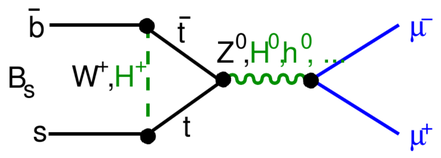
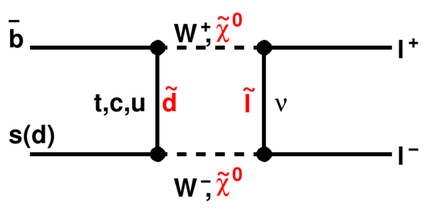
$B^0_{s(d)} \to \mu\mu$ Search with 1.14 fb^{-1} of CMS Data

Motivation

- Highly suppressed in the Standard Model
  - flavor-changing neutral current: b → s(d)
  - internal quark annihilation: $(f_B/m_B)^2 \approx 2\times10^{-3}$
  - helicity suppressed by factors of m_μ^2
- Enhanced in many models of new physics (green and red contributions to the diagrams)
- $B_s^0 \to \mu\mu$ and $B^0 \to \mu\mu$ are enhanced separately in models containing lepto-quarks, SUSY with non-universal Higgs, and MSSM with large tanβ (proportional to $\tan^6\beta$)



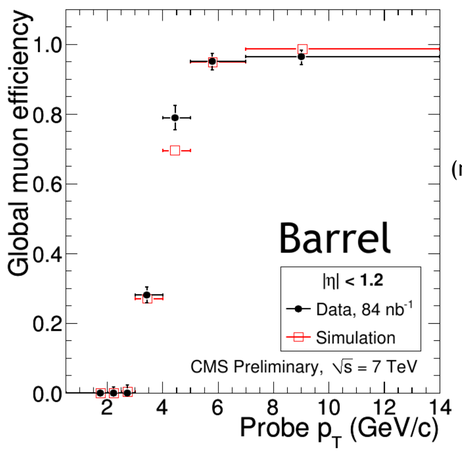


$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) = (1.0 \pm 0.1) \times 10^{-10}$$

(Buras 2010)

Muon Reconstruction

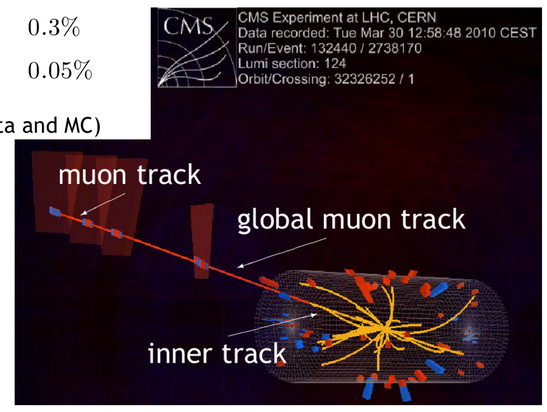
- Large muon system
  - pseudorapidity coverage up to 2.4
  - 3–4 layers of muon chambers, each containing 6–12 measurement planes
- Two reconstruction algorithms: inside-out and outside-in (both required for this analysis)
- Well-understood efficiency and misidentification rates



Muon misidentification

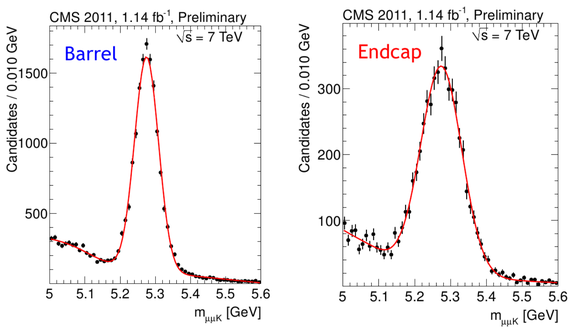
$$\varepsilon(\mu|\pi) \leq 0.3\%$$
$$\varepsilon(\mu|K) \leq 0.3\%$$
$$\varepsilon(\mu|p) \leq 0.05\%$$

