Light vector meson photoproduction from nuclear targets in the energy range 6 to 10.5 GeV

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Duke University
Vector quarkonia mini workshop
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The SRC-CT experiment

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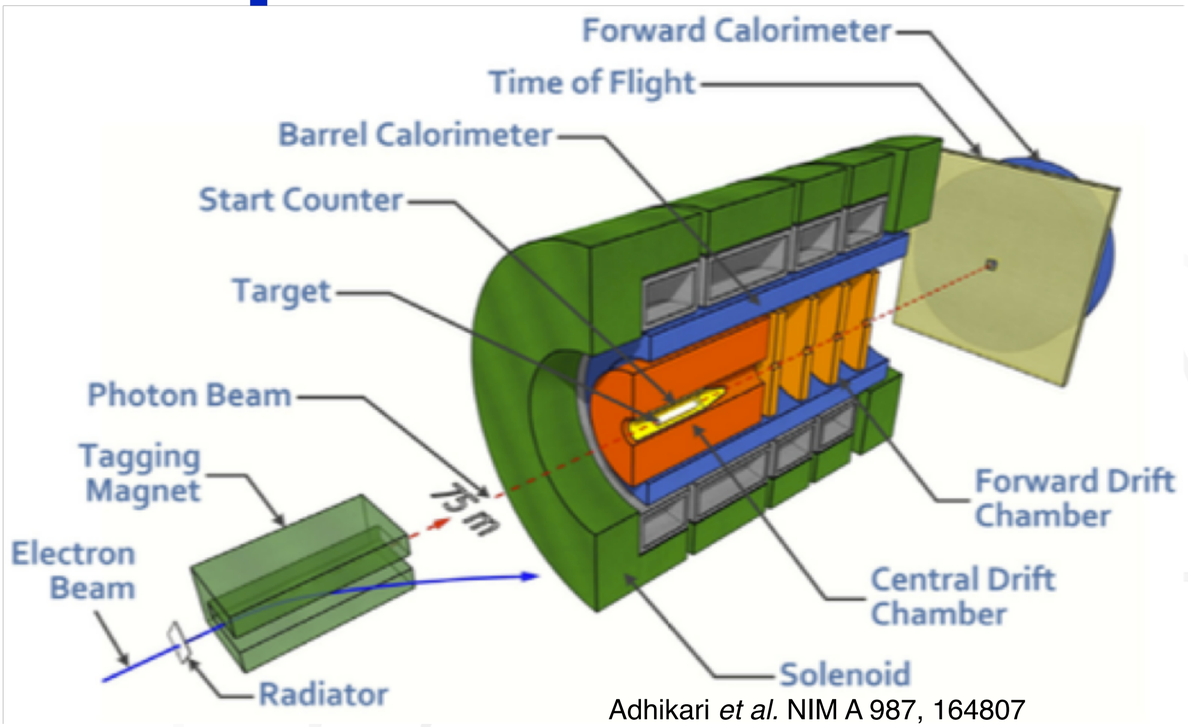
- Short range correlation (SRC), color transparency (CT) and bound nucleon structure

- Fall 2021 at JLab Hall D with GlueX detector



Adhikari *et al.* NIM A 987, 164807

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- 40 calendar days running of 3 nuclear targets
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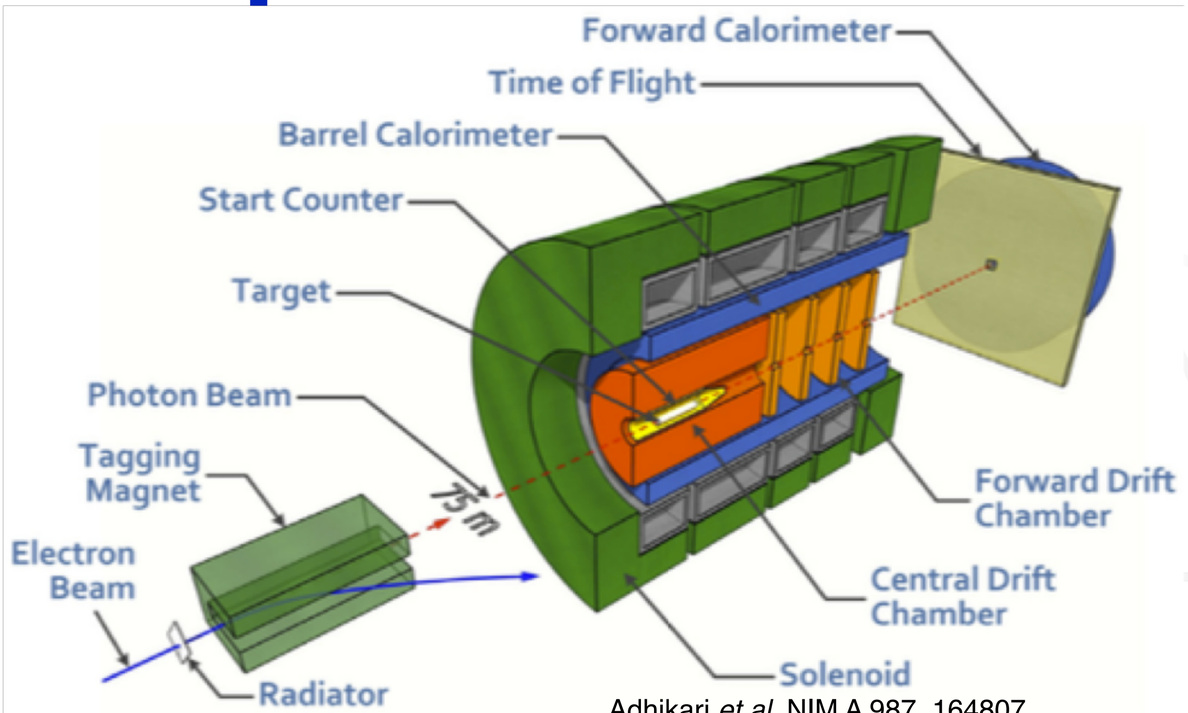

