

INCLUSIVE PHOTOPRODUCTION OF J/ψ IN ELECTRON-PROTON COLLISIONS AT THE ELECTRON-ION COLLIDER

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work done in collaboration with Carlo Flore, Jean-Philippe Lansberg &
Hua-Sheng Shao, in IJCLab (Orsay)

Virtual Quarkonia as Tools 2021, March 21-26, 2021

Part I

Introducing quarkonium production

Quarkonium Production Model

See Phys.Rept. 889 (2020) 1-106 and EPJC (2016) 76:107 for reviews

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 - 3 COLOUR EVAPORATION MODEL: based on **quark-hadron duality**; only the invariant mass matters; semi-soft gluons emissions; colour-wise decorrelated $c\bar{c}$ prod. and hadr.

Part II

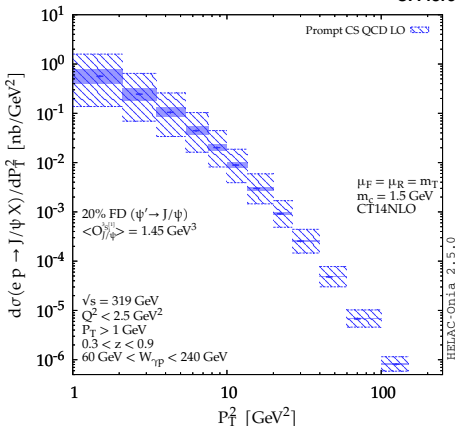
Photoproduction at mid and high P_T at HERA

Different contributions in the CSM up to NLO

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$$\gamma + g \rightarrow \psi + g @ \alpha\alpha_s^2$$

Notes:

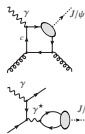
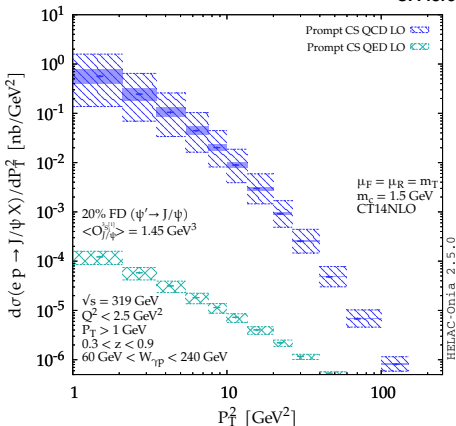
All the computations were done with HELAC-ONIA. The scale and mass uncertainties are shown by the hatched and solid bands.

H.S. Shao, CPC198 (2016) 238; See also <https://nloaccess.in2p3.fr>

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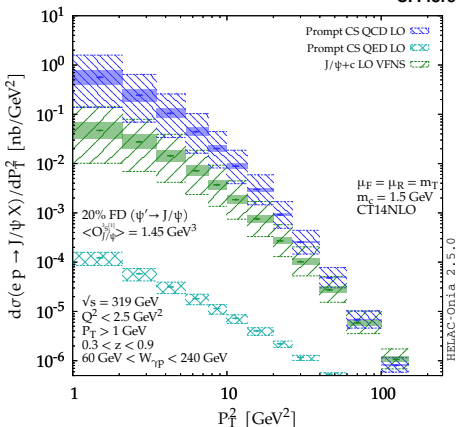
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$$\left\{ \begin{array}{l} \gamma + c \rightarrow \psi + c @ \alpha \alpha_s^2 w. 4 \text{ Flavour Scheme} \\ \gamma + g \rightarrow \psi + c + \bar{c} @ \alpha \alpha_s^3 w. 3 \text{ Flavour Scheme} \end{array} \right. \text{ [also NEW !]}$$

