The RICH Detectors of the LHCb Experiment

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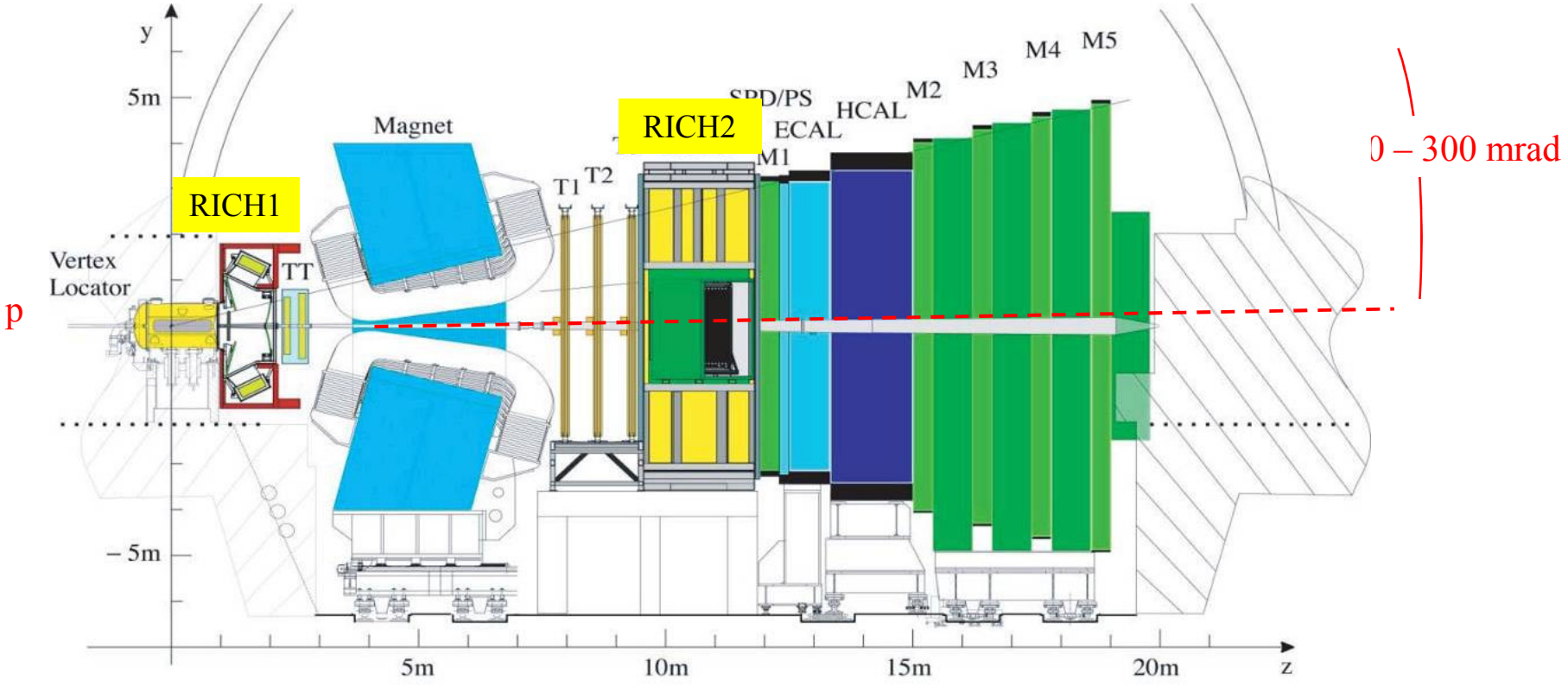
on behalf of the LHCb RICH Collaboration

1. LHCb RICH1 and RICH2
2. The photon detector: pixel-HPD
3. Images from laser, projector and …. particles
4. Conclusions

The LHCb RICHes

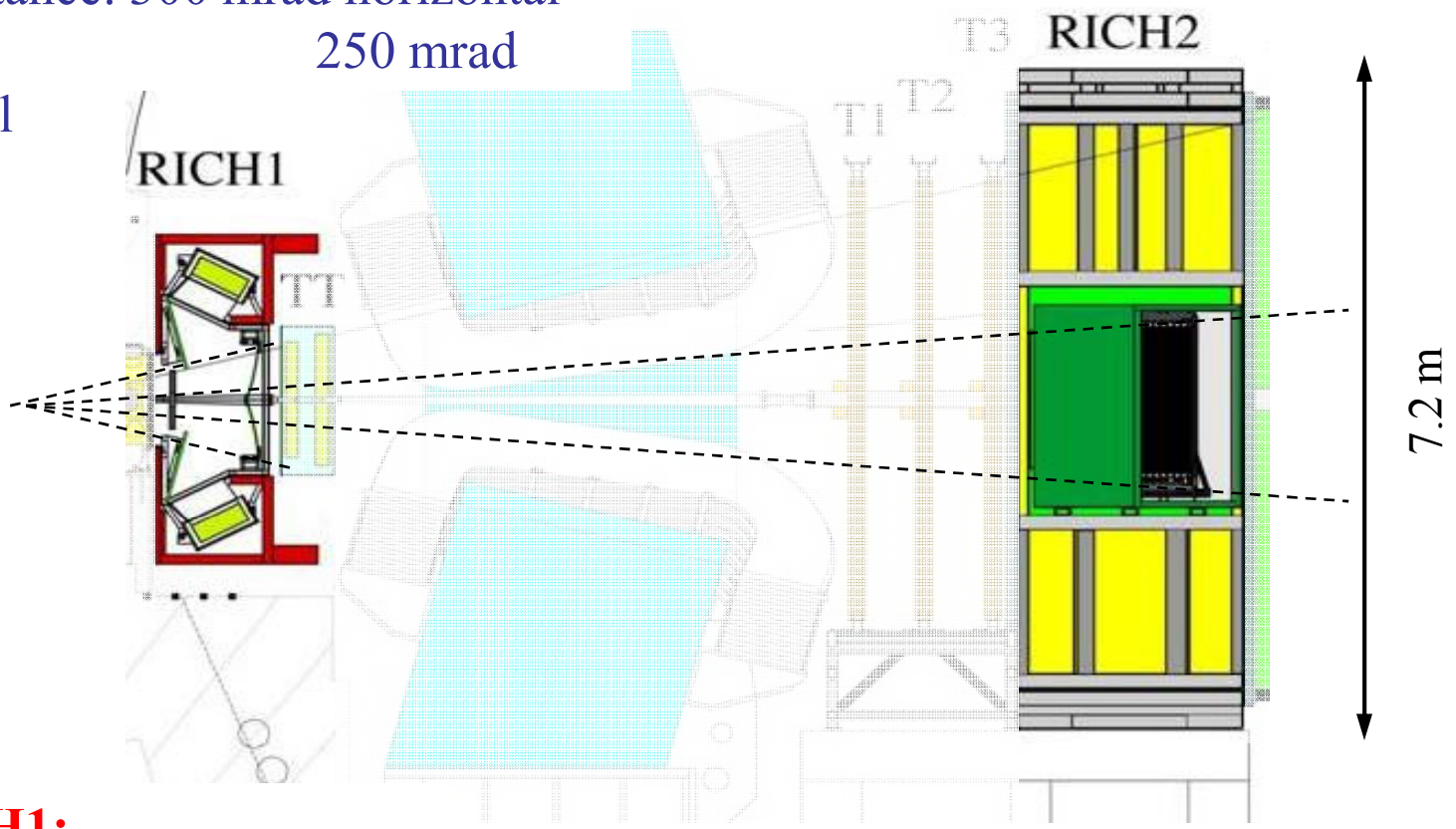
- LHCb is a dedicated B physics experiment at the LHC searching for new physics through precision measurement of CP violation and rare decays
- B hadrons are predominantly produced in the forward direction → single-arm spectrometer including two RICH detectors for charged hadron identification



