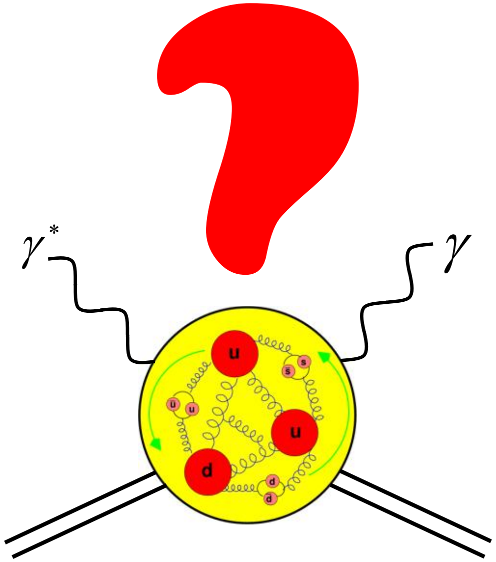
Polarized Electrons and Positrons for Hadron Imaging

Eric Voutier

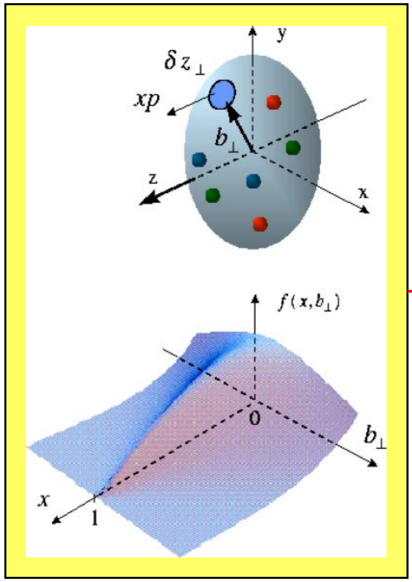
Laboratoire de Physique Subatomique et de Cosmologie
Grenoble, France



- (i) Generalized parton distributions
- (ii) Relation to observables
- (iii) Experimental status
- (iv) Polarized positron production
- (v) Polarization transfert
- (vi) Potential performances
- (vii) The PEPPo experiment @ JLab
- (viii) Conclusions

Parton Imaging

- **GPDs** are the **appropriate** framework to deal with the **partonic structure** of hadrons and offer the unprecedented possibility to access the **spatial distribution** of partons.



M. Burkardt, PRD 62 (2000) 071503 M.Diehl, EPJC 25 (2002) 223

- **GPDs** = GPDs(Q^2,x,ξ,t) whose perpendicular component of the momentum transfer to the nucleon is **Fourier conjugate** to the **transverse position** of partons.

- **GPDs** encode the **correlations between partons** and contain information about the dynamics of the system like the **angular momentum** or the **distribution of the strong forces** experienced by quarks and gluons inside hadrons.

X. Ji, PRL 78 (1997) 610 M. Polyakov, PL B555 (2003) 57

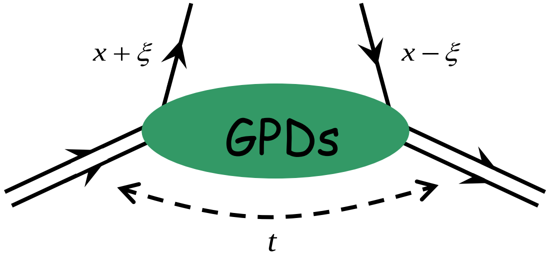
GPDs can be interpreted as a 1/Q resolution **distribution** in the **transverse plane** of partons with **longitudinal momentum** x.

A new light on hadron structure

The GPDs Framework

D. Müller et al., FP 42 (1994) 101 A.V. Radyushkin, PRD 56 (1997) 5524 X. Ji, PRL 78 (1997) 610

Coherence between quantum states of different helicity, longitudinal momentum and transverse position.



x Initial longitudinal momentum fraction
-2ξ Transferred longitudinal momentum fraction (skewness)
$(-t)^{1/2}$ Momentum transfer to the nucleon

❖ At leading twist, the partonic structure of the nucleon is described by **4** quark **helicity conserving** and **chiral even** GPDs and **4** quark **helicity flipping** and **chiral odd** GPDs (**+8 gluon GPDs**).

P. Hoodbhoy, X. Ji, PRD 58 (1998) 054006 M. Diehl, EPJC 19 (2001) 485

$$H^q, E^q, \tilde{H}^q, \tilde{E}^q \qquad H_T^q, E_T^q, \tilde{H}_T^q, \tilde{E}_T^q$$

❖ In the forward limit (t → 0, ξ → 0), **H's** reduce to the **forward parton distributions** (density, helicity, transversity).

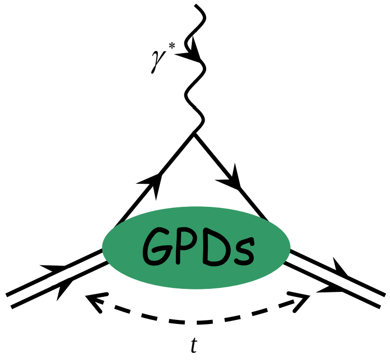
❖ **E's**, which involve **nucleon helicity flip**, do not have a DIS equivalent.

$$H^q(x,0,0) = q(x) \qquad \tilde{H}^q(x,0,0) = \Delta q(x) \qquad H_T^q(x,0,0) = \delta q(x)$$

$$H^g(x,0,0) = x\,g(x) \qquad \tilde{H}^g(x,0,0) = x\,\Delta g(x) \qquad \left\{H, E, \tilde{H}, \tilde{E}\right\}_T^g(x,0,0) = 0$$

E's are
new and unknown
distributions

Generalized parton distributions



ξ independence from Lorentz invariance

Form Factors

- The **first Mellin moments** relate GPDs to **Dirac** (H^q), **Pauli** (E^q), **axial** ($\tilde{H}^q$), and **pseudo-scalar** ($\tilde{E}^q$) nucleon form factors.

$$\int_{-1}^{+1} dx\, E^q(x,\xi,t) = F_2^q(t) \qquad \int_{-1}^{+1} dx\, \tilde{E}^q(x,\xi,t) = G_P^q(t)$$

- Similar relations relate chiral odd GPDs to tensor form factors.

$$\int_{-1}^{+1} dx\, \left[2\tilde{H}_T^q(x,0,0) + E_T^q(x,0,0)\right] = \kappa_T^q$$

Transverse spin-flavor dipole moment in an unpolarized nucleon

X. Ji, PRL 78 (1997) 610 M. Polyakov, PLB 555 (2003) 57 M. Burkardt, PRD 72 (2005) 094020

Energy Momentum Tensor

- The **second Mellin moments** relate GPDs to the **nucleon dynamics**, i.e. **parton angular momentum** and **strong forces** distributions.

$$\boxed{J^q = \frac{1}{2}\Delta\Sigma^q + L^q = \frac{1}{2}\int_{-1}^{+1} dx\, x\left[H^q(x,\xi,0) + E^q(x,\xi,0)\right]}$$

$$J_\perp^q = \frac{1}{4}\int_{-1}^{+1} dx\, x\left[H_T^q(x,0,0) + 2\tilde{H}_T^q(x,0,0) + E_T^q(x,0,0)\right]$$

Correlation between quark spin and angular momentum in an unpolarized nucleon

GPDs unify in the same universal framework **parton distributions**, **form factors**, and the **spin of the nucleon**.

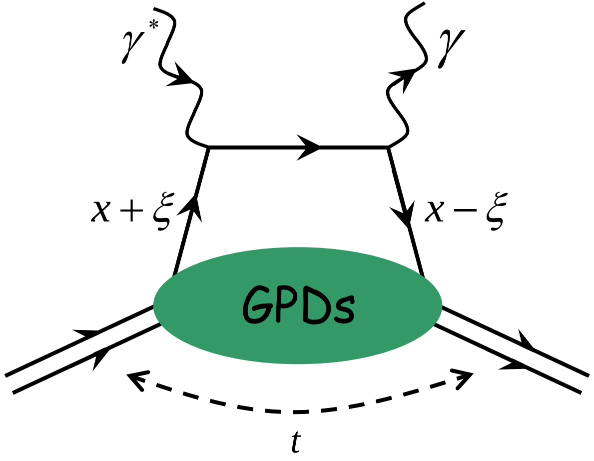
Hard Exclusive Scattering

J.C. Collins, L. Frankfurt, M. Strikman, PRD56 (1997) 2982   X. Ji, J. Osborne, PRD 58 (1998) 094018   J.C. Collins, A. Freund, PRD 59 (1999) 074009

GPDs can be accessed via **exclusive reactions** in the **Bjorken** kinematic **regime**, where the cross section can be expressed as a convolution of a **known hard scattering kernel** with an **unkown soft matrix element** related to the nucleon structure (**GPDs**).

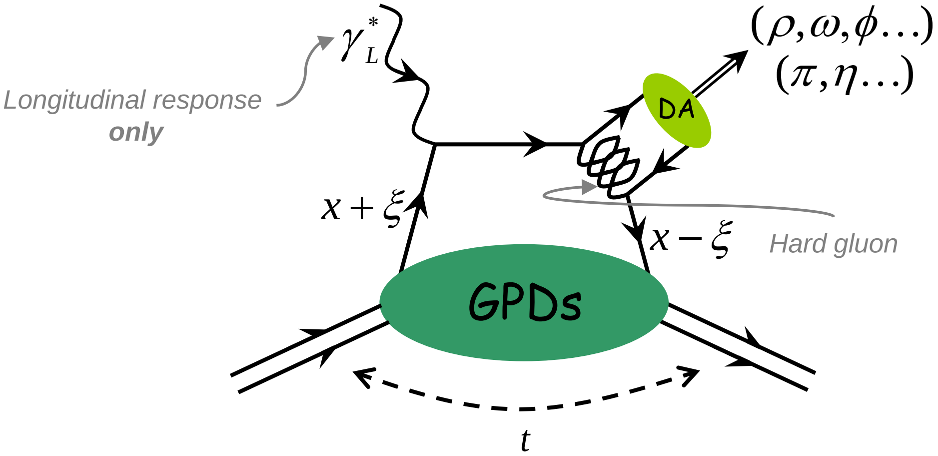
DVCS

Deeply Virtual Compton Scattering



DVMP

Deeply Virtual Meson Production



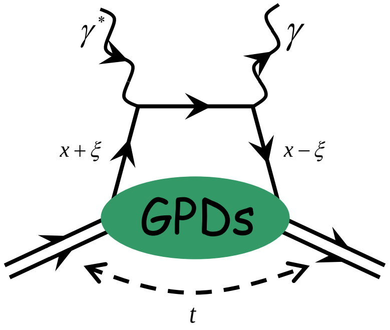
- ❖ **Additional amplitudes** contribute to the reaction process and **interfere** with the DVCS amplitude.

- ❖ Factorisation applies only to **longitudinally polarized virtual photons** whose contribution to the electroproduction cross section must **be isolated**.

- ❖ Meson production acts as a **GPD** and a **flavor filter**.

