Toward a 3D map of the quarks in the atomic nuclei

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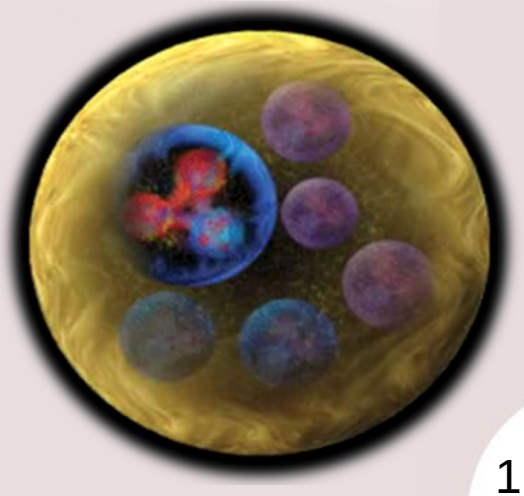

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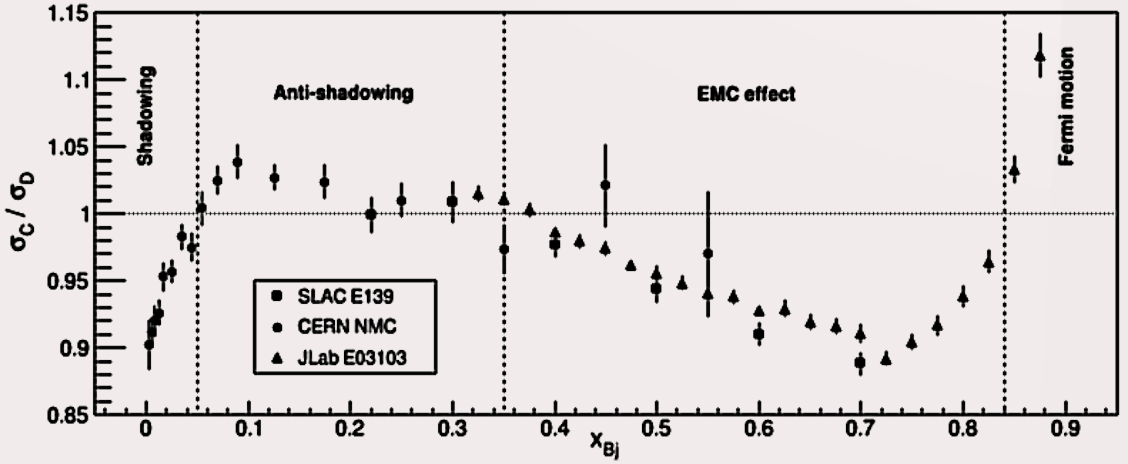
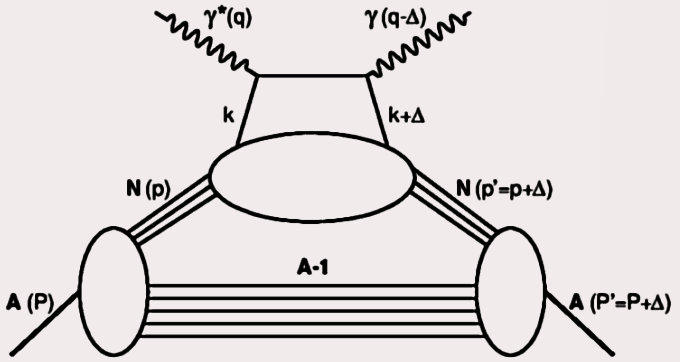
DVCS on Nuclei

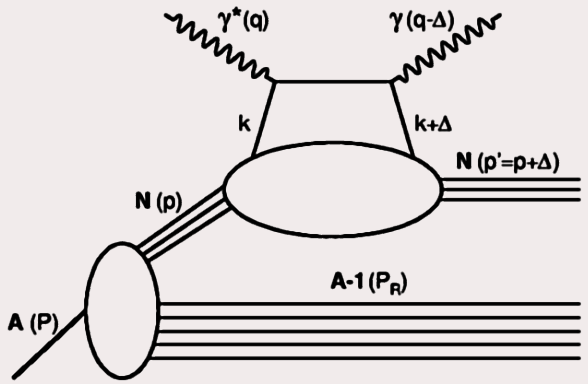
- **Coherent and incoherent**
  - Nuclei vs bound nucleon
- **The spin-0 simplification**
  - Only one GPD for Helium-4

    → 2 CFFs
  - Allows model independent extraction of the GPD
- **Impulse plane wave approximation**
  - Convolution of nucleons in nuclei and partons in nucleons distributions
  - Only nucleons are considered

    → Allows to probe non-nucleonic degrees of freedom
  - No interaction with A-1
  - Fermi motion (including some off-shellness)
- **Perfect probe into the EMC effect**
  - Offer localization with the *t* dependence
  - Gives access to non-nucleonic degrees of freedom

