LHCb

- Une expérience dédiée à la violation de CP au LHC
  - → mesure de précision dans le domaine des mésons beaux et charmés

Les hadrons beaux

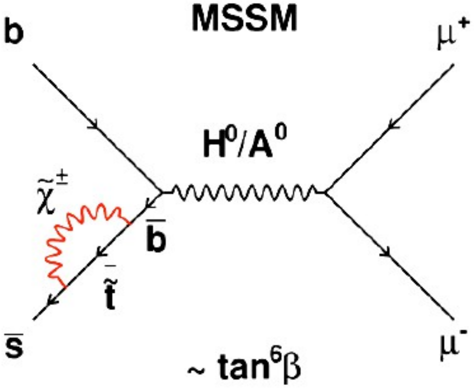
Les mésons neutres : B^0 / B_d ($b\bar{d}$) et B_s ($b\bar{s}$)

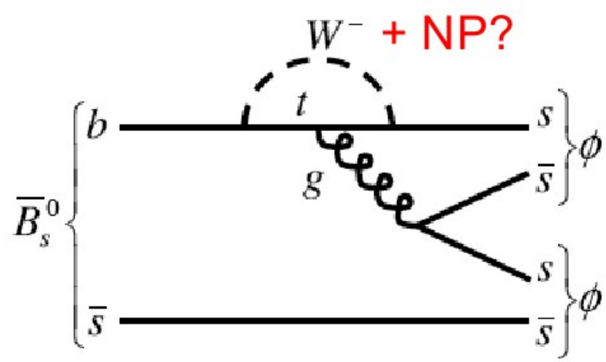
- → oscillent comme les kaons
  - mais plus rapidement
- → masse :
  - B_d = 5.3 GeV/c^2
  - B_d = 5.4 GeV/c^2
- → durée de vie : τ = 1.5 10^{-12} s
  - D = ~ 1 cm

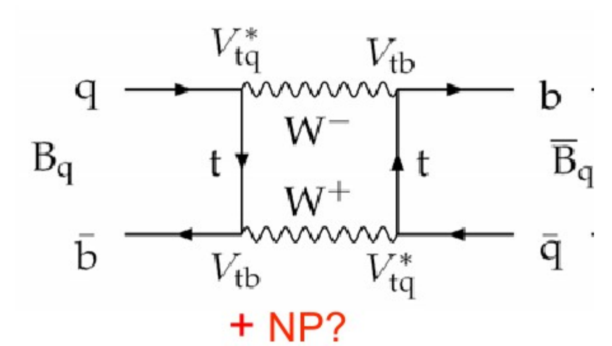
LHCb : a dedicated flavour physics experiment at LHC

ATLAS & CMS search for direct production of new states

LHCb designed to see their indirect effect on charm & beauty decays via virtual production in loop diagrams







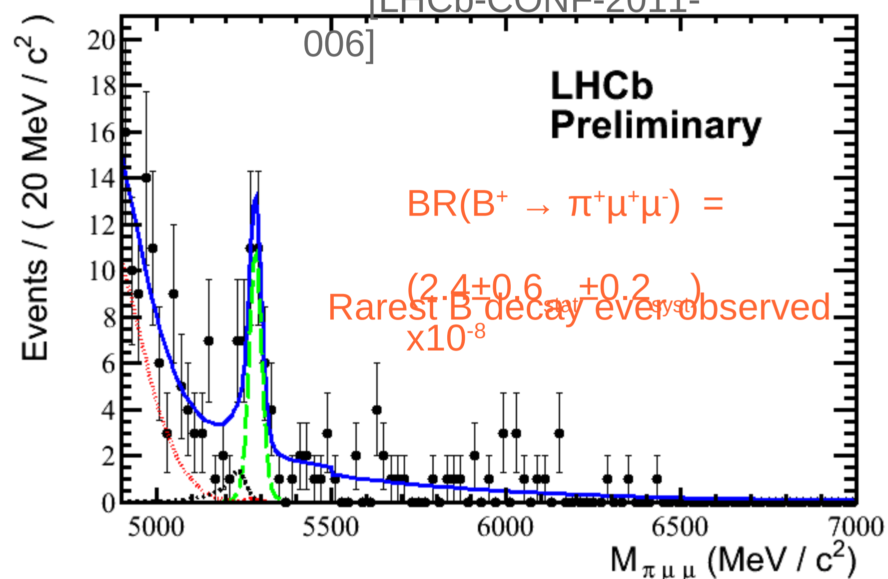
Key topics in LHCb :

- CP violation : check whether it is due to a single phase in the quark mixing (CKM) matrix, as in the Standard Model
- Rare decays : FCNC decays (e.g. BS → μ+μ-) are strongly suppressed in the Standard Model, may be enhanced by new physics processes

Beauty and Charm production at LHC

LHC is a Flavor Factory, @ 7 TeV :

- σ(pp → cc X) = ~ 6 mb [LHCb-CONF-2010-013]
- σ(pp → bb X) = ~0.3 mb [PLB 694 (2010) 209]
- B factories : σ(e+e- → bb)@Y(4S) = ~ 1 nb



[LHCb-CONF-2011-006]

BR($B^+ \to \pi^+\mu^+\mu^-$) = ($2.4 \pm 0.6_{stat} \pm 0.2_{syst}$) $\times 10^{-8}$

Rarest B decay ever observed

Challenging background condition :

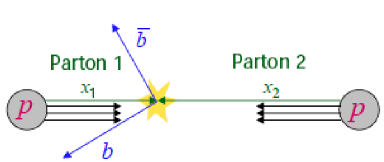
- σ(pp →X)inel = 60 mb [JINST 7 (2012) P01010]

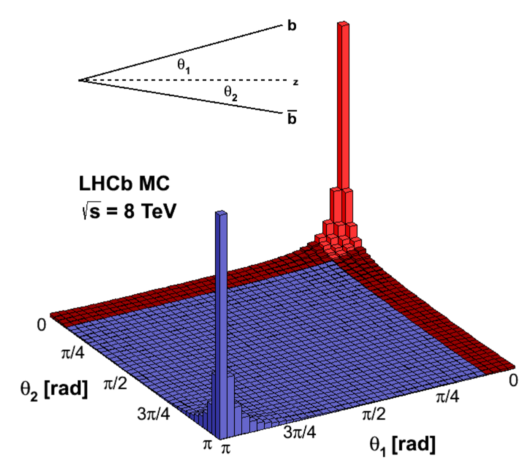
All B hadron species are produced

cf. P. Bobovici's talk

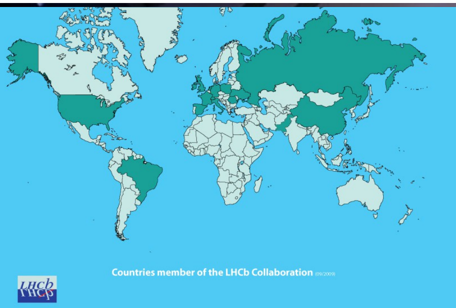
- New states discovered, e.g. Λb*(5912/5920) orbitally-excited states [arXiv:1205.3452v1]
- New decay mode discovered, e.g. BC+ → J/Ψ π+π-π+ [PRL 108, 2012, p. 251802]
- BS is rich and little explored

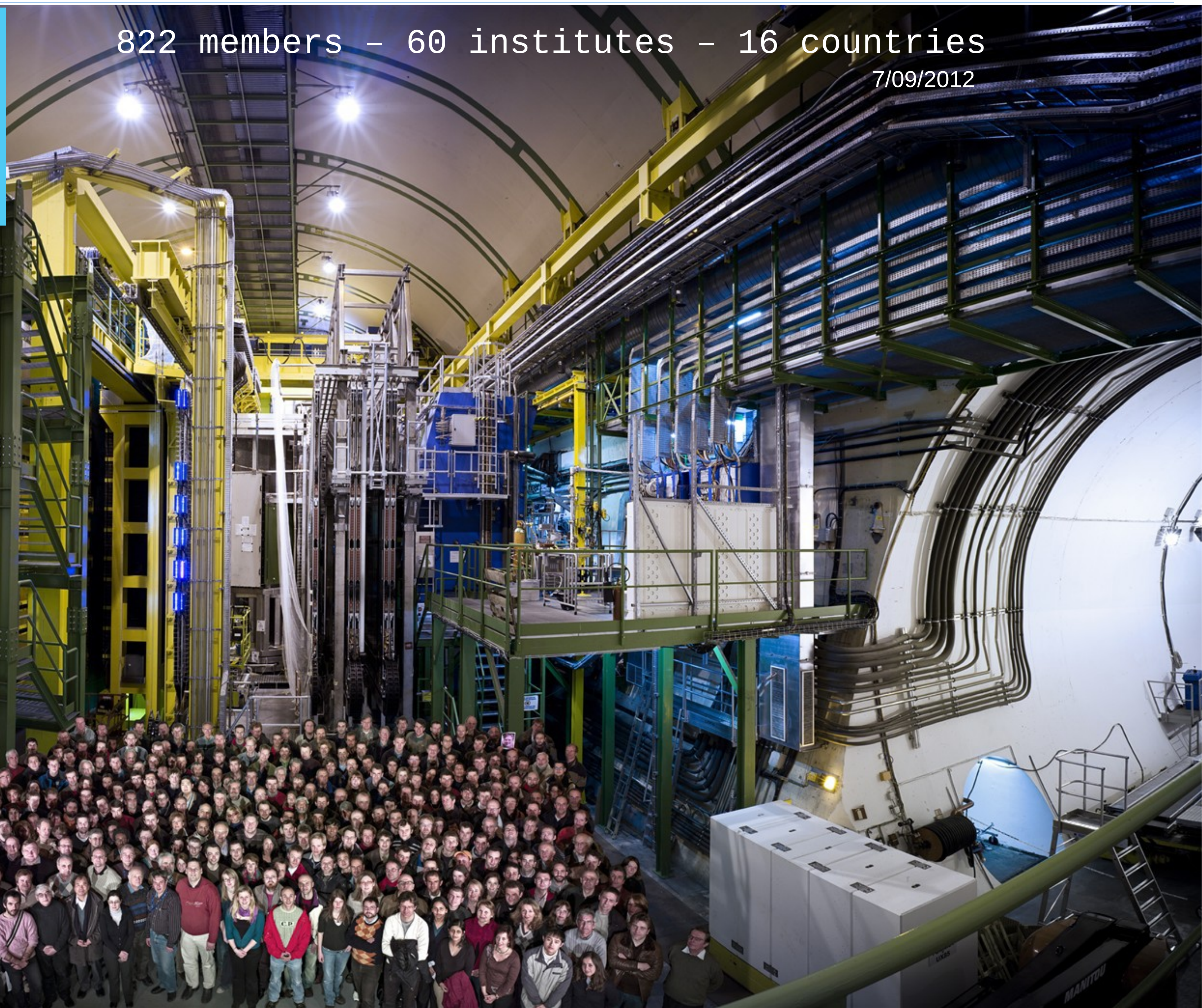
bb/cc pairs are produced predominantly in the forward or backward directions





