



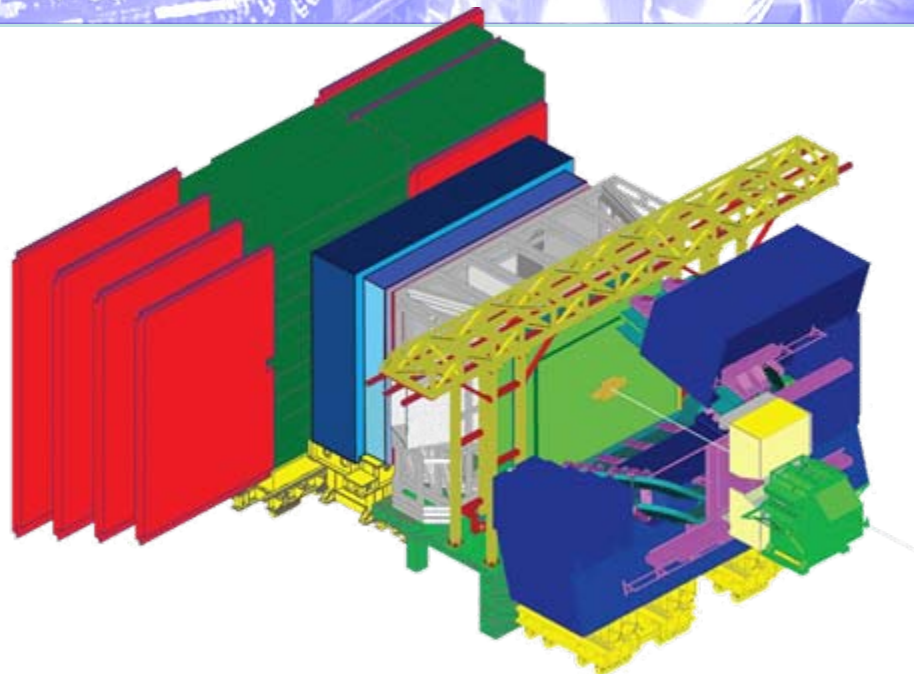
Themis Bowcock  
UNIVERSITY OF  
LIVERPOOL



# Commissioning the LHCb Vertex Detector



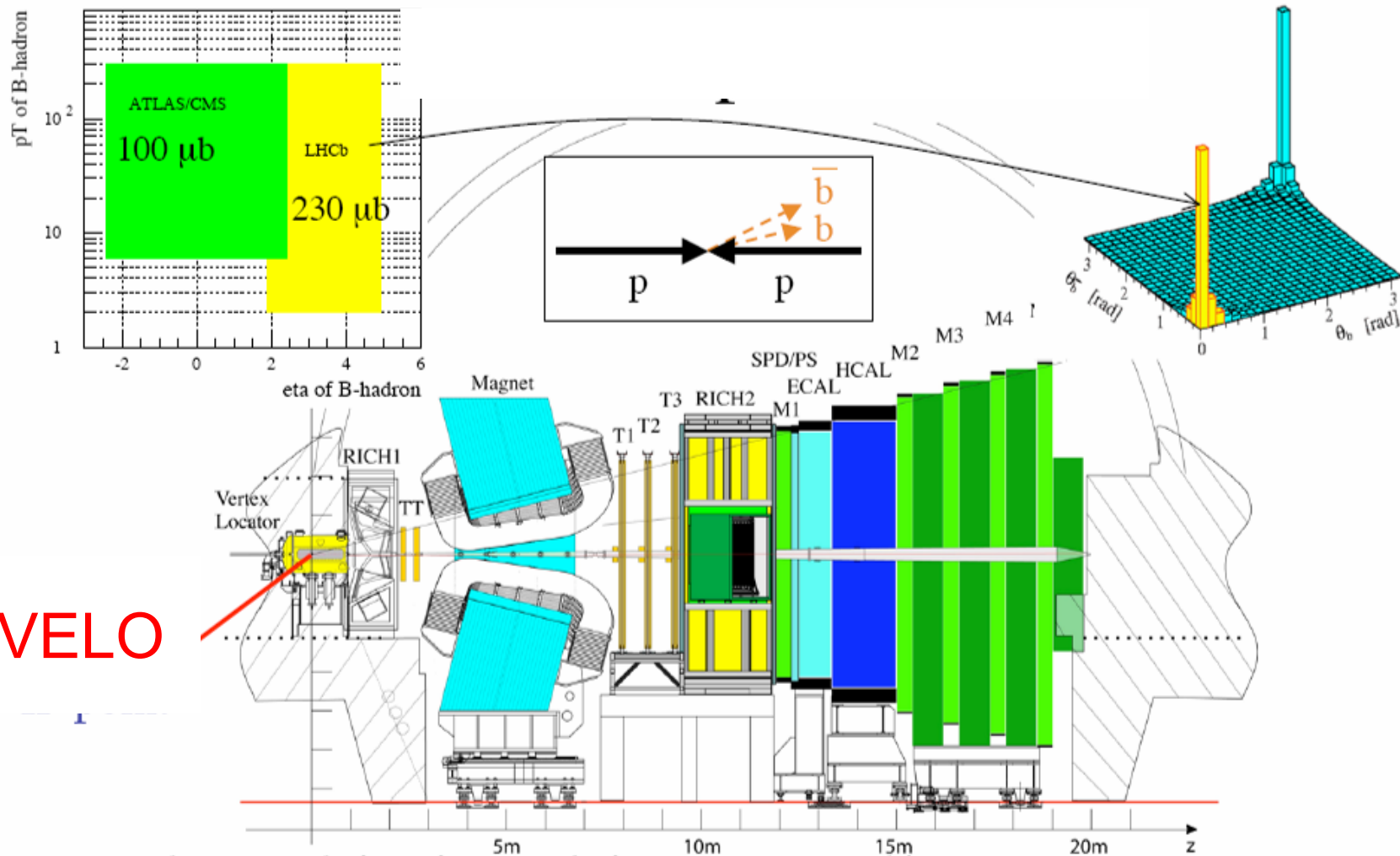
# Overview



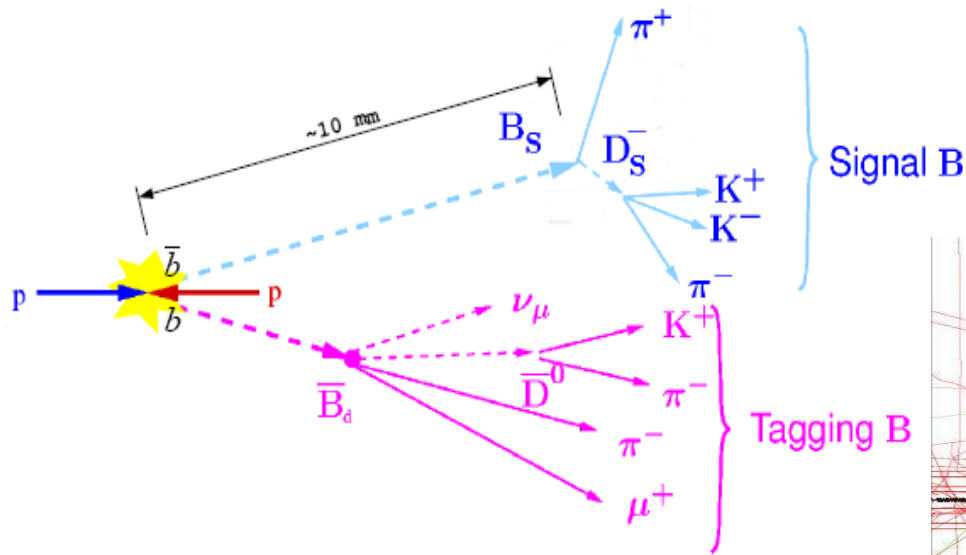
- LHCb
- Vertex Detector
- Commissioning
- Summary



