Heavy flavor results from CMS

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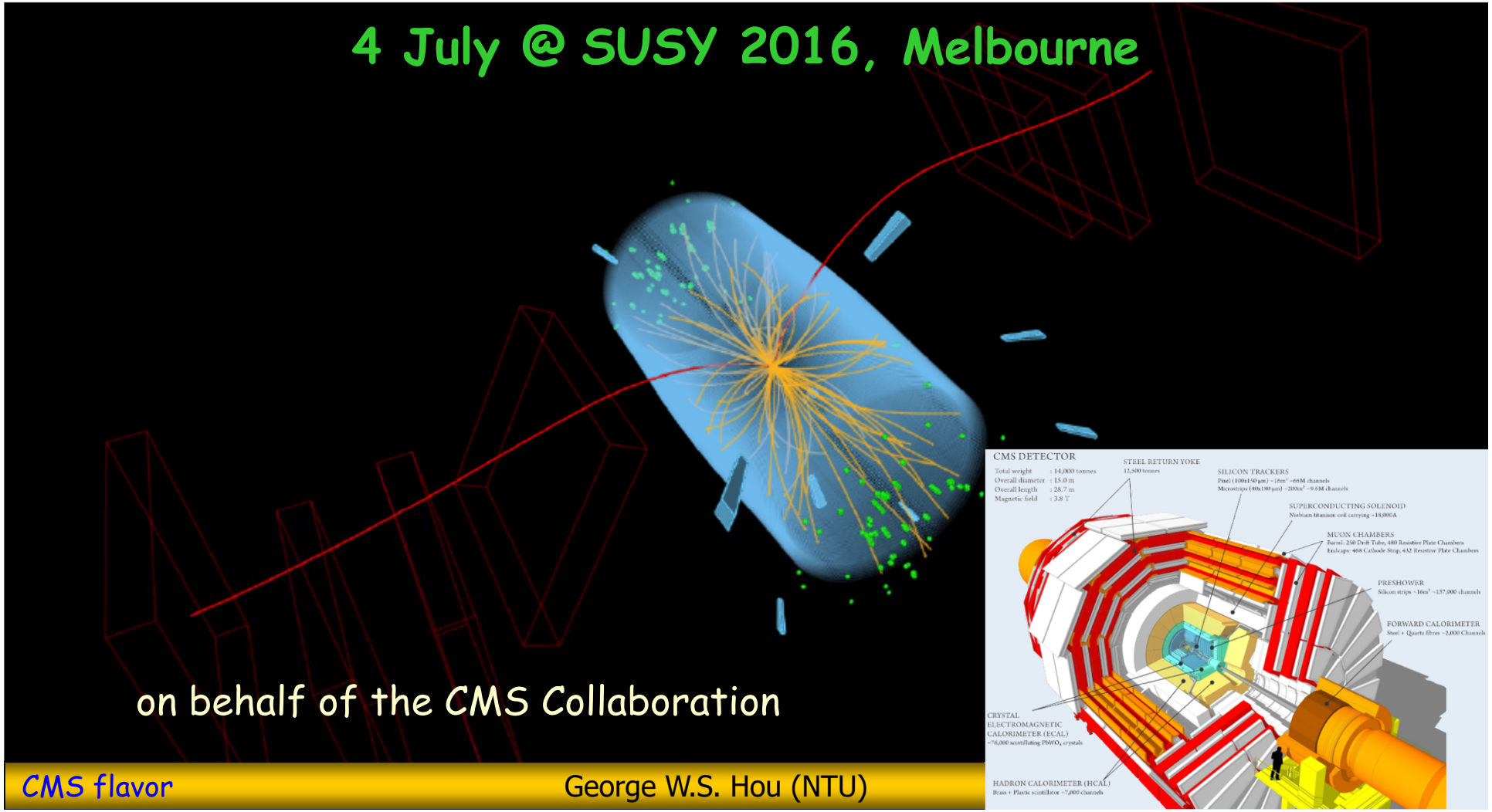
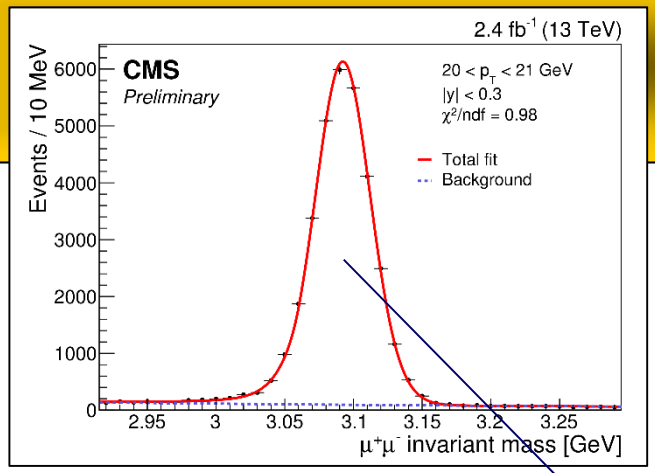
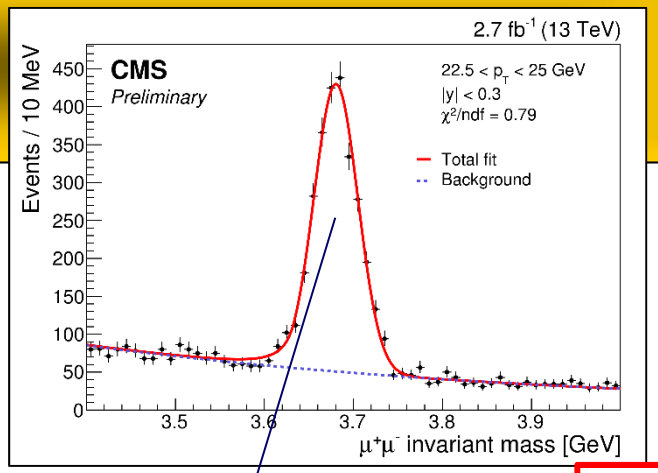
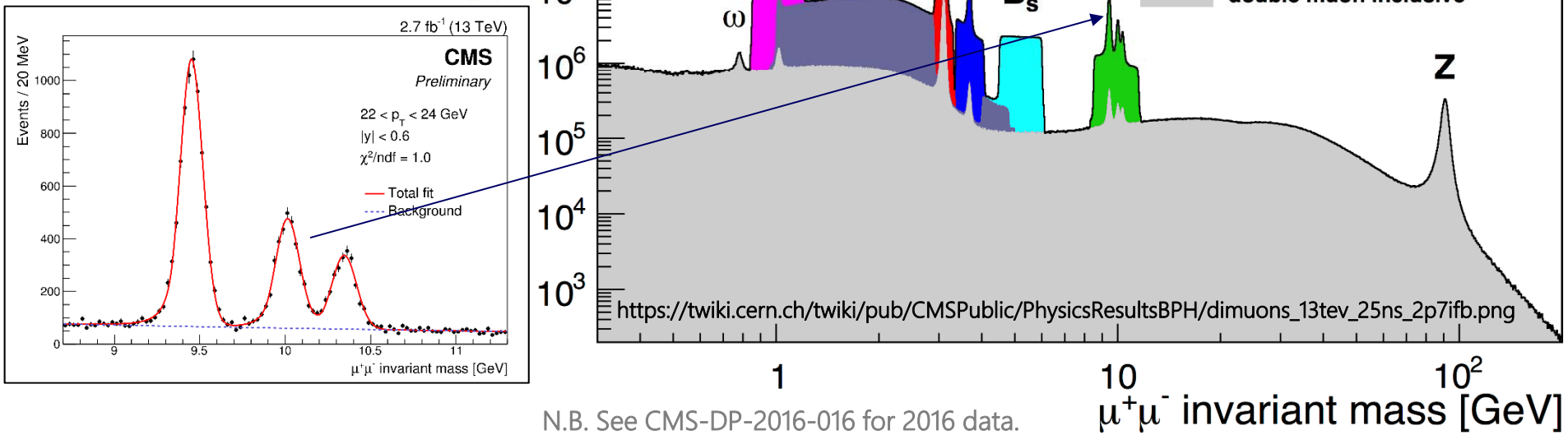


