

# Preliminary Cross Section Measurements of the $\gamma n \rightarrow \pi^- p$ Reaction from 6 to 11 GeV

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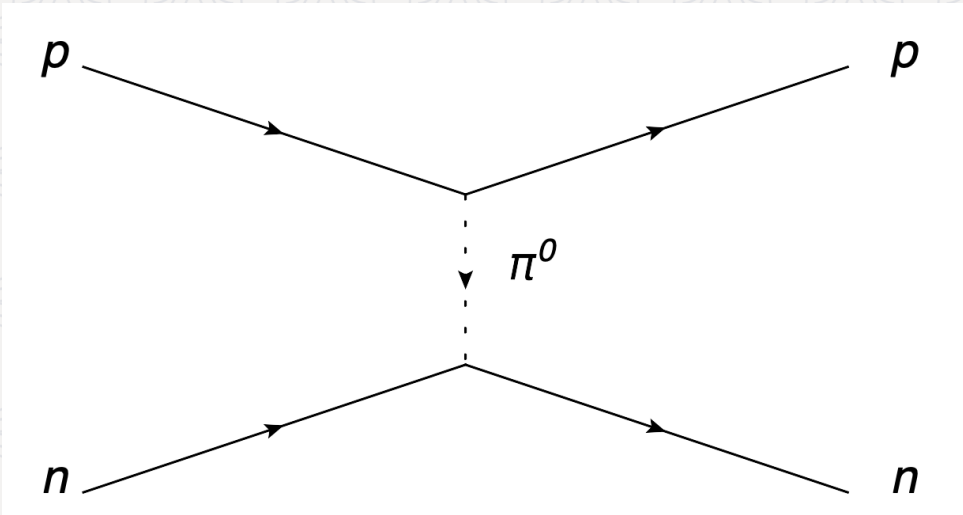
The Jefferson Lab logo, featuring a red swoosh above the text "Jefferson Lab".

**Jefferson Lab**

This work is supported in part by the U.S. Department of  
Energy under Contract No. DE-FG02-03ER41231

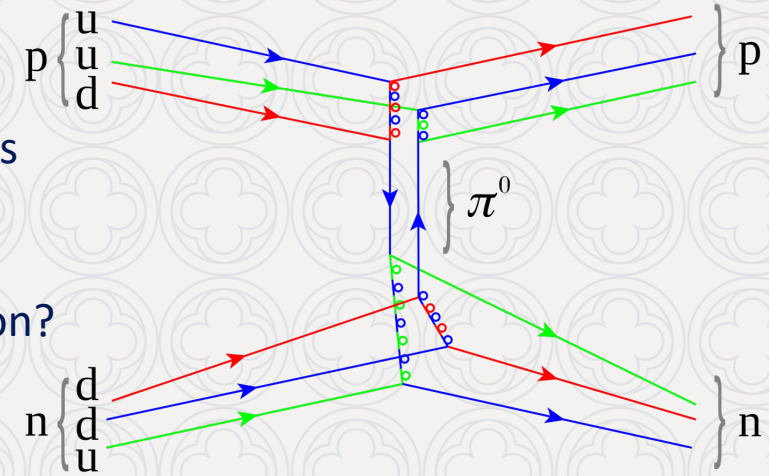
# Quark-gluon or nucleon-meson d.o.f.

Nucleon-meson effective degrees of freedom  
Traditional picture of nuclear physics  
works well at low energies



Quark-gluon degrees of freedom  
QCD picture of nuclear physics  
works well at high energies

Gap between these two pictures  
What behavior?  
What model?  
What signatures onset of transition?

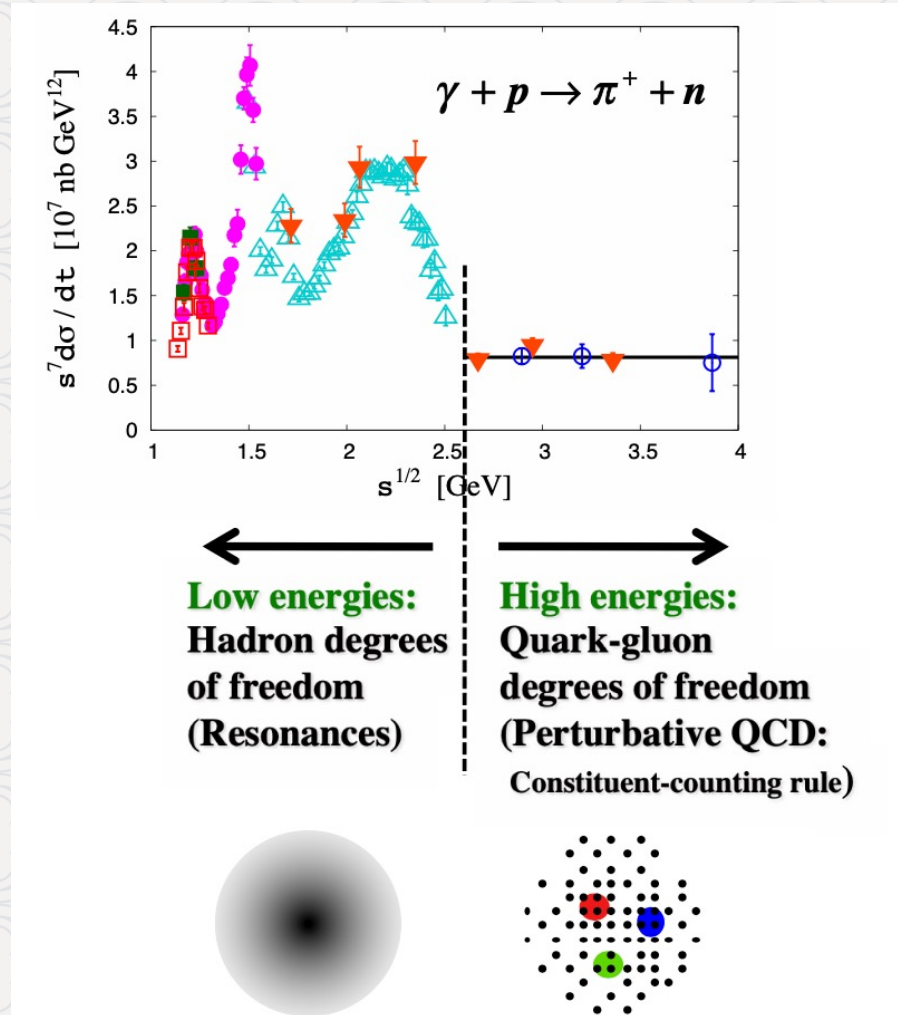


[https://en.wikipedia.org/wiki/Strong\\_interaction](https://en.wikipedia.org/wiki/Strong_interaction)



