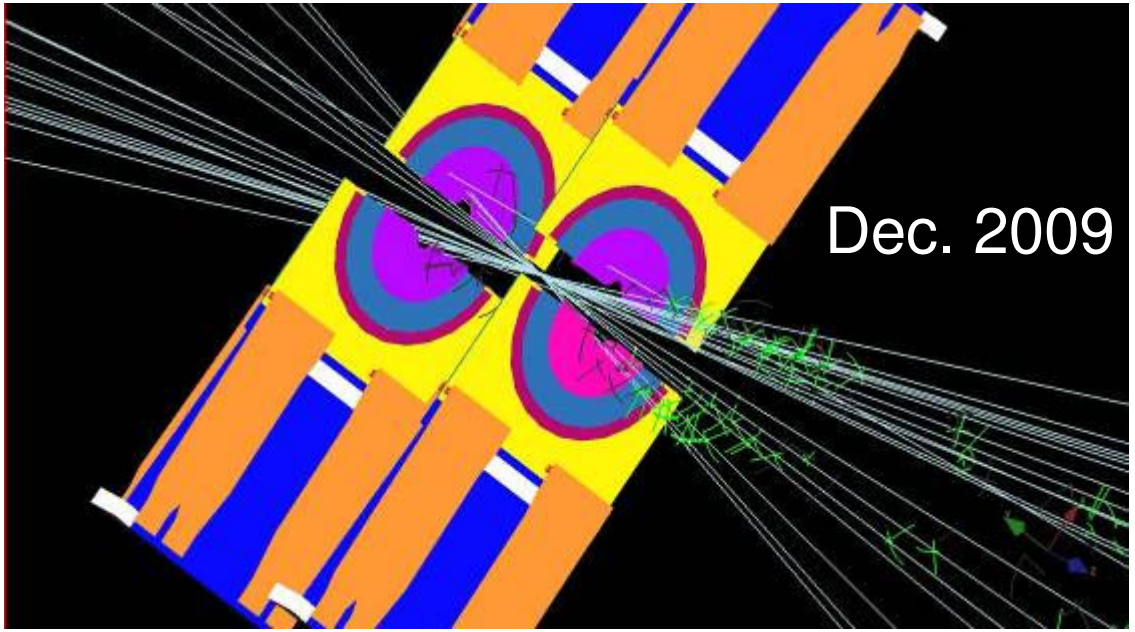
First results from the LHCb Vertex Locator

- Act 1: LHCb Intro.
- Act 2: Velo Design
- Act 3: Initial Performance



Chris Parkes *for* LHCb VELO group Vienna Conference 2010

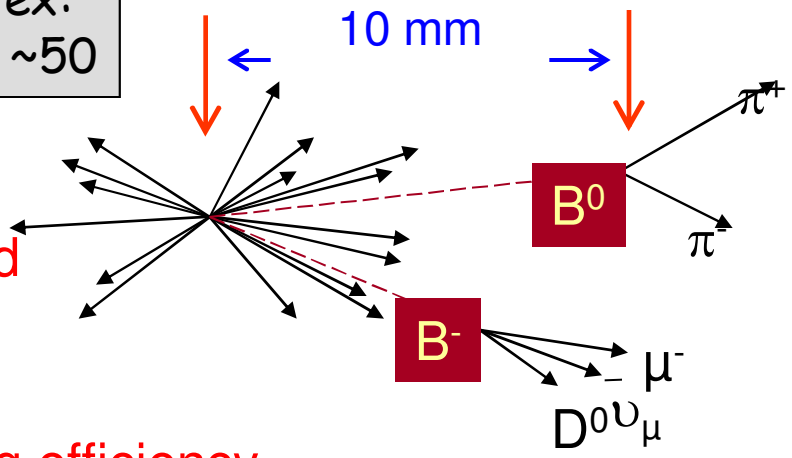
Introducing LHCb

LHCb is a dedicated experiment to study flavour physics at the LHC

- Search for New Physics in quantum loop processes
- CP violation and rare decays allowing to probe beyond the LHC energy frontier

B decay vertices: a few tracks

Primary vertex: many tracks ~50

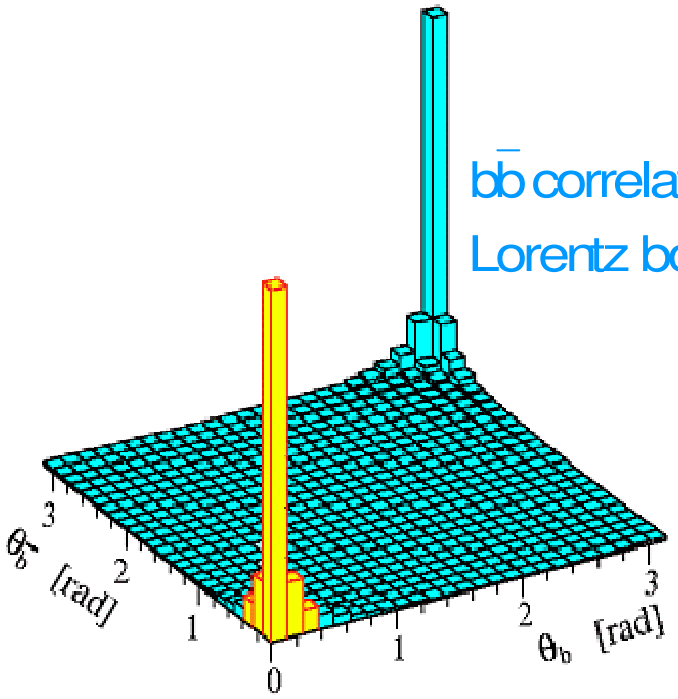


Detector requirements

- Efficient trigger for both leptonic and hadronic final states
- Excellent vertex finding and tracking efficiency
- Outstanding particle identification

B Production

- LHC: pp-collisions @ 2→7→14 TeV
- 2 fb^{-1} in data taking year of 10^7s, 10^{12} $b\bar{b}$ pairs

