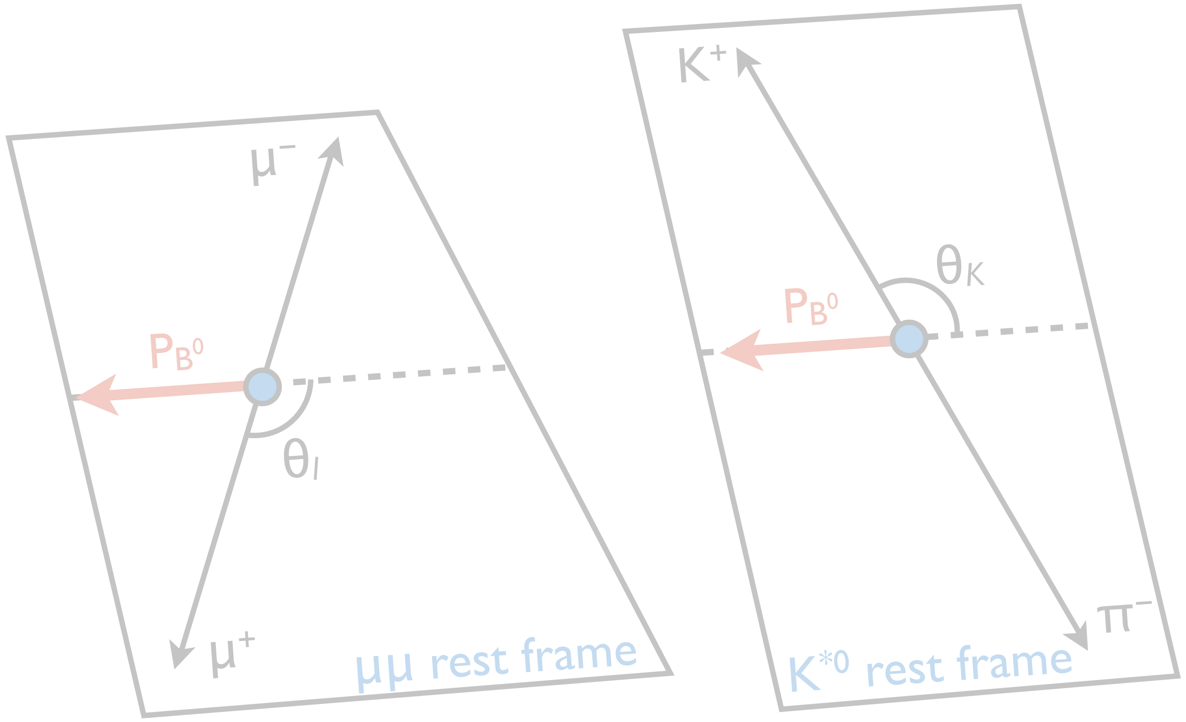

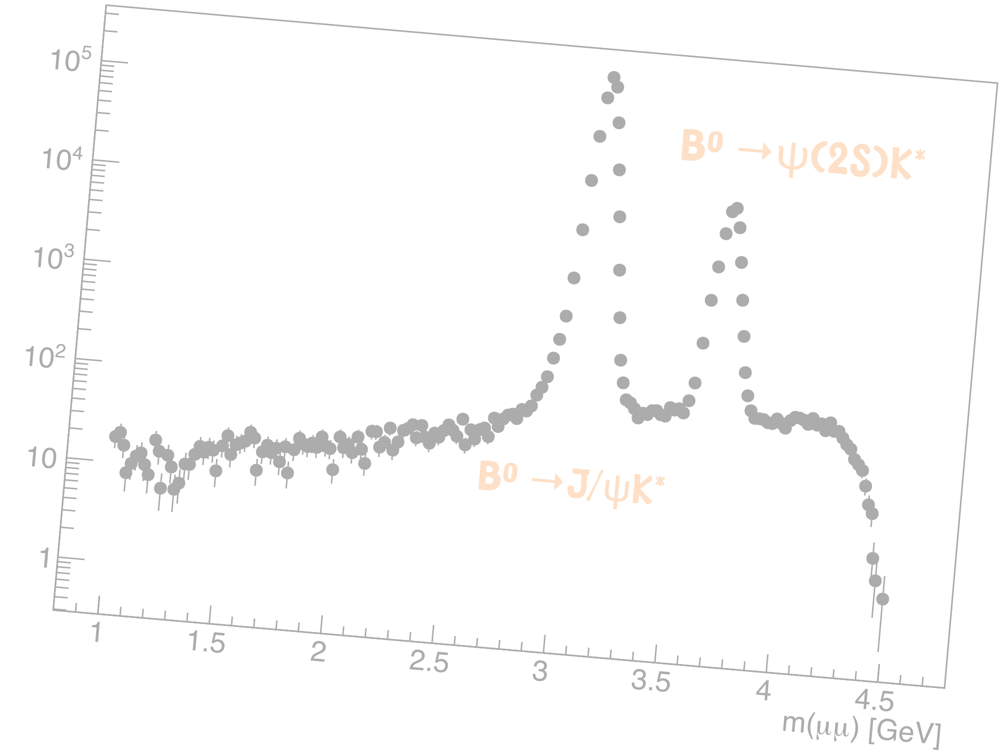

CMS contribution to b→sll binning discussion

Sara Fiorendi (University of Tennessee) for the CMS Collaboration

LHC Heavy Flavour WG topical meeting: b→sll

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outline

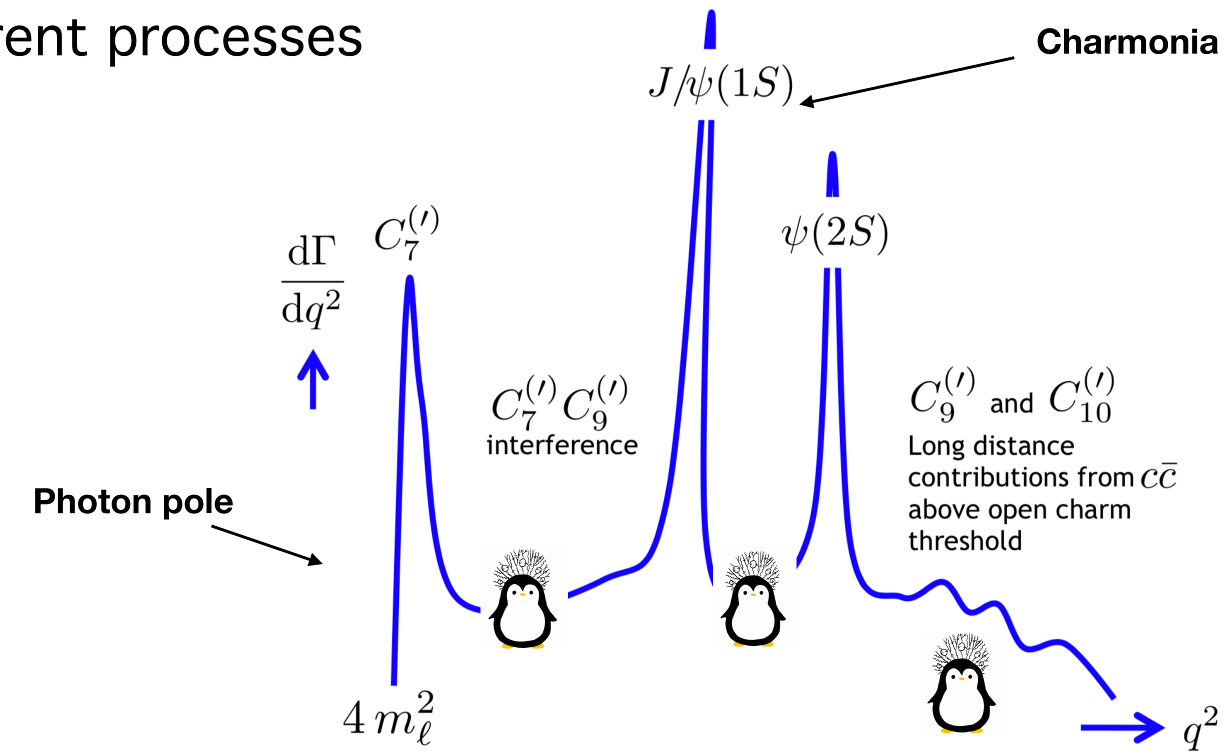
- Introduction
- Angular analysis ingredients
- Considerations about binning choices in CMS & among the experiments
- Prospects for Run3

Introduction

- In CMS, b→sll decays are extensively studied to measure possible NP contributions, via:
  - differential BRs
  - angular observables
  - Lepton Flavor Universality tests

