Measurement of prompt and non-prompt J/ψ in pPb collisions at $\sqrt{S_{NN}}$ = 5.02 TeV

Songkyo Lee*, Lamia Benhabib, Yongsun Kim, Hyunchul Kim, Mihee Jo, Kisoo Lee

dilepton Meeting
9th April 2014

HIN-14-009

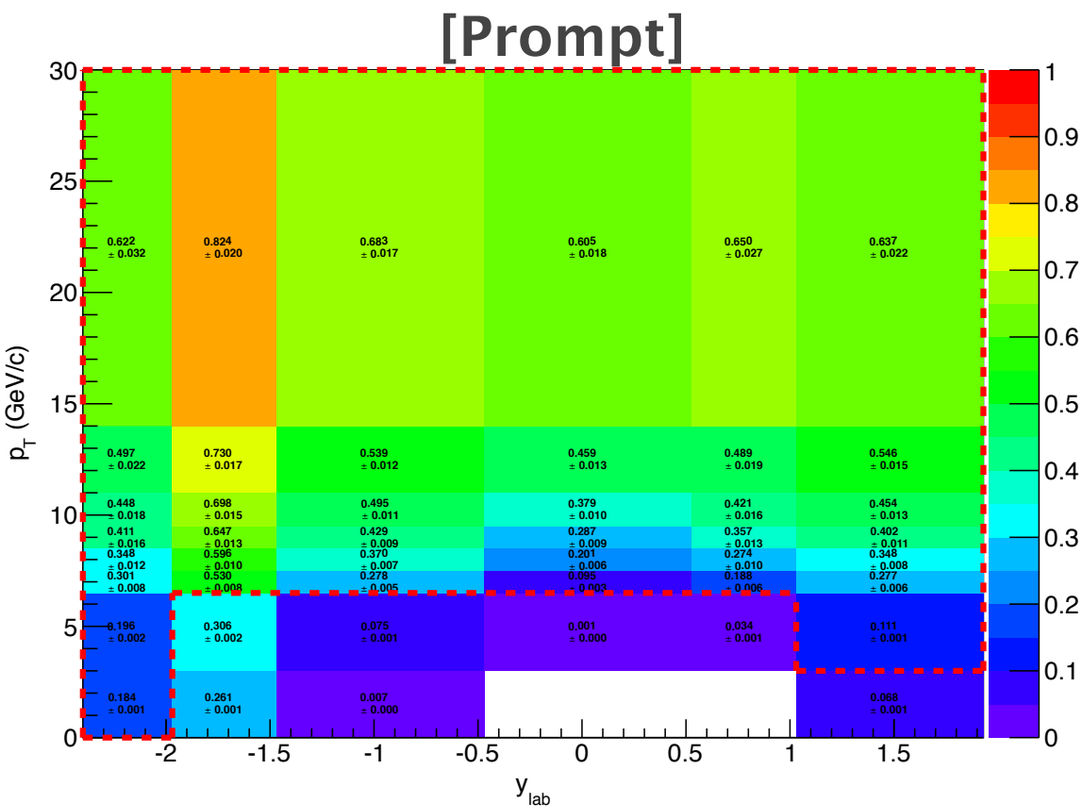
- **Pre-approved on 3rd April, Thursday**
- ~~**1st ARC review meeting within 1 week**~~

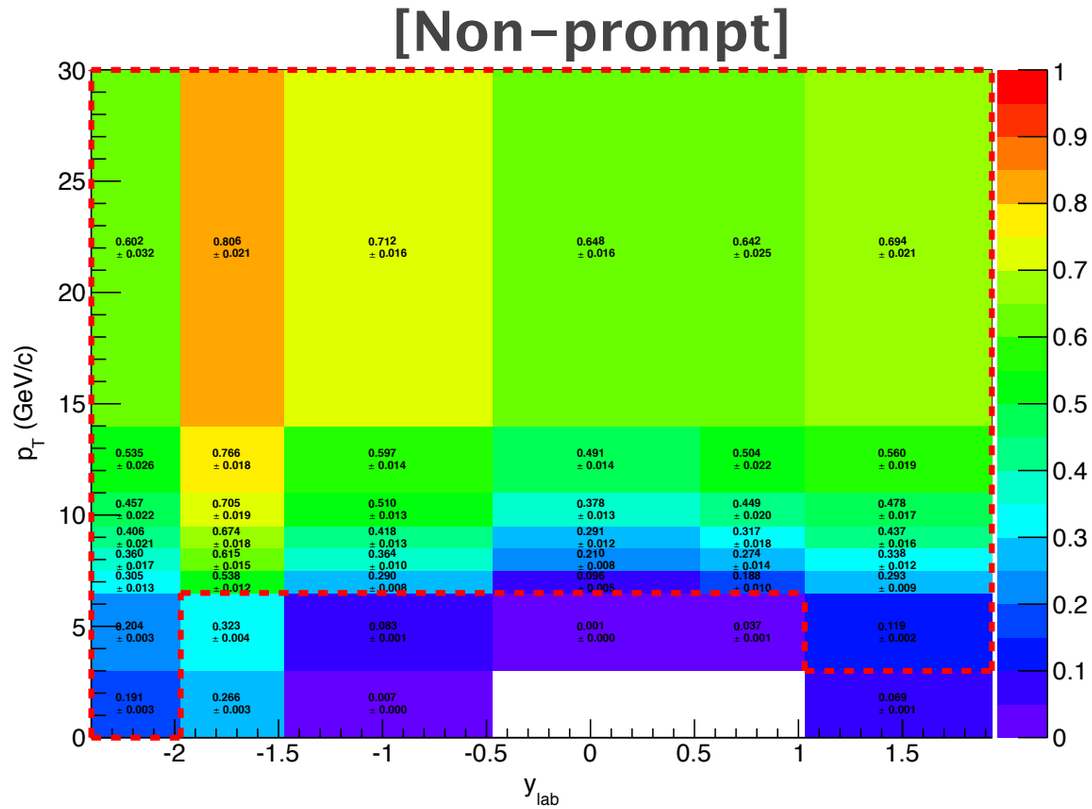
- **Latest documentation**
  - 2nd version of PAS available, 11 pages
    http://cms.cern.ch/iCMS/analysisadmin/get?analysis=HIN-14-009-pas-v1.pdf
  - Detailed analysis note : AN-13-346, 109 pages
    http://cms.cern.ch:80/iCMS/jsp/openfile.jsp?tp=draft&files=AN2013_346_v3.pdf

Acceptance

- **Non-prompt J/psi MC sample ready**
  - Previous : Only prompt MC sample has been used for acceptance correction
  - Now : <u>prompt</u> and <u>non-prompt</u> MC sample separately

- **e.g.) binning for cross-section measurement**





- Acceptance values are a bit higher for non-prompt
- No dramatical changes in $\mathbf{R_{FB}}$ because forward and backward are canceled.

Re-weight using TNP

- **Scale Factor**
  - get p_T distribution for 3 different η ranges and calculate SF as [TNP data]/[TNP MC].
    η range has been changed according to comments from muon POG
    (barrel vs endcap) $-2.4 < \eta < -0.8$, $-0.8 < \eta < 0.8$, $0.8 < \eta < 1.93$

  - Definition of probe for tracking efficiency has been changed (HI to pp definition)
    - previous : Correlation between muID and tracking efficiency
      Only trigger efficiency is used for SF
    - Now : No correlation between muID and tracking efficiency
      muID, tracking, and trigger efficiencies are multiplied and used for SF

$$\text{TNP corrected Efficiency} = \text{MC Efficiency} \otimes \frac{\text{TNP DATA efficiency of } \mu^+}{\text{TNP MC efficiency of } \mu^+} \frac{\text{TNP DATA efficiency of } \mu^-}{\text{TNP MC efficiency of } \mu^-}$$

Results : Cross-section

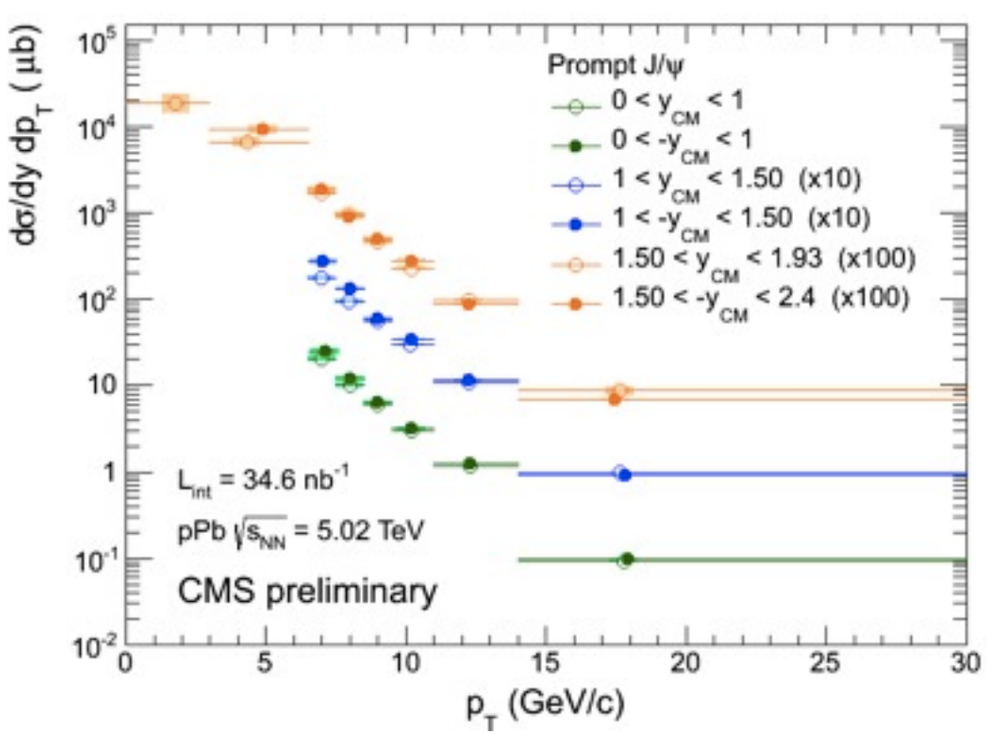
Double differential cross-section

PAS Fig.3 - Fig.4

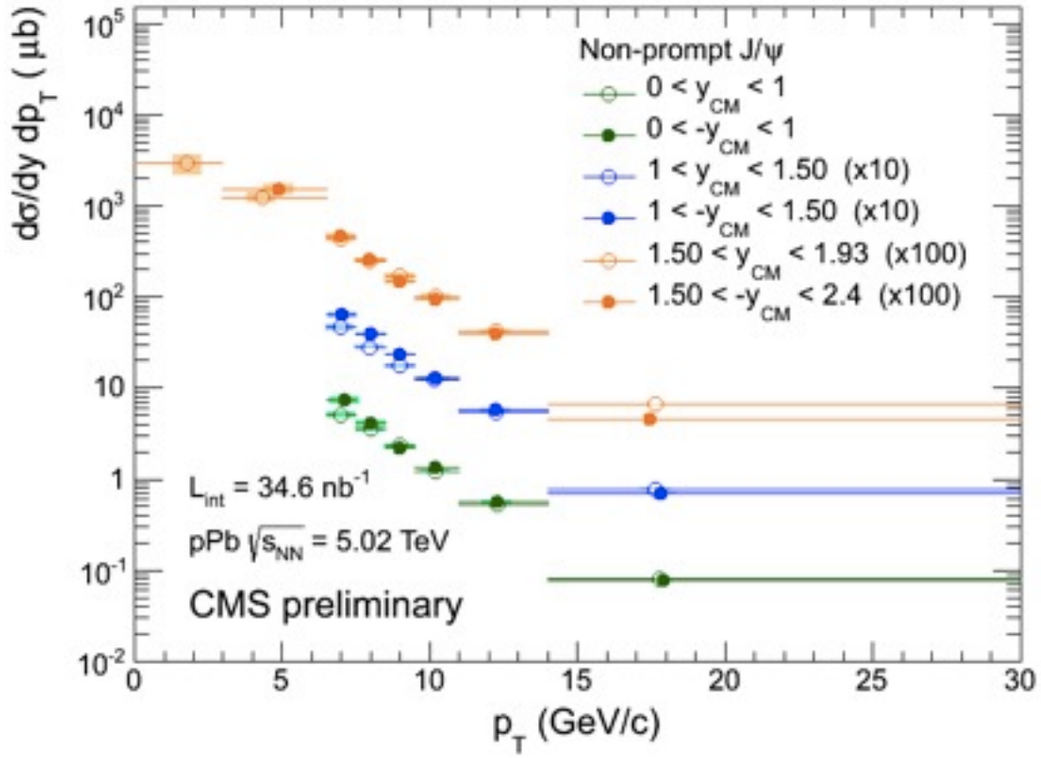
$$\frac{d^2\sigma}{dp_T dy} = \frac{N^{corr}(J/\psi \to \mu^+\mu^-)}{L_{int} \times B(J/\psi \to \mu^+\mu^-) \times \Delta p_T \Delta y}$$

- $N^{corr}(J/\psi \to \mu^+\mu^-)$ is the acceptance and the efficiency corrected number of J/ψ decayed in the $\mu^+\mu^-$ channel in given bin;
- $L_{int} = (34.6 \pm 1.6) nb^{-1}$ is the integrated luminosity;
- $B(J/\psi \to \mu^+\mu^-) = (5.93 \pm 0.06)\%$ is the branching ratio of the $J/\psi \to \mu^+\mu^-$ decay;
- Δp_T and Δy are the widths of the (p_T,y) bin.

