Particle Identification with the LHCb Experiment

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On behalf of the LHCb Experiment

IV INTERNATIONAL SYMPOSIUM ON LHC PHYSICS AND DETECTORS

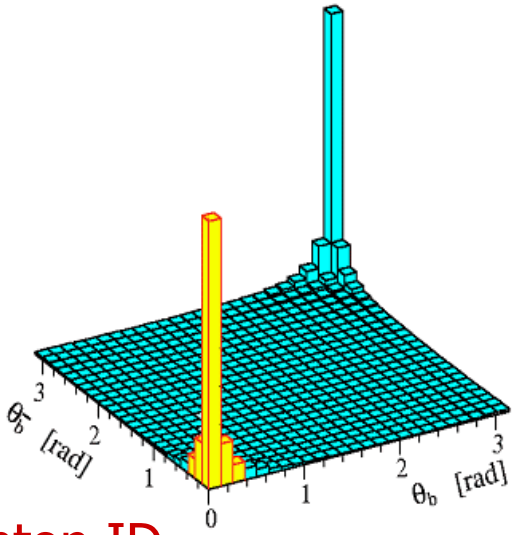
Introduction

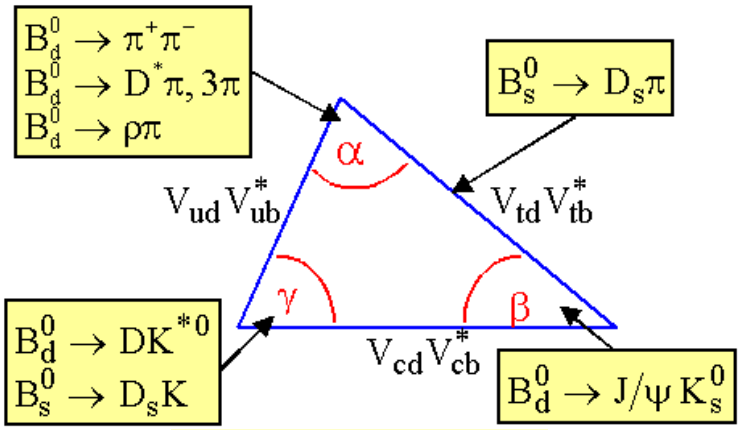
- LHCb Goals and Detector Overview
- Hadron Identification
  - System Requirements
  - Design Status
  - Reconstruction and Performance
- Lepton Identification
  - Methods and Performance
- Summary

Experimental Goals

Precision Measurements of CP Violation in b decays

- Large Samples of b decays
  - At LHC startup, $N_{bb} = 10^{12}$ / year
  - b production predominately at small polar angles
    - LHCb optimized as single forward arm spectrometer



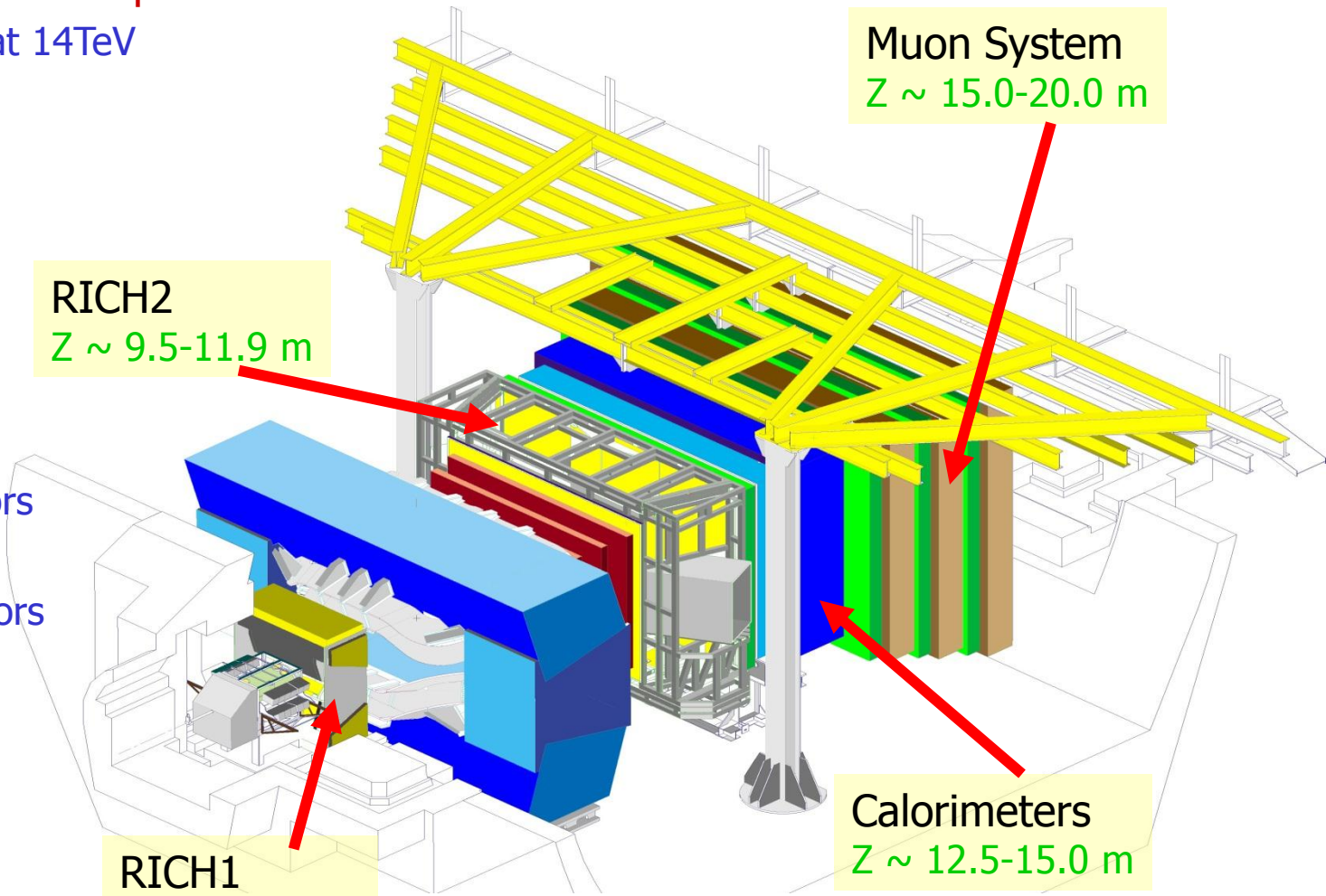


Example decays

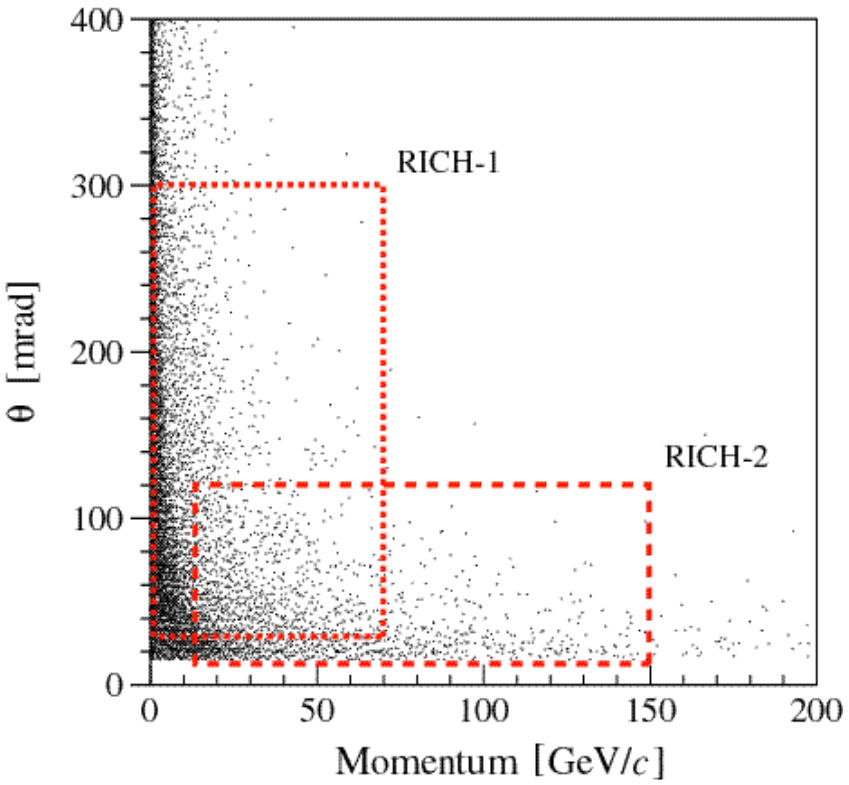
- Hadron and Lepton ID
  - Many pure hadronic final states
    - Particle identification (π/K) essential
  - Leptonic final states
    - Efficient electron/muon ID
  - Flavour tagging

LHCb Experiment

- Dedicated B physics Experiment at the LHC
  - pp collisions at 14TeV
- Acceptance :
  - 15-300mrad (bending)
  - 15-250mrad (non-bending)
- Particle ID
  - RICH detectors
  - Calorimeters
  - Muon Detectors
- For complete overview see other LHCb speakers