The LHCb Collaboration



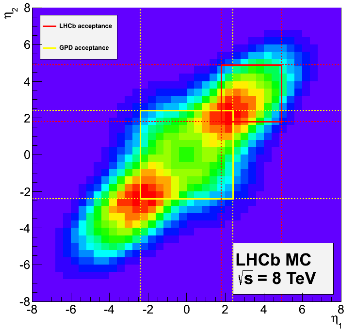


822 members – 60 institutes – 16 countries

7/09/2012

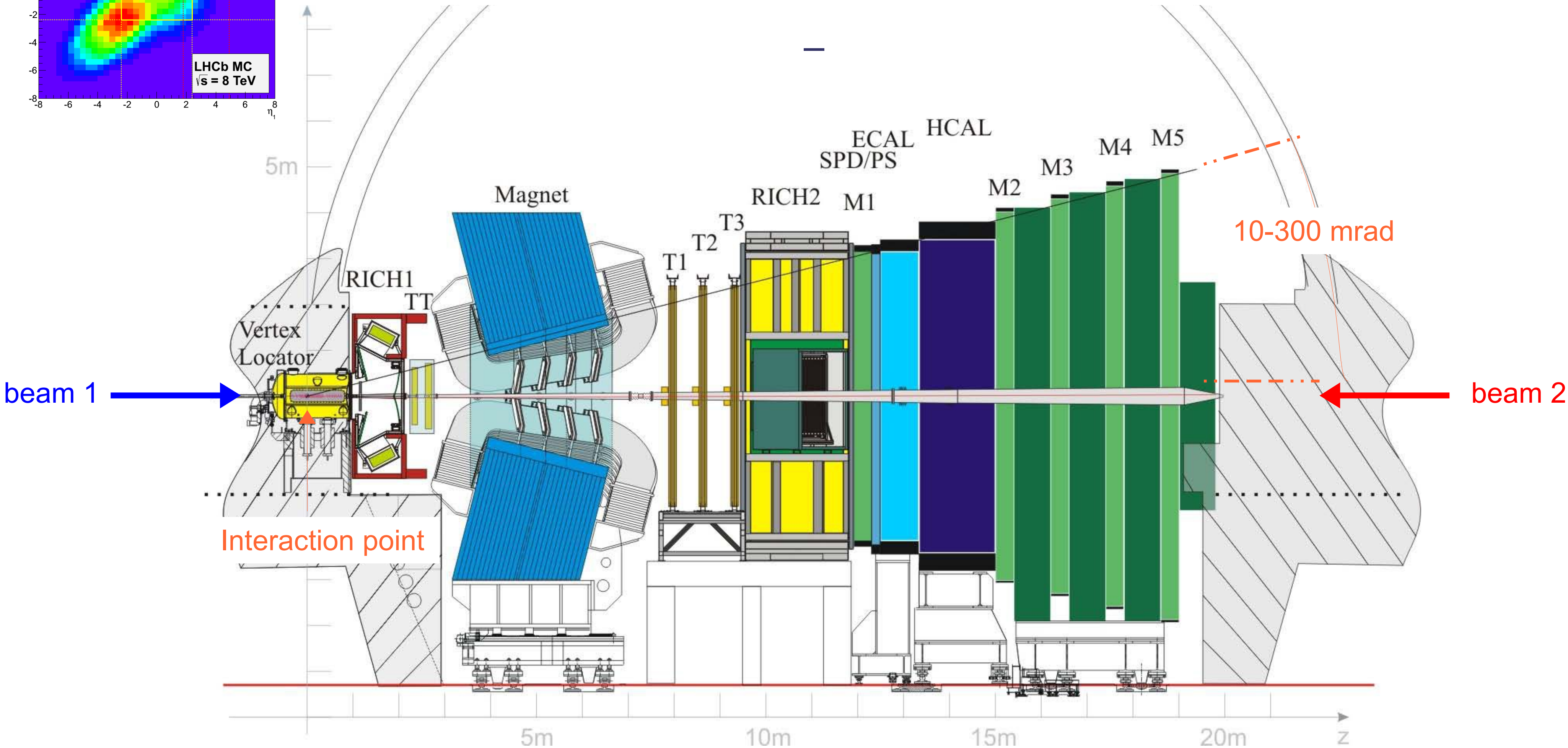
LHCb : a forward spectrometer

B forward-peaked production → LHCb is a forward spectrometer



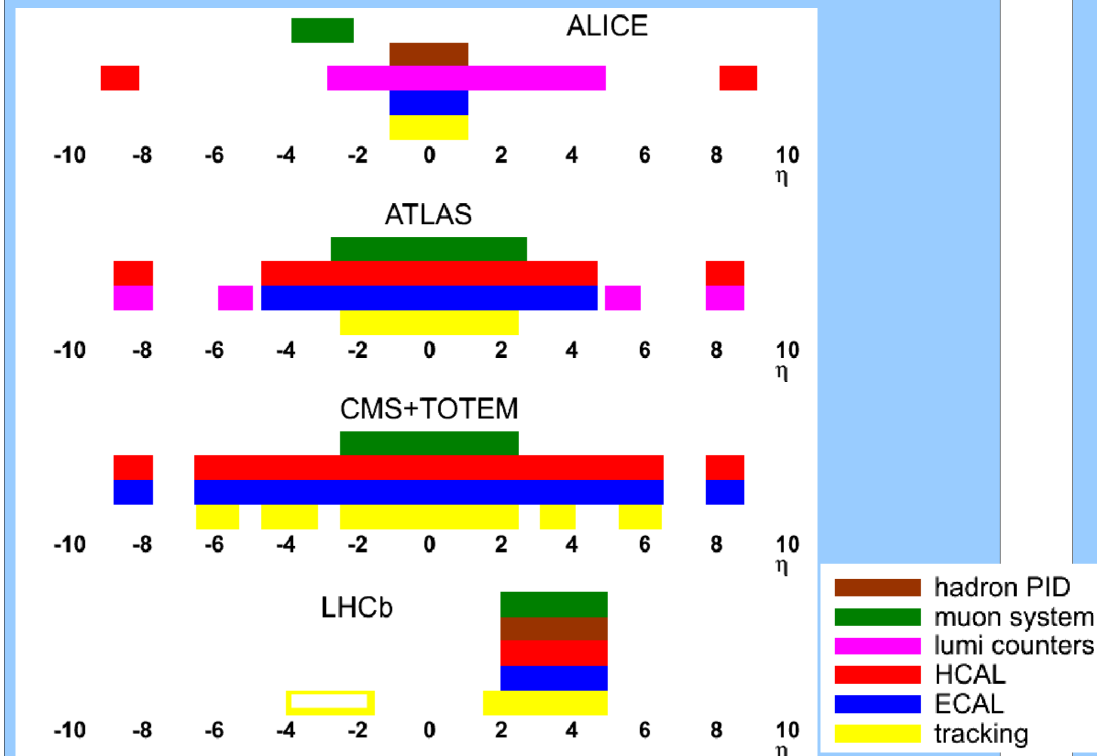
– (operating in collider mode)

