B physics at ATLAS and CMS

Marcella Bona
(QMUL)

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B physics in ATLAS and CMS

- somewhat limited *(wo)*man power and trigger efficiencies
  - but a good variety of analyses
  - $B_{(s)}$ oscillations in all-tracks final state
  - Dedicated trigger for $B_{(s)}$ to $\mu\mu$
  - $K^*\mu\mu$ angular analysis and many other topics (b production, spectroscopy, etc)
- 15% of the bandwidth is allocated to B Physics
- Dedicated L1 soft-muon triggers to keep sensitivity at high luminosity
- some recent (2018) results
  - ATLAS: $B_{(s)}$ to $\mu\mu$, $K^*\mu\mu$ angular analysis, $B_s\pi$ searches
  - CMS: $K+/K^*\mu\mu$ angular analysis, observations of $\chi_{b1,2}$ and $B^*_{s1,2}$
- and some prospects
  - electrons and ratio possibilities
  - high luminosity

rare B decays $B_{(s)} \rightarrow \mu^+\mu^-$

ATLAS:

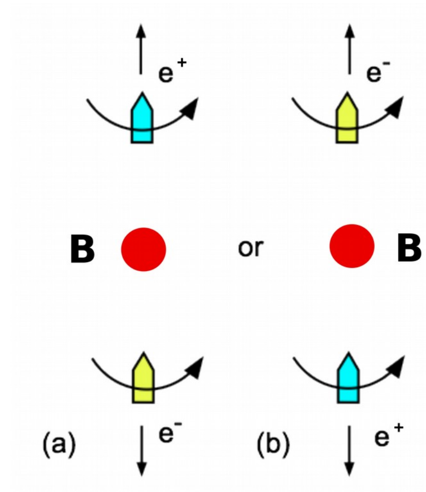
EPJ C76 (2016) 513, arXiv:1604.04263

ATLAS-CONF-2018-046 (2018)

CMS

Nature (2015) 14474, arXiv:1411.4413

Motivations and predictions

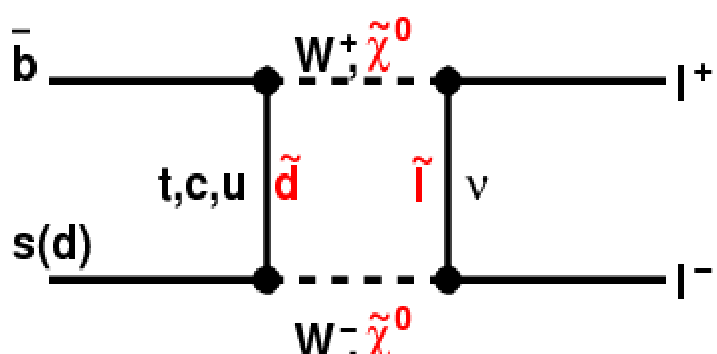


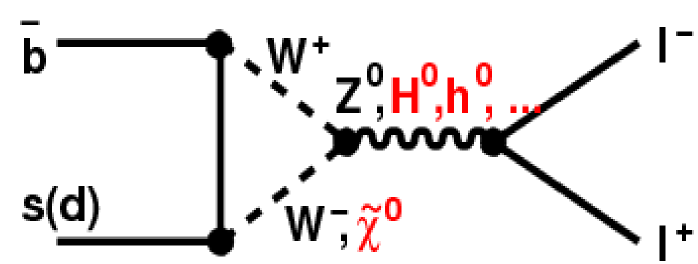
- Decays of B^0 and B^0_S into two leptons have to proceed through Flavour Changing Neutral Currents (FCNC)
  → forbidden at tree level in the SM
- In addition, they are CKM and helicity suppressed.
- Within the SM, they can be calculated with small theoretical uncertainties of order 6-8%

meson type	Lepton type *e*	μ	τ
B^0	$(2.48 \pm 0.21)10^{-15}$	$(1.06 \pm 0.09)10^{-10}$	$(2.22 \pm 0.19)10^{-8}$
B^0_s	$(8.54 \pm 0.55)10^{-14}$	$(3.65 \pm 0.23)10^{-9}$	$(7.73 \pm 0.49)10^{-7}$

Bobeth et al., PRL 112 (2104) 101801 [includes NLO EM and NNLO QCD corrections]

- Perfect ground for indirect new physics searches:
  - virtual new particles can contribute to the loop
  - both enhancement and suppression effects are possible

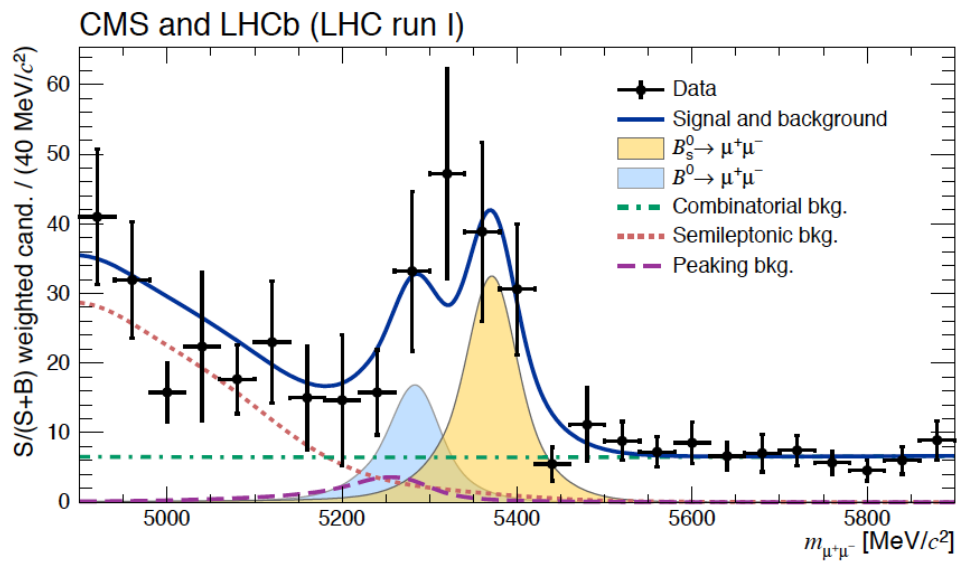




CMS analysis on full Run 1 data (with LHCb)

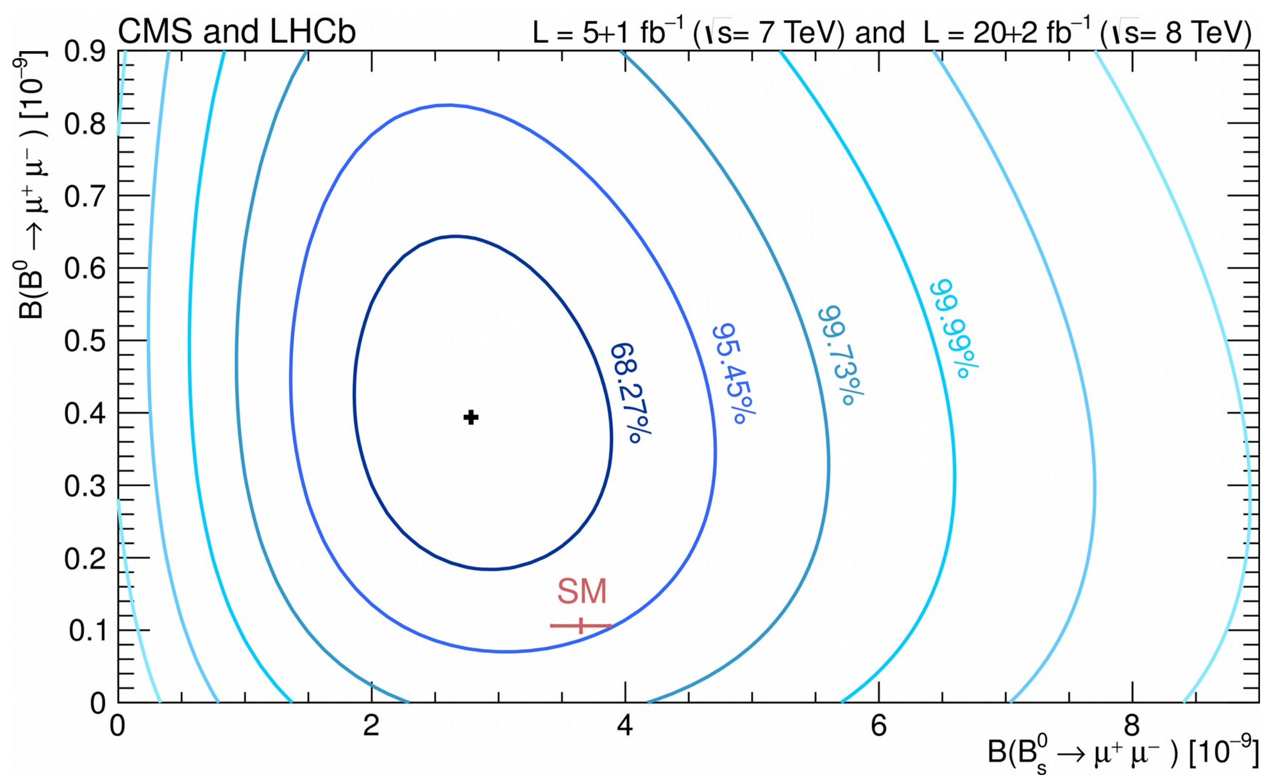
CMS and LHCb, Nature (2015) 14474 arXiv:1411.4413

Simultaneous 20 bin CMS+LHCb fit



6.2σ (7.4σ exp.)

$B(B^0_s \to \mu^+\mu^-) = 3.9^{+1.6}_{-1.4} \times 10^{-10}$



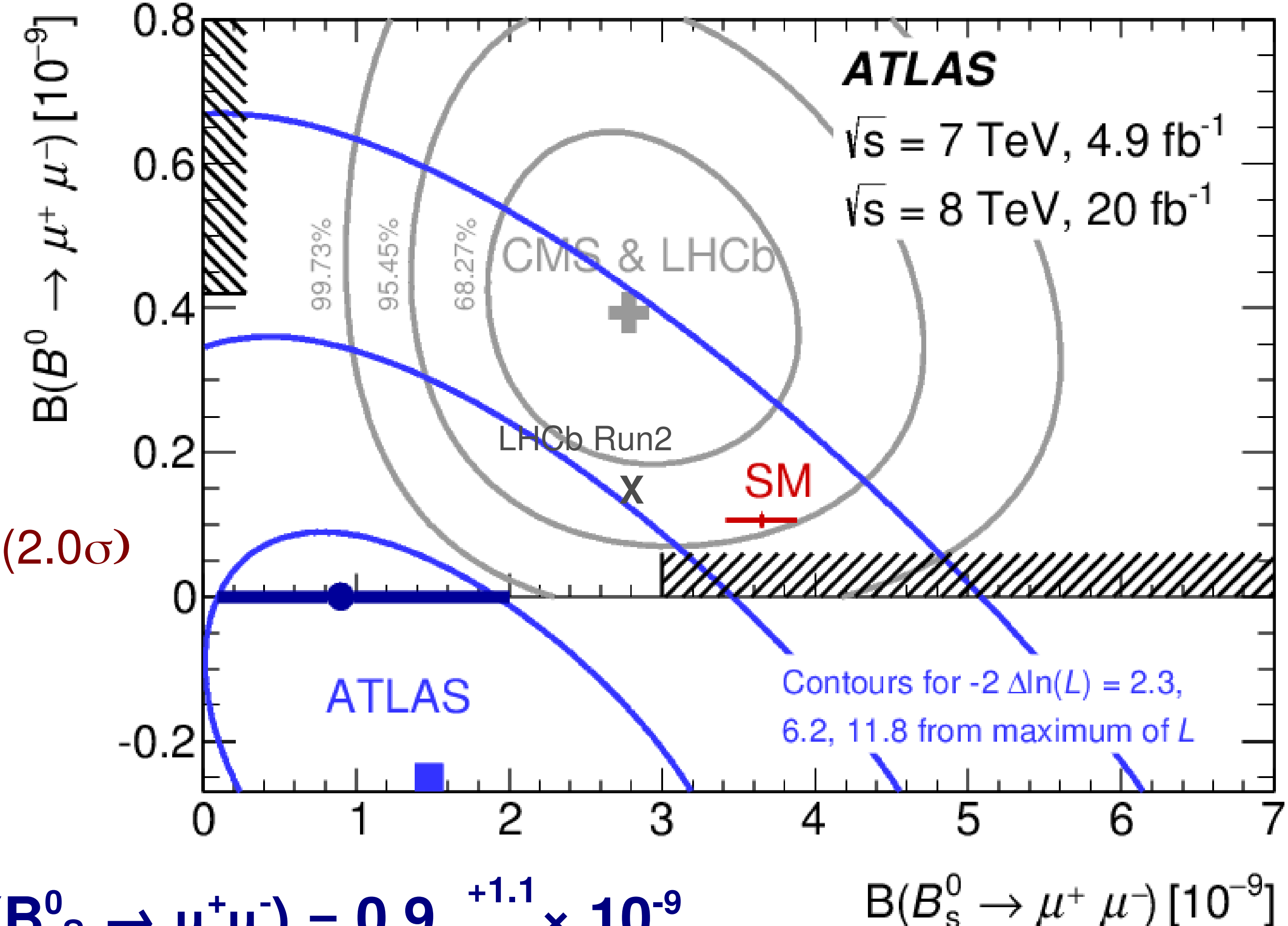
$B(B^0_s \to \mu^+\mu^-) = 3.0^{+1.0}_{-0.9} \times 10^{-9}$

3.2σ (0.8σ exp.)

ATLAS analysis on full Run 1 data

ATLAS, EPJ C76 (2016) 513, arXiv:1604.04263

$B(B^0 \to \mu^+\mu^-) < 4.2 \times 10^{-10}$ at 95% CL



compatibility of the simultaneous fit with the SM:
p-value = 0.048 (2.0σ)

reduced tension in B^0 with the SM with the Run2 LHCb result
arXiv:1703.05747

$B(B^0_s \to \mu^+\mu^-) = 0.9^{+1.1}_{-0.8} \times 10^{-9}$

ATLAS analysis on 2015-2016 Run 2 data

ATLAS-CONF-2018-046

- 36.2/fb dataset of 2015-2016 data taking:
  - effectively 26.3/fb for B → μ μ
  - 15.1/fb for B → J/ψΦ and B → J/ψK
- Trigger: higher thresholds [4-6 GeV] than in Run1,
  - Lxy > 0 request at trigger level

$$\mathcal{B}(B^0_{(s)} \to \mu^+\mu^-) = \frac{N_{d(s)}}{\varepsilon_{\mu^+\mu^-}} \times \frac{\varepsilon_{J/\psi K^+}}{N_{J/\psi K^+}} \times \frac{f_u}{f_{d(s)}} \times \left[\mathcal{B}(B^+ \to J/\psi K^+) \times \mathcal{B}(J/\psi \to \mu^+\mu^-)\right]$$

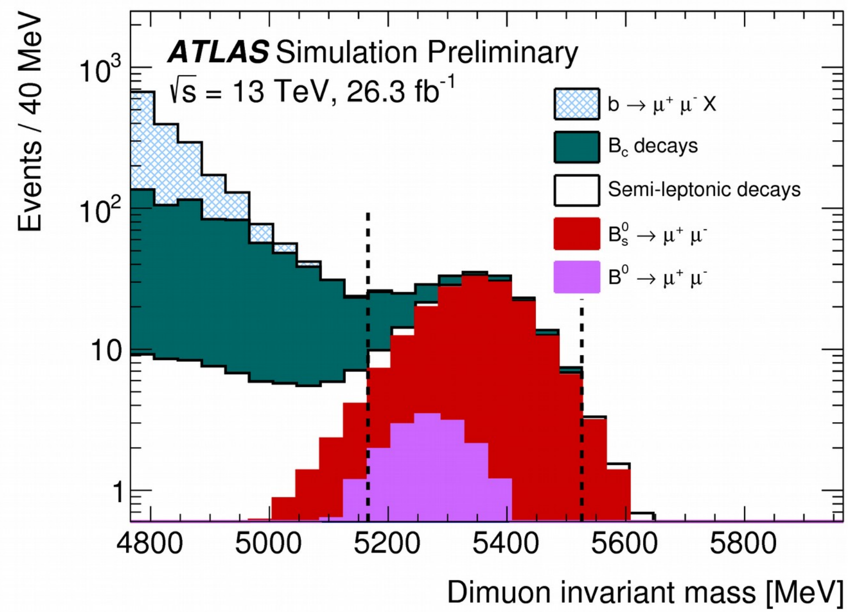
- correction for the different hadronisation probabilities for B^0_S and B^0 vs $B^\pm$
- include the $B^\pm$ and J/ψ branching fractions
- correction for the efficiencies of the two channels
- normalisation yield and efficiency ratio define the factor:

