The LHCb detector

Eddy Jans
(Nikhef)
on behalf of the LHCb collaboration

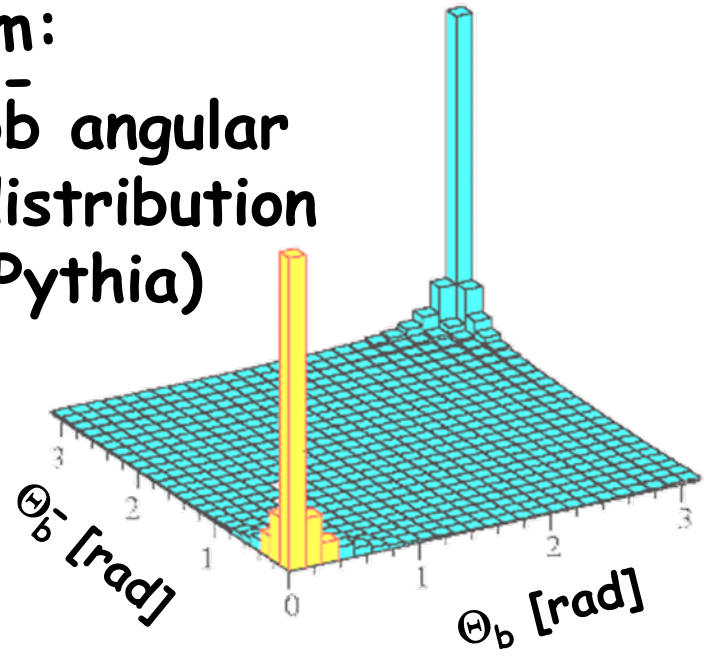
- **design of sub-detectors, trigger and DAQ**
- **performance: resolutions and PID-properties**
- **commissioning with cosmics and beam induced events**
- **outlook for physics in 2010**

Design specifications

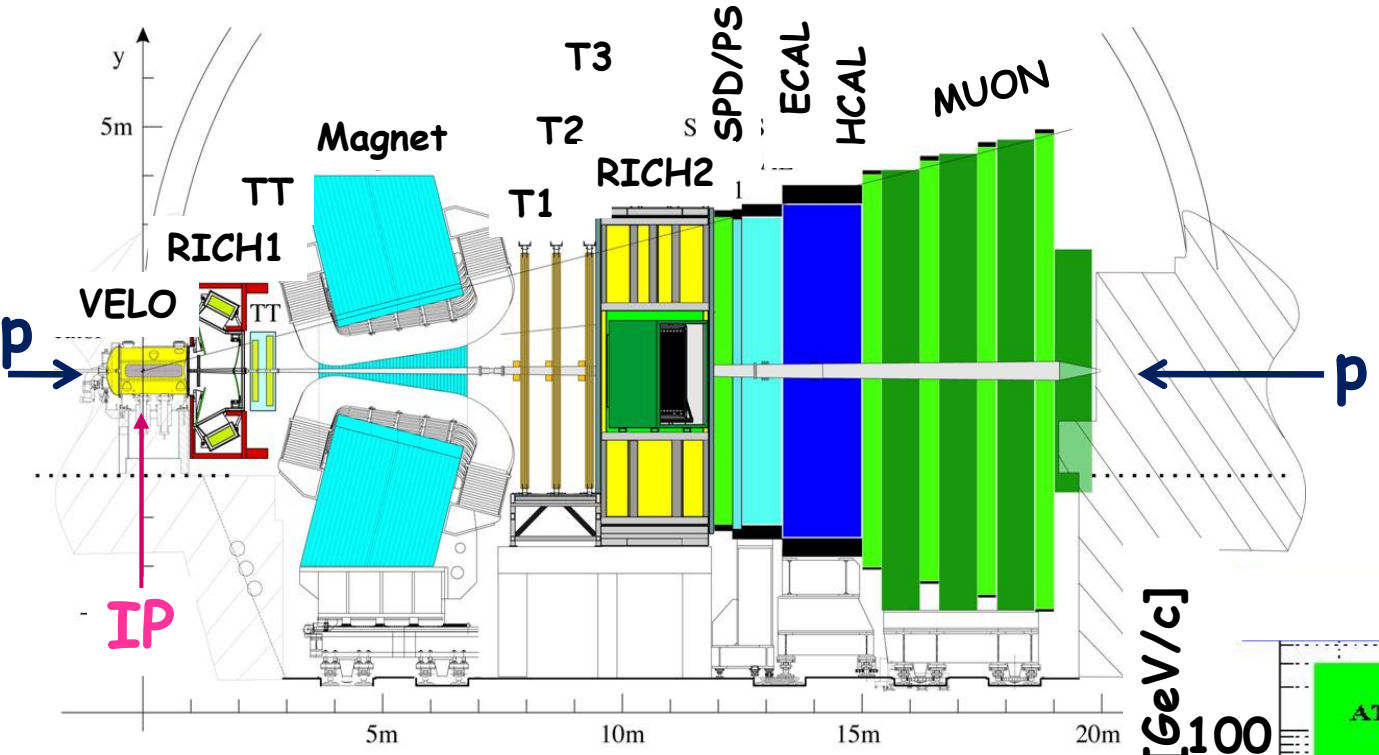
LHCb is a dedicated setup for B-physics studies at LHC

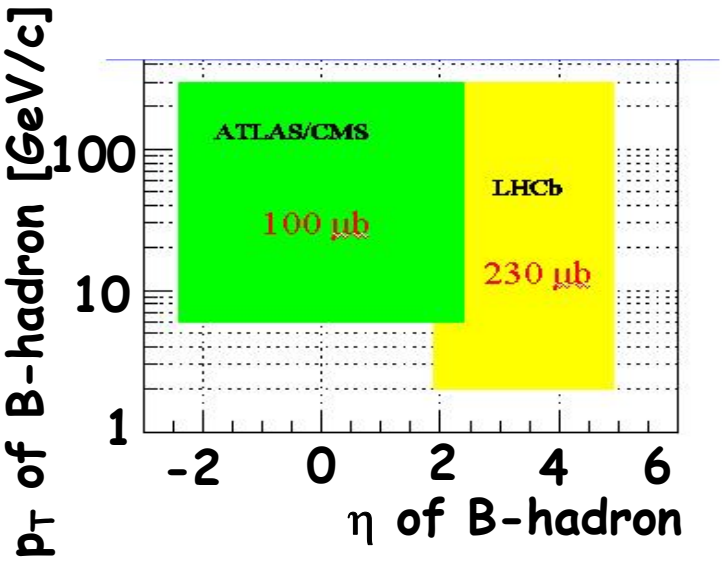
- pp-collisions at E_{cm}=14 TeV. $\sigma_{inel.}$~ 80 mb, $\sigma_{b\bar{b}}$~ 0.5 mb
- will produce full B-hadron spectrum:
  $B^0, B^{\pm}, B_s^0, B_c^{\pm}, \Lambda_b^0$

$b\bar{b}$ angular distribution (Pythia)



- angular acc. 15-300 (250) mrad
- $\mathcal{L}_{LHCb}$ ~ 2×10^{32} cm^{-2}s^{-1} $\rightarrow$
  maximal probability for a single pp-interaction/BX
- 15 kHz of B-decays in the acceptance
- search for New Physics in CP-violation and rare decays of beauty and charm flavoured hadrons