on behalf of the CMS Collaboration

CMS PAS BPH-15-005
[additional figures]







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

Outline

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

   Run 1 Highlight; SUSY relevance? Prospects

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

   (8 TeV) angular analysis

3. φ_s & $\Delta\Gamma_s$

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

4. Recent results [σ_{onia} at 13 TeV (p. 2)

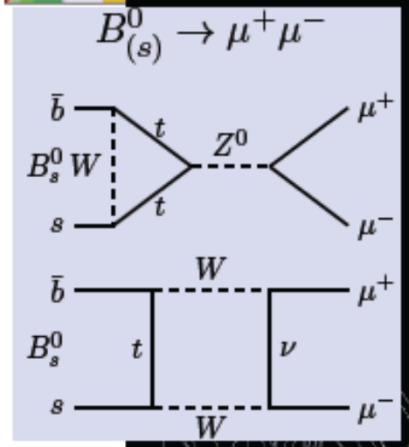
   observation of $\Upsilon(1S)$ pair production; σ_{B^+} at 13 TeV

5. Discussion and Conclusion

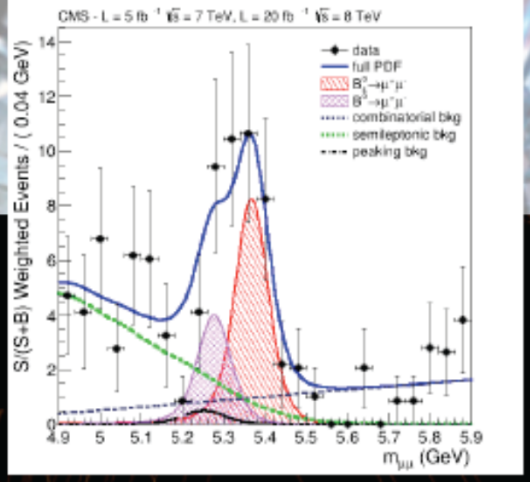
1. $B_s \to \mu^+\mu^-$ & $B_d \to \mu^+\mu^-$

