IOP HEPP Conference 2005

The LHCb RICH Detectors

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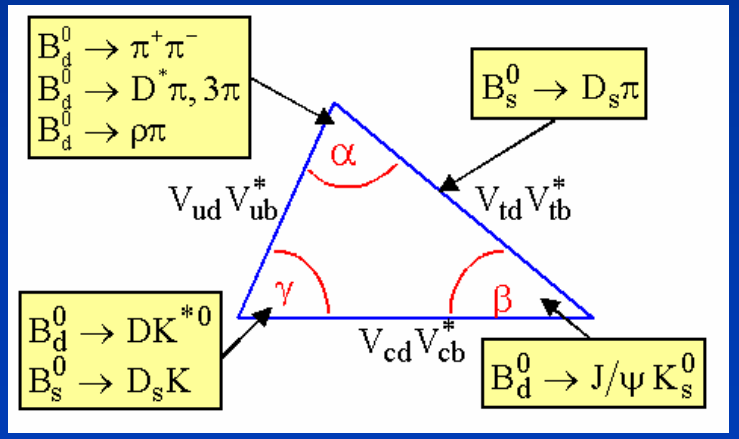
Outline

- LHCb Goals & Detector Overview
- Particle Identification
- LHCb RICH Detectors
  - Design & Performance
  - Photon-detectors & Readout Electronics
  - System Test of a Prototype RICH2 Detector

The LHCb Experiment

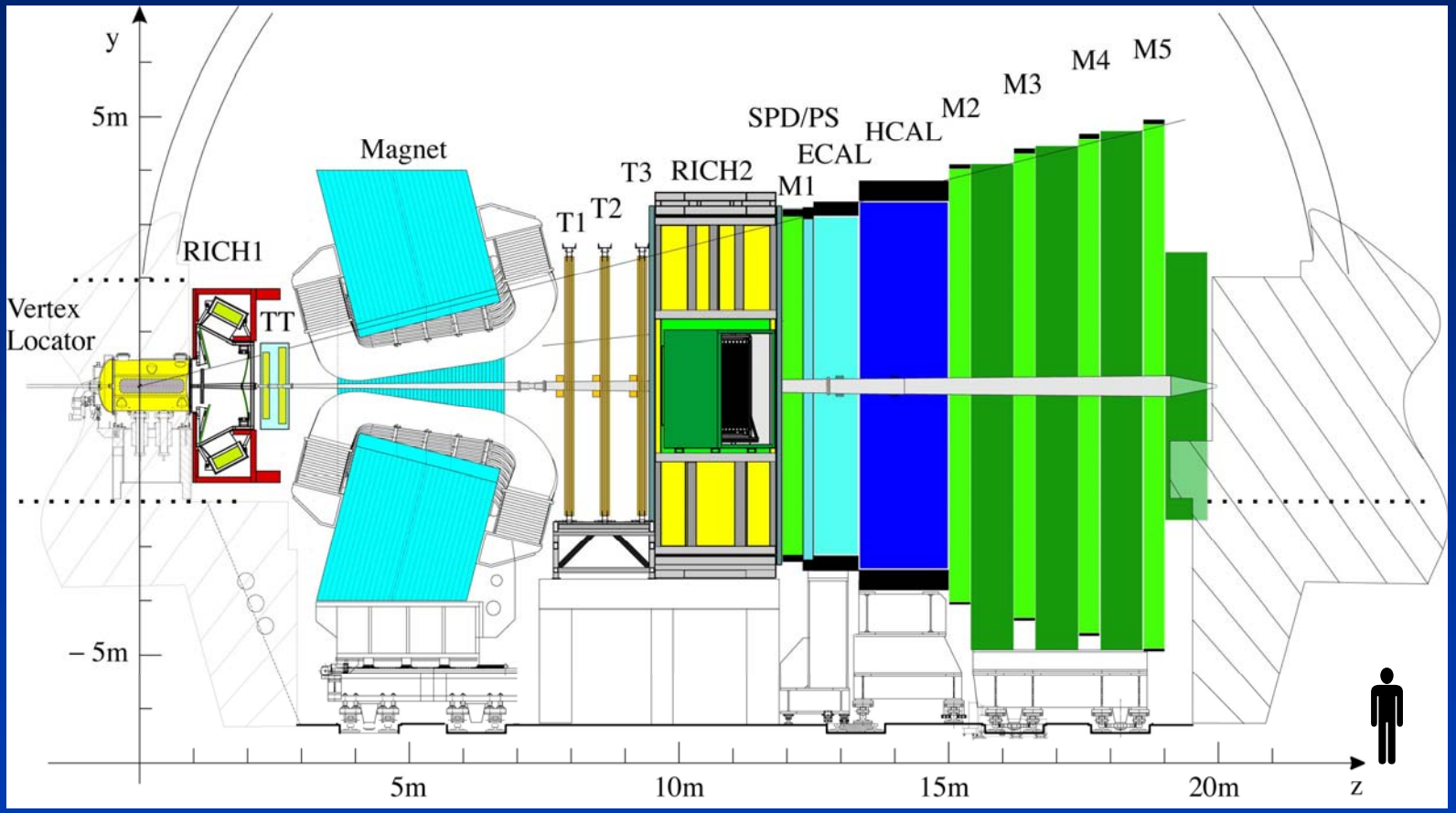
- Forward one-arm spectrometer dedicated to the study of CP violation and rare B-decays at LHC
  - Check consistency of SM through precision measurement of angles and sides of the CKM triangle
  - Search for new physics in rare & SM forbidden decays

- Important to reconstruct & trigger on wide range of decay modes to make independent measurements
  - $B_d \rightarrow J/\psi\, K_S$, $D^* \pi$, $D^0 K^*$, $\pi\,\pi$, $K\,\pi$, …
  - $B_s \rightarrow J/\psi\, \phi$, $D_S\, K$, KK, …

