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On behalf of the LHCb commissioning team

3 October 2008

LHCb commissioning

- **What had to be done**
  - Technical challenges
- **Before first beam: Cosmics**
- **First beams**
  - TED shots
  - Circulating beam
- **What will come next…**

What had to be done

What is commissioning ?

- Bring all components (Sub-Detectors and service systems) to operational state.
- Define, implement and validate the tools and procedures needed to run the detector as a whole
- Organise the activities to reach the ready state in time.

The most important is building a team spirit

- Detectors were built for years by **independent teams**, used to work alone and to decide what was good for them, without too much constraints.
- Now one builds a **single experiment** out of these teams, the interest of the experiment may conflict with the sub-group wishes.
- This takes some time, people have to get used to work together, to accept to no longer being their own master...

How we did it

- **Start in 2006 with regular meetings**
  - Specification documents
  - Scenario for commissioning and operation
    - Defines what has to be implemented, and how
  - Build slowly a team spirit
- **From early 2008: monthly commissioning weeks**
  - Put together the various systems and teams
  - Identify problems, help each other, celebrate progresses
- **From July 2008: Regular shifts**
  - First during working hours only
  - Then 24/7 from August 18th until recently...

Technical challenges

Central control system

- From a single screen, **configure** the whole system (from front-end electronics to event filter farm tasks) in a few clicks, in a reasonable amount of time
  - Below 10 minutes for a cold start
  - ~one minute if the front-end was already configured
- **Monitor** the system centrally
  - Alarm and error screen
  - Data monitoring
- Run the detector with a **limited shift crew**
  - Two persons after the initial heroic times
  - Piquets for all sub-systems and detectors
- PVSS with FSM is used everywhere

Readout at 1 MHz

- Hardware trigger rate is designed to reach 1 MHz in 2009
  - Only ~ 100 kHz possible in 2008 due to the limited capacity of the network and event filter farm, buying late gives you more for your money.

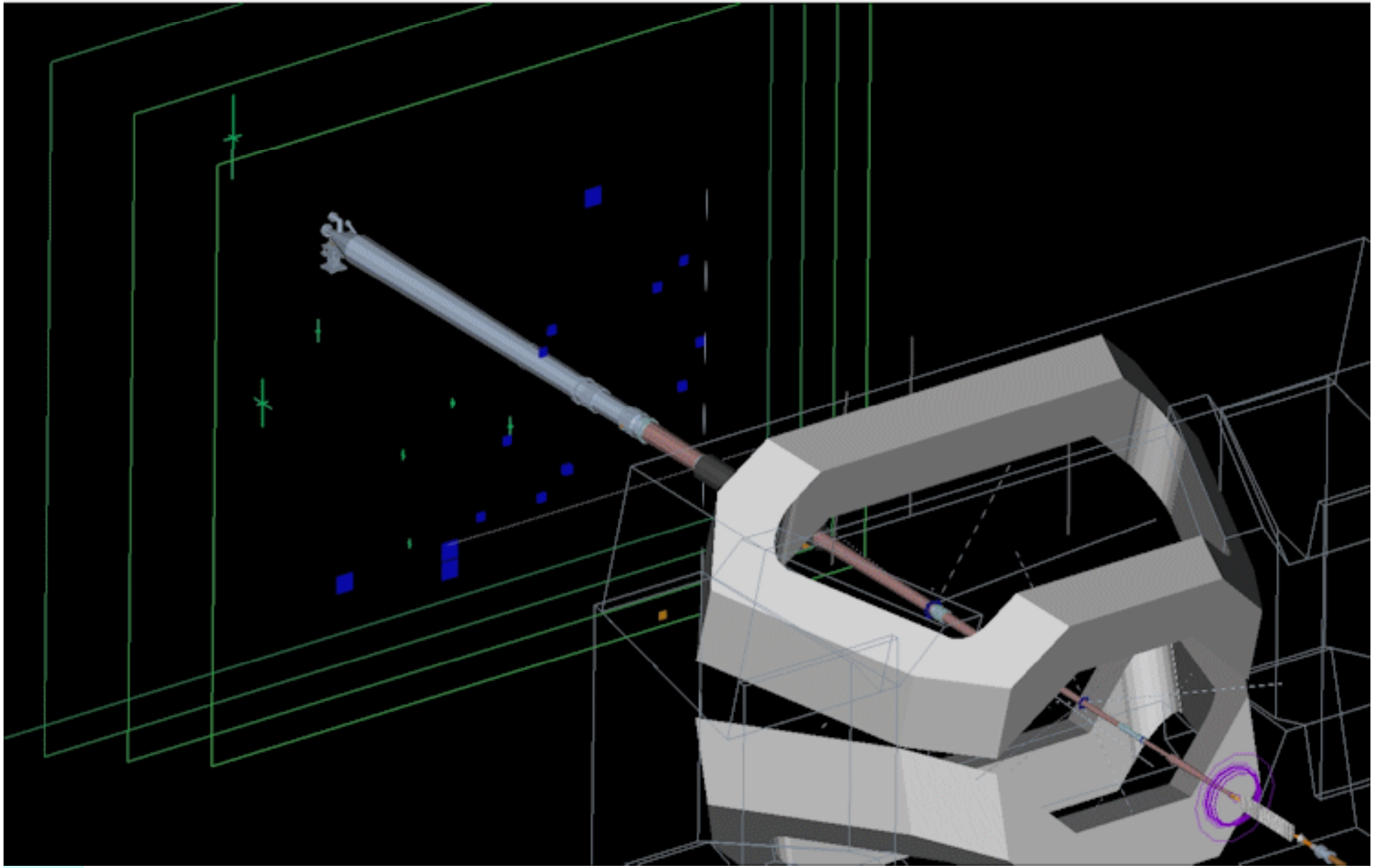
Data storage at 2 kHz

- Available in 2008

Time alignment to a few ns

- Readout of **consecutive crossing** from a single trigger is a fundamental tool
- This allows measuring the leakage in preceding and following clock cycles, and then minimizing it.
- Up to +-7 clock cycles = 15 consecutive crossings!

10.9. 2008 11:25:26 -25ns



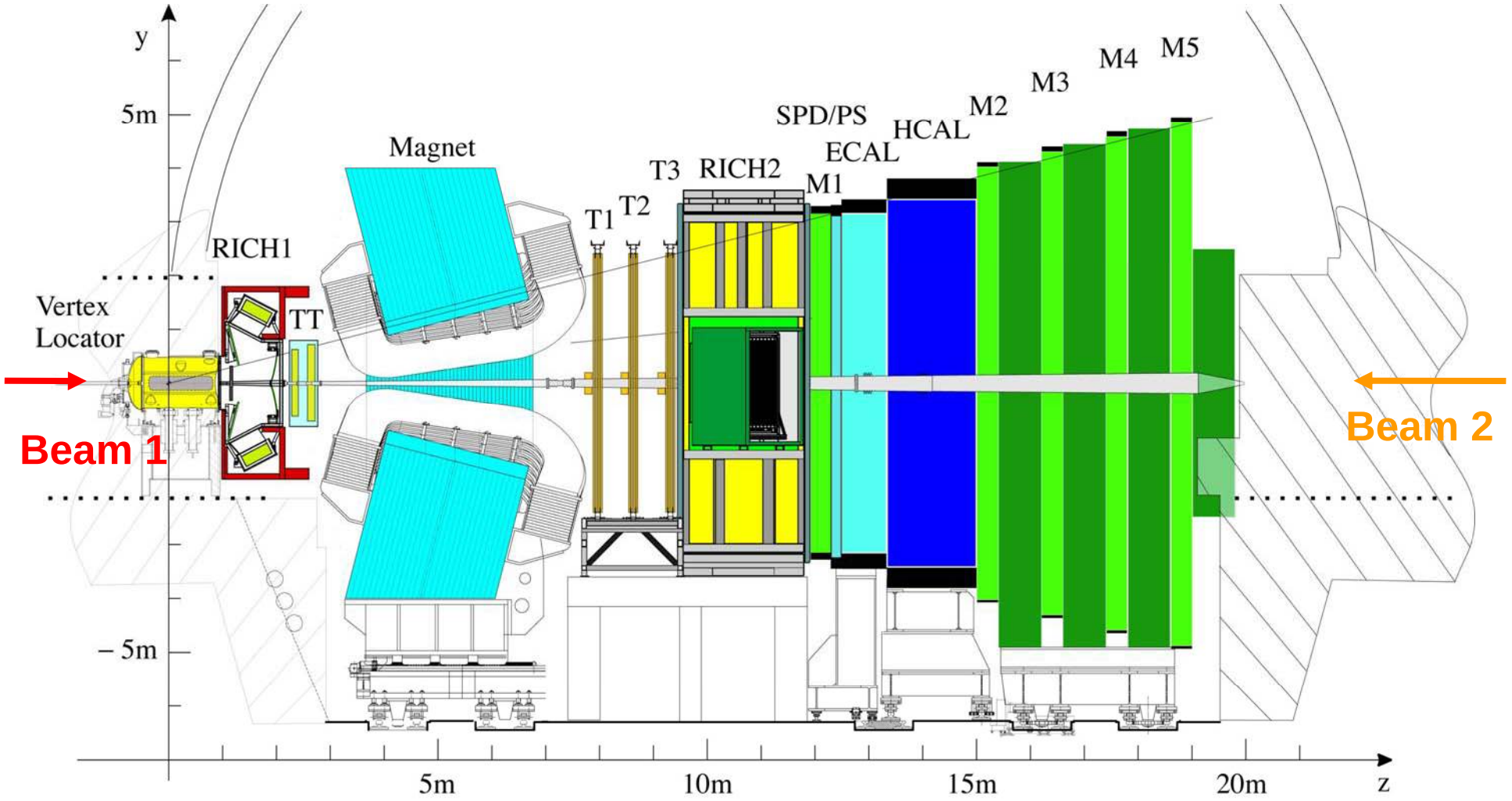
First tools : Cosmics

LHCb is NOT well suited for cosmics

- "fixed target" layout, tracks at +- 200 mrad from horizontal!
- Such horizontal cosmic tracks are rare, well below 1 Hz.

