Local Fitting of DVCS data

Michel Guidal

IPN Orsay

Bochum, 11/02/2014

1/ From data to CFFs (first steps)

2/ From CFFs to nucleon imaging (first steps)

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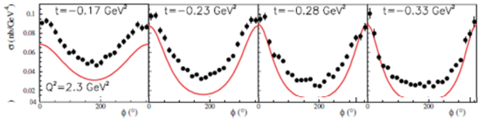
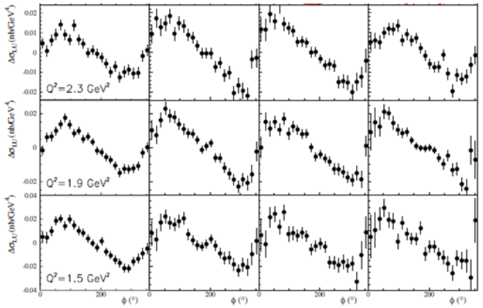
JLab
Hall A

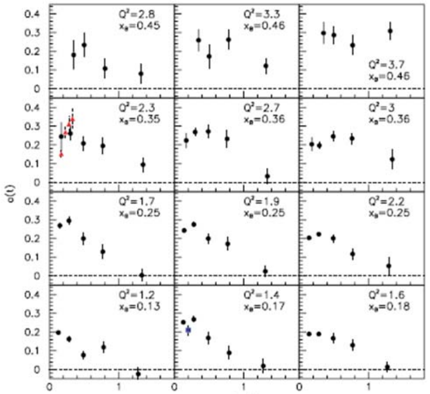


DVCS
unpol. X-section

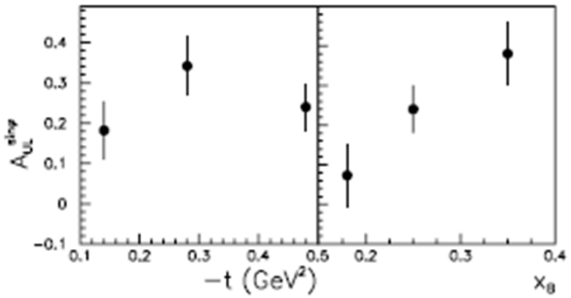


DVCS
B-pol. X-section

JLab
CLAS

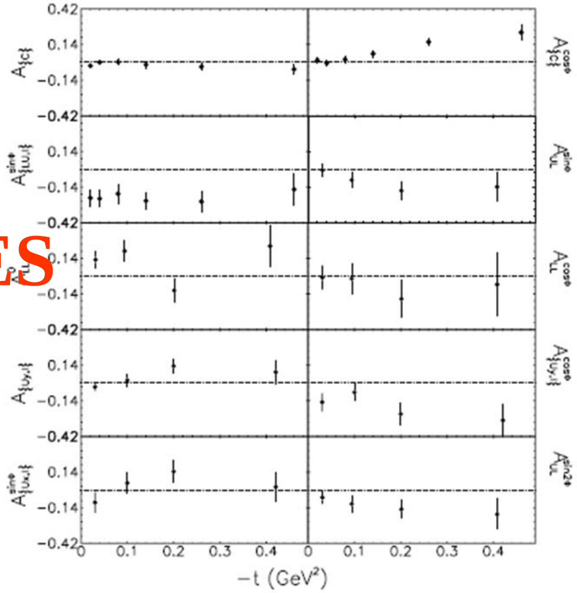


DVCS
BSA



DVCS
lTSA

HERMES



DVCS
BSA,lTSA,tTSA,BCA

In general, 8 GPD quantities accessible

(Compton Form Factors)

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

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

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

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

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

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

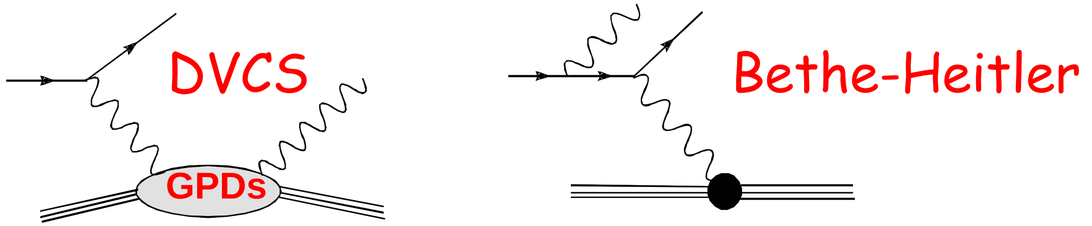
$$\tilde{H}_{Im} = \tilde{H}(\xi,\xi,t) + \tilde{H}(-\xi,\xi,t) \quad \text{and} \quad (7)$$

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

with

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

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



Can one recover the 8 CFFs from the DVCS observables?

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

Two (quasi-) model-independent approaches to extract, at fixed x_B, t and Q^2 (« local » fitting), the CFFs from the DVCS observables

1/ «Brute force » fitting

χ^2 minimization (with MINUIT + MINOS) of the available DVCS observables at a given x_B, t and Q^2 point by varying the CFFs within a limited hyper-space (e.g. 5xVGG)

The problem can be (largely) underconstrained:
JLab Hall A: pol. and unpol. X-sections
JLab CLAS: BSA + TSA

⇒ 2 constraints and 8 parameters !

However, as some observables are largely dominated by a single or a few CFFs, there is a convergence (i.e. a well-defined minimum χ^2) for these latter CFFs.

The contribution of the non-converging CFF enters in the error bar of the converging ones.

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

2/ Mapping and linearization

If enough observables measured, one has a system of 8 equations with 8 unknowns

Given reasonable approximations (leading-twist dominance, neglect of some $1/Q^2$ terms,...), the system can be linear (practical for the error propagation)

