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

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for Pre-approval Meeting
19th March 2014

ARC Members

- David d'Enterria (chairperson)
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- Camelia Maria Moronov
- Charles Felix Maguire

Documentation

- First version of PAS available, 10 pages
  http://cms.cern.ch/iCMS/analysisadmin/get?analysis=HIN-14-009-pas-v0.pdf
- Detailed analysis note : AN-13-346, 86 pages
  http://cms.cern.ch/iCMS/jsp/openfile.jsp?tp=draft&files=AN2013_346_v2.pdf
- Wiki :
  https://twiki.cern.ch/twiki/bin/viewauth/CMS/PAcharm2013

Target : QM 2014

CMS PAS HIN-14-009

DRAFT
CMS Physics Analysis Summary

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

The CMS Collaboration

Abstract

Prmopt and Non-prompt J/ψ are measured in pPb collisions at a centre-of-mass energy per nucleon pair of 5.02 TeV. The datasets used in the analysis correspond to recorded integrated luminosities of 35 nb^{-1} recorded by CMS in 2013. The kinematic range of observed J/ψ is transeverse momentum of 3.5 GeV/c to 30 GeV/c and rapidity of $-1.93 < y < 1.93$. Cross section and forward-backward asymmetry are studied to investigate the cold nuclear matter effect. A significant forward-backward asymmetry is observed for low p_T range. The phenomenon is manifest for central collisional events which was selected by high energy deposition in HF sub-detector installed at very forward rapidity ($4.2 < |\eta| < 5$).

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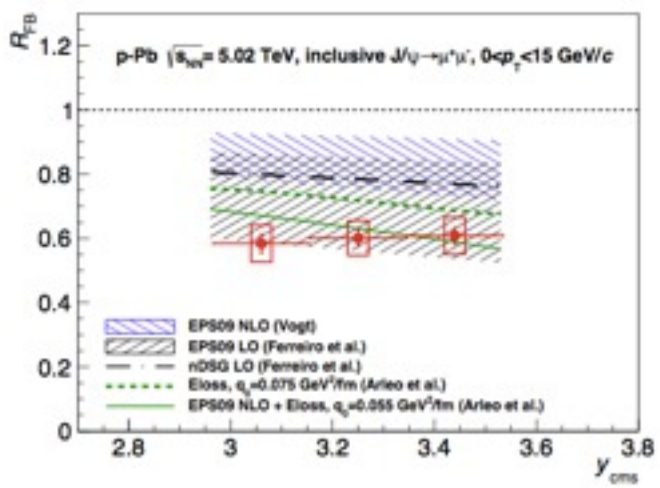
PDFAuthor:	Lamia Benhabib, Mihee Jo, Hyunchul Kim, Yongsun Kim, Kisoo Lee, Songkyo Lee
PDFTitle:	Jpsi production in pPb collisions
PDFSubject:	CMS
PDFKeywords:	physics, dimuons, proton Lead, charmonia, suppression, quark gluon plasma, shadowing

Please also verify that the abstract does not use any user defined symbols

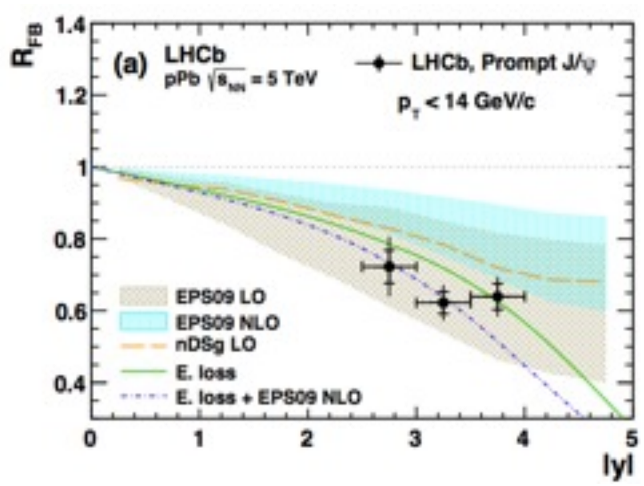
Outline

- **Introduction**
- **Event selection**
  - Datasets, trigger
- **Muon selection**
- **Signal extraction**
  - Prompt & non-prompt J/ψ
- **Acceptance correction**
- **Efficiency correction**
  - Efficiency from Monte Carlo study
  - TNP results and weighting
- **Results**
  - J/psi production cross-section
  - Forward-backward production ratio R_{FB}
  - E_T^{HF} dependency
- **Summary**

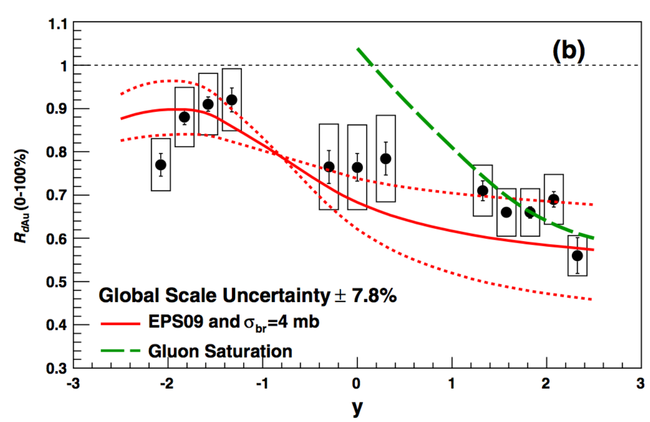
- **J/ψ R_{FB} from ALICE**
  - p_T < 15 GeV/c
  - 2.96< $|y_{CM}|$ < 3.53



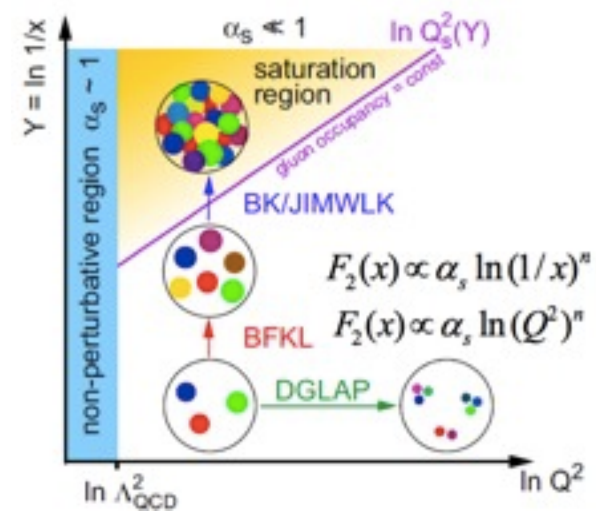
- **J/ψ R_{FB} from LHCb**
  - p_T < 14 GeV/c
  - 2< $|y_{CM}|$ < 5

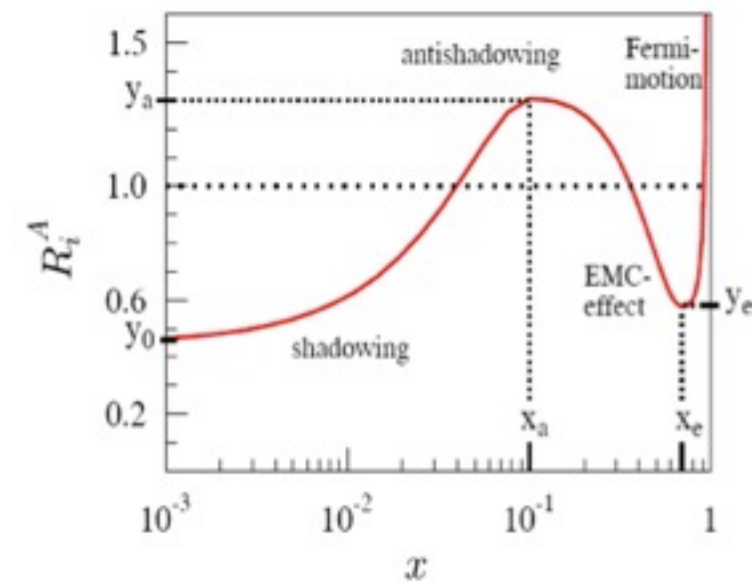


- **J/ψ R_{dAu} from RHIC**
  - p_T all (relatively low)
  - 0< $|y_{CM}|$ < 2.2



- **Although kinematic ranges are different, all results show the similar trends**
  - Forward/Backward < 1
  - Gluon saturation or shadowing at low x? (forward y & lower p_T)





- **J/ψ R_{FB} from CMS**
  - Investigate different kinematics ranges (mid-rapidity, higher p_T)
  - measure the multiplicity dependence

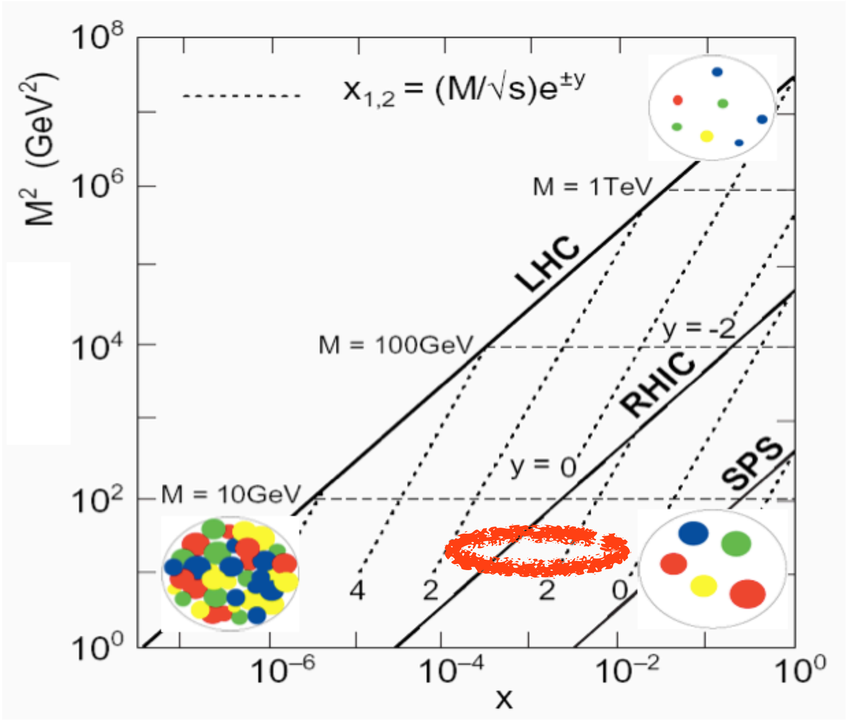
Introduction

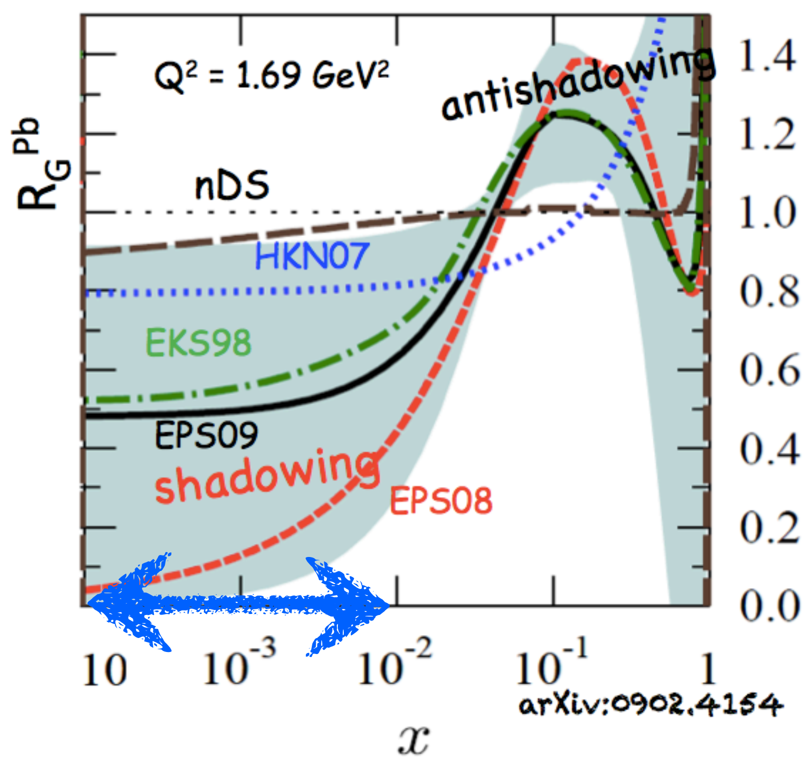
- **Rough calculation for x_2 (of Pb) range**
  - **In case of 2→1 process**

$$x_2 = \frac{Q}{\sqrt{S_{NN}}} e^{-y}$$

where $Q^2 = M^2 = M_{J/\psi}^2 + p_T^2$

- **Forward region (y_{CM} = 1.93)**
  (for p_T=6.5–30 GeV/c)
  x_2 = 0.0002 – 0.001
- **Backward region (y_{CM} = –1.93)**
  (for p_T=6.5–30 GeV/c)
  x_2 = 0.01 – 0.04





- R_i^{pPb} is different for various nPDFs (small x)
- We expect to investigate shadowing regions

Event Selection

- **pPb 2013 prompt reco datasets**
  - /PAMuon/HIRun2013-PromptReco-v1/RECO
  - CMSSW_5_3_8_HI_patch2 with the global tag GR_P_V43D:All
  - pp RECO algorithm is used
  - two subsets
    1. proton going to −z direction : run 210498-211256, L_{int} = 20.07±0.7 nb^{-1}
    2. proton going to +z direction : run 211313-211631, L_{int} = 14.0±0.5 nb^{-1}

       (run 210498-210658 with alignment problems are reconstructed again)
  - Trigger selection : HLT_PAL1DoubleMuOpen_v1

- **Onia2MuMu skim**
  - CVS : UserCode/tdahms/HiSkim/HiOnia2MuMu
  - same used in the pPb Upsilon analysis (HIN-13-003)
  - contains all pairs of tracker muons with $m_{\mu\mu}$ > 2GeV/c^2
  - pA pile-up events are rejected

https://twiki.cern.ch/twiki/bin/viewauth/CMS/HIOnia2MuMuSkimProcessingDetails2013

Muon Selection

- **Acceptance cut for single muons**
  - same with the pp 7 TeV J/ψ analysis

$-2.4 < \eta < 1.93$ (in lab frame)

$$
\begin{aligned}
|\eta^{\mu}| < 1.3 &\rightarrow p_{T}^{\mu} > 3.3\ GeV/c \\
1.3 < |\eta^{\mu}| < 2.2 &\rightarrow p^{\mu} > 2.9\ GeV/c \\
2.2 < |\eta^{\mu}| < 2.4 &\rightarrow p_{T}^{\mu} > 0.8\ GeV/c
\end{aligned}
$$

- **Muon quality criteria**
  - Recommended soft muon ID cut from muon POG

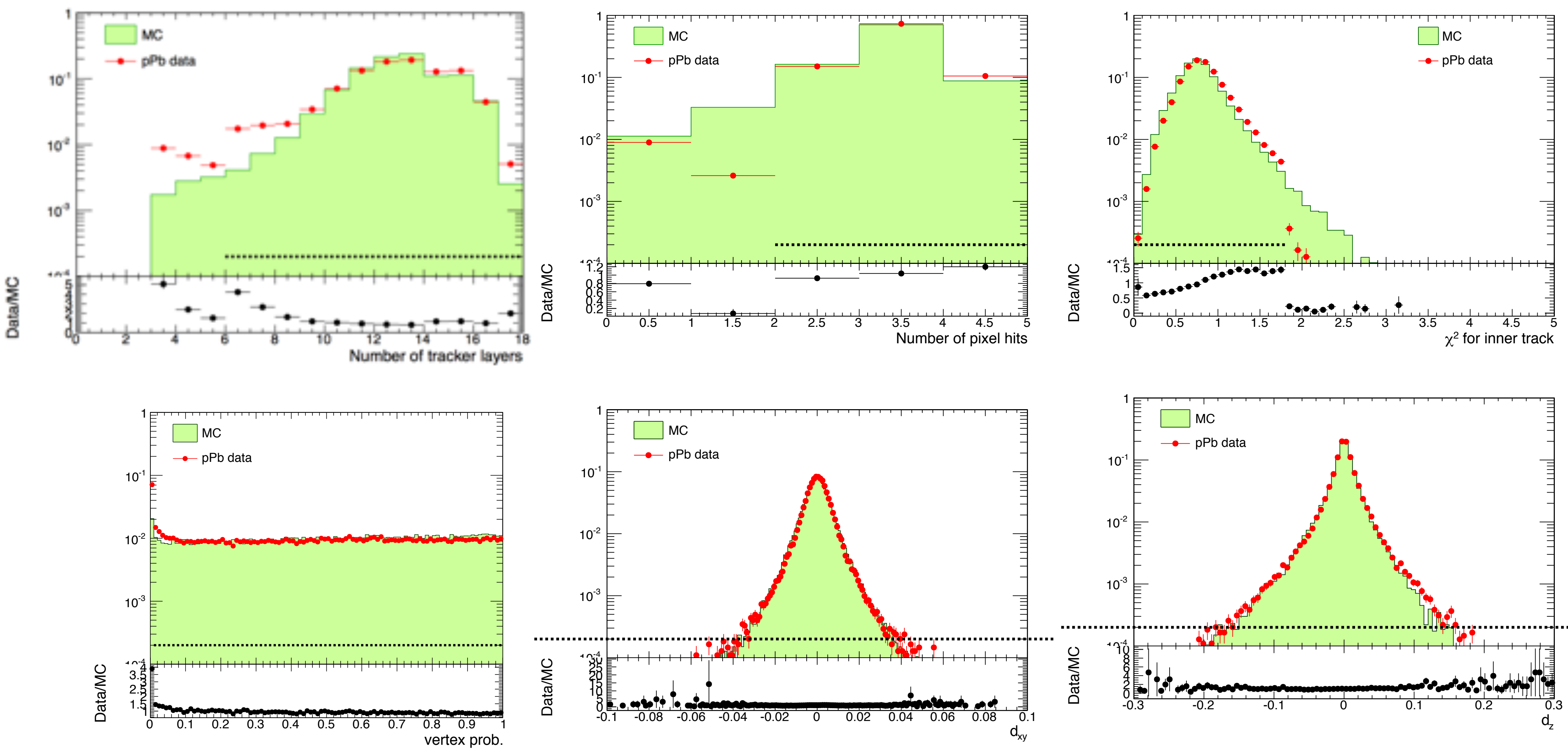
TrackerLayers > 5.0
PixelLayer > 1
Abs(Chi2InNormalized) < 1.8
Abs(Dxy) < 3.0
Abs(Dz) < 30
TrackerMuArbitrated == 1
StationTight = 1
VertexProbability > 0.01

Single muon ID variables

updated after frozen

DATA vs Prompt MC

- single muon acceptance cut, trigger matching,
  mass range [2.95–3.25] GeV/c^2 and kinematic range(p_T, y) of J/ψ selected
- L_{xy} cut is applied to DATA to remove non-prompt contribution
- Applying all the other cuts except one in distribution



- They agree in the selected regions (black dashed line).
- TnP and Muon ID will be presented in muon POG meeting for validation.