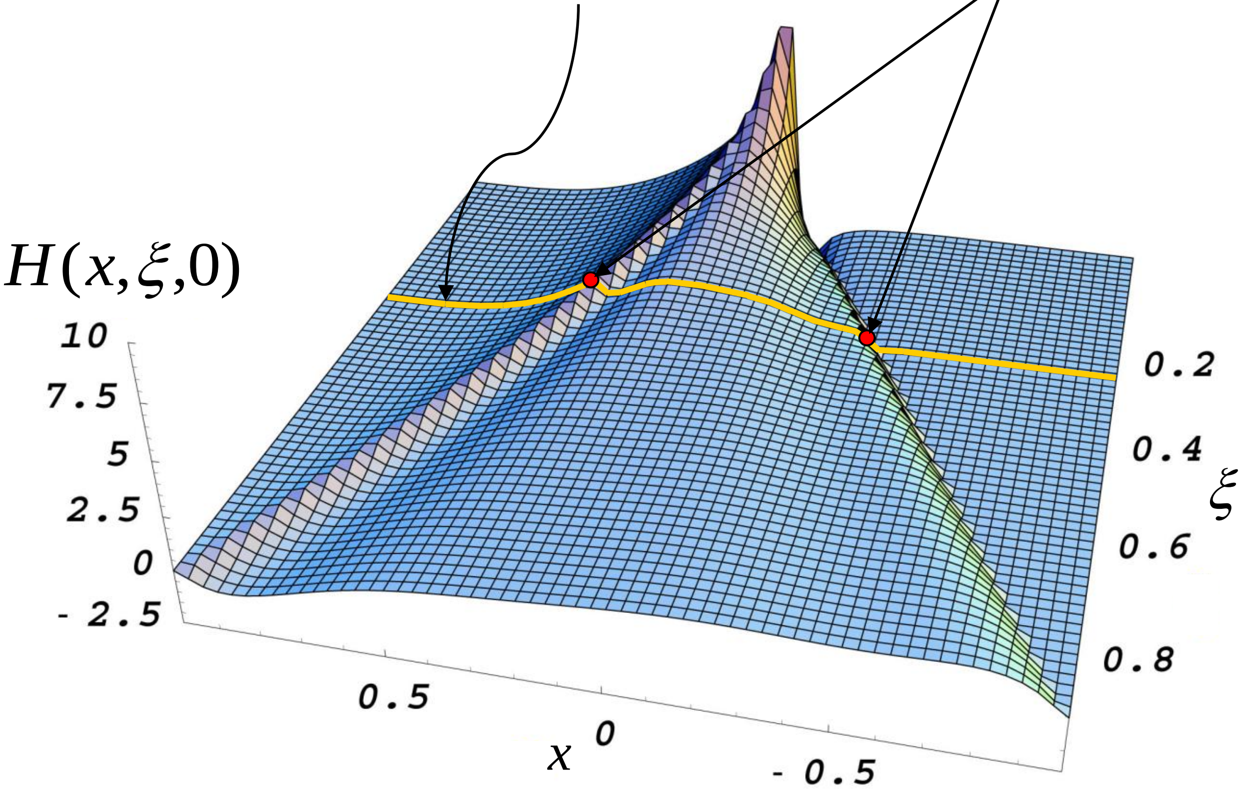
Relation to observables

GPDs enter the cross section of hard scattering processes via Compton form factors, that are integrals over the intermediate parton longitudinal momenta.



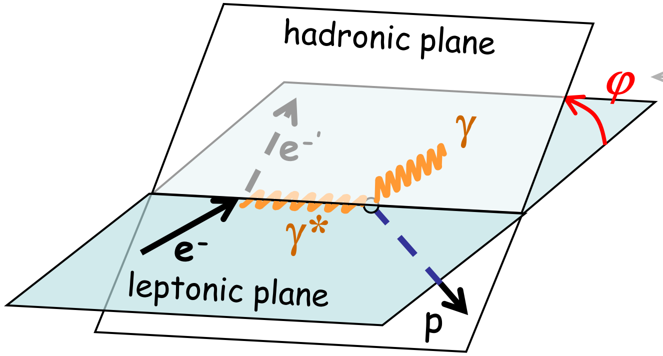
$$\xi = \frac{x_B}{2-x_B}$$

$$\sigma \propto \int_{-1}^{+1} dx \, \frac{\mathrm{GPD}(x,\xi,t)}{x \pm \xi \mp i\varepsilon} = \mathcal{P}\int_{-1}^{+1} dx \, \frac{\mathrm{GPD}(x,\xi,t)}{x \pm \xi} \pm i\pi\, \mathrm{GPD}(x=\pm\xi,\xi,t)$$



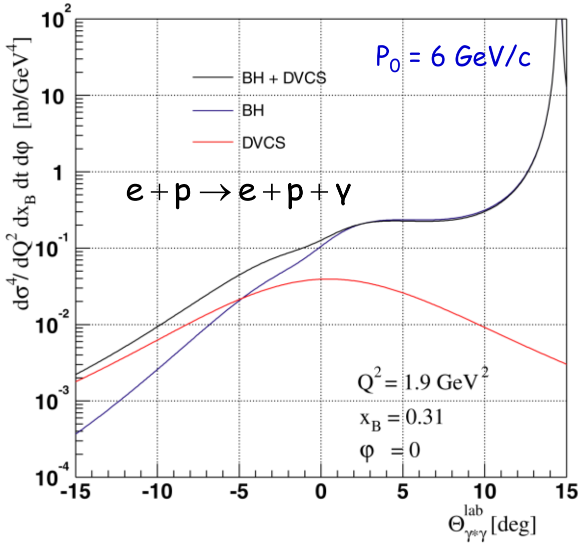
$Q^2 >> M^2$ $-t << Q^2$

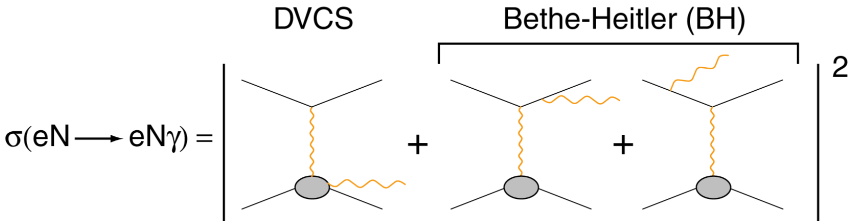
Photon Electroproduction



Out-of-plane angle entering the harmonic development of the reaction amplitude

A.V. Belitsky, D. Müller, A. Kirchner, NPB 629 (2002) 323





- ❖ The **Bethe-Heitler** (BH) process where the real photon is emitted either by the incoming or outgoing electron **interferes** with DVCS.
- ❖ **DVCS** & **BH** are **indistinguishable** but the **BH** amplitude is exactly calculable and **known** at low t.
- ❖ The **relative importance** of each process is beam energy and **kinematics dependent**.

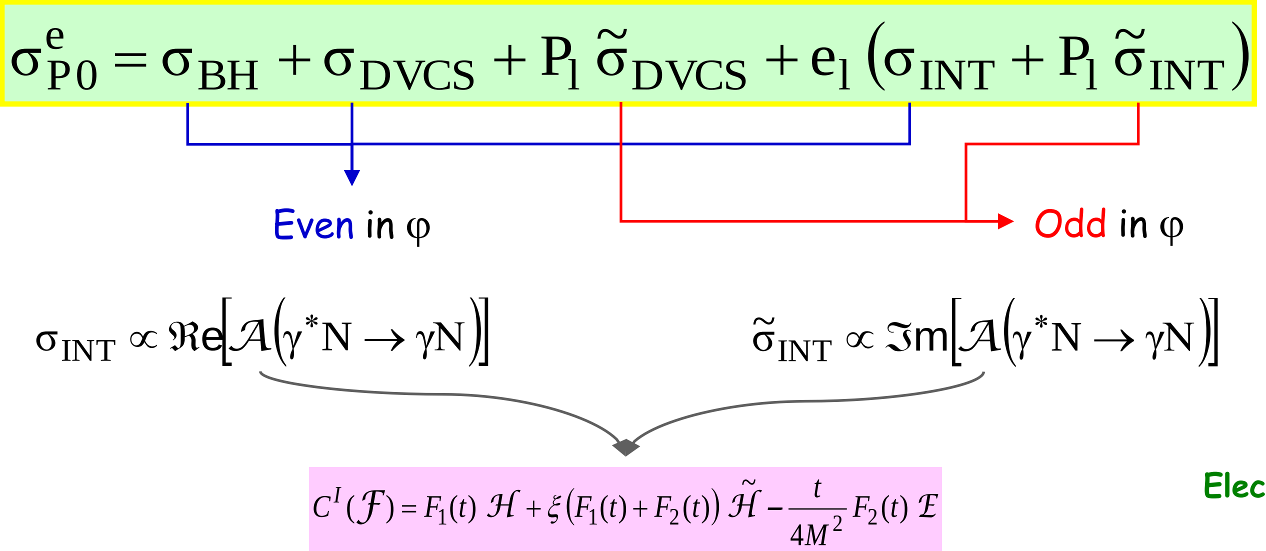
Polarization observables help to single-out the DVCS amplitude.

Relation to observables

Differential Cross section

Unpolarized Target

M. Diehl at the CLAS12 European Workshop, Genova, February 25-28, 2009



$$\sigma^{e}_{P0} = \sigma_{BH} + \sigma_{DVCS} + P_l\, \tilde{\sigma}_{DVCS} + e_l \left(\sigma_{INT} + P_l\, \tilde{\sigma}_{INT} \right)$$

Even in φ

Odd in φ

$$\sigma_{INT} \propto \Re e\left[\mathcal{A}\left(\gamma^{*}N \to \gamma N\right)\right] \qquad \tilde{\sigma}_{INT} \propto \Im m\left[\mathcal{A}\left(\gamma^{*}N \to \gamma N\right)\right]$$

$$C^{I}(\mathcal{F}) = F_1(t)\, \mathcal{H} + \xi\left(F_1(t) + F_2(t)\right) \tilde{\mathcal{H}} - \frac{t}{4M^2} F_2(t)\, \mathcal{E}$$

Electron observables

$$\sigma^{-}_{00} = \sigma_{BH} + \sigma_{DVCS} - \sigma_{INT}$$

$$\sigma^{-}_{+0} - \sigma^{-}_{-0} = 2\tilde{\sigma}_{DVCS} - 2\tilde{\sigma}_{INT}$$

Electron & positron observables

$$\sigma^{+}_{00} - \sigma^{-}_{00} = 2\sigma_{INT}$$

$$\left[\sigma^{+}_{+0} - \sigma^{+}_{-0}\right] - \left[\sigma^{-}_{+0} - \sigma^{-}_{-0}\right] = \left[\sigma^{+}_{+0} - \sigma^{-}_{+0}\right] - \left[\sigma^{+}_{-0} - \sigma^{-}_{-0}\right] = 4\tilde{\sigma}_{INT}$$

Polarized electrons and positrons allow to separate the four unknown components of the cross section for electro-production of photons.

