Photodetectors for the LHCb RICH

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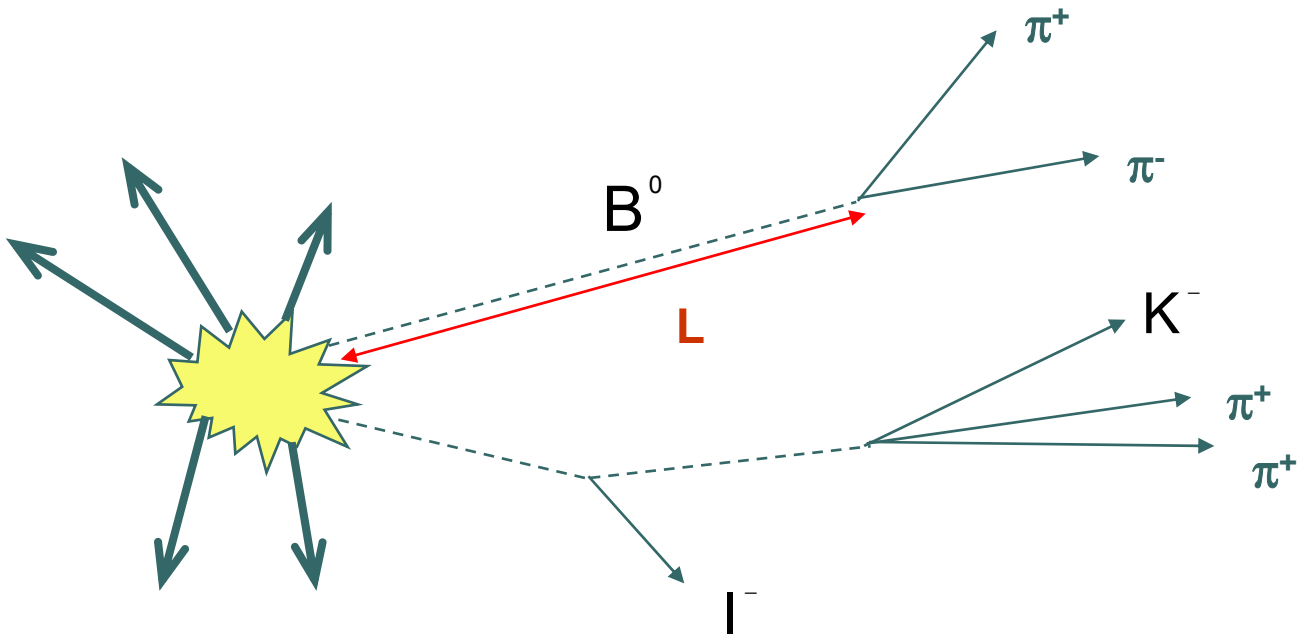
Introduction

- Overview of experiment
  - LHCb
  - **R**ing **I**maging **C**herenkov **D**etectors (RICH)
  - Importance of particle identification
- Photodetectors for the RICH
  - Development of first 40 MHz prototype **H**ybrid **P**hoton **D**etectors (HPDs)

LHCb Physics - an example B event



What do you want to know?

- **B decay length** & **momentum** of decay products (and therefore proper time $t = \frac{mL}{pc}$)
- **Was it a** B **or** $\bar{B}$**?** Tag by looking at lepton/K sign of other b-hadron in event

