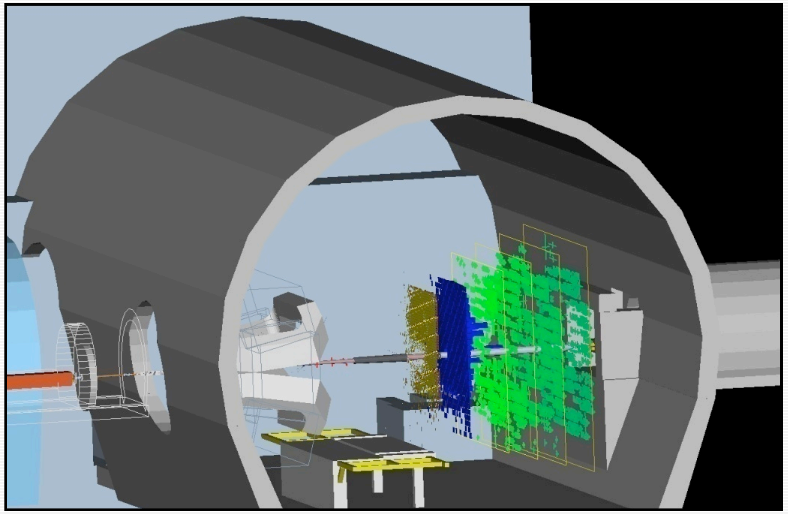
Commissioning and Early Physics at LHCb

DISCRETE '08
Symposium on Prospects in the Physics of Discrete Symmetries

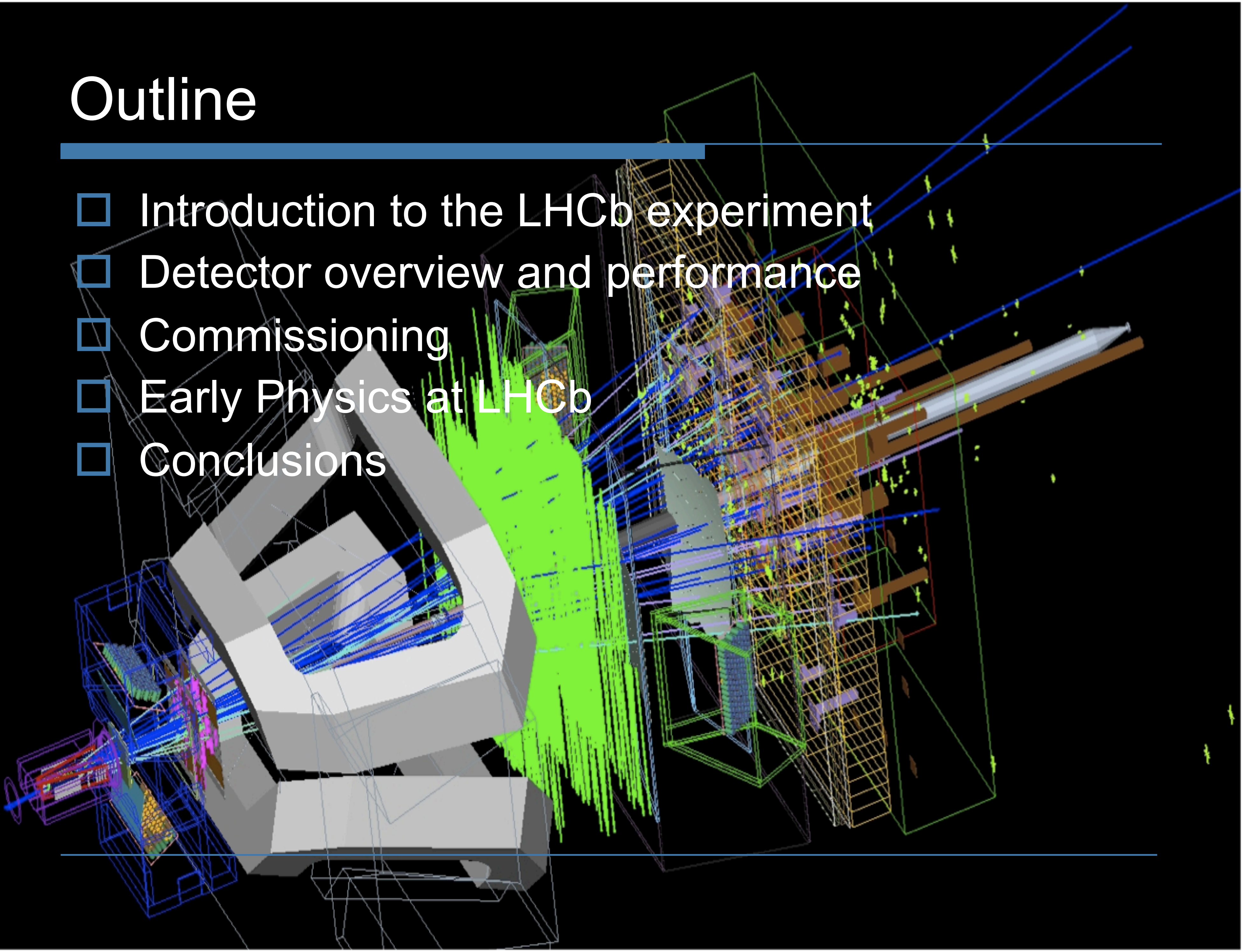
December 11-16 2008



Abraham Gallas (USC) for the LHCb collaboration

Outline

- Introduction to the LHCb experiment
- Detector overview and performance
- Commissioning
- Early Physics at LHCb
- Conclusions

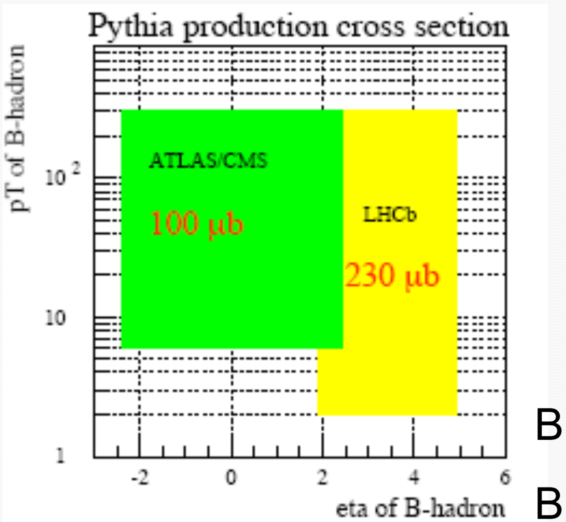


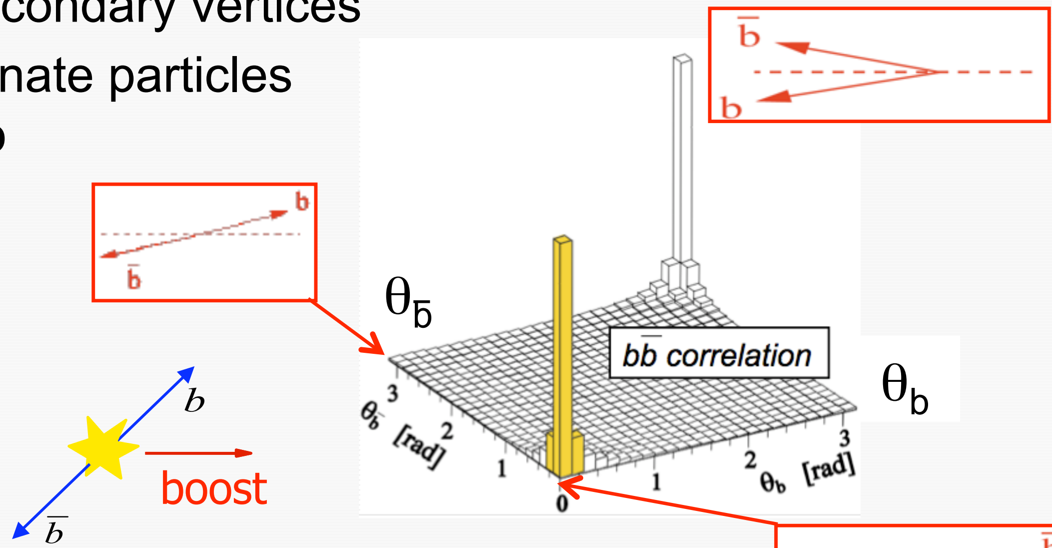
The LHCb experiment

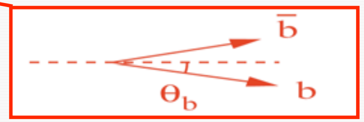
- Dedicated B physics experiment at the LHC
- Advantages of beauty physics at hadron colliders:
  - High value of the beauty cross section expected at 14 TeV: $\sigma_{bb} \sim 500\ \mu b$ (the e+e- cross section at $\Upsilon(4s)$ is 1 nb)
  - Access to all b-hadrons: B_d, B_u, B_s, b-baryons and B_c
- The Challenge:
  - Multiplicity of tracks (~30 tracks per rapidity unit)
  - Rate of background events: $\sigma_{inel} \sim 80$ mb
- Running conditions:
  - Reduced luminosity by locally defocusing the beams: $\mathcal{L} = 2\times10^{32}\ cm^{-2}s^{-1}$
  - $\mathcal{L}$ set to maximize the probability of single interaction per bunch crossing
  - @ nominal $\mathcal{L}$, 10^{12} $b\bar{b}$ pairs produced per year of data taking (2 fb^{-1})

The LHCb detector

- Forward geometry: $b\bar{b}$ pair production peaks at small θ angles, with small relative opening angles
- Selective and efficient trigger system, also on fully hadronic B decay modes
- Tracking and vertex reconstruction for good mass resolution and proper time measurements of secondary vertices
- PID capability to discriminate particles in the final states: **μ,π,K,p**



