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

A. Deur

02/20/2019

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

Draft LOI available at https://userweb.jlab.org/~deurpam/GDH_HD_proposal.pdf
Please let me know if you want to join.

The Gerasimov-Drell-Hearn sum rule

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

Spin-dependent photoproduction cross-sections

Photon energy

Mass

spin

anomalous magnetic moment

- Fundamental Quantum Field Theory prediction. Applicable to any type of target.
- Conditions for the sum rule to be valid:
  - Spin-dependent forward Compton amplitude $f_2(\nu)$ must vanish at large ν (no-subtraction hypothesis).
  - Imaginary part of f_2, $(\sigma^{3/2}-\sigma^{1/2})$ must decrease with ν faster than $\sim 1/\ln(\nu)$ (for the integral to converge).
- Unpolarized version of GDH sum rule, $\int(\sigma^{3/2}+\sigma^{1/2})d\nu$, does not converge.
- Integral gets its major contribution for $\nu<3$ GeV (measured at LEGS/MAMI/ELSA), but if the sum rule fails, it would happen at high energy. $\nu>3$ GeV not measured yet (SLAC E159 was supposed to do it).
- Polarized cross-section unknown at large ν. 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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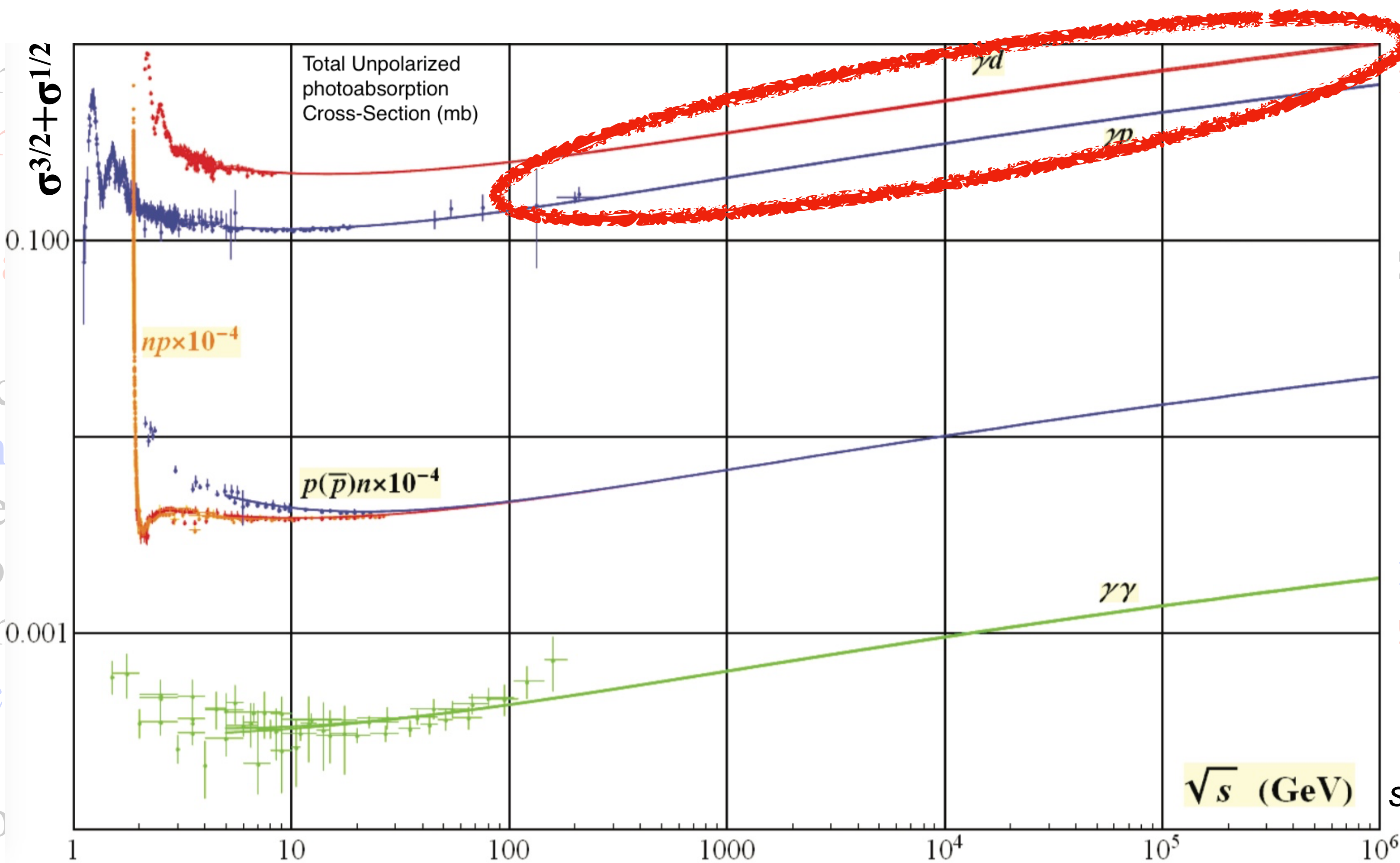

