Hadron Collider Physics Symposium

HCP 2009 Evian

Evian, France

16 – 20 November, 2009

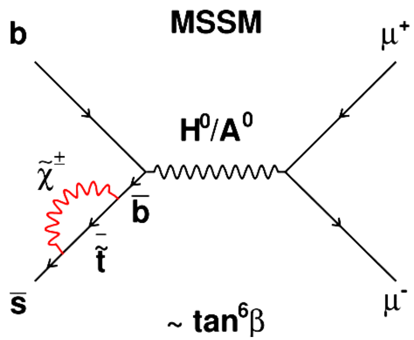
LHCb Detector Global Status

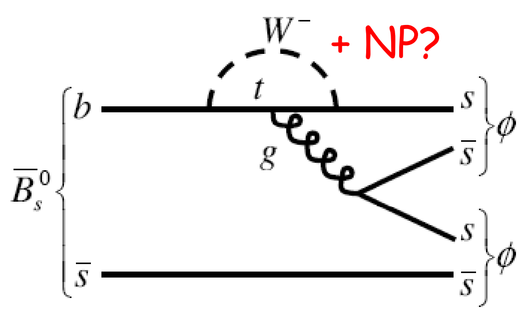
Outline:

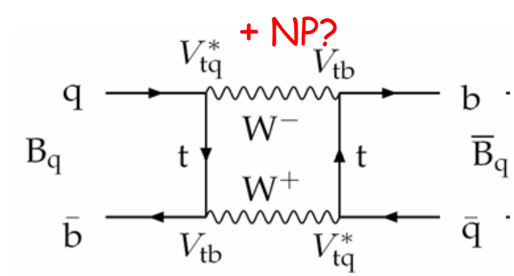
- Introduction to the LHCb Experiment
- Detector overview and status of subsystems
- Expected performance and physics goals in 2010
- Conclusions

The LHCb Experiment

- LHCb is a dedicated B physics experiment at LHC
- Enormous progress in recent years from the B factories and Tevatron
  What remains to be done at the LHC?
- Focus has changed: from seeking to verify the CKM picture to searching for signs of New Physics beyond the Standard Model in the flavour sector
- $b \rightarrow s$ transitions: still limited knowledge, space for NP effects
- Flavour physics observables have sensitivity to new particles at high mass scales via their virtual effects in loop diagrams:



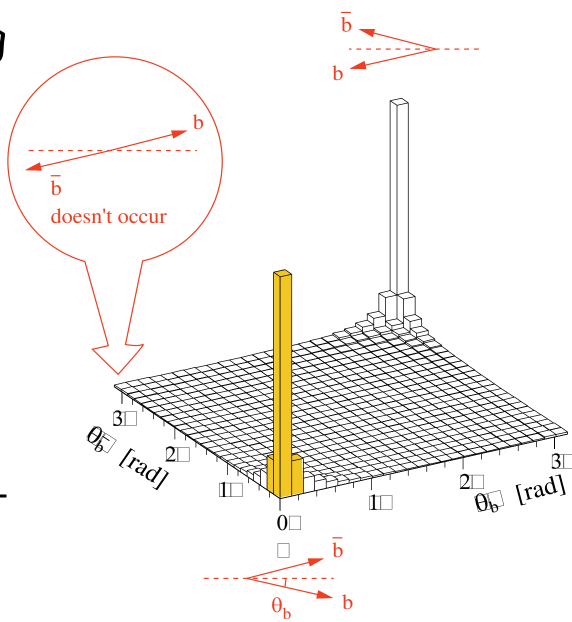




→ More on **Indirect New Physics searches with B-decays at the LHC** in the talk of Olivier Schneider tomorrow

The LHCb Experiment

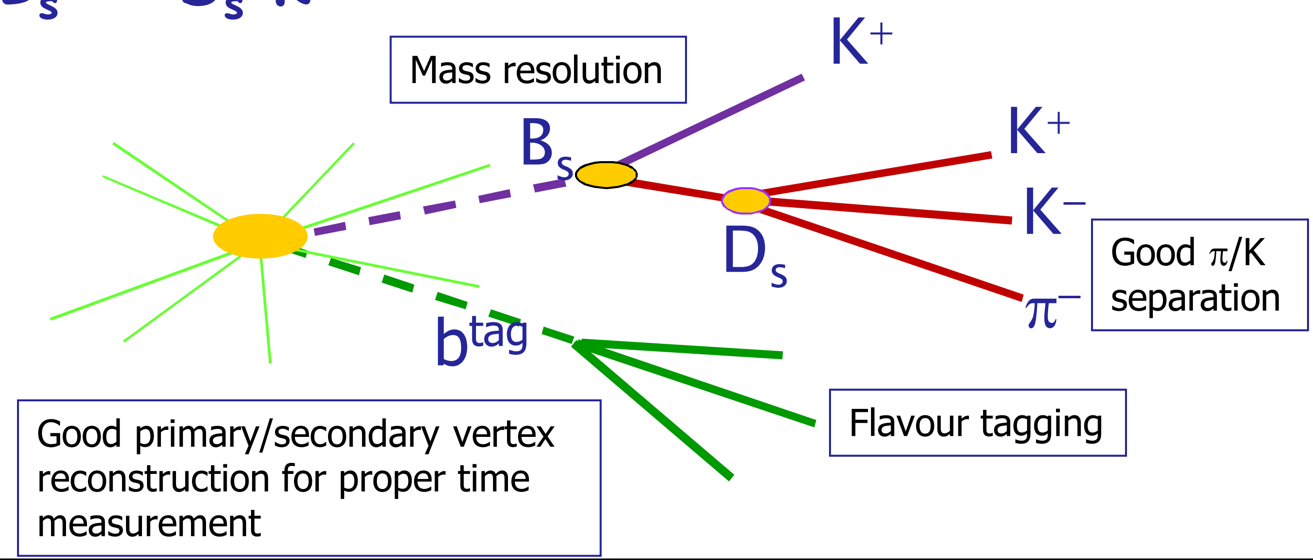
- **Advantages of beauty physics at hadron colliders:**
  - High value of beauty cross section expected at ~10 TeV:
    - $\sigma_{bb} \sim 500\ \mu b$ (e+e- cross section at Y(4s) is 1 nb)
  - Access to all b-hadrons: $B^{\pm}$, B^0, B_s, B_c, b-baryons
- **The challenges**
  - Multiplicity of tracks (~50 tracks in the acceptance)
  - Rate of background events: $\sigma_{inel} \sim 80$ mb
- **LHCb running conditions:**
  - Luminosity limited to ~2x10^{32} cm^{-2} s^{-1} to maximize the probability of single interaction per bunch crossing
  - 2fb^{-1} per nominal year (10^7s),
  - ~ 10^{12} $b\bar{b}$ pairs produced per year
- **LHCb acceptance:**
  - Forward single arm spectrometer 1.9<η<4.9
    - b-hadrons produced at low angle
    - Correlated bb-production in same hemisphere

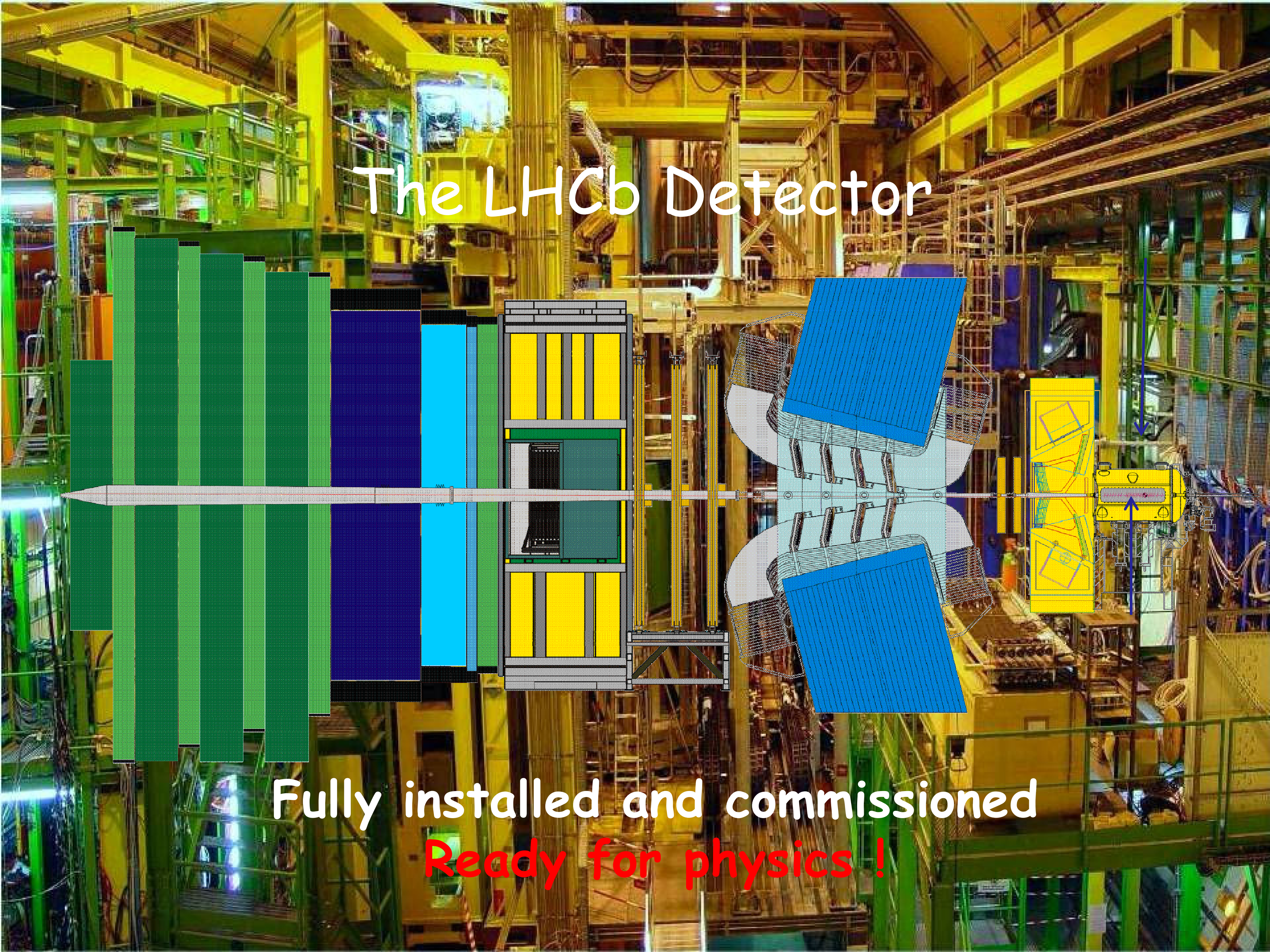


LHCb Key Features

- Highly efficient trigger for both hadronic and leptonic final states to enable high statistics data collection
- Vertexing/tracking for secondary vertex identification and proper time measurement
- Mass resolution to reduce background
- Particle identification

Example: $B_s \rightarrow D_s K$




The LHCb Detector
Fully installed and commissioned
Ready for physics !

Commissioning of LHCb

- First attempt to perform time synchronization and space alignment using cosmics and LHC beam induced events.

