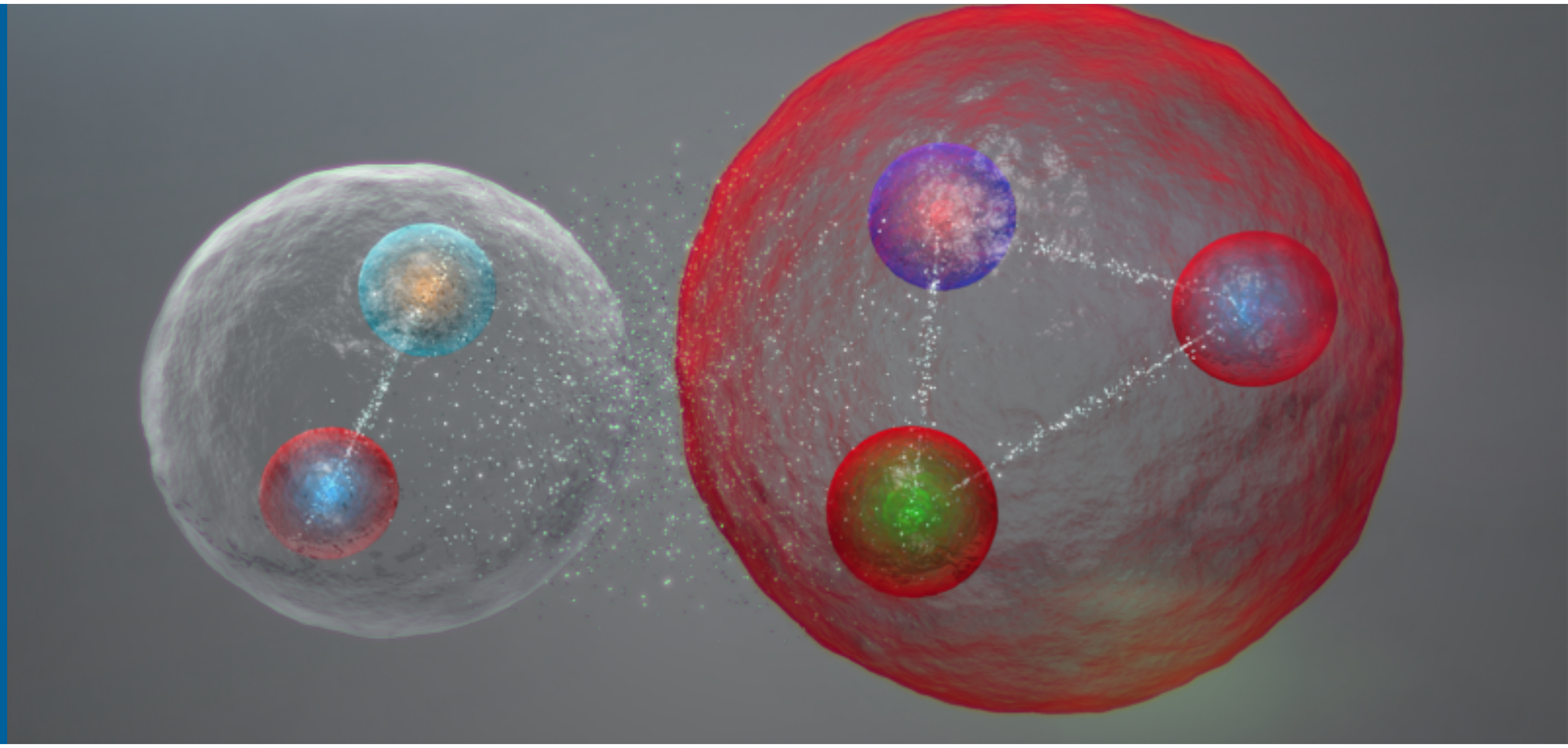
MAXIMIZING PHYSICS REACH FOR DVMP

REQUIREMENTS FOR A SECOND IR DETECTOR IN REGARD TO J/PSI AND UPSILON PRODUCTION



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U.S. DEPARTMENT OF ENERGY
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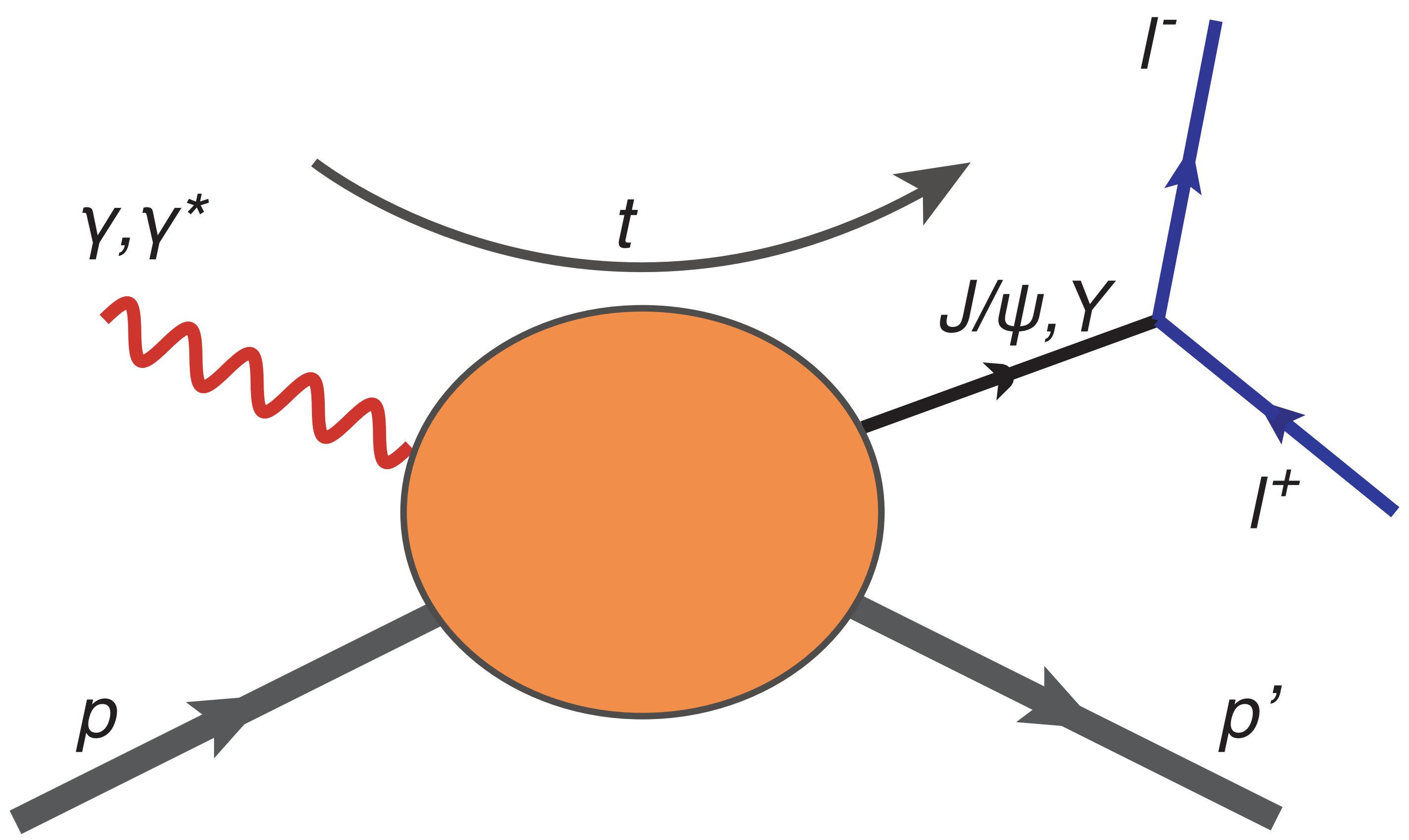
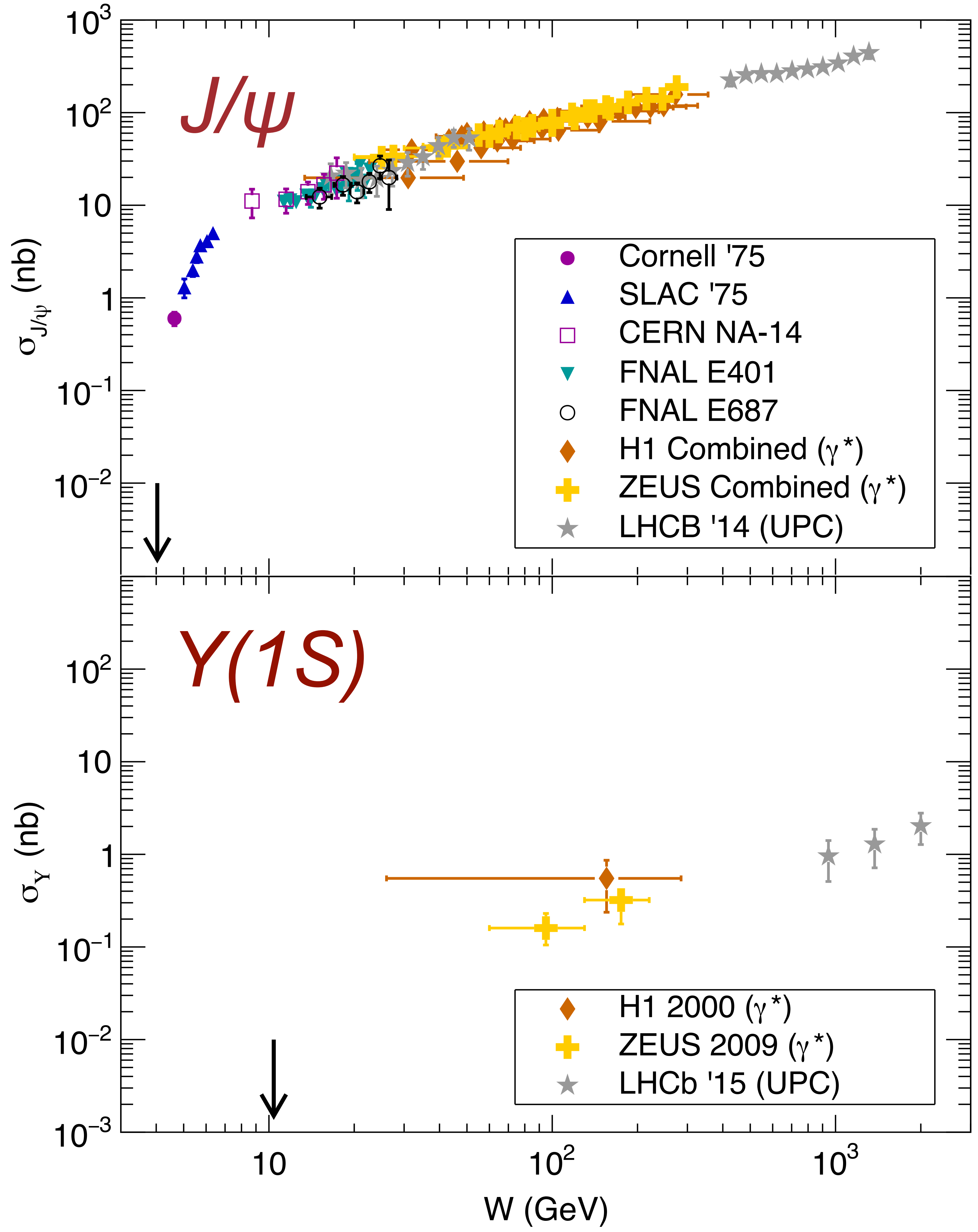
First IR2@EIC Workshop
March 18, 2021