First CMS + LHCb combined publication

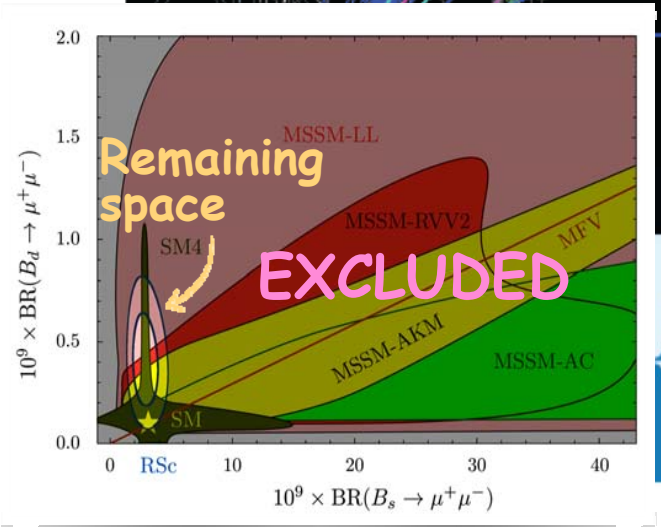
$B_s \to \mu\mu$

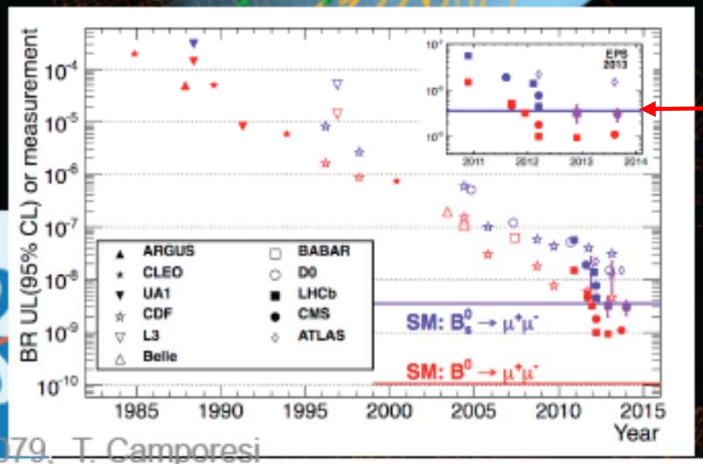


Nature 522 (2015) 68-72
May 2015



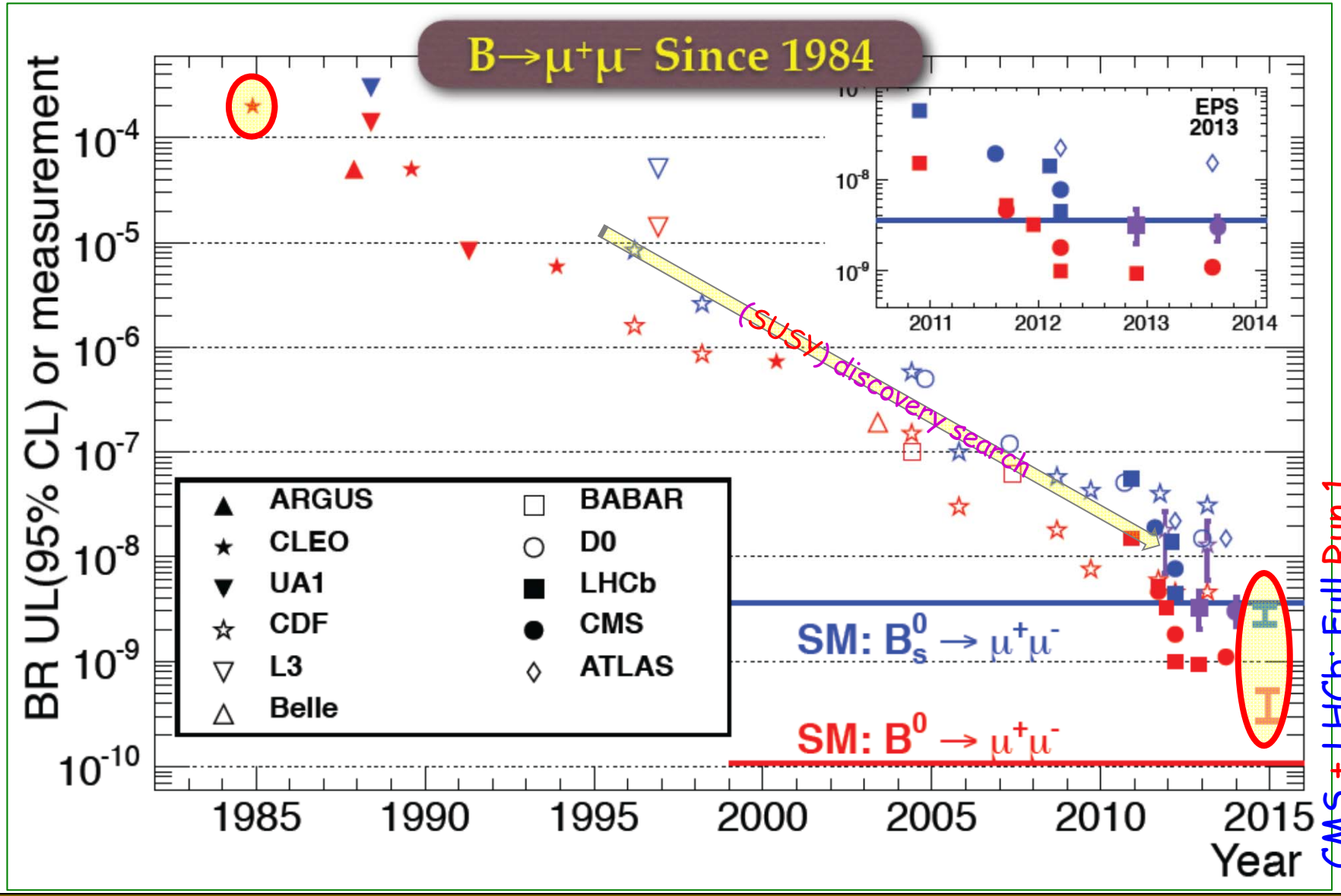
Branching ratio: 3×10^{-9}!





