Hirschegg, 18/01/2011

Deep Virtual Compton Scattering: From data to GPDs

M. Guidal, IPN Orsay

A few basic definitions/features of GPDs

A DVCS fitter code

Review of the data (JLab, HERMES)

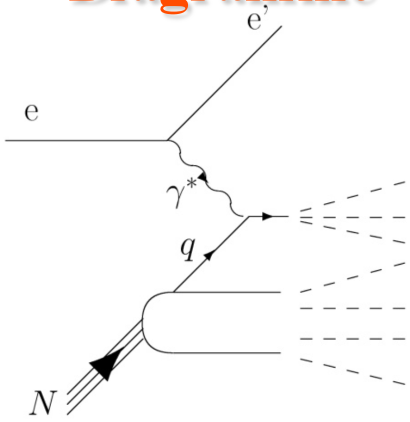
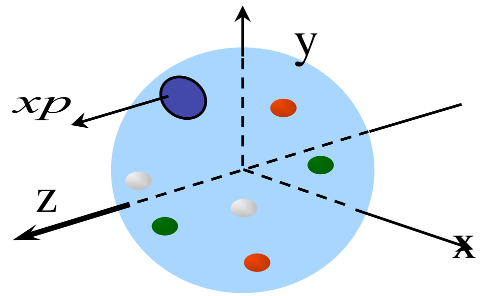
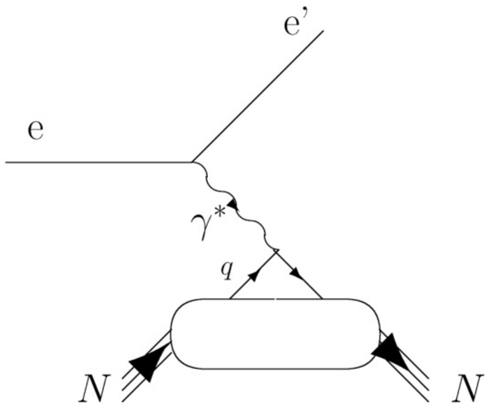
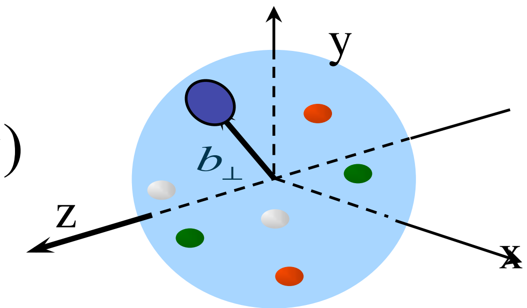
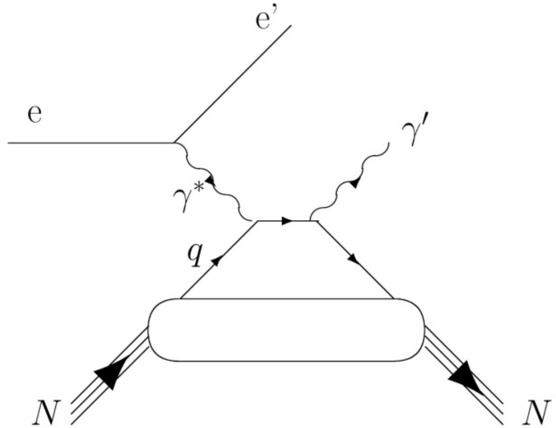
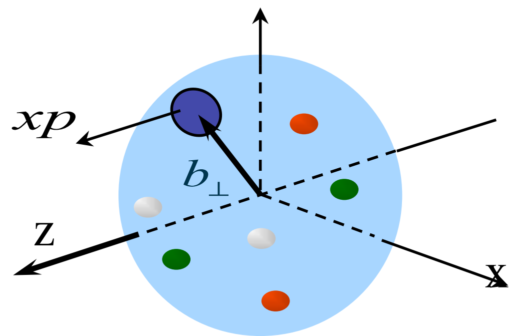
First extractions of the H_{Re}, H_{Im} and $\tilde{H}_{Im}$ CFFs

A few basic definitions/features of GPDs

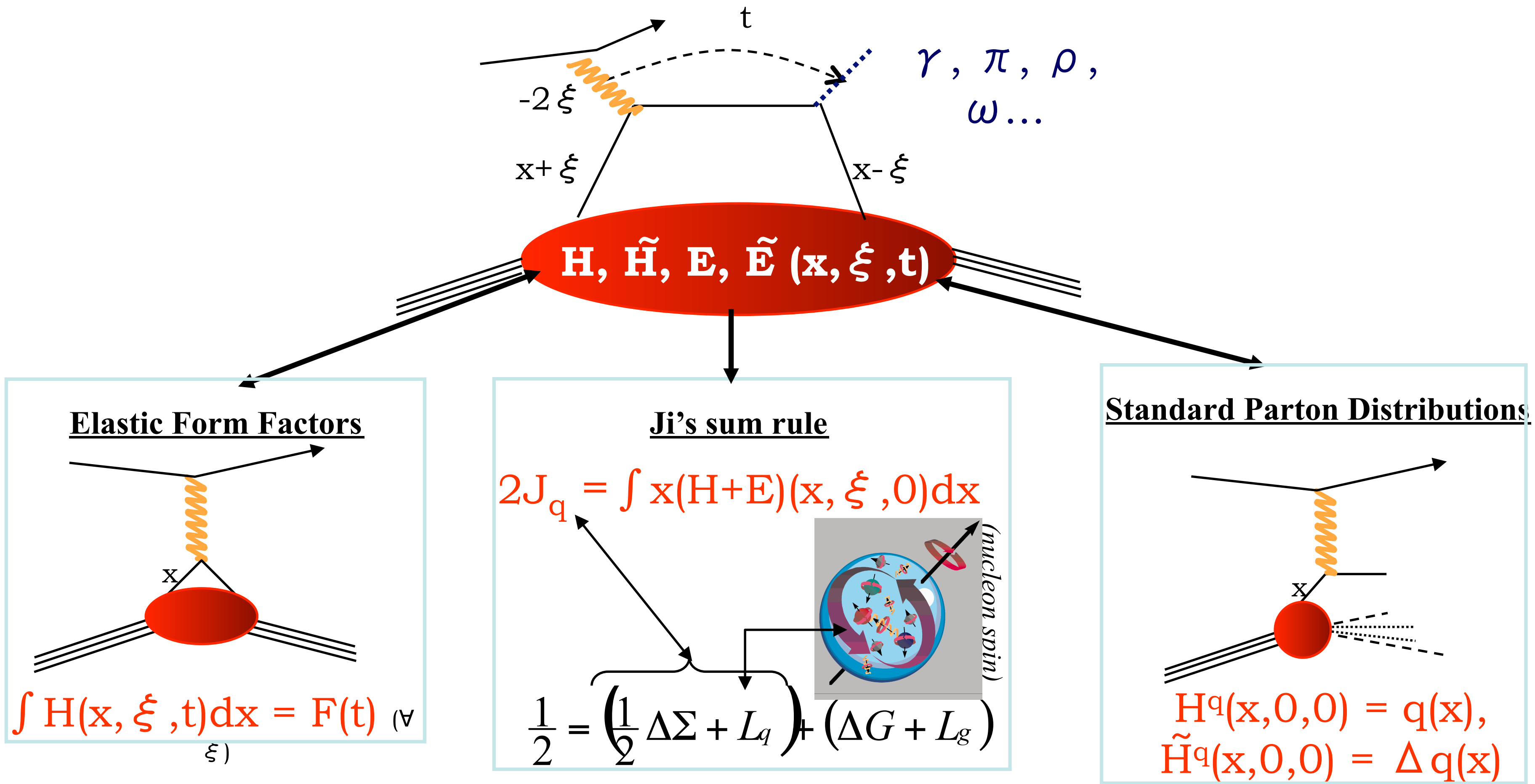
A DVCS fitter code

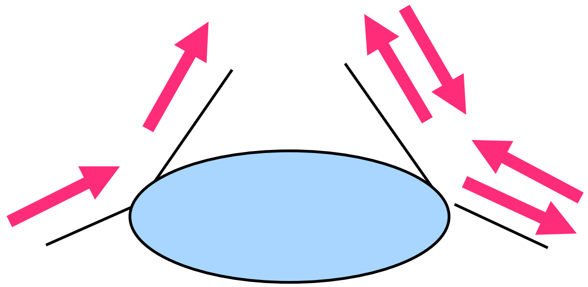
Review of the data (JLab, HERMES)

First extractions of the H_{Re}, H_{Im} and $\tilde{H}_{Im}$ CFFs

Process	Diagramme	Structure function	Interpretation
ep ⇨ eX		$f_1(x), g_1(x)$	
ep ⇨ ep		$F_1(t), F_2(t), G_A(t), G_P(t)$	
ep ⇨ epγ		$H(x,\xi,t), E(x,\xi,t),$ $\widetilde{H}(x,\xi,t), \widetilde{E}(x,\xi,t)$	

(restricting myself to LT-LO, chiral even, quark sector)

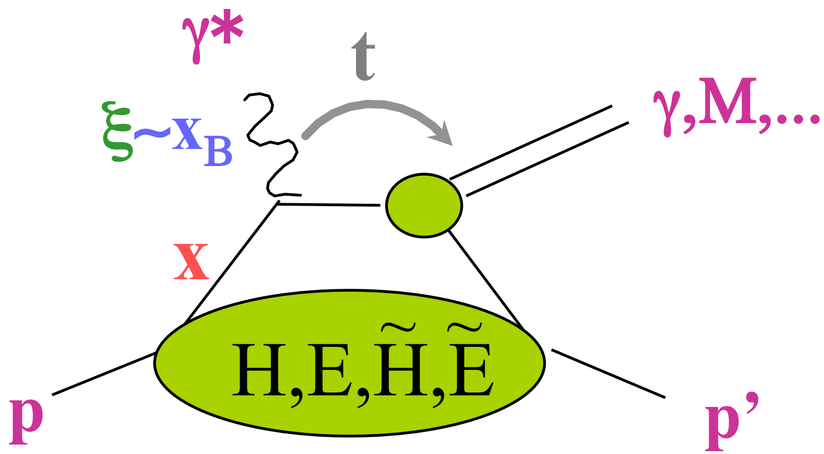




H	***E***	***q spin average***
H̃	***Ẽ***	***q spin diff.***
N spin no flip	***N spin flip***	

$H^q(x,\xi,t)$ but only ξ and t accessible experimentally

$$\xi = \frac{x_B/2}{1-x_B/2} \qquad t=(p-p')^2$$



$x \neq x_B$!

$$\frac{d\sigma}{d\xi\, dt} \sim \left| A\int_{-1}^{1} \frac{H^q(x,\xi,t)}{x-\xi+i\varepsilon}\,dx + B\int_{-1}^{1} \frac{E^q(x,\xi,t)}{x-\xi+i\varepsilon}\,dx + \ldots \right|^2$$

