Update on the Psi2S

- Signal extraction vs centrality and vs pT
- Acc x efficiency
- Systematic uncertainties
- First RAA results vs centrality and pT

Signal extraction Ev. Mixing - centrality bins

- 2 signal functions:
  - double CB or NA60
- 5 background functions
  - VWG, 2Exp, Pol1, Pol2, 1Exp
- 2 fitting ranges:
  - 2-5, 2.2-4.5 GeV/c2
- 2 tails for CB2 function:
  - MC or pp@13TeV

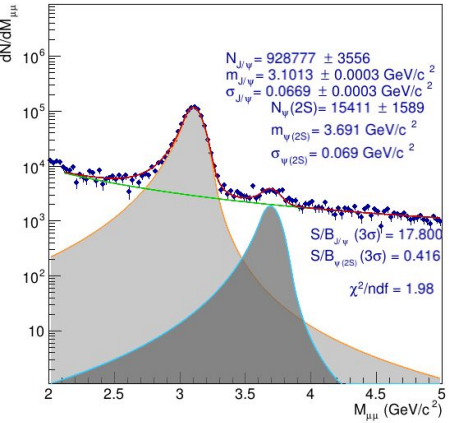
30 tests

(x2 weight assigned to the NA60 functions, since only one set of tails was tested)

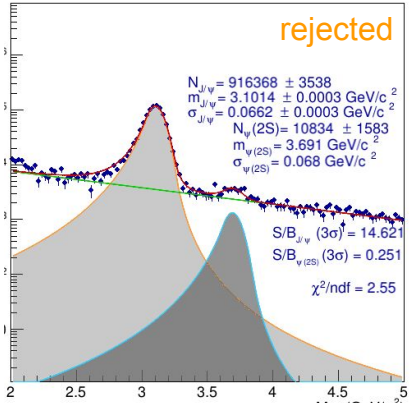
- Cut on chi2/ndf <2.5

Examples of Ev. Mixing fits - 090%

CB2+VWG

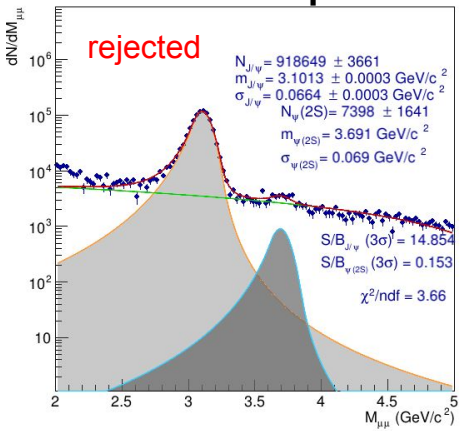


CB2+Exp

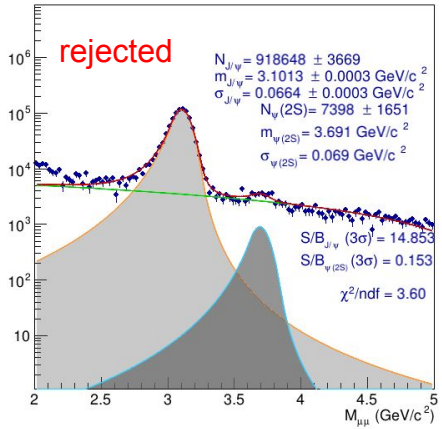


- Combinations of various signal and background functions
- Tails MC
- Fit 2-5 GeV/c2

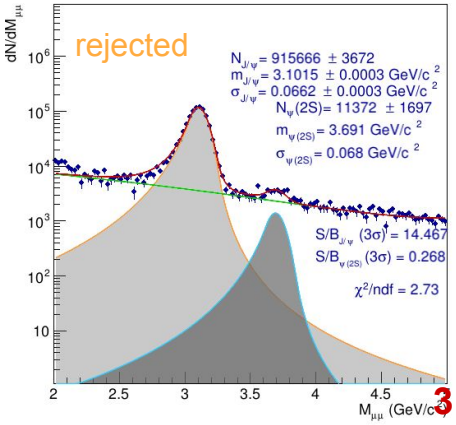
CB2+2Exp



CB2+Pol1



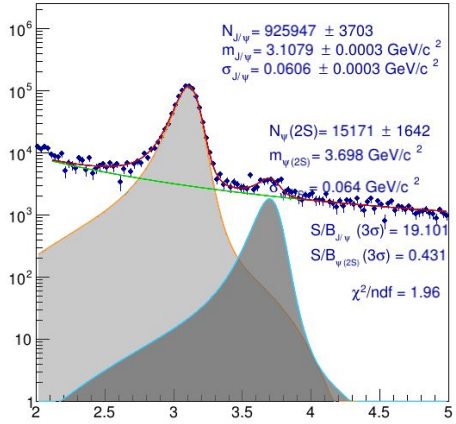
CB2+Pol2



0-90% and 0-20% are the worst bins to fit

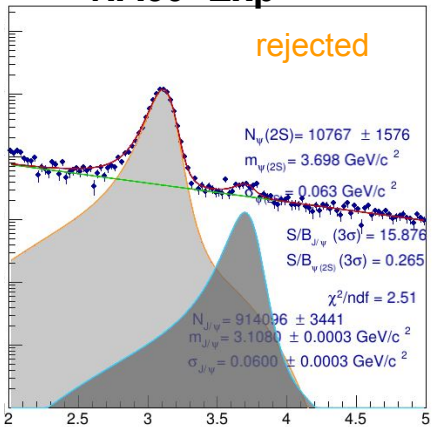
Examples of Ev. Mixing fits - 090%

NA60+VWG



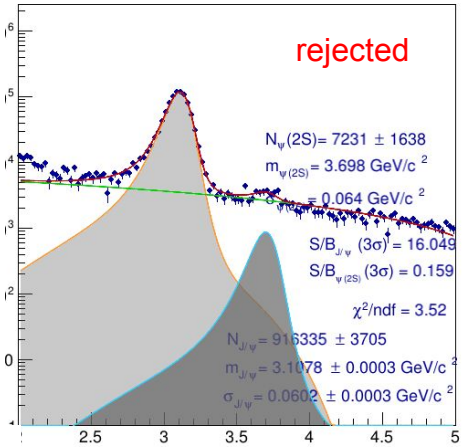
NA60+Exp

rejected

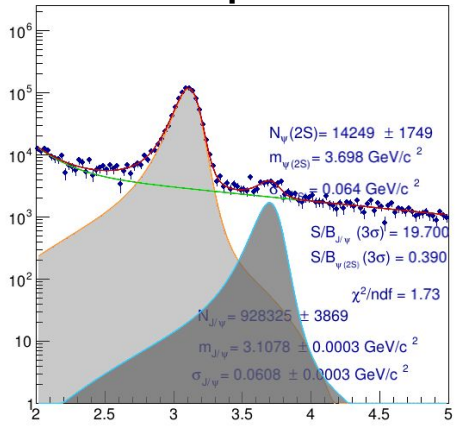


NA60+Pol1

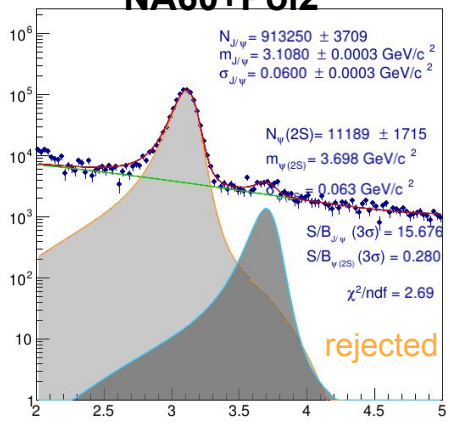
rejected



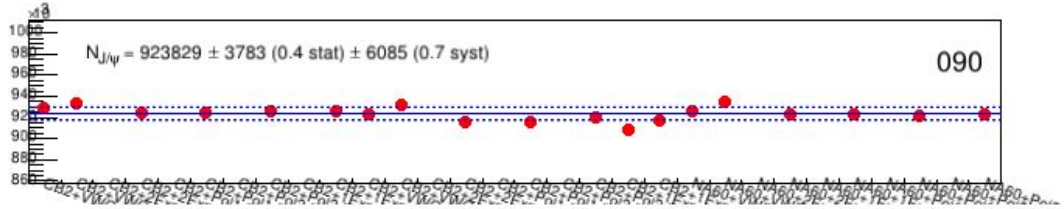
NA60+2Exp

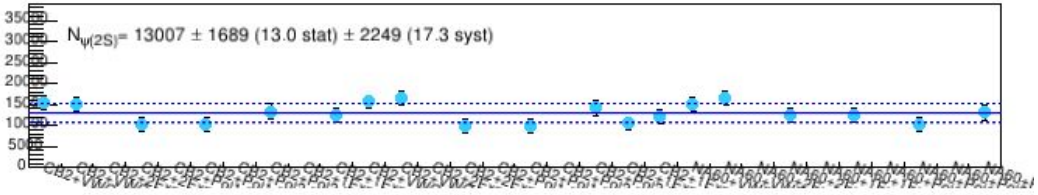


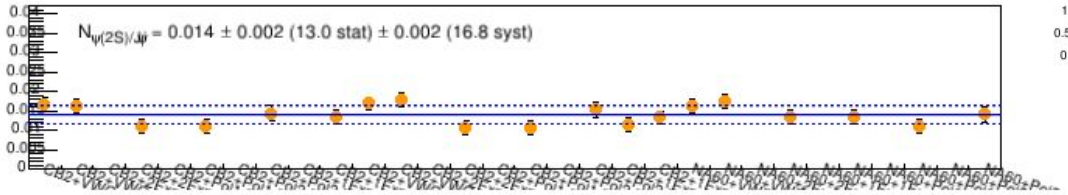
NA60+Pol2

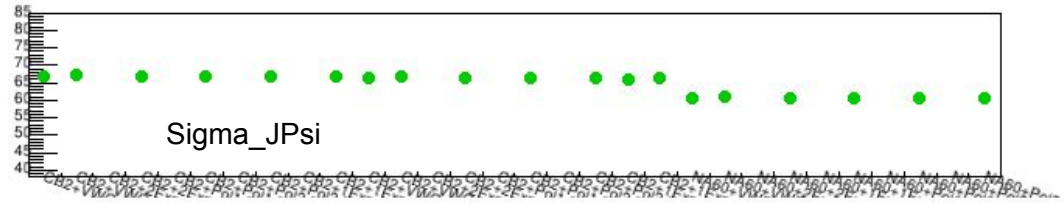


Signal extraction Ev. Mixing - 090%

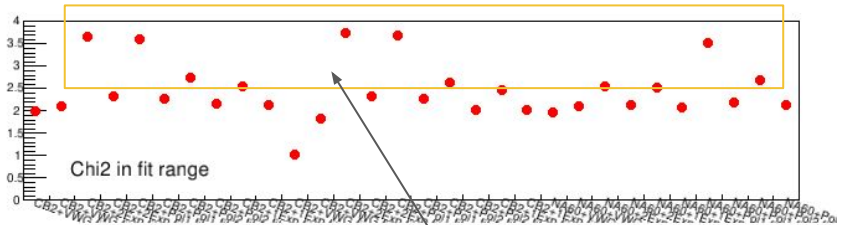






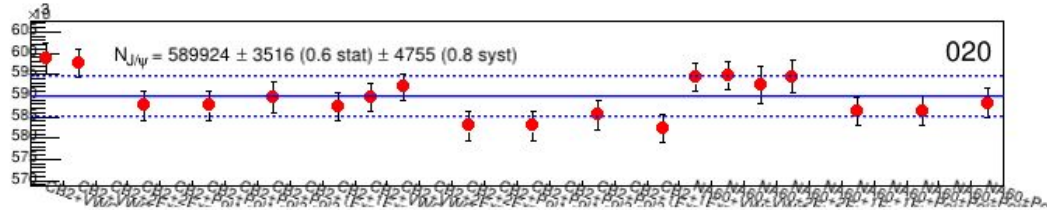


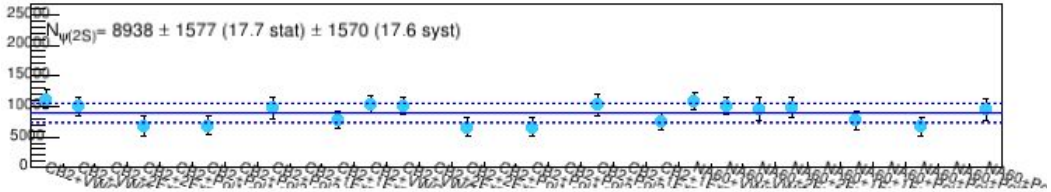
- Ev mixing normalised between 2-8 GeV/c2
- Chi2/ndf cut < 2.5

