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The Ring Imaging CHerenkov detectors of the LHCb experiment

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on behalf of the LHCb RICH Collaboration

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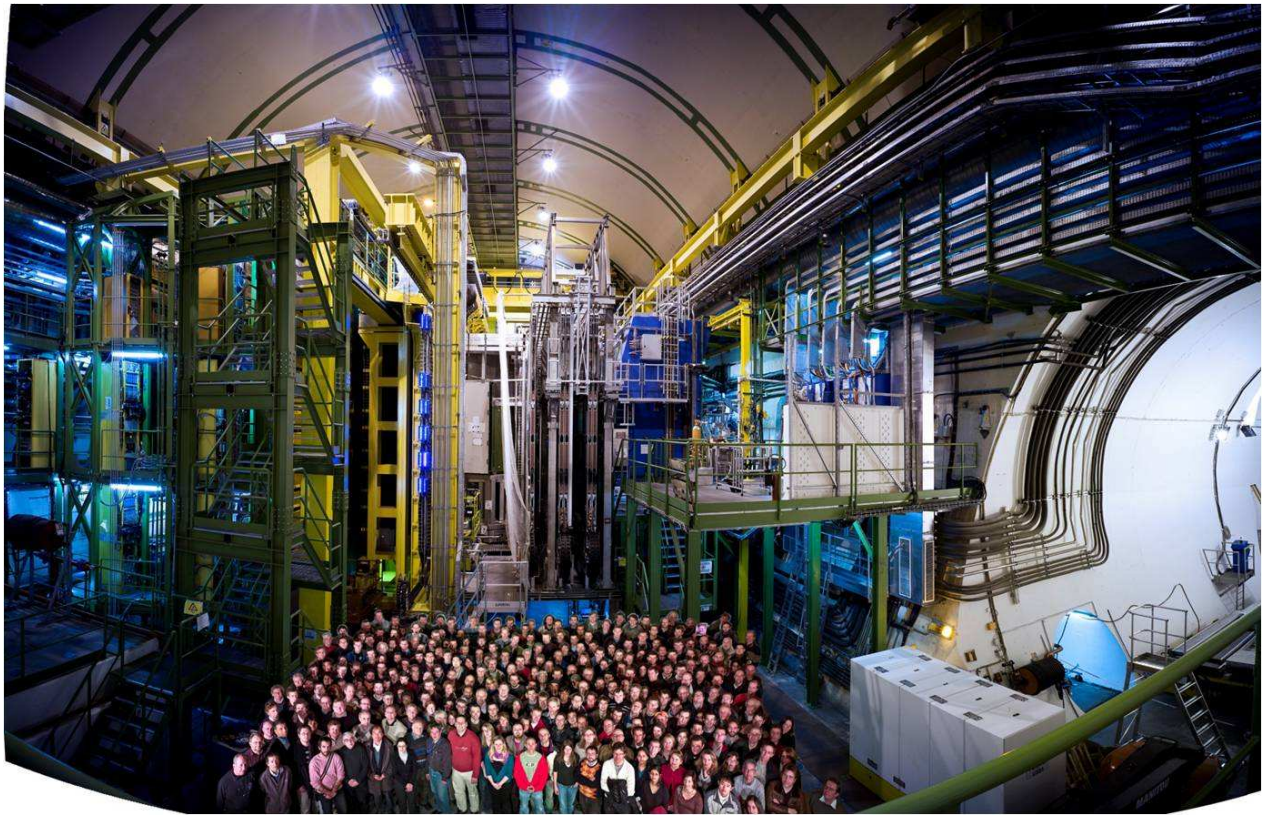
Outlook

- the LHCb experiment at the Large Hadron Collider (LHC)
- the Ring Imaging CHerenkov detectors
  - radiators
  - layout
  - photon detection system
- calibration and alignment
- resolutions achieved
- conclusions

