Results and prospects for quarkonium studies using hadronic decays

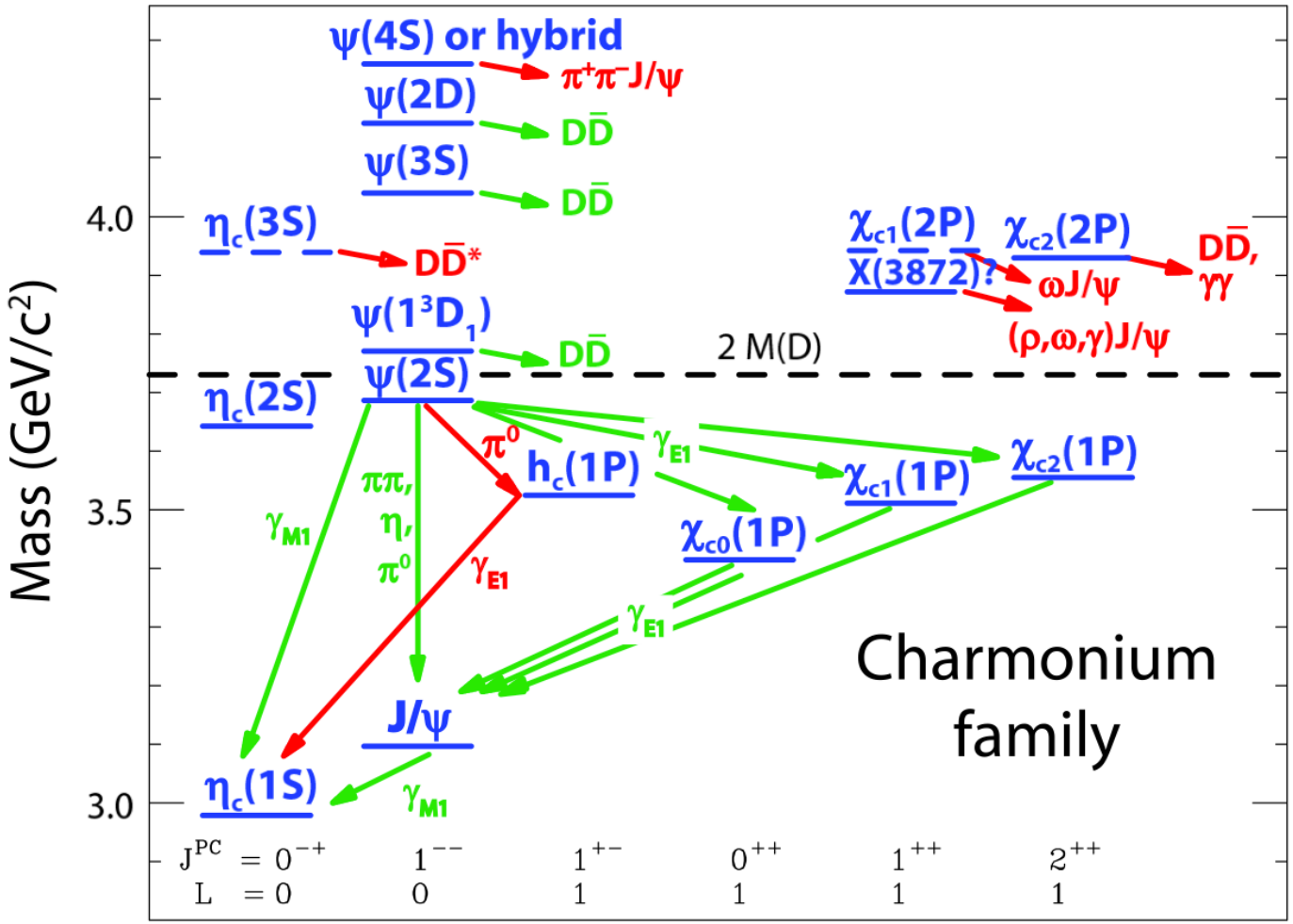
Jibo HE (UCAS)

Quarkonia As Tools 2024

Centre Paul Langevin, Aussois (France)

