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Study of B_c^+ decays at CMS

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Outline

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- MC signal and background shape
- Data fit result
- Efficiencies
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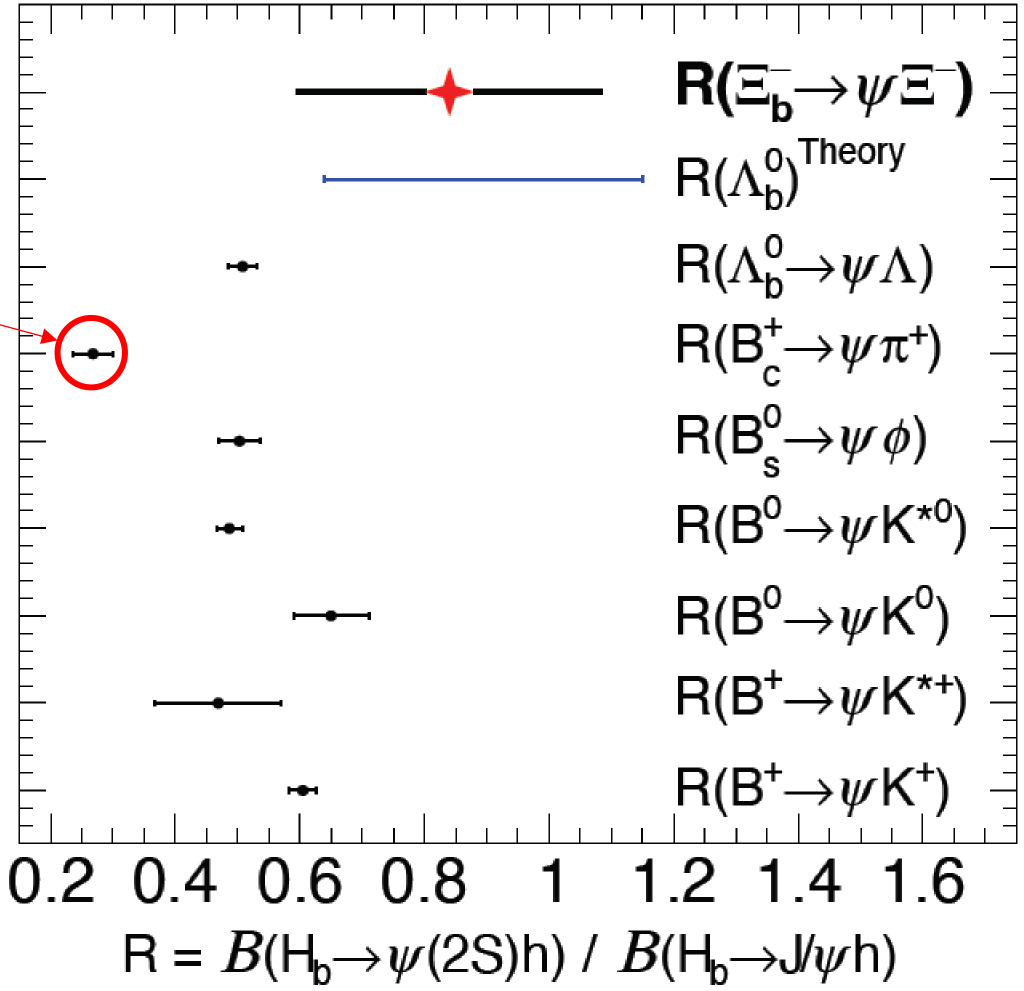
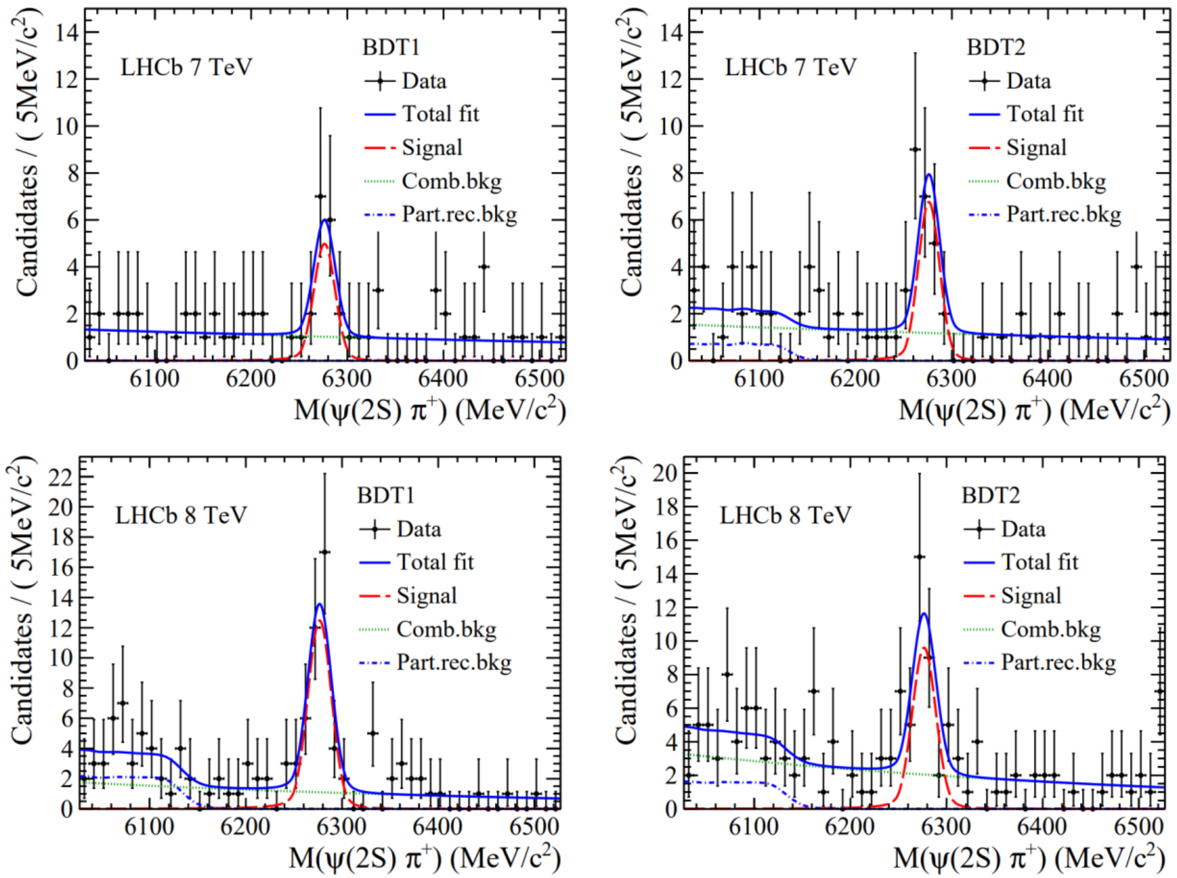
Motivation

- Probability ratios of similar decays, such as the two-particle decays of ground states of b hadrons at the [ψ(2S) h] and [J/ψ h], where h is a light hadron, have been measured quite accurately. Comparing the ratios, we can see that for the B_c meson the ratio R stands out from the general pattern.
  The reason is probably related to the internal dynamics of B_c decay. Measuring branching fractions of b hadrons allows us to test the predictions and approaches of theoretical models used in the calculation of the decays.
- The decay was discovered in the LHCb experiment. The first result for R was based on data from RunI. The second LHCb measurement was obtained using both RunI and RunII data (with unc. ~7.4%).
- Our interest is to confirm or refute this observation in a new, independent measurement, and to improve the accuracy of the world average value.



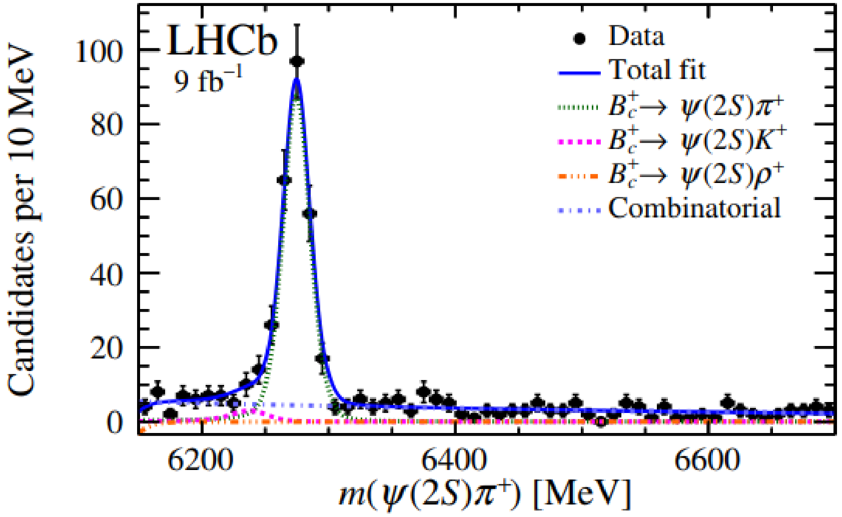
LHCb results

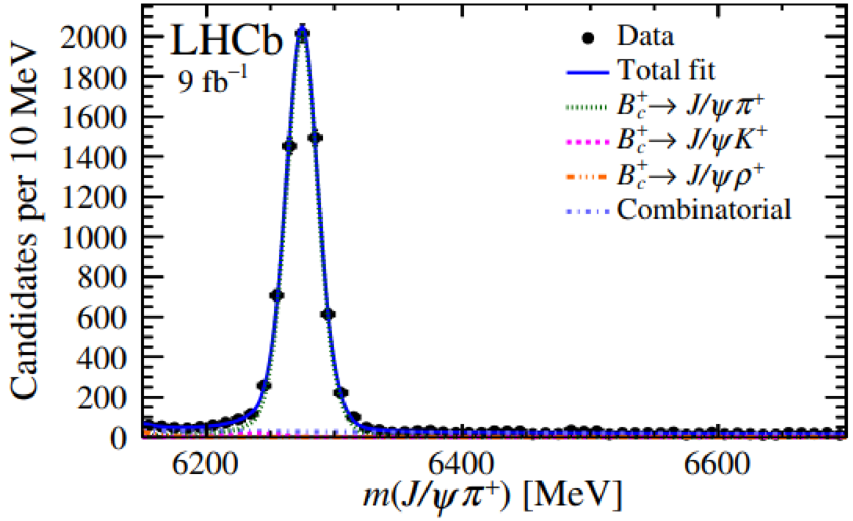
RunI data only



$$R_{\mathcal{B}} = 0.268 \pm 0.032\,(\text{stat}) \pm 0.007\,(\text{syst}) \pm 0.006\,(\text{BF})$$

