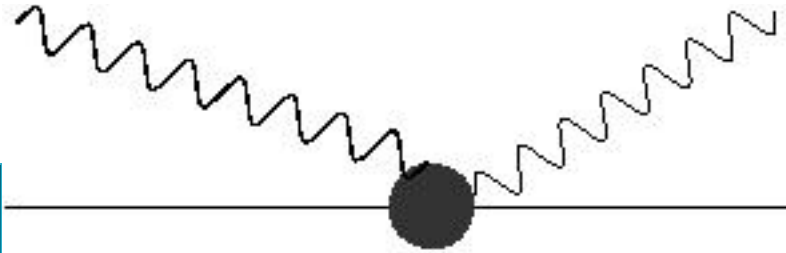


# Inelastic Compton Scattering on The Deuteron

## Neutron Polarizability Extraction

## Hadron 2015


**Berhan Demissie**
**GWU**

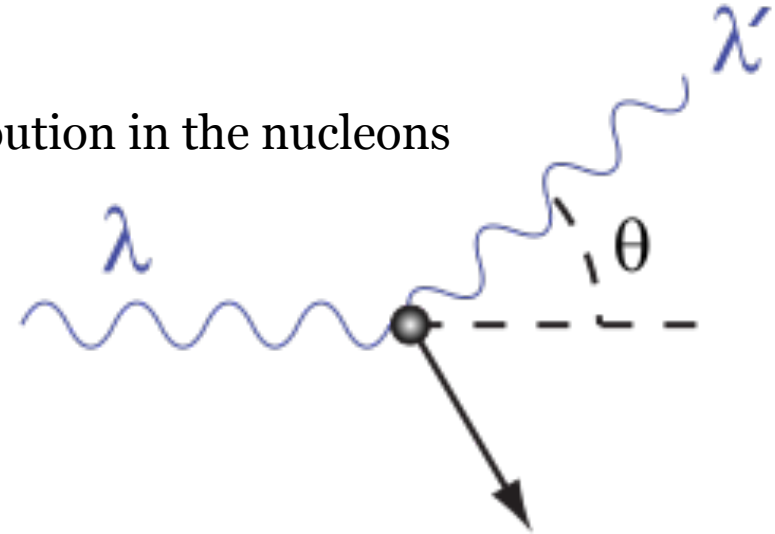
## Nucleon Scalar Polarizabilities

- Measure stiffness of charge and current distribution in the nucleons
- Nucleon mass splitting $\sim \beta_{p-n} = \beta_p - \beta_n$

  **Walker-Loud et al PhysRevLett.108.232301**
  **Gasser et al arXiv:1506.6747**

  ➔ Mirror Nuclei

  ➔ Big Bang Nucleosynthesis (BBN)




**Two photon response processes : Compton Scattering**

## ChiPT Effective Field Theory

- Effective Lagrangian of Nucleons and Mesons which satisfy unitarity, analyticity, Lorentz, CPT, chiral symmetries.

➡ **Model independent**

- Counting rule and Expansion Parameters:

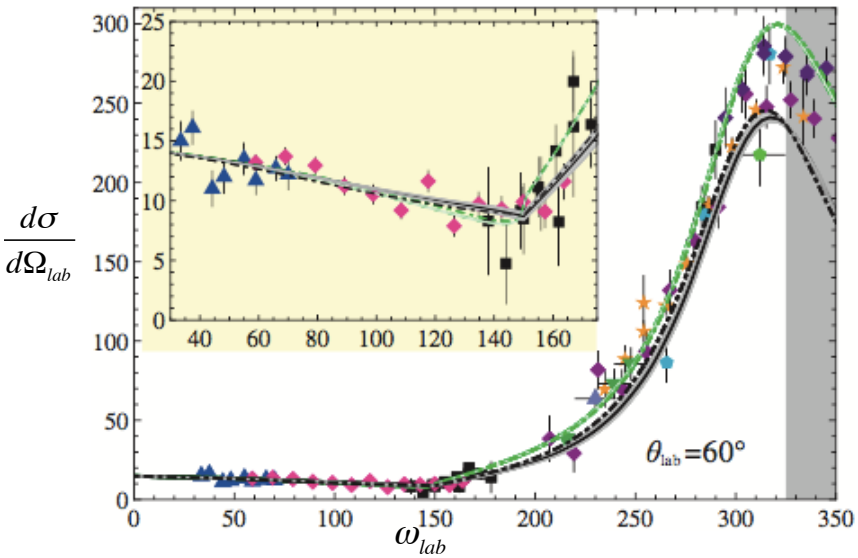
$$\frac{Q(=q, m_\pi, m_\Delta - m)}{\Lambda}$$