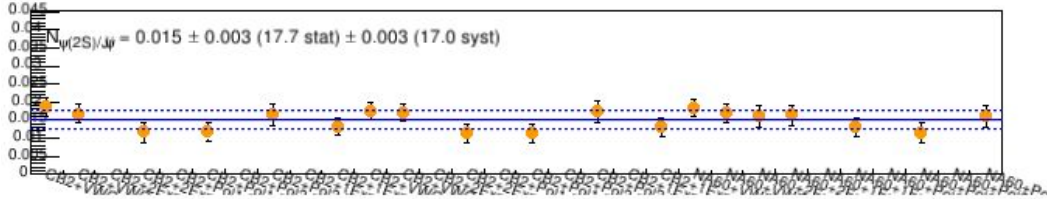


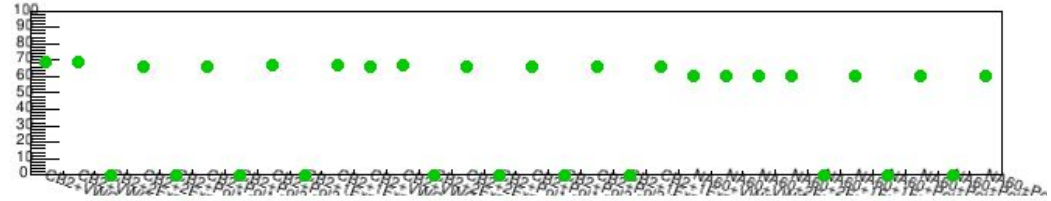
11 fits removed because of Chi2/ndf >2.5

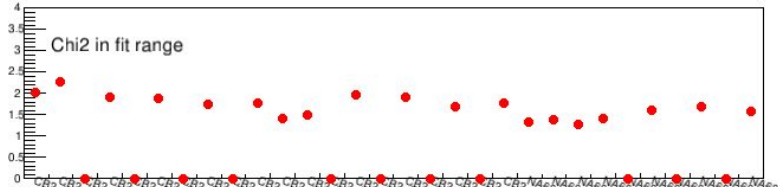
Signal extraction Ev. Mixing - 020%





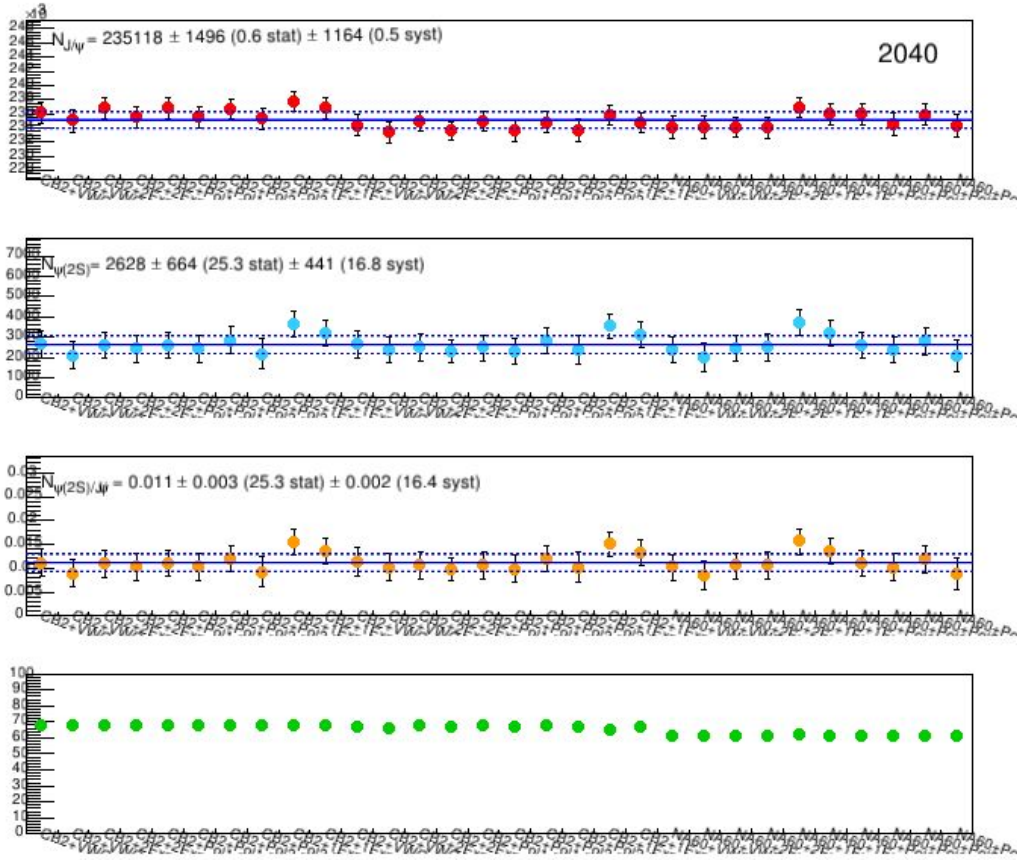


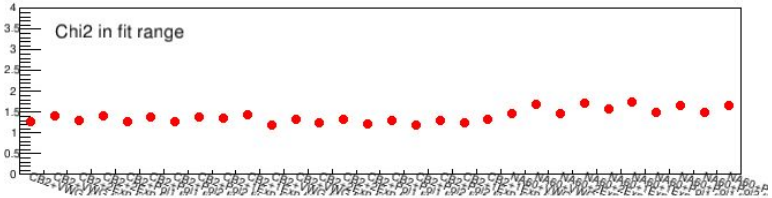




Chi2/ndf =0 → corresponds to the fits that are removed because of the chi2 cut

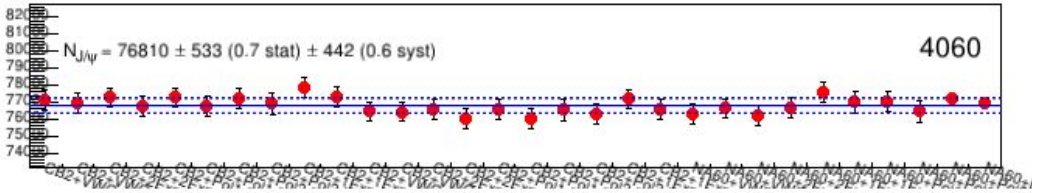
Signal extraction Ev. Mixing - 2040%

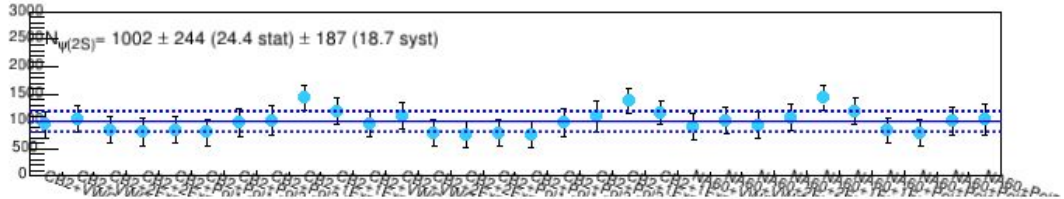


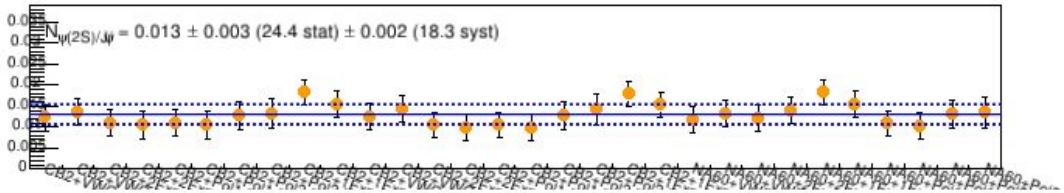


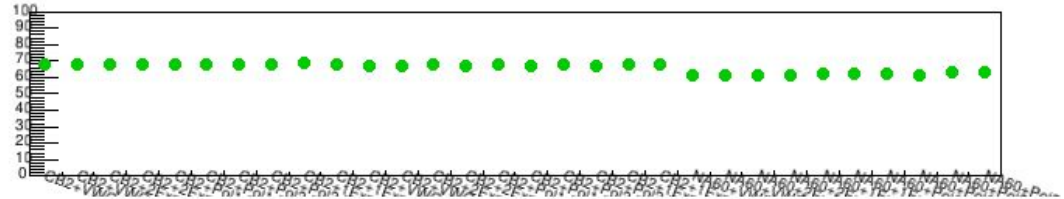
No more fits are removed because of the Chi2 cut

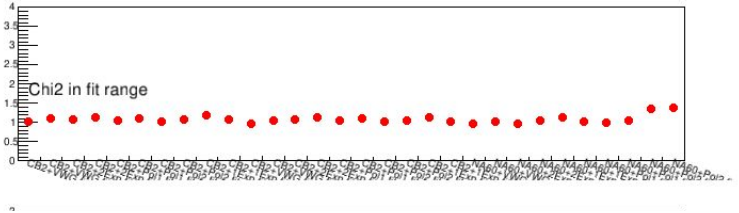
Signal extraction Ev. Mixing - 4060%





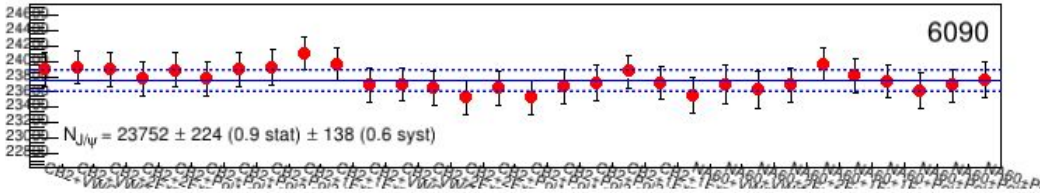


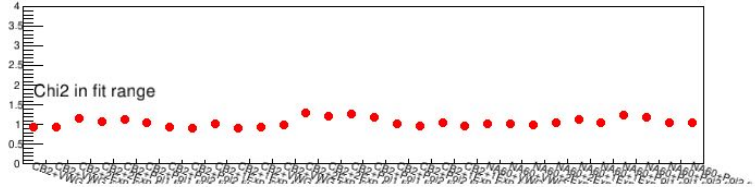


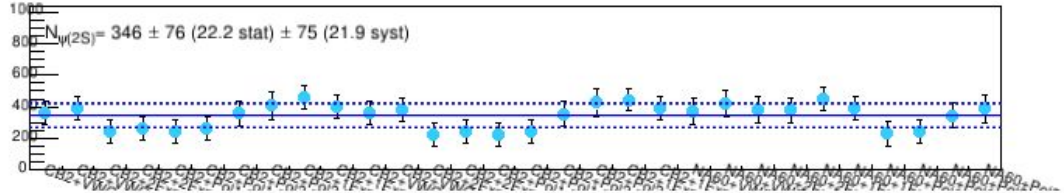


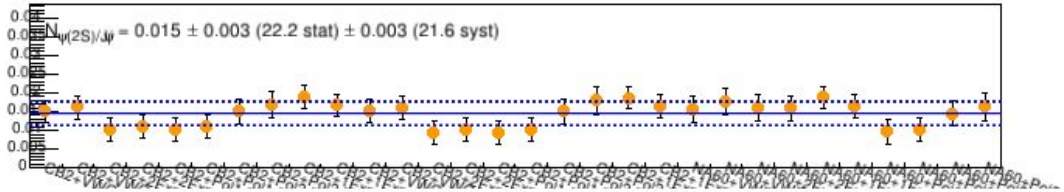
No more fits are removed because of the Chi2 cut

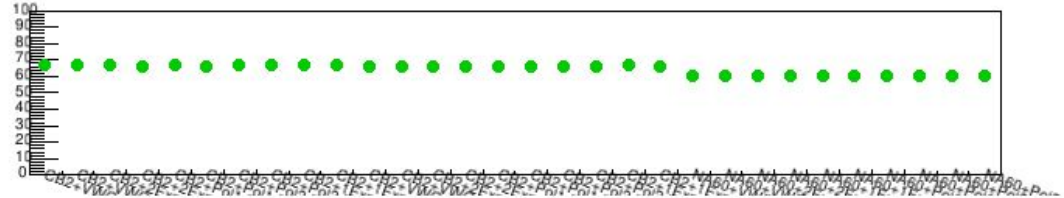
Signal extraction Ev. Mixing - 6090%











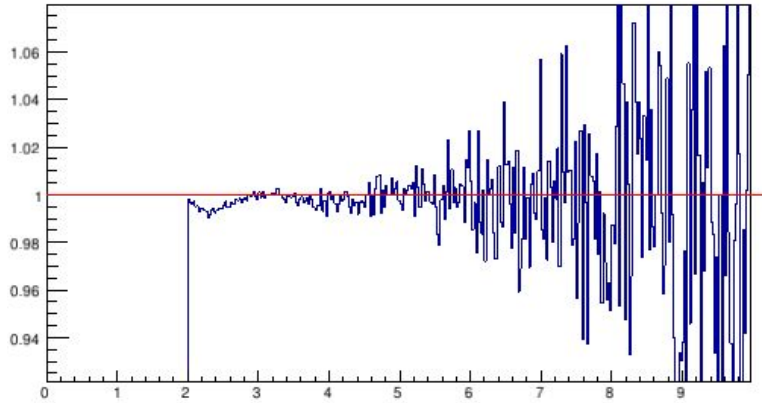
No more fits are removed because of the Chi2 cut