- Studies are performed in integrated ranges of di-lepton mass square, q^2, as different q^2 regions probe different processes

- In this talk we will focus on analyses with two muons in the final state
  - experimentally "easy" to trigger thanks to the two muons in the final state



Analysis strategy overview

using the $B^0 \to K^*\mu\mu$ case as example of a typical angular analysis

- Analysis is **binned** in q^2 intervals
- In each q^2 bin, we perform an unbinned maximum likelihood fit to (m, θ_k, θ_l, ϕ) with

signal component

$$\mathrm{pdf}(m, \cos\theta_K, \cos\theta_l, \phi) = Y_S \Big[S^C(m)\, S^a(\cos\theta_K, \cos\theta_l, \phi)\, \epsilon^C(\cos\theta_K, \cos\theta_l, \phi)$$
$$+ R \cdot S^M(m)\, S^a(-\cos\theta_K, -\cos\theta_l, -\phi)\, \epsilon^M(\cos\theta_K, \cos\theta_l, \phi) \Big]$$
$$+ Y_B\, B^m(m)\, B^a(\cos\theta_K, \cos\theta_l, \phi)$$

background component

angular bkg shape

Y_S and Y_B are the signal and background yields, respectively

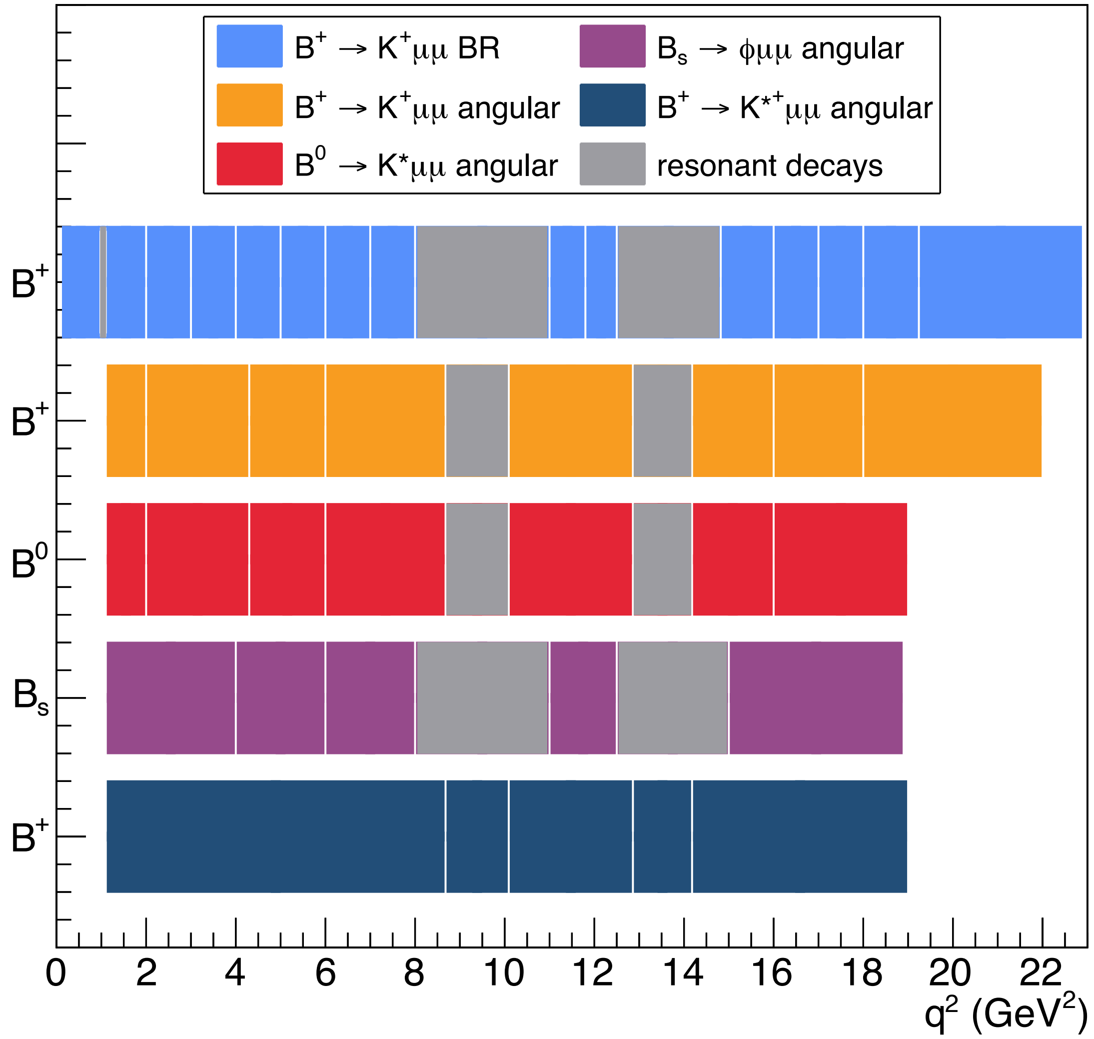
the angular shape of the bkg component is estimated using the **angular distributions of the data sidebands**