LHCb detector

Tracking and dipole magnet

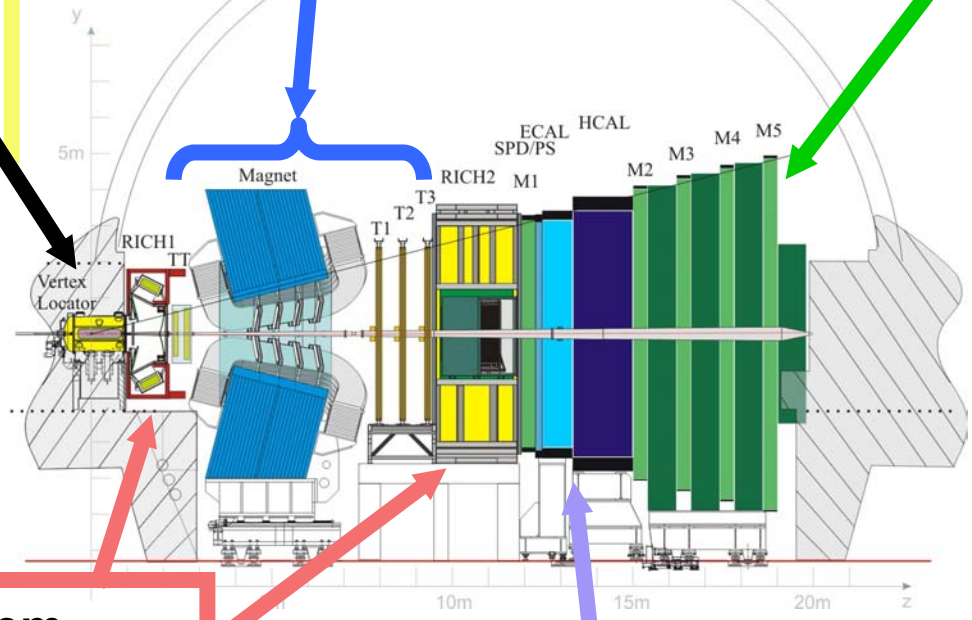
Measures track directions and momenta

Muon System

Vertex Locator

Silicon strip detector

~30μm resolution



RICH System

Charged Hadron identification

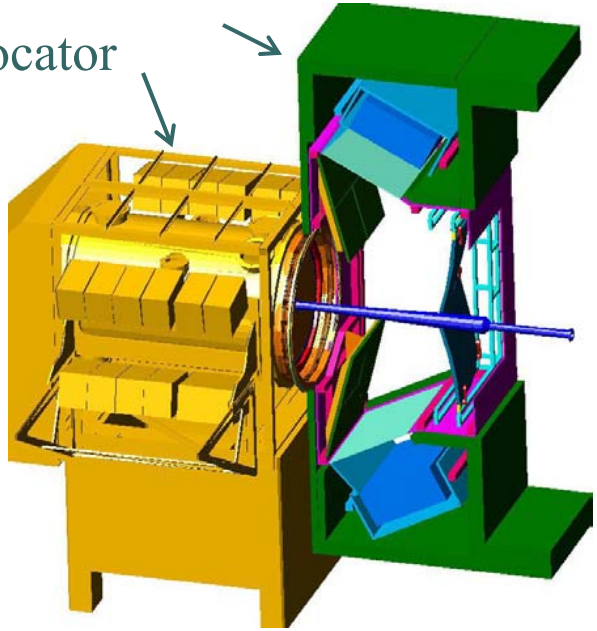
Calorimeter System

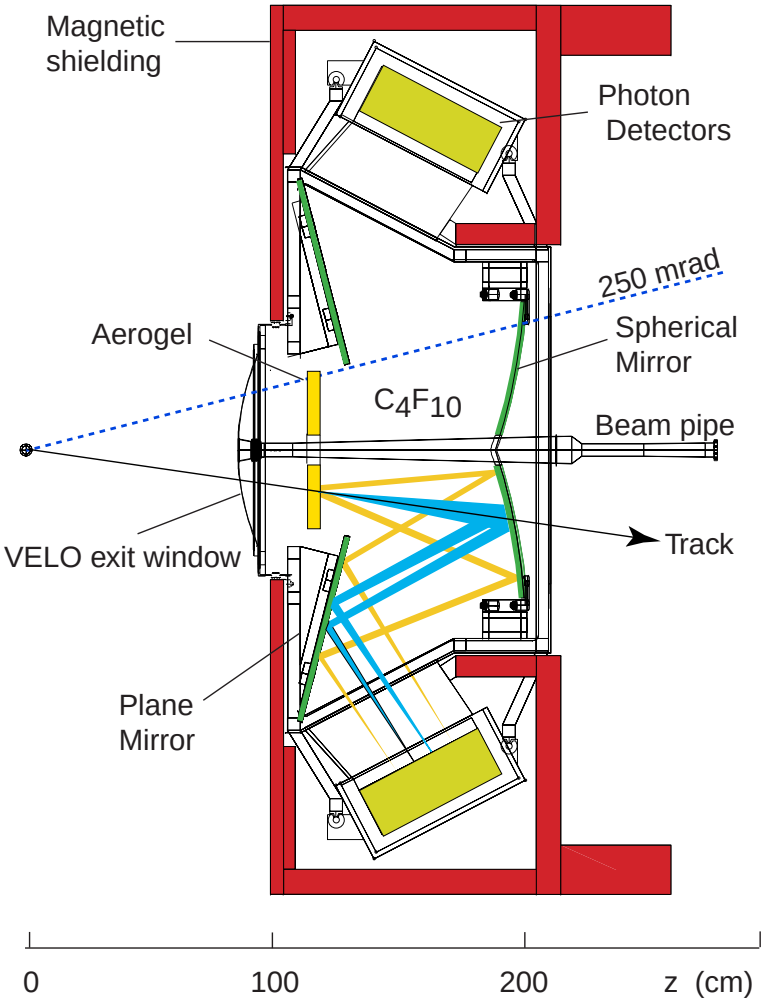
Identifies electrons, hadrons and neutrals