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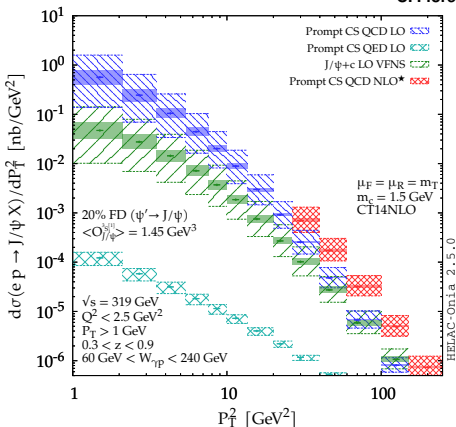
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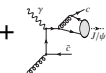
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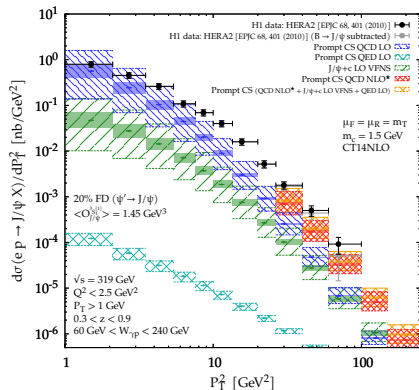
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NLO* only contains the real-emission contributions with an IR cut-off and is expected to account for the leading P_T contributions at NLO (P_T^{-6}). It has been successfully checked against full NLO computations for $P_T > 3 \text{ GeV}$.

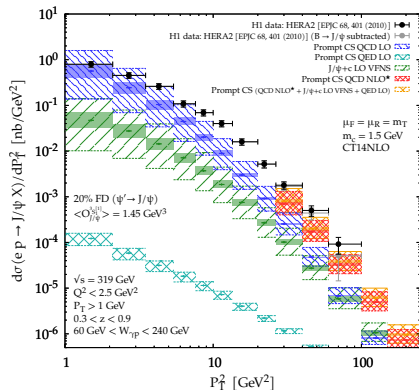
Comparison to the latest HERA data by H1

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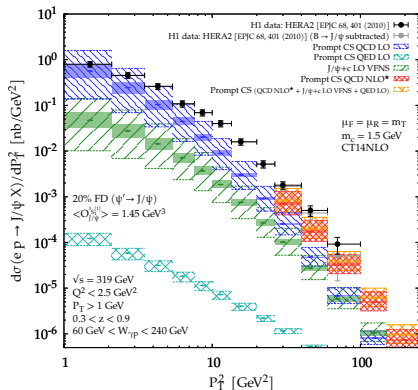
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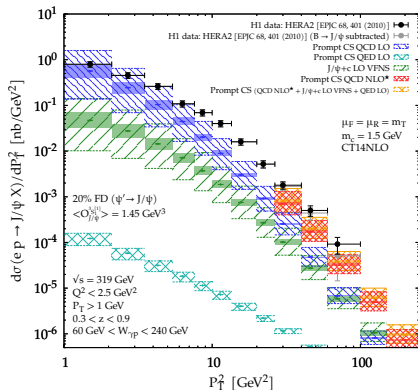
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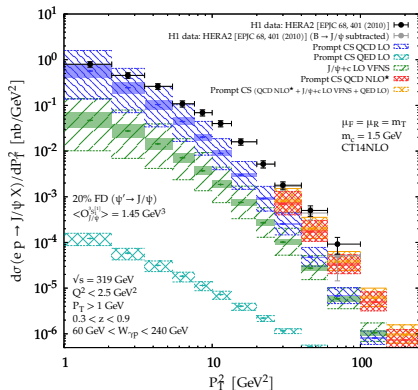
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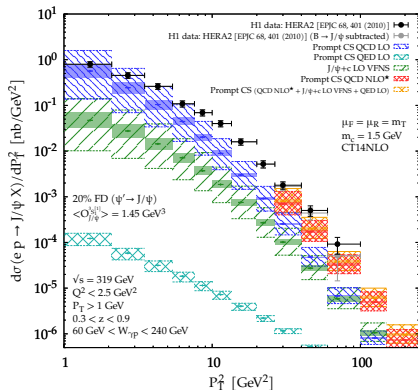
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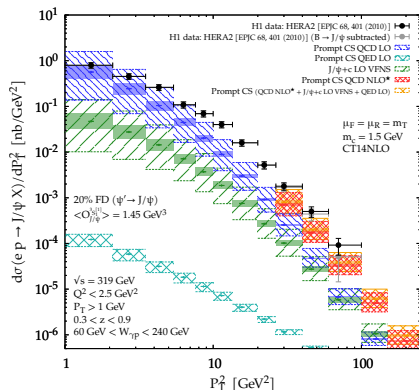
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The CSM up to $\alpha\alpha_s^3$ reproduces photoproduction at HERA