Impact of event mixing normalization

Normalization of the +/- spectra:

$$R_{\mathrm{acc}} = \frac{N^{+-}_{\mathrm{mixed}}}{2\sqrt{N^{++}_{\mathrm{mixed}} N^{--}_{\mathrm{mixed}}}}.$$

$$F = \frac{\int_{m_1}^{m_2} 2R_{\mathrm{acc}} \sqrt{N^{++}_{\mathrm{real}} N^{--}_{\mathrm{real}}}\,\mathrm{d}m}{\int_{m_1}^{m_2} N^{+-}_{\mathrm{mixed}}\,\mathrm{d}m}$$

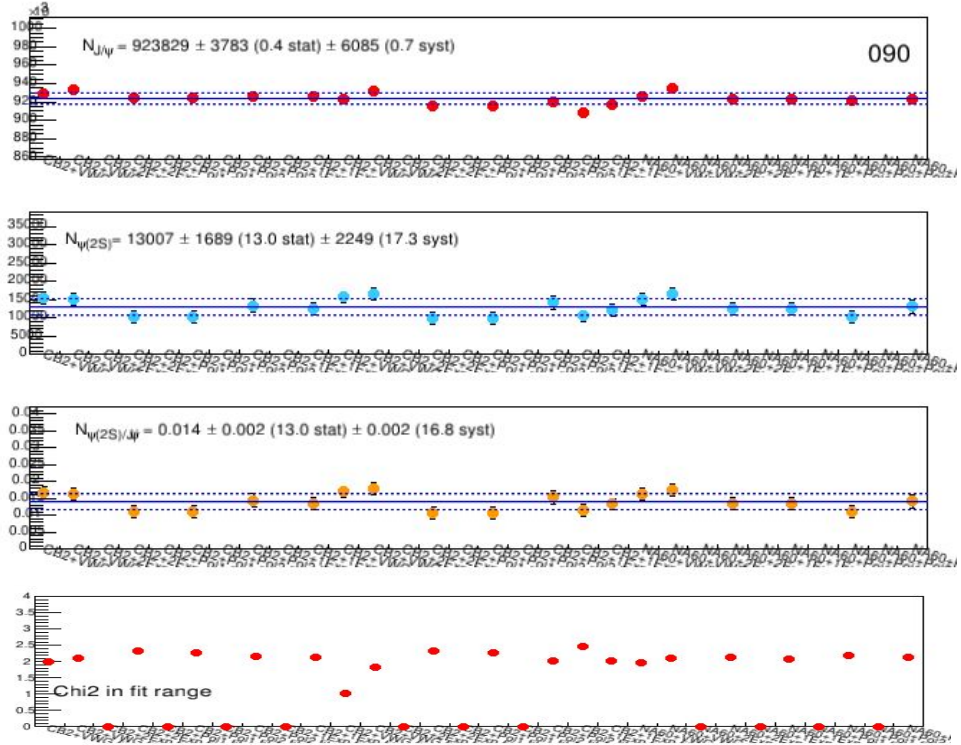


So far m1 = 2GeV/c2, m2 = 8 GeV/c2

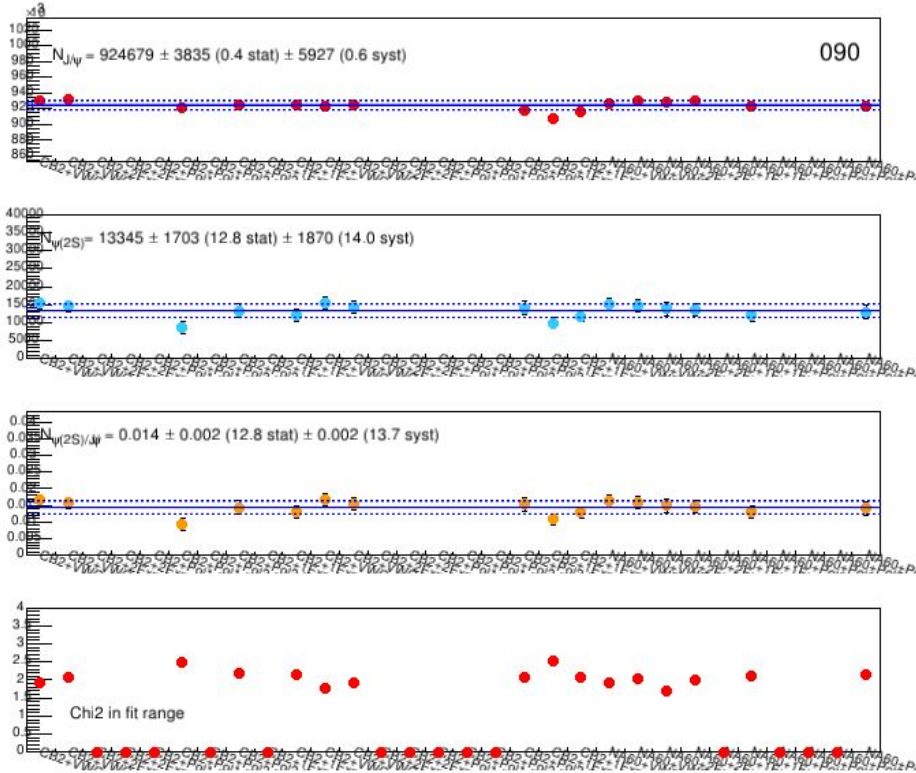
Check sensitivity to the normalization range, using 2.5 - 7 GeV/c2

Impact of event mixing normalization

Ev. Mix normalization **2 - 8 GeV/c2,** Chi2/ndf<2.5

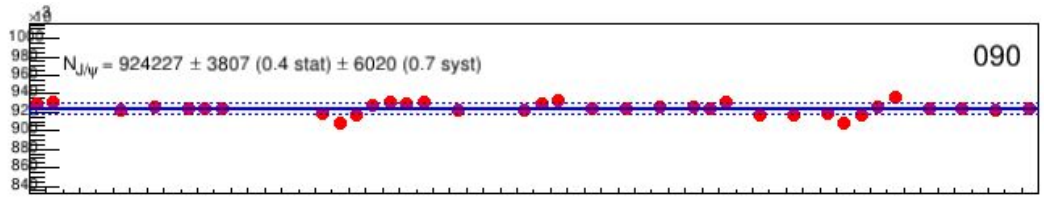


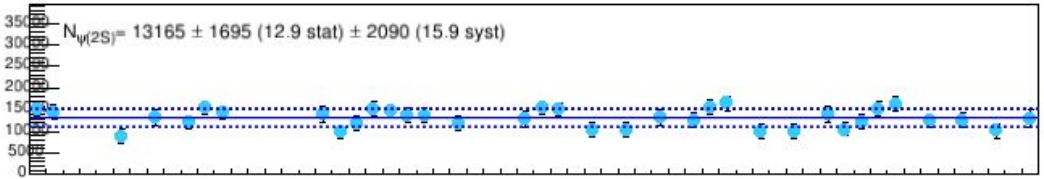
Ev. Mix normalization **2.5 - 7 GeV/c2,** Chi2/ndf<2.5

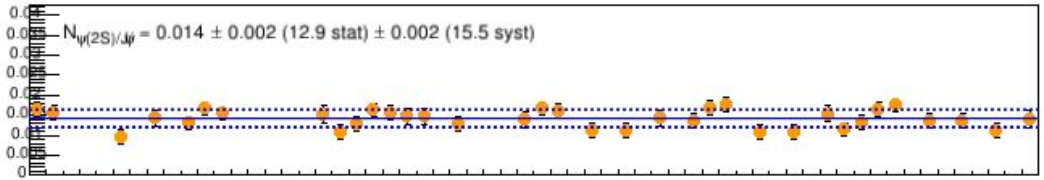


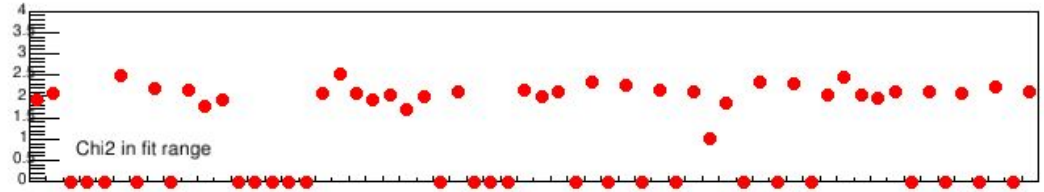
0-90%: difference in the average values well within the syst. uncertainties
Same conclusions for all centrality bins

Signal extraction Ev. Mixing - 090% - 60 tests









Chi2/ndf<2.5

Include tests based on both normalizations → **total of 60 tests**

JPsi signal extraction: mixing range

%	Mixing (norm - 2-8)	Mixing (norm - 2.5-7 + 2-8)
0-90	923829 +- 3783 (0.4%) +- 6085 (0.7%)	924227+-3897(0.4%)+-6020 (0.7%)
0-20	589924 +- 3516 (0.6%) +- 4755 (0.8%)	589946+-3606 (0.6%)+-5565 (0.9%)
20-40	235118 +- 1496 (0.6%) +- 1164 (0.5%)	235410 +-1529 (0.6%)+-1252 (0.5%)
40-60	76810+- 533 (0.7%) +- 442 (0.6%)	76872+- 597 (0.8%) +- 433 (0.6%)
60-90	23752 +- 224 (0.9%) +- 138 (0.6%)	23766 +- 236 (1%) +- 136 (0.6%)

Sum 0-90%	925604 (<0.2% from integrated 0-90%)	925994 (<0.2% from integrated 0-90%)

Chi2/ndf<2.5

- The sum of the 4 centrality bins is in good agreement with the integrated 0-90%
- Differences are well within the uncertainties
- No significant difference if the norm range 2.5-7 is included

Psi(2S) signal extraction: mixing range

%	Mixing (norm - 2-8)	Mixing (norm - 2.5-7 + 2-8)
0-90	13007 +- 1689 (12%) +- 2249 (17%)	13165+-1695 (12.9%)+-2090 (15.9%)
0-20	8938 +- 1577 (15%) +- 1570 (18%)	8777 +- 1556 (18%) +- 1570 (23%)
20-40	2628 +- 664 (23%) +- 441 (17%)	2920+-669 (23%)+-646 (22%)
40-60	1002 +- 244 (24%) +- 187 (19%)	1070+-247 (23%)+-192 (18%)
60-90	346 +- 76 (22%) +- 75 (22%)	358 +- 77 (22%) +- 67 (19%)

Sum 0-90%	12914 (0.7% wrt integrated 0-90%)	13125 (0.3% wrt integrated 0-90%)

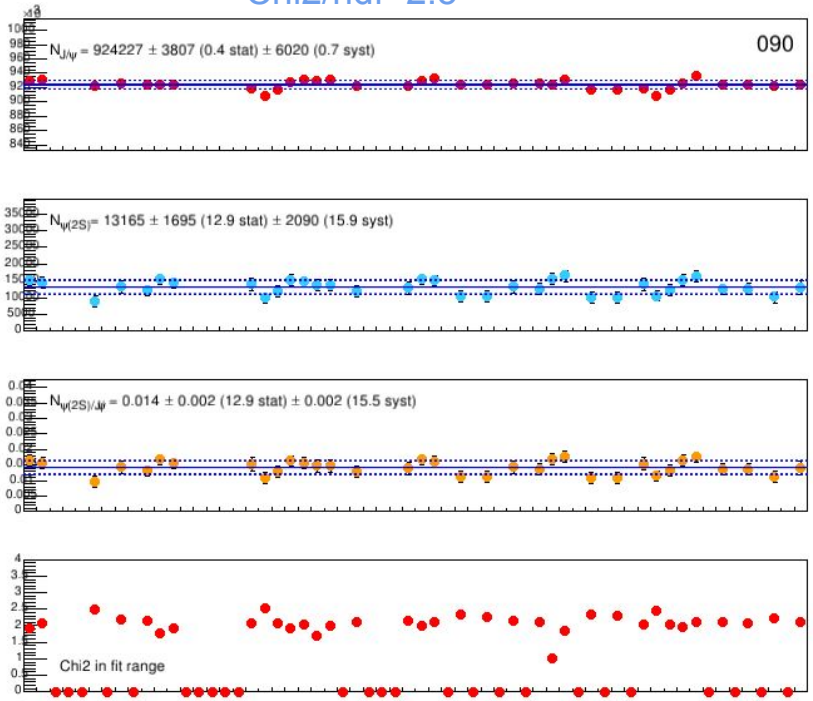
Chi2/ndf<2.5

- The sum of the 4 centrality bins is in good agreement with the integrated 0-90%
- In all bins the difference is well within the uncertainties

