第七届中国LHC物理研讨会

Non-prompt J/ψ production as a function of multiplicity in pp collisions at $\sqrt{s} = 13$ TeV with ALICE

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Content

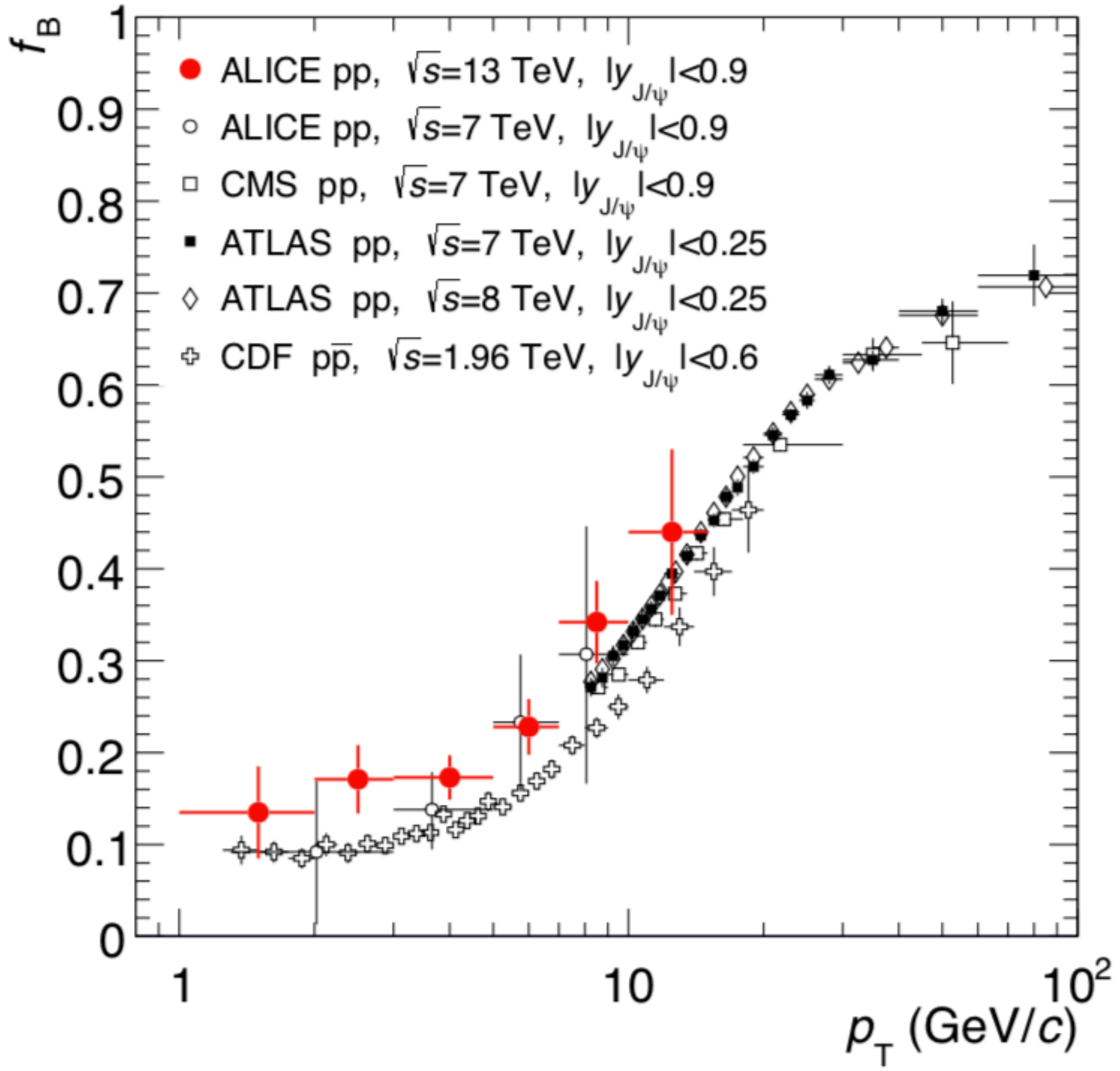
- Motivation
- Experimental setup
- Analysis Procedure
- Results
- Summary and outlook

Motivation

- The study of the production of hidden and open heavy-flavour hadrons in proton–proton (pp) collisions provides an essential test of QCD, involving both the perturbative and non-perturbative regimes of this theory.
- In particular, the production of the J/ψ meson is the subject of many theoretical calculations. The cornerstone of all the theoretical approaches is the factorization theorem, since the heavy hadron production with large p_{T}, the $c\bar{c}$ pair production cross section can be computed perturbatively, and there're lots of models to describe it.

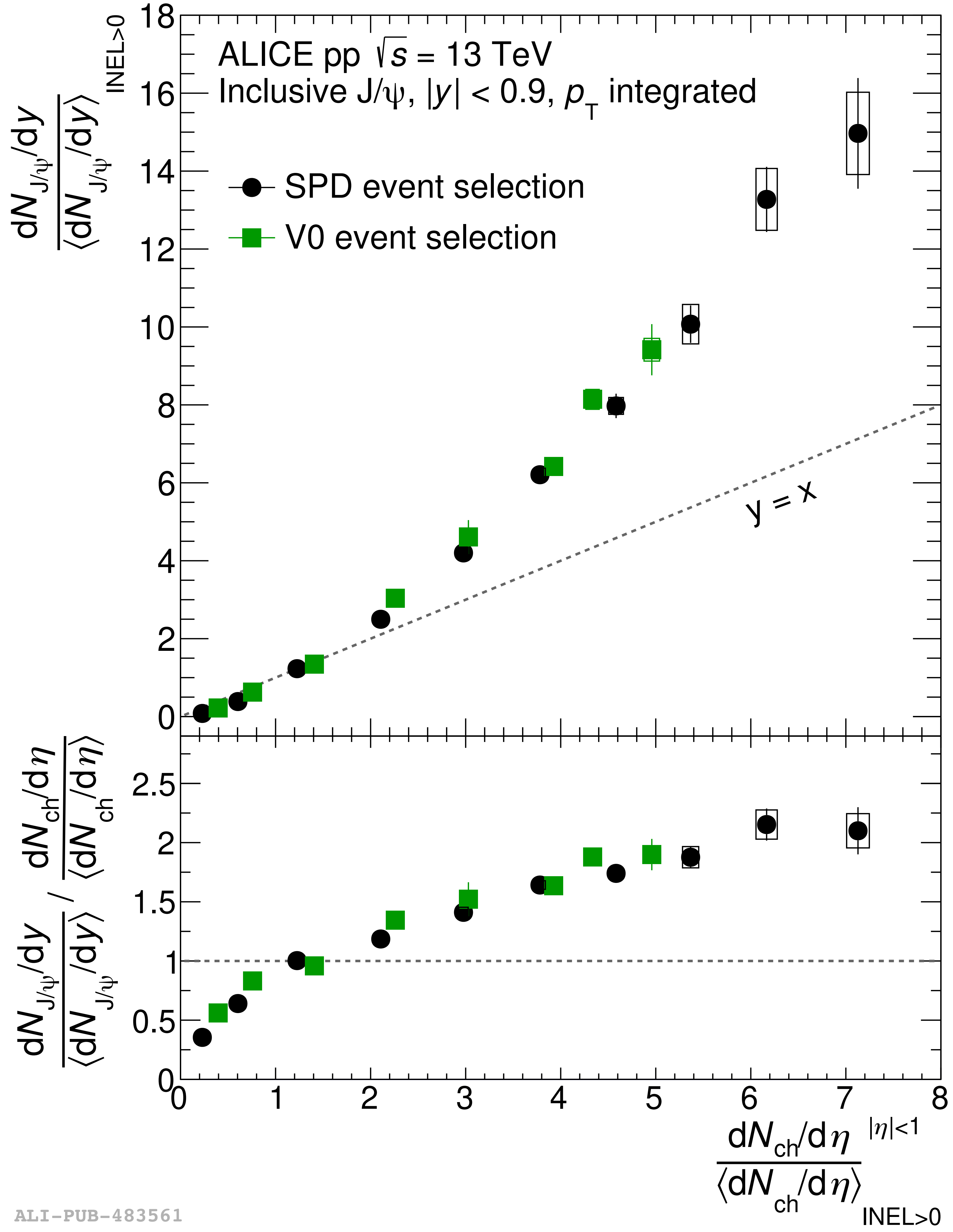
- The inclusive J/ψ yield measured at hadron colliders can be considered as originating from different processes which can be separate prompt and non-prompt charmonium.

- Non-prompt J/ψ production is directly related to open beauty hadron production cross section :
  - Study prompt charmonium production mechanisms
  - Accurately calculate B hadron decay at low p_{T}



Motivation

- The event-multiplicity dependent production of charmonium and open charm hadrons in pp and p–Pb collisions are observables having the potential to give new insights on processes at the parton level.
- The general observation is an increase of open and hidden charm production with charged-particle multiplicity measured at midrapidity.
- Several theoretical models can predict a correlation of the normalized J/ψ production with the normalized event multiplicity which is stronger than linear.
- We expect to see how non-prompt spectra increase with multiplicity and the dependence.