[Prompt]



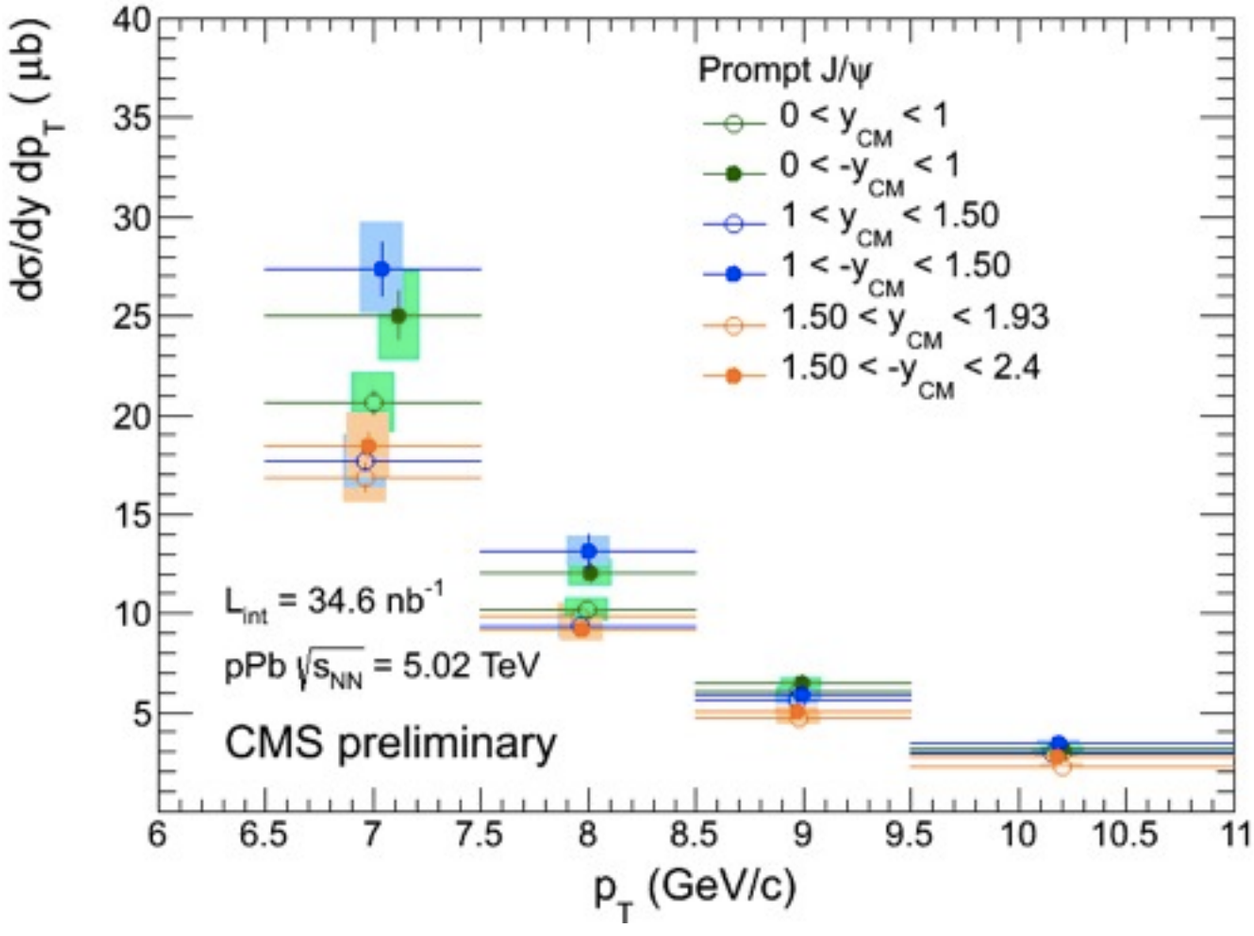
[Non-prompt]

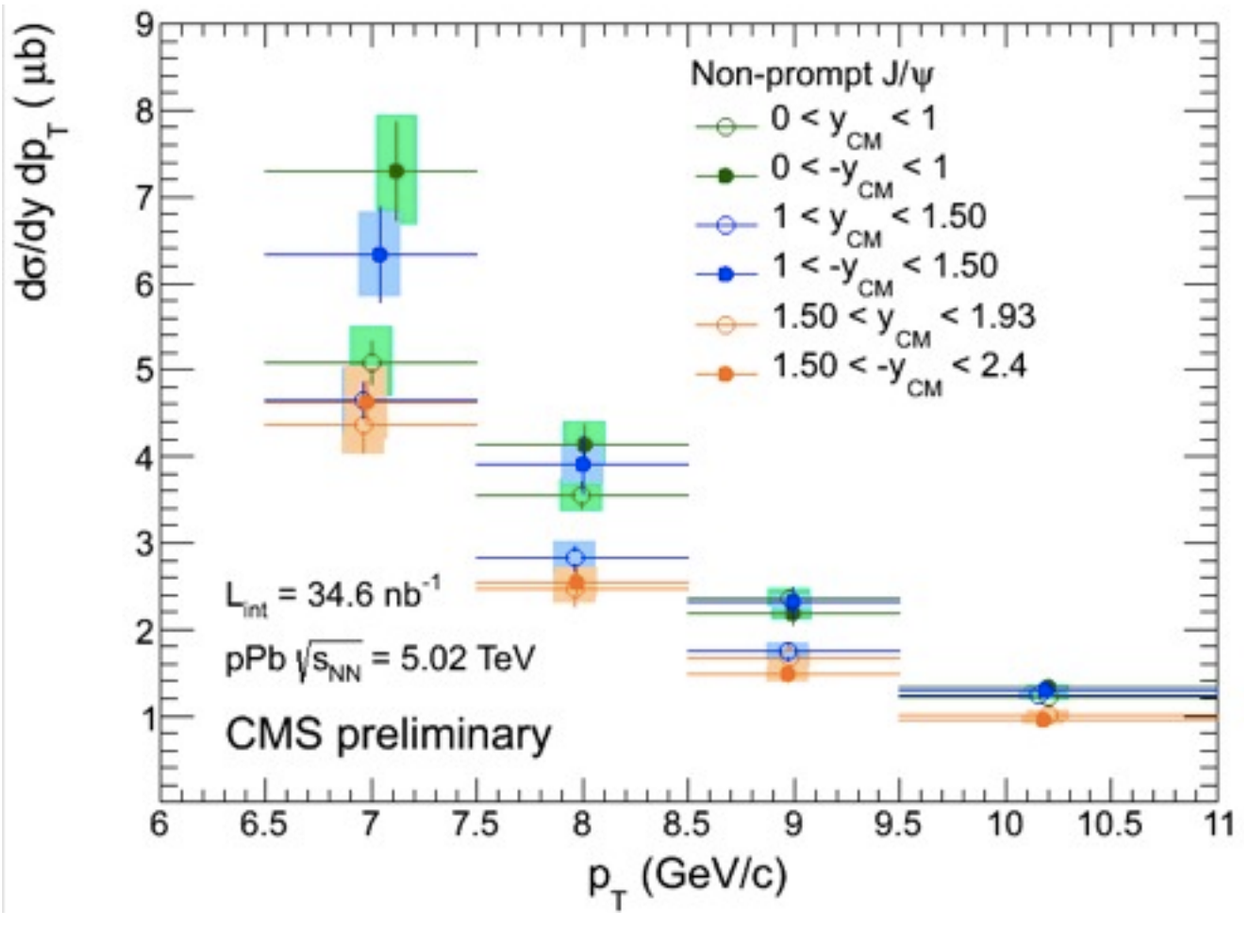


- Fitting qualities improved & systematic uncertainties updated
- Comments : uncertainty for luminosity & branching ratio should be added
- Comments : draw y_{CM} dependence (e.g. for p_T 6.5-30 GeV/c)

Results : Cross-section

- **Double differential cross-section**
  - y axis : Linear scale
  - x axis : $6 < p_T < 11$ GeV/c zoomed-in.





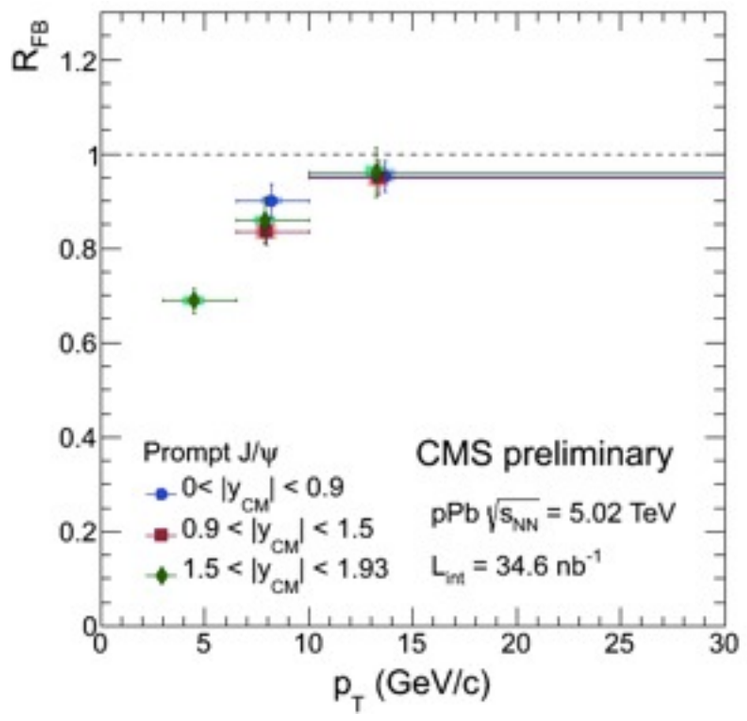
- Most forward & backward regions (orange) are hard to compare directly because their rapidity bin widths are not same.

