Results on production and decay of B hadrons and onia and X(5568) state search in CMS

EPS Conference on High Energy Physics
Venice, Italy 5-12 July 2017

Polikarpov Sergey (MEPhI, Moscow)

on behalf of CMS collaboration

July 6th, 2017

Outline

- Lifetime measurements of b hadrons reconstructed in final states with a J/ψ meson
- Observation of $\Upsilon(1S)$ pair production in proton-proton collisions at $\sqrt{s}=8$ TeV
- Search for X(5568)

Charge conjugate candidates are implied throughout the presentation

Lifetime measurements of b hadrons

- Many models have accurate predictions for b hadron lifetimes and their ratios, HQE model estimates are in agreement with existing measurements
- CMS is capable of making the lifetime measurements with precision competitive to LHCb and B-factories, using a J/ψ trigger
- There was some discrepancy in B_c^+ lifetime: LHCb results exceed Tevatron results (~500 fs *vs* ~450 fs) and a new independent measurement is needed to resolve it
- The presented results include measurement of B^0, B_s^0, B_c^+, and Λ_b^0 lifetimes

Lifetime measurements of b hadrons

- The lifetime is measured using variable $ct = \frac{L_{xy}}{(\beta\gamma)_T} = L_{xy}\frac{M}{p_T}$
- Dataset: 19.7 fb^{-1} of pp collisions at 8 TeV (2012)
- Triggered by $J/\psi \to \mu^+\mu^-$
- The following decays are used (always $J/\psi \to \mu^+\mu^-$):
  - $B^0 \to J/\psi\ K^*(892)^0$, $K^*(892)^0 \to K^+\pi^-$
  - $B^0 \to J/\psi\ K^0_S$, $K^0_S \to \pi^+\pi^-$
  - $B^0_s \to J/\psi\ \varphi(1020)$, $\varphi(1020) \to K^+K^-$
  - $B^0_s \to J/\psi\ \pi^+\pi^-$ (in $f(980)^0$ region)
  - $\Lambda^0_b \to J/\psi\ \Lambda^0$, $\Lambda^0 \to p^+\pi^-$
  - $B^+_c \to J/\psi\ \pi^+$ (and reference $B^+ \to J/\psi\ K^+$)

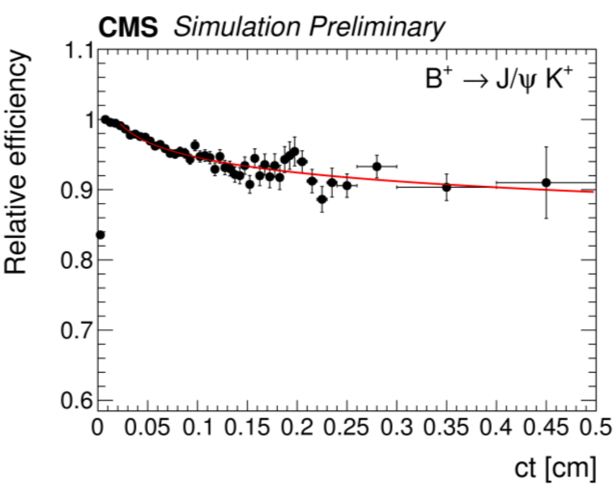
Lifetime measurements of b hadrons

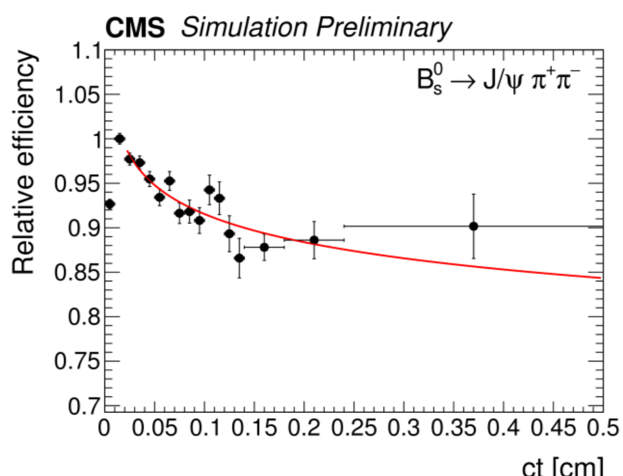
- For each b-hadron, a 3-dimensional unbinned maximum-likelihood fit is used: m, ct, σ_{ct}

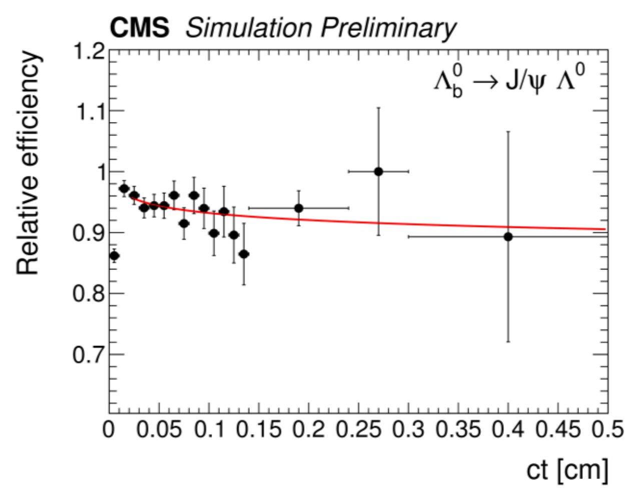
b-hadron mass → m; per-event *ct* uncertainty → σ_{ct}

