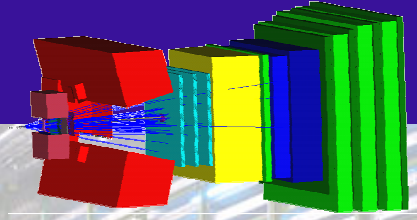


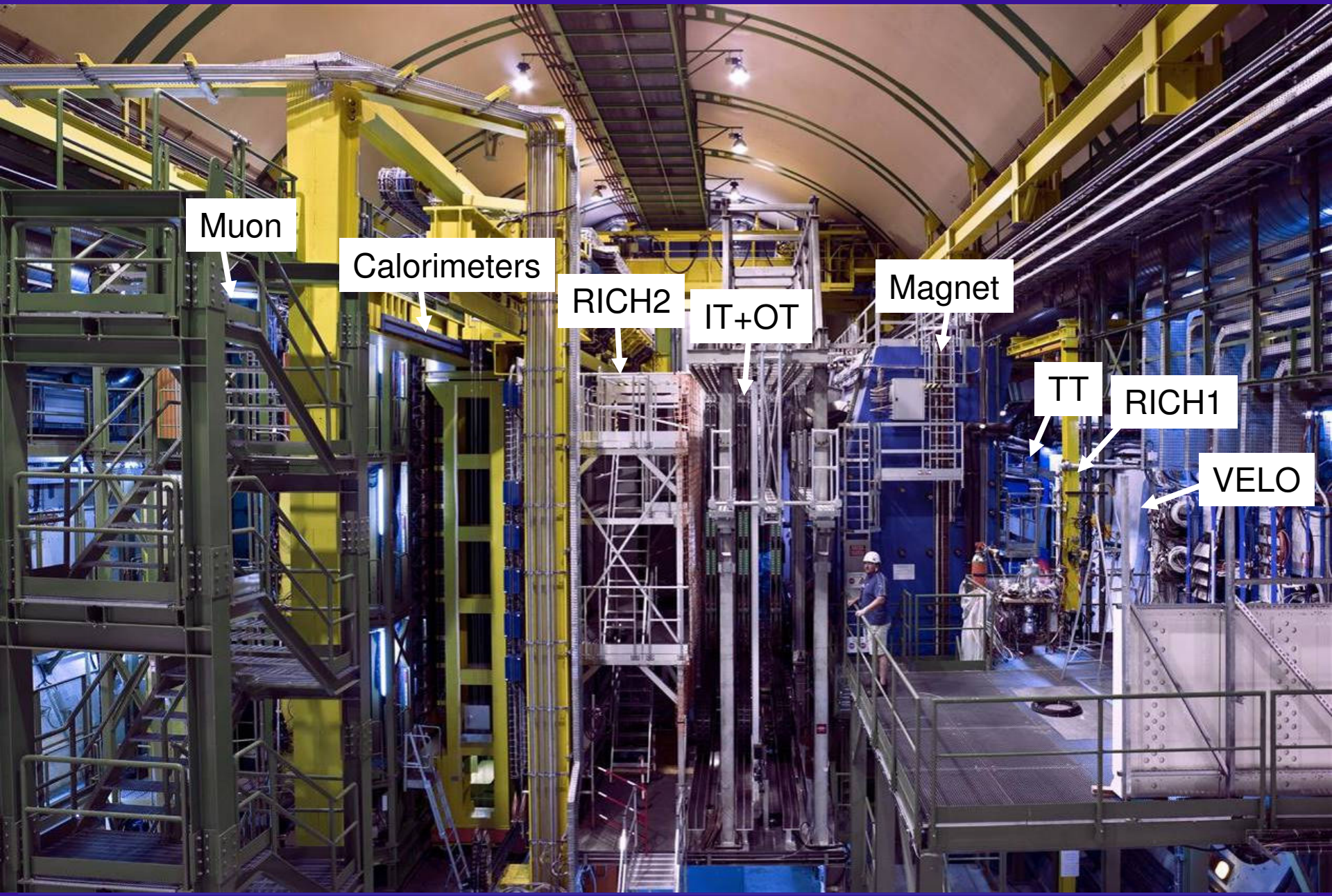
LHCb: Preparation for LHC beam

Jeroen van Tilburg
(Universität Zürich)

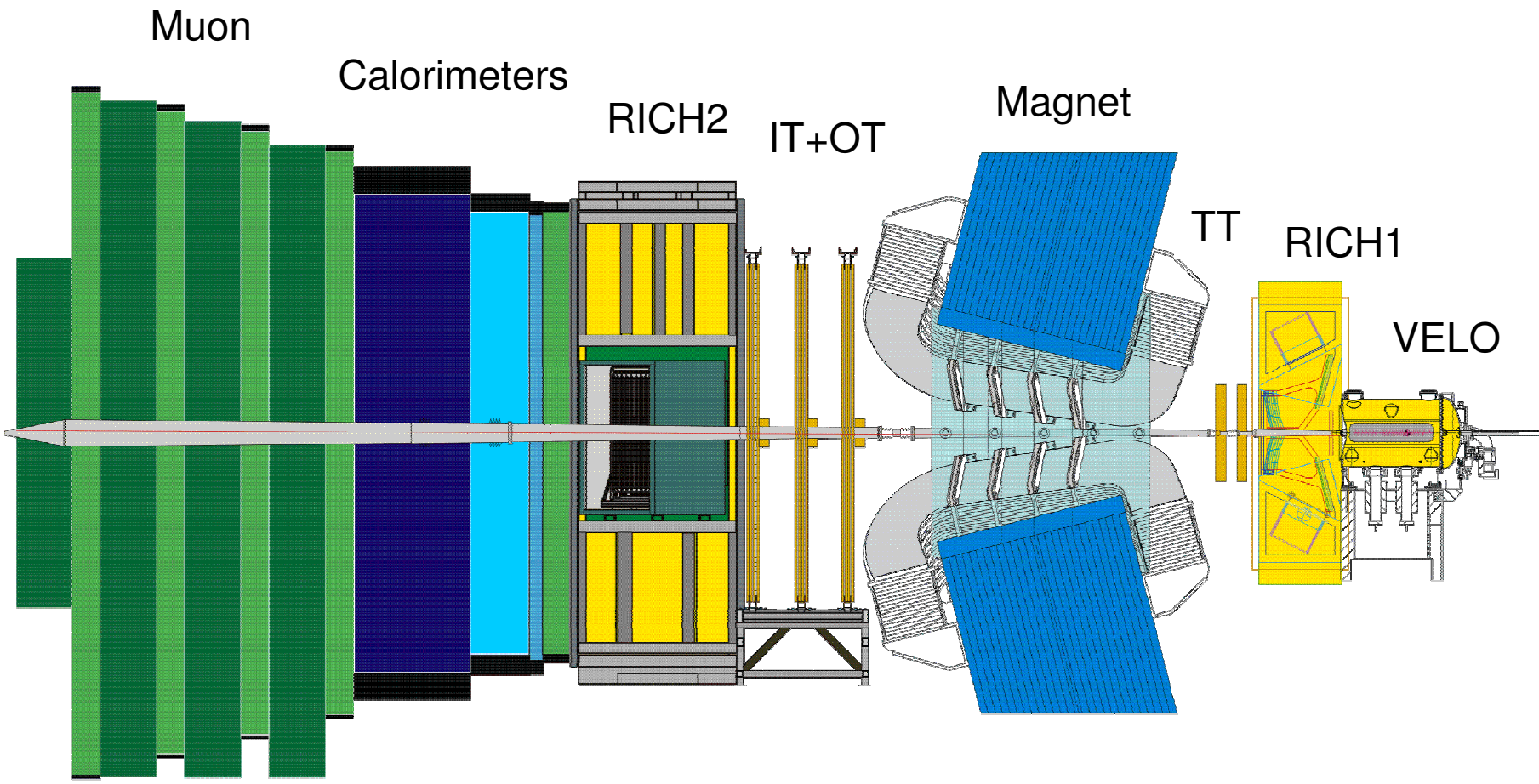
CHIPP meeting
Appenberg, 24-25 August 2009

