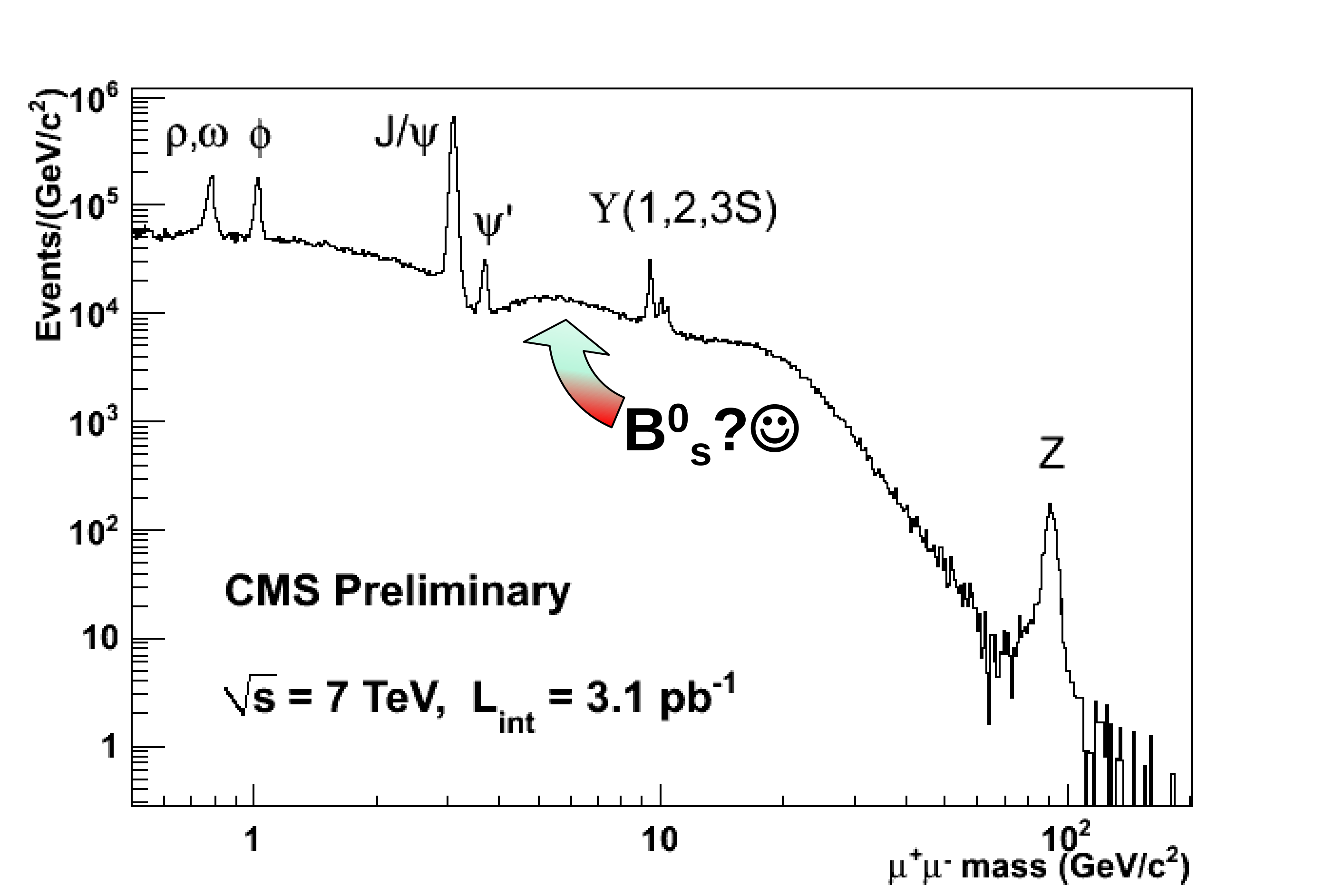
HQL2010: Heavy Quarks and Leptons 2010, 11-15 Oct 2010,
Laboratori Nazionali di Frascati dell'INFN, Frascati (Italia)

Dimuon decays and rare B decays prospects from CMS



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for the CMS Collaboration

Outlook

CMS

Muon results with real data

$B^0_s \rightarrow \mu^+\mu^-$ analysis and prospects

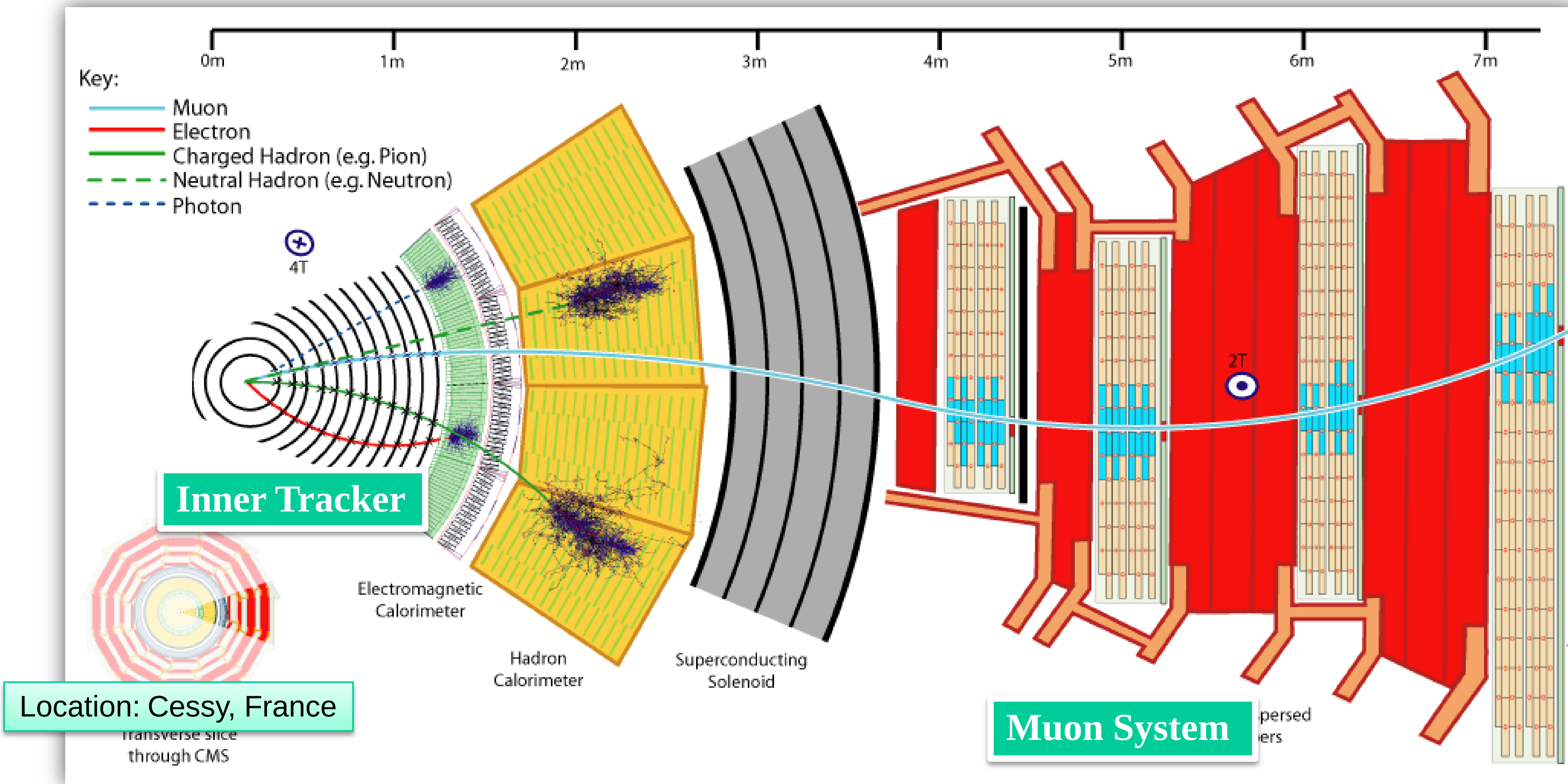
Main Sources:
BPH-07-001
BPH-10-002
BPH-10-003
MUO-10-002

