

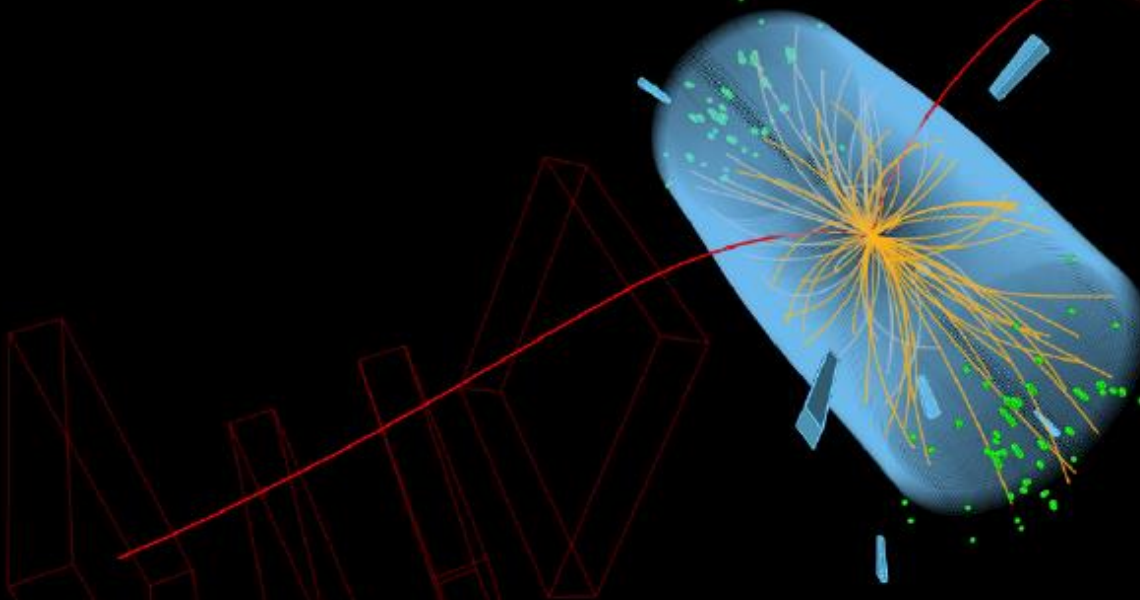


Heavy flavor results from CMS

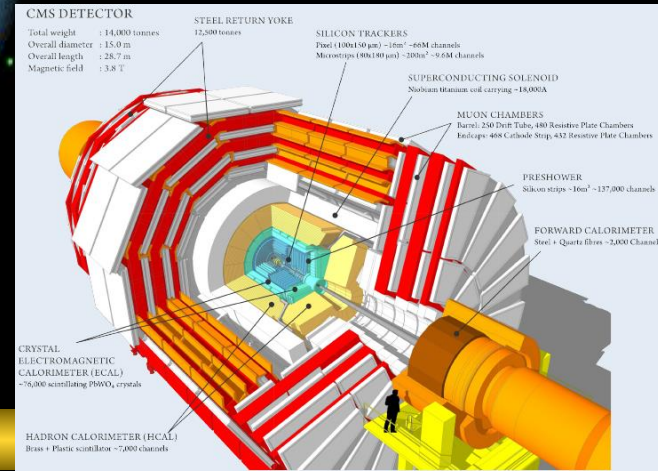


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National Taiwan University

4 July @ SUSY 2016, Melbourne

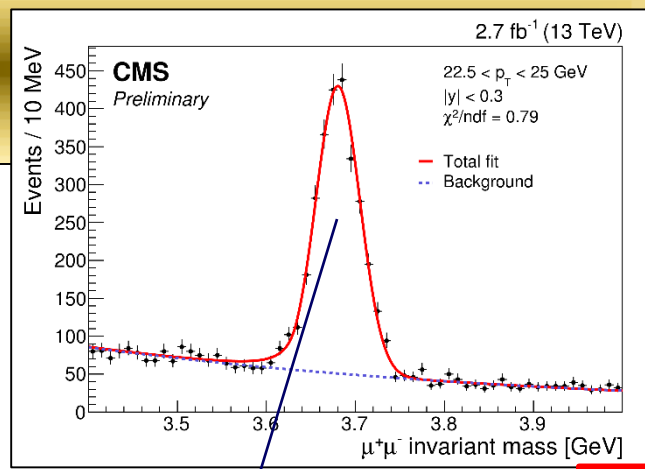
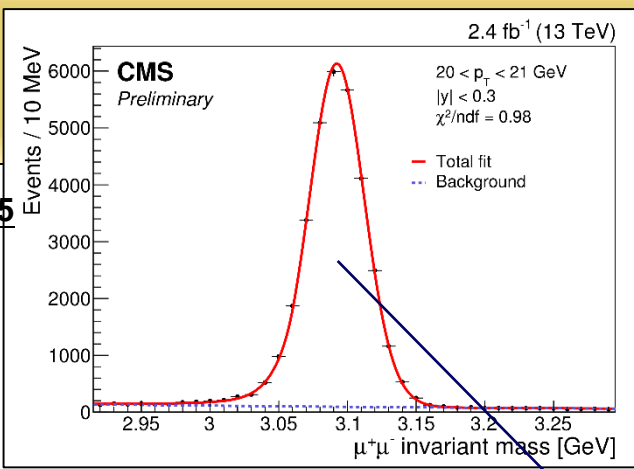