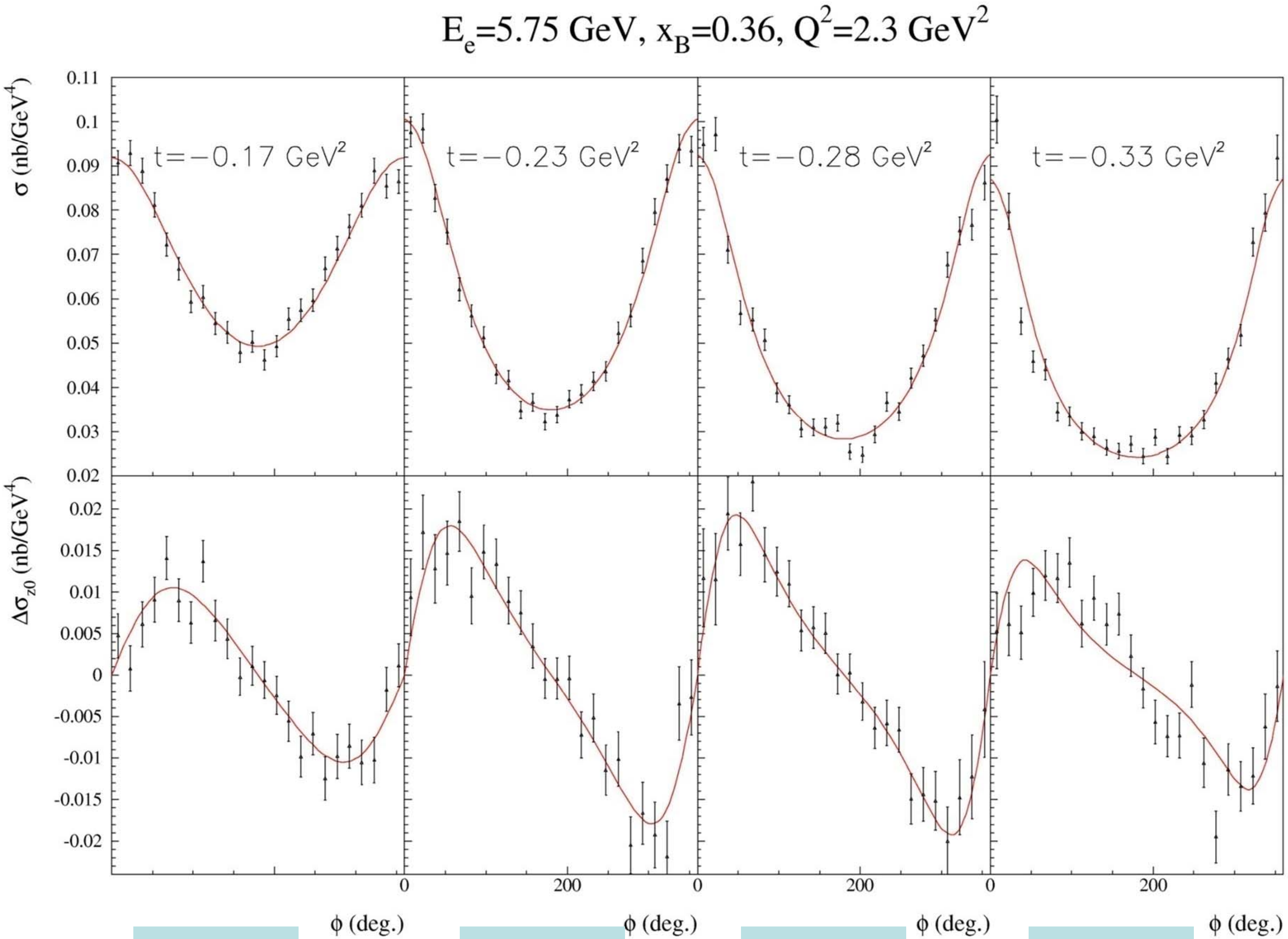
$$\begin{pmatrix} A_{\mathrm{LU,I}}^{\sin(1\phi)} \\ A_{\mathrm{UL,+}}^{\sin(1\phi)} \\ A_{\mathrm{UT,I}}^{\sin(\varphi)\cos(1\phi)} \\ A_{\mathrm{UT,I}}^{\cos(\varphi)\sin(1\phi)} \end{pmatrix} \Rightarrow \Im\mathrm{m} \begin{pmatrix} \mathcal{H} \\ \widetilde{\mathcal{H}} \\ \mathcal{E} \\ \overline{\mathcal{E}} \end{pmatrix}, \quad \begin{pmatrix} A_{\mathrm{C}}^{\cos(1\phi)} \\ A_{\mathrm{LL,+}}^{\cos(1\phi)} \\ A_{\mathrm{LT,I}}^{\sin(\varphi)\sin(1\phi)} \\ A_{\mathrm{LT,I}}^{\cos(\varphi)\cos(1\phi)} \end{pmatrix} \Rightarrow \Re\mathrm{e} \begin{pmatrix} \mathcal{H} \\ \widetilde{\mathcal{H}} \\ \mathcal{E} \\ \overline{\mathcal{E}} \end{pmatrix}$$