EXCLUSIVE QUARKONIUM PRODUCTION

What do we know?



$$\sigma_{tot}^{\gamma p} = \int_{t_{min}}^{t_{max}} dt \frac{d\sigma}{dt}$$



- *J/ψ* photo-production well-constrained at high energies
- *Υ(1S)*: not much available
- **Almost no data near threshold**
- **Electro-production almost completely unconstrained**

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- **Gluonic Van der Waals force**, possible quarkonium-nucleon/nucleus bound states
- **Mechanism** for quarkonium production
- Test **SRC universality** with a gluonic probe

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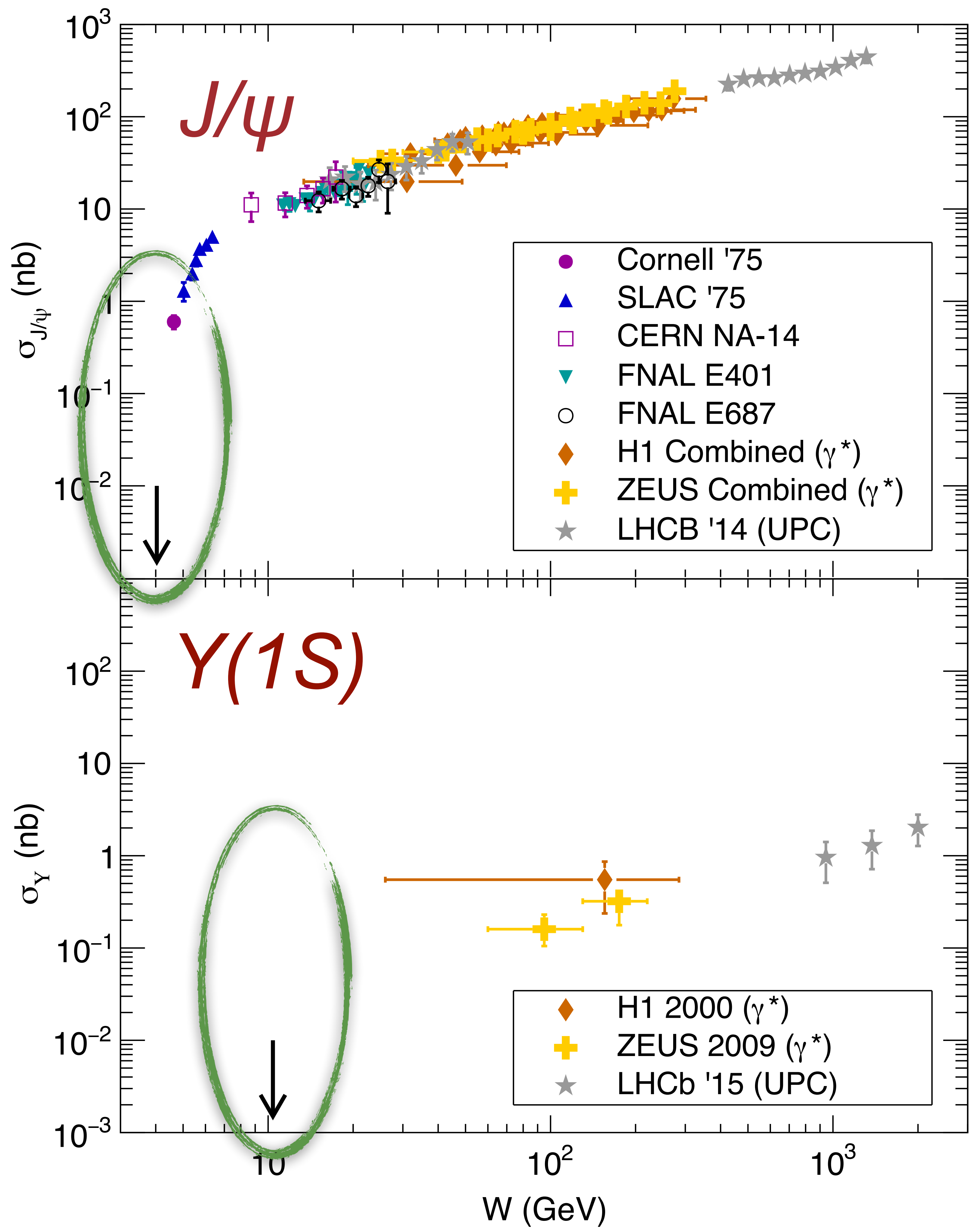
J/ψ at JLab
$Y(1s)$ at EIC



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Electro-Production at high energies:

- **Access Gluon GPD:** Full 3D tomography of the gluonic structure of the nucleon
- **Matter radius** of nuclei
- Sensitive to onset of **saturation**
- L-T Separation and Q^2 dependence of R for quarkonium production

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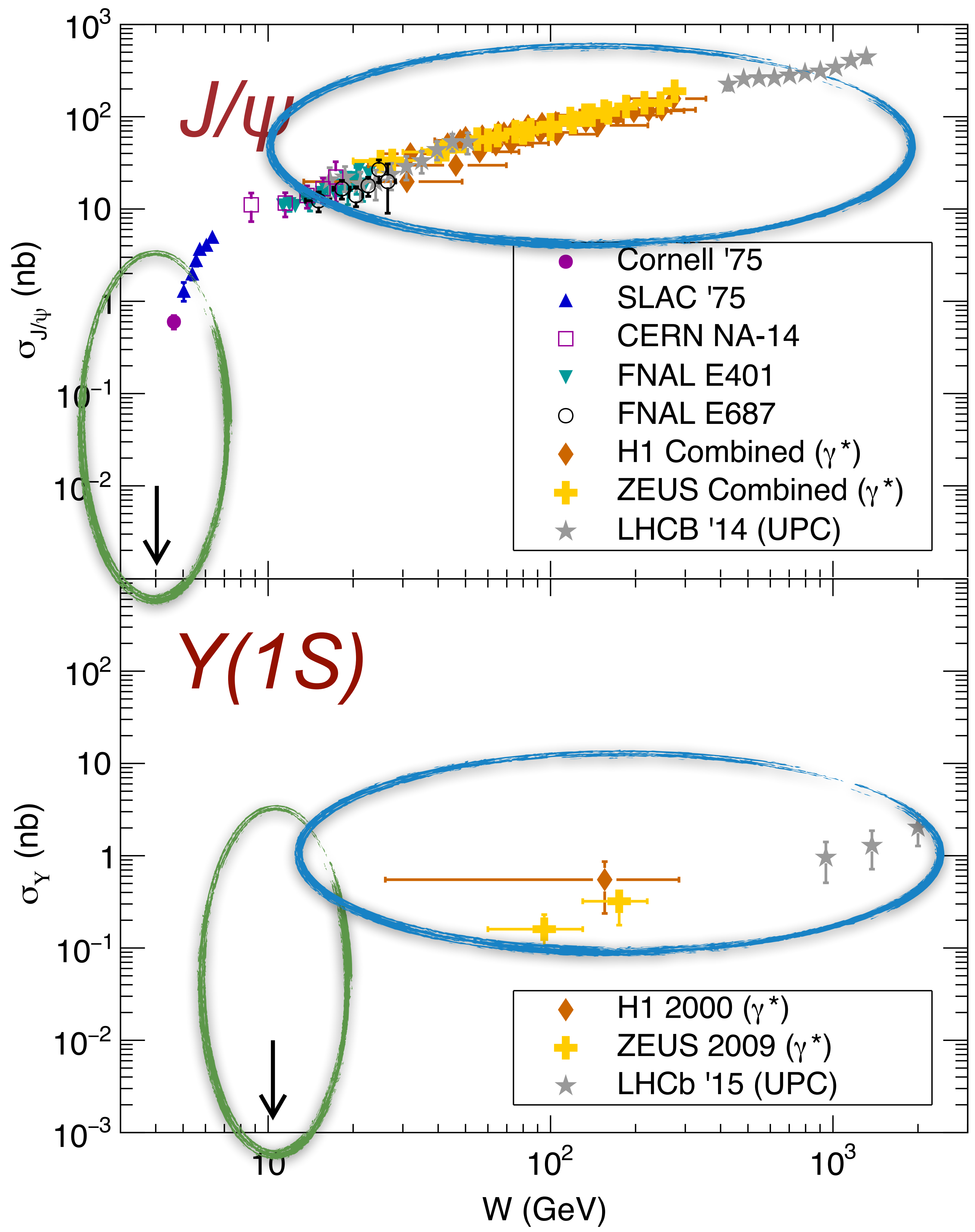
J/ψ at JLab
Y(1s) at EIC