Binning for the analysis

- **For differential cross-section**
  - y_{CM} [−2.4, −1.5, −1, 0, 1, 1.5, 1.93]
  - p_T [0, 3, 6.5, 7.5, 8.5, 9.5, 11, 14, 30] GeV/c
    (p_T < 6.5 GeV/c bins are only for the most forward & backward bins)

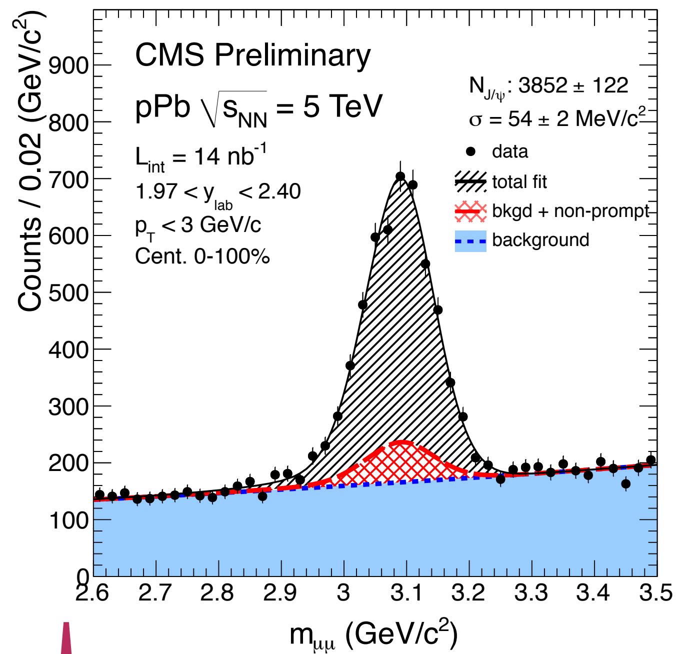
- **For R_{FB} measurement**
  - y_{CM} [−1.93, −1.5, −1.2, −0.9, −0.5, 0, 0.5, 0.9, 1.2, 1.5, 1.93]
  - p_T [3, 6.5, 8.5, 11, 30] GeV/c
    (p_T < 6.5 GeV/c bins are only for the most forward & backward bins)

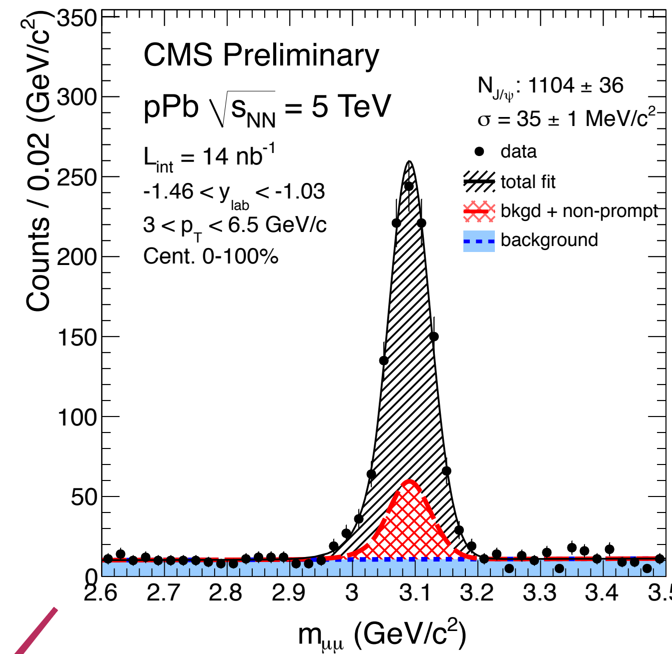
- **For E_T^{HF} dependent R_{FB}**
  - y_{CM} [−1.93, −1.5, −0.9, 0, 0.9, 1.5, 1.93]
  - p_T [3, 6.5, 10, 30] GeV/c
    (p_T < 6.5 GeV/c bins are only for the most forward & backward bins)

p_T binning

- Binning for the low p_T

Most forward bin
$0 < p_T < 3$ GeV/c





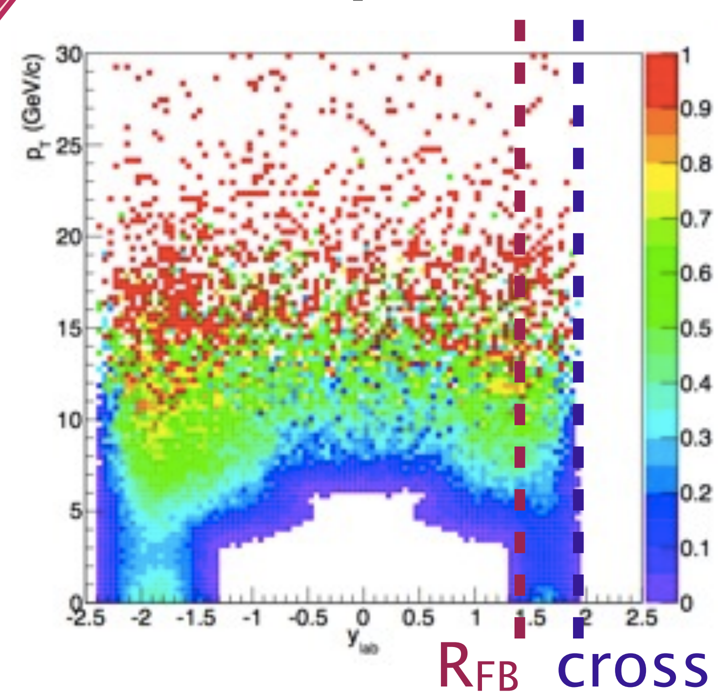
Most Backward bin
$3 < p_T < 6.5$ GeV/c

(No signals in
$0 < p_T < 3$ GeV/c)

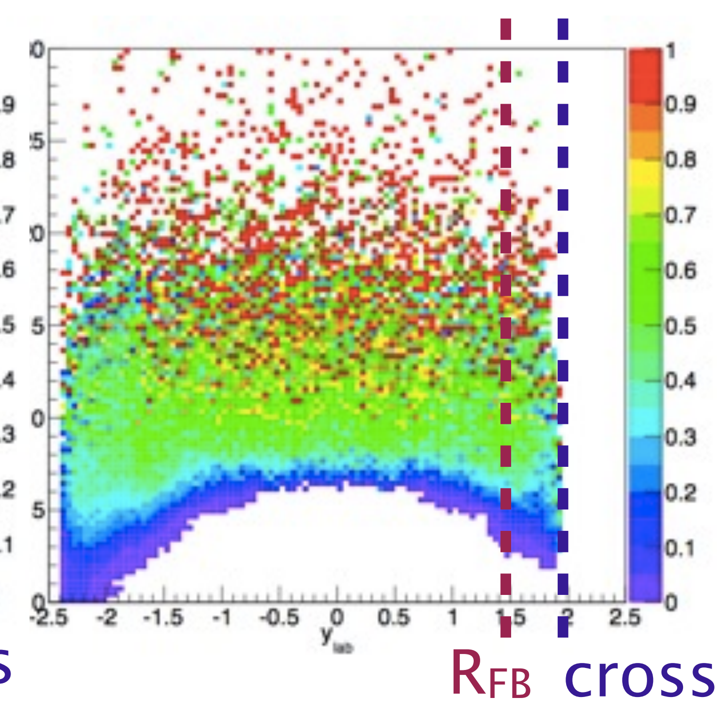
- included in <u>cross-section</u>
- can not be added in <u>R_{FB}</u>
  (where y_{CM} bin is symmetric)

- y_{CM}=[1.5-1.93] and
  p_T= [3-6.5] GeV/c bin
  is added in <u>R_{FB}</u>

[Acceptance]



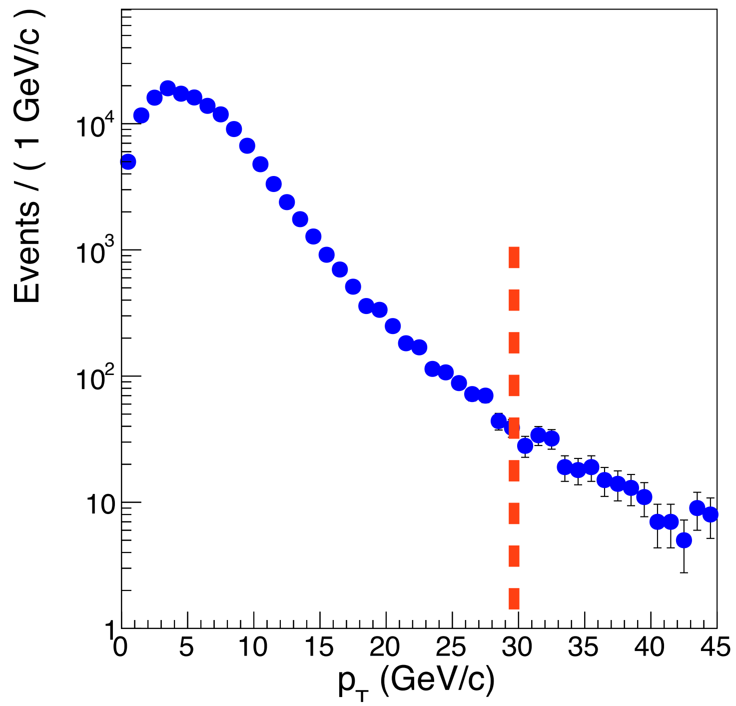
[Efficiency]

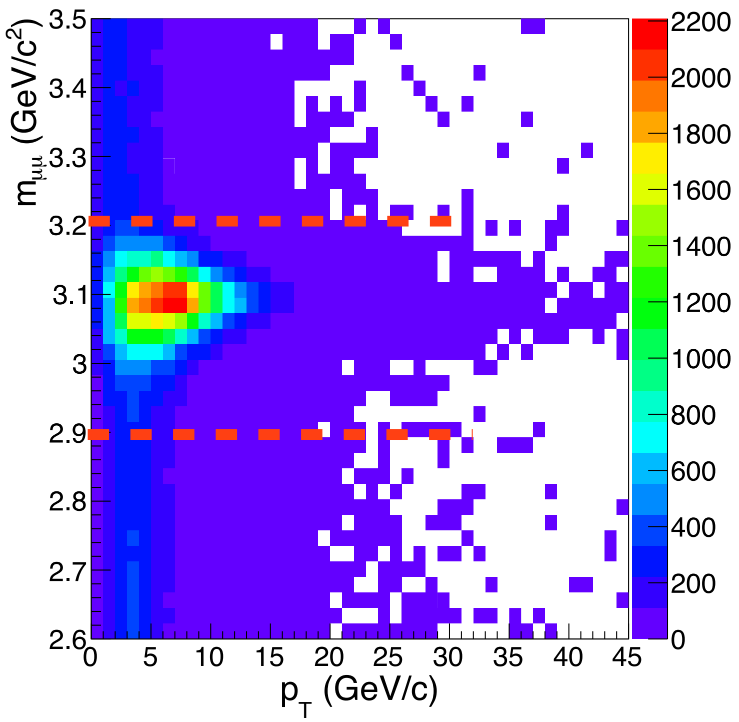


FW **BW** **FW** **BW**

Binning for the high p_T

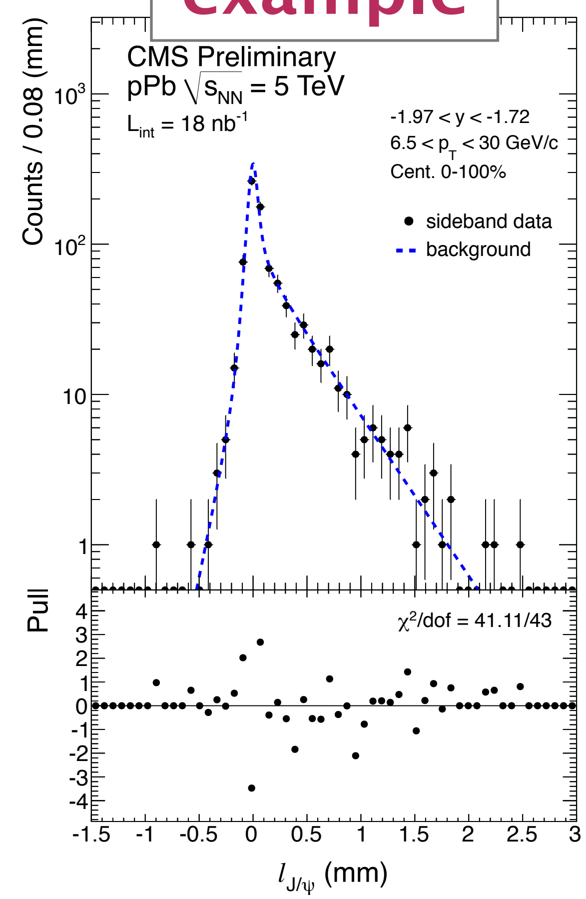
- dimuon distributions in datasets (from 2nd run periods)



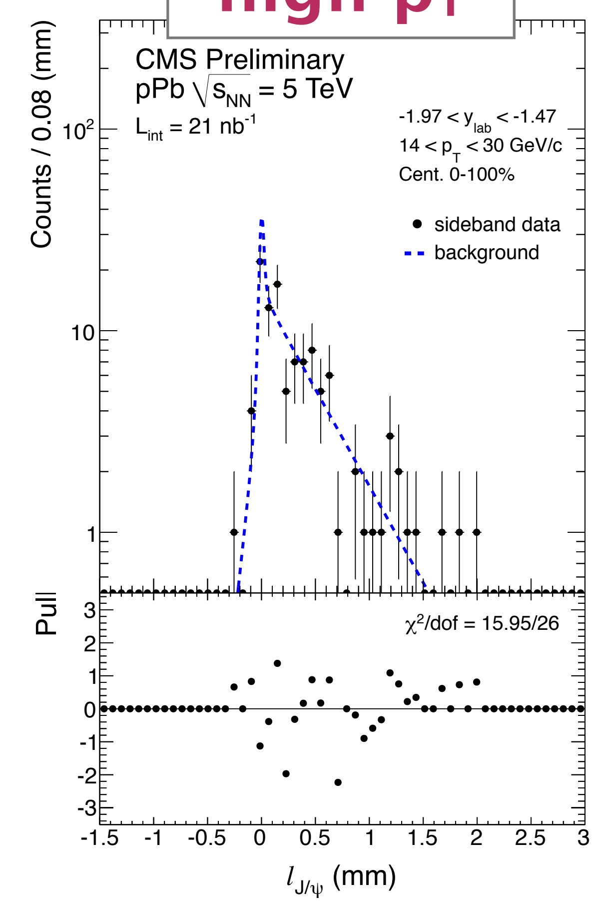


- Set the p_T upper limit 30 GeV/c depending on the number of signals
- For higher p_T bin (with wide bin width), not enough statistics in the sideband regions to fit the $\ell_{J/\psi}$ shape of background.

example



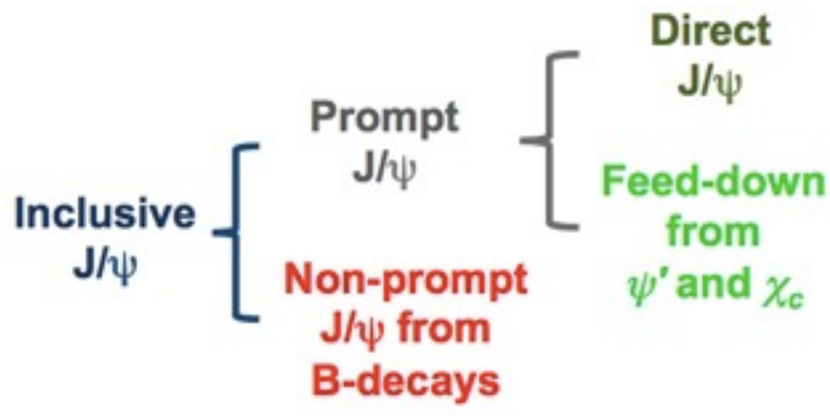
high p_T



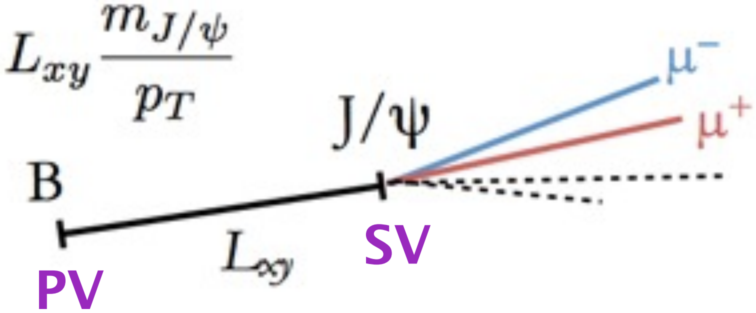
Signal Extraction

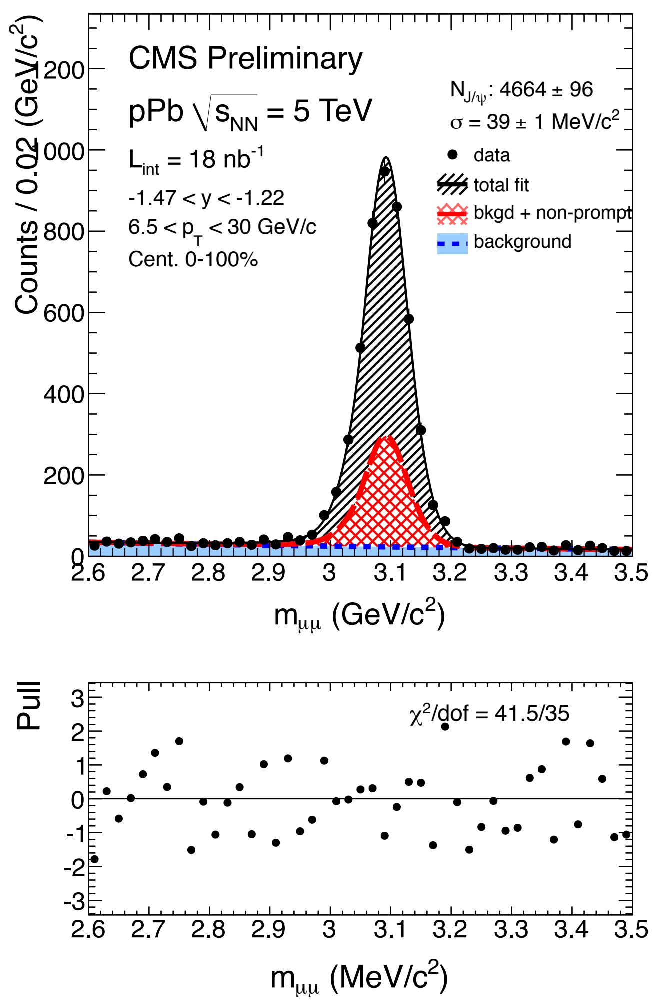
- **Separation of prompt J/ψ and non-prompt J/ψ**
  - 2-Dimensional simultaneous fit for $m_{\mu\mu}$ & $\ell_{J/\psi}$
  - Fitting procedure is same with the pp & PbPb analysis

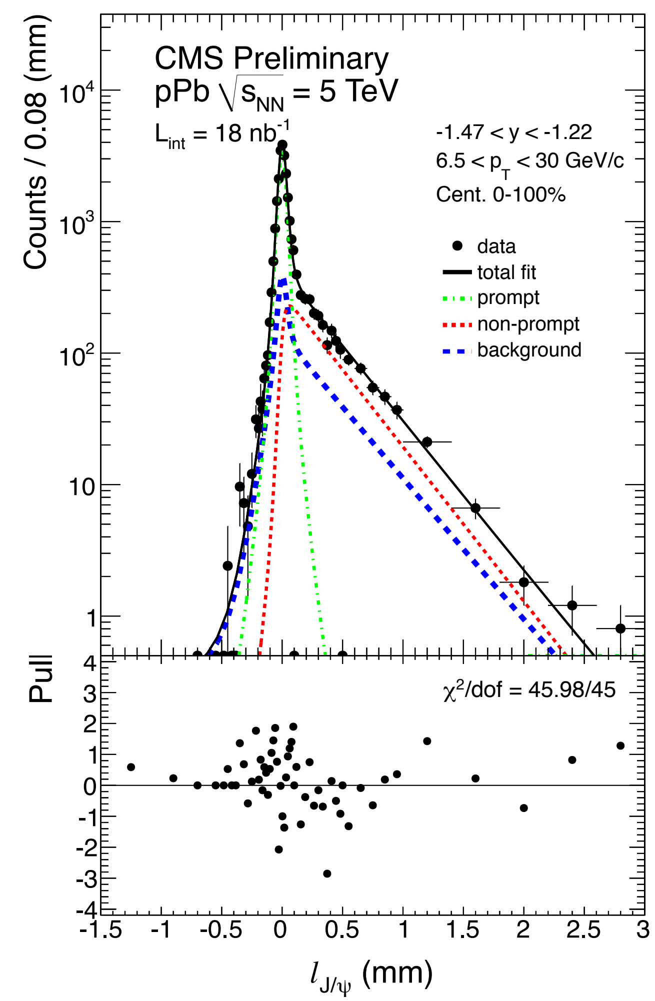
lifetime of the b hadrons ($\mathcal{O}(500)\ \mu m/c$)



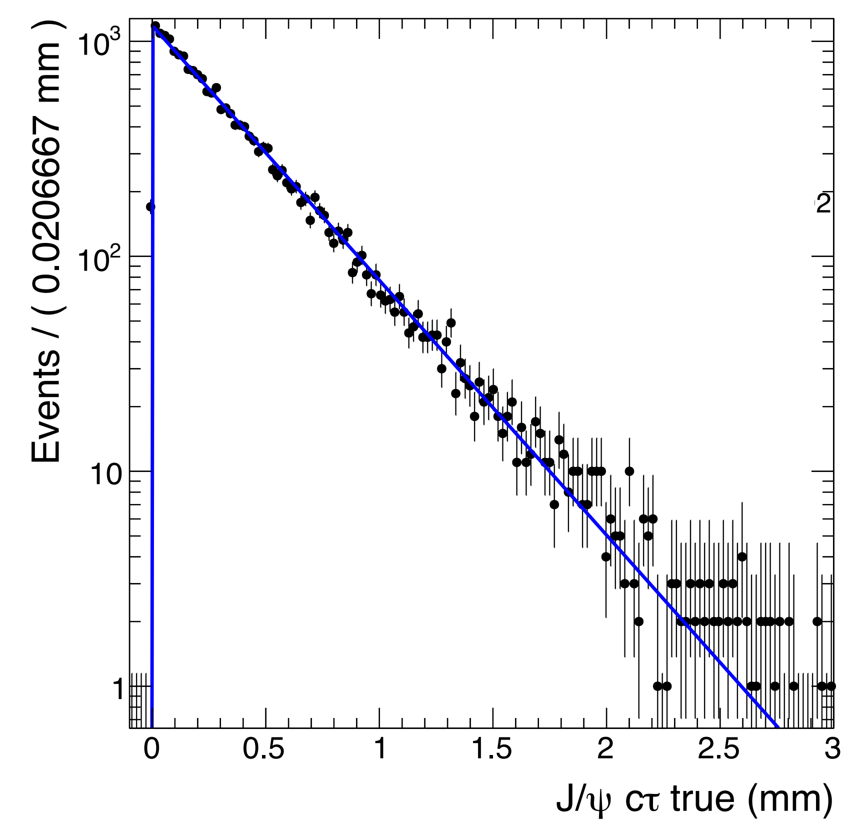
$$\ell_{J/\psi} = L_{xy}\frac{m_{J/\psi}}{p_T}$$