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

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

K. Kumericki, D. Mueller, M. Murray, arXiv:1301.1230 hep-ph, arXiv:1302.7308 hep-ph

Hall A : σ & $\Delta\sigma_{LU}$, x_B=0.36,Q^2=2.3,t=.17,.23,.28,.33

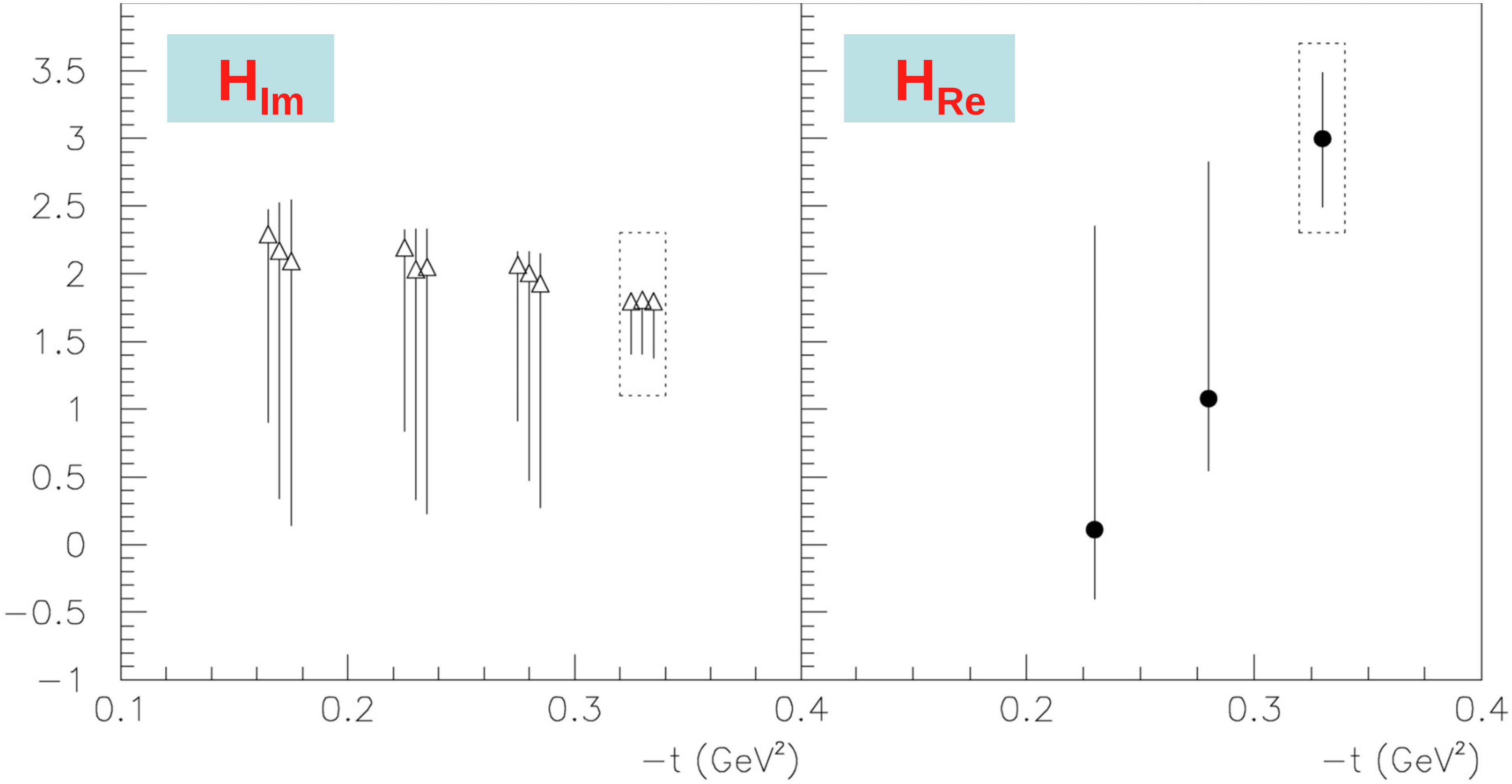


χ^2=1.01

χ^2=0.92

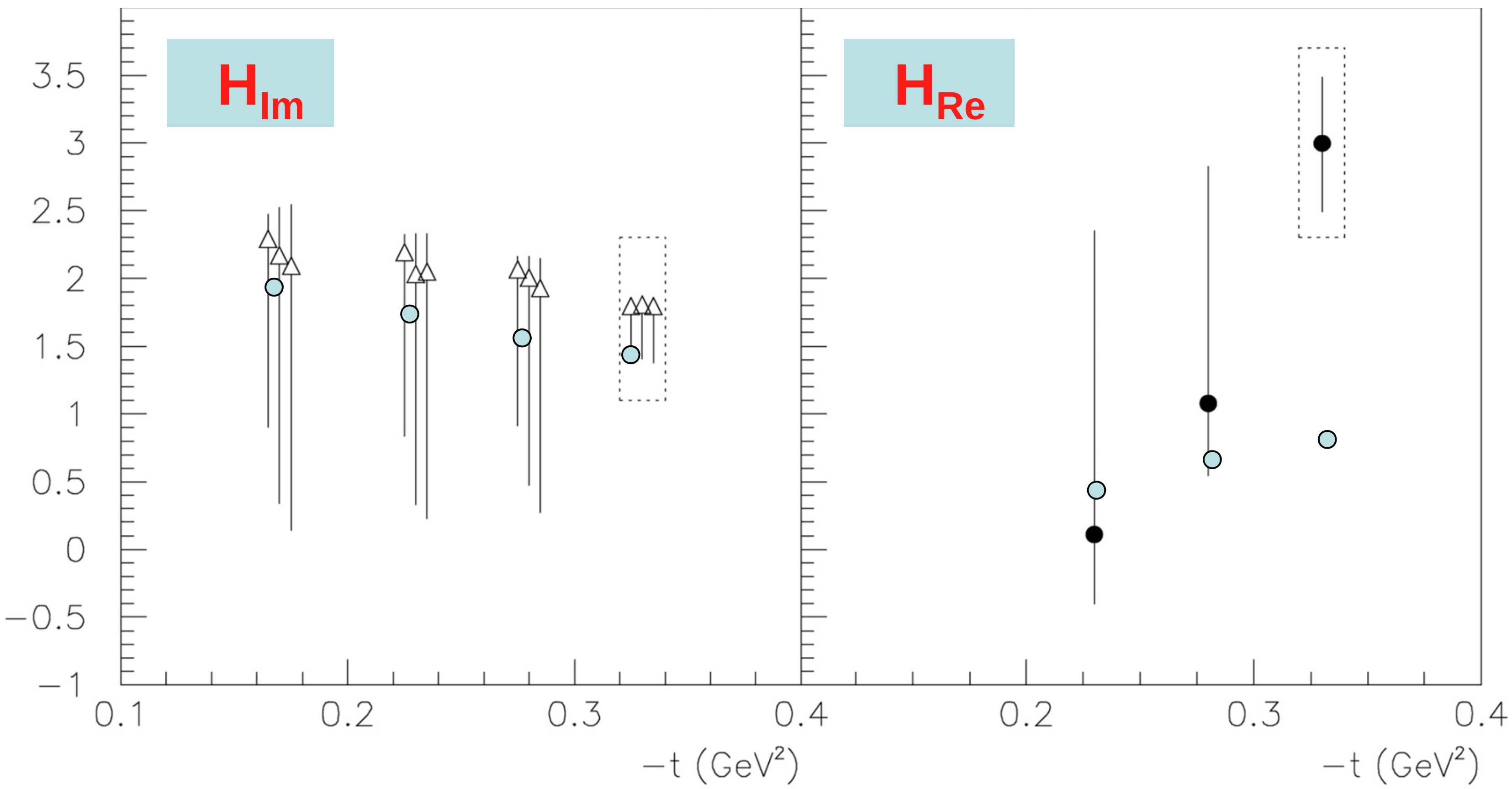
χ^2=1.44

χ^2=2.31



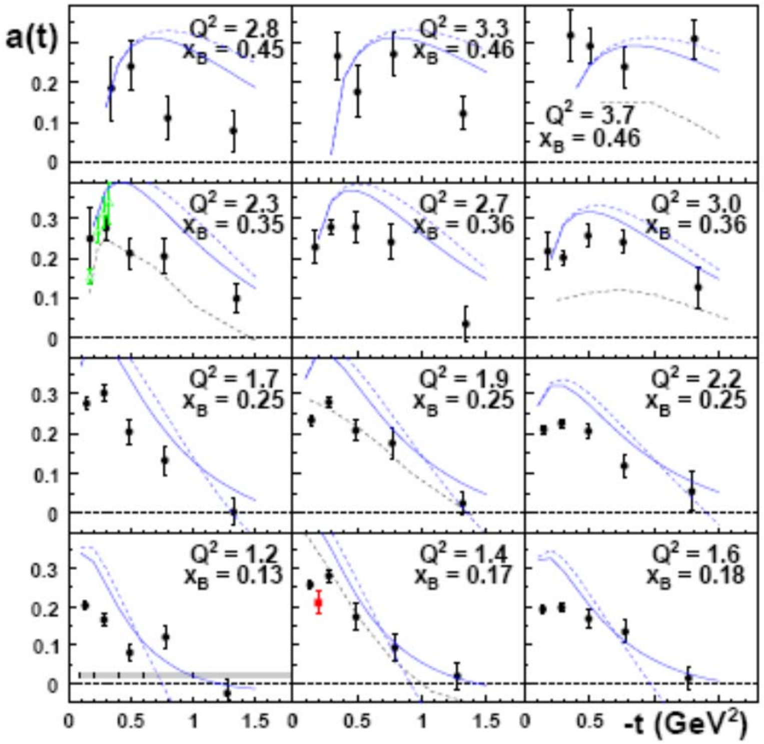
