French-Korean Particle Physics Workshop

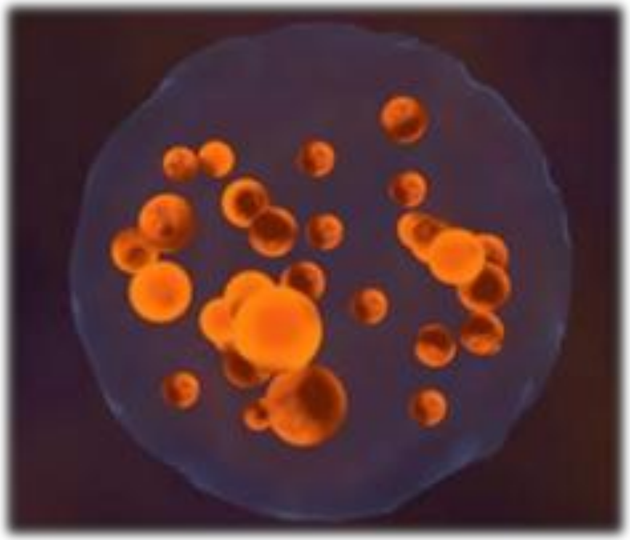
Generalised Parton Distributions (GPDs)

May 10, 2017

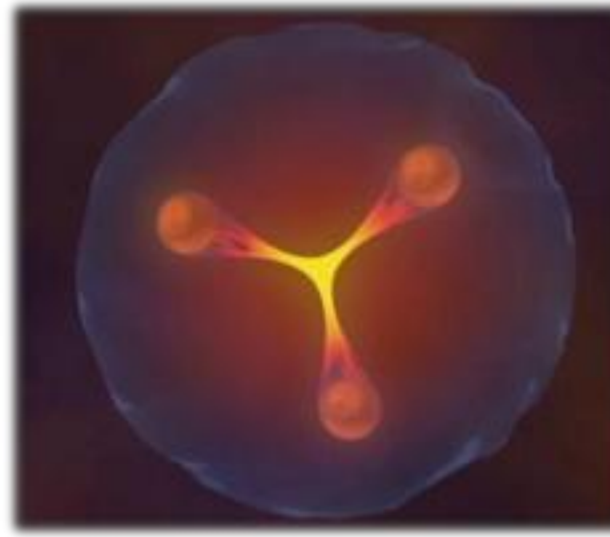
SPhN/IRFU (CEA-Saclay), IPN-Orsay (CNRS/IN2P3)

Kyungpook National University

OUR GOAL: TO UNDERSTAND THE STRUCTURE OF THE NUCLEON



Degrees of freedom at high energy: quarks and gluons.
Perturbation theory



Bound states at low energy: hadrons.
A unique laboratory to study QCD

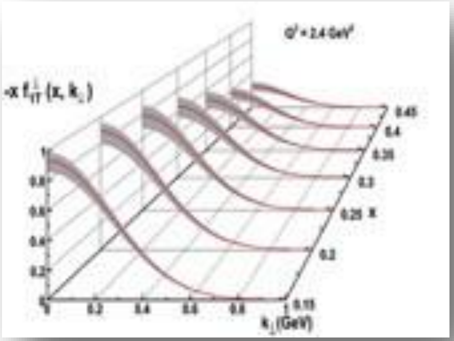
The observed states are not the degrees of freedom but…

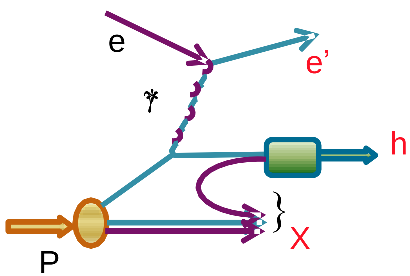
… **factorisation allows us to relate them to degrees of freedom in some 'hard' processes**

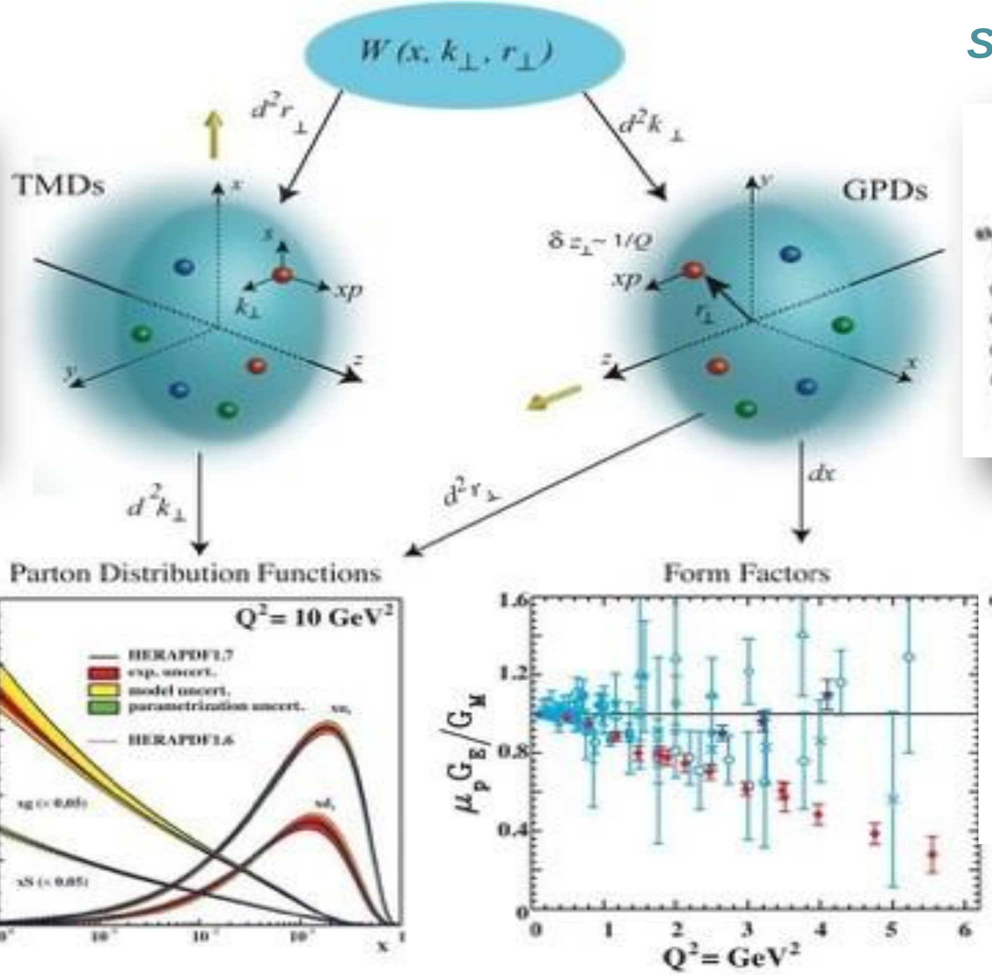
DISTRIBUTIONS ENCODING THE NUCLEON STRUCTURE