–



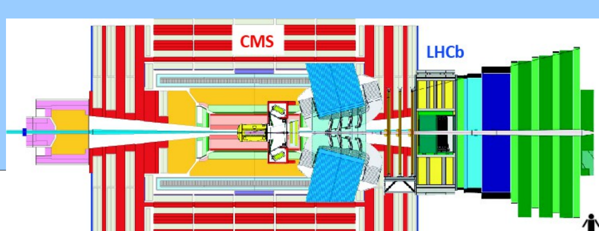
LHCb : a forward spectrometer

With unique rapidity coverage at LHC



– LHCb acceptance : 2 <η < 5

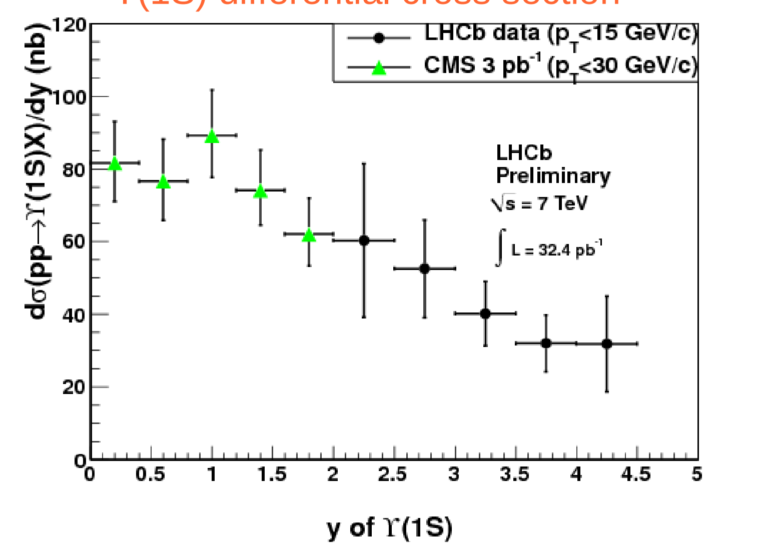
– fully covered by tracking and PID



→ complementary measurements

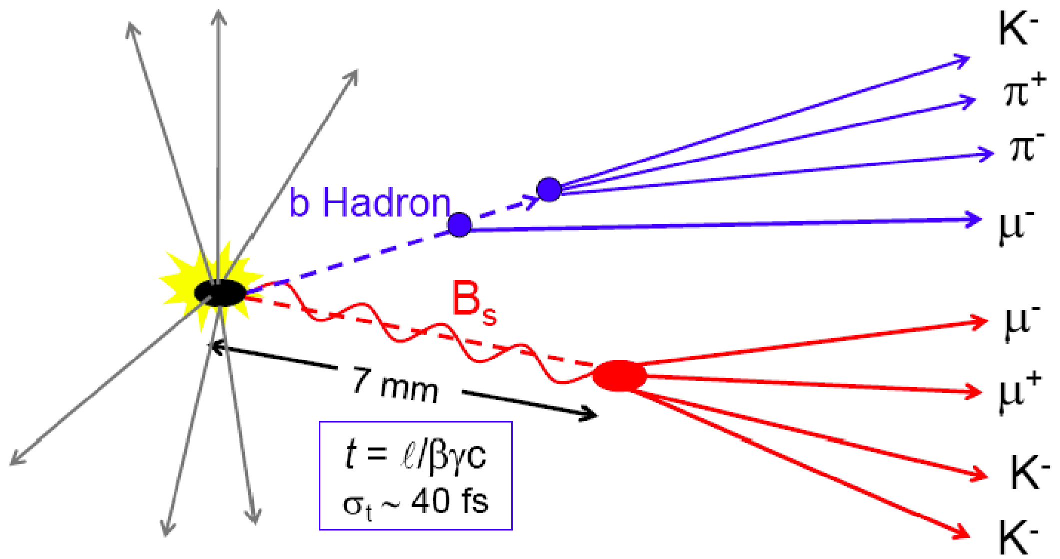
W charge asymmetry

Υ(1S) differential cross section



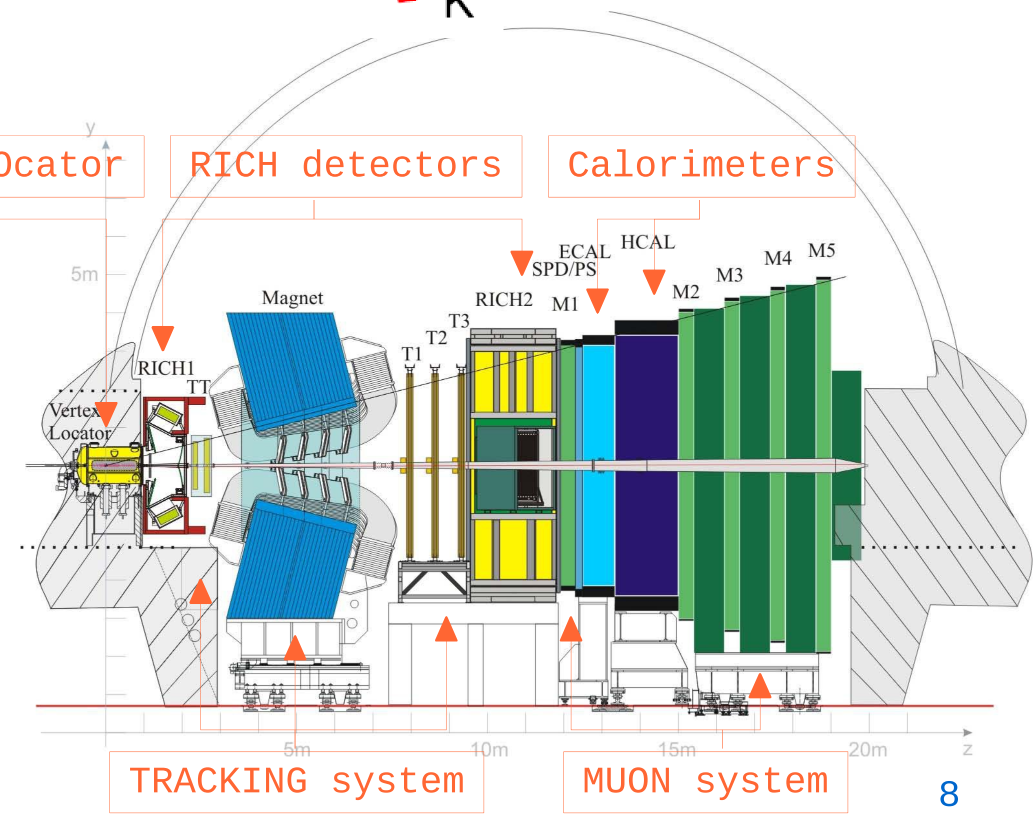
LHCb : a forward spectrometer optimised for heavy flavors

Typical topology :

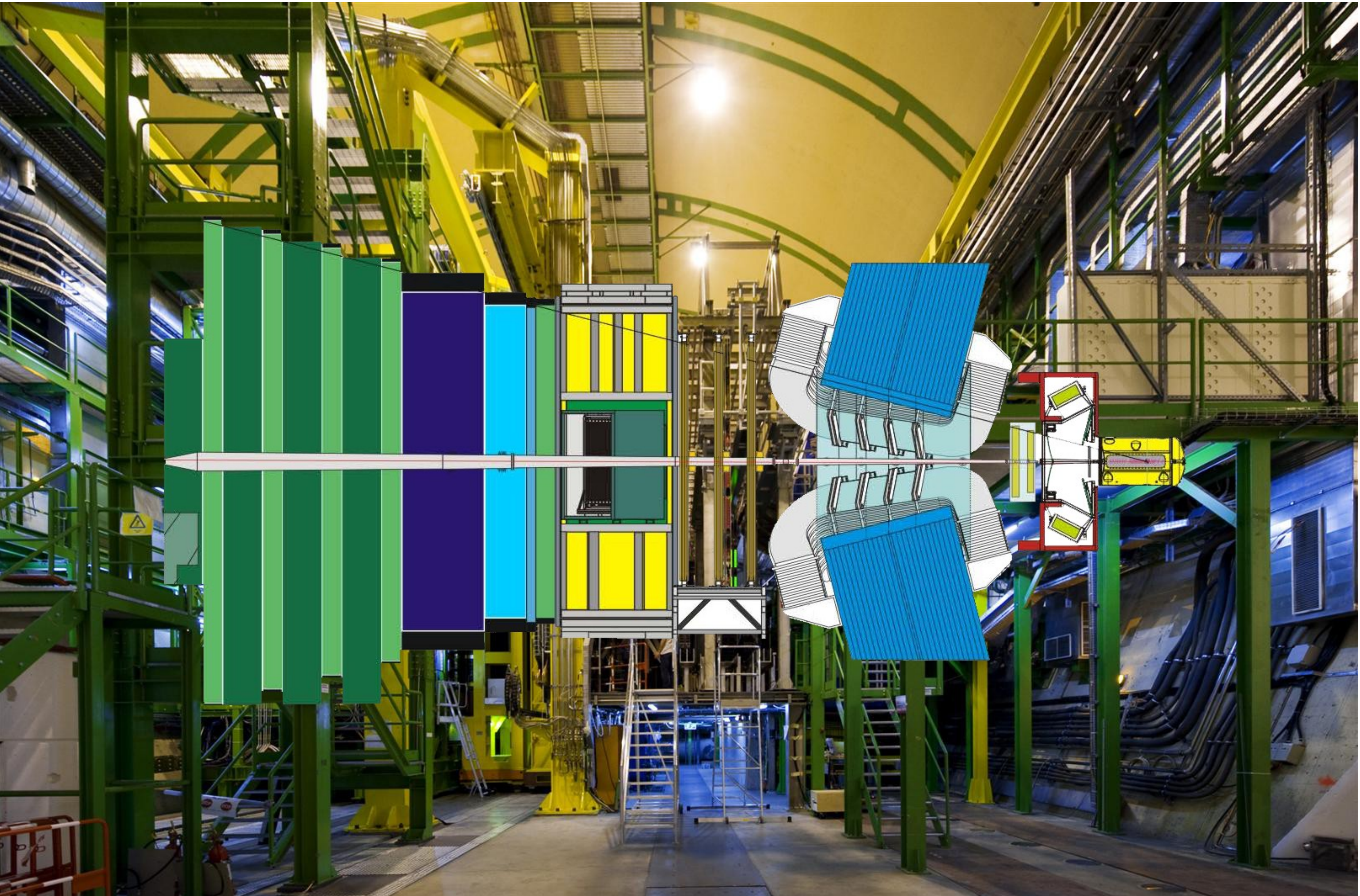


Key features :

- Resolve fast BS oscillation
  - → excellent vertex resolution
- Background reduction :
  - → very good impact parameter resolution
  - → good mass resolution
  - → good particle identification (K/π)
- Collect high statistics :
  - → efficient trigger for both hadronic and leptonic final states

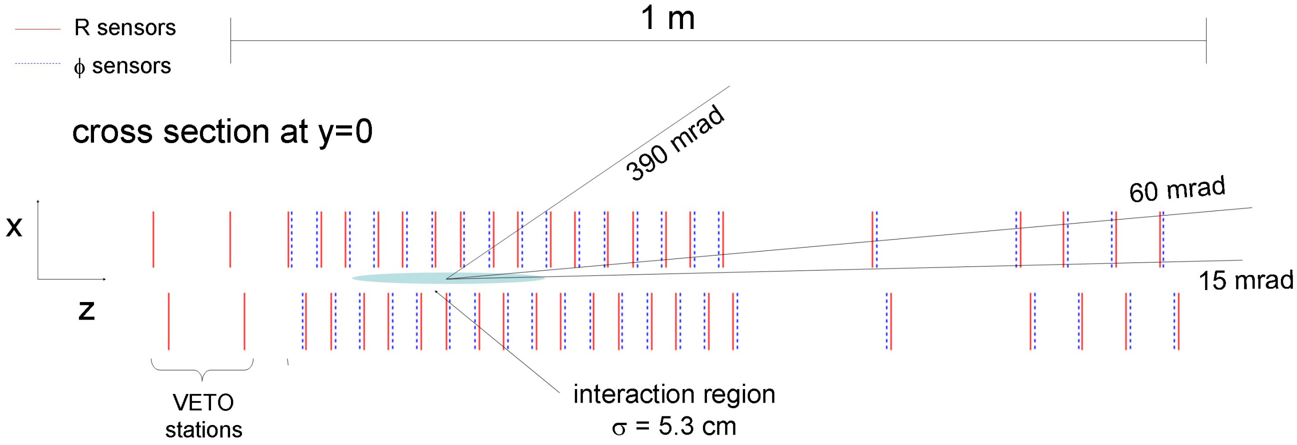


LHCb detector

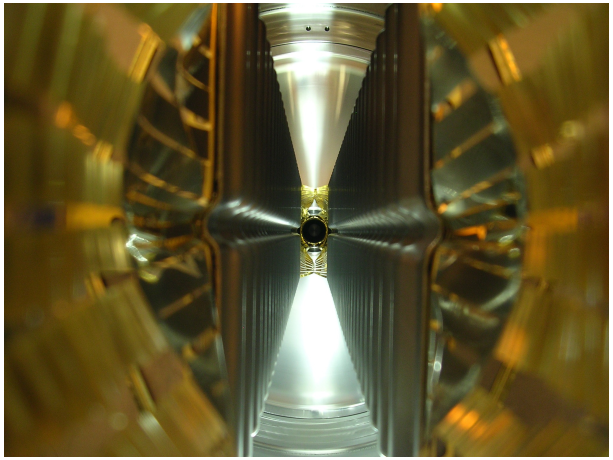


Vertex detection : the VErtex LOcator (VELO)

