



UNIVERSITÀ
DEGLI STUDI DI BARI
ALDO MORO



χ_b reconstruction & X_b searches into
 $\chi_b(1P)\pi^+\pi^-$ and $\Upsilon(1S)\pi^+\pi^-$ final states

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2nd year report

Supervisor : A.Pompili

Outline

- ❖ **Physics motivation**
- ❖ **HLT development for $\Upsilon(nS)$ triggering dedicated to the search of the X_b state**
- ❖ **Reconstruction of $\Upsilon(nS)$ & $\chi_{bj}(mP)$ states ($n,m = 1, 2, 3; j=1,2$)**
- ❖ **X_b searches into $\Upsilon(1S) \pi^+\pi^-$ final state**
- ❖ **X_b searches into $\chi_b(1P) \pi^+\pi^-$ final state**
- ❖ **Future plans**

Physics motivation

- With the 2012 dataset (8TeV) CMS searched for the X_b state, the bottomonium “counterpart” of the X(3872), suggested by heavy quark symmetry, by looking for the $X_b \rightarrow \Upsilon(1S) \pi^+ \pi^-$ decay.

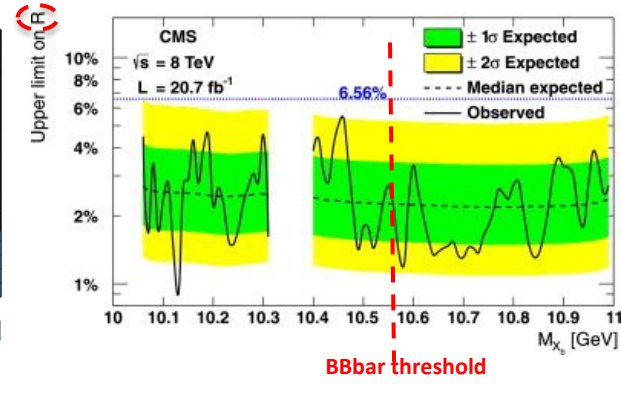
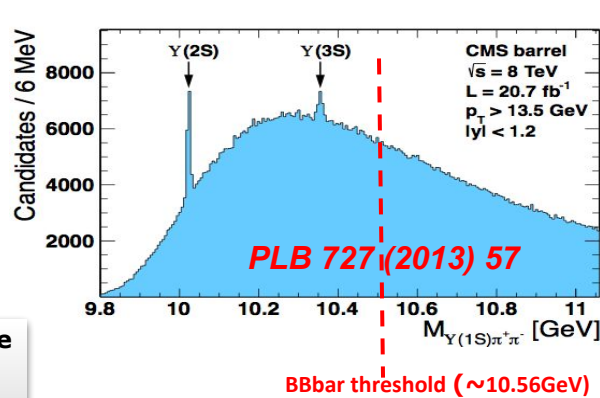
Analysis strategy:

Search for a peak other than known $Y(2S)$ & $Y(3S)$ in the $Y(1S)\pi\pi$ spectrum within 10-11GeV mass window

CMS set 95% CL upper limit on the ratio R of the inclusive production xsections times BFs to $Y(1S)\pi\pi$ (the one for X_b is unknown):

$$R = \frac{\sigma(pp \rightarrow X_b \rightarrow Y(1S)\pi^+\pi^-)}{\sigma(pp \rightarrow Y(2S) \rightarrow Y(1S)\pi^+\pi^-)}$$

Observed UL range: 0.9% to 5.4% for CMS



- With higher statistics Run-II data we want to search for the X_b state also in the decay $X_b \rightarrow \chi_b(1P) \pi^+ \pi^-$ decay that would be more promising than the suppressed $X_b \rightarrow \Upsilon(1S) \pi^+ \pi^-$ decay [according to the theoretical paper, by M.Karliner and J.Rosner, Phys. Rev. D 91 (2015) 014014].

- $X_b \rightarrow \chi_b(1P) \pi^+ \pi^-$ $\chi_b(1P) \rightarrow Y(1S) \gamma$
- $X_b \rightarrow Y(1S) \pi^+ \pi^-$

HLT development for $\Upsilon(nS)$ triggering dedicated to the search of the X_b state

HLT paths for $Y(ns)$ triggering (for X_b search 2018)

We have put together the 2017 paths into just a single path satisfying spectroscopy & polarization sub-groups needs :

HLT_Dimuon12_Upsilon_y1p4

- ❖ $p_T(\mu^+\mu^-) > 12$ GeV
- ❖ $m(\mu^+\mu^-) \in [8.5, 11.5]$ GeV
- ❖ $|y(\mu^+\mu^-)| < 1.4$

instead of

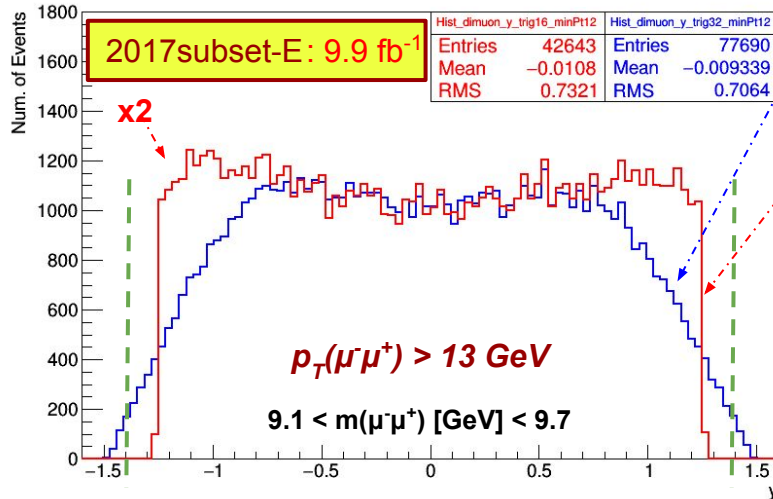
HLT_Dimuon12_Upsilon_eta1p5

- ❖ $p_T(\mu^+\mu^-) > 12$ GeV
- ❖ $m(\mu^+\mu^-) \in [8.5, 11.5]$ GeV
- ❖ $|\eta(\mu)| < 1.5$



HLT_Dimuon10_Upsilon_Barrel_Seagulls

- ❖ $p_T(\mu^+\mu^-) > 10$ GeV
- ❖ $m(\mu^+\mu^-) \in [8.5, 11.5]$ GeV
- ❖ $|y(\mu^+\mu^-)| < 1.25$
- ❖ Only Seagulls



Common L1 seed:

L1_DoubleMu4p5er2p0_SQ_OS_Mass7to18

Datasets, trigger, offline selection

- ❖ **Data Sets:**
 - /MuOnia/Run2016B-07Aug17_ver2-v1/AOD, L = **5.505 fb⁻¹**
 - /MuOnia/Run2016C-07Aug17-v1/AOD, L = **2.435 fb⁻¹**
 - /MuOnia/Run2016D-07Aug17-v1/AOD, L = **4.064 fb⁻¹**
 - /MuOnia/Run2016E-07Aug17-v1/AOD, L = **0.984 fb⁻¹**
 - /MuOnia/Run2016F-07Aug17-v1/AOD, L = **3.120 fb⁻¹**
 - /MuOnia/Run2016G-07Aug17-v2/AOD, L = **0.712 fb⁻¹**
 - /MuOnia/Run2016H-07Aug17-v1/AOD, L = **8.869 fb⁻¹**

 - /MuOnia/Run2017B-17Nov2017-v1/MINIAOD, L = **4.939 fb⁻¹**
 - /MuOnia/Run2017C-17Nov2017-v1/MINIAOD, L = **9.966 fb⁻¹**
 - /MuOnia/Run2017D-17Nov2017-v1/MINIAOD, L = **4.352 fb⁻¹**
 - /MuOnia/Run2017E-17Nov2017-v1/MINIAOD, L = **9.531 fb⁻¹**
 - /MuOnia/Run2017F-17Nov2017-v1/MINIAOD, L = **13.629 fb⁻¹**

