Nucleon Structure Studies with CLAS12 at Jefferson Lab: Timelike Compton Scattering

13 November 2020

Pierre Chatagnon *for the ee analysis group*

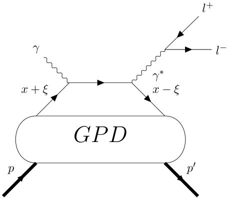
November 2020 CLAS collaboration meeting

chatagnon@ipno.in2p3.fr

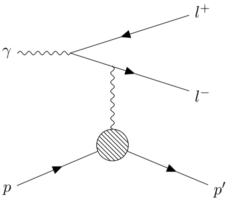
From DVCS to TCS

DVCS: $ep \to e'p'\gamma$ **TCS**: $\gamma p \to e^+e^-p'$

TCS



Bethe-Heitler



TCS process

In the Bjorken regime ($Q'^2 \gg t$) **factorization** applies. The real photon scatters off a single quark.
The soft part is parametrized by **GPDs**, which appears in integrals called **CFFs**.
DVCS: $\gamma^* p \to \gamma p'$ **TCS**: $\gamma p \to \gamma^* p'$

Compton Form Factors

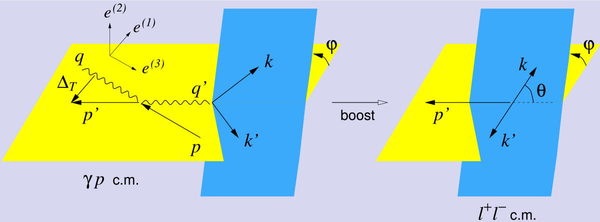
$$\mathcal{H} = \sum_q e_q^2 \{ i\pi \left[H^q(\xi,\xi,t) - H^q(-\xi,\xi,t) \right] + \mathcal{P} \int_{-1}^{1} dx H^q(x,\xi,t) \left[\frac{1}{\xi - x} - \frac{1}{\xi + x} \right] \}$$

$\gamma p \to e^+e^-p'$ cross section

$$\sigma_{\gamma p \to e^+e^-p} = \sigma_{TCS} + \sigma_{BH} + \sigma_{INT}$$

The TCS-only cross section is orders of magnitude lower than the BH one.
The contribution from **BH-TCS interference** is also sensitive to CFFs (in a linear manner).

$\gamma p \to e^+ e^- p'$ kinematics and cross sections



TCS	DVCS
$Q'^2 = (k+k')^2$	Q^2
$t = (p'-p)^2$	t
$\tau = \frac{Q'^2}{2p\cdot q}$	x_B
$\xi = \frac{\tau}{2-\tau}$	ξ

Figure and formulae in Berger et al., *The European Physical Journal C*, 2002

$L = \frac{(Q'^2-t)^2-b^2}{4}$ $\quad L_0 = \frac{Q'^4 \sin^2\theta}{4}$ $\quad b = 2(k-k')(p-p')$ $\quad s = (p+q)^2$ $\quad t_0 = -\frac{4\xi^2 M^2}{(1-\xi^2)}$

BH cross section

$$\frac{d\sigma_{BH}}{dQ^2\, dt\, d\Omega} \simeq \frac{\alpha_{em}^3}{2\pi s^2}\frac{1}{-t}\frac{1+\cos^2\theta}{\sin^2\theta}\left[\left(F_1^2 - \frac{t}{4m_p^2}F_2^2\right)\frac{2}{\tau^2}\frac{\Delta_T^2}{-t} + (F_1+F_2)^2\right]$$

Unpolarized interference cross section

$$\frac{d^4\sigma_{INT}}{dQ'^2 dt d\Omega} = -\frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{m_p}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}\left[\cos(\phi)\frac{1+\cos^2(\theta)}{\sin(\theta)}\mathrm{Re}\tilde{M}^{--} + \ldots\right]$$

$$\to \tilde{M}^{--} = \frac{2\sqrt{t_0-t}}{M}\frac{1-\xi}{1+\xi}\left[F_1\mathcal{H} - \xi(F_1+F_2)\tilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}\right]$$

$\gamma p \to e^+ e^- p'$ kinematics and cross sections

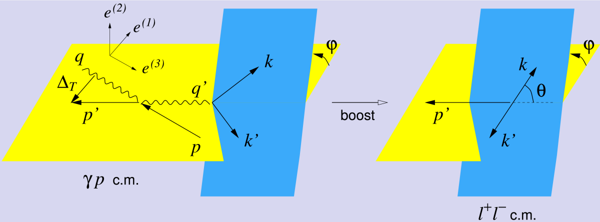


Figure and formulae in Berger et al., *The European Physical Journal C*, 2002

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$\xi = \frac{\tau}{2-\tau}$	ξ

$L = \frac{(Q'^2-t)^2-b^2}{4}$ $\quad L_0 = \frac{Q'^4 \sin^2\theta}{4}$ $\quad b = 2(k-k')(p-p')$ $\quad s = (p+q)^2$ $\quad t_0 = -\frac{4\xi^2 M^2}{(1-\xi^2)}$

Polarized interference cross section

$$\frac{d^4\sigma_{INT}}{dQ'^2 dt d\Omega} = \frac{d^4\sigma_{INT}\,|_{\mathrm{unpol.}}}{dQ'^2 dt d\Omega}$$

$$-\nu \frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{M}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}\left[\sin(\phi)\frac{1+\cos^2(\theta)}{\sin(\theta)}\,\mathrm{Im}\tilde{M}^{--} + \ldots\right]$$

$$\to \tilde{M}^{--} = \frac{2\sqrt{t_0-t}}{M}\frac{1-\xi}{1+\xi}\left[F_1\mathcal{H} - \xi(F_1+F_2)\tilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}\right]$$

