



# Study of $J/\psi$ Photoproduction off Deuteron

## LOI12-17-001

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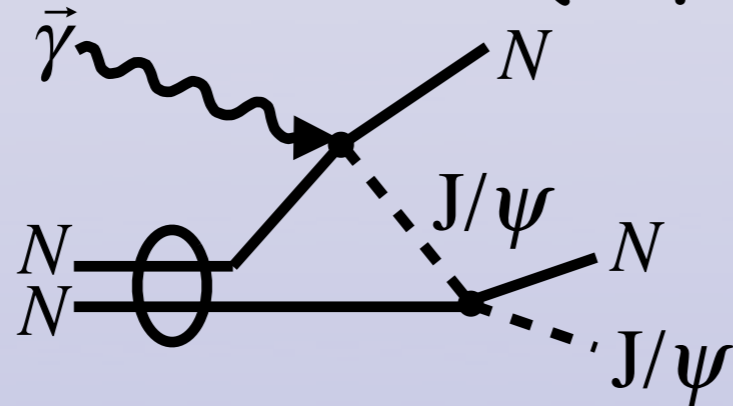
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# Near Threshold $J/\psi$ Production off Deuteron

## The Program

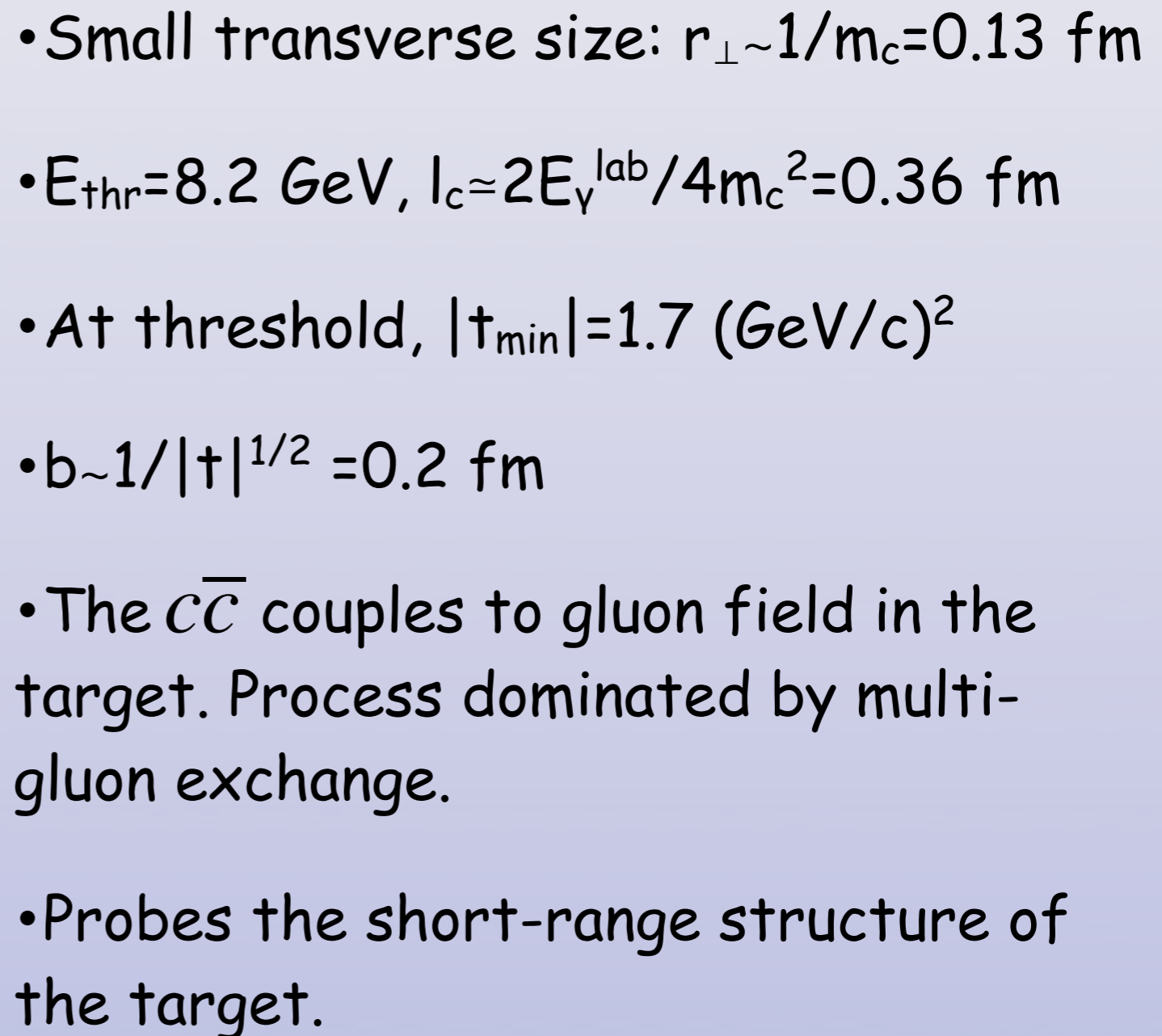
- Incoherent photoproduction:  $\gamma d \rightarrow J/\psi pn$ 
  - Quasi-free photoproduction off proton:  $\gamma(p) \rightarrow J/\psi p$
  - Quasi-free photoproduction off neutron:  $\gamma(n) \rightarrow J/\psi n$
  - Final-State Interactions ( $J/\psi N$  rescattering)



- Coherent photoproduction:  $\gamma d \rightarrow J/\psi d$

Plan: To develop LOI into a run-group proposal for RG B and submit to PAC in Summer 2018. Standard CLAS12 configuration.

# Why $J/\psi$ ?

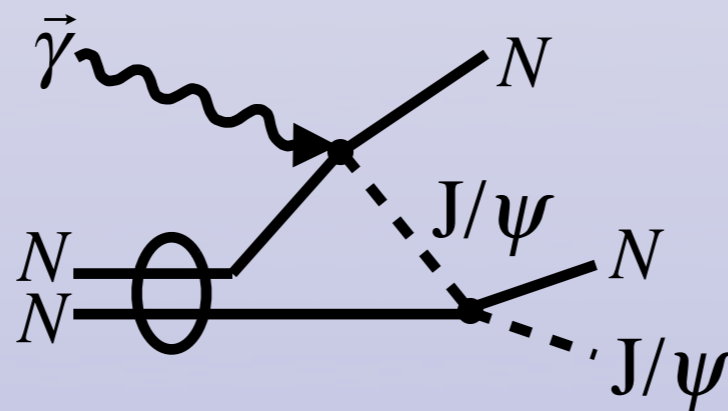


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# Near-Threshold $J/\psi$ Production off Deuteron