Differential Cross section

Polarized Target

M. Diehl at the CLAS12 European Workshop, Genova, February 25-28, 2009

$$\sigma^{e}_{PS} = \sigma^{e}_{P0} + S\left[P_l\,\Delta\sigma_{BH} + \left(\Delta\tilde{\sigma}_{DVCS} + P_l\,\Delta\sigma_{DVCS}\right) + e_l\left(\Delta\tilde{\sigma}_{INT} + P_l\,\Delta\sigma_{INT}\right)\right]$$

Polarized targets allow to access other GPD combinations

$$C^{I}_{LP}(\mathcal{F}) = F_1(t)\;\tilde{\mathcal{H}} + \xi\left(F_1(t) + F_2(t)\right)\mathcal{H} + \frac{\xi^2}{1+\xi}\left(F_1(t) + F_2(t)\right)\mathcal{E} - \xi\left(\frac{\xi}{1+\xi}F_1(t) + \frac{t}{4M^2}F_2(t)\right)\tilde{\mathcal{E}}$$

$$C^{I}_{TP-}(\mathcal{F}) = \left(\frac{\xi^2}{1+\xi}F_1(t) - \frac{1}{2+\xi}\frac{t}{M^2}F_2(t)\right)\mathcal{H} + \left(\frac{1}{1+\xi}\frac{t}{4M^2}\left[(2+\xi)F_1(t) + \xi^2 F_2(t)\right] + \xi^2 F_1(t)\right)\mathcal{E} + \frac{\xi^2}{1+\xi}\left(F_1(t) + F_2(t)\right)\tilde{\mathcal{H}} - \frac{\xi^2}{1+\xi}\frac{t}{4M^2}\left(F_1(t) + F_2(t)\right)\tilde{\mathcal{E}}$$

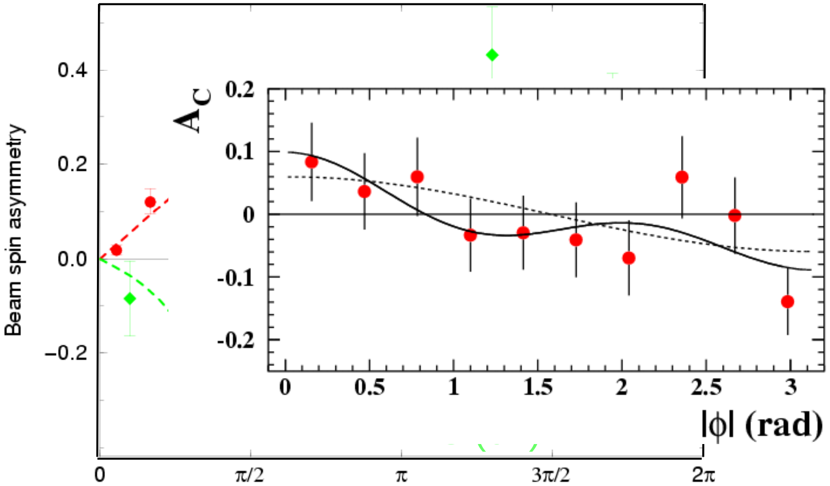
Additional electron observables

$$\sigma^{-}_{0+} - \sigma^{-}_{0-} = 2\Delta\tilde{\sigma}_{DVCS} - 2\Delta\tilde{\sigma}_{INT}$$

$$\left[\sigma^{-}_{++} - \sigma^{-}_{+-}\right] - \left[\sigma^{-}_{-+} - \sigma^{-}_{--}\right] = 4\,\Delta\sigma_{BH} + 4\,\Delta\sigma_{DVCS} - 4\,\Delta\sigma_{INT}$$

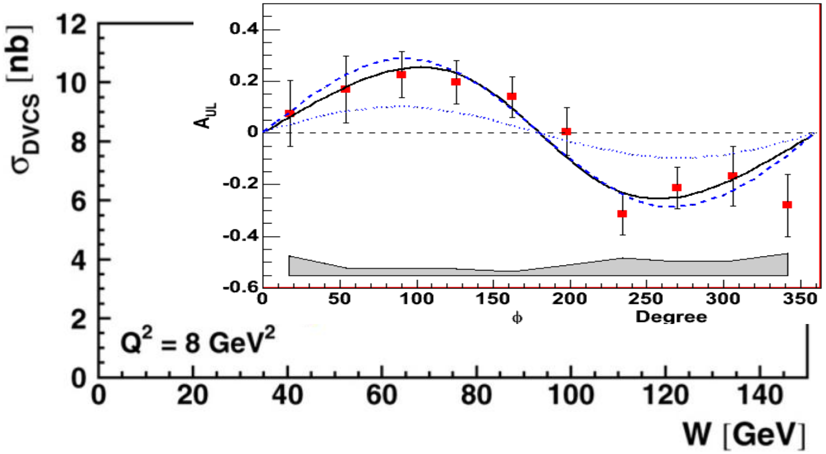
❖ Four new cross section components that may be separated from *Rosenbluth-like* experiments, or the combination of **polarized electrons and positrons** measurements at the same kinematics.

What did we learn ?



A. Airapetian et al., PRL 87 (2001) 182001
S. Stepanyan et al., PRL 87 (2001) 182002
C. Adloff et al., PLB 517 (2001) 47
S. Chekanov et al., PLB 573 (2003) 46
F.D. Aaron et al., PLB 659 (2008) 796

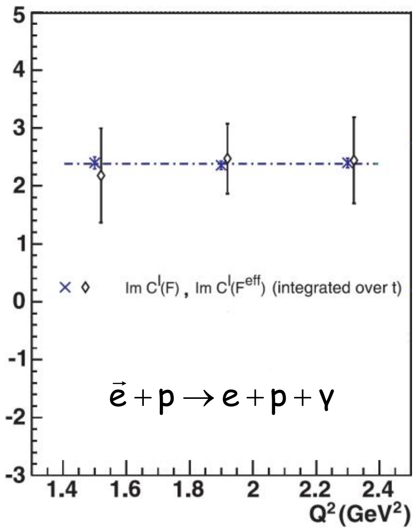
S. Chen et al., PRL 97 (2006) 072002
A. Airapetian et al., PRD 75 (2007) 011103

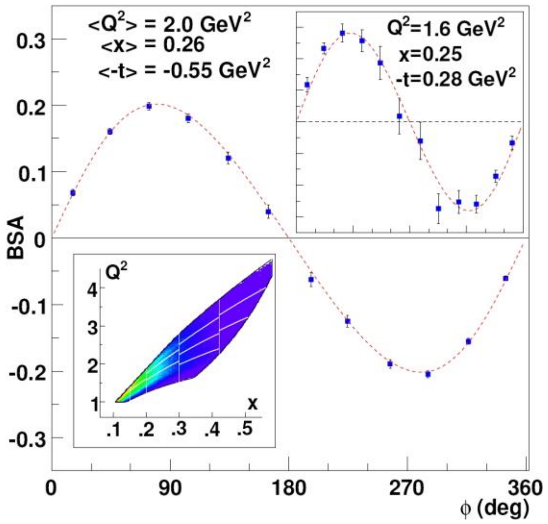


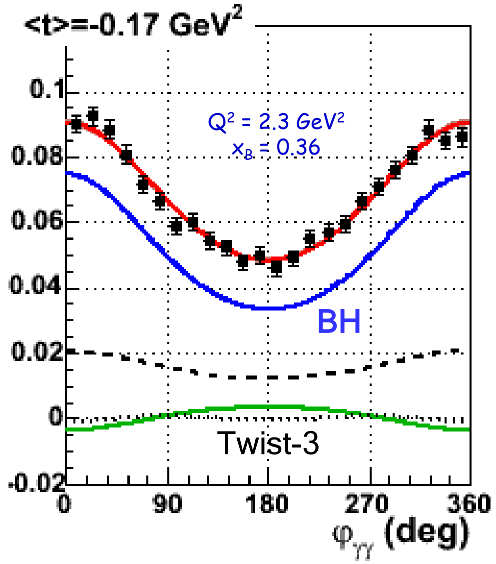
- ❖ Proof of the **existence** of a **DVCS signal** at HERMES and JLab from a non-zero **beam spin asymmetry**, and at H1 and ZEUS from sizeable **cross sections**.
- ❖ **Beam charge asymmetries** and **longitudinal target spin asymmetries** are showing a **DVCS signal**.

Experimental status

C. Muñoz-Camacho et al., PRL 97 (2006) 262002 F.-X. Girod, R.A. Niyazov et al., PRL 100 (2008) 162002
A. Airapetian et al., arXiv:1004.0177 [hep-ex]



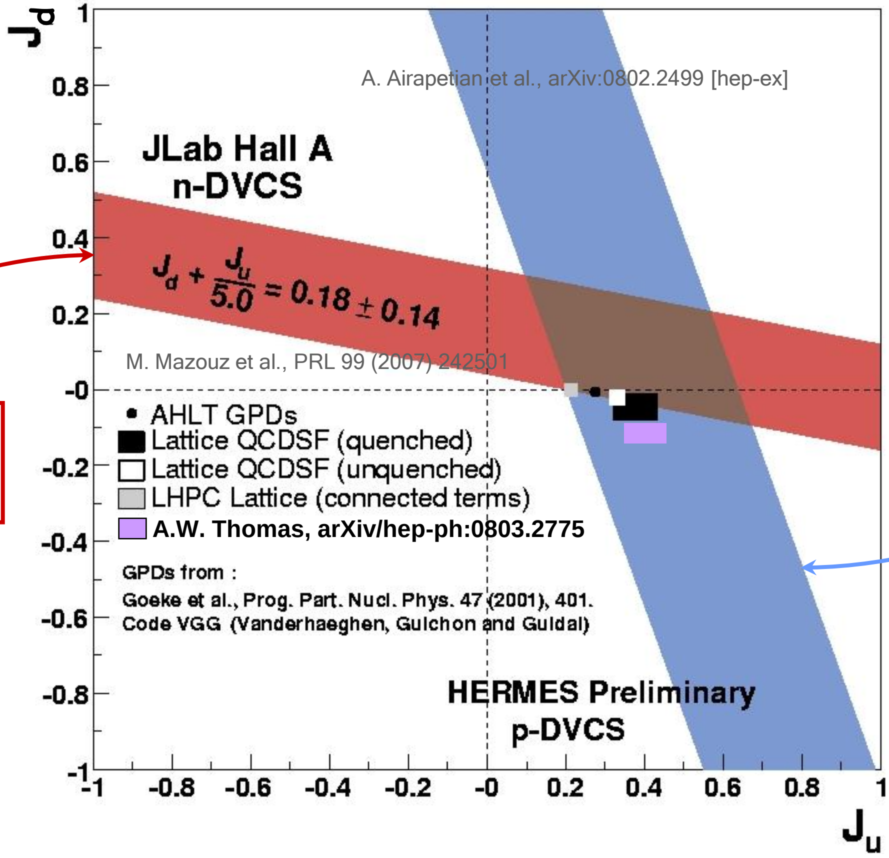




- ❖ **GPD** based calculations, beyond the $\mathcal{H}$ dominance hypothesis, **reproduce** reasonably well the main features of the data (some inconsistencies exist with respect to A_{UL} and A_{LL}).

- ❖ Calculations based on **hadronic degrees of freedom**, within a Regge approach, are in fair agreement with data up to 2.3 GeV^2.

Model Dependent Quark Angular Momenta

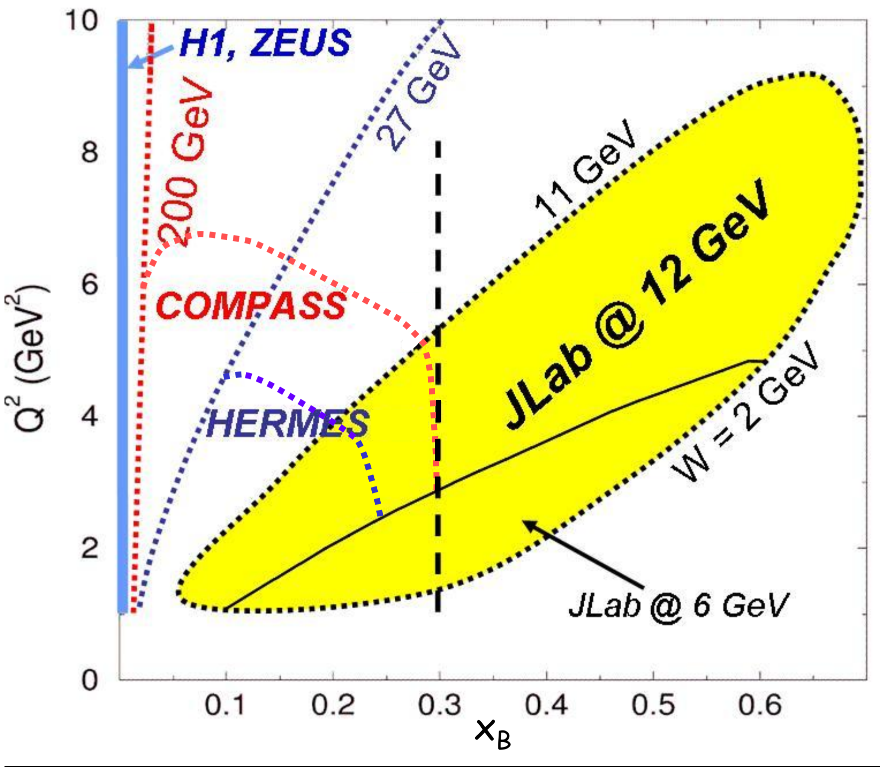


Measurements off **neutron**
are sensitive to J_d
(u quark in the neutron)

Measurements off **proton**
are sensitive to J_u
(u quark in the proton)

Neutron and transversally polarized proton targets are essential equipments for the hunt of the quark orbital momentum.