What CMS is

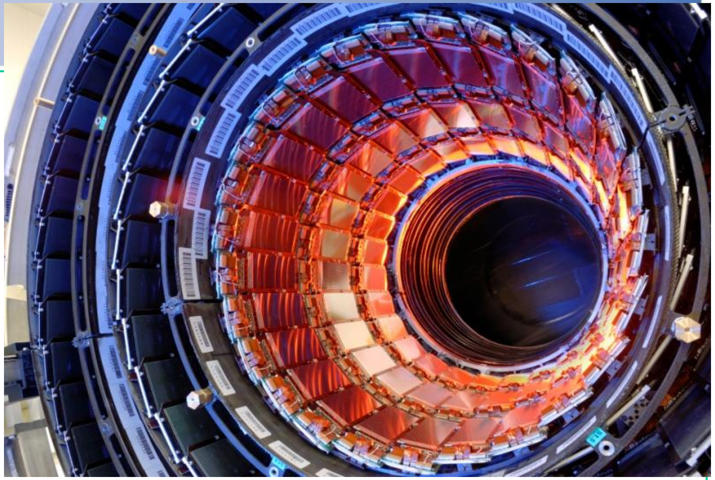
Compact Muon Solenid

*** Size: 21 m long, 15 m wide and 15 m high. Weight: 12 500 tonnes**

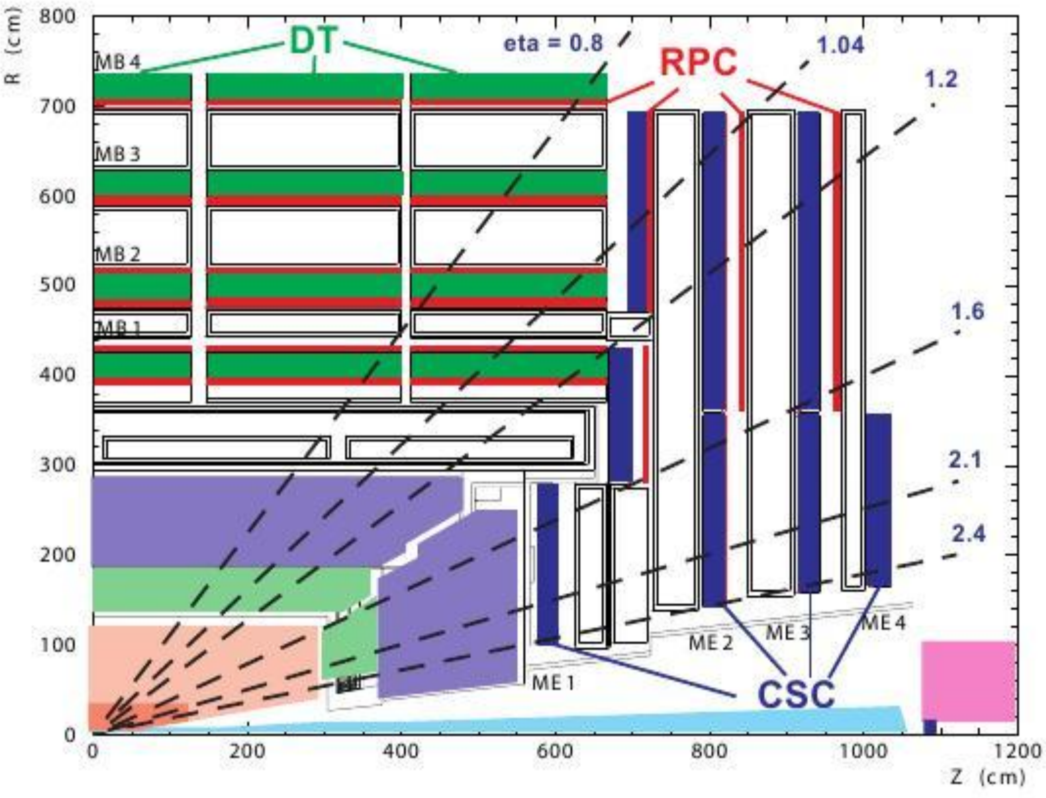
*** Solenoid B = 3.8 T**



Tracker and Muon systems

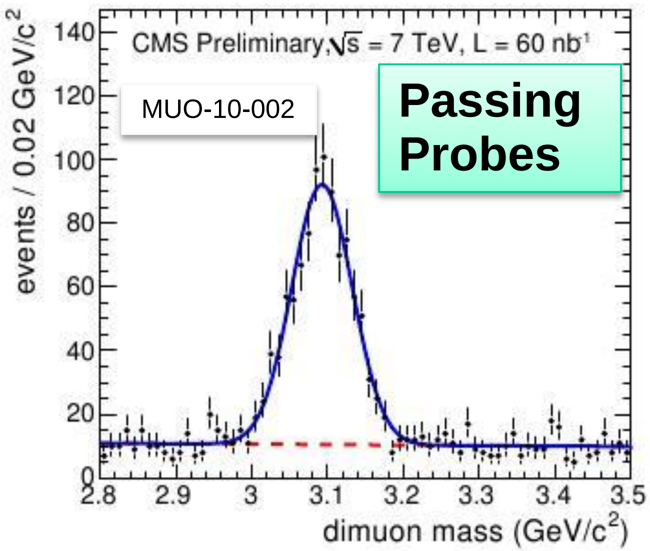


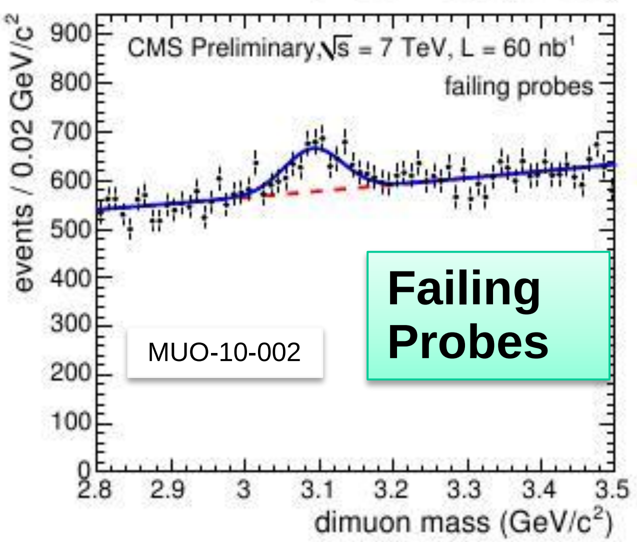
- **Tracker:**
  - **3 pixel layers + at least 10 strip layers for**
    - **pT measurement**
    - **vertex reconstruction**
- **Muon Chambers:**
  - **3 different sub-detectors for muons (Drift Tube, Resistive Plate Chambers and Cathode Strip Chambers)**
    - **muon identification**
    - **pT measurement for Stand Alone and Global Muons**
- **Track and Muon coverage:** **$|\eta| < 2.4$**

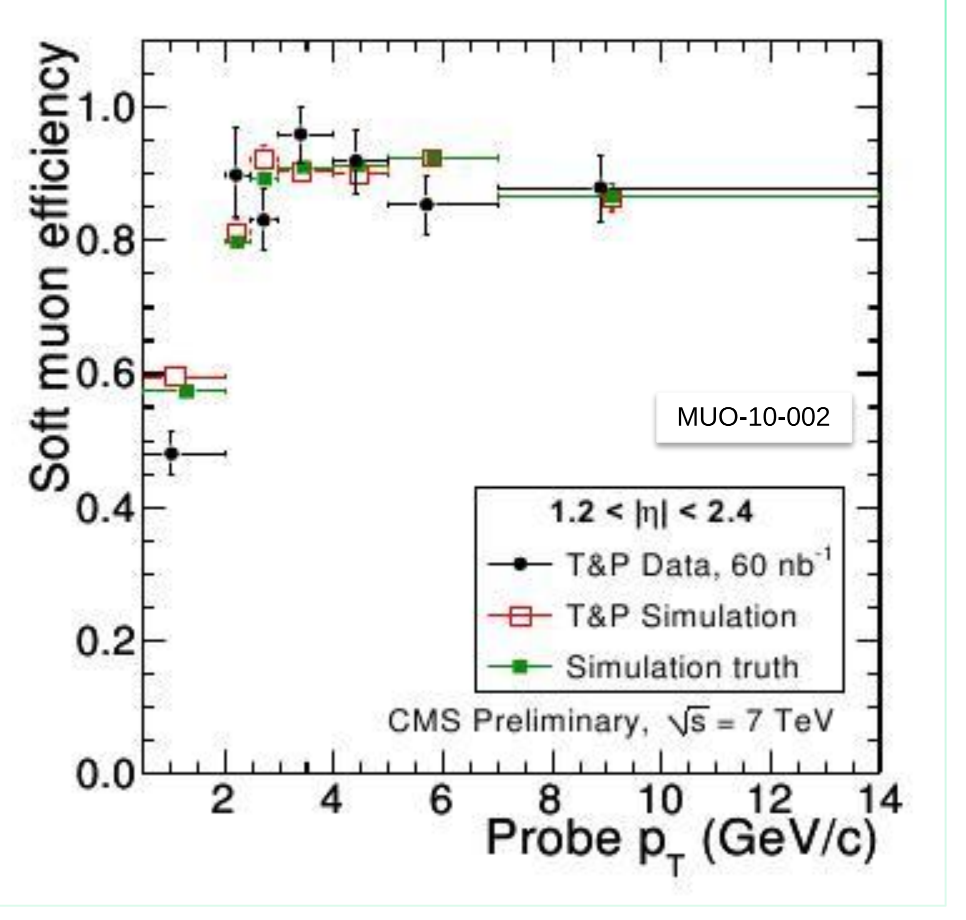


CMS Muon Results with real data: Efficiencies with Tag & Probe Data-Driven Technique

- Take events from a well known resonance, like a J/ψ
- Tag a well reconstructed muon
- Probe the second muon to test if it passes the efficiency request