TMDs: Fraction of longitudinal momentum x et transverse momentum k

Scan in momentum

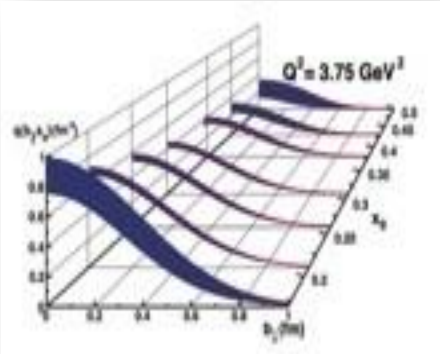


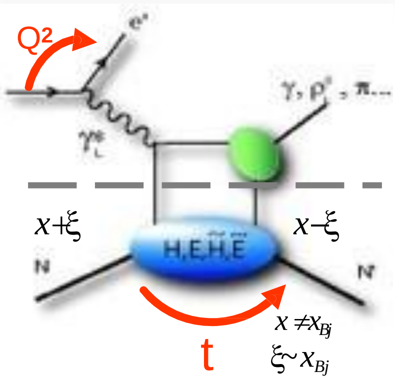




GPDs: Fraction of longitudinal momentum x et transverse position b

Scan in position

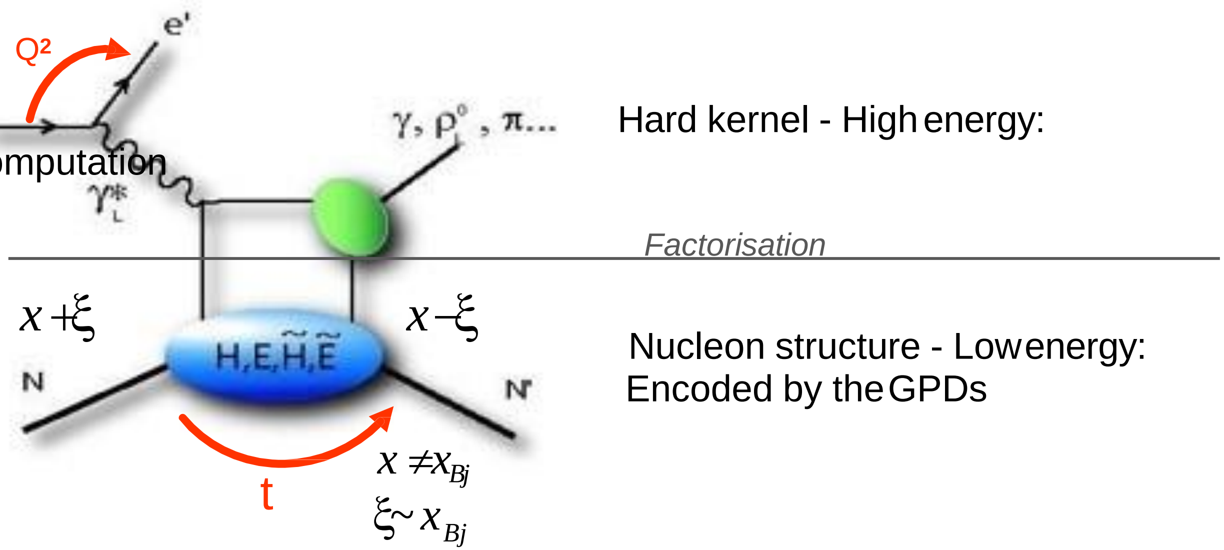




ACCESSING THE GENERALIZED PARTON DISTRIBUTIONS

The generalized parton distributions (GPDs) indirectly parametrize the cross sections of deep exclusive processes.

Hard kernel - High energy: perturbative computation



Nucleon structure - Low energy: Encoded by the GPDs

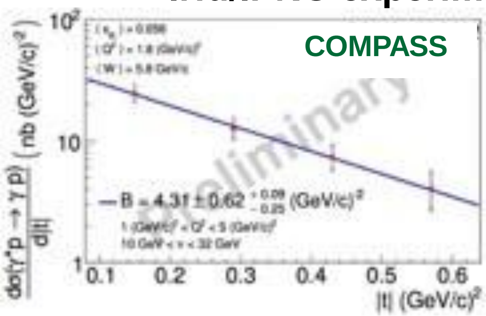
The amplitude is a linear combination of complex integral of GPDs called Compton Form Factors (CFFs).