$s=M^2+2M\nu$

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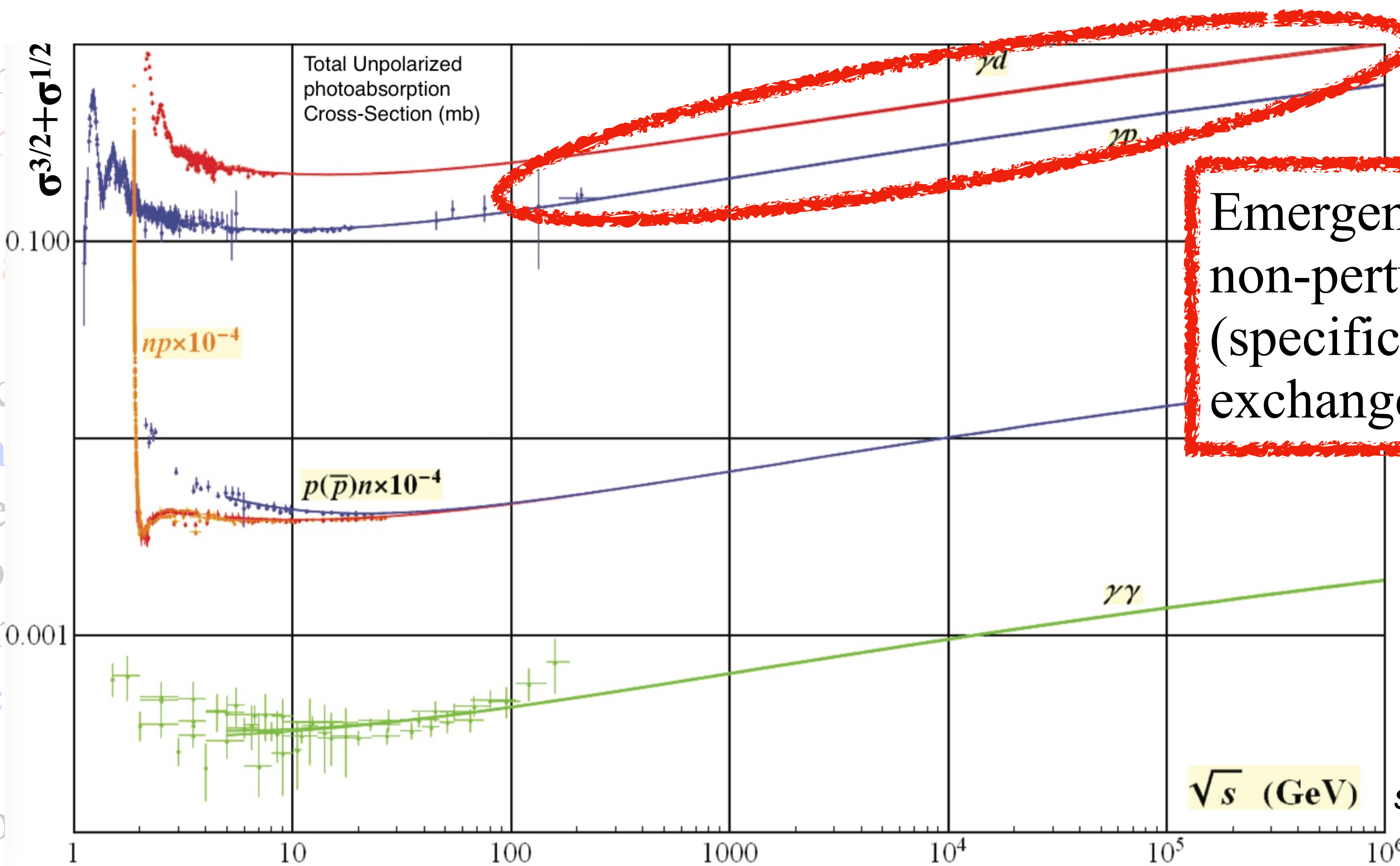

Emergence high-energy non-pertubative reactions (specifically here: pomeron exchange).