on behalf of the CMS Collaboration



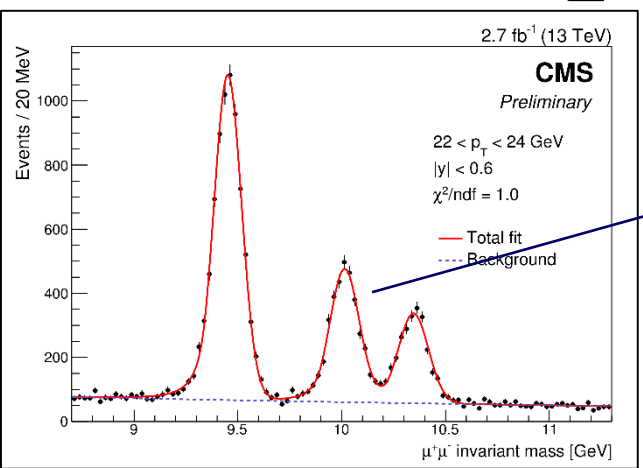
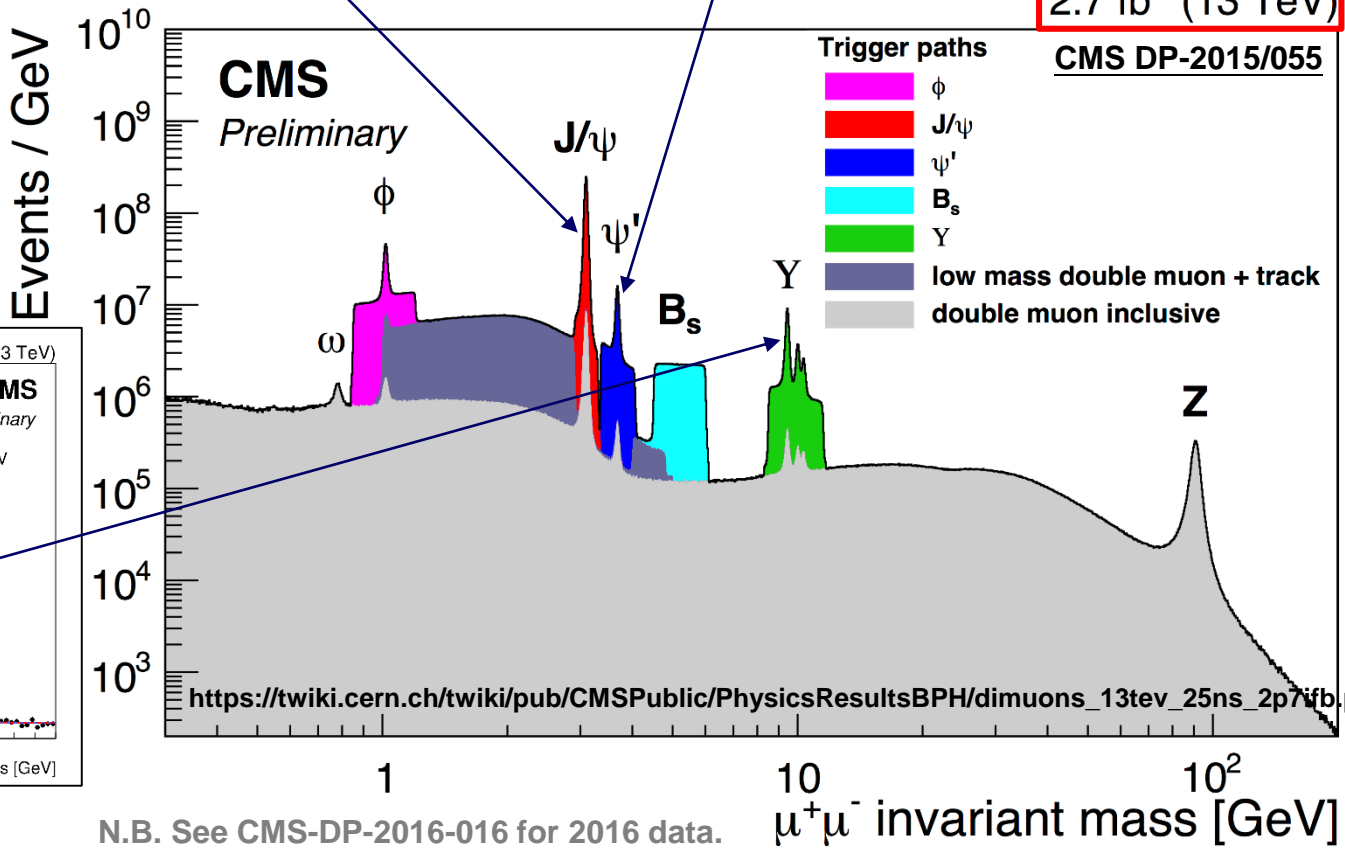


CMS PAS BPH-15-005
[additional figures]



2.7 fb⁻¹ (13 TeV)

CMS DP-2015/055



N.B. See CMS-DP-2016-016 for 2016 data.

1. $B_s \rightarrow \mu^+ \mu^-$ & $B_d \rightarrow \mu^+ \mu^-$

Run 1 Highlight; SUSY relevance? Prospects

2. $B^0 \rightarrow K^{*0} \mu^+ \mu^-$

(8 TeV) angular analysis

3. φ_s & $\Delta\Gamma_s$

8 TeV; $B_s \rightarrow J/\psi \pi^+ \pi^-$ Br in $f_0(980)$ region

4. Recent results

[σ_{onia} at 13 TeV (p. 2)

observation of $\Upsilon(1S)$ pair production; σ_{B^+} at 13 TeV

5. Discussion and Conclusion

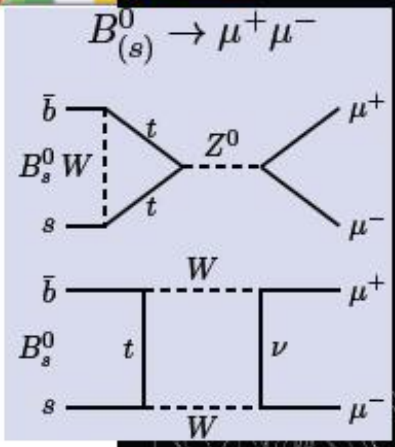
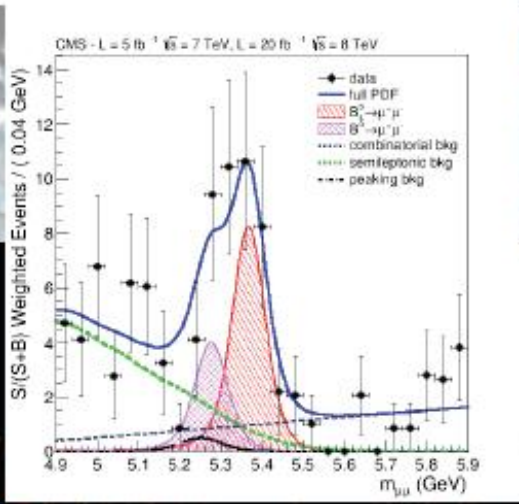
1. $B_s \rightarrow \mu^+ \mu^-$ & $B_d \rightarrow \mu^+ \mu^-$



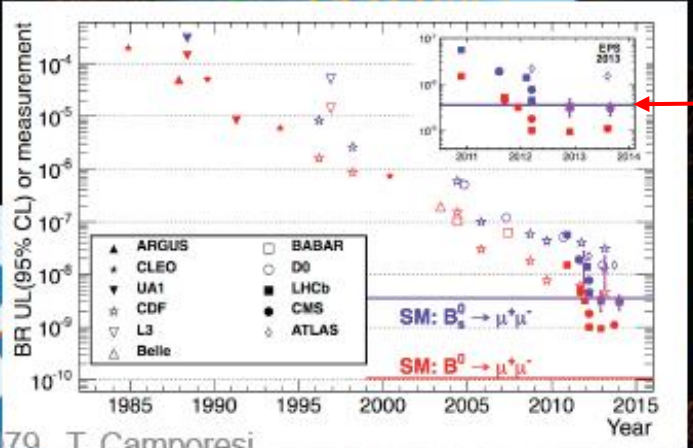
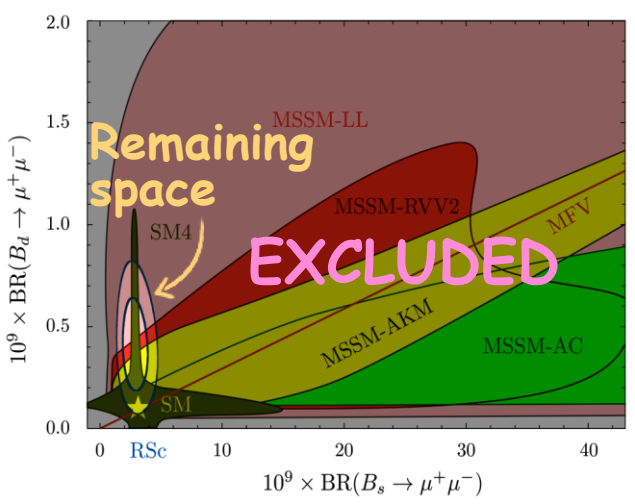
First CMS + LHCb combined publication

