b hadrons as novel probes of the quark-gluon plasma

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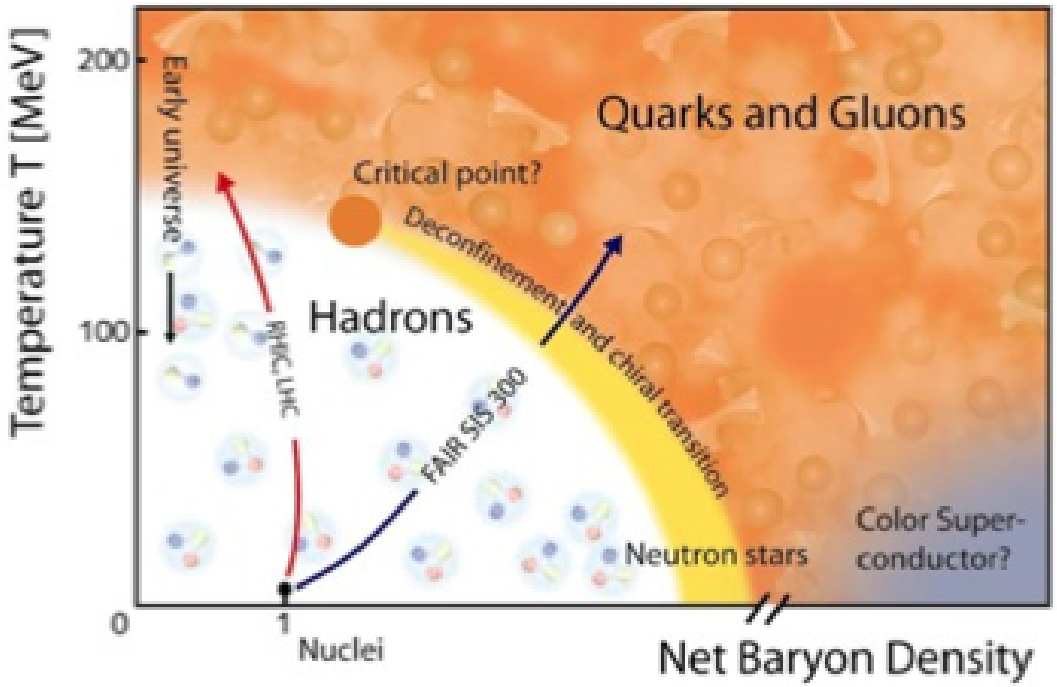
Quark-Gluon Plasma

- State of matter formed by deconfined quarks and gluons
- Predicted to exist by QCD under extreme conditions of temperature and/or density
- Heavy ion collisions allow to recreate and study the QGP medium properties

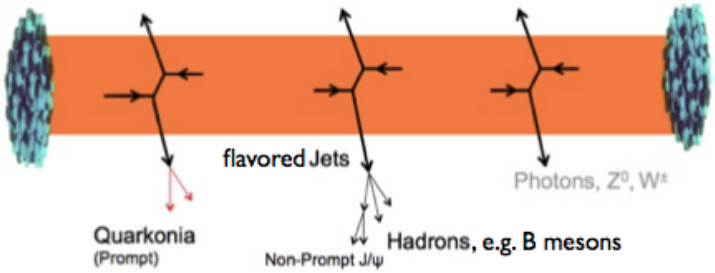


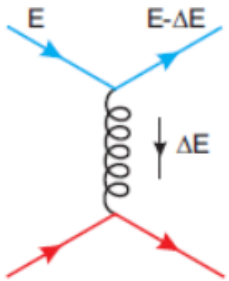
Probing the Quark-Gluon Plasma

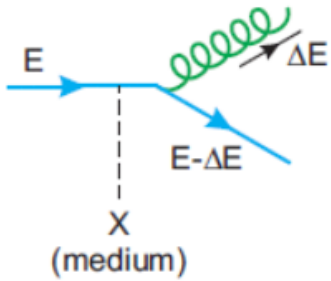
- Heavy-flavour states are ideal "hard probes" for studying the QGP
- Hard-scattered partons are expected to loose energy through:
  - Elastic Collisions
  - Medium induced gluon radiation

$$\Downarrow$$

- Yield supression of high p_T hadrons, when compared to the vacuum
- The study of different hadron species allows to study the flavour dependence of energy loss in the medium





