The operation of the LHCb RICH photon detection system in a charged particle test beam

Presented by S.Brisbane on behalf of the LHCb collaboration

Goals

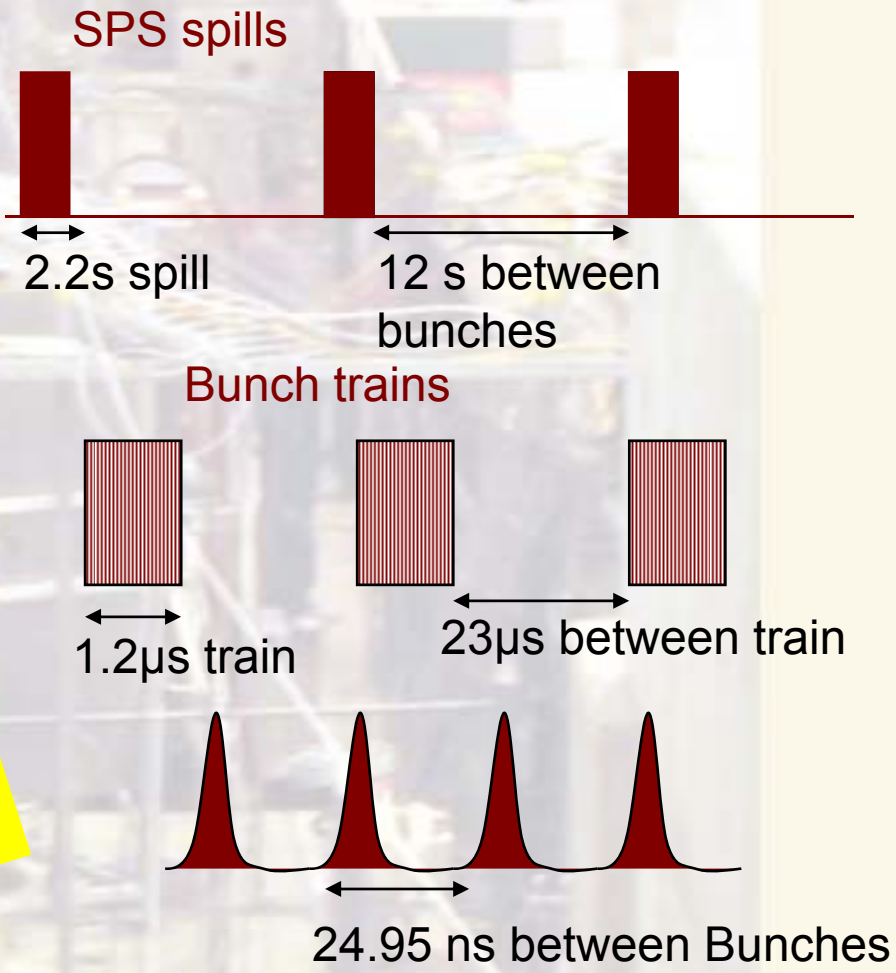
- In This Talk:
  - Validation of LHCb RICH* final hardware
  - Synchronous data taking at LHC bunch crossing rate
  - Estimate the photoelectron yield with a C_4F_{10} radiator
  - Determining the Cherenkov angular resolution in C_4F_{10}
- Check LHCb RICH alignment procedure (to be discussed by A.Papanestis, 19th October)

*For details of the full RICH detector in LHCb I refer you to the talk by N.Harnew on 16th October “An overview of the LHCb RICH detector status”