⇨ x : mute variable ***Deconvolution needed !***

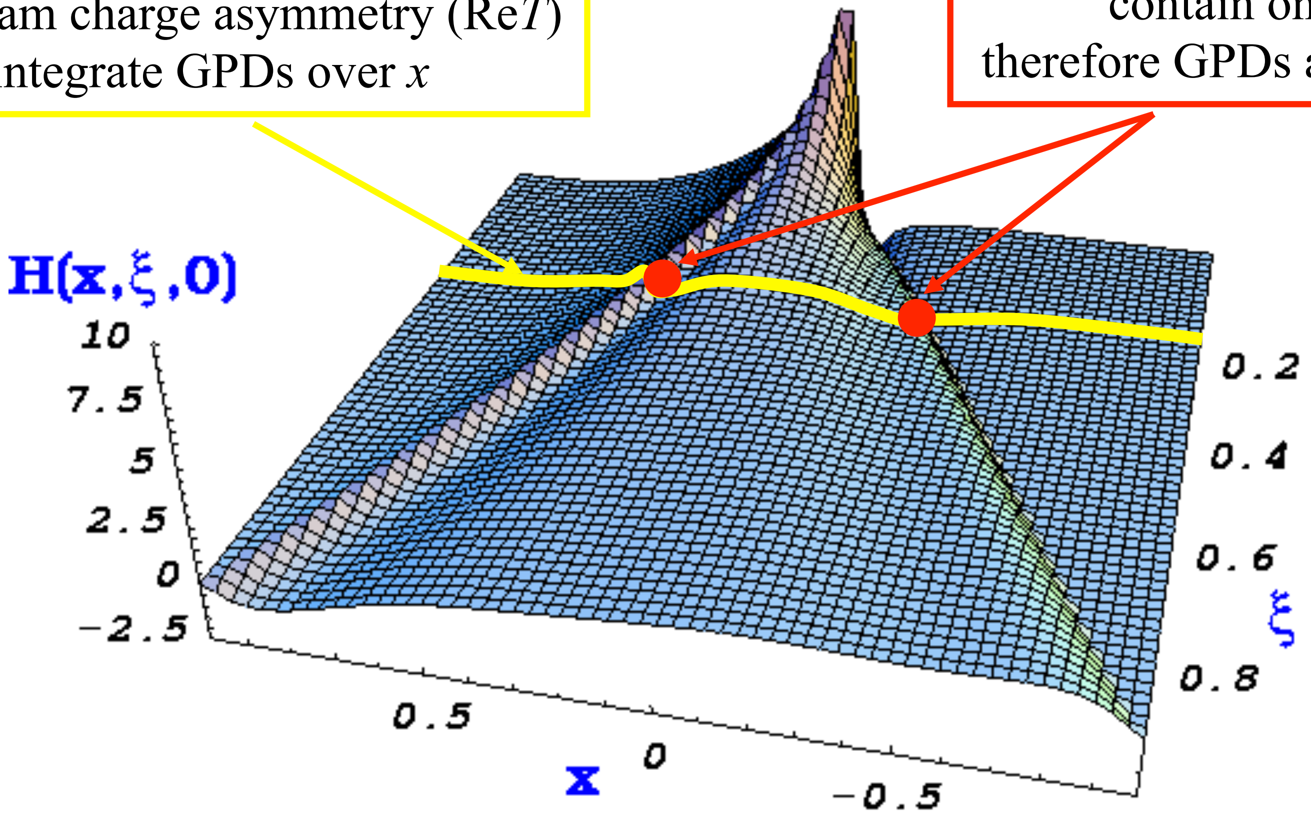
GPD and DVCS

(at leading order:)

$$T^{DVCS} \sim \int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi + i\varepsilon} dx + \ldots \sim \quad P\int_{-1}^{+1} \frac{H(x,\xi,t)}{x \pm \xi} dx - i\pi H(\pm\xi,\xi,t) + \ldots$$

Cross-section measurement and beam charge asymmetry (ReT) integrate GPDs over x

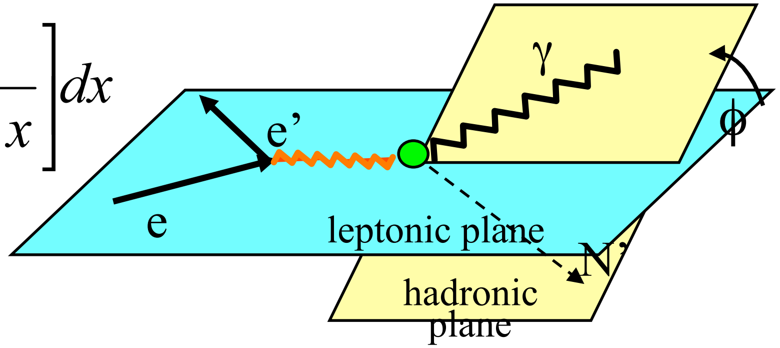
Beam or target spin asymmetry contain only ImT, therefore GPDs at $x = \xi$ and $-\xi$



Extracting GPDs from DVCS observables

$$Re\mathcal{H}_q = e_q^2 P\int_0^{+1}\left(H^q(x,\xi,t) - H^q(-x,\xi,t)\right)\left[\frac{1}{\xi - x} + \frac{1}{\xi + x}\right]dx$$

$$Im\mathcal{H}_q = \pi e_q^2 \left[H^q(\xi,\xi,t) - H^q(-\xi,\xi,t)\right]$$



$\xi = x_B/(2-x_B)$ $k = -t/4M^2$

Proton Neutron

Polarized beam, unpolarized target (BSA) :

$\Delta\sigma_{LU} \sim \sin\phi\ \mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\tilde{\mathcal{H}} - kF_2\mathcal{E}\}d\phi$ ⇒ $Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p, \mathcal{E}_p\}$; $Im\{\mathcal{H}_n, \tilde{\mathcal{H}}_n, \mathcal{E}_n\}$

Unpolarized beam, longitudinal target (lTSA) :

$\Delta\sigma_{UL} \sim \sin\phi\,\mathrm{Im}\{F_1\tilde{\mathcal{H}} + \xi(F_1+F_2)(\mathcal{H} + x_B/2\,\mathcal{E}) - \xi kF_2\,\tilde{\mathcal{E}} + \ldots\}d\phi$ ⇒ $Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$; $Im\{\mathcal{H}_n, \mathcal{E}_n, \tilde{\mathcal{E}}_n\}$

Polarized beam, longitudinal target (BlTSA) :

$\Delta\sigma_{LL} \sim (A + B\cos\phi)\mathrm{Re}\{F_1\tilde{\mathcal{H}} + \xi(F_1+F_2)(\mathcal{H} + x_B/2\,\mathcal{E})\ldots\}d\phi$ ⇒ $Re\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$; $Re\{\mathcal{H}_n, \mathcal{E}_n, \tilde{\mathcal{E}}_n\}$

Unpolarized beam, transverse target (tTSA) :

$\Delta\sigma_{UT} \sim \sin\phi\,\mathrm{Im}\{k(F_2\mathcal{H} - F_1\mathcal{E}) + \ldots\}d\phi$ ⇒ $Im\{\mathcal{H}_p, \mathcal{E}_p\}$; $Im\{\mathcal{H}_n\}$

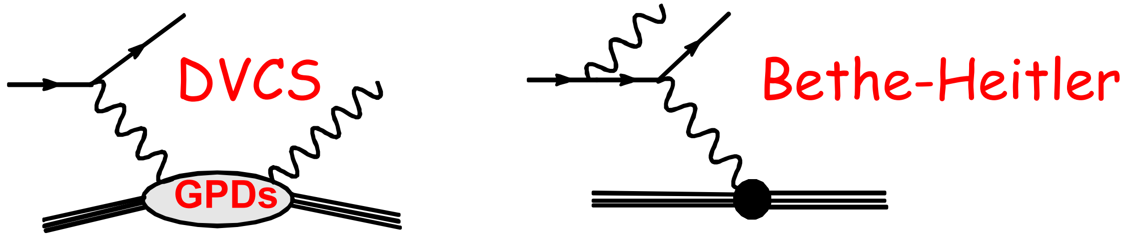
A few basic definitions/features of GPDs

A DVCS fitter code

Review of the data (JLab, HERMES)

First extractions of the H_{Re}, H_{Im} and $\tilde{H}_{Im}$ CFFs

Given the well-established LT-LO DVCS+BH amplitude



Can one recover the CFFs from data ?

Obs=Amp(DVCS+BH) $\otimes$ CFFs

Model-independent fit, at fixed x_B, t and Q^2,
of DVCS observables with
MINUIT + MINOS

8 unknowns (the CFFs), non-linear problem, strong correlations

Only 3 CFFs come out from the fit with finite error bars:
H_{Im} , $\tilde{H}_{Im}$ and H_{Re}

Compton Form Factors

$$H_{Re} = P\int_0^1 dx\,[H(x,\xi,t) - H(-x,\xi,t)]\,C^+(x,\xi) \quad (1)$$

$$E_{Re} = P\int_0^1 dx\,[E(x,\xi,t) - E(-x,\xi,t)]\,C^+(x,\xi) \quad (2)$$

$$\tilde{H}_{Re} = P\int_0^1 dx\left[\tilde{H}(x,\xi,t) + \tilde{H}(-x,\xi,t)\right]C^-(x,\xi) \quad (3)$$

$$\tilde{E}_{Re} = P\int_0^1 dx\left[\tilde{E}(x,\xi,t) + \tilde{E}(-x,\xi,t)\right]C^-(x,\xi) \quad (4)$$

$$H_{Im} = H(\xi,\xi,t) - H(-\xi,\xi,t), \quad (5)$$

$$E_{Im} = E(\xi,\xi,t) - E(-\xi,\xi,t), \quad (6)$$

$$\tilde{H}_{Im} = \tilde{H}(\xi,\xi,t) + \tilde{H}(-\xi,\xi,t) \quad \text{and} \quad (7)$$

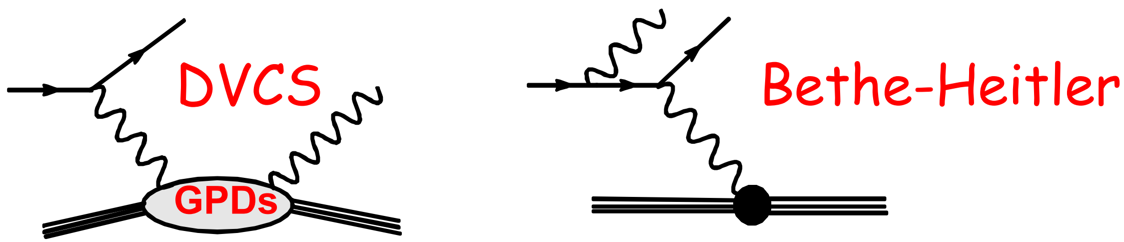
$$\tilde{E}_{Im} = \tilde{E}(\xi,\xi,t) + \tilde{E}(-\xi,\xi,t) \quad (8)$$

with

$$C^{\pm}(x,\xi) = \frac{1}{x-\xi} \pm \frac{1}{x+\xi}. \quad (9)$$

(in practice, $\tilde{E}_{Im}$ set to 0)

Given the well-established LT-LO DVCS+BH amplitude



Can one recover the CFFs from data ?