(measured in data and MC)

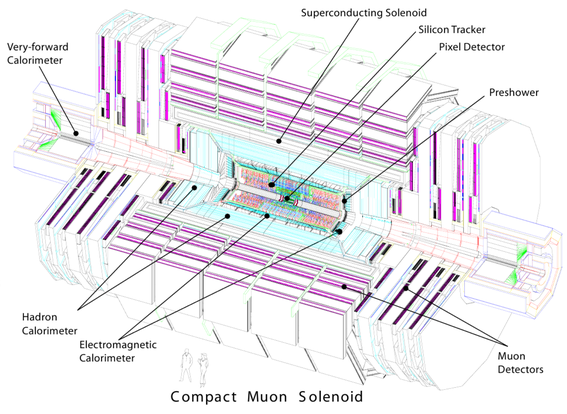


Detector Resolution

$B^\pm \to J/\psi K^\pm$ mass resolutions



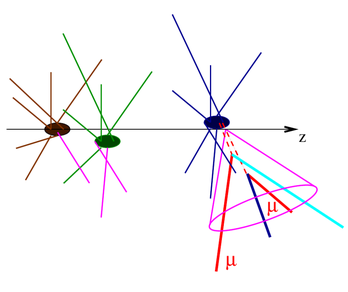
CMS detector



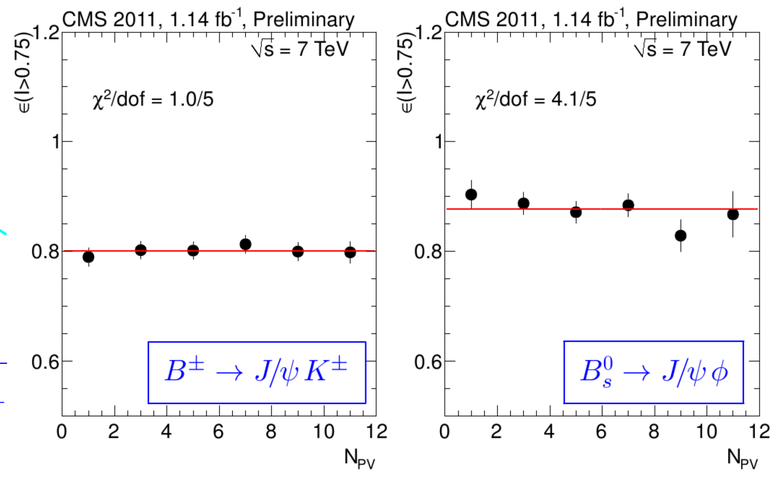
Component	Characteristics	resolutions
Pixel	3/2 Si layers	$\delta_z \approx 20\,\mu$m, $\delta_\phi \approx 10\,\mu$m
Tracker	10/12 Si strips	$\delta(p_\perp)/p_\perp \approx 1\%$
ECAL	$PbWO_4$	$\delta E/E \approx 3\%/\sqrt{E} \oplus 0.5\%$
HCAL (B)	Brass/Sc, $> 7.2\lambda$	$\delta E/E \approx 100\sqrt{E}\%$
HCAL (F)	Fe/Quartz	$\delta(\not{E}_T) \approx 0.98\sqrt{\sum E_T}$
Magnet	3.8 T solenoid	
Muons	DT/CSC + RPC	$\delta(p_\perp)/p_\perp \approx 10\%$ (STA)

(Lack of) Dependence on Pile-Up

- High-quality alignment and deterministic annealing reconstruction of primary vertices yields significant separation of collision centers
- Track-based quantities are restricted to the primary vertex responsible for the muon pair
- Independence of isolation and flight significance cuts tested with data up to $N_{PV} = 12$
- Current average $N_{PV} = 5.5$



$$I = \frac{p_\perp(\mu^+\mu^-)}{p_\perp(\mu^+\mu^-) + \sum_{\Delta R<1} p_\perp}$$