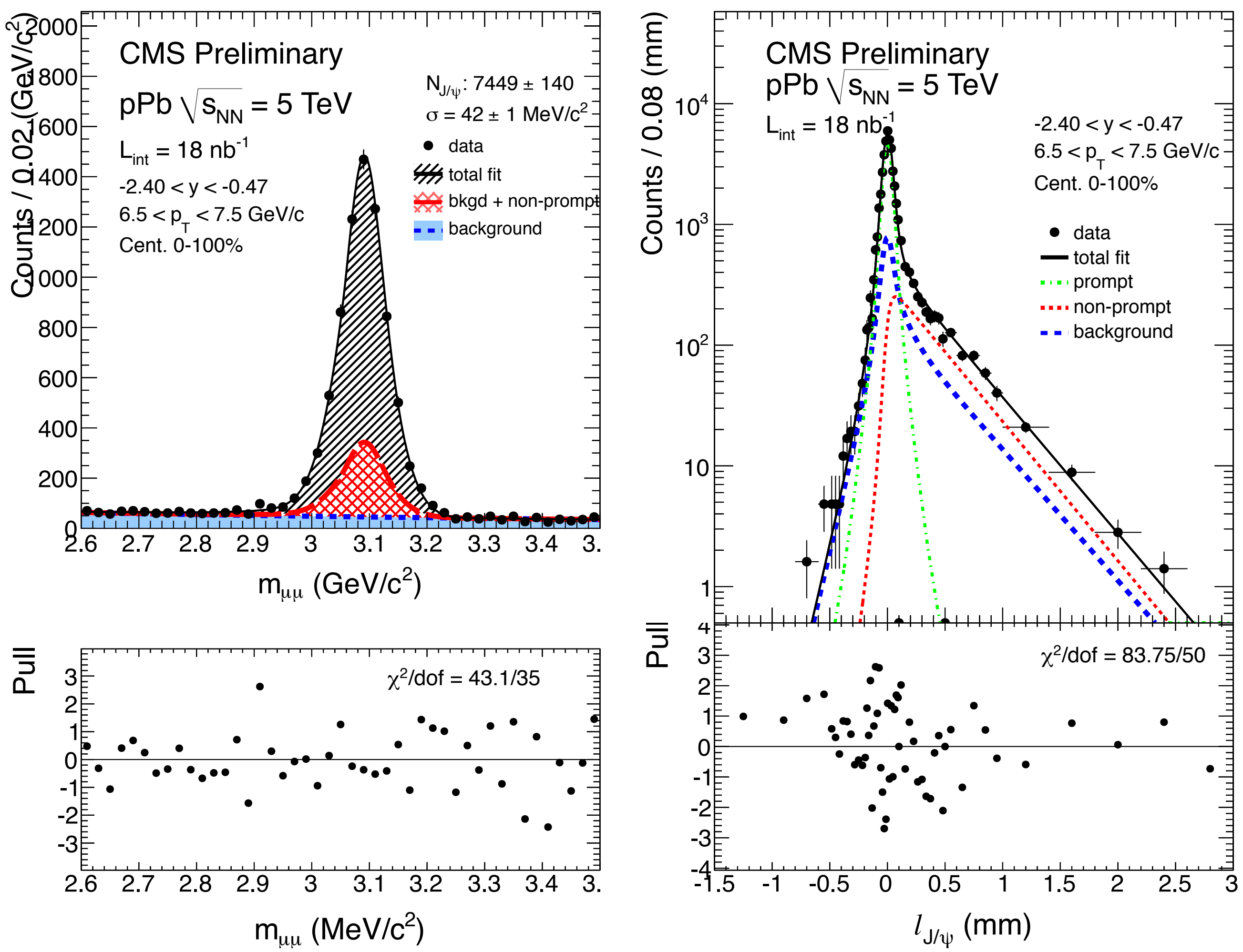
- **Non-prompt MC**



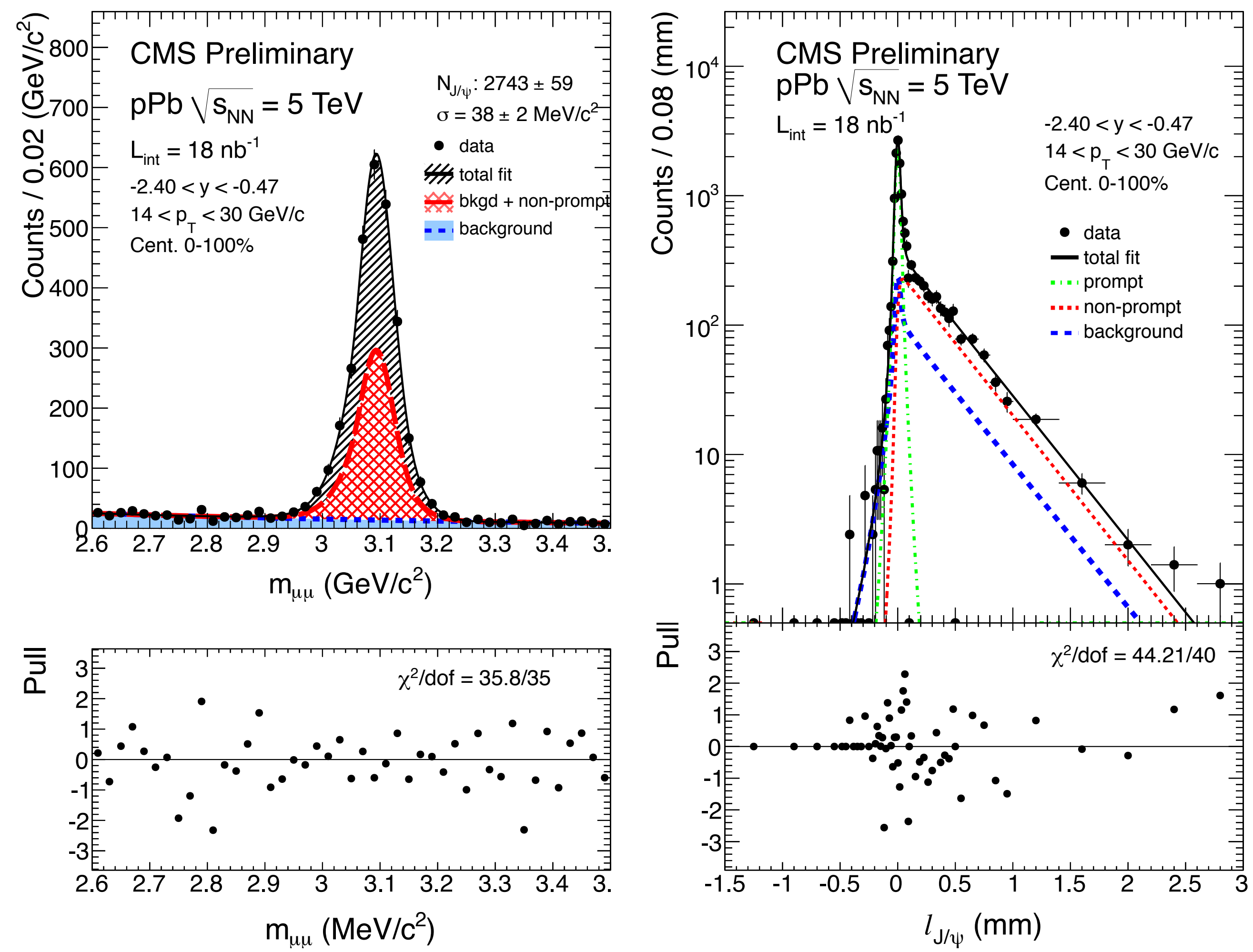
Signal Extraction

- **Mass and $\ell_{J/\psi}$ plots of some bins (1st run period)**
  - $-2.4 < y_{lab} < -0.47$

$6.5 < p_T < 7.5$ GeV/c



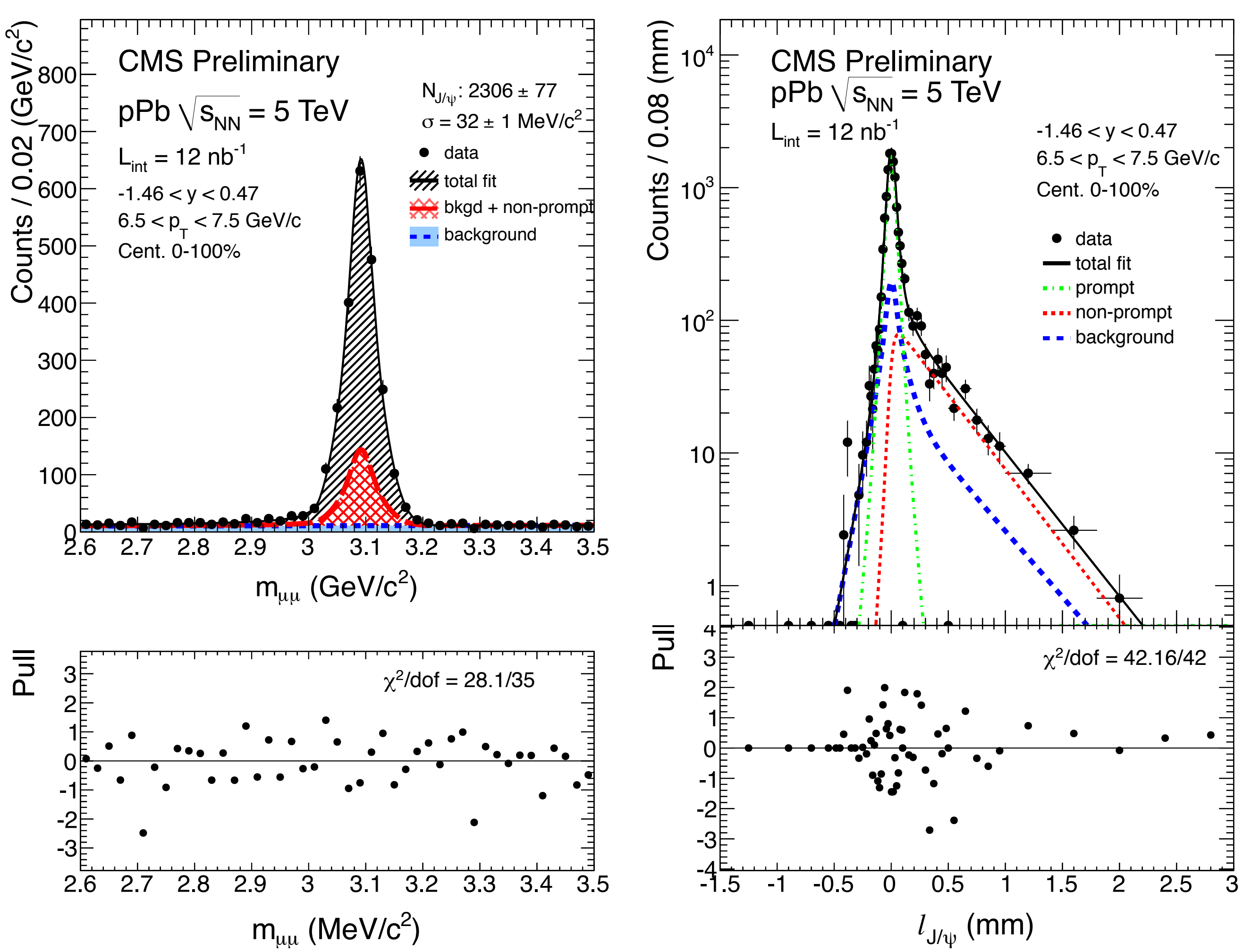
$14.0 < p_T < 30$ GeV/c



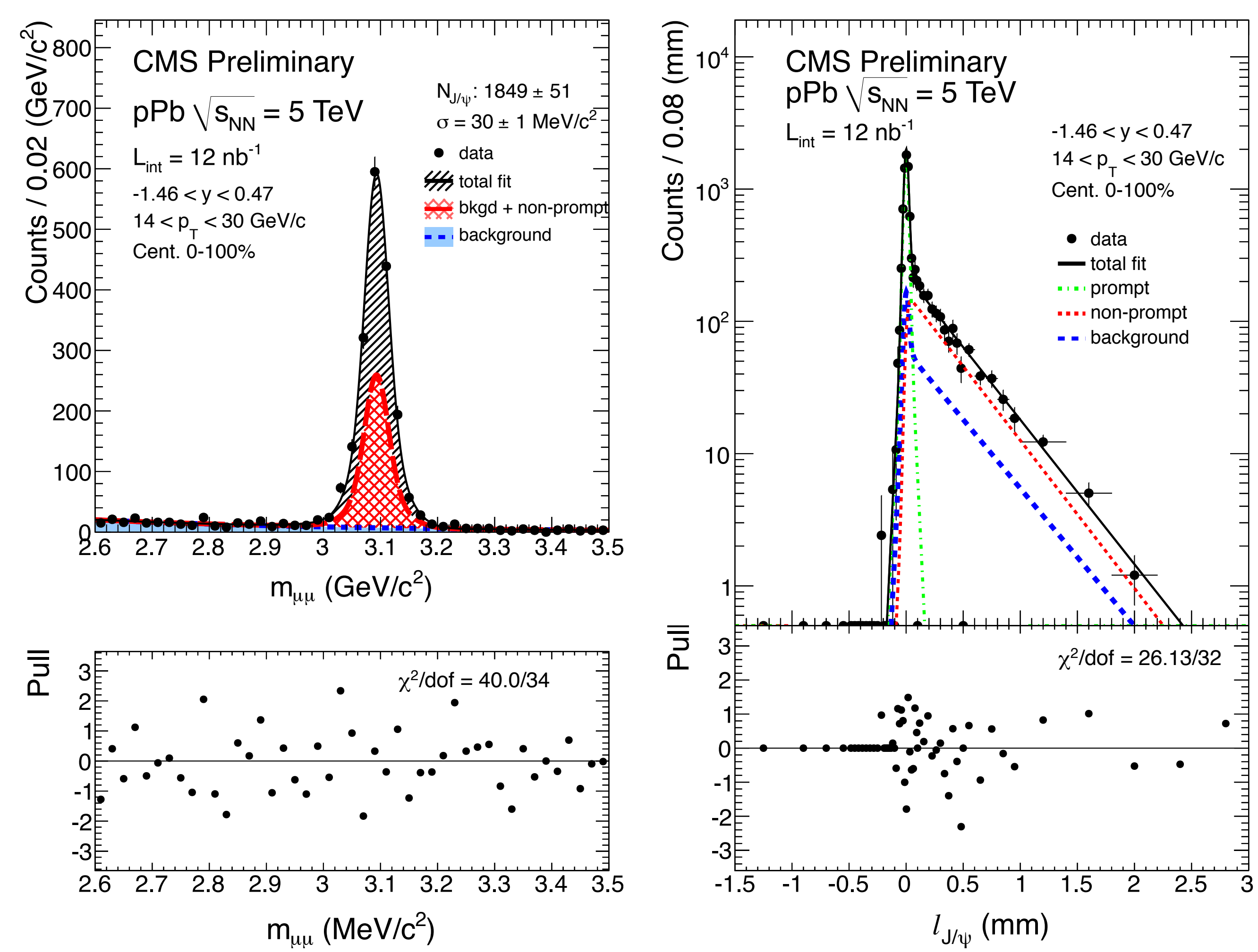
* All the plots for other bins are on AN (appendix A)

- **Mass and $\ell_{J/\psi}$ plots of some bins (2nd run period)**
  - $-1.46 < y_{lab} < 0.47$

$6.5 < p_T < 7.5$ GeV/c



$14.0 < p_T < 30$ GeV/c



* All the plots for other bins are on AN (appendix A)

Signal Extraction

- **Systematic uncertainties (4 alternative shape and method)**
  - $m_{\mu\mu}$ distribution of signal

    one gaussian + one crystal ball → one crystal ball

  - $m_{\mu\mu}$ distribution of background

    exponential → 1st order polynomial

  - $\ell_{J/\psi}$ distribution of prompt MC (resolution function)

    sum of two gauss → only one gauss

  - $\ell_{J/\psi}$ distribution of non-prompt MC

    exponential for lifetime shape → from MC lifetime template

Acceptance Correction

- **pp boosted 5 TeV prompt J/ψ sample used**
  - produced with the same configuration setting as the official, from which the kinematic filters on the signal were removed
- **Acceptance definition**

$$\alpha = \frac{N^{dimuon}_{reconstructible,M1}(p_T, y)}{N^{dimuon}_{generated}(p_T, y)}$$

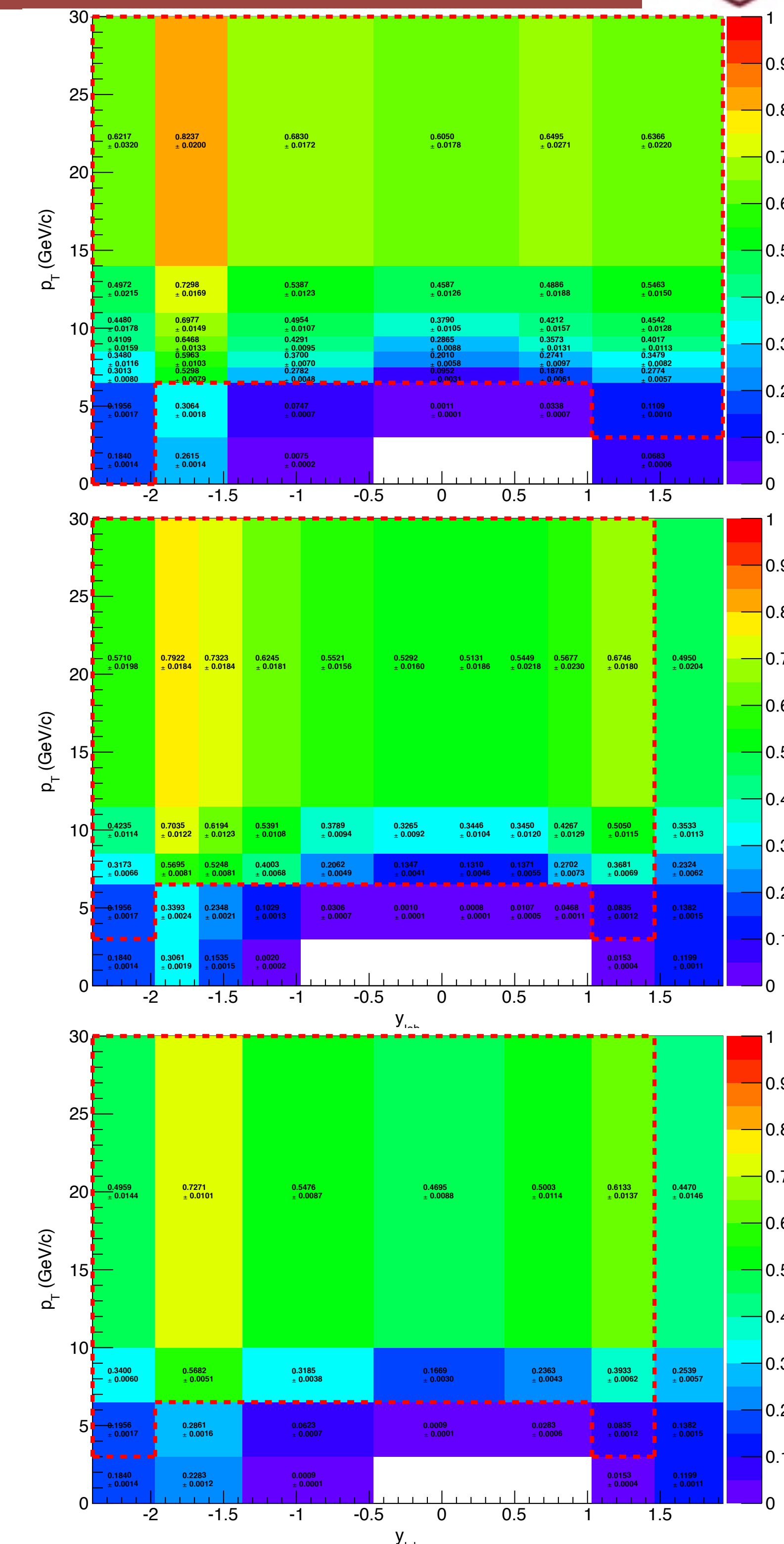
- **dimuon condition**
  - μ^{+-} pairs from J/ψ
  - within $-2.4 < y_{lab} < 1.93$

- **reconstructable**

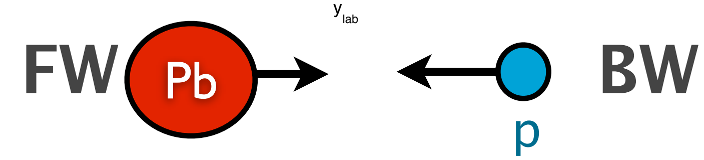
$-2.4 < \eta < 1.93$

$$|\eta^{\mu}| < 1.3 \rightarrow p_T^{\mu} > 3.3\ GeV/c$$
$$1.3 < |\eta^{\mu}| < 2.2 \rightarrow p^{\mu} > 2.9\ GeV/c$$
$$2.2 < |\eta^{\mu}| < 2.4 \rightarrow p_T^{\mu} > 0.8\ GeV/c$$

- **mass cut M1**
  - $2.6 < m_{\mu\mu} < 3.5\ GeV/c^2$



- 2D-correction for p_T & y
  - Upper : Cross-section
  - Middle : R_{FB}
  - BOTTOM : R_{FB} with E_T^{HF}



Acceptance Correction

- **Systematic Uncertainties (4 cases)**
  - Shapes of the generated p_T and y distributions are varied linearly by ±30%
    1. p_T up +30%
    2. p_T down -30%
    3. y up +30%
    4. y down -30%
  - This method is consistent with
    PbPb quarkonia[HIN-10-006] and pPb Upsilon analysis[HIN-13-003].