The two RICHes

For hadron ID efficient p/K separation up to ~100 GeV/c

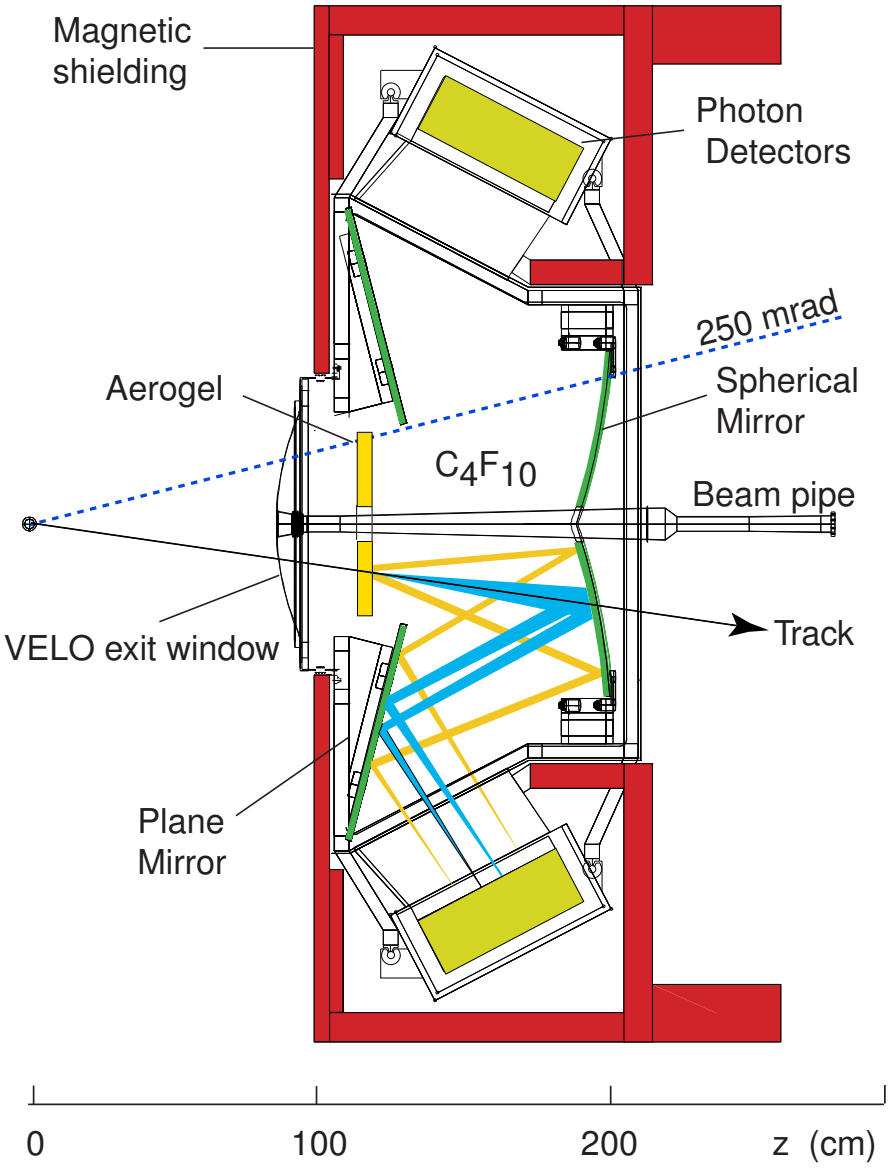
Acceptance: 300 mrad horizontal
250 mrad
vertical



RICH1:
Low momentum tracks,
Full acc. angle
- Aerogel: 2 - 10 GeV/c
- C_4F_{10}: 10 - 60 GeV/c

RICH2:
High momentum tracks,
Narrow acc. angle, 120 mrad
- CF_4: 16 - 100 GeV/c

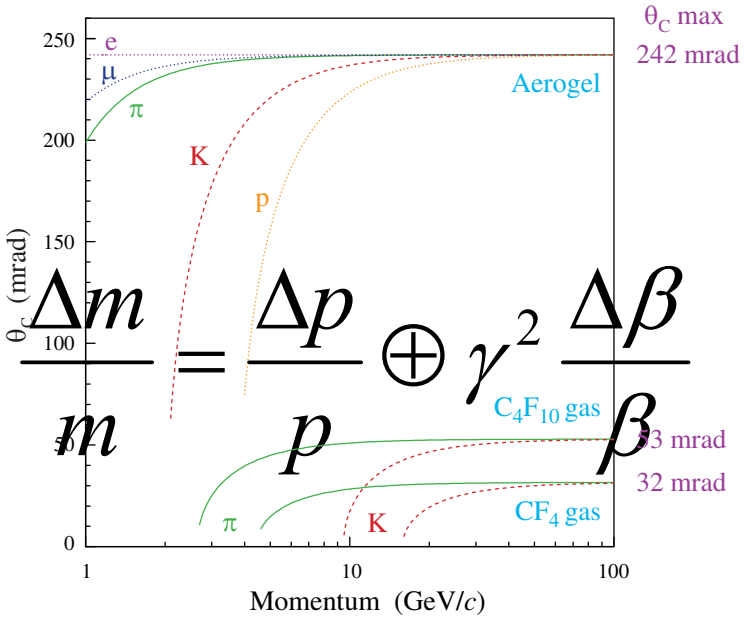
The RICH 1 Detector



How does it work?

$$\beta = \frac{1}{n\cos\vartheta}$$

Via a mirror system, the light cone is imaged on the photon detector plane as a ring, with its diameter proportional to ϑ



