RICH detectors for LHCb

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On behalf of the LHCb RICH collaboration

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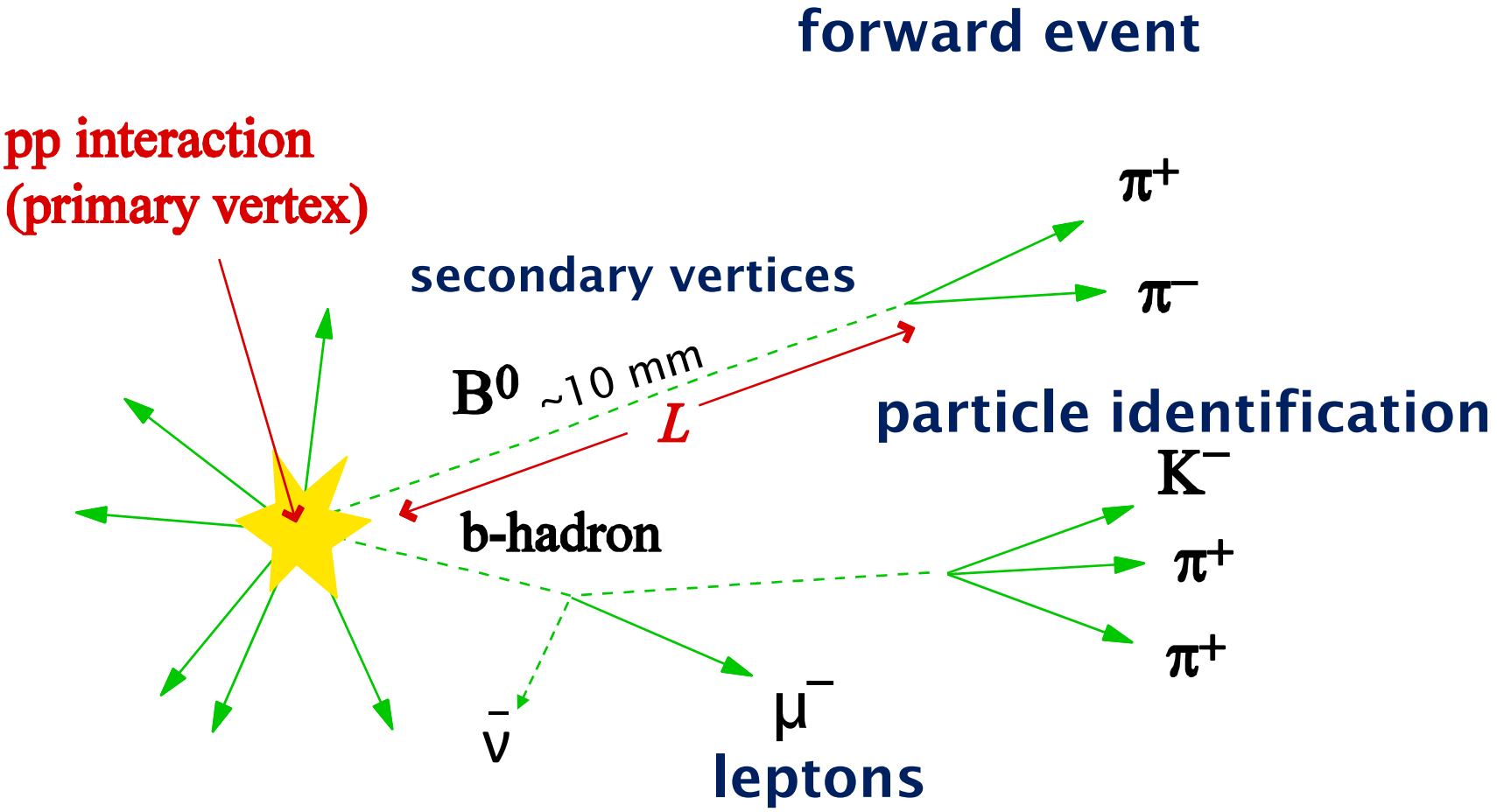
Outline of the talk

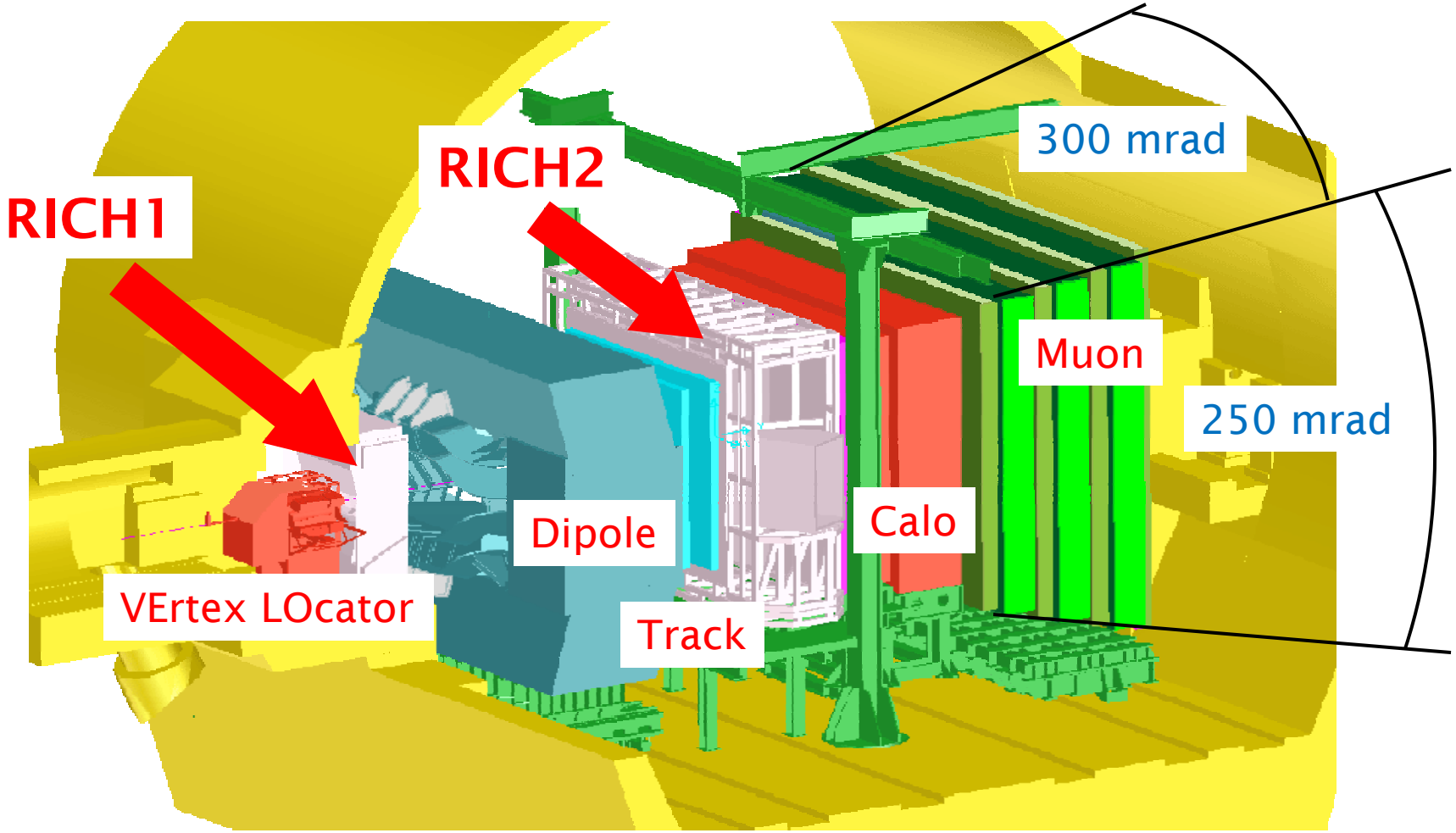
- The LHCb experiment
- RICH1 & RICH2
- The Hybrid Photon Detector (HPD)
- The aerogel radiator
- Commissioning and performance
- Summary

