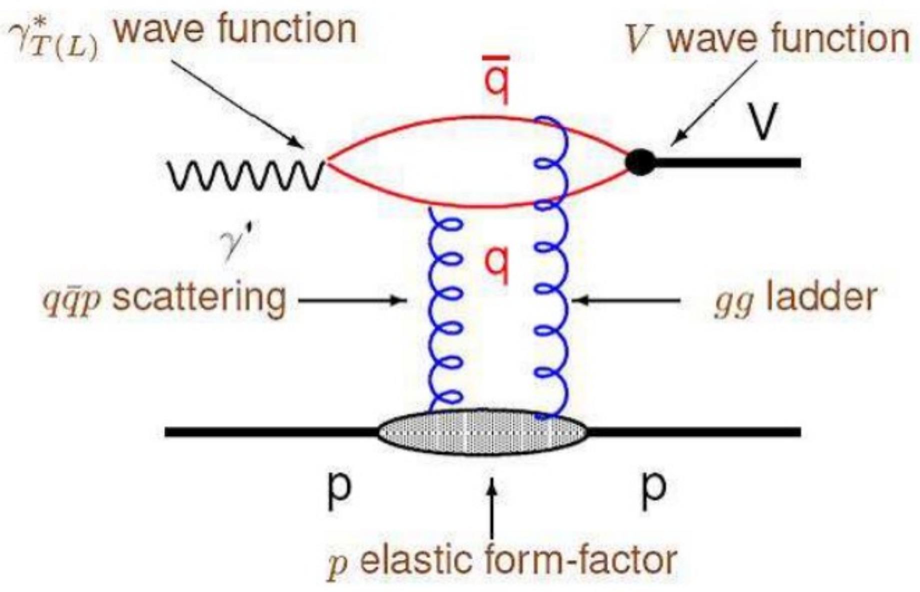

Lowest-order VM production diagram.
A. Levy, Exclusive vector meson electroproduction at HERA. 2007. arXiv:0711.0737

Investigation of Vector Meson Backward-Production Capabilities at the EIC

Zachary Sweger
University of California, Davis

Supported in part by

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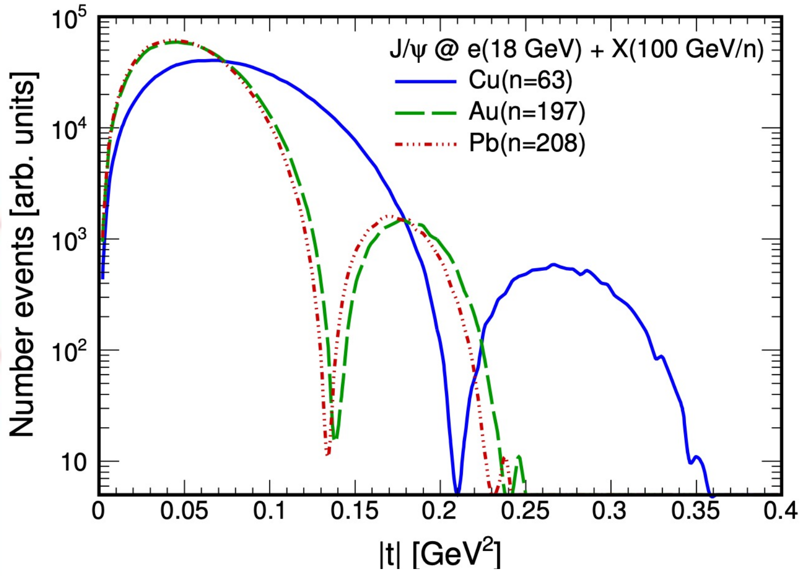
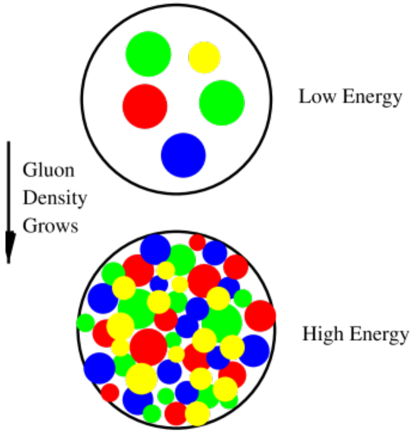
Vector Meson Production