7-13 Jan 2024

Charmonium



[E. Eichten et al., Rev.Mod.Phys.80 (2008) 1161]

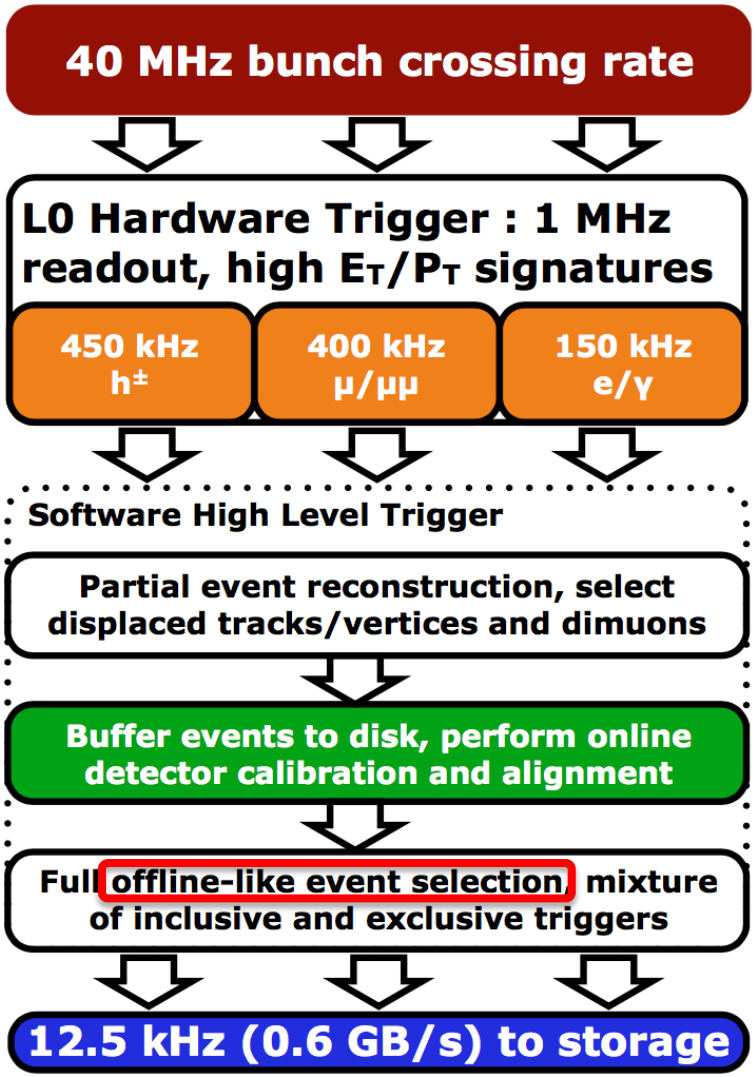
Hadronic decays

- Sizable branching fractions

	$\mathcal{B} \times 10^3$								
	$p\bar{p}$	$\phi\phi$	ϕK^+K^-	$\phi\pi^+\pi^-$	$\Lambda\overline{\Lambda}$	$\Xi^+\Xi^-$	$\Lambda(1520)\overline{\Lambda}(1520)$	$\eta_c\gamma$	$p\bar{p}\pi^+\pi^-$
η_c	1.35 ± 0.13	1.58 ± 0.19	2.9 ± 1.4	unknown	1.02 ± 0.23	0.90 ± 0.26	-	-	5.5 ± 1.9
J/ψ	2.12 ± 0.03	forbidden	0.83 ± 0.11	0.94 ± 0.15	1.89 ± 0.09	0.97 ± 0.08	unknown	17 ± 4	6.0 ± 0.5
χ_{c0}	0.22 ± 0.01	0.80 ± 0.07	0.97 ± 0.25	unknown	0.36 ± 0.02	0.45 ± 0.02	0.31 ± 0.12	forbidden	2.1 ± 0.7
h_c	< 0.17	forbidden	unknown	unknown	unknown	unknown	unknown	570 ± 50	3.3 ± 0.6
χ_{c1}	0.076 ± 0.003	0.42 ± 0.05	0.41 ± 0.15	unknown	0.13 ± 0.01	0.06 ± 0.01	< 0.09	forbidden	0.50 ± 0.19
χ_{c2}	0.073 ± 0.003	1.06 ± 0.09	1.42 ± 0.29	unknown	0.18 ± 0.02	0.14 ± 0.01	0.46 ± 0.15	forbidden	1.32 ± 0.34
η_c'	< 2.0	< 1.0	unknown	unknown	unknown	unknown	unknown	forbidden	seen
ψ'	0.29 ± 0.01	forbidden	0.07 ± 0.02	0.12 ± 0.03	0.38 ± 0.01	0.29 ± 0.01	unknown	3.4 ± 0.5	0.60 ± 0.04