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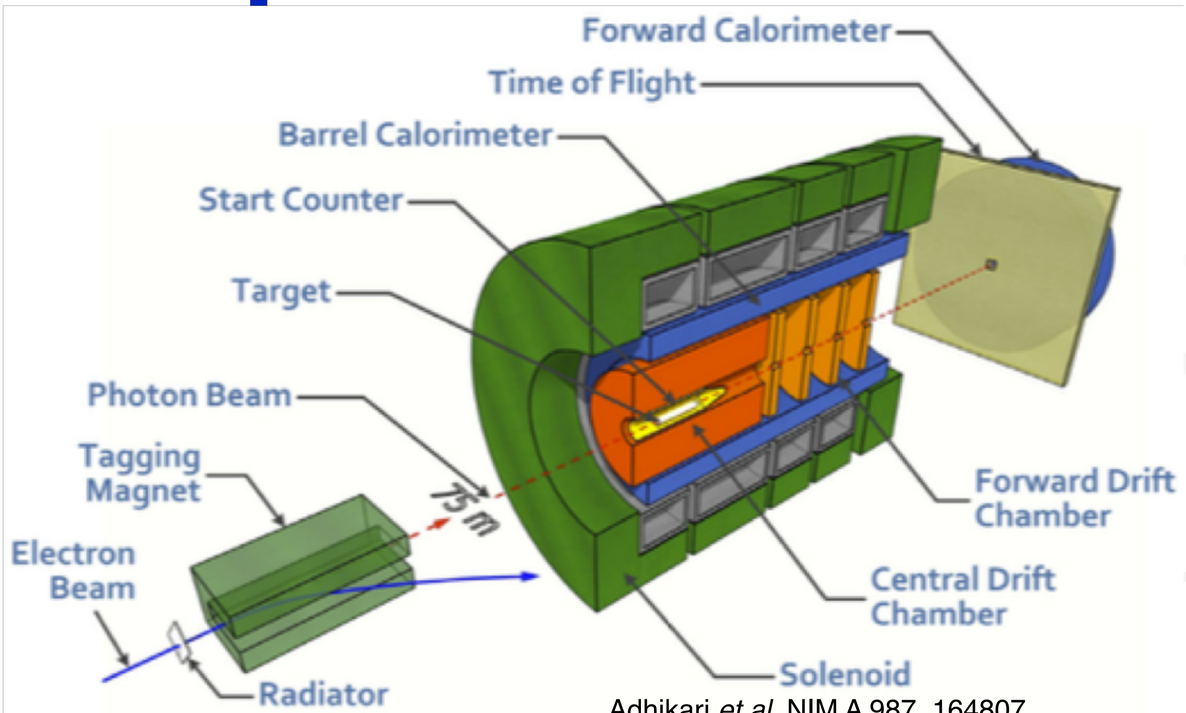
- Published the first near-threshold and sub threshold J/ψ photoproduction off nuclei



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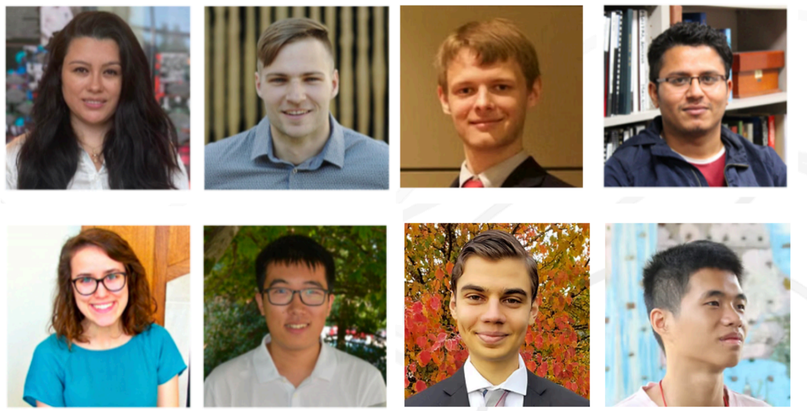

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- Deuteron knockout: $\gamma + {}^{4}\mathrm{He}/{}^{12}\mathrm{C} \rightarrow V + d + X$
  - Data yield extracted

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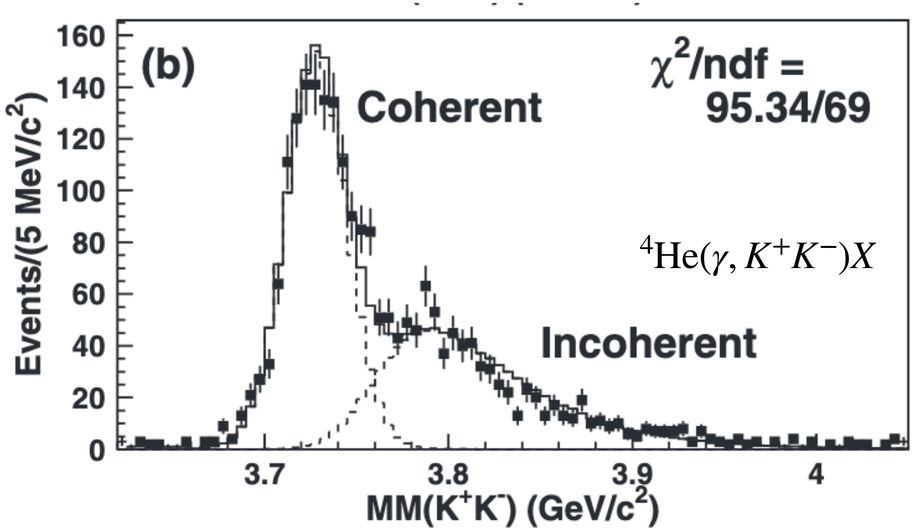
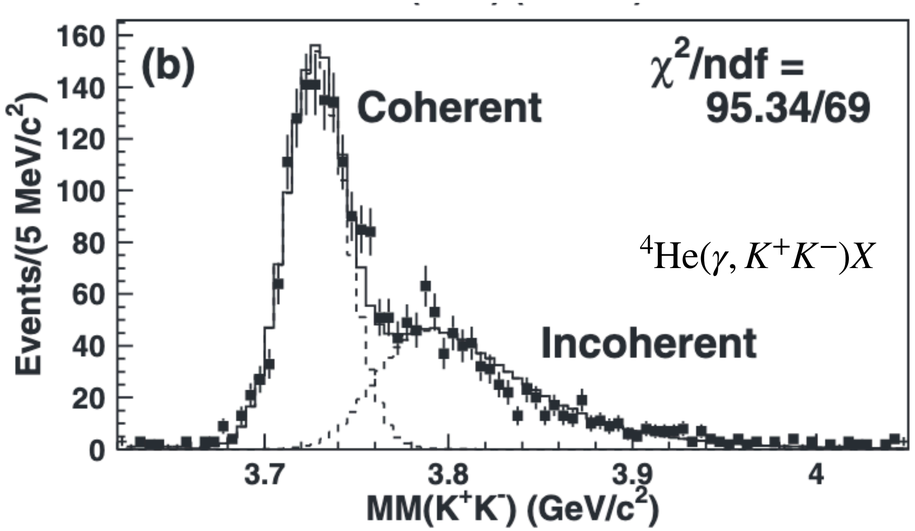