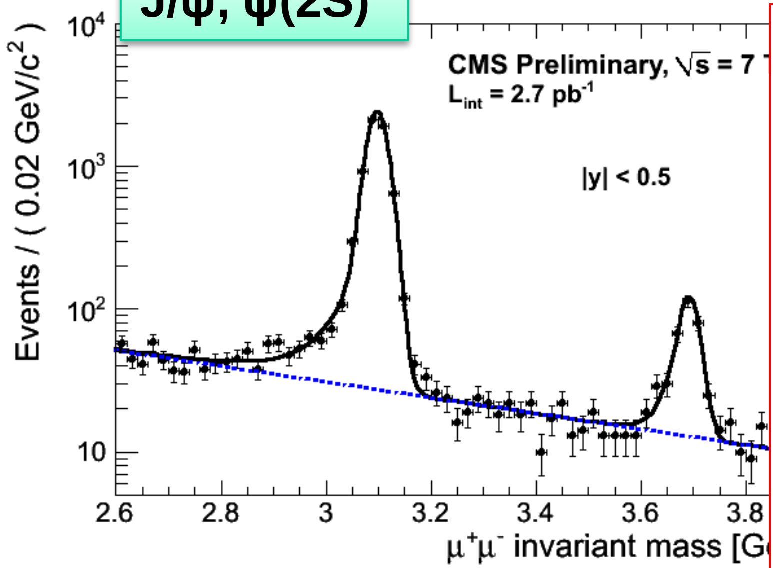




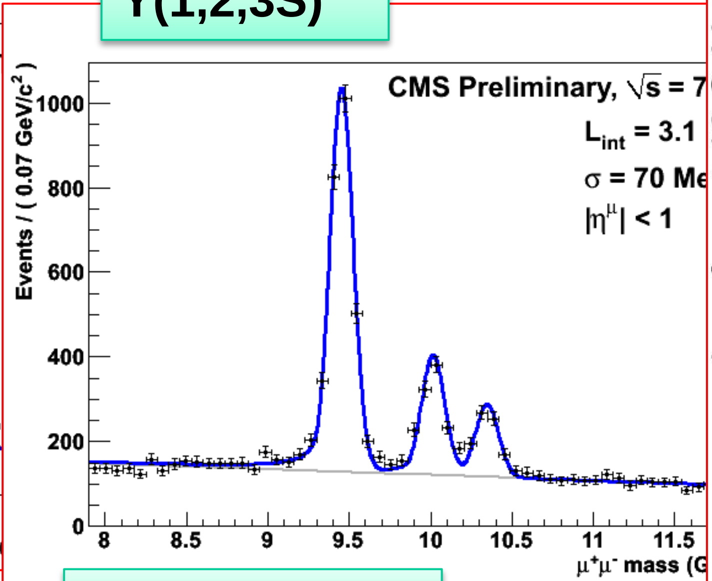


Some CMS di-muon results

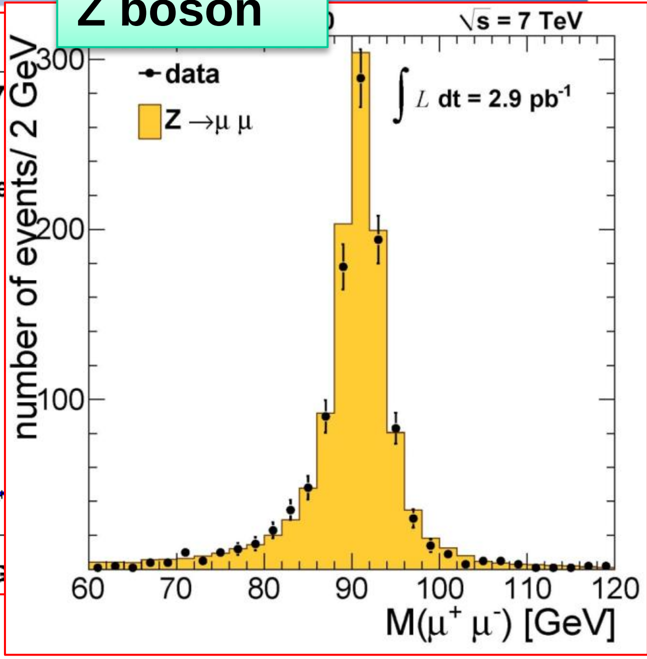
J/ψ, ψ(2S)



Υ(1,2,3S)