- High multiplicity in *pp* collisions, high level of background due to too many combinations, chanllenging even for LHCb that has excellent hadron particle-identification

The LHCb trigger (2018)

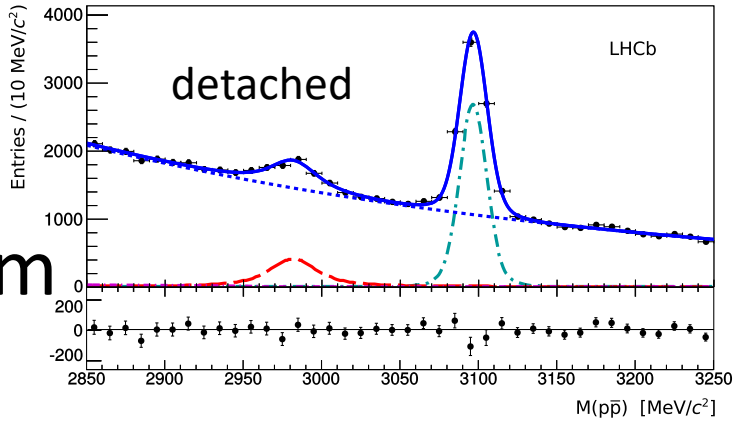


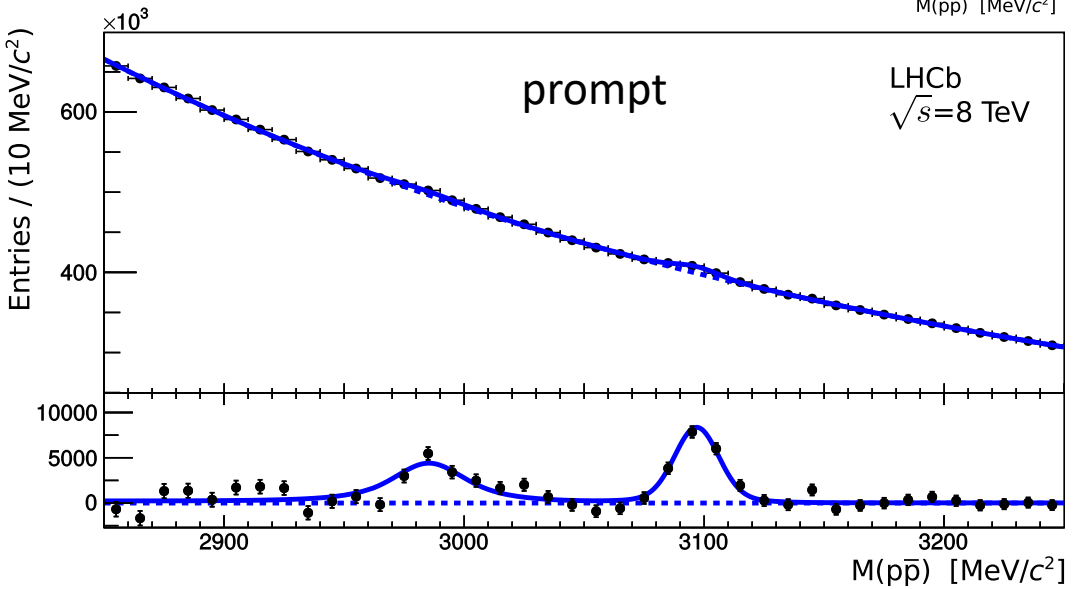
- L0, Hardware
  - $p_{\mathrm{T}}(\mu_1) \times p_{\mathrm{T}}(\mu_2) >$ (1.5 GeV)^2
  - $p_{\mathrm{T}}(\mu) >$ 1.8 GeV
  - $E_{\mathrm{T}}(e) >$ 2.4 GeV
  - $E_{\mathrm{T}}(\gamma) >$ 3.0 GeV
  - $E_{\mathrm{T}}(h) >$ 3.7 GeV
- High Level Trigger
  - Stage1, p_{T}, IP
  - Stage2, full selection

