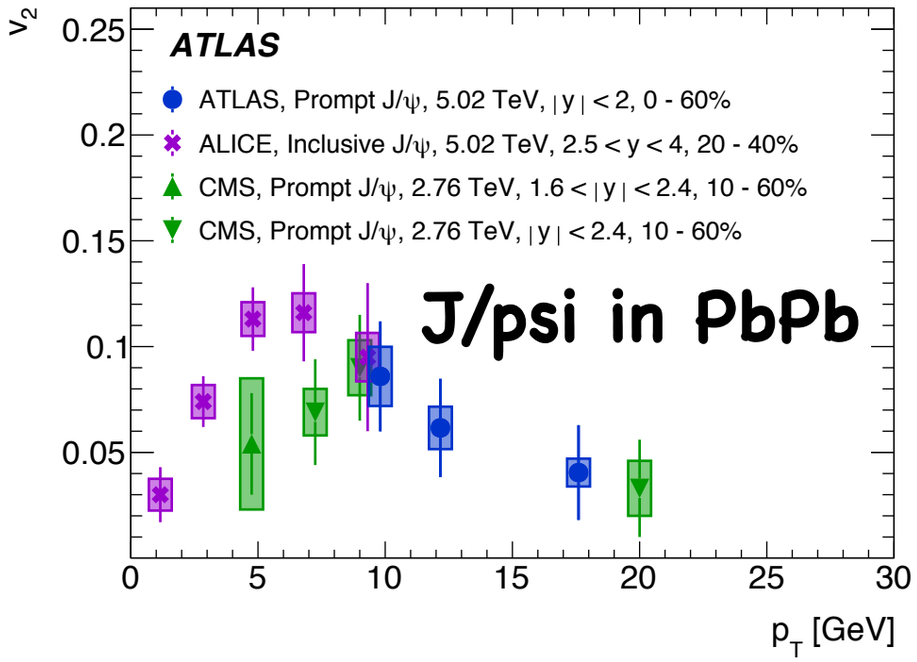
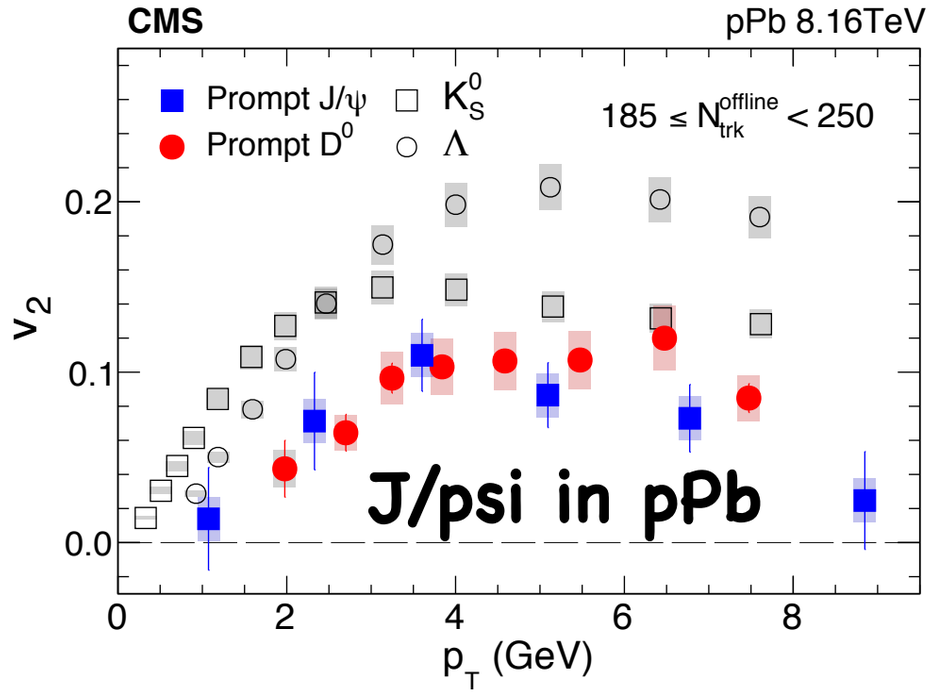
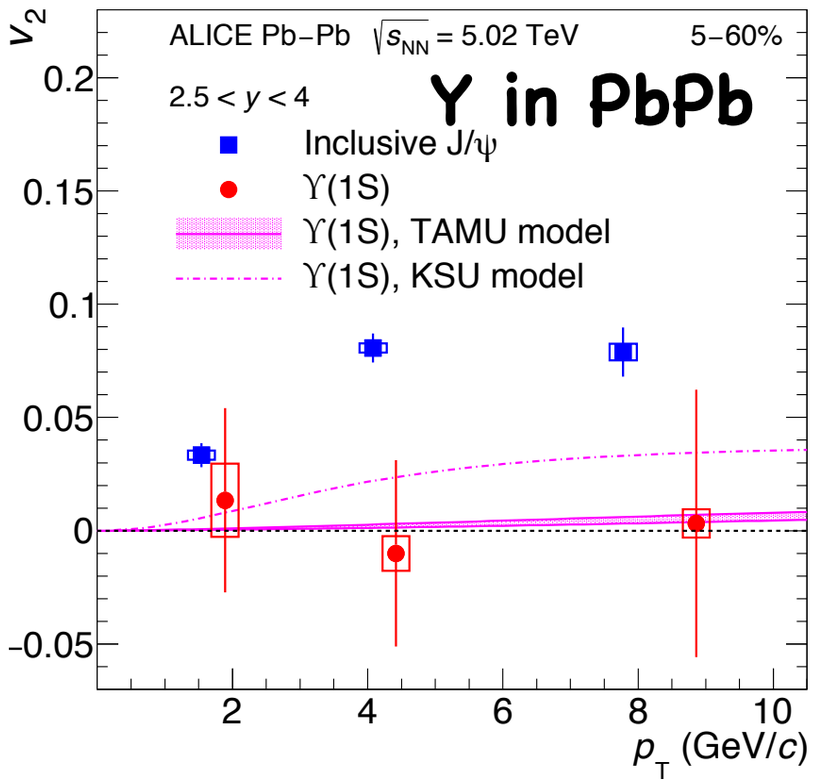
Quarkonium v_2 in LHC



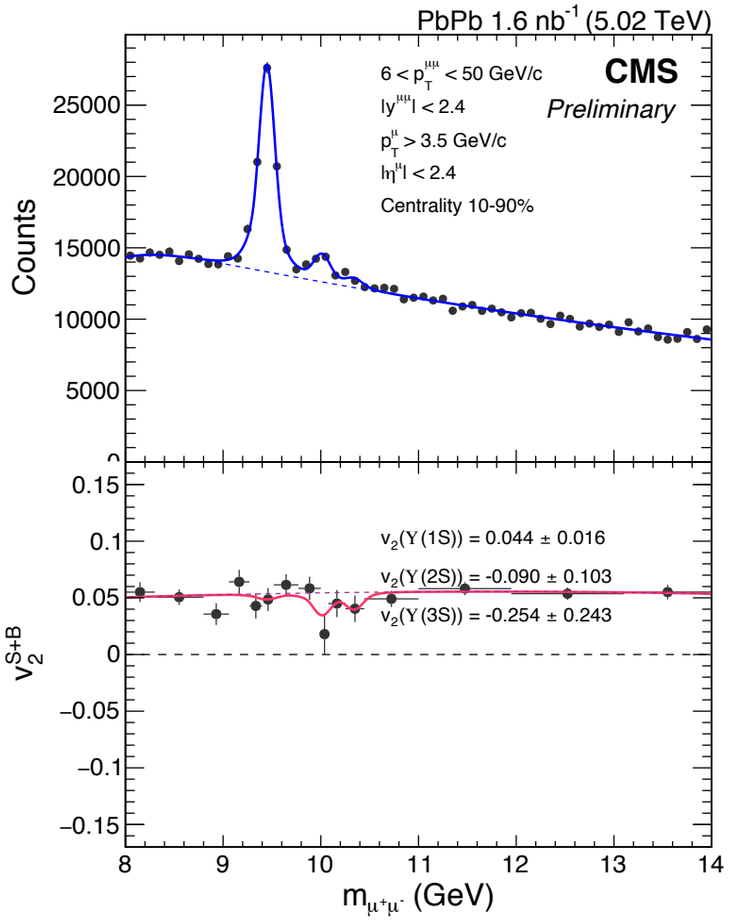




Scalar product method

$$v_2\{SP\} = \frac{\langle Q_2 Q_{2A}^* \rangle}{\sqrt{\frac{\langle Q_{2A} Q_{2B}^* \rangle \langle Q_{2A} Q_{2C}^* \rangle}{\langle Q_{2B} Q_{2C}^* \rangle}}}$$