## Incoherent Photoproduction: $J/\psi N$ FSI

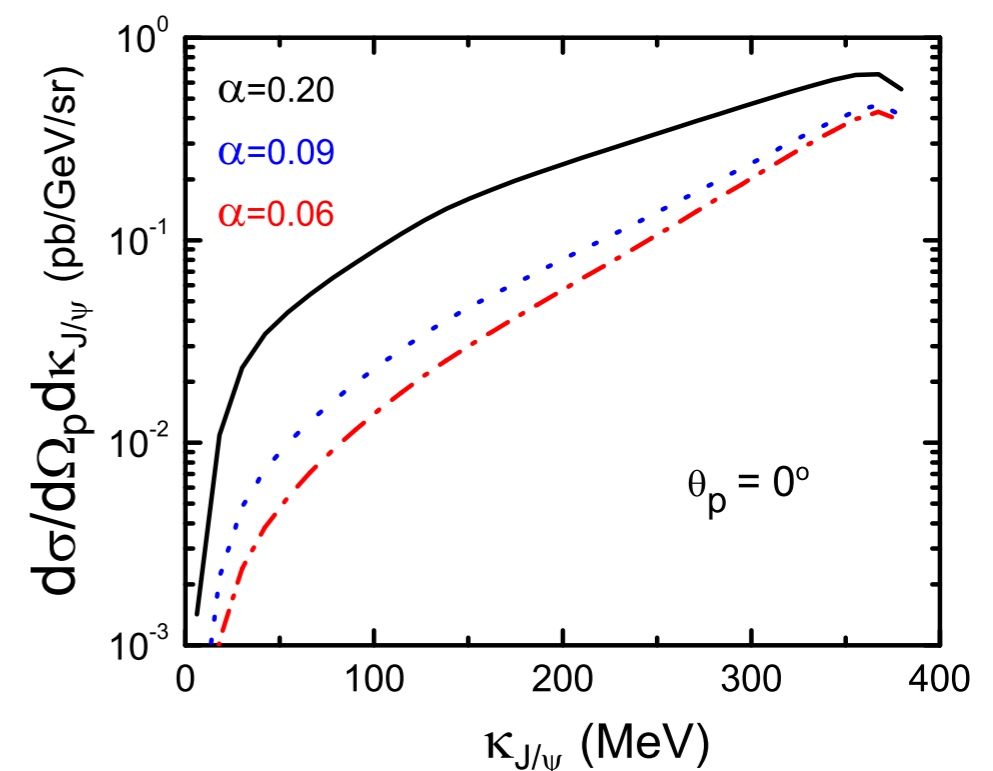
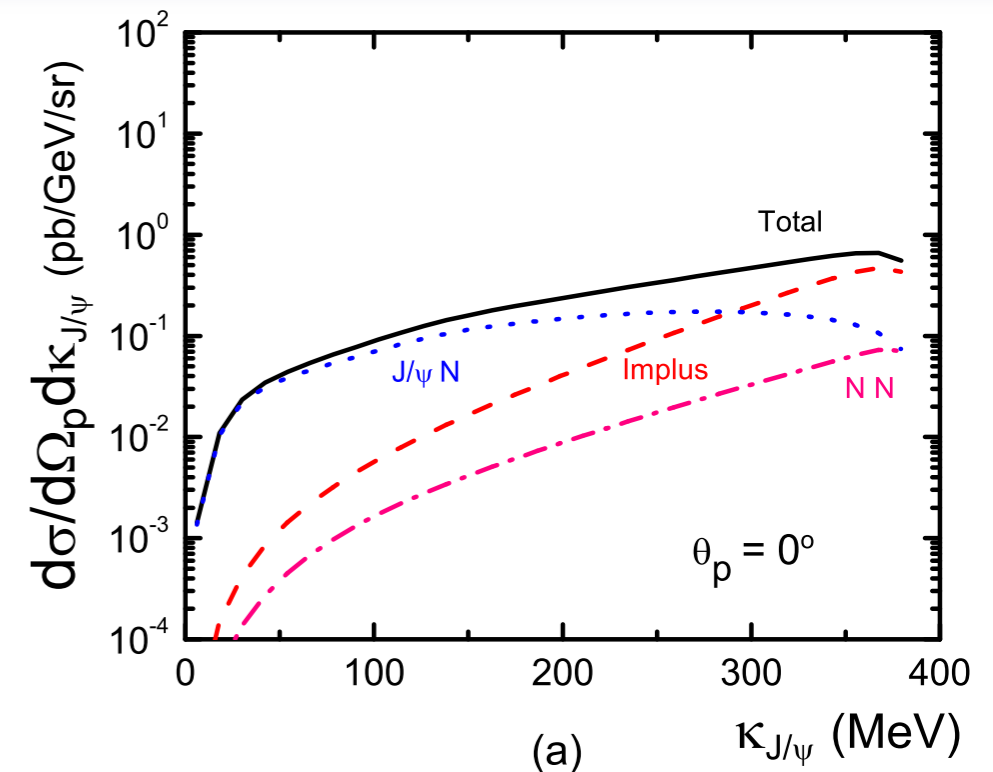
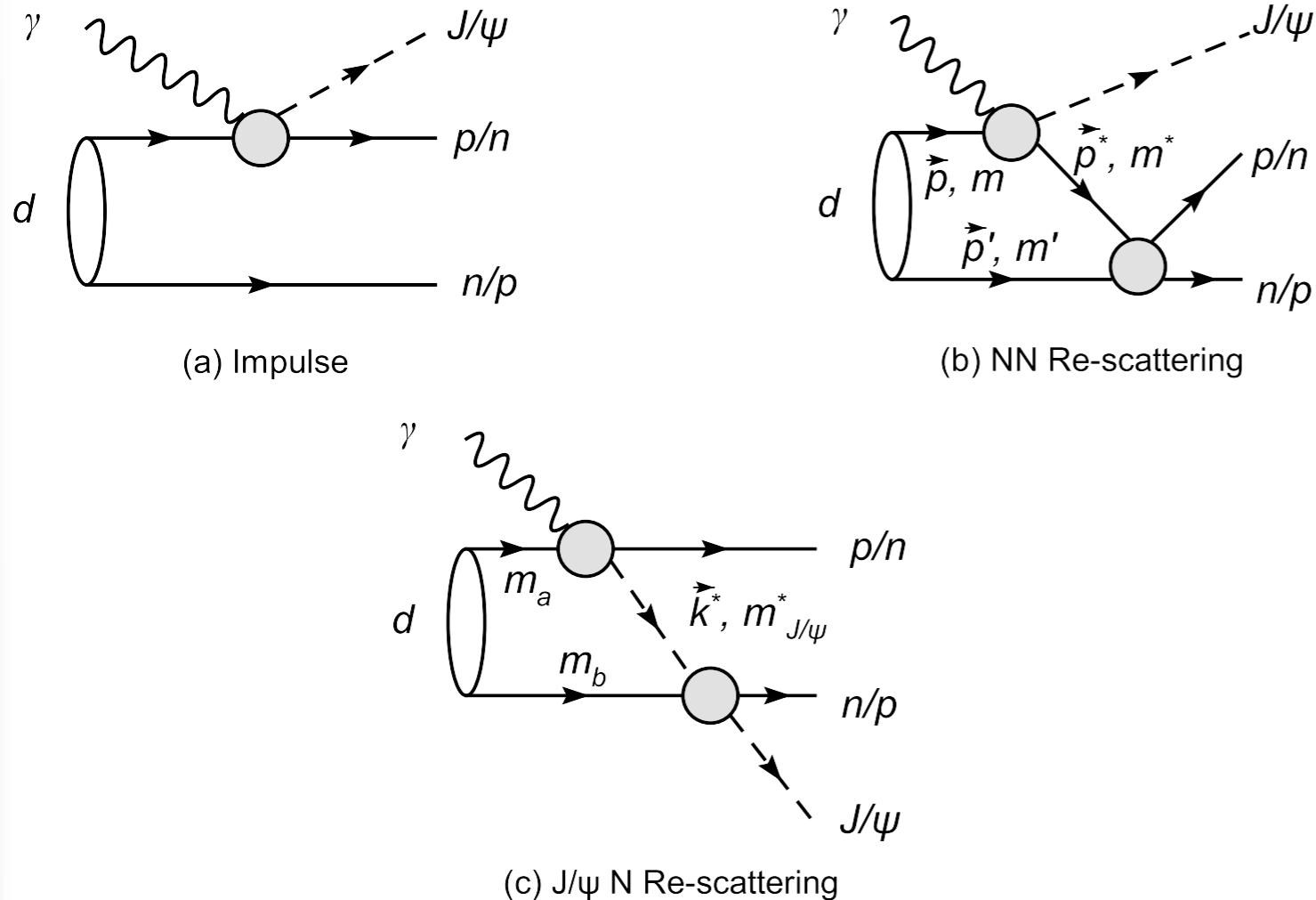
- Direct access to  $J/\psi N \rightarrow J/\psi N$  and the elementary  $J/\psi N$  total cross section ( $l_F \sim 1 \text{ fm}$ ).
  - $\sigma_{J/\psi N} < 1 \text{ mb}$  (from  $J/\psi$  on  $N$ )
  - $\sigma_{J/\psi N} \sim 3.5 \text{ mb}$  (from  $A$  dependence of nuclear absorption).
  - $\sigma_{J/\psi N} \geq 17 \text{ mb}$  (multiple expansion and low-energy theorems in QCD).