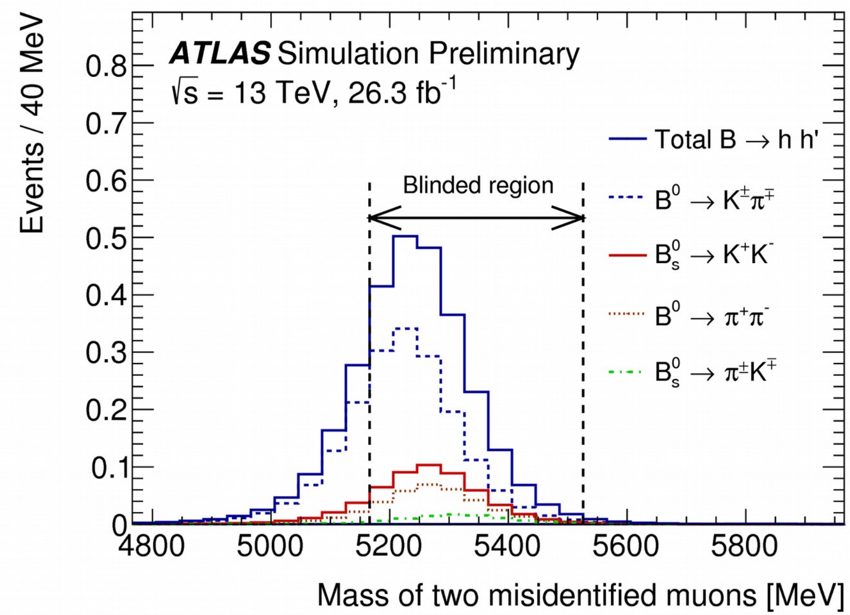
$$\mathcal{D}_{\text{norm}} = N_{J/\psi K^+} \left(\frac{\varepsilon_{\mu^+\mu^-}}{\varepsilon_{J/\psi\, K^+}} \right)$$

Background contributions

In order of relative magnitude:

- combinatorial background:
    - two real muons from different b quarks
- partially reconstructed B decays:
    - two real muons
    - Same Vertex (SV): $B \to \mu\mu X$ decays
    - Same Side (SS): semileptonic decay cascad
      ($b \to c\mu\nu \to s(d)\mu\mu\nu\nu$)
    - B_c decays: like $B_c \to J/\psi\ \mu\nu$
    - all these accumulate at low values of the dimuon invariant mass
- semileptonic B and B_S decays:
    - one real muon and a charged hadron.
- peaking background from charmless hadronic $B_{(S)}$ decays:
    - B decays into two hadrons h (kaons and pions): $B^0_{(S)} \to hh'$
    - smaller component, but overlays with the signal in dimuon invariant mass

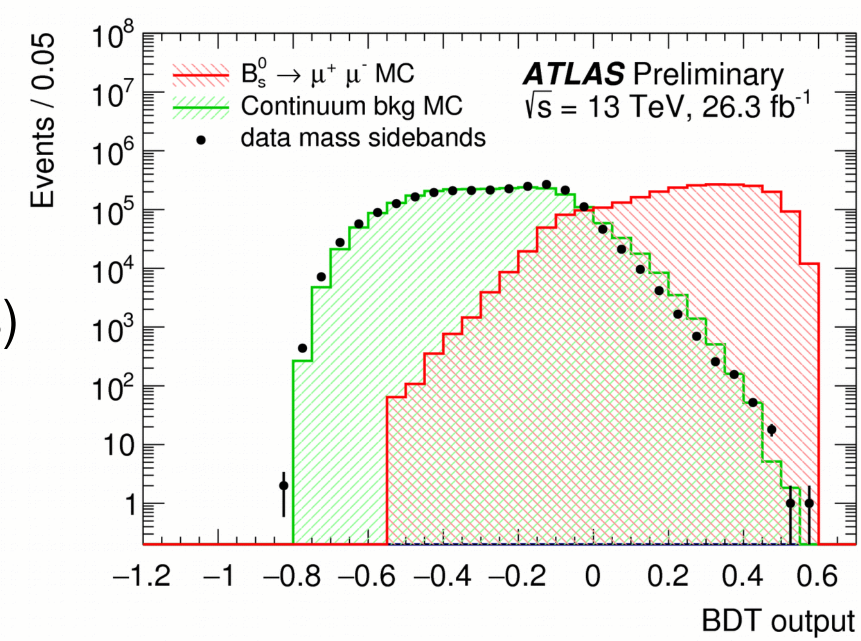




Tight muon-ID against hadron misidentification

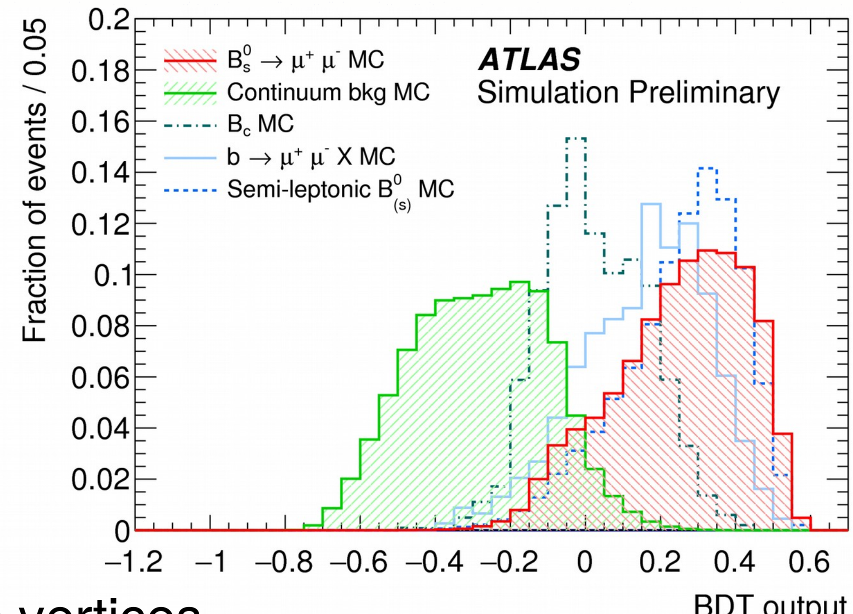
- mis-identification reduced by 0.39^2 using standard ‘tight’ ATLAS selections
- studied on simulated samples
- validated on control regions
- negligible misidentification of protons (< 0.01%)
- misidentification is 0.08%(0.10%) for K(π).

peaking-background events: 2.7±1.3



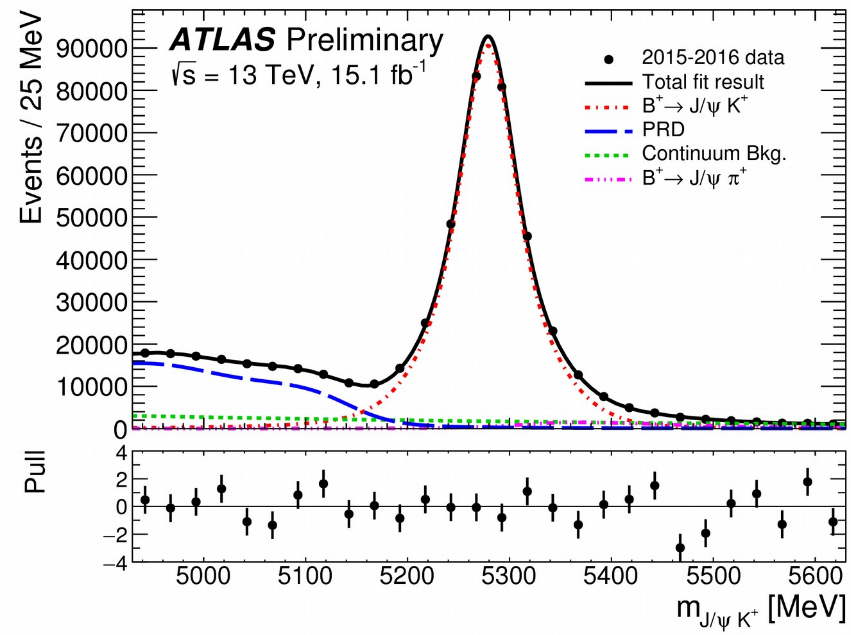
BDT against combinatorial bkg

- MVA classifier to discriminate from signal
- trained and tested on mass sidebands
  - divided in 3 subsets
    - 3 independent BDTs
    - compatible performance
- 15 variables related to properties of B candidates, muons from the B decay, other tracks from the same collision and to pile-up vertices.



Normalisation B yield extraction

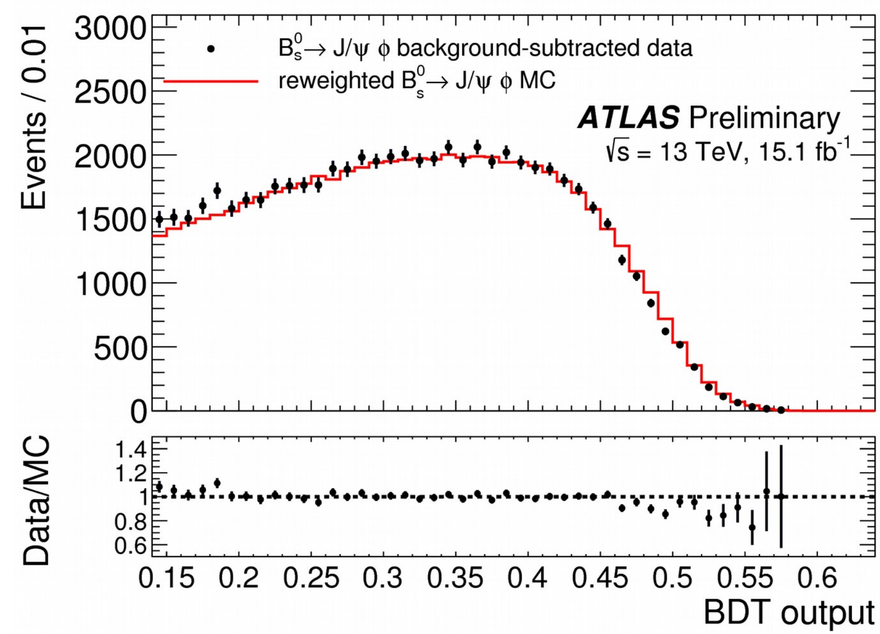
- unbinned maximum likelihood fit of the invariant mass $m_{J/\psi K} \rightarrow m_{\mu\mu K}$
- cross-checked with raw relative yield of $J/\psi\pi$ over $J/\psi K$ ratio
  $\rho_{\pi/K}$ = (3.71 ± 0.09)%



$$\mathcal{D}_{\rm norm} = N_{J/\psi K^+} \left(\frac{\varepsilon_{\mu^+\mu^-}}{\varepsilon_{J/\psi K^+}} \right)$$

Efficiency ratio $\varepsilon_{\mu\mu}/\varepsilon_{J/\psi K}$

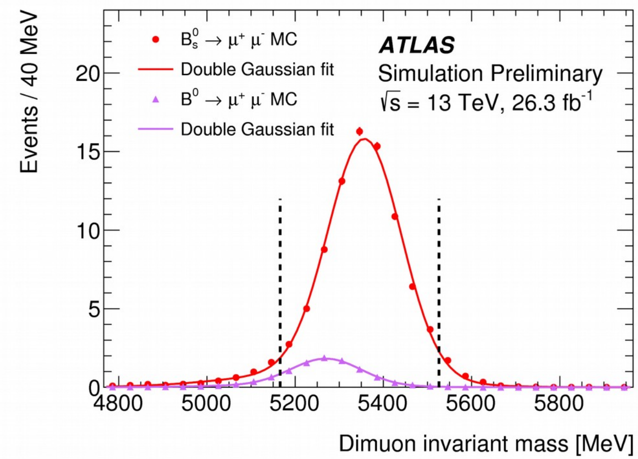
- efficiency ratio from MC
- systematic from data-MC discrepancies
- For B^0_S: 2.7% correction for lifetime difference of the B^0_S mass eigenstates

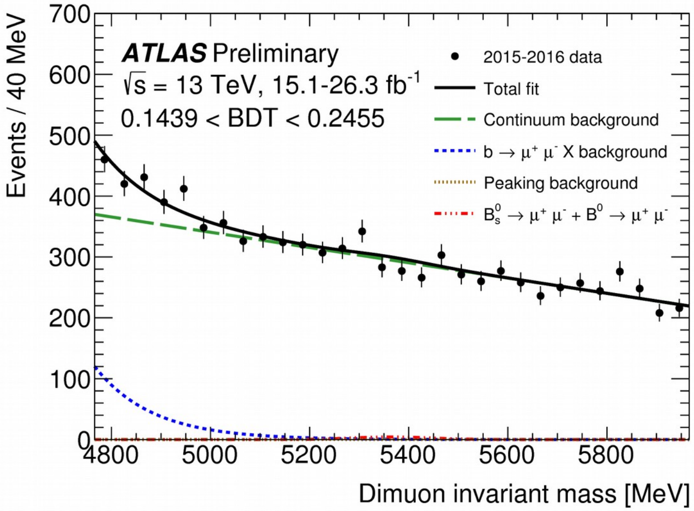


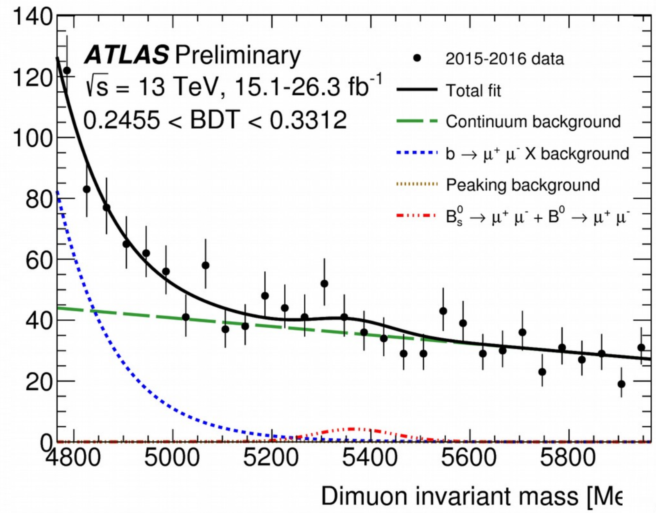
Source	Contribution (%)
Statistical	0.8
BDT Input Variables	3.2
Kaon Tracking Efficiency	1.5
Muon trigger and reconstruction	1.0
Kinematic Reweighting (DDW)	0.8
Pile-up Reweighting	0.6

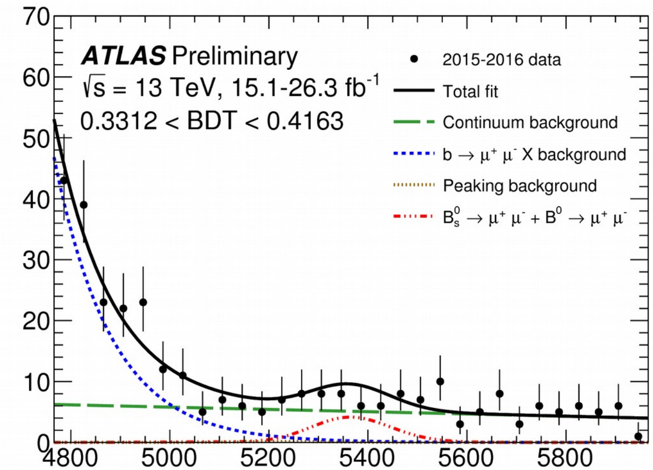
Signal yield extraction

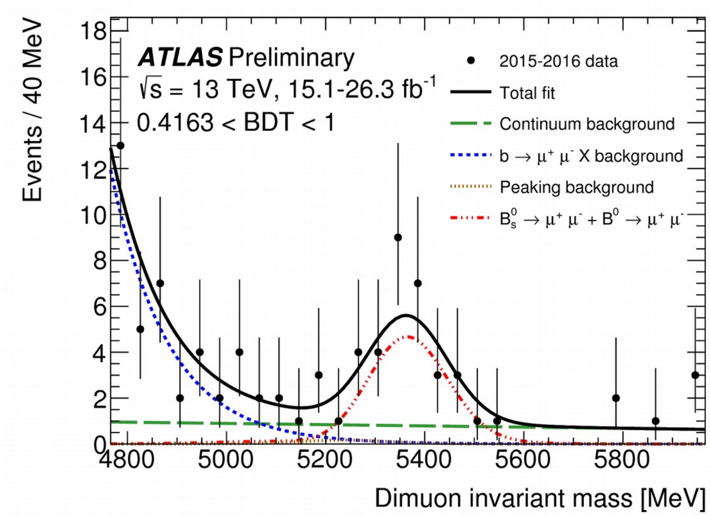
- signal yields extracted with a unbinned maximum likelihood fit to the dimuon mass
- fit performed simultaneously in four BDT bins
  - 18% signal efficiency