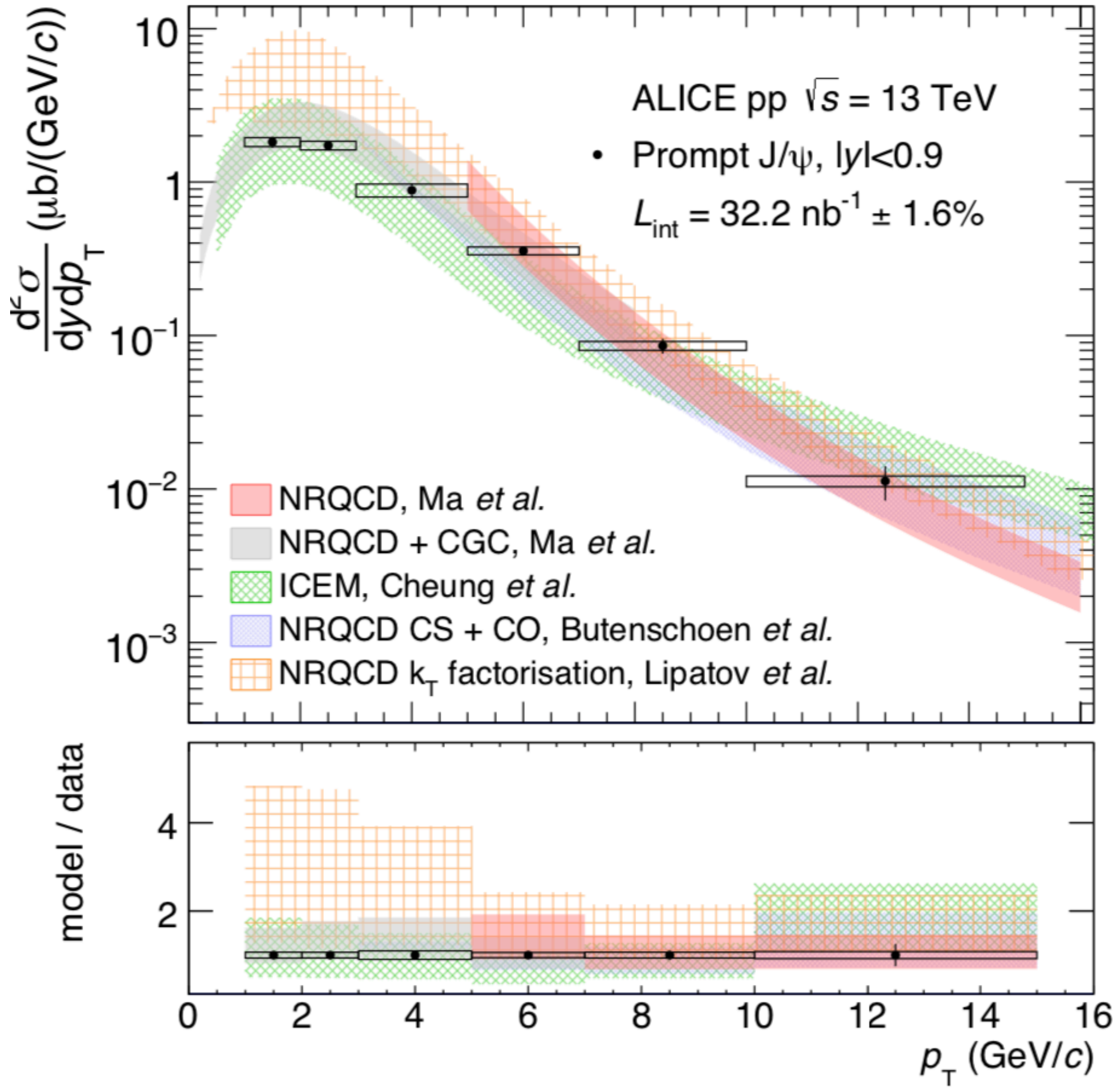


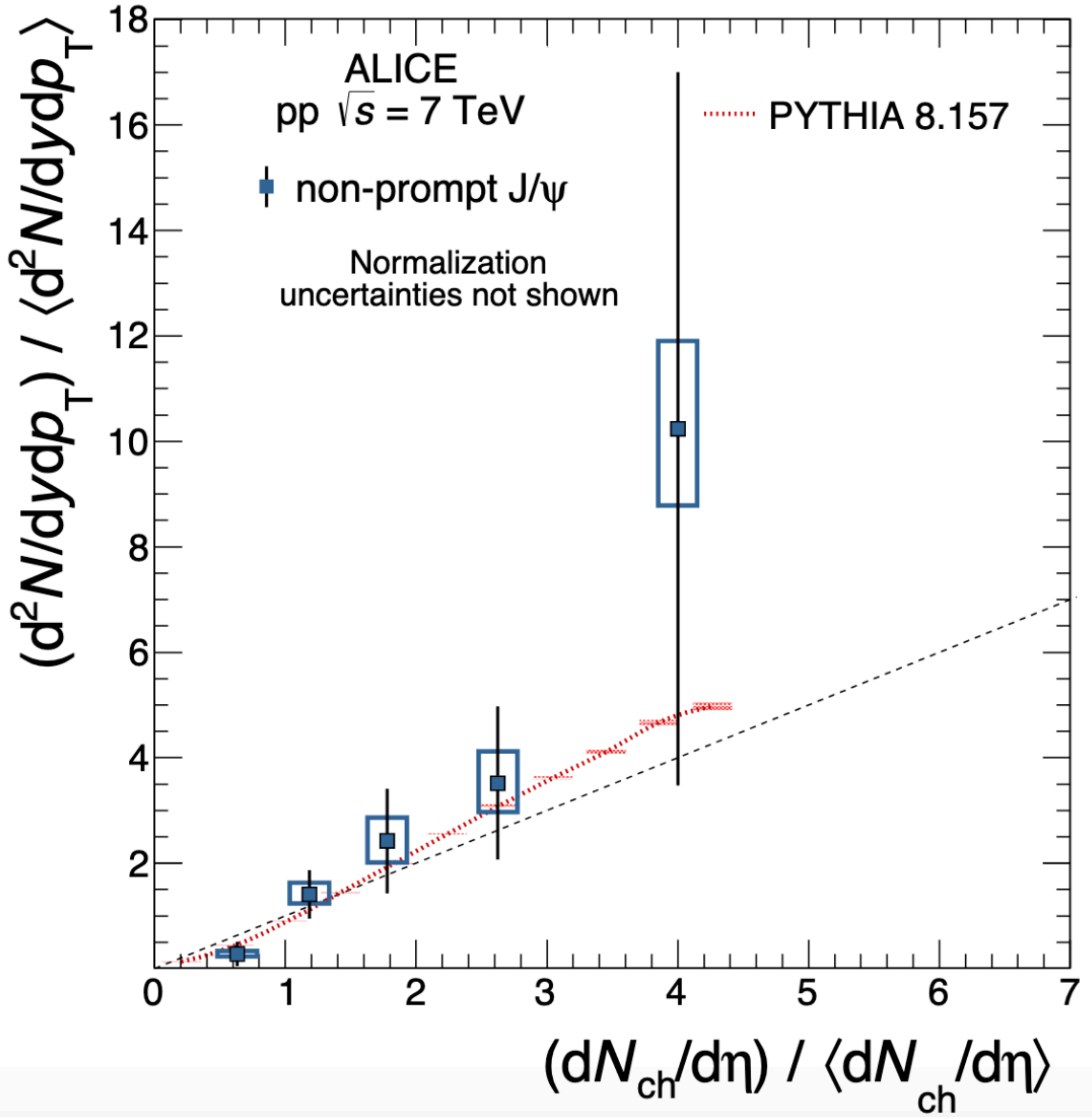
Motivation

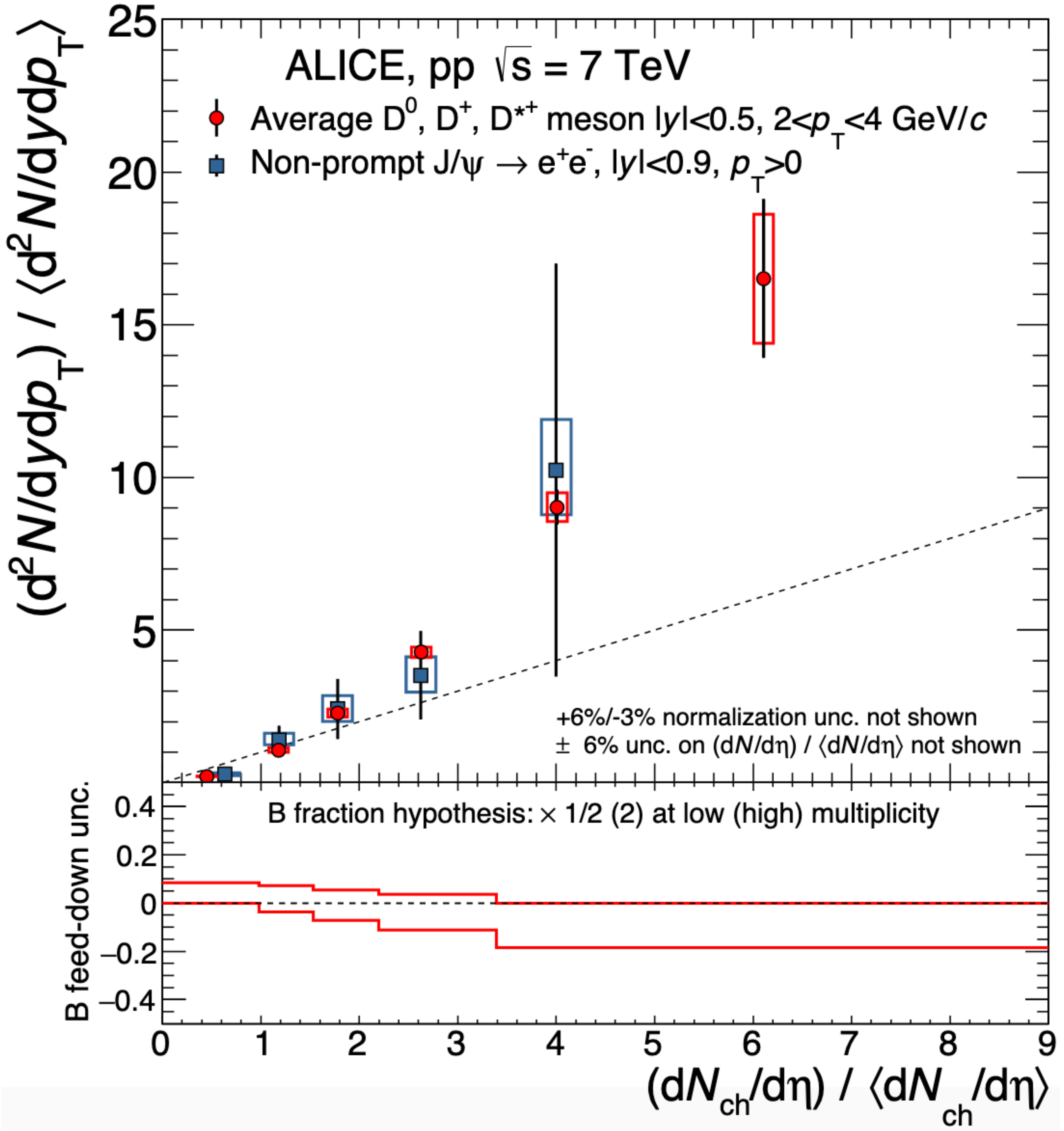
◉ ALICE has studied the multiplicity dependence in pp collisions.

at 7 TeV and 13 TeV of

- inclusive J/ψ production at mid- and forward-rapidity
- prompt J/ψ (including feed down from ψ(2S) and χ_c),
- non-prompt J/ψ and D-meson production at midrapidity







Non-prompt J/ψ production vs multiplicity at 13 TeV is responsible by this analysis