- **Q_2 : Dimuon**
- **Q_A : opposite side HF**
- **Q_B : same side HF**
- **Q_C : tracks in $|\eta| < 0.75$**



$$v_2^{Sig+Bkg}(m_{\mu^+\mu^-}) = \alpha_1(m_{\mu^+\mu^-}) \bullet v_2^{Sig(1S)} + \alpha_2(m_{\mu^+\mu^-}) \bullet v_2^{Sig(2S)} + \alpha_3(m_{\mu^+\mu^-}) \bullet v_2^{Sig(3S)} + (1 - \alpha(m_{\mu^+\mu^-})) \bullet v_2^{Bkg}(m_{\mu^+\mu^-})$$

$$\alpha_1(m_{\mu^+\mu^-}) = \frac{S_1(m_{\mu^+\mu^-})}{S_1(m_{\mu^+\mu^-}) + S_2(m_{\mu^+\mu^-}) + S_3(m_{\mu^+\mu^-}) + B(m_{\mu^+\mu^-})}$$

$$\alpha_2(m_{\mu^+\mu^-}) = \frac{S_2(m_{\mu^+\mu^-})}{S_1(m_{\mu^+\mu^-}) + S_2(m_{\mu^+\mu^-}) + S_3(m_{\mu^+\mu^-}) + B(m_{\mu^+\mu^-})}$$

$$\alpha_3(m_{\mu^+\mu^-}) = \frac{S_3(m_{\mu^+\mu^-})}{S_1(m_{\mu^+\mu^-}) + S_2(m_{\mu^+\mu^-}) + S_3(m_{\mu^+\mu^-}) + B(m_{\mu^+\mu^-})}$$

$$\alpha(m_{\mu^+\mu^-}) = \frac{S_1(m_{\mu^+\mu^-}) + S_2(m_{\mu^+\mu^-}) + S_3(m_{\mu^+\mu^-})}{S_1(m_{\mu^+\mu^-}) + S_2(m_{\mu^+\mu^-}) + S_3(m_{\mu^+\mu^-}) + B(m_{\mu^+\mu^-})}$$

Analysis flow chart

1. Reweighting

DATA

MC

All param. free fit

Dimuon Counts

Ratio of dN/dpT b/w data & MC
(Raw yield / T&P corrected MC)

T&P

2. Correction Factor

MC → Acceptance x Efficiency

3. Signal parameter

DATA

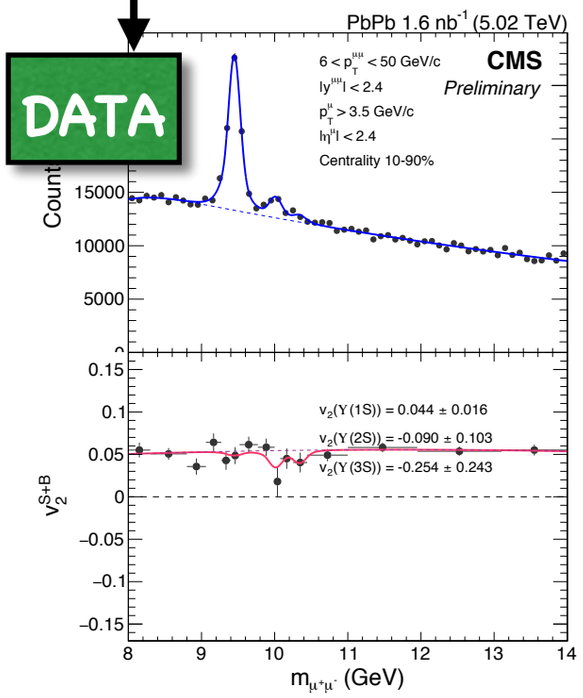
Inv. Mass Fit
- Cent. 0-90%
- Each p_T bin

- Fix Signal Parameter
- Initial seed bkg parm.

Simultaneous Fit

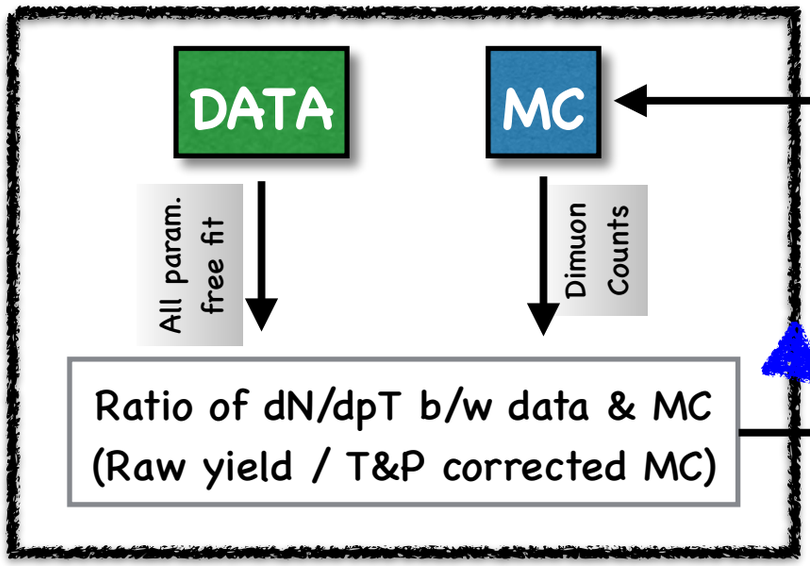
4. v_2 extraction

DATA



Systematic Uncertainty

1. Reweighting



1&2. dN/dpT reweighting

- Nominal : Acceptance (O) & Efficiency (O)
- Acceptance syst : Acceptance (X) & Efficiency (O)
- Efficiency syst : Acceptance (O) & Efficiency (X)