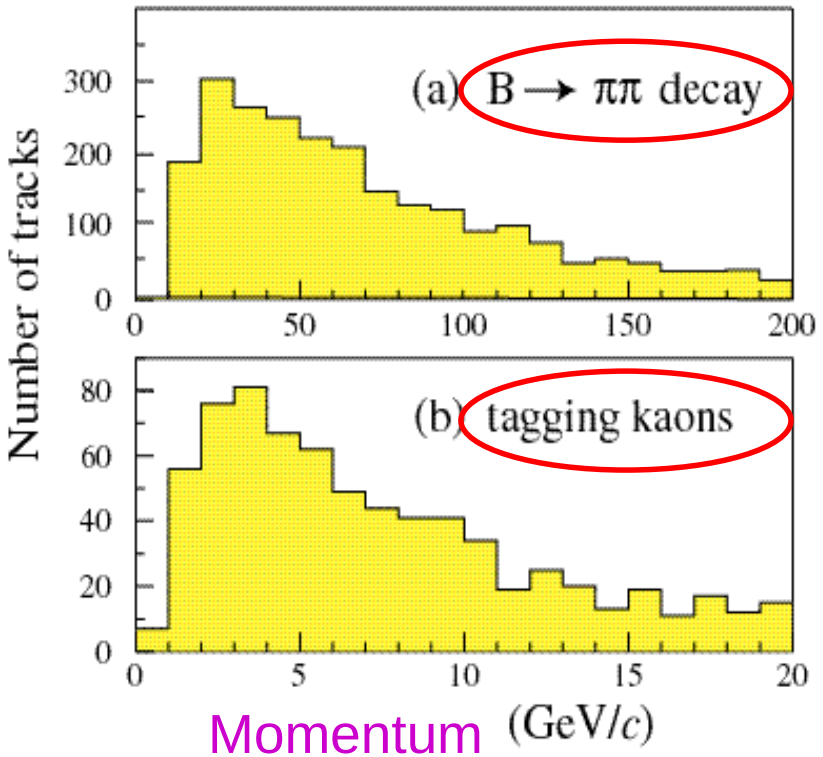


Physics with Hadron Identification



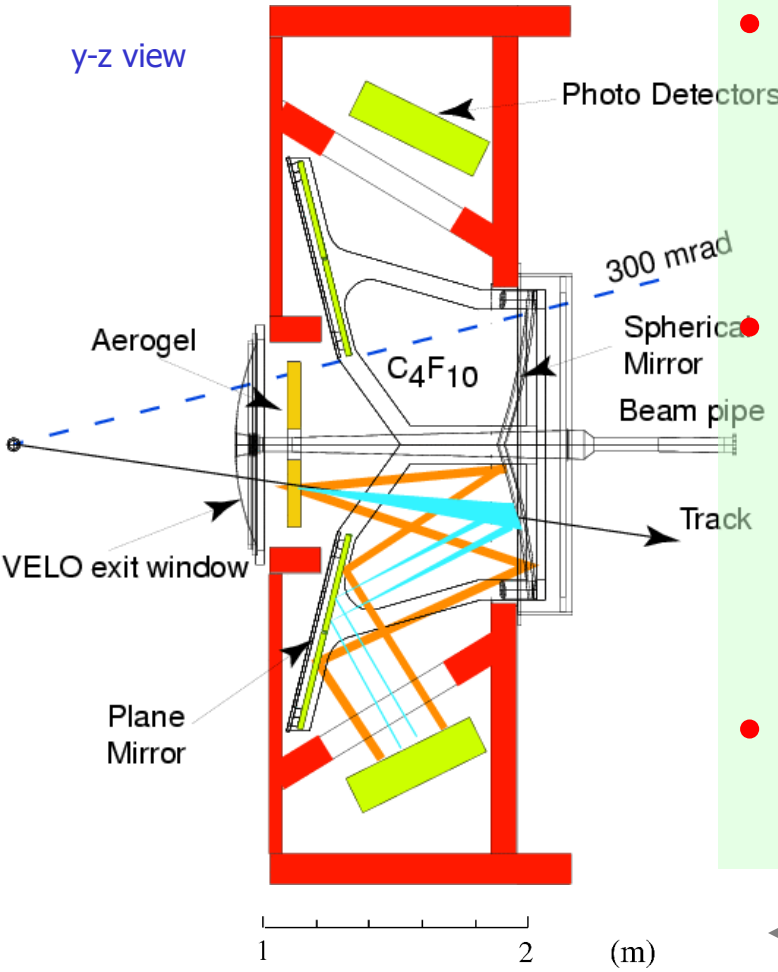
- Two independent detectors
  - "RICH1" : Aerogel and C_4F_{10}
  - "RICH2" : CF_4

- Require π/K separation for 1-150 GeV/c



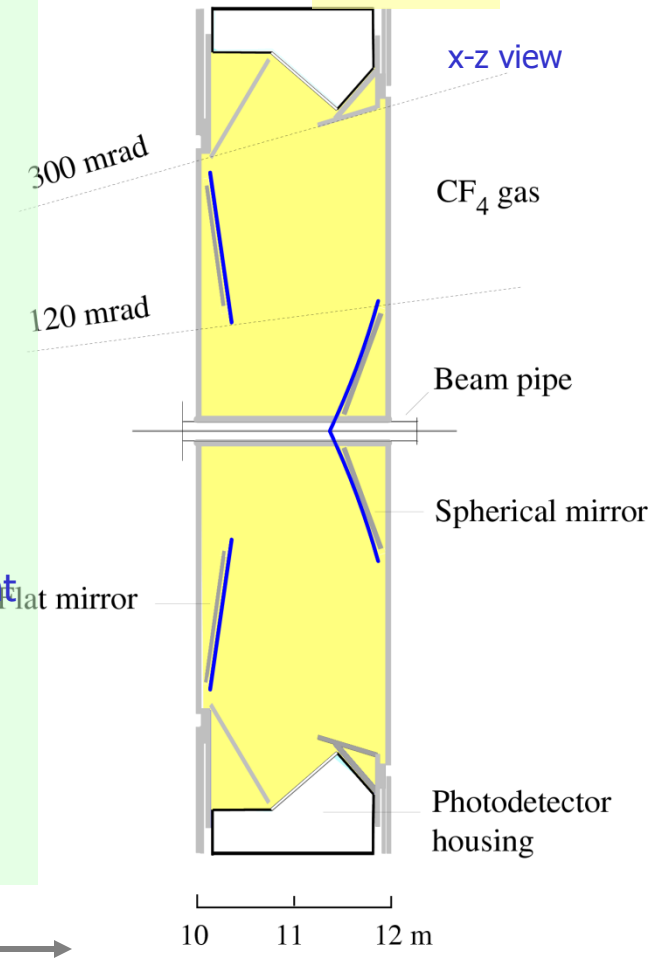
RICH System

RICH1



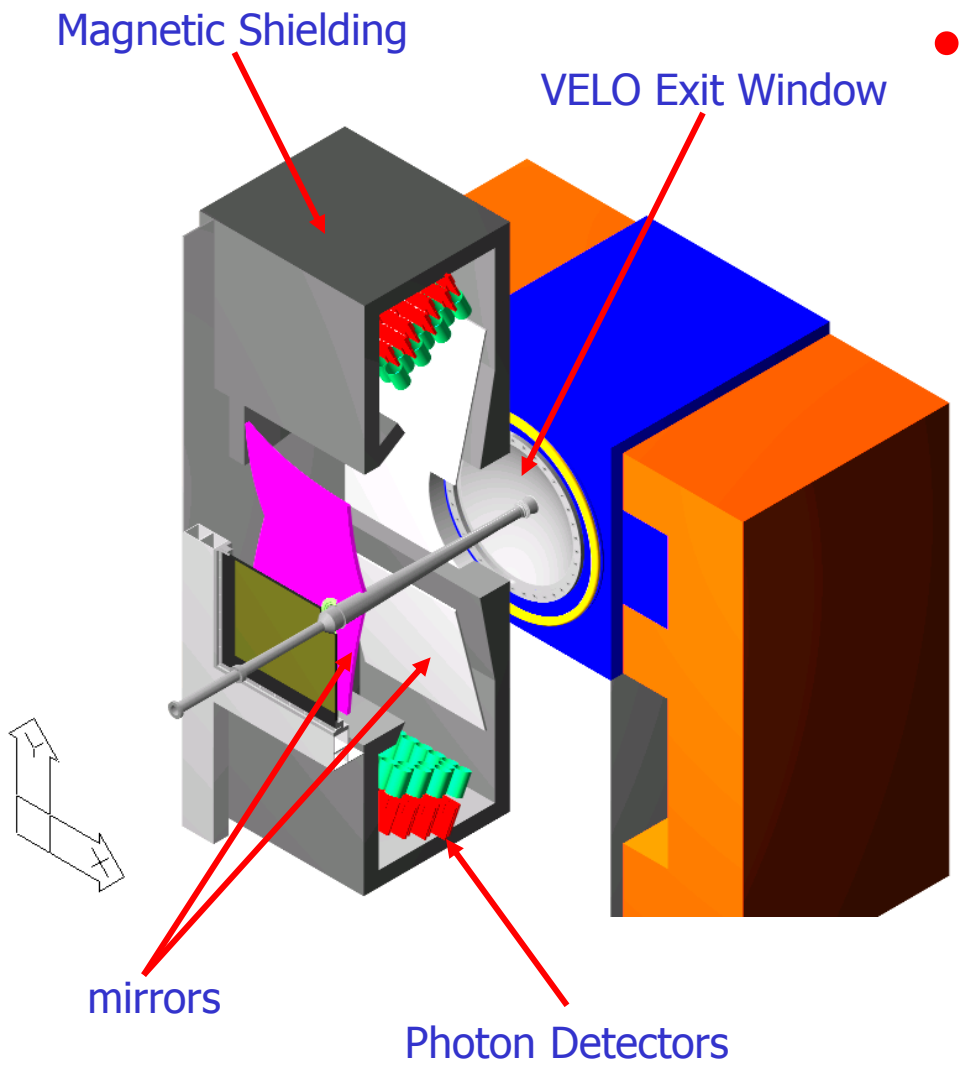
- Different radiator media
- Spherical Mirrors
  - Focus Cherenkov radiation
  - Tilted to keep photon detectors outside acceptance
- Secondary flat mirrors
  - Photon detectors further out of acceptance
  - Maximise radiator length within z footprint
  - Helps with magnetic shielding
- Acceptance
  - Rich1 25-300mrad
  - Rich2 15-120mrad