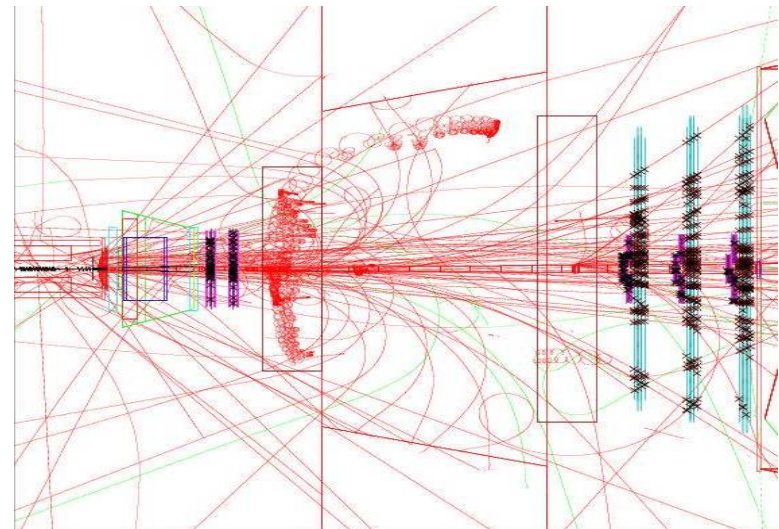
# LHCb: Spectrometer



# LHCb: Triggering on B's



Write data to disk  $\sim 2$ kHz



# Physics

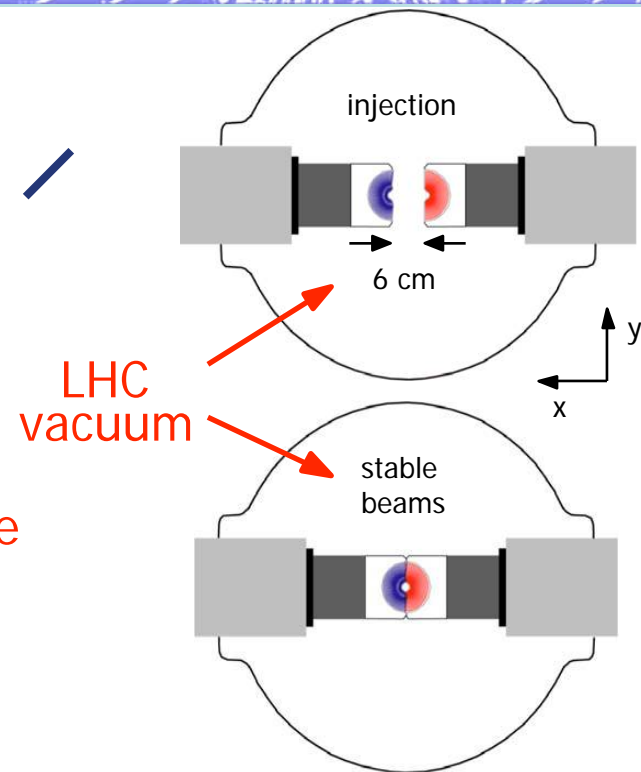
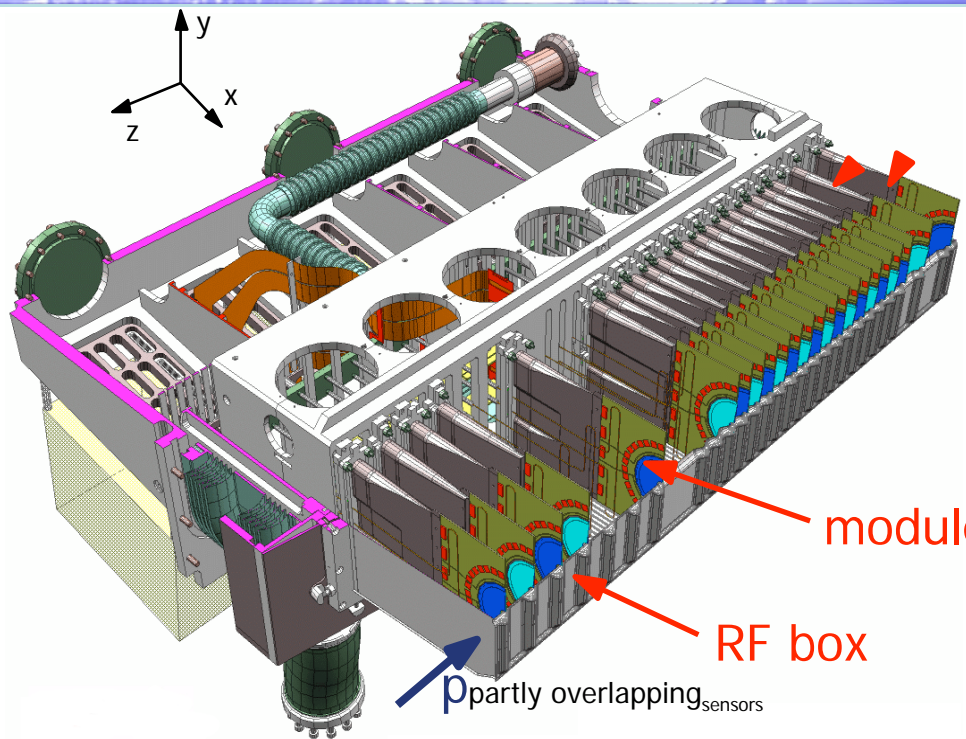
- Flavour
  - CP violating phases
  - CKM
- New Physics
  - Rare B Decays
  - High Reach
  - Exotics
- SM
  - $W/Z$  In new regions

Quantum Excitations  
measurements of  
amplitudes and phases

# LHCb: VELO Requirements

- Good vertexing
  - Primary vertex  $< 10$  microns
  - IP parameter  $\sim 40 \mu\text{m}$  (40fs time resolution)
    - close to LHC beam (vacuum)
  - high radiation levels  $< 10^{15} \text{p/cm}^2$
  - Close to Beam = moving detectors
- Tracking
- 2D trigger algorithm
  - R-phi geometry
- Low mass  $\sim 10\% X_0$

# VELO: Mechanics Overview



- 2 retractable detector halves
- 21 stations per half with an R and  $\varphi$  sensor