MC Efficiency

- **pp boosted 5 TeV, official MC sample for prompt & non-prompt**
  PYTHIA6_JPsiWithFSR_tuneD6T_5TeV02%2Ftdahms-Onia2MuMu_Jpsi_HiWinter13-pa_STARTHI53_V25-v1
  PYTHIA6_inclBtoPsiMuMu_5TeV02%2Ftdahms-Onia2MuMu_InclB2Psi_HiWinter13-pa_STARTHI53_V25-v1

- **Efficiency definition**

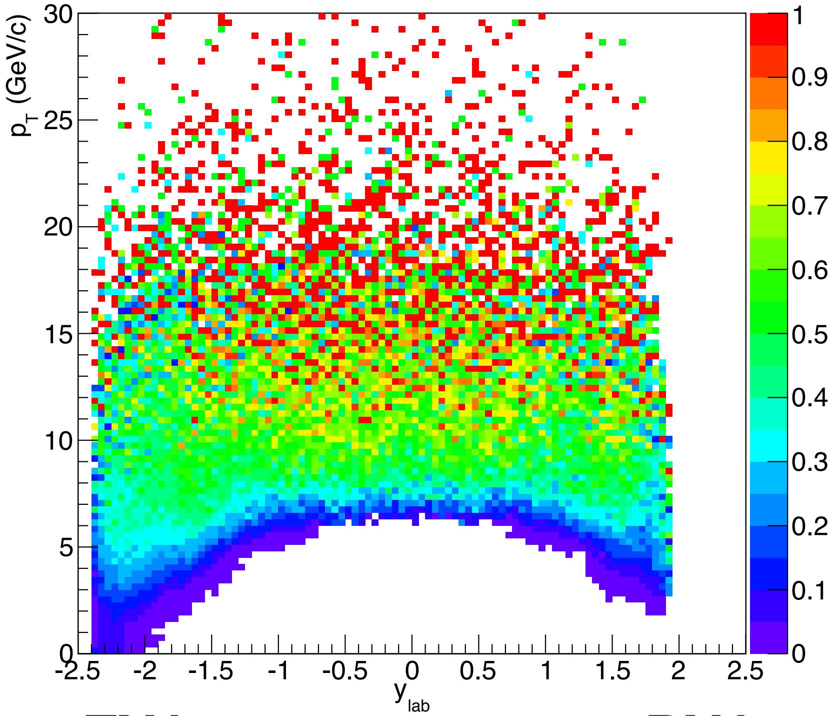
$$\varepsilon = \frac{N_{detectable}^{dimuons\ reconstructed, M2, muIDcut, triggerselection}(p_T, y)}{N_{detectable}^{dimuon\ generated, M1}(p_T, y)}$$

  - Denominator (GEN)= dimuon + acceptance cut + mass cut 1
  - Numerator (RECO)= dimuon + acceptance cut + mass cut 2 + mu ID cut + trigger selection

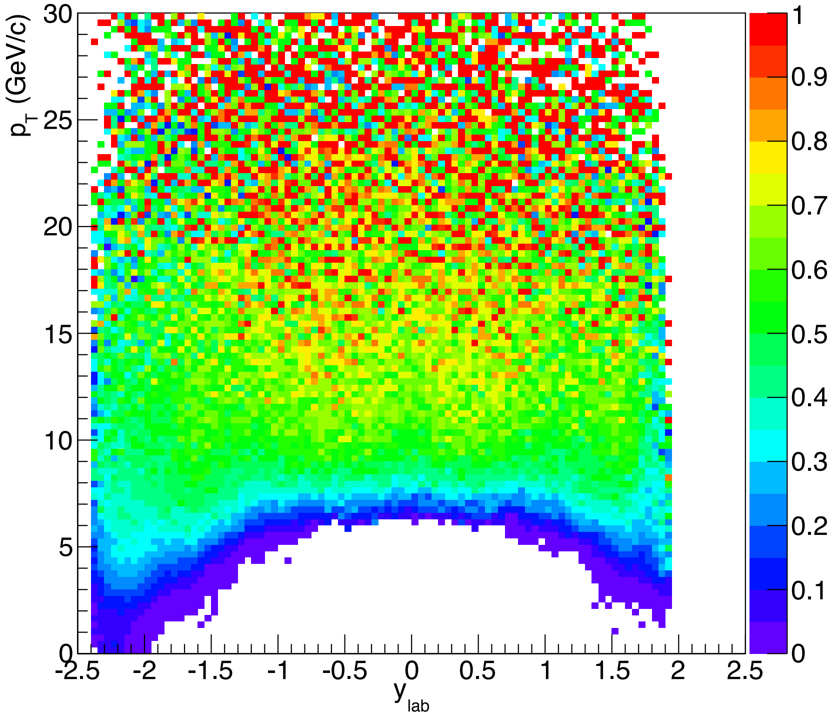
- **mass cut 1**
  2.6 < m < 3.5 GeV/c^2
- **mass cut 2**
  2.95 < m < 3.25 GeV/c^2

* Tighter mass cut 2 is used for the peak counting method

[Prompt]



[Non-prompt]



FW BW FW BW

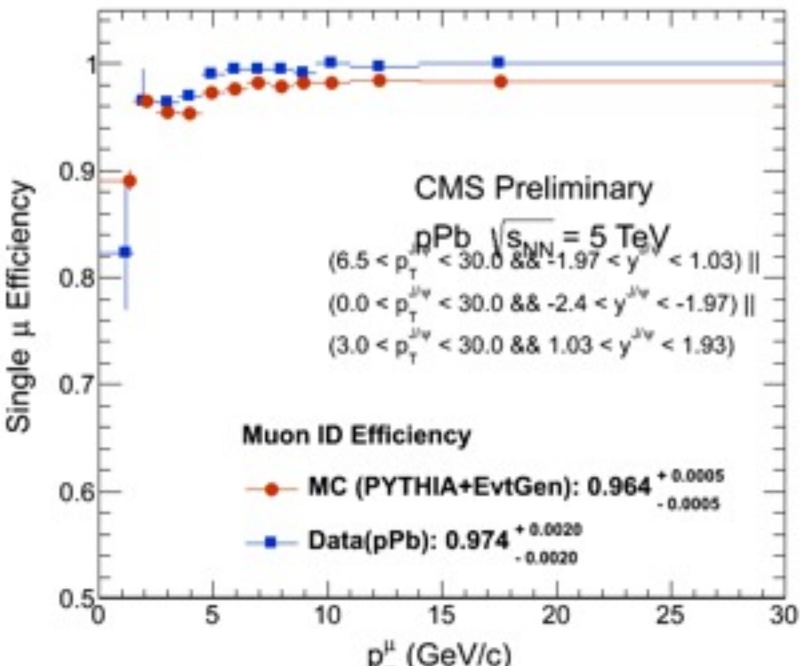
Tag and Probe

updated after frozen

Tag and Probe

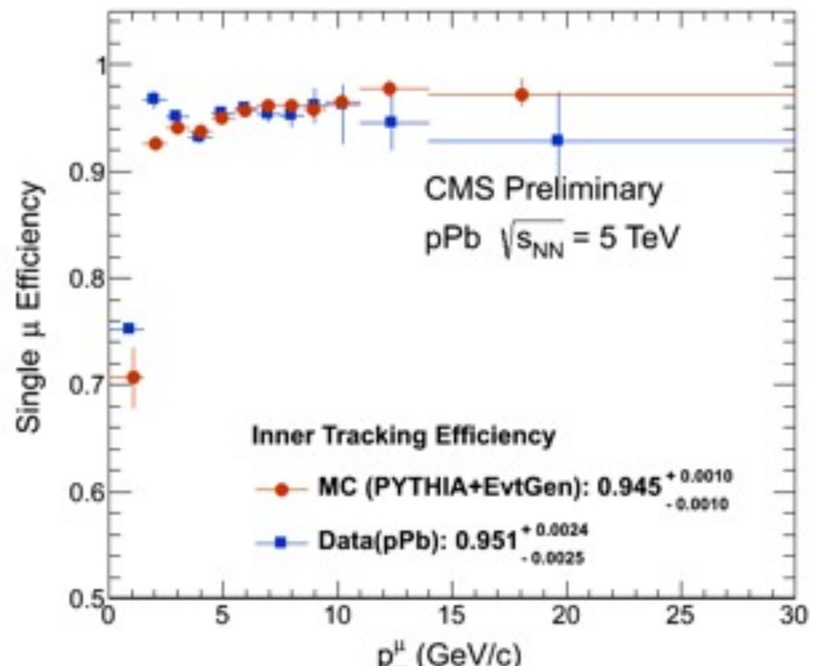
- efficiency = passing/(passing + failing)
- Trigger matching is corrected

[muon ID efficiency]



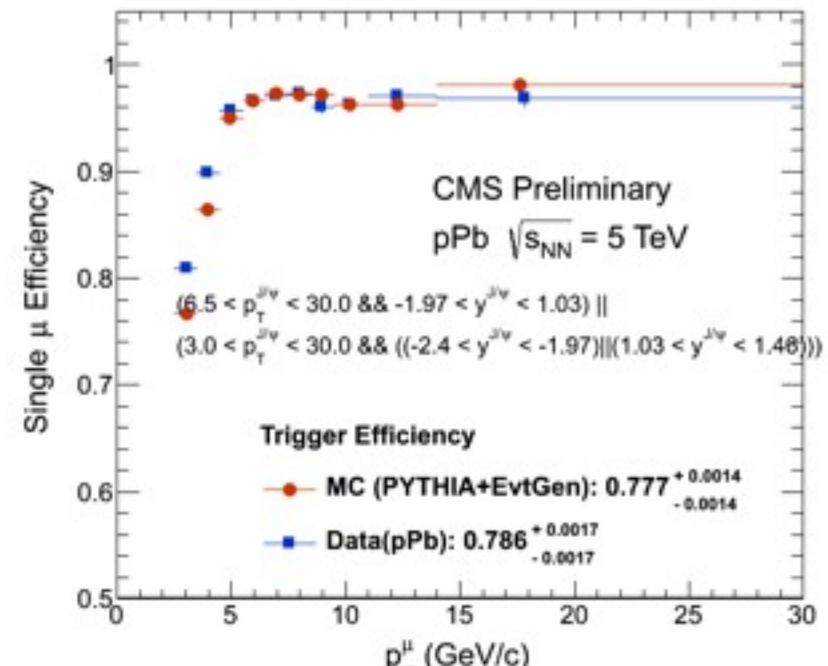
- Tag : trkMu with double trig
- Probe : caloMu without trig
- Passing : matched to trkMu

[Tracking efficiency]

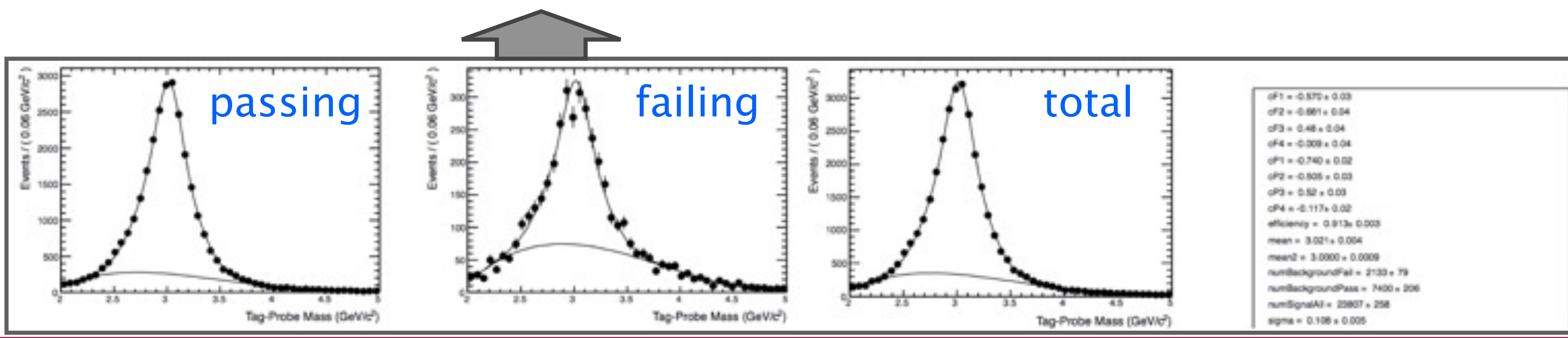


- Tag :trkMu with double trig
- Probe : outer track is non-null
- Passing : matched to trkMu

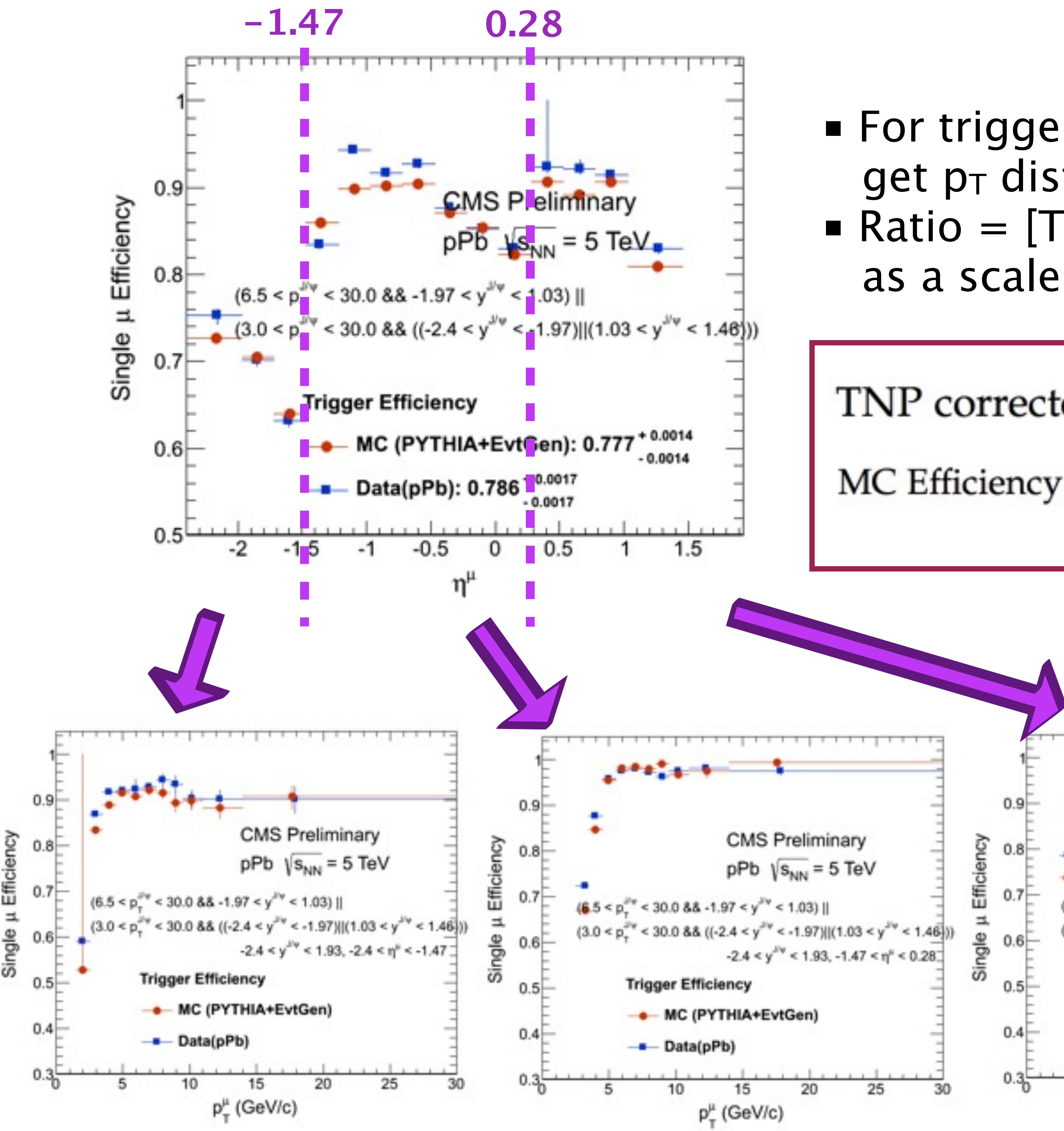
[Trigger efficiency]



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

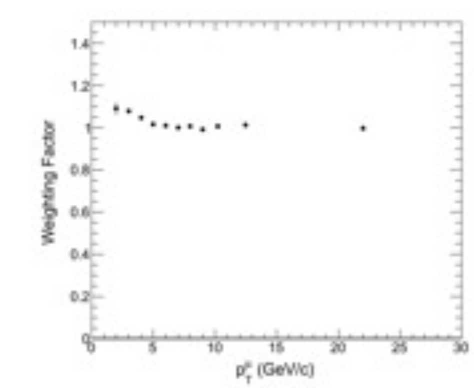


Re-weight using TNP



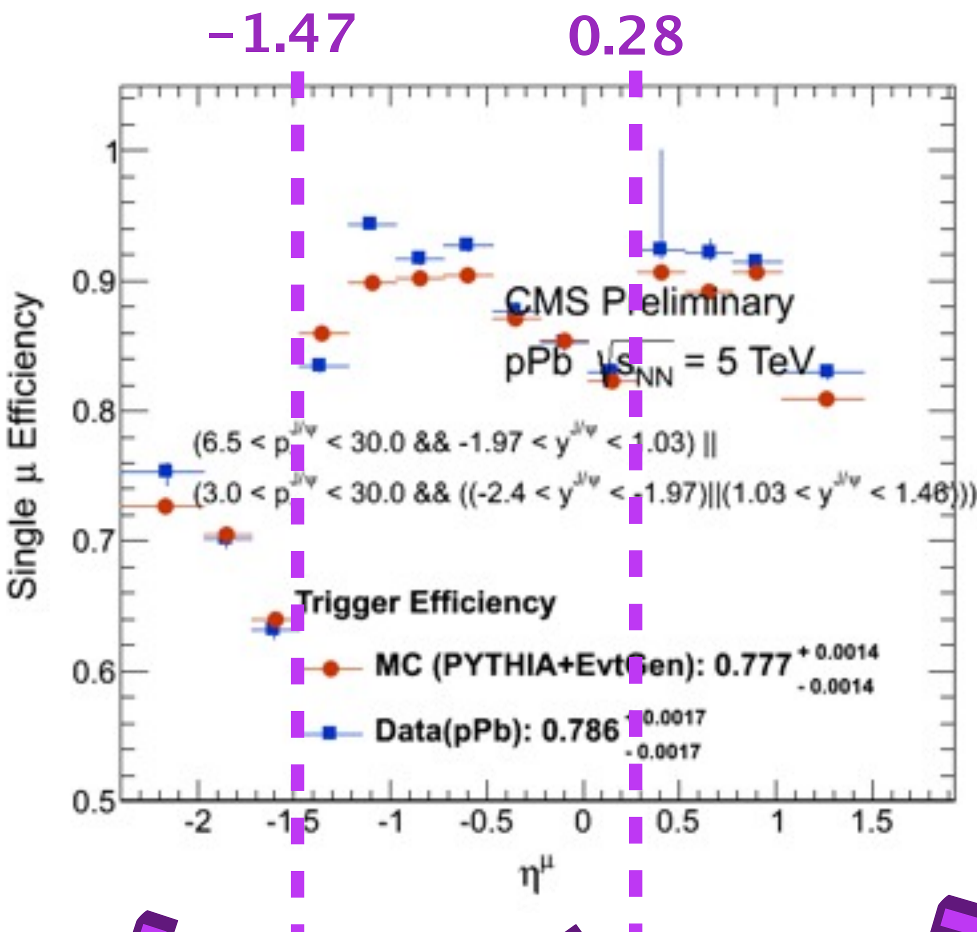
- For trigger efficiency, get p_T distributions for 3 different eta ranges.
- Ratio = [TNP Data]/[TNP MC] as a scale factor for MC efficiency

