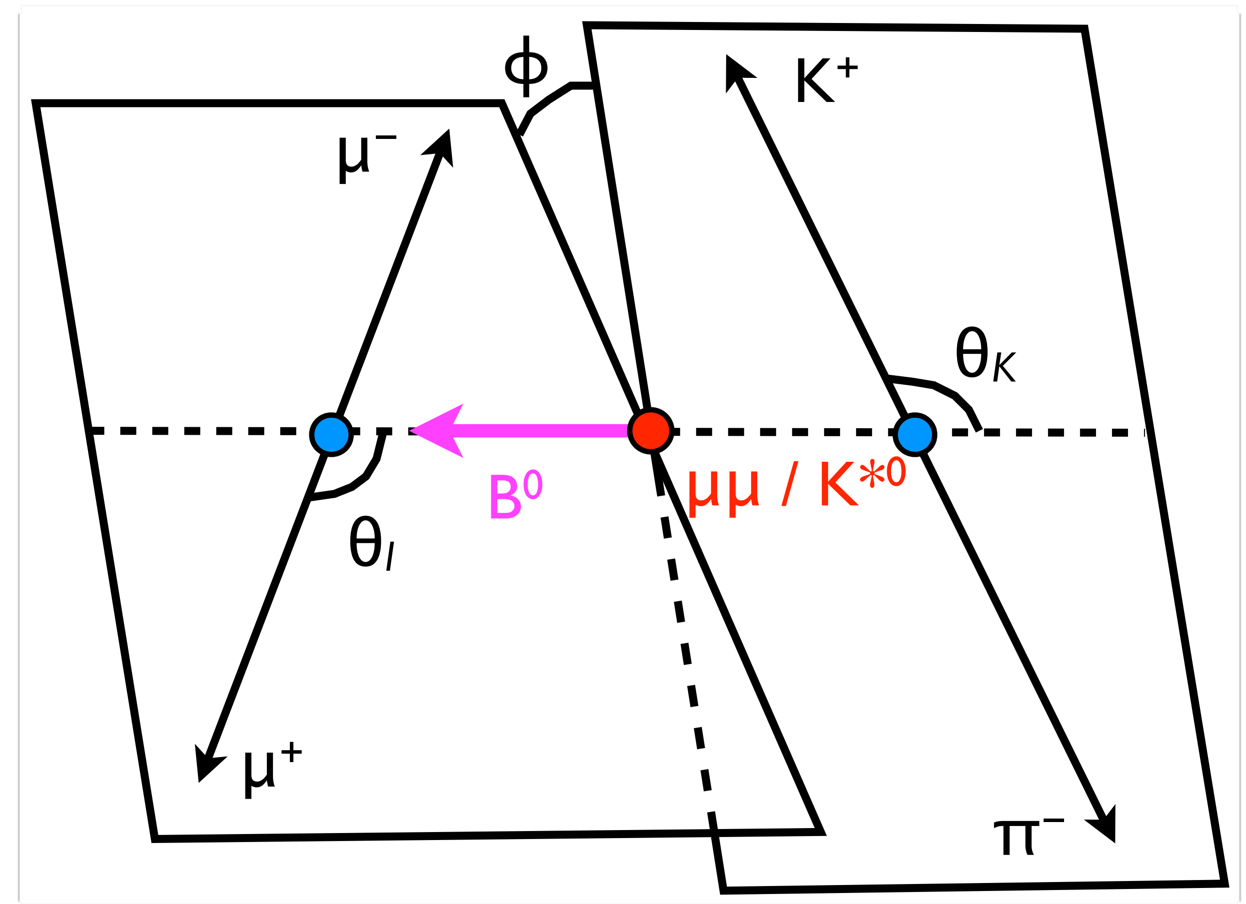
VI workshop italiano sulla fisica p-p a LHC

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



LHCb: arXiv 1304.6325
Atlas: ATLAS-CONF-2013-038
CMS: CMS PAS BPH-11-009

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LHCb: Nicola Serra (University of Zurich, Switzerland)

10/05/2013

Outline

- Motivation for $B^0 \to K^{*0} \mu^+ \mu^-$ analysis
- Comparison of detector performance
- Event selections
- Peaking backgrounds
- Fit strategies
- Corrections for instrumental effects
- Statistical and systematic uncertainties
- Measurement comparison
- Discussion

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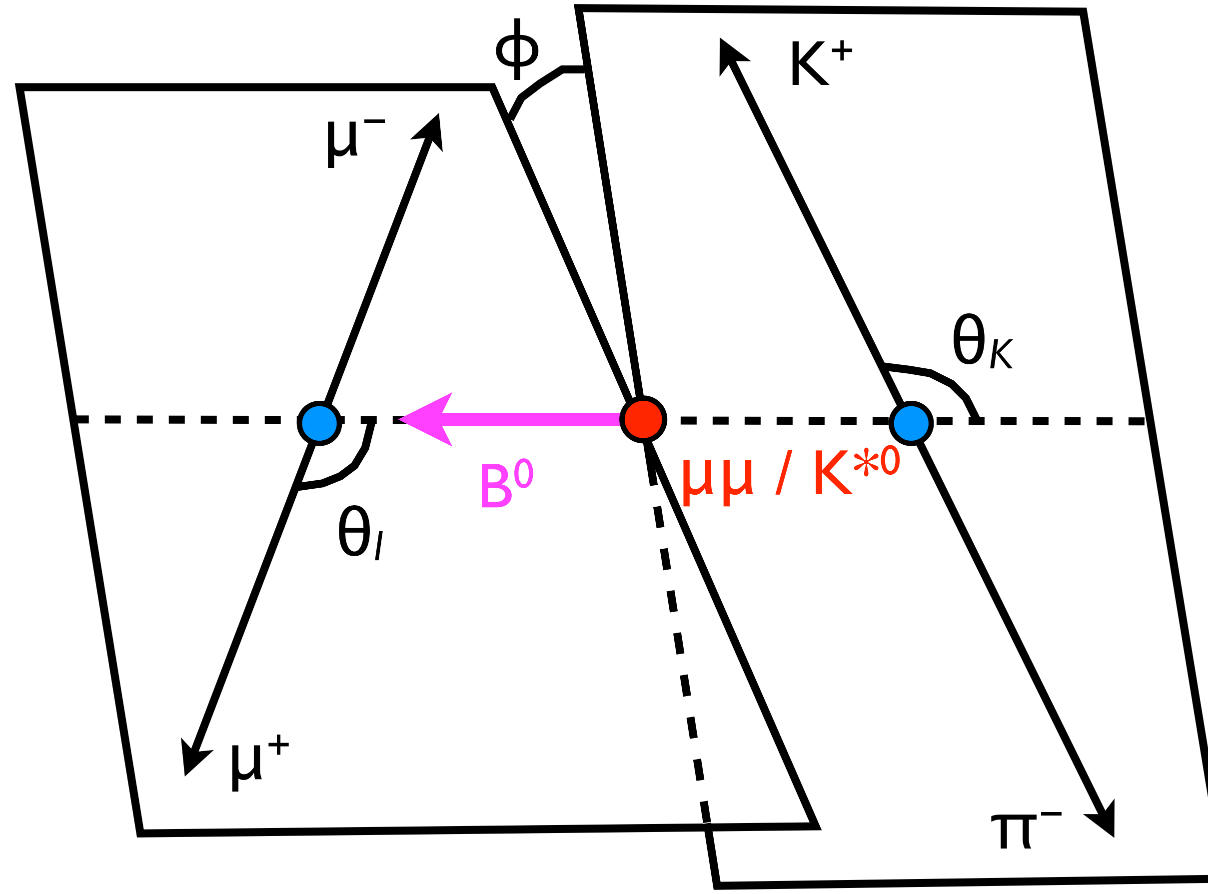
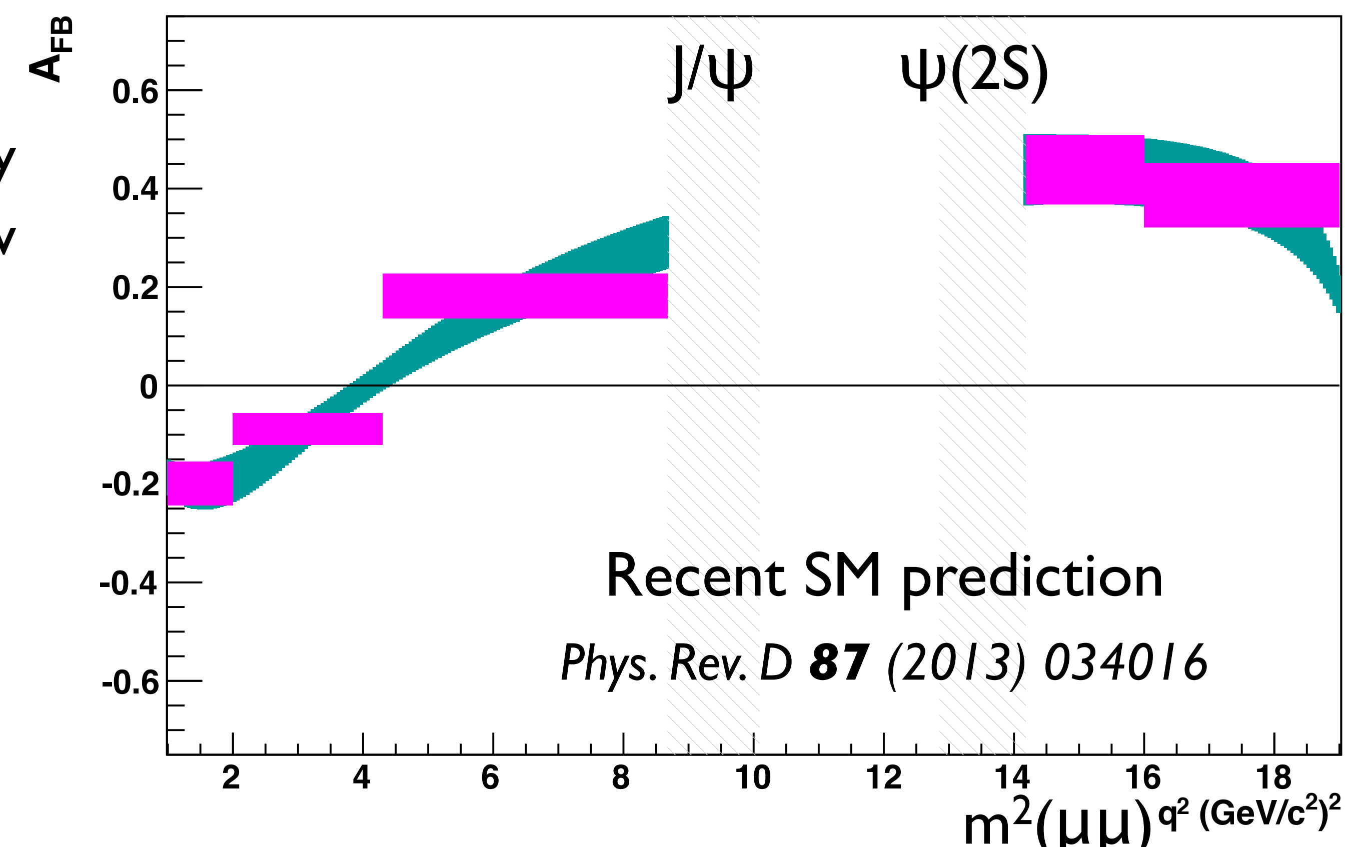
Motivation for $B^0 \to K^{*0} \mu^+ \mu^-$ analysis

- **$B^0 \to K^{*0} \mu^+ \mu^-$** described within the SM as flavor changing neutral current process ➜ **(a)** small SM rates **(b)** small theoretical uncertainties **(c)** new physics predictions that differ from SM **(d)** experimental accessibility ➜ **good candidate for indirect searches for new phenomena**



- The decay is fully described with three angles (θ_l, θ_K, Φ) and $q^2 = m^2(\mu\mu)$

- Example of angular observables theoretically predicted with relatively small uncertainties at low q^2: μμ forward-backward asymmetry (**A_{FB}**)



- Useful resonant control channels:
  - $B^0 \to J/\psi\ (\mu^+ \mu^-)\ K^{*0}$
  - $B^0 \to \psi(2S)\ (\mu^+ \mu^-)\ K^{*0}$

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Interesting / accessible observables

- Assuming equal numbers of B^0 and B^0bar

$$
\begin{aligned}
\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\Big[& \boxed{S_1^s}\sin^2\theta_K + \boxed{S_1^c}\cos^2\theta_K + \\
& \boxed{S_2^s}\sin^2\theta_K\cos 2\theta_\ell + \boxed{S_2^c}\cos^2\theta_K\cos 2\theta_\ell + \\
& \boxed{S_3}\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \boxed{S_4}\sin 2\theta_K\sin 2\theta_\ell\cos\phi + \\
& \boxed{S_5}\sin 2\theta_K\sin\theta_\ell\cos\phi + \boxed{S_6}\sin^2\theta_K\cos\theta_\ell + \\
& \boxed{S_7}\sin 2\theta_K\sin\theta_\ell\sin\phi + \boxed{S_8}\sin 2\theta_K\sin 2\theta_\ell\sin\phi + \\
& \boxed{S_9}\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi \Big],
\end{aligned}
$$

Complete description of the decay rate:
11 variables !

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Interesting / accessible observables

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\Big[\boxed{S_1^s}\sin^2\theta_K + \boxed{S_1^c}\cos^2\theta_K + \boxed{S_2^s}\sin^2\theta_K\cos 2\theta_\ell + \boxed{S_2^c}\cos^2\theta_K\cos 2\theta_\ell + \boxed{S_3}\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \cancel{S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi} + \cancel{S_5\sin 2\theta_K\sin\theta_\ell\cos\phi} + \boxed{S_6}\sin^2\theta_K\cos\theta_\ell + \cancel{S_7\sin 2\theta_K\sin\theta_\ell\sin\phi} + \cancel{S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi} + \boxed{S_9}\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big],$$

$\boxed{\mathbf{A_9}} \leftarrow \boxed{S_9}$

For $q^2 \gg 4m^2_\mu$:

- $S^c_1 = -S^c_2 = \mathbf{F_L}$
- $3/4 \cdot S^s_1 = 4 \cdot S^s_2 = (1-\mathbf{F_L})$

- $\Phi \rightarrow \Phi$ for B^0; $\Phi \rightarrow -\Phi$ for B^0_{bar} ➜ S_9 becomes $\mathbf{A_9}$ which is not suppressed by the small size of the strong phase (look at CP-asymmetries)
- Folding $\hat{\Phi} = \Phi$ if $\Phi > 0$; $\hat{\Phi} = \Phi + \pi$ if $\Phi \leq 0$
- $\mathbf{A_{FB}} = -3/4 \cdot S_6$

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Interesting / accessible observables

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\Big[\boxed{S_1^s}\sin^2\theta_K + \boxed{S_1^c}\cos^2\theta_K + \boxed{S_2^s}\sin^2\theta_K\cos 2\theta_\ell + \boxed{S_2^c}\cos^2\theta_K\cos 2\theta_\ell + \boxed{S_3}\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \cancel{S_4\sin 2\theta_K\sin 2\theta_\ell\cos\phi} + \cancel{S_5\sin 2\theta_K\sin\theta_\ell\cos\phi} + \boxed{S_6}\sin^2\theta_K\cos\theta_\ell + \cancel{S_7\sin 2\theta_K\sin\theta_\ell\sin\phi} + \cancel{S_8\sin 2\theta_K\sin 2\theta_\ell\sin\phi} + \boxed{S_9}\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi\Big],$$

$\boxed{\mathbf{A_9}} \leftarrow \boxed{S_9}$

For $q^2 \gg 4m^2_\mu$:

- $S^c_1 = -S^c_2 = \mathbf{F_L}$
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- Folding $\hat{\Phi} = \Phi$ if $\Phi > 0$; $\hat{\Phi} = \Phi + \pi$ if $\Phi \leq 0$
- $\mathbf{A_{FB}} = -3/4 \cdot S_6$

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\hat{\phi}} = \frac{9}{16\pi}\Big[\boxed{F_\mathrm{L}}\cos^2\theta_K + \frac{3}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K) - \boxed{F_\mathrm{L}}\cos^2\theta_K(2\cos^2\theta_\ell - 1) + \frac{1}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K)(2\cos^2\theta_\ell-1) + \boxed{S_3}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} + \frac{4}{3}\boxed{A_\mathrm{FB}}(1-\cos^2\theta_K)\cos\theta_\ell + \boxed{A_9}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi}\Big]$$

4 variables !