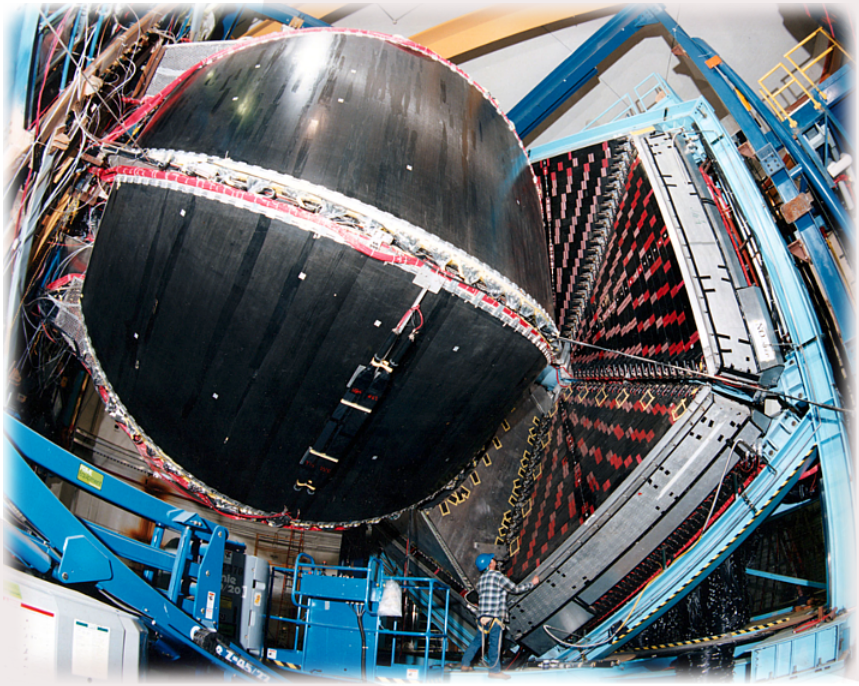






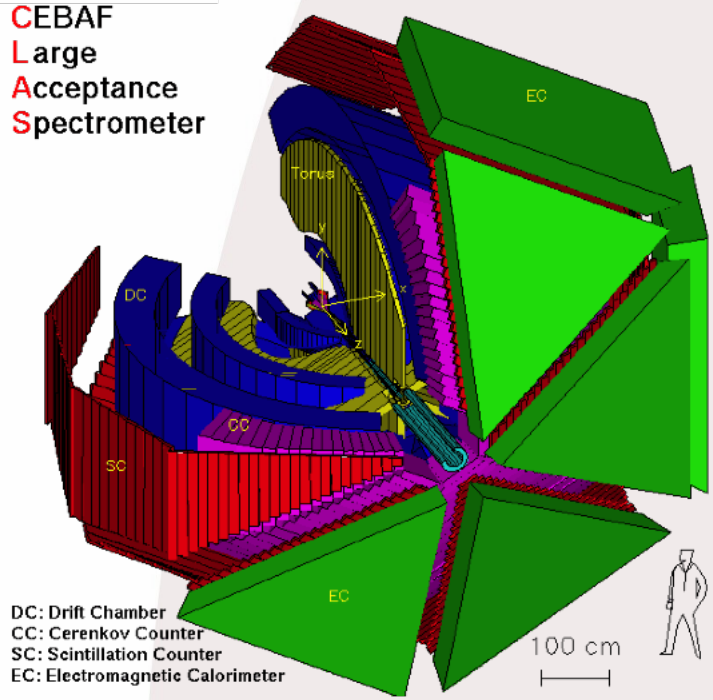
Measuring DVCS on Helium

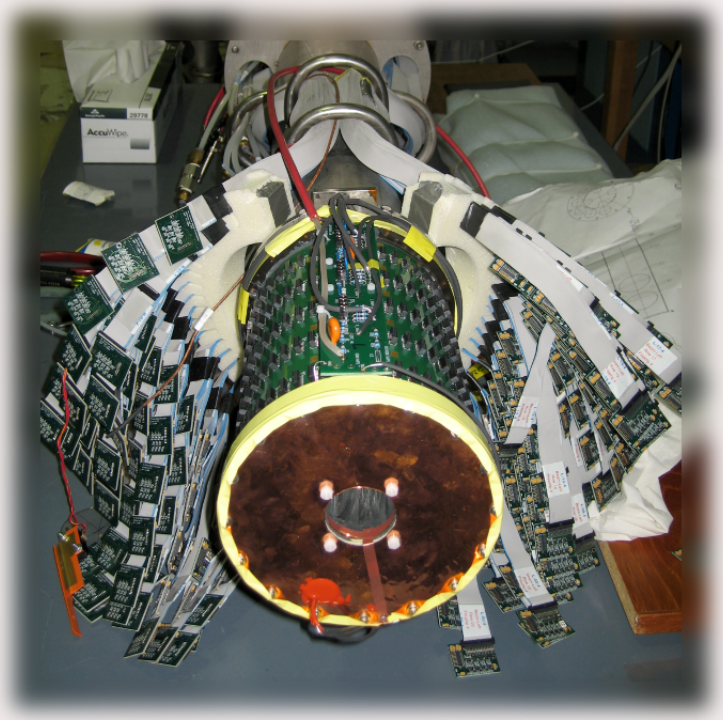
- **Jefferson Laboratory**
  - Provides a 6 GeV electron beam (now up to 12 GeV)
  - High quality beam
    - 100% duty factor
    - Around 150 µm wide
    - Intensity up to 100 µA