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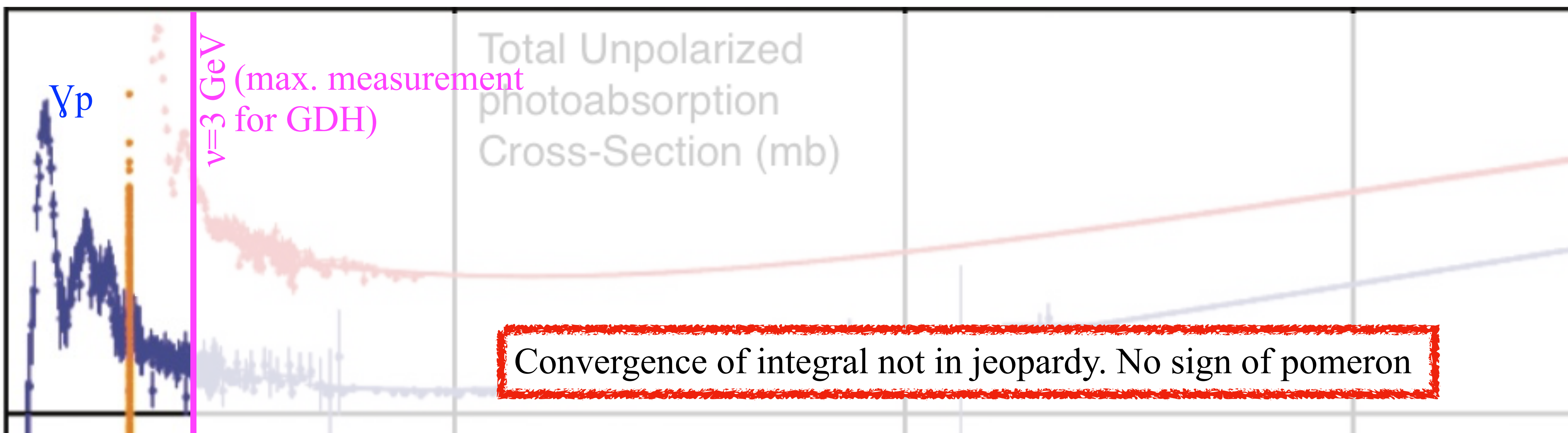

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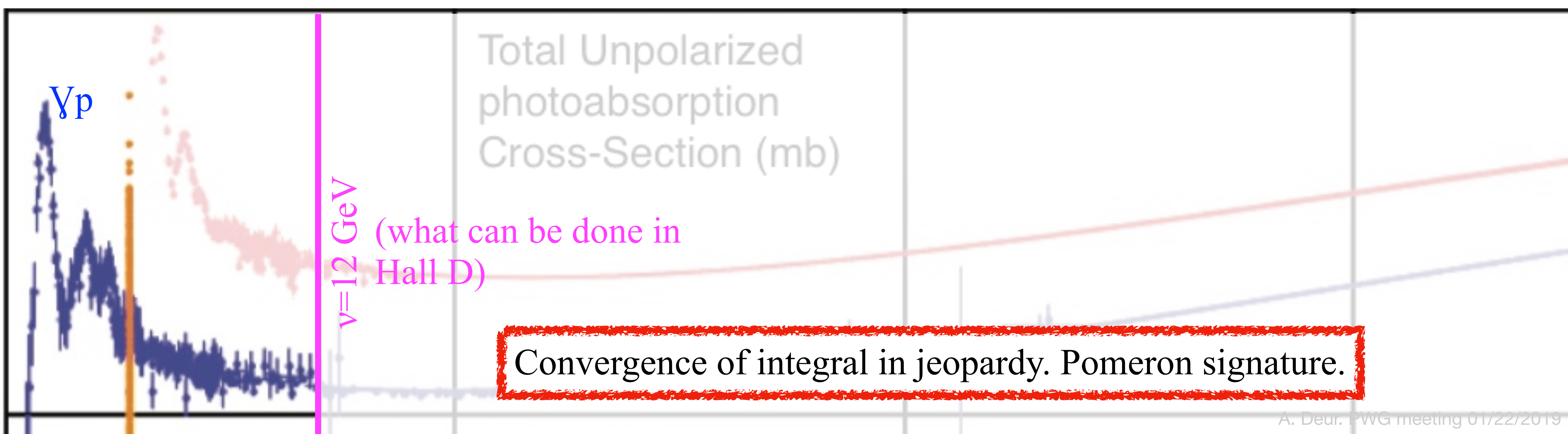

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- Need to measure both proton and neutron (deuteron) for isospin separation. Regge theory: isoscalar and isovector contributions to $(\sigma^{3/2}-\sigma^{1/2})$ come from different meson families ($f_1(1285)$ and $a_1(1260)$ respectively).

