RARE BEAUTY DECAYS

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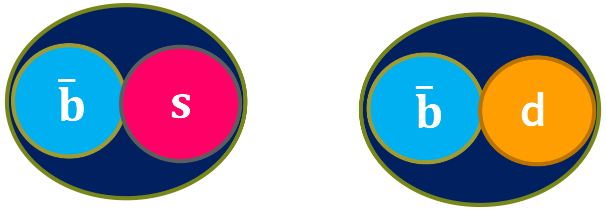
Introduction

Goal- Study how the upcoming upgrades of the CMS detector will help to improve the measurements related with the rare decays:

- $B^0_s \rightarrow \mu^+\mu^-$
- $B^0 \rightarrow \mu^+\mu^-$

B^0_s



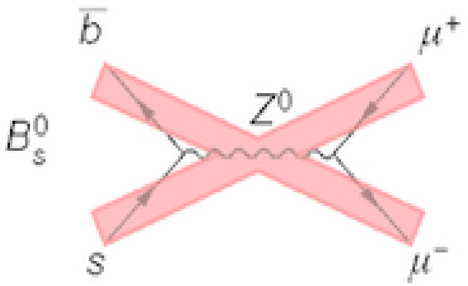
B^0

These decays are highly suppressed in the SM :

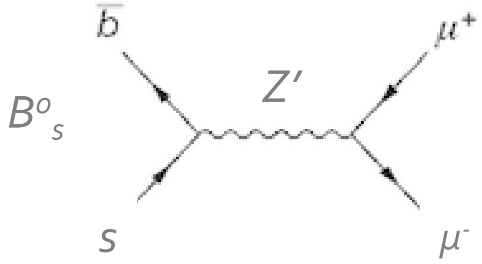
- $BF(B^0_s \rightarrow \mu^+\mu^-)_{SM} = (3.66 \pm 0.23)x10^{-9}$
- $BF(B^0 \rightarrow \mu^+\mu^-)_{SM} = (1.06 \pm 0.09)x10^{-10}$

FCNC is forbidden in SM!