Swiss Institute of Particle Physics

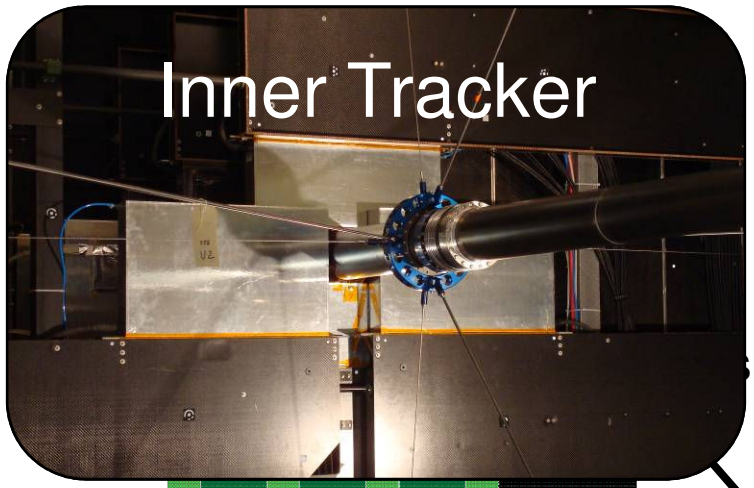
LHCb setup



LHCb setup



LHCb setup



Swiss contributions

EPFL

Uni Zürich

RICH2

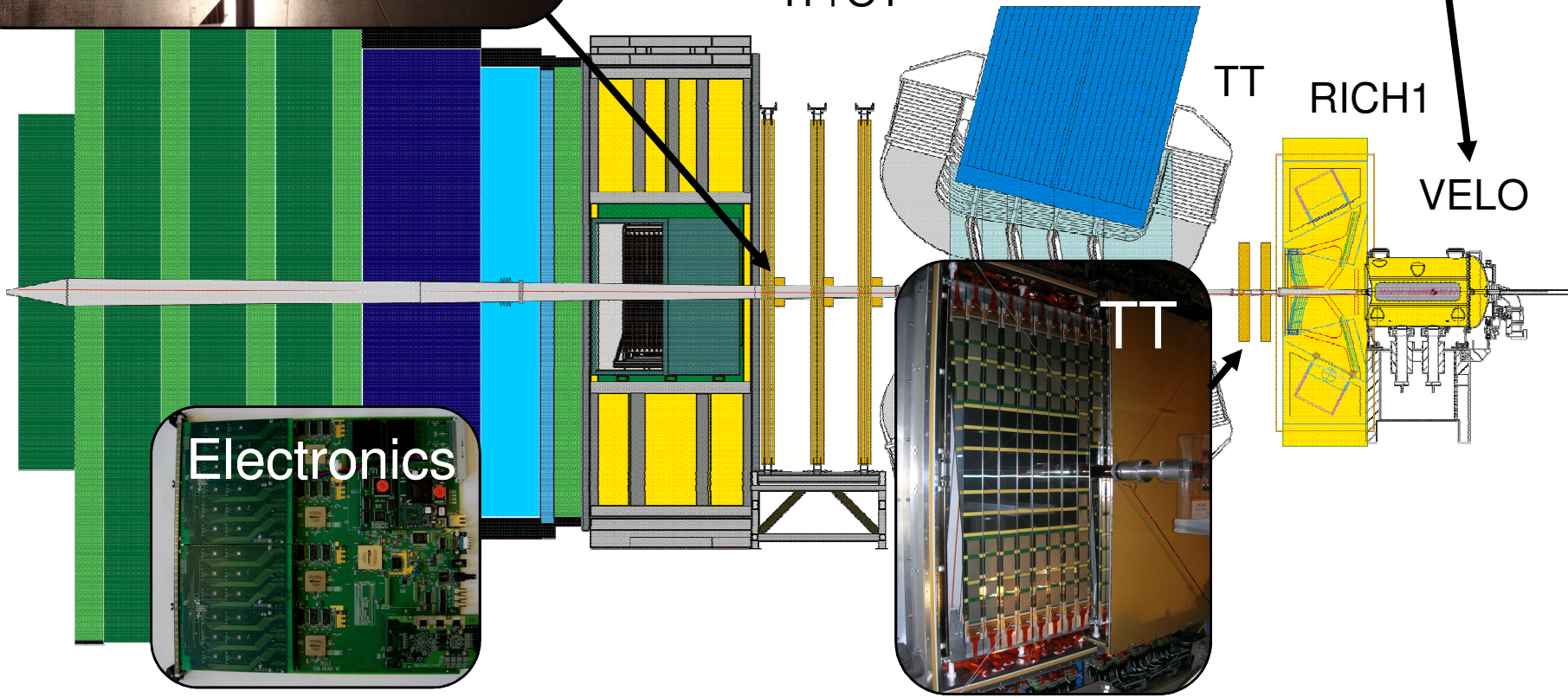
IT+OT

Magnet

TT

RICH1

VELO



Shutdown activities

Many shutdown activities from Sep 08 – now.
→ Never-ending improvements (apart from M1 installation).