Hiraiwa *et al*. PRC 97, 035208 (2018)

Coherent production

- $\gamma + A \rightarrow V + A$
- Able to access the nuclear GFFs
- Usually mixed with incoherent production
- Recoiling deuterons would have enough energy to be detected



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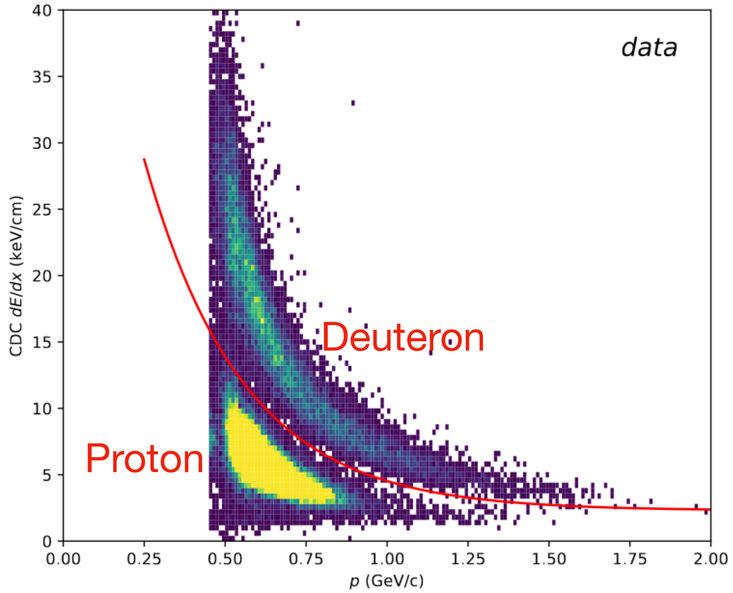

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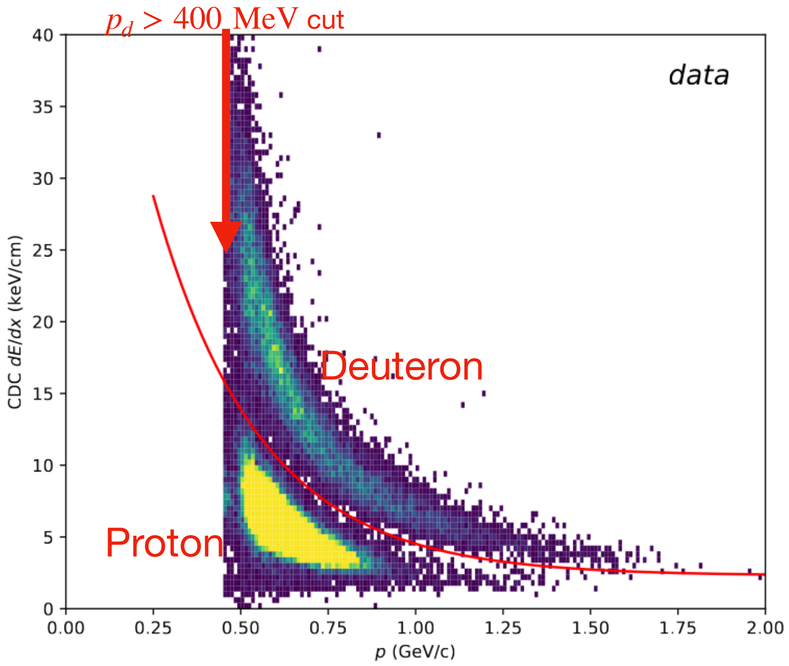