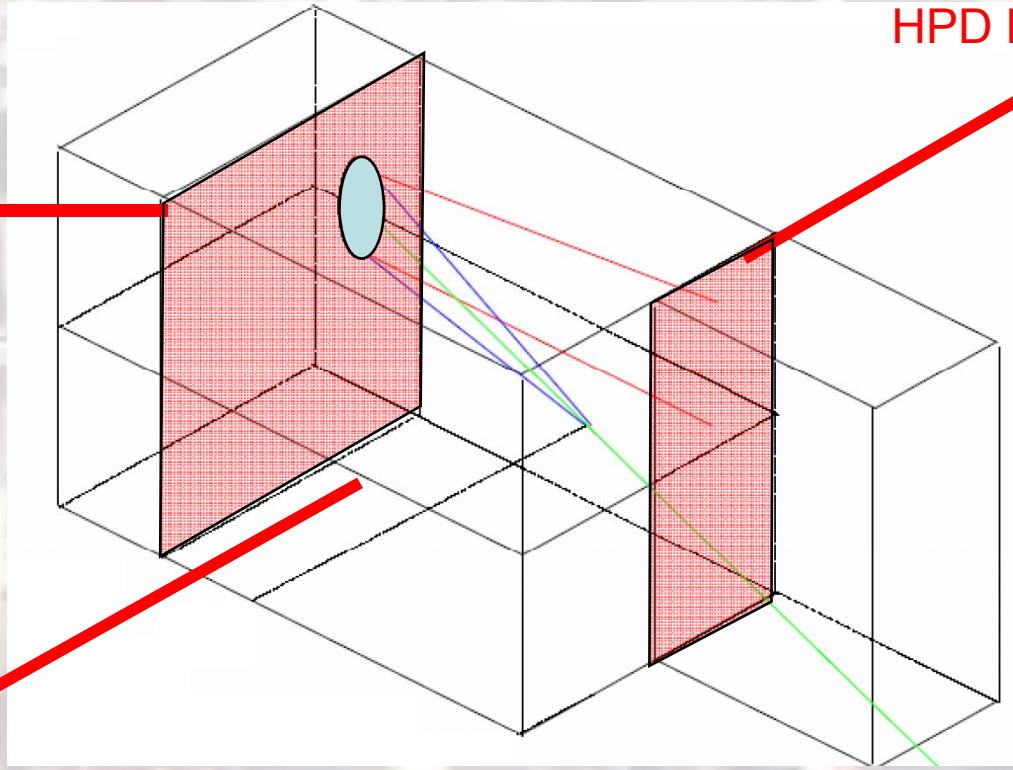
Beam structure

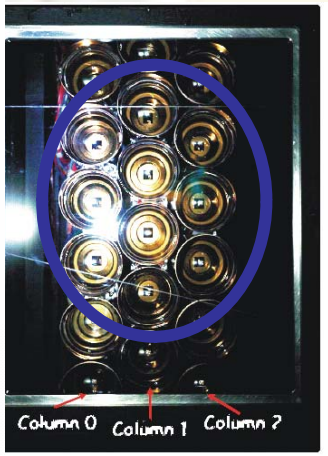
- Bunches at 80 GeV/c
- Electrons, pions are saturated in the radiators used
- particle composition extracted from fit to data
  - 90% saturated tracks
    - Expect mostly pions
  - ~7% kaons
  - ~3% anti-protons
- Average <1 particle per bunch train
- Electronics synchronous with beam

First test beam with the LHC bunch spacing



Test Beam Vessel





10 HPDs in acceptance

HPD

10 HPDs in test beam acceptance

– Vacuum tube of diameter 83 mm

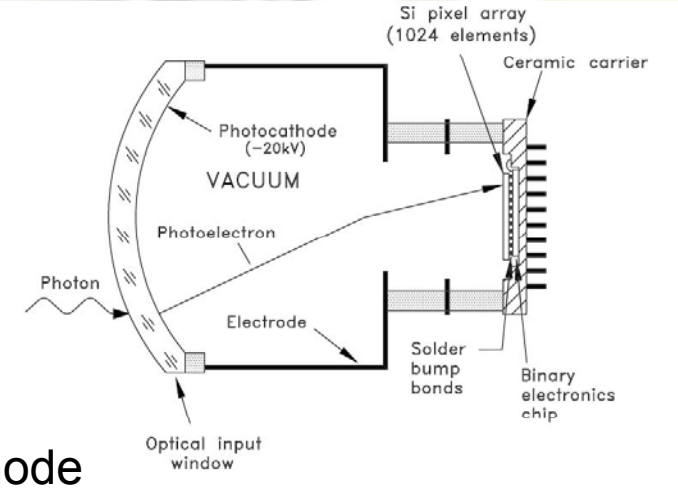
– S20 multi-alkali cathode sensitive at 200-600 nm