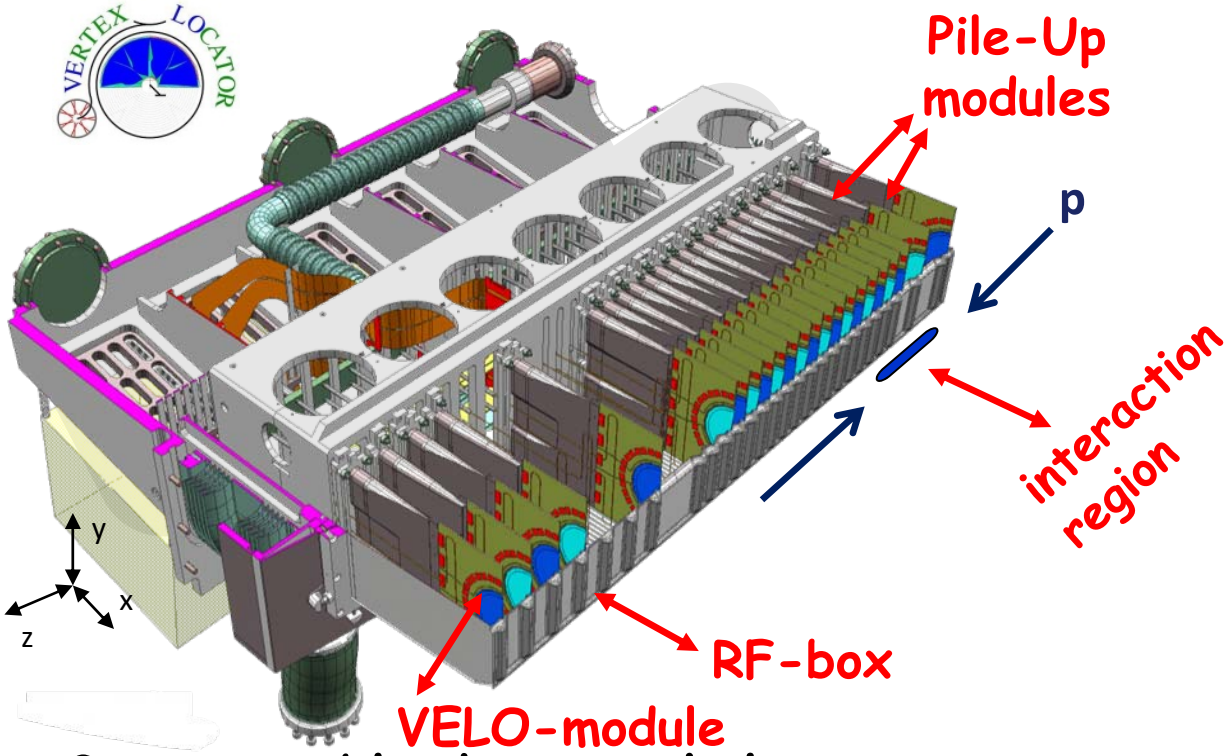




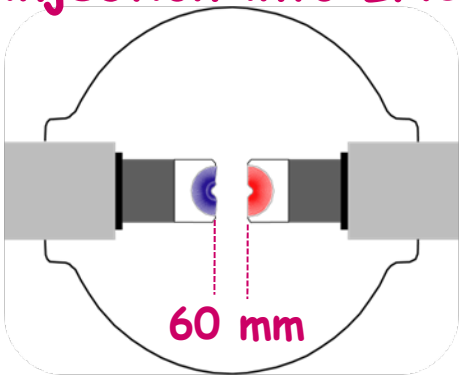
Design optimized for B-physics:

- vertex resolution
- momentum resolution
- P.I.D. properties
- flexible and efficient trigger

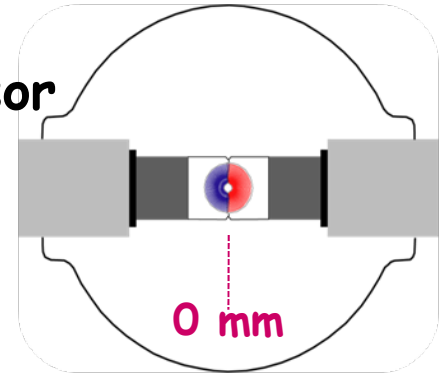
VErtex LOcator



injection into LHC



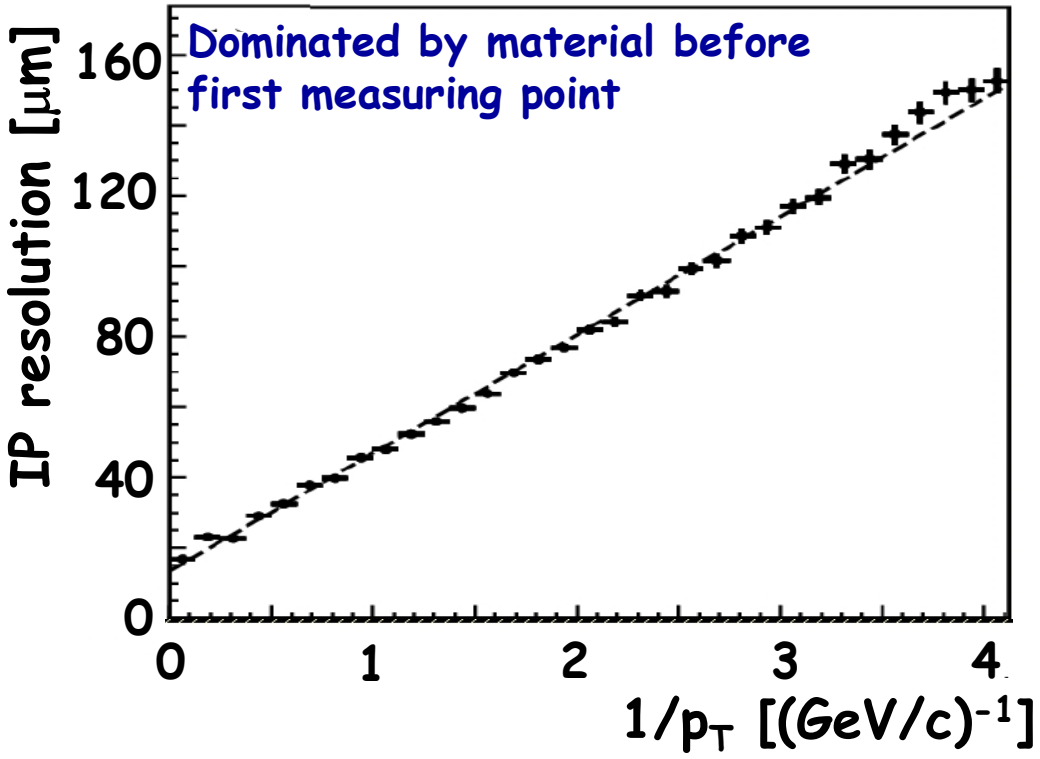
stable beams



- 2 retractable detector halves
- 21 VELO-modules/half, each with an R- and ϕ-sensor
- 2 Pile-Up modules per half ($\rightarrow$ L0-trigger)
- operates in secondary vacuum
- bi-phase CO_2 cooling system
- very non-homogeneous radiation profile
- 300 μm thick Si at 7 (37) mm from beam when closed (open)
- 300 μm corrugated foil separates detector from beam vacuum

Vertex reconstruction by VELO

- Resolution in determination of Primary Vertex
  - * x,y: ~ 9 μm
  - * z: ~ 44 μm

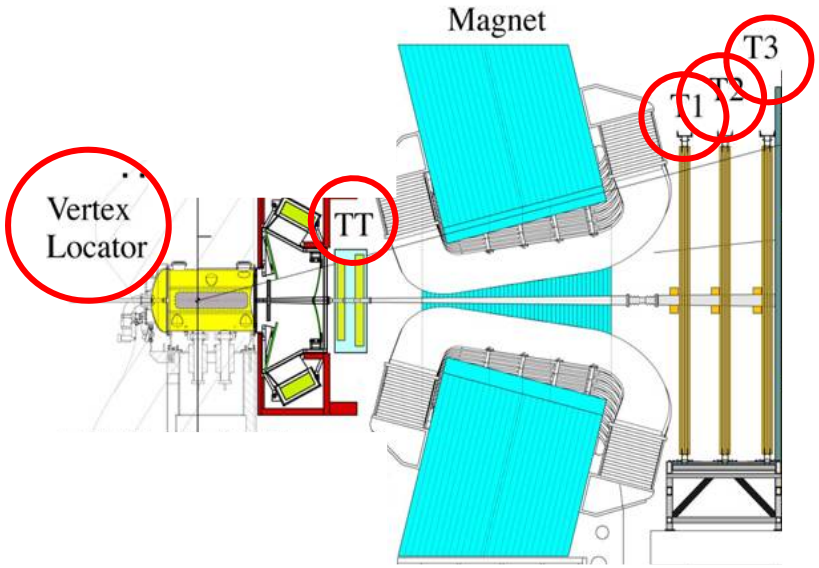


$\sigma_{IP} \sim 14 + 35/p_T$ [μm]

