# Measurement of the high-energy contribution to the Gerasimov-Drell-Hearn sum

A. Deur

05/16/2019

Work done with J. Stevens (W&M) and S. Sirca (Ljubljana Univ.)

Draft document available at https://userweb.jlab.org/~deurpam/GDH_HD_proposal.pdf
Will be shortened into more concise LOI.

# The Gerasimov-Drell-Hearn sum rule

Spin-dependent photoproduction cross-sections

$$\int_{\nu_{thr}}^{\infty}\left(\sigma^{3/2}-\sigma^{1/2}\right)\frac{d\nu}{\nu} = \frac{4\alpha S\pi^2\kappa^2}{M^2}$$

anomalous magnetic moment

Photon energy

Mass

spin

- Fundamental Quantum Field Theory prediction. Applicable to any type of target.

- Conditions for the sum rule to be valid:
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- Polarized cross-section unknown at large $\nu$. Expected to be described by Regge theory.

- Straightforward experiment.

- With its tagger, large solid angle detector and high flux, Hall D is the natural place to do the experiment.

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  - Possible violation mechanisms:
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- Need to be past the resonance bumps to perform Regge-based fit to:
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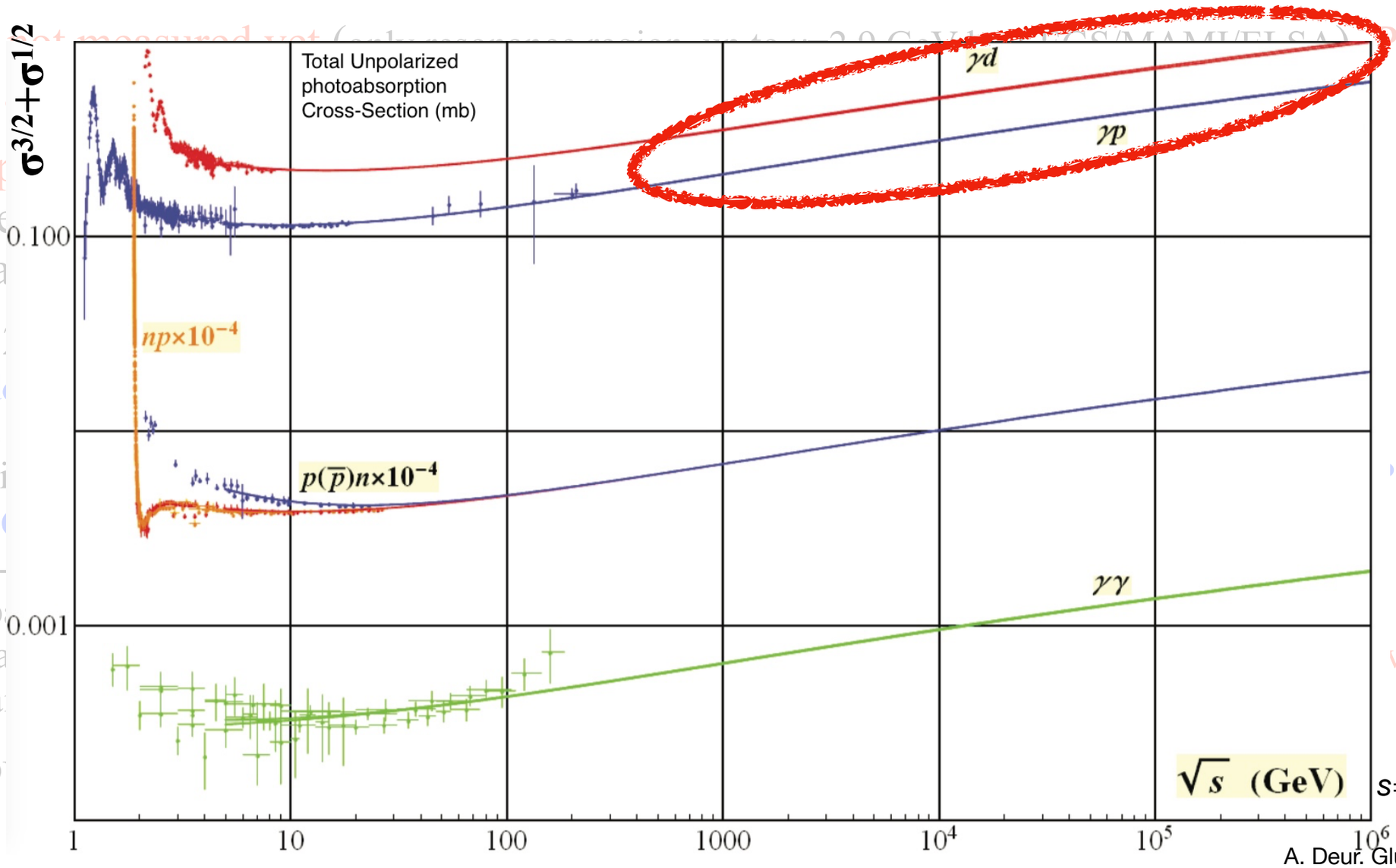


$s=M^2+2M\nu$

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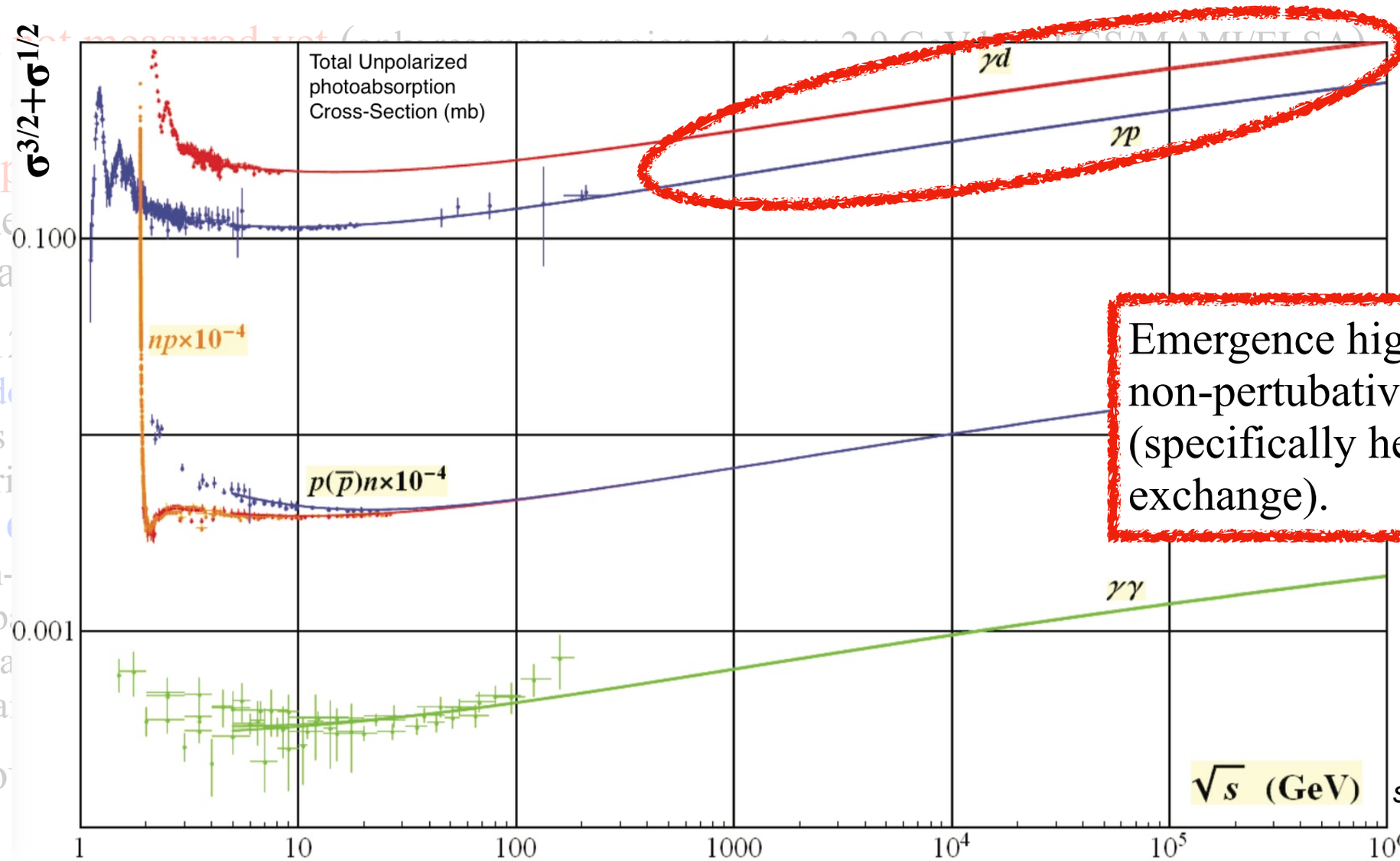


Emergence high-energy non-pertubative reactions (specifically here: pomeron exchange).