Binning choice: motivations

- Due to the small BR, even after Run2 the **analyses are still statistically limited**
- Binning choice driven by the available statistics
    - obviously the **signal yield** must be above a certain amount in order to "meaningful" have statistic uncertainties
    - given that our samples are not background free, we should also retain a sufficient number of **events in the sidebands** to be able to model the angular distribution of the bkg in the signal region
- also, the **dimuon resonances** should be removed from the signal sample → expected contamination influences the boundary choice
- finally, **historical reasons** have played a role in the current adopted binning schemes
    - ease of comparing to previous results

Binning schemes

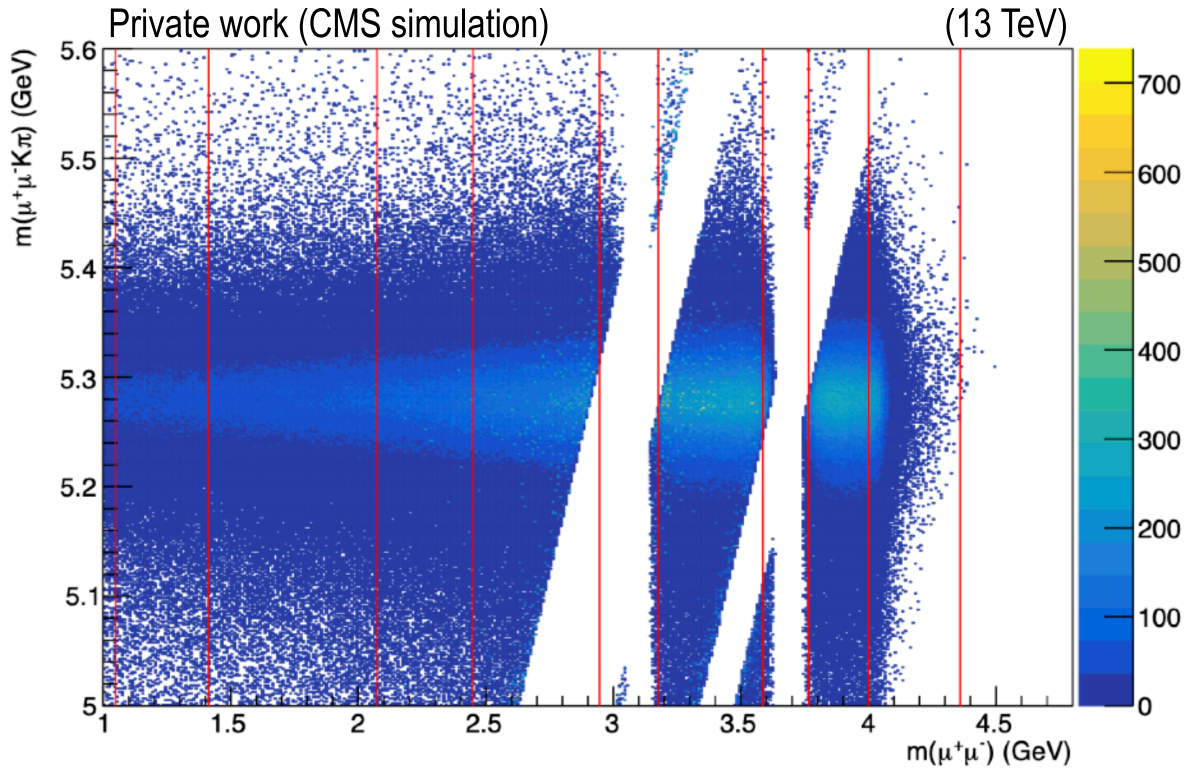
- Choices currently adopted by the various (angular) analyses in CMS