b-Physics at the LHC

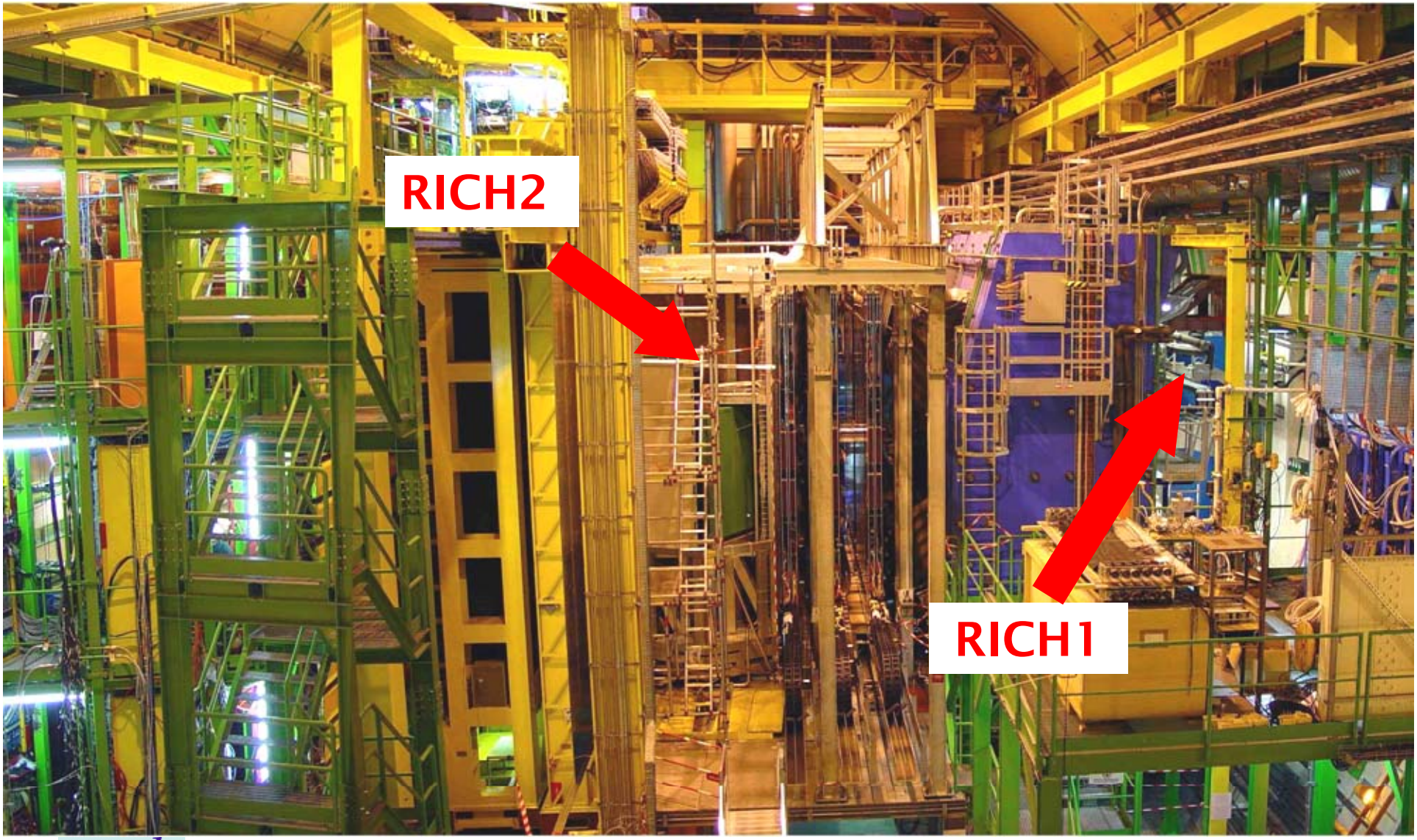


The LHCb experiment

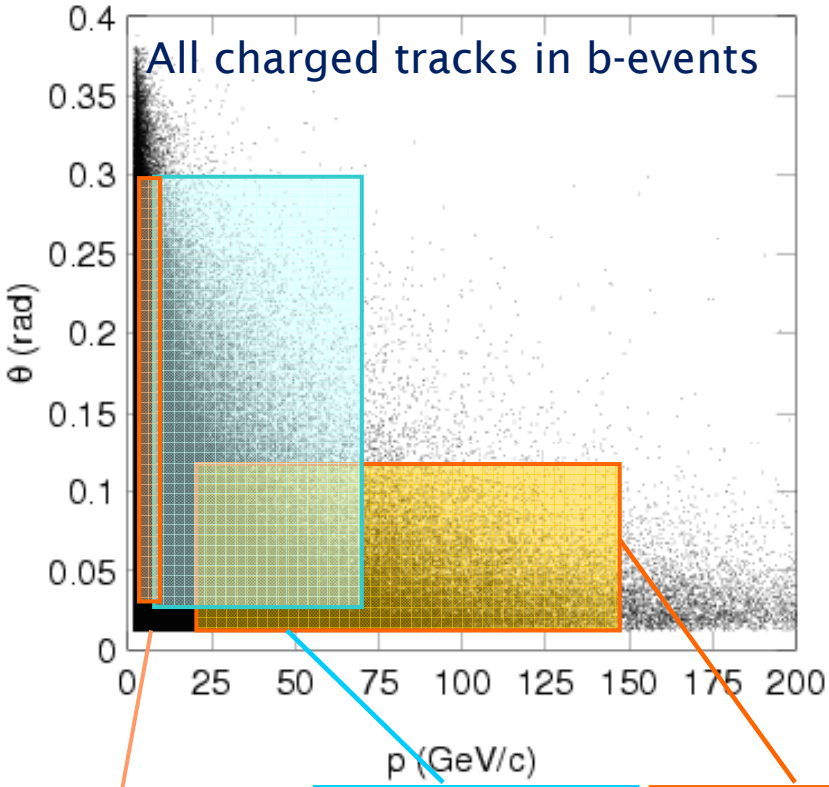
Two Ring Imaging Cherenkov detectors provide p/K/π identification