$B_s \rightarrow \mu\mu$

Nature 522 (2015) 68-72
May 2015



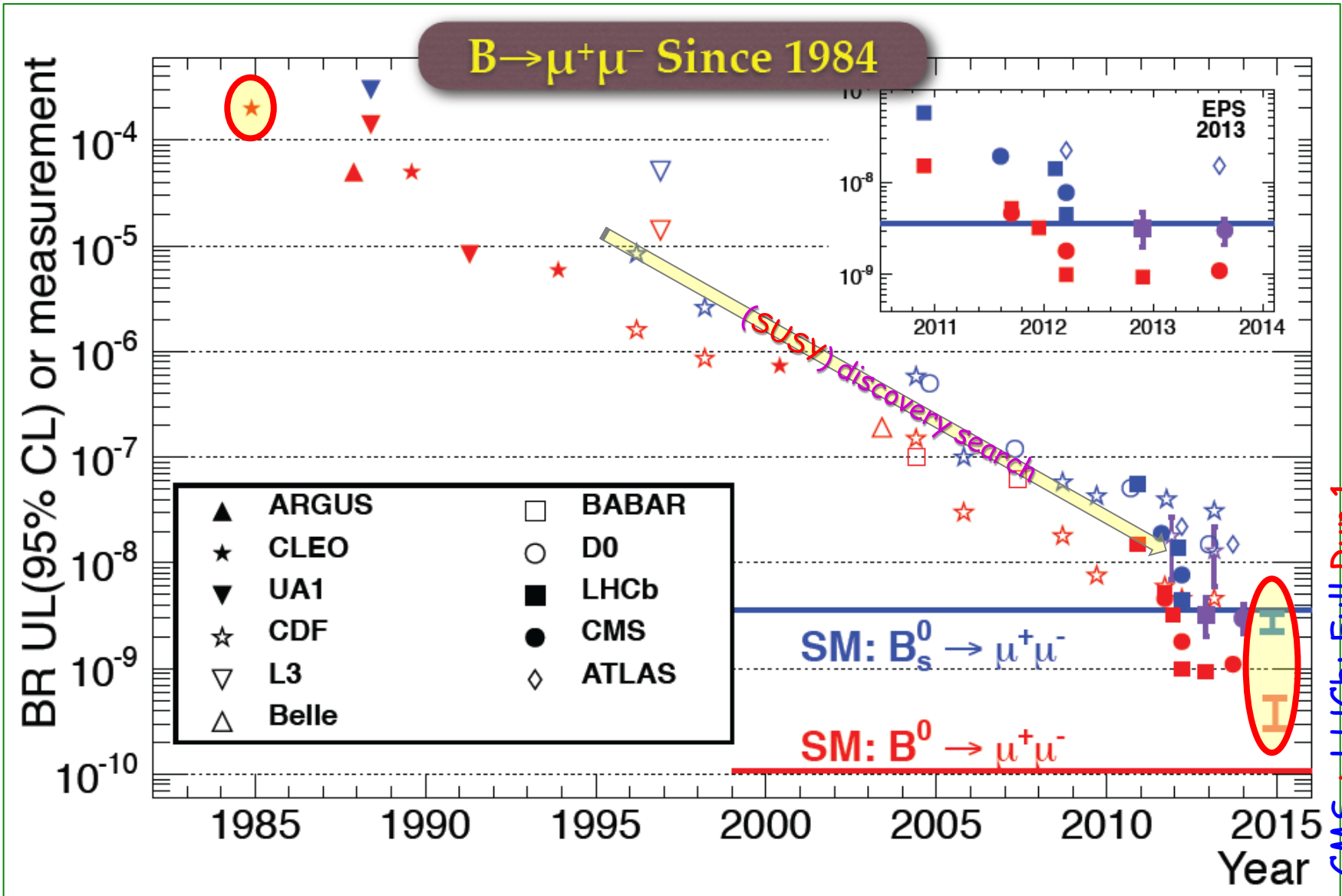
Branching ratio: 3×10^{-9} !



SM



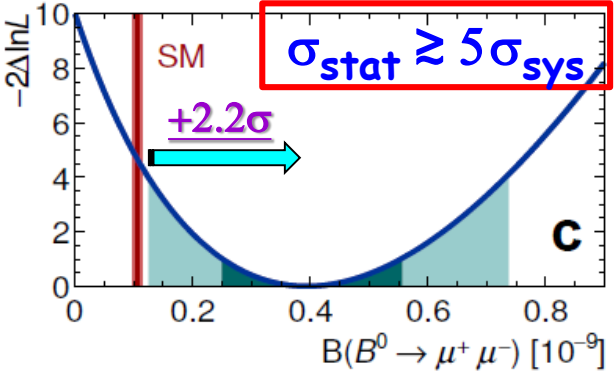
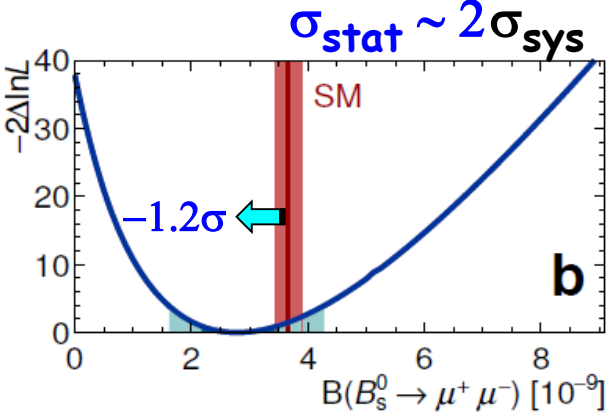
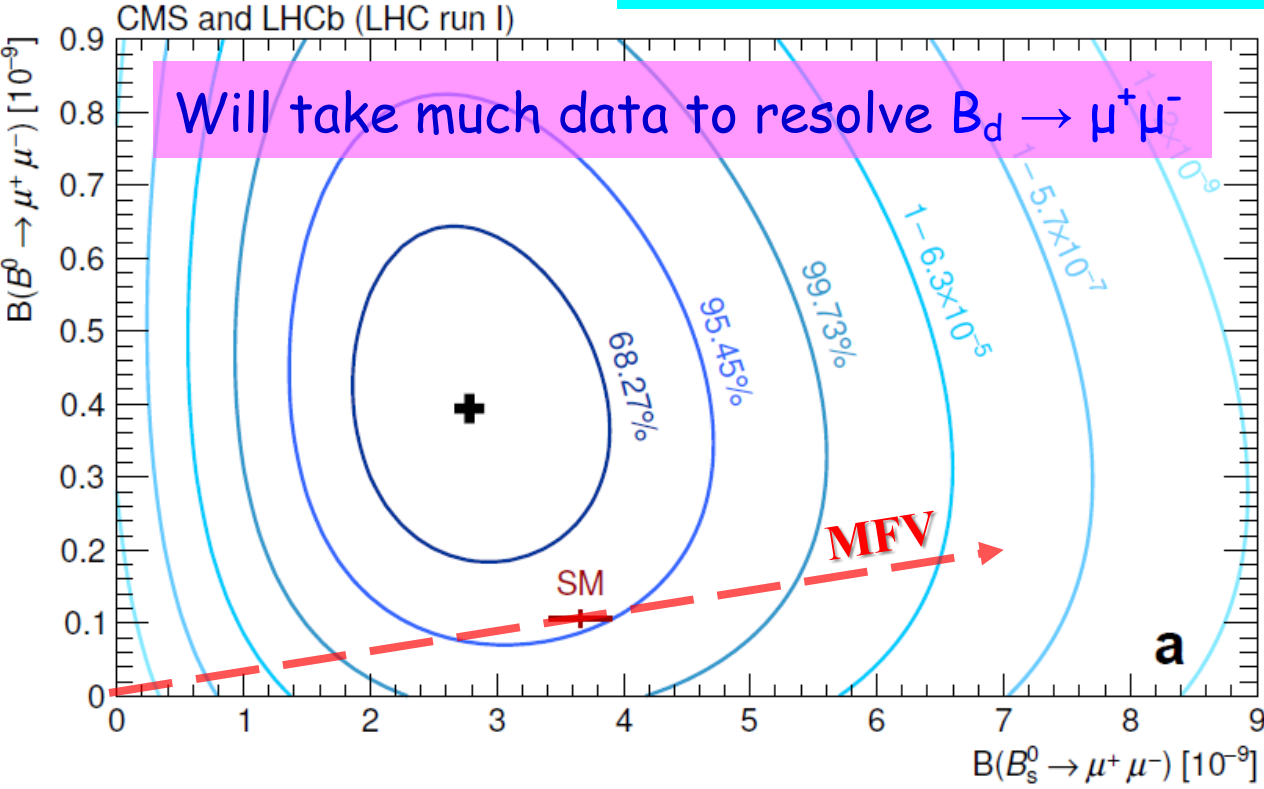
$B_s \rightarrow \mu^+\mu^-$ & $B_d \rightarrow \mu^+\mu^-$