△ **Result of the (model independent) fit**

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



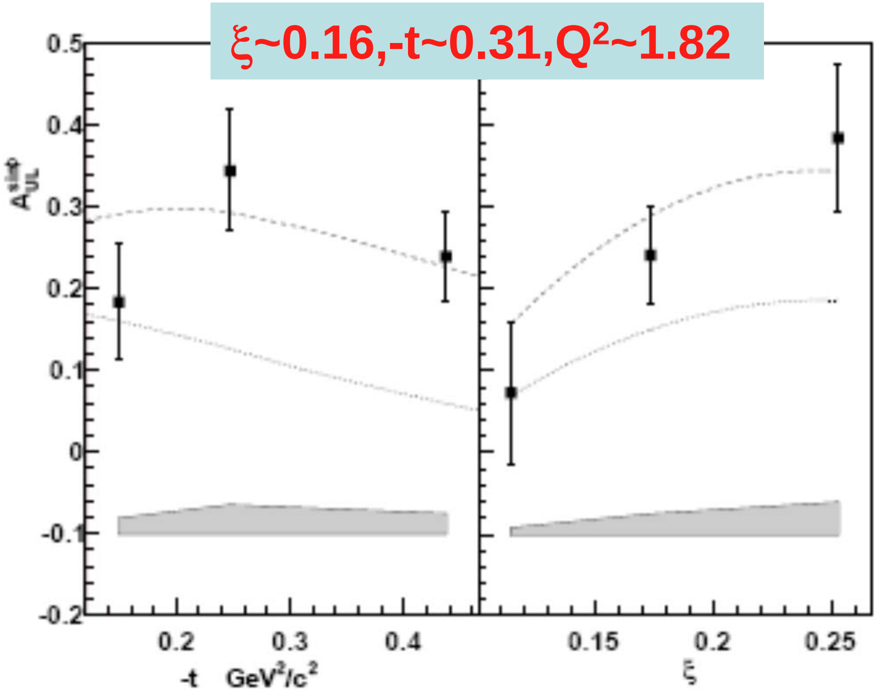
△ **Result of the (model independent) fit**

○ **VGG prediction**



CLAS DVCS BSAs

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

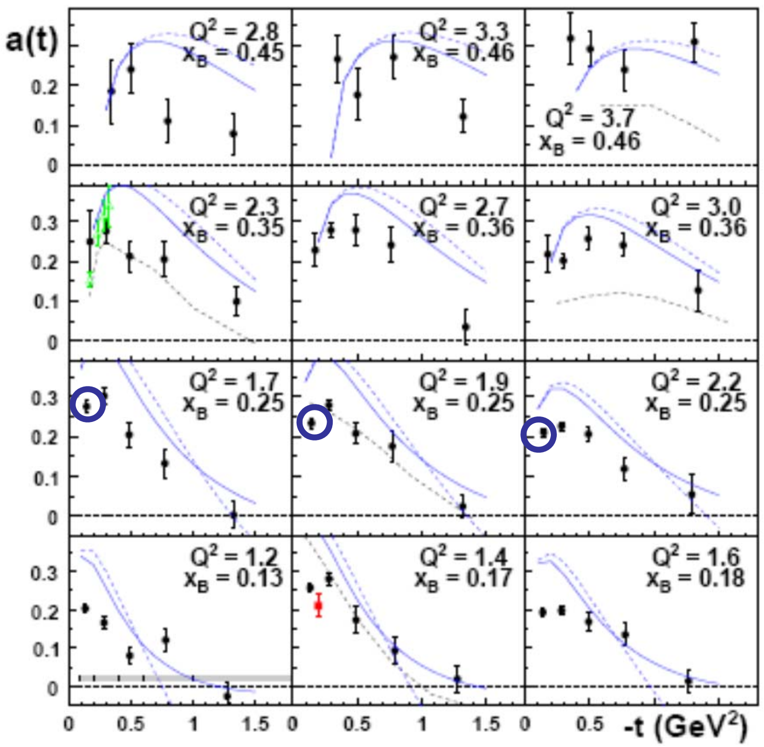


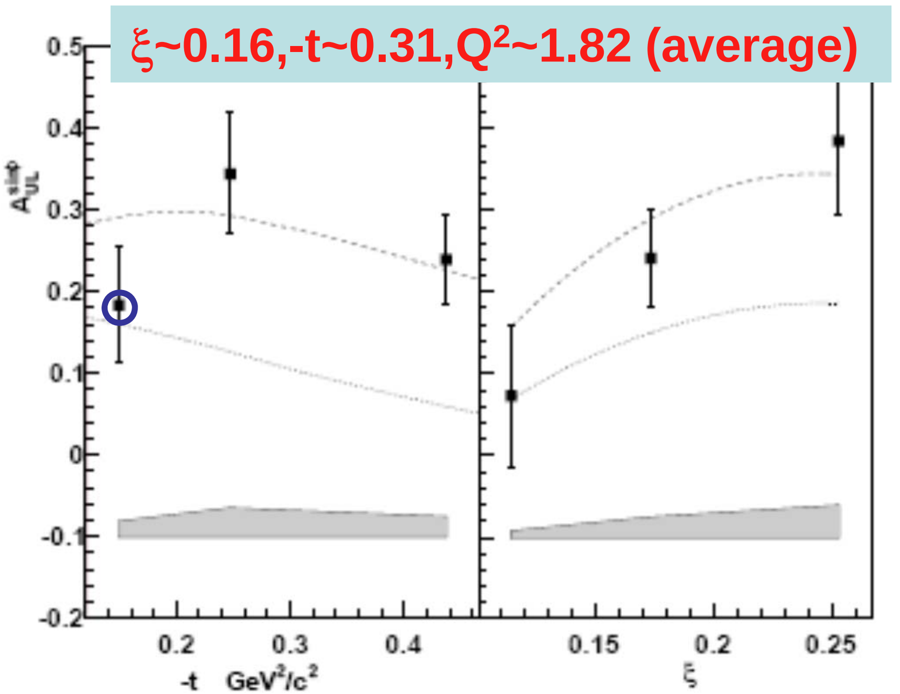
CLAS DVCS ℓTSAs

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)