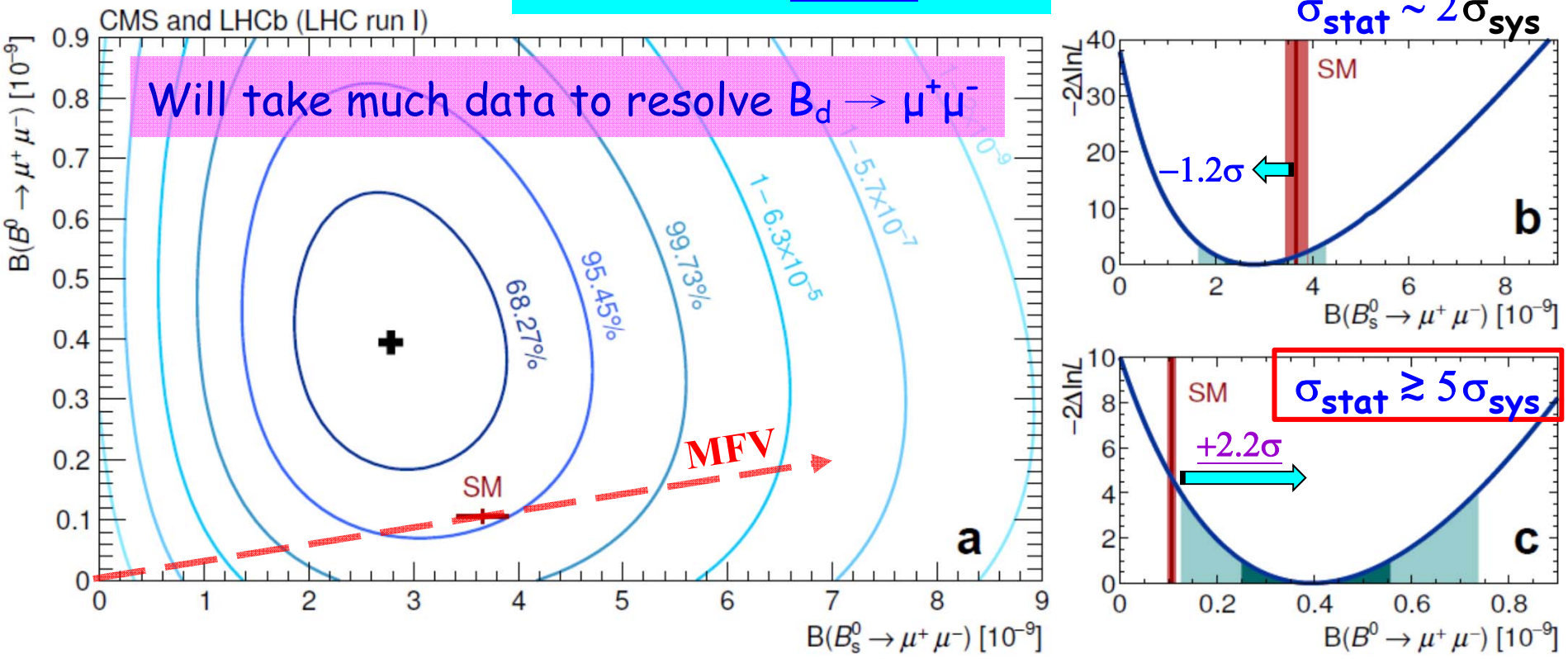
SM

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



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

CMS + LHCb: Full Run 1
1411.4413 → *Nature 2015*



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

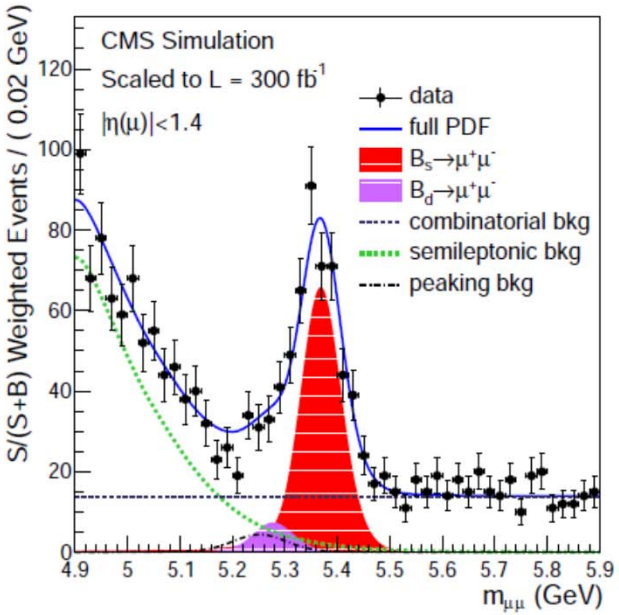
→ ~ 3.7 x SM

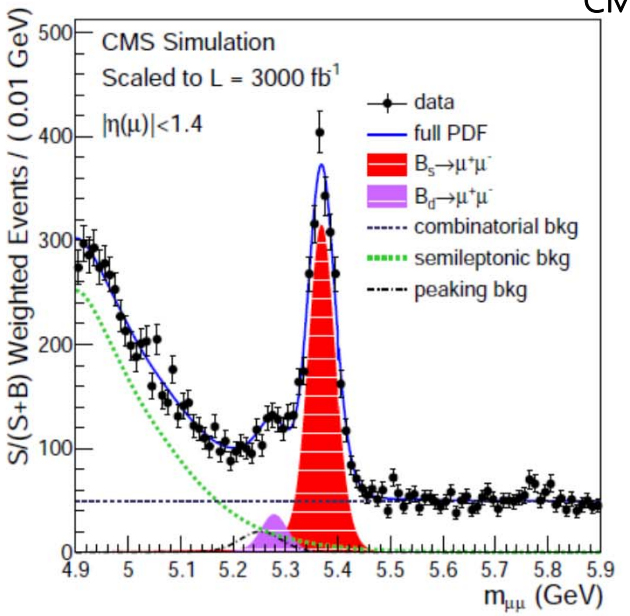
But: Peaking BG

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

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

CMS PAS FTR-14-015





Estimate of analysis sensitivity

assume SM Br

$\mathcal{L}$ (fb^{-1})	$N(B_s^0)$	$N(B^0)$	$\delta\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	$\delta\mathcal{B}(B^0 \to \mu^+\mu^-)$	B^0 sign.	$\delta\frac{\mathcal{B}(B^0\to\mu^+\mu^-)}{\mathcal{B}(B_s^0\to\mu^+\mu^-)}$
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 $B_d \to \mu^+\mu^-$ at SM Br can be observed at Phase II

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

$B^0 \to K^{*0}(K^+\pi^-)\mu^+\mu^-$ angular analysis (8 TeV)

angular observables: θ_l, θ_K, φ

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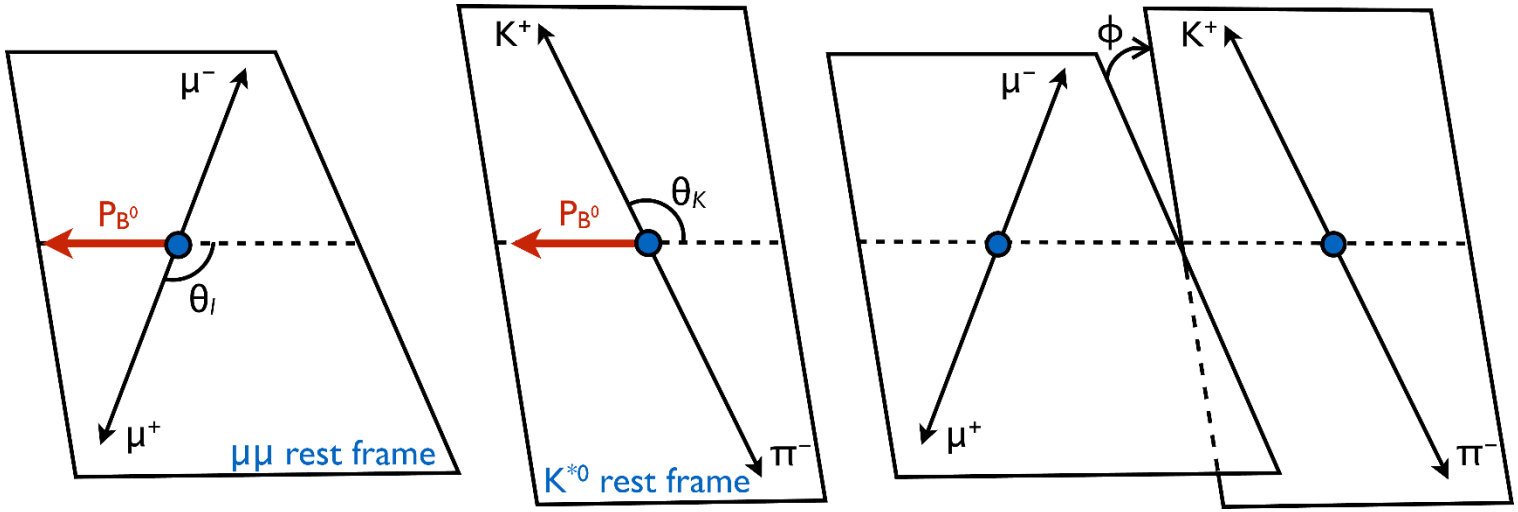
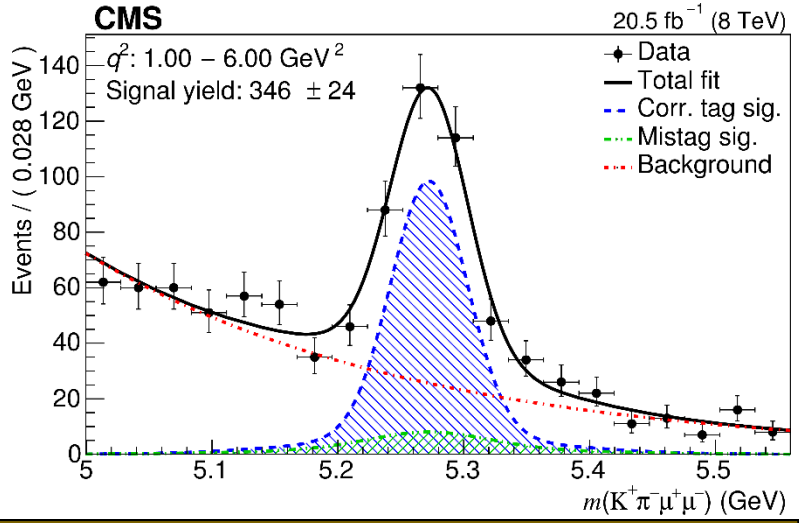


