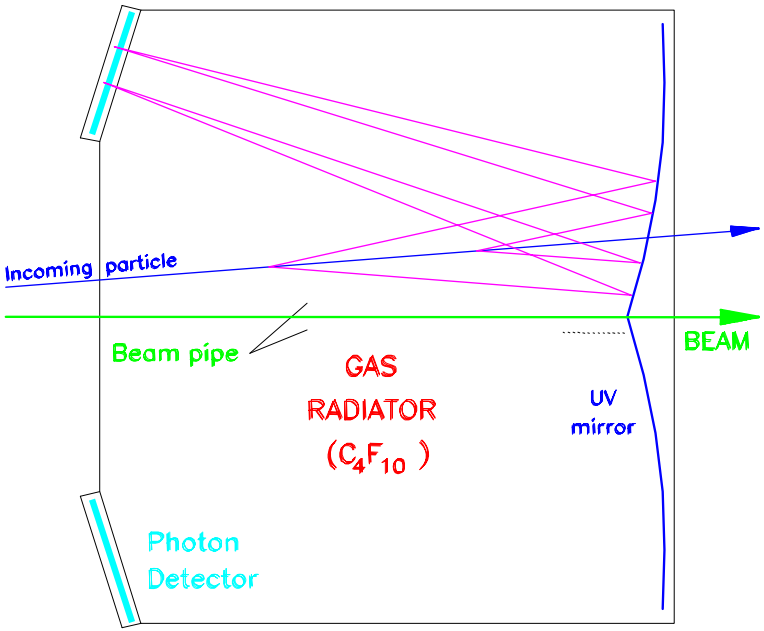
The COMPASS experiment

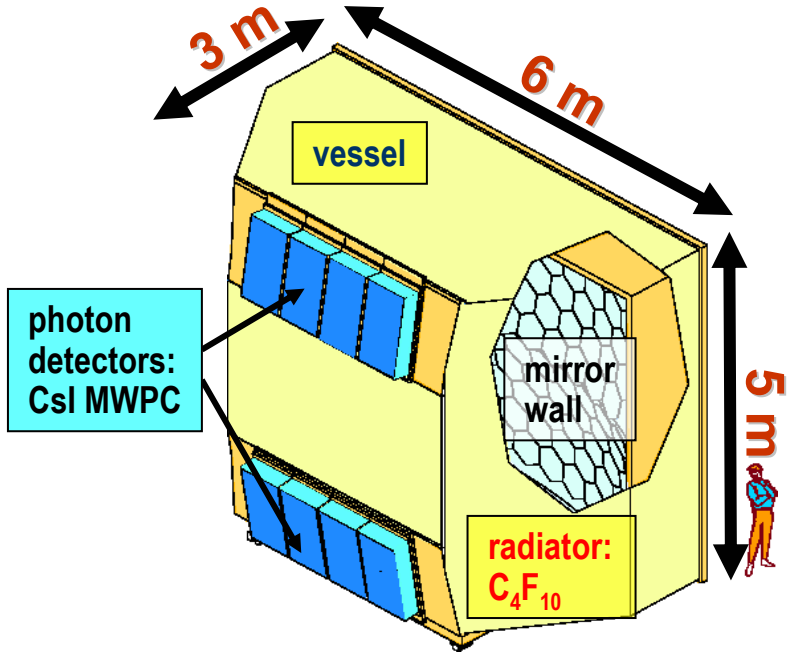
COmmon Muon Proton Apparatus for Structure and Spectroscopy
(~270 physicists, 25 institutes, 11 countries)

Investigation of the nucleon structure:



The COMPASS RICH detector
(2003-2004, before upgrade)





- **radiator gas:** C_4F_{10}, good transparency > 160 nm, low chromaticity
- **mirror:** 20 m² surface, VUV reflectance (160-210 nm) > 80%
- **photon-detectors:** Multi Wire Proportional Chamber, total surface 5.3 m²
- **angular acceptance:** ± 250 mrad horizontal, ± 200 mrad vertical
- **read-out:** 83.000 channels (pixels)

Upgrade motivation: Experimental challenges

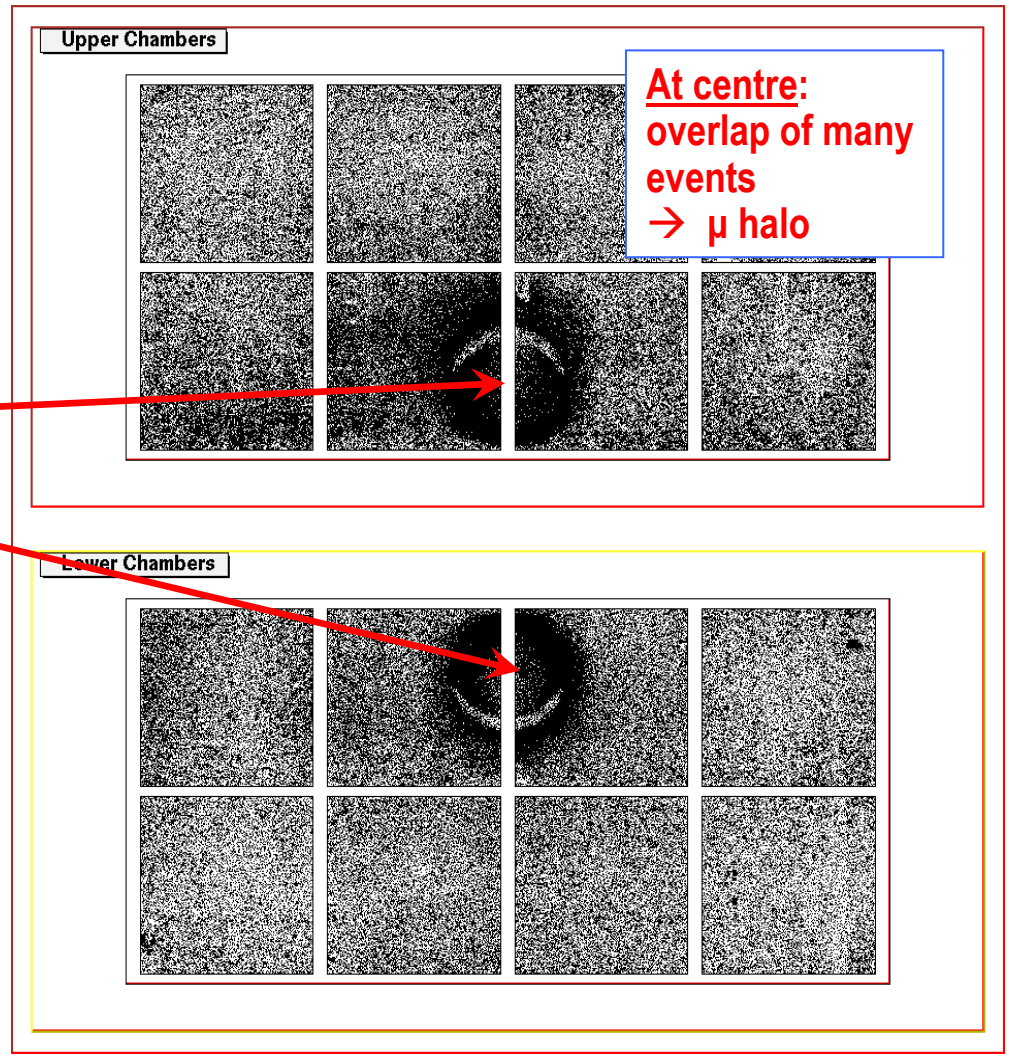
- **Previous read-out:**
  Gassiplex-chip, integration time ~3μs

- **Experimental environment**
  - large uncorrelated background
    (memory of MWPC + read-out,
    muon halo)

- **High rate operation**
  → **increased beam intensity:**
  presently: 40 MHz
  goal: 100 MHz

  → **increased trigger rates:**
  presently: 20 kHz
  up to: 100 kHz

  → **no dead time (Luminosity)**



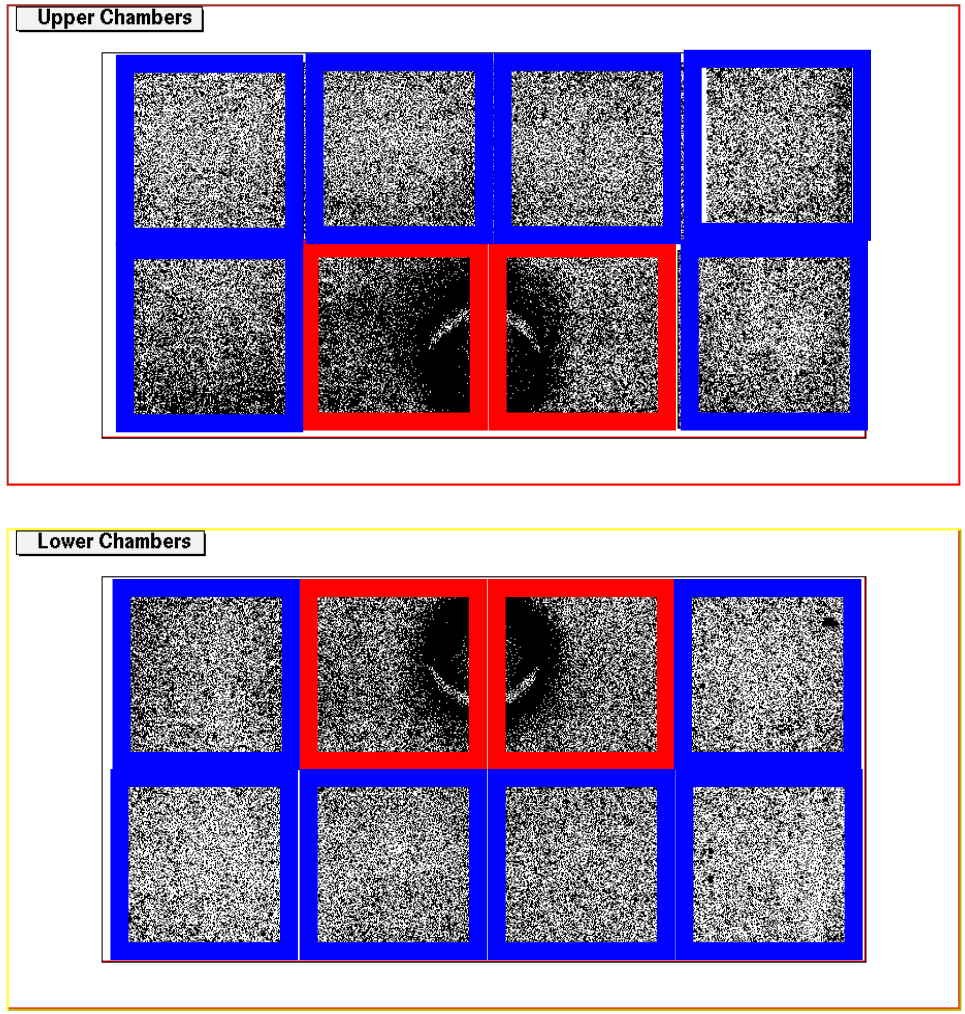
The upgrade project for 2006 data taking

Multi Wire Proportional Chambers:
(MWPC, in use since 2001)

- CsI photo cathodes
- new read-out system: APV chip
  (negligible dead time)
- time resolution (CsI with MWPC + ro):
  ~ 3 µs → < 40 ns

Fast photon detection:

- Multi Anode PMTs (MAPMT, 576 pc)
- individual telescopes
- read-out
  → sensitive FE: MAD chip
  → high resolution TDC: F1 chip
- time resolution: few ns
- no MWPC



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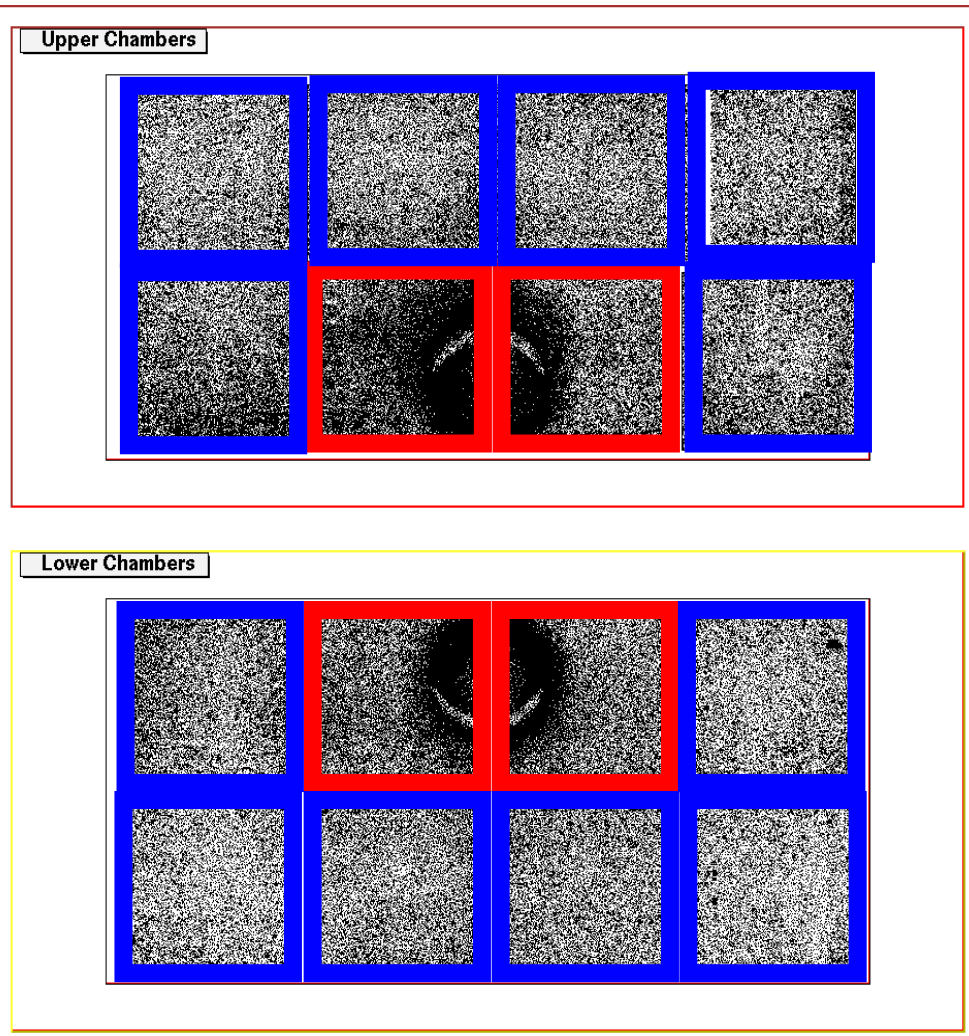
not discussed in this talk



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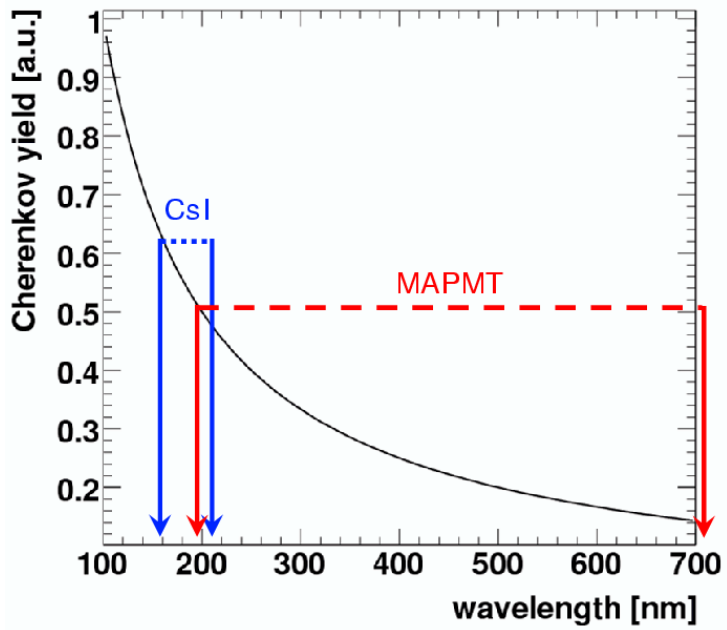
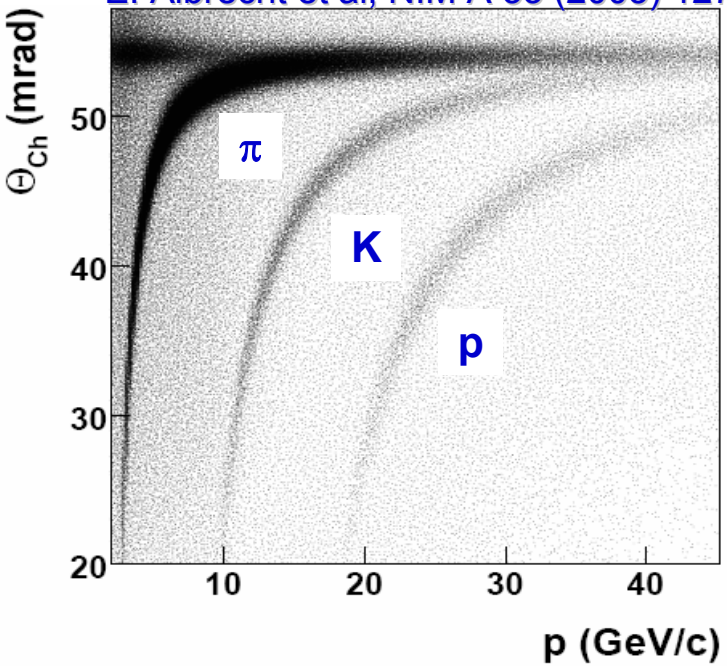
Upgraded RICH resolution