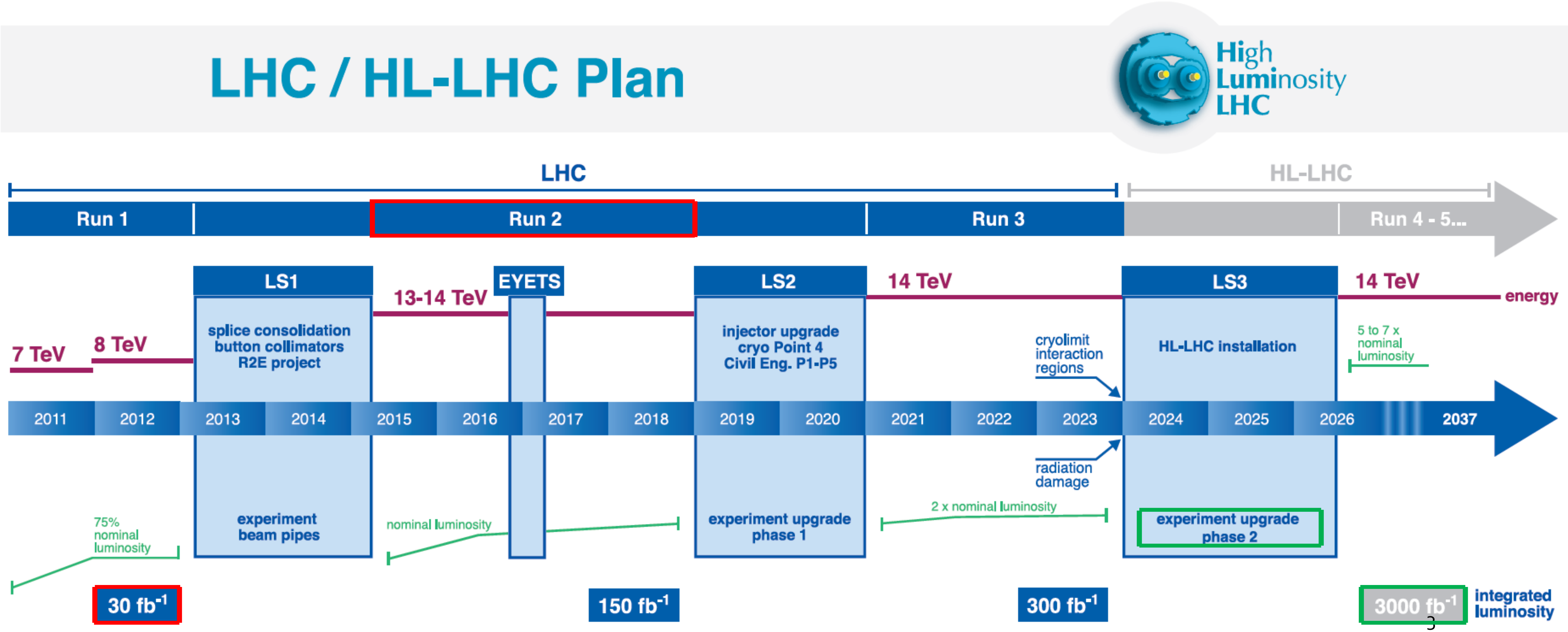
SM



BSM



Timeline of CMS/LHC upgrades



Analysis

In our analysis we use data from simulations and perform two different types of studies:

- Mass studies
- Toy studies

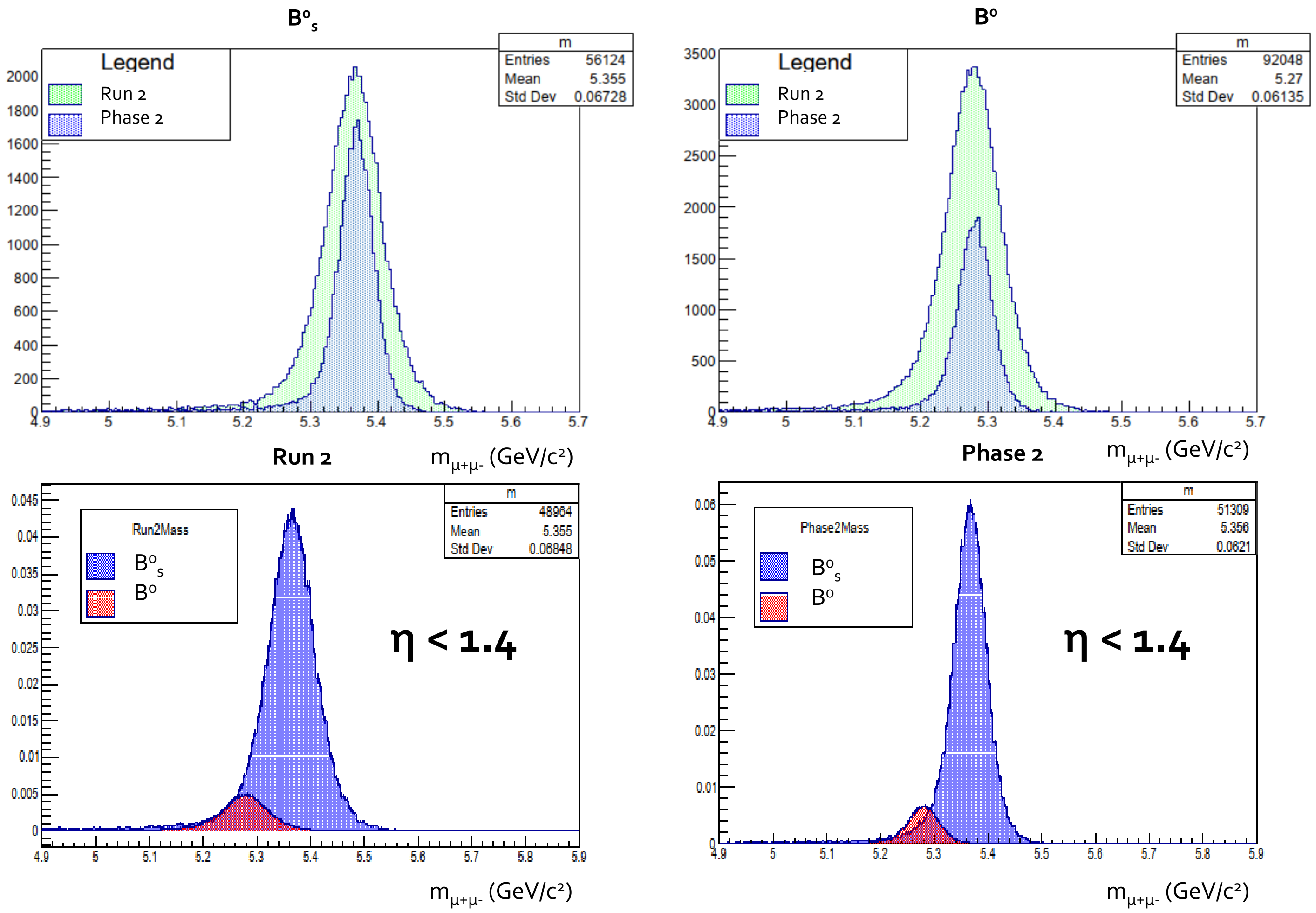
We calculate the branching fractions using the formula:

$$B\left(B_{s,d} \to \mu^+\mu^-\right) = \frac{N(B_{s,d} \to \mu^+\mu^-)}{N(B^\pm \to J/\psi K^\pm)} \times B(B^\pm \to J/\psi K^\pm) \times \frac{\varepsilon(B^\pm)}{\varepsilon(B_{s,d})} \times \frac{f_u}{f_{s,d}}$$

where we use $B^\pm \to J/\psi K^\pm$ as a normalization channel.

MASS STUDIES

Run 2 vs Phase 2 – B^o_s and B^o Peak Separation



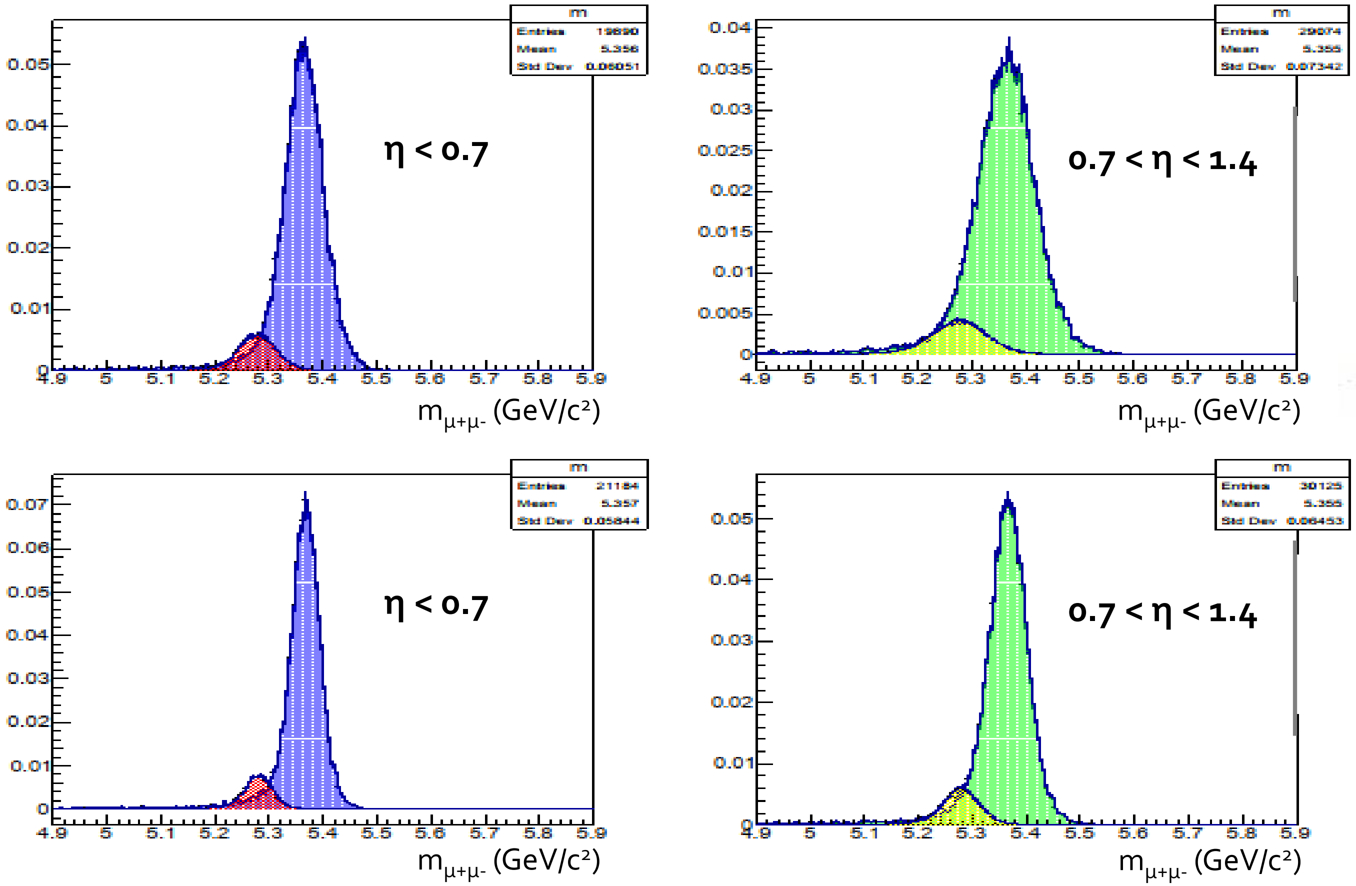
In Phase 2:

- The mass distribution width is narrower
- The B^o_s and B^o peak separation is better
- The background effect of $B^o_s \rightarrow \mu^+\mu^-$ in $B^o \rightarrow \mu^+\mu^-$ is lower

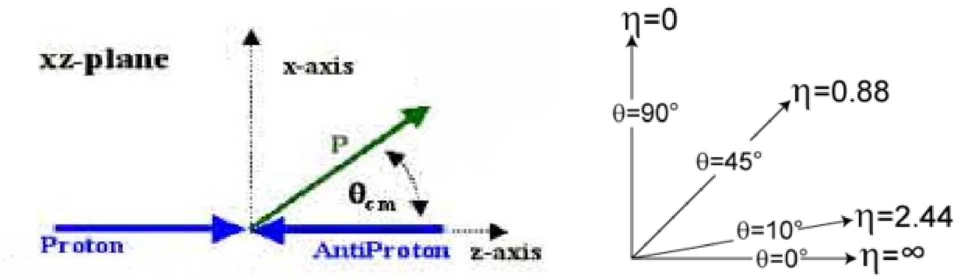
Run 2 vs Phase 2 – B^o_s and B^o Peak Separation (Discrimination between two η regions)

Run 2

Phase 2



Pseudorapidity

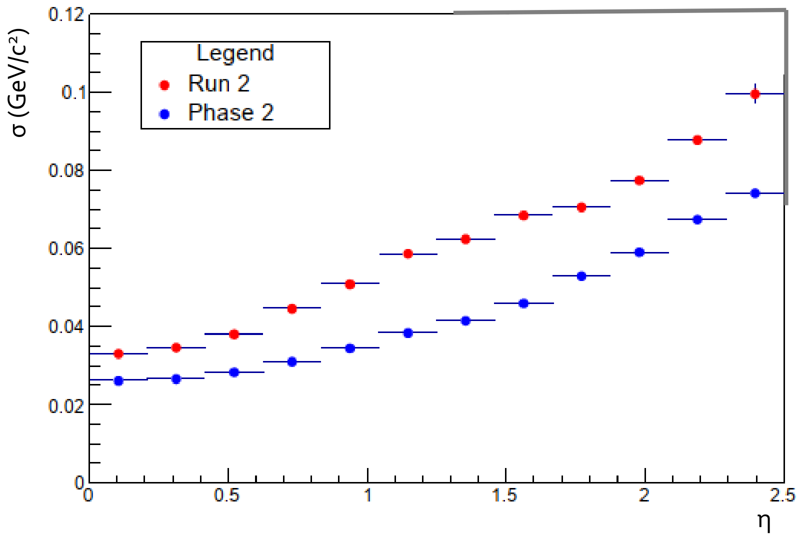


$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right)$$

The peak separation is even better for lower η regions.