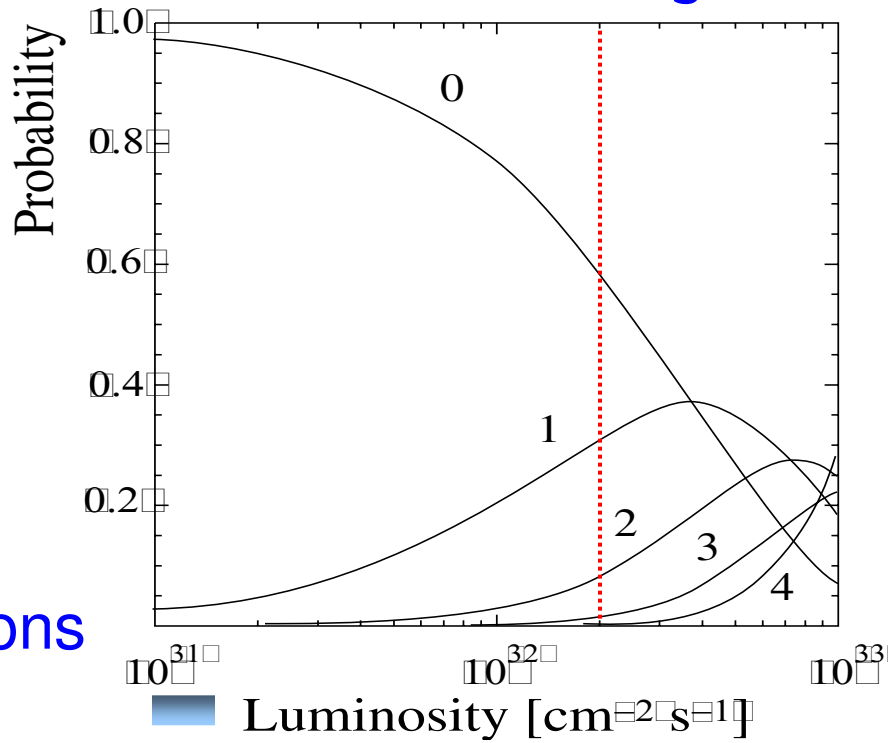


LHCb: forward spectrometer

15-250 mrad acceptance

η = 1.9-4.9

Interactions/crossing

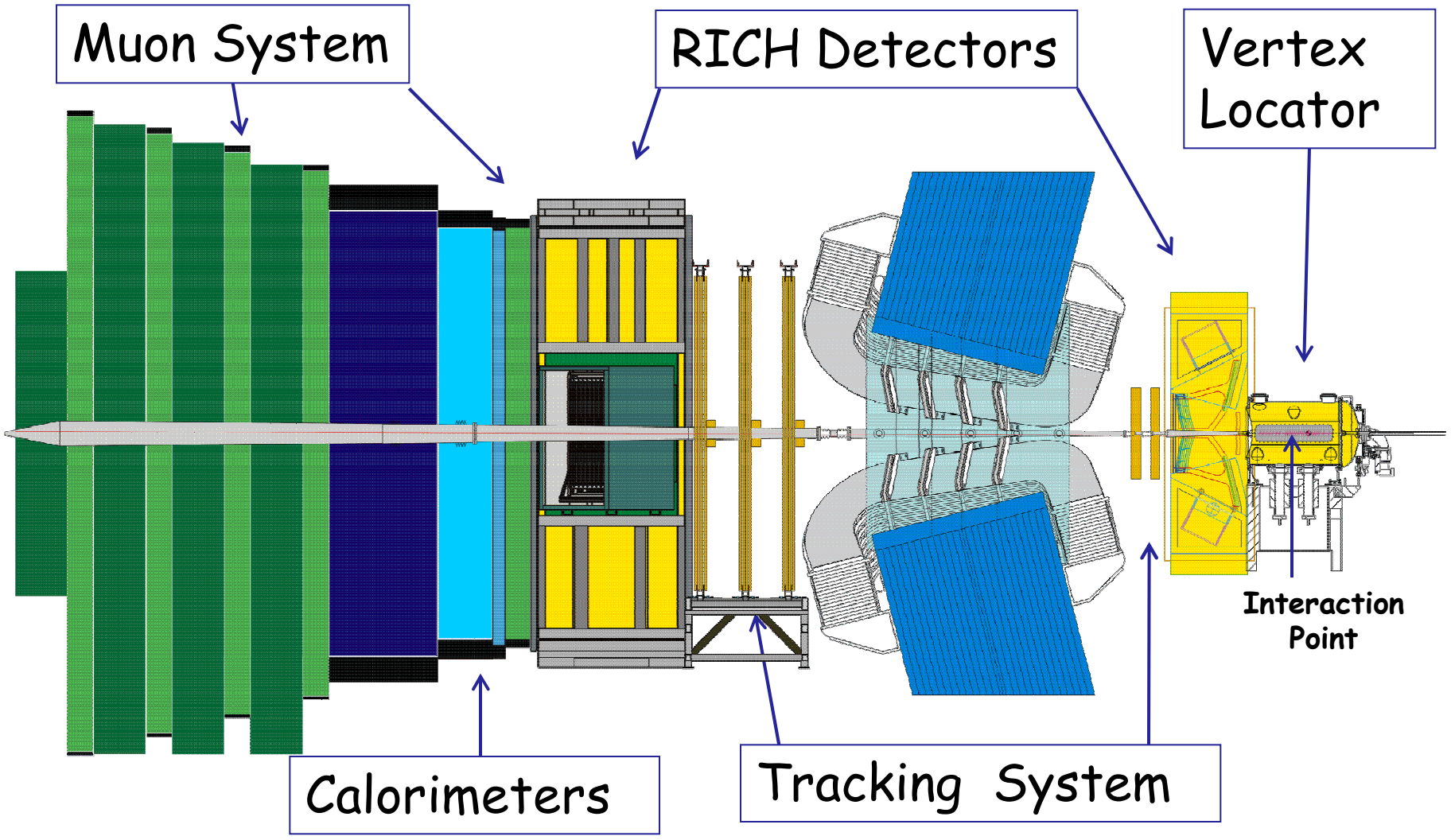


- Pile-up at high luminosity
  - choose 2x10^{32} cm^{-2} s^{-1}

➔most events have single interactions

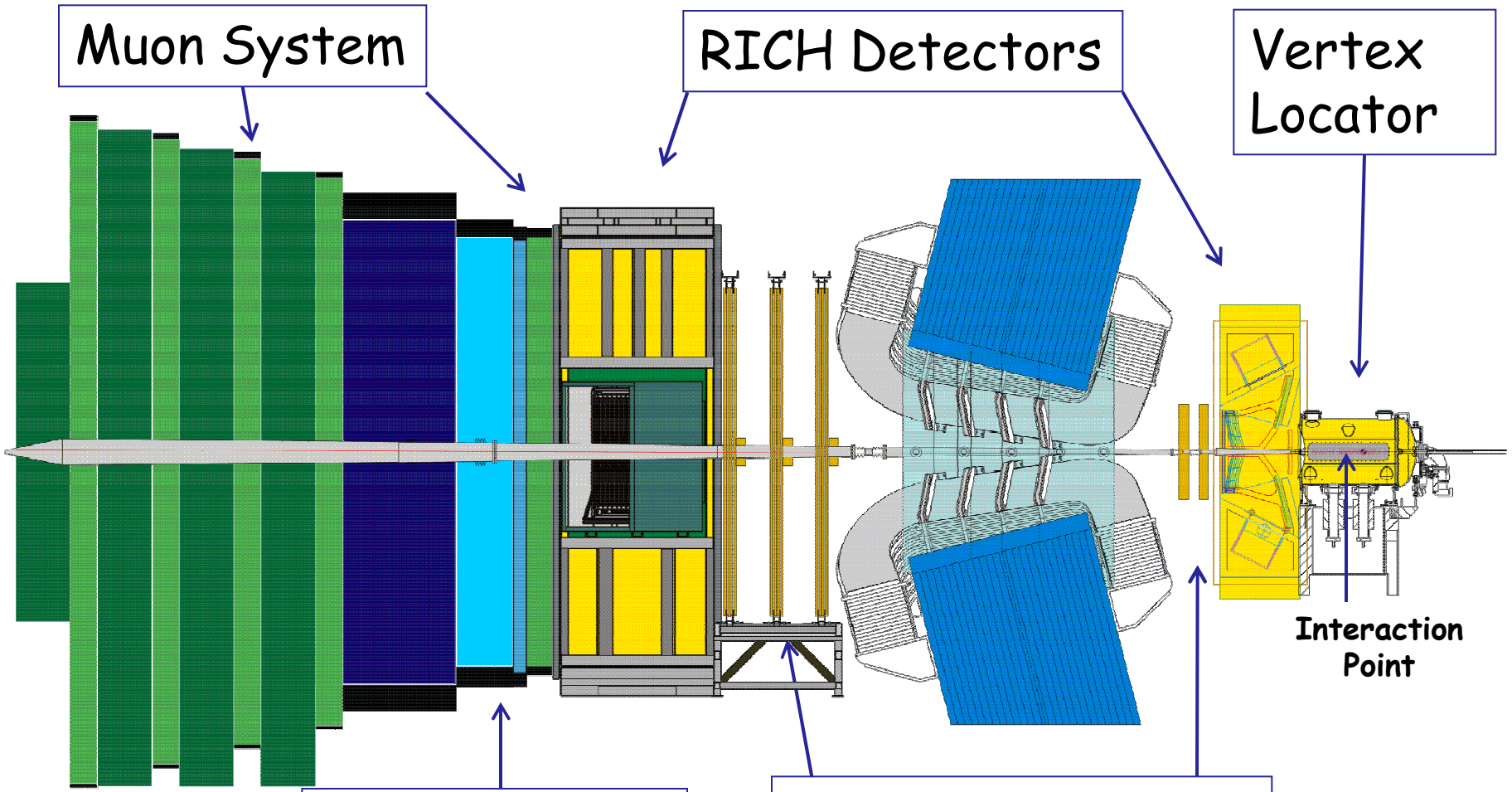
LHC will reach early in run

The LHCb Detector



The LHCb Detector

Poster: Davide Pinci

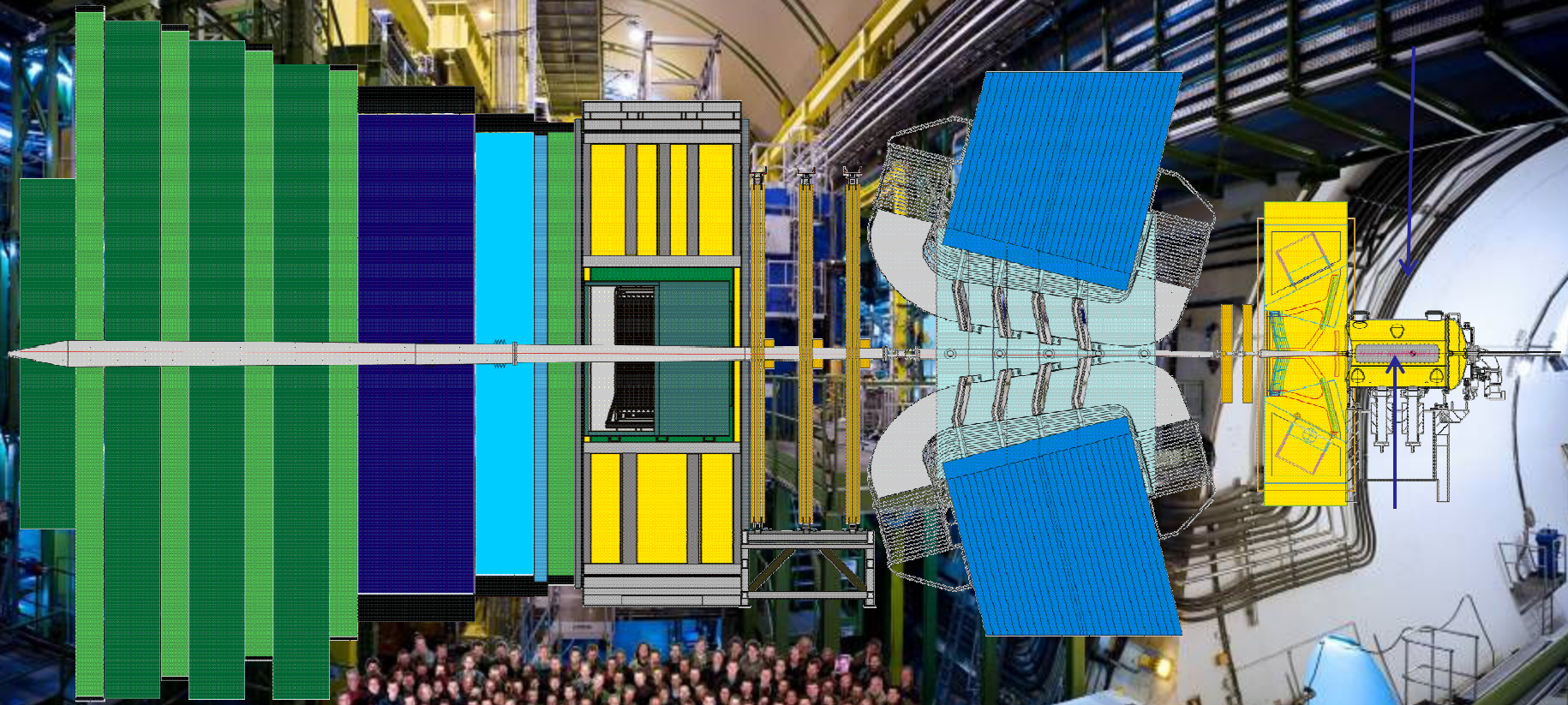


Talk: Miriam Calvo Gomez

Talk: Antonio Pellegrino

Poster: Jeroen van Tilburg

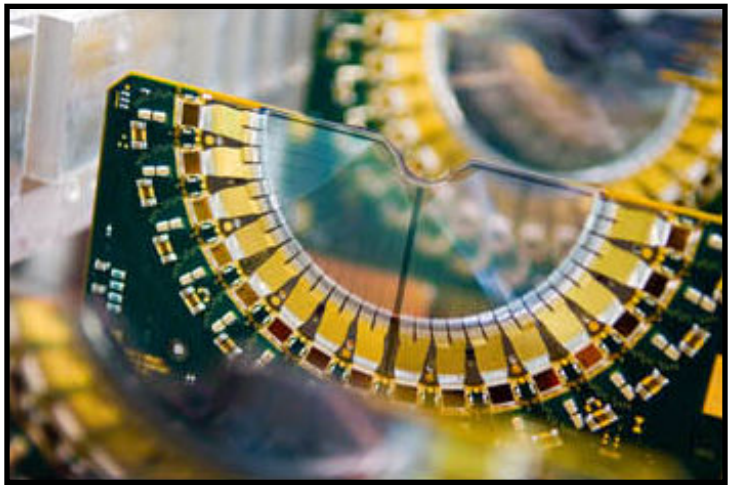
The LHCb Detector



Fully installed and commissioned

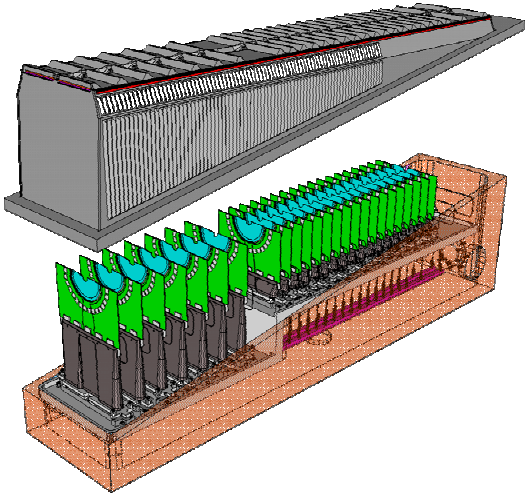
Conducting first physics !