What will we learn ?



- ❖ The **energy upgrade** of the **CEBAF** accelerator allows access to the **high x_B** region which requires **large luminosity**.

- ❖ The **DVCS** project at **COMPASS** will explore **intermediate x_B** (0.01-0.10) with a reasonable overlap with the **JLab 12 GeV** kinematic domain.

$\Delta\sigma_{z0}$ $\Delta\sigma_{0j}$ $\Delta\sigma^{\pm}_{z0}$ $\Delta\sigma^{\pm}_{0j}$

Imaginary parts

σ $\Delta\sigma^{\pm}$ $\Delta\sigma_{zj}$ $\Delta\sigma^{\pm}_{zj}$

Real parts

It remains a theoretical concern to extract GPDs from CFFs.

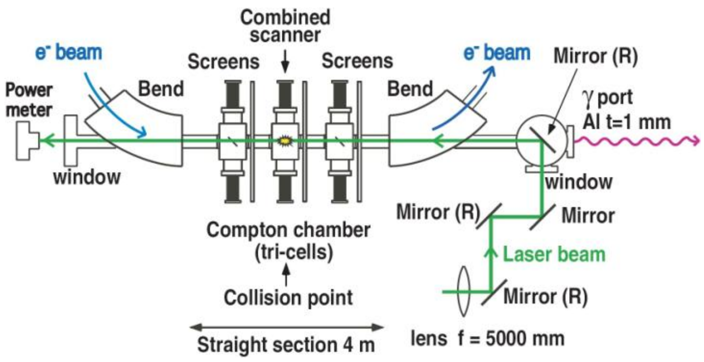
Polarized positron production

High Energy Schemes

The production of **polarized positrons** follow a two step process: first the production of **circularly polarized photons**, and then the **polarization transfert** from pair creation.

Compton Backscattering

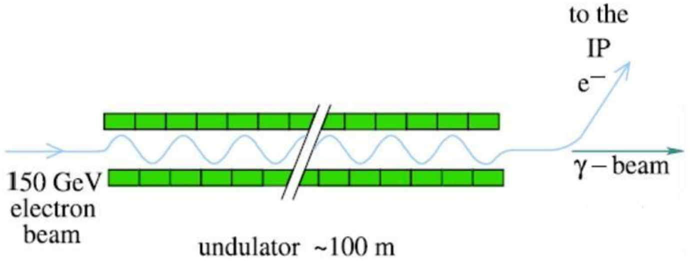
T. Omori et al, PRL 96 (2006) 114801

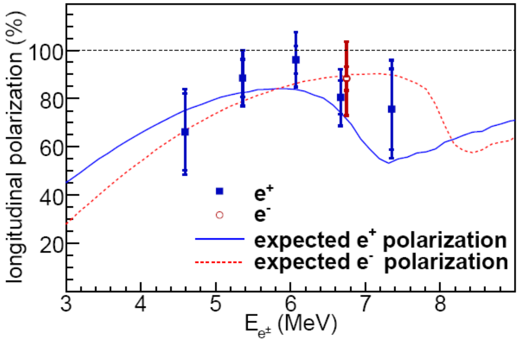


P(e^+) = 73 ± 15 ± 19 %

Undulator

G. Alexander et al, PRL 100 (2008) 210801

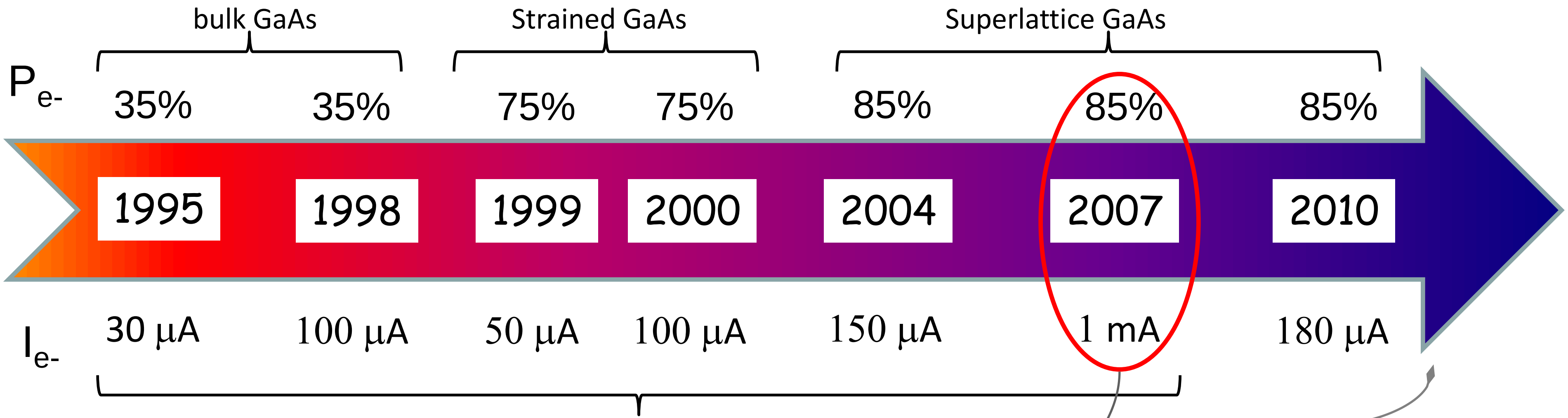




Polarized Bremsstrahlung

E.G. Bessonov, A.A. Mikhailichenko, EPAC (1996)   A.P. Potylitsin, NIM A398 (1997) 395

- Within a high Z target, longitudinally polarized e^-'s radiate circularly polarized γ's.
- Within the same/different target, circularly polarized γ's create longitudinally polarized e^+'s.



	bulk GaAs		Strained GaAs		Superlattice GaAs		
P_{e-}	35%	35%	75%	75%	85%	85%	85%
	1995	1998	1999	2000	2004	2007	2010
I_{e-}	30 μA	100 μA	50 μA	100 μA	150 μA	1 mA	180 μA

All operating with suitable photocathode lifetime to sustain weeks of operation

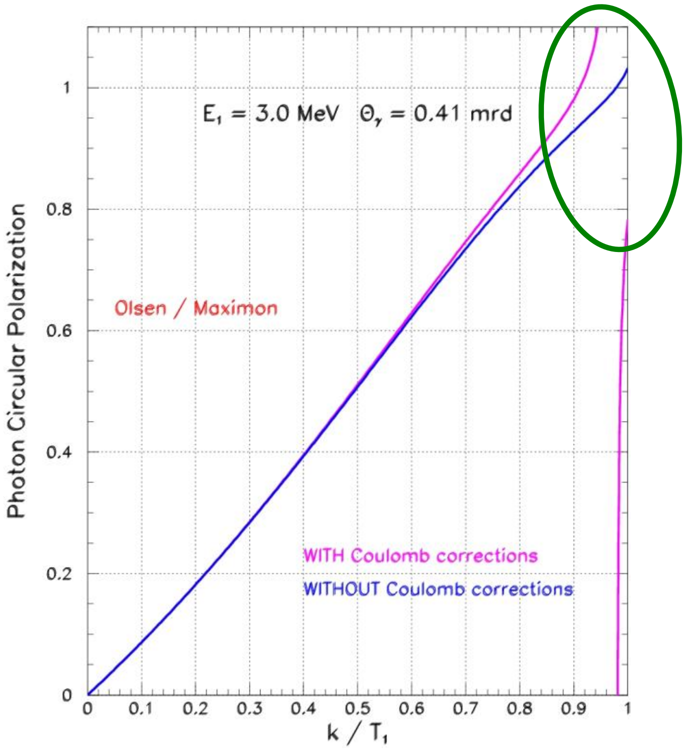
Evolution of CEBAF polarized electron source

J. Grames et al., Proc. of XXII^nd Particle Accelerator Conference, Albuquerque (NM, USA), June 25-29, 2007

Bremsstrahlung

H. Olsen, L. Maximon, PR114 (1959) 887

- The most currently used framework to evaluate polarization transferts for polarized bremsstrahlung and pair creation processes is the O&M work developped in the Born approximation for relativistic particles and small scattering angles.



- The observed **singularity** reflects the known problem of unpolarized cross sections in the **tip region**: **Coulomb corrections** appear **too strong** for heavy nuclei, leading to **negative cross sections**.

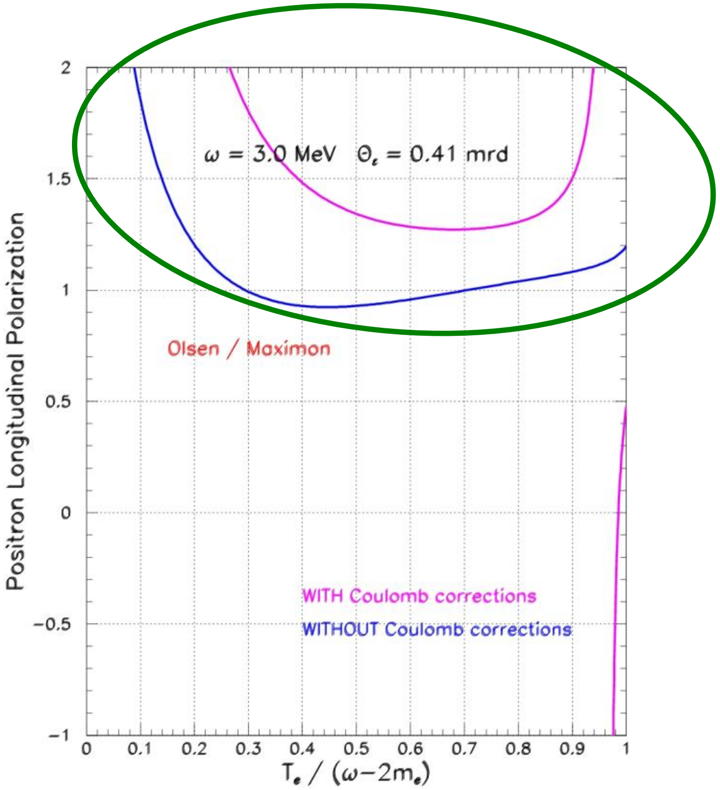
- **Unphysical polarization transferts remain** even when neglecting Coulomb corrections.

- The **full screening** case **does not** reflect any peculiar features.