Obs=Amp(DVCS+BH) $\otimes$ CFFs

Model-independent fit, at fixed x_B, t and Q^2, of DVCS observables with MINUIT + MINOS

7 unknowns (the CFFs), non-linear problem, strong correlations

Only 3 CFFs come out from the fit with finite error bars:

H_{Im} , $\tilde{H}_{Im}$ and H_{Re}

M.G. EPJA 37 (2008) 319   M.G. & H. Moutarde, EPJA 42 (2009) 71

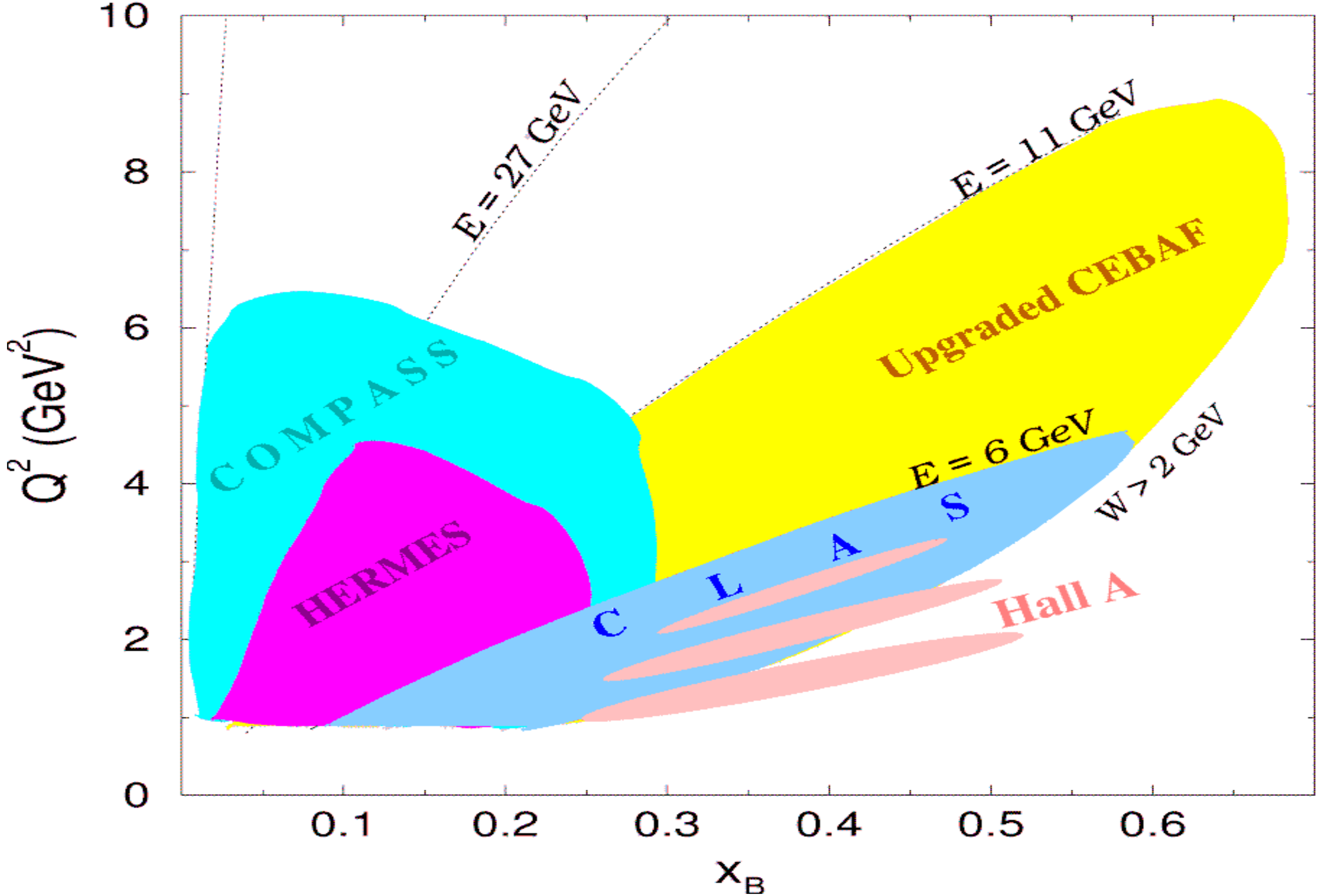
M.G. PLB 689 (2010) 156   M.G. PLB 693 (2010) 17

The experimental actors

DESY	
HERMES	***H1/ZEUS***
p-DVCS BSA,BCA, tTSA,lTSA,BlTSA	p-DVCS X-sec,BCA

JLab	
Hall A	***Hall B***
p-DVCS (Bpol.) X-sec	p-DVCS BSAs,lTSAs

CERN
COMPASS
p-DVCS X-sec,BSA,BCA, tTSA,lTSA,BlTSA

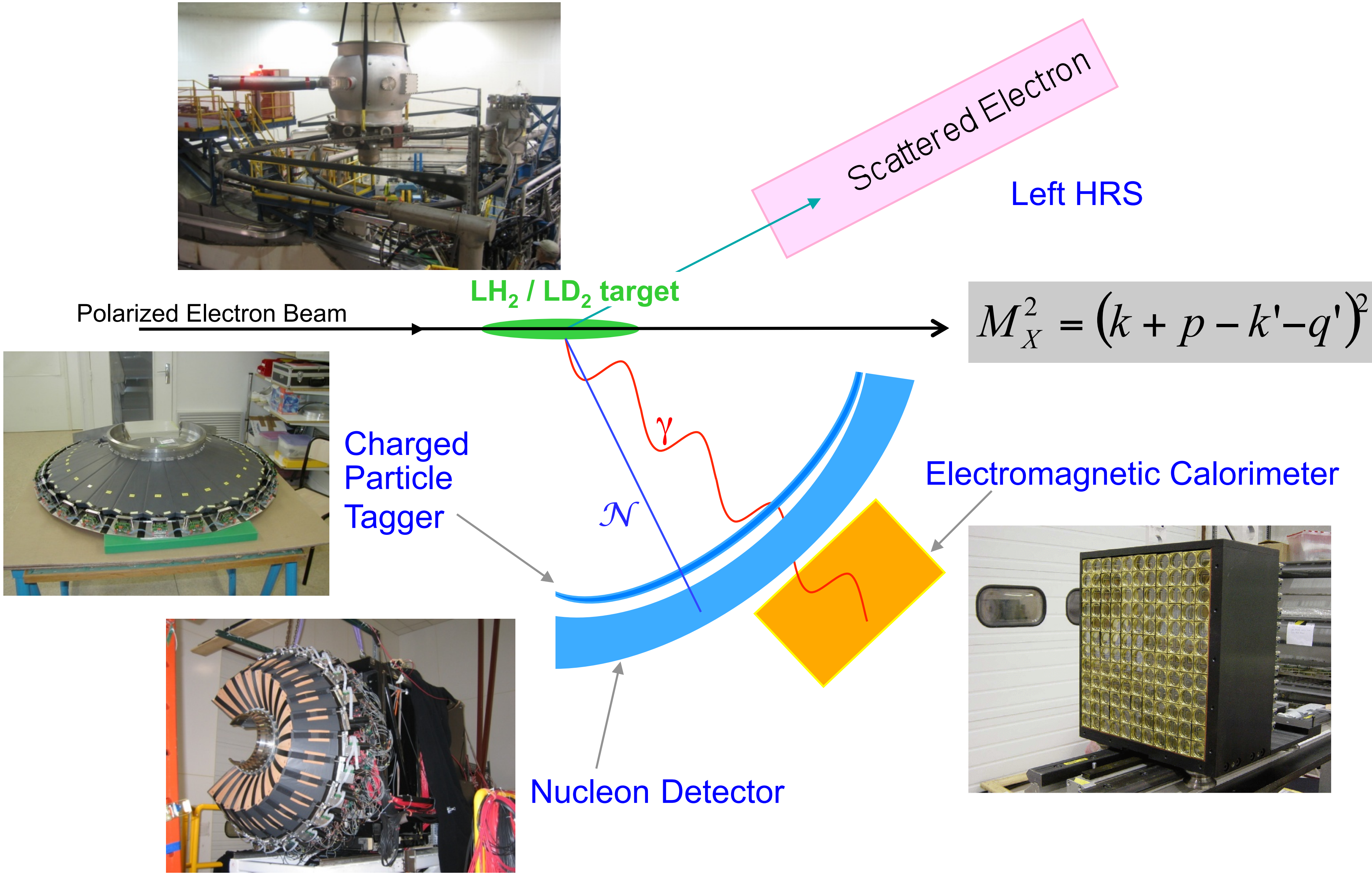


10
8
6
4
2
0
0.1
0.2
0.3
0.4
0.5
0.6
Q^2 (GeV^2)
x_B
E = 27 GeV
E = 11 GeV
E = 6 GeV
W > 2 GeV
COMPASS
HERMES
Upgraded CEBAF
C L A S
Hall A