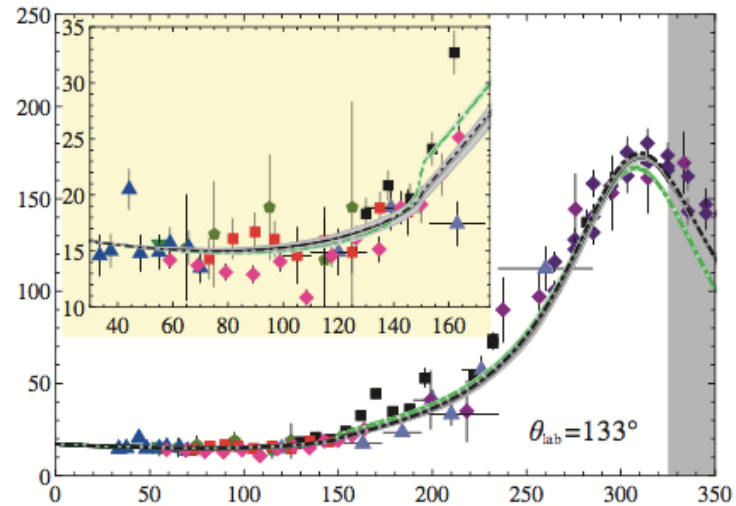
➡ **Well-defined uncertainties ~ $Q^{n+1}$**

## Latest values from p(γ,γ)p and d(γ,γ)d

**$\omega \sim m_\pi$ up to N$^4$LO** **$\omega \sim M_\Delta - M_N$ up to NLO**

- Pion and Δ(1232) degrees of freedom




McGovern et al, 2013 ,Eur. Phy. J. A

$\alpha_p = 10.7 \pm 0.4(\text{stat}) \pm 0.2(\text{Baldin}) \pm 0.3(\text{theory})$ $\alpha_n = 11.1 \pm 1.8(\text{stat}) \pm 0.4(\text{Baldin}) \pm 0.8(\text{theory})$

$\beta_p = 3.1 \mp 0.4(\text{stat}) \pm 0.2(\text{Baldin}) \mp 0.3(\text{theory})$ $\beta_n = 3.1 \mp 1.8(\text{stat}) \pm 0.4(\text{Baldin}) \mp 0.8(\text{theory})$

✓ **Treat all Compton data within the same framework**

✓ **Corroborate and improve accuracy of $\alpha_n$ and $\beta_n$ independently**

- *d(γ,γn)p in χEFT*

# $d(\gamma,\gamma n)p \sim n(\gamma,\gamma)n$

## Non χEFT Approach

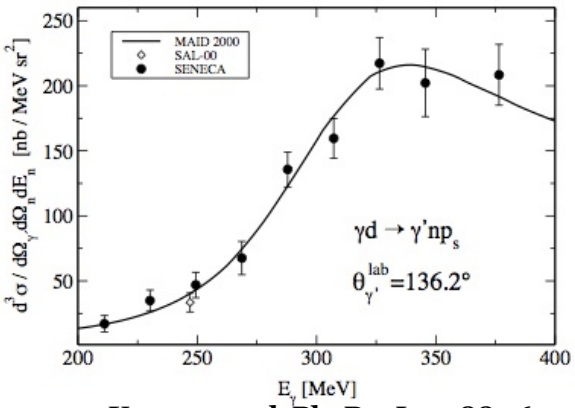
Few-Body Systems 16, 101–125 (1994)

Few-Body Systems



**Photon Scattering on Quasi-Free Neutrons in the Reaction $\gamma d \to \gamma' np$ and Neutron Polarizabilities**

M. I. Levchuk[1], A. I. L'vov[2], and V. A. Petrun'kin[2]




Kossert et al PhyRevLett.88.162301

**NQFP**- neutron quasi-free peak kinematic region

- Ep $\leq$ 1.1 MeV
- Polarizability sensitive $E_\gamma$ : 200-400MeV

$$\alpha_n = 12.5 \pm 1.8(\text{stat.})^{1.1}_{-0.6}(\text{syst.}) \pm 1.1(\text{mod.})$$