Important quantity for being able to measure the high B_s oscillation frequency

Tracks

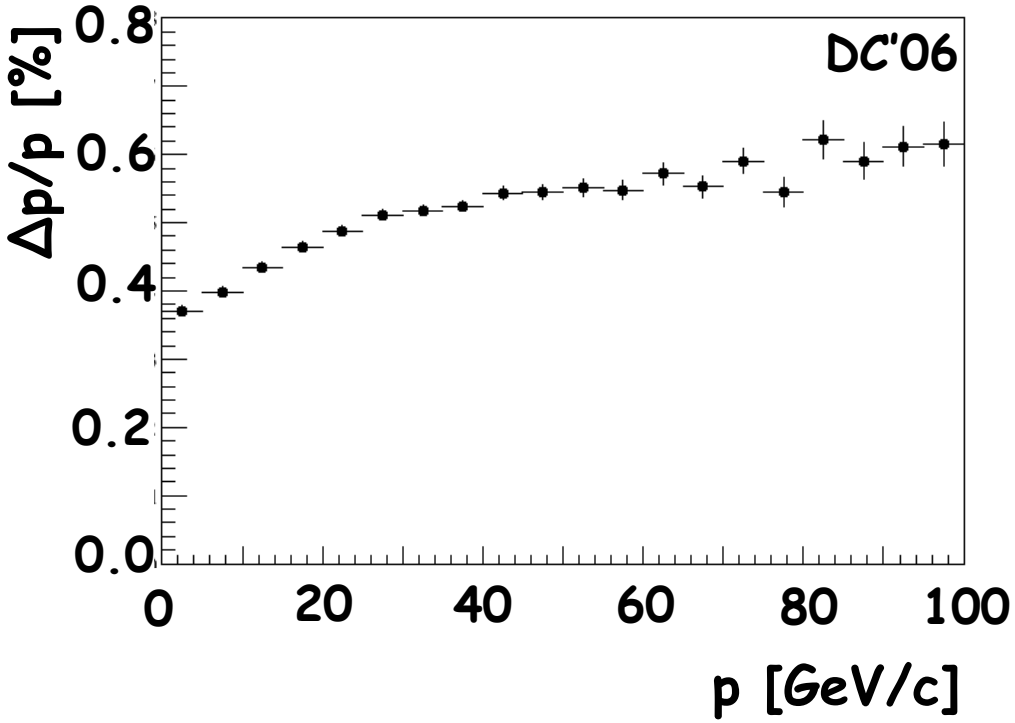
Si: VErtex LOcator, TT and IT; straw tubes: OT



$\int B.dL = 4$ Tm

TT: 4 layers, full acc.:1.5x1.3 m^2

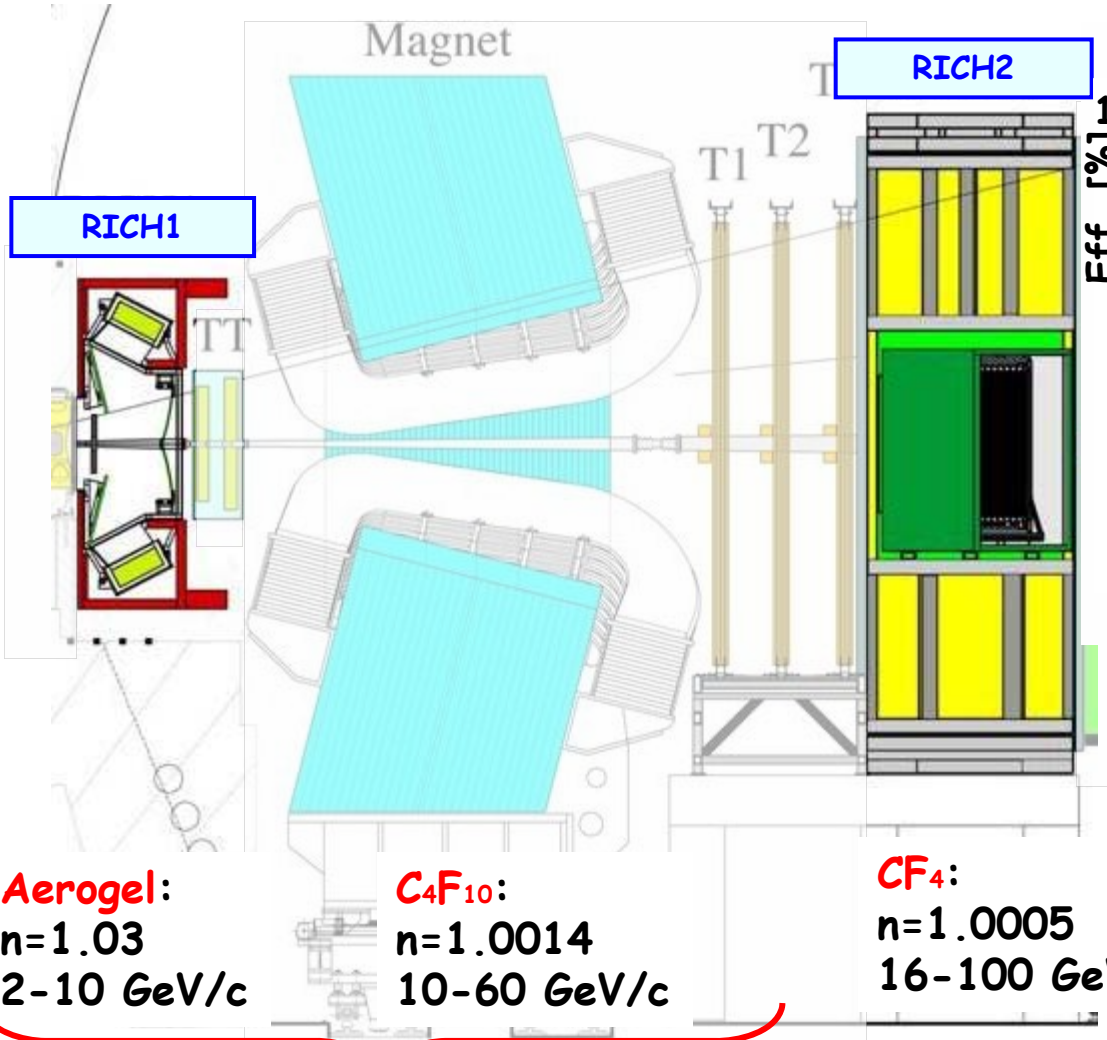
3 T-stations: each 4 layers of 1.2x0.4 m^2 (IT)+ 6x5 m^2 (OT)

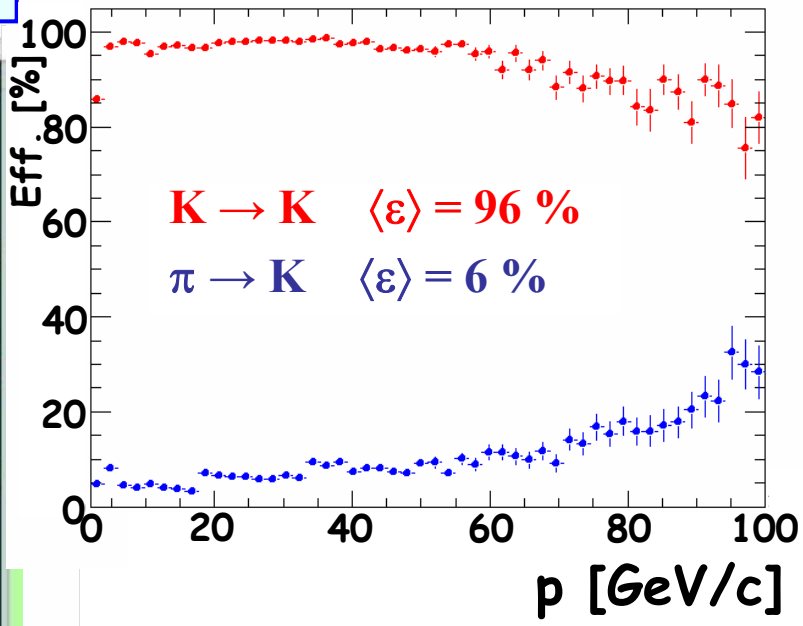


Momentum resolution:

$\Delta p/p \sim 0.4\text{-}0.6$ %

πK-separation: RICH system





Excellent K/π separation for 2 GeV/c < p < 100 GeV/c

Aerogel: n=1.03 2-10 GeV/c

C_4F_{10}: n=1.0014 10-60 GeV/c

CF_4: n=1.0005 16-100 GeV/c

RICH1: 25-250 mrad vertical, 300 mrad horizontal

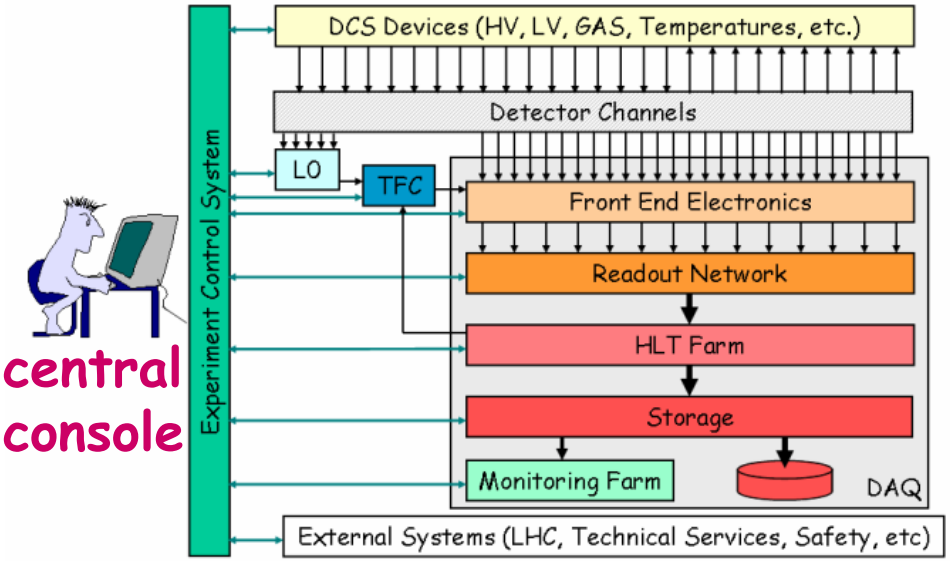
RICH2: 15-100 mrad vertical, 120 mrad horizontal

Calorimeters + Muon systems

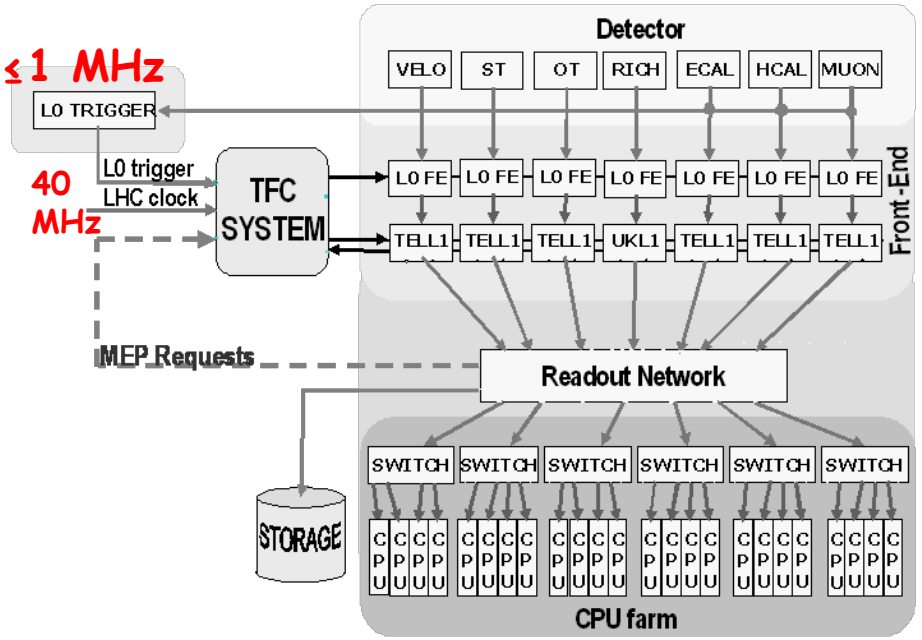
- **Preshower**, 12 mm Lead wall, **S**(cintillator)**P**(ad)**D**(etector)
  15 mm thick scintillator pads
- **ECAL**
  Shaslick design: 66 layers of 2 mm lead and 4 mm scintillator material.
  Energy resolution: $(9.4\pm0.2)\%/\sqrt{E} \oplus (0.83\pm0.02)\%$
- **HCAL**
  iron (16 mm) x scintillator (4 mm) tile design
  Energy resolution: $(69\pm5)\%/\sqrt{E} \oplus (9\pm2)\%$
- **Muon**
  Five stations equipped with MWPCs interleaved with 80 cm thick steel walls. Inner part of M1 (before ECAL) are triple-GEMs. p_T resolution of ~20%.

Each: - projective geometry towards vertex and a varying granularity to obtain "equal" occupancy/cell
- part of L0-decision of the Trigger

Detector control system



Detector readout

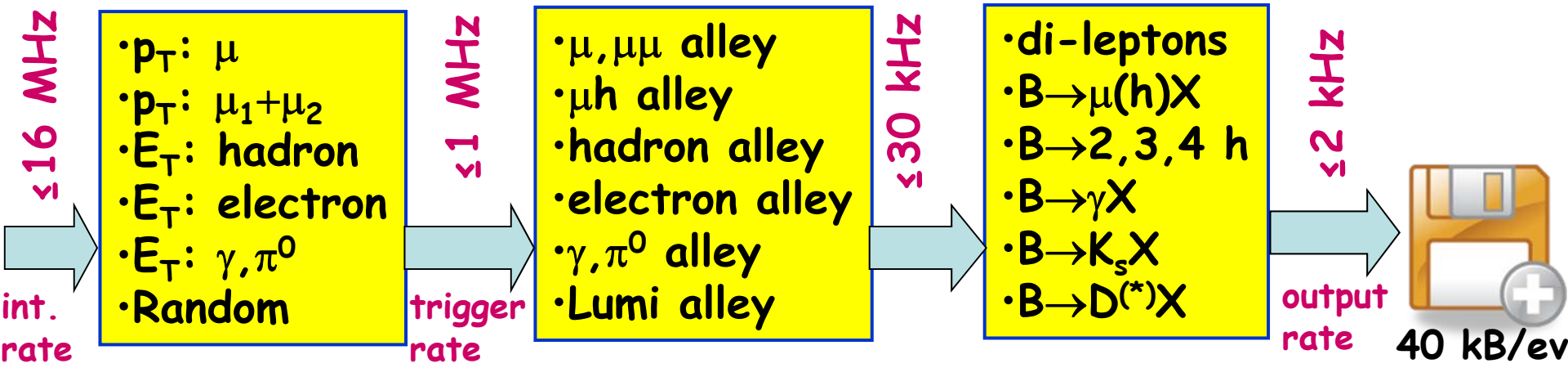


Commissioning

- first each sub-detector, later all together
- hardware initialization and control
- warm startup O(1 min)

Full detector readout achieved, while triggering at 1 MHz.

Trigger



L0-decision unit (<4 μs):

- PU: rejection of pile-up events
- CALO: selection of e,γ,π^0,hadron
- Muon: selection of μ and μμ

Trigger	had	μ	μμ	$e^{\pm}$	γ	π^0
p_T> [GeV]	3.5	1.3	Σ>1.5	2.6	2.3	4.5

High-Level Trigger code runs in farm (4400 Cores) with full detector info.

