# Measurements of strange and non-strange beauty hadron production in PbPb collisions at 5.02 TeV with the CMS detector

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on behalf of the CMS collaboration

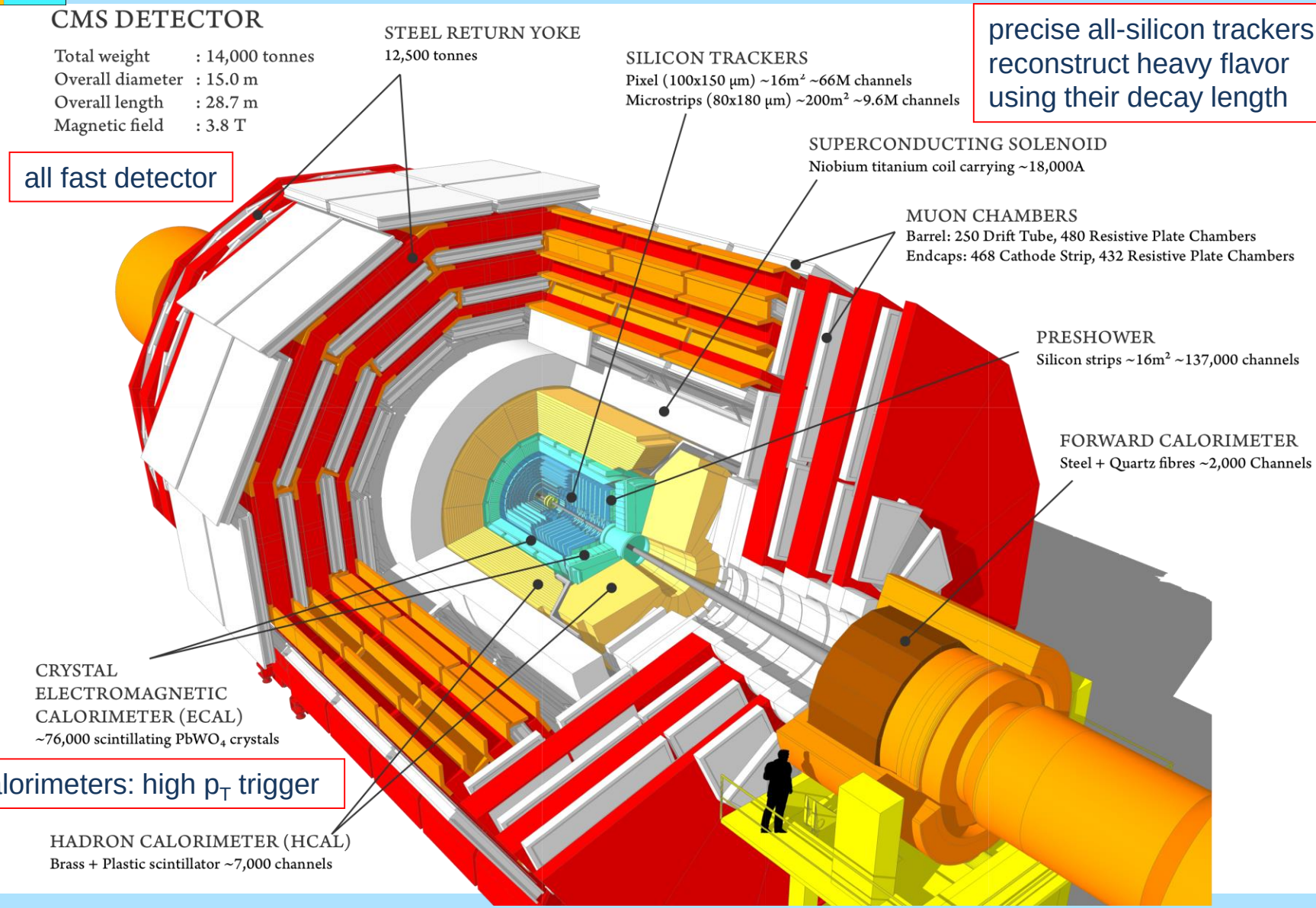
# OUTLINE

- Physics motivations
- Data analysis techniques
  - Beauty measurements via decay D and J/$\psi$
  - Full reconstruction of B and $B_s$ decays
- Results
- Summary

# Physics motivation

- Heavy quark energy loss, coalescence/hadronization
- Heavy, predominantly produced in early hard scatterings, carry information about QGP evolution history
- Heavy quarks lose energy in QGP medium by collisional and radiative interactions
- Beauty: heavier and cleaner than Charm
- $B_s$/B: strangeness enhancement, coalescence