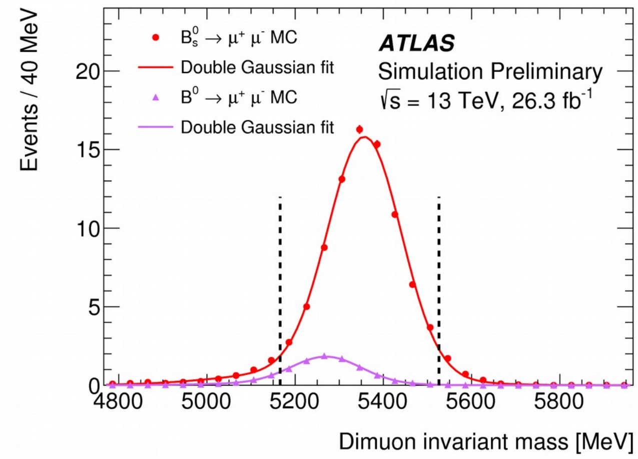


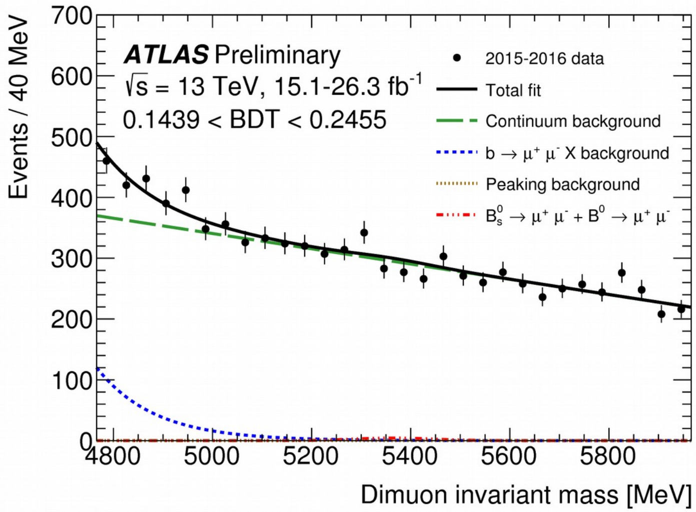


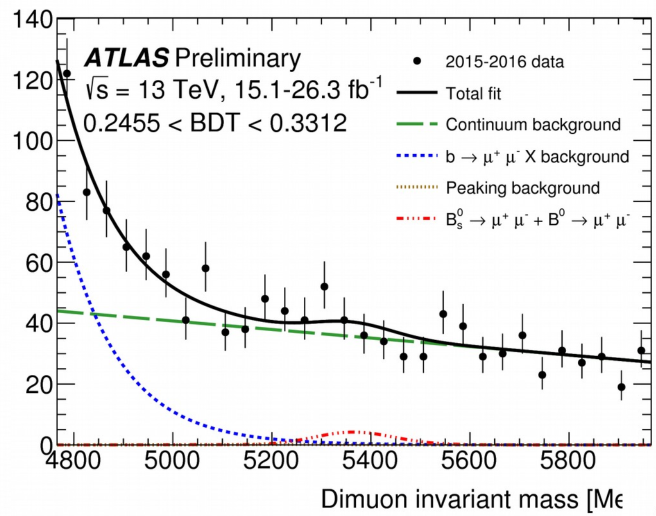
- signals, B to hh: 3 double Gaussians
- continuum: first order polynomial
- partially reconstructed B: exponential
- semi-leptonic: exponential

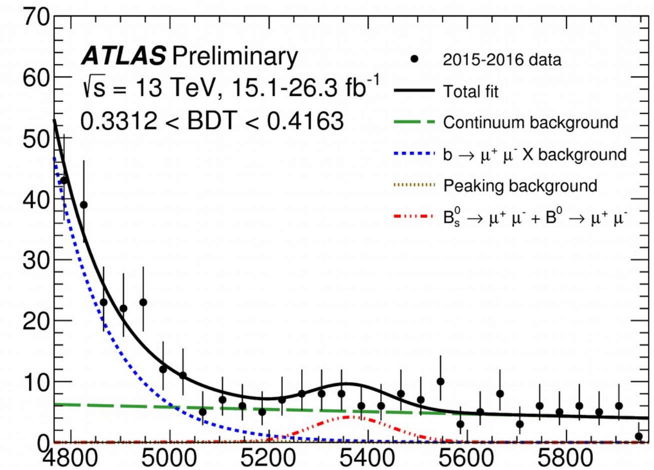
Signal yield extraction

- yields unconstrained:
  - $N_S = 80 \pm 22$ and $N_d = -12 \pm 20$
- expected from the SM:
  - $N_S = 91 \pm$ and $N_d = 10$





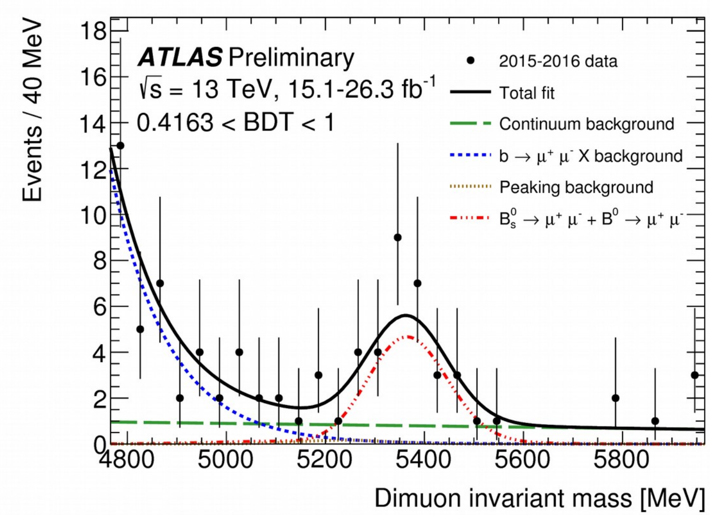




- consistent with Standard Model predictions
- likelihood maximum:

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(3.21^{+0.90+0.48}_{-0.83-0.31}\right) \times 10^{-9}$$

$$\mathcal{B}(B^0 \to \mu^+\mu^-) = \left(-1.3^{+2.2+0.7}_{-1.9-0.8}\right) \times 10^{-10}$$

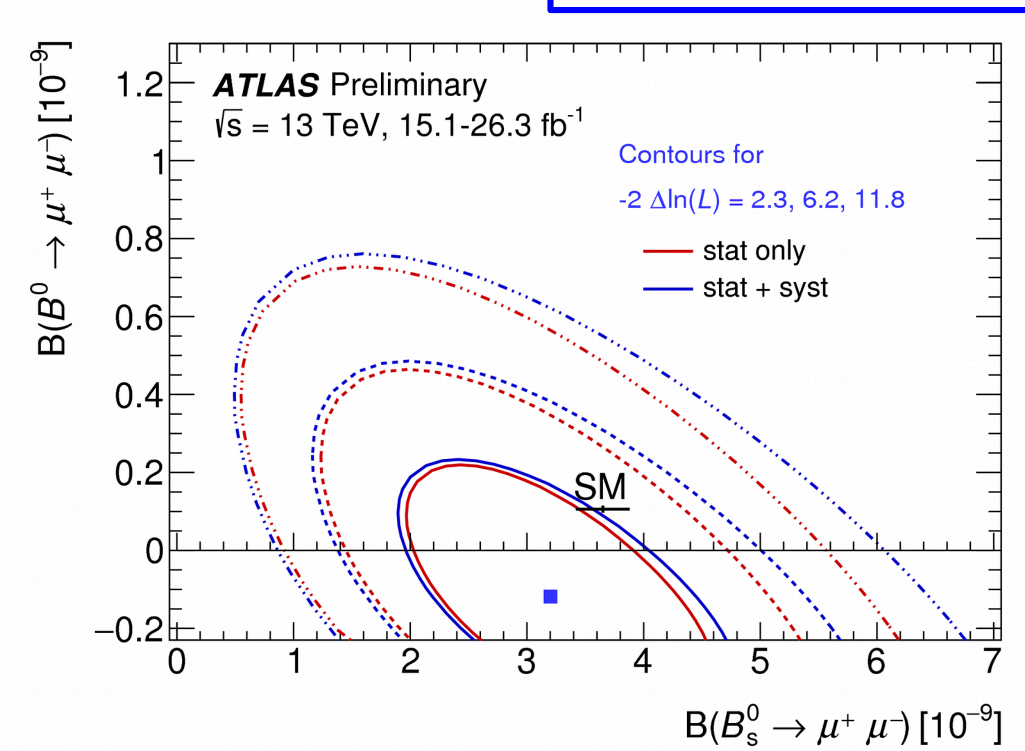


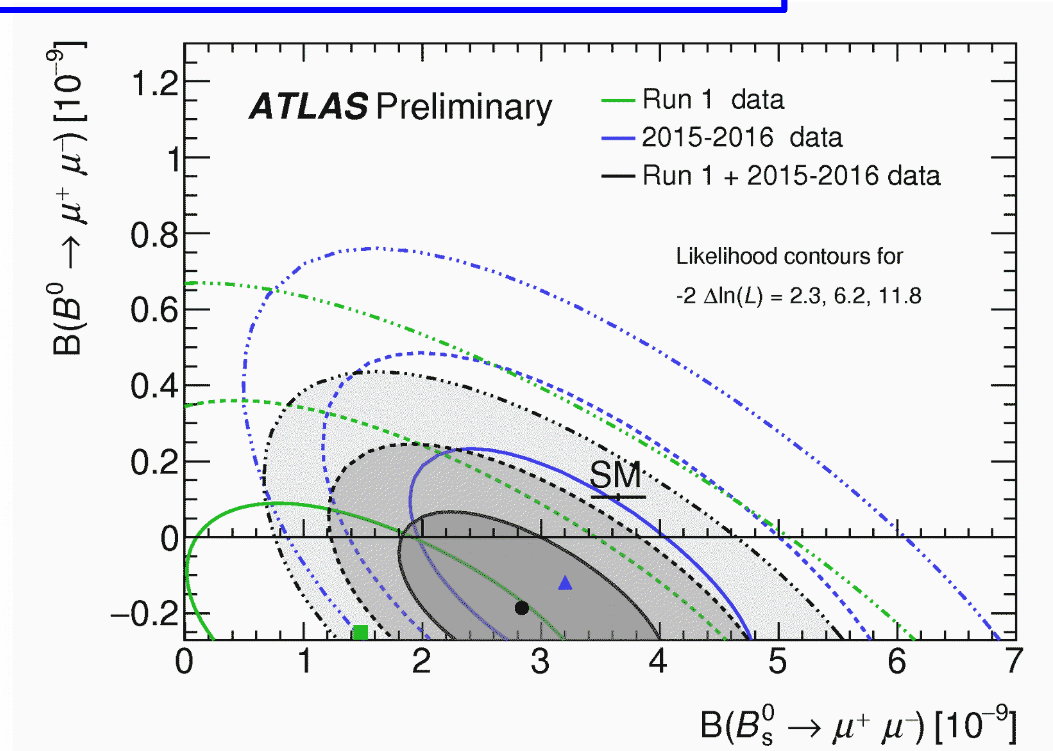
Combination of Run 1 and Run 2 results at ATLAS

Neyman Contours yield for Run 2:

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(3.21^{+0.96+0.49}_{-0.91-0.30}\right) \times 10^{-9} = \left(3.2^{+1.1}_{-1.0}\right) \times 10^{-9}$$

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 4.3 \times 10^{-10}$$ @ 95% CL





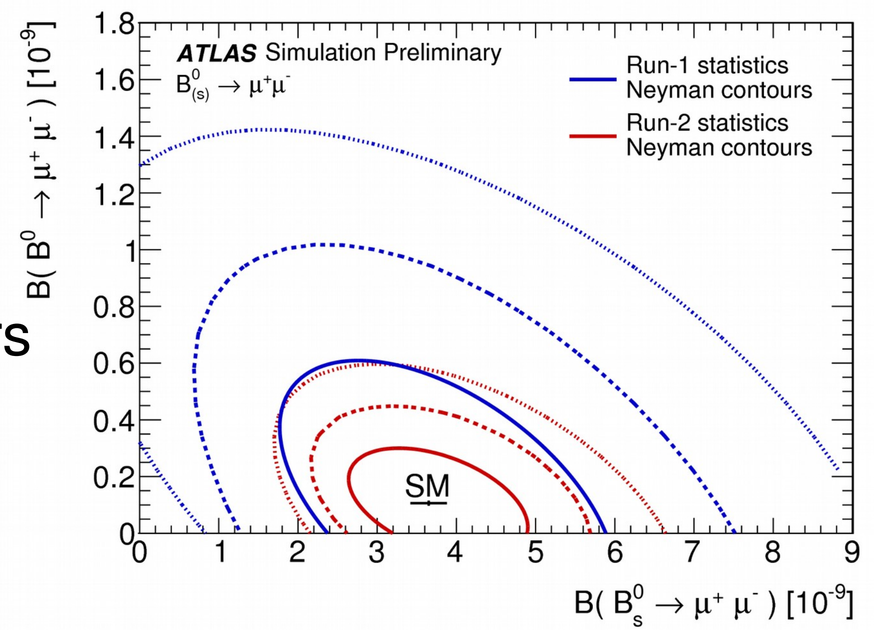
Run 1 + Run 2 (2015+2016) combination:
Compatible with SM at 2.4σ

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(2.8^{+0.8}_{-0.7}\right) \times 10^{-9}$$

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 2.1 \times 10^{-10}$$

Prospect on rare B decays $B_{(s)} \rightarrow \mu^+\mu^-$ at ATLAS

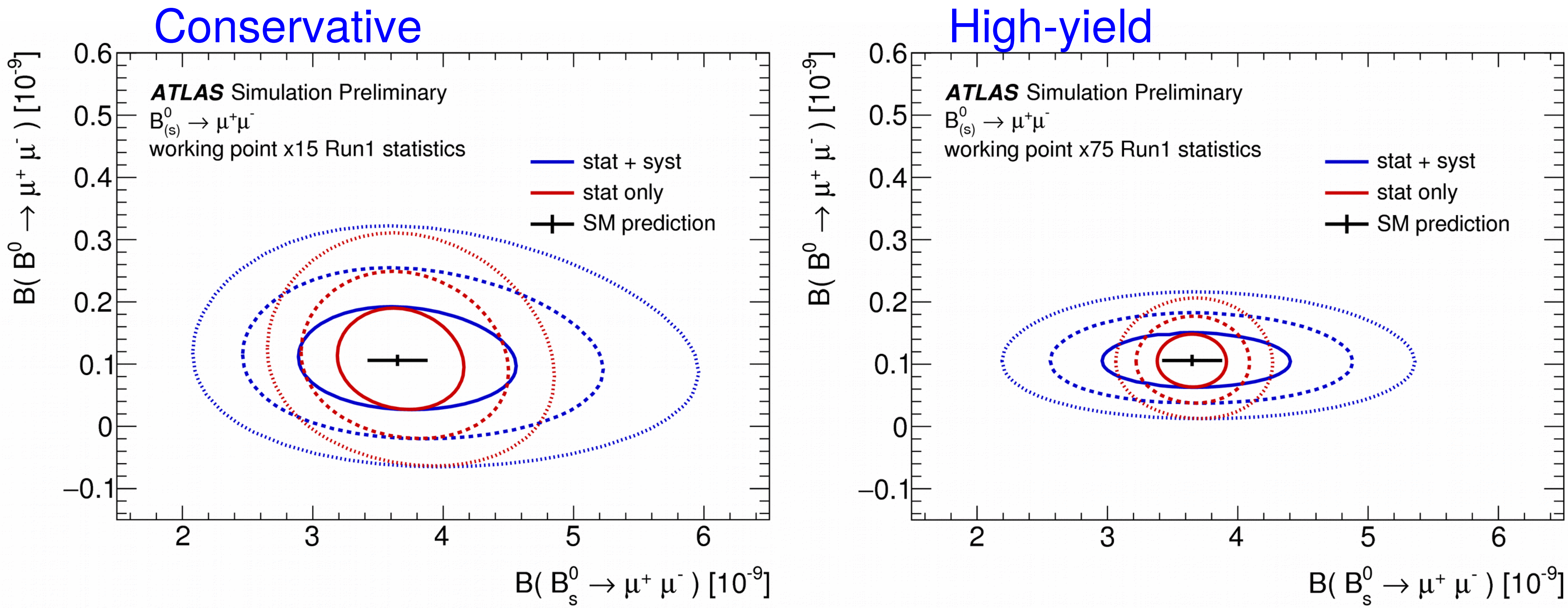
ATL-PHYS-PUB-2018-005



- Full Run 2:
  - assuming 130/fb
  - σ(bb): 8 TeV → 13/14 TeV → x1.7
  - 2MU6||MU6_MU4 topological triggers (6 GeV p_T thresholds)
  - Estimate N(Run 2) ~7 x N(Run 1)

- HL-LHC → 3 trigger scenarios: dimuon transverse momentum thresholds ($p^{\mu 1}_T$, $p^{\mu 2}_T$):
  - Conservative: (10 GeV, 10 GeV) → ×15 Run 1 statistics;
  - Intermediate: (6 GeV, 10 GeV) → ×60 Run 1 statistics;
  - High-yield: (6 GeV, 6 GeV) → ×75 Run 1 statistics.