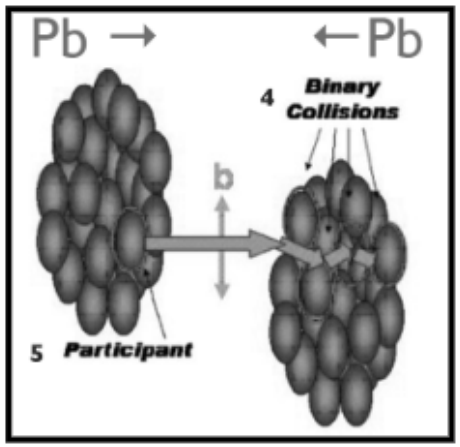


Nuclear Modification Factor

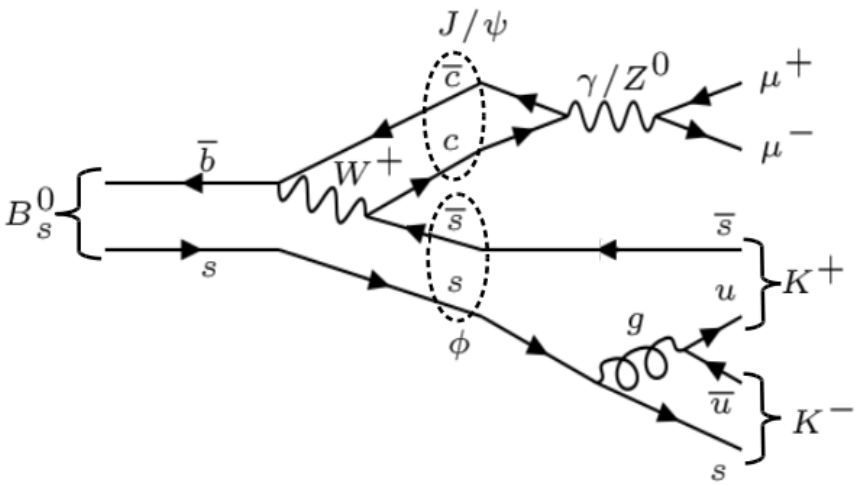
- Measures the effect of the medium on the hadron yields

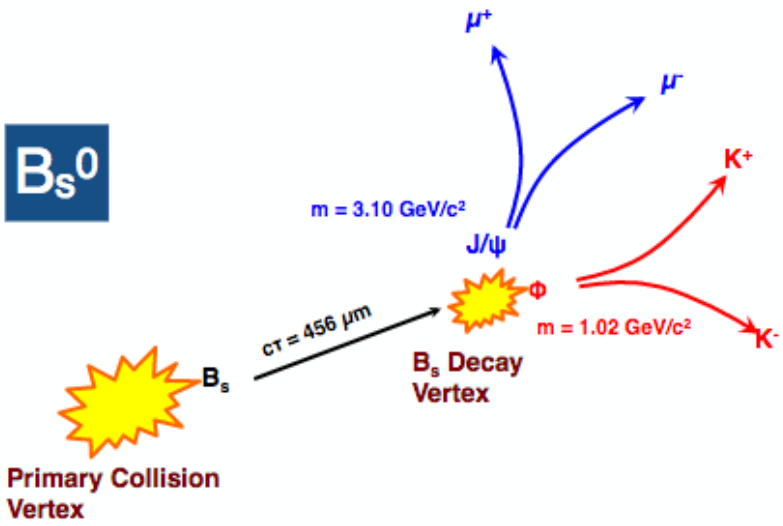
$$R_{AA}(p_T) = \frac{1}{< N_{coll} >} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$

- N_{coll} - Number of binary nucleon-nucleon collisions
- R_{AA} <1 - Supression
- R_{AA} >1 - Enhancement



B Meson Decay Channel





Selection

- Muon Acceptance:

$$\begin{aligned} p_T^\mu &> 3.5\,\text{GeV}/c && \text{for } |\eta^\mu| < 1.2 \\ p_T^\mu &> (5.77 - 1.8 \times |\eta^\mu|)\,\text{GeV}/c && \text{for } 1.2 \leq |\eta^\mu| < 2.1 \\ p_T^\mu &> 1.8\,\text{GeV}/c && \text{for } 2.1 \leq |\eta^\mu| < 2.4 \end{aligned}$$

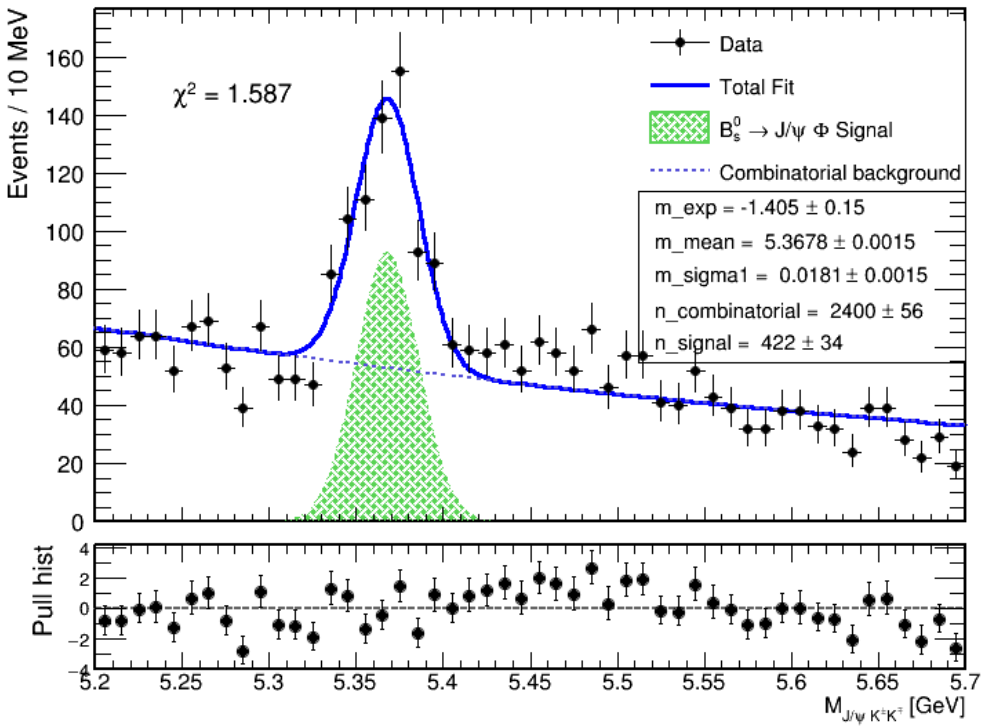
- Muon ID:
  - Primary Vertex and muon track distance, Dxy (Dz)<0.3 (20) cm
  - Tracker (Pixel) layer with $>$ 5 (0) measurement
- Track Selection:
  - p_T >0.7 GeV
  - y <2.4