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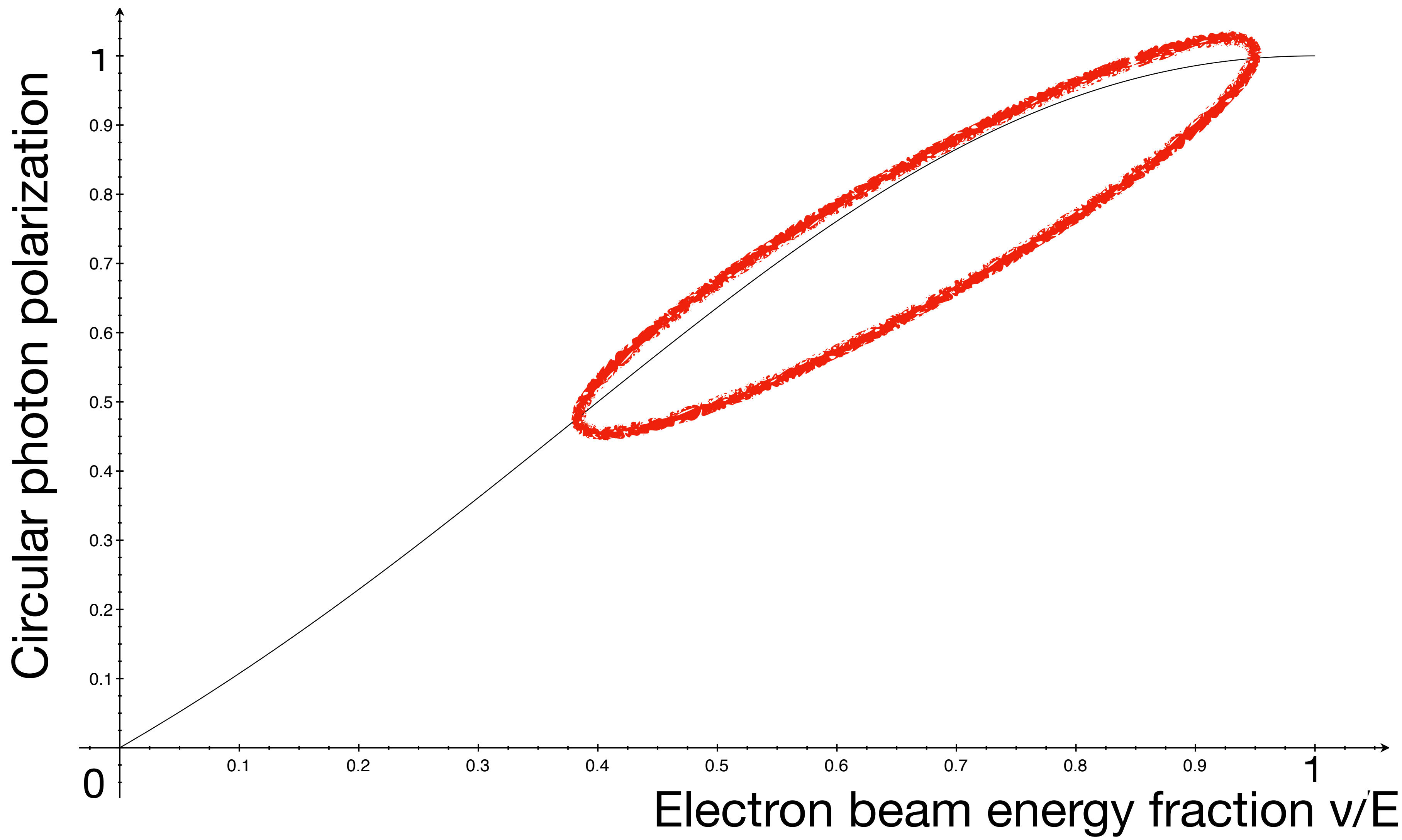
Circularly polarized beam

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

- Polarized electron beam;
- Amorphous radiator.