J/ψ and
Y(1s) at EIC

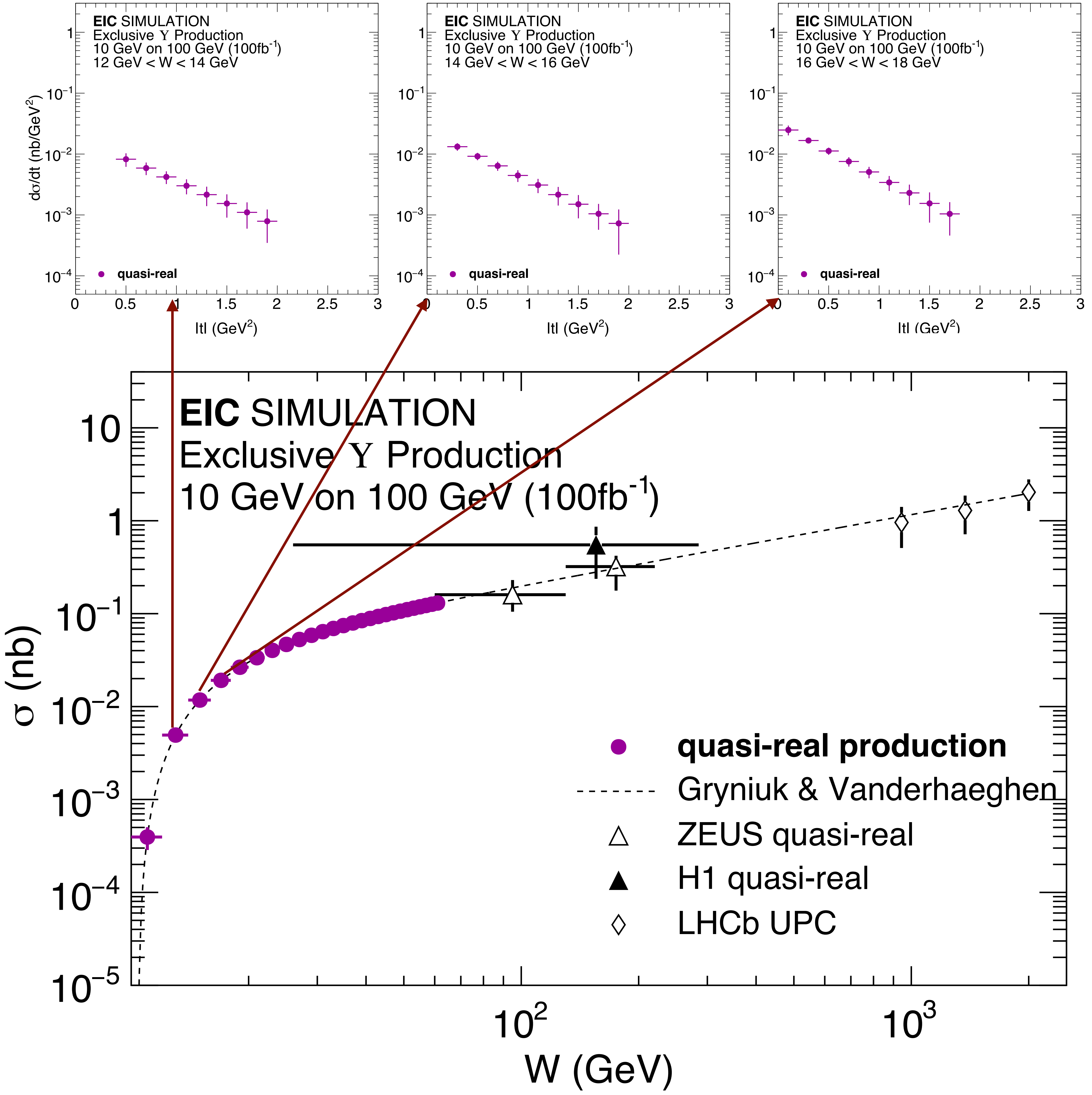


S. Joosten, Z.-E. Meziani, PoS QCDEV2017 017 (2018)

Υ(1S) PHOTOPRODUCTION AT EIC

…Threshold measurement possible!

- **Quasi-real production** at an EIC
- Both electron and muon channel
- 2D cross section (in |t| and W), additional lever arm in Q^2 also available (electroproduction)
- **Fully exclusive** reaction
- Can go **to near-threshold region**



Y(1S) PHOTOPRODUCTION AT EIC

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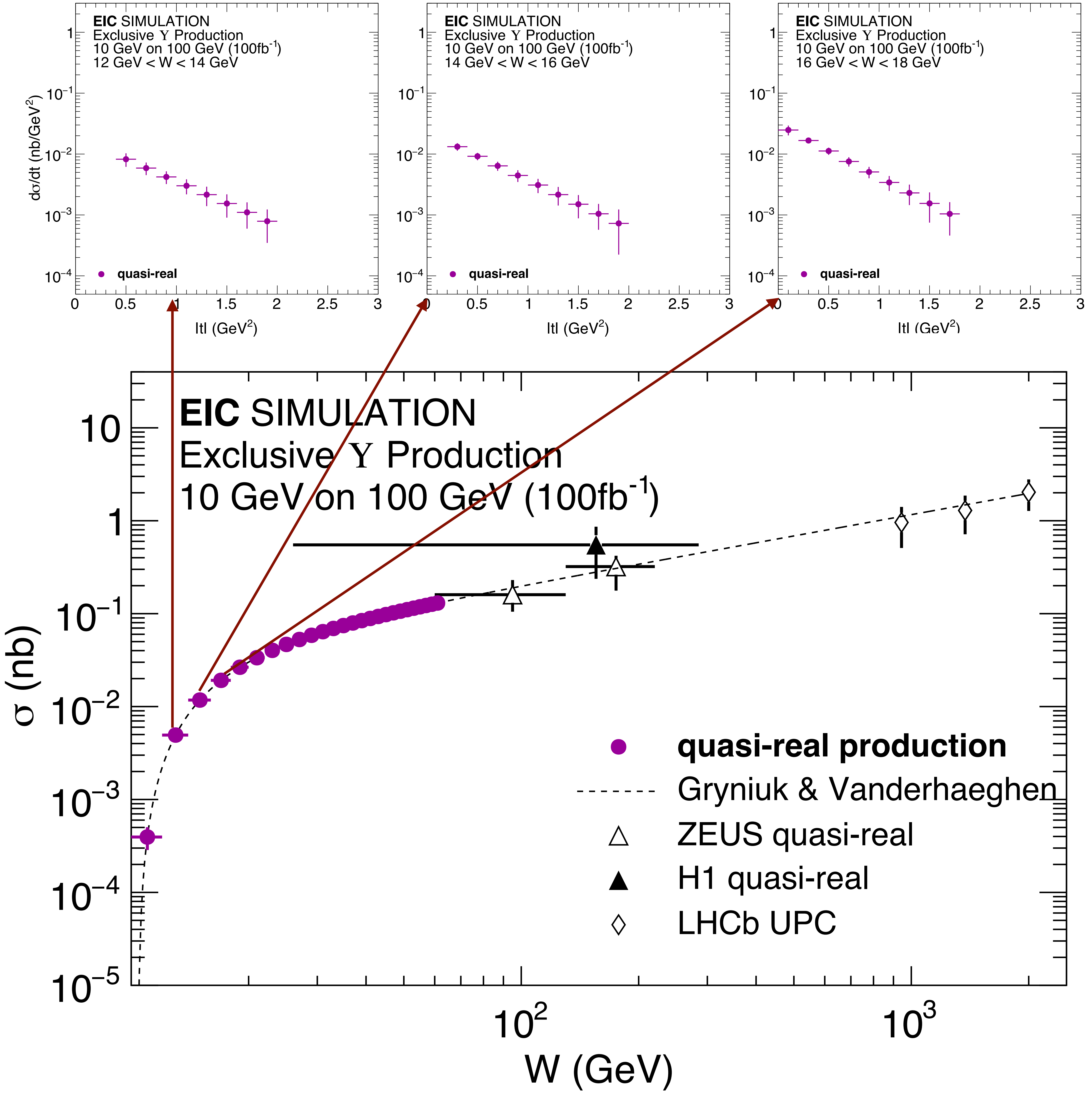
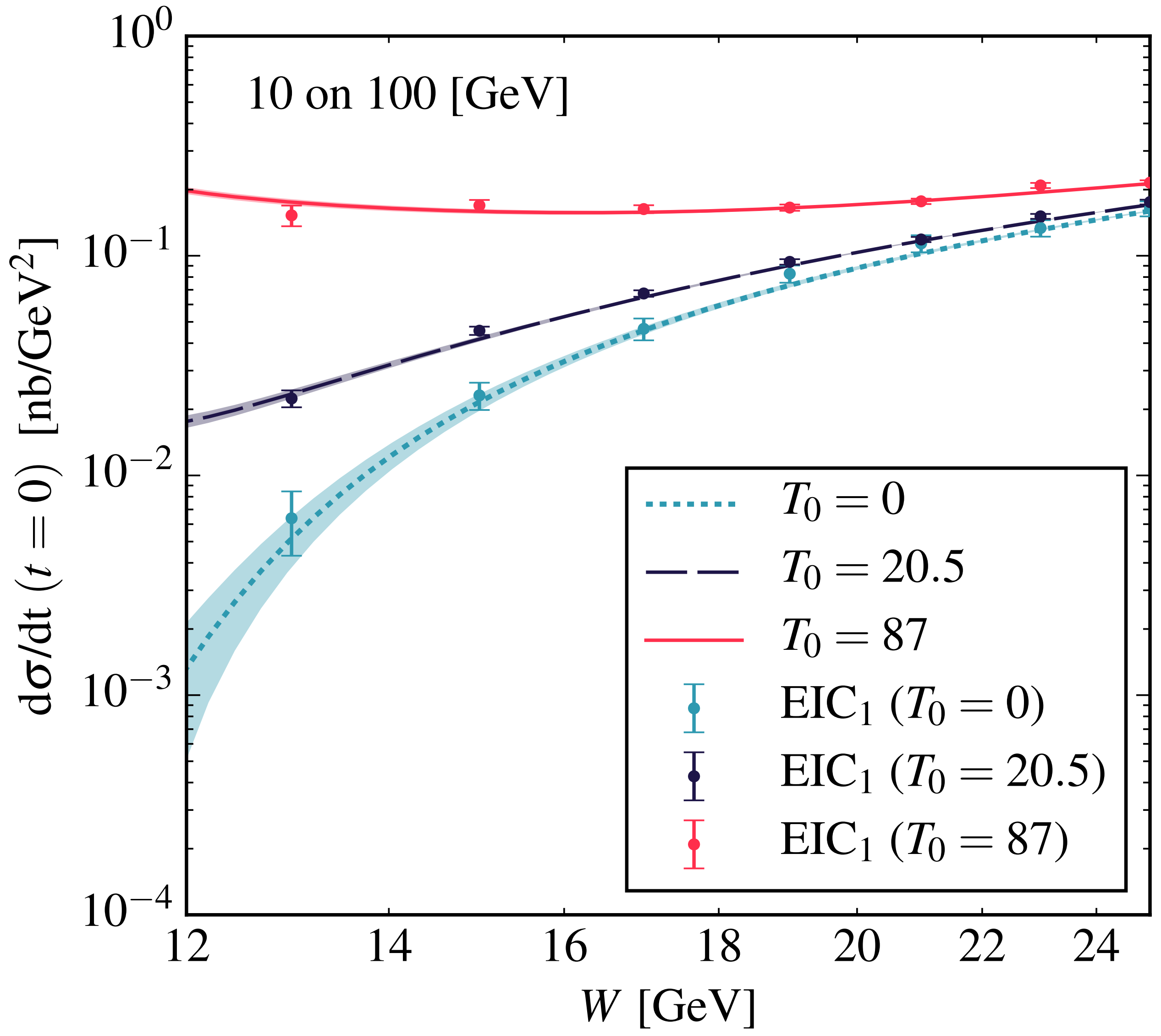
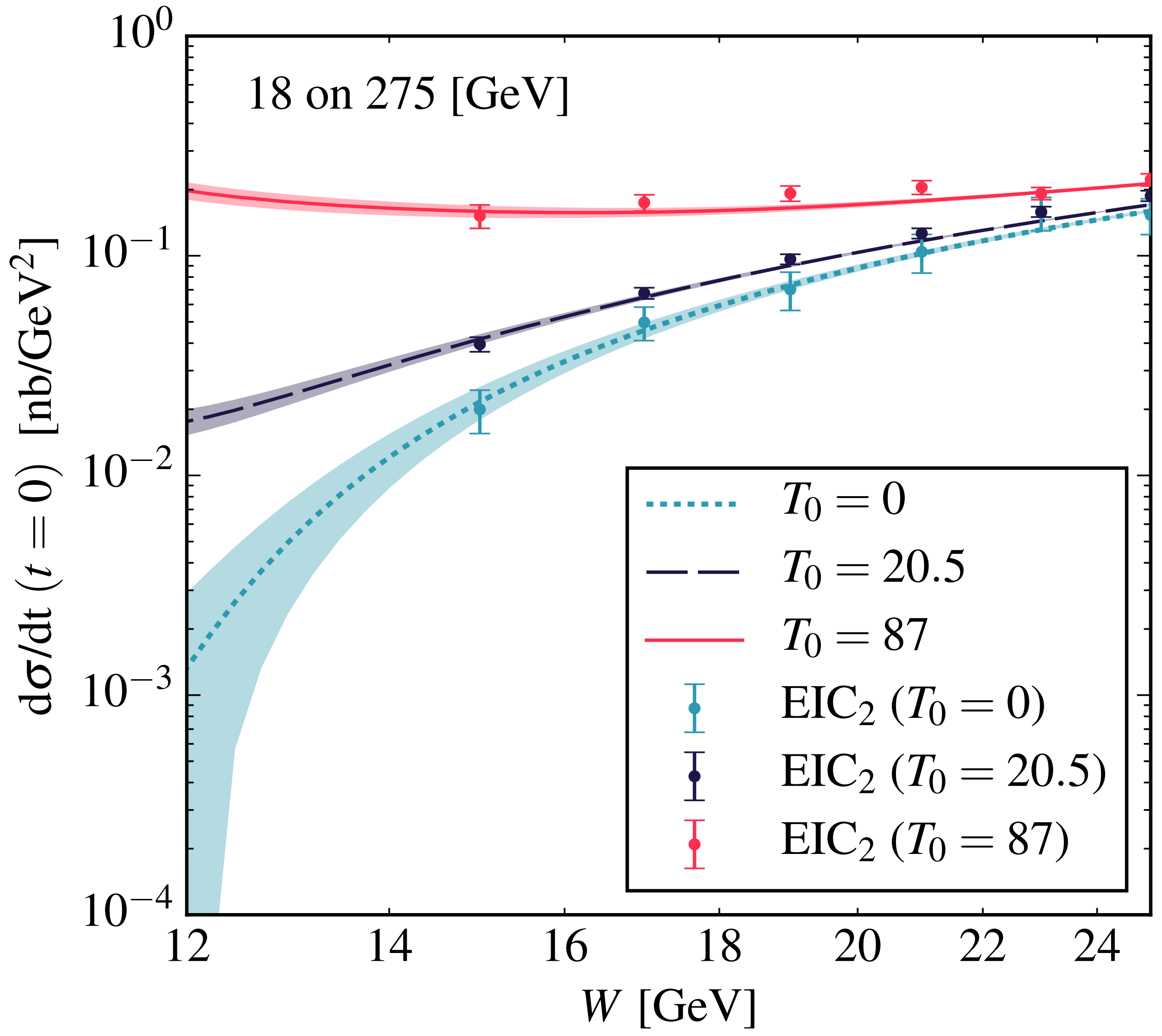