RICH detectors

RICH1 detector

Vertex locator

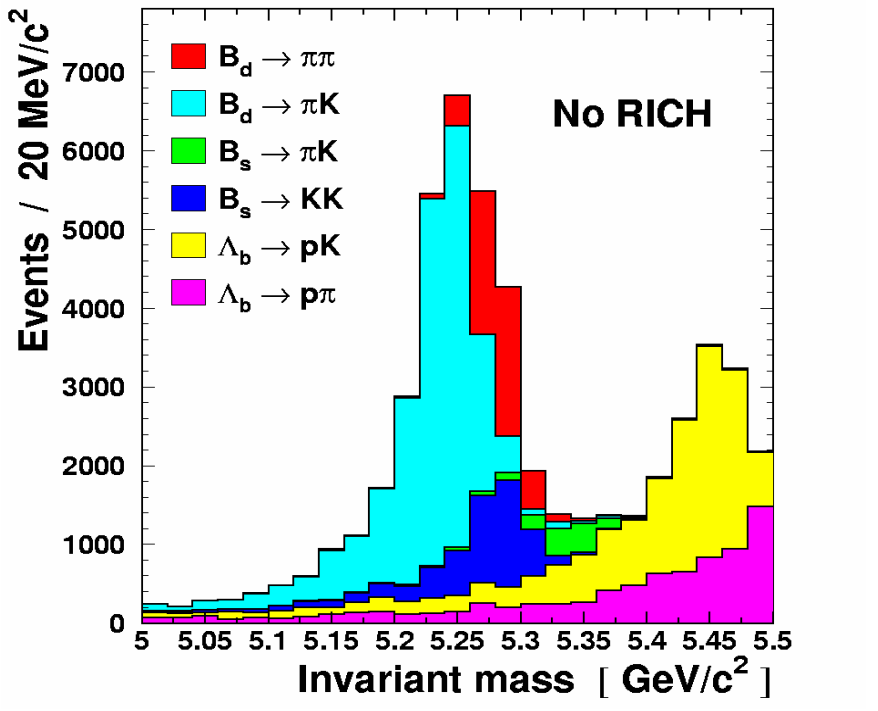


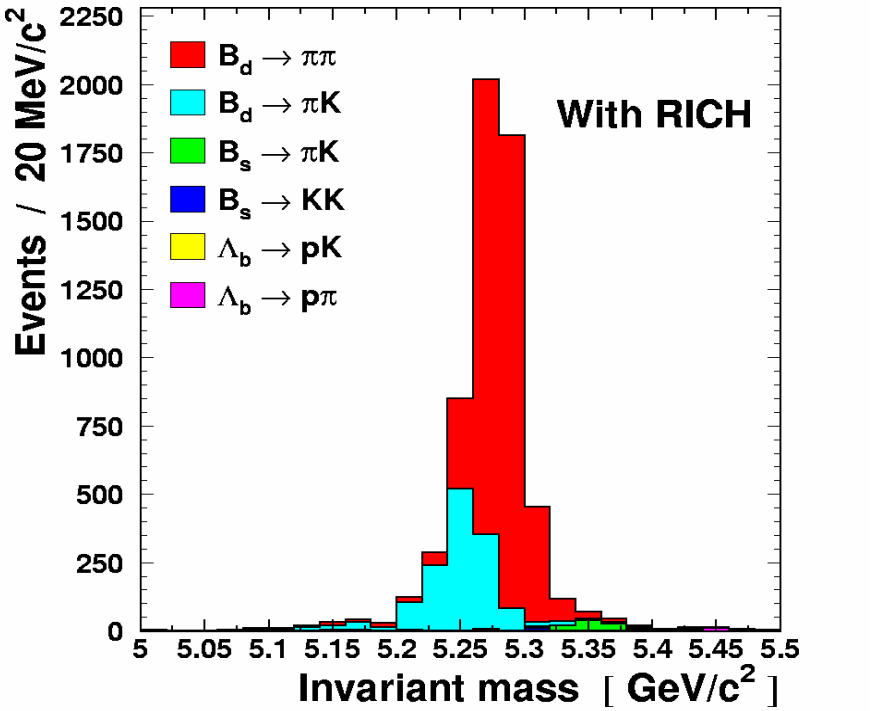


RICH2 has CF_4 gas radiator
for ID of high momentum tracks

3σ π - K separation for 3 < p < 80 GeV

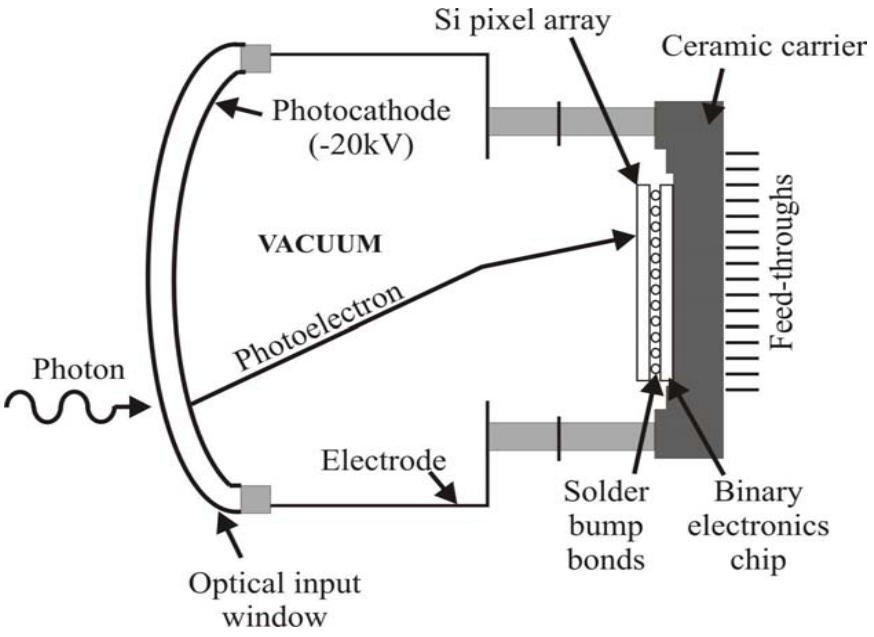
Importance of Particle Identification

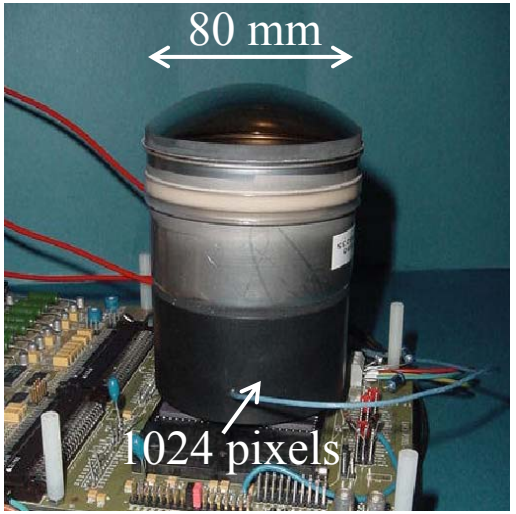




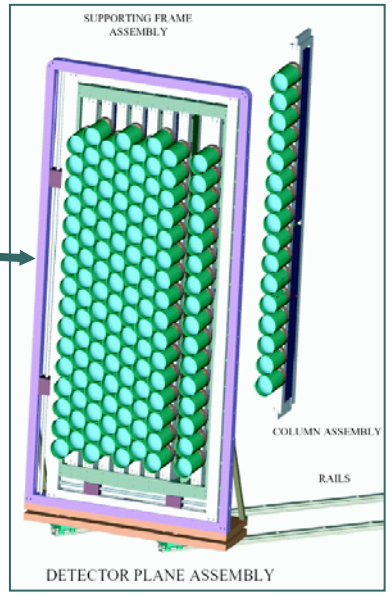