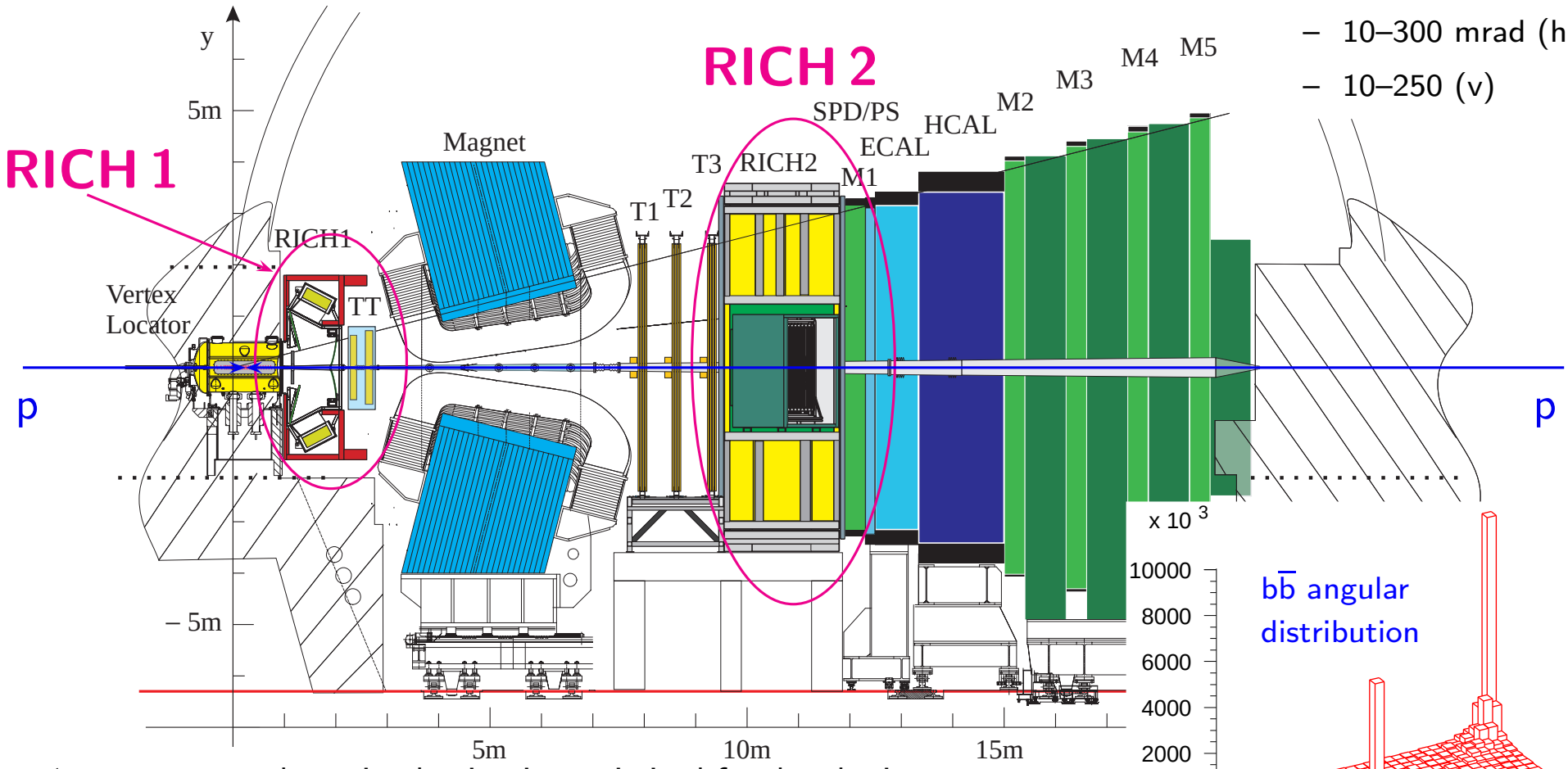
The LHCb Collaboration

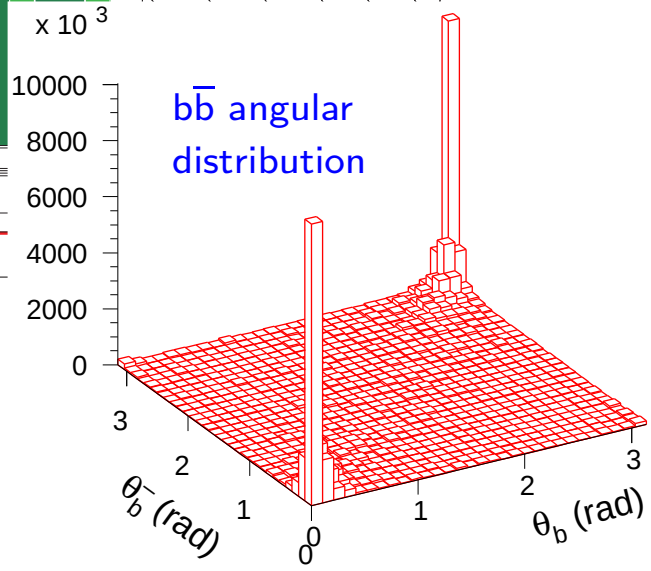


more about the performance in A. Papanestis' presentation

The LHCb experiment

angular acceptance
- 10–300 mrad (h)
- 10–250 (v)

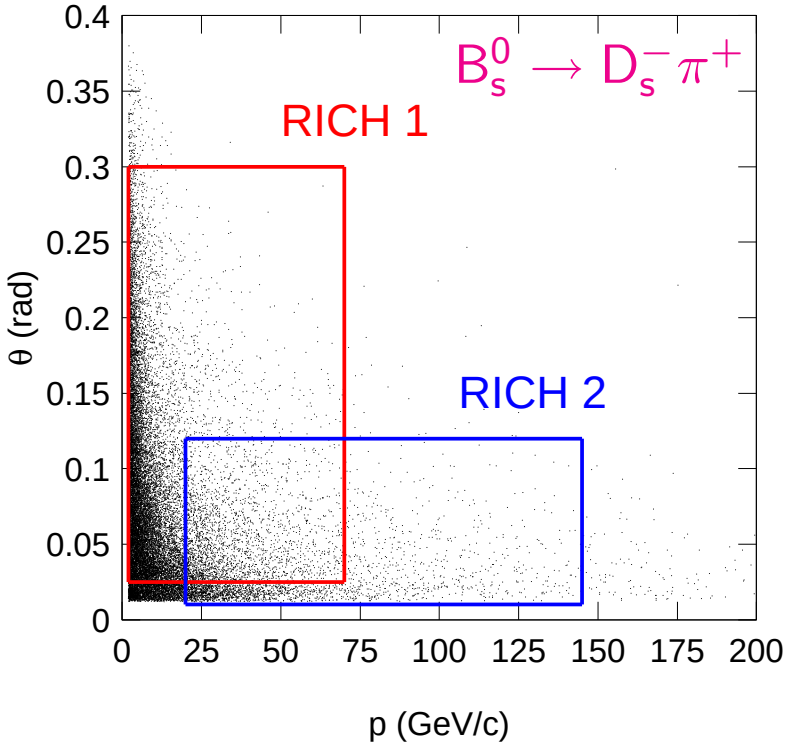


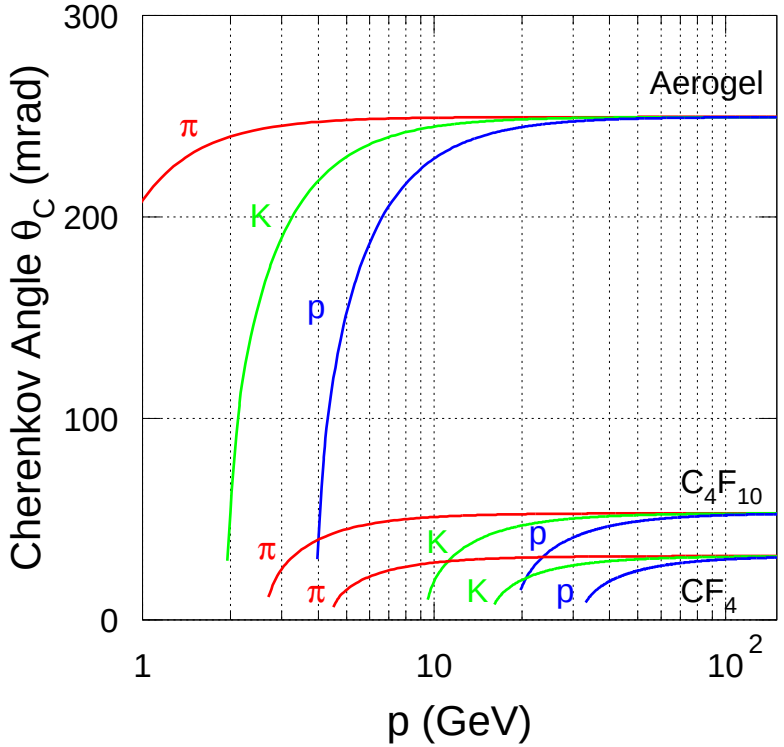


$b\bar{b}$ angular distribution

1. geometry and running luminosity optimized for the physics programme
2. high efficiency trigger (hadronic and leptonic modes)
3. excellent tracking and vertexing
4. powerful positive particle identification