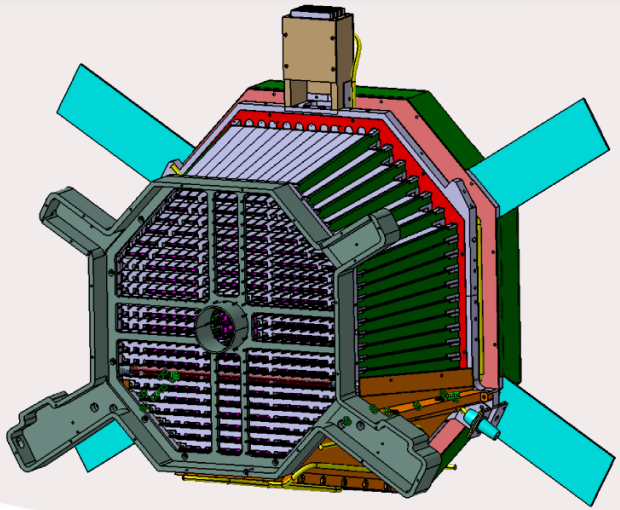
- **CEBAF Large Acceptance Spectrometer**
  - Nearly 4π
  - Offers electron and proton identification for our experiment
  - Recording rates up to 8 kHz

Experimental Apparatus

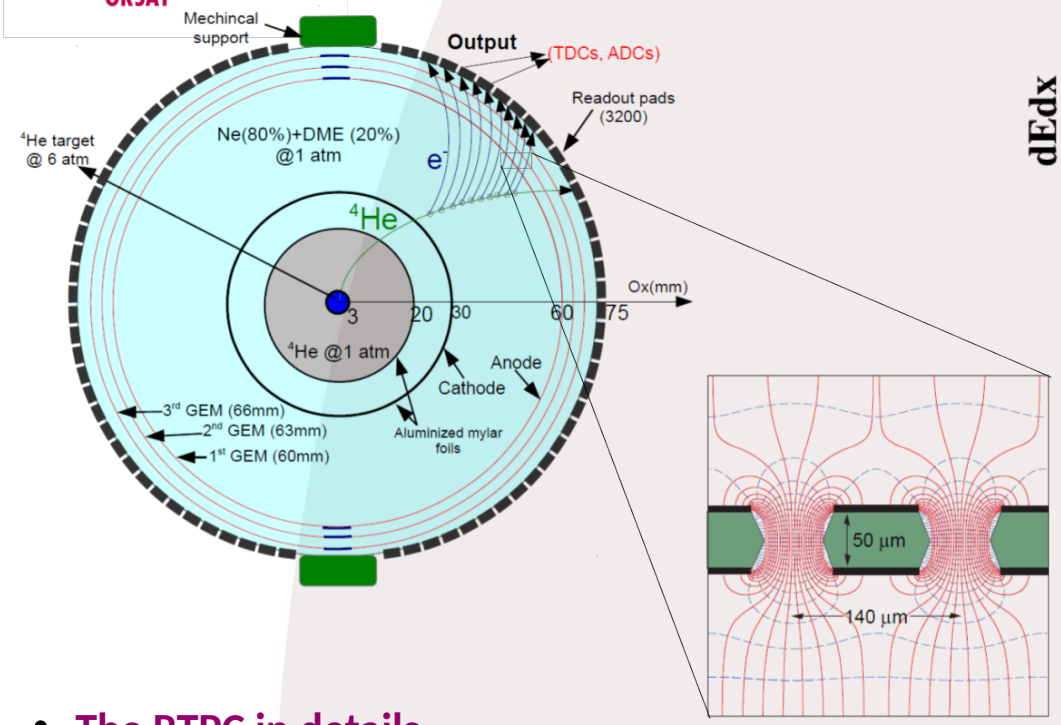




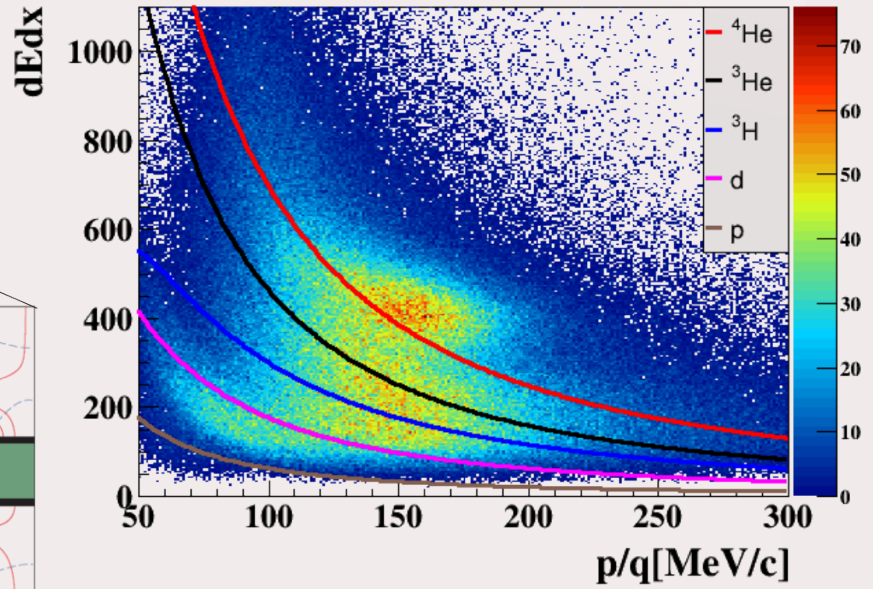
- **Experimental challenges**
  - Detecting very forward photons
  - Detecting very low energy alphas (~7 MeV)
- **Radial Time Projection Chamber**
  - Small TPC placed around the target
- **Inner Calorimeter**
  - Very forward electromagnetic calorimeter