Allows decays of interest to be separated from other b-decay channels

Hybrid Photon Detector



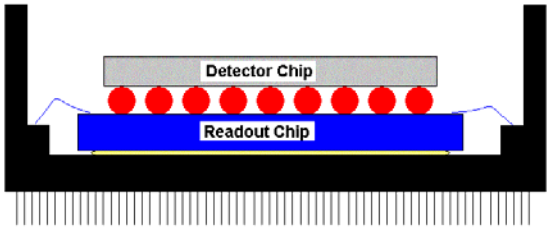


RICH2
HPD Plane



Aim to produce first prototypes working at 40 MHz

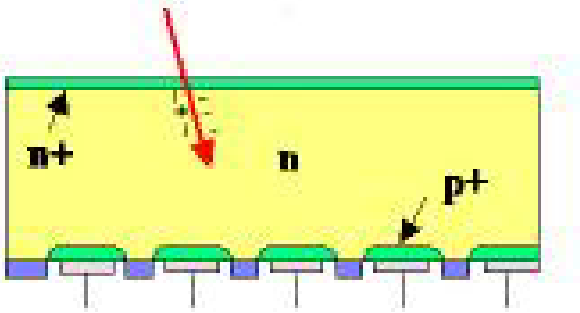
HPD production
Step 1:- The anode



- Silicon detector bump-bonded to readout chip
- Glued and wire bonded in ceramic carrier
- 32×32 pixels