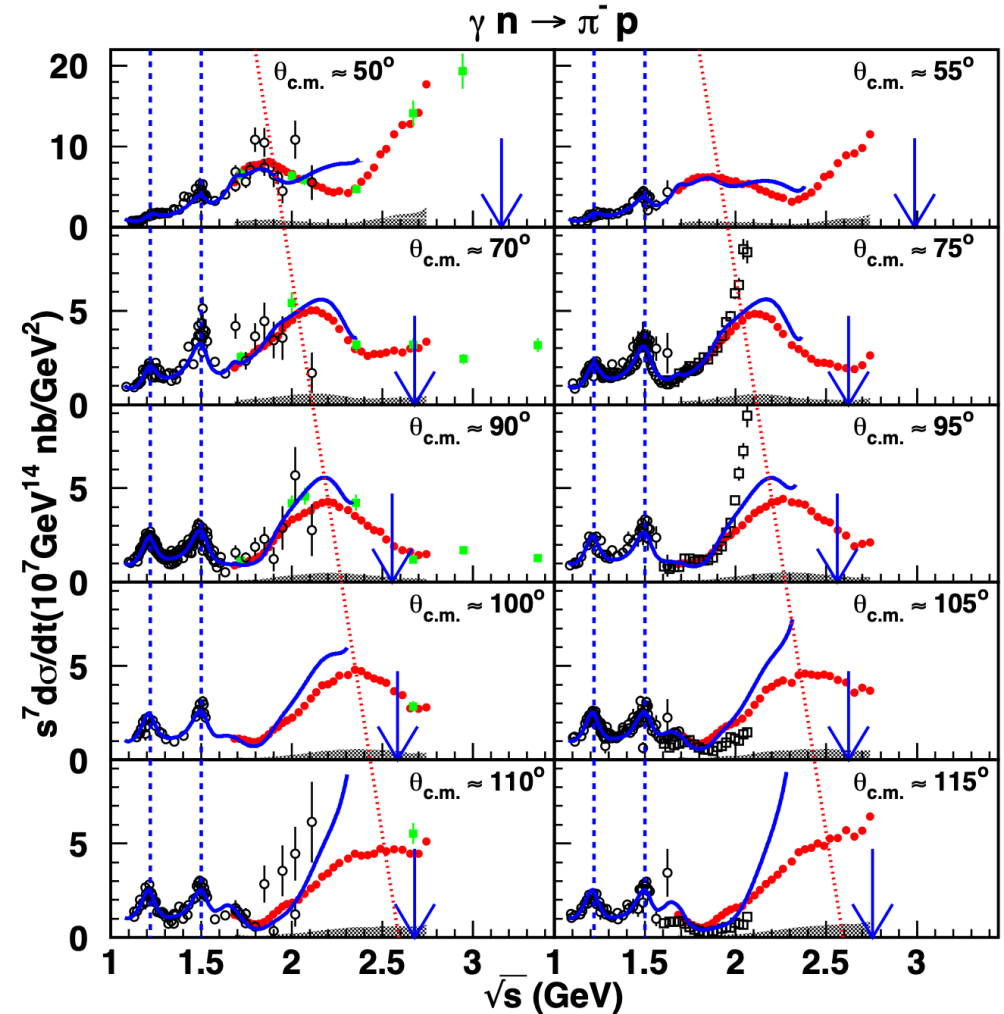
# Constituent counting rule (CCR)

- Proposed as signature of such transition
- For exclusive processes
- $\frac{d\sigma}{dt} (AB \rightarrow CD) |_{s,t \rightarrow \infty} \sim s^{2-n} f(\theta_{c.m.})$
- $n$ : number of elementary fields
- $\theta_{c.m.}$ : C.M. scattering angle
- Global scaling behavior at fixed angle
- pQCD suggests oscillation around scaling value



# $\gamma n \rightarrow \pi^- p$ reaction measured at JLab

- Deuterium target at Hall A and B from JLab 6 GeV era
- Scaling behavior is seen from 70-100 deg
- Higher energy is needed for other angles

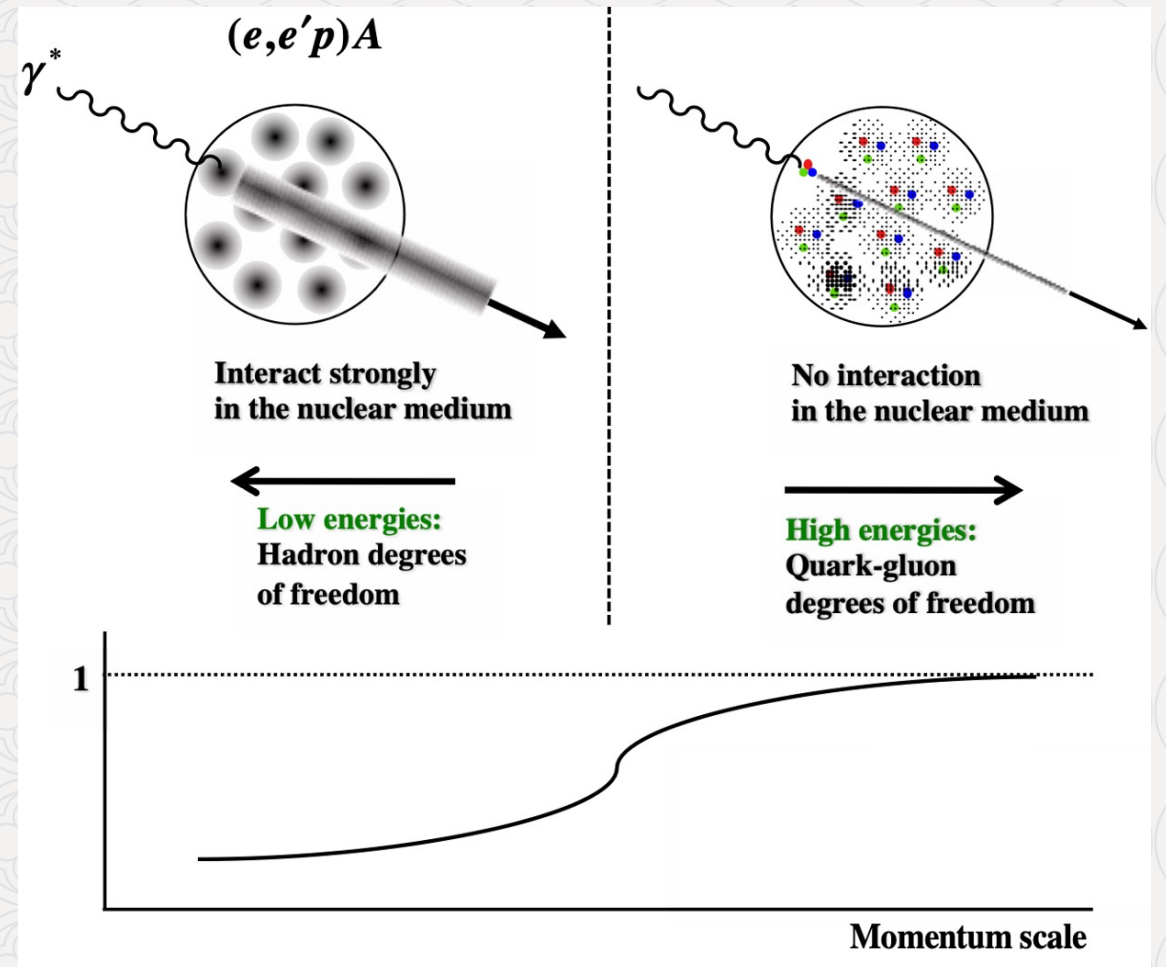


W. Chen *et al.*, Phys. Rev. Lett. **103**, 012301



# Onset of color transparency

- Nuclear transparency:  $\sigma_{bound} / \sigma_{free}$
- QCD predicts color transparency
- Color singlet, small transverse size configurations preferred in exclusive processes
- Vanishing of final state interactions at large  $s, t$
- Deviation from Glauber calculation