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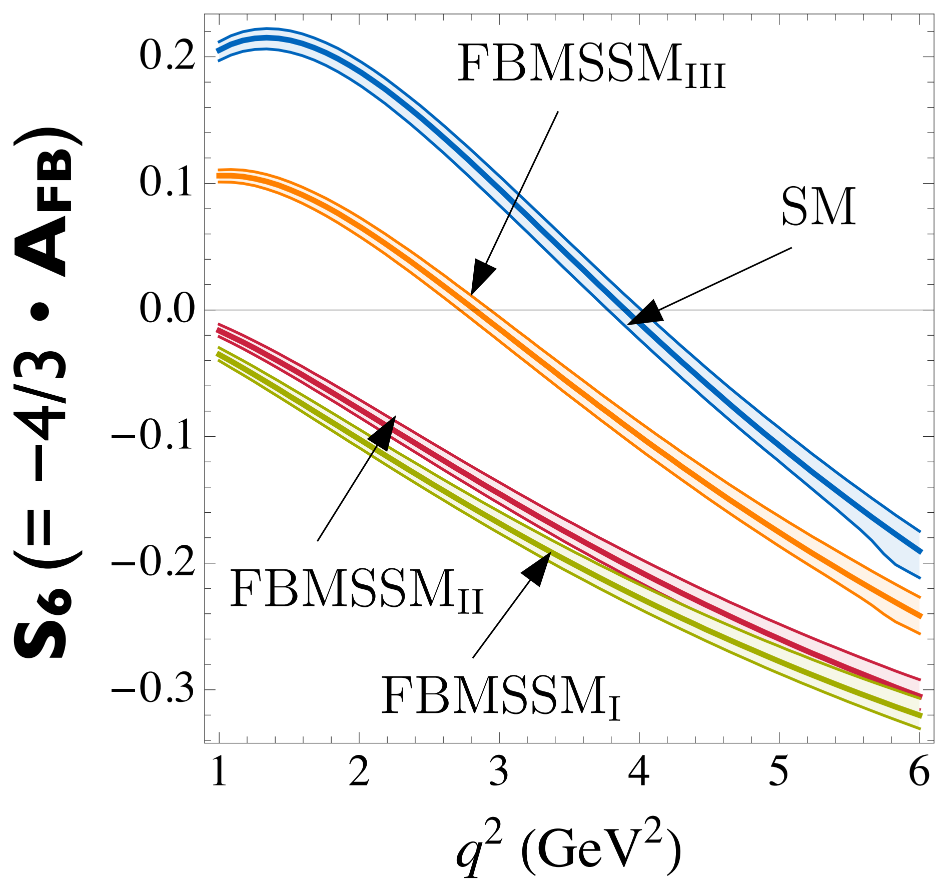
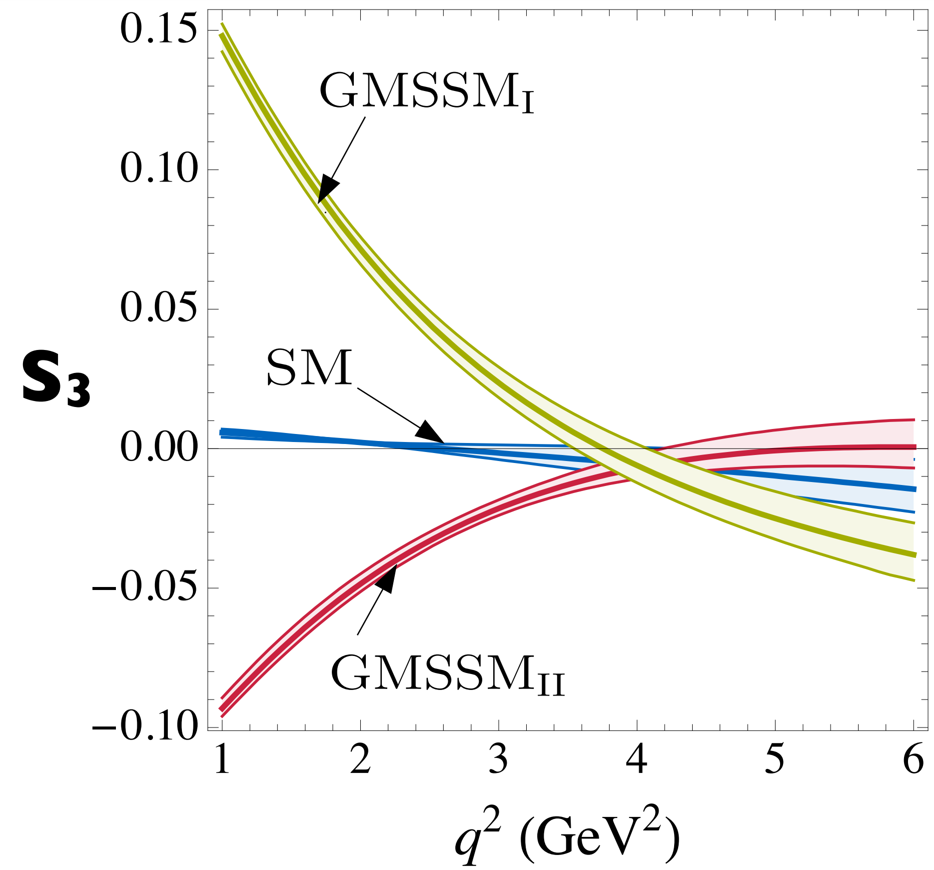
Motivation for $B^0 \to K^{*0} \mu^+ \mu^-$ analysis



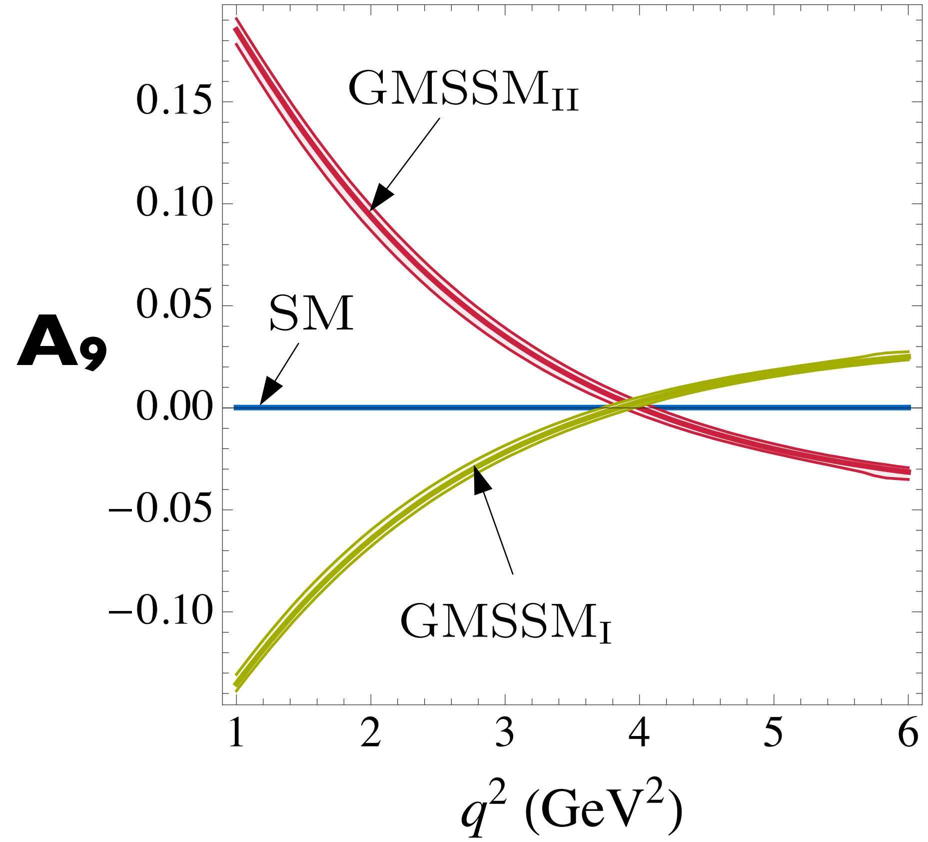


SM vs plausible SM extensions:

JHEP 01 (2009) 019

- General MSSM
- Flavor Blind MSSM

Dramatic change of trends versus q^2



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Comparisons

Analysis performed with 2011 data:

- **LHCb** collected ~1 fb^{-1}
- **Atlas** collected ~4.9 fb^{-1}
- **CMS** collected ~5.2 fb^{-1}

Comparison of detector performance

	LHCb	**Atlas**	**CMS**
Pseudorapidity coverage	$2 < \eta < 5$	$\|\eta\| < 2.5$	$\|\eta\| < 2.5$
(transverse) momentum resolution	0.4 – 0.6% from 5 to 100 GeV/c	4 – 8% from 4 to 10 GeV/c and 4% for > 10 GeV/c	1.5% up to 100 GeV/c
Impact parameter resolution	20 μm	12 μm	15 μm
Mass resolution $J/\psi \to \mu\mu$	13 MeV/c^2	46 MeV/c^2	28 MeV/c^2
K – π ID ($B^0 \to K^{*0}(K^+ \pi^-) \mu^+ \mu^-$)	RICH: separation in range 2 – 100 GeV/c	No detector for particle ID	No detector for particle ID

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LHCb event selection

(a) Cut-based selection:

Trigger

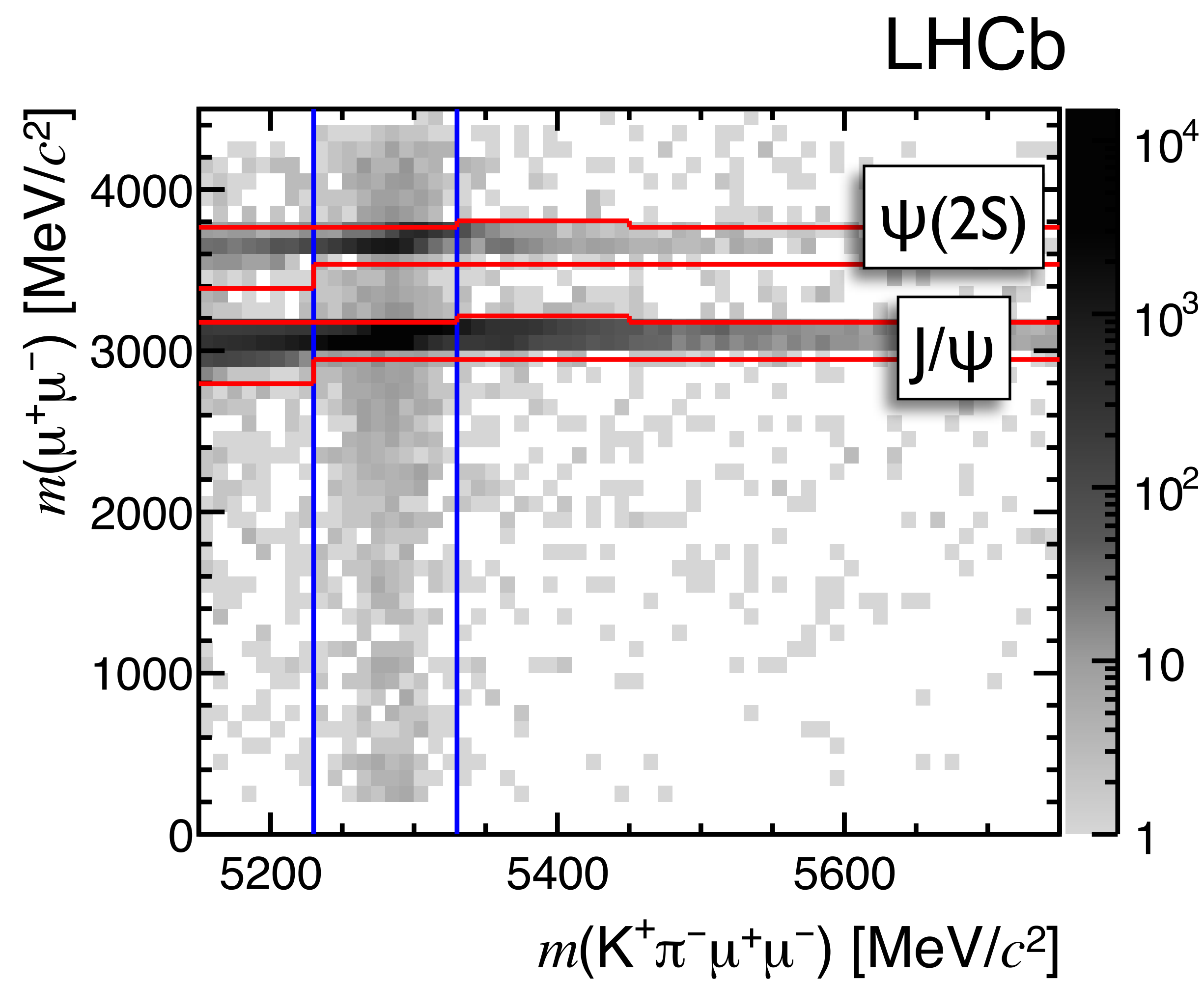
- at least one μ with $p_T(\mu) > 1.5$ GeV/c
- at least one hadron with $p_T(h) > 1.5$ GeV/c
- tracks impact parameter "big" w.r.t. PV
- **kinematic properties B^0 candidates**

B^0 selections

- separation between B^0 vtx. and Primary Vtx. (PV)
- B^0 impact parameter "small" w.r.t. PV
- B^0 α "small" (angle between B^0 momentum and line of flight PV$-B^0$ vtx.)