# CMS detector




precise all-silicon trackers: reconstruct heavy flavor using their decay length

all fast detector

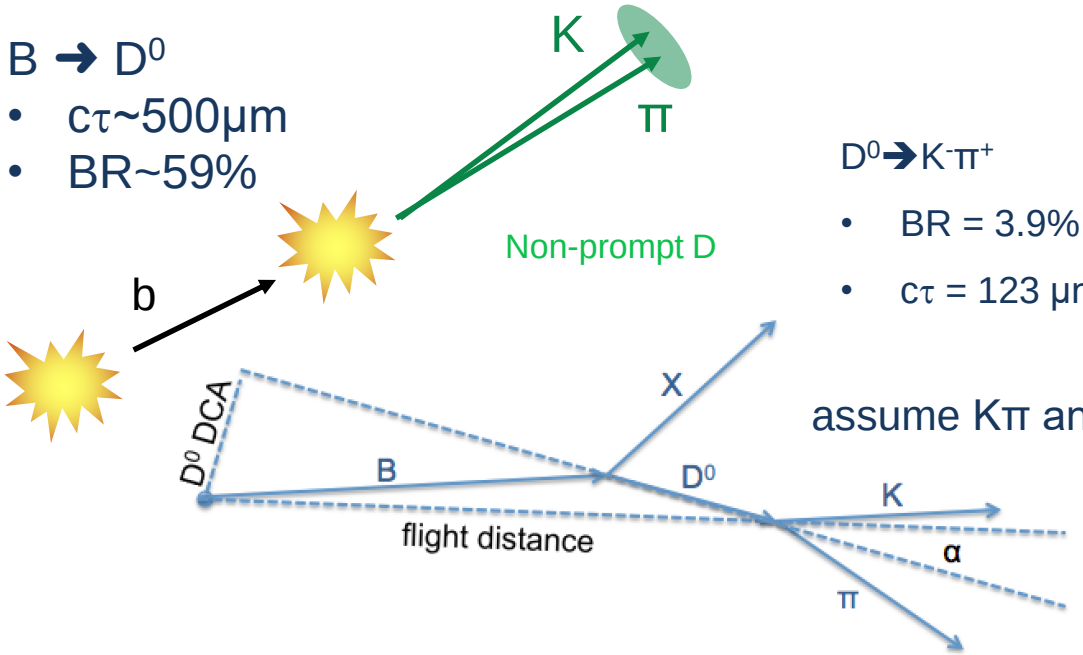
calorimeters: high $p_T$ trigger

# B measurement via decay D

## B➜$D^0$ and prompt-$D^0$ separation

- B➜$D^0$: non-zero DCA (Distance of Closest Approach) due to B decay
- Prompt-$D^0$: DCA only from track and vertex resolution

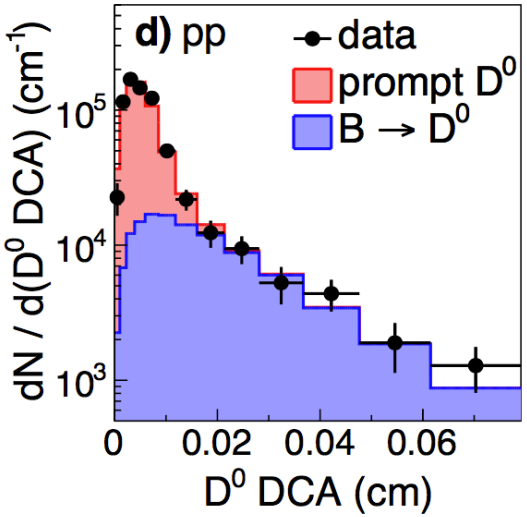
B ➜ $D^0$
- cτ~500μm
- BR~59%

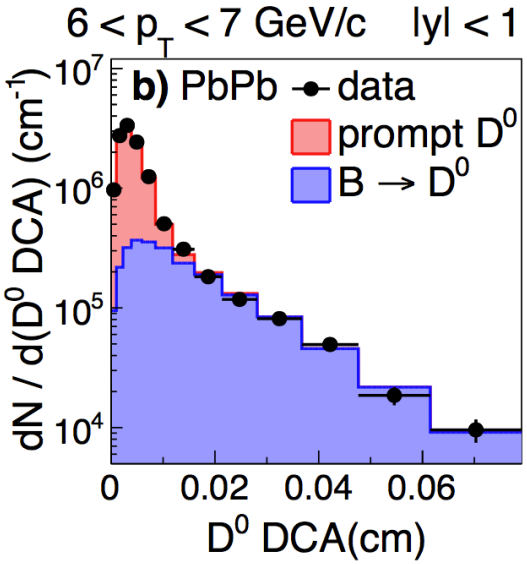



$D^0$➜$K^-\pi^+$
- BR = 3.9%
- cτ = 123 μm

assume Kπ and πK

1. Track pair fit to a common vertex ➞ D candidates
2. Signal extraction in DCA interval ➞ DCA distribution
3. Template fit (from simulation) on DCA to extract non-prompt D