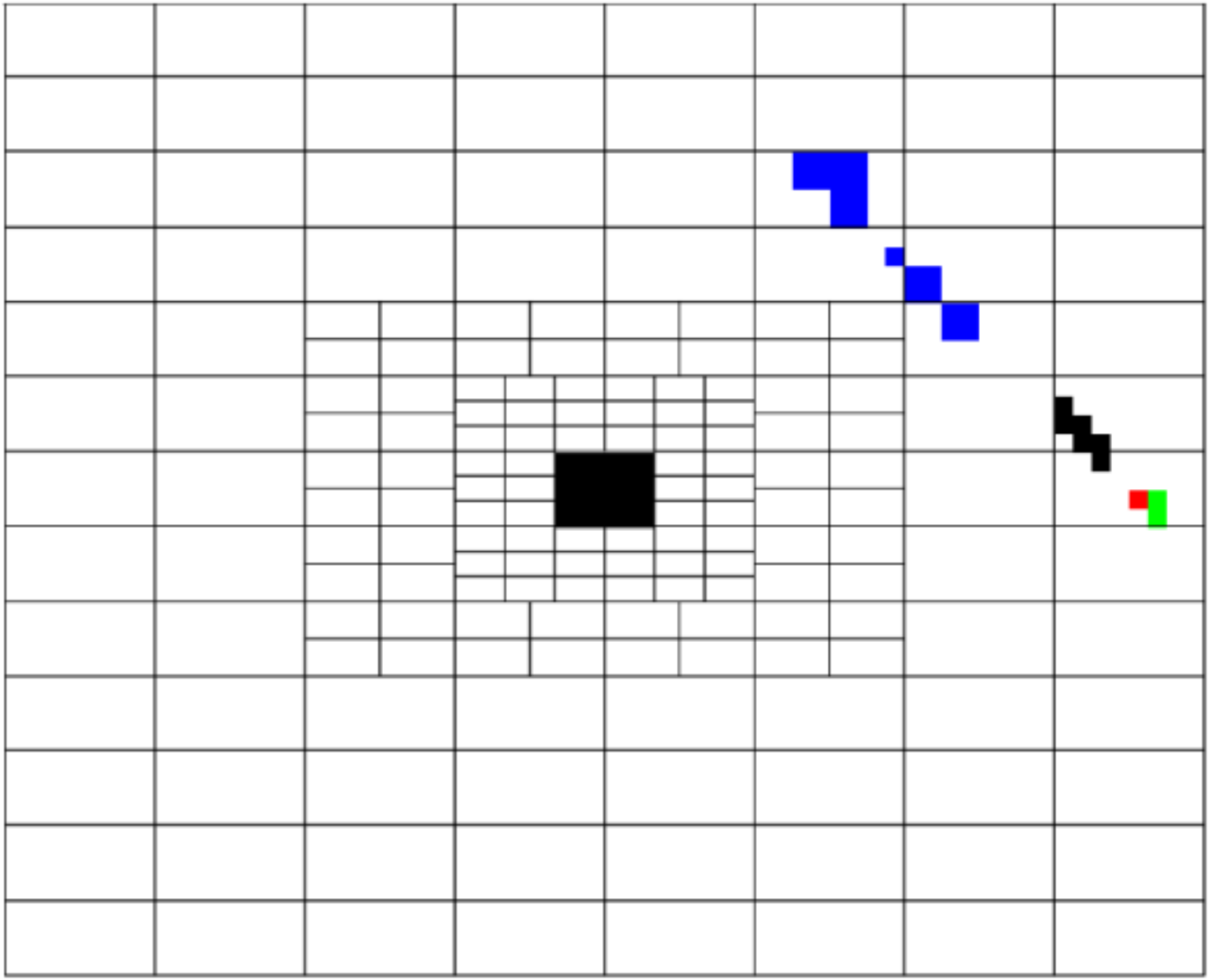
But cosmics are still useful

- More vertical cosmics can be used inside one detector (or a few neighbouring ones) to time align various parts together
- The L0 trigger can be used to trigger on them
  - ECAL and HCAL calorimeters, with a high gain to see MIP
  - Muon trigger without spatial correlation (pointing geometry) constraint
- The basic building blocks of the L0 trigger have been commissioned this way at the end of 2007.


y
5m
Magnet
RICH1
Vertex
Locator
TT
T1
T2
T3
RICH2
M1
SPD/PS
ECAL
HCAL
M2
M3
M4
M5
Beam 1
Beam 2
– 5m
5m
10m
15m
20m
z

Cosmics in the Calorimeters

- **Trigger on a coincidence ECAL-HCAL**
  - Single channel noise too high for just an OR of ~10k channels at low threshold
    - The calorimeters are NOT intended to measure MIP, but high energy showers!
  - Coincidence rate ~10 Hz, mainly close-to-vertical cosmics
    - Allows inter-cell time alignment
  - Nice events
    - Adjust relative timing of the 4 components of the calorimeter
    - Map dead / inefficient cells / regions
      - ➔ Then understand and fix the problems...
  - Cosmics come from top
    - Slope gives direction, and then time-of-flight corrections.

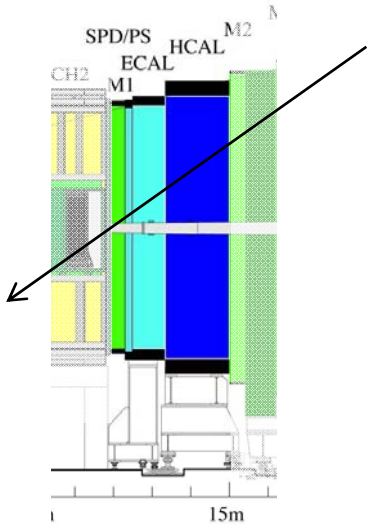


HCAL

ECAL

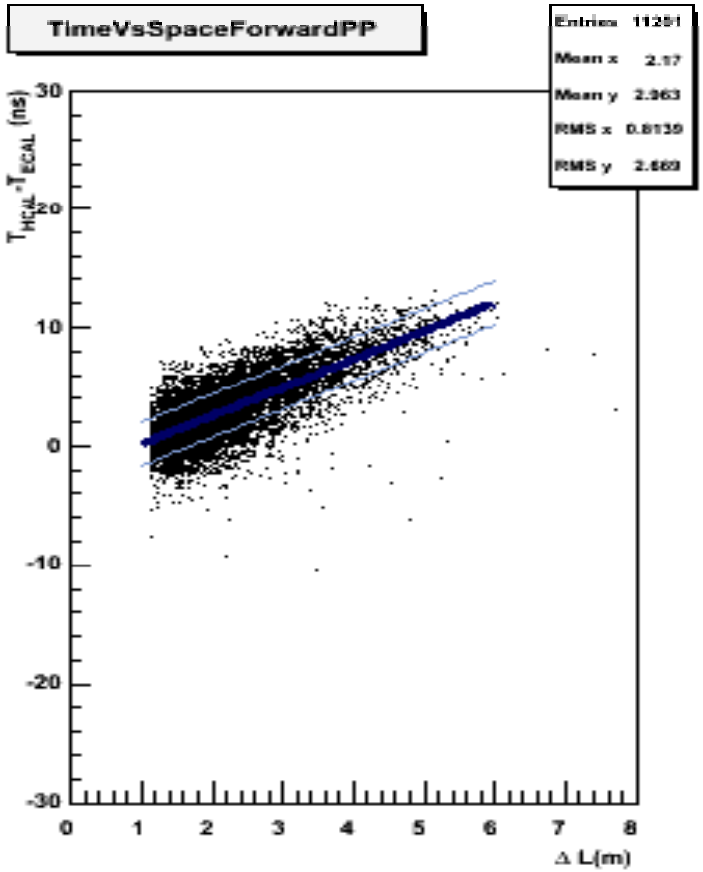
Preshower

SPD



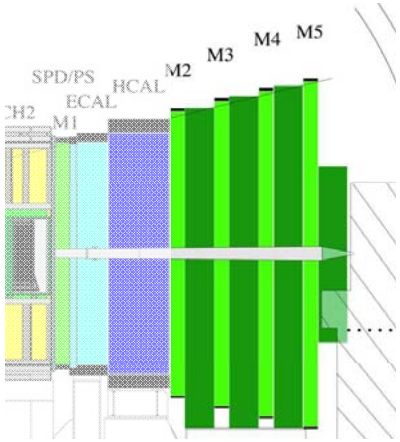
This gives the time alignment

- **The calorimeter pulse shape is known**
  - Measured on test beams.
  - From the ratio between consecutive BX one can deduce the time
  - And compare the two detectors
  - Resolution about 3 ns
  - Correlation is just the speed of light!