- At  $E_e = 11 \text{ GeV}$ ,  $p_{J/\psi, \text{lab}} = 5 - 10 \text{ GeV}$ ,  $W_{J/\psi N} = 4.6 - 5.7 \text{ GeV}$ .

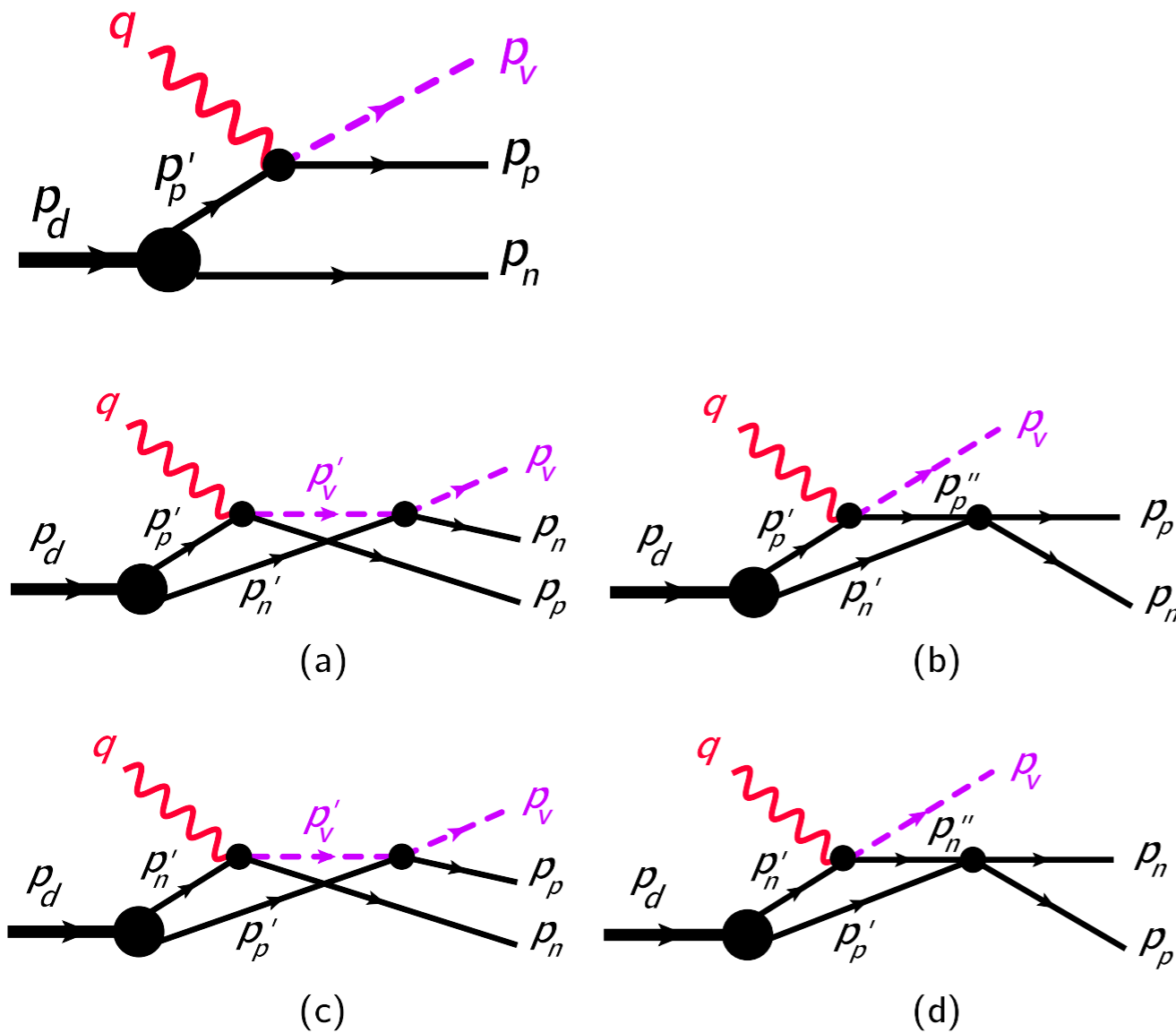
# Near-Threshold $J/\psi$ Production off Deuteron