 - /MuOnia/Run2018A-06Jun2018-v1/MINIAOD, L = **10.126 fb⁻¹**
 - /MuOnia/Run2018B-PromptReco-v1/MINIAOD, L = **6.458 fb⁻¹**
 - /MuOnia/Run2018B-PromptReco-v2/MINIAOD, L=**0,410 fb⁻¹**
 - /MuOnia/Run2018C-PromptReco-v1/MINIAOD, L=**0,473 fb⁻¹**
 - /MuOnia/Run2018C-PromptReco-v2/MINIAOD, L=**3,299 fb⁻¹**
 - /MuOnia/Run2018C-PromptReco-v3/MINIAOD, L=**2,840 fb⁻¹**
 - /MuOnia/Run2018D-PromptReco-v2/MINIAOD, L=**18,505 fb⁻¹**

- ❖ **Integrated luminosity processed: L = 110.217 fb⁻¹**
 - **2016 Data:** L = **25.689 fb⁻¹**
 - **2017 Data:** L = **42.417 fb⁻¹**
 - **2018 Data:** L = **42.111 fb⁻¹**

- ❖ **Triggers:**
 - HLT_Dimuon8_Upsilon_Barrel (2016)**
 - HLT_Dimuon12_Upsilon_eta1p5 (2017, beginning 2018)**
 - HLT_Dimuon12_Upsilon_y1p4 (2018 after run 315974)**

- ❖ **Offline selection criteria:**

- For $\Upsilon(1S)\text{pipi}$:**

- 4-track VertexProb > 1%,

- $p_T(\mu\mu) > 12 \text{ GeV}$,

- $9.3 < M(\mu\mu) < 9.6 \text{ GeV}$

- $D_{xy}(\pi) < 3\text{cm}$ (very loose)

- For $\chi_b(1P)\text{pipi}$:**

- $(\chi_b\text{-cand}+2\text{tracks})$ VertexProb > 1%,

- $p_T(\mu\mu) > 12 \text{ GeV}$,

- $9.3 < M(\mu\mu) < 9.6 \text{ GeV}$,

- $9.87 < M(\chi_b(1P)) < 9.92$,

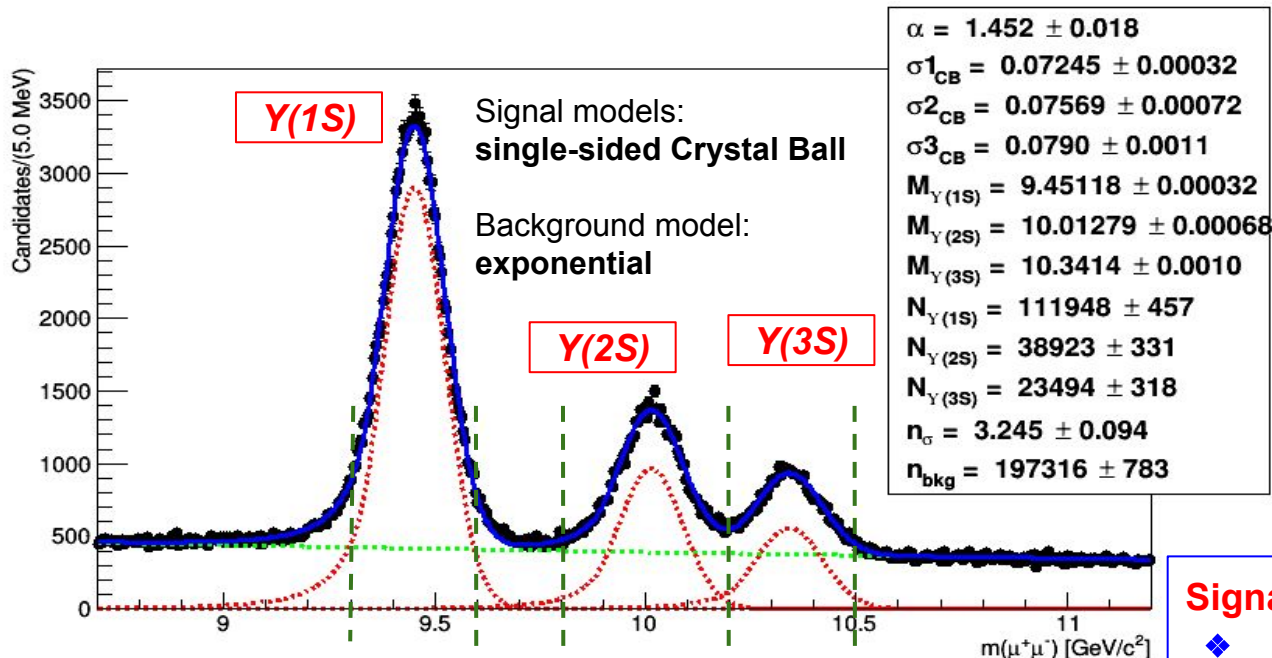
- Energy(photon) > 400 MeV

- $D_{xy}(\pi) < 3\text{cm}$ (very loose)

- ❖ **Privately produced signal MC samples**
(RunIIFall2017 config.)

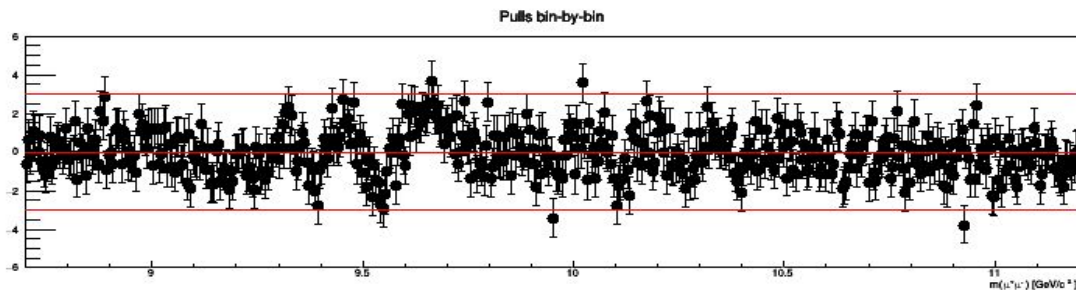
Reconstruction of
 $Y(nS)$ [$n = 1, 2, 3$]
&
 $\chi_{bj}(mP)$ states [$m = 1, 2, 3$]
with converted photons