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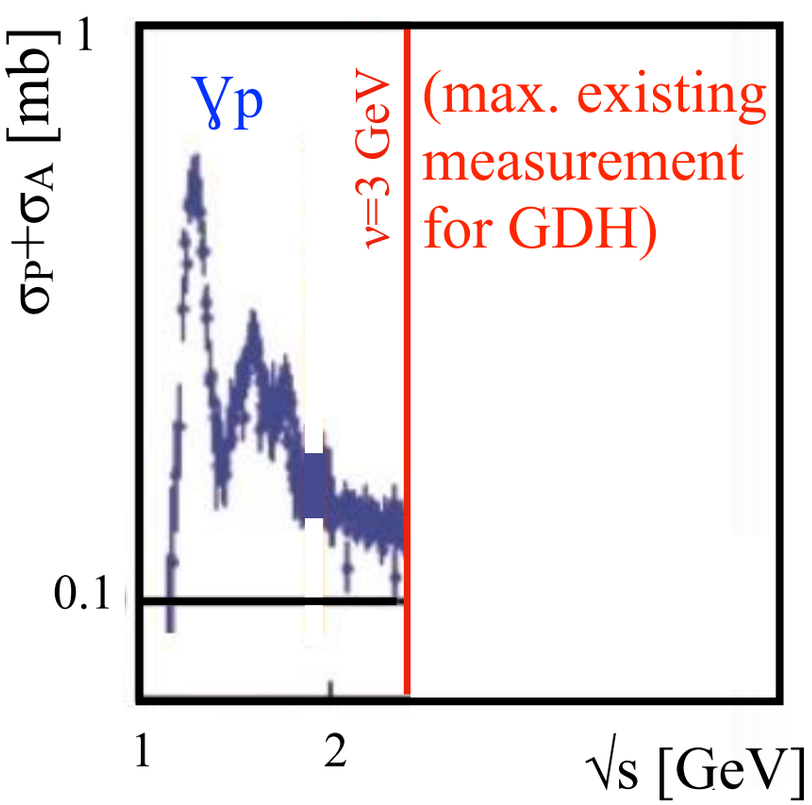


Convergence of integral not in jeopardy. No sign of pomeron

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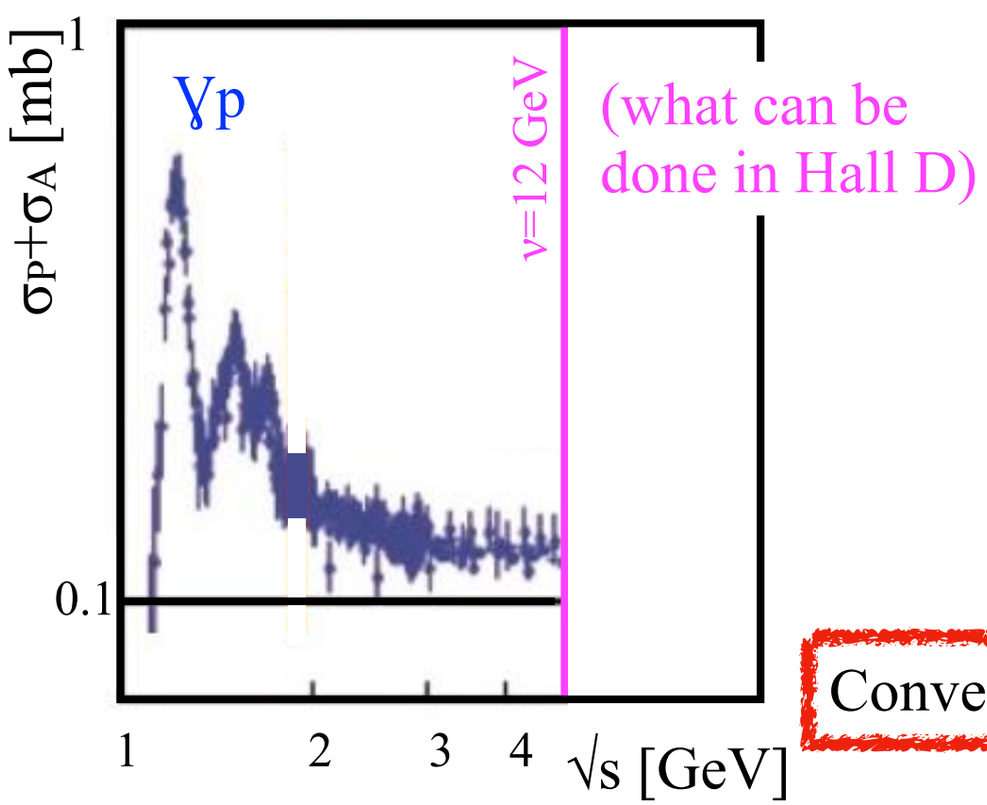


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$$\int_{\nu_{thr}}^{\infty}(\sigma^{3/2}-\sigma^{1/2})\frac{d\nu}{\nu}=\frac{2\alpha\pi^2\kappa^2}{M^2}$$

- Need to measure both proton and neutron (deuteron) for isospin separation. Regge theory: isoscalar and isovector contributions to $(\sigma^{3/2}-\sigma^{1/2})$ come from different meson families ($f_1(1285)$ and $a_1(1260)$ respectively).

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- Measure yield difference $\Delta y(\nu) = N^{3/2} - N^{1/2}$. Cross section difference $(\sigma^{3/2}-\sigma^{1/2})$ not imperative.
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  For ex. if $\sigma^{3/2}-\sigma^{1/2} = a\nu^b$, primary goal is to get $b$, without need to extract an accurate $a$.
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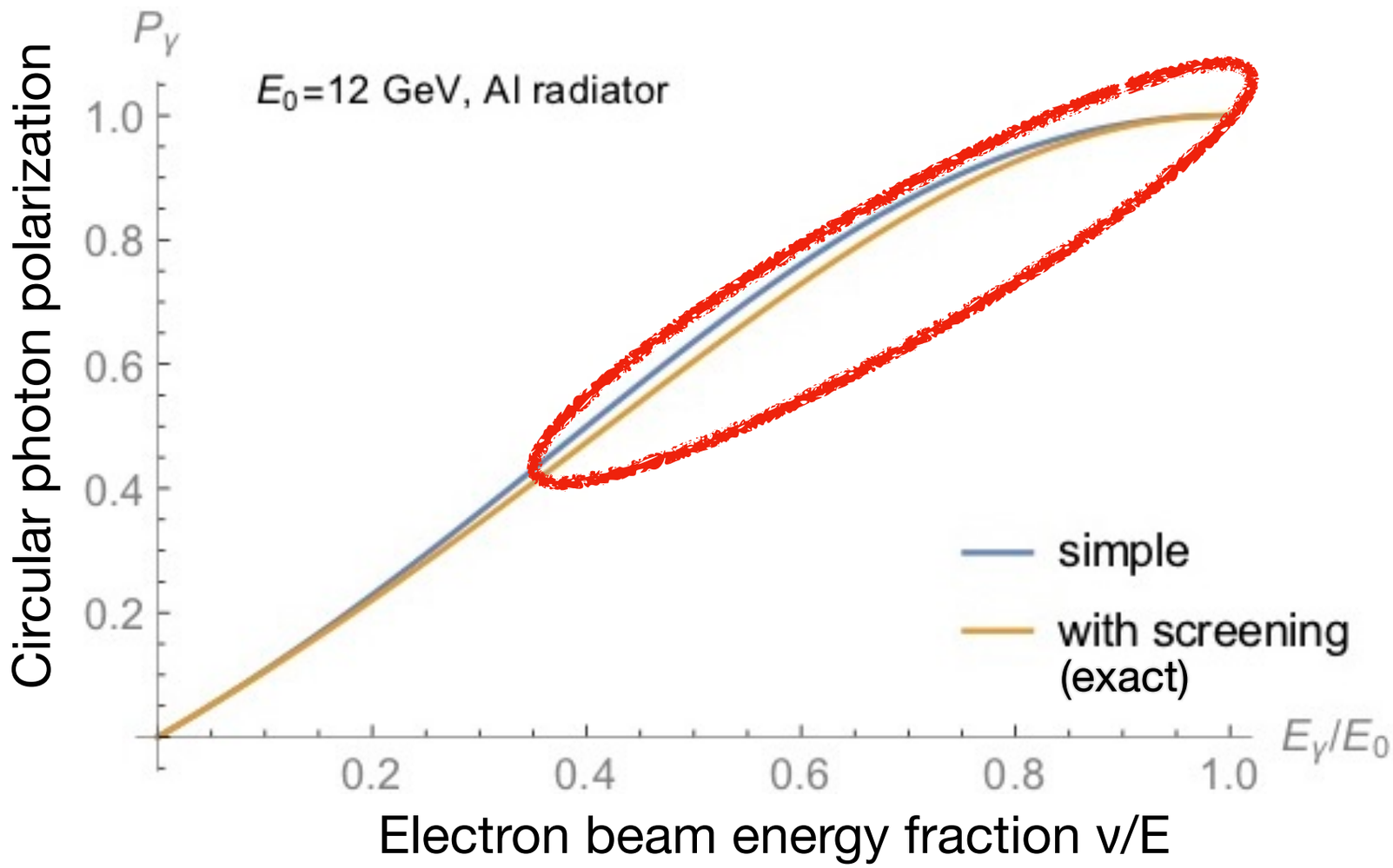


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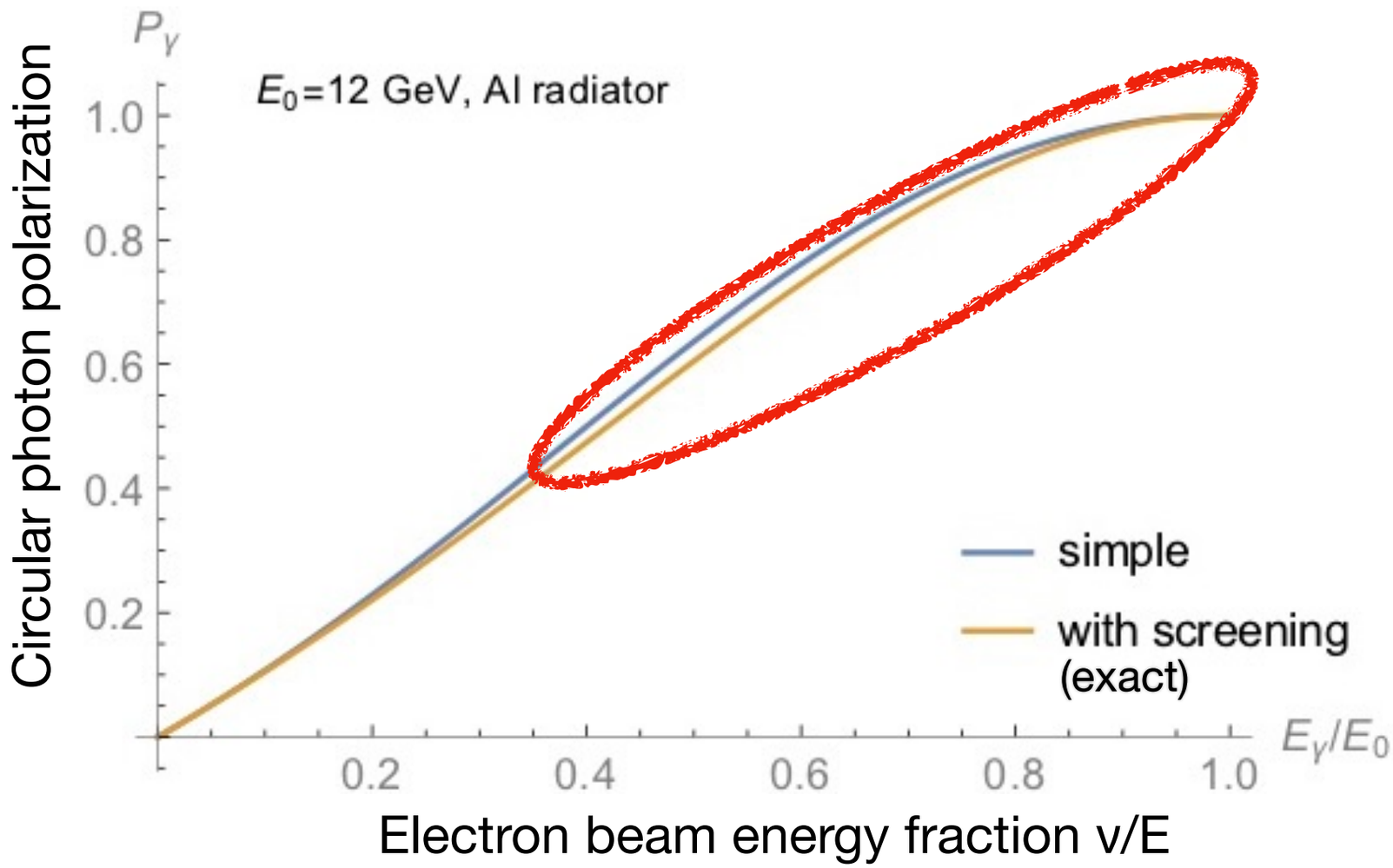