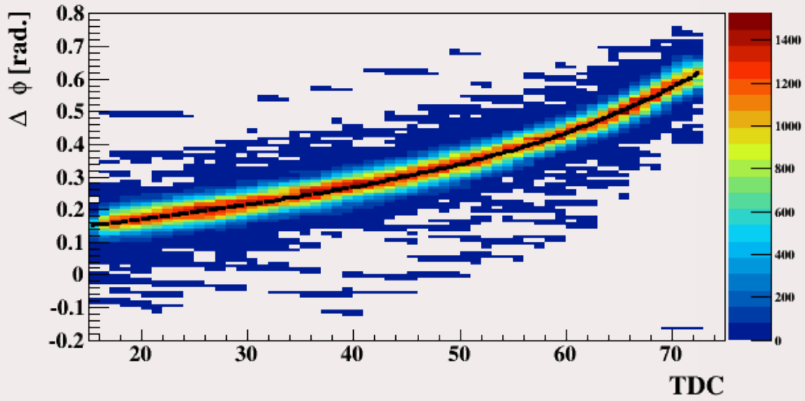


The RTPC detector



Good tracks @ 1.2 GeV

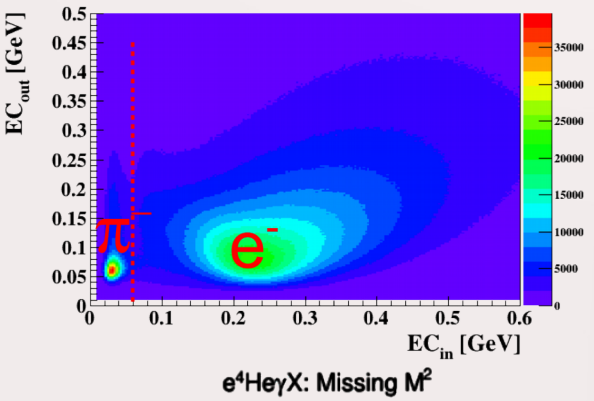


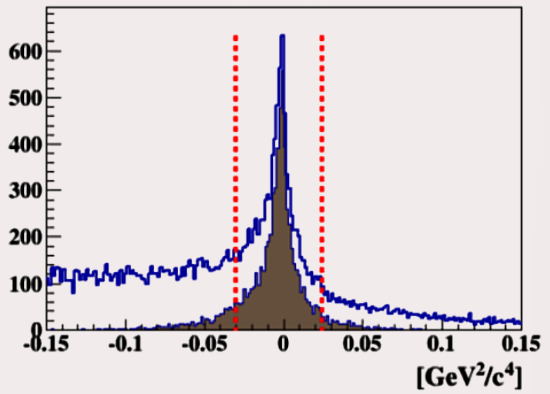


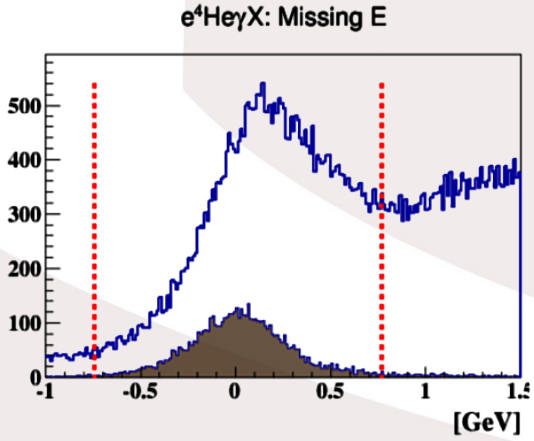
- **The RTPC in details**
  - 250mm long / 150mm diameter
  - Drift region of 30mm (1500V)
  - Amplification is obtained with 3 layers of GEM
  - Signal is collected on 3200 pads in 100 ns time bins
- **Solenoid**
  - 4.5 T to shield from Moller electrons and curve particles in the RTPC
- **Calibration**
  - Use of Helium elastic scattering obtained with 1.2 GeV electron beam