Selection

- J/Ψ candidate selection:
  - Fitted muon pair mass within PDG mass $\pm$ 0.15 GeV
- B candidates selection:
  - $|y|$ <2.4
  - χ^2 confidence level of the B vertex, chi2cl> 1.32×10^{-2}
  - ratio of the distance between PV and SV in the transverse plane normalized by its uncertainty, d0/d0Err>2
  - angle between B displacement and B momentum in the transverse plane, cos(θ) >0.26

B_s production at 5.02 TeV in the vacuum

Mass Fitting

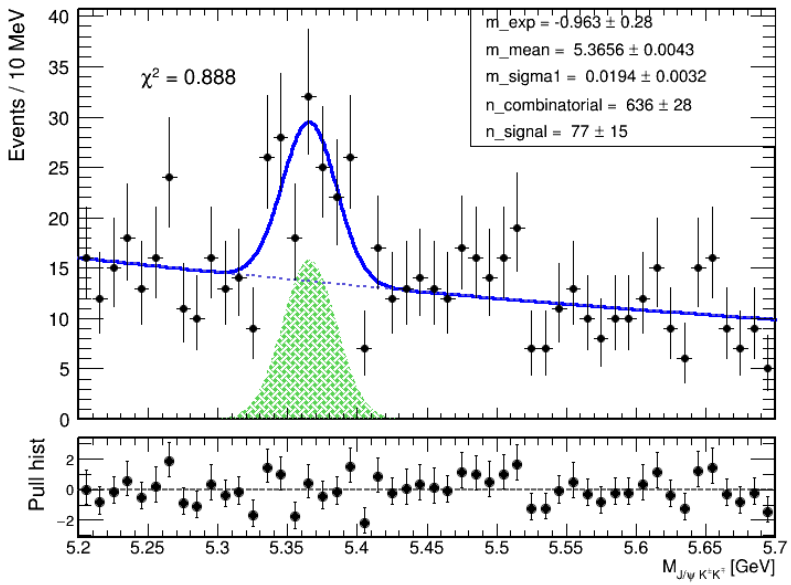


- PDF's used:
  - Signal: One Gaussian
  - Background: Exponential Function

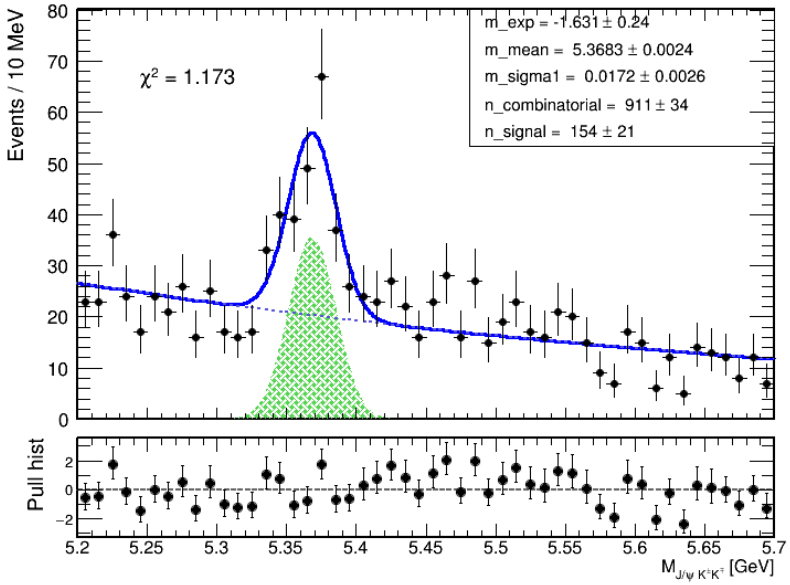
B_s production at 5.02 TeV in the vacuum

Mass Fitting

p_T: [5,10]



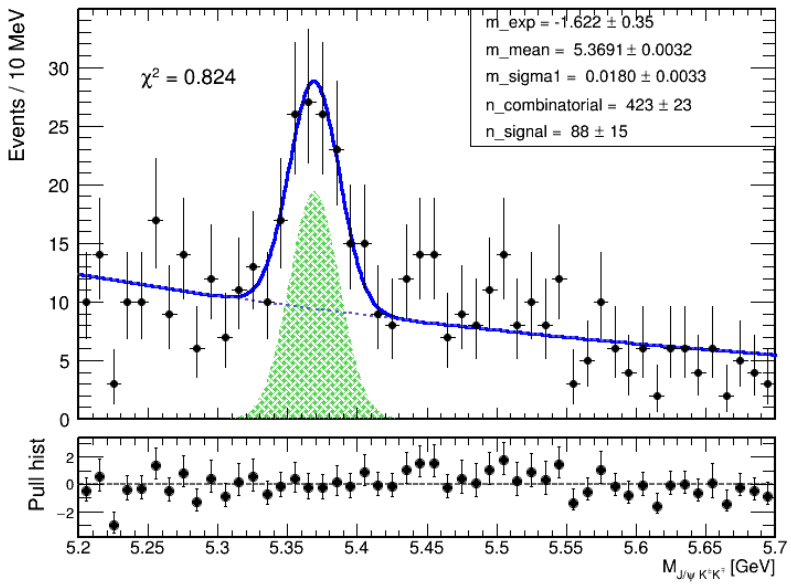
p_T: [10,15]