S-wave bottomonium states

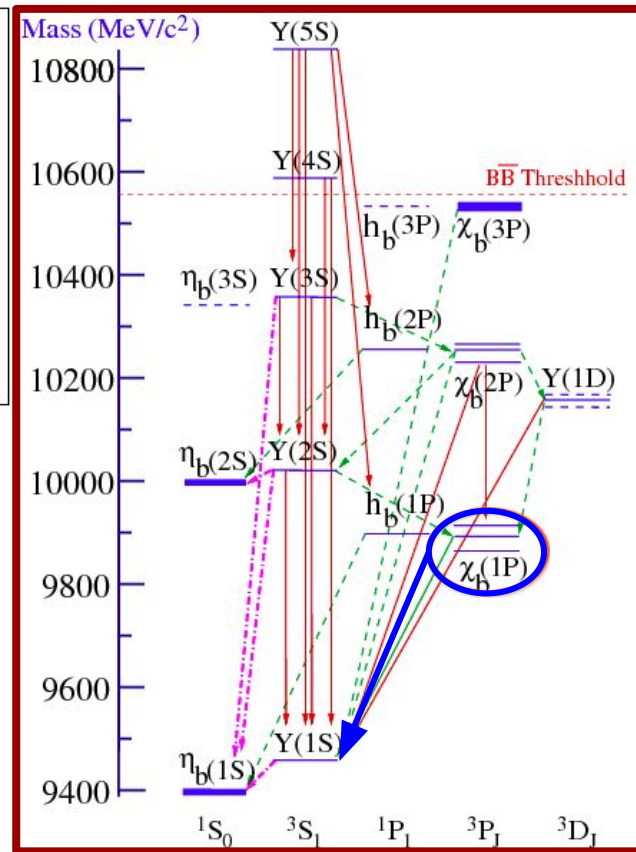
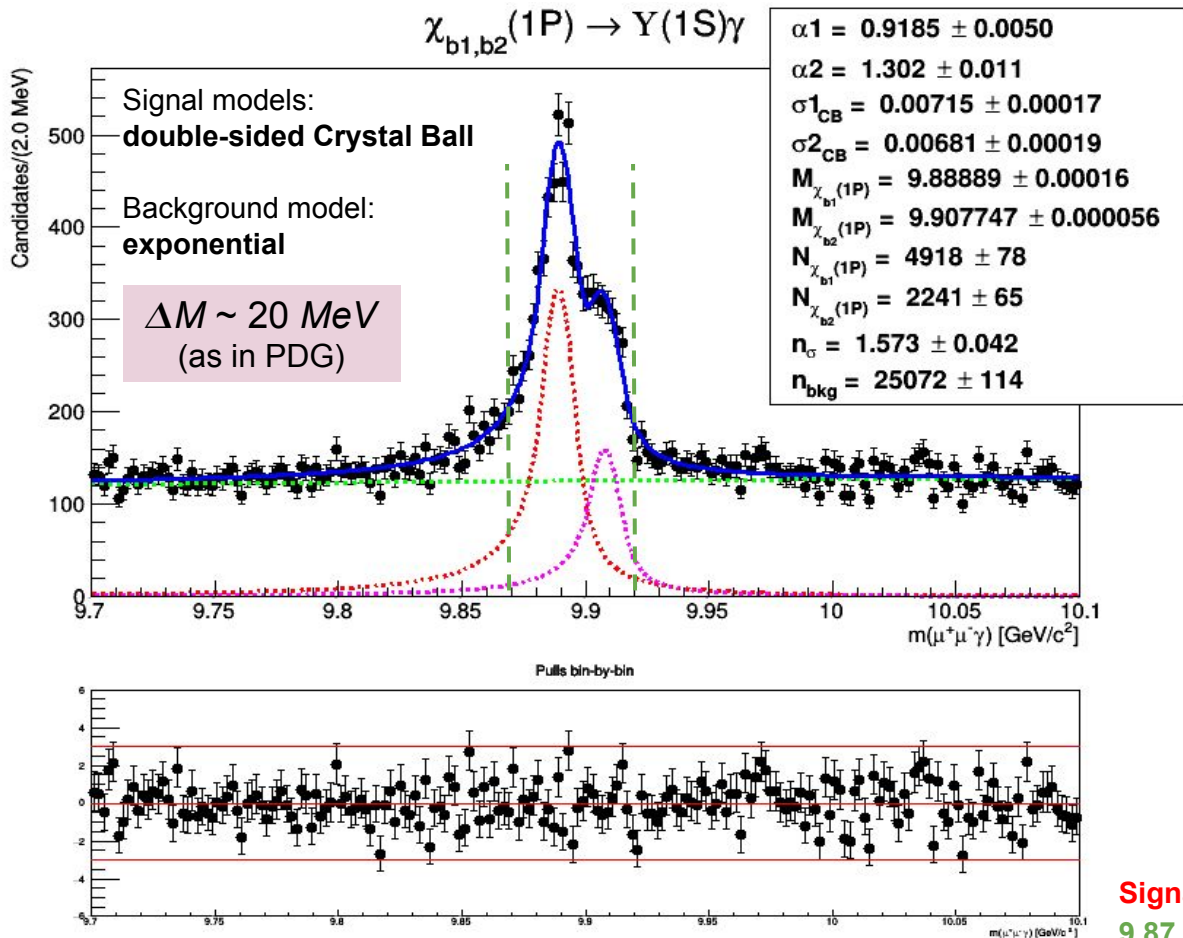


Signal windows to reconstruct χ_b :

- ◆ $9.3 < Y(1S) < 9.6$
- ◆ $9.7 < Y(2S) < 10.2$
- ◆ $10.2 < Y(3S) < 10.5$

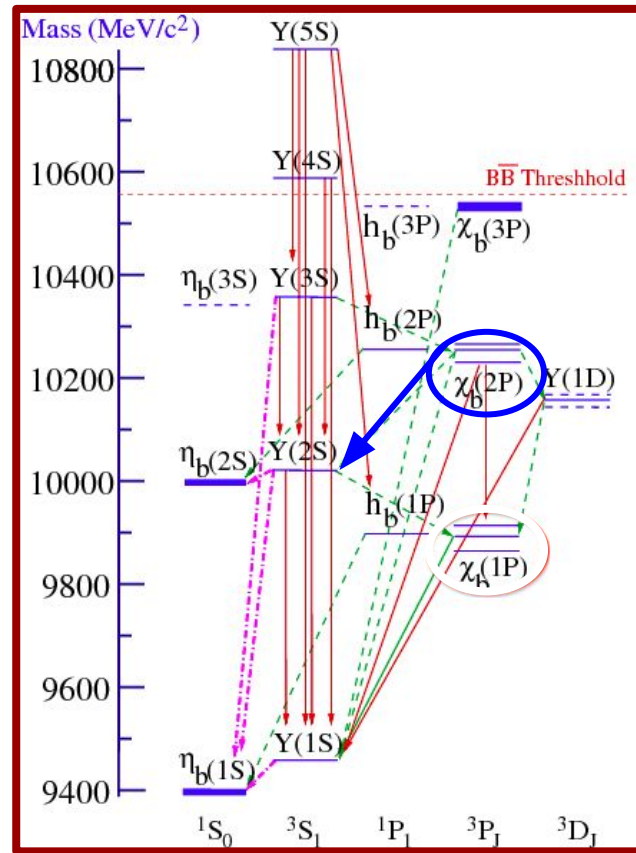
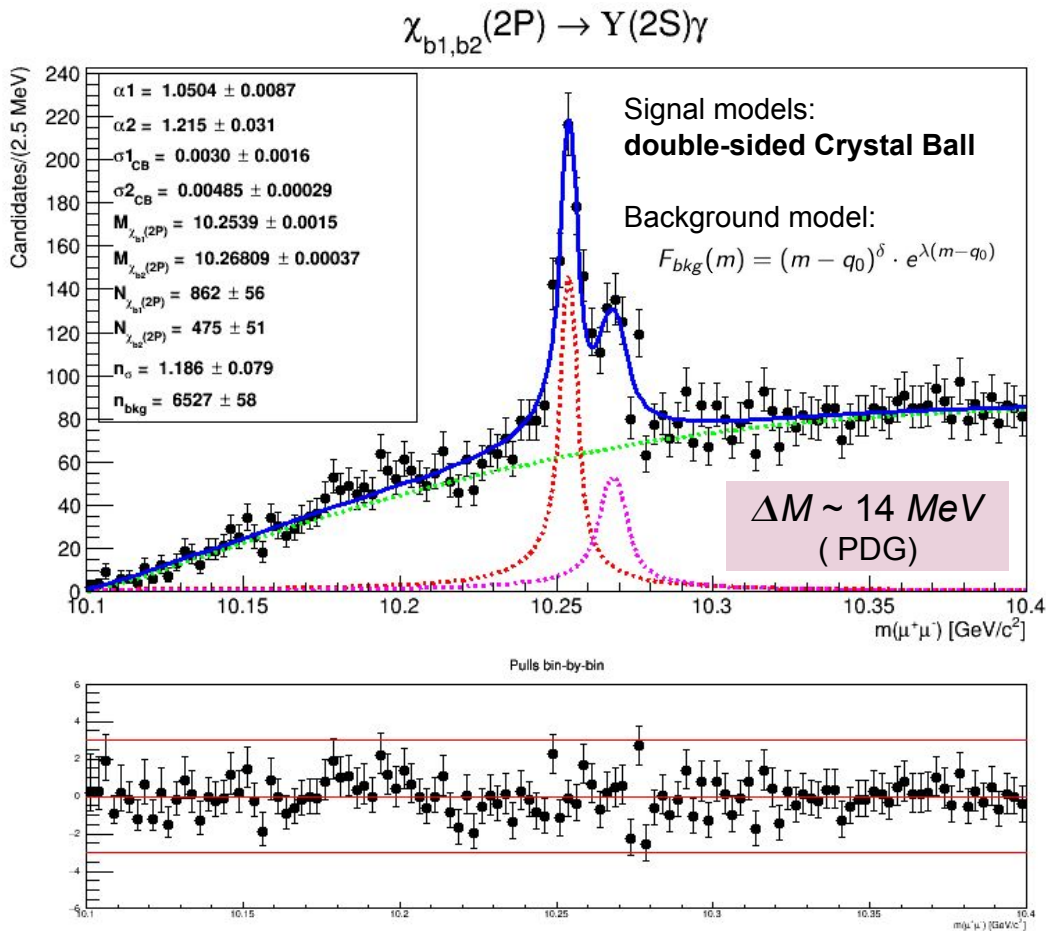