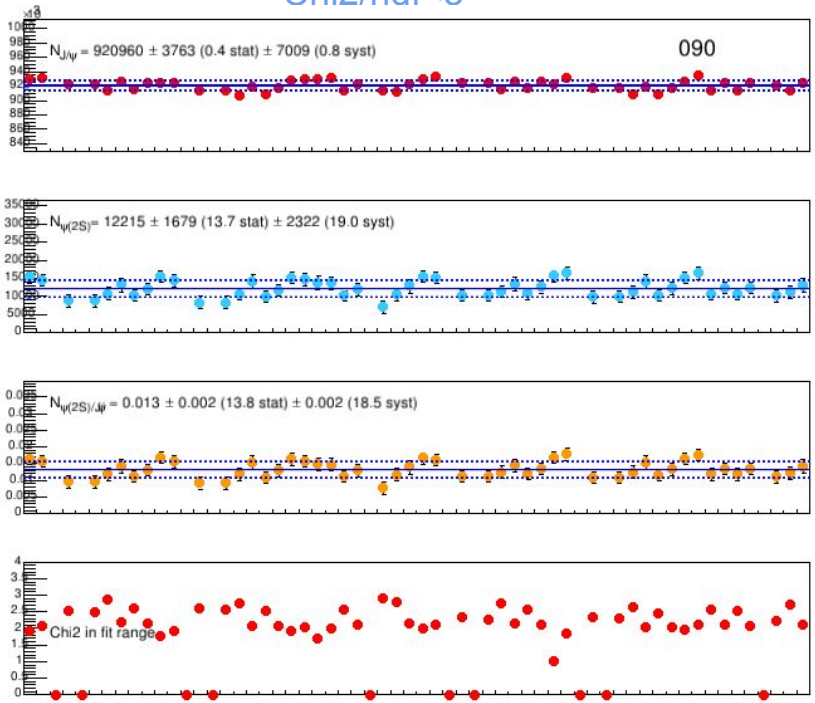
Impact of chi2 cut

Starting from these 60 tests, check the impact of the chi2 cut

Chi2/ndf<2.5



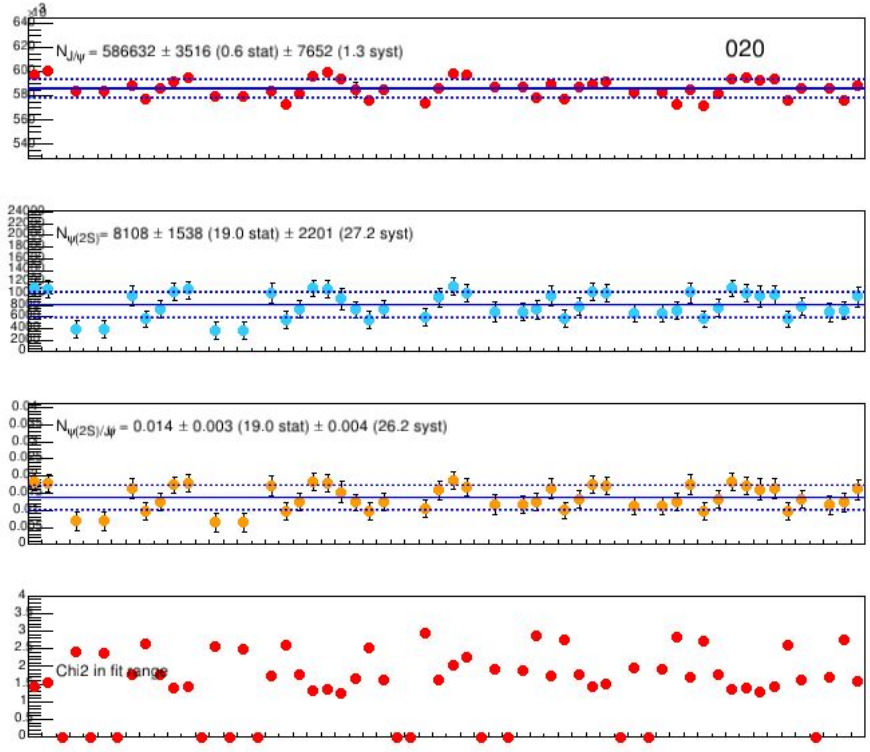
Chi2/ndf<3



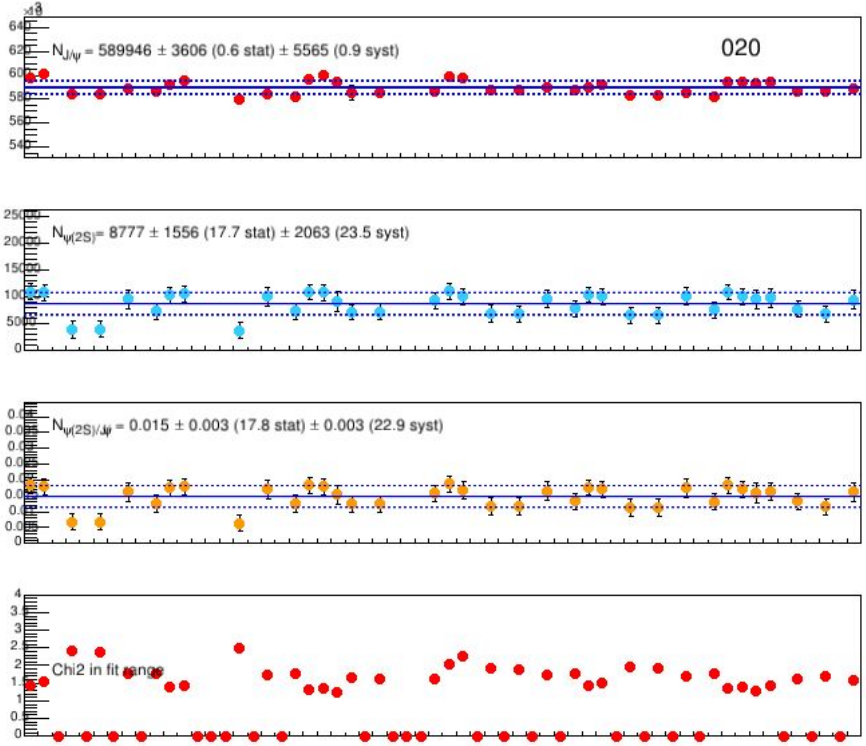
Chi2/ndf cut removes fits only in 0-90% and 0-20%

Signal extraction Ev. Mixing - 020% - 60 tests

Chi2/ndf<3



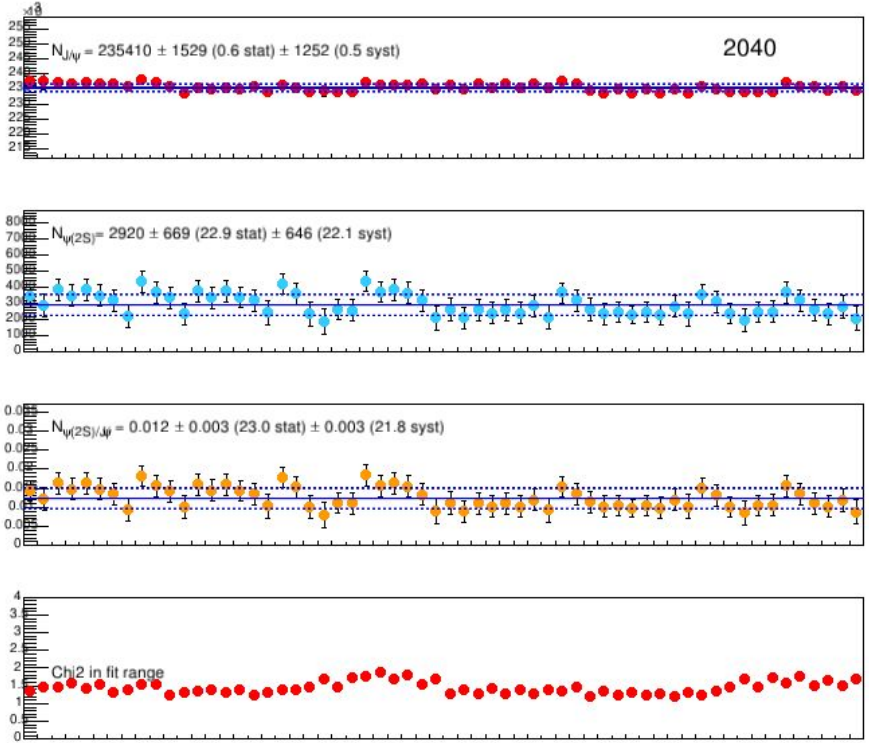
Chi2/ndf<2.5



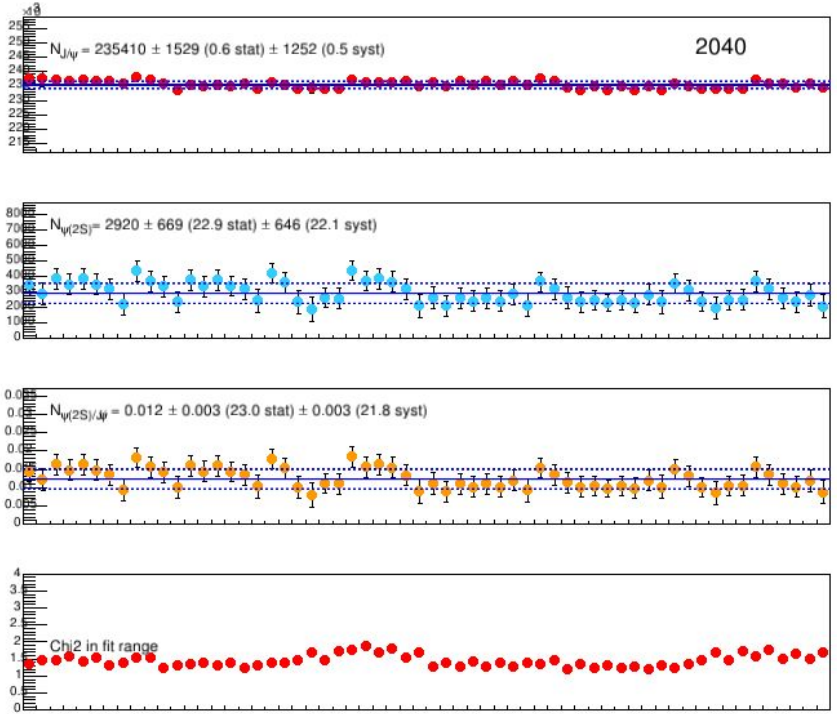
Chi2/ndf cut removes fits only in 0-90% and 0-20%