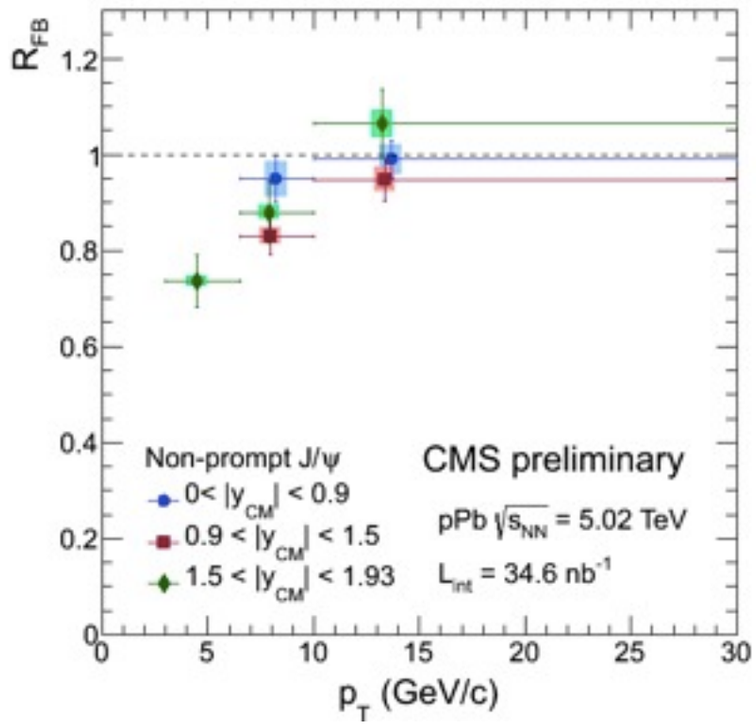
Outline

$$R_{FB} = \frac{[N_{J/\psi}/(A*\epsilon)]^{FW}}{[N_{J/\psi}/(A*\epsilon)]^{BW}}$$

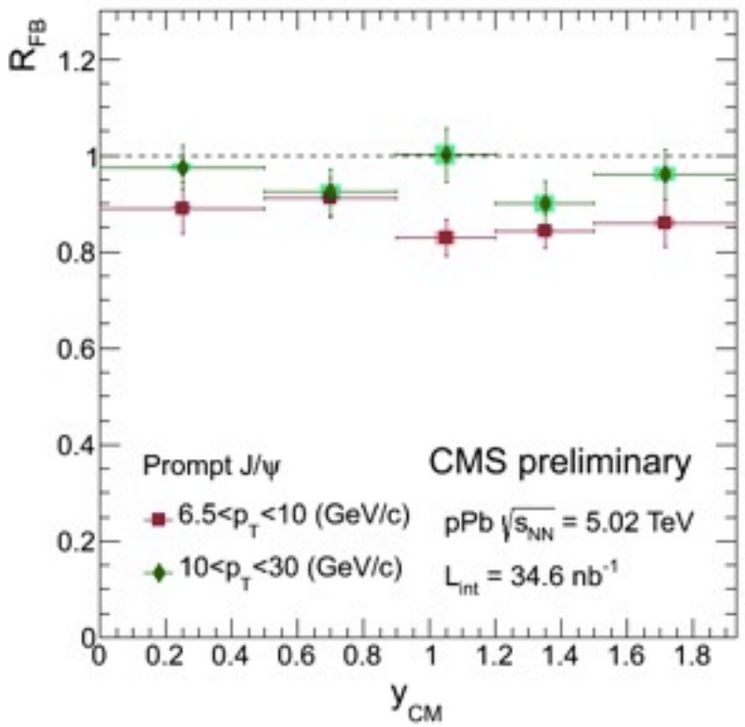
- Fitting qualities improved
- Systematic uncertainties updated

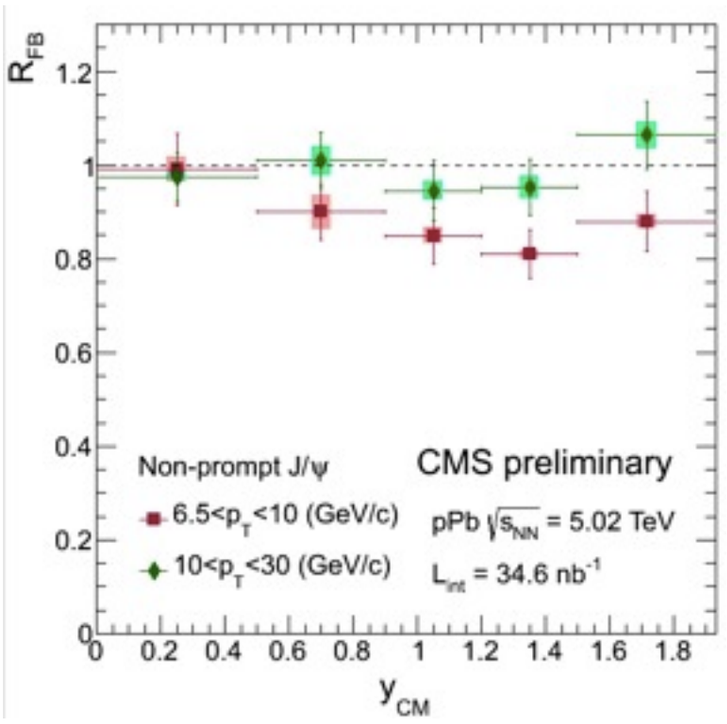
PAS Fig.6 – Fig.7





- **R_{FB} vs y_{CM} are added**
- No strong rapidity dependence (mid-rapidity regions and difference between y_{CM} values of forward and backward are small)



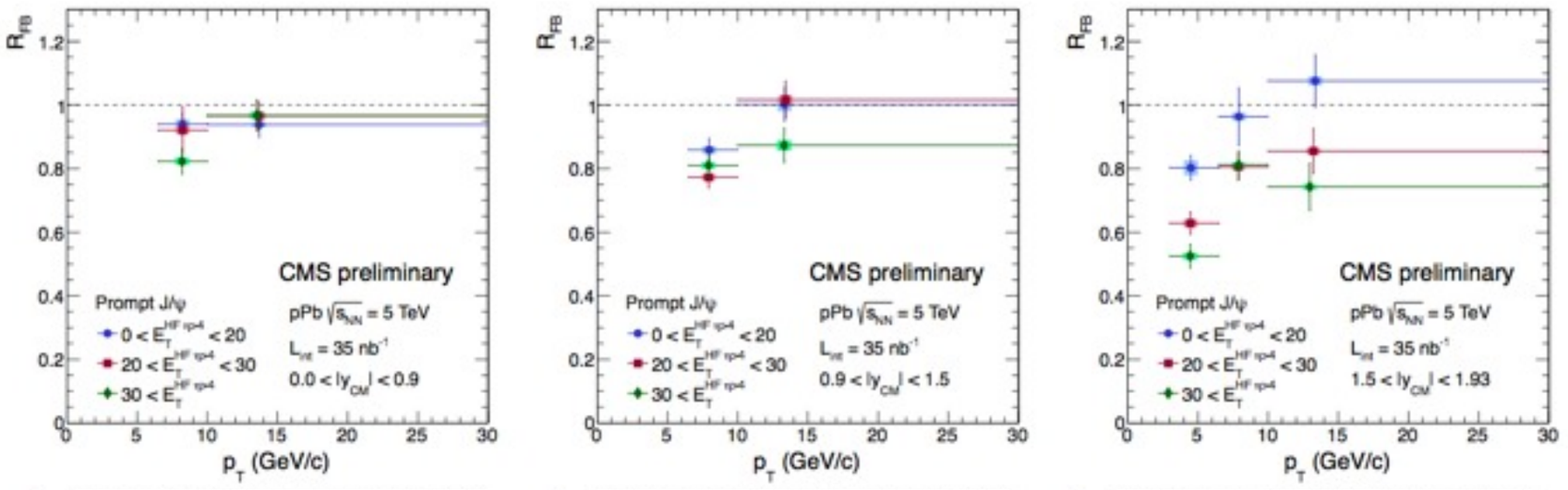


Results : E_T^{HF} dependence

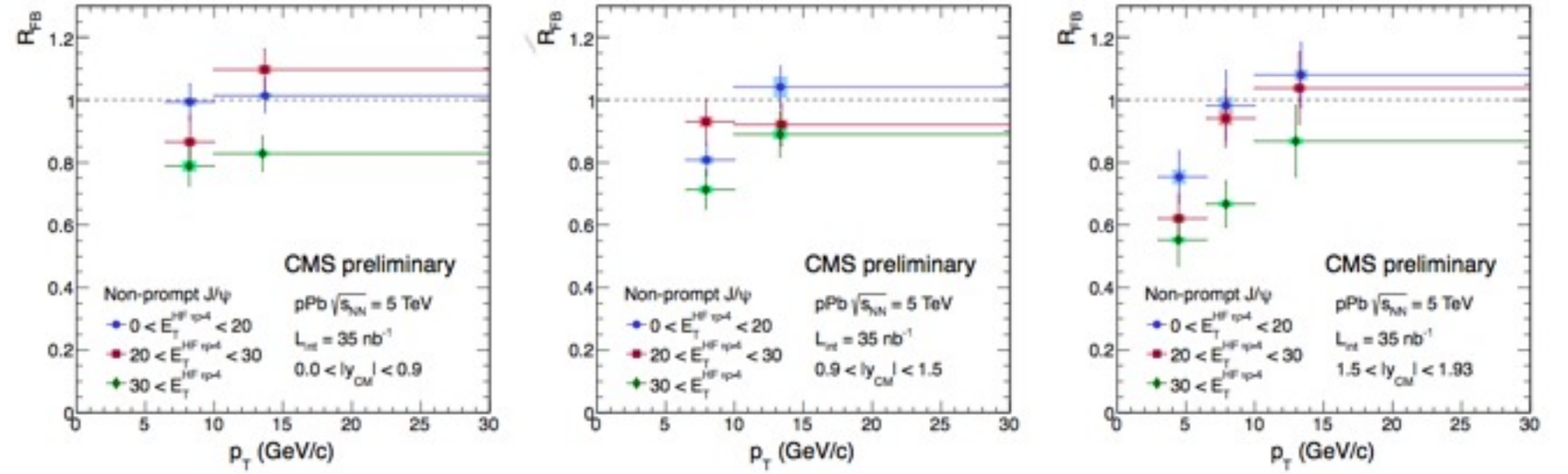
PAS Fig.8 – Fig.9

$|y_{CM}|$ larger

[Prompt]



[Non-prompt]

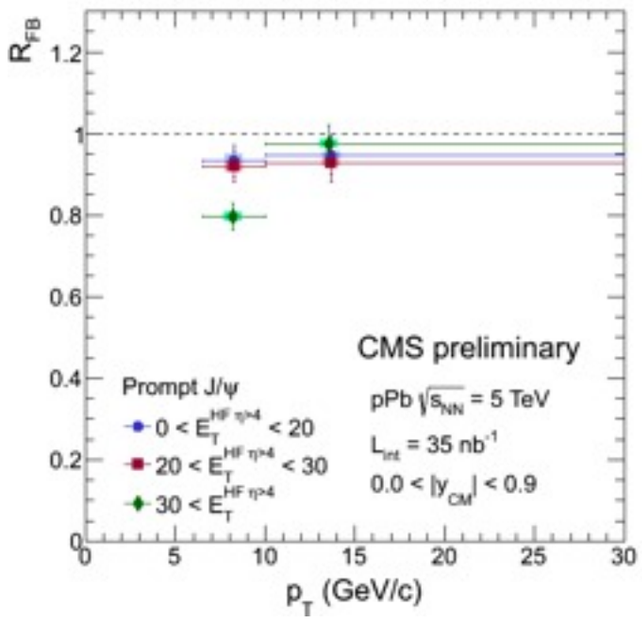


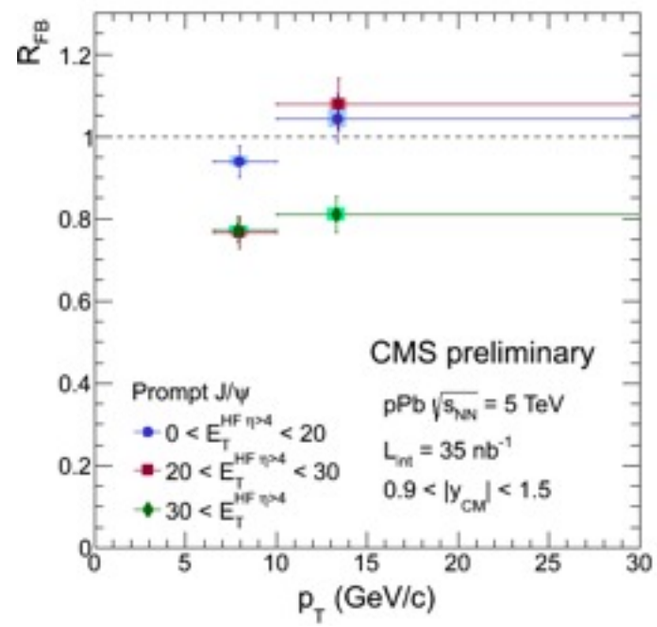
- We are discussing how to display the result :
  1. current plots : legend = different event activity, plots = different rapidity
  2. current plots : legend = different rapidity, plots = different event activity
  3. **R_{FB} vs event activity (after some bins merged)** *