Both $\mathrm{Im}\mathcal{H}$ and $\mathrm{Re}\mathcal{H}$ can be accessed in TCS

Motivations to measure TCS

Test of universality of GPDs

- TCS is parametrized by GPDs
- **Comparison between DVCS and TCS** results allows to test the **universality** of GPDs
- TCS does not involve Distribution Amplitudes unlike Deeply Virtual Meson Production
  $\rightarrow$ direct comparison between DVCS and TCS

Real part of CFFs and nucleon D-term

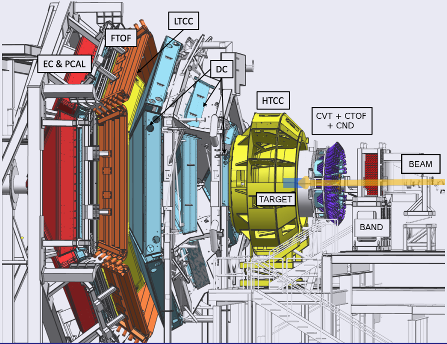
- As for DVCS, TCS unpolarized cross section is sensitive to $\mathrm{Re}\mathcal{H}$, which is still not well constrained by existing data.
- The CFFs dispersion relation at leading order and leading twist :

$$\mathrm{Re}\mathcal{H}(\xi, t) = \mathcal{P}\int_{-1}^{1} dx \left(\frac{1}{\xi - x} - \frac{1}{\xi + x}\right) \mathrm{Im}\mathcal{H}(\xi, t) + D(t)$$

- $D(t)$ can be related to the **mechanical properties** of the nucleon.

Review in Polyakov, Schweitzer, *International Journal of Modern Physics A*, 2018

Experimental setup and data set



Usual RG-A configuration of CLAS12

Figure in Burkert et al., *NIM A*, 2020

Data set used in this work

- **Fall 2018** run period
- ***LH_2*** target / **10.6 GeV** beam / RG-A
- Inbending torus magnetic field
- Accumulated charge: $\sim$ 150 mC ($\sim$ 200 fb^{-1})

Difficulties to combine with other data sets: $\neq$ beam energy, outbending ($\neq$ angular range)

Other TCS experiments

- CLAS12: first time measurement in the resonance free region
- Hall C: proposal for TCS on tranversely polarized target
- Solid: long-term project

Strategy of the analysis

$$e\ p \to (e')\gamma p \to (e')e^+e^-p'$$

1) Particle Identification

- Identify the detected particles for each event
- Calculate momenta/vertex of the identified particles

2) Corrections and fiducial cuts

- Correct the momenta of the particles
  - Energy loss from MC
  - Data driven corrections
- Apply fiducial cuts

3) Event Selection

- Exclusivity cuts
- Kinematic cuts

4) Computation of observables

- Cross-section ratio R
- Forward-backward asymmetry A_{FB}
- Photon polarization asymmetry *BSA*

5) Interpretation of the results

- Comparison with pure BH contribution from MC
- Model/data comparison (VGG and GK models)

Simulations

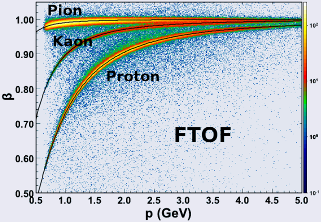
- $\gamma p \to e^+e^-p'$ weighted event generator, developed by R.Paremuzyan, validated during my thesis
- Final state particles are passed through *GEMC*

Particle identification

Hadrons (for protons)

- Tracking: p from curvature in the magnetic field
- Time-of-flight: t_{tof}
- $\beta = \frac{P_L}{t_{tof}\ c}$

→ Use nominal EB cuts (χ^2 cut included in systematics)



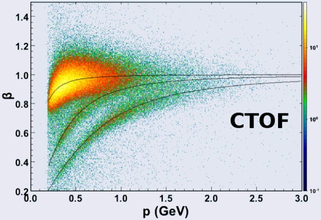


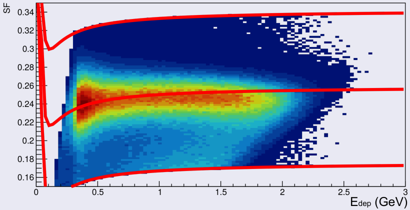
Figure in Burkert et al., *NIM A*, 2020

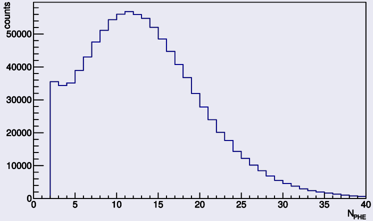
Leptons (for electrons and positrons)

Calorimeters: $SF = \frac{E_{dep}}{p}$

Cherenkov: $p_{Ch.} = \frac{mc}{\sqrt{n^2-1}}$

if p<4.9 GeV, $N_{PHE}(HTCC) > 2$





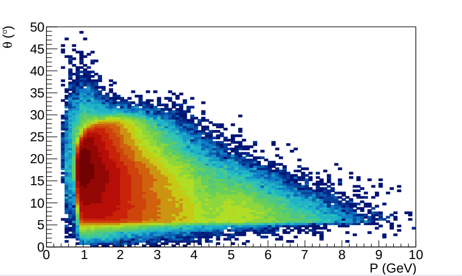
Positron identification (1)

Included in the RG-A analysis note ($\simeq$ 25th August 2020)