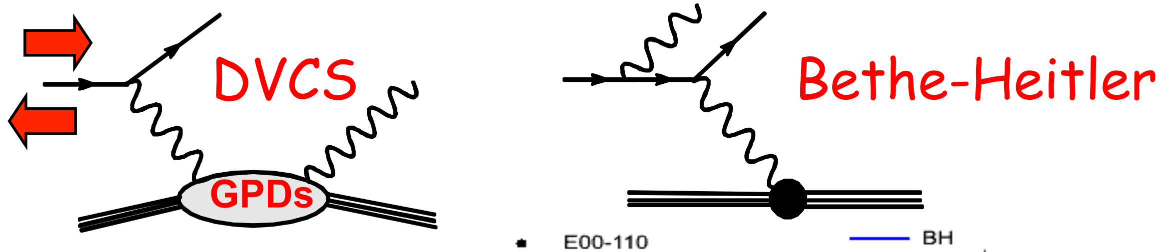
HALL A

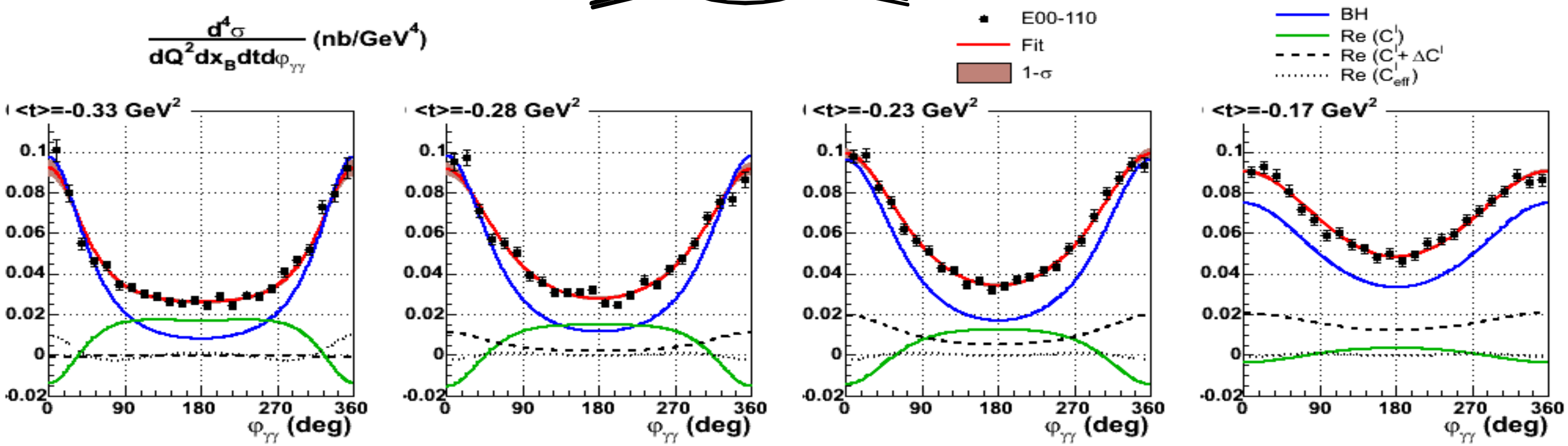
DVCS@JLab

ep ⟶ epγ

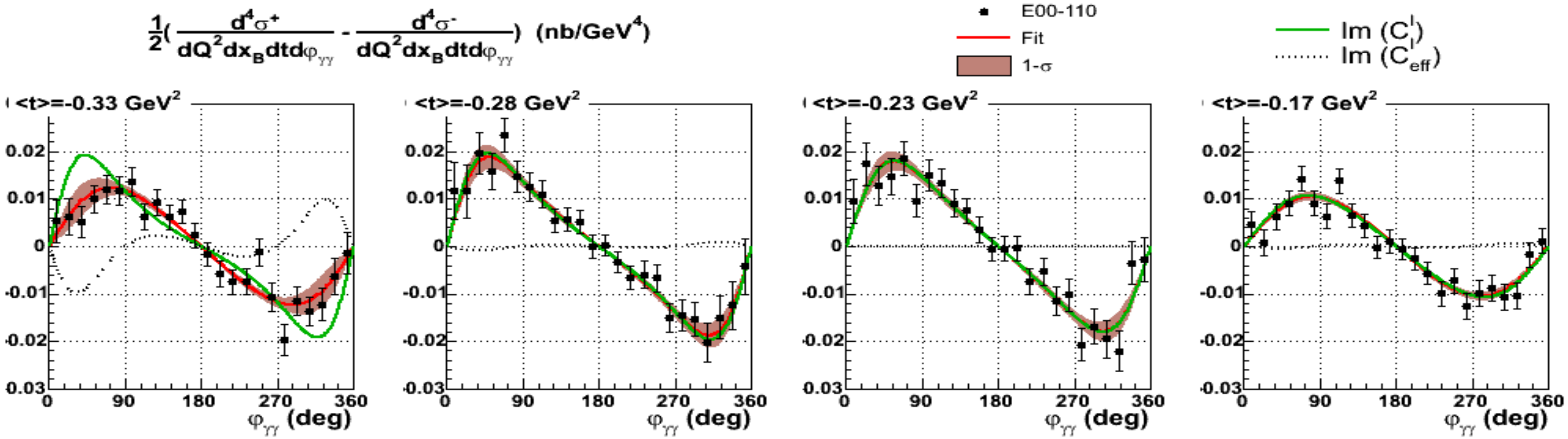


Unpolarized cross sections



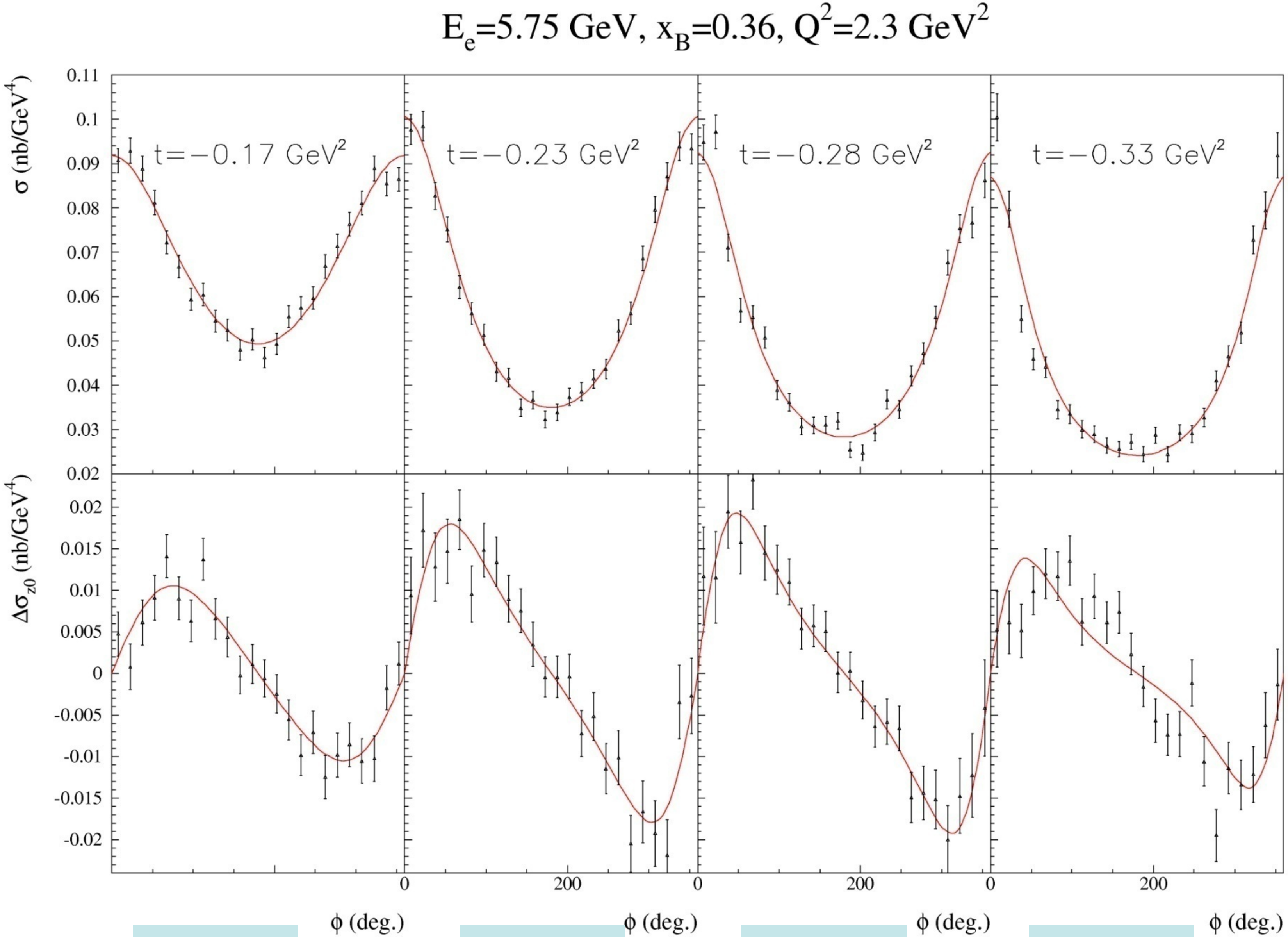


Difference of (beam-)polarized cross sections

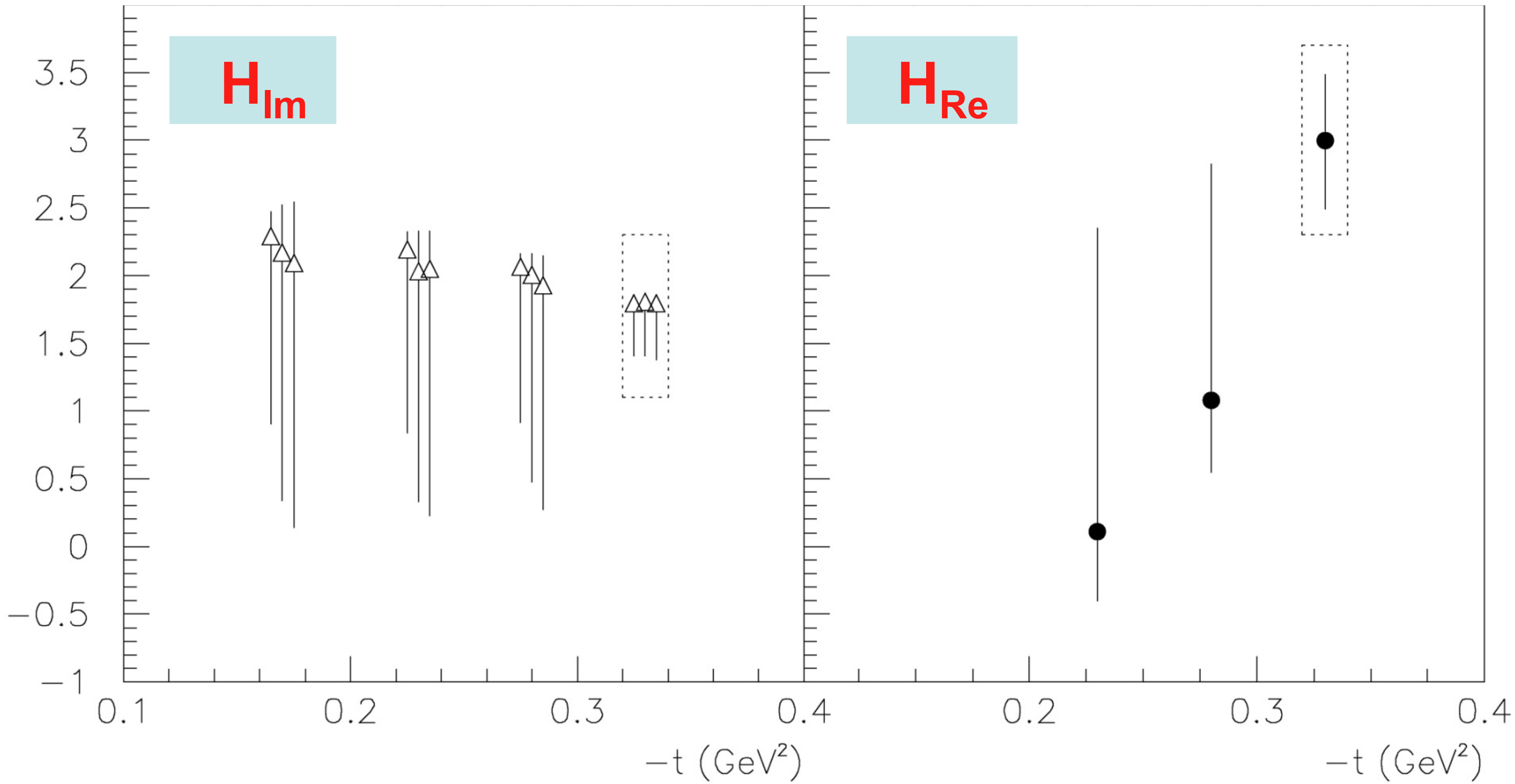


JLab Hall A Collaboration, PRL 97:262002,2006

Hall A : σ & σ_{z0} , x_B=0.36,Q^2=2.3,t=.17,.23,.28,.33



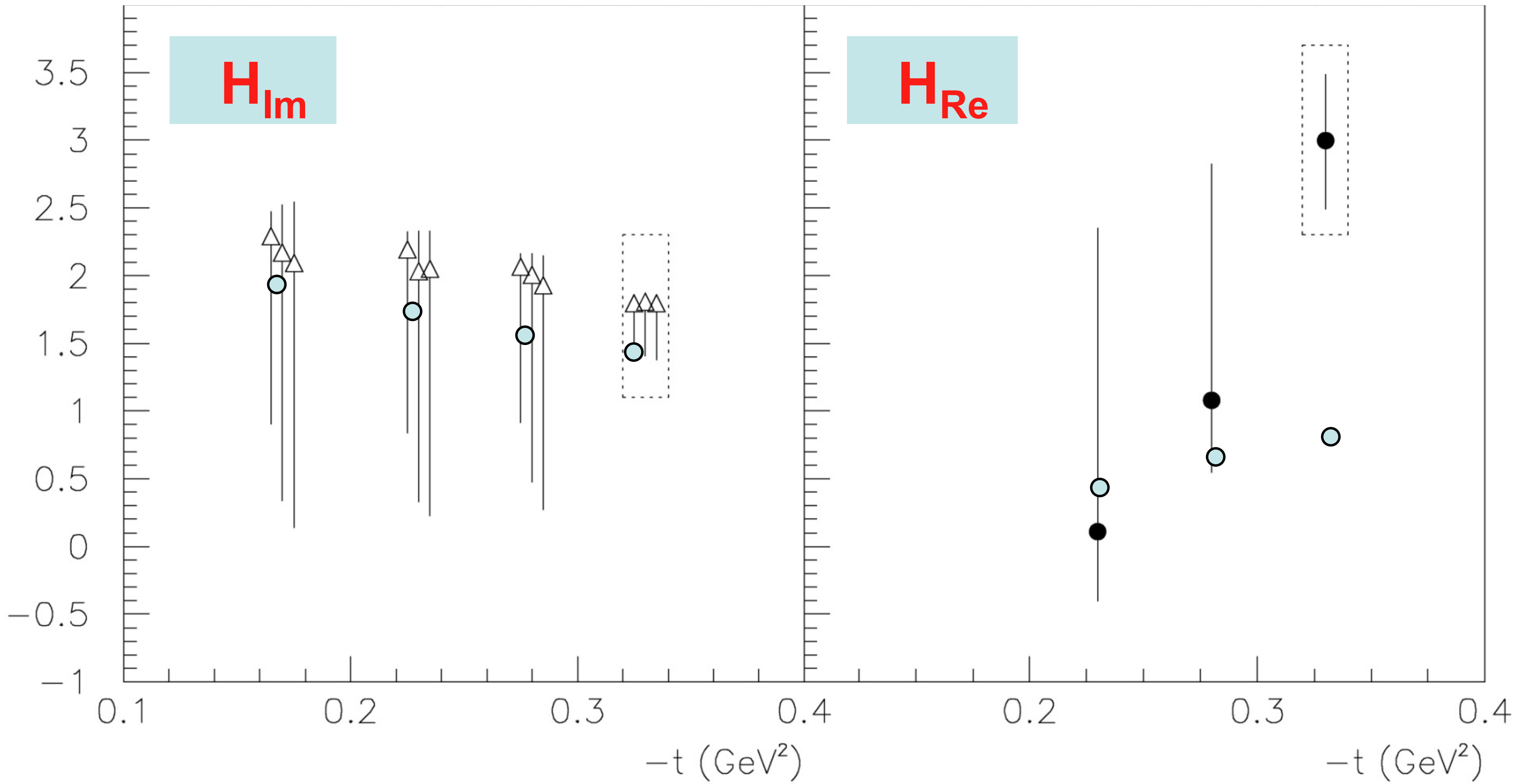