## Incoherent Photoproduction: $J/\psi N$ FSI

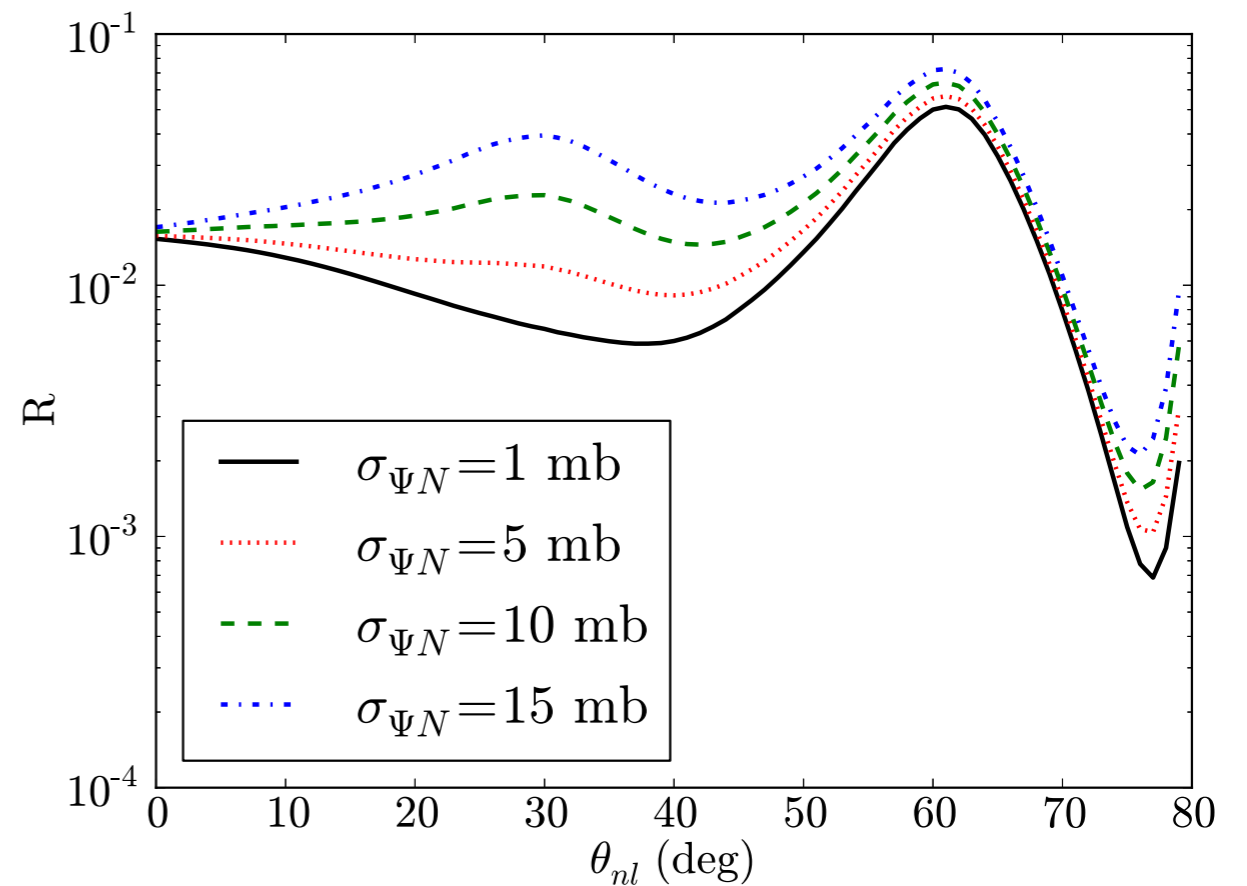


# Near-Threshold $J/\psi$ Production off Deuteron

## Incoherent Photoproduction: $J/\psi N$ FSI



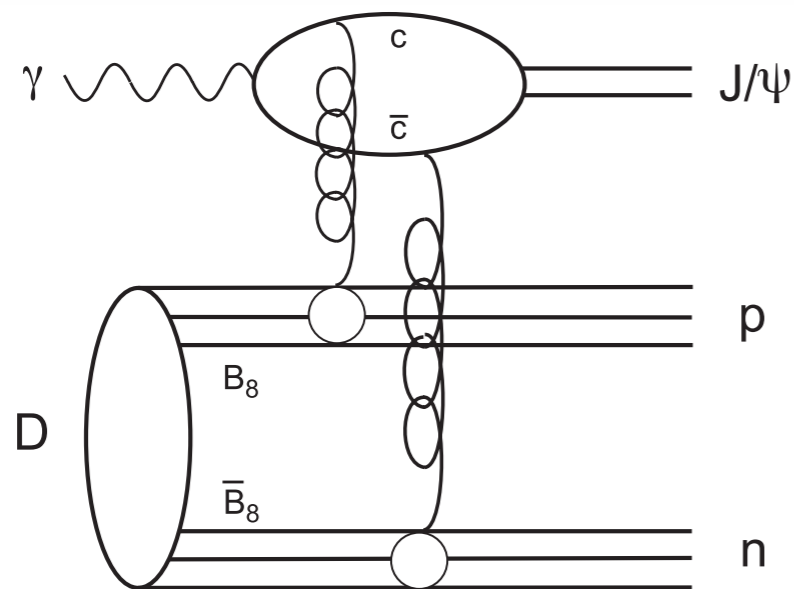
$$R = \frac{\sigma(p_n = 600 \text{ MeV})}{\sigma(p_n = 200 \text{ MeV})}$$



# Near-Threshold $J/\psi$ Production off Deuteron

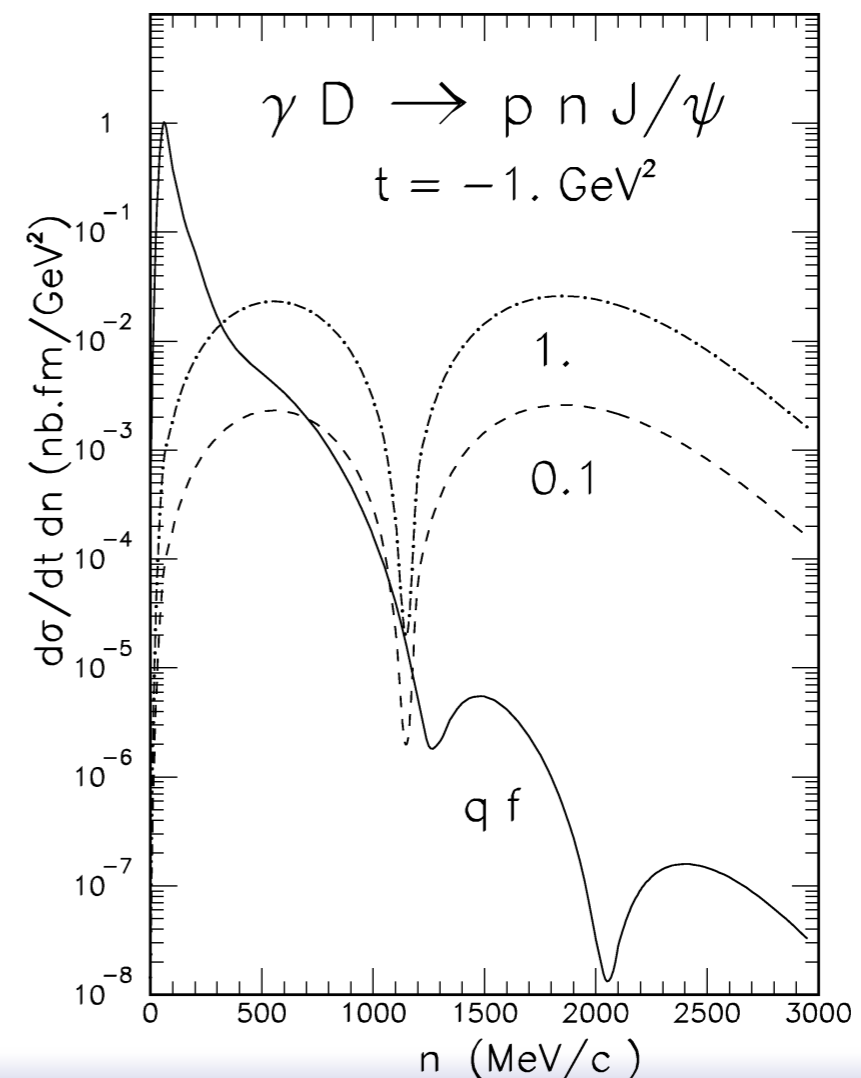
## Incoherent Photoproduction: $J/\psi N$ FSI