Pair Creation

H. Olsen, L. Maximon, PR114 (1959) 887

- **Pair creation** is obtained **from bremsstrahlung** expressions by kinematical substitutions



❖ **Unphysical polarization transferts** are observed at small energy over the full kinematic range, independently of Coulomb correction effects.

❖ The **full screening** case **does not** reflect any peculiar features.

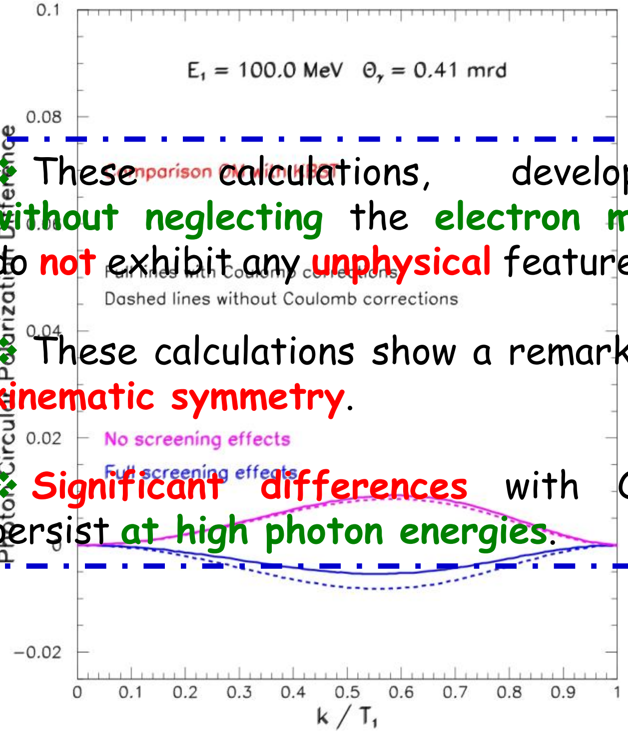
Some features of **O&M calculations** are **not valid**

Bremsstrahlung and Pair Creation

Revisited...

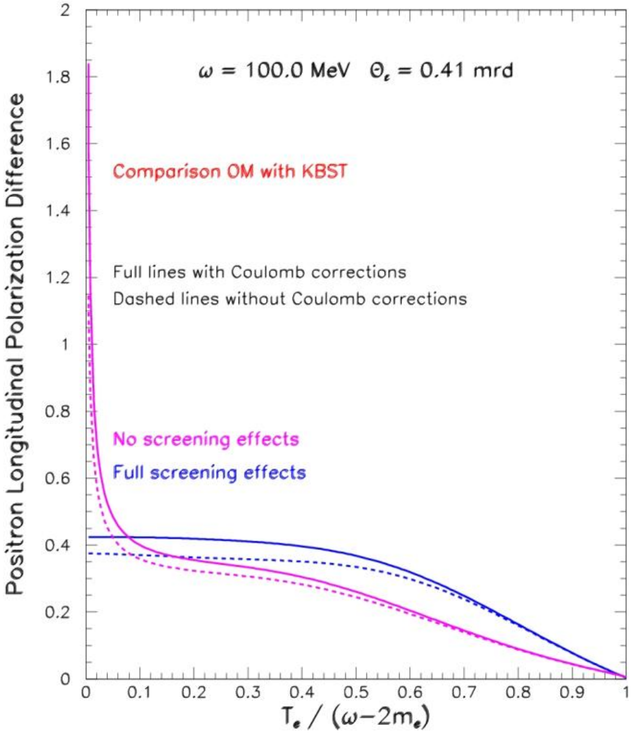
E.A. Kuraev, Y.M. Bystritskiy, M. Shatnev, E. Tomasi-Gustafsson, PRC 81 (2010) 055208

BREMSSTRAHLUNG



- ❖ These calculations, developped **without neglecting** the **electron mass**, do **not** exhibit any **unphysical** features.
- ❖ These calculations show a remarkable **kinematic symmetry**.
- ❖ **Significant differences** with O&M persist **at high photon energies**.

PAIR CREATION



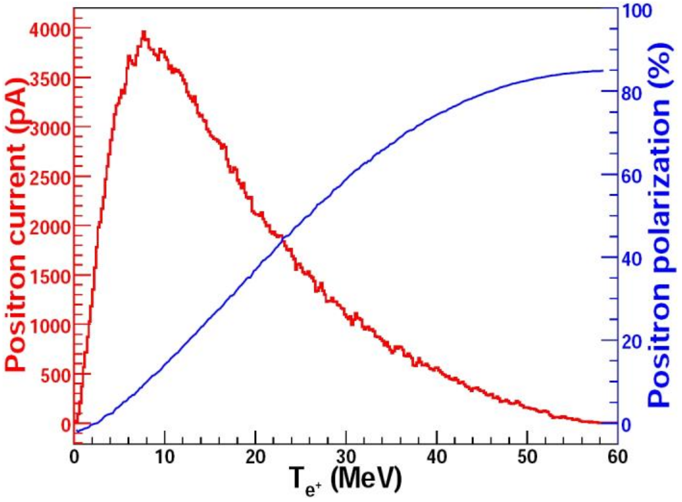
Talk of Yu Bistriskiy on Wednesday

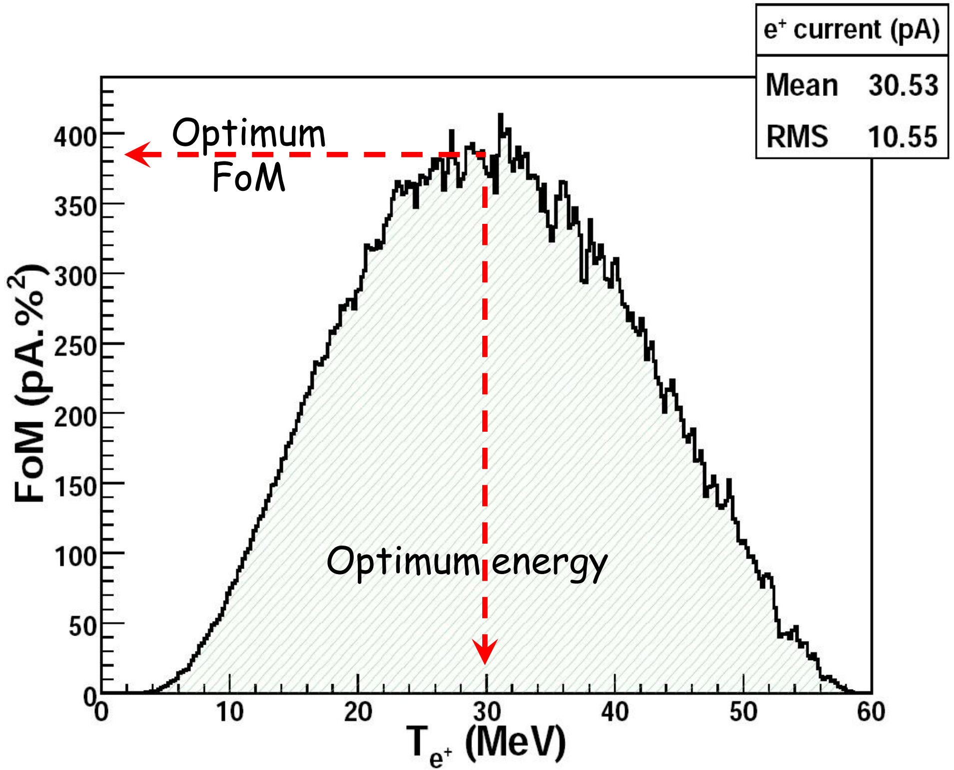
e^+ Figure of Merit

- The **Figure of Merit** is the quantity of interest for the accuracy of a measurement which combines the **incident flux** of particles and its **polarisation**.

(GEANT4 simulations based on the full screening case of O&M)

$$\Delta\theta_{e^+} = \pm 10^\circ \qquad \Delta E_{e^+} = \pm 0.25\,\mathrm{MeV}$$

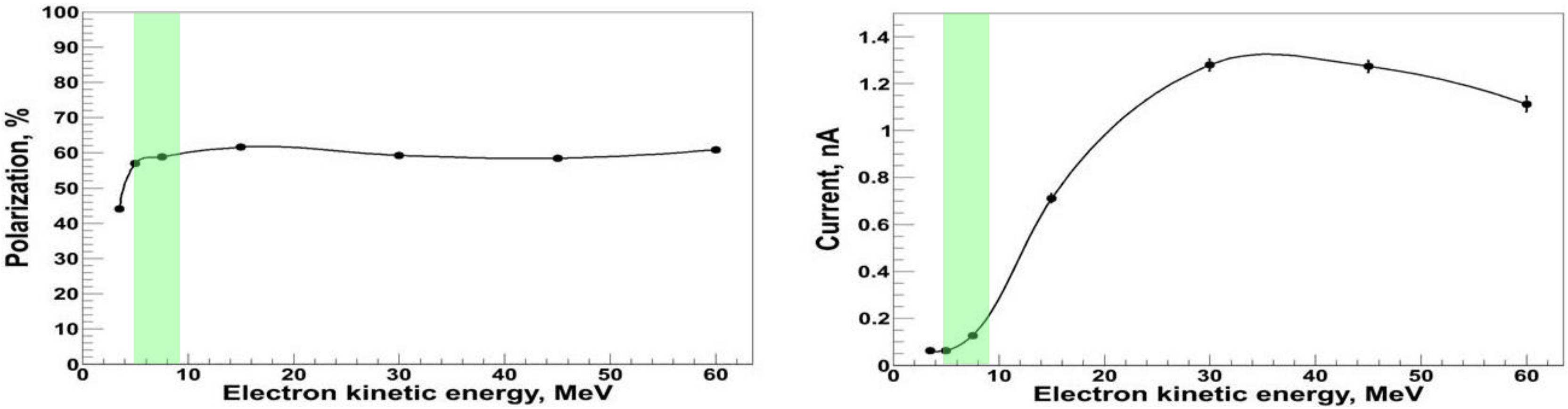




$$\boxed{\mathrm{FoM} = I_{e^+} \times P_{e^+}^2}$$

$$I_{e^-} = 1\,\mathrm{mA} \qquad P_{e^-} = 85\,\% \qquad t_W = 100\,\mu\mathrm{m}$$

Potential performances



- The typical potential **polarized positron efficiencies** of a **polarized bremsstrahlung source** are 10^{-6} in **intensity** and 0.7 in **polarisation**.

The **target material** and **thickness**, and the **e$^+$ capture system** can be optimized to improve **performances**.

- The **PEPPo** experiment **@ JLab** (P_e = 5-9 MeV/c, I_e = 1-10 μA, P ≥ 85%) will **test** this **concept**.