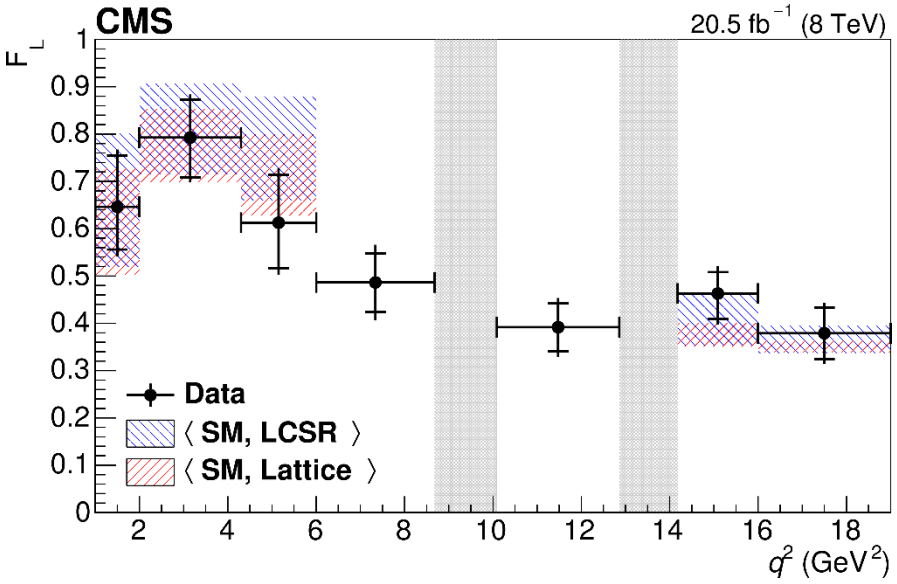
Integrating out φ, extract observables for each q^2 from an unbinned, extended maximum-likelihood fit to:

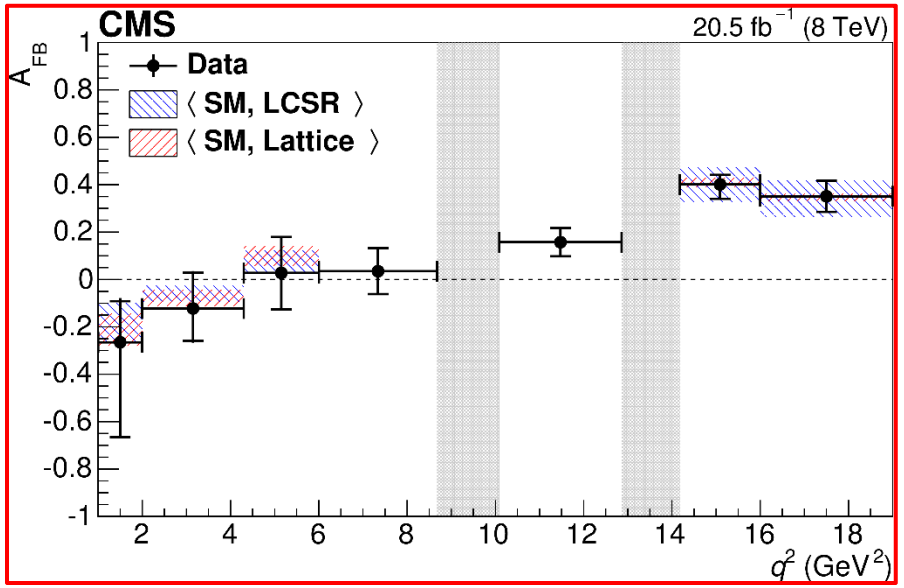
θ_l, θ_K; $m(K^+\pi^-\mu^+\mu^-)$



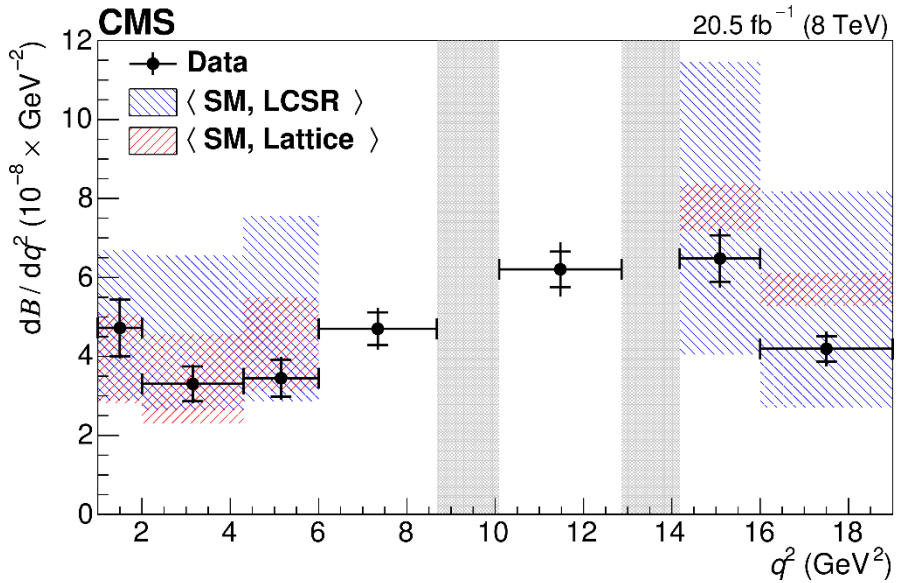
1430 signal events in fitted data

$B^0 \to K^{*0}(K^+\pi^-)\mu^+\mu^-$ results (8 TeV)