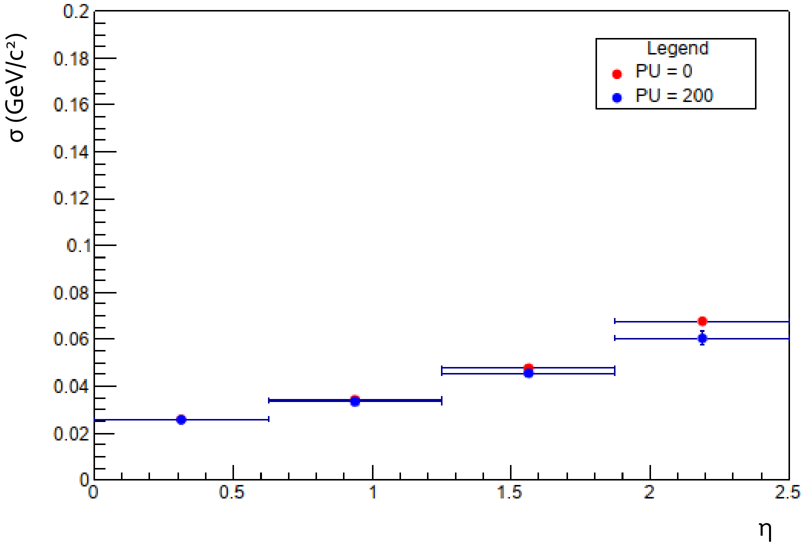
Mass Resolution as a Function of η

Run 2 vs Phase 2



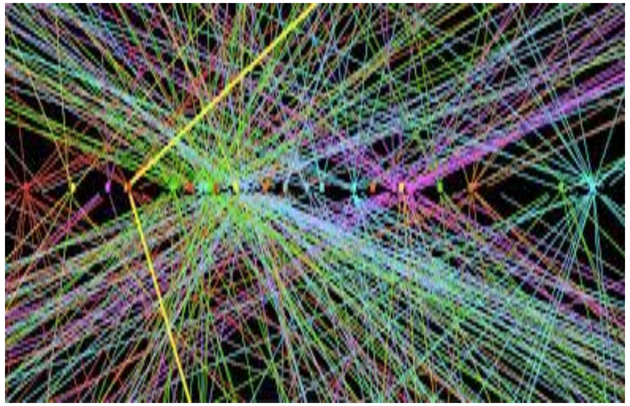
The mass resolution is lower for Phase 2 and for lower η regions.

Effect of the Pile Up



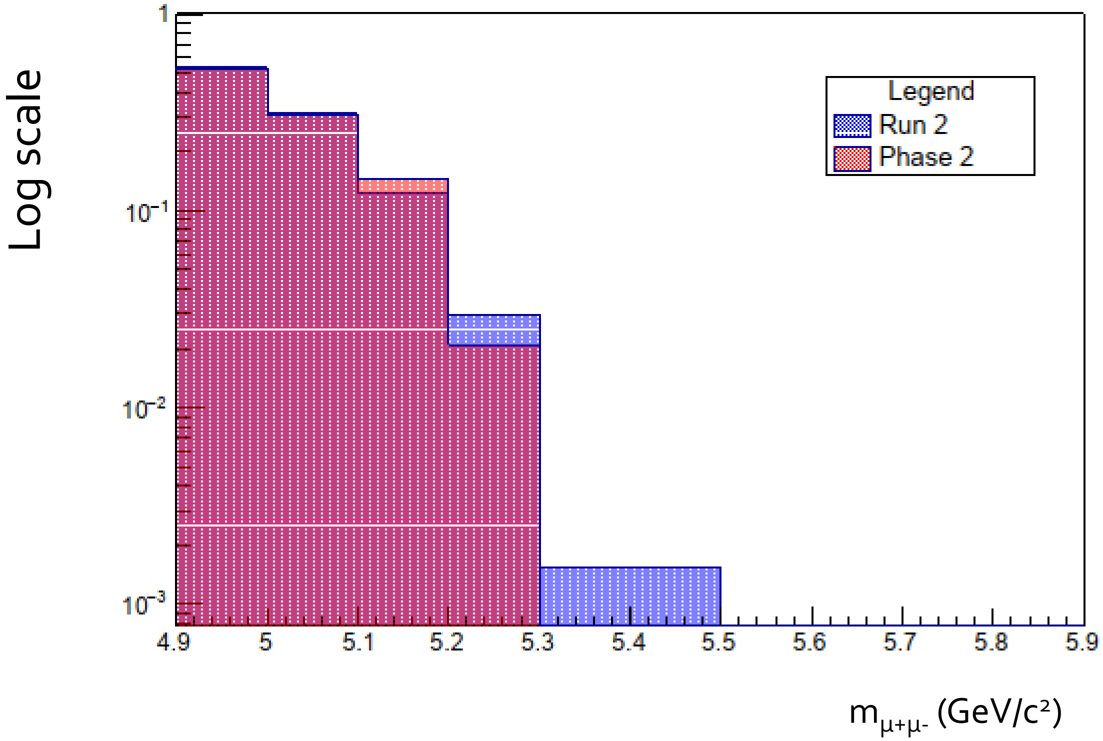
The increase in pile up doesn't affect the mass resolution significantly.

Pile Up



Products of proton-proton collisions that aren't the interaction of interest.