RICH2



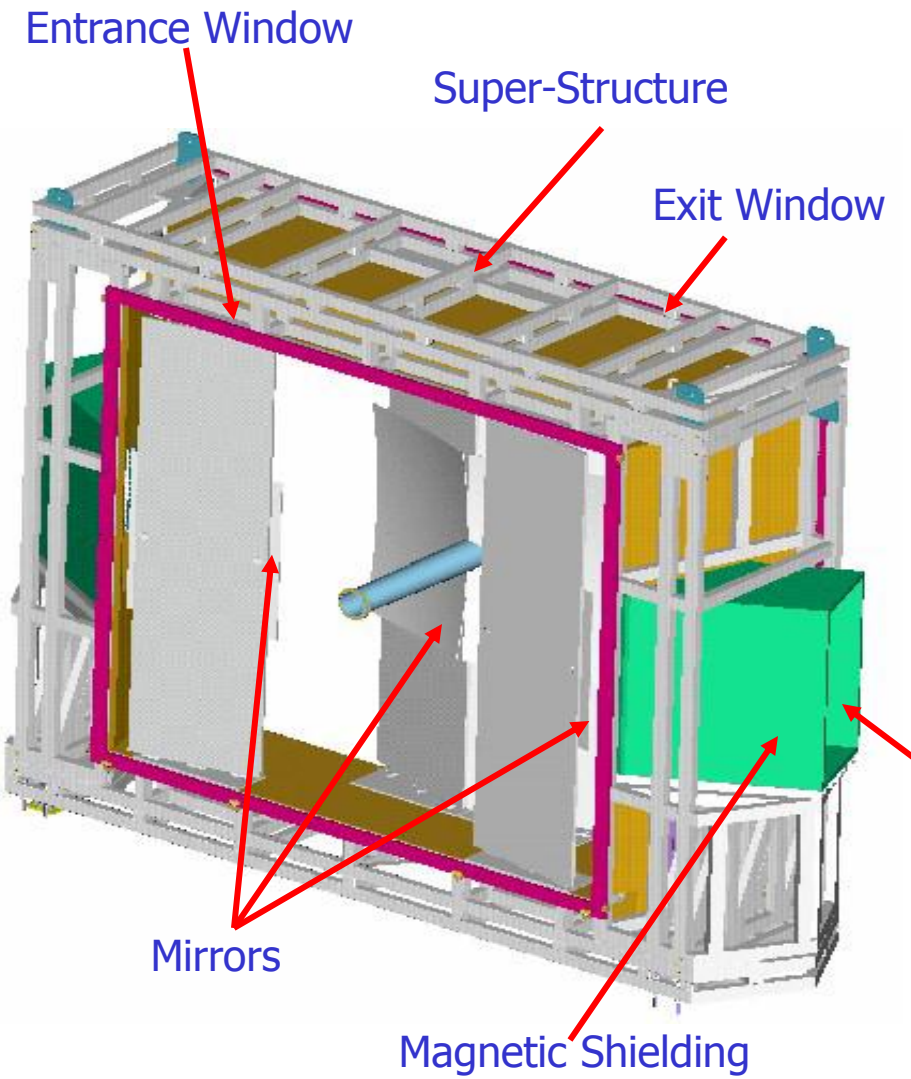
Note Scale Difference

RICH1 Design

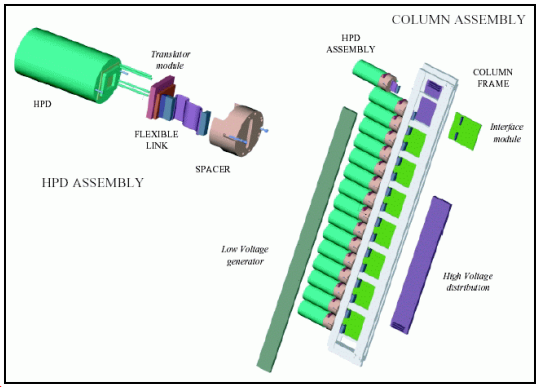


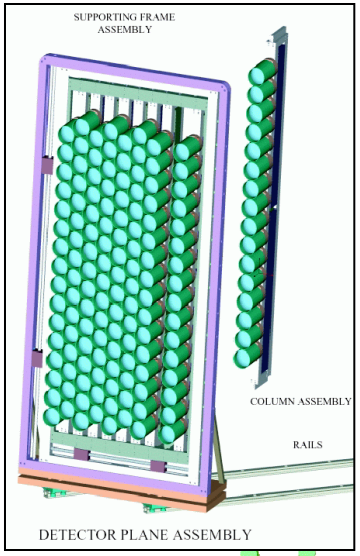
- Extensively redesigned for LHCb re-optimisation
  - X_0 reduced from 14% to 8.3%
    - 5.7% due to radiators
  - λ_I reduced from 4.5% to 3.1%
    - Entrance window removed. Sealed to VELO instead
    - Low mass mirrors
      - Glass coated Be, carbon-fibre composites
  - Increased Magnetic Field for trigger
    - Increased Shielding
      - Maintain field at photon detectors to <10 Gauss
    - Secondary flat mirrors
    - Vertical orientation to increase B field on axis

Rich2 Engineering



- Tracking station removal
  - → 20% length increase
- EDR approved 03/2002
  - Extensive structural analysis
    - Magnetic fields
    - Gravitation deflections
    - Seismic event stability

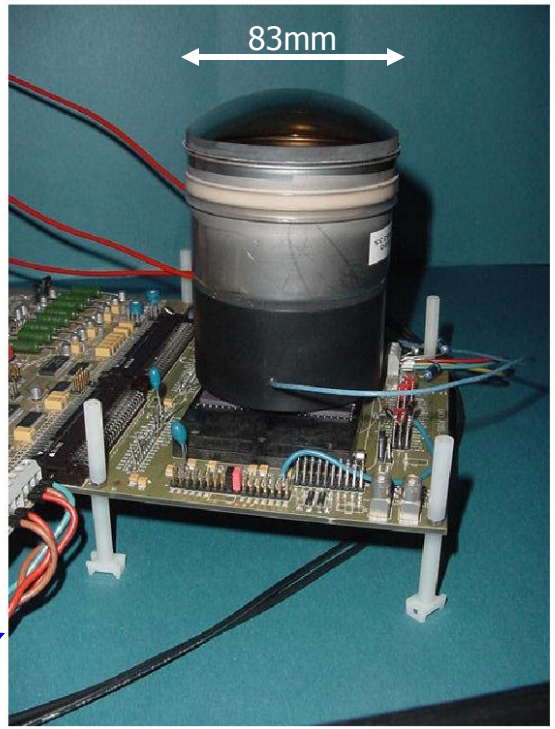


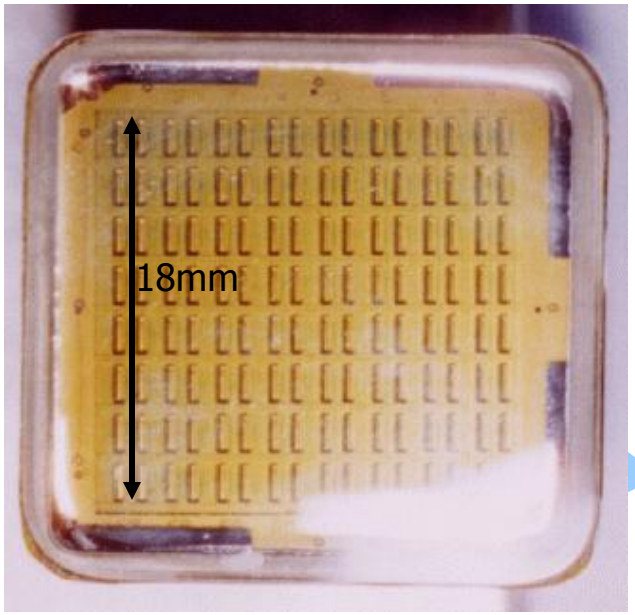


Photon Detectors

Photon Detector Requirements

- Coverage of 2.6 m^2 with highest possible acceptance
  - Granularity of 2.5 x 2.5 mm^2
- Single photon sensitivity for λ = 200-600nm
- LHC speed readout at 40 MHz





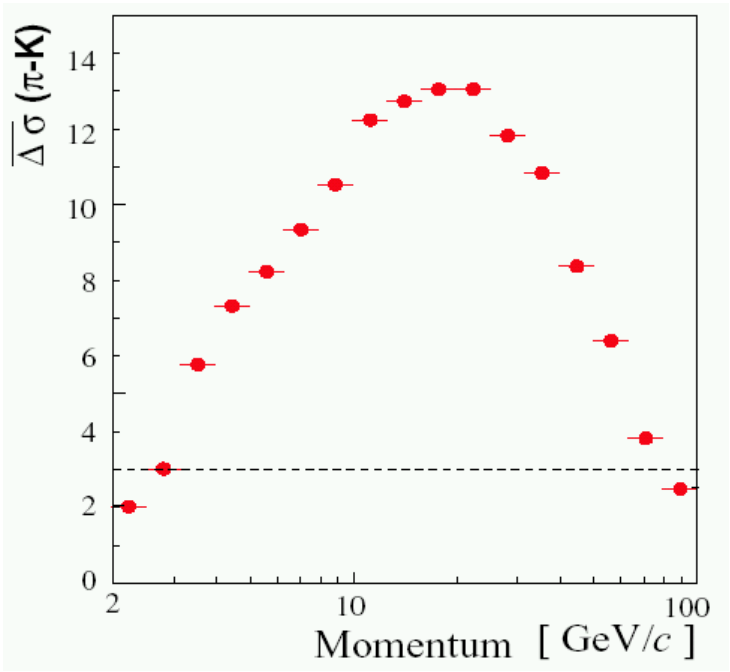
Baseline : **H**ybrid **P**hoton **D**etectors (coll. CERN, DEP)