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



$B^0 \to K^{*0}(K^+\pi^-)\mu^+\mu^-$: combining 8 & 7 TeV

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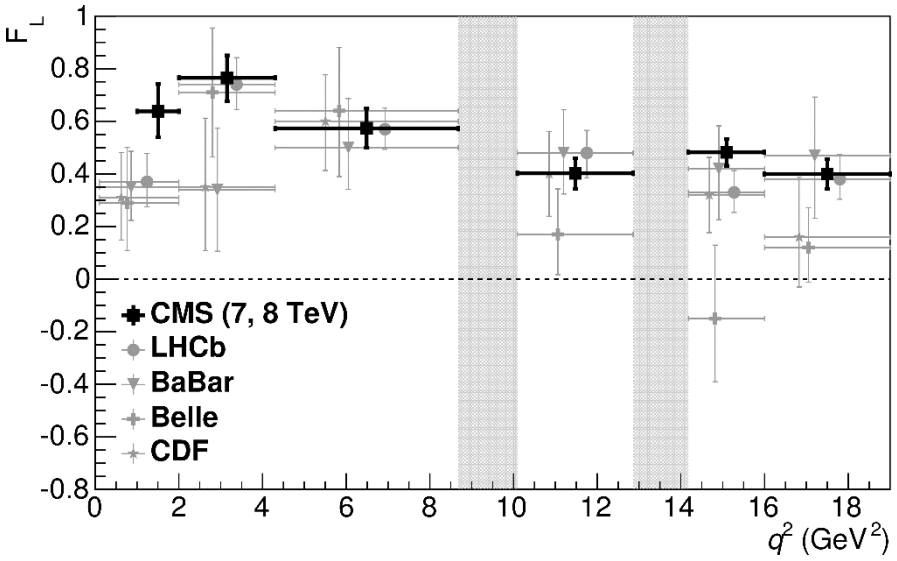
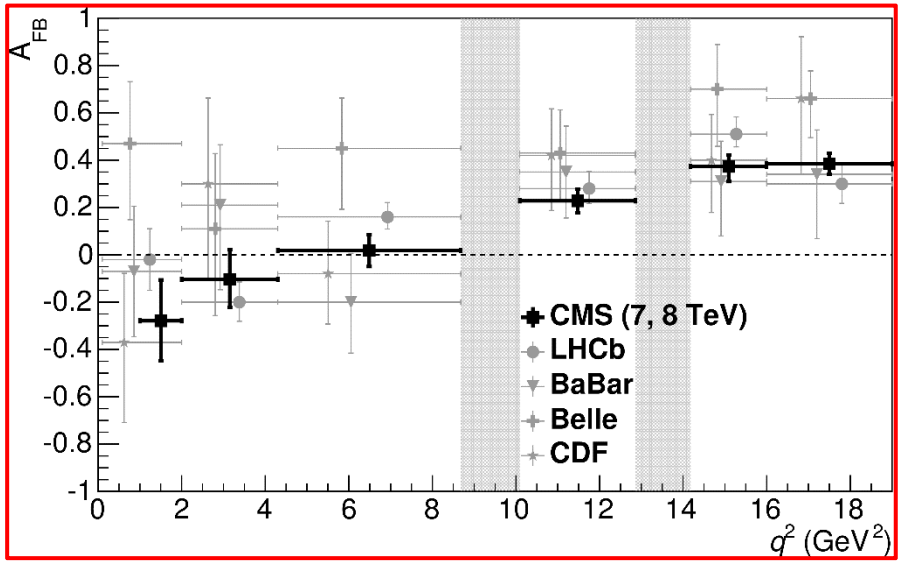
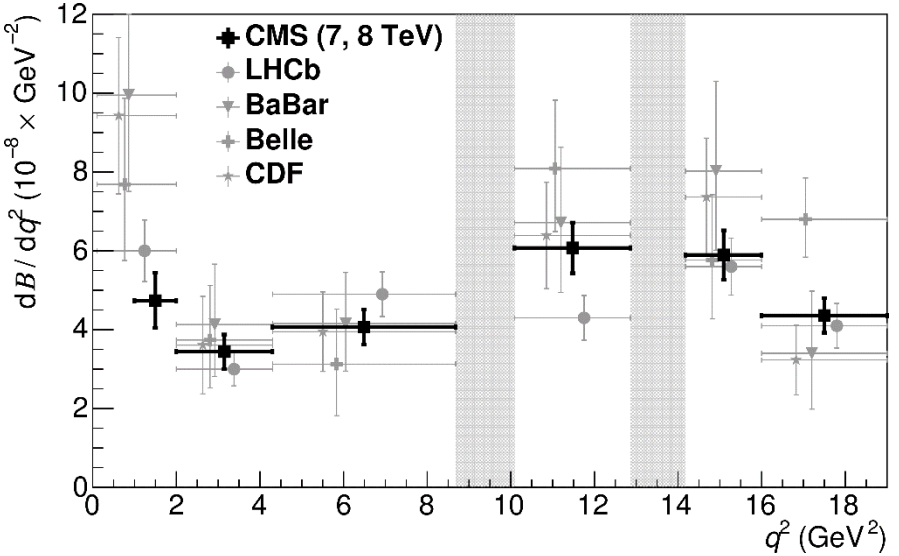




- The measurements are among the most precise to date.
- In good agreement with SM (LCSR & Lattice) predictions.
- Consistent with measurements by LHCb, CDF, BaBar and Belle.



3. ϕ_s & $\Delta\Gamma_s$

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

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

$B_s \to J/\psi\phi(1020) \to \mu^+\mu^-K^+K^-$ (8 TeV)

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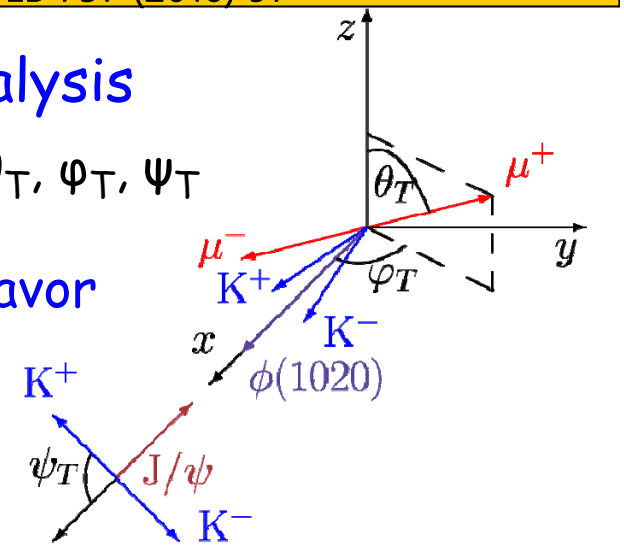
Time-dependent, flavour-tagged angular analysis