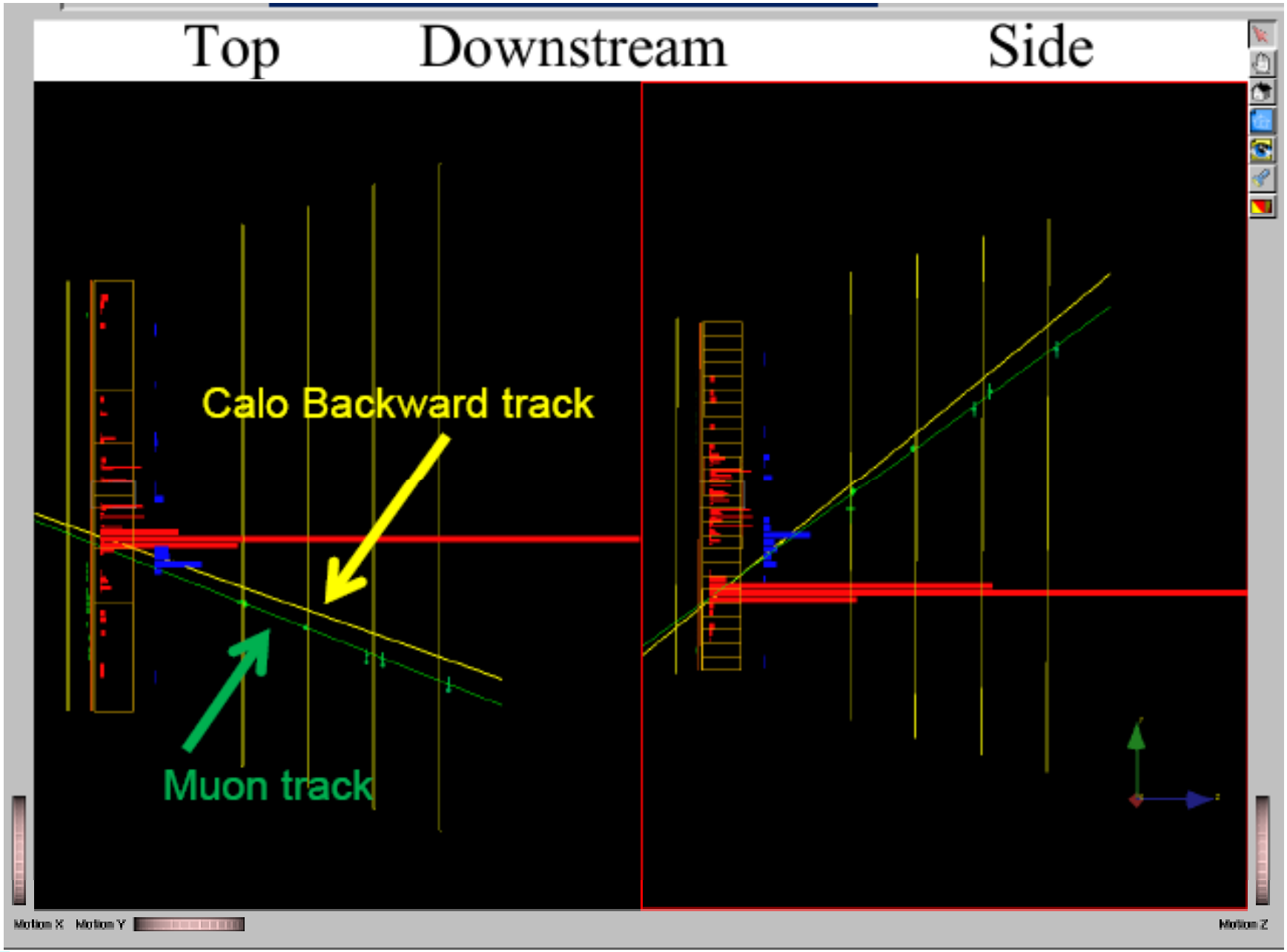
Cosmics with the Muon detector

- **Normal physics trigger requires a pointing track**
  - M2 and M3 and M4 and M5 in a pointing geometry...
  - Efficiency for cosmics too low, ~ few mHz !
  - But one can relax the requirements