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

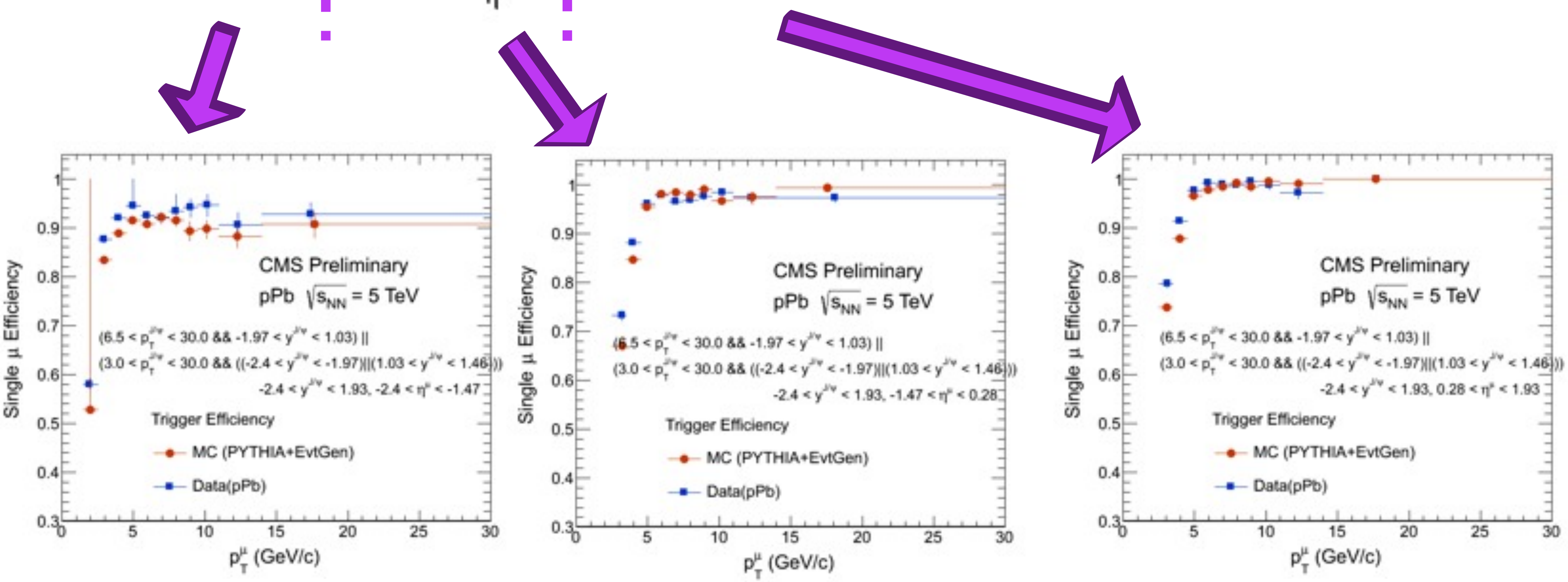


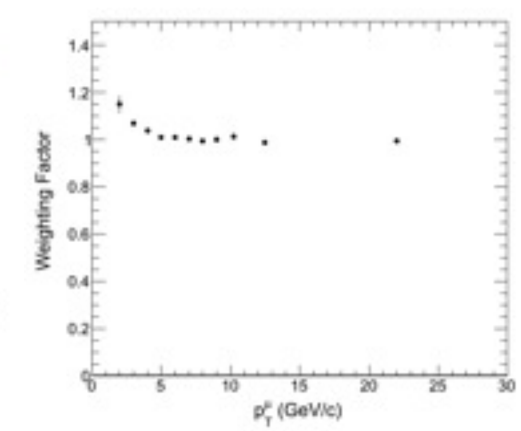
1st run period

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

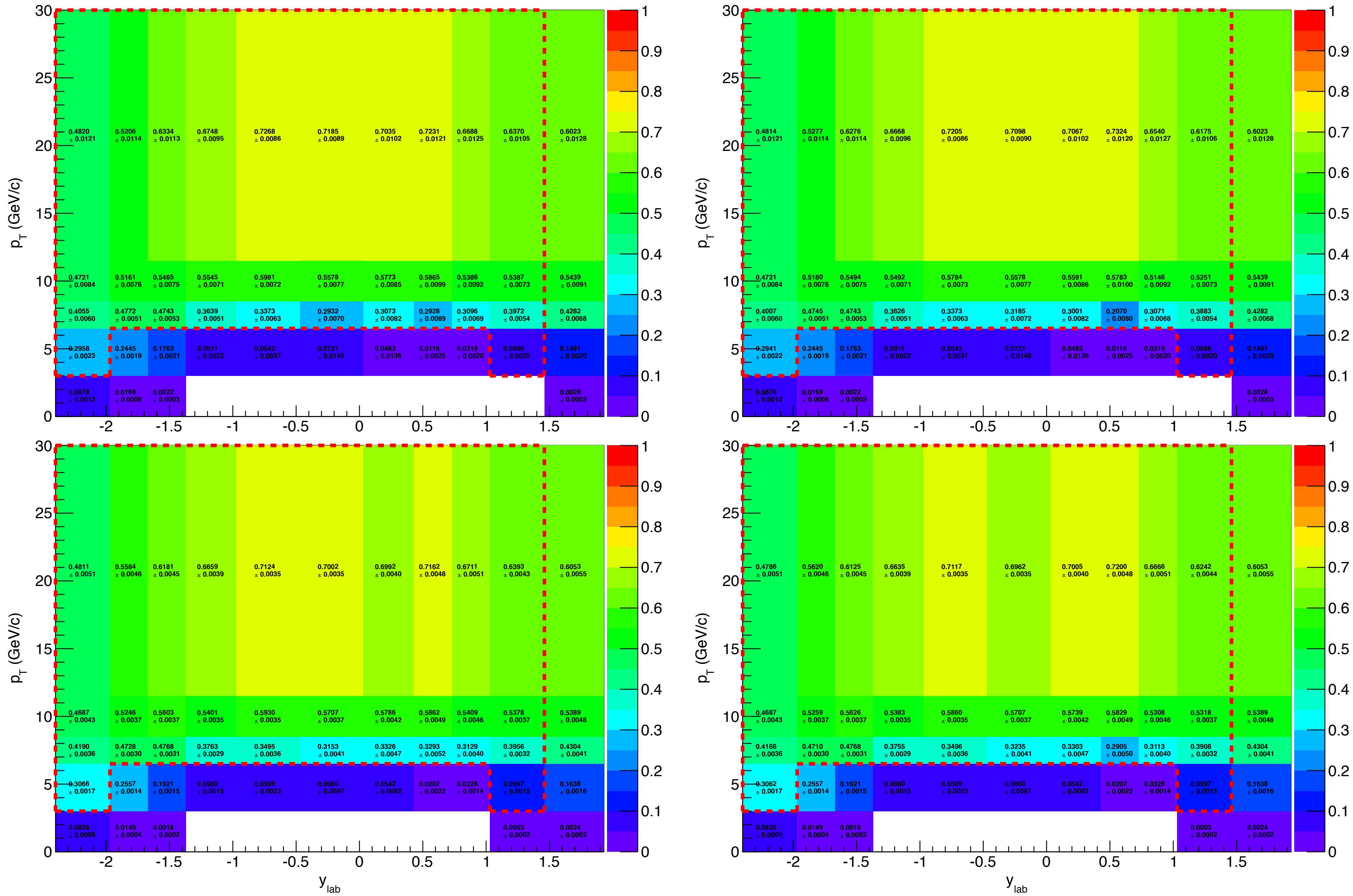
Efficiency

- 2D efficiency table p_T vs y_{lab} for R_{FB} measurement
- Results for other binning are on AN

[1st run] [2nd run]

[Prompt]

[Non-prompt]



Systematic Uncertainties

- Consider the difference between MC efficiency and TNP weighted efficiency

Results : Cross-section

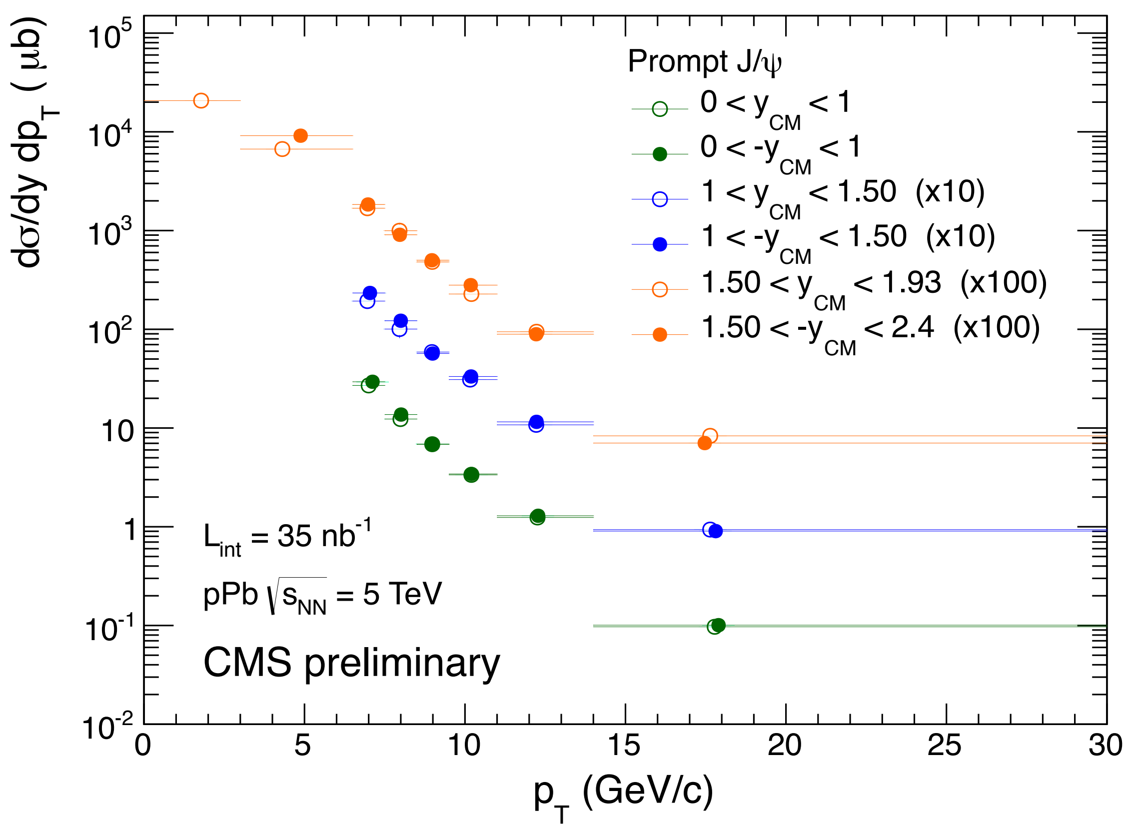
Double differential cross-section

PAS Fig.4 – Fig.5

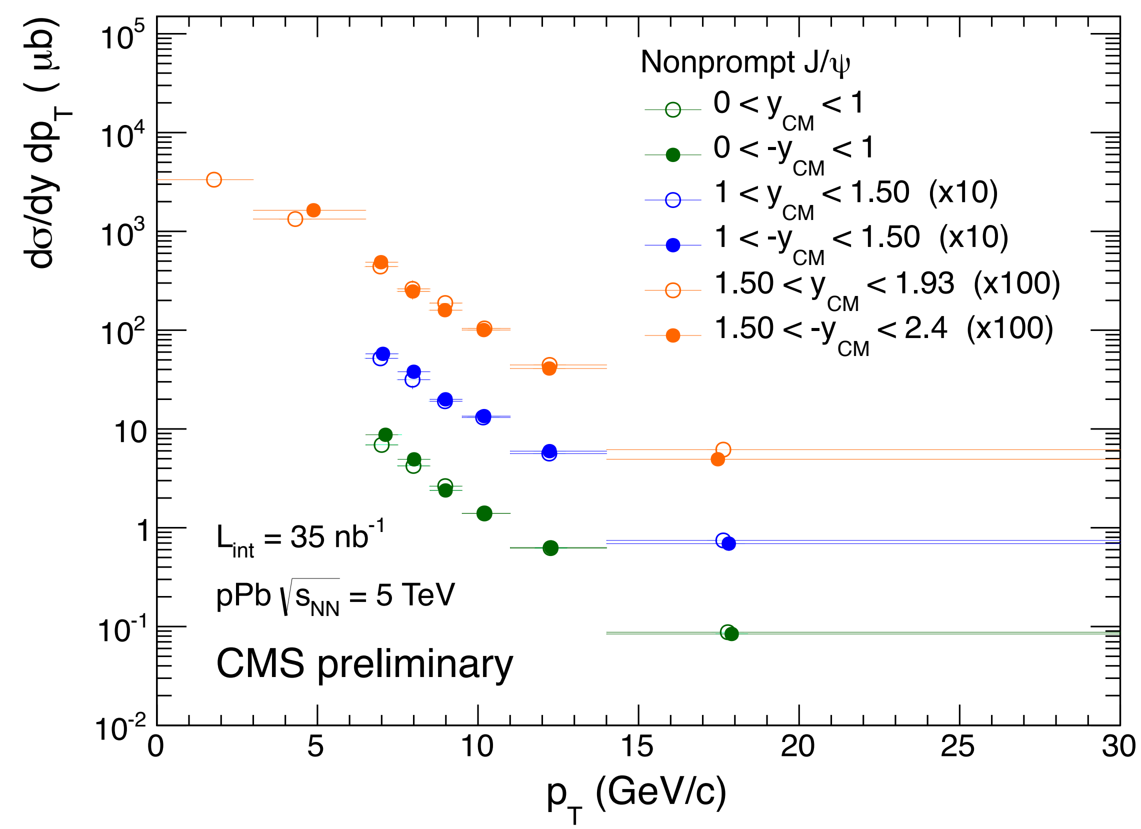
$$\frac{d^2\sigma}{dp_T dy} = \frac{N^{corr}(J/\psi \to \mu^+\mu^-)}{L_{int} \times B(J/\psi \to \mu^+\mu^-) \times \Delta p_T \Delta y}$$

- $N^{corr}(J/\psi \to \mu^+\mu^-)$ 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]



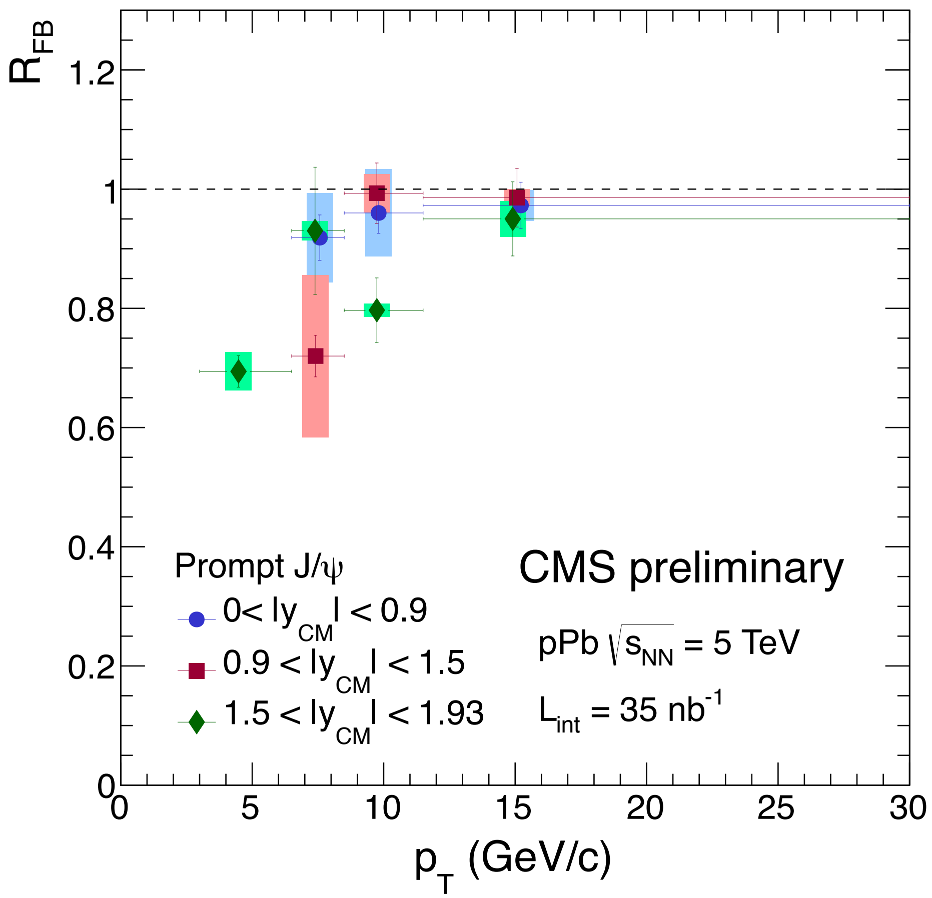
- No strong rapidity dependence
- Clue for the different production yield in forward and backward for low p_T
- Systematic uncertainties will be updated.

Results : R_{FB} vs p_T

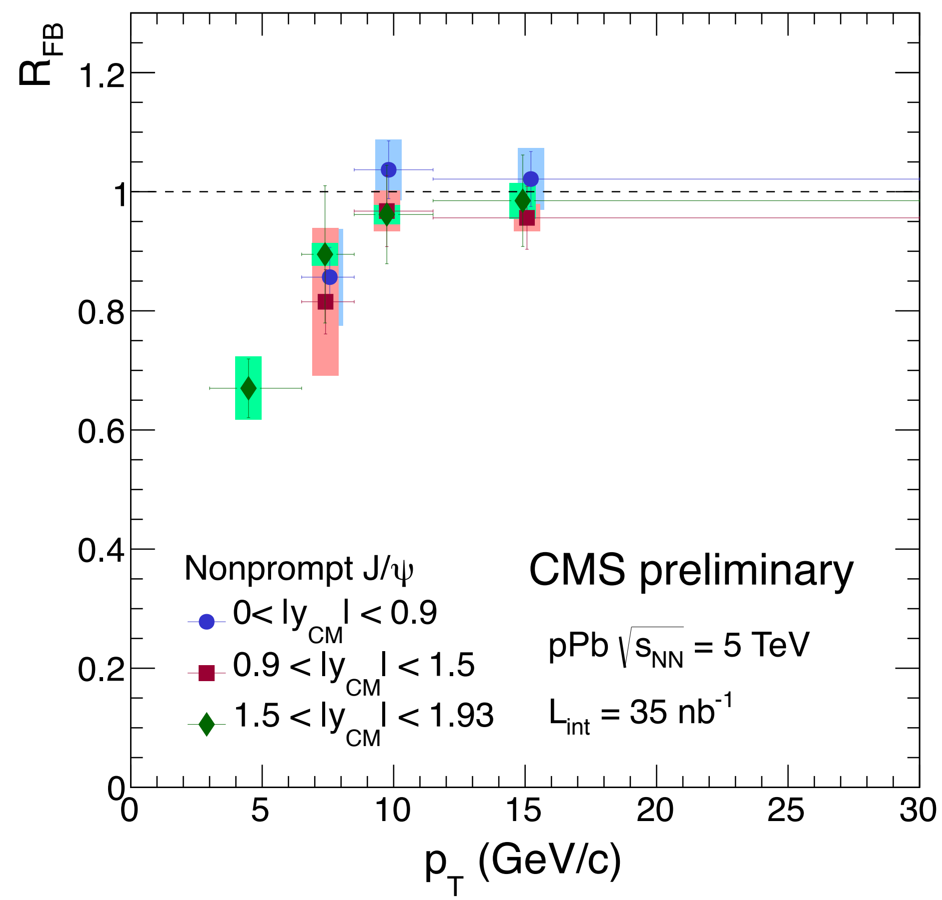
$$R_{FB} = \frac{[N_{J/\psi}/(A*\epsilon)]^{FW}}{[N_{J/\psi}/(A*\epsilon)]^{BW}}$$

PAS Fig.6

[Prompt]



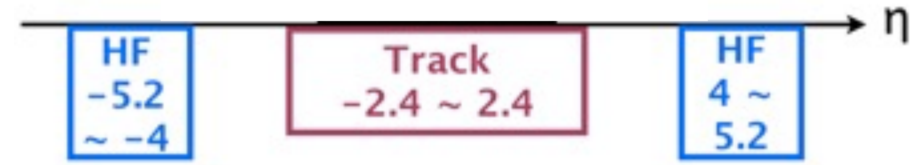
[Non-prompt]



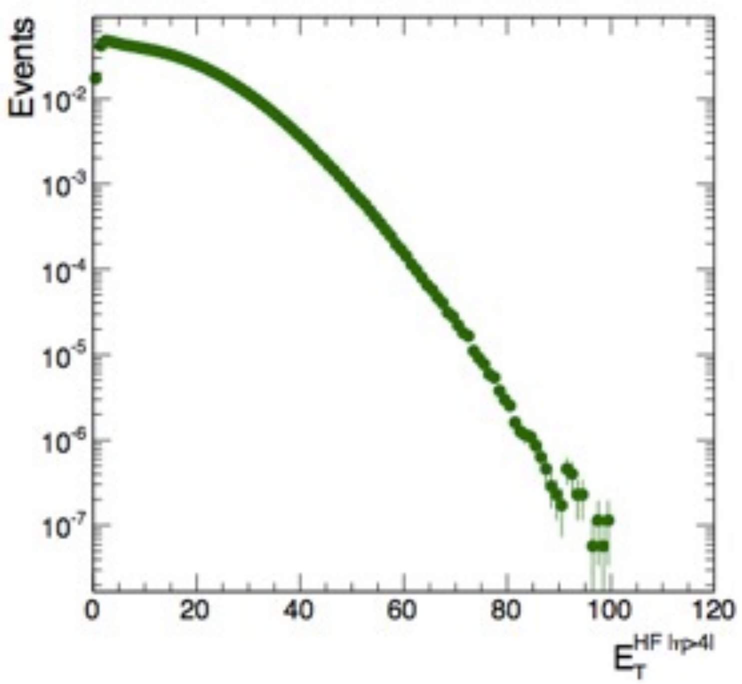
- No strong dependency on rapidity
- R_{FB} decreases smaller than unity as p_T becomes lower (smaller x).
- Improving systematic uncertainties in progress

Multiplicity variables

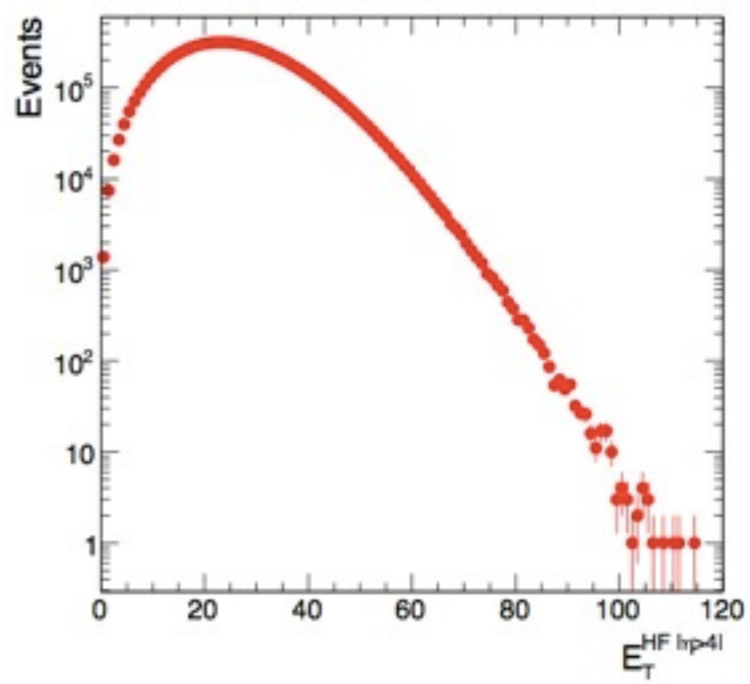
- **Two variables for multiplicity**
  - 1. $N_{tracks}^{|\eta<2.4|}$ (binning : 0, 65, 95, 350)
  - 2. $E_T^{HF\ |\eta>4|}$ (binning : 0, 20, 30, 120 GeV) *
  - We investigated dependence on $E_T^{HF\ |\eta>4|}$



[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.