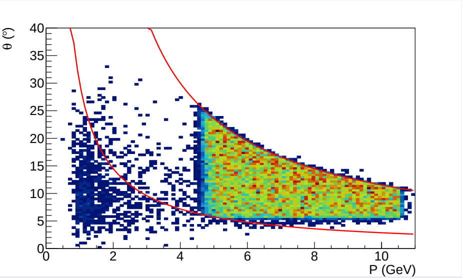
Evidence for π^+ identified as e^+ by the CLAS12 PID algorithm

Positrons identified by the CLAS12 PID

Data



Simulated π^+



Definitions

Signal: e^+ identified as e^+ Background: π^+ identified as e^+

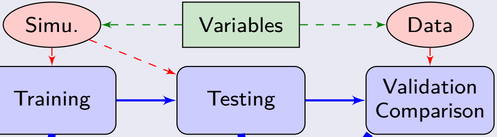
Strategy and discriminating variables

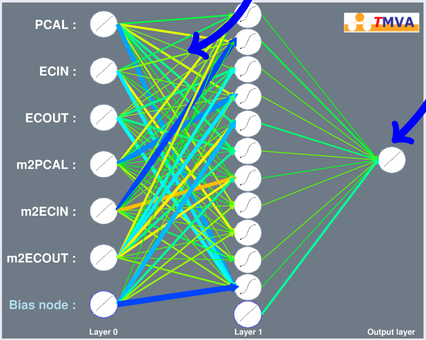
Positron: electromagnetic shower Pion: Minimum Ionizing Particle (MIP)

$$SF_{\text{EC Layer}} = \frac{E_{dep}(\text{EC Layer})}{P} \qquad M_2 = \frac{1}{3}\sum_{U,V,W} \frac{\sum_{\text{strip}} (x-D)^2 \cdot \ln(E)}{\sum_{\text{strip}} \ln(E)} \rightarrow \textbf{6 variables}$$

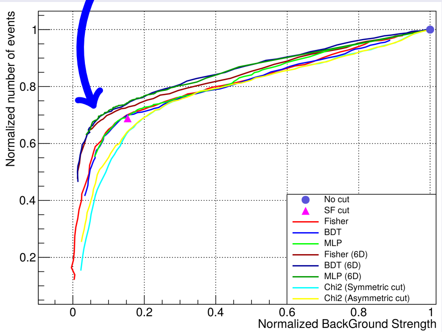
Positron identification (2)

Neural network analysis



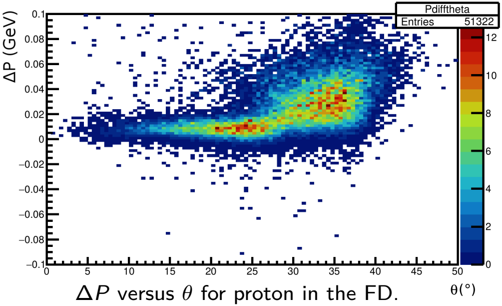


Signal $\rightarrow 1$ Background $\rightarrow 0$



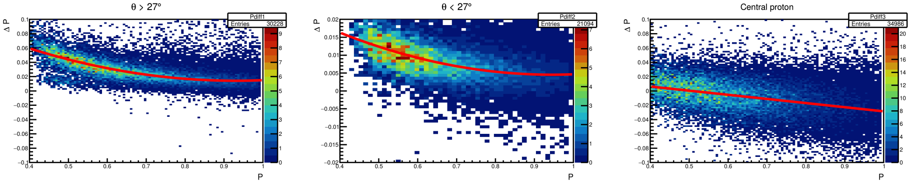
- Signal + Background $\Rightarrow \gamma p \rightarrow e^+ e^- p'$
- Background $\Rightarrow ep \rightarrow e\pi^+(n)$

Proton Momentum Corrections: MC corrections



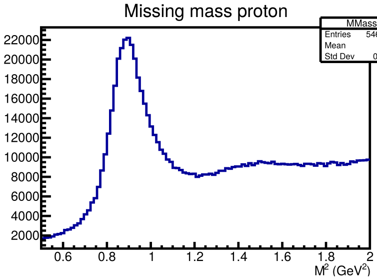
ΔP versus θ for proton in the FD.

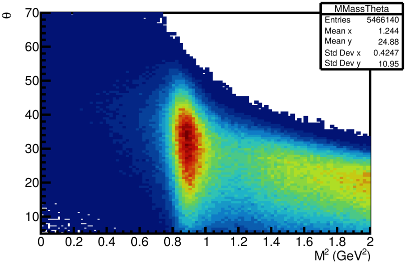
- TCS MC events are passed through the full chain simulation.
- Generated and reconstructed momenta for protons are compared.
- 3 regions are considered: FD $\theta < 27°$, FD $\theta > 27°$ and CD.



Momentum correction is parameterized as a function of P and corrected in simulation and data.

Proton Momentum Corrections: Central corrections (1)

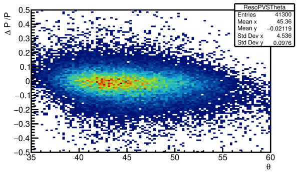


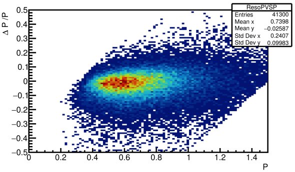


Missing proton mass spectrum; as a function of the missing particle θ angle.