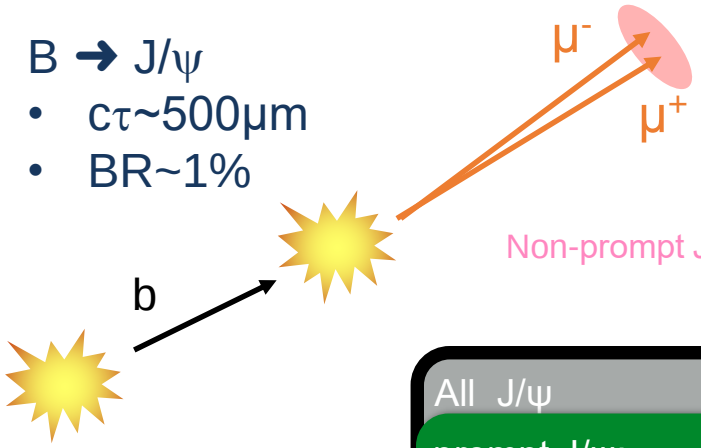




CMS, arXiv:1810.11102

# B measurement via decay J/ψ

B➜J/ψ and prompt-J/ψ separation

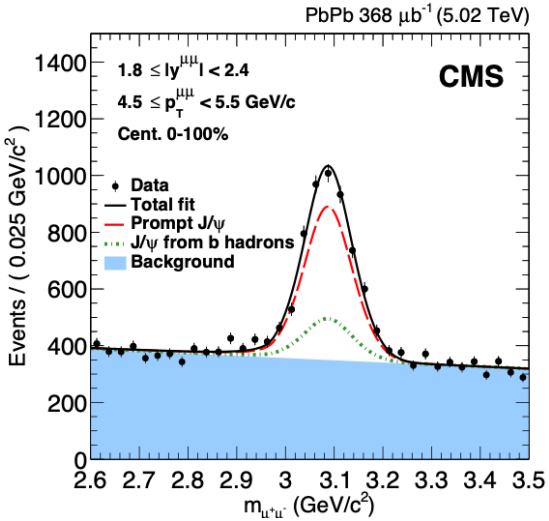
B ➜ J/ψ
- cτ~500μm
- BR~1%

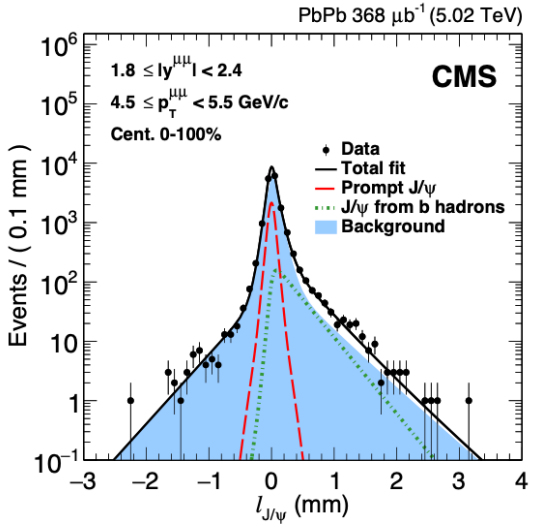



All J/ψ

prompt J/ψ:
direct production
+ feed down (ex ψ')

non-prompt J/ψ:
from B decays (ex B ➜ J/ψ X)



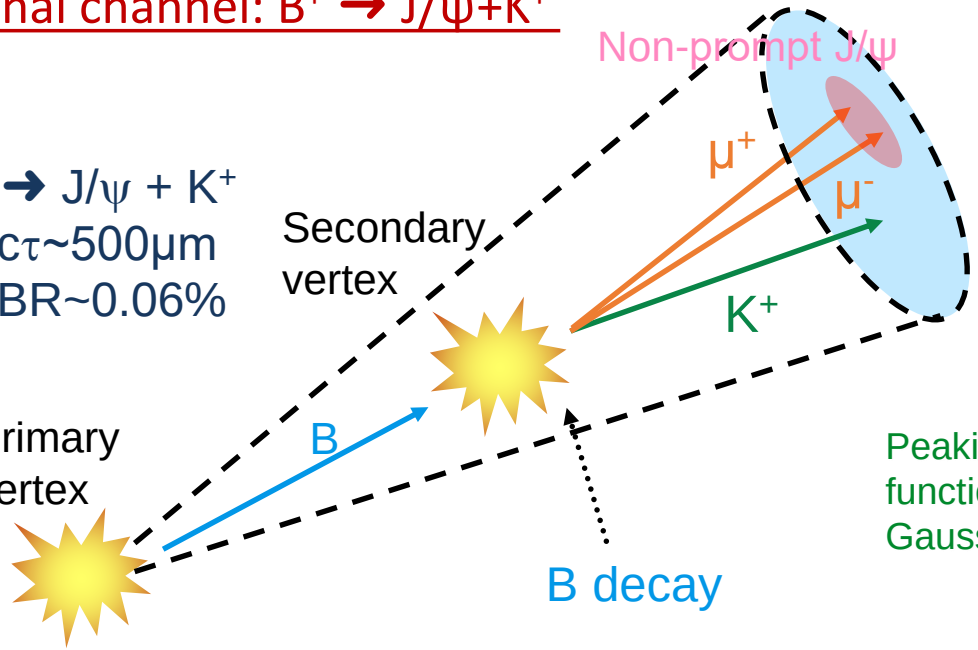




1. Muon pair fit to a common vertex ➞ J/ψ candidates
2. 2D Fit on invariant mass and decay length spectra
3. Extracted yields corrected by a data-driven approach (tag & probe)