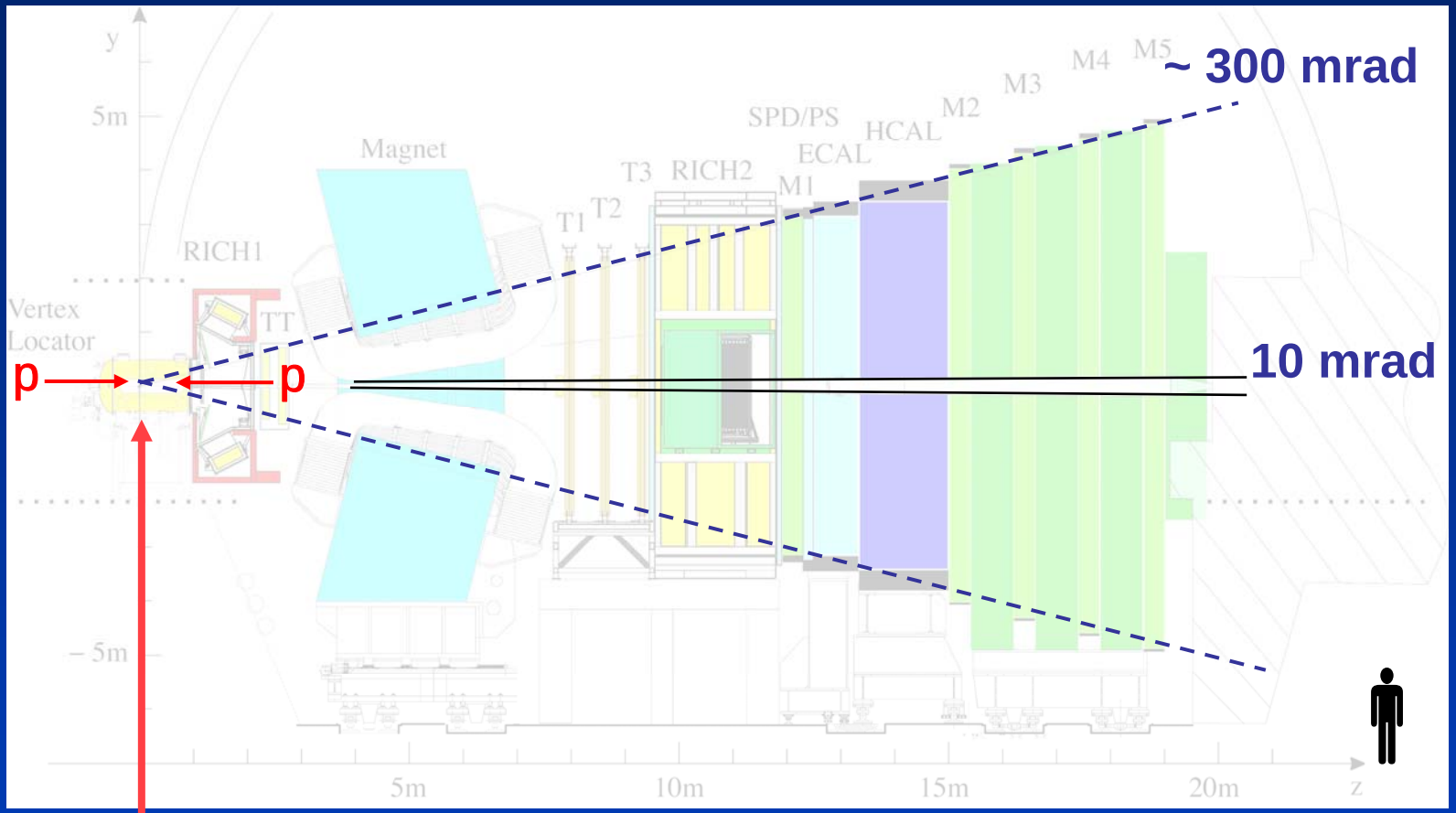


Particle Identification (π/K) essential

The LHCb Detector

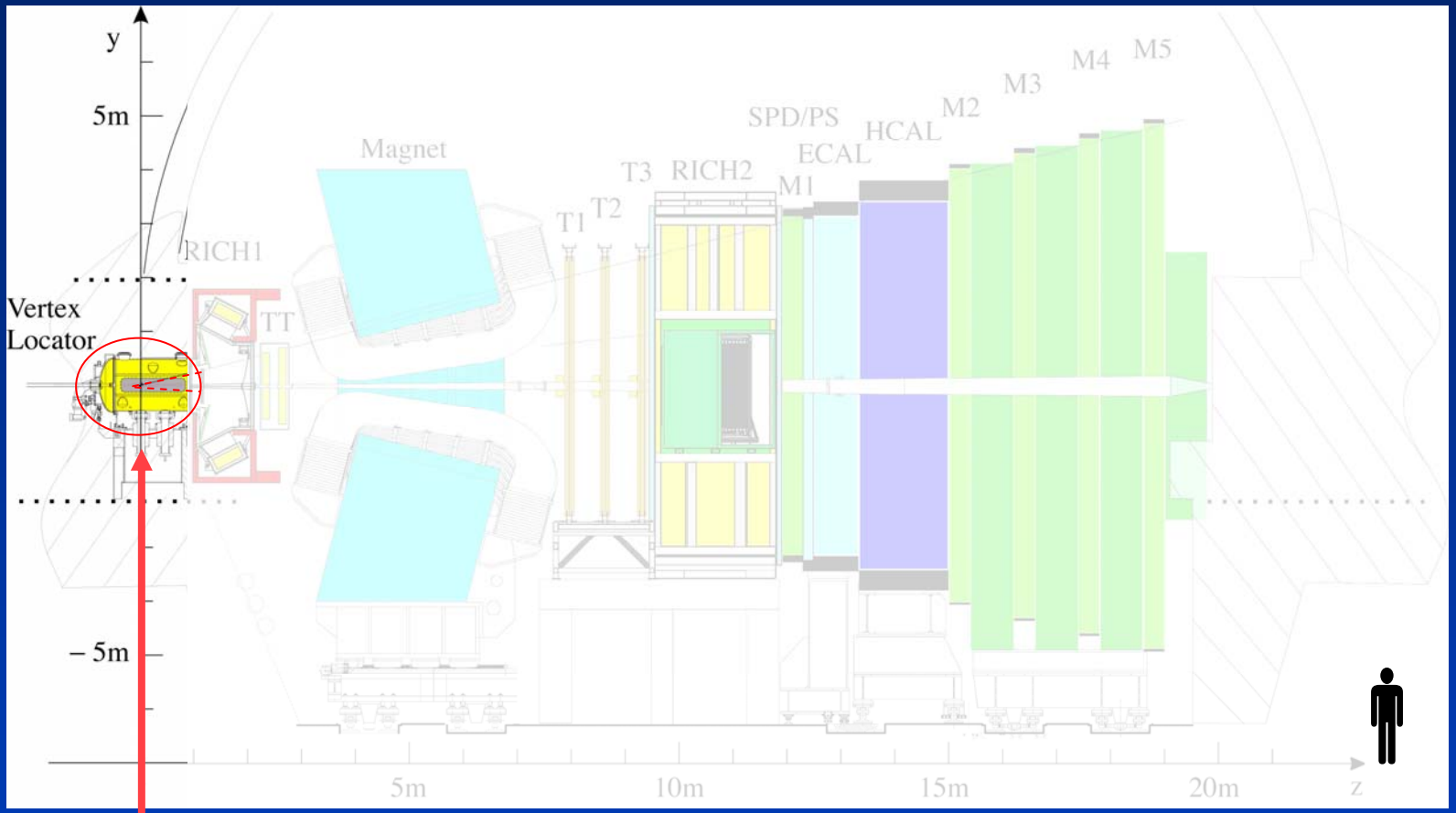


The LHCb Detector



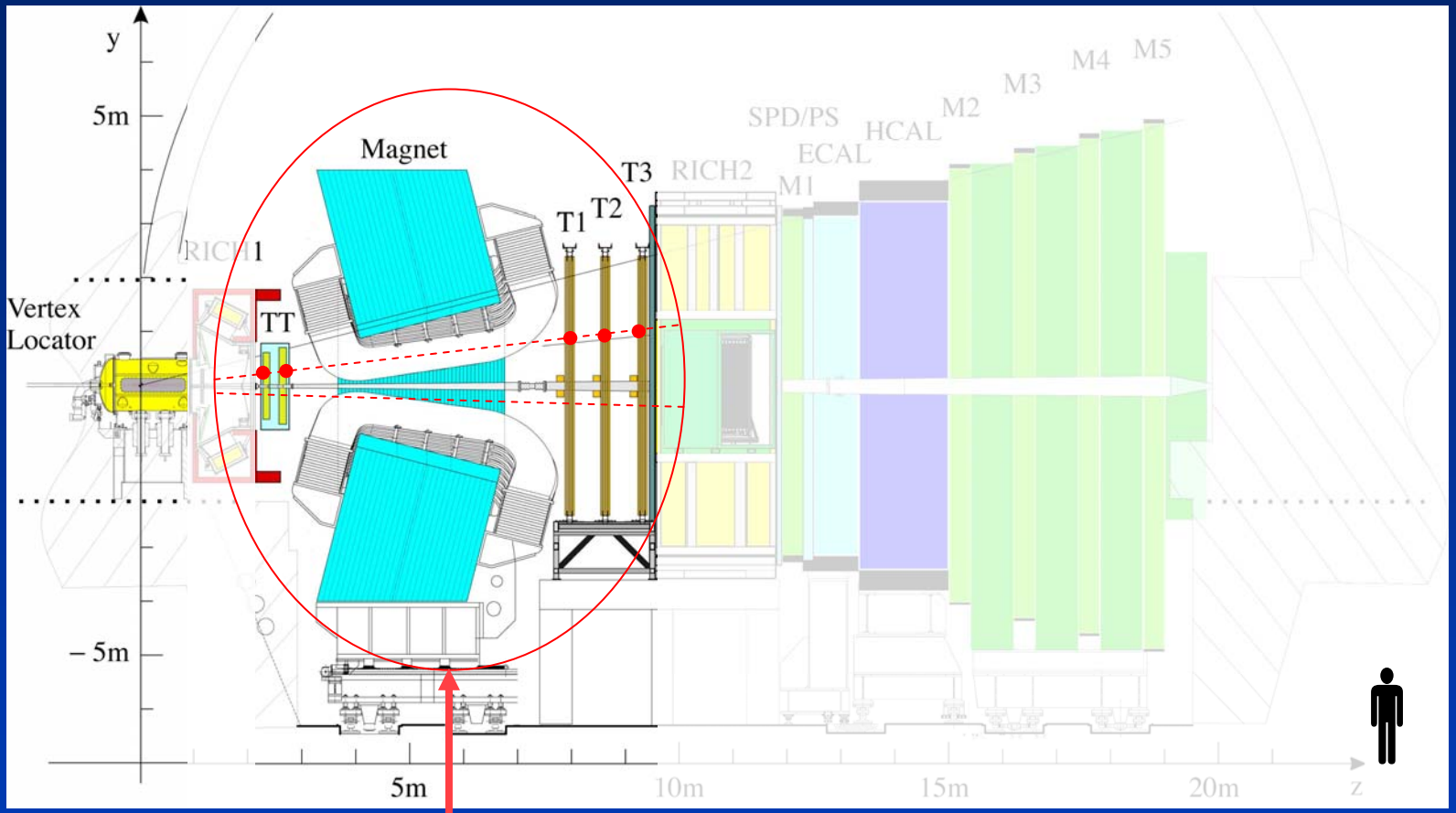
interaction point

The LHCb Detector



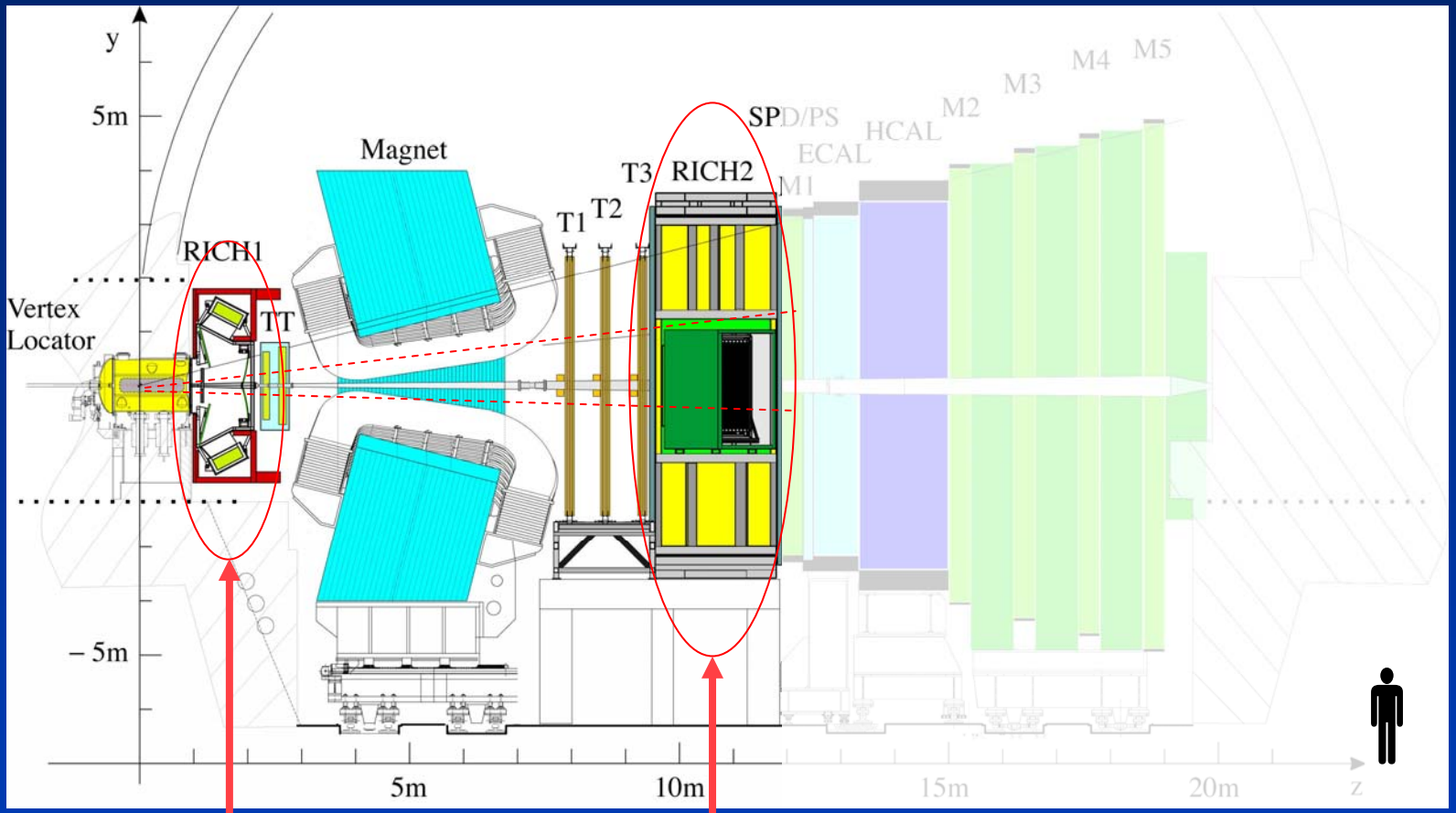