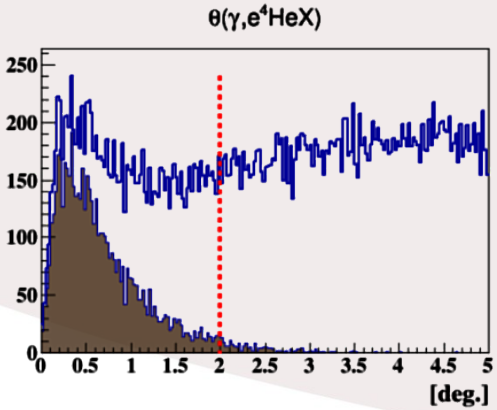
Selecting DVCS

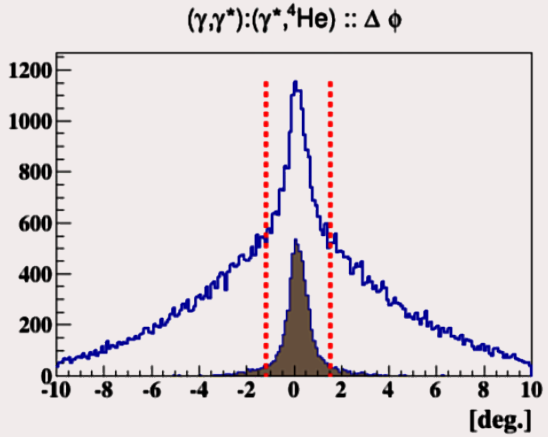
- **Particle Identification**
  - Identification of electron, protons, photons and helium nuclei
- **Exclusivity cuts**
  - Perform missing energy and momentum cuts to insure that we have all the products
- **Corrections**
  - Subtract the irreducible π^0 background
  - Associated systematic errors appear much smaller than the statistical errors
- **Identical for both coherent and incoherent channels**



