Aging measurements of a TMAE based photon detectors for the HERA-B RICH

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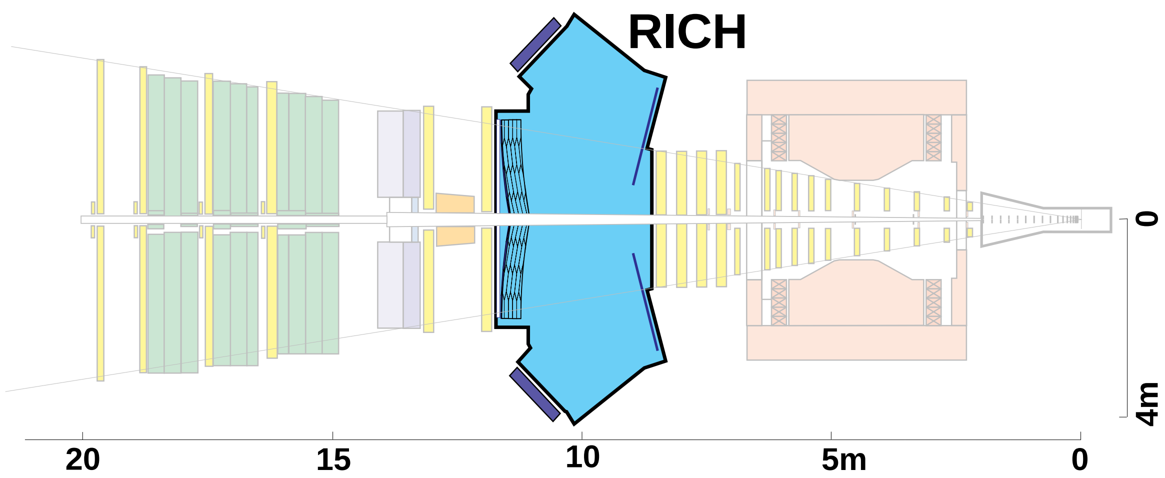
- The HERA-B RICH
  - HERA-B, RICH goal and implementation
  - Radiator, mirrors, focal plane
  - Photon detector requirements
- TMAE photon detectors
  - Design principle, history of prototypes
  - Aging experiences
- Final Aging Measurement
  - Setup, monitoring, predictions
  - Results (and more findings)
- Conclusion

The HERA-B RICH

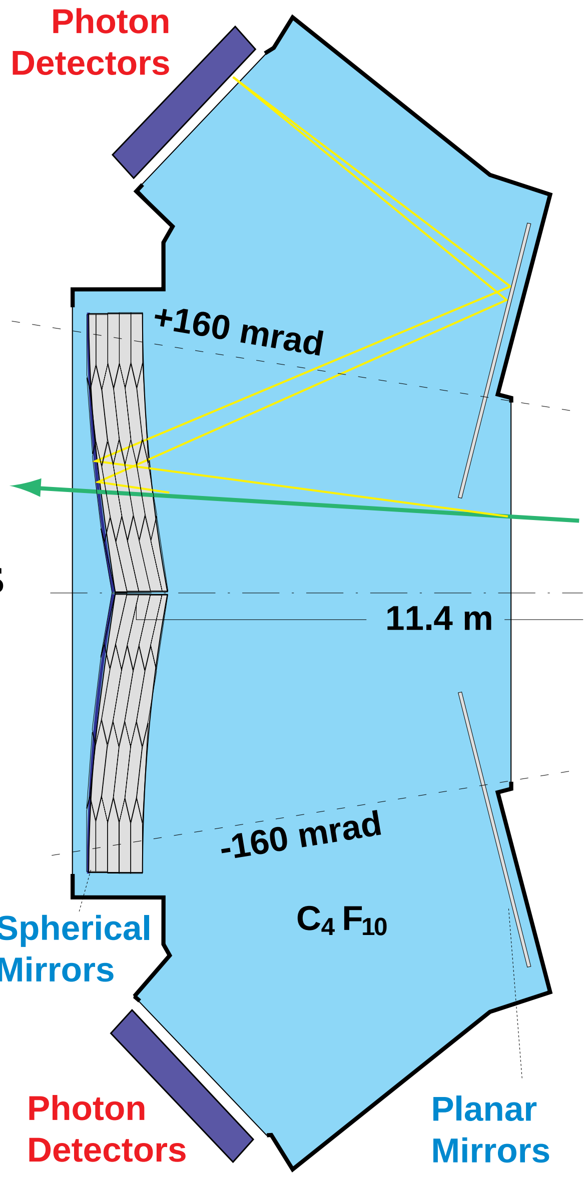
❑ HERA-B

- Fixed target detector at the 920 GeV HERA proton ring at DESY
- Goal : measure *CP* violation in *B*-system
  - ➥ Interaction rate 40 MHz, multiple interactions per bunch crossing, hundreds of charged tracks
- the RICH has to
  - ➥ identify hadrons; tag flavor of B decays
  - ➥ cover full acceptance: ±160 mrad vertical, ±250 mrad horizontal (bending plane)
  - ➥ achieve 3σ π/K separation for $10 < p < 75$ GeV/c
- Implementation
  - ▼ Single RICH in the middle of the detector
  - ▼ Horizontal space ≈ 3m
  - ▼ Vertical space ± 4m from the beam-line
  - ▼ Photon detectors outside of acceptance



HERA-B RICH details

- Radiator
  - C_4F_{10}
  - $n - 1 = 1.35 \times 10^{-3}$
  - $\theta_C = 52$ mrad
  - 100 m^3 stainless steel vessel
  - 12 m^2 of quartz windows



- Mirrors
  - Split spherical (r = 11.4 m) 80 hexagonal elements, area 24 m^2
  - Planar mirrors move focal plane above and below radiator vessel

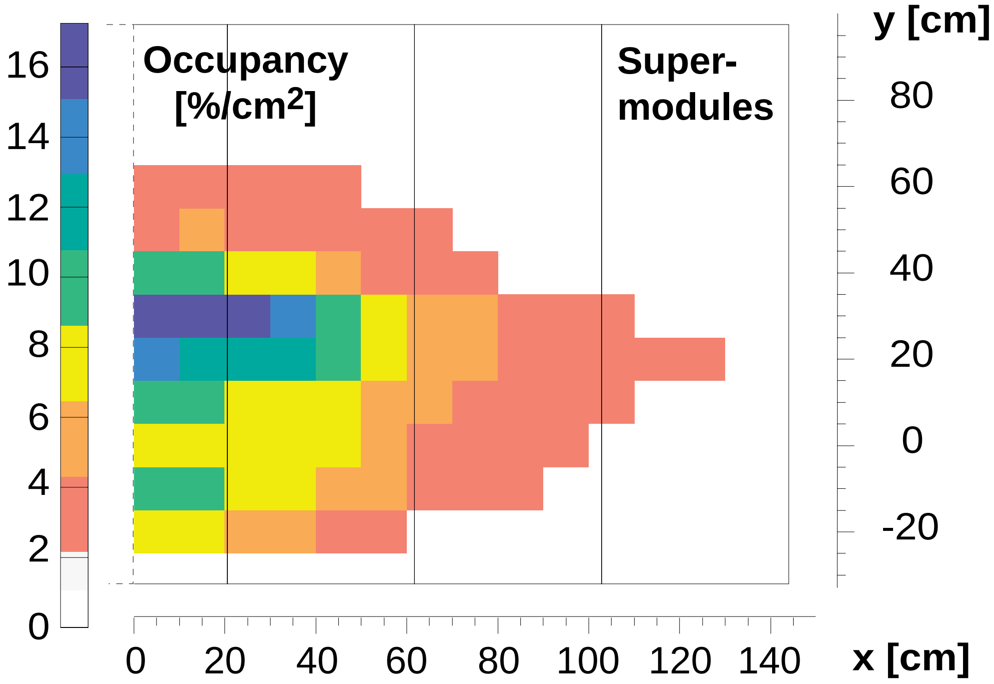
- Focal Plane
  - Two planes 1.2×3 m^2, above and below the radiator
  - Optimal cell size: 9 mm (limited by dispersion in C_4F_{10})

Photon Detector

❑ Number of photons

- π/K separation requires at least 20 detected photons per $\beta = 1$ track.