$$ct = \frac{L_{xy}}{(\beta\gamma)_T} = L_{xy}\frac{M}{p_{\mathrm{T}}}$$

- Efficiency dependence on *ct* is taken into account in the fits



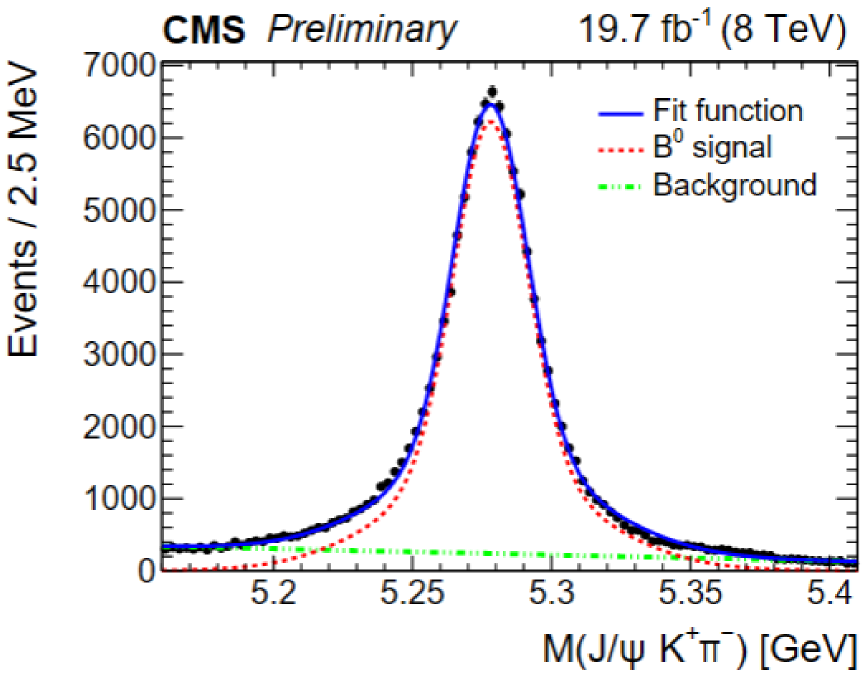


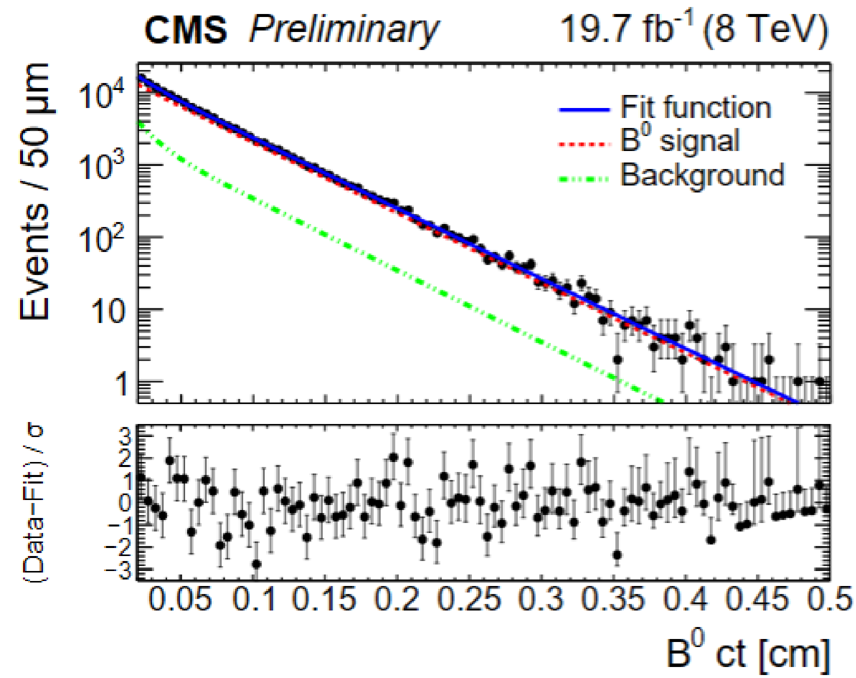


More details in backup

Lifetime measurements of b hadrons

- $B^0 \to J/\psi\ K^*(892)^0$, $K^*(892)^0 \to K^+\pi^-$





p_T(leading/subleading track) > 2.5 / 1.5 GeV

K-π mass assignment: closer to $M^{PDG}(K^*(892)^0)$

$0.796 < m(K^*(892)^0) < 0.988$ GeV

$p_T(K^*(892)^0) > 3.5$ GeV

$p_T(B^0) > 13$ GeV

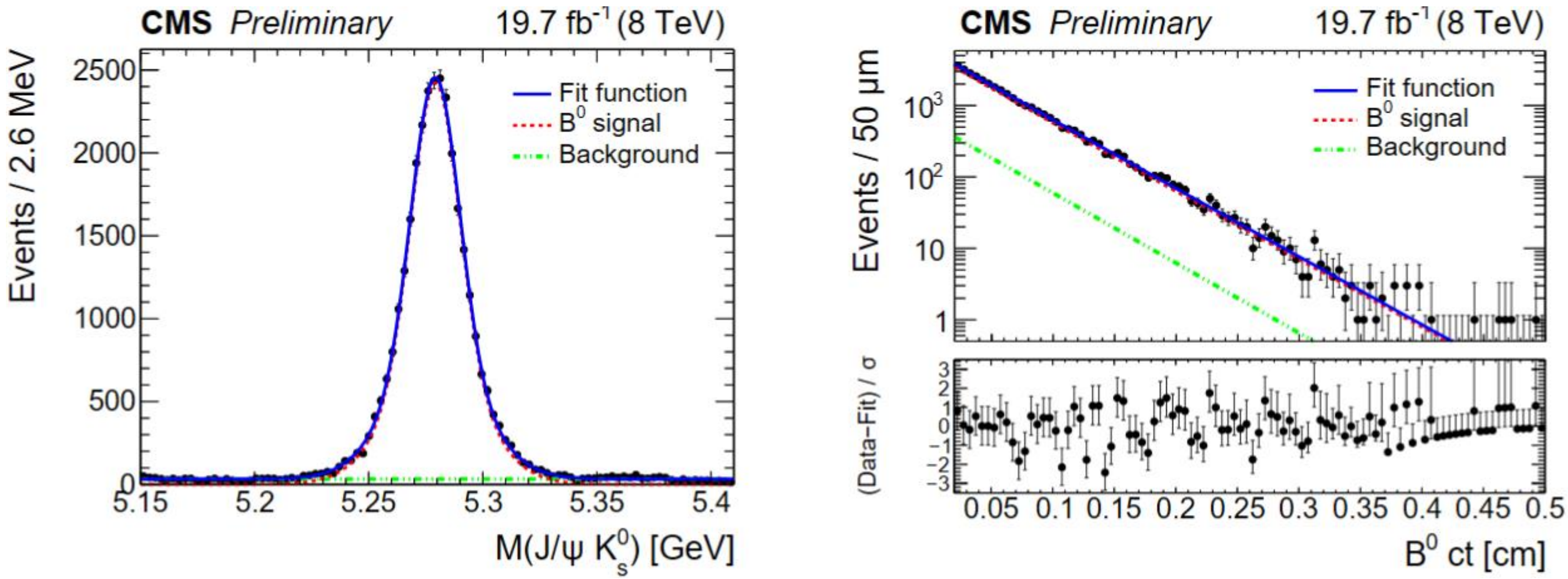
Fit results:

$$c\tau\left(B^0 \to J/\psi\ K^*(892)^0\right) = 453.0 \pm 1.6\ \mu m$$

CMS-PAS-BPH-13-008

Lifetime measurements of b hadrons

- $B^0 \to J/\psi\, K^0_S$, $K^0_S \to \pi^+\pi^-$



K^0_S mass constraint, Λ^0 vetoed

p_T(leading track) > 1.8 GeV

track $d_{xy}/\sigma > 2$, K^0_S vertex $L_{xy}/\sigma > 15$

$0.4876 < m(K^0_S) < 0.5076$ GeV

$p_T(B^0) > 13$ GeV

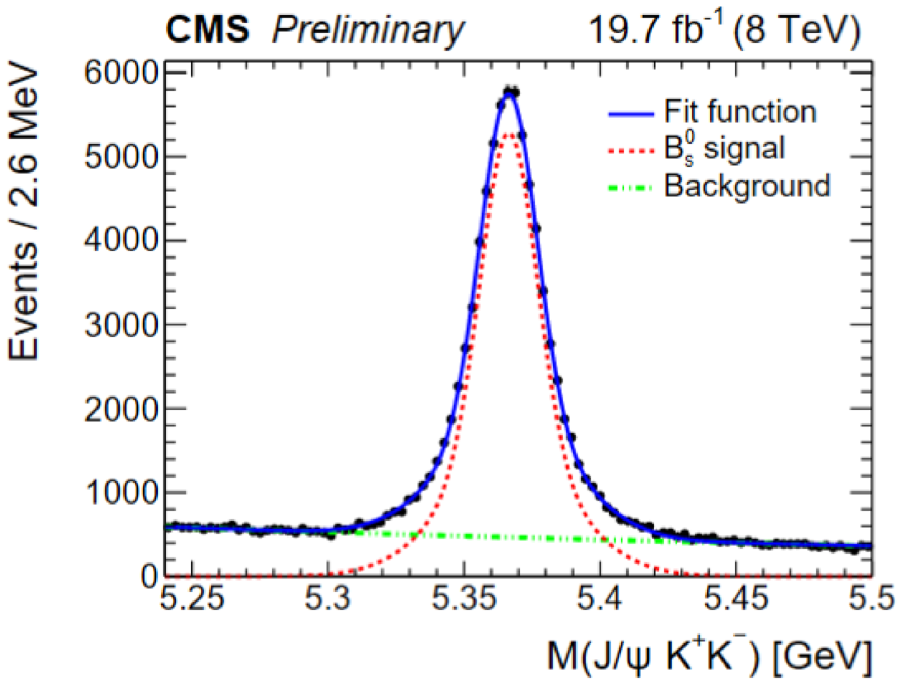
Fit results:

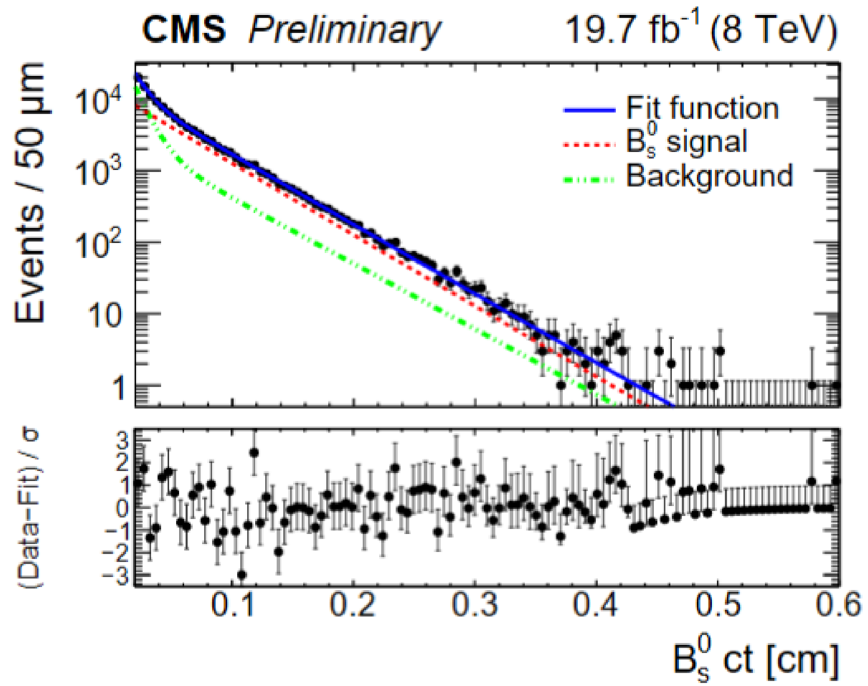
$$c\tau\,(B^0 \to J/\psi\, K^0_S) = 457.8 \pm 2.7\ \mu m$$

consistent with previous slide

Lifetime measurements of b hadrons

- $B_s^0 \rightarrow J/\psi\ \varphi(1020)$, $\varphi(1020) \rightarrow K^+K^-$





$p_T(K^\pm) > 0.7$ GeV

$1.0095 < m(K^+K^-) < 1.0295$ GeV

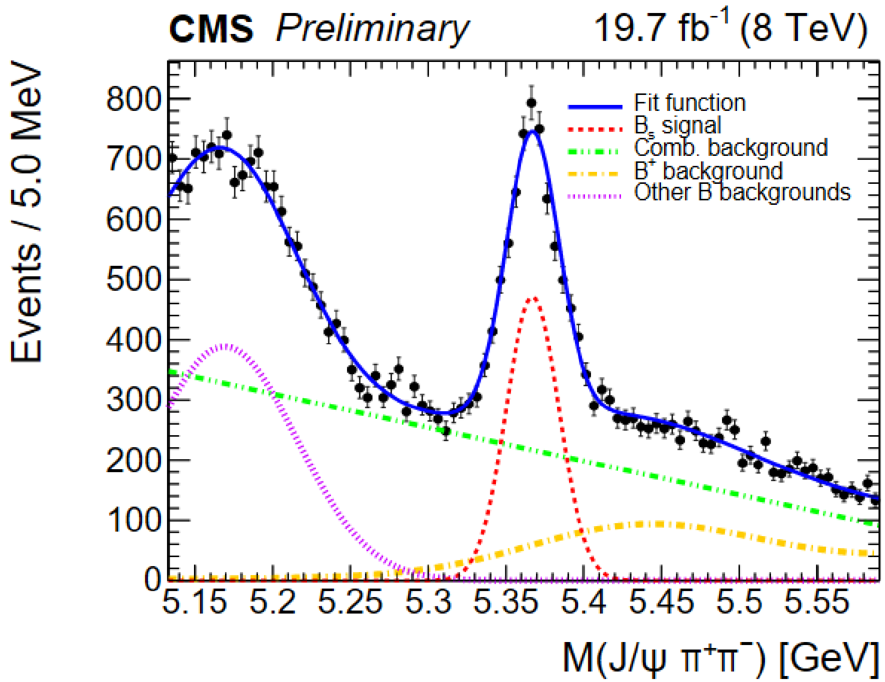
Fit results:

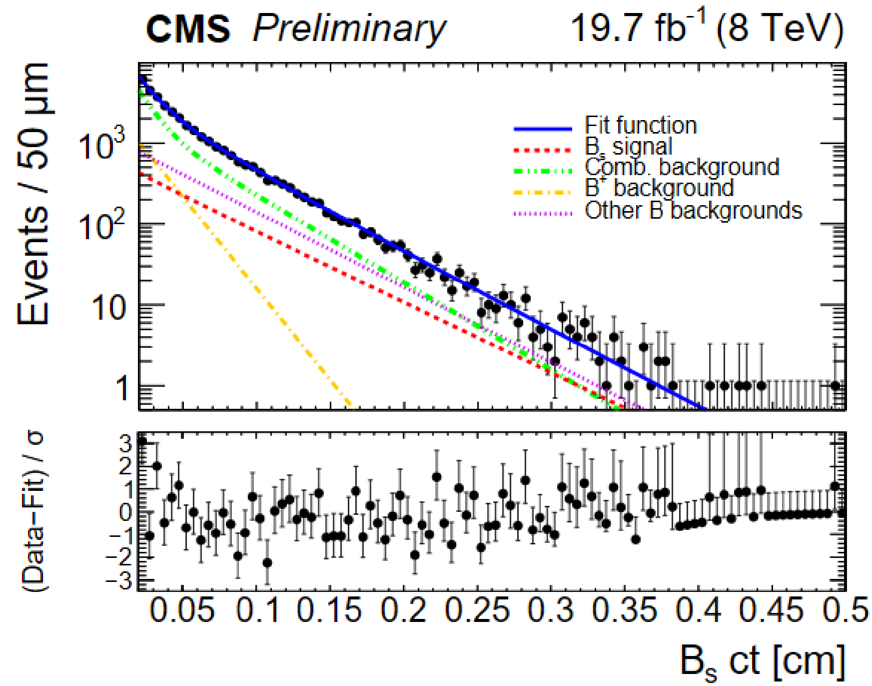
$$c\tau\left(B_s^0 \rightarrow J/\psi\ \varphi(1020)\right) = 445.2 \pm 2.0\ \mu m$$

CMS-PAS-BPH-13-008

Lifetime measurements of b hadrons

- $B_s^0 \to J/\psi\ \pi^+\pi^-$ (in $f(980)^0$ region)





p_T(leading/subleading track) > 2.5 / 1.5 GeV

$0.924 < m(\pi^+\pi^-) < 1.0204$ GeV

$p_T(\pi^+\pi^-) > 3.5$ GeV

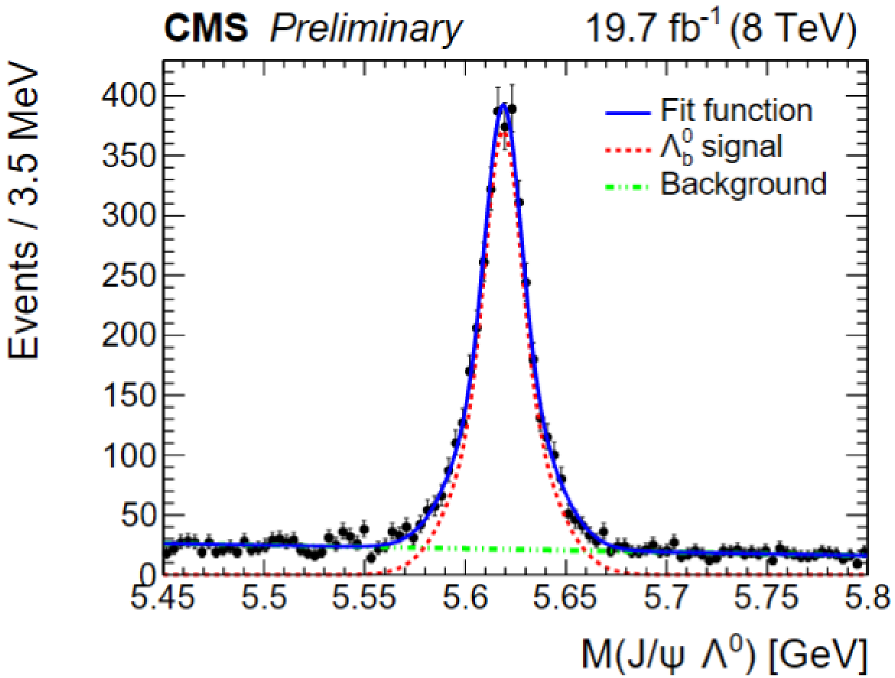
$p_T(B_s^0) > 13$ GeV

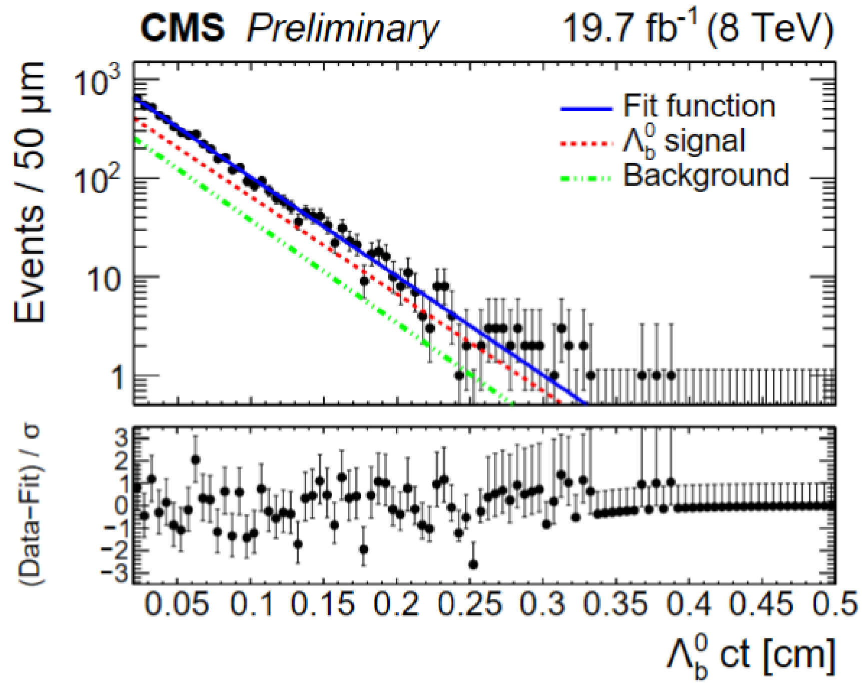
Fit results:

$$c\tau\,(B_s^0 \to J/\psi\ \pi^+\pi^-) = 504.3 \pm 10.5\ \mu m$$

Lifetime measurements of b hadrons

- $\Lambda_b^0 \to J/\psi\, \Lambda^0$, $\Lambda^0 \to p\pi^-$





Λ^0 mass constraint, K_S^0 vetoed

p_T(leading track) > 1.8 GeV

track $d_{xy}/\sigma > 2$, Λ^0 vertex $L_{xy}/\sigma > 15$

$1.1096 < m(\Lambda^0) < 1.1216$ GeV

$p_T(\Lambda_b^0) > 13$ GeV

Fit results:

$$c\tau\,(\Lambda_b^0 \to J/\psi\, \Lambda^0) = 457.8 \pm 2.7\ \mu m$$

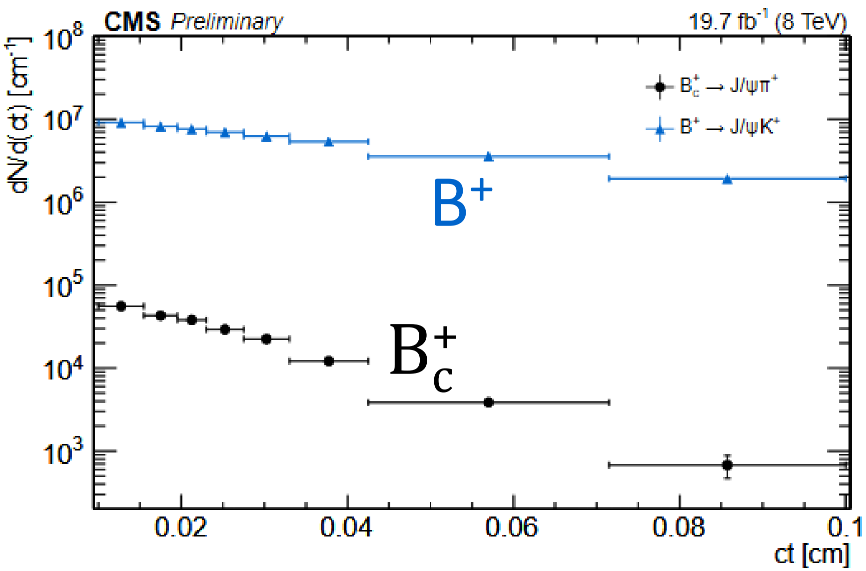
Lifetime measurements of b hadrons

- $B_c^+ \rightarrow J/\psi\ \pi^+$ (using reference $B^+ \rightarrow J/\psi\ K^+$)