RunI and RunII data





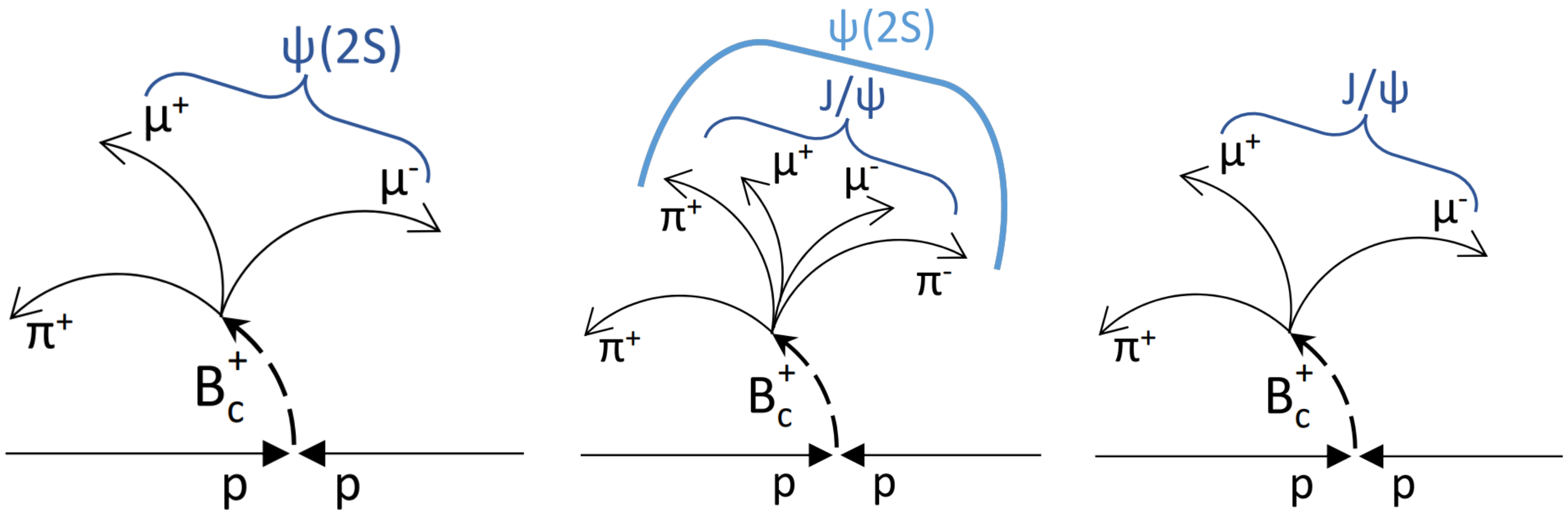
$$R_{\psi(2S)/J/\psi} = 0.254 \pm 0.018\,(\text{stat}) \pm 0.003\,(\text{syst}) \pm 0.005\,(\text{BF})$$

Full RunII(2016-2018) and RunIII(2022-2033) experimental data is used

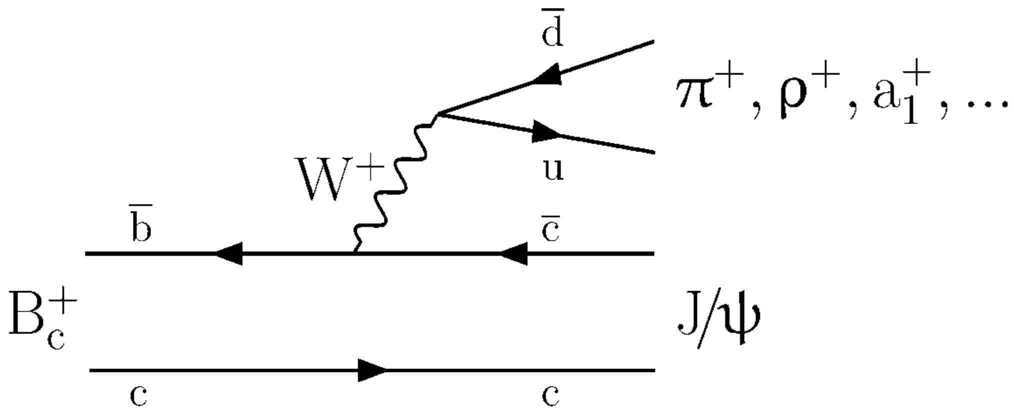
Channels

1. **$B_c^{\pm} \rightarrow \psi(2S)\, \pi^{\pm}$**
   where $\psi(2S) \rightarrow \mu^+\mu^-$

2. **$B_c^{\pm} \rightarrow \psi(2S)\, \pi^{\pm}$**
   where $\psi(2S) \rightarrow J/\psi\, \pi^+\pi^-$



3. **Normalizing channel**
   $B_c^{\pm} \rightarrow J/\psi\, \pi^{\pm}$
   where $J/\psi \rightarrow \mu^+\mu^-$



Simulation

The BCVEGPY generator, which is interfaced to the PYTHIA parton shower and hadronization model, is used to simulate charmed B meson production. The B hadron decays are modelled with EVTGEN. Final-state radiation is included in EVTGEN using PHOTOS. The events are then passed through a detailed GEANT4-based simulation of the CMS detector and the same trigger and reconstruction algorithms used on data. The simulation includes additional interactions due to additional pp collisions in each bunch crossing (pileup).

- $B_c^+ \to \psi(2S)\pi^+[\psi(2S) \to \mu^+\mu^-]$ MC samples:
  - Forced decays:
    - $B_c^+ \to \psi(2S)\pi^+, \psi(2S) \to \mu^+\mu^-$ [70.8%] (PHOTOS SVS, PHOTOS VLL models, respectively)
    - $B_c^+ \to \psi(2S)\pi^+, \psi(2S) \to \mu^+\mu^-$ [5.6%] (PHOTOS SVS, PHOTOS VLL models, respectively)
    - $B_c^+ \to \psi(2S)\pi^+, \psi(2S) \to \mu^+\mu^-$ [23.6%] (PHOTOS SVV_HELAMP, PHOTOS VLL models, respectively)

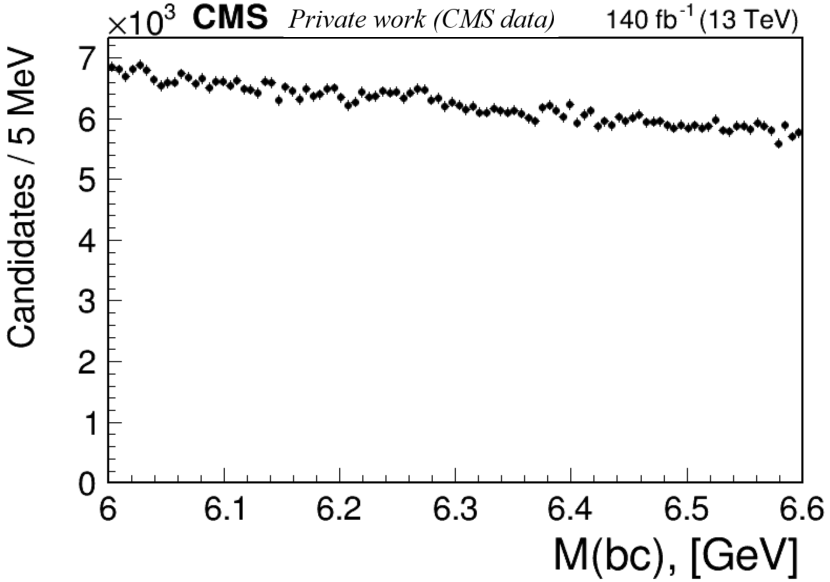
- $B_c^+ \to \psi(2S)\pi^+[\psi(2S) \to J/\psi\pi^+\pi^-]$ MC samples:
  - Forced decays:
    - $B_c^+ \to \psi(2S)\pi^+, \psi(2S) \to J/\psi\pi^+\pi^-, J/\psi \to \mu^+\mu^-$ [70.8%] (PHOTOS SVS, VVPIPI, PHOTOS VLL models, respectively)
    - $B_c^+ \to \psi(2S)\pi^+, \psi(2S) \to J/\psi\pi^+\pi^-, J/\psi \to \mu^+\mu^-$ [5.6%] (PHOTOS SVS, VVPIPI, PHOTOS VLL models, respectively)
    - $B_c^+ \to \psi(2S)\pi^+, \psi(2S) \to J/\psi\pi^+\pi^-, J/\psi \to \mu^+\mu^-$ [23.6%] (PHOTOS SVV_HELAMP, VVPIPI, PHOTOS VLL models, respectively)

- $B_c^+ \to J/\psi\pi^+$ MC samples:
  - Forced decays:
    - $B_c^+ \to J/\psi\pi^+, J/\psi \to \mu^+\mu^-$ [70.8%] (PHOTOS SVS, PHOTOS VLL models, respectively)
    - $B_c^+ \to J/\psi\pi^+, J/\psi \to \mu^+\mu^-$ [5.6%] (PHOTOS SVS, PHOTOS VLL models, respectively)
    - $B_c^+ \to J/\psi\rho^+, J/\psi \to \mu^+\mu^-, \rho^+ \to \pi^+\pi^0$ [23.6%] (PHOTOS SVV_HELAMP, PHOTOS VLL models, respectively)

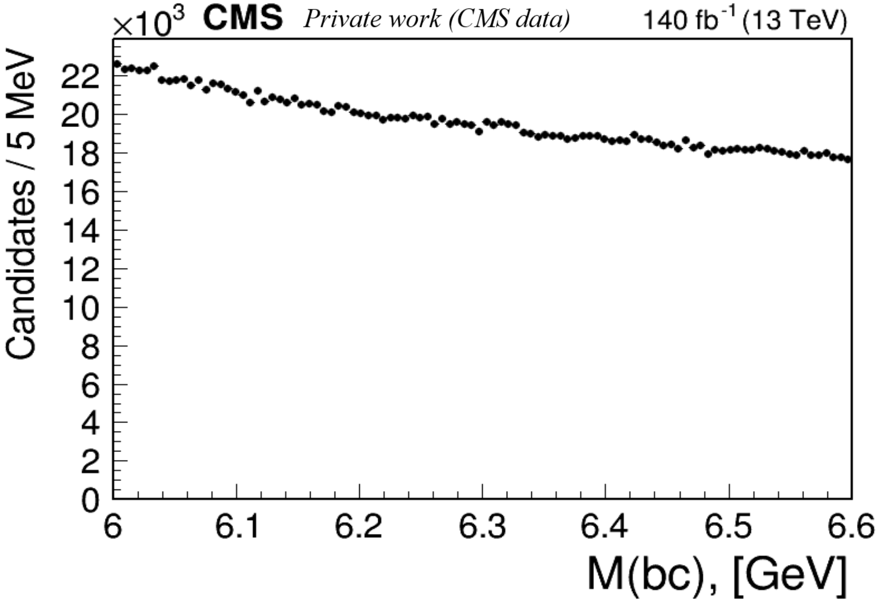
Preselection

- **Standard B physics analysis preselection is performed.**
- Used 2016-2018 datasets RunII data and 2022-2023 RunIII data.
  Trigger optimized to select μμ $+ track$ for RunII and μμ for RunIII in final state.
  Muons are matched to the trigger.
- B_c meson vertex required to be displaced from the PV in the transverse (XY) plane
- PV is selected by the smallest angle between B_c meson momentum and the straight line passing through PV and B_c decay vertex
- B_c meson momentum required to point to the PV in the XY plane
- Ψ(2S) (or J/ψ) is result of μμ vertex fit with mass constraint
- The normalization channel is chosen according to the similar decay topology to reduce the systematic uncertainties.