The Cherenkov radiators



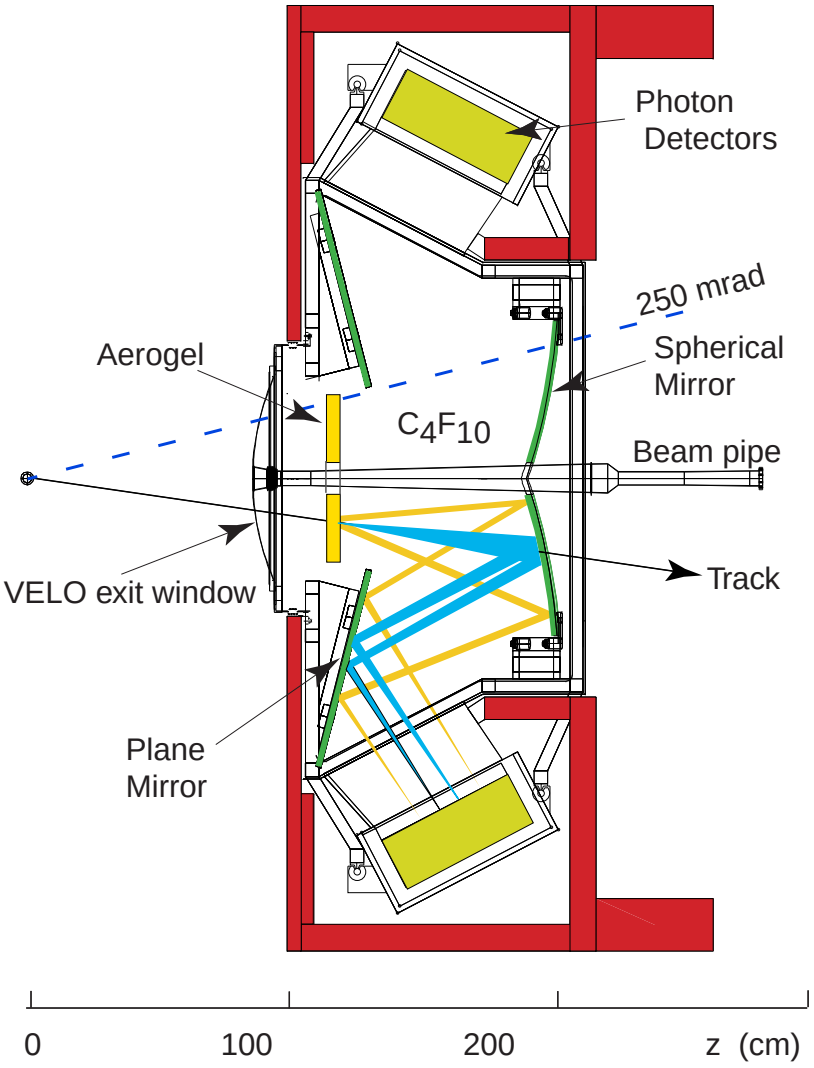


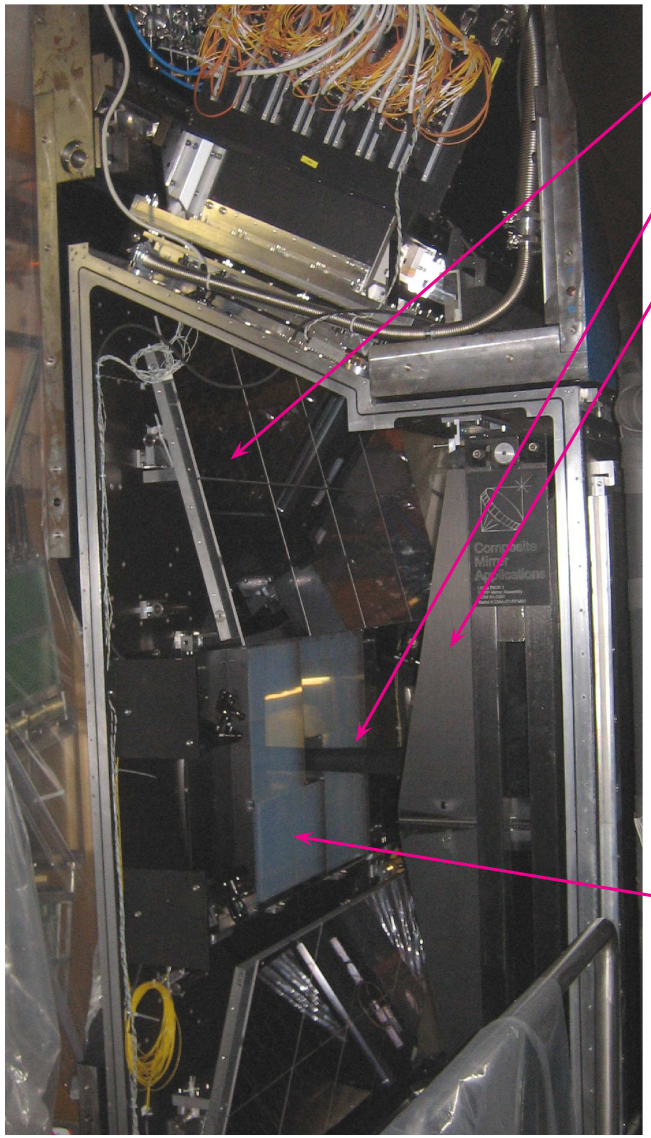
Radiator	Aerogel	C_4F_{10}	CF_4
L	5 cm	85 cm	167 cm
n	1.03	1.0014	1.0005
Momentum	1–10 GeV/c	up to 60 GeV/c	up to 100 GeV/c
θ_C^{max}	242 mrad	53 mrad	32 mrad
$\sigma^{tot}(\theta_C)$	2.6 mrad	1.5 mrad	0.7 mrad
$\mathcal{N}_{pe}$	6.7	30.3	21.9

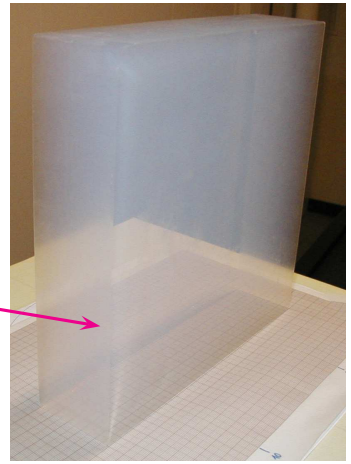
Monte–Carlo

The LHCb Collaboration, 2008 JINST 3 S08005

RICH 1 layout







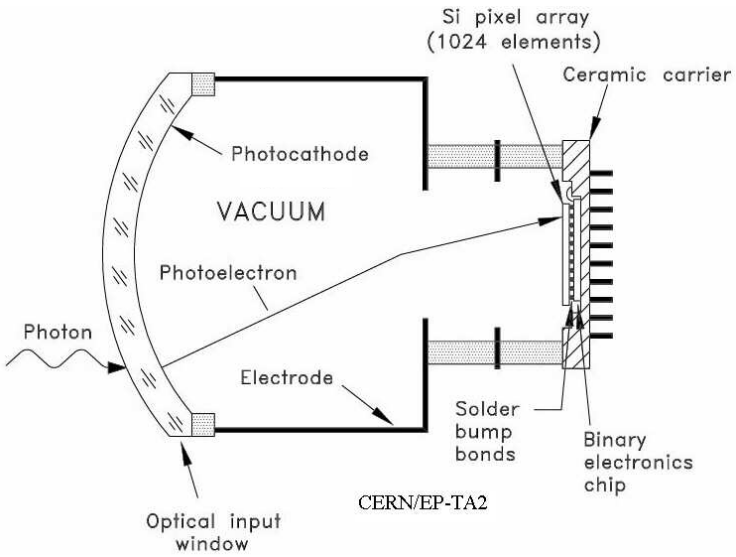
16 silica aerogel tiles

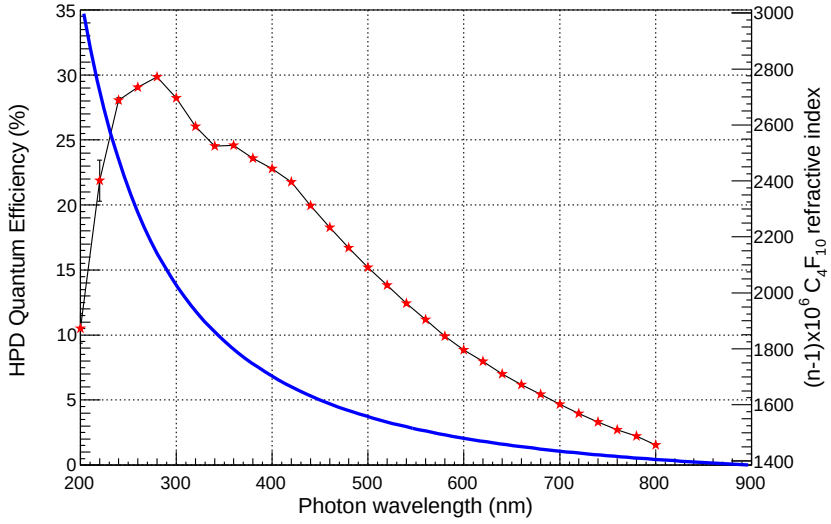
similar layout for RICH 2, but rotated by 90 degrees