- Sensitivity to hidden-color component of the deuteron wave function.



Hidden-color component contribution dominates the cross section above neutron momenta of 500 MeV/c.

May dominate subthreshold photoproduction (on deuteron:  $E_{\text{thr}}=5.66$  GeV).



$$\frac{d\sigma}{dt d|\vec{n}|} = \frac{d\sigma}{dt} \Big|_{\gamma p \rightarrow J/\psi p} 4\pi \vec{n}^2 \left[ \varphi_{cc} \left( \frac{\vec{n}}{2} \right) \right]^2 \frac{F_1^4(t/4)}{F_1^2(t)}$$

# Near-Threshold $J/\psi$ Production off Deuteron

## More Physics

- Coherent photoproduction off Deuteron: access to the deuteron two-gluon form factor ( $E_{\text{thr}}=5.66 \text{ GeV}$ ,  $|t_{\text{min}}|=3.63 \text{ (GeV/c)}^2$ ).
- Quasi-free photoproduction off neutron.
  - Probe the two gluon-exchange mechanism, which is “flavor-blind”, via the ratio  $\frac{\sigma_{\gamma n \rightarrow J/\psi n}}{\sigma_{\gamma p \rightarrow J/\psi p}}$ .
- Search for neutral hidden-charm pentaquark signal,  $P_c^0$ , (isospin partner of  $P_c^+$ ).

