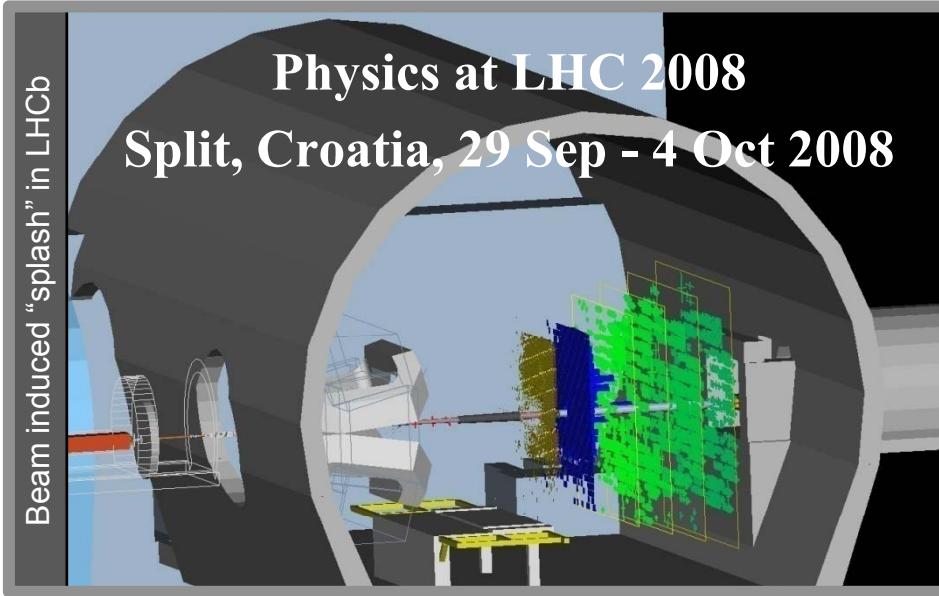


(Towards) First Physics with LHCb



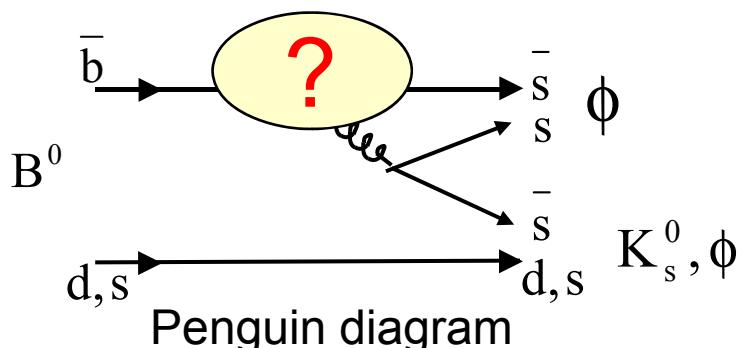
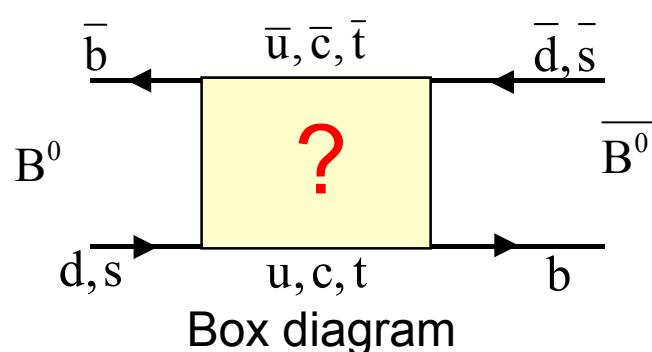
- Introduction
- Detector overview and performance
- Extracting physics from (very) first data

presented by
Andreas Schopper (CERN)

on behalf of the  Collaboration

LHCb is a heavy flavour precision experiment searching for new physics in CP-Violation and Rare Decays

New Physics models introduce new particles, dynamics and/or symmetries at a higher energy scale (expected in the TeV region) with virtual particles that appear e.g. in loop mediated processes



$$\boxed{\Delta m} \neq \Delta m^{SM} \propto |V_{td,ts}^2|$$

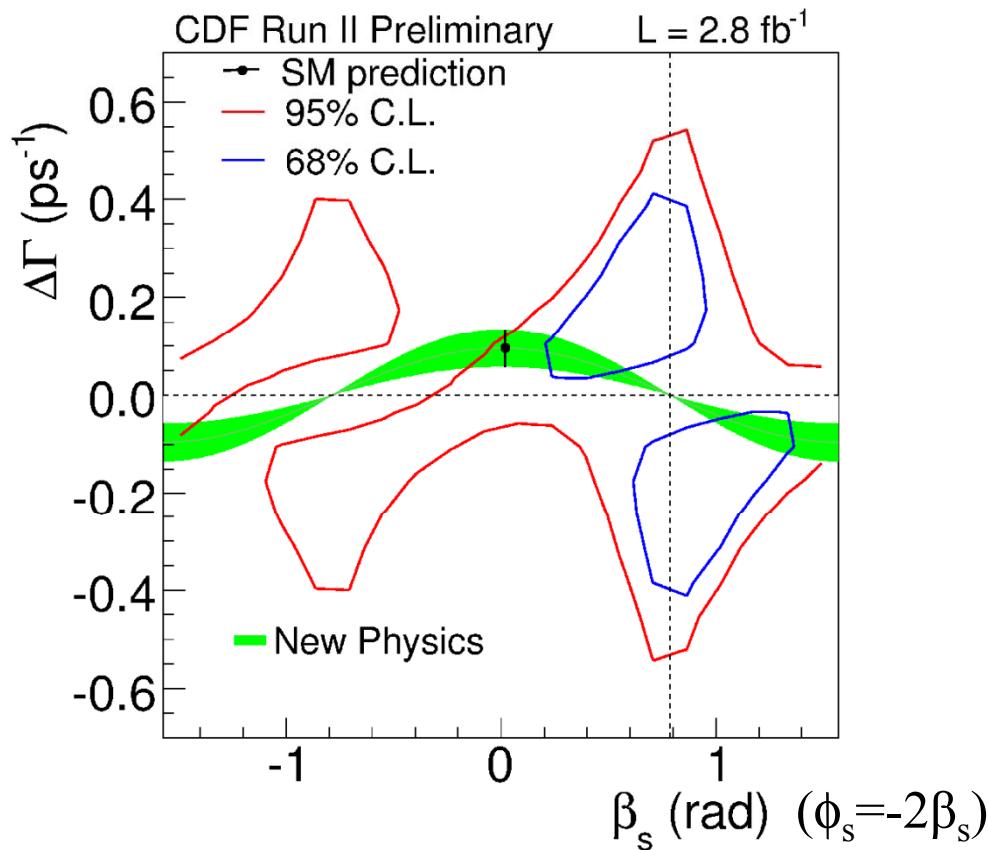
$$\boxed{\phi_d} \neq \phi_d^{SM} = -\arg\{V_{td}^2\} = 2\beta, \quad \boxed{\phi_s} \neq \phi_s^{SM} = -\arg\{V_{ts}^2\} = -2\beta_s$$

- B-physics measurements probe New Physics and are complementary to direct searches
- will allow to understand the nature and flavour structure of possible New Physics

Search for New Physics

- are New physics already around the corner?

CDF Public Note 9458 (August 2008)



- SM consistency at 7% level

LHCb key measurements

In CP-violation:

- B_s - \bar{B}_s mixing angle ϕ_s
- weak phase γ in trees
- weak phase γ in loops

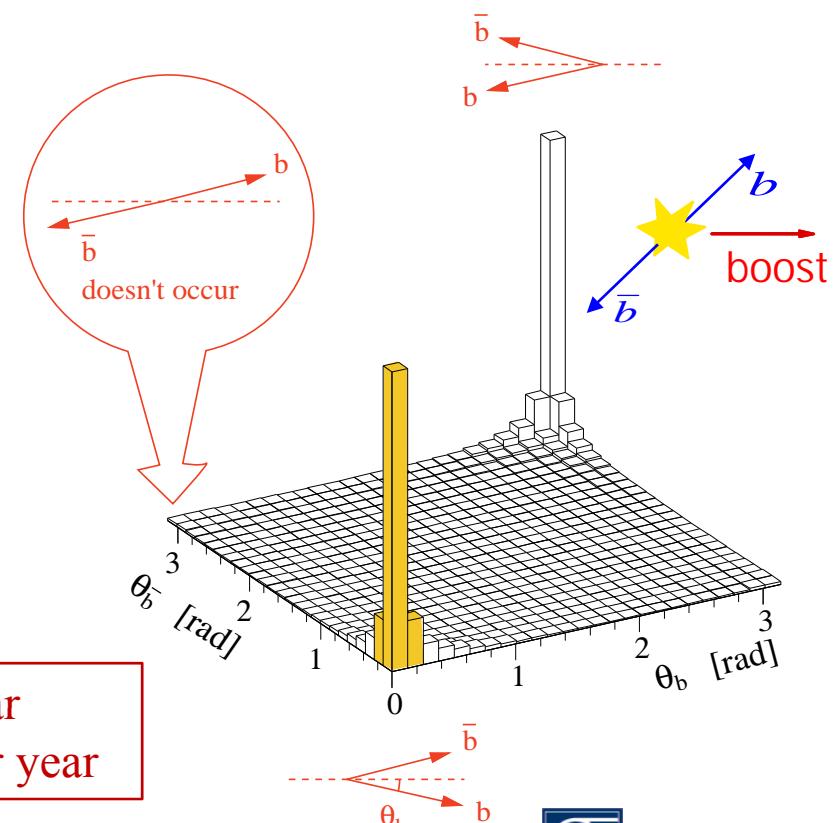
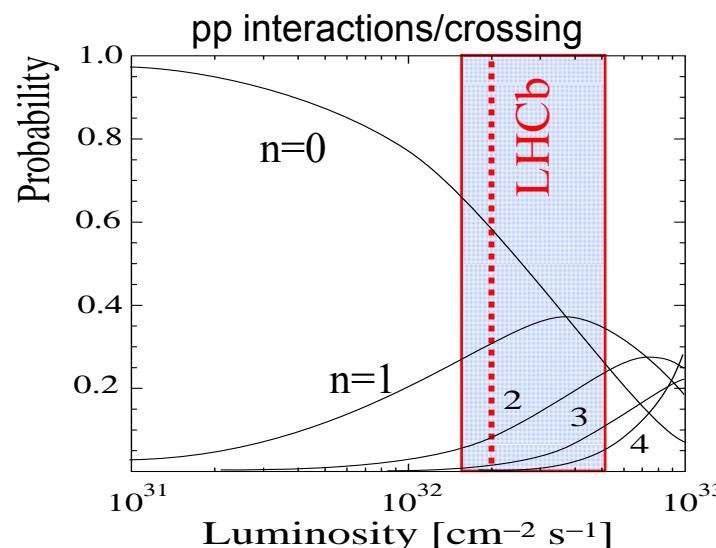
In Rare Decays:

- branching ratio of $B_s \rightarrow \mu\mu$
- forward-backward asymmetry in $B \rightarrow K^*\mu\mu$
- polarization of photon in radiative penguin decays

→ see talks by Andrei Golutvin,
Alessia Satta, Val Gibson,
William Robert Reece
and poster by Lesya Shchutska
and Bogdan Popovici

B production in LHCb

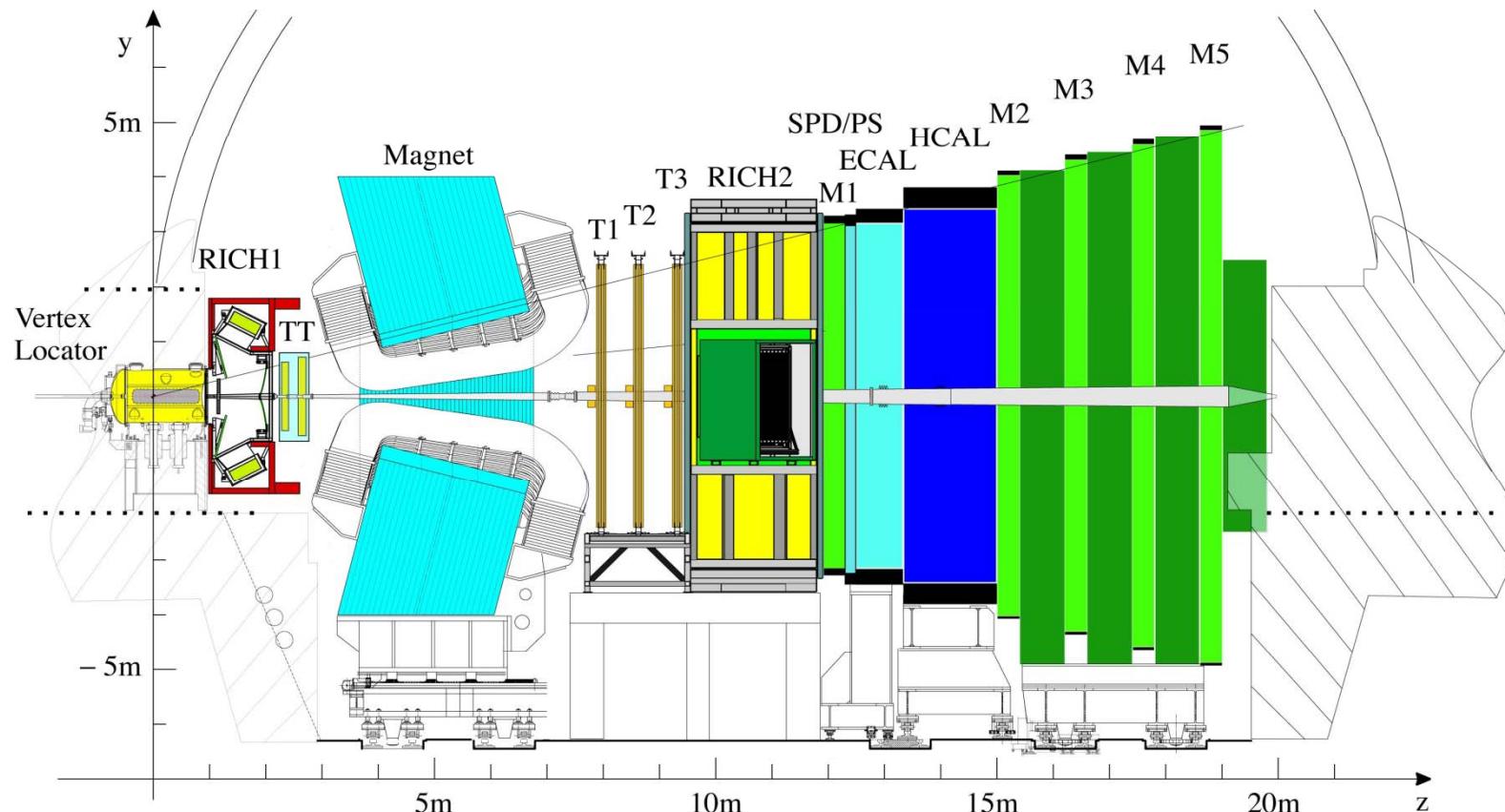
- ✓ $b\bar{b}$ pair production correlated and sharply peaked forward-backward
 - Single-arm forward spectrometer : $\theta \sim 15\text{-}300$ mrad (rapidity range: $4.9 > \eta > 1.9$)
 - Cross section of $b\bar{b}$ production in LHCb acceptance: $\sigma_{b\bar{b}} \sim 230 \mu\text{b}$
 - B^+ (40%), B^0 (40%), B_s (10%), b-baryons (10%), B_c (< 0.1%)
- ✓ LHCb limits luminosity to few $10^{32} \text{ cm}^{-2}\text{s}^{-1}$ instead of $10^{34} \text{ cm}^{-2}\text{s}^{-1}$
by not focusing the beam as much as ATLAS and CMS
 - maximizes probability of a single interaction per crossing
 - design luminosity soon after start-up



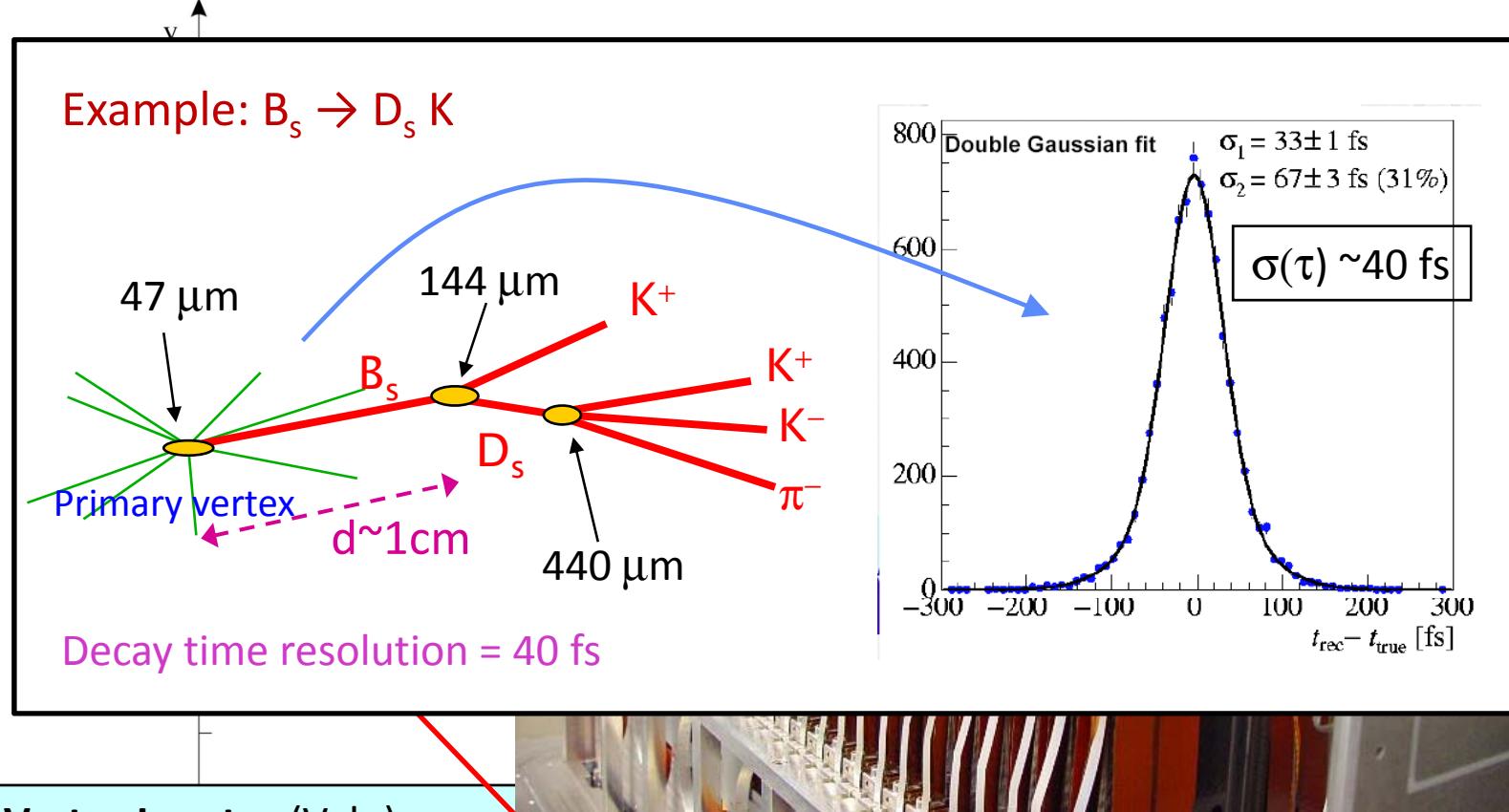
→ collect 2fb^{-1} per nominal year
→ $\sim 10^{12} b\bar{b}$ pairs produced per year