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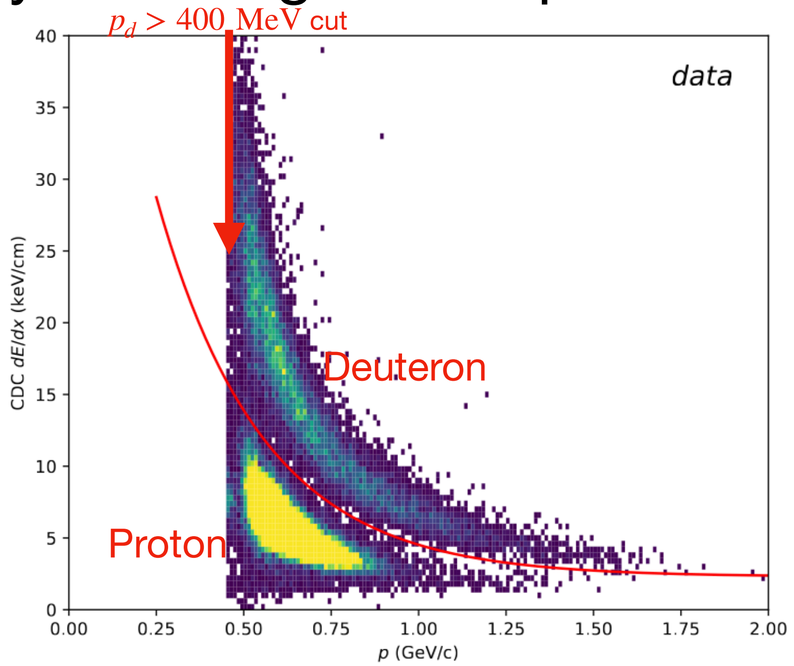
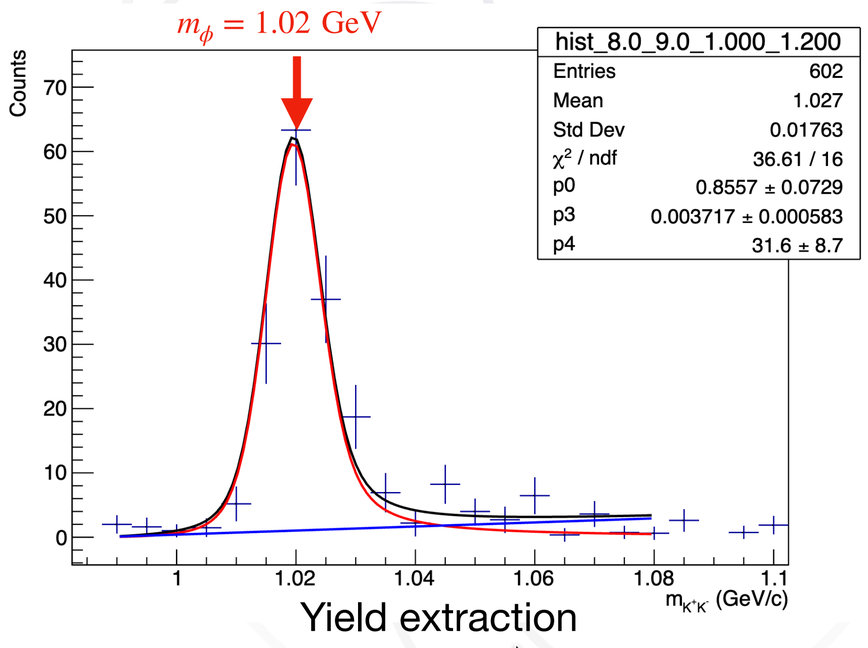
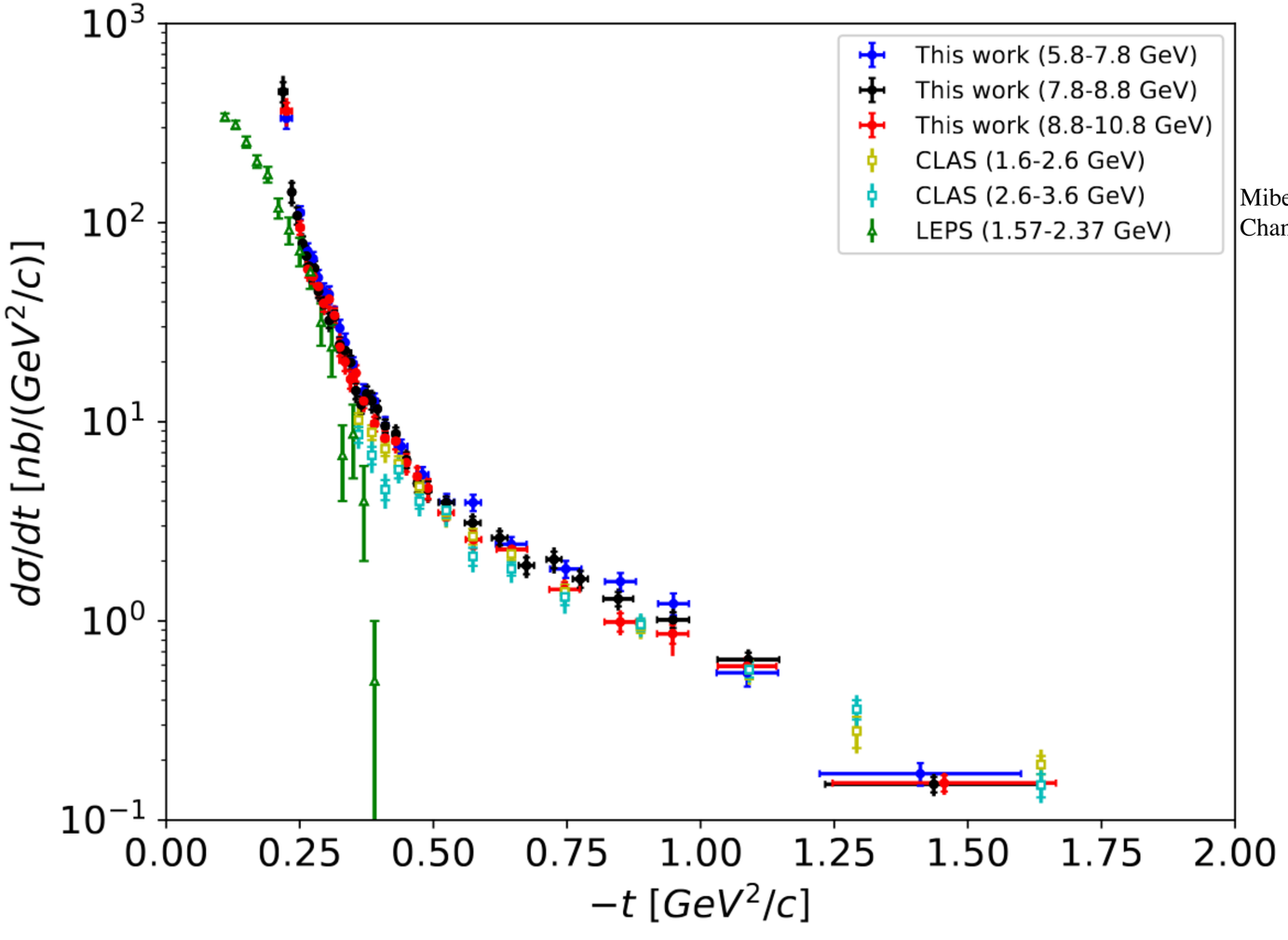
- Very clean signal sample is acquired after event selection