Vertex Locator

The LHCb Detector



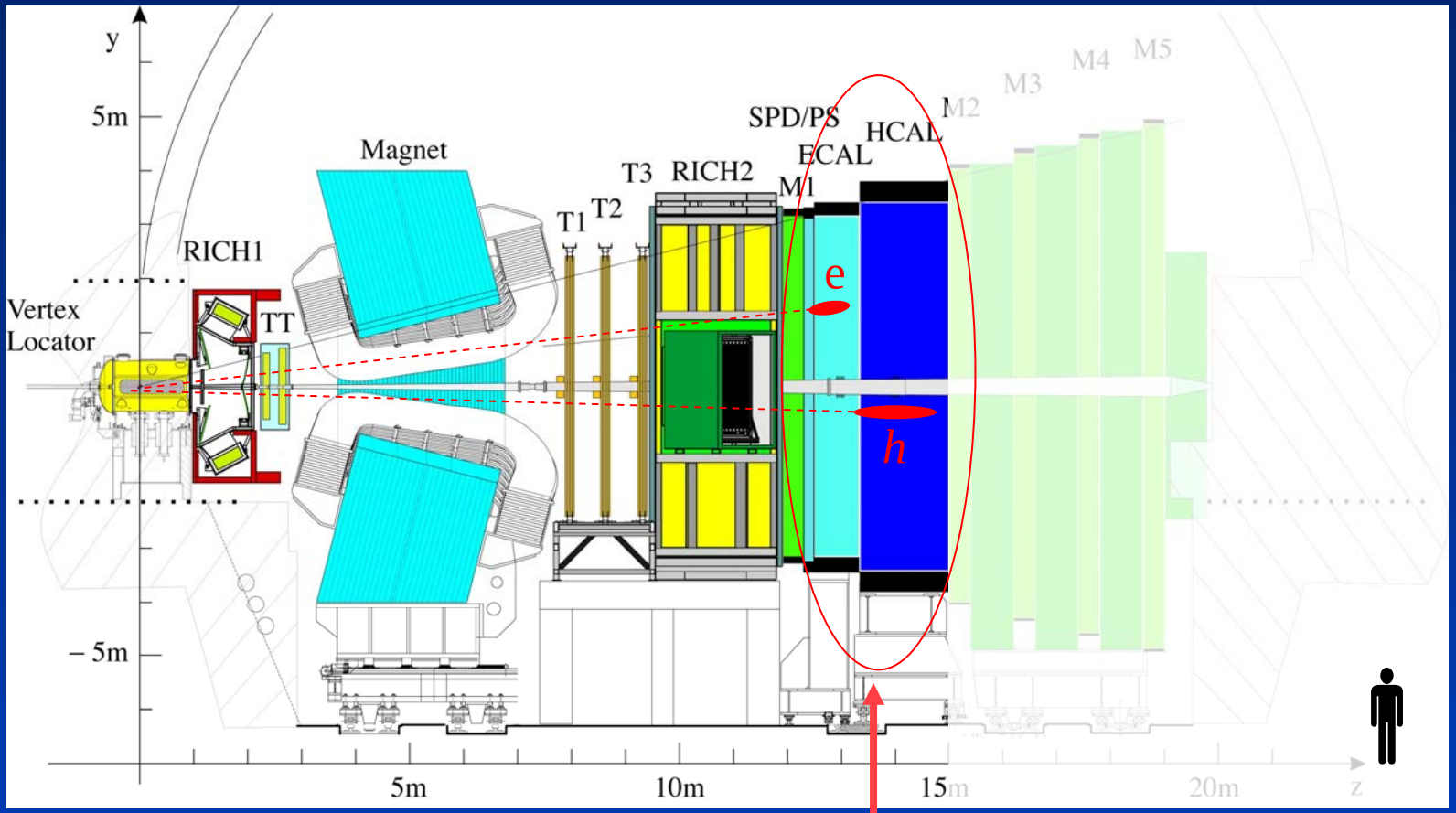
Dipole magnet & tracking stations

The LHCb Detector



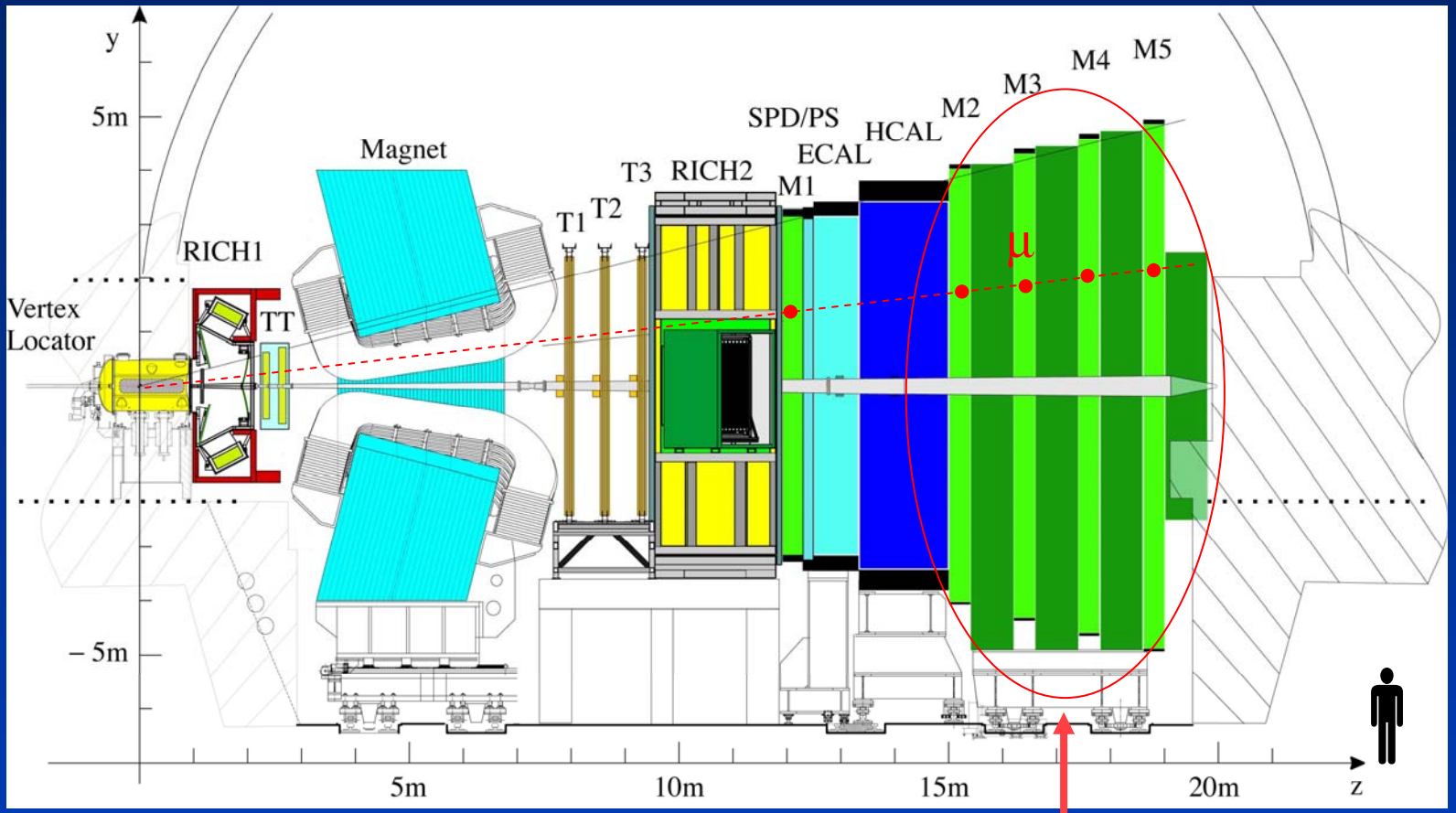
2 Ring Imaging CHerenkov (RICH) detectors for charged particle identification