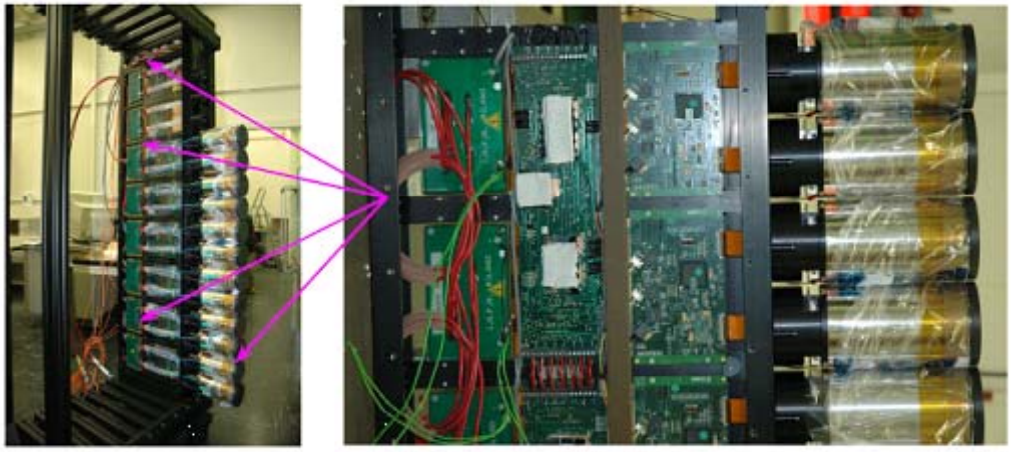
– 31 % average peak quantum efficiency

– Cross focussing optics

– Binary readout of hits recorded by pixels on the anode

– Refer to previous 2 talks for more details on the HPDs

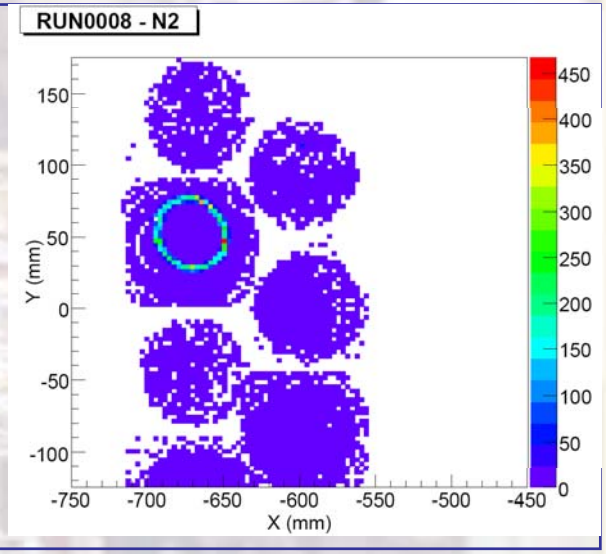


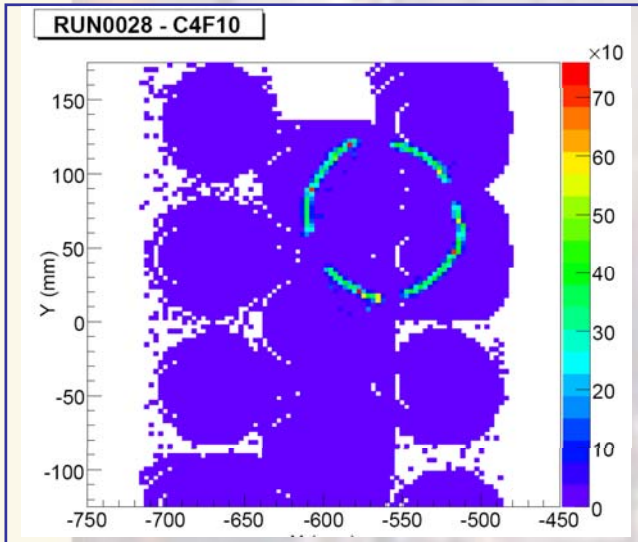


Radiators

N_2

- n-1 ~ $3 \cdot 10^{-4}$ at NTP
- Ring image contained in single HPD
- Cherenkov angle resolution minimally affected by alignment
- Photon yield integrated over 2π
- Simplest scenario
- 1 run taken for each HPD with mirror focus in HPD centre