Detector overview and performance

walk through the detector
with the example of a $B_s \rightarrow D_s K$ decay



B-Vertex Measurement



Vertex Locator (Velo)

Silicon strip detector with
~ 5 μm hit resolution
→ 30 μm IP resolution

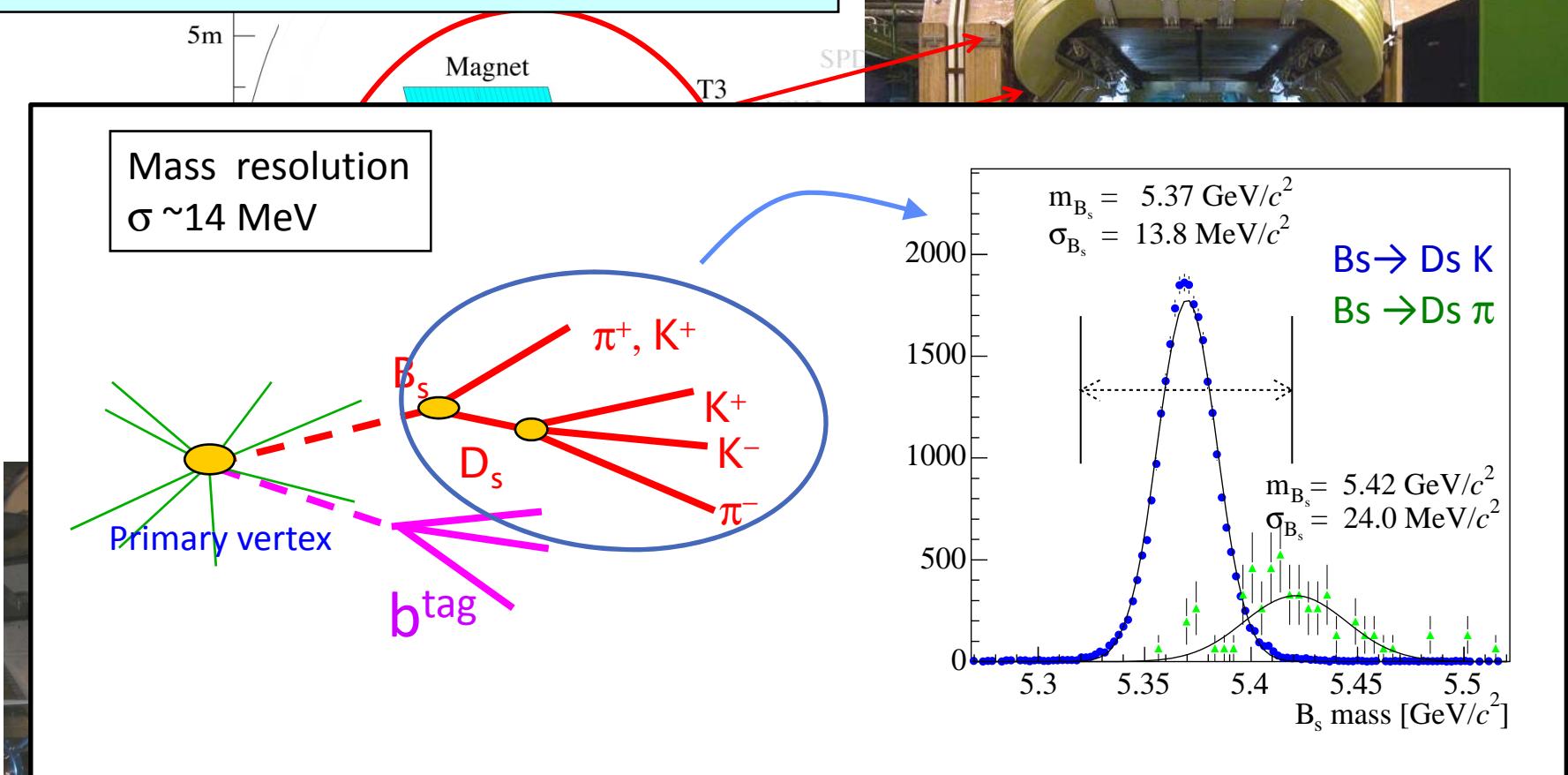


Vertexing:

- trigger on impact parameter
- measurement of decay distance (time)