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- Running one short experiment: not enough to invest in HDice.
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  $\Rightarrow$ use FROST

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- Two months to install the target. No commissioning needed.

FROST characteristics:

- Dynamical Nuclear Polarization on Butanol ($C_4H_9OH$ or $C_4D_9OD$)
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- Only longitudinal polarization needed. Anti-parallel polarization possible. Useful for GDH but not required.
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# Expectations

- 1 week of running on proton: Minimum time, given two months investment to install the target.
  ⇒ 10 days on deuteron so that neutron uncertainty is similar to proton's one.
- For expectations, assume Regge theory:

$$\sigma^{3/2}-\sigma^{1/2} = c_2 s^{\alpha_{f_1}-1} \pm c_1 s^{\alpha_{a_1}-1}$$

proton

neutron

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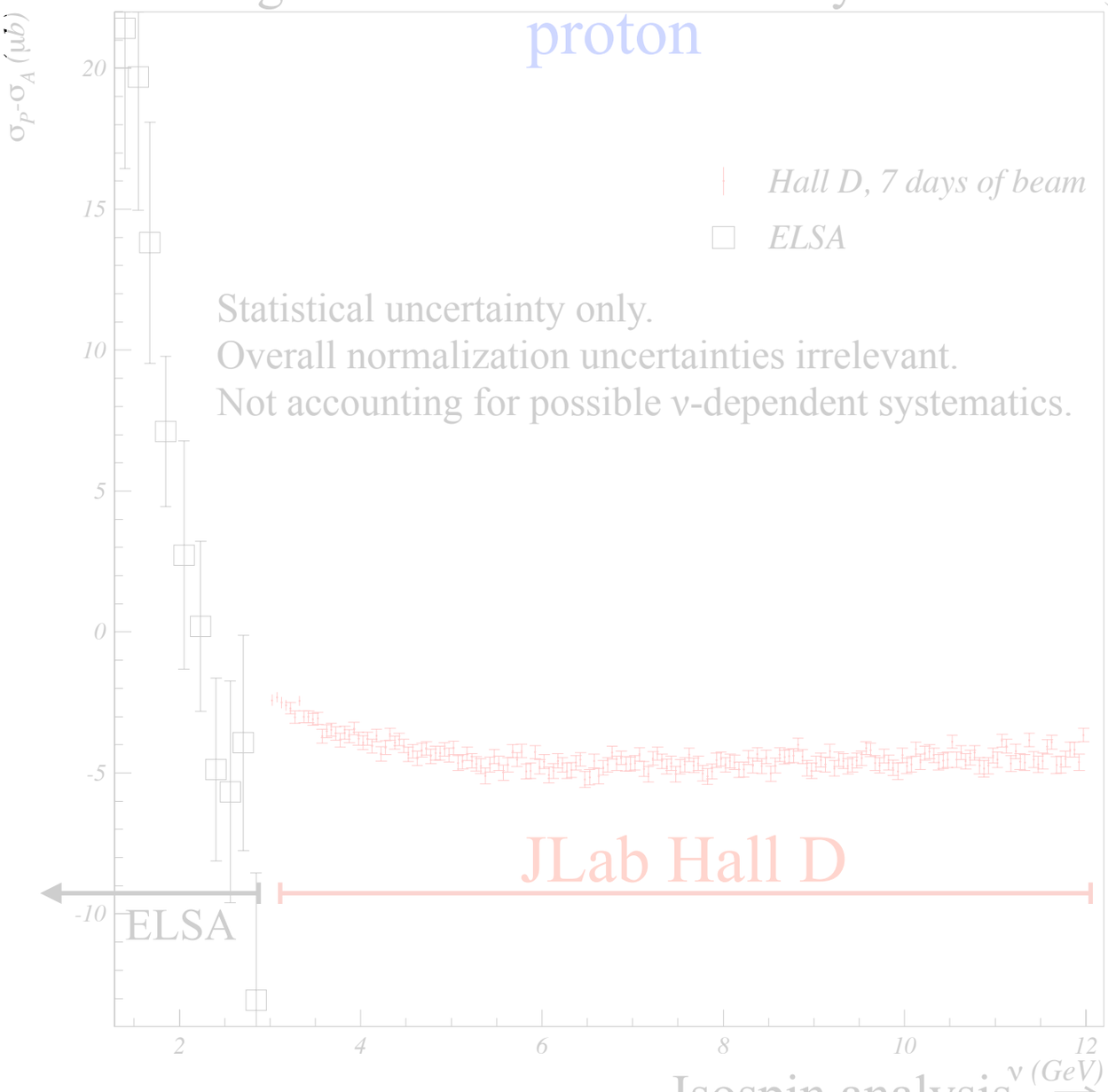