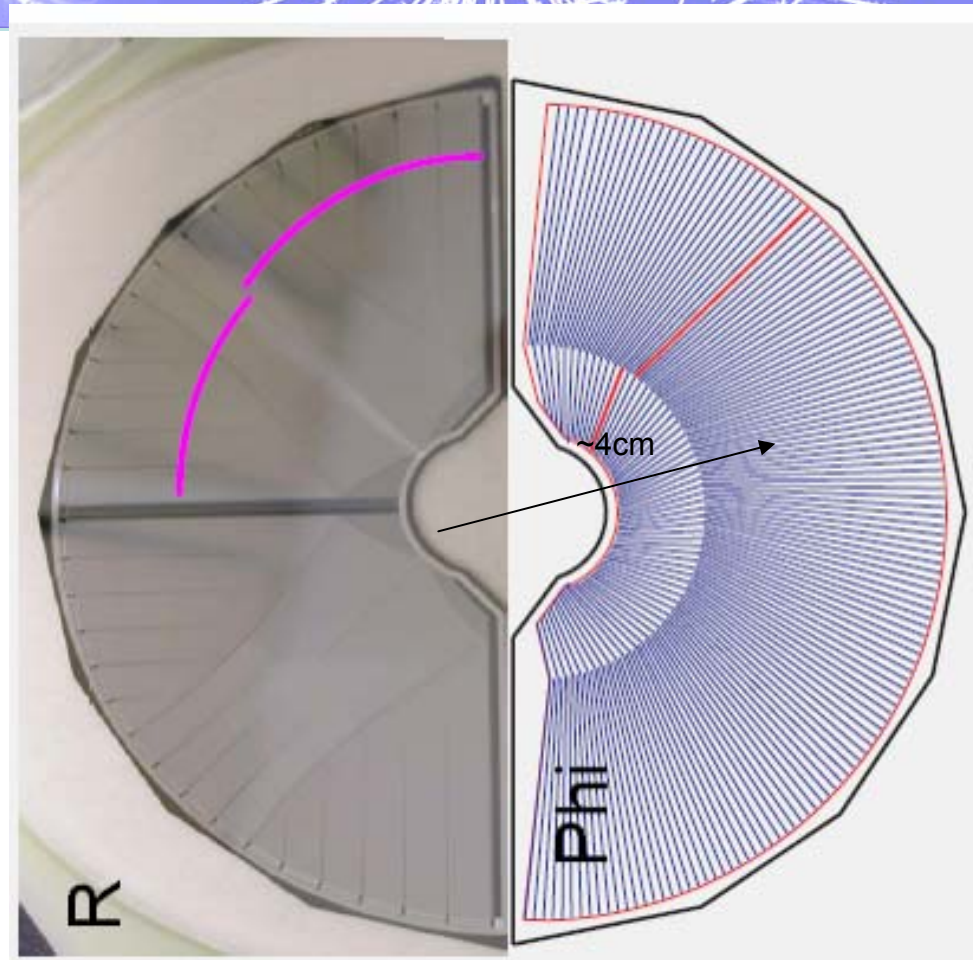


# Module

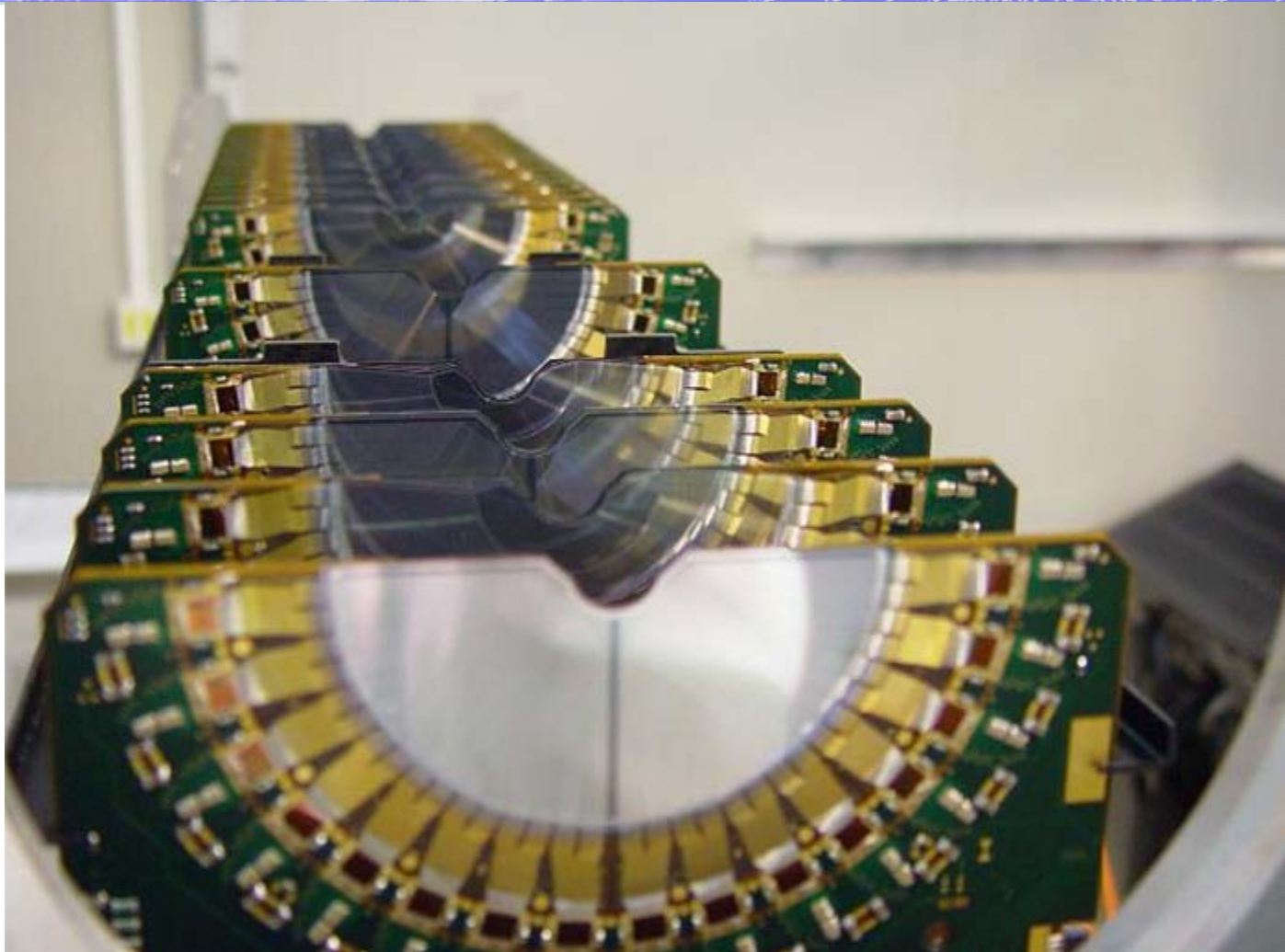


# VELO: Sensors

- highly segmented
- $n^+n$
- double metal layer
- 2048 strips/sensor
- Laser cut
- Design operation
  - $T = -7^\circ\text{C}$
- $\sim 40$  micron inner pitch