$\eta_c(1S)$ production at 7/8 TeV

[LHCb, EJPC 75 (2015) 311]

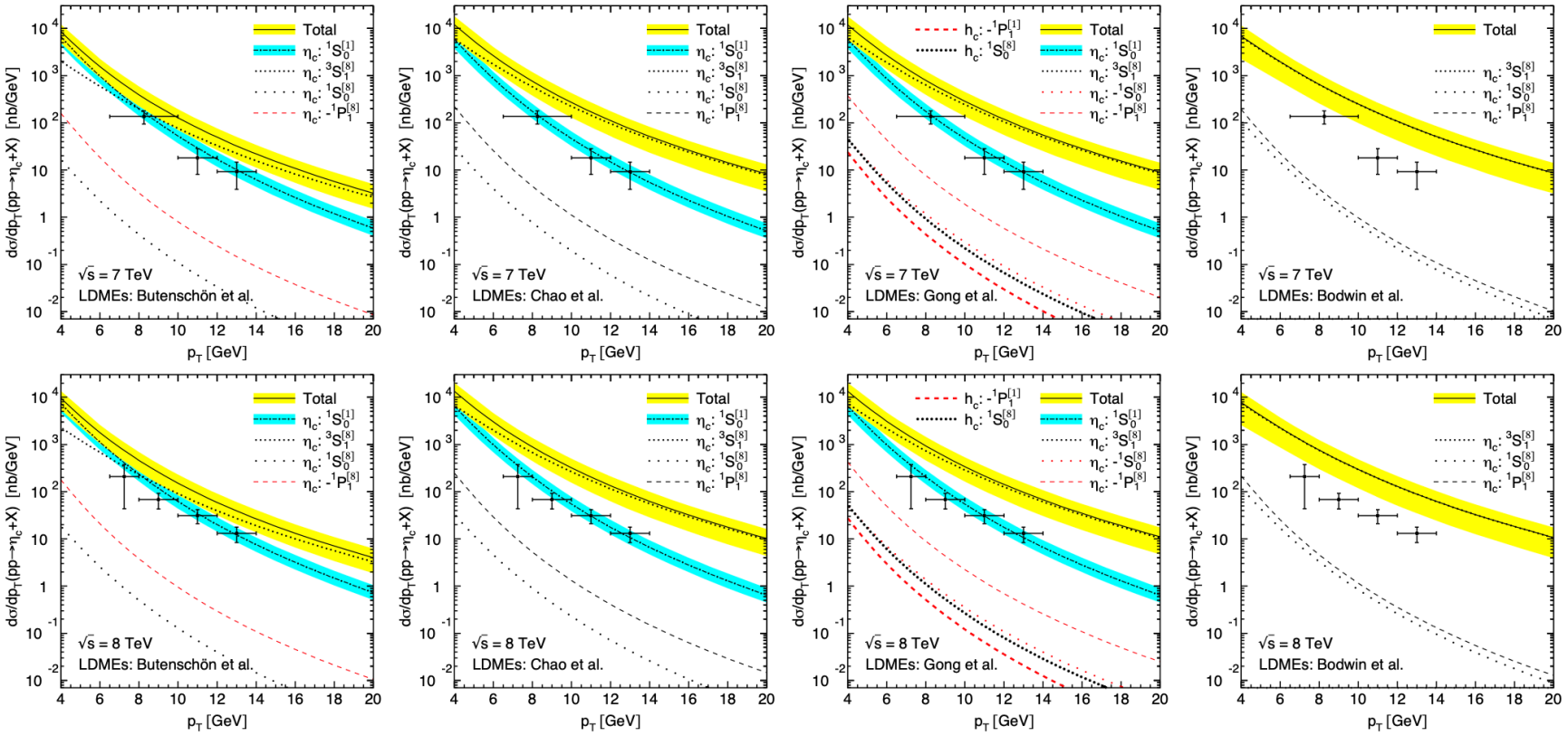
- $\eta_c(1S)$ hadroproduction firstly measured by LHCb
- Prompt signal suffers from high background