❑ Occupancy from MC



- 10–15% /cm^2 per event (for 30 photons/ring), shown for $^1/_4$ focal plane
- Event rate up to 40 MHz

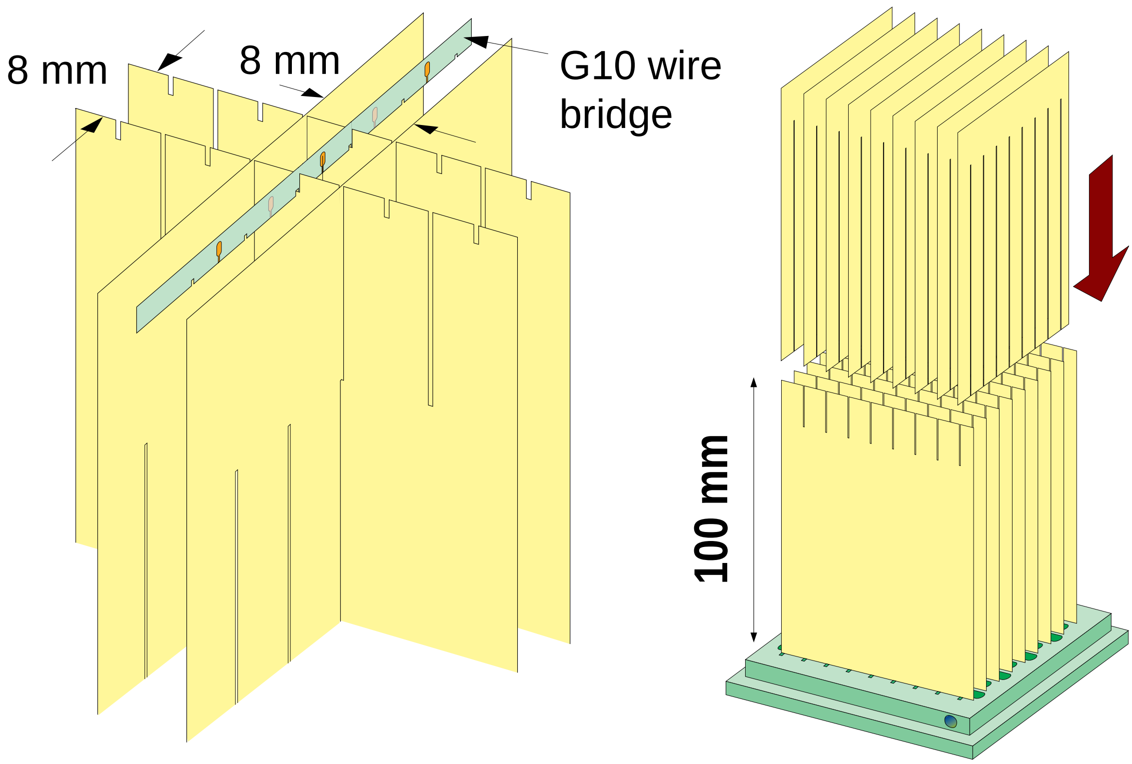
➡ Photon detector has to survive a photon rate of 4 MHz/cm^2 for at least one year

Aging Measurements are essential

HERA-B TMAE Chambers

❑ Common Design Principle

- Square cell $8 \times 8 \times 100\ \text{mm}^3$, formed by 0.2 mm thick intersecting metal sheets
- Anode wire, 25–50 µm diameter, strung at center between "bridge" and base
- Photons enter parallel to wire



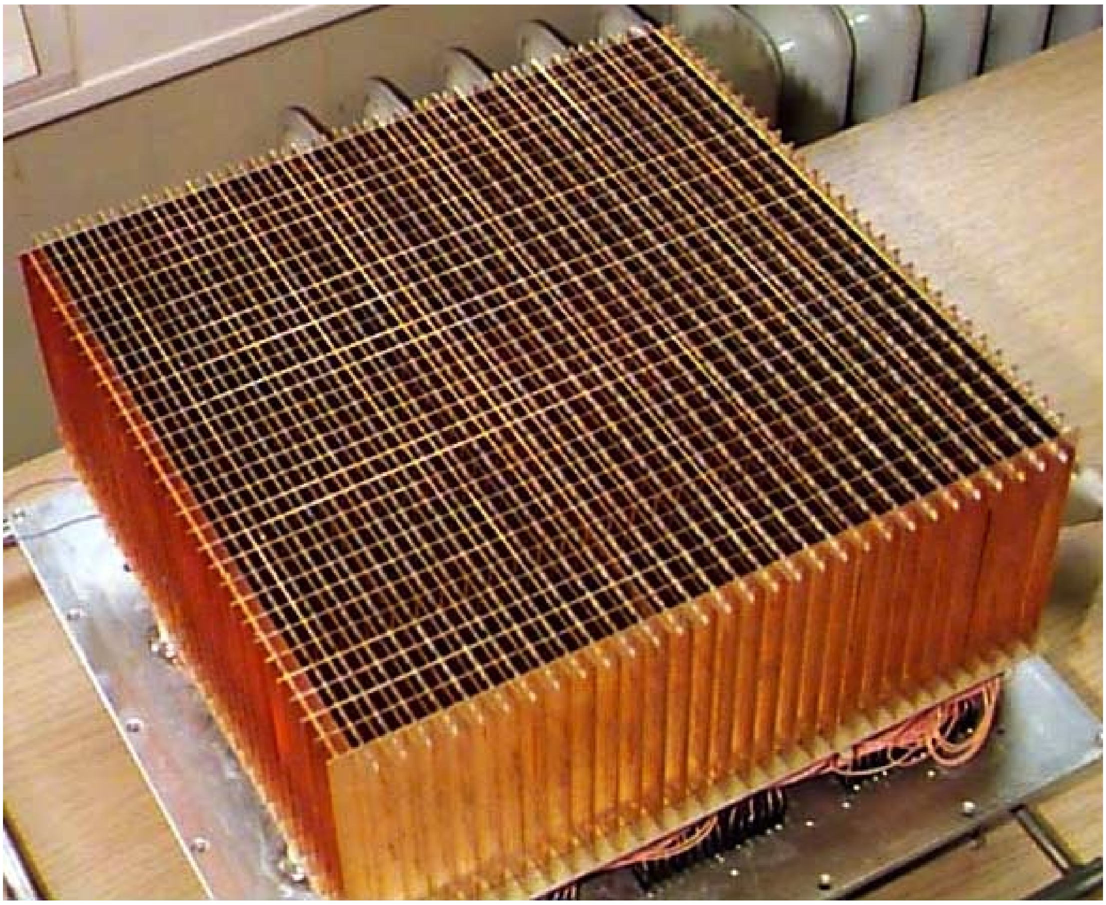
❑ TMAE Operation

- Fraction (usually 50%) of gas bubbled through TMAE; chamber and bubbler at room temperature → no condensation
- Cathode at – HV (2–3 kV); gain several 10^5
- Photon absorption (≈ 5 cm) < chamber length