Differential cross sections

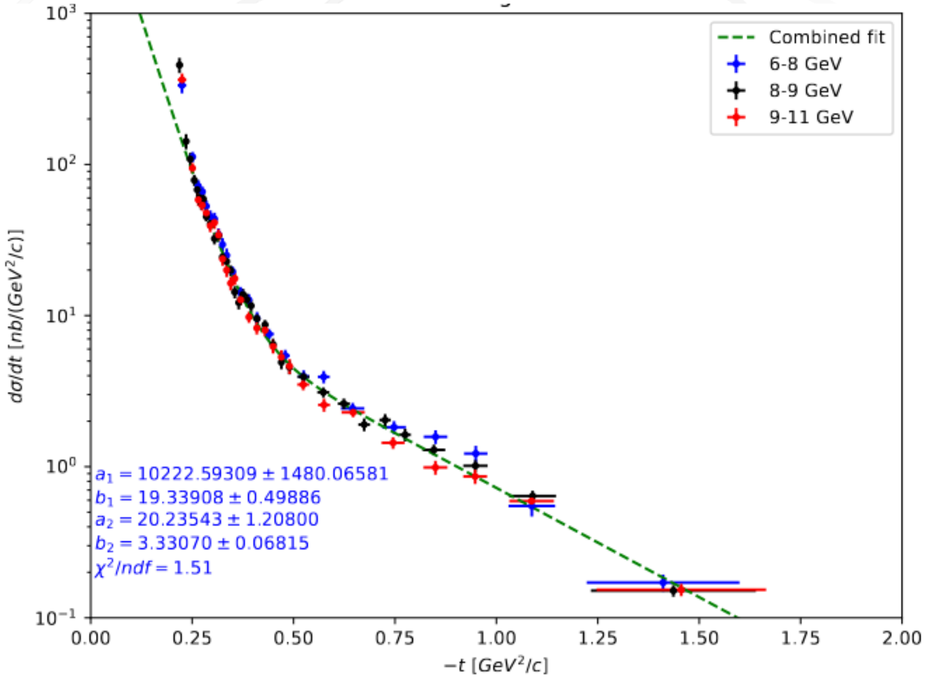
- Compare with previous measurements closer to the threshold



Mibe *et al*. PRC 76, 052202(R) (2007)
Chang *et al*. PLB 658 (2008) 209–215

Deuteron mass radius (exploratory)

- Assume a dipole form of gluon GFF: $G(t) = \dfrac{M}{(1 - t/m_{\mathrm{s}}^2)^2}$
- Deuteron mass radius: $\sqrt{\langle R_{\mathrm{m}}^2 \rangle} = \dfrac{6}{M}\dfrac{dG(t)}{dt}\Big|_{t=0} = \sqrt{\dfrac{12}{m_{\mathrm{s}}^2}}$
- $\dfrac{d\sigma}{dt} \propto G^2(t)$
- $\sqrt{\langle R_{\mathrm{m}}^2 \rangle} = \sqrt{3b} \times 0.197 \text{ fm/GeV}^{-1} = 1.50 \pm 0.19 \text{ fm}$



Fit with double exponential

Kharzeev, PRD 104, 054015 (2021)

Extract $\phi - N$ interaction parameters

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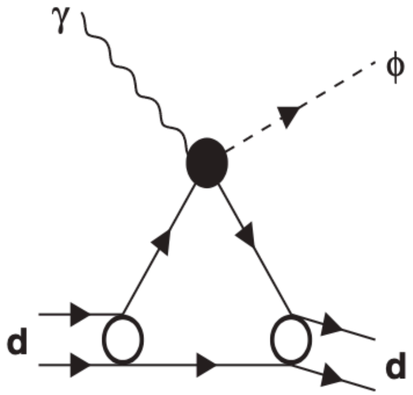
Single scattering

One nucleon receives all the momentum transfer

Dominates at low |t|



Frankfurt *et al.* NPA 622 (1997) 511-537

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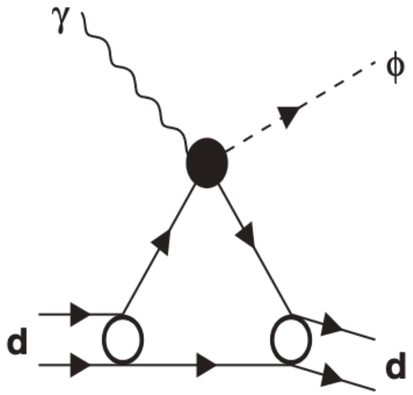

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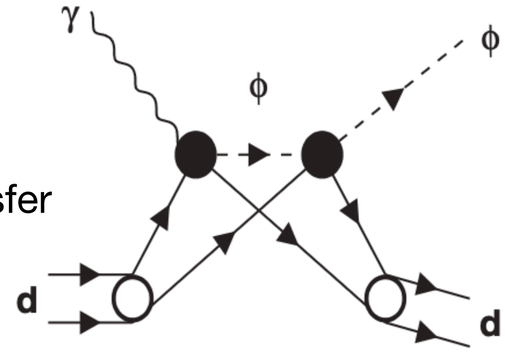

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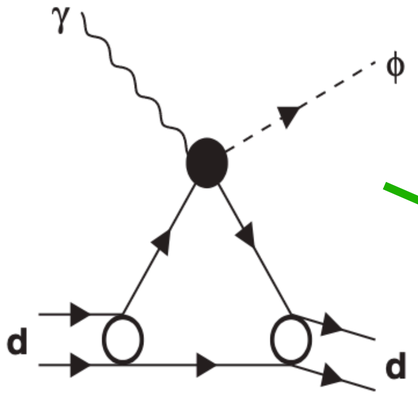