$B_s \rightarrow \mu^+ \mu^-$ & $B_d \rightarrow \mu^+ \mu^-$

CMS + LHCb: Full Run 1
1411.4413 \rightarrow *Nature* 2015



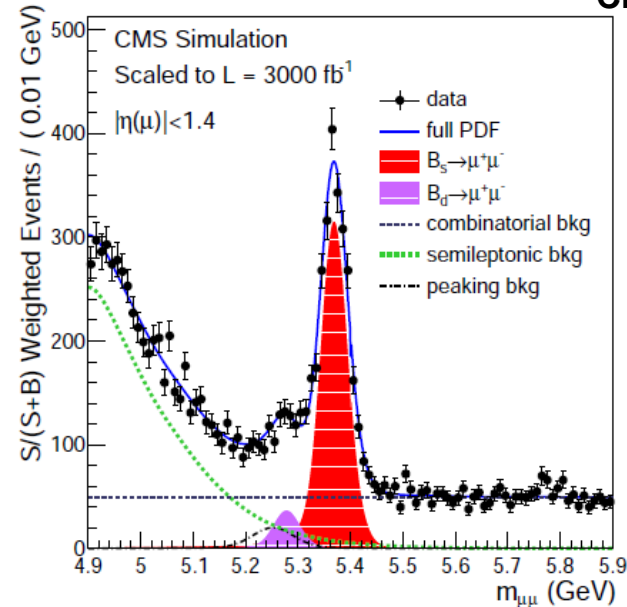
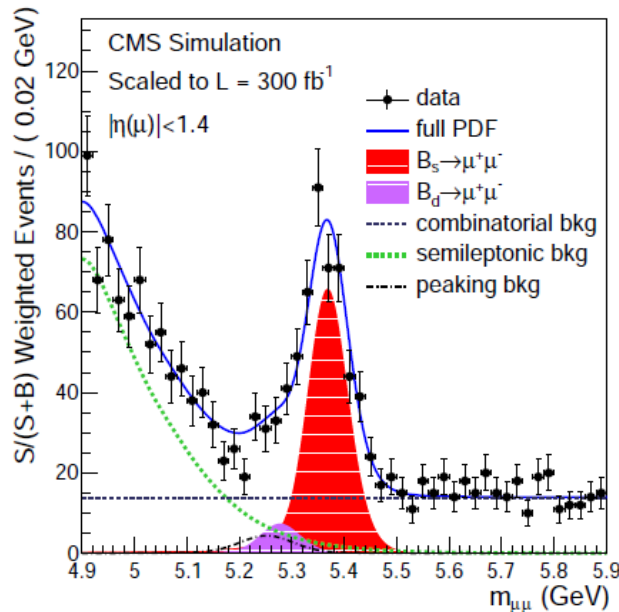
One paper in (exotic) SUSY, by Dutta and Mimura
1501.02044 (PRD)

$\sim 3.7 \times \text{SM}$
But: Peaking BG

MFV: Minimal Flavor Violation (only CKM as source): 0807.5039 etc.

$B_s \rightarrow \mu^+\mu^-$ & $B_d \rightarrow \mu^+\mu^-$ prospects

CMS PAS FTR-14-01



Estimate of analysis sensitivity

assume SM Br

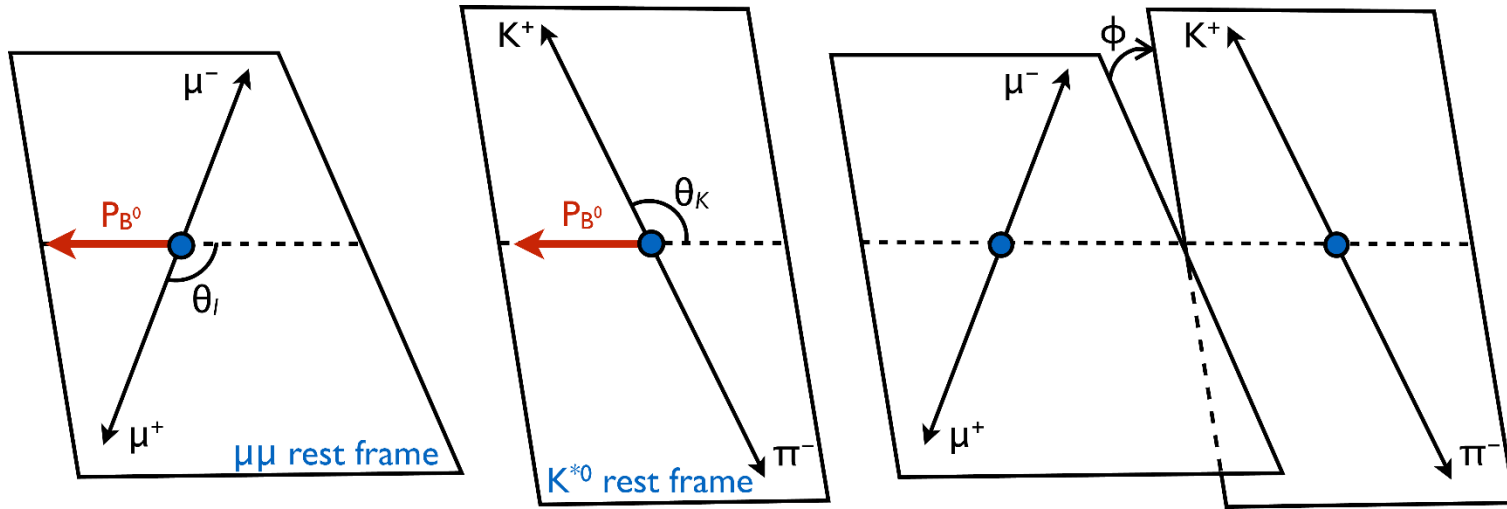
$\mathcal{L} \text{ (fb}^{-1}\text{)}$	$N(B_s^0)$	$N(B^0)$	$\delta\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$	$\delta\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)$	B^0 sign.	$\delta \frac{\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)}{\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)}$
20	18.2	2.2	35%	> 100%	$0.0 - 1.5 \sigma$	> 100%
100	159	19	14%	63%	$0.6 - 2.5 \sigma$	66%
300	478	57	12%	41%	$1.5 - 3.5 \sigma$	43%
300 (barrel)	346	42	13%	48%	$1.2 - 3.3 \sigma$	50%
3000 (barrel)	2250	271	11%	18%	$5.6 - 8.0 \sigma$	21%