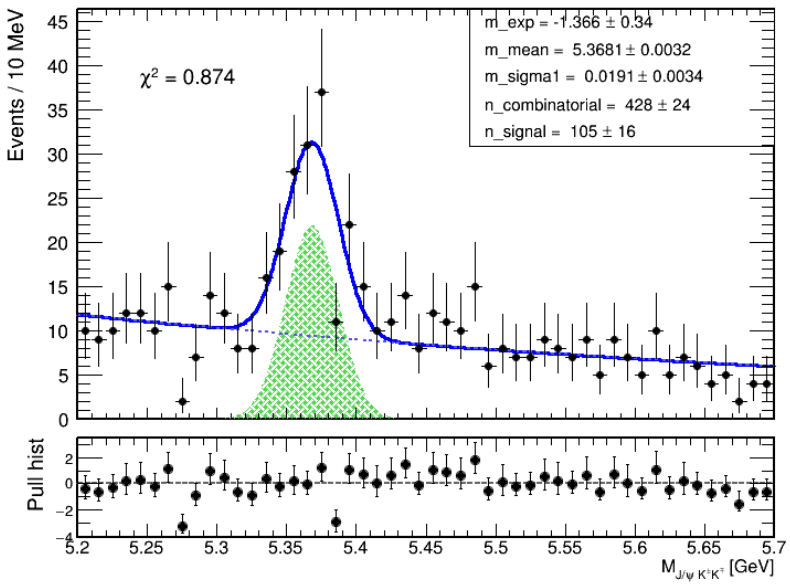
B_s production at 5.02 TeV in the vacuum

Mass Fitting

p_T: [15,20]



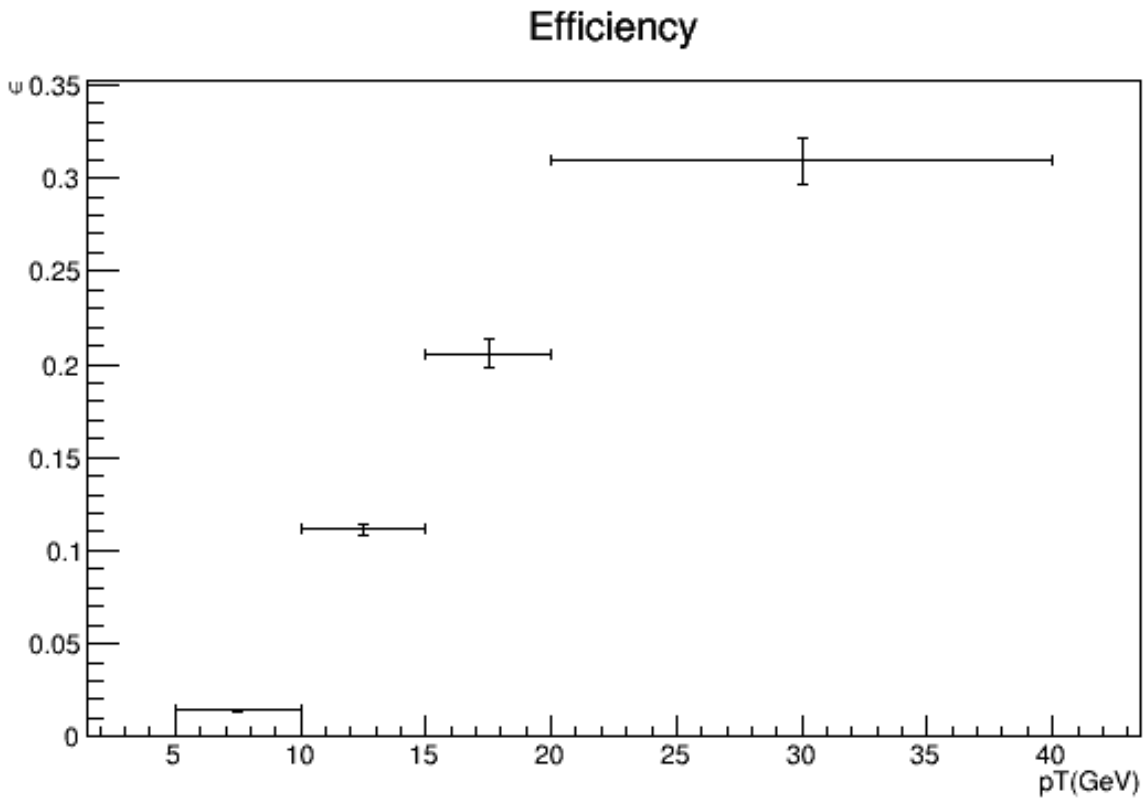
p_T: [20,40]



B_s production at 5.02 TeV in the vacuum

Efficiencies

- The efficiencies are determined from signal MC simulation
- It's a measurement of how much signal is lost by the selection (including trigger, reconstruction, offline cuts)