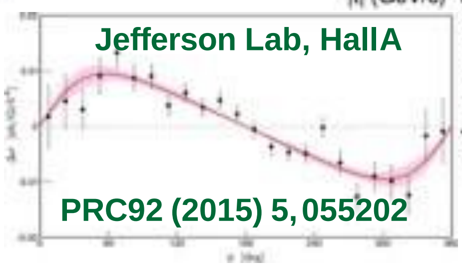
$$CFF = \int (GPD \otimes HARD\ KERNEL)\, dx$$

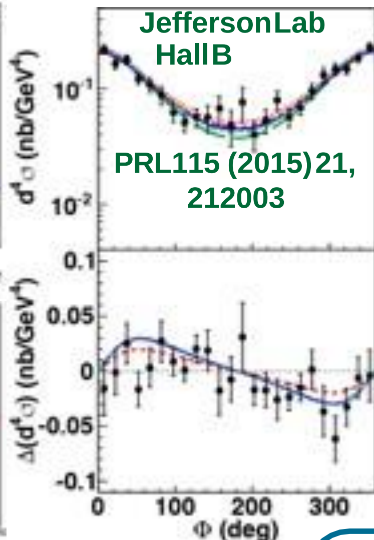
The GPDs are universal: Meson or photon electroproduction are parametrized by the same GPDs.

OUR STRATEGY: FROM DATA TO PHENOMENOLOGY

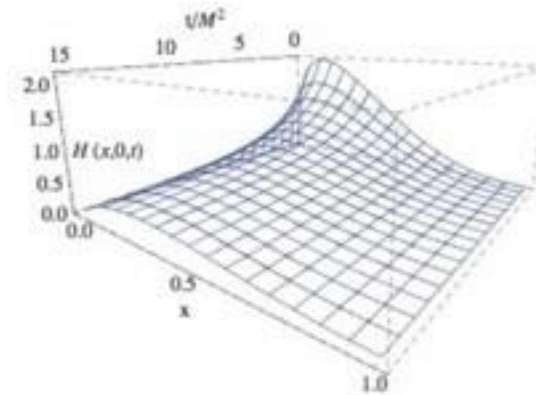
DVCS cross-section results from
Irfu/IPNO experimental teams







Generalized Parton Distributions Models, Parametrizations from
Irfu/IPNO phenomenology teams



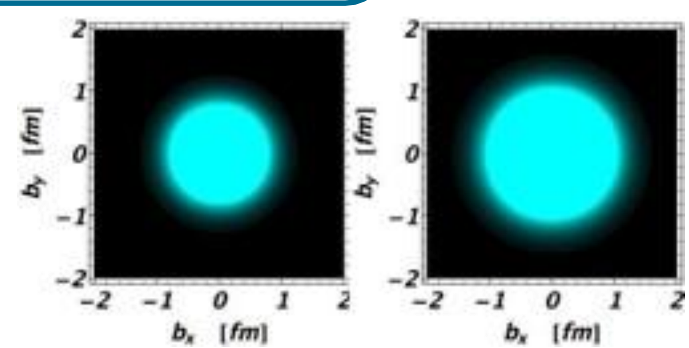
PLB (2015) 190-196

arXiv:1512.06174

NSAC Long Range Plan (2015)

First 3D pictures of the nucleon

An ANR PARTONS result !



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H^q	$\tilde{H}^q$	E^q	$\tilde{E}^q$	parton helicity conserving (chiral-even) GPDs
H_T^q	$\tilde{H}_T^q$	E_T^q	$\tilde{E}_T^q$	parton helicity-flip (chiral-odd) GPDs

For π^0 electroproduction the GPDs appear in the flavor combinations:

$$F_i^{\pi^0} = (e_u F_i^u - e_d F_i^d)/\sqrt{2}$$

x	average parton momentum fraction
$\xi \simeq \frac{2x_B}{2-x_B}$	(skewness) difference between the initial and final fractions of the longitudinal momentum carried by the struck parton
$t = (p - p')^2$	momentum transfer between initial and final nucleons

The GPDs depend on three kinematic variables,

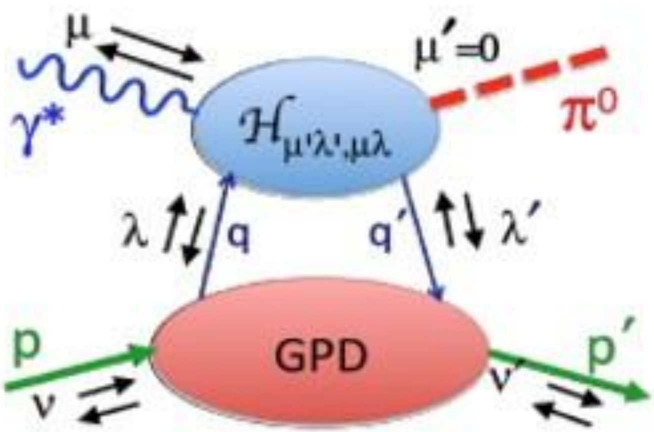
e.g. $H^q(x, \xi, t)$

UNPOLARIZED STRUCTURE FUNCTIONS:

$$\sigma_L \sim \left\{(1-\xi^2)\left|\langle\tilde{H}\rangle\right|^2 - 2\xi^2\mathrm{Re}\left[\langle\tilde{H}\rangle^*\langle\tilde{E}\rangle\right] - \frac{t'}{4m^2}\xi^2\left|\langle\tilde{E}\rangle\right|^2\right\}$$

$$\sigma_T \sim \left[(1-\xi^2)\left|\langle H_T\rangle\right|^2 - \frac{t'}{8m^2}\left|\langle \bar{E}_T\rangle\right|^2\right]$$

$$\sigma_{TT} \sim \left|\langle\bar{E}_T\rangle\right|^2$$



POLARIZED OBSERVABLES:

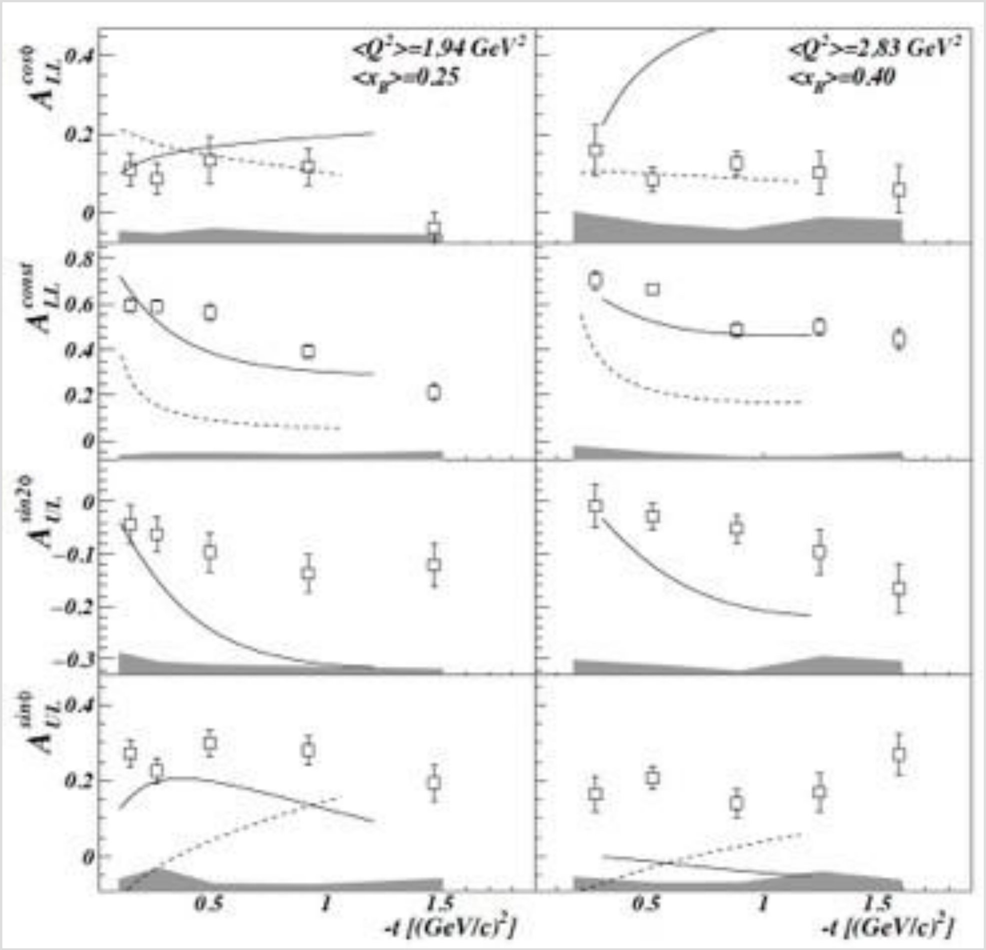
$$A_{LU}^{\sin\phi}\sigma_0 \sim \mathrm{Im}\left[\langle H_T\rangle^*\langle\tilde{E}\rangle\right]$$

$$A_{UL}^{\sin\phi}\sigma_0 \sim \mathrm{Im}\left[\langle\bar{E}_T\rangle^*\langle\tilde{H}\rangle + \xi\langle H_T\rangle^*\langle\tilde{E}\rangle\right]$$

$$A_{LL}^{\cos 0\phi}\sigma_0 \sim \left|\langle H_T\rangle\right|^2$$

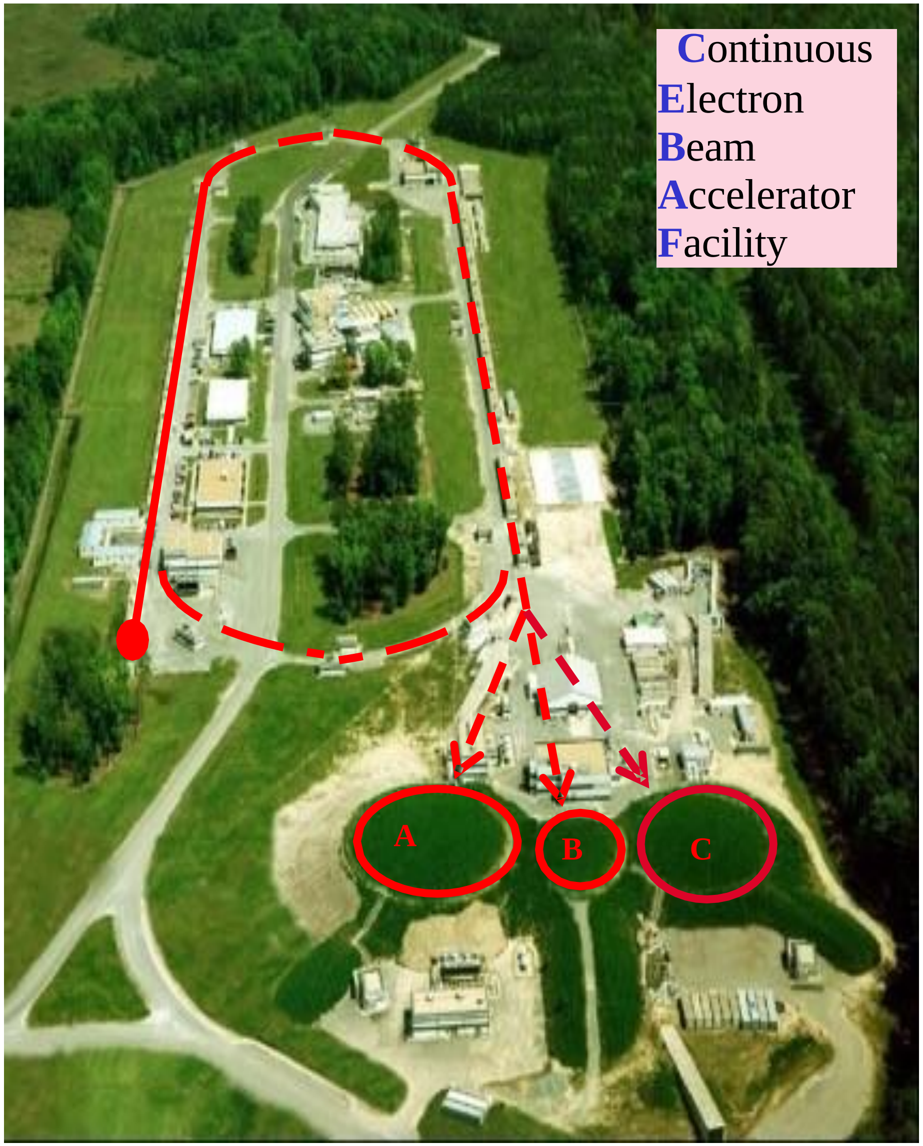
$$A_{LL}^{\cos\phi}\sigma_0 \sim \mathrm{Re}\left[\langle\bar{E}_T\rangle^*\langle\tilde{H}\rangle + \xi\langle H_T\rangle^*\langle\tilde{E}\rangle\right]$$