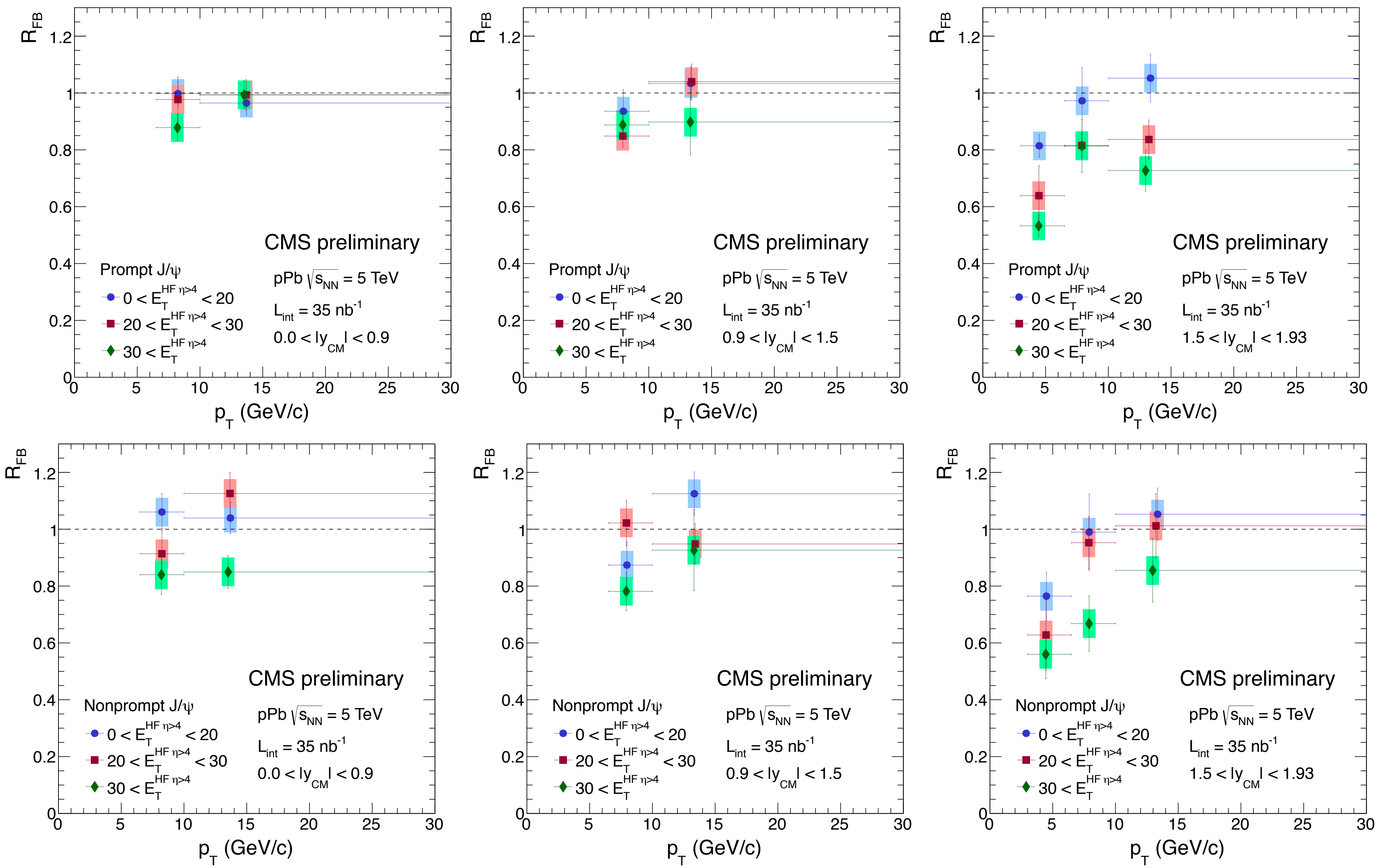
Results : E_T^{HF} dependence

$|y_{CM}|$ larger

PAS Fig.7 – Fig.9

[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

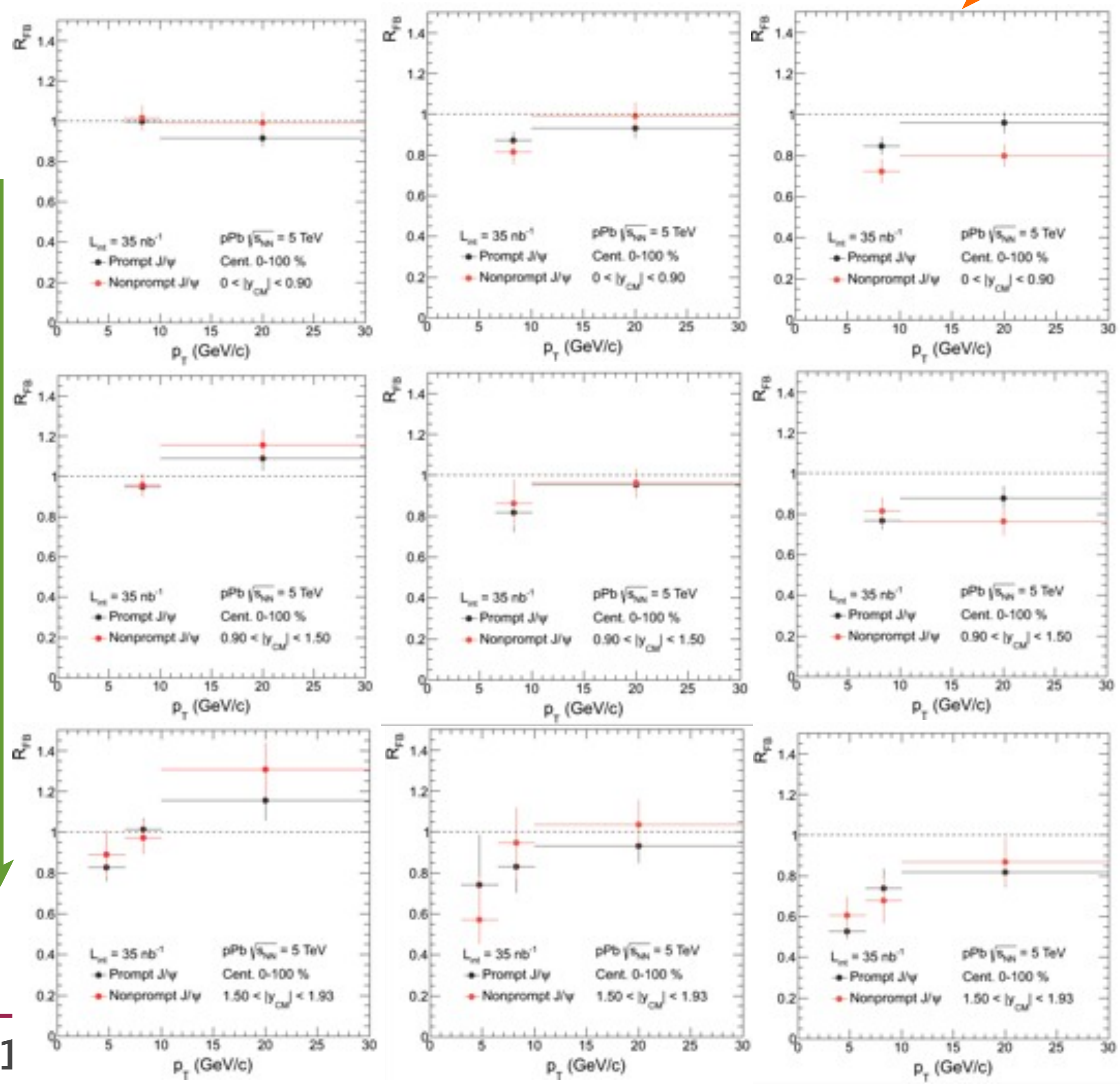
- **Preliminary results for dependency on N_{tracks}**
  - Not plotted in <p_T> and and systematic uncertainties are in progress
  - Extracted signals will be double-checked later.

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

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

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

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



- Similar trends with E_T^{HF} bins

Summary

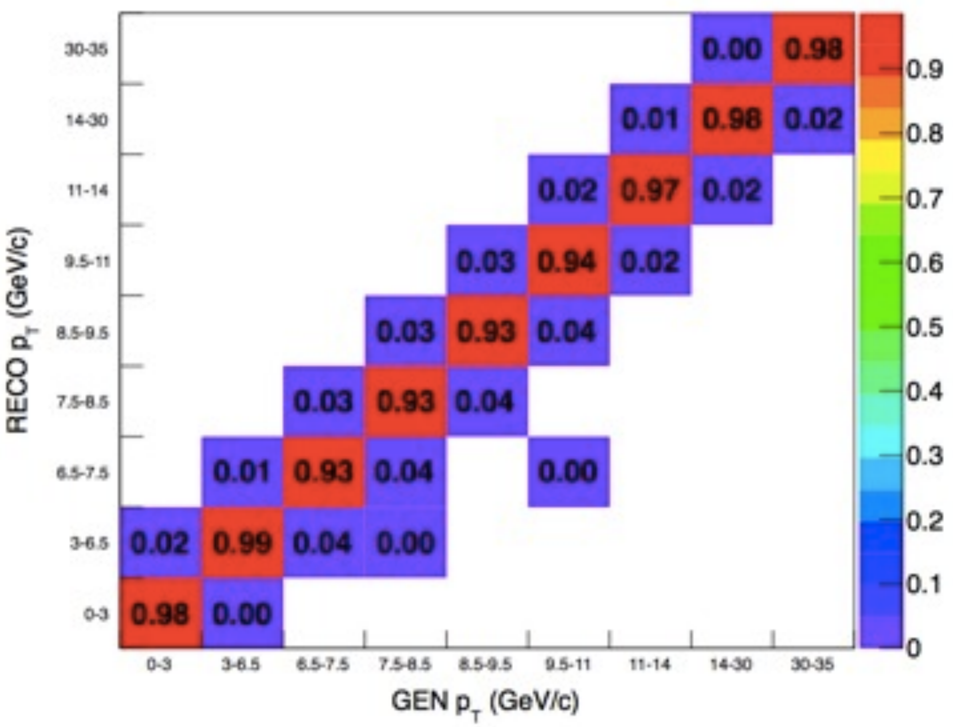
- Finalize systematic uncertainties
- Fine-tuning and double-checking on signal extraction results
- N_{tracks} dependence for R_{FB} measurement
- complete above items within 1 week

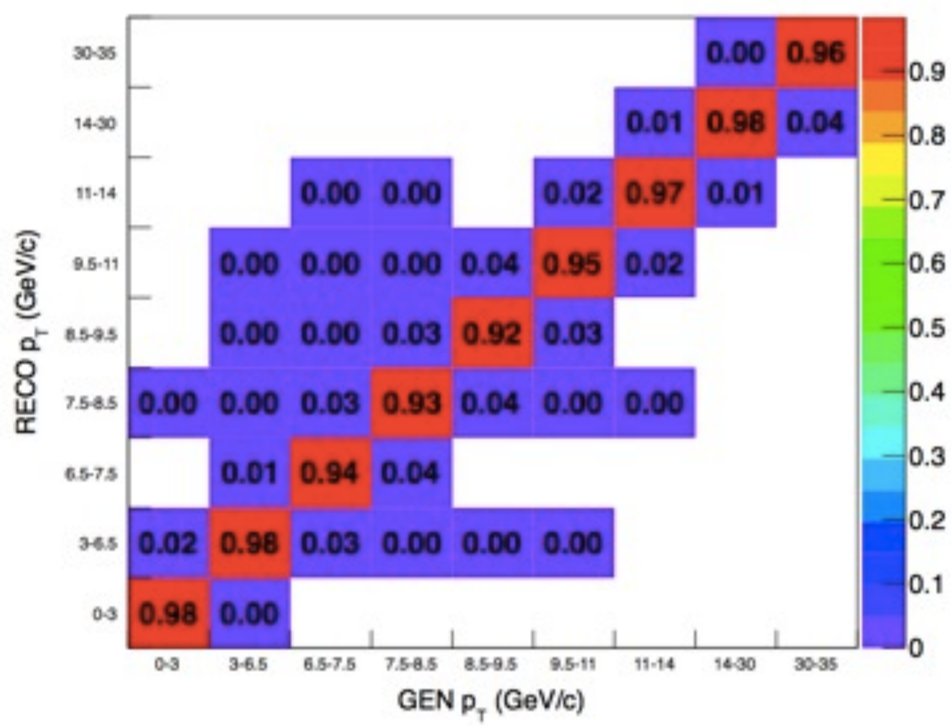
- We believe that our final results will not be altered considerably after complete above lists which are fine-tuning.

BACK-UP

Unfolding

- **Matrix of the reconstructed vs generated p_T**
  - Prompt J/ψ
  - Non-prompt J/ψ





- Check the amount of resolution effects (bin migration)
- e.g.) Prompt J/ψ generated in 6.5-7.5 GeV/c bin

  4% of them are reconstructed in 5.0-6.5 GeV/c

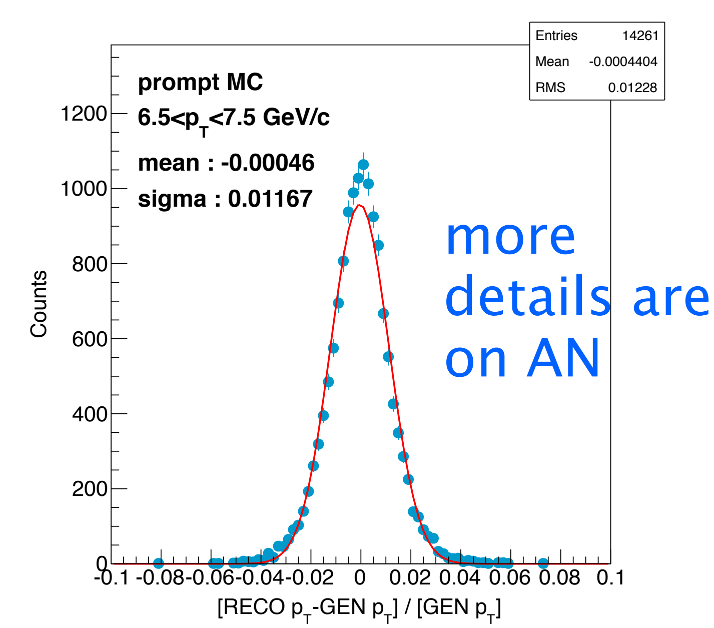
  93% of them are correctly reconstructed in 6.5-7.5 GeV/c

  3% of them are reconstructed in 7.5-8.5 GeV/c

- RECO p_T and GEN p_T show a strong correlation.

  -> Unfolding will not be used in this analysis

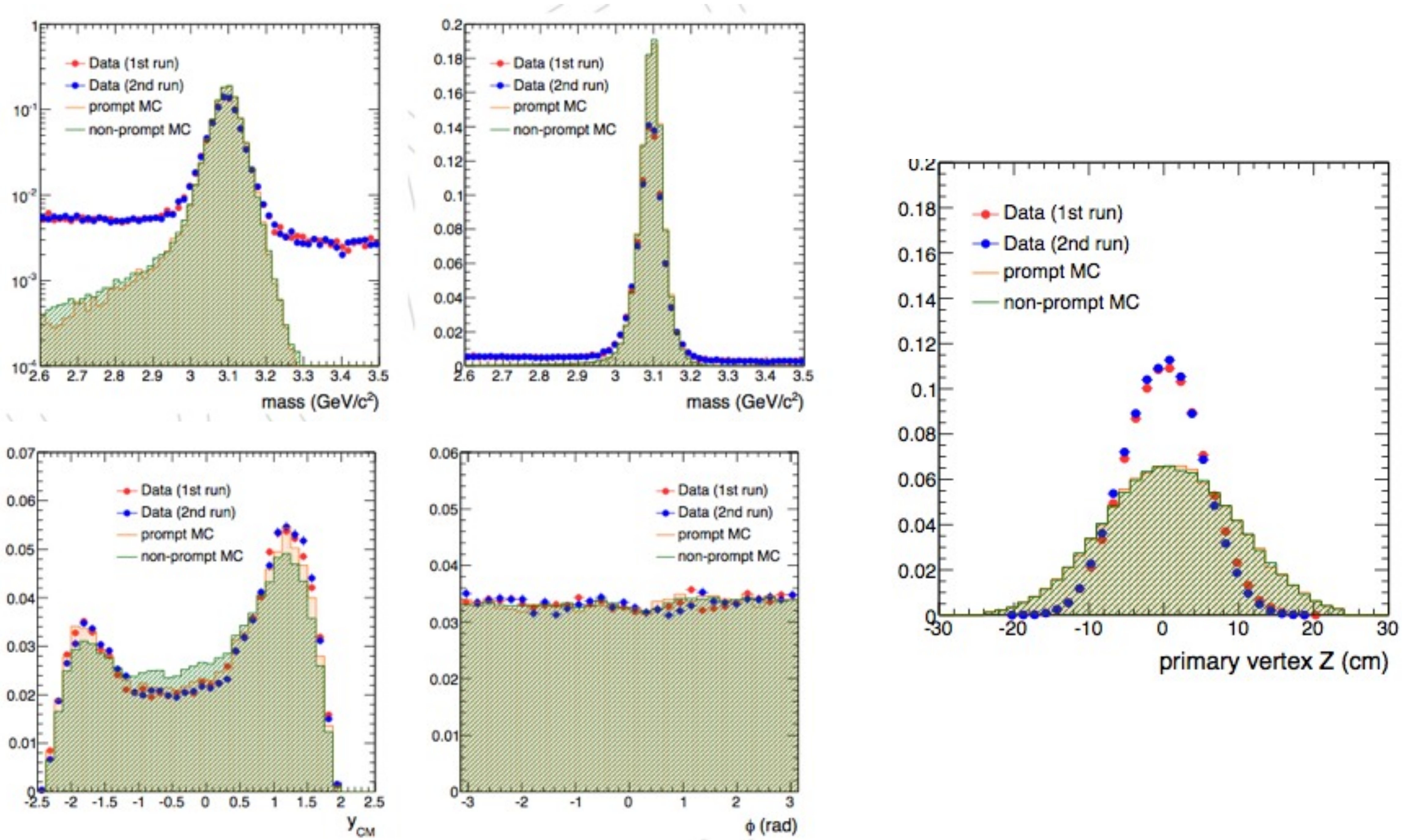
$\frac{\mathrm{RECO}p_T - \mathrm{GEN}p_T}{\mathrm{GEN}p_T}$ distribution



more details are on AN

MC vs DATA

- Distribution from DATA and MC samples (prompt and non-prompt)



Rapidity binning for R_{FB}

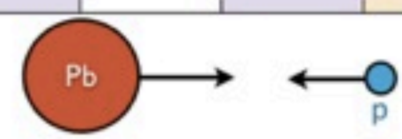
Rapidity shift

- For R_{FB}, we selected the symmetric bins in CM frame

1. Run 210498-211256 (18/nb)

Ref. system	Pb+p	symmetric bins in CM					
LAB		-2.4	-1.47	-0.47	0.53	1.46	2.4
COLLISION (CM)		1.93	1	0	-1	-1.93	-2.87

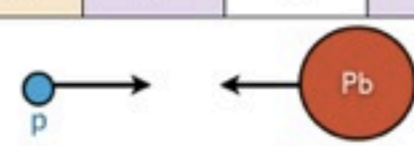
$\eta_{cm} = -(\eta_{lab} + 0.465)$

Forward  Backward

2. Run 211313-211631 (12/nb)

Ref. system	p+Pb		symmetric bins in CM				
LAB		-2.4	-1.46	-0.53	0.47	1.47	2.4
COLLISION (CM)		-2.87	-1.93	-1	0	1	1.93