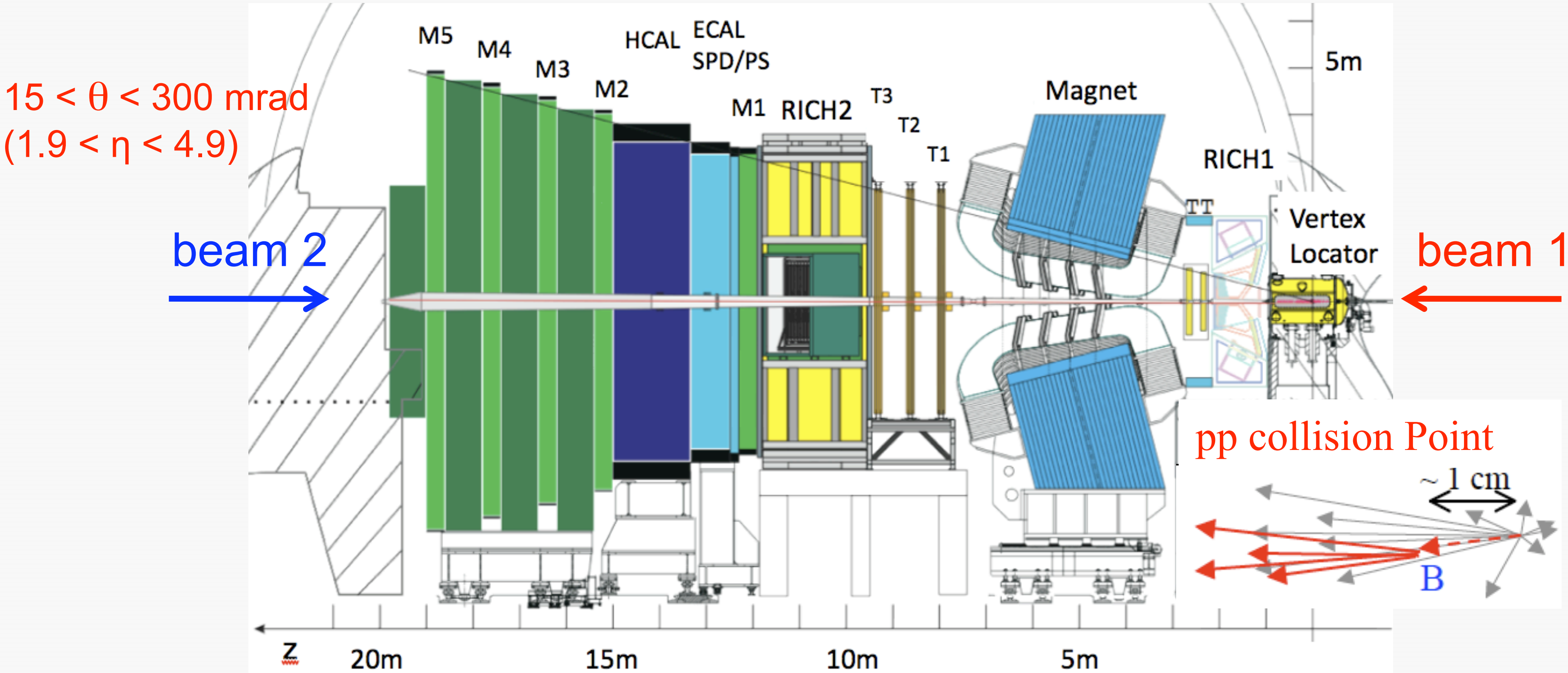




B meson average momentum p ~ 80 GeV/c

B meson average transverse momentum $p_{\perp}$ ~ 5 GeV/c

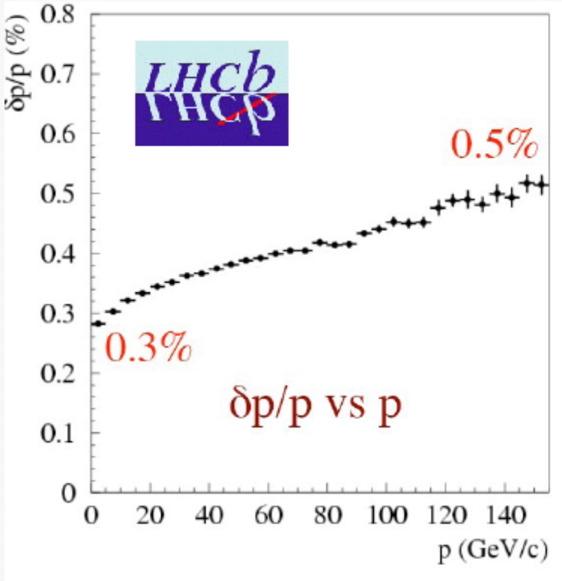
The LHCb detector (II)

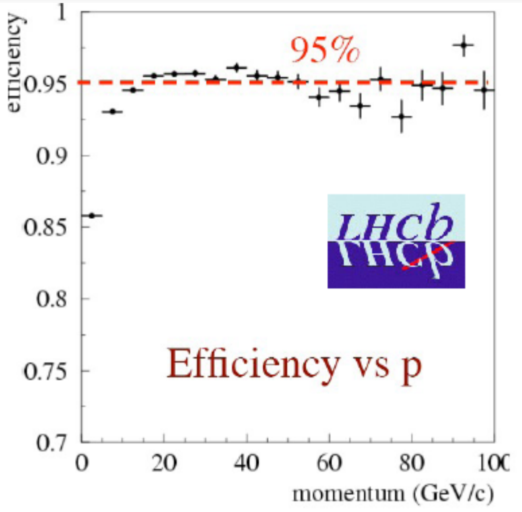


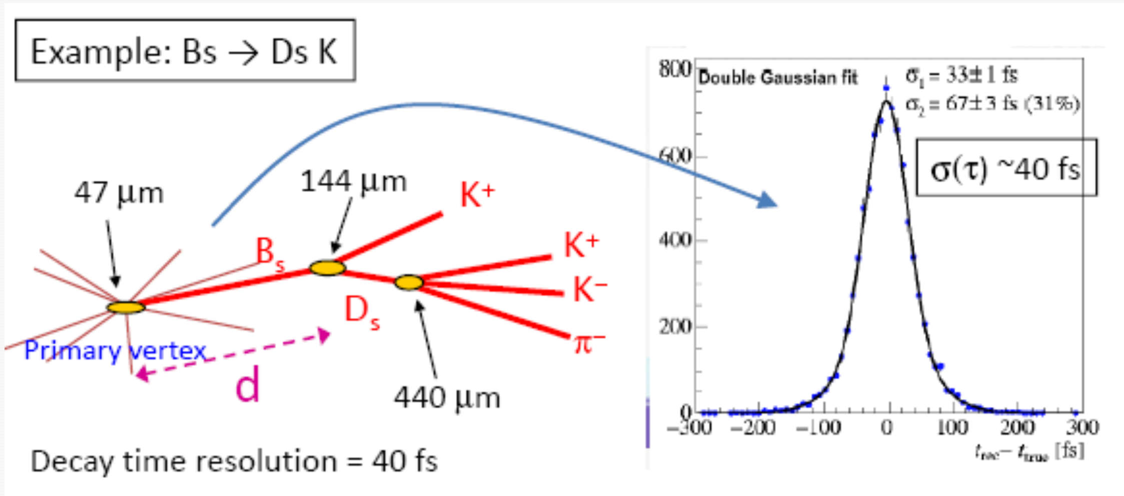
VELO: Silicon Strip detector for precise primary and secondary vertex reconstruction
TT. T1,T2,T3 (IT+OT) : tracking stations, Silicon Strip and Straws to detect charged particles
Magnet: Warm Al, 4Tm (10m), 4,2 MWs, dB/B = 10^{-4}
RICH1, RICH2: Ring Imaging Cherenkov detectors for π/K/p separation
ECAL, HCAL, SPD/PS: electromagnetic and hadronic calorimeters for trigger and energy flow
M1-M5: Muon stations for muon identication

Detector performances

- $\delta p/p$, depending on p: 0.3% ÷ 0.5%
- Mass resolution: 10÷20 MeV/c^2
- High efficiency on “long tracks” from B decays: 95%
  4% ghosts for tracks with p_T> 0.5 GeV/c.
- Impact parameter resolution : σ_{IP} ~ 30 μm
- Proper time resolution: 40 fs.