Reconstruction of primary and decay vertices, track seeds, + trigger input



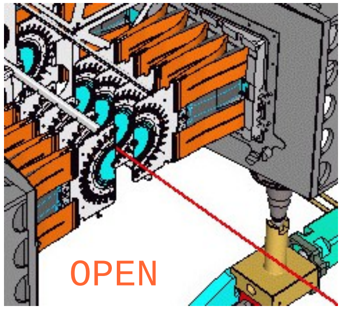
The VELO seen by the LHC beams

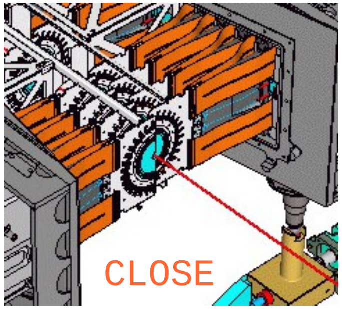


21 modules of R-Φ sensors

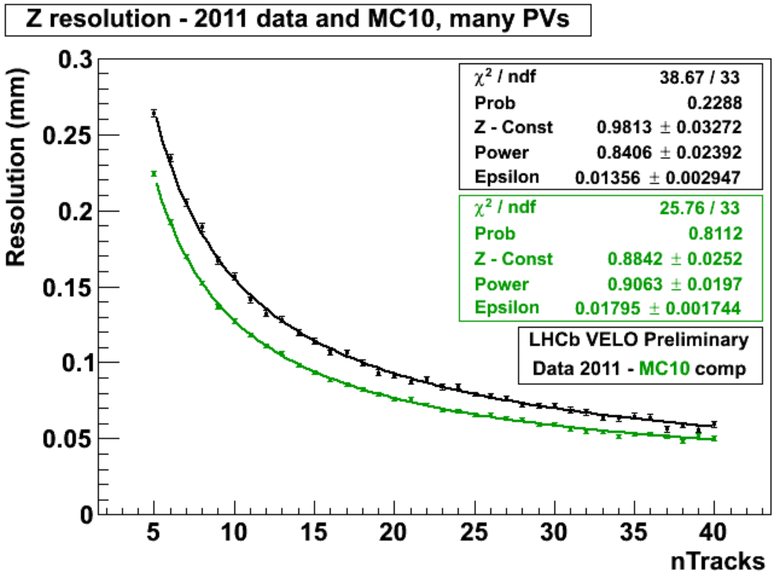
Movable device (retracted for safety during beam injection) :

- 35 mm from beam out of physics
- 8 mm from beam during physics

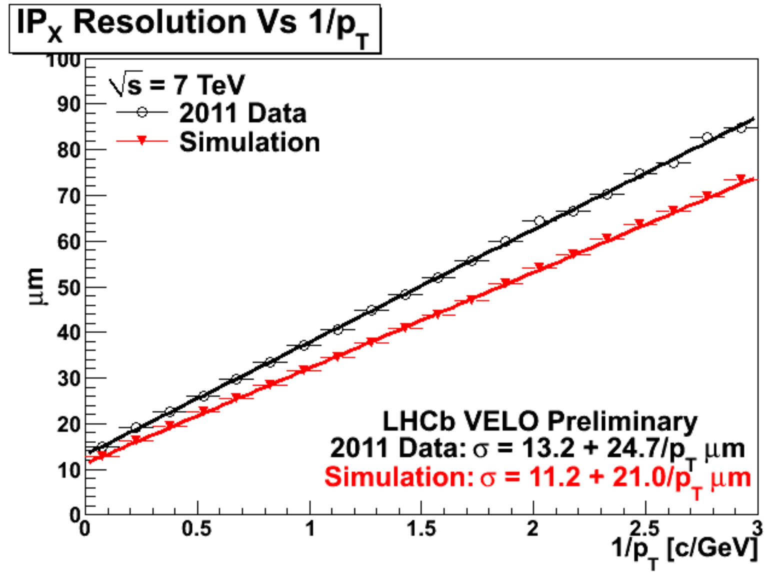




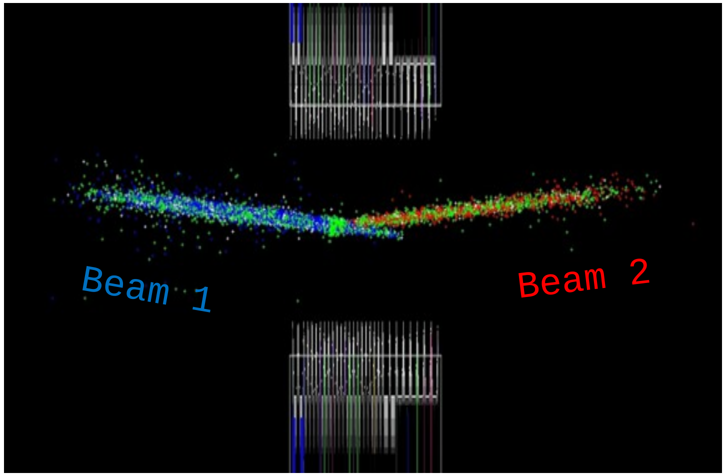
Vertex detection : performances



For 25 tracks : $\sigma_X \approx \sigma_Y \approx 16$ μm, $\sigma_Z \approx 76$ μm

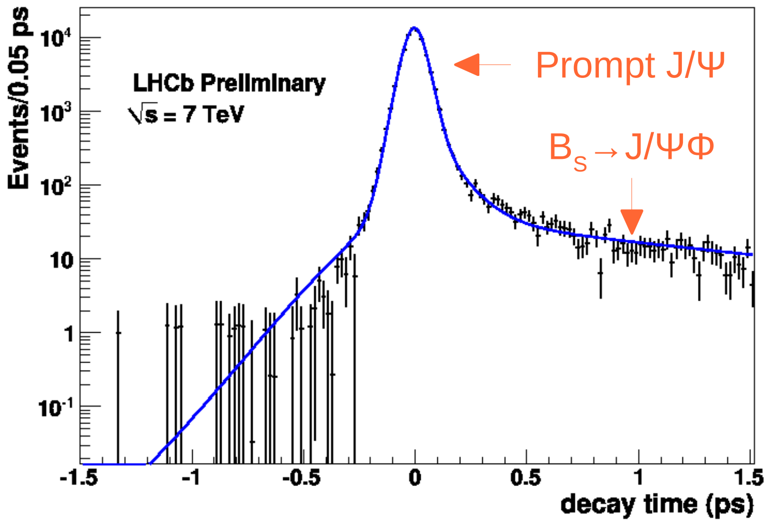


Impact parameter resolution
for high p_T track : ~ 20 μm



[PLB 693 69]

Reconstructed beam-gaz vertices
(used for luminosity measurement)



[CONF-2012-002]

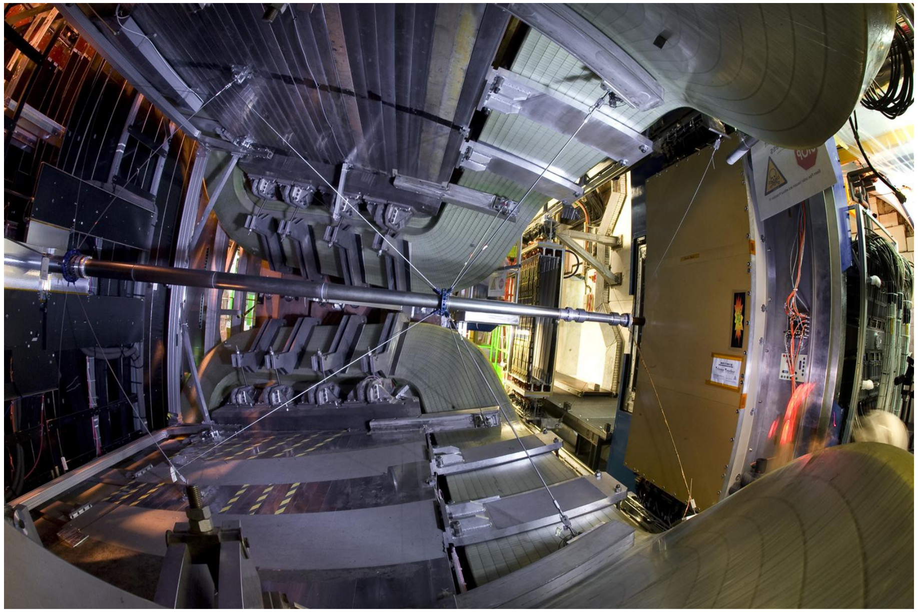
Proper time resolution : σ_t = ~ 45 fs
(cf. $\lambda = 2\pi/\Delta m_s$ ~350 fs)

The Tracking System

System :

- 1 tracking station before magnet (TT) :
  - → 4 layers of Si-Strips sensors
- Magnet
  - → ∫Bdl = ~ 4 Tm ; polarity switched regularly
- 3 tracking stations after magnet,
- 4 layers each split into:
  - → Inner Tracker (Si-sensors)
  - → Outer Tracker (straw tube)

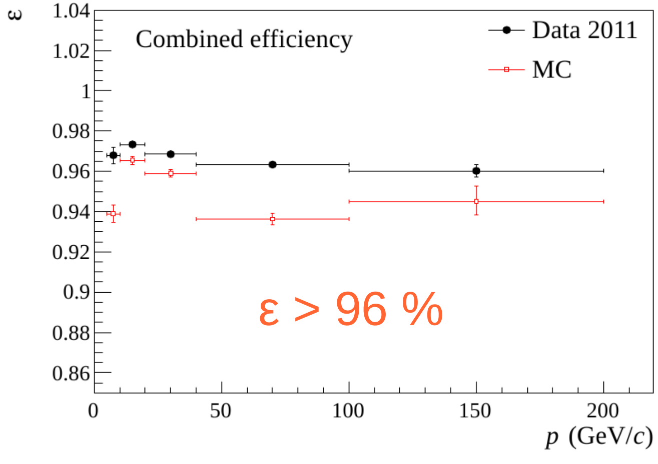
T1 TT



Track finding :

- Long tracks : high-momentum tracks traversing the full LHCb tracking setup
  - → combine track seeds in VELO and T-stations and add TT hits
  - → measured with highest precision
  - → most numerous in the main LHCb acceptance

Track finding efficiency

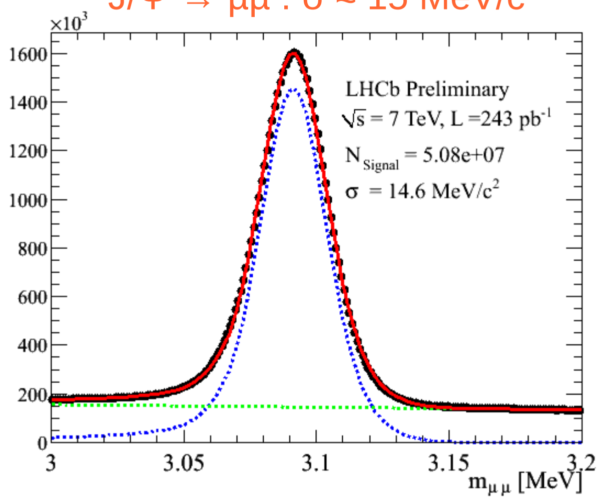


[LHCb-PUB-2011-025]

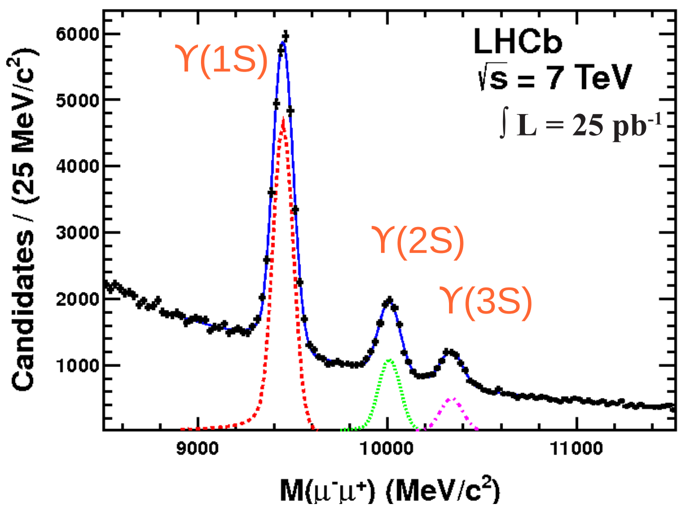
Tracking performances

Momentum resolution : σ(p)/p = 0.4-0.6% (5-100 GeV/c)