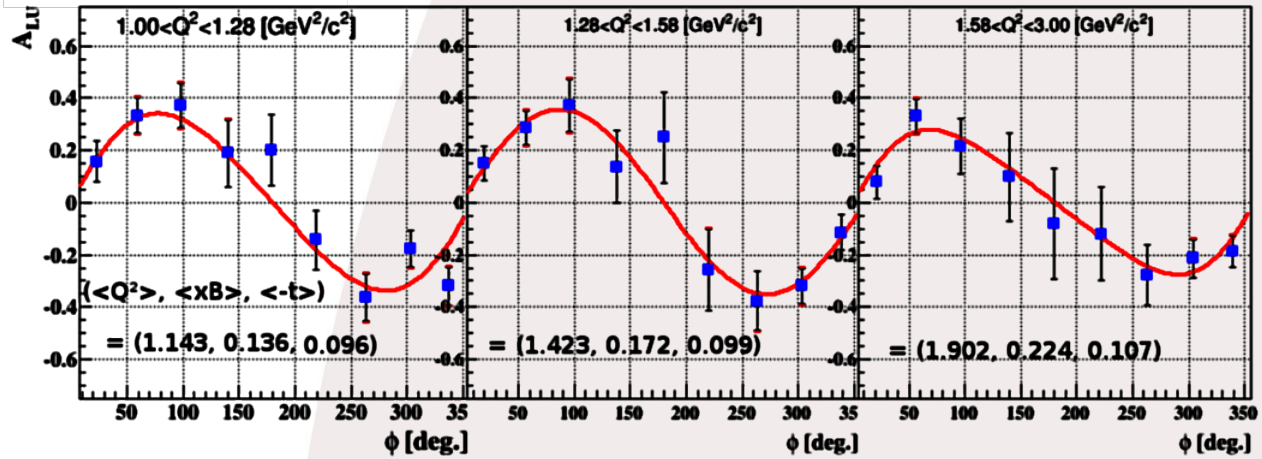


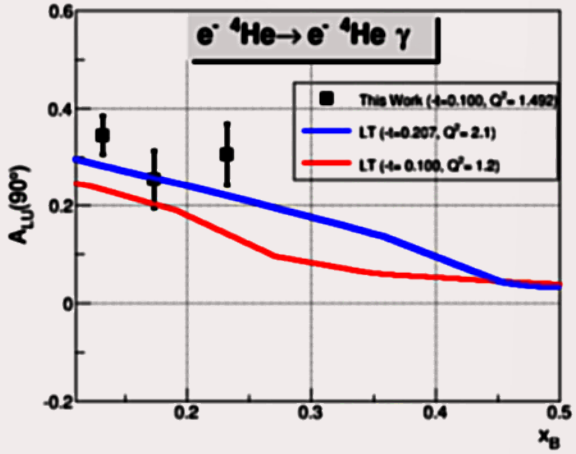




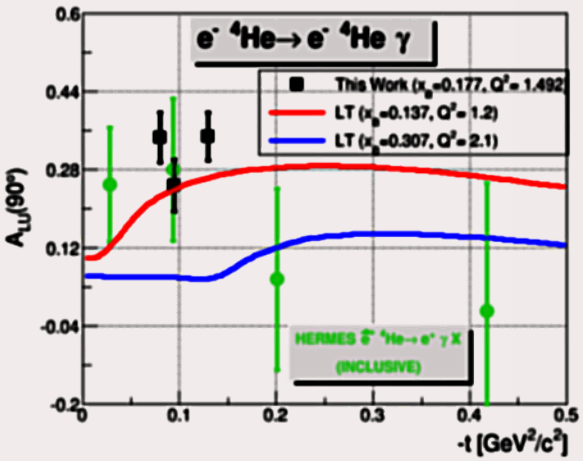


The Coherent DVCS





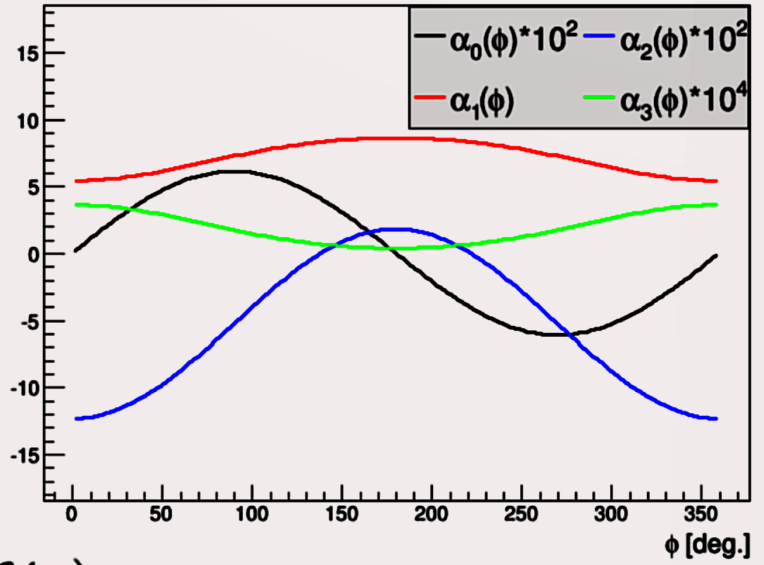
$$A_{LU} = \frac{d^5\sigma^+ - d^5\sigma^-}{d^5\sigma^+ + d^5\sigma^-} = \frac{1}{P_B}\frac{N^+ - N^-}{N^+ + N^-}$$



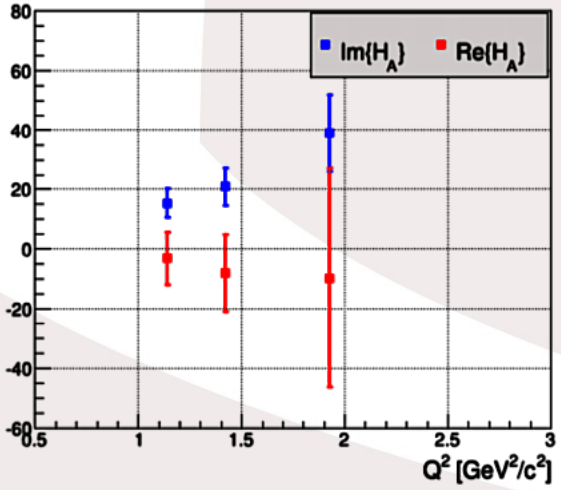
- **Coherent DVCS on helium**
  - Shows very strong beam spin asymmetry
  - Expected factor ~2 increase from PWIA prediction
- **Interpretation**
  - The very strong signal proves that we are indeed probing the nuclei as a whole
  - Predictions based on binding are significantly below our measurement

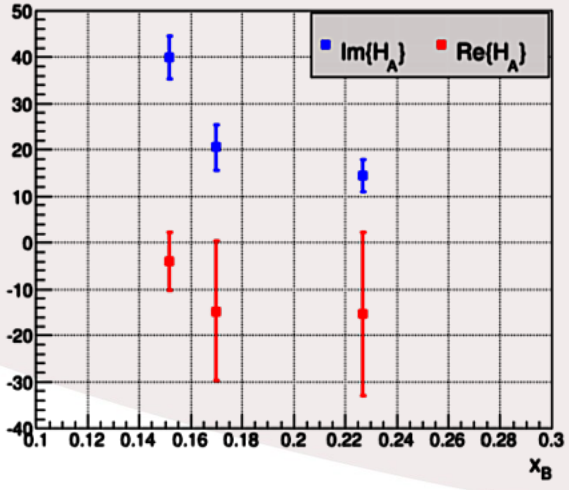
Extraction of the CFF

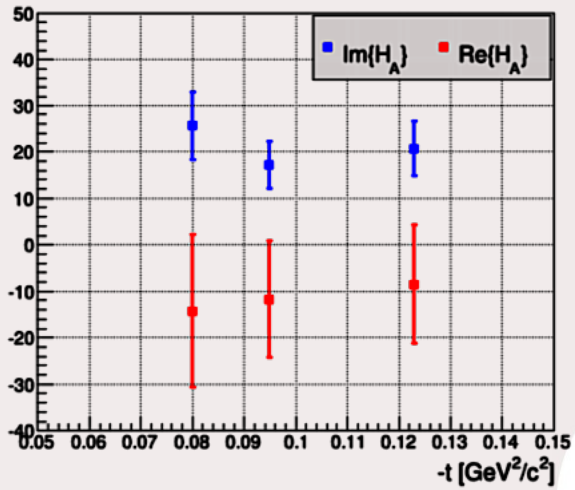
- **Simple extraction**
  - Spin-0 → 1 GPD → 2 CFF
  - Their different contributions in phi allows to separate their contributions
  - The different contributions are exactly calculable within perturbative QCD
  - We are mostly sensitive at the imaginary part
  - More precise measurement will be needed to extract the real part