Prospect on rare B decays $B_{(s)} \rightarrow \mu^+\mu^-$ at ATLAS

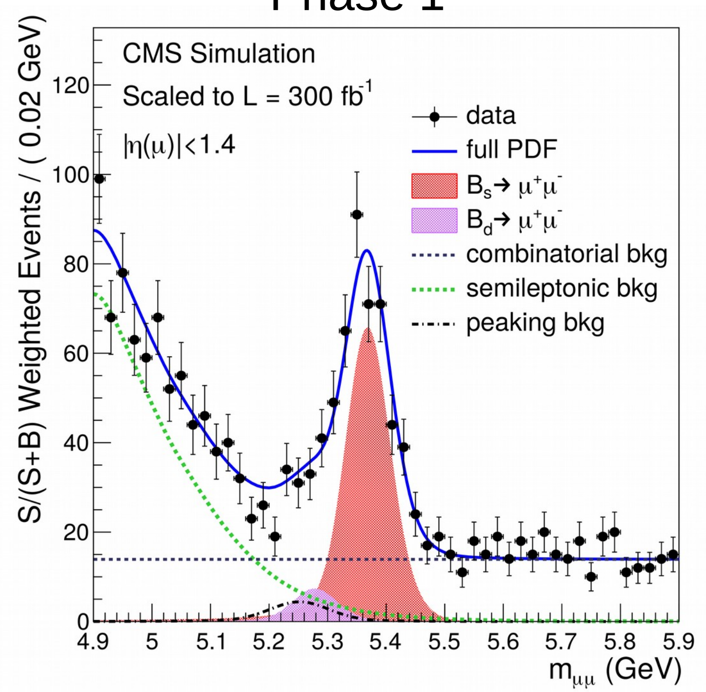


	$\mathcal{B}(B^0_s \to \mu^+\mu^-)$		$\mathcal{B}(B^0 \to \mu^+\mu^-)$	
	stat $[10^{-10}]$	stat + syst $[10^{-10}]$	stat $[10^{-10}]$	stat + syst $[10^{-10}]$
Run 2	7.0	8.3	1.42	1.43
HL-LHC: Conservative	3.2	5.5	0.53	0.54
HL-LHC: Intermediate	1.9	4.7	0.30	0.31
HL-LHC: High-yield	1.8	4.6	0.27	0.28

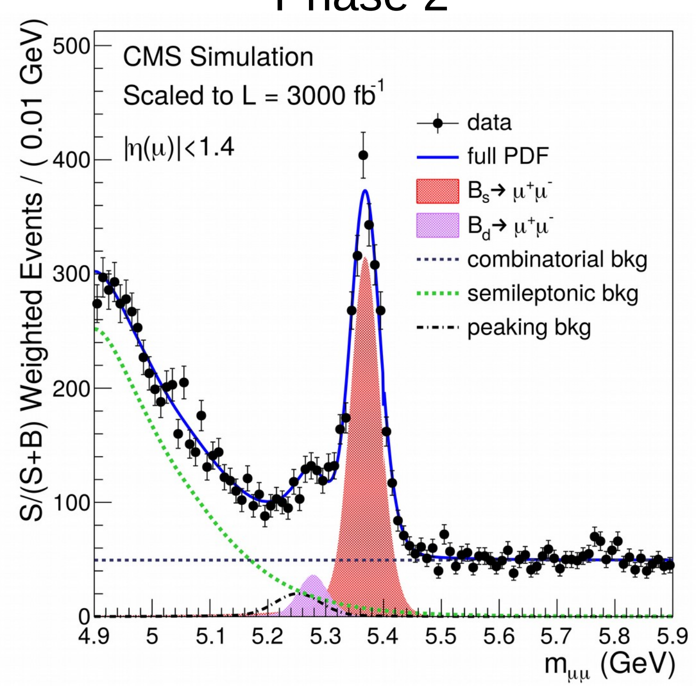
Prospect on rare B decays $B_{(s)} \rightarrow \mu^+\mu^-$ at CMS

FTR-14-015

Phase 1



Phase 2



Phase 2 with improved tracker:

- Improvement in the momentum resolution leads to about 40% gain in mass resolution for |η| < 1.0.
- about 25 % improvement in mass peak separation

Estimate of analysis sensitivity

$\mathcal{L}$ (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%

Angular analysis on $B \to K^{*}\mu\mu$

ATLAS

JHEP 10 (2018) 047, arXiv:1805.04000

CMS

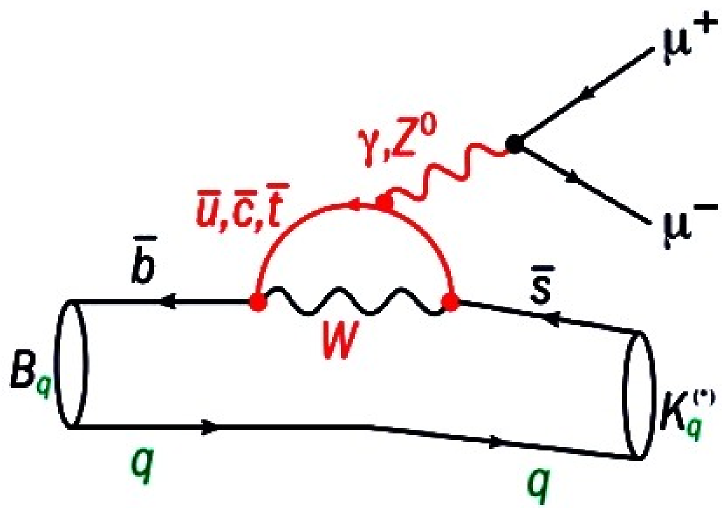
2011 data: Phys. Lett. B 727 (2013) 77

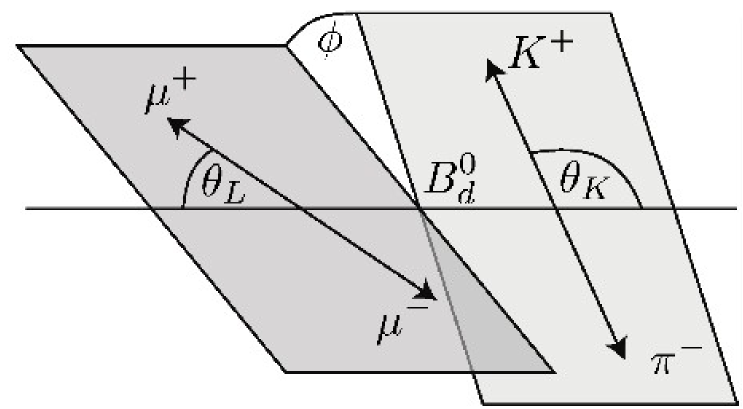
2012 data: Phys. Lett. B 753 (2016) 424

PLB 781 (2018) 517, arXiv:1710.02846

Angular analysis on $B \rightarrow K^*\mu\mu$

- another way to look at FCNC: $b \rightarrow s$ transition with a BR ~ 1.1 10^{-6}
- angular distribution of the 4 particles in the final state sensitive to new physics for the interference of NP and SM diagrams
  - allows measuring a large set of angular parameters sensitive to Wilson coefficients $C^{(\prime)}_7$, $C^{(\prime)}_9$, $C^{(\prime)}_{10}$, $C^{(\prime)}_{S,P}$





- decay described by three angles (θ_L, θ_K, ϕ) and the di-muon mass squared $q^2 \rightarrow$ the angular distribution is analysed in finite bins of q^2 as a function of θ_L, θ_K and ϕ.
- LHCb reports a 3.4σ deviation from the SM.

JHEP 02 (2016) 104
arXiv:1512.04442

Angular analysis on $B \to K^*\mu\mu$

- B^0 flavour eigenstate can be identified through the $K^* \to K^- \pi^+$ decay
- angular distribution given by:

$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{d\cos\theta_\ell d\cos\theta_K d\phi dq^2} = \frac{9}{32\pi}\Big[\frac{3(1-F_L)}{4}\sin^2\theta_K + F_L\cos^2\theta_K + \frac{1-F_L}{4}\sin^2\theta_K\cos 2\theta_\ell$$
$$-F_L\cos^2\theta_K\cos 2\theta_\ell + S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi$$
$$+S_5\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell$$
$$+S_7\sin 2\theta_K\sin\theta_\ell\sin\phi + S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi$$
$$+S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big].$$

- the S parameters are translated into the $P^{(')}$ parameters via

$$P_1 = \frac{2S_3}{1-F_L} \qquad P'_{i=4,5,6,8} = \frac{S_{j=4,5,7,8}}{\sqrt{F_L(1-F_L)}}$$

- the $P^{(')}$ parameters are expected to have a reduced dependence on the hadronic form factors.
- ATLAS and CMS need to fold the angular distribution via trigonometric relations to reduce the number of free parameters

Analysis strategy for $B \rightarrow K^*\mu\mu$ at CMS

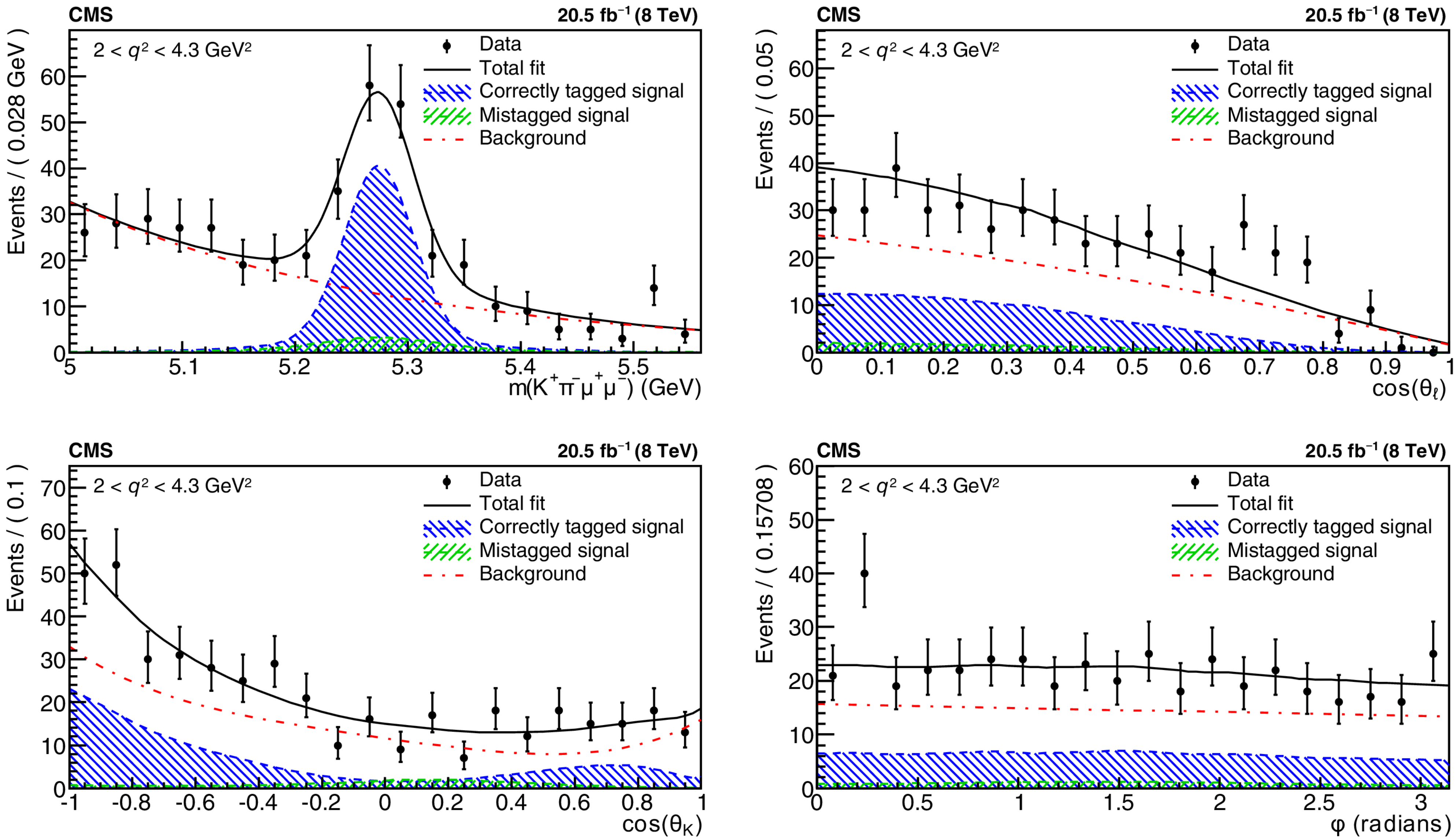
- Phys. Lett. B 727 (2013) 77 and Phys. Lett. B 753 (2016) 424
  - A_{FB} and F_L parameters and differential branching fraction measured
  - no deviations from SM prediction
- PLB 781 (2018) 517
  - fold around $\phi = 0$ and $\theta_\ell = \pi/2 \rightarrow$ 6 parameters $\rightarrow$ still too many
  - F_L, F_S , and A_S fixed from previous CMS measurement
  - P_1 and P'_5 measured, A^5_S nuisance parameter
  - q^2 range divided in 9 bins:
    - 7 signal bins, in each the angular analysis performed independently
    - 2 control-region bins, for resonant decays $B^0 \rightarrow J/\psi K^*$ / $B^0 \rightarrow \psi' K^*$
  - flavour assignment: mis-tagged event fraction 14%, measured on MC
  - two-step fit performed for 7 (+2 control regions) q^2 bins:
    - fit mass sidebands to determine the background shape
    - fit whole mass spectrum to extract 5 parameters: 2 yields, P_1, P'_5, A^5_S

Analysis strategy for $B \to K^*\mu\mu$ at ATLAS

- Data collected in 2012 at 8 TeV with 20.3 fb^{-1} Run 1 data
- Measured in 6 (overlapping) bins of q^2 in the range [0.04, 6] GeV^2
- 4 sets of fits for three parameters (F_L , S_3 and S_j with j=4,5,7,8)
- Selection of triggers with muon p_T thresholds starting at 4 GeV
- K* tagged by the kaon sign:
  - dilution from mistag probability included in $(1-2\langle w\rangle)$:
    - $\langle w\rangle \sim 10.9(1)\%$ with small dependence on q^2
- 787 events selected with $q^2 < 6$ GeV^2
- Extended unbinned maximum likelihood fits in each of the fit variants in each q^2 bin:
  - two step fit procedure: first fit the invariant mass distribution
  - then add to the fit the angular distributions to extract the F_L and S(P) parameters
- Signal shape studies from control samples K^*J/ψ and $K^*\psi(2S)$