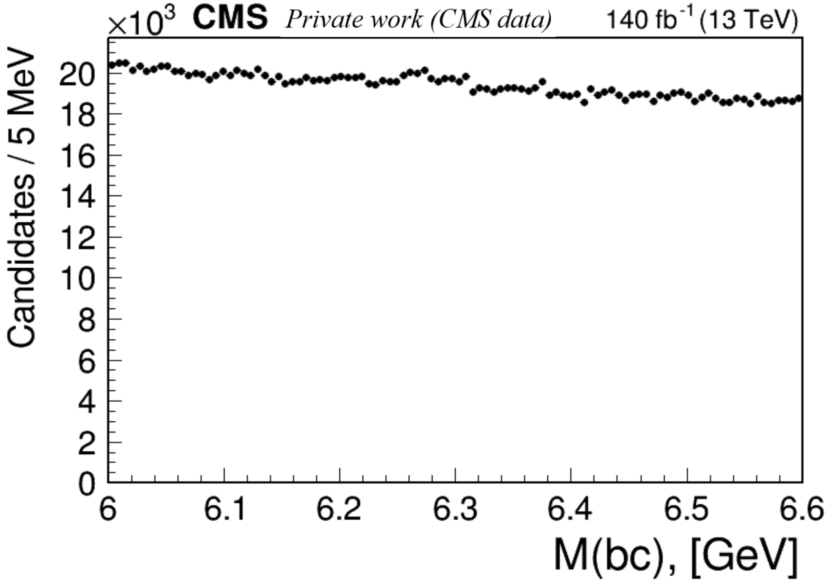
B_c^+ mass distributions after preselection



$B_c^+ \to \psi(2S)[\psi(2S) \to \mu^+\mu^-]\ \pi^+$



$B_c^+ \to \psi(2S)[\psi(2S) \to J/\psi\ \pi^+\pi^-]\ \pi^+$



$B_c^+ \to J/\psi[J/\psi \to \mu^+\mu^-]\ \pi^+$

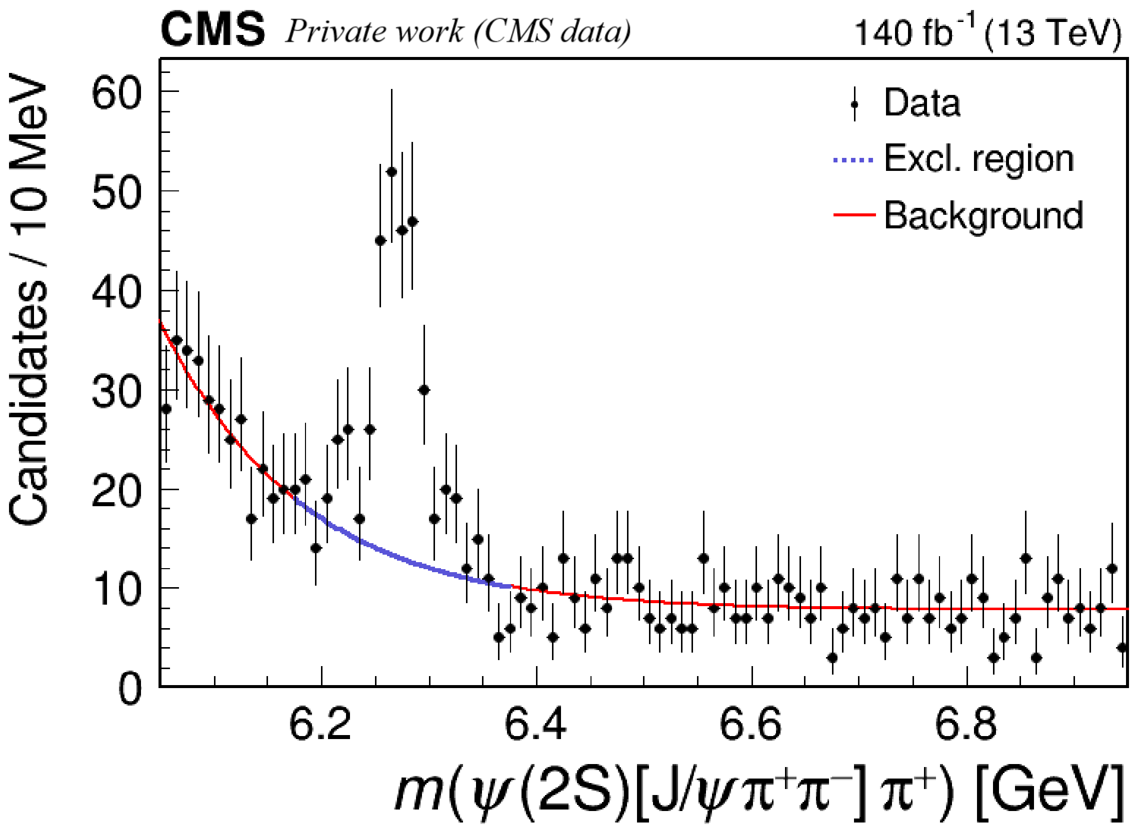
Optimization of selection criteria

- Serial scans on variables were performed to find optimal value of cut by maximizing ***f*** value
- When ***f*** achieves the maximum value corresponding cut is fixed, and its value is used in next scans
- When iteration shows the same result as previous one the procedure of optimization is considered to be completed

Punzi figure of merit is used for the optimization:

$$\boldsymbol{f} = \boldsymbol{S}/(\frac{463}{13} + 4\sqrt{\boldsymbol{B}} + 5\sqrt{25 + 8\sqrt{\boldsymbol{B}} + 4\boldsymbol{B}})$$

- **S** is number of signal events from simulation
- **B** is expected number of background events. The data from the experiment is used, the region $m_{PDG}(\mathrm{Bc}) \pm \sim 3\sigma_{eff}$ is excluded from the fit. The integral in the excluded region is **B**.



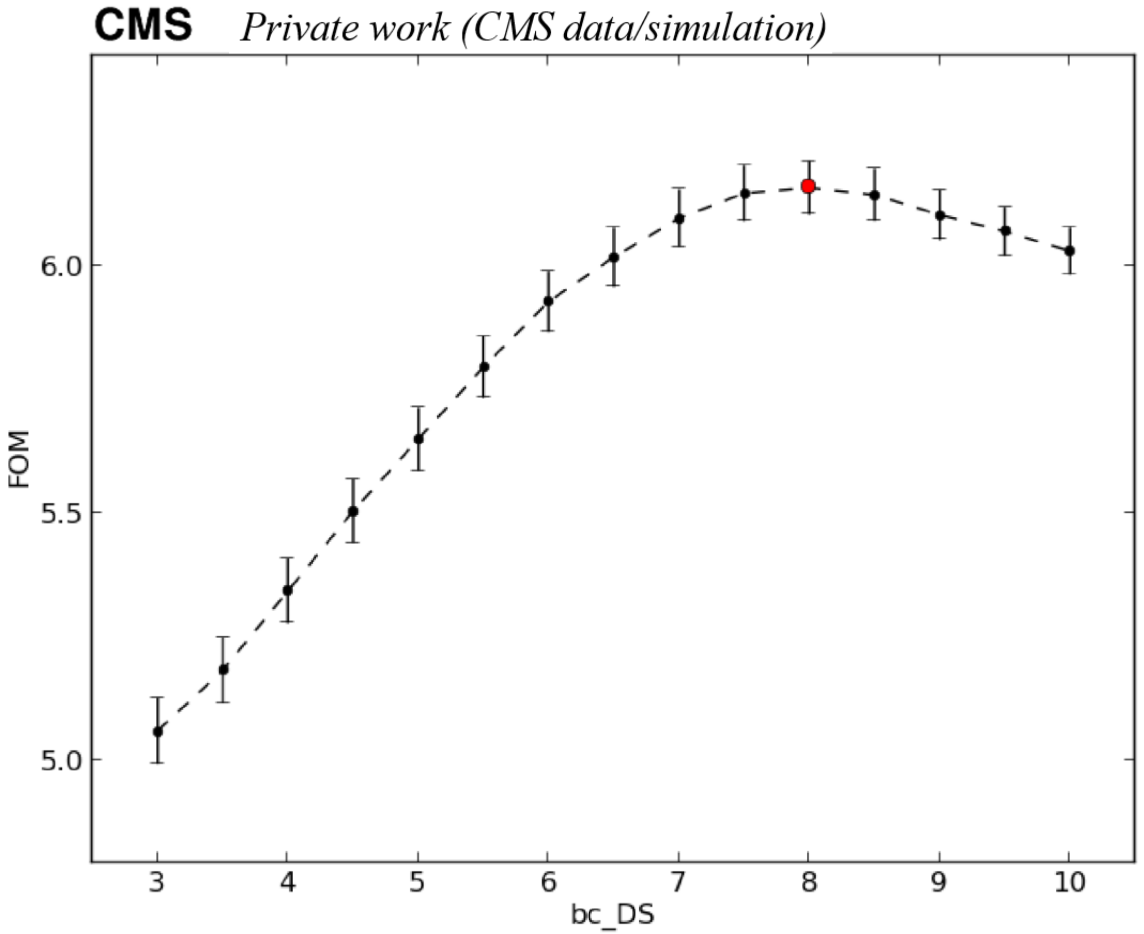
Optimization of selection criteria

Variables to have been optimized

- $p_T(B_c)$
- $p_T(\psi(2S))$ and/or $p_T(J/\psi)$
- $p_T(\pi^{\pm})$ from $\mathbf{B_c}$
- $L_{XY}/\sigma_{L_{XY}}(B_c, PV)$The events
- $P_{vtx}(B_c)$
- IPS($\pi^{\pm}$, PV)
- -lg(1 - cos($\overrightarrow{L_{XY}}$, $\overrightarrow{p_T}$) (B_c))

for $\mathbf{B_c^+ \to \psi(2S)[\psi(2S) \to J/\psi\, \pi^+\pi^-]\, \pi^+}$

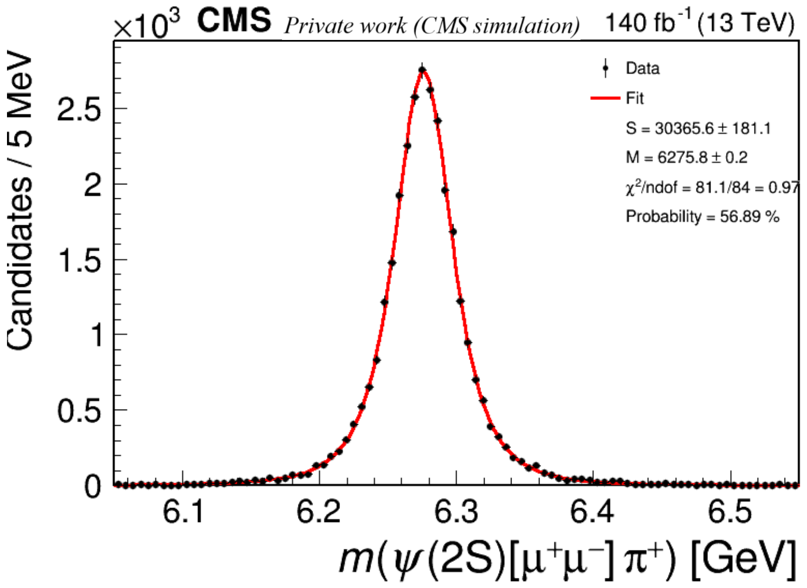
- m($\pi^+\pi^-$) from $\boldsymbol{\psi(2S)}$
- m($\psi(2S)$)