TMAE Chamber Prototypes

❑ “DESY” Chamber

- First large 1024 cell 32 × 32 unit; 25 µm ∅ gold-plated tungsten wire



- Operated with a simple CH_4-TMAE gas system read out by ARGUS electronics
- Tested argon filled mini-RICH in DESY T24 electron beam

Successful low-rate UV photon detector,
24 photons/ring, knocked out CsI alternative;
presented at RICH 95, Uppsala

First TMAE Aging Results

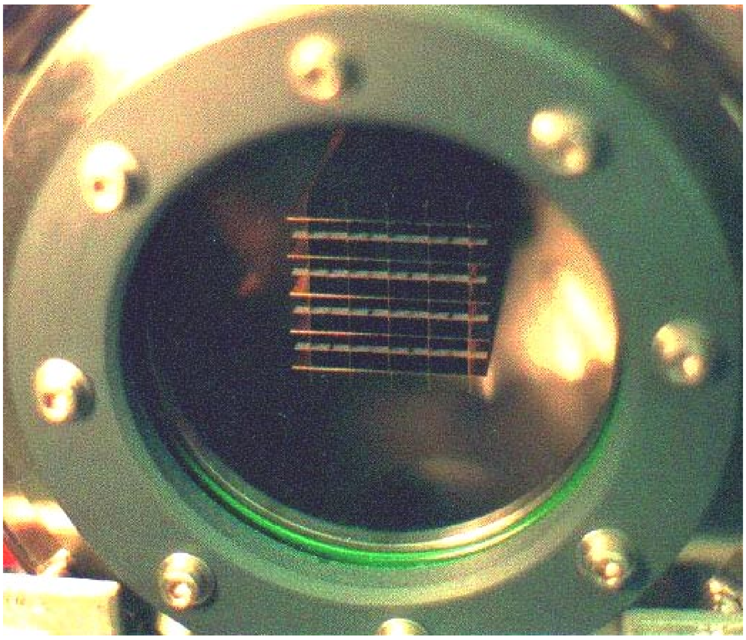
❑ "DESY" Chamber

- Small 4 × 4 cell area aged by D_2 lamp; TMAE purity questionable, no verification with Cerenkov light

➜ Rapid loss of current and gain after one day at HERA-B rate (2–3 MHz/cm^2)

❑ "Houston" Chamber

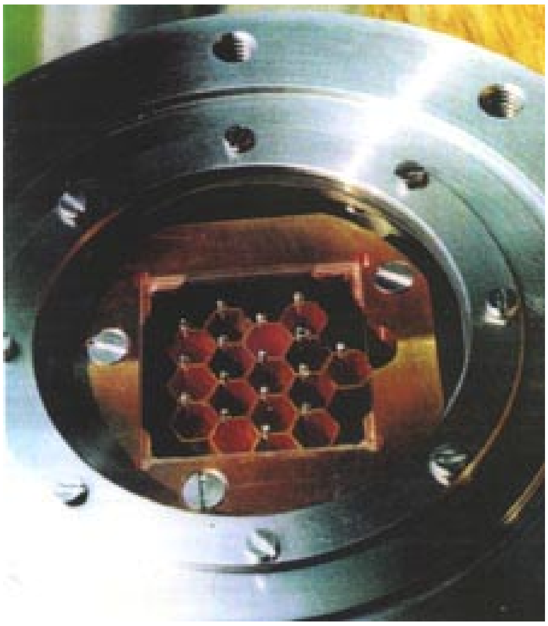
- Small 4 × 4 chamber using thicker 45 µm wire, aged with H_2 lamp;
  - Started at too high dose; absolute photon rate unknown
  - pre-amps not sensitive enough (> 20 fC)



➜ No large drop of gain observed – might have been missed, no absolute verification possible

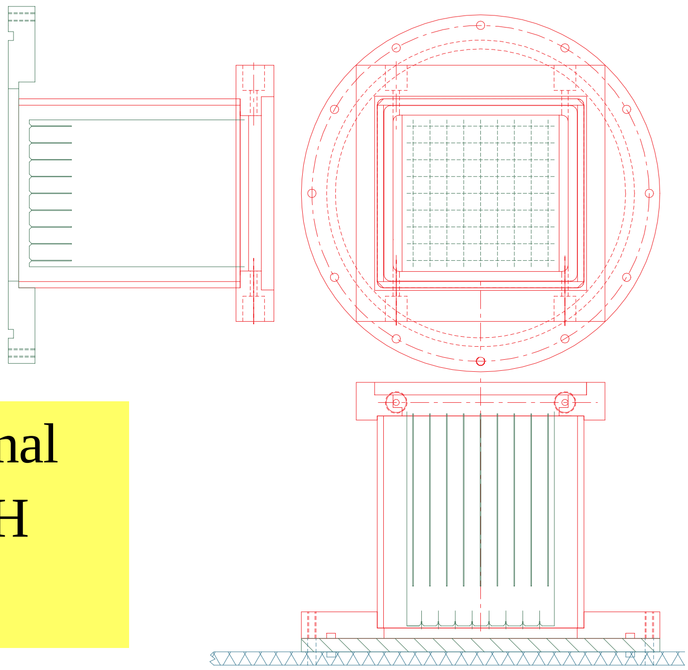
More TMAE aging

- Other Chambers
  - Hexagonal cells, wire glued to quartz window
  - CF_4 + Isobutane + TMAE mixture



➜ Large drop of gain observed, no Cerenkov verification, barometric pressure effects

- "Austin" Chamber – last chance
  - 8 x 8 standard design, 45 µm "thick" wire
  - Single G10 backplane, forced gas flow pattern; TMAE hard DP190 glue
  - Compact 90 mm square housing minimizing dead space



TMAE

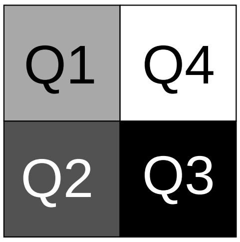
ok ??