$\chi_{b1,2}(1P) \rightarrow Y(1S)\gamma$



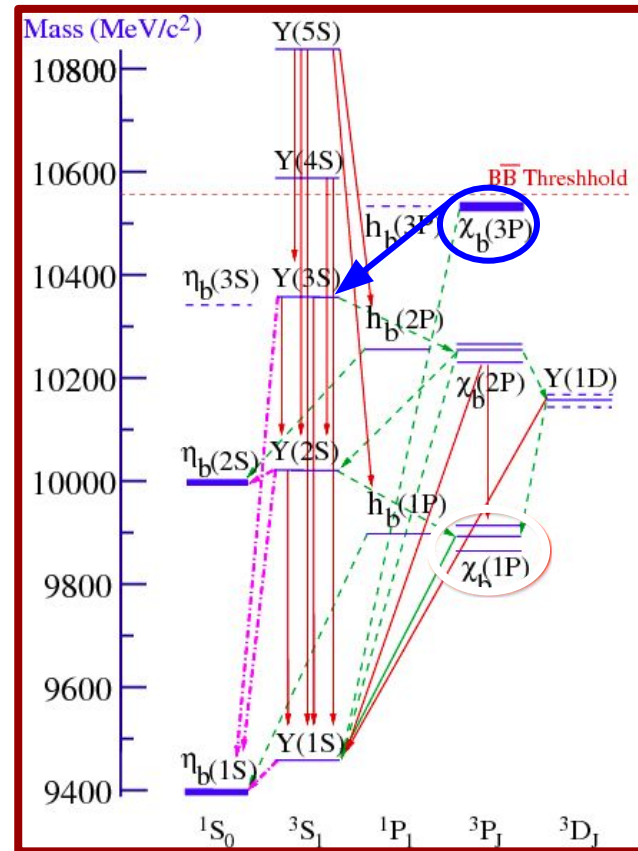
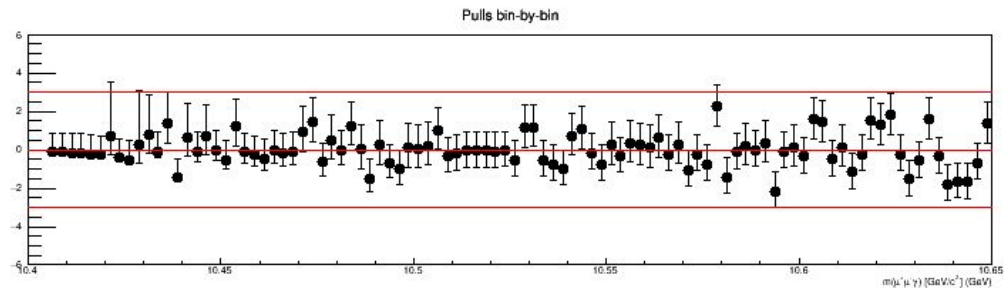
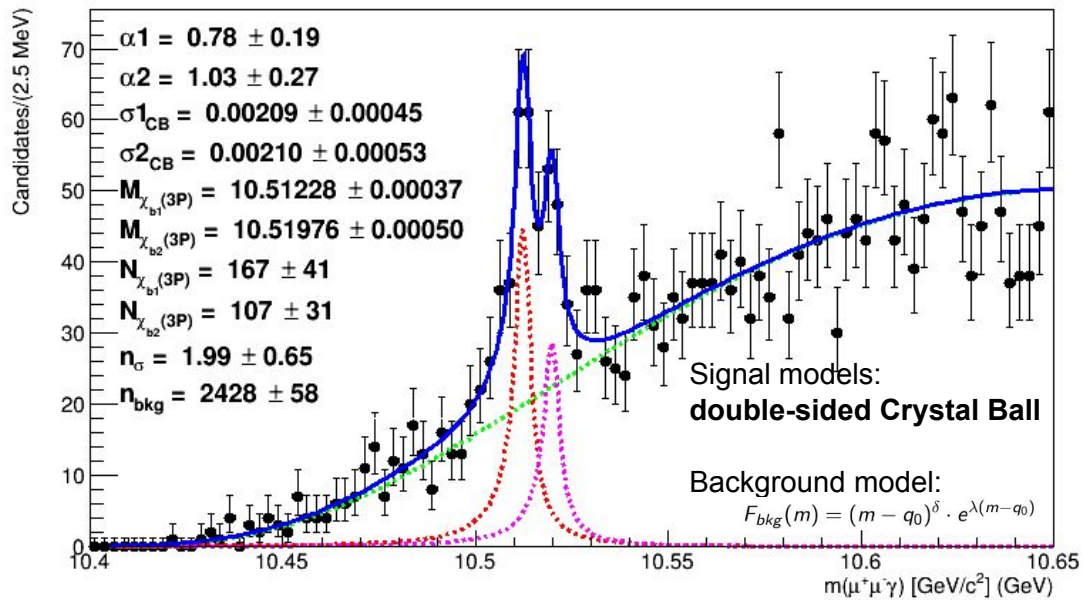
Signal window to reconstruct $\chi_b(1P)\pi\pi$:
 $9.87 < \chi_{b1,2}(1P) < 9.92$

$\chi_{b1,2}(2P) \rightarrow Y(2S)\gamma$



$\chi_{b1,2}(3P) \rightarrow Y(3S)\gamma$

$\chi_{b1,b2}(3P) \rightarrow Y(3S)\gamma$

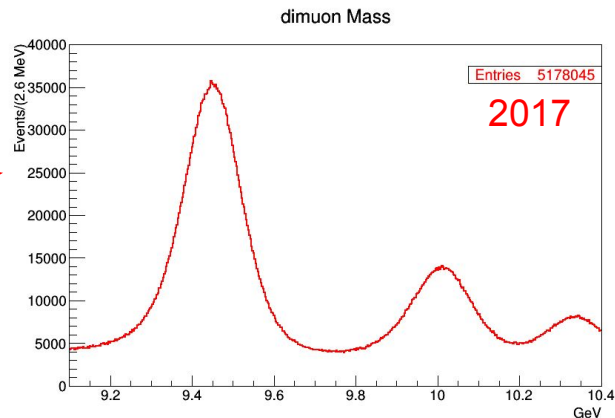
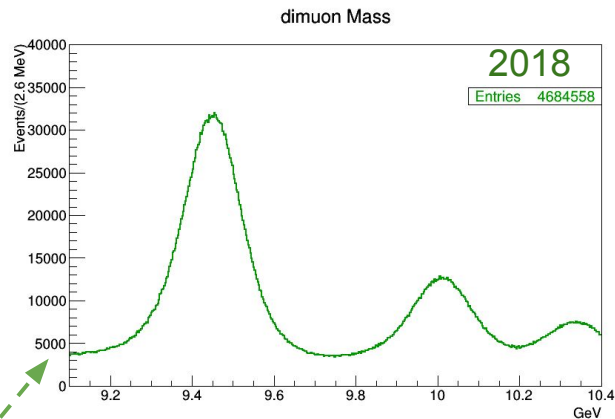
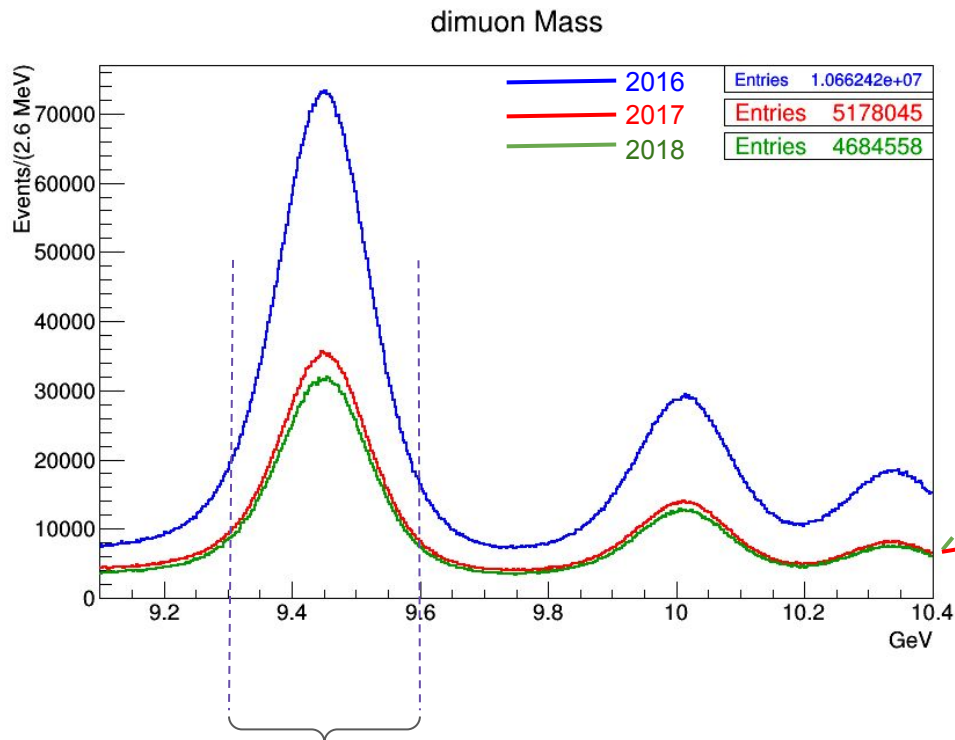