- ***Y(1s)*** production possible at threshold!
- Sensitivity down to ~10^{-3} nb!

THRESHOLD PHYSICS AT HIGH ENERGIES?



Setting 1: 10 on 100 GeV
Medium-energy configuration



Setting 2: 18 on 275 GeV
High-energy configuration

In principle more threshold events with higher energies (as the virtual photon flux rises quickly for lower values of *y*)

Medium energy configuration factor of 2-3 better uncertainties compared to high-energy configuration due to better reach near threshold.

Setting	$T_{\Upsilon p}(0)$	$a_{\Upsilon p}$ (in fm)	B_{Υ} (in MeV)
1	0	$\simeq 0$	$\simeq 0$
	20.5 ± 0.9	0.016 ± 0.001	0.78 ± 0.03
	87 ± 2	0.066 ± 0.001	3.23 ± 0.06
2	0	$\simeq 0$	$\simeq 0$
	20.5 ± 1.9	0.016 ± 0.001	0.78 ± 0.07
	87 ± 4	0.066 ± 0.003	3.23 ± 0.16

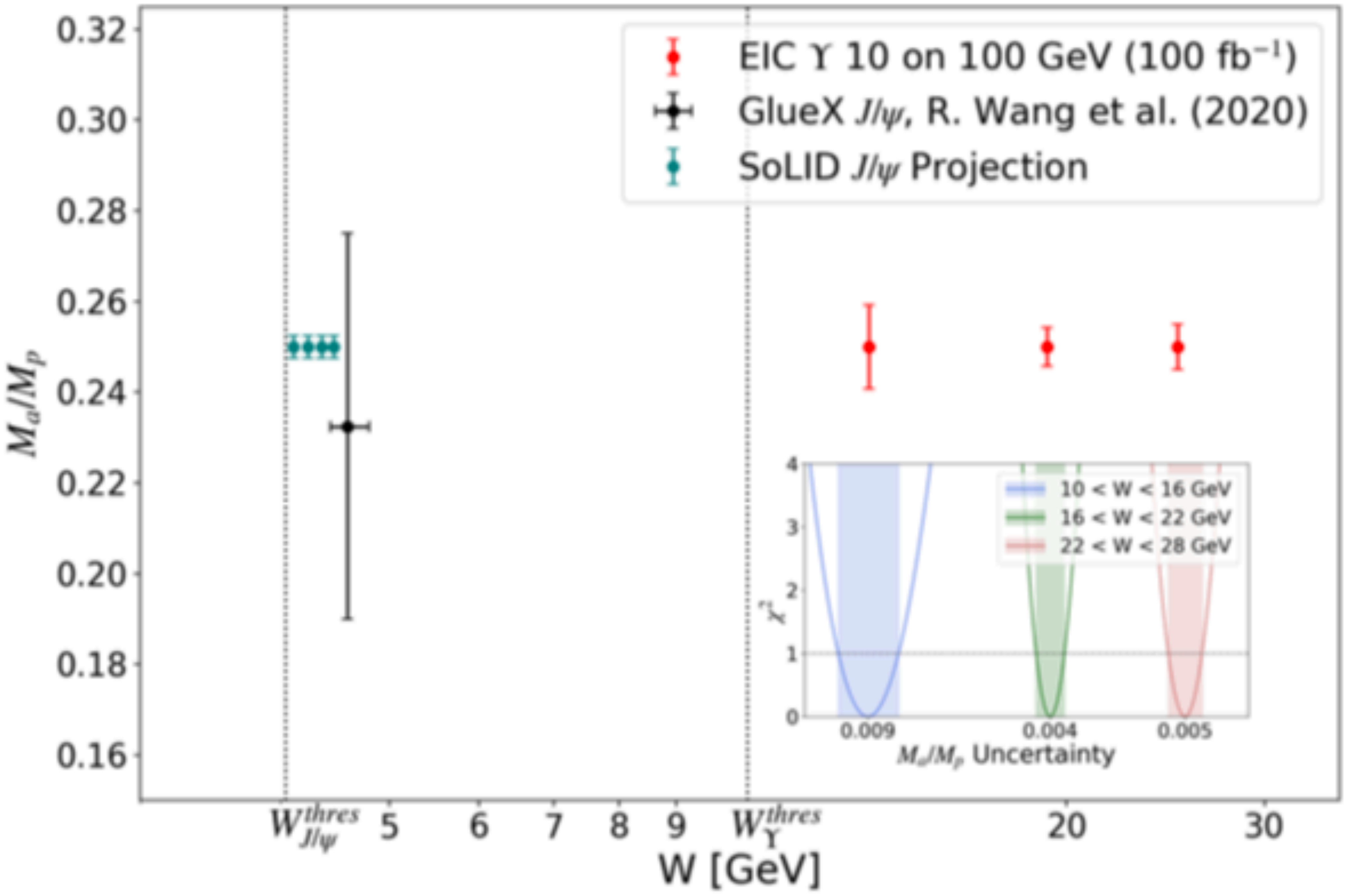
O. Gryniuk, S.Joosten *et al.* PRD 102, 014016 (2020)

What limits threshold physics at EIC?