Michael Lomnitz and Spencer Klein. Phys. Rev. C **99**, 015203 (2019)

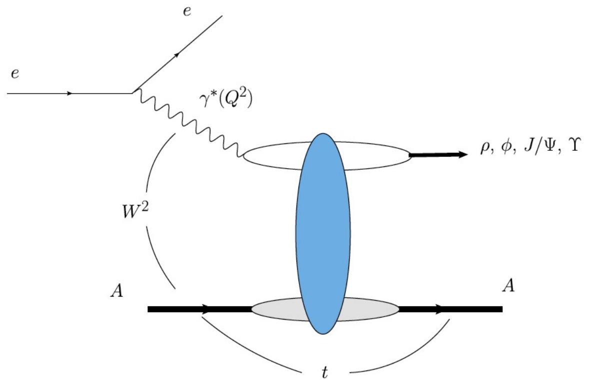
Why VM Production

- Electro/photo production of vector mesons will be studied at EIC
- e A → e V A offers insight into nucleon structure
  - gluon structure function
  - gluon saturation
  - shadowing

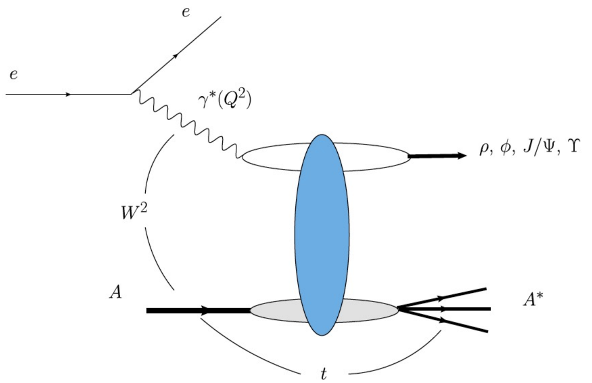


VM Production Mechanisms

- Incoherent production: inelastic, partial-nucleus interaction
- Coherent production: elastic scatter, whole-nucleus interaction
- Coherent production is modeled by
  - Reggeon exchange (meson exchange)
  - Pomeron exchange (2-gluon exchange at lowest order, vacuum quantum numbers)