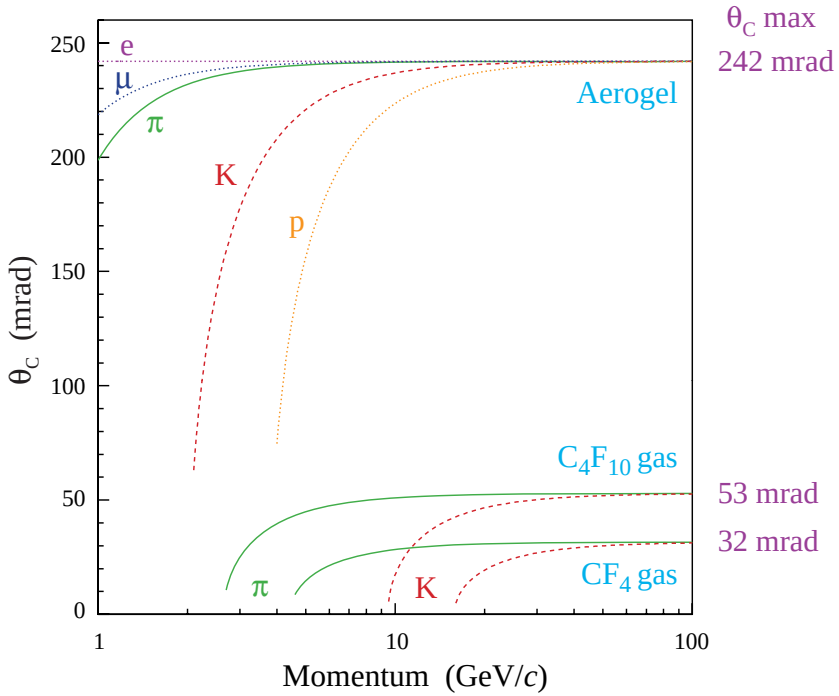


The experimental site



Cherenkov radiators





θ_C max
242 mrad

53 mrad

32 mrad

Silica Aerogel
n=1.03
1-10 GeV/c

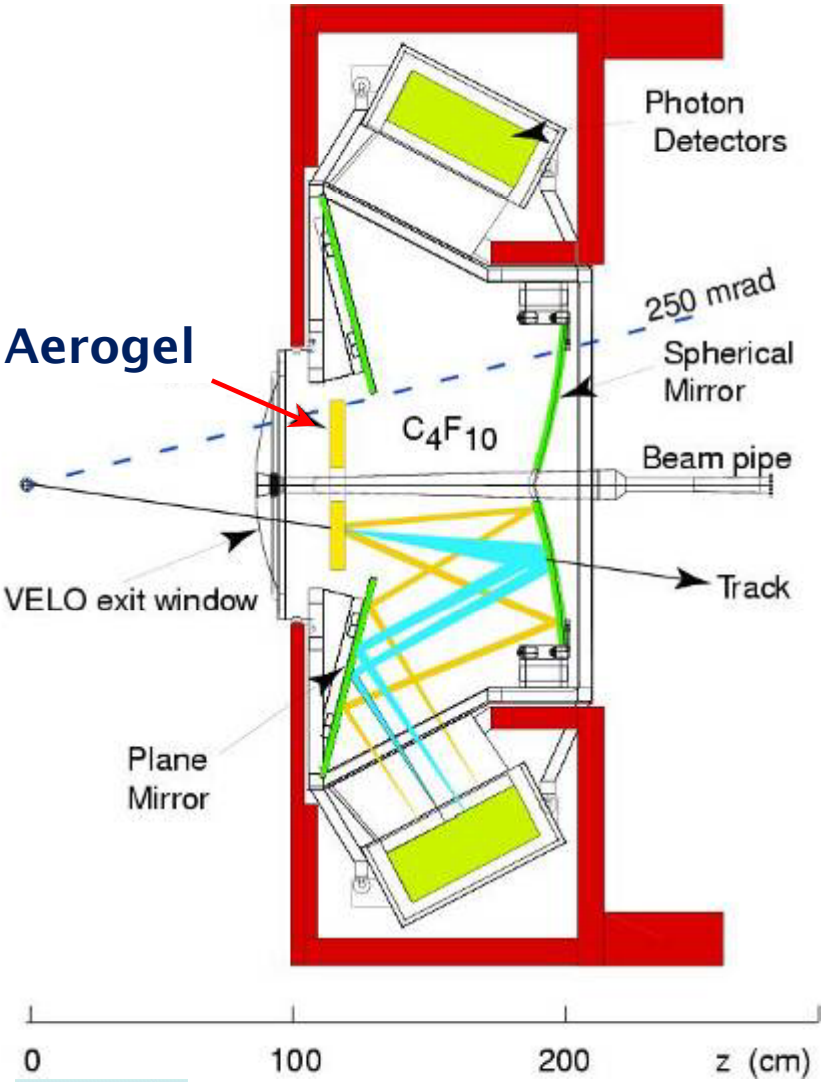
C_4F_{10} gas
n=1.0014
Up to ~70 GeV/c

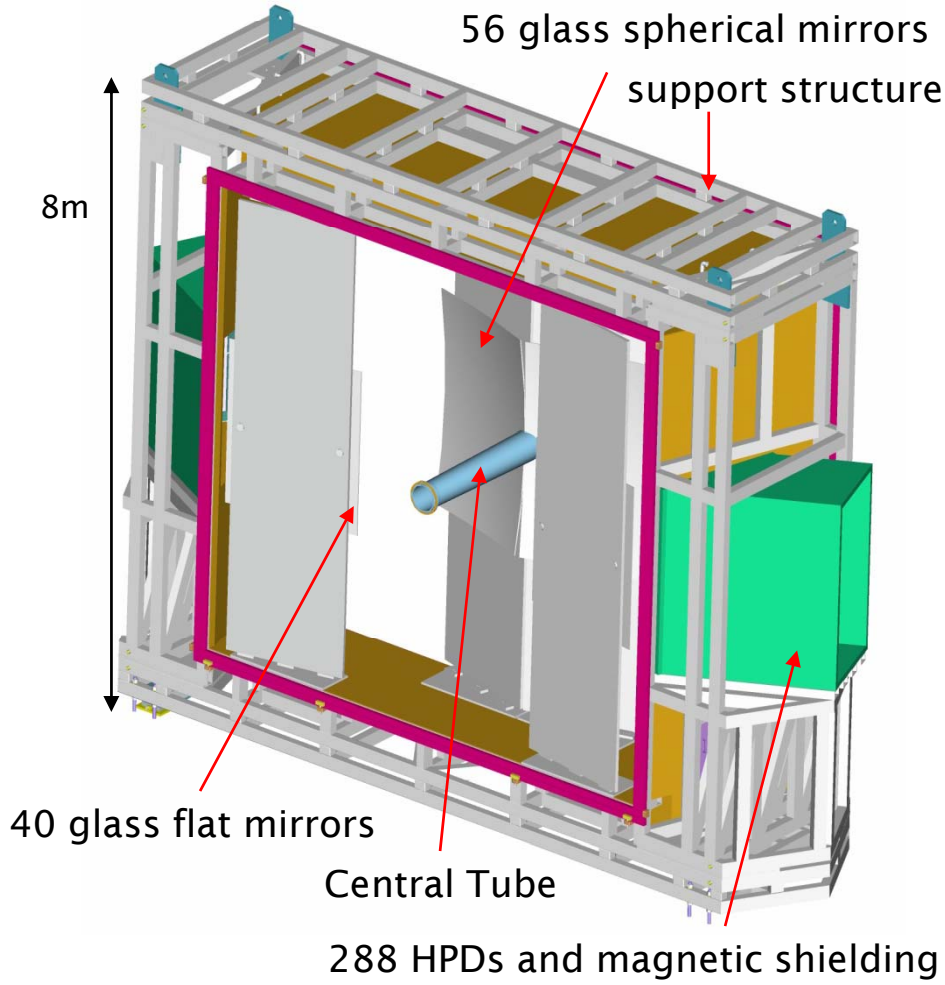
CF_4 gas
n=1.0005
Beyond ~100 GeV/c

RICH1:
25→250 mrad vertical
25→ 300 mrad horizontal

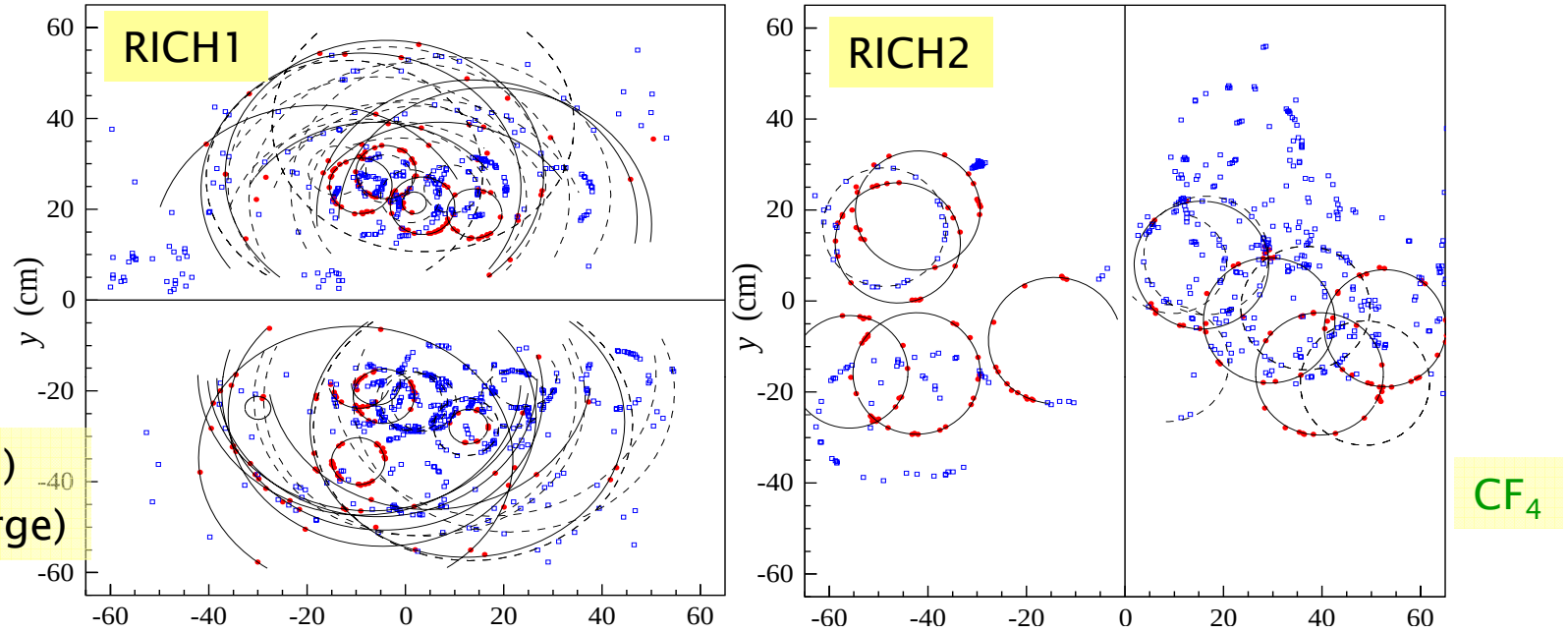
RICH2:
15→100 mrad vertical,
15→ 120 mrad horizontal

RICH layout


Photon
Detectors
250 mrad
Aerogel
Spherical
Mirror
C_4F_{10}
Beam pipe
VELO exit window
Track
Plane
Mirror
0
100
200
z (cm)


56 glass spherical mirrors
support structure
8m
40 glass flat mirrors
Central Tube
288 HPDs and magnetic shielding

Photon detectors requirements



C_4F_{10} (small)
Aerogel (large)