Momentum and Mass measurement

Momentum meas. + direction (VELO):
Mass resolution for background suppression



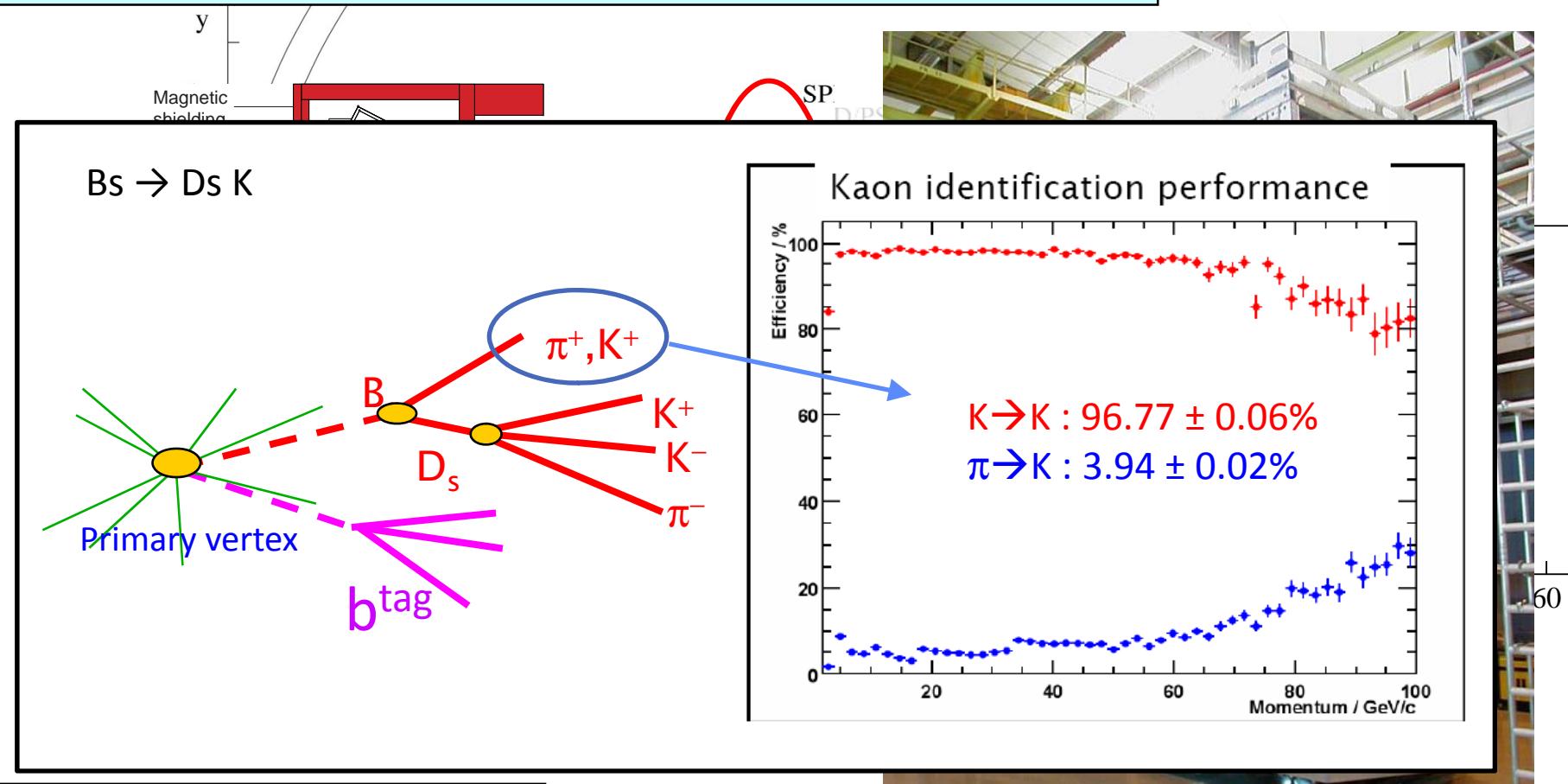
Split, 2 October 2008

Physics at LHC 2008



Particle Identification

RICH: K/ π identification using Cherenkov light emission angle

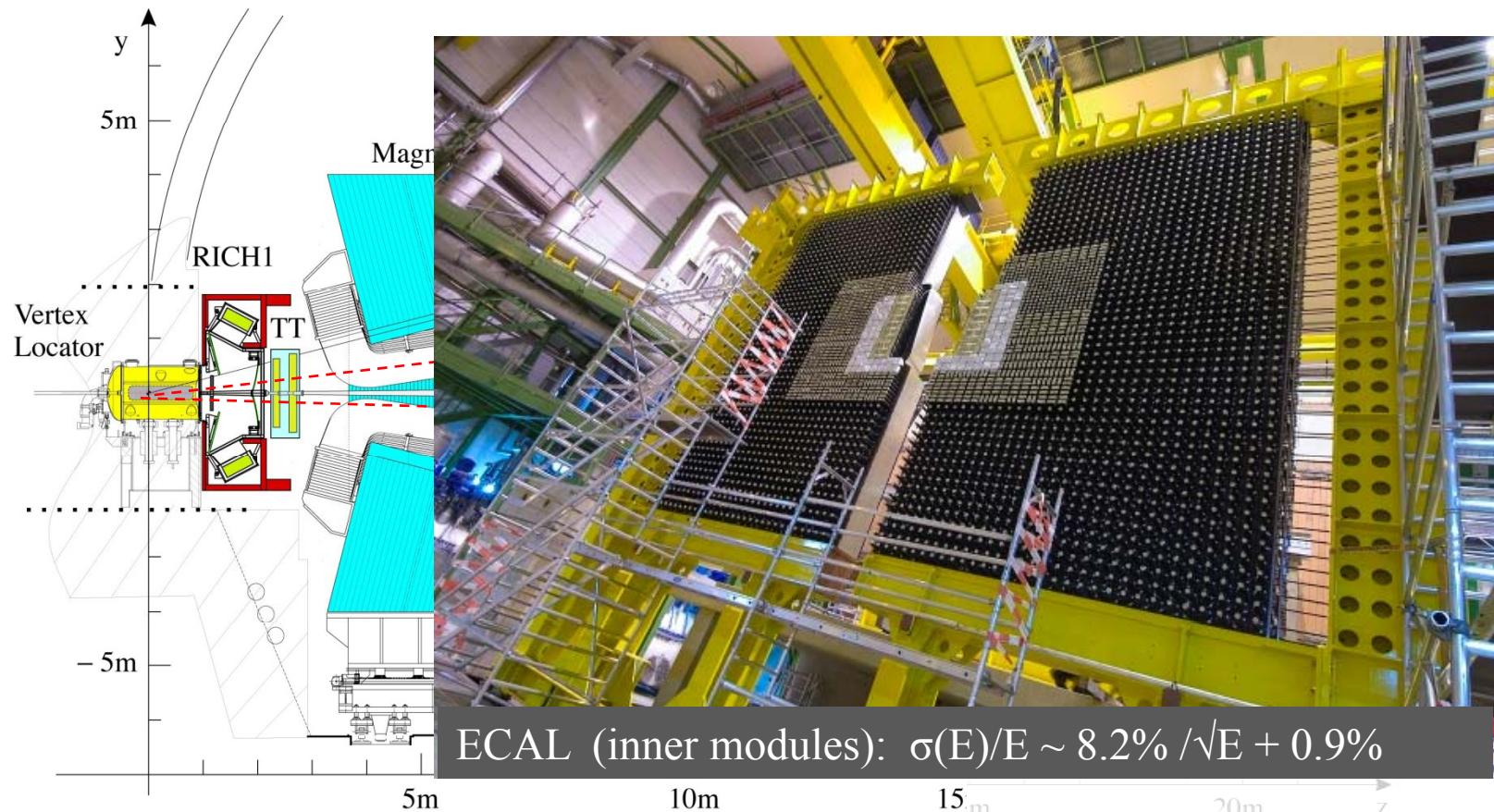


RICH1: 5 cm aerogel $n=1.03$
4 m³ C₄F₁₀ $n=1.0014$



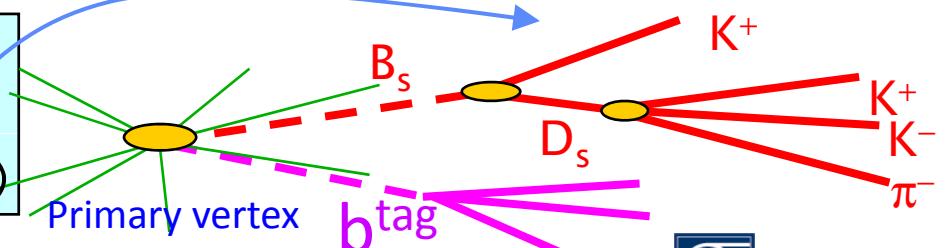
RICH2: 100 m³ CF₄ $n=1.0005$

Particle identification and L0 trigger

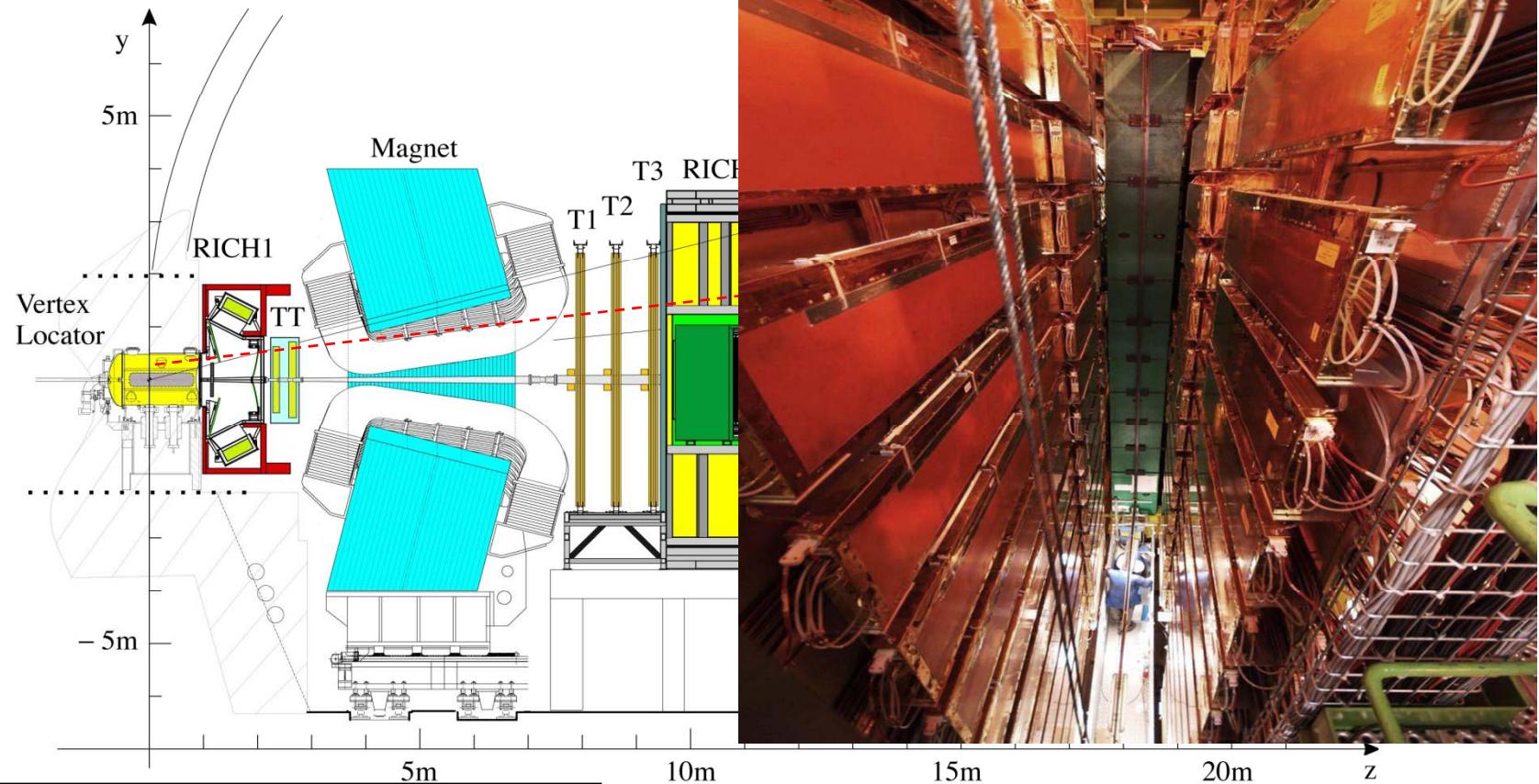


Calorimeter system :

- Identify electrons, hadrons, π^0, γ
- Level 0 trigger: high E_T electron and hadron

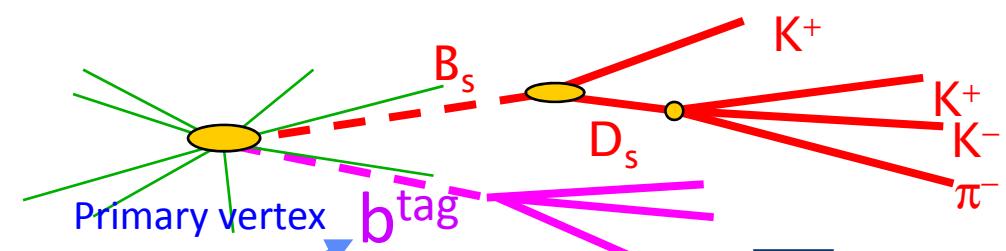


Particle identification and L0 trigger

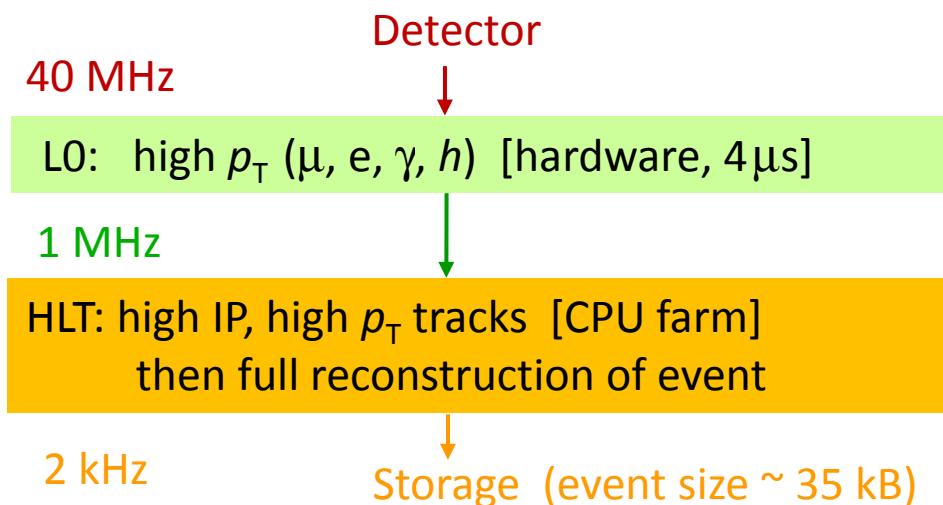


Muon system:

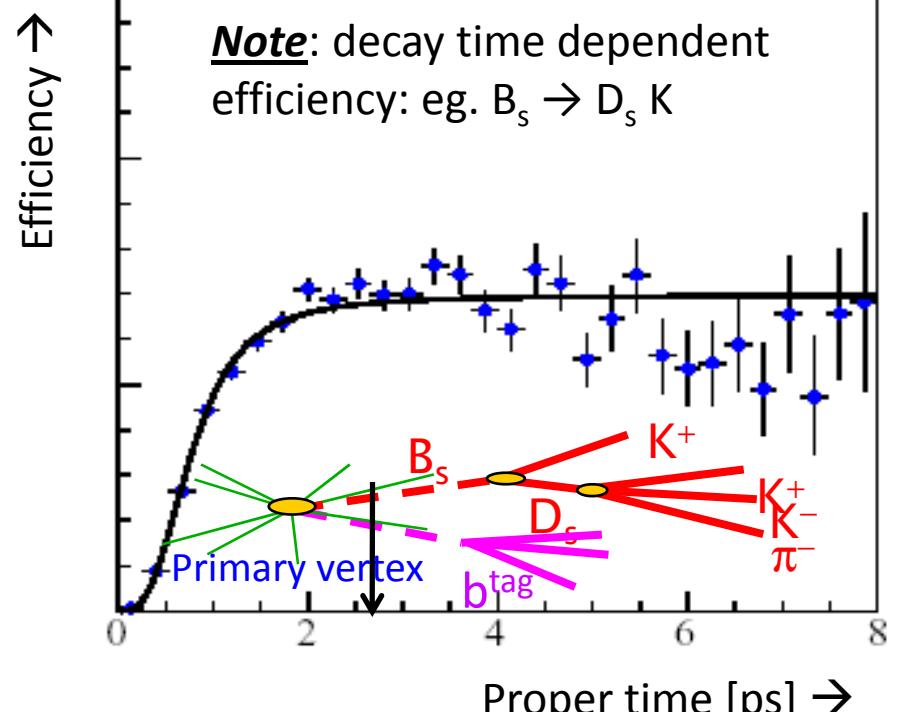
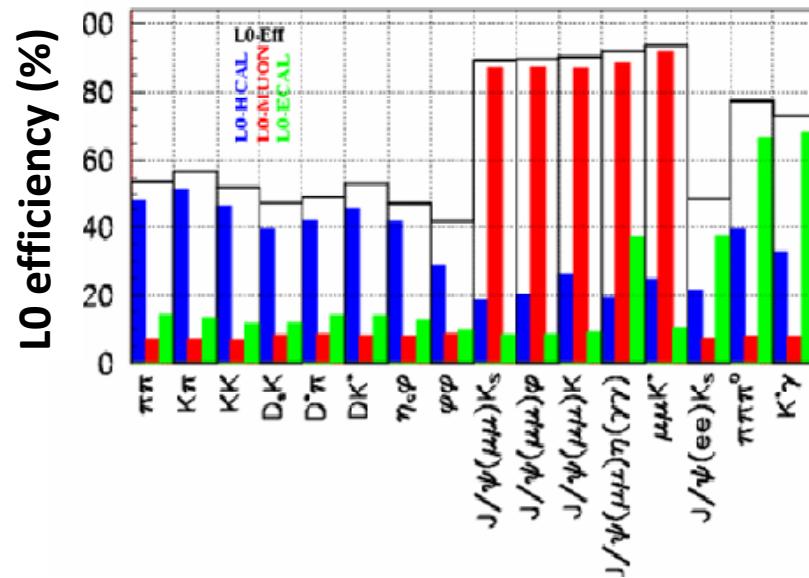
- Level 0 trigger: High P_t muons
- contributing to flavour tagging:
 $\varepsilon D^2 = \varepsilon (1-2w)^2 \approx 6\%$



LHCb trigger



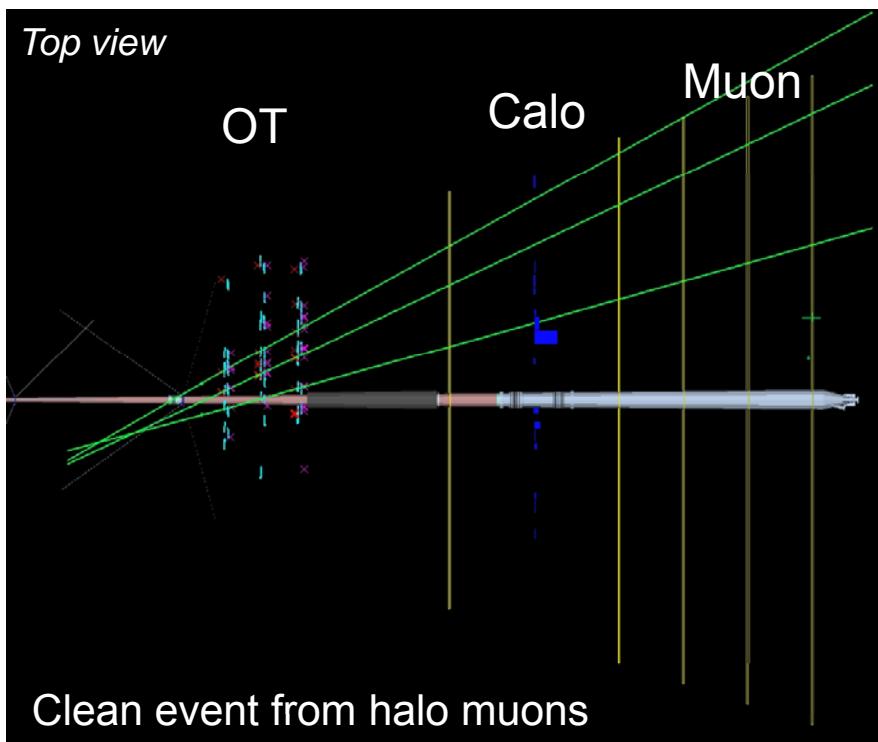
HLT rate	Event type	Physics
200 Hz	Exclusive B candidates	B (core program)
600 Hz	High mass di-muons	J/ψ , $b \rightarrow J/\psi X$ (unbiased)
300 Hz	D^* candidates	Charm (mixing & CPV)
900 Hz	Inclusive b (e.g. $b \rightarrow \mu$)	B (data mining)



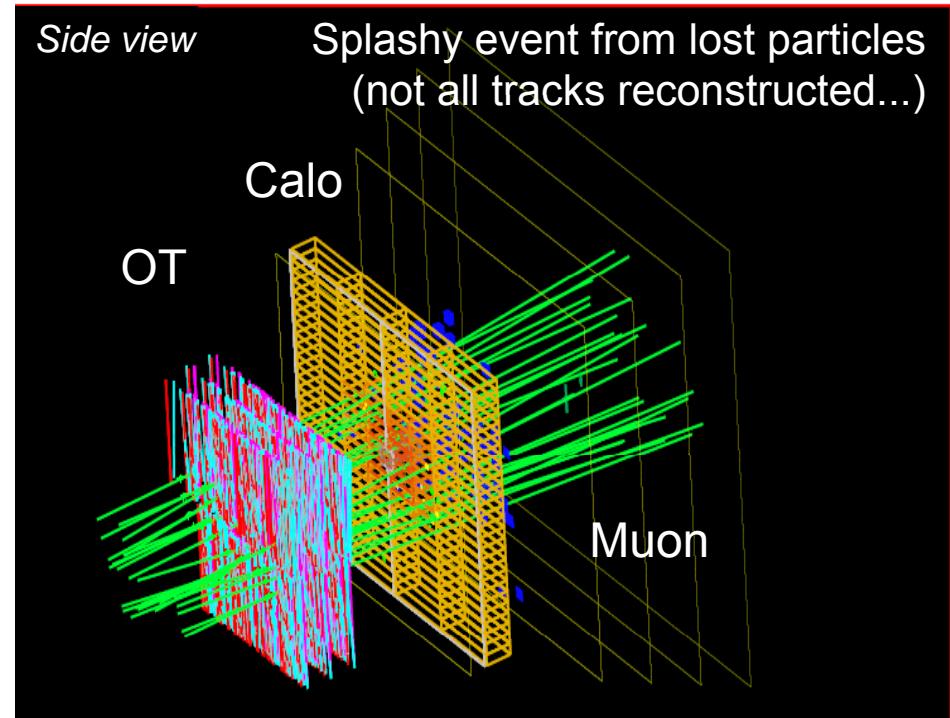
Status of LHCb

(→ see talk by Olivier Callot)