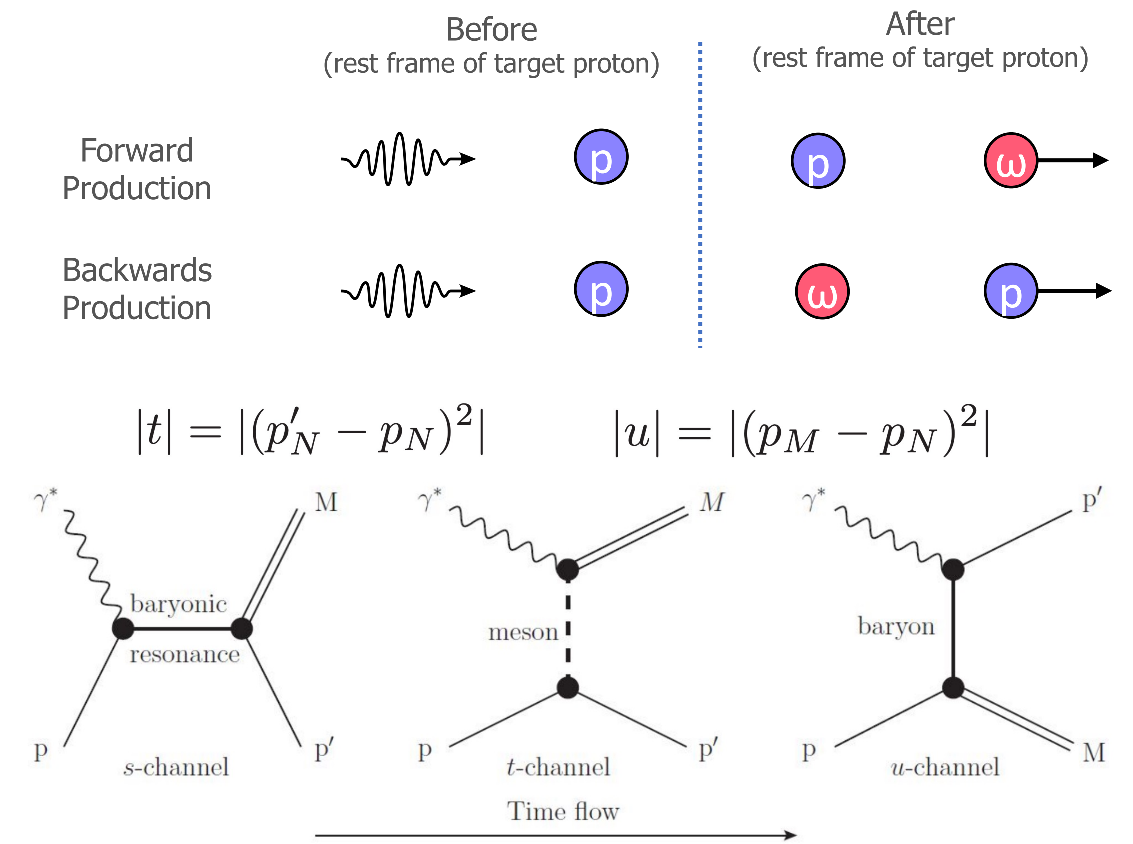
Coherent Production



Incoherent Production

M. Krelina et al. / Nuclear Physics A 989 (2019) 187–200

Backwards (u-channel) Production



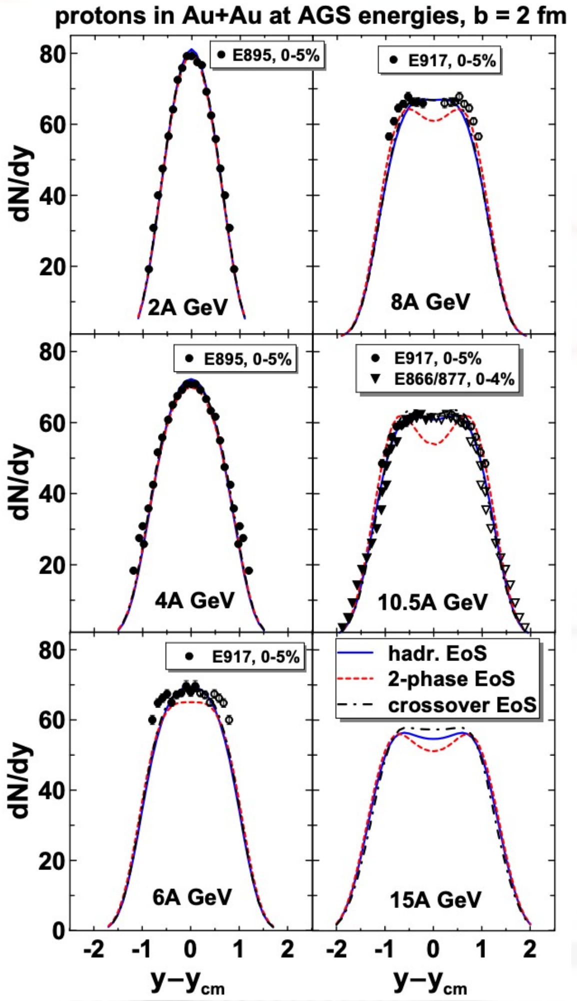
Contributions to VM production from Mandelstam variables. Wenliang (Bill) Li (William and Mary). GPD Workshop at Stony Brook University

Forward vs Backwards Production

- Forward Production
  - t-channel: low Mandelstam t, high u
  - Momentum transfer from target is small
  - VM is produced in backwards (e^--going) direction
  - Proton in forward direction
    - Proton rapidity only slightly modified
- Backwards Production
  - u-channel: low Mandelstam u, high t
  - Momentum transfer from target is large
  - VM produced in forwards (p-going) direction
  - Proton in backwards direction
    - Proton shifted many units in rapidity
  - Similarities with stopping in heavy ion collisions

u-channel Physics and Baryon Stopping

UCDAVIS
UNIVERSITY OF CALIFORNIA



Net-proton rapidity distributions at AGS compared with three distinct models of EoS