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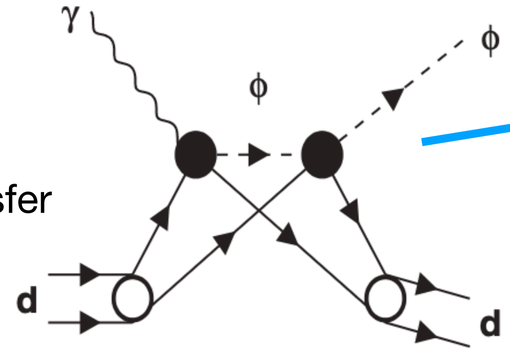

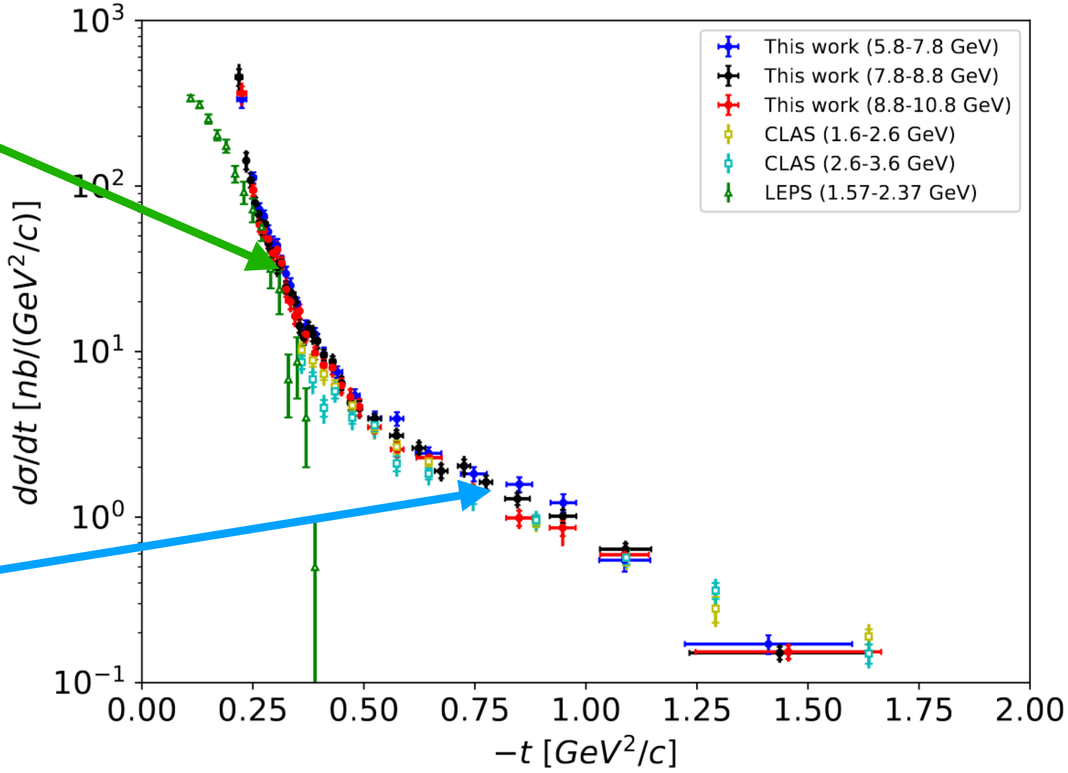

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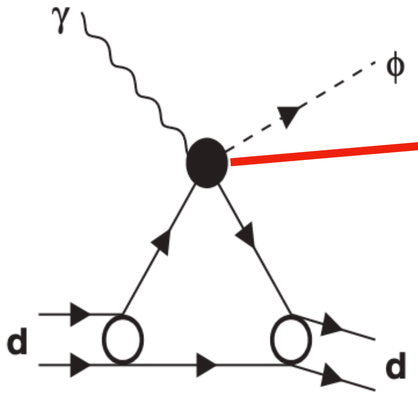

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$$f_{\gamma N} \propto \sigma_{\gamma N}(1 + \alpha_{\gamma N} i)e^{-b_{\gamma N} t}$$

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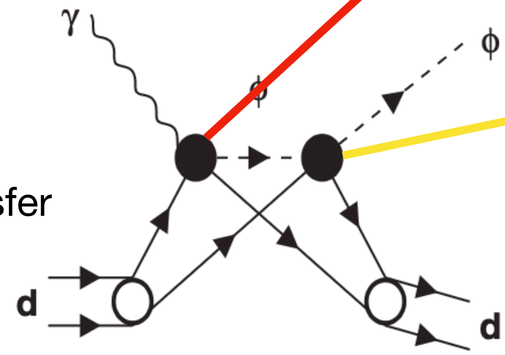