CMS, EPJC 78 (2018) 509

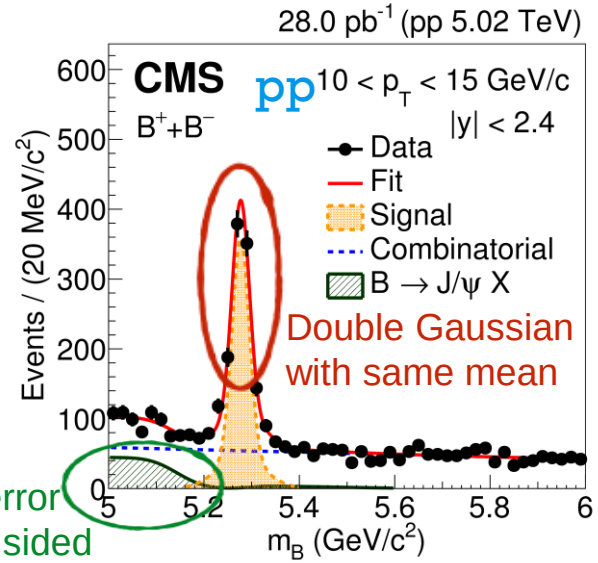
# Full reconstruction of B

Signal channel: $B^+ \rightarrow J/\psi + K^+$

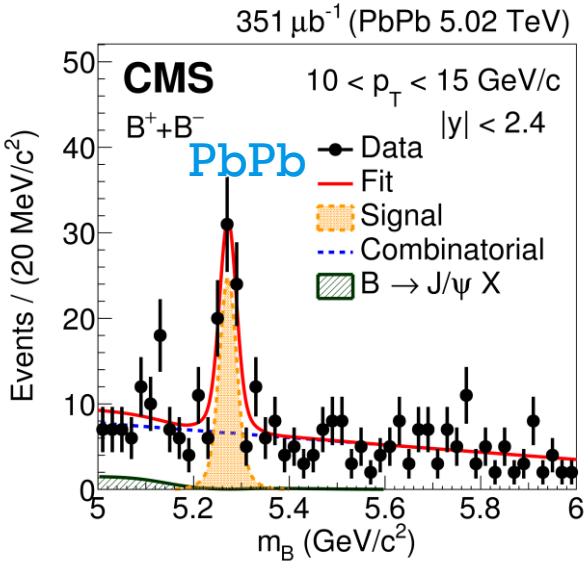



$B^+ \rightarrow J/\psi + K^+$
- $c\tau$~500μm
- BR~0.06%

b quark → $B^+$, $B^-$, $B^0$




Peaking BG: error function + two sided Gaussian



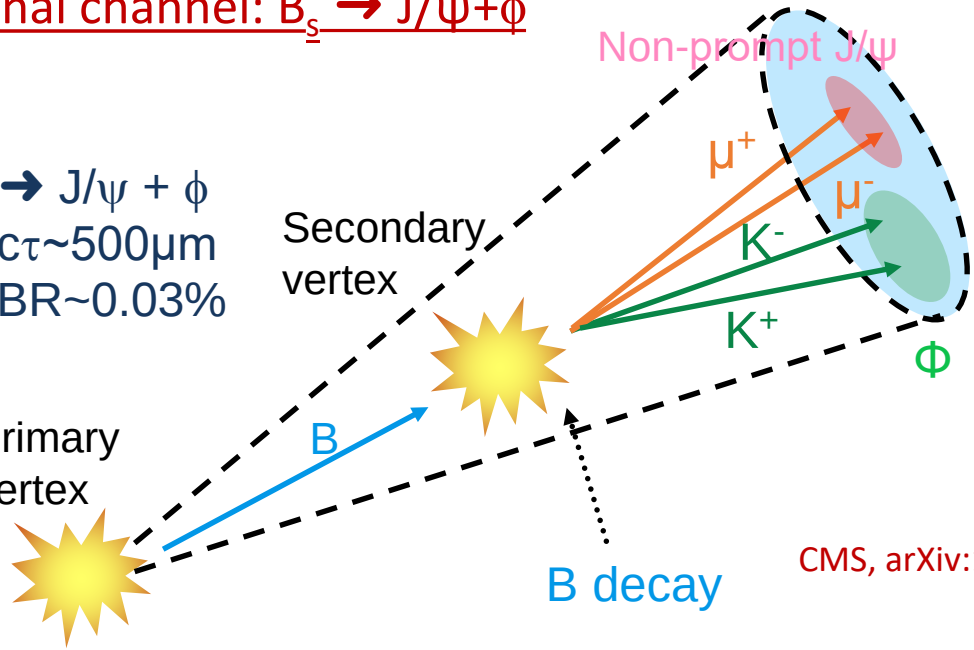

CMS, PRL 119 (2017) 152301

- Muon pair + track (kaon mass) → common vertex fitting
- fit on invariant mass spectra (maximum likelihood)
- Peaking background: $B^+ \rightarrow J/\psi + K^{*+}$, $B^0 \rightarrow J/\psi + K^{*0}$…etc