$\eta_c(1S)$ production at 7/8 TeV

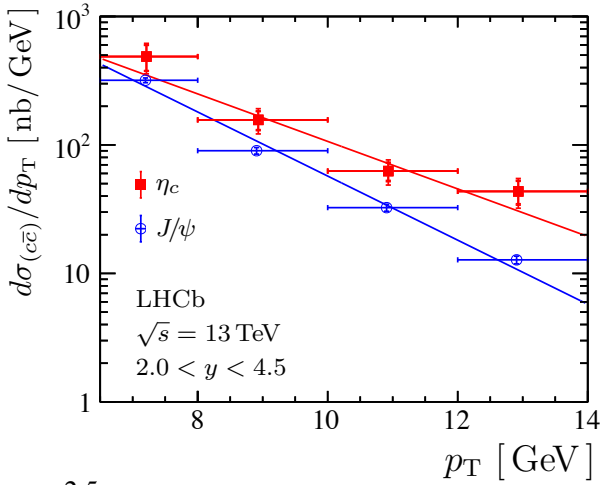
- Results described by NLO CS?

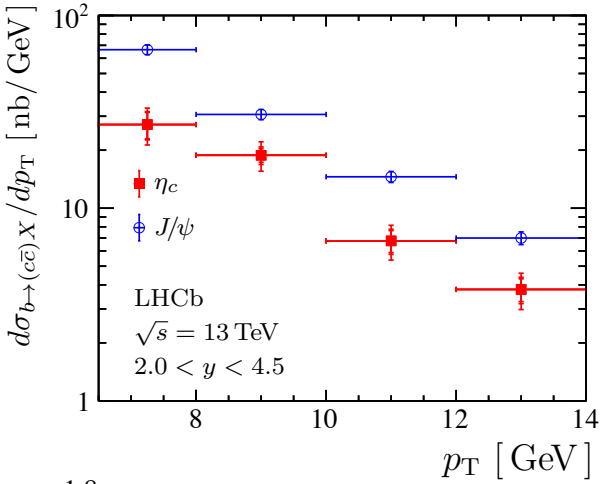


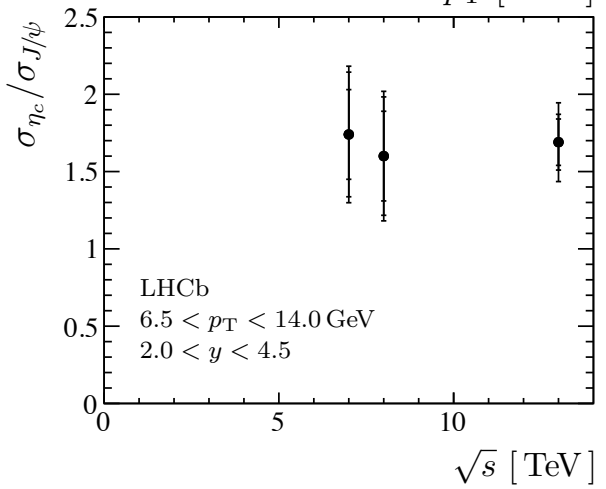
[M. Butenschoen, et al., PRL 114 (2015) 092004]