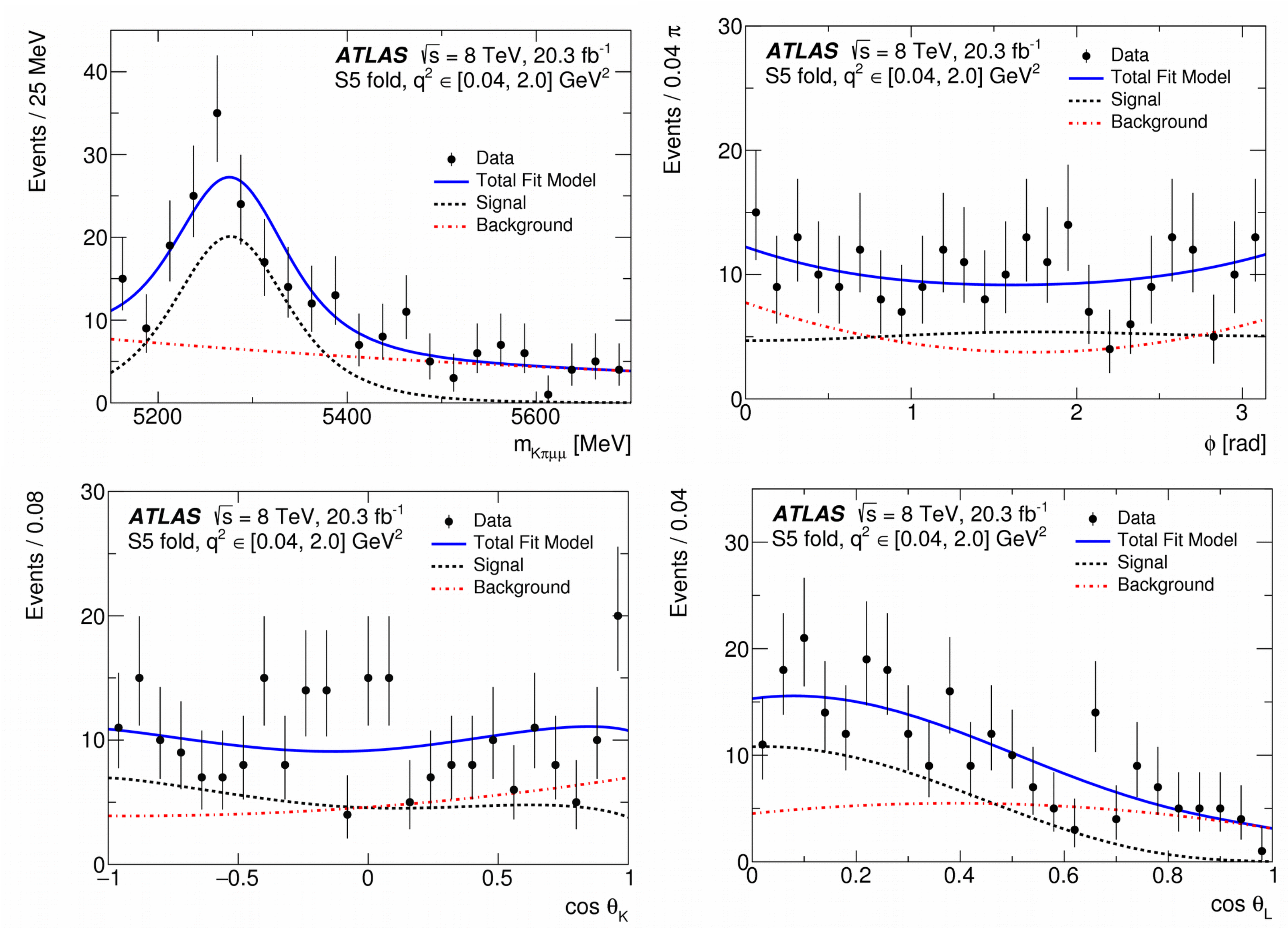
Fit projections for CMS

- fit projection for second bin: $2.0 < q^2 < 4.3\ \mathrm{GeV}^2$.



Fit projections for ATLAS

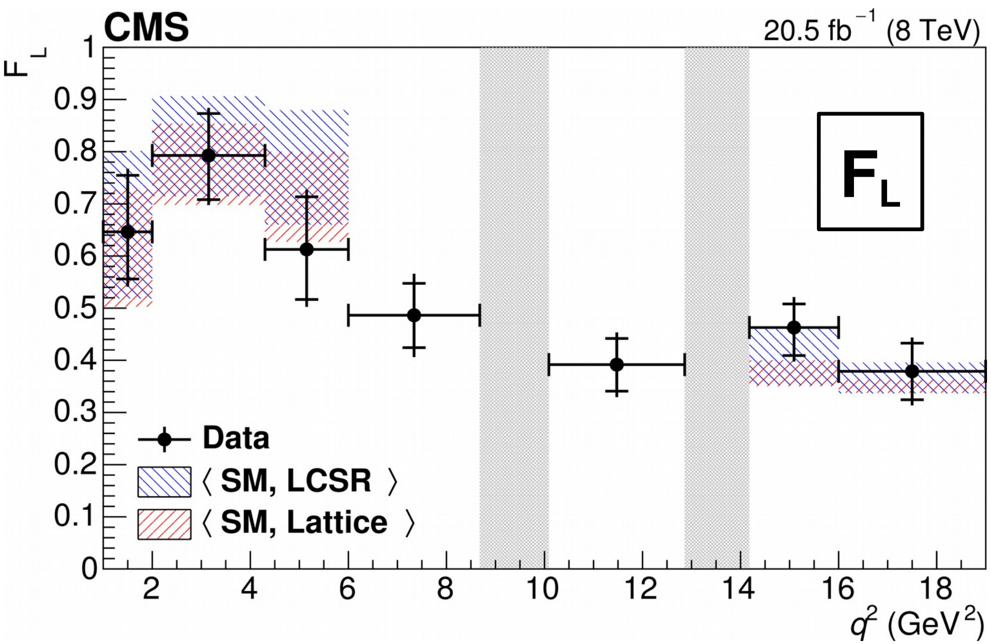
- fit m(K*μμ), cosθ_L , cosθ_K and ϕ to isolate signal and extract parameters of interest.

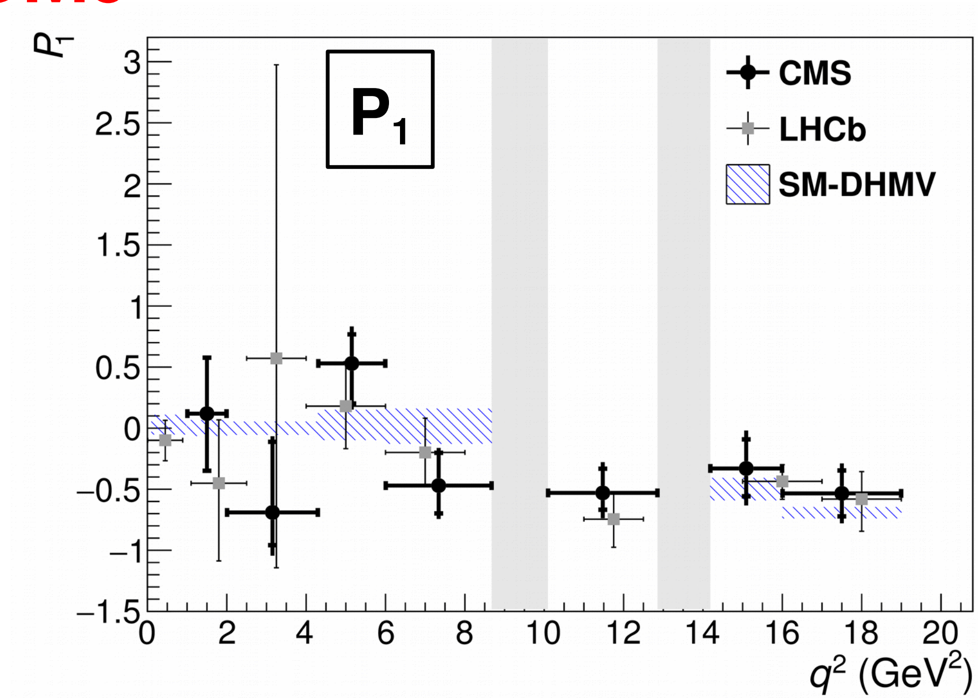


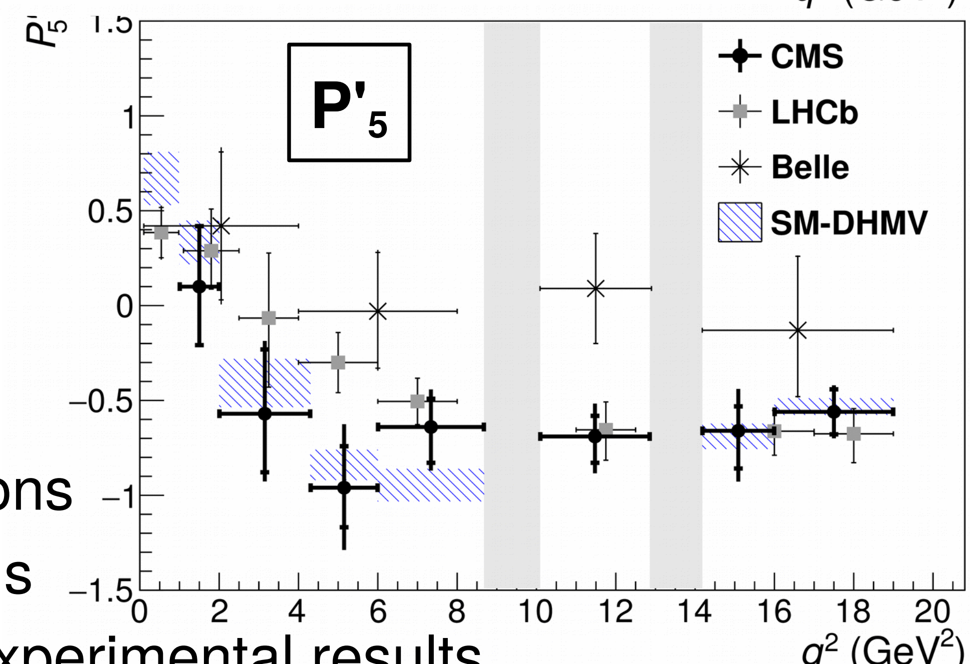
- Data shown for [0.04,2.0] GeV^2
- projections for the S_5 fit.
- Approx 106-128 signal events in 2 GeV^2 q^2 bin.
- Similar results for the other q^2 bins and other fit variants.

Angular analysis results at CMS

- No deviations from SM prediction



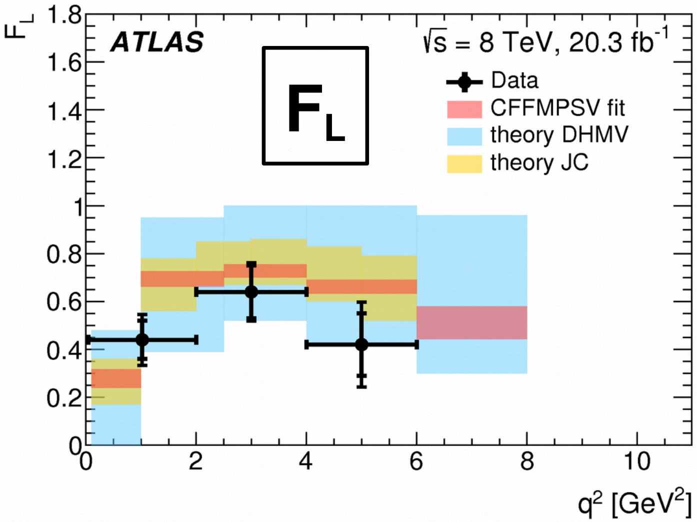


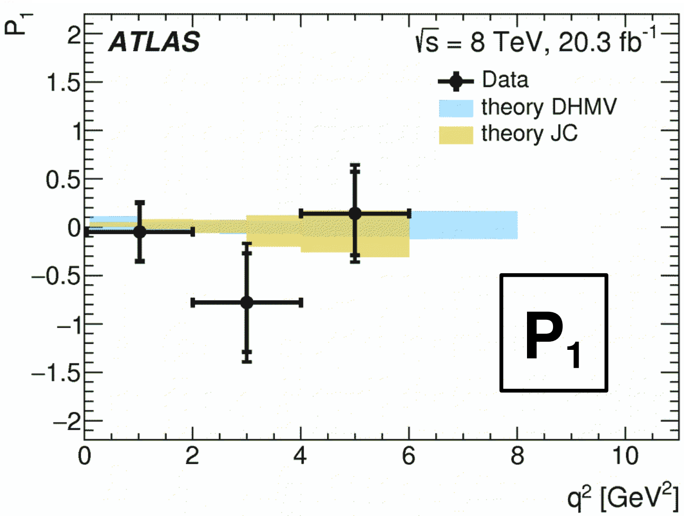


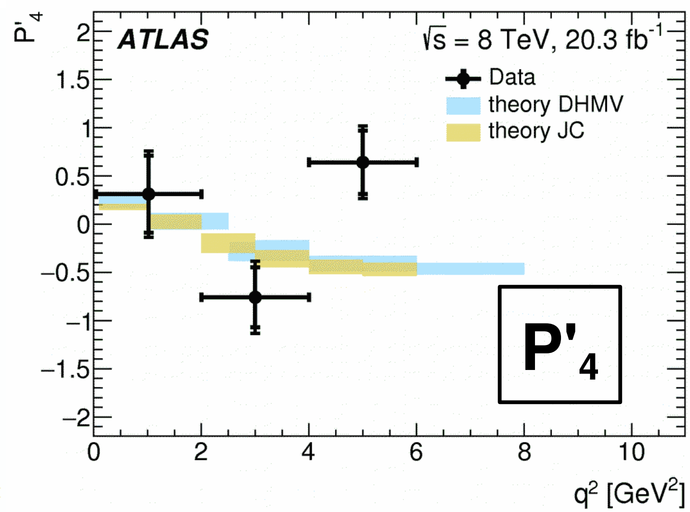
- SM-DHMV prediction computed
  - using soft form factors
    + parametrised power corrections
  - hadronic charm-loop from calculations
- results compatible with SM predictions
- no significant deviations from other experimental results

Angular analysis results at ATLAS

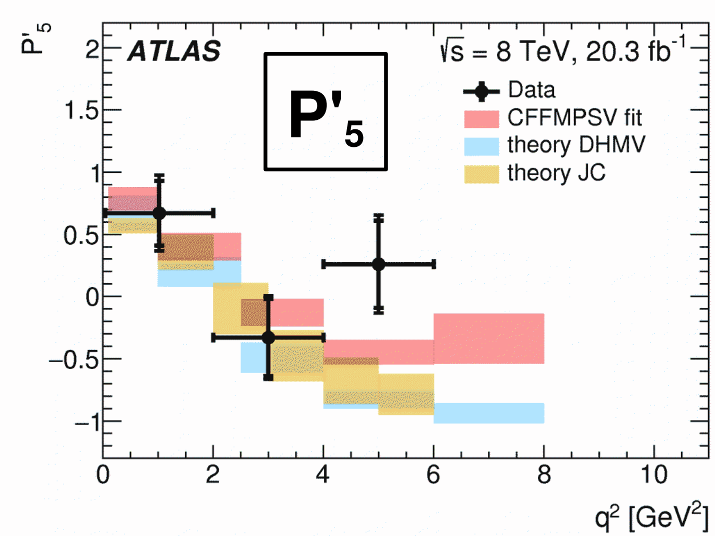
- Results are compatible with theoretical calculations & fits:







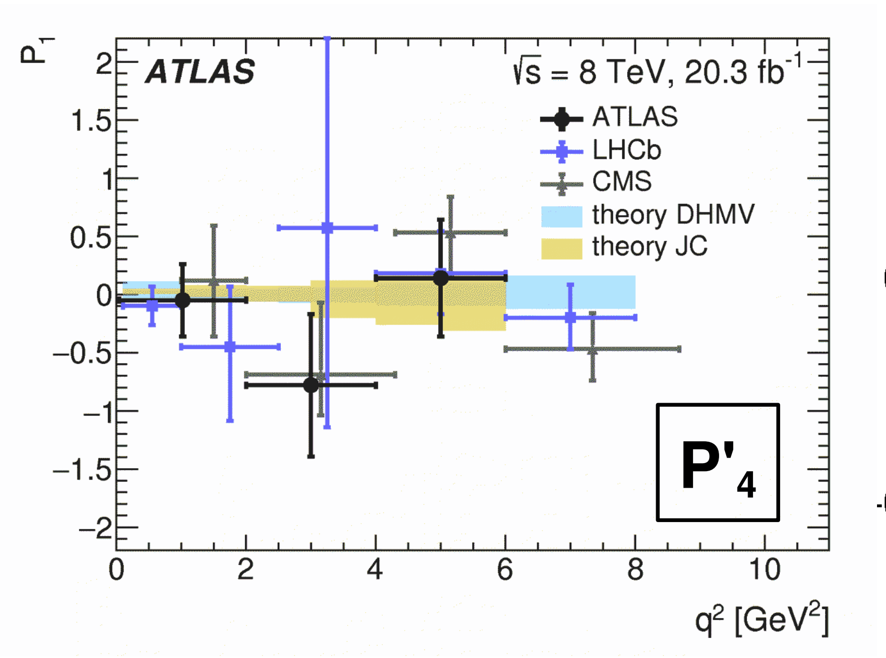
q^2 [GeV^2]	P_1	P'_4	P'_5
[0.04, 2.0]	$-0.05 \pm 0.30 \pm 0.08$	$0.31 \pm 0.40 \pm 0.20$	$0.67 \pm 0.26 \pm 0.16$
[2.0, 4.0]	$-0.78 \pm 0.51 \pm 0.34$	$-0.76 \pm 0.31 \pm 0.21$	$-0.33 \pm 0.31 \pm 0.13$
[4.0, 6.0]	$0.14 \pm 0.43 \pm 0.26$	$0.64 \pm 0.33 \pm 0.18$	$0.26 \pm 0.35 \pm 0.18$
[0.04, 4.0]	$-0.22 \pm 0.26 \pm 0.16$	$-0.30 \pm 0.24 \pm 0.17$	$0.32 \pm 0.21 \pm 0.11$
[1.1, 6.0]	$-0.17 \pm 0.31 \pm 0.13$	$0.05 \pm 0.22 \pm 0.14$	$0.01 \pm 0.21 \pm 0.08$
[0.04, 6.0]	$-0.15 \pm 0.23 \pm 0.10$	$0.05 \pm 0.20 \pm 0.14$	$0.27 \pm 0.19 \pm 0.06$