Z boson

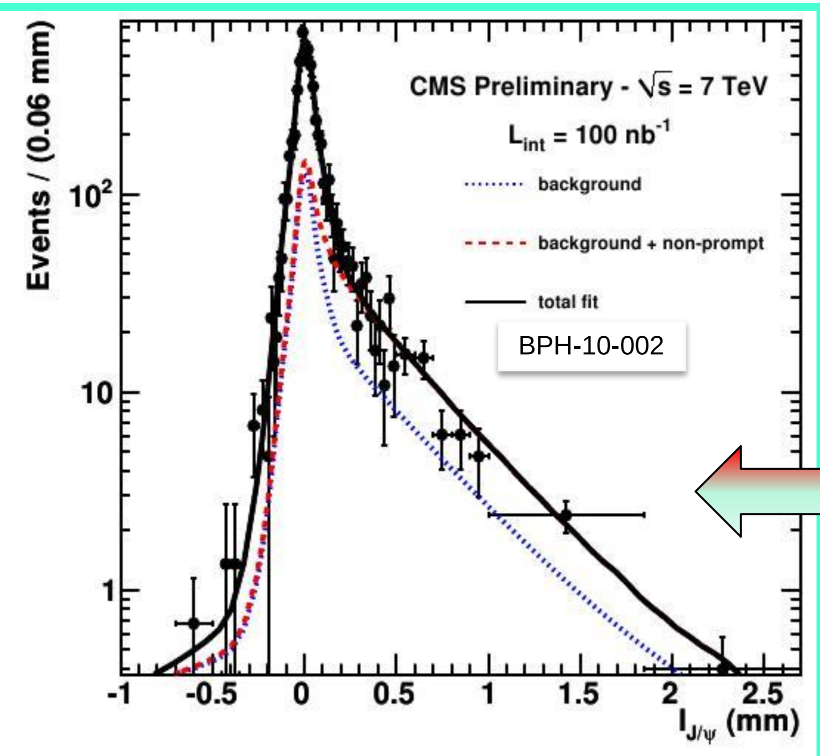


Invariant Mass

- **Tight resonance resolutions:**

from 20 MeV to 100 MeV, depending on η

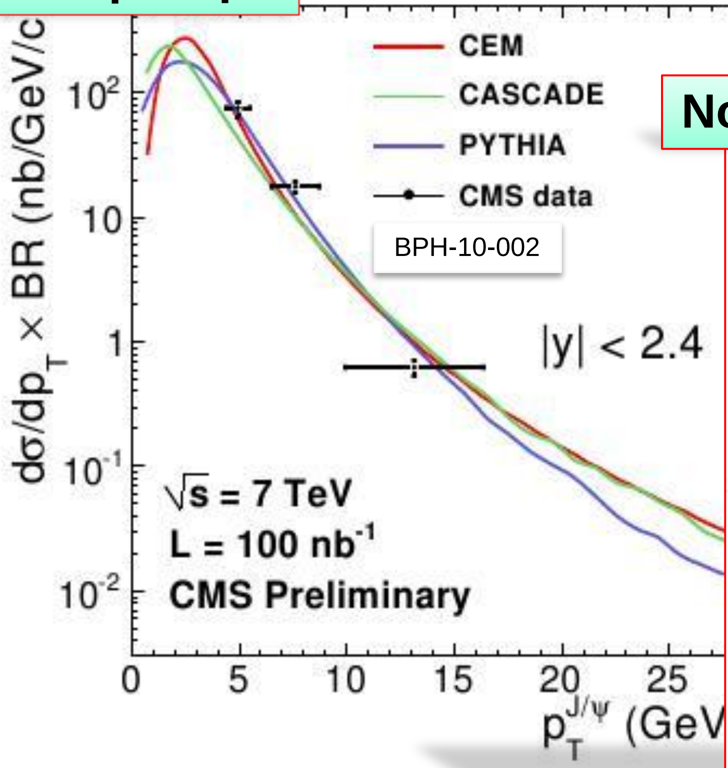
Decay Length



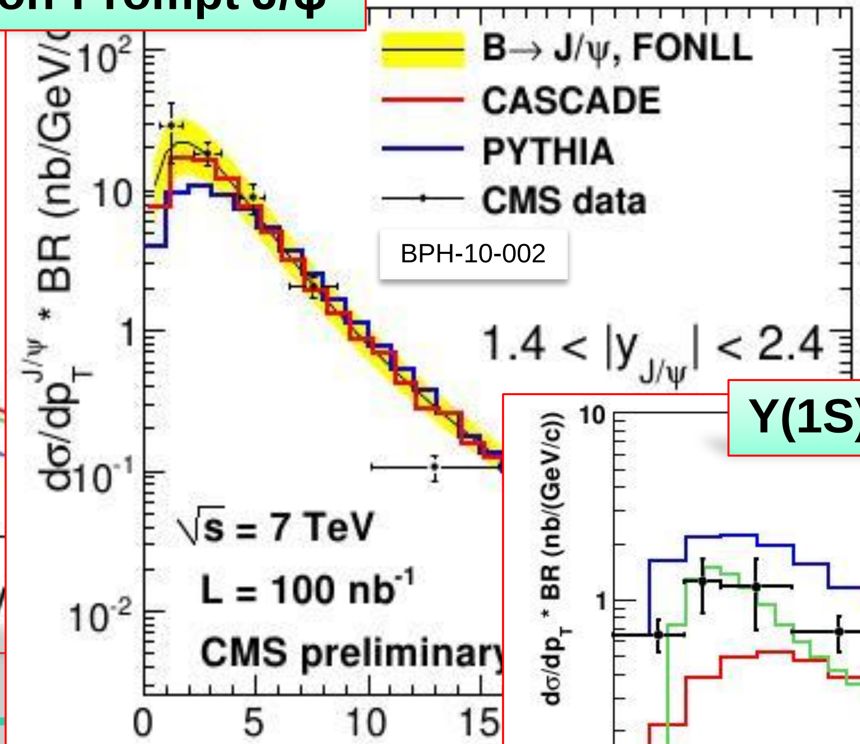
- **Inner Tracker permits to distinguish between the possible secondary vertex and the primary vertex**

Some CMS di-muon results: Quarkonia Cross sections

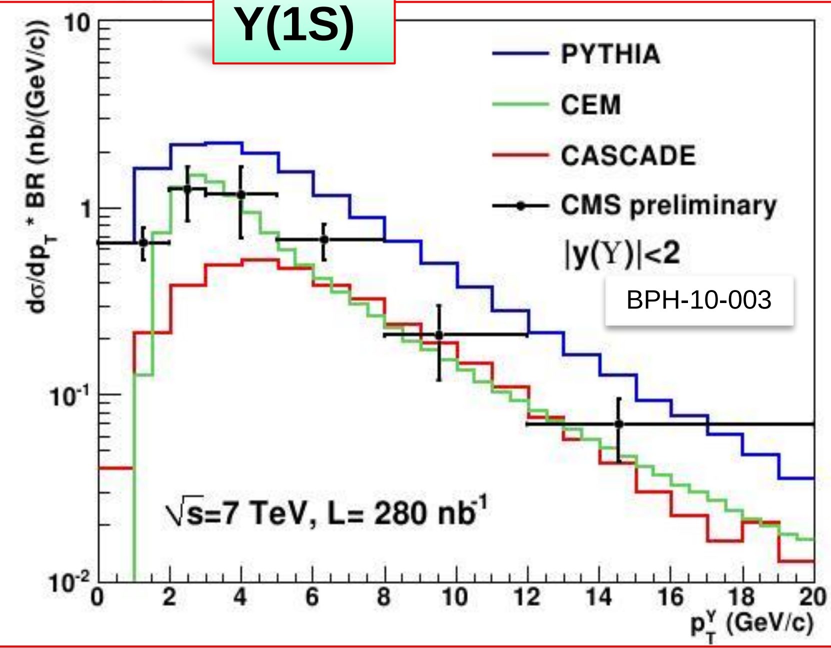
Prompt J/ψ



Non-Prompt J/ψ



Y(1S)



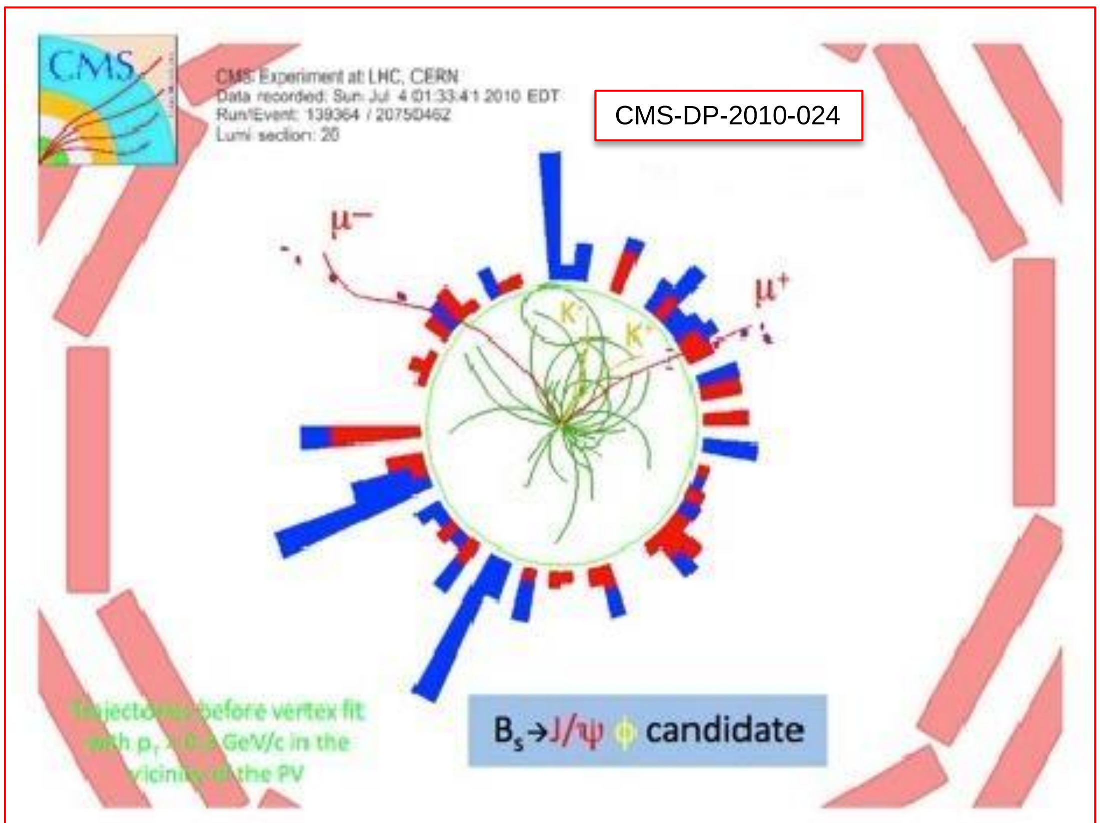
$\sigma(J/\psi) = 289.1 \pm 16.7 \pm 60.1$ nb
($4 < p_T < 30$ GeV, $|y| < 2.4$)

$\sigma(J/\psi$ non prompt$) = 56.1 \pm 5.5 \pm 7.2$ nb
($p_T > 4$ GeV/c, $|y| < 2.4$)

σ (Y(1S)) = $8.3 \pm 0.5 \pm 1.3$ nb ($|y| < 2.0$)
(Y(2S)+Y(3S))/Y(1S) = $0.44 \pm 0.06 \pm 0.05$

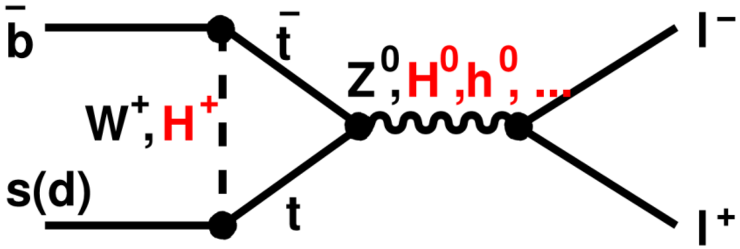
$B^0_s \rightarrow \mu^+\mu^-$ analysis and prospects

- **B hadrons are an ideal tool for advancing our current understanding of the flavor sector of the SM, and searching for effects originating from physics beyond the SM:**
  - **large production rate**
  - **easy to identify:**
    - **due to their long lifetime and relatively high mass**

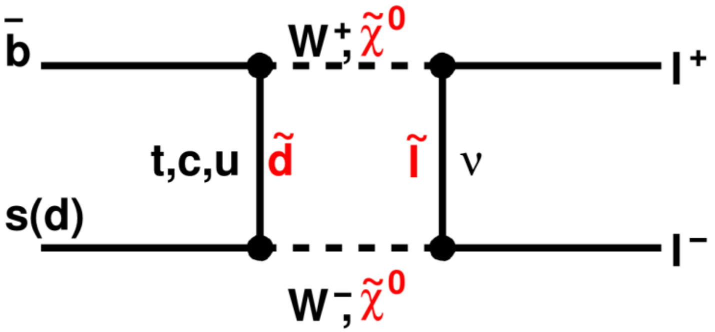


A sensitive probe of physics beyond the SM: $B^0_s \rightarrow \mu^+\mu^-$

- In the SM, $BR(B^0_s \rightarrow \mu^+\mu^-) = (3.86 \pm 0.15) \times 10^{-9}$ since it involves:
  - flavor-changing neutral current $b \rightarrow s$
  - internal quark annihilation
  - helicity suppression



- Current best limits (90% CL):
  - D0 9.3×10^{-8} (2 /fb)
  - CDF 4.3×10^{-8} (3.7 /fb)