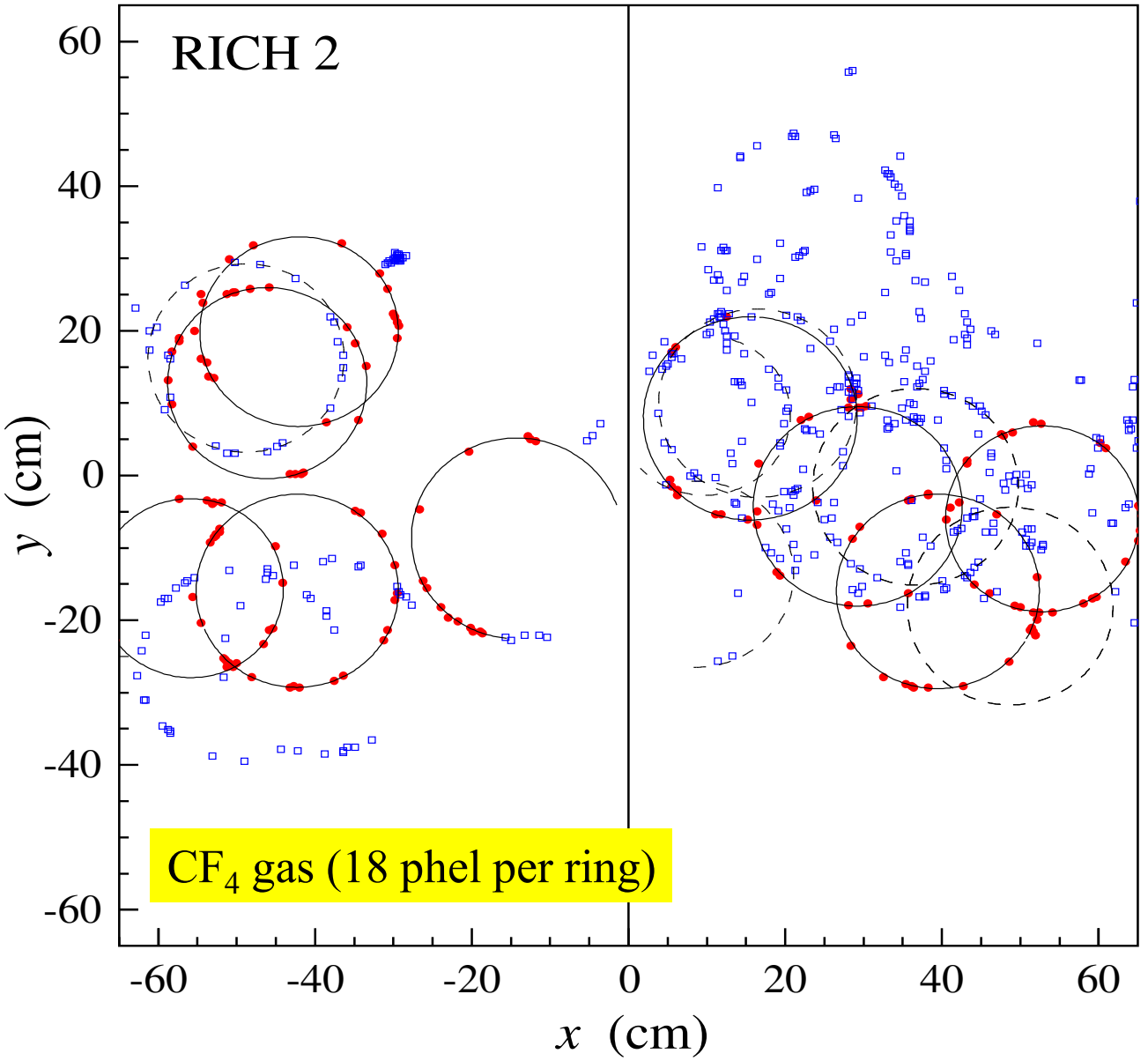
$$\frac{\Delta m}{m} = \frac{\Delta p}{p} \oplus \gamma^2 \frac{\Delta \beta}{\beta}$$