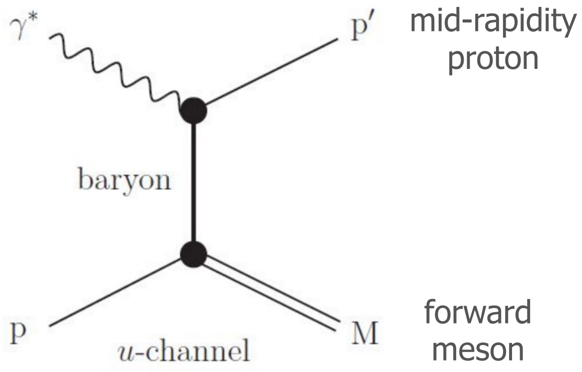
Stopping in Heavy-Ion Collisions

- Baryons participating in a collision can be shifted many units in rapidity
- Generally more collisions → more stopping
- Models of stopping using various equations of state indicate sensitivity to EoS
  - Onset of deconfinement may be probed by baryon stopping
  - **Understanding behavior of midrapidity baryons as a function of energy is critical** (see left)

Yu.B. Ivanov. Phys Lett B, Vol 721, Issues 1–3, 2013, 123-130, ISSN 0370-2693

Stopping in ep collisions

- Single collision causes large momentum transfer
- u-channel mechanism is not well-understood as a function of energy
- ep collision is simple system for studying midrapidity proton behavior in absence of deconfinement and hot QCD effects
- **This gives us a better understanding of mechanisms contributing to baryon stopping in larger systems**