The photon detection system (i)

detection of Cherenkov photons by a set of 484 pixel Hybrid Photon Detectors (HPDs)

- vacuum photon detector technology with silicon pixel read–out
- diametre 83 mm, height 120 mm
- quartz spherical window with S20 multi–alkali photocathode
- 200 – 600 nm sensitive wavelength range
- average QE improved during production up to $\sim 35\%$
- cross focusing optics ($\Delta V = 18$ kV), demag factor ~ 5
- photoelectrons focused on the pixelized silicon anode
- $\sim$ 500k pixels over the large area ~ 3.5 m^2

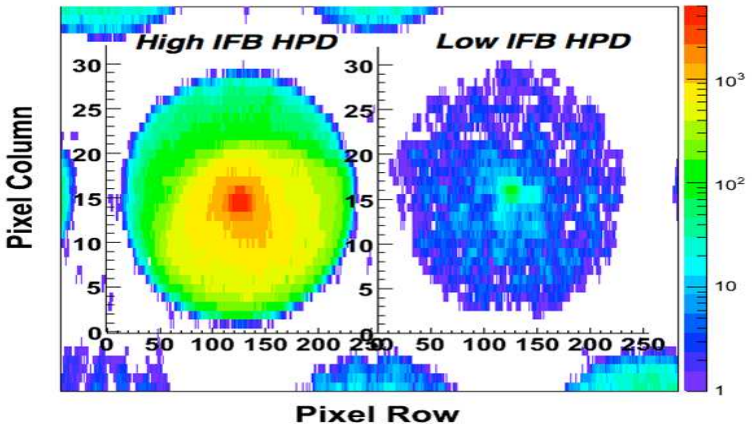




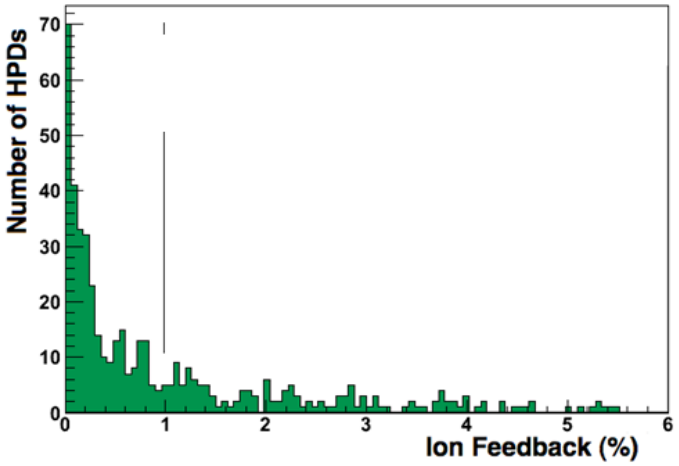
The photon detection system (ii)

- very low dark count rate ($\sim$ 0.04 photoelectrons per event on average)
  - limited thermo–ionic emission
  - low–noise electronics
- ion feedback
  - ionization of residual gas atoms by accelerated photon electrons
  - signal generated with $\sim$ 250 ns delay
  - in–situ measurements with a cw laser ($\lambda = 635$ nm) to monitor the quality of vacuum
  - record IFB from cluster size and monitor evolution in time (typically ΔIFB $< 0.5\%$ per year)

high IFB low IFB



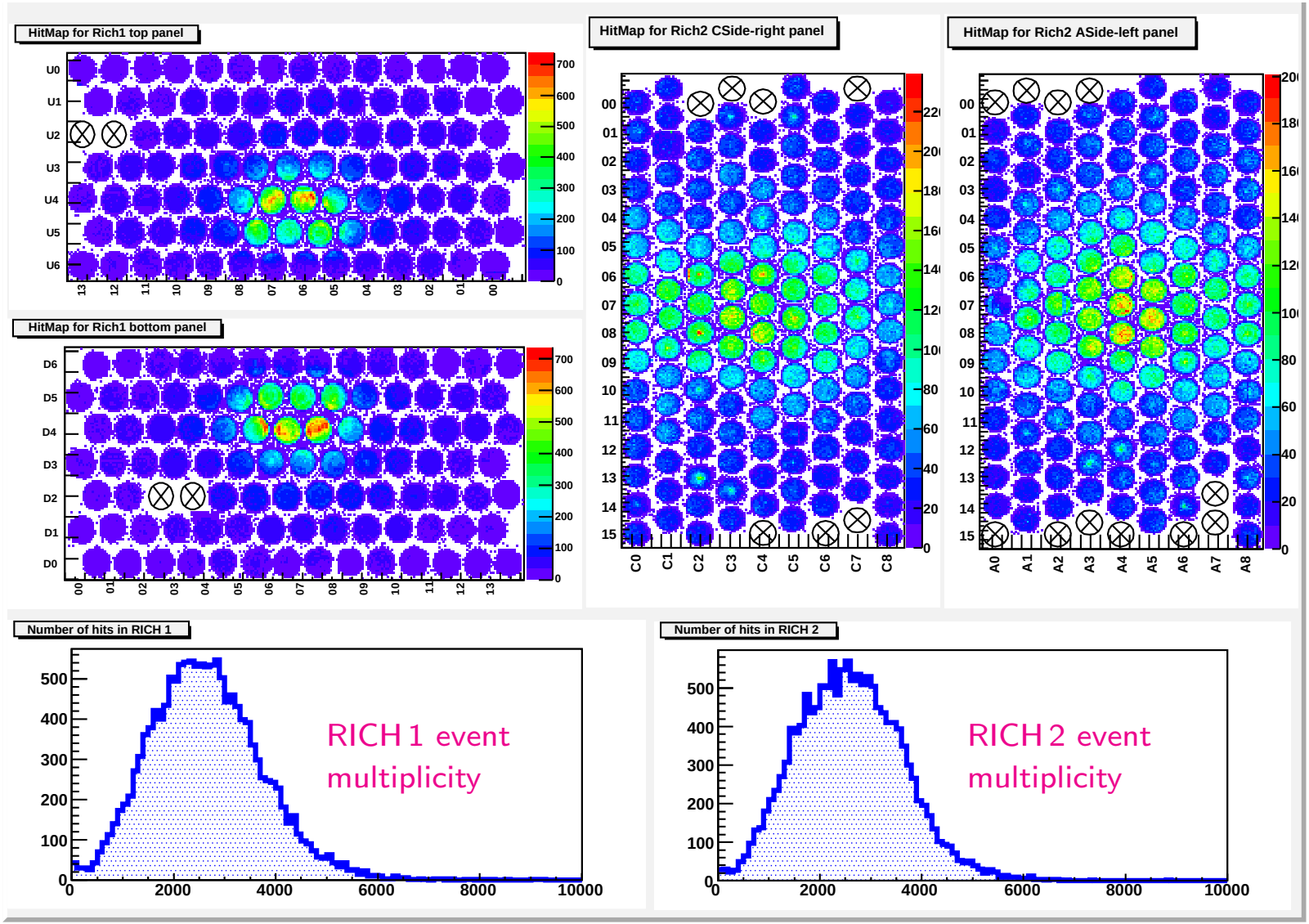
from dark count data



From dream to reality (i)