$\Delta M \sim 7.5 \text{ MeV}$ (for 2017 only)
 statistically compatible with CMS paper
 Phys.Rev.Lett.121 (2018) 092002 (backup)

$\gamma(1S) \pi^+ \pi^-$ final state

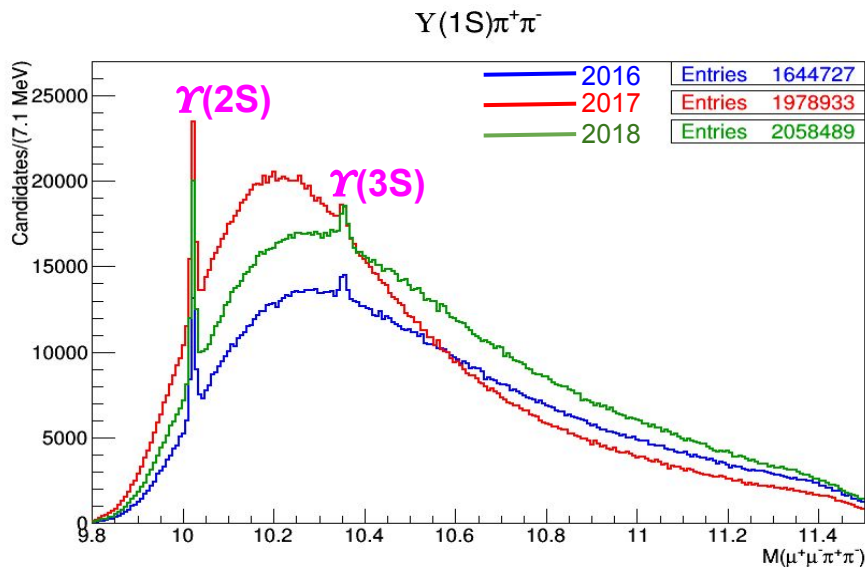
Dimuon S-wave candidates

Note: Y(1S) candidates are more in 2016 because of the lower trigger threshold



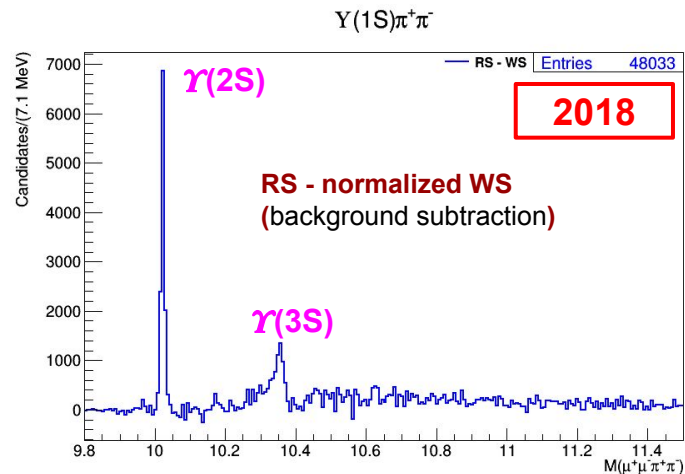
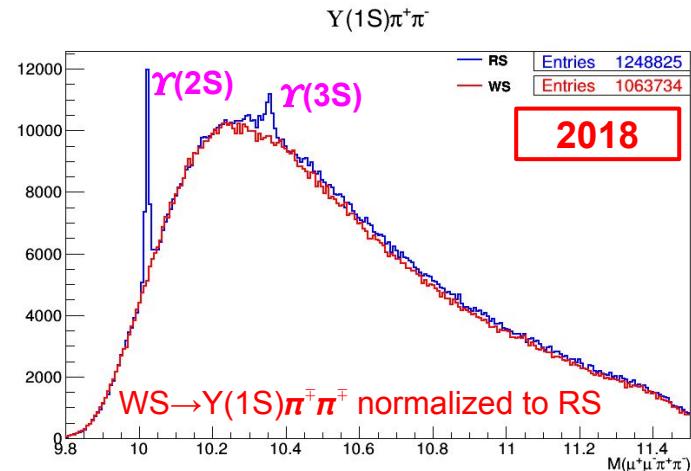
The Y(1S) candidates in this mass window are used to reconstruct $X_b \rightarrow Y(1S)\pi^+\pi^-$ candidates

$\Upsilon(1S)\pi^+\pi^-$



Note: $\Upsilon(1S)$ kinematically constrained to enhance mass resolution

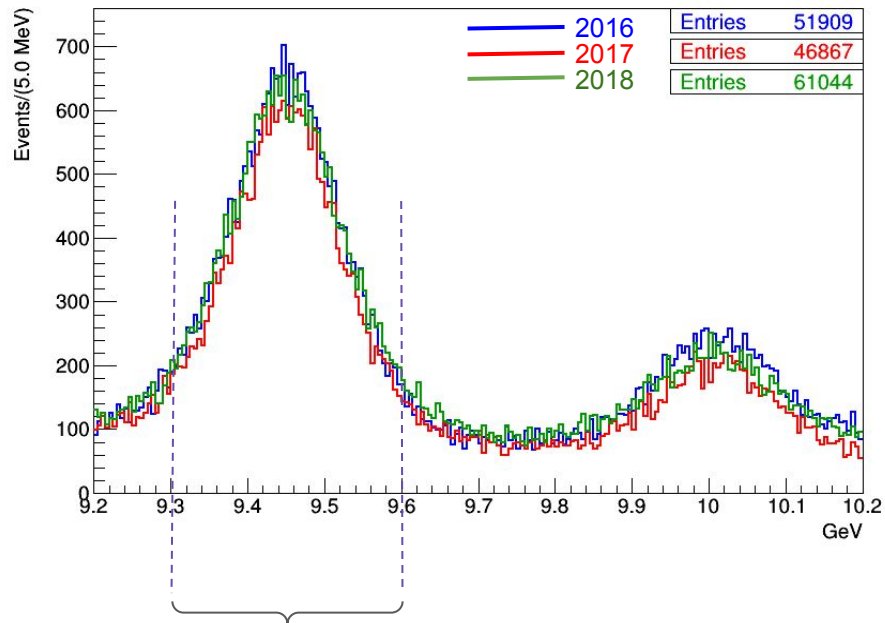
(*) WS normalized to the RS area once signal peaks are removed