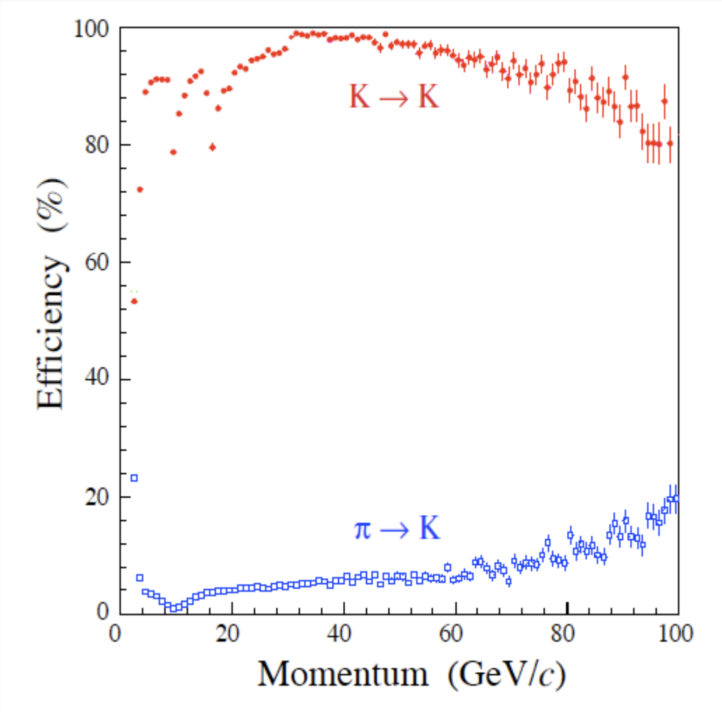




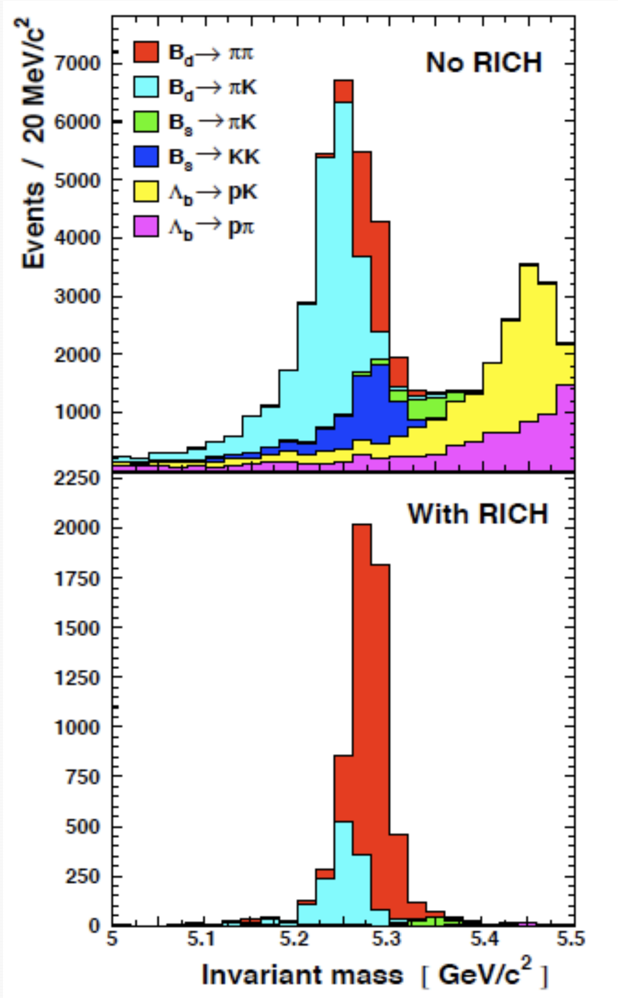


Detector performances: PID

π–K separation



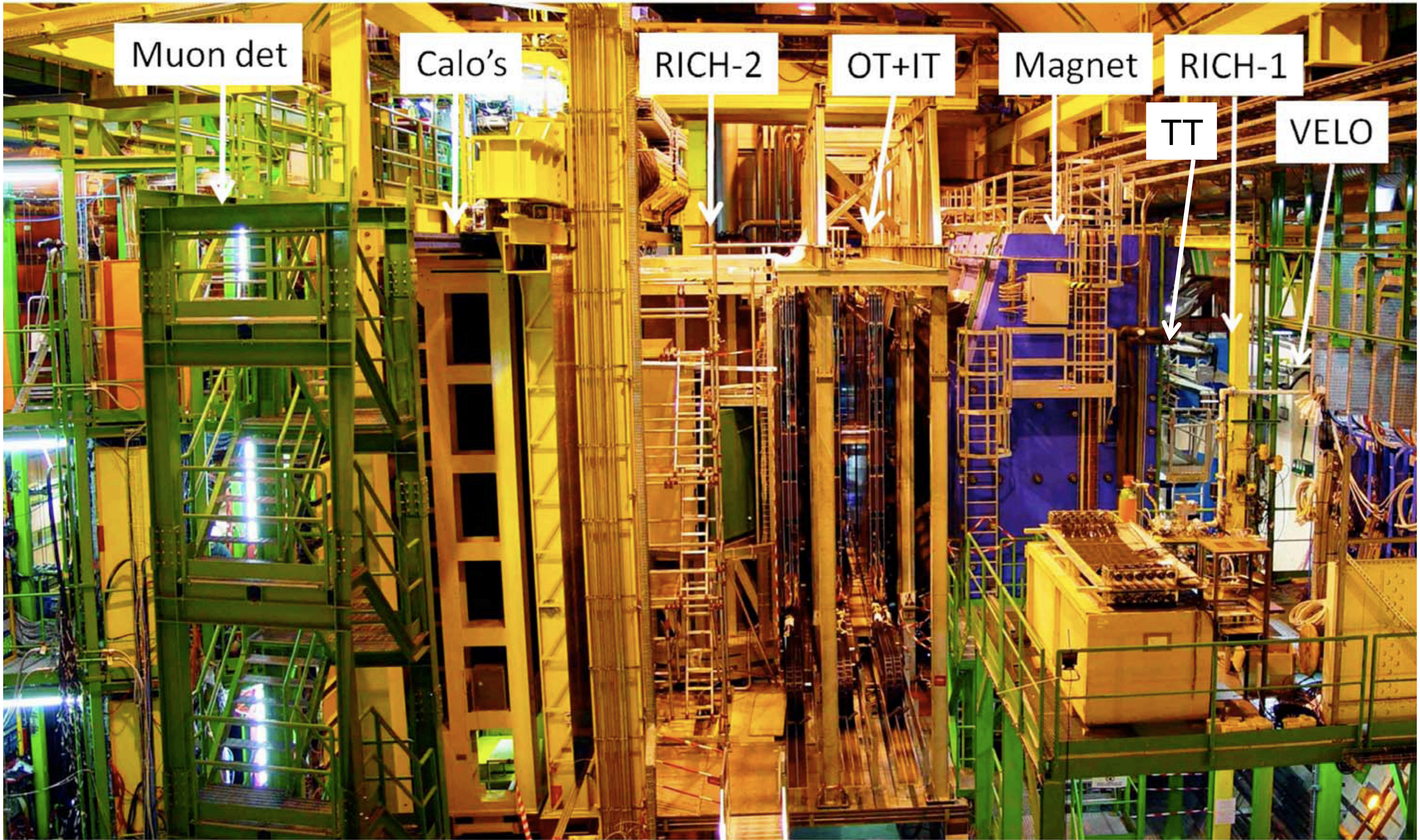
Kaon ID ~ 88%
Pion mis-ID ~ 3%



The LHCb trigger

- LHCb needs a trigger to effectively select B events
- The trigger is organized in two layers:
  - The Level 0 trigger selects events with high p_t particles in the final state, detected in the calorimeters and muon detectors, reducing the input rate from 40 MHz to 1MHz.
    - L0 is a hardware trigger implemented on custom electronics (4 μs latency)
  - The High Level Trigger selects exclusive B decay modes as well as auxiliary signals for systematic studies, like inclusive B decays.
    - HLT is a software trigger, implemented as selection algorithms running on a computing farm with ~O(K) CPUs.
    - The HLT starts with confirming the high pt L0-candidates, after which it selects events with fully or partially reconstructed B-decay modes.
- The DAQ rate after the HLT is 2kHz (event size ~35 Kb)
- Minimum Bias data can be recorded at a maximum rate of 2kHz
- MB physics can be performed on early data with large samples

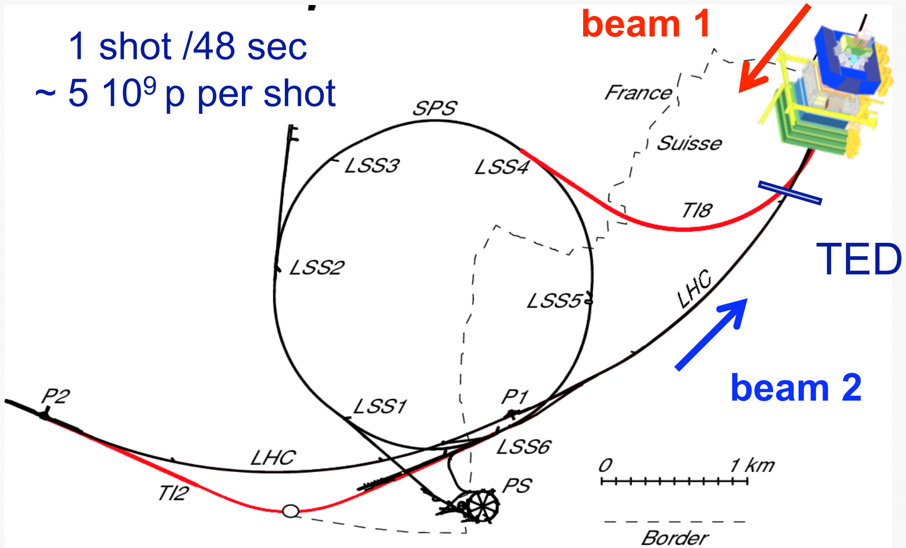
The Detector

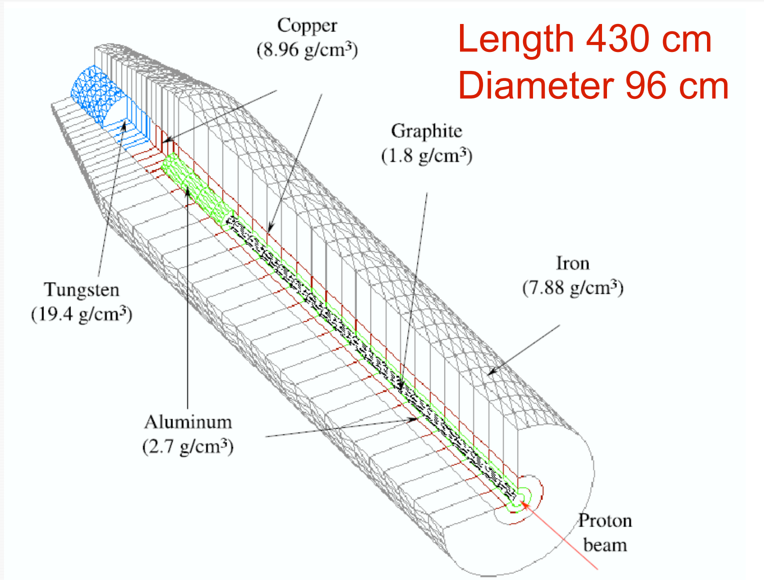


Ready for Physics

Commissioning

1. Commissioning of each subdetector individually:
   - Define first initial settings of time alignment, geometrical survey and working parameters
2. Commissioning of LHCb as a whole without particle beams:
   - Exercise with full load in the system
   - Global cosmic data taking (LHCb NOT well suited for cosmics, rate well below 1 Hz, still very useful)
3. Commissioning with particle beams to insure proper readout and trigger:
   - Start with single beams at injection energy:
     - TED beam stopper about 340 m behind LHCb (particles in the wrong direction 10 particles cm^{-2})
     - TDI is a beam absorber 50 m from LHCb after the kicker (100 times more particles)
   - Alignment of the detector in time and space.