Signal extraction Ev. Mixing - 2040% - 60 tests

Chi2/ndf<2.5



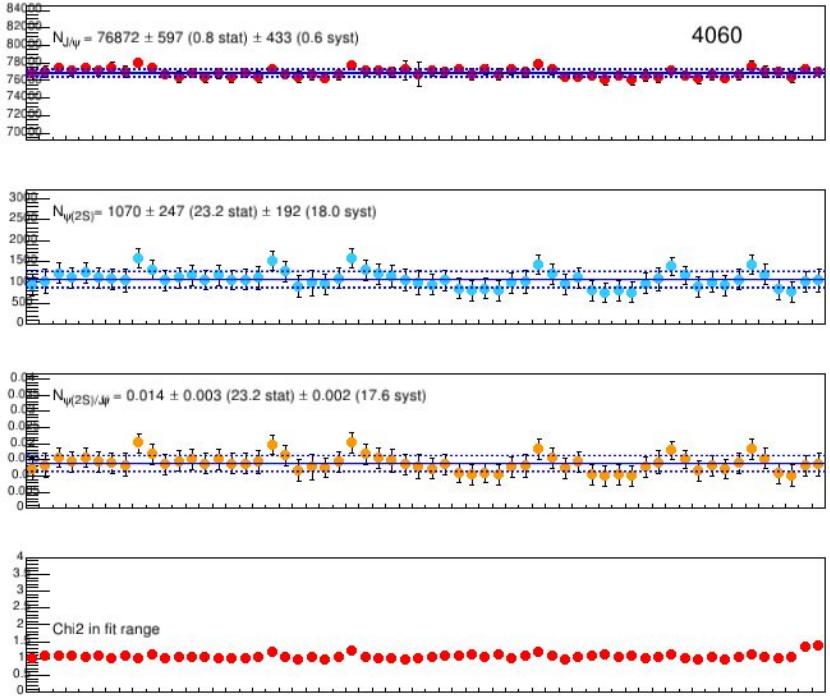
Chi2/ndf<3



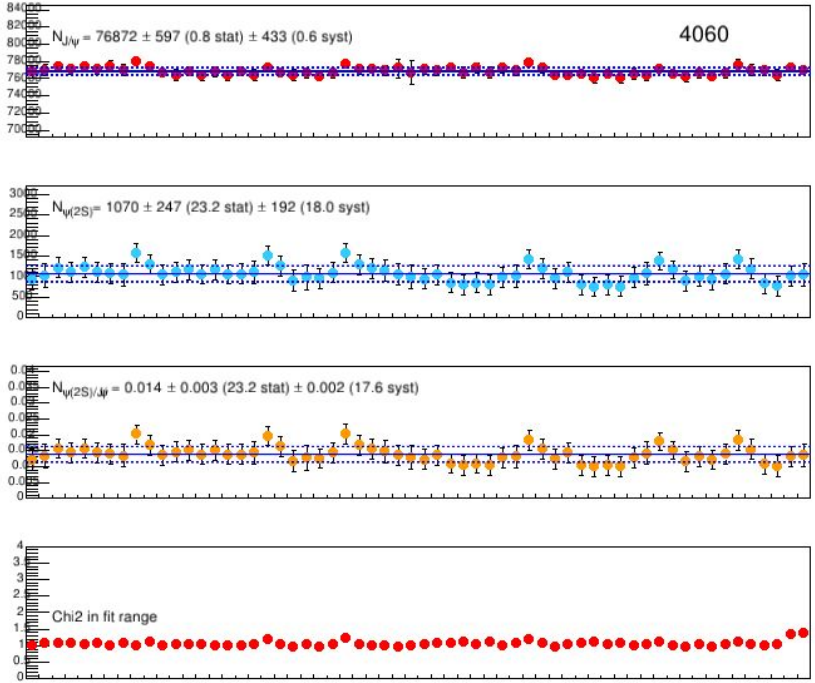
Chi2cut has no impact

Signal extraction Ev. Mixing - 4060% - 60 tests

Chi2/ndf<2.5



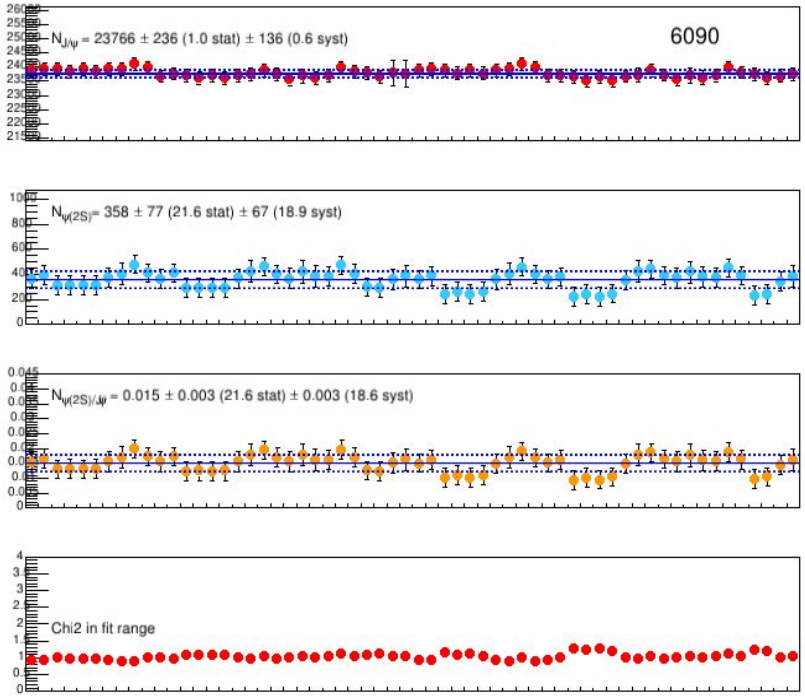
Chi2/ndf<3



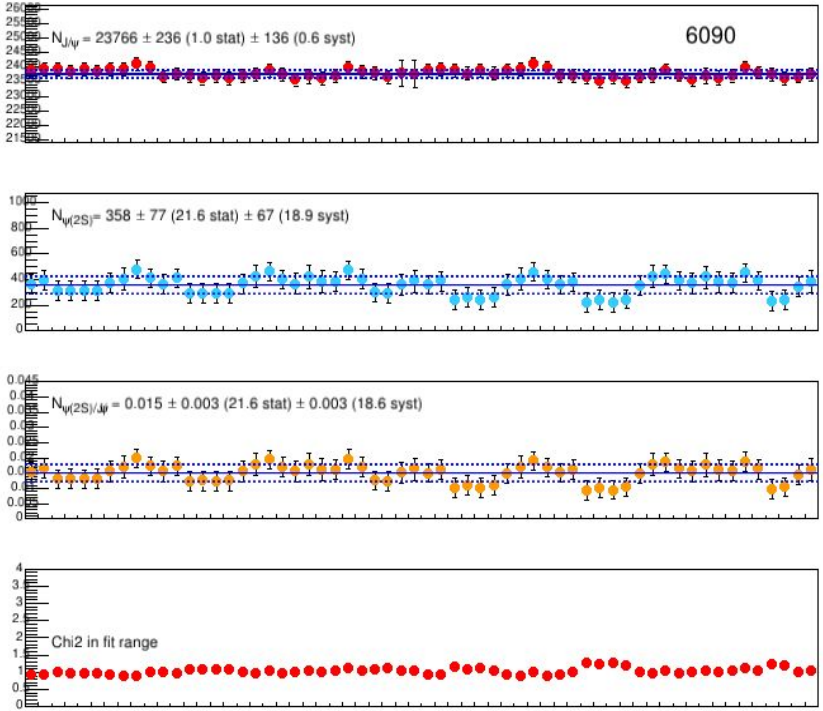
Chi2cut has no impact

Signal extraction Ev. Mixing - 6090% - 60 tests

Chi2/ndf<2.5



Chi2/ndf<3



Chi2cut has no impact

JPsi signal extraction: chi2 cut

%	Chi2/ndf < 3	Chi2/ndf < 2.5
0-90	920960 +- 3763 (0.4%) +- 7009 (0.8%)	924227+-3897(0.4%)+-6020(0.7%)
0-20	586632 +- 3516 (0.6%) +- 7652 (1.3%)	589946+-3606(0.6%)+-5565 (0.9%)
20-40	235410 +- 1529 (0.6%) +- 1252 (0.5%)	235410 +-1529(0.6%)+-1252 (0.5%)
40-60	76872 +- 597 (0.8%) +- 433 (0.6%)	76872+- 597 (0.8%) +- 433 (0.6%)
60-90	23766 +- 236 (1.0%) +- 136 (0.6%)	23766 +- 236 (1%) +- 136 (0.6%)

Sum 0-90%	922680 (<0.2% from integrated 0-90%)	925994 (<0.2% from integrated 0-90%)

Ev. mix. Norm in 2.5-7 + 2-8

- Differences always within the uncertainties
- Differences only in 0-90 and 0-20%

Psi(2S) signal extraction: chi2 cut

%	Chi2/ndf <3	Chi2/ndf <2.5
0-90	12215 +- 1679 (14%) +- 2322 (19%)	13165+-1695 (12.9%)+-2090 (15.9%)
0-20	8108 +- 1538 (19%) +- 2201 (27%)	8777 +- 1556 (18%) +- 1570 (23%)
20-40	2920 +- 669 (23%) +- 646 (22%)	2920+-669 (23%)+-646 (22%)
40-60	1070 +- 247 (23%) +- 192 (18%)	1070+-247 (23%)+-192 (18%)
60-90	358 +- 77 (22%) +- 67 (19%)	358 +- 77 (22%) +- 67 (19%)

Sum 0-90%	12456 (2% wrt integrated 0-90%)	13125 (0.3% wrt integrated 0-90%)

Ev. mix. Norm in 2.5-7 + 2-8

- Differences only in 090% and 020%
- Sum of bins closer to integrated value if chi2/ndf cut = 2.5

in the following:
- chi2/ndf cut = 2.5 applied
- ev. mix. norm in 2.5-7 + 2-8 GeV/c2

Signal extraction Ev. Mixing - pT bins

- 2 signal functions:
  - double CB or NA60
- 5 background functions
  - VWG, Pol2, 1Exp
- 2 fitting ranges:
  - 2-5, 2.2-4.5 GeV/c2
- 2 tails for CB2 function:
  - MC or pp@13TeV

18 tests

(x2 weight assigned to the NA60 functions, since only one set of tails was tested)

- Cut on chi2/ndf <2.5

For the moment:

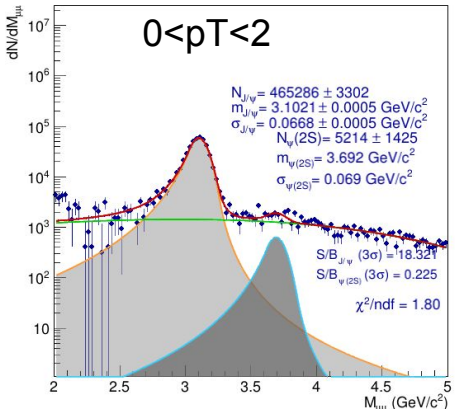
- same tails for all pt bins
- ev. mixing normalisation range only in 2-8 GeV/c2

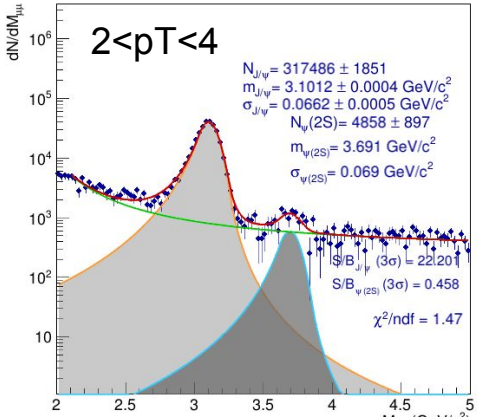
5 pT bins:

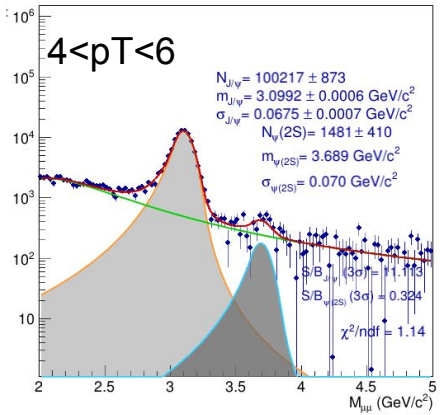
- 0-2
- 2-4
- 4-6
- 6-8
- 8-12

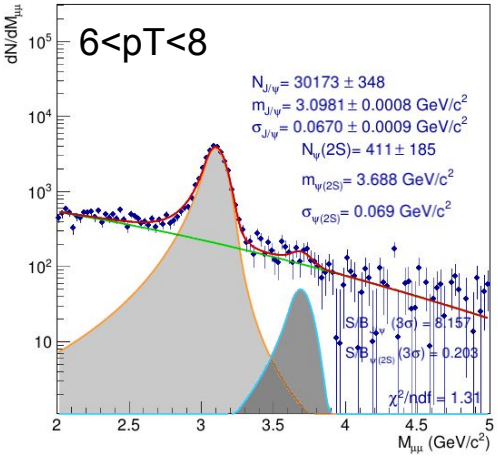
} can probably be merged

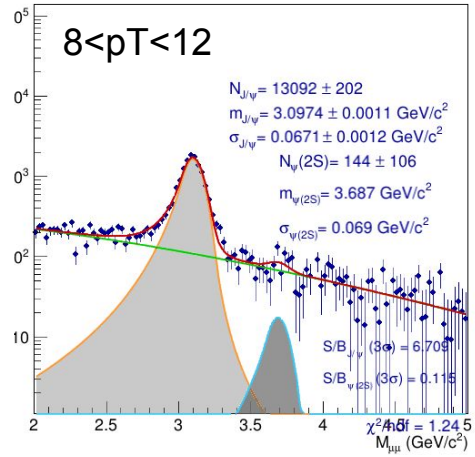
Examples of fits





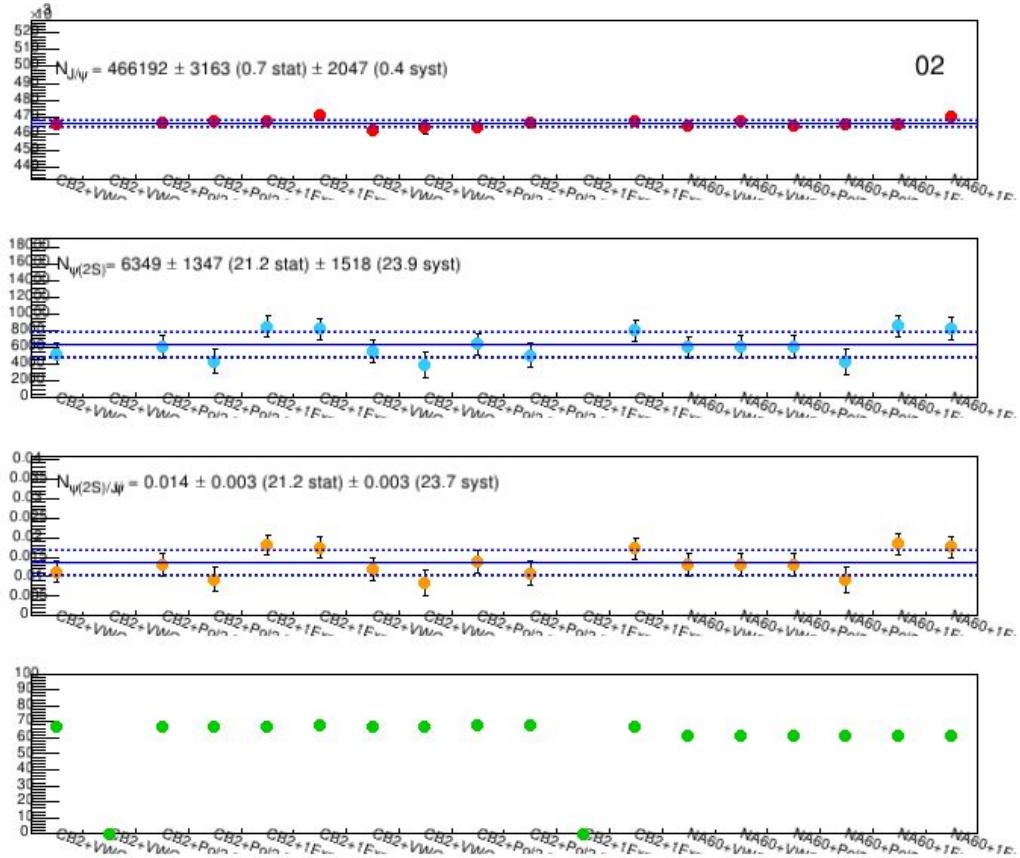


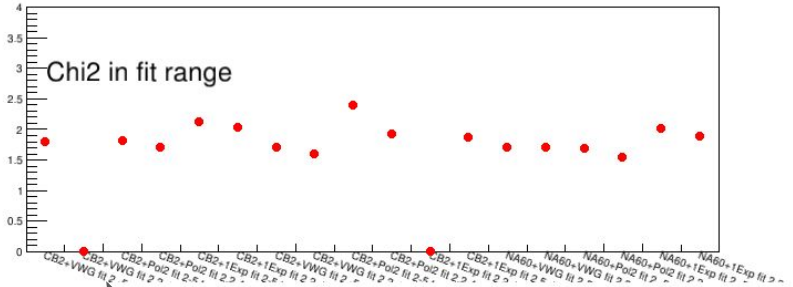




- CB2+ VWG
- 2<M<5
- MC tails
- Ev Mix norm 2-8

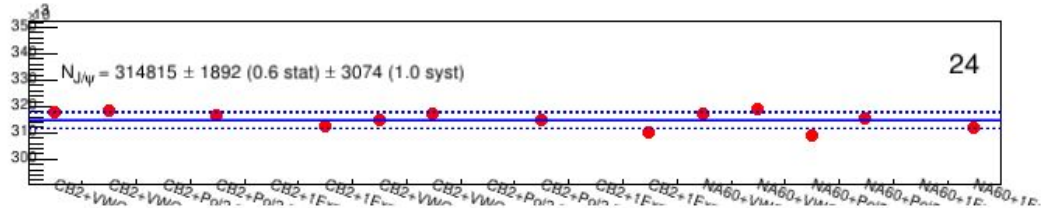
Signal extraction Ev. Mixing - 0<pT<2

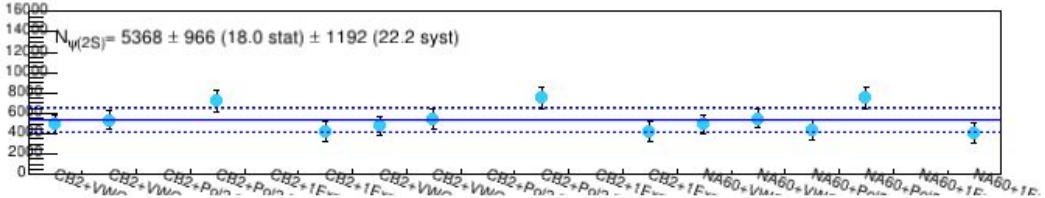


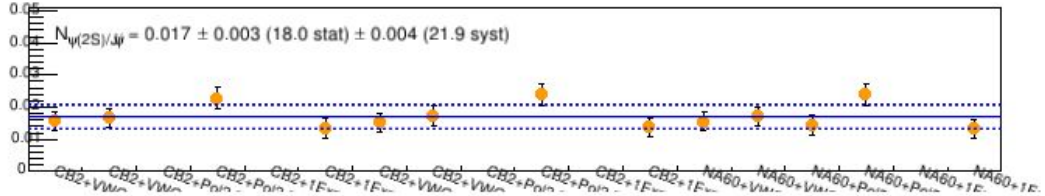


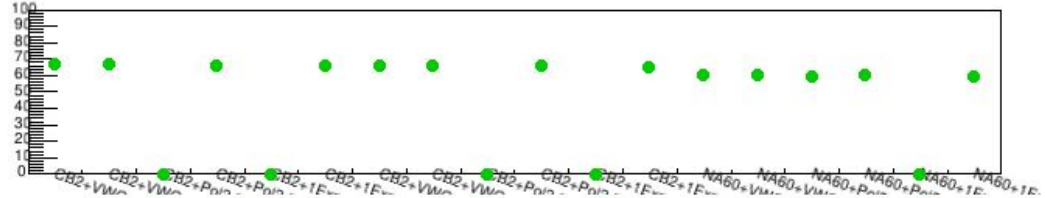
Chi2/ndf = 0 corresponds to those fits with chi2/ndf > 2.5