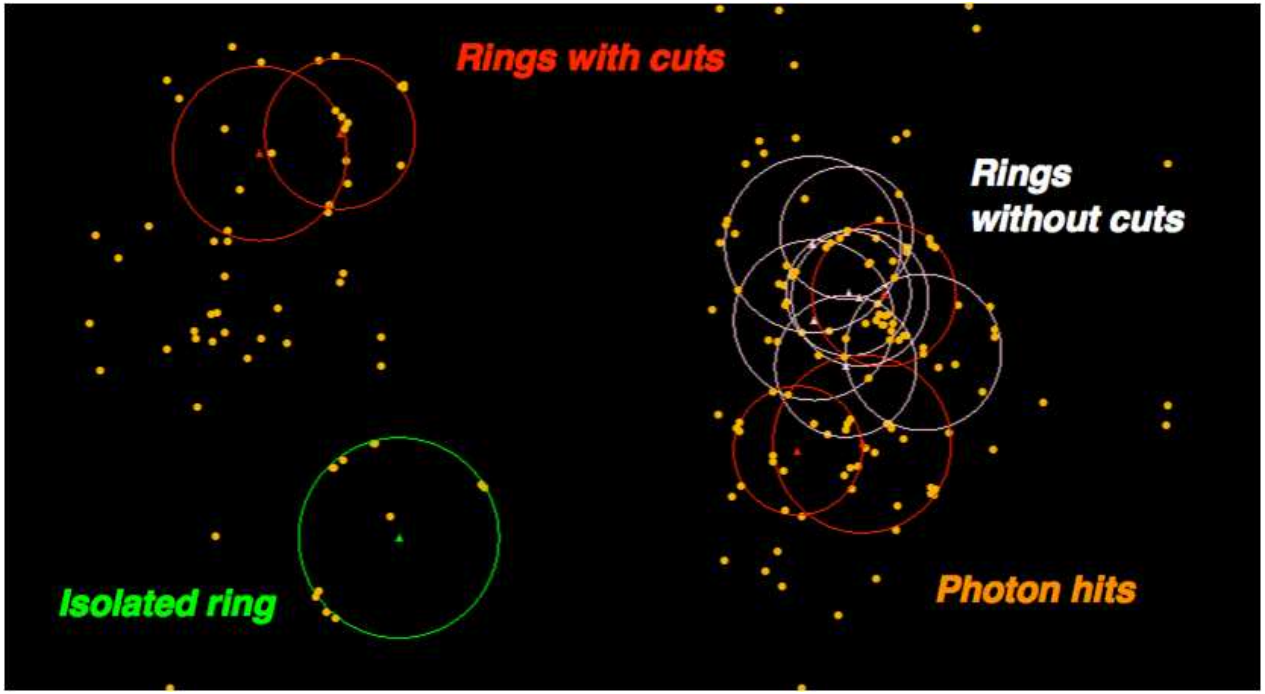
/RICH/Commissioning/LHCb/Default

Run 90567, started 2011-04-30 23:29:41, duration: 00:34:52



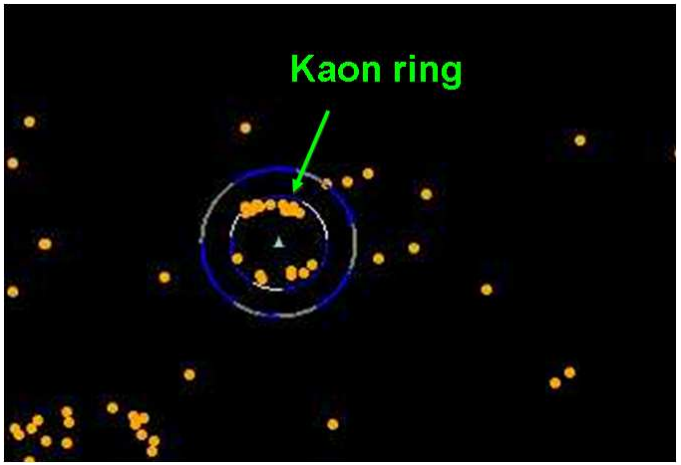
From dream to reality (ii)

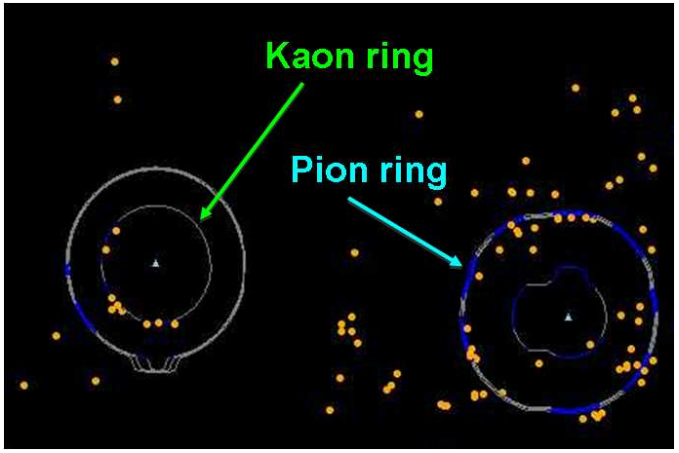
nice and clear Cherenkov rings reconstructed on–line



RICH 2 event display: single pp collision at $\sqrt{s} = 0.9$ TeV (Dec 2009)

RICH 1 HPD panel: single pp collision





RICH 2 HPD panel: single pp collision

Calibrating the RICH detectors

key features to get the best performance ever from the RICH system

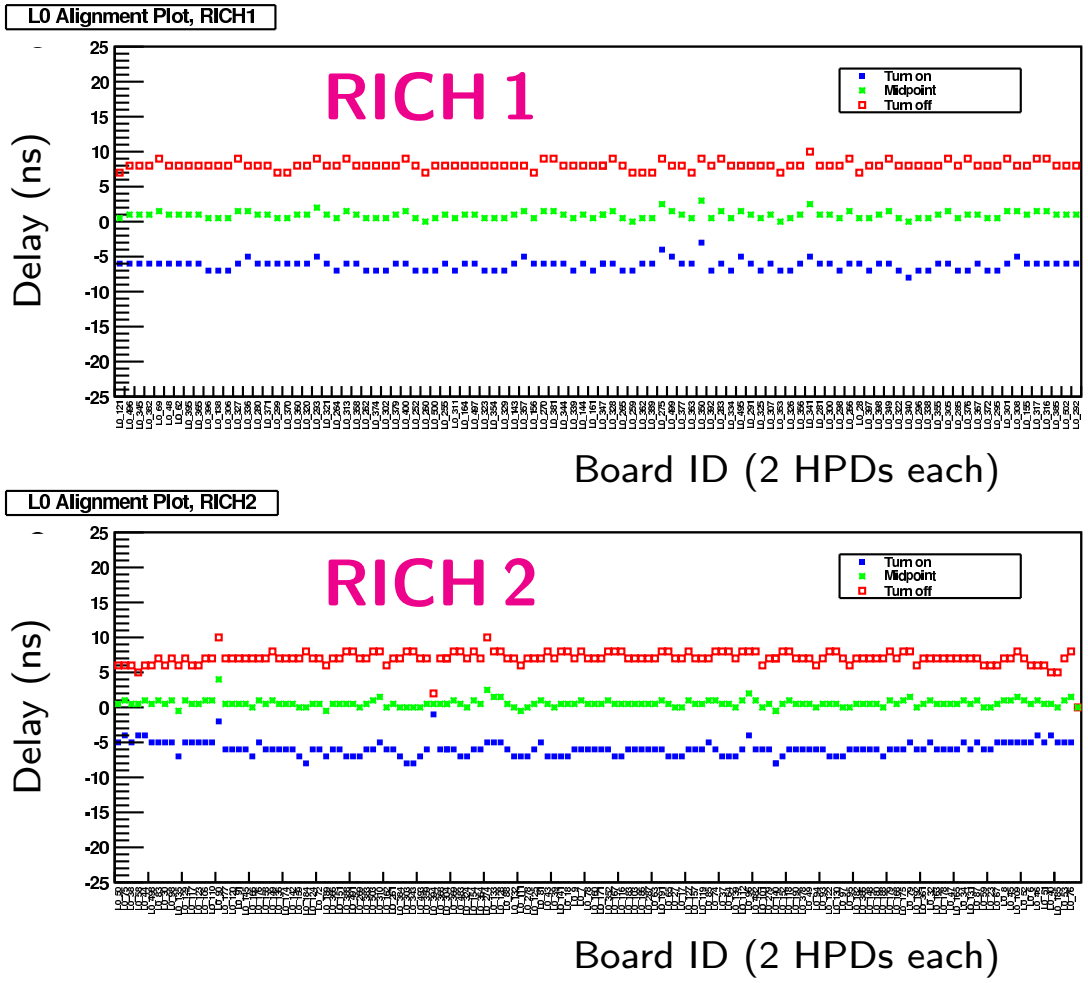
- DAQ time alignment
- spherical and flat mirrors alignment (*)
- magnetic distortion corrections (*)
- calibration of the gaseous refractive indices (T, P, composition)
- calibration of the refractive indices of the tiles of silica aerogel
- HPD imaging calibration (*)