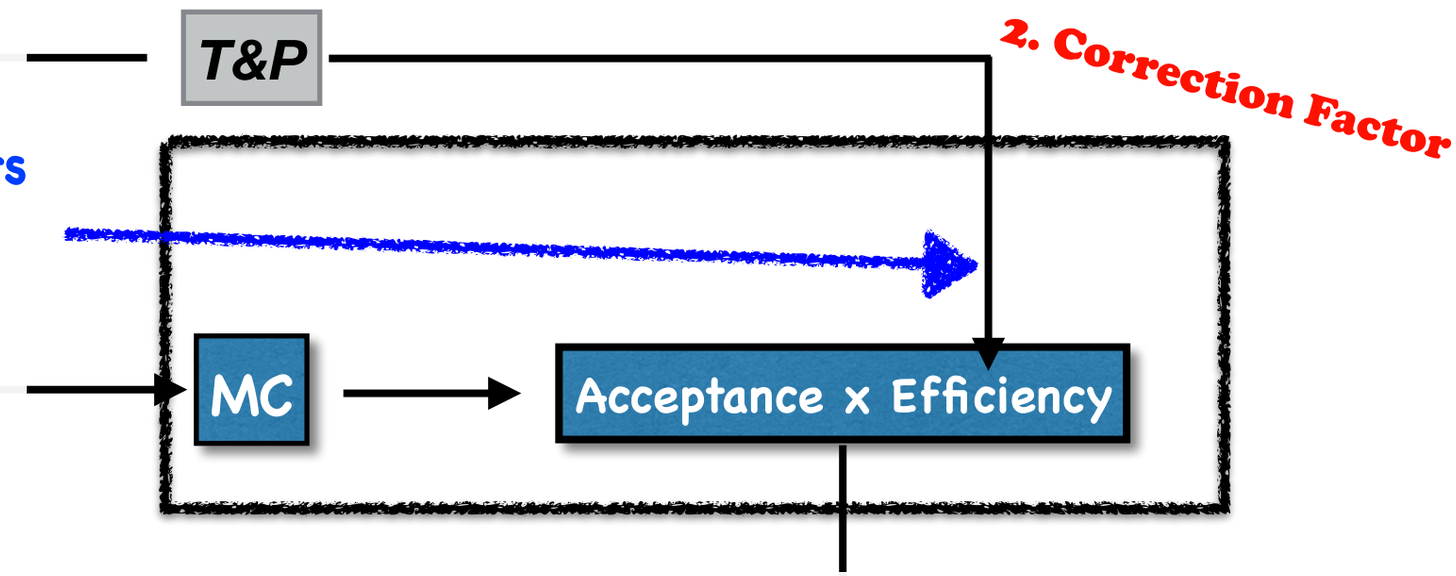
3. Signal parameter

4. v_2 extraction

Systematic Uncertainty

3. T&P correction

- Nominal : Acc x Eff w T&P scale factors
- T&P sys : T&P sys up/down
- T&P stat : T&P stat up/down
- ➡ Take max. dev. for sys/stat variation
- ➡ Quadrature sum for sys & stat



Systematic Uncertainty

4. Signal PDF Variation
- Nominal : Double CB function
- Alternative : CB + Gaus

5. Background PDF Variation
- Nominal : Erf x Exp
- Alternative : 4th order cheb. pol.

6. Signal Parameter
- Nominal : Fix signal parm.
- Alternative : Release one by one

➡ Take Max. Dev. as syst. unc.

3. Signal parameter

DATA

Inv. Mass Fit
- Cent. 0-90%
- Each p_T bin

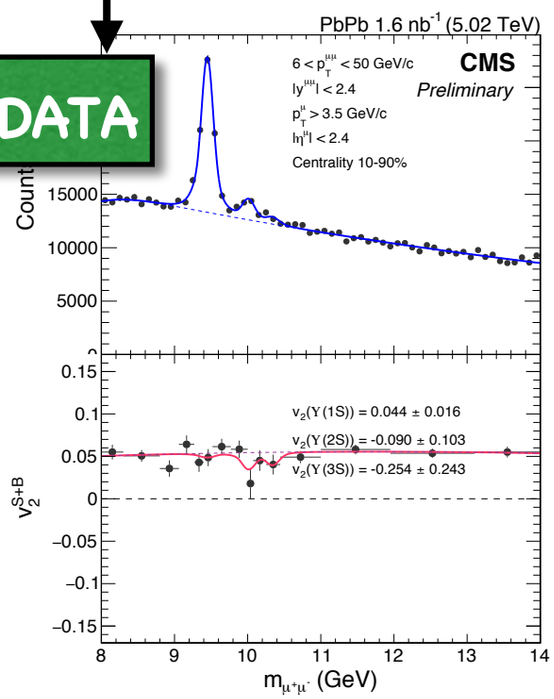
- Fix Signal Parameter
- Initial seed bkg parm.

7. v_2 bkg function
- Nominal : 2nd order poly.
- Alternative : 3rd order poly.

Simultaneous Fit

4. v_2 extraction

DATA

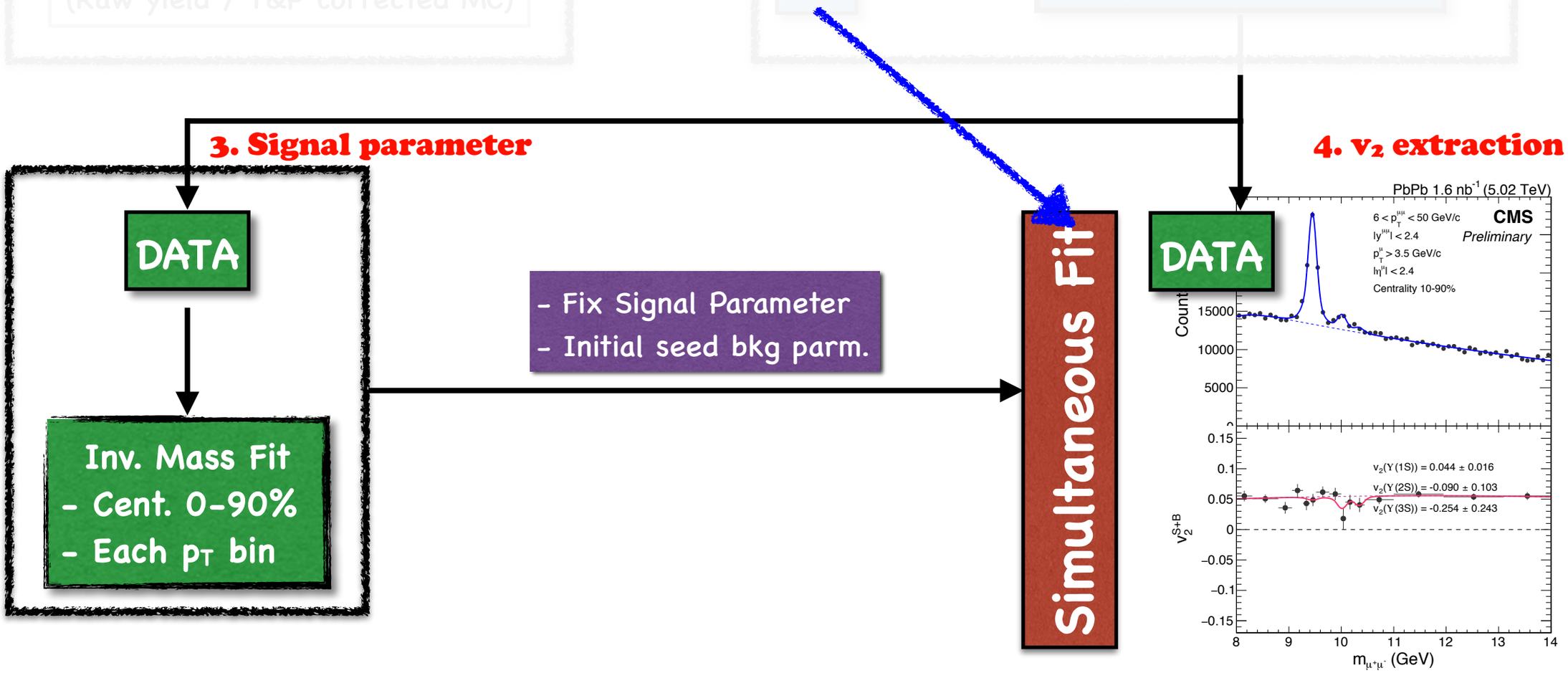


Systematic Uncertainty

8. Event Selection

- Nominal : Centrality table with nominal HF bin edge
- Alternative : Centrality table with HF up/down variation