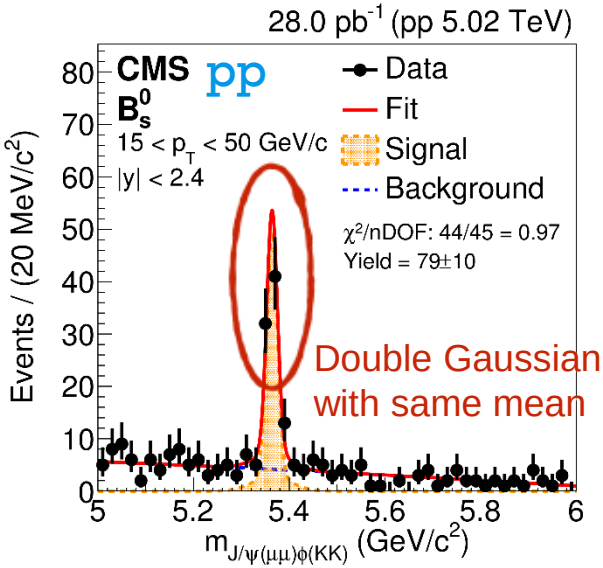
# Full reconstruction of $B_s$

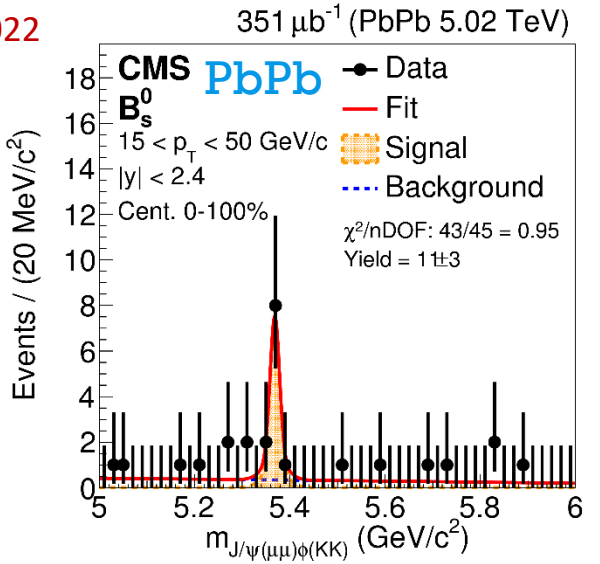
Signal channel: $B_s \rightarrow J/\psi+\phi$

$B_s \rightarrow J/\psi + \phi$
- $c\tau$~500μm
- BR~0.03%



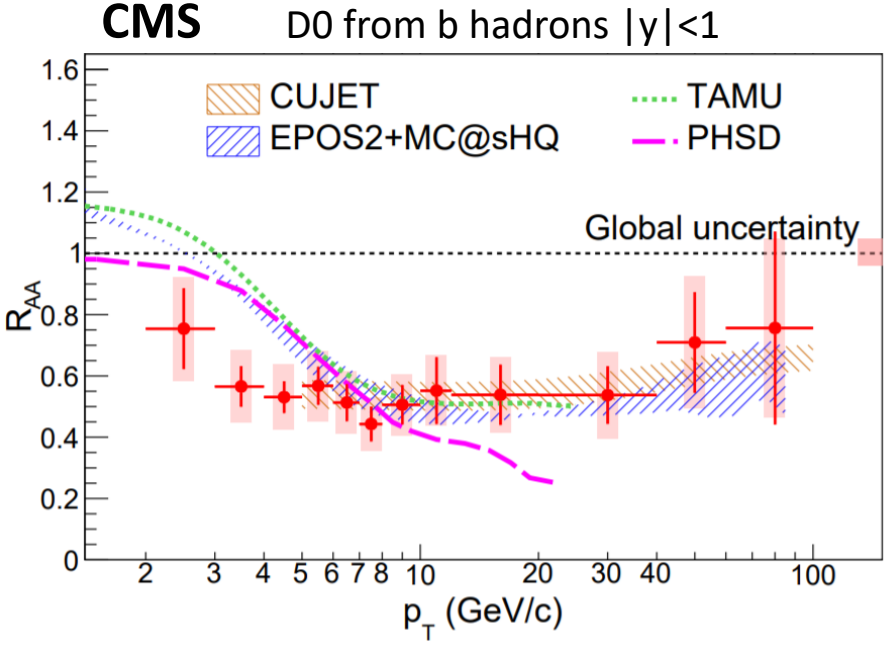

CMS, arXiv:1810.03022




- Muon pair + track (kaon mass) → common vertex fitting
- fit on invariant mass spectra (maximum likelihood)
- Narrow natural width of Φ meson → no peaking background components