Kπ selections

- **CP-state assignment: RICH detector**
- $| m(K\pi) - m(K^{*0}_{PDG}) | < 100$ MeV/c^2



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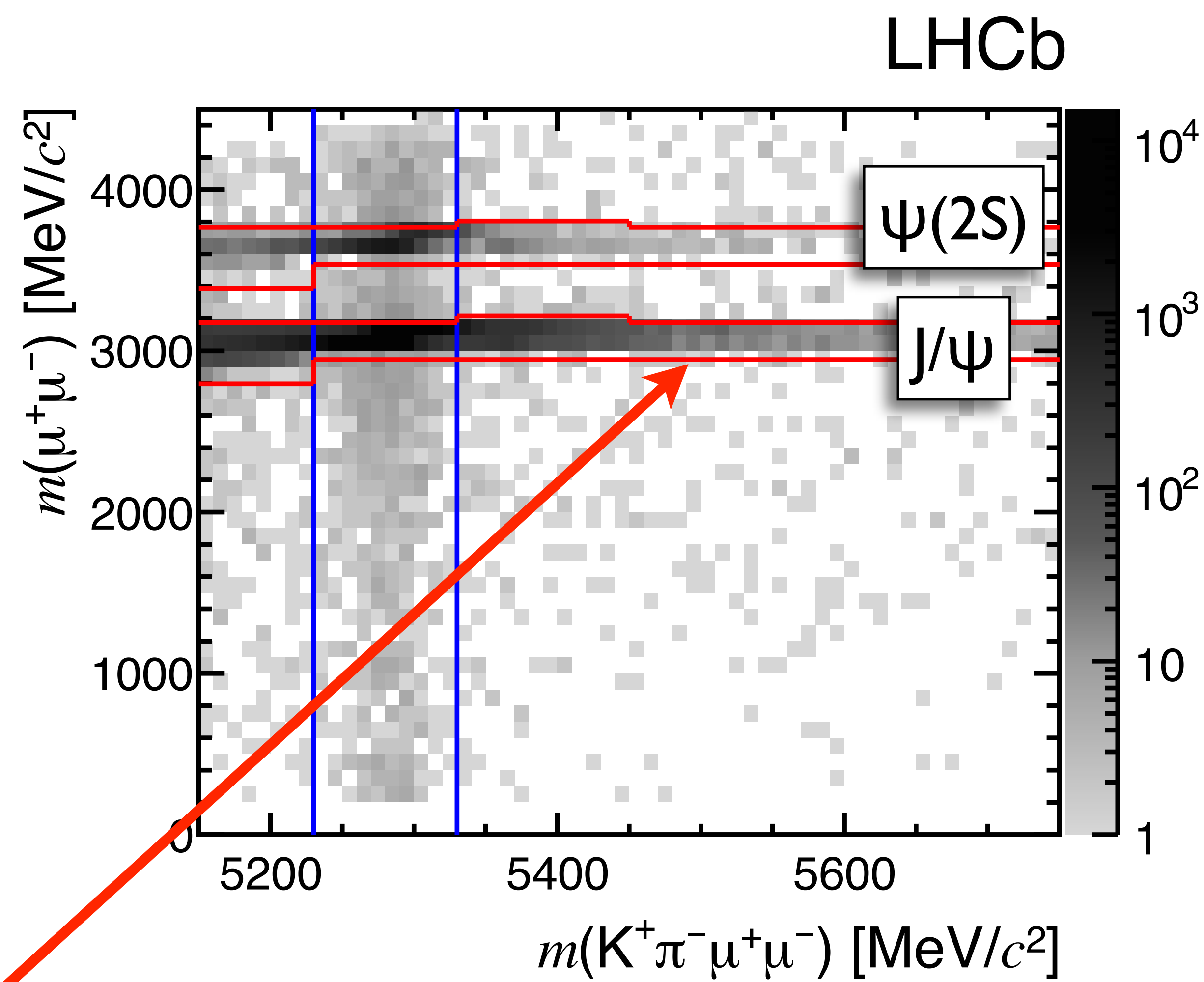
LHCb event selection

(b) BDT-based selection:

- training on 36 pb^{-1} of data: $B^0 \rightarrow J/\psi\ (\mu\mu)\ K^{*0}$ (representative of signal) and $5350 < m(K\pi\mu\mu) < 5600\ MeV/c^2$ (representative of background)
- containing cut-based variables, quality B^0 vtx., χ^2 tracks, likelihood K−π separation



Resonant channels rejection

- $2946 < m(\mu\mu) < 3176\ MeV/c^2$ and $3586 < m(\mu\mu) < 3766\ MeV/c^2$ or
- $2796 < m(\mu\mu) < 3176\ MeV/c^2$ and $3436 < m(\mu\mu) < 3766\ MeV/c^2$ for $m(K\pi\mu\mu)$ in left-hand tail or
- $2946 < m(\mu\mu) < 3201\ MeV/c^2$ and $3586 < m(\mu\mu) < 3791\ MeV/c^2$ for $m(K\pi\mu\mu)$ in right-hand tail

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Atlas vs CMS event selection

Atlas

Muon-based trigger

- two μ with $p_T(\mu) > 4$ GeV/c or $p_T(\mu_1) > 6$ GeV/c and $p_T(\mu_2) > 4$ GeV/c
- prescale

Track selections

- offline μ no need match trigger μ
- $\mu\mu$ vtx. X^2/dof < 10
- tracks $p_T > 0.5$ GeV/c

Kπ selections

- CP-state assignment:
  - **closest distance K^{*0}_{PDG} mass**
- $|m(K\pi) - m(K^{*0}_{PDG})| < 46$ MeV/c^2
- $p_T(K\pi) > 3$ GeV/c

CMS

Dedicated muon-based trigger

- $\mu\mu$ vtx. L / σ > 3 (transverse)
- $1 < m(\mu\mu) < 4.8$ GeV/c^2
- $p_T(\mu) > 3, 4, 4.5, 5$ GeV/c (depending on trigger)
- $\mu\mu$ vtx. CL > 5%, 15% (depending on trigger)

Track selections

- offline μ-match trigger μ, hadron fail μ-ID
- $p_T(h) > 0.75$ GeV/c
- impact parameter(h) / σ > 1.3 (transverse)

Kπ selections

- CP-state assignment:
  - **reject event if both K^{*0} and $\overline{K}^{*0}$ masses within ~1Γ from PDG mass**
  - **closest distance K^{*0}_{PDG} mass**
- $|m(K\pi) - m(K^{*0}_{PDG})| < 80$ MeV/c^2

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Atlas vs CMS event selection

Atlas

B^0 selections

- B^0 $\tau/\sigma_\tau > 12.75$
- B^0 vtx. χ^2/dof < 2
- B^0 $\cos(\alpha) > 0.999$ (angle between B^0 momentum and line of flight PV−B^0 vtx.)

CMS

B^0 selections

- B^0 vtx. $L / \sigma > 12$ (transverse)
- B^0 vtx. CL > 9%
- B^0 $\cos(\alpha) > 0.9994$ (angle between B^0 momentum and line of flight)

Atlas

Resonant channels rejection

- $| m(\mu\mu) - m(J/\psi_{PDG}) | > 3\sigma$ and $| m(\mu\mu) - m(\psi(2S)_{PDG}) | > 3\sigma$
- **$| m(B^0_{RECO}) - m(B^0_{PDG}) - (m(\mu\mu_{RECO}) - m(J/\psi_{PDG} \,|\, \psi(2S)_{PDG})) | < 130$ MeV/c^2**

CMS

Resonant channels rejection

- $m(\mu\mu) < m(J/\psi_{PDG}) - 5\sigma$ or $m(\mu\mu) > m(J/\psi_{PDG}) + 3\sigma$ and $| m(\mu\mu) - m(\psi(2S)_{PDG}) | > 3\sigma$

- Quantities referred to PV with higher p_T

- Quantities referred to beam spot ➜ pileup insensitive

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Peaking backgrounds

	LHCb	Atlas	CMS
$B_s \to \Phi\ \mu\mu$	Cut on KK mass w.r.t. $\Phi(1020)$	Considered negligible	Cut on KK mass w.r.t. $\Phi(1020)$
$\Lambda_b \to \Lambda^*(1520)\ \mu\mu$	Cut on pK mass w.r.t. $\Lambda^*(1520)$	Considered negligible	Considered negligible
$B_s \to K^{*0}\ \mu\mu$	1% considered as syst. uncertainty	Considered negligible	Considered negligible
$B^0 \to J/\psi\ K^{*0}$ (μ mis-ID as K or π)	$3036 < (m(K\mu)$ or $m(\pi\mu)) < 3156$ MeV/c^2	Considered negligible	Considered negligible
$B^0 \to \psi(2S)\ K^{*0}$ (μ mis-ID as K or π)	Similar to $B^0 \to J/\psi\ K^{*0}$	Considered negligible	Considered negligible
$B^+ \to K^+\ \mu\mu$ (π from other B decays)	$5230 < m(K\mu\mu) < 5330$ MeV/c^2	Syst. uncertainty: remove evt. if $m(K\mu\mu)$ compatible with B^0	Considered negligible

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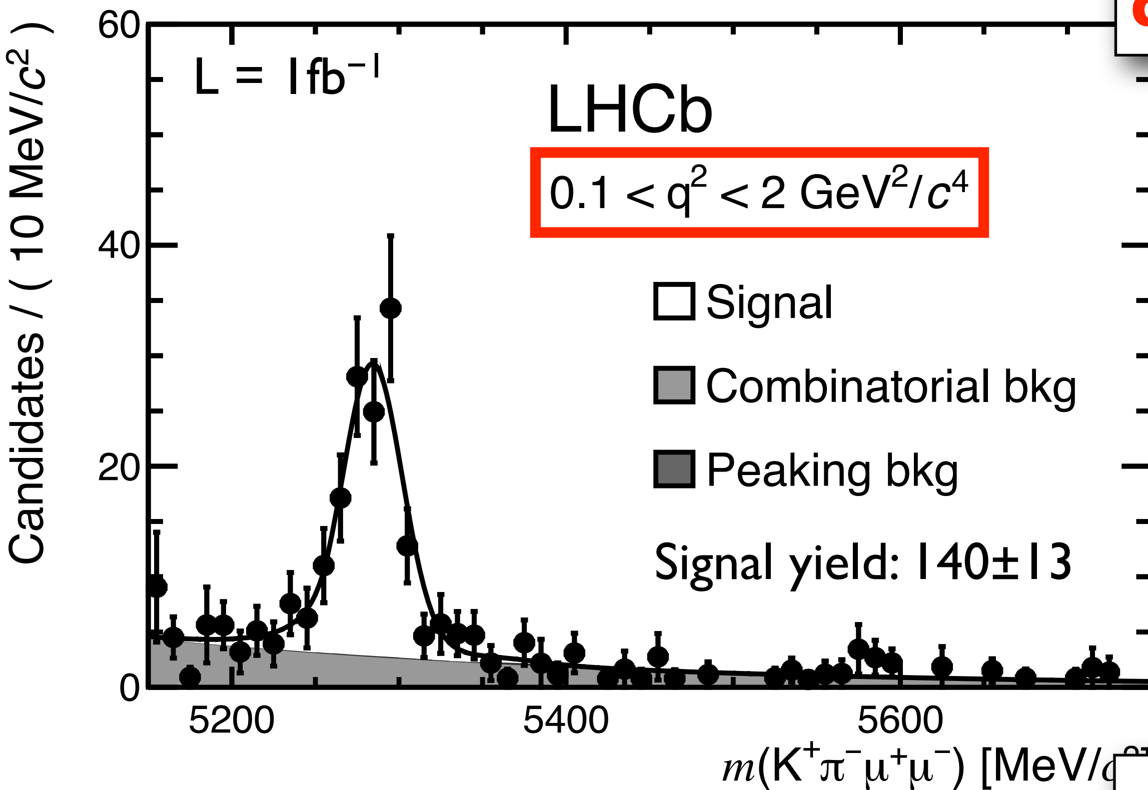
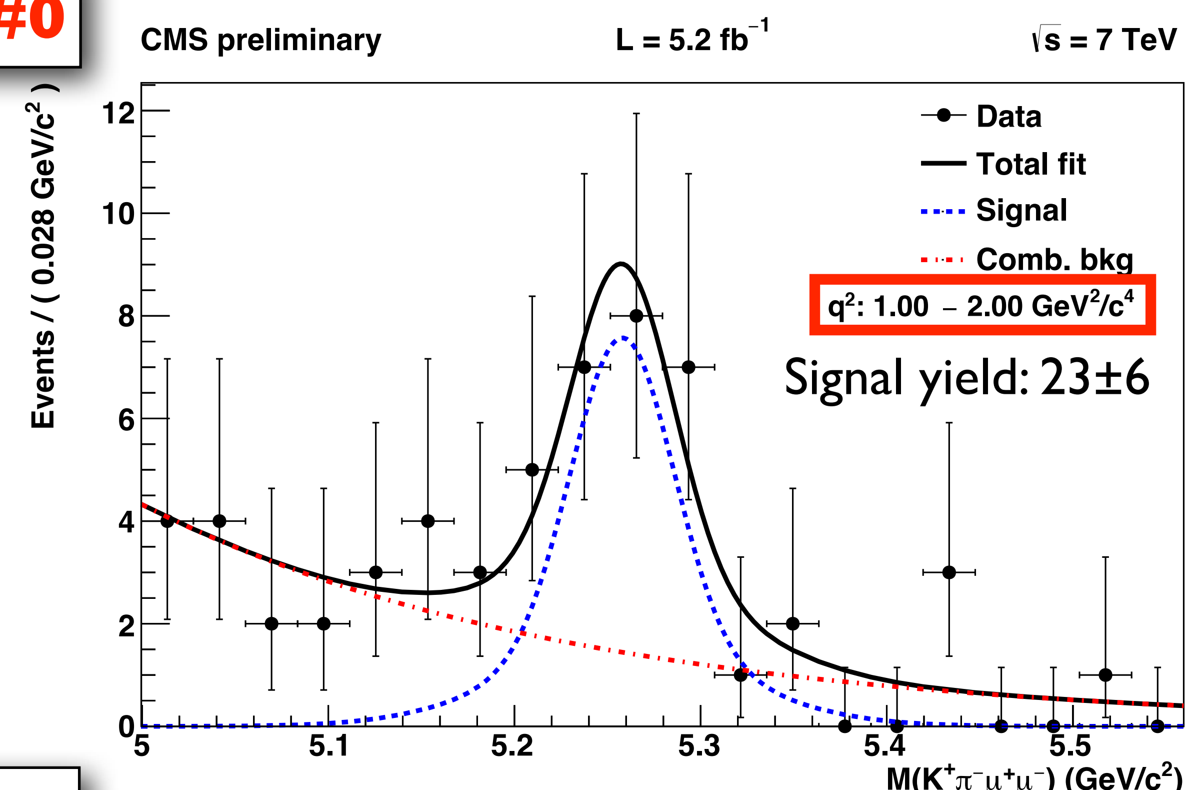
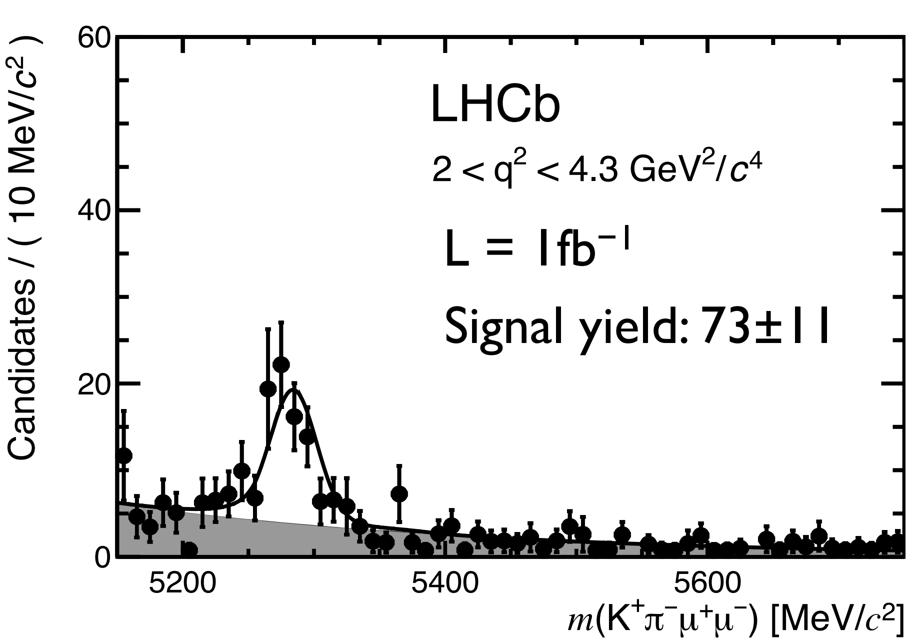
Signal comparison