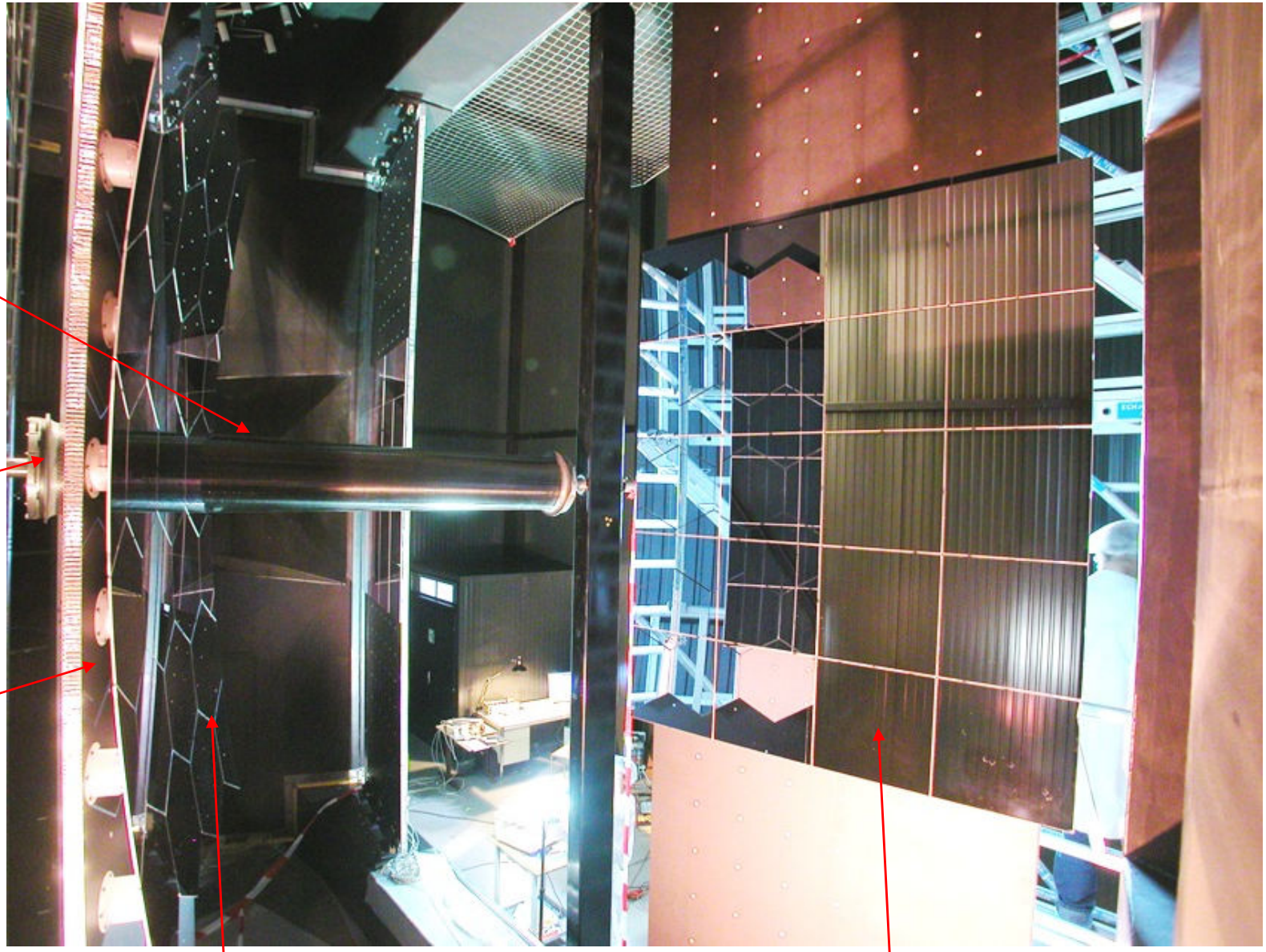
What we expect to see

Simulated event in RICH2 from 14 TeV collision:

high multiplicity, overlapping rings, few hits per ring.

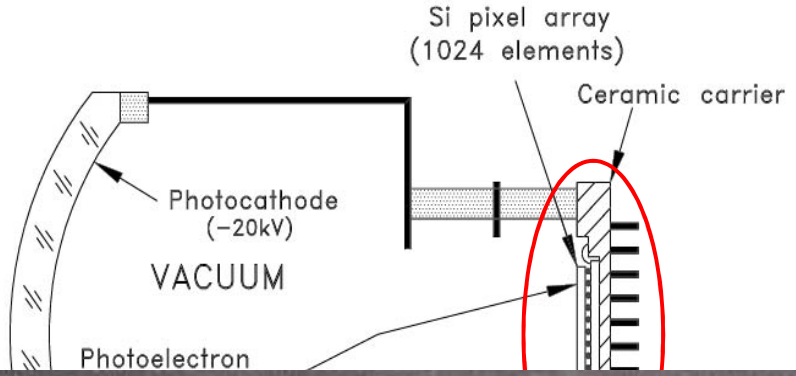
In red: hits connected to reconstructed tracks

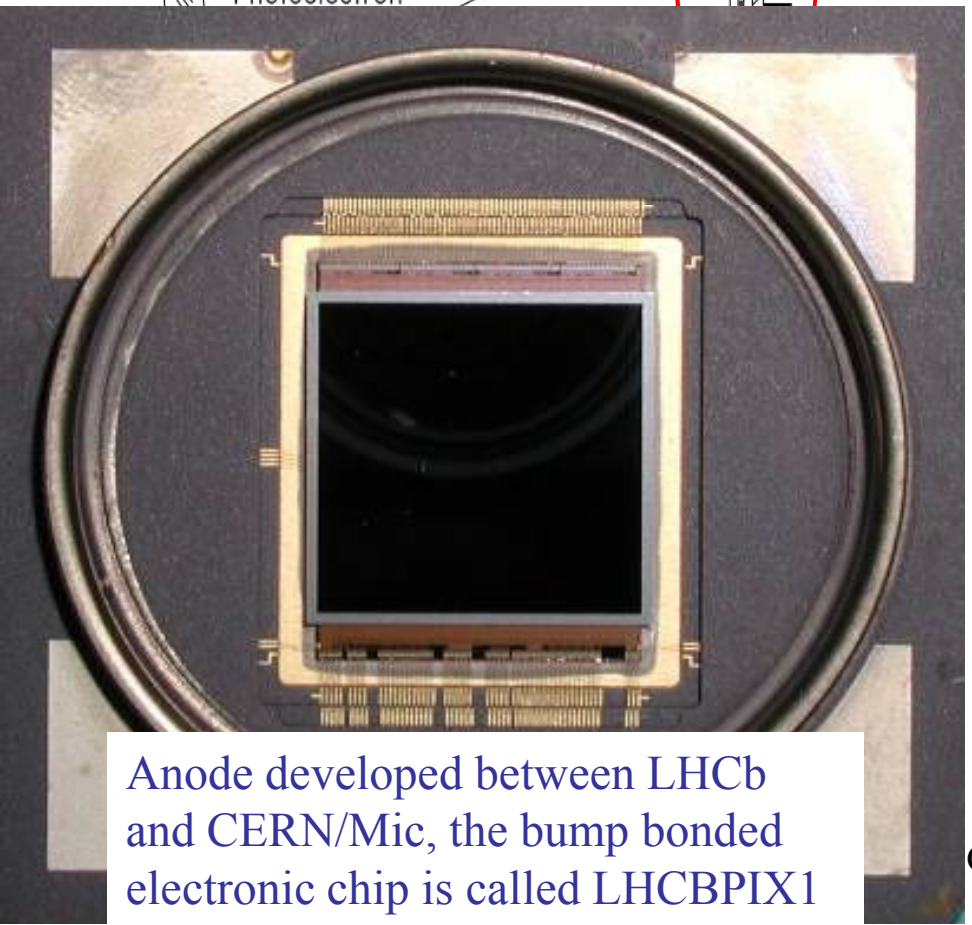



Central carbon fibre tube to allow for the beam pipe
Mirror support and fine adjustment
Panels honeycomb structure
Spherical mirrors array
Flat mirrors array

The RICHes photon detector system

The Pixel - Hybrid Photon Detector





Anode developed between LHCb and CERN/Mic, the bump bonded electronic chip is called LHCBPIX1

Photon detector:

Quartz window, Multialkali photocathode

Cross-focussing optics:

De-magnification by ~5

20 kV operating voltage

Active diameter 75mm

Anode:

256×32 pixel Si-sensor array

bump-bonded to binary readout chip

assembly encapsulated in vacuum tube

8-fold binary OR

➨ effective 32×32 pixel array

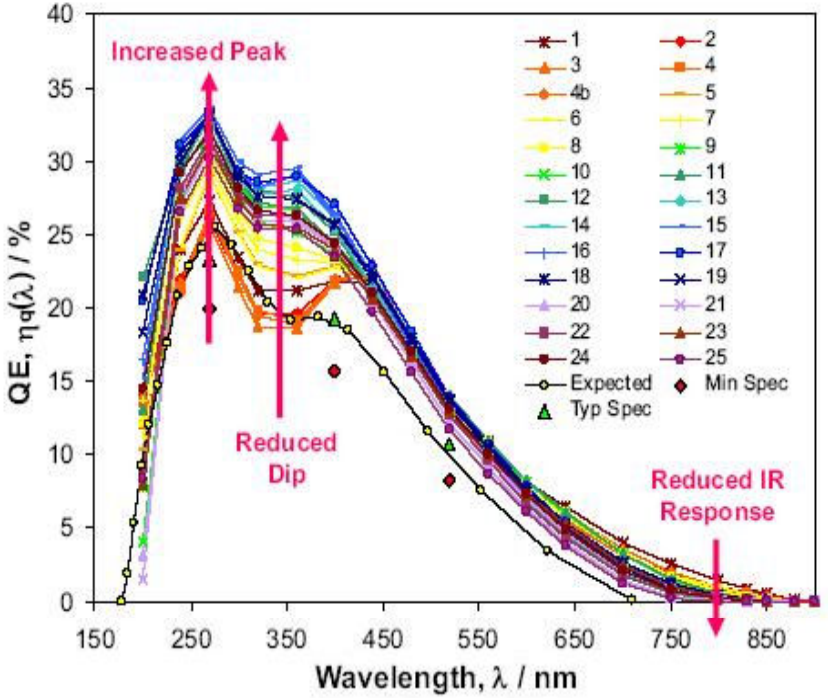
pixel size 500µm×500µm

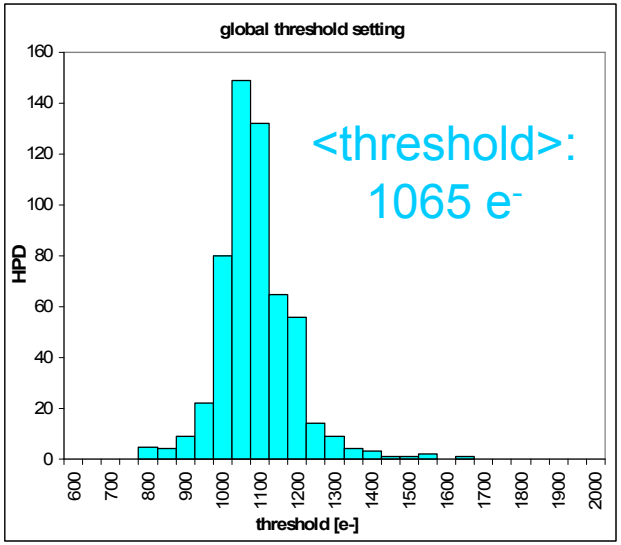
The Pixel - Hybrid Photon Detector

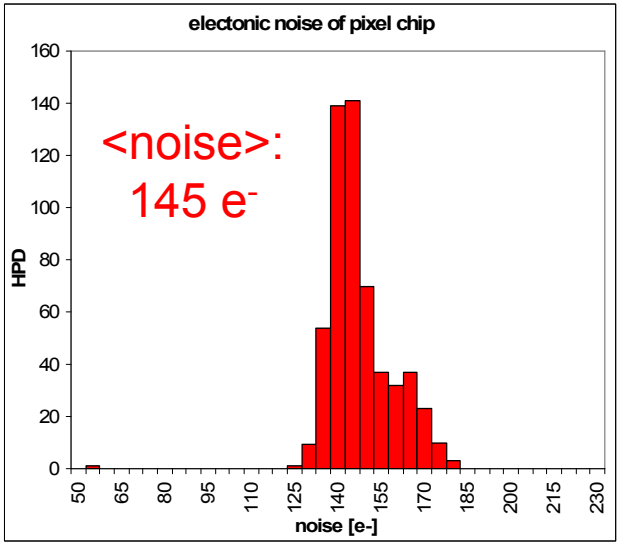
QE is ~27% in the range 230 – 430 nm and improving with production.

Avr. threshold and noise are low (compared to one phel signal, ~5000 e/h pairs).

Excellent signal to noise ratio achieved by small pixel sizes and bump-bonded front-end electronics.