# Near-Threshold $J/\psi$ Deuteron Photoproduction

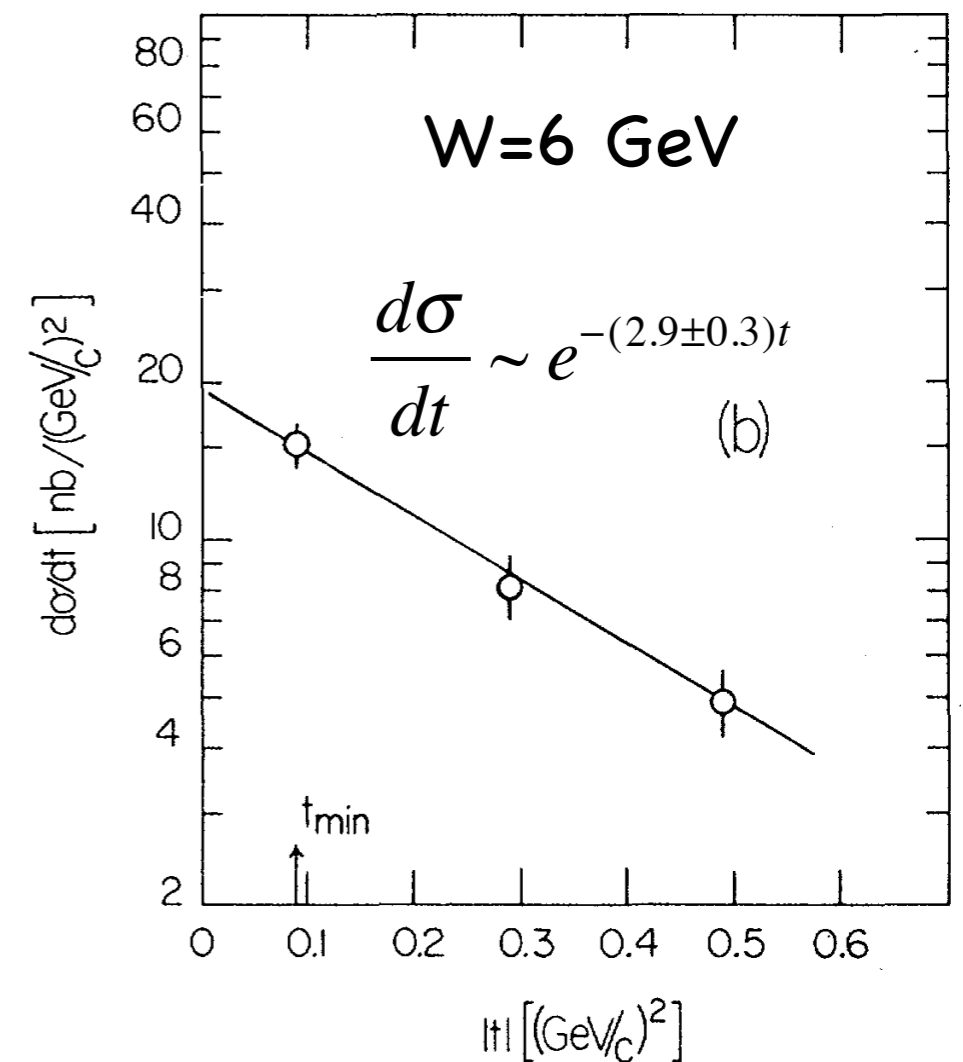
## Previous Measurements

SLAC, untagged real photon beam,  $e^+e^-$  and  $\mu^+\mu^-$  detected

$$\sigma_{tot}(J/\psi - N) \leq 0.8 \text{ mb}$$

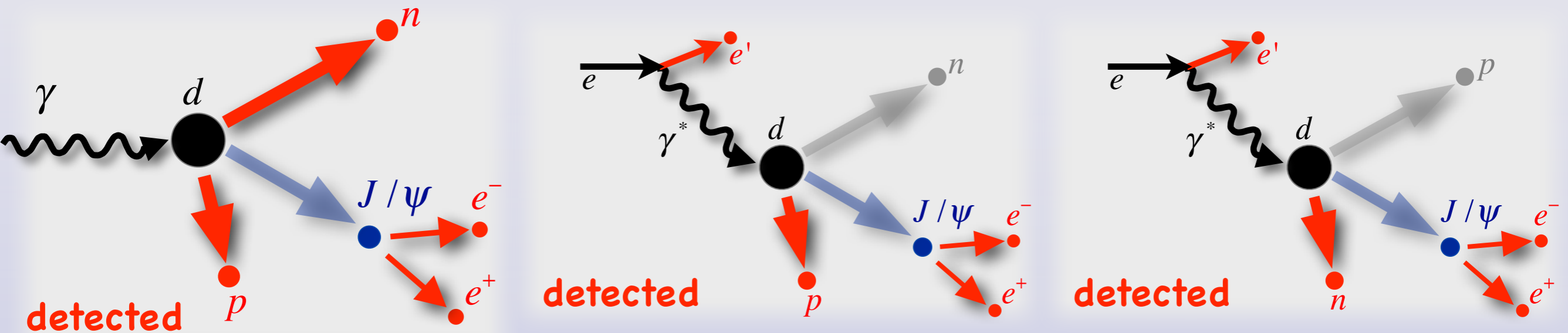
TABLE I. Differential cross sections and kinematic conditions for the data points of this experiment.  $t' \equiv t - t_{\min}$ .

$k$ (GeV)	$E_0$ (GeV)	$t_{\min}$ (GeV/c) <sup>2</sup>	$t'$ (GeV/c) <sup>2</sup>	$d\sigma(t)/dt$ [nb/(GeV/c) <sup>2</sup> ]
$\psi(3100)$ from deuterium target				
21.0	21.5	0.069	0.0	$14.6 \pm 1.2$
19.0	20.0	0.088	0.0	$15.0 \pm 1.0$
19.0	19.5	0.088	0.0	$12.0 \pm 1.1$
17.0	17.5	0.116	0.0	$10.8 \pm 1.0$
16.0	16.5	0.135	0.0	$8.2 \pm 1.1$
15.0	20.0	0.160	0.0	$7.7 \pm 1.5$
15.0	16.0	0.160	0.0	$5.9 \pm 1.0$
13.0	13.5	0.236	0.0	$3.8 \pm 0.8$
19.0	20.0	0.088	0.20	$8.2 \pm 1.1$
19.0	20.0	0.088	0.40	$4.9 \pm 0.7$



# Near-Threshold $J/\psi$ Deuteron Photoproduction with CLAS12

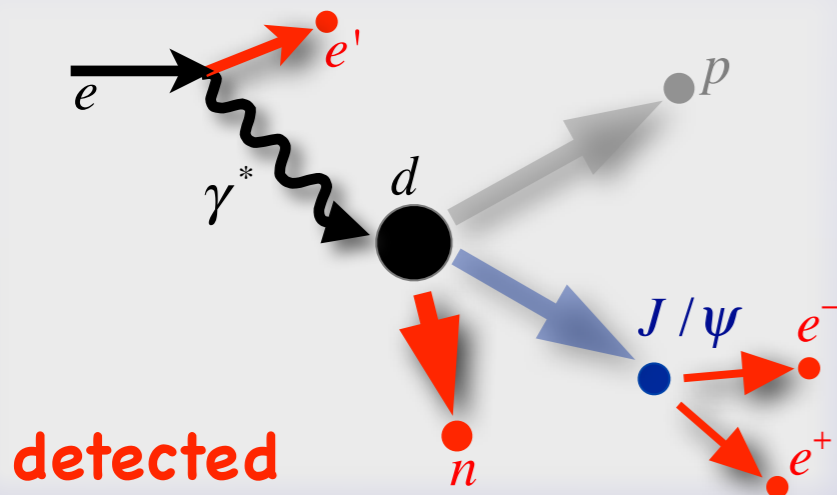
## Fully Exclusive Measurements of Incoherent Photoproduction



- Will run together with RunGroup B: 11 GeV, unpolarized d target, forward tagger, central neutron detector.
- Standard CLAS12 electron trigger
- Acceptance, expected yields, and optimal CLAS settings to be estimated.

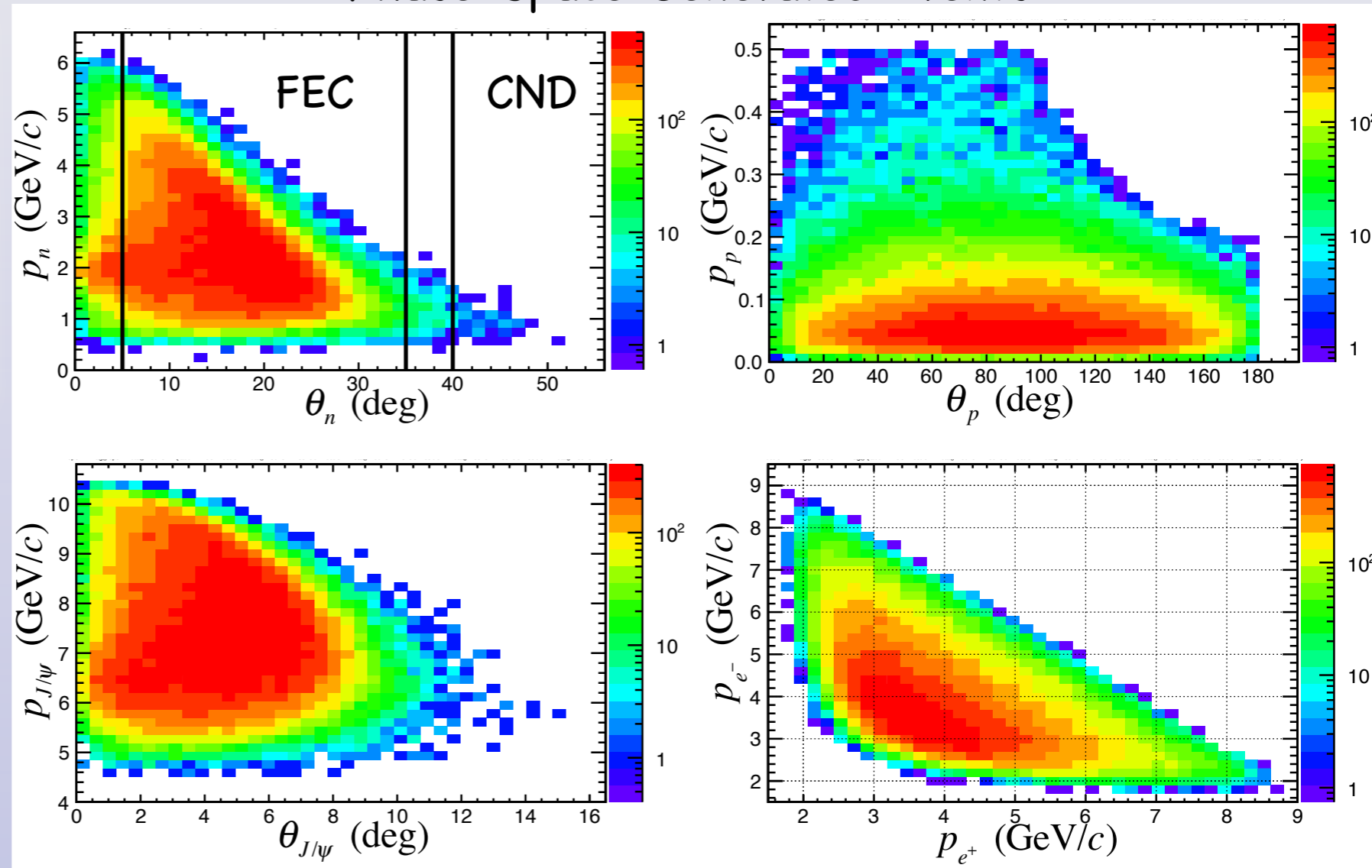
# Near-Threshold $J/\psi$ Deuteron Photoproduction with CLAS12