Experimental setup

◉**Time Projection Chamber (TPC):**

tracking, PID via dE/dx

◉**Inner Tracking System (ITS):**

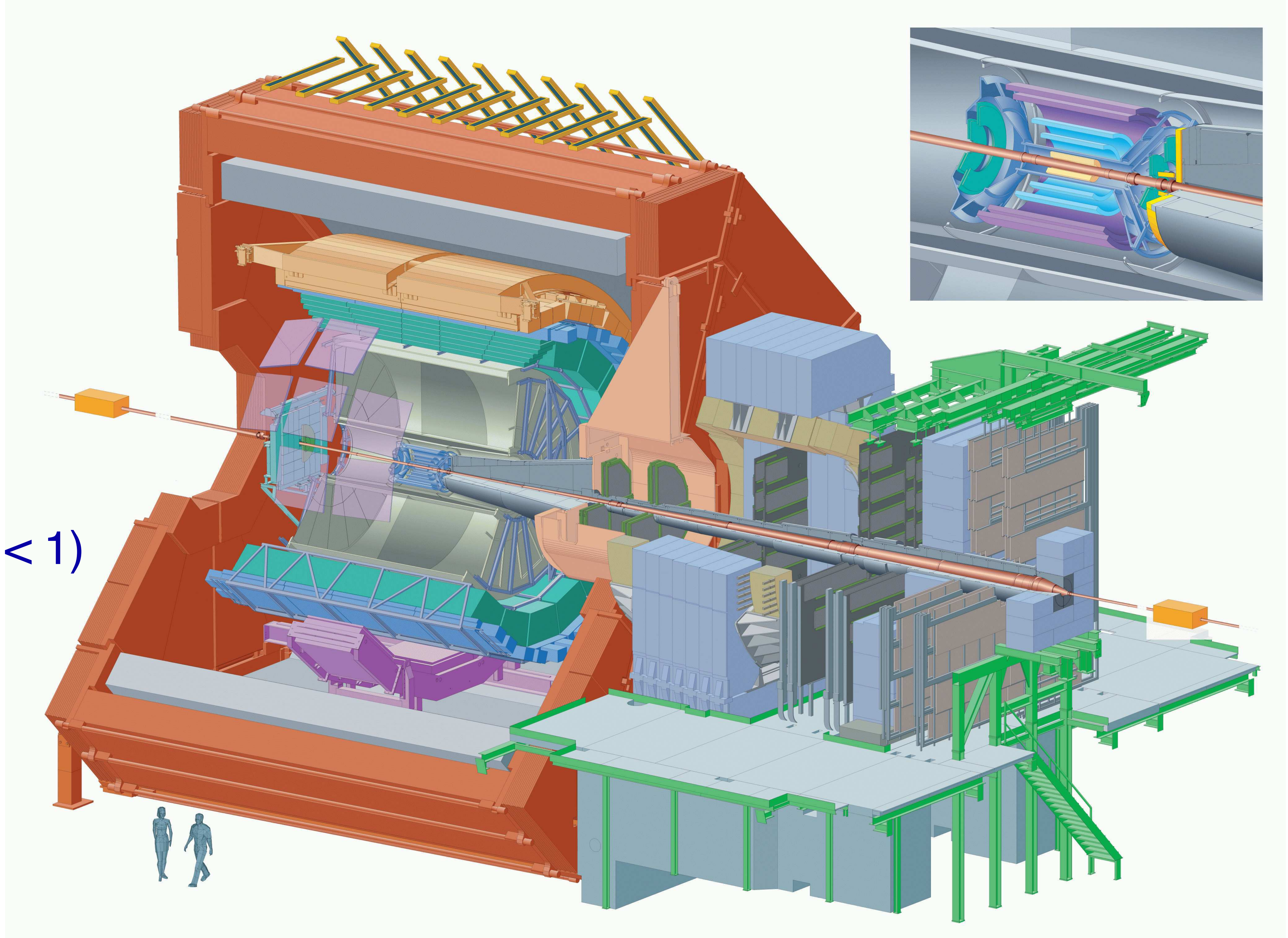
- vertexing, tracking, triggering
- which include SPD SSD SDD 3 subdetectors,
- **SPD** :
- good vertex resolution and multiplicity estimator ($|\eta| < 1$)