Run 2 vs Phase 2 – Contamination from Semileptonic Background



- No contamination in the region $5.3 < m < 5.5$ GeV/c²
- Decrease of about 30 % in the region $5.2 < m < 5.3$ GeV/c²

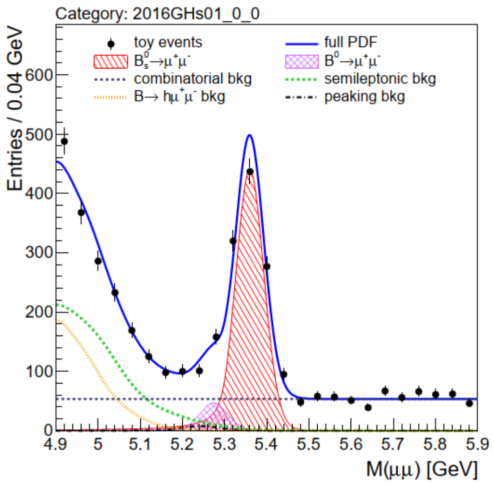
$B^0 \rightarrow \pi^- \mu^+ \nu$
(neutrino can't be detected and pion is misidentified as a muon)
$B^0 \rightarrow \pi^0 \mu^+ \mu^-$
(neutral pion is not reconstructed)

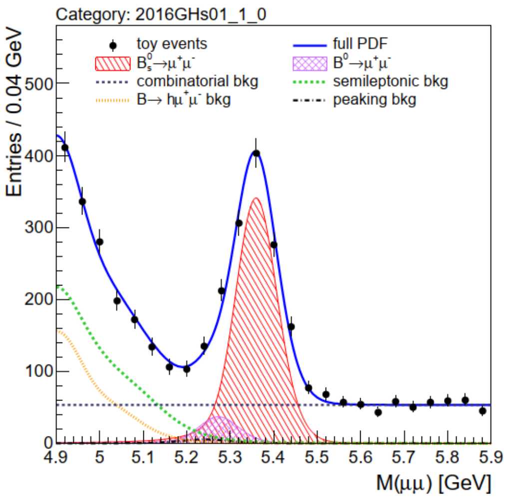
TOY STUDIES

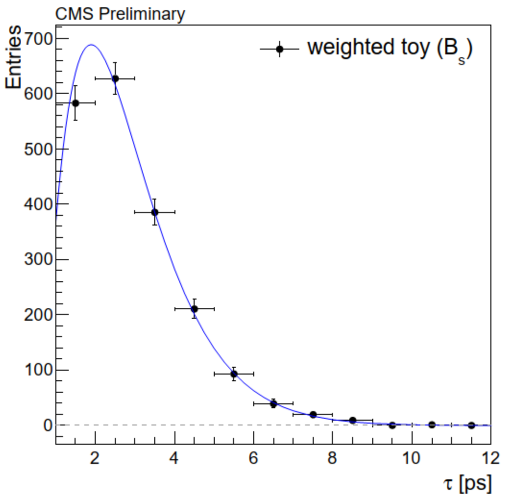
What are toy studies?

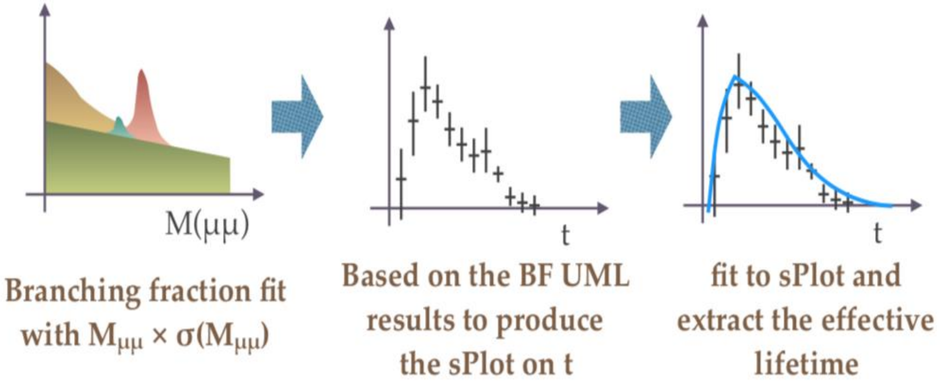
- We perform toy MC studies to estimate the sensitivity of the branching fraction and the effective lifetime measurements.
- It is carried out by generating the toy events based on the model and expected yields.
- The model includes different PDF shapes, including mass and mass resolutions for signal and background components.
- The expected yields are scaled from the Run 2 analysis expectations.