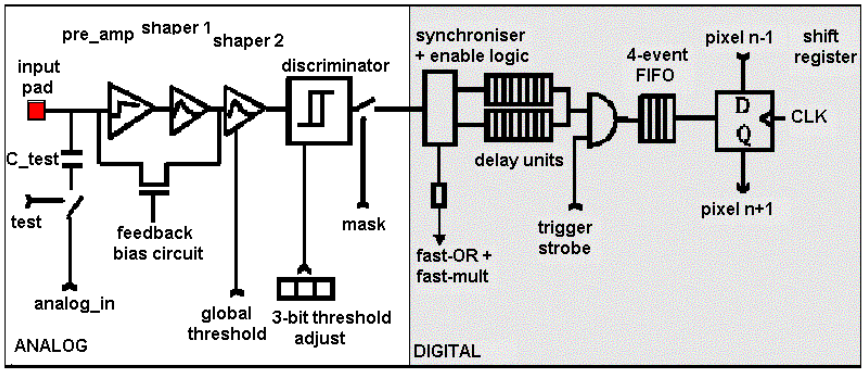
Silicon Sensor

1 photoelectron → 3000-5000 e-h pairs

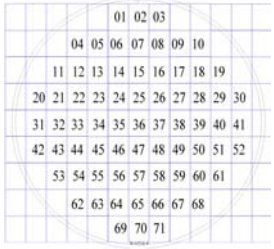


Pixel Cell

Charge amplified, shaped & discriminated in each pixel→digital output

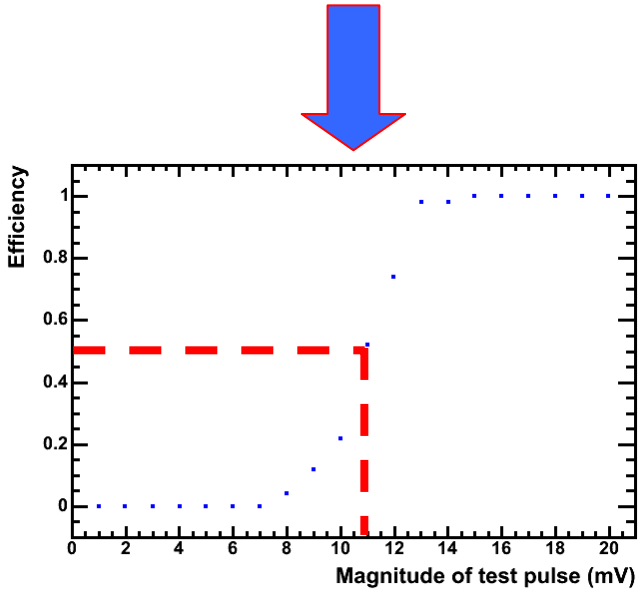


Select Good Readout Chips



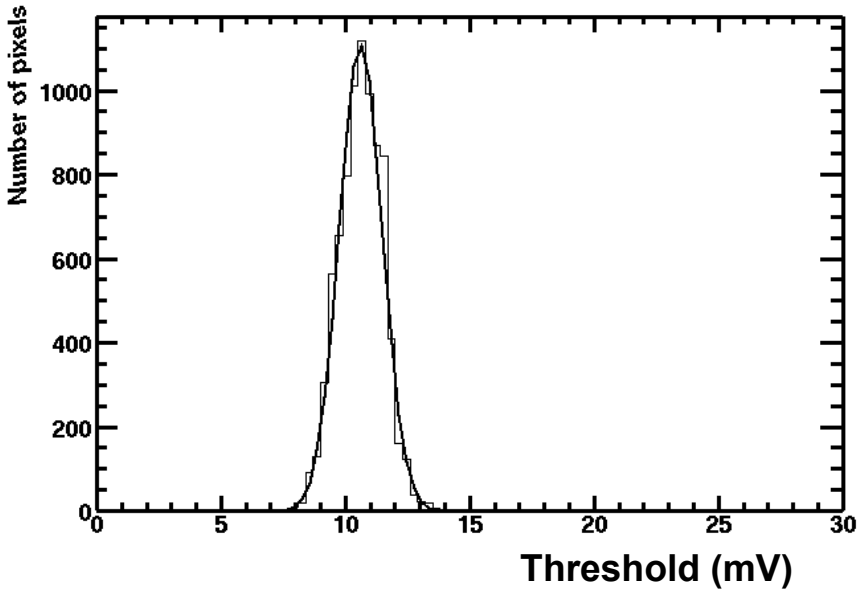
Wafer Map

- Carry out threshold scan
  - Send test pulses to each pixel
  - S-curve for each pixel