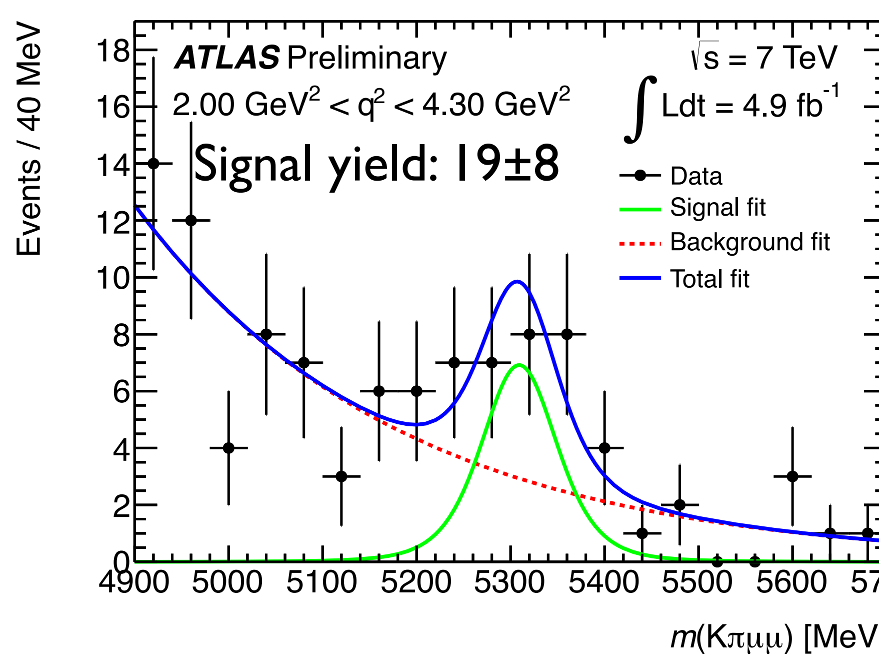
q^2 bin #0

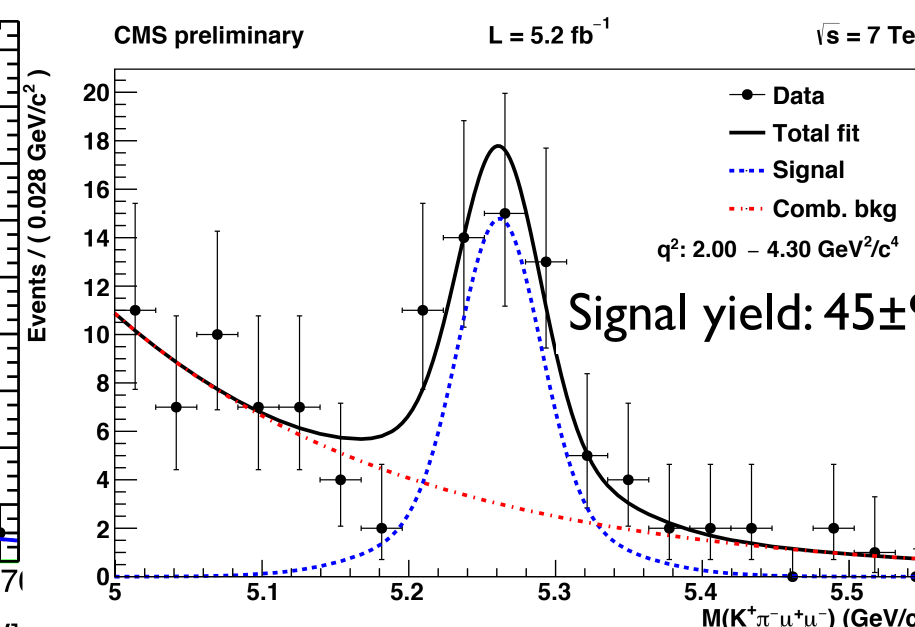




q^2 bin #1







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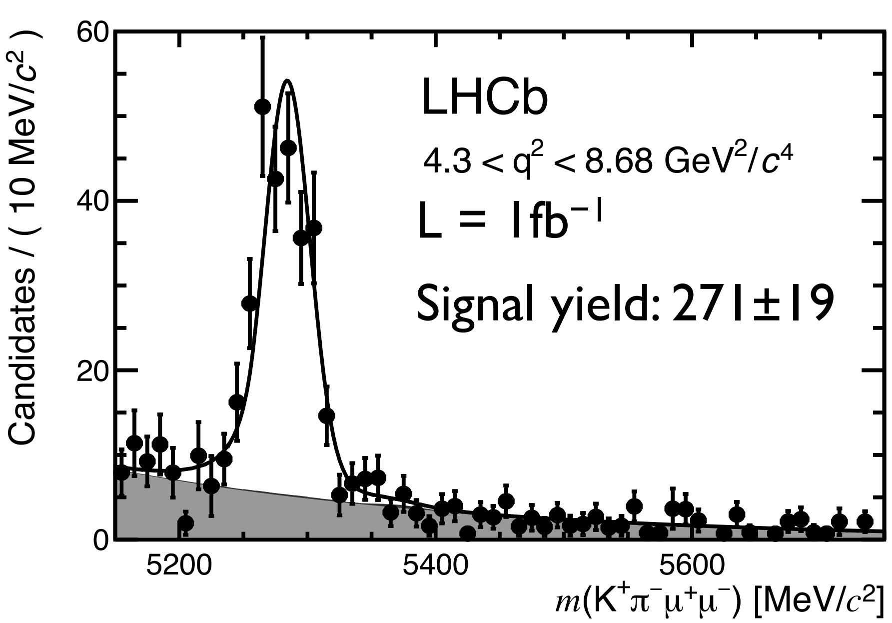
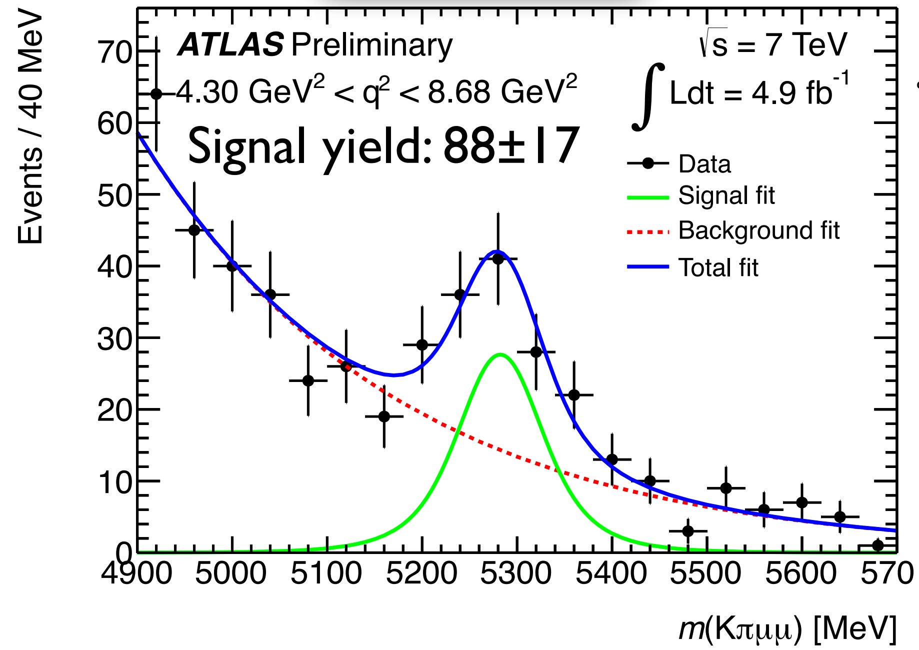
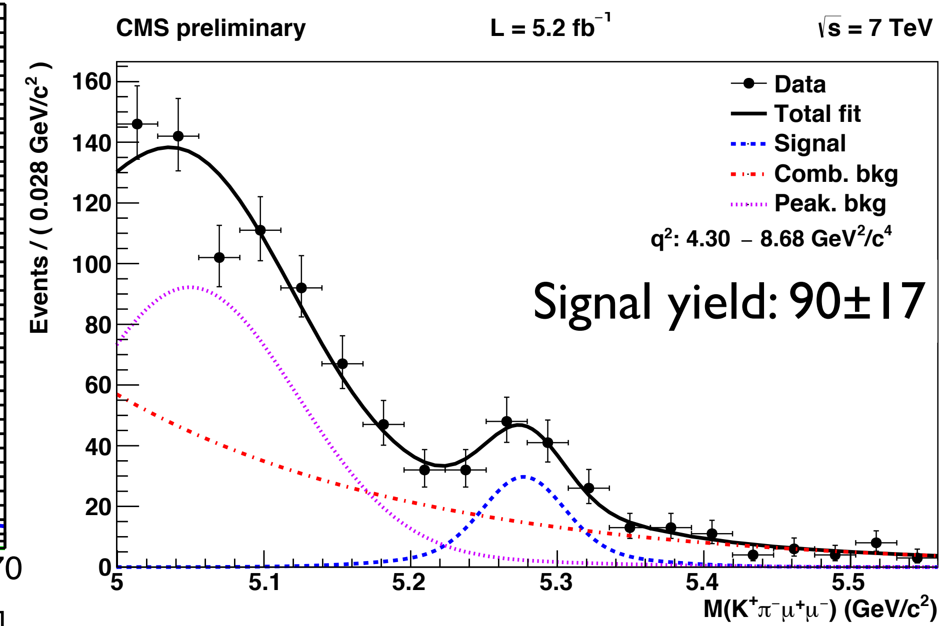
Signal comparison

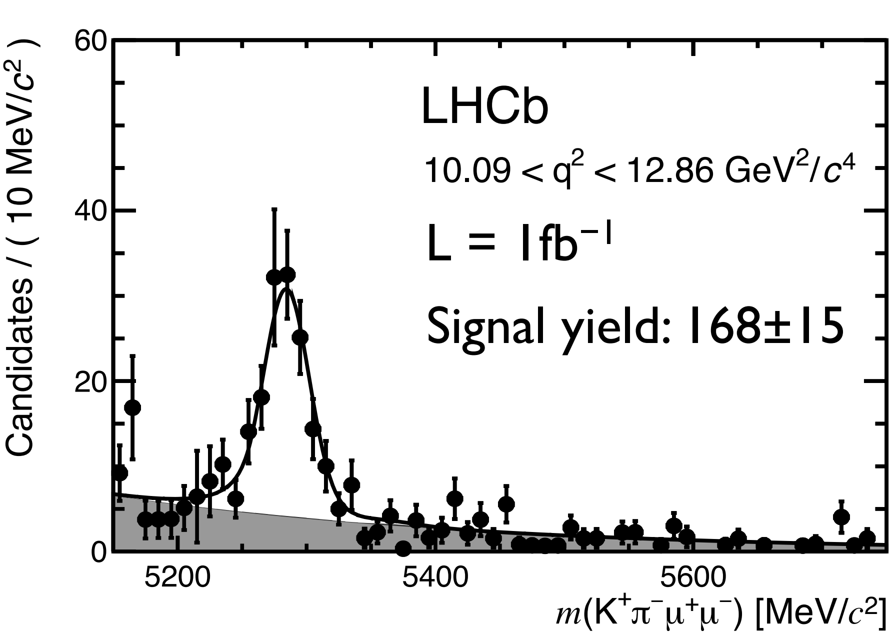
q^2 bin #2

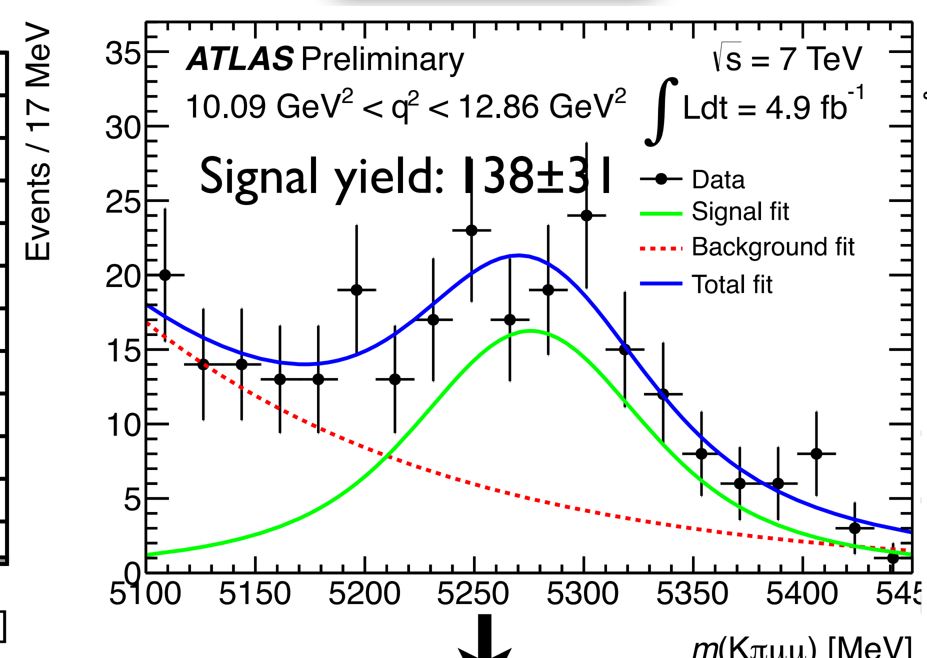


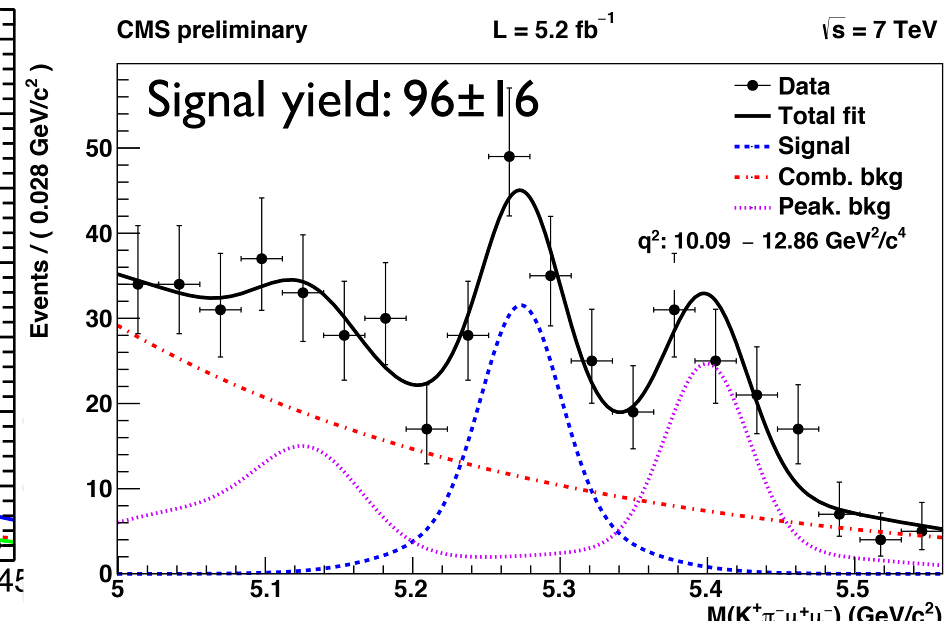




q^2 bin #3







q^2 dependence of $K\pi\mu\mu$-mass range due to feedthrough from resonant channels