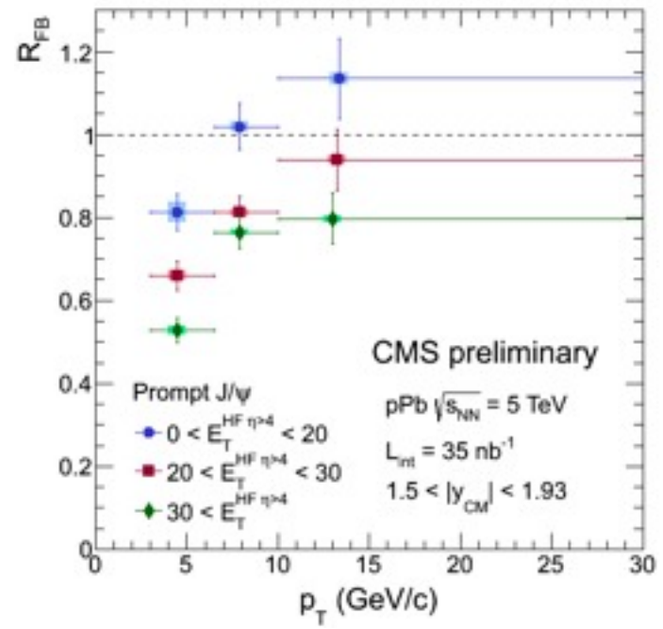
Results : N_{tracks} dependence

$|y_{CM}|$ larger

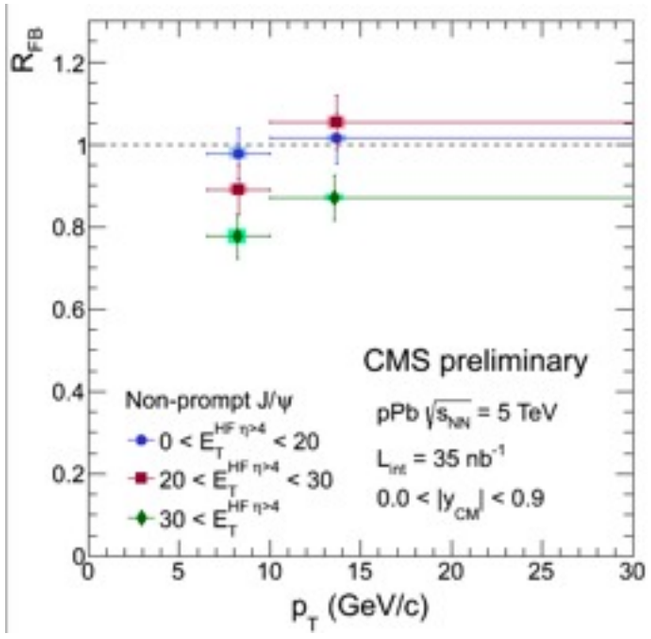
[Prompt]

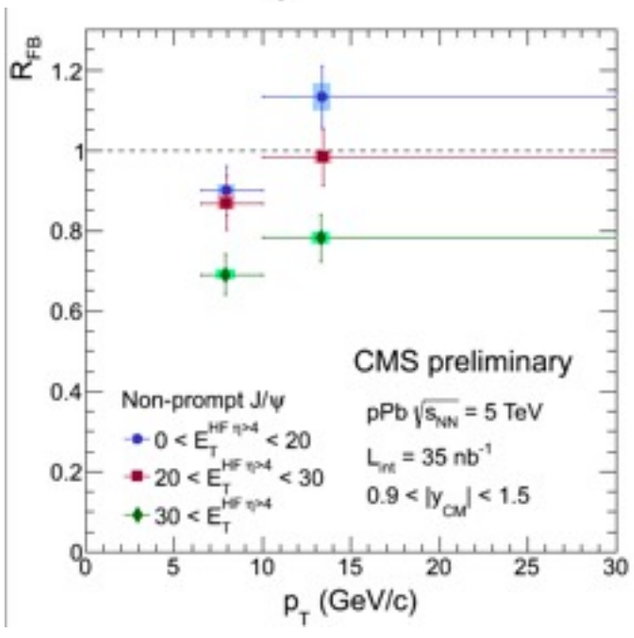


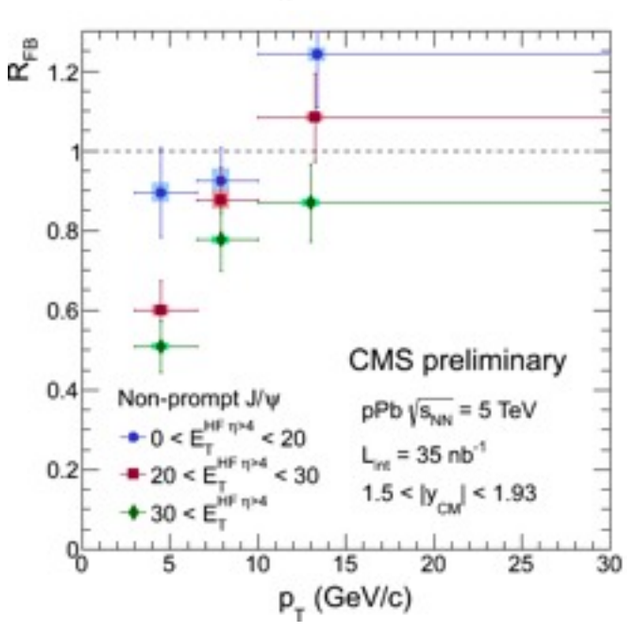




[Non-prompt]







- E_T^{HF} and N_{tracks} dependence show similar trends

Summary & future plan

- **R_{pPb} (See Yongsun's slide)**
- **[Corrected DATA] vs [generated MC] – pT & rapidity distributions**
- **Further study for systematic uncertainties**

	prompt J/ψ (%)	non-prompt J/ψ (%)
Yield extraction	0.12–1.45	0.55–2.78
Acceptance estimation	0.04–1.42	0.04–1.42
TNP weighted Efficiency	0.14-25.42	0.06-25.55
Total	0.51–25.33	0.71–25.58

- **some supporting materials for fitting mechanism**

BACK-UP

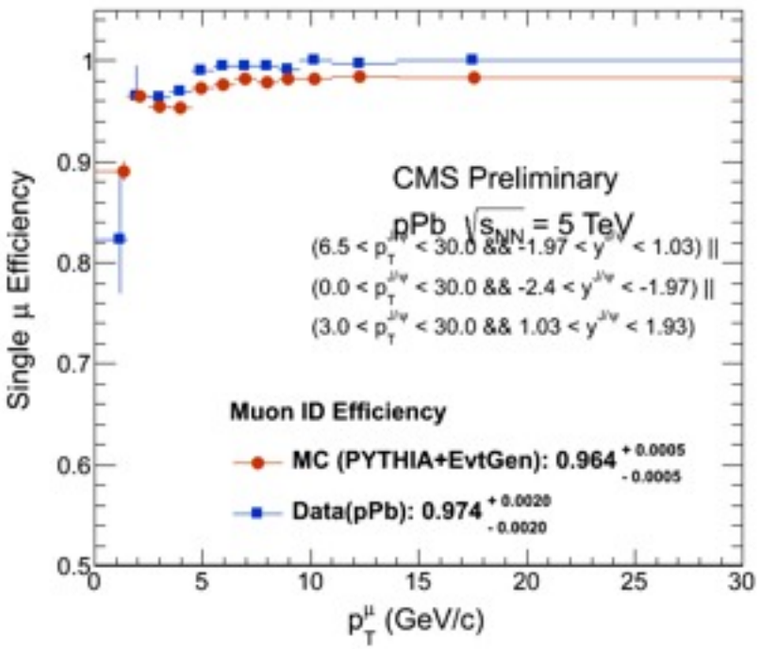
Tag and Probe

updated after frozen

Tag and Probe

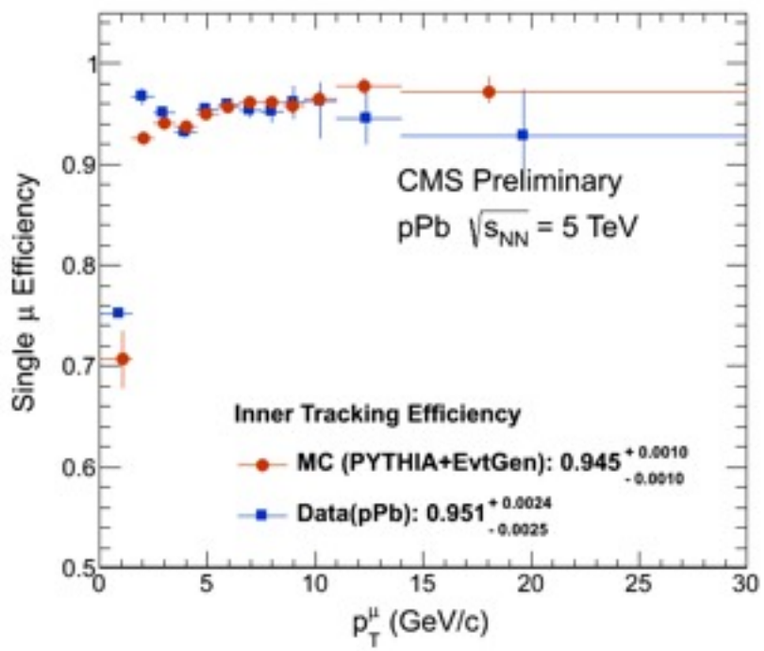
- efficiency = passing/(passing + failing)
- Trigger matching is corrected

[muon ID efficiency]



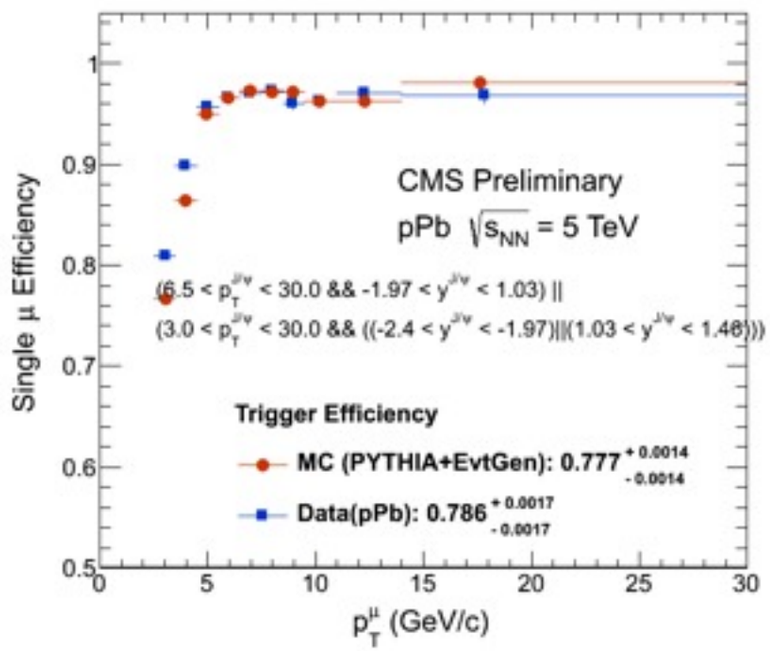
- Tag : trkMu with double trig
- Probe : caloMu without trig
- Passing : matched to trkMu