- LHCb detector fully installed and commissioned (except M1), including L0 trigger
- All sub-detectors have undergone the first time and space alignment with cosmics & LHC beam induced particles

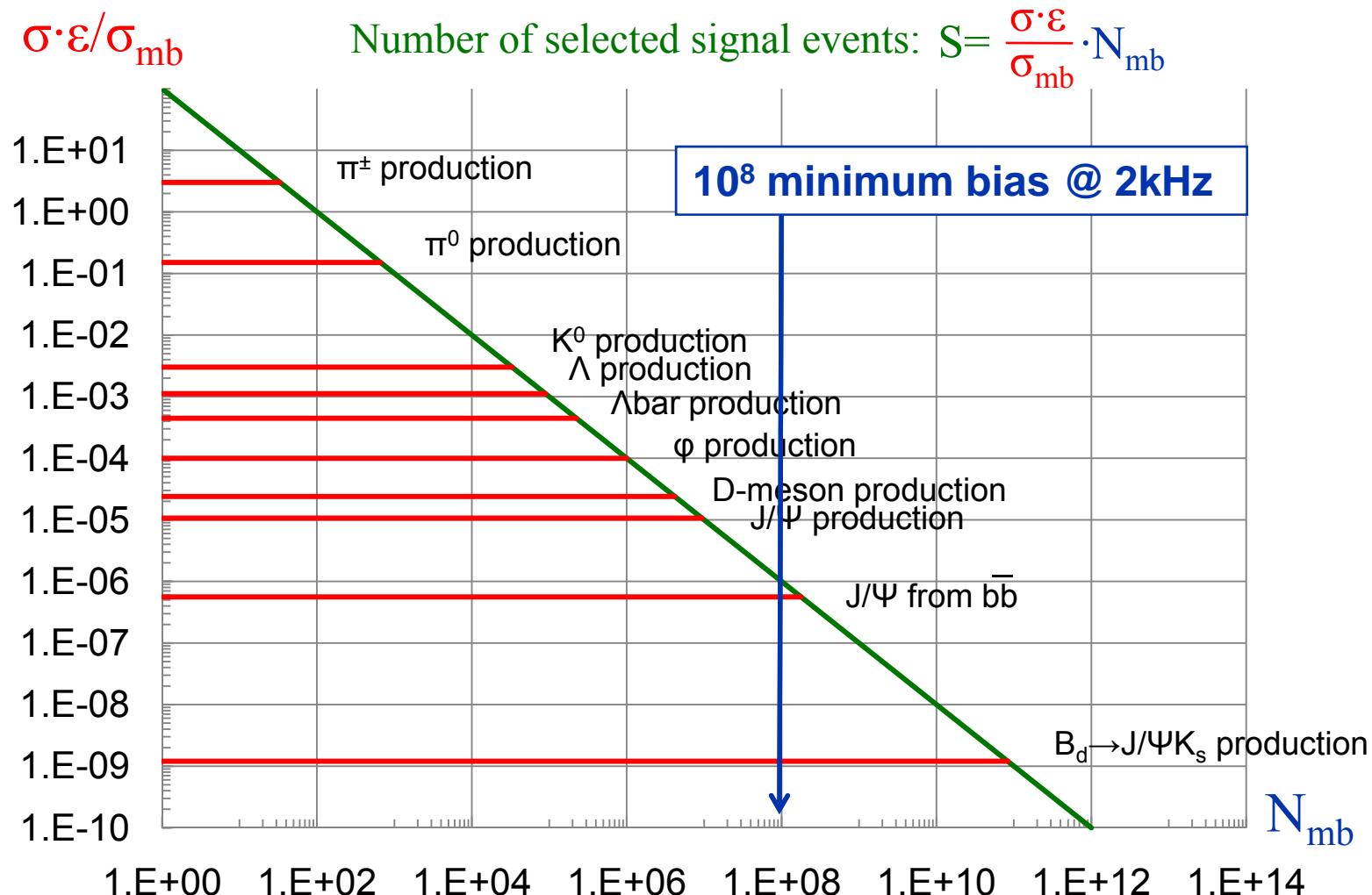


Events with LHC beam induced particles



Extracting physics from (very) first data

Exploit minimum bias data



Exploiting minimum bias data

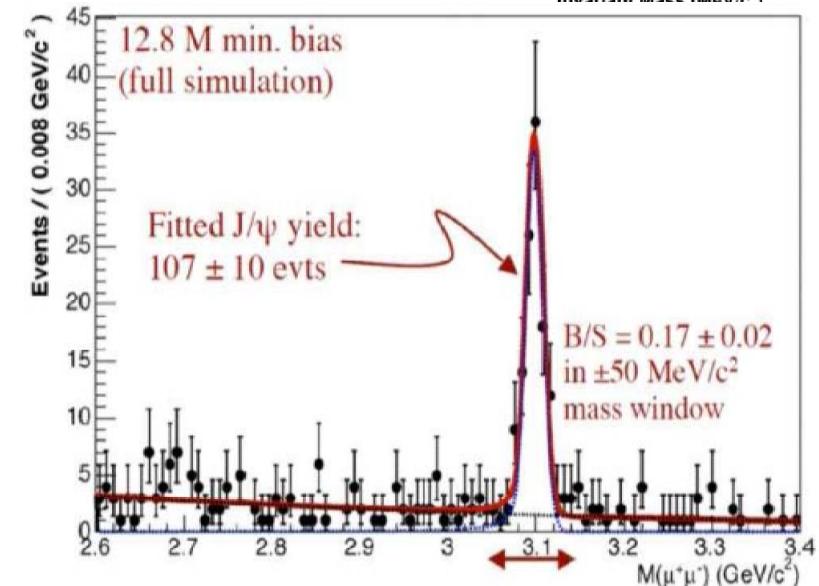
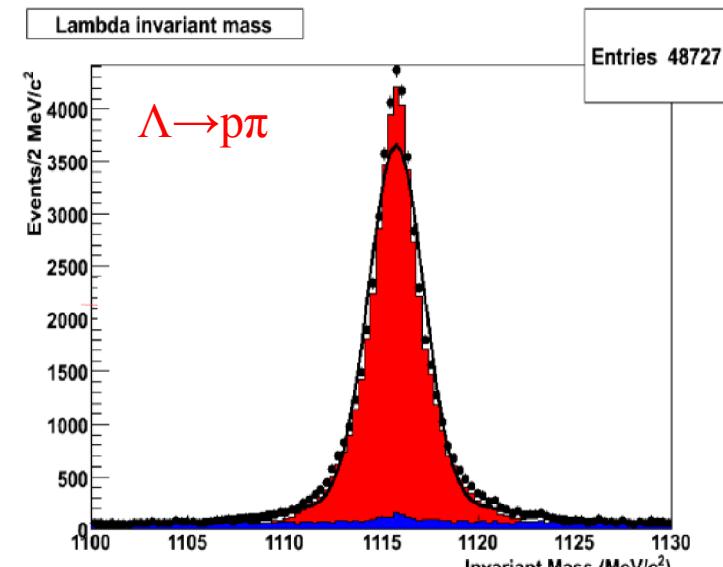
in 10^8 minimum bias events

- ✓ plenty of $K_s \rightarrow \pi\pi$ and $\Lambda \rightarrow p\pi$
- ✓ 95% purity with kinematical and vertex cuts only
 - clean & unbiased sample for PID studies
 - study hadron identification performance

- ✓ collect 1400 $J/\psi \rightarrow \mu\mu$
- ✓ use triggered J/ψ data with p_t -cut on single muon
 - second muon unbiased for PID studies
 - study muon identification performance

- ✓ search for $D \rightarrow K\pi$, $K\pi\pi$, $K^0_S\pi\pi$, $K\pi\pi^0$
 - assess background levels, resolutions & relative efficiencies
 - demonstrate capability to reconstruct first final states

~ 40 mins @ $10^{31} \text{ cm}^{-2} \text{ s}^{-1}$
→ ~50k $\Lambda \rightarrow p\pi$ events