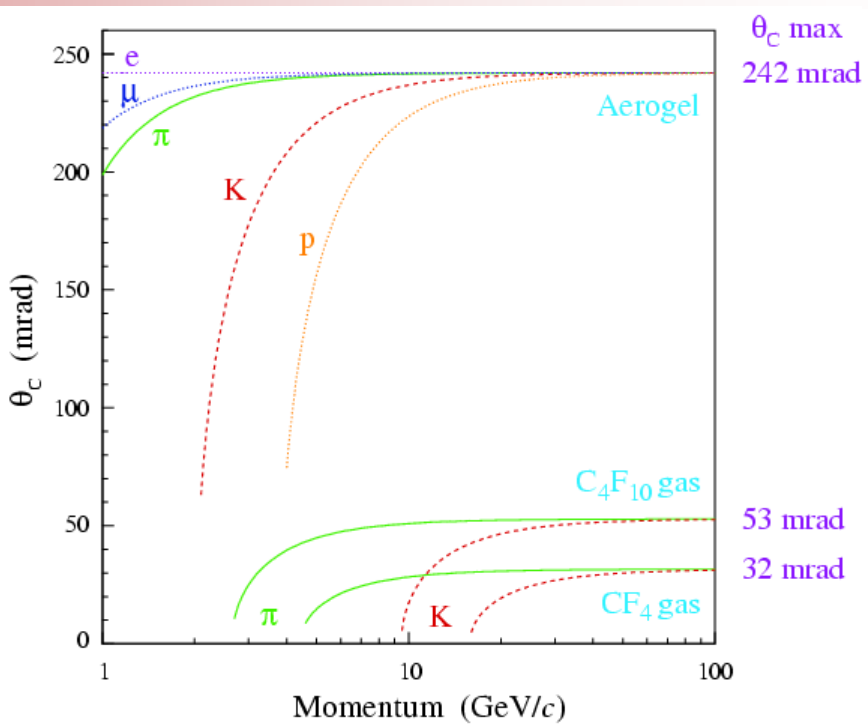
Backup : **M**ulti-**A**node **P**hoto**M**ultipiler (Hamamatsu)

Cherenkov Radiators

$$\cos(\theta_c) = \frac{1}{n \cdot v/c}$$

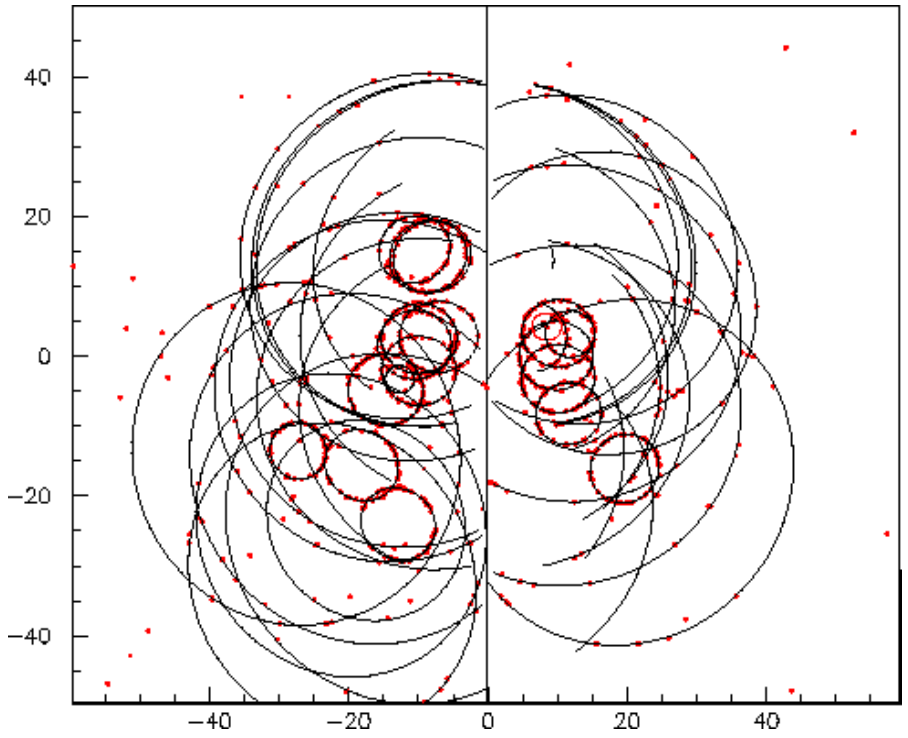
- Overall the 3 radiators provide excellent π/K separation over the full momentum range





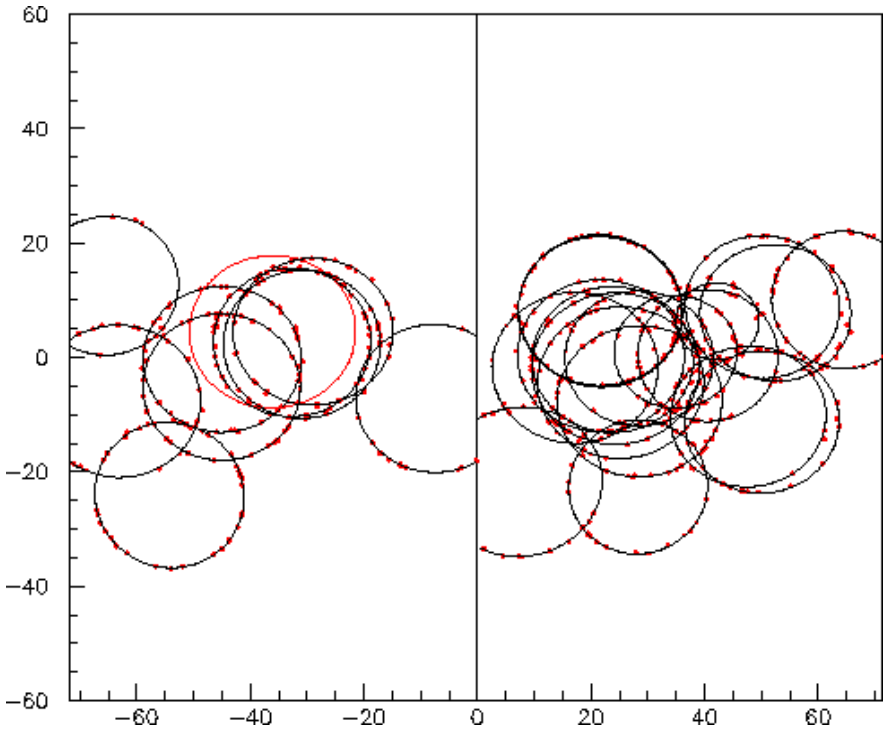
	Aerogel	C_4F_{10}	CF_4	
L	50	850	1670	mm
n	1.03	1.0014	1.0005	
θ	242	53	32	mrad
π	0.6	2.6	4.4	GeV/c
K	2.0	9.3	15.6	GeV/c

Cherenkov Rings



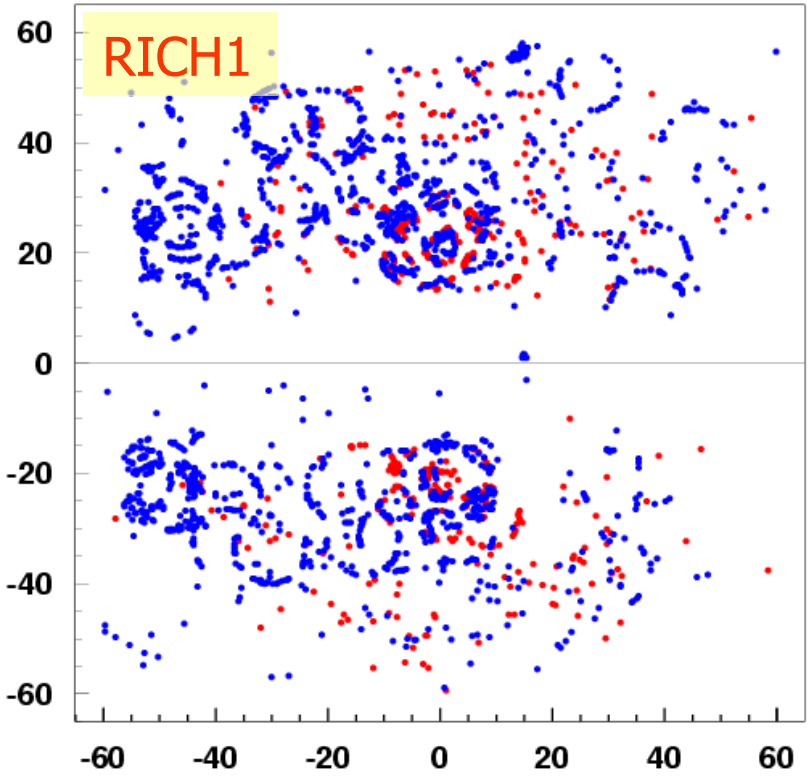
C_4F_{10} (small)
Aerogel (large)