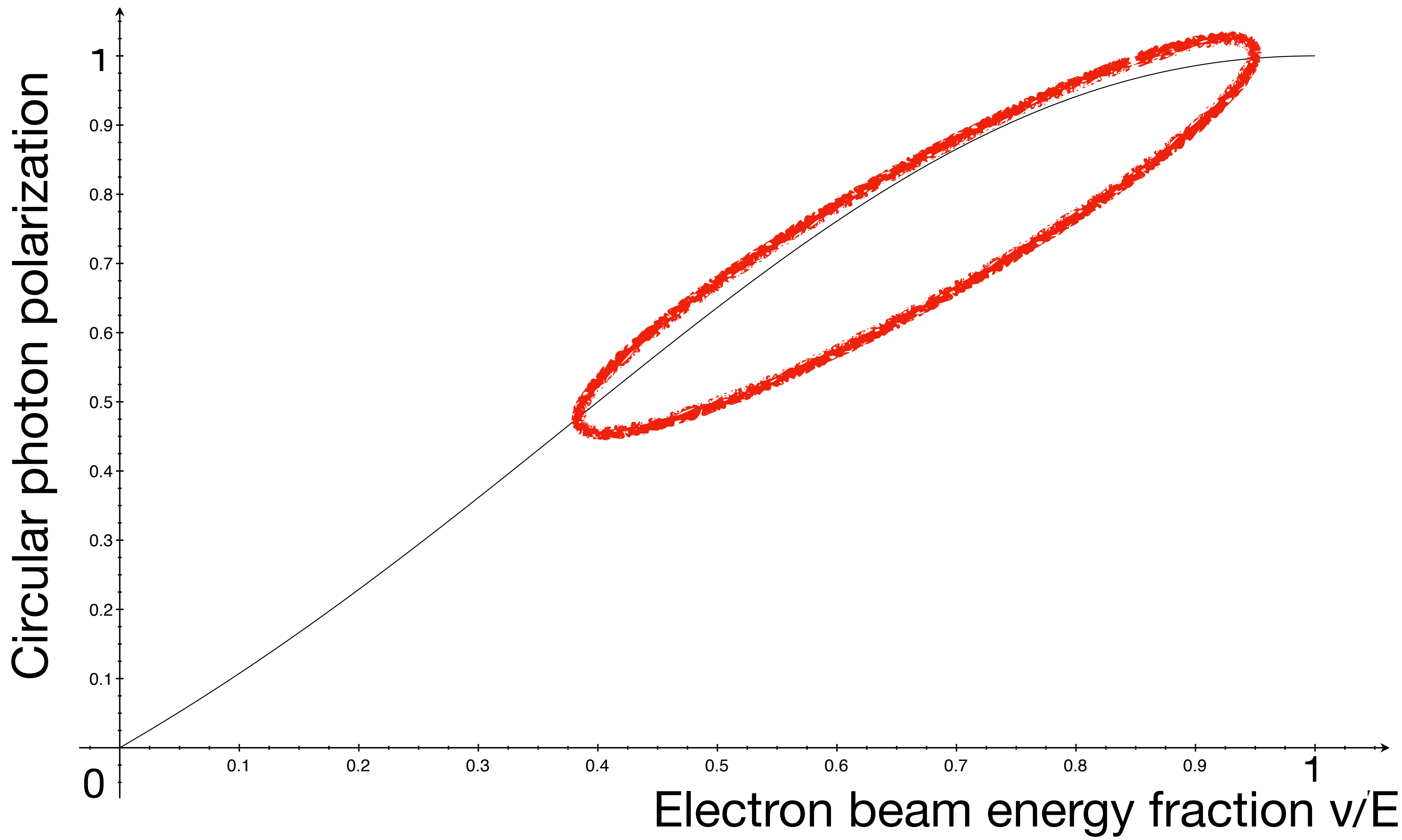
- Needed
  - Electron beam helicity reporting
  - Beam charge asymmetry control

- Not needed
  - polarimetry (can still be done with injector's Mott polarimeter+spin precession).
  - flux knowledge
  - High photon energy resolution (present < 0.5% more than enough).

Circularly polarized beam

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

- Polarized electron beam;
- Amorphous radiator.



- Needed
  - Electron beam helicity reporting
  - Beam charge asymmetry control

- Not needed
  - polarimetry (can still be done with injector's Mott polarimeter+spin precession).
  - flux knowledge
  - High photon energy resolution (present < 0.5% more than enough).

Polarized target

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- Options are polarized HDice or FROST
  - HDice: best figure of merit (low dilution, high sustainable photon flux), but complex to prepare and use.
  - FROST: best polarization, easier to use, but high dilution and lower maximum flux.

  - Running one short experiment: not enough to invest in HDice.
  - FROST dilution not an issue for GDH thanks to high rate Hall D DAQ: total rate with max flux<DAQ limit. Also, dilution cancels in physics analysis: $(N^{3/2}+N^0) - (N^{1/2}+N^0) = N^{3/2} - N^{1/2}$

    $\Rightarrow$ use FROST

  - Target group prefers to build dedicated Hall D FROST target rather than import Hall B one.
  - Two months to install the target. No commissioning needed.