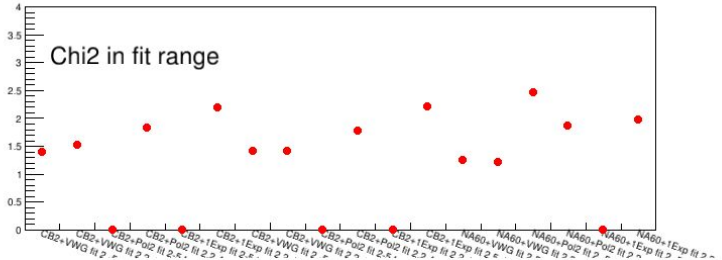
Signal extraction Ev. Mixing - 2<pT<4



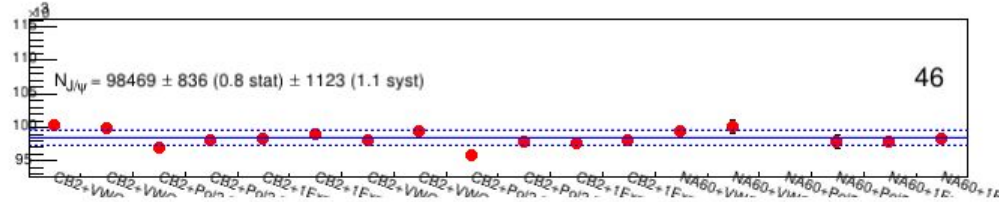


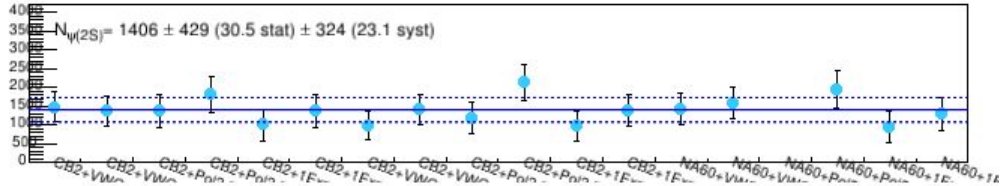


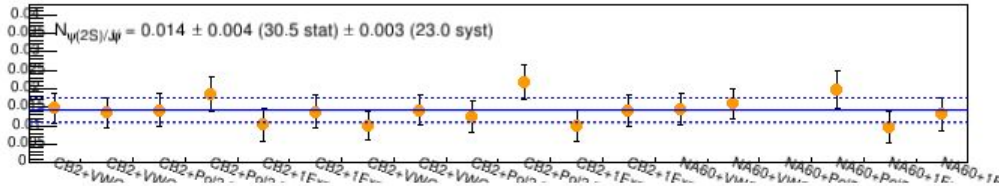


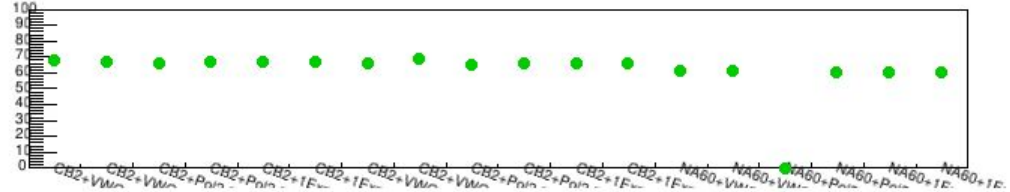


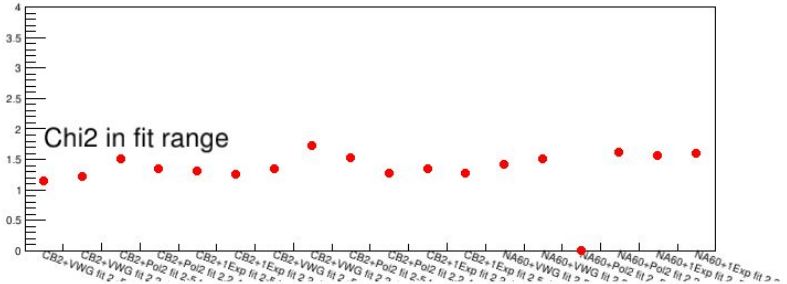
Signal extraction Ev. Mixing - 4<pT<6



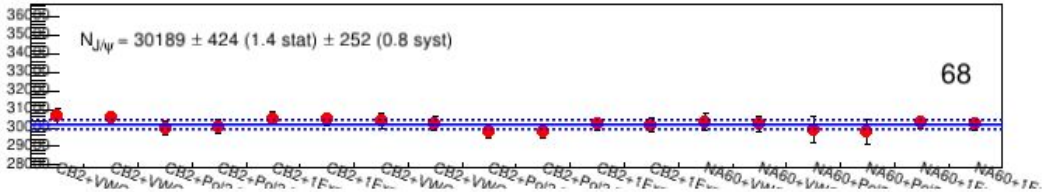


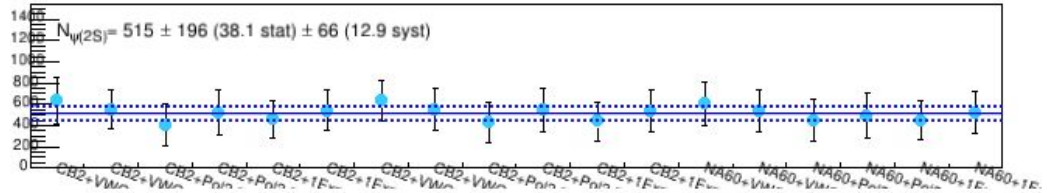


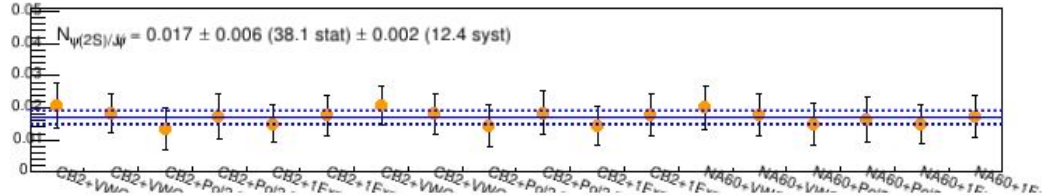


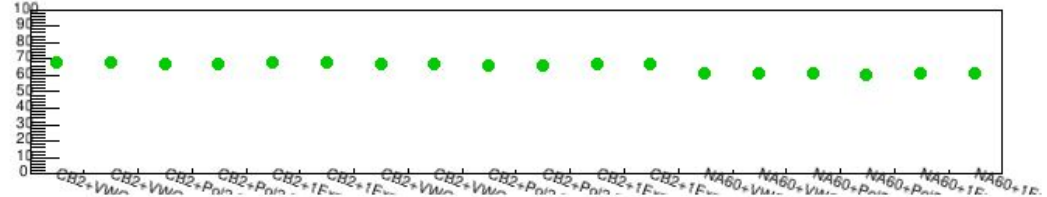


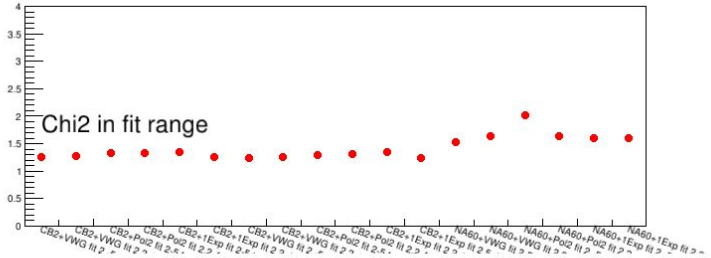
Signal extraction Ev. Mixing - 6<pT<8



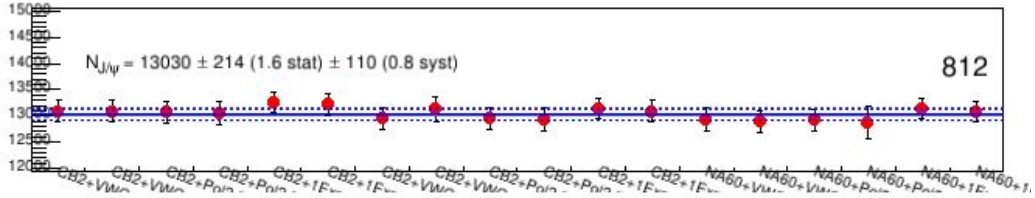


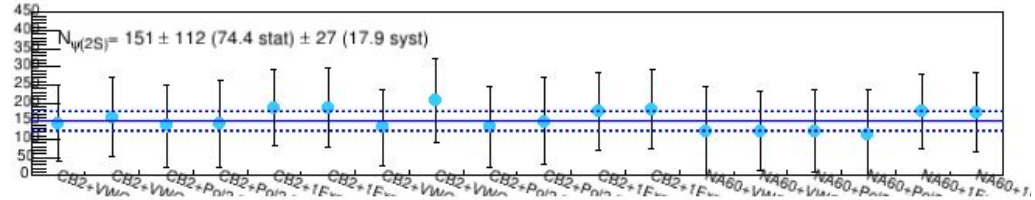


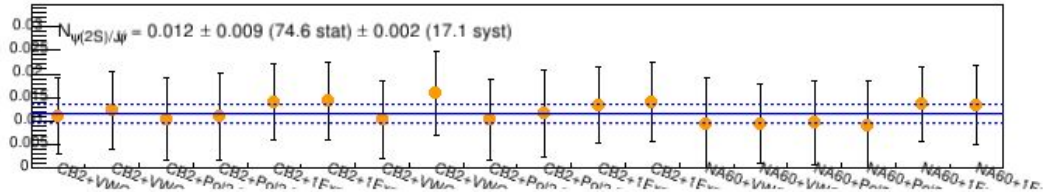


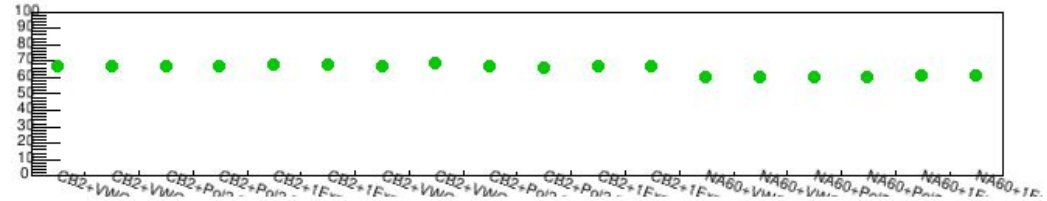


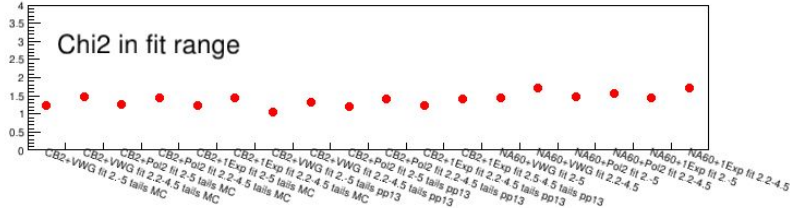
Signal extraction Ev. Mixing - 8<pT<12











Signal extraction JPsi and Psi2S vs pT

	JPsi	Psi2S
0-2	466192 +- 3163 (0.7%) +- 2047 (0.4%)	6349 +- 1347 (21%) +- 1518 (24%)
2-4	314815 +- 1892 (0.6%) +- 3074 (1%)	5368 +- 966 (18%) +- 1192 (22%)
4-6	98469 +- 836 (0.8%) +- 1123 (1.1%)	1406 +- 429 (30%) +- 324 (23%)
6-8	30189 +- 424 (1.4%) +- 252 (0.8%)	515 +- 196 (38%) +- 66 (13%)
8-12	13030 +- 214 (1.6%) +- 110 (0.8%)	151 +- 112 (74%) +- 27 (18%)

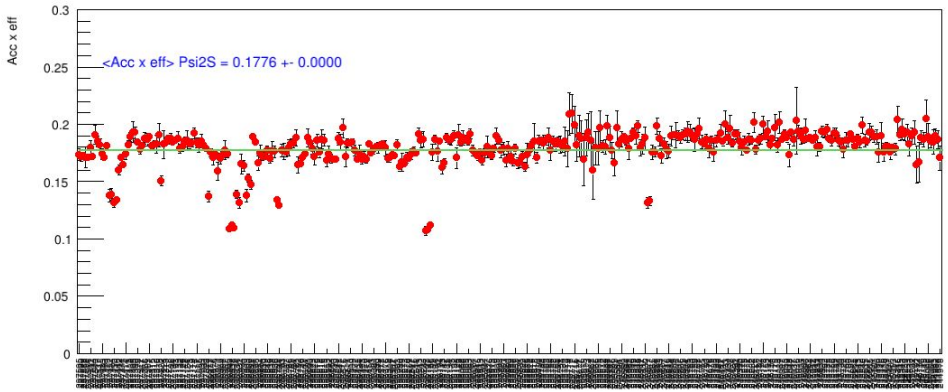
Sum (pt)	922695	13789
090%	923829 +- 3783 (0.4%) +- 6085 (0.7%)	13007 +- 1689 (12%) +- 2249 (17%)

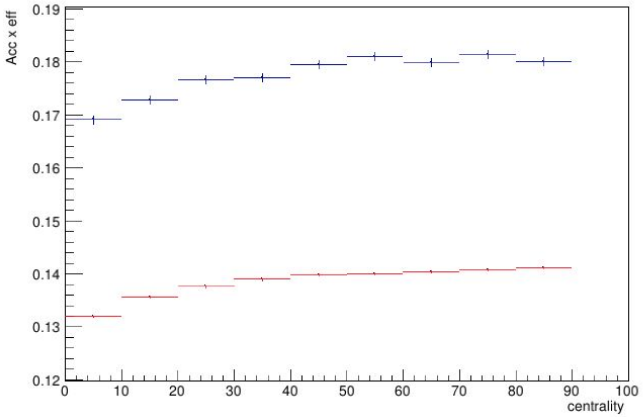
To do:

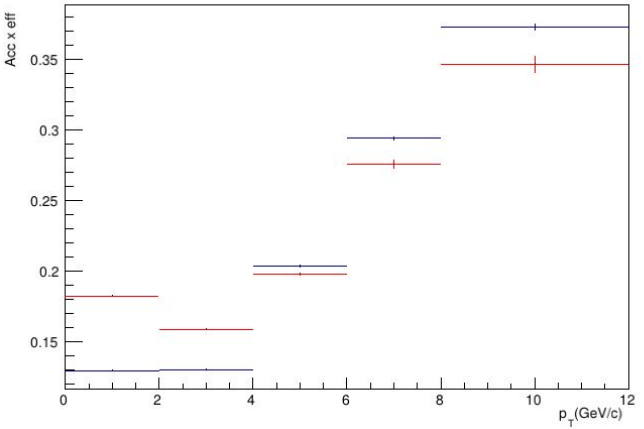
- Add alternative normalization range (no significant impact is expected)
- Merge last two pT bins

Acceptance x efficiency

Obtained from PbPb embedding MC (LHC16e2, LHC16e2_plus, LHC19a2)







embedding is done in CINT7 events
→ two weights are needed, to account for:

1) number of CMUL7 in each run
2) centrality dependence

Psi2S Acc x eff = 0.173
J/Psi Acc x eff = 0.135

(to be checked)

pp reference@5TeV

JPsi pp reference arXiv:2109.15240

2.5<y<4, pT<12GeV/c

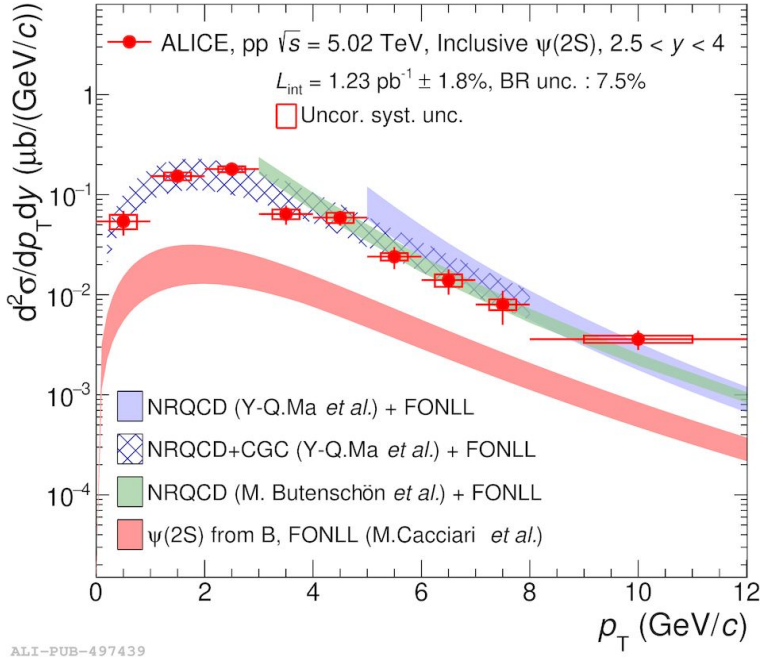
σ = 5.88 +- 0.03 +- 0.34 μb

Psi(2S) pp reference arXiv:2109.15240

2.5<y<4, pT<12GeV/c

σ = 0.87 +- 0.06 +- 0.10 μb

JPsi and Psi2S vs pT
→ cross sections in narrower bins have been combined



(I used number from the corresponding AN, to be checked)

Systematics vs centrality

So far based on

- PLB 766 (2017) 212 → 2015 analysis vs centrality and vs pT (in 0-90%)
- AN from Chun-Lu → 2015+2018, p_T analysis but in 0-20%
- Quantities tuned for this analysis

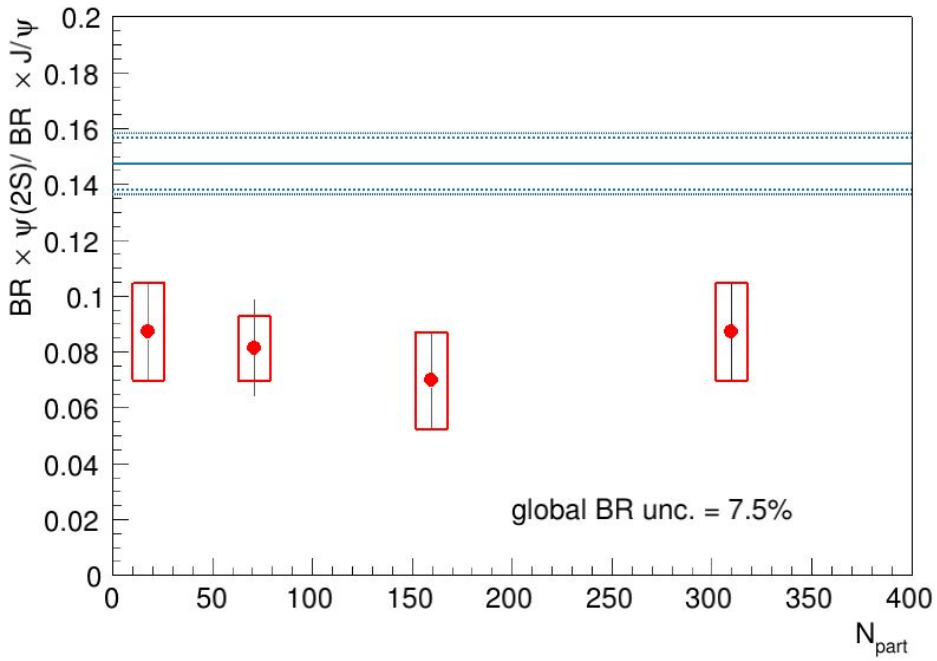
Systematics vs centrality

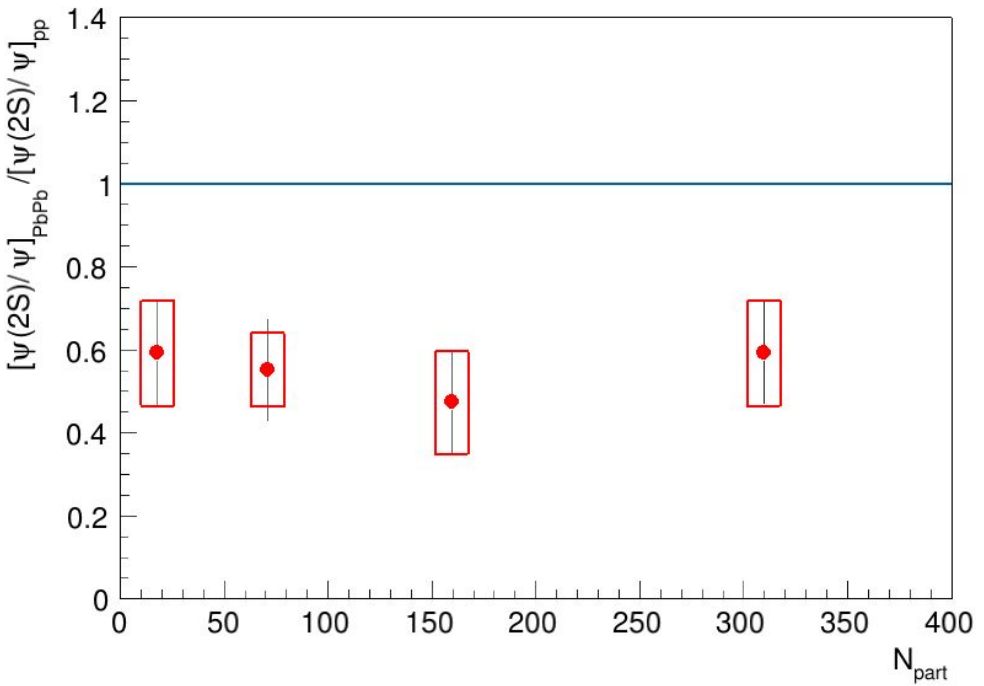
	J/Psi	Psi(2S)	
Signal extr.	0.5-0.9%	16-23%	this analysis (impact of σ ψ2S missing)
Tracking	3%	3%	PLB 766 (2017) 212 + AN
Trigger	3.6%	3.6%	PLB 766 (2017) 212 (slightly less in AN)
Matching	1%	1%	PLB 766 (2017) 212 + AN
MC input	2%	2%	PLB 766 (2017) 212, use same as J/Psi
FNorm	0.7%	0.7%	AN
TAA	1-2%	1-2%	ALICE-PUBLIC-2018-011 (approx values)
Centrality	0-3.2%	0-3.2%	Computed on JPsi, in ad hoc bins, as in PLB 766 (2017) 212,
pp reference	5.8% (syst) 0.5% (stat)	11% (syst) 7% (stat)	arXiv:2109.15240 (stat+syst)