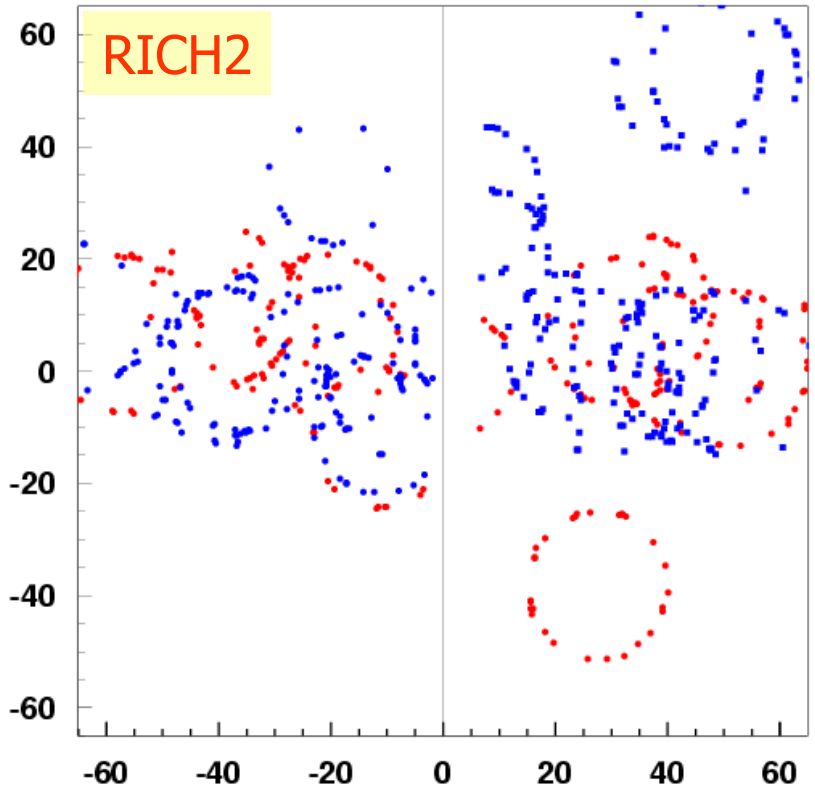
CF_4



More Realistic Simulation…

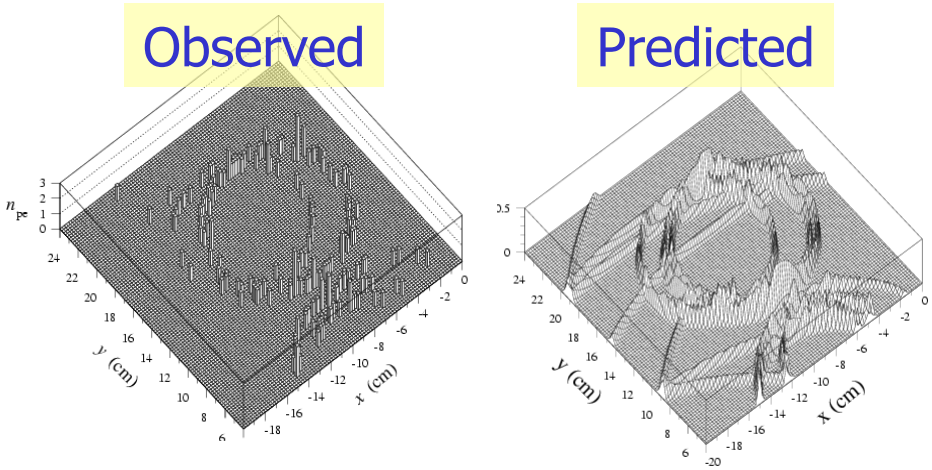
- Full GEANT3 based simulation used in performance studies
  - Fully realistic background simulation
  - Very busy environment ⇒ RICH pattern recognition is a complex task

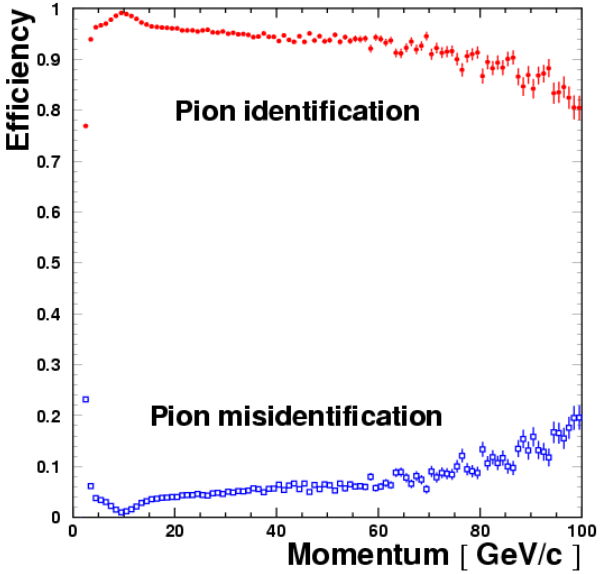


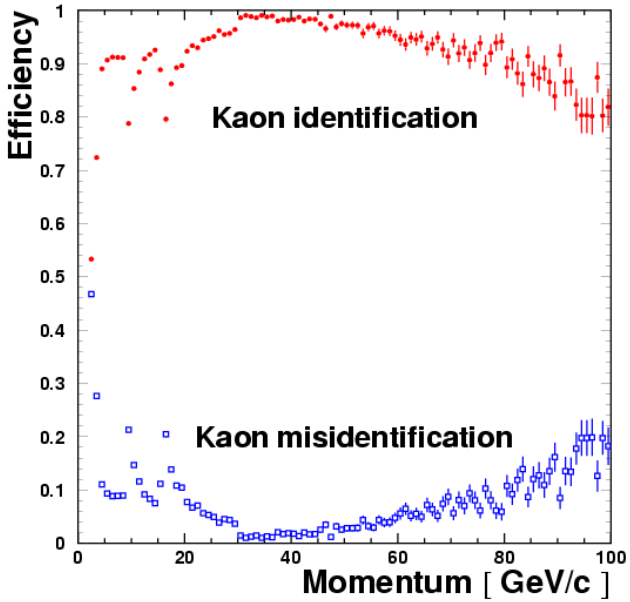


RICH Pattern Recognition

- Pattern recognition approaches
  - Track based : Global
    - Precise treatment of overall event
    - Offline reconstruction
  - Track based : Local
    - Fast single track approach
  - Other approaches also under study
    - E.g Ring Finders, Maximum Entropy.





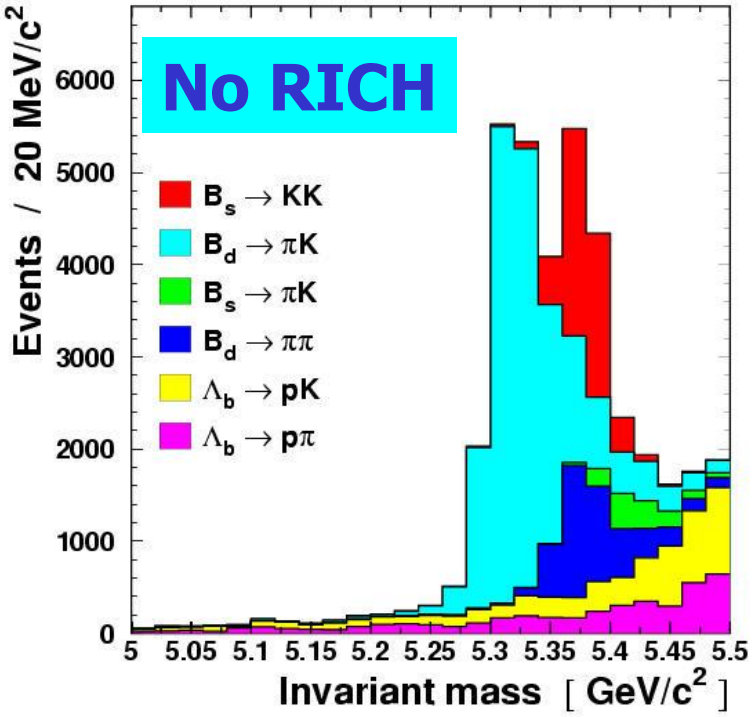


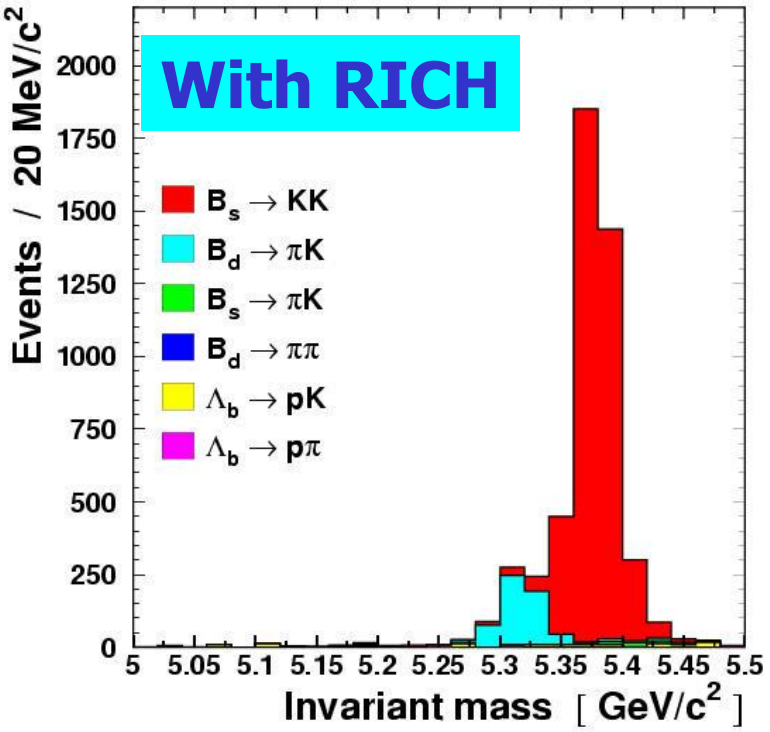
- Cherenkov Angle resolution (mrad)
  - Aerogel 1.82
  - C_4F_{10} 1.26
  - CF_4 0.59
- No. Detected Photons
  - Aerogel 7
  - C_4F_{10} 30
  - CF_4 23