- In MSSM the BR can be enhanced by orders of magnitude:
  - $BR(B^0_s \rightarrow \mu^+\mu^-)$ is proportional to $\tan^6(\beta)$

- $BR(B^0_s \rightarrow \mu^+\mu^-)$ measurement can give a lower bound on $\tan(\beta)$

$$\tan(\beta) = \frac{v_u}{v_d}$$

Vacuum expectation values of Higgs bosons up and down

The $B^0_s \to \mu^+\mu^-$ analysis in CMS

- Use a relative normalization to the well-measured decay

$B^\pm \to J/\psi K^\pm$

$J/\psi \to \mu^+\mu^-$

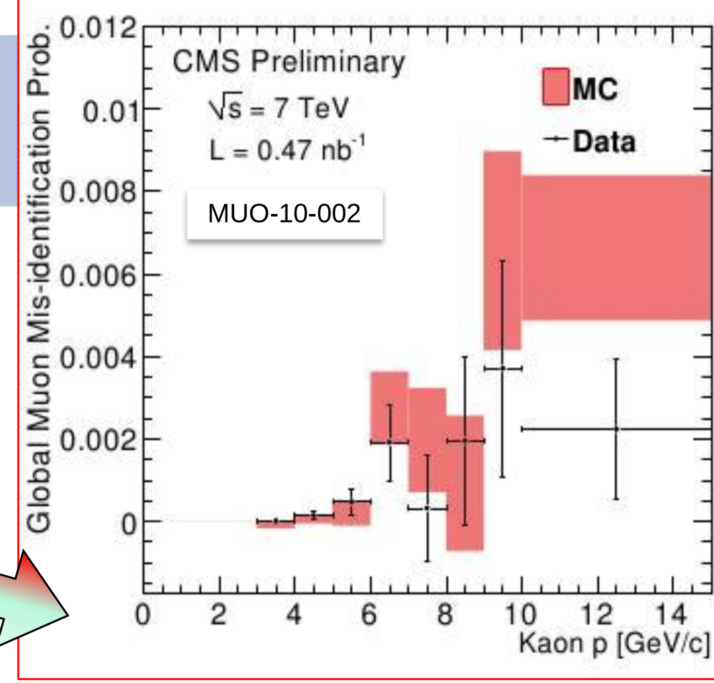
to avoid a dependence on

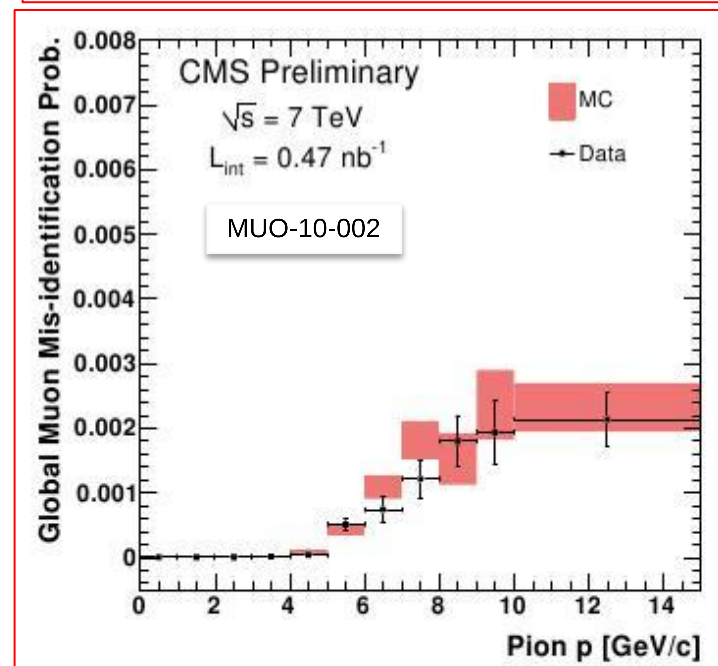
- the unknown *b*bbar production cross section
- on the integrated luminosity
- to cancel many systematic uncertainties

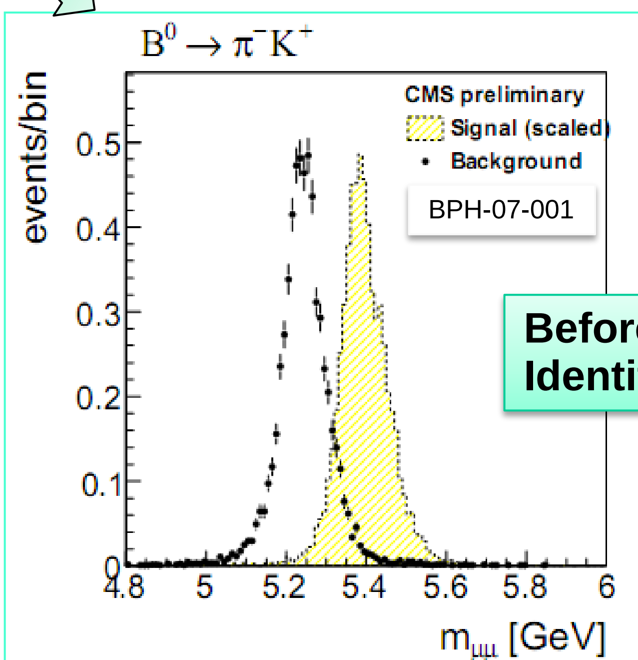
$$\mathcal{B}(B^0_s \to \mu^+\mu^-) = \frac{N(n_{obs}, n_B, n_S)}{N(B^\pm \to J/\psi K^\pm)} \frac{f_u}{f_s} \frac{\alpha_{B^+}}{\alpha_{B^0_s}} \frac{\varepsilon^{trig}_{B^+}}{\varepsilon^{trig}_{B^0_s}} \frac{\varepsilon^{ana}_{B^+}}{\varepsilon^{ana}_{B^0_s}} \mathcal{B}(B^\pm \to J/\psi K^\pm) \mathcal{B}(J/\psi \to \mu^+\mu^-)$$

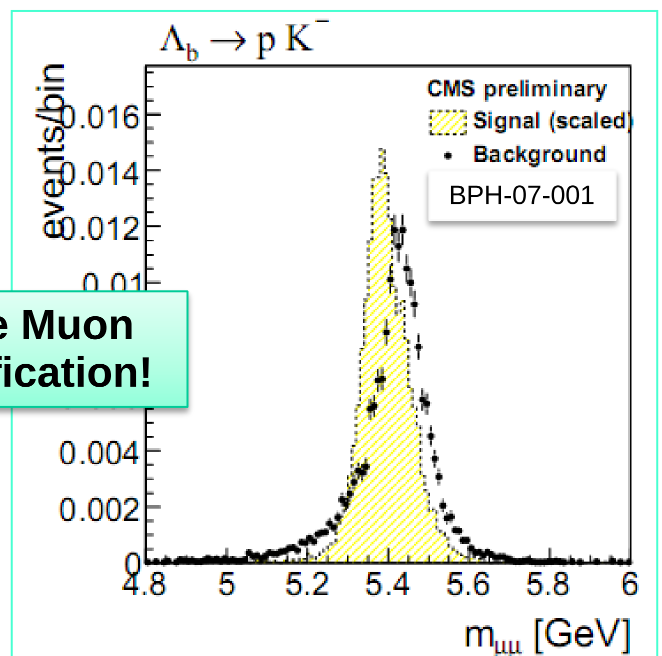
Background sources

1. *qq*bar events with both $q \rightarrow \mu X$ ($q = b,c$)
2. QCD events where a true muon is combined with a hadron misidentified as muon
3. rare B and Λ_b decays (hadronic, semileptonic, and radiative decays)
   1. peaking ($B^0_s \rightarrow KK$, $\Lambda \rightarrow pK$)
   2. non peaking background (determined with side-bands)