- Aims at correcting the momentum reconstruction in the CVT.
- Use $ep \to e(p')\pi^+\pi^-$ reaction, where the missing proton goes in the CD. Missing proton kinematics are compared to reconstructed ones.
- At $\theta > 37^\circ$, there is very low background $\to$ clean one-to-one matching

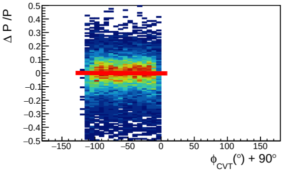
Proton Momentum Corrections: Central corrections (2)

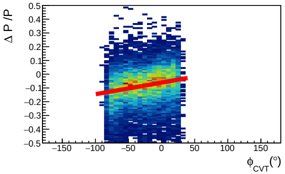


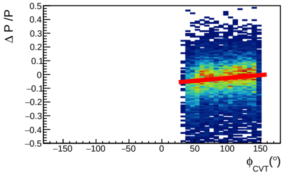


- No large shift seen in the θ and momentum dependence

$\Delta P/P$ versus θ and momentum for proton in the CD



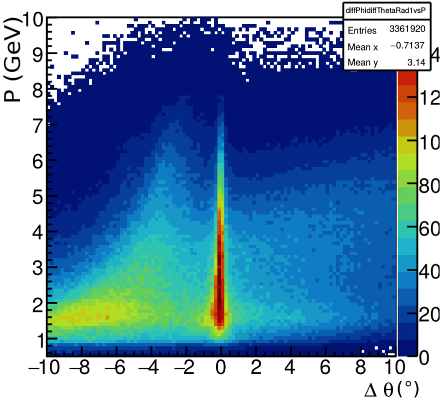




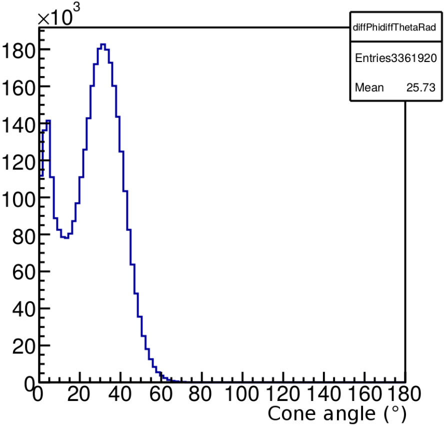
$\Delta P/P$ versus ϕ_{CVT} for the three sectors of the CVT, and the last layer (id 12) of the CVT

- Correction applied for each of the three regions, only for data.
- $\frac{\Delta P}{P}$ is parametrized as a function of the local ϕ angle of the last layer of the CVT

Lepton Momentum Corrections: photon corrections at the vertex



$\Delta\theta_{e^-/\gamma}$ versus P_{e^-} (DATA)



Cone angle between electrons and photons.

At the vertex, some photons are produced very close to leptons. γ momenta is added to the lepton momentum within $-1.5^\circ < \Delta\theta < 1.5^\circ$ and *Cone angle* $< 10^\circ$. Applied in both simulation and data. Full details were given in Joseph's talk yesterday.

Event selection

Final state selection from PID

$$e\ p \rightarrow (e')\gamma p \rightarrow (X)\ \overbrace{e^+ e^- p'}$$

Exclusivity cuts

$p_X = p_{beam} + p_{target} - p_{e^+} - p_{e^-} - p_{p'}$

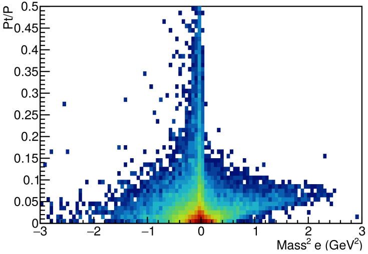
$|M_X^2| < 0.4\ \mathrm{GeV}^2$

Quasi-real photoproduction

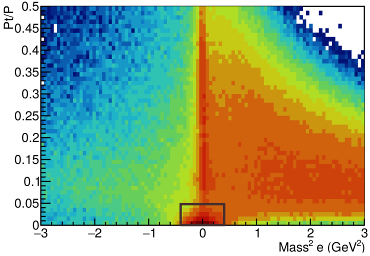
$$\frac{Pt_X}{P_X} < 0.05$$
$$\rightarrow Q^2 < 0.1\ \mathrm{GeV}^2$$

Values of the cuts from simulations

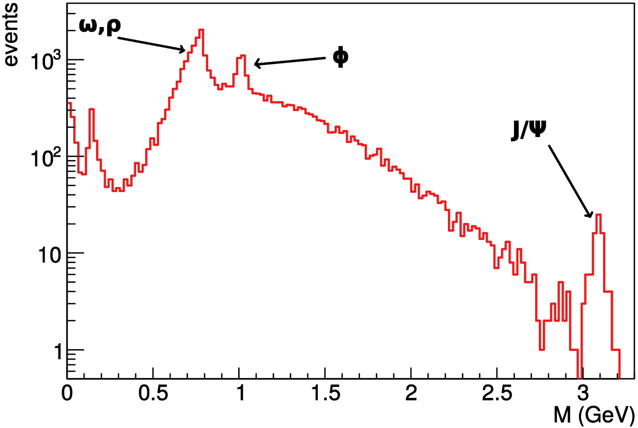
Simulation



Data

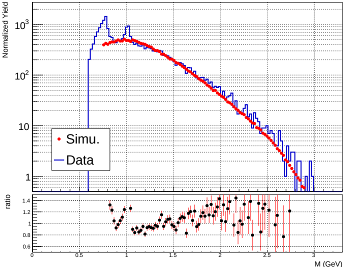


Lepton pair mass spectrum



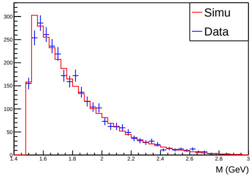
Vector mesons peaks are visible: ω (770 MeV), ρ (782 MeV), Φ (1020 MeV) and J/Ψ (3096 MeV)