$B^+ \to K^+\mu\mu$	$B^0 \to K^*\mu\mu$	$B_s \to \phi\mu\mu$
1.1 - 2	1.1 - 2	1.1 - 4
2 - 4.3	2 - 4.3	4 - 6
4.3 - 6	4.3 - 6	6 - 8
6 - 8.68	6 - 8.68	8 - 11 (J/ψ)
8.68 - 10.09 (J/ψ)	8.68 - 10.09 (J/ψ)	11 - 12.5
10.09 - 12.86	10.09 - 12.86	12.5 - 15 ($\psi(2S)$)
12.86 - 14.18 ($\psi(2S)$)	12.86 - 14.18 ($\psi(2S)$)	15 - 18.9
14.18 - 16	14.18 - 16	
16 - 18	16- 19	
18 - 22		

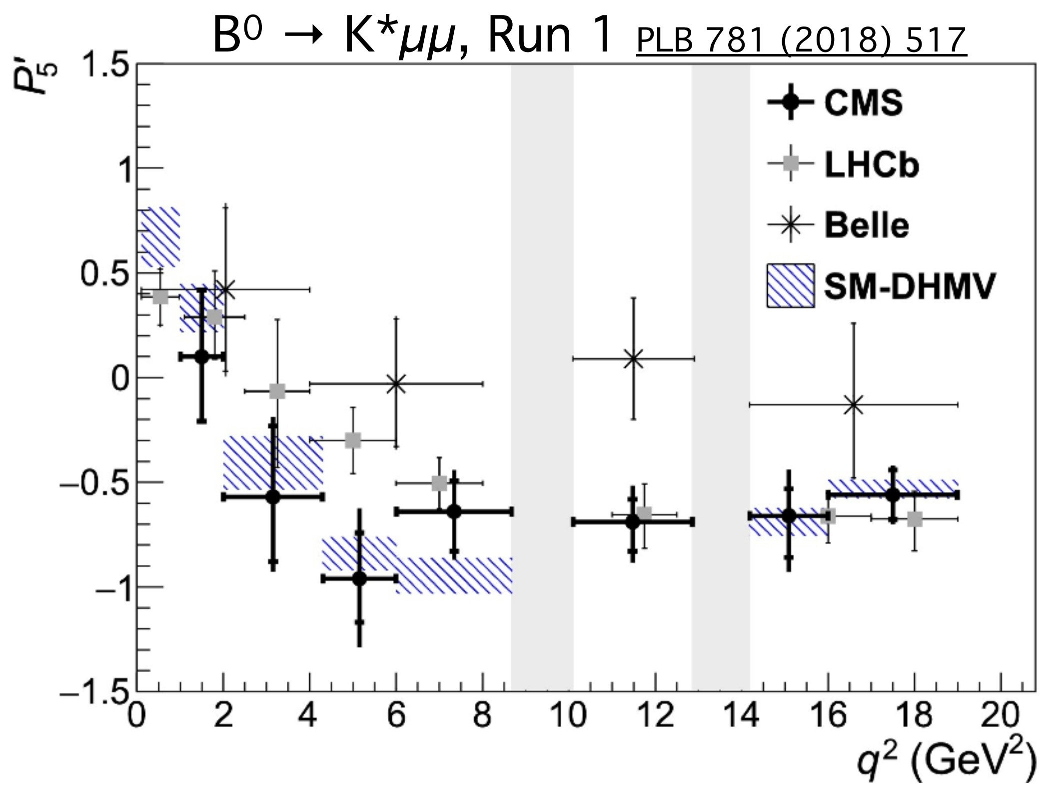
Resonant contamination

- Almost all analyses implement a "diagonal" selection in order to reject
- a fraction of events from the control channels still leaks into the adjoining q^2 bins
  - mainly due to the presence of an unreconstructed photon from the charmonium decay
- This contamination is removed from the signal region by applying combined requirements on q and the B^0 candidate invariant mass
  - usually tuned independently for the dimuon mass regions below the J/ψ, between the J/ψ and the ψ(2S), and above the ψ(2S)