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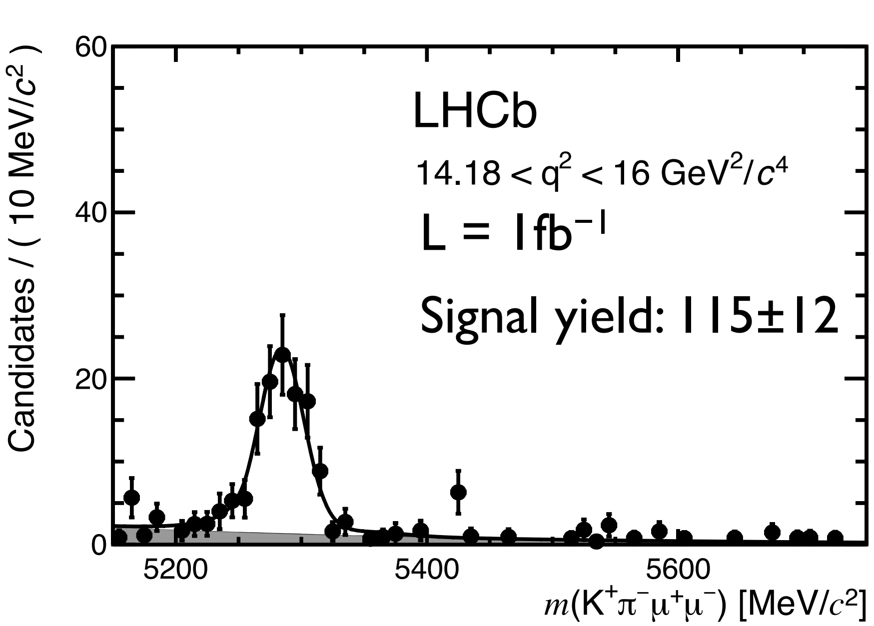
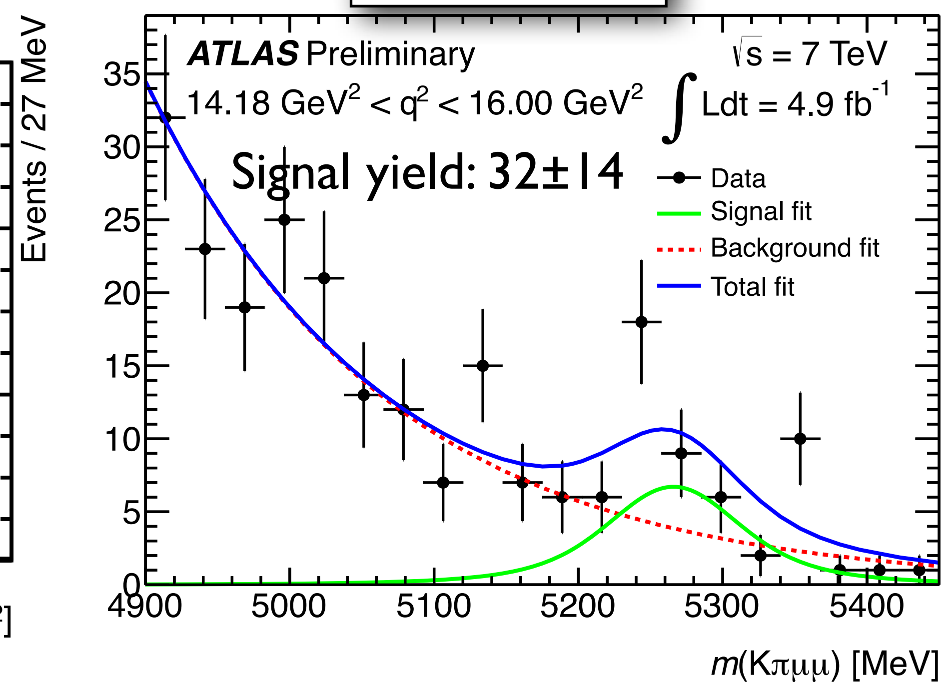
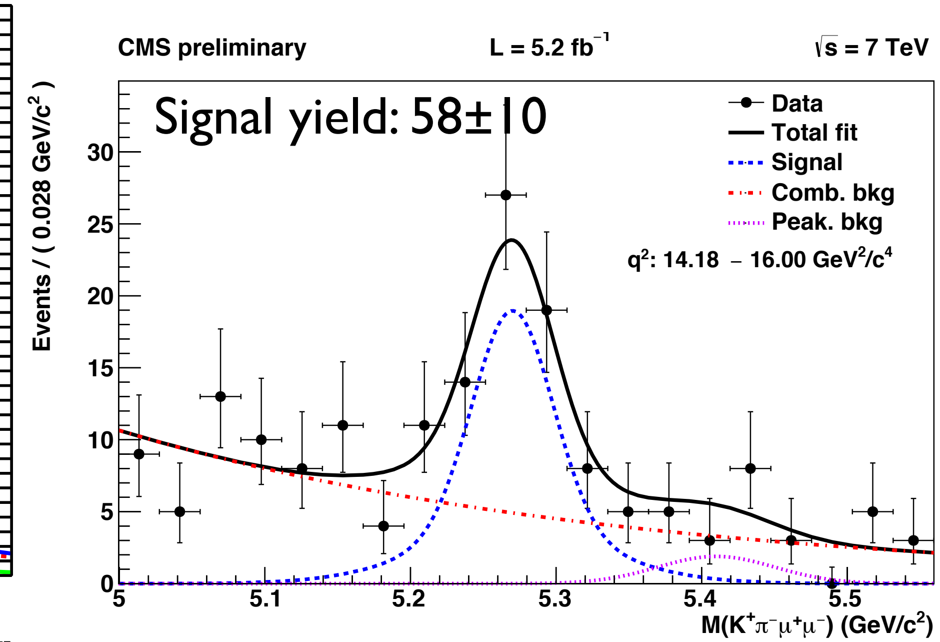
Signal comparison

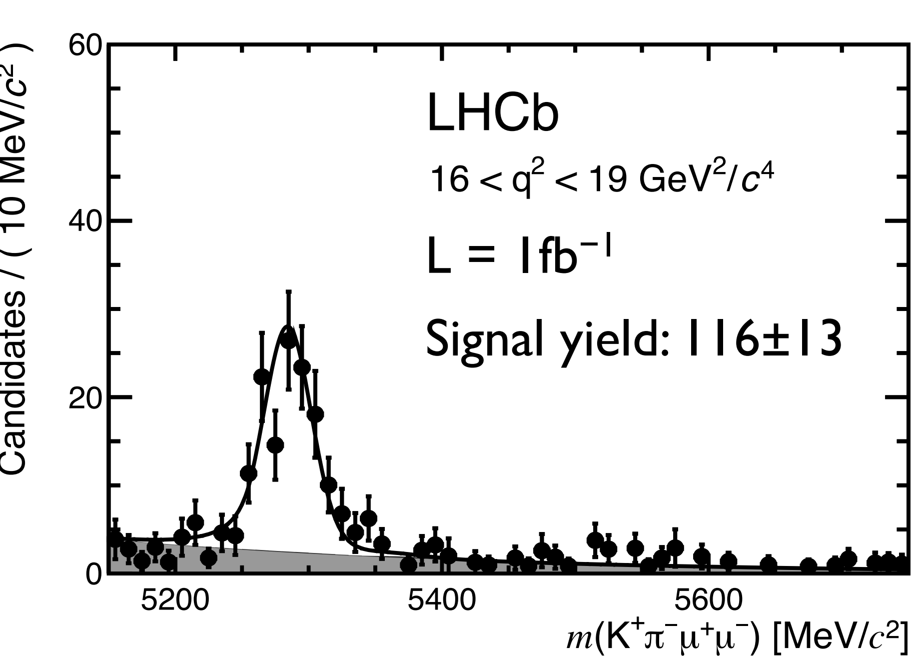
q^2 bin #4

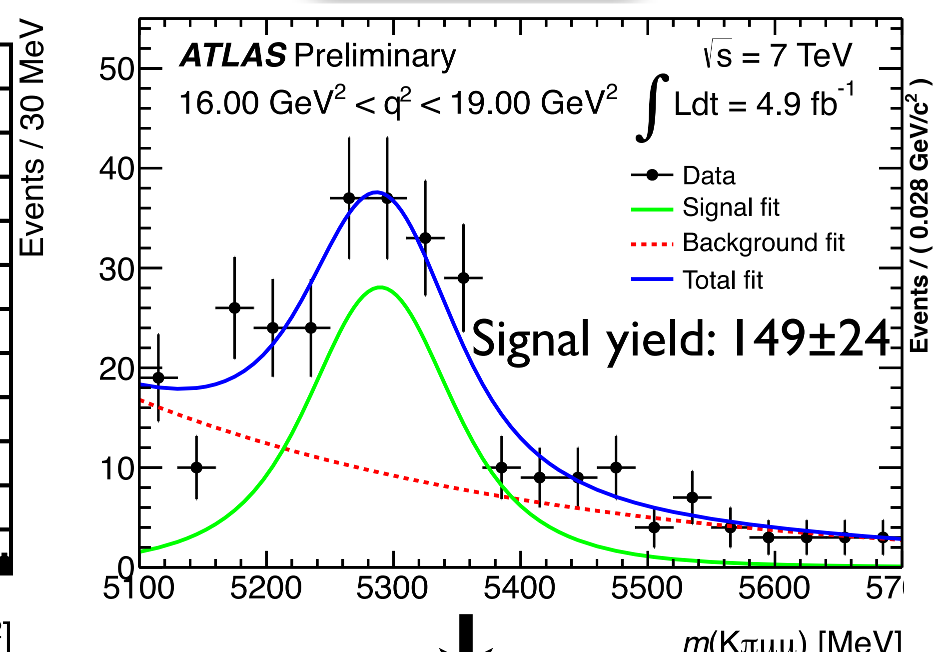


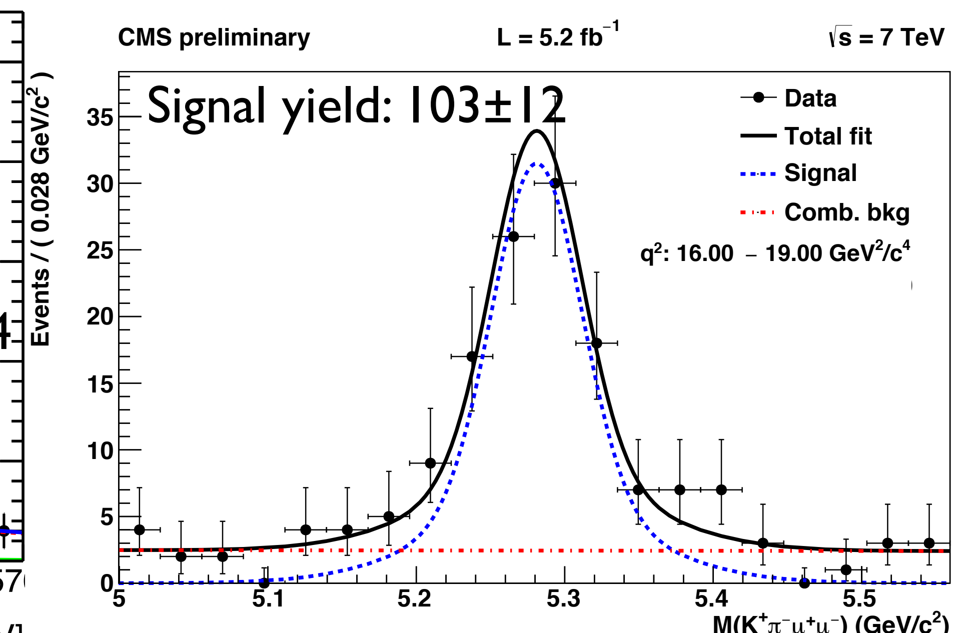




q^2 bin #5







$\Downarrow$

q^2 dependence of Kπμμ-mass range due to feedthrough from resonant channels

Fit strategies

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\hat{\phi}} = \frac{9}{16\pi}\Big[\boxed{F_\mathrm{L}}\cos^2\theta_K + \frac{3}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K) - \boxed{F_\mathrm{L}}\cos^2\theta_K(2\cos^2\theta_\ell-1) + \frac{1}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K)(2\cos^2\theta_\ell-1) + \boxed{S_3}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} + \frac{4}{3}\boxed{A_\mathrm{FB}}(1-\cos^2\theta_K)\cos\theta_\ell + \boxed{A_9}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi}\Big]$$

LHCb: simultaneous fit to all observables

- Fit Kπμμ-mass + (θ_K, θ_l, Φ): measure **F_L, A_{FB}, S_3, A_9**
- Fit Kπμμ-mass: measure yield ➜ ***dBF/dq²***

Atlas: sequential fit to partial decay rates

- Fit Kπμμ-mass: determine shape and yields
- Fit θ_K: measure **F_L**
- Fit θ_l: measure **A_{FB}**

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{dq^2 d\cos\theta_K} = \frac{3}{2}\boxed{F_L}(q^2)\cos^2\theta_K + \frac{3}{4}\left(1-\boxed{F_L}(q^2)\right)\left(1-\cos^2\theta_K\right)$$

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{dq^2 d\cos\theta_L} = \frac{3}{4}\boxed{F_L}(q^2)\left(1-\cos^2\theta_L\right) + \frac{3}{8}\left(1-\boxed{F_L}(q^2)\right)\left(1+\cos^2\theta_L\right) + \boxed{A_{FB}}(q^2)\cos\theta_L$$

$$\frac{1}{\Gamma}\frac{d^3\Gamma}{d\cos\theta_k d\cos\theta_l dq^2} = \frac{9}{16}\left\{\left[\frac{2}{3}\boxed{F_S} + \frac{4}{3}\boxed{A_S}\cos\theta_k\right](1-\cos^2\theta_l) + (1-\boxed{F_S})\left[2\boxed{F_L}\cos^2\theta_k(1-\cos^2\theta_l) + \frac{1}{2}(1-\boxed{F_L})(1-\cos^2\theta_k)(1+\cos^2\theta_l) + \frac{4}{3}\boxed{A_{FB}}(1-\cos^2\theta_k)\cos\theta_l\right]\right\}$$

CMS: ~simultaneous fit and S-wave contribution

- Fit Kπμμ-mass + (θ_K, θ_l) in control channel $B^0 \to J/\psi\, K^{*0}$: measure **F_L, A_{FB}, F_S, A_S**
- Fit Kπμμ-mass + (θ_K, θ_l): measure **F_L, A_{FB}**
- Fit Kπμμ-mass: measure yield ➜ ***dBF/dq²***