(*) see A. Papanestis' presentation

The DAQ time alignment

two methods developed to maximize the photon detection efficiency

- internal stand–alone alignment with pulsed laser
- global alignment and fine–tuning with collisions



efficiency response to colliding beams

turn–on, middle, turn–off points

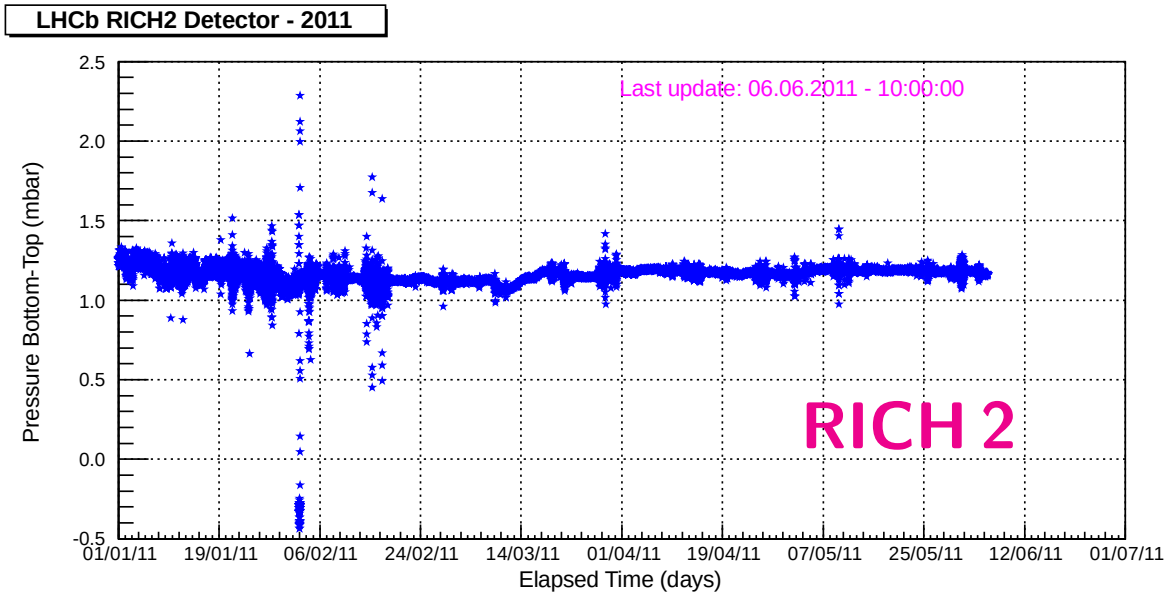
	Delay	RMS
RICH 1	0.93 ns	0.52 ns
RICH 2	0.59 ns	0.54 ns

very sharp distributions and excellent time resolutions

The gas system

gaseous radiators conditions and compositions important to achieve a good resolution

- temperature and pressure variations due to atmospheric changes
- hydrostatic pressure difference to monitor the composition
  - precision of the system $\sim$ 0.1 hPa
- composition of the gas periodically checked with dedicated measurement from chromatography
- off–line fine calibration with data on a run–by–run basis to match the correct refractive index



	RICH 1	RICH 2
C_4F_{10}	99.4%	–
CF_4	–	92.8%
N_2	0.4%	1.3%
CO_2 (*)	0.1%	5.9%
O_2	0.1%	$<$200 ppm

(April 2011)

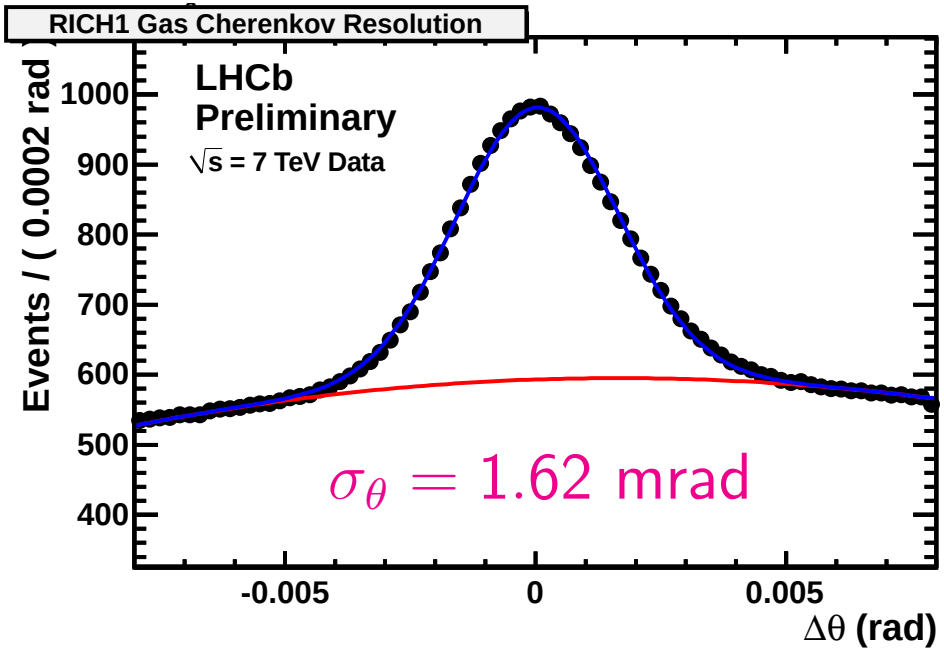
(*) CO_2 is currently used in RICH 2 to suppress the scintillation of the CF_4 radiator

The resolutions (i)