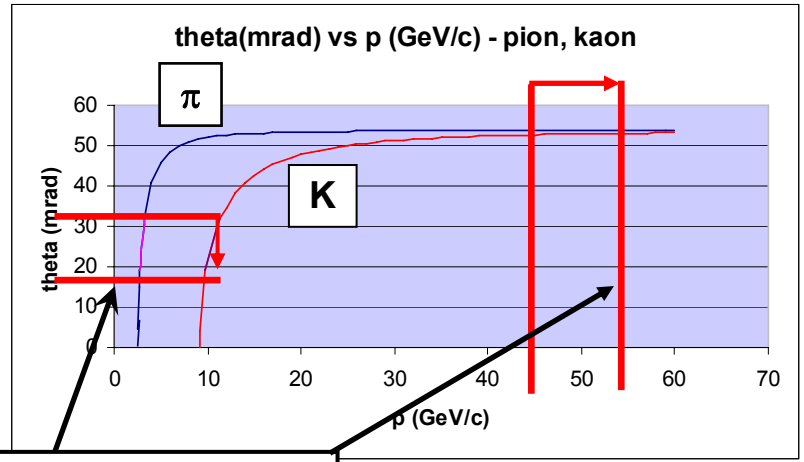
Expected performances:

- σ_{ph} = 2.4 mrad (ß ≈ 1) - before: 1.2 mrad
- N_{ph}/ring ≈ 50 (ß ≈ 1) - before: 14
- σ_{ring} ≈ 0.4 mrad (ß ≈ 1)
  - before: 0.6 mrad
- 2σ π/K separation at p ≈ 50 GeV/c
  - before: 43 GeV/c



E. Albrecht et al, NIM A 33 (2003) 127

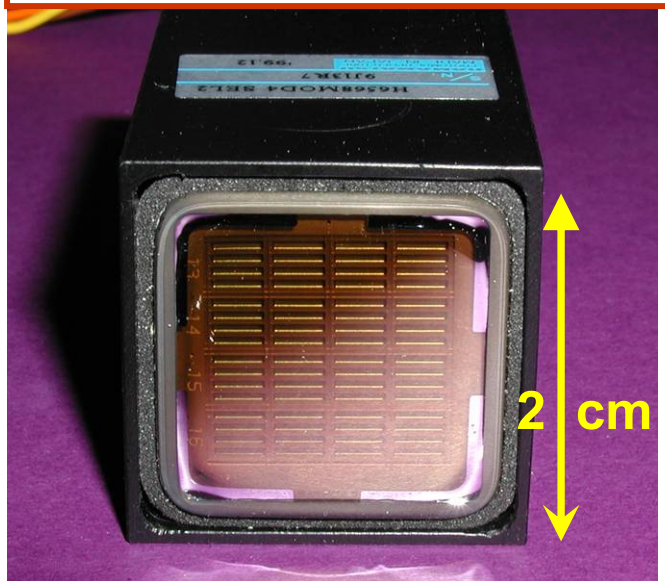




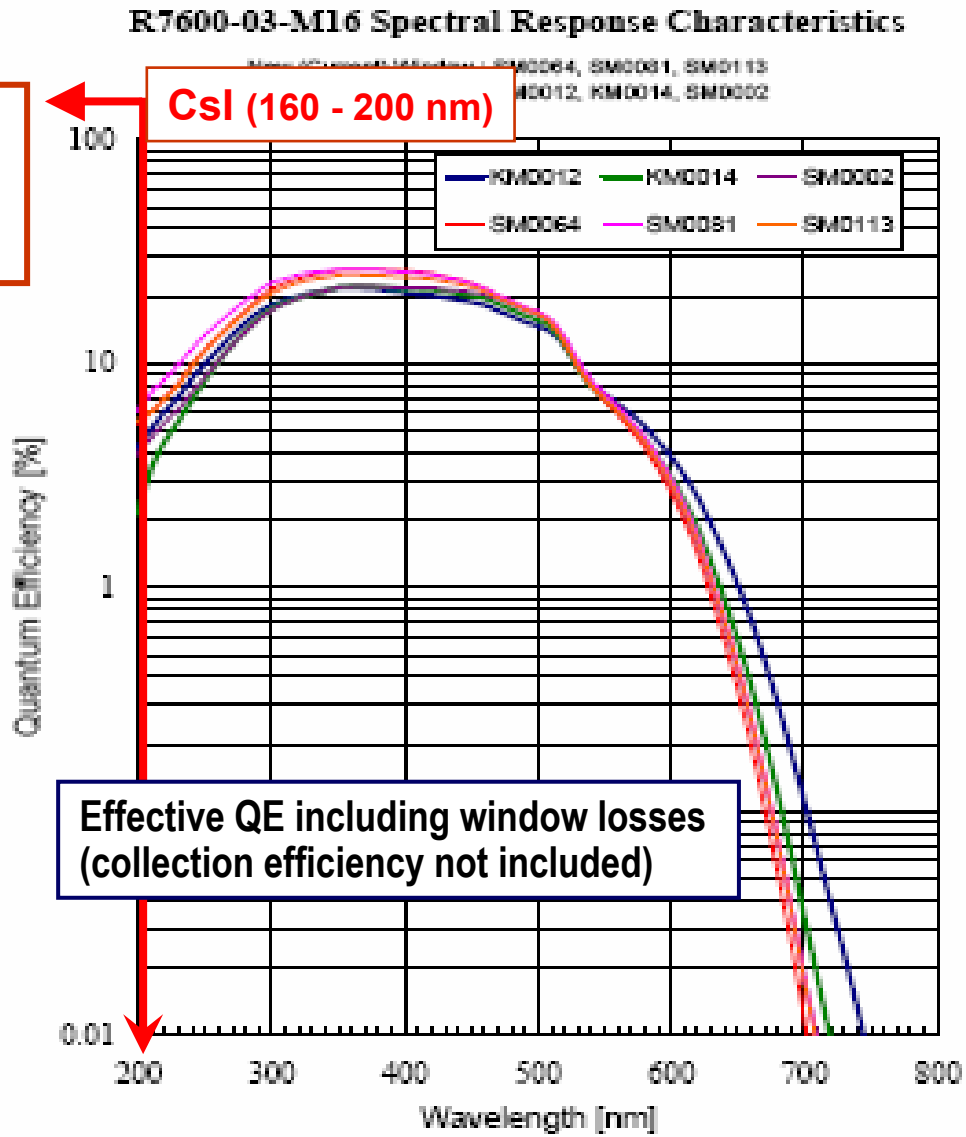
PID capability extended by upgrade

Hamamatsu R7600-03-M16 photomultiplier

Larger number of detected Cherenkov photons, due to larger wavelength range:

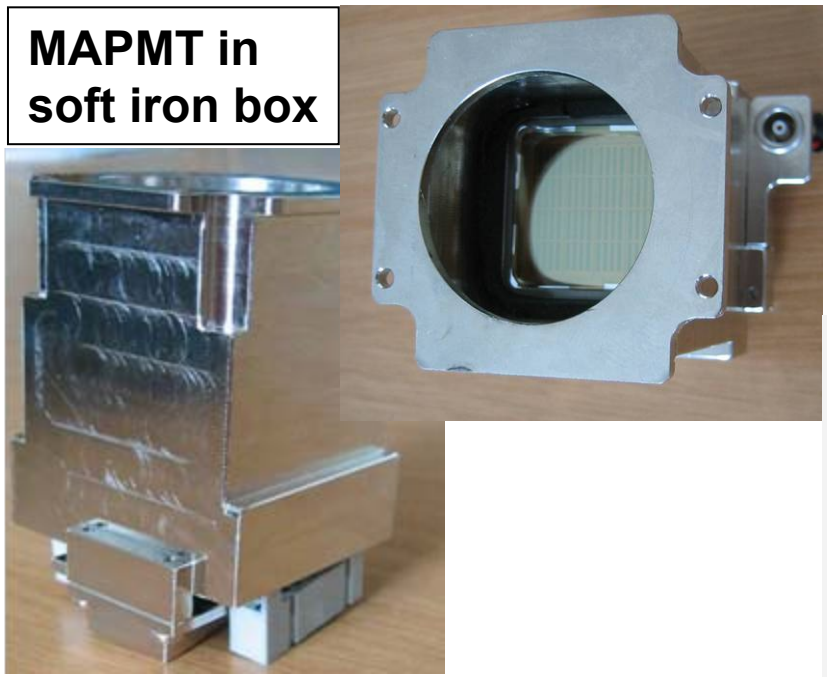


- bialkali photocathode
- 18 x 18 mm^2 active area
- 16 pixel
- time resolution 300 ps
- UV transparent borosilicate glass window

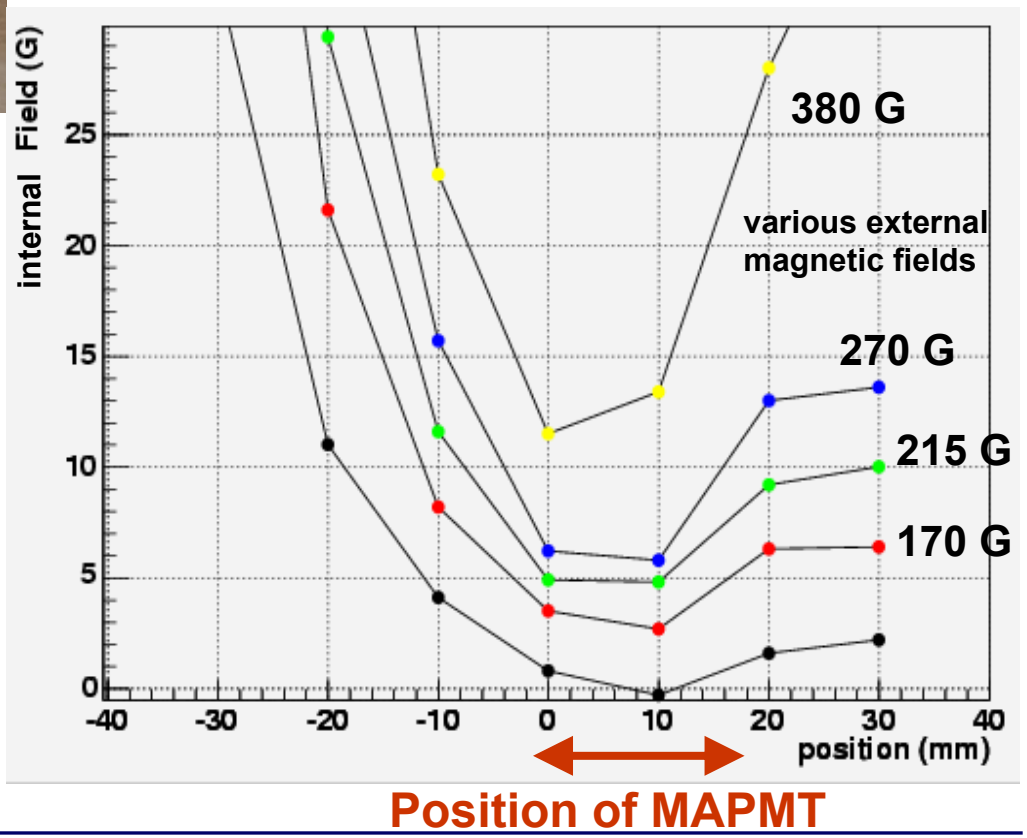


Hamamatsu R7600-03-M16 photomultiplier

MAPMT in soft iron box



- fringe magnetic field (SM1): < 200 G
- no efficiency loss of MAPMTs: 20 G
- magnetic field measured inside shielding:
  (field direction perpendicular MAPMT axis)



- bialkali photocathode
- 18 x 18 mm^2 active area
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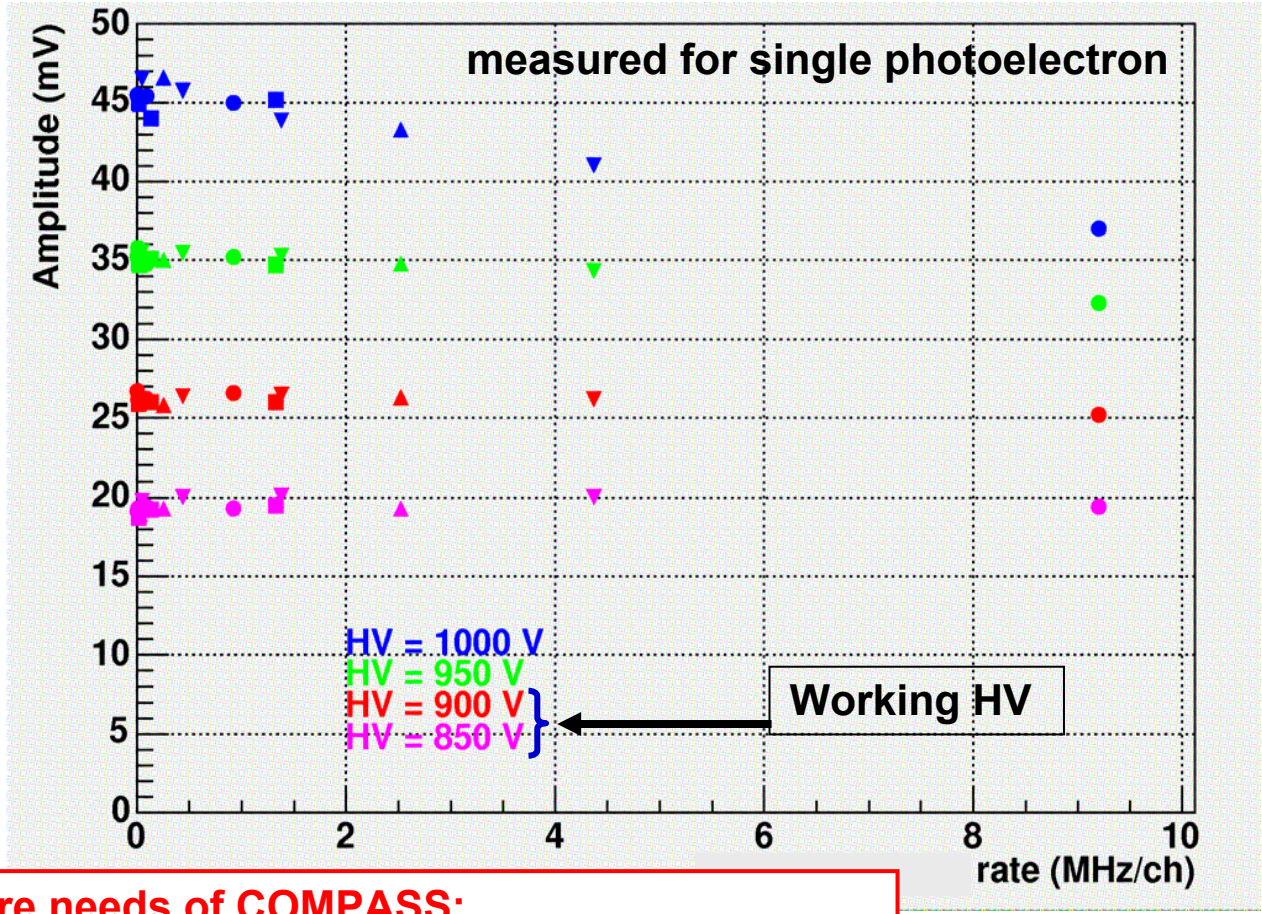
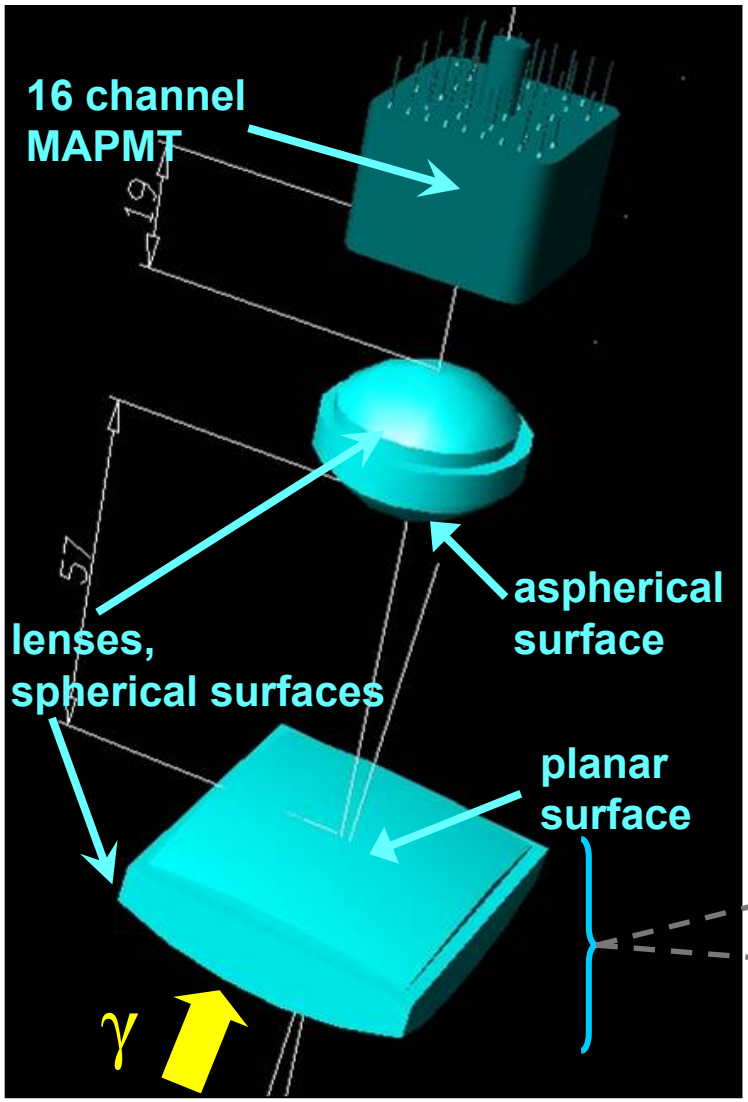
RICH upgrade – MAPMT rate capability