χ^2=1.01 χ^2=0.92 χ^2=1.44 χ^2=2.31



△ **Result of the (model independent) fit**

Bounds (for ALL CFFs):
{-3,3}, {-5,5}, {-7,7} x VGG

M.G. EPJA 37 (2008) 319



△ **Result of the (model independent) fit**

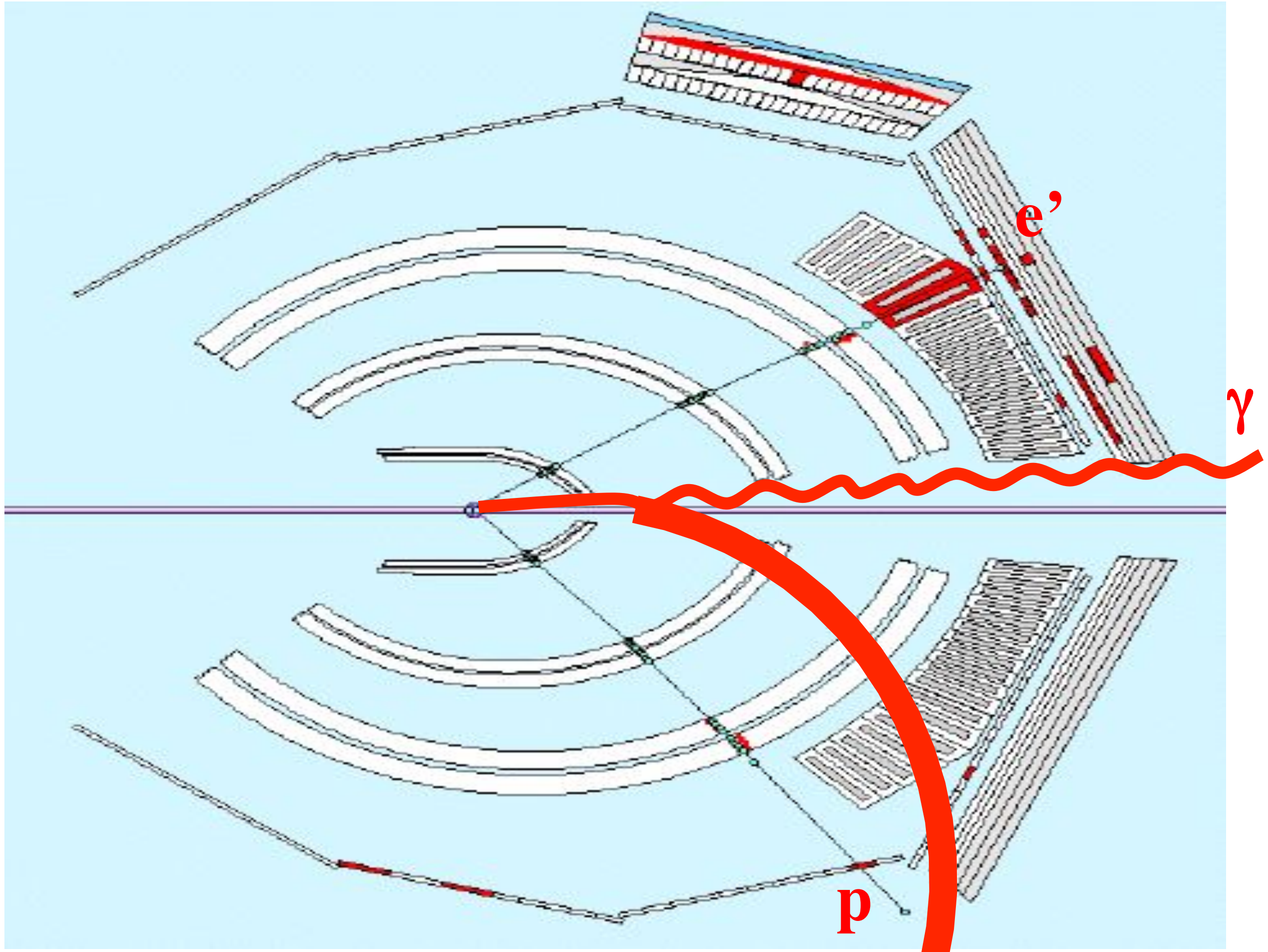
∘ **VGG prediction**

M.G. EPJA 37 (2008) 319

DVCS@JLab

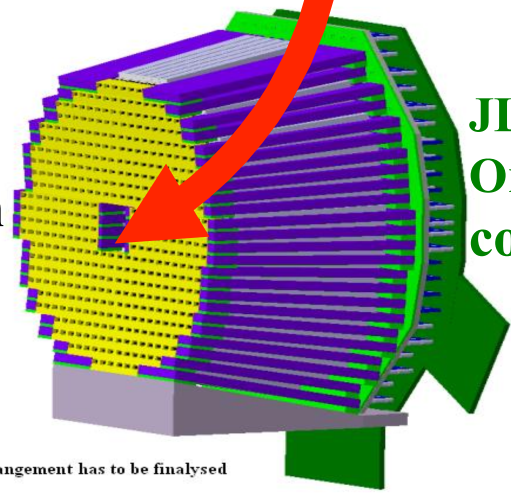
HALL B

ep⇨ epγ



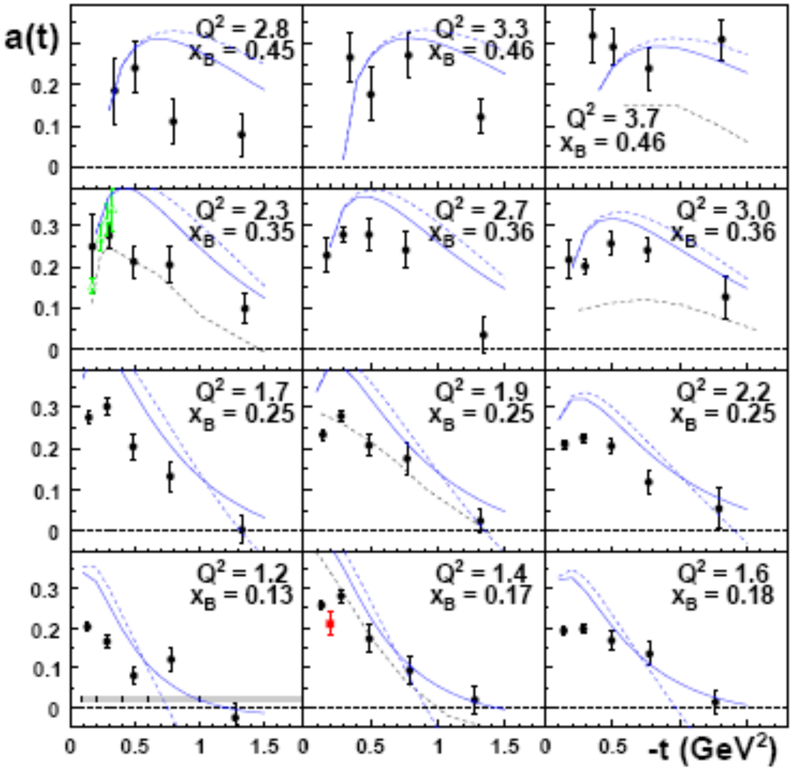
$420\ PbWO_4$ crystals : ~$10x10\ mm^2$, l=160 mm