The LHCb Detector



Calorimeter system to identify electrons, hadrons and neutrals

The LHCb Detector

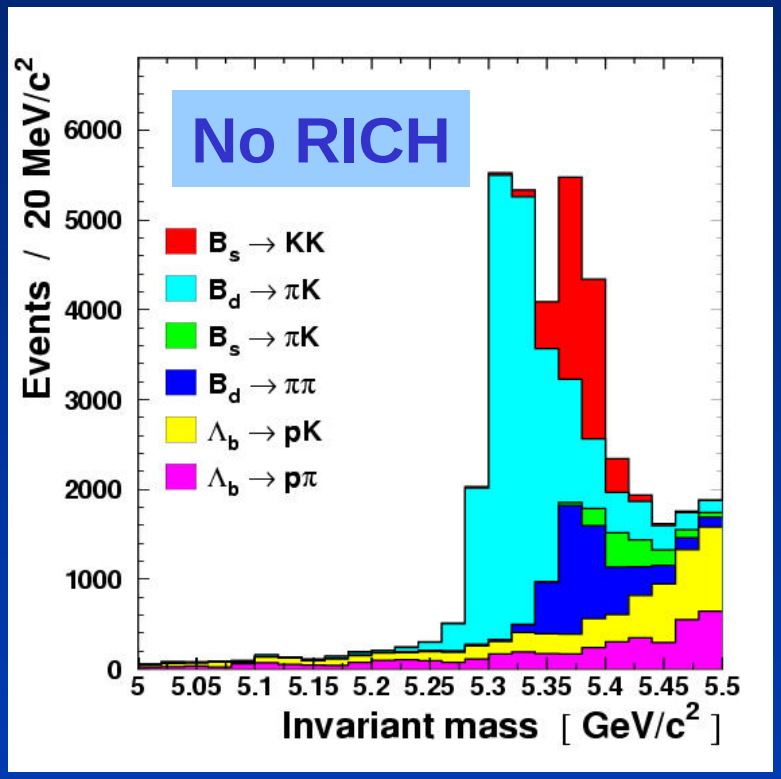


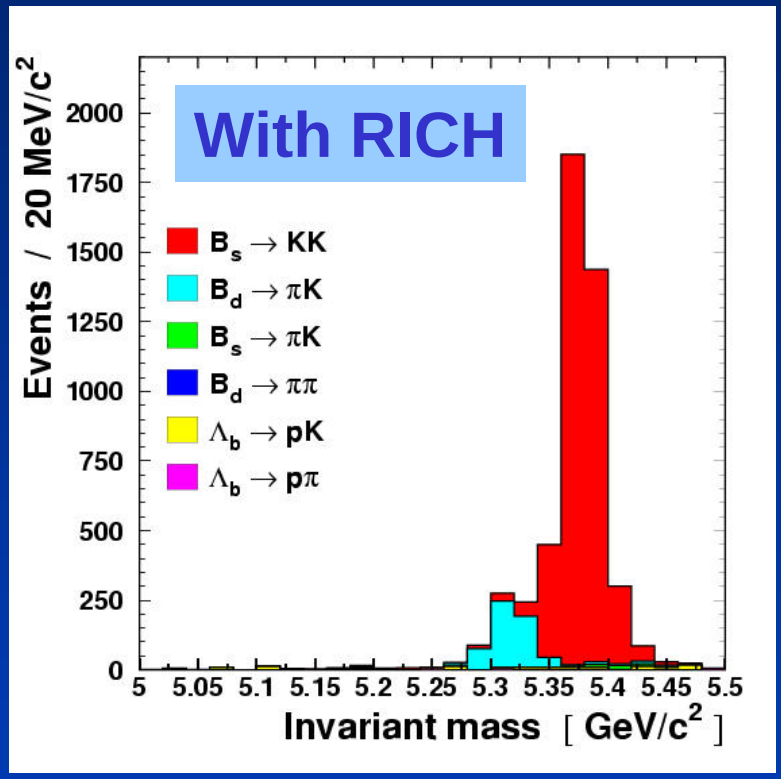
Muon system

Hadron Identification with RICH

cumulative plots!

Consider: $B_s \to K^+K^-$





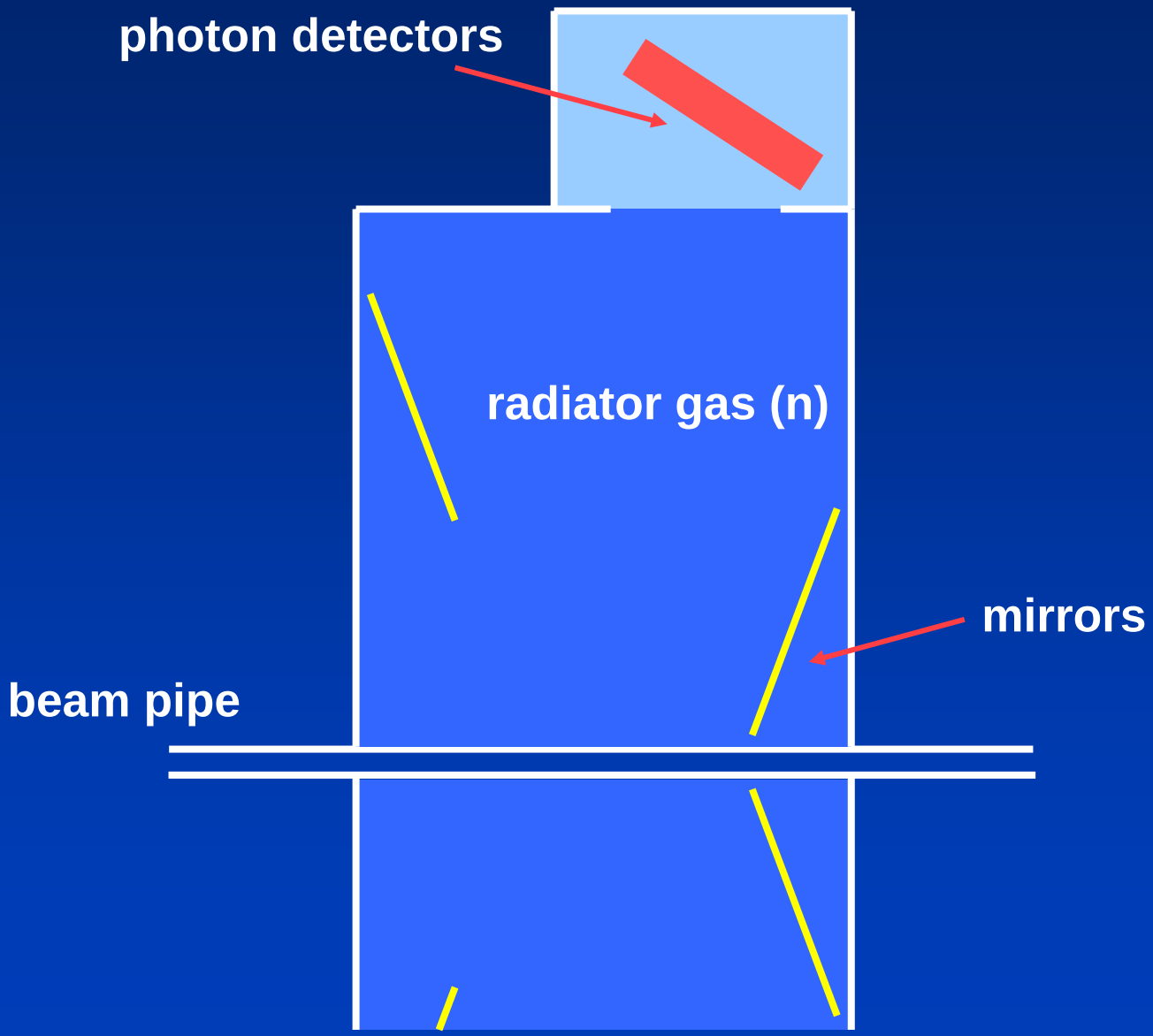
Signal purity 13%

Signal purity 84%

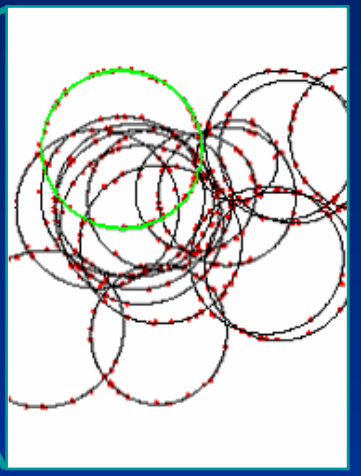
Efficiency 79%

RICH essential for hadronic decays

Cartoon RICH Detector



Cartoon RICH Detector



charged particle

θ_C

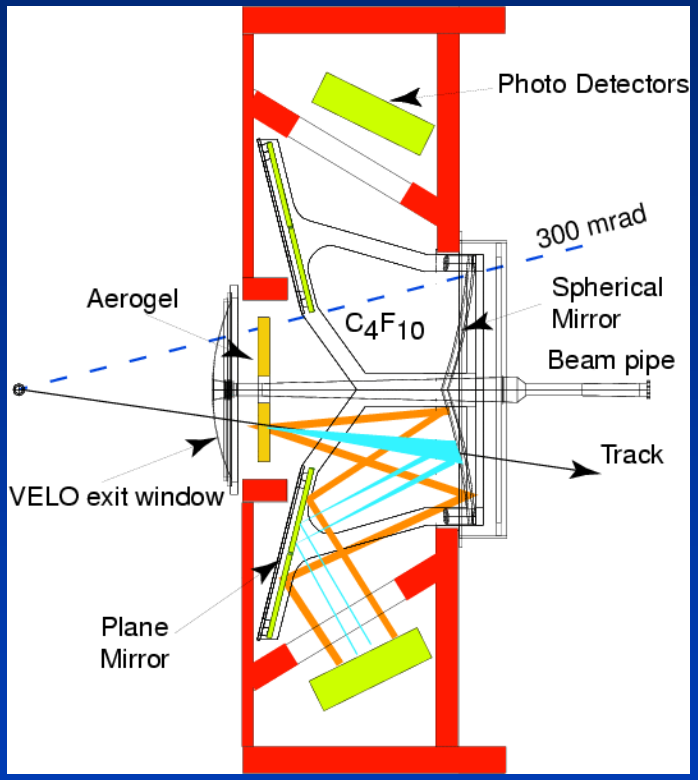
$$\cos(\theta_C) = \frac{1}{n}\sqrt{\left(1+\left(\frac{m}{p}\right)^2\right)}$$

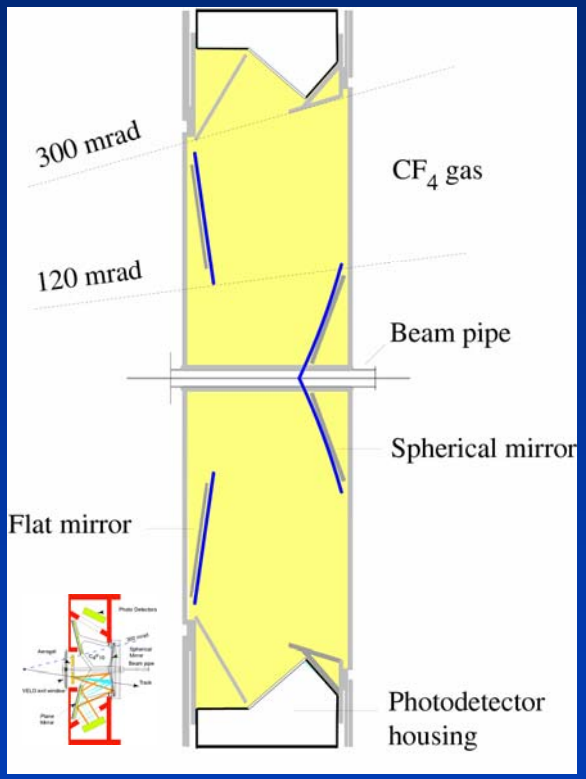
particle mass!