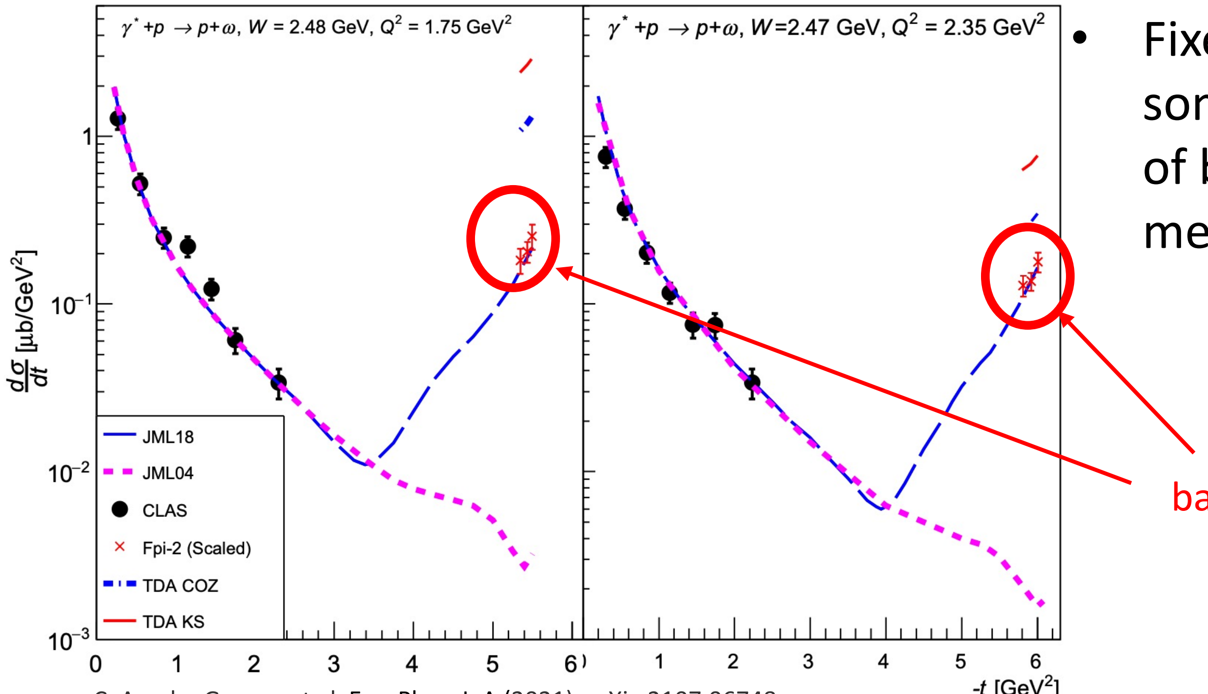


u-channel proton stopping in ep collision

Existing Data on Backwards Production

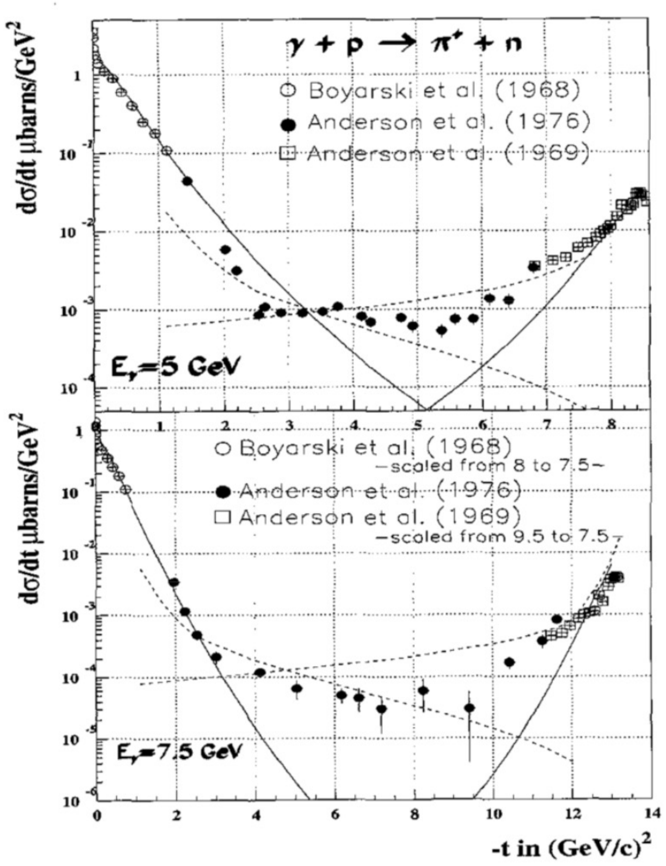
Experimental Measurements

- u-channel VM production has been measured at several Jlab experiments as well as early fixed-target experiments
- Fpi-2 experiment has measured the backwards production cross section of ω's as a function of t
- JLab Hall C experiments also measured the backwards prod. cross-sections