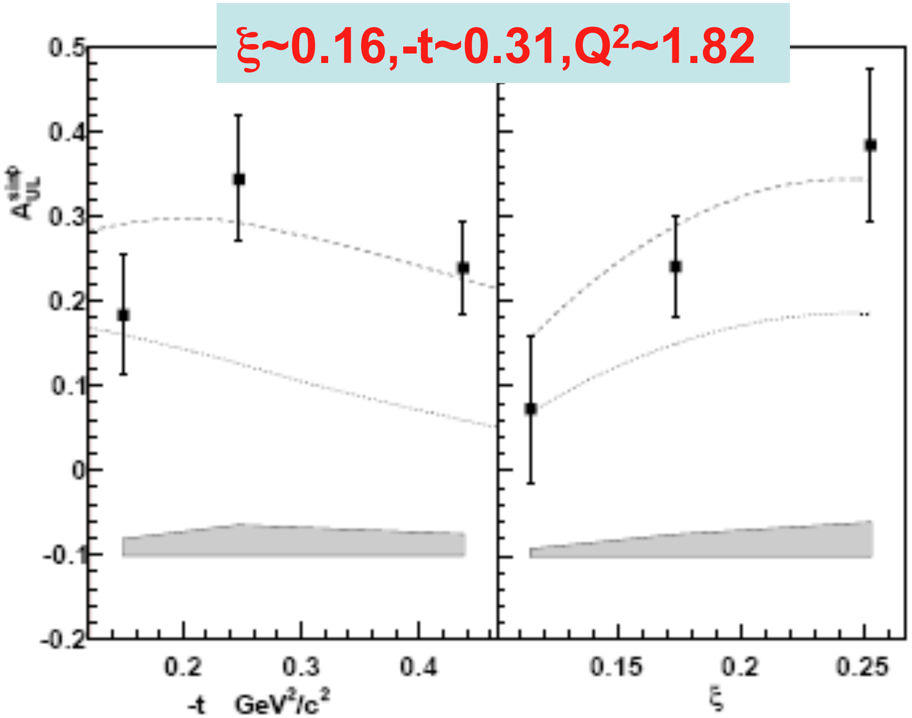
Read-out : APDs +preamps



JLab/ITEP/ Orsay/Saclay collaboration

ROSIER Ph. 18-02-03





CLAS DVCS BSAs

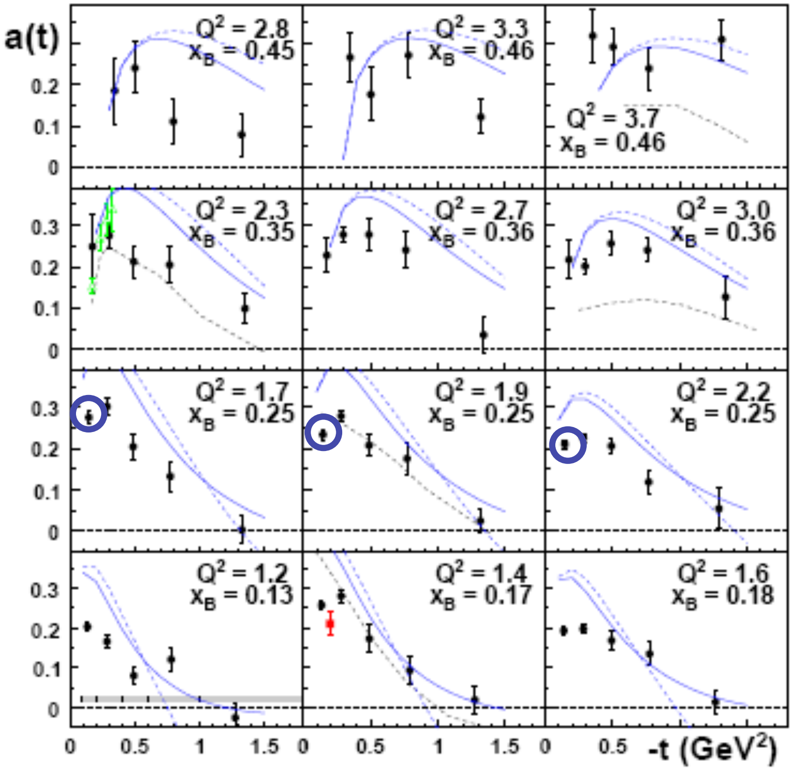
F.-X. Girod et al., Phys. Rev. Lett. **100**, 162002 (2008).

CLAS DVCS ℓTSAs

S. Chen et al., Phys. Rev. Lett. **97**, 072002 (2006).

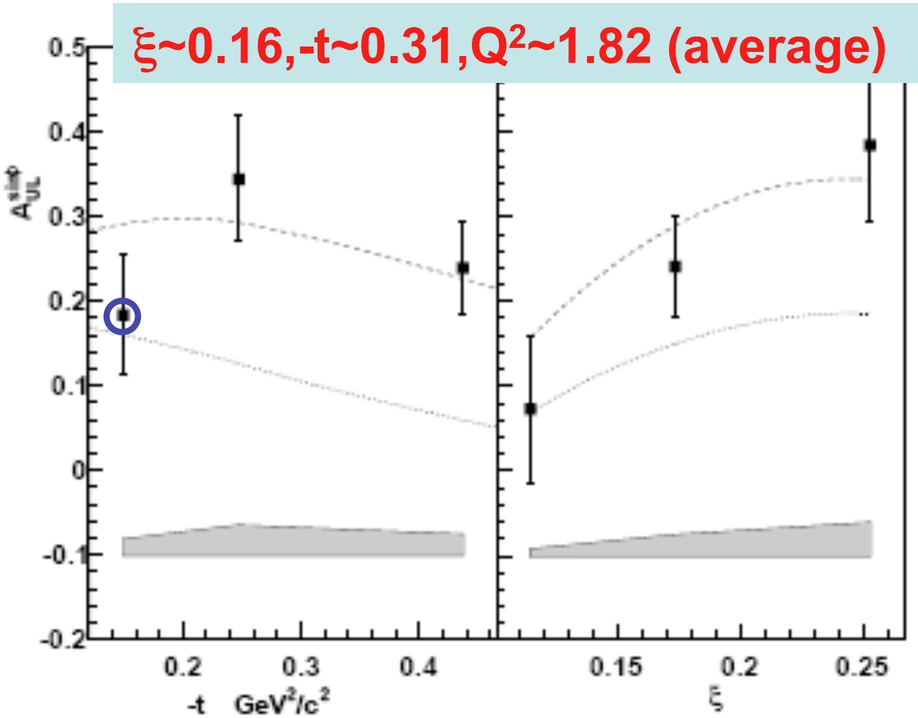
Can we extract (in a model-independent way) some CFFs from fitting (simultaneously) the CLAS DVCS BSAs and TSAs ?

(at approximatively the same kinematics)



CLAS DVCS BSAs

F.-X. Girod et al., Phys. Rev. Lett. **100**, 162002 (2008).



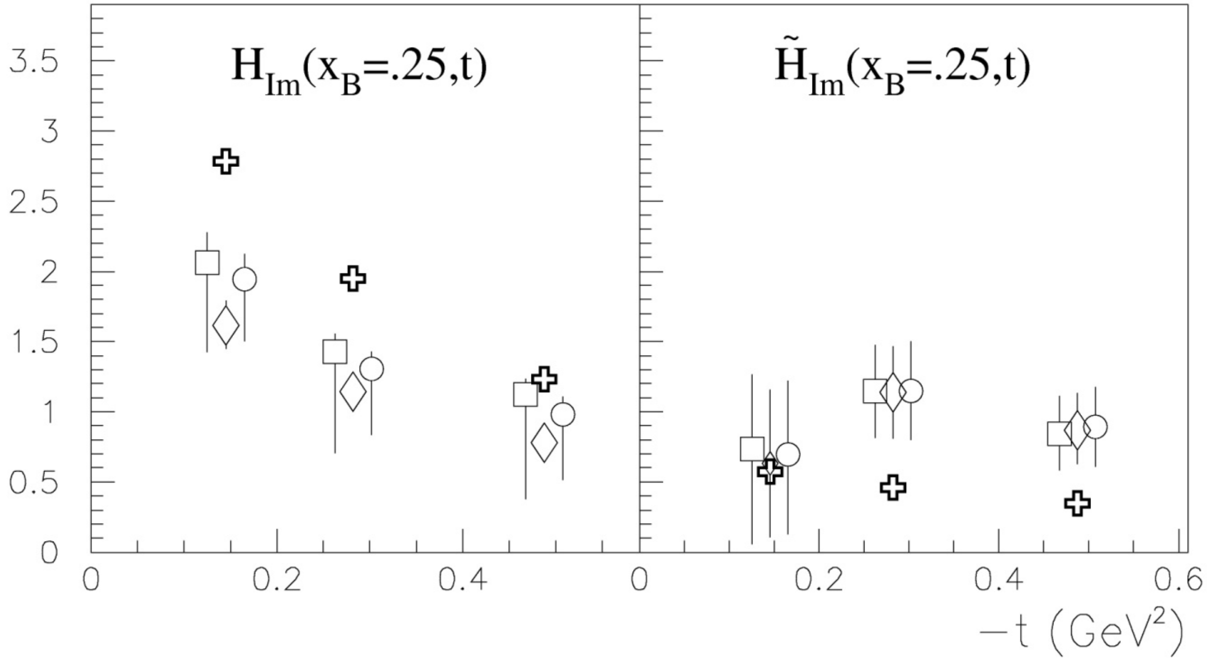
CLAS DVCS ℓTSAs

S. Chen et al., Phys. Rev. Lett. **97**, 072002 (2006).

Can we extract (in a model-independent way) some CFFs from fitting (simultaneously) the CLAS DVCS BSAs and TSAs ?

(at approximatively the same kinematics)

t-dependence at fixed x_B of H_{Im} & $\tilde{H}_{Im}$



Axial charge more concentrated than electromagnetic charge ?