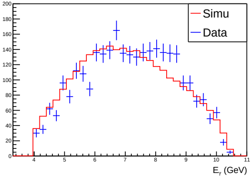
Data/Simulation comparison



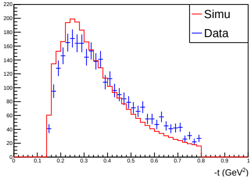
Phase space of interest

- $1.5\ \mathrm{GeV} < M_{e^+e^-} = \sqrt{Q'^2} < 3\ \mathrm{GeV}$
- $0.15\ \mathrm{GeV}^2 < -t < 0.8\ \mathrm{GeV}^2$
- $4\ \mathrm{GeV} < E_\gamma < 10.6\ \mathrm{GeV}.$

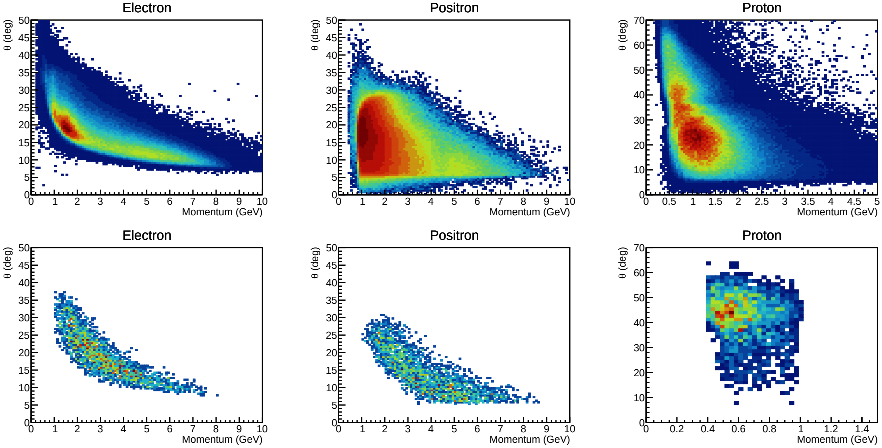




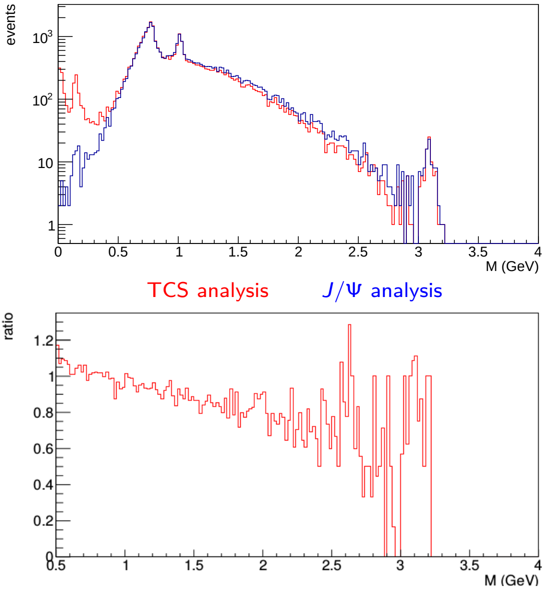
- Data/BH comparison in the high mass region
- No evident high mass vector meson production (ρ (1450 MeV, 1700 MeV))



Kinematics


Electron
Positron
Proton
θ (deg)
Momentum (GeV)
Electron
Positron
Proton
θ (deg)
Momentum (GeV)

Analysis cross-check (in progress)



Cross-check using the parallel analysis of J. Newton on J/Ψ. Different cuts are used:

- Different method for positron ID
- HTCC timing cut to reduces low-mass BG
- Different fiducial cuts

Slight discrepancy is being investigated.

Acceptance

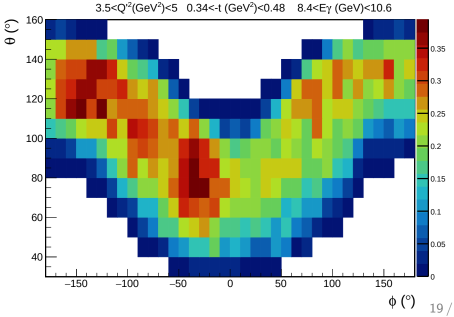
Acceptance calculation using BH-weighted events

$$Acc_{\mathcal{B}} = \frac{N_{\mathcal{B}}^{REC}}{N_{\mathcal{B}}^{GEN}} \qquad N_{\mathcal{B}}^{REC} = \sum_{REC \in \mathcal{B}} Eff_{corr}\ w \qquad N_{\mathcal{B}}^{GEN} = \sum_{GEN \in \mathcal{B}} w$$

Multidimensional binning of the acceptance

4 bins in $-t$, 3 bins in E_γ and Q'^2, 10° x 10° bins in the ϕ/θ plane. Bins with $\frac{\Delta Acc}{Acc} > 0.5$ and $Acc < 0.05$ are discarded (ΔAcc is statistical error).

Large region with no acceptance ($\phi \sim 0^\circ/\theta \sim 180^\circ$ and $\phi \sim 180^\circ/\theta \sim 0^\circ$)



Currently used

Efficiency correction from **background merging** using random trigger events

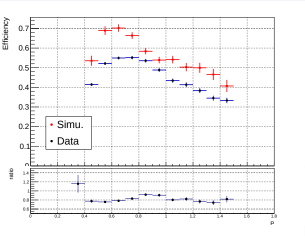
Being validated

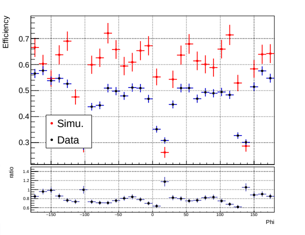
Data-driven correction for the proton detection efficiency derived using $ep \to e'\pi^+\pi^-(p')$ reaction

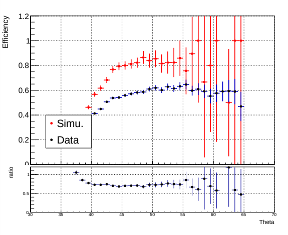
Data driven proton efficiency correction (validation in progress)

Use $ep \to ep'\rho \to e(p')\pi^+\pi^-$ reaction (data or *genev* simulation), using kinematic variables of the missing proton.