Threshold defined at 50% efficiency

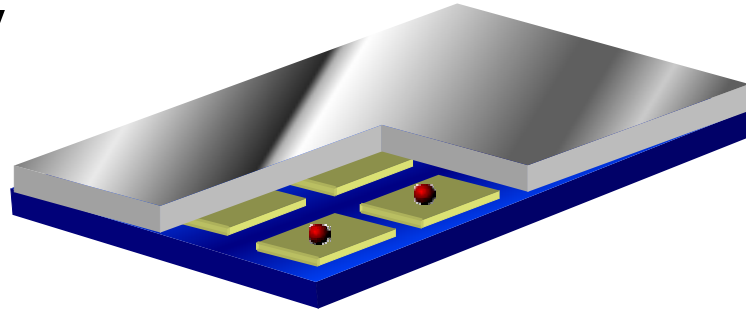
Narrow threshold spread across chip



Expected signals of 30-50 mV,
threshold well below signal level

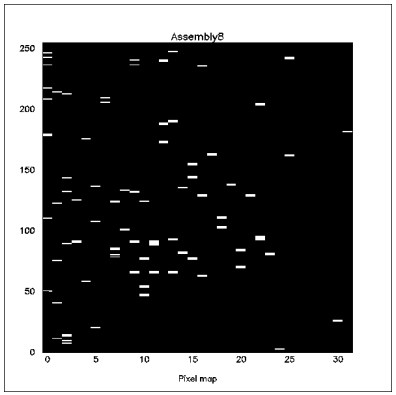
Chip Yield ~ 45%

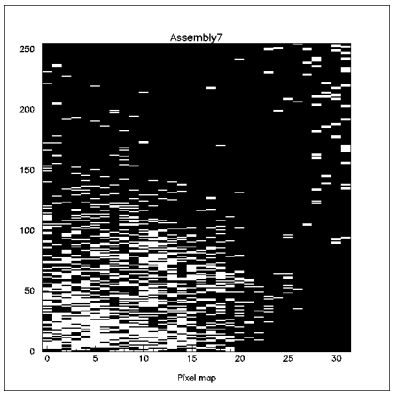
Anode Assembly



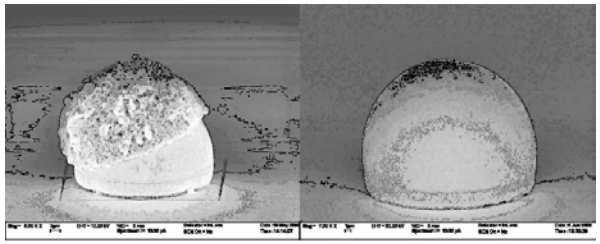
- High Lead (90%Pb – 10%Si) solder bumps deposited on readout chip
  - High melting point ~ 300 °C
- Has chip survived bump-bonding process?
- Test bond quality using ^{90}Sr source
- Poor results due to ‘crust’ on bump

Results from 1st batch



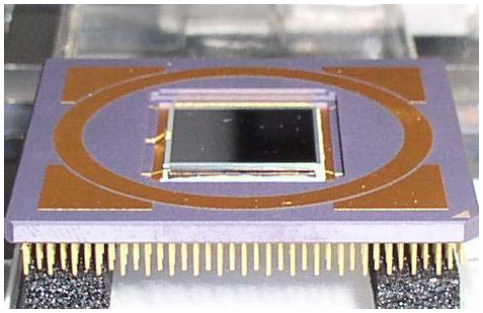


98.5% **85.0%**



‘Crust’ problem solved and not present in later batches

Will the bump bonds survive?