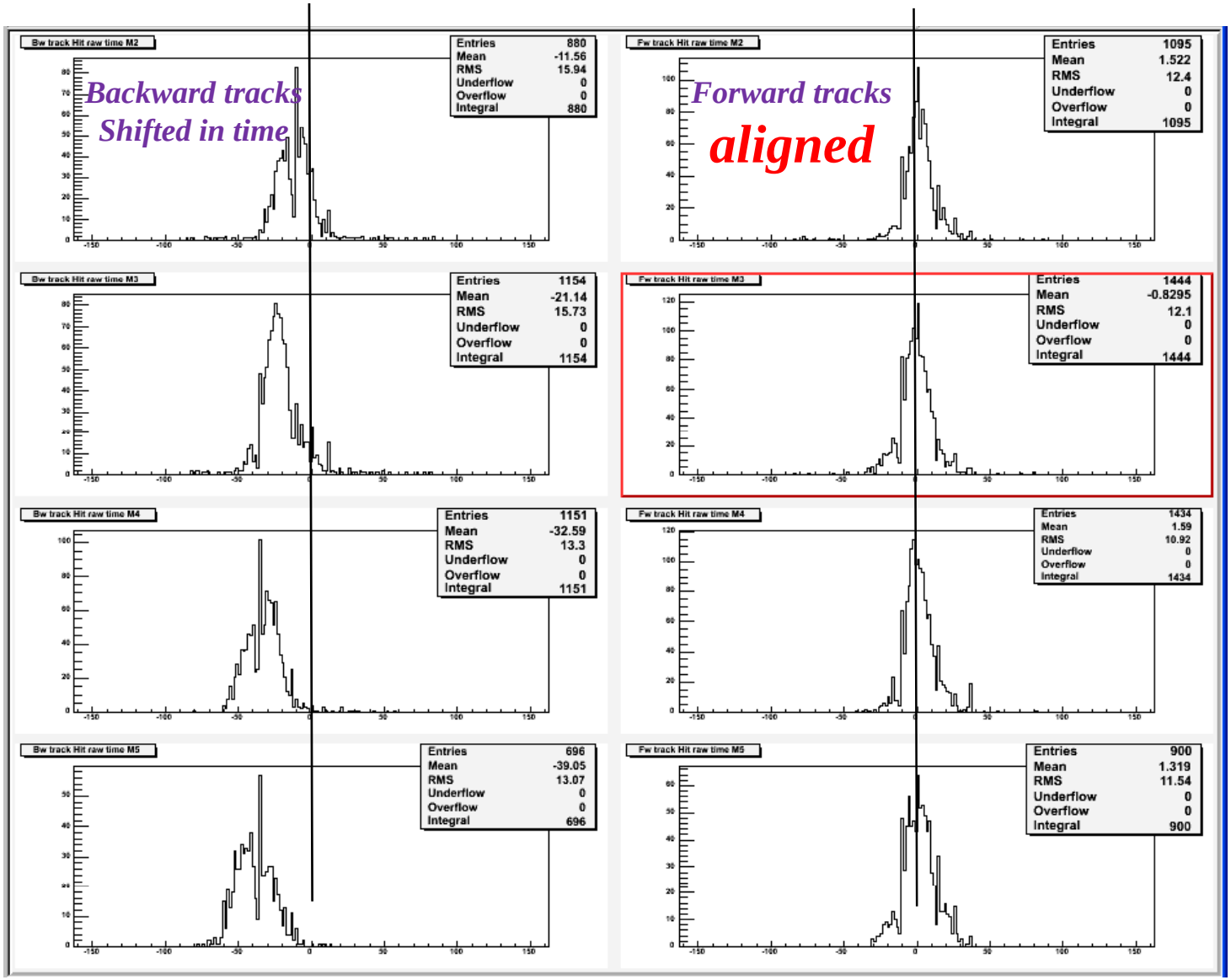


- **Trigger on a coincidence M4-M5**
  - Almost no pointing constraint

- **Many events fire both triggers**


Top
Downstream
Side
Calo Backward track
Muon track

◆Time alignment of the muon stations



M2

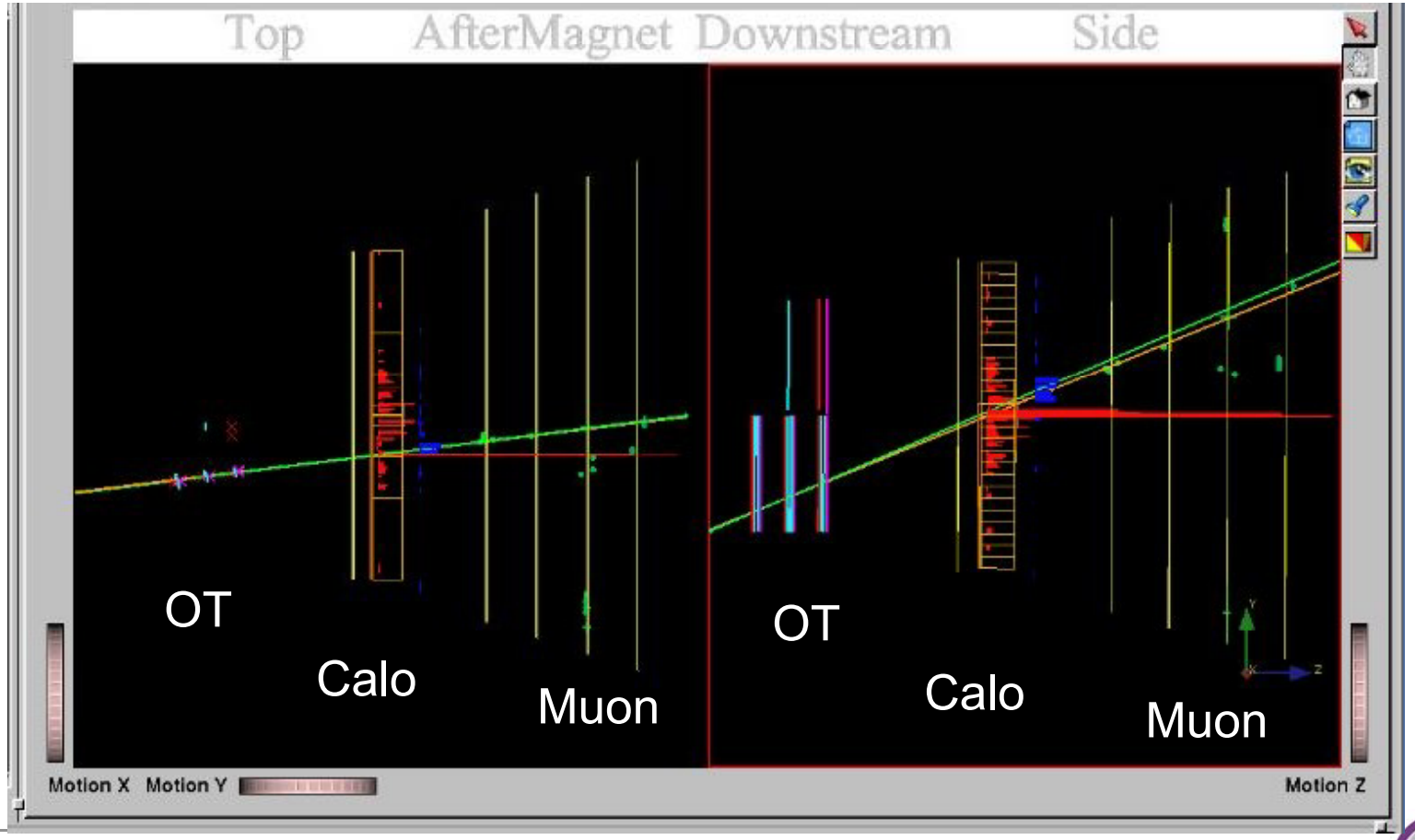
M3

M4

M5

Cosmics for the tracking detectors

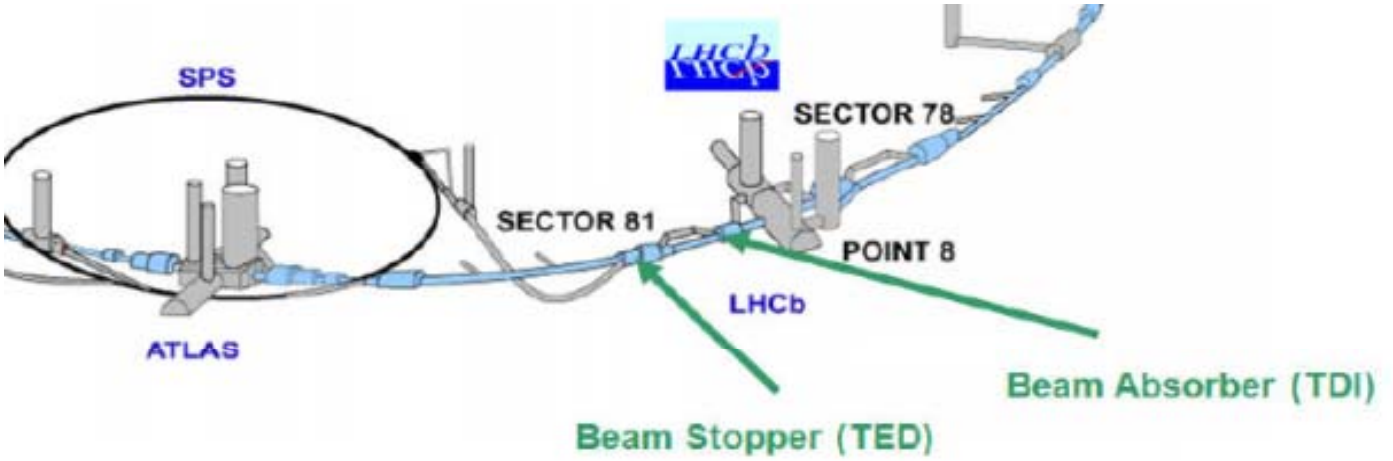
- **Triggered by the Calo / Muon, tracks are seen**
  - Easy for OT, similar surface as the Calo...
  - Marginal for IT (small), TT (too far), Velo (small and far...)



First beam

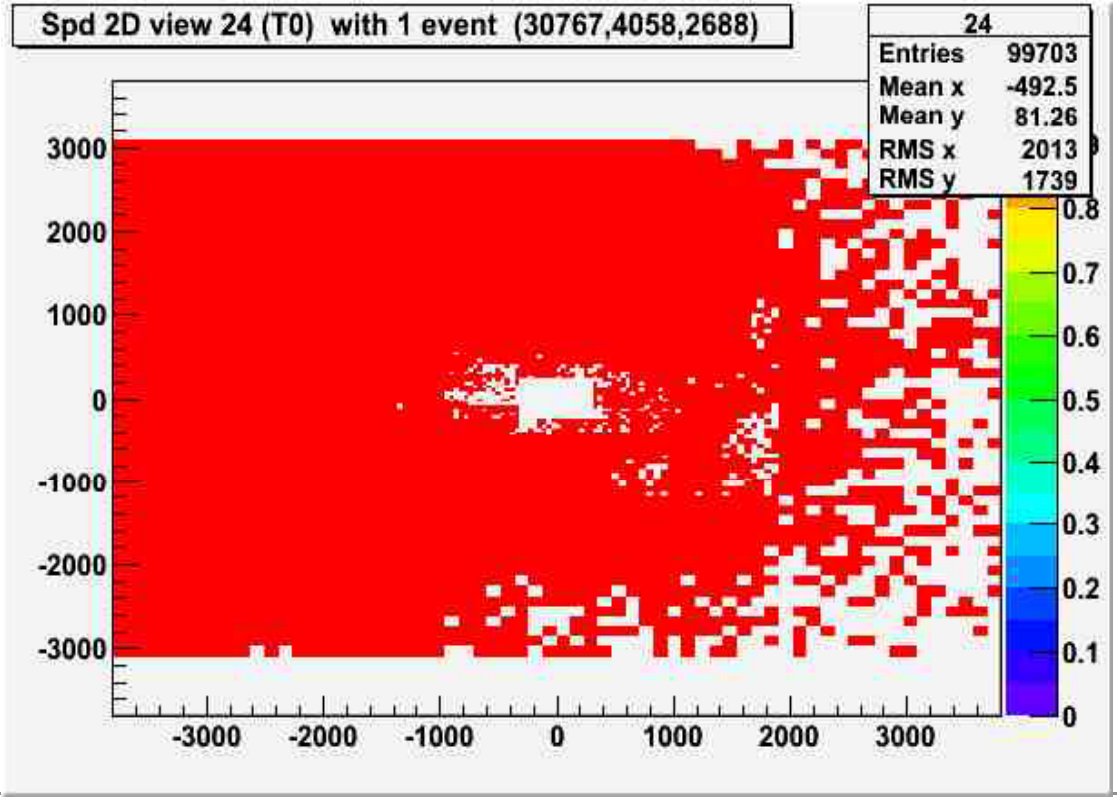
◆LHCb is near the Beam 2 injection line

- TED beam stopper about 300 m behind LHCb
  - Particles will arrive in the wrong direction !
  - The beam is not centred on axis, still going up-left
  - Expect around **10 particles per cm^2**
- TDI is a beam absorber after the injection kicker, about 50 m from LHCb
  - Almost direct view...
  - **~100 times more particles!**