In the CD







$$Eff_{DATA} = \frac{N_{REC}}{N_{Missing}} \qquad Eff_{SIMU} = \frac{N_{REC}}{N_{Missing}} \qquad Eff_{Corr} = \frac{Eff_{DATA}}{Eff_{SIMU}}$$

- In the CD: 4 bins in momentum, 2 bins in θ, 30 in ϕ
- In the FD: 1-dimension correction: 9 bins in momentum

- Ultimately, this correction will be included in the systematics.
- This correction is included in my thesis work, but need a final validation.

Timelike Compton Scattering with CLAS12

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Results

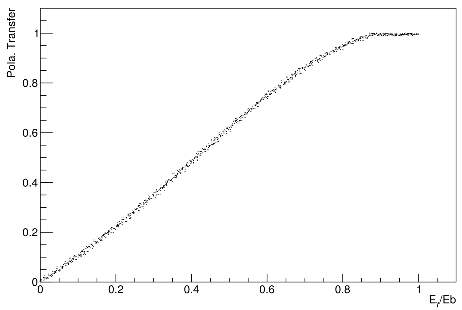
Observable 1: Photon polarization asymmetry (BSA)

Access to the imaginary part of CFFs

$$BSA = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{-\frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{m_p}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}\,\sin\phi\,\frac{(1+\cos^2\theta)}{\sin(\theta)}\,\mathrm{Im}\tilde{M}^{--}}{d\sigma_{BH}}$$

Experimental measurement

- $BSA(-t, E\gamma, M;\phi) = \frac{1}{Pol_{eff}}\frac{N^+ - N^-}{N^+ + N^-}$
  where $N^{\pm} = \sum \frac{1}{Acc} Pol_{transf.}$
- $Pol_{transf.}$ is the **transferred polarization** from the **electron to the photon**
- Pol_{eff} is the **polarization of the CEBAF** electron beam ($\simeq 85\%$)
- The ϕ-distribution is fitted with a sine function



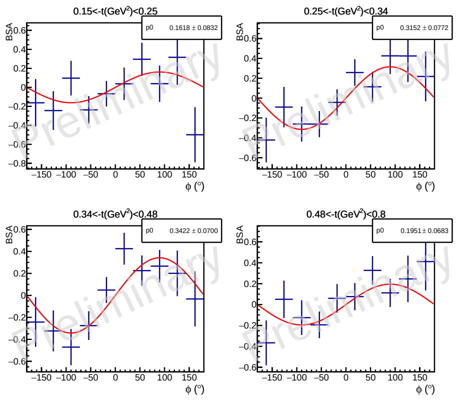
Observable 1: Photon polarization asymmetry (BSA)

Access to the imaginary part of CFFs

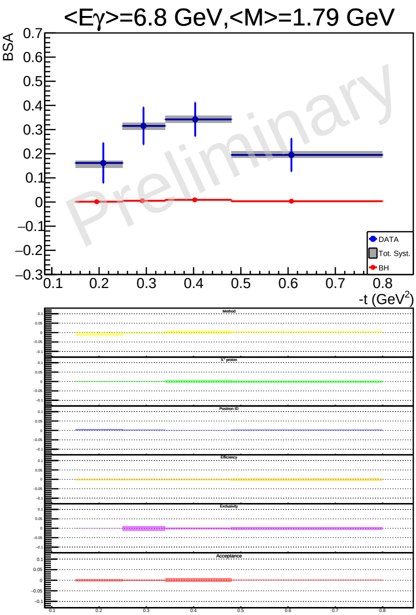
$$BSA = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{-\frac{\alpha_{em}^3}{4\pi s^2}\frac{1}{-t}\frac{m_p}{Q'}\frac{1}{\tau\sqrt{1-\tau}}\frac{L_0}{L}\,\sin\phi\,\frac{(1+\cos^2\theta)}{\sin(\theta)}\,\mathrm{Im}\tilde{M}^{--}}{d\sigma_{BH}}$$

Experimental measurement

- $BSA(-t, E\gamma, M; \phi) = \frac{1}{Pol_{eff}}\frac{N^+ - N^-}{N^+ + N^-}$ where $N^{\pm} = \sum \frac{1}{Acc} Pol_{transf.}$
- $Pol_{transf.}$ is the **transferred polarization** from the **electron to the photon**
- Pol_{eff} is the **polarization of the CEBAF** electron beam ($\simeq 85\%$)
- The ϕ-distribution is fitted with a sine function



Systematics



Method

- Calculate observable in CLAS12 acceptance for generated BH events, and full-chain simulated events.