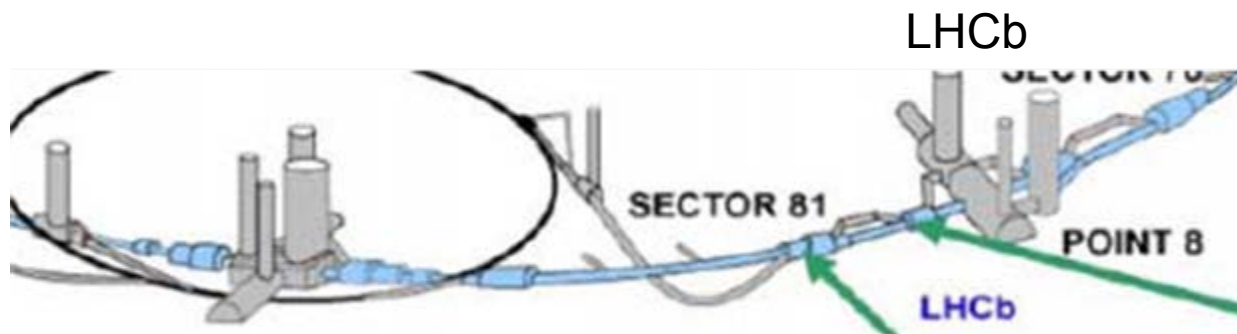


# Modules: Complete halves



# Timeline for Commissioning

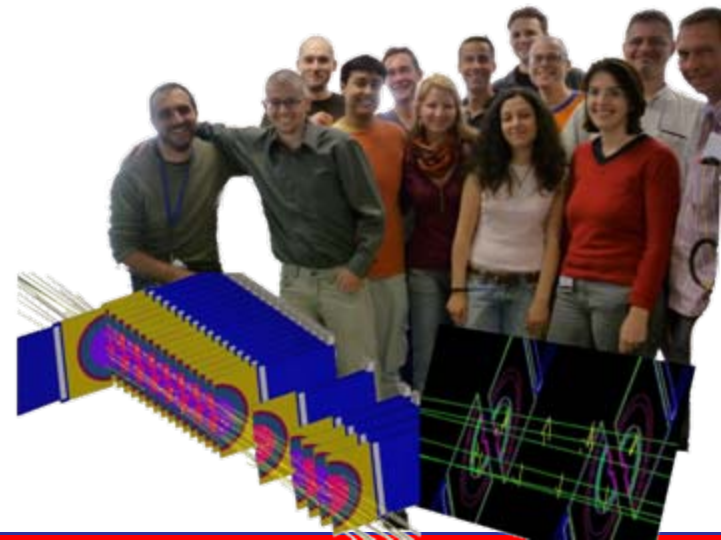
- Installed 2007
  - Cannot use cosmics
- 2008 Tests
  - Injection from SPS into LHC – “beam stopped”
  - Particles injected from Muon chamber direction!
- 2009 Tests
  - Timing
  - High Rate R/O (1MHz)
  - Operation under final conditions (vacuum & temp)



# TED June 2009

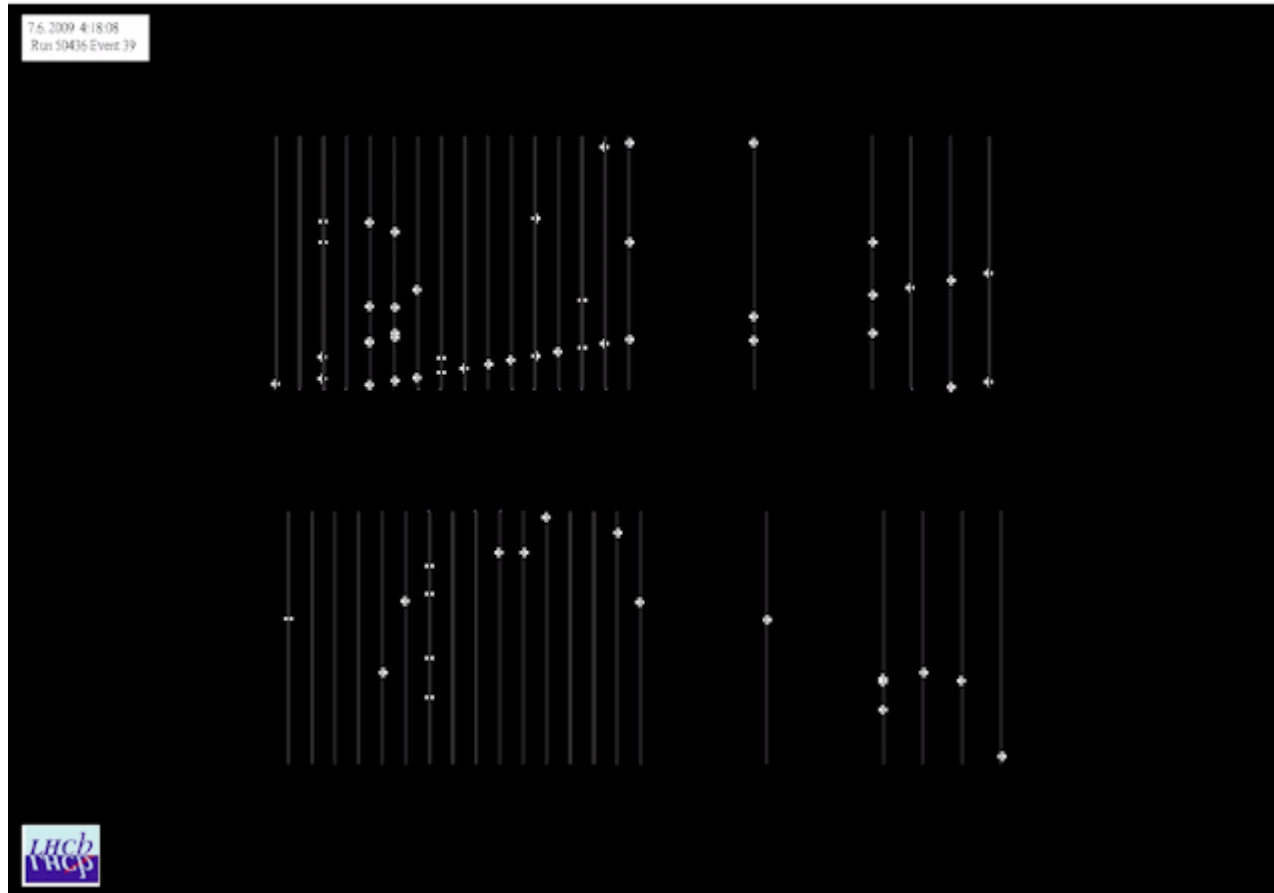
- Powered all HV channels
- Very stable VELO operation
- Single bunches every 48 s
  - Multiple time sample for timing
- Bunch trains 12 consecutive bunches 25ns spacing:
  - Single time sample
  - zero-suppressed (physics) data
- 50k Tracks collected