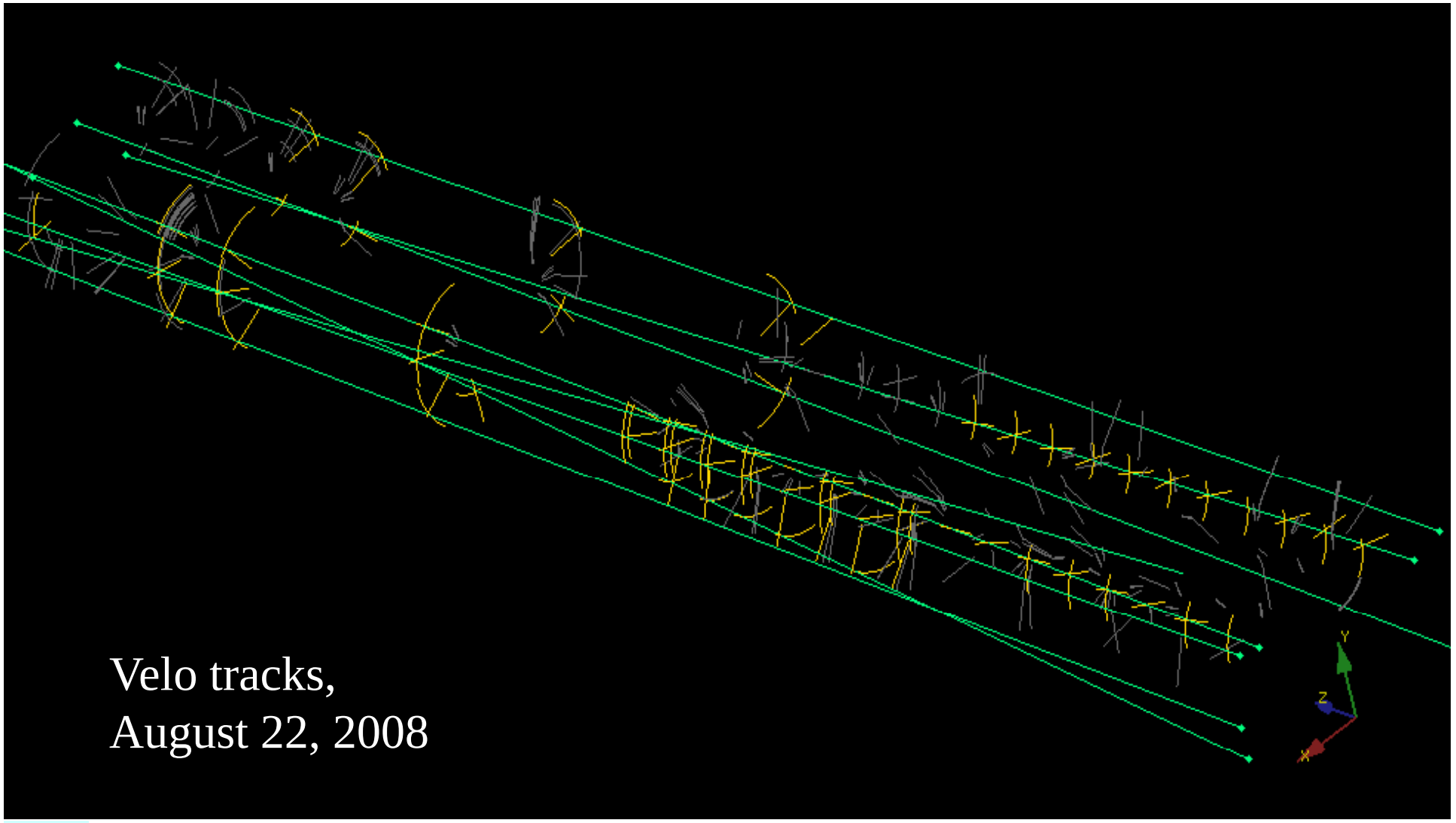


TED events

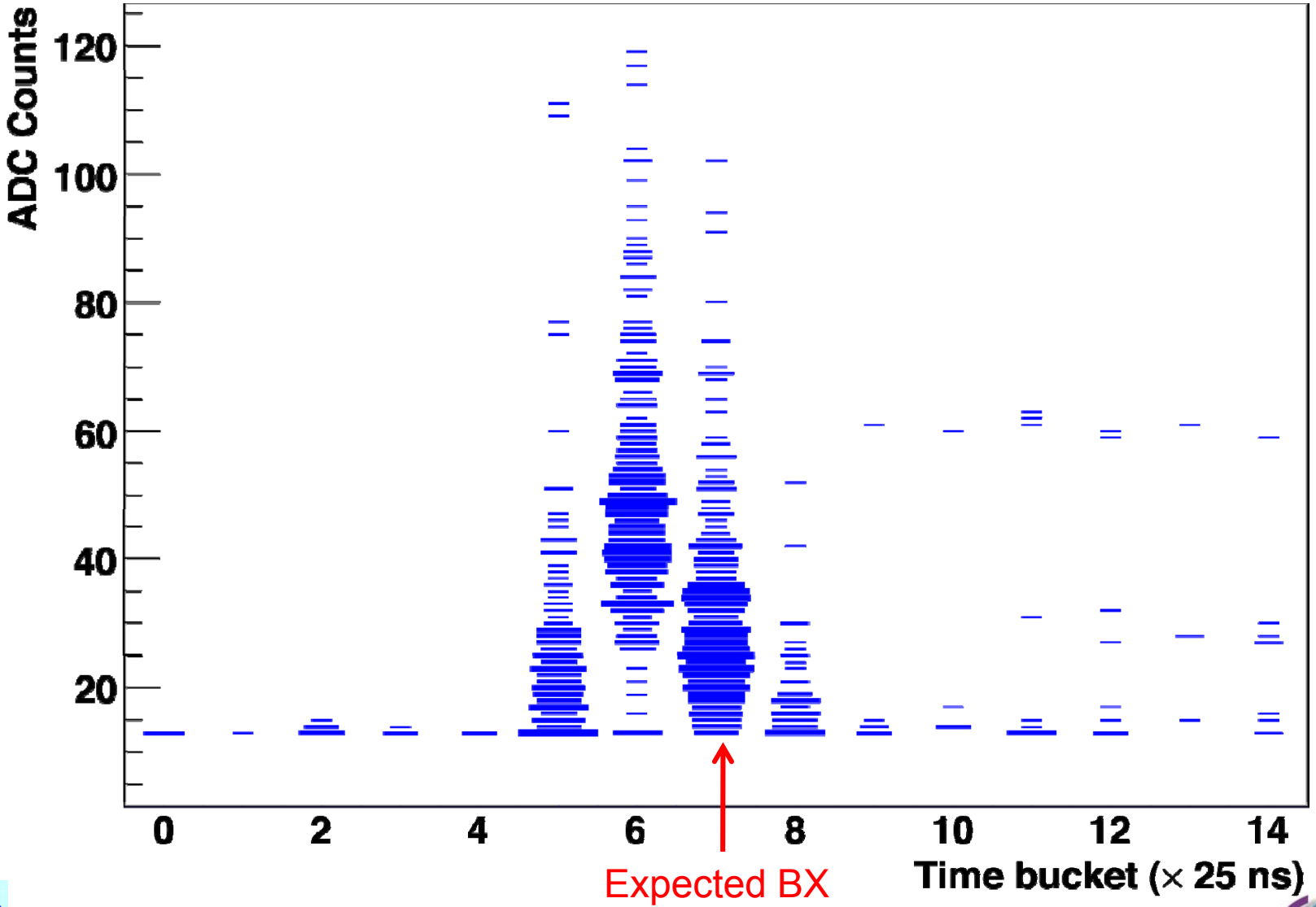
- **Very large occupancy**
  - More than 4000 cells fired (over 6000)
  - Most of them with many, many particles !
  - Trigger on SPD ,multiplicity > 10...



TED events are nice !