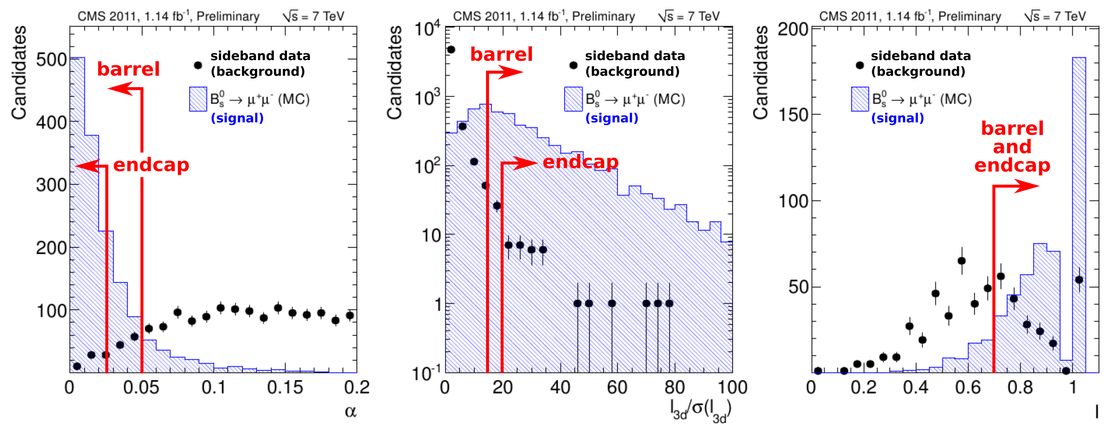


Analysis

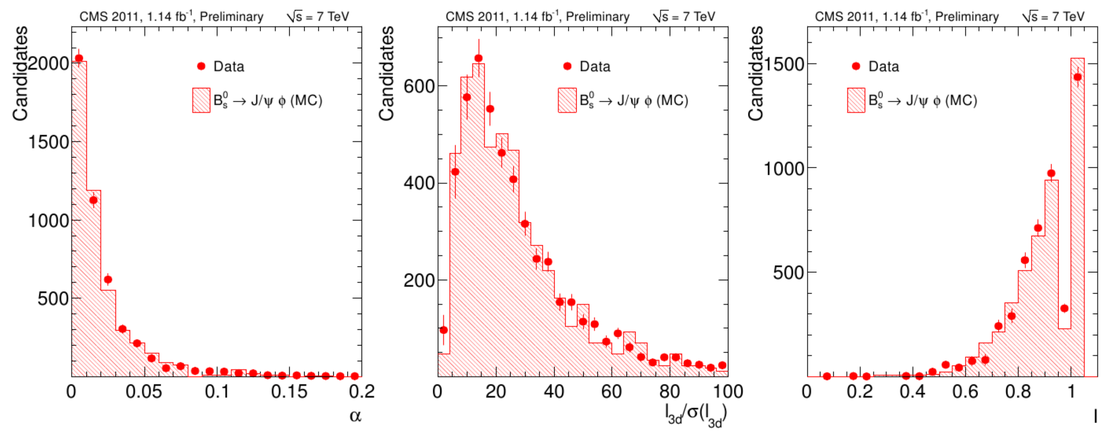
- Barrel (both muon $|\eta| < 1.4$) and endcap (at least one $|\eta| \geq 1.4$) treated as separate channels
- Signal branching fractions measured relative to normalization samples

$$\mathcal{B}(B_s^0 \to \mu\mu) = \frac{N_S}{N_{obs}^{B^\pm}} \frac{f_u}{f_s} \frac{\varepsilon_{tot}^{B^\pm}}{\varepsilon_{tot}} \mathcal{B}(B^\pm \to J/\psi\, K^\pm)$$