Even $B_d \rightarrow \mu^+\mu^-$ at SM Br can be observed at Phase II

$$2. B^0 \rightarrow K^{*0} \mu^+ \mu^-$$

angular observables: θ_l, θ_K, ϕ

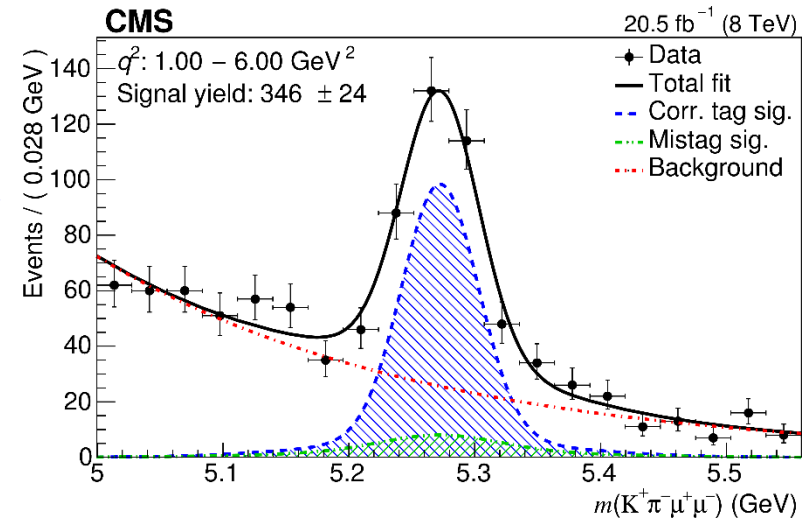
PLB 753 (2016) 424

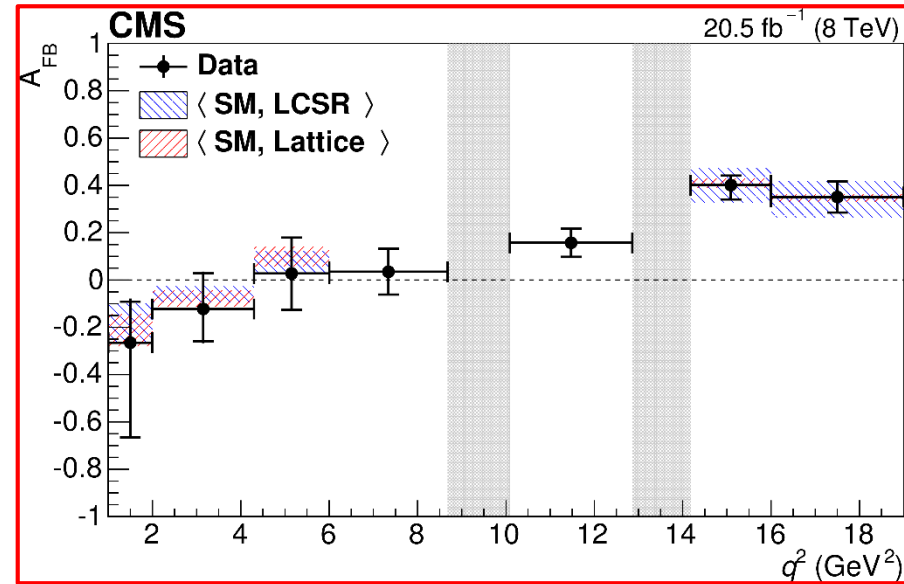
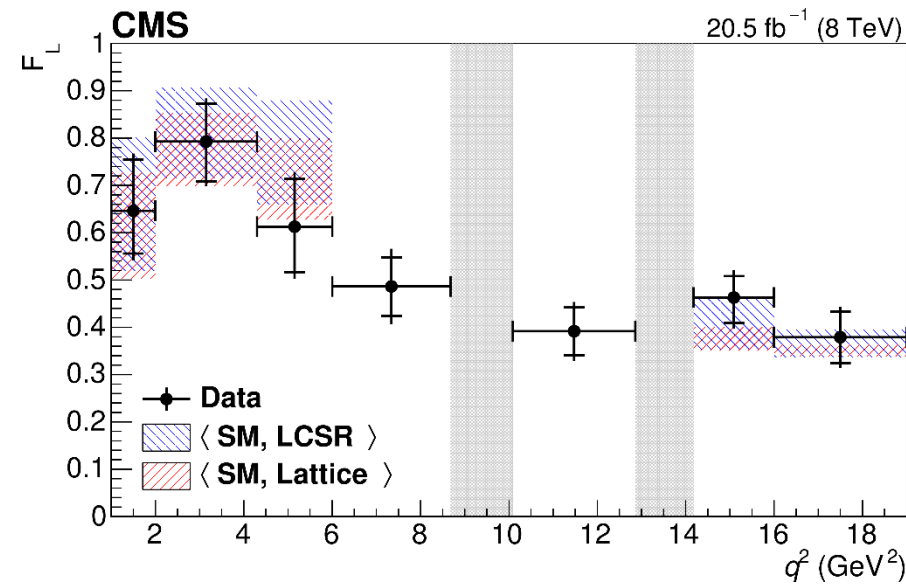


Integrating out ϕ , extract observables for each q^2 from an unbinned, extended maximum-likelihood fit to:

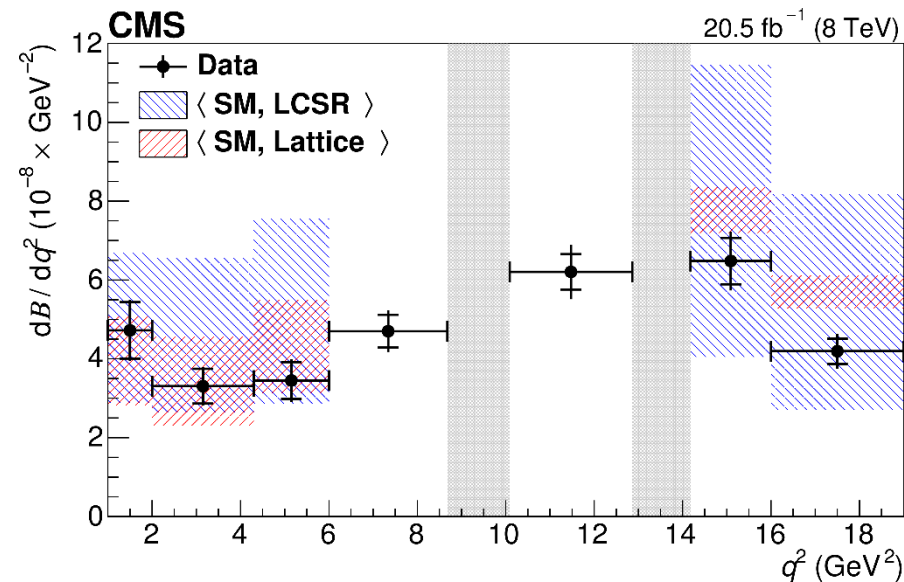
$\theta_l, \theta_K; \underline{m(K^+\pi^-\mu^+\mu^-)}$