Will bring decision on final choice of HERA-B RICH photon detector

"Final" TMAE aging measurement

❑ Goals

- Use prototype as close as possible to final design = "Austin" 64-ch chamber
- New "ultra clean" gas system; evaporate 5% of TMAE by washing with nitrogen
- Age at HERA-B rate of 3 MHz/cm^2 for at least one month; vary exposure by hole-mask in front of chamber



- Set gain to 2×10^5 at 2650 V
- Measure gain and efficiency to detect Cherenkov photons during aging process
- Record all environmental parameters

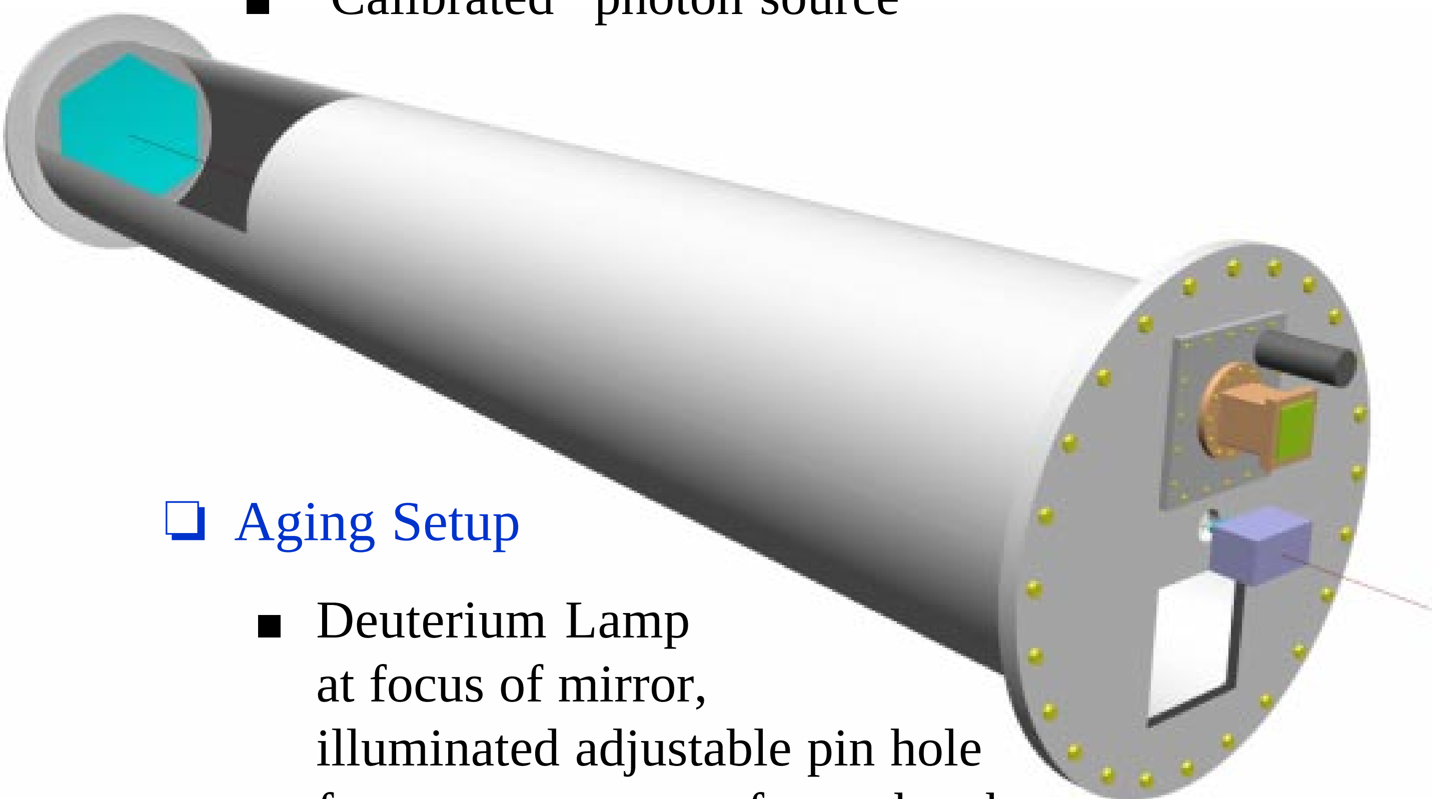
❑ Measurement Details

- All 64 channels read out by ARGUS µVDC system (4 low-noise pre-amps, amplifier, discriminator, TDC)
- Amplified signals also fed into programmable discriminators and 24-bit scalers.
- DC drain recorded per quadrant by Keithley electrometer

T24 Test Beam RICH

❑ RICH at DESY electron test beam T24

- 3–5 GeV electrons, divergence of beam recorded by a pair of tracking chambers
- 5 m argon radiator; f = 5 m UV mirror
- Two 25 × 25 cm^2 quartz exit windows allow test of various photon detectors
- “Calibrated” photon source



❑ Aging Setup

- Deuterium Lamp
  at focus of mirror,
  illuminated adjustable pin hole
  for even exposure of test chambers
- Monitoring of lamp output by
  UV PMT at 200 ± 20 nm (interference filter)
- Barometric pressure and various temperatures monitored

Monitoring of Aging Process

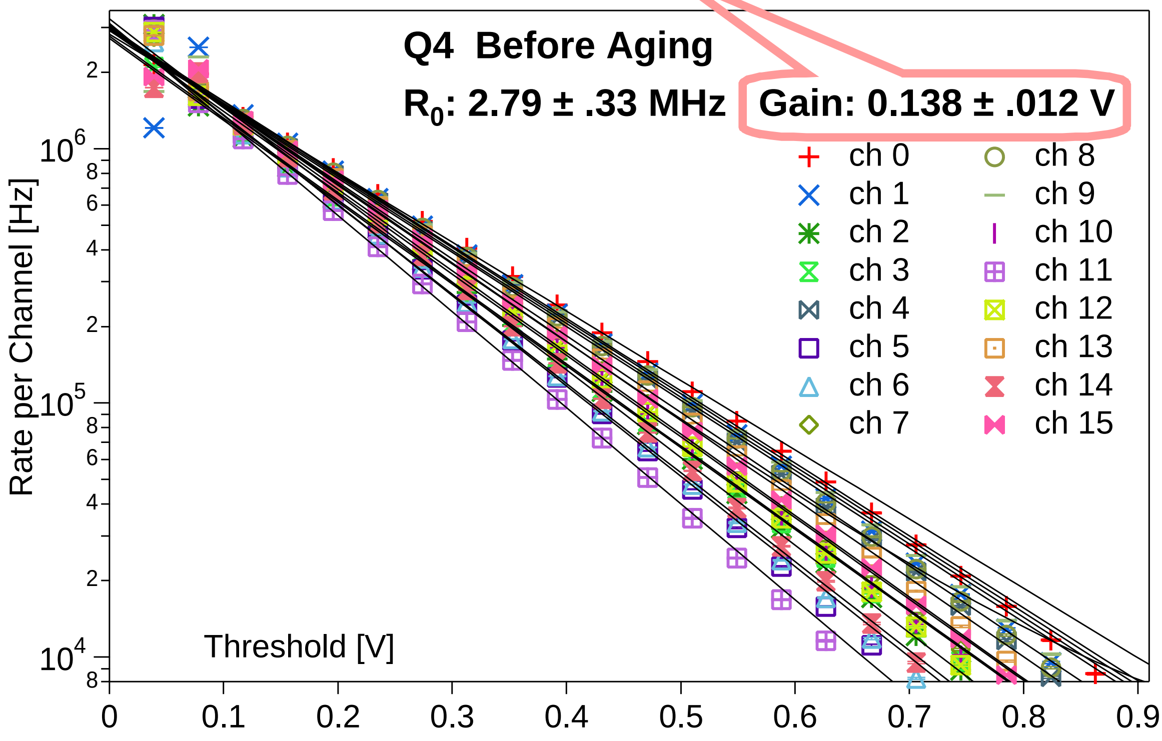
- Continuously – about every minute
  - Chamber current and high voltage
  - Count rate for each channel at fixed threshold
  - Rate of monitoring PMT (light output of D_2 lamp)
  - Temperature of TMAE bubbler, chamber, radiator and ambient air
  - Barometric pressure