A Proof of Principle

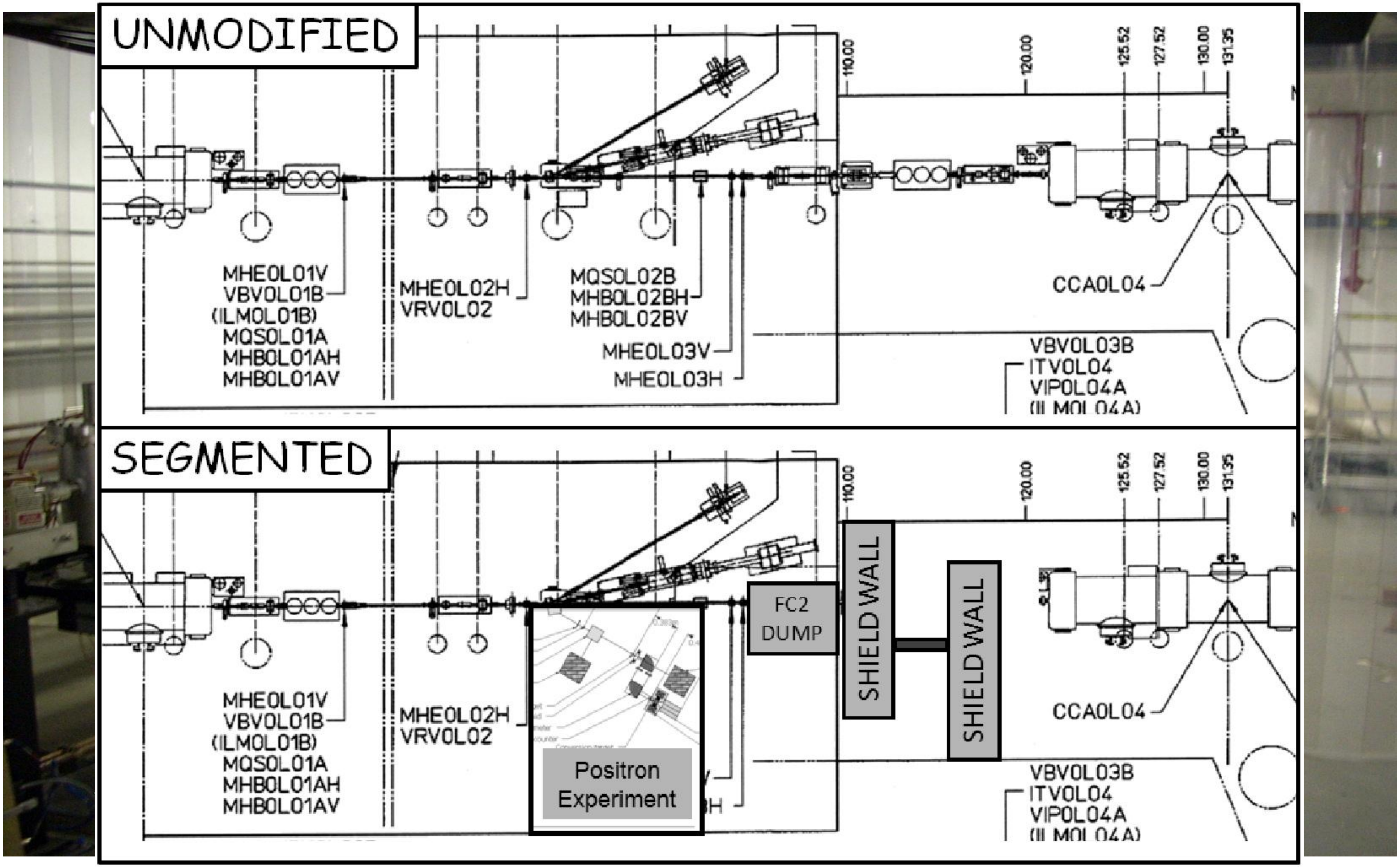
An experiment to **test** the **production** of **polarized positrons** from polarized bremsstralhung is currently designed.

The **positron yield** and **polarization distributions** will be **measured**.

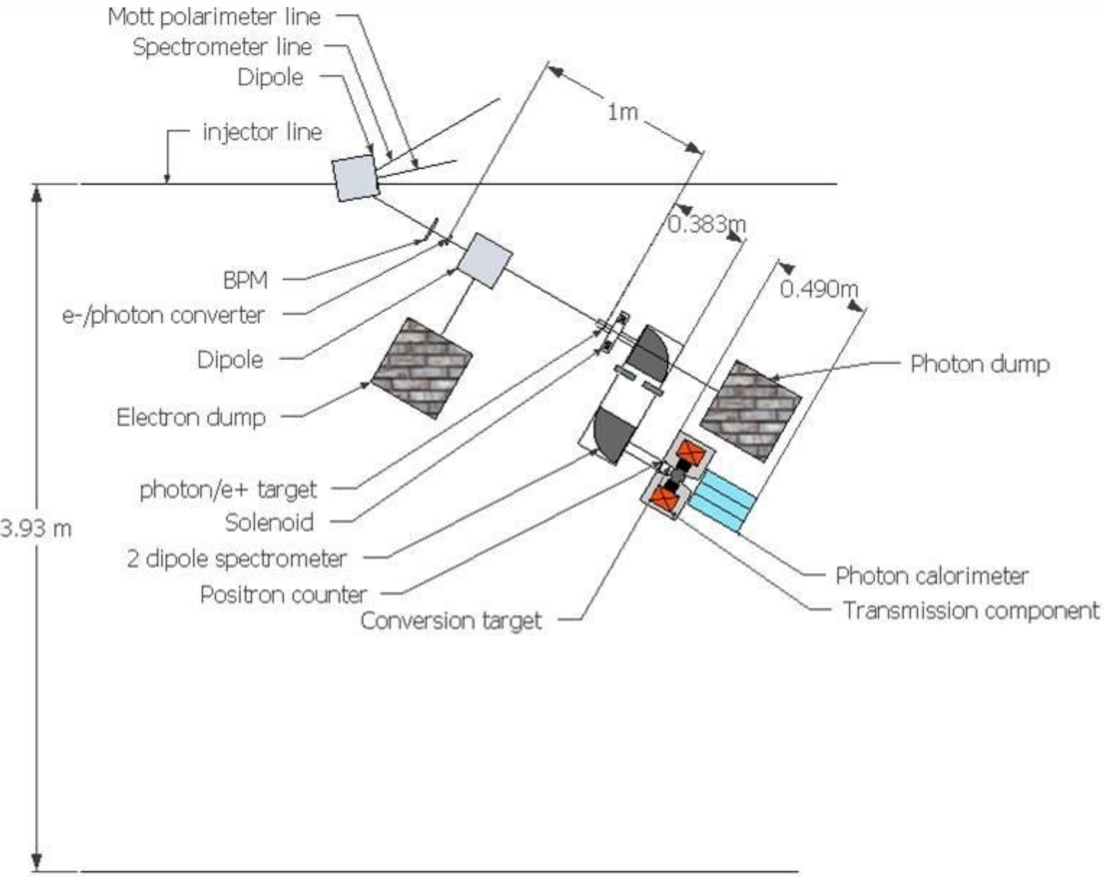
The experiment will be performed at the CEBAF injector (T ≤ **10 MeV**) on a new dedicated **e^+ line**, designed to sustain ~30 μA electron current, and is expected to run during the 6 months shutdown of **2011**.

The e^+ line will be equiped with γ and **e^+** production production targets, and the **magnetic collection & selection system & Compton transmission polarimeter** used in the **E166** experiment at SLAC.

The PEPPo experiment @ JLab



Experimental Strategy



- ❖ The **electron beam** will be **characterized** in energy and polarization with the standard measurement devices.
- ❖ The transmission **polarimeter** will be **cross-calibrated** in electron with respect to the Mott polarimeter.
- ❖ **Systematic** misalignement and transverse polarization effects will be **evaluated**.
- ❖ The energy distribution of the positron **polarization** and **yield** will be **measured**, from a **Compton transmission polarimeter**.

Summary

GPDs offer the unique opportunity to access the **3D partonic structure** of the nucleon and the contribution of the **quark angular momentum** to the nucleon spin.

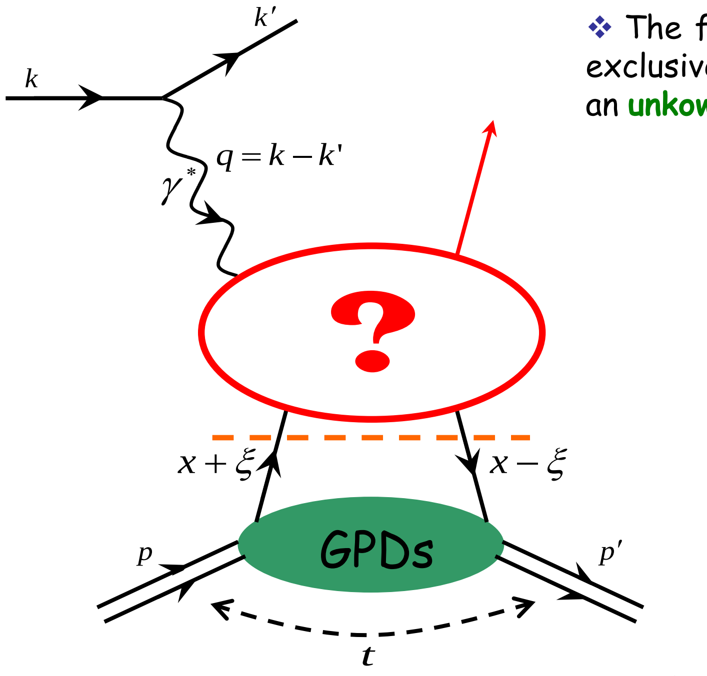
In this effort, **neutron** and **transversally polarized proton** targets are **essential**.

Polarized electrons and **positrons** provide an unambiguous **separation** of the different contributions to the γ **electroproduction** cross section.

The PEPPo experiment @ JLab will test the concept of a polarized positron source based on polarized bremsstralhung and will investigate the polarization transfert puzzle.

Hard Exclusive Scattering

J.C. Collins, L. Frankfurt, M. Strikman, PRD56 (1997) 2982 X. Ji, J. Osborne, PRD 58 (1998) 094018 J.C. Collins, A. Freund, PRD 59 (1999) 074009



$$Q^2=-(k-k')^2 \qquad t=(p-p')^2=\Delta^2 \qquad x_B=\frac{Q^2}{2p\cdot q}$$

- The factorization theorem allows to express the cross section for deep exclusive processes as a convolution of a known hard scattering kernel with an unkown soft matrix element related to the nucleon structure (GPDs).

Factorization
Interaction with elementary partons ($Q^2 \gg M^2$)
Separation of perturbative and non-perturbative scales ($-t \ll Q^2$)
Hardness

GPD(Q^2,x,ξ,t)
Probe tagging (ξ)
Production of one additional particle ($\Delta_\perp$)
Final state identification
Exclusivity

The key requirements for the experimental study of GPDs are luminosity and resolution.

Neutron Target

Neutron targets provide new linear combinations of GPDs

From polarized beam cross section difference

$$C_n^I(\mathcal{F}) = F_1(t)\,\mathcal{H} + \xi\left(F_1(t)+F_2(t)\right)\tilde{\mathcal{H}} - \boxed{\frac{t}{4M^2}F_2(t)\,\mathcal{E}}$$

Suppressed because $F_1(t)$ is small

Suppressed because of cancellation between u and d quarks

$$\Im m\{\mathcal{E}\} = \pi\sum_q e_q^2\left[E^q(\xi,\xi,t) - E^q(-\xi,\xi,t)\right] \Rightarrow$$

Neutron and **proton** targets are **sensitive** to the **u** quark flavor and, following isospin symmetry, appear then **complementary**.

Neutron targets allow to access the least known and constrained GPD that appears in the nucleon spin sum rule.