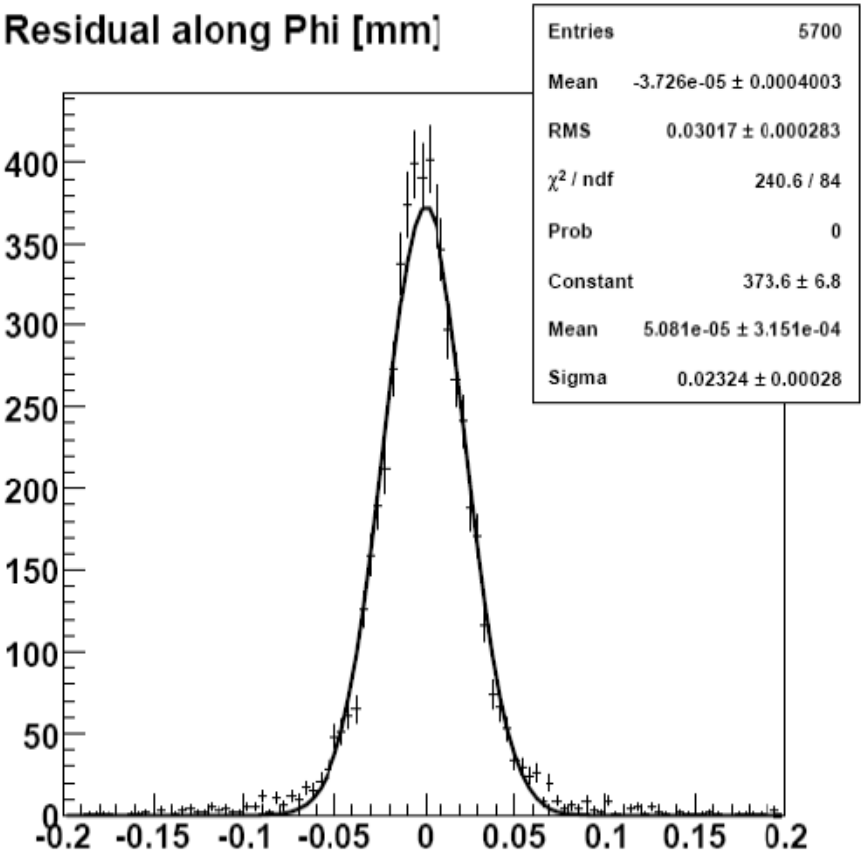


Time alignment with TED



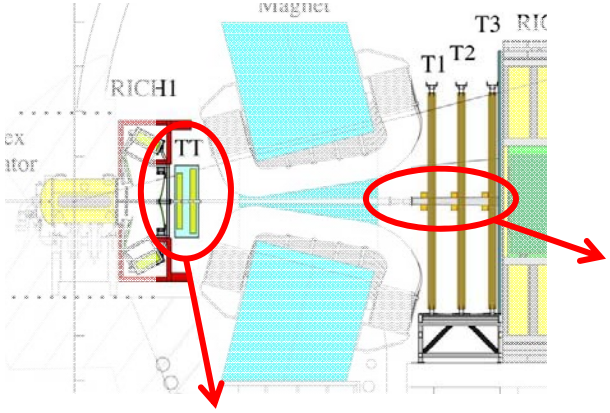
Space alignment

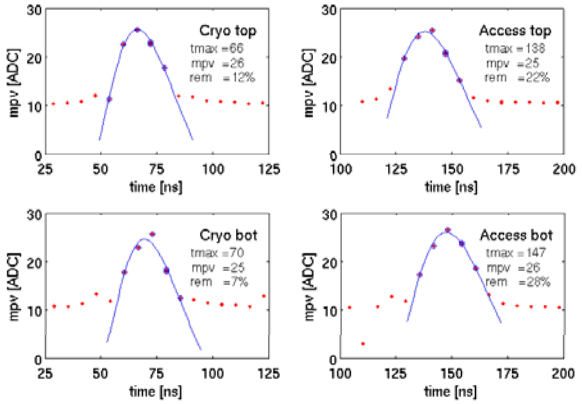
- **Measure the tracks residual**
  - Simple track fit (no momentum)
  - Tracks are long
    - Average 8 space points/track
  - The Velo is aligned to ~20 μm
    - For R and Phi sensors.

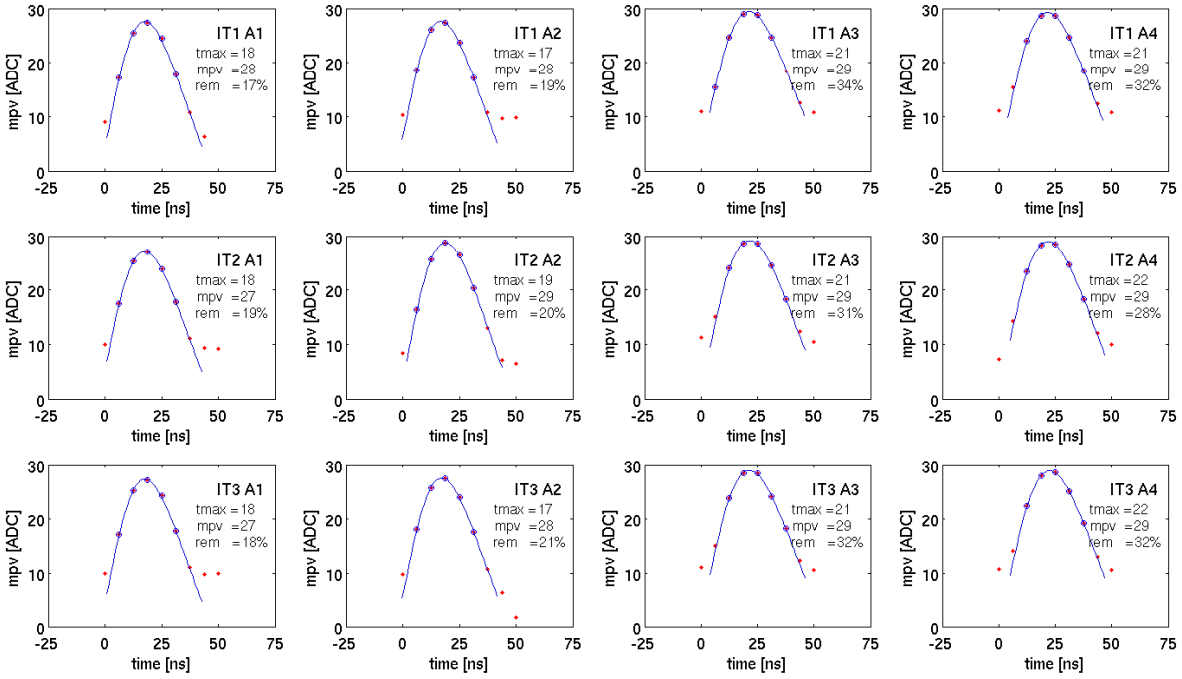


Also for IT and TT

- **Delay scan with TED data, September 5**
  - Sharp peak in average ionisation, 5 ns steps.
  - Very high multiplicity events...



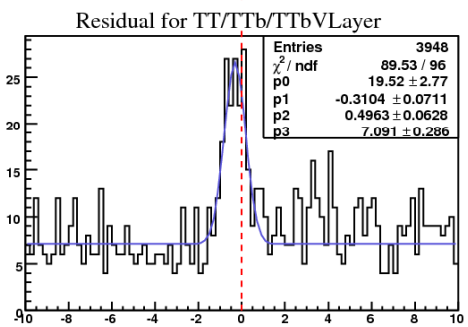


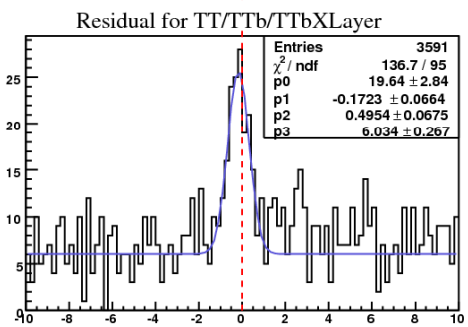


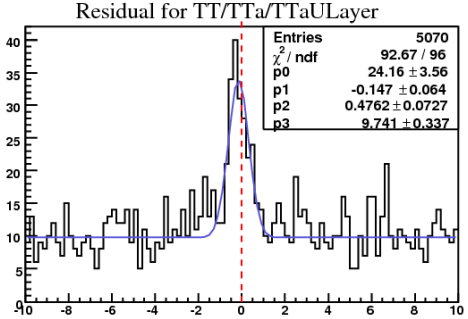
Space alignment

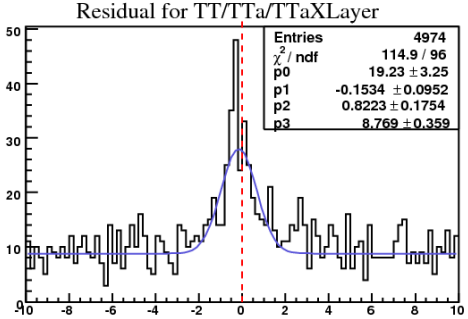
◆Extrapolate Velo tracks

- Distance to clusters in TT and IT
- Large combinatory due to huge occupancy
  - 10 tracks/cm^2, normal value is 20 tracks in the whole detector