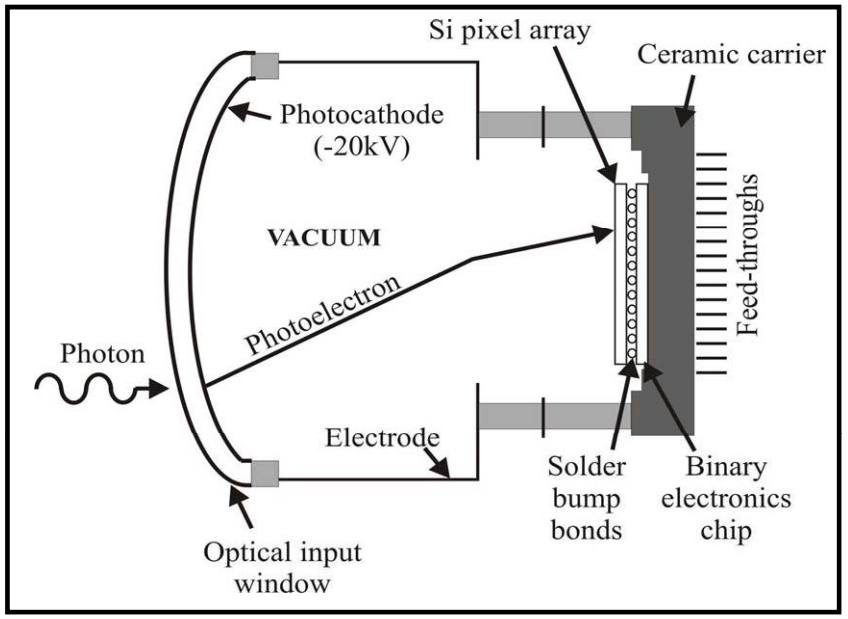
CF_4

Hits in the photon detectors for one event (full LHCb simulation)

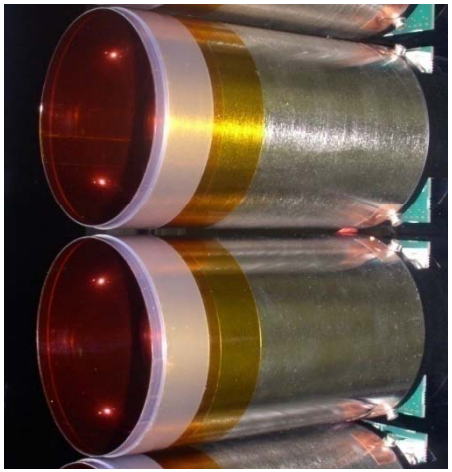
total area:	3.3 m^2	active area fraction:	63%
single photon sensitivity:	200 - 600 nm	# of channels:	500k
quantum efficiency:	>20%	LHCb DAQ rate:	40MHz
good granularity:	2.5 x 2.5 mm^2	rad. tolerant:	3kRad/year

Pixel Hybrid Photon Detectors

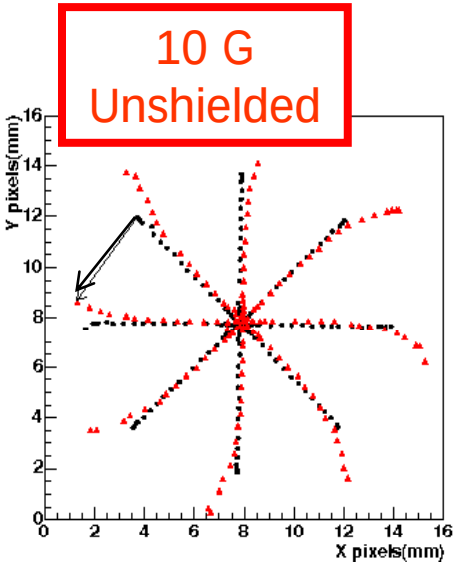
- Pixel HPDs developed in collaboration with industry (Photonis-DEP lead partner)
- Vacuum tube with silicon pixel readout (Quartz window with S20 photocathode)
- 75 mm active diameter
- 484 HPDs to meet the requirements
- Factor 5 demagnification @ 20kV
- Encapsulated electronics:
  - 8192 pixels logically OR-ed in groups of 8 to form a matrix of 32 x 32
  - binary output of 1024 channels

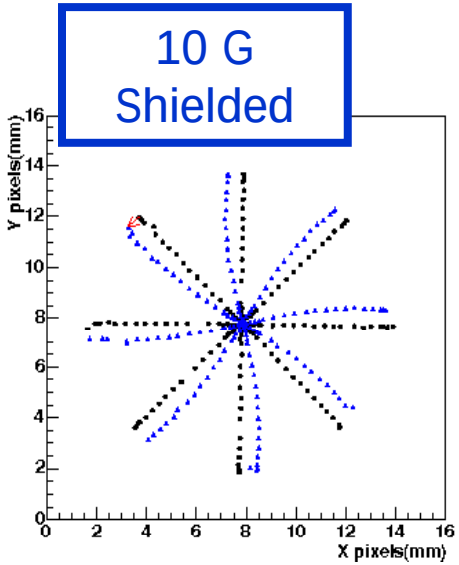


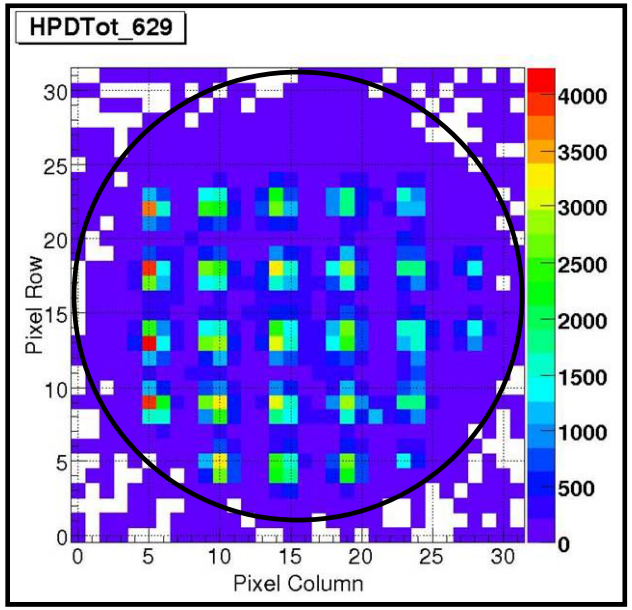
Magnetic distorsions



Residual distorsions monitored and corrected for by projecting patterns on the HPDs in situ