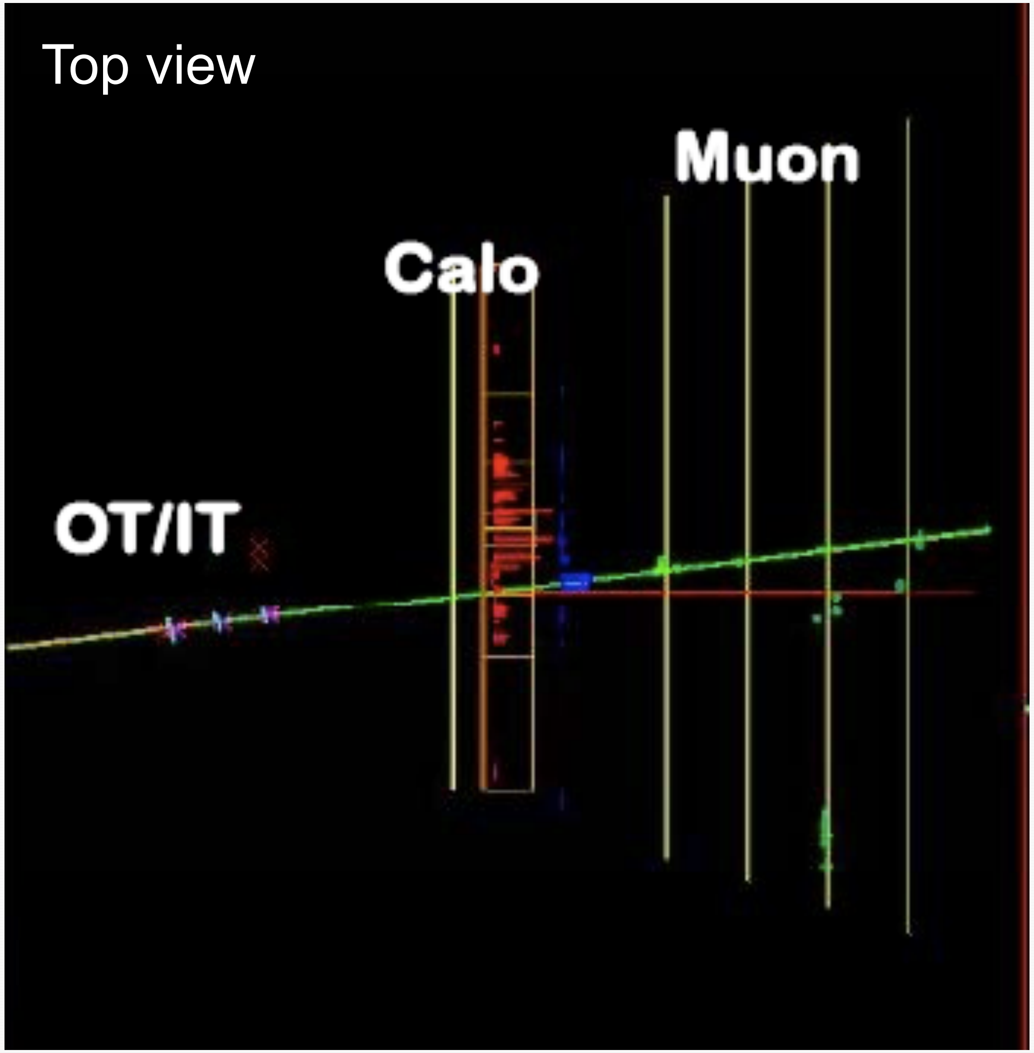




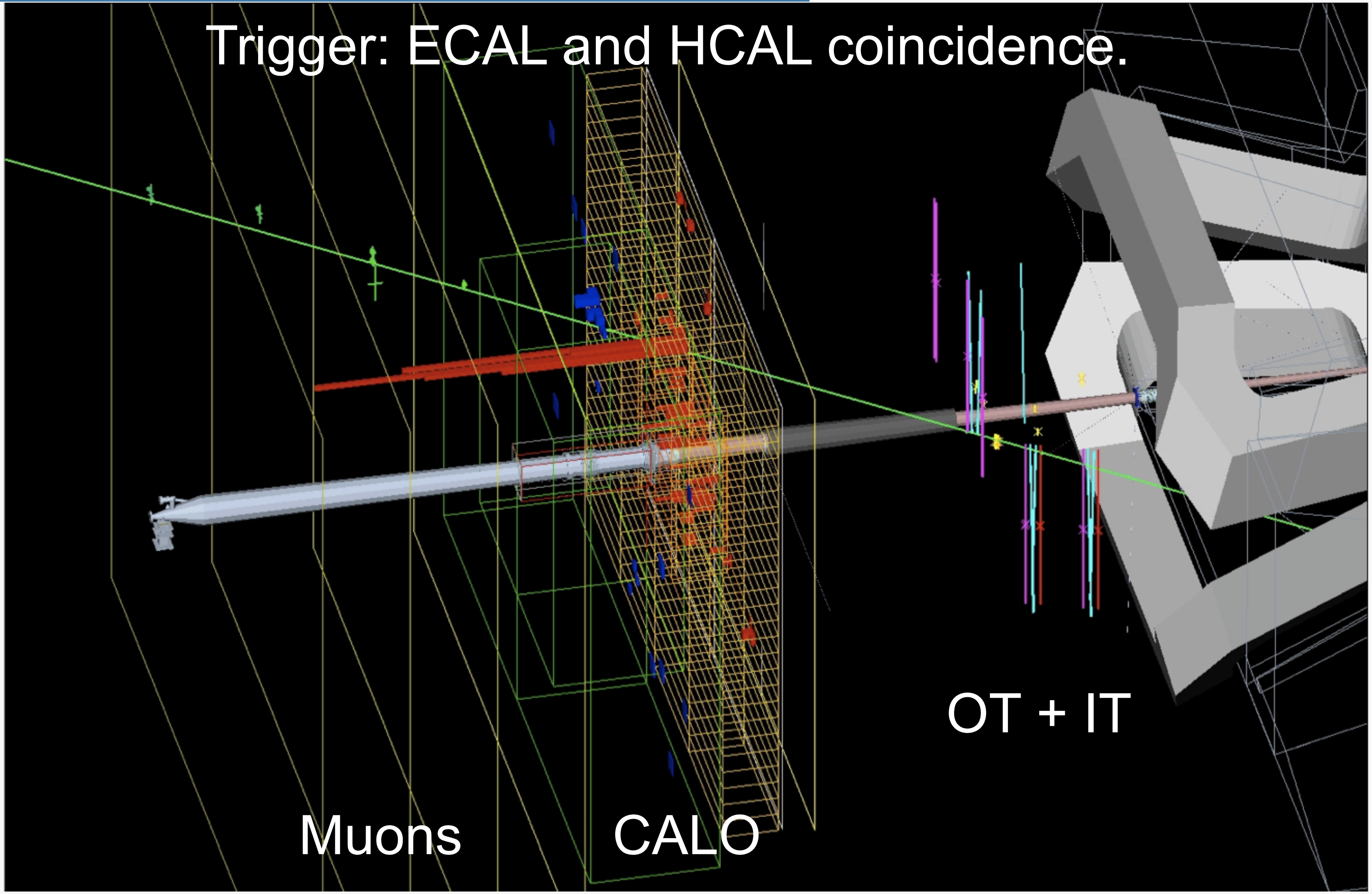
Commissioning: COSMICS

2nd July:
CALO+ Muons
+OT+IT+TT

Trigger: ECAL and
HCAL coincidence

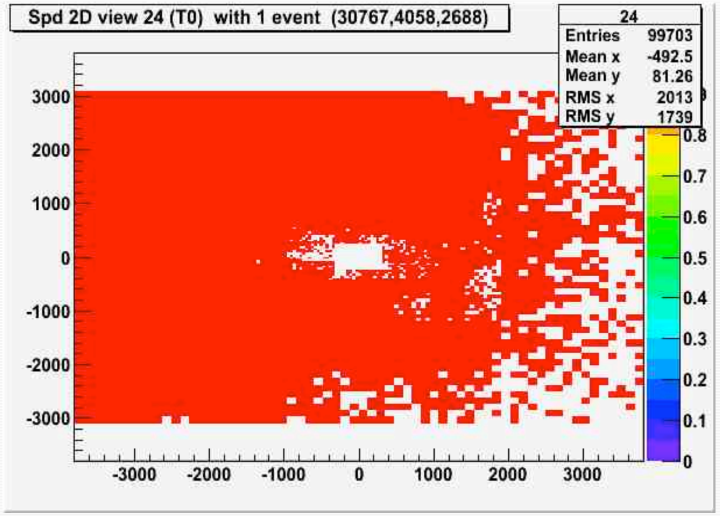


Commissioning: COSMICS



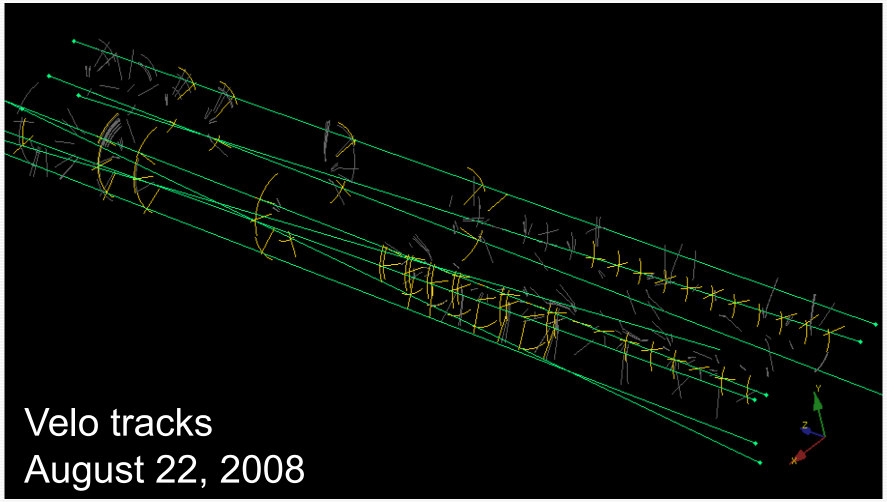
Commissioning: Time alignment

Muon	Cosmics & TED
Calorimeters	Cosmics
RICH	TED
OT	cosmics & particles from beam 1 splashes
IT&TT	cosmics & TED
VELO	TED