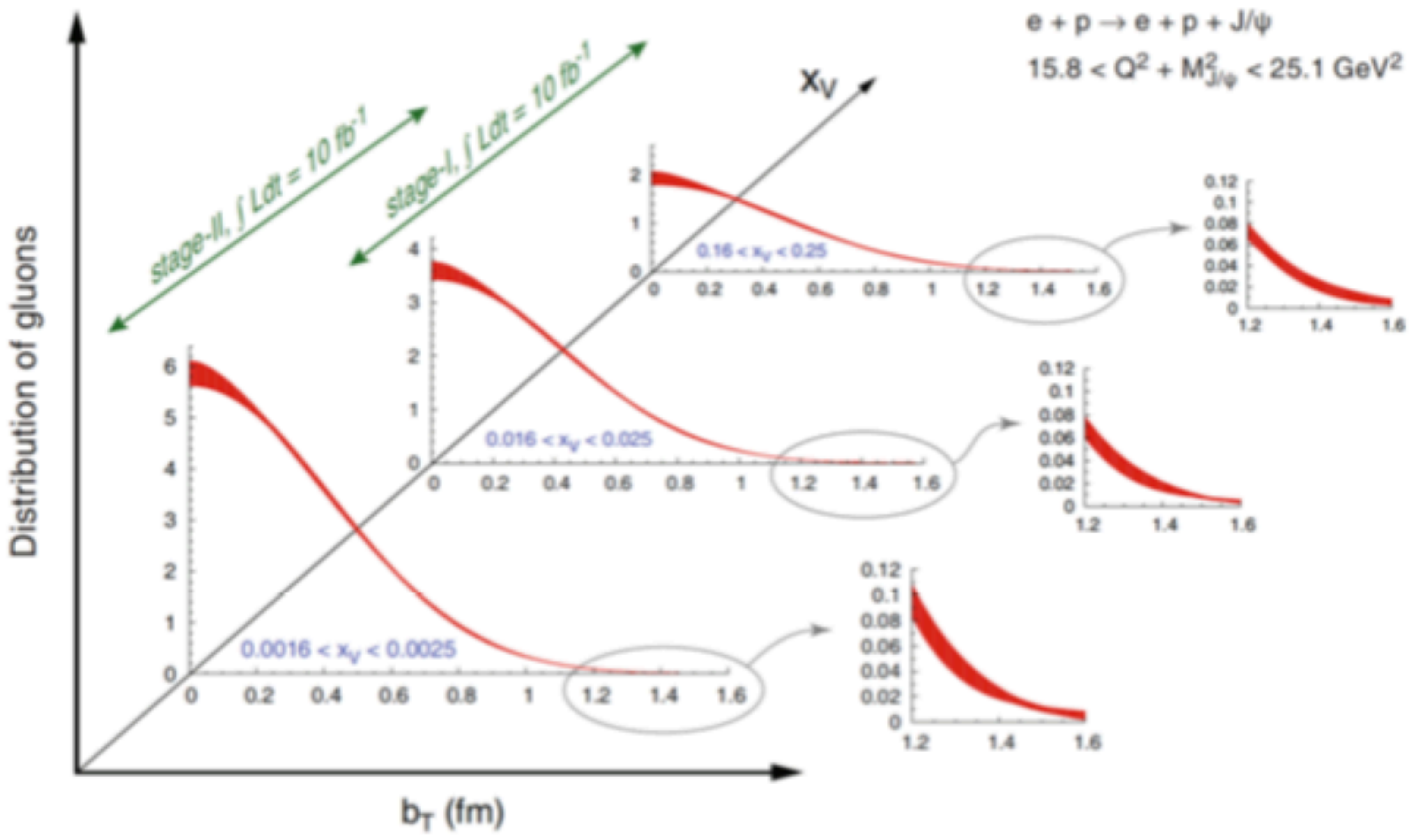
- **Reach toward lower values of *W* limited by experimental resolution**, which imposes a lower limit on *y = P.q/P.k ~ 0.01*.
- This makes threshold *J/ψ* very hard to do, and limits sensitivity to threshold *Υ* at higher beam energies.