$\chi_{b1,2}(1P) \pi^+ \pi^-$ final state

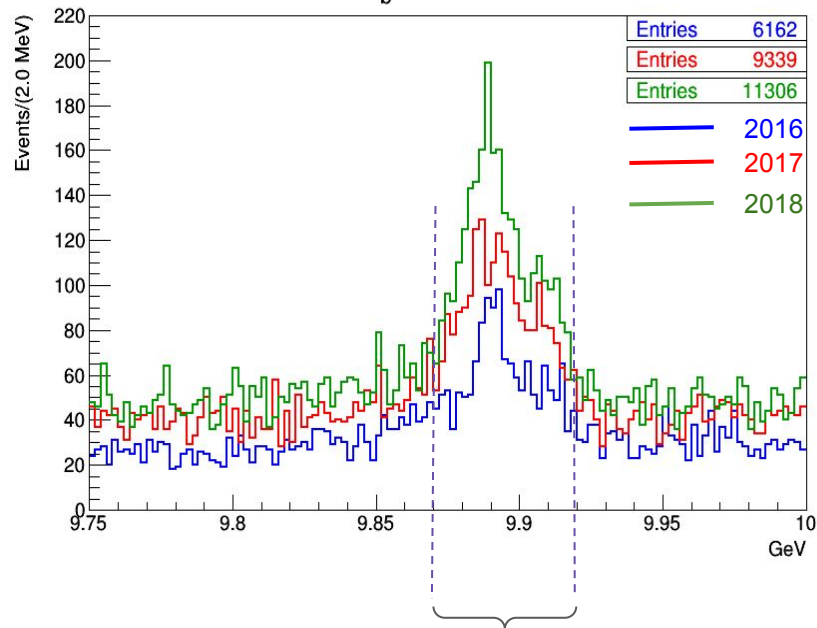
Y(1S) & $\chi_{b1,2}(1P)$

dimuon Mass



The Y(1S) candidates in this mass window are used to reconstruct $\chi_b(1P)$ candidates

$\chi_b(1P)$ Mass



The $\chi_b(1P)$ candidates in this mass window are used to reconstruct $X_b \rightarrow \chi_b(1P)\pi^+\pi^-$ candidates

- $\chi_b(1P) \rightarrow Y(1S)\gamma$ with converted photons
- Y(1S) kinematically constrained to enhance mass resolution

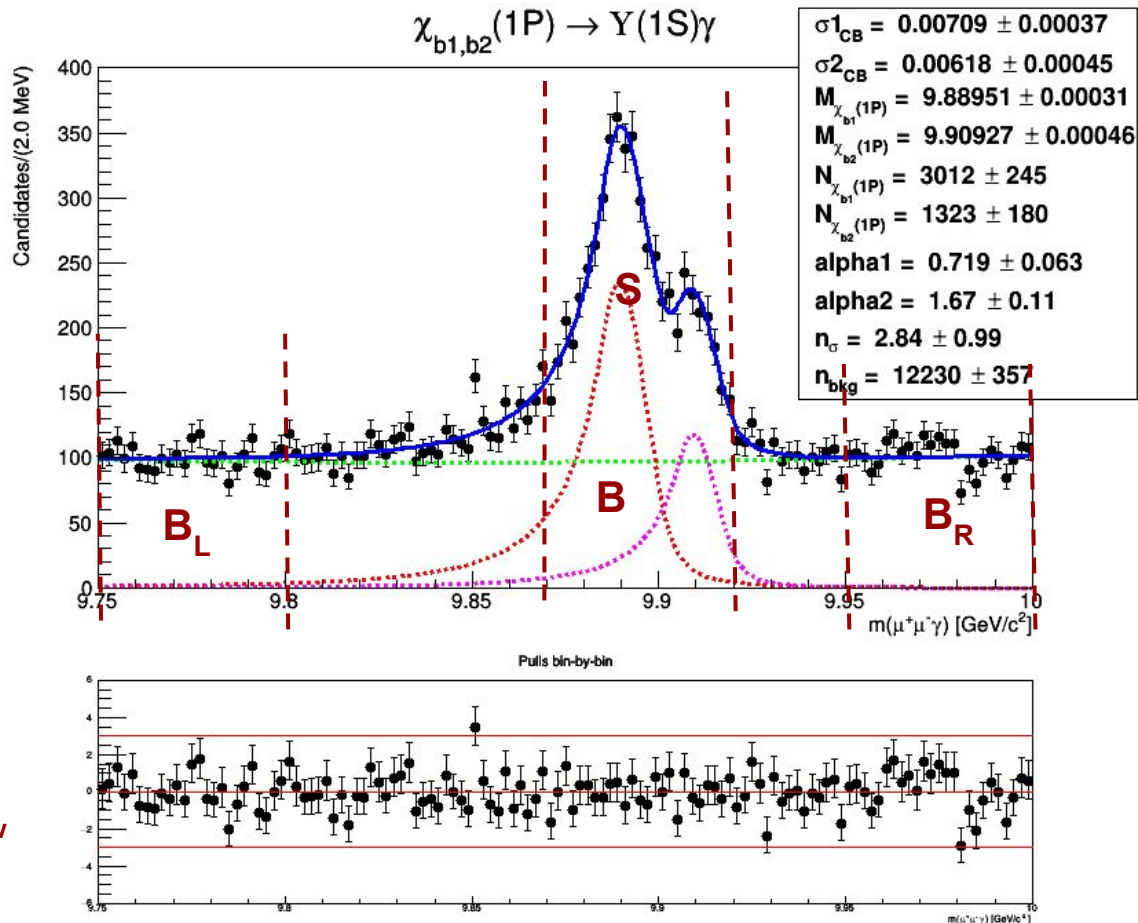
$\chi_{b1,2}(1P)$ signal

2016-2017-2018
all together

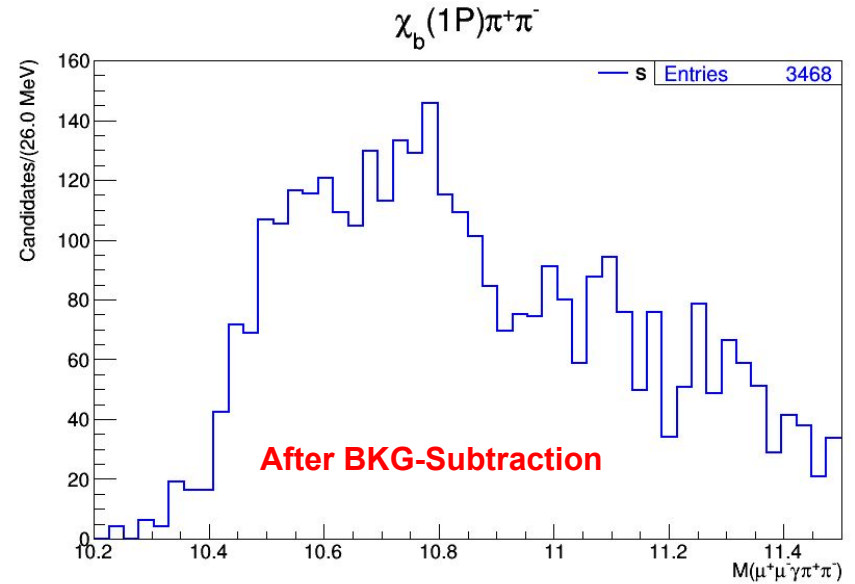
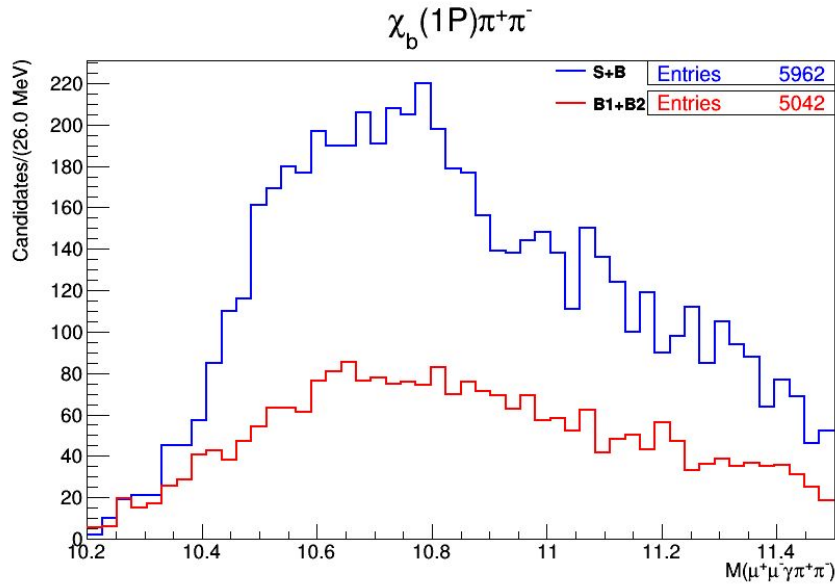
S : Signal
B : BKG in signal region
 B_L : Left sideband BKG
 B_R : Right sideband BKG