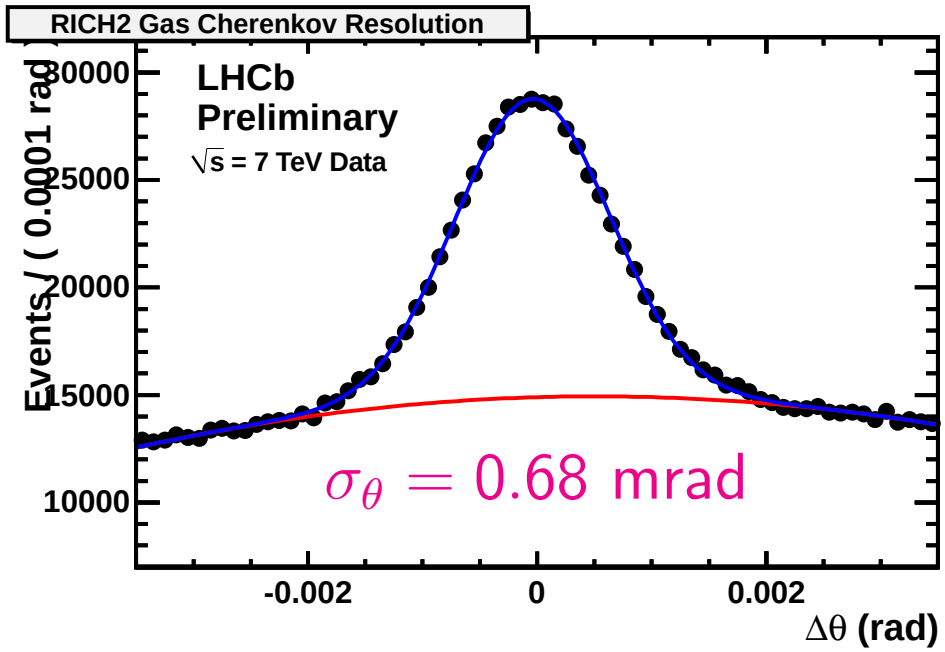
2010 data performance of gaseous radiators

- angular resolutions determined on a run–by–run basis
- excellent stability over the full year

RICH 1



RICH 2



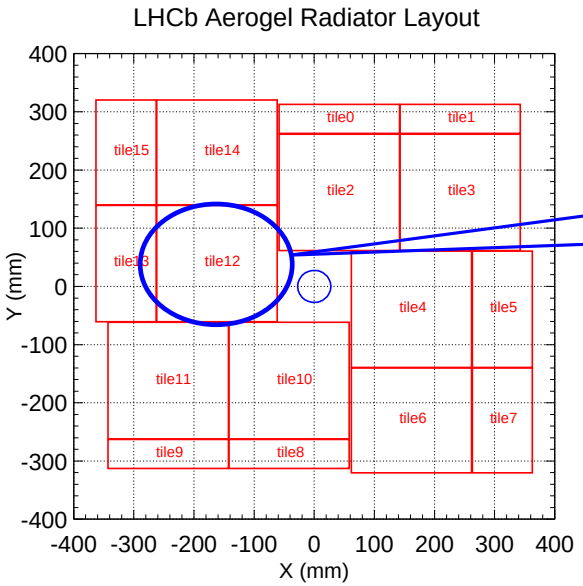
	C_4F_{10}	CF_4
$\sigma^{tot}(\theta_C)$	1.5 mrad	0.7 mrad

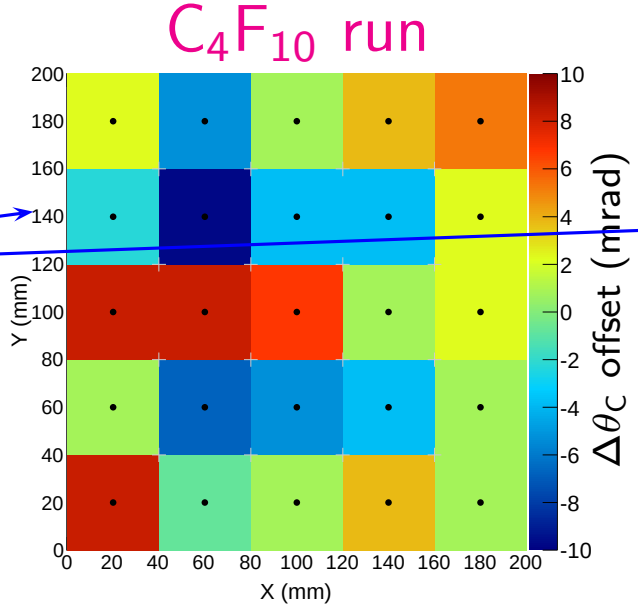
Monte–Carlo

The LHCb Collaboration, 2008 JINST 3 S08005

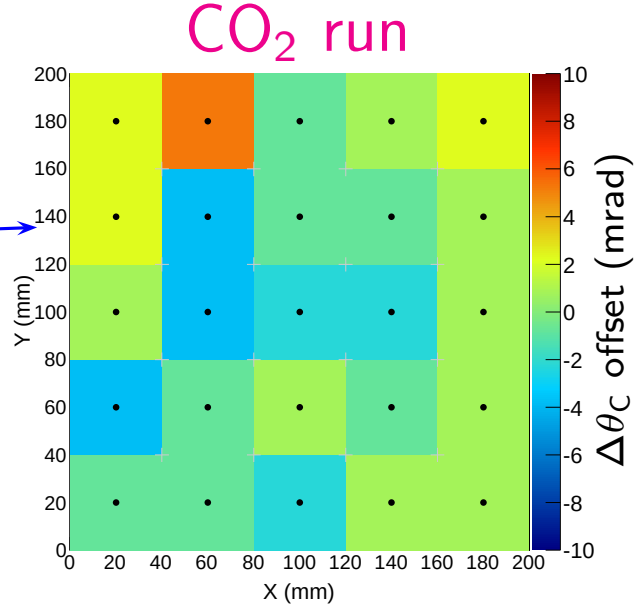
The resolutions (ii)

- 16 tiles of silica aerogel, 5 cm thick, in contact with C_4F_{10}
- photoelectron yield and angular resolution not quite as good as expected
- depth investigation during 2010
  - worsening due to absorbed C_4F_{10}
  - forward scattering enhanced $\longrightarrow$ additional scattering contribution up to 3.4 mrad
  - loss of photoelectrons $\longrightarrow$ up to –25% expected
- test run with CO_2 performed at the beginning of this year $\longrightarrow$ optical conditions successfully restored
- gas–tight housing box under construction (installation during the next end of the year stop)
- new challenge to improve the resolution: refractive index variation in a given block enhanced by C_4F_{10}