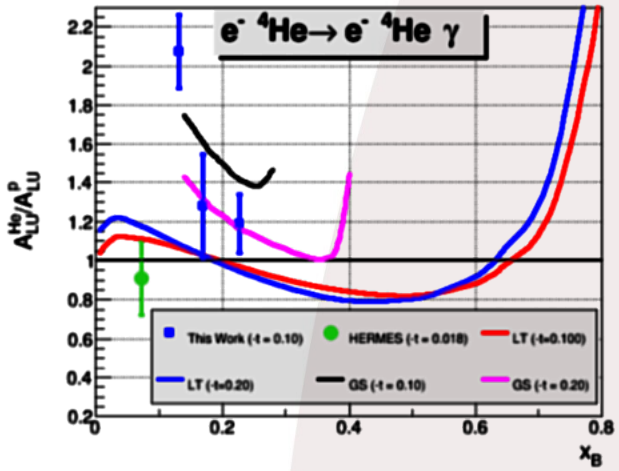
$$A_{LU}(\phi) = \frac{\alpha_0(\phi)\,\Im m(\mathcal{H}_A)}{\alpha_1(\phi) + \alpha_2(\phi)\,\Re e(\mathcal{H}_A) + \alpha_3(\phi)\,\left(\Re e(\mathcal{H}_A)^2 + \Im m(\mathcal{H}_A)^2\right)}$$