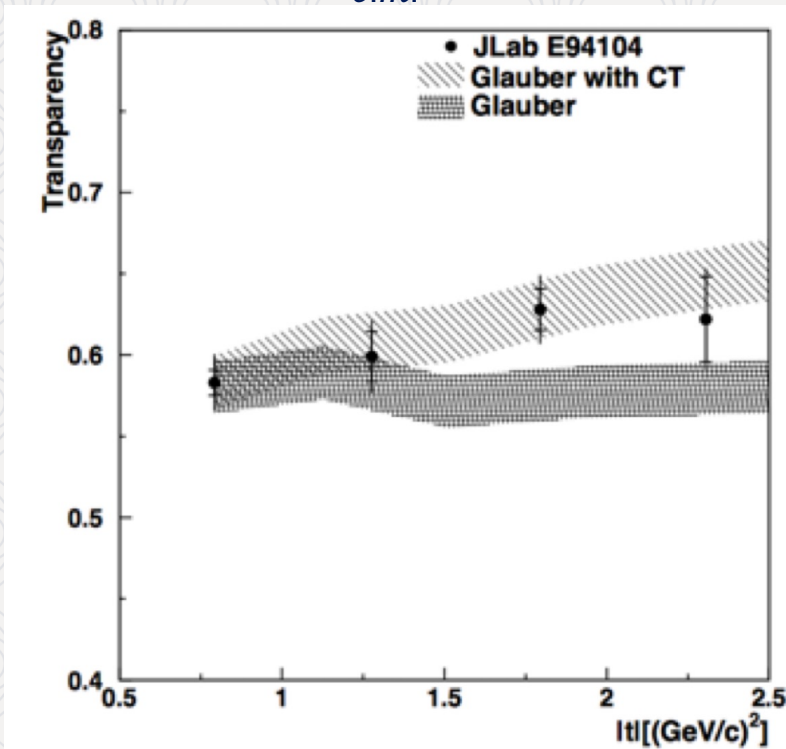


S. Kumano, Physics **2022**, 4(2), 565-577

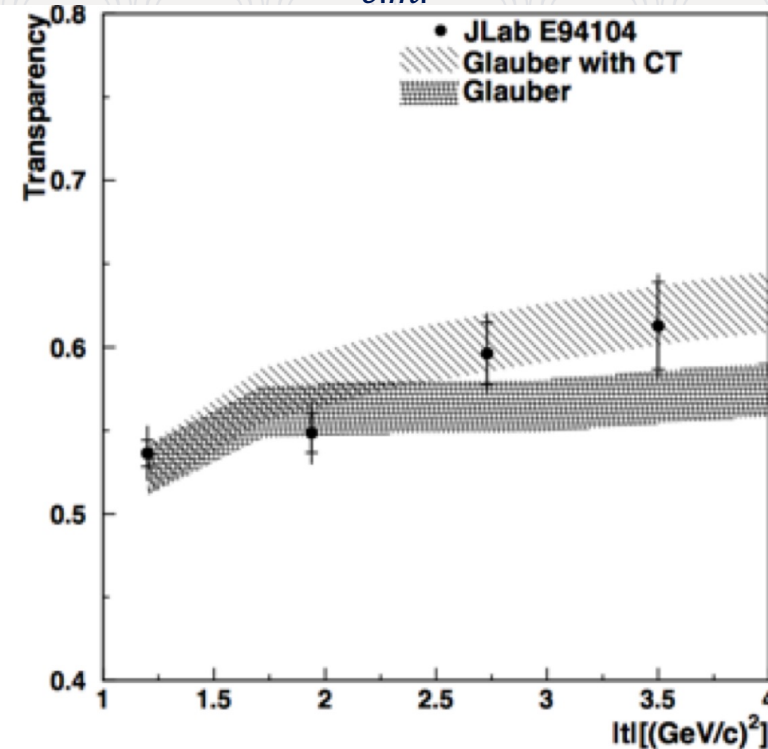
# $\gamma n \rightarrow \pi^- p$ reaction measured at JLab

- Transparency of  $\gamma n \rightarrow \pi^- p$  on helium from JLab 6 GeV
- Energy not high enough to distinguish

$\theta_{c.m.} = 70^\circ$



$\theta_{c.m.} = 90^\circ$



D. Dutta *et al.*, Phys. Rev. C 68, 021001(R)



# The SRC-CT experiment

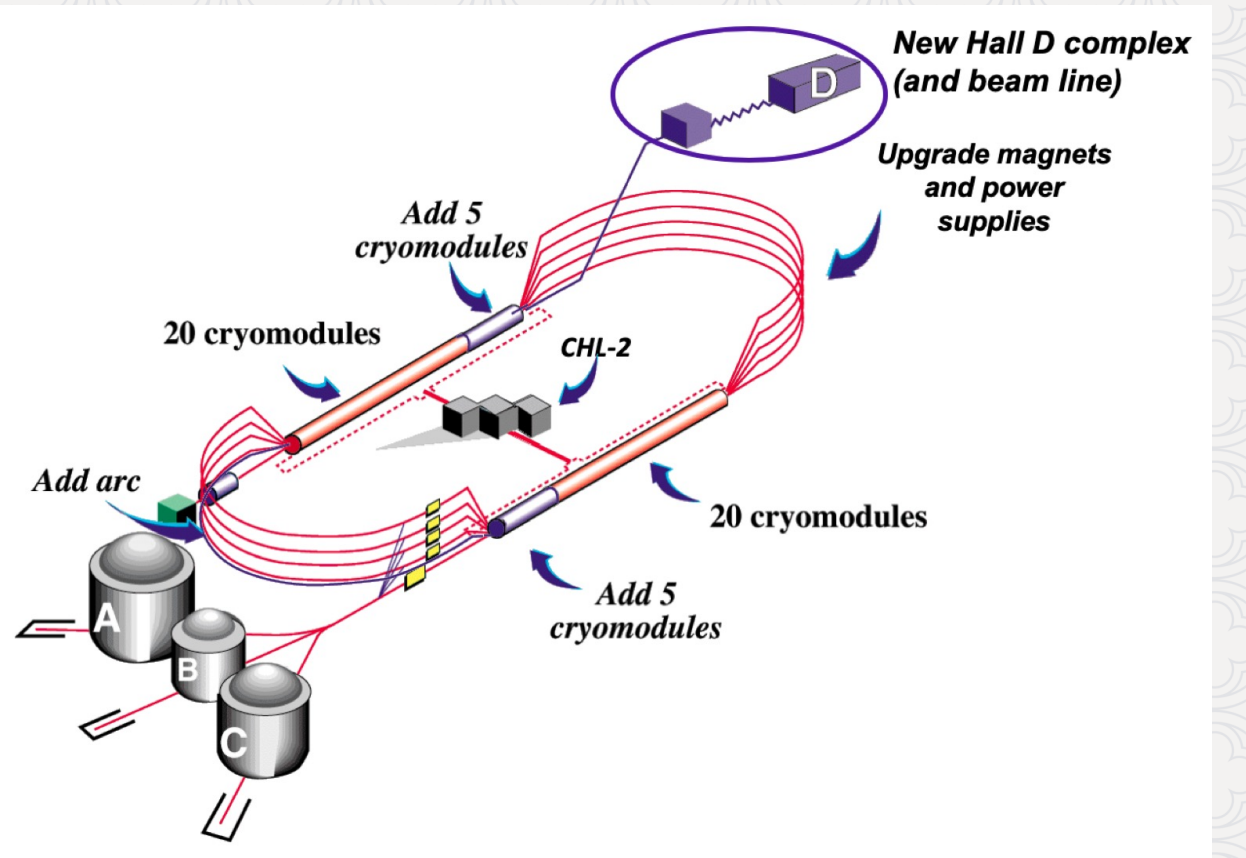
- SRC-CT (E12-19-003), Nov 6 to Dec 21, 2021, JLab Hall D
- Short range correlation (SRC) and color transparency (CT)
- 10.8 GeV linearly polarized photon beam
- Nuclear targets: deuterium, helium-4, carbon-12
- Collaboration from MIT, GWU, MSU, Duke, Tel Aviv, ODU and JLab