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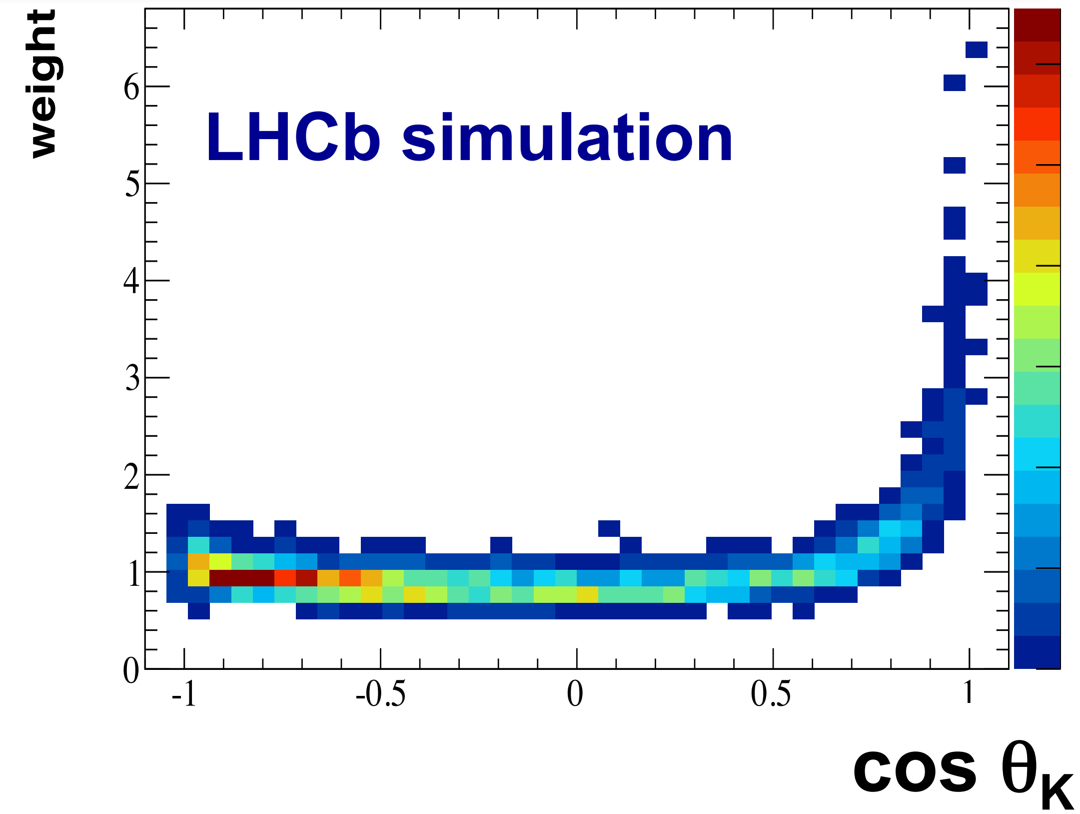
Corrections for instrumental effects

LHCb:

- from MC after data/MC reweighing, factorize contributions: $\varepsilon(\cos\theta_l)\bullet\varepsilon(\cos\theta_K)\bullet\varepsilon(\Phi)$
- fine q^2 binning:
  - q^2 width 0.1 for $q^2 < 1$ GeV^2/c^4
  - q^2 width 0.2 for $1 < q^2 < 6$ GeV^2/c^4
  - q^2 width 0.5 for $6 < q^2$ GeV^2/c^4
- binned only vs. q^2, applied as event-by-event weight

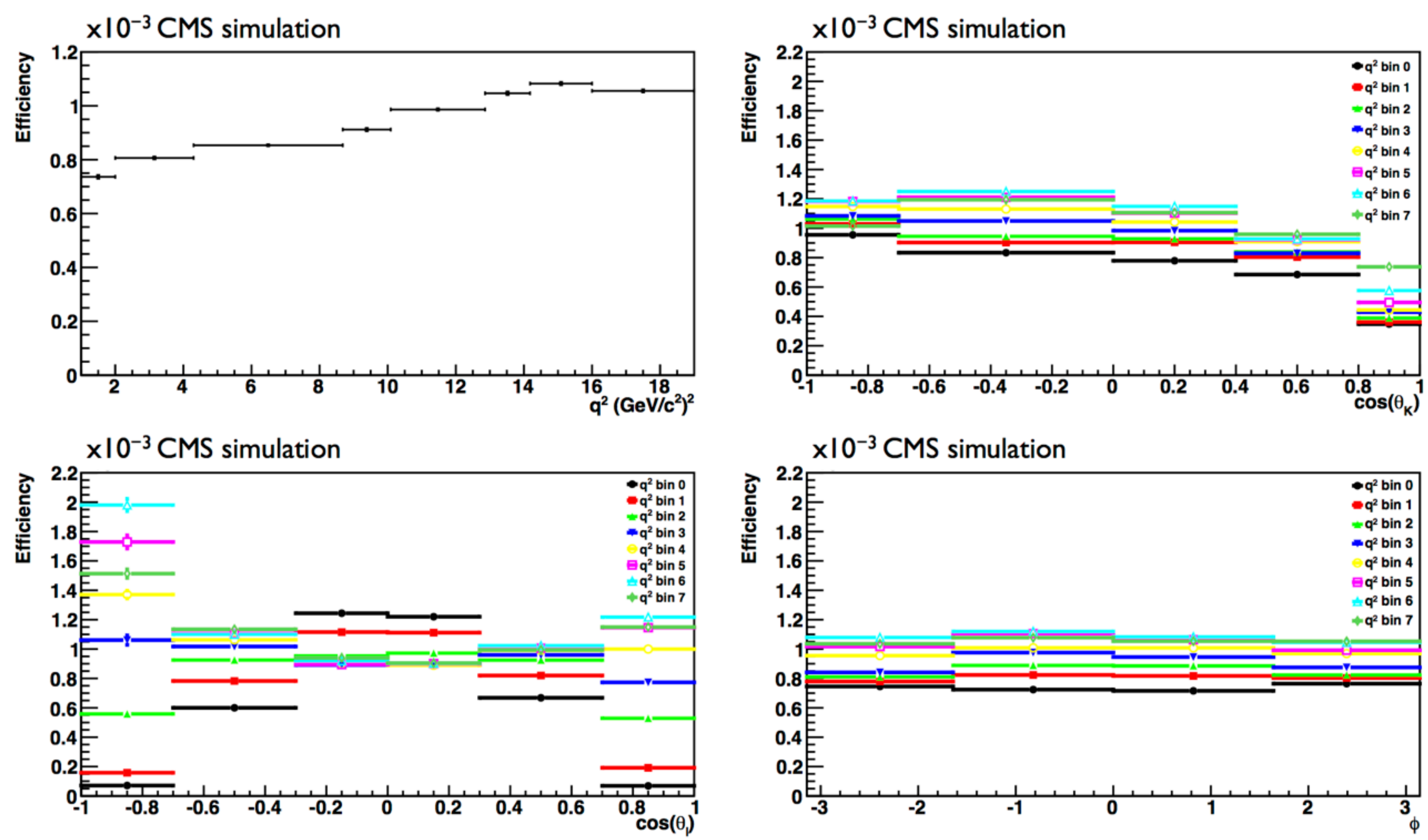


Atlas:

- entirely from MC, factorize contributions: $\varepsilon(\cos\theta_l)\bullet\varepsilon(\cos\theta_K)$
- binned in all variables, described with continuous 1D function vs. angles, applied in likelihood

CMS:

- entirely from MC, account for correlations: $\varepsilon(\cos\theta_l,\cos\theta_K)$
- binned in all variables, described with continuous 2D function vs. angles, applied in likelihood



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Statistical and systematic uncertainties

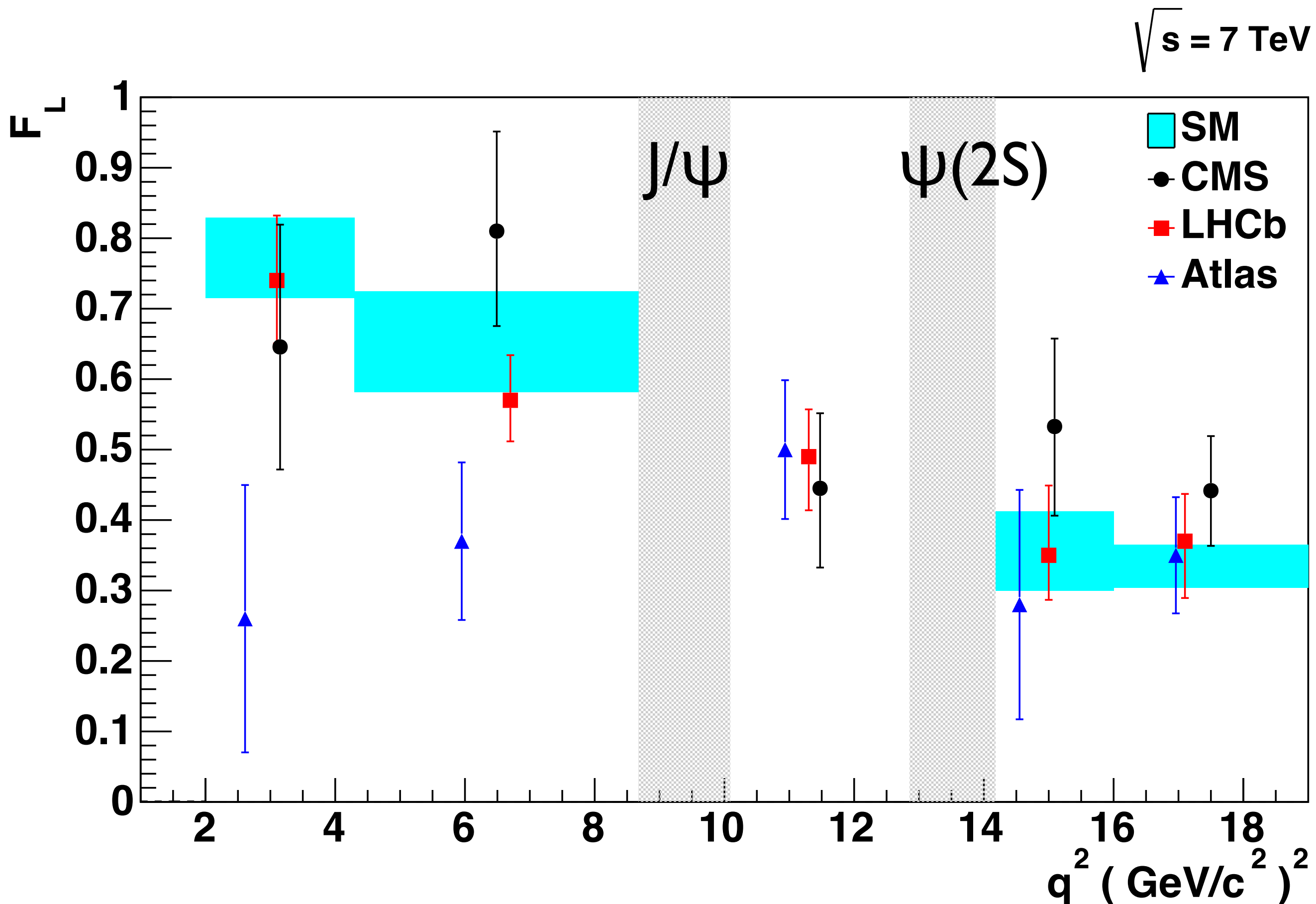
Evaluation of the statistical uncertainty

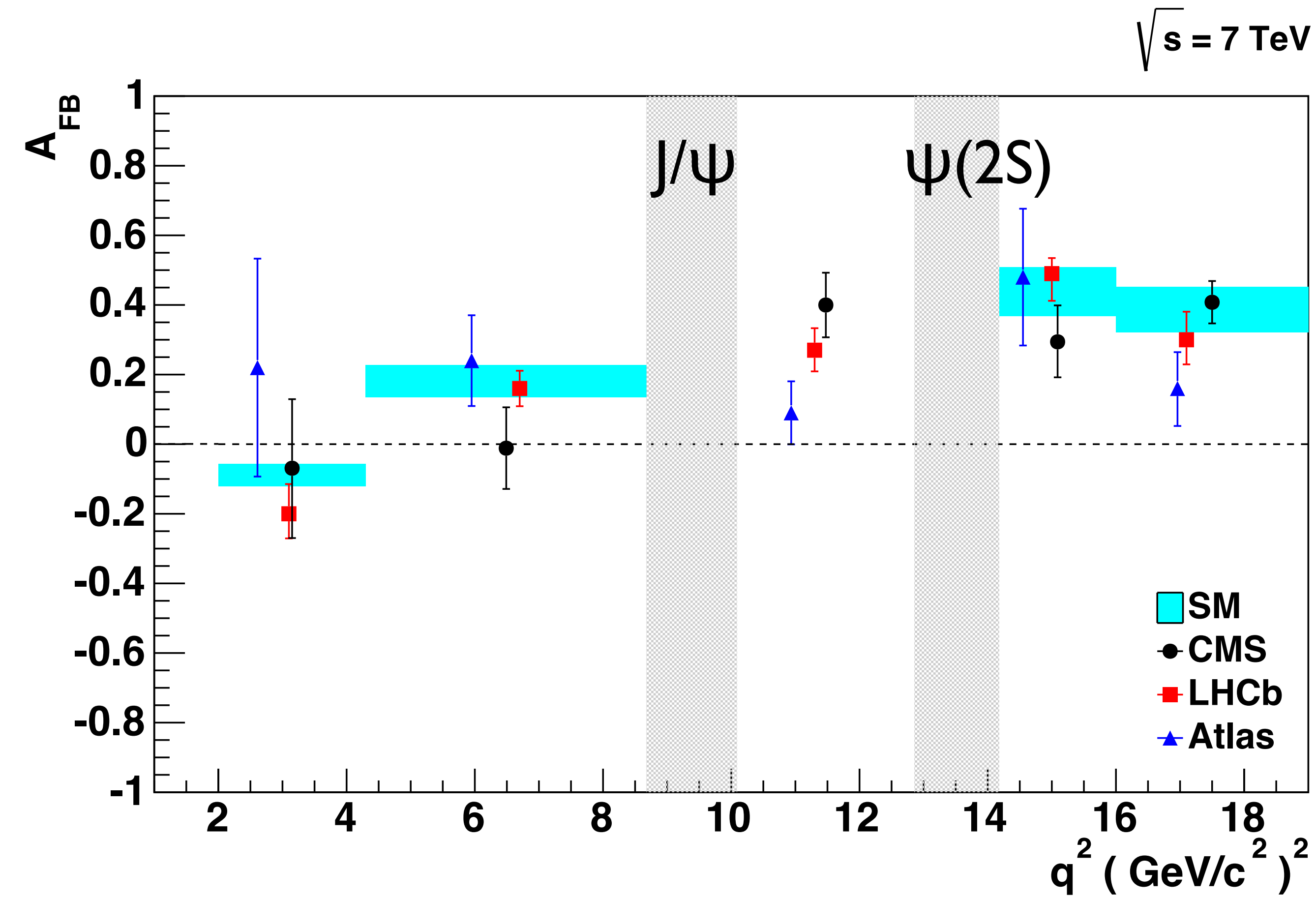
- **LHCb** (potential bias from even-weights and p.d.f. boundaries): **pseudo-experiments**
- **Atlas** (potential bias from p.d.f. boundaries): **symmetric errors out of the fit**
- **CMS** (potential bias from p.d.f. boundaries): **a-symmetric errors out of the fit**