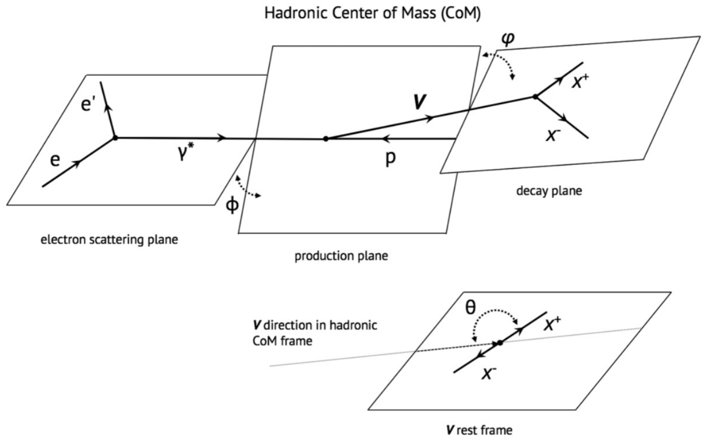


C. Ayerbe Gayoso et al. Eur. Phys. J. A (2021). arXiv:2107.06748

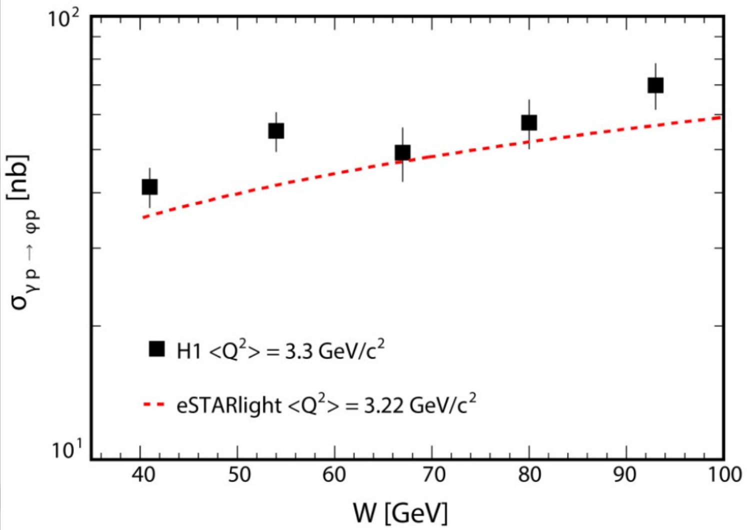
- Fixed-target experiments made some of the first measurements of backwards production of mesons



M. Guidal et al., Phys. Lett. B400, 6 (1997).



Kinematics of VM production and decay in eSTARlight



Benchmarking eSTARlight against HERA data. Michael Lomnitz and Spencer Klein. Phys. Rev. C **99**, 015203 – Published 11 January 2019

eSTARlight

Background on eSTARlight

- Models VM production in electron-ion collisions at finite photon virtuality
  - ➢ Includes a variety of vector mesons (ρ, ρ', ω, J/ψ, ψ(2S), ϒ)
  - ➢ Wide range of COM energies
  - ➢ Simulates final-state particle kinematics
- Complete kinematics simulations at variable energies make this a useful tool for informing detector design for EIC
- Variable photon virtuality (Q^2) allows predictions of production cross section scaling with Q^2

$$\sigma(eA \to eAV) = \int \frac{dW}{W} \int dk \int dQ^2 \frac{d^2 N_\gamma}{dk\, dQ^2} \sigma_{\gamma^* A \to VA}(W, Q^2)$$

Backward Physics in eSTARlight

UC DAVIS UNIVERSITY OF CALIFORNIA

Modeling u-channel Production

C. Ayerbe Gayoso et al. Progress and Opportunities in Backward angle (u-channel) Physics. Eur. Phys. J. A (2021). arXiv:2107.06748

- eSTARlight has been modified include backward production!
- **The strategy: exploit similarities to t-channel**

$$\frac{d\sigma}{dt} \sim e^{-Bt} \longrightarrow \frac{d\sigma}{du} \sim e^{-Cu}$$

- Scaling depends on the meson produced
- B (12 GeV^{-2}) and C (32 GeV^{-2}) relate to size of production region which differs in t and u channels due to role of meson vs baryon exchange trajectories
- Effect of photon virtuality estimated with similar behavior to t-channel

$$\sigma_{\gamma^* p\to\omega p}(W,Q^2) = \sigma_{\gamma^* p\to\omega p}(W,Q^2=0)\left(\frac{M_\omega^2}{M_\omega^2+Q^2}\right)^n$$

- Assumption based on data from HERA forward-production (a source of uncertainty)
- Rates: Forward production: predicted rate ~(billion events)/10^7s

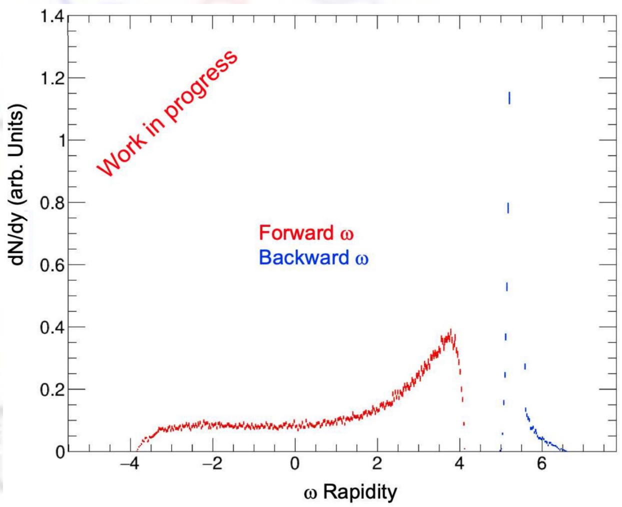
  Backward production: predicted rate ~(10 million events)/10^7s
- This model was developed by Aaron Stanek (LBNL) and implemented by Samuel Heppelmann (UC Davis)