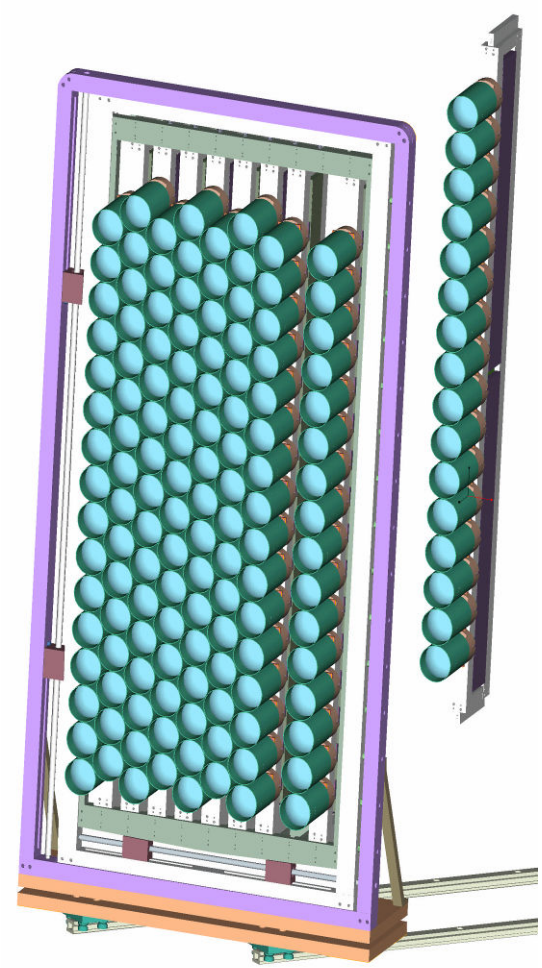


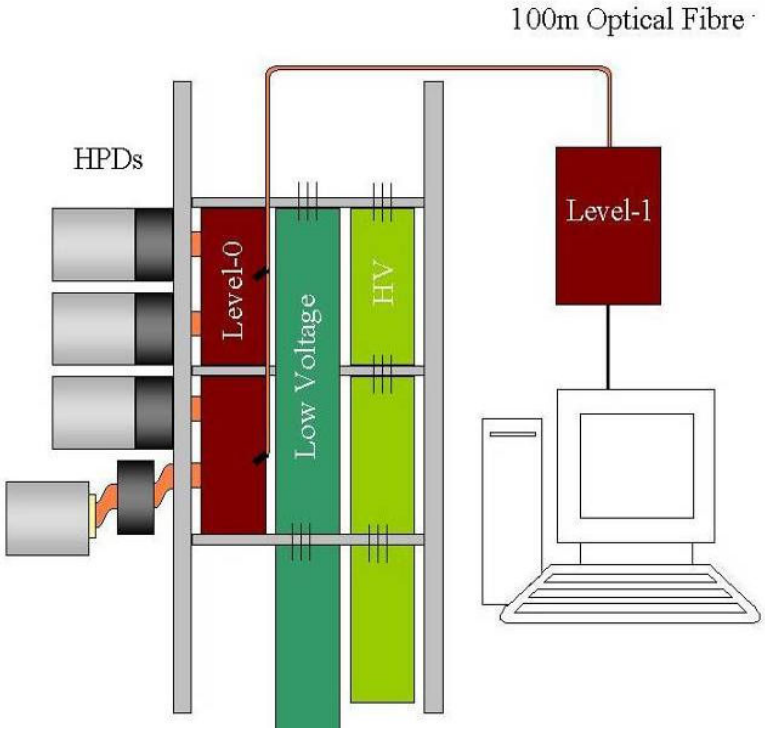




The photon detector plane

HPDs mounted in columns, to cover detector plane
In total 484 tubes, for ~ $3m^2$ and 65% overall active area

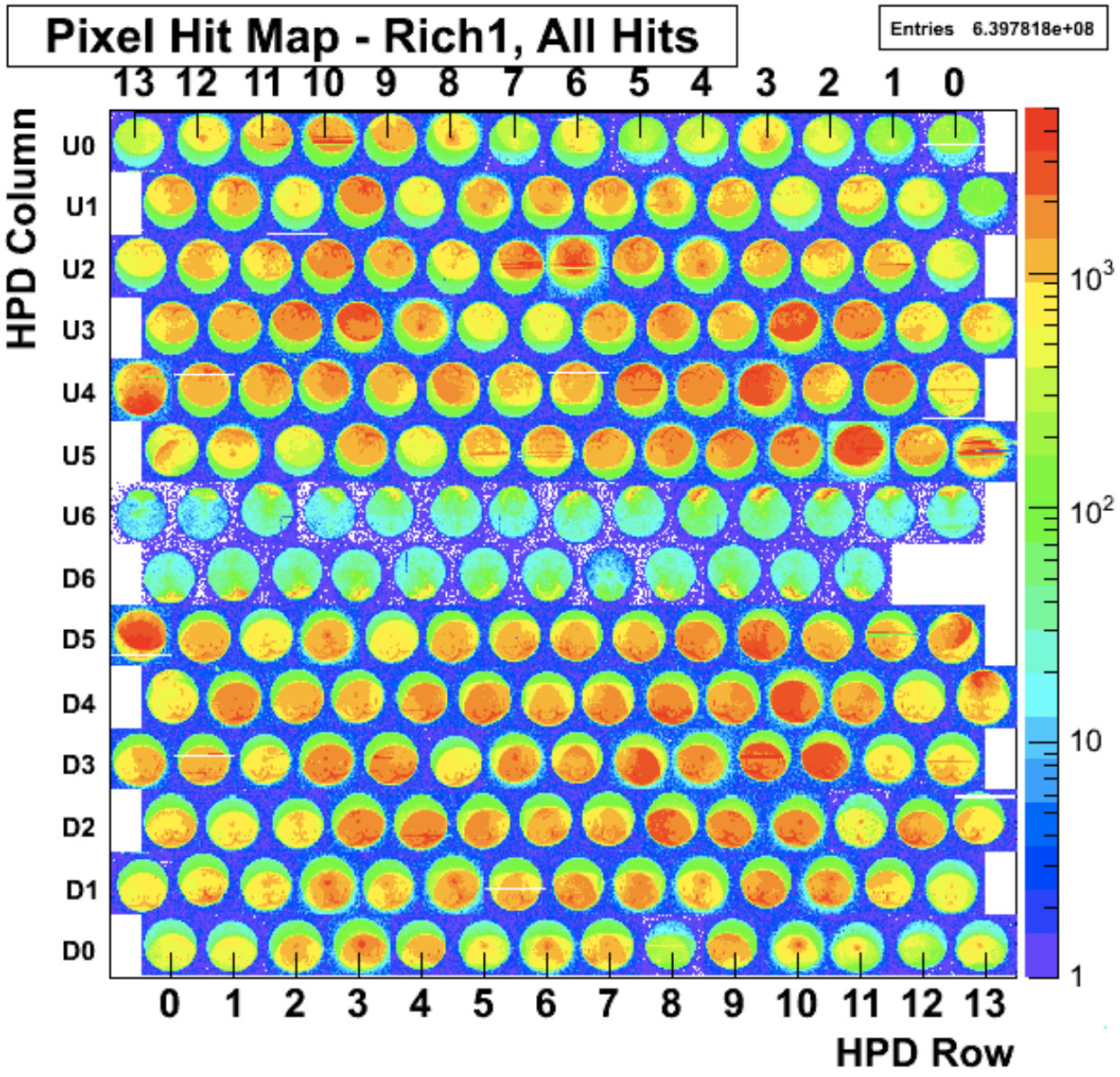




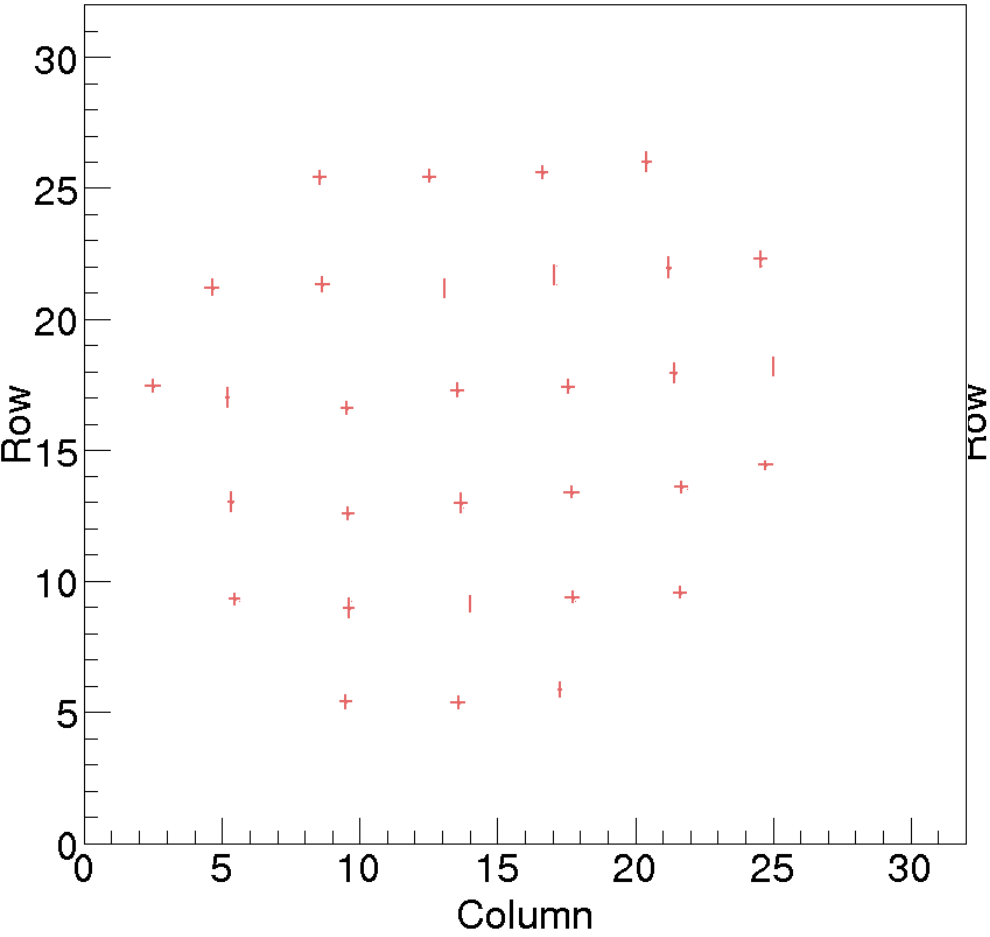
Services for HV, LV, and readout electronics mounted in frame