Comparison to other experiments

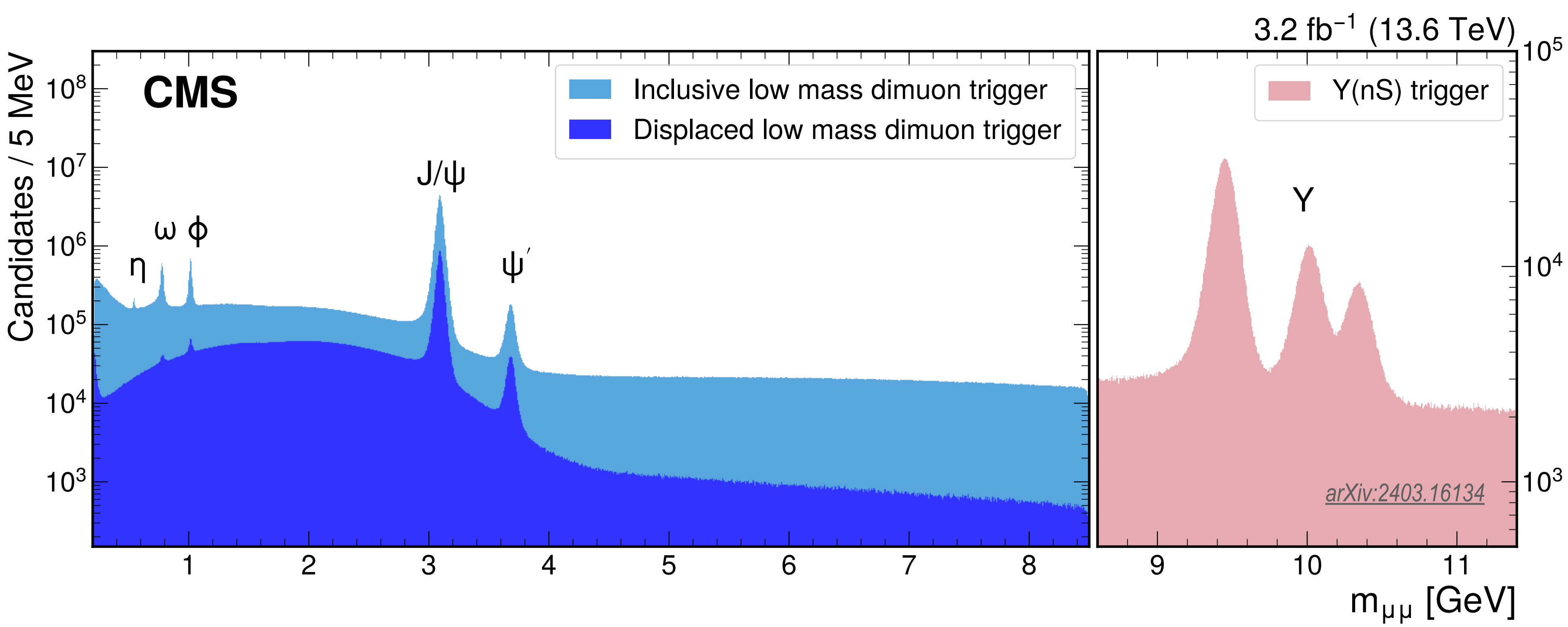
- The comparison among the results from different Collaborations is currently very difficult as the bin definitions are overlapping



- Similarly, theory predictions shown on such plots are only coherent with one set of measurements
- It's crucial to **agree on common bin boundaries among the experiments**

Prospects for Run3

- We expect to collect around 250 fb^{-1} at the end of Run3 → factor ~1.8 x Run2 stat
- The trigger strategy has been further improved
  - the main HLT path used for the b→ $s\mu\mu$ analyses will have better reconstruction efficiency for low p_T muons, as well as no requirement on the presence of an additional track
    - large increase in the signal yield per fb^{-1} compared to the Run2 dimuon+track triggers is foreseen for final states like $B^0 \to J/\psi K^0_S$
    - smaller improvement for decay chains where all the final particles come from a common vertex
- The analyses will **still be statistically dominated**, even with the current binning



Conclusions and more specific questions

- We need to **agree on a recommended binning scheme common among the experiments**

- Does it make sense to go close to the resonances?
  - if theory predictions are not valid there, there's no reason for the experiments to go as close as possible

- About the region above the ψ(2S), flavio authors report that their predictions are not valid below 15 GeV. Is this caveat valid also for other predictions?
  - again, this could impact the choice of the lower edge of the first bin above the ψ(2S)

- About the region above the ψ(2S), we understand that large bins are preferred.
  Could you confirm/better define what large means in this case?