# $R_{AA}$ of beauty from decay $D^0$ & J/ψ



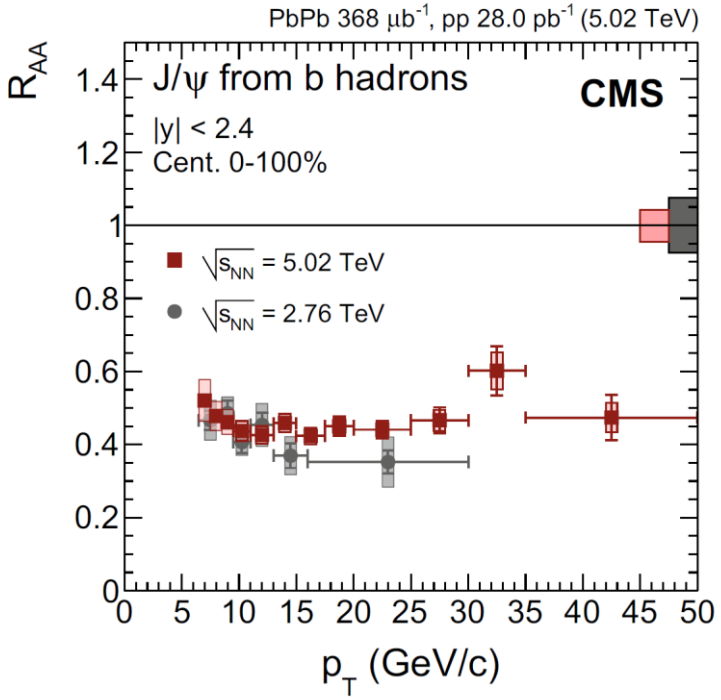

CMS, arXiv:1810.11102

Jiechen et al., JHEP**2** (2016) 169

Gossiaux et al NPA931 (2014) 581

He et al. PLB **735** (2014) 445

Song et al. PRC **92** (2015)