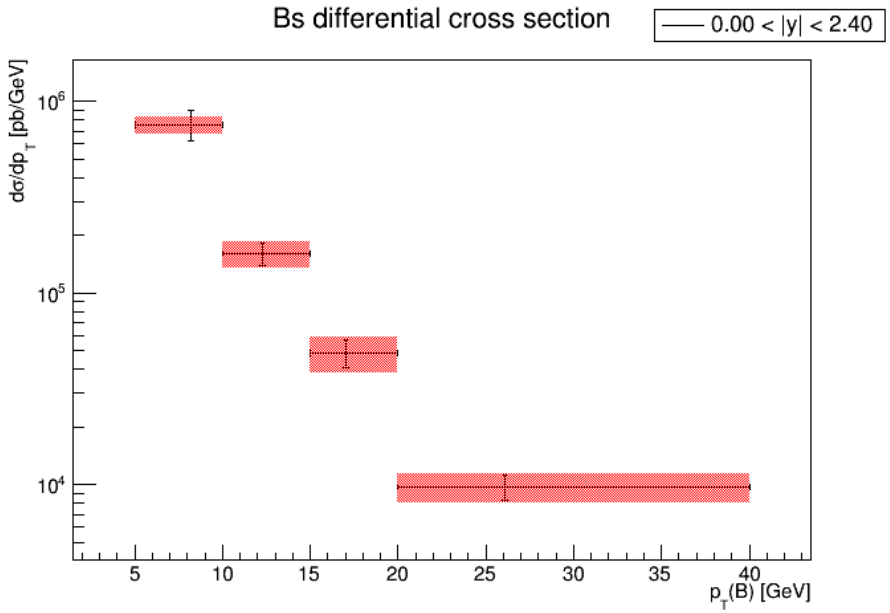


B_s production at 5.02 TeV in the vacuum

Cross Sections

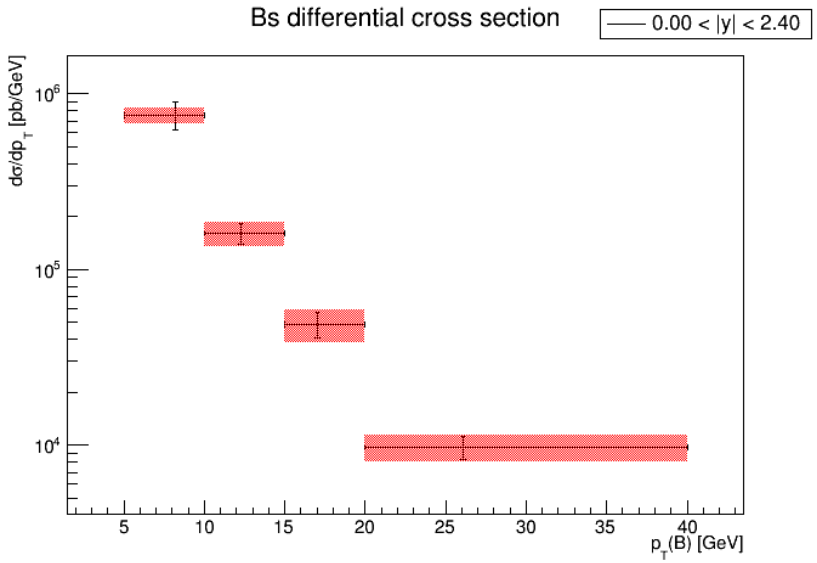
$$\frac{d\sigma}{dp_T} = \frac{N^B}{2\,\epsilon\,\mathcal{L}\,\mathcal{B}\,\Delta p_T}$$

- $\mathcal{L} = 28\ pb^{-1}$ (2.3 % uncertainty)
- $\mathcal{B} = 3.15 \times 10^{-5}$ (3.1 % uncertainty)