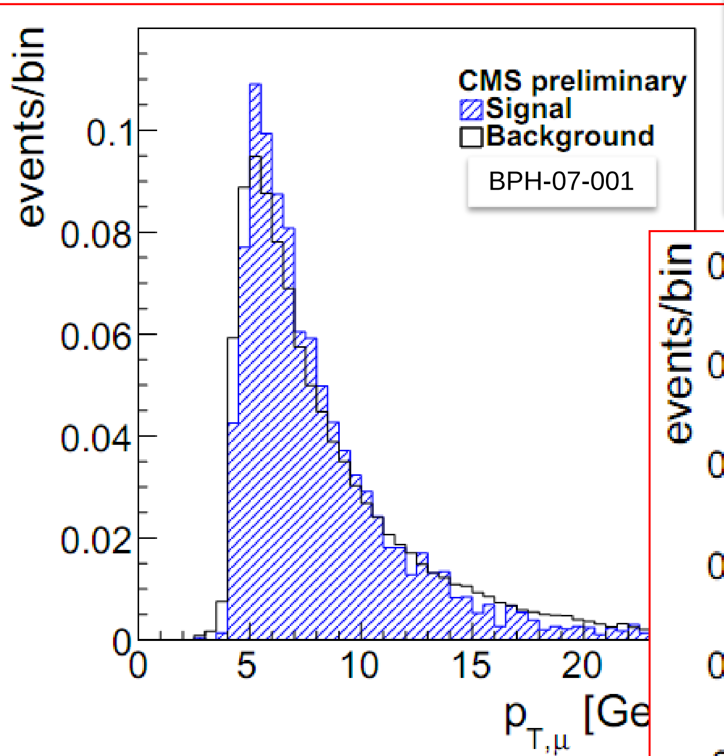




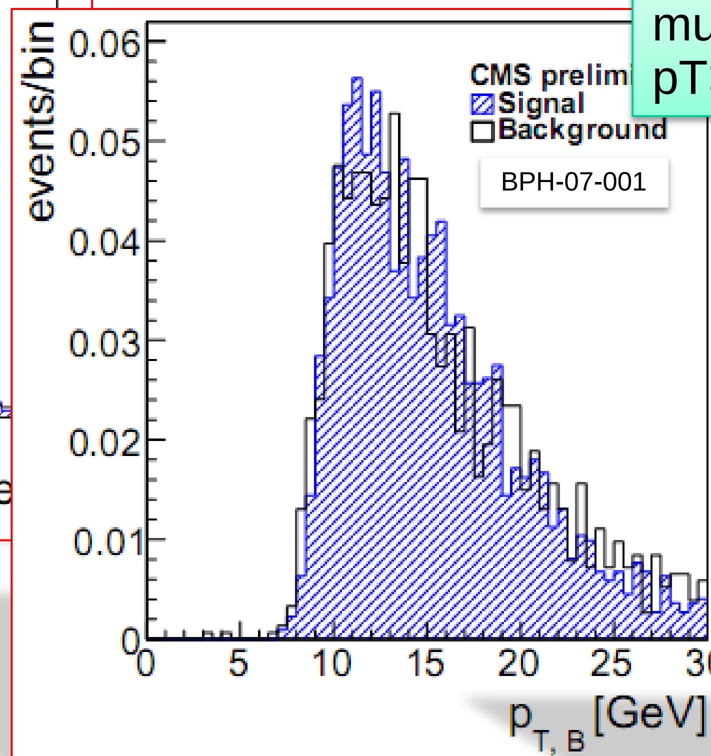
Before Muon Identification!

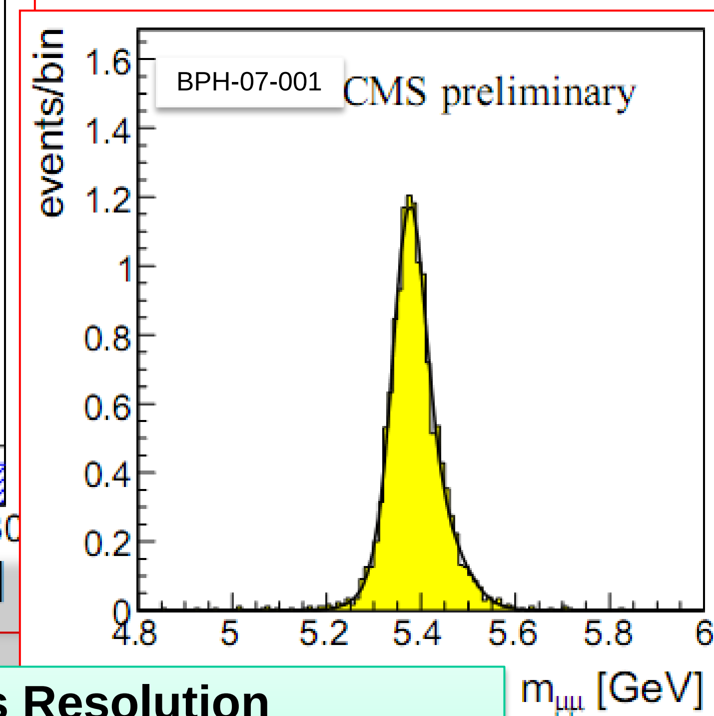
Reconstructed muons and di-muons: Kinematical selections

Muon Selections:
2 Global Muons with the smallest ηφ separation
pT> 4 GeV/c
|η|<2.4



B^0_s made vertexing muon pairs
pT> 5 GeV/c





Mass Resolution
σ = 53.0±1.4 MeV

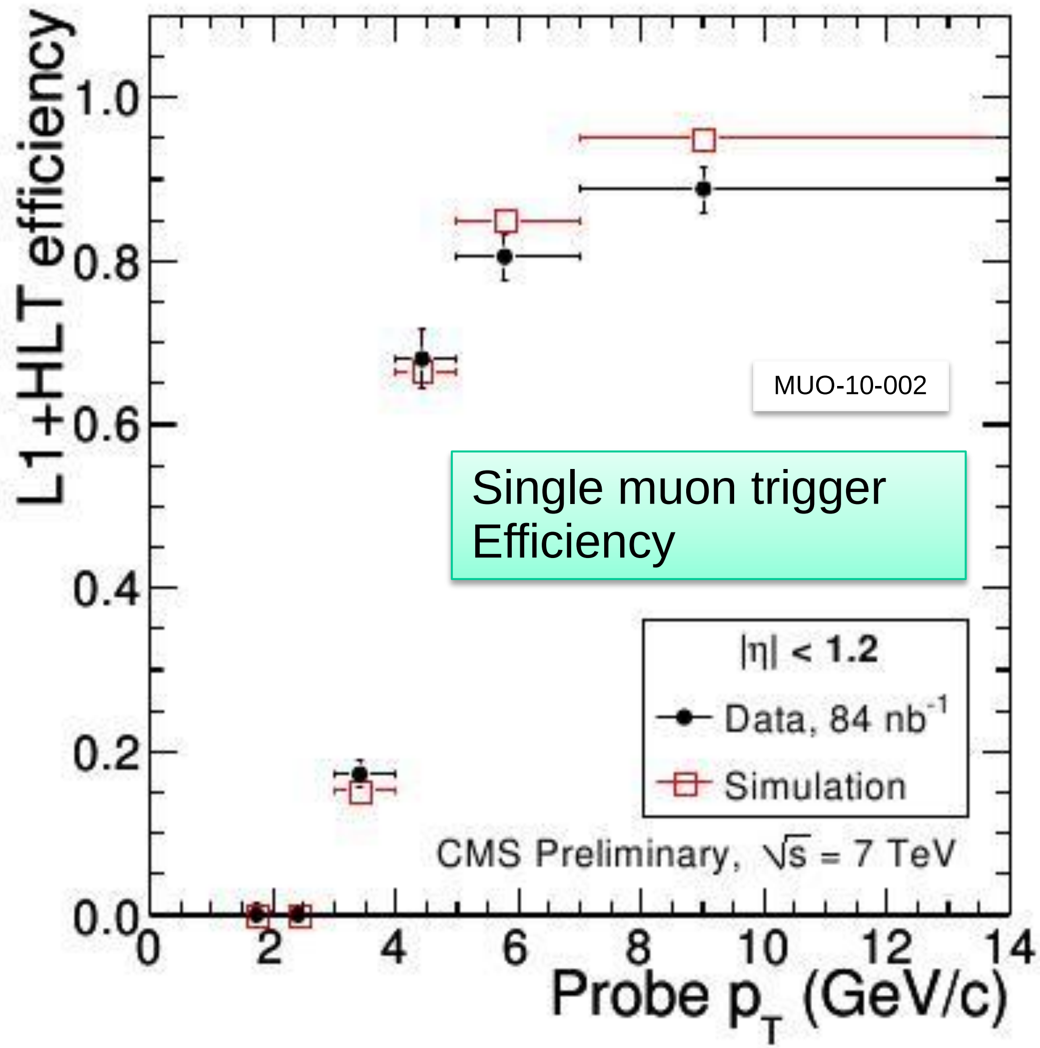
(Second momentum of double gaussian fit)

Muon Trigger

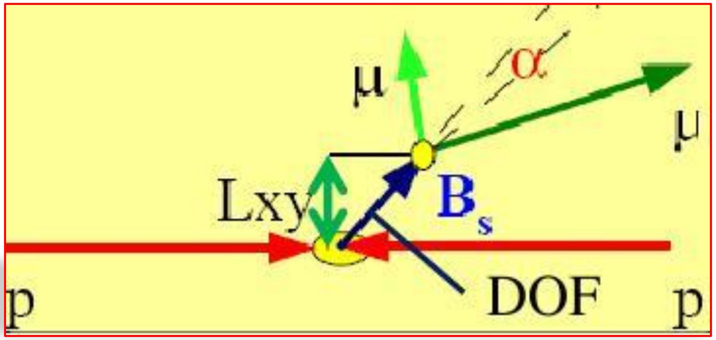
Integrated Luminosity ~ 1 fb^{-1}

Instantaneous Luminosity 1E32 $cm^{-2}s^{-1}$

- **Trigger:**
  - **2 Global Muons**
  - **p_T > 3 GeV/c**
  - **Vertex Quality $\chi^2 < 10$**
  - **significance(Lxy) > 3**
  - **cos α > 0.9**