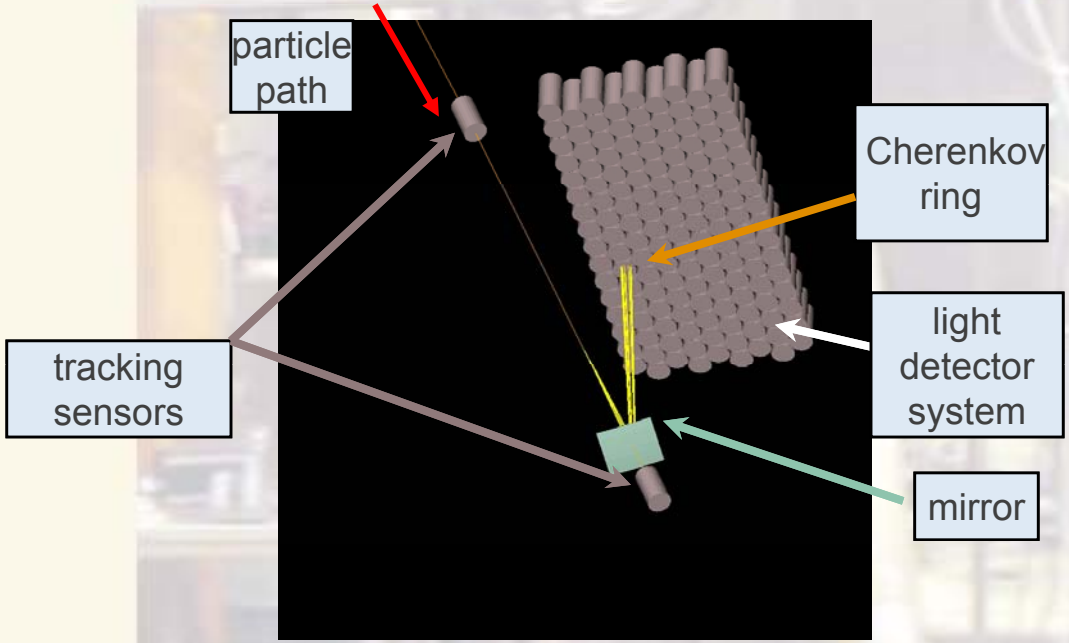


C_4F_{10}

- n -1 ~ $14 \cdot 10^{-4}$ at NTP
- Cherenkov angle is ~55 mrad
  - Ring spans multiple HPDs
  - HPD relative alignments important
- Photon yield statistics lower due to gaps
- Runs taken so rings fall on 3 or 4 HPDs
- Chosen as gas radiator in RICH 1

Simulation

- Full LHCb Monte-Carlo framework based on GEANT 4
  - Full simulation of particle interactions with material
  - Geometry specially modified from RICH 2 for the test beam
  - Particles generated with measured beam composition