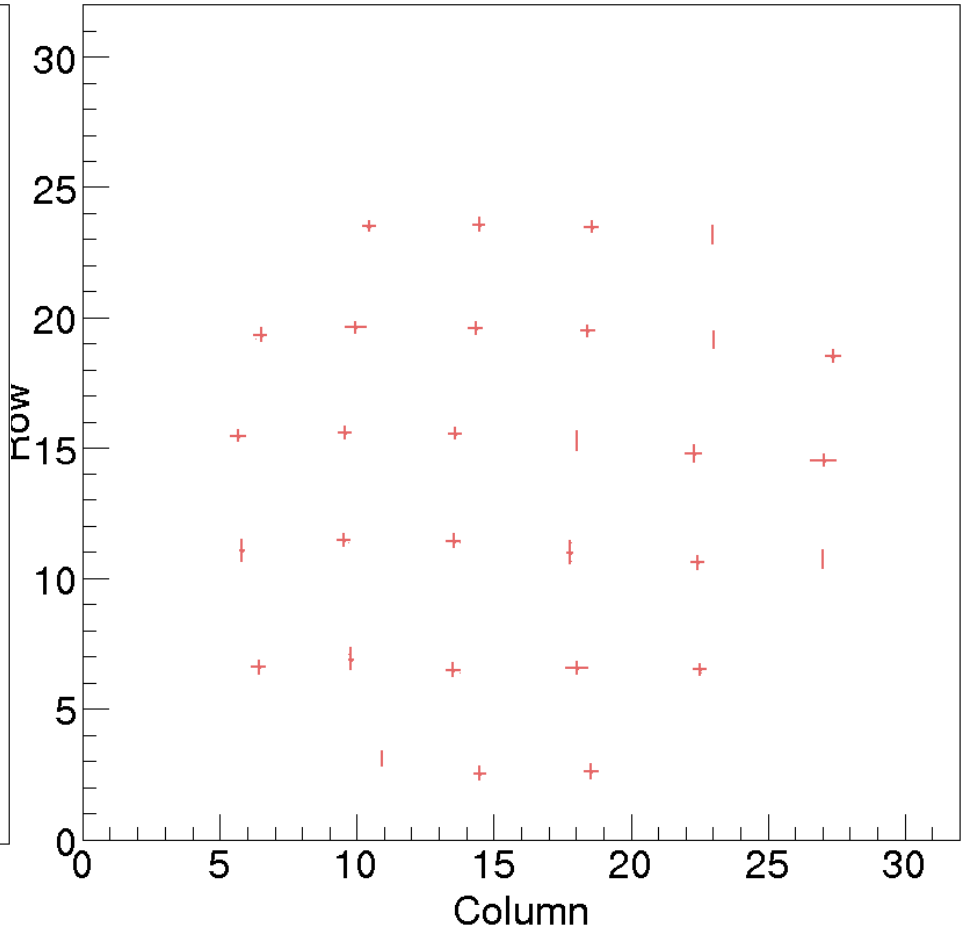
A few examples of images from the RICHes

CW Laser illumination of RICH1 (~800 phel/trigger in total)



Improve precision by finding the CoG





First bear

RICH2 beam related recorded events (8 accumulated)

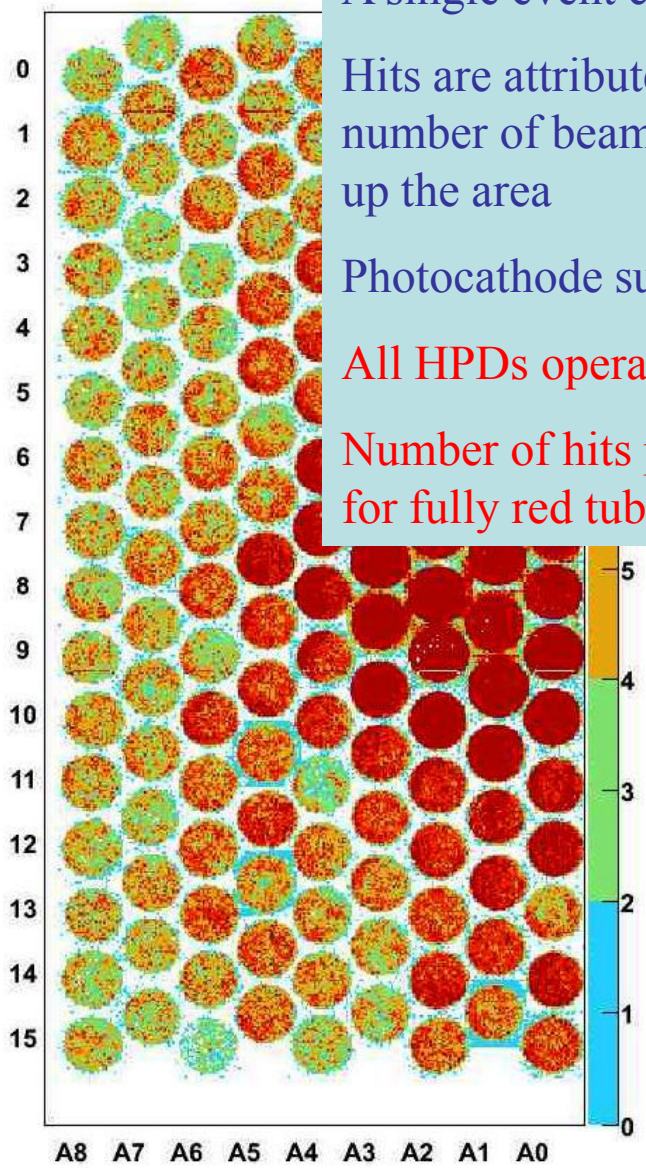
A single event contains more than 140000 recorded hits