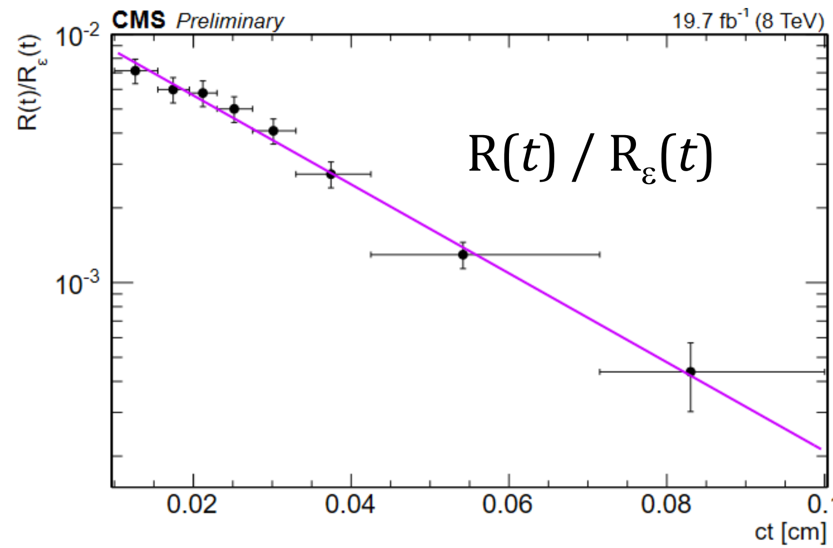
$R(t) = [\ N(B_c^+)\ /\ N(B^+)\ ](t) = R_\varepsilon(t)\ \exp(-\Delta\Gamma t)$

$$\Delta\Gamma \equiv \Gamma_{B_c^+} - \Gamma_{B^+} = \frac{1}{\tau_{B_c^+}} - \frac{1}{\tau_{B^+}}$$

Signal yields in bins of ct



Efficiency-corrected yield ratio



$p_T(K^+/\pi^+) > 3.3$ GeV; $p_T(B^+_{(c)}) > 10$ GeV; $|y|\ (B^+_{(c)}) < 2.2$

This "reference" method was used by LHCb Phys.Lett.B 742 (2015) 29 → $c\tau\ (B_c^+) = 153.9 \pm 3.7\ \mu m$

Fit result: $\Delta\Gamma = 4.12 \pm 0.30$ c/mm ⟶ $c\tau\ (B_c^+) = 162.3 \pm 8.2\ \mu m$

Using $\tau(B^+) = 1.638 \pm 0.004$ ps (PDG)

Lifetime measurements of b hadrons

Systematic uncertainties

- **The high.stat. and most precise mode $B^+ \to J/\psi\ K^+$ is used to validate the absolute cτ accuracy**
- **Common sources :**
  - PV selection
  - Detector alignment
  - Finite MC size
  - Choice of approximation functions
  - ct resolution and absolute cτ accuracy
- **Channel-specific:**
  - $B^0 \to J/\psi\ K^*(892)^0$: K-π mass assignment
  - $B_s^0 \to J/\psi\ \pi^+\pi^-$: $B^+ \to J/\psi\ K^+$ contribution; $\pi^+\pi^-$ mass window
  - $B_s^0 \to J/\psi\ \varphi(1020)$: ct range (since different lifetime of eigenstates); Non-resonant $B_s^0 \to J/\psi\ K^+K^-$ contribution (CP-odd)
  - $B_c^+ \to J/\psi\ \pi^+$: ct binning

Lifetime measurements of b hadrons

Results

$$c\tau_{B^0} = 453.0 \pm 1.6\,(\text{stat}) \pm 1.5\,(\text{syst})\ \mu\text{m (in J}/\psi\text{K}^*(892)^0),$$
$$c\tau_{B^0} = 457.8 \pm 2.7\,(\text{stat}) \pm 2.7\,(\text{syst})\ \mu\text{m (in J}/\psi\text{K}^0_S),$$
$$c\tau_{B^0_s} = 504.3 \pm 10.5\,(\text{stat}) \pm 3.7\,(\text{syst})\ \mu\text{m (in J}/\psi\pi^+\pi^-),$$
$$c\tau_{B^0_s} = 443.9 \pm 2.0\,(\text{stat}) \pm 1.2\,(\text{syst})\ \mu\text{m (in J}/\psi\phi(1020)),$$
$$c\tau_{\Lambda^0_b} = 443.1 \pm 8.2\,(\text{stat}) \pm 2.7\,(\text{syst})\ \mu\text{m}.$$
$$c\tau_{B_c^+} = 162.3 \pm 8.2\,(\text{stat}) \pm 4.7\,(\text{syst}) \pm 0.1\,(\tau_{B^+})\ \mu\text{m},$$

In agreement with LHCb (JHEP 1404 (2014) 114, Phys.Lett.B 742 (2015) 29) and world-average values (PDG)

Lifetime measurement precision it at the level of best measurements

Confirm larger (w.r.t Tevatron [*]) $\mathbf{B_c^+}$ lifetime, in agreement with LHCb [**]

Interest on the theory side: *Precise B_c^+ lifetime measurements can provide new constraints on new-physics interpretations of the anomalies observed in $B \to D^{(*)}\tau\nu$,* Phys. Rev. Lett. 118 (2017) 081802

[*] Phys. Rev. Lett.97(2006) 012002, Phys. Rev. D.87(2013) 011101, Phys. Rev. Lett.102(2009) 092001
[**] JHEP74(2014) 2839, Phys. Lett. B742(2015) 29

Outline

- Lifetime measurements of b hadrons reconstructed in final states with a J/ψ meson
- **Observation of Υ(1S) pair production in proton-proton collisions at $\sqrt{s}$=8 TeV**
- Search for X(5568)

Observation of Υ(1S) pair production

Quarkonium pair production cross-section measurements are one of the key points in understanding SPS and DPS contributions and the parton structure of the proton

Υ(1S) pair production in pp collisions at $\sqrt{s}$=8 TeV is **observed** by CMS using a data set of 20.7 fb^{-1} , using dimuon Υ decay

$p_T(\mu) > 3.5$ GeV, $|\eta(\mu)| < 2.4$, $|y(\Upsilon)| < 2.0$
$P_{vtx}(\Upsilon) > 0.005$, $P_{vtx}(4\mu) > 0.05$,

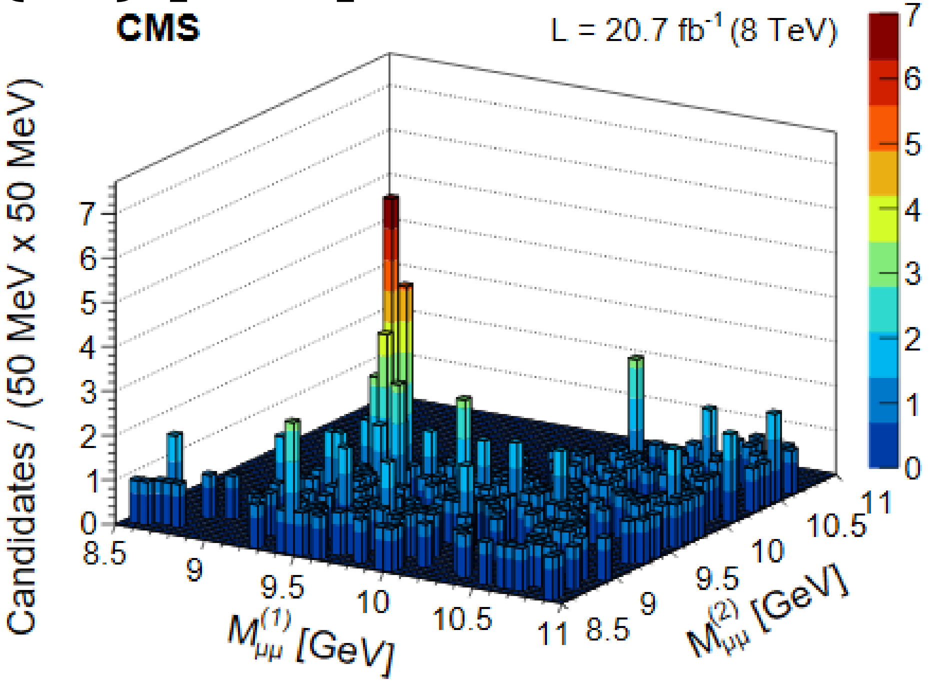
Using 2-dimensional fit to $\{M^1_{\mu\mu}, M^2_{\mu\mu}\}$ where $M^1_{\mu\mu} > M^2_{\mu\mu}$

If more than one ΥΥ candidate is found, an event is discarded

Observation of Υ(1S) pair production

2-dimensional distribution

$\{M^1_{\mu\mu}, M^2_{\mu\mu}\}$ $\quad M^1_{\mu\mu} > M^2_{\mu\mu}$



None of 1D $M_{\mu\mu}$ distributions shows signs of Υ(3S)

2-dimensional fit has 5 components:

- Υ(1S)Υ(1S) signal
- Υ(2S)Υ(1S) signal
- Υ(1S)–combinatorial
- Υ(2S)–combinatorial
- combinatorial–combinatorial

other contributions are negligible

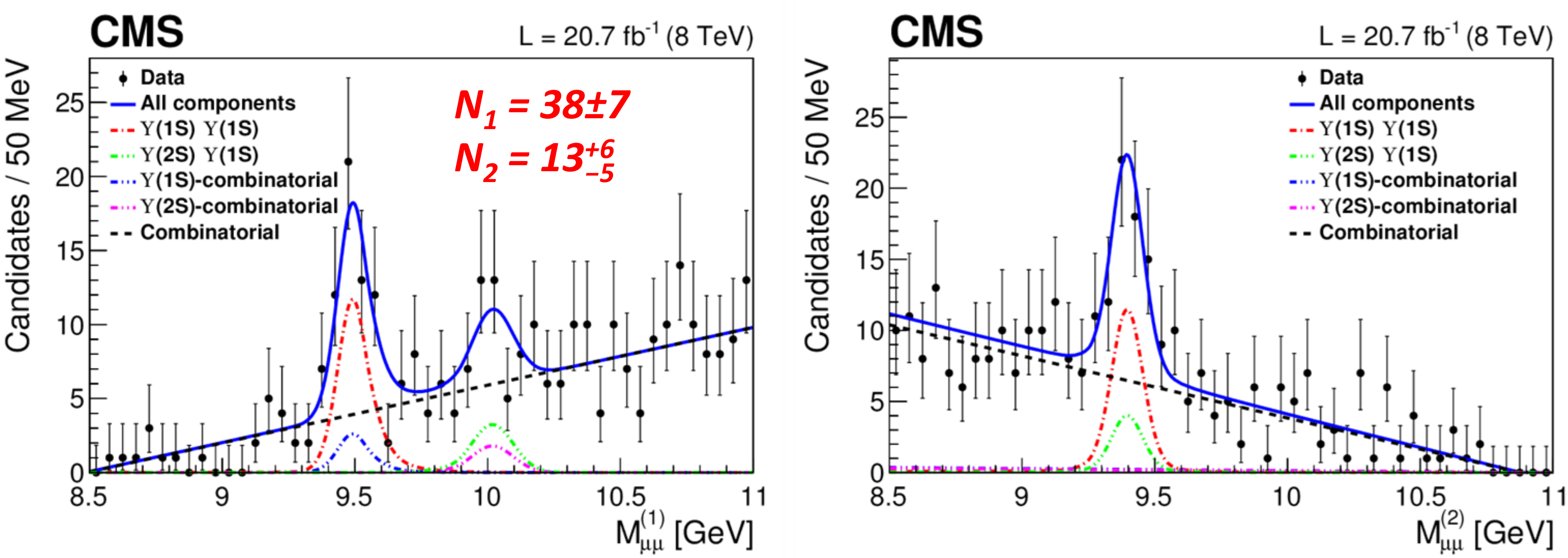
Signals: Double Crystall-ball with fixed shape parameters