→ we will restrict to CSM for our EIC predictions

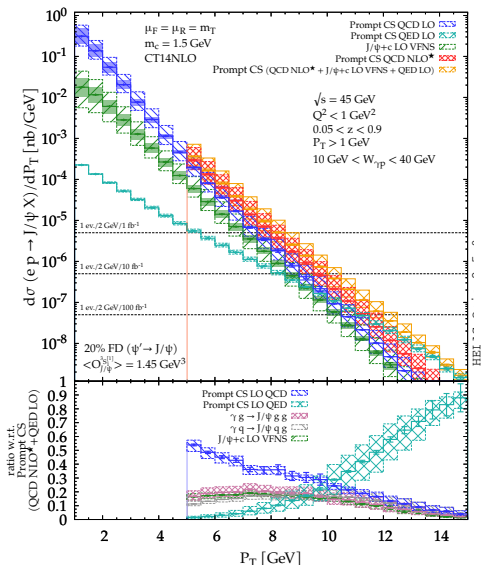
Part III

Photoproduction at mid and high P_T at the Electron-Ion Collider

Predictions for the EIC : $J/\psi + X$

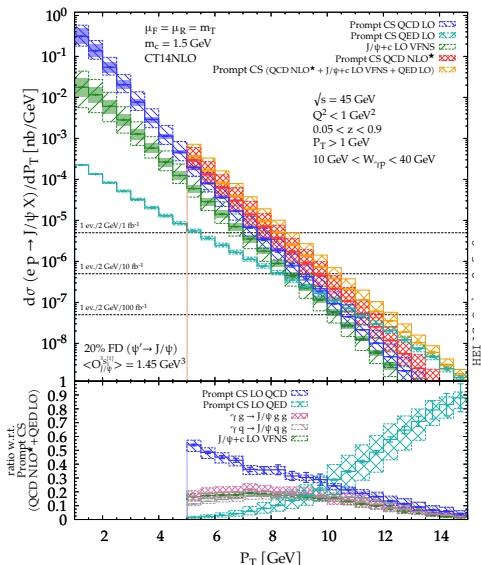
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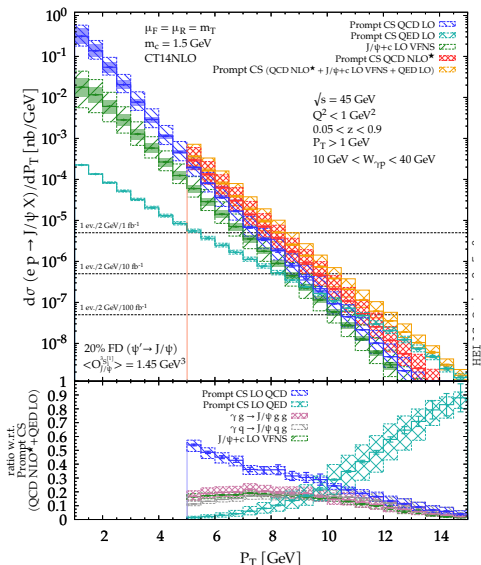
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- At $\sqrt{s_{ep}} = 45 \text{ GeV}$, one gets into valence region
- Yield steeply falling with P_T
- Yield can be measured up to $P_T \sim 11 \text{ GeV}$ with $\mathcal{L} = 100 \text{ fb}^{-1}$
[using both ee and $\mu\mu$ decay channels and $\varepsilon_{J/\psi} \simeq 80\%$]