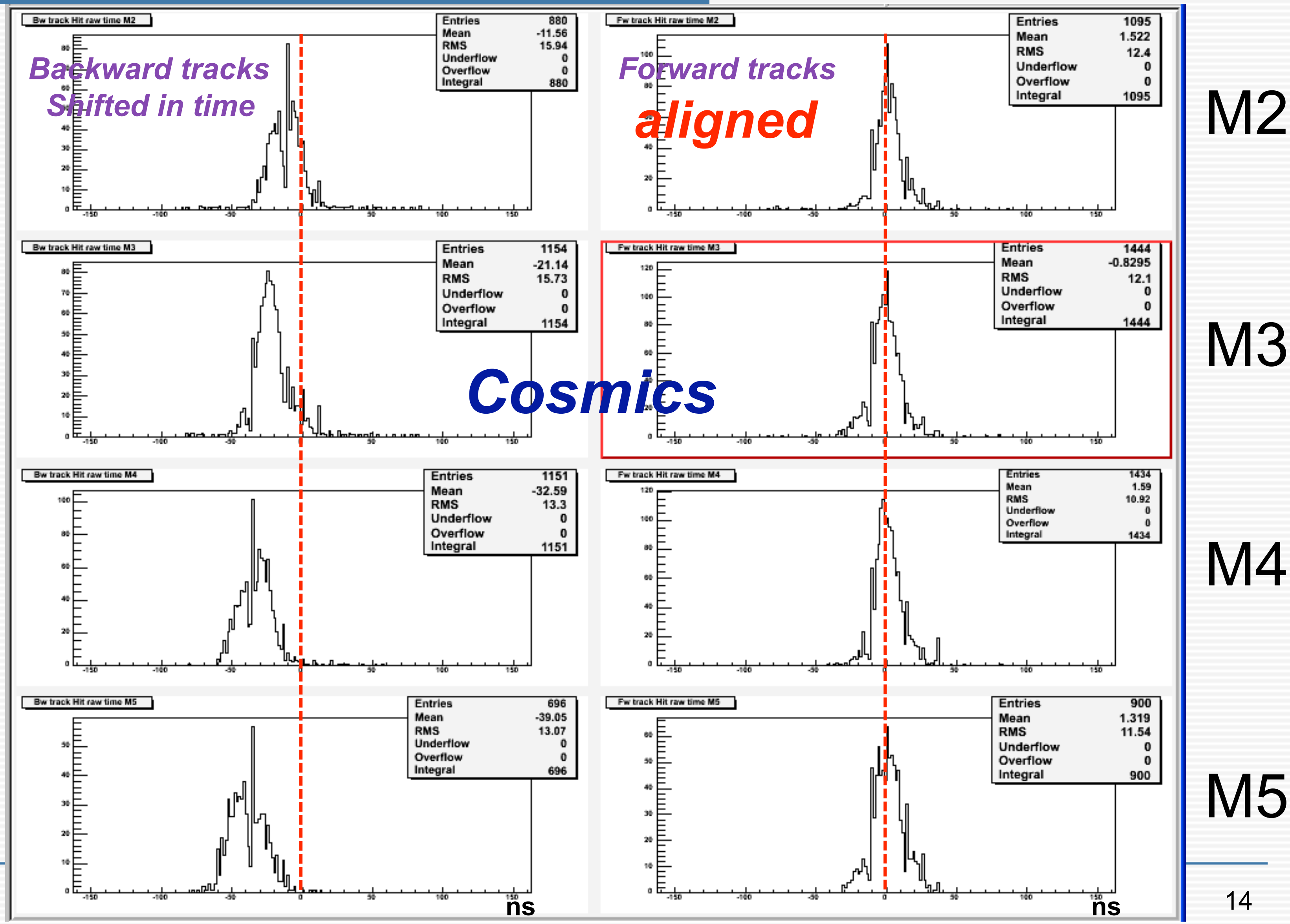


HCAL & ECAL trigger used for cosmic data

SPD multiplicity and Muon triggers for the TED and Beam-1 data



Commissioning: time alignment muon stations



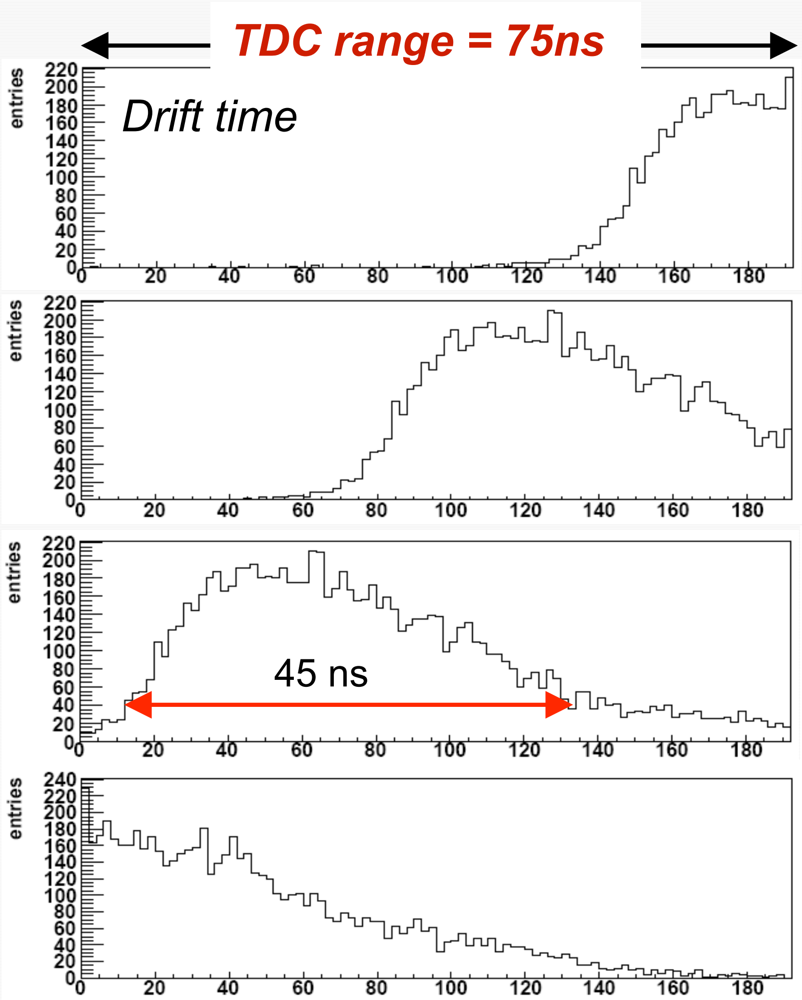
Commissioning: OT time alignment

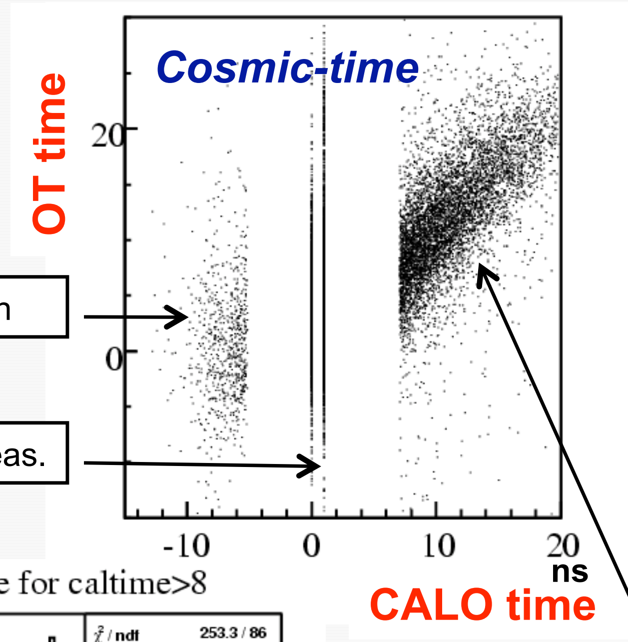
- 50 ns

- 25 ns

Trigger

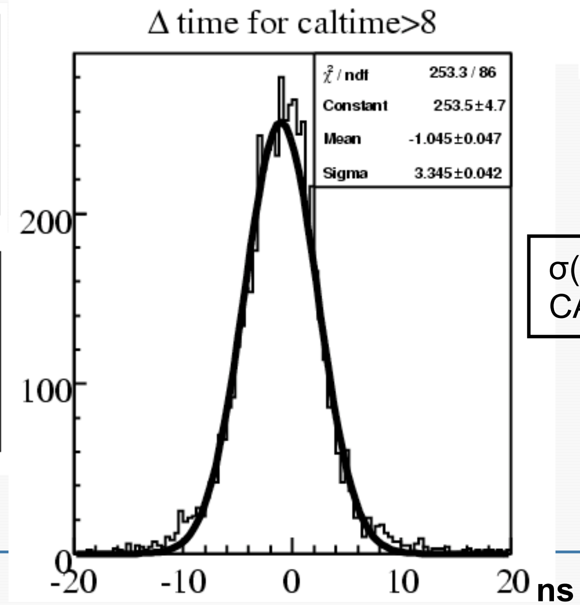
+ 25ns





No correlation

No CALO meas.



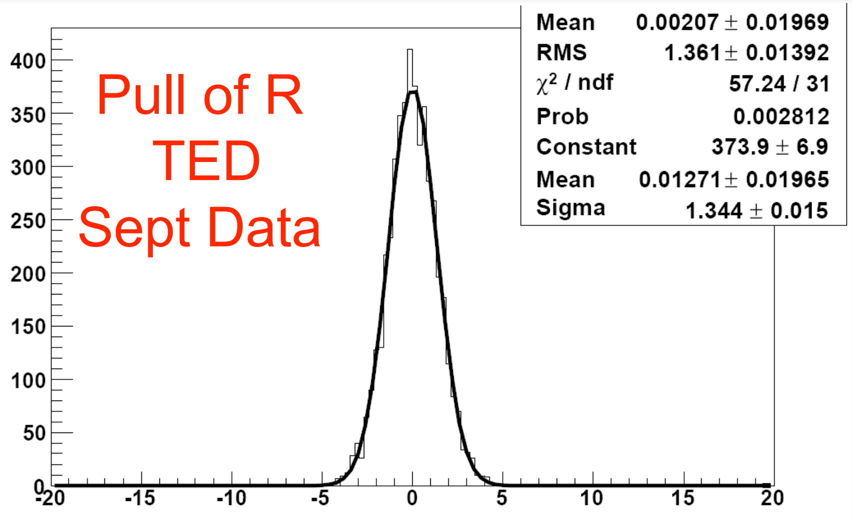
$\sigma(t_{OT} - t_{calo})$ ~ 3.3 ns where CALO meas. good (t>8ns)

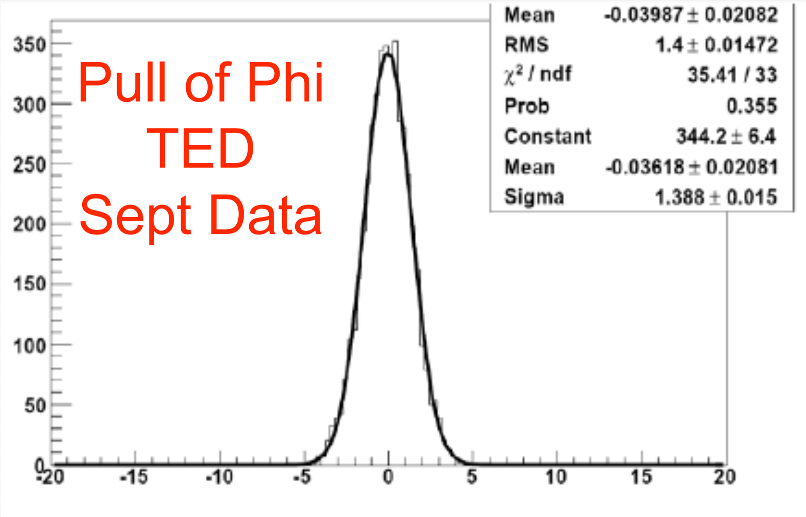
Run 33062: Beam 1 splash events

6 events with ~50 tracks/event