◉**VZERO:**

- amplitude measured in the V0A

  ($2.8 < \eta < 5.1$) + V0C ($-3.7 < \eta < -1.7$) arrays,

  and as multiplicity estimator

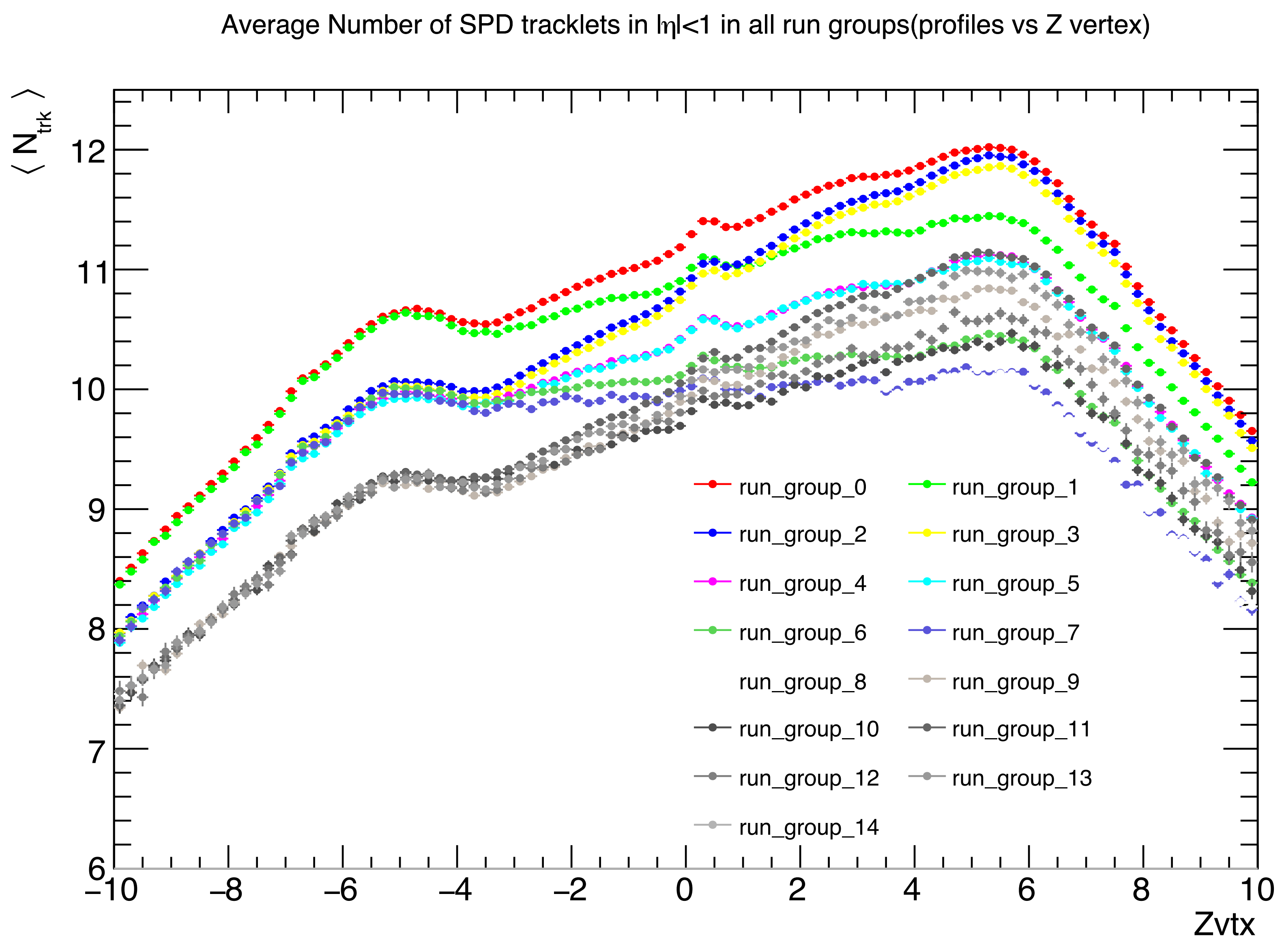


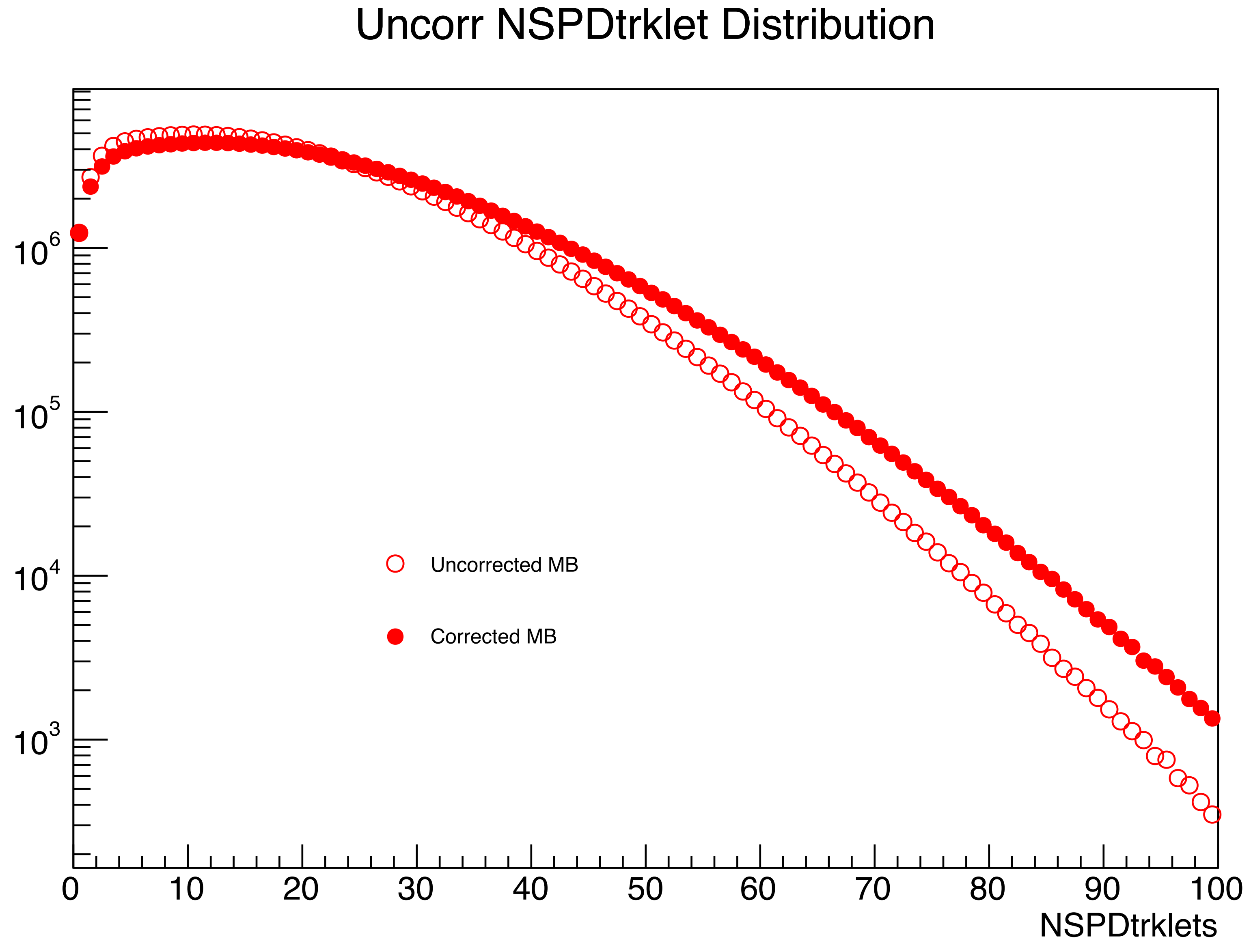
Multiplicity estimation

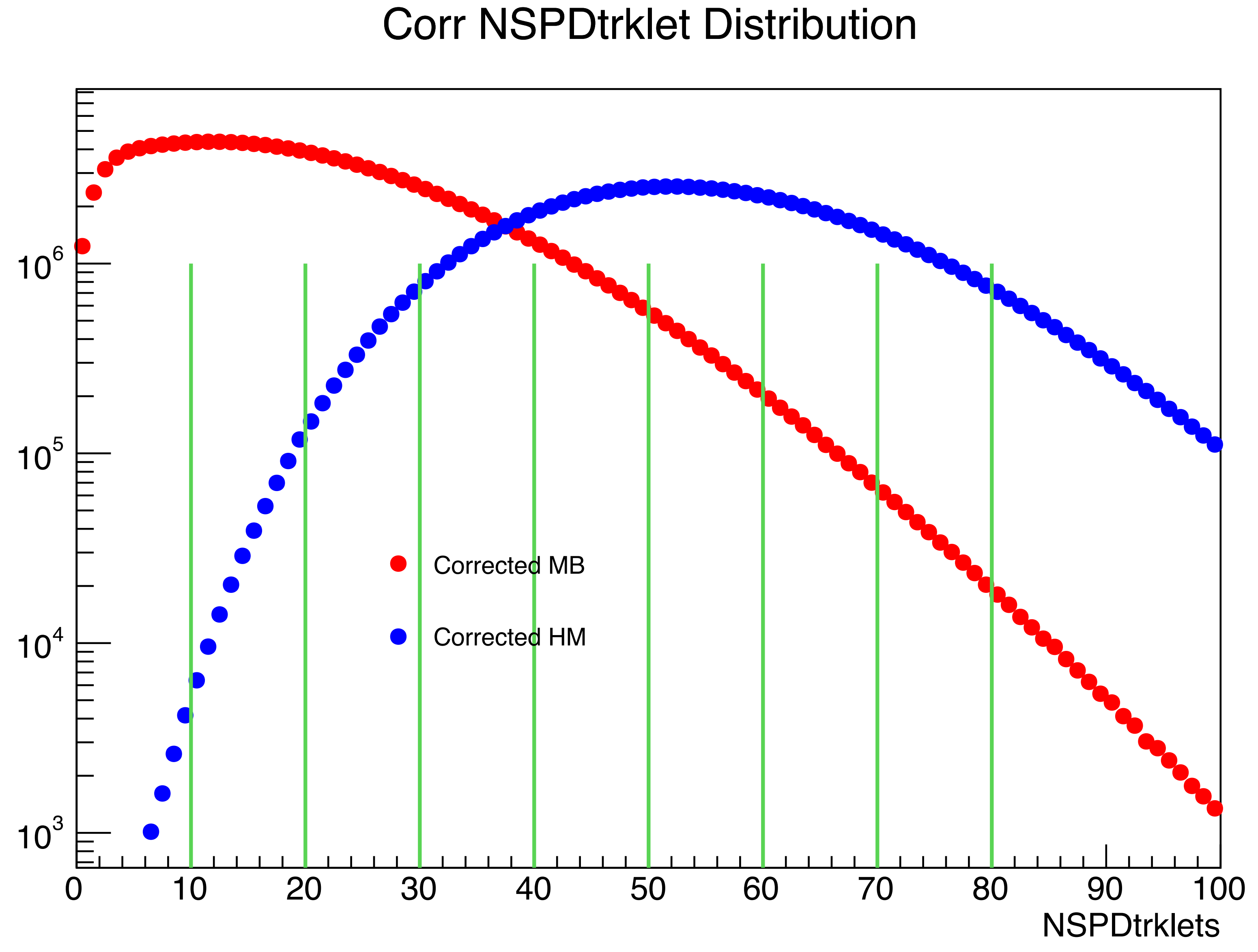
◉Correction for vtxz dependence of the number of SPD tracklets

Due to the acceptance of SPD detector , and inactive channels, $\langle N \rangle_{\mathrm{SPDtrklets}}$ has dependence with Zvtx, also due to SPD performance it's also dependent with run number, so we should correct it by following formula:

$$n^{\mathrm{corr}}_{\mathrm{trk}} = n_{\mathrm{trk}} + \mathrm{Possion}(\Delta n_{\mathrm{trk}}) \qquad \text{where} \qquad \Delta n_{\mathrm{trk}} = \left(\frac{n^{\mathrm{ref}}_{\mathrm{trk}}}{\langle N_{\mathrm{trk}} \rangle (\mathrm{vtxz}, \mathrm{run})} - 1\right) * n_{\mathrm{trk}}$$







Multiplicity estimation

- To select events based on the primary charged-particle multiplicity, the number of SPD tracklets in $|\eta| < 1$ is used. And it should determined by the correlated number of reconstucted SPD tracklets.
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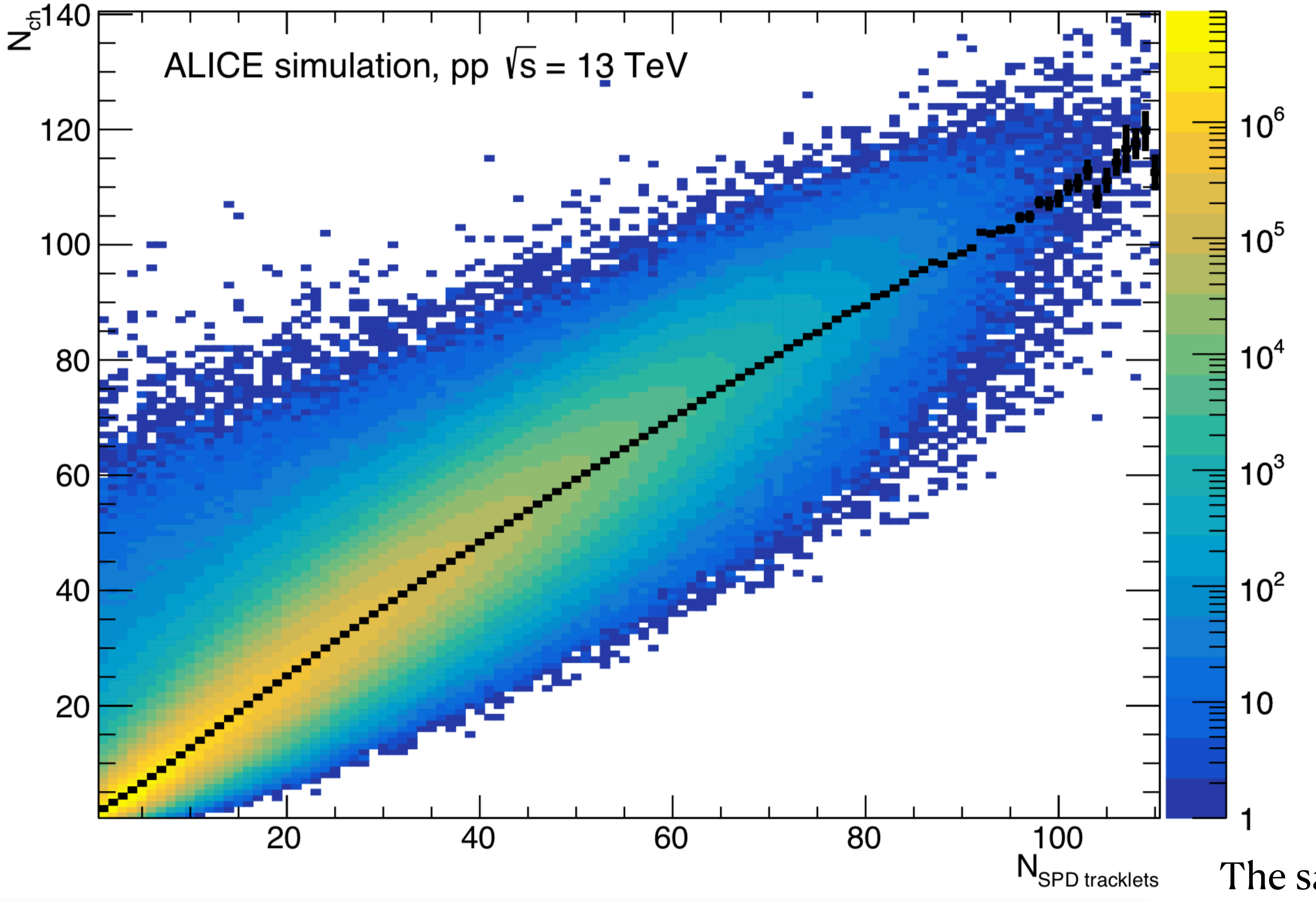


Correlation of charged-particle muliplitiicy vs SPD tracklets

min n_{trk}^{corr}	max n_{trk}^{corr}	$\langle N_{ch} \rangle / \langle n_{ch,INEL>0} \rangle$
4	10	0.393 ± 0.005
11	20	1.227 ± 0.017
21	30	2.109 ± 0.031
31	40	2.981 ± 0.046
41	50	3.786 ± 0.055
51	60	4.588 ± 0.071
61	70	5.373 ± 0.080
71	80	6.174 ± 0.102
81	100	7.136 ± 0.110

The same as the inclusive J/psi as a function of multiplicity with ALICE

Non-prompt J/ψ separation

The J/ψ candidates are formed by considering all opposite charged dielectron pairs.

The inclusive J/ψ yield measured at hadron colliders can be considered as originating from three main different processes, which include prompt and non-prompt collision procedure:

prompt -> direct produce.

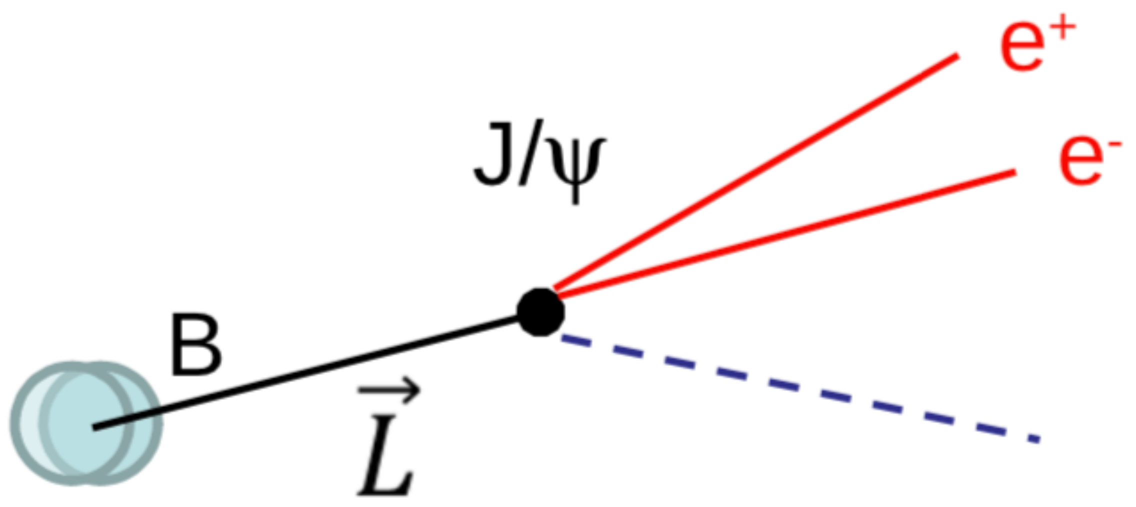
non-prompt -> B hadron decay.