- Resolution
- Efficiency
- Alignment \*

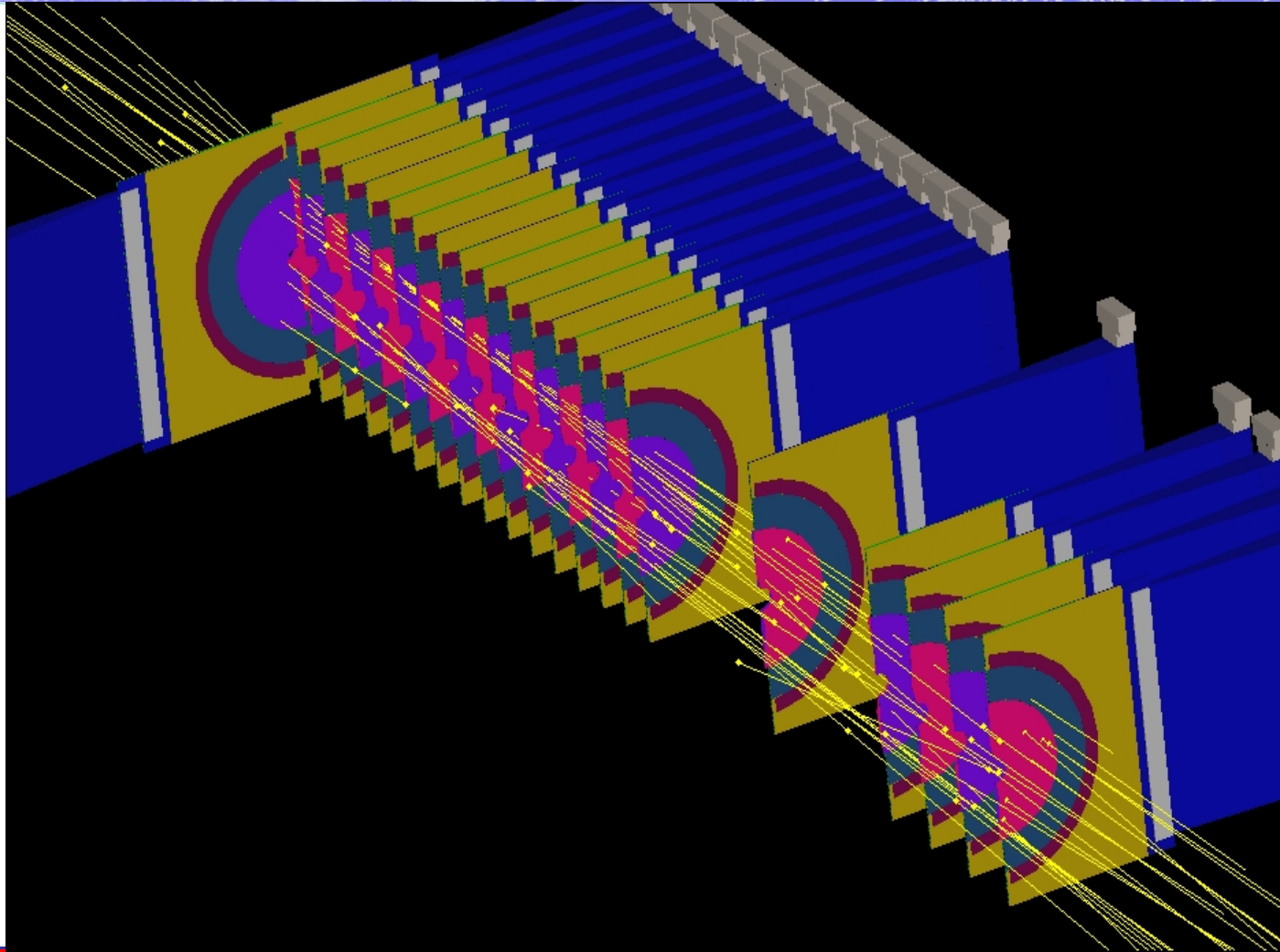


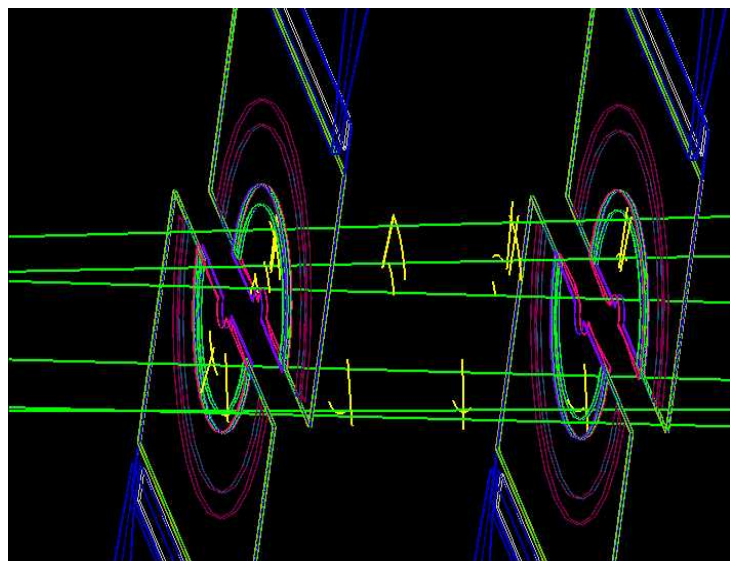
# A few events...