Single muon trigger Efficiency



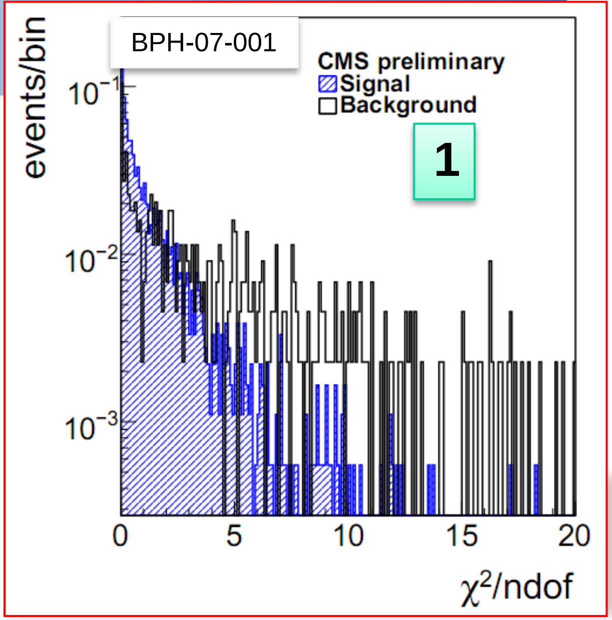
Global Muon:
global fit between tracker track and stand-alone muon tracks

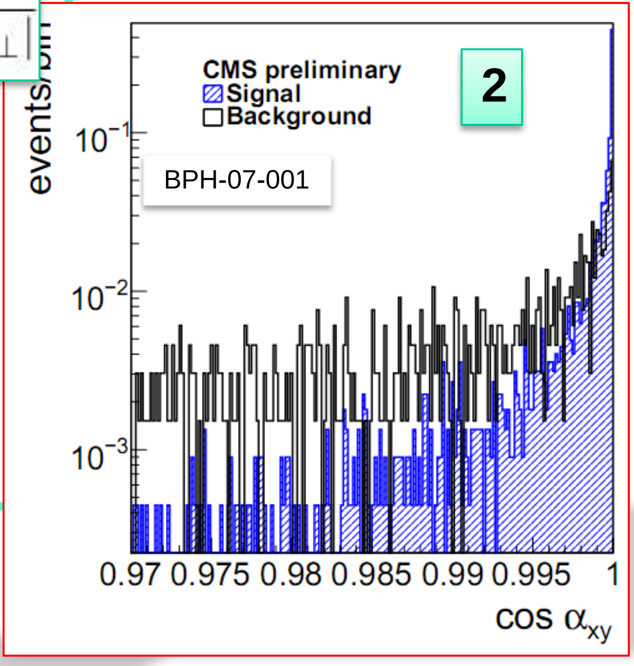
Event Selections

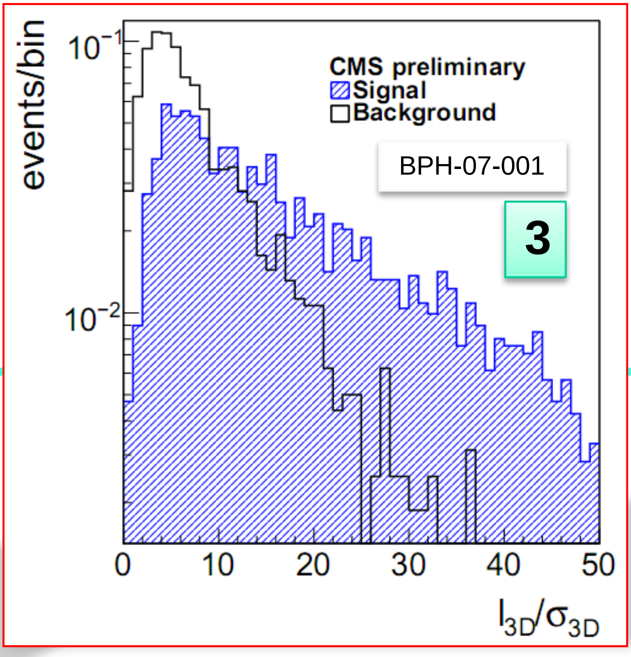
1. **Vertexing the muon pair.** Non peaking background muons come from separate vertices
2. **Angle of decay α of the dimuon.** The pT vector of the B_s is close to the direction of the secondary vertex from the primary vertex
3. **Decay length significance**
4. **Isolation around the dimuon**

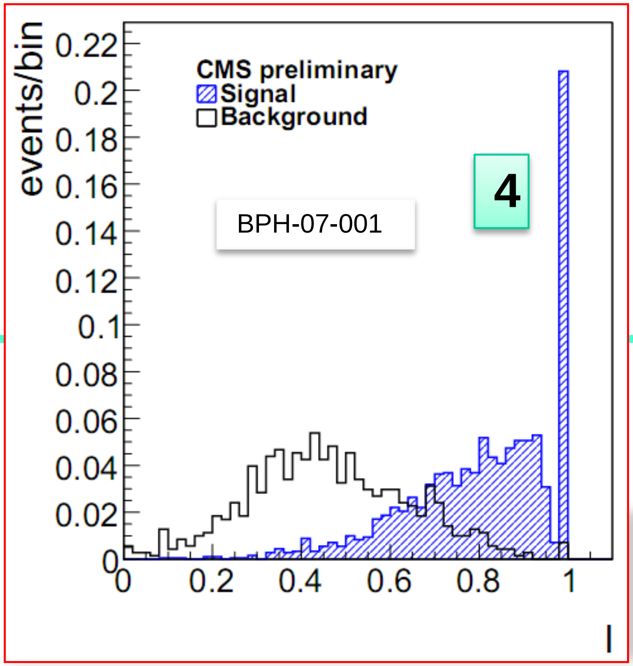
$$I = \frac{p_\perp(B^0_s)}{p_\perp(B^0_s) + \sum_{trk} |p_\perp|}$$

$R = \sqrt{(\Delta\eta^2 + \Delta\varphi^2)} = 1$
pT > 0.9 GeV









Efficiency of selections

	Signal Efficiency	*bb*bar → μμX bkg Efficiency
Trigger	0.171	0.016
Good Events	0.130	0.013
Mass Cut 4.8 – 6 GeV	0.130	6.15 E-4
Event Selections	0.024	4.61 E-8
In B^0_s mass range ±100 MeV	0.023	7.82 E-9

selection criteria optimized by determining the lowest achievable upper limit on the branching fraction in a multi-dimensional grid search

Gen. Signal #	103
Rec. Signal #	2.23
Rec. Background # (including rare B decays)	6.53