Target and Double Spin Asymmetry Moments of Exclusive π^0 Electroproduction as a Function of $-t$



- The curves show the predictions from two GPDs models: GK (dashed) and GGL (solid).
- Andrey KIM, Ph.D. Thesis KNU (2014)
- A. Kim et al. / Physics Letters B 768 (2017) 168–173

JEFFERSON LAB:
TO STUDY THE VALENCE REGION

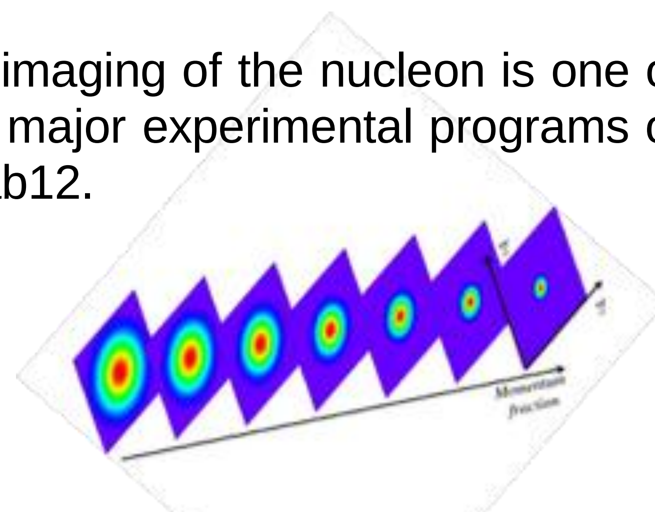


- Longitudinally polarized electron beam recently upgraded from 6 to 12 GeV

- Three complementary experimental Halls:
  - Hall A: precision, high luminosity
  - Hall B: Large acceptance
  - Hall C: High momentum and high luminosity

Running on fixed target (liquid Hydrogen).

- 3D-imaging of the nucleon is one of the major experimental programs of JLab12.

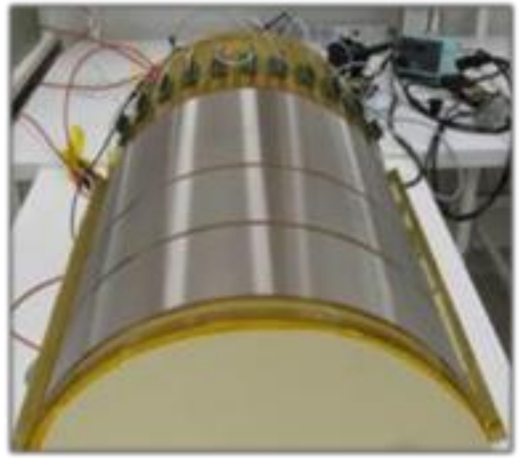


STRONG INVOLVEMENT OF IRFU/IPNO AT JLAB12

In Hall B:

- Hardware contributions for CLAS12 spectrometer.
- Leaders of the DVCS experimental program on proton and neutron.

Micromegas trackers by Irfu



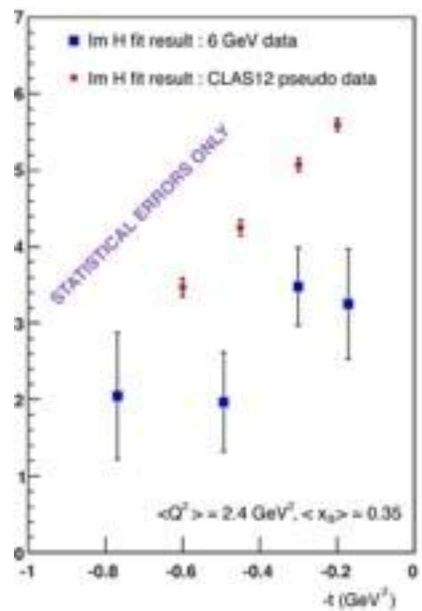
Recoil neutron detector by IPNO

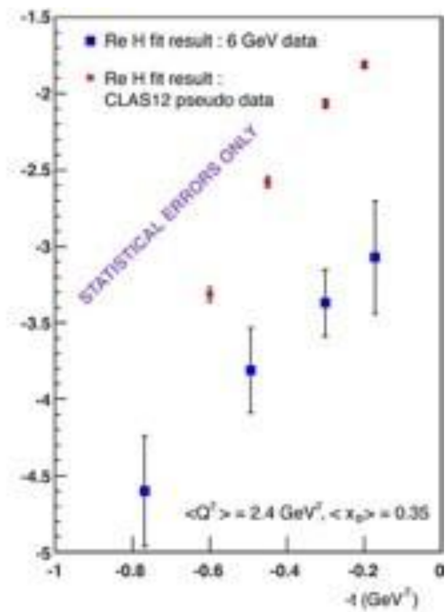
In Hall A:

First experiment running with the 12 GeV beam at Jefferson Lab for unprecedented high statistical precision DVCS measurements.