[Tracking efficiency]

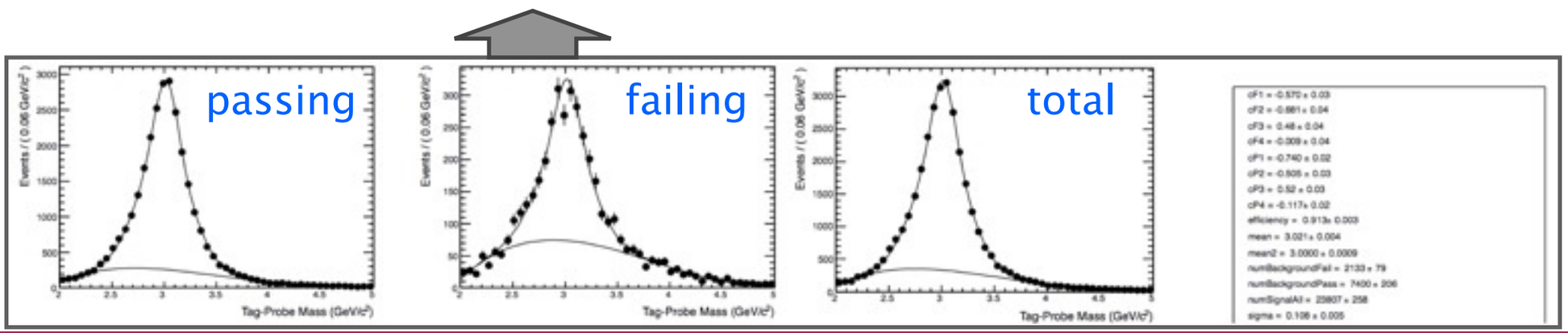


- Tag :trkMu with double trig
- Probe : outer track is non-null
- Passing : matched to trkMu

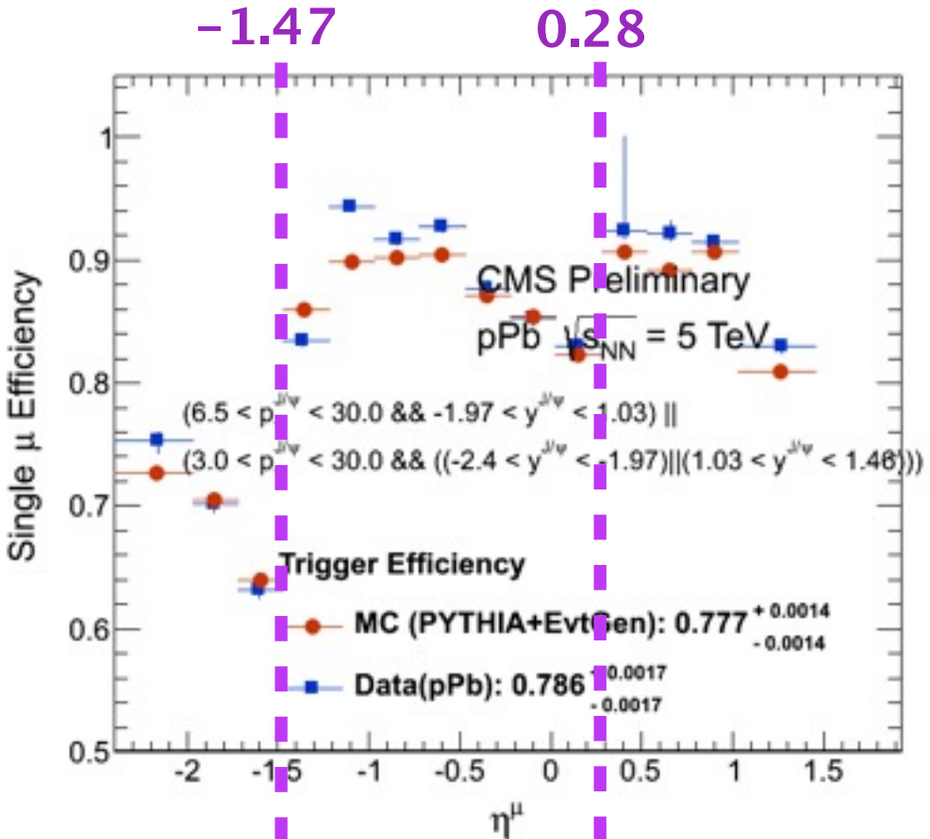
[Trigger efficiency]



- Tag :trkMu with single trig
- Probe : trkMu without trig
- Passing : matched to double trig

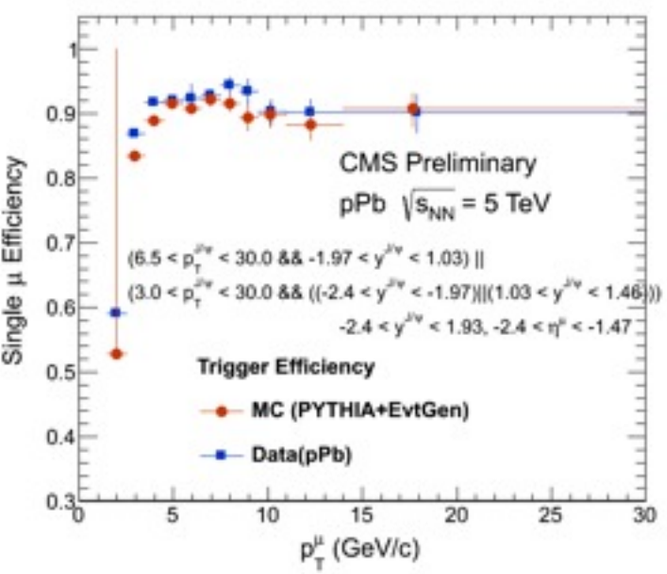


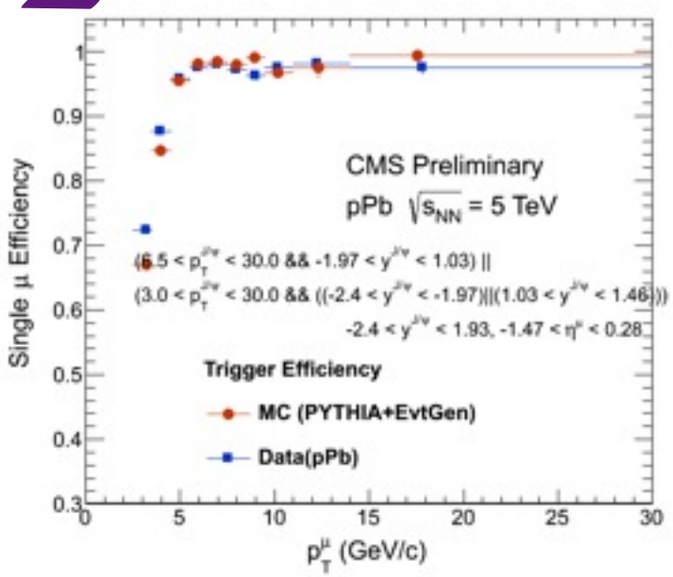
Re-weight using TNP

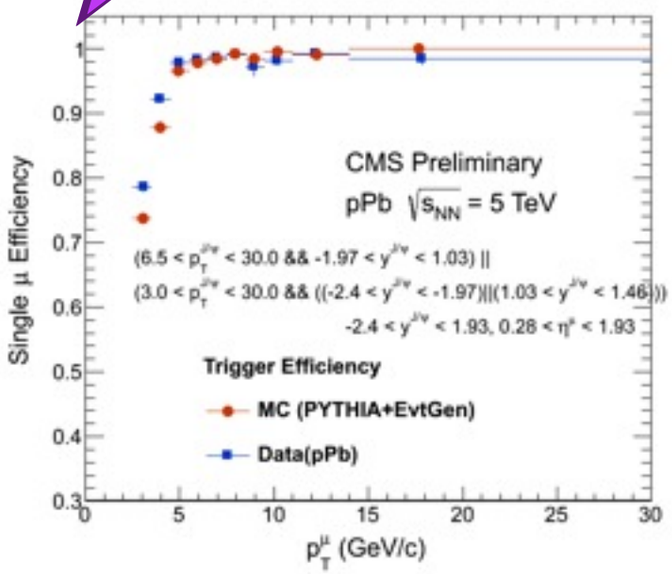


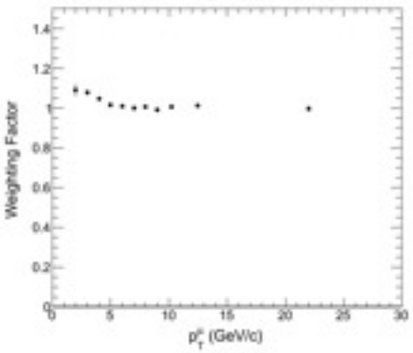
- For trigger efficiency,
  get p_T distributions for 3 different eta ranges.
- Ratio = [TNP Data]/[TNP MC]
  as a scale factor for MC efficiency

$$\text{TNP corrected Efficiency} = \text{MC Efficiency} \otimes \frac{\text{TNP DATA efficiency of } \mu^+}{\text{TNP MC efficiency of } \mu^+} \frac{\text{TNP DATA efficiency of } \mu^-}{\text{TNP MC efficiency of } \mu^-}$$