➡ Maximum deviation is quoted as systematic uncertainty

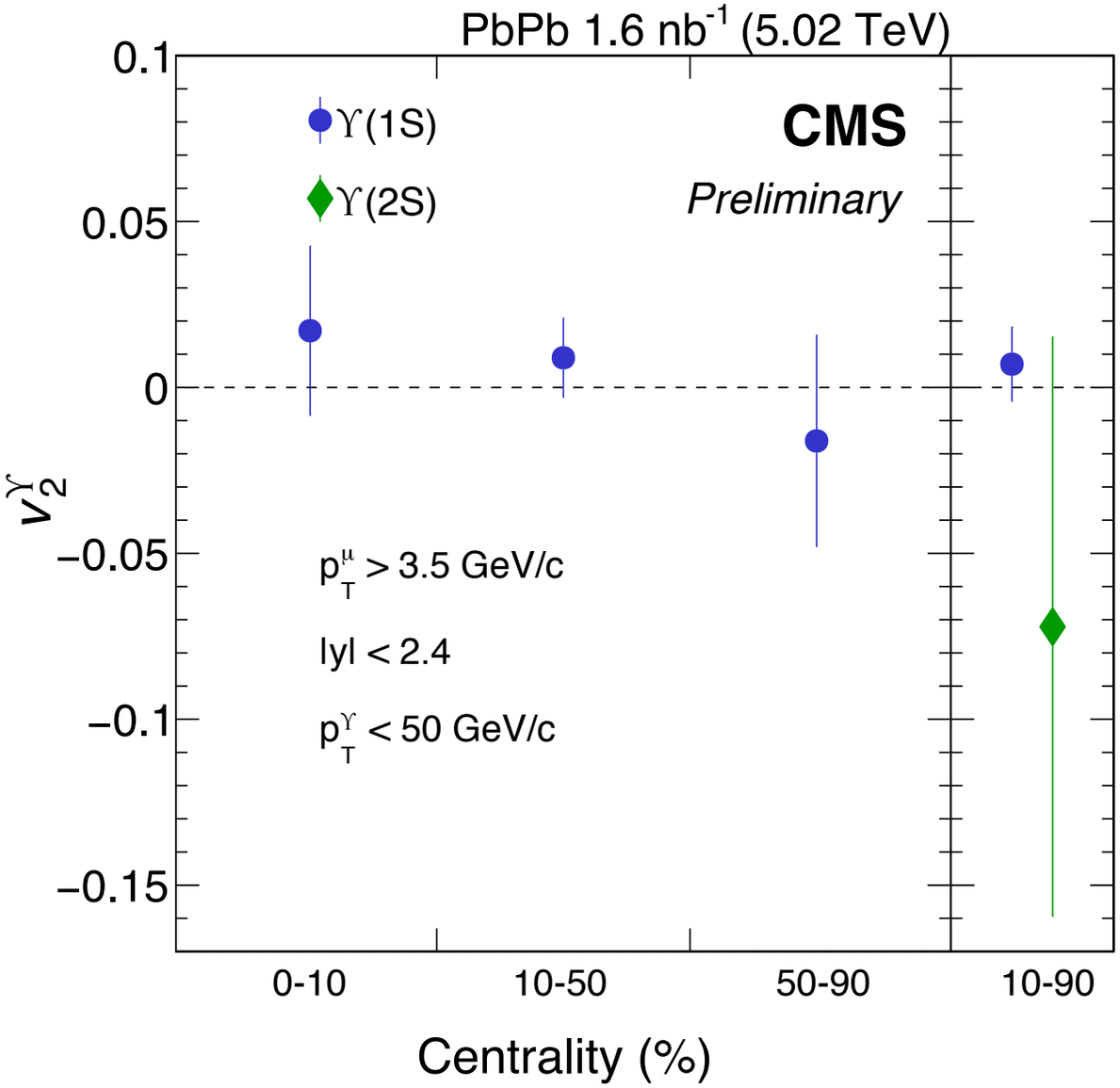


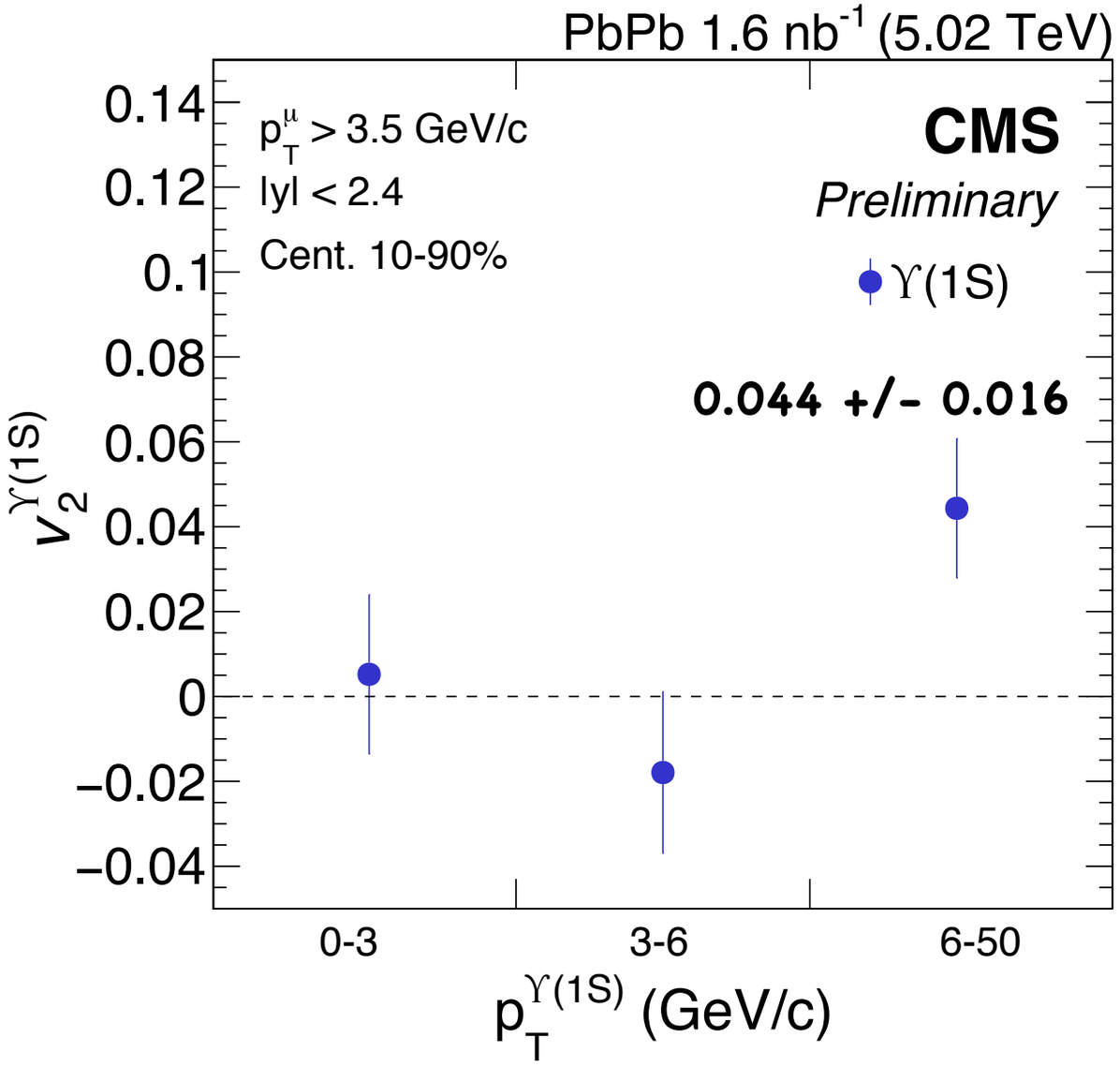
Status

- **p_T reweighing (Done)**
- **Correction Factors for Acc x Eff (Done)**
- **Inv. Mass Fit to obtain signal parameters (Done)**
- **Nominal Result (Done)**