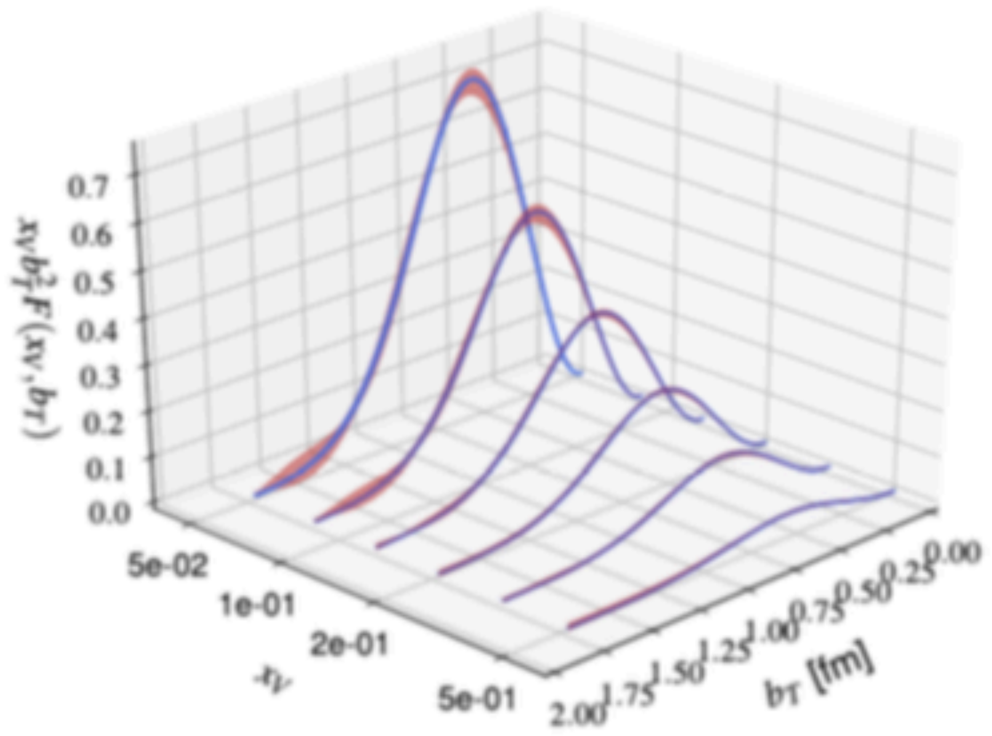
PROJECTED RESULTS FROM YELLOW REPORT

Quantum anomalous energy from Upsilon photoproduction



3D gluon imaging from *J/ψ* and *Υ* DVMP

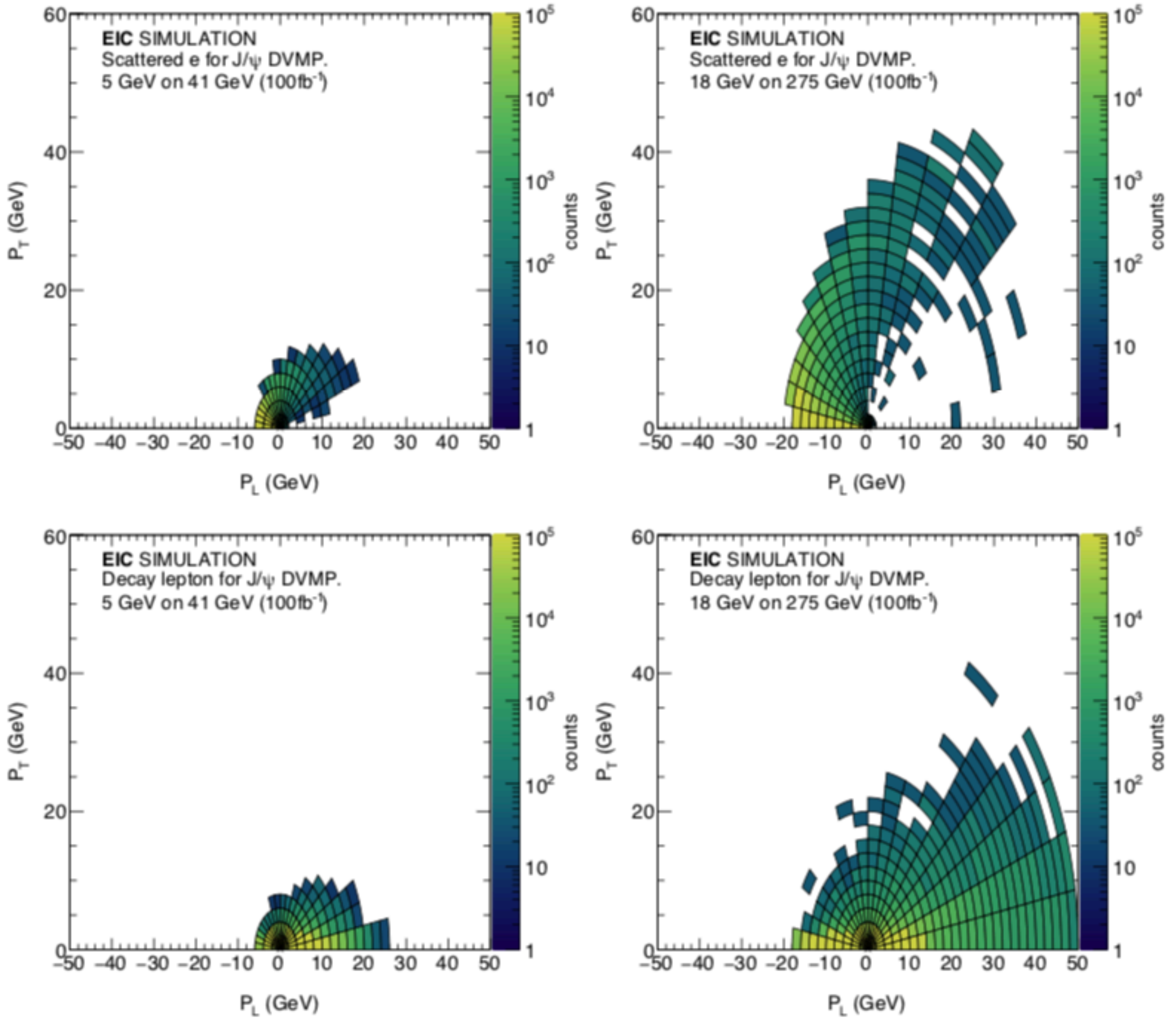




…Assuming 100fb^{-1}

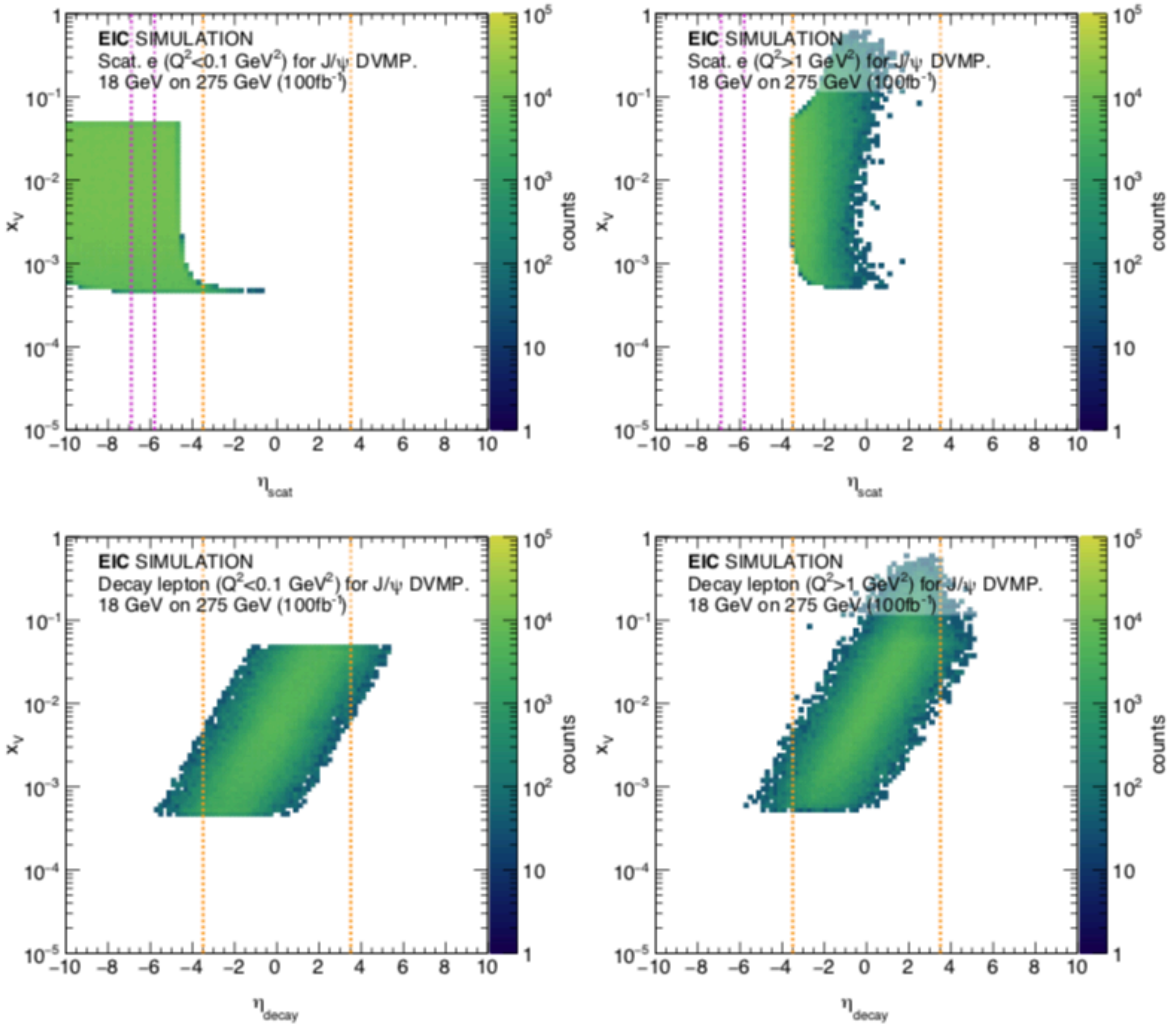
LEPTON

Where do the leptons go?



LEPTONS

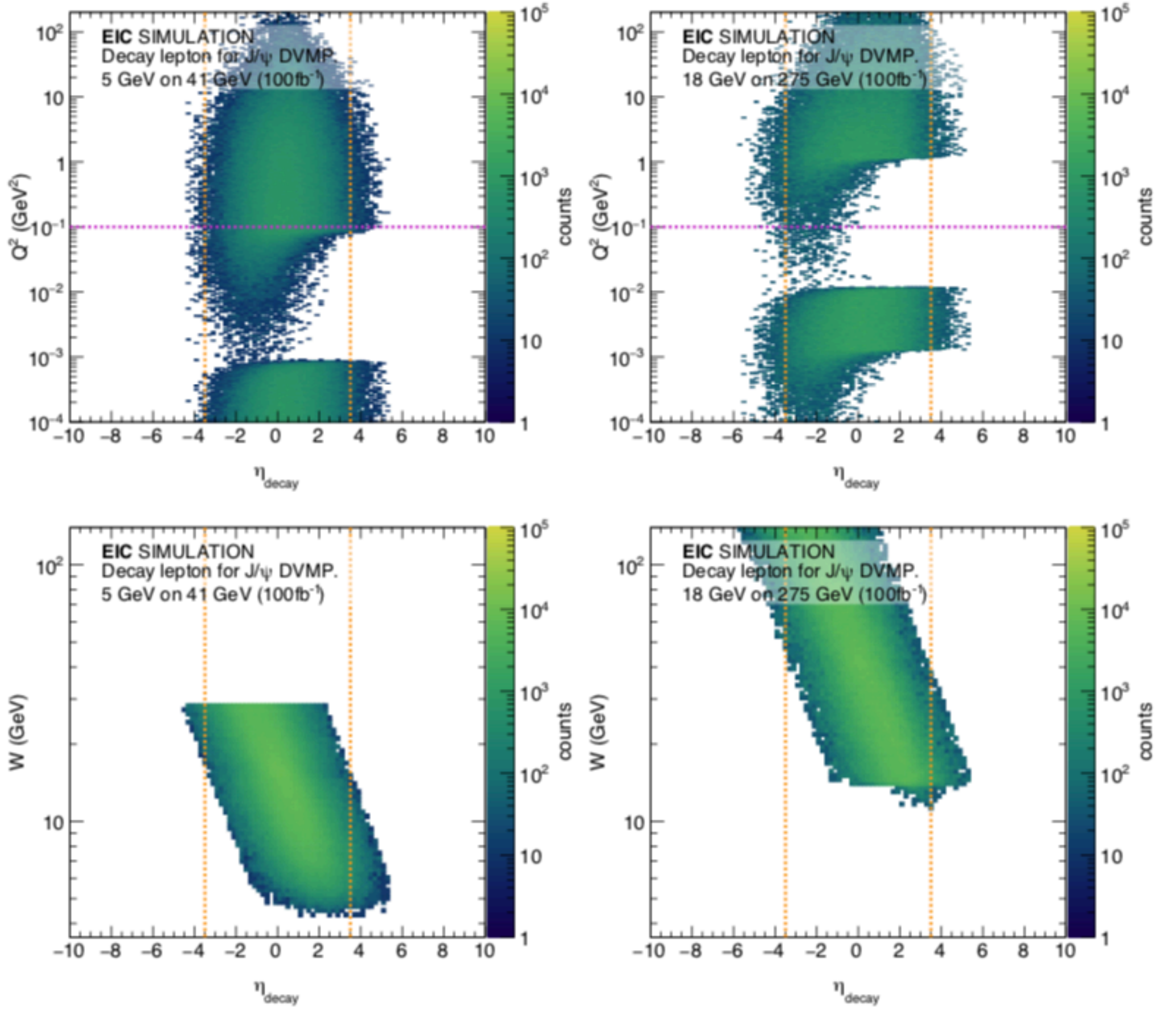
Nominal rapidity coverage on scattered lepton covers entire x-range even at the highest energy



LEPTONS

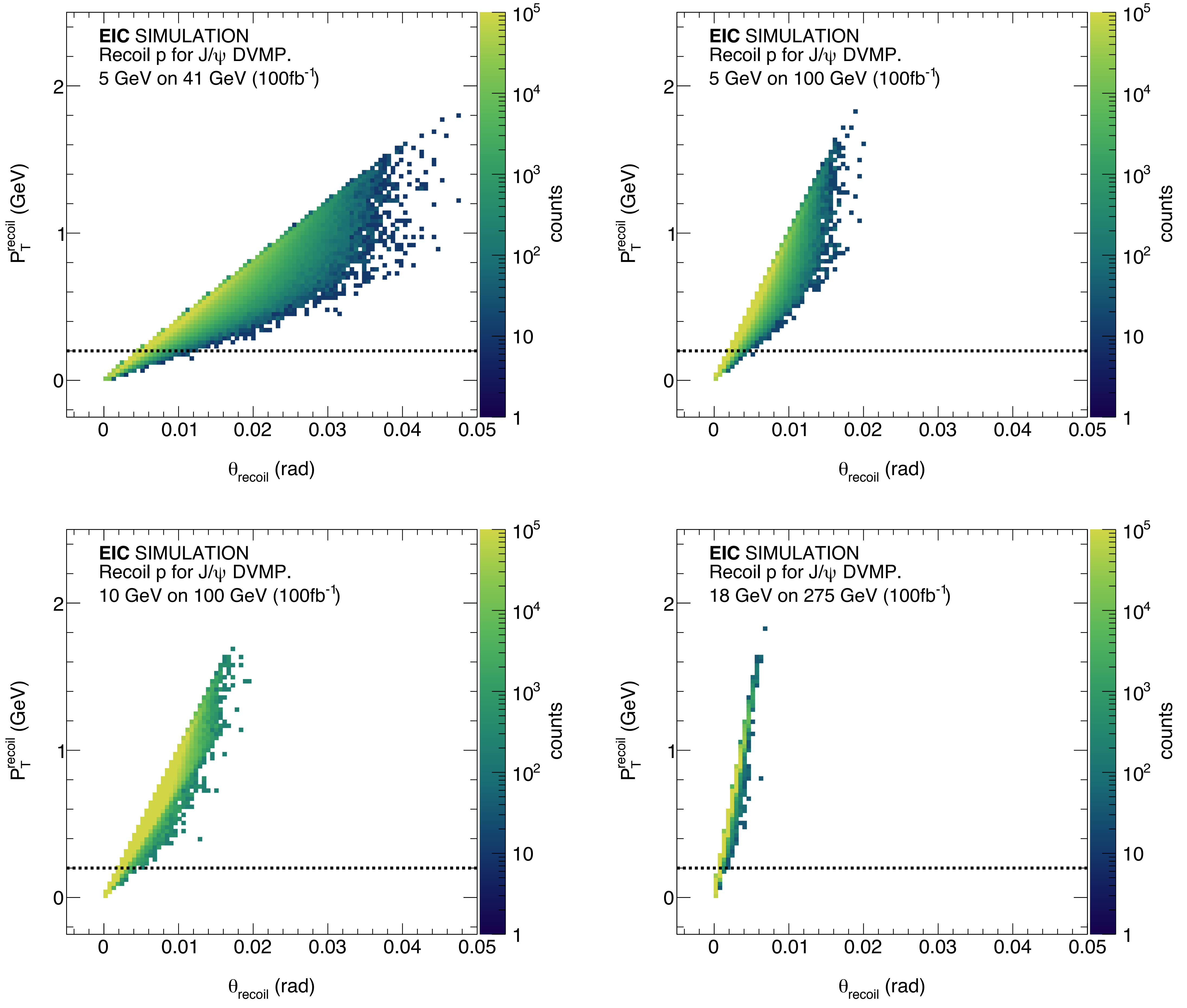
Q^2 coverage for imaging not limited by nominal acceptance