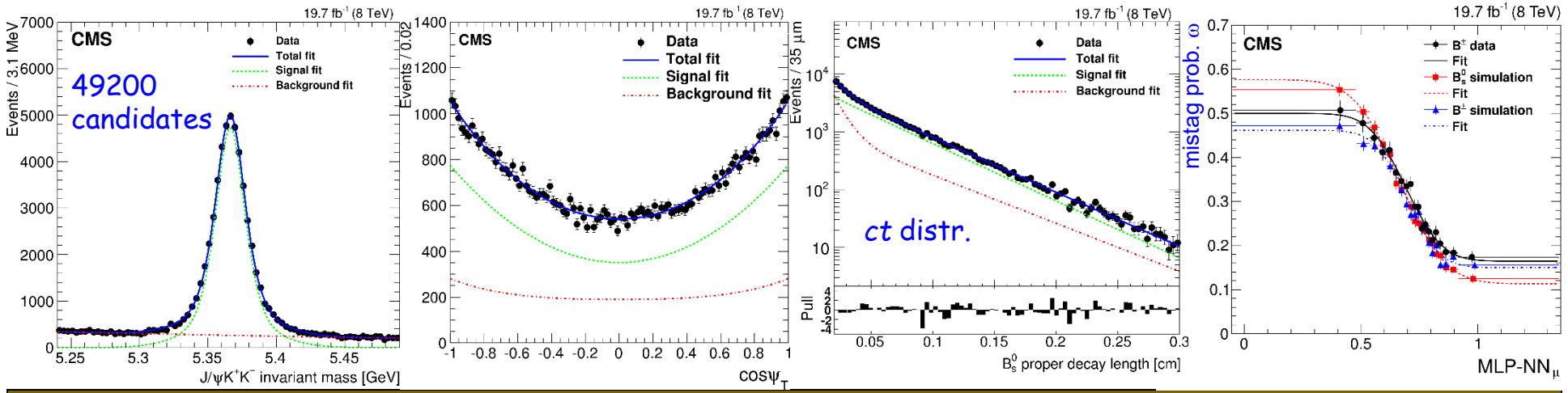
transversity basis: θ_T, φ_T, ψ_T



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

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

70500 events used in the fit (5650 tagged)



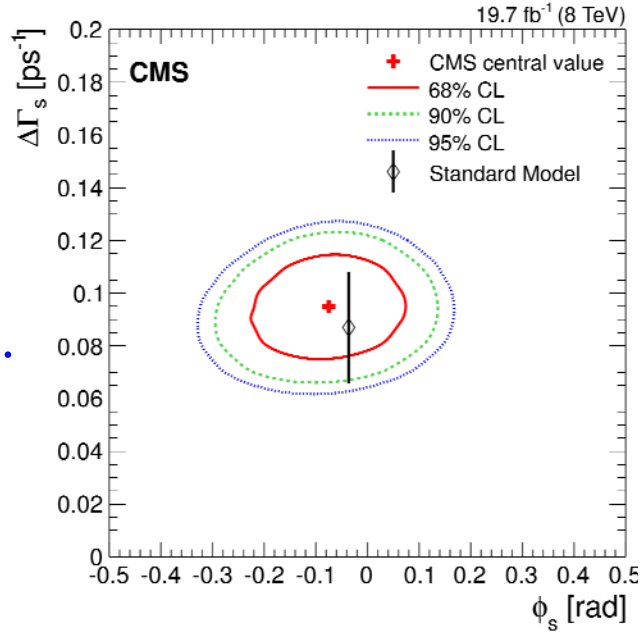
ϕ_s & $\Delta\Gamma_s$ result

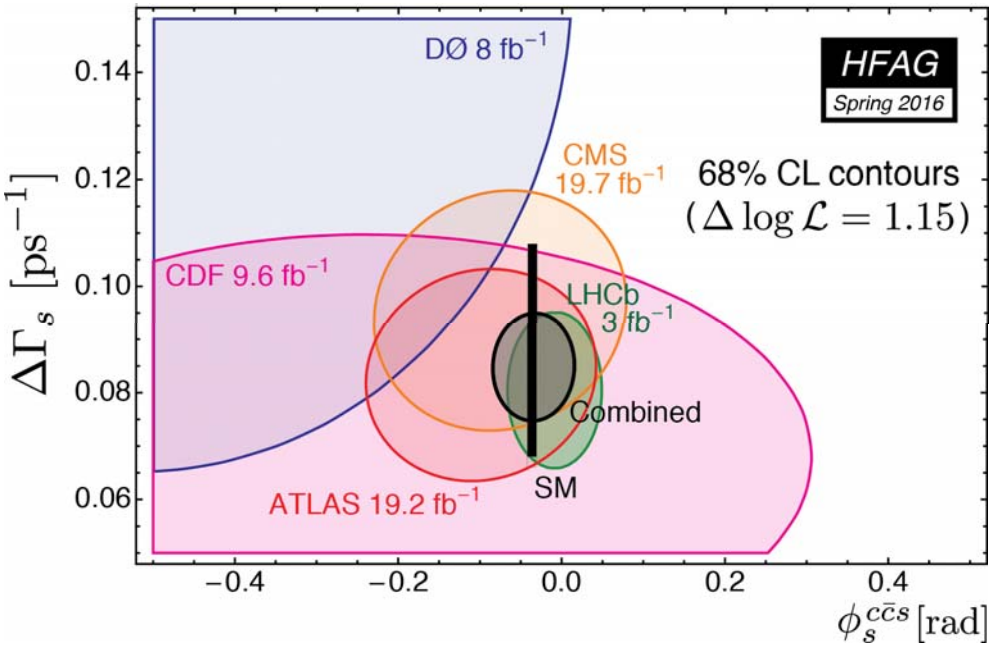
$\phi_s = -0.075 \pm 0.097\,(\text{stat}) \pm 0.031\,(\text{syst})$ rad

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

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

Error Stat.-dominant → improve at Run 2!





current world average

-0.033 ± 0.033

cf. LHCb Run 1 value: -0.010 ± 0.039

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

(7 TeV)