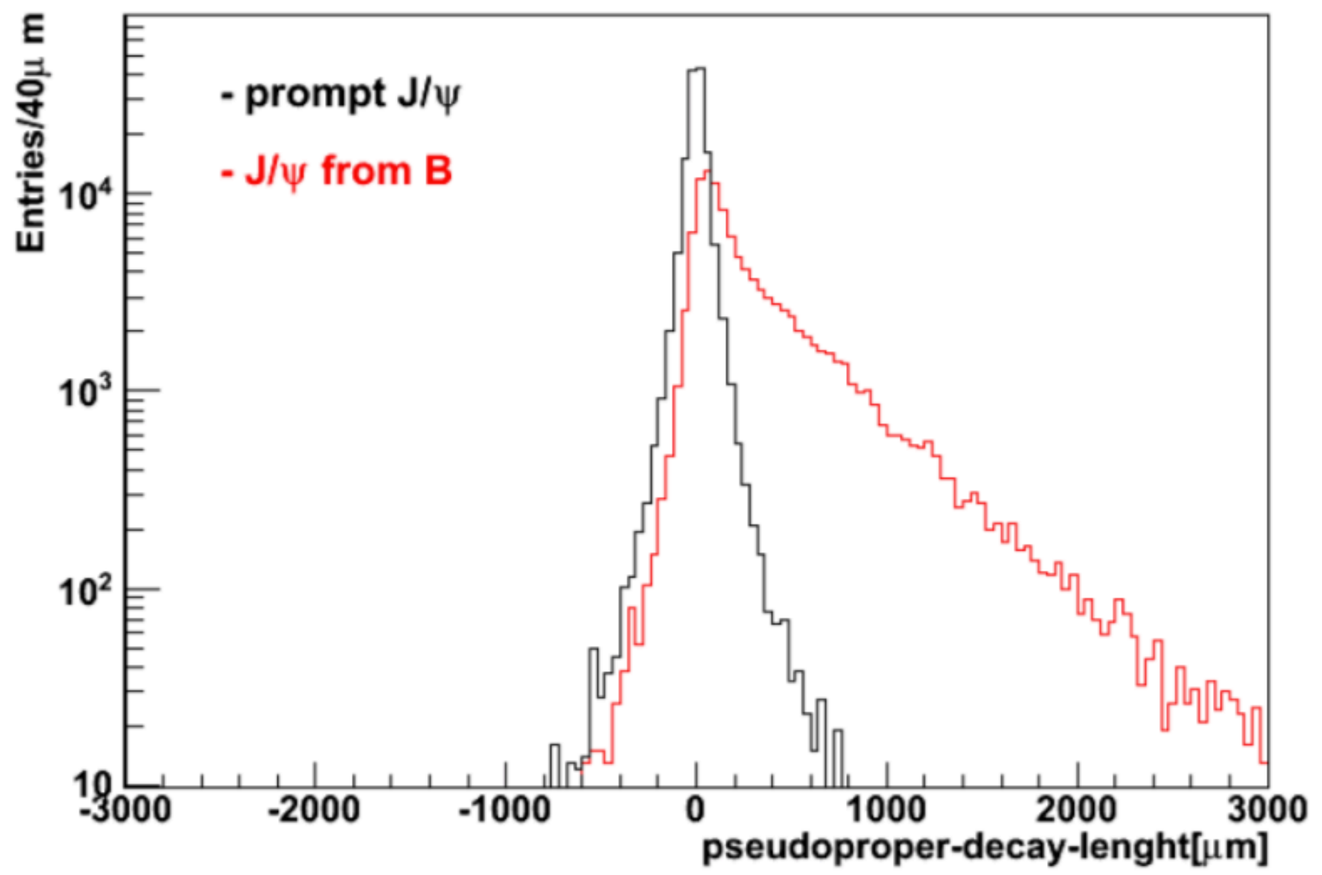
Prompt J/ψ mesons are separated from those orignating from beauty hadrons decay, exploiting the displacement between the primary vertex of J/ψ.

The measurement of fraction of J/ψ mesons originating from beauty-hadron decays is named f_{B} ,which is after efficiency correction applied on the measured results $f_{\mathrm{B}}^{\mathrm{uncorrected}}$, which is carried out through an unbind two-dimensional likelihood fit procedure, which is applied on invariant mass and pseudo-proper decay length of J/ψ.

The pseudo-proper decay length (x) is defined as

$$x = \frac{c \cdot \overrightarrow{L} \cdot \hat{p}_{\mathrm{T}} \cdot M_{\mathrm{J}/\psi}}{|\overrightarrow{p}_{\mathrm{T}}|}$$





Track and pair candidate selection

Decay channel : $\mathrm{J}/\psi \rightarrow \mathrm{e}^{+}\mathrm{e}^{-}$

Track selection : select dielectric pair candidates

Criteria:

◉**track kinematics**

remove combinatorial background from low-p_{T} electrons

◉**track quality**

ITS, TPC, and Impact parameter requirement

◉**electron identification**

TPC dE/dx

◉**rejection of electrons from photon conv.**

Pairing candidate:

$|y| < 0.9,$

$p_{\mathrm{T}} \in [1.0,\ 15.0]\ \mathrm{GeV}/c$

daughters of candidate have at least one hit in two of SPD layers

Variables	Cut values
$\|\eta\|$	<|0.9|
p_T	>1.0 GeV/c
|DCAxy|	<0.5 cm
|DCAz|	<2.0 cm
TPC $n\sigma_e$	[-3,3]
TPC $n\sigma_\pi$	>3.5
TPC $n\sigma_p$	>3.5
reject kinks	yes
request ITS refit	yes
request TPC refit	yes
request SPDany	yes
TPC $\|\chi^2\|$	[0,4]
ITS $\|\chi^2\|$	[0,36]
TPC Ncls.	[70,160]
ITS Ncls. shared	[0,1]

Likelihood fit

After we extract inclusive J/ψ signal, we can separate prompt and non-prompt J/ψ. As we discuss above , we use maximum likelihood fit method. The fit procedure maximizes the logarithm of a likelihood function:

$$\ln\{L\} = \sum_{i=1}^{N} \ln\{F(x^i, m^i_{\mathrm{e^+e^-}})\}$$

its components

$$F(x, m_{\mathrm{e^+e^-}}) = f_{\mathrm{Sig}} \cdot F_{\mathrm{Sig}}(x) \cdot M_{\mathrm{Sig}}(m_{\mathrm{e^+e^-}}) + (1 - f_{\mathrm{Sig}}) \cdot F_{\mathrm{Bkg}}(x) \cdot M_{\mathrm{Bkg}}(m_{\mathrm{e^+e^-}})$$

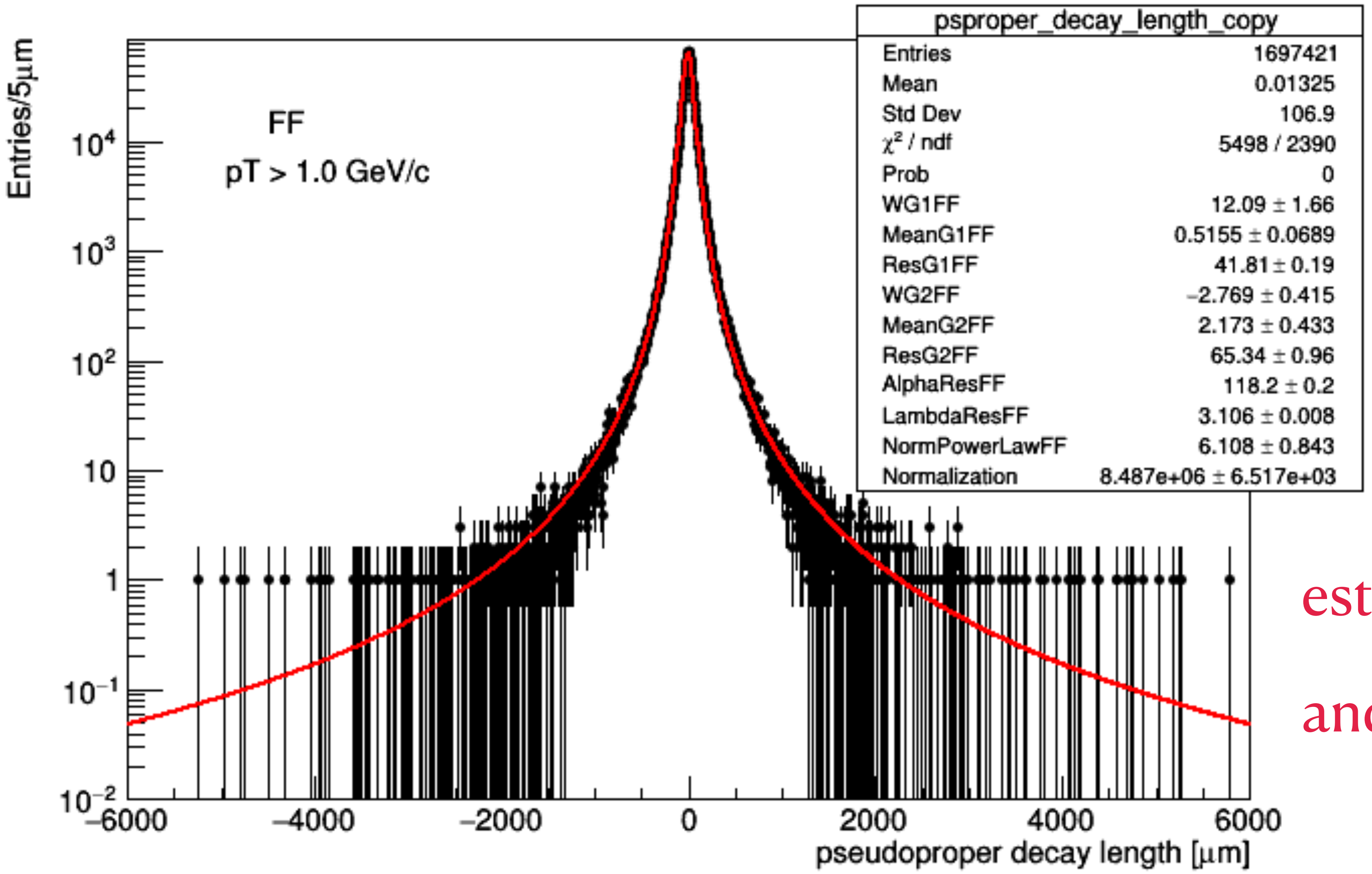
where,

N is J/ψ number ($2.4 < \mathrm{M} < 3.6\ \mathrm{GeV}/c^2$)