Mass Projections and sPlot Technique









sPlot Technique

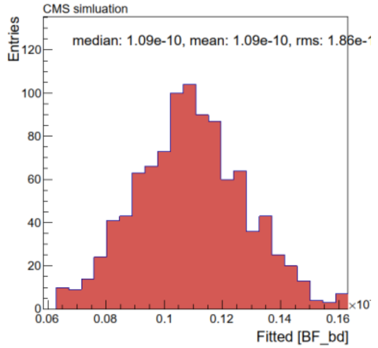
Decay time PDF is a single exponential convoluted with a Gaussian function.

(mudar range?)

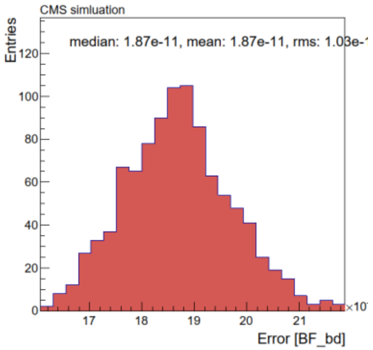
Toy Performance – Branching Fractions

	BF Mean	BF Error	Pull Fit	Significance

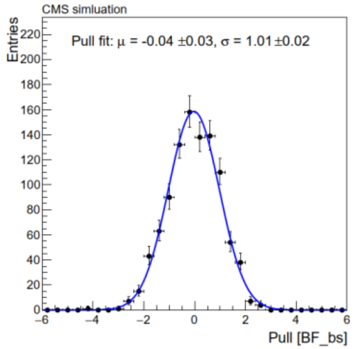
B^0

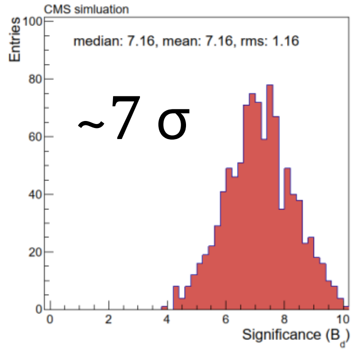


1.09×10^{-10}

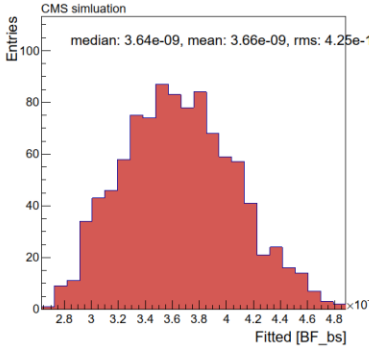


1.87×10^{-11}

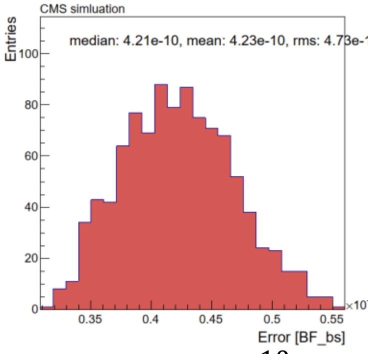




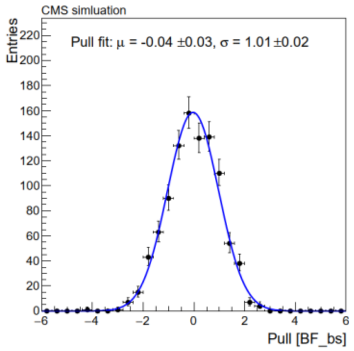
B^0_s

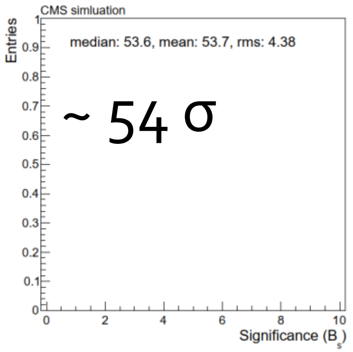


3.64×10^{-9}



4.21×10^{-10}





Relative Uncertainty on BF

	Run 2	Phase 2
$B^0_s \to \mu^+\mu^-$	30 %	12 %
$B^0 \to \mu^+\mu^-$	>100 %	17 %

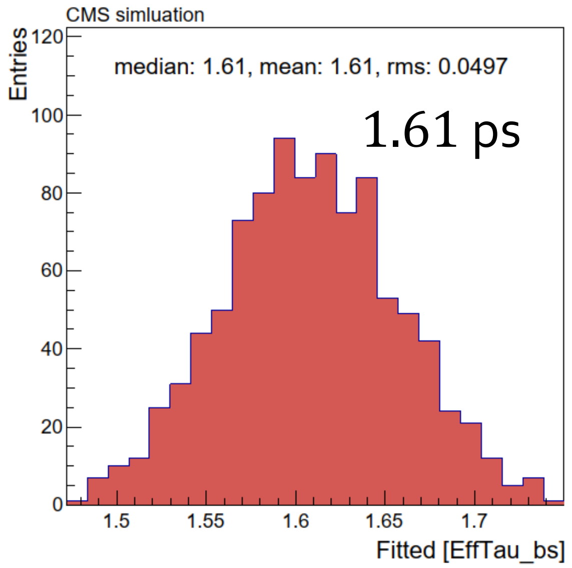
Significance of $B^0 \to \mu^+\mu^-$

Run 2	Phase 2
0σ – 1,1σ	6σ – 8,3 σ

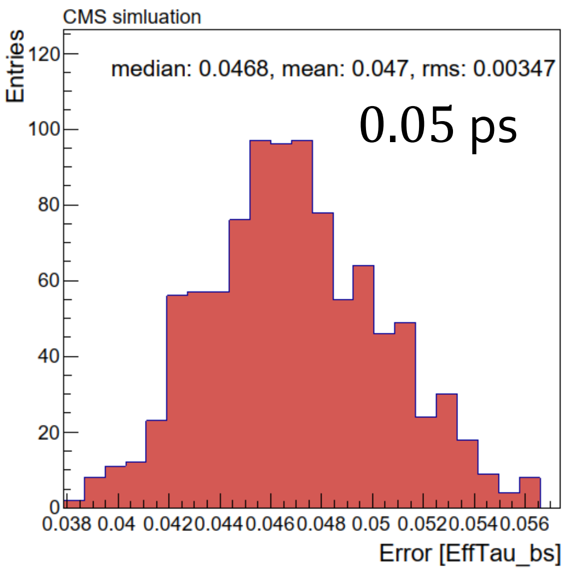
We'll be able to observe $B^0 \to \mu^+\mu^-$!