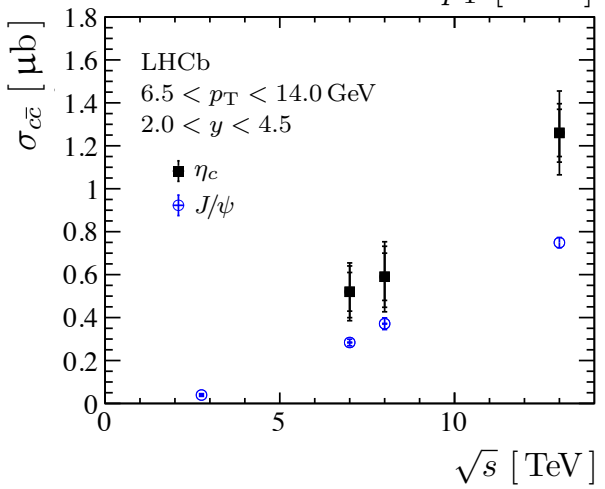
$\eta_c(1S)$ production at 13 TeV

[LHCb, EPJC 80 (2020) 191]





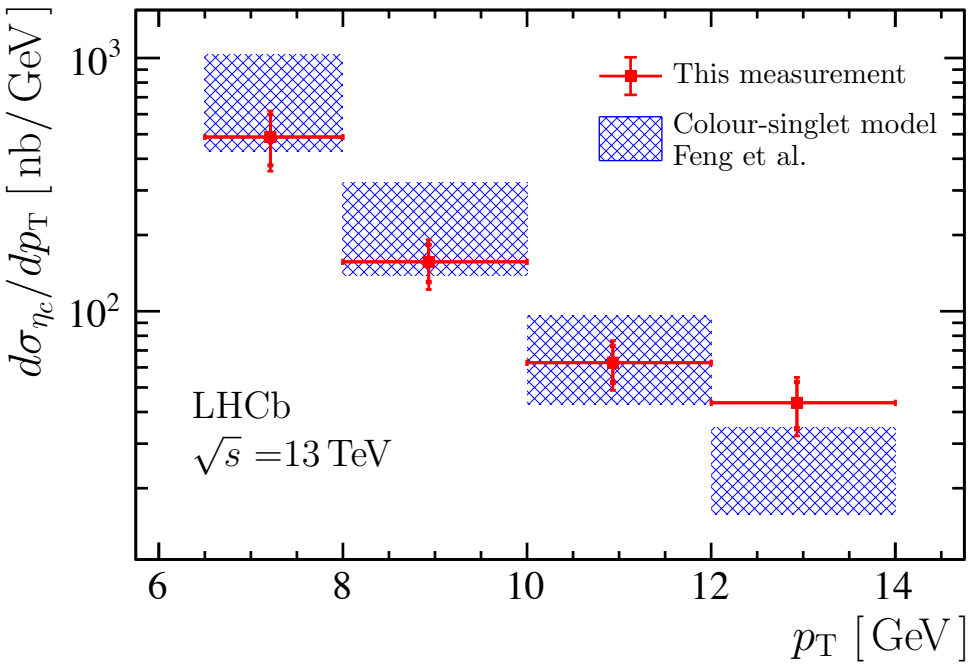




$\eta_c(1S)$ production at 13 TeV

[LHCb, EPJC 80 (2020) 191]

- Comparison w/ CS, good agreement
- Theoretical precision limited by scale uncertainty



$$\left(\sigma_{\eta_c}^{\text{prompt}}\right)_{13\,\text{TeV}}^{6.5<p_T<14.0\,\text{GeV},\,2.0<y<4.5} = 1.26 \pm 0.11 \pm 0.08 \pm 0.14\,\mu\text{b},$$

Prediction: $1.56^{+0.83}_{-0.49}\,(\text{scale})^{+0.38}_{-0.17}\,(\text{CT14NLO})\ \mu\text{b}$

[Y. Feng, et al., NPB 945 (2019) 114662]

Prospects at LHCb (for discussion)