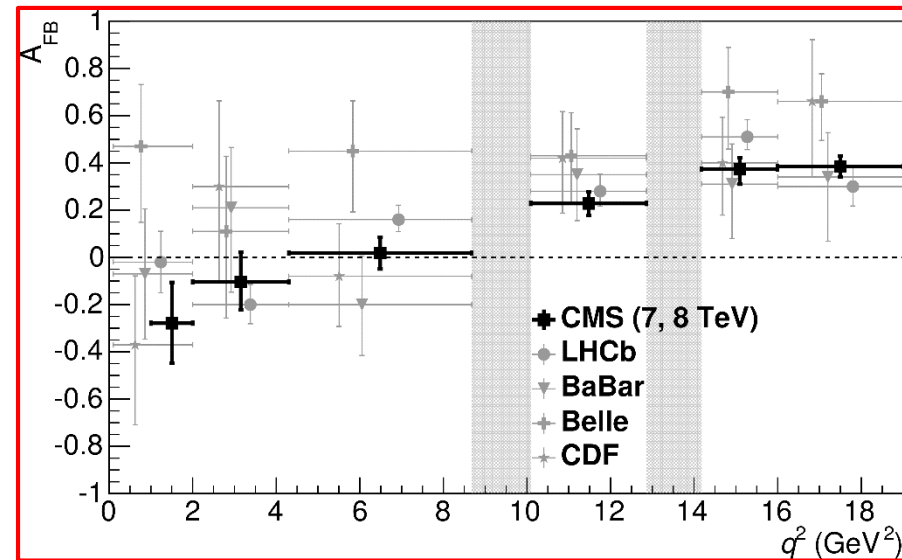
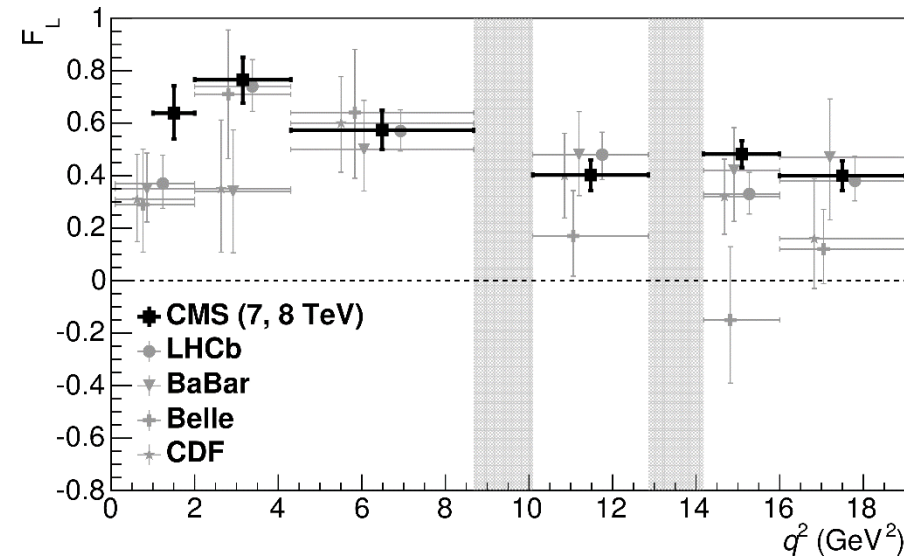
1430 signal events in fitted data



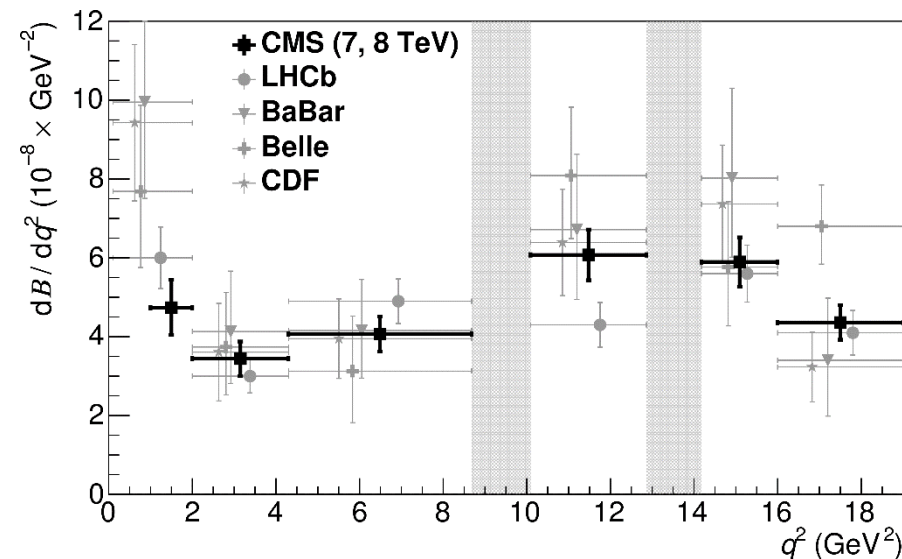


- The measurements are among the most precise to date.
- In good agreement with SM (LCSR & Lattice) predictions.





- The measurements are among the most precise to date.
- In good agreement with SM (LCSR & Lattice) predictions.
- Consistent with measurements by LHCb, CDF, BaBar and Belle.



3. ϕ_s & $\Delta\Gamma_s$

$\phi_s \simeq -2\beta_s$, where $\beta_s = \arg(-V_{ts}V_{tb}^*/V_{cs}V_{cb}^*)$