$9.87 < S+B < 9.2$
 $9.75 < B_L < 9.8$
 $9.95 < B_R < 10$

❖ The $\chi_b(1P)$ candidates in S+B mass window are used to reconstruct $X_b \rightarrow \chi_b(1P)\pi^+\pi^-$ candidates



$\chi_b(1P)\pi^+\pi^-$

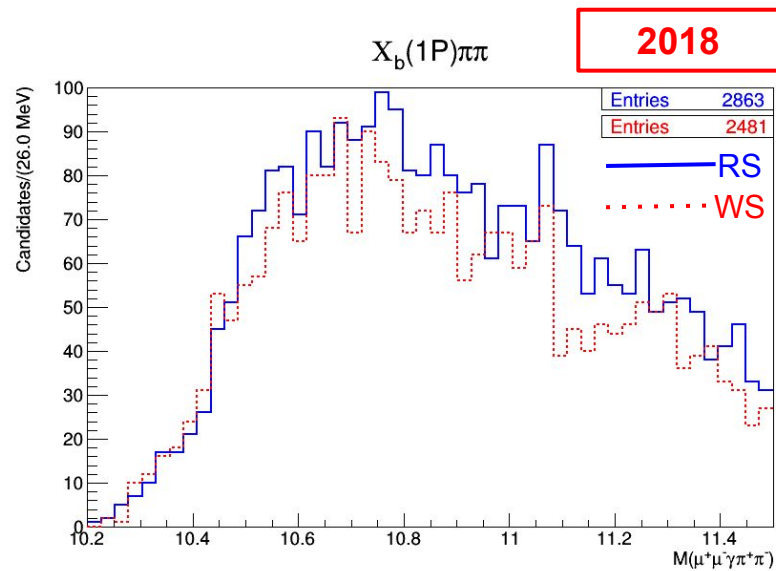
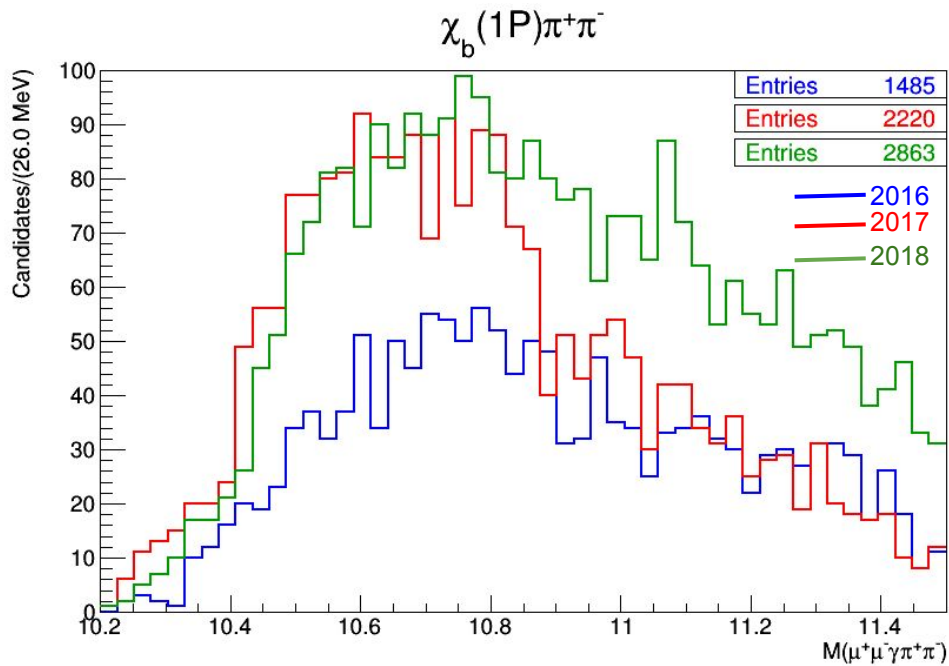


2016-2017-2018

B_L+B_R is normalized to B

- ❖ Left hand side plot shows **signal+BKG** (in blue) in signal region superimposed to **BKG sidebands** (normalized to BKG in the signal region) (in red)
- ❖ Right hand side plot shows entries only for signal :
 $S = (S+B) - [(B_L+B_R) \times B / (B_L+B_R)]$

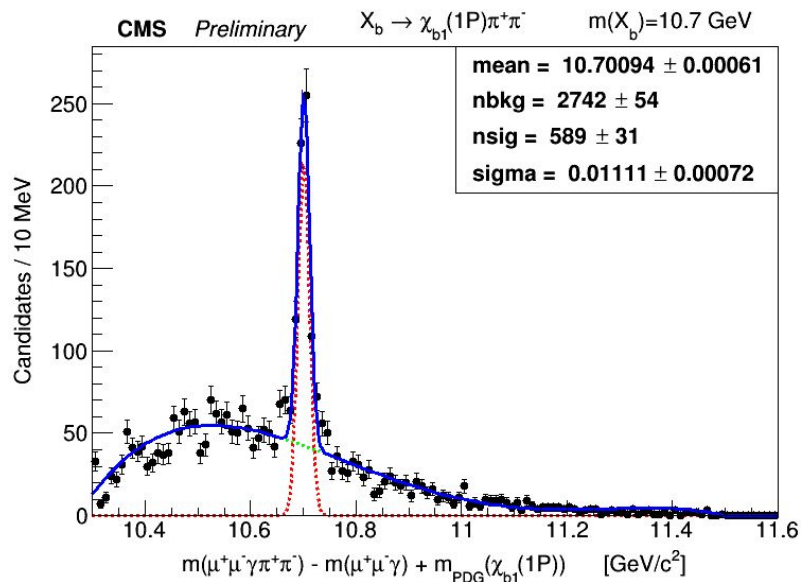
$\chi_b(1P)\pi^+\pi^-$



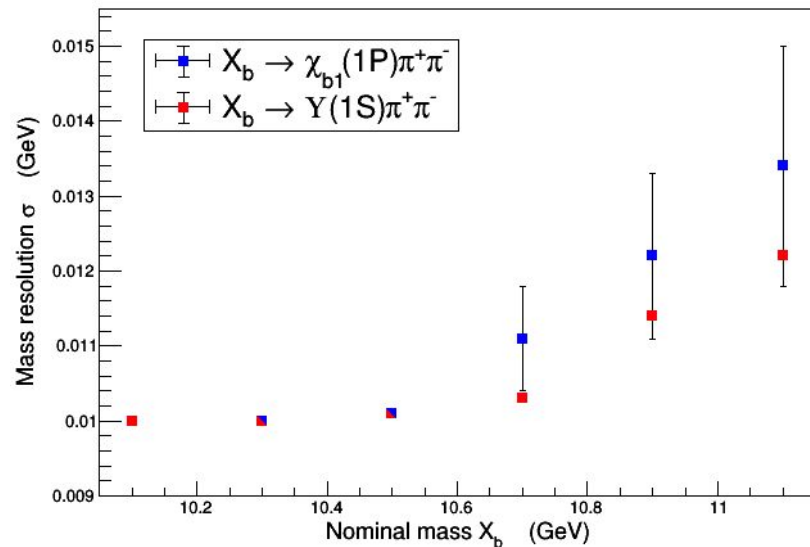
Distributions under investigation

Monte Carlo generation & Studies

Produced several signal (X_b) MC samples generated at different assigned mass values for X_b (and null intrinsic widths)



MASS RESOLUTION behaviour
(as expected increases with nominal X_b mass)



- Monte Carlo samples to be used to estimate reconstruction efficiencies

Future plan

- Adding full 2018 statistics as soon as last part of data taking will be over
- Need to estimate reconstruction efficiencies from MC samples
- Perform studies to better understand efficiency conversion of photons, and to understand backgrounds.
- Set up and configure the upper limit CMS software for our case

Attended schools, conferences and projects

- ❖ CMS BPH Workshop, CERN, 9-10 Apr 2018
- ❖ Research project MX18MO11 within the Executive Program of Scientific and Technological Collaboration between Italy and Mexico 2018-2020, Mexico City, (Mexico), 30 April - 29 May 2018
- ❖ XXX National Seminar of Nuclear and Subnuclear Physics “F. Romano”, Otranto (Italy), 5-12 Jun 2018
- ❖ Second International PhD School on Open Science Cloud, Perugia (Italy), 17-21 Sep 2018

List of publications

I have CMS Collaboration authorship (about 180 papers).