## Fully Exclusive Measurements of Incoherent Photoproduction



- quasi-real, tagged photons
- n detection in Forward EC, possible CND
- $J/\psi$ : from  $e^+e^-$  decay

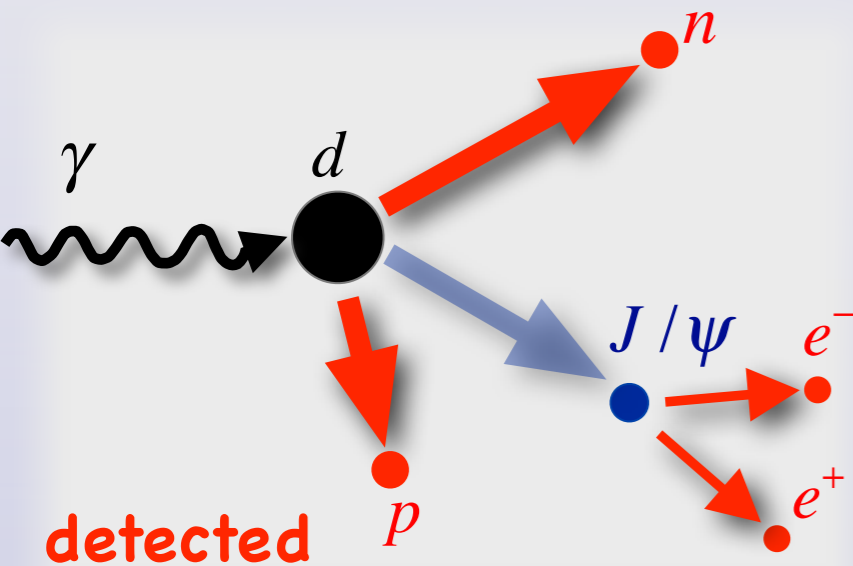
Phase-Space Generated Events



This topology yields primarily  $q\bar{q}$  events off neutron.

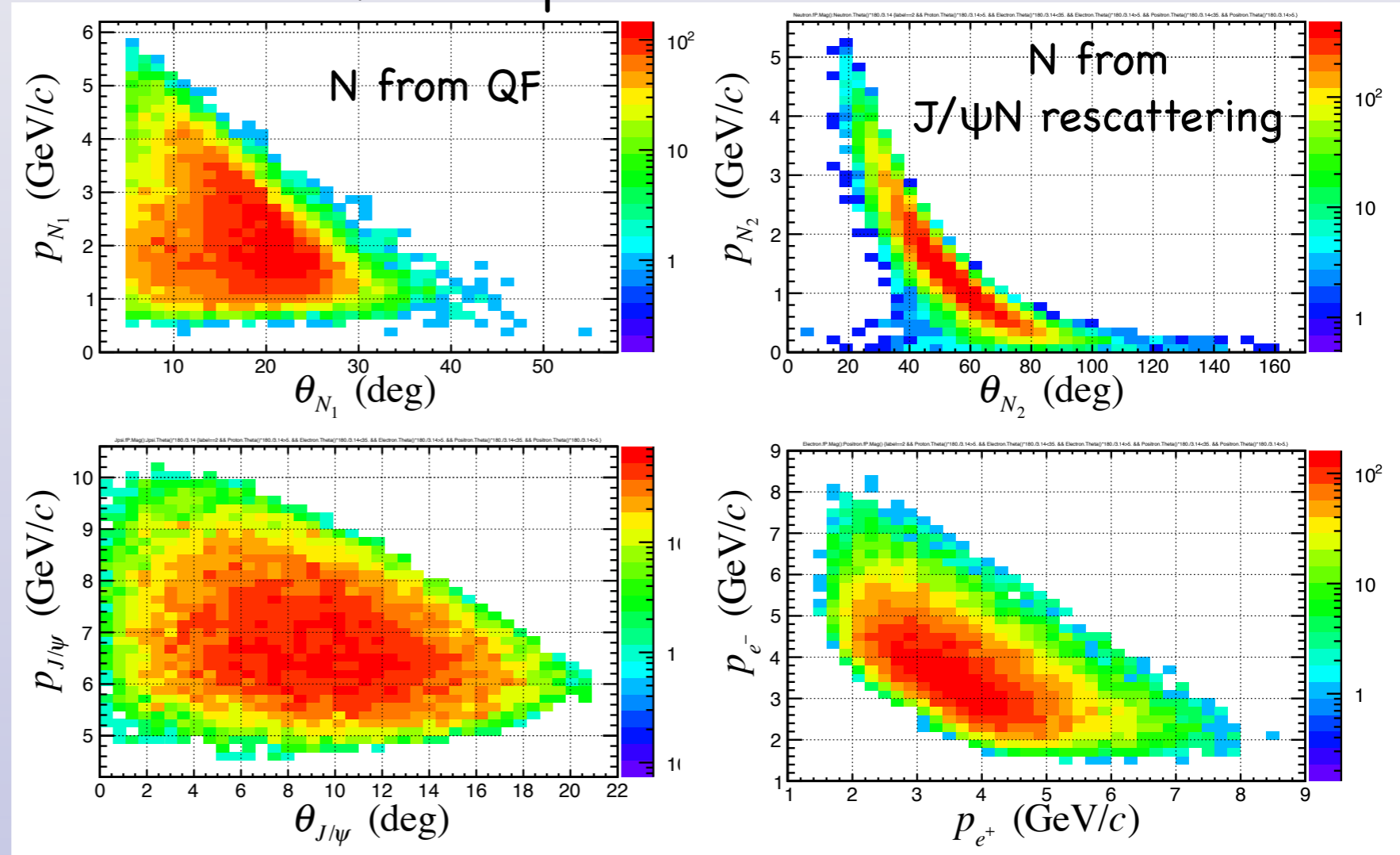
# Near-Threshold $J/\psi$ Deuteron Photoproduction with CLAS12

## Fully Exclusive Measurements of Incoherent Photoproduction



- untagged photons: all final-state particles detected; primarily  $J/\psi p$  rescattering
- tagged photons:  $e'$  in FT  
 $\gamma d \rightarrow p J/\psi X (X \equiv n)$   
 $\gamma d \rightarrow n J/\psi X (X \equiv p)$