Experimental status

E03-106 → n-DVCS

P.Y. Bertin, C.E. Hyde, F. Sabatié, E. Voutier *et al.*

M. Mazouz et al., PRL 99 (2007) 242501

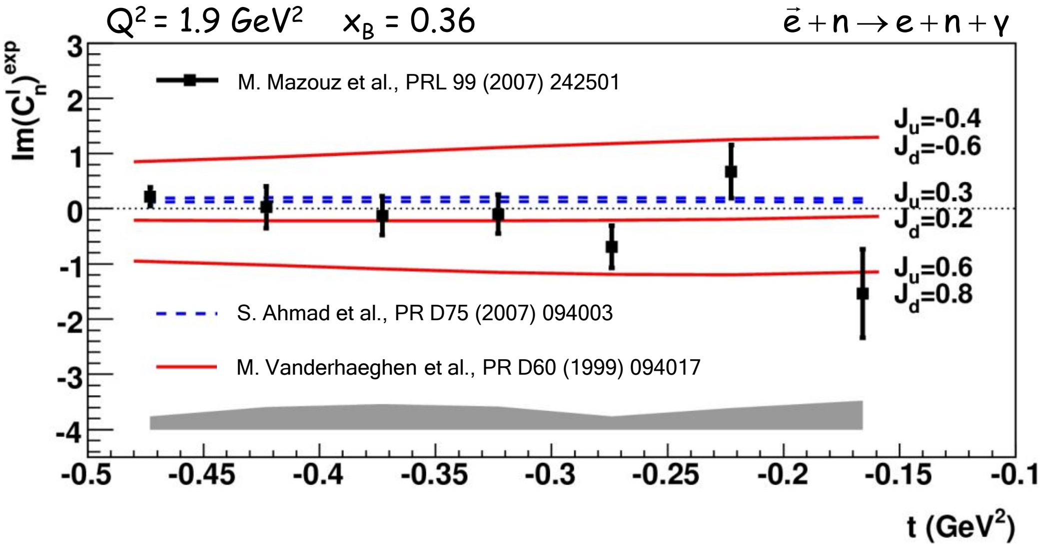
Impulse approximation

$$D(e,e'\gamma)X = p(e,e'\gamma)p + n(e,e'\gamma)n + d(e,e'\gamma)d + \cdots$$

✦

$$\frac{1}{2}\left[\frac{d^5\vec{\sigma}_{D_2-H_2}}{dQ^2\,dx_B\,dt\,d\phi_e\,d\varphi} - \frac{d^5\overleftarrow{\sigma}_{D_2-H_2}}{dQ^2\,dx_B\,dt\,d\phi_e\,d\varphi}\right] = \frac{\Gamma_{3n}(x_B,Q^2,t)}{P_{1n}(\varphi)\,P_{2n}(\varphi)}\,s^I_{1n}\sin(\varphi) + \frac{\Gamma_{3d}(x_B,Q^2,t)}{P_{1d}(\varphi)\,P_{2d}(\varphi)}\,s^I_{1d}\sin(\varphi)$$

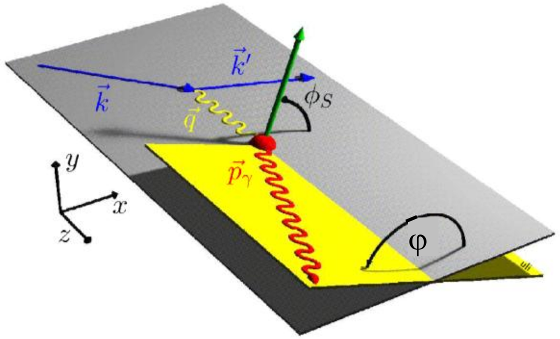
Twist-2



- ❖ The **twist-2** effective harmonic coefficients of the neutron are **small**, compatible with **zero**.
- ❖ The measured **t-dependence** can be used to **constrain** the parametrization of the GPD **E**, within a particular model.

Polarized Neutron Target

A. Belitsky, D. Müller, A. Kirchner, NP B629 (2002) 323



The **twist-2 target spin asymmetries** are derived below in the case of a polarized neutron, assuming that the **Dirac form factor** and the **non spin-flip polarisation dependent** GPD are **0**.

Longitudinal Target Spin Asymmetry

$$\sigma^{\rightarrow} - \sigma^{\leftarrow} \propto \xi F_2(t)\,\Im\mathfrak{m}\left\{\mathcal{H} + \frac{\xi}{1+\xi}\mathcal{E} - \frac{t}{4M^2}\tilde{\mathcal{E}}\right\}\sin(\varphi)$$

Transverse Target Spin Asymmetry

$$\sigma^{\uparrow} - \sigma^{\downarrow} \propto \left[c_0^{DVCS} + c_0^I\right]\sin(\varphi - \phi_S) + c_1^I \sin(\varphi - \phi_S)\cos(\varphi) + s_1^I \cos(\varphi - \phi_S)\sin(\varphi)$$

$$c_0^I \propto 2\xi\frac{t}{4M^2}F_2(t)\frac{(2-y)^2}{1-y}\Im\mathfrak{m}\left\{\frac{\xi}{1+\xi}\left[\mathcal{E} - \tilde{\mathcal{E}}\right] - \frac{1-\xi}{\xi}\mathcal{H}\right\} + \frac{t}{M^2}F_2(t)\Im\mathfrak{m}\{\mathcal{H}\}$$

$$c_1^I \propto 2\xi\frac{t}{4M^2}F_2(t)\Im\mathfrak{m}\left\{\frac{\xi}{1+\xi}\left[\mathcal{E} - \tilde{\mathcal{E}}\right] - \frac{1-\xi}{\xi}\mathcal{H}\right\}$$

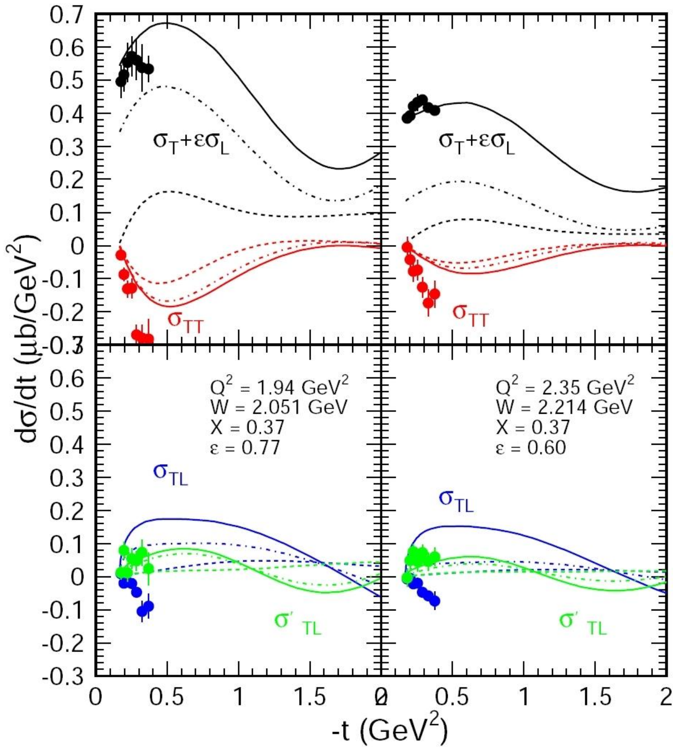
$$s_1^I \propto \frac{2\xi^2}{1+\xi}F_2(t)\Im\mathfrak{m}\left\{\mathcal{H} + \frac{\xi}{1+\xi}\mathcal{E} + \frac{\mathrm{t}}{4\mathrm{M}^2}\left(\frac{1}{\xi}\mathcal{E} - \tilde{\mathcal{E}}\right)\right\}$$

$$c_0^{DVCS} \propto (1+\xi)\,\Im\mathfrak{m}\left\{\mathcal{H}\mathcal{E}^* - \mathcal{E}\mathcal{H}^*\right\}$$

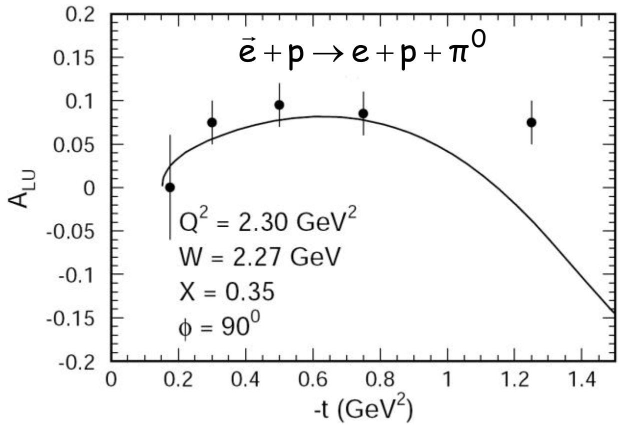
The most sensitive coefficient to $\mathcal{E}$ appears to originate from the **pure DVCS** amplitude while the **kinematical factors enhance** $\mathcal{H}$ in the other coefficients.

What did we learn ?

R. De Masi et al., PRC 77 (2008) 042201 E. Fuchey et al., arXiv:1003.2938 [nucl-ex]
J.-M. Laget, arXiv:1004.1949 [hep-ex]



$\vec{e} + p \rightarrow e + p + \pi^0$



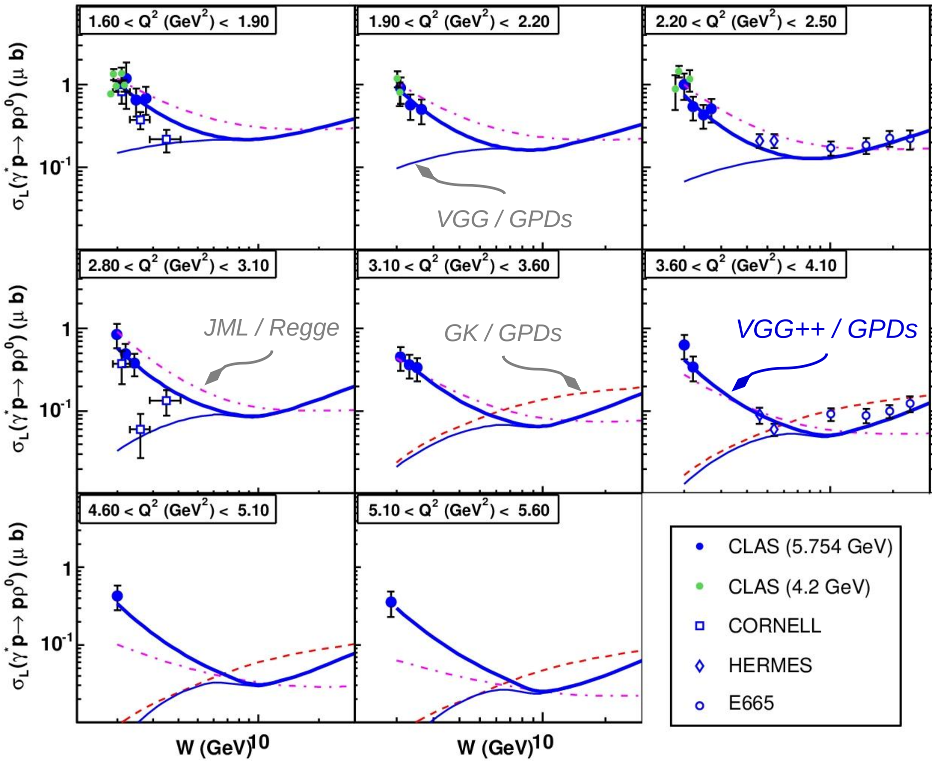
Pion Production

- Non-zero asymmetries have been reported in π^0 production, suggesting that both longitudinal and tranverse amplitudes contribute to the process.
- A Regge approach considering vector meson exchanges is reasonably succesfull in reproducing π^0 cross sections.

What did we learn ?

S.A. Morrow et al., EPJA 39 (2009) 5 A. Airapetian et al., PLB 679 (2009) 100
S.V. Goloskokov, P. Kroll, EPJC 50 (2007) 829; 59 (2009) 809.