Many tests and improvements

- Hardware replacements (repairs) and improvements (safety, reliability).
- Optimization of the control system. Integration of all components.
- Improvement and development of online monitoring.
- Installation of full readout network for 1 MHz data acquisition.
- FEST: exercise data flow up to Tier1s by injecting simulated events into farm.
- Continuously checking for cable swaps, bad connections, hardware failures, debugging, better understanding of detector.
- A large fraction of LHCb readout channels working without problems

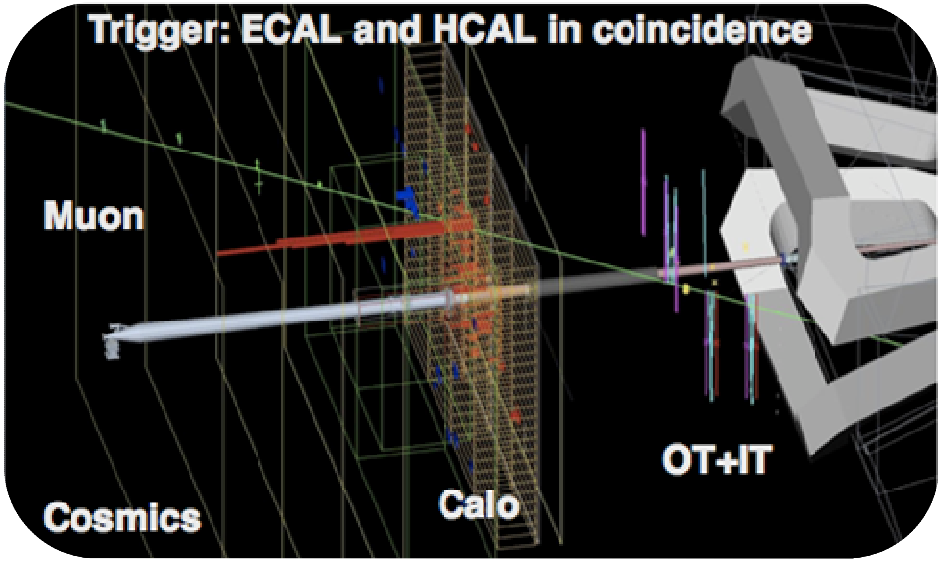
Fraction of working channels

VELO	99.0%
TT	99.75%
IT	99.7%

Cosmic events

LHCb geometry not ideal to measure cosmics
→ only large systems benefit from cosmics
(Muon, Calo and OT)

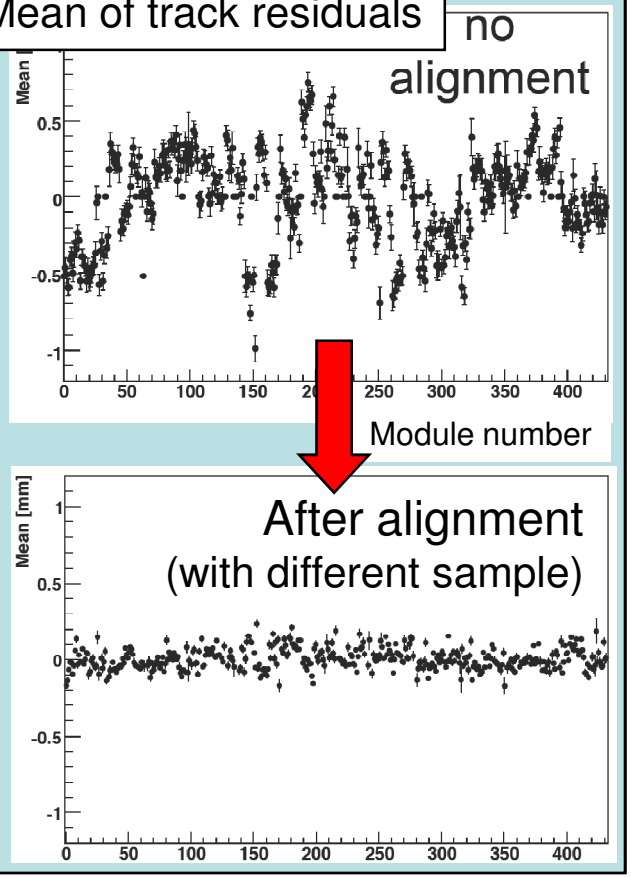
- Few Hz trigger on cosmics.
- About 3 M triggers acquired in summer 2008.
- Muon and Calo synchronized to few ns.
- Commissioning of L0 trigger.
- Muon aligned to ~200 micron (130k tracks used).
- OT aligned to ~100 micron (20k tracks used). →



IT lacks statistics:
→ only 90 tracks pass 2 IT stations
→ only 2 tracks pass all 3 IT stations.