Combinatorial: polynomial

JHEP05(2017)013

Observation of Υ(1S) pair production

Result



Significance of Υ(1S)Υ(1S) is well above 5σ, Υ(2S)Υ(1S) – 2.6σ

Cross-section:

Details in backup

$$\sigma(\Upsilon(1S)\Upsilon(1S)) = 68.8 \pm 12.7(\text{stat}) \pm 7.4(\text{syst}) \pm 2.8(\mathcal{B})$$

in pp collisions at $\sqrt{s}$=8 TeV, for $|y(\Upsilon)| < 2.0$

If Υ are produced with different polarizations, the measured cross-section varies in [-38%, +36%]

JHEP05(2017)013

Outline

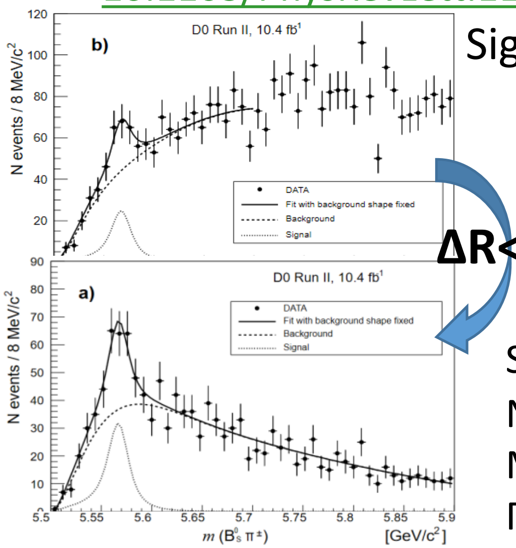
- Lifetime measurements of b hadrons reconstructed in final states with a J/ψ meson
- Observation of Υ(1S) pair production in proton-proton collisions at $\sqrt{s}$=8 TeV
- **Search for X(5568)**

Search for X(5568)

DØ Collaboration:

Evidence for a $B_s^0\pi^\pm$ state

10.1103/PhysRevLett.117.022003



Significance: **3.9σ**

Significance: **5.1σ**

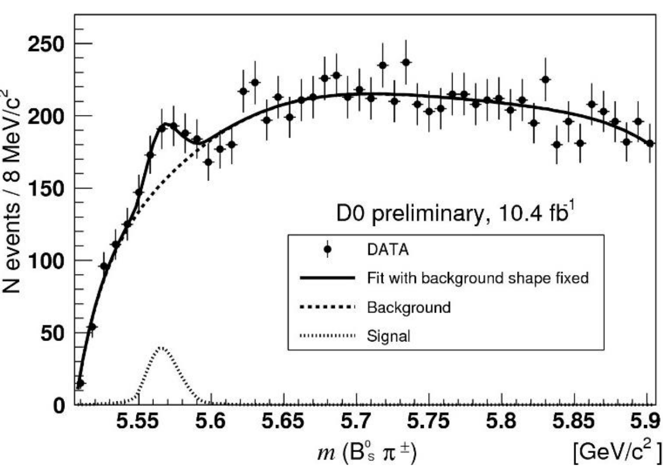
N_X = 133 ± 31

M_X = 5567.8 ± 2.9 MeV

Γ_X = 21.9 ± 6.4 MeV

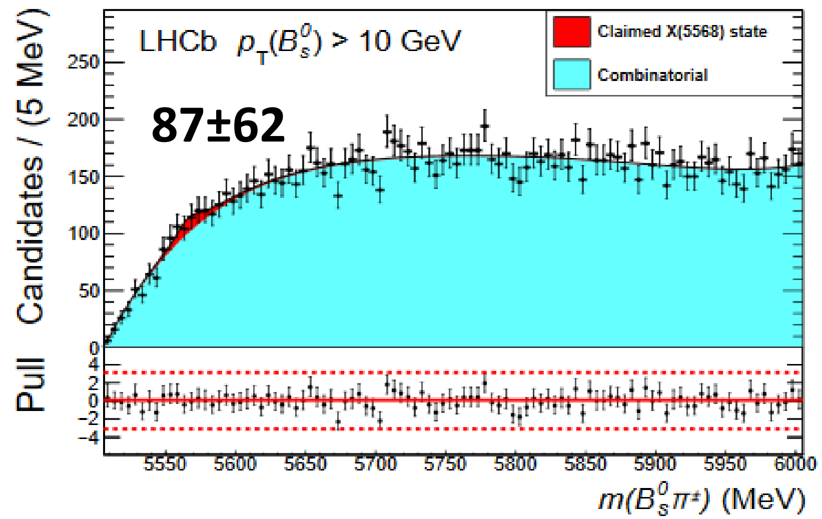
Later confirmed D0 Conference Note 6496

Using semileptonic B_s^0 decay channel



LHCb collaboration **does not see** X(5568) using much larger and cleaner B_s^0 sample

Phys.Rev.Lett.117,152003(2016)



$$\rho_X \equiv \frac{\sigma(p\bar{p} \to X(5568) + \text{anything}) \times \mathcal{B}(X(5568) \to B_s^0\pi^\pm)}{\sigma(p\bar{p} \to B_s^0 + \text{anything})}$$

DØ measured

ρ_X = 8.6±2.4% $(10 < p_T(B_s^0) < 30\ \text{GeV})$

LHCb set upper limit

ρ_X < 2.4% @ 95%CL $(p_T(B_s^0) > 10)$

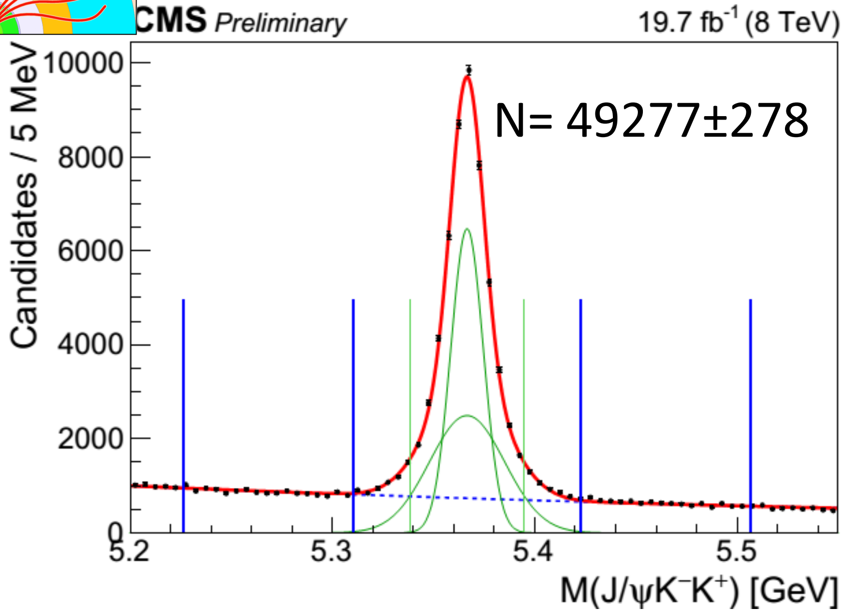
Search for X(5568)

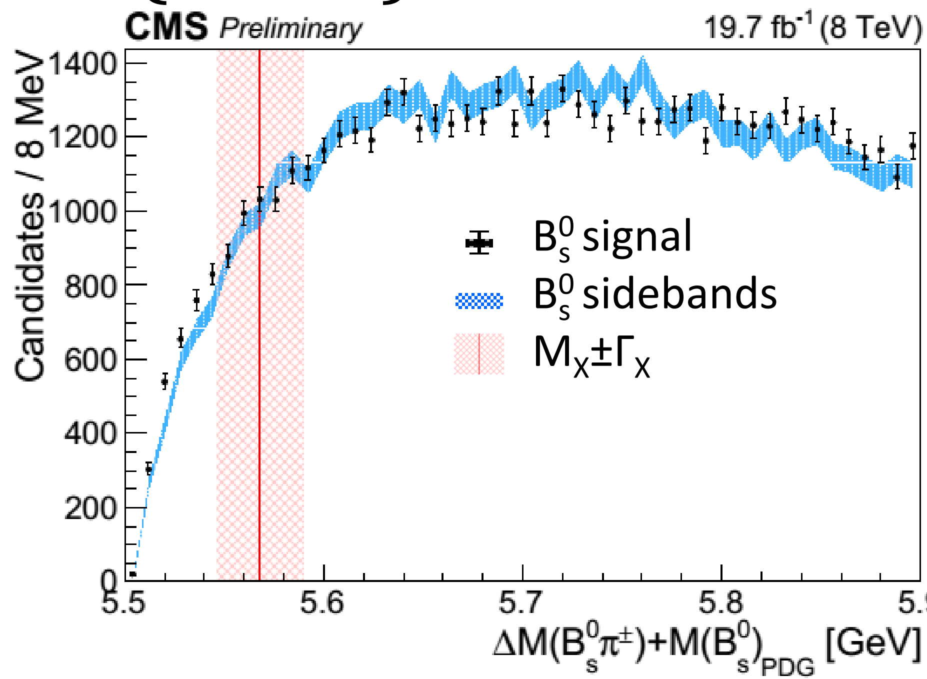
- LHCb and DØ inconsistency ⇒ another independent analysis is needed
- There are theoretical papers both for and against X(5568) existence
- CMS can probe the p_T, η region complementary to LHCb and closer to DØ
  - Dataset: 19.7 fb^{-1} of pp collisions at 8 TeV (2012)
  - Use $B_s^0 \to J/\psi\, \varphi(1020)$, $\varphi(1020) \to K^+K^-$ decays
  - Triggered by displaced $J/\psi \to \mu^+\mu^-$
  - $p_T(K^\pm) > 0.7$ GeV, $p_T(B_s^0) > 10$ GeV,
  - $|m(K^+K^-) - m_\varphi^{PDG}| < 10$ MeV $Lxy/\sigma_{Lxy}(B_s^0) > 3$
  - $\cos\alpha_T(B_s^0) > 0.99$ * $P_{vtx}(B_s^0) > 1\%$