MC signal shape

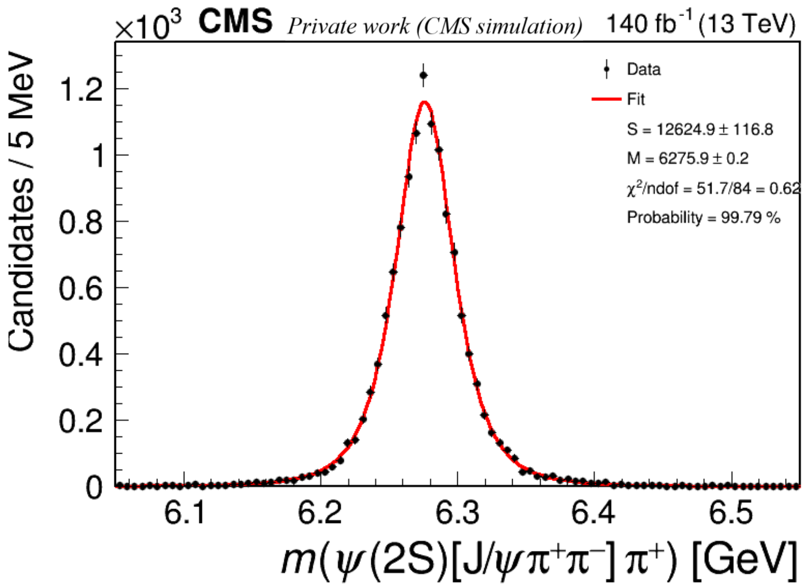
RunII

$B_c^+ \to \psi(2S)[\psi(2S) \to \mu^+\mu^-]\ \pi^+$



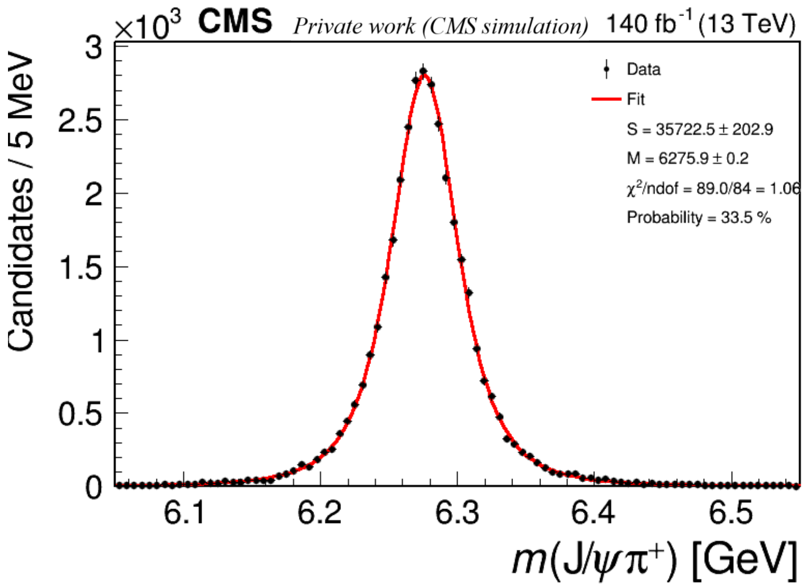
M = 6275.8±0.2 MeV

$B_c^+ \to \psi(2S)[\psi(2S) \to J/\psi\ \pi^+\pi^-]\ \pi^+$



M = 6275.9±0.2 MeV

$B_c^+ \to J/\psi[J/\psi \to \mu^+\mu^-]\ \pi^+$



M = 6275.9±0.2 MeV

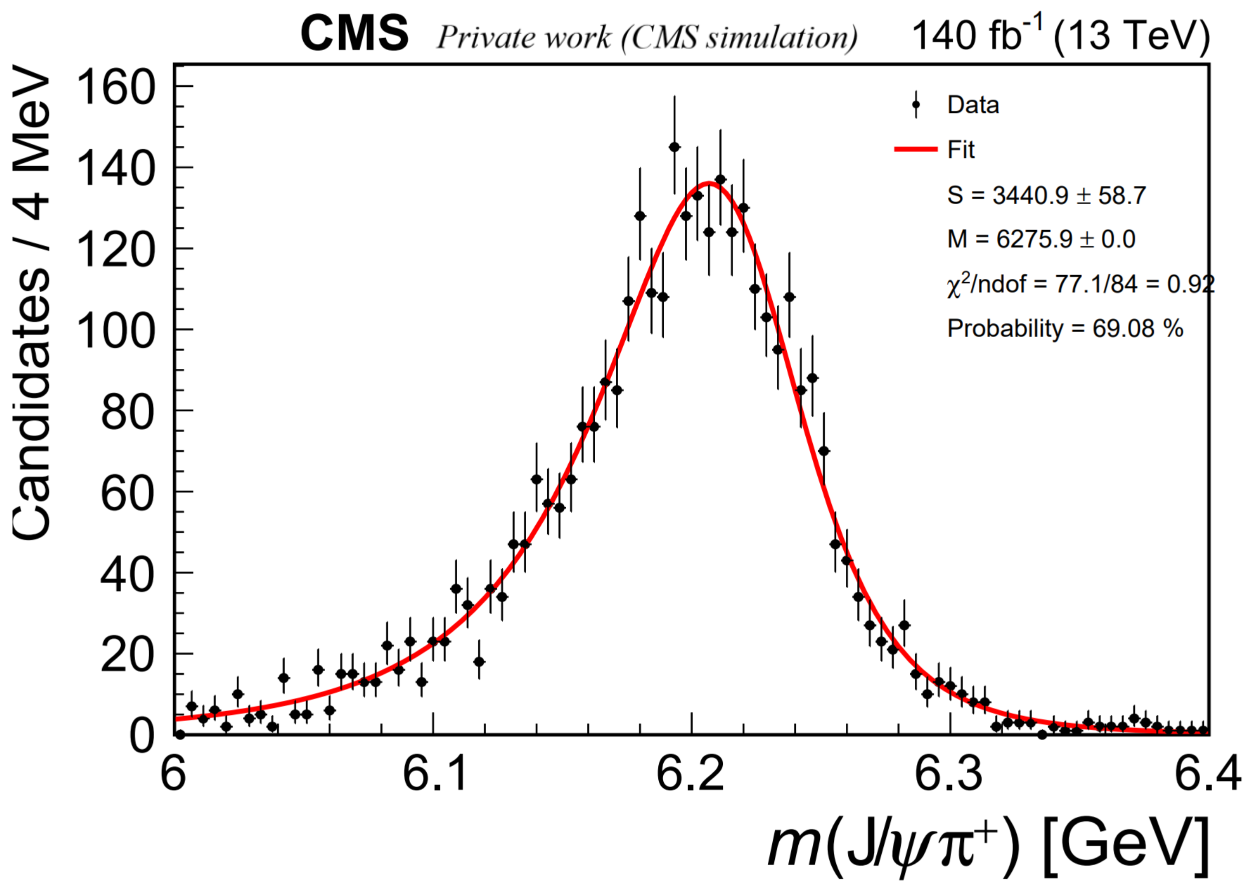
Student T function is used as signal shape

MC background shape

RunII

Reflection

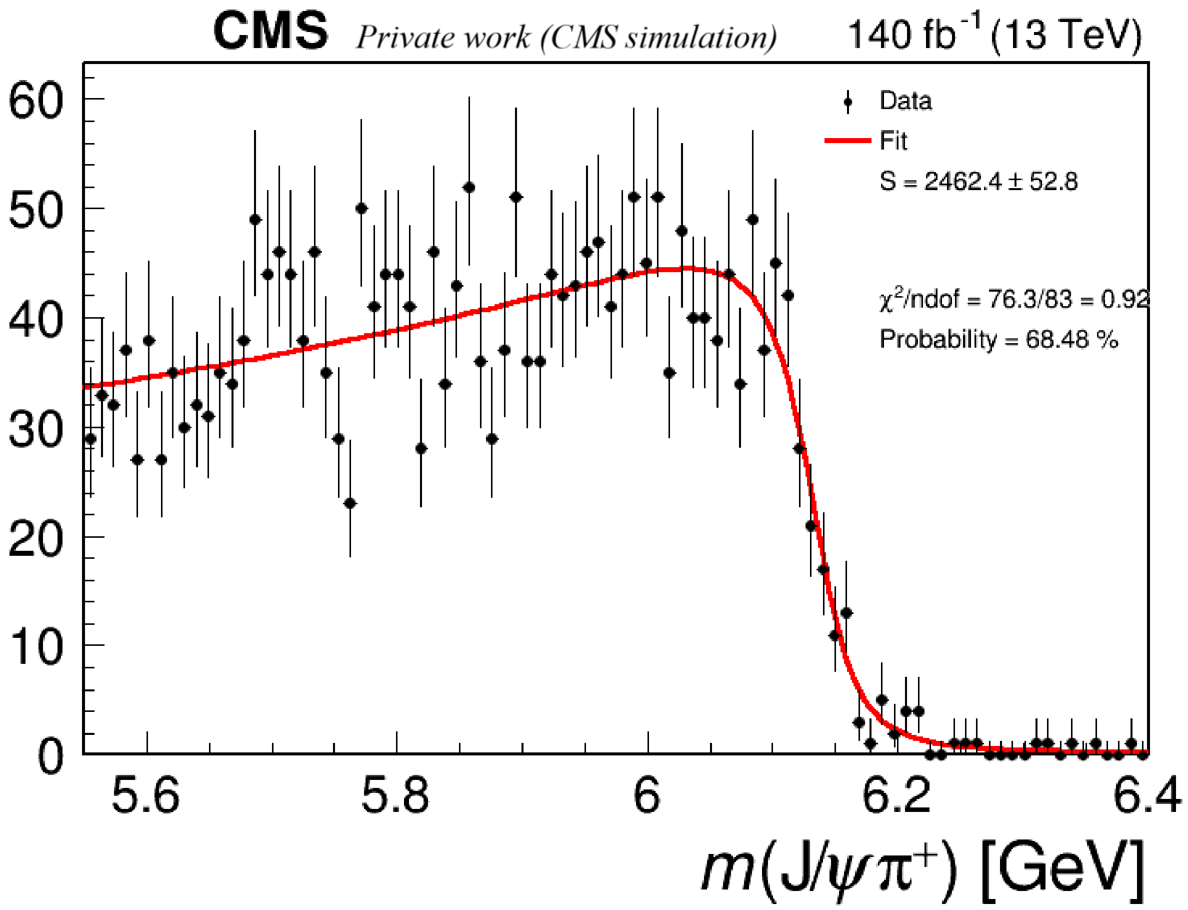
$B_c^+ \to J/\psi[J/\psi \to \mu^+\mu^-]\ K^+$