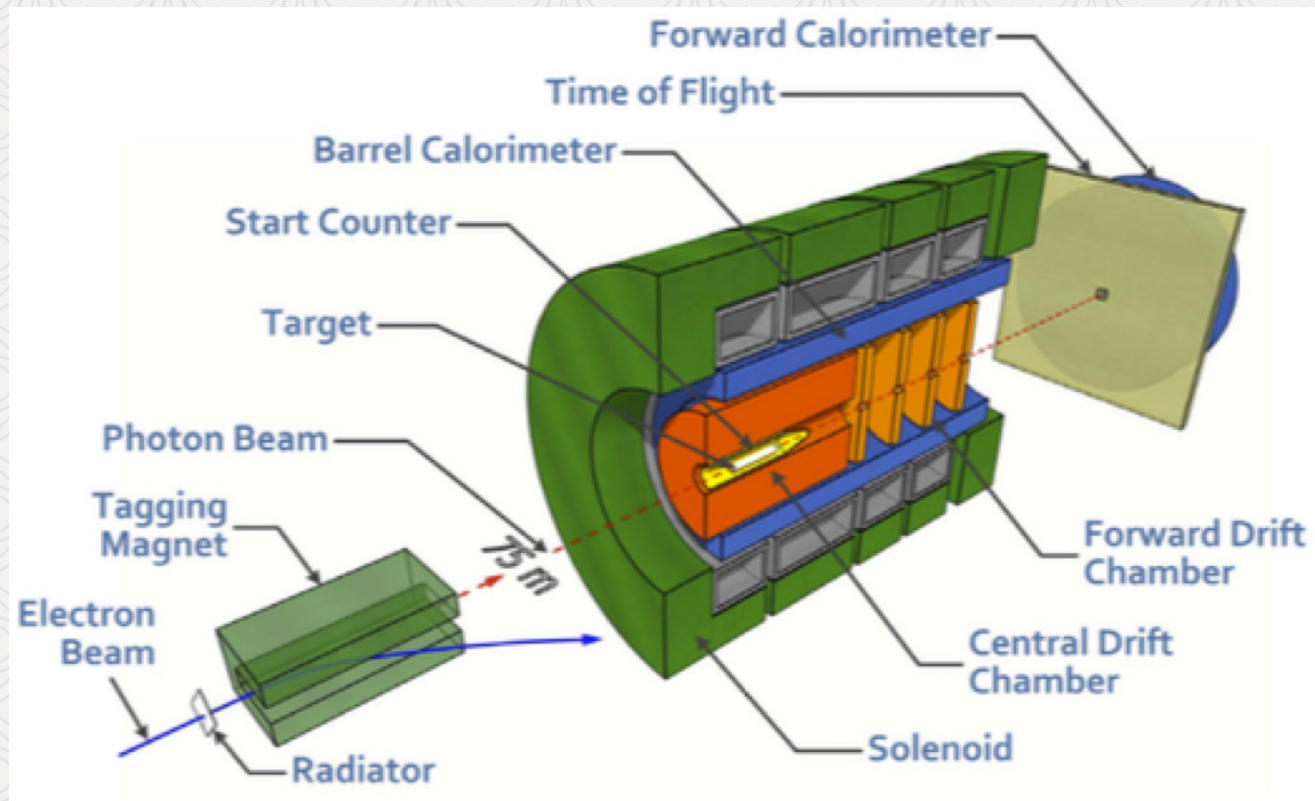


# Experimental apparatus

CEBAF accelerator



GlueX detector

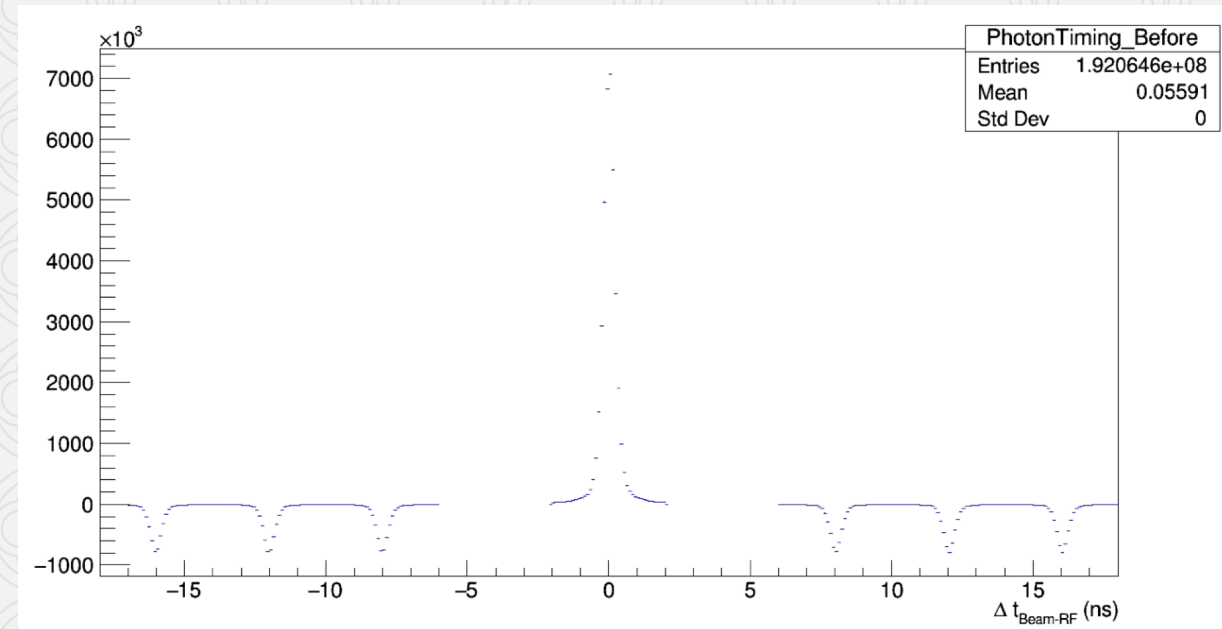


S. Adhikari *et al.*, NIM A, 987:164807, 2021.

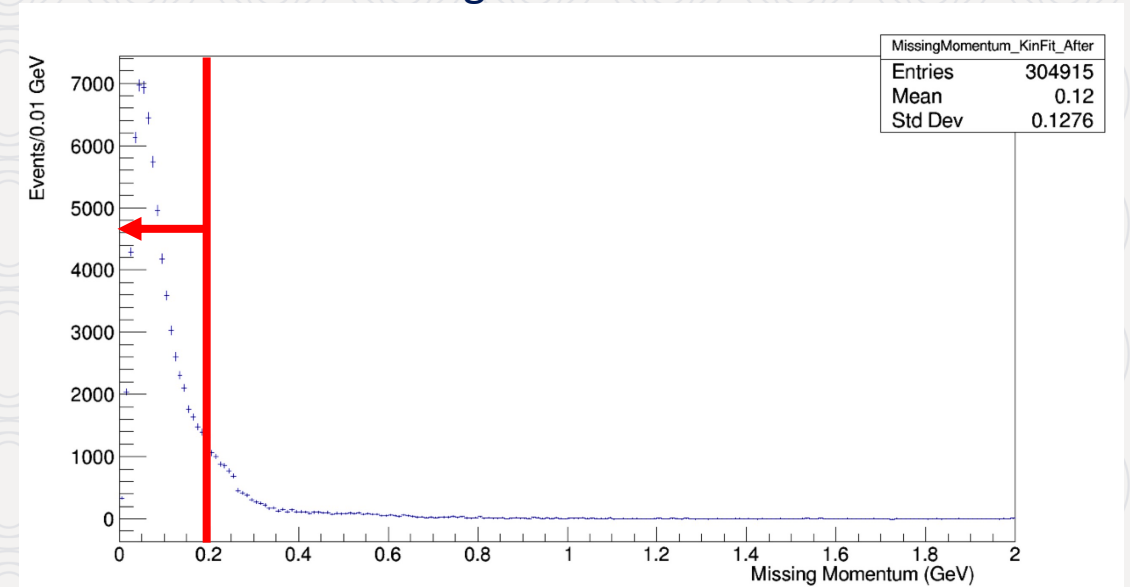


# Event selection

- Initial skimming
  - Kinematic fitting of common vertex converged
  - 1 extra track and 4 extra showers
  - Standard GlueX PID cuts
  - Photons within 4 beam bunches from the RF
- Finer cuts
  - No extra tracks or showers
  - Kinematic fitting  $CL > 0.01$