FROST characteristics:

- Dynamical Nuclear Polarization on Butanol (C_4H_9OH or C_4D_9OD)
- P and D polarizations: up to 90%. Need to be re-polarized every 5-7 days (5h process).
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•Measure total photoproduction yield.

•BCal, FCal, Compcal. (CDC/FDC a priori not needed.): 0.2° to 145° polar coverage. (Compare to 1.6° to 174° coverage by ELSA's GDH detector). 2π azimuthal coverage.

•DAQ: total unpol. photoprod. cross-section: ~120 μb. ⇒ 33 kHz on H-butanol and 40 Khz on D-butanol. (Not accounting for target window and electromagnetic background).

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$\Rightarrow$ 2 weeks on deuteron so that neutron uncertainty is similar to proton's one.

- For expectations, assume Regge theory:

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$s=2M\nu+M^2$, α_{f1}, α_{a1}: Regge intercepts of $f_1(1285)$ and $a_1(1260)$ trajectories, and $c_{2,1}$: parameters.

- 2.5×10^7 s^{-1} tagged flux ($3<\nu<12$ GeV), Pb=80%, Pt=80%, $\Delta\Omega=0.75\times\pi$, 80% detector efficiency.
- 5cm target on usual butanol density

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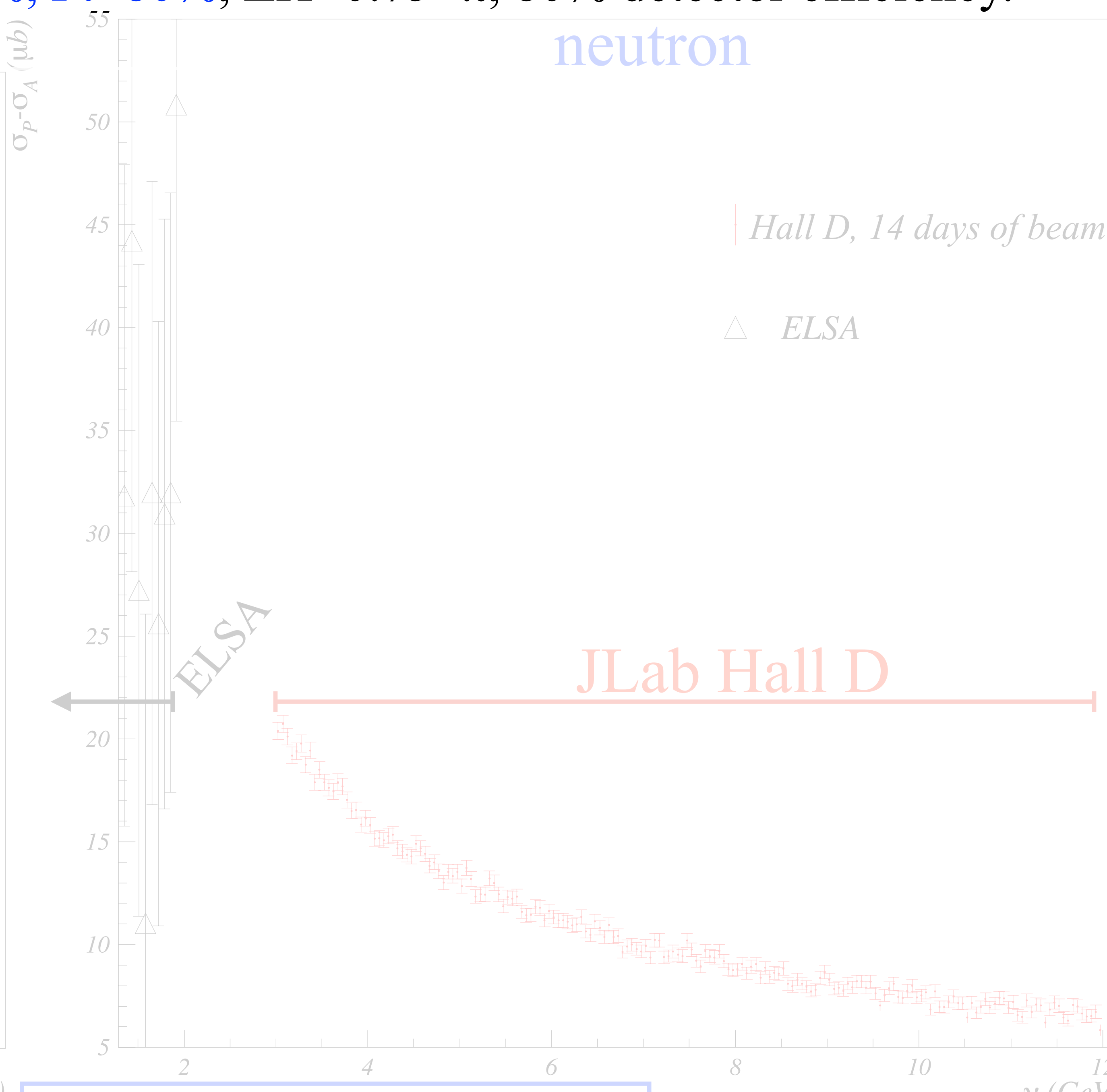