Systematics vs pT

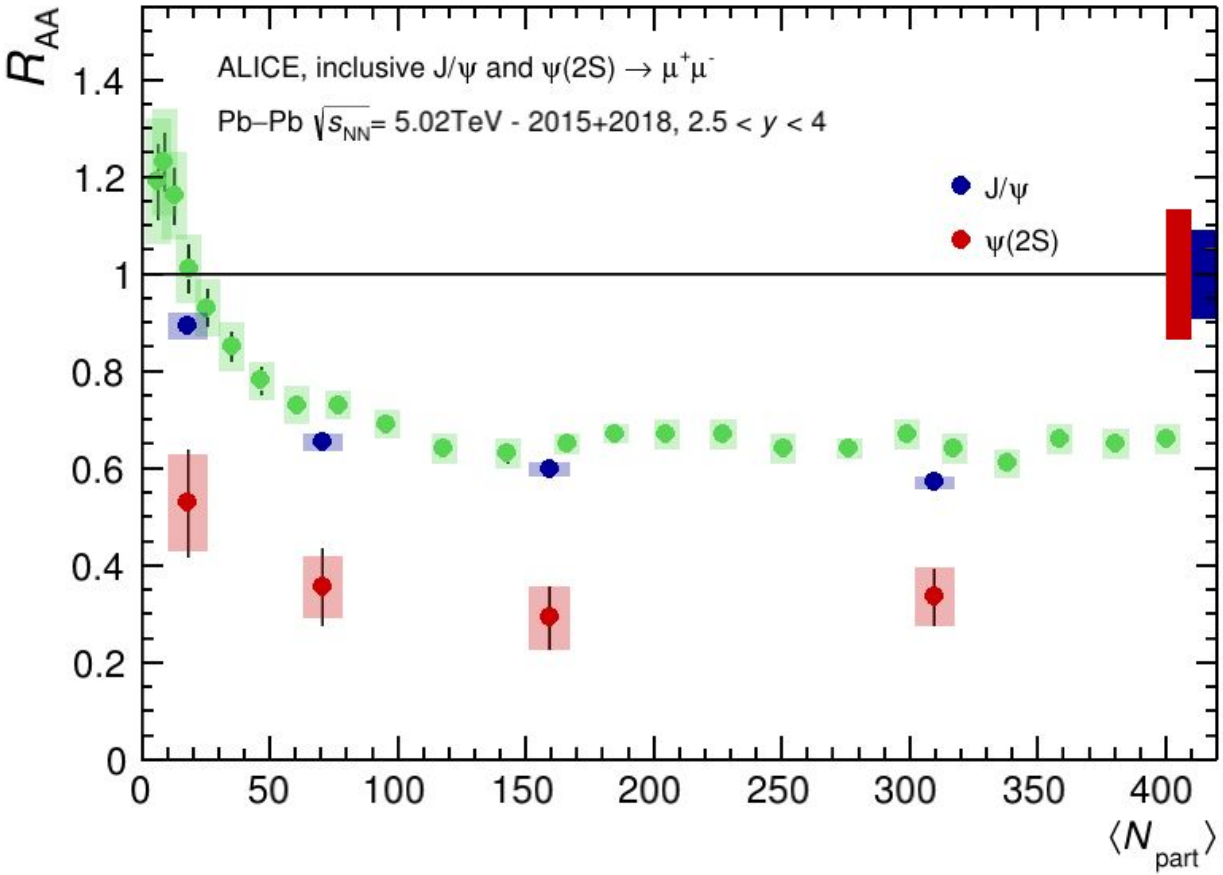
	J/Psi	Psi(2S)	
Signal extr.	0.4-1.1%	13-24%	this analysis (impact of σ ψ2S missing)
Tracking	3%	3%	PLB 766 (2017) 212 and AN (3%+1%)
Trigger	3.3+1%	3.3+1%	AN, assuming 0-20% values
Matching	1%	1%	PLB 766 (2017) 212 + AN
MC input	3.5%	3.5%	AN, assuming 0-20% value, use same as J/Psi
FNorm	0.7%	0.7%	AN
TAA	3.2%	3.2%	ALICE-PUBLIC-2018-011 (approx)
pp reference	0.8-3.8 (stat+syst)	6.6-13.1 (stat+syst)	arXiv:2109.15240 (stat+syst)

Psi2S/Psi and double ratio



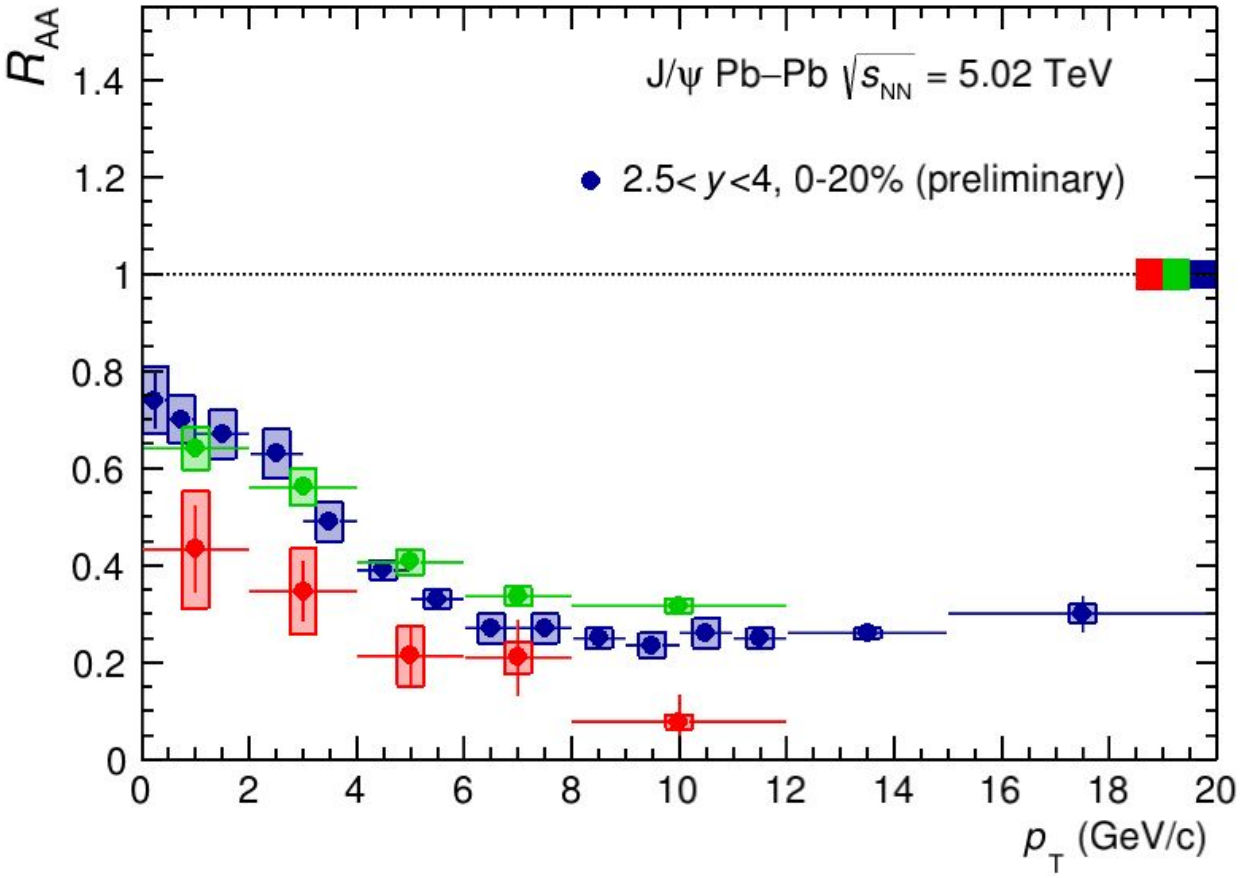


RAA vs centrality



JPsi new ref. 5% higher

RAA vs pT

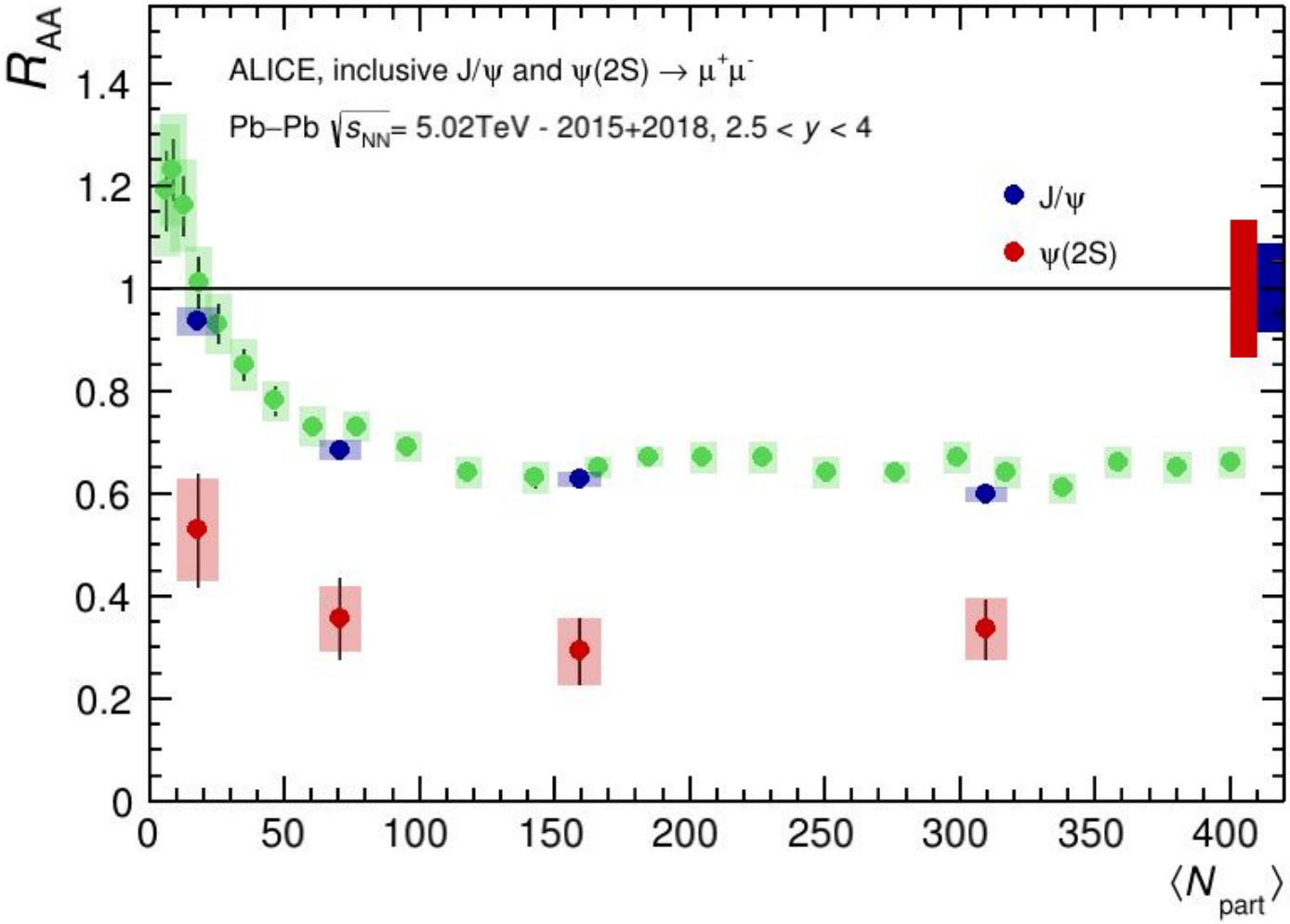


- JPsi preliminary results are in 0-20%
- Psi2S R_{AA} might also be computed in 0-20%
- Merge 2 last bins

To do

- Finalise signal extraction in pT bins
- Finalise all remaining quantities
- Paper proposal?

Backup slides


R_{AA}
ALICE, inclusive J/ψ and ψ(2S) → μ⁺μ⁻
Pb–Pb $\sqrt{s_{NN}}$= 5.02TeV - 2015+2018, 2.5 < y < 4
J/ψ
ψ(2S)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
400
⟨N_{part}⟩

Old pp ref