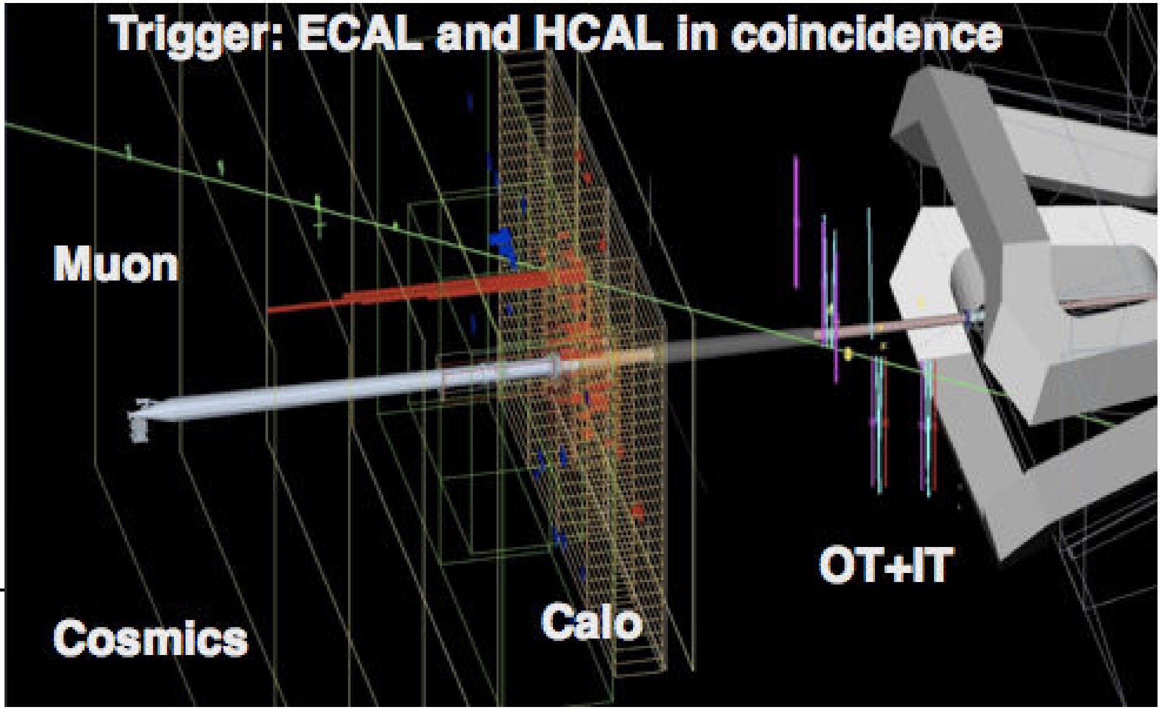
→ Details on **LHCb Tracking commissioning** and spatial alignment in the talk of Stephanie Hansmann-Menzemer later on

- Use of cosmics non-trivial since LHCb is horizontal and located deep underground → works effectively only for big sub-systems located downward the magnet: Outer Tracker (OT), Calorimeter and Muon

Few Hz Trigger on "horizontal" cosmic tracks

- Muon & CALO synchronized to a few ns

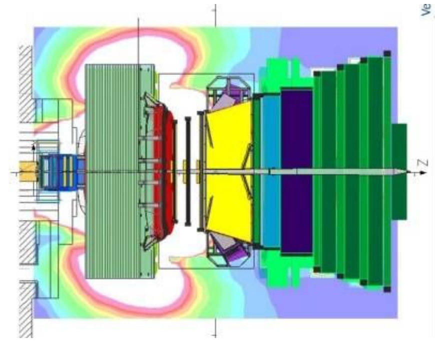
- L0 trigger commissioned

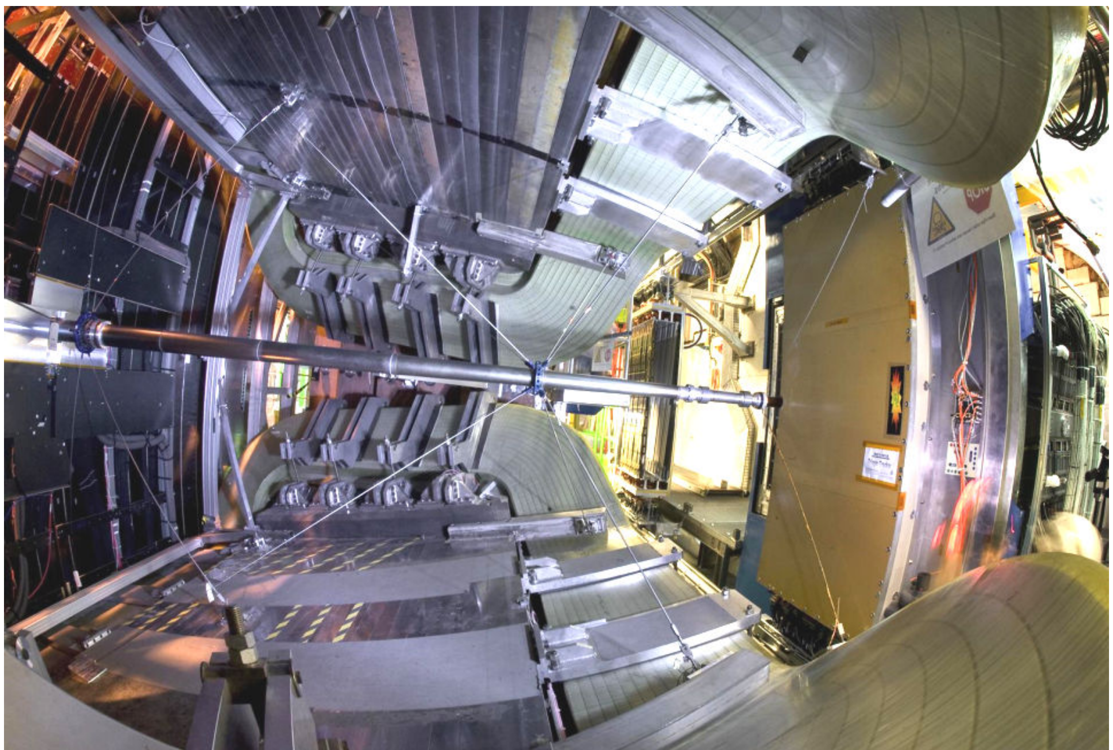


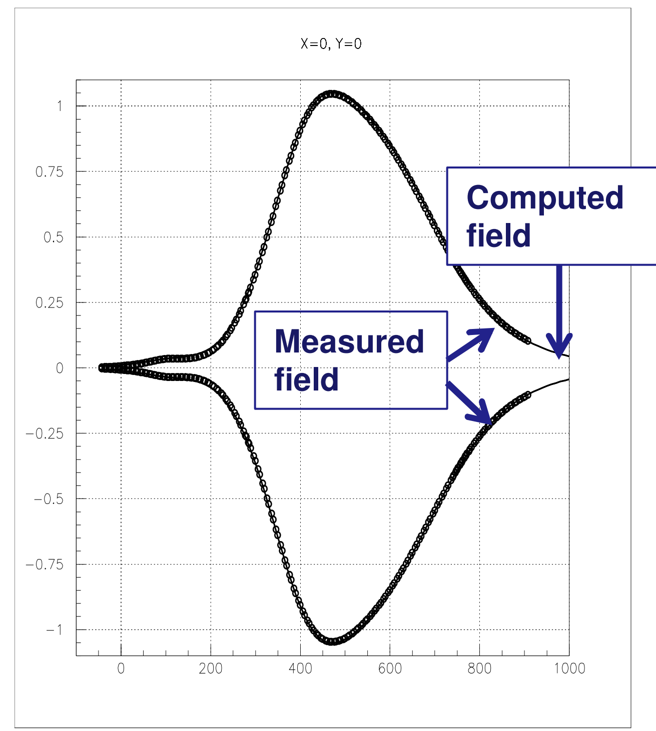
Warm Dipole Magnet

Conductor:	Aluminium
Integrated field:	4 Tm (10m)
Peak field	1.1 T
Weight	1600 tons
Power	4.2 MW

Fringe field < 50G

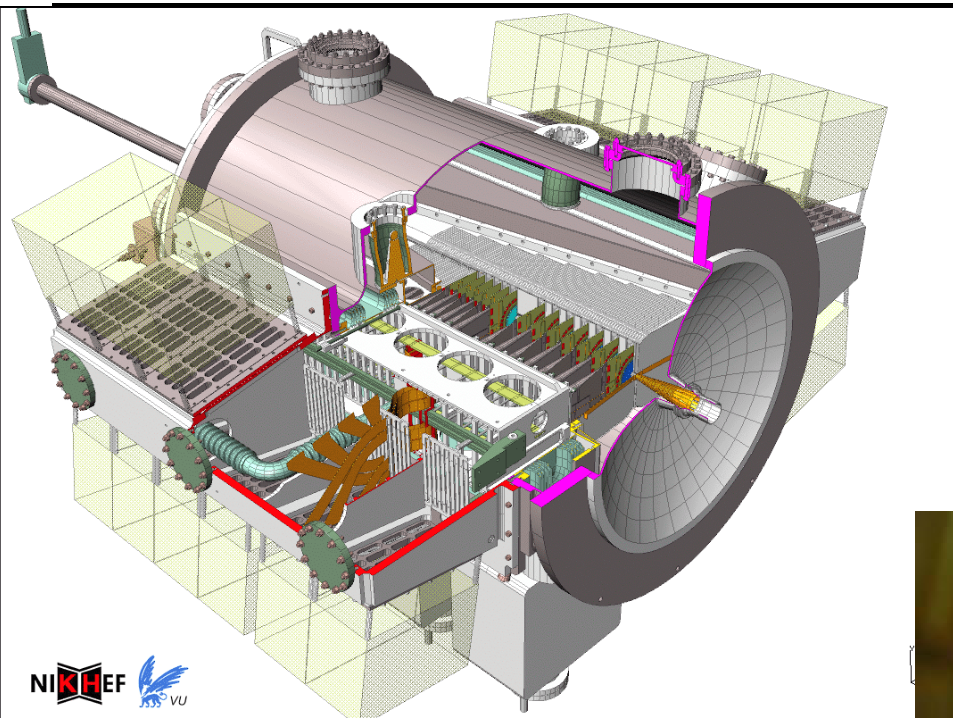


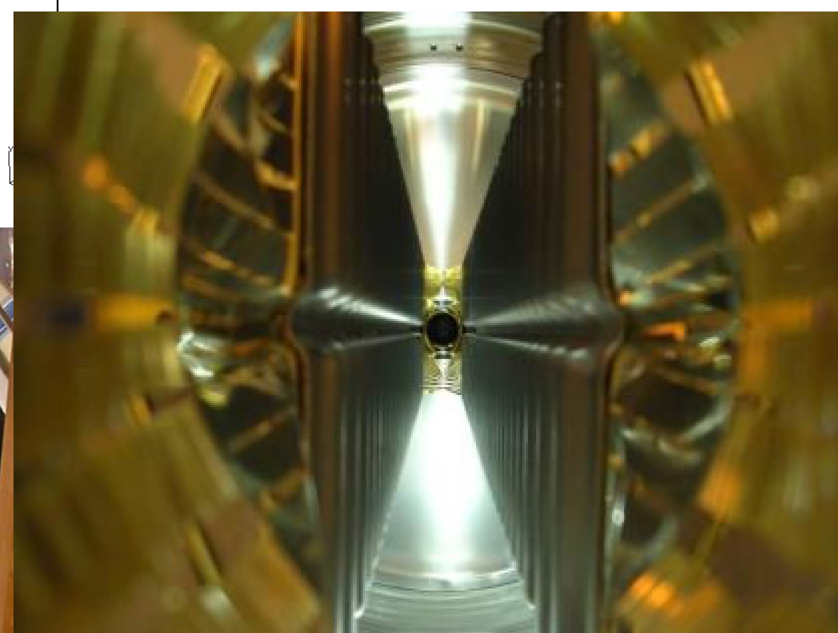




VErtex LOcator

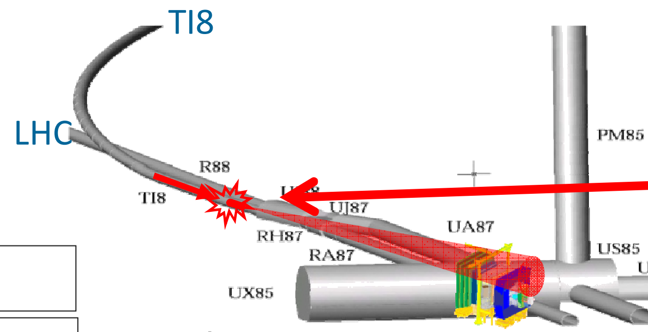
- Silicon strip detector
- 21 stations, each with
- R and Phi sensors
- In beam secondary vacuum
- Retractable by 30mm

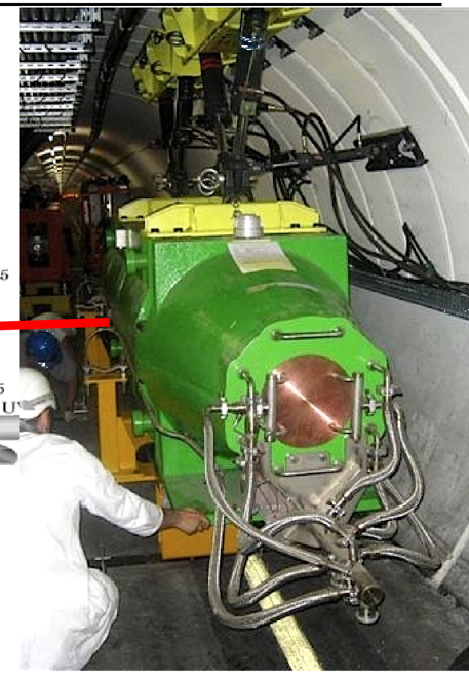


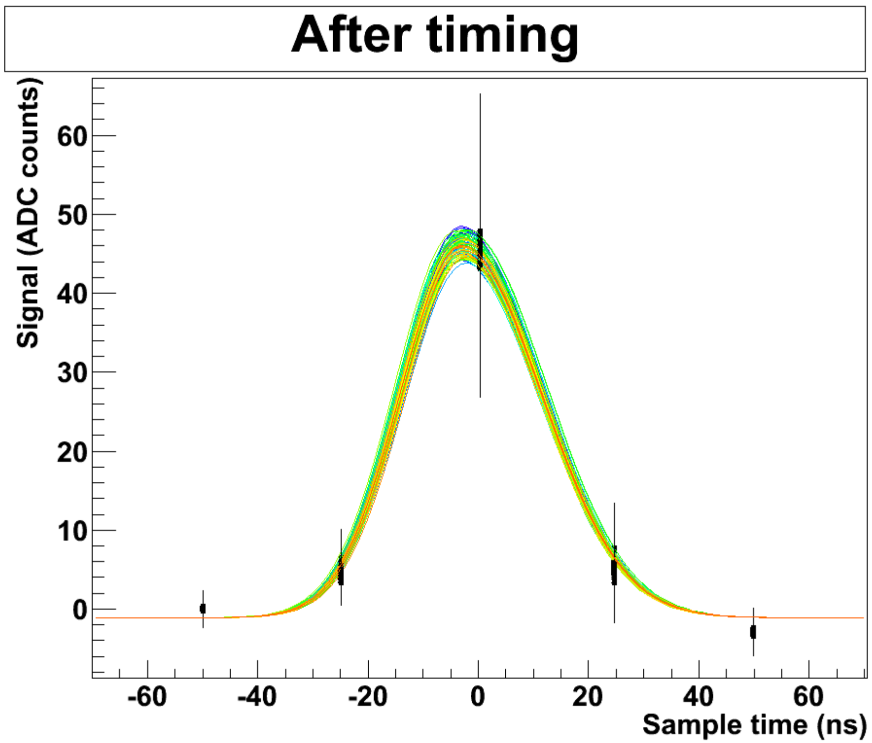


VELO time alignment with TED runs

- **Transfer line External beam Dump**
- Shots every 48 seconds
- Typical occupancy of
  7 clusters/sensor/event