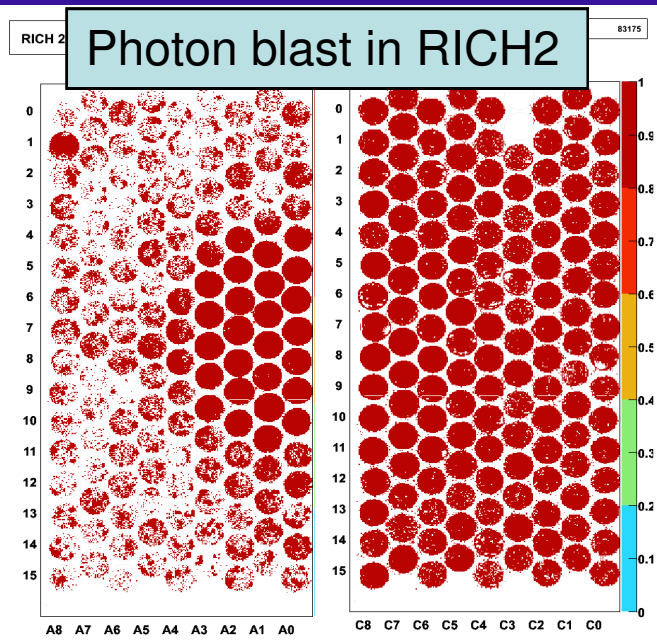
OT alignment

Mean of track residuals



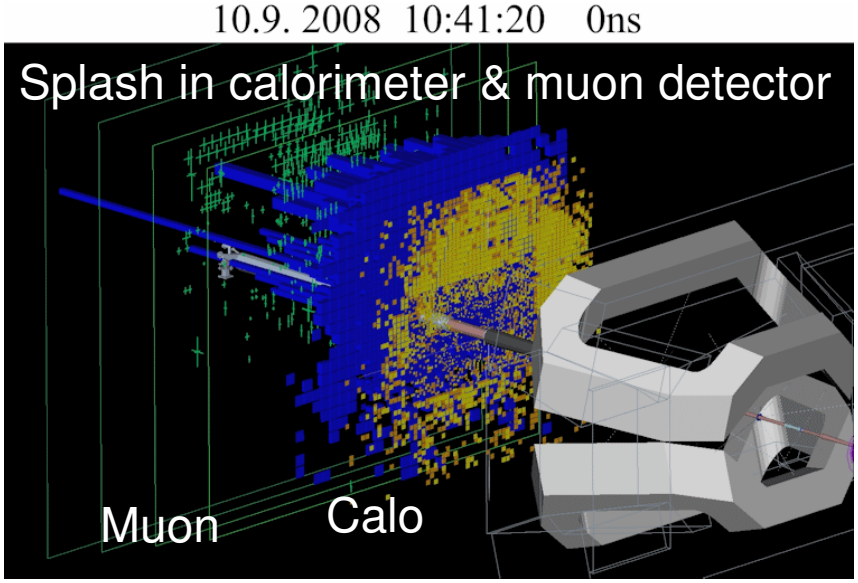
Beam induced events (beam 1)

An hour of circulating beam is more interesting than a month of cosmics.

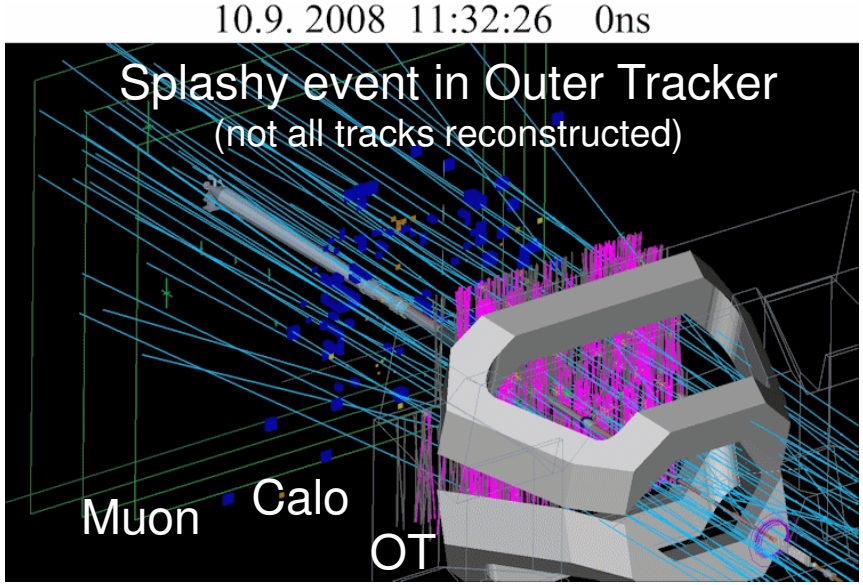


Photon blast in RICH2

- Data taken on Sep 10th 2008.
- Circulating beam 1 (“right direction”).
- Detected halo & splash events (beam on collimator).
- Muon, Calo, RICH2 and OT on. Silicon detectors off.
- Useful for synchronization and experiment operation.
- Successful start for LHCb, yet too short.



Splash in calorimeter & muon detector



Splashy event in Outer Tracker
(not all tracks reconstructed)

Beam induced events (TED)

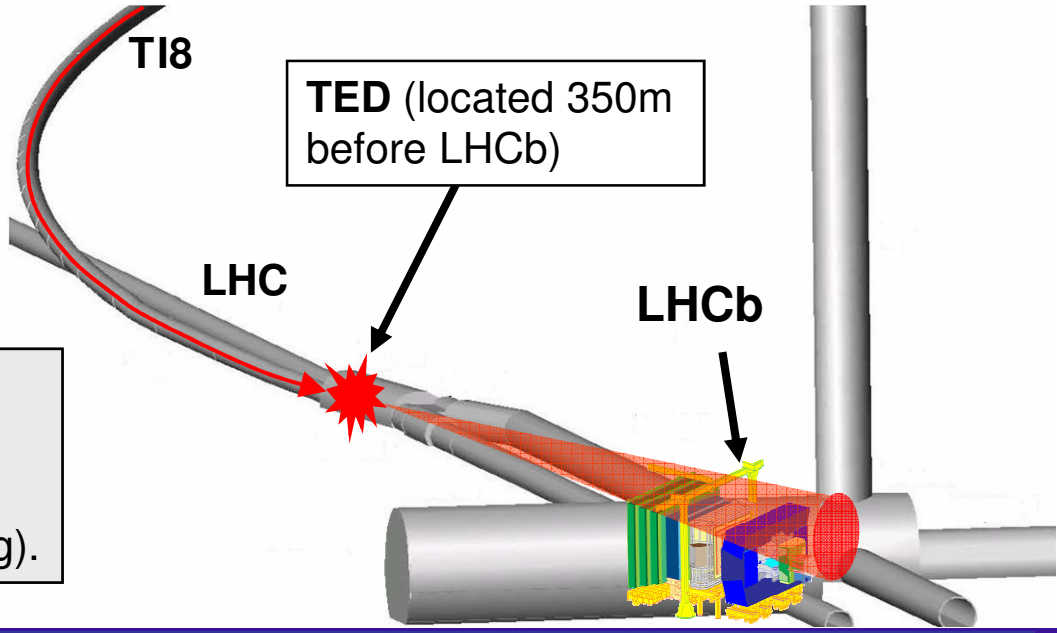
→ LHC injection tests very useful for commissioning silicon detectors!

- Beam dump (TED) before injection to LHC ring.
- Shot every 48 seconds with $2x10^9 – 5x10^{10}$ protons.
- Particles (mainly ~10 GeV muons) in "wrong direction".
- Trigger provided by calorimeter (SPD)
- Useful exercise for fine-timing of subdetectors (few ns).
- Very different strip occupancies (at $5x10^9$ protons):
  → **VELO**: < 0.2%, **IT**: 6%, **TT**: 10%.