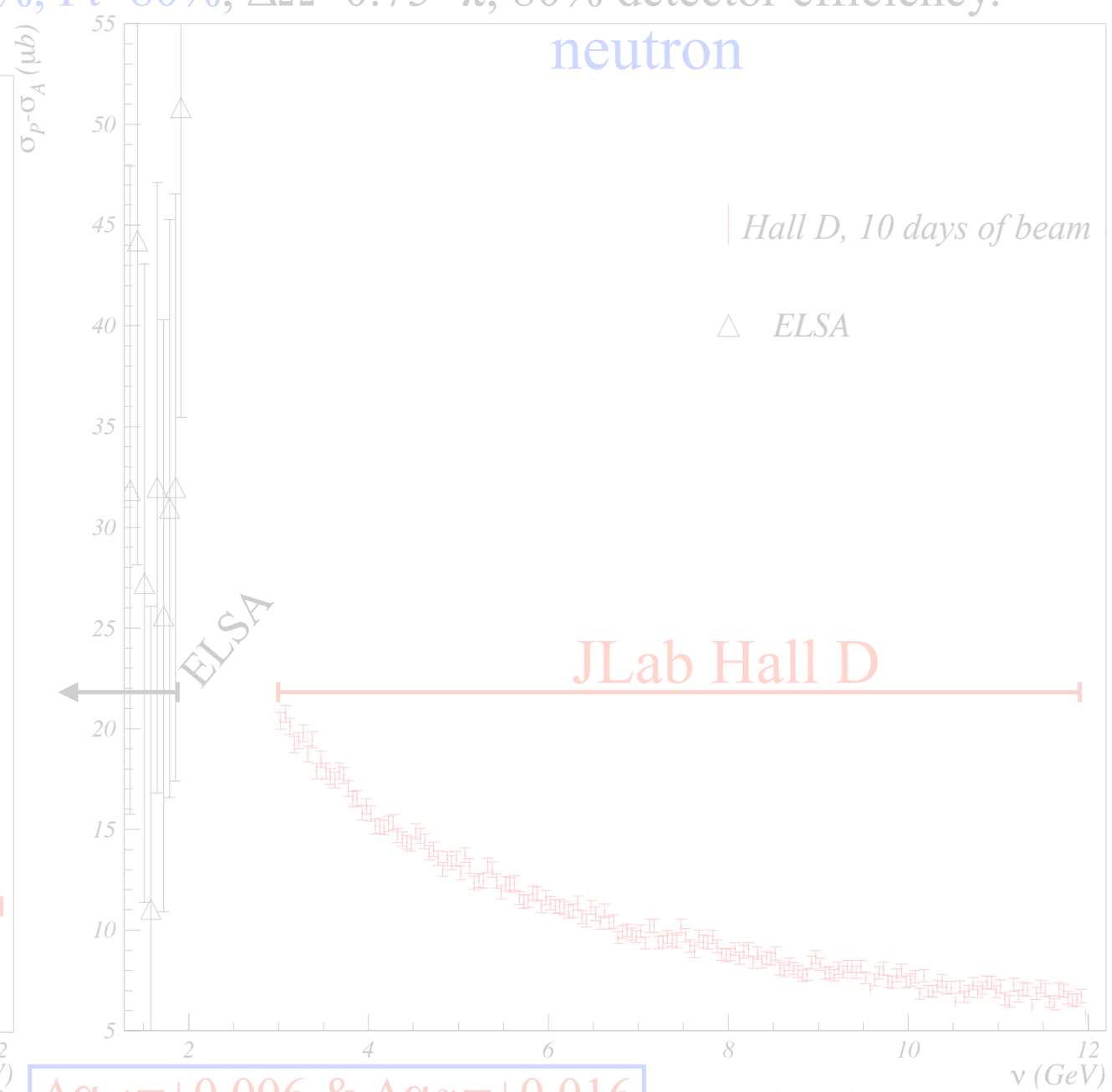


Isospin analysis ⇒ $\Delta\alpha_{a1}=\pm0.006$ & $\Delta\alpha_{f1}=\pm0.016$

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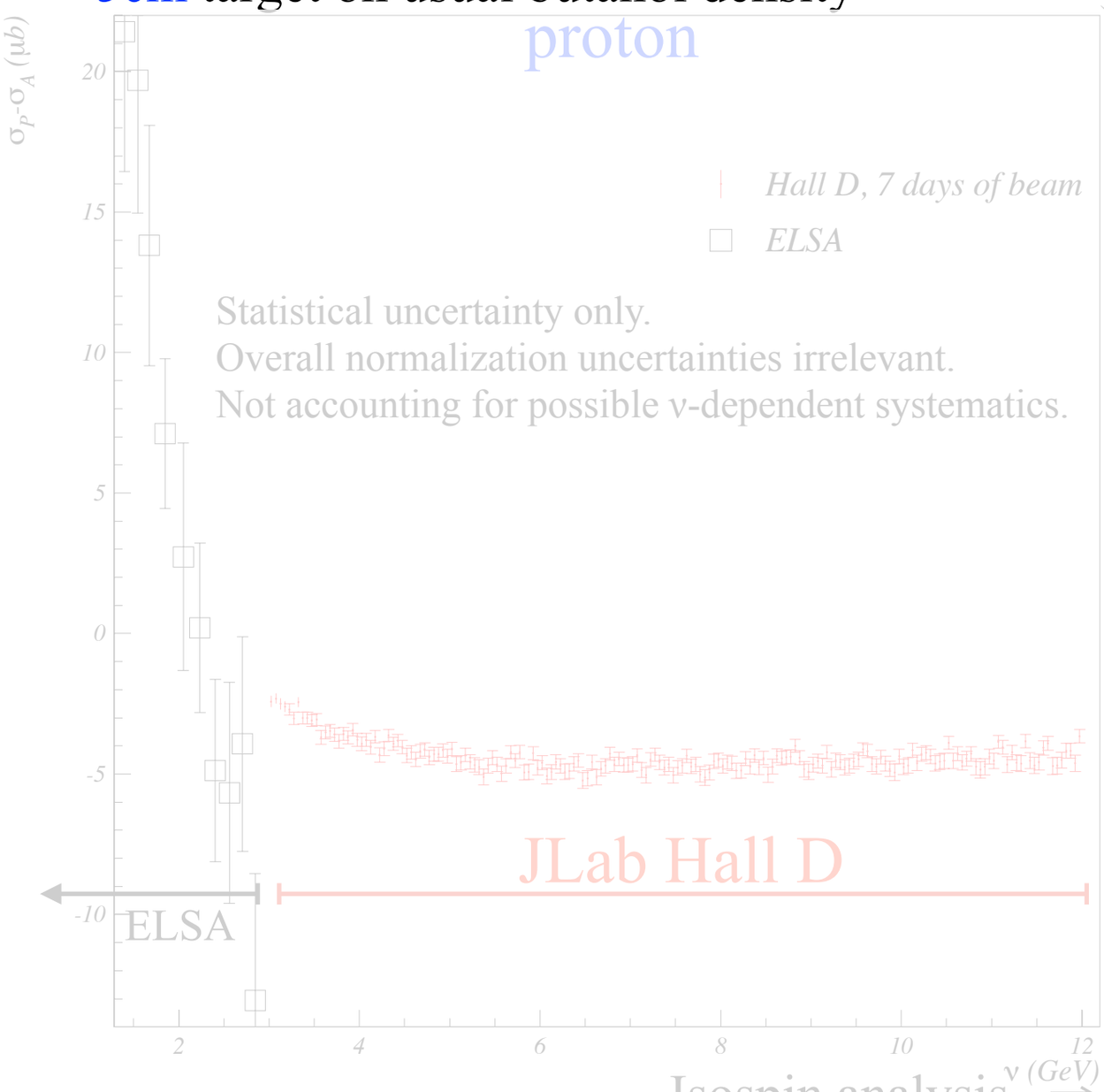


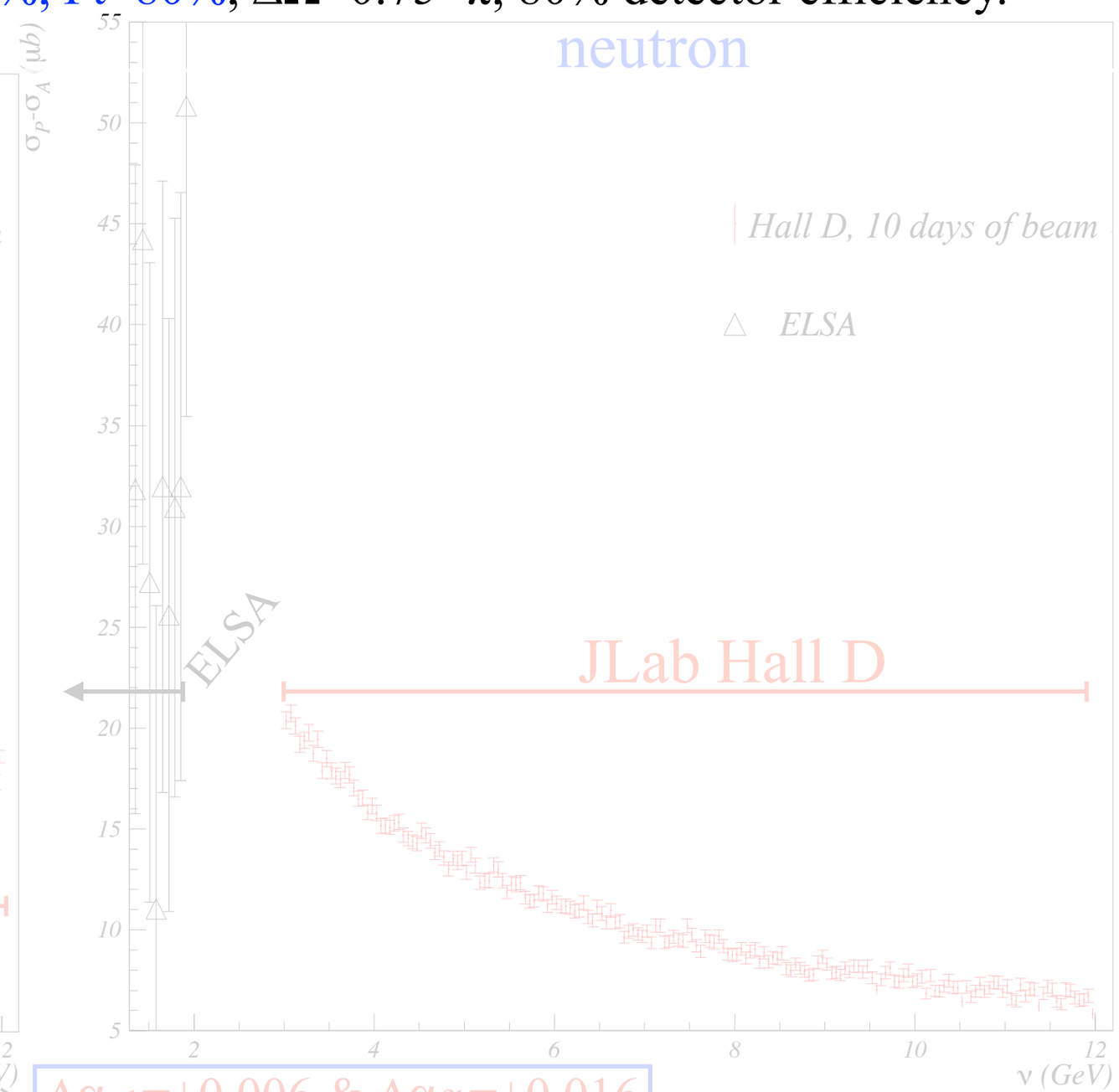


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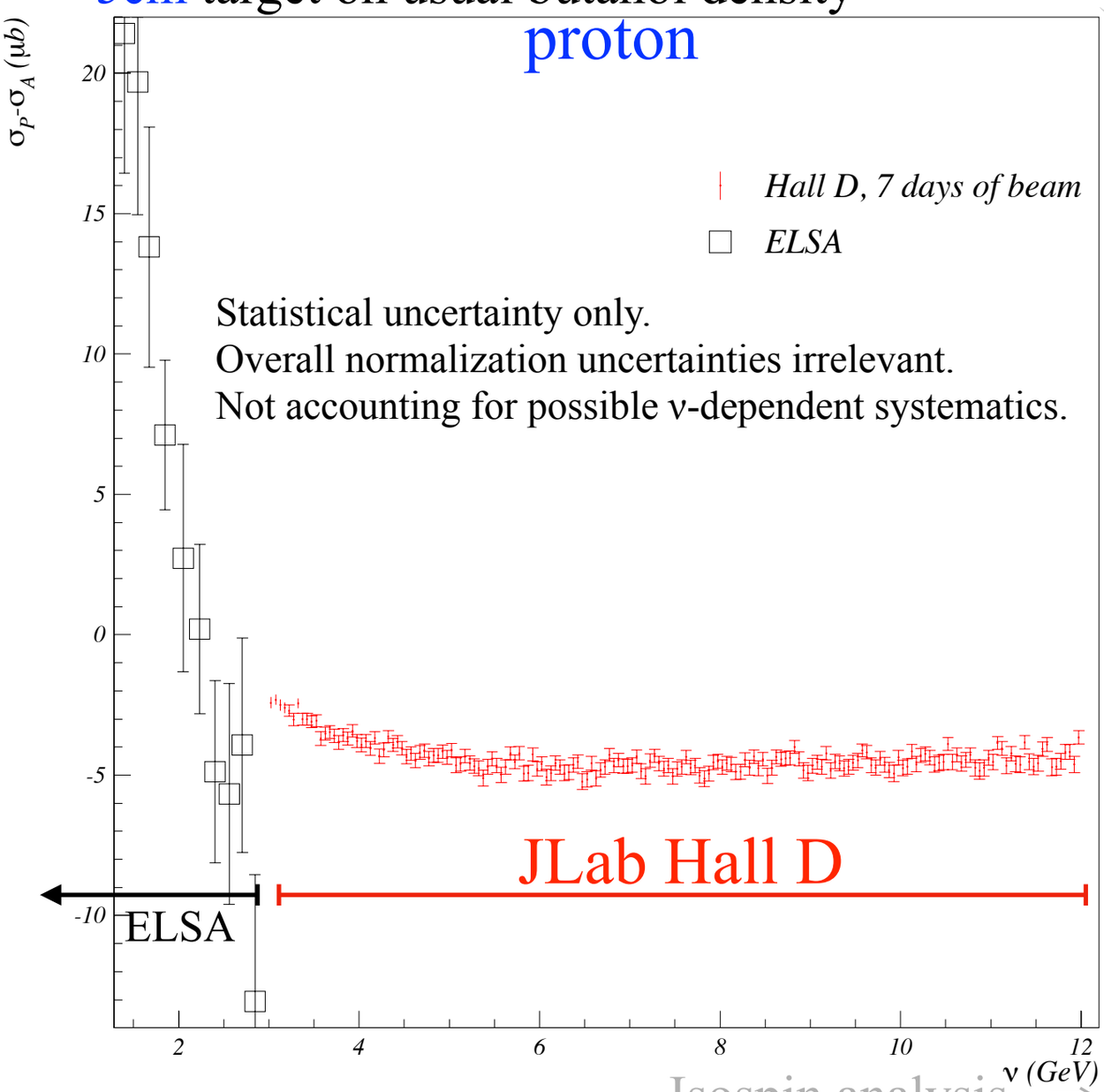