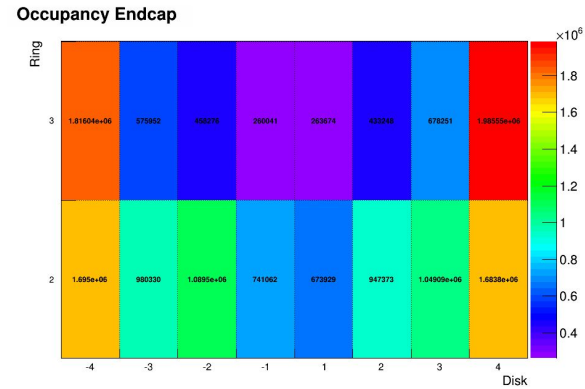
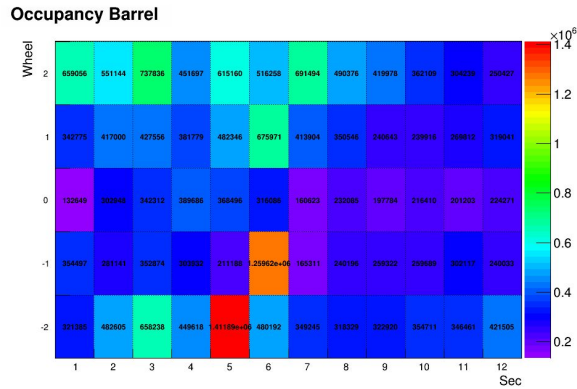
- ▶ **“Measurement of B_s^0 meson production in pp and PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV”**, CMS Collaboration. Phys. Rev. 120 (2018) 202005, arXiv:1810.03022 [hep-ex]. CMS-HIN-17-008, CERN-EP-2018-257.
- ▶ **“Observation of the $\chi_{b1}(3P)$ and $\chi_{b2}(3P)$ and measurement of their masses”**, CMS Collaboration. Phys. Rev. 121 (2018) 092002, arXiv:1805.11192 [hep-ex]. CMS-BPH-17-008, CERN-EP-2018-134.
- ▶ **“Angular analysis of the decay $B^+ \rightarrow K^+ \mu^+ \mu^-$ in proton-proton collisions at $\sqrt{s} = 8$ TeV”**, CMS Collaboration. arXiv:1806.00636 [hep-ex]. CMS-BPH-15-001, CERN-EP-2018-125.
- ▶ **“Observation of the $Z \rightarrow \psi \ell^+ \ell^-$ decay in pp collisions at $\sqrt{s} = 13$ TeV”**, CMS Collaboration. arXiv:1806.04213 [hep-ex]. CMS-BPH-16-001, CERN-EP-2018-131.
- ▶ **“Studies of $B_{s2}^*(5840)^0$ and $B_{s1}(5830)^0$ mesons including the observation of the $B_{s2}^*(5840)^0 \rightarrow B^0 K_S^0$ decay in proton-proton collisions at $\sqrt{s} = 8$ TeV”**, CMS Collaboration. arXiv:1809.03578 [hep-ex]. CMS-BPH-16-003, CERN-EP-2018-224.
- ▶ **“Measurement of the Λ_b polarization and angular parameters in $\Lambda_b \rightarrow J/\psi \Lambda$ decays from pp collisions at $\sqrt{s} = 7$ and 8 TeV”**, CMS Collaboration. arXiv:1802.04867 [hep-ex]. CMS-BPH-15-002, CERN-EP-2017-331.

THANK YOU

BACKUP

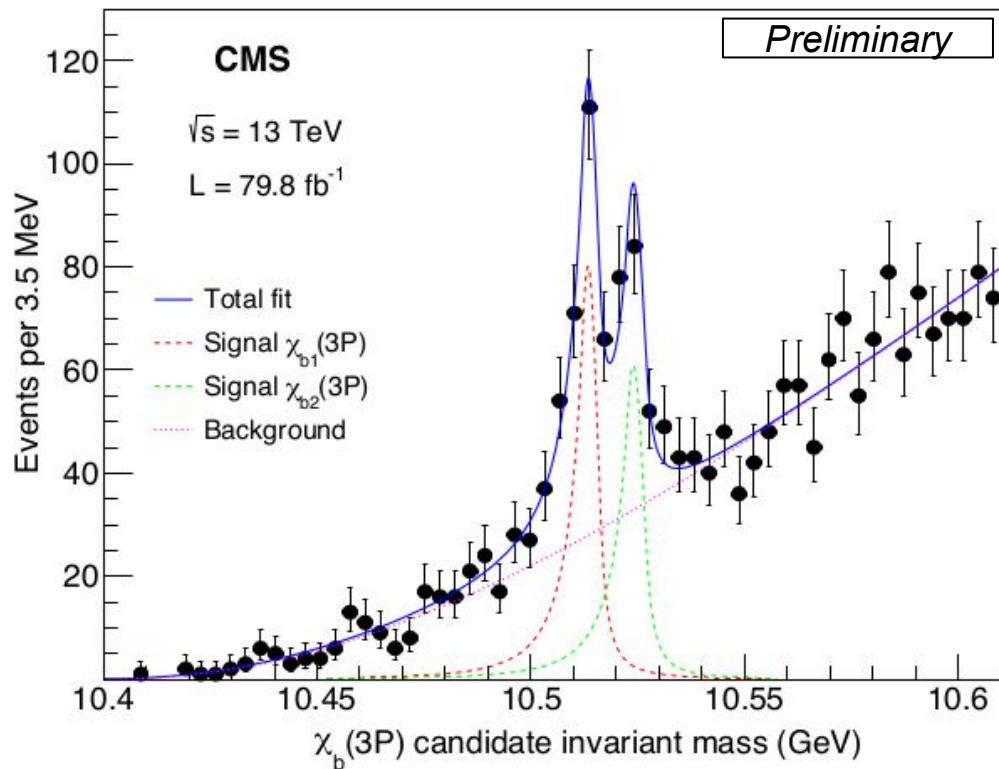
Study and development of RPC DQM

- DQM is divided into two main repositories within the CMS software: “CMSSW” and “DMWM” repositories. The former is used to produce and harvest histograms describing the data taken by CMS, the latter to manage such histograms for online and offline shifter layouts.



- *I have worked taking care of these histograms (additions, bug fixes, etc.).*
- *Also before technical stop, in the RPC DPG, we have been planning to have some DQM plots which can compare the new readout chains (TwinMux, CPPF and OMTF) and their inputs unpacked versus existing legacy readout. It is still on going with integration test for online and offline DQM.*

$\chi_{b1,b2}(3P) \rightarrow Y(3S)\gamma$ - BACKUP



$$\Delta M \equiv M(\chi_{b2}(3P)) - M(\chi_{b1}(3P))$$

$$\Delta M = 10.61 \pm 0.63 \text{ MeV}$$

$$M(\chi_{b1}(3P)) = 10\,513.42 \pm 0.41 \text{ MeV}$$