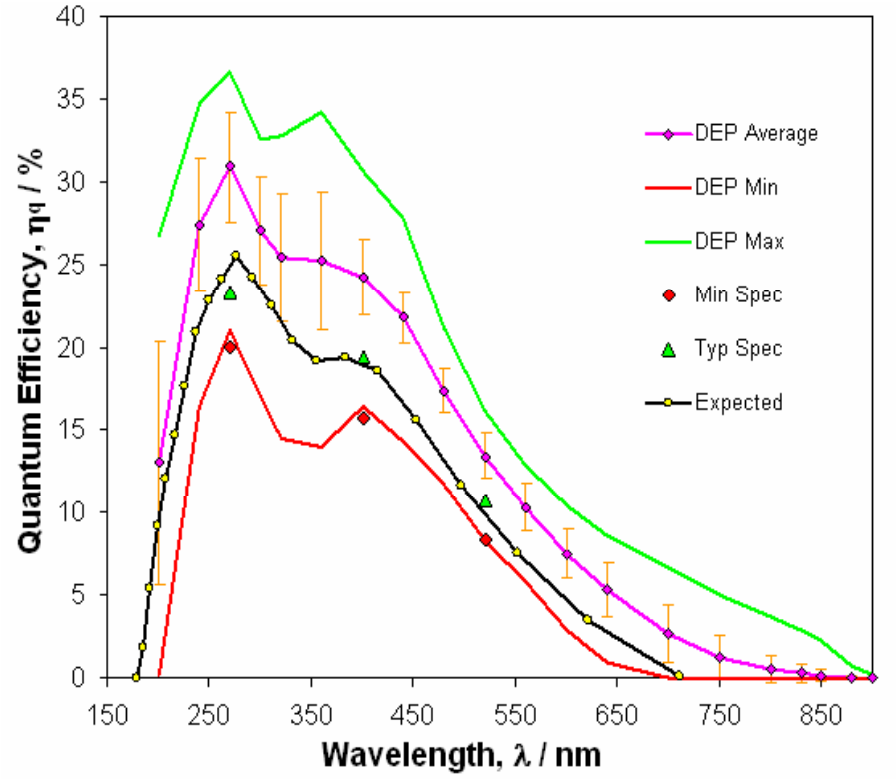






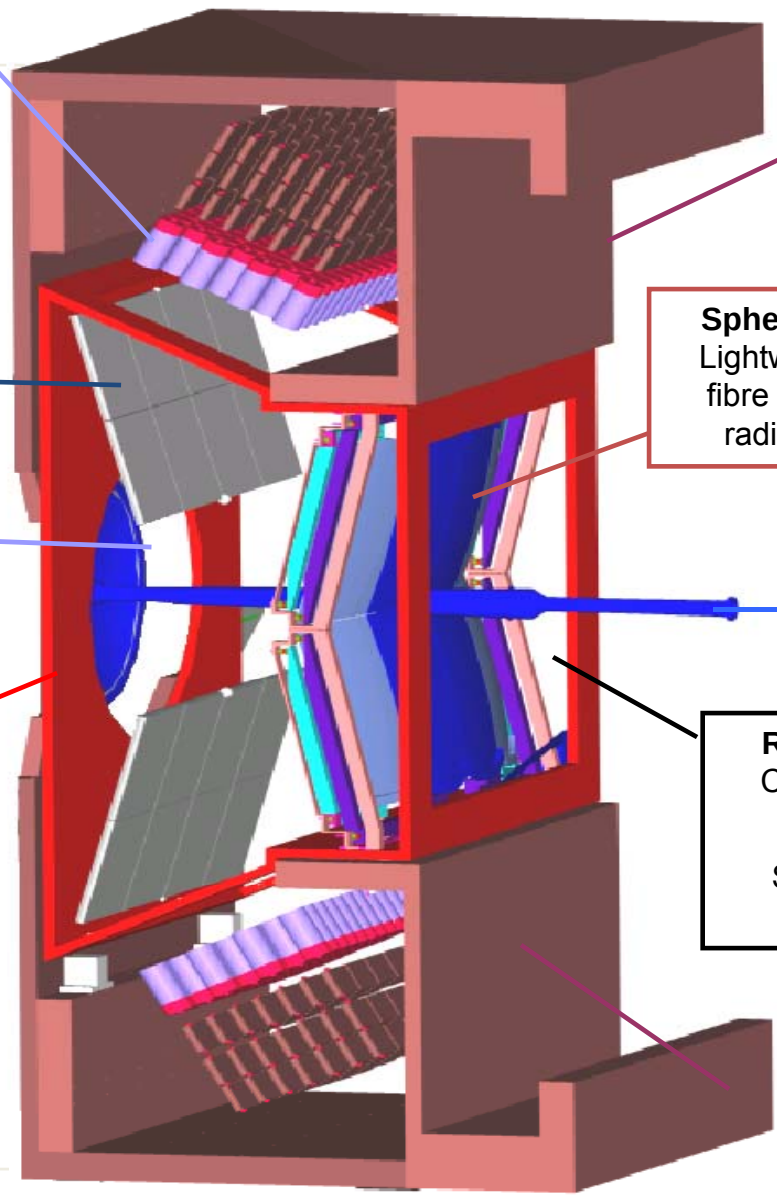
HPD qualification

- Two Photon Detector Test Facilities (PDTFs) have qualified all 550 HPDs produced by Photonis/DEP.
- 98% of tubes have passed the selection criteria.
- Excellent response, QE, dark counts, ion feedback .



The development and serial production of very high quantum efficiency photocathodes for the HPD has been an ouststanding technological success

RICH1 schematics



Photon detector plane 14 by 7 Hybrid Photon Detectors (HPDs)

Upper Magnetic Shielding

Glass Planar Mirrors

Spherical Mirrors Lightweight carbon fibre mirrors 1.5% radiation length

Aerogel goes here

Beryllium beampipe

(defines RICH1 inner acceptance)

RICH1 Exit Window Carbon fibre & PMMI foam

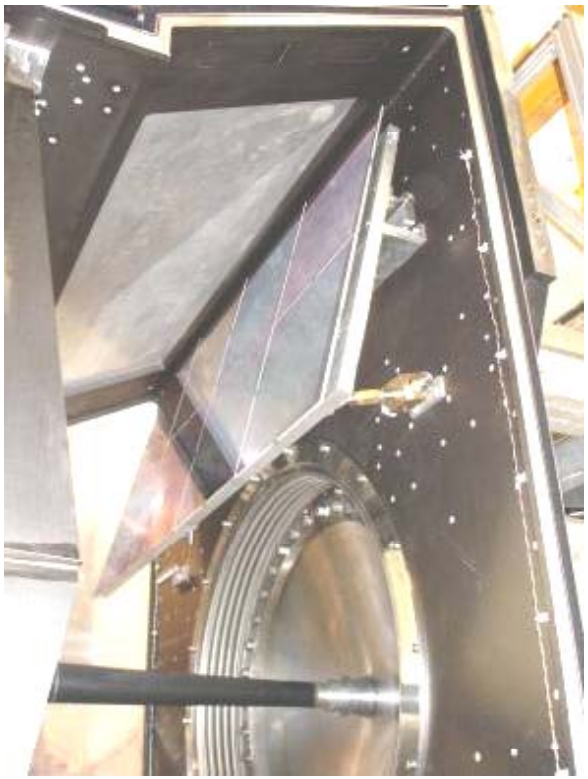
Sealed direct to the beampipe.

Gas Enclosure supports mirrors and aerogel, contains C_4F_{10}

4m

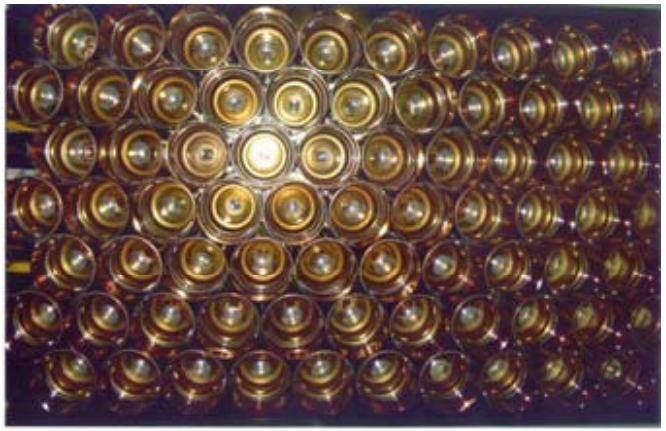
RICH1 installation

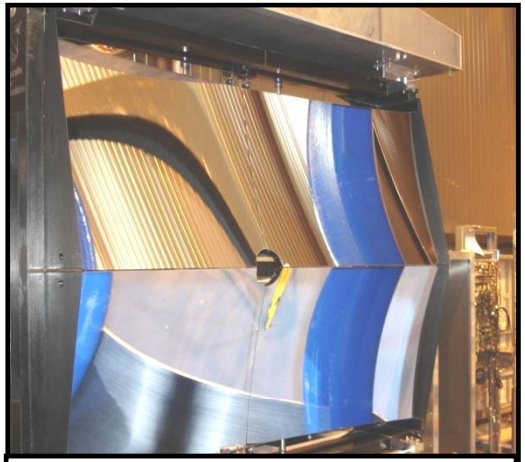
Beryllium beampipe, seal to VELO and flat mirrors