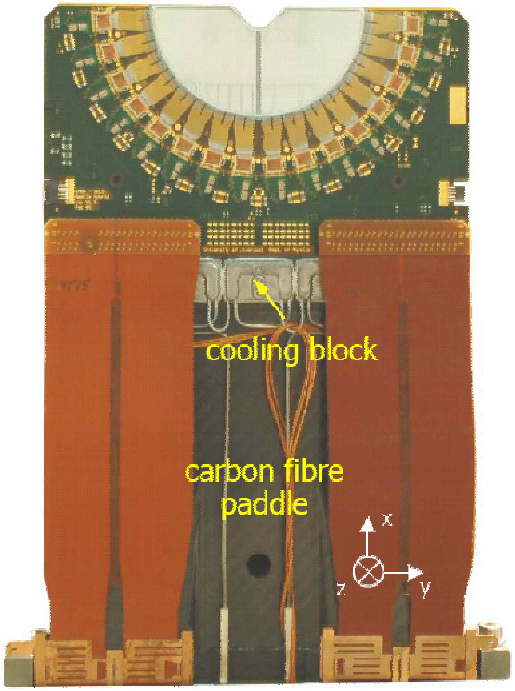
Act 2:
VELO Design



Velo Roles

- Primary / b decay Vertex reconstruction
- Standalone Tracking
  - A principle tracking device for the experiment
- Second Level Trigger
  - Fast tracking

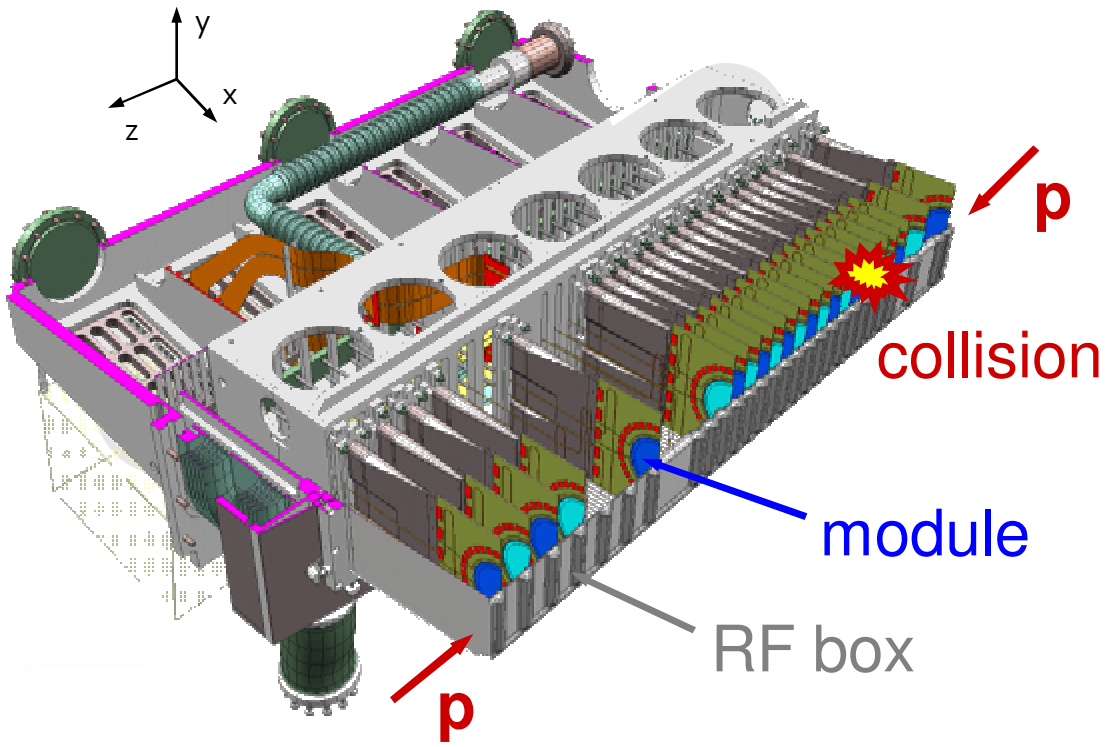


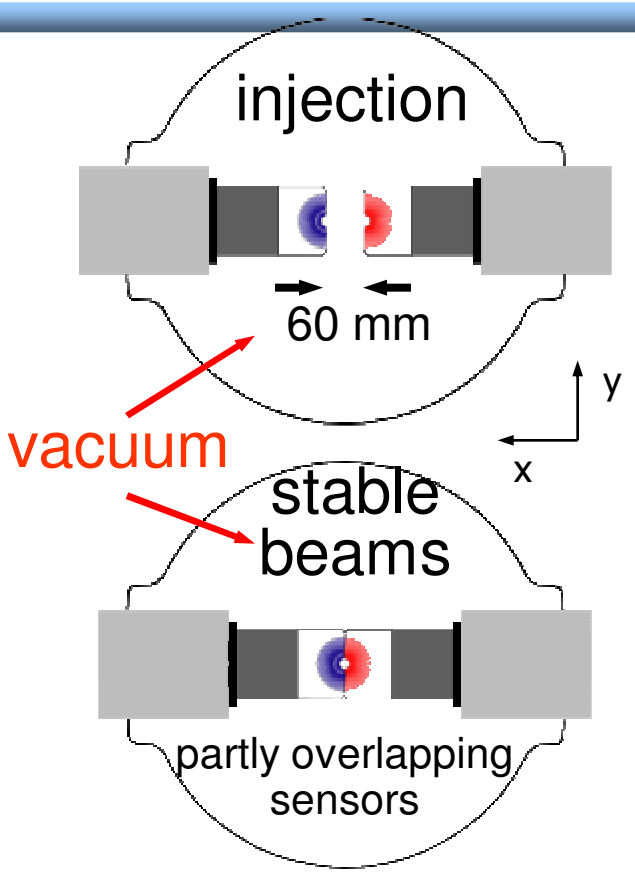


Velo Modules

- n-*on*-n & 1 n-*on*-p
- Two semi-circular designs
  - R-measuring
  - Phi-measuring
- double metal layer readout
- 2048 strips, 40-100 µm pitch
- .25 µm Analogue Readout
- TPG core Hybrid, CF paddles

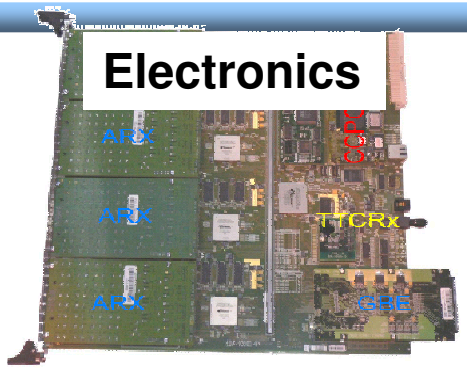
VELO Layout

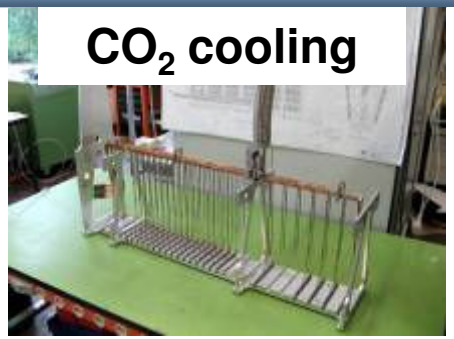


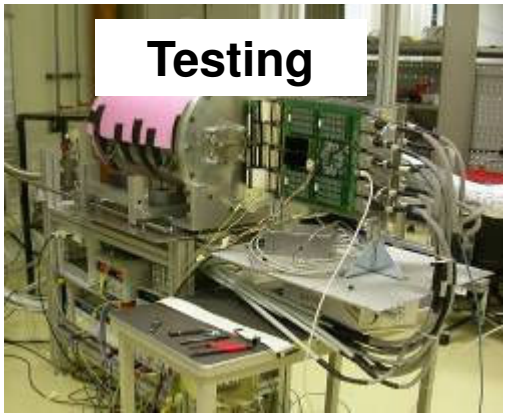


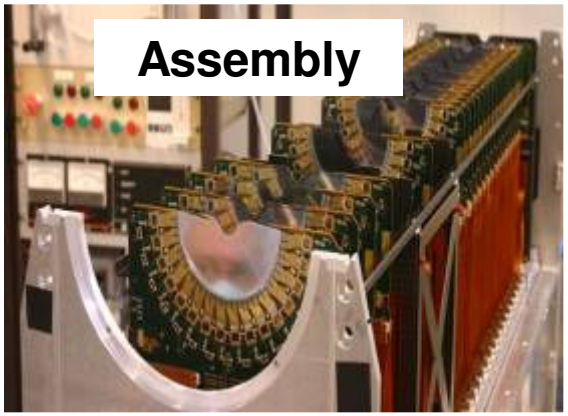
- 2 retractable detector halves
- 21 stations per half with an R and ϕ sensor
- Operates in secondary vacuum
- 300 μm foil separates detector from beam vacuum
- 8 mm from LHC beam