VELO RZ

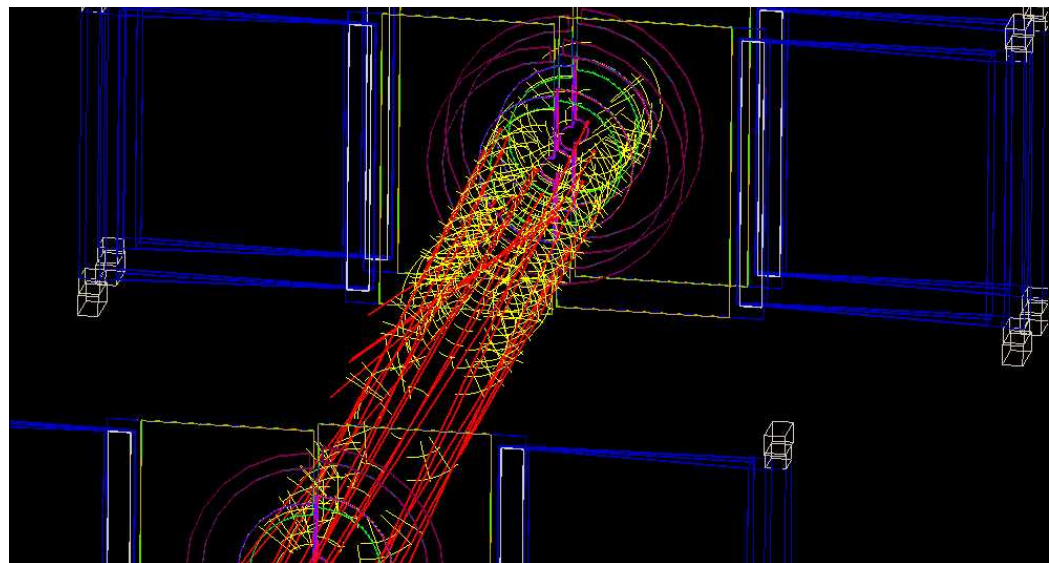


# Event 2009





Low intensity

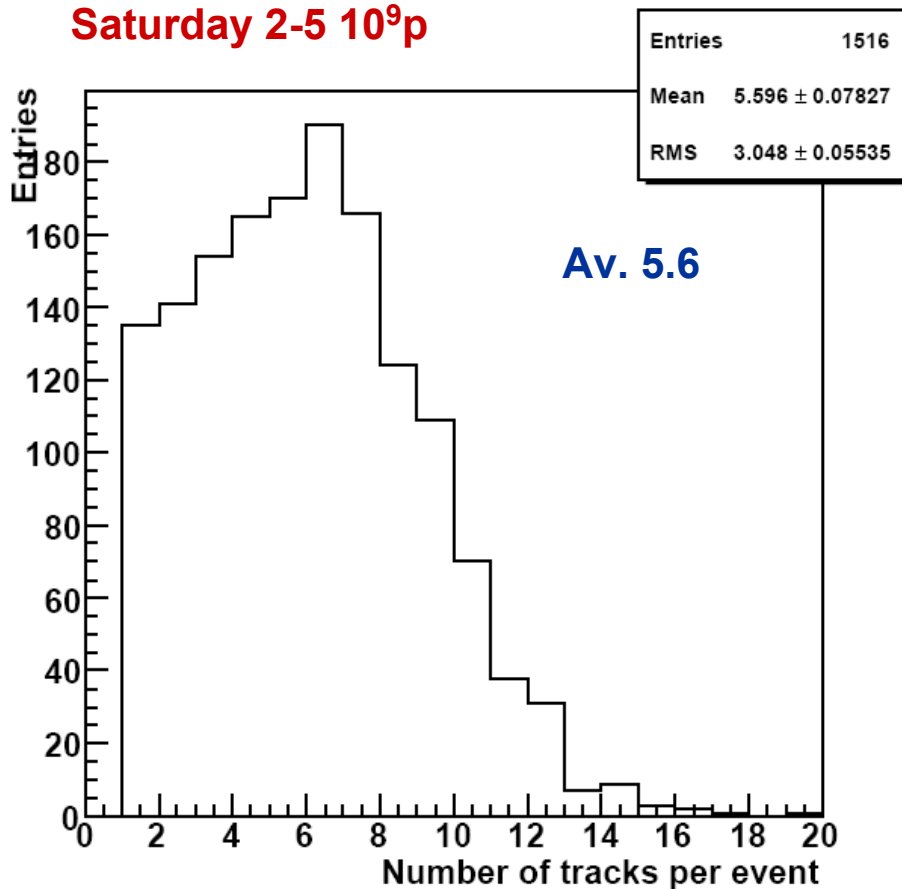


Higher intensity

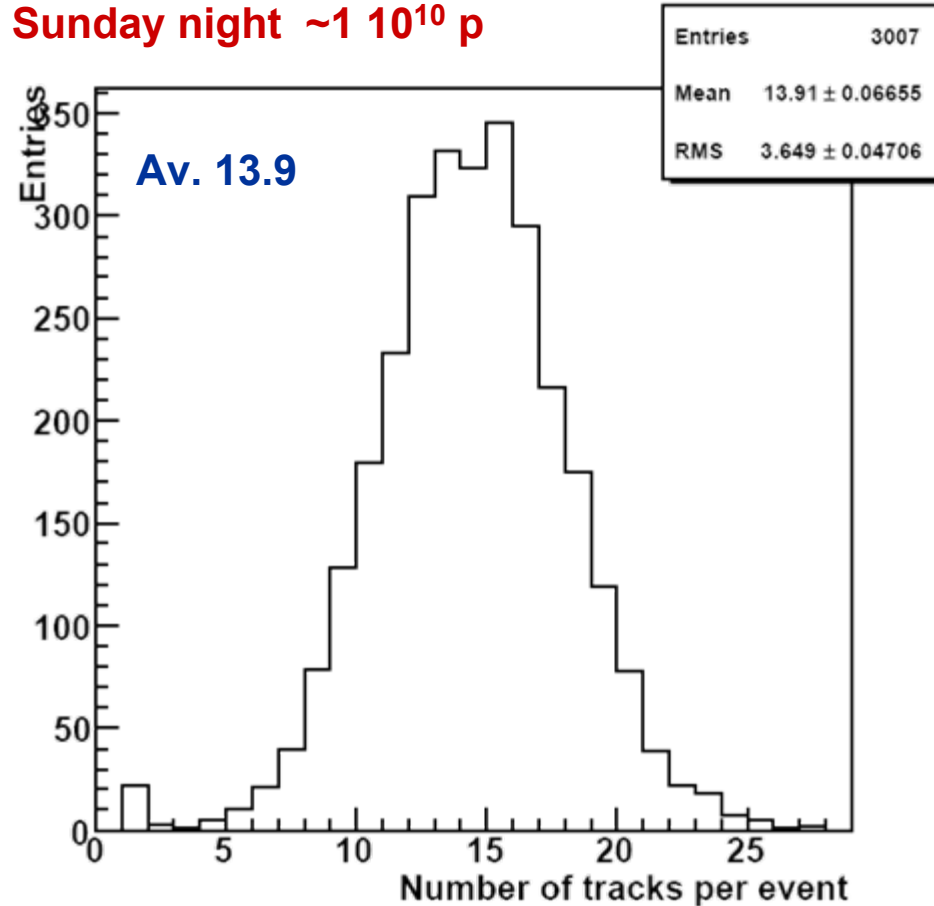


# Number of tracks/event

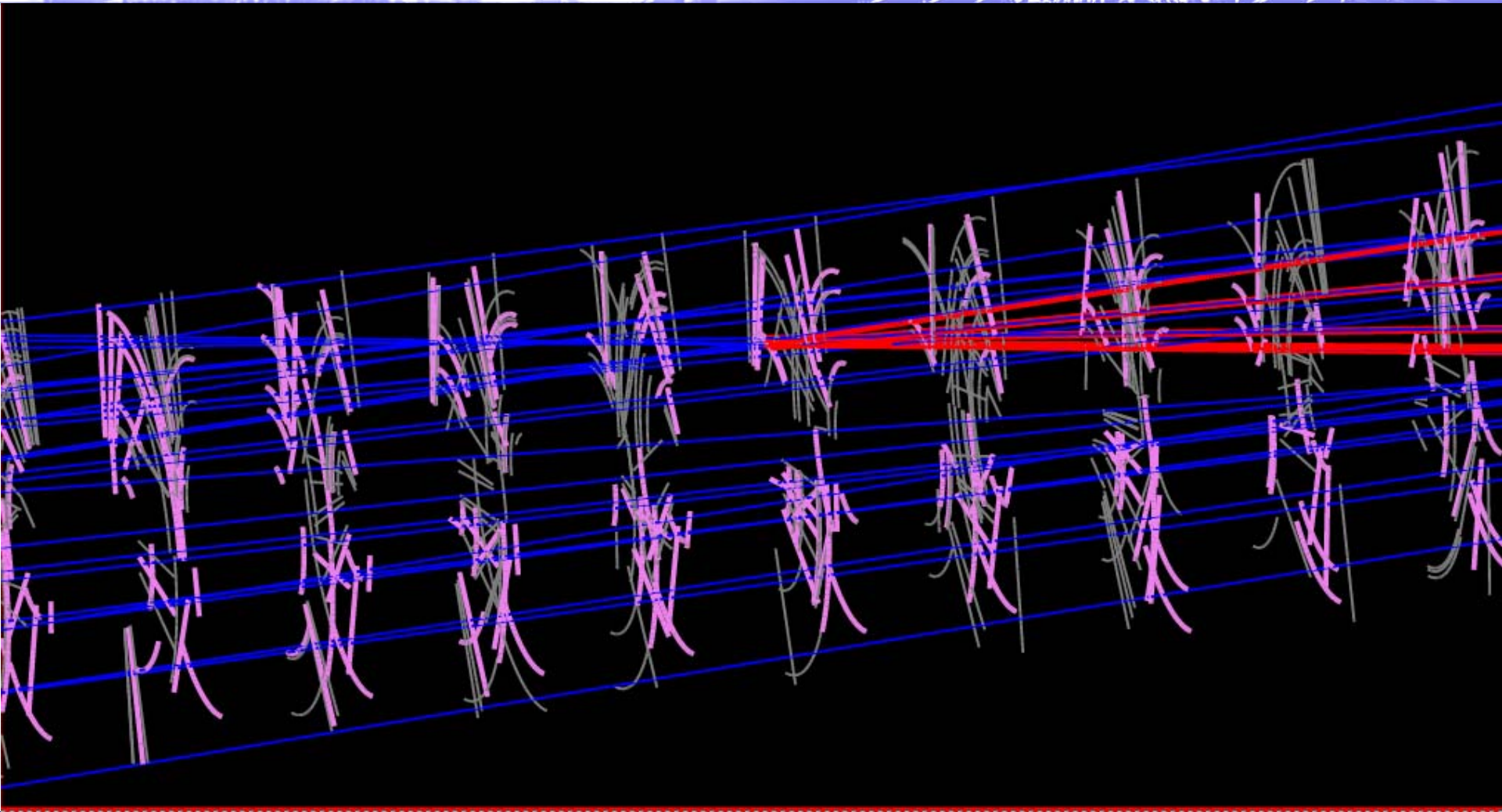
Saturday 2-5 10<sup>9</sup>p



Sunday night ~1 10<sup>10</sup> p

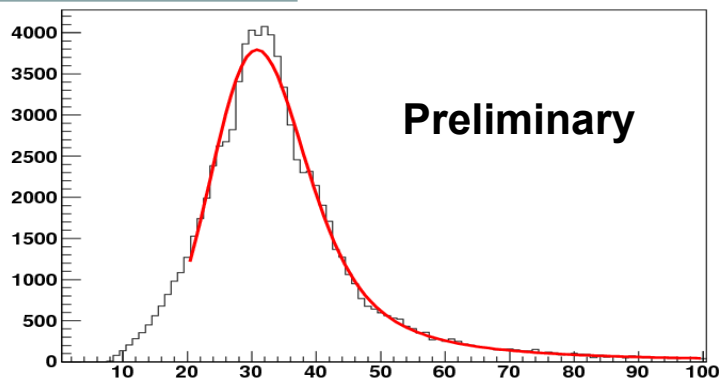


# Searching for vertices

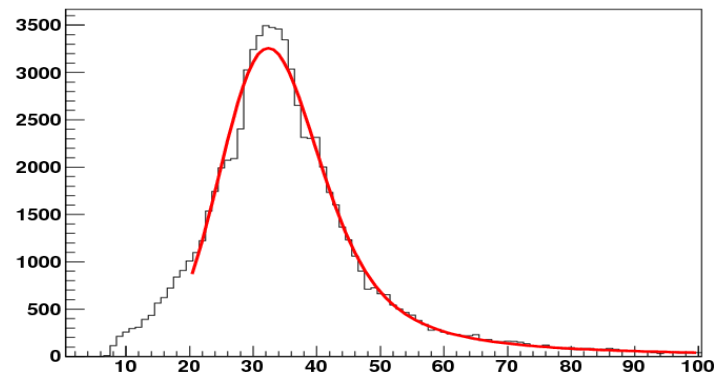


# ADC sums (S/N) 2009

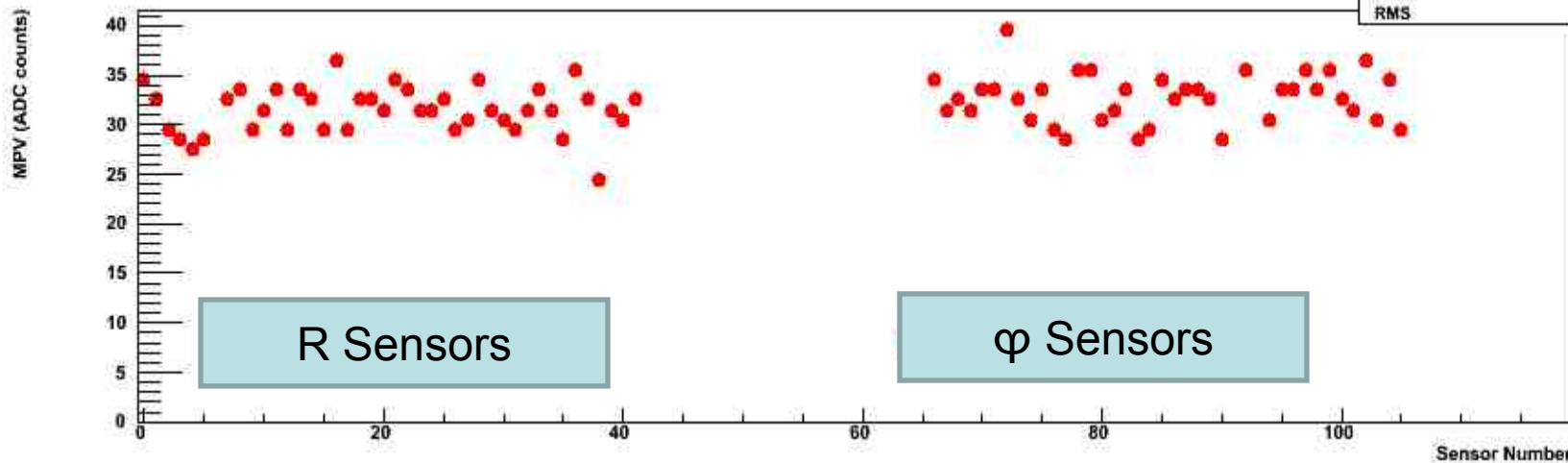