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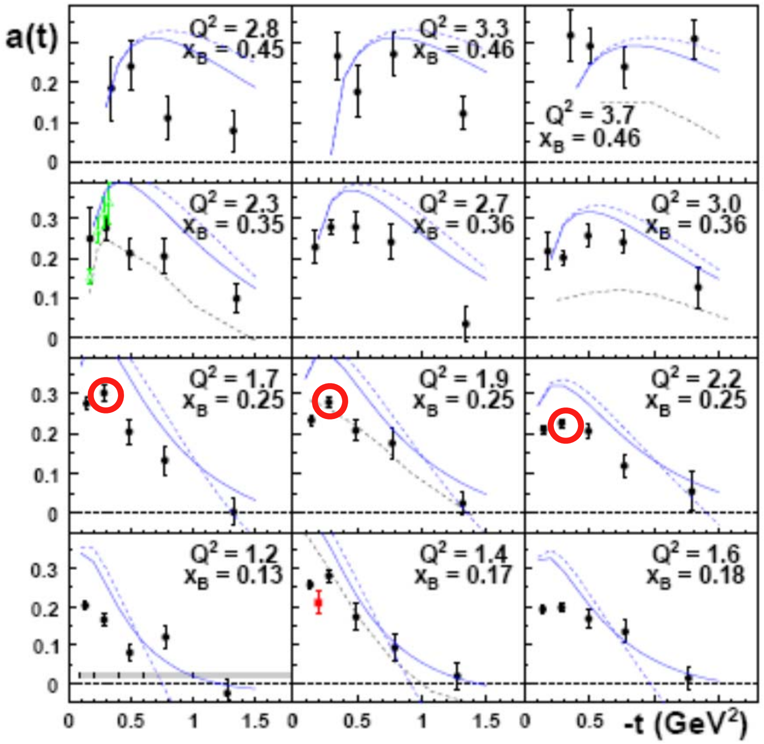

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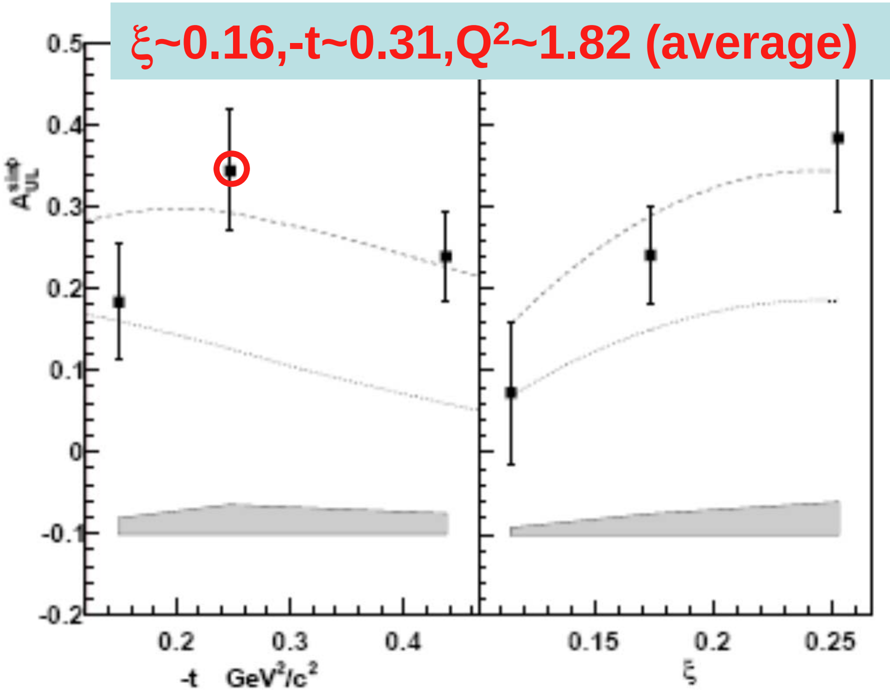

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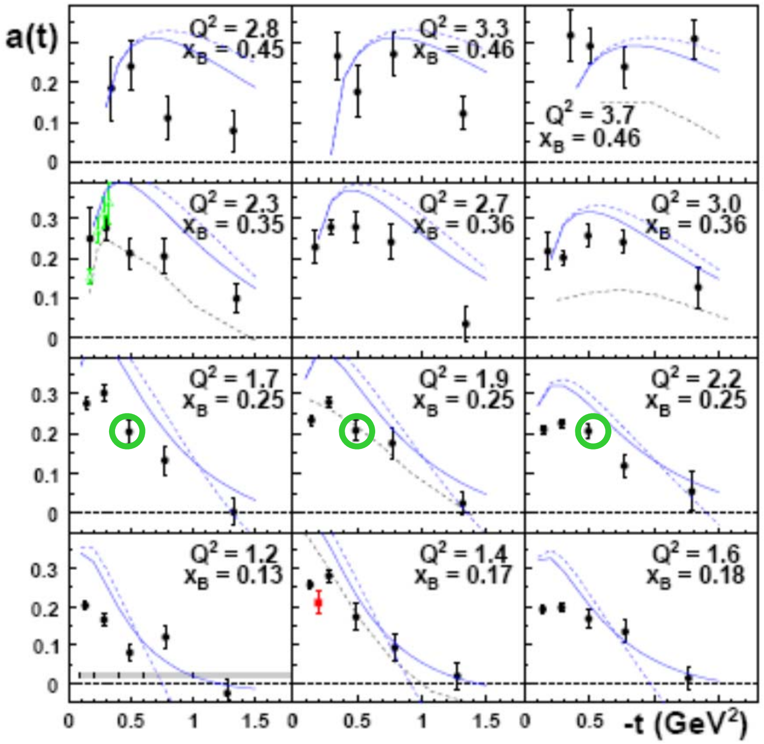