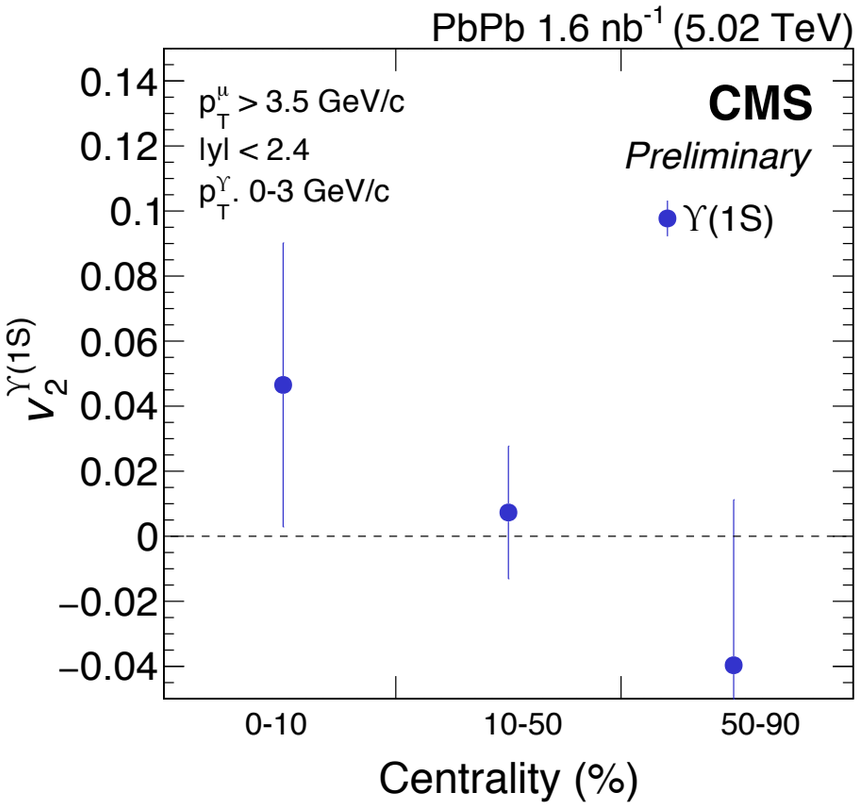
- **Systematics (OnGoing)**
  1. **Acceptance**
  2. **Efficiency**
  3. **T&P**
  4. **Signal PDF variation**
  5. **Background PDF variation**
  6. **Signal parameter release**
  7. **v_2 background function**
  8. **Event selection**

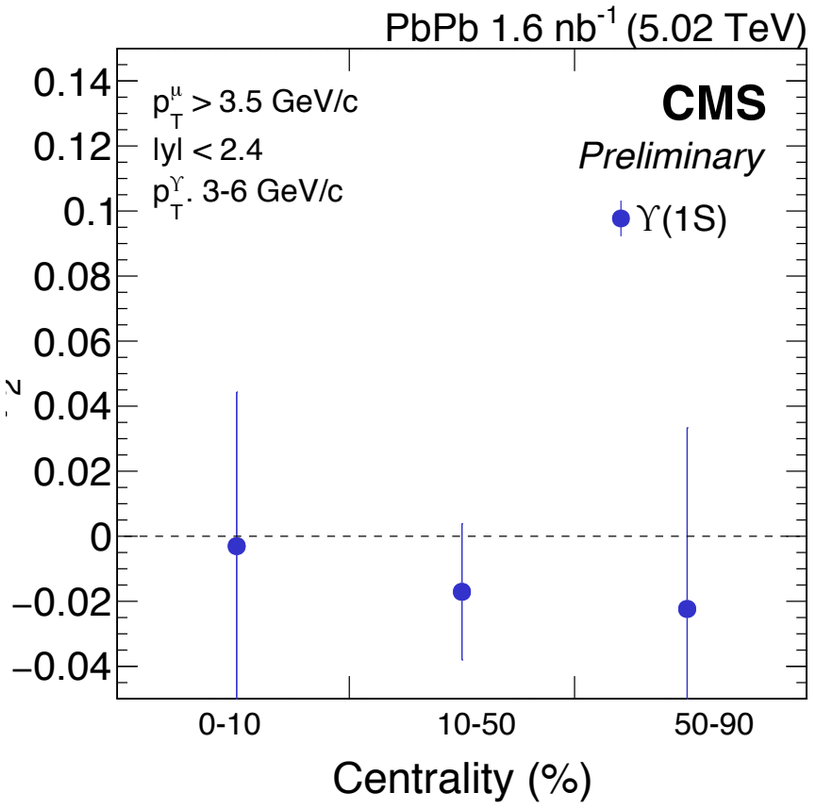
Results

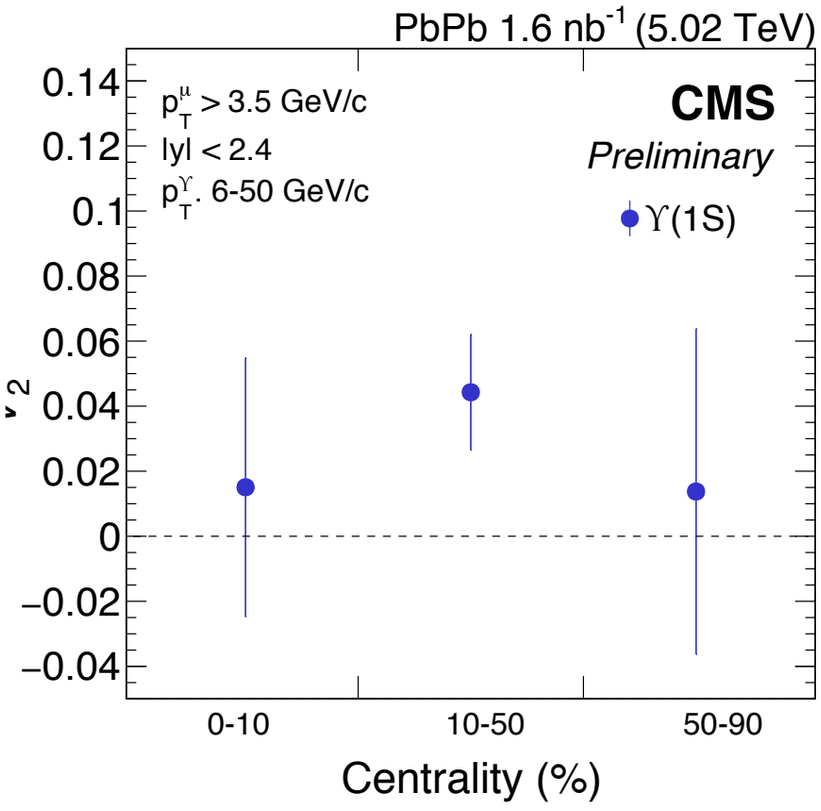

PbPb 1.6 nb^{-1} (5.02 TeV)
CMS
Preliminary
Υ(1S)
Υ(2S)
$p_T^{\mu} > 3.5$ GeV/c
|y| < 2.4
$p_T^{\Upsilon} < 50$ GeV/c
v_2^{Υ}
0.1
0.05
0
−0.05
−0.1
−0.15
0-10
10-50
50-90
10-90
Centrality (%)


PbPb 1.6 nb^{-1} (5.02 TeV)
CMS
Preliminary
$p_T^{\mu} > 3.5$ GeV/c
|y| < 2.4
Cent. 10-90%
Υ(1S)
0.044 +/- 0.016
$v_2^{\Upsilon(1S)}$
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
0-3
3-6
6-50
$p_T^{\Upsilon(1S)}$ (GeV/c)