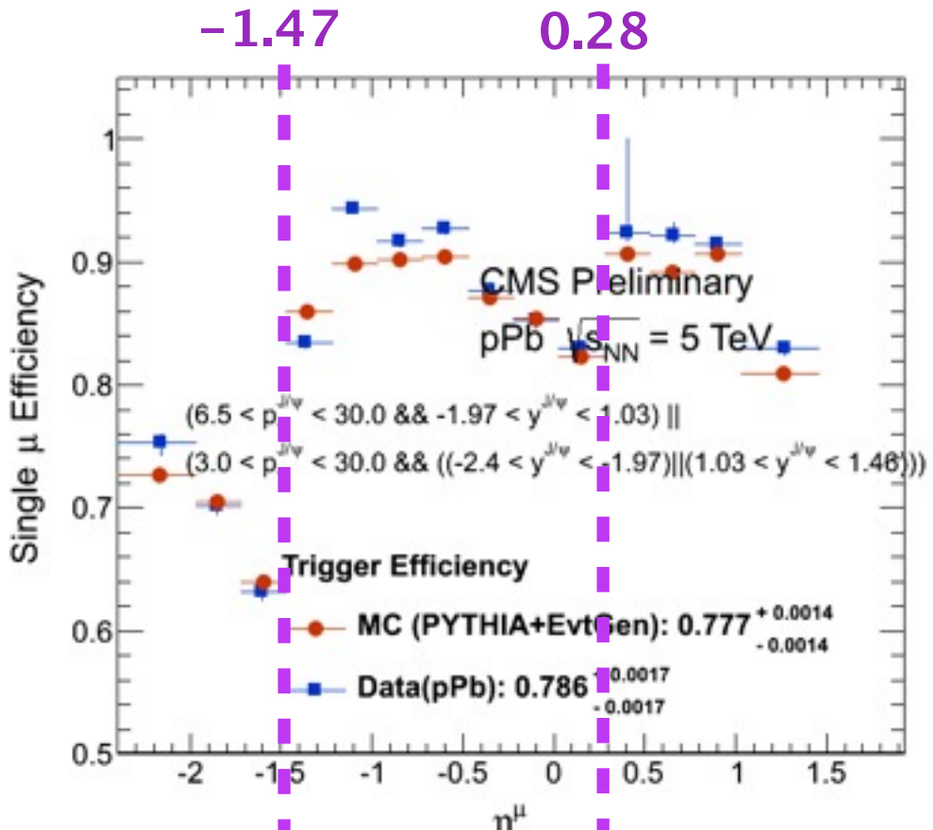




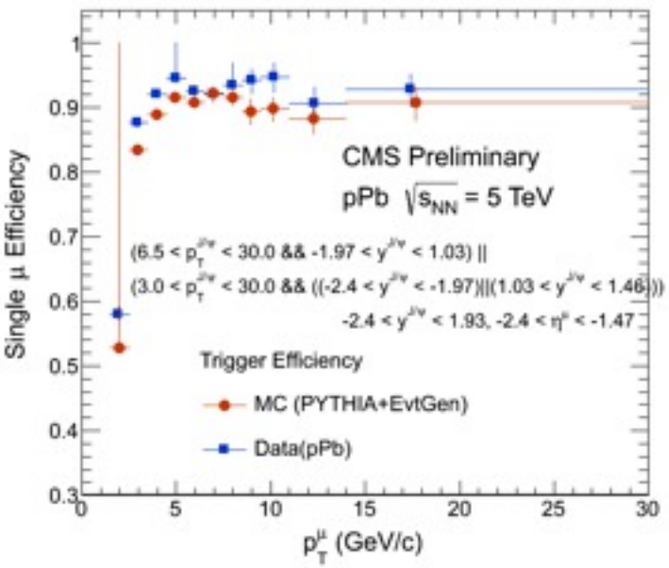


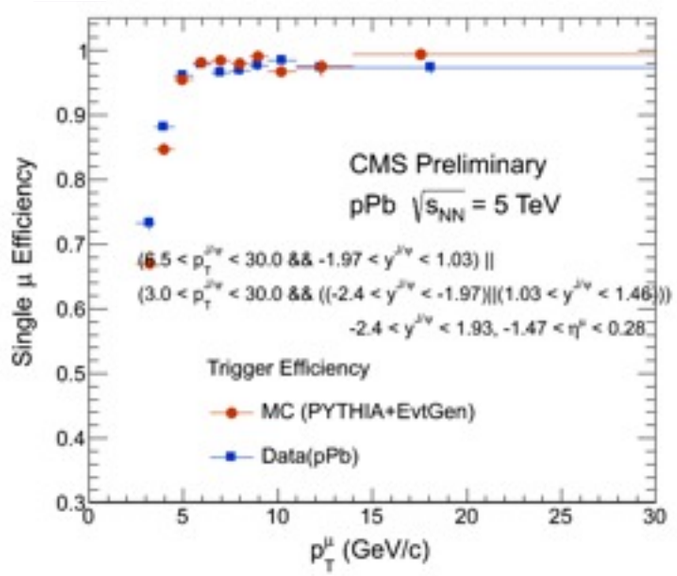
1st run period

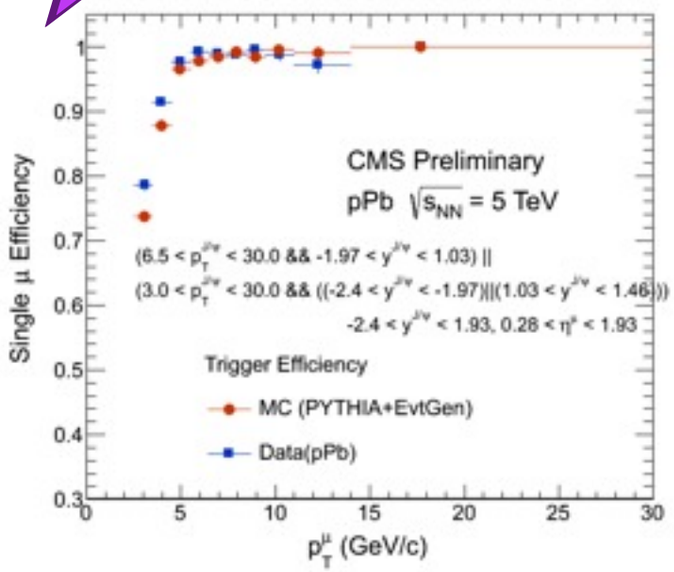
Re-weight using TNP

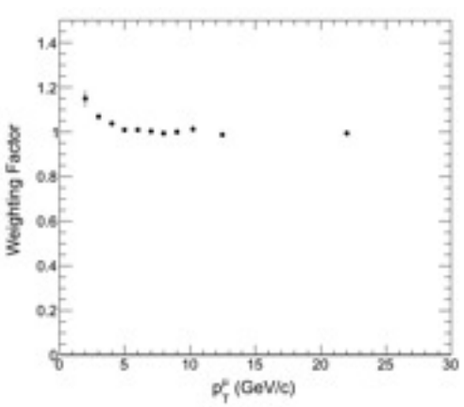


- Same weighting procedure is done for the 2nd run period.
- MC sample is one-way boosted to the same direction with 1st run. (expect to be compensated by weighting)
- Not much differences between 1st & 2nd run









2nd run period

Results : Cross-section

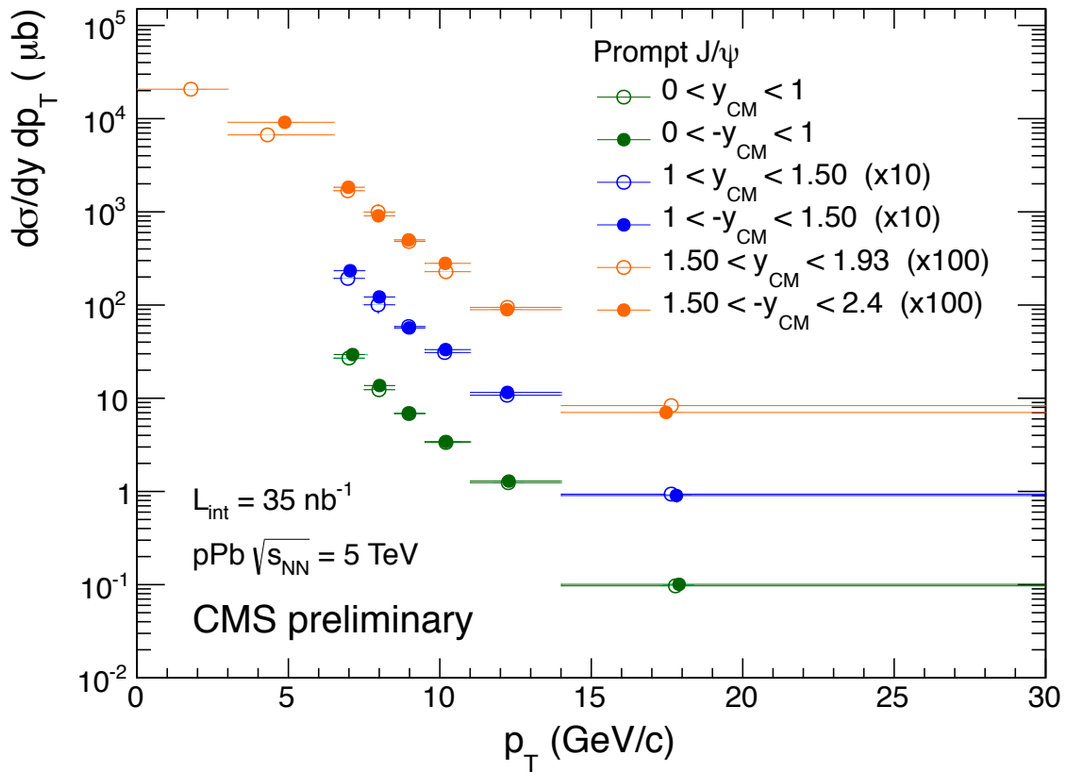
Double differential cross-section

PAS Fig.4 - Fig.5

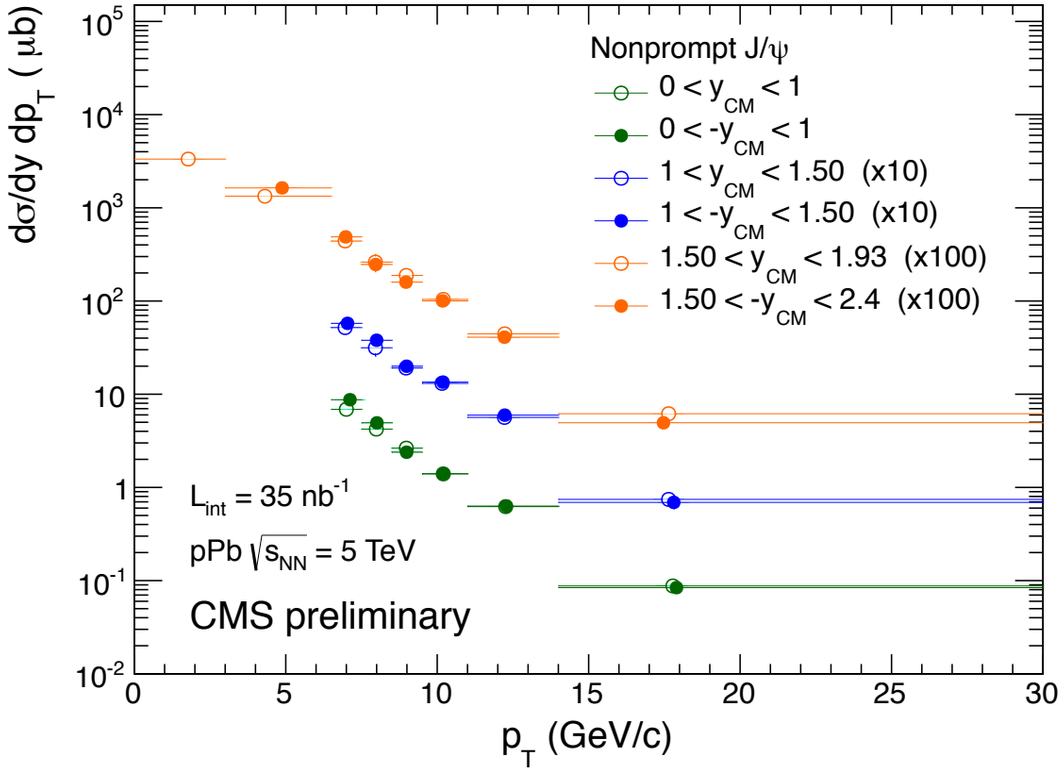
$$\frac{d^2\sigma}{dp_T dy} = \frac{N^{corr}(J/\psi \to \mu^+\mu^-)}{L_{int} \times B(J/\psi \to \mu^+\mu^-) \times \Delta p_T \Delta y}$$

- $N^{corr}(J/\psi \to \mu^+\mu^-)$ is the acceptance and the efficiency corrected number of J/ψ decayed in the $\mu^+\mu^-$ channel in given bin;
- $L_{int} = (34.6 \pm 1.6) nb^{-1}$ is the integrated luminosity;
- $B(J/\psi \to \mu^+\mu^-) = (5.93 \pm 0.06)\%$ is the branching ratio of the $J/\psi \to \mu^+\mu^-$ decay;
- Δp_T and Δy are the widths of the (p_T,y) bin.