## R Sensors



## $\varphi$ Sensors



## MPV Vs Sensor



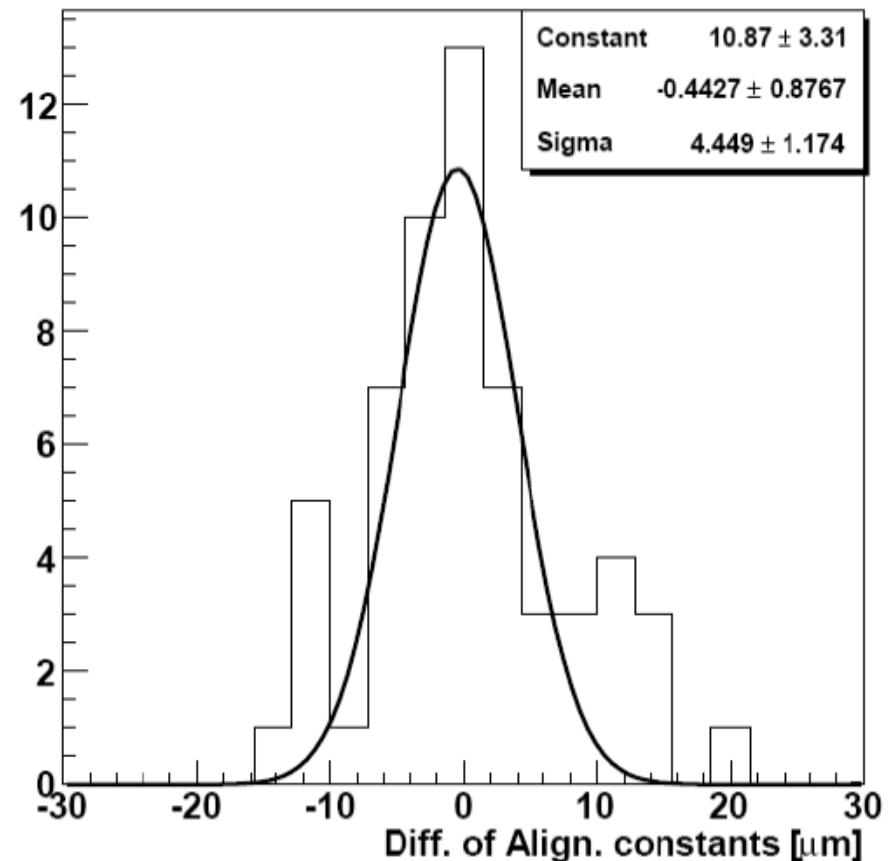
Entries	80
Mean	52.44
RMS	34.24

# Signal and Resolution

- S:N > 20:1
  - Sensor types similar!
- Physics Mode
  - Zero Suppressed(ZS)
  - Some non-NZS readout for diagnostics
- Resolution
  - TED ~“normal”
    - Resolution ~ 80% \* binary
  - In Physics  $\langle\theta\rangle\sim 8^\circ$ 
    - Resolution expected from testbeam & simulation ~ 5-10 $\mu\text{m}$  at inner radius
  - Under intense irradiation
    - Resolution  $\rightarrow$  binary