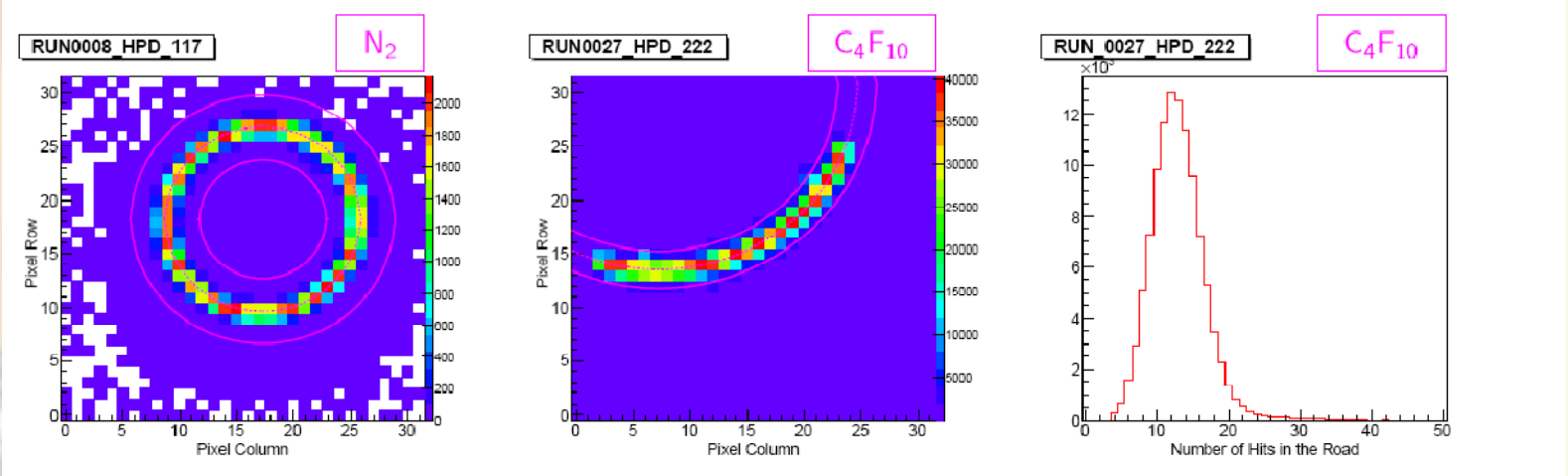
Simulation of test beam used to check C_4F_{10} photoelectron expected yields