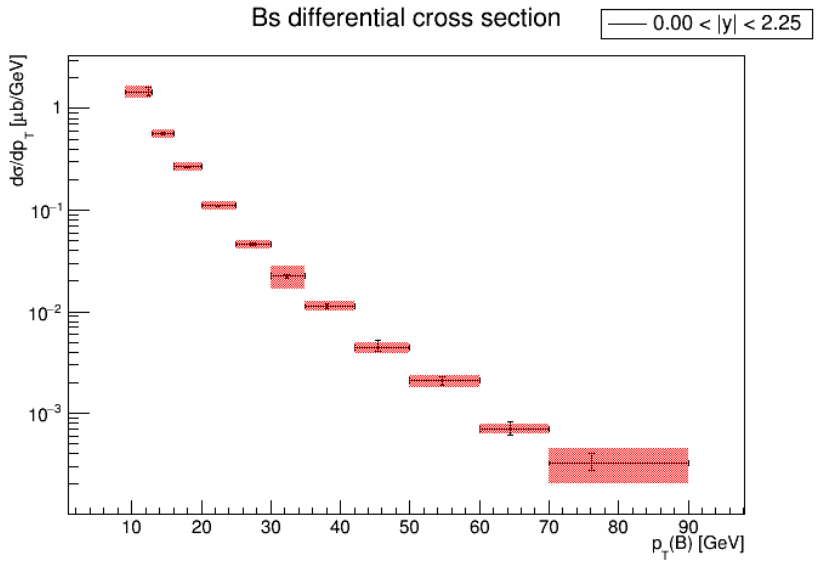


B_s production in the vacuum at 5.02 TeV

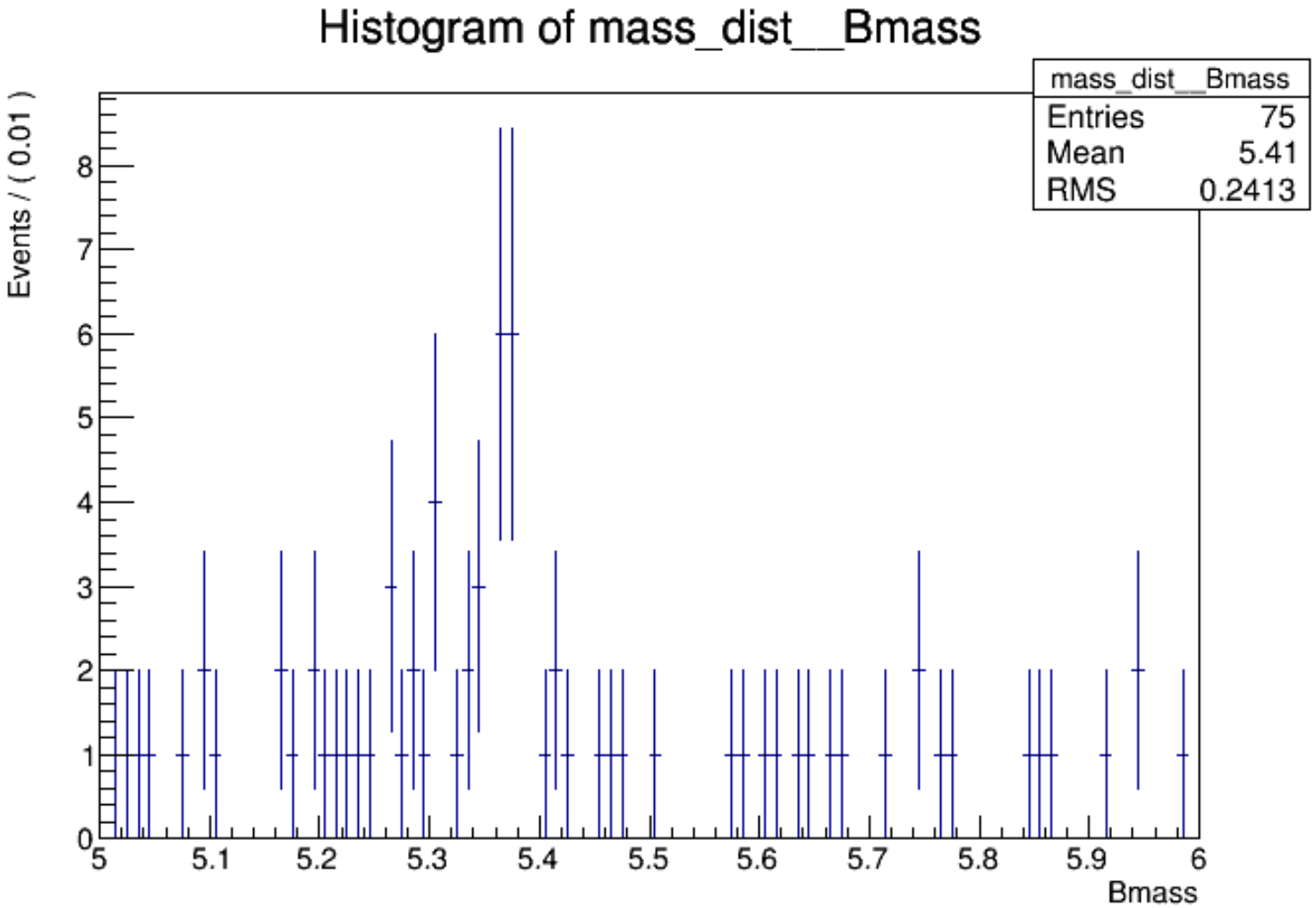
5 TeV
(this work)



13 TeV
(summer 2016 project)



Probing the Medium (PbPb collisons at 5 TeV)