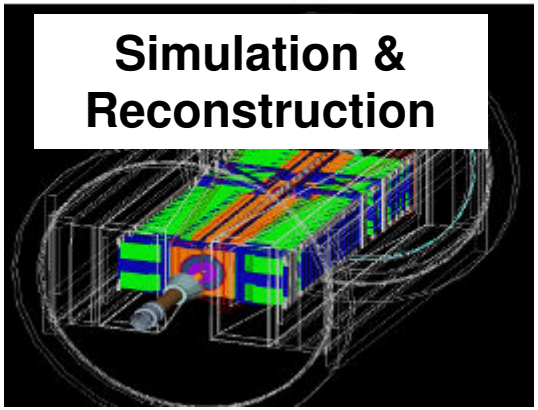
Production, Testing and Installation



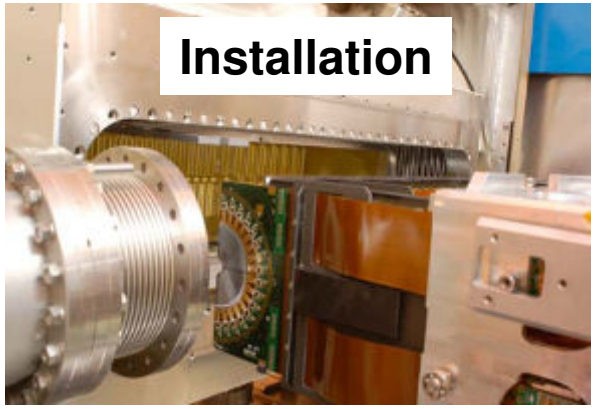


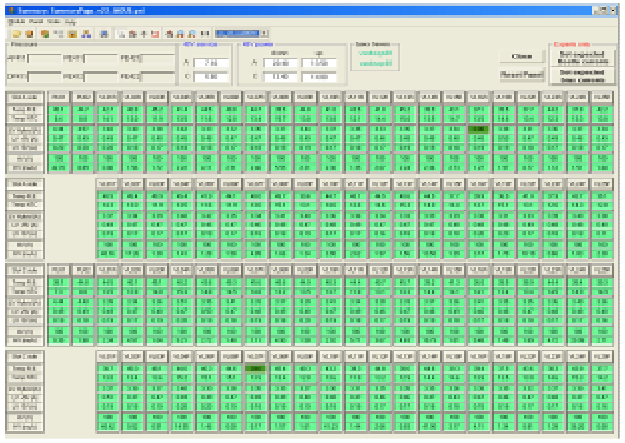






1997-2007
Design to
Installation





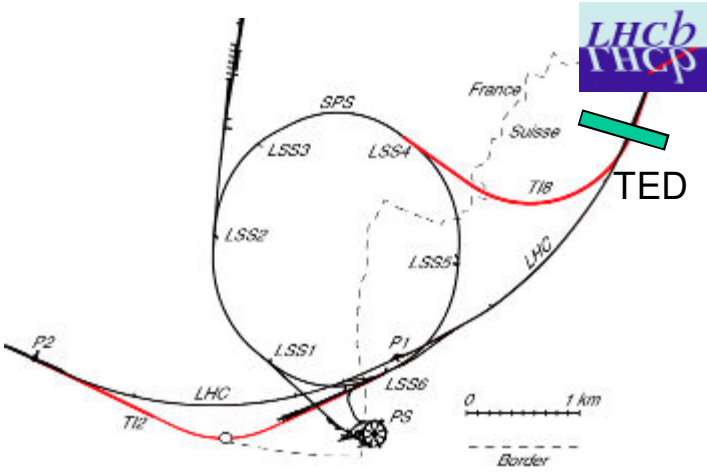
Act 3:
Performance with first LHC data

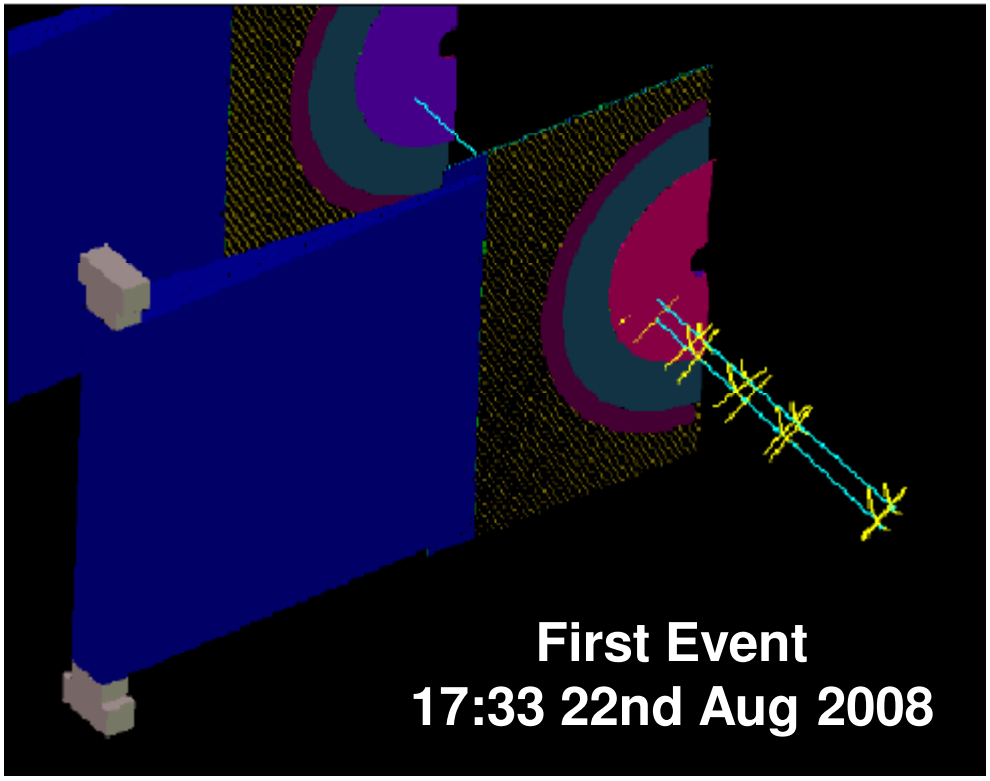
10 years – that's longer than I took to write my first symphony

First Tracks 2008

Nucl. Instr. Meth. A Vol. 604, 2009, 1

- LHC synchronisation test
- Beam collision with absorber
- Reconstruct tracks through VELO
- First Alignment & Resolution



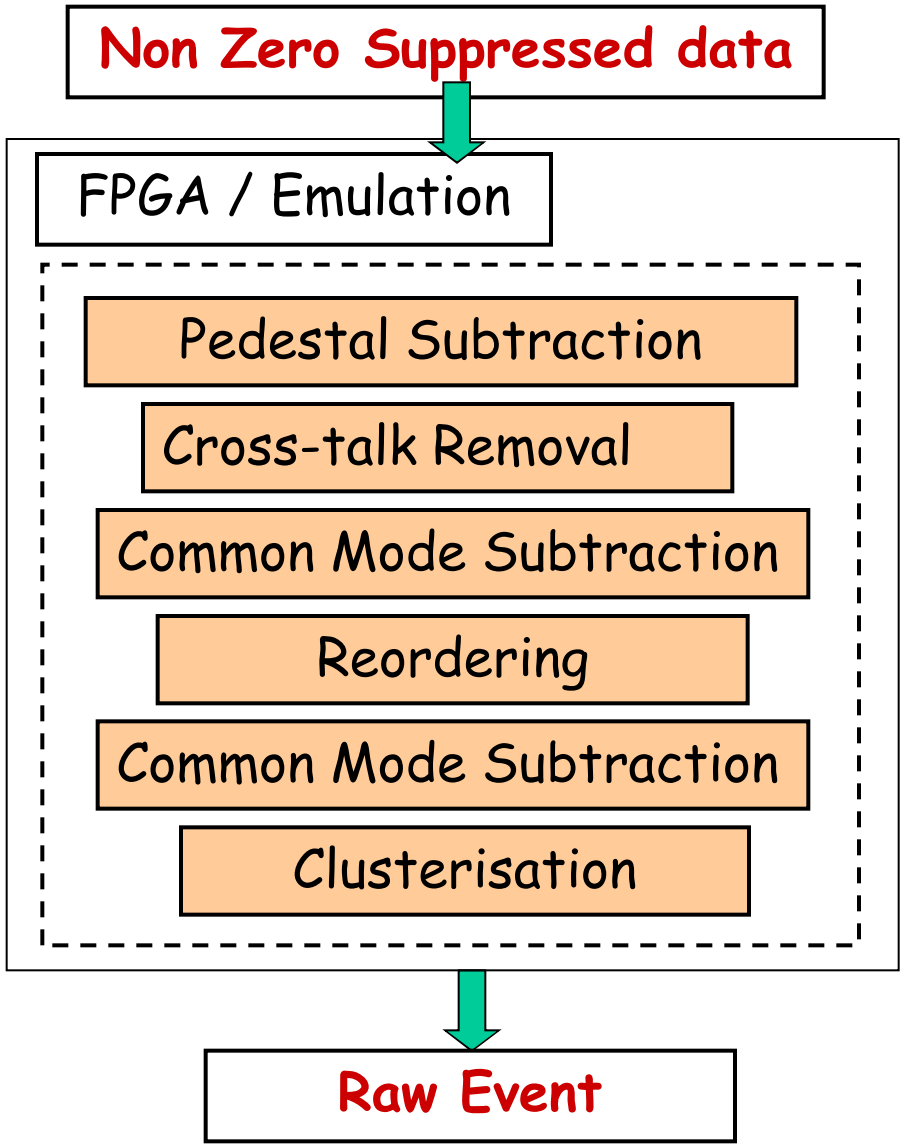


•LHC accident September 2008

•2008-2009 Commissioning & Optimisation

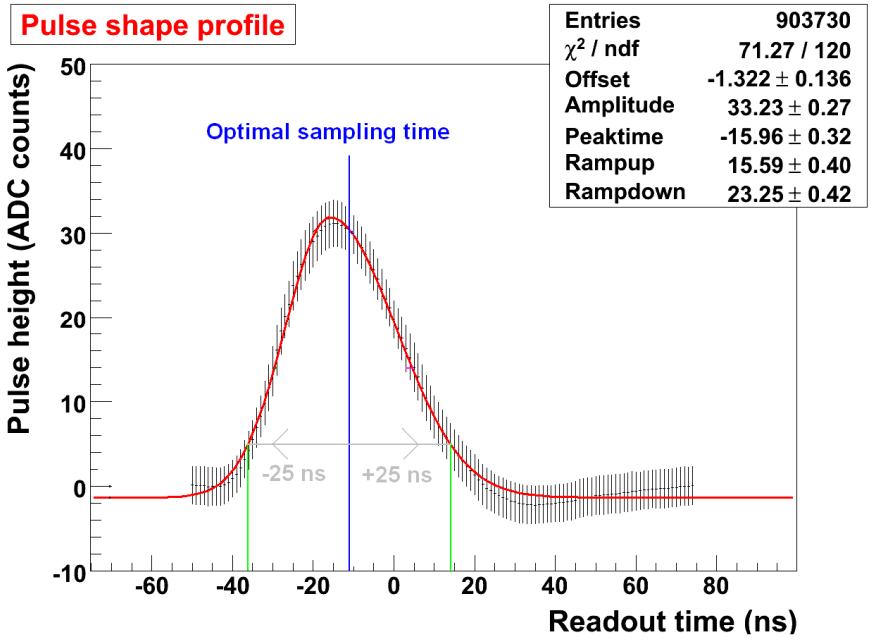
Data Processing

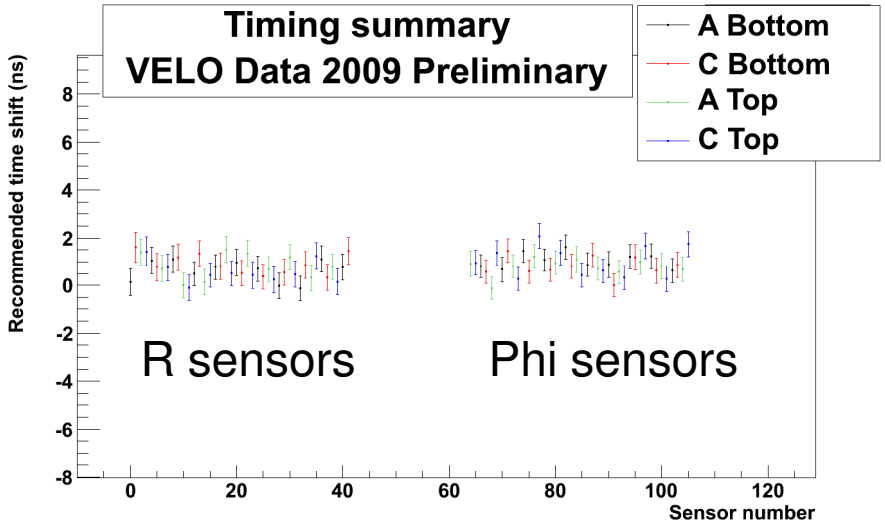
- FPGA processing
  - **10^6 parameters**
- Bit-perfect emulation in full software
  - **Low rate non-zero suppressed data**
- **Off-line optimise algorithm performance**