Hadron ID : Physics Performance

- **RICH essential for hadronic decays**
- Example : $B_s \rightarrow K^+K^-$
- Sensitive to CKM angle γ

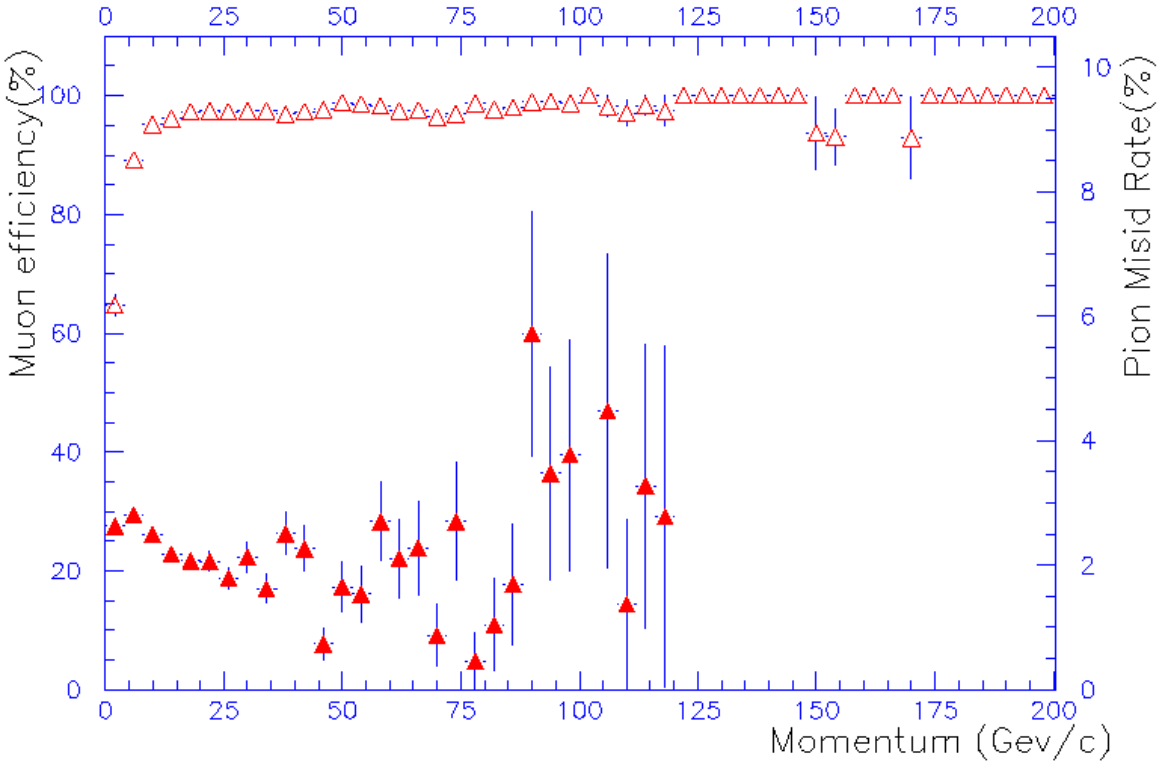
- Signal Purity improved from 13% to 84% with RICH
- Signal Efficiency 79%





Muon Identification

- Muons selected by searching for muon stations hits compatible with reconstructed track extrapolations
  - Compare track slopes and distance of muon station hits from track extrapolation



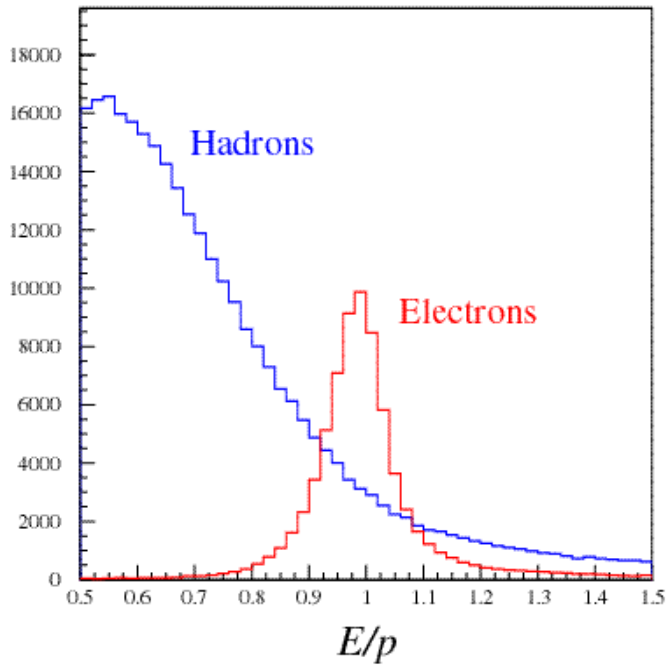
For P>3GeV/c

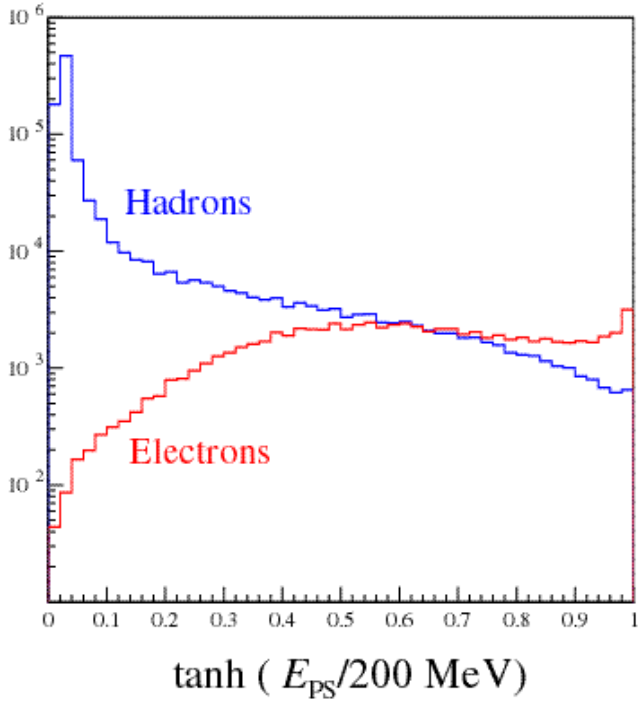
$\mu_{eff} = 96.7 \pm 0.2$ %

$\pi_{misid} = 2.50 \pm 0.04$ %

Electron Identification

- Discriminating variables
  - Electromagnetic Calorimeter cluster energy / reconstructed track momentum (E/P)
  - Energy deposition in pre-shower detector (E_{PS})

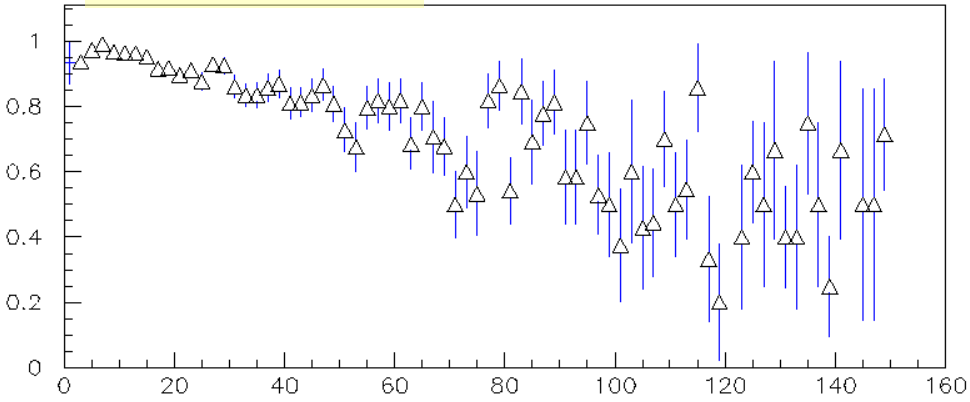




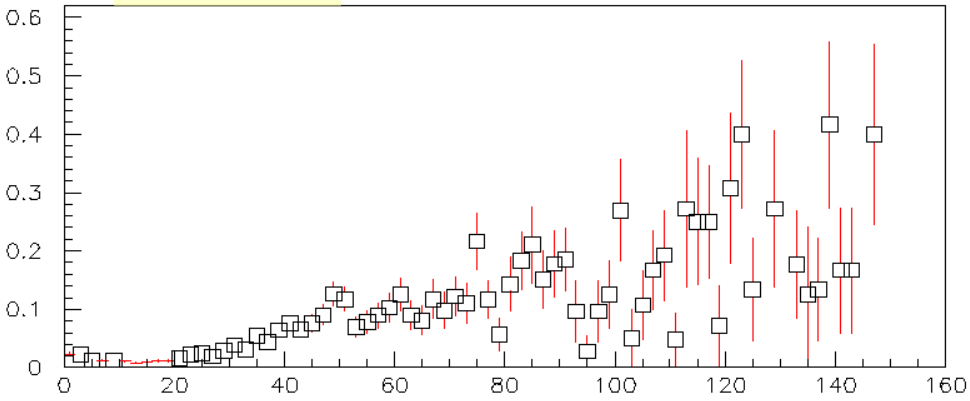
Combined ID with RICH

- RICH Detectors can also discriminate leptons
  - RICH alone has too high background rates
  - Combining lepton ID with RICH information can also improve lepton identification performance