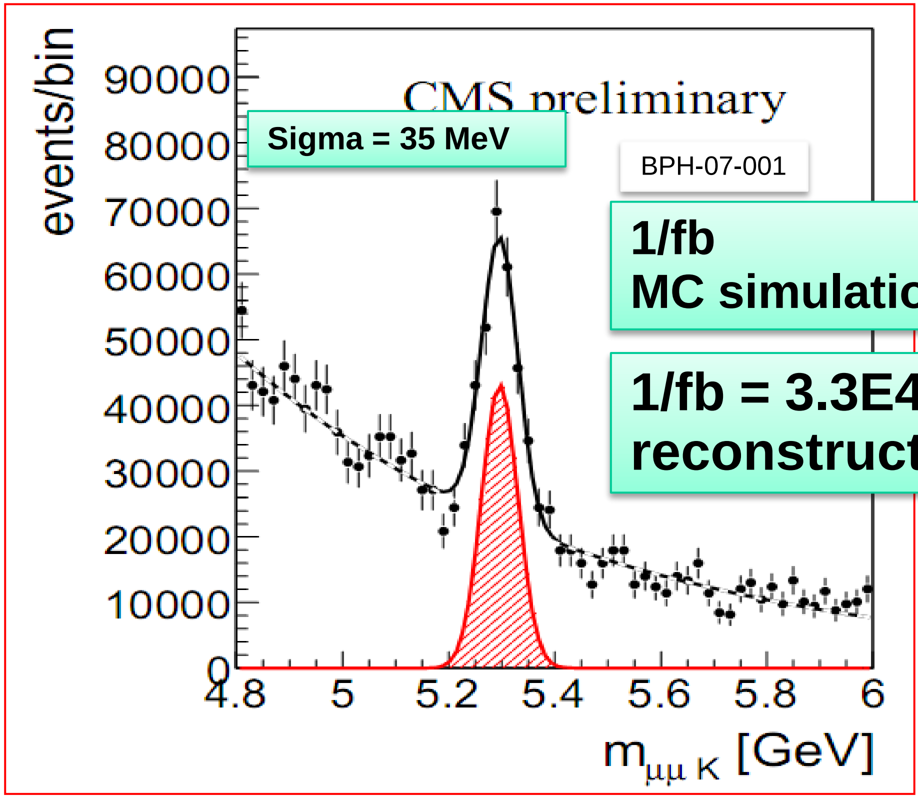
1 /fb

Upper Limit at 90% CL

$$\mathcal{B}(B^0_s \to \mu^+\mu^-) \leq 1.6 \times 10^{-8}$$

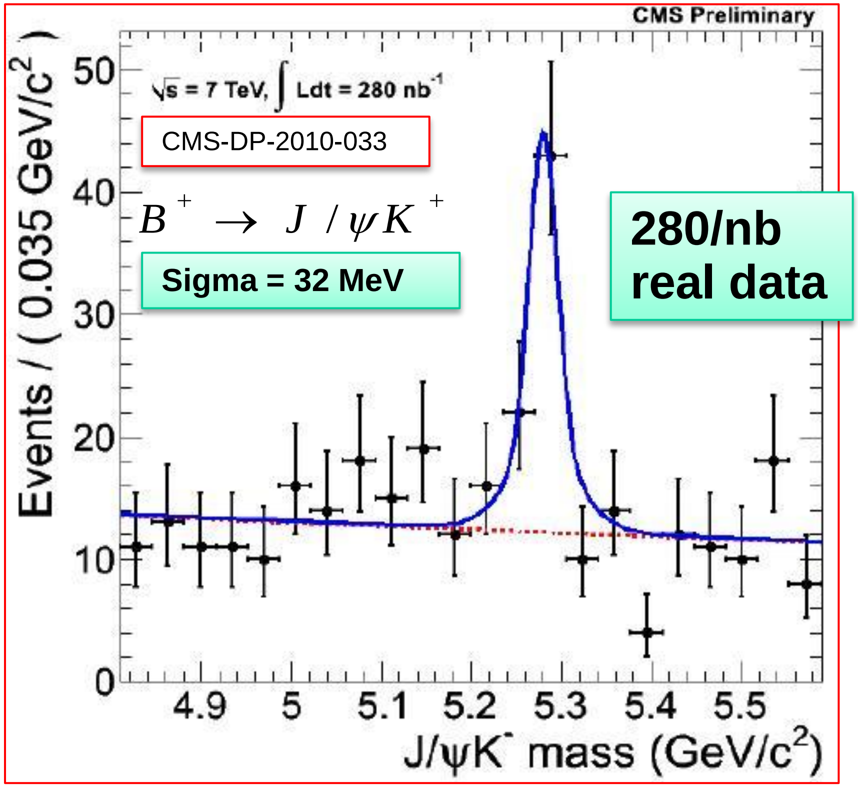
A look to the normalization Sample: $B^{\pm} \rightarrow J/\psi K^{\pm}$

- **Large and well measured branching fraction**
- **but one additional track**
- **hadronization between $B^{\pm}$ and B^{0} may differ**
- **Selection requirements as similar to signal as possible:**
  - **Decay vertex reconstructed using only the two muons, no mass constraints**



1/fb
MC simulation

1/fb = 3.3E4
reconstructed events



280/nb
real data

Conclusions

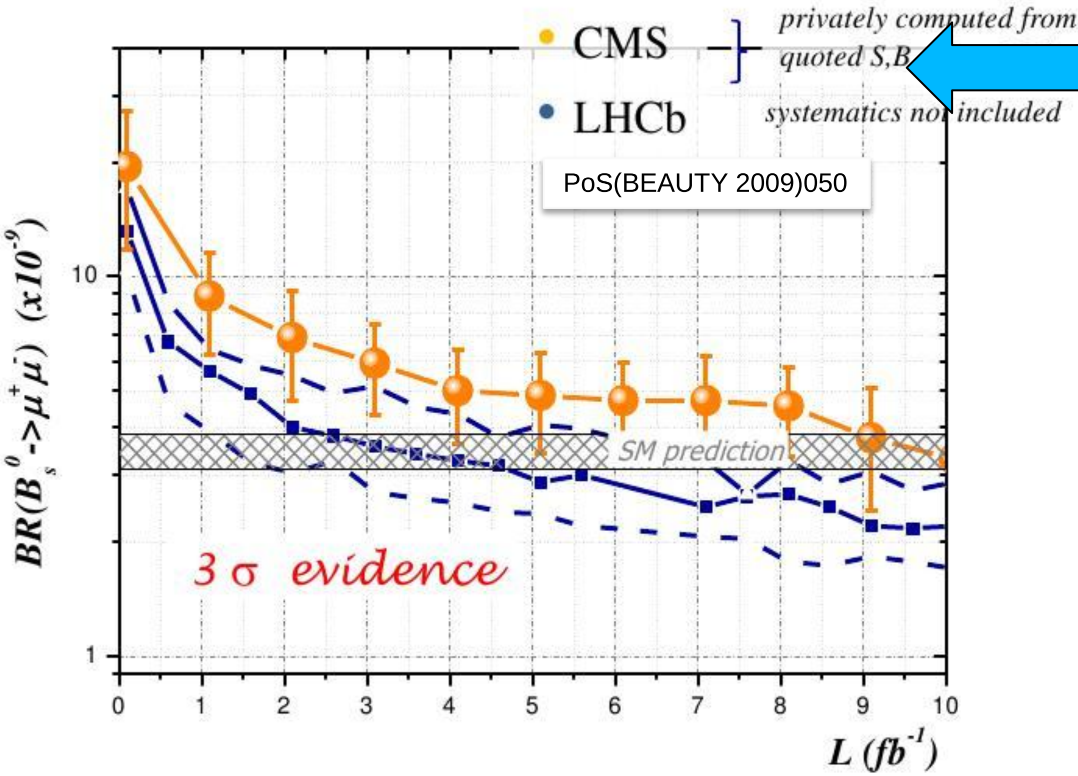
- End of next year we could get 1/fb: constraint on new physics models

- 7 TeV instead of 14 TeV:
  - b cross section is about a factor 2 lower

- But possible analysis improvements:
  - Looser triggers
  - Tracker Muons
    - raise trigger and identification efficiencies

BACKUP

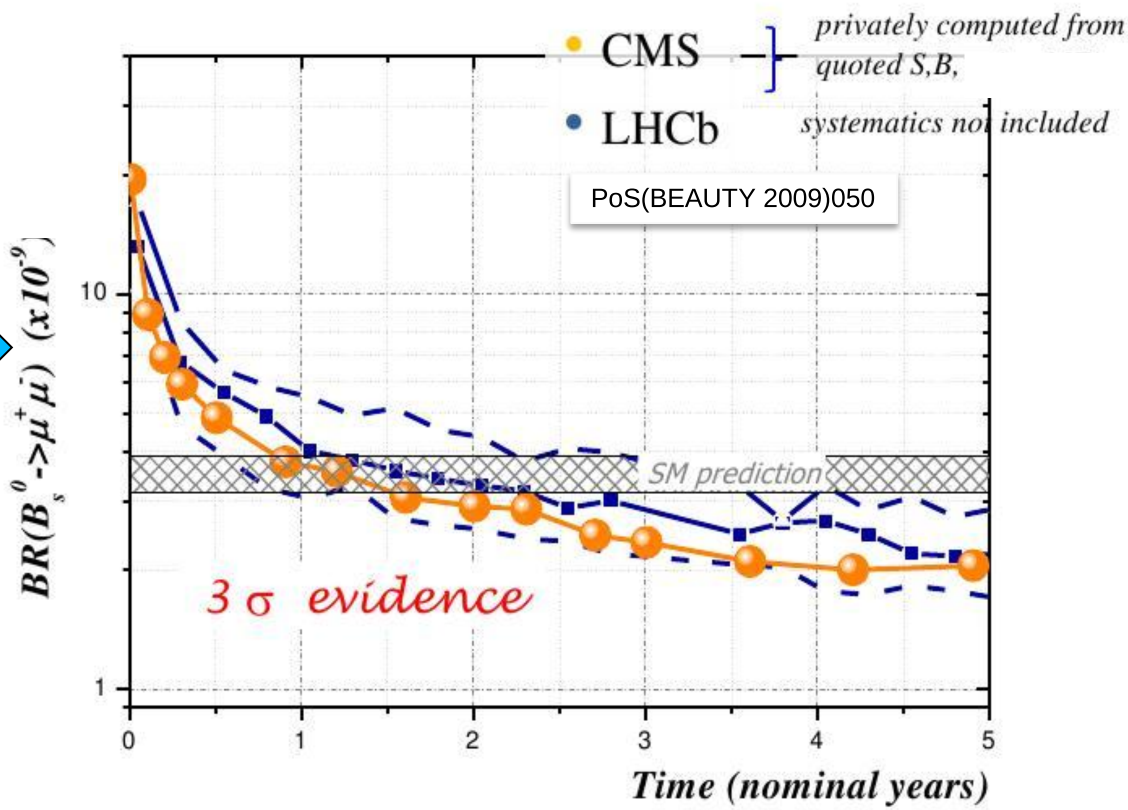
A comparison with LHCb for a 3σ evidence



Integrated Luminosity

Time

LHCb is expected to get less instantaneous luminosity with respect to CMS and Atlas



Assuming nominal luminosities since the beginning

CMS → $L = 10^{33}\ cm^{-2}s^{-1}$

LHCb → $L = 2x10^{32}\ cm^{-2}s^{-1}$