Johnson$^{\text{refl.}}$

Partially reconstructed

$B_c^+ \to J/\psi[J/\psi \to \mu^+\mu^-]\ \rho^+[\pi^+\ \pi^0]$



Johnson$^{\text{part. reco}}$

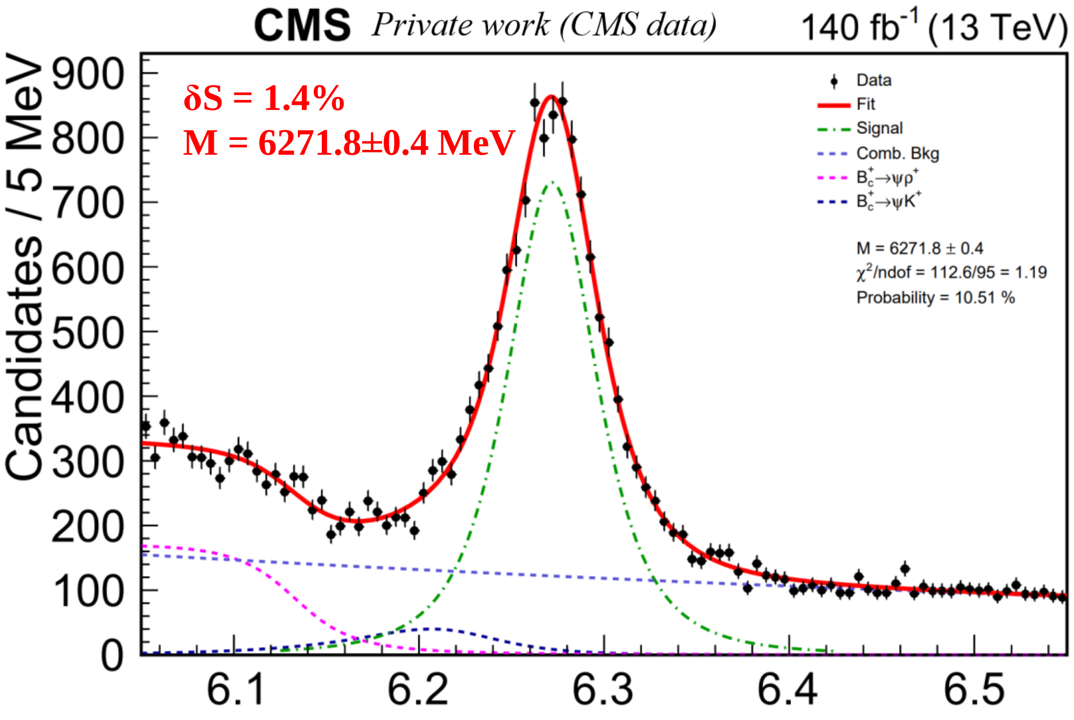
Normalizing channel fit RunII

$B_c^+ \to J/\psi[J/\psi \to \mu^+\mu^-]\,\pi^+$

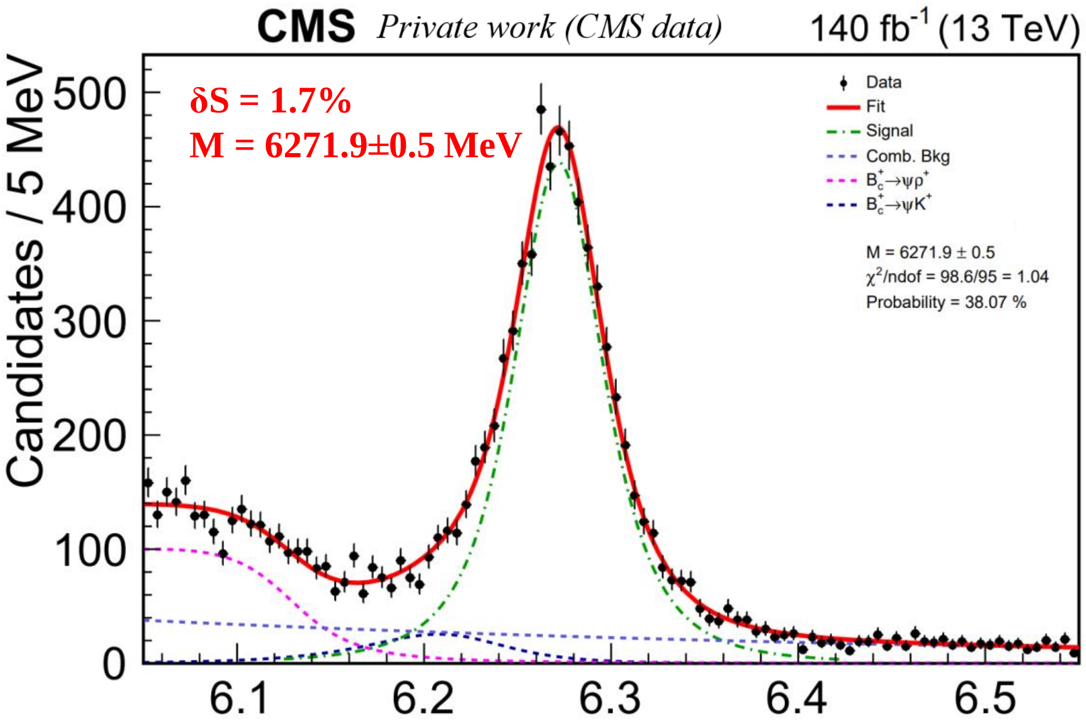
Bkg: exponent + Johnson$^{part.\ reco}$ + Johnson$^{refl.}$

Johnson$^{refl.}$: shape fixed to MC and normalization fixed to branching fractions ratio and gen. efficiencies

Johnson$^{part.\ reco}$: fixed shape to MC



For $\psi(2S) \to \mu^+\mu^-$



For $\psi(2S) \to J/\psi\,\pi^+\pi^-$

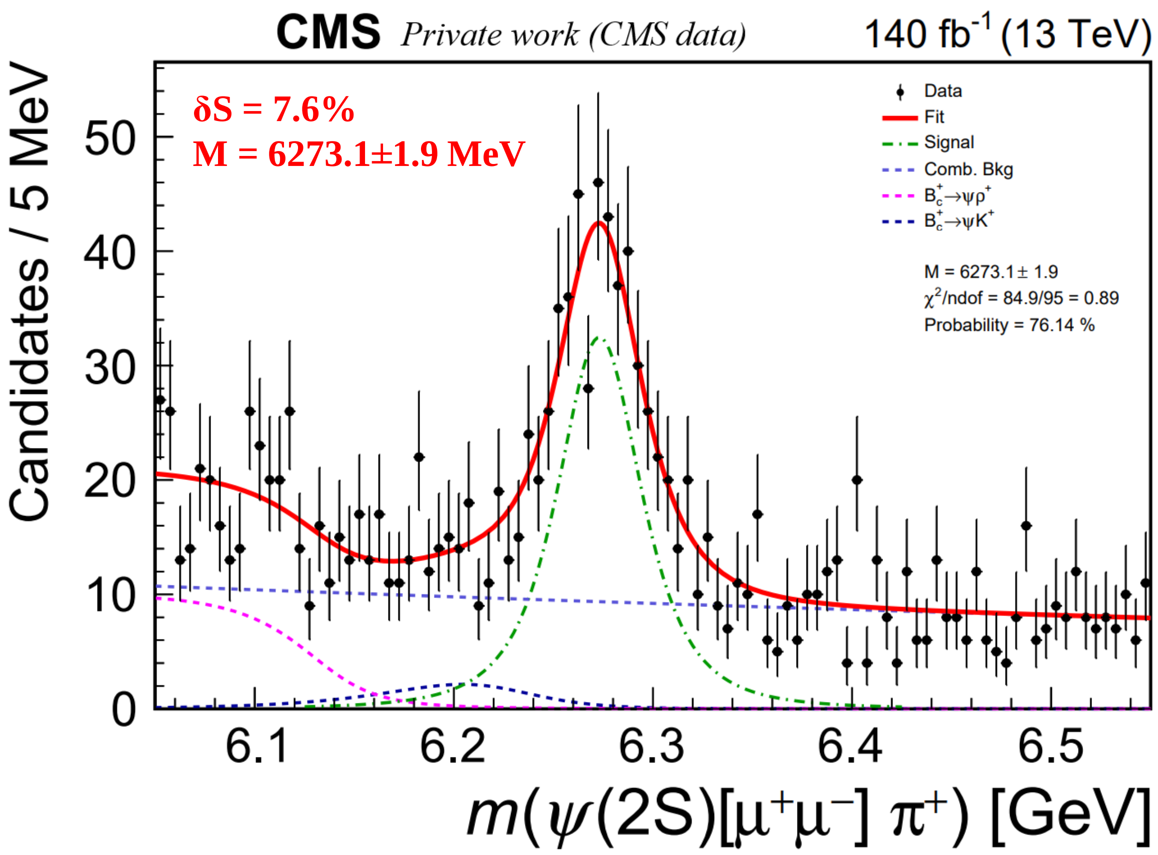
Signal: **Student T** with **parameters fixed** to MC but **free mean**