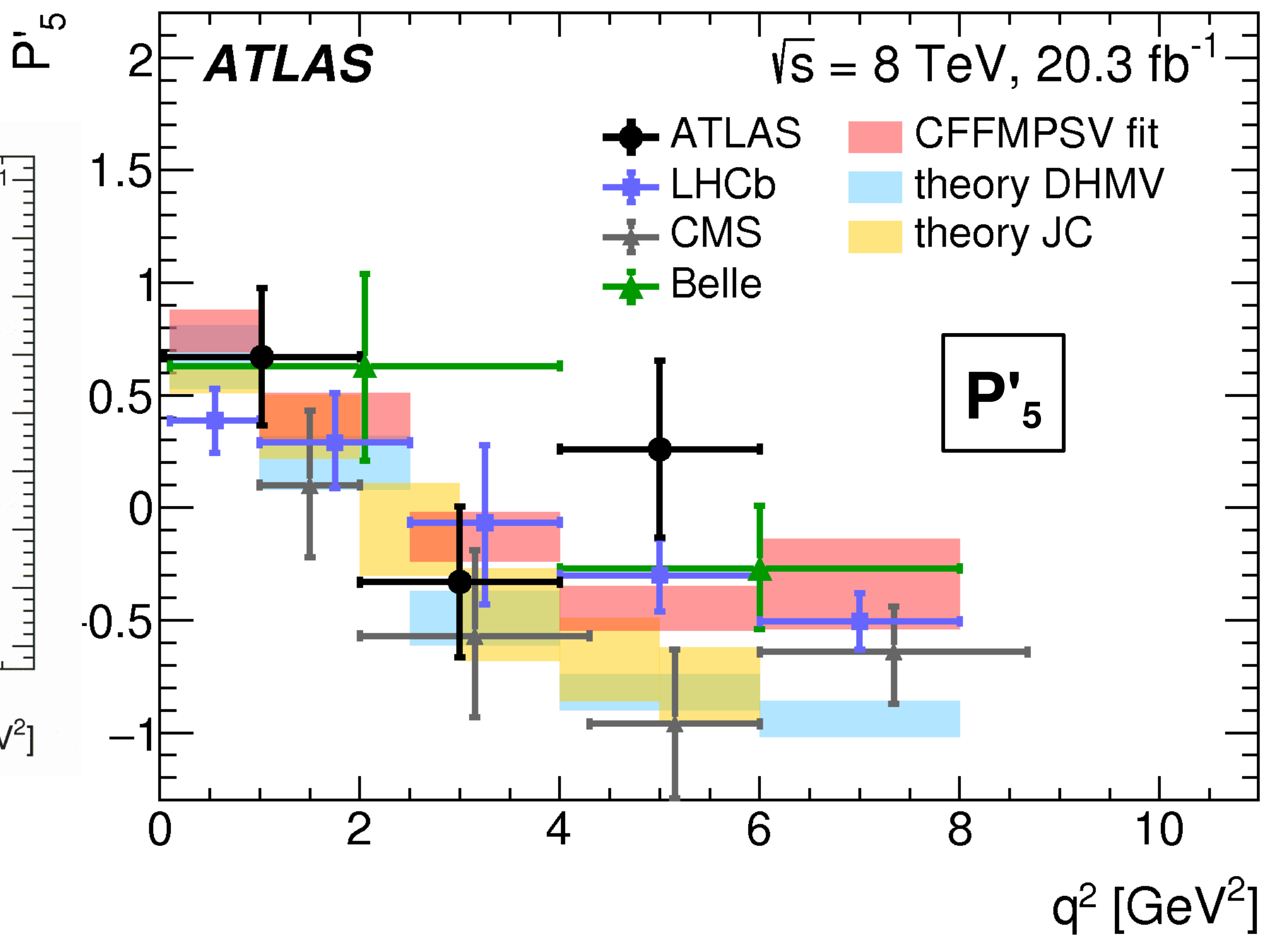


OPE and LHCb data fit: CFFMPSV: Ciuchini et al.; JHEP 06 (2016) 116.
QCD factorisation: DMVH: Decotes-Genon et al.; JHEP 12 (2014) 125.
JC: Jäger-Camalich; Phys. Rev. D93 (2016) 014028.

Angular analysis results at ATLAS and CMS

- ATLAS gets deviations of about 2.5σ (2.7σ) from DHMV in P'_4(P'_5) in [4,6] GeV^2





CFFMPSV: Ciuchini et al.; JHEP 06 (2016) 116.
DHMV: Decotes-Genon et al.; JHEP 12 (2014) 125.
JC: Jäger-Camalich; Phys. Rev. D93 (2016) 014028.

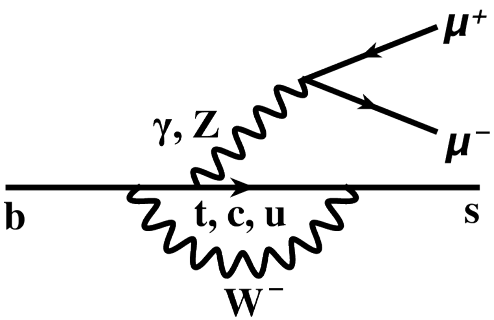
Angular analysis on $B \rightarrow K^{+}\mu\mu$

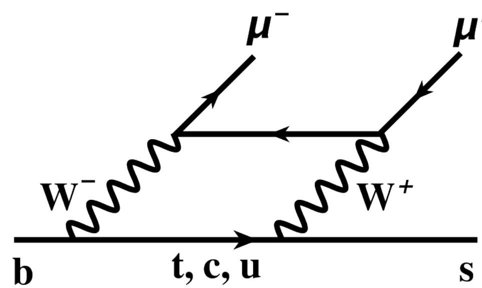
CMS

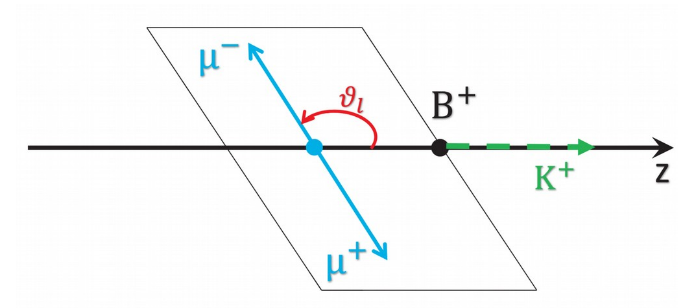
Accepted in Phys. Rev. D,
CMS-BPH-15-001, arXiv:1806.00636

Angular analysis on B → K⁺μμ at CMS

- another FCNC: b → s transition with a BR ~ 4.5 10^{-7}



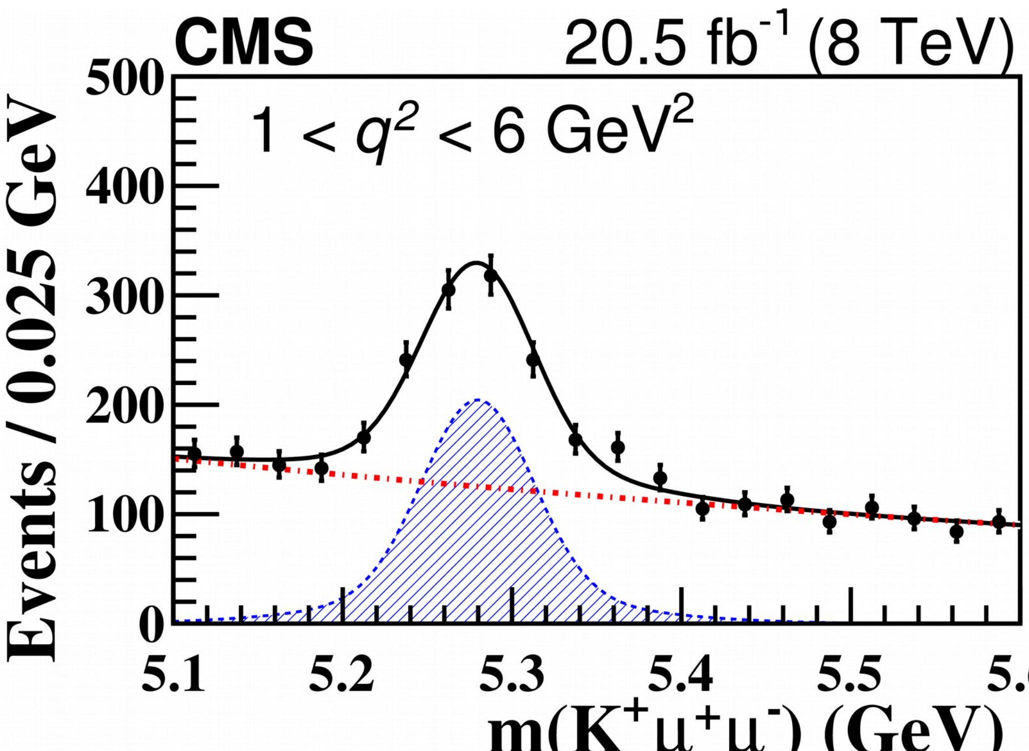


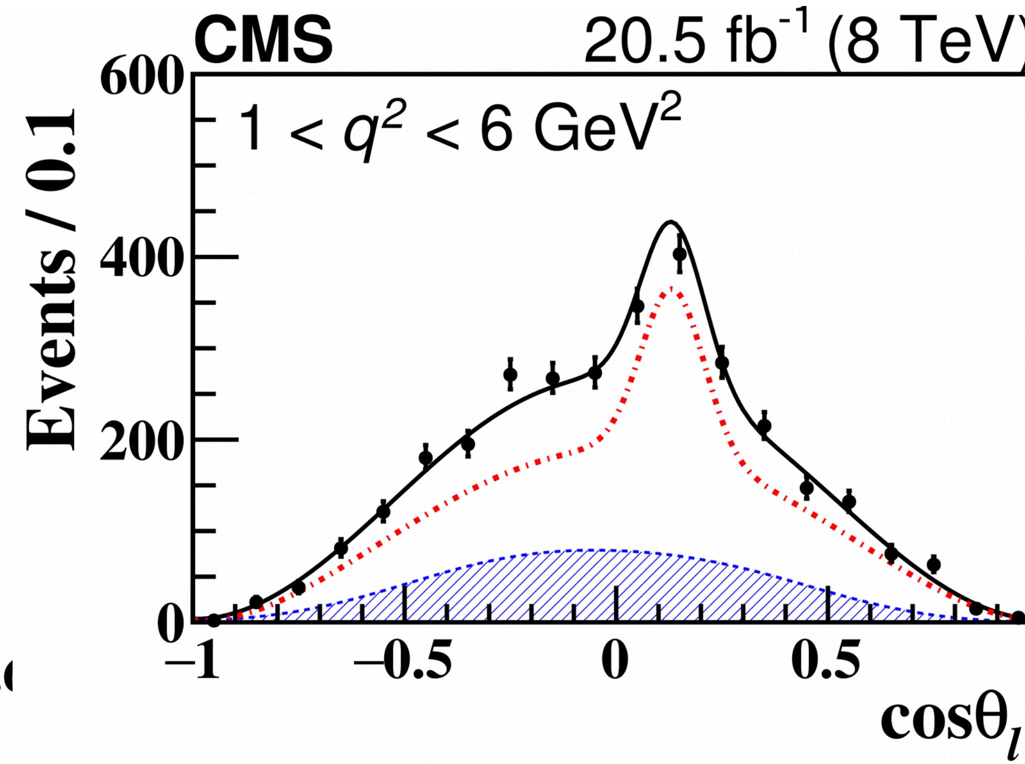


- Fully described by the angle θ_ℓ and $q^2 = M_{\mu\mu}$
- Angular decay rate: $\frac{1}{d\Gamma/dq^2}\frac{d^2\Gamma}{dq^2 d\cos\theta_l} = \frac{3}{4}(1-F_H)\left(1-\cos^2\theta_\ell\right)+\frac{1}{2}F_H+\mathcal{A}_{FB}\cos\theta_\ell$
- The forward-backward asymmetry of the muons, A_{FB}, and the angular parameter F_H extracted via angular analysis
- Range [1, 22] GeV^2 of q^2 divided in 9 bins
  - analysis performed in 7 signal bins
  - 2 bins with $B^+ \to J/\psi K^+$ and $B^+ \to \psi' K^+$ are control channels
  - 2 additional special bins: [1-6] GeV^2 (clean predictions) and [1-22] GeV^2 (full signal)

Angular analysis on $B \to K^+\mu\mu$ at CMS

- Two-step unbinned extended maximum likelihood fit performed:
  - fit mass sidebands to determine the background shape
    - fixed in second step
  - fit whole mass spectrum with 4 floating parameters
    - 2 yields + 2 angular param

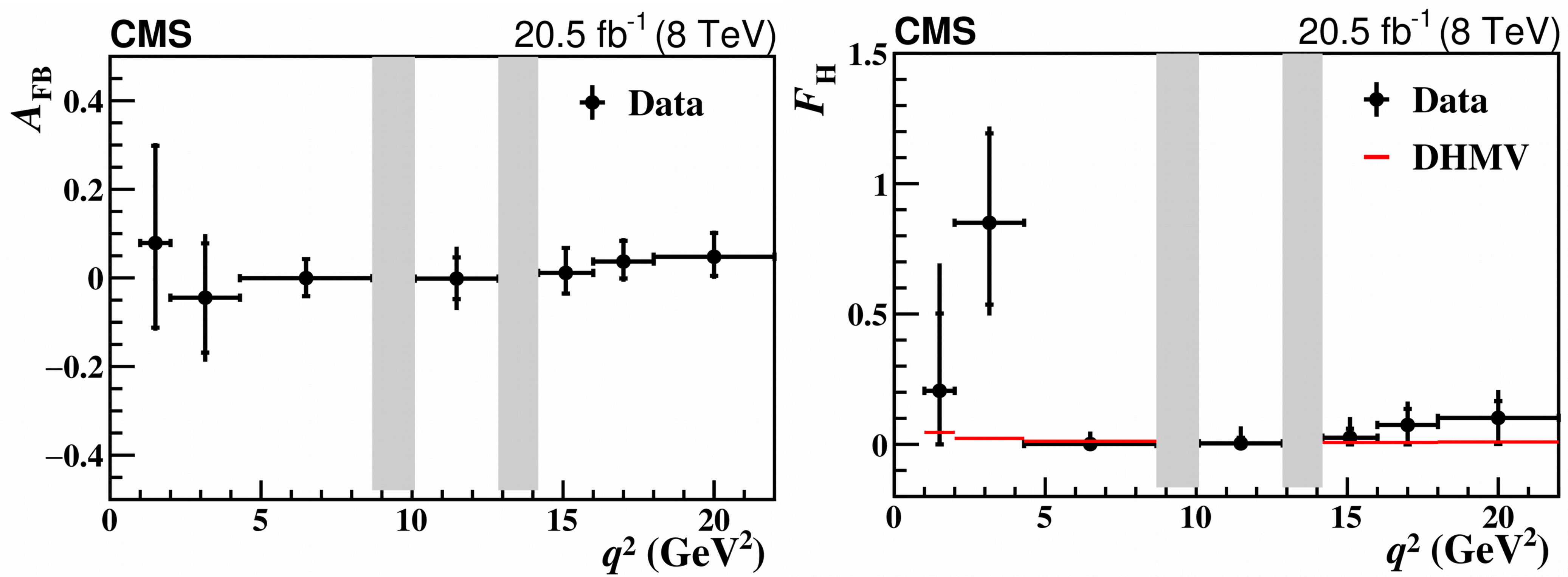




fit projections for special bin $1 < q^2 < 6\ GeV^2$

Angular analysis on $B \to K^{+}\mu\mu$ at CMS

- Inner error bar is statistical uncertainty
- Full bar is total uncertainty
- Results compatible with SM predictions within uncertainties