HLT1:

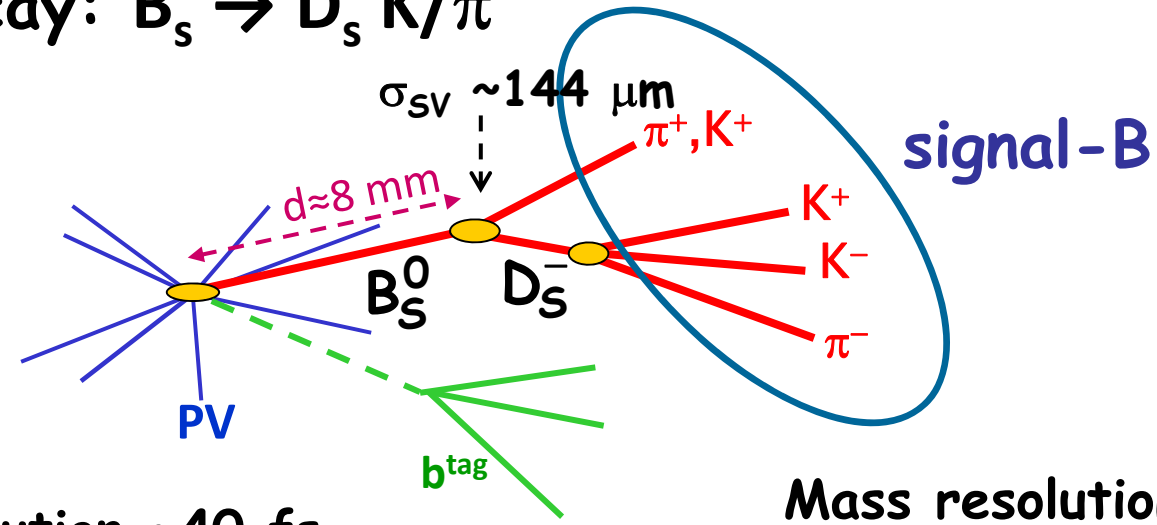
- verification of L0-objects
- add info of VELO and T-stations
- impact parameter and invariant mass

HLT2:

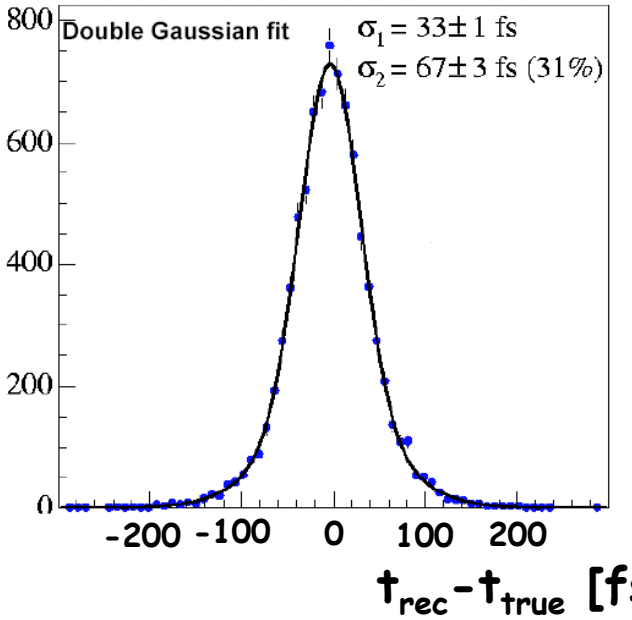
- + inclusive and exclusive selections using full event reconstruction

LHCb Expected Performance

Typical B-decay: $B_s \rightarrow D_s$ K/π

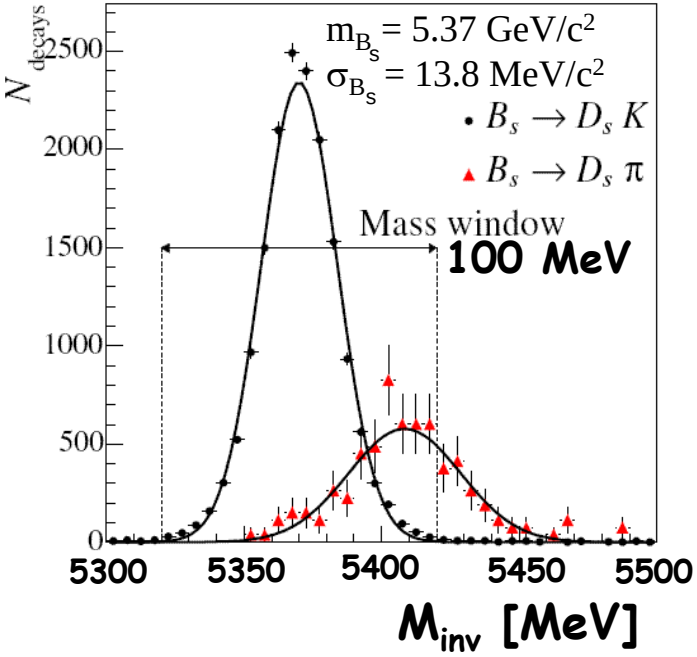


Decay time resolution ~40 fs



Crucial for time-dependent B-measurements

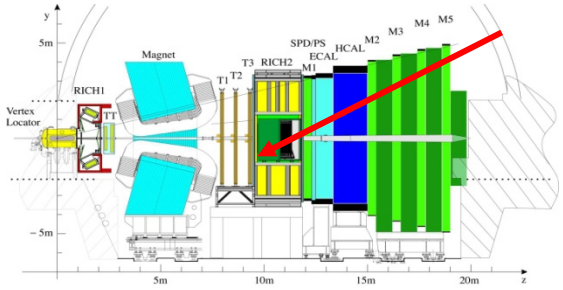
Mass resolution 14 MeV

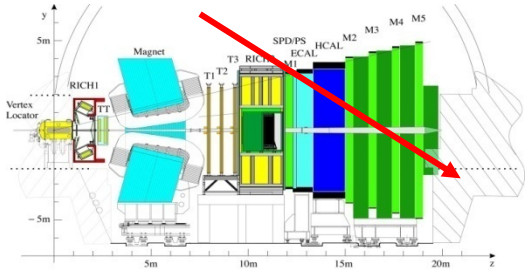


Commissioning with cosmics

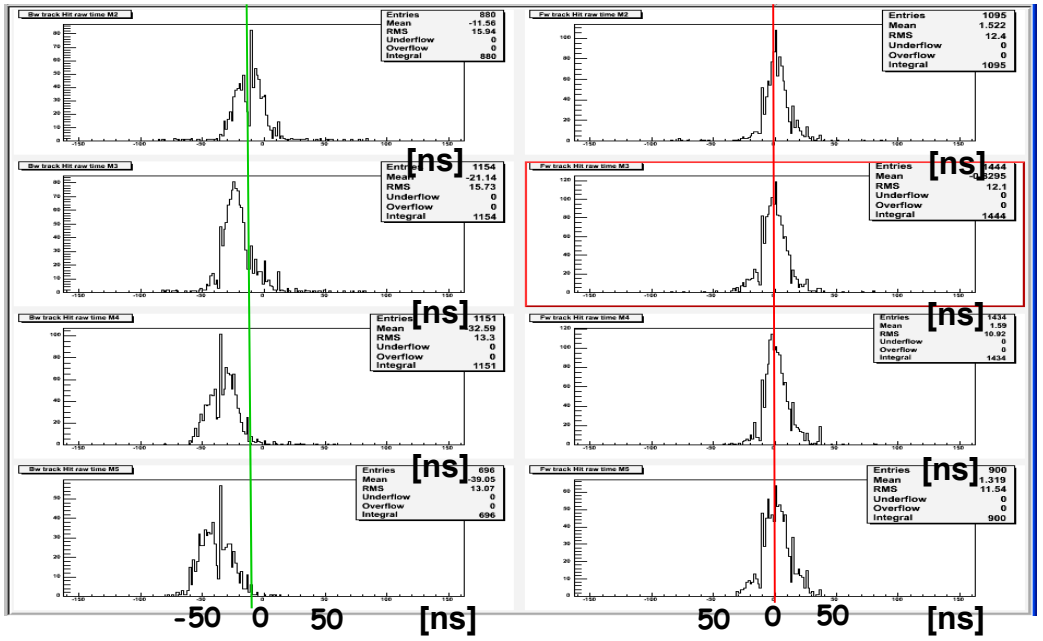
First-order time and space alignment of some sub-detectors