- Event selection (grid-search optimized):
  - $p_T > 4.5$ GeV/c (highest-pT muon), 4.0 (second muon), and 6.5 (vector sum)
  - track $\chi^2 < 1.6$
  - 3D pointing angle α, 3D flight significance $\ell/\sigma(\ell)$, and isolation shown below
  - additional isolation for endcap: non-muon closest approach to B vertex > 150 μm

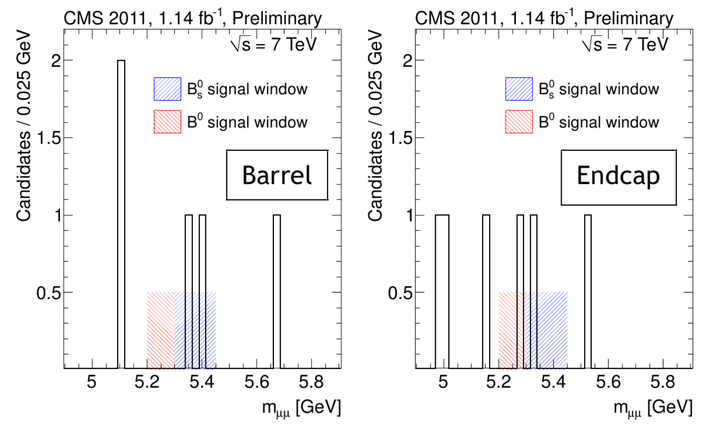


- Validate Monte Carlo by comparing $B_S^0 \to J/\psi\,\varphi$ data with simulation



Results

- 17% systematic uncertainty (dominated by f_u/f_s ratio)
- Consistent with the Standard Model and no $B_{s(d)} \to \mu\mu$ observation
- Upper limits from CL_S
- Constrains new physics models (not shown here)



	Barrel		Endcap	
	$B^0 \to \mu^+\mu^-$	$B_s^0 \to \mu^+\mu^-$	$B^0 \to \mu^+\mu^-$	$B_s^0 \to \mu^+\mu^-$
Acceptance	$(24.62 \pm 0.99) \times 10^{-2}$	$(24.72 \pm 0.99) \times 10^{-2}$	$(22.61 \pm 0.91) \times 10^{-2}$	$(23.14 \pm 0.93) \times 10^{-2}$
$\varepsilon_{analysis}$	$(2.23 \pm 0.19) \times 10^{-2}$	$(2.22 \pm 0.19) \times 10^{-2}$	$(1.16 \pm 0.10) \times 10^{-2}$	$(1.24 \pm 0.11) \times 10^{-2}$
ε_{tot}	$(0.36 \pm 0.04) \times 10^{-2}$	$(0.36 \pm 0.04) \times 10^{-2}$	$(0.21 \pm 0.02) \times 10^{-2}$	$(0.21 \pm 0.02) \times 10^{-2}$
N_{signal}^{exp}	0.065 ± 0.011	0.80 ± 0.16	0.025 ± 0.004	0.36 ± 0.07
N_{bg}^{exp}	0.40 ± 0.23	0.60 ± 0.35	0.53 ± 0.27	0.80 ± 0.40
N_{peak}^{exp}	0.25 ± 0.06	0.07 ± 0.02	0.16 ± 0.04	0.04 ± 0.01
N_{obs}	0	2	1	1

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 1.9 \times 10^{-8} \quad (95\%\ \text{C.L.})$$
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 1.6 \times 10^{-8} \quad (90\%\ \text{C.L.})$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 4.6 \times 10^{-9} \quad (95\%\ \text{C.L.})$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 3.7 \times 10^{-9} \quad (90\%\ \text{C.L.})$$

p values for background-only hypothesis
- $B_s^0 \to \mu^+\mu^-$: 0.11
- $B^0 \to \mu^+\mu^-$: 0.40

p value for $5.6 \times$ SM (cf. arXiv:1107.2304)
- $B_s^0 \to \mu^+\mu^-$: 0.053

see https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsBPH for more

Poster prepared by Jim Pivarski on behalf of the CMS Collaboration