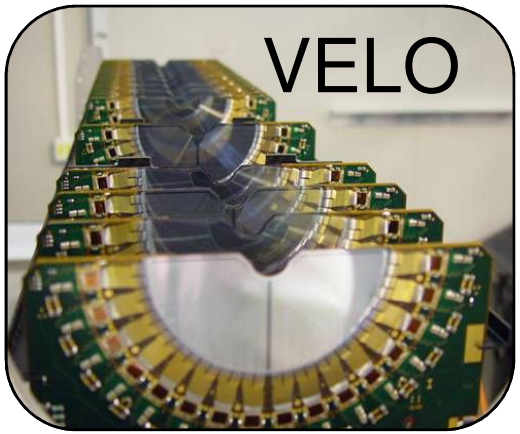
TED runs:
- Aug/Sep 2008
- June 2009
- Oct 2009 (expected)

TED08:
- Intensity ~$5x10^9$ protons.
- Single shots every 48 seconds.

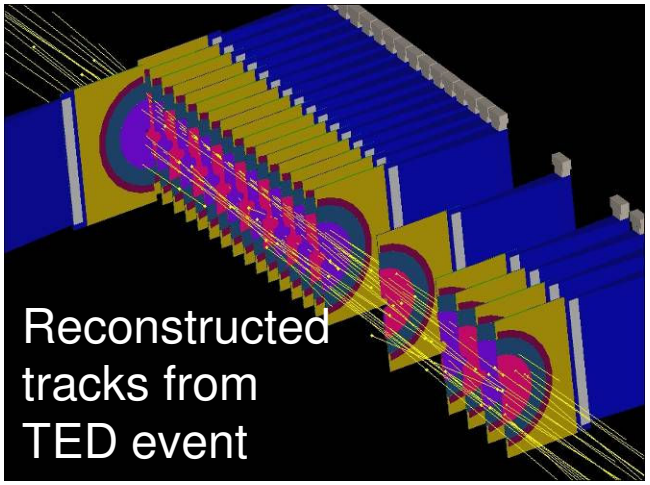
TED09:
- Intensity $2x10^9 – 5x10^{10}$ protons.
- Single shots every 48 seconds.
- Bunch trains (12 shots with 25 ns spacing).



VELO TED results

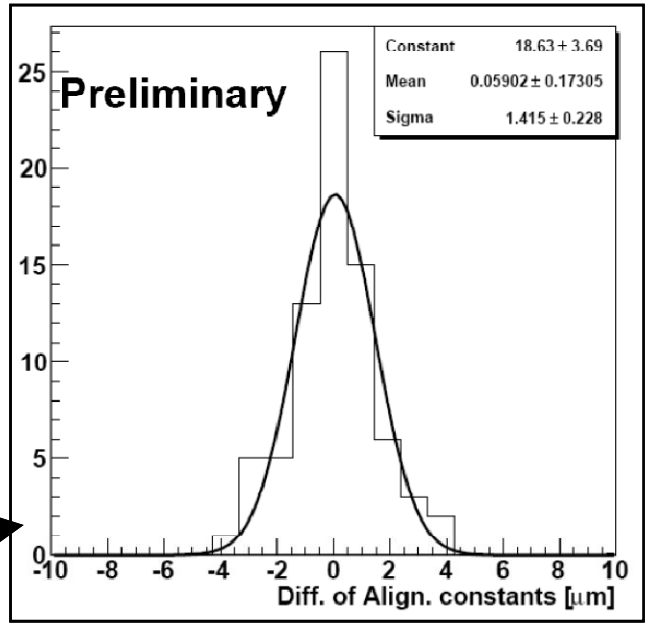


- Two retractable halves.
- 21 modules, each with a r- and φ-measuring sensor.
- Strip pitch: 36–102 μm.
- S/N > 20



TED08:
- VELO in open position.
- 2000 tracks (about 6 tracks per event).
- Modules within 10 μm of metrology.
- Module alignment precision about 5 μm.

TED09:
- VELO in (almost) closed position
  → alignment of two halves possible (1k tracks).
- More than 50k tracks (6–14 tracks per event)
  → sensor alignment possible.
- Module alignment precision 1.4 μm.