  - Charged tracks PID  $FOM > 0.01$
  - Photon energy  $> 6$  GeV
  - Common vertex within target cell
  - Missing momentum cuts

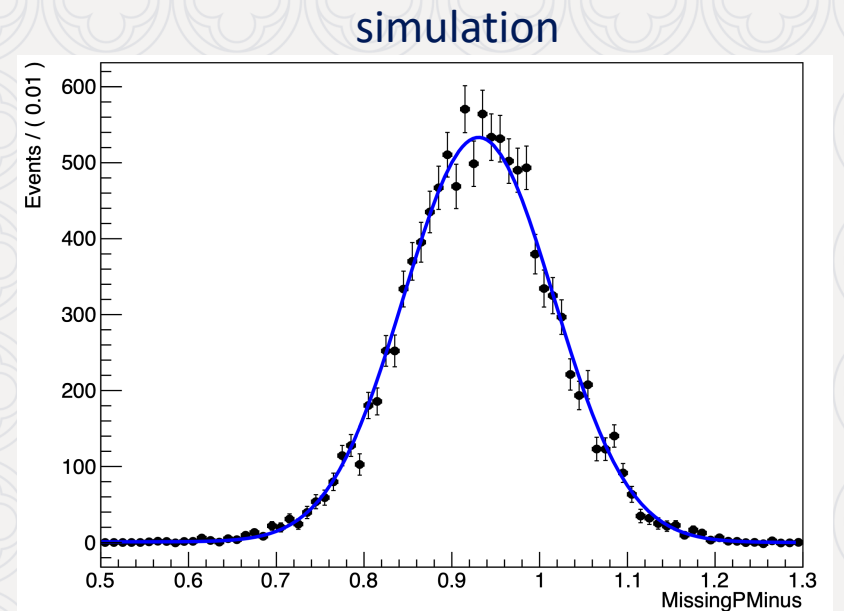
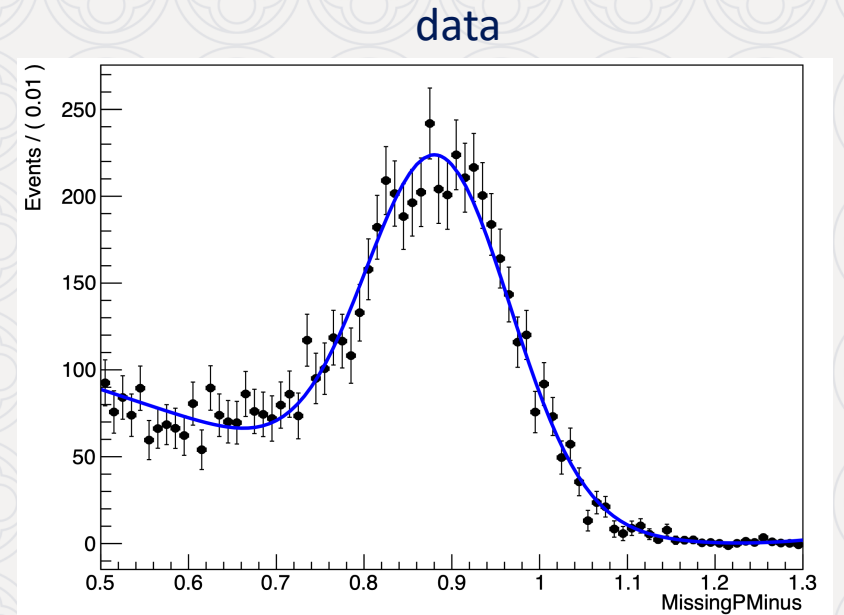


Missing momentum cut



# Yield extraction

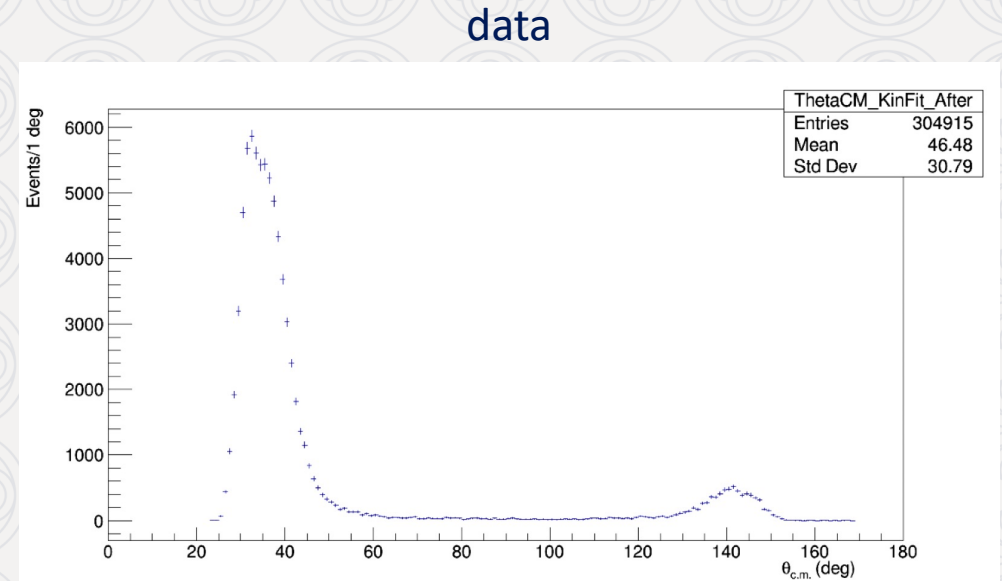
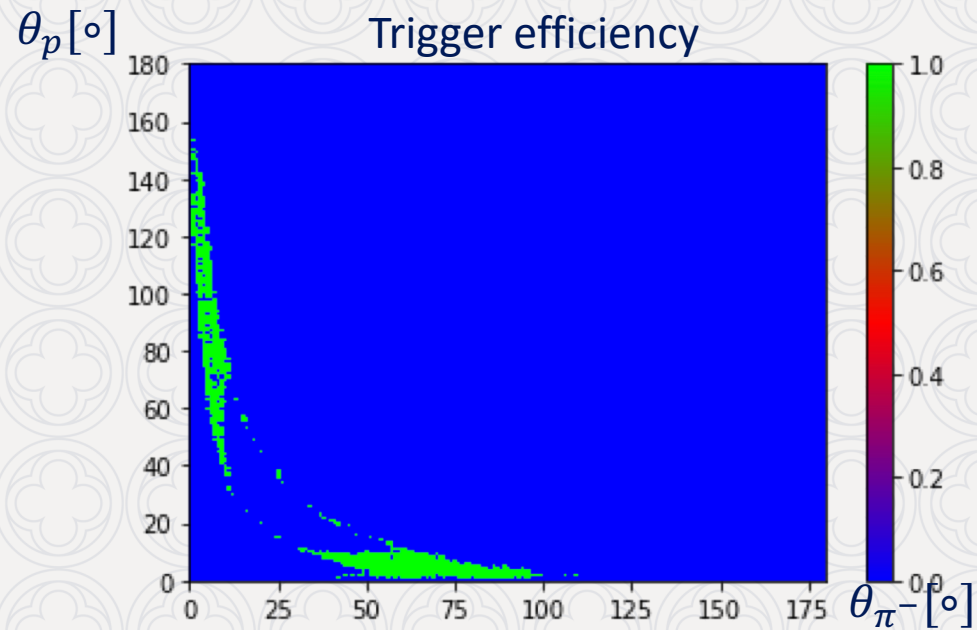
- Minus momentum of the missing neutron
- $P^- = E - P^z$
- Much better resolution than missing mass
- Signal events centered around neutron mass
- Fit with function of Gaussian plus polynomial