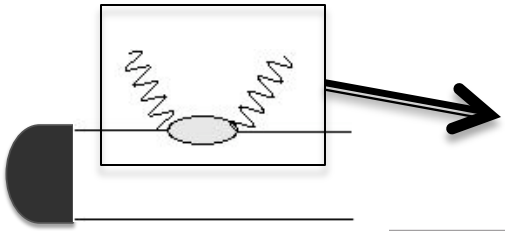
$$\beta_n = 2.7 \mp 1.8(\text{stat.})^{0.6}_{-1.1}(\text{syst.}) \mp 1.1(\text{mod.})$$

## Re-Analysis in χEFT Approach

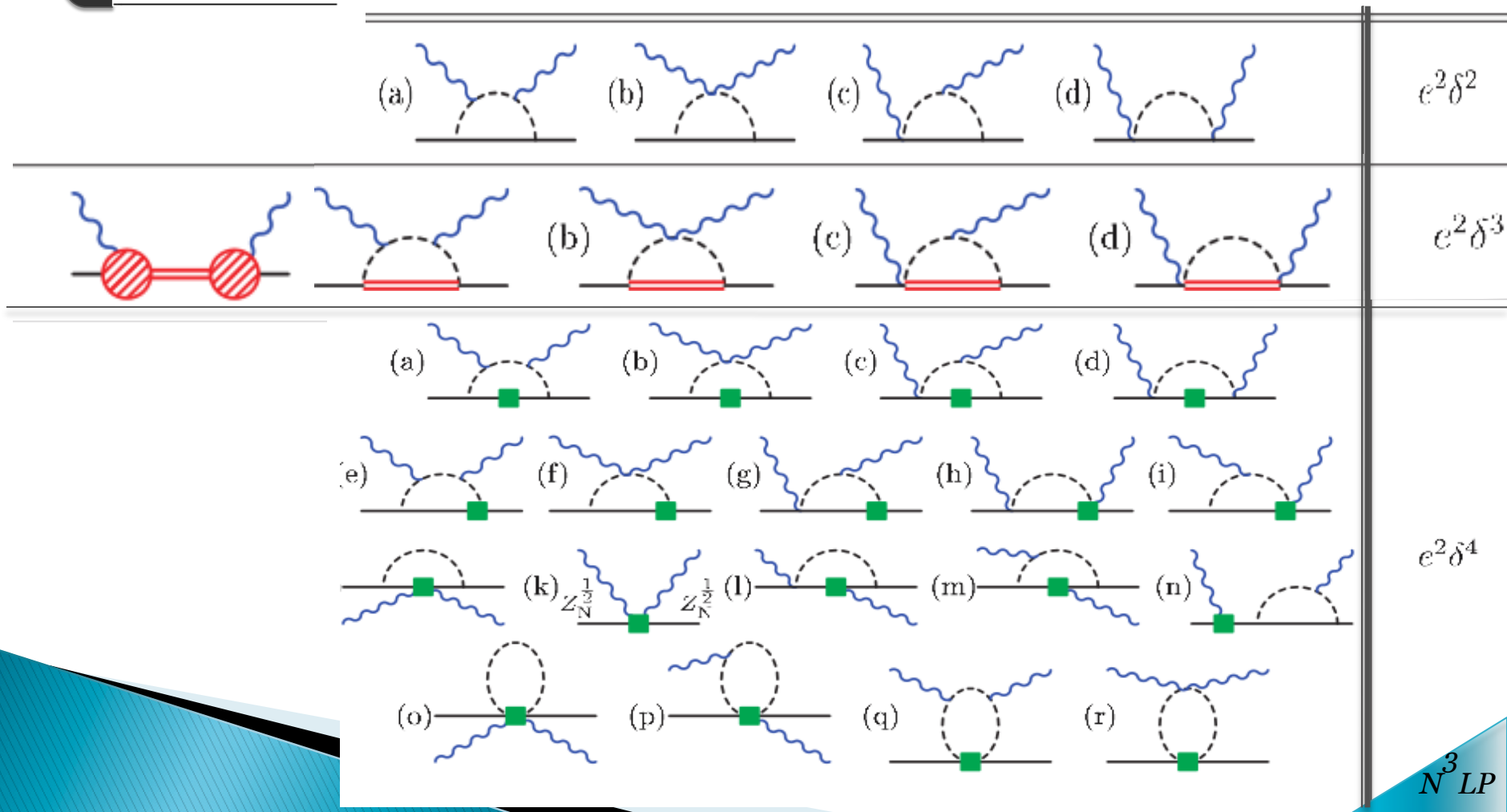
- Model independent
- Well controlled uncertainties
- Treatment of the channel in χEFT