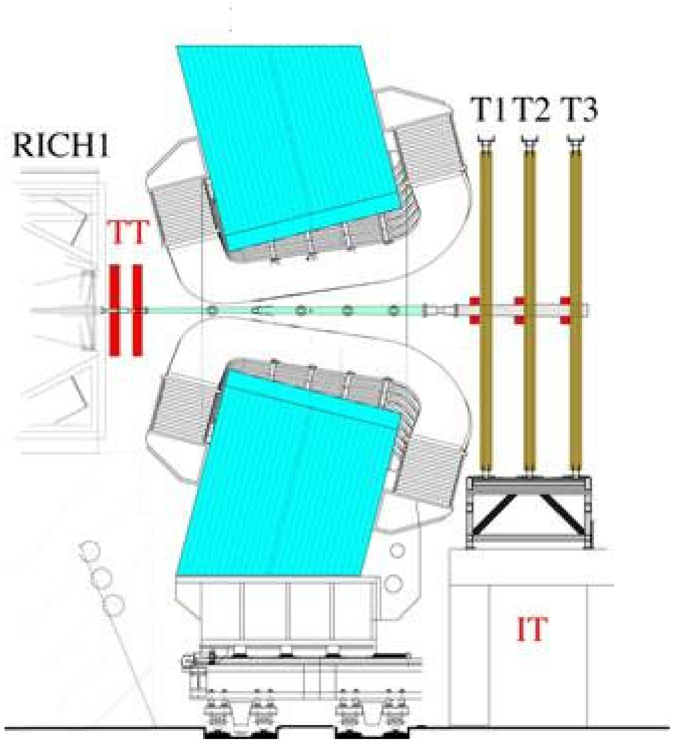


- The procedure to tune the timing with data has been established

- Timing accuracy < 2 ns can be achieved with 125 clusters/sensor/step

Tracking System

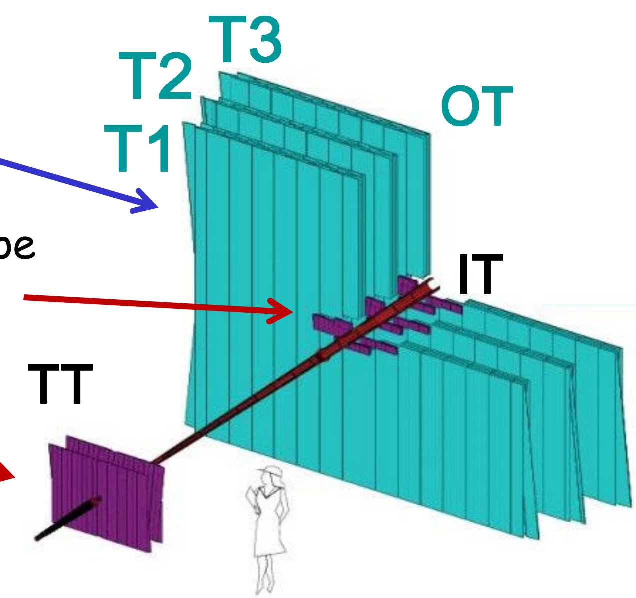
Trigger Tracker (TT) and 3 Tracking Stations (T1,T2,T3), each with 4 detection planes (0°,+5°,-5°,0°)



Outer Tracker
Straw Tubes
(56 k ch)

Inner Tracker
~0.5 m^2 around beam pipe
Si –μ-strip detectors
(130k ch)

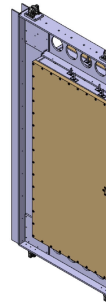
Trigger Tracker
Si –μ-strip detectors
~1.4×1.2 m^2 (144k ch)

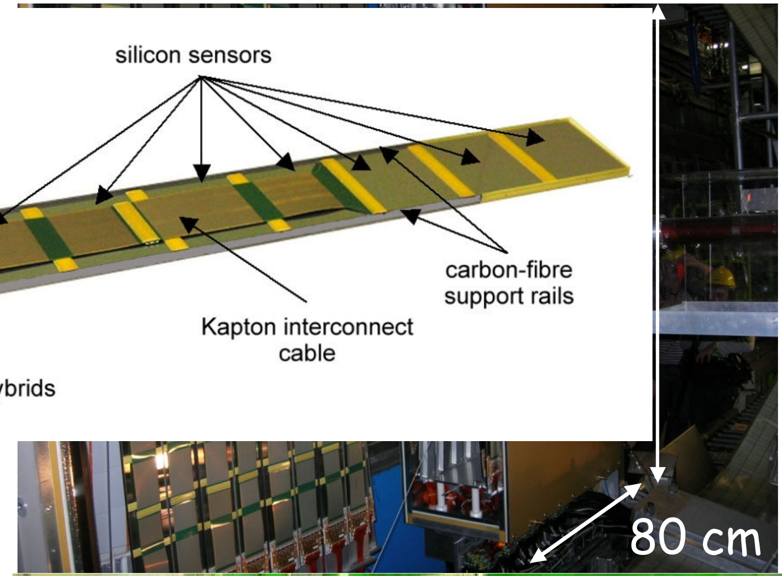


Silicon Trackers

Trigger Tracker:

- 500 μm thick Si μ-strip sensors
- 7-sensor long ladders, 183 μm pitch
- Area of 8.2 m^2 covered with 896 sensors, 280 r/o sectors,
- 99.7% of channels functional





→ Provides tracking info for triggering
→ Tracking of low momentum particles

Inner Tracker:

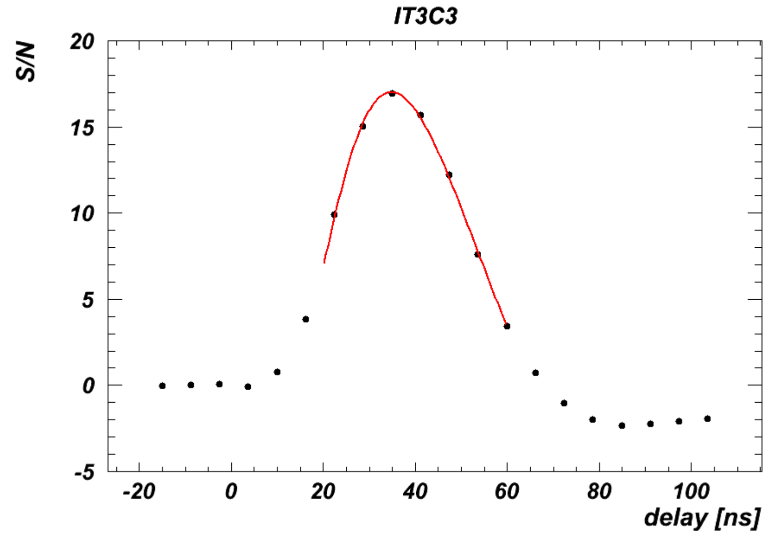
- 320 (410) μm for 1 (2)-sensor ladders
- Readout pitch 198 μm pitch
- Area of 4.2 m^2 covered with 504 sensors, 336 ladders
- 99.4% of channels functional

→ Provides tracking in high flux region ($5 \times 10^5 cm^{-2} s^{-1}$), 2% of area 20% of tracks

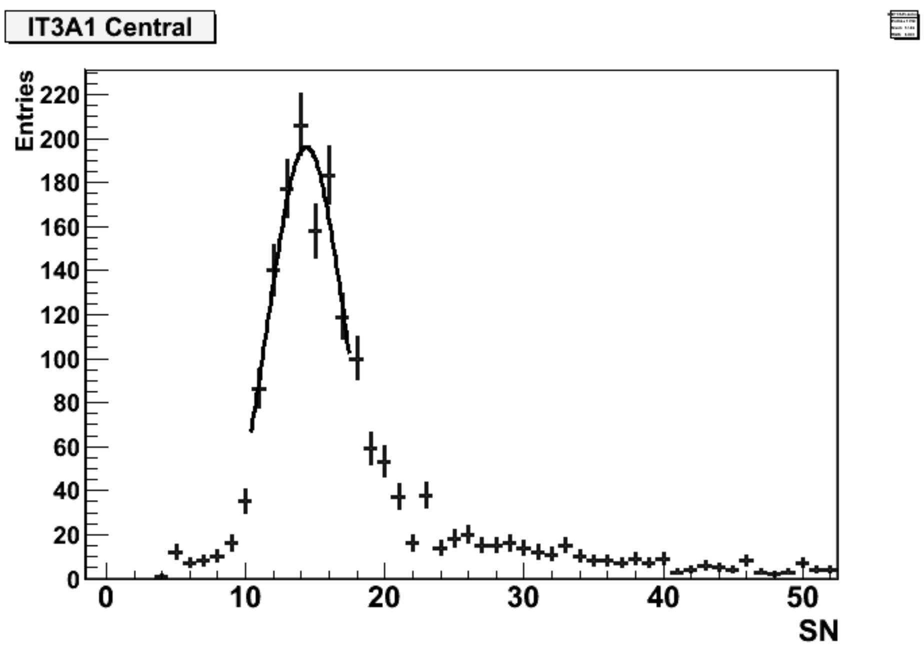
IT Time Alignment with TED runs

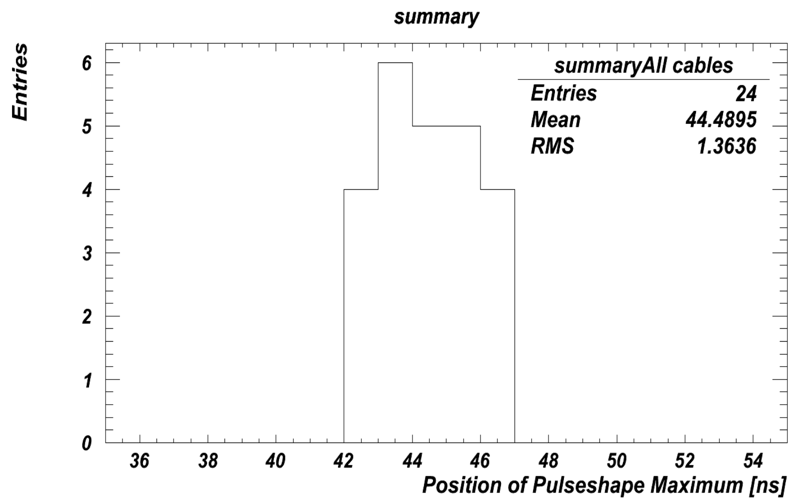
- Different cable lengths for various detector parts
- Time of flight different per station

- Time delay scans
  (collected charge vs sampling time)