Toy Performance – Effective Lifetime of B^o_s

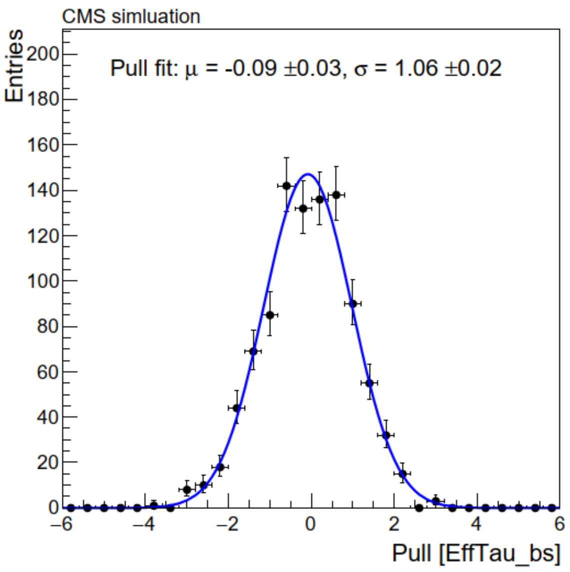
Eff. Lifetime Mean



Eff. Lifetime Error



Pull Fit



Absolute Uncertainty

Run 2	Phase 2
0,55	0,05

Conclusions

The upcoming upgrades of CMS will enable us to improve significantly the measurements related with the decays $B^0_s \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$.

From our mass studies we conclude that Phase 2 will allow us to:

- Lower the mass resolutions
- Lower the background effect of $B^0_s \to \mu^+\mu^-$ in the decay $B^0 \to \mu^+\mu^-$
- Lower the contamination from semileptonic background

And from our toy studies we conclude that Phase 2 will also allow us to:

- Observe $B^0 \to \mu^+\mu^-$ with a statistical significance of $\sim 7\,\sigma$
- Lower the uncertainties in the branching fraction measurements
- Lower the absolute uncertainty on the effective lifetime of B^0_s : (1.61 ± 0.05) ps