$$F_{\mathrm{Sig}} = f'_{\mathrm{B}} \cdot F_{\mathrm{B}} + (1 - f'_{\mathrm{B}}) \cdot F_{\mathrm{Prompt}}$$

$$\boxed{F_{\mathrm{Prompt}} = \delta(x') \otimes R(x' - x) = R(x)}$$

$$F_B(x) = \chi_B(x') \otimes R(x)$$



estimated from MC study

and no much multiplicity dependence

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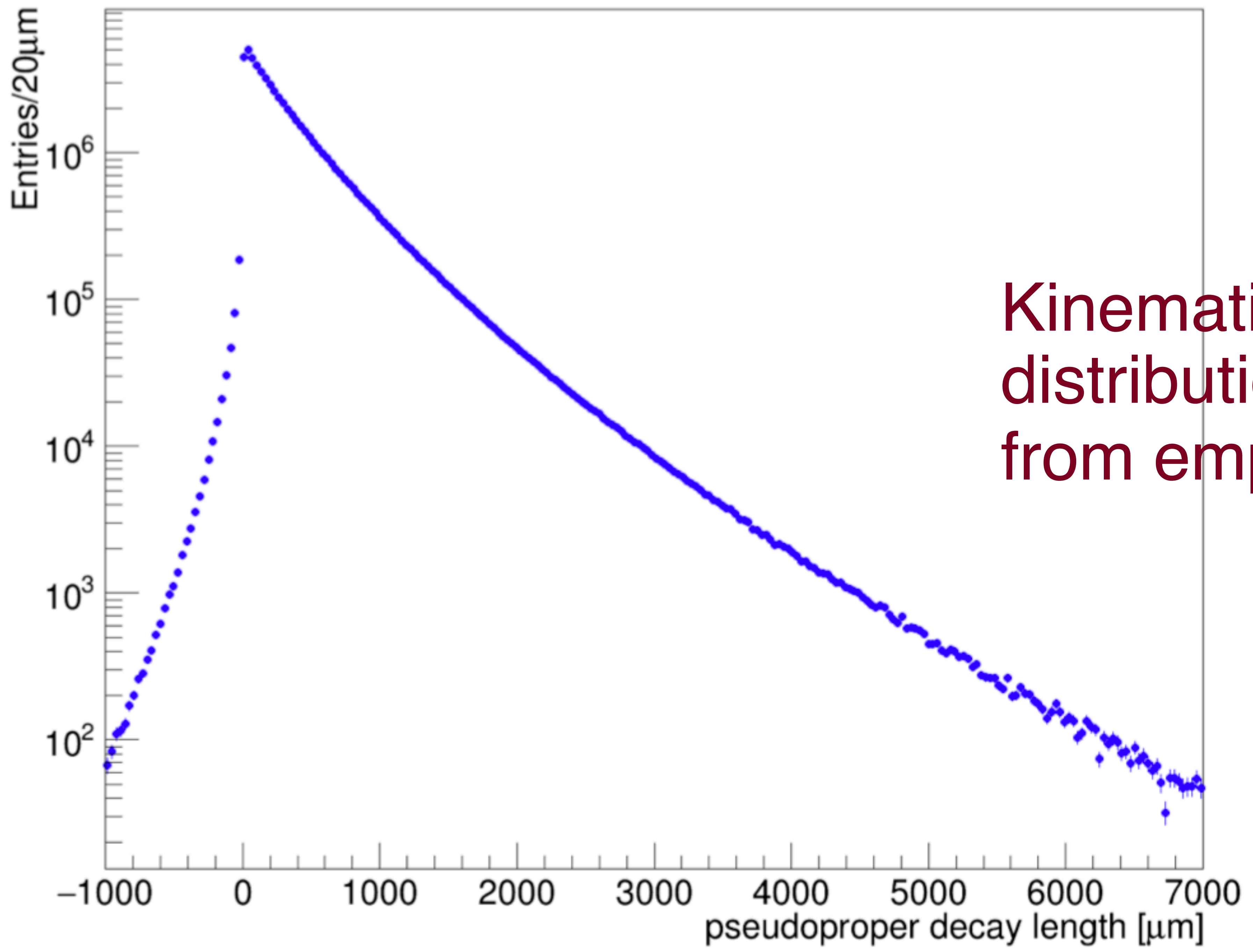

Kinematic pseudo-proper decay length distribution $\chi_{\mathrm{B}}(x)$ of secondary J/ψ from employed MC from non prompt

Likelihood fit

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$$F(x, m_{\mathrm{e^+e^-}}) = f_{\mathrm{Sig}} \cdot F_{\mathrm{Sig}}(x) \cdot M_{\mathrm{Sig}}(m_{\mathrm{e^+e^-}}) + (1 - f_{\mathrm{Sig}}) \cdot \boxed{F_{\mathrm{Bkg}}(x)} \cdot M_{\mathrm{Bkg}}(m_{\mathrm{e^+e^-}})$$

where,

N is J/ψ number

$F_{\mathrm{Sig}} = f'_{\mathrm{B}} \cdot F_{\mathrm{B}} + (1 - f'_{\mathrm{B}}) \cdot F_{\mathrm{Prompt}}$

$F_{\mathrm{Prompt}} = \delta(x') \otimes R(x' - x) = R(x)$

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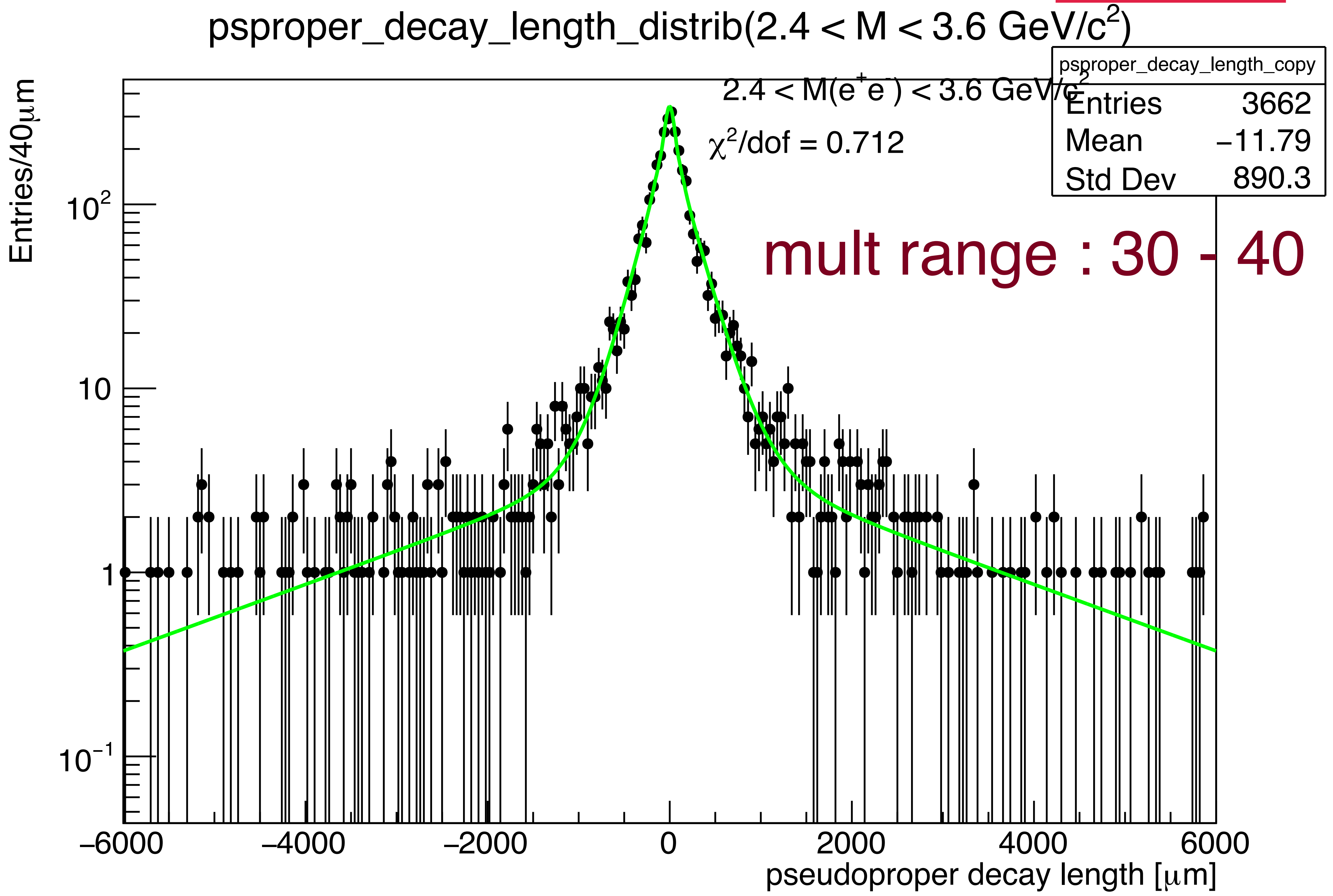