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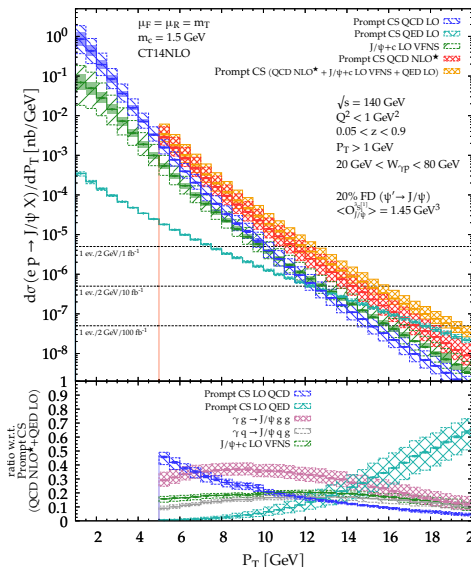


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- photon-quark** fusion contributes more than 30 % for $P_T > 8 \text{ GeV}$

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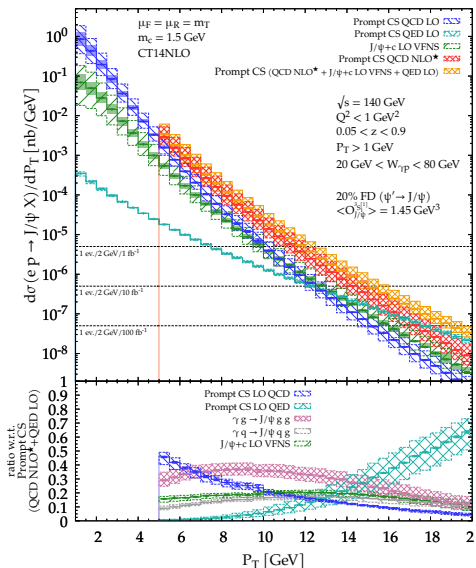
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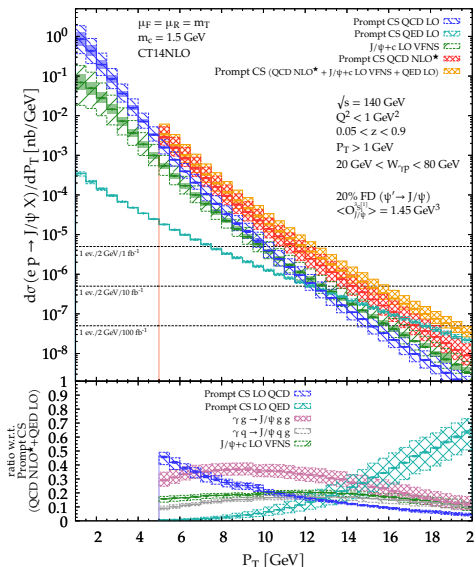
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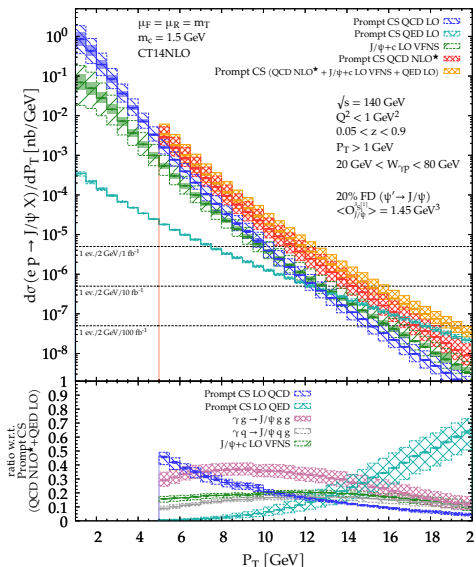
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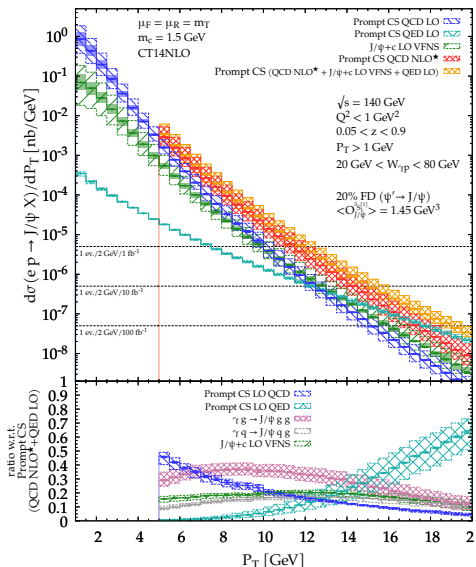
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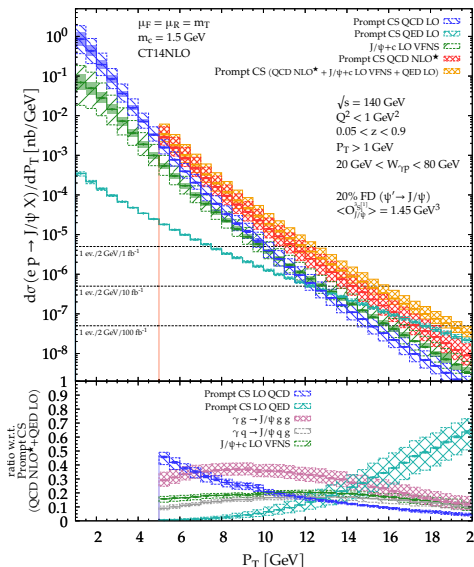
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- We expect the $d\sigma$ to vanish when $E_{\text{jet}_2}^{J/\psi \text{ rest fr.}} \rightarrow 0$