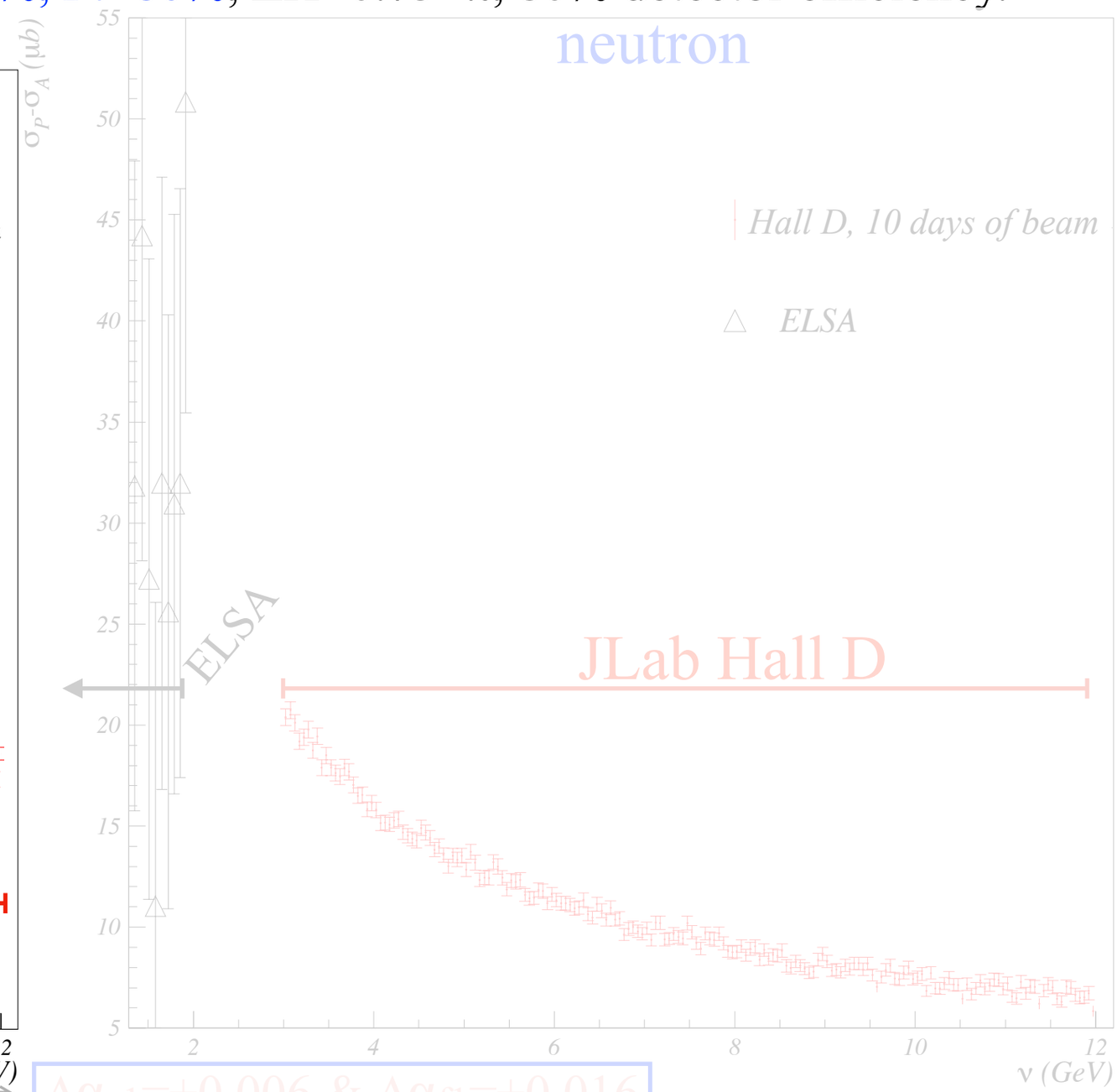


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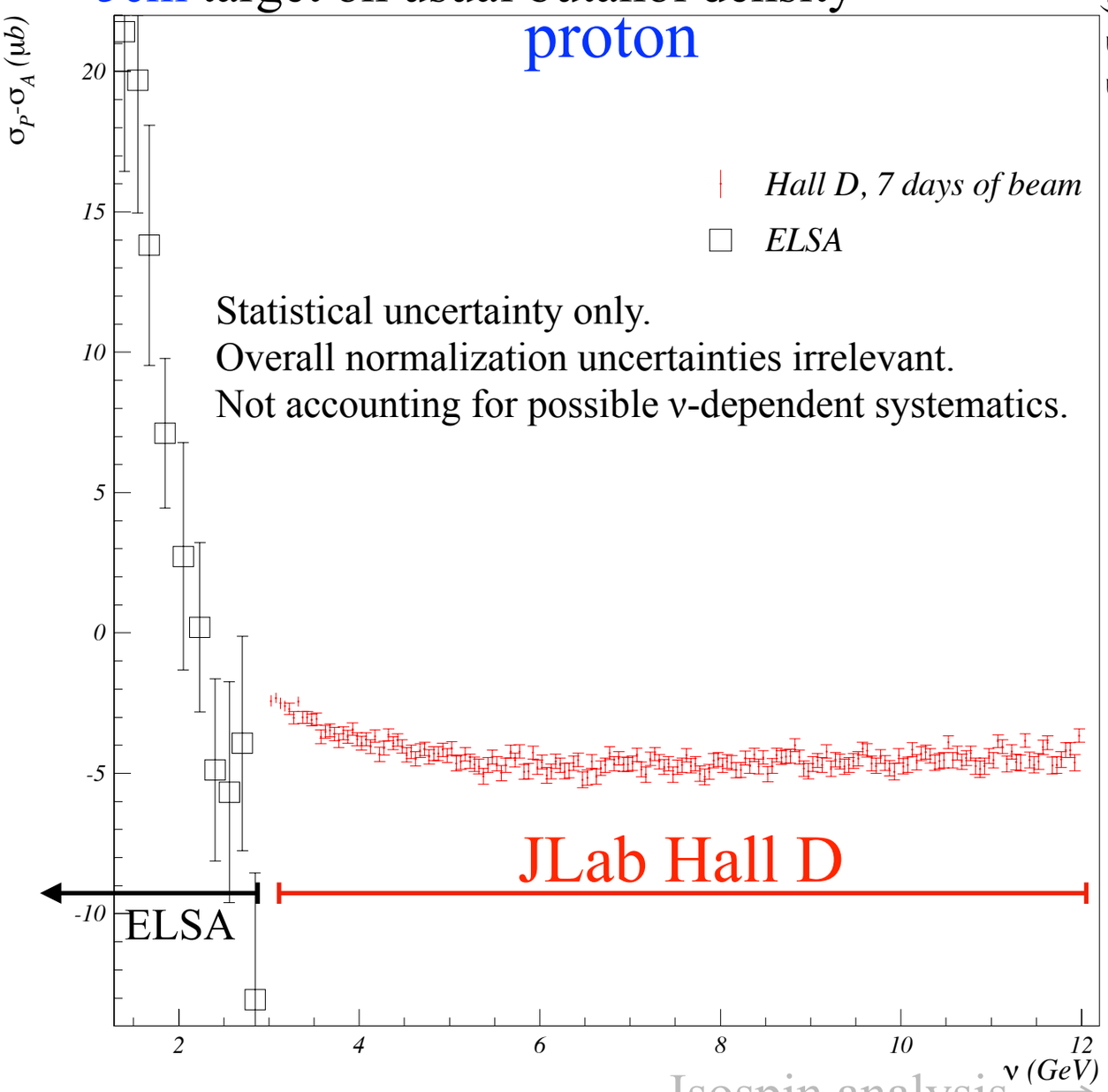