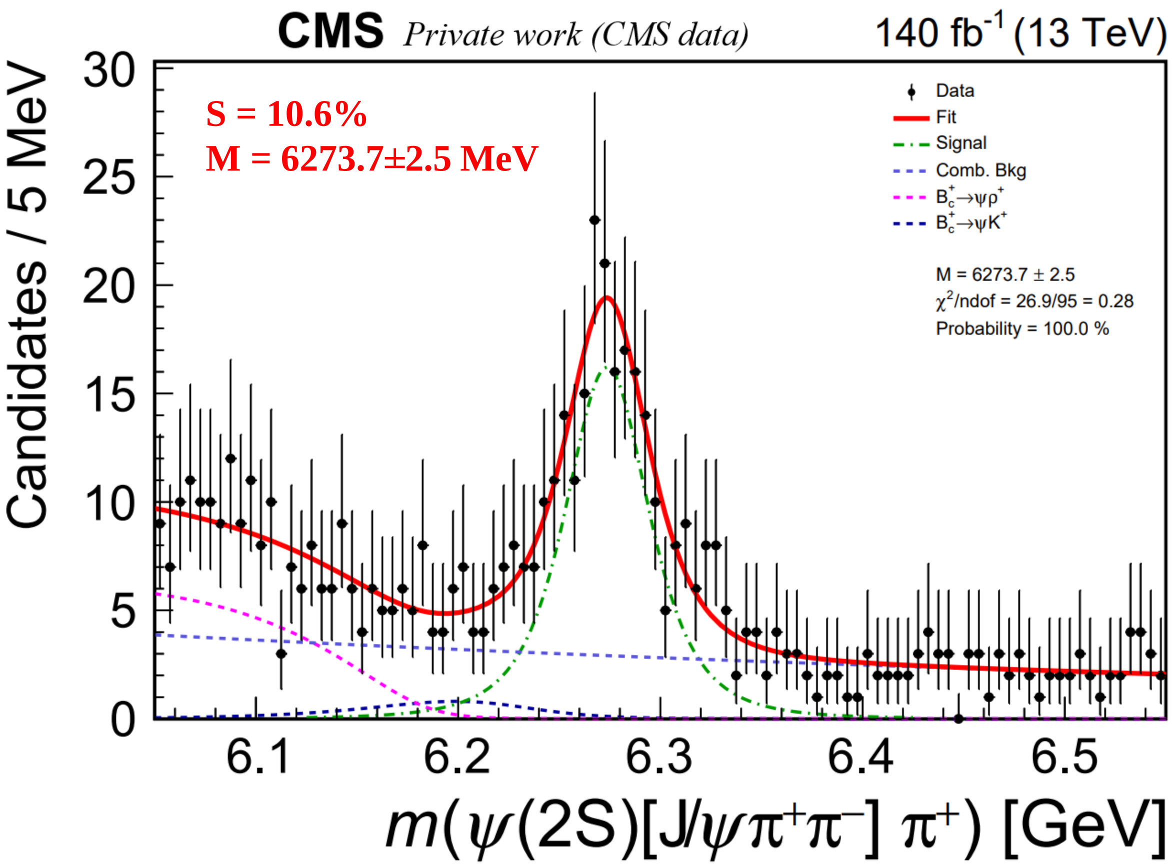
Signal channels fit RunII

Bkg: exponent + Johnson$^{part.\ reco}$ + Johnson$^{refl.}$

Johnson$^{refl.}$: shape fixed to MC and normalization fixed to branching fractions ratio and gen. efficiencies

Johnson$^{part.\ reco}$: fixed shape to MC





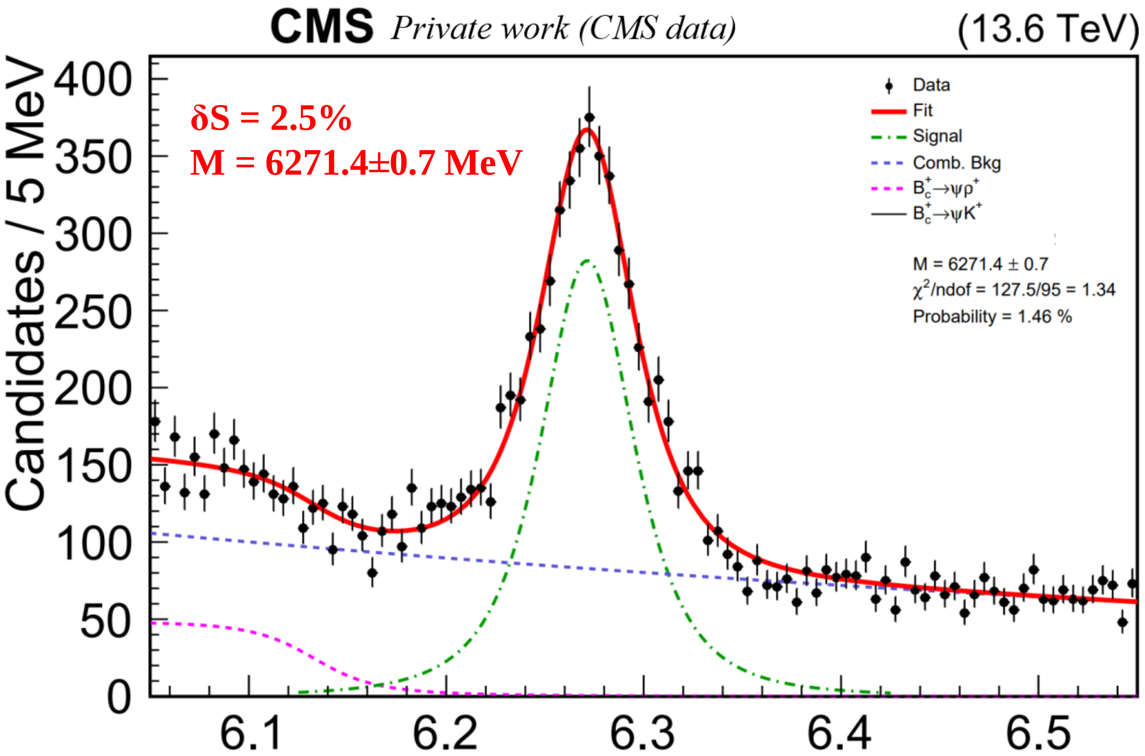
Signal: Student T with **parameters fixed** to MC but **free mean**

Normalizing channel fit RunIII

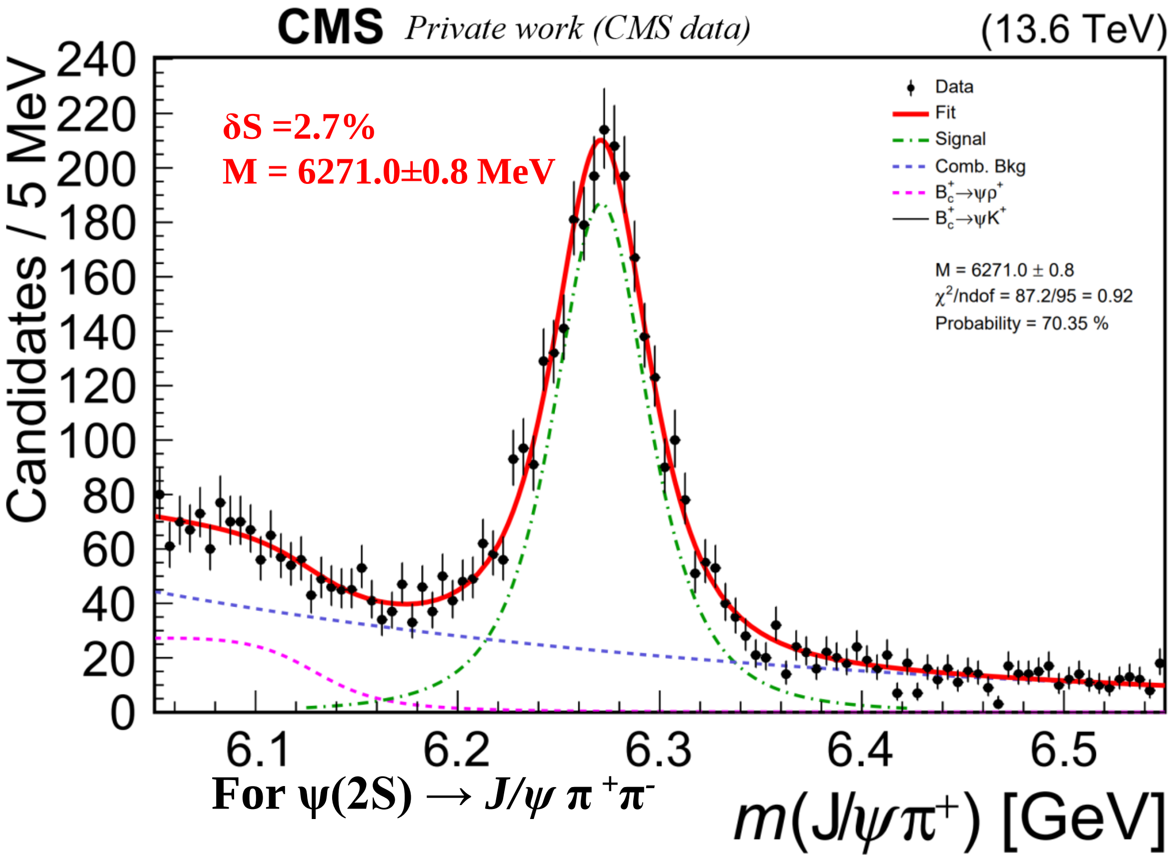
$B_c^+ \to J/\psi[J/\psi \to \mu^+\mu^-]\,\pi^+$