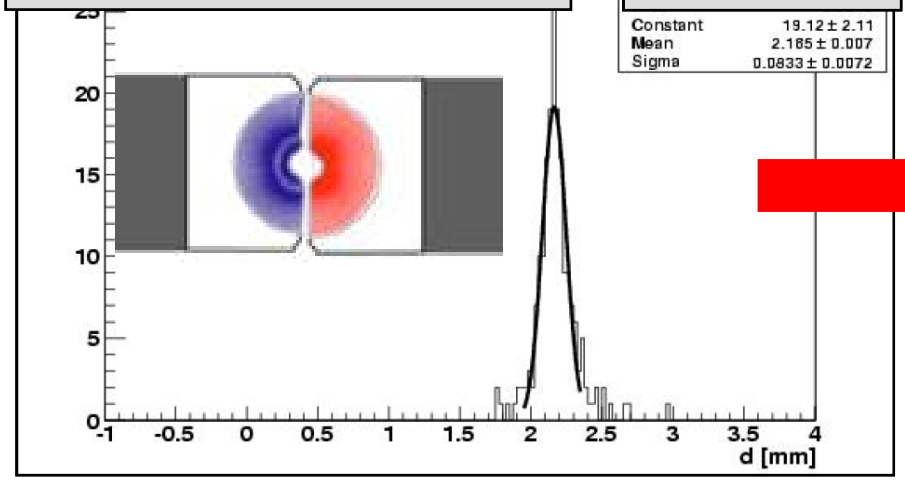


VELO TED results

Moved VELO halves during the TED09 run by 450 µm

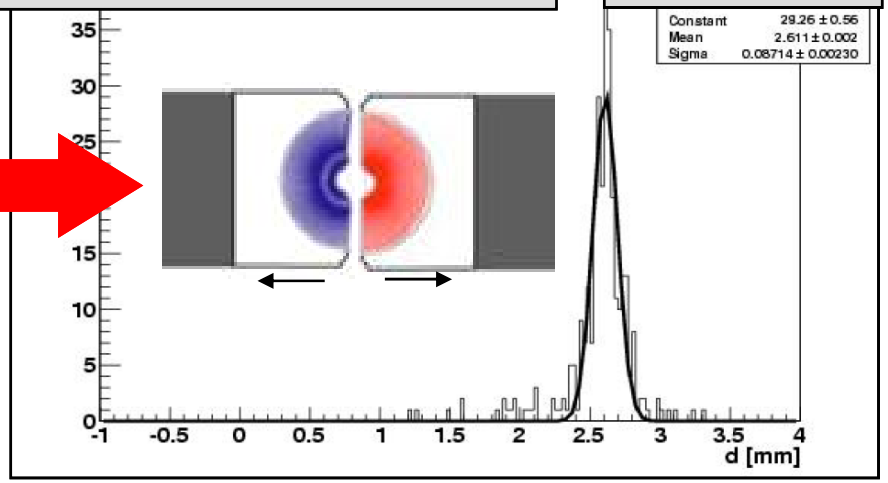
Reconstructed distance between halves

Before movement



Reconstructed distance between halves

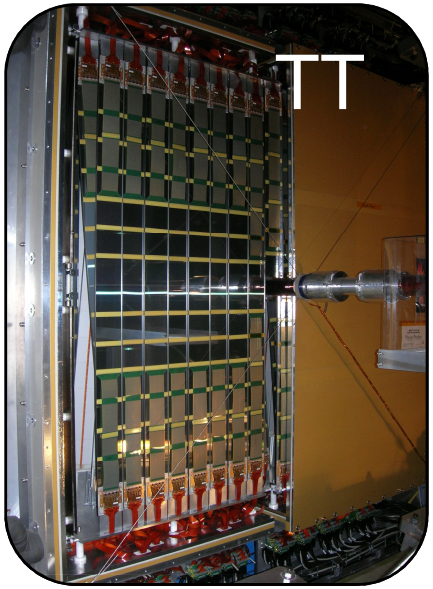
After movement



Reconstruction sees movement of 445 ±10 µm (blind analysis!)

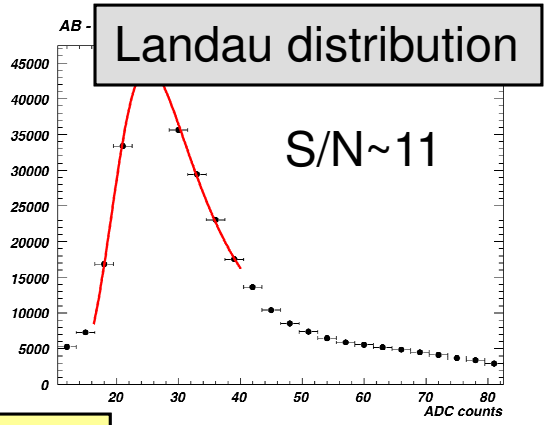
Two halves can be aligned with high accuracy!

TT TED results

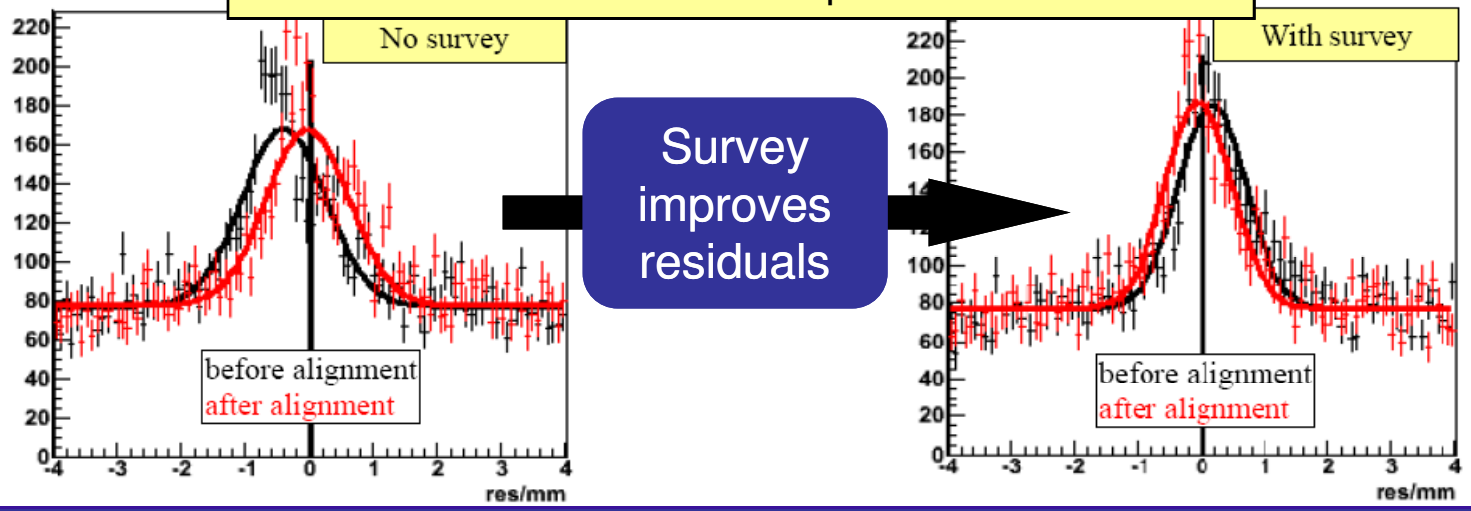


- Four layers (0º,+5º,–5º,0º) of 150 x 130 cm.
- Strip pitch: 183 μm. 64 modules with 14 sensors each.
- Module (supports) surveyed to 50 μm precision.
- Only 4 layers → no standalone track reconstruction.

- Use TED08 data for alignment (TED09 under study).
- Extrapolate VELO tracks to TT (~550 tracks found).
- Tracks limited around beam pipe.
- Alignment of full station (2 dof).

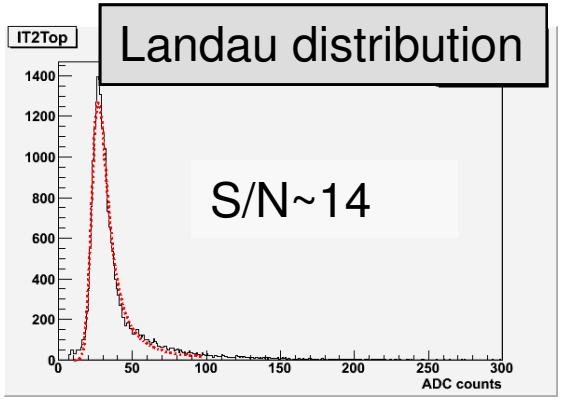


Residuals of TT hits from extrapolated VELO tracks.