Time Alignment

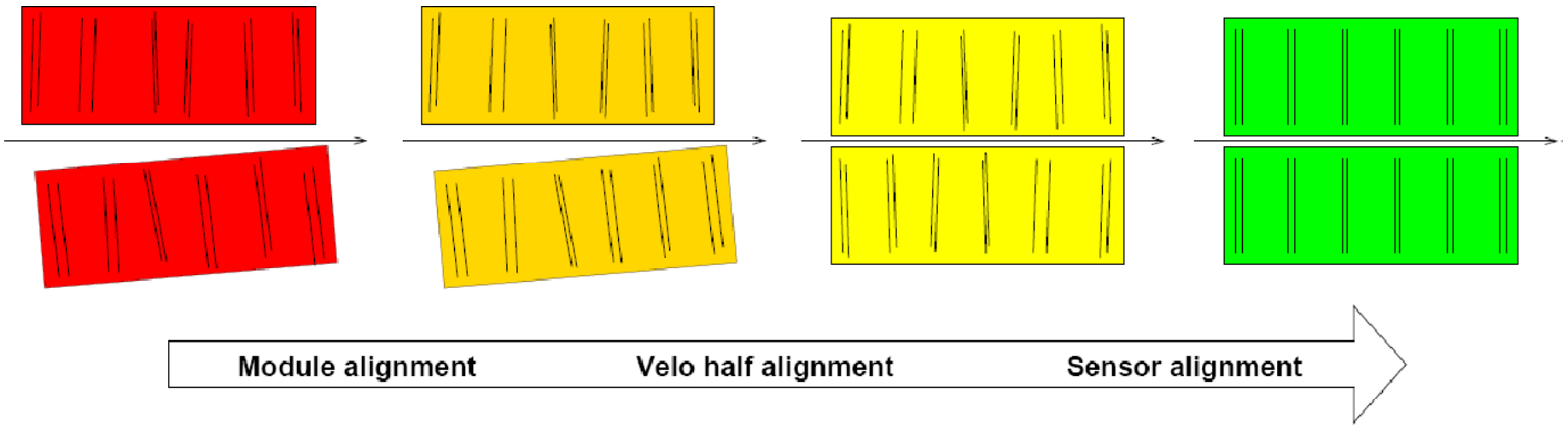
- Tune front-end chip sampling time
- Optimise for
  - Maximum signal
  - Minimum spillover
    - Next & previous
- Each sensor adjusted separately:
  - time of flight
  - cable length



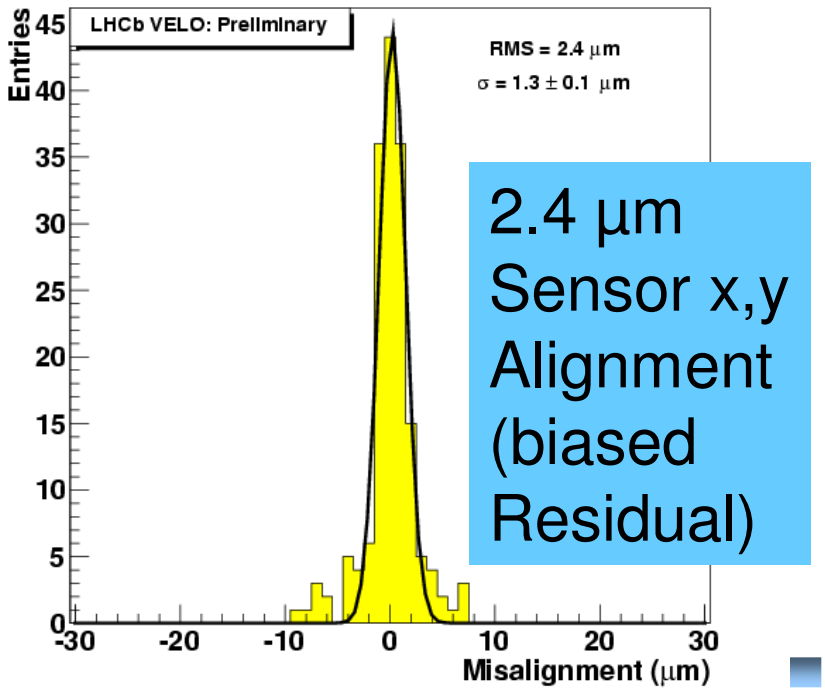


Alignment 1

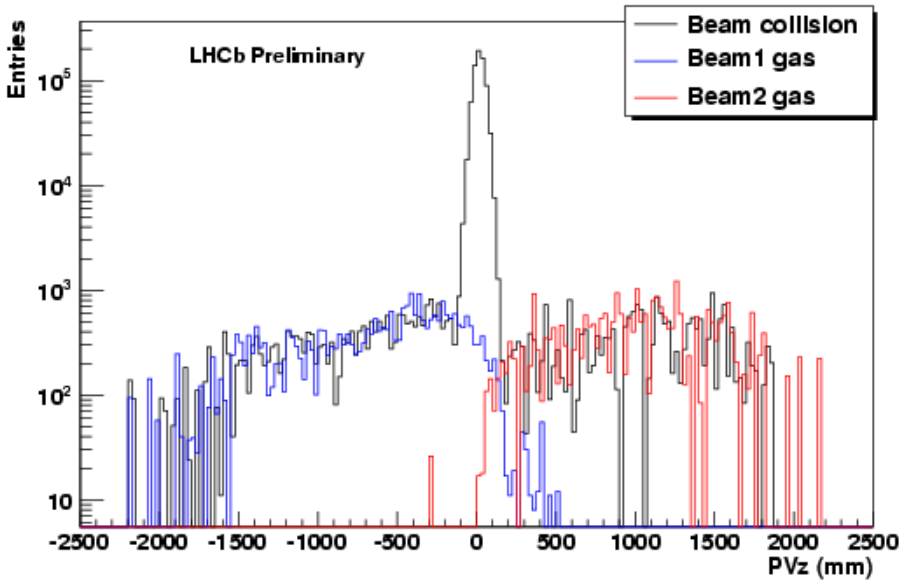
Nucl. Instr. and Meth. A596 (2008) 157-163
Nucl. Instr. and Meth. A596 (2008) 164-171



- Velo moved for each LHC injection
- Decay length measurement
  - Alignment is key
- Motion system resolver position updated in reconstruction
- Track based alignment in three stages

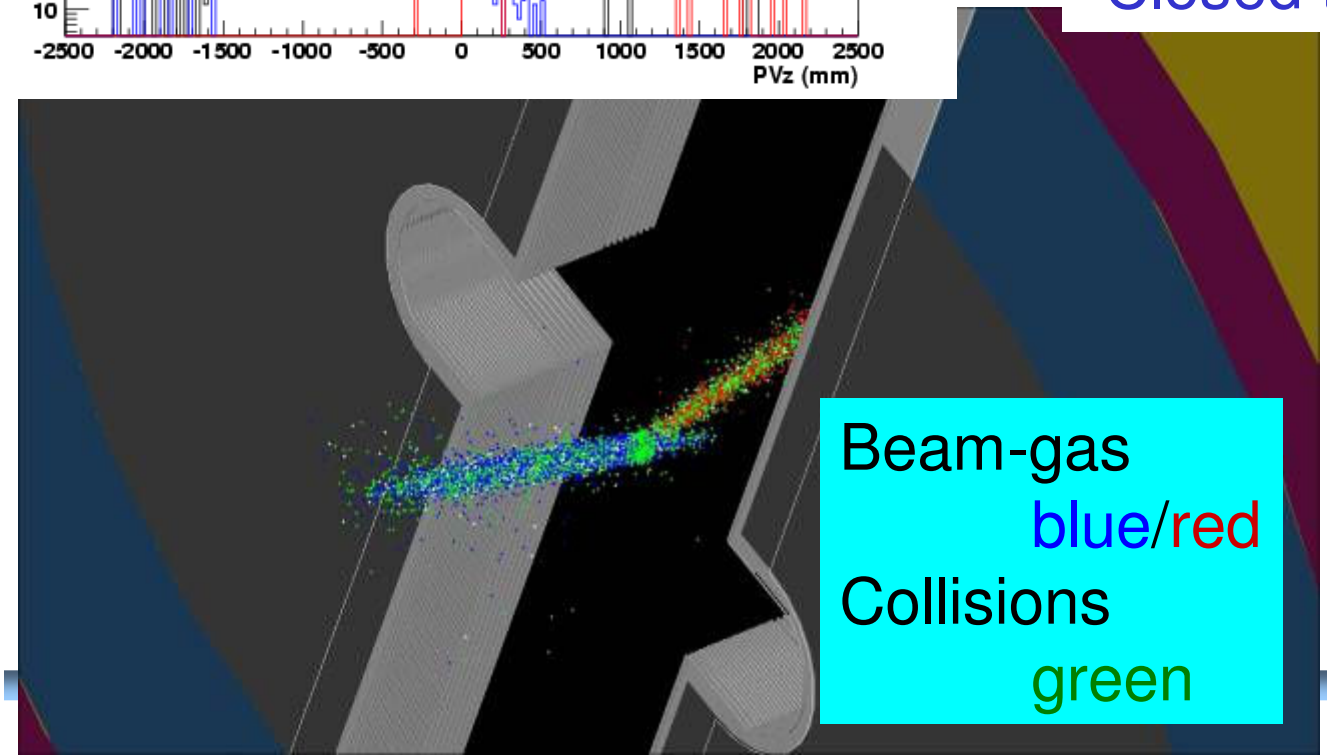


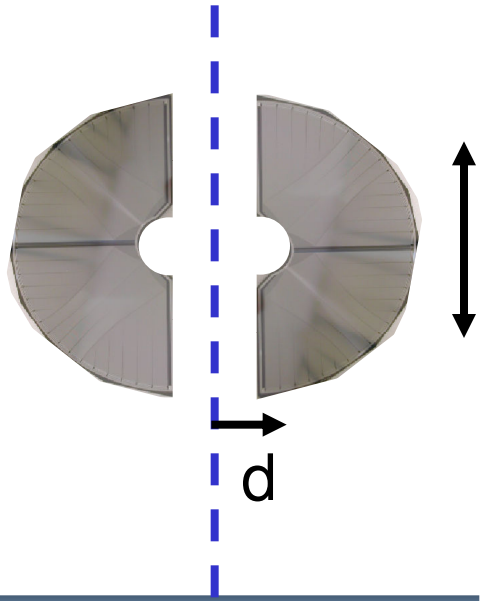
Vertices



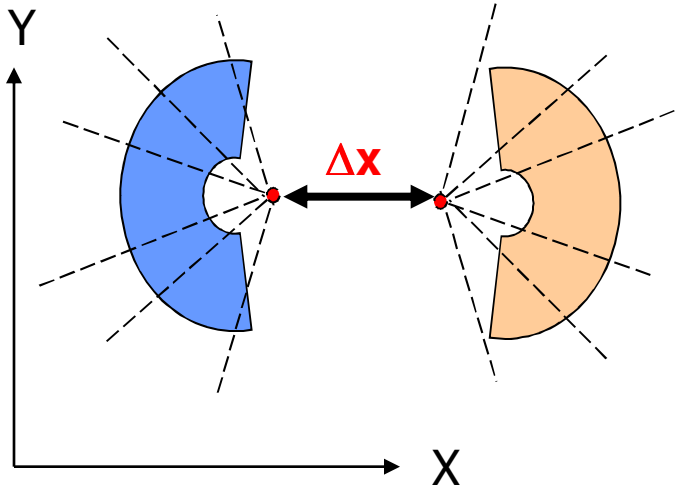
- Contributions from collisions & Beam-gas
- Beam-gas removed with Bunch ID and Vertex cuts in analyses in this talk