Upper HPD box

98 HPDs

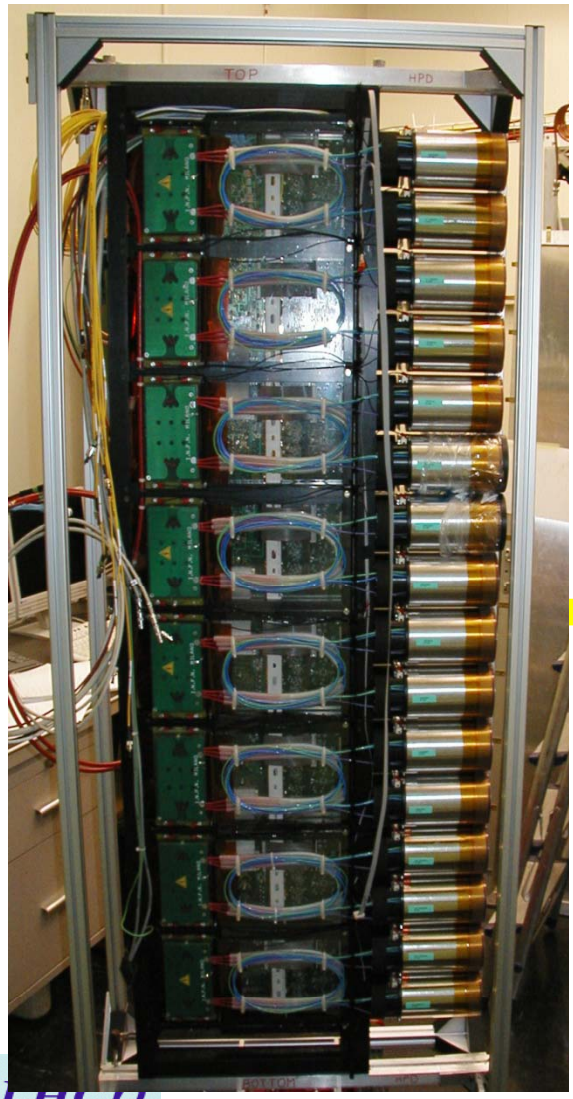




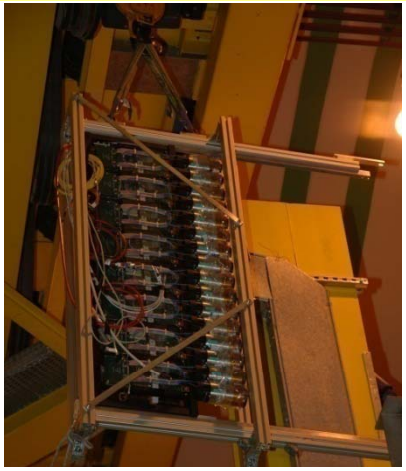
Carbon Fibre Mirrors

RICH2

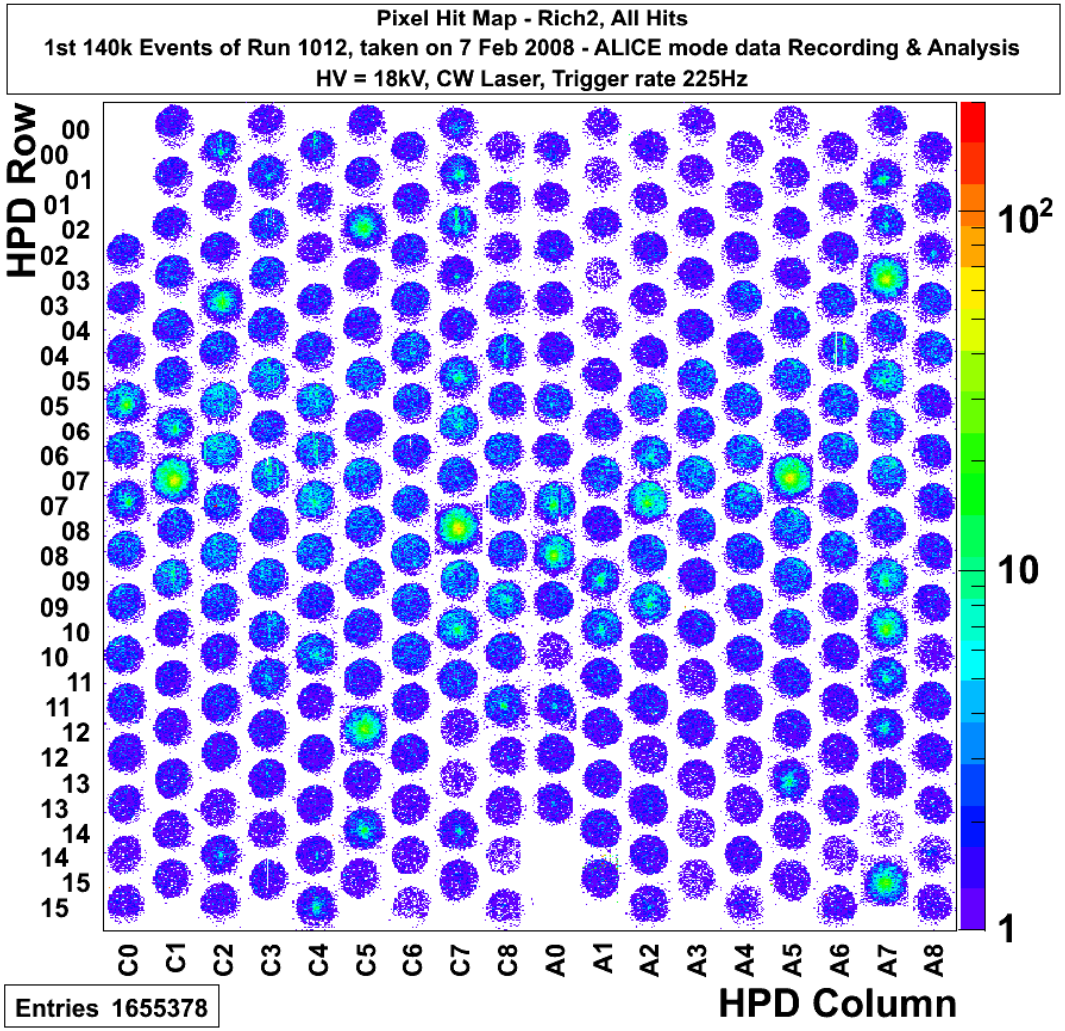
HPD column module



HPD modules inserted here



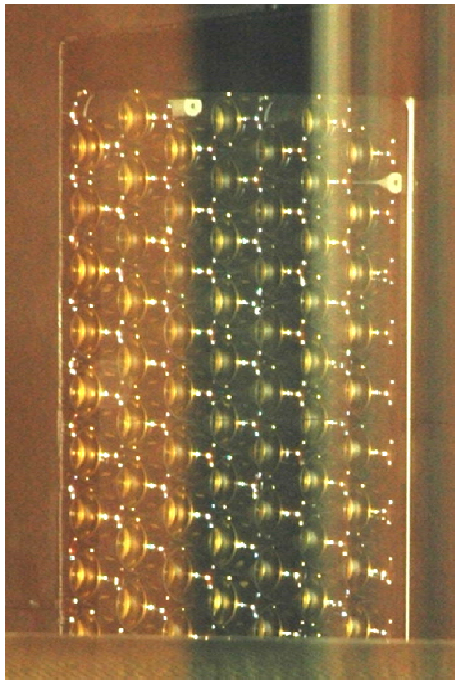
RICH2 Commissioning



RICH2 HPD planes, pulsed laser

Routine operation with high voltage and full integration into LHCb Control system and Data acquisition system.

Ready for collisions!



HPD array from inside RICH2

Silica aerogel

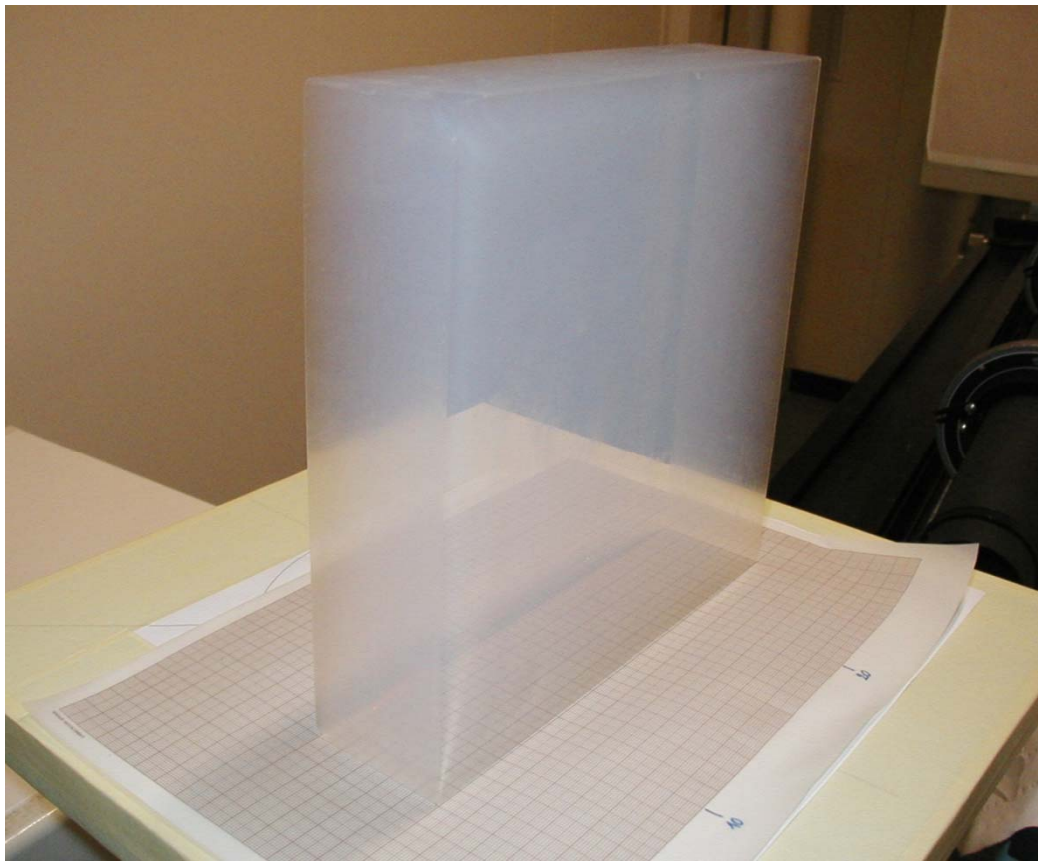
Hygroscopic, produced by Boreskov Institute of Catalysis Novisibirsk

- 30 litres produced for LHCb
- 200x200x50 mm tiles – the largest ever
- Exceptional clarity