Hits are attributed to Cherenkov light in the vessel, due to the large number of beam particles slightly splashing on a collimator and filling up the area

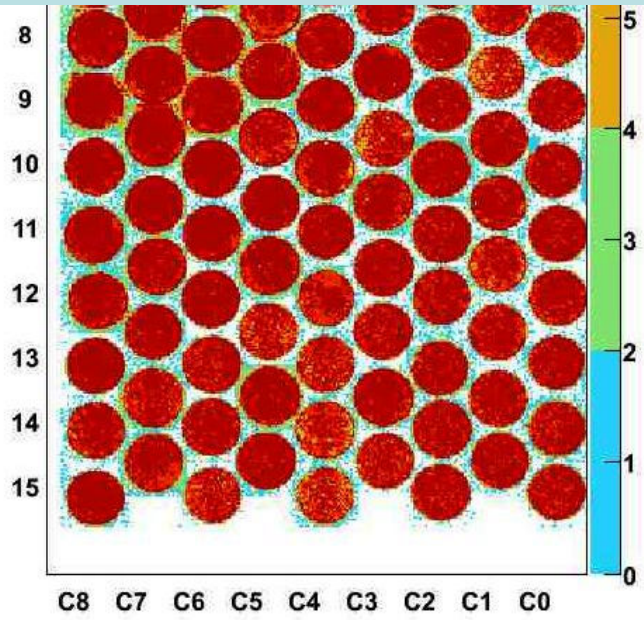
Photocathode surface is clearly defined (no electronic noise)

All HPDs operational

Number of hits per tube could be more than 2000 (overlaps on pixels) for fully red tubes



A-side



C-side

Summary

The RICH System of the LHCb detector is a powerful eye to measure particles velocity, via ring imaging. And, together with their momentum measured by the trackers, to proceed to their identification.

The Cherenkov photons are generated in Aerogel, CF_4 and C_4F_{10}

The optical resolution of the HPD ~2.5 mm, while the system Cherenkov angle resolution goes from ~0.7 mrad to 2 mrad depending on radiator and geometry.

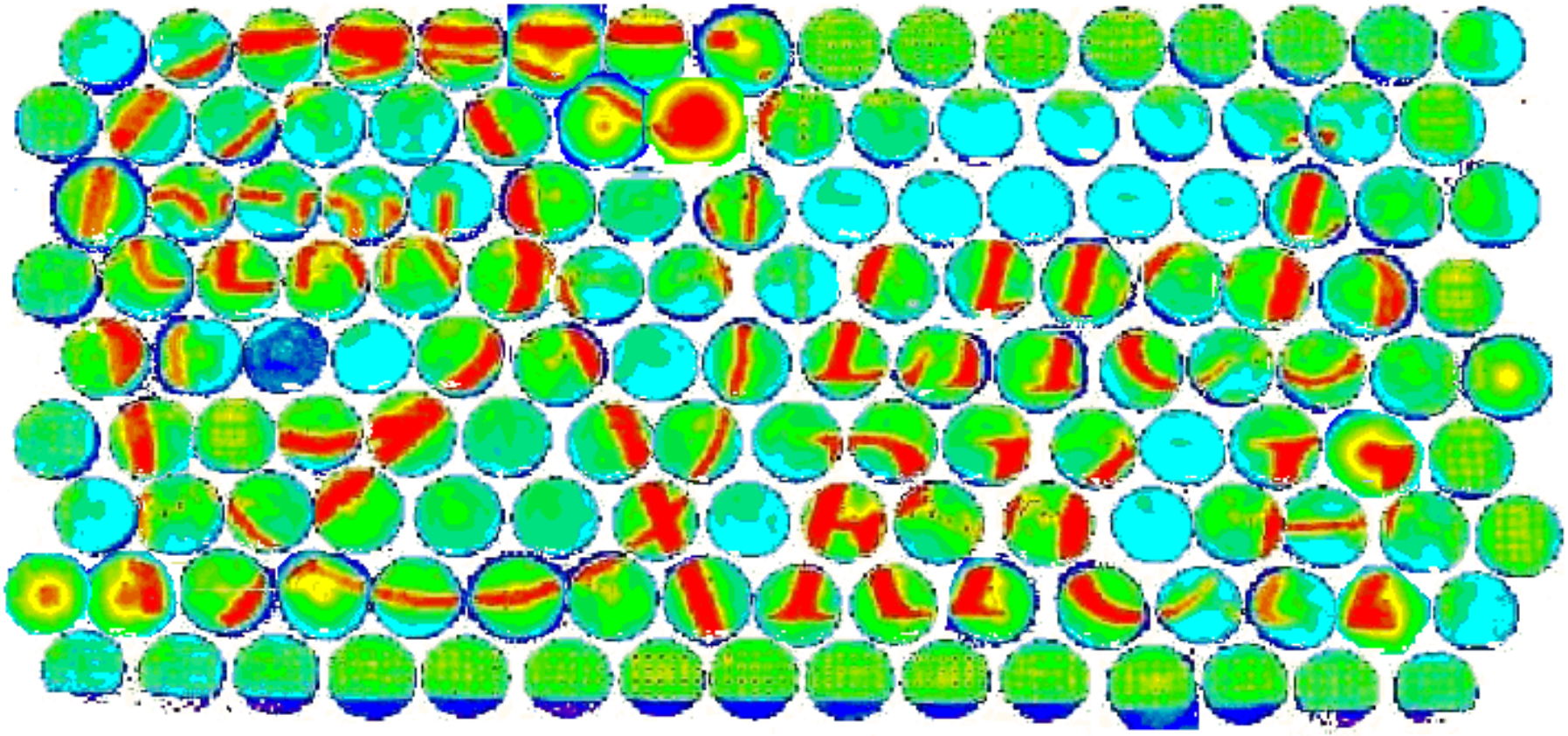
The optical systems consist of mirror arrays, optimized for precision, reflectivity and minimum material.

~500000 channels on the photon detector planes can detect and store at a rate of 40 MHz the single photon.

The readout rate is expected to be ~ 1 MHz.

Conclusions

We have been waiting to see the first rings in our RICHes, … and these will come only with the beams. Meanwhile, the only rings we have been able to produce…



Single photon accumulated image taken shining from a projector on one side of RICH2. The light level over the whole surface is ~100 phel per 25 ns event.