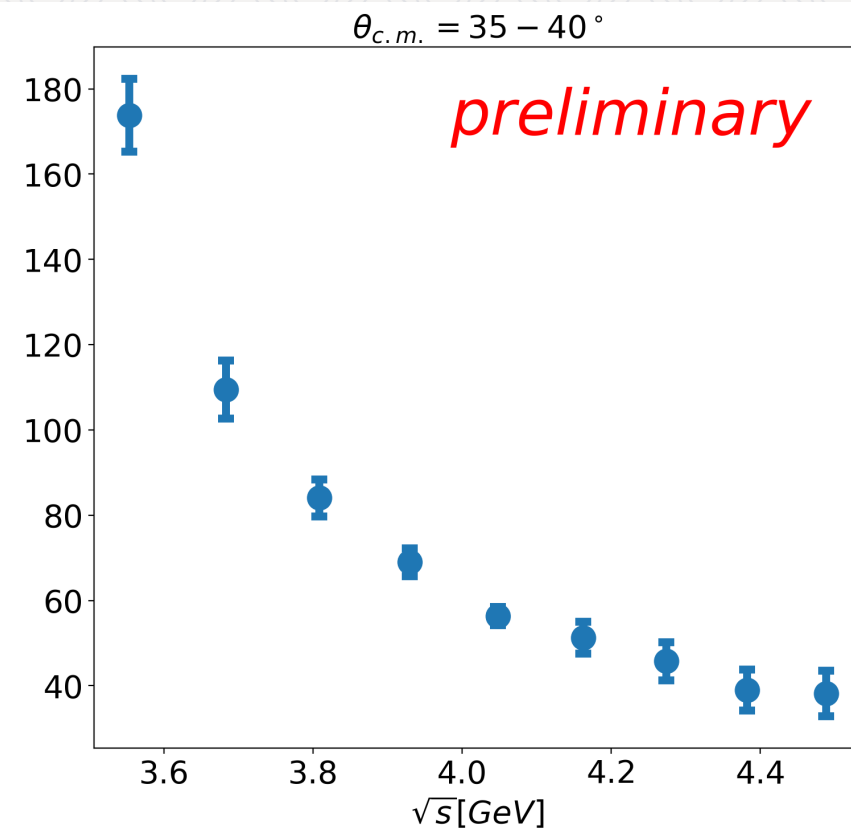
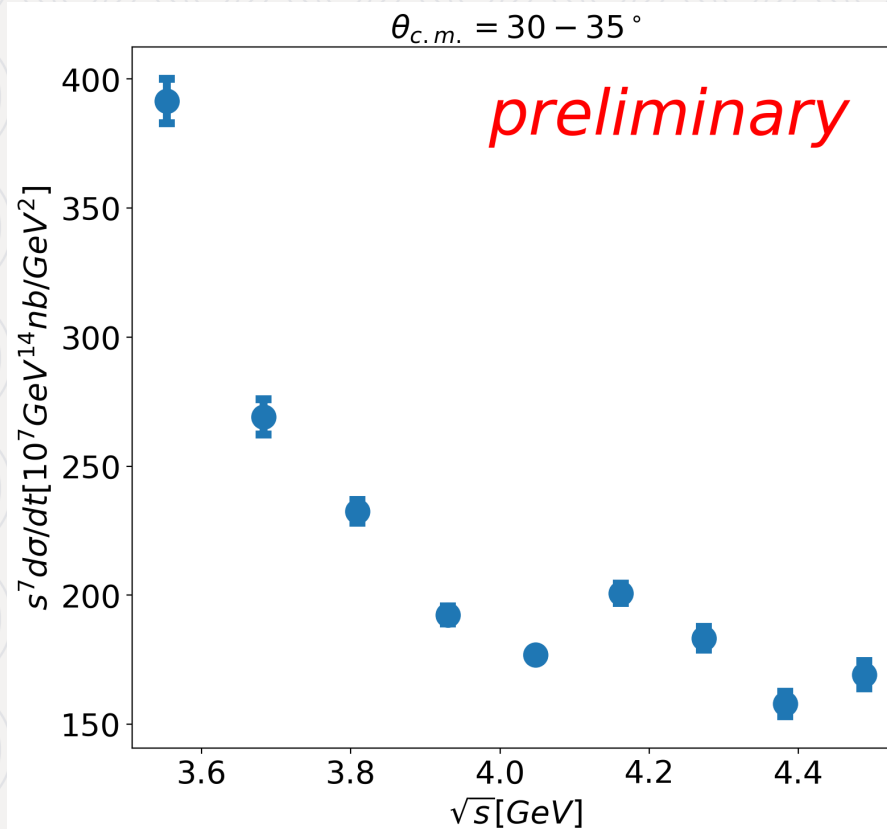
# Other components

- Transparency on deuterium: constant of 0.95 is used
- Acceptance affected by the trigger setting