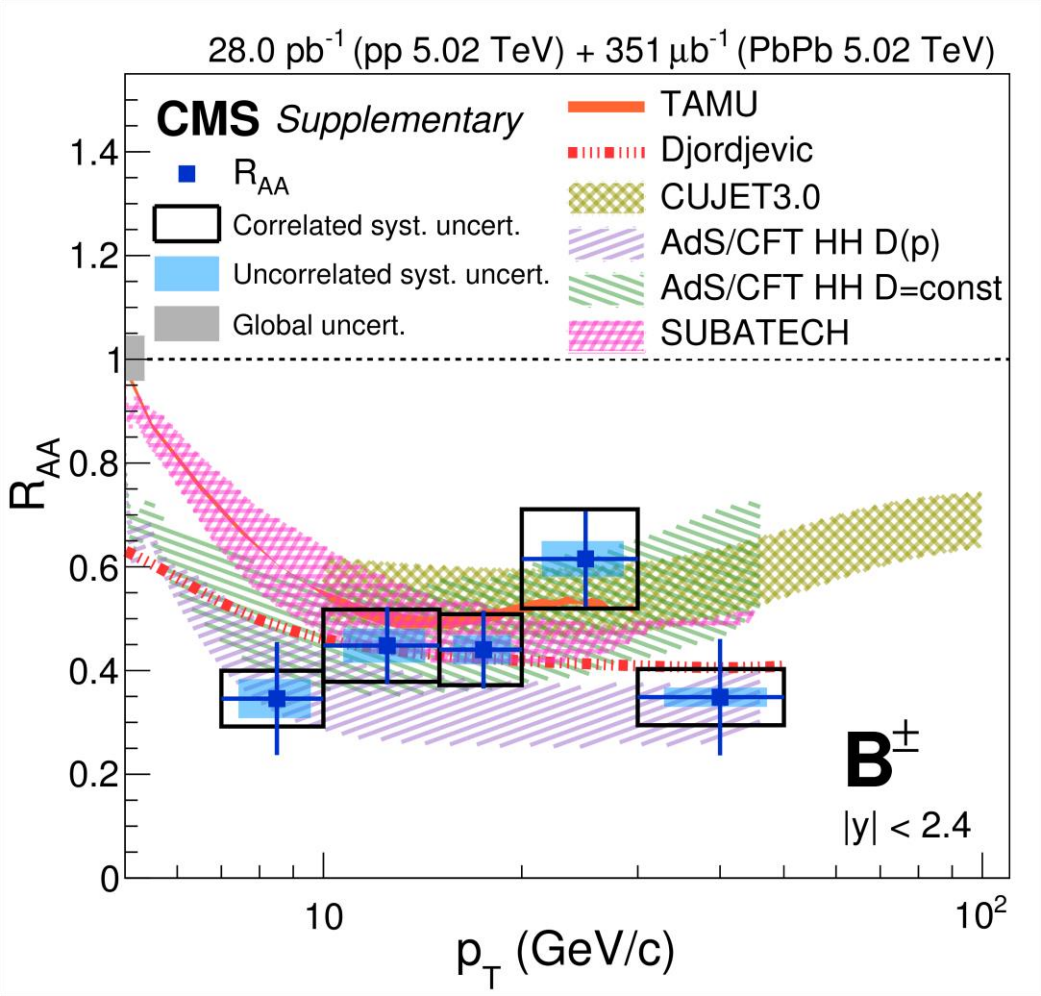



CMS, EPJC 78 (2018) 509 (5.02 TeV)

CMS, EPJC 77 (2017) 252 (2.76 TeV)

- High $p_T$: need collisional + rad. energy loss (e.g., CUJET), only collisional energy loss (PHSD) not seem to work.
- Low $p_T$: hint of stronger suppression than models: baryon enhancement? BR (b baryon➔$D^0$) << (B➔$D^0$)

# Fully reconstructed $B^+$ result

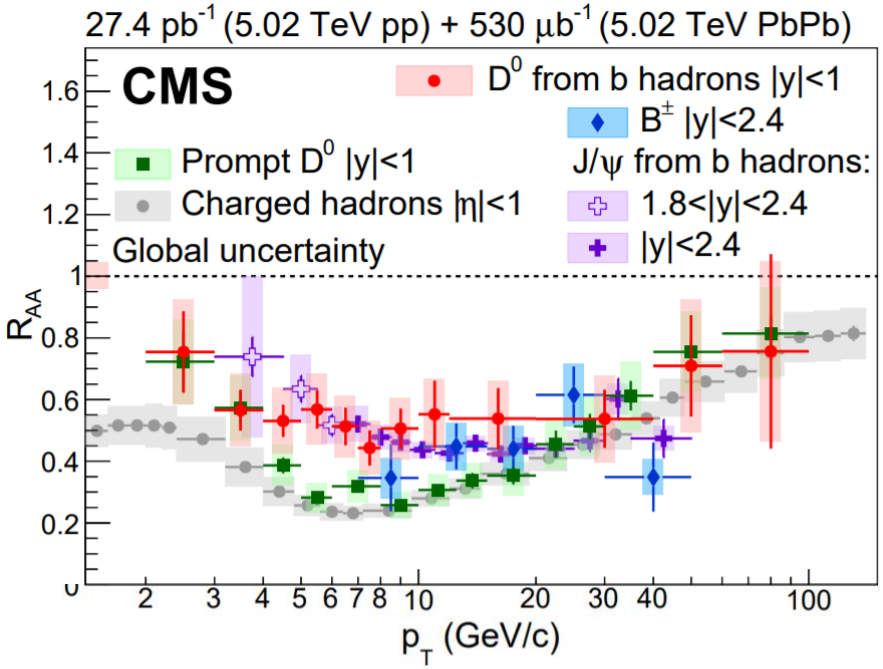



CMS, PRL 119 (2017) 152301

He et al. PLB**735**(2014)445
Djordjevic, *PRC***94**(2016)044908
Xu et al. JHEP**02**(2016)169
Horowitz, PRD91(2015)085019
Gossiaux et al NPA931(2014)581

- Suppression of $B^+$ meson
- $B^+$ meson $R_{AA}$ ~ 0.3 to 0.6 with no obvious trend within uncertainty
- Compatible with theory within uncertainty for $p_T$ 10-50 GeV/c
- Necessity for high $p_T$ measurement : distinguishing pQCD vs AdS/CFT base models