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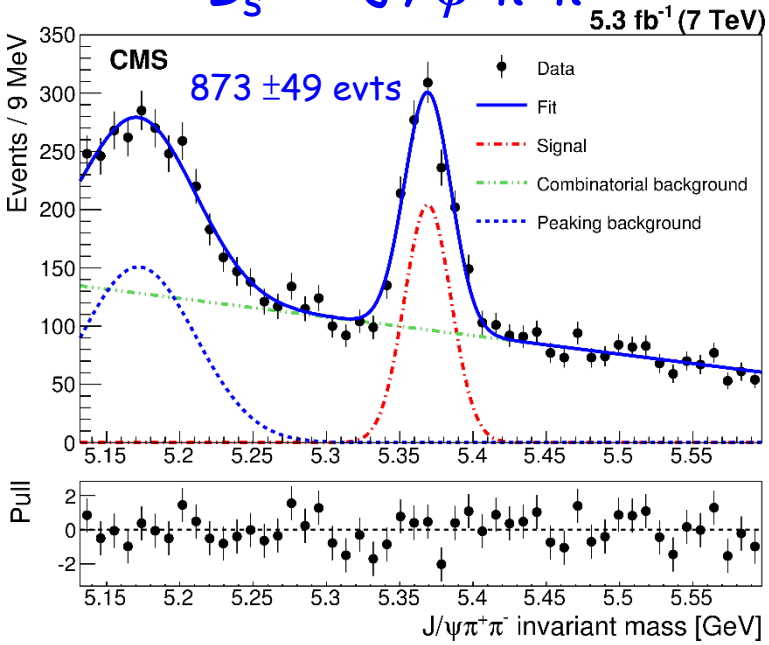
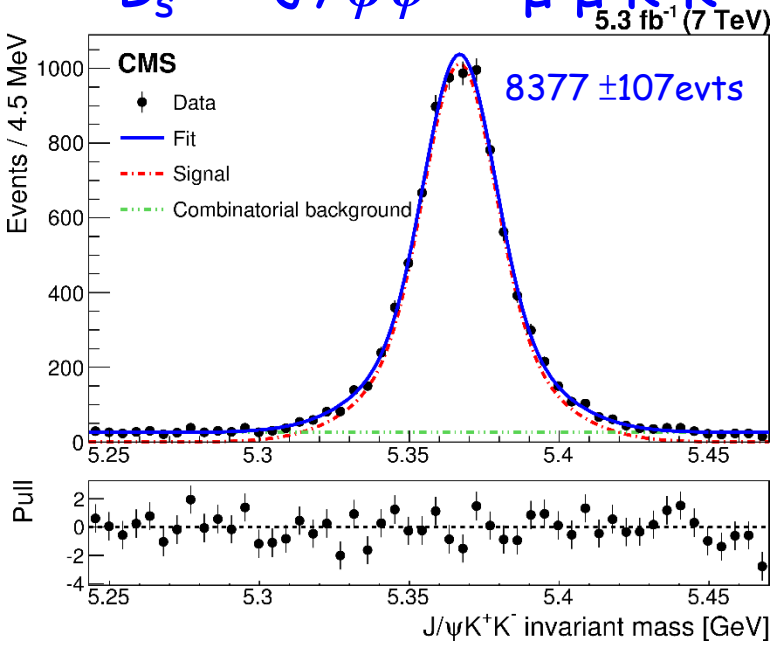
$B_s \to J/\psi \overbrace{\pi^+\pi^-}^{\text{in } f_0(980) \text{ region}}$



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



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

Consistent with theoretical prediction, and with other measurements.

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

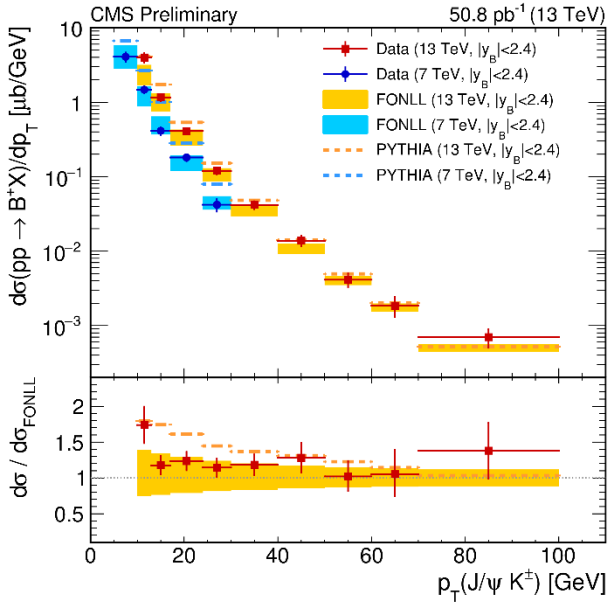
4. Recent results

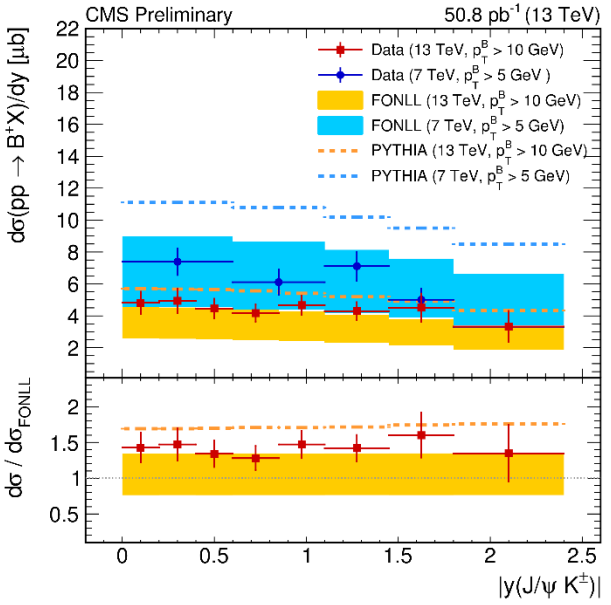
- Observation of $\Upsilon(1S)$ pair production CMS PAS BPH-14-008

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

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

- Measurement of B^+ cross section at 13 TeV CMS PAS BPH-15-004





Discussion and Conclusion

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

- $B_s \to \mu^+\mu^-$ observed (together with LHCb) with Run 1 data;
  $B_d \to \mu^+\mu^-$ shows hint above SM expectation.
  Run 2: former would become measured by single exp't;
  definitely pursue latter!
- $B^0 \to K^{*0}\mu^+\mu^-$: 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 $B_s \to J/\psi f_0(980) \to \mu^+\mu^-\pi^+\pi^-$ can be done).

Aim is SM, Game is New Physics.