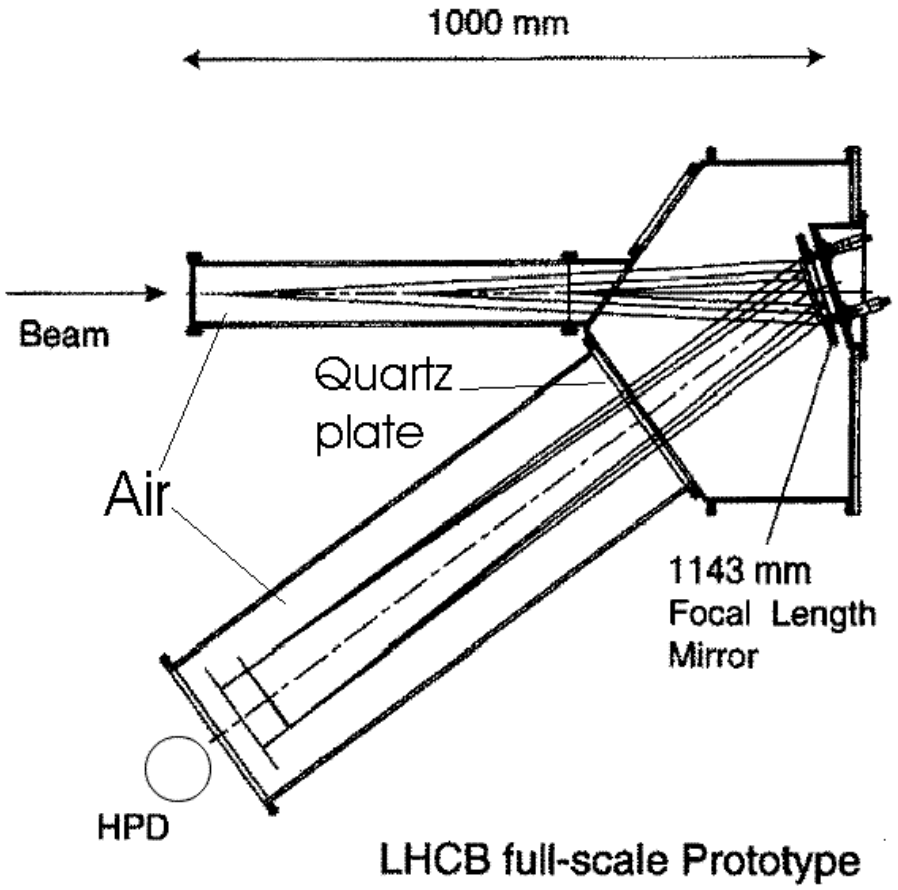
- Packaging – glue temperature ~ 400 °C
- Encapsulation & bake-out cycles @ 300 °C

The Answer – YES!

- Two prototype 40 MHz HPDs produced and tested in lab (Lisa's talk) and in test beam