- Gain – every 30 minutes
  - Threshold curve: Counts for 1 s at 24 values V_{th} from 0 to 1 V threshold (70 mV = 1 fC)
  - Distribution of charges is very close to exponential (single electron spectrum)
  - Fit $R_0 \exp(-V_{th}/g)$ to data of each channel; g is gain, R_0 rate at 0 V threshold

- Cherenkov Efficiency, number of detected photons – every 1–3 days
  - Ring (r =129 mm in Ar) placed on detector
  - Turn D_2 lamp off, remove hole-mask, let electron beam in
  - Take runs of approximately 10 000 triggers
  - TDC hit information for all 64 channels

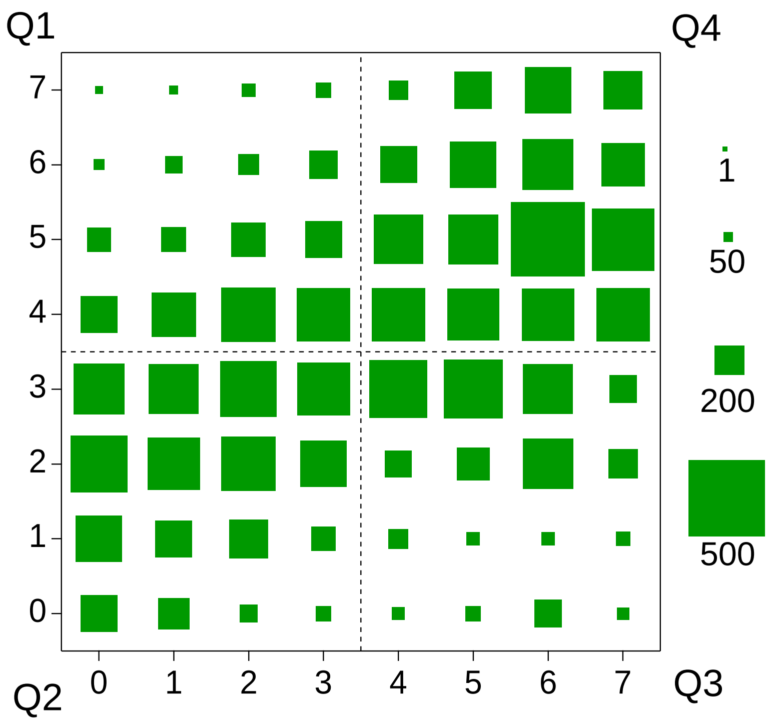
Before Aging

- Rate vs. threshold, Gain



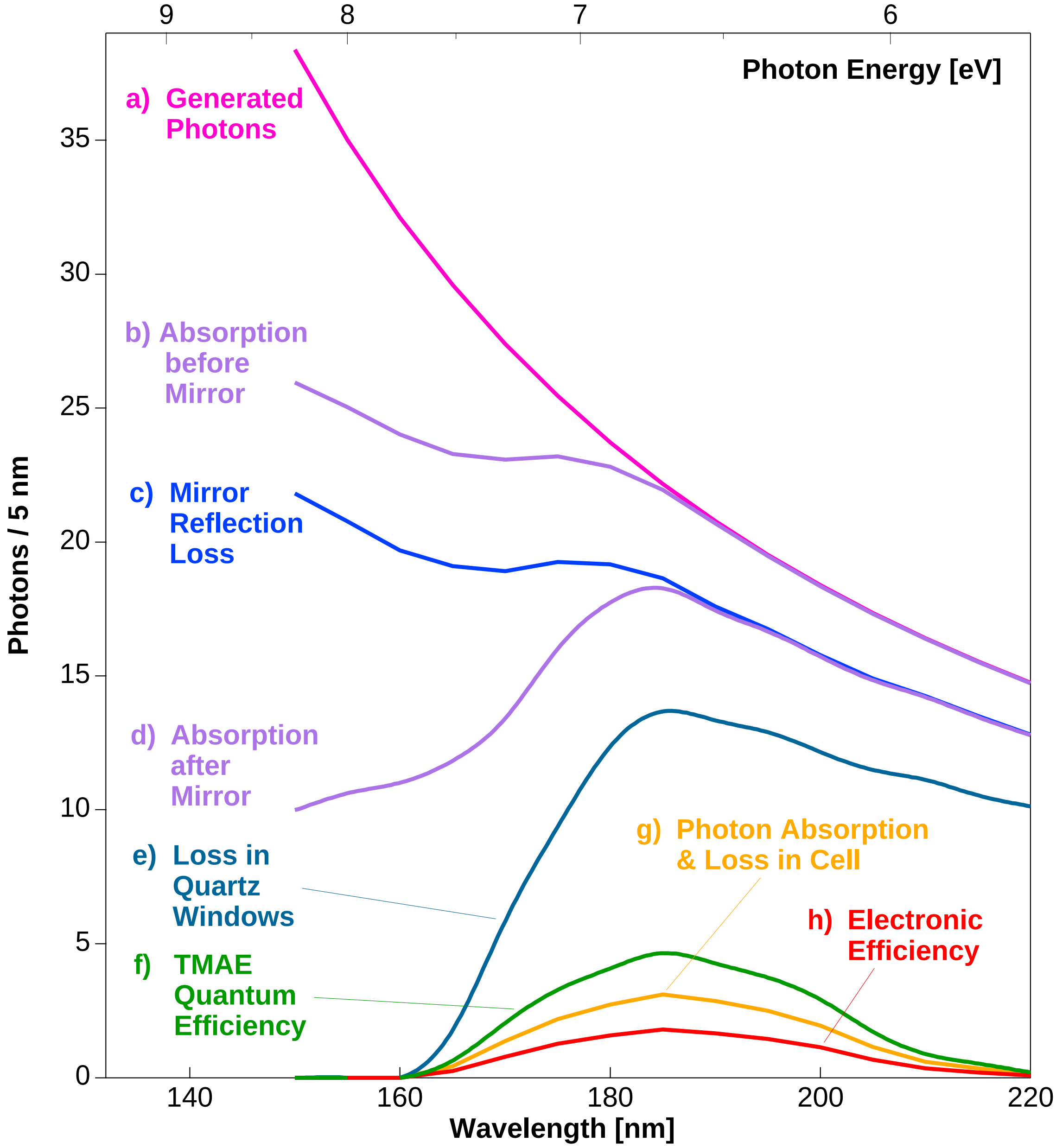
- Cherenkov Efficiency
  - 10 000 triggers, 1.6 hits / event
  - 11% of ring
  - BG correction

T24 measurement:
11.5 ± 0.5
photons / **full** ring



Predicted Cherenkov Efficiency

- Complete model of test beam RICH
  - Starts with $dn/dE \approx 370\ \mathrm{eV}^{-1}\ \mathrm{cm}^{-1}\left(1-\beta^{-2}n^{-2}(E)\right)L_{rad}$ considers Rayleigh and O_2/H_2O absorption in Ar; Mirror, quartz-window properties measured