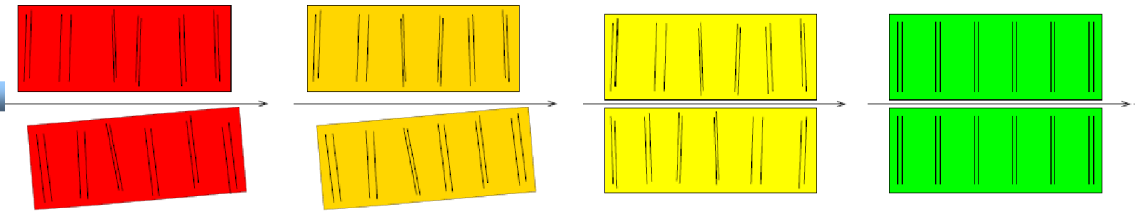
- Closed to ±15mm



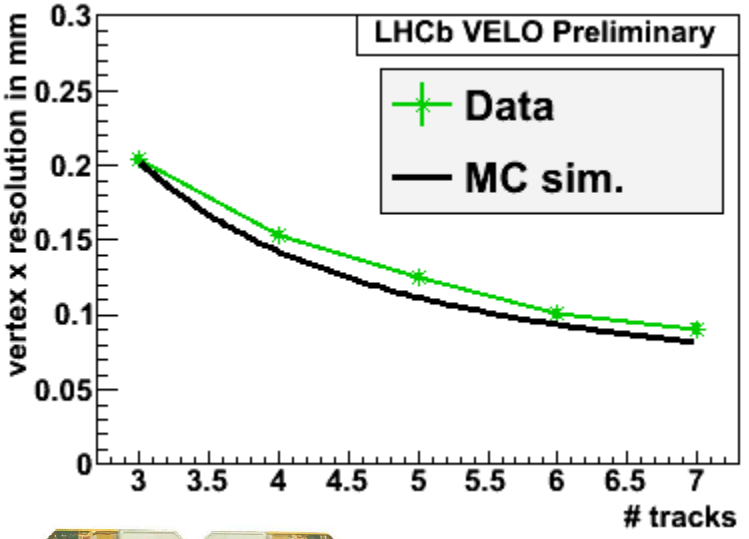


Alignment 2



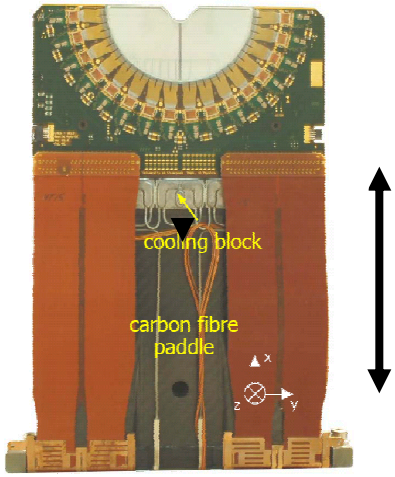


Module alignment → Velo half alignment → Sensor alignment



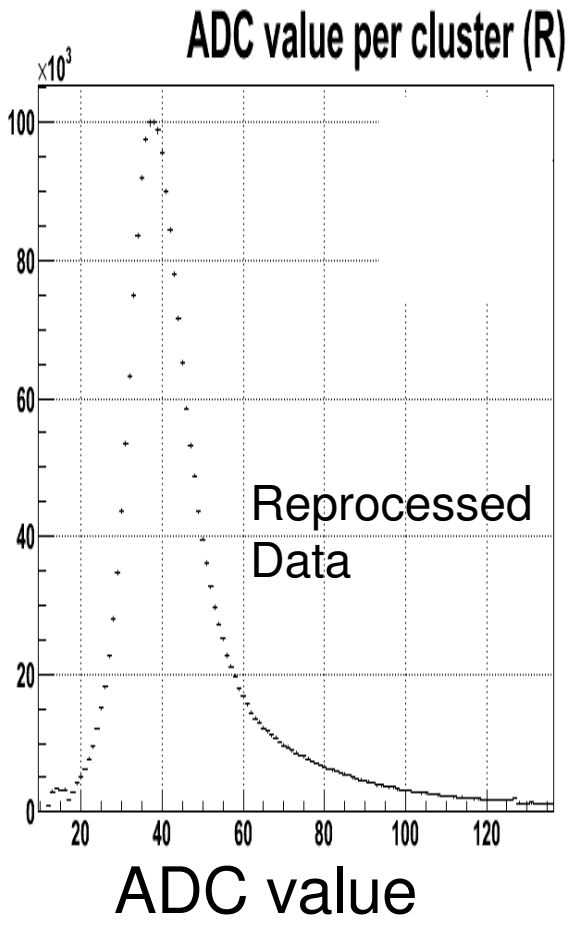
- Align two halves by fitting positions of primary vertices using tracks in each half

- X, Y translations ± 10 μm
- Z translations ± 30 μm

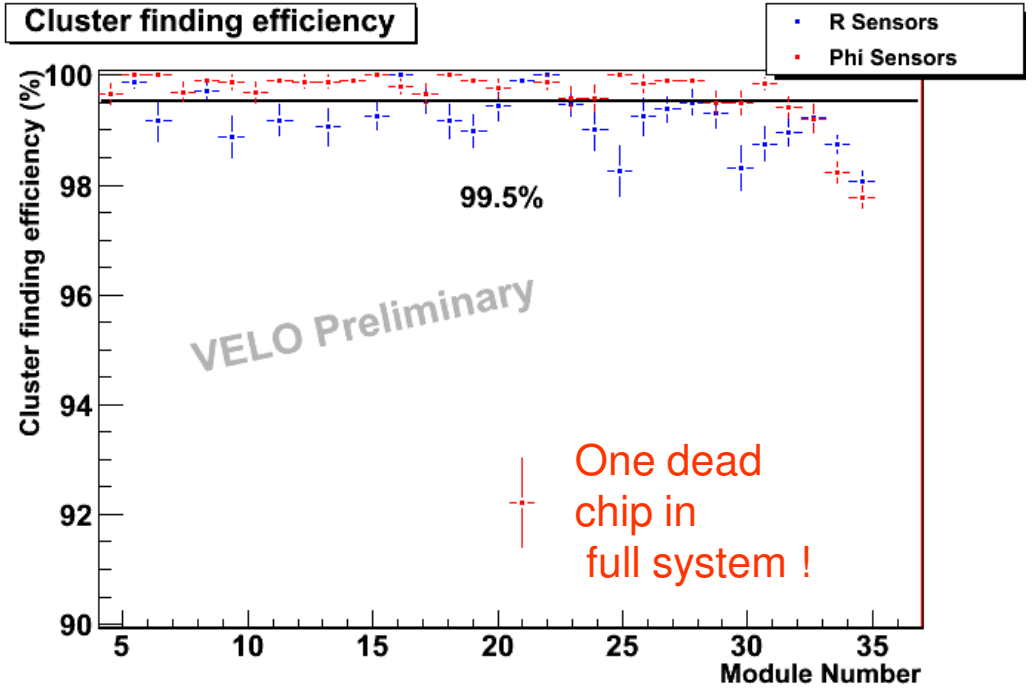


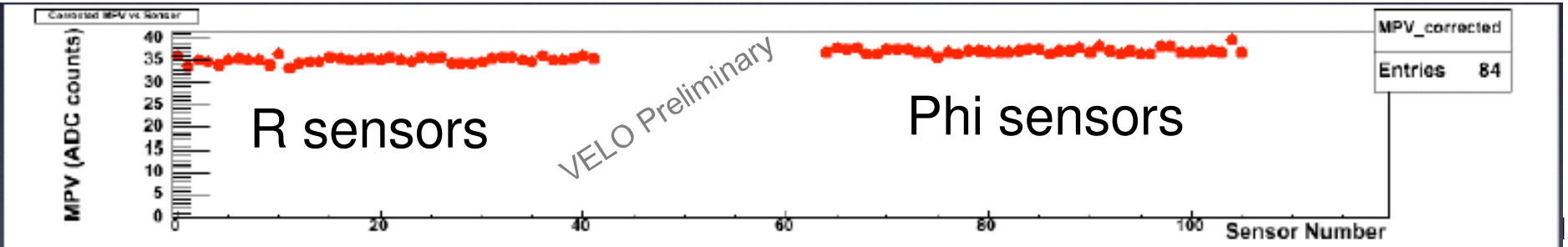
- Carbon-Fibre Expansion ~ 1μm/°C
- Using absorber collision data at higher T.
- Data taking at stable T

Cluster ADCs



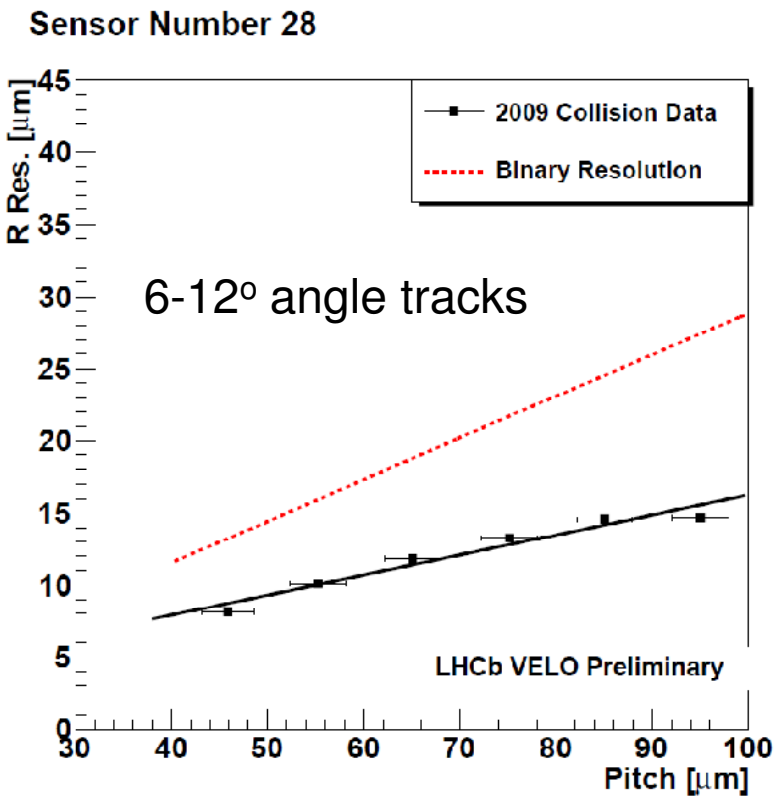
- S/N = 20:1
- Cluster finding efficiency = 99.5 %
  - Track extrapolation, full area