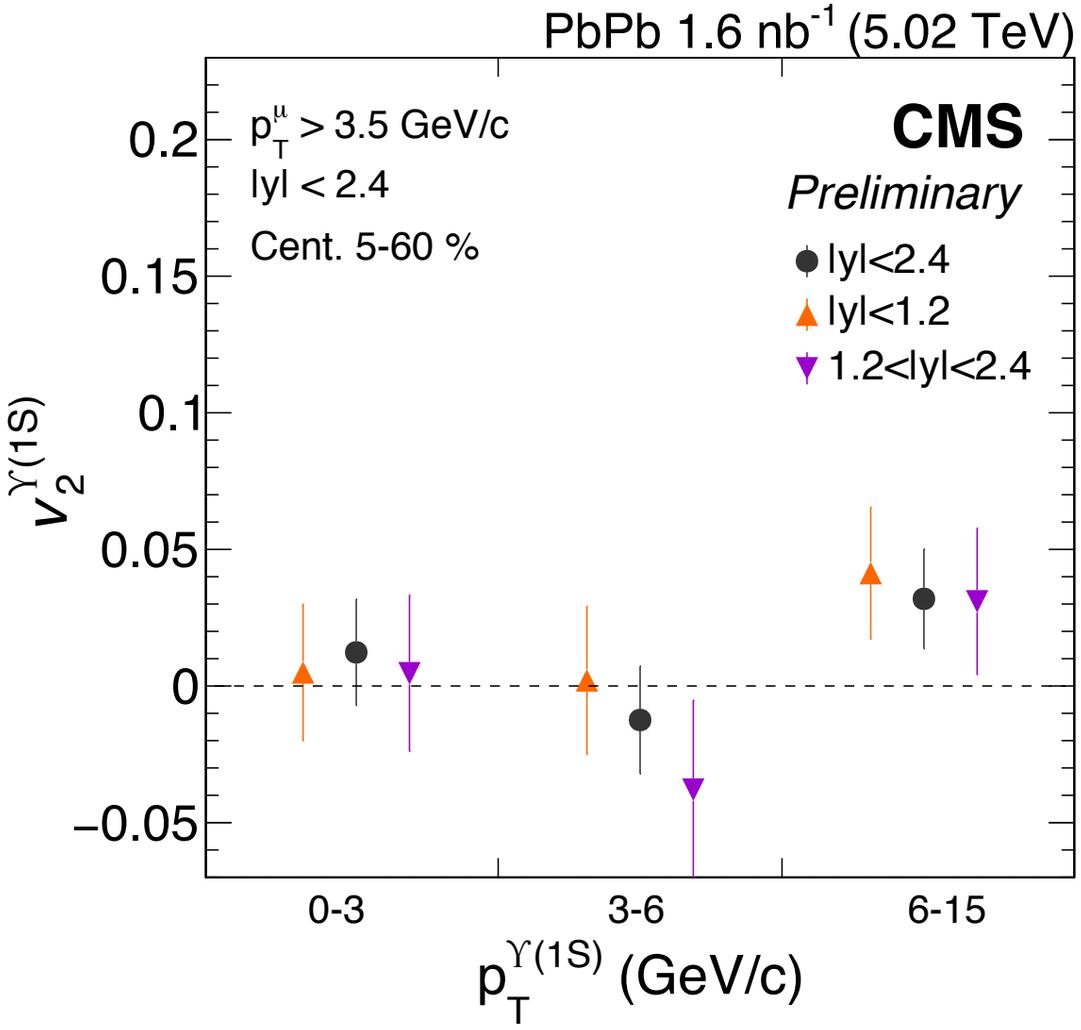
Results

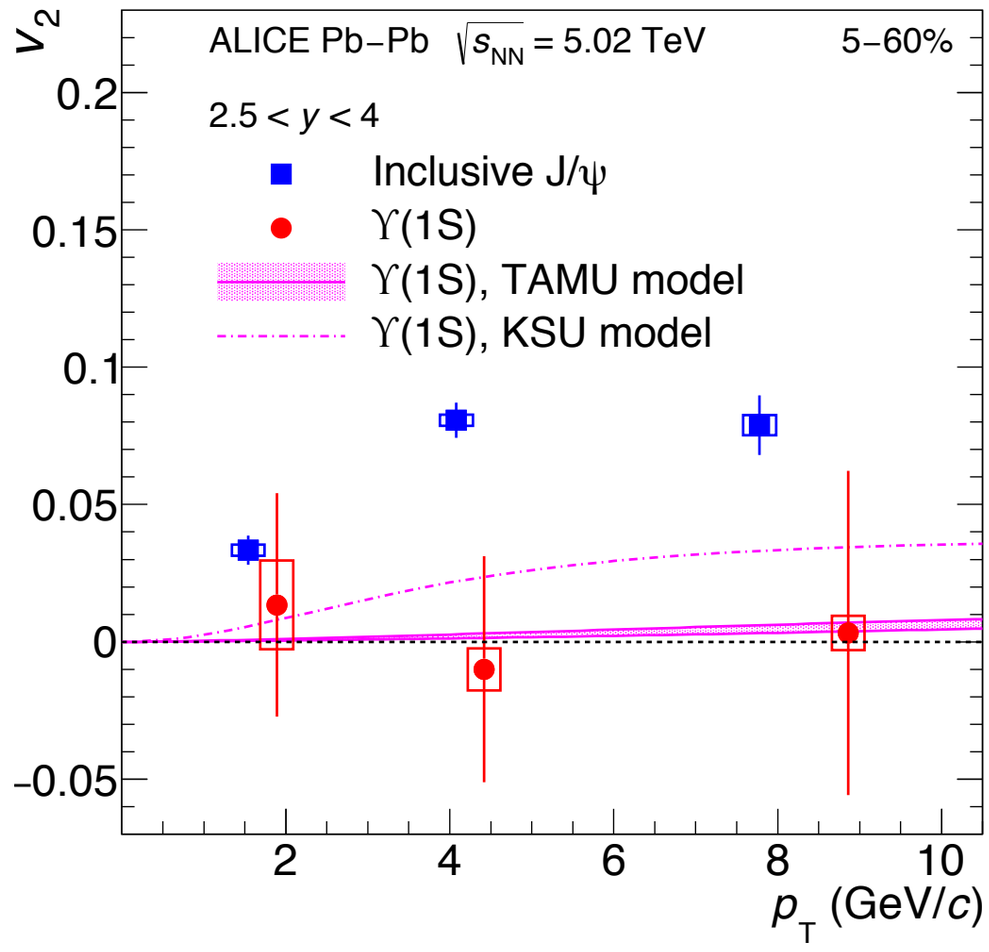

PbPb 1.6 nb^{-1} (5.02 TeV)
p_T^μ > 3.5 GeV/c
|y| < 2.4
p_T^Υ. 0-3 GeV/c
CMS
Preliminary
Υ(1S)
$v_2^{\Upsilon(1S)}$
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
0-10
10-50
50-90
Centrality (%)


PbPb 1.6 nb^{-1} (5.02 TeV)
p_T^μ > 3.5 GeV/c
|y| < 2.4
p_T^Υ. 3-6 GeV/c
CMS
Preliminary
Υ(1S)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
0-10
10-50
50-90
Centrality (%)