* $\alpha_T = B_s^0$ pointing angle to PV in xy plane

CMS-PAS-BPH-16-002

Search for X(5568)





Fit: Double Gaussian function with common mean + exp

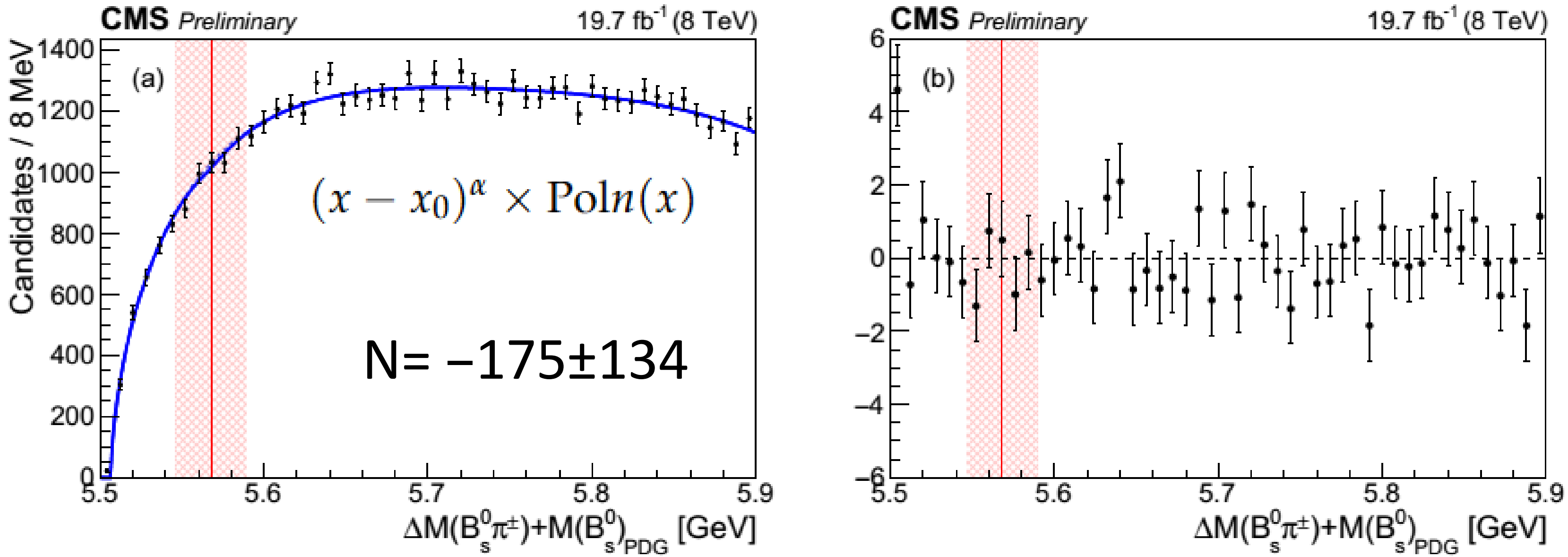
$$\sigma_{eff} = \left[(1-f)\sigma_1^2 + f\sigma_2^2\right]^{1/2} \simeq 14 \text{ MeV}$$

The distribution does not have any visible peaks and is in a good agreement with sidebands

B_s^0 signal window $\pm 2\sigma_{eff}$

B_s^0 sidebands $[-10\sigma_{eff}, -4\sigma_{eff}] \cup [+4\sigma_{eff}, +10\sigma_{eff}]$

Search for X(5568)



$$\rho_X \equiv \frac{\sigma(pp \to X(5568) + \text{anything}) \times \mathcal{B}(X(5568) \to B_s^0\pi^\pm)}{\sigma(pp \to B_s^0 + \text{anything})} = \frac{N_{X(5568)}}{N_{B_s^0} \times \epsilon_{rel}}$$

Obtained upper limit **$\rho_X < 3.9\%$ @ 95%CL** ($p_T(B_s^0)$>10 GeV)

DØ measured $\rho_X = 8.6 \pm 2.4\%$ (10<$p_T(B_s^0)$<30 GeV)

The result is preliminary, uses very conservative systematic uncertainty.

The updated one will become public in several weeks,

Keep an eye on arXiv or [CMS BPH physics results]

Summary

- b hadrons lifetimes are measured

$$
\begin{aligned}
c\tau_{B^0} &= 453.0 \pm 1.6\,(\text{stat}) \ \pm 1.5\,(\text{syst})\ \mu\text{m (in J}/\psi\text{K}^*(892)^0), \\
c\tau_{B^0} &= 457.8 \pm 2.7\,(\text{stat}) \ \pm 2.7\,(\text{syst})\ \mu\text{m (in J}/\psi\text{K}^0_\text{S}), \\
c\tau_{B^0_s} &= 504.3 \pm 10.5\,(\text{stat}) \ \pm 3.7\,(\text{syst})\ \mu\text{m (in J}/\psi\pi^+\pi^-), \\
c\tau_{B^0_s} &= 443.9 \pm 2.0\,(\text{stat}) \ \pm 1.2\,(\text{syst})\ \mu\text{m (in J}/\psi\phi(1020)), \\
c\tau_{\Lambda^0_b} &= 443.1 \pm 8.2\,(\text{stat}) \ \pm 2.7\,(\text{syst})\ \mu\text{m}.
\end{aligned}
$$

$$
c\tau_{B_c^+} = 162.3 \pm 8.2\,(\text{stat}) \pm 4.7\,(\text{syst}) \pm 0.1\,(\tau_{B^+})\ \mu\text{m},
$$

  - Results agree with w.a. and have precision at the level of the best measurements

- Υ(1S) pair production is observed in pp collisions at $\sqrt{s}$=8 TeV

- X(5568) is searched for, no excess is found, in agreement with LHCb result

  - Paper with updated limit will become public soon (in a few weeks)

BACKUP

Lifetime measurements of b hadrons

Efficiency dependence on $c\tau$

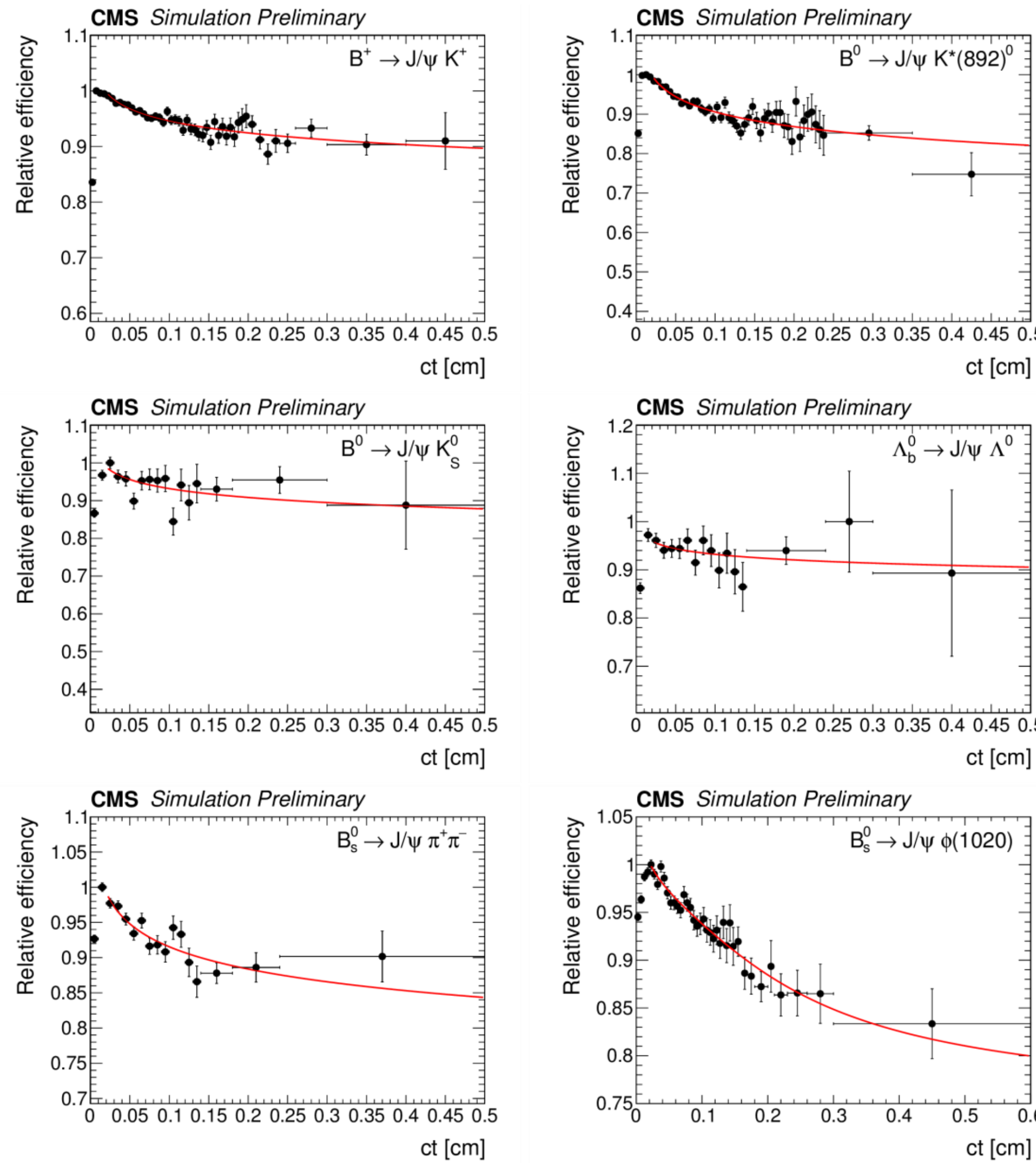
Y-axis scale is arbitrary

Fit with inverse power function

In the baseline selection, $c\tau$>0.02 cm is applied to avoid turn-on region

(>0.01 cm for $B^{+}_{(c)}$)