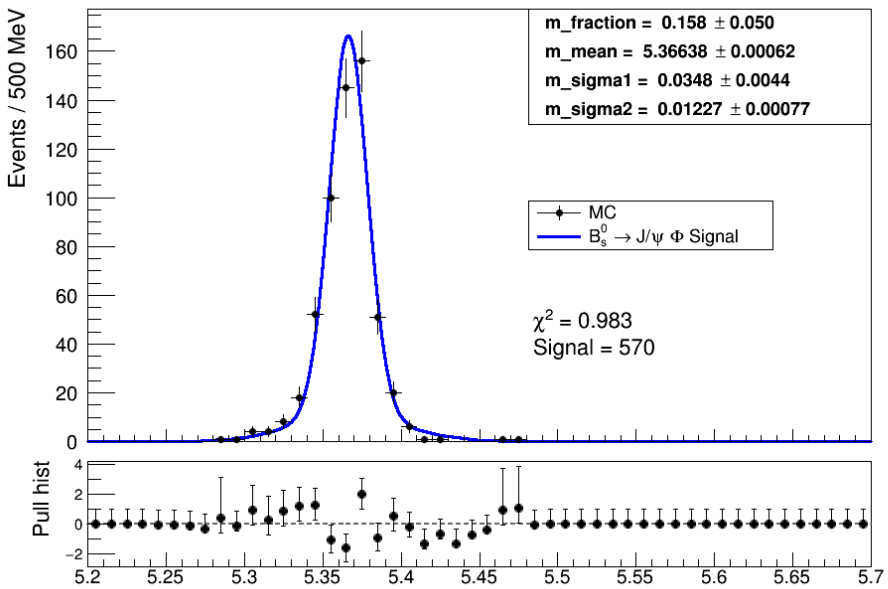


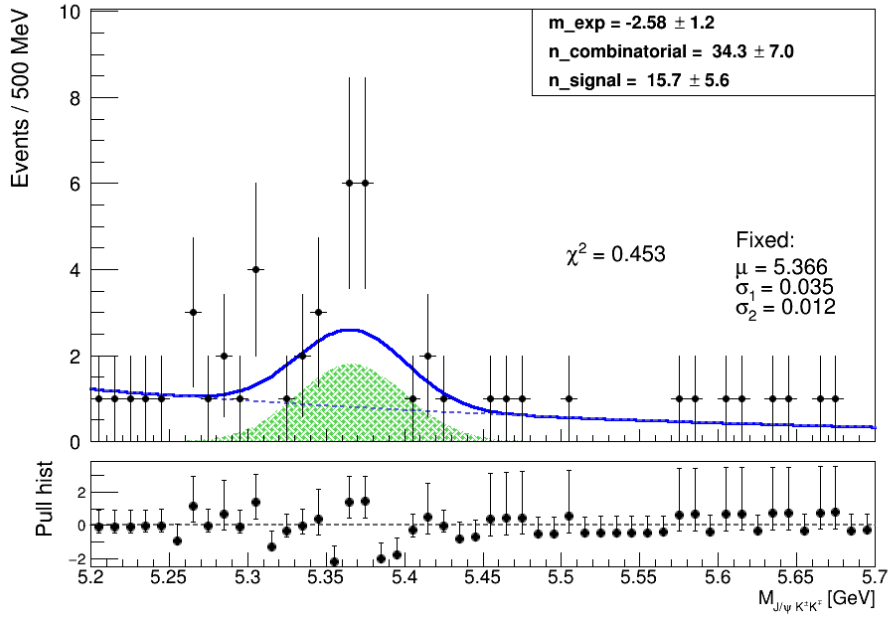
- Preliminary selection, not yet optimised.

Probing the Medium (PbPb collisons at 5 TeV)

Mass Fitting

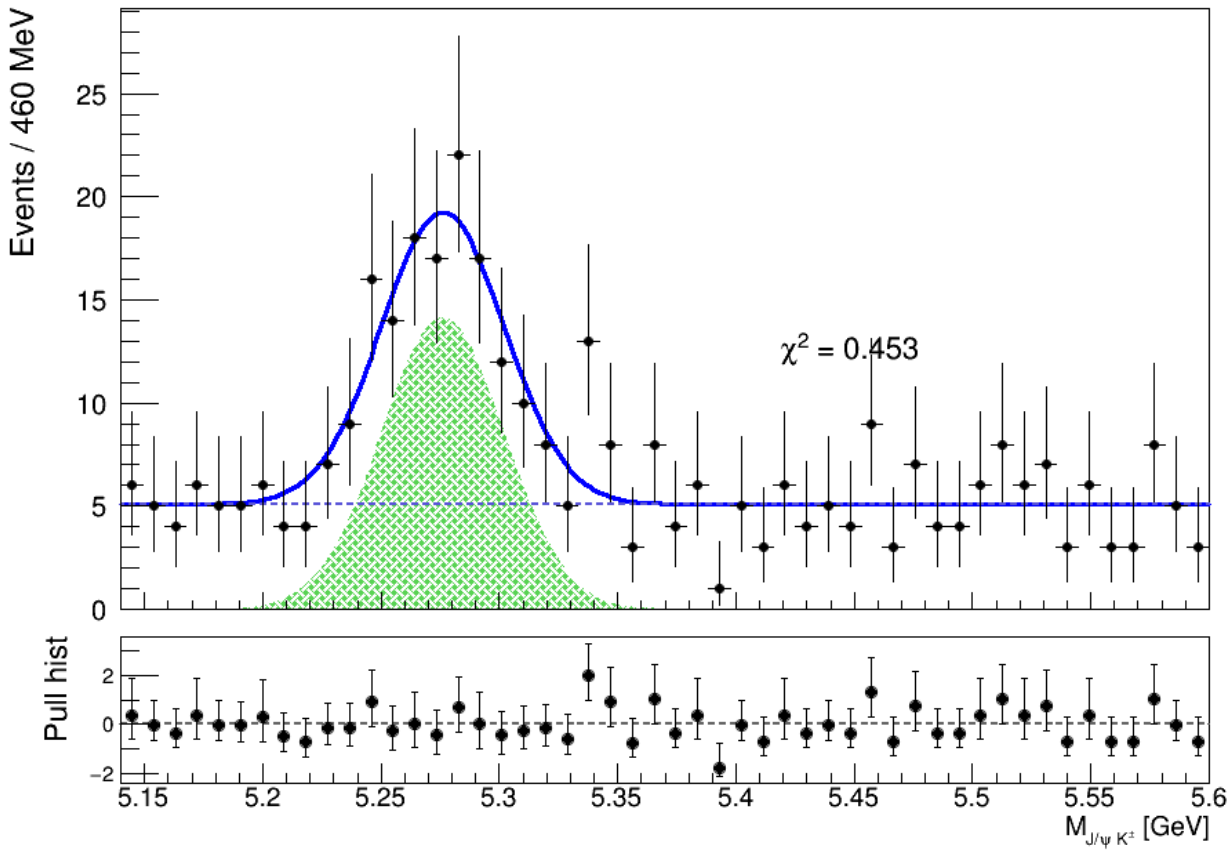
- Not enough events in the data to let all parameters free
- Fix signal shape from MC simulation