Every contribution to the photo electron yield should be understood and modelled

Test Beam to provide the tuning of the simulation ready for the LHC next year

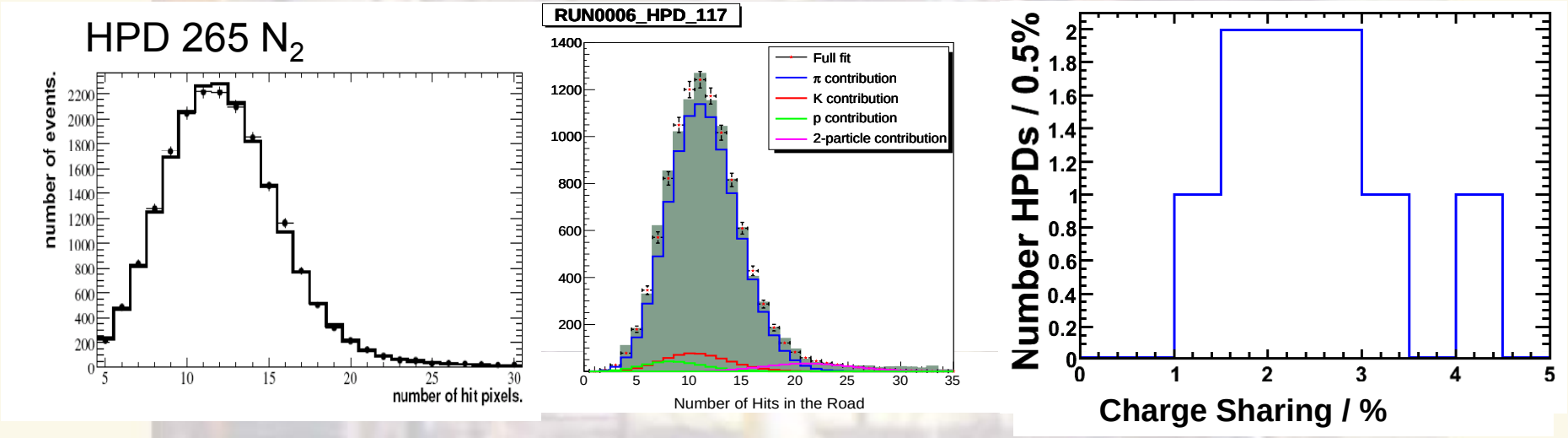
Event selection for photoelectron yield

1. Fit rings around the N_2 and C_4F_{10} data on event-by-event basis
   - Require at least 5 hits in each event
   - Ring is fit with a circle
2. Define signal region as a road around the average ring radius, <R>
   - Road is <R> ±3 pixels for N_2 and <R> ±1.7 for C_4F_{10} data
   - Select events with 4 or more hits inside the road
   - Events with 3 or more hits outside this road are rejected
3. Histogram the number of hits in the road for each event



Modelling Photoelectron yield

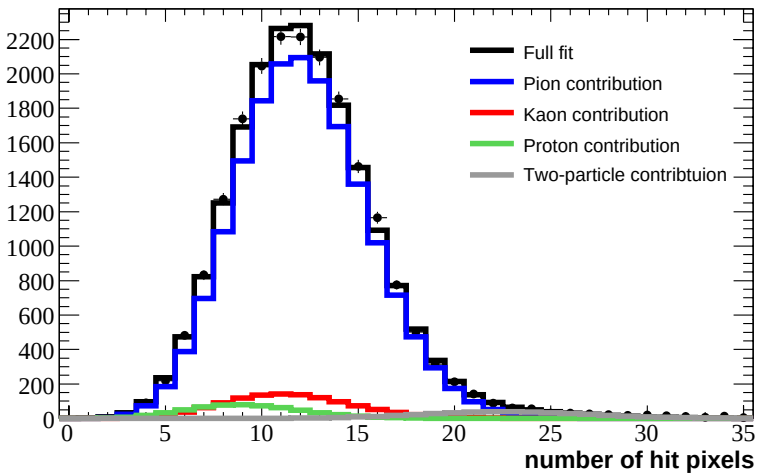
- Extract yield from a fit to the number of hit pixels
- Series of terms in fit model
  - Sum of Poisson contributions modelling Cherenkov emission from π, K, p
  - Abundances of above particles left as free parameters
  - Terms in fit allowing for 1, 2 (and 3) beam particles per event
- Term to model probability that 2 photoelectrons strike the same pixel but only 1 hit recorded
- Fixed term to allow for a single photoelectron to produce multiple adjacent hits
  - Due to sharing of charge between pixels
  - We measure this charge sharing for each HPD using a low intensity light source in vessel

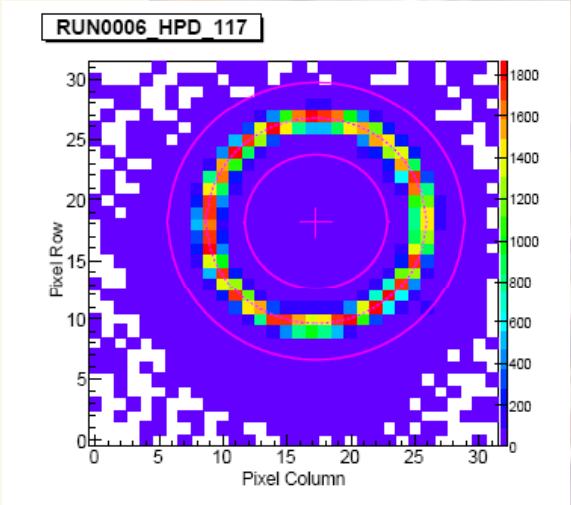


Photoelectron yield in N_2

- HPD 117 measured, repeated for 264, 265
- Dominant particles are saturated
- Expected yield determined analytically
  - Error dominated by assumed 5 % error on QRT (detector efficiency)
- Quantum efficiency measured by manufacturer
- χ^2 of fit for HPD 117 31.5/21