Bkg: exponent + Johnson$^{\text{part. reco}}$

Johnson$^{\text{part. reco}}$: fixed shape to MC



For $\psi(2S) \to \mu^+\mu^-$



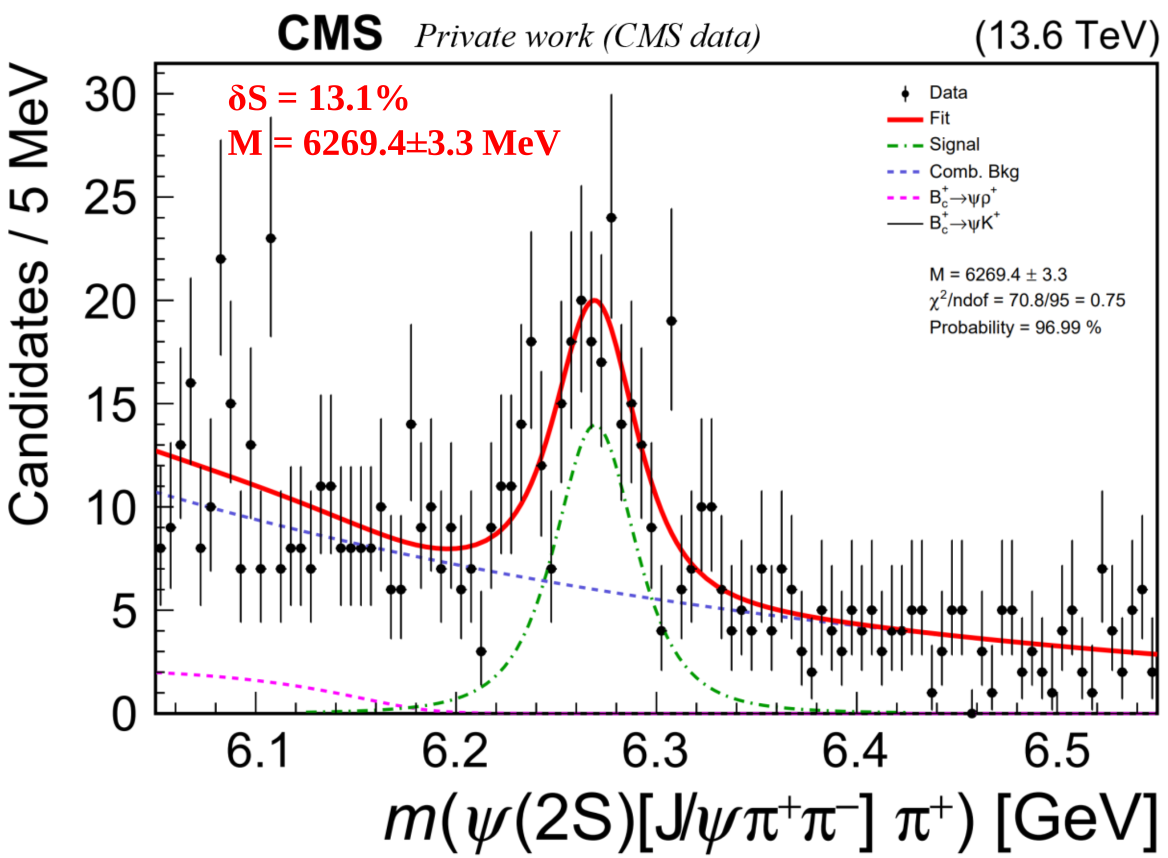
For $\psi(2S) \to J/\psi\,\pi^+\pi^-$

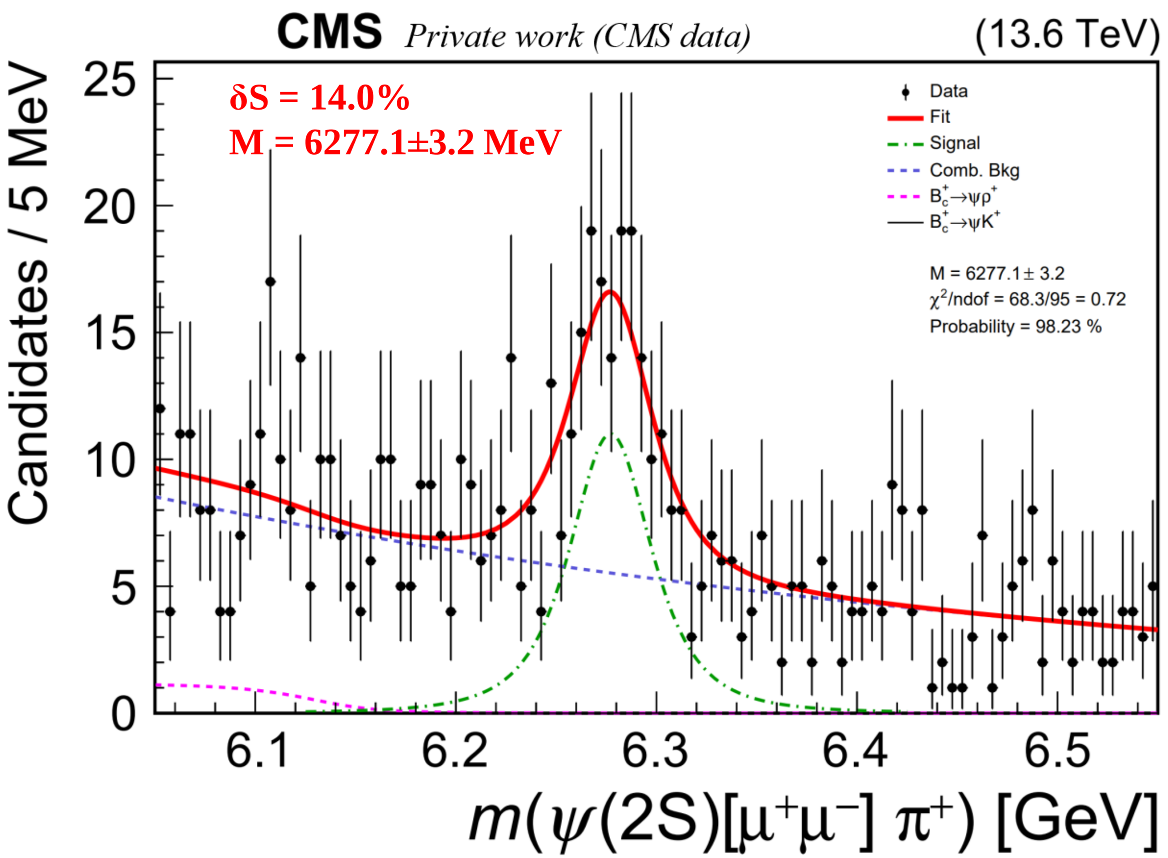
Signal: **Student T** with **parameters fixed** to MC but **free mean**

Signal channels fit RunIII

Bkg: exponent + Johnson$^{\text{part. reco}}$

Johnson$^{\text{part. reco}}$: fixed shape to MC





Signal: **Student T** with **parameters fixed** to MC but **free mean**

Efficiencies: generator filter and selection

- **Generator filter efficiency** is an efficiency of soft requirements applied at the generator level on the transverse momentum and abseta of generated particles. It is a fraction of generated events that pass these requirements.
- **Reconstruction and selection efficiency** is the ratio of the number of reconstructed in MC events (after all cuts) to the number of generated events.

$$\epsilon = \epsilon_{gen} \times \epsilon_{reco\&sel} = \frac{N_{gen,filtered}}{N_{gen,unfiltered}} \times \frac{N_{reco}}{N_{gen-DAS}}$$

Efficiencies ratio is multiplied by a random value for analysis to be blind.

Measurement of branching fractions ratio RunII

$B_c^+ \to \psi(2S)[\psi(2S) \to \mu^+\mu^-]\,\pi^+$

$$\mathcal{R}_1 \equiv \frac{\mathcal{B}(B_c^+ \to \psi(2S)\pi^+)}{\mathcal{B}(B_c^+ \to J/\psi\pi^+)} = \frac{N(B_c^+ \to \psi(2S)\pi^+)}{N(B_c^+ \to J/\psi\pi^+)} \frac{\epsilon_{J/\psi\pi^+}}{\epsilon_{\psi(2S)\pi^+}} \times \frac{\mathcal{B}(J/\psi \to \mu^+\mu^-)}{\mathcal{B}(\psi(2S) \to \mu^+\mu^-)}$$

Baseline

Signal	Comb. bkg	Refl.	Part. reco
StudentT	Exp	Johnson	Johnson

Statistic unc.

Signal	7.6%
Normalizing	1.4%

Total unc. <u>13.8%</u>

Branching unc. ~8%

Source	Uncertainty (%)
Signal model	0.8
Comb. bkg model	0.2
Refl. model	2.6
Part. reco model	0.9
Signal model (normalizing)	1.1
Comb. bkg model (normalizing)	0.2
Refl. model (normalizing)	1.3
Part. reco model (normalizing)	0.4
Limited size of MC samples	0.9
Trigger efficiency	0.0
Total	3.5

LHCb result: $R_{\psi(2S)/J/\psi} = 0.254 \pm 0.018\,(\text{stat}) \pm 0.003\,(\text{syst}) \pm 0.005\,(\text{BF})$

Measurement of branching fractions ratio RunII

$B_c^+ \to \psi(2S)[\psi(2S) \to J/\psi\, \pi^+\pi^-]\, \pi^+$

$$\mathcal{R}_2 \equiv \frac{\mathcal{B}(B_c^+ \to \psi(2S)\pi^+)}{\mathcal{B}(B_c^+ \to J/\psi\pi^+)} = \frac{N(B_c^+ \to \psi(2S)\pi^+)}{N(B_c^+ \to J/\psi\pi^+)} \frac{\epsilon_{J/\psi\pi^+}}{\epsilon_{\psi(2S)\pi^+}} \times \frac{1}{\mathcal{B}(\psi(2S) \to J/\psi\pi^+\pi^-)}$$

Signal	Comb. bkg	Refl.	Part. reco
StudentT	Exp	Johnson	Johnson

Statistic unc.

Signal 10.6%

Normalizing 1.7%

Total unc. <u>12.5%</u>

Branching unc. ~1%

Source	Uncertainty (%)
Signal model	0.9
Comb. bkg model	1.0
Refl. model	3.4
Part. reco model	1.0
Signal model (normalizing)	1.3
Comb. bkg model (normalizing)	0.5
Refl. model (normalizing)	0.7
Part. reco model (normalizing)	2.9
Limited size of MC samples	1.2
Tracking efficiency	4.2
Total	6.7

LHCb result: $R_{\psi(2S)/J/\psi} = 0.254 \pm 0.018\,(\text{stat}) \pm 0.003\,(\text{syst}) \pm 0.005\,(\text{BF})$

Summary

- Processing full RunII and RunIII data
- Simulation
- Cuts optimization with Punzi FOM
- Signal and background shapes
- Efficiencies
- Results for branching fractions ratios

Plans

- Systematic uncertainties
- RunIII data

The end.

Back up

B_c^+

$I(J^P) = 0(0^-)$

I, J, P need confirmation.

Quantum numbers shown are quark-model predictions.

Mass $m = 6274.47 \pm 0.32$ MeV

$m_{B_c^+} - m_{B_s^0} = 907.8 \pm 0.5$ MeV

Mean life $\tau = (0.510 \pm 0.009) \times 10^{-12}$ s

Variables

The variables were selected taking into account the decay process topology. The lifetime of B_c^+ is big enough for a noticeable flight distance from its production vertices.