Scanning sampling time

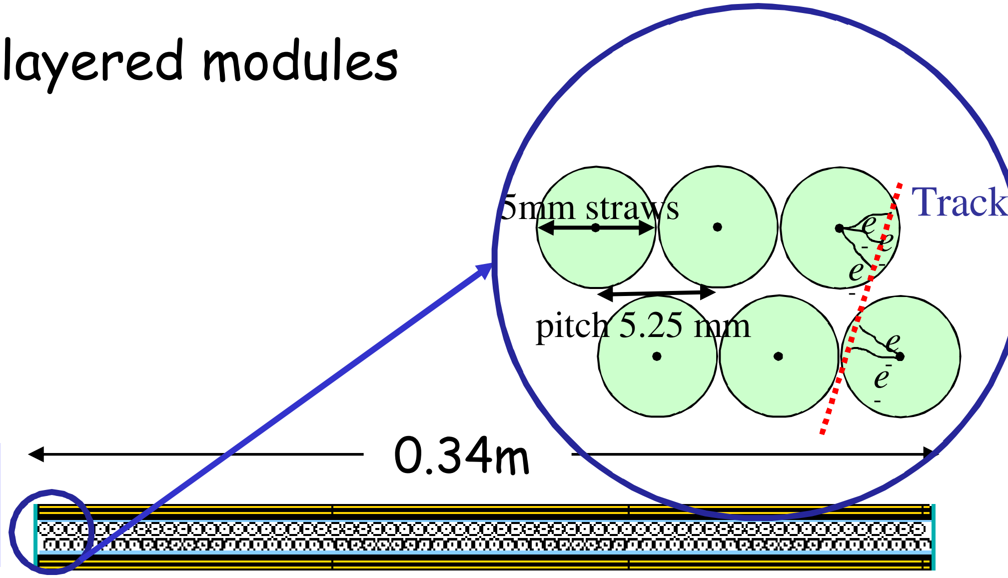


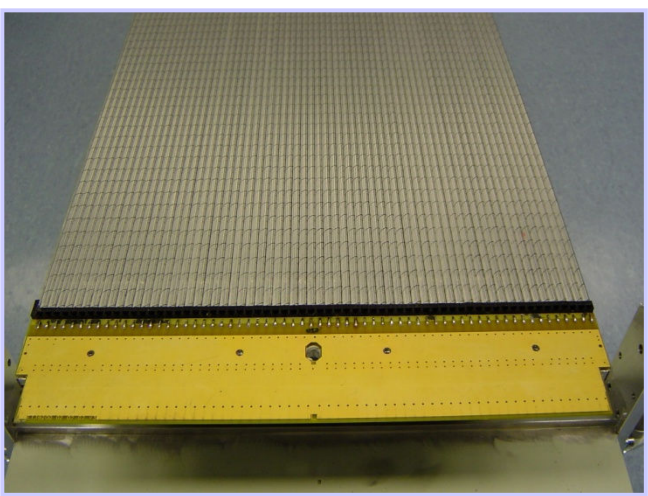


→ Detector internally time aligned with accuracy of 1.4 ns

Outer Tracker

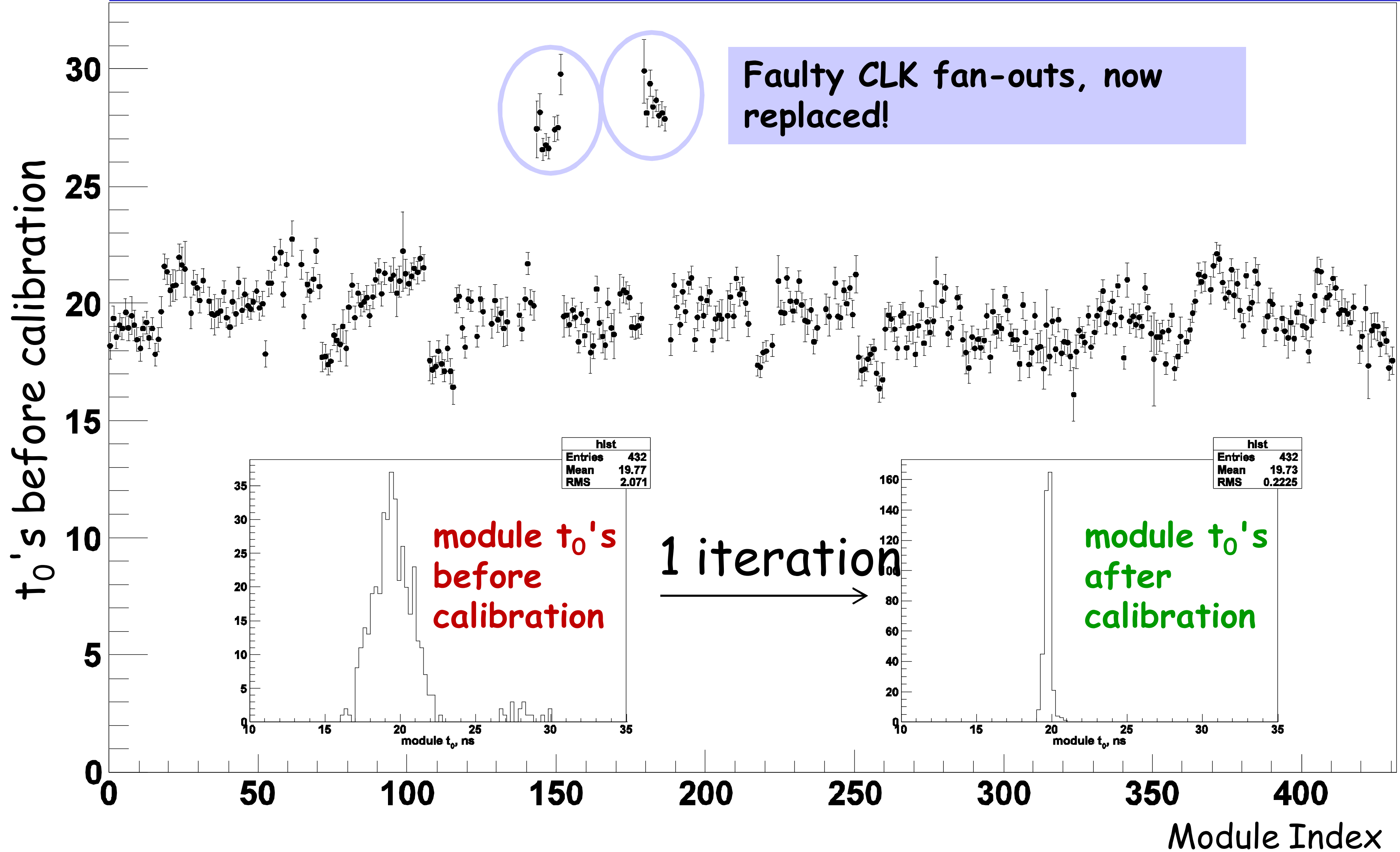
- Straw Tube Packed in double layered modules
- Modules 64 cells wide
- Modules have 0.37% of X_0
- Gas: Ar/CO_2 (70/30)





Outer Tracker Time Alignment

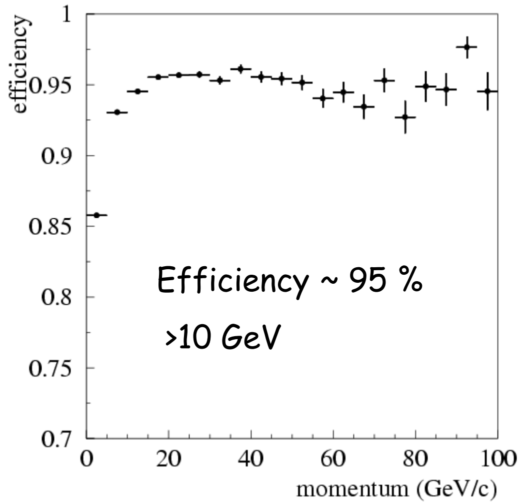
t_0 correction using average drift time per module

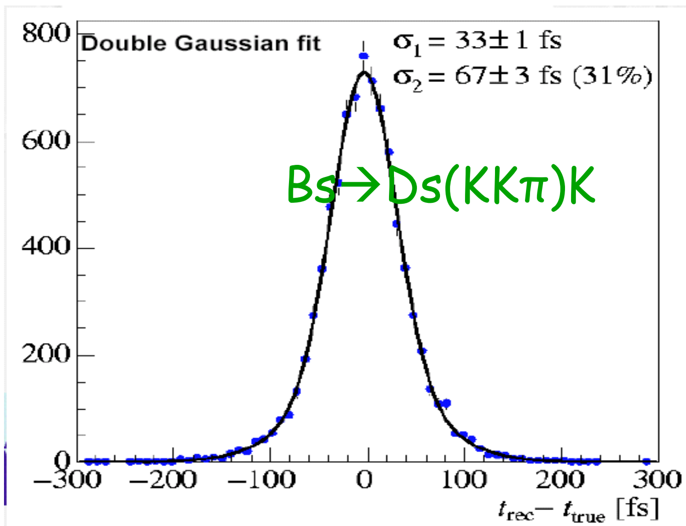


Detector Performances: Tracking

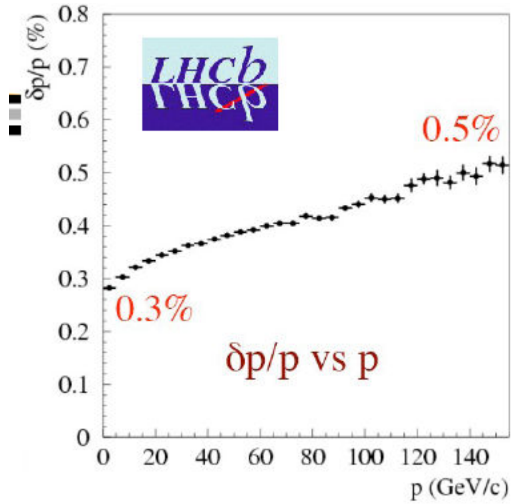
- Expected tracking performances:
  - Efficiency > 95% for tracks from B decays crossing whole detector
  - $\delta p/p$, depending on p: 0.3% ÷ 0.5%
  - Impact parameter resolution : σ_{IP} ~ 30 μm

→ Details in talk of Stephanie on **LHCb Tracking Commissioning**





Proper time resolution ~ 40 fs

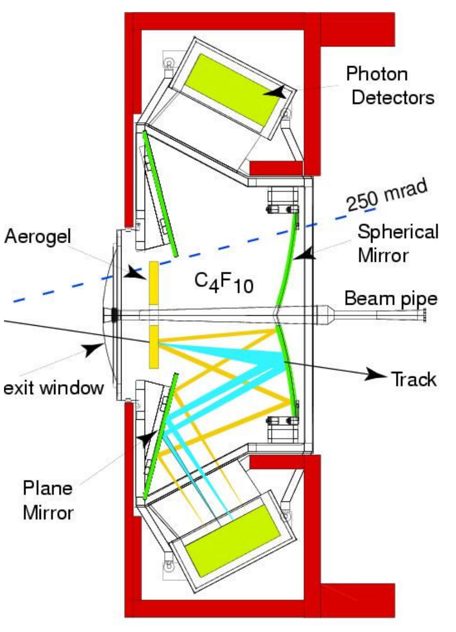


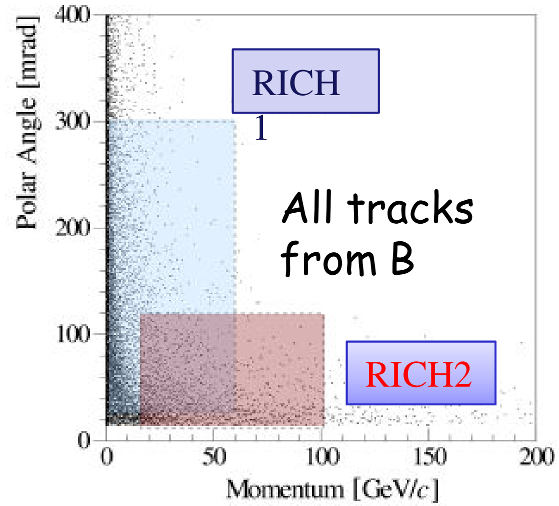
RICH Detectors

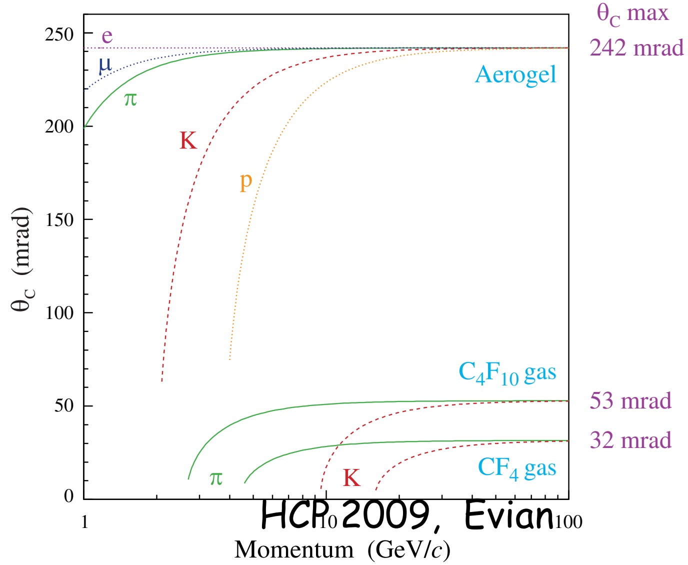
- Two RICHes are needed to cover angular and momentum acceptance
- The RICH detectors allow π - K Identification from ~2 to 100 GeV

RICH 1:

Aerogel n=1.03 (5 cm)
C_4F_{10} n=1.0014 (85 cm)