Searches and Observations

ATLAS

search for $X \rightarrow B_s \pi^{\pm}$:

Phys. Rev. Lett. 120 (2018) 202007, arXiv:1802.01840

CMS

Measurements of $B^{*}_{s2}(5840)^0$ and $B_{s1}(5830)^0$:

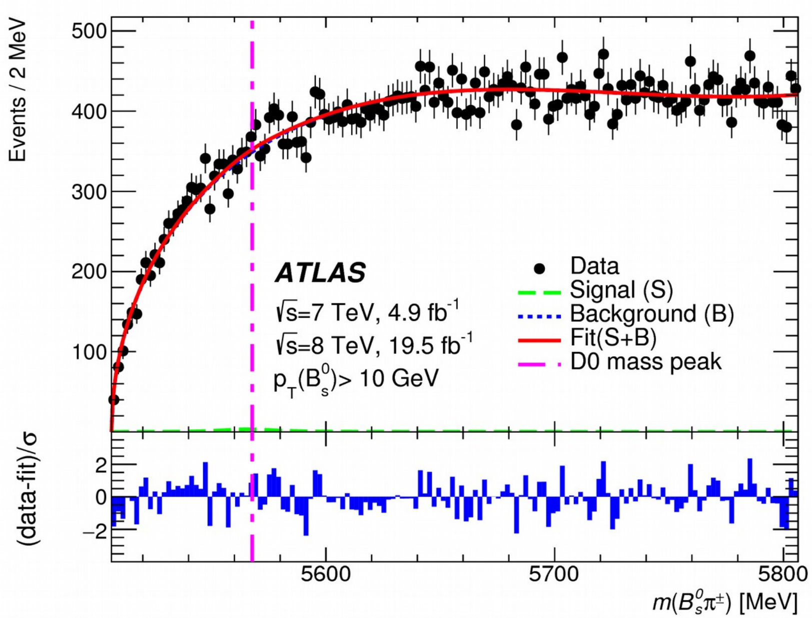
Eur. Phys. J. C 78 (2018) 939, arXiv:1809.03578

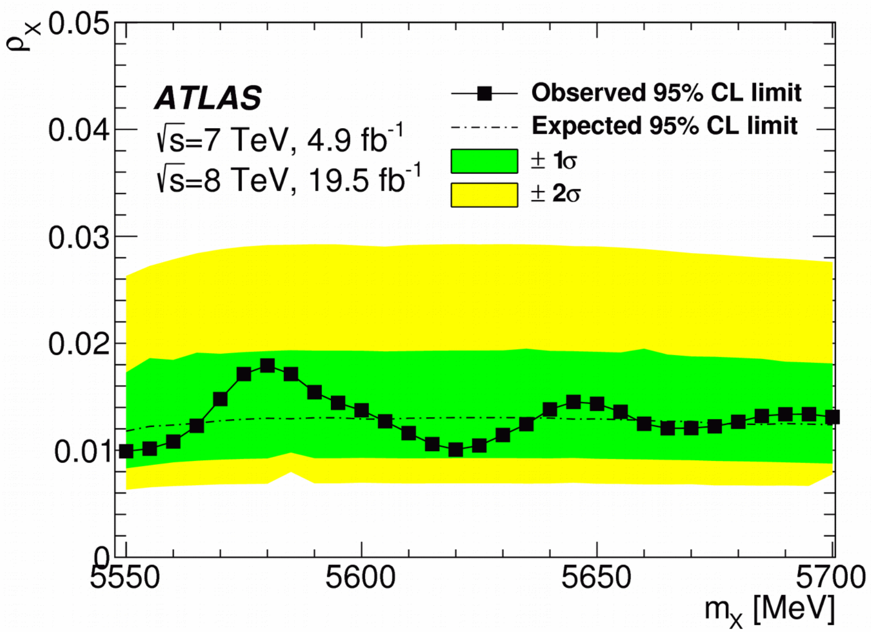
Observation of the $\chi_{b1}(3P)$ and $\chi_{b2}(3P)$:

Phys. Rev. Lett. 121 (2018) 092002, arXiv:1805.11192

Search for $X \rightarrow B_s\pi^{\pm}$ at ATLAS

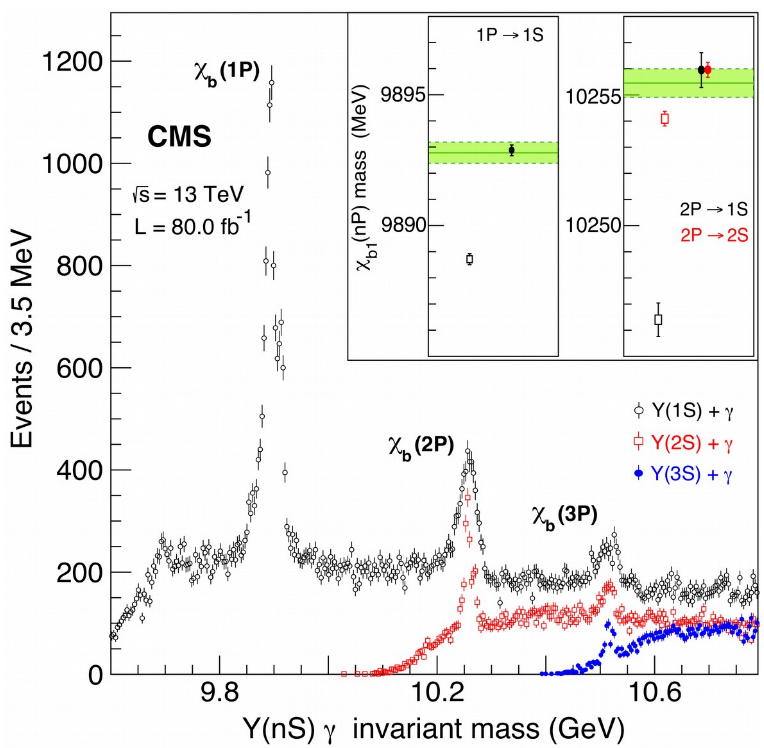
- Search for the narrow structure, X(5568), reported by the D0 Collaboration in the decay sequence $X \rightarrow B^0_s\pi^{\pm}$, $B^0_s \rightarrow J/\psi\phi$
- Full Run 1: 4.9/fb of pp collisions at 7 TeV and 19.5/fb at 8 TeV
- No significant signal was found
- Upper limits on the number of signal events and on the production rate relative to B^0_s mesons, ρ_X,
  - $N(X)<382$ and $\rho_X<0.016$ for B^0_s mesons with $p_T > 10$ GeV
  - $N(X)<356$ and $\rho_X<0.017$ for $p_T > 15$ GeV

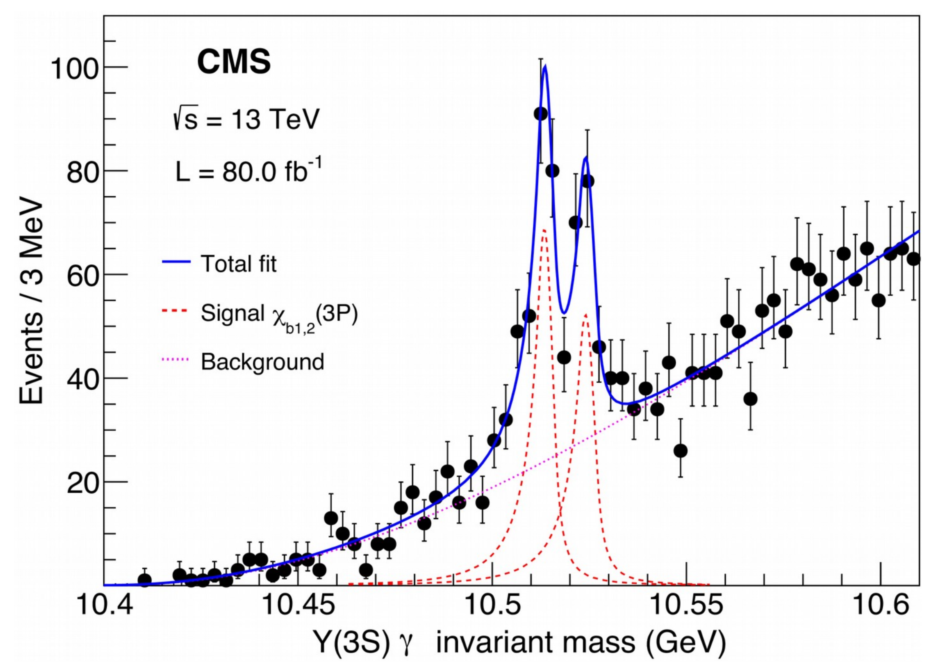




Observation of $\chi_{b1}(3P)$ and $\chi_{b2}(3P)$ at CMS

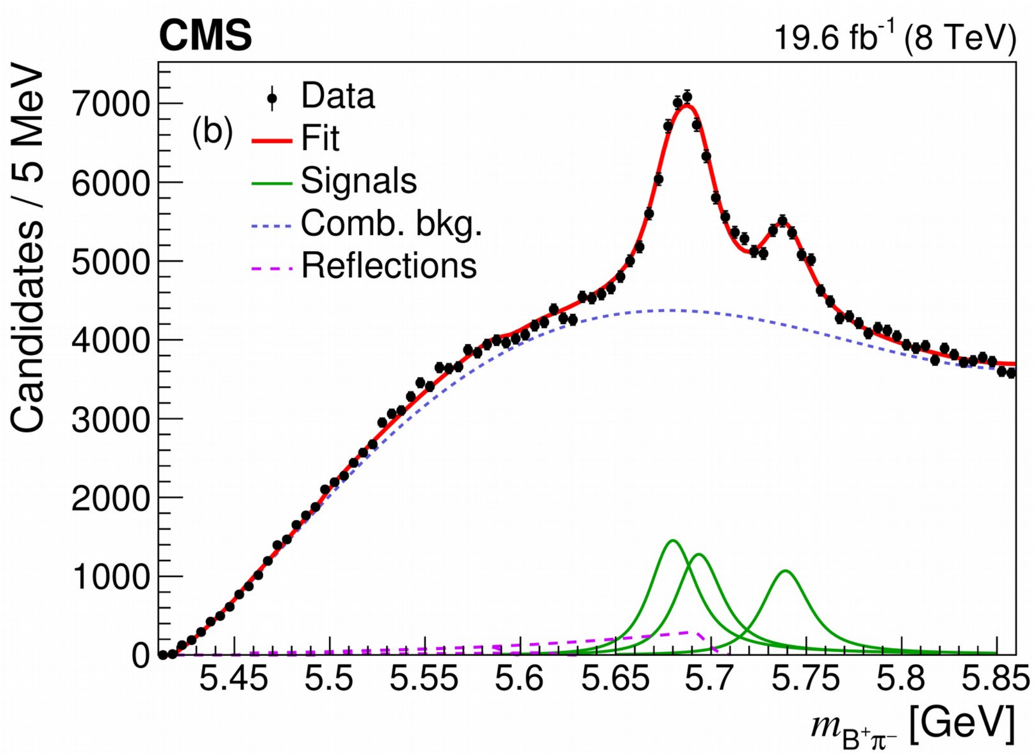
- $\chi_{b1}(3P)$ and $\chi_{b2}(3P)$ states observed through their Y(3S)γ decays
- Run 2 data: 80/fb at 13 TeV
- low-energy photons detected after converting to e^+e^- pairs in the tracker
- first time that the J=1 and 2 states are well resolved and their masses individually measured: 10 513.42 ± 0.41 (stat) ± 0.18 (syst) MeV and 10 524.02 ± 0.57 (stat) ± 0.18 (syst) MeV
- mass splitting is measured to be 10.60 ± 0.64 (stat) ± 0.17 (syst) MeV

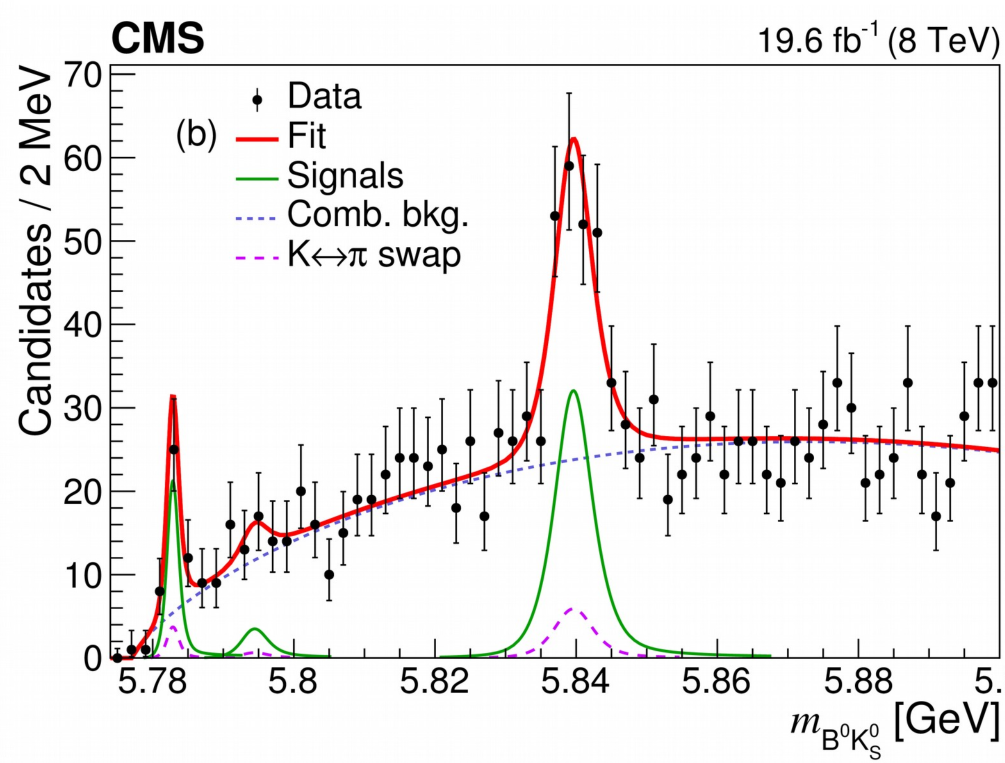




Measurements of $B^*_{s2}(5840)^0$ and $B_{s1}(5830)^0$ at CMS

- Measurements of $B^*_{s2}(5840)^0$ and $B_{s1}(5830)^0$ mesons on 19.6/fb at 8 TeV
- P-wave B^0_s meson decays into $B^{(*)+}K^-$ and $B^{(*)0}K^0_S$
- B^+ and B^0 mesons are identified via decays $B^+\to J/\psi K^+$ and $B^0\to J/\psi K^*(892)^0$
- masses of P-wave B^0_s meson states and $B^*_{s2}(5840)^0$ width measured
- first measurement of the mass difference between charged and neutral B^*
- $B^*_{s2}(5840)^0 \to B^0K^0_s$ observed and measured relative to $B^*_{s2}(5840)^0 \to B^+K^-$





Perspective of ATLAS & CMS

CERN-EP-2018-058
CMS-DP-2012/022
D.Zanzi @ICHEP 2018
J. Hirschauer @LPCC Open Session
M.Pierini @CERN Workshop on B anomalies

Future Prospect for ATLAS and CMS

- General purpose experiments can be competitive on favourable final states
- Dimuon is the quintessence of low-p_T experimental clean signature @LHC
- More statistics will allow to improve these results
- New trigger functionalities (e.g., tracking @L1) will allow to deal with 200 PU
- Detector limitation: experiments designed to do something else, namely cover 10-1000 GeV range
  - going below 10 GeV (e.g., with electrons and muons) requires effort
- Limited trigger bandwidth (general purpose vs. dedicated experiments)
- Needed customisation (reconstruction, trigger, etc.) vs working force (<50 people)
- Muons are the essential handle for flavour physics in ATLAS & CMS
- Electron reconstruction at ATLAS & CMS is about matching a track to >= 1
  - At low pT, the track might not even make it to the calorimeter and, in any case, deposits are very low energetic: difficult to disentangle them from noise, pileup, etc
- Clearly, growing interest in flavour (thanks to LHCb anomalies) is helping here.
- Still, there is much to do in view of HL-LHC

New ideas for data collection

Scouting

- Since 2010, CMS is taking special “scouting” streams:
  - Run reconstruction in trigger farm (muons, jets, ...)
  - Write object features (e.g., four momenta) rather than the full event
  - Few KB traded for 1 MB: can write thousands more
  - Same now by ATLAS (TLA), LHCb (TurboStream + upgrade) and ALICE