HPD 265 N_2





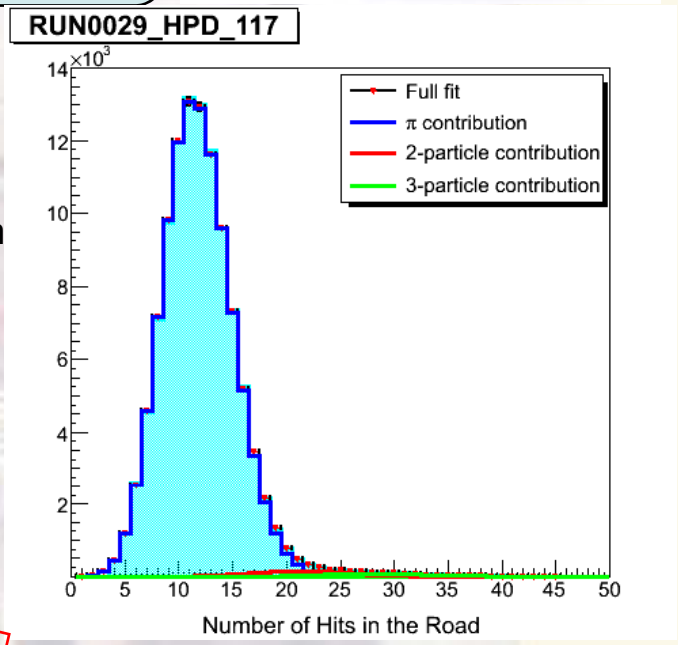
Results are 12 p.e, in good agreement with expected yields

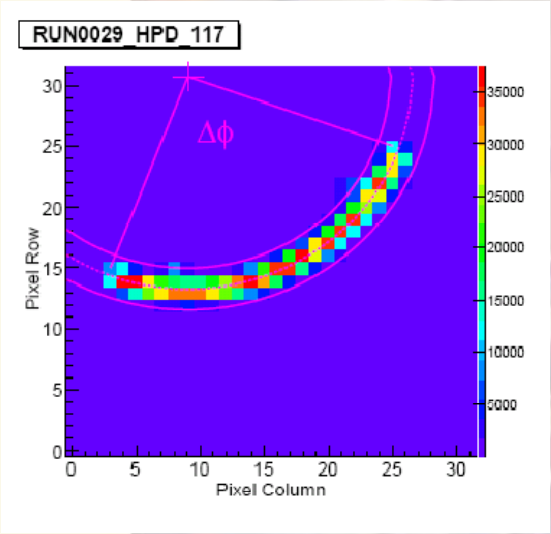
Preliminary

HPD	Measured Yield	Expected Yield
117	12.32±0.12	12.20±0.62
264	13.14±0.13	14.09±0.70
265	12.56±0.12	12.81±0.65

Photoelectron yield in C_4F_{10}

- Allow for a 3 particle contribution, with only pions in the fit
- χ^2 of fit for 117 19/21; suggests model is sufficient
- Multiple particle terms amount to 2% of total
- Expected yield determined from full LHCb Monte Carlo simulation
- Yield is 9 photo-electrons per saturated particle per radian, consistent with simulated yields
  - 10 % Spread in N_{pe}, consistent with Q.E. variations between tubes
  - dμ/dΔφ ratio checked and varies around ring following measured quantum efficiency





HPD	Data $\mu/\Delta\phi$
36	10.7±0.2
88	8.3±0.5
116	8.6±0.3
117	8.5±0.4
222	9.0±0.5
223	8.9±0.3
265	8.8±0.3
282	9.4±0.6
283	9.2±0.6
	9.1±0.7