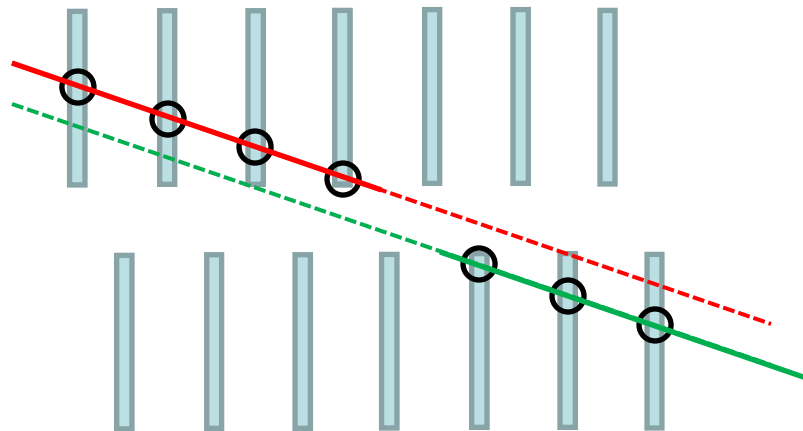
# Alignment 2008

- Detector Designed to be stable  $\Delta T \sim 70^\circ\text{C}$ 
  - 0 CTE composites and module mechanics
  - Aluminium support structure is thermally stabilized to  $\pm 1^\circ\text{C}$
- 2008 Alignment Performed with TED data
  - Modules within  $10\mu\text{m}$  of metrology
  - Note: Si built to be within  $10\mu\text{m}$  of nominal position
- 2009 –
  - Alignment changed  $< 5\mu\text{m}$

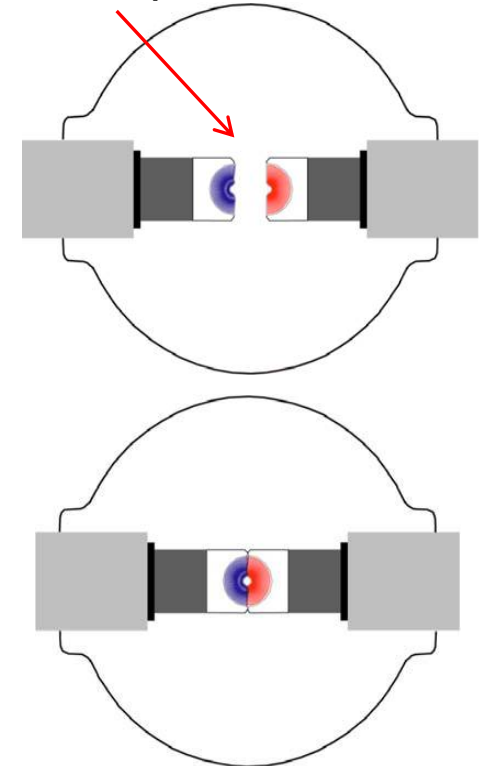


# Alignment 2009

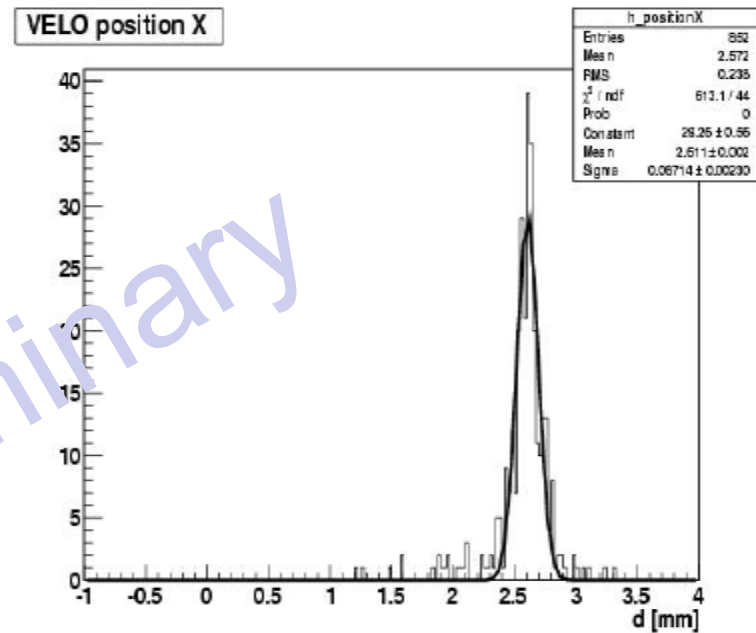
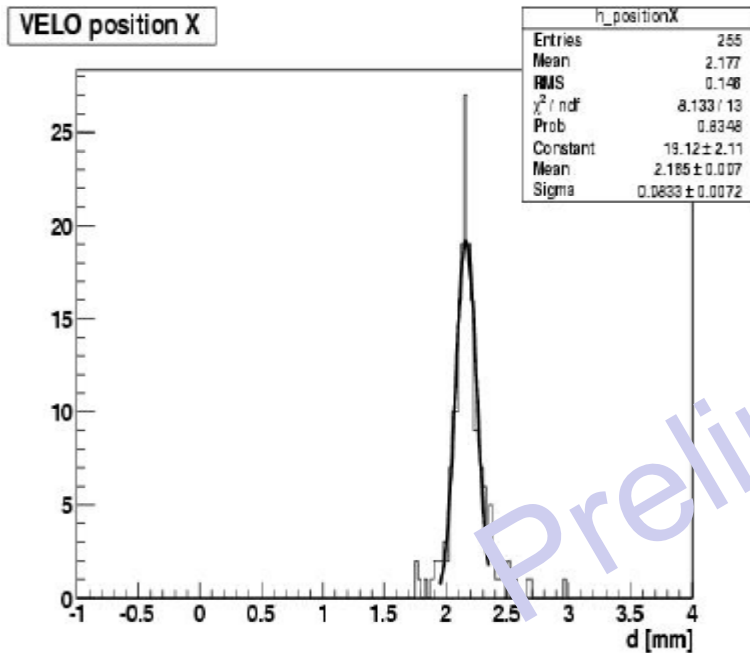
- High Statistics permitted checking ability to check how far apart the halves were using “traversing tracks”



Detector open



# Detector half separation



Detector halves separated by 2.000mm and 2.450mm i.e.  $\Delta x = 450 \mu\text{m}$   
Analysis sees  $\Delta x = 445 \pm 10 \mu\text{m}$  (with only 1000 tracks!)

# Summary

- LHCb VELO has achieved required performance for physics
  - Improvements always possible!
  - Detector behaves according to design
- Test in Aug 2009 of full system in final configuration
  - vacuum
  - $T_{\text{cool}} \sim -30^{\circ}\text{C}$
- Ready for Data Taking!