In Hall C:

Using the high momentum spectrometer, access unexplored kinematical domain for DVCS and meson production.





GPD Computing made simple. Differential studies: physical models and numerical methods.

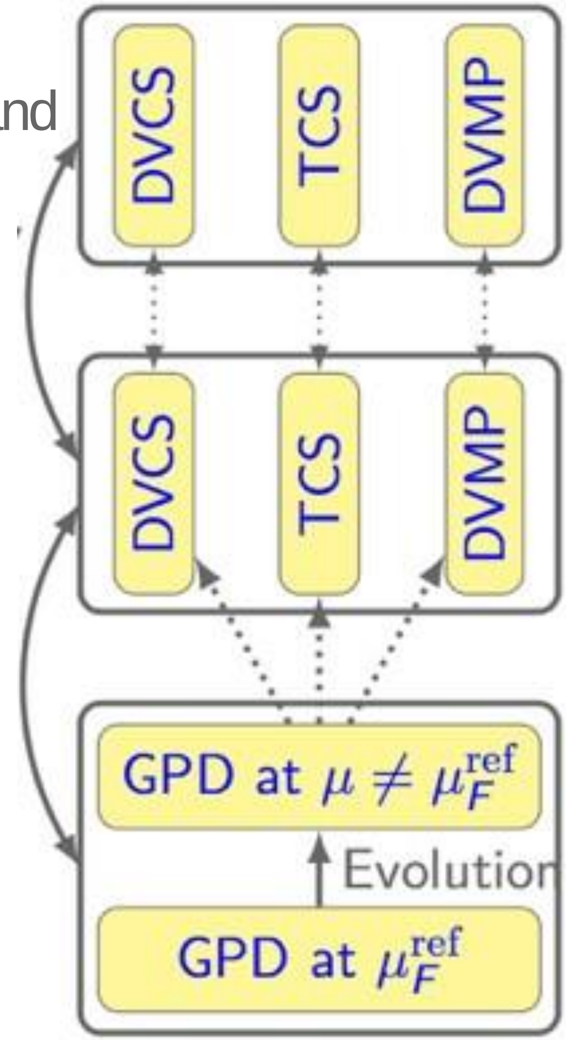
[Phenomenology of Generalized Parton Distributions](#)

[PARTONS Project](#)

Full processes
Experimental data and phenomenology

Small distance
Computation of amplitudes

Large distance
First principles and fundamental parameters

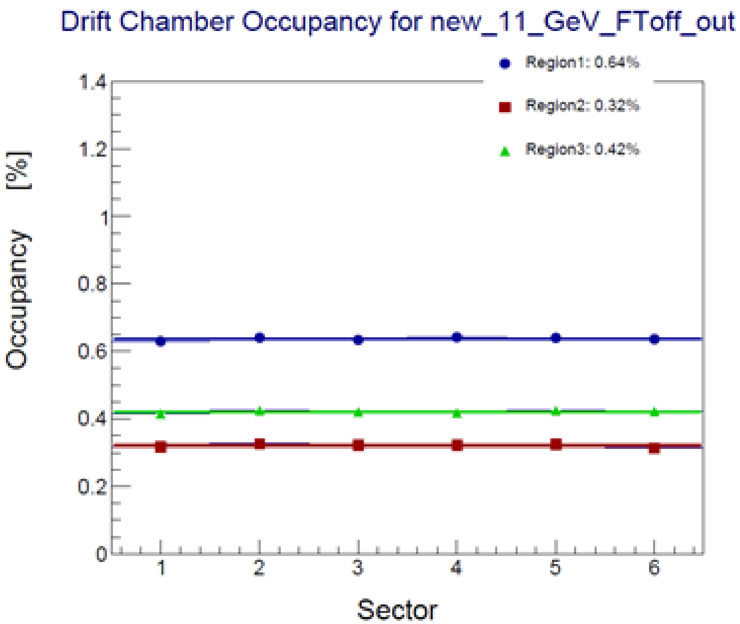


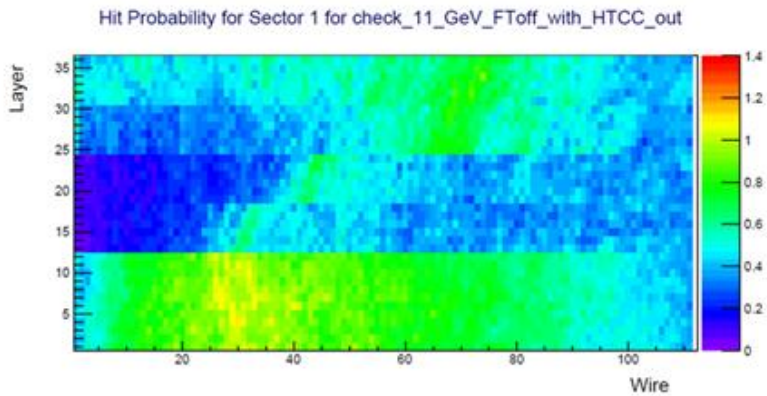
- Many observables
- Kinematic reach

- Perturbative approximations.
- Physical models.
- Fits.
- Numerical methods.
- Accuracy and speed