SM: $2\beta_s = 0.0363^{+0.0016}_{-0.0015}$ rad

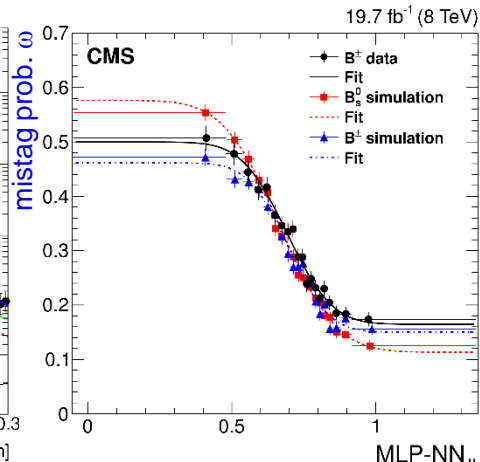
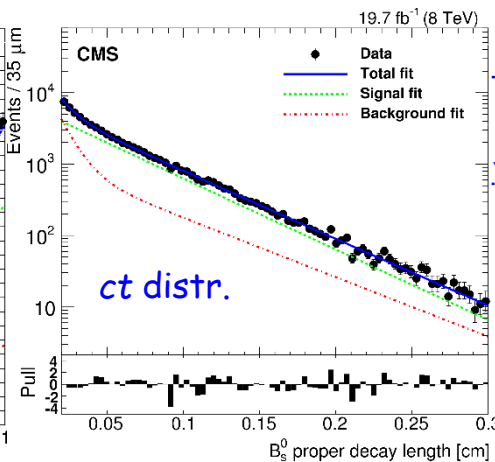
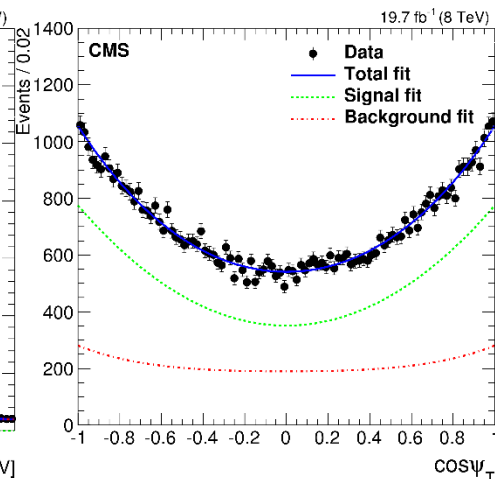
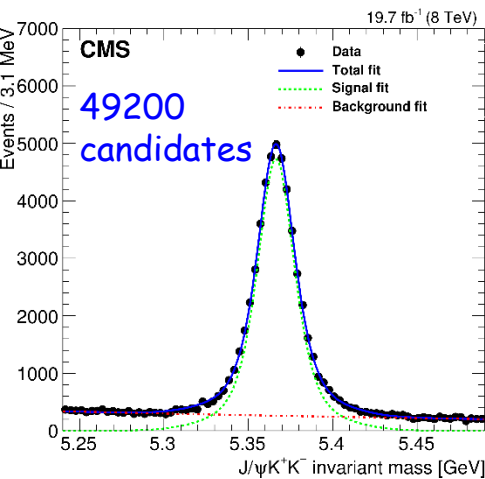
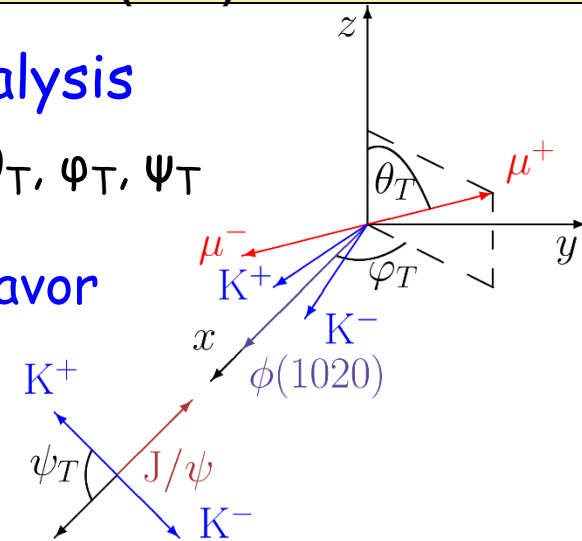
Time-dependent, flavour-tagged angular analysis

transversity basis: $\theta_T, \varphi_T, \psi_T$

Opposite-side (OS) lepton (e, μ) tagging of B_s flavor

Unbinned maximum-likelihood fit to the data:
three angles, m_{B_s}, ct, σ_{ct} , flavor-tag

70500 events used in the fit (5650 tagged)

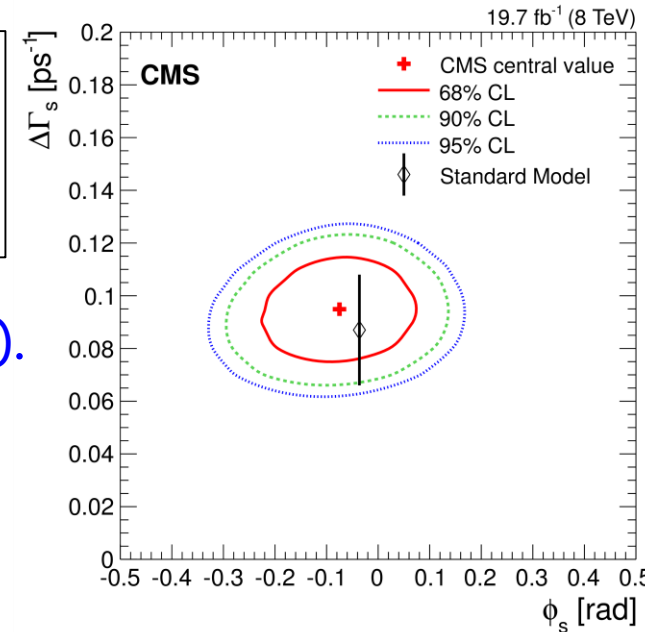


$$\phi_s = -0.075 \pm 0.097 \text{ (stat)} \pm 0.031 \text{ (syst) rad}$$

$$\Delta\Gamma_s = 0.095 \pm 0.013 \text{ (stat)} \pm 0.007 \text{ (syst) ps}^{-1}$$

Consistent with SM, and with LHCb (and ATLAS).

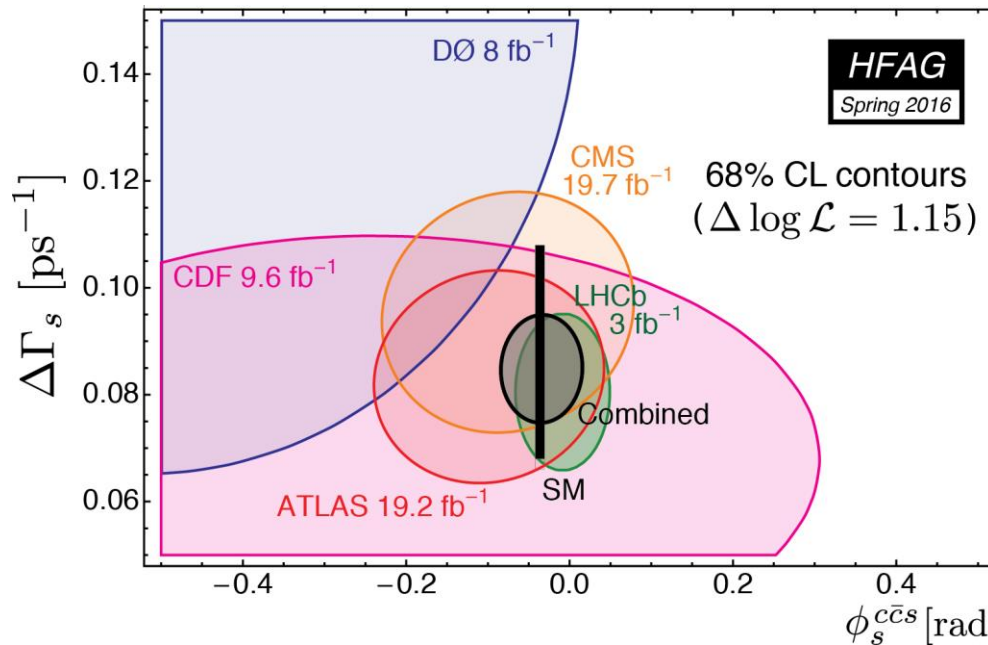
Error Stat.-dominant \rightarrow improve at Run 2!