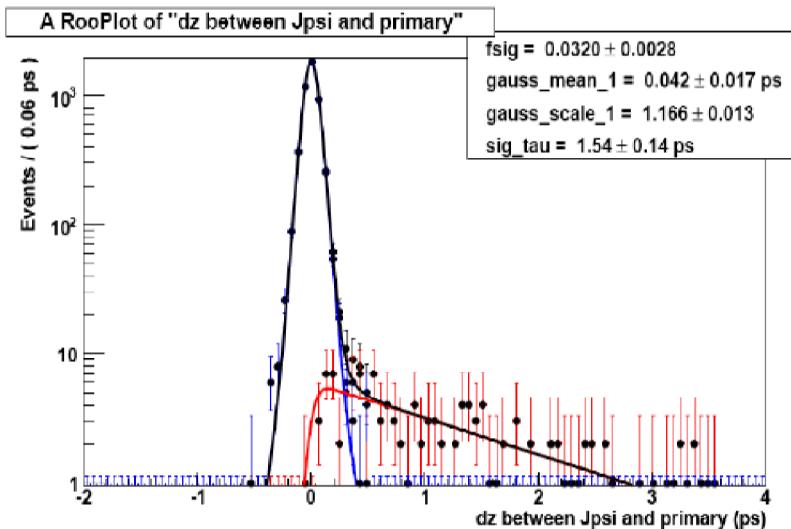
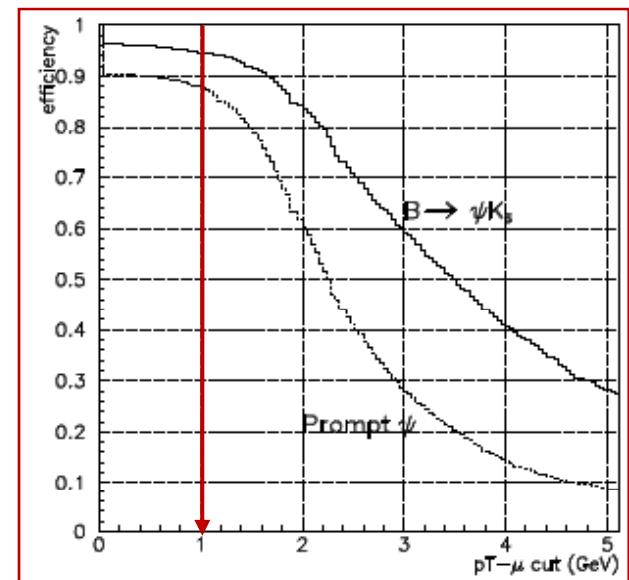
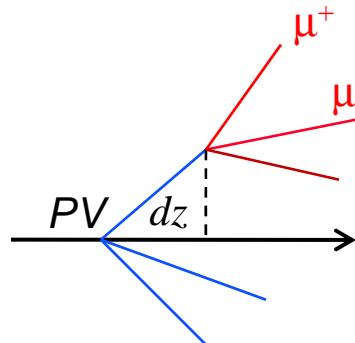


Exploiting first muon trigger data

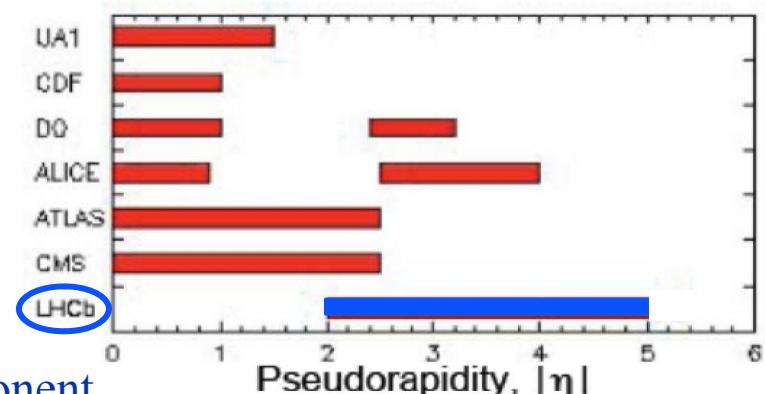
applying J/ψ trigger with p_t -cut on single muon
 → expect $\sim 10^6 J/\psi \rightarrow \mu\mu$ with 1 pb^{-1}

- Reconstruct $J/\psi \rightarrow \mu\mu$ and disentangle fraction of prompt and detached J/ψ 's
- discriminating variable:

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



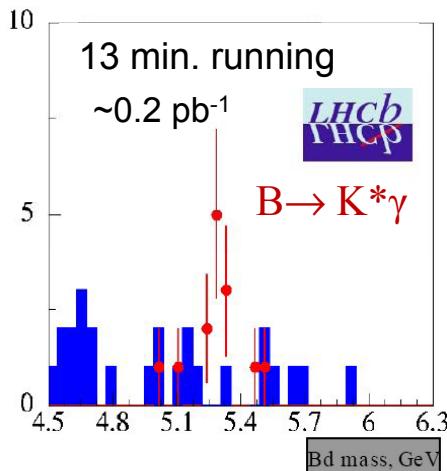
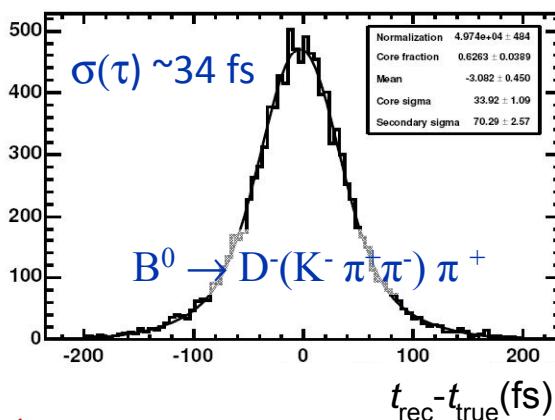
- Measure prompt J/ψ and $b\bar{b}$ cross section in a region not accessible to other collider experiments



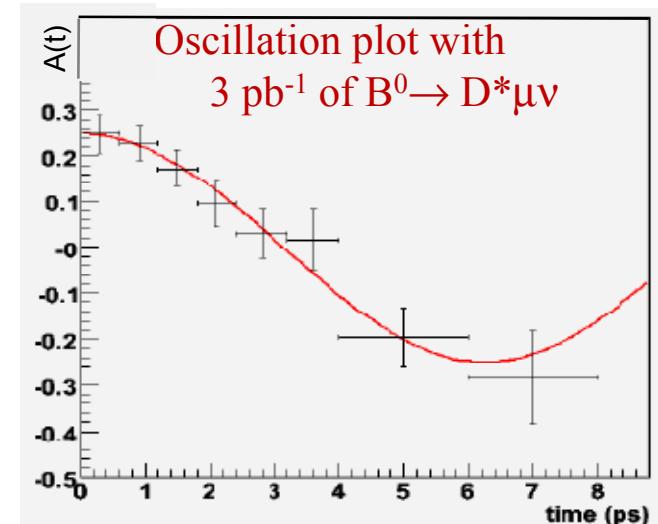
- study proper time resolution with prompt component

Exploiting $\sim 5 \text{ pb}^{-1}$ of data with full trigger

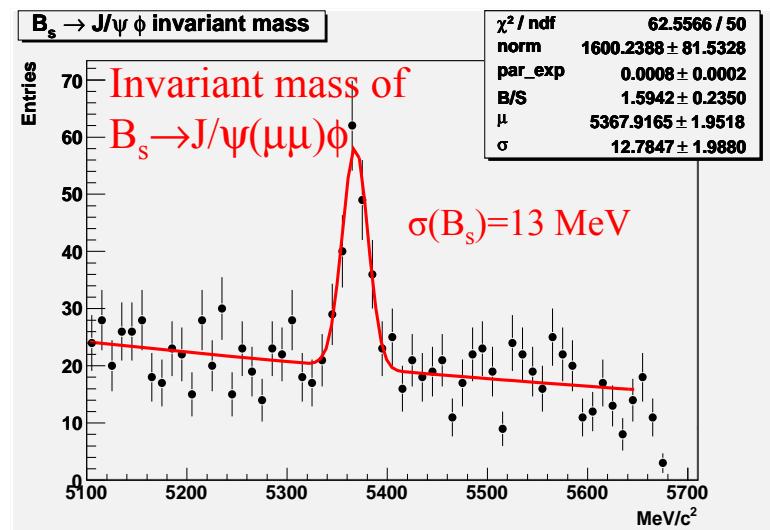
- ✓ 23k $B^0 \rightarrow D^* \mu \nu$ (\sim days of data taking)
 - tagging studies with flavour specific modes
- ✓ 3.2k $B^+ \rightarrow J/\psi K^+$
 - selection does not require lifetime cut
 - unbiased lifetime distribution to determine resolution
- ✓ 4.3k $B^0 \rightarrow D^- (K^- \pi^+ \pi^-) \pi^+$
 - measure B^0 lifetime
 - reach current precision (0.009 ps) with 60k events



- ✓ 3.7k $B \rightarrow K^* \gamma$
 - reference channel for all radiative loop decays
- ✓ 2.3k $B \rightarrow J/\psi K^*$
 - exercise fit machinery for analysis of $B_s \rightarrow J/\psi \phi$



- ✓ Select first 285 $B_s \rightarrow J/\psi \phi$



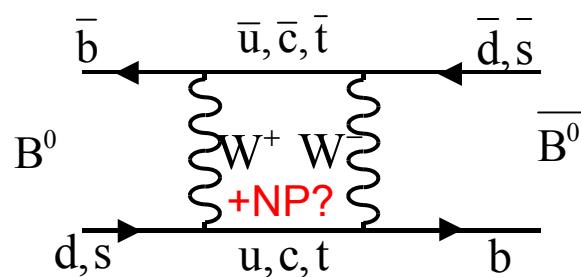
Exploiting $\sim 0.5 \text{ fb}^{-1}$ of data with full trigger

(1/4 of a nominal year)

➤ measure B_s - \bar{B}_s mixing phase ϕ_s in $B_s \rightarrow J/\psi(\mu\mu)\phi$

✓ Sensitive to New Physics effects in mixing

$$\gg \phi_s = \phi_s(\text{SM}) + \phi_s(\text{NP})$$



$$\gg \text{in SM: } \phi_s = -2\beta_s = -\arg(V_{ts}^2) \sim -0.04$$

✓ $J/\psi\phi$ is not a pure CP eigenstate

(2 CP even, 1 CP odd amplitude)

➤ need to fit angular distributions of decay final states as function of proper time

✓ with 28'500 reconstructed $B_s \rightarrow J/\psi(\mu\mu)\phi$ signal events
(before tagging)