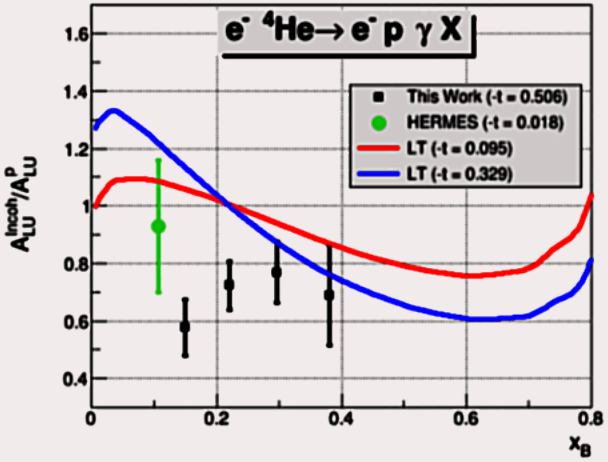


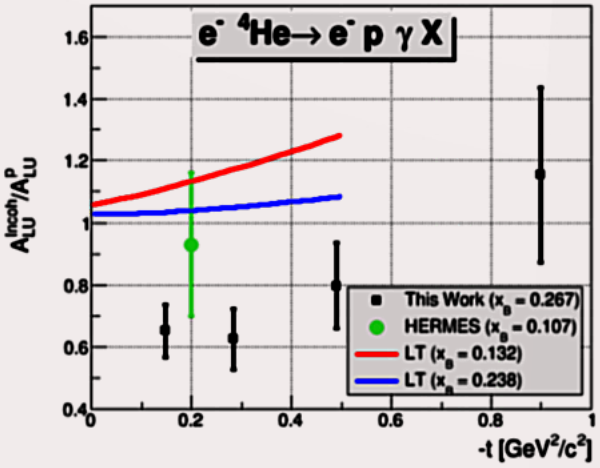


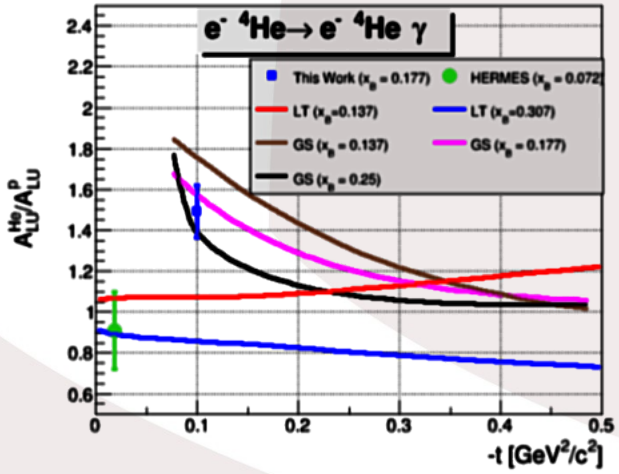


The Generalized EMC Ratio









Generalized EMC ratio

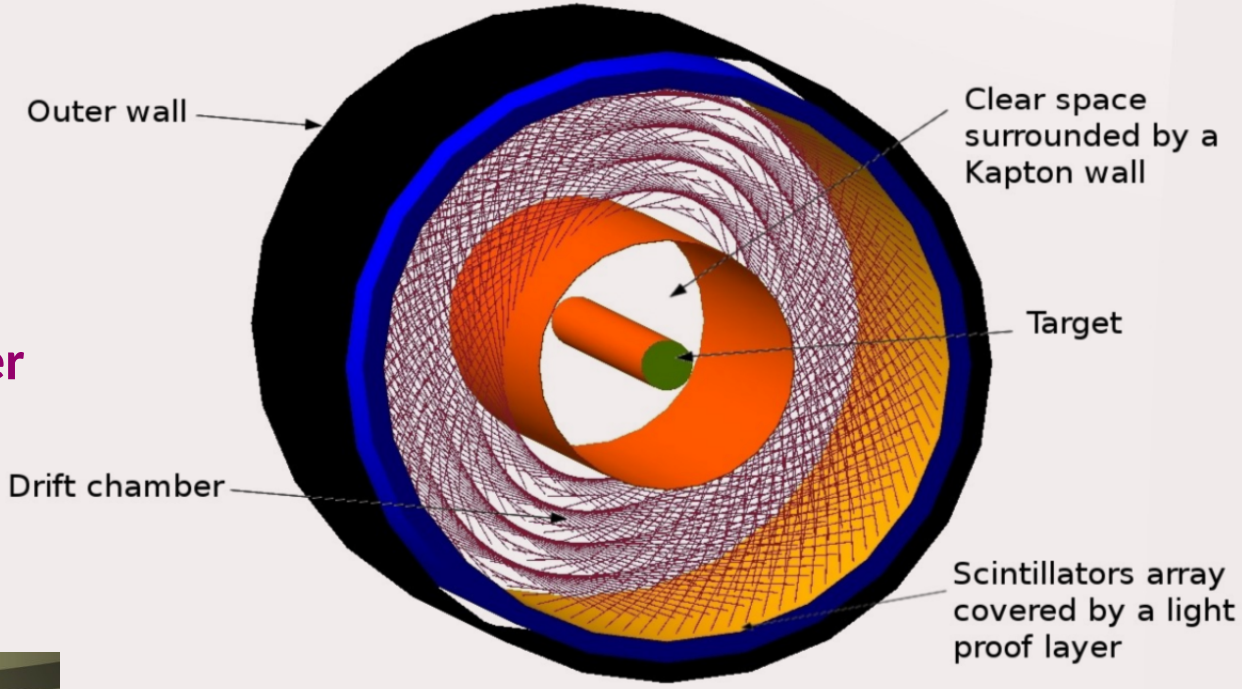
- Coherent/proton
  - The expected form factor slope is present

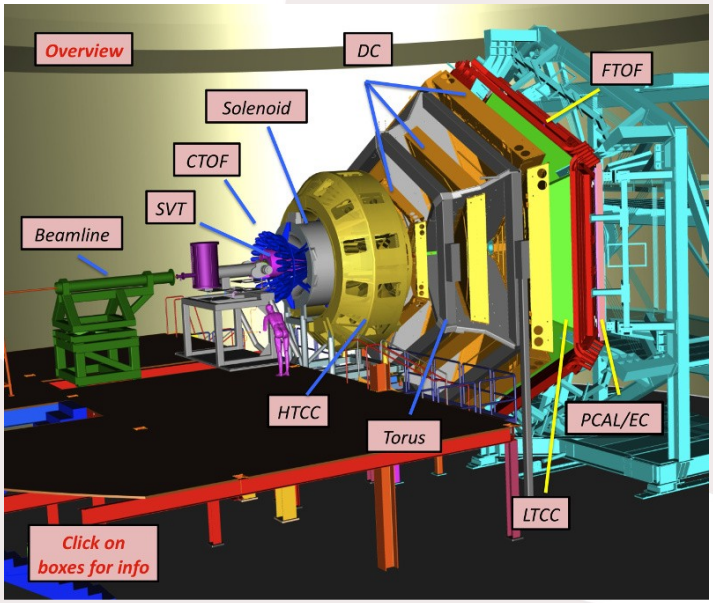
    V. Guzey and M. Strikman Phys. Rev. C 68, 015204
- Incoherent/proton
  - Suppressed compared to the binding model from

    S. Liuti and S.K. Taneja Phys.Rev. C72 (2005) 032201

Going to CLAS12

- **An extension at CLAS12**
  - For more statistics
  - And more kinematic coverage
- **Possibility to look at other nuclei and processes**
  - DVCS on deuterium
  - Tagged EMC





- **The ALERT detector**
  - Different technologies:
    - Drift Chamber & Scintillators
    - On going R&D
  - Faster detector
    - Allow integration in the trigger
    - Necessary to get maximum luminosity

Summary

- **We now explore nuclei in 3D with DVCS**
  - The theory is solid and actually simpler than for nucleons
  - Data has confirmed our expectations
- **It is important to expend measurements to nuclei**
  - It is what we need to explain the EMC effect
  - It is a whole new view into the nuclei beyond nucleons
- **The first exclusive measurement of nuclear DVCS has been performed in JLab**
  - Using a low energy RTPC for helium recoils
  - First results show basic trends:
    - Large asymmetry signal for coherent DVCS
    - Suppression on the incoherent channel
- **Perspectives**
  - More theoretical work will come with these new results
  - We will extend our measurement with JLab 12 GeV