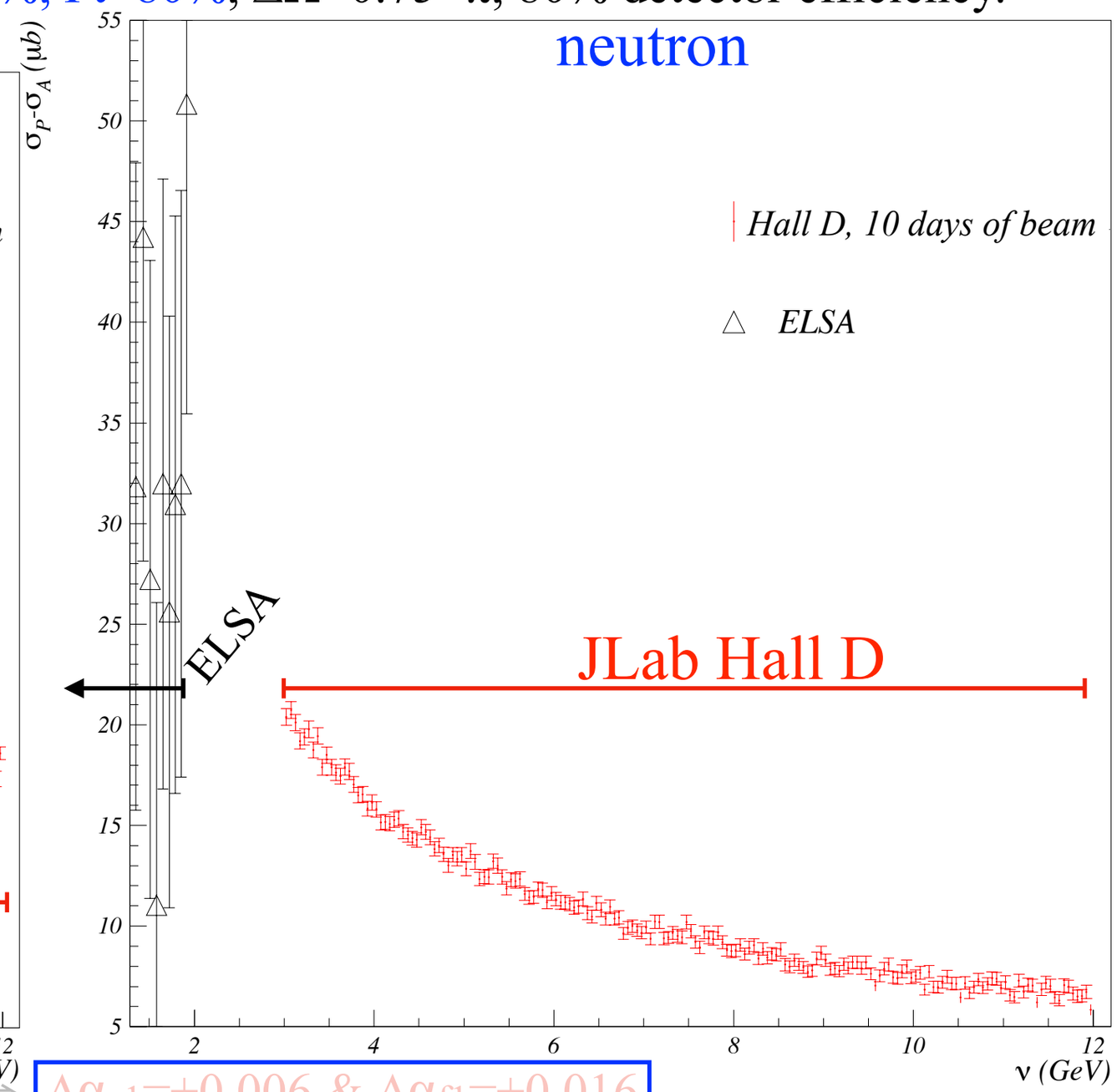


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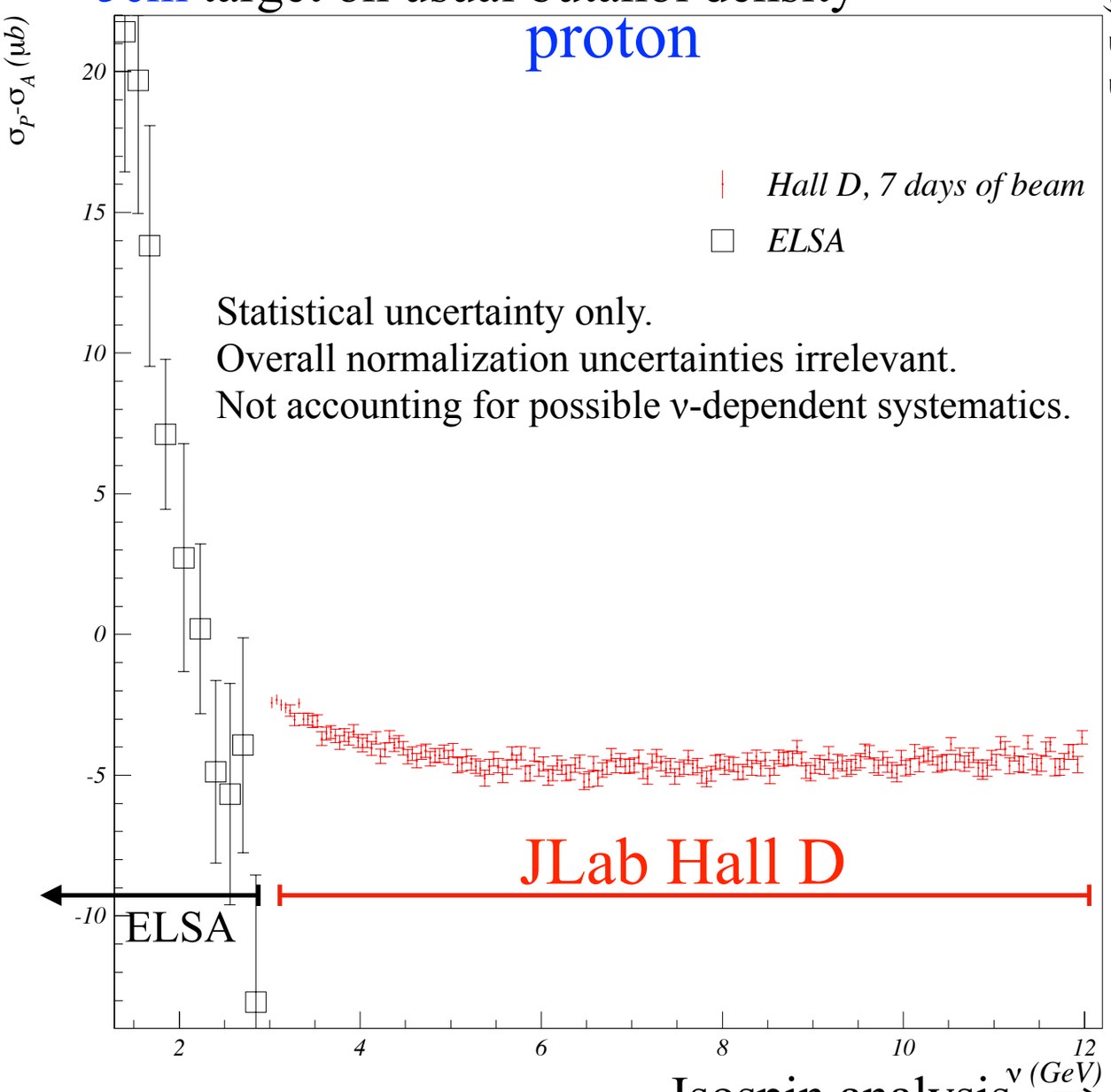