$\gamma^*_L + p \rightarrow \rho_L + p$ @ CLAS (5.74 GeV)



$x_B = Q^2 / \left(W^2 + Q^2 - M^2 \right)$

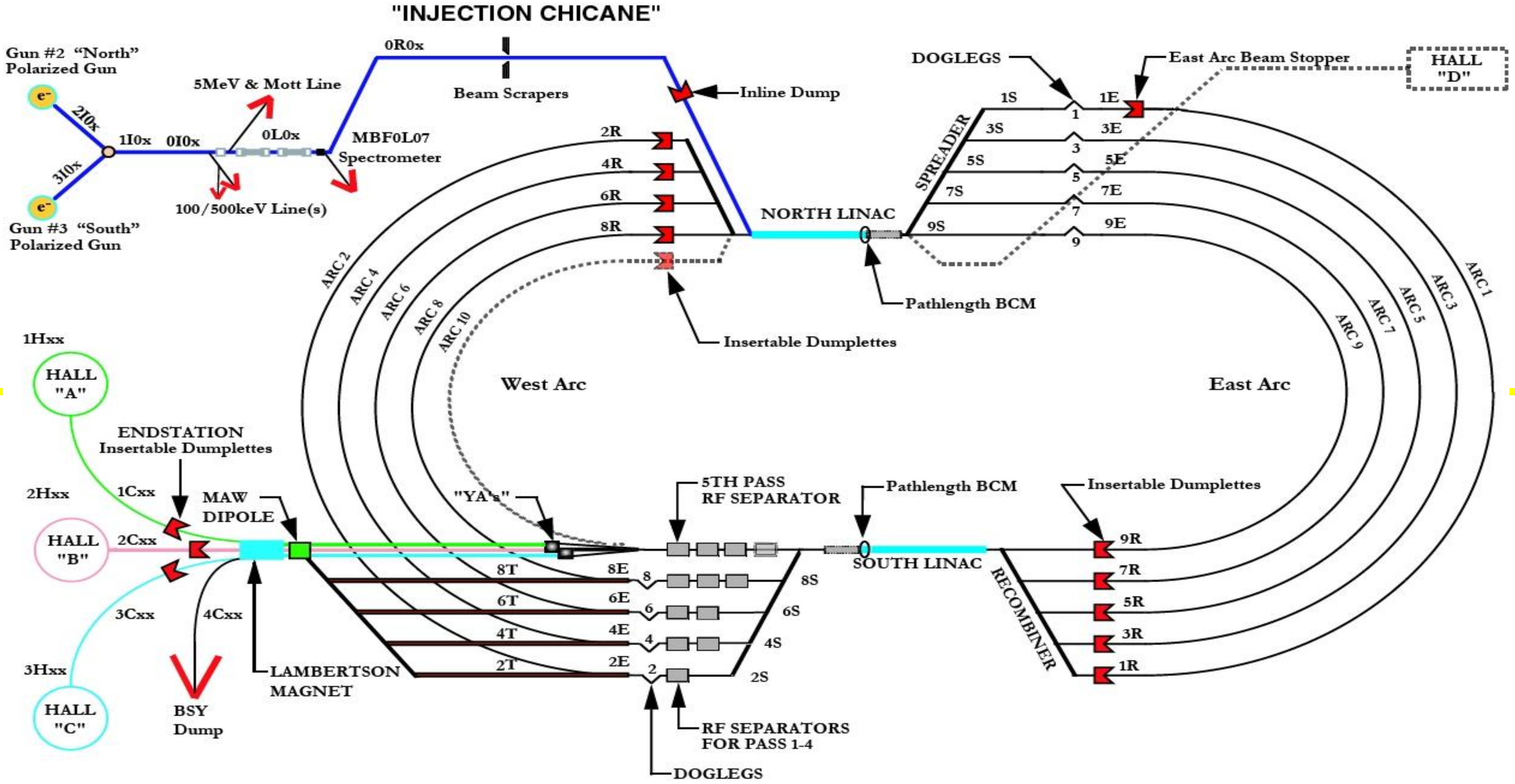
Rho Production

❖ **Standard GPD** calculations **fail** to reproduce data in the **valence region**, while **successfull** at **large W**.

❖ Data can be interpreted in terms of **hadronic degrees of freedom**, following a **Regge** approach.

❖ A **violation** of the **s-channel helicity conservation** has been reported in ρ^0 production on transversally polarized protons at **small x**.

e^+ Beam Concept



Geometric Emittance < **5 mm-mrad** *Absolute Energy Spread* < **1 MeV**

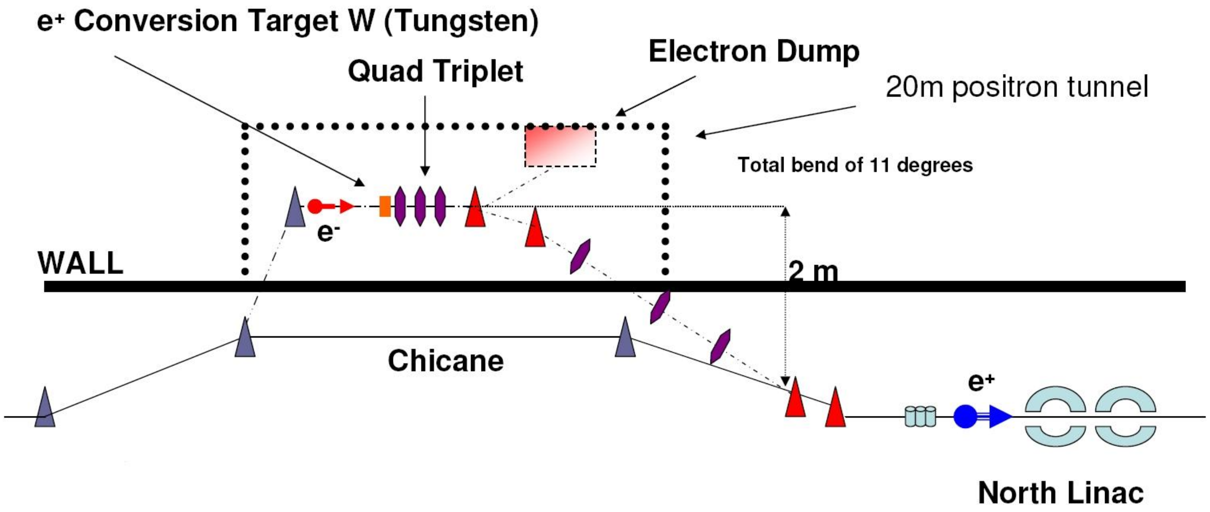
Beam Current > 50 nA *Bunch Length* < 2 ps

Duty Factor = 100 % *Frequency* = 1497 MHz

Polarized positron production

S. Golge et al., Proc. of the International Workshop on Positrons at Jefferson Lab, Newport News (VA, USA), March 25-27, 2009

- A **possible concept** involves the construction of a **dedicated e⁺ tunnel** at the end of the injector and parallel to the north linac.
- Positrons would be produced with **120 MeV e⁻** (JLab 12 GeV) incident on a tungsten target.
- **e⁺**'s are **selected** with a **quadrupole triplet** and **transported** to the accelerator section.



G4beamline simulations indicate a global efficiency of 10^{-5} e^+/e^- for 120 MeV e^- off a 3 mm W target.

10 mA e^- → 100 nA e^+

A. Freyberger, Proc. of the International Workshop on Positrons at Jefferson Lab, Newport News (VA, USA), March 25-27, 2009

❖ *Accelerator magnets*

Most magnet power supplies are reversible except the arc dipoles which requires a manual action.
The e^- to e^+ **switching time** will **limit** the **precision** on a **charge asymmetry** measurement.

❖ *Beam diagnostics*

Beam position monitors and viewers will work as long as the e^+ current is **≥ 50 nA**.

❖ *Beam modes*

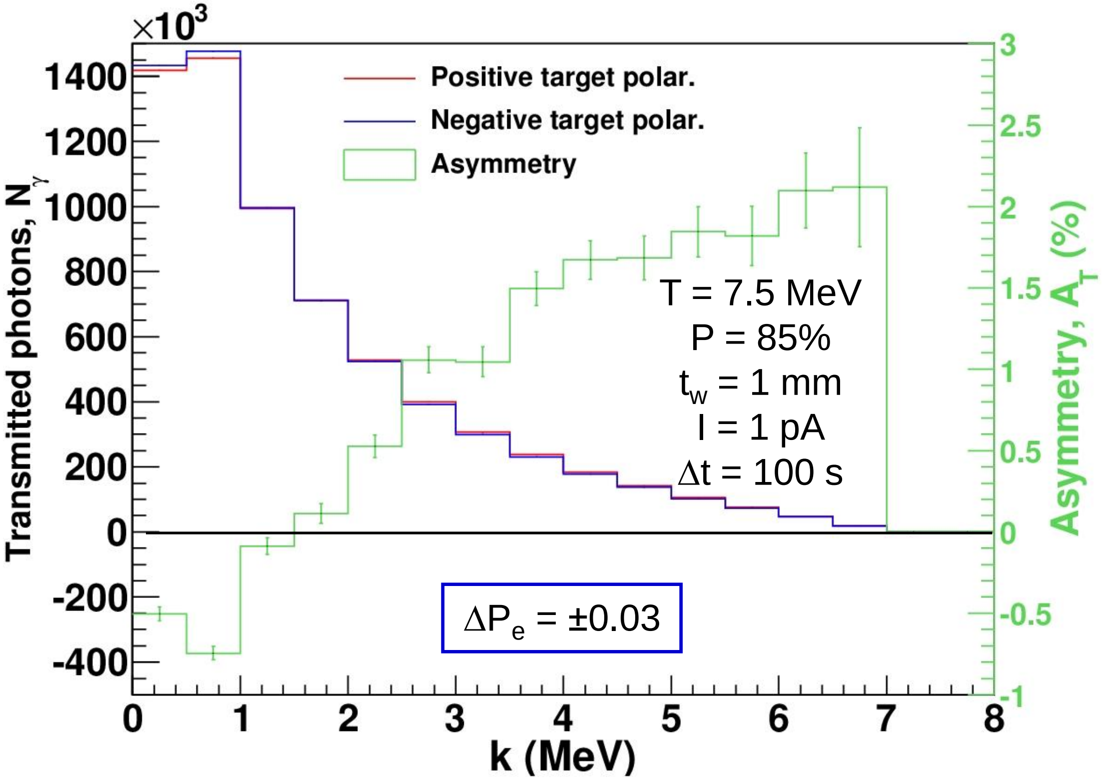
The **tune mode** based on a pulsed beam about tens of **μA** and 250 μs long and used for beam steering will need to be redefined because of the **small e^+ current**.

❖ *RF system*

Each pass in the linac are adjusted in phase with each other via the adjustement of their pathlength with the arc dogleg sections. The **diagnostic** that measures the **phase difference** between passes require **tune mode beam of sufficient current** (μA).

Compton Transmission Polarimetry

- Polarized **e±** convert into circularly polarized **photons** into a tungsten target.
- The **photon** polarization is analyzed via **Compton** scattering off a magnetized iron target.



$$A_T = \frac{N^+ - N^-}{N^+ + N^-} = \tanh\left(-P_\gamma P_t \mu_1 L\right)$$

$$\mu_1 = \rho_e \int d\theta d\varphi \frac{d^2\sigma^0}{d\theta d\varphi} A_C(\theta)$$

$$\boxed{P_e = \frac{A_T}{P_t A_e}}$$

❖ The analyzing power A_e is obtained from electron beam **calibration** data and **simulations**.

❖ A data acquisition system with **high rate** capabilities (~1 MHz) is forseen (250 MHz flash ADC).