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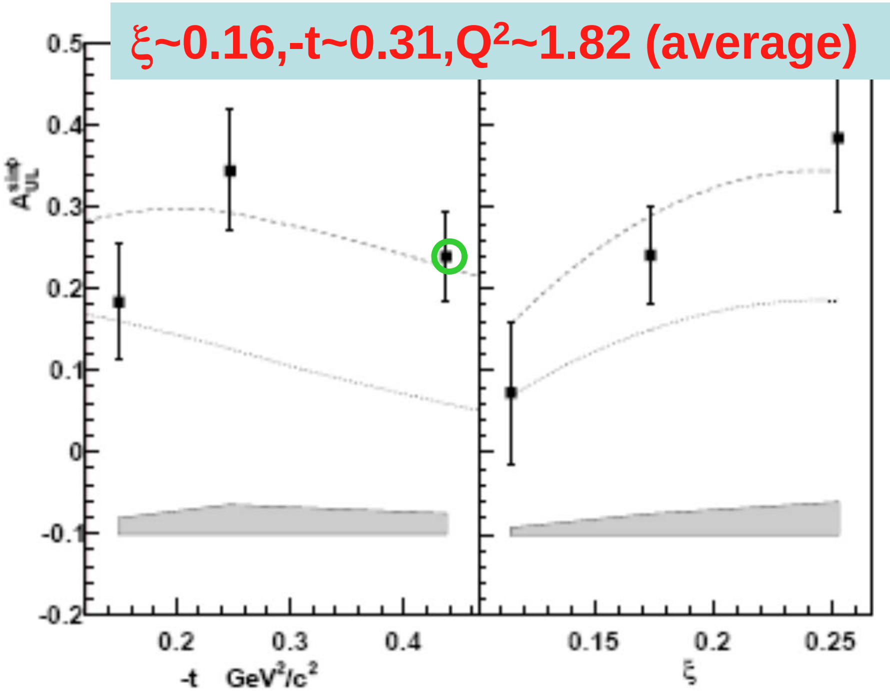
F.-X. Girod et al., Phys. Rev. Lett. **100**, 162002 (2008).



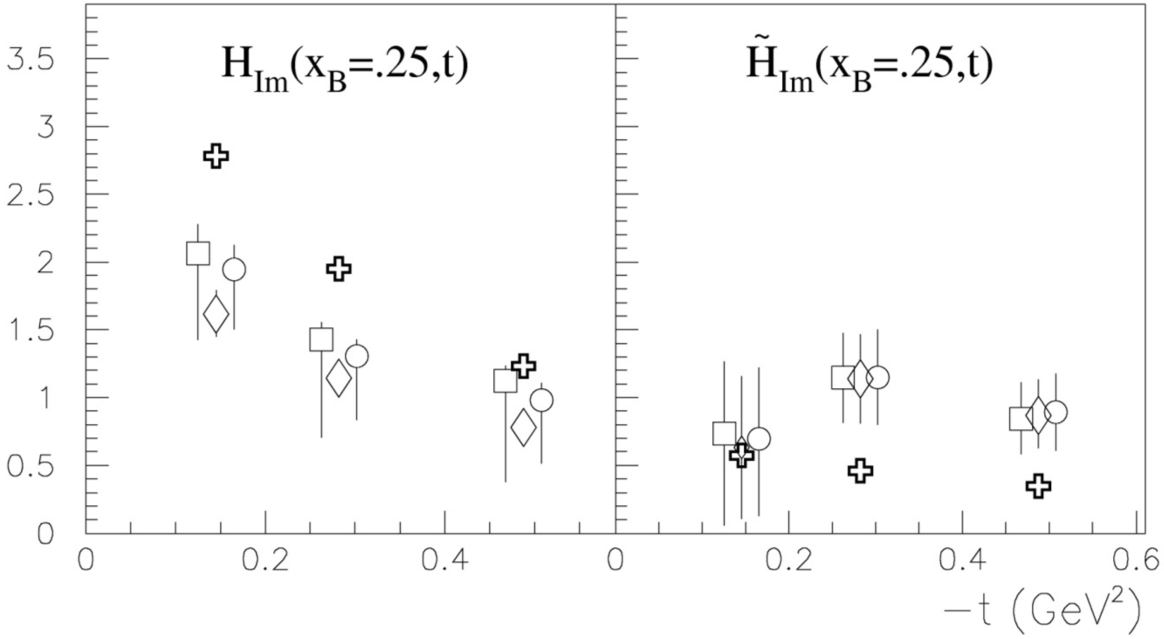
CLAS DVCS ℓTSAs

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 approximately the same kinematics)

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



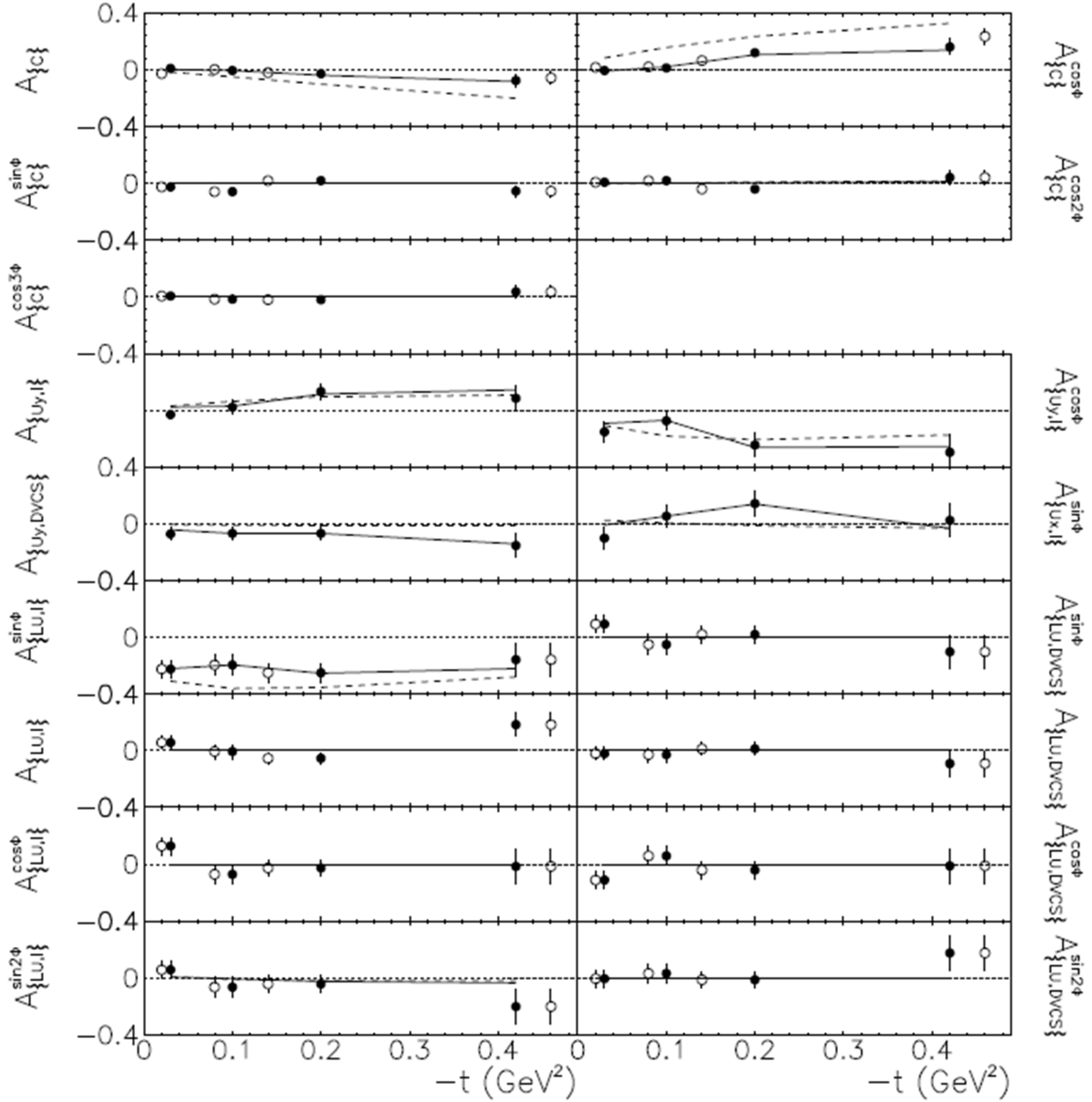
Axial charge more concentrated than electromagnetic charge ?