J/Ψ → μμ : σ ≈ 15 MeV/c²

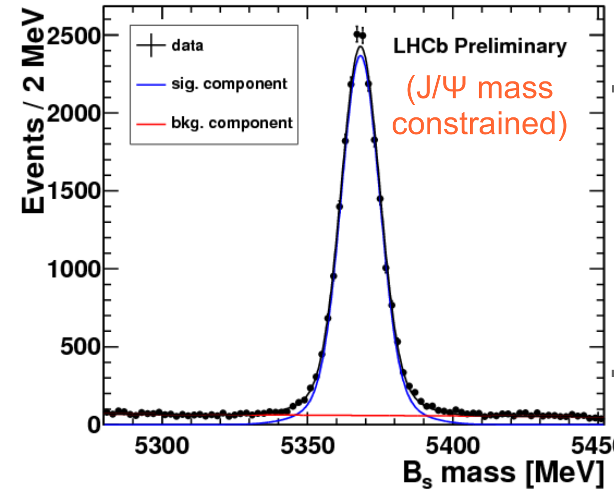


ϒ(1S) → μμ : σ ≈ 54 MeV/c²



[Eur.Phys. J. C, (72),6]

$B_s \to J/\Psi\Phi$: σ ≈ 8 MeV/c²



[CONF-2012-002]

cf. [CMS DPS-2010-040] ~ 16 MeV/c²
[ATLAS CONF-2011-050] ~ 22 MeV/c²

Momentum scale and detector alignment well controlled :

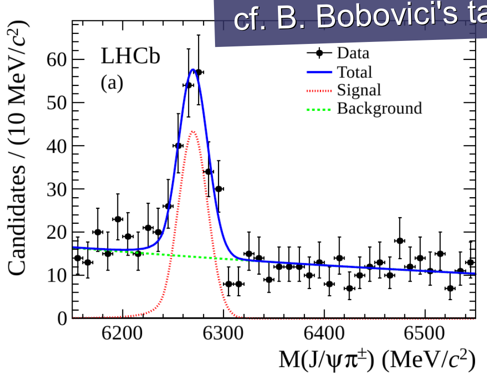
B hadron mass world's best measurements (2010 data only, 37pb⁻¹)

Quantity	LHCb measurement	Best previous measurement	PDG fit
$M(B^+)$	5279.38 ± 0.35	5279.10 ± 0.55	5279.17 ± 0.29
$M(B^0)$	5279.58 ± 0.32	5279.63 ± 0.62	5279.50 ± 0.30
$M(B^0_s)$	5366.90 ± 0.36	5366.01 ± 0.80	5366.3 ± 0.6
$M(\Lambda^0_b)$	5619.19 ± 0.76	5619.7 ± 1.7	–
$M(B^0) - M(B^+)$	0.20 ± 0.20	0.33 ± 0.06	0.33 ± 0.06
$M(B^0_s) - M(B^+)$	87.52 ± 0.32	–	–
$M(\Lambda^0_b) - M(B^+)$	339.81 ± 0.72	–	–

[PLB 708 (2012) 241]

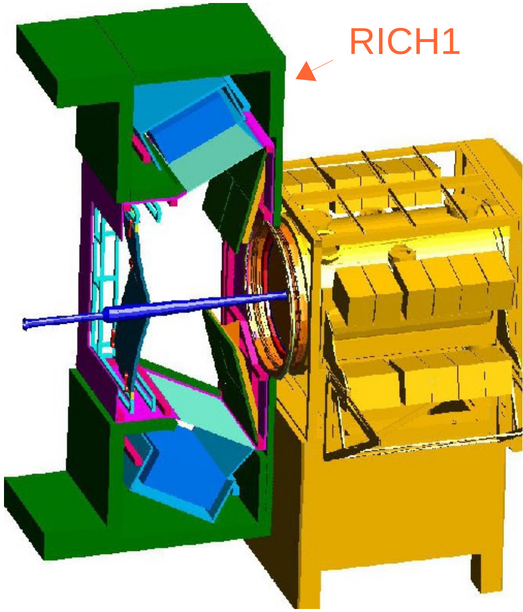
B_c^+ mass also measured

cf. B. Bobovici's talk



[arXiv:1209.5634]

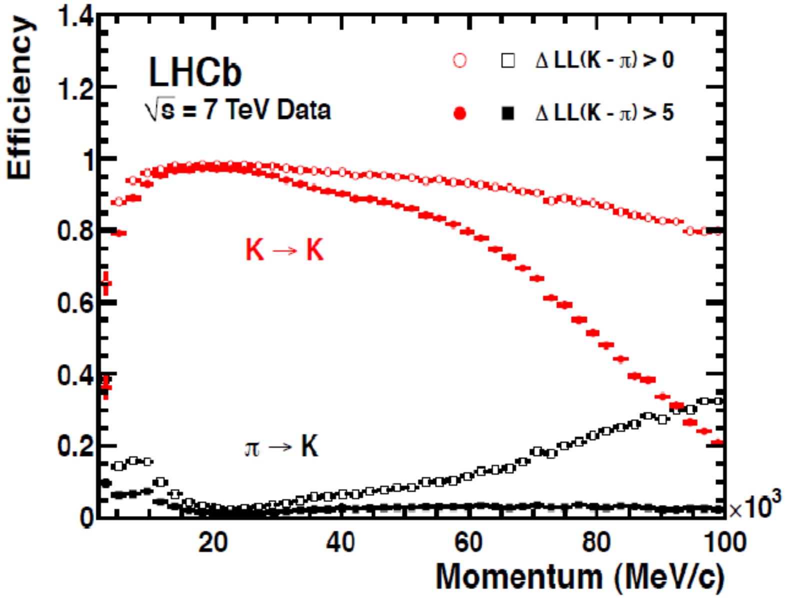
Particle identification : the RICH detectors



K/π separation over the full 1-100 GeV/c range

The detectors :

- RICH1 :
  - → full angular acceptance
  - → covers low momentum range : 1-60 GeV/c
  - → aerogel & C4F10 radiators
- RICH2 :
  - → limited angular acceptance (~±15 → ~±100 mrad)
  - → high momentum range : ~15 GeV/c - > 100 GeV/c
  - → CF4 radiator
- Hybrid Photon Detectors (HPDs)
  - → 500 each with 1024 pixels
  - → High efficiency, low noise



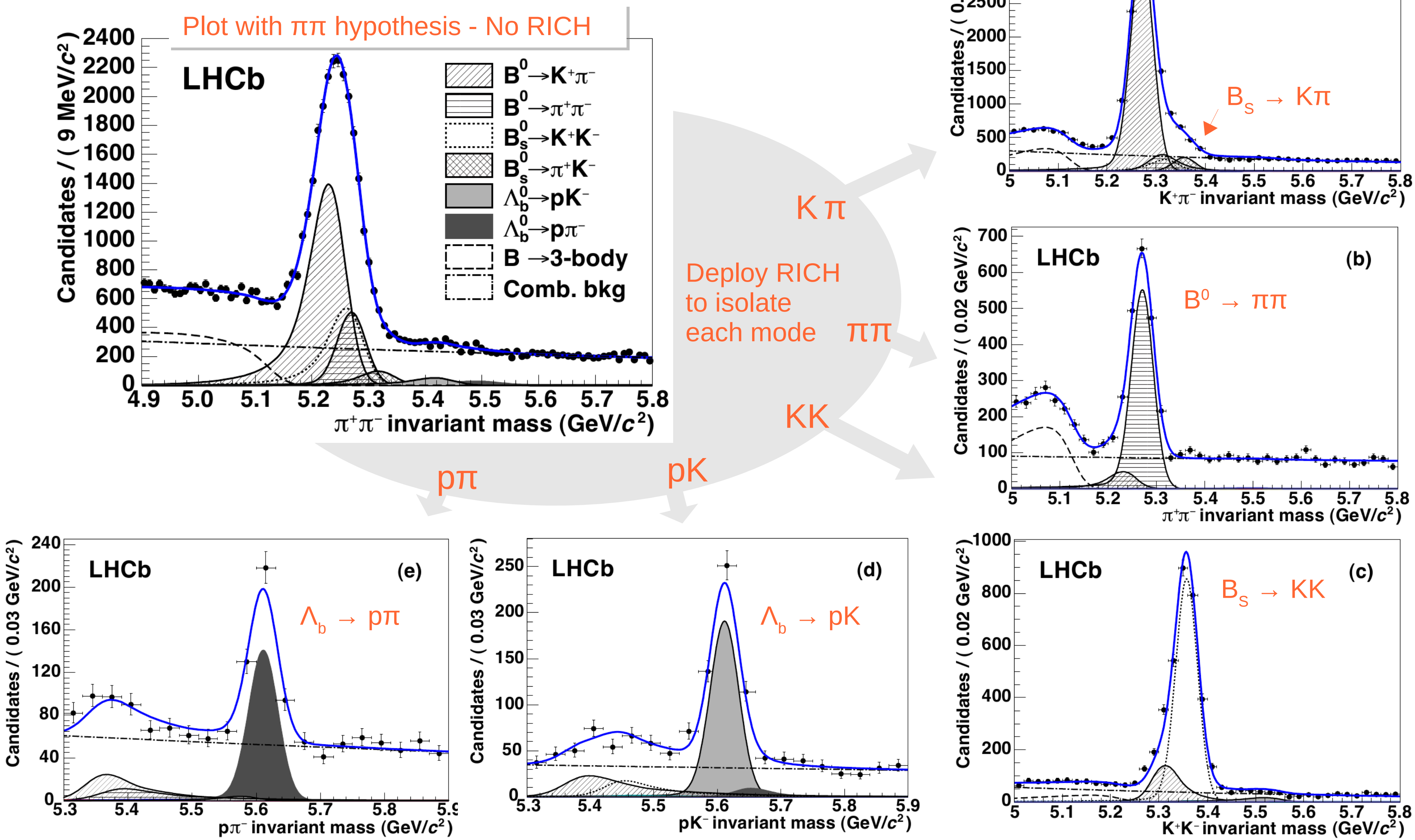
Performances

- ε ≈ 95 % for 5% π-K misID probability
- performances well described by simulation