χ^2 proton

- Calculate observable without cut on the proton ID χ^2 or with a 3-σ cut

Positron Identification

- Vary the positron ID cut (0.5 ± 0.1)

Efficiency

- With BG merging or with proton efficiency

Exclusivity cuts

- Vary the values of the exclusivity cuts: $0.04 < Pt/P < 0.05$, $0.3\ \mathrm{GeV}^2 < M_X^2 < 0.4\ \mathrm{GeV}^2$

Dominant systematic uncertainty

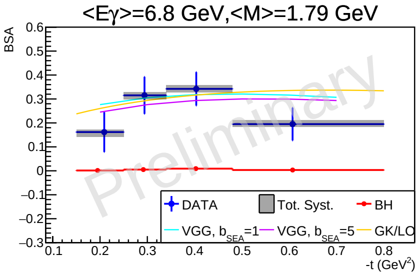
Acceptance

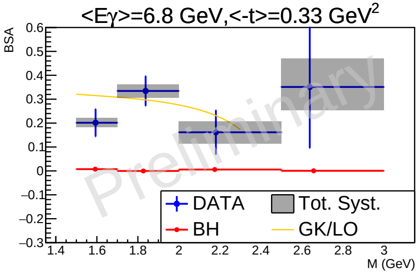
- Calculate observable with acceptance produced using BH-weighted events or flat weights (equal to 1)

- Errors are added in quadrature for each bin
- Total syst. always smaller than stat. error

Results for the BSA

- First time measurement
- A **sizeable asymmetry** is measured (above the expected vanishing BSA of BH)
  $\rightarrow$ **signature of TCS**
- Experimental BSA measured in CLAS12 acceptance compared to model predictions integrated in $\theta \in [\pi/4, 3\pi/4]$, and evaluated at the BH mean kinematic point shown above each plot
- Theoretical predictions were provided by M.Vanderhaeghen (using the VGG model) and P.Sznajder (using the GK model)
- Size of the asymmetry is **well reproduced** by VGG and GK models
  $\rightarrow$ **model dependent hints for universality of GPDs**
- Mass-dependence is also consistent with the prediction of the GK model





Potentially publishable plots

Observable 2: cross-section ratio R

Weighted cross section ratio (Berger, Diehl, Pire (2002))

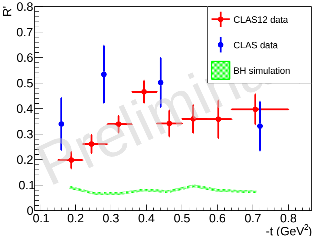
$$R(\sqrt{s}, Q'^2, t) = \frac{\int_0^{2\pi} d\phi \ \cos\phi \frac{dS}{dQ'^2 dt d\phi}}{\int_0^{2\pi} d\phi \frac{dS}{dQ'^2 dt d\phi}} \qquad \frac{dS}{dQ'^2 dt d\phi} = \int_{\pi/4}^{3\pi/4} d\theta \frac{L}{L_0} \frac{d\sigma}{dQ'^2 dt d\phi d\theta}$$

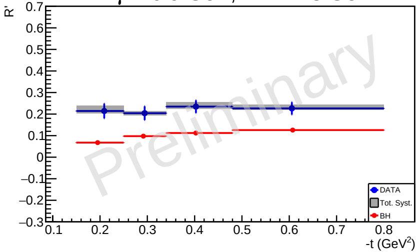
Experimental measurement

$$R' = \frac{\sum_\phi Y_\phi \cdot cos(\phi)}{\sum_\phi Y_\phi} \qquad Y_\phi = \sum_{\theta \in [\frac{\pi}{4}, \frac{3\pi}{4}]} \frac{L}{L_0} \frac{1}{Acc}$$

The sum is restricted to CLAS12 acceptance, inducing false asymmetries → comparison with models is difficult. Nevertheless, a clear signal is visible above the BH contribution

Comparison with CLAS unpublished results
$1.1 \text{ GeV} < M < 1.7 \text{ GeV}$





Observable 3: Forward-Backward asymmetry

- Concept explored for J/Ψ production (Gryniuk, Vanderhaeghen, *Phys. Rev. D*, 2016), no predictions for TCS have been published yet
- Use the different parity of the TCS and BH amplitudes under the inversion of the leptons
  $k \leftrightarrow k' \iff (\theta, \phi) \leftrightarrow (180^\circ - \theta, 180^\circ + \phi)$

BH cross section

$$\frac{d\sigma_{BH}}{dQ^2\, dt\, d\Omega} \propto \boxed{\frac{1+\cos^2\theta}{\sin^2\theta}} \xrightarrow{FB} \frac{d\sigma_{BH}}{dQ^2\, dt\, d\Omega}$$

Int. cross section

$$\frac{d^4\sigma_{INT}}{dQ'^2 dt d\Omega} \propto \boxed{\frac{L_0}{L} cos(\phi) \frac{1+cos^2(\theta)}{sin(\theta)}} \xrightarrow{FB} -\frac{d\sigma_{INT}}{dQ^2\, dt\, d\Omega}$$

A_{FB} formula

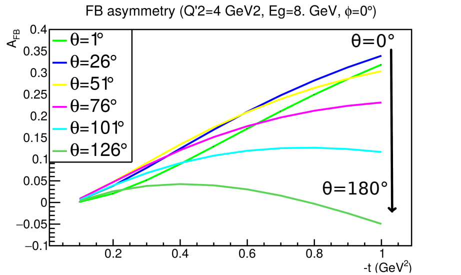
$$A_{FB}(\theta_0, \phi_0) = \frac{d\sigma(\theta_0, \phi_0) - d\sigma(180^\circ - \theta_0, 180^\circ + \phi_0)}{d\sigma(\theta_0, \phi_0) + d\sigma(180^\circ - \theta_0, 180^\circ + \phi_0)} = \frac{-\frac{\alpha_{em}^3}{4\pi s^2} \frac{1}{-t} \frac{m_p}{Q'} \frac{1}{\tau\sqrt{1-\tau}} \frac{L_0}{L} \cos\phi_0 \frac{(1+\cos^2\theta_0)}{\sin(\theta_0)} \boxed{\mathrm{Re}\tilde{M}^{--}}}{d\sigma_{BH}}$$

- Access to the real part of the CFFs with no integration over angles
- Removes large dependencies on angular acceptance $\rightarrow$ direct comparison with models
- But smaller phase space $\rightarrow$ lower statistics