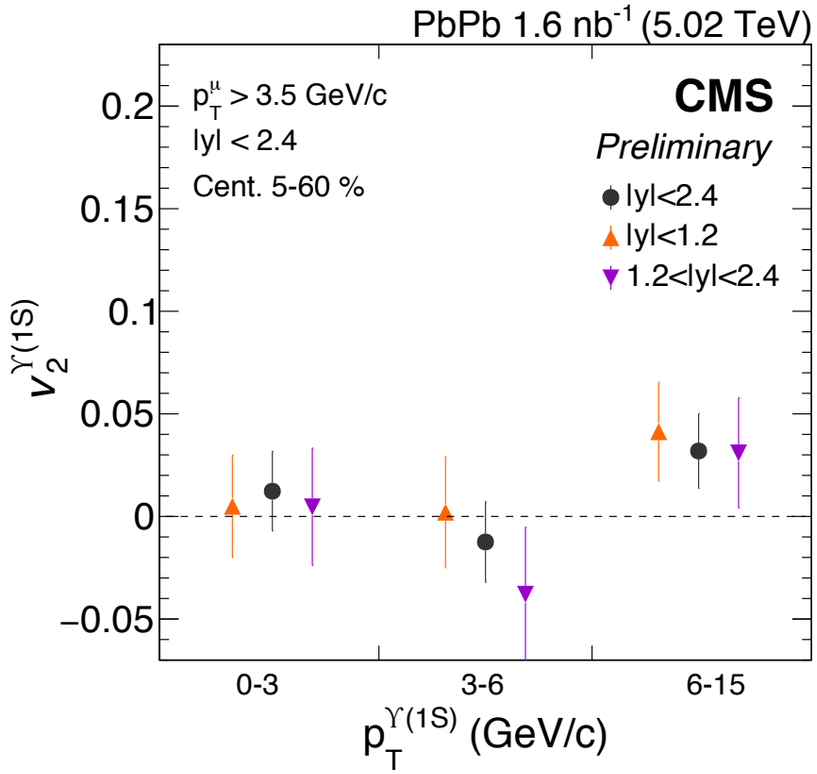

PbPb 1.6 nb^{-1} (5.02 TeV)
p_T^μ > 3.5 GeV/c
|y| < 2.4
p_T^Υ. 6-50 GeV/c
CMS
Preliminary
Υ(1S)
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
0-10
10-50
50-90
Centrality (%)