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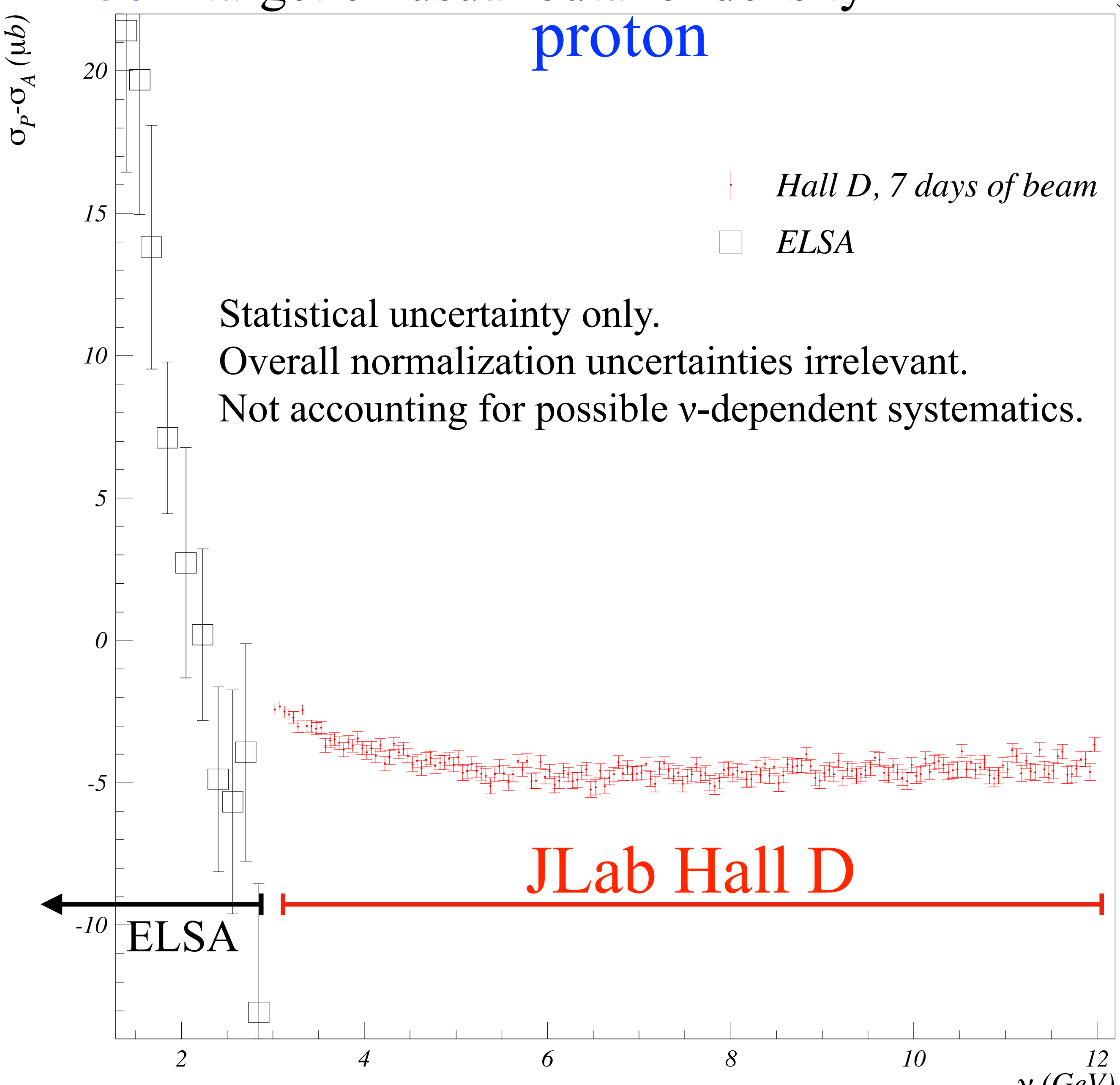