→ All Compton scattering data in the same framework

## Impulse Approximation

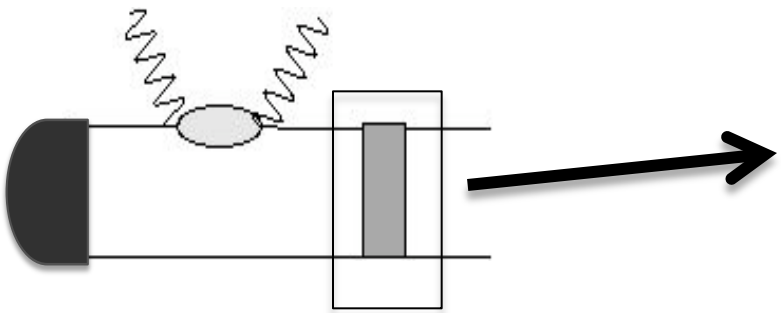


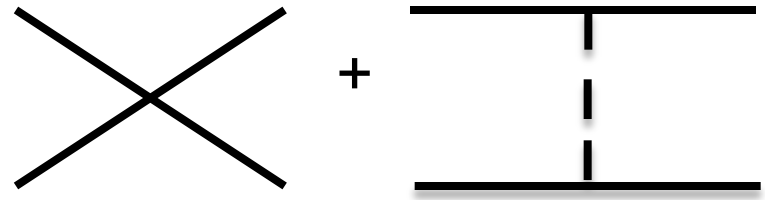
**Born +**




$N^3LP$

## Final State Interaction



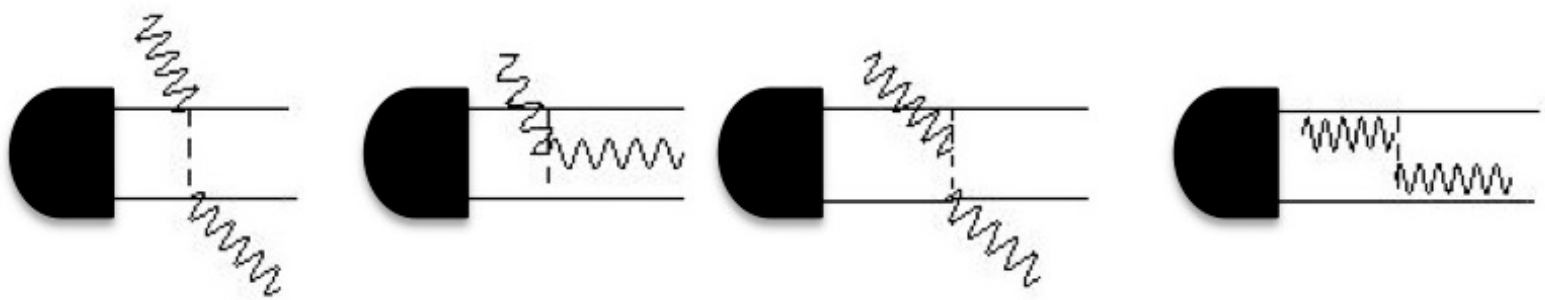


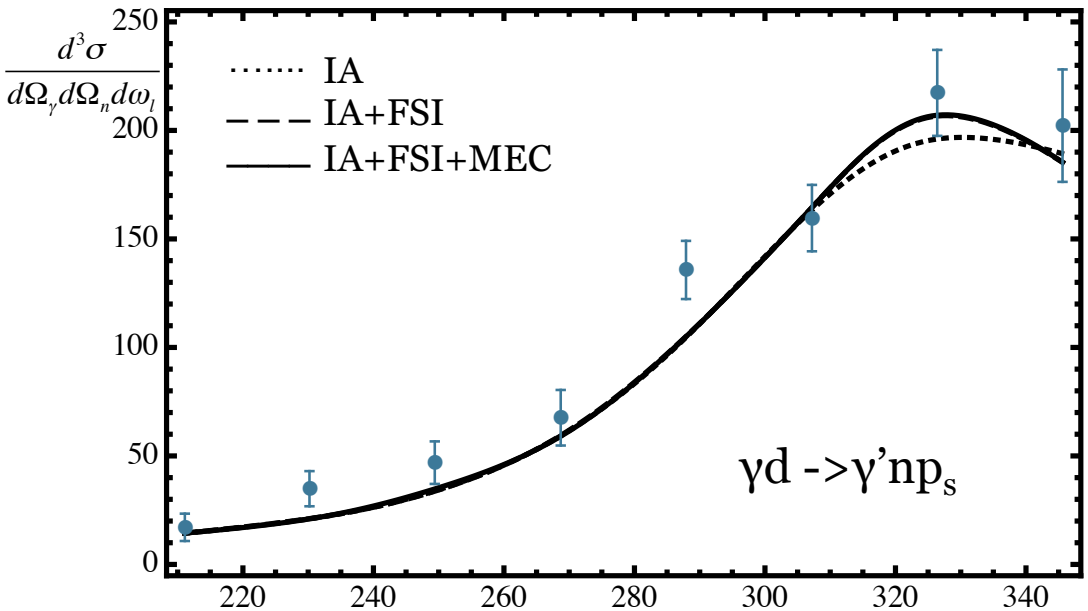
$V_{ct} = C_s + \sigma_1 \bullet \sigma_2 C_t$ $\qquad$ $V_{1\pi}$