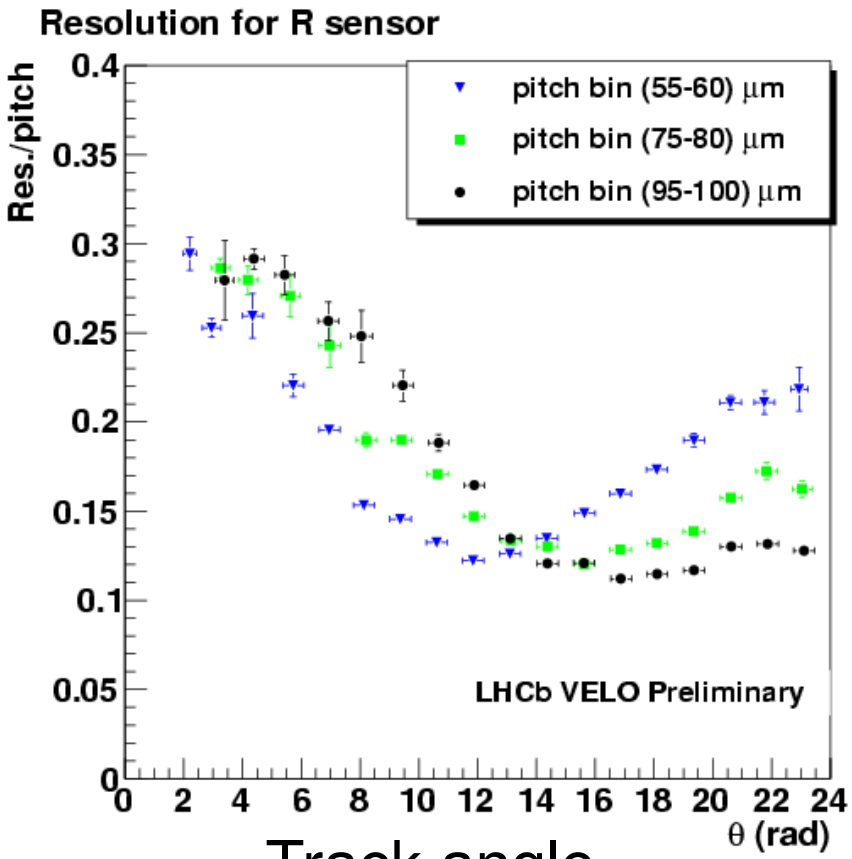




Single Hit Resolution

- Detector resolution from corrected residuals
- 7 µm resolution, angle average, at 40 µm pitch

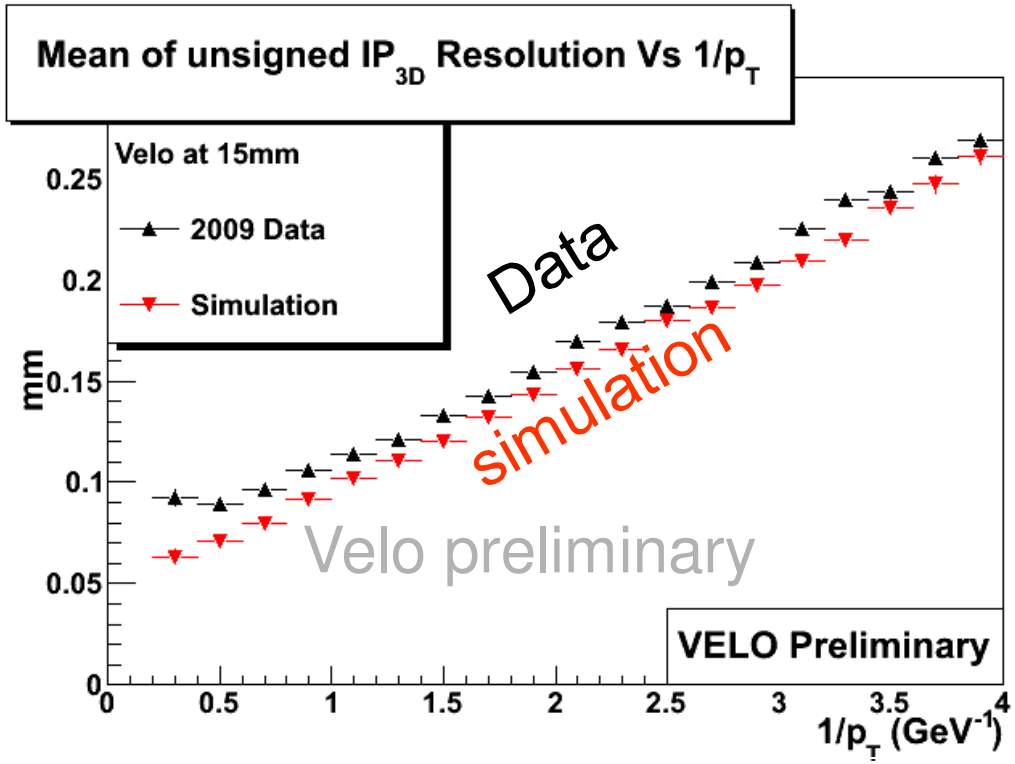




Track angle

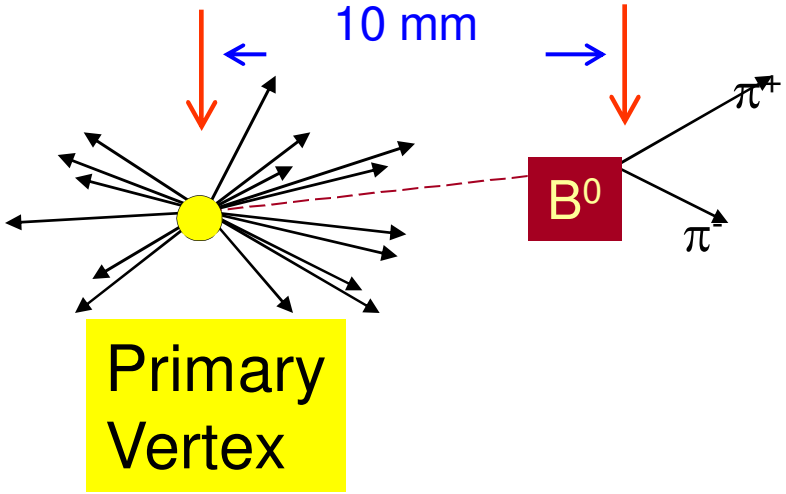
- Resolution improves as charge sharing increases
- Weighted cluster centre

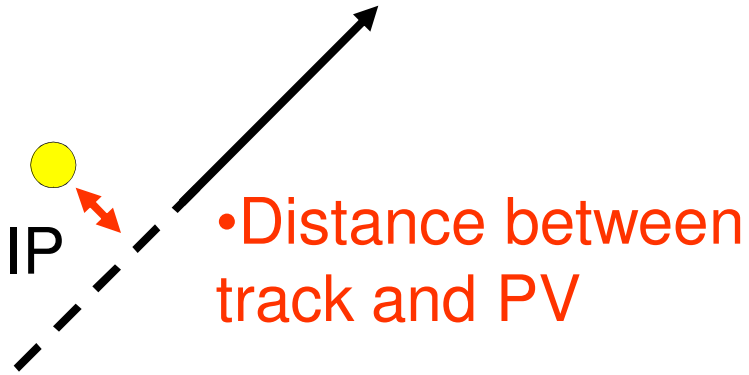
Impact Parameters



- Already reasonable agreement with simulation over primary momentum range
- Velo at 15mm open

•Key Physics quantity in identifying long lived B meson decay

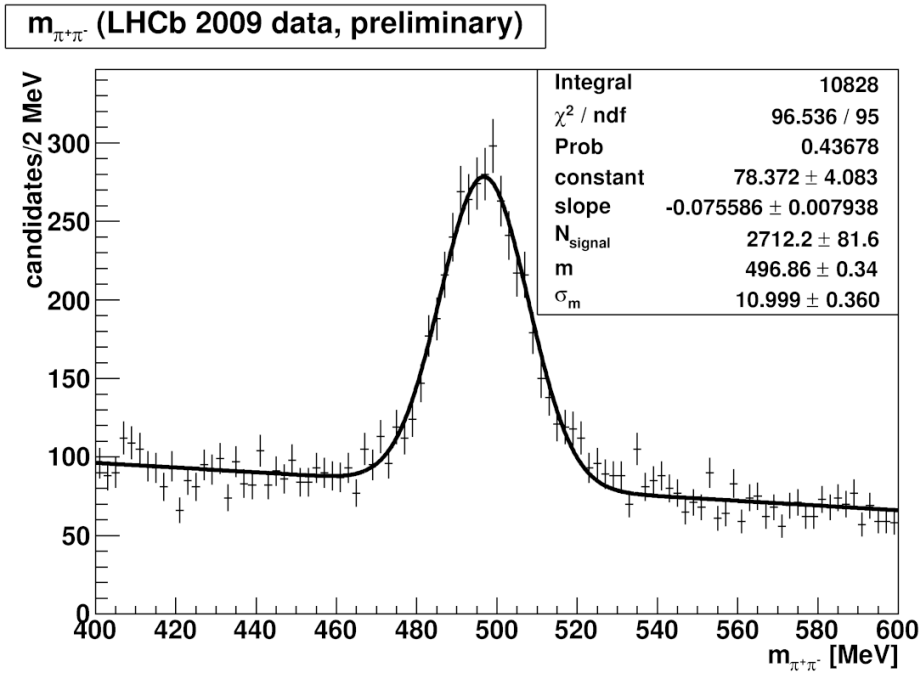


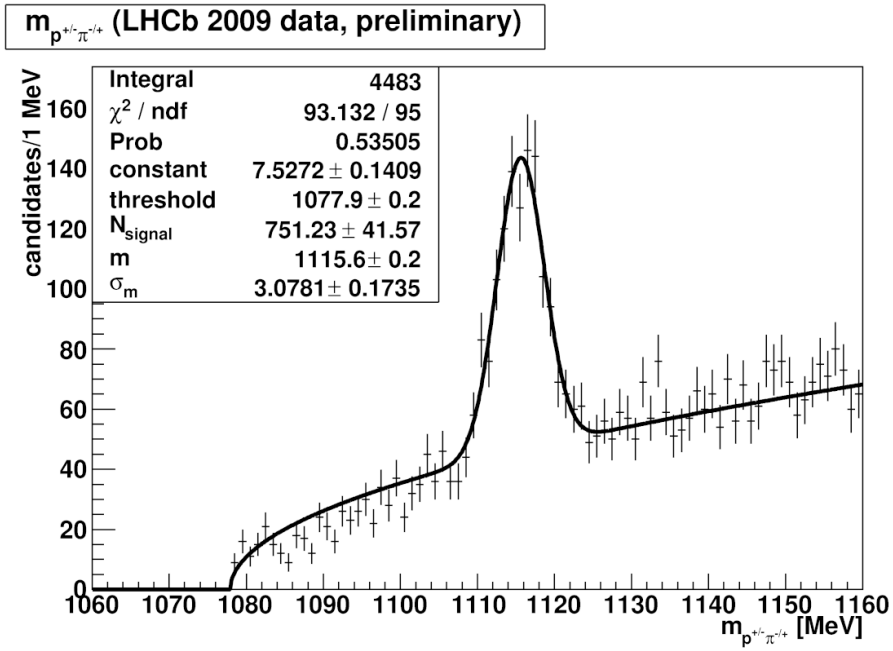


K_S and Λ

- Without VELO

Tracking detectors were well calibrated at the start-up !