Commissioning: Space alignment VELO

- Measure the tracks residuals
  - Simple track fit (no momentum)
  - The VELO is aligned to ~10 μm, for RPhi modules
    - since installation sensors did not move (geometrical survey ~20 μm)

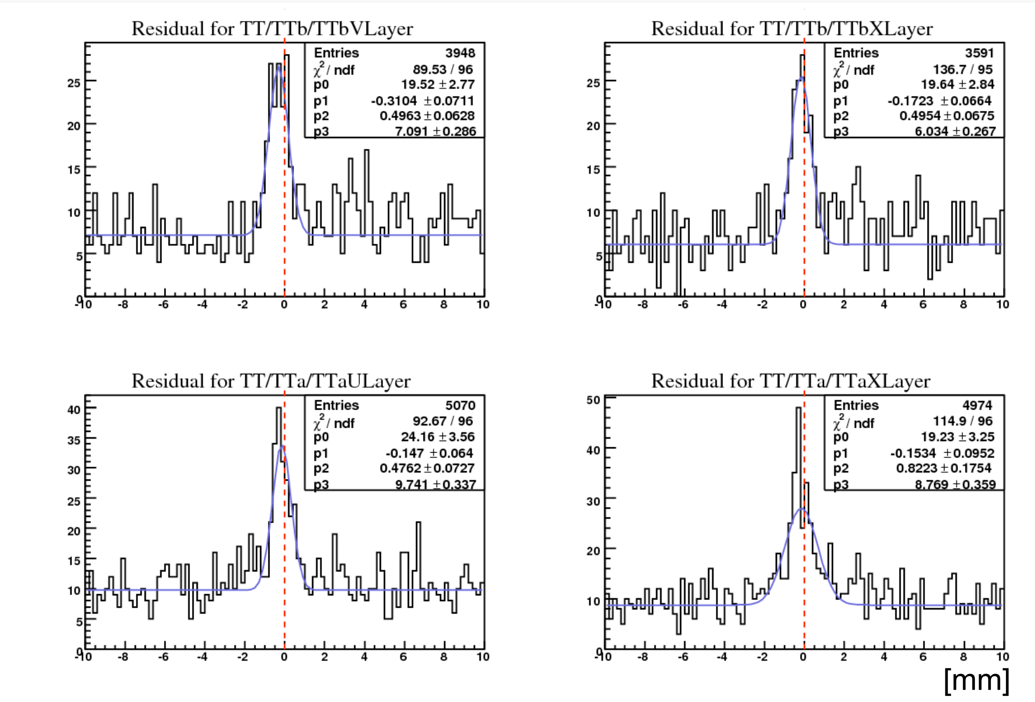


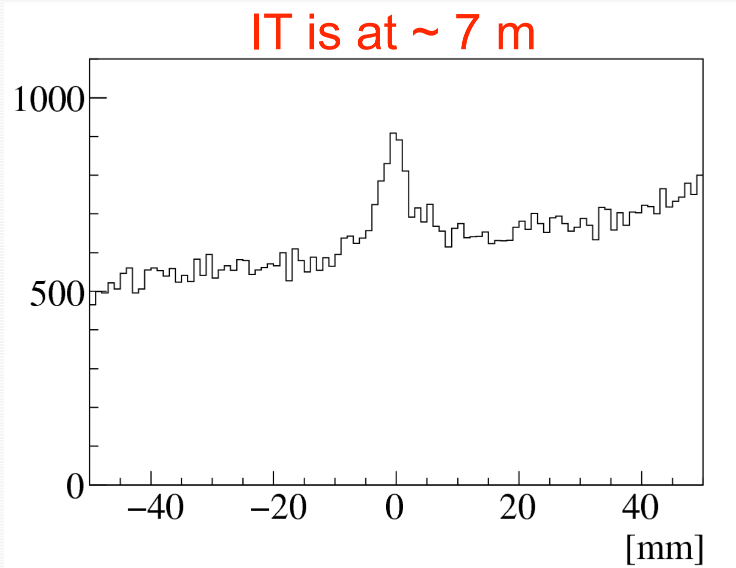


Commissioning: Space alignment IT and TT

- Extrapolate VELO tracks
  - Distance to clusters in TT and IT (no software alignment)
  - Large combinatorial due to huge occupancy
    - 0.1 tracks/cm^2, nominal value is 20 tracks in the whole detector (5000 clusters/evt in the 12 detection planes)