$\eta_{cm} = \eta_{lab} - 0.465$

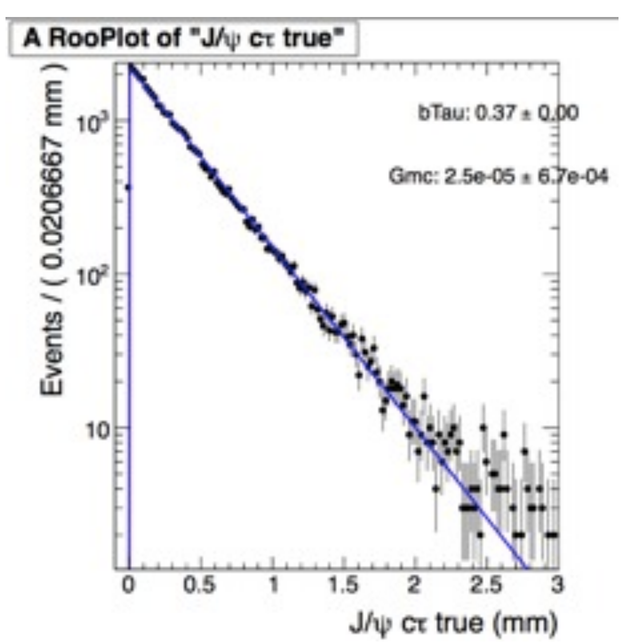
Backward  Forward

y_{CM}	[1st run] y_{lab}	[2nd run] y_{lab}
1.93	-2.4	2.4
1.5	-1.97	1.97
1.25	-1.72	1.72
1.0	-1.47	1.47
0.75	-1.22	1.22
0.5	-0.97	0.97
0.25	-0.72	0.72
0.0	-0.47	0.47
-0.25	-0.22	0.22
-0.5	0.03	-0.03
-0.75	0.28	-0.28
-1.0	0.53	-0.53
-1.25	0.78	-0.78
-1.5	1.03	-1.03
-1.93	1.46	-1.46

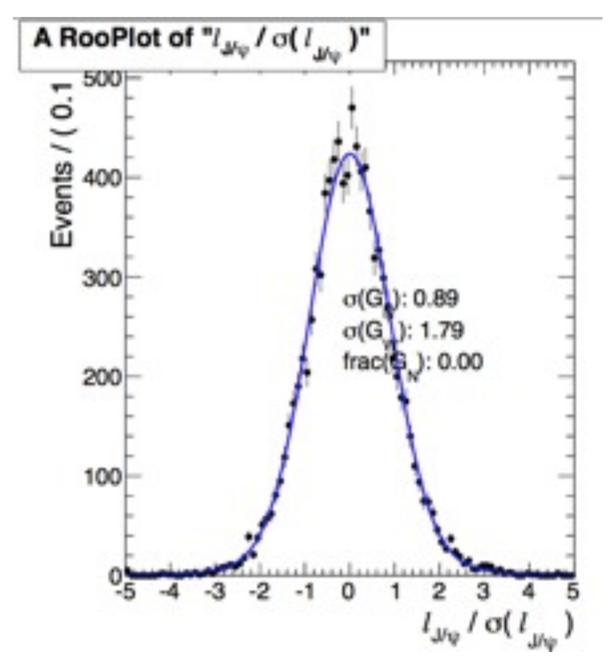
PEE method

- PDF for ideal detector F_{true}
- PDF for realistic detector $F_R = F_{true} \otimes R(l|\mu,\sigma_l)$
    - $l_{J/\psi}$ err $\sigma_l \Leftarrow$ vertex position $\Leftarrow$ ptl trajectory
      $\therefore$ detector resolution varies <u>from event to event</u>

      - Each events characterized by (l,dl), not (l)
      - s_i : more weighting for smaller dl
- PDF enhanced $F_E = F_{true} \otimes R(l|\mu, s_i\sigma_l)$



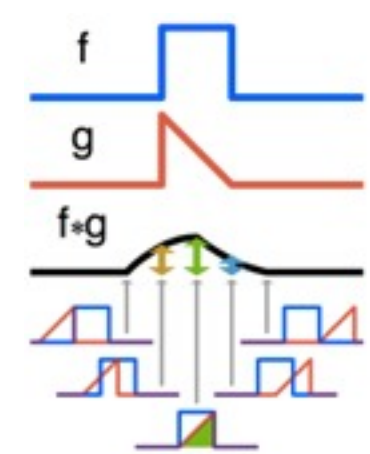
F_{true}



$R(l|\mu, s_i\sigma_l)$

[Convolution]

$$(f * g)(t) \stackrel{\text{def}}{=} \int_{-\infty}^{\infty} f(\tau)\, g(t-\tau)\, d\tau$$
$$= \int_{-\infty}^{\infty} f(t-\tau)\, g(\tau)\, d\tau.$$



PEE method

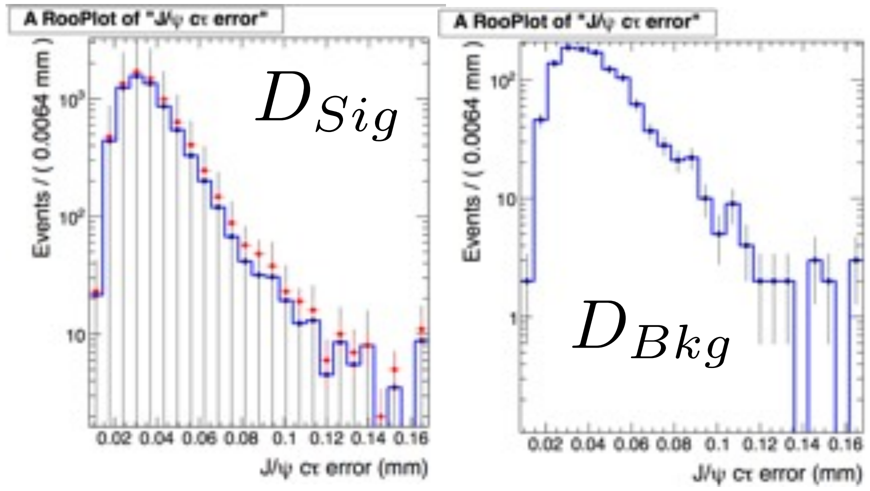
- $m_{\mu\mu}$ & $l_{J/\psi}$: 2-D fit by a log-likelihood $\ln L = -\sum_{i=1}^{N} \ln F(\ell_{J/\psi}, m_{\mu\mu})$

w/o PEE : $F(\ell_{J/\psi}, m_{\mu\mu}) = f_{Sig} \cdot F_{Sig}(\ell_{J/\psi}) \cdot M_{Sig}(m_{\mu\mu}) + (1 - f_{Sig}) \cdot F_{Bkg}(\ell_{J/\psi}) \cdot M_{Bkg}(m_{\mu\mu})$

w PEE :

$$F(\ell_{J/\psi}, m_{\mu\mu}) = \int [f_{Sig} \cdot \boxed{D_{Sig}(\sigma_\ell)} F_{Sig}(\ell_{J/\psi}, \sigma_\ell) \cdot M_{Sig}(m_{\mu\mu}) + (1 - f_{Sig}) \cdot \boxed{D_{Bkg}(\sigma_\ell)} F_{Bkg}(\ell_{J/\psi}, \sigma_\ell) \cdot M_{Bkg}(m_{\mu\mu})] d\sigma_\ell.$$

- f_{Sig} : fraction of signal(inclusive J/Ψ)
  $D_{sig,Bkg}$: distributions of the errors
  $M_{Sig}(m_{\mu\mu})$: 1 Gaussain + 1 CB
  $M_{Bkg}(m_{\mu\mu})$: exponential
  $F_{Sig,Bkq}(l_{J/\psi})$:



w/o PEE : $F_{Sig,Bkg}(\ell_{J/\psi}) = \sum_i F^{true}_{Sig,Bkg}(\ell_{J/\psi}) \otimes R_i(\ell_{J/\psi} - \ell'_{J/\psi} | \mu, \sigma_i)$

w PEE : $F_{Sig,Bkg}(\ell_{J/\psi}, \sigma_\ell) = \sum_i F^{true}_{Sig,Bkg}(\ell_{J/\psi}) \otimes R_i(\ell_{J/\psi} - \ell'_{J/\psi} | \mu, \boxed{s_i \sigma_\ell})$

$$F^{true}_{Sig}(\ell_{J/\psi}) = f_b \bar{F}_B(\ell_{J/\psi}) + (1 - f_b) F_{Prompt}(\ell_{J/\psi})$$

- f_B : fraction of non-prompt J/Ψ
  $F_p(l_{J/\psi})$: simply resolution func.(Gaussian)
  $F_B(l_{J/\psi})$: convolution of resolution func. & non prompt MC $l_{J/\psi}$ dist.

Signal extraction

- **Fitting procedure**

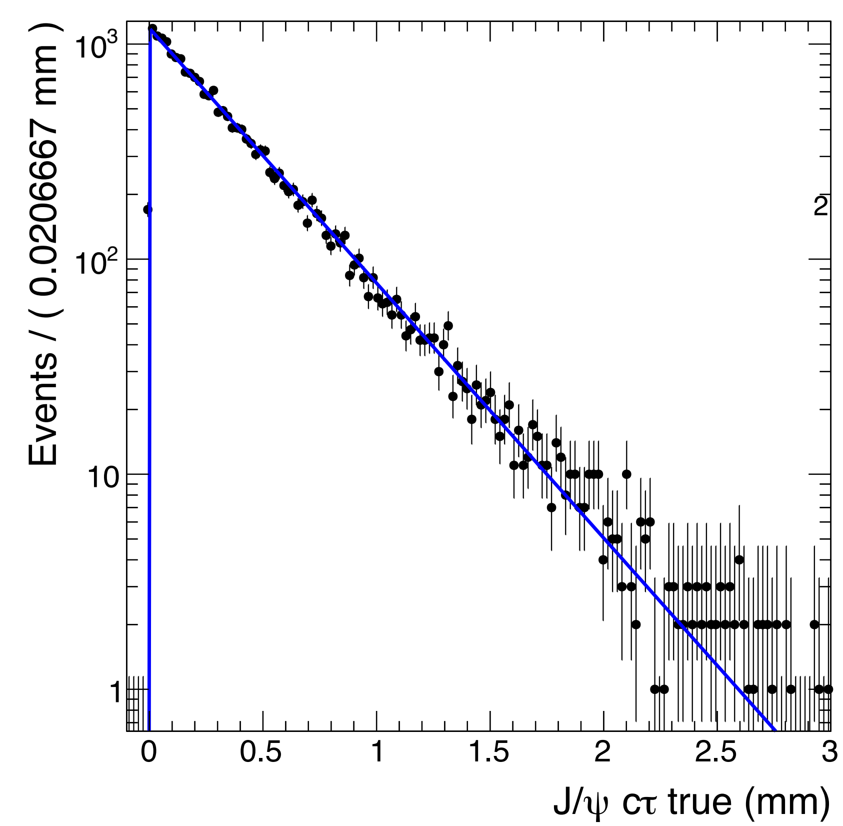
1. Dimuon invariant mass fit

- Get the yield of signal(inclusive) and background
- Background : one exponential functions
- Signal : one Gaussian + one Crystal ball functions (∵ final state radiation)

$$f_{CB}(m) = \begin{cases} \frac{N}{\sqrt{2\pi}\sigma_{CB}} \exp\left(-\frac{(m-m_0)^2}{2\sigma_{CB}^2}\right), & \text{for } \frac{m-m_0}{\sigma_{CB}} > -\alpha; \\ \frac{N}{\sqrt{2\pi}\sigma_{CB}} \left(\frac{n}{|\alpha|}\right)^n \exp\left(-\frac{|\alpha|^2}{2}\right) \left(\frac{n}{|\alpha|} - |\alpha| - \frac{m-m_0}{\sigma_{CB}}\right)^{-n}, & \text{for } \frac{m-m_0}{\sigma_{CB}} \leq -\alpha. \end{cases}$$

2. Non-prompt MC template

- constrain $\ell_{J/\psi}$ (true) of non-prompt J/ψ

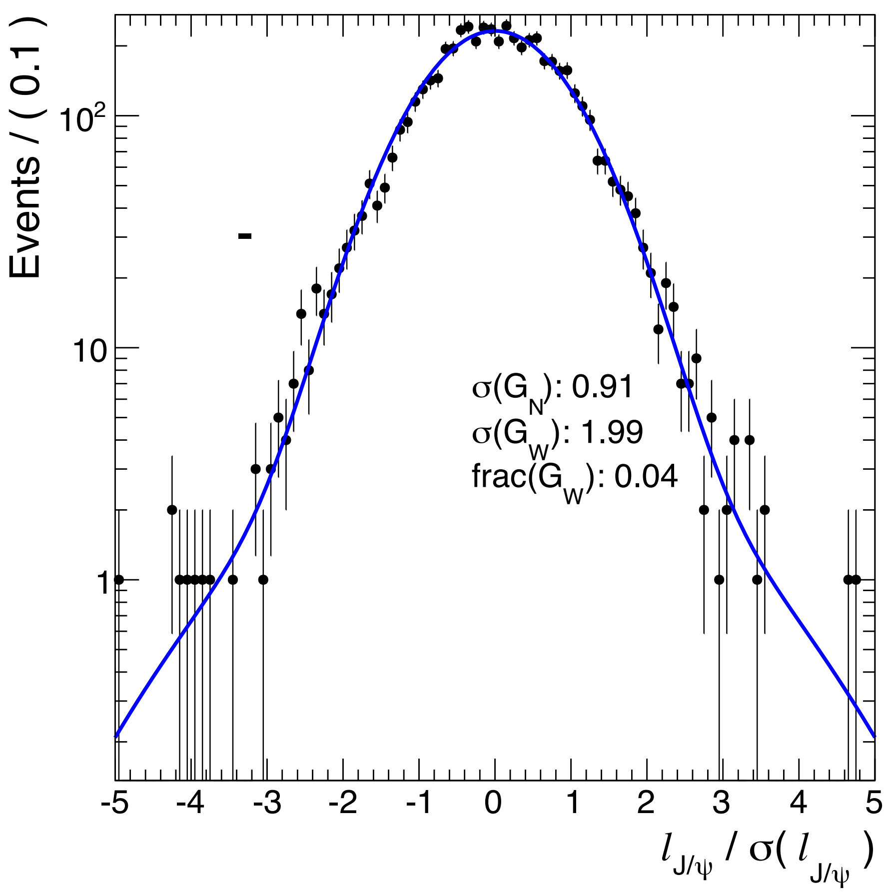


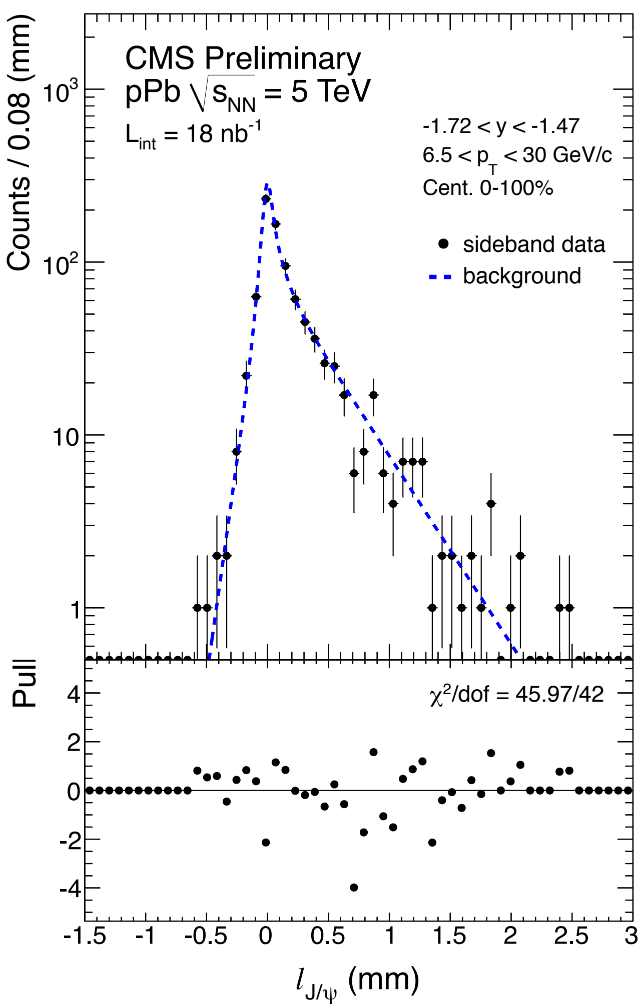
3. prompt MC template

- PEE (Per Event Error) method
- Resolution shape : sum of 2 gaussians

4. The mass sideband regions [2.6–2.9] and [3.2–3.5] GeV/c²

- background $\ell_{J/\psi}$ distribution
- Combination of exponential decay functions with 3 different slopes (Standard background functions invented by CDF)