# Scaled cross section on deuterium

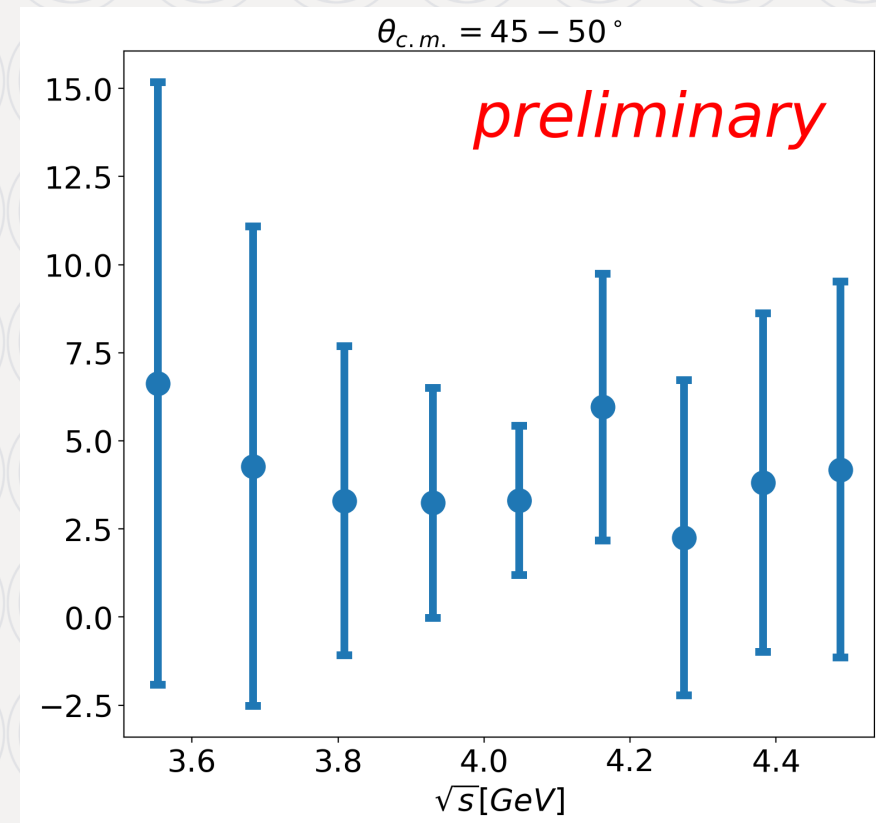
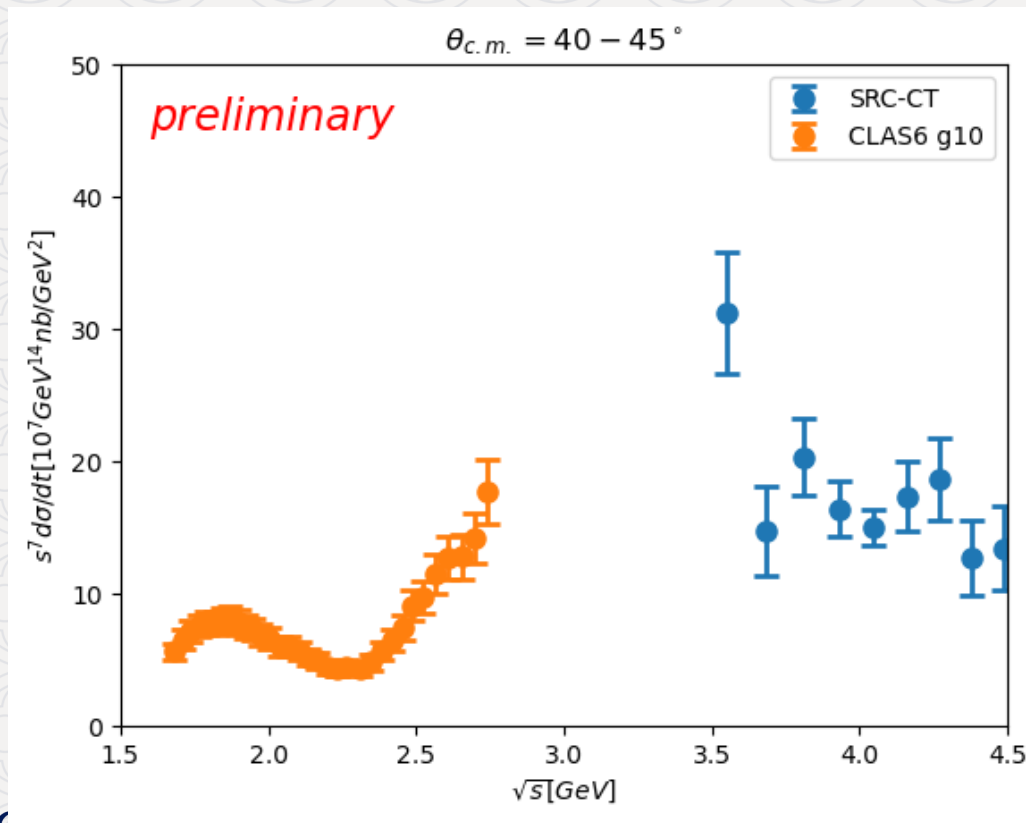
- Statistical errors only
- Possible QCD oscillation is observed