Part IV

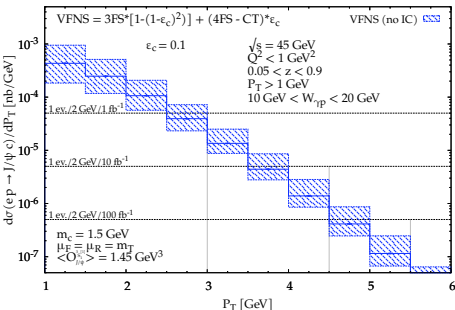
J/ψ +charm associated production at the EIC

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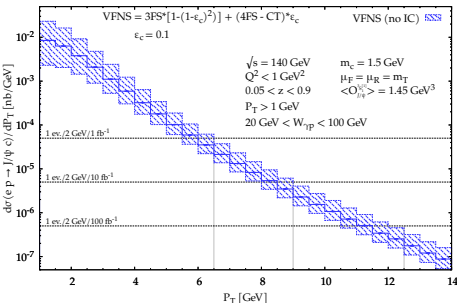
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- Same LO VFNS computation previously shown in green except for the **charm-detection efficiency**
 ϵ_c : $VFNS = 3FS \times (1 - (1 - \epsilon)^2) + (4FS - CT) \times \epsilon$
- At $\sqrt{s_{ep}} = 45$ GeV, yield limited to **low P_T** even with $\mathcal{L} = 100 \text{ fb}^{-1}$
- But it is clearly observable if $\epsilon_c = 0.1$ with $\mathcal{O}(500, 50, 5)$ events for $\mathcal{L} = (100, 10, 1) \text{ fb}^{-1}$

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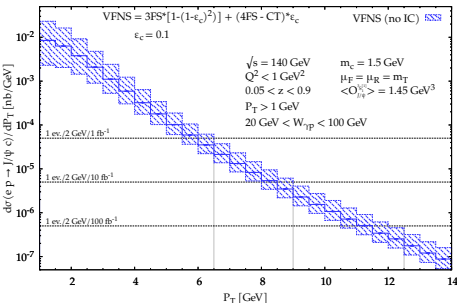
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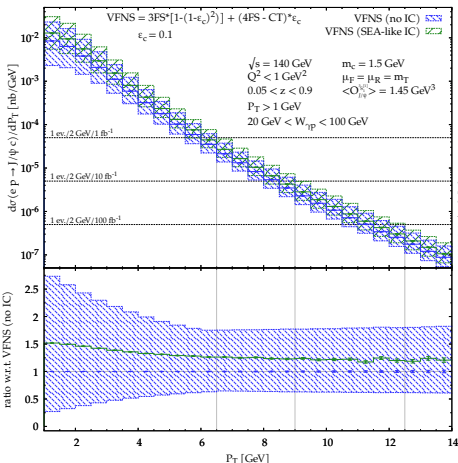