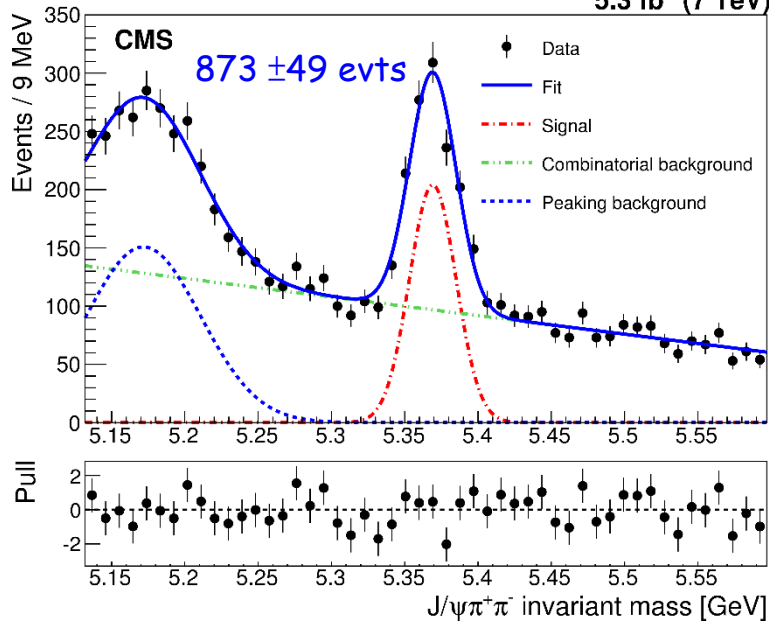
current world average

$$-0.033 \pm 0.033$$

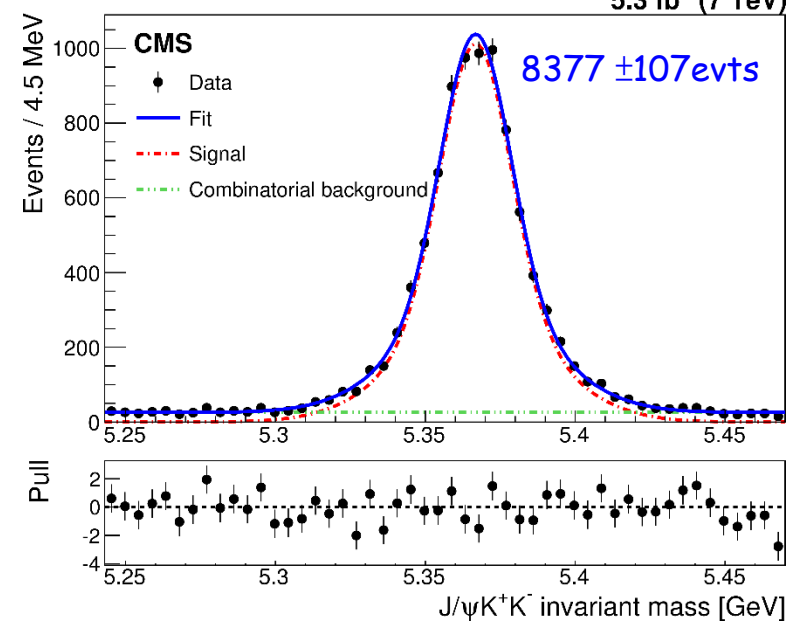
cf. LHCb Run 1 value: -0.010 ± 0.039



in $f_0(980)$ region
 $B_s \rightarrow J/\psi \pi^+ \pi^-$



$B_s \rightarrow J/\psi \phi \rightarrow \mu^+ \mu^- K^+ K^-$



$$\frac{\mathcal{B}(B_s^0 \rightarrow J/\psi f_0) \mathcal{B}(f_0 \rightarrow \pi^+ \pi^-)}{\mathcal{B}(B_s^0 \rightarrow J/\psi \phi) \mathcal{B}(\phi \rightarrow K^+ K^-)} = 0.140 \pm 0.008 \text{ (stat)} \pm 0.023 \text{ (syst)}$$

Consistent with theoretical prediction, and with other measurements.

CPV measurement in $B_s \rightarrow J/\psi f_0(980) \rightarrow \mu^+ \mu^- \pi^+ \pi^-$ possible (not easy) with angular analysis + tagging.

4. Recent results

- Observation of $\Upsilon(1S)$ pair production

CMS PAS BPH-14-

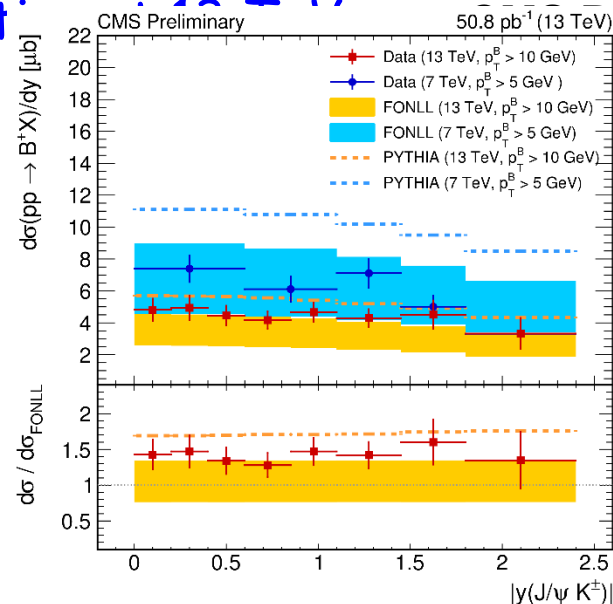
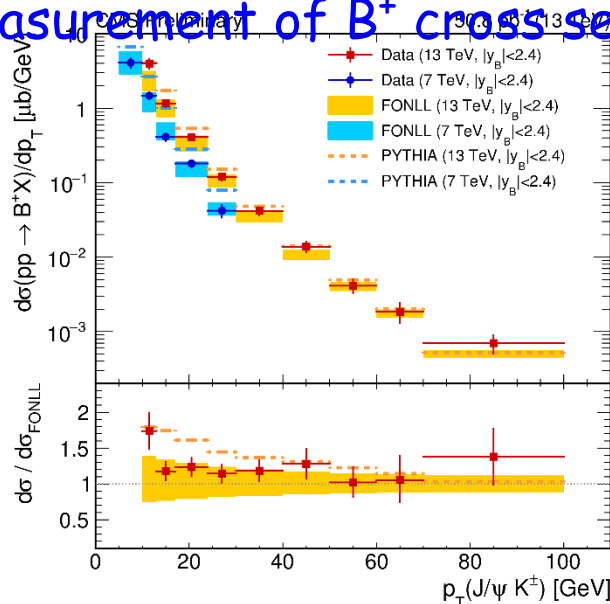
008

With 20.7 fb^{-1} at 8 TeV, observe $38 \pm 7 \Upsilon(1S)\Upsilon(1S)$ events [$\Upsilon(1S) \rightarrow \mu^+\mu^-$] and local significance $> 5\sigma$.

N.B. J/ψ pair production is observed by LHCb and CMS in pp collisions

- Measurement of B^+ cross sect.

004



S BPH-15-

- ▶ P_5' is being pursued;
- ▶ Flavor naturally extends to Top (FCNC/FCNH) and Higgs ($\mu\tau$).
No time to cover (and not my charge). "Orthogonal" to SUSY.

- $B_s \rightarrow \mu^+\mu^-$ observed (together with LHCb) with Run 1 data;
 $B_d \rightarrow \mu^+\mu^-$ shows hint above SM expectation.
Run 2: former would become measured by single exp't;
definitely pursue latter!
- $B^0 \rightarrow K^{*0}\mu^+\mu^-$: Run 1 angular analysis measurements.
Continue at Run 2, including P_5' .
- φ_s & $\Delta\Gamma_s$: main contributor using Run 1 data.
Continue at Run 2 (nice if $B_s \rightarrow J/\psi f_0(980) \rightarrow \mu^+\mu^-\pi^+\pi^-$ can be done).

Aim is SM, Game is New Physics.