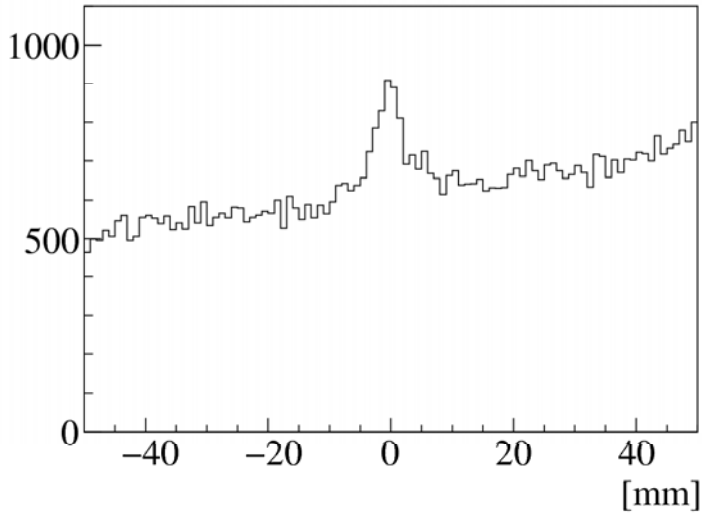






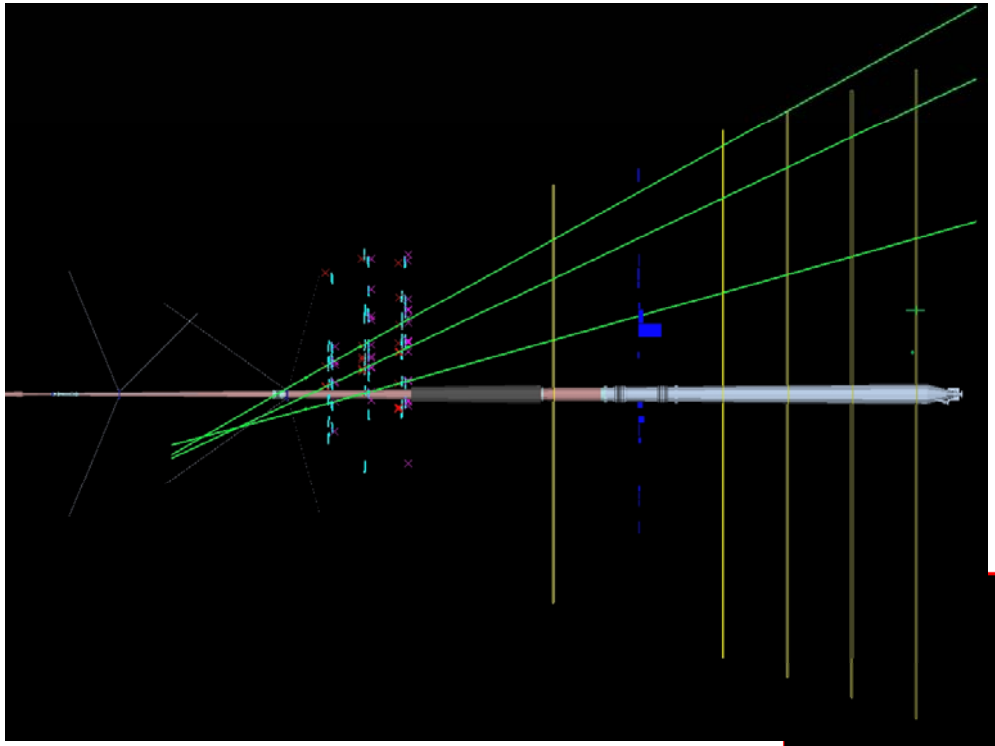


IT is at ~ 7 m

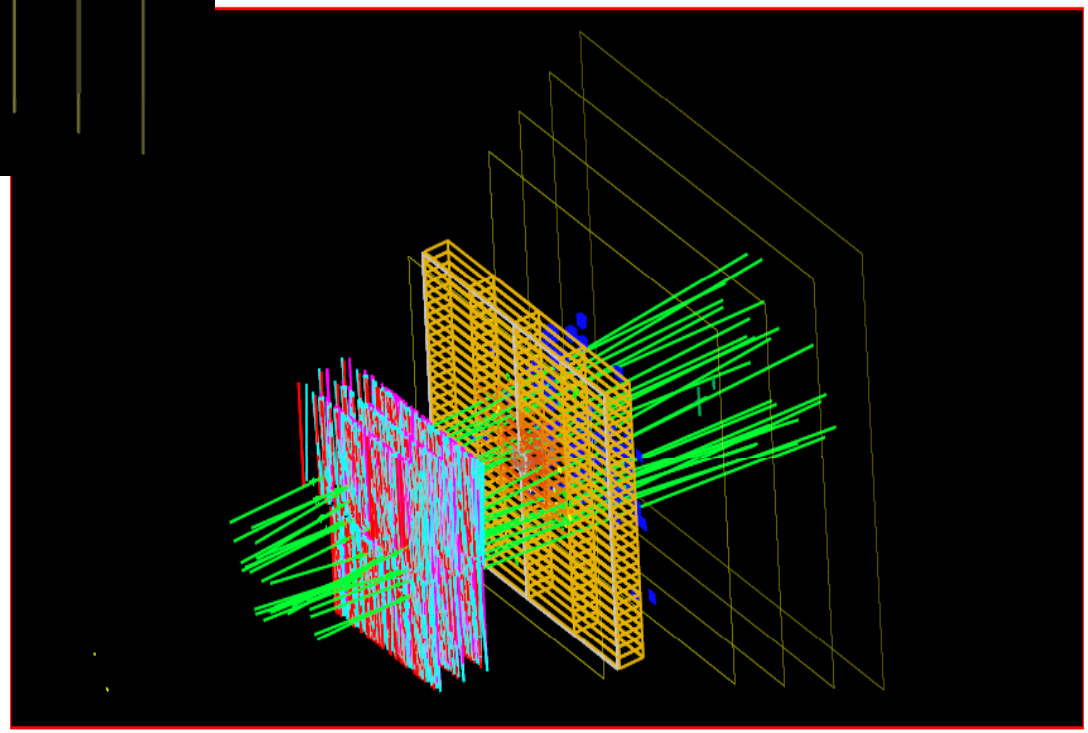


With beam

- **Beam 2 is injected near LHCb**
  - But particles travels in the wrong direction
  - And injection is 'dirty', detectors can't be ON at that time...
- **Beam 1 is what we want**
  - Comes from far, which means the environment (beam) is clean
- **We got beam1 only during the 'media day'**
  - Single shots to a collimator in front of LHCb
  - Passing through on a single turn
  - During ½ hour...
- **We would have loved to get more !!!!!**