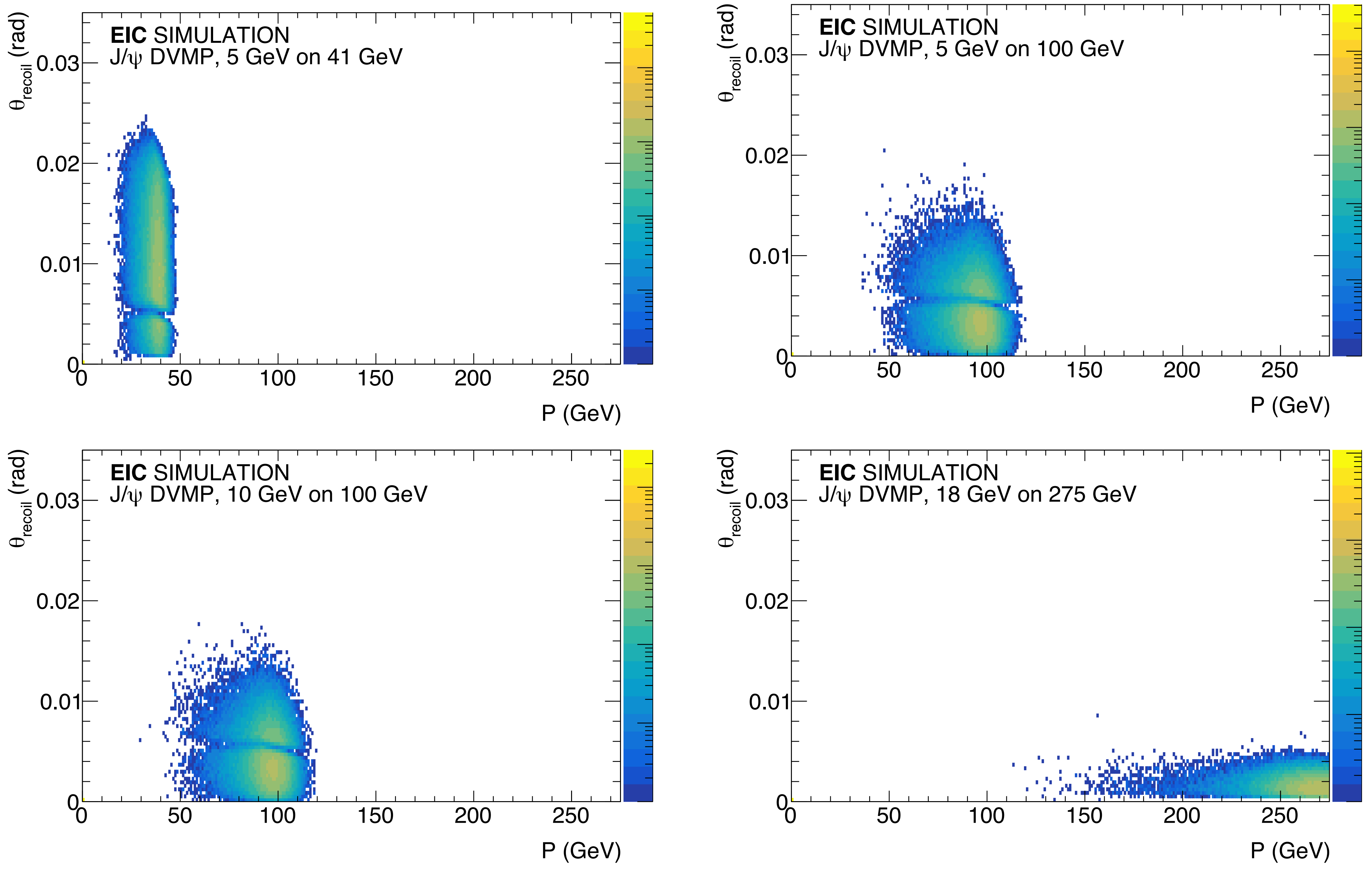
Nominal rapidity coverage leads to some loss in statistics near threshold at all energies. More coverage above $\eta > 3.5$ would lead to (modest) boost in statistics.



RECOIL PROTONS REQUIRE FAR-FORWARD DETECTION

Need continuous far-forward detection with roman pots and B0





Proposed nominal far-forward system in YR can do the job for DVMP on the proton. Lower energies depend mostly on B0

Lower pT coverage may be important for exclusive coherent/incoherent reactions off nuclei

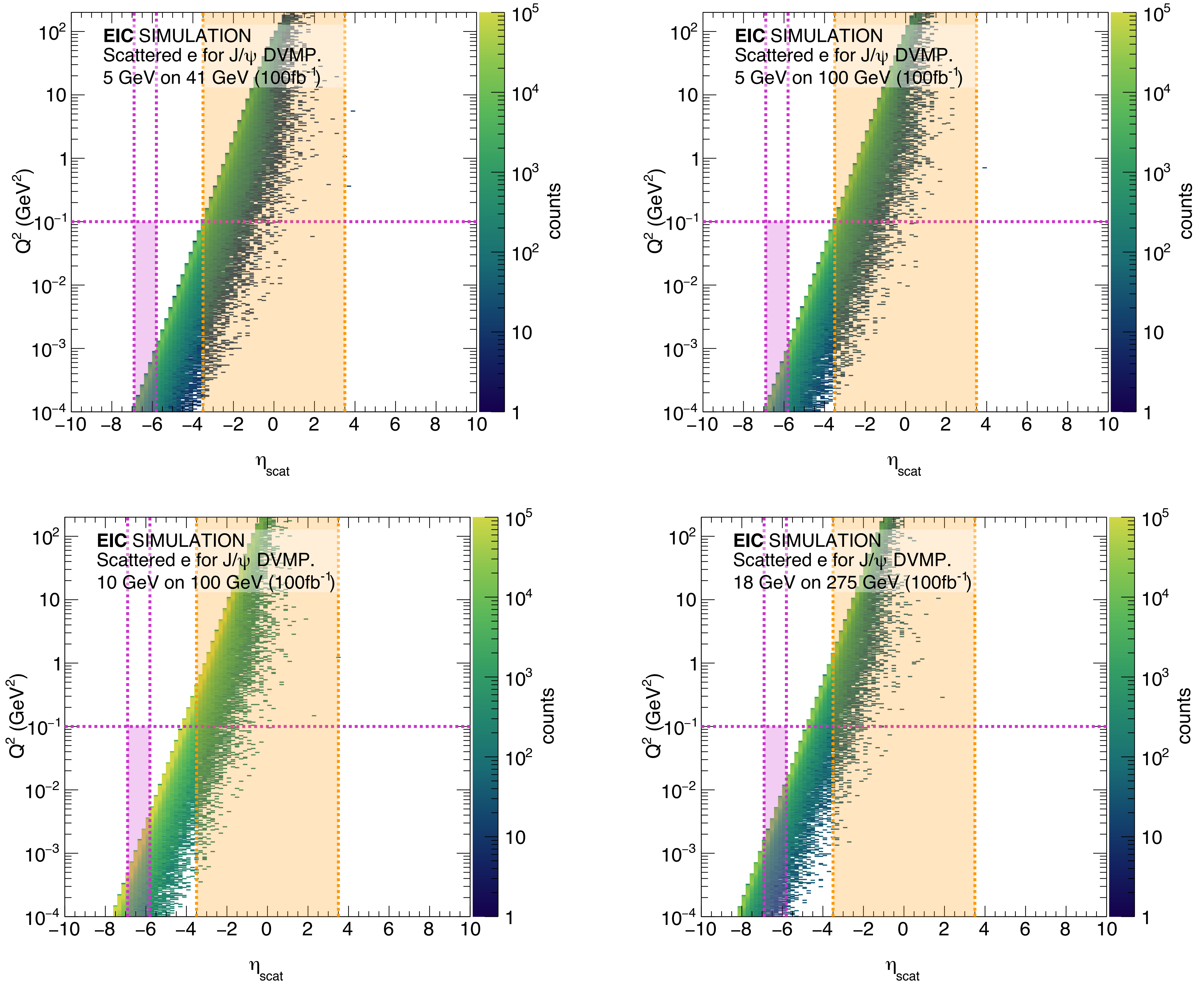
PHOTOPRODUCTION PERFORMANCE

Nominal reference detector not optimized for exclusive quasi-real production

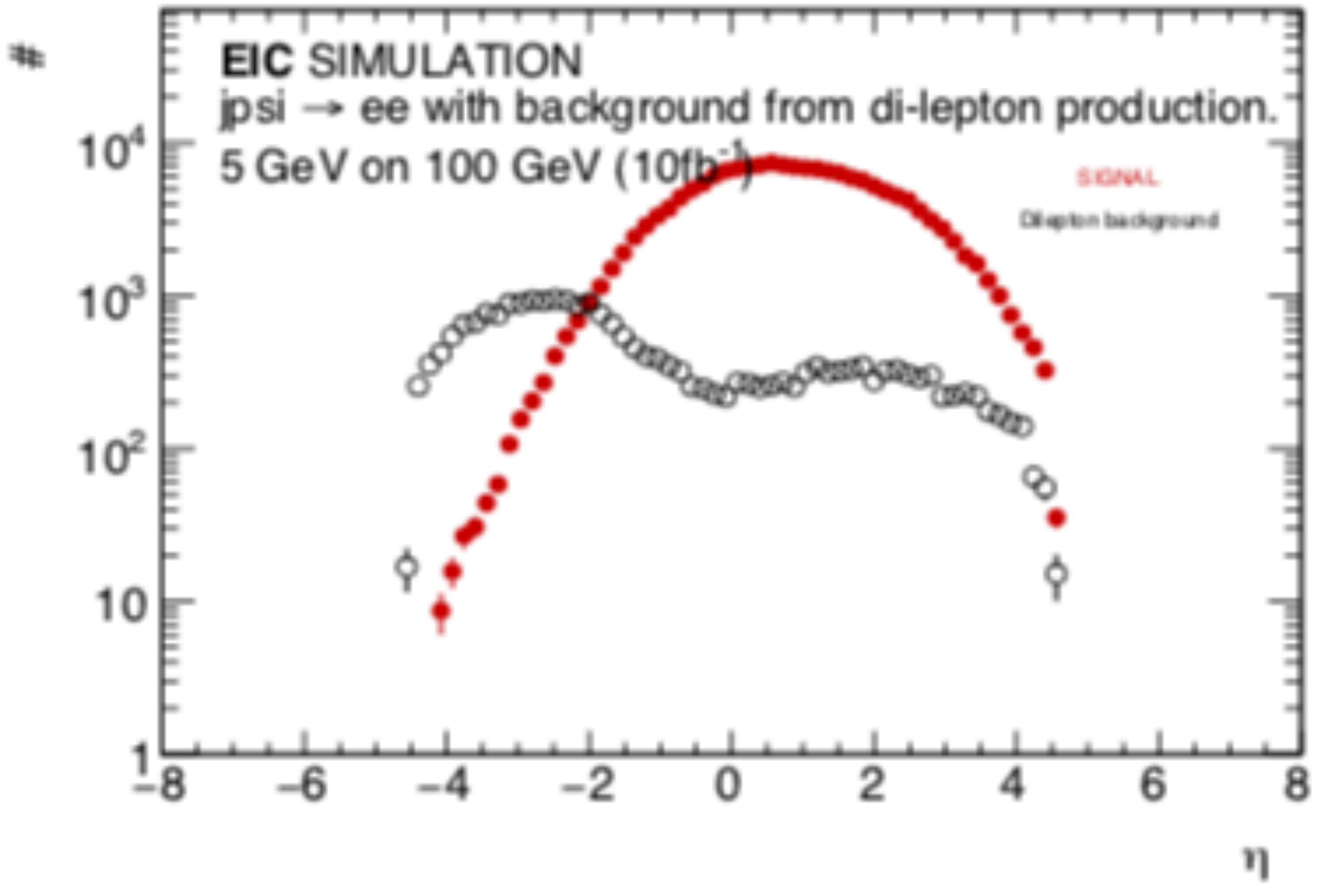
Pink: low-Q2 tagger
Orange: nominal central detector with |η| < 3.5