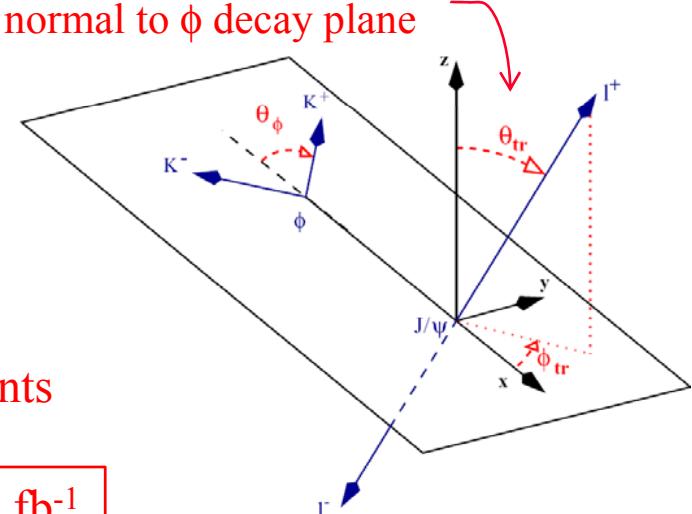
$$\rightarrow \sigma_{\text{stat}}(\phi_s) \sim 0.06 \text{ with } 0.5 \text{ fb}^{-1}$$

$$A_{CP}(t) = \frac{\Gamma[\bar{B}_s(t) \rightarrow f] - \Gamma[B_s(t) \rightarrow f]}{\Gamma[\bar{B}_s(t) \rightarrow f] + \Gamma[B_s(t) \rightarrow f]}$$

$$A_{CP}(t) = \frac{\eta_f \sin \phi_s \sin(\Delta m_s)t}{\cosh(\Delta \Gamma_s t/2) - \eta_f \cos \phi_s \sinh(\Delta \Gamma_s t/2)}$$

$\eta_f = +, -$ 1 CP eigenstates

$\Theta_{tr} =$ angle between l^+ and normal to ϕ decay plane



Exploiting $\sim 0.5 \text{ fb}^{-1}$ of data with full trigger

➤ measure BR of rare decay $B_s \rightarrow \mu^+ \mu^-$

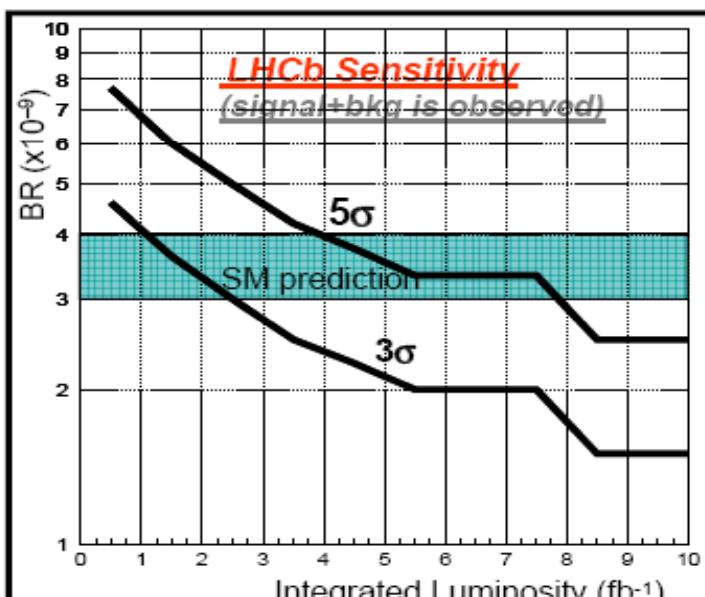
- ✓ Very rare loop decay, sensitive to New Physics
- ✓ $\text{BR} \sim 3.5 \times 10^{-9}$ in SM, can be strongly enhanced in SUSY

Main issue is background rejection:

- dominated by $B \rightarrow \mu^+ X$, $\bar{B} \rightarrow \mu^- X$ decays
- good mass resolution and PID essential

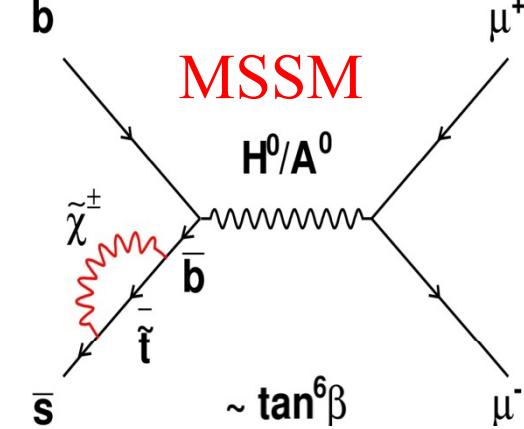
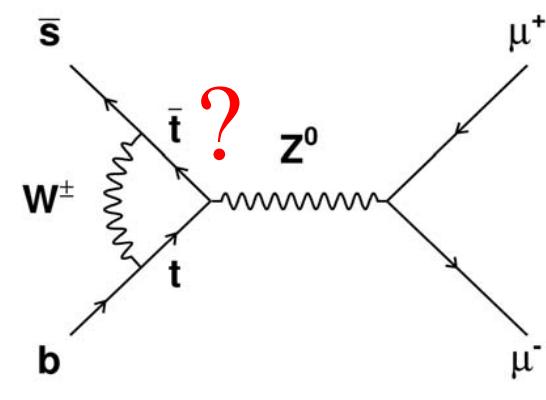
LHCb expected performance:

- with 0.5 fb^{-1} : exclude BR values down to SM value
- with 2 fb^{-1} : 3σ evidence of SM signal
- with 10 fb^{-1} : $> 5\sigma$ observation of SM signal

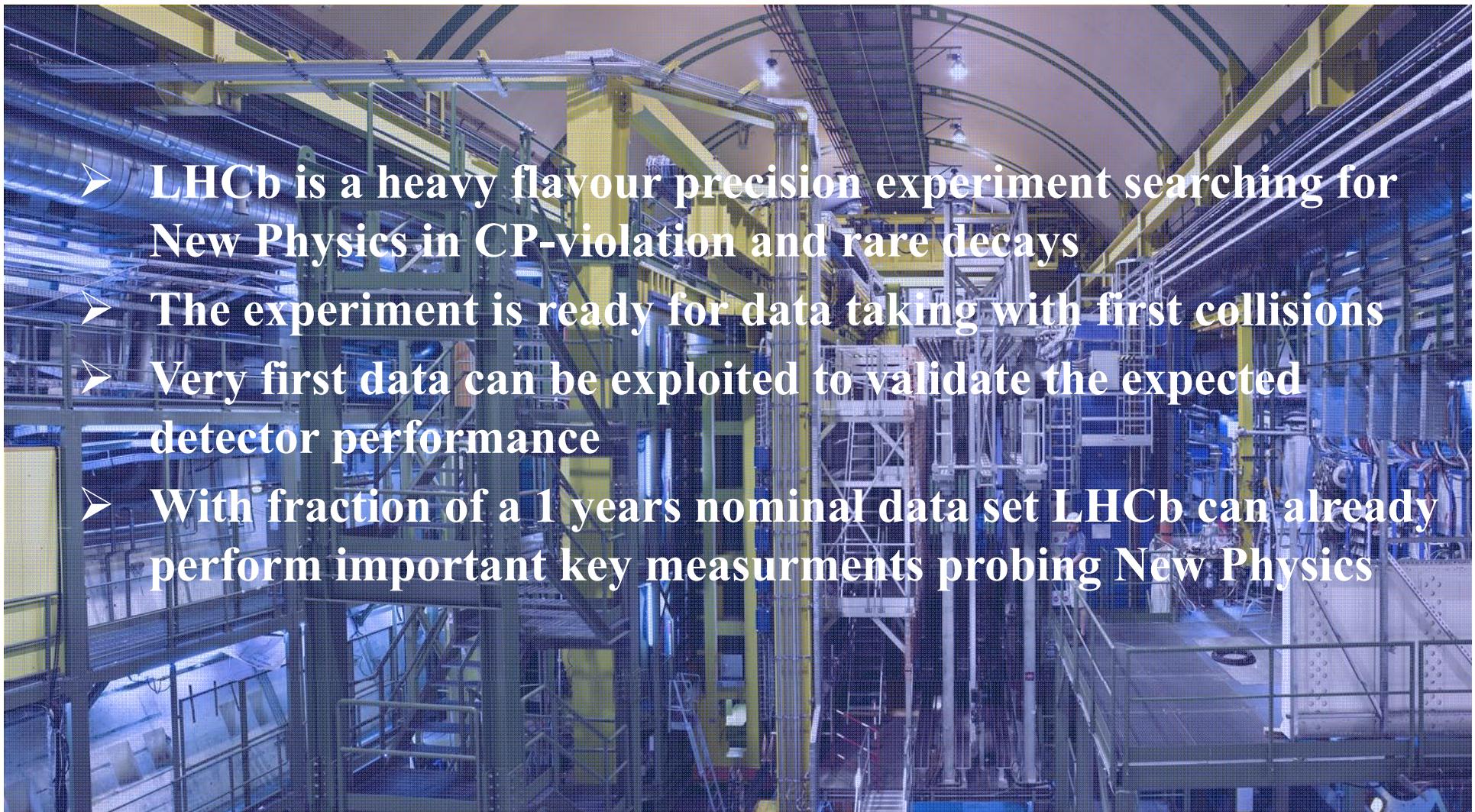


Current limit from CDF
 $\text{BR}(B_s \rightarrow \mu\mu) < 4.7 \times 10^{-8}$

(1/4 of a nominal year)



Conclusion

- 
- LHCb is a heavy flavour precision experiment searching for New Physics in CP-violation and rare decays
 - The experiment is ready for data taking with first collisions
 - Very first data can be exploited to validate the expected detector performance
 - With fraction of a 1 years nominal data set LHCb can already perform important key measurements probing New Physics