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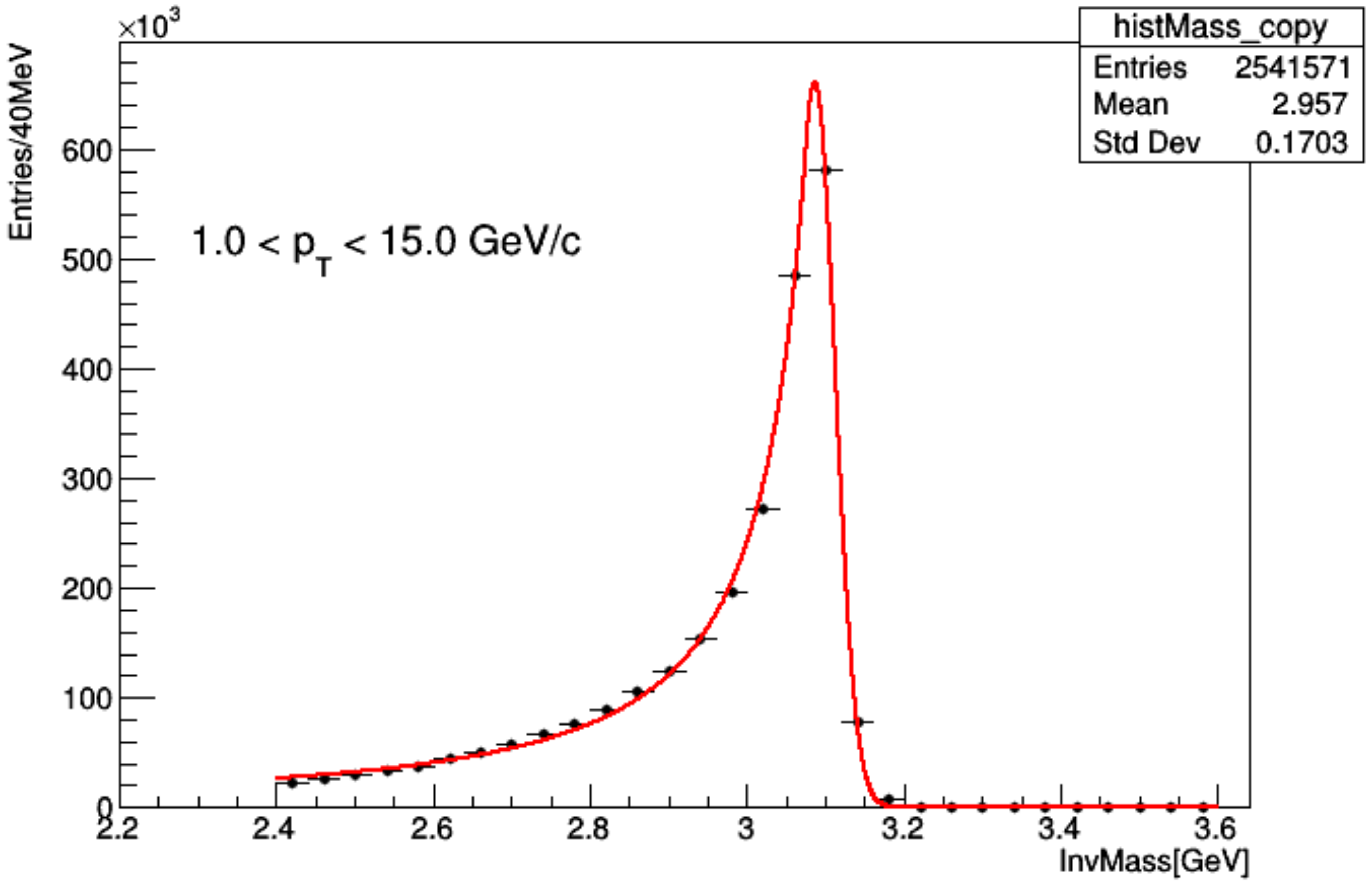
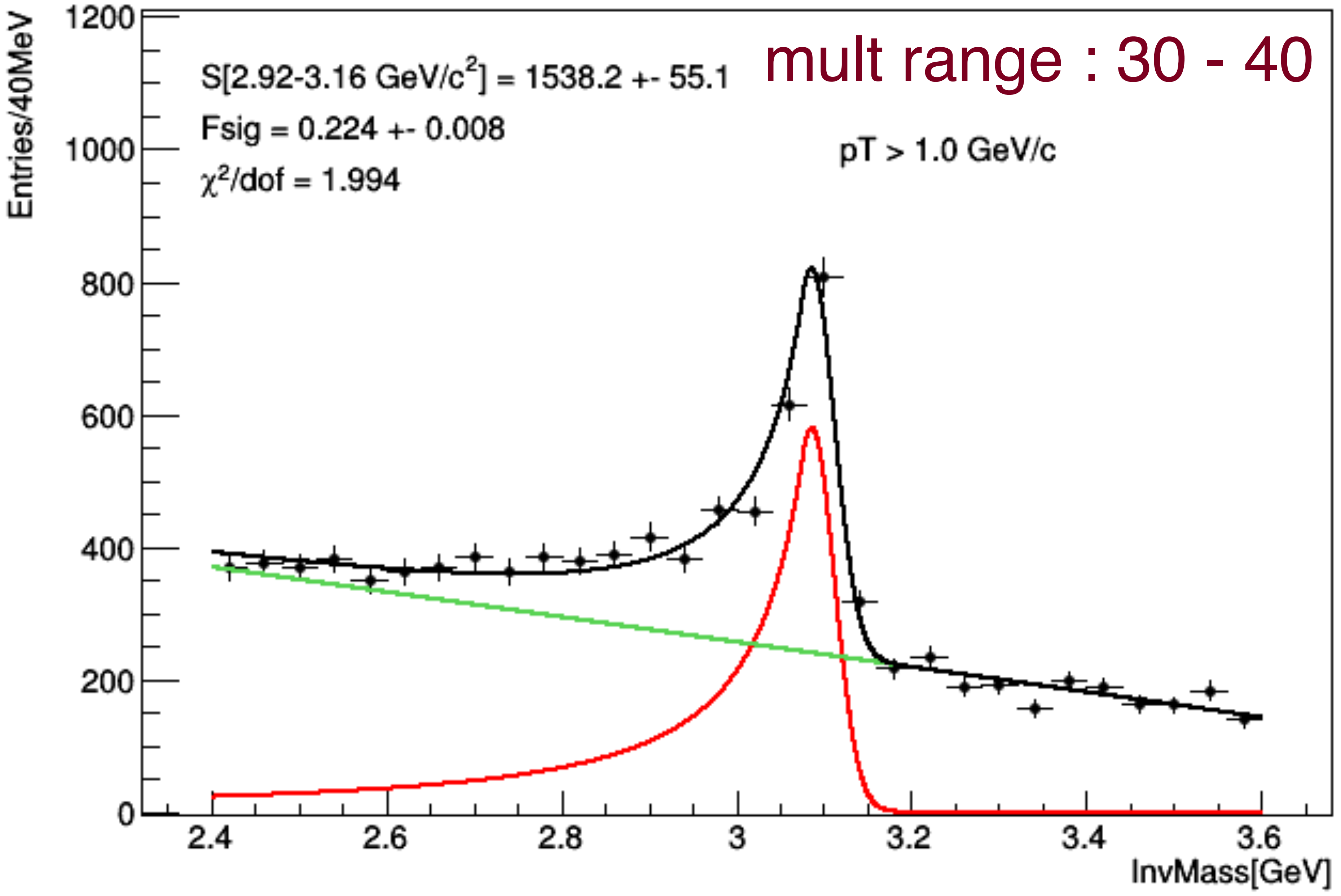
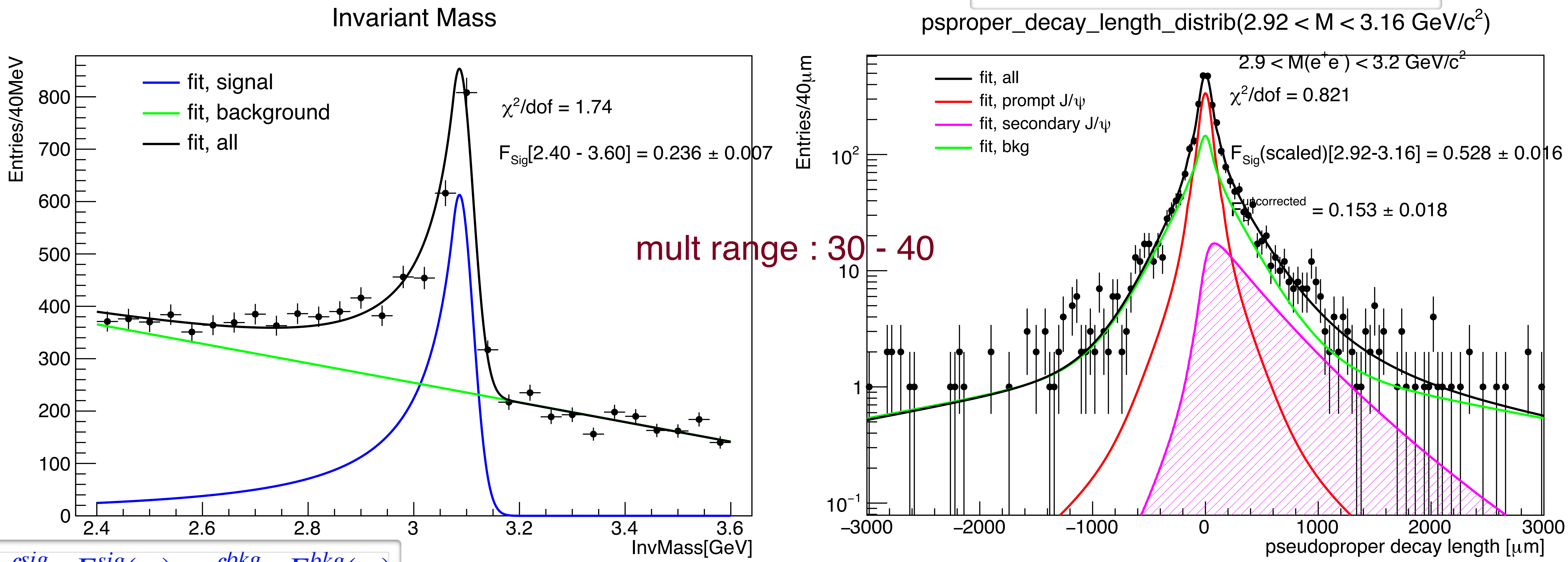




Likelihood fit

We use the likelihood function $\ln\{L\} = \sum_{i=1}^{N} \ln\{F(x^i, m^i_{e^+e^-})\}$ to estimate the most "proper" parameters to describe the fraction of components of prompt and non-prompt J/ψ PDFs, which can retrieve the $f_B^{\text{uncorrected}}$ factor from measured inclusive J/ψ raw yield.