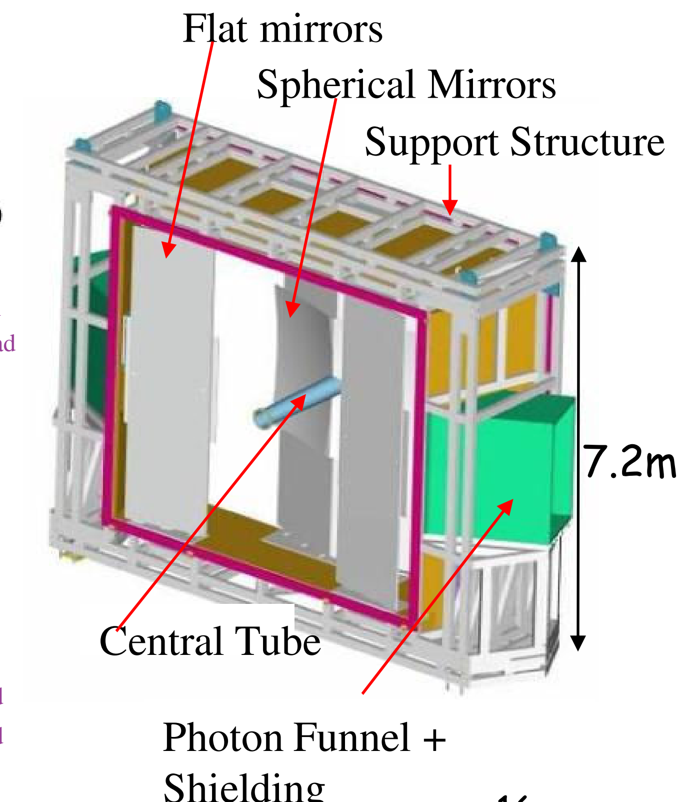






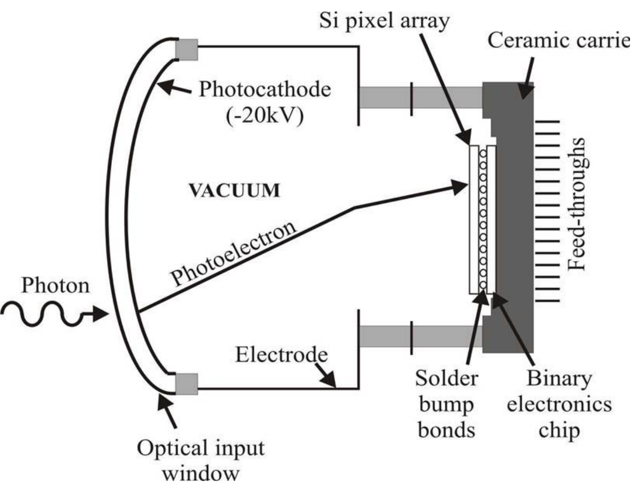
RICH 2:

CF_4 n=1.0005 (167 cm)



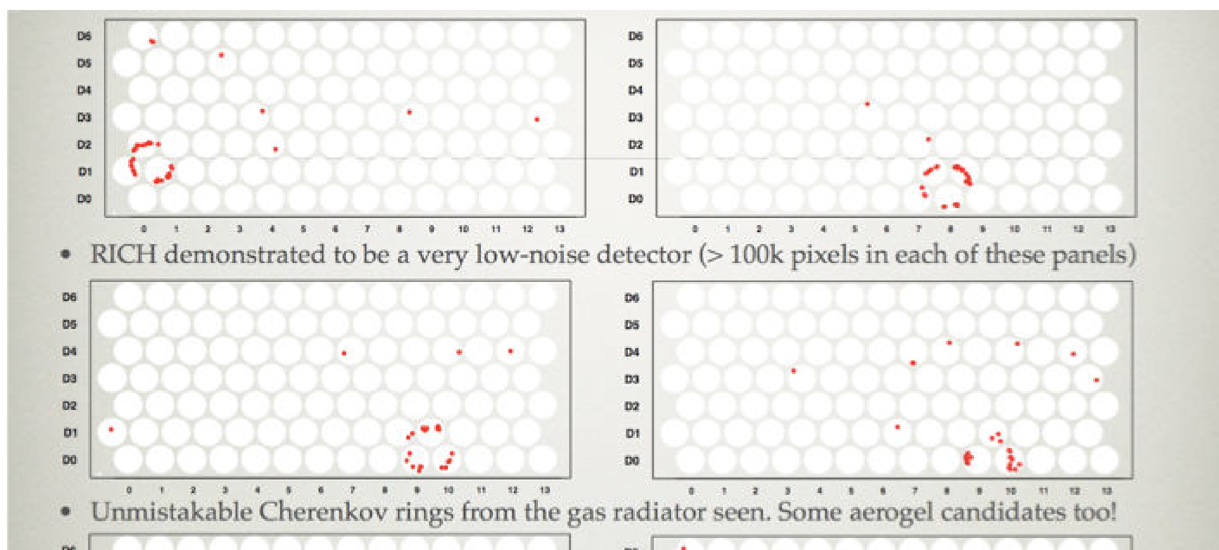
RICH photon detector system

- **Pixel Hybrid Photon Detector (HPD):**
- Photon Detector:
  - Quartz window, multi-alkali photocathode
  - 20 kV operating voltage
  - Demagnification of ~5
  - Active diameter 75mm
- Anode:
  - Pixel Si-sensor array bump bonded to binary readout chip
  - Assembly encapsulated in vacuum tube
  - effective pixel array of $0.5 \times 0.5\ mm^2$ each

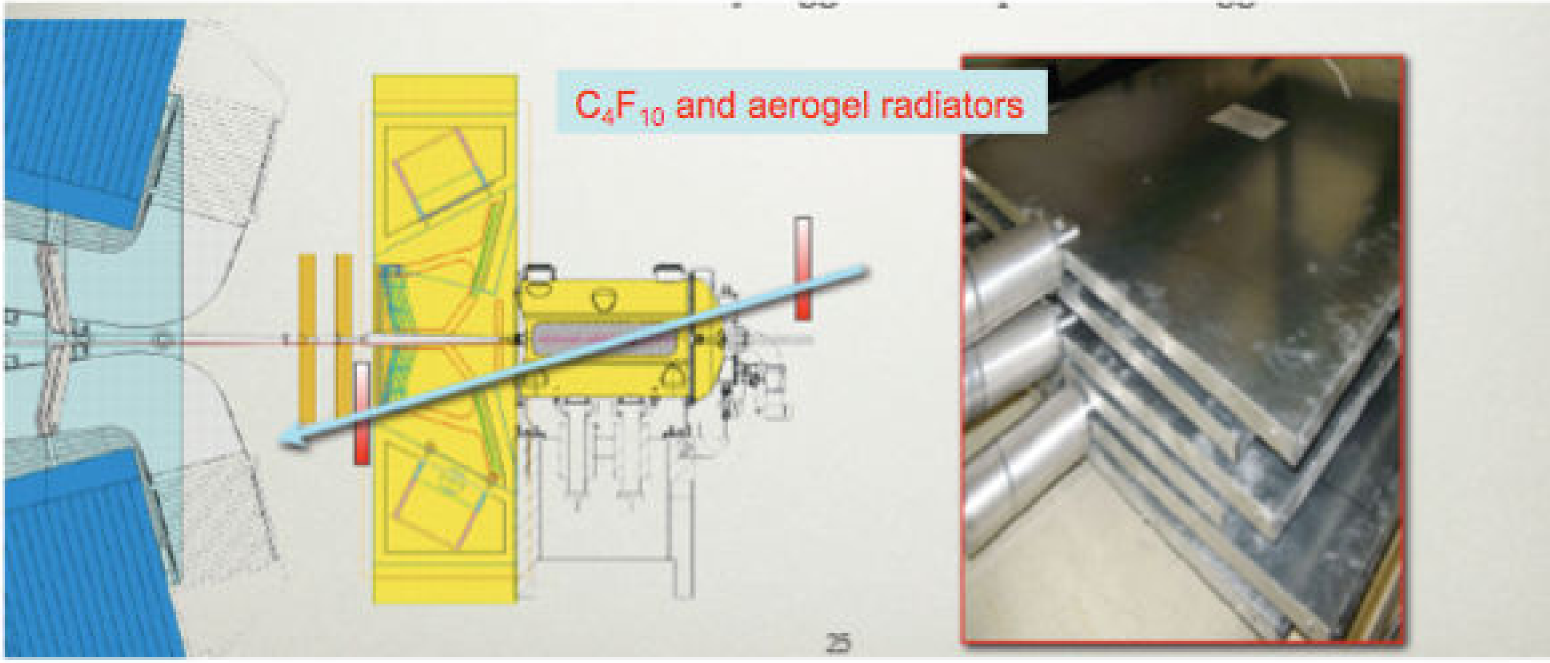


B. Schmidt

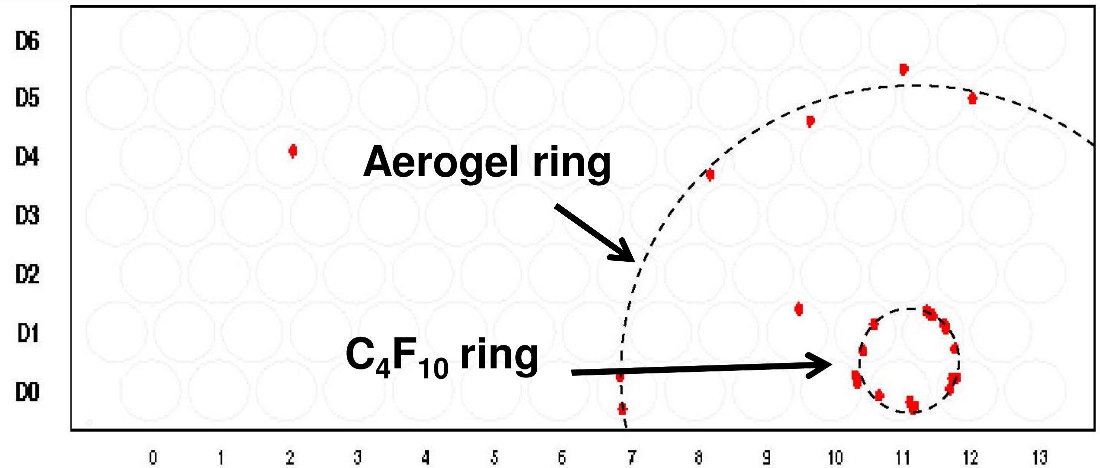
→ Excellent signal to noise ratio achieved by



Cosmic rays in RICH1

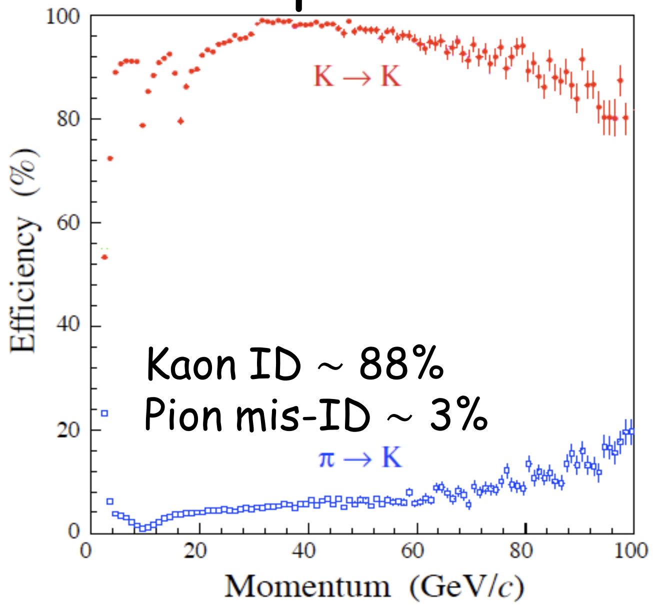


Ratio of the rings radii corresponds to the ratio of the C_4F_{10} and aerogel refractive indexes



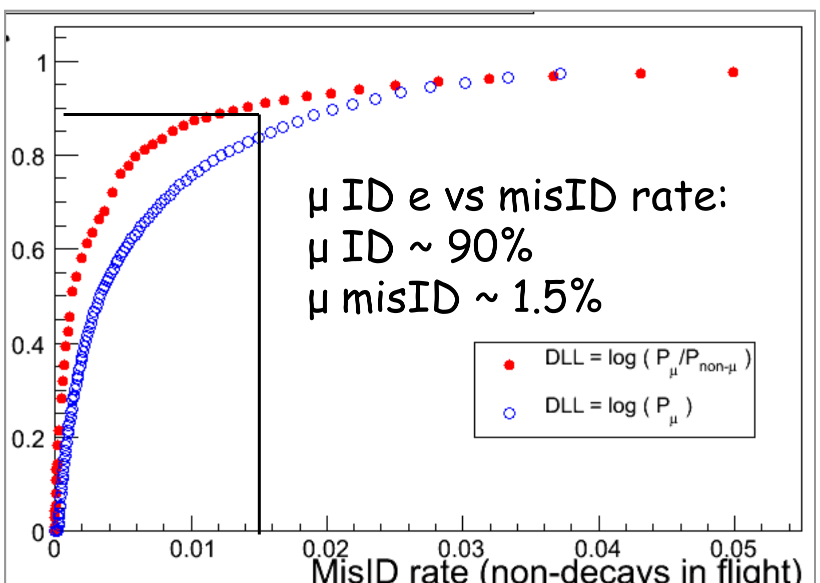
Expected Performances: PID

π−K separation

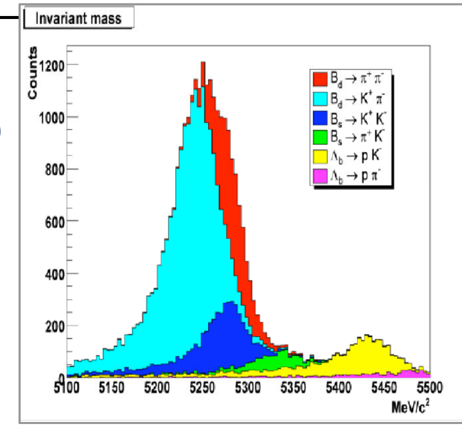


Good π−K separation in 2-100 GeV/c range

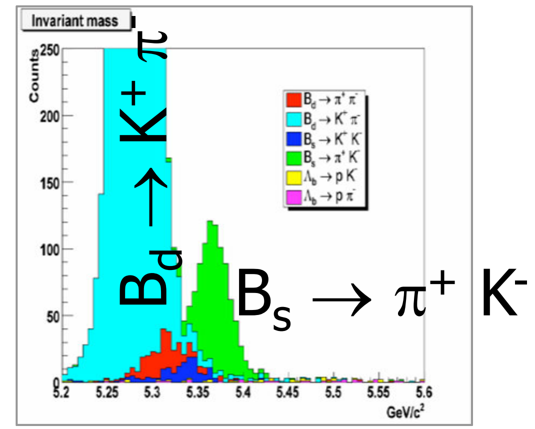
- Low momentum:
  - Tagging kaons
- High momentum
  - Clean separation of $B_{d,s} \to hh$ modes