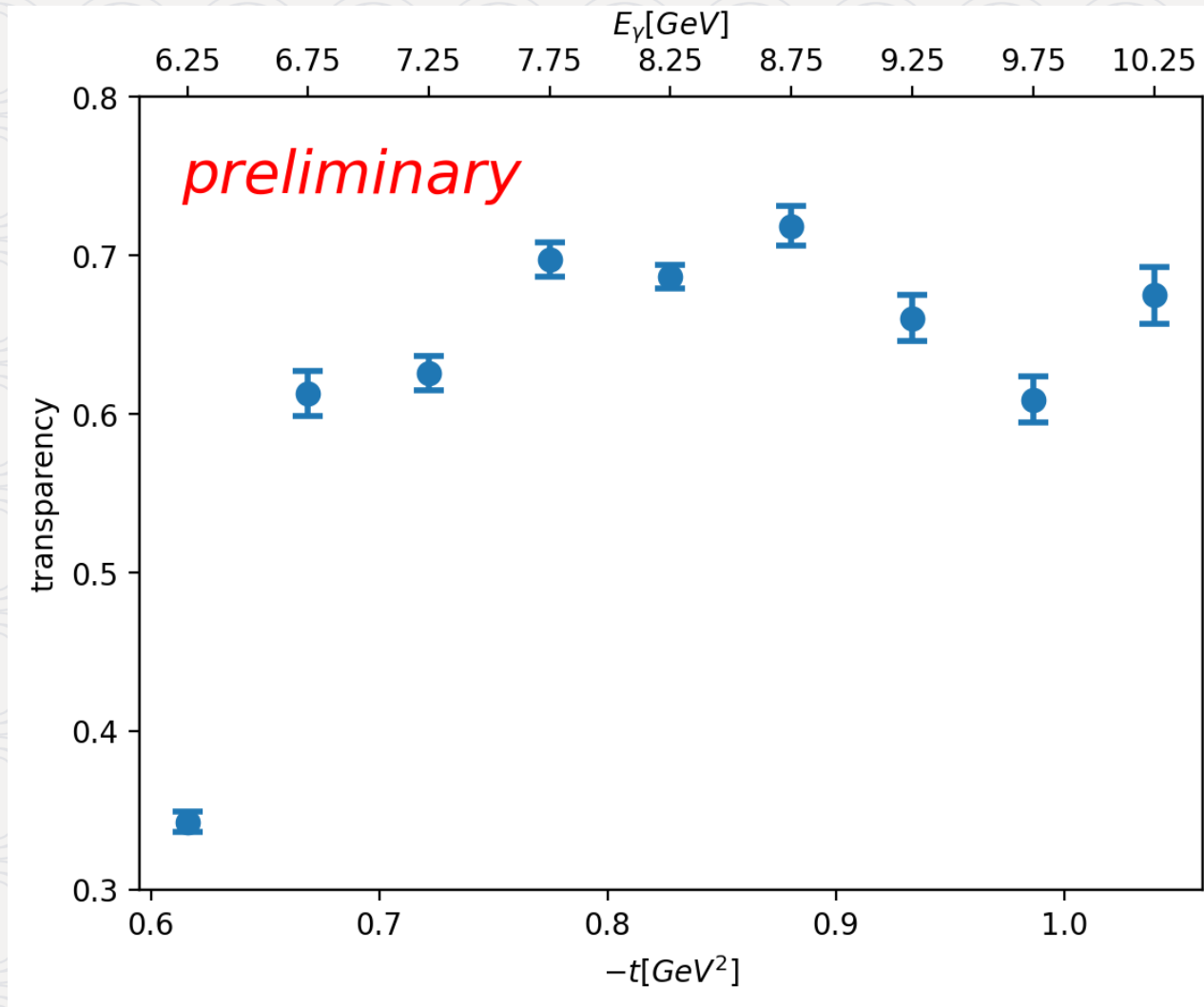
# Scaled cross section on deuterium

- Statistical errors only
- Compared with CLAS6 data



# Nuclear transparency on helium

- At  $\theta_{c.m.} = 30^\circ$

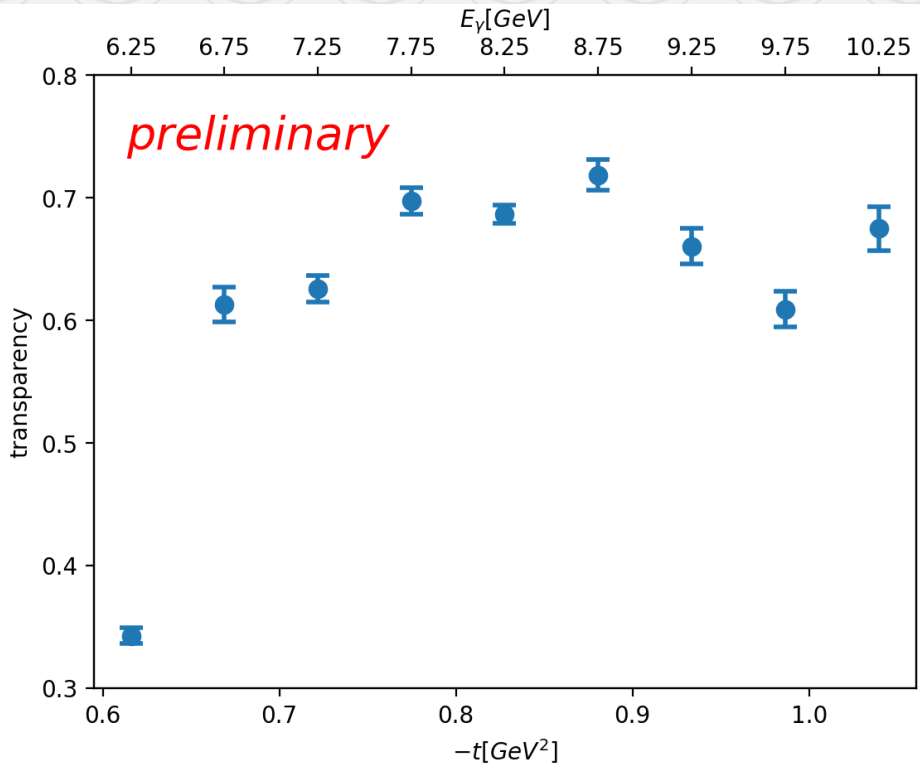




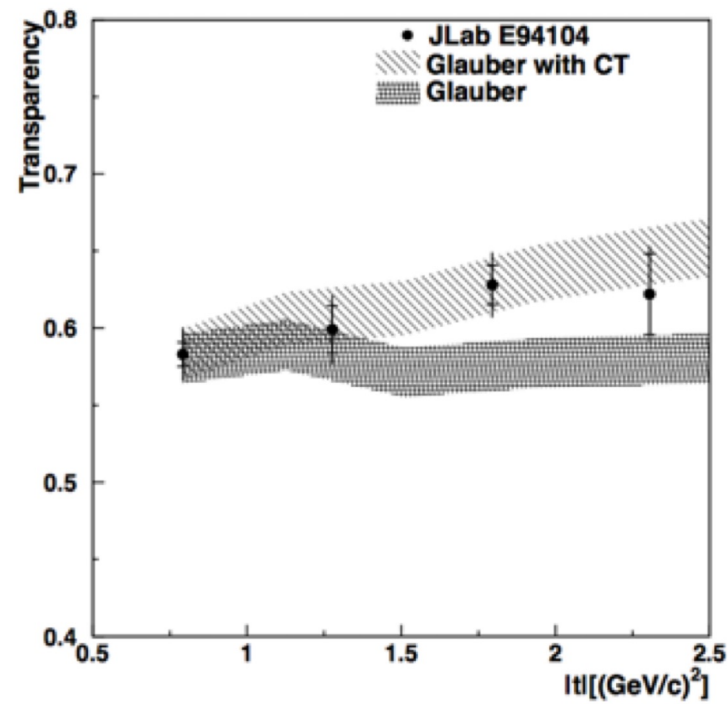
# Nuclear transparency on helium

- Compared with Hall A data

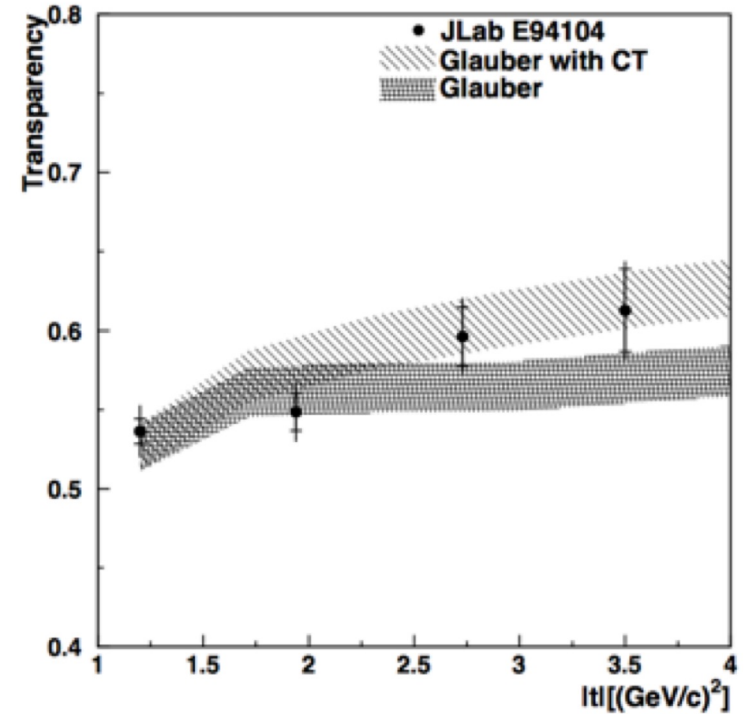
$\theta_{c.m.} = 30^\circ$



$\theta_{c.m.} = 70^\circ$



$\theta_{c.m.} = 90^\circ$



# Summary

- Pion photo-production is an important process to study the transition between quark-gluon to nucleon-meson degrees of freedom
- SRC-CT experiment offers a great opportunity to extend previous measurement of  $\gamma n \rightarrow \pi^- p$  reaction at JLab to higher energy and new targets
- Preliminary results confirmed the scaling of the cross section at new angles and suggested the oscillation around the scaling value
- More investigation is under way and new results will follow shortly