$$F_x = f_x^{sig} \cdot F^{sig}(x) + f_x^{bkg} \cdot F^{bkg}(x)$$

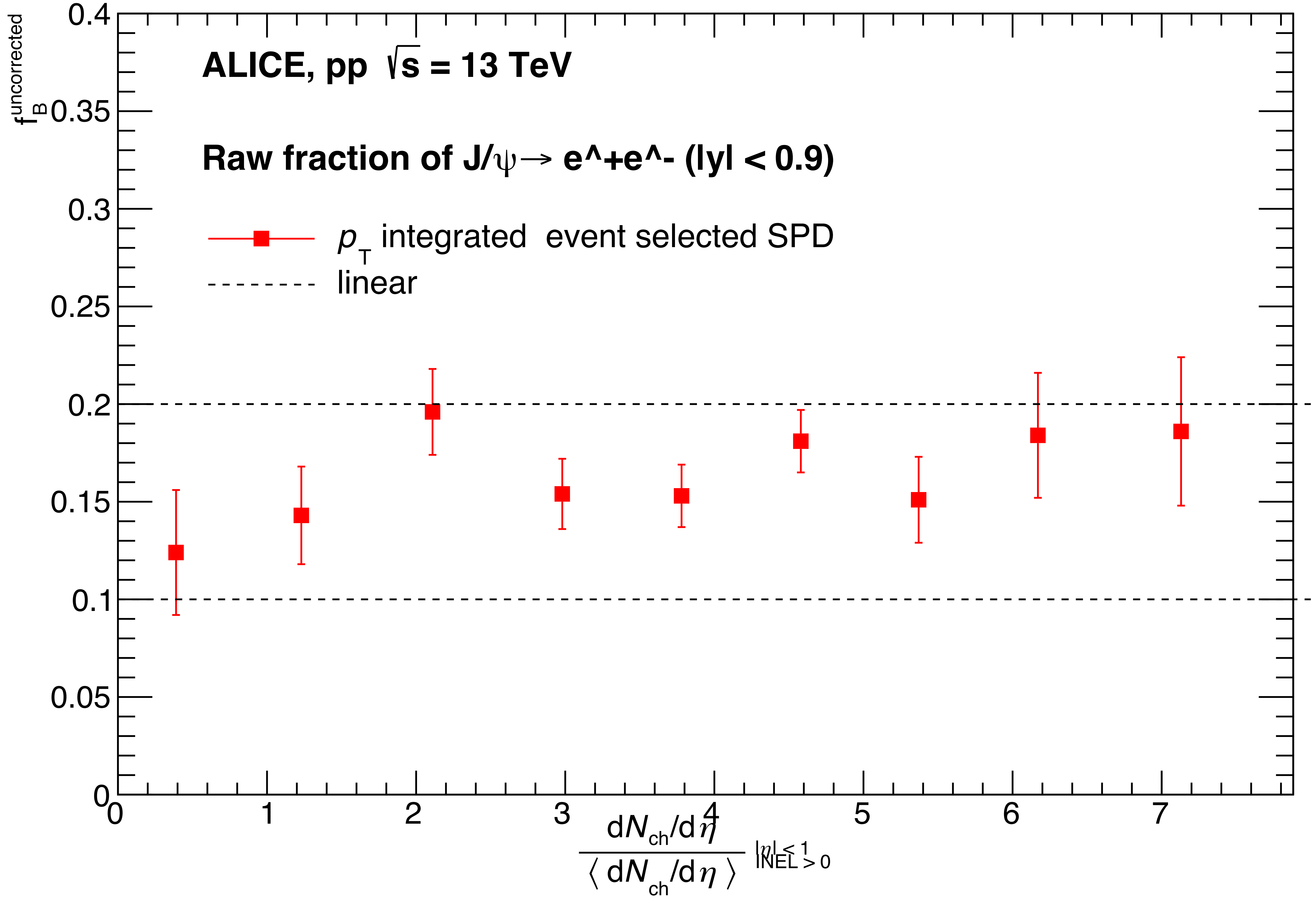


$$F_m = f_m^{sig} \cdot F^{sig}(m) + f_m^{bkg} \cdot F^{bkg}(m)$$

simultaneously fit projected on invariant mass and x distribution of J/ψ

Results

As the raw measured reconstructed ***number of SPD tracklets*** convert to ***primary charged-particle multiplicity*** , we get the $f_{\mathrm{B}}^{\mathrm{uncorrected}}$ vs $(\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta)/\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$



min $n_{\mathrm{trk}}^{\mathrm{corr}}$	max $n_{\mathrm{trk}}^{\mathrm{corr}}$	$\langle N_{\mathrm{ch}} \rangle / \langle n_{\mathrm{ch,INEL>0}} \rangle$
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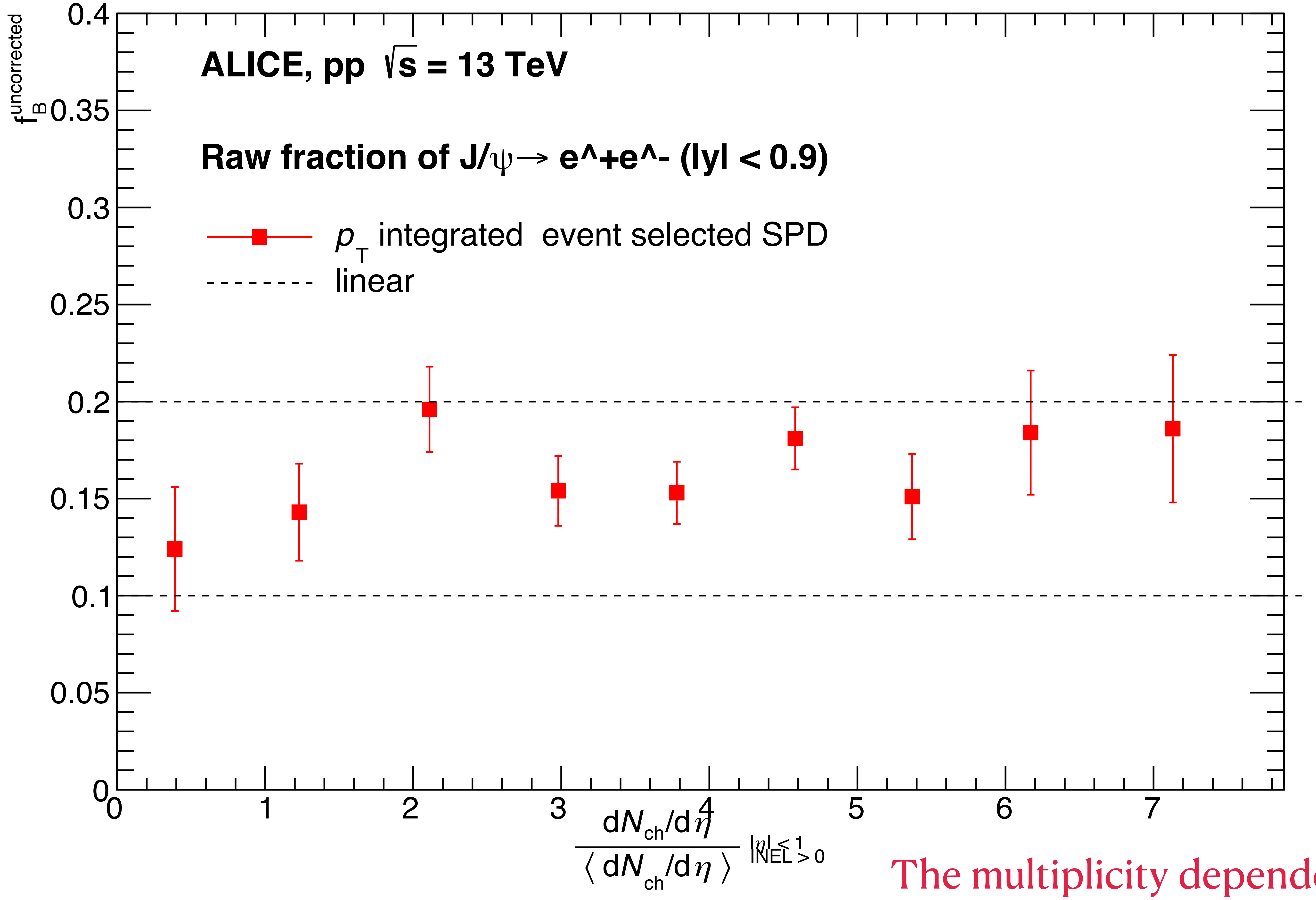

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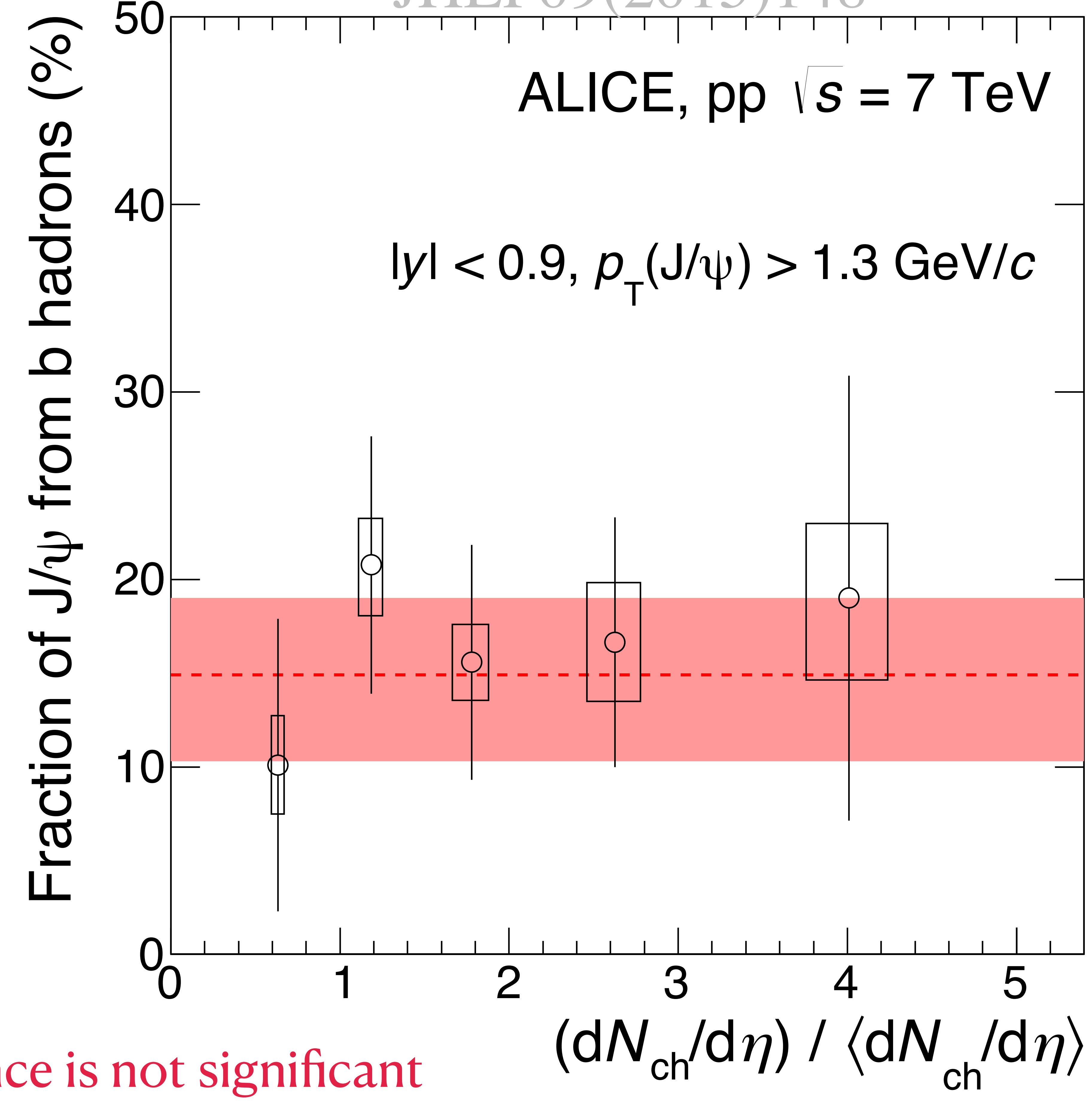

The multiplicity dependence is not significant

Summary & outlook

Summary

- Inclusive J/ψ has been reconstructed in multiplicity intervals via number of SPD tracklets.
- Uncorrected fraction of non-prompt J/ψ has been retrieved via maximum likelihood fit method as a function of multiplicity.
- There is no significant dependence vs multiplicity (uncorrected f_{B}), with non-negligible fluctuation, but with smaller statistic uncertainty than the one @ 7 TeV

Outlook

- Acceptance and efficiency correction via the efficiency study and test from MC (expected no much high dependence with multiplicity).
- Continue the systematic uncertainty analysis.
- Give non-prompt J/ψ production measurement vs multiplicity.

Reference used in this presentation

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Thank you!

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