- mean signal amplitude vs. rate / pixel
- pulsed light source synchronous to trigger + random background from lamp



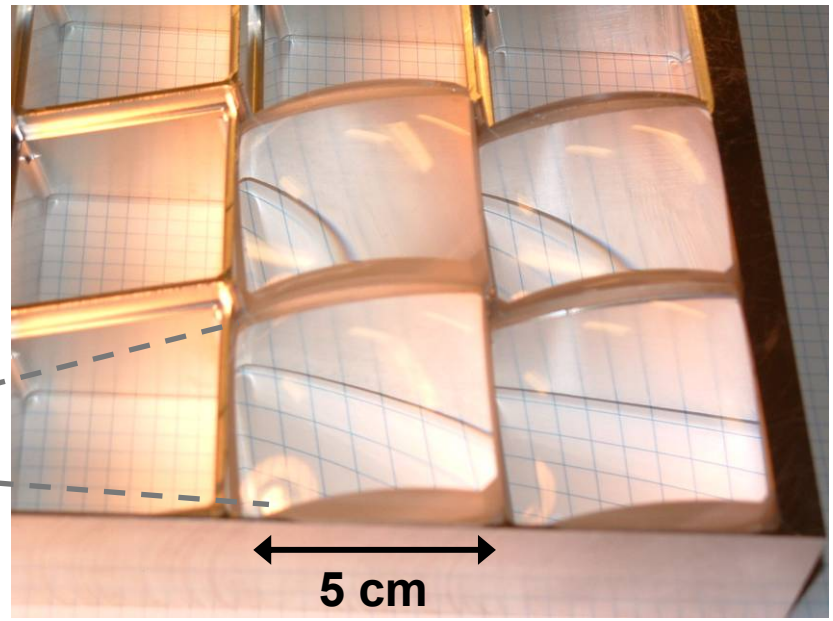
Goal / future needs of COMPASS:
operate up to 5MHz/pixel single photoelectron rates
=> no rate limitation from MAPMT

576 telescopes made of silica lenses



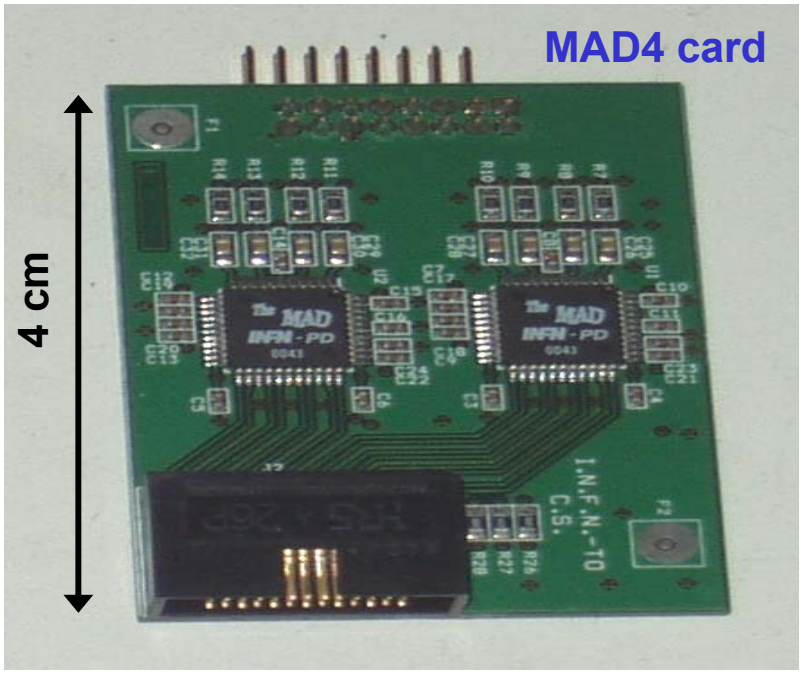
Telescope system consisting of 2 lenses:

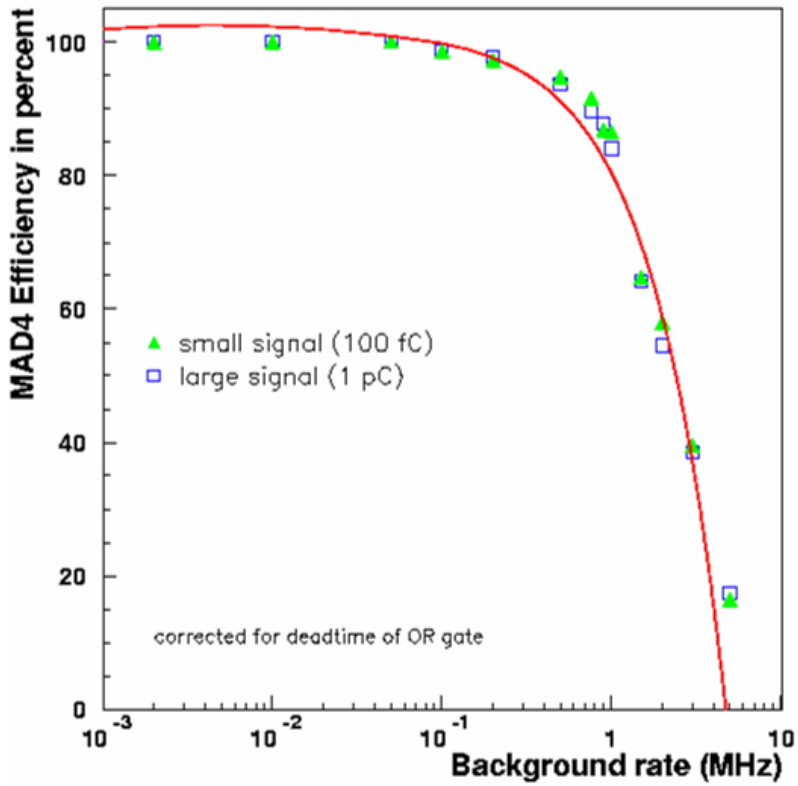
- Purpose: Focussing Cherenkov photons on MAPMTs (factor 7)
- UV transparent quartz lenses
- large geometrical acceptance
- minimum image distortion
- optimised by Zemax simulation



Analogue read-out electronics: MAD4 preamplifier-discriminator

- up to ~ 1 MHz/channel; possible upgrade in 2008: CMAD ~ 5 MHz hit rate per channel
- low noise (connected to PMT) ~ 5-7 fC
- PMT signal (single photon) ~ 1 pC (at 900 V)
- clear separation signal / noise



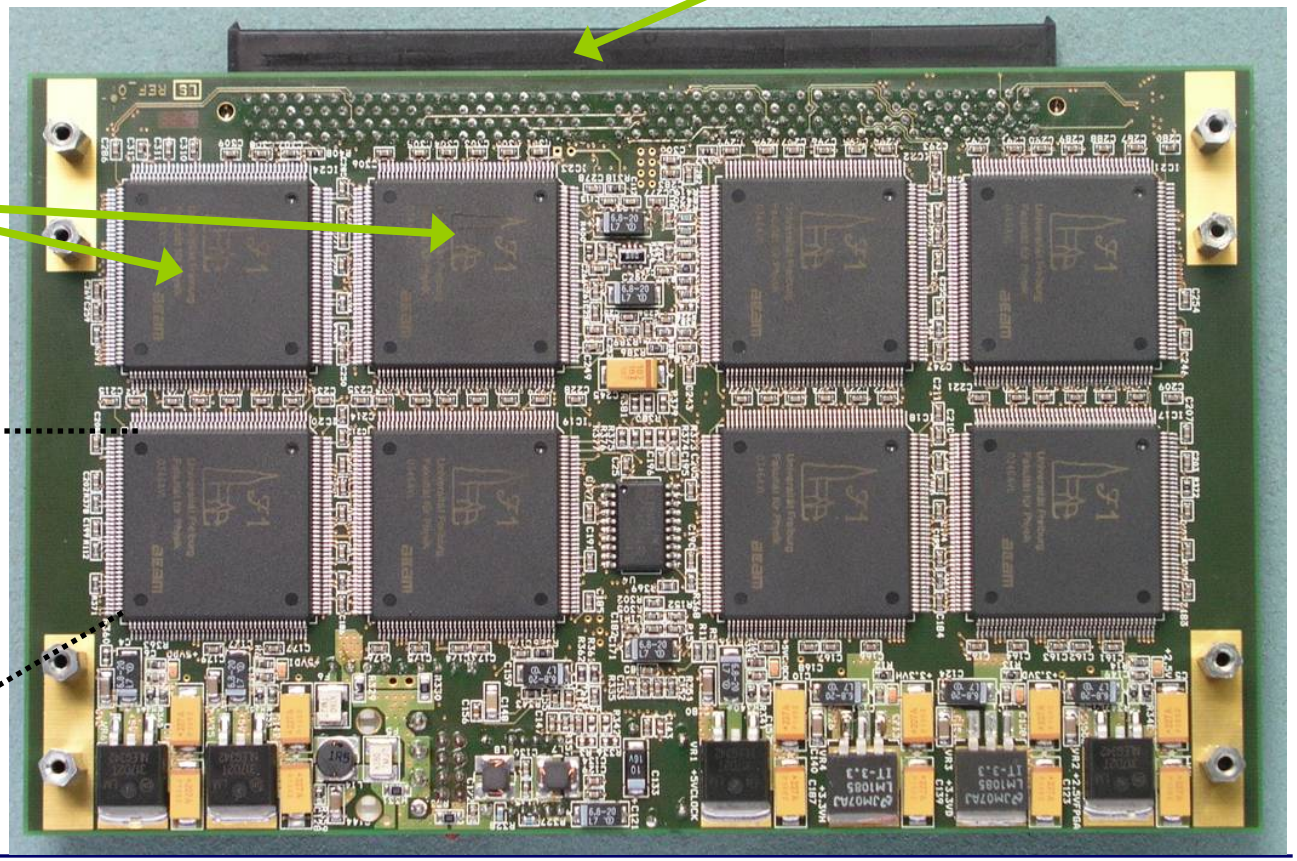


Digital read-out electronics: DREISAM card (Dreisam is a small river in Freiburg)

- 64 channels per card , compact solution
- data transfer optically (40 MByte/s)
- max rates per channel 10 MHz @ 100 kHz trigger rate
- time resolution < 100 ps
- based on dead time free F1-TDC

Connector to MAD4

8 F1-TDCs



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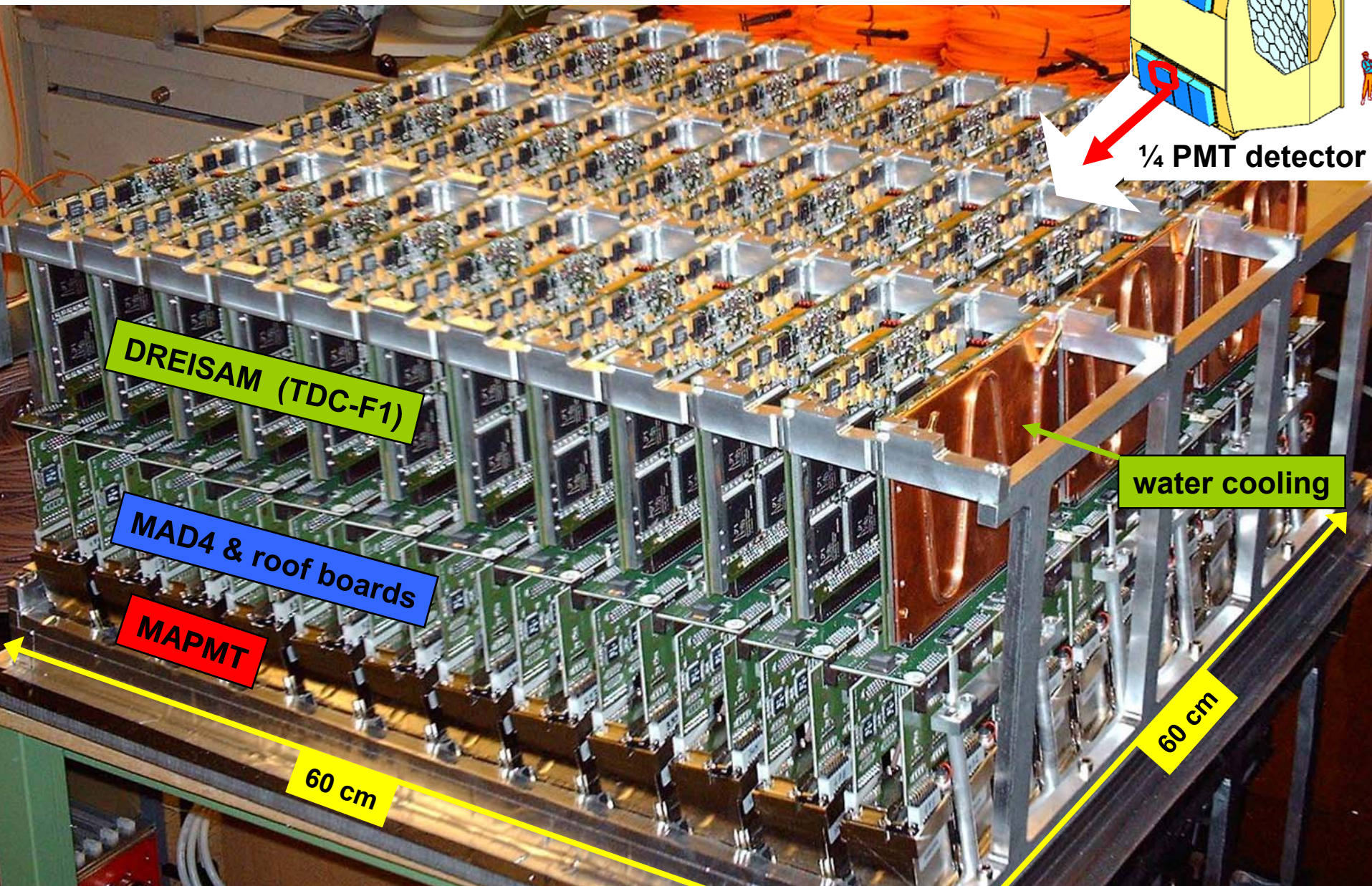
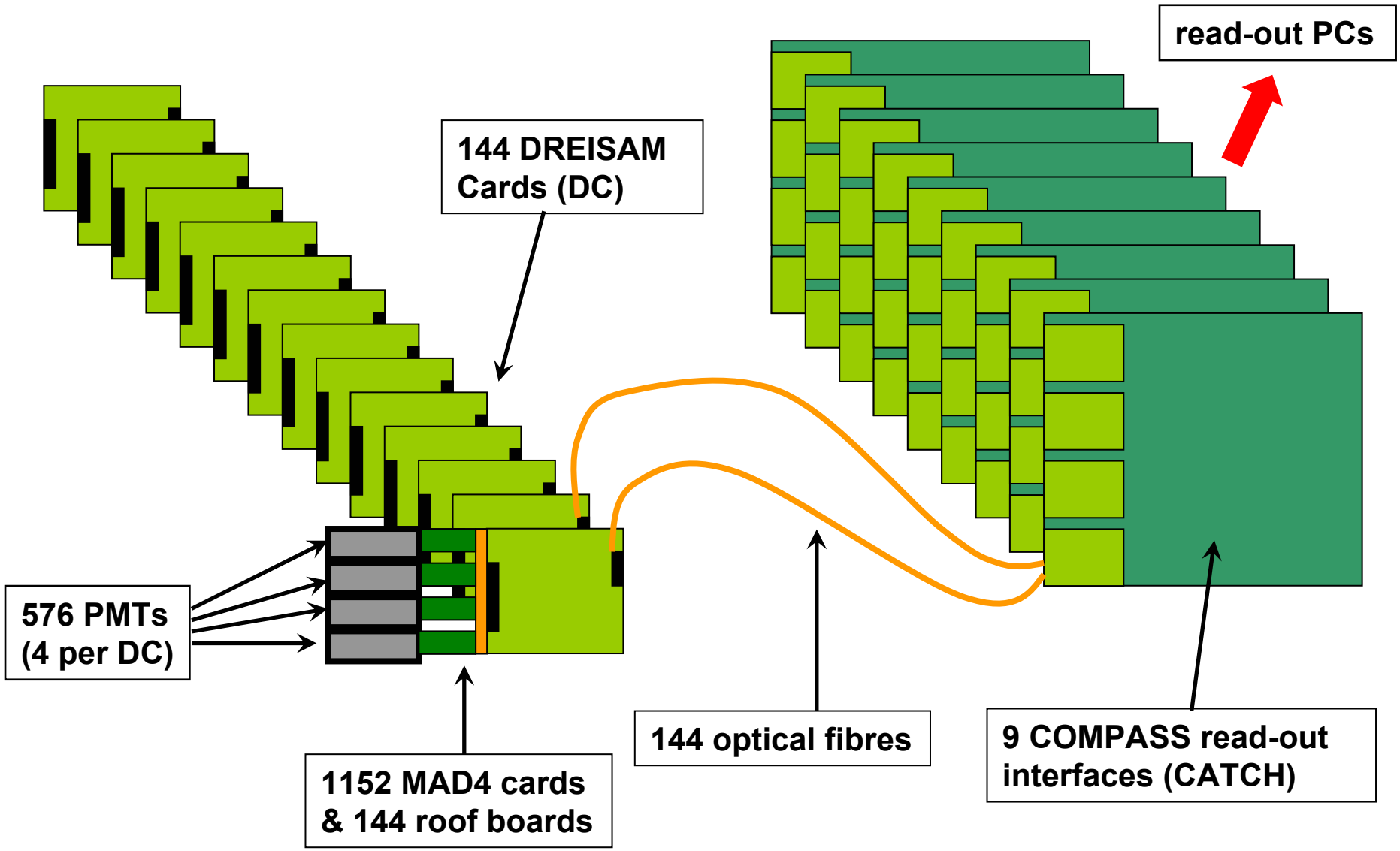
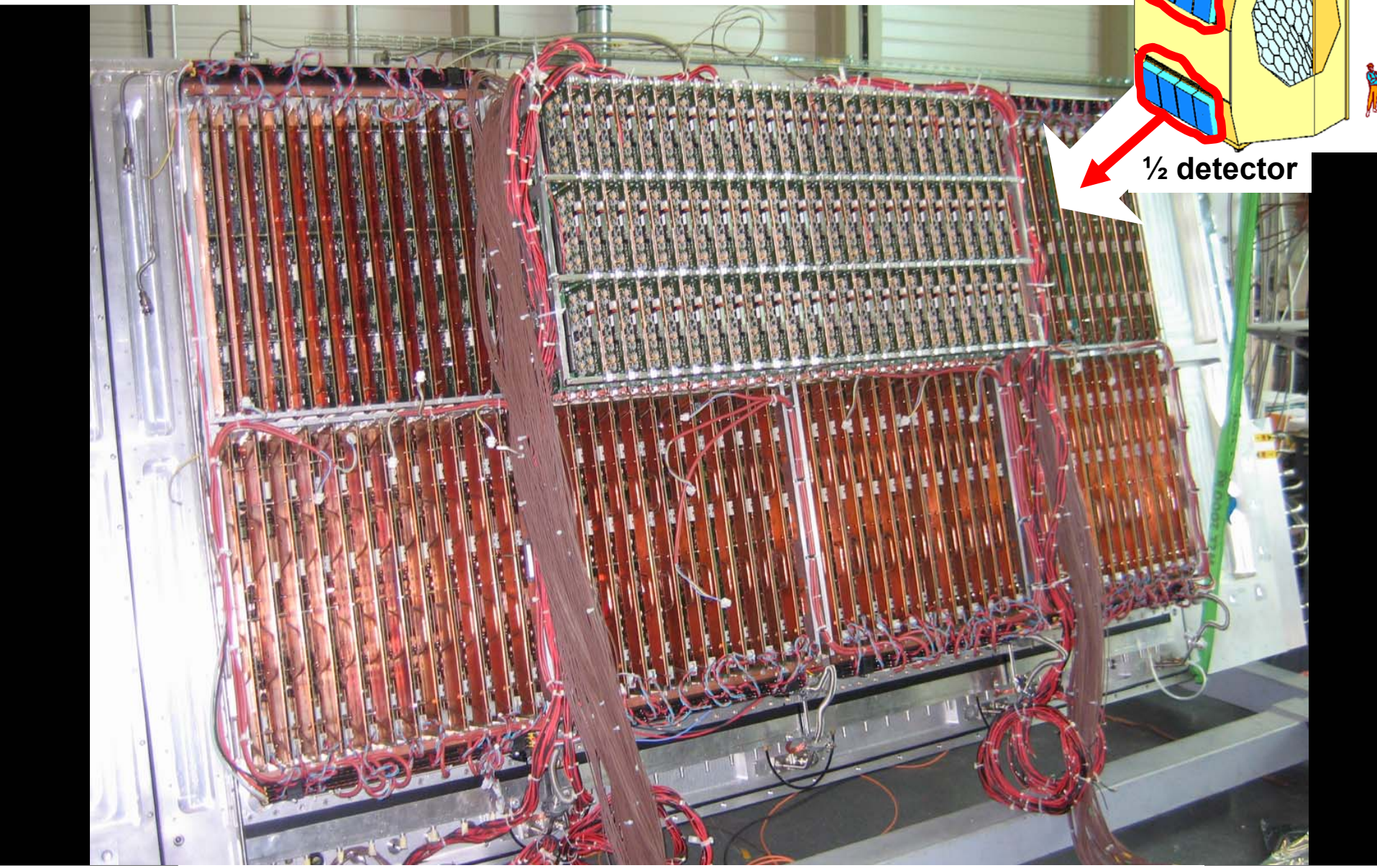
Read-out electronics of 1st quarter