2 RICH, 3 Radiators

Require particle identification over range 2-100 GeV/c

(Bristol, Cambridge, CERN, Edinburgh, Glasgow, Imperial, Oxford, RAL)





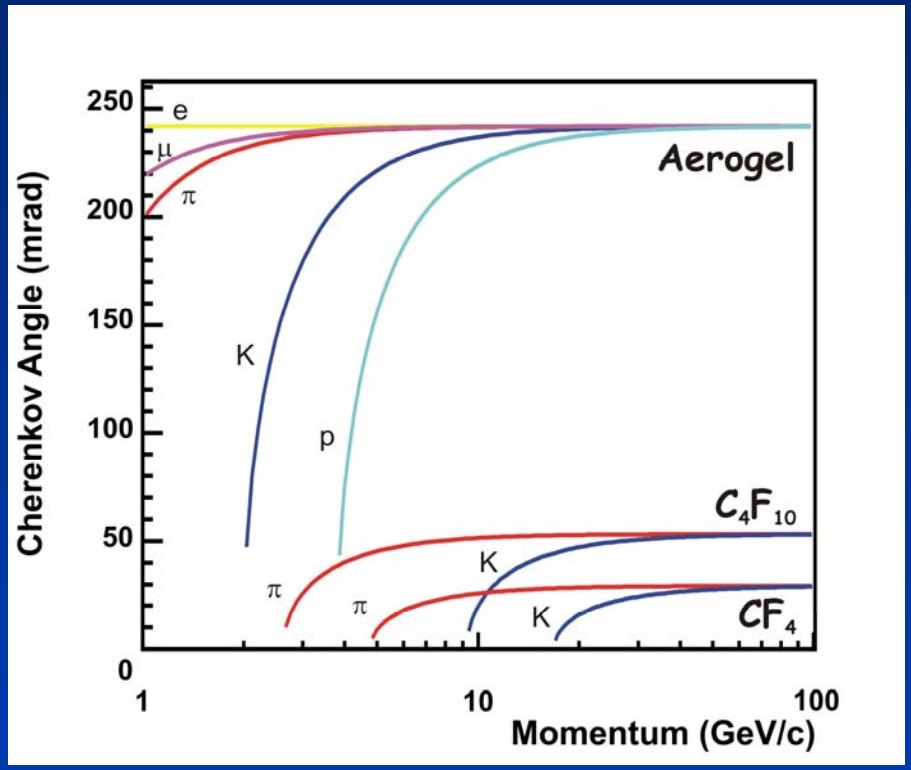
RICH1

- Aerogel (2 - ~10 GeV/c)
- C4F10 (10 - ~60 GeV/c)

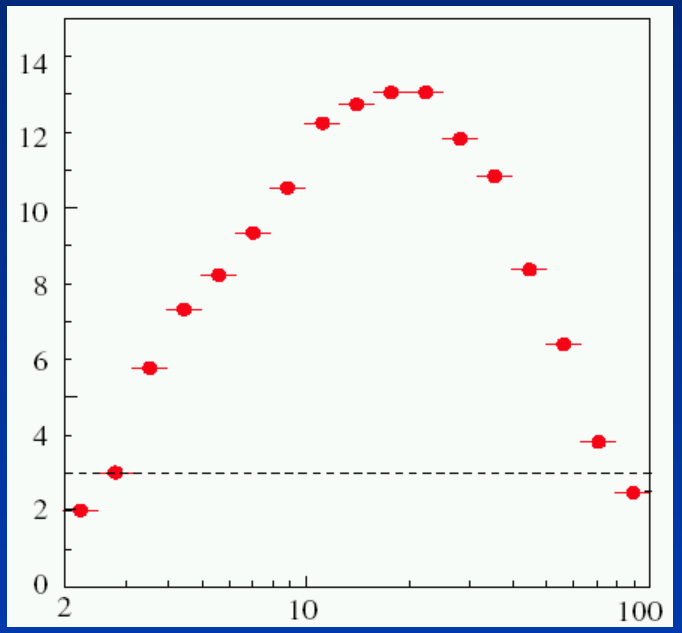
RICH2

- CF4 (16 – 100 GeV/c)

Simulated Performance



π / K separation



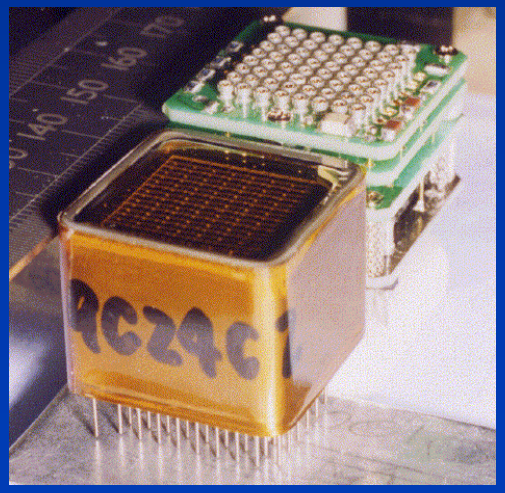
Momentum (GeV/c)

3 radiators provide excellent pion/kaon separation !

Photon Detector Specification

Requirements

- Single photon sensitive in visible & near-UV
- 2.5x2.5 mm^2 granularity
- High active to total area ratio ~ 70%
- Fast readout - 25ns time resolution
- Survive magnetic field of 25 Gauss

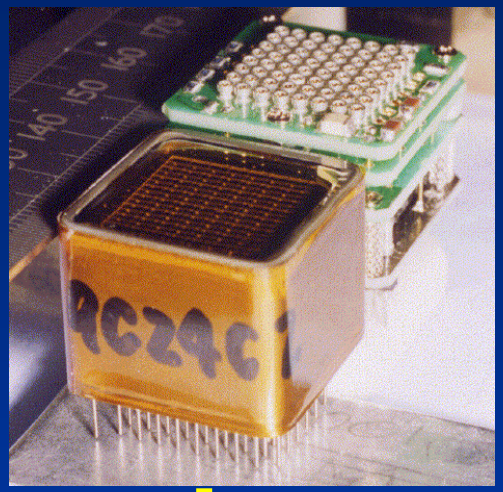


Multianode Photomultiplier
(Hamamatsu)

or

Hybrid Photon Detector
(DEP/CERN)

Multianode Photo Multipliers with Beetle-Chip Readout

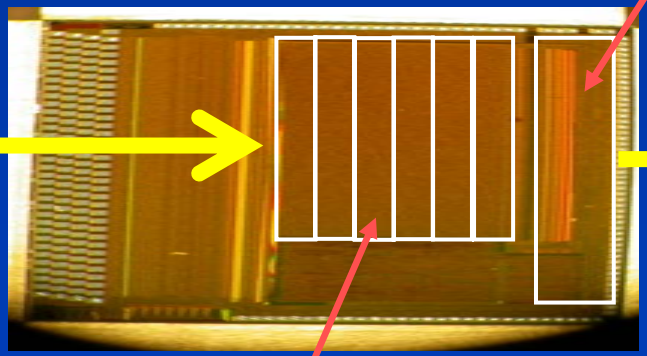


- Single photo tube with 8x8 array of 64 dynode chains
- Quartz lens used to increase active area from 38% → 85%
- Effective pixel size 2.1mm² → 3.2 mm²

sample at 40MHz

Beetle-Chip

multiplexer



analogue or binary readout modes

analogue pipeline (4μs)

MaPMT / Beetle Test Beam

Aim

- Demonstrate that MaPMT with Beetle chip readout meets the LHCb photon detector specification

Studies made of ...

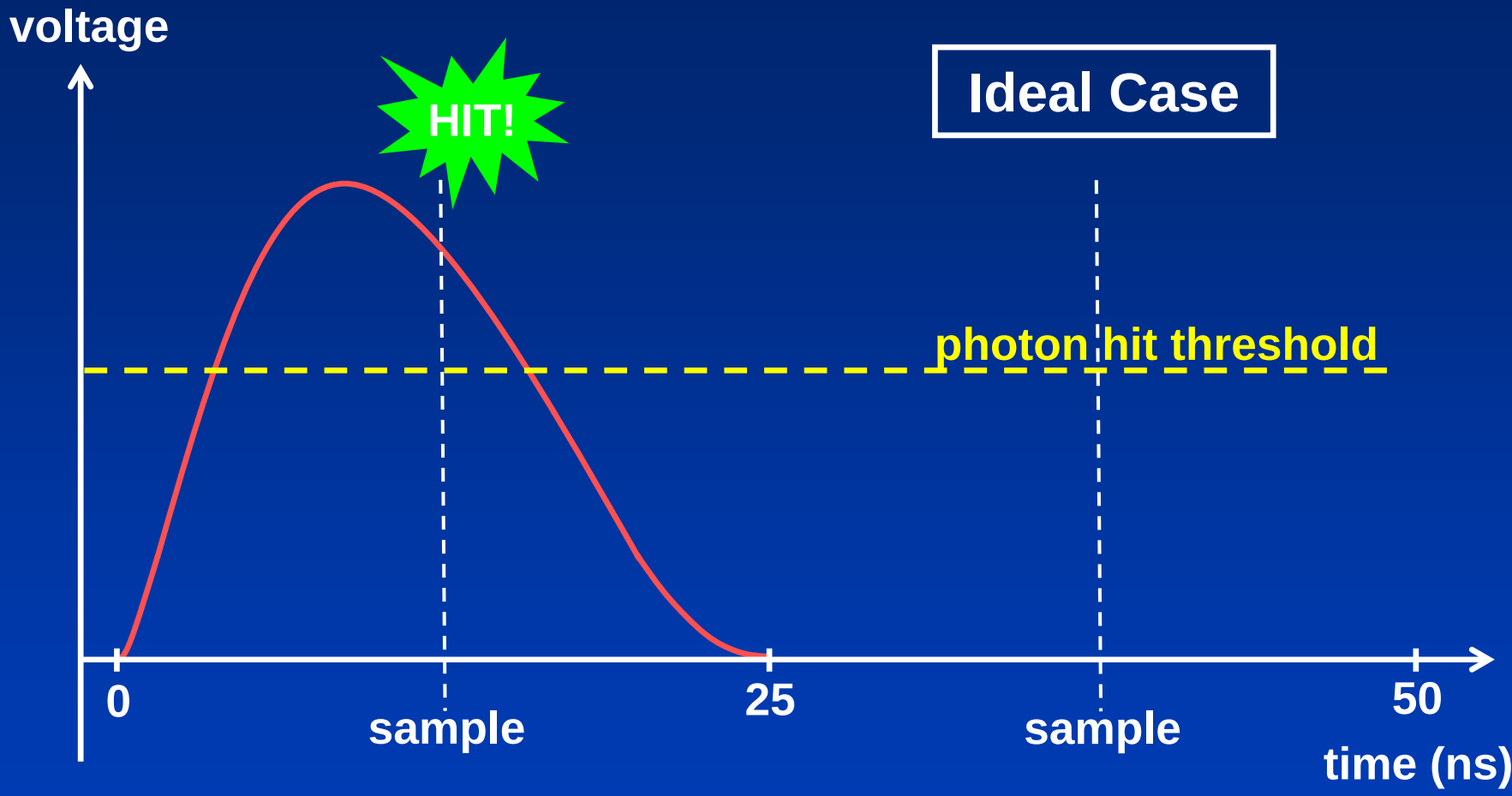
- 8 dynode MaPMT with Beetle 1.2
- 12 dynode MaPMT with Beetle 1.2 MA0
  (Heidelberg, Oxford)

} HV characteristics
Crosstalk
Pulse shape

Why measure the pulse shape ?