□ **Fit with 7 CFFs (boundaries 5xVGG CFFs)**

○ **Fit with 7 CFFs (boundaries 3xVGG CFFs)**

◇ **Fit with ONLY H and $\tilde{H}$**

✣ **VGG prediction**

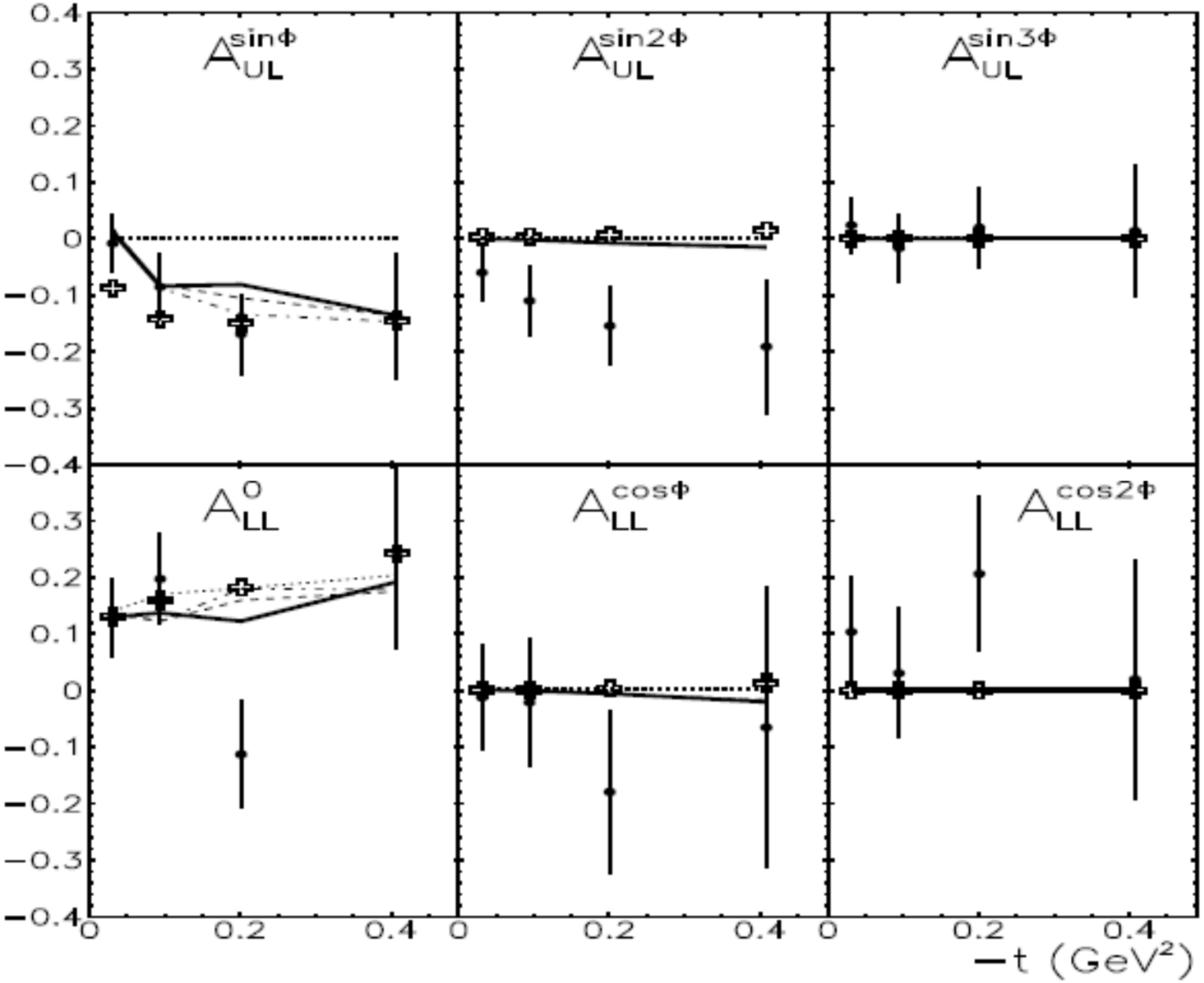


Result of fit

VGG prediction

A_{UL} and A_{LL} from HERMES :