$C_s$ and $C_t$ fixed

- n p bound system : deuteron
  - ✓ $E_b$ = 2.224 MeV
- n p scattering
  - ✓ scat. length = -23.7 fm

## Meson Exchange Current

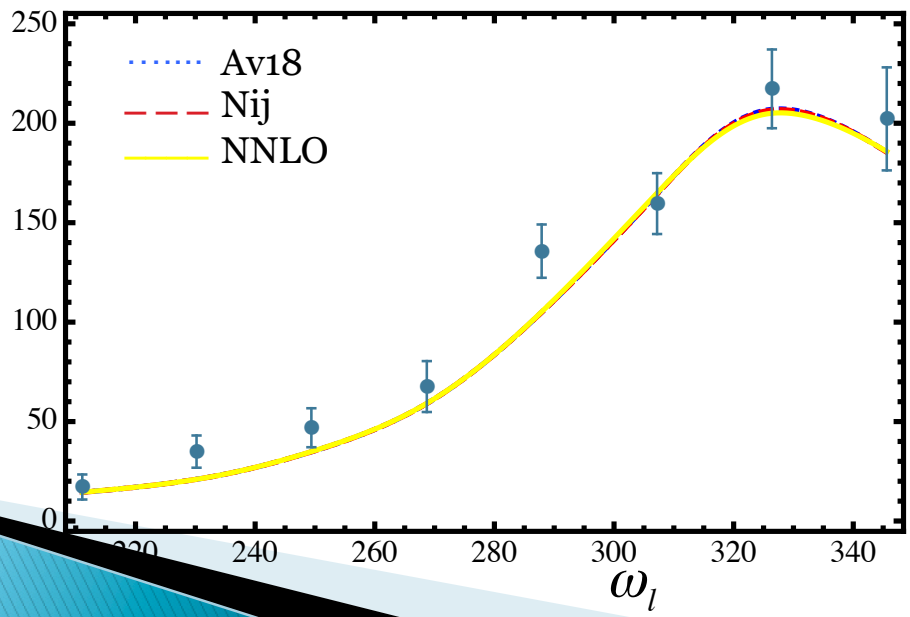




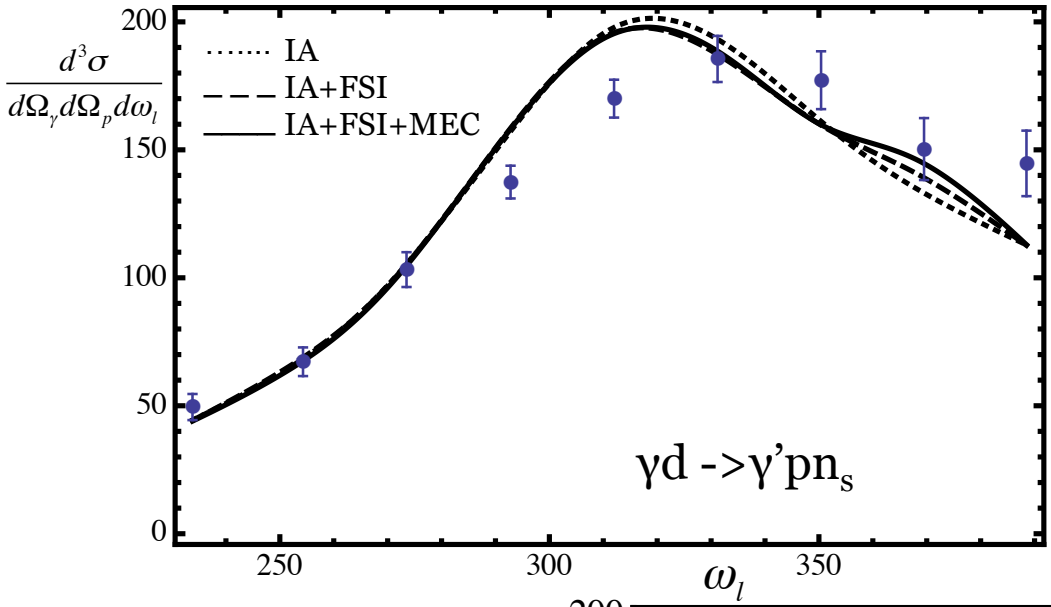

**Currently established values**

$\alpha_n = 11.55$ $\beta_n = 3.65$

$\chi^2$ /d.o.f = 1.2



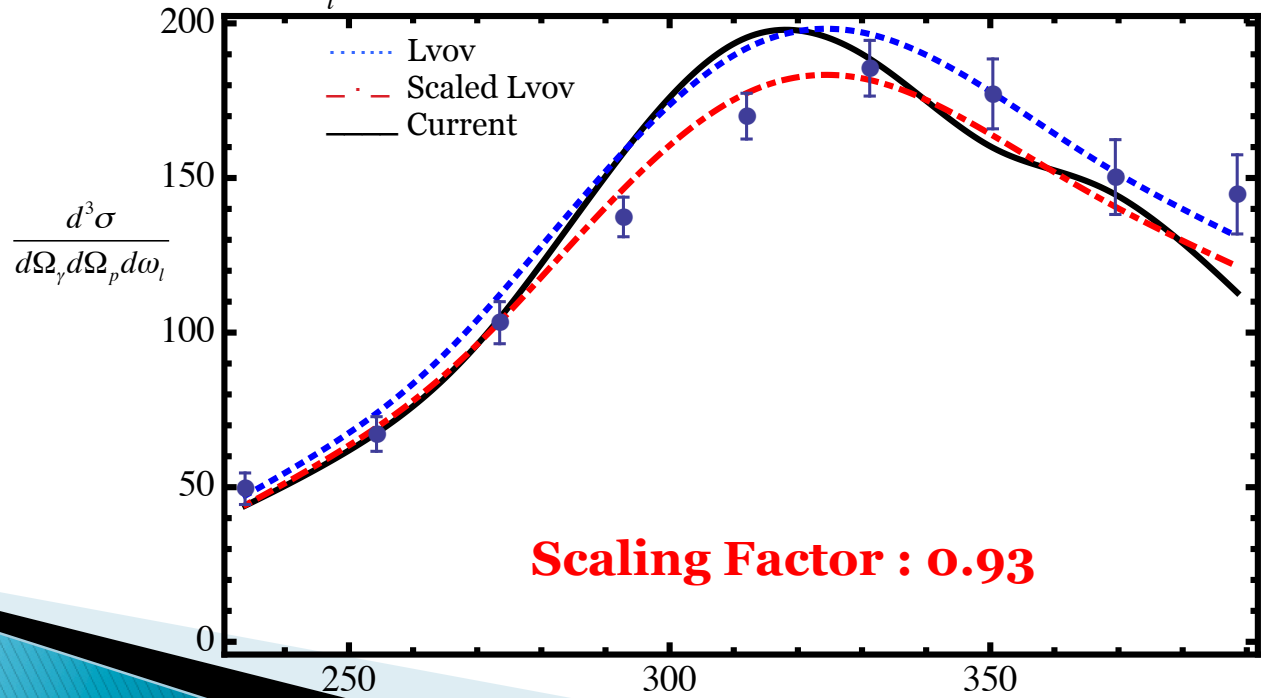

**No significant deuteron wave function dependence.**




**Currently established values**

$\alpha_p = 10.65$ $\beta_p = 3.15$

$\chi^2$ /d.o.f = 3.4



Future Goals :

- Improve the description of proton quasi-free region
  - ✓ Establish consistent description of data from elastic Compton on the proton and quasi-free proton from inelastic Compton on the deuteron
- Extract $\alpha_n$ and $\beta_n$
- Extract $\gamma^{(n)}_{\pi}$
- Implementation which separates inelastic Compton events from elastic ones for Hiγs experiments

# Conclusion

- Neutron polarizability from $\gamma n \rightarrow \gamma n$

- $\chi$EFT is - model independent
  - well defined uncertainties

- Analyze all Compton data using the same framework – $\chi$EFT

- data-theory consistency shows discrepancy

- Stay tuned for more!

Thank You