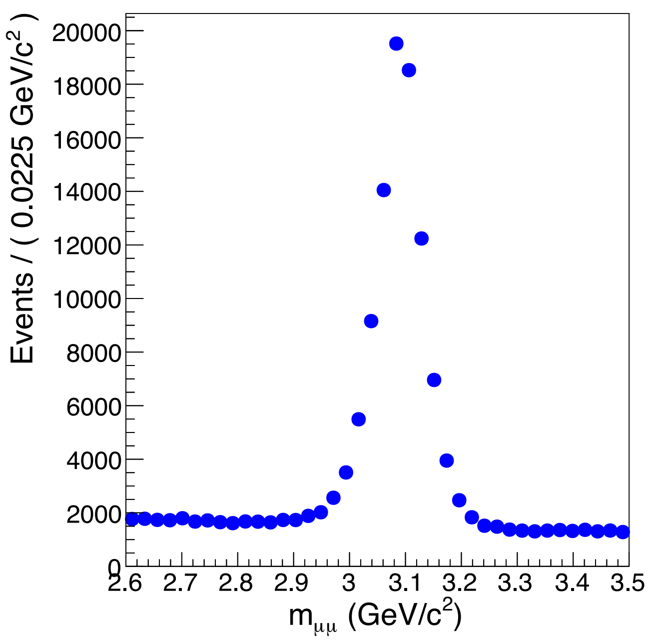


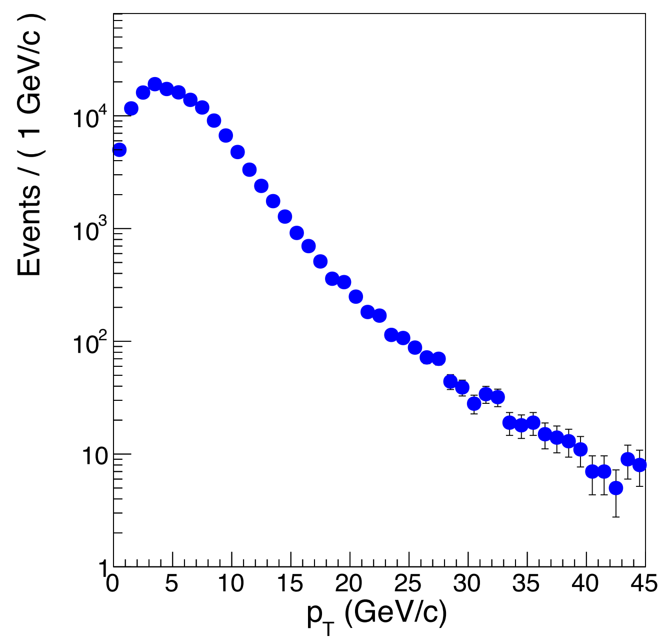


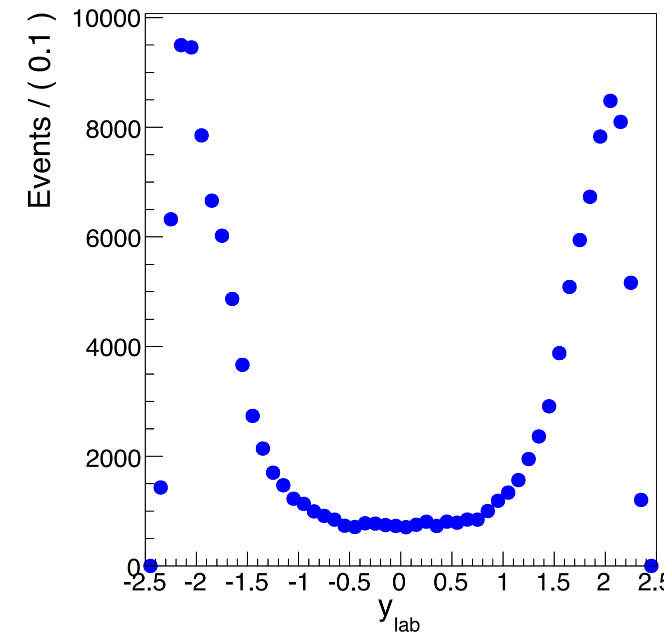
5. total PDF fitting

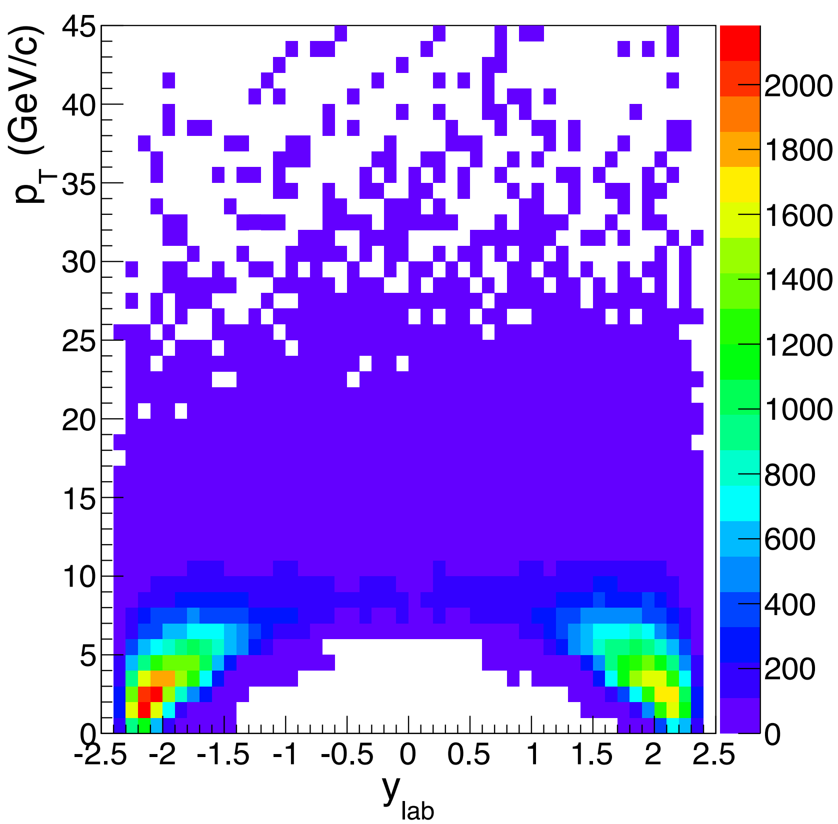
- Get the b-fraction

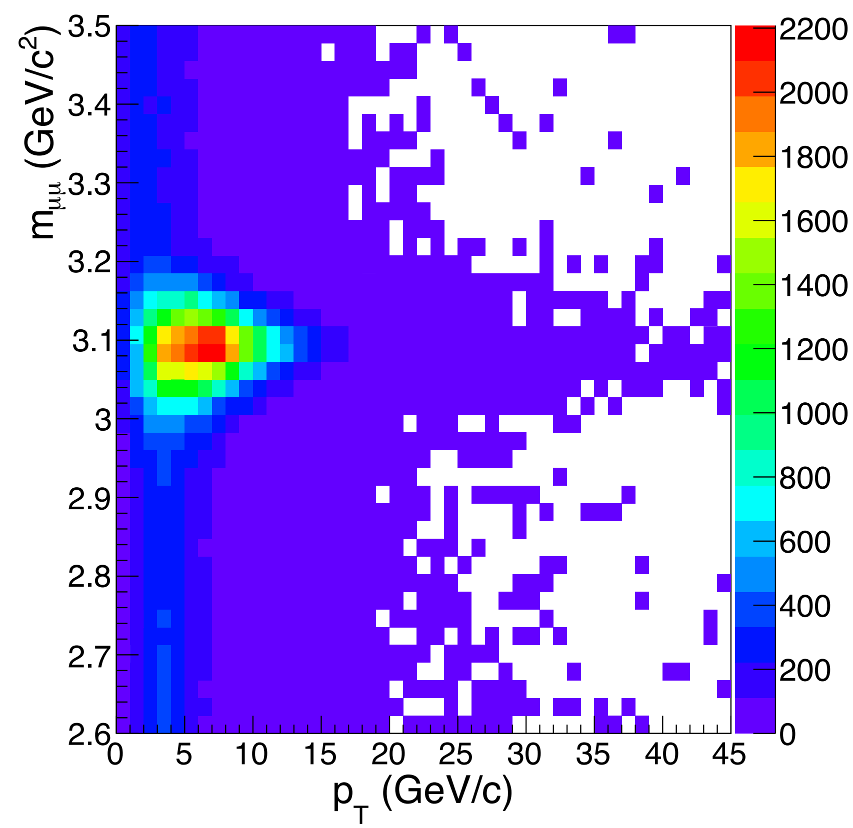
- **dimuon distributions in datasets (from 2nd run periods)**







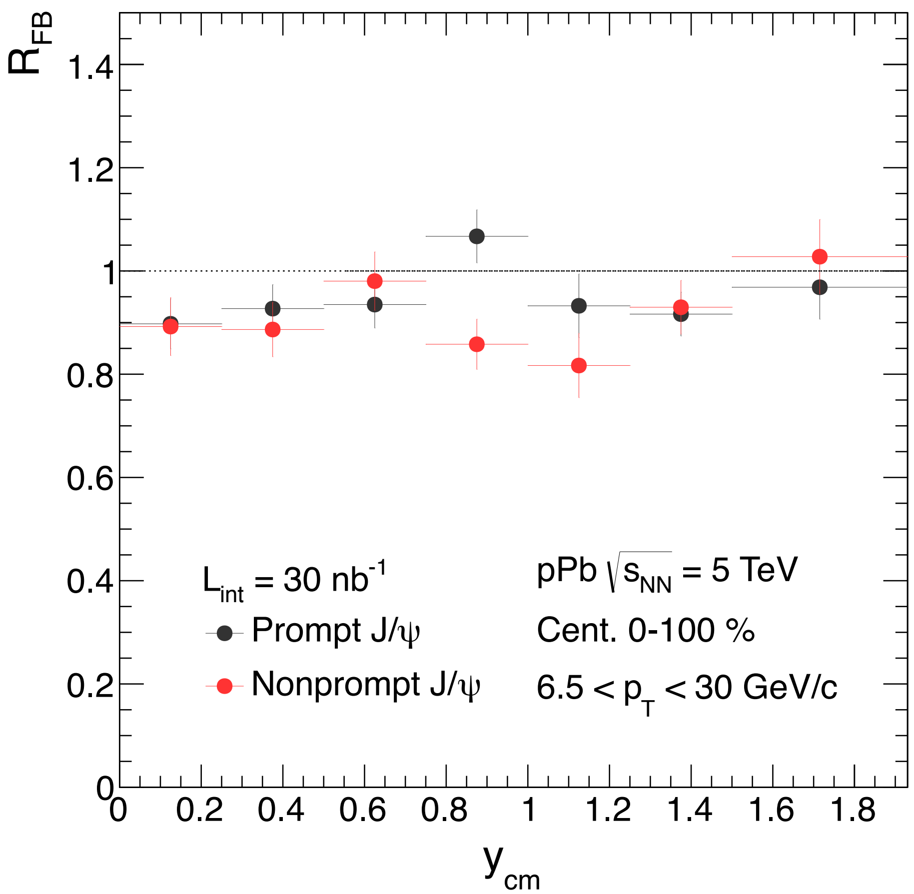




Results : R_{FB} vs y_{CM}

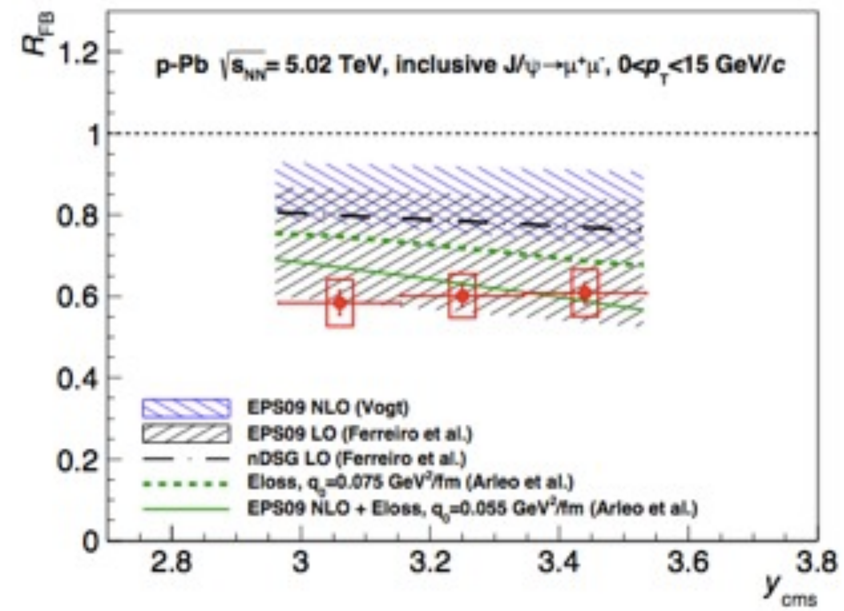
Kinematic ranges are different! (Not apple to apple)

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

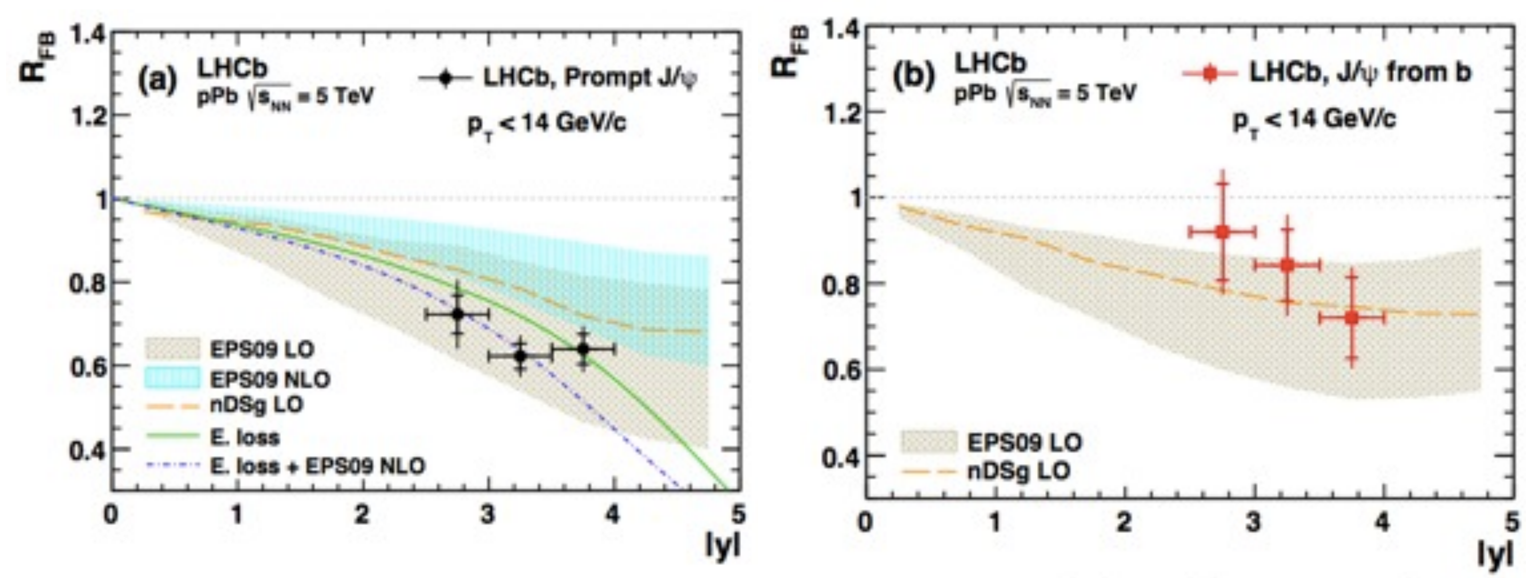


Result before 2D-correction

- **ALICE**
  - p_T < 15 GeV/c & 2.96< $|y_{CM}|$ < 3.53



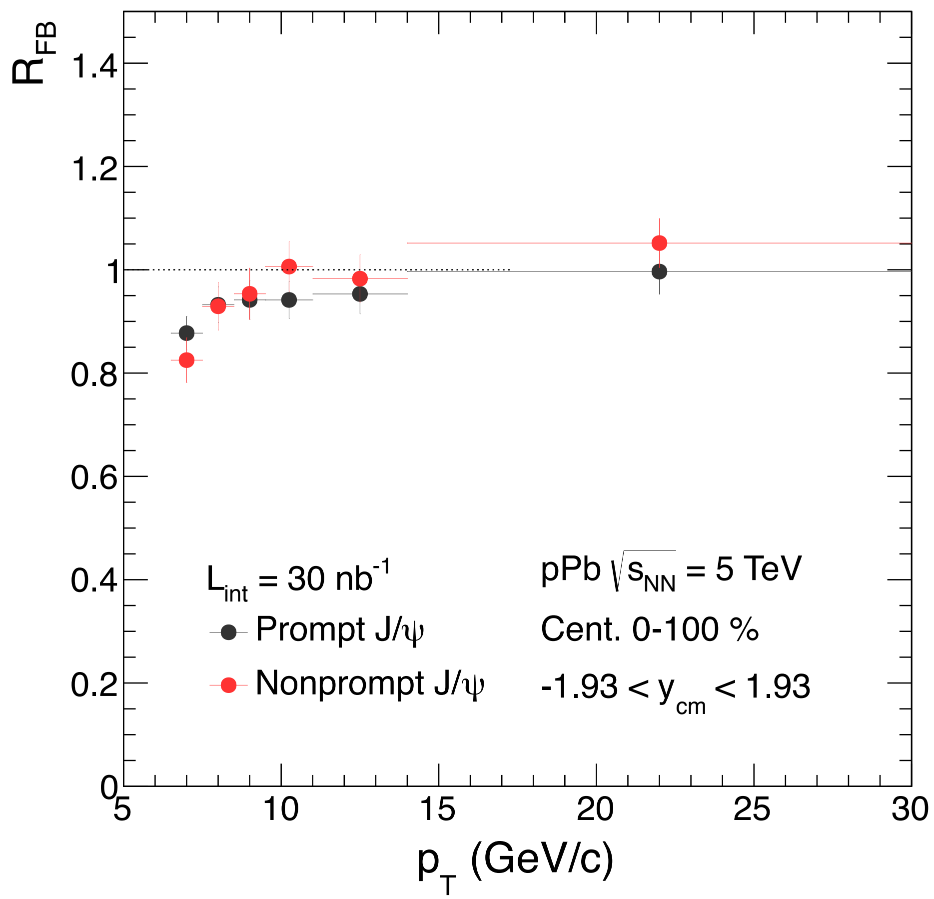
- **LHCb**
  - p_T < 14 GeV/c & 2< $|y_{CM}|$ < 5



Results : R_{FB} vs p_T

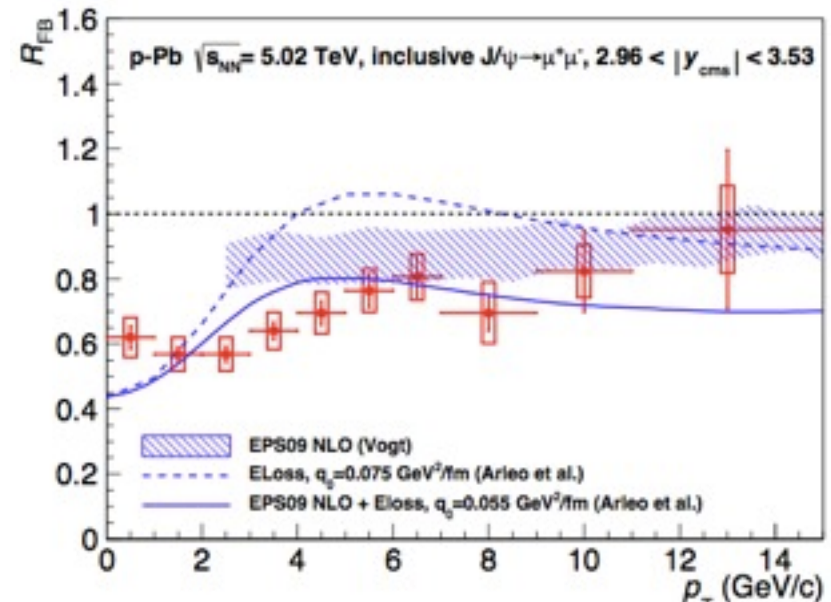
Kinematic ranges are different! (Not apple to apple)

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

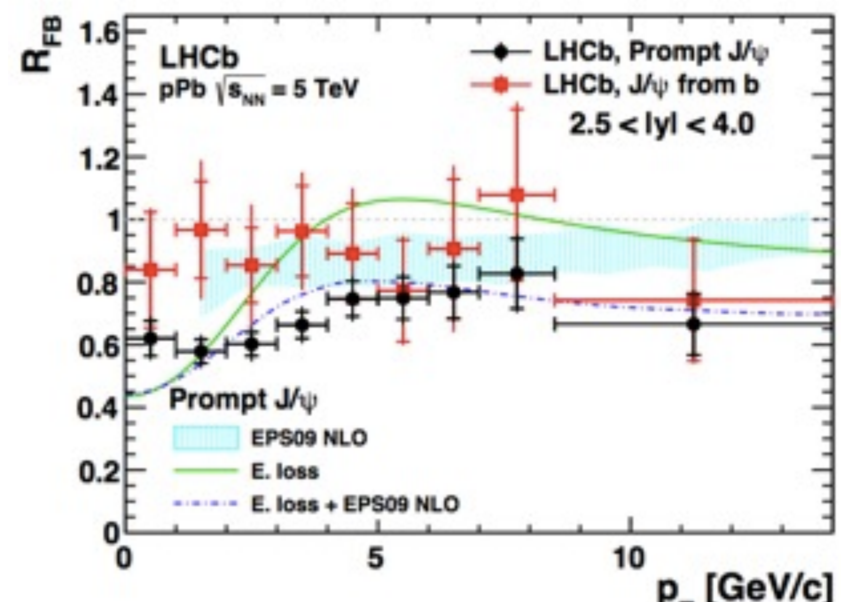


Result before 2D-correction

- **ALICE**
  - p_T < 15 GeV/c & 2.96< $|y_{CM}|$ < 3.53

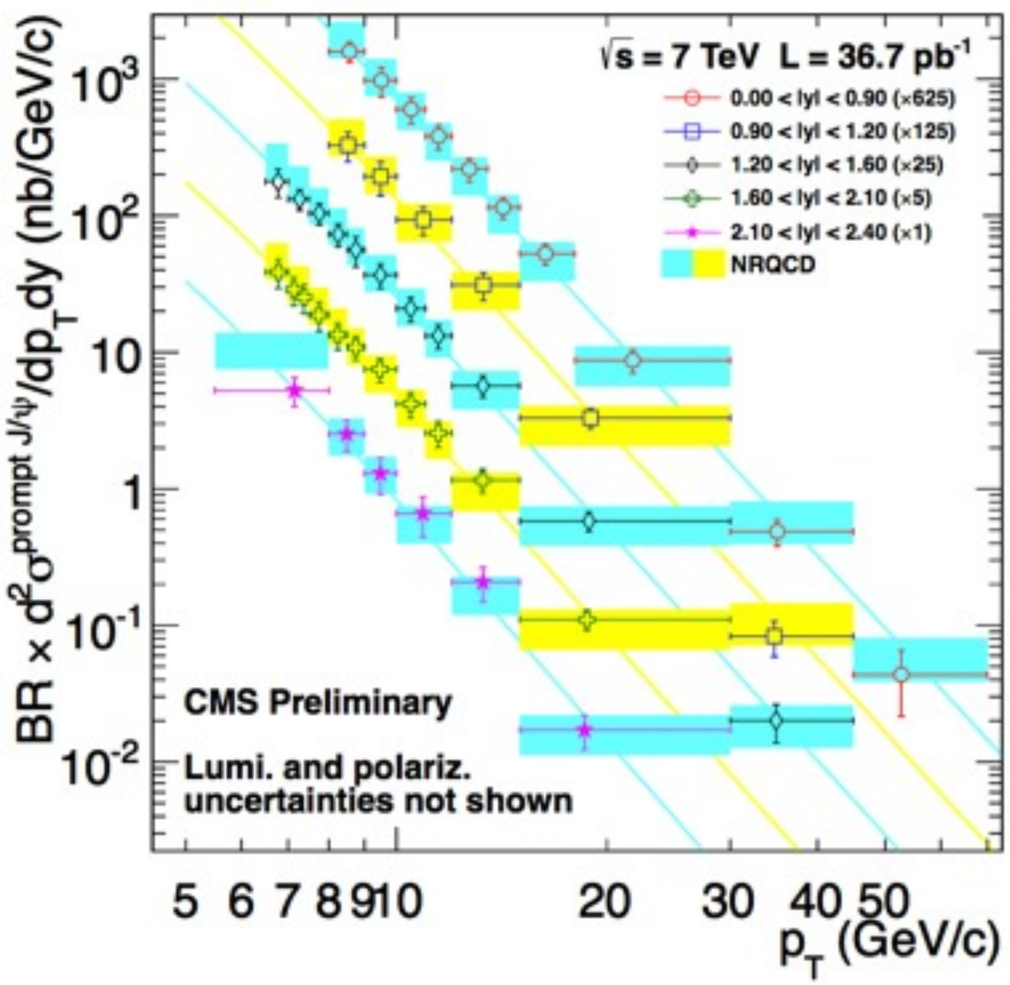


- **LHCb**
  - p_T < 14 GeV/c & 2< $|y_{CM}|$ < 5



- **BPH-10-014**

[Prompt]



[non-prompt]