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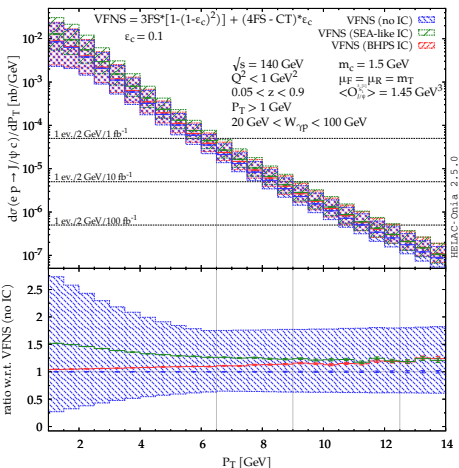


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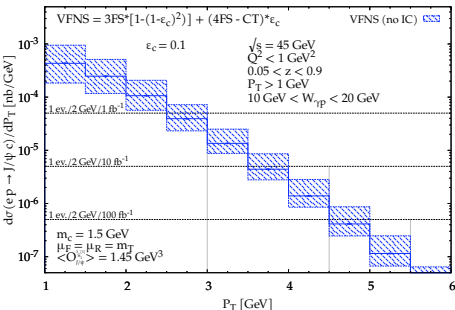


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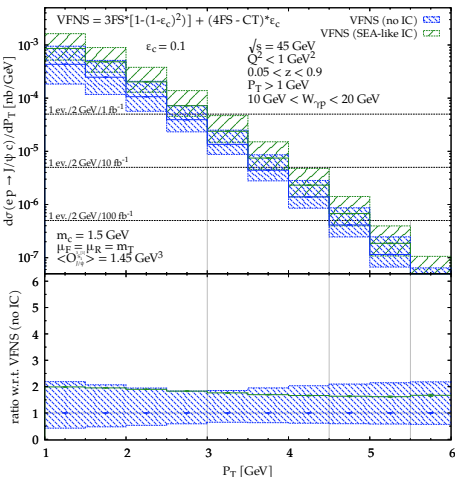


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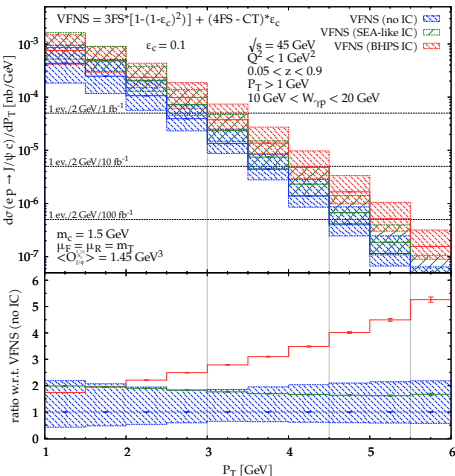


- Same LO VFNS computation previously shown in green except for the **charm-detection efficiency** ϵ_c : $VFNS = 3FS \times (1 - (1 - \epsilon)^2) + (4FS - CT) \times \epsilon$
- At $\sqrt{s_{ep}} = 45$ GeV, yield limited to **low P_T** even with $\mathcal{L} = 100 \text{ fb}^{-1}$
- But it is clearly observable if $\epsilon_c = 0.1$ with $\mathcal{O}(500, 50, 5)$ **events for $\mathcal{L} = (100, 10, 1) \text{ fb}^{-1}$**
- At $\sqrt{s_{ep}} = 140$ GeV, P_T range up to 10 GeV with **up to thousands of events with $\mathcal{L} = 100 \text{ fb}^{-1}$**
- Could be observed via **charm jet**

- 4FS $\gamma c \rightarrow J/\psi c$ depend on $c(x)$ and could be enhanced by **intrinsic charm**
- Small effect at $\sqrt{s_{ep}} = 140$ GeV [We used IC $c(x)$ encoded in CT14NNLO]
- Measurable effect at $\sqrt{s_{ep}} = 45$ GeV

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Thank you for attention!