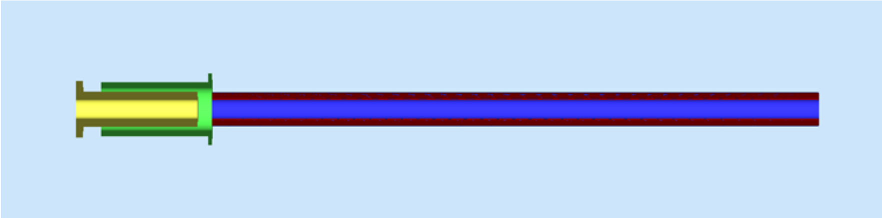
KNU Contribution to CLAS12 Background Studies and Software Projects

- ❑ Investigation of occupancy/hit probability due to background

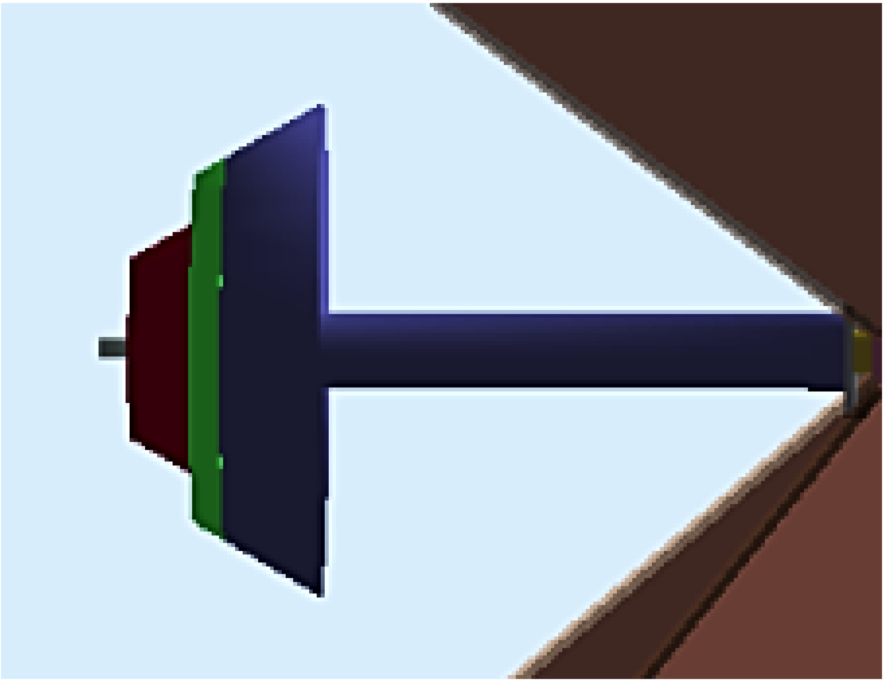




- ❑ Optimization of shielding designs

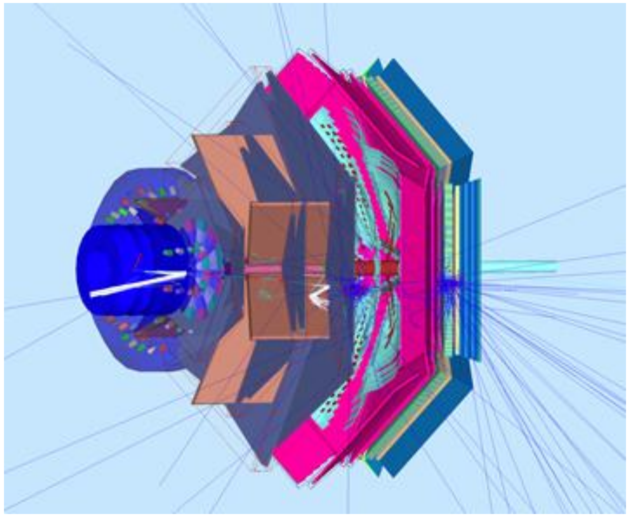


Torus region beamline shielding

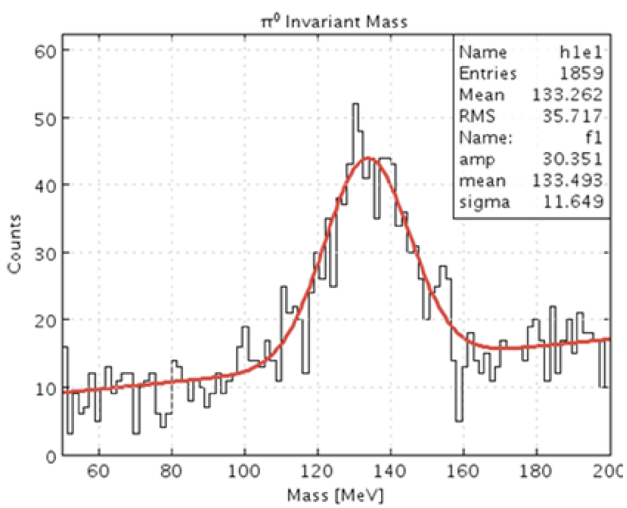


Shielding for DDVCS experiment

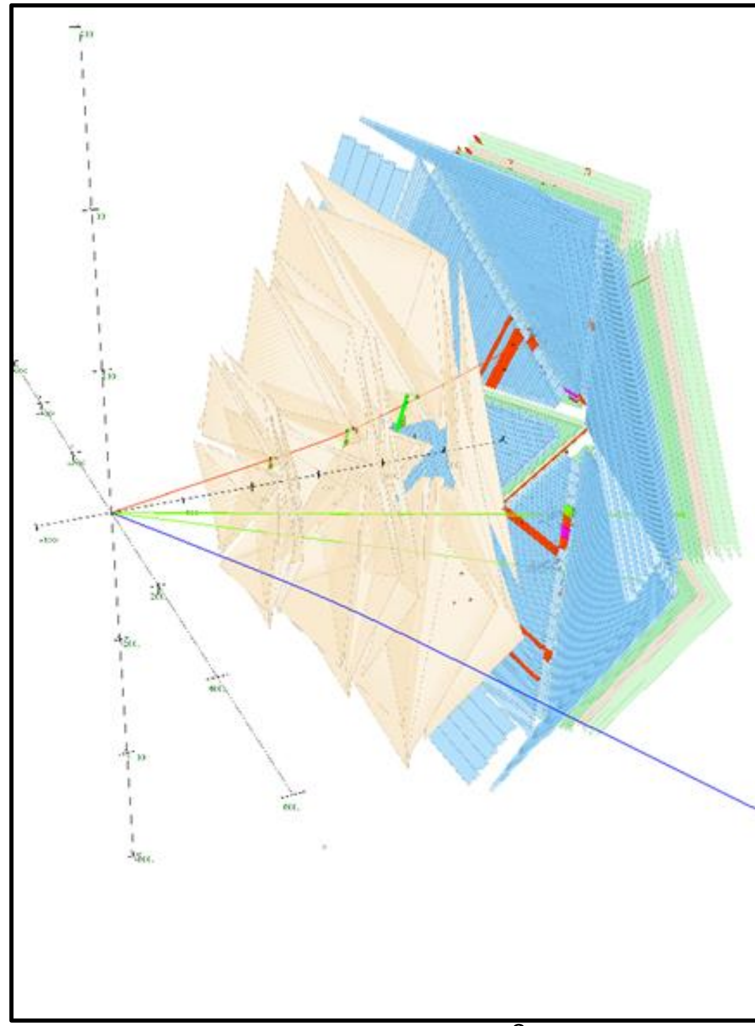
DVCS and DVπ^0P Simulations



DVCS event simulation

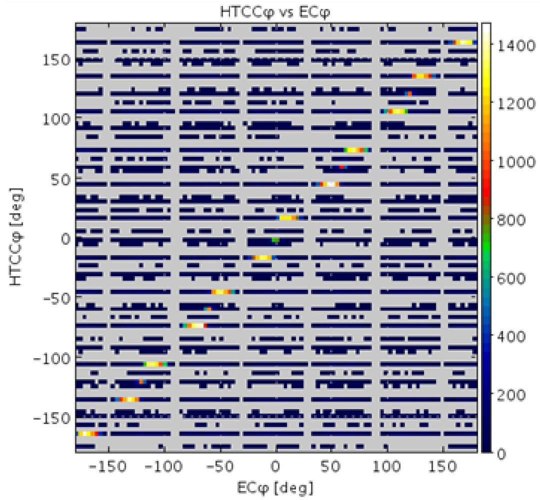


Reconstructed π^0 invariant mass with background

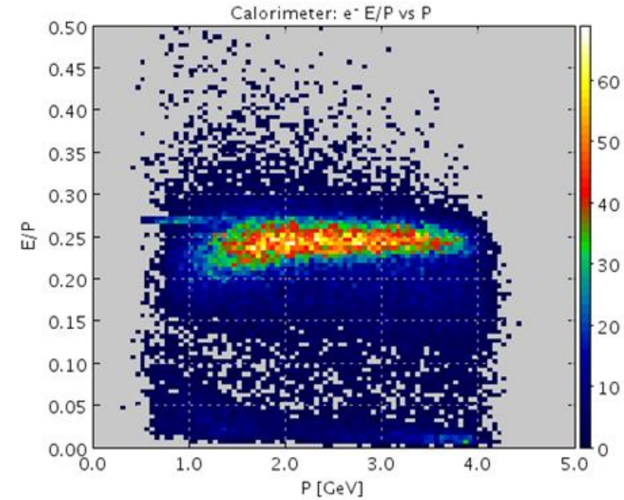