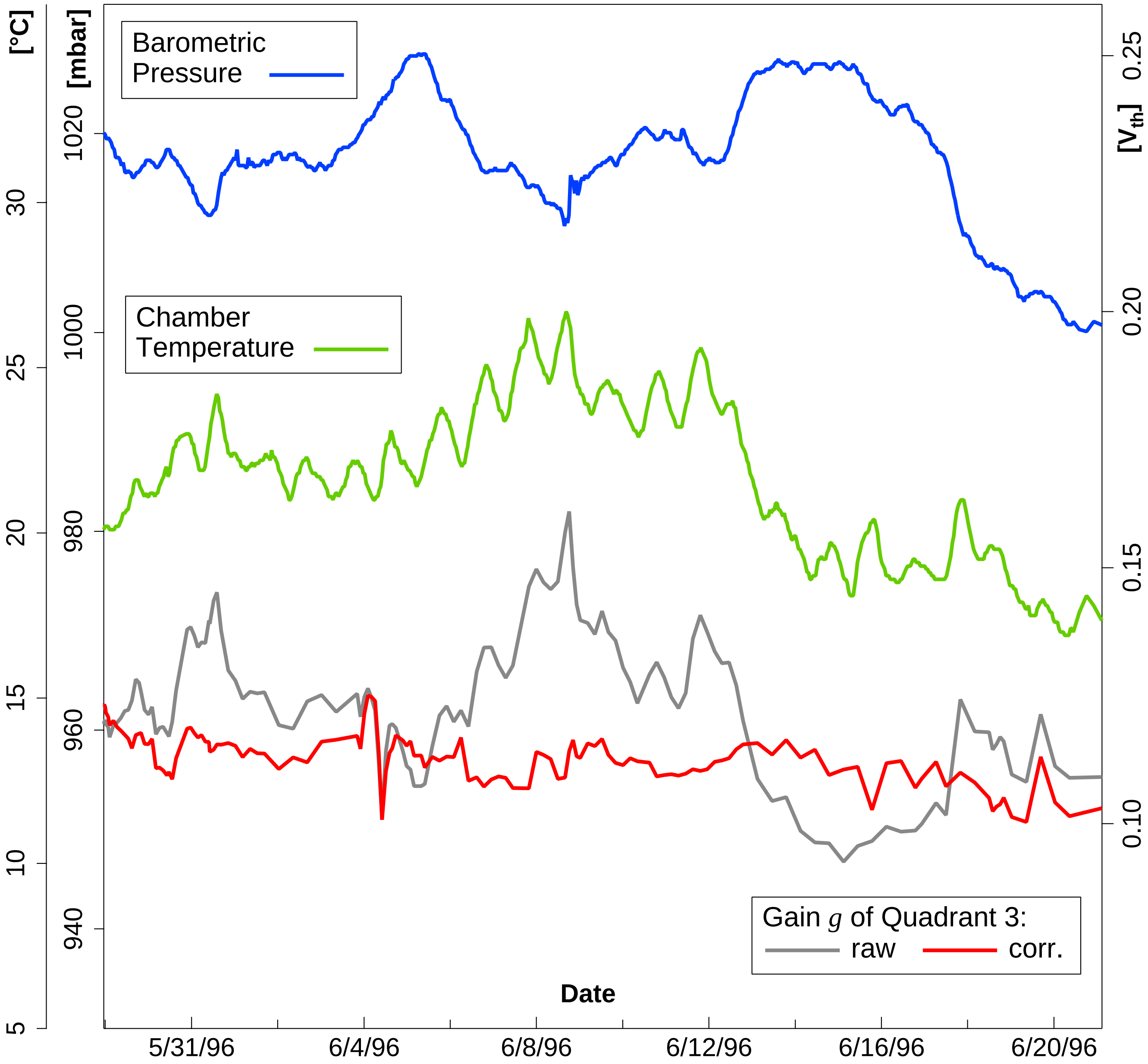


T24 prediction: 11.2 ± 1.5 photons / full ring

HERA-B (L_{rad} = 2.75m, C_4F_{10}): 26 photons / ring ✔

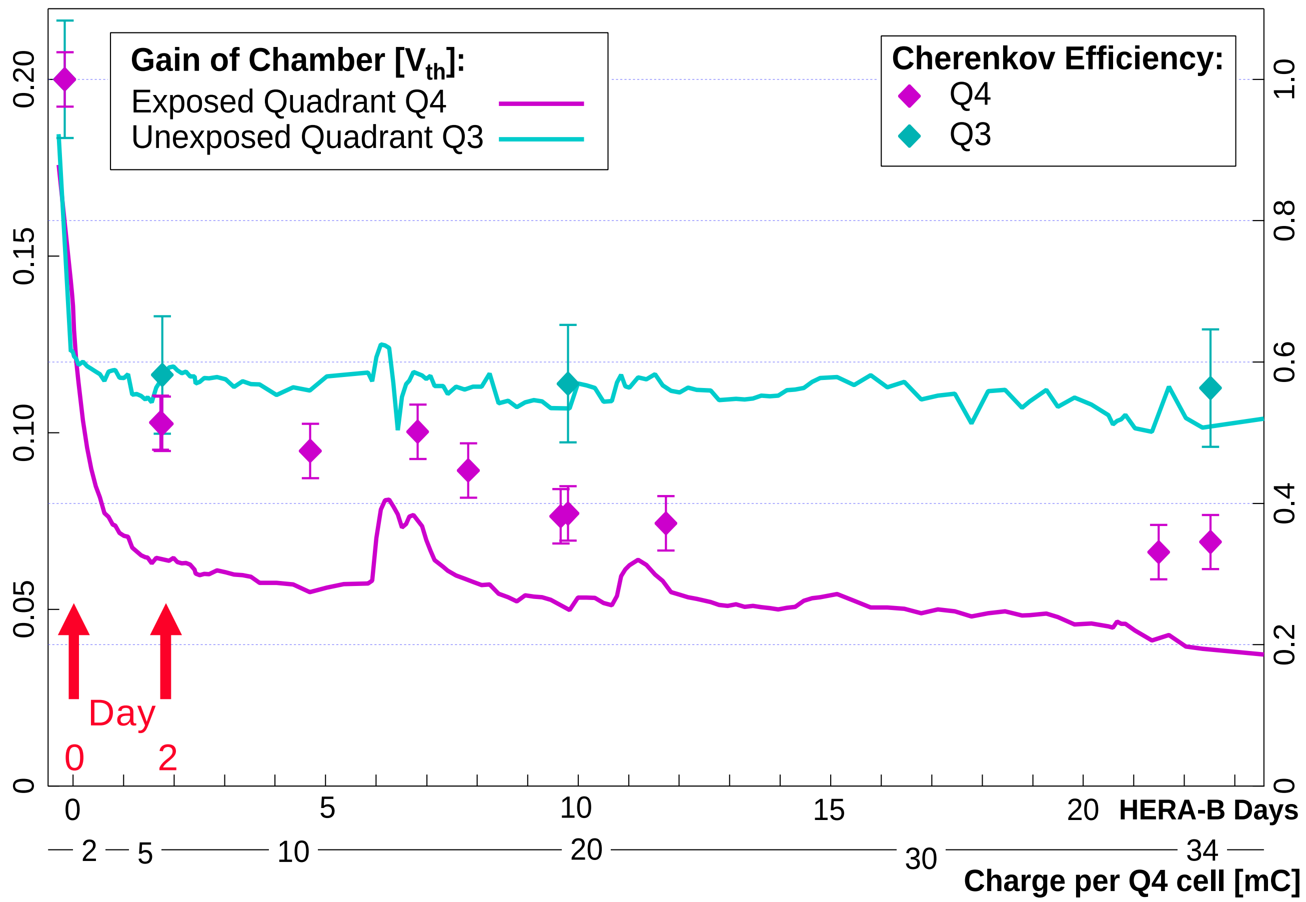
Environmental Factors

- Barometric pressure and temperature influence the gain of the chamber
  - Correction: $g_{corr} = g_{raw}\ \mathrm{e}^{12.6\left(2 - p_0/p - T/T_0\right)}$
  - Removes large variations
  - Correction applied to gain and Cherenkov Efficiency