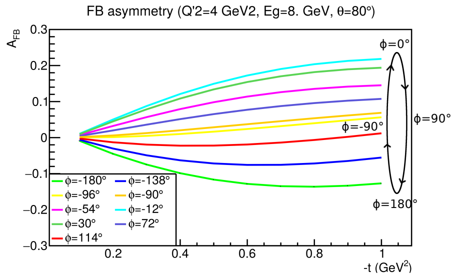
A_{FB} phenomenology

Kinematic and model dependencies (using the VGG model)

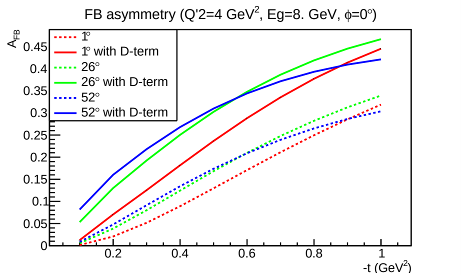
Dependence in θ



Dependence in ϕ



Impact of the D-term



- Kinematic dependencies were studied in order to determine the best integration range for the measurement

Experimental forward angular range

$$\phi \in [-40^\circ, 40^\circ],\ \theta \in [50^\circ, 80^\circ]$$

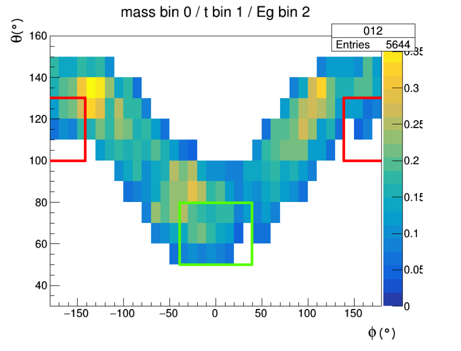
- The D-term has a large effect on the asymmetry

A_{FB} measurement

- Forward direction: Integration range $\mathcal{I}_F$, $\phi \in [-40^\circ, 40^\circ]$ and $\theta \in [50^\circ, 80^\circ]$.
- Backward direction: Integration range $\mathcal{I}_B$, $\phi < -140^\circ$ *or* $\phi > 140^\circ$ and $\theta \in [100^\circ, 130^\circ]$.

Bin Volume correction

- Some $E_\gamma/Q'^2/t$ acceptance bins do not cover the whole integration range.
- Correction to take into account the "hole" in acceptance.
- The volume covered by the acceptance Vol_{Acc} in the forward and backward directions are calculated.
- Correction factors are given by: $Vol_{corr} = Vol_{Acc}/Vol_{\mathcal{I}}$.
- 2 sets of volume correction factors, for each $E_\gamma/Q'^2/t$ acceptance bin.

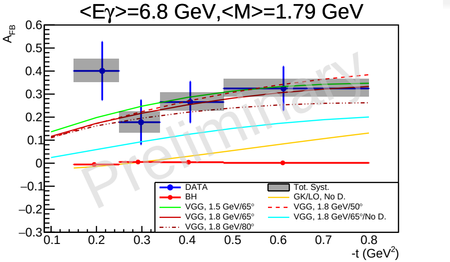


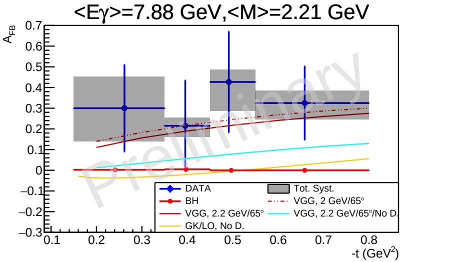
- $A_{FB} = \frac{N_F - N_B}{N_F + N_B}$ $\qquad N_{F/B} = \sum \frac{1}{Acc \times CorrVol_{F/B}}$
- Error bars given by propagating $\delta\sigma \propto \sqrt{\sum (1/Acc \cdot Vol_{corr})^2}$

A_{FB} (selected results)

- A_{FB} measured in two mass regions: $M \in [1.5\ \mathrm{GeV}, 3\ \mathrm{GeV}]$ and $M \in [2\ \mathrm{GeV}, 3\ \mathrm{GeV}]$ (known resonance-free region)
- The measured A_{FB} is non-zero: **evidence for signal** beyond pure BH contribution
- Three model predictions
  1. VGG without D-term
  2. VGG with D-term

     D-term in Pasquini et al., *Physics Letters B*, 2014
  3. GK/LO without D-term
- Measured asymmetry is better reproduced by the VGG model **including the D-term** in both mass bins
- Large error bars → upcoming CLAS12 data will allow deeper insight on TCS





Potentially publishable plots

Paper take aways and near future plans

This analysis includes:

- A new positron identification procedure based on **neural networks**
- MC and data-driven **momentum correction**
- A complete acceptance study
- A phenomenological study of the **TCS A_{FB}** using the VGG model
- The measurement of **three observables**: BSA, R ratio and A_{FB}
- The evaluation of systematic uncertainties on the measurements

The physic message we want to convey:

- TCS/BH observables were measured for the **first time**. Sizeable BSA and A_{FB} are **clear signatures of TCS**
- The results obtained allow to draw physical conclusions:
  - the BSA is well reproduced by models that reproduce existing DVCS data
    $\rightarrow$ hints for **universality of GPDs**
  - the Forward/Backward asymmetry appears to be sensitive to the D-term
    $\rightarrow$ promising path to the measurement of the **mechanical properties of the proton**

The path toward publication

- Analysis note written and submitted to review (30th September 2020)
- Cross-check well under way
- Final systematic checks and validation of the efficiency corrections (almost) done
- Writting of the article to start in December (PRL)

Many thanks to the CLAS collaboration !