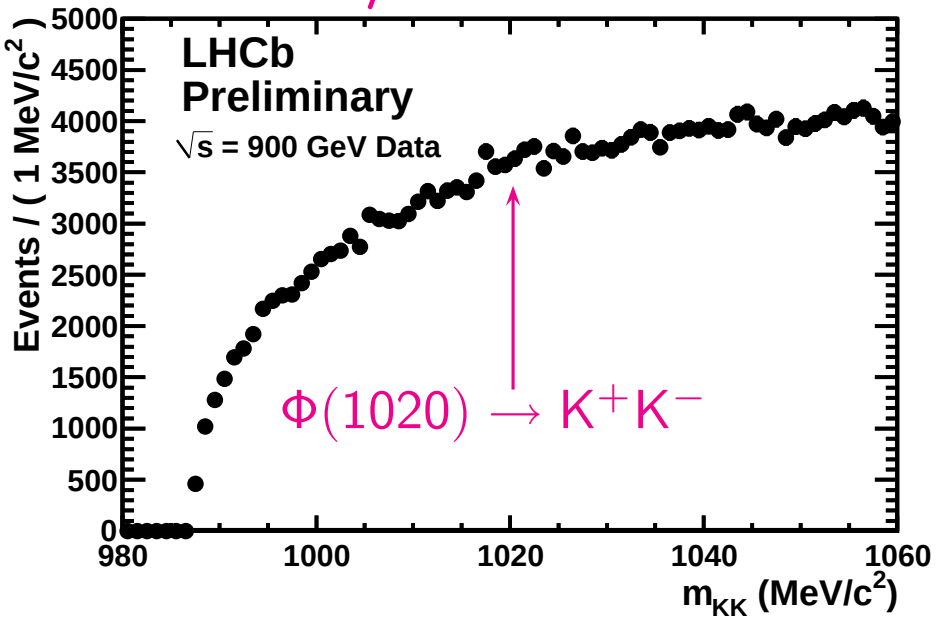
spread: 4.73 mrad



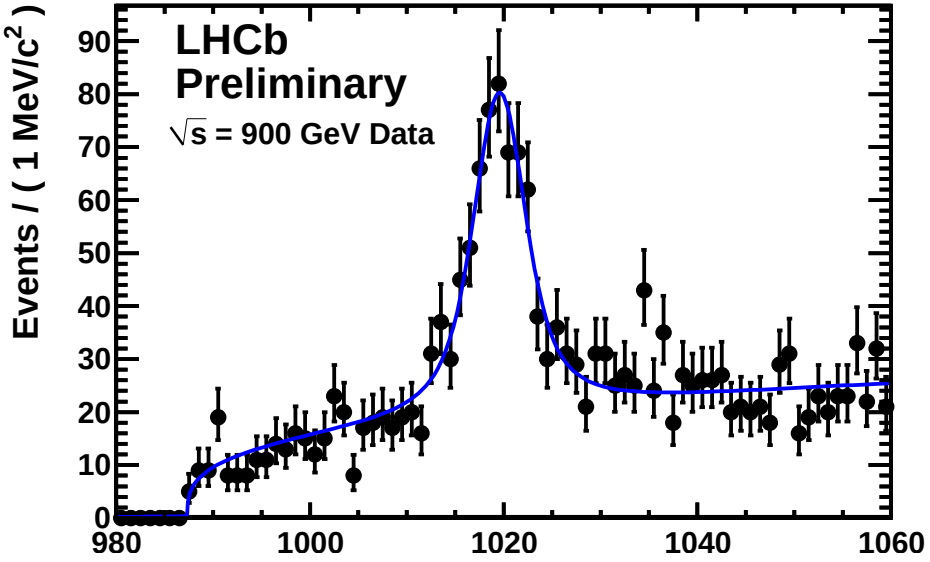
spread: 2.07 mrad

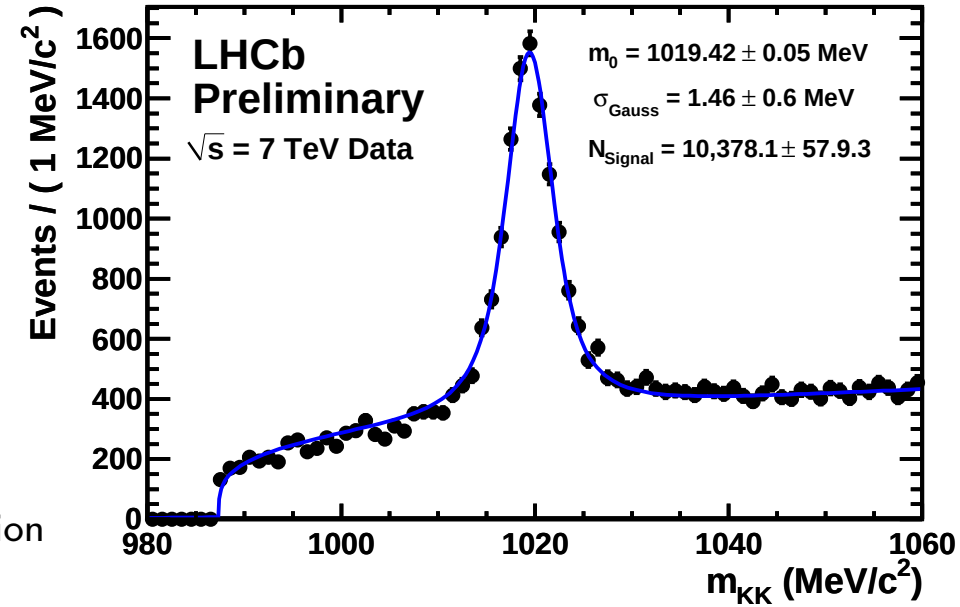
The power of RICH Particle Identification

w/o RICH PID



w/ RICH PID



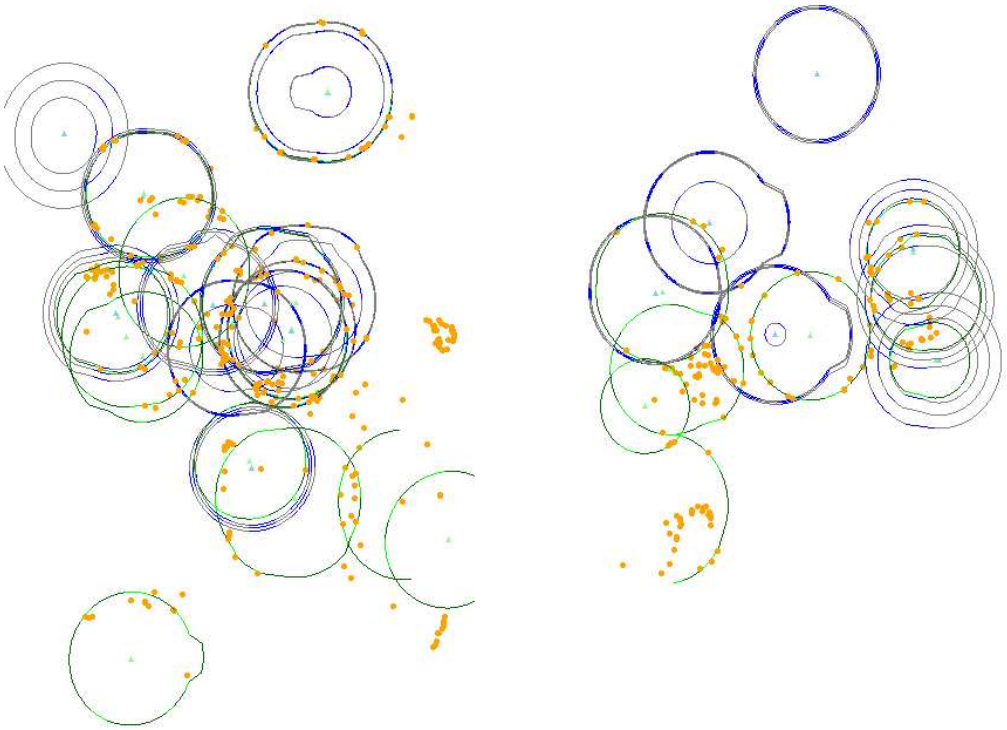


- $\Phi(1020) \longrightarrow K^+K^-$
- powerful pattern recognition routines
- evident importance of RICH particle identification
  - dedicated analysis to calibrate the PID
  - excellent S/B ratio

more about the performance in A. Papanestis' presentation

Conclusions

- the LHCb RICH system is fully operational and taking data
- calibrations and alignments routinely done with data
- excellent resolutions in agreement with expectation
- photoelectron yield studies started
- particle identification performance – see A. Papanestis' presentation



RICH 2 HPD panel
Cherenkov photons
of single pp collision
(from trackless ring analysis)