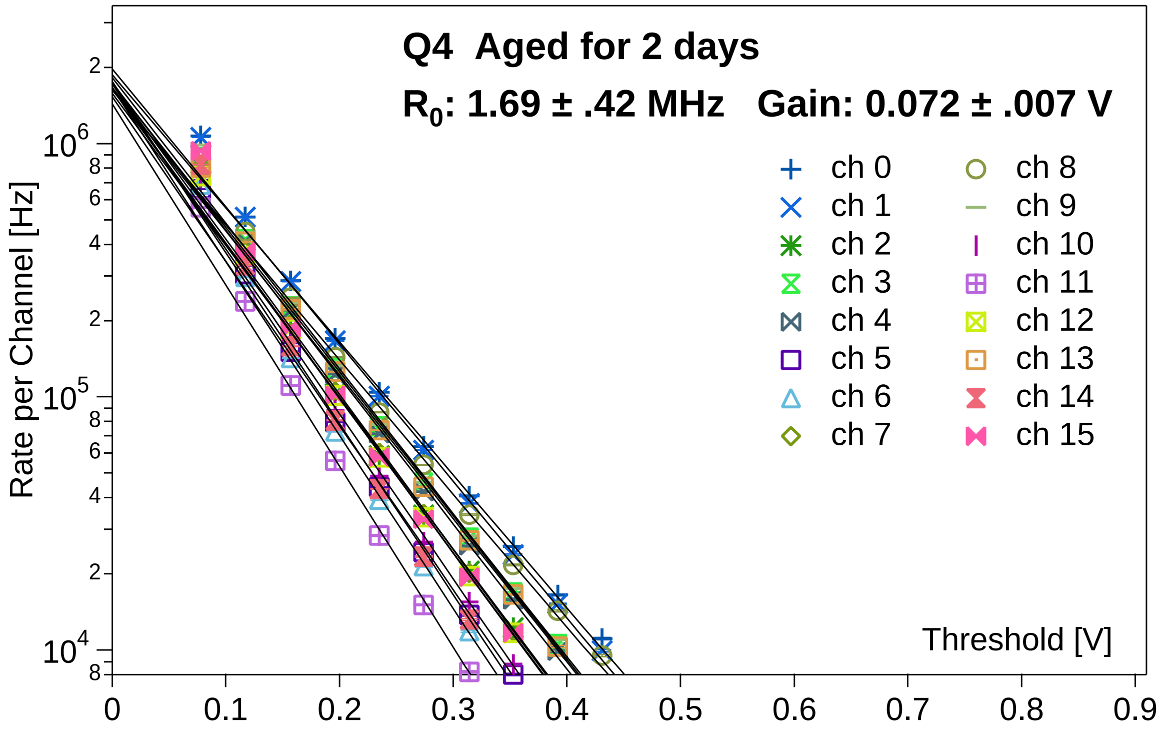
Results

- First aging run (duration ≈ 24 days)
- Fully exposed quadrant Q4
  - ➜ Gain *and* Cherenkov Efficiency drop to < 50% during the first two days; continue to drop at 10% / week
- Unexposed quadrant Q3
  - ➜ Gain *and* Cherenkov Efficiency drop to ≈ 66% during the first two days, then falls at ≈ 3% / week