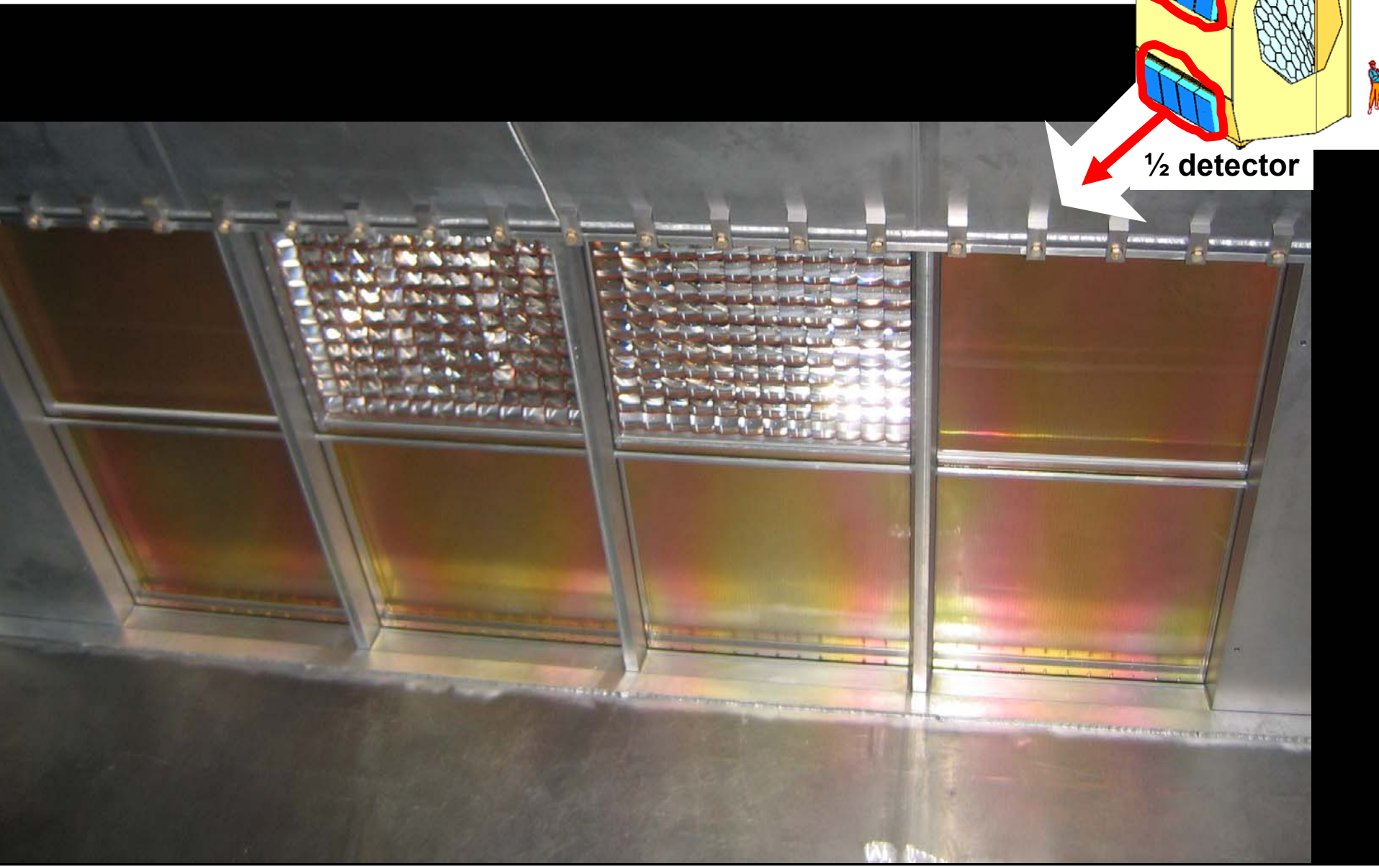
Data transfer

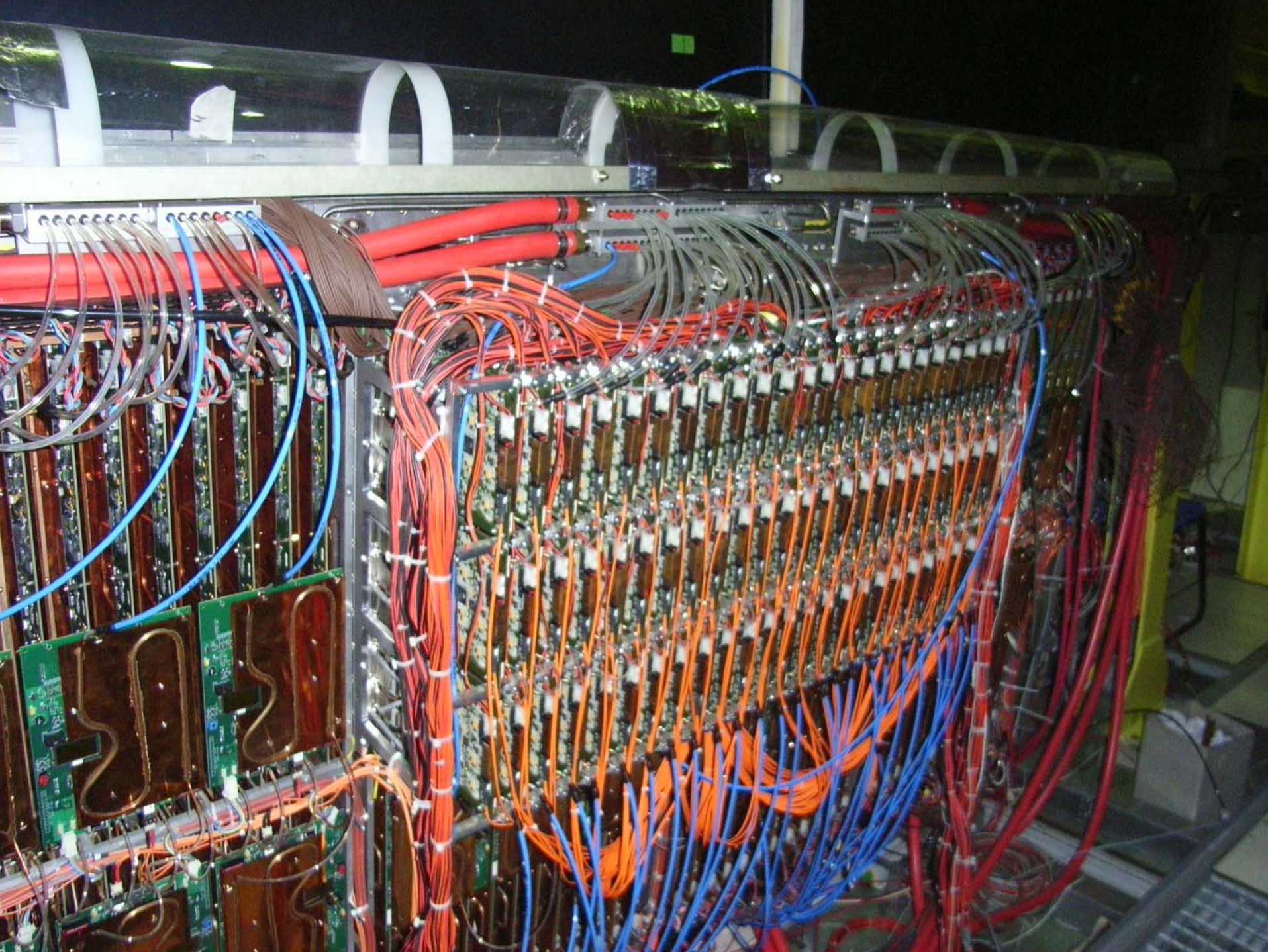


Half upgraded detector



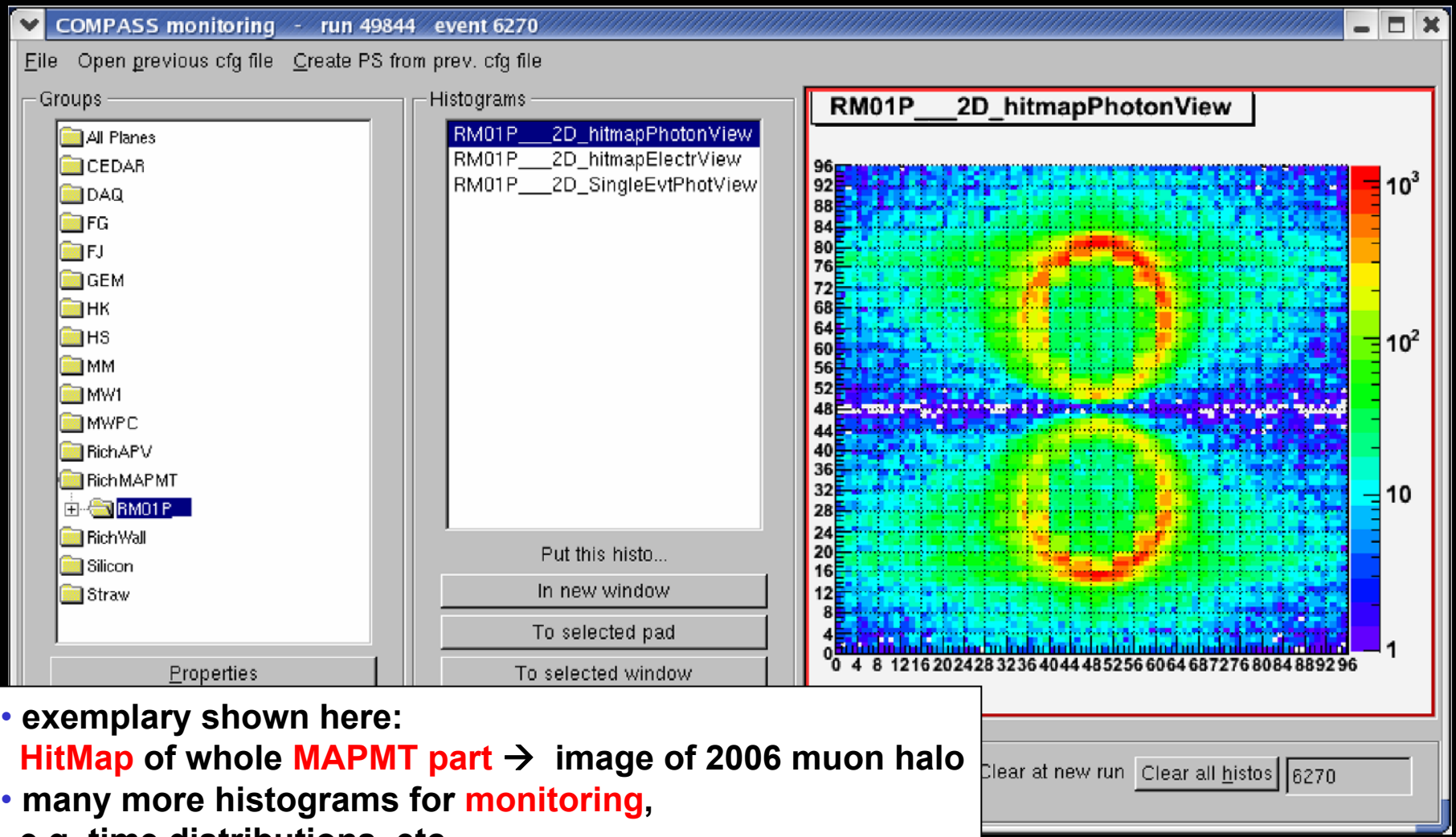
Half upgraded detector- from inside





Monitoring of RICH MAPMT with COOOL

(COMPASS Object Oriented Library)