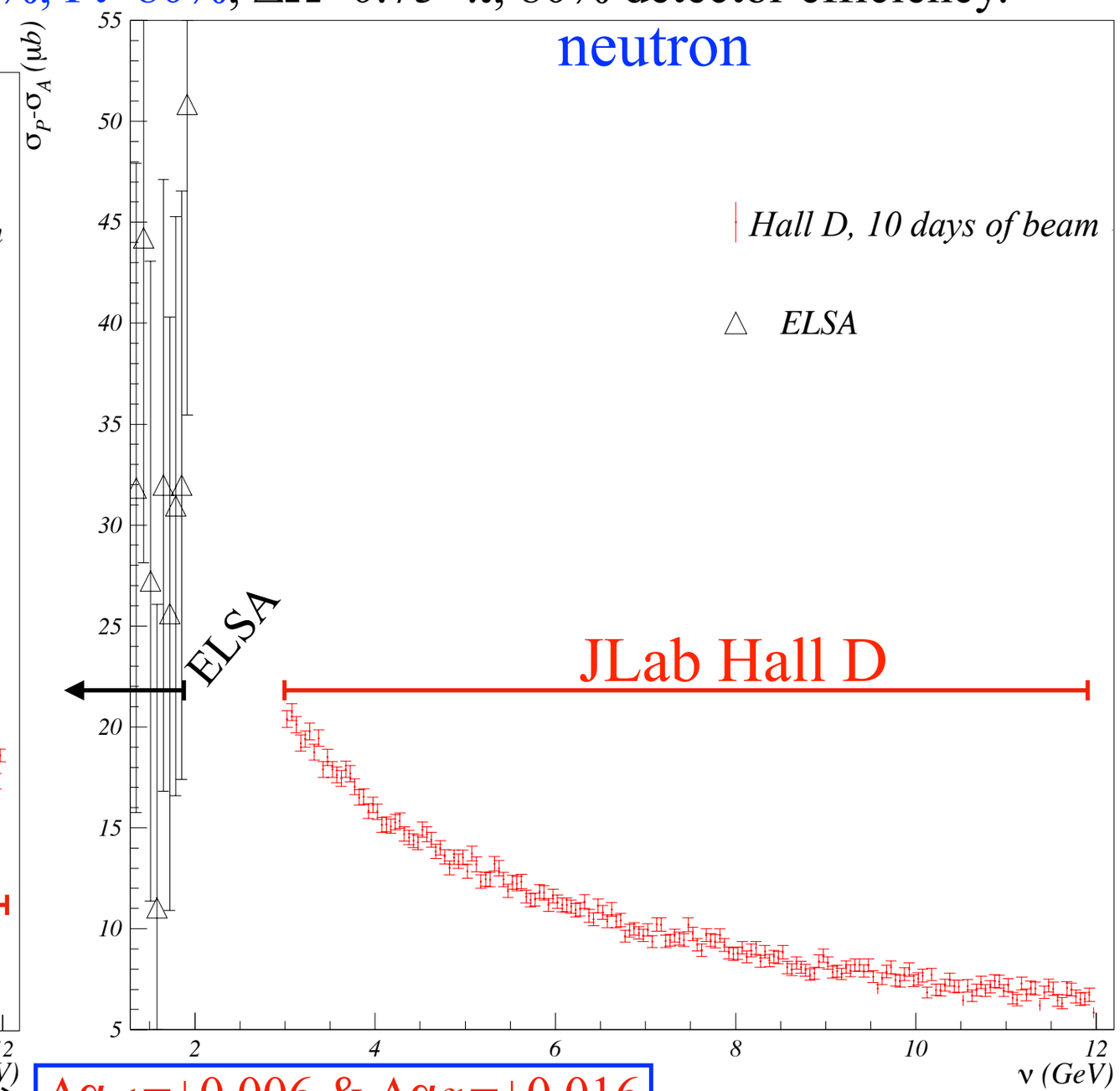


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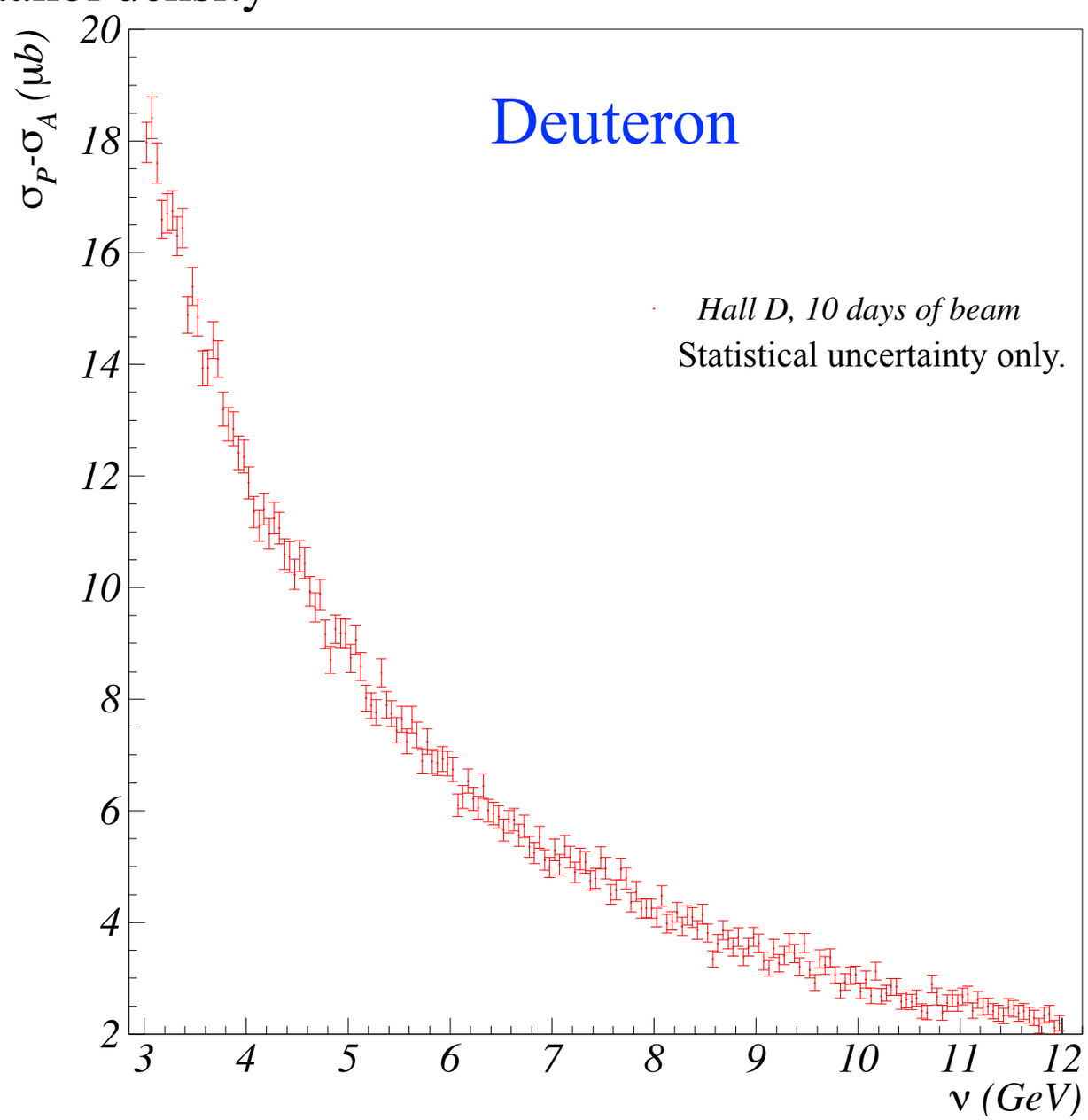


Should measure well the first non-zero deuteron signal in diffractive domain.

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$$\int_{\nu_{thr}}^{\infty}(\sigma^{3/2}-\sigma^{1/2})\frac{d\nu}{\nu}=\frac{2\alpha\pi^2\kappa^2}{M^2}$$

- Measuring ν-behavior (e.g. of $\alpha_{f1}$ and $\alpha_{a1}$ in case ($N^{3/2} - N^{1/2}$) follows Regge theory) will test the convergence of GDH sum (primary goal)

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- If Regge theory works: $\Delta\alpha_{a1} = \pm 0.006$ & $\Delta\alpha_{f1} = \pm 0.016$. Compare to $\Delta\alpha_{a1} = \pm 0.23$ & $\Delta\alpha_{f1} = \pm 0.22$ from ELSA.

This will enable a reliable assessment of the contribution up to $\nu \rightarrow \infty$.

- First measurement of non-zero polarized signal for deuteron in diffractive region.

- Assuming:
  - Beam polarimetry: $\Delta Pb=4\%$
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  - Target dilution 3%
  - Unpolarized cross-section normalization: 1%

Will improve accuracy of GDH Sum Rule determination by 25%

Will allow the extraction of the real and imaginary parts of Compton amplitude $f_2$.

Will improve calculation of hyperfine splitting in Hydrogen by constraining DIS spin structure function $g_1$ for $Q^2=0$. Impact for proton radius puzzle.

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This will enab

Precise enough to resolve the discrepancy between DIS data and Regge theory.

Regge theory predicts $\alpha_{a1} \cong -0.34$, while

Several DIS fits yield $\alpha_{a1} \cong +0.45$.

- First measure

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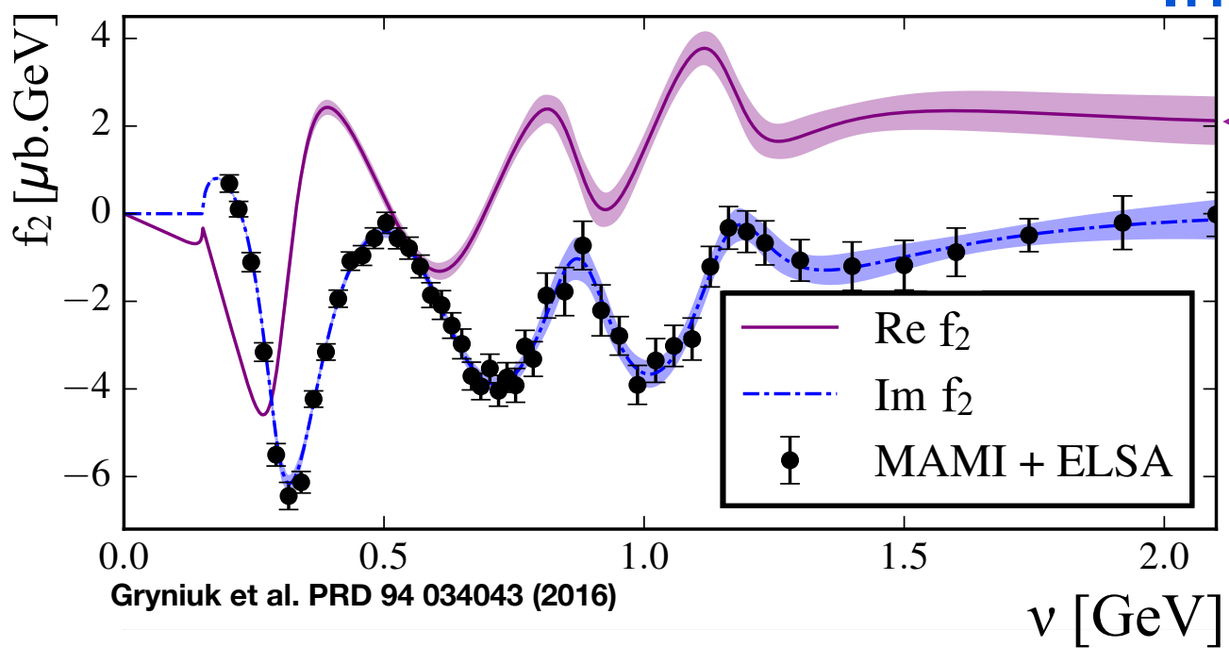


Gryniuk et al. PRD 94 034043 (2016)

Dispersive analysis from Im($f_2$) data. Large ν data will constrain both Re($f_2$) and Im($f_2$) error bands.