- Look for Spillover & Overshoot

Spillover & Overshoot



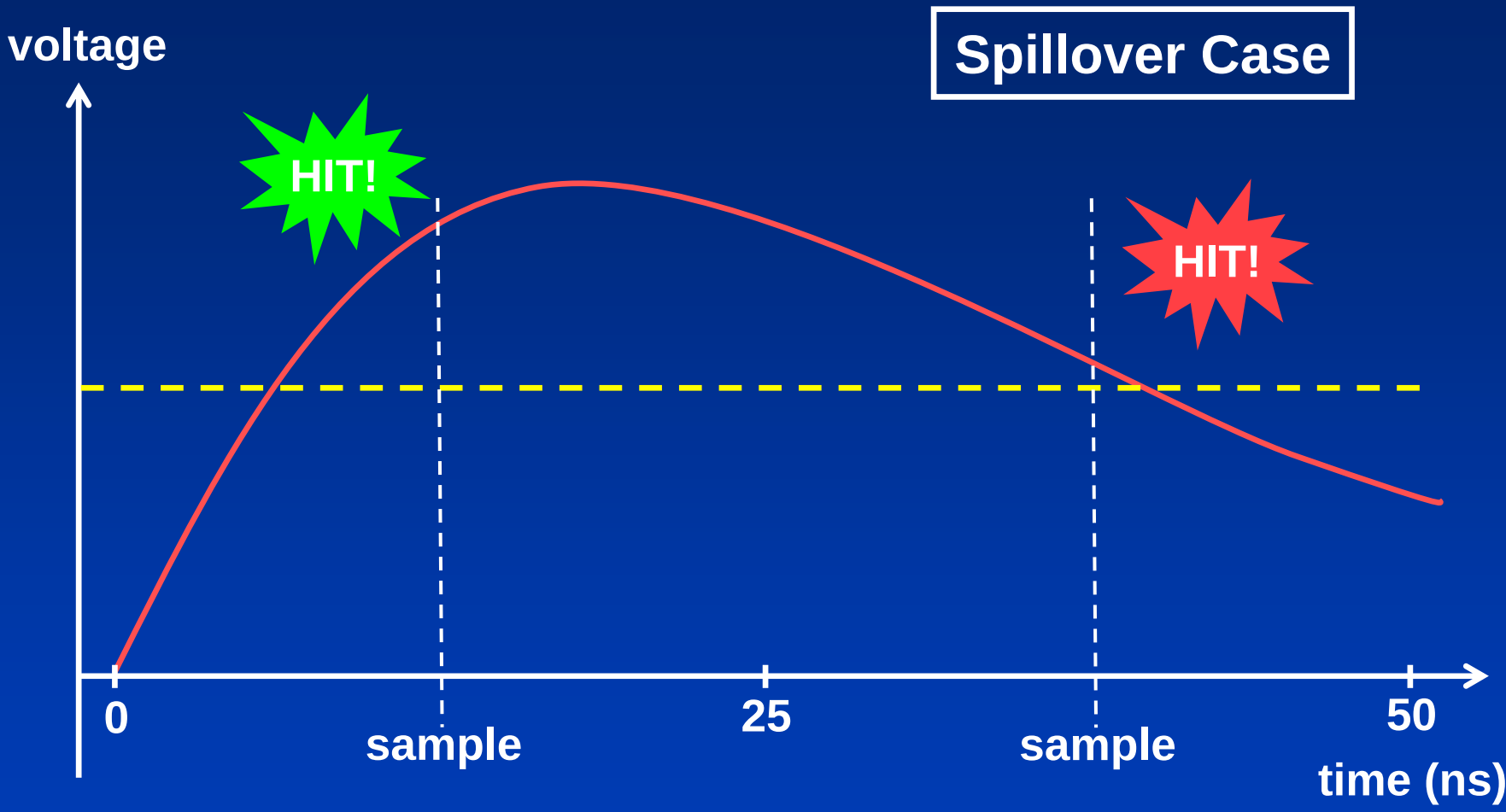
Bunch Crossing 1

photon

hit

Bunch Crossing 2

Spillover & Overshoot



Bunch Crossing 1

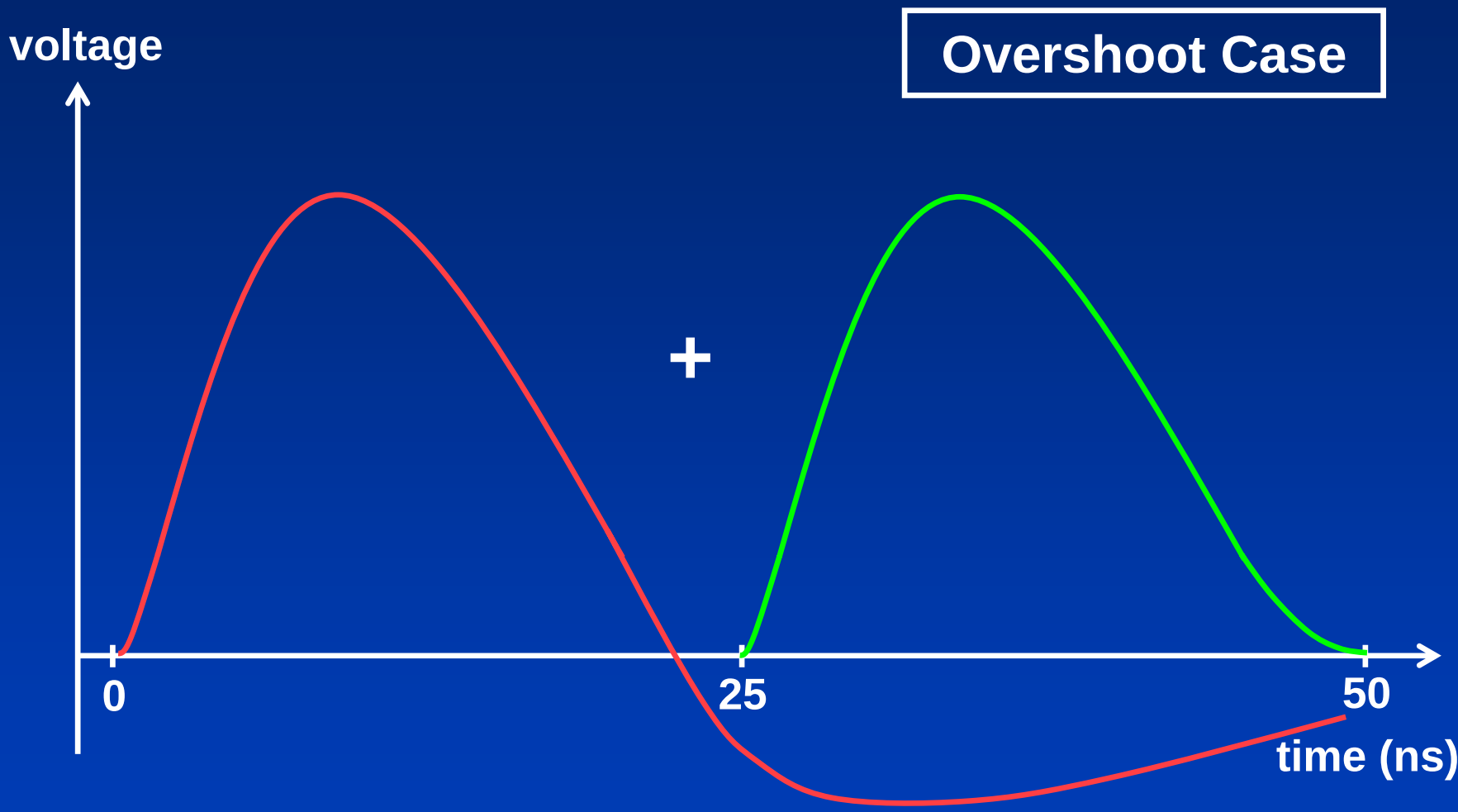
photon

hit

Bunch Crossing 2

ghost hit

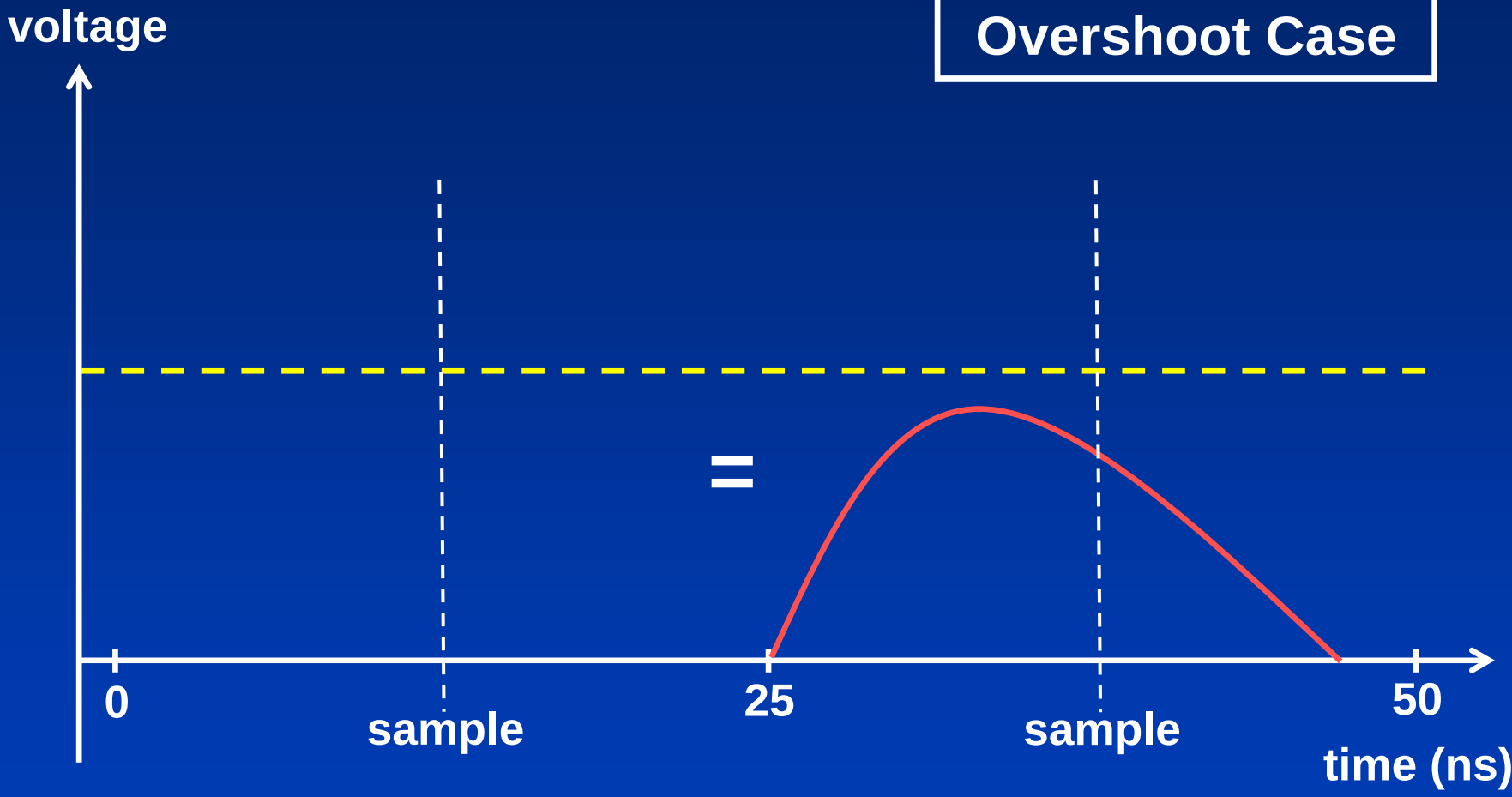
Spillover & Overshoot



Bunch Crossing 1

Bunch Crossing 2

Spillover & Overshoot



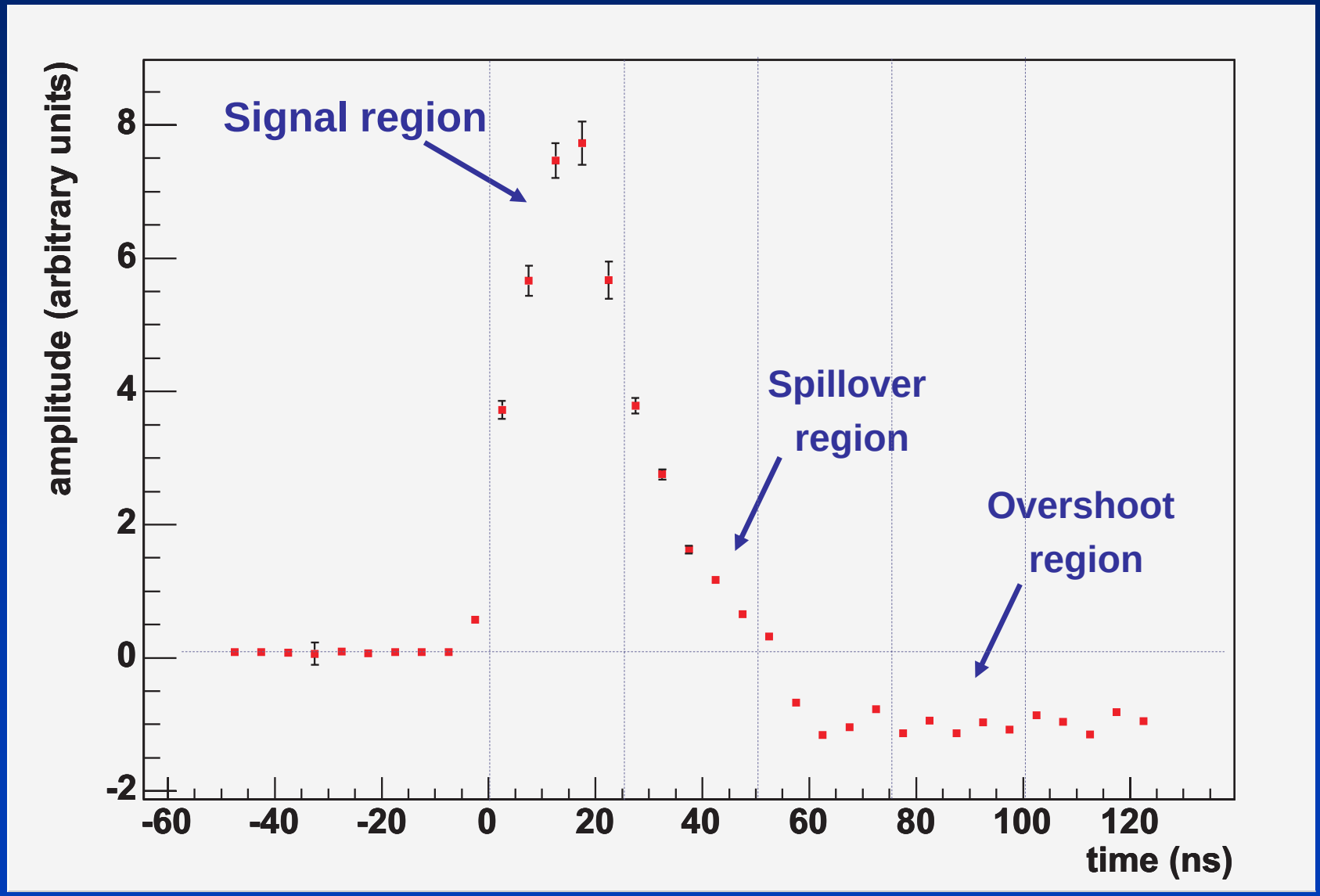
Bunch Crossing 1

photon → ✓ hit

Bunch Crossing 2

photon → ✗ no hit

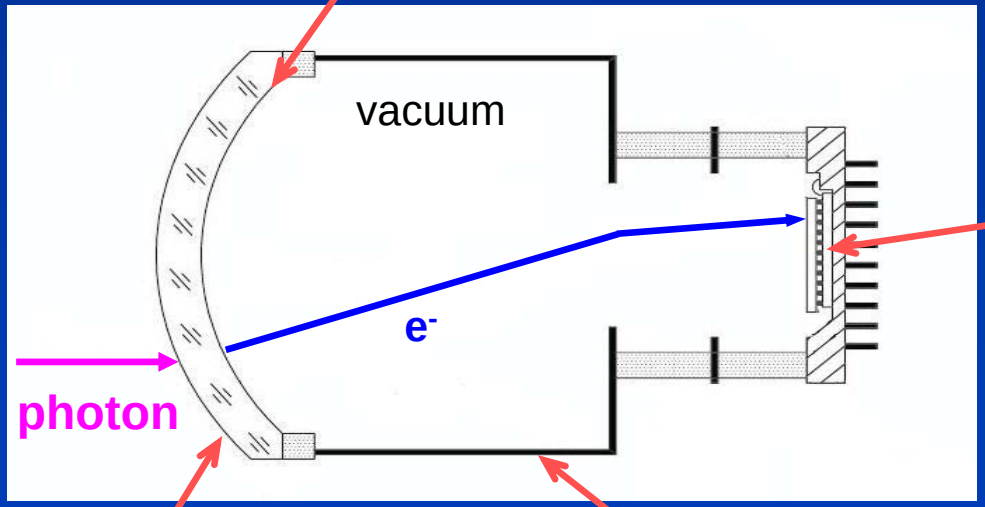
Beetle 1.2 MA0 Pulse Shape