TED data



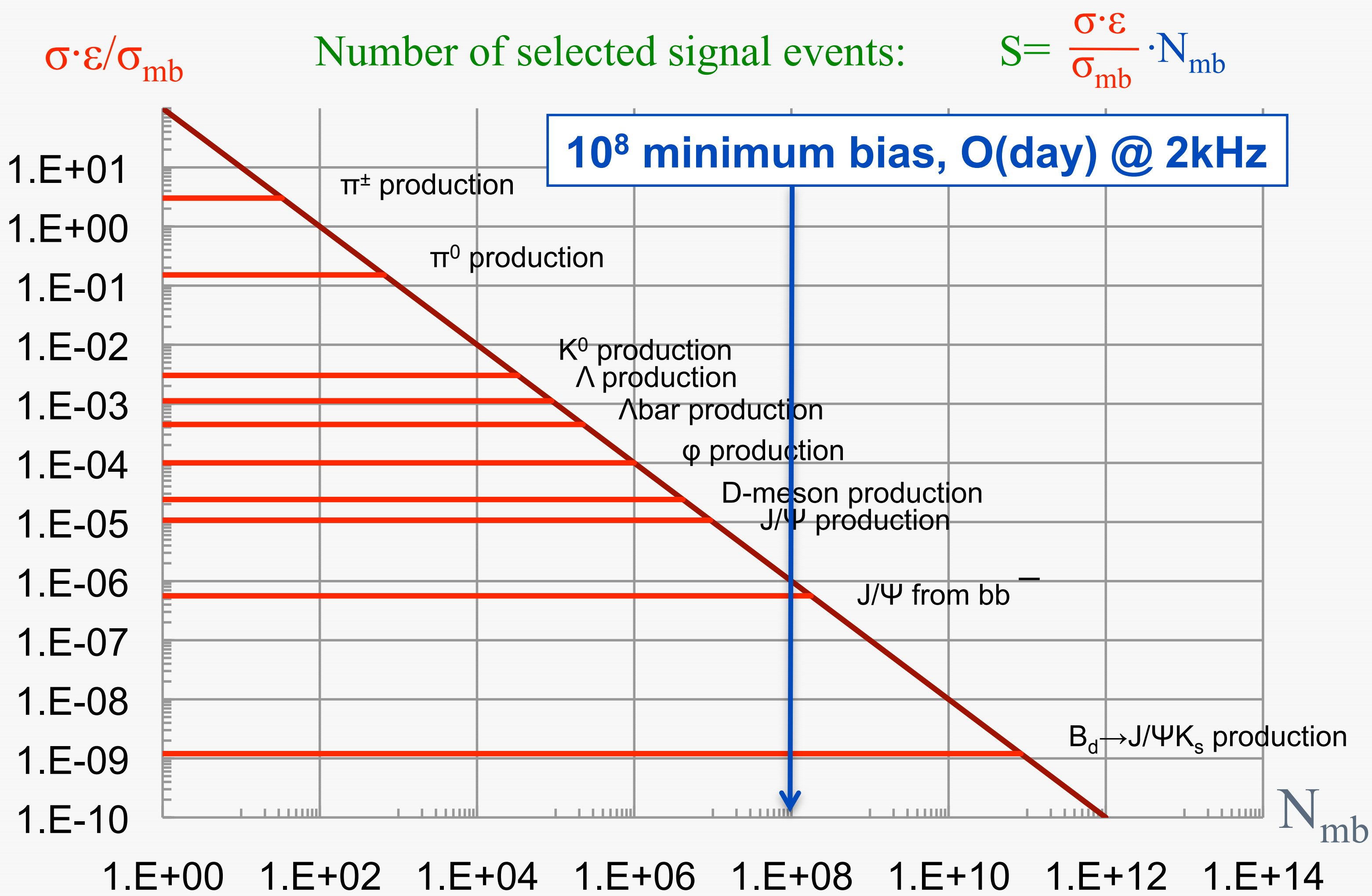


Clear correlations IT, TT and VELO

LHCb´s Physics scope

- CP-violation (see M. Adinolfi talk)
- Rare decays (see H. Ruiz talk)
- Soft QCD physics, first physics with minimum bias data
- Quarkonia and B physics, first physics with J/ψ
- Electroweak physics
- Higgs and exotica (see A. Camboni talk)

Early LHCb Physics: Exploit minimum bias data



Early data and Physics

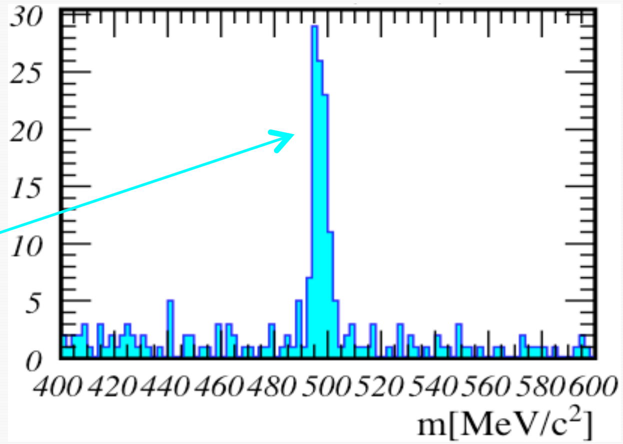
- First datasets:
  - ~10^7 visible pp int. passing zero-bias trigger
  - ~10^8 visible pp int. passing minimum-bias trigger
    - L0 with small HCAL E_T cut to reject empty events
  - ~10^9 events passing single muon trigger
    - L0 with small muon p_T cut (< 1 GeV/c) and no IP cut + corresponding HLT
  - events passing more complex (full) L0 and HLT

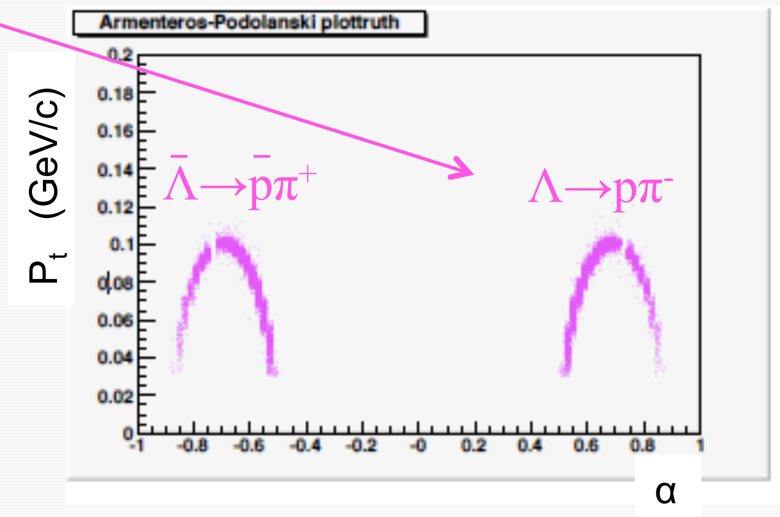
- First physics:
  (production studies vs p_T, η, φ, x_F,, polarization, …)
  - minimum bias physics
    - charged tracks, K_S, Λ, $\Lambda/\bar{\Lambda}$ ratio, ϕ, ... without PID
    - then π, K, p, and ratios
  - dimuon physics
    - Prompt J/ψ and $b \rightarrow J/\psi$
    - other quarkonia, X(3872)
    - $Z \rightarrow \mu\mu$
  - exclusive D and B physics

Exploiting minimum bias data

In 10^8 minimum bias events

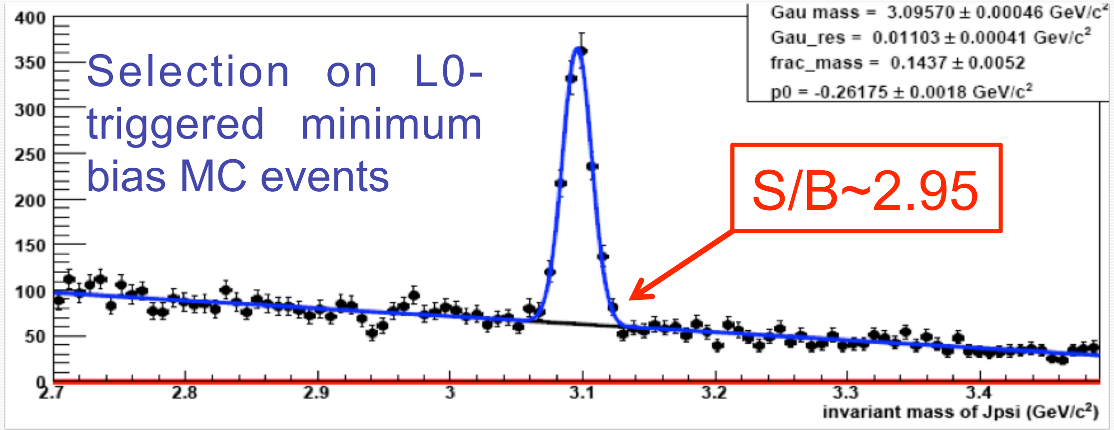
- Plenty of V^0s: K_s, Λ, $\bar{\Lambda}$, differential distributions (η, p_T)
- Analysis with only few kinematical and vertex cuts:
  - K_s signal out of 10k minimum bias events
- We can obtain a clean and unbiased sample for PID studies:
  - O(100k) Λ in 100M minimum bias events, 96% purity
- Strangeness studies:
  - Strange quarks are necessarily the result of the hadronization therefore strangeness probes the fragmentation field in an unique way
  - Λ hyperon can give insights on beam remnant fragmentation issues.
  - Input to hadronization/fragmentation models from inclusive distributions of strange particles in a unique η range (1.9÷4.9)
  - Baryon to meson ratios (Λ/K_s vs p_T), m_T distributions, p_T spectra for different species of strange particles … there are many theoretical models that can be challenged in a unknown territory
  - …