[Prompt]



[Non-prompt]



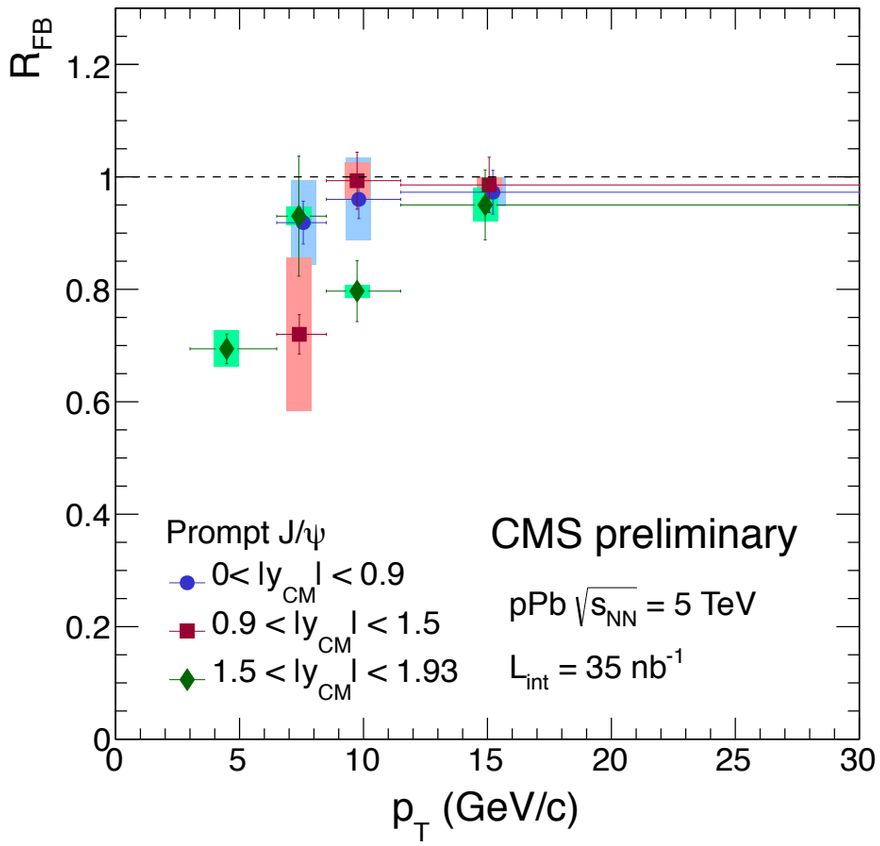
- No strong rapidity dependence
- Clue for the different production yield in forward and backward for low p_T
- Systematic uncertainties will be updated.

Results : R_{FB} vs p_T

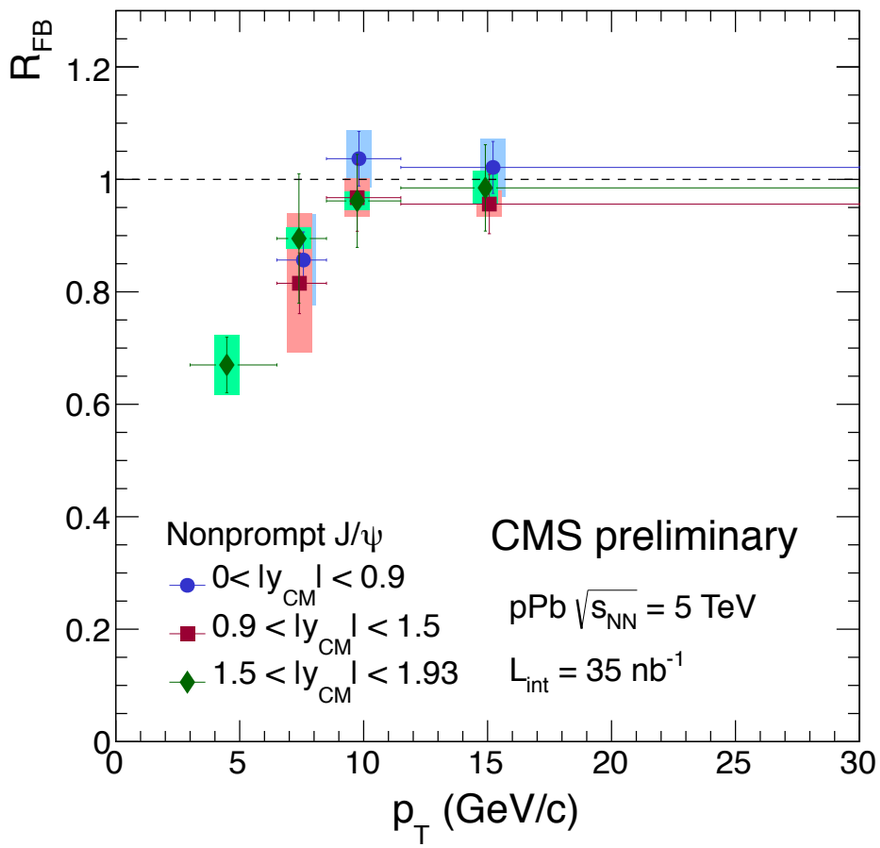
$$R_{FB} = \frac{[N_{J/\psi}/(A*\epsilon)]^{FW}}{[N_{J/\psi}/(A*\epsilon)]^{BW}}$$

PAS Fig.6

[Prompt]



[Non-prompt]

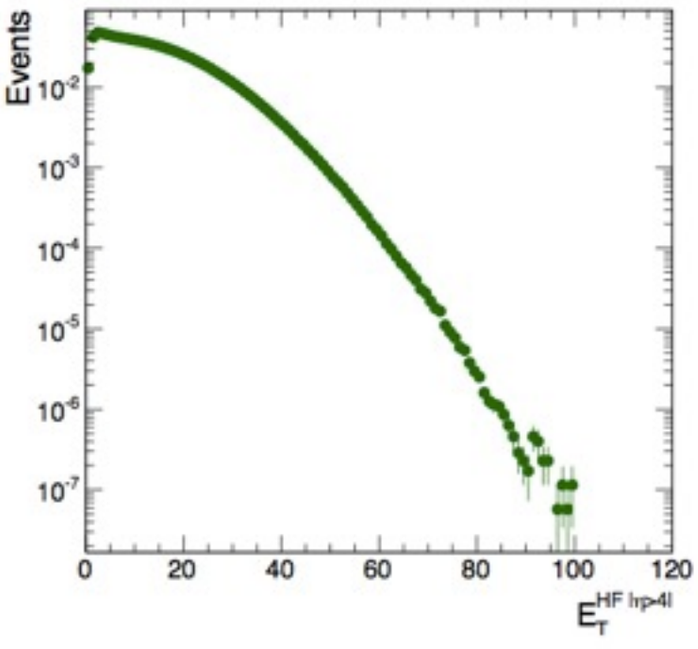


- No strong dependency on rapidity
- R_{FB} decreases smaller than unity as p_T becomes lower (smaller x).
- Improving systematic uncertainties in progress

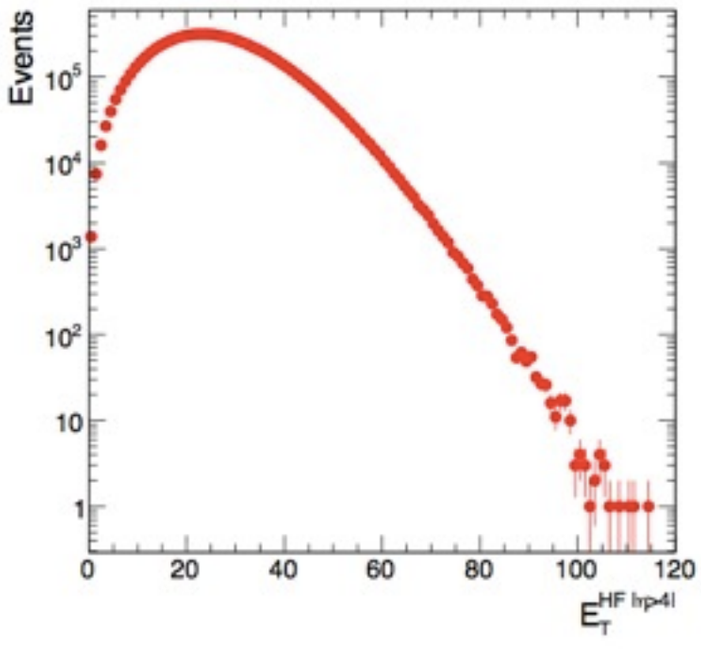
Multiplicity variables

- **Two variables for multiplicity**
  - 1. N_{tracks} $^{|\eta<2.4|}$ (binning : 0, 65, 95, 350)
  - 2. E_T^{HF} $^{|\eta>4|}$ (binning : 0, 20, 30, 120 GeV) *
  - We investigated dependence on E_T^{HF} $^{|\eta>4|}$

[min-bias sample]



[muon sample]



[Fractions in min-bias sample]

	$[E_T^{\|\eta\|>4}]$	$\langle E_T^{\|\eta\|>4}\rangle$	Frac
pPb	0–20.0	9.4	73%
min-	20.0–30.0	24.3	18%
bias	$\geq$ 30.0	37.2	9%

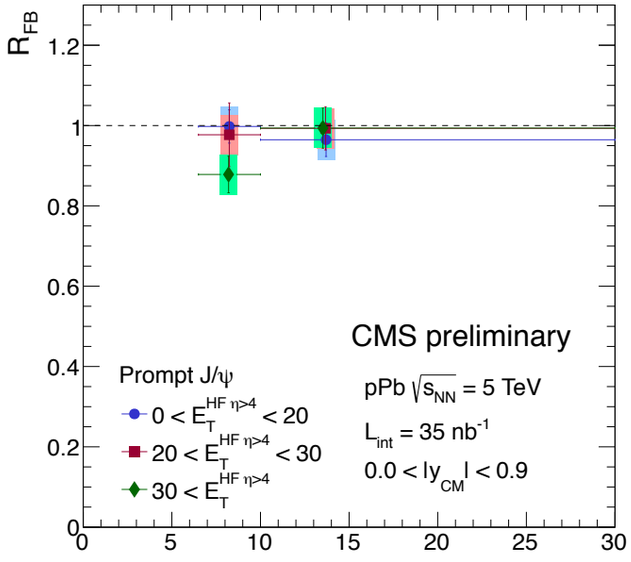
- Fraction for each bins are selected ~30% in muon sample according to statistics for fitting procedure.

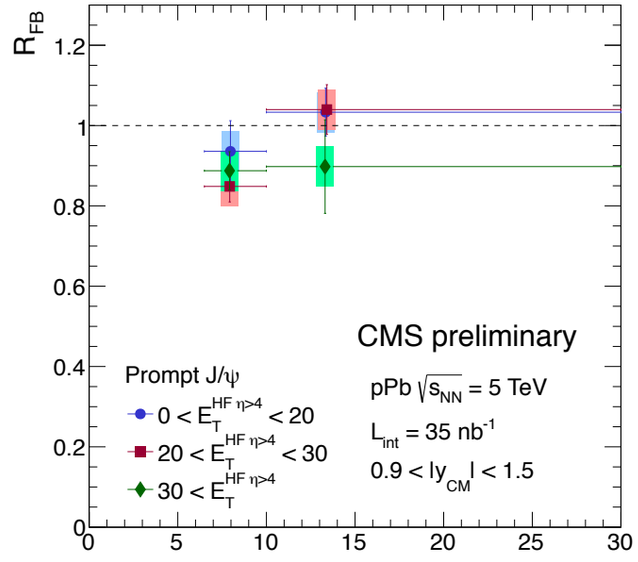
Results : E_T^{HF} dependence

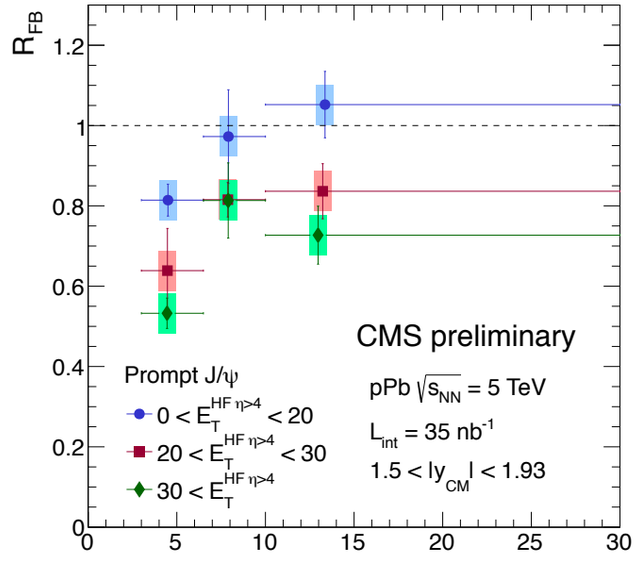
PAS Fig.7 – Fig.9

$|y_{CM}|$ larger

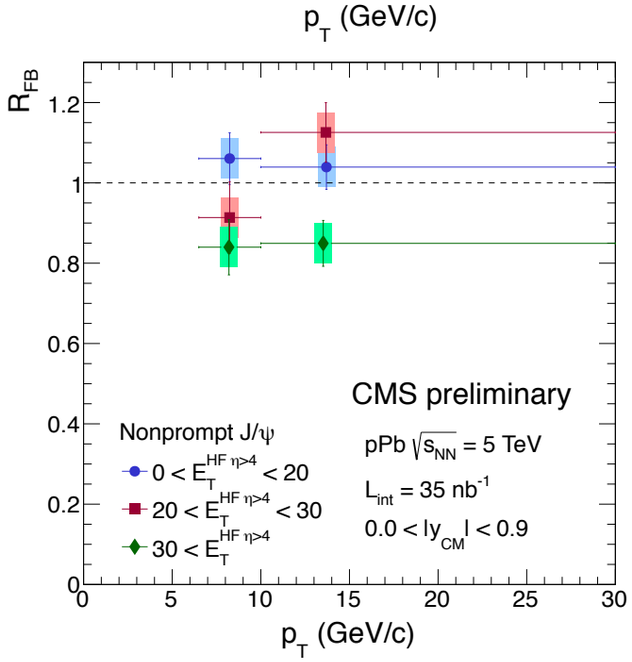
[Prompt]