Electron Efficiency

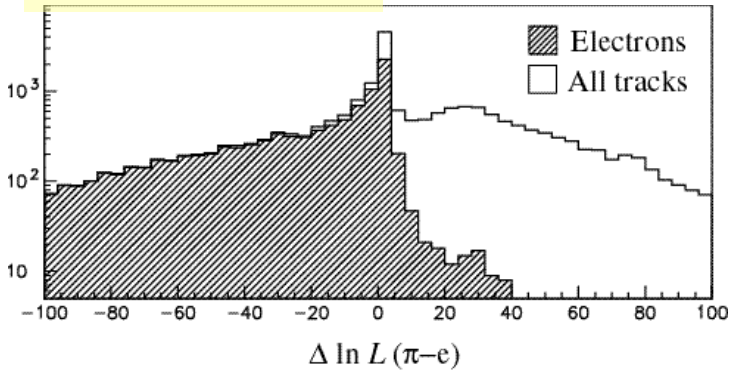


Pion Mis-ID



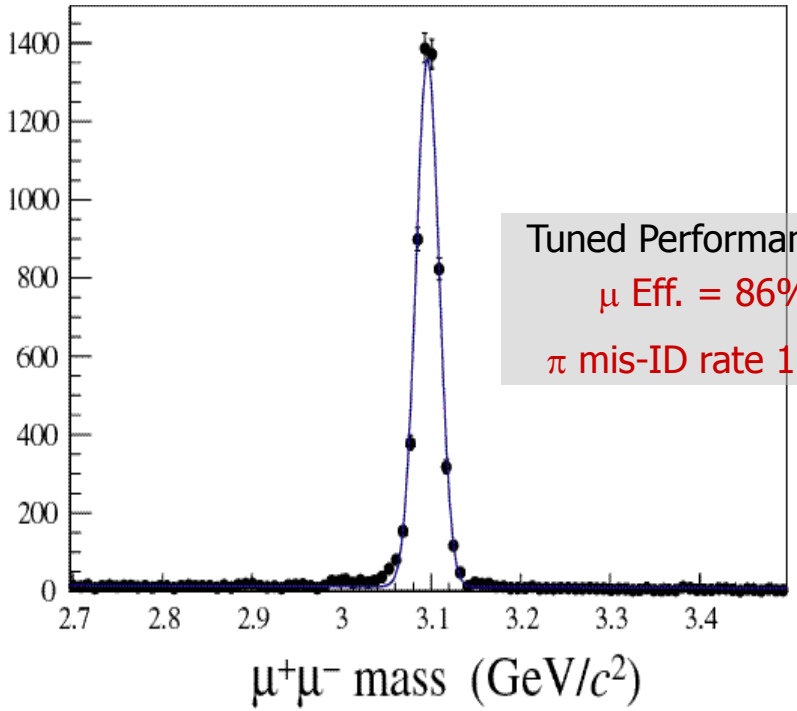
Momentum / GeV/c

RICH Electron ID



Lepton ID : Physics Performance

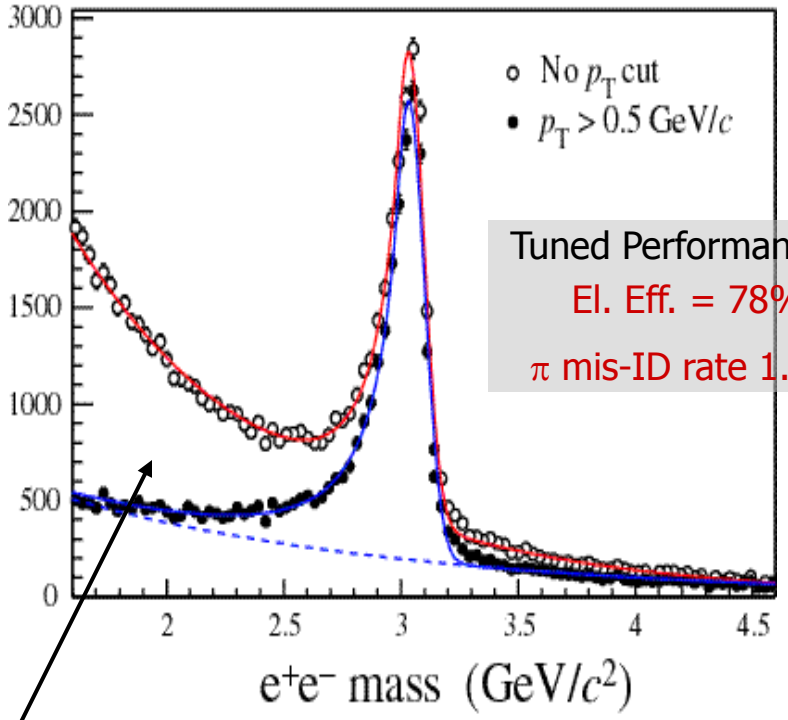
- Performance example
  - J/ψ reconstruction in $B_s \rightarrow (J/\psi \rightarrow l^+l^-)\ \phi$



Tuned Performance :-

μ Eff. = 86%

π mis-ID rate 1.0%



Tuned Performance :-

El. Eff. = 78%

π mis-ID rate 1.0%

- Electron background predominately secondary electrons and ghosts
- Rejected efficiently with P_T cut

Conclusions

Particle ID using is essential for the LHCb physics program

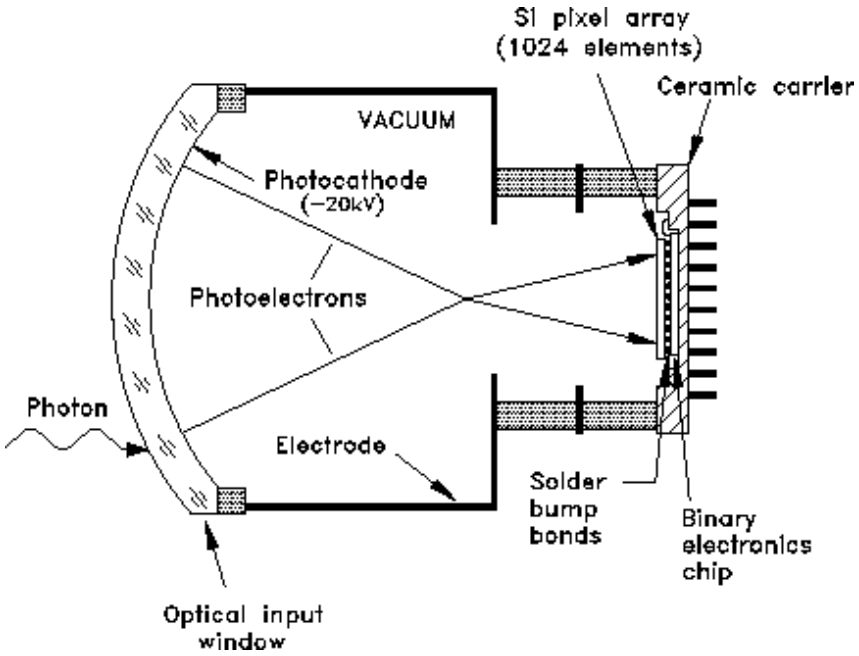
- LHCb has been re-optimised for reduced material budget
  - Major re-design of RICH1 - Work progressing well
  - RICH2 project is now entering construction stage
  - Calorimeter and Muon projects well advanced

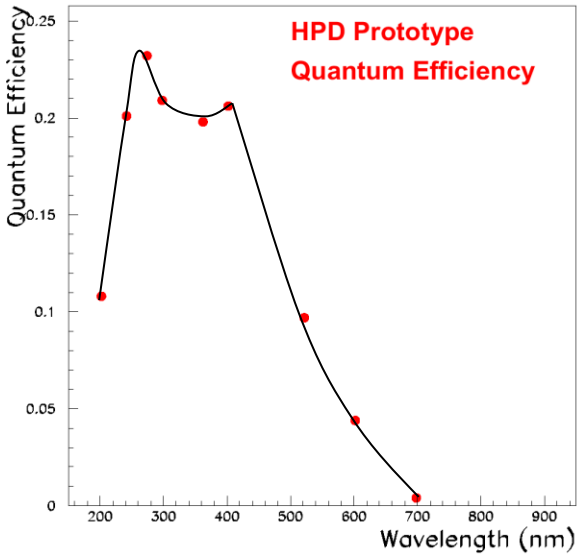
LHCb on schedule for first data at the LHC startup in 2007

Additional Material

Pixel Hybrid Photon Detector

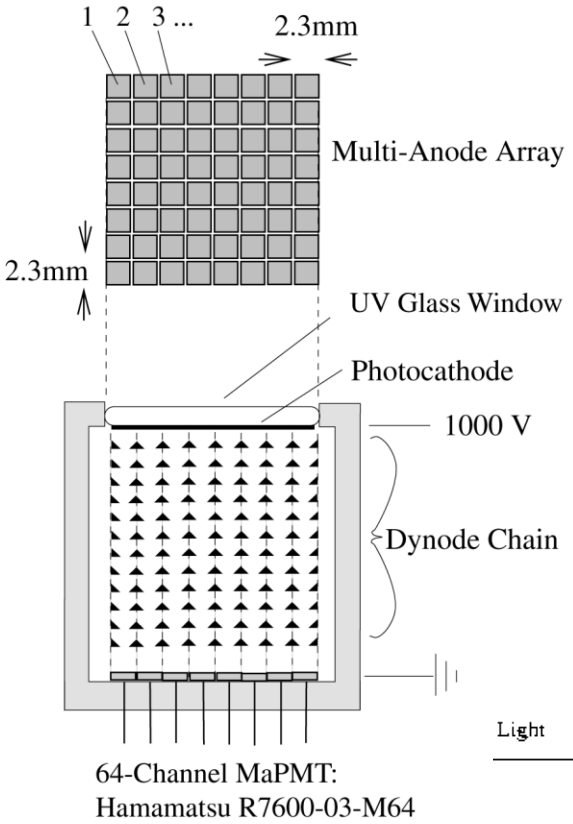
- Encapsulated 1024 pixel sensor
- PhotoCathode
  - Total diameter of 83mm
  - Active diameter of 72mm
    - 82% active area
  - HV -20kV, giving 5000 photo-electron signal
  - S20 photocathode with QE > 20%