Probing the Medium (PbPb collisons at 5 TeV)

B^+ Decay Channel



First ever fully reconstructed B mesons in ion collisions

Probing the Medium (PbPb collisons at 5 TeV)

R_{AA} Determination

$$\frac{1}{T_{AA}} \frac{dN_{PbPb}{}^{B}}{dp_T} = \frac{N_{PbPb}{}^{B}}{2\ N_{MB}\ T_{AA}\ \epsilon\ \mathcal{B}\ \Delta p_T}$$

$$R_{AA}(p_T) = \frac{1}{T_{AA}} \frac{dN_{PbPb}/dp_T}{d\sigma_{pp}/dp_T}$$

- T_{AA} (nuclear overlap function) = 5.61 mb^{-1} (+2.8%, -3.4% uncertainty)
- NMB (number of minimum bias events) = 2.4×10^9 (1% uncertainty)
- $\mathcal{B} = 3.15 \times 10^{-5}$ (3.1 % uncertainty)
- $\epsilon = 0.02$ (0.09 % uncertainty) $\rightarrow$ calculated just for the p_T bin [15,40]

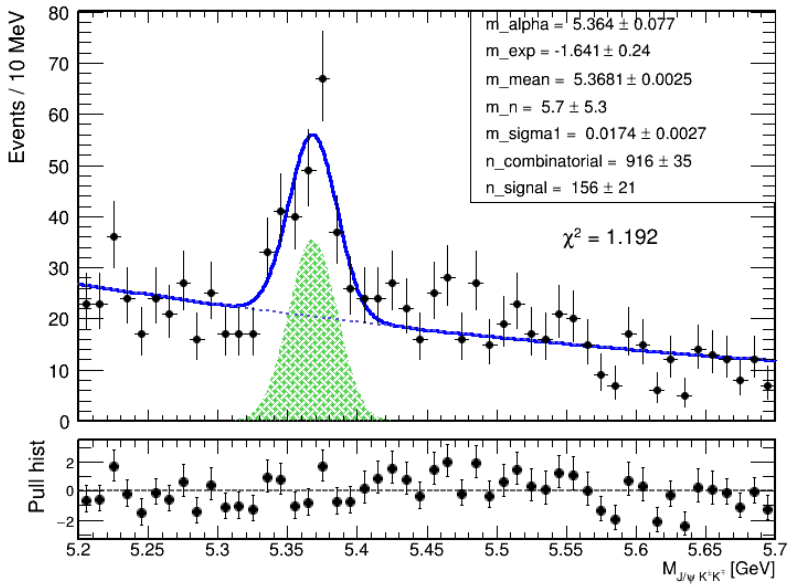
Summary and Prospects

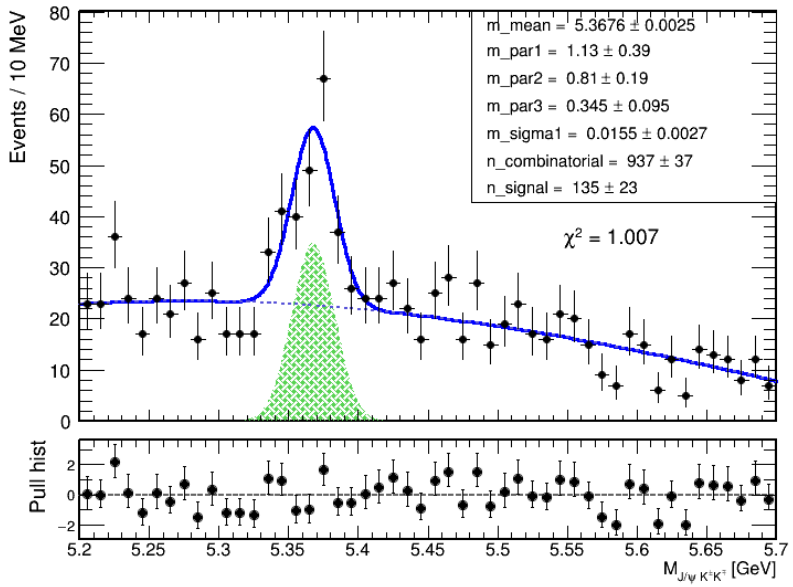
- CMS has reconstructed B hadrons for the first time ever in heavy ion colllisions
  - challenging, but benefits from excelent muon and vertexing capabilities of the detector
- have made first attempt to reconstruct a rarer and particularly interesting meson state: B_s
  - measurement dominated by statistical uncertainty
  - attempting selection optimization with ANN
  - more ion data will allow a more robust determination of the suppression factor
- heavy flavor being actively explored as a new probe to characterize the formed QGP medium

BACK-UP

Systematic Uncertainties

PDF Variation





Systematic Uncertainties

Mass Range Variation