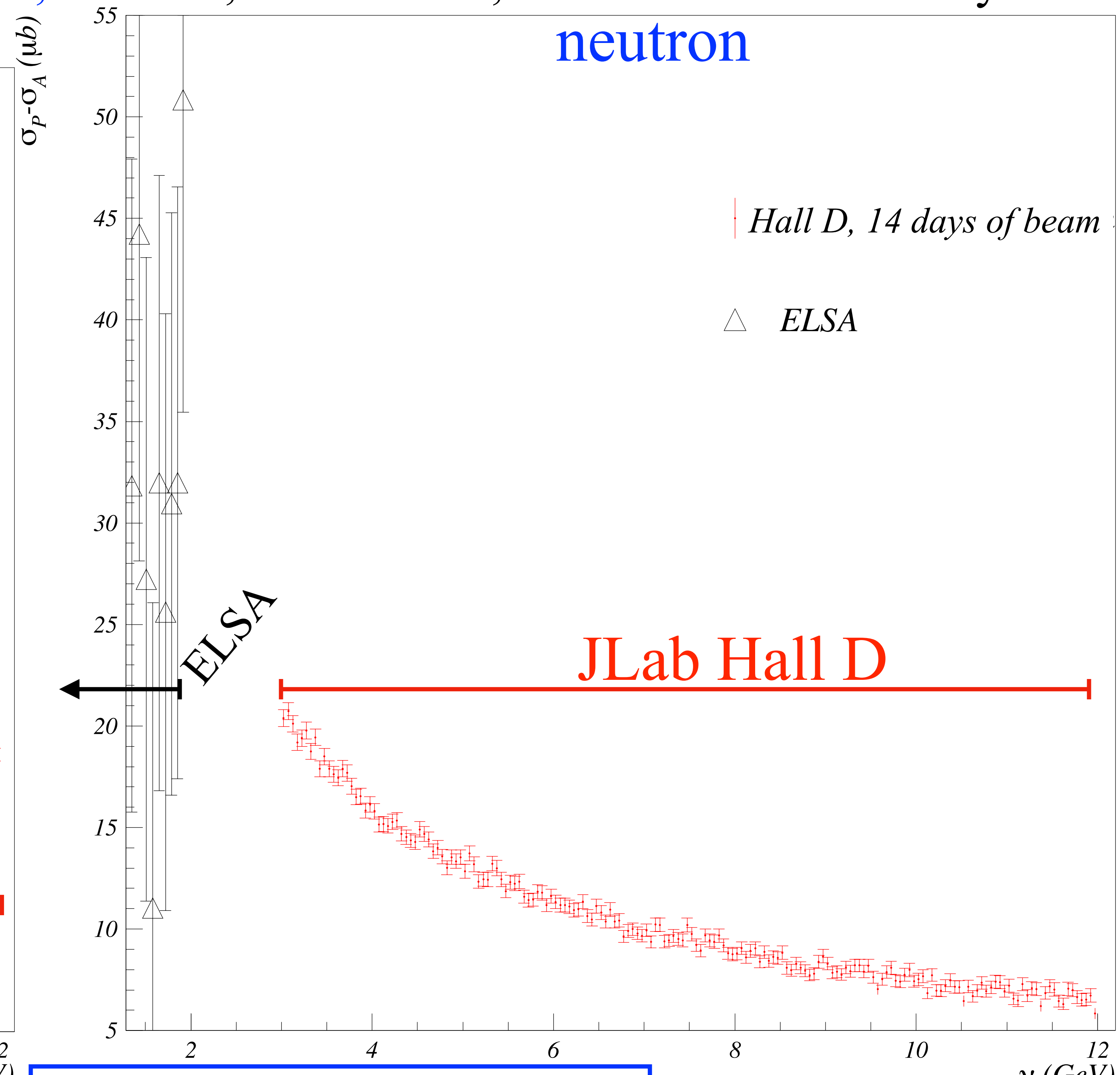

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- Measuring ν-behavior (e.g. of α_{f1} and α_{a1} in case $(N^{3/2}-N^{1/2})$ follows Regge theory) will test the convergence of GDH sum (primary goal)

- If Regge theory works: $\Delta\alpha_{a1}=\pm0.006$ & $\Delta\alpha_{f1}=\pm0.016$. Compare to $\Delta\alpha_{a1}=\pm0.23$ & $\Delta\alpha_{f1}=\pm0.22$ from ELSA

- Assuming:
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will improve accuracy of GDH Sum Rule determination by 25% (secondary goal)

Example of interpretation: sensitivity to quark compositeness

- Anomalous magnetic moment κ: low-energy probe of compositeness, e.g. Discovery that $\kappa_p \neq 0$ (1930s) was first evidence of proton compositeness, well before high-energy scattering experiments.
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