Double Deeply Virtual Compton Scattering: Physics motivations, what we want to measure and difficulties, idea for a setup in Hall C

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Physics Motivations

Unpolarized DDVCS. Below: Feynman diagram at leading twist/order for DDVCS & interfering BH



DDVCS Access GPDs $Q^{2} = Q^{2}$ greater than 1 GeV² Depends on x, xi, t + evolution BH "type I" (behavior similar to DVCS one)

BH "type II" (behavior similar to TCS one)

depends on Form Factors (t), calculable

Physics Motivations

- Access GPDs from DDVCS form factors at x != ξ
- DVCS & TCS: only for x=ξ. DDVCS: lever arm by varying relative virtuality of the 2 photons Q² and Q²
- Necessary to constrain models on **extrapolating to \xi=0** for tomographic interpretations
- Interplay between spacelike and timelike "dominant" region
- Other applications such as angular dependances, exploring timelike vs spacelike NLO and higher twist effects within same reaction and with same experimental setup... Indirect hints on GPDs universality
- GTMDs with angular dependances? [S. Liuti proposition]
- ERBL region of GPDs (mesons exchanges, real) no constraints yet

- And much more!

Some theoretical references

A. Belitsky, S. Muller, PRL 90 n2, 022001-1, 2003

M. Guidal, M. Vanderhaeghen, PRL 90 n1, 022001-1, 2003

M. Diehl, Generalized Parton Distributions, physics report 388 (2003) 41-277 see around page 164, + other parts before and after

S. Wallon, Hard exclusive processes in perturbative QCD, from medium to asymptotical energies (updated 2017) see after page 109 + other parts after

Various notations and theory framework, Motivations



 $\xi = + \text{ component of P=(p+p') in light cone frame. GPDs depend on it. "skewness"}$ $\xi = -\Delta.\overline{q} / P.\overline{q} = (Q^2+Q'^2) / (2s + Q^2 - Q'^2 - 2m^2 + t)$ with $\Delta = (p'-p) = (q-q')$ and $t = \Delta^2$; $\overline{q} = (q+q')/2$, P = (p+p') (standard in litterature) notations: η in Belitski, Muller; ξ in Guidal, Vanderhaeghen; Wallon; Diehl (articles ref. next slide)

 $\xi' = + \text{ component of } \overline{q} = (q+q')/2 \text{ in light cone frame. quark propagator depend on it (red notations) can be related to <math>x_{bj}$ $\xi' = -\overline{q}^2 / 2P.\overline{q} = (Q^2 - Q'^2 + t/2)/(2s + Q^2 - Q'^2 - 2m^2 + t) \rightarrow \text{Im}(CFF) \text{ at } x = \pm \xi' \neq \xi$ notations: ξ in Belitski, Muller; ρ in Diehl; not explicited in Wallon; $2\xi-\xi'$ in Guidal, Vanderhaeghen

at asymtotic limits and q² or q¹² = 0 \rightarrow DVCS: $\xi'=\xi$; TCS: $\xi'=-\xi$. Im(CFFs) at x = $\pm\xi = \pm\xi'$

Various notations and theory framework, Motivations

• In what region do we want to measure the GPDs? following Diehl's interpretations DVCS and TCS get GPDs at the limit between DGLAP and ERBL regions ERBL region need contrain for models, DDVCS seems better for studies in this regions what about extracting points in DGLAP region?

 $\xi > |\xi'|$: ERBL region; $\xi < |\xi'|$ DGLAP region

Quark propagator normalized to ξ at asymtotic limit: $(1-Q'^2/Q^2) / (1+Q'^2/Q^2) \rightarrow up$ to t/Q^2 factor, we play with respective value of Q² and Q'² to go "out of diagonal" for GPD \rightarrow neglecting t, we are restricted to $\xi > |\xi'|$



What we want to measure and difficulties





BH



BH

peak when y' becomes collinear to e related to $\varphi_{LH}=0$, and depends $\cos\theta_{\gamma\gamma}$ (kinematics) and "y" \rightarrow e' angle

2 peaks when μ + or μ - become collinear to γ related to ϕ_{μ} =0 and 180°,

and depends $\cos\!\theta_{_{VV}}$ (kinematics) which position the value of $\theta_{_{CM}}$ for the peaks

Measurement: Unpolarized DDVCS+BH + beam polarized x-sec

First order: 6 diagrams, 2 DDVCS, 2+2 BH

Goal: extract CFFs, extrapolation of GPDs at (x,0,t)

DifficultIES: BH peaks and angular correlations

- Understanding of angular correlations in TCS help us a lot here!

Need to redefine observables and integration range for type II
type I: ok, only being careful at acceptances

What we want to measure and difficulties

• expected behavior in θ , from BH2 (2 quasi-singularities coming from e+ or e- becomes collinear to the beam)



 $\gamma P \rightarrow \gamma' P'$ kinematics positions the peaks, at asymtotic limit: 0° and 180°. larger $\theta \gamma \gamma$: peaks close to 90

each peak associated to 1 diagram (I+ or I-): important to have a symmetric spectrometer configuration tc detect the muons if we want to get the whole range around 90° and avoid favoring one diagram vs the other

⇒ I will run a table of cuts in θ vs (t, xbj, Q², Q²) then, BH2 can be under control. peaks (solvable) at 0° and 180° in the ϕ CM distribution







BH₁ Mostly depends on y, "Under control"

BH₂ difficult! Studies of angular correlations peaks & quasi-singularities in acceptance



GEANT4 (Work in Progress)









Тор

Left

A few hint of physics simulations (more next time)

Generated weighted DDVCS distributions (DEEPGen) as a function of: Q², Q², t, xbj, phi (initial), phi (pair), theta (final), E=11 GeV



Some 1D kinematic distributions (as generated)

A few hint of physics simulations (more next time)



A few hint of physics simulations (more next time)



Kinematic bins and what can we access? [all t]



Kinematic bins and what can we access? [large t]

Binning in ξ , ξ' , at large -t (3) 0.35 < -t < 0.55 GeV²



Kinematic bins and what can we access? [low/medium t]



Summary 1/2

Physics:

- Motivations, strong case: Access ERBL region of GPDs & tomographic interpretations
- Very few references, lots of work needs to be done, but lot is already done
- Taking very different approaches than past work done by various group of people, including personal work
- 2 major things: angular correlations [should be OK with TCS studies] + resolutions in all variables, in particular proton momentum and t [main things to solve for realistic experiment]
- Can explore a few kinematic regions
- Soon: studies on CFF extraction, impact of experimental resolutions and uncertainties, extrapolating to xi=0

Summary 2/2

Setup and Monte-Carlo:

- Starting from DVCS at NPS setup, currently running simulations from Ho-San. Using HMS (P') + NPS (e')
- Addition of shielding + 3 layers of muons hodoscopes behind HMS and NPS. Additions for proton or no HMS? <u>Studying various options</u>
- Several options to explore with various acceptances. Initial exploration (not fully realistic) gave optimistic results for 60 days at 50 to 100 uA (work from 2019, never presented)

In progress / Our to do list:

- Implementation of various setup options
- Running generated particles through few setup options, counting rates, select a setup
- Realistic projections for physics + observables
- Interpretations with updated generator, improved model, fits, CFFs to GPDs

Any input is very welcome!