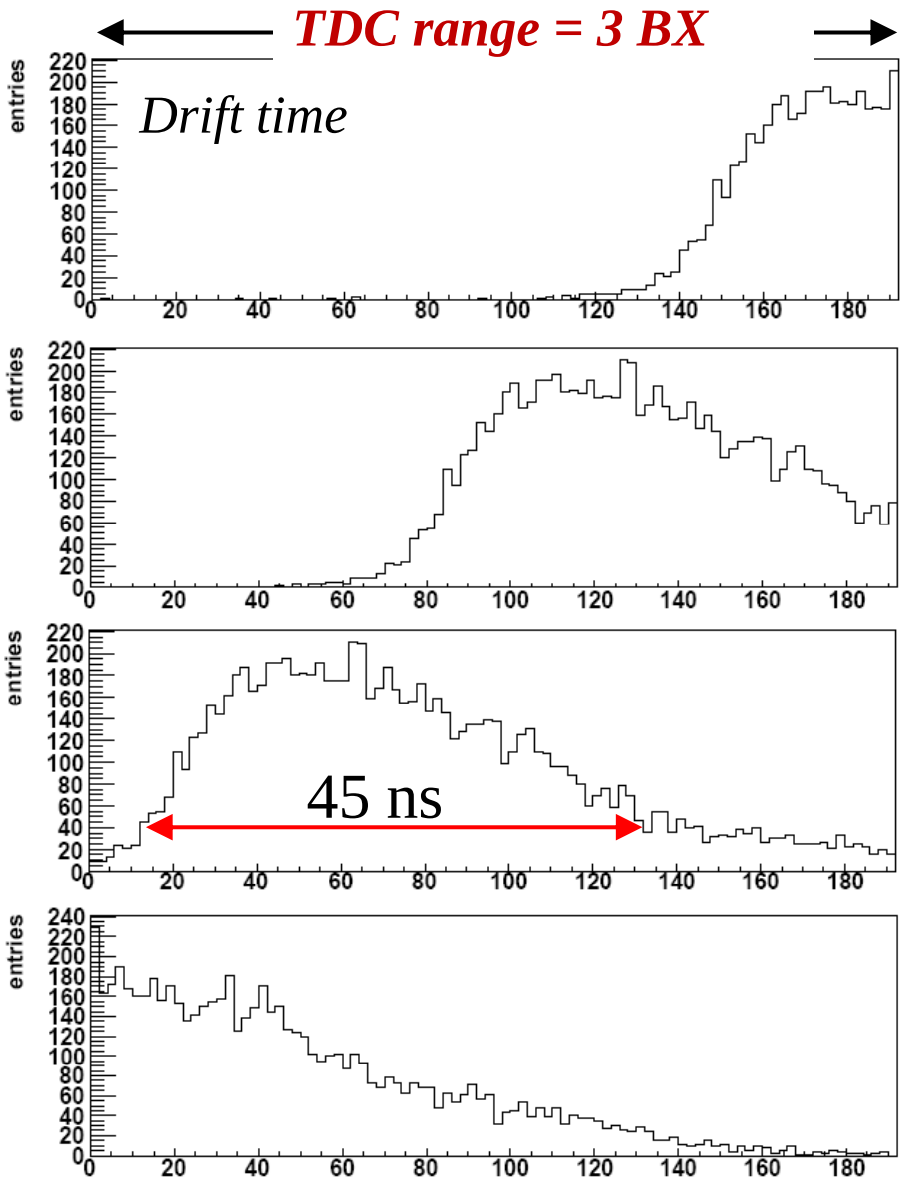


Clean event



Splashy event
(not all tracks reconstructed...)

OT time alignment, 6 'splashy' events



Trigger

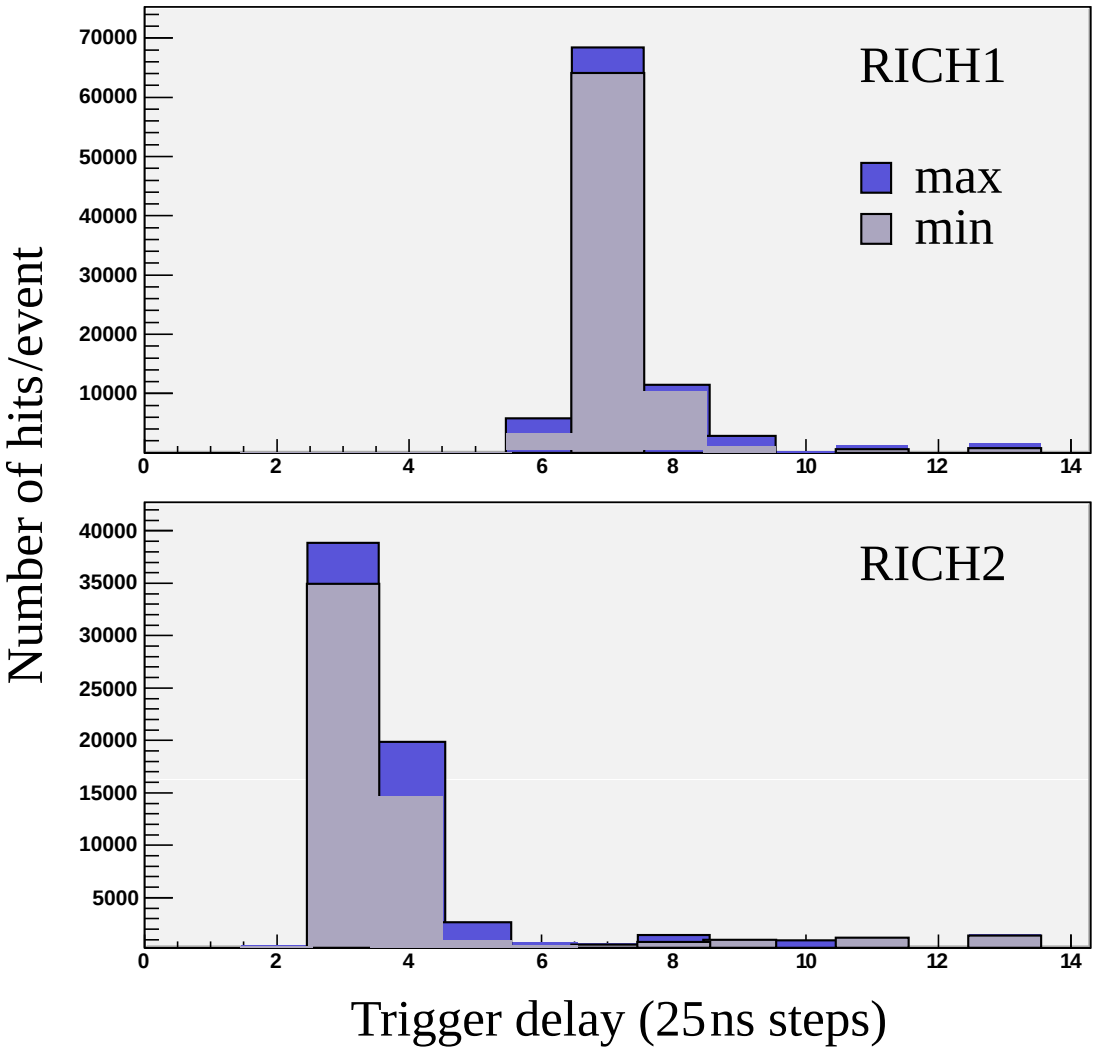
BX = n - 2

BX = n - 1

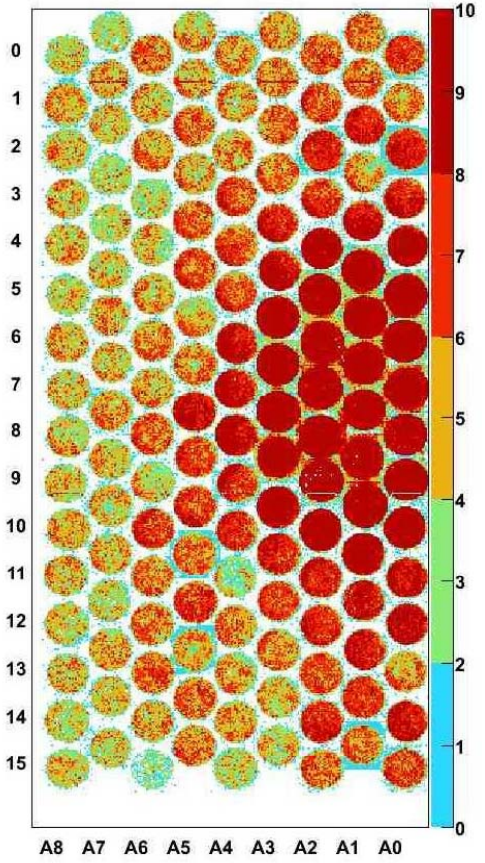
BX = n

BX = n + 1

RICH time alignment



Lot of HPD hits!
30 events
Beam 1 on collimator



And now...

- **We were ready for Beam 1 events**
  - Detector was time aligned (coarse, +- 10 ns)
  - Beam-gas with circulating beam
    - Expected a fraction of Hz
  - Or 450 GeV collisions
    - Expected a few hundred Hz, with vertices in the Velo...

- **Brutal end of a dream, the LHC started so well...**
  - Back to cosmics...
  - But we learned a lot with these few days full of excitement
    - Time and space alignment
    - Operational procedures
    - Improvements needed...

Other aspects

Beam and radiation monitoring

- Beam Condition Monitor commissioned
  - Diamond sensors to detect in ½ turn high radiation
  - It triggered once a dump, which was justified.
- Synchronisation with the RF clock tested OK.
- Data exchanges with LHC

Data monitoring

- Online monitoring farm publishes histograms
- Online presenter (root based) with dedicated database
  - Many pre-defined pages to be looked at.
- Online event display, a variant of the offline one “Panoramix”
  - All previously shown events

System monitoring

- Status of the Event Filter farm, 200 nodes this year
- Alarm and Error Screen
  - PVSS based central error display

Shift and piquet organisation tool

- Internal LHCb development

Celebrations...

Waiting for 2009

- **Many improvements foreseen**
  - Fix problems that appeared only in the full scale system
  - Improve monitoring performance
  - Make more robust / fault tolerant the readout system
- **Commission the full scale readout**
  - 1 MHz requires full network and CPU, delivery in February 2009
- **Re-commission the work together**
  - To get ready for beam in spring
  - To rebuild the team spirit after a long shutdown

Summary

- **LHCb has become an experiment**
  - Not only a collection of sub-detectors
  - Learn from each other, share problems and solutions
- **We were ready in time**
  - Cosmics gave a first working point
  - TED events end of August gave the first LHC-induced tracks ever
  - Time alignment and space alignment done at first level
    - Better accuracy with more data
- **Now back to…**
  - Fixing problems
  - Installing the only missing part of the detector, M1

Congratulations to the *LHC* builders and operators for this wonderful start-up
(until the sector 34 failure)

LHCb started very well

Waiting for a fantastic run in 2009 with high energy and good luminosity