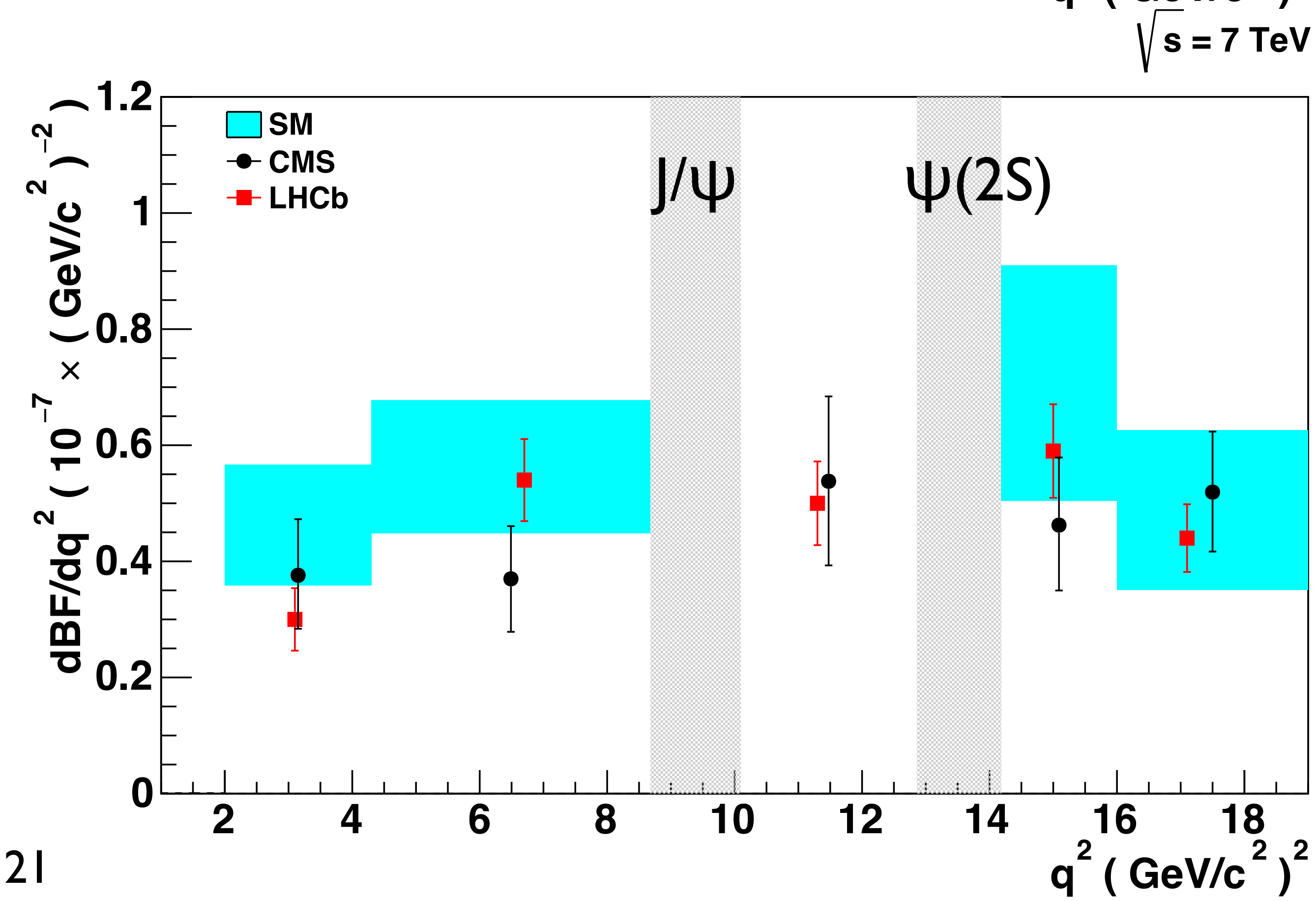
Relative importance of systematic uncertainties	**LHCb**	**Atlas**	**CMS**
Efficiency shape	Major	Relevant	Relevant dBF/dq^2
Feed-through from resonant channels	N.A.	Major	Small
Peaking background	Small	Relevant	Considered negligible
Background angular shape	Small	Small	Major
S-wave contribution	Relevant	Negligible	Small
Fit procedure	Negligible	Major q^2 bin #1 A_{FB}	Relevant dBF/dq^2
Wrong K−π assignment	Small (0.85% CP-mistag)	Small (12.5% CP-mistag)	Small (10% CP-mistag)

In all experiments total **uncertainty dominated** by **statistical error**

Measurement comparison

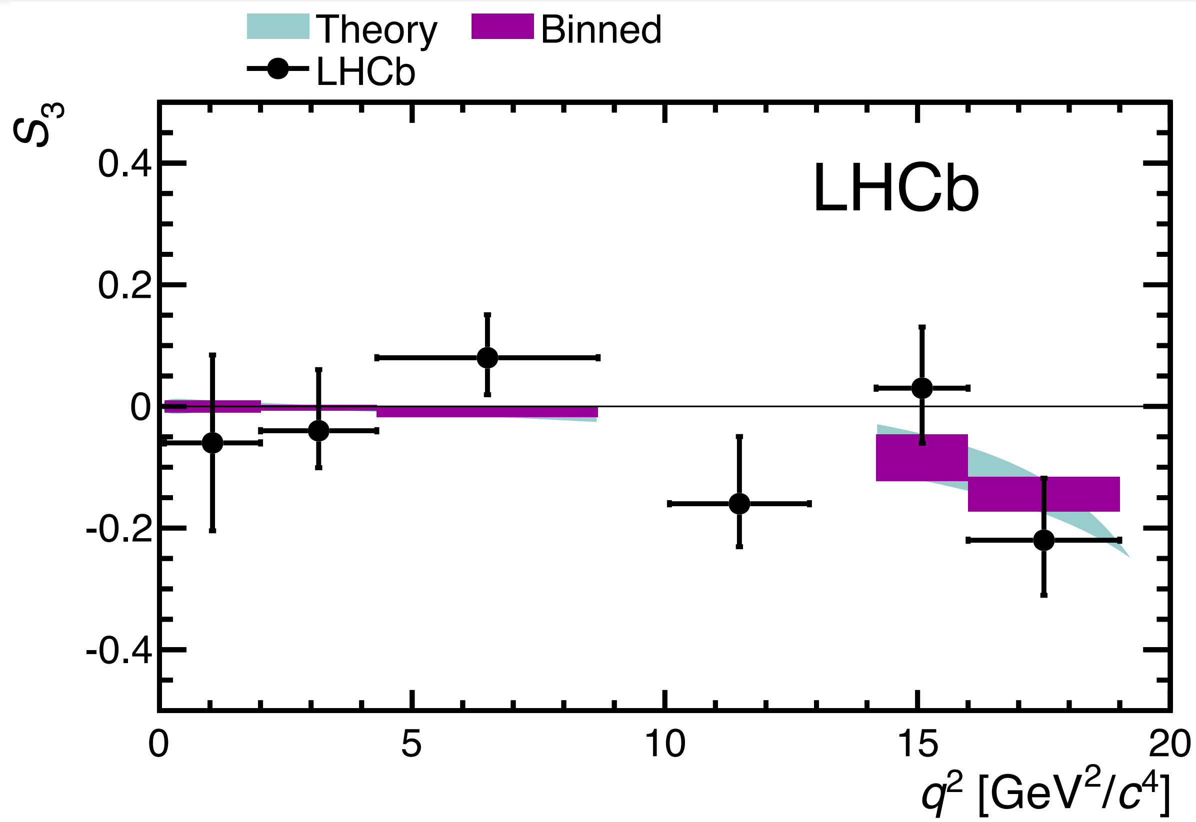


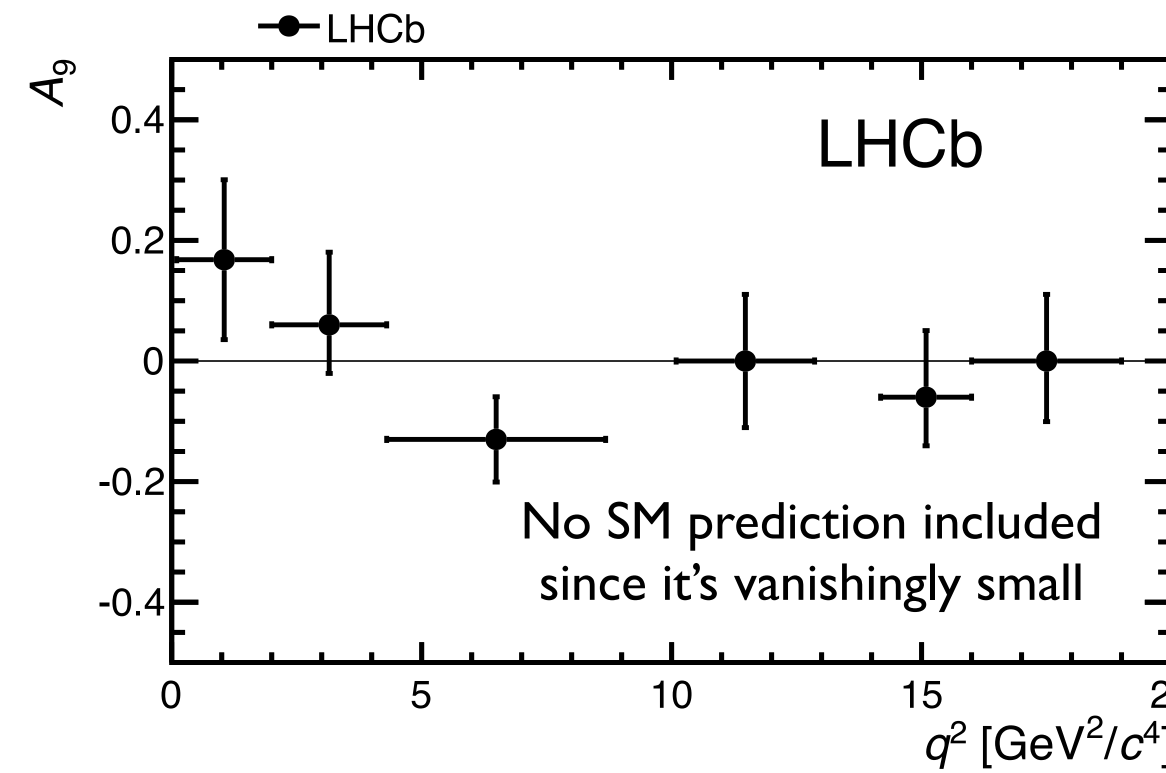




- **Cyan region:** standard model properly averaged over the bin (Phys. Rev. D **87** (2013) 034016)
- **LHCb:** arXiv 1304.6325
- **Atlas:** ATLAS-CONF-2013-038 (data points are slightly shifted along q^2 for readability purposes)
- **CMS:** CMS PAS BPH-11-009

Measurement comparison





LHCb: A_{FB} zero crossing point ($1 < q^2 < 7.8$ GeV^2/c^4):
$q^2_0 = 4.9 \pm 0.9$ GeV^2/c^4

SM predictions: $q^2_0 = 4.36 +0.33/-0.31$ GeV^2/c^4

- **Reference to decay rates:**
  - JHEP 01 (2009) 019
  - Phys. Rev. D 71, 094009 (2005)
  - Phys. Rev. D 87, 034016 (2013)
  - JHEP 03 (2013) 027

Best theoretical predictions: **$1 < q^2 < 6$ GeV^2/c^4**	**LHCb**	**Atlas**	**CMS**
F_L	$0.65+0.08/-0.07\pm0.03$	$0.18\pm0.15\pm0.03$	$0.68\pm0.10\pm0.02$
A_{FB}	$-0.17\pm0.06\pm0.04$	$0.07\pm0.20\pm0.07$	$-0.07\pm0.12\pm0.01$
dBF/dq^2	$3.4\pm0.3+0.4/-0.5$	Not measured	$4.4\pm0.6\pm0.7$

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Discussion

LHCb prospects for 2012 data analysis

$$
\begin{aligned}
\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\phi} = \frac{9}{32\pi}\Big[& S_1^s\sin^2\theta_K + S_1^c\cos^2\theta_K + \\
& S_2^s\sin^2\theta_K\cos 2\theta_\ell + S_2^c\cos^2\theta_K\cos 2\theta_\ell + \\
& S_3\sin^2\theta_K\sin^2\theta_\ell\cos 2\phi + \boxed{S_4}\sin 2\theta_K\sin 2\theta_\ell\cos\phi + \\
& \boxed{S_5}\sin 2\theta_K\sin\theta_\ell\cos\phi + S_6\sin^2\theta_K\cos\theta_\ell + \\
& \boxed{S_7}\sin 2\theta_K\sin\theta_\ell\sin\phi + \boxed{S_8}\sin 2\theta_K\sin 2\theta_\ell\sin\phi + \\
& S_9\sin^2\theta_K\sin^2\theta_\ell\sin 2\phi \Big] ,
\end{aligned}
$$

σ(pp → b-bar):
from 238 μb @ 7 TeV to 270 μb @ 8 TeV

- During **2012** LHCb collected **~2 fb^{-1}**
- Overall LHCb should have **~4000** signal events in 2011+2012
- Statistical error still dominant uncertainty

LHCb plans to measure:

- full set of observables ($\boxed{}$ variables have never been measured as of now)
- full set of CP-asymmetry variables (Φ → Φ for B^0; Φ → −Φ for B^0_{bar} ➜ $\mathbf{S_x}$ becomes $\mathbf{A_x}$):
  $\mathbf{A_3}$, $\mathbf{A_4}$, $\mathbf{A_5}$, $\mathbf{A_6}$, $\mathbf{A_7}$, and $\mathbf{A_8}$ (in addition to $\mathbf{A_9}$)

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Atlas prospects for 2012 data analysis

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\hat{\phi}} = \frac{9}{16\pi}\Big[\boxed{F_\mathrm{L}}\cos^2\theta_K + \frac{3}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K) - \boxed{F_\mathrm{L}}\cos^2\theta_K(2\cos^2\theta_\ell - 1) + \frac{1}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K)(2\cos^2\theta_\ell-1) + \boxed{S_3}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} + \frac{4}{3}\boxed{A_\mathrm{FB}}(1-\cos^2\theta_K)\cos\theta_\ell + \boxed{A_9}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi}\Big]$$

- During **2012** Atlas collected **~22 fb^{-1}**
- Statistical error still dominant uncertainty

Modification to the analysis:

- use EvtGen to describe the decay
- move to MVA and improve choice of PV (based on B^0 impact parameter)
- dedicated trigger(s) for most of 2012
- simultaneous fit Kπμμ-mass and angles

Atlas plans to re-measure:

- **A_{FB}, F_L**

Atlas foresees also to measure:

- **dBF/dq^2**, **S_3**, and **A_9**

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CMS prospects for 2012 data analysis

$$\frac{1}{\mathrm{d}\Gamma/\mathrm{d}q^2}\frac{\mathrm{d}^4\Gamma}{\mathrm{d}q^2\,\mathrm{d}\cos\theta_\ell\,\mathrm{d}\cos\theta_K\,\mathrm{d}\hat{\phi}} = \frac{9}{16\pi}\Big[\boxed{F_\mathrm{L}}\cos^2\theta_K + \frac{3}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K) - \boxed{F_\mathrm{L}}\cos^2\theta_K(2\cos^2\theta_\ell - 1) + \frac{1}{4}(1-\boxed{F_\mathrm{L}})(1-\cos^2\theta_K)(2\cos^2\theta_\ell-1) + \boxed{S_3}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\cos 2\hat{\phi} + \frac{4}{3}\boxed{A_\mathrm{FB}}(1-\cos^2\theta_K)\cos\theta_\ell + \boxed{A_9}(1-\cos^2\theta_K)(1-\cos^2\theta_\ell)\sin 2\hat{\phi}\Big]$$