Result Details

❑ Gain at day 2

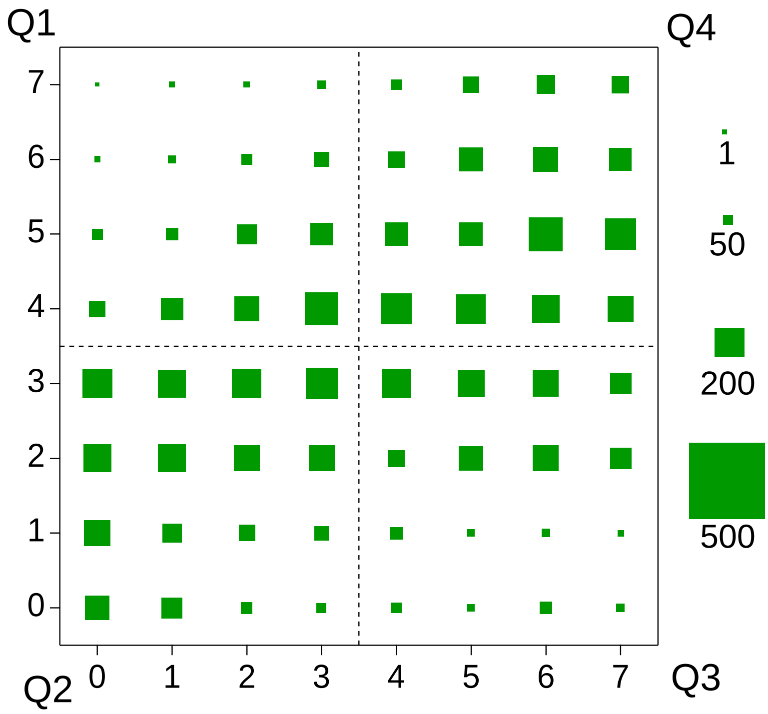


❑ Cherenkov Efficiency at day 2

Measurement: 4.6 ± 0.3 photons / ring

Prediction for
HERA-B:
10 photons / ring

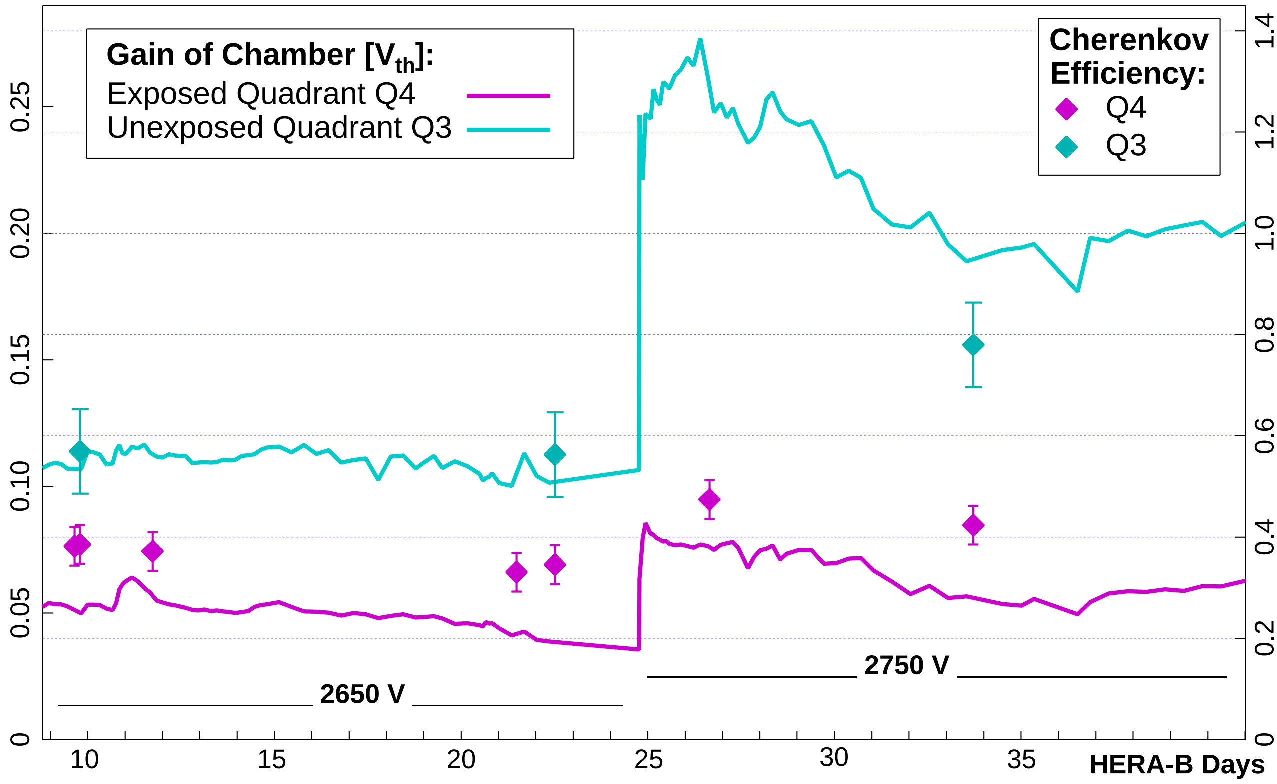
Not sufficient !



More Findings

❑ Increase of Operating Voltage

- Aging started at 2650 V, with an initial gain of approximately 2×10^5
- Increase by 100 to 2750 V



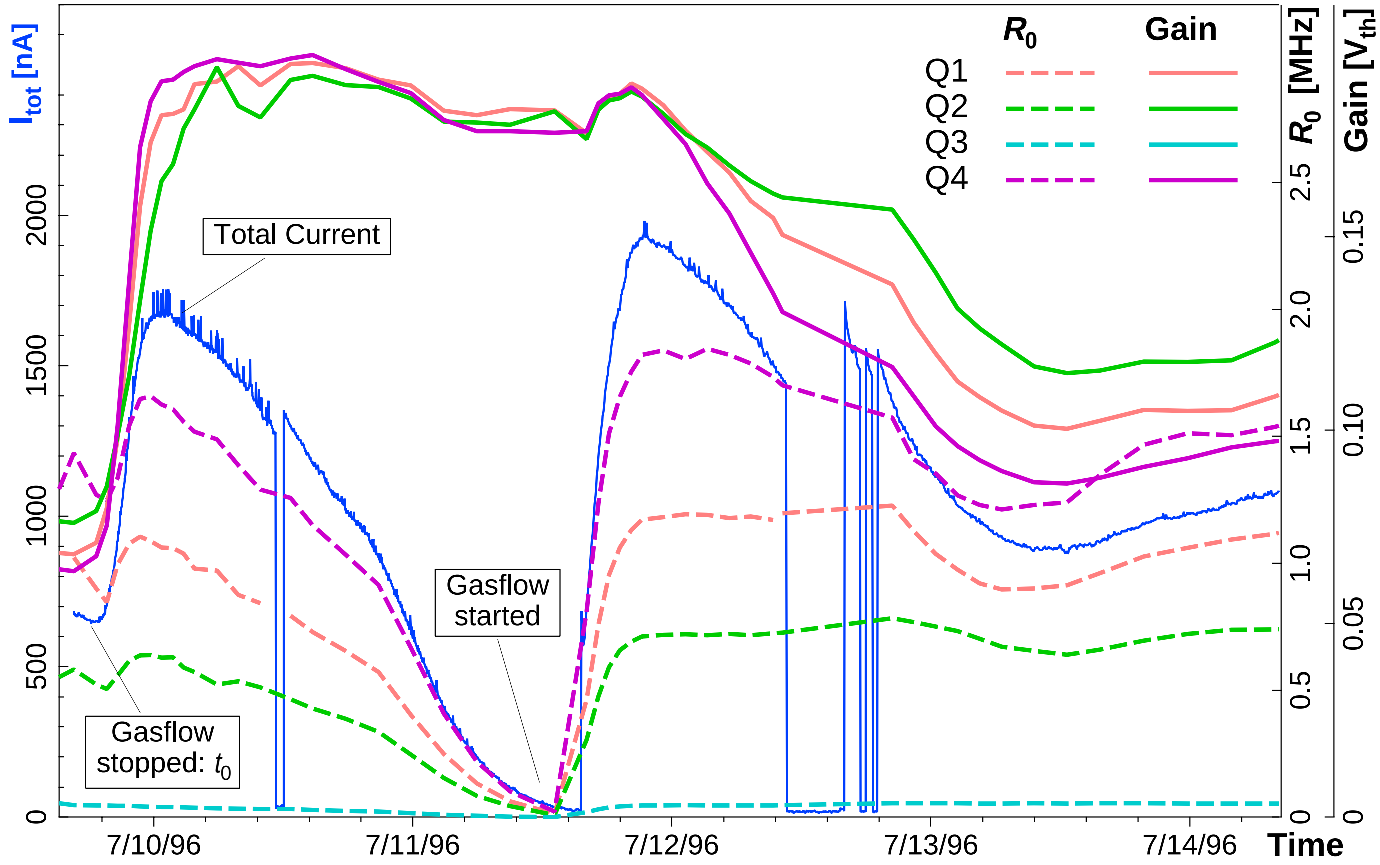
➜ Gain and Cherenkov Efficiency go up as expected; but start to drop afterwards

❑ Further Increase to 2850 V

- Gains go up – chamber becomes unstable (currents increase, secondary avalanches)
- Cherenkov Efficiency killed by background

❑ Effects of a total gas flow stop

- First observed accidentally by running a methane bottle empty
- Repeated under controlled conditions



After stop of gas flow:

➜ Gain recovers within 5h (× 3 increase for exposed)

then

➜ Current and rates drop to zero within 36 h

After restoration of flow:

➜ Current and rates go up; aging continues as usual

Conclusion

- All tested TMAE based proportional chamber prototypes cannot survive the high rate environment of HERA-B
- Initial rapid loss of gain followed by a moderate stabilization observed even for non-exposed areas of the same chamber
- Based on these findings, HERA-B decided to invest 1,500,000 $ into multi-anode PMTs to use as photon detector in the Cherenkov system

A note found on our office door after abandoning the TMAE solution:

Support the RICH

Give to HAMAMATSU