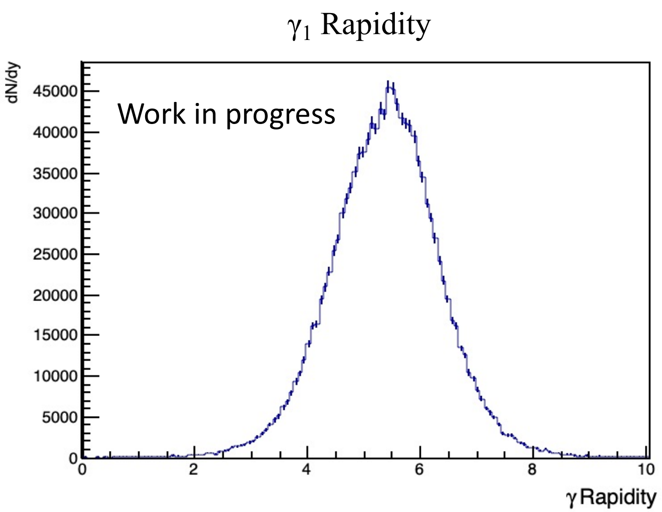
F.D. Aaron et al. (H1), JHEP 05, 032 (2010)

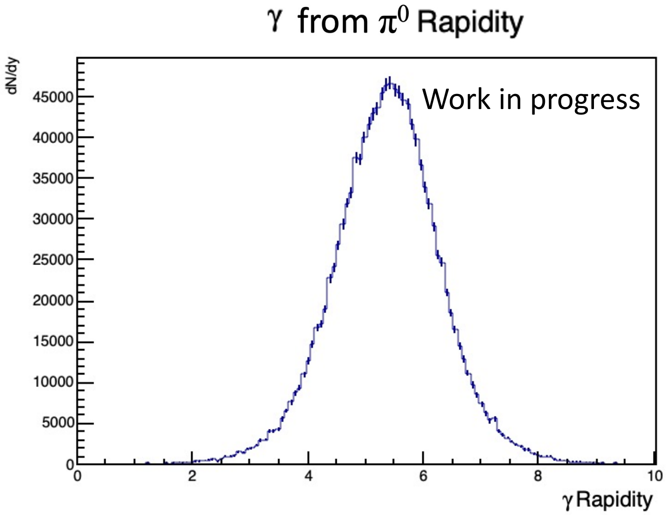
Preliminary Analysis of Backward ω Production

ω Production at EIC

- Data exists from JLab for benchmarking eSTARlight
- Spin of backward-produced ω still under discussion. In forward-production, ω has same polarization as photon. This polarization is being compared against unpolarized ω in u-channel
- $\omega \rightarrow \gamma_1 \pi^0 \rightarrow \gamma_1(\gamma_2\gamma_3)$ is fully calorimetric
- Example: 100k u-channel events with 100 GeV protons on 18 GeV electrons at EIC:







- **Preliminary conclusion: far-forward EM calorimetry is necessary for EIC experiments that aim to study u-channel physics**

Conclusions and Outlook

- Vector meson production at the EIC will be an interesting reaction channel to probe nuclear structure over a broad range of energies
- u-channel VM production explores an alternative reaction channel to t-channel production and can shed light on role of Reggeons and Pomerons
- u-channel measurements at the EIC will improve understanding of mechanisms involved in baryon stopping. Interesting as a control for large systems
- Backward VM decay daughter detection requires far-forward EM calorimetry
- Next step: feed eSTARlight products into various EIC detector models.
    - Investigate detection rates
    - Explore performance across EIC beam energies