	$\mathcal{B} \times 10^3$								
	$p\bar{p}$	$\phi\phi$	ϕK^+K^-	$\phi\pi^+\pi^-$	$\Lambda\bar{\Lambda}$	$\Xi^+\Xi^-$	$\Lambda(1520)\bar{\Lambda}(1520)$	$\eta_c\gamma$	$p\bar{p}\pi^+\pi^-$
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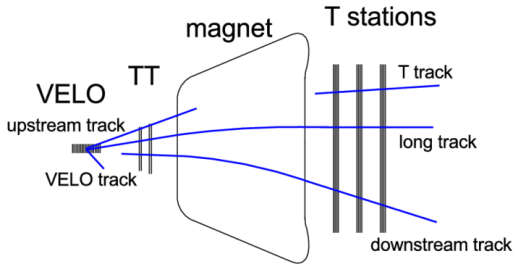
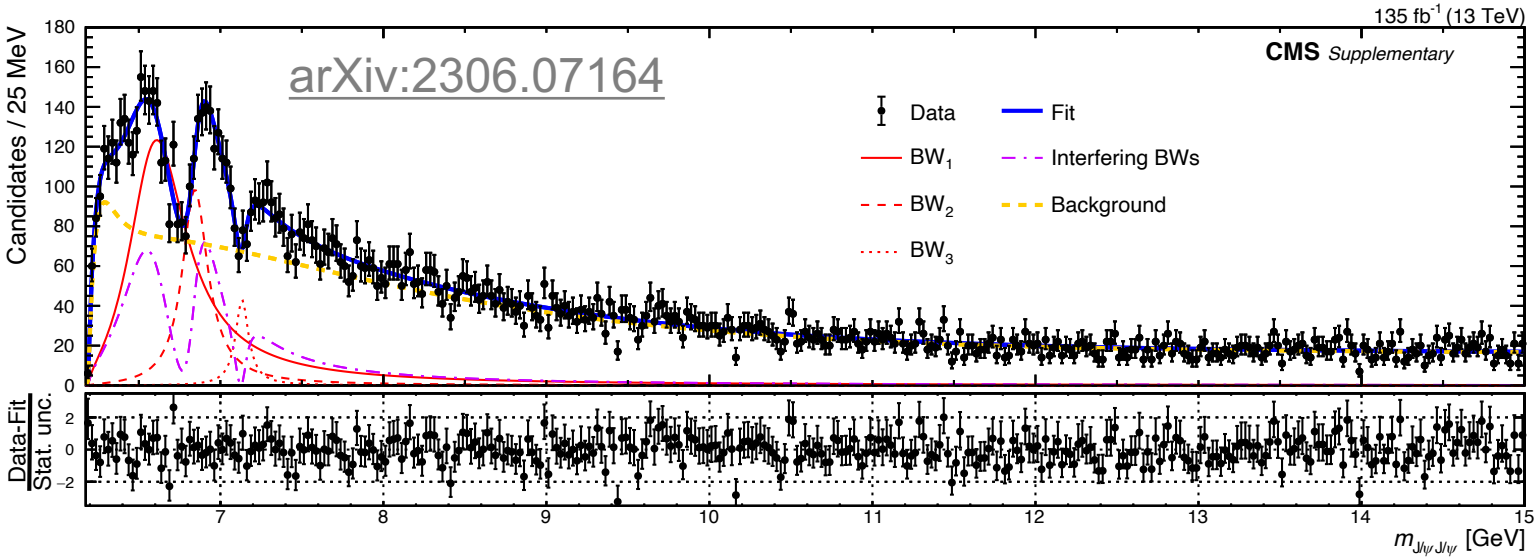
- Charmonia to $p\bar{p}$ at 13 TeV
  - $\eta_c(1S)$ p_{T} extended to 5-20 GeV (was 6.5-14 GeV), upper limits on $\eta_c(2S), h_c(1P)$, to be public soon
- Charmonia to $p\bar{p}\pi^+\pi^-$, as $\phi\phi, \phi KK$
  - No trigger (and chanllenging) for hadroproduction, first $\mathcal{B}(b \to h_c X)$ possible, still useful?
- Λ reconstruction not very efficient, improved in Run-3



Bottomonia?

- Decays to double-charmonium
  - CMS/ATLAS can do a good job on $J/\psi J/\psi$



  - $J/\psi\eta_c$
- Wishlists from theoretical side?