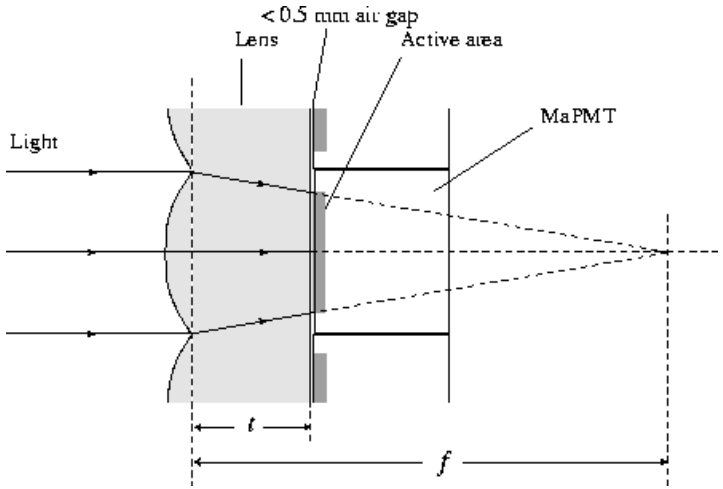
- Cross-focussing and 5 times demagnification
- Anode
  - Silicon pixel detector, bump bonded to readout chip
- Number requirements
  - RICH1 : 168 HPDs
  - RICH2 : 262 HPDs

MaPMTs

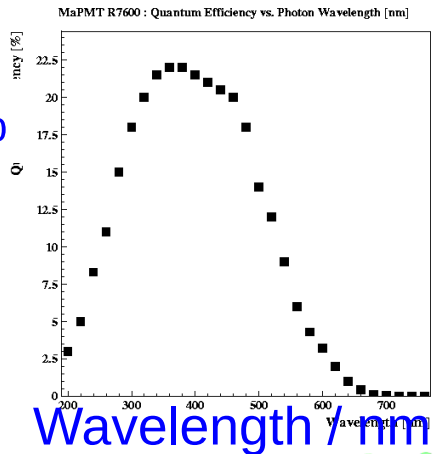


64-Channel MaPMT:
Hamamatsu R7600-03-M64

- 8x8 array of 64 dynode chains
  - 2.1 mm pixel size, 0.2mm gap
- 3.10^5 gain at 800V
- Bialkali photo cathode
  - QE = 22% (λ = 380 nm)
- UV glass window
- Active area fraction 38%
- Increased to 85% with Quartz lens



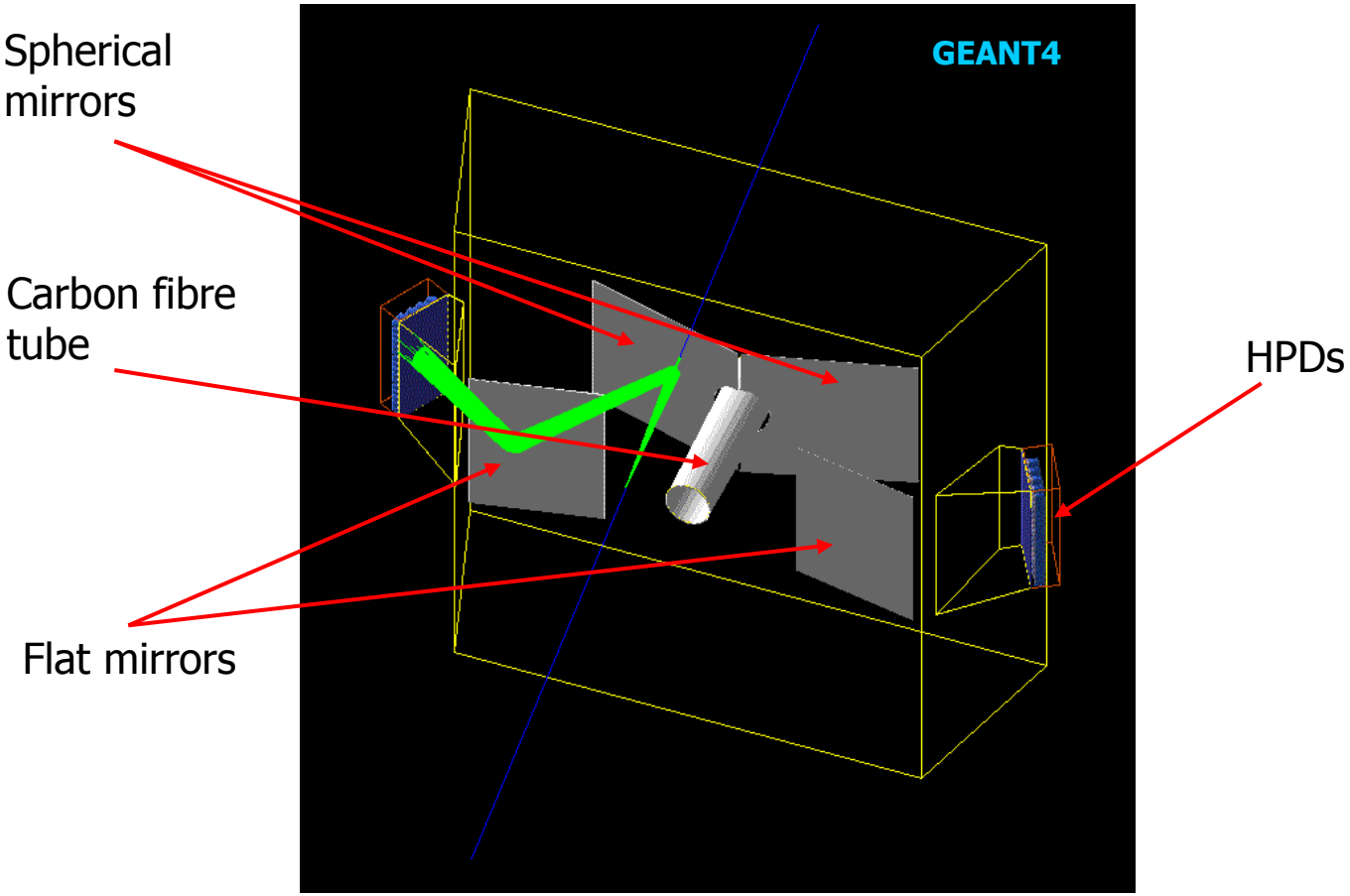
QE / %



Wavelength / nm

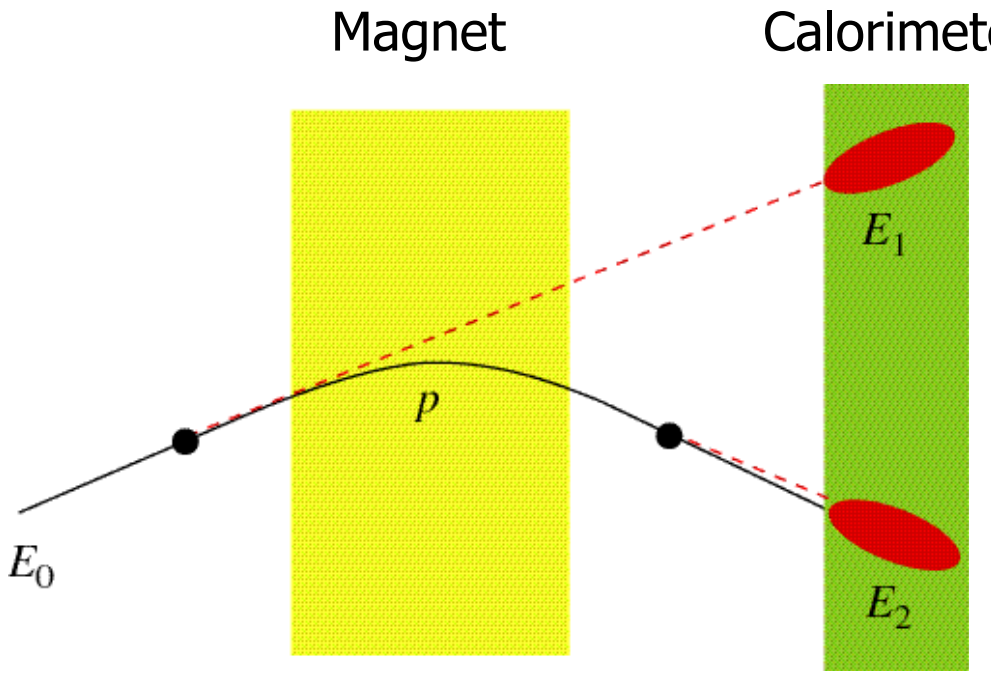
Transition to Geant4

- Transition to Object-Oriented GEANT4 simulation well under way



Bremsstrahlung Correction

- Correction require to account for Bremsstrahlung before and after the Magnet
  - Simplified in re-optimsed LHCb detector due to removal of material inside the magnet



Momentum $p = E_2$

$E_o = E_1 + E_2$