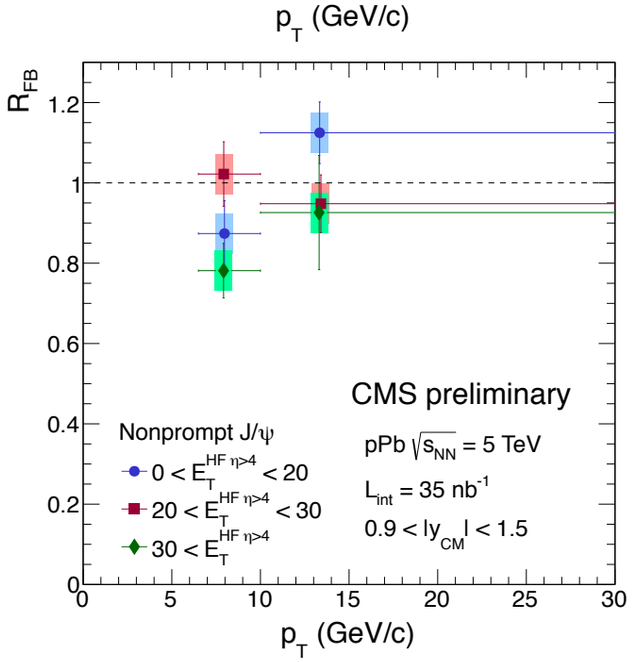


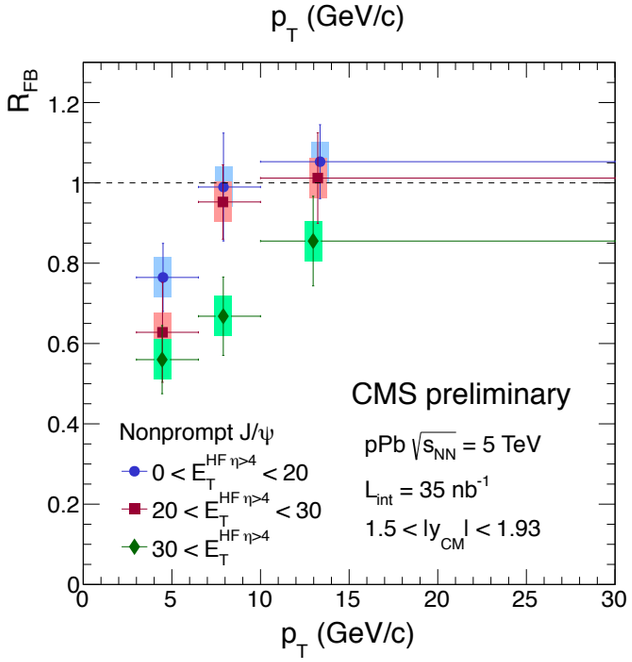




[Non-prompt]







- R_{FB} becomes smaller for lower p_T and higher multiplicity.
- Improving systematic uncertainties in progress.

Systematic Uncertainties

- **Total systematic uncertainties**

$$= \sqrt{(\text{Acceptance})^2+(\text{TNP weighted Efficiency})^2 + (\text{Fitting})^2}$$

- Acceptance : 0.07 – 0.96 %
- TNP weighted Efficiency : 0.36– 17.08 %
- Fitting : 0.16–14.74 %
- Total : 1.4–19 %

- Systematic uncertainties are calculated to be conservative.

N_{tracks} dependence

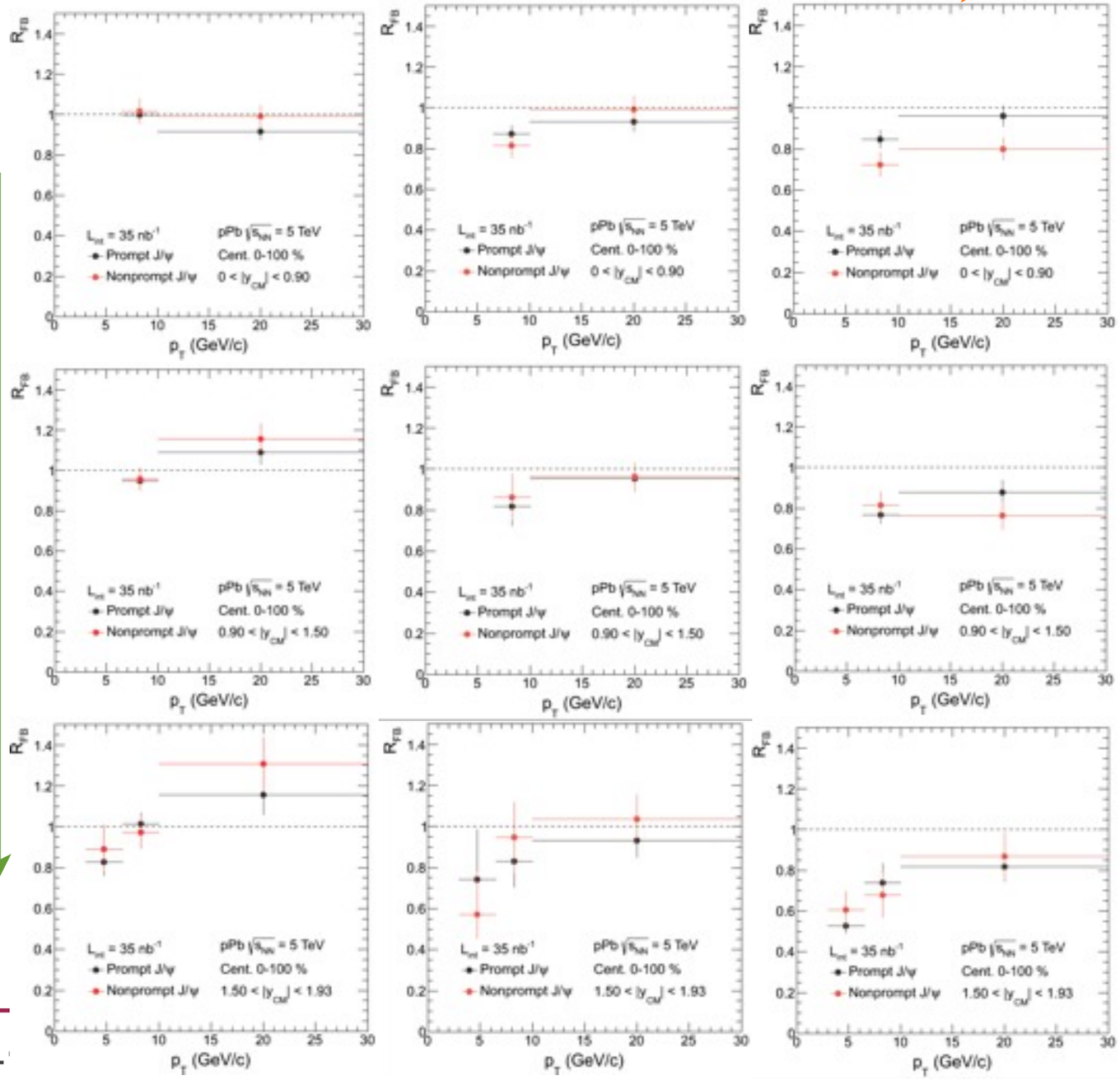
- **Preliminary results for dependency on N_{tracks}**
  - Not plotted in $<p_T>$ and and systematic uncertainties are in progress
  - Extracted signals will be double-checked later.

$0<N_{tracks}<65$ $65<N_{tracks}<95$ $95<N_{tracks}$

$0<|y_{CM}|<0.9$

$0.9<|y_{CM}|<1.5$

$1.5<|y_{CM}|<1.93$

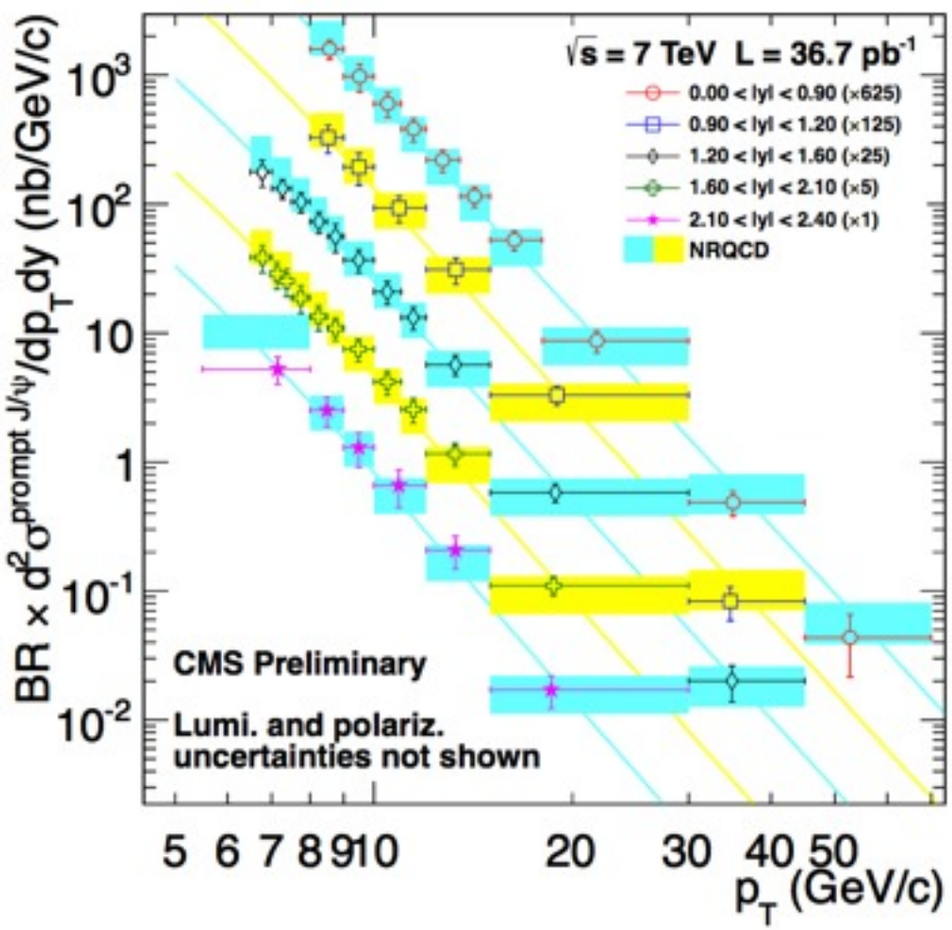


- Similar trends with E_T^{HF} bins

pp from theoretical prediction

- **BPH-10-014**

[Prompt]



[non-prompt]