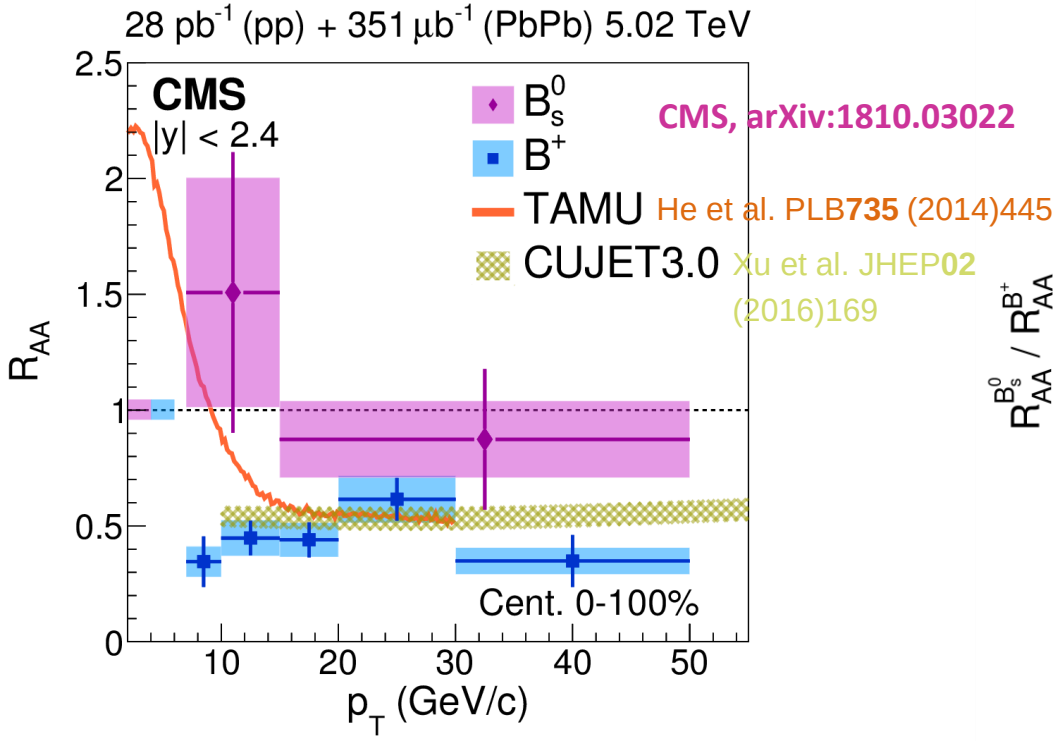
# $R_{AA}$ zoo: B vs. D vs. light




B→D: CMS, arXiv:1810.11102
B→J/ψ: CMS, EPJC 78 (2018) 509
B$^{\pm}$: CMS, PRL 119 (2017) 152301
D$^0$: CMS, PLB 782 (2018) 474
Charged hadrons: CMS, JHEP 04 (2017) 039

- Compatible results: non-prompt D, non-prompt J/ψ and B$^+$
- Beauty seems to separate from charm and light flavor up to ~ 20 GeV
  - quark mass ordering
  - parent B $p_T$ ≠ daughter D$^0$ or $J/\psi$ $p_T$
- Beauty, charm and light merging ~ 20 GeV

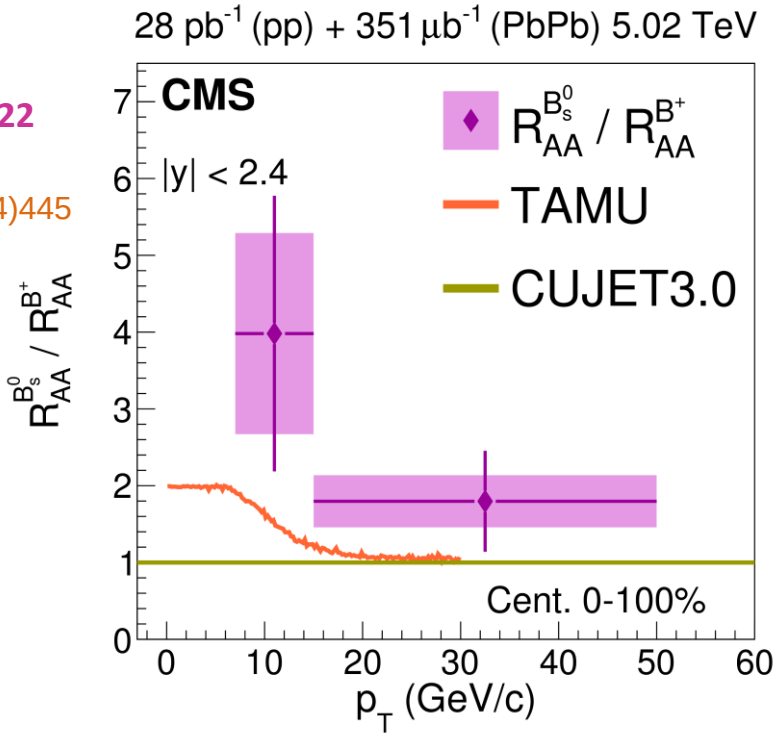
# Fully reconstructed $B_s$ result




CMS, arXiv:1810.03022

He et al. PLB**735** (2014)445

Xu et al. JHEP**02** (2016)169




- Large stat. and syst. uncertainties. Correlated syst. cancel in $B_s$ / $B^+$ $R_{AA}$ ratio.
- Hint of less $B_s$ suppression
- 2018 HI data and beyond → more precise measurement

# Summary and Outlook

- CMS beauty measurements: results are consistent
- Suppression for $B^+$, non-prompt J/ψ, and non-prompt D
- Beauty hadrons appear less suppressed than charm and light flavor up to ~20 GeV
- First $B_s$ measurement in heavy ion collision
- HL-LHC data with more precise measurements
  - ~4x increase in luminosity in year 2018
  - ~20x MB data statistics in year 2018
  - Pixel detector upgrade: 3 ➔ 4 layers