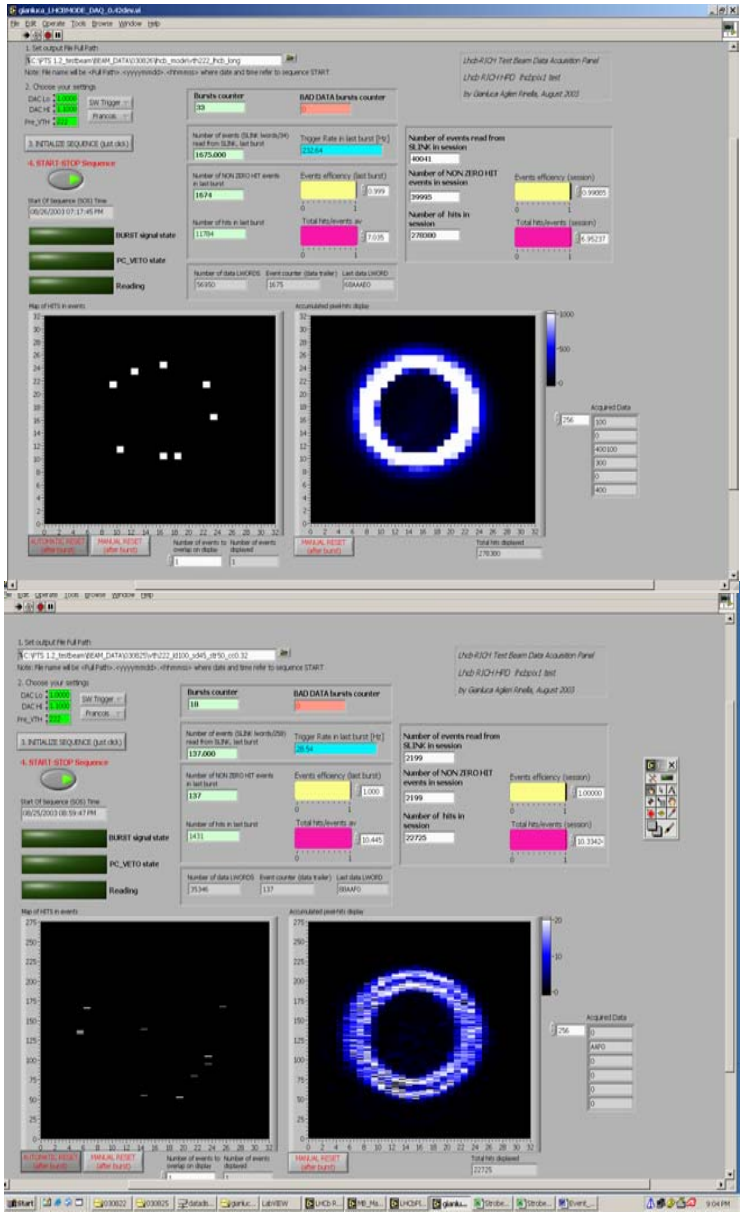
HPD Test Beam

- **CERN, PS T9 Test beam area, east hall**
  - 10 GeV/c negative particles
- **Vessel**
  - UK RICH1 prototype
  - Air rings
- **Triggering system**
  - 4 scintillators coupled to PM tubes

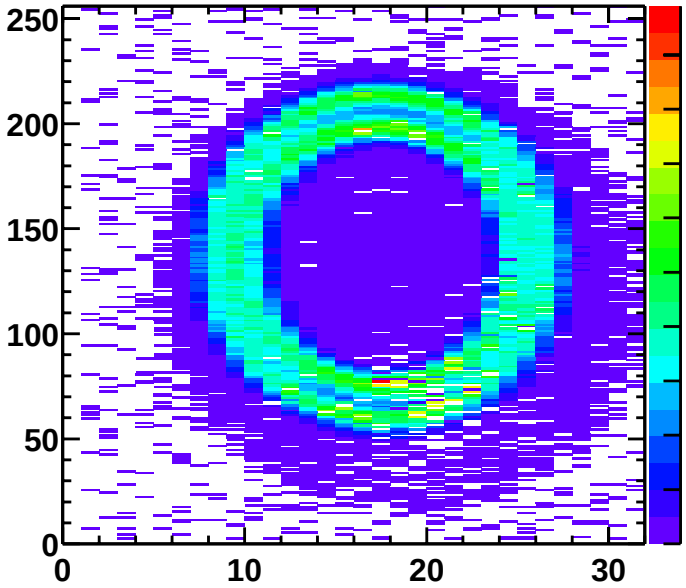


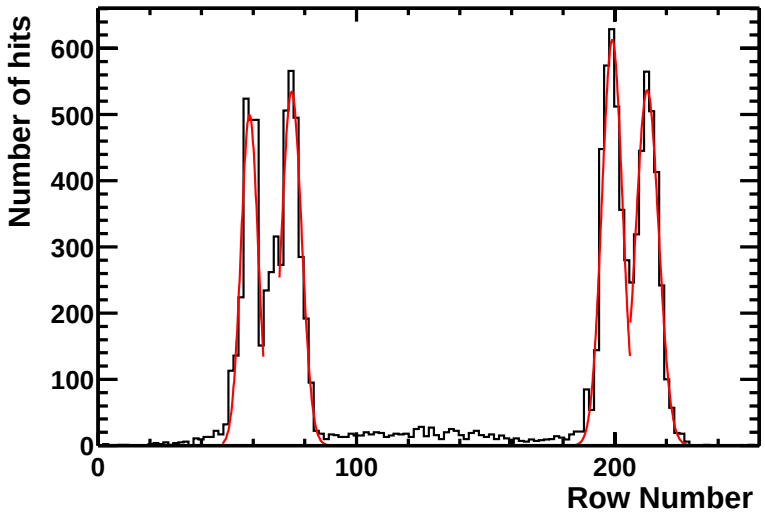
HPD Test beam – online display

- Cherenkov air rings
- LHCb readout mode (32×32 pixels)
- Alice mode readout (256×32)
- 2 rings visible
  - What are the particles?



What are the particles?





	Expected θ_C (mrad)
electron	24.9
muon	22.5
pion	20.6
kaon	Below threshold
proton	Below threshold

	Measured θ_C (mrad)
Outer ring	24.83
Inner ring	20.02

Measured cherenkov photons from electrons and pions

Conclusions + future

- 2 working 40 MHz HPD prototypes were produced
- Both measured Cherenkov photons in testbeam
- HPDs were selected as the photodetector for the LHCb RICH
- Second batch of prototypes is being produced, before production starts in October
  - Results from second batch good so far