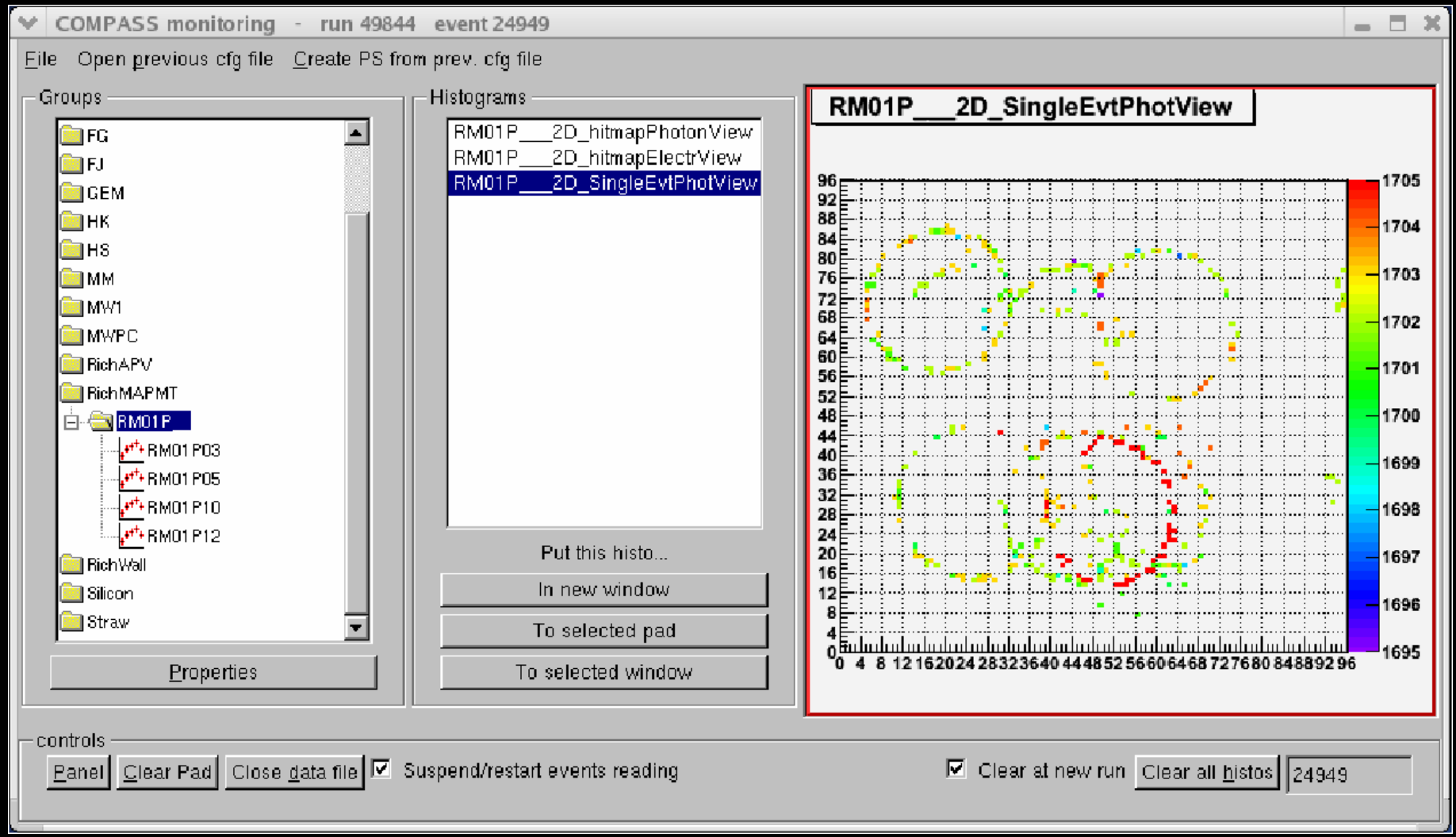


- **exemplary shown here:**
  HitMap of whole MAPMT part → image of 2006 muon halo
- **many more histograms for monitoring,**
  e.g. time distributions, etc

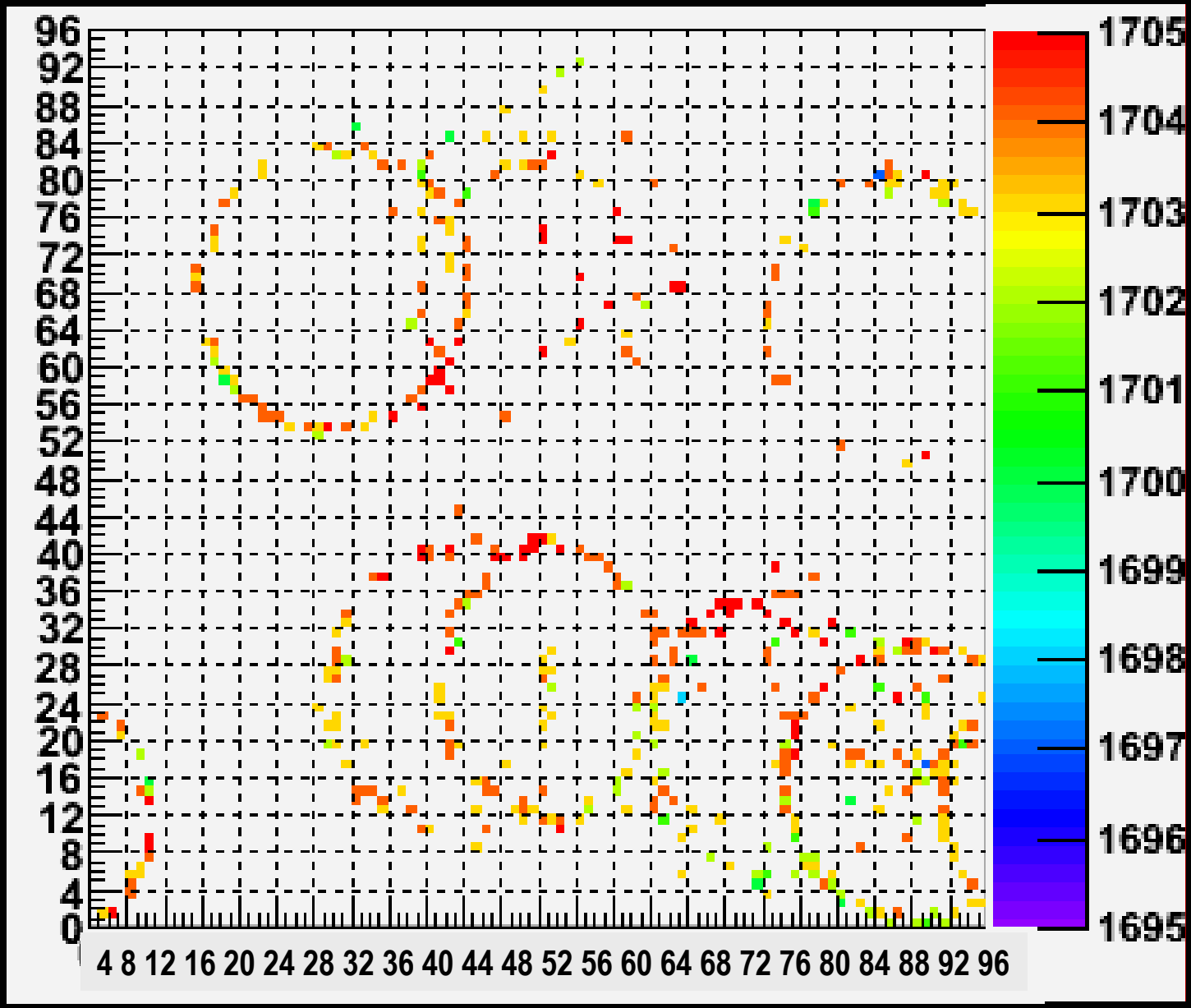
Monitoring of RICH MAPMT with COOOL

(COMPASS Object Oriented Library)

Online event display for central detector part, i.e. MAPMT part

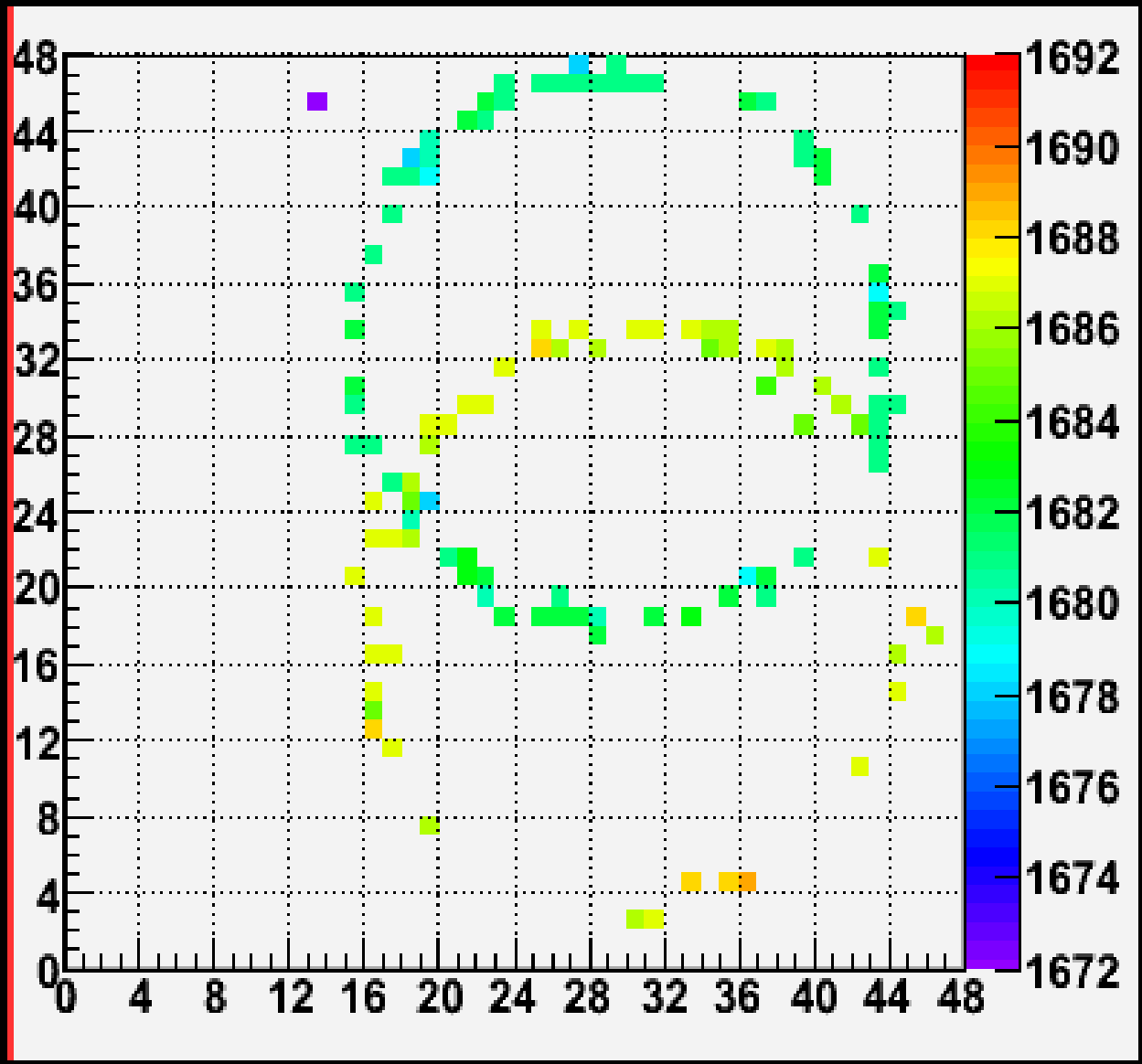


Online event display: 1st hadron rings beginning of 2006 SPS run



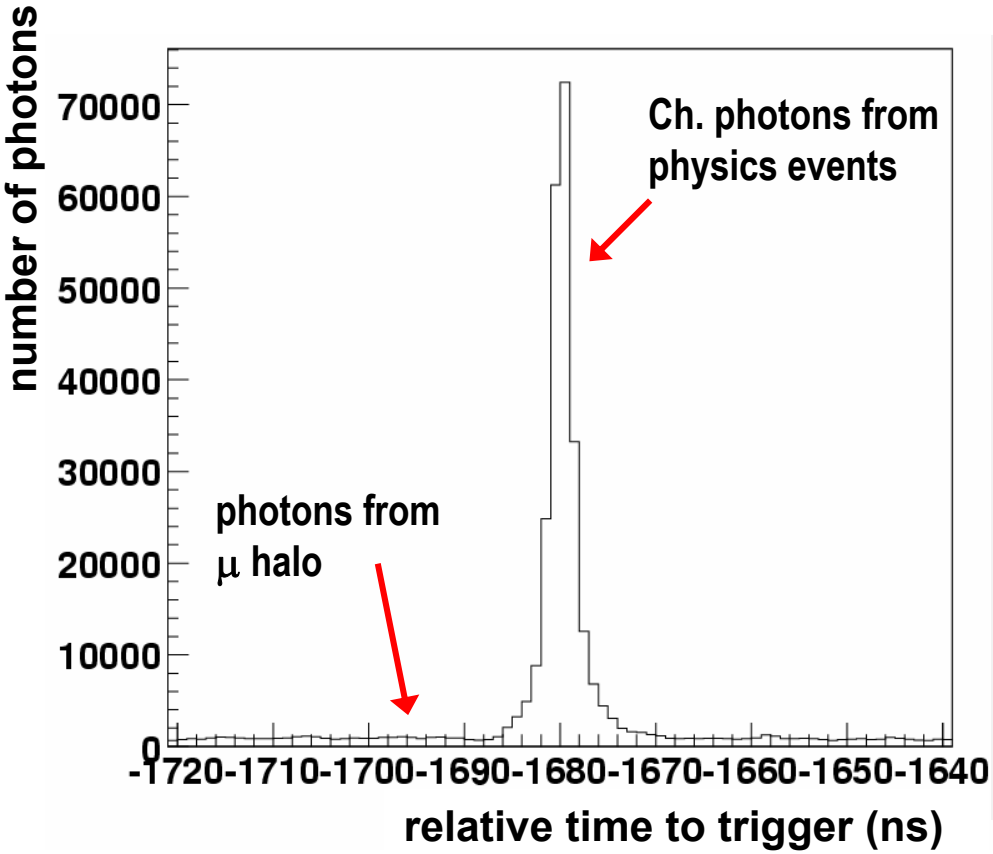
Here, 10 ns time window applied.

Time resolution is useful for correctly assigning hits to rings:

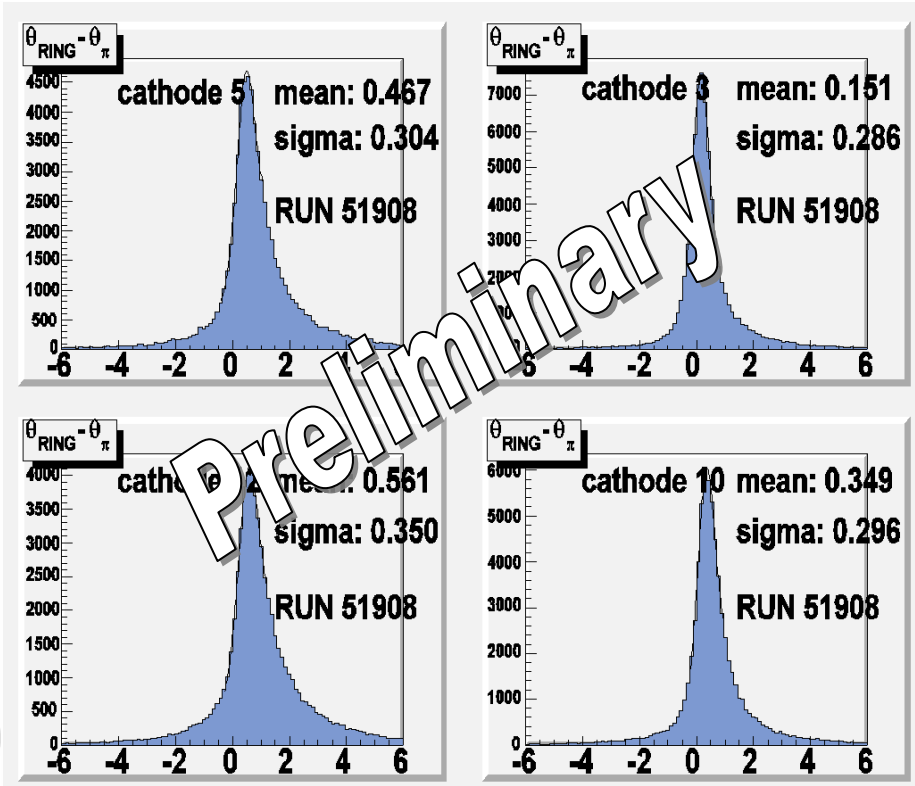


Cherenkov photon time distribution

time spectrum



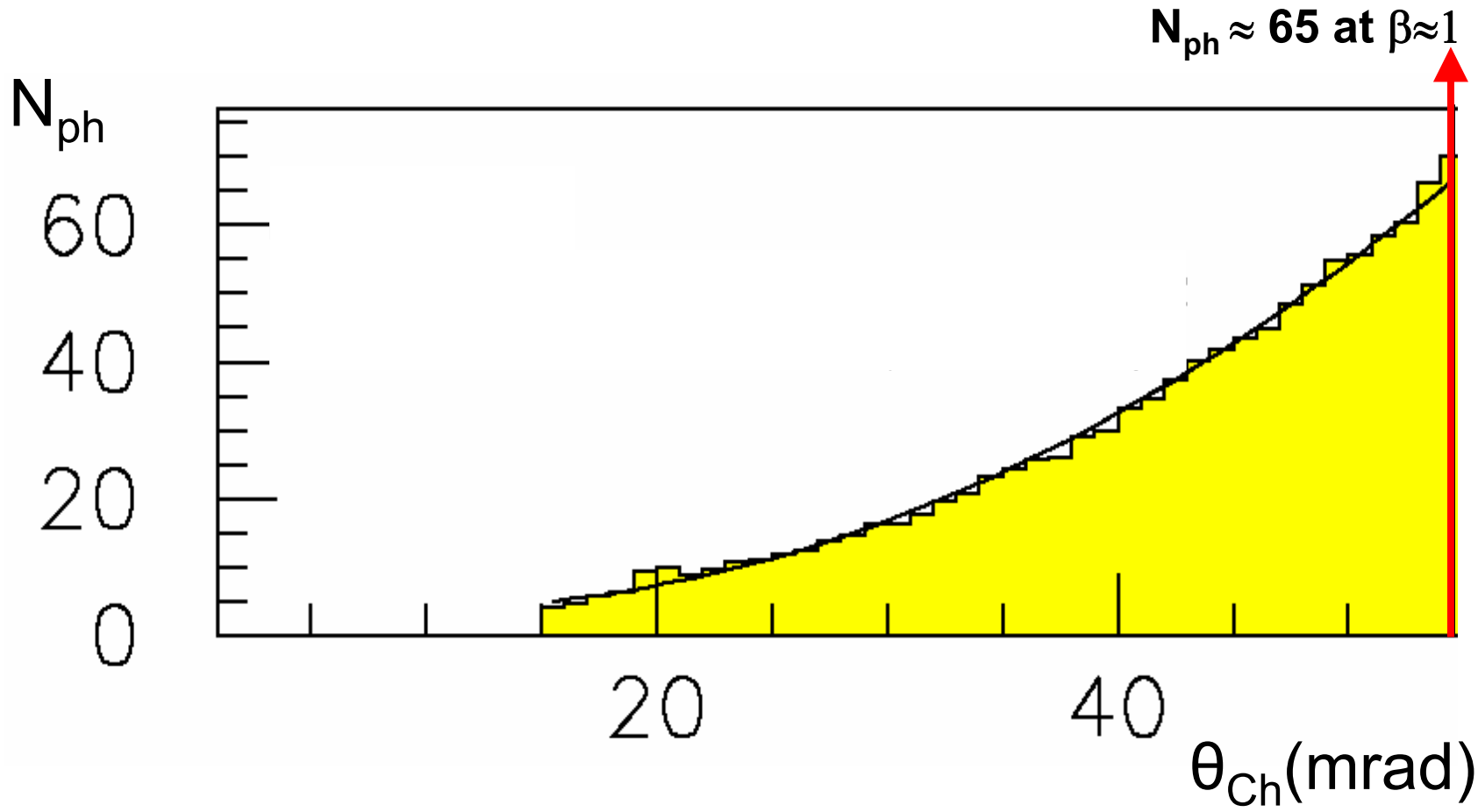
ring resolution



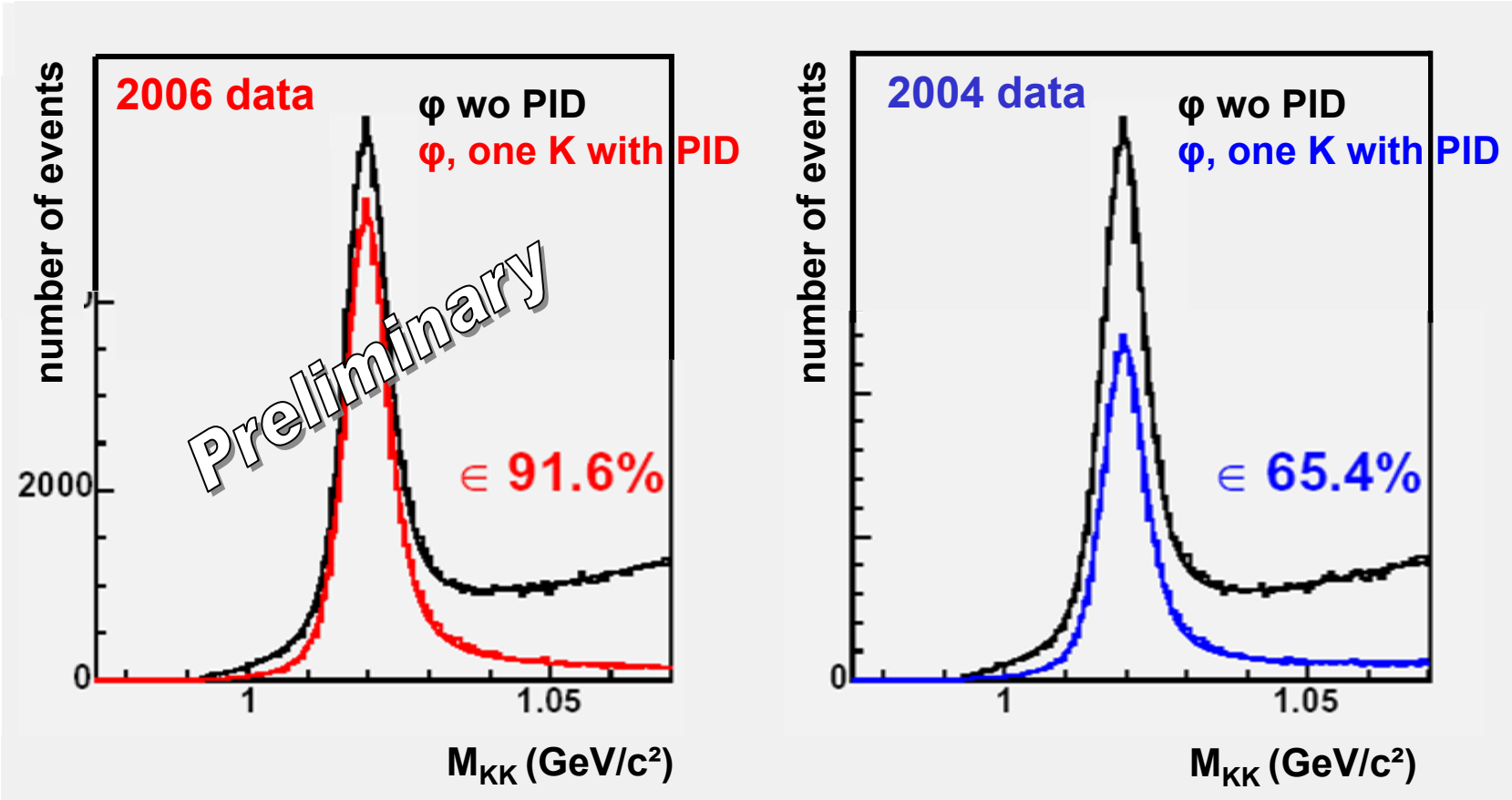
→ Excellent background suppression!

→ Improved ring resolution: σ ~ 0.3mrad

Number of photons per ring



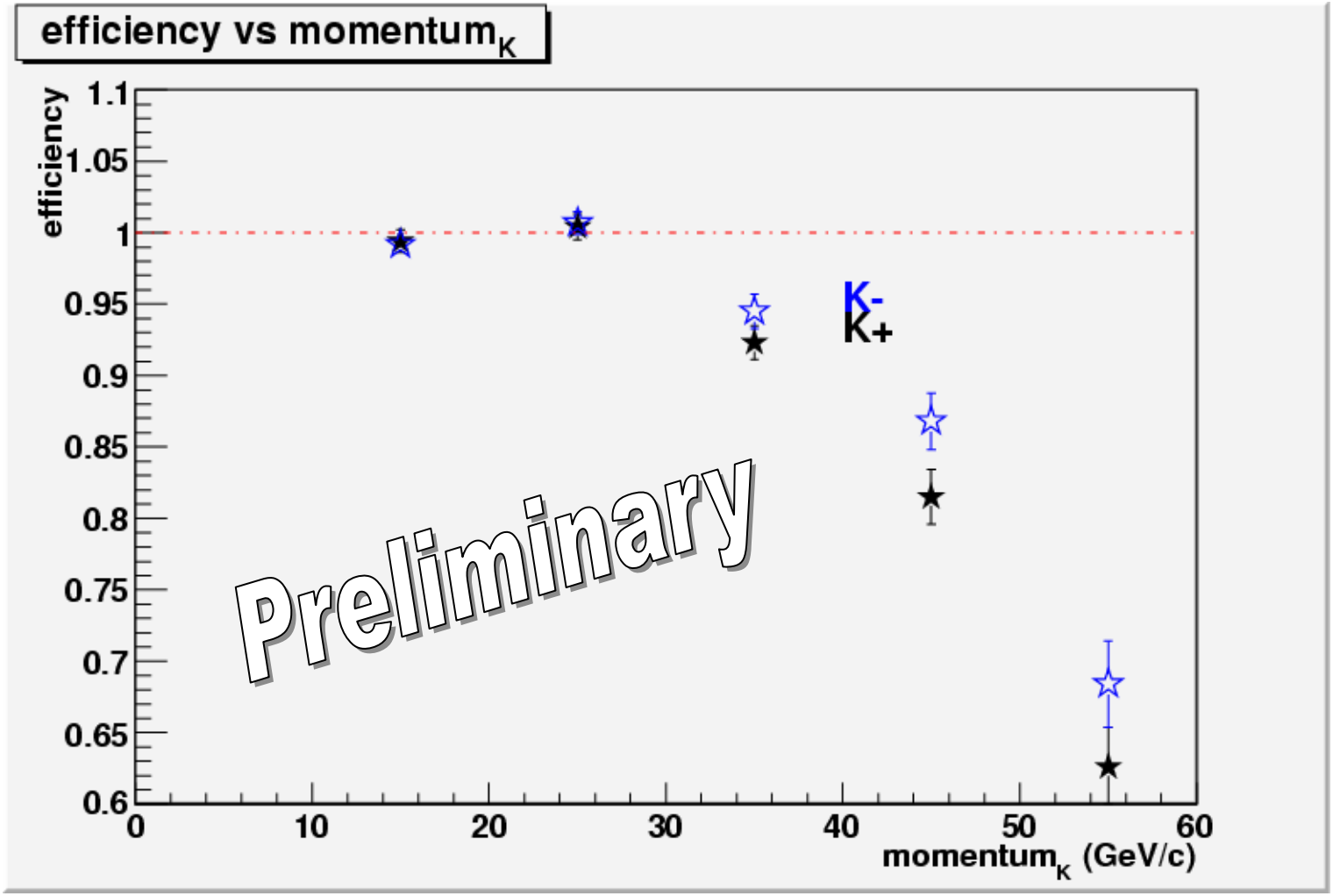
Reconstruction efficiency for Kaons



- **Efficiency** for correctly identify a Kaon: $\varepsilon_K = 92\%$ (65% for 2004)
  → Study based on Kaons from decay of excl. produced φ (1020) (Ch. tresh. < p_K < 60 GeV)

- **Purity** for Kaons ($K_S \rightarrow 2\pi$): 99% (65% for 2004)
  → probability of misidentification of a true pion as a kaon estimated using pions from decay of exclusively produced K_s

Performances based on 2006 data



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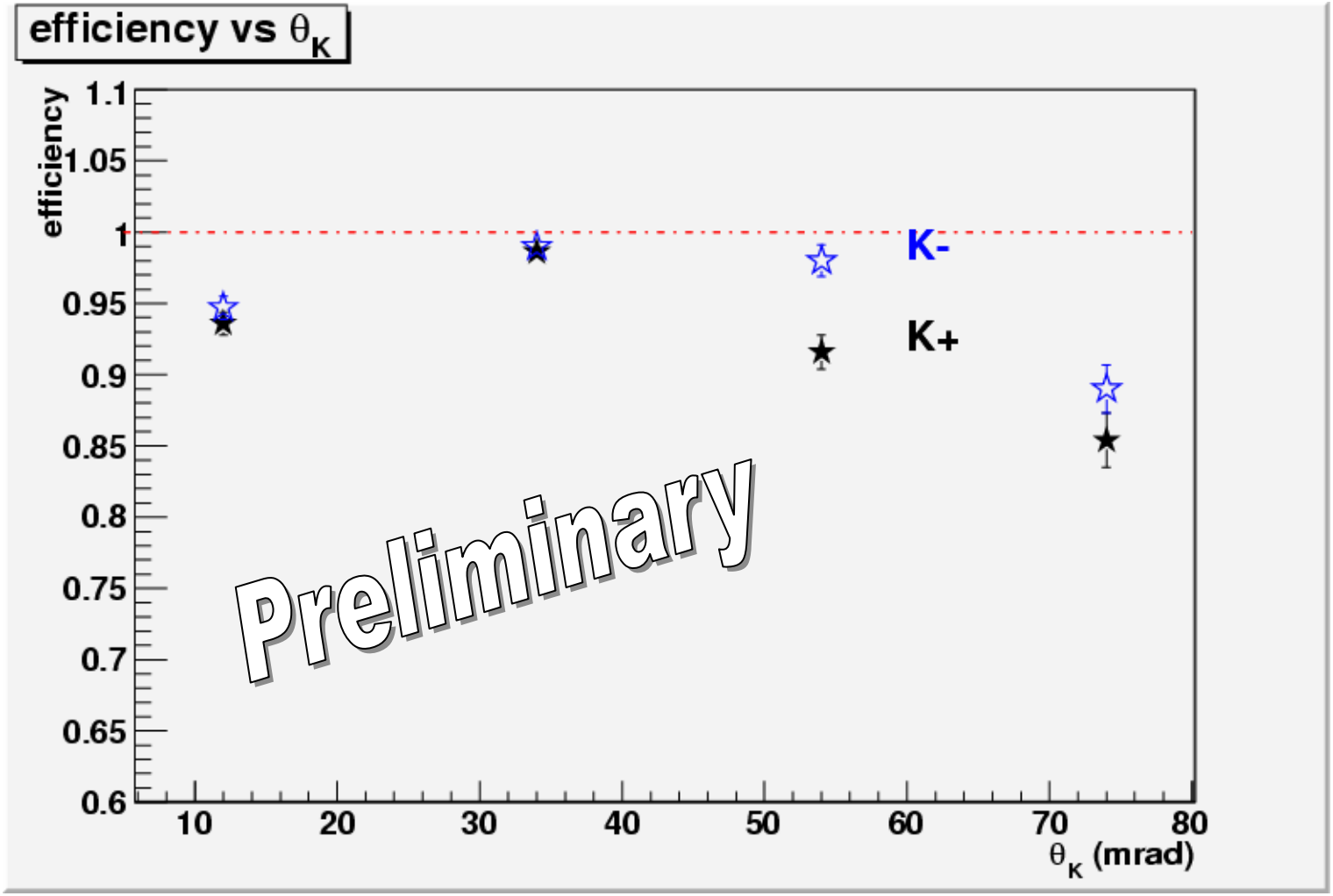

Performances of upgraded RICH detector

Excellent performances (based on 2006 data):

- N_{ph}/ring (ß≈1) **> 60** before upgrade: 14
- time resolution **< 1 ns** before upgrade: 3 µs
- $\sigma_{ring} \approx$ **0.3 mrad** (ß≈1) before upgrade: 0.6mrad
- **2σ** π/K separation at p_h **>55 GeV/c** before upgrade: 43 GeV/c
- excellent suppression of background from µ halo,
- performances as expected (and better)

Conclusions

- **Major upgrade of COMPASS RICH-1 has been performed. i.e.**
  a) exchange of read-out electronics for CsI MWPC (outer region)
  b) new fast photon detection system based on MAPMTs (central region)

- **Design & construction took 1.5 y only: Nov 2004 – May 2006**
  → **ready for SPS 2006 run, June 2006**

- **Excellent performances, based on 2006 data**

- **Capable at up to ~100 kHz trigger rate (COMPASS future needs)**

- **Very effective team: The COMPASS Rich Upgrade Group**

➔ **Stay tuned for new exciting COMPASS results !**

Status presented thanks to many colleagues … The COMPASS RICH upgrade team:

P.Abbon(11), M.Alekseev(12), H.Angerer(9), M. Apollonio(13), R.Birsa(13), P.Bordalo(7), F.Bradamante(13), A.Bressan(13), L.Busso(12), M.Chiosso(12), P.Ciliberti(13), M.L.Colantoni(1), S.Costa(12), N.Dibiase(12), T.Dafni(11), S.Dalla Torre(13), V.Diaz(13), V.Duic(13), E.Delagnes(11), H.Deschamps(11), W.Eyrich(4), D.Faso(12), A.Ferrero(12), M.Finger(10), M.Finger Jr(10), H.Fischer(5), S.Gerassimov(9), M.Giorgi(13), B.Gobbo(13), R.Hagemann(5), D.von Harrach(8), F.H.Heinsius(5), R. Joosten(2), B.Ketzer(9), K.Königsmann(5), V.N. Kolosov(3)*, I.Konorov(9), D.Kramer(6), F.Kunne(11), S. Levorato(13), A.Maggiora(12), A.Magnon(11), A.Mann(9), A.Martin(13), G.Menon(13), A.Mutter(5), O. Nähle(2), D.Neyret(11), F.Nerling(5), P.Pagano(13), S.Paul(9), S.Panebianco(11), D.Panzieri(1), G.Pesaro(13),C. Pizzolotto(4), J. Polak(6), P.Rebourgeard(11), E. Rocco(13), F.Robinet(11), P.Schiavon(13), C.Schill(5), P.Schoenmeier(4), L.Silva(7), M.Slunecka(10), L.Steiger(10), F.Sozzi(13), M.Sulc(6), M.Svec(6), F.Tessarotto(13), A.Teufel(4), H. Wollny(5)