Tracking efficiency is the reason for non-flat shape [JINST 9 (2014)(10)]



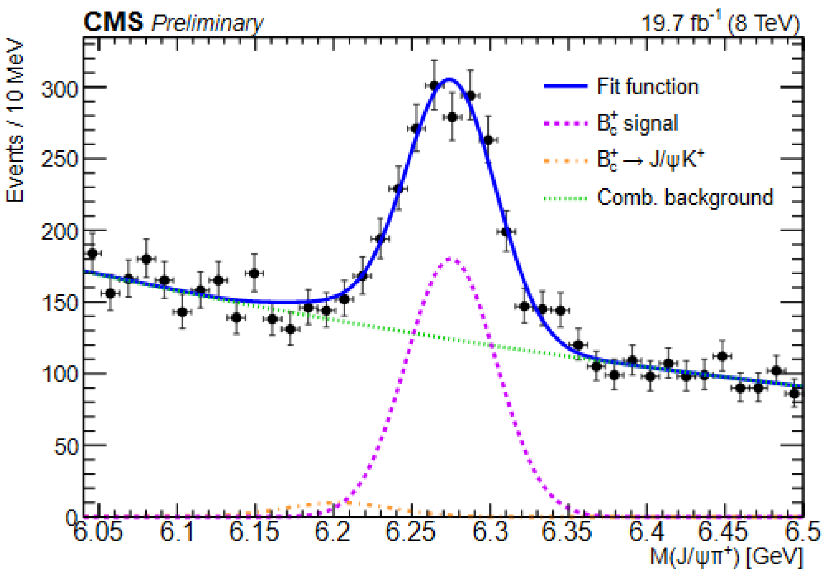
CMS-PAS-BPH-13-008

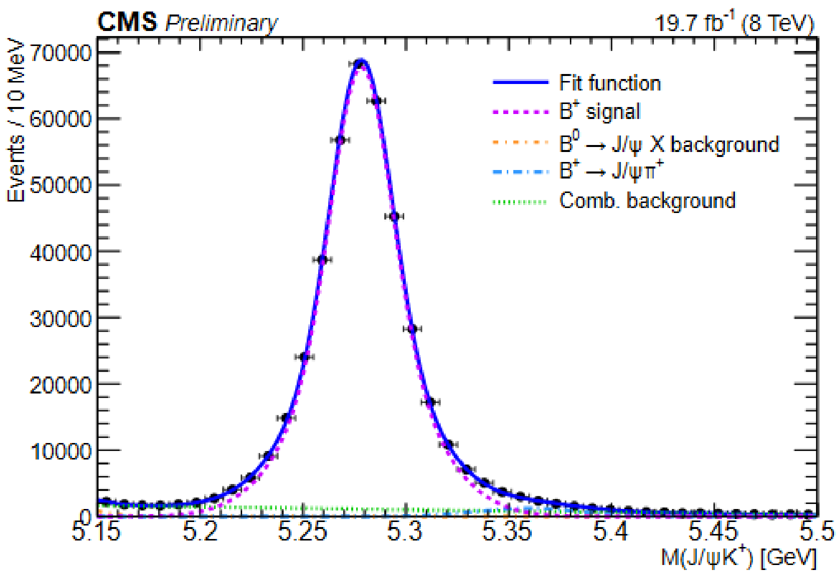
Lifetime measurements of b hadrons

- $B_c^+ \rightarrow J/\psi\, \pi^+$ (using reference $B^+ \rightarrow J/\psi\, K^+$)

$$R(t) = [\, N(B_c^+) / N(B^+)\,](t) = R_\varepsilon(t) \exp(-\Delta\Gamma t)$$

$$\Delta\Gamma \equiv \Gamma_{B_c^+} - \Gamma_{B^+} = \frac{1}{\tau_{B_c^+}} - \frac{1}{\tau_{B^+}}$$



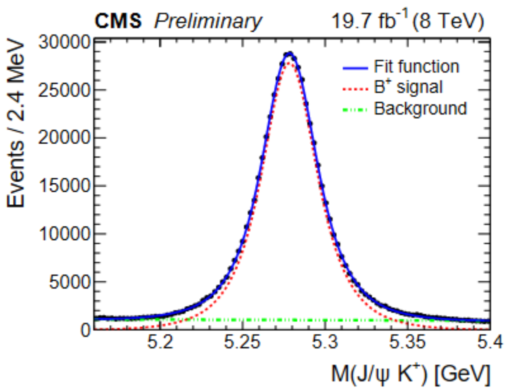


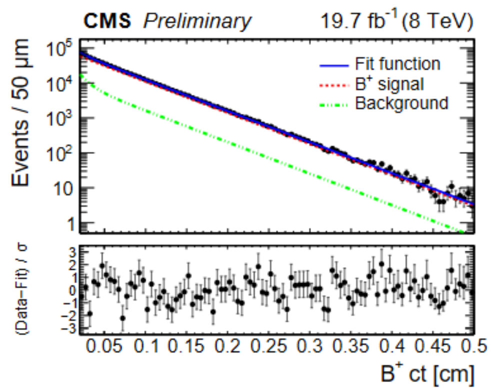
$p_T(K^+) > 3.3$ GeV; $p_T(\pi^+) > 3.3$ GeV; $p_T(B^+_{(c)}) > 10$ GeV $|y|\, (B^+_{(c)}) < 2.2$

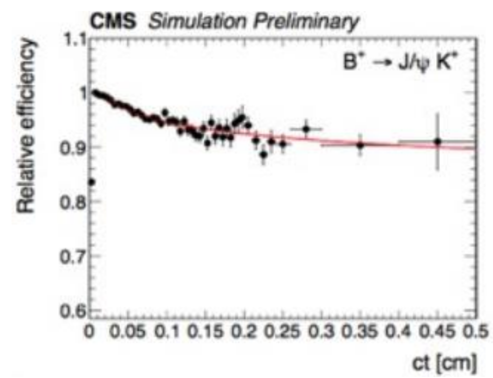
Lifetime measurements of b hadrons

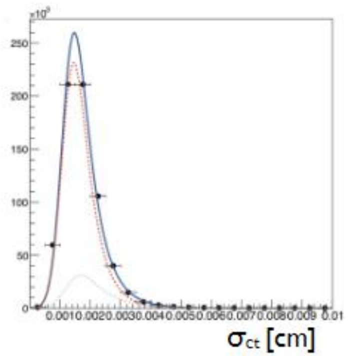
- $B^+ \to J/\psi\, K^+$ $p_T(K^+) > 3.3$ GeV; $p_T(B^+) > 10$ GeV

$$L_{sig}(m,t,\sigma_t) \sim L(m) \times \{e^{-t'/\tau} \otimes G(t-t';\sigma_t)\}.\,\varepsilon(t) \times L(\sigma_t)$$









Gaussian for signal, exponential for background

the lifetime component $e^{-t'/\tau}$ is smeared with per-candidate detector resolution σ_t and corrected by reconstruction and selection biases described by the t-efficiency function $\varepsilon(t)$

Observation of ϒ(1S) pair production

Component	Uncertainty (%)
Resonance shape	7.9
Simulation	4.9
Efficiency	3.7
Acceptance	2.8
Integrated luminosity	2.6
Total	10.7

$$\sigma_{\text{fid}} = \frac{N_{\text{signal}}\,\overline{\omega}}{\mathcal{L}\,[\mathcal{B}(\Upsilon(1S) \to \mu^+\mu^-)]^2}, \qquad (2)$$

where $\overline{\omega}$ is the average correction factor that accounts for the inefficiencies stemming from reconstruction, identification, and trigger requirements, as well as the fraction of events lost because of the muon acceptance criteria, $\mathcal{L}$ is the integrated luminosity, and $\mathcal{B}(\Upsilon(1S) \to \mu^+\mu^-) = (2.48 \pm 0.05)\%$ is the world-average branching fraction of the $\Upsilon(1S)$ to $\mu^+\mu^-$ [42].