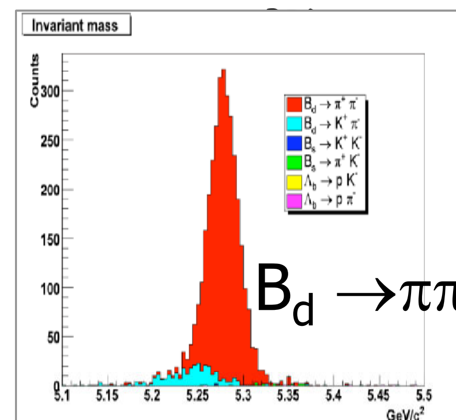


No PID



With PID





Calorimeter System

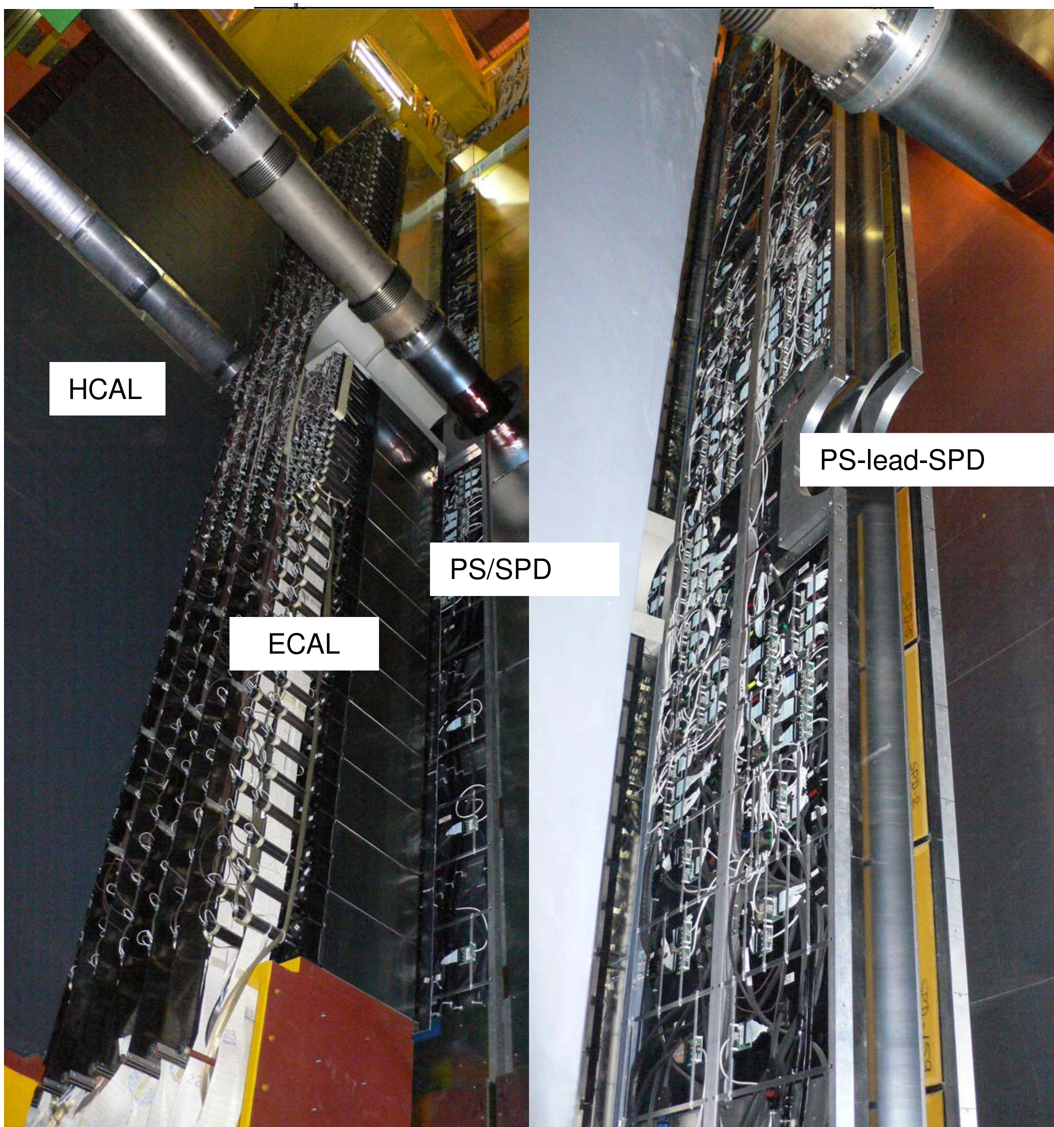
- HCAL, ECAL, Preshower, Scintillator Pad Detector to identify e, h, π^0,γ
- Triggering on high E_T electrons and hadrons, multiplicity (SPD)

SPD/PS
Scintillator Pad - $2X_0$ lead – Scintillator Pad
2 x 6016 pads, 15 mm thick; Granularity:
40x40 mm^2, 60x60 mm^2, 120x120 mm^2
WLS fibres are used to collect the light

ECAL Sashlik
66 layers of 2mm Pb/ 4mm scintillator: 25 X_0
6016 channels
Segmented in sections of 9,4,1 cell.
Light collected through WLS fibres bunch.

HCAL tile calorimeter
Iron-Scintillator longitudinal tiles
1468 channels, 5.6 λ_I

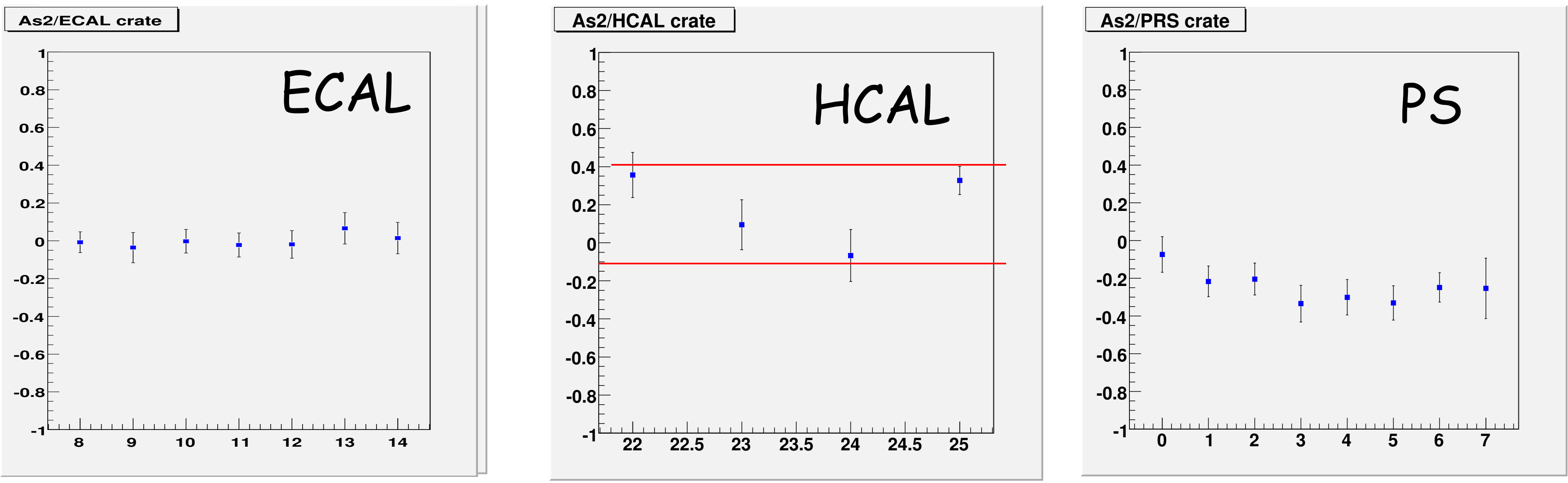
For all calorimeters
>99.9% channels working



Calorimeter Time Alignment

- **With cosmic rays:** timing estimation within a detector is
  - ECAL/HCAL :~3ns
  - PS/SPD : ~5ns
- **TED runs:** checks ECAL/HCAL/PS using asymmetry of deposited energy on 2 BX: $\frac{\text{Previous-Current}}{\text{Previous+Current}}$

After time alignment



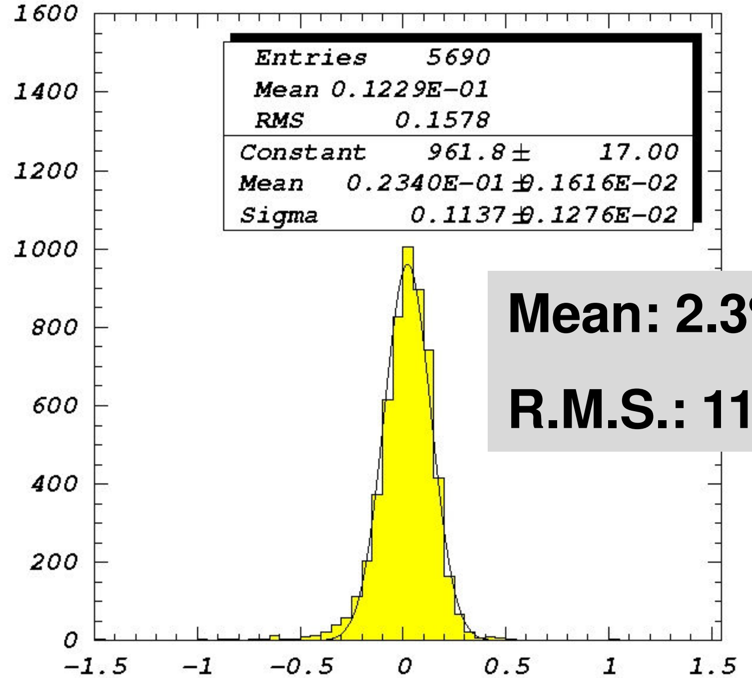
Calorimeter Gain Calibration

Comparison of the ECAL PMT gain measured in situ using the LED calibration system with previous measurements done in Hamamatsu

Taking into account that all modules have been measured with cosmics before the installation, ECAL is inter-calibrated to ~ 10% at the start-up

Several methods to reach 1% level using π^0 signals have been tested with MC data.

Regular gain calibrations for the HCAL are done with a ^{137}Cs source.