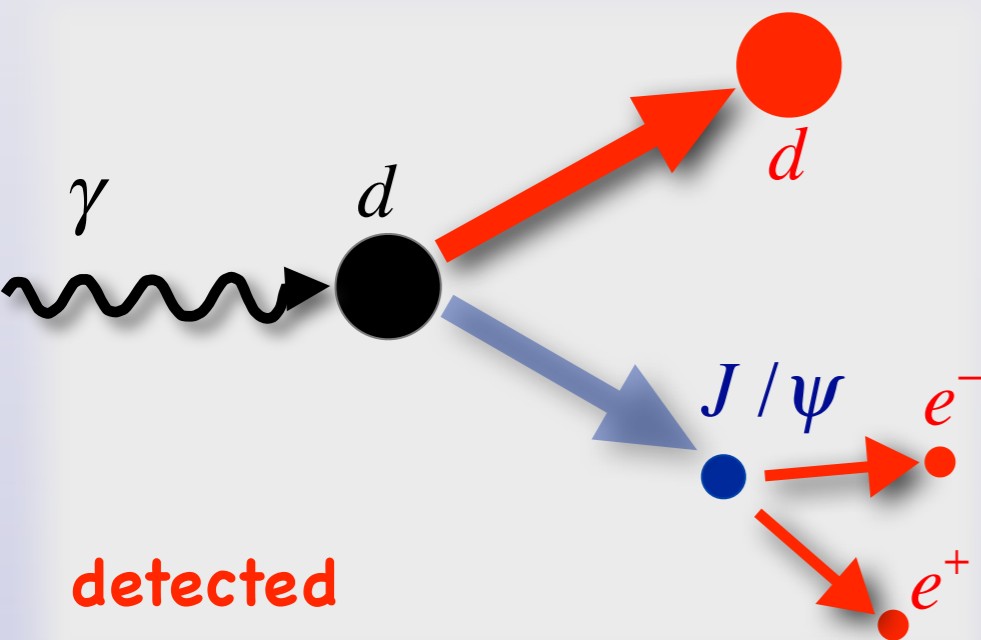
### Phase-Space Generated Events



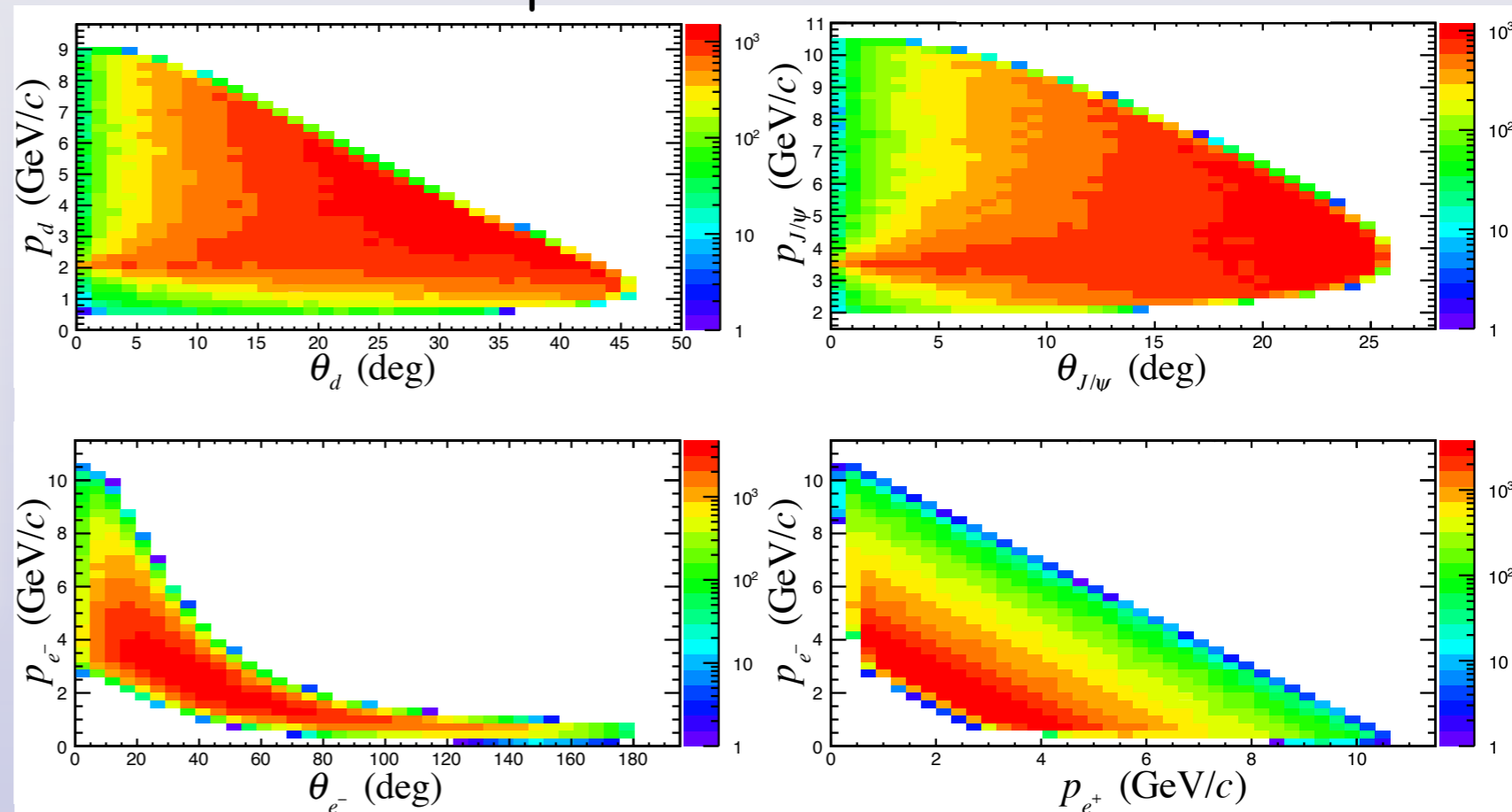
Several event topologies to obtain FSI-dominated yields.

# Near-Threshold $J/\psi$ Deuteron Photoproduction with CLAS12

## Fully Exclusive Measurements of Coherent Photoproduction



Phase-Space Generated Events



- Deuteron must be detected.
- Smaller counting rates expected, compared to incoherent production.
- We will look for possible signal in various topologies (tagged and untagged) in data.

# Summary and Outlook

- Window of opportunity to measure the cross section for photoproduction of  $J/\psi$  off the deuteron with CLAS12 and to study:
  - gluonic structure of deuteron
  - $J/\psi$ -N interaction through rescattering
  - $J/\psi$ -n photoproduction
- Will explore extracting polarization observables, such as beam-spin asymmetry.
- In preparation for a Run-Group Proposal to next PAC.

The End