Particle identification : illustration of K-π separation

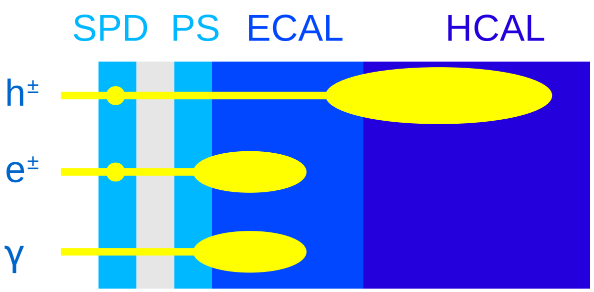
cf. C. Fitzpatrick 's talk

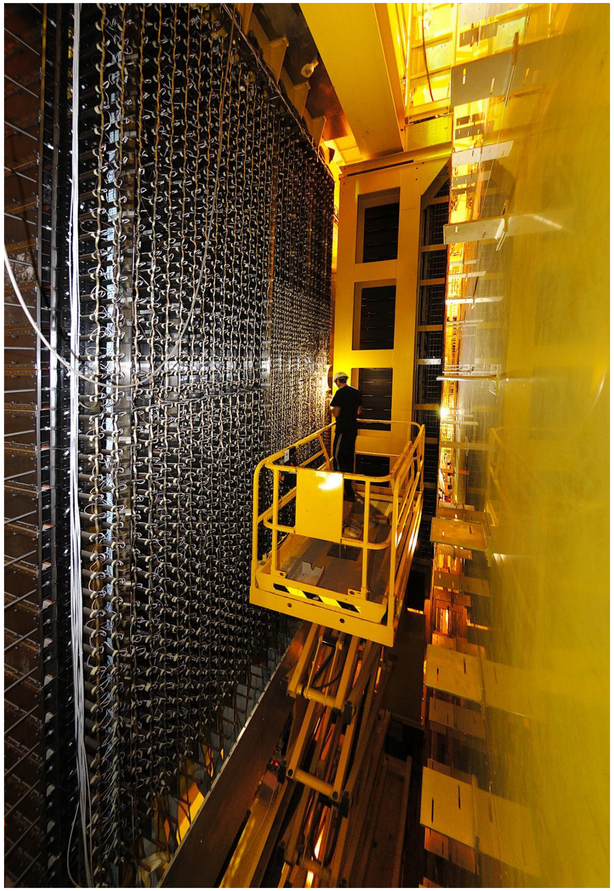
Charmless B decays : sensitive probes of CKM matrix



[arXiv:1206.2794]

Particle identification : the calorimeters




The ECAL detector

Scintillator Pad Detector / PreShower :

- robust e/γ and e/hadron separation
- single layer scintillator tiles separated by Pb sheet (2.5 X0)
- $\varepsilon(e^\pm)$ = 90% for 5% e-hadron MisID

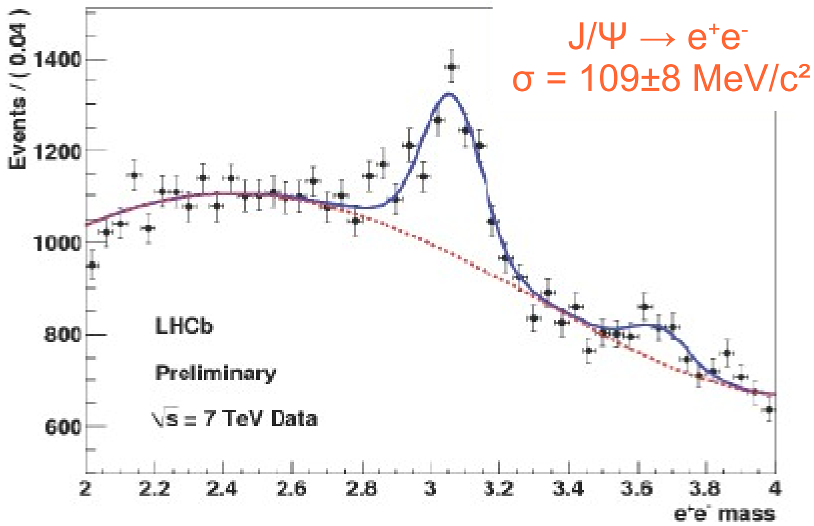
Electromagnetic CALorimeter :

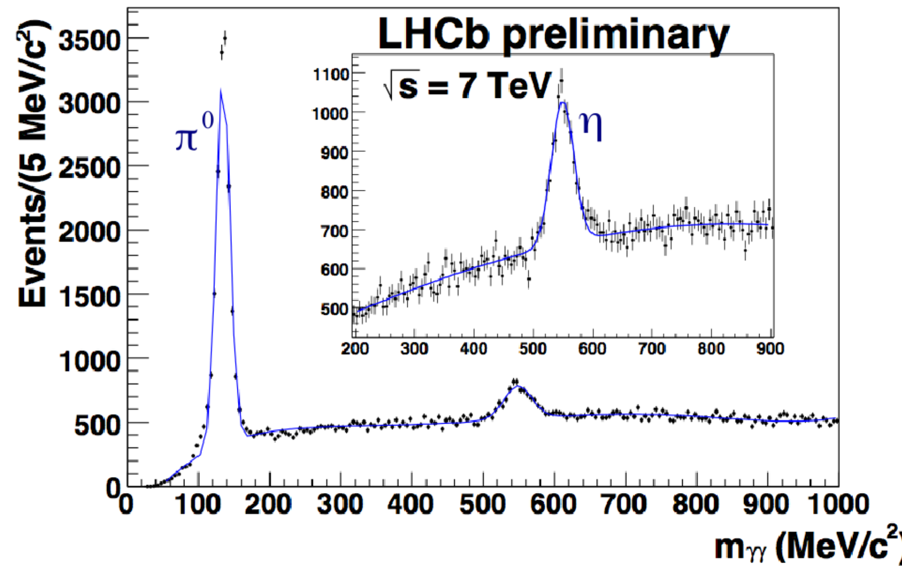
- e and γ energy measurement
- trigger on electromagnetic decay channels
- Pb plates / scintillator tiles (25 X0)
- $\sigma(E)/E = 10\%/\sqrt{E(GeV)} + 1\%$ (nominal)

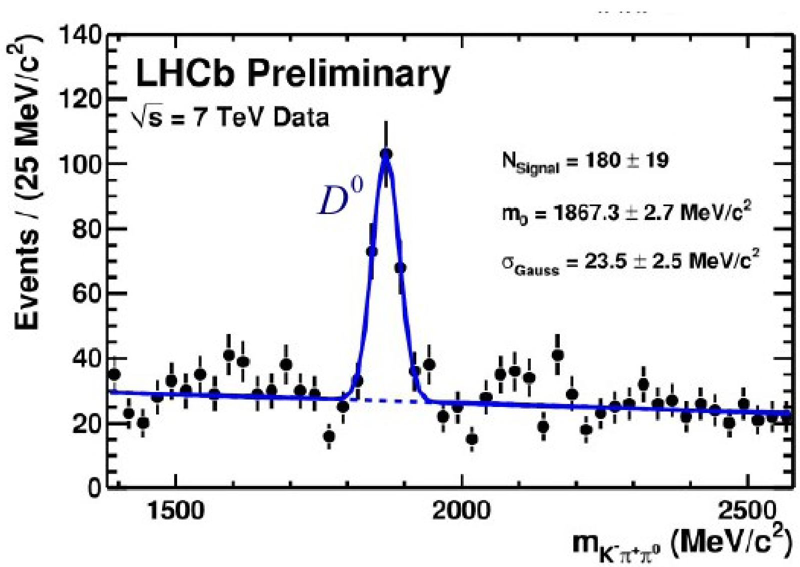
Hadronic CALorimeter :

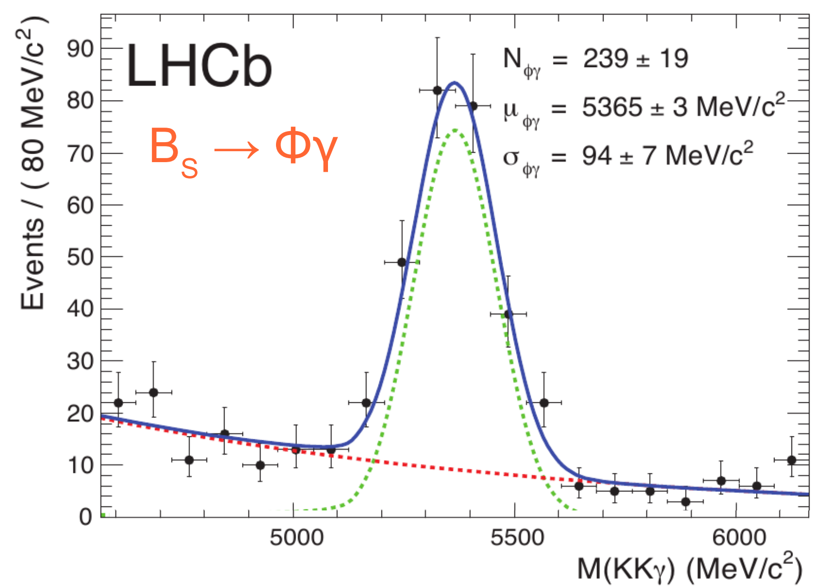
- energy measurement for hadron
- trigger on hadronic decay channels
- Fe plates / scintillator tiles
- $\sigma(E)/E = 69\%/\sqrt{E(GeV)} + 9\%$ (nominal), moderate but enough for triggering

Particle identification : electron, photon and π^0







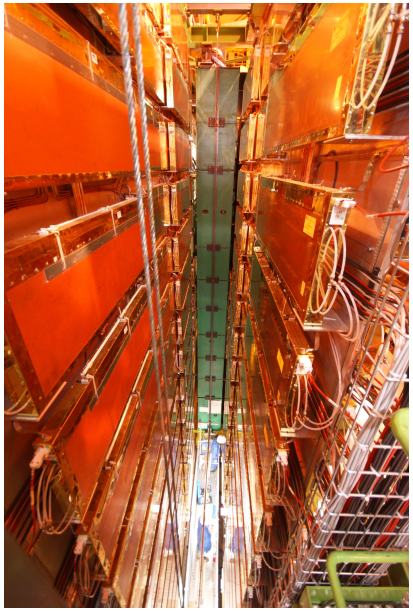


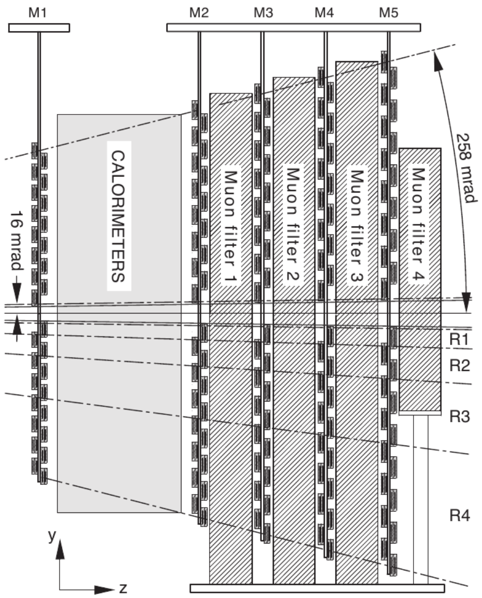
[arXiv:1202.6267]