Time alignment of muon chambers



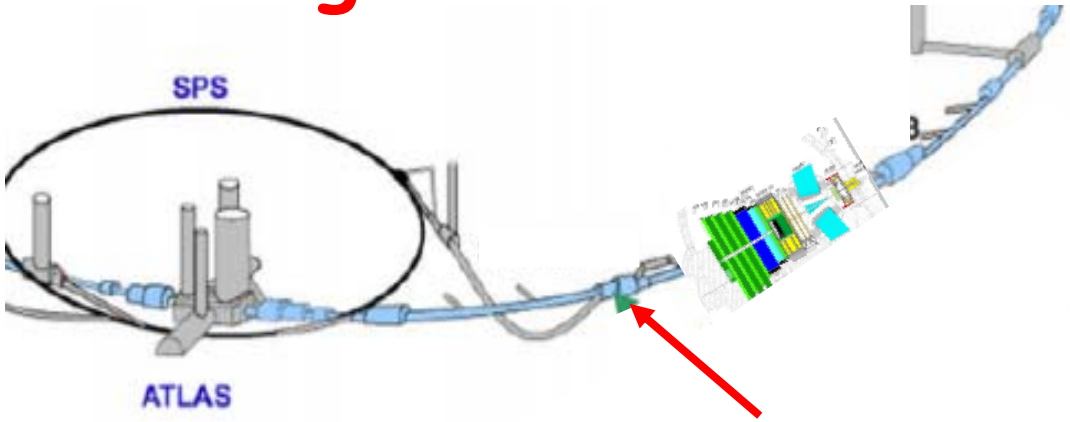


Backward tracks are skewed

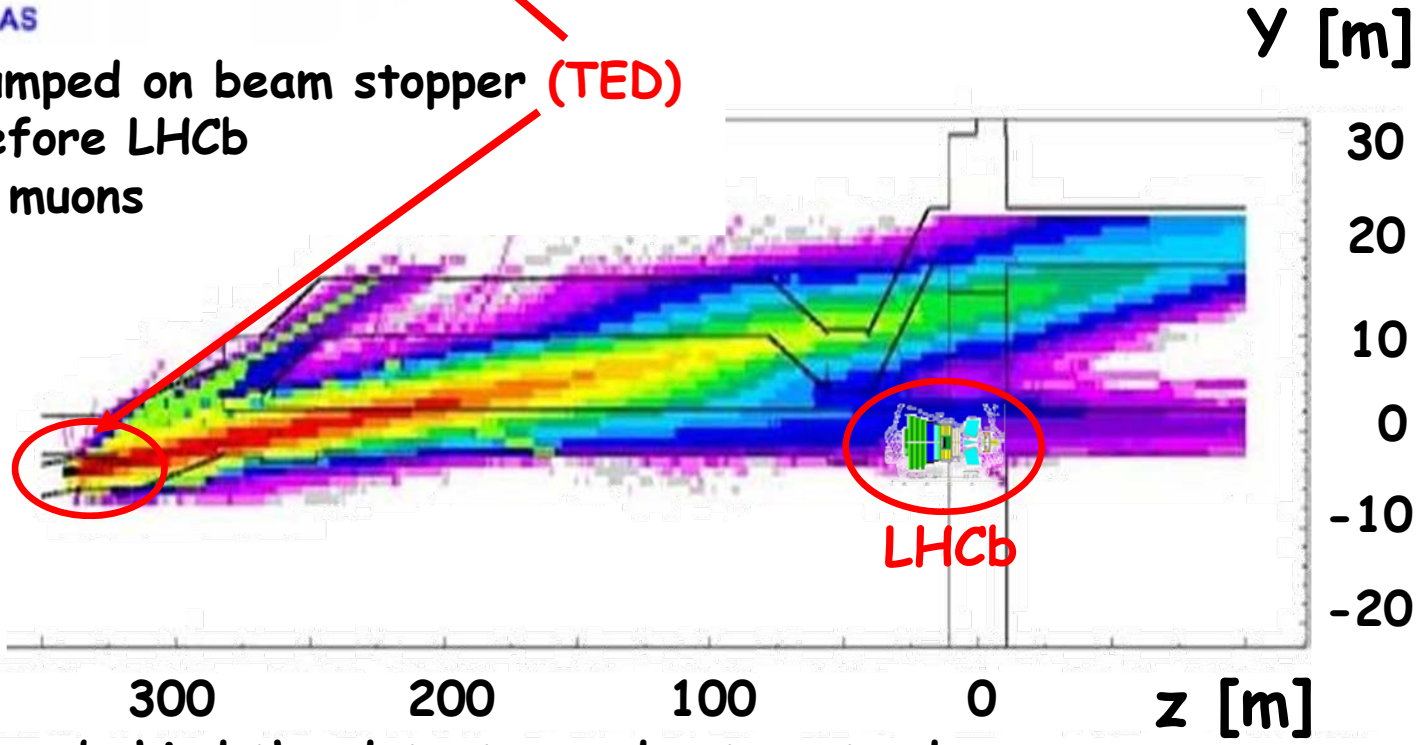


Forward tracks are aligned to about 3 ns precision

Commissioning with beam-induced events



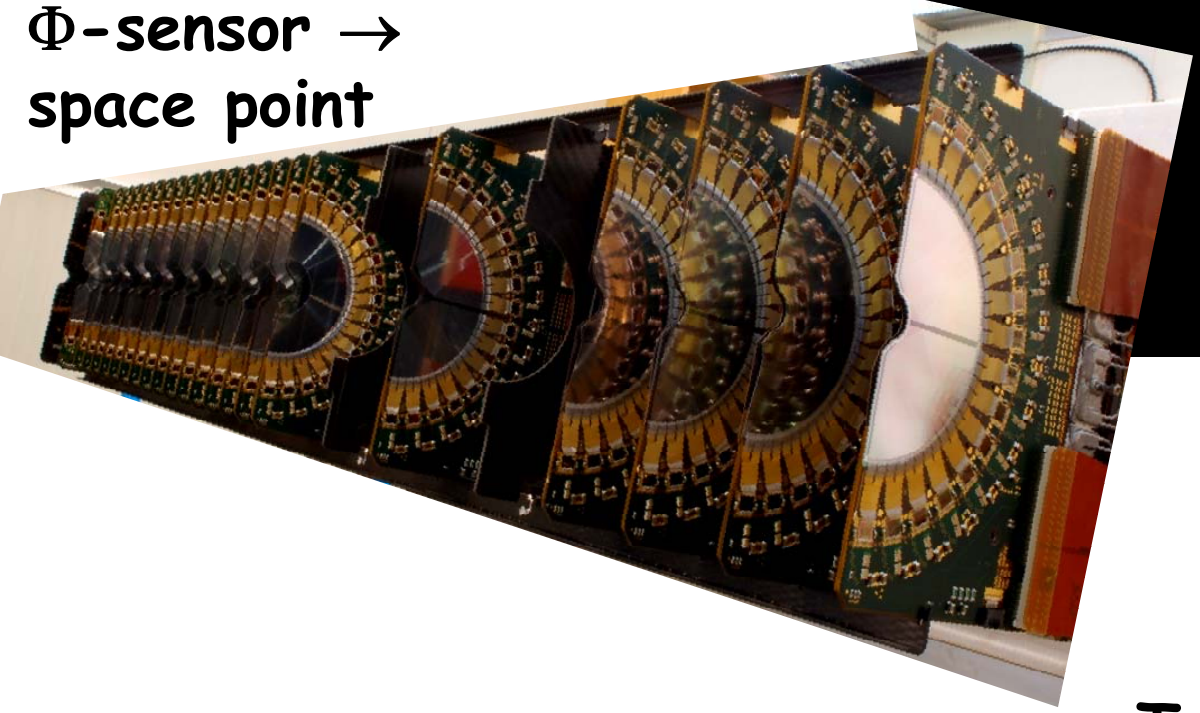
CW beam of SPS dumped on beam stopper (TED)
located at 340 m before LHCb
→ shower of mainly muons