The designation used in the Table 1 and initial selection criteria lists are described below:

- Distance significance
  $L_{xy}/\sigma_{L_{xy}}(B_c^+\_PV)$
- Cosine between particle momentum and the straight line passing through birth vertex and decay vertex
  $cos(\overrightarrow{L_{xy}}, \overrightarrow{p_T})(B_c^+\_PV)$
- Transverse momentum
  pions with index are sorted according to its p_T and mother particle
  (e.g. $\pi^{\pm}{}_1$ is the particle with the highest p_T among pions from $\psi(2S) \to J/\psi\pi^+\pi^-$ decay, $\pi^{\pm}{}_3$ or $\pi^{\pm}$ is a pion from B_c^+ decay)
- Vertex fit probability
  $P_{vtx}(J/\psi)$
- Two-dimensional impact parameter significance of daughter particle
  $IPS(\pi^+\_B_c^+)$

Variables // Preselection

The initial selection criteria are:

Decay $B_c^+ \to \psi(2S)\pi^+[\psi(2S) \to \mu^+\mu^-]$

- $3500\,\text{MeV} < M(\psi(2S)) < 4050\,\text{MeV}$
- $L_{xy}/\sigma_{L_{xy}}(B_c^+\_PV) > 3$
- $cos(\overrightarrow{L_{xy}}, \overrightarrow{p_T})(B_c^+\_PV) > 0.99$
- $P_{vtx}(B_c^+) > 5\%, P_{vtx}(J/\psi) > 5\%$
- $p_T(B_c^+) > 8\,\text{GeV}, p_T(\psi(2S)) > 7\,\text{GeV}, p_T(\pi^{\pm}{}_3) > 1.2\,\text{GeV}, p_T(\mu^{\pm}) > 4.0\,\text{GeV}$
- $|\eta(\pi^{\pm})| < 2.4, |\eta(\mu^{\pm})| < 2.4$

Decay $B_c^+ \to \psi(2S)\pi^+[\psi(2S) \to J/\psi\pi^+\pi^-]$

- $3670\,\text{MeV} < M(\psi(2S)) < 3705\,\text{MeV}$
- $L_{xy}/\sigma_{L_{xy}}(B_c^+\_PV) > 3$
- $cos(\overrightarrow{L_{xy}}, \overrightarrow{p_T})(B_c^+\_PV) > 0.99$
- $P_{vtx}(B_c^+) > 5\%, p_T(J/\psi) > 7\,\text{GeV}, P_{vtx}(J/\psi) > 5\%$
- $p_T(B_c^+) > 8\,\text{GeV}, p_T(\pi^{\pm}{}_{3(1,2)}) > 1.2(0.6)\,\text{GeV}, p_T(\mu^{\pm}) > 4.0\,\text{GeV}$
- $|\eta(\pi^{\pm})| < 2.4, |\eta(\mu^{\pm})| < 2.4$
- Opposite charge of pion candidates from $\psi(2S)$ decay

Decay $B_c^+ \to J/\psi\pi^+$

- $2900\,\text{MeV} < M(J/\psi) < 3300\,\text{MeV}$
- $L_{xy}/\sigma_{L_{xy}}(B_c^+\_PV) > 3$
- $cos(\overrightarrow{L_{xy}}, \overrightarrow{p_T})(B_c^+\_PV) > 0.99$
- $P_{vtx}(B_c^+) > 5\%, P_{vtx}(J/\psi) > 5\%$
- $p_T(B_c^+) > 8\,\text{GeV}, p_T(J/\psi) > 7\,\text{GeV}, p_T(\pi^{\pm}{}_3) > 1.2\,\text{GeV}, p_T(\mu^{\pm}) > 4.0\,\text{GeV}$
- $|\eta(\pi^{\pm})| < 2.4, |\eta(\mu^{\pm})| < 2.4$

Optimized

Variable	$B_c^+ \to \psi(2S)\pi^+[\psi(2S) \to J/\psi\pi^+\pi^-]$	$B_c^+ \to J/\psi\pi^+$
$\lvert M(\psi(2S)) - M(\psi(2S))\rvert$, MeV	< 10	
p_T (B_c^+), GeV	> 13.5	> 13.5
$L_{xy}/\sigma_{L_{xy}}(B_c^+\_PV)$	> 8.2	> 8.2
P_{vtx} (J/ψ)	> 0.05	
P_{vtx} (B_c^+)	> 0.23	> 0.23
$\lg cos(\overrightarrow{L_{xy}}, \overrightarrow{p_T})(B_c^+\_PV)$	> 3.2	> 3.2
p_T ($\pi^+{}_3$), GeV	> 2.6	> 2.6
p_T ($\psi(2S)$), GeV	> 9.0	> 7.0
p_T (J/ψ), GeV	> 7.0	
p_T (π_1), GeV	> 0.8	
p_T (π_2), GeV	> 0.4	
$IPS(\pi_{1,2})$	> 0.0	
$IPS(\pi_3)$	> 4.6	> 4.6
$M(\pi_1\pi_2)$, GeV	> 0.37	
$M(\pi_1\pi_2)$, GeV	< 0.6	
p_T ($\mu^\pm$), GeV	> 4.0	> 4.0

Variable	$B_c^+ \to \psi(2S)\pi^+[\psi(2S) \to \mu^+\mu^-]$	$B_c^+ \to J/\psi\pi^+$
p_T (B_c^+), GeV	> 9.5	> 9.5
$L_{xy}/\sigma_{L_{xy}}(B_c^+\_PV)$	> 5.2	> 5.2
P_{vtx} ($\psi(2S)$)	> 0.05	> 0.05
P_{vtx} (B_c^+)	> 0.25	> 0.25
p_T (π^+), GeV	> 2.0	> 2.0
$\lg cos(\overrightarrow{L_{xy}}, \overrightarrow{p_T})(B_c^+\_PV)$	> 2.7	> 2.7
p_T ($\psi(2S)$), GeV	> 7.0	> 7.0
$IPS(\pi^+\_B_c^+)$	> 3.1	> 3.1
p_T ($\mu^\pm$), GeV	> 4.0	> 4.0

Baseline

Signal	Comb. bkg	Refl.	Part. reco
StudentT	Exp	Johnson	Johnson

The uncertainty related to the finite size of MC samples is considered as systematic uncertainty. They are taken from the efficiency ratios in Section 6, $\Delta_{\vartheta 1}/\vartheta_1 = 0.9\% for \mathcal{R}_1$ and $\Delta_{\vartheta 2}/\vartheta_2 = 1.2\%$ for $\mathcal{R}_2$.

Since we have two addditional tracks in $\psi(2S) \rightarrow J/\psi\pi^+\pi^-$ channel we add 4.2% uncertainty to systematics due to two-track reconstruction efficiency [?].

In all of the signal and background shapes variations one model changes and the other ones are fixed to the baseline. The result oof the model variation is shown in table

Signal Hypothesis Variation

Function
Johnson (signal)
2 Gaussian (signal)
3 Gaussian (signal)
Johnson (normalizing)
2 Gaussian (normalizing)
3 Gaussian (normalizing)

Background Hypothesis Variation

Function
1-degree polynimial (signal)
2-degree polynimial (signal)
1-degree polynimial (normalizing)
2-degree polynimial (normalizing)

Reflection Hypothesis Variation

Function
Johnson (signal)
No contribution (signal)
Johnson (normalizing)
No contribution (normalizing)

Part. Reconstructed Hypothesis Variation

Function
Crystall Ball (signal)
Crystall Ball $\times$ Gaussian (signal)
Argus (signal)
ARGUS $\times$ Gaussian (signal)
Crystall Ball (normalizing)
Crystall Ball $\times$ Gaussian (normalizing)
Argus (normalizing)
ARGUS $\times$ Gaussian (normalizing)

Channels

1. **$B_c^{\pm} \to \psi(2S)\ \pi^{\pm}$**
   where $\psi(2S) \to \mu^{+}\mu^{-}$

2. **$B_c^{\pm} \to \psi(2S)\ \pi^{\pm}$**
   where $\psi(2S) \to J/\psi\ \pi^{+}\pi^{-}$

3. **Normalizing channel**
   $B_c^{\pm} \to J/\psi\ \pi^{\pm}$
   where $J/\psi \to \mu^{+}\mu^{-}$

Full RunII(2016-2018) experimental data is used:

/Charmonium/Run2016B-ver2_HIPM_UL2016_MiniAODv2-v1/MINIAOD
/Charmonium/Run2016C-HIPM_UL2016_MiniAODv2-v1/MINIAOD
/Charmonium/Run2016D-HIPM_UL2016_MiniAODv2-v1/MINIAOD
/Charmonium/Run2016E-HIPM_UL2016_MiniAODv2-v1/MINIAOD
/Charmonium/Run2016F-HIPM_UL2016_MiniAODv2-v1/MINIAOD
/Charmonium/Run2016F-UL2016_MiniAODv2-v1/MINIAOD
/Charmonium/Run2016G-UL2016_MiniAODv2-v1/MINIAOD
/Charmonium/Run2016H-UL2016_MiniAODv2-v2/MINIAOD

/Charmonium/Run2017B-UL2017_MiniAODv2-v1/MINIAOD
/Charmonium/Run2017C-UL2017_MiniAODv2-v1/MINIAOD
/Charmonium/Run2017D-UL2017_MiniAODv2-v1/MINIAOD
/Charmonium/Run2017E-UL2017_MiniAODv2-v1/MINIAOD
/Charmonium/Run2017F-UL2017_MiniAODv2-v1/MINIAOD

/Charmonium/Run2018A-UL2018_MiniAODv2-v1/MINIAOD
/Charmonium/Run2018B-UL2018_MiniAODv2-v1/MINIAOD
/Charmonium/Run2018C-UL2018_MiniAODv2-v1/MINIAOD
/Charmonium/Run2018D-UL2018_MiniAODv2-v1/MINIAOD

MC samples

1. **$B_c^+ \to \psi(2S)[\psi(2S) \to \mu^+\mu^-]\ \pi^+$**
   - /BcToPsi2SPi_PMM_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL16MiniAODAPVv2-106X_mcRun2_asymptotic_preVFP_v11-v2/MINIAODSIM
   - /BcToPsi2SPi_PMM_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL16MiniAODv2-106X_mcRun2_asymptotic_v17-v2/MINIAODSIM
   - /BcToPsi2SPi_PMM_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v2/MINIAODSIM
   - /BcToPsi2SPi_PMM_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL18MiniAODv2-106X_upgrade2018_realistic_v16_L1v1-v2/MINIAODSIM

2. **$B_c^+ \to \psi(2S)[\psi(2S) \to J/\psi\ \pi^+\pi^-]\ \pi^+$**
   - /BcToPsi2SPi_PJPP_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL16MiniAODAPVv2-106X_mcRun2_asymptotic_preVFP_v11-v3/MINIAODSIM
   - /BcToPsi2SPi_PJPP_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL16MiniAODv2-106X_mcRun2_asymptotic_v17-v2/MINIAODSIM
   - /BcToPsi2SPi_PJPP_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9-v2/MINIAODSIM
   - /BcToPsi2SPi_PJPP_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL18MiniAODv2-106X_upgrade2018_realistic_v16_L1v1-v2/MINIAODSIM

3. **Normalizing channel $B_c^+ \to J/\psi[J/\psi \to \mu^+\mu^-]\ \pi^+$**
   - /BcToJpsPi_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL16MiniAODAPVv2-106X_mcRun2_asymptotic_preVFP_v11_ext1-v2/MINIAODSIM
   - /BcToJpsPi_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL16MiniAODv2-106X_mcRun2_asymptotic_v17_ext1-v2/MINIAODSIM
   - /BcToJpsPi_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL17MiniAODv2-106X_mc2017_realistic_v9_ext1-v2/MINIAODSIM
   - /BcToJpsPi_TuneCP5_13TeV-bcvegpy2-pythia8-evtgen/RunIISummer20UL18MiniAODv2-106X_upgrade2018_realistic_v16_L1v1_ext1-v2/MINIAODSIM

Psi->Jpsi Pi Pi