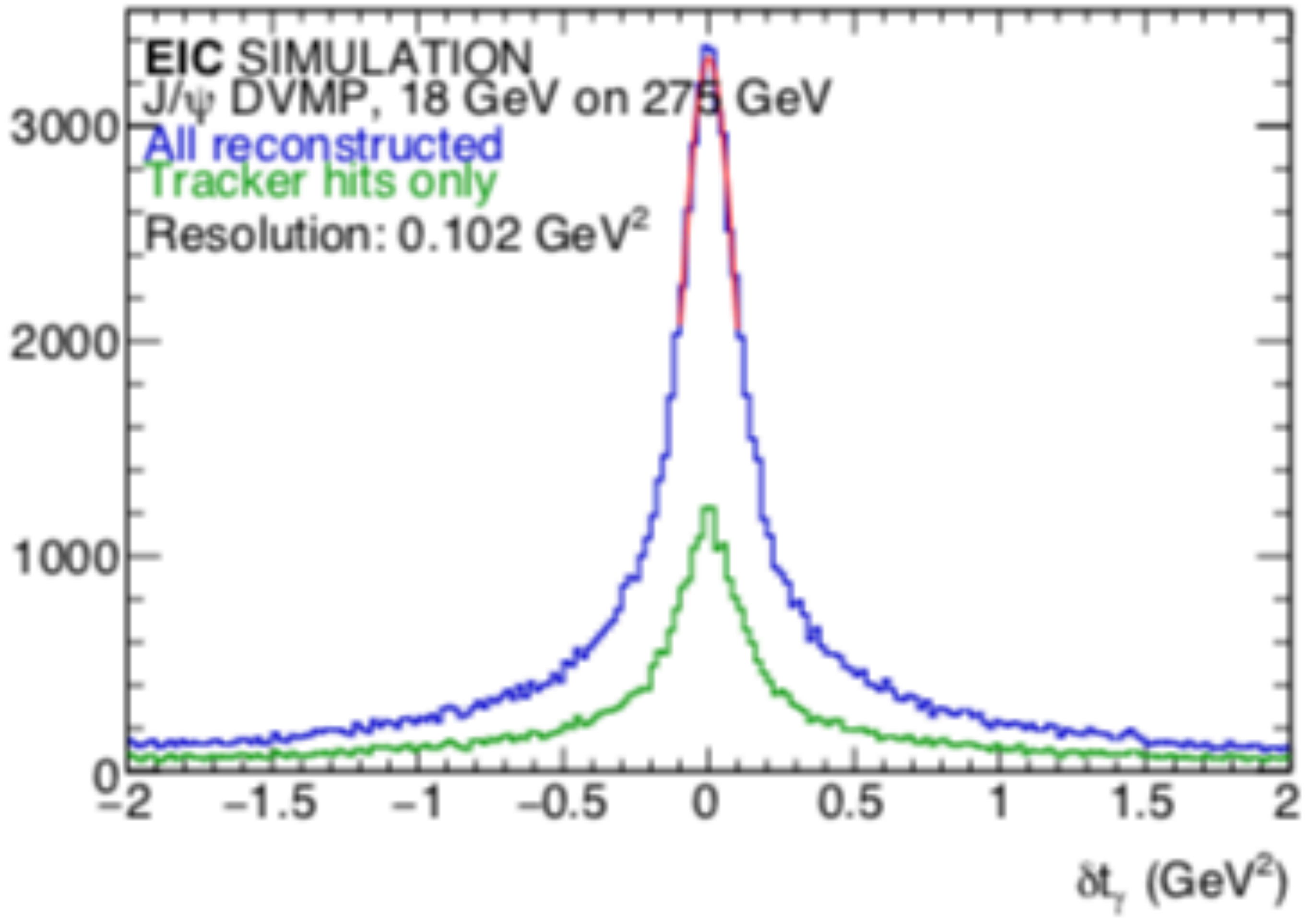
Extended **central detector acceptance below η < -3.5** will boost quasi real acceptance

Maybe easier, an **extended low-Q2 tagger** acceptance can dramatically increase rates



CASE FOR MUON DETECTION





Why?

Control Bethe-Heitler background in backward region

Improved resolution

Different systematic uncertainties (cross check of electron-positron channel)

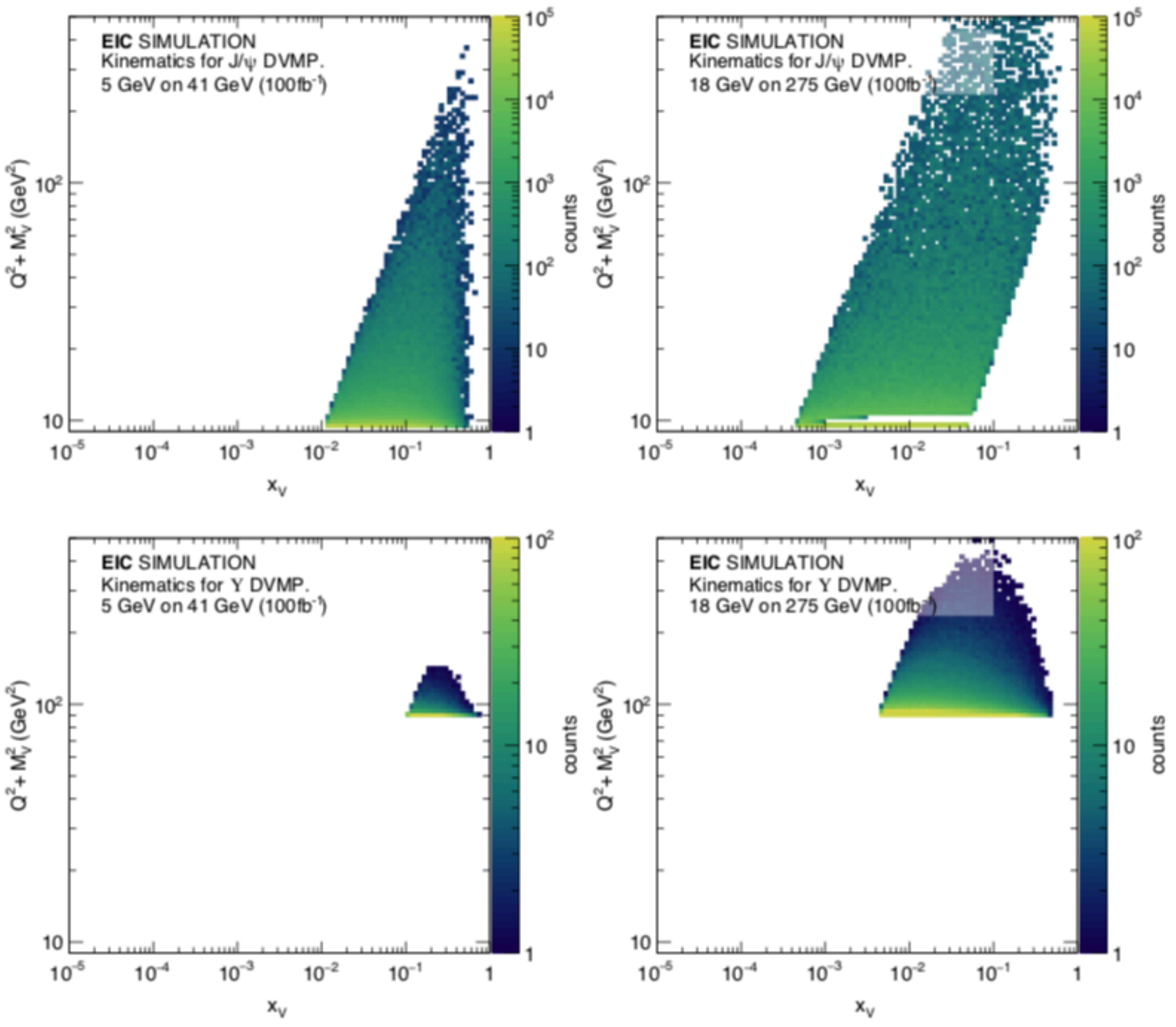
Double statistics (important for threshold region

Detector considerations

Muon detection does not necessarily need dedicated system:

1. Energy from tracking
2. PID through calorimetry (cluster profile in a sampling/imaging calorimeter, and in the hadronic calorimeter)
3. Do not need perfect pion rejection, as exclusivity + narrow vector meson mass + requirement that there be 2 muons significantly reduces background

ARGUMENTS FOR A COMPLEMENTARY APPROACH



Medium-energies maximize DVMP threshold reach: higher energies restricted by resolution at low y.

To maximize photoproduction (true for all energies): Good acceptance in backward region, and good low-*Q^2* tagger

Higher-energy configurations more potent for GPD imaging due to greater photon flux, larger Q^2 coverage. Note, intrinsically already at larger x (large quarkonium mass shifts kinematics to higher x)

Medium and low energy in particular need higher luminosity to get balanced statistics for entire phase space

Comprehensive DVMP program needs high luminosity at both high and medium energies: O(100fb^{-1} ~ 110 days at 10^^{34}/cm/s)