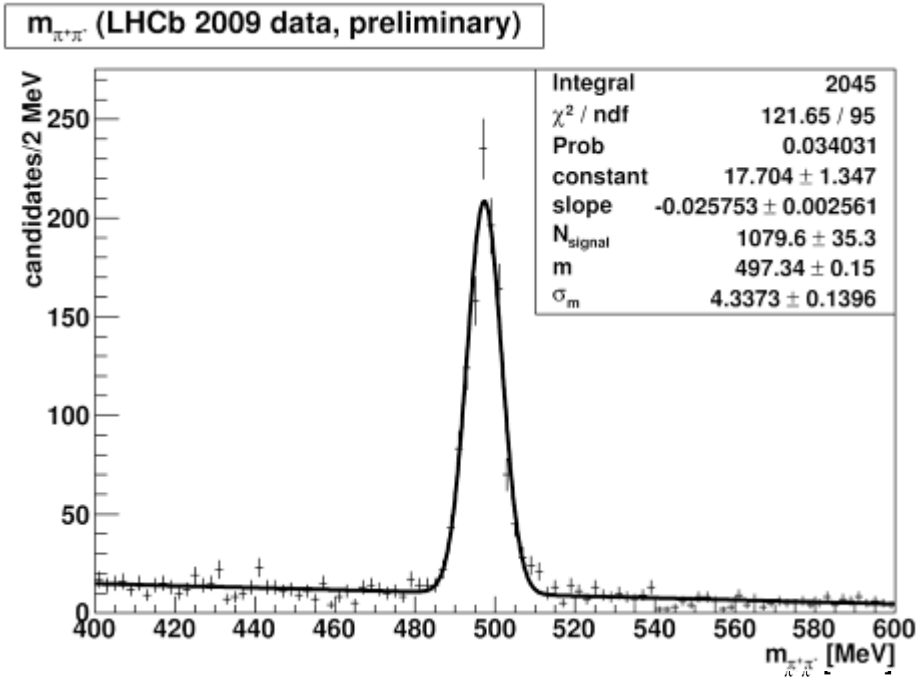
σ	= 11.0 ± 0.4	MeV/c^2
M(Ks)	= 496.9 ± 0.3	MeV/c^2
$M(Ks^{PDG})$	= 497.7	MeV/c^2

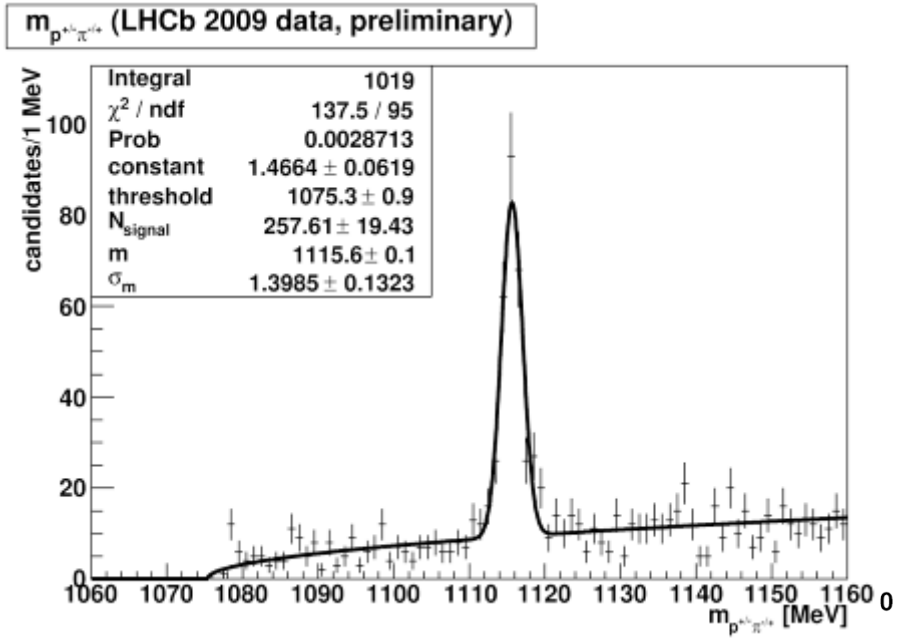
σ	= 3.1 ± 0.2	MeV/c^2
$M(\Lambda)$	= 1115.6 ± 0.2	MeV/c^2
$M(\Lambda^{PDG})$	= 1115.7	MeV/c^2

K_S and Λ

- With VELO

Power of precision vertexing – even with VELO 15mm open





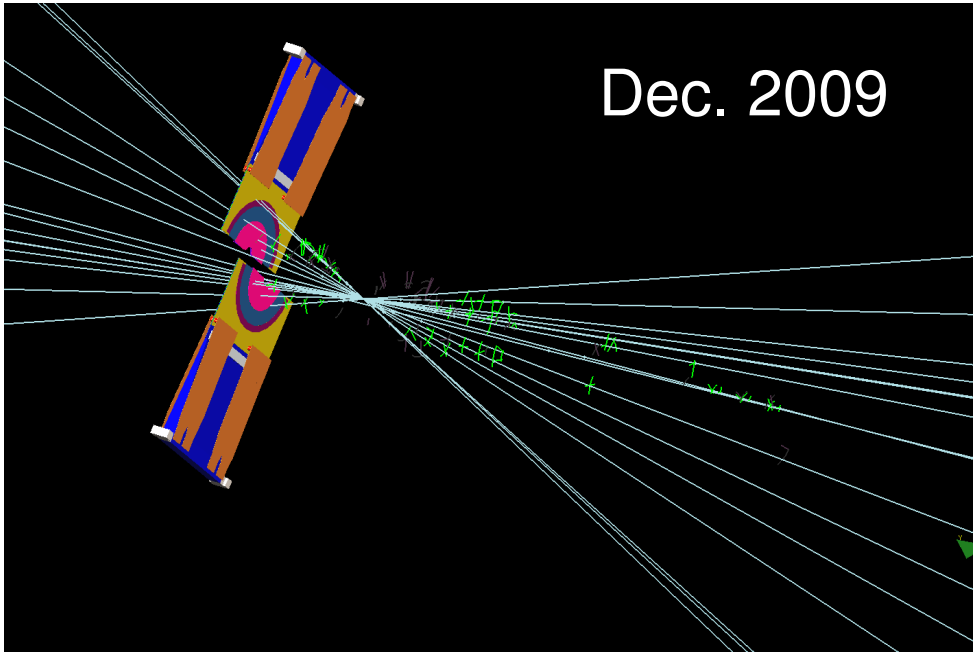
σ	$= 4.3 \pm 0.1$	MeV/c^2	σ	$= 1.4 \pm 0.1$	MeV/c^2
$M(Ks)$	$= 497.3 \pm 0.2$	MeV/c^2	$M(\Lambda)$	$= 1115.6 \pm 0.1$	MeV/c^2
$M(Ks^{PDG})$	$= 497.7$	MeV/c^2	$M(\Lambda^{PDG})$	$= 1115.7$	MeV/c^2

Summary

- First LHC operation demonstrated

- Preliminary VELO performance:
  - 99.5% Cluster Finding Efficiency
  - < 7 µm resolution
  - 4 µm sensor alignment

- Further improvements anticipated

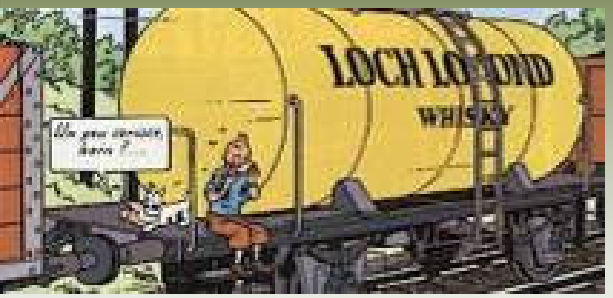


Vertex2010

University of Glasgow

Department of Physics & Astronomy

19th International Workshop on Vertex Detectors



6-11 June 2010, Loch Lomond, Scotland

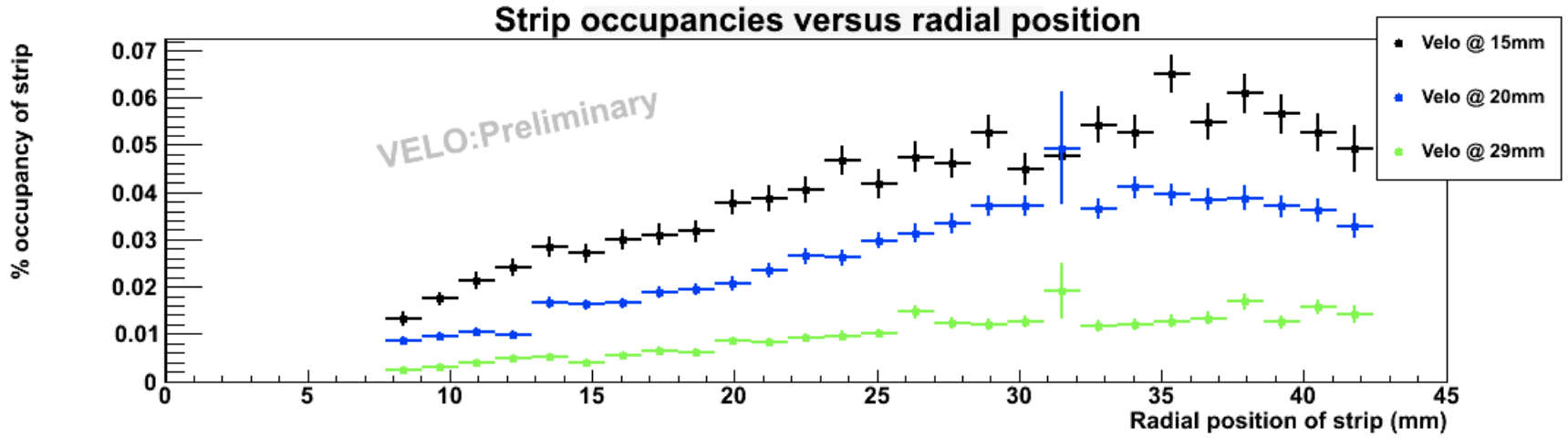
Workshop topics:

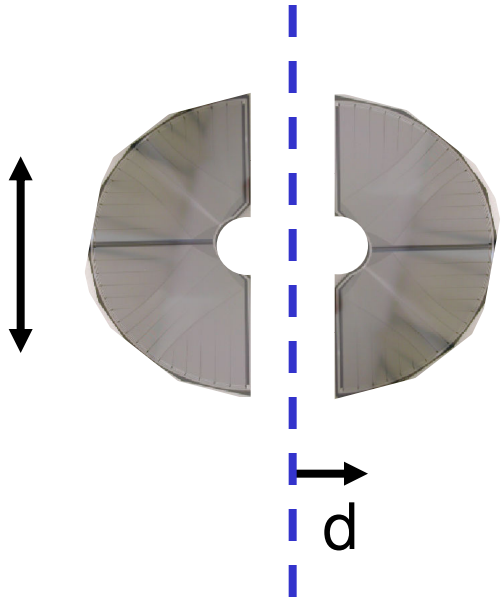
- LHC vertex detector performance
- Novel detectors
- Radiation hardness
- Tracking, vertexing and alignment
- LHC upgrades and other new experiments
- Vertex triggering
- Applications in other fields

E-mail : vertex2010@physics.gla.ac.uk

http://www.vertex2010.physics.gla.ac.uk

Velo Closing, Occupancy





- Extreme care taken on VELO closing
- Primary vertex monitoring
- Beam position monitors
- Data quality checks
  - occupancy, noise, common mode….