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- χ^2 analysis performed to constrain the values of $b_{\phi N}$ and $\sigma_{\phi N}$
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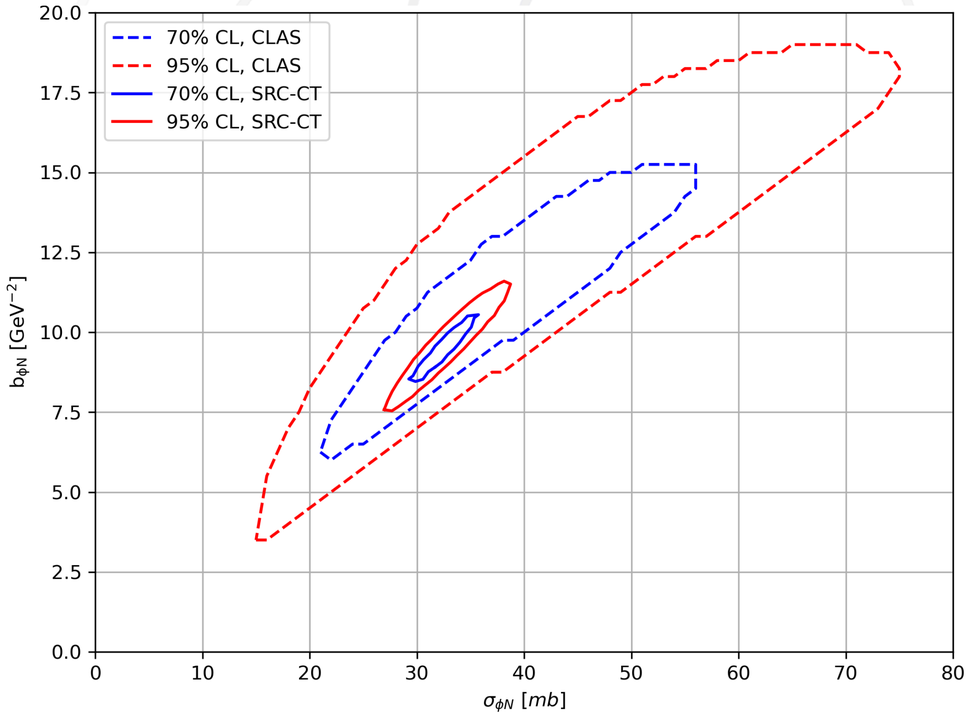
  - Set $\alpha_{\gamma N} = \alpha_{\phi N} = 0$, assuming purely imaginary amplitudes
- Found $\sigma_{\phi N} \approx 30$ mb , $b_{\phi N} \approx 9$ GeV^{-2}
  - Both much larger than free space

    ($\sigma_{\phi N} \approx 10$ mb , $b_{\phi N} \approx 6$ GeV^{-2})
  - Larger ϕ mass radius?



Qian *et al.* PLB 680 (2009) 417–422

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  - High precision measurement of $\phi - N$ cross section
  - Tensor polarized deuterium target
  - Approved with A- rating, 65 PAC days
- Proposal PR12-25-002
  - Threshold J/ψ photoproduction as a probe of nuclear gluon structure
  - Liquid He-4 target
  - Approved with B+ rating, 85 PAC days

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Conclusions

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- The SRC-CT experiment is the pilot experiment of running on nuclear targets with GlueX detector in Hall D
- The dataset offers great opportunities to study a variety of light vector meson photoproduction channels
- Coherent ϕ photoproduction off the deuteron has been measured and provides potential to study the mechanical properties of the deuteron.
- Analysis found $\sigma_{\phi N} \approx 30$ mb , $b_{\phi N} \approx 9$ GeV^{-2}, with significant differences from exclusive photoproduction from free protons
- New experiments with high statistics are approved and would benefit significantly from more theory input

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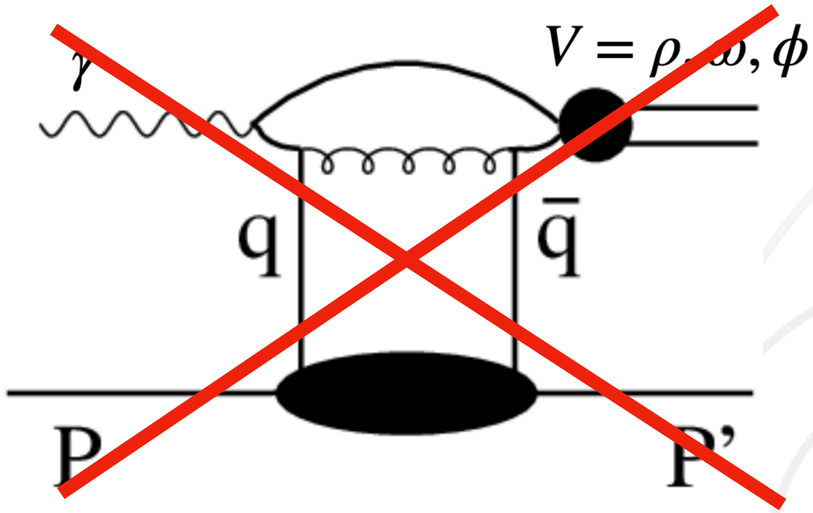
Backups

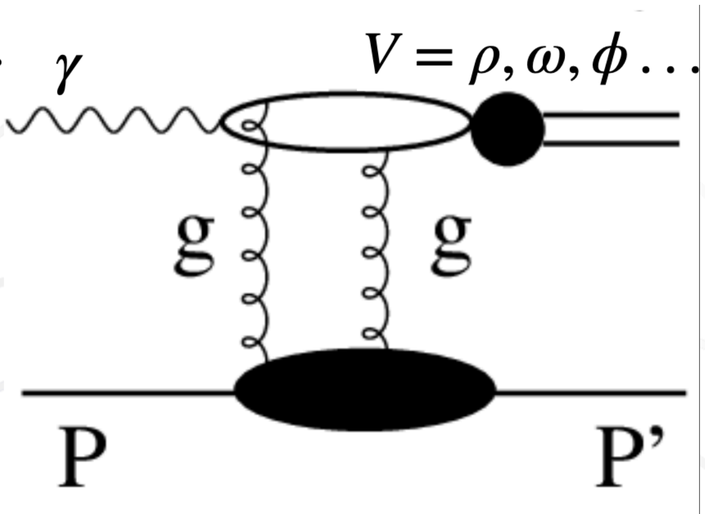
Uniqueness of ϕ meson

- $\phi(1020) \approx s\bar{s}$
- Unique to study gluon exchange at low energies!
- $\sigma_{\phi N}$ provides essential information for QCD inspired models