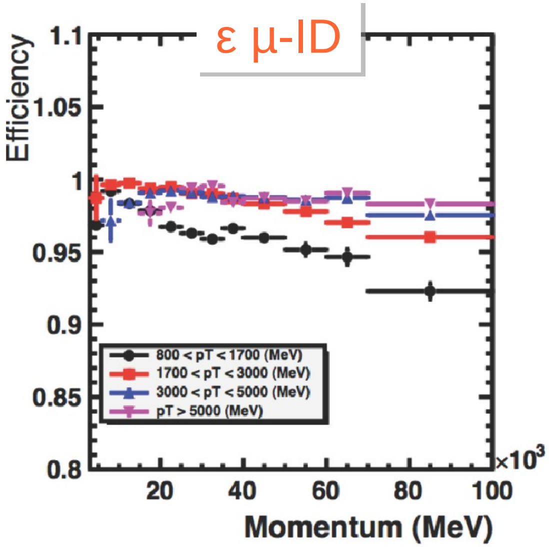
Particle identification : the muon system

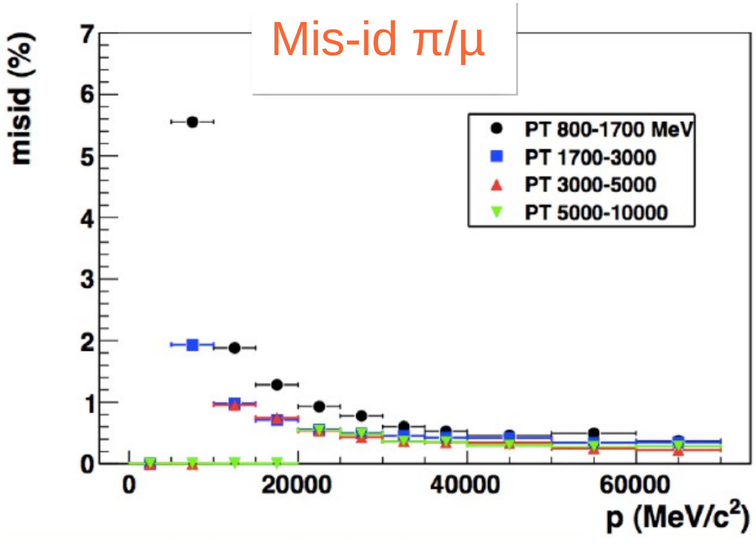
5 stations interleaved with iron absorbers

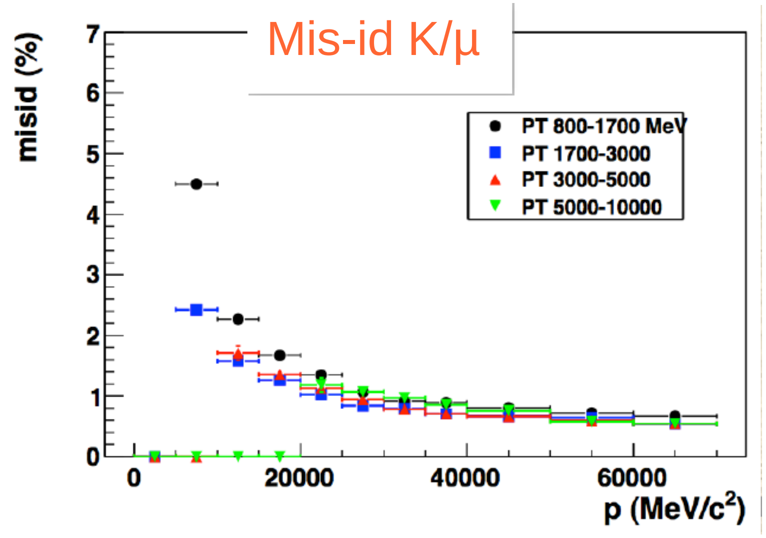
- muon identification
- trigger on muonic decay channels
- Muon ID ε(μ) = 97 % for 1-3% π-μ MisID



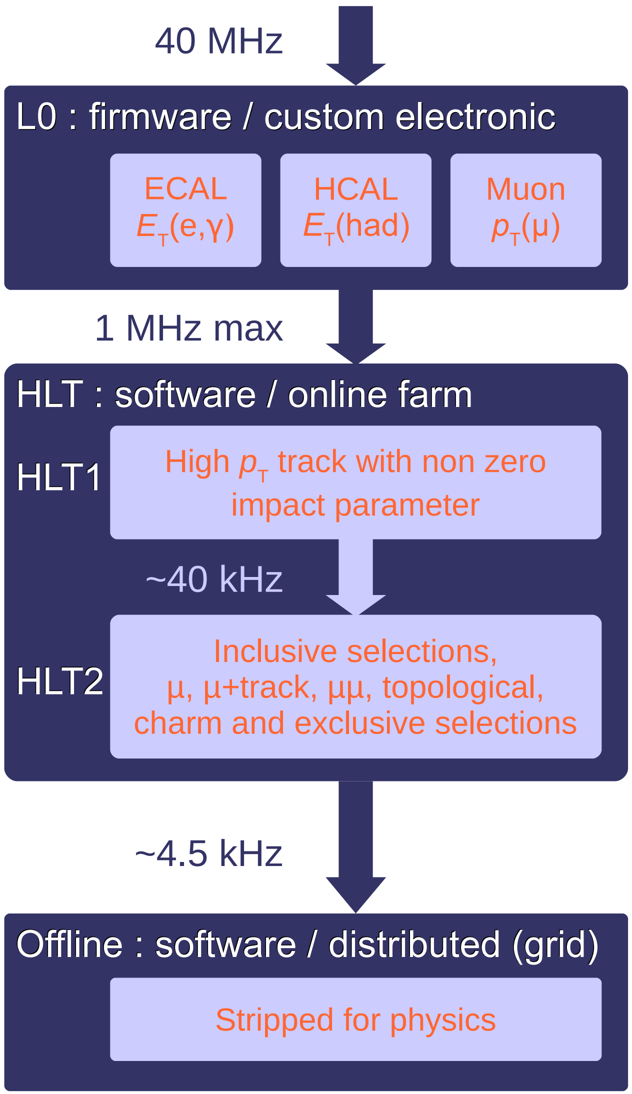








Trigger & stripping



L0 : custom electronic @40Mhz, 4 μs latency

– search for high-pT μ, e, γ, hadron candidates
  → pT(μ)>1.4; ET(e/γ)>2.7; ET(hadron)>3.6 [GeV]

HLT : software trigger

– ~ 30000 tasks in parallel on ~1500 nodes
– HLT1 : add Impact Parameters cuts
– HLT2 : global event reconstruction tuned for HLT

Efficiencies :

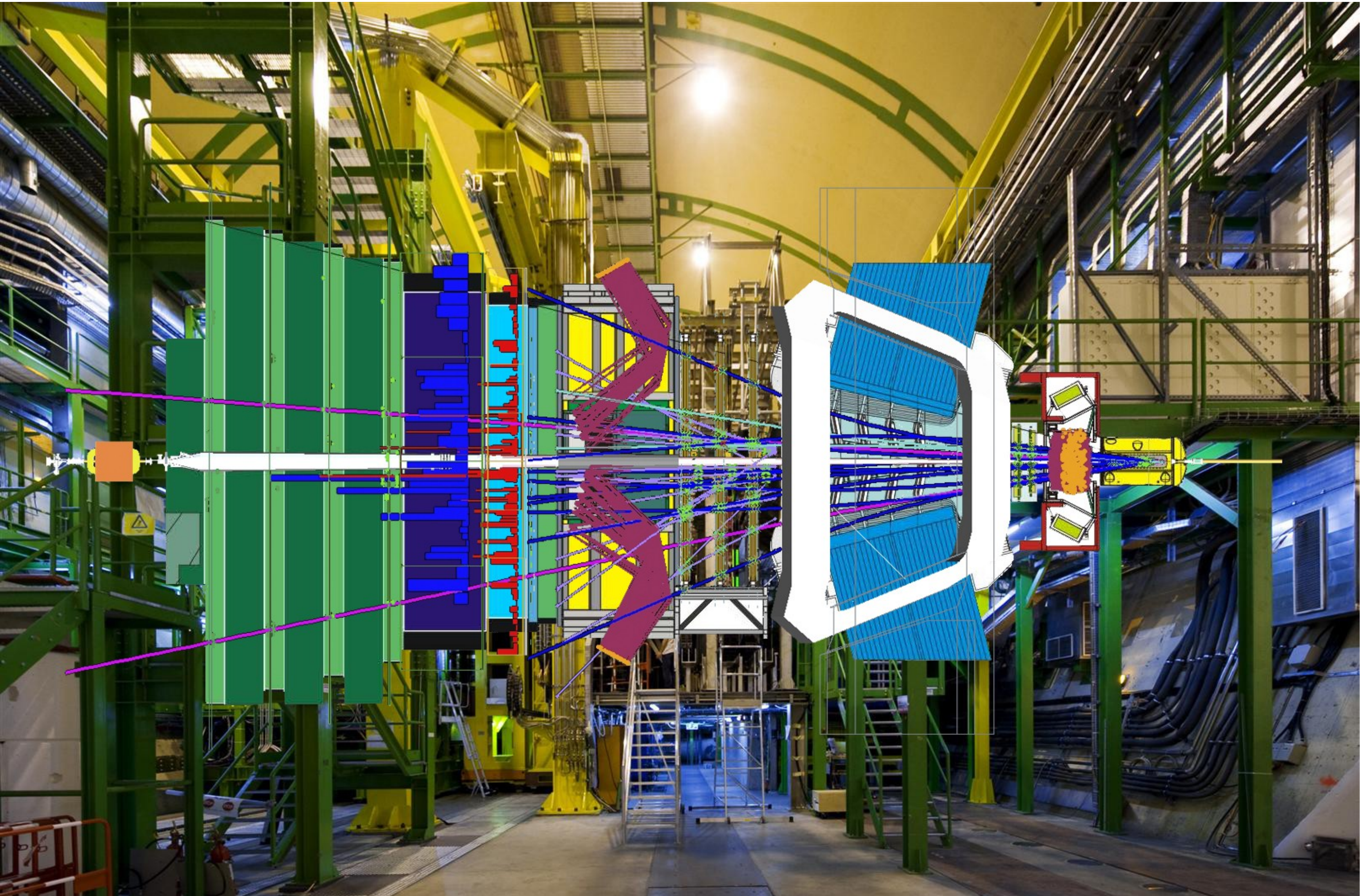
– di-muons channels : ~ 90 %
– multi-body hadronic final states : 30 %
–

cf. H. Dijkstra's talk

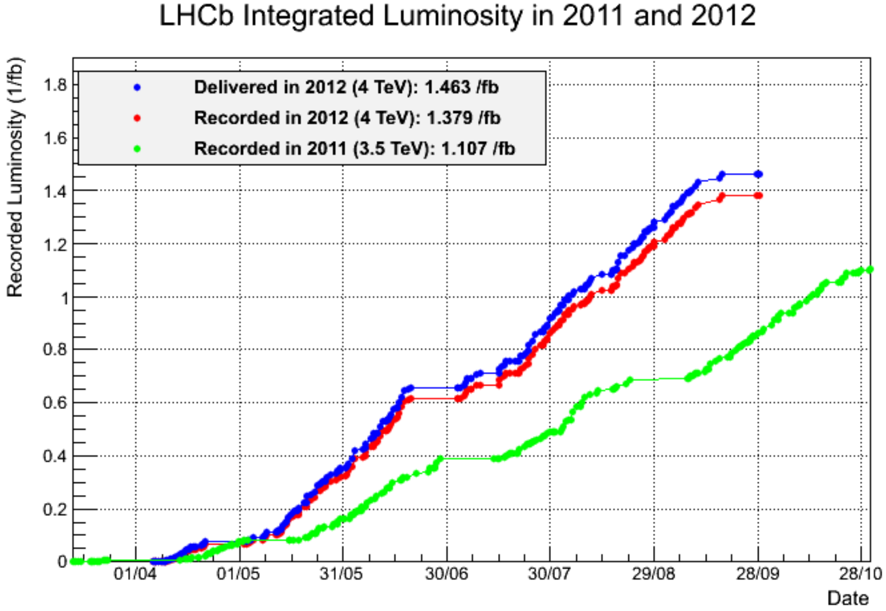
Offline : ~1010 events, 700 TB recorded/year