extra

Yellow Report studies on binning

- For the YR exercise, we studied a possible splitting of the current bins in narrower ones with the HL-LHC expected statistics
  - to better constrain, e.g., the P_5' shape at low q^2
- Criteria: statistical uncertainty of the order of the total systematic uncertainty in the same bin
  - with additional constraint width > $5\sigma_{\mu\mu}$
- 14 bins between 2 and 6 GeV^2

- Main caveats: based on Run1 analysis
  - not full angular analysis
  - selection in Run2 has already improved wrt Run1 by a factor of 30%

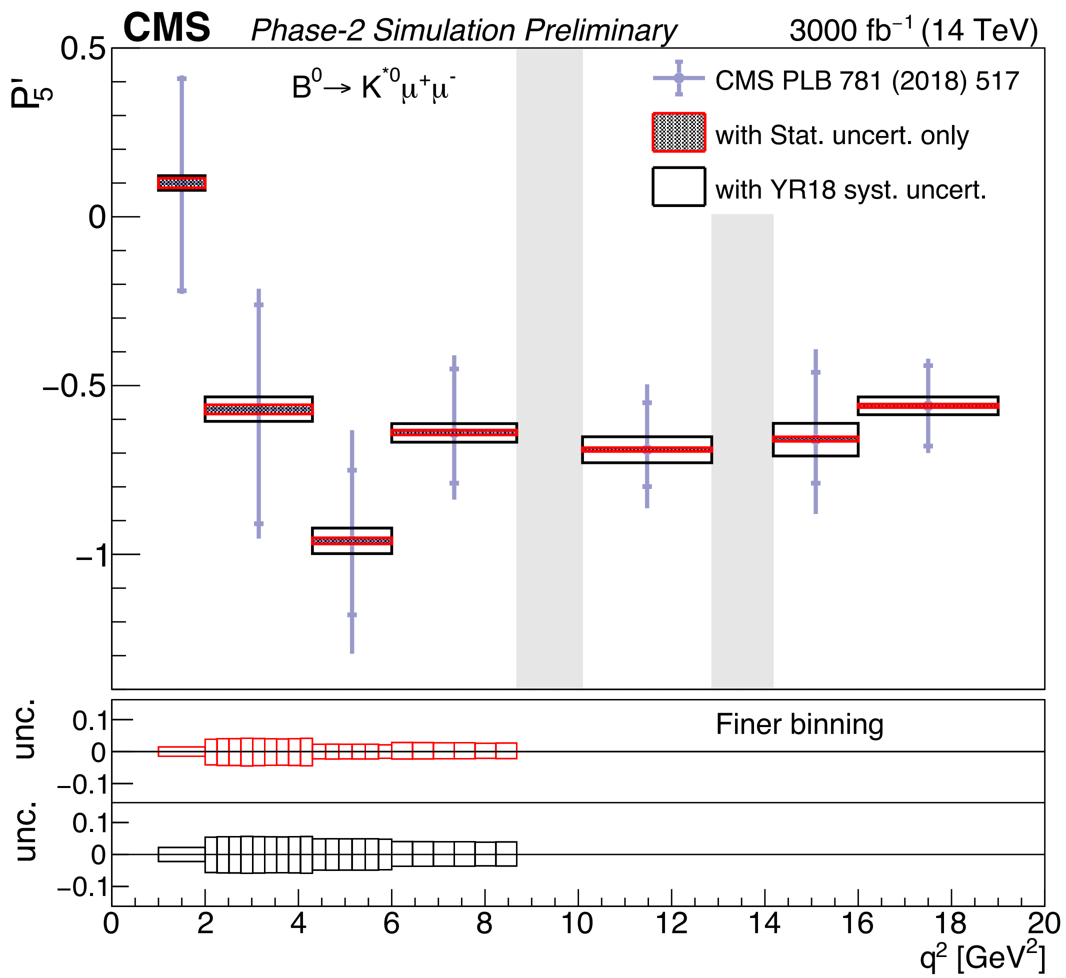


Figure 3: Projected statistical (hatched regions) and total (open boxes) uncertainties on the P'_5 parameter versus q^2 in the Phase-2 scenario with an integrated luminosity of $3000\,fb^{-1}$. The CMS Run I measurement of P'_5 is shown by circles with inner vertical bars representing the statistical uncertainties and outer vertical bars representing the total uncertainties. The vertical shaded regions correspond to the J/ψ and ψ' resonances. The two lower pads represent the statistical (upper pad) and total (lower pad) uncertainties with the finer q^2 binning.