Quark exchange

Suppressed in $\phi - N$ interaction due to no common valence quark

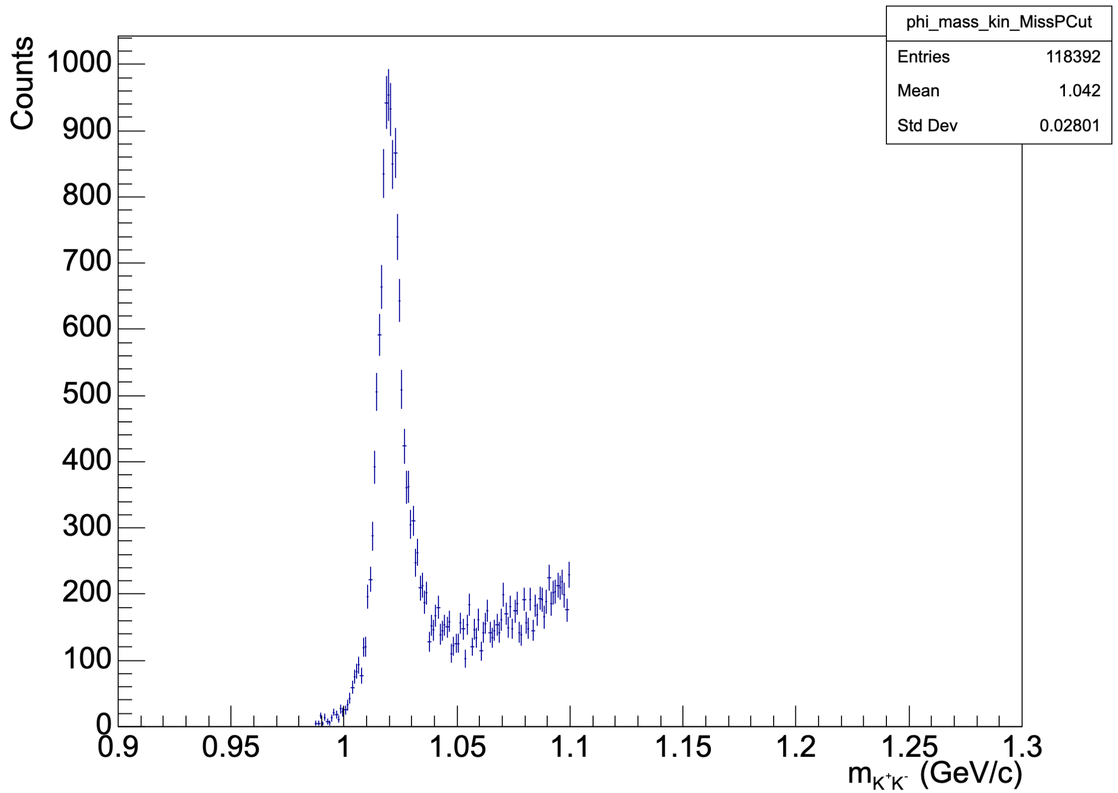


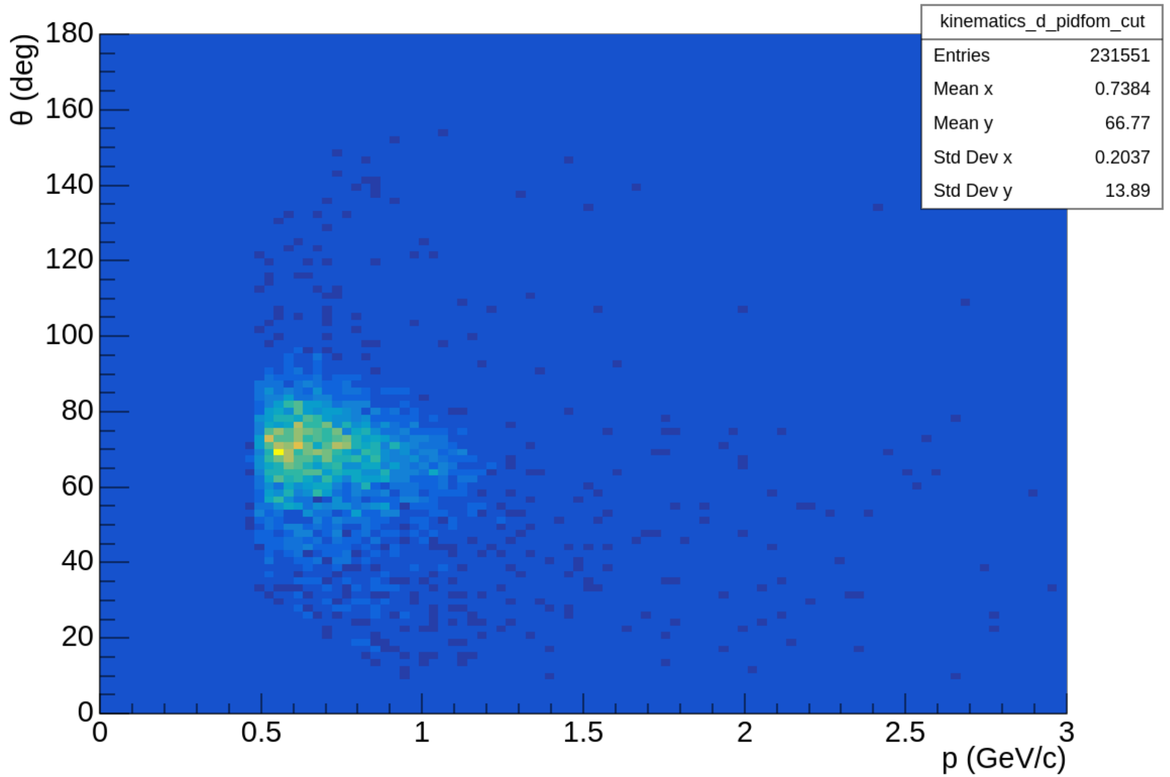
Gluon exchange

Dominant in $\phi - N$ interaction universal in hadron interactions

Outlook

- Deuteron knockout from helium and carbon target
- $\gamma A \rightarrow \phi dX$





Latest development

- D-wave of the deuteron can be isolated with tensor polarization
- Important tool to study SRC and CT
- Coherent ρ photoproduction offers the easiest measurement opportunity