Mean: 2.3%

R.M.S.: 11.4%

(G(LED) – G(HAM)) / G(LED)

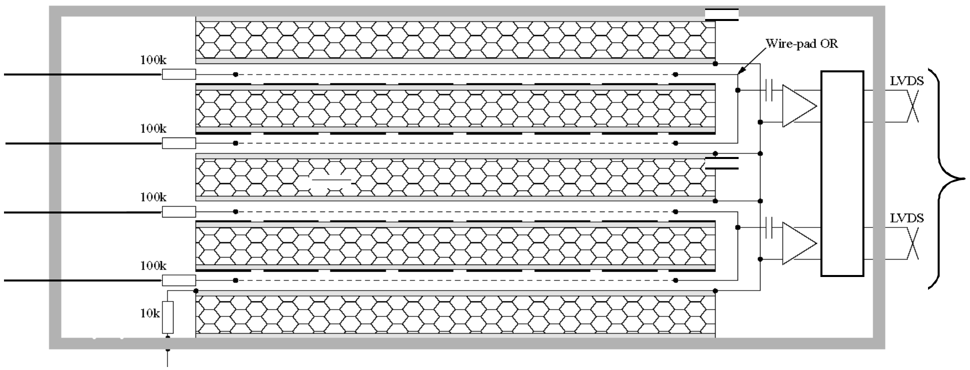
Muon System

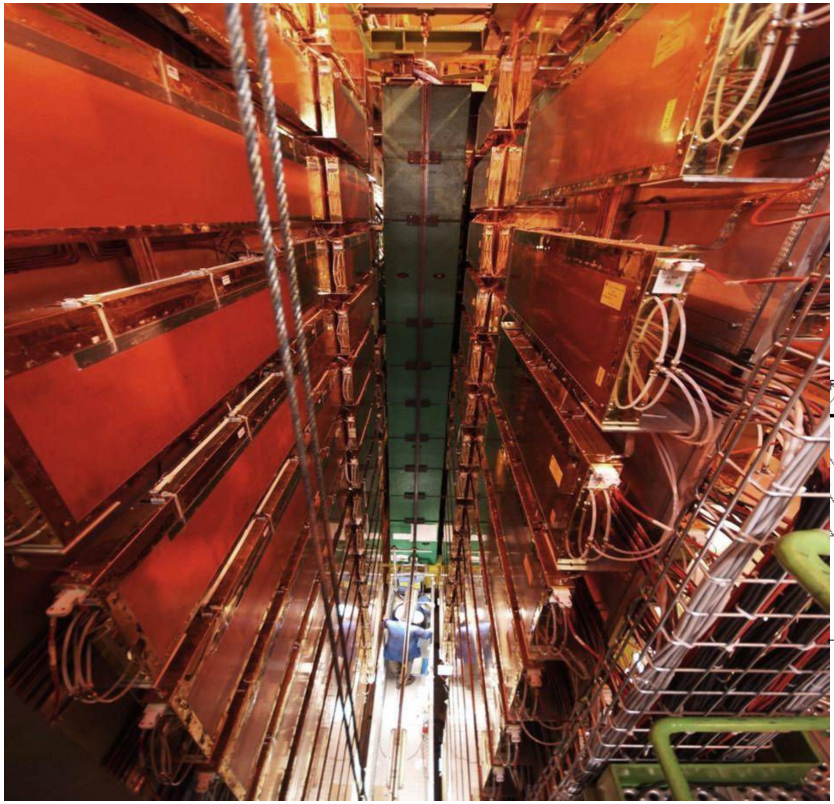
- Identification of muons
- Triggering on muons produced in the decay of b-hadrons by measuring P_T

- **5 Muon stations**, M1 in front and M2-M5 behind the calorimeters
- **Hadron Absorber of 20 λ**

- **4 regions** with different granularity, equipped with MWPC (4 gas-gaps); M1R1 uses triple GEMs Gas mixture: Ar/CO2/CF4

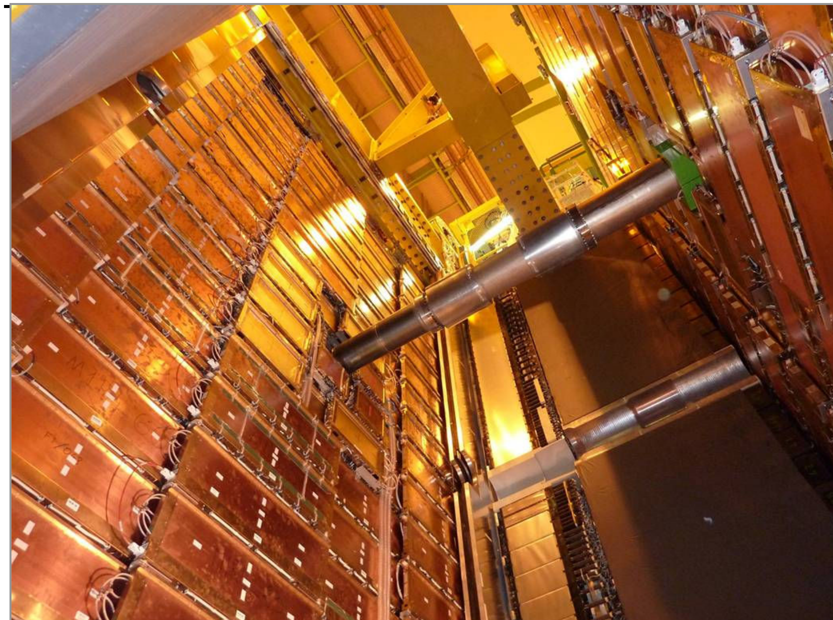
- 1380 chambers covering 435m^2 122k FE-ch., reduced to 26k r/o ch.



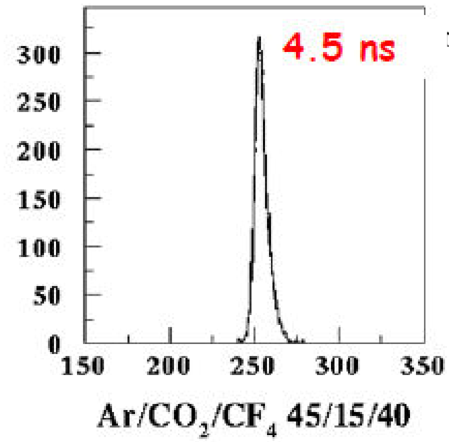


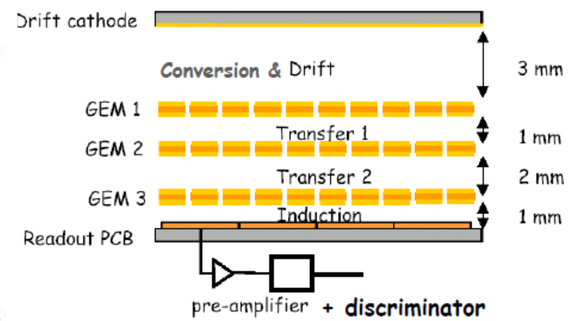
- >99.7% of channels operational
- Average station efficiency: 99.3% (corrected for non-projectivity of tracks and taken over several bunch crossings)

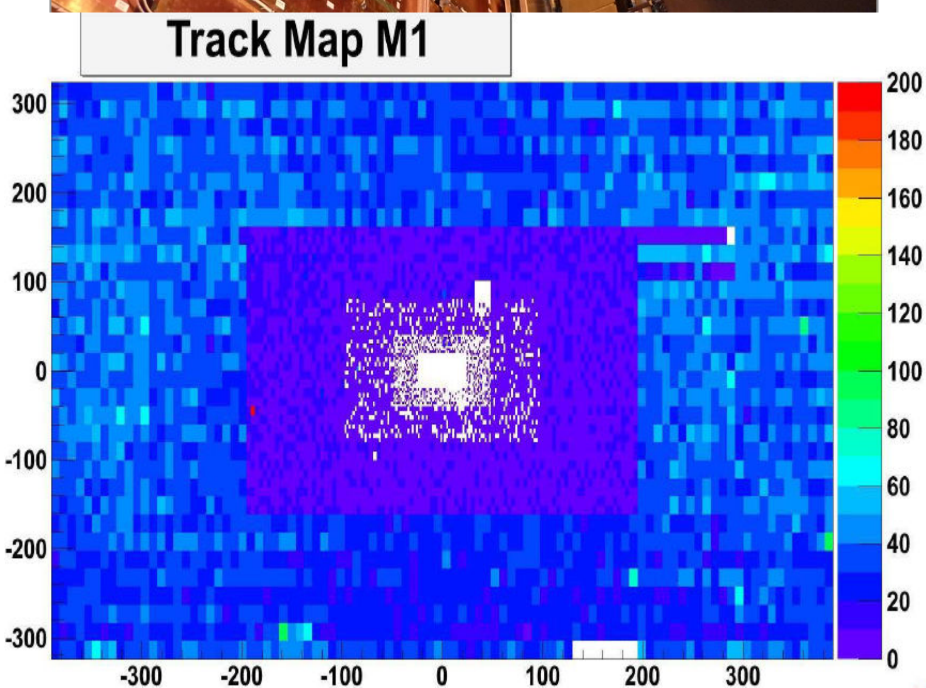
M1 readiness

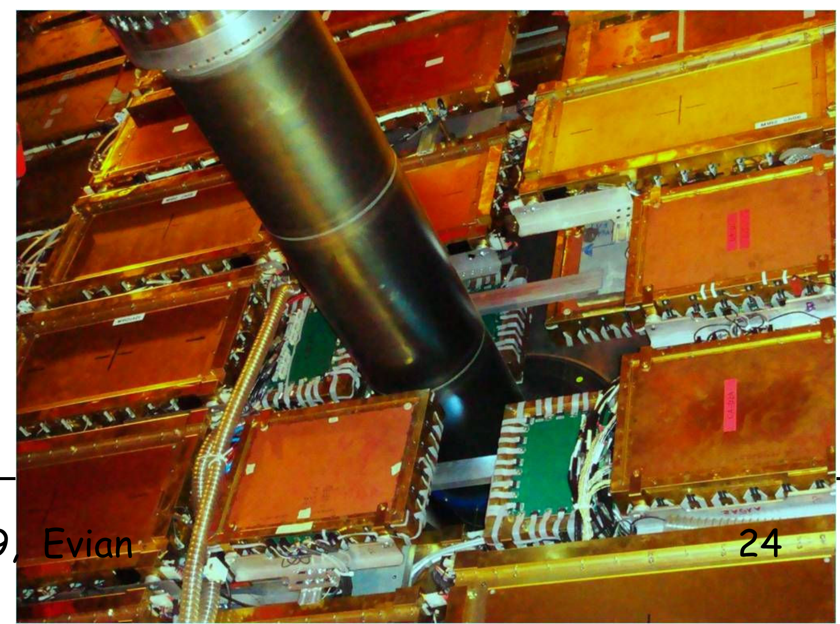


Triple GEMs in M1:

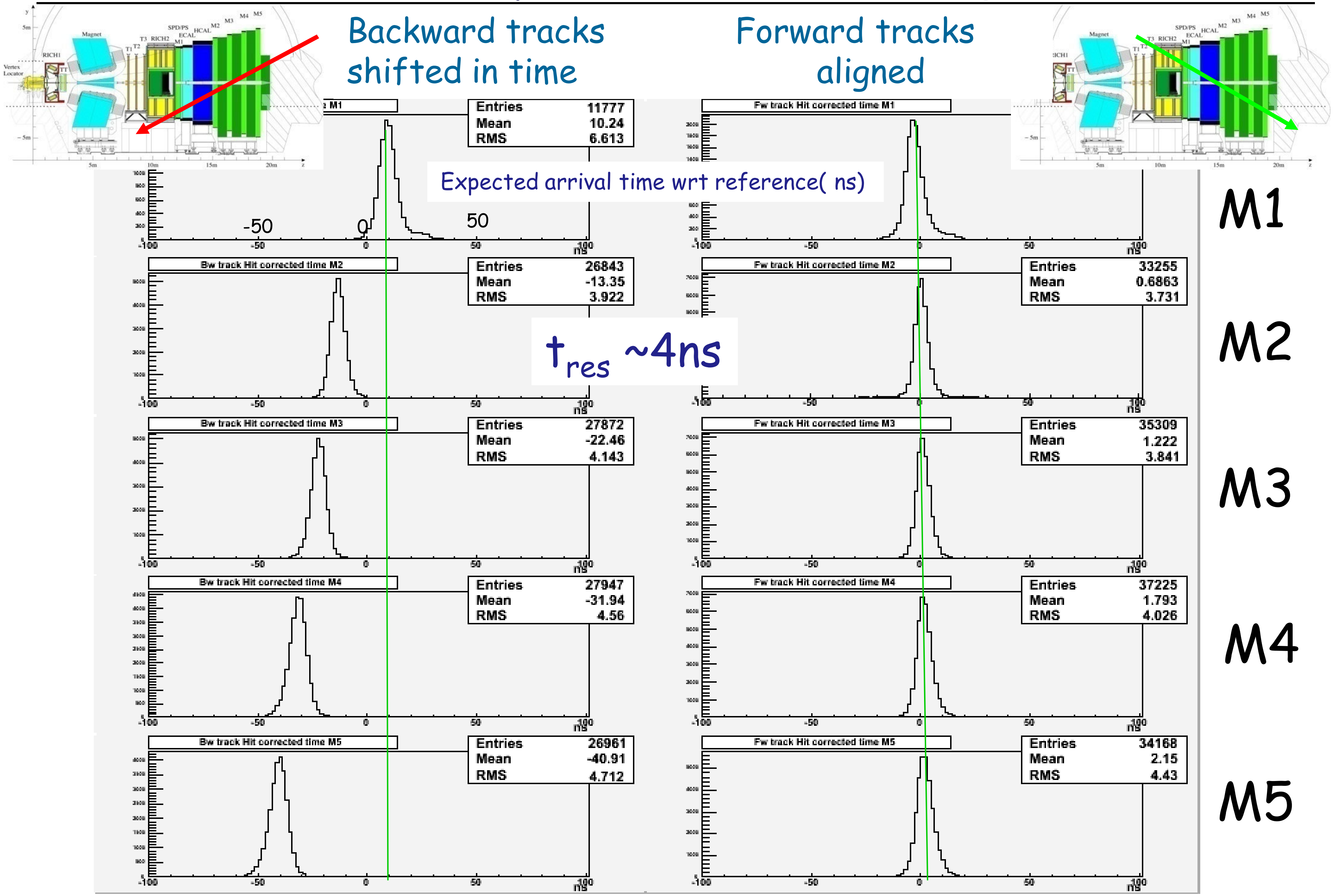




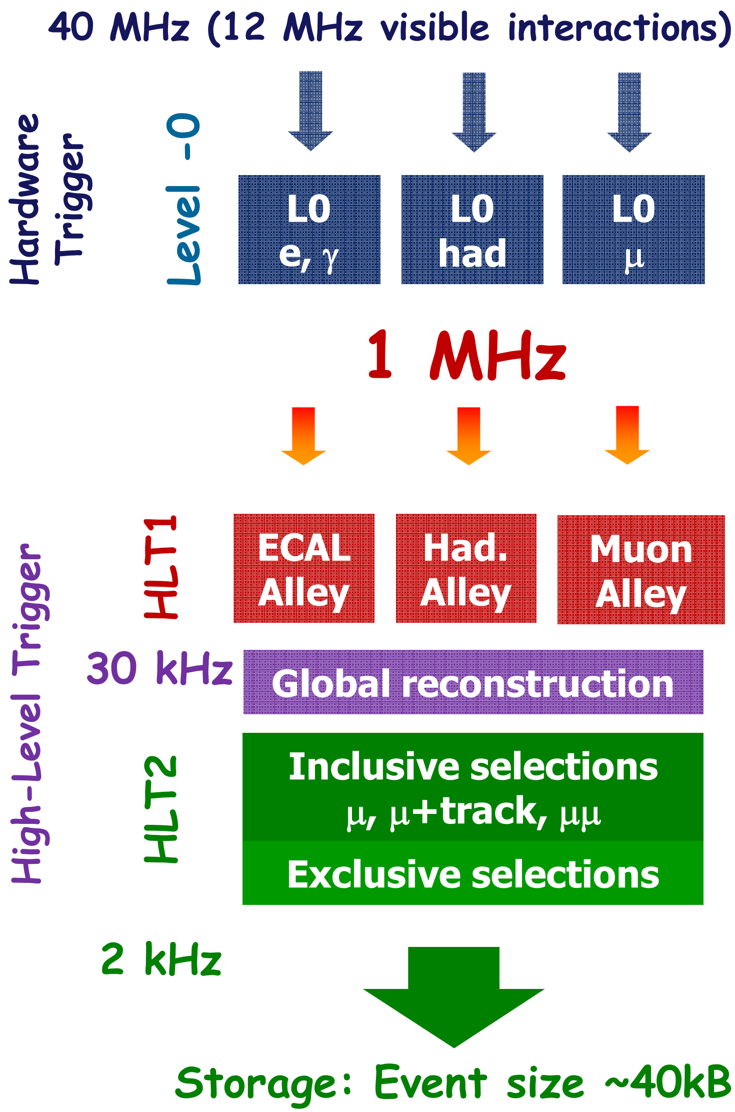




Muon system Time Alignment



LHCb Trigger



Trigger is crucial as σ_{bb} is less than 1% of total inelastic cross section and B decays of interest typically have BR < 10^{-5}

High Level Trigger (C++ application)

Event Filter Farm with up to 1000 16-core nodes

HLT1: Check L0 candidate with more complete info (tracking), adding impact parameter

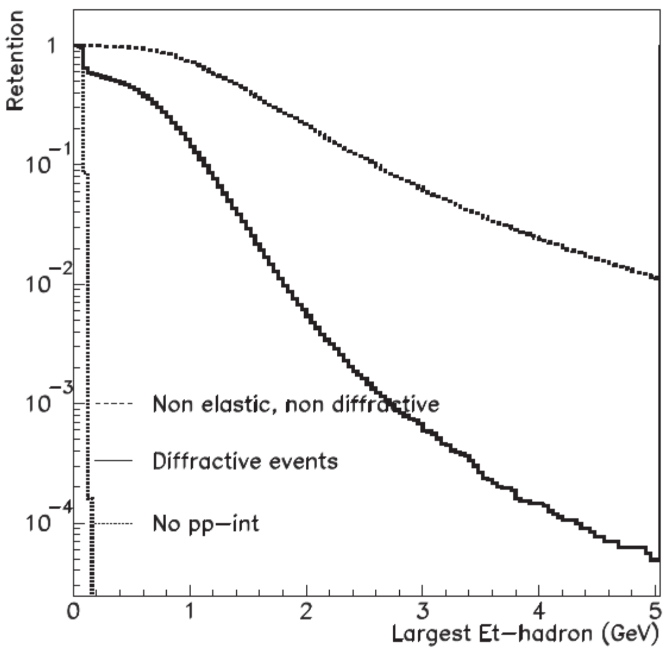
HLT2: global event reconstruction + selections.

	ε(L0)	ε(HLT)	ε(total)
Hadronic	50%	80%	40%
Electromagnetic	70 %	60%	40%
Muon	90%	80%	70%

First Minimum Bias Events

- Large Minimum Bias samples will be collected as soon as the LHC delivers p-p collisions
  → 10^8 events O (day) @ 2kHz

- Simple (and unbiased) interaction- or MB-triggers:
  - (HCAL > 500 MeV AND SPD > 2)
    OR (L0Muon > 500 MeV)
  - Scintillator Pad detector
    - Cut on SPD multiplicity
  - Hadron Calorimeter
    - Cut on largest E_T hadron
  - Later on also ECAL



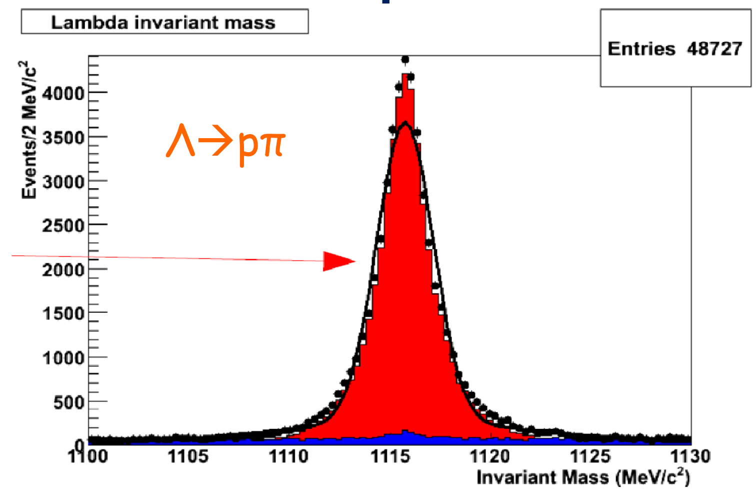
First Minimum Bias Events

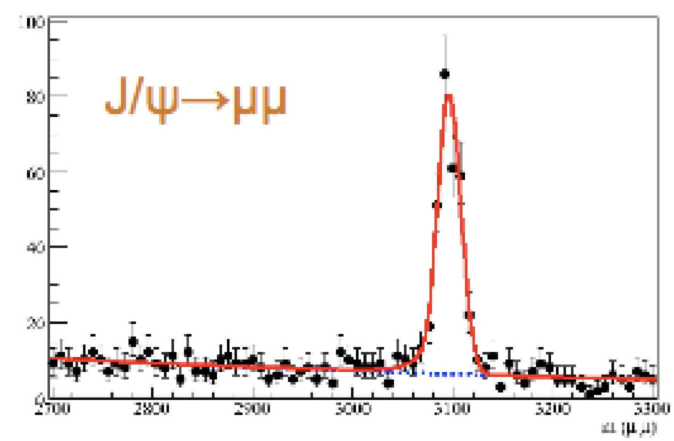
- **Minimum Bias samples will be used for PID-studies and -calibration**

- **Very large clean samples of Ks → ππ and Λ → pπ**

- 95% purities achievable using kinematical and vertex cuts

~ 40 mins @ 10^{31} $cm^{-2}s^{-1}$ with
2 kHz interaction trigger



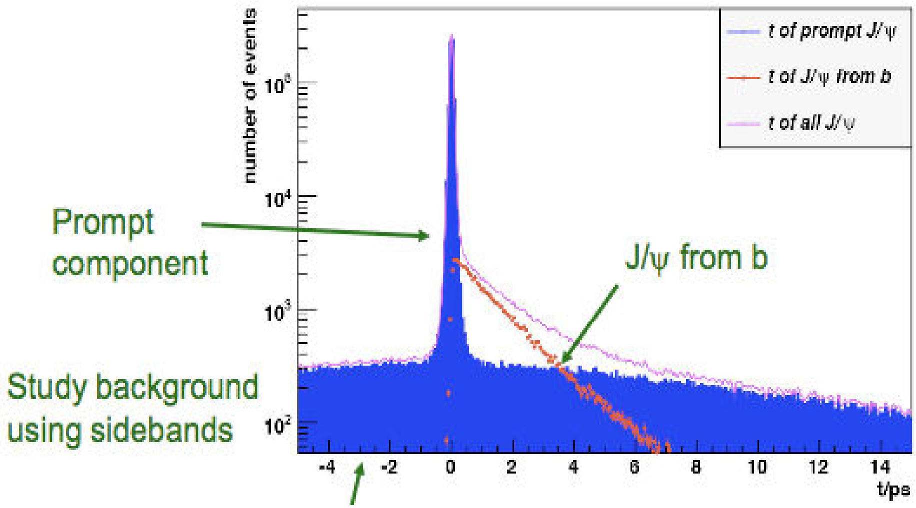


- **J/ψ trigger on single muon with p_T cut ($6x10^5$ev/pb^{-1})**

→one muon unbiased for PID studies
and momentum calibration

First Measurements in 2010

- **J/ψ physics & production cross-sections: ~ 1-5 pb^{-1}**
- Use fit to proper time distribution to disentangle fraction of prompt from detached J/ψ component
- Measure diff. cross-section for prompt J/ψ and and bb production cross-section (from secondary J/ψ) in region inaccessible to other experiment



- **D-meson production**
  Detailed studies of D→hh are an important step to understand B→hh channels

- **Exclusive B- and D-decays**
  Analysis commissioning in hadronic modes

- **Charm physics 20pb^{-1} and upward**
  Exciting possibilities even with low luminosity

Channel	Yield / 10 pb^{-1}
$B^0 \to K\pi$	340
$B \to D(K\pi)X$	31k
$B^+ \to D(K\pi)\pi^+$	1900
$B^+ \to D(K\pi)K^+$	160
$B_s \to D_s\pi^+$	320

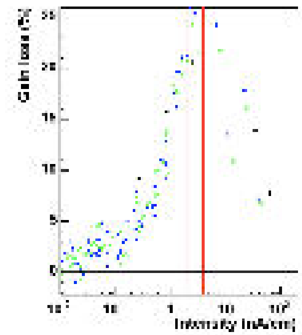
Conclusions

- The installation of LHCb is fully completed, and all detector elements are commissioned and ready for data taking.
- Cosmics and LHC induced tracks (TED runs) were very useful to commission the detector.
- Large Minimum Bias data samples will be collected in the forward region at a rate of 2kHz, as soon as the LHC delivers pp-collisions.
- First data will be used for calibration of the detector and trigger in particular, followed by a first exploration of low P_T physics at LHC energies.

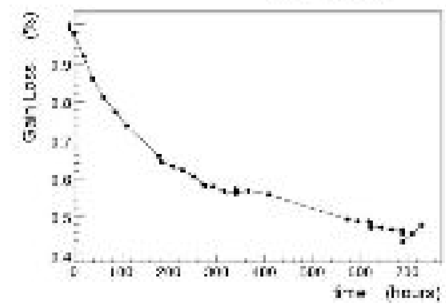
→ **LHCb is fully operational for the Physics Run in 2010**

Backup

Aging Studies

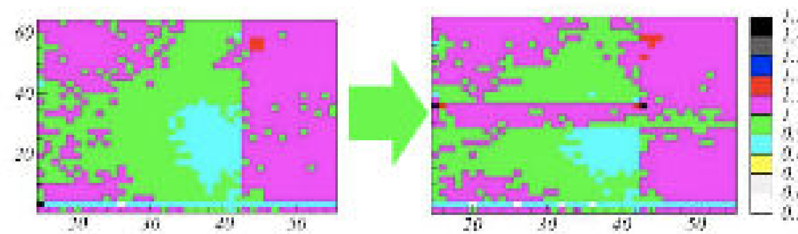


- *The LHCb OT shows ageing*
- *Ageing is caused by glue (Araldite AY 103-1 + HY 991)*
  - *only at moderate irradiation intensities (~3 nA)*
  - *only upstream of the irradiation source → ozone*
  - *Composition of AY 103-1 now known*

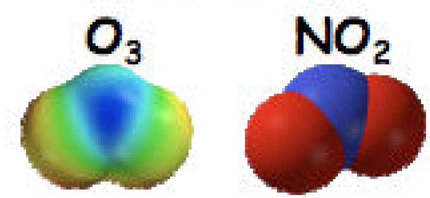


- ***Long-term flushing and heating reduce ageing***

- ***The addition of O2 to the gas reduces ageing***
  - *Small reduction of signal response due to O2*
  - *No influence on drift properties*
  - ***2% will be added to the gas mixture***



- *HV training can repair the ageing damage*
  - *Does not damage anode wire*



- *Downstream prevention of ageing is due to **ozone***
  - *Next test: find stable substances with similar ability*
    - *Tests with NO2 are ongoing.*

M.Blom, "Ageing Studies on the LHCb OT", 11th Pisa meeting on advanced detectors