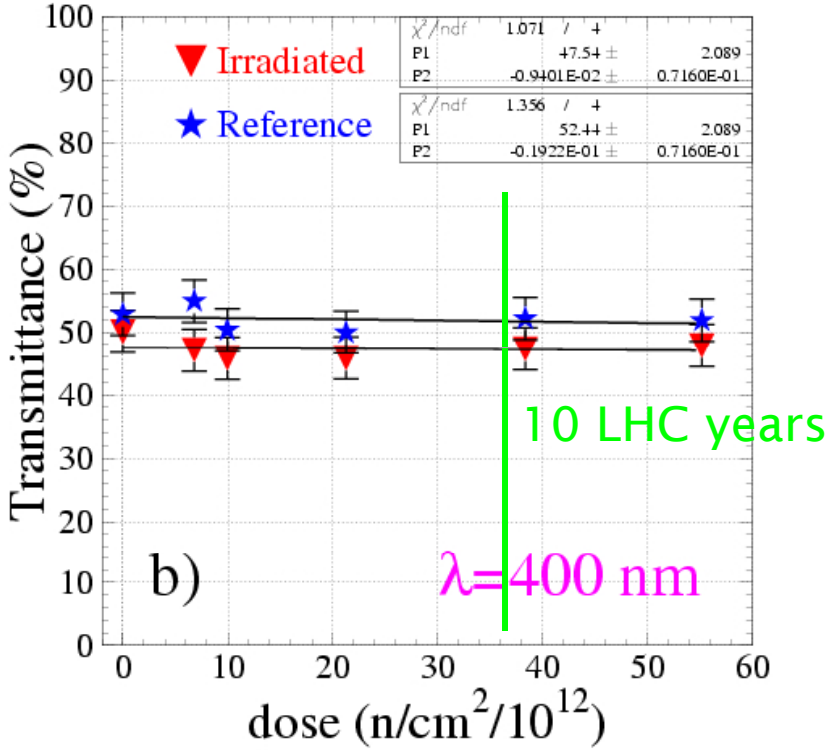
$C \sim 0.005\ \mu m^4 cm^{-1}$

$I/I_0 = A \exp -(Ct/\lambda^4)$

for thickness t in cm



Aerogel for LHCb



Successfully tested against:

- humidity : loss of transparency recovered by baking at 500 °C
- radiation: neutron, proton and γ up to several LHCb lifetimes
- exposure to C_4F_{10} : tolerable slight modification of optical parameters

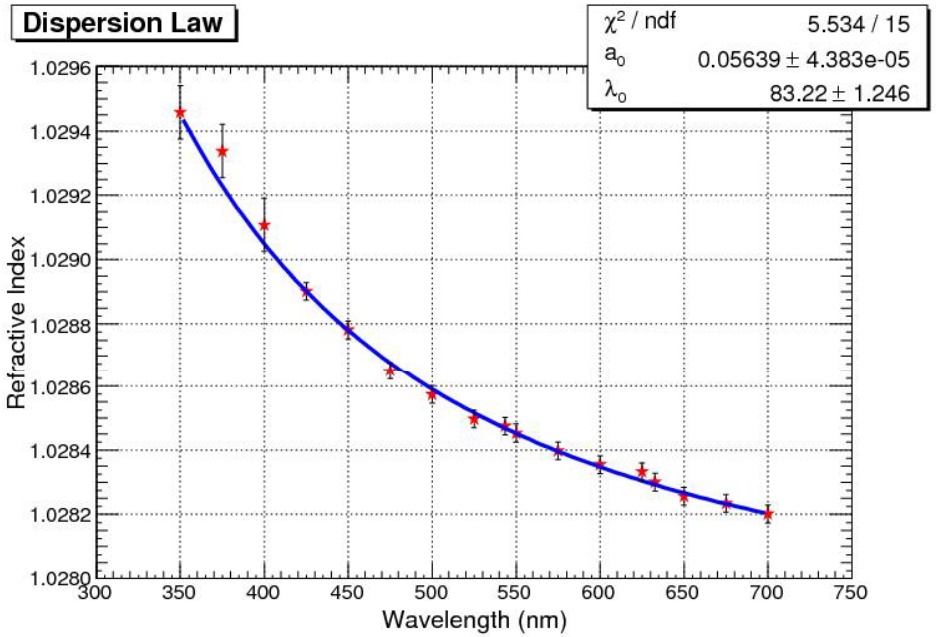
Performance of the aerogel as radiator for the RICH of LHCb has been confirmed by several tests on charged particle beams over the years

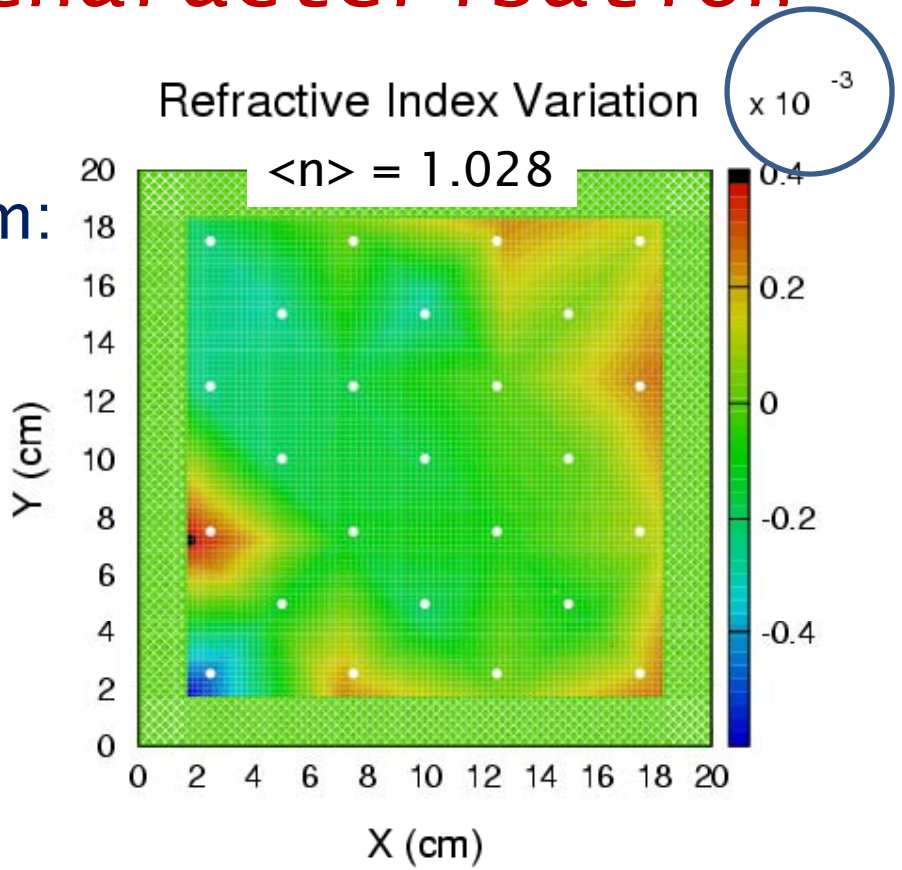
Refractive index characterisation

Homogeneity measured with laser and charged particle beam:

$\sigma(n-1)/(n-1) \sim 0.76\%$

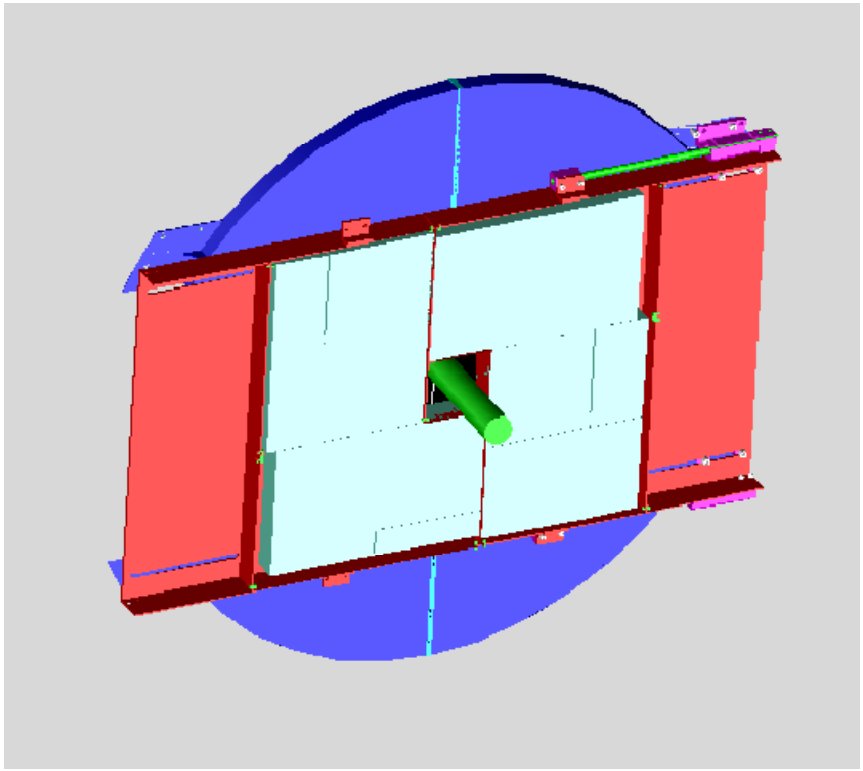
(contribution to $\sigma_\theta \sim 0.8$ mrad)