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(7) LIP, Lisbon, Portugal

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(9) Technische Universität München, Physik Department, Garching, Germany

(10) Charles University, Praga, Czech Republic and JINR, Dubna, Russia

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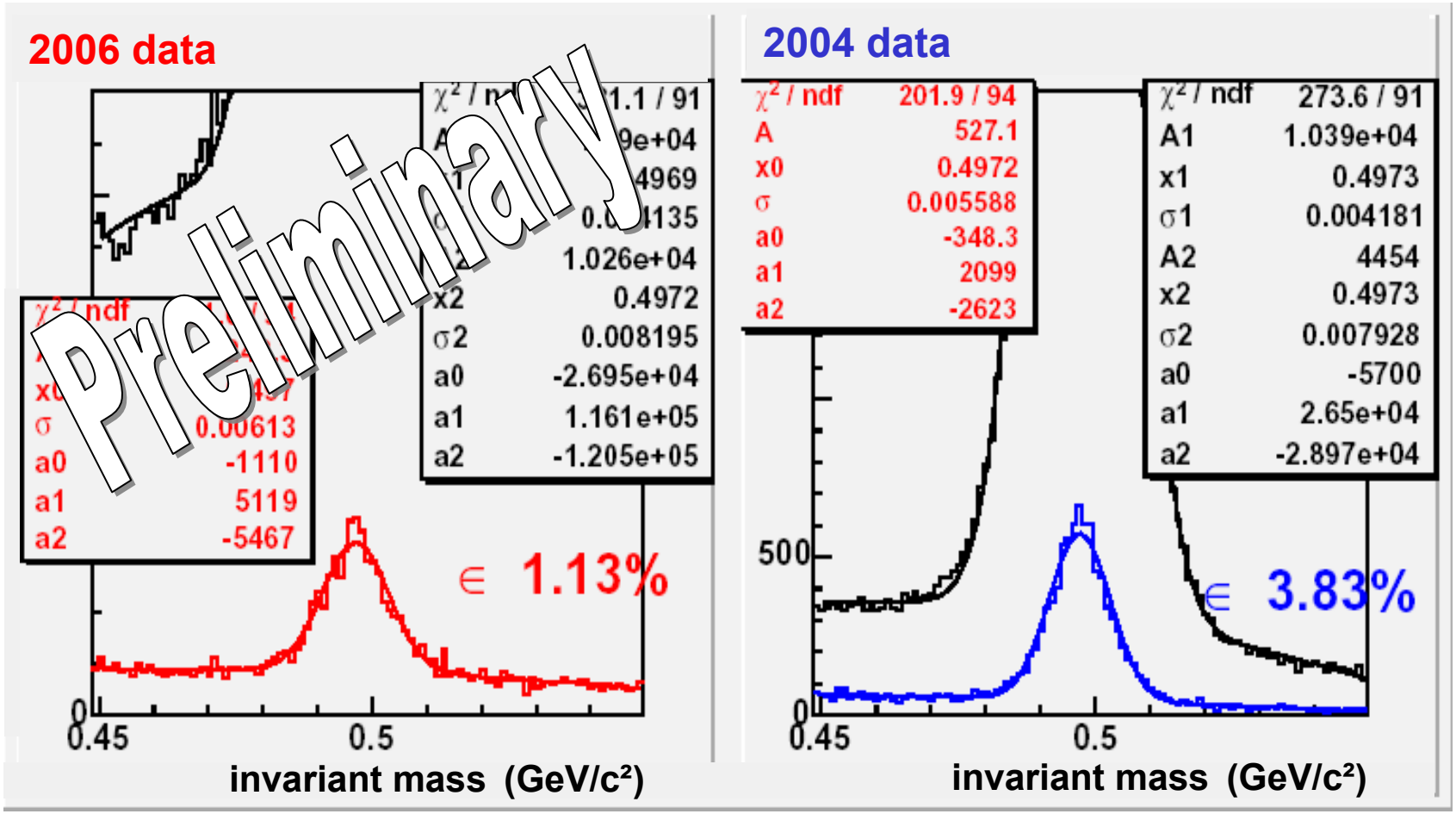
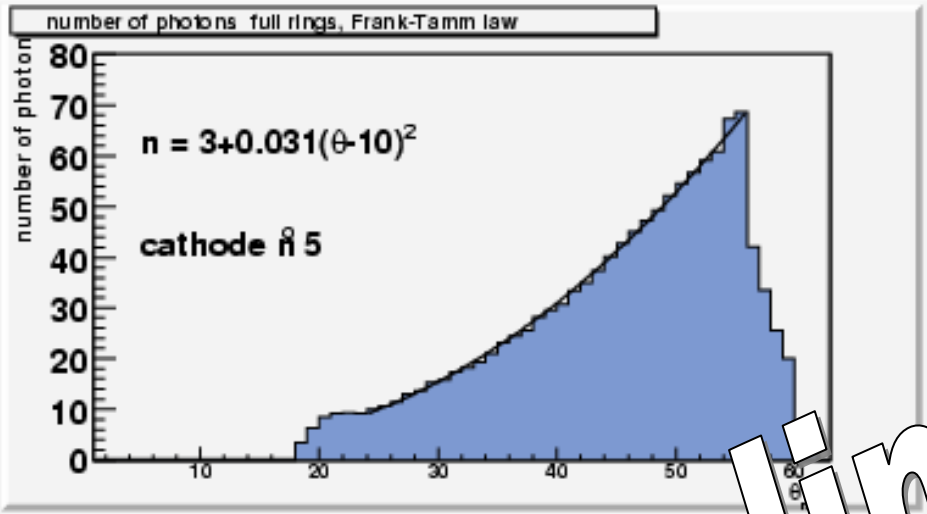
Backup Slides

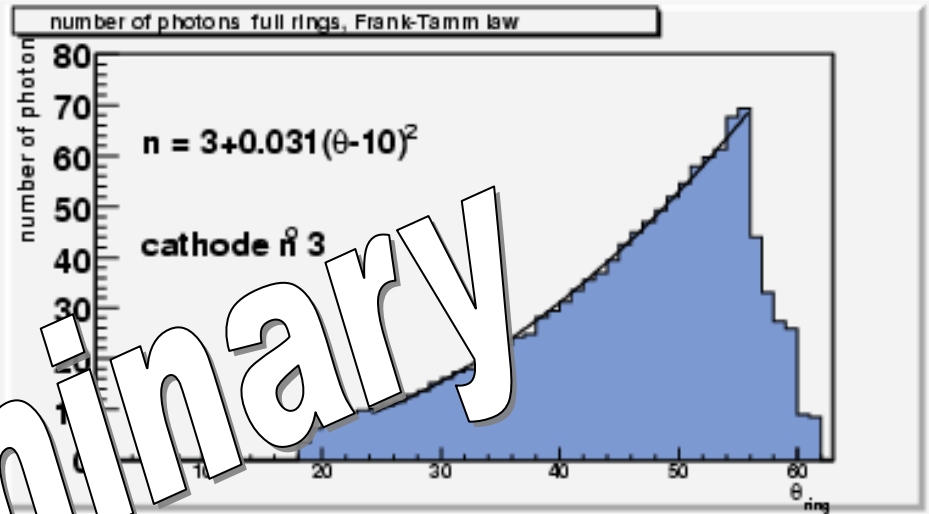
Improved purity

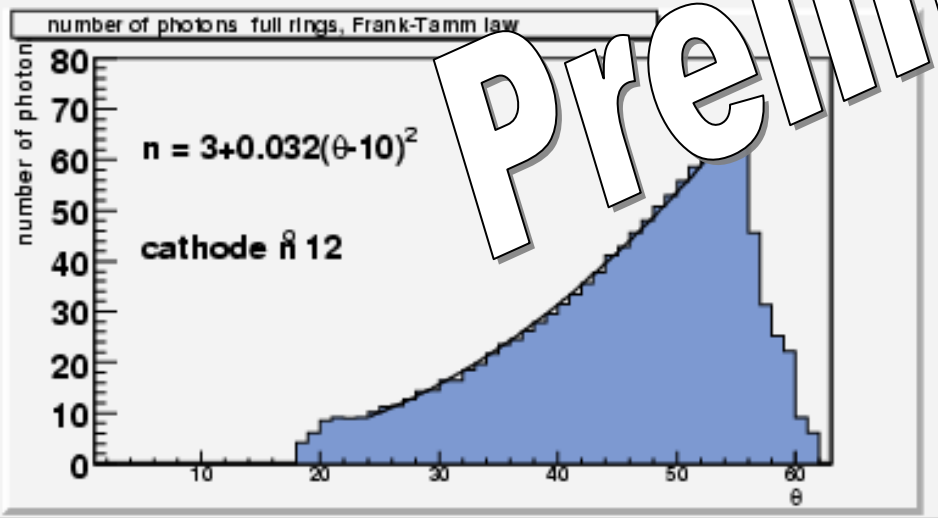


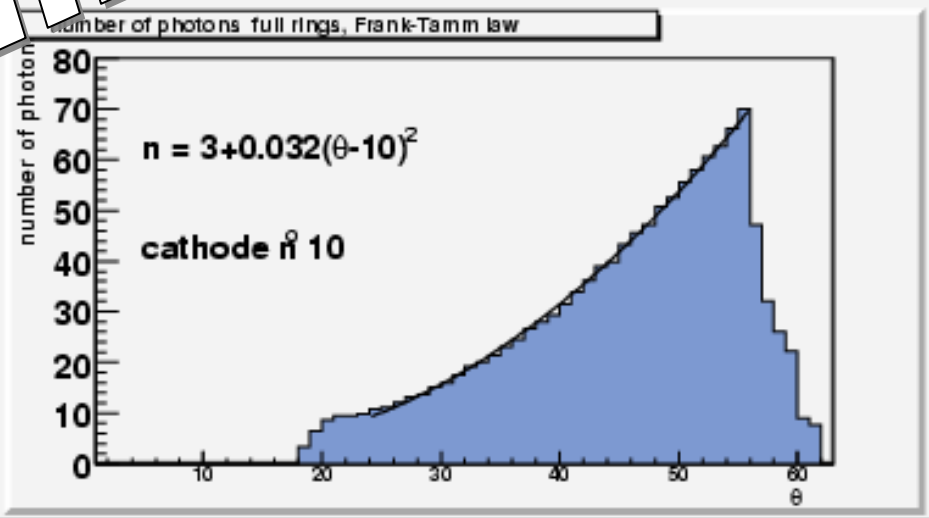
- probability of misidentification of a true pion as a kaon estimated using pions from decay of exclusively produced K_s
- purity for Kaons ($K_S \rightarrow 2\pi$): 99%

Performances based on 2006 data





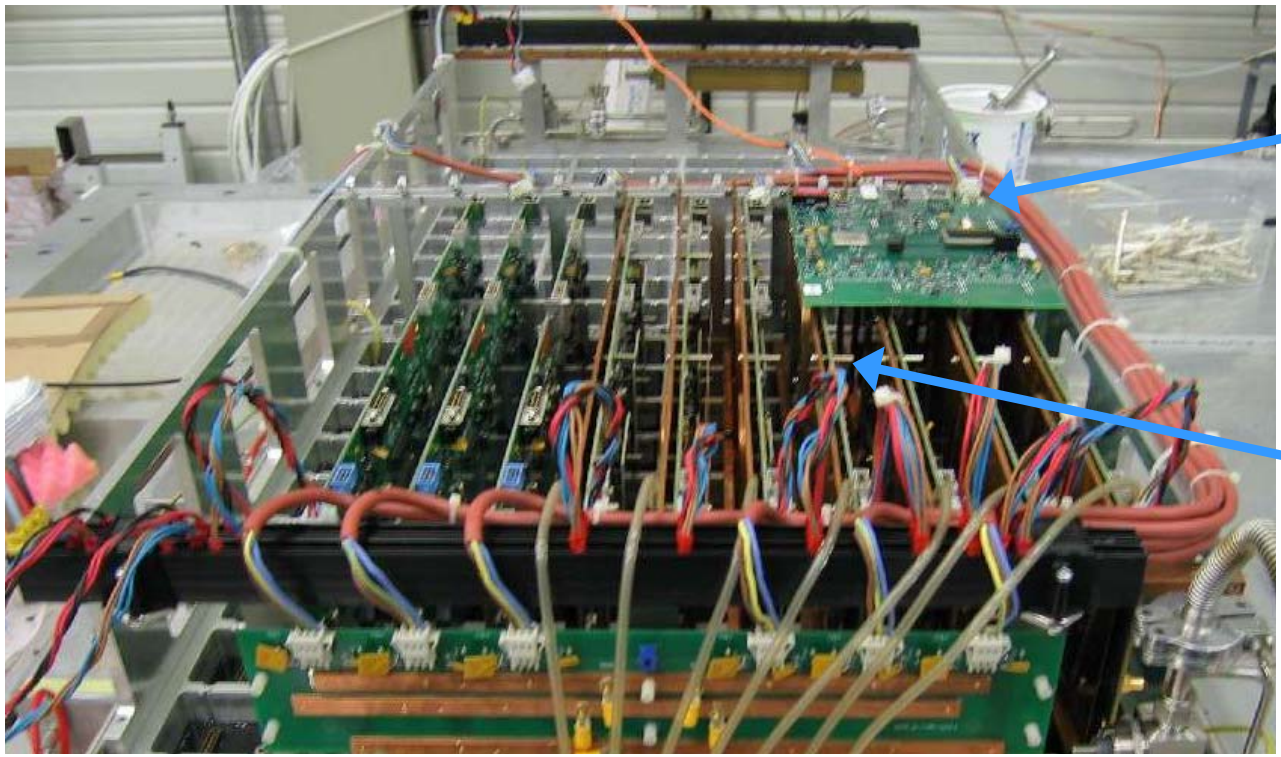




Preliminary

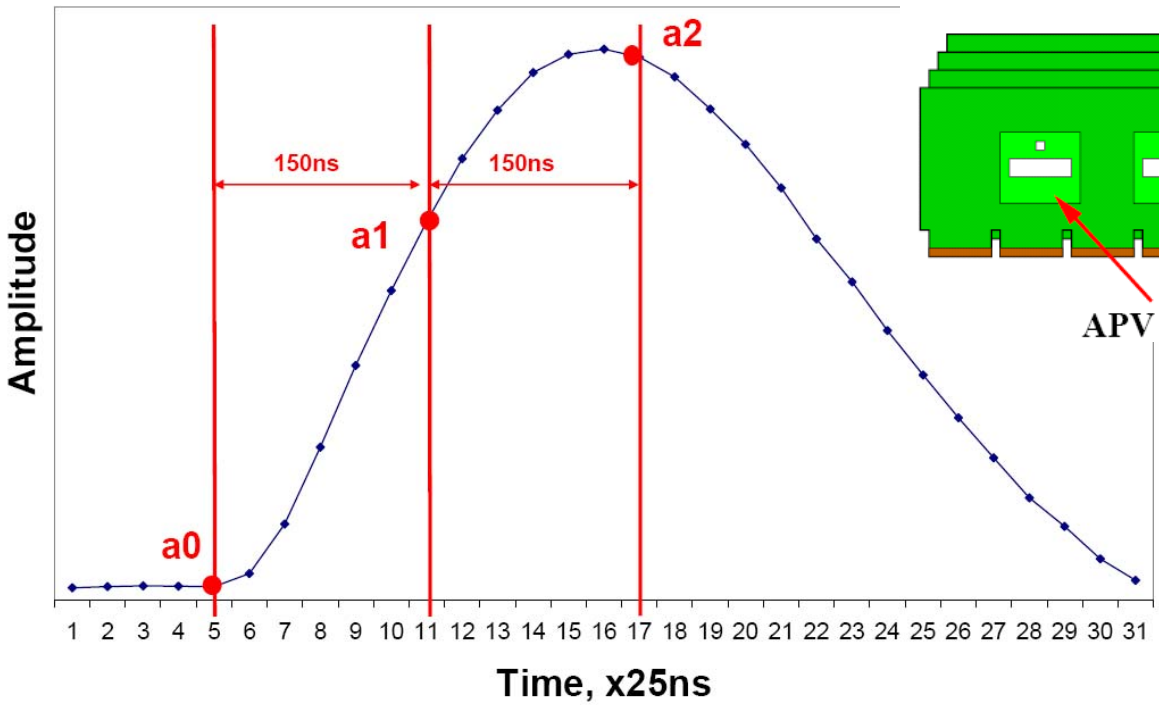
The new APV read-out of MWPC (outer part)