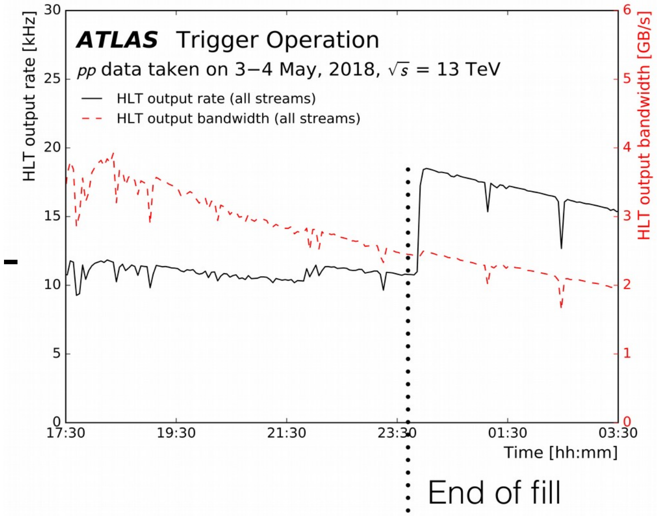
Parking

- Limitation to write 1000 evt/sec is not the trigger itself
- The problem is computing resources downstream → disk & CPU power
- In 2012, both ATLAS&CMS took more data, counting on shutdown computing pledges & opportunistic computing resources to process them
- Extra 300-350 Hz of “parked” data are collected to extend the physics program: standard model measurements and searches for new physics
- The triggers defining the parked datasets are either a looser version of the core physics triggers (for instance with reduced pT thresholds on the reconstructed objects) or brand-new triggers with small overlap with the rest

Data taking in 2018 for ATLAS and CMS

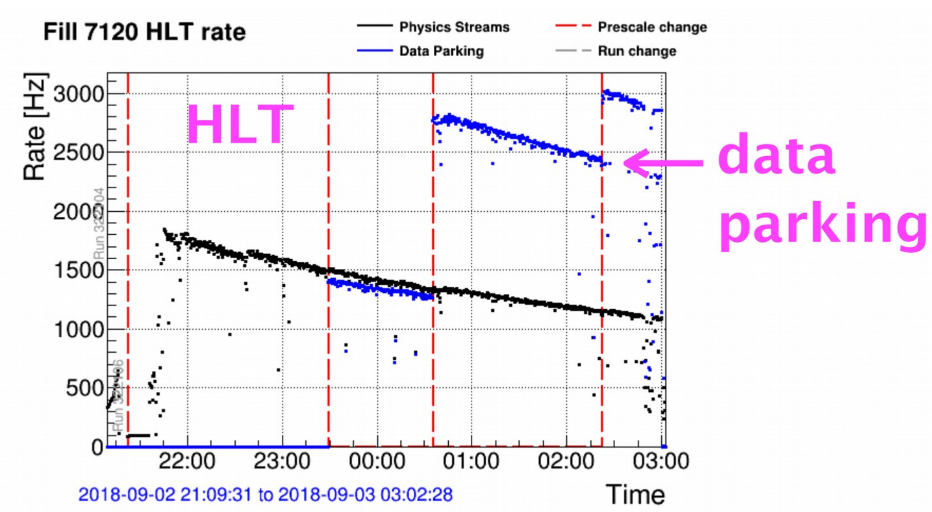
ATLAS data taking in 2018

- After few hours of collisions, L1 rate and HLT processing slots free up thanks to luminosity exponential decay
- High-rate and CPU-intensive triggers can be enabled within the data storage output limitation
- Strategy is used for the Trigger-level Analysis (ATL-DAQ-PUB-2017-003) → total HLT output is only marginally increased by these additional events
- End-of-fill strategy used for triggers for B-physics signals



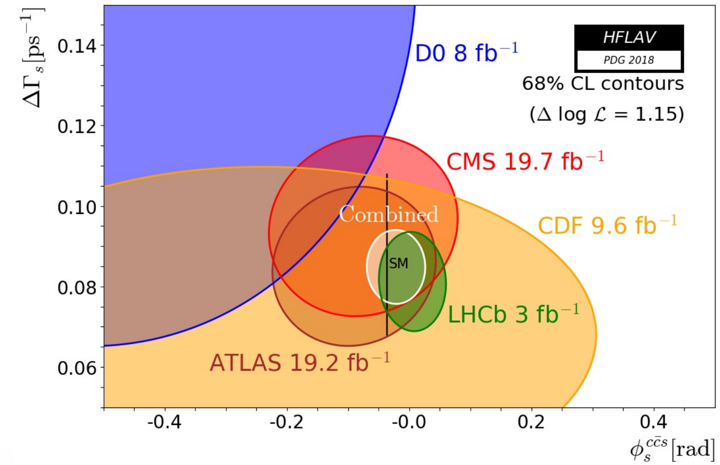
CMS data taking in 2018

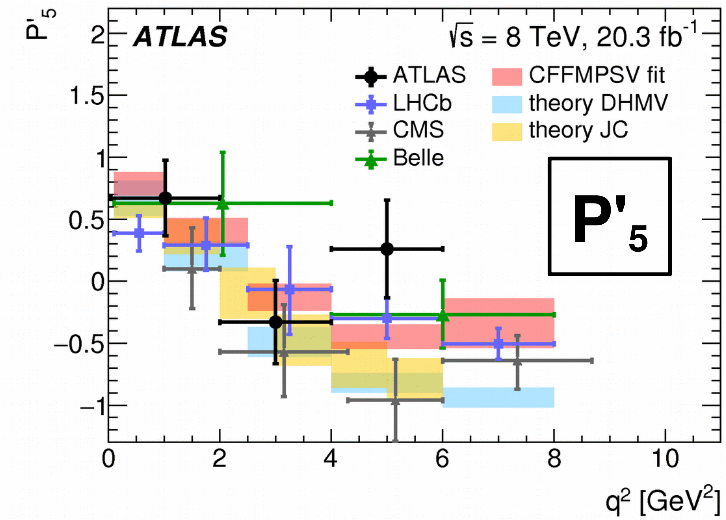
- Smooth running since May: only minor updates to the trigger implemented
- L1 trigger rate → 95 kHz at 2×10^{34} cm^{-2}s^{-1}
  - able to lower L1 thresholds for single Egamma, MET, di-tau to improve HLT turn-on curves
- HLT rate → 1.8 kHz at 2×10^{34} cm^{-2}s^{-1}
  - averages 1.1 kHz over 12h fill
- "parking" an unbiased sample of B mesons
  - so far recorded over 9B events

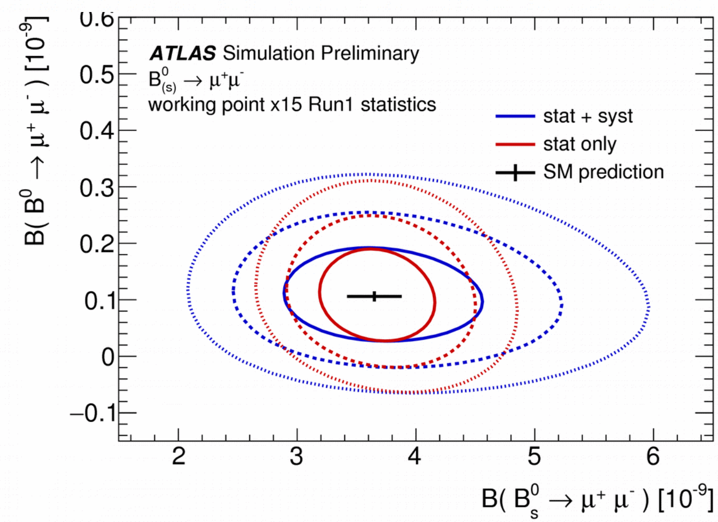


Conclusions

- B physics in ATLAS and CMS is more challenging but still much alive and with promising perspectives
- the B anomalies are boosting a wider interest in flavour
- various ways to counteract the low trigger efficiency
- still quite limited manpower in general







back-up slides

Results from the fits

q^2 [GeV^2]	n_{signal}	$n_{\text{background}}$
[0.04, 2.0]	128 ± 22	122 ± 22
[2.0, 4.0]	106 ± 23	113 ± 23
[4.0, 6.0]	114 ± 24	204 ± 26
[0.04, 4.0]	236 ± 31	233 ± 32
[1.1, 6.0]	275 ± 35	363 ± 36
[0.04, 6.0]	342 ± 39	445 ± 40

signal and background yields from the first fit step

- Results obtained are generally statistically limited:

q^2 [GeV^2]	F_L	S_3	S_4	S_5	S_7	S_8
[0.04, 2.0]	$0.44 \pm 0.08 \pm 0.07$	$-0.02 \pm 0.09 \pm 0.02$	$0.19 \pm 0.25 \pm 0.10$	$0.33 \pm 0.13 \pm 0.06$	$-0.09 \pm 0.10 \pm 0.02$	$-0.11 \pm 0.19 \pm 0.07$
[2.0, 4.0]	$0.64 \pm 0.11 \pm 0.05$	$-0.15 \pm 0.10 \pm 0.07$	$-0.47 \pm 0.19 \pm 0.10$	$-0.16 \pm 0.15 \pm 0.05$	$0.15 \pm 0.14 \pm 0.09$	$0.41 \pm 0.16 \pm 0.15$
[4.0, 6.0]	$0.42 \pm 0.13 \pm 0.12$	$0.00 \pm 0.12 \pm 0.07$	$0.40 \pm 0.21 \pm 0.09$	$0.13 \pm 0.18 \pm 0.07$	$0.03 \pm 0.13 \pm 0.07$	$-0.09 \pm 0.16 \pm 0.04$
[0.04, 4.0]	$0.52 \pm 0.07 \pm 0.06$	$-0.05 \pm 0.06 \pm 0.04$	$-0.19 \pm 0.16 \pm 0.09$	$0.16 \pm 0.10 \pm 0.04$	$0.01 \pm 0.08 \pm 0.05$	$0.15 \pm 0.13 \pm 0.10$
[1.1, 6.0]	$0.56 \pm 0.07 \pm 0.06$	$-0.04 \pm 0.07 \pm 0.03$	$0.03 \pm 0.14 \pm 0.07$	$0.00 \pm 0.10 \pm 0.03$	$0.02 \pm 0.08 \pm 0.06$	$0.09 \pm 0.11 \pm 0.08$
[0.04, 6.0]	$0.50 \pm 0.06 \pm 0.04$	$-0.04 \pm 0.06 \pm 0.03$	$0.03 \pm 0.13 \pm 0.07$	$0.14 \pm 0.09 \pm 0.03$	$0.02 \pm 0.07 \pm 0.05$	$0.05 \pm 0.10 \pm 0.07$

q^2 [GeV^2]	P_1	P'_4	P'_5	P'_6	P'_8
[0.04, 2.0]	$-0.06 \pm 0.30 \pm 0.10$	$0.39 \pm 0.51 \pm 0.25$	$0.67 \pm 0.26 \pm 0.16$	$-0.18 \pm 0.21 \pm 0.04$	$-0.22 \pm 0.38 \pm 0.14$
[2.0, 4.0]	$-0.78 \pm 0.51 \pm 0.42$	$-0.96 \pm 0.39 \pm 0.26$	$-0.33 \pm 0.31 \pm 0.13$	$0.31 \pm 0.28 \pm 0.19$	$0.84 \pm 0.32 \pm 0.31$
[4.0, 6.0]	$0.00 \pm 0.47 \pm 0.26$	$0.81 \pm 0.42 \pm 0.24$	$0.26 \pm 0.35 \pm 0.17$	$0.06 \pm 0.27 \pm 0.13$	$-0.19 \pm 0.33 \pm 0.07$
[0.04, 4.0]	$-0.22 \pm 0.26 \pm 0.16$	$-0.38 \pm 0.31 \pm 0.22$	$0.32 \pm 0.21 \pm 0.10$	$0.01 \pm 0.17 \pm 0.10$	$0.30 \pm 0.26 \pm 0.19$
[1.1, 6.0]	$-0.17 \pm 0.31 \pm 0.14$	$0.07 \pm 0.28 \pm 0.18$	$0.01 \pm 0.21 \pm 0.07$	$0.03 \pm 0.17 \pm 0.11$	$0.18 \pm 0.22 \pm 0.16$
[0.04, 6.0]	$-0.15 \pm 0.23 \pm 0.10$	$0.07 \pm 0.26 \pm 0.18$	$0.27 \pm 0.19 \pm 0.07$	$0.03 \pm 0.15 \pm 0.10$	$0.11 \pm 0.21 \pm 0.14$

Systematic uncertainties

- Main systematic uncertainties come from backgrounds:
  - $\cos\theta_K \sim 1$ peaking component:
    - $B \rightarrow K/\pi\ \mu\mu + X$ and combinatoric $K\pi$ (fake K*)
    - veto on three-body mass or $\cos\theta_K$ cut
  - $|\cos\theta_L| \sim 0.7$ peaking component:
    - partially reconstructed $B \rightarrow D \rightarrow X$ decays
    - veto around the charmed meson masses.
- background shape choice
- acceptance functions, alignment and B-field calibration
- S-wave contributions (~5%) result in a small systematic error.
- Other backgrounds from exclusive mode neglected in the fit are included and the systematic uncertainty assessed

- F_L: largest systematic from $\cos\theta_K$ and $\cos\theta_L$, backgrounds: 0.11
- S_j: systematics also from background uncertainties: 0.01-0.13

Systematic table for K*μμ angular analysis

Source	F_L	S_3	S_4	S_5	S_7	S_8
Combinatoric $K\pi$ (fake K^*) background	0.03	0.03	0.05	0.03	0.06	0.13
D and B^+ veto	0.11	0.04	0.05	0.03	0.01	0.05
Background p.d.f. shape	0.04	0.04	0.03	0.02	0.03	0.01
Acceptance function	0.01	0.01	0.07	0.01	0.01	0.01
Partially reconstructed decay background	0.03	0.05	0.02	0.06	0.05	0.05
Alignment and B field calibration	0.02	0.04	0.05	0.03	0.04	0.03
Fit bias	0.01	0.01	0.02	0.02	0.01	0.04
Data/MC differences for p_T	0.02	0.02	0.01	0.01	0.01	0.01
S-wave	0.01	0.01	0.01	0.01	0.01	0.02
Nuisance parameters	0.01	0.01	0.01	0.01	0.01	0.01
Λ_b, B^+ and B_s background	0.01	0.01	0.01	0.01	0.01	0.01
Misreconstructed signal	0.01	0.01	0.01	0.01	0.01	0.01
Dilution	–	–	0.01	0.01	–	–

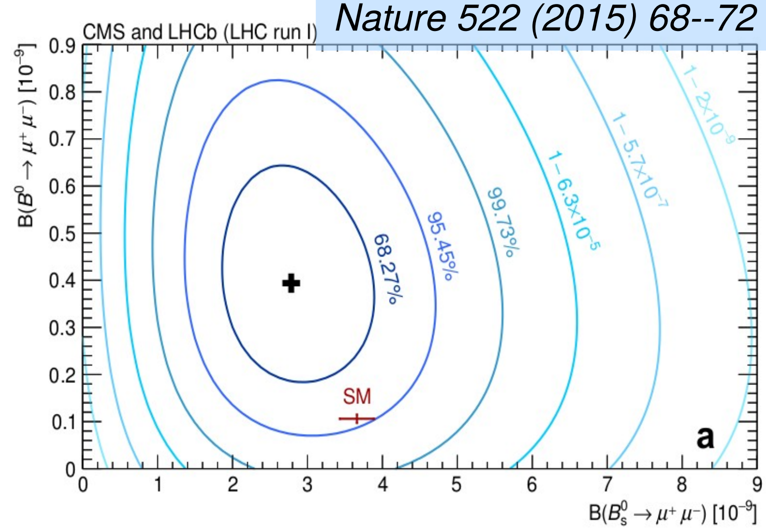
Previous and latest results

- Combination from CMS and LHCb:
  - 6σ observation for the B^0_s channel:

    $\mathbf{B(B^0_s \to \mu^+\mu^-) = (2.8\ ^{+0.7}_{-0.6})\ 10^{-9}}$
  - 3σ evidence for the B^0 channel:

    $\mathbf{B(B^0 \to \mu^+\mu^-) = (3.9\ ^{+1.6}_{-1.4})\ 10^{-10}}$
  - some tension with the SM

CMS and LHCb, Nature 522 (2015) 68--72



- Latest result from LHCb on Run2:
  - 7.8σ observation for the B^0_s channel

    $\mathbf{B(B^0_s \to \mu^+\mu^-) = (2.8 \pm 0.6)\ 10^{-9}}$
  - 1.9σ effect for the B^0 channel:

    $\mathbf{B(B^0 \to \mu^+\mu^-) = (1.6\ ^{+1.1}_{-0.9})\ 10^{-10}}$

    $\mathbf{< 3.4\ 10^{-10}}$
  - reduced tension with the SM

LHCb, arXiv:1703.05747