Reconstructed DVπ^0P event

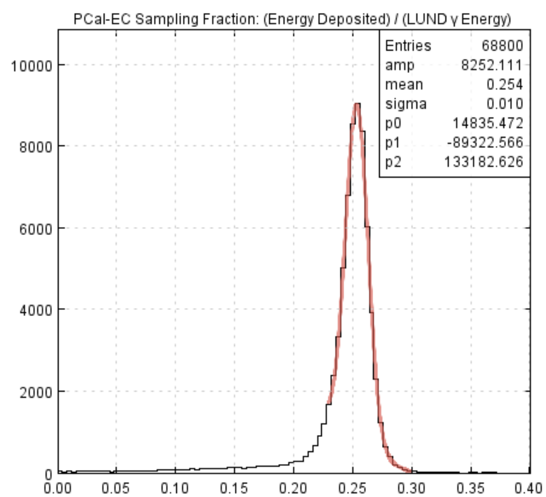
Validation and Development of CLAS12 Reconstruction Package



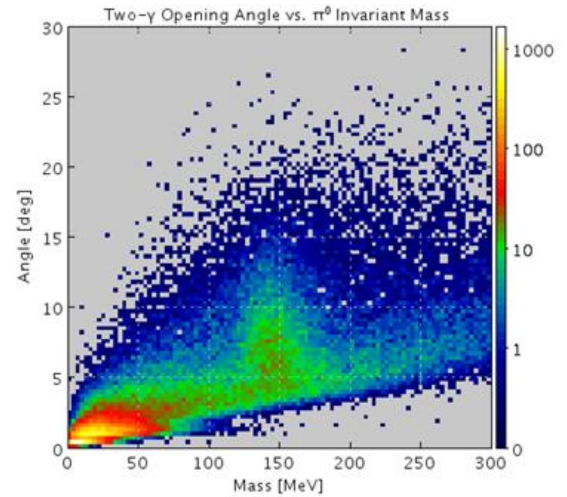
HTCC and EC responses for electron ID



Reconstructed electron momentum and deposited energy



Sampling fraction for photon energy reconstruction



Reconstructed 2-γ invariant mass and opening angle

French Hadron Physics Group and Collaborators

[Phenomenology of Generalized Parton Distributions]

[PARTONS Project]

Korean Hadron Physics Group and Collaborators

KNU Theory Group

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