The factor $\overline{\omega}$ is the inverse product of per-event efficiencies, ϵ_i, and acceptances, a_i, averaged over the events that pass selection cuts. For the calculation of the total cross section, values of $\mathcal{L} = 20.7\,\text{fb}^{-1}$, $N_{\text{signal}} = 38 \pm 7$, and $\overline{\omega} = 23.06$ are used. Under the assumption that both $\Upsilon(1S)$ mesons decay isotropically, the total cross section for $\Upsilon(1S)$ pair production is measured to be $\sigma_{\text{fid}} = 68.8 \pm 12.7\,(\text{stat}) \pm 7.4\,(\text{syst}) \pm 2.8\,(\mathcal{B})$ pb, where the uncertainties are statistical,

JHEP05(2017)013

Observation of $\Upsilon(1S)$ pair production

In quarkonium pair production, the measurement of the effective cross section σ_{eff} depends on the fraction of DPS, which is usually estimated either as a residual to the SPS prediction or as the result of a fit to the rapidity or azimuthal angle difference between quarkonia pairs. To estimate σ_{eff} using the fiducial $\Upsilon(1S)$ pair production cross section σ_{fid}, the following formula is used [7]:

$$\sigma_{\text{eff}} = \frac{[\sigma(\Upsilon)]^2}{2\, f_{\text{DPS}}\, \sigma_{\text{fid}}\, [\mathcal{B}(\Upsilon(1S) \to \mu^+\mu^-)]^2}, \quad (3)$$

where $\sigma(\Upsilon)$ is the cross section for single-$\Upsilon(1S)$ production [43] extrapolated to the fiducial region ($|y^{\Upsilon}| < 2.0$) and f_{DPS} is the fraction of the DPS contribution. To estimate the effective cross section, we use $\sigma(\Upsilon) = 7.5 \pm 0.6\,\text{nb}$ and a value of $f_{\text{DPS}} \approx 10\%$ [8], which gives $\sigma_{\text{eff}} \approx 6.6\,\text{mb}$. The cross section for $\Upsilon(1S)$ pair production, assuming SPS with feed-down from higher Υ states, is $48\,\text{pb}$ [8]. This result, combined with our measurement, gives $f_{\text{DPS}} \simeq 30\%$, and with this estimation, σ_{eff} is calculated to be $\approx 2.2\,\text{mb}$. These two estimates of σ_{eff} are consistent with the range of values from the heavy-quarkonium measurements (2–8 mb) [21, 22], but are smaller than that from multijet studies (12–20 mb) [17–20]. The quarkonium final states are dominantly produced from gluon-gluon interactions, while the jet-related channels that correspond to higher values of σ_{eff} are produced by quark-antiquark and quark-gluon parton interactions. The trend in the measured effective cross section might indicate that the average transverse distance between gluons in the proton is smaller than between quarks, or between quarks and gluons.

Search for X(5568)

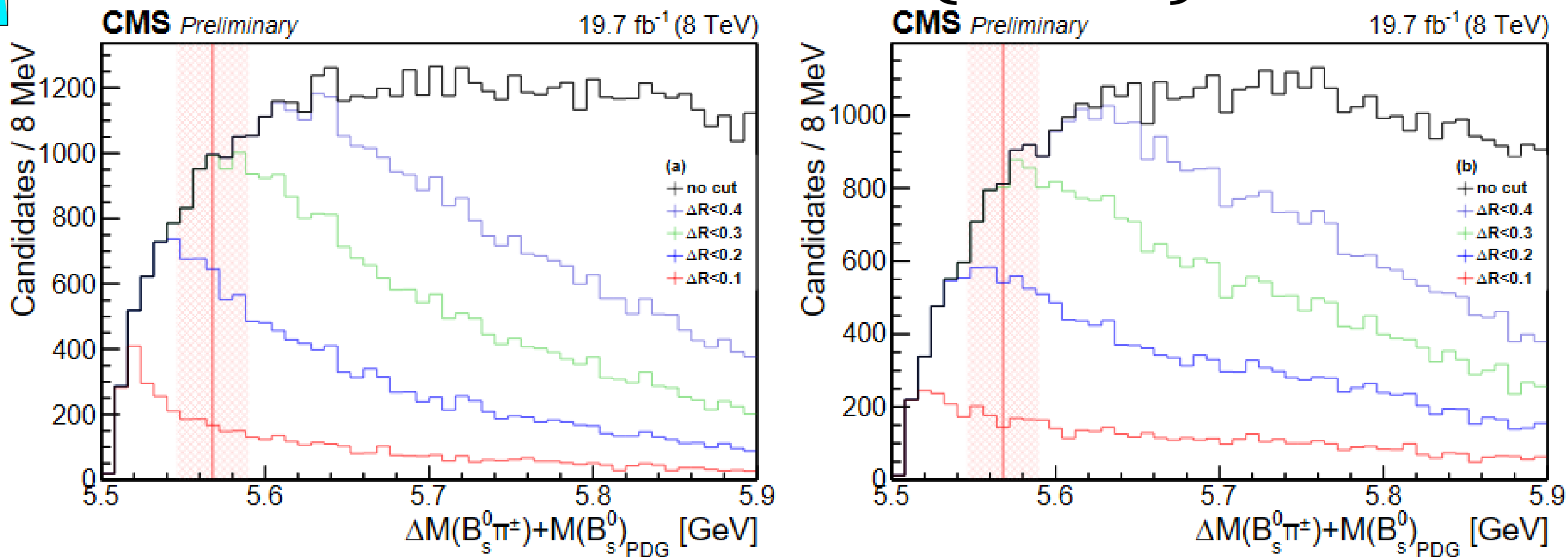


Figure 3: $M^{\Delta}(\mathrm{B_s^0}\pi^{\pm})$ distribution of events in (a) the $\mathrm{B_s^0}$ signal region and (b) $\mathrm{B_s^0}$ sidebands with different ΔR (cone cut) requirements: no cut (black), $\Delta R<0.4$ (violet), $\Delta R<0.3$ (green), $\Delta R<0.2$ (blue) and $\Delta R<0.1$ (red). The uncertainties are not shown for the sake of clarity. The (red) vertical band indicates the region $M_X \pm \Gamma_X$ around the mass of the claimed $X(5568)$ state.

The D∅ Collaboration observes a peak with a significance above 5σ only when a limit is imposed on the difference between the directions of the $\mathrm{B_s^0}$ and pion candidates, specifically, $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} < 0.3$. This "cone cut" changes abruptly the $M^{\Delta}(\mathrm{B_s^0}\pi^{\pm})$ distribution shape, as shown in Fig. 3. It can simulate a peak shape or potentially enhance the significance of a statistical fluctuation in the data and, therefore, it is not used in this analysis. Additional cross-checks show that the fit of the distributions with this cut using a smooth background plus a signal function can result in a signal yield not compatible with zero, in both signal and sideband $\mathrm{B_s^0}$ regions.

Search for X(5568)

Remove $|m(K^+K^-) - m_{\varphi}^{PDG}| < 10$ MeV cut

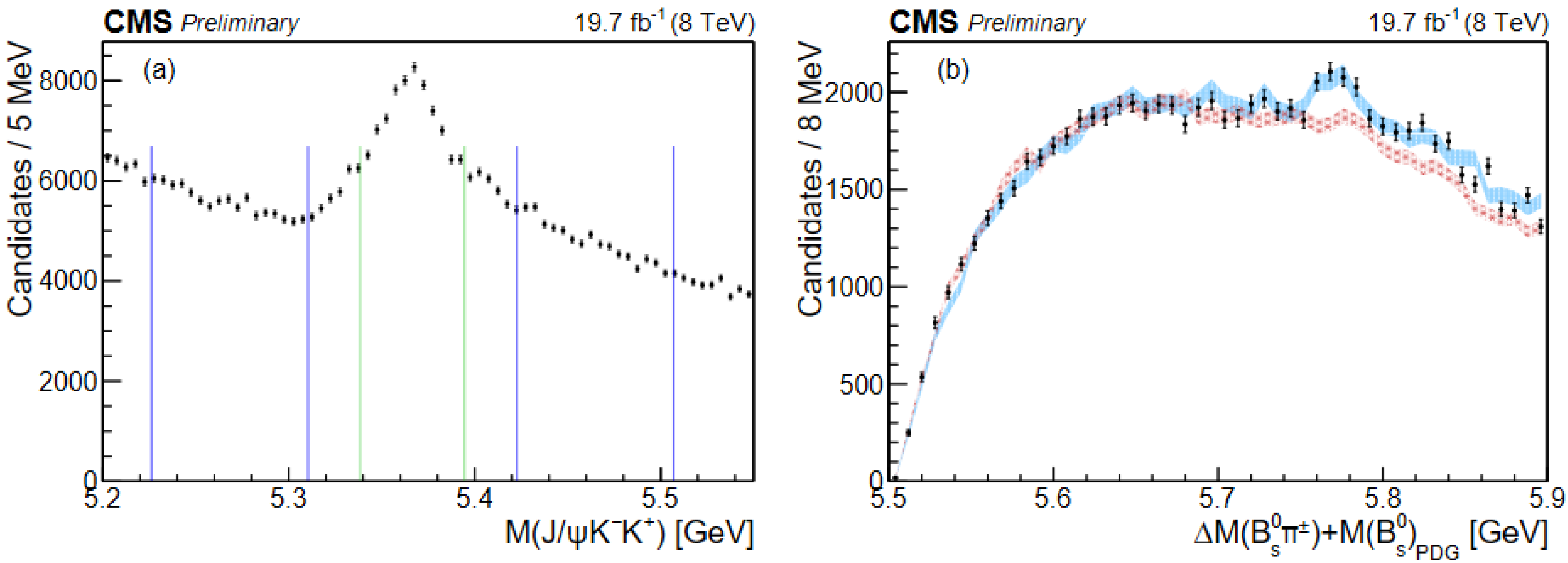


Figure 4: (a) $J/\psi K^+K^-$ invariant mass distribution for events with the K^+K^- invariant mass window removed and $p_T(B_s^0) > 25$ GeV, $p_T(\pi^\pm) > 1$ GeV, $p_T(K^\pm) > 1$ GeV. The $B^0 \to J/\psi K^+\pi^-$ decay contaminates the signal and the right sideband regions. (b) The corresponding $M^\Delta(B_s^0\pi^\pm)$ distributions for the B_s^0 signal (black points with error bars), B_s^0 left sideband (red band, made of stars) and B_s^0 right sideband (blue dotted band) regions. All distributions are equally normalized from the mass threshold up to 5.74 GeV. Contributions from $B_{1,2}^{(*)+} \to B^{(*)0}\pi^+$ decays (and charge-conjugates) are seen around $M^\Delta(B_s^0\pi^\pm) \sim 5.77$ GeV and higher masses coming only from the B_s^0 signal and right sideband regions.