σ(pp → b-bar):
from 238 μb @ 7 TeV to 270 μb @ 8 TeV

- During **2012** CMS collected **~22 fb^{-1}**
- Overall CMS should have **~2700 signal events** in 2011+2012
- Statistical error still dominant uncertainty

CMS plans to re-measure:

- **A_{FB}, F_L, d*BF*/dq^2**

CMS foresees also to measure:

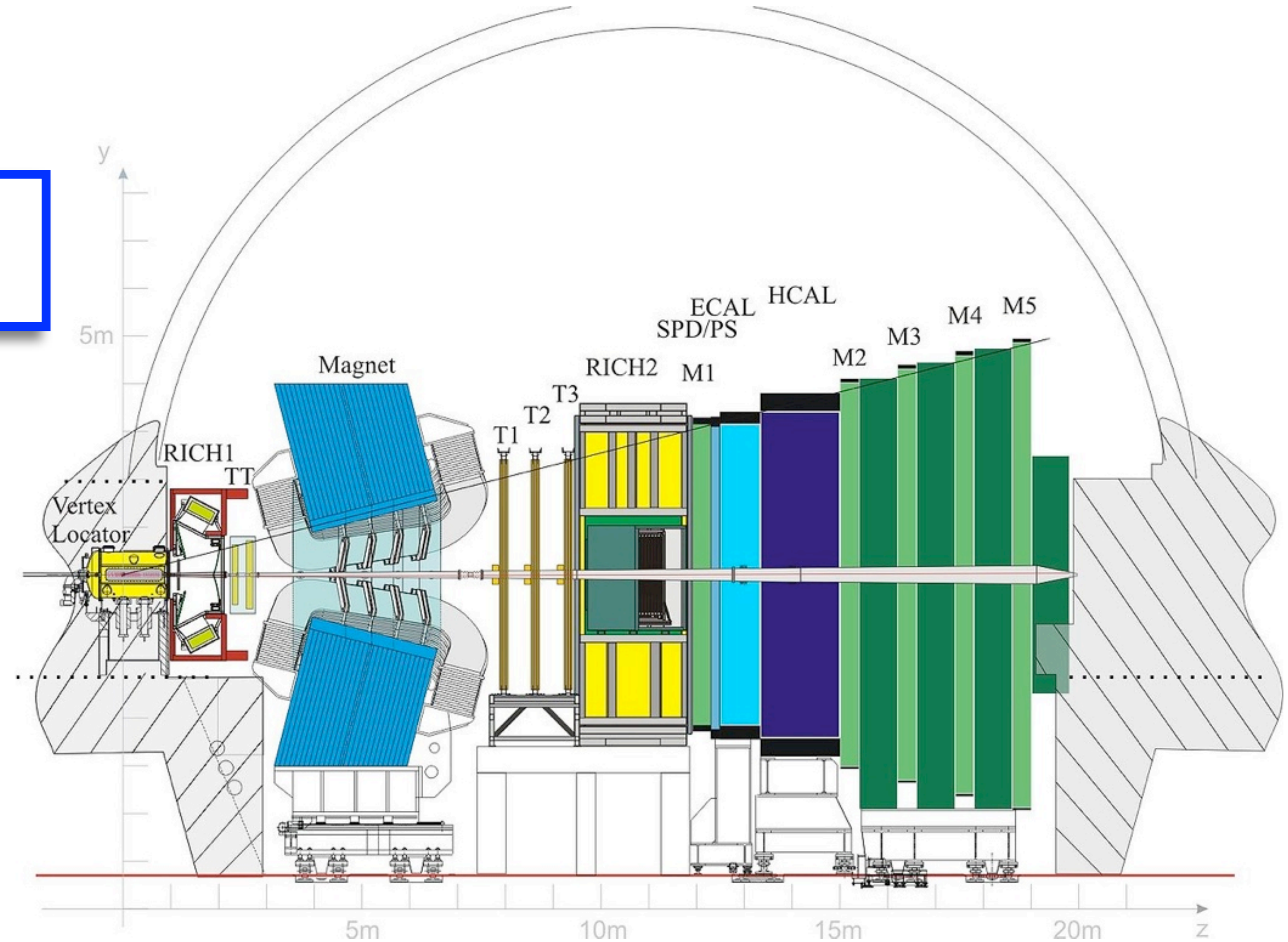
- **zero crossing point of A_{FB}**
- remaining angular parameters: **S_3, S_9** from a full fit
- some CP-asymmetry parameters (e.g. **A_9** and in **d*BF*/dq^2**)

Backup

LHCb detector

Muon ID:

- track match with *n* μ-segments (p_T dependent)

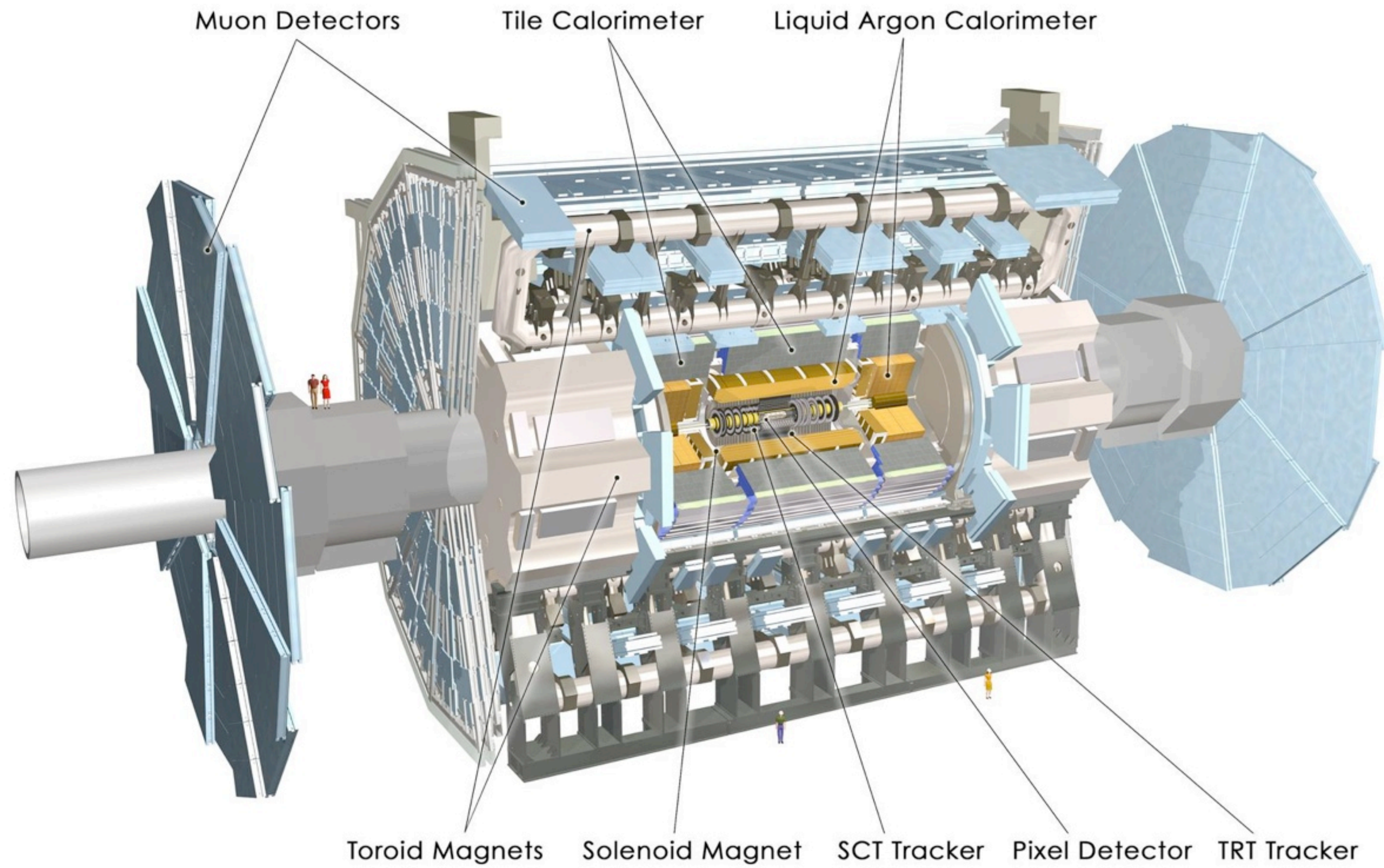


- Pseudorapidity coverage: $2 < \eta < 5$
- Momentum resolution: 0.4 − 0.6% from 5 to 100 GeV/c tracks
- Impact parameter resolution: 20 μm
- Muon misidentification: ~0.5%
- Mass resolution $J/\psi \to \mu\mu$: 13 MeV/c^2
- RICH detectors: kao-pion separation in momentum range 2 − 100 GeV/c

Atlas detector

Muon ID:

- track match with μ-segment
- pixel hits > 1
- SCT hits > 6
- TRT hits > 9
- p_T > 3.5 GeV/c
- $|\eta| < 2.5$



- Pseudorapidity coverage: $|\eta| < 2.5$
- Transverse momentum resolution: 4 − 8% from 4 to 10 GeV/c and 4% for > 10 GeV/c tracks
- Impact parameter resolution: 12 μm
- Muon misidentification: ~0.4%
- Mass resolution $J/\psi \to \mu\mu$: 46 MeV/c^2
- No detector for particle ID

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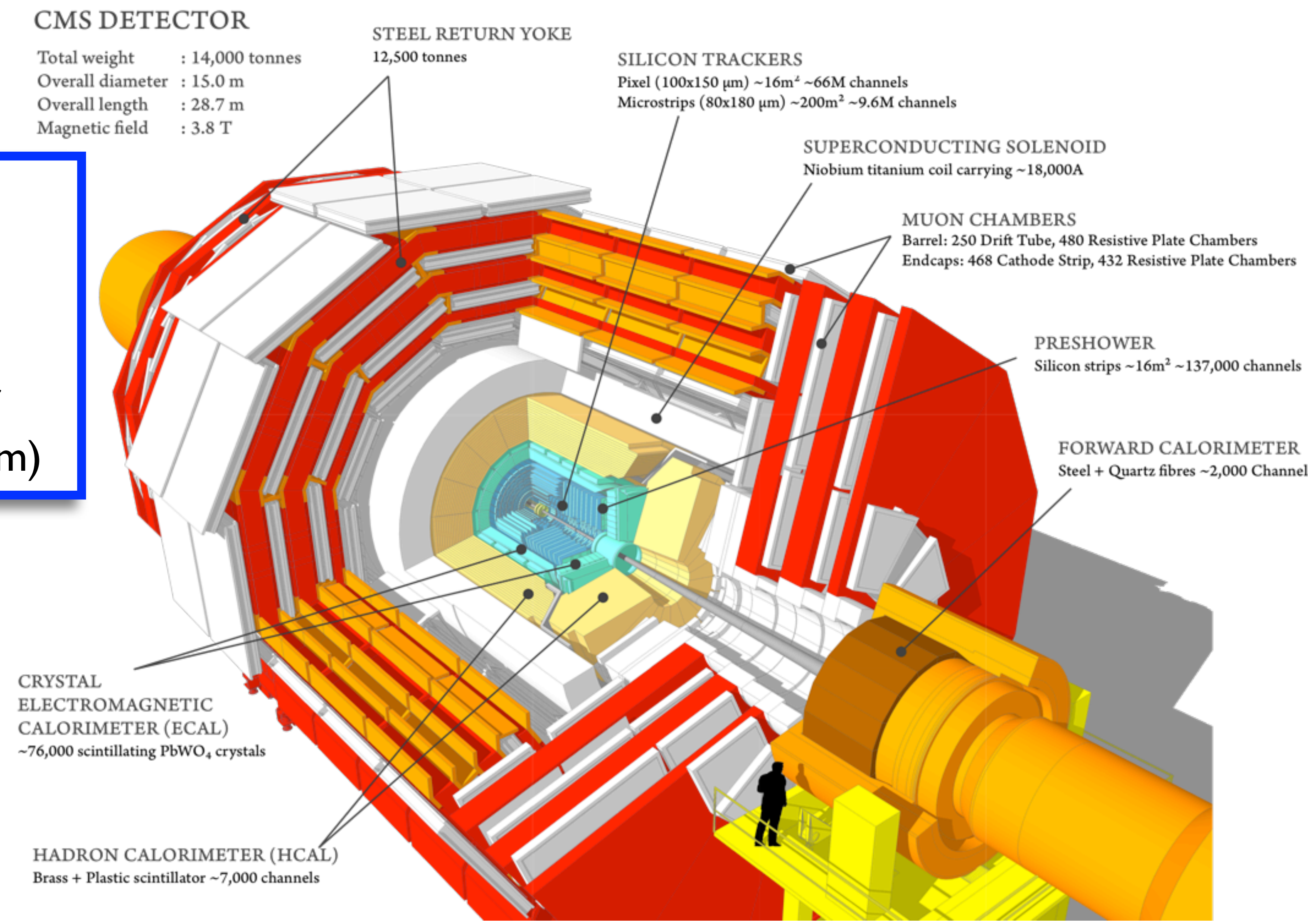
CMS detector



Muon ID:

- track match with at least 1 μ-segment
- track fit χ^2/dof < 1.8
- hits in tracker > 11, with > 2 in pixel detector
- transverse (long.) impact param. < 3 cm (30 cm)

- Pseudorapidity coverage: $|\eta| < 2.5$
- Transverse momentum resolution: 1.5% up to 100 GeV/c tracks
- Impact parameter resolution: 15 μm
- Muon misidentification: ~0.2%
- Mass resolution $J/\psi \to \mu\mu$: 28 MeV/c^2
- No detector for particle ID

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Other FCNC $b \to s$ decays

The FCNC ($b \to s$) decays are a goldmine for new physics searches

- **$B^+ \to K^{*+}(\pi^+ K^0_s (\pi^+\pi^-)) \mu\mu$**
  - $\Gamma \sim 1/7$ of $B^0 \to K^{*0} \mu\mu$ (assumed 30% eff. due to K^0_s reco.)
  - Can help to improve statistics for $B^0 \to K^{*0} \mu\mu$ studies

- **$B^+ \to K^+ \mu\mu$ (and $B^0 \to K^0 \mu^+ \mu^-$)**
  - Γ similar to ($\Gamma \sim 1/3$ of) $B^0 \to K^{*0} \mu\mu$
  - Certain degree of complementarity with $B^0 \to K^{*0} \mu\mu$ ➜ important probe of right-handed currents

  Preliminary analysis by LHCb (arXiv: 1209.4284)

- **$\Lambda_b \to \Lambda^0 (p\pi) \mu\mu$**
  - $\Gamma \sim 1/5$ of $B^0 \to K^{*0} \mu\mu$ (assumed 1/3 K^0_s eff. due to soft π)
  - Λ_b and Λ^0 are spin-1/2 particles ➜ unlike the B^0 decay, this decay is sensitive to right-handed couplings which are suppressed in SM ➜ also this decay is somewhat complementary to $B^0 \to K^{*0} \mu\mu$

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