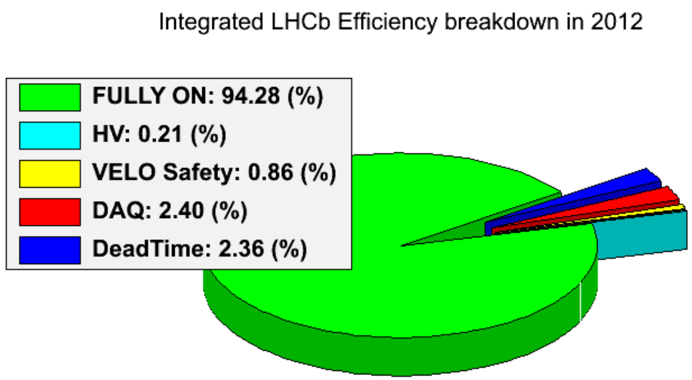
– centralized stripping selections to reduces to samples with 0(107) events for individual analyses
  → ~800 selections

LHCb Operation



Data Taking





Recorded Luminosity :

- 2010 : 37 pb-1 @ 7 TeV
- 2011 : 1 fb-1 @ 7 TeV
- 2012 : aim at 2.2 fb-1 @ 8 TeV
- (as of end of September : 1.4 fb-1)
  - → expect σ(bb) increased by ~15% w.r.t 7TeV

Efficiencies :

- > 90 % data taking efficiency
- ~99 % working detector channels
- > 99% of recorded data good for analysis

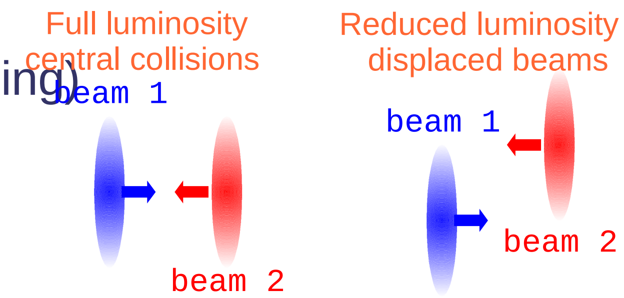
Luminosity

LHCb designed luminosity :

– Linst = 2x1032 cm-2s-1 with µ=0.4 (# of visible pp int./crossing)

– Precision physics depending on vertex structure

→ easier in a low-pileup environment

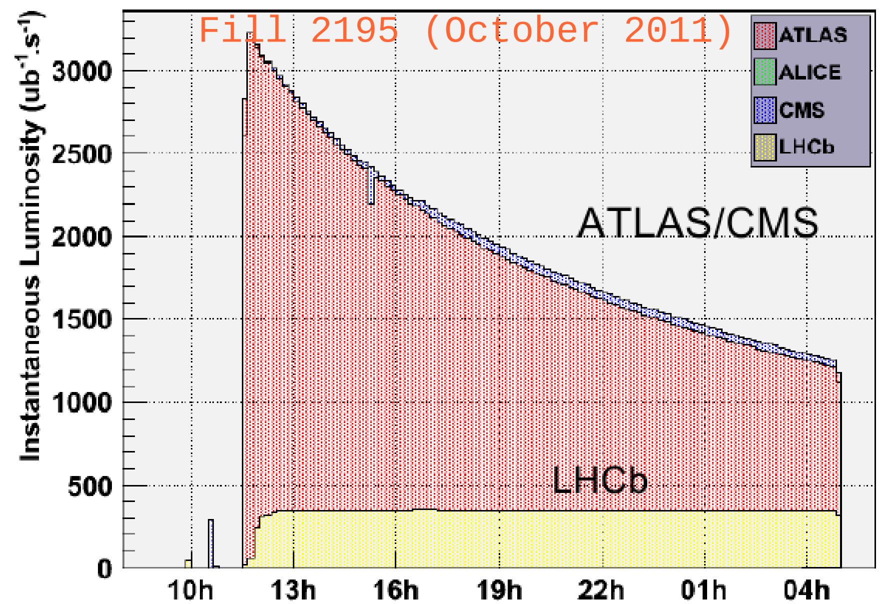


Luminosity levelling at LHCb

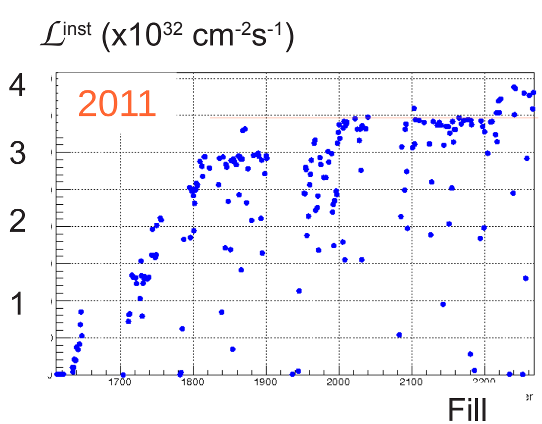
– run with constant luminosity

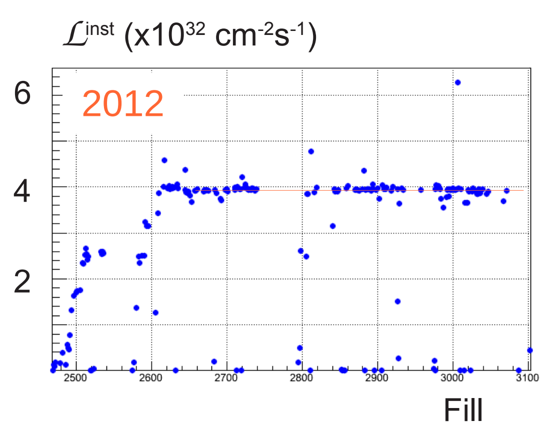
→ beam overlap adjusted regularly

– automatic procedure between LHC&LHCb



2011 & 2012 instantaneous luminosities :





2011 : $\mathcal{L}^{inst}$ = ~ 3.5x10^{32} cm^{-2}s^{-1}, µ = ~1.5

2012 : $\mathcal{L}^{inst}$ = ~ 4.0x10^{32} cm^{-2}s^{-1}, µ = ~1.7

2012 novelties

Optimisation of data acquisition :

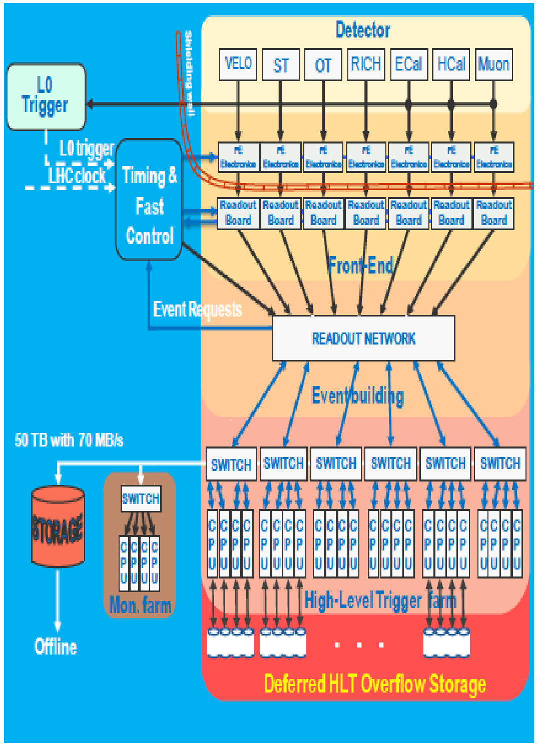
– L0 rate from 925 kHz to 975 kHz
– allow to run at higher luminosity

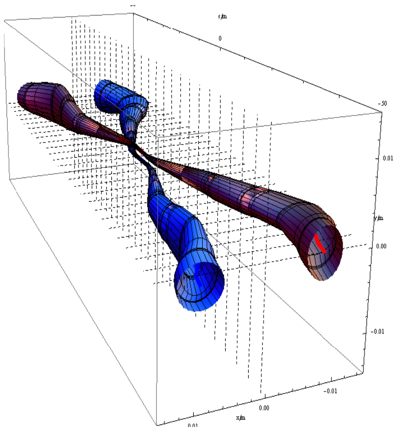
Deferred HLT triggering :a

– the HLT processing of a fraction (20%) of the L0 rate is deferred
– deferred event are written to disk and processed by the HLT in the inter-fill gap
– equivalent to 20% gain in CPU power

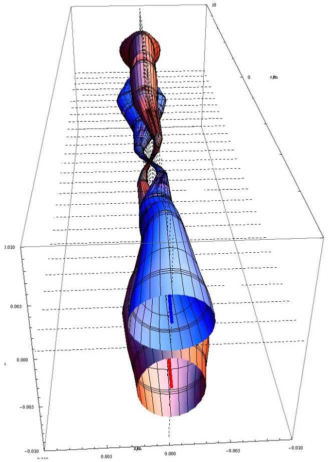
LHC optics :

– beams crossing angle change from horizontal plane in 2011 to vertical plane in 2012
– decoupled from LHCb magnet polarity change (H bending)
– minimize systematic effects





2011



2012

Conclusions

LHCb detector achievements :

- excellent vertex resolution
- great tracking performances
- robust particle identification
- flexible and efficient trigger

LHCb operation :

- smooth and efficient
- sustain luminosity higher than designed value

LHCb able to deliver high-quality physics results

- ~70 submitted papers
- world's best measurements of many important physics parameters
- upgrade activities launched

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→ Overview → M. Patel
→ Rare decays → M.O. Bettler
→ CP violation → C. Fitzpatrick
→ b-hadron production → B.Popovici

Thank you for your attention

↘ conclusion