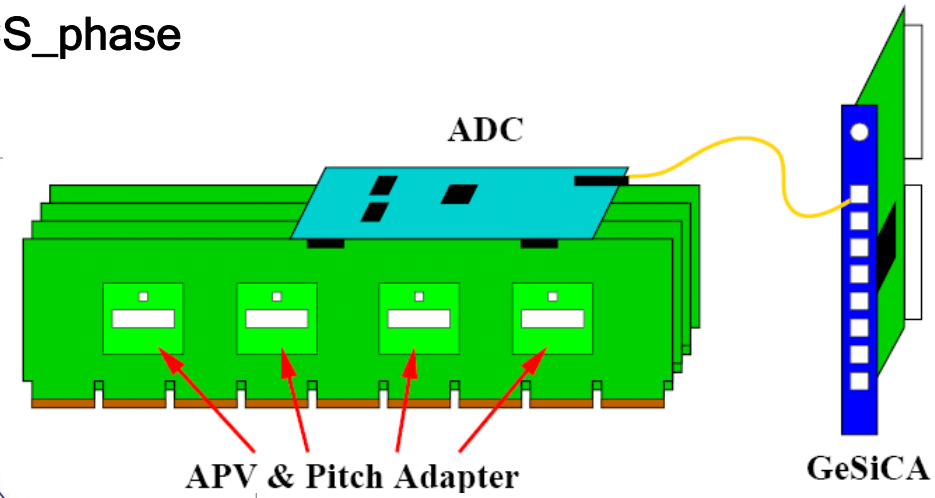
- fast read-out based on the APV analogue preamplifier
- connected to 12 bit pipeline ADCs, 40 MHz sampling, ~ 300 ns peaking time
- low deadtime → readout rates up to 100 kHz possible
- 3 amplitude samples per trigger => reconstruction of hit time
- signal time: T = a1/a2 * 156.25 - TCS_phase



The new APV read-out of MWPC (outer part)

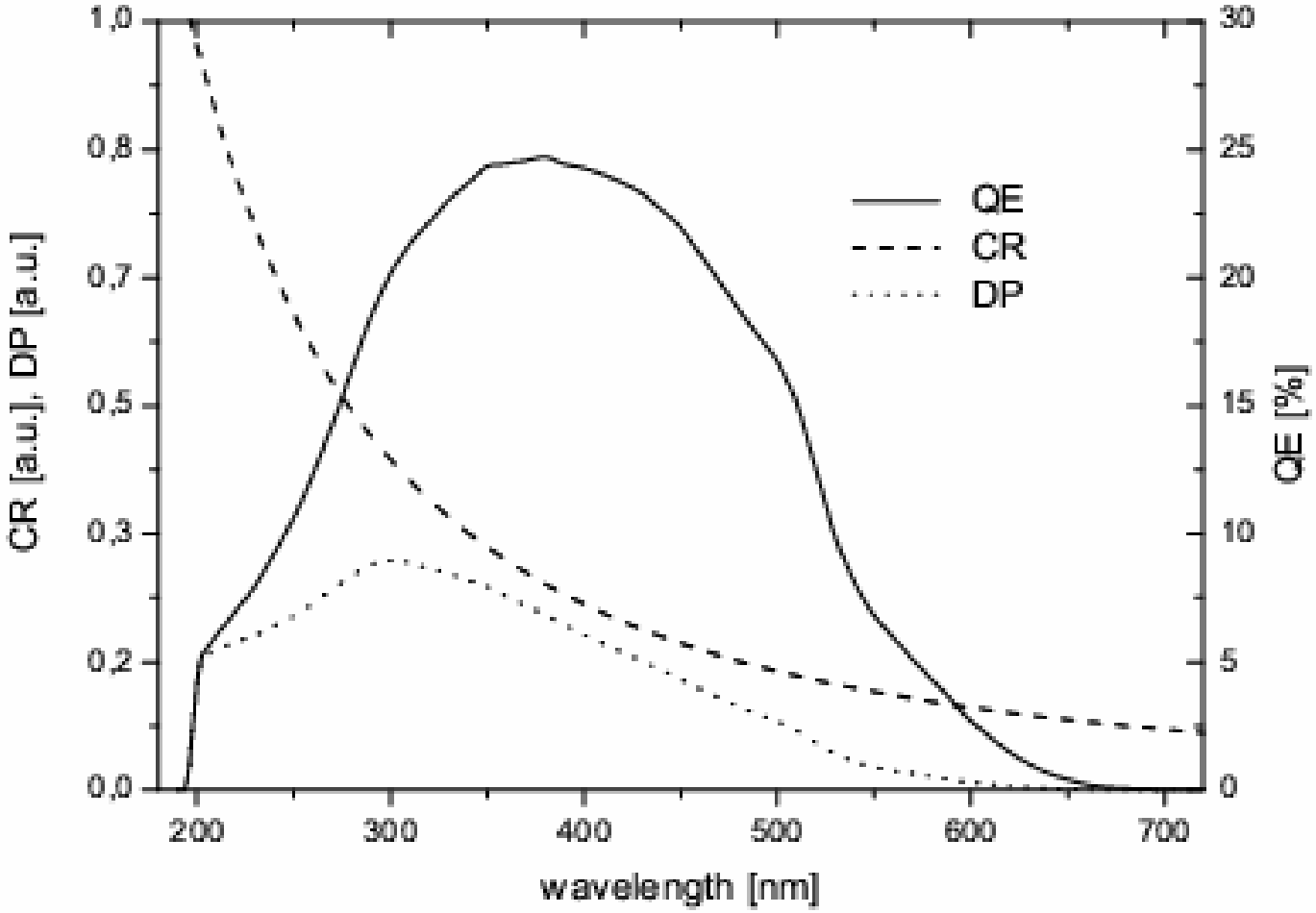
- **fast read-out** based on the APV analogue preamplifier
- connected to 12 bit pipeline ADCs, **40 MHz sampling**, ~ 300 ns peaking time
- **low deadtime** → readout rates up to 100 kHz possible
- 3 amplitude samples per trigger => **reconstruction of hit time**
- signal time: T = a1/a2 * 156.25 - TCS_phase



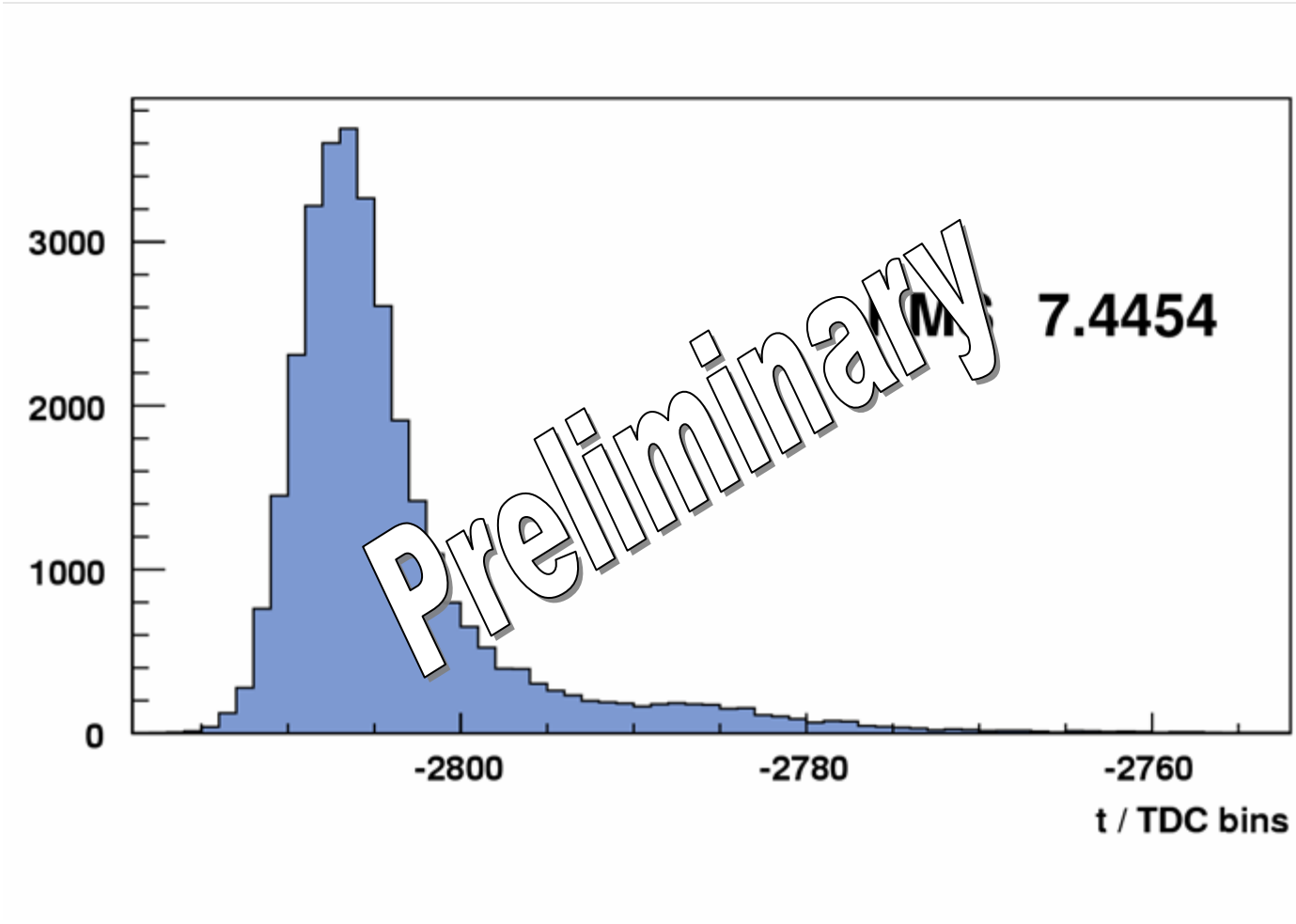


- in total: 62208 channels
- each FE board reads 432 chan
- one ADC card per 4 FE boards

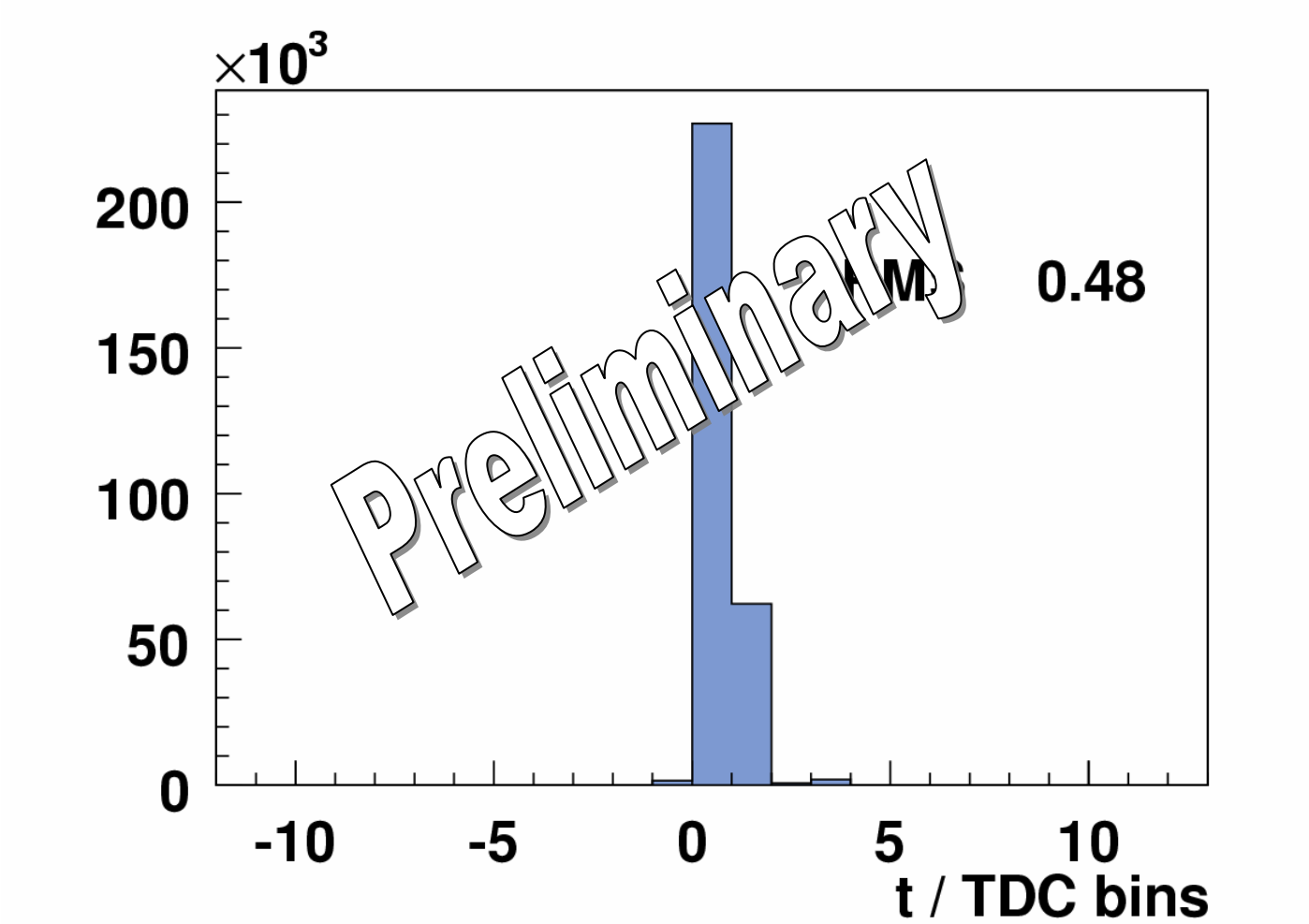
RICH upgrade based on MAPMT- principle



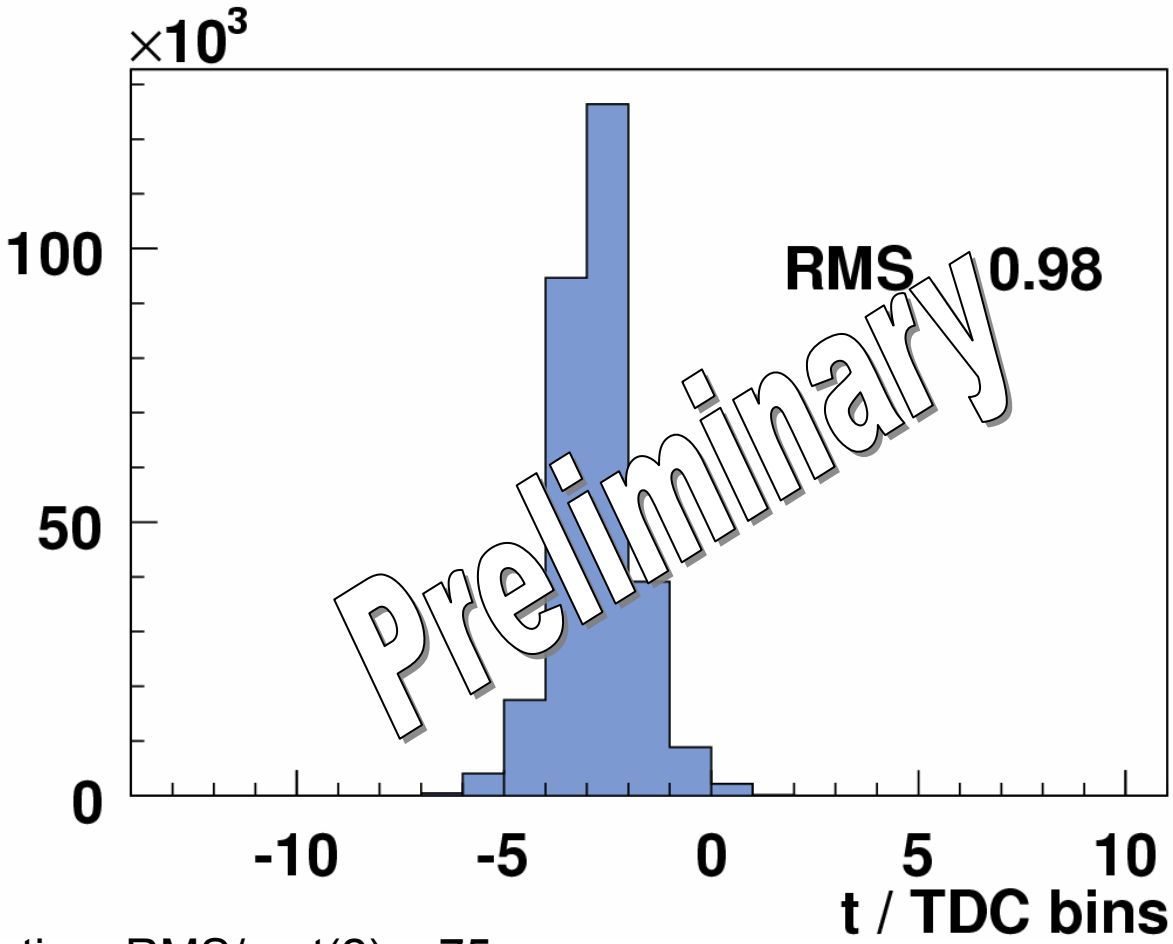
RICH upgrade – time resolution of smallest unit (here: MAPMT+MAD+DREISAM)



RICH upgrade – time resolution of smallest unit (here: DREISAM – neighboured channels)



RICH upgrade – time resolution of smallest unit (here: DREISAM card)



Time resolution: RMS/sqrt(2) = 75 ps