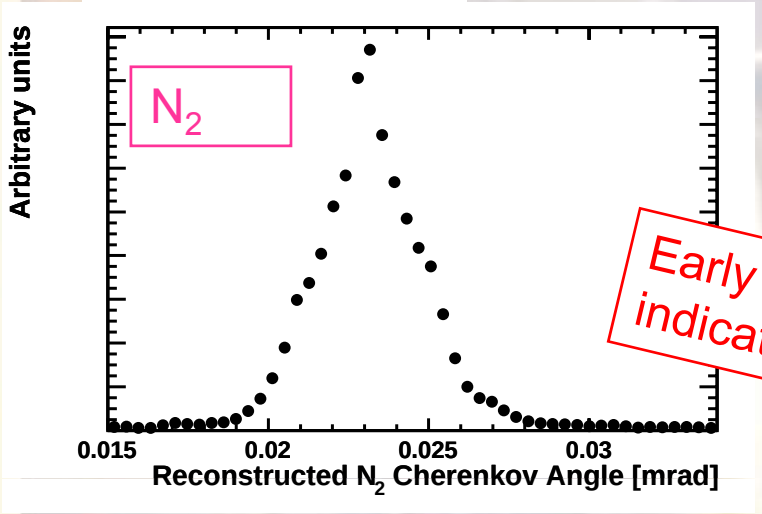
Preliminary

- Evaluate systematics
  - Vary size of the photoelectron road
  - Previously fixed values in the fit allowed to vary with Gaussian penalty term
  - Remove 3 particle term
  - Change fit range
- Systematics contribute at 5 % level

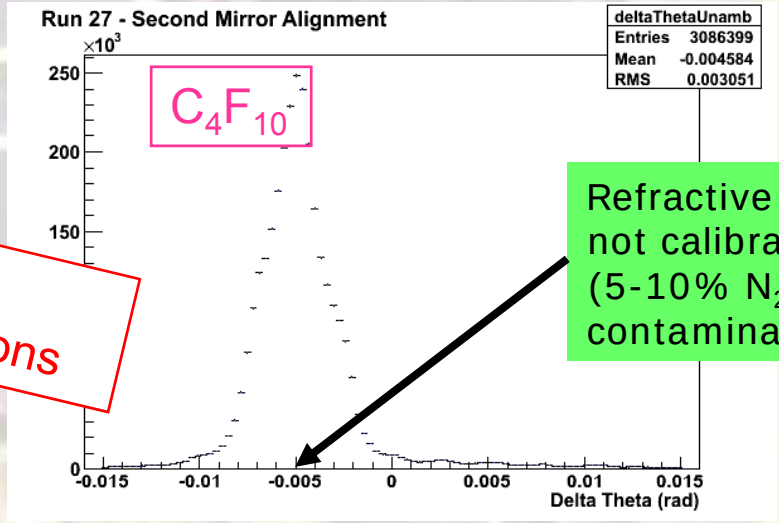
Early Cherenkov Angle Study

- Encouraging early results for Cherenkov angle resolution using ray tracing
- Single photon resolution in N_2 likely to be around 1.6 mrad
  - Ongoing work to understand relative importance of the various components of the contributions to the resolution.
- Studies in C_4F_{10} suggest angular resolution is also ~1.6 mrad
  - Excellent resolution reached due to iterative alignment procedure
    - Will be discussed in detail on Friday

HPD117



Early indications



Refractive index not calibrated (5-10% N_2 contamination)

Summary

- Data acquisition at LHC clock frequency successful
- Photo-electron yields meet requirement for detector
- Simulation and reconstruction with the full LHCb framework successful
- First studies of Cherenkov angle resolution in progress with encouraging early results

- Photon detection system of LHCb working in realistic environment

LHCb RICH 2 arriving at the pit