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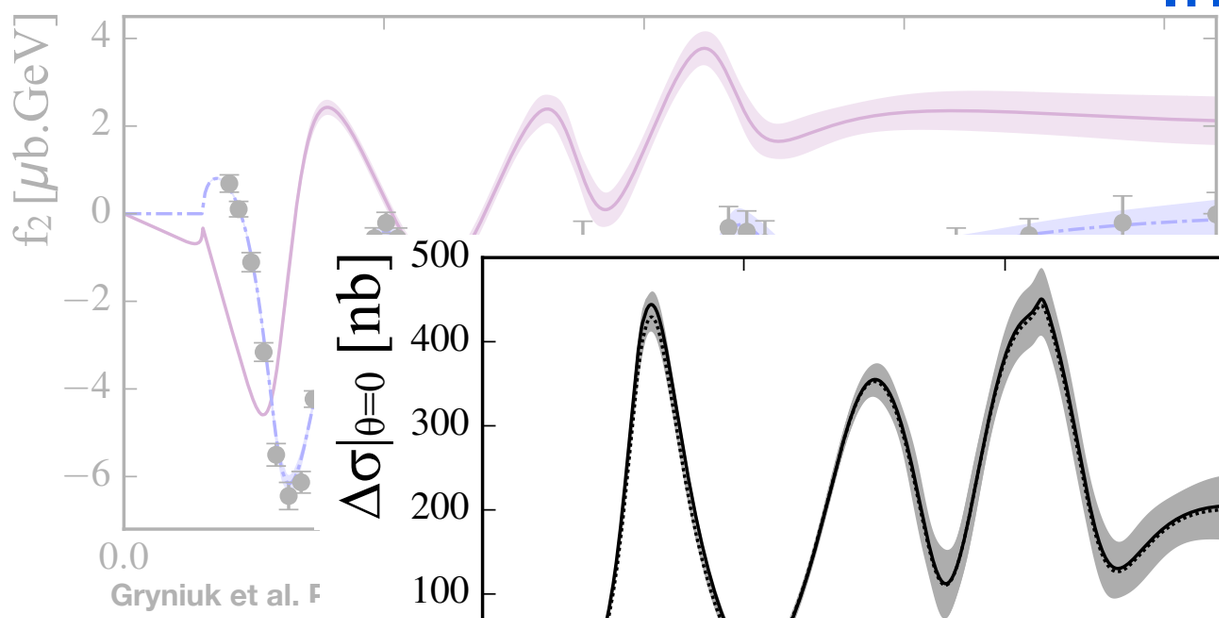
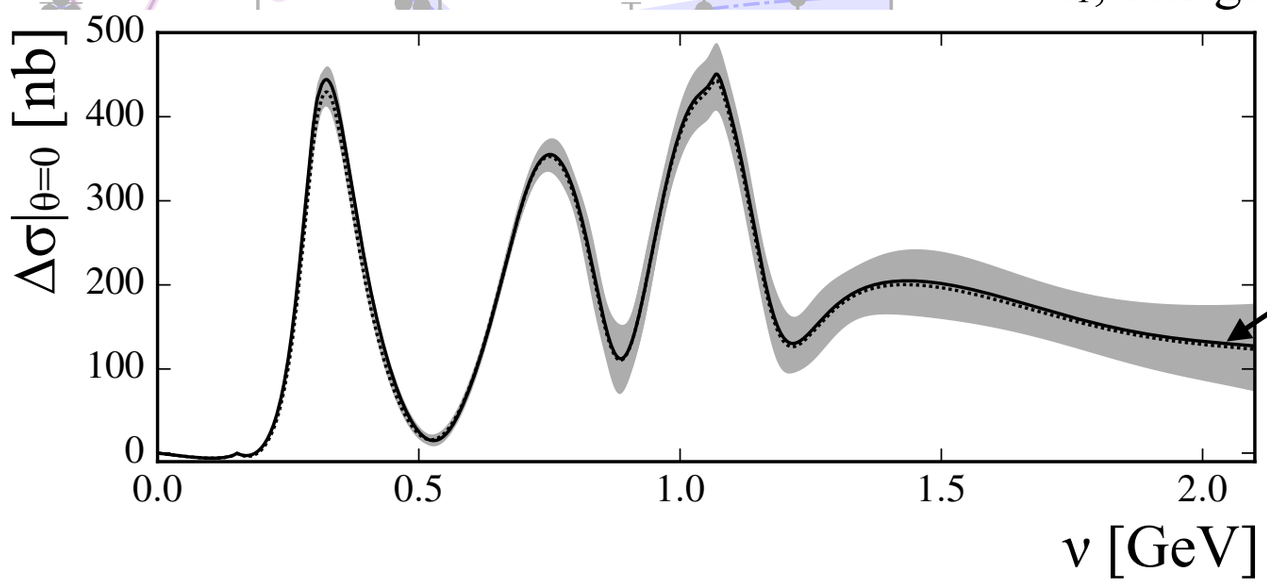



From $Re(f_2)$ and $Im(f_2)$ and the well measured unpolarized $f_1$, one gets $\sigma^{3/2}-\sigma^{1/2} \stackrel{def}{=} \Delta\sigma$ in the forward limit.

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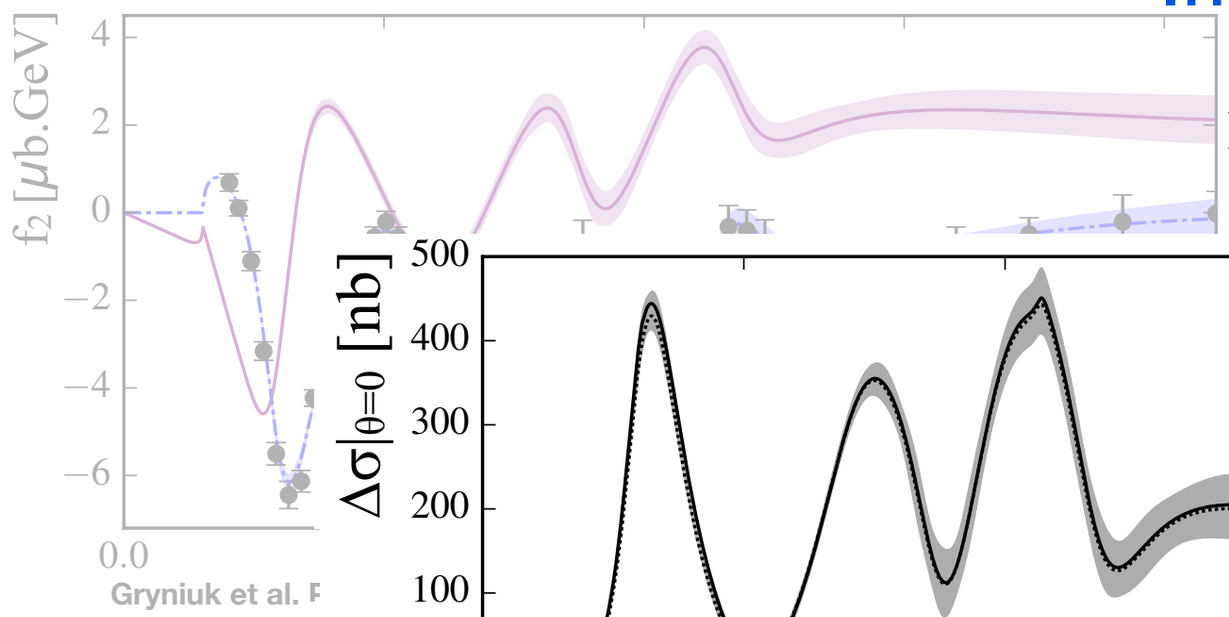


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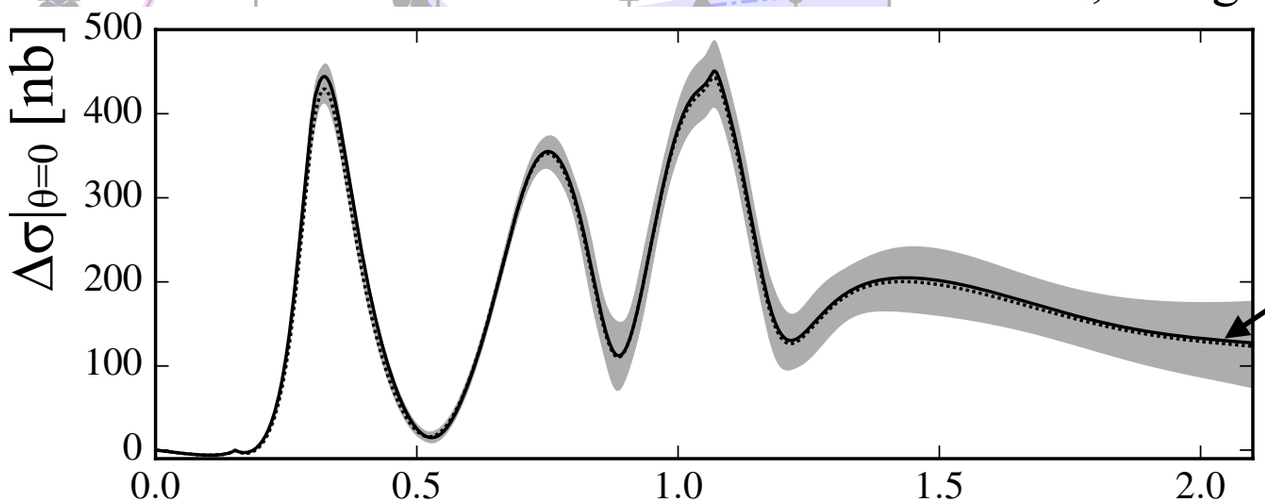


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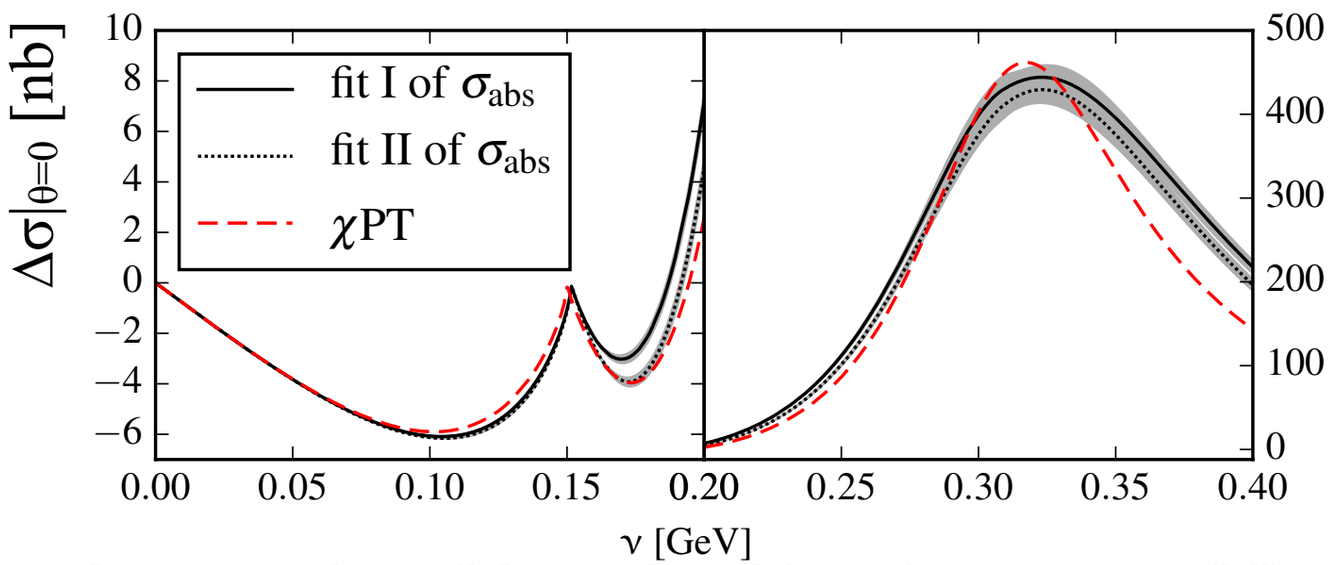


Chiral Perturbation Theory (χpT) calculation available.

$\Delta\sigma|_{\theta=0}$ very sensitive to chiral loops.

$\Longrightarrow$ Test of χpT at $Q^2=0$.

Complement JLab program GDH at low $Q^2$ that tested and challenged χpT in the polarized sector.

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