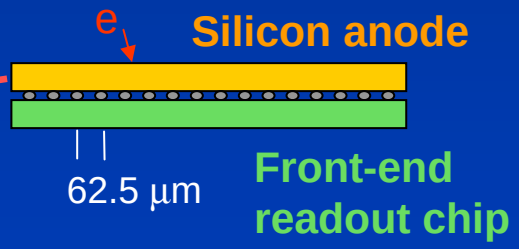


Hybrid Photon Detectors

- Electrostatic cross focusing optics
- 32x256 pixel silicon anode bump bonded to 40MHz binary readout chip
- Effective pixel size 2.5mm^2

(CERN, DEP)





Readout Electronics

(Cambridge, Oxford, CERN)

40 MHz

Data

Pixel Chip

1 MHz

trg., clk

Trigger & Timing Control

Pixel chip control & multiplex

L0 Board

L0 trigger, clk

1 MHz

L1 trigger, clk

Event Processing Farm

~40 kHz

L1 Board

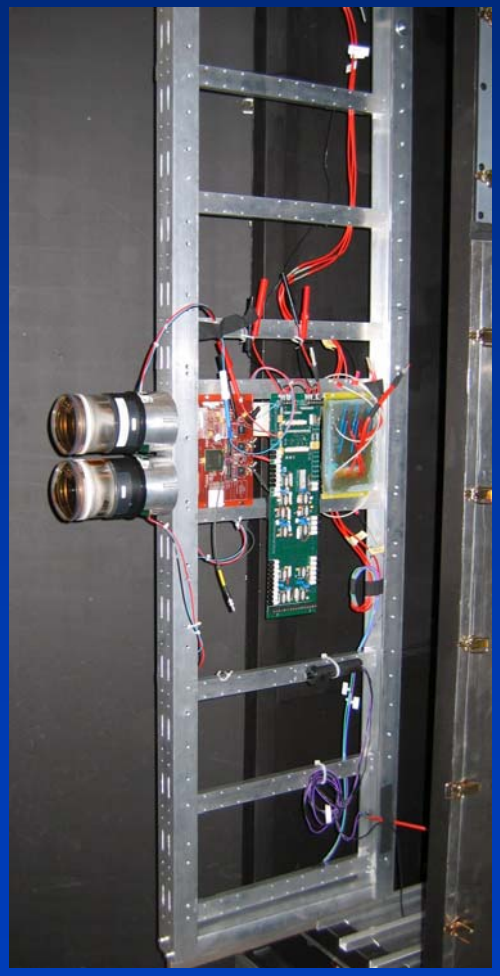
Buffer, de-randomise, zero suppress & multiplex