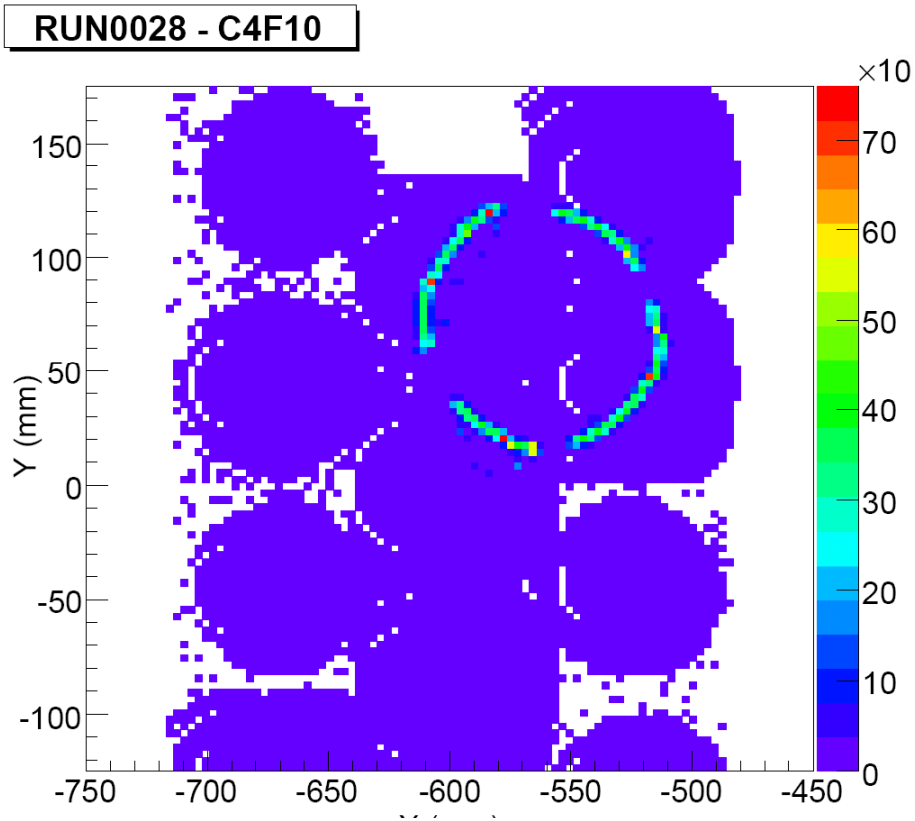
Refractive index measured over wide wavelength range

Aerogel mechanics



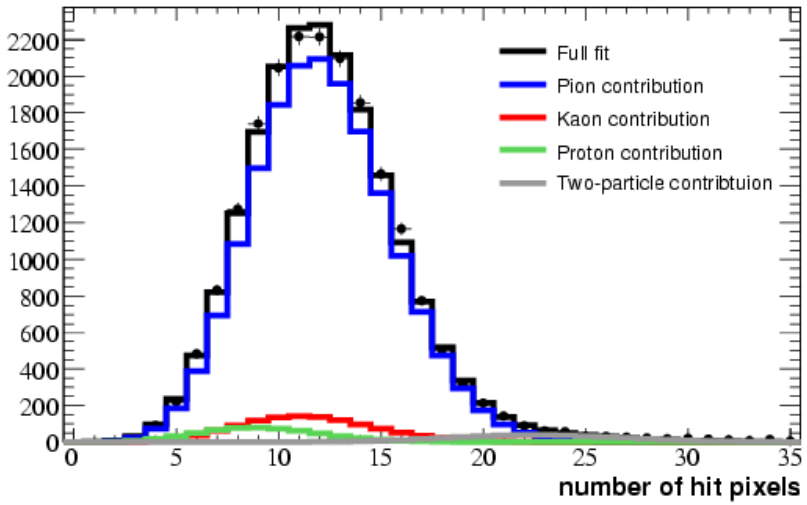
Carbon fiber box with wings to stop photons radiated upstream of aerogel
D263 glass filter to kill scattered photons and improve resolution
Trial installation successful, aerogel goes in as last component in spring

RICH performance

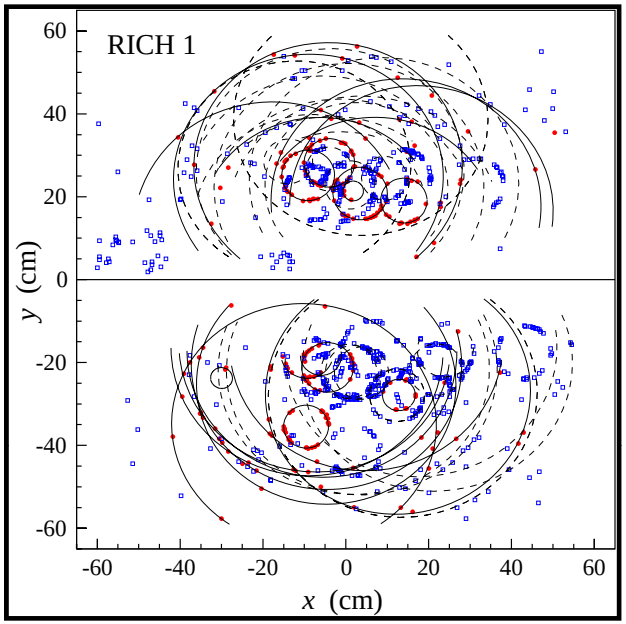


Pixel map of a C_4F_{10} ring focussed on 4 HPDs integrated over ~50k events

- Performance of the RICH system has been verified in a 80 GeV/c charged particle beam at CERN SPS. C_4F_{10} ~1m radiator length
- Realistic 25 ns beam structure
- Final RICH hardware and DAQ
- Full simulation results for photon yield and θ_c resolution have been validated

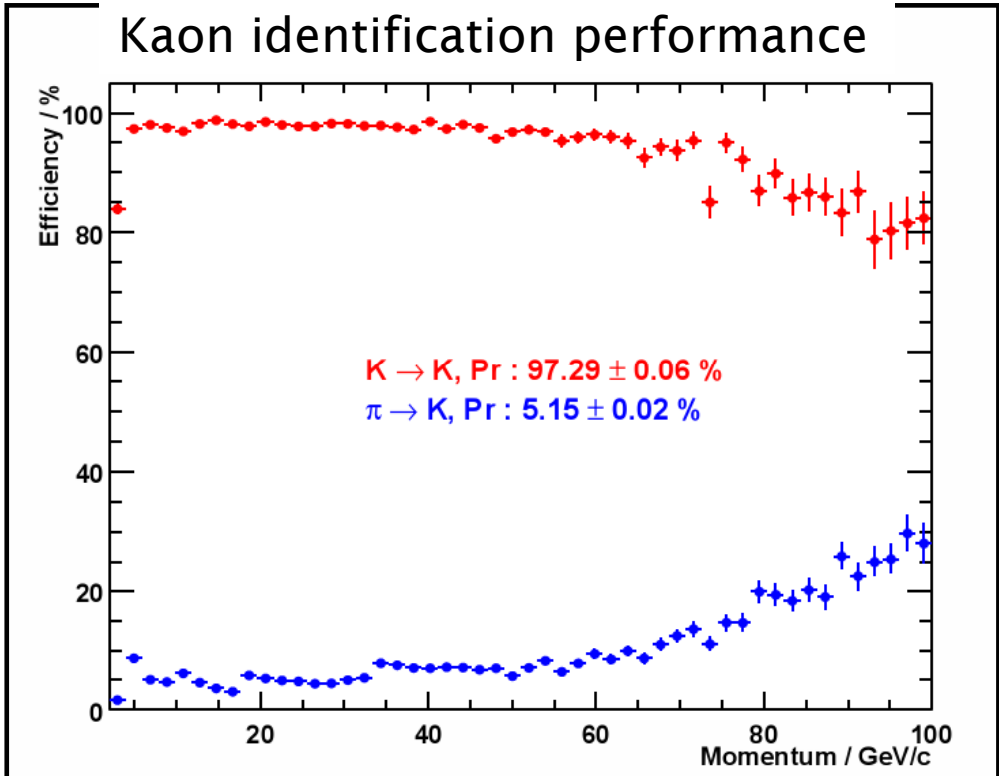


Particle ID performance



- **Ring finding**
  - The algorithm uses tracks, and performs a global likelihood fit to particle hypotheses across both RICH detectors.
- **π – K separation**
  - Excellent efficiency and low mis-ID rate

	Aerogel	C_4F_{10}	CF_4
photon yield isolated tracks	5.3	24.0	18.4
single p.e. resolution (mrad)	2.6	1.5	0.7



Summary and prospects

- LHCb RICH project in good shape
- RICH2 fully equipped, commissioning is already at an advanced stage
- RICH1 is almost completed, commissioning will benefit from RICH2 experience
- Excellent quality and highly performing HPDs
- The RICH system will contribute to physics results starting from LHC day one.