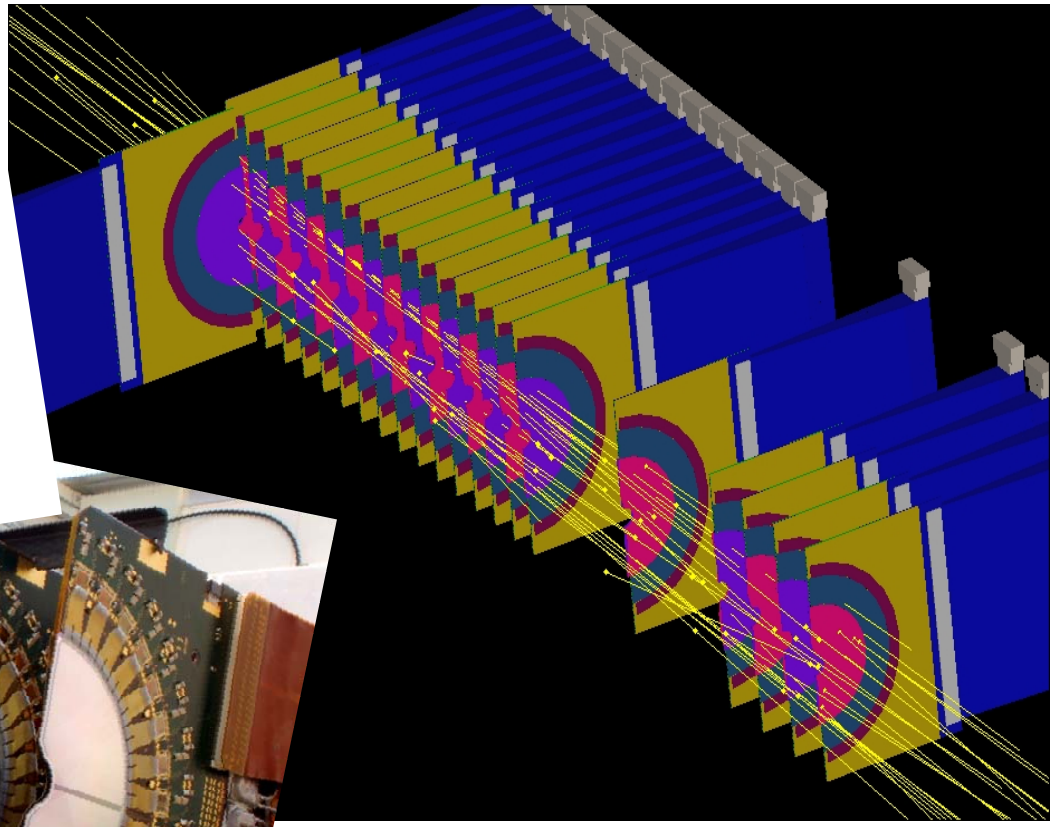


Particles coming from behind the detector and not centred.
Flux/shot in VELO: ~0.5 particles/cm^2

VELO-event displays

VELO-half with 21 double-sided modules, each with an R and Φ-sensor → space point





~10 tracks / event

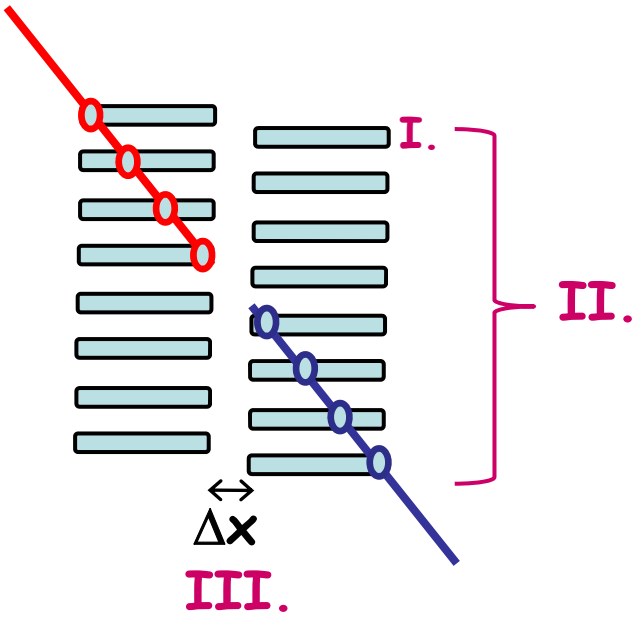
Trigger provided by SPD

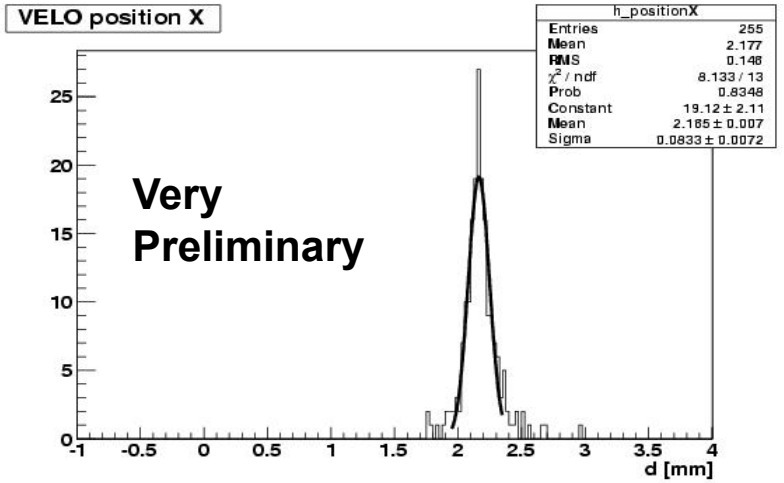
Highlights from space domain
Preliminary VELO alignment from "TED-events"

I. R to Φ-sensor alignment/module w.r.t. metrology: Δ≤6.6 μm

II. Module displacements/half w.r.t. metrology via track fitting: Δ≤7.5 μm

III. VELO-half distance from crossing tracks





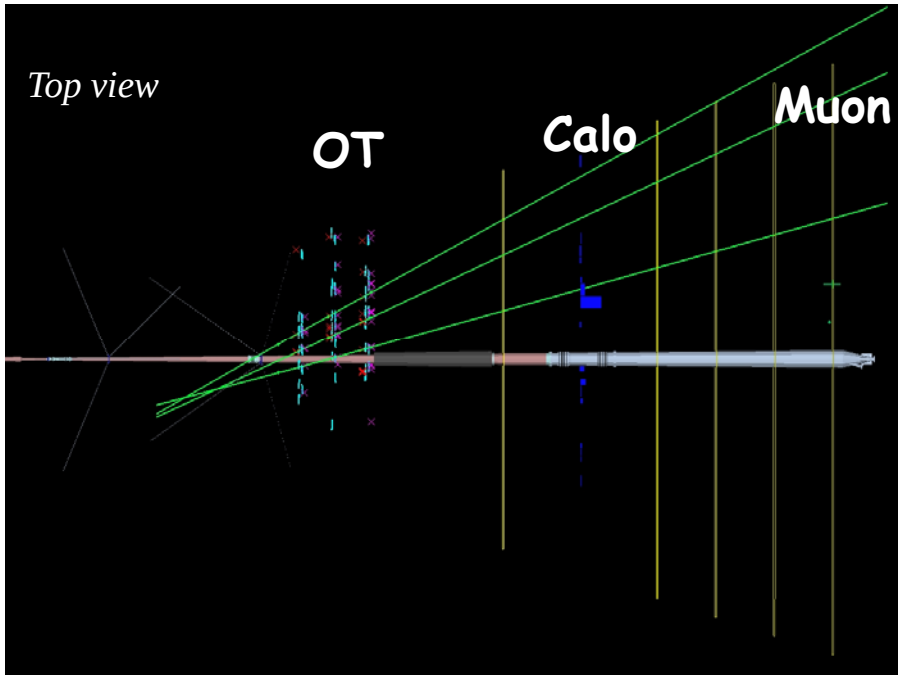
data taken in 2 positions:

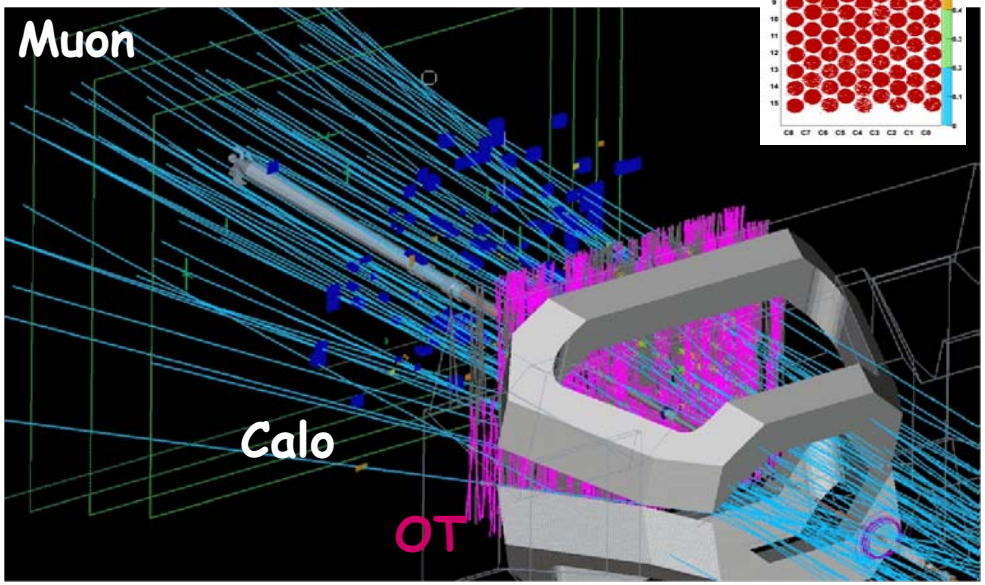
Δ selected: 445 μm

Δ analysed: 448 ± 10 μm

Events from circulating beams in Sep. '08

Events taken during circulating Beam1 look either like low multiplicity events or splashes





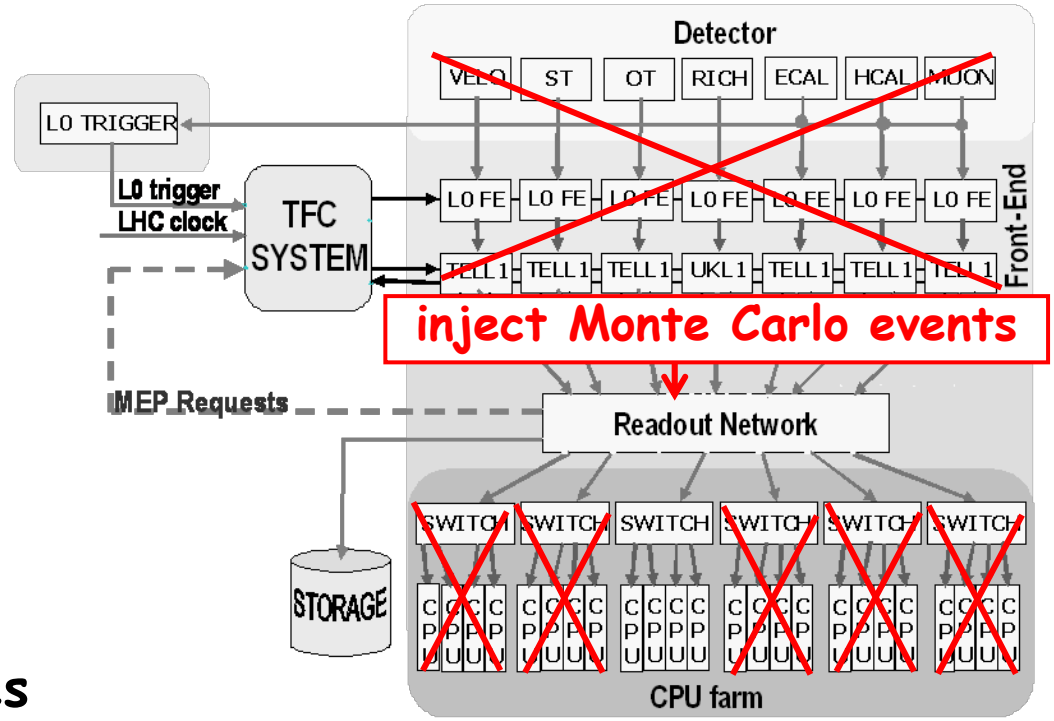
~80 tracks/event

Full Experiment System Test

- everything except the "real detector"

Exercise:

- run control
- data stream
- dynamic farm node balancing
- HLT1 and HLT2 code
- data monitoring
- data quality tools
- store crucial info in databases
- data storage (to tape and to the GRID)



Performs according to specs.

Expected operations 2009

- **TED-run** in September:
  Improve space and time alignment of the silicon detectors VELO+TT+IT in closed (= physics) position

- **collisions at 450 GeV**
  - VELO open, no LHCb B-field
  - Few shifts for final time and space alignment

- As soon as possible move to highest possible safe and stable energy ≥ 2 TeV. Then VELO can be closed, LHCb magnet switched on and commissioning continue.

Selected physics topics in 2010 (#1)

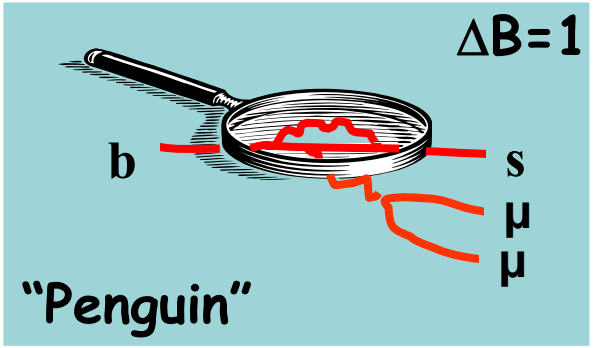
Function of time, E_{beam} and integrated luminosity

- collect ~100 M minimum-bias and ~1 M μ(μ)-events
  - * Track efficiencies, reconstruction performance, particle ID,….
  - * Checking and tuning MC parameters,
  - * Exercise fit machinery for analysis
  - Calibration signals: $K^0_S \to \pi\pi$, $\Lambda \to p\pi$
  - $J/\Psi \to \mu\mu$ separate prompt and $b \to J/\Psi$ production cross section as a function of p_T and η
  - strangeness production and hadronization: $\frac{\overline{\Lambda}}{\Lambda}(p_T, \eta)$

See talk #328 on "Inclusive production at LHCb" by F. Dettori at 14h48 on Monday in session Heavy Flavor Physics I

Selected physics topics in 2010 (#2)

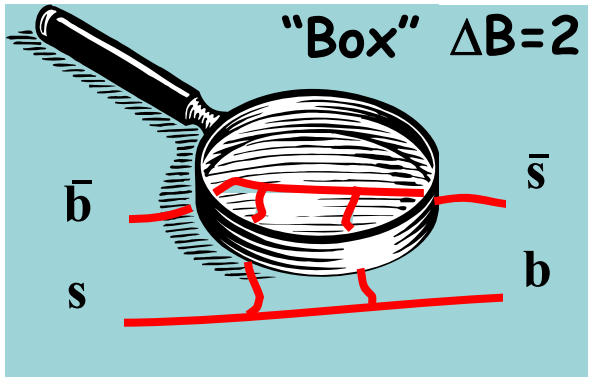
- Rare decays sensitive to NP
  BR of $B_s^0 \rightarrow \mu^+\mu^-$
  Requires excellent vertexing properties and mass resolution



See talk #270 on "NP and Rare decays at LHCb" by M-O. Bettler at 17h10 on Thursday in session Beyond Standard Model III

- Determination of B_s-mixing phase ϕ_s from the flavour-tagged angular analysis of $B_s^0 \rightarrow J/\Psi\ \phi$

See talk #271 on "NP and CP-violation at LHCb" by S. Blusk at 14h30 on Thursday in session CP-violation III



Summary

- LHCb-detector is fully installed, tuned and commissioned as far as possible with cosmics and beam-induced events
- Control software, DAQ, HLTs are being tested regularly and improved where necessary
- LHCb is ready for beam and looking forward to exciting physics in the heavy-flavor sector