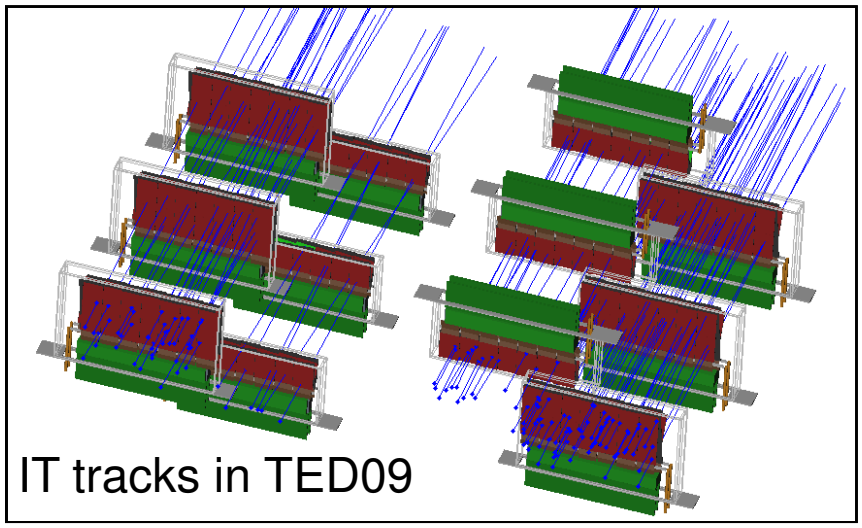
IT TED results

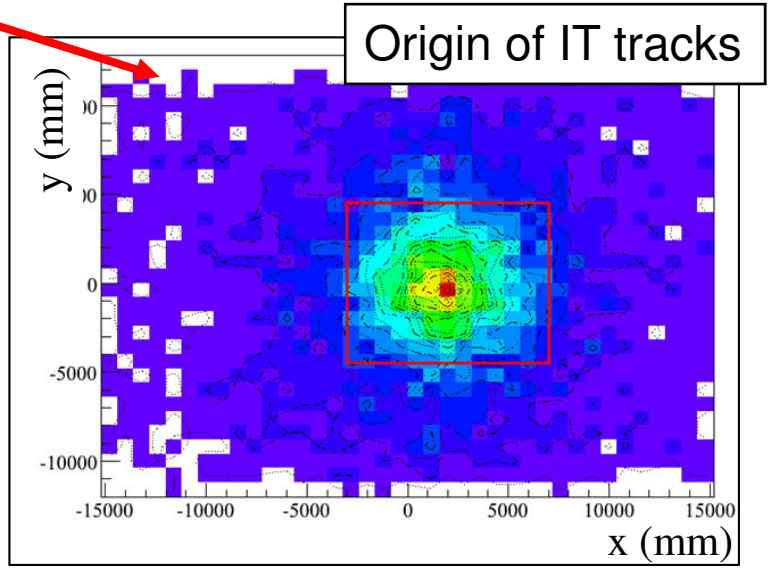
- 3 stations with 4 boxes each.
- Each box has 4 layers (0º,+5º,–5º,0º).
- Strip pitch: 198 μm.
- Standalone track reconstruction.



Fighting combinatorics

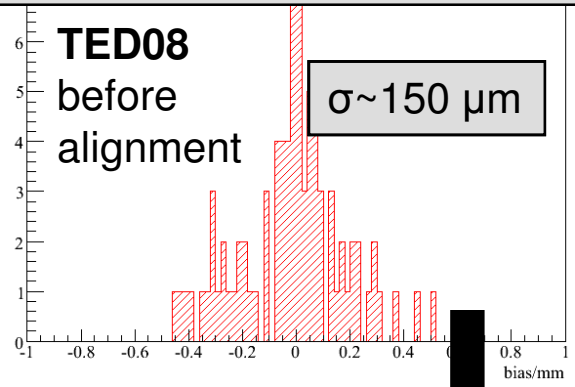
- Use run with lowest occupancy (~3% occupancy).
- Start from initial pre-aligned detector.
- Iterate track finding and alignment with evolving χ^2 cuts.
- Require tracks to point back to TED.

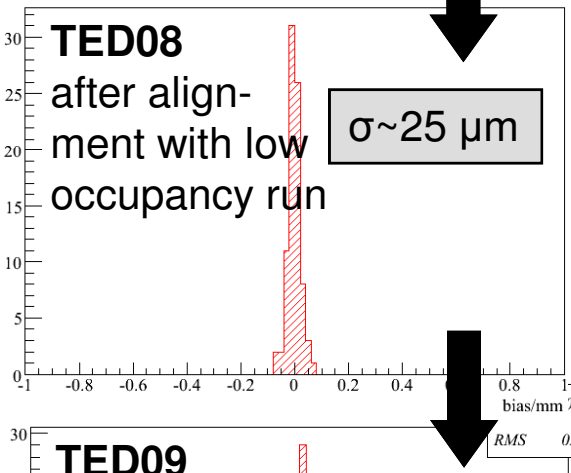


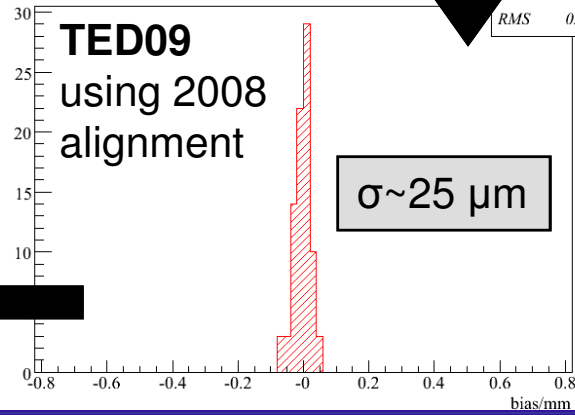


IT TED results

Mean track residual for each ladder







TED08:
- IT in closed position.
- Lowest occupancy runs: 5k tracks.
- Alignment of boxes (3 dof), layers (2 dof) and ladders (1 dof).
- Layer alignment precision ~10 μm.
- Ladder alignment precision ~25 μm.

TED09:
- IT in open position (±60 cm).
- Runs with lowest occupancy: 12k tracks (total: 50k)
- Alignment of boxes (3 dof), layers (2 dof) and ladders (1 dof).
- Estimated ladder alignment precision ~10 μm.
- Data currently under study.