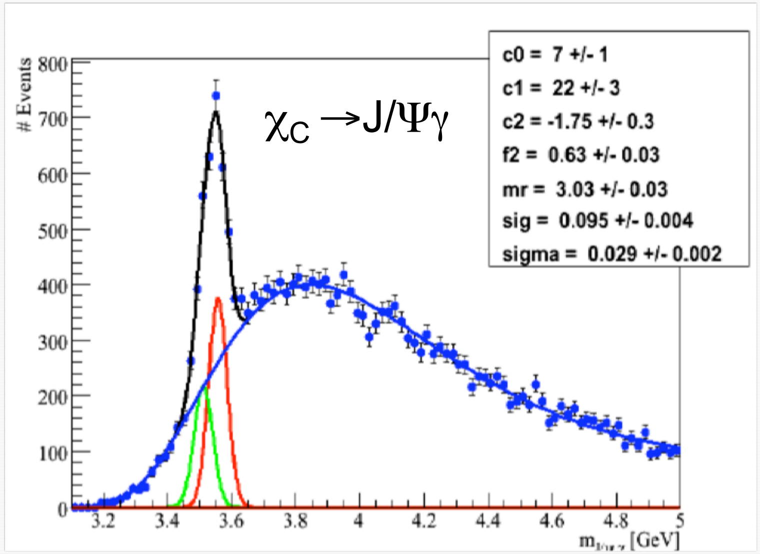
Dimuon physics

- $J/\Psi \rightarrow \mu\mu$, production:
  - separate prompt J/Ψ from detached $b \rightarrow J/\Psi$.
  - measure prompt J/Ψ and $b\bar{b}$ differential cross sections (we need luminosity)



  - Expect 300K $J/\Psi \rightarrow \mu\mu$ per 0.5 pb^{-1} 10^9 single muon triggers (but MC has only color-singlet, color-octet contrib seen at CDF)

- $\Psi(2s) \rightarrow \mu\mu$
  - measure the $\Psi(2s)$ to J/Ψ production ratio, no luminosity measurement is needed.

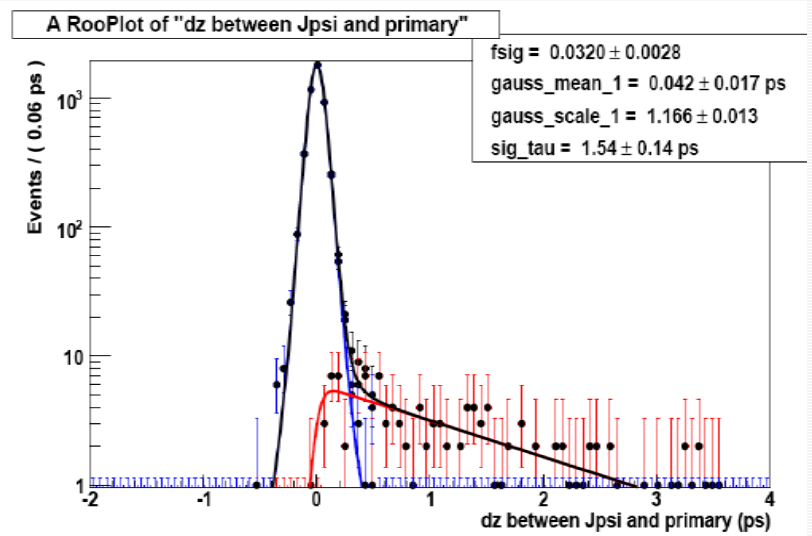


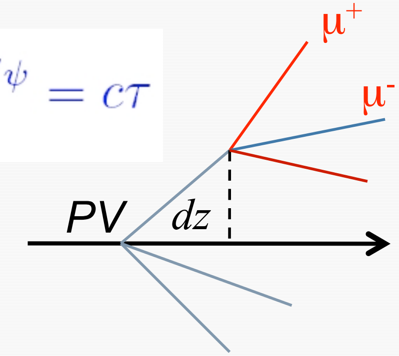
- Other quarkonia production (ratios) and spectroscopy:
  - $\chi_C \rightarrow J/\Psi\gamma$, $Y(1S) \rightarrow \mu\mu$, …
  - $X(3872) \rightarrow J/\psi\,\pi\pi$, $Z^+ \rightarrow \psi(2S)\pi^+$, $Y_b \rightarrow Y(1S)\pi\pi$, ...

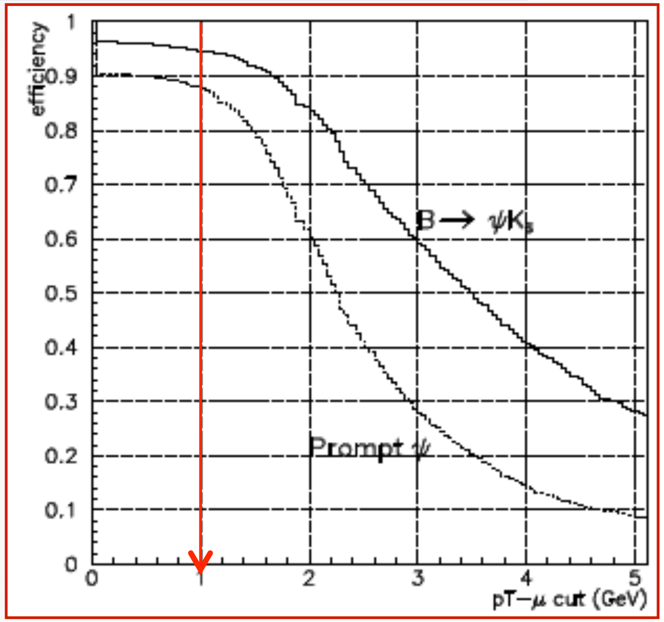
Dimuon physics

- Reconstruct J/ψ→μμ and disentangle fraction of prompt and detached J/ψ's
- discriminating variable:

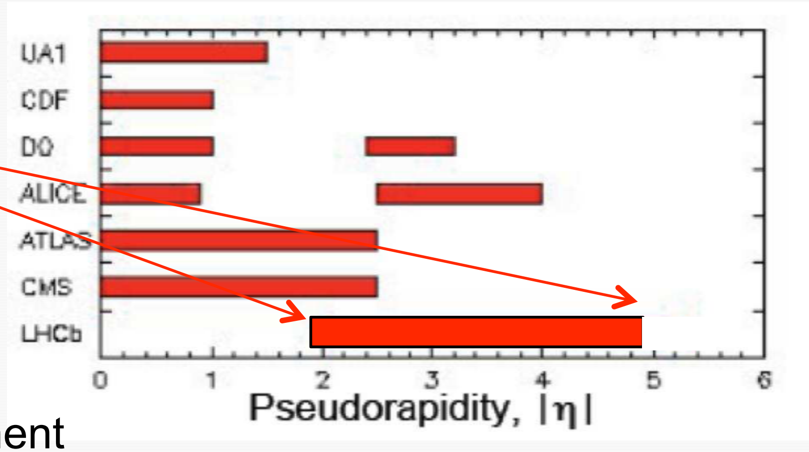
$$t = \frac{dz}{p_z} \times M^{J/\psi} \approx \frac{d}{p} \times M^{J/\psi} = c\tau$$







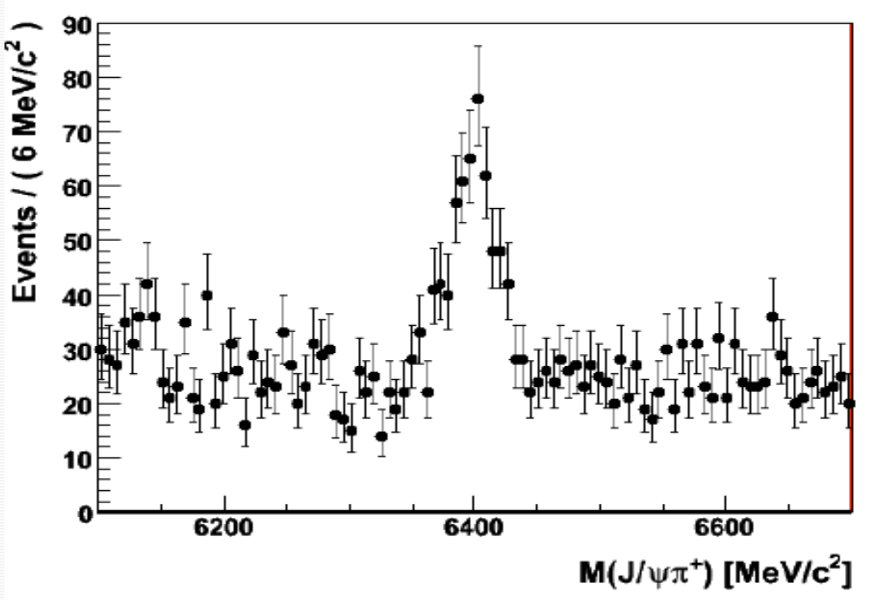
Prompt J/ψ and $b\bar{b}$ cross section in a new region



- Measure @ same time J/Ψ polarization since the acceptance depends on it.
- study proper time resolution with prompt component

B_c mass and lifetime measurements

- Use $B_c^+ \rightarrow J/\psi\ \pi^+$ decay mode:
  - Expect ~311 events for 1 fb^{-1}, with 1.15< B/S <2.15
- B_c^+ mass measurement (1 fb^{-1}):
  - Expect ±1.4 (stat) ±1.5 (syst) MeV/c^2
    best measurement CDF: ±2.9 ±2.5 MeV/c^2
- B_c^+ lifetime measurement (1 fb^{-1}):
  - expect ±0.029 (stat) ±0.016 (syst) ps
    - best measurement D0: ±0.038 ±0.032 ps
- Study of $B_c^+ \rightarrow J/\psi\ \mu^+\nu$ in progress



Conclusions

- The LHCb detector is (was) ready to take data
- Large Minimum Bias data samples, will be collected in the forward region covered by the LHCb detector at a rate of 2kHz, as soon as the LHC delivers pp collisions
- At the beginning, the efforts of the collaboration will be devoted to the Minimum Bias event analysis, to calibrate the detector, and start tuning the MC parameters, and then produce physics results with early data