System Test of a Prototype RICH2 Detector

Aim

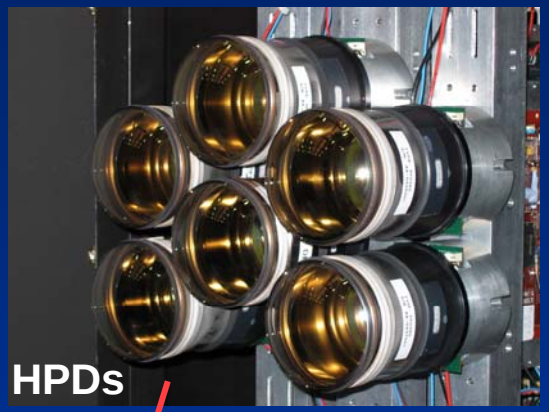
Ensure that HPD & other elements of RICH detector will work in a realistic LHC environment;

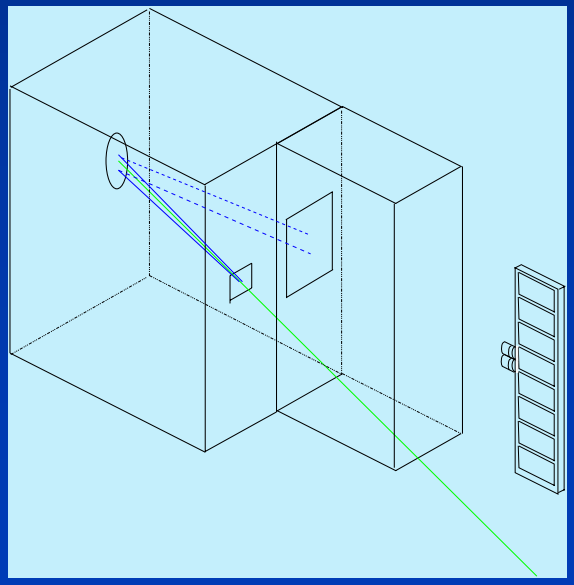
- **Preproduction HPD**
- **Readout electronics**
- **Mechanics**
- **Power distribution**

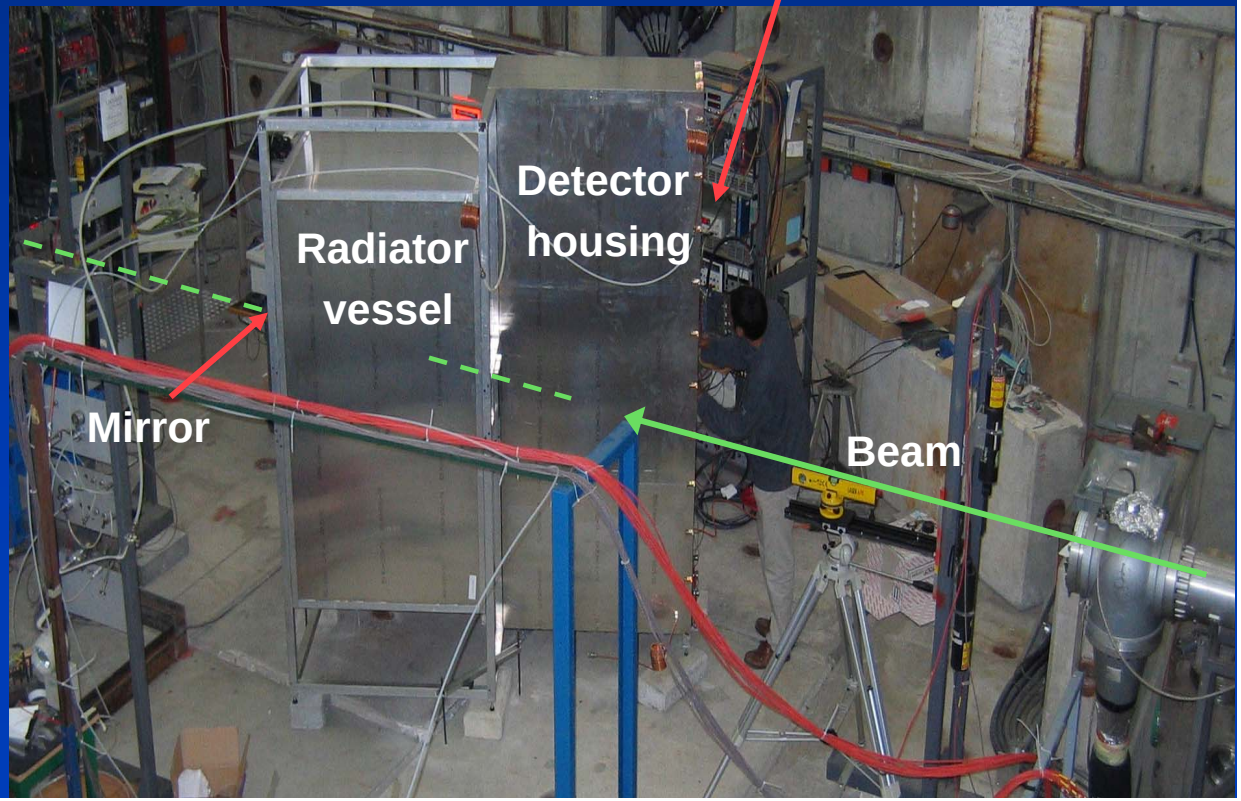


Test beam Set-up

- CERN 10 GeV/c pion & electron beam
- Prototype detector (N_2 & C_4F_{10} radiators)
- 6 HPDs on 3 columns tested







System Test Readout Electronics

40 MHz

Data

Pixel Chip

1 MHz

trg., clk

Trigger & Timing Control

L0 Board

L0 trigger, clk

1 MHz

L1 trigger, clk

Event Processing Farm

~40 kHz

L1 Board

System Test Readout Electronics

40 MHz

Data

Pixel Chip

Scintillators

trigger

trg., clk

Trigger & Timing Control

trigger, clk

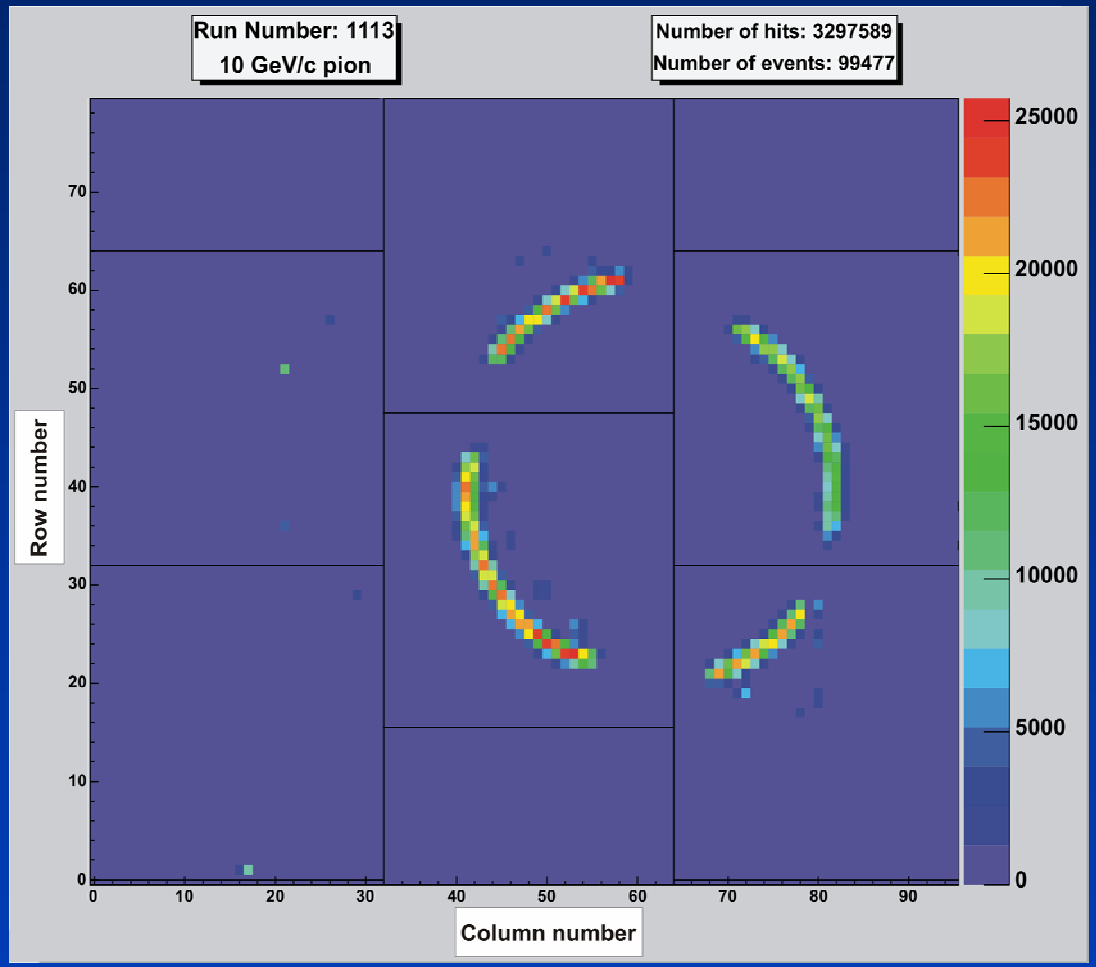
L0 Board

L1 Board

~40 kHz

Storage

Cherenkov Ring



- Data of 6 HPDs readout at full LHC readout speed
- Ongoing analysis…

C_4F_{10} pion run: 100,000 events

Summary

The RICH Detectors are essential for Particle Identification at LHCb.

A prototype RICH2 detector has been built & tested.
Demonstrated integration of:

- HPD
- Readout Electronics
- Mechanics

Summary

Construction well underway!