Confirms 2008 ladder alignment precision

Physics analysis

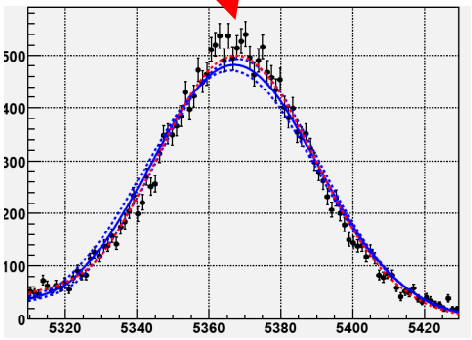
Many Swiss physics activities

- Charmonium production (X,Y,Z states)
- Λ (and K_s) production
- Forward electroweak physics
- Higgs and exotic SUSY
- LFV in $\tau \to 3\mu$
- β_s mixing phase from $B_s \to J/\psi\, \varphi$
- $B \to l^+l^-\, K^{(*)}$ decay
- Rare decay $B_s \to \mu^+\mu^-$

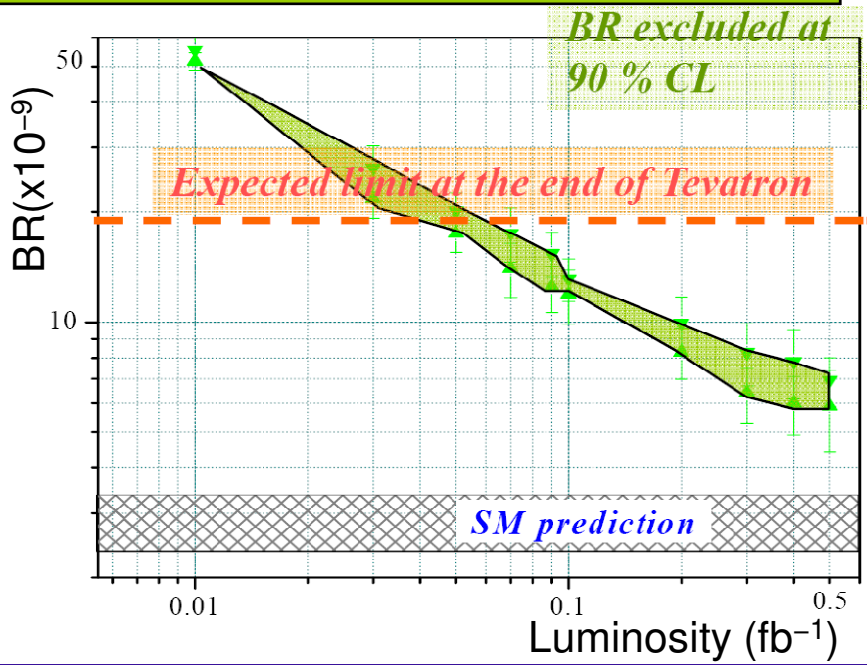
Example: $B_s \to \mu^+\mu^-$

Key features:

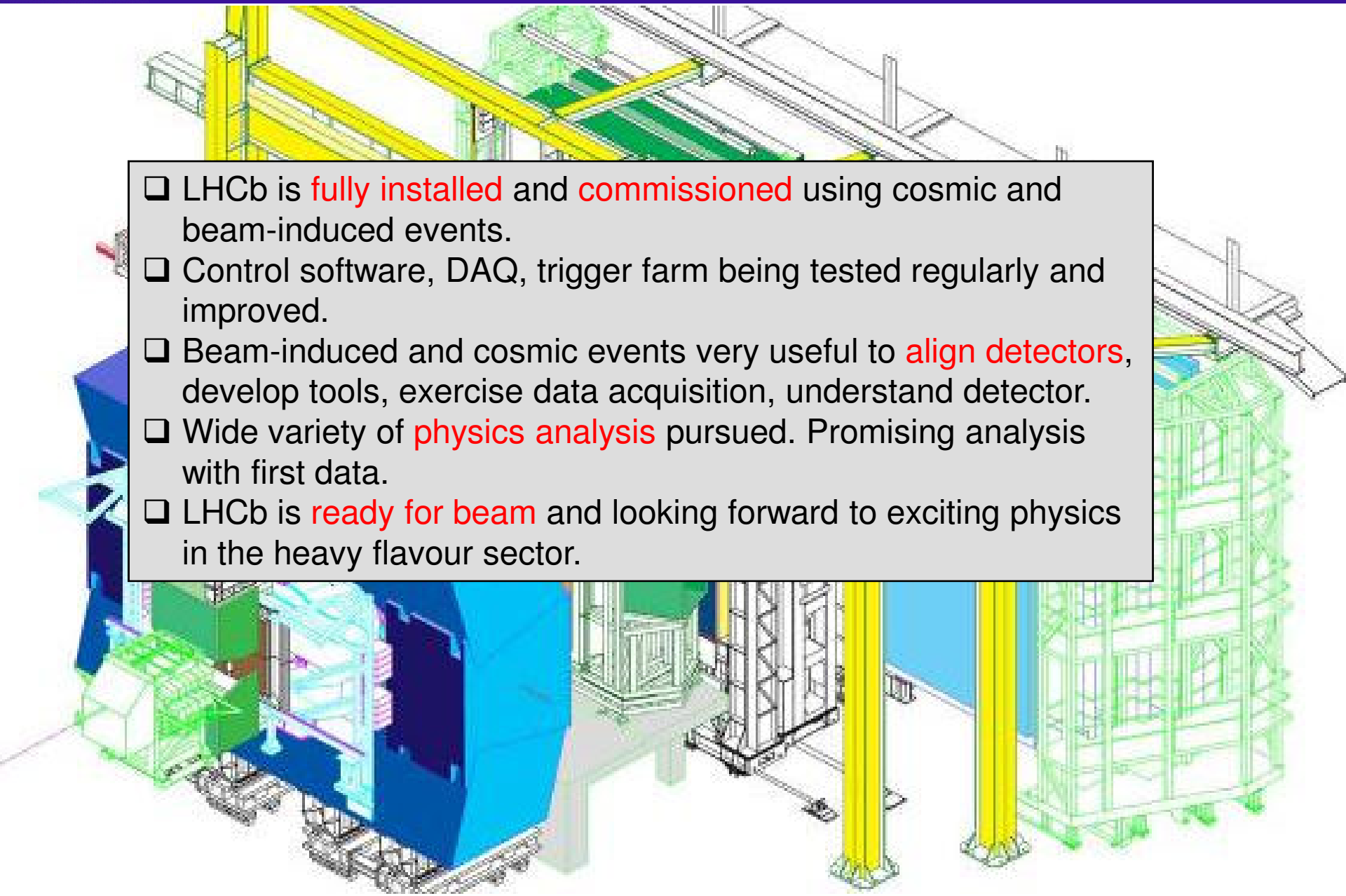
- High trigger efficiency.
- Use control channels to normalize BR.
- Good mass resolution of 20 MeV (requires well-aligned detector).



Improve upper limit with 2009/2010 data.



Summary



- LHCb is fully installed and commissioned using cosmic and beam-induced events.
- Control software, DAQ, trigger farm being tested regularly and improved.
- Beam-induced and cosmic events very useful to align detectors, develop tools, exercise data acquisition, understand detector.
- Wide variety of physics analysis pursued. Promising analysis with first data.
- LHCb is ready for beam and looking forward to exciting physics in the heavy flavour sector.