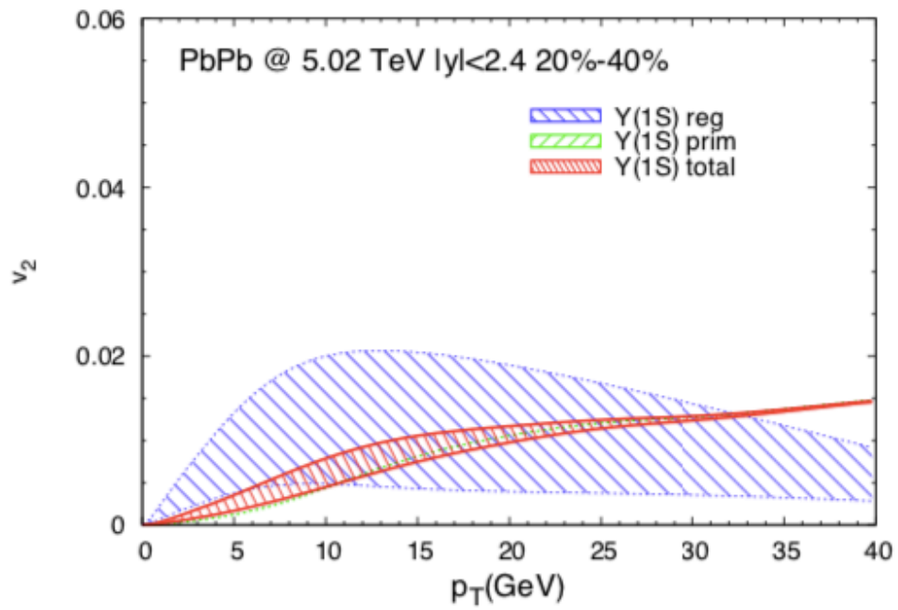
Results with ALICE

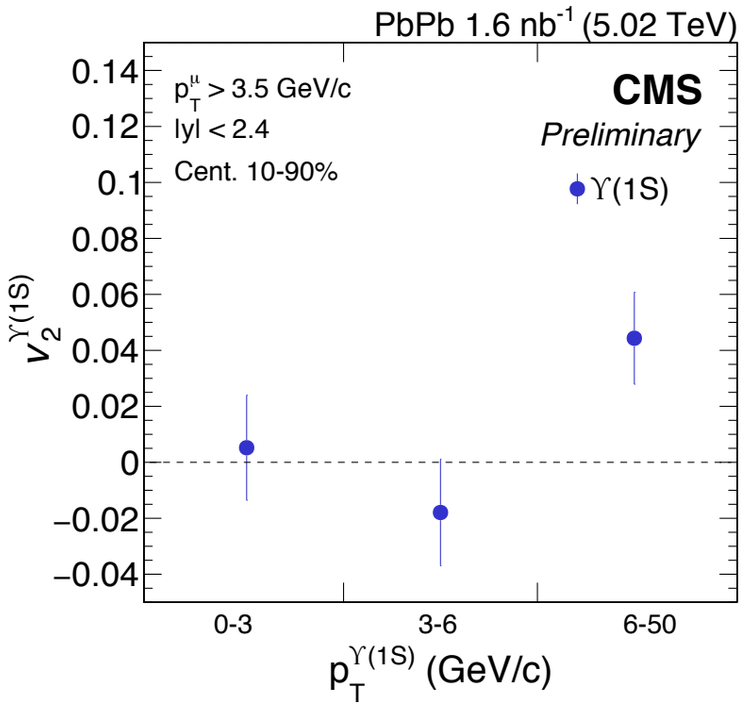


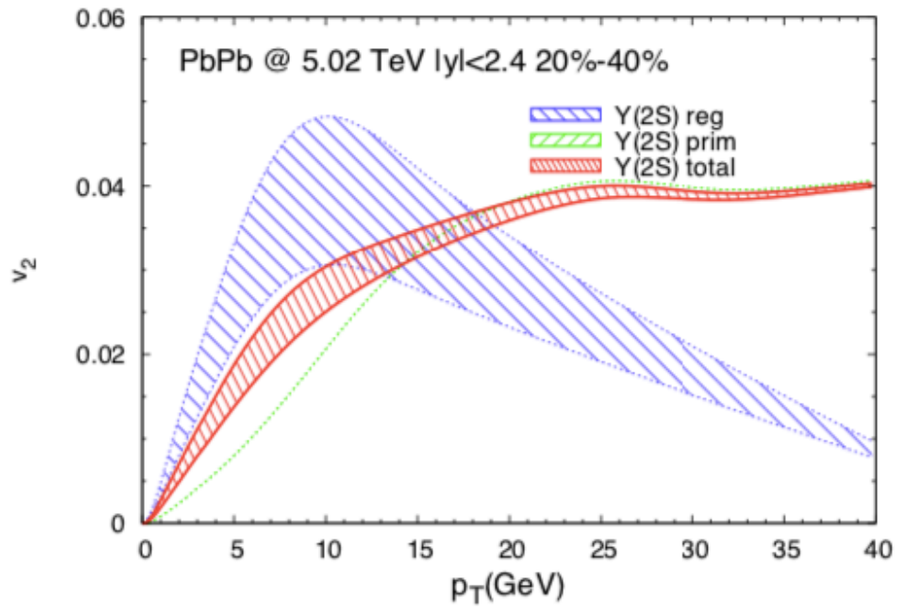


Comparison with Model





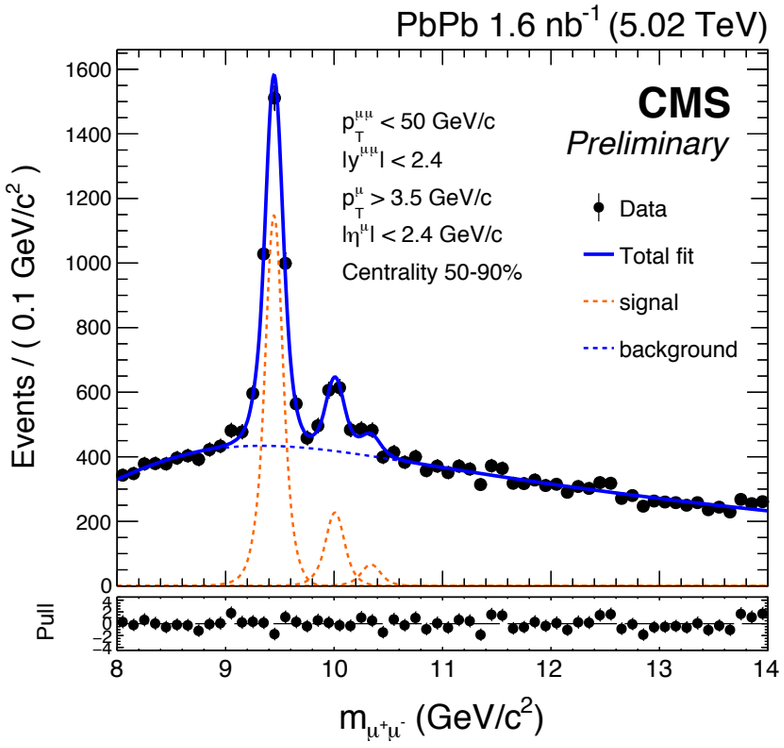


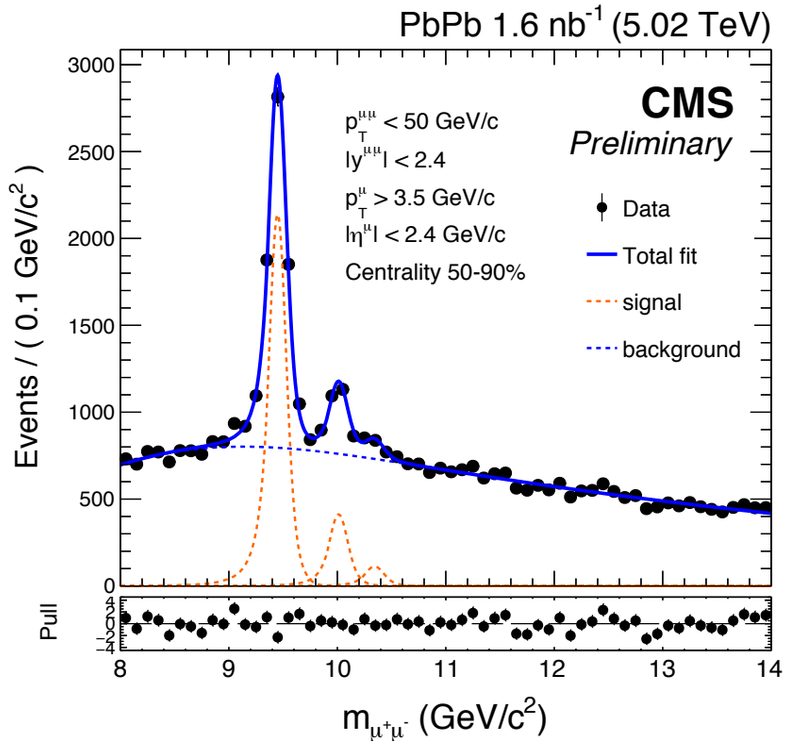


Summary

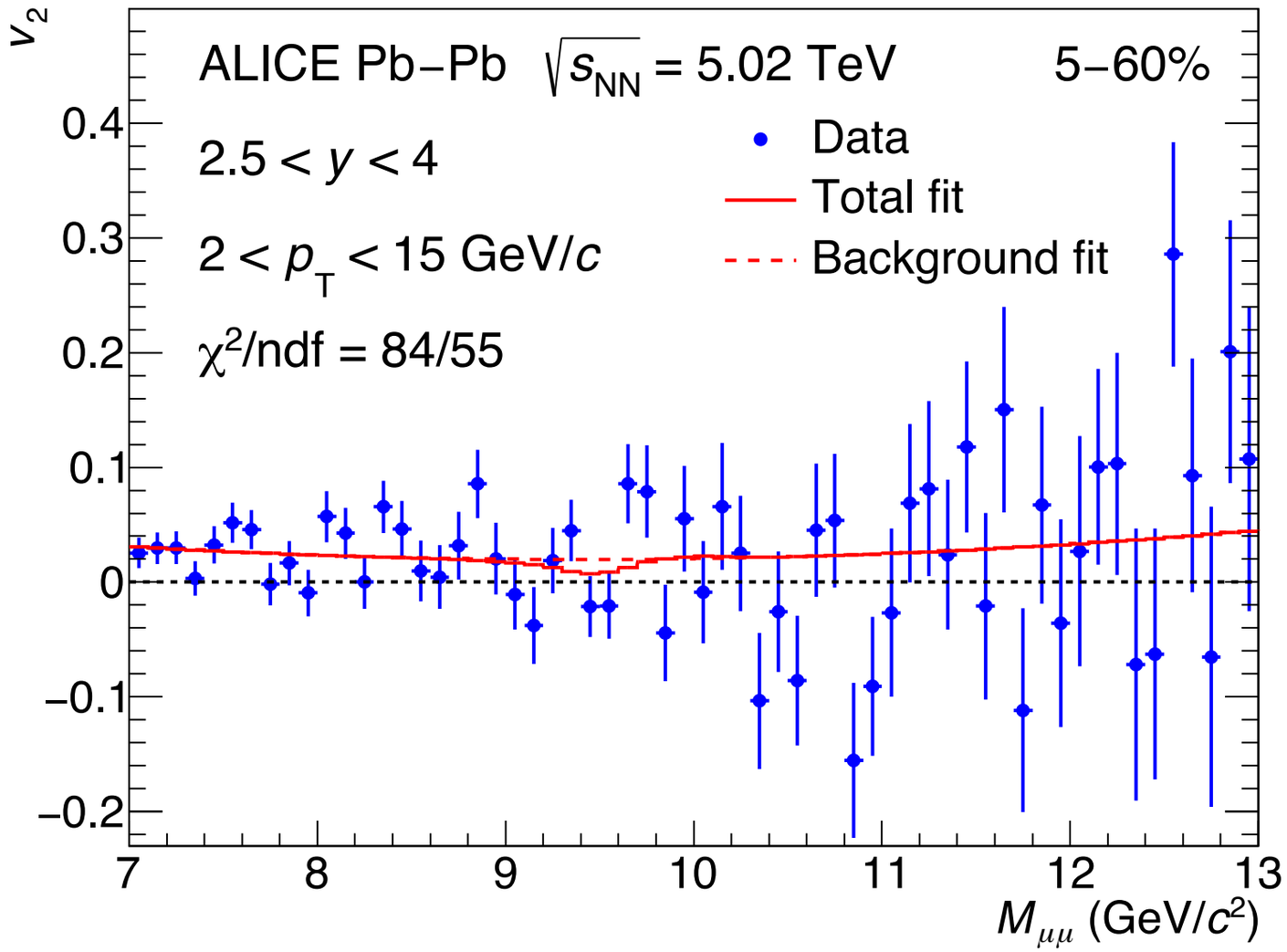
- **Plan**
  - **Finalize Pre-Approval homework this week (ARC GR deadline : Aug 30th)**
  - **Approval next month**
  - **Aim for QM 2019**

- **Discussion**
  - **Replace signal fraction with sPlot technique?**
  - **T&P vs centrality?**
  - **Want to use peripheral trigger above cent. > 50% ?**
  - **L1DoubleMuOpen vs L2&L3 combined trigger**





ALICE v2


v_2
ALICE Pb–Pb $\sqrt{s_{NN}}$ = 5.02 TeV
5–60%
2.5 < y < 4
2 < p_T < 15 GeV/c
χ^2/ndf = 84/55
Data
Total fit
Background fit
0.4
0.3
0.2
0.1
0
−0.1
−0.2
7
8
9
10
11
12
13
$M_{\mu\mu}$ (GeV/c^2)