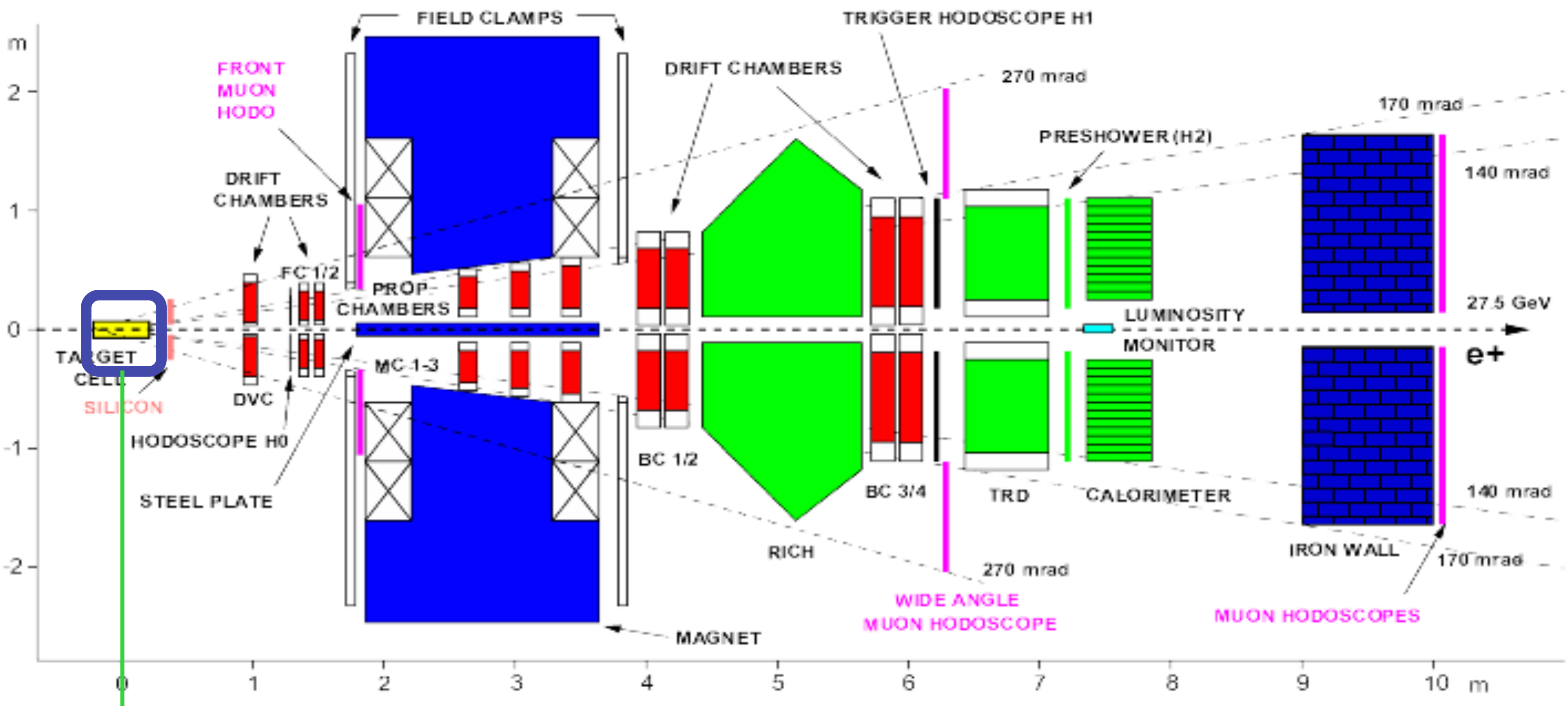
□ Fit with 7 CFFs (boundaries 5xVGG CFFs)

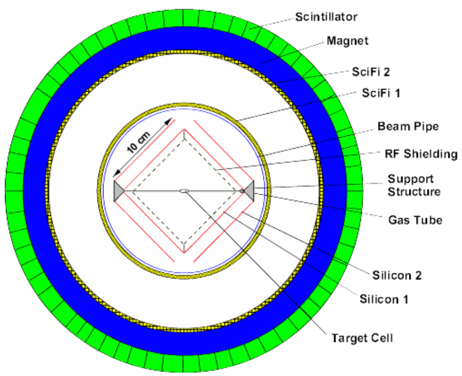
○ Fit with 7 CFFs (boundaries 3xVGG CFFs)

◇ Fit with ONLY H and $\tilde{H}$

✣ VGG prediction

M.G. PLB 689 (2010) 156





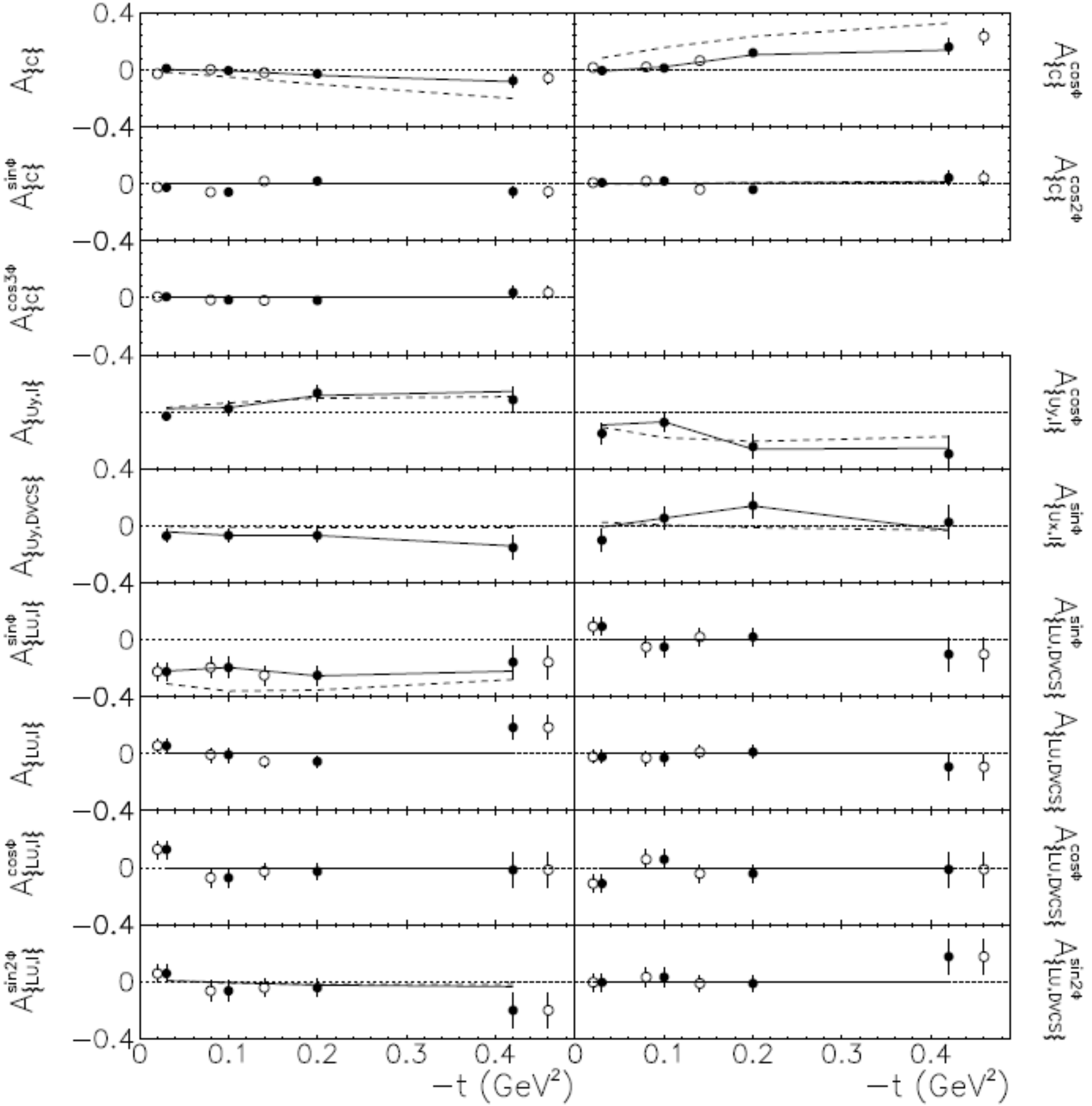
hermes

p-DVCS BSA, BCA, ITSA, tTSA, BITSA

A. Airapetian et al., JHEP 0806, 066 (2008)

A. Airapetian et al., JHEP 0911, 083 (2009)

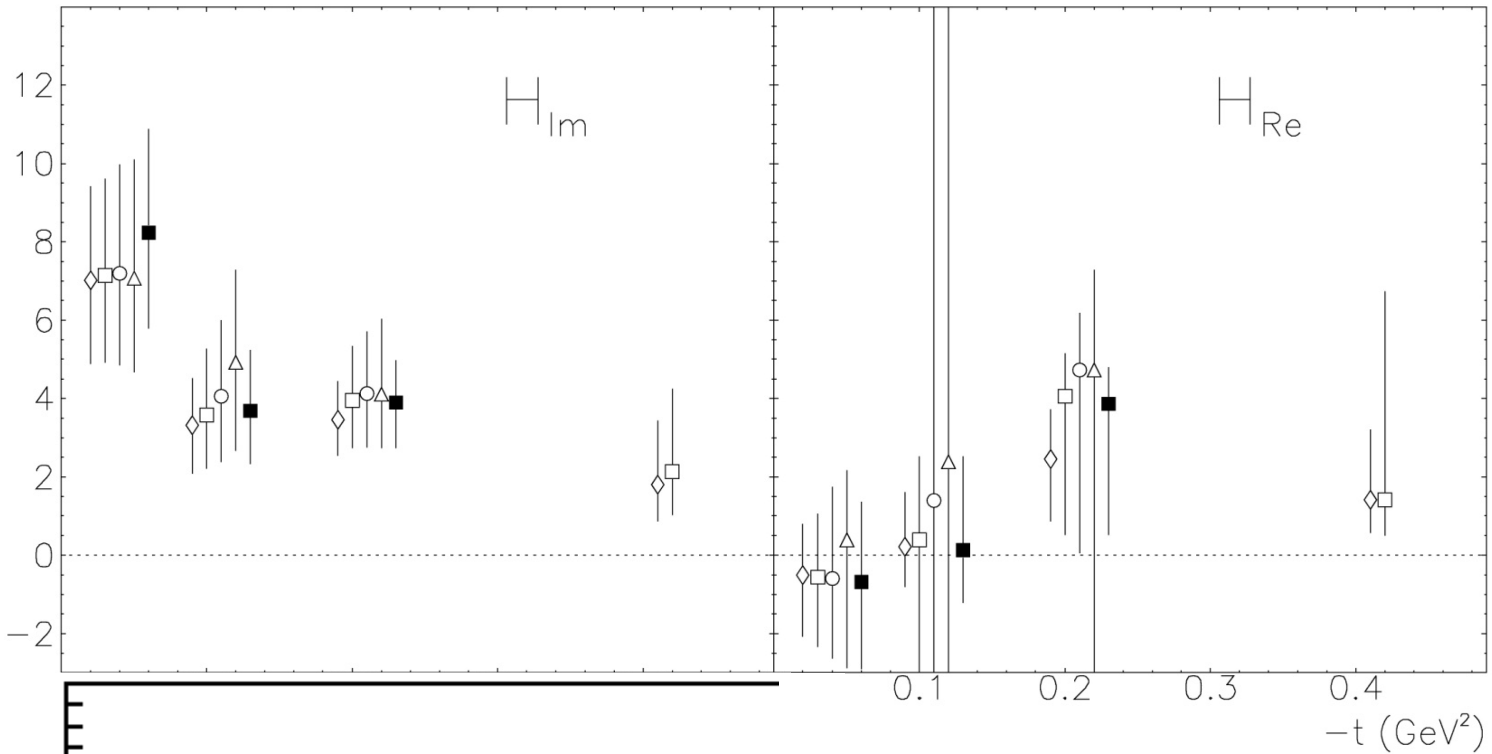
A. Airapetian et al., JHEP 1006, 019 (2010)



17 out of 23
Φ moments

Result of fit

VGG prediction



Average kinematics

■ x_B=0.09,Q^2=2.5

Bounds:

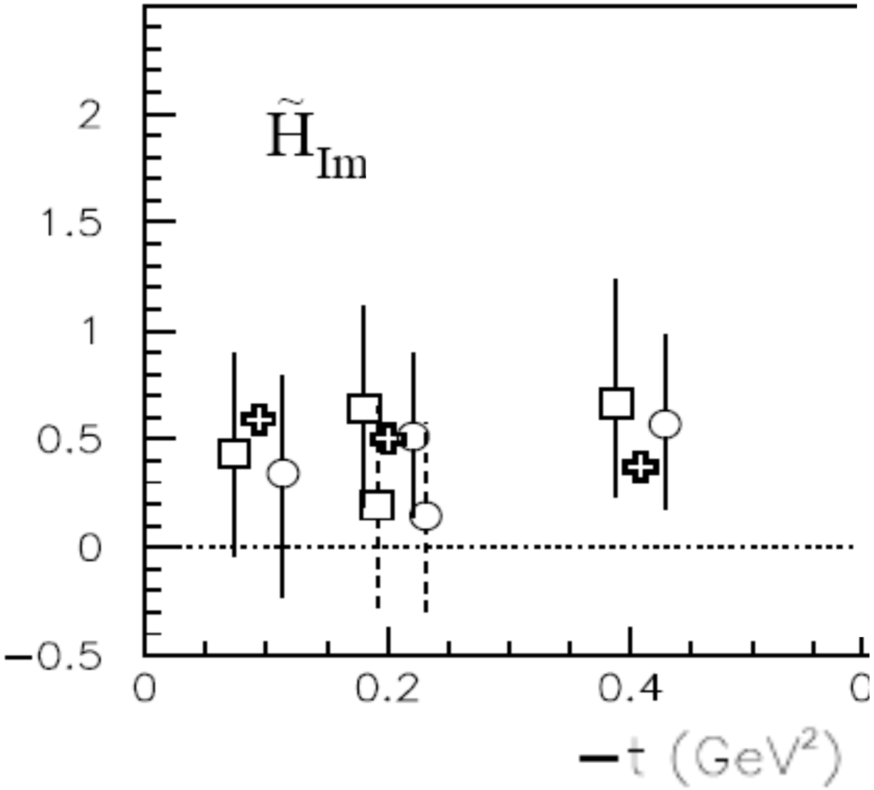
◇ {-3,3} x VGG

□ {-5,5} x VGG

○ {-7,7} x VGG

△ {-10,10} x VGG

M.G. & H. Moutarde
EPJA 37 (2008) 319



Bounds:

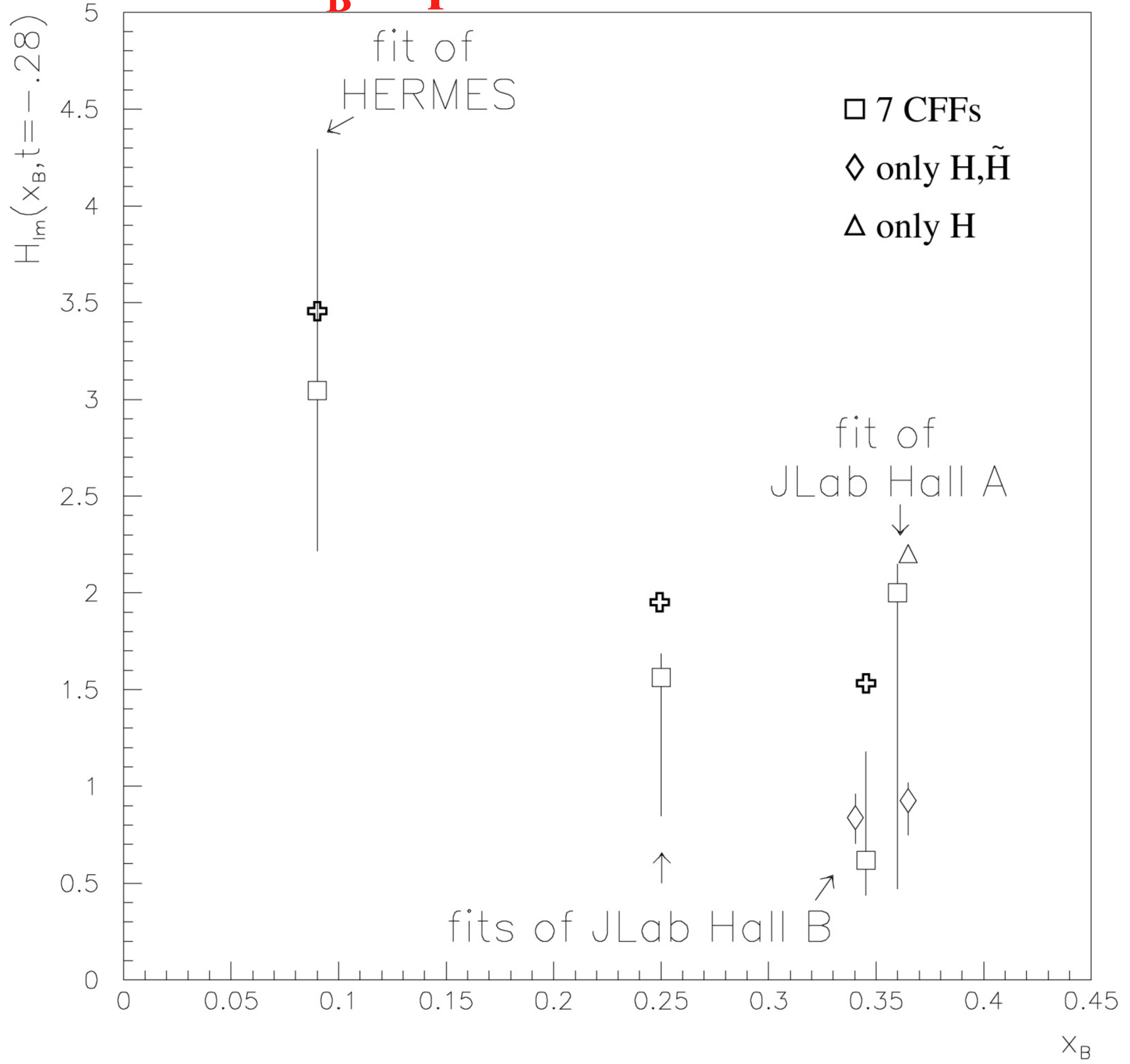
□ {-5,5} x VGG

○ {-3,3} x VGG

VGG prediction

M.G. PLB 693 (2010) 17

x_B dependence at fixed t



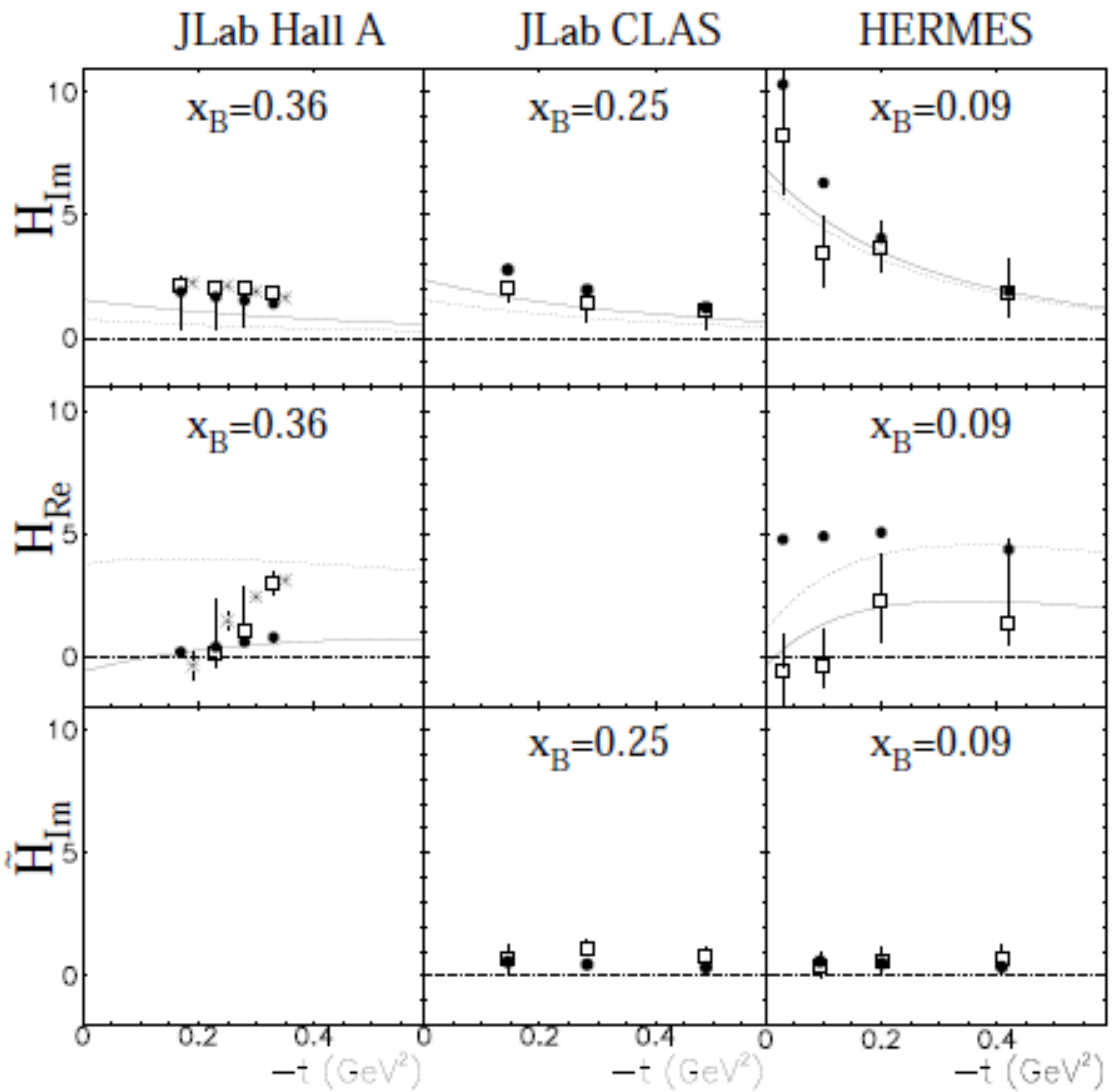


Figure 1: The $H_{\rm Im}$, $H_{\rm Re}$ and $\tilde{H}_{\rm Im}$ CFFs, as defined in Eqs.1, 5 and 7, as a function of $-t$. The empty squares show the results of our works, the stars the result of the CFF fit of Ref. [22], the curves the results of the model-based fit of Ref. [23] and the solid points show the predictions of the VGG model [13, 4, 21].

- *First CFFs model independent fits (leading-twist/leading order approximation); "Minimal theoretical input"*
- *Procedure tested by Monte-Carlo*
- *Procedure is working on real data;*
  extraction of H_{im}, H_{Re} and $\tilde{H}_{Im}$ at JLab (cross sections)
  and HERMES (asymmetries) energies
- *Relatively large uncertainties on extracted CFFs*
  (due to lack of observables -and precision on data-)
- *Introducing more theoretical input will reduce*
  uncertainties (but model dependency)
- *Large flow of new observables and data expected soon;*
  will bring much more experimental constraints to extract
  CFFs with minimum theoretical input