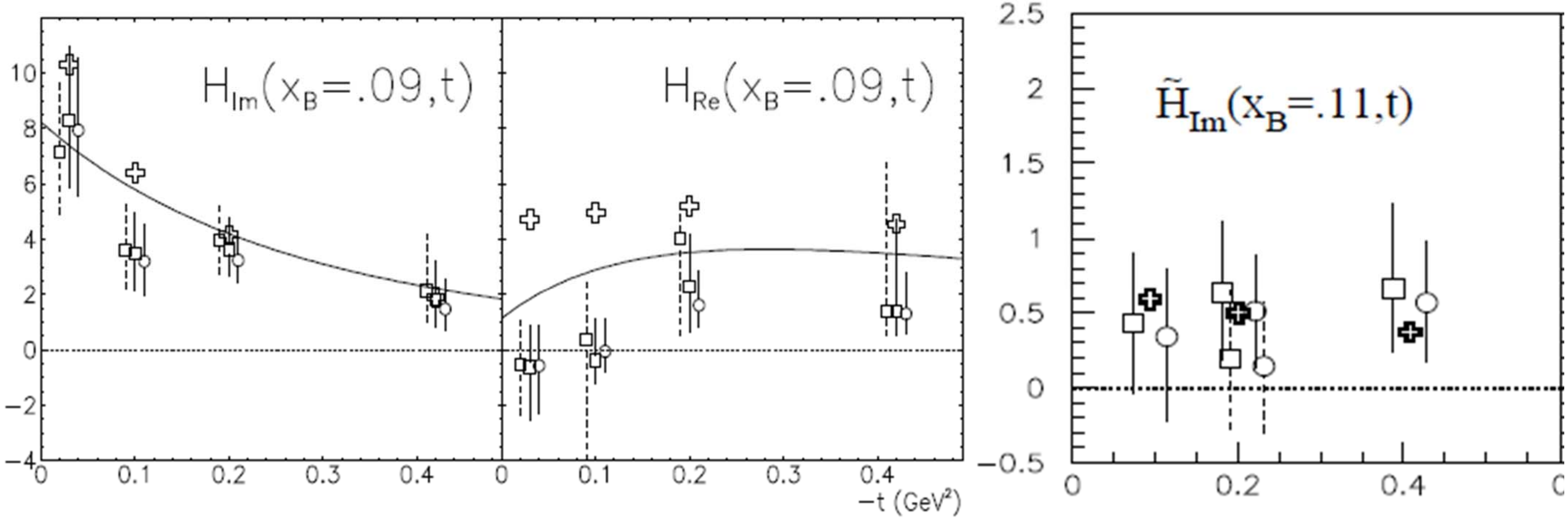
A. Airapetian et al., JHEP 1006 (2010) 019

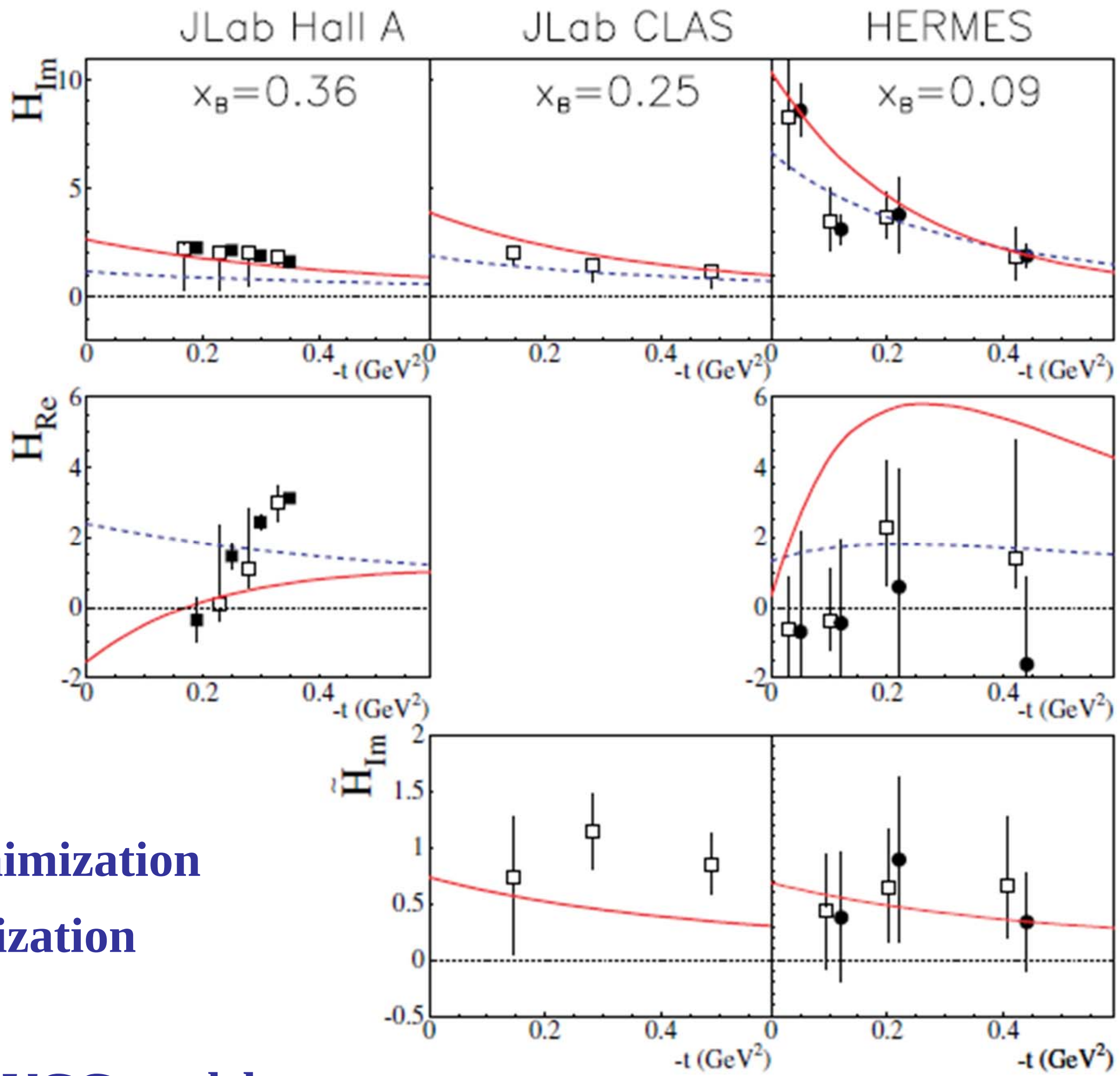


Fitted simultaneously with A_C, A_{LU} and A_{TU}

t-dependence at HERMES of the CFFs

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





□ χ^2 minimization

● linearization

VGG model

KM10 model/fit

■ Moutarde 10 model/fit

1/ From data to CFFs (first steps)

2/ From CFFs to nucleon imaging (first steps)

From CFFs to spatial densities

How to go from momentum coordinates (t)
to space-time coordinates (b) ?
(with error propagation)

$$H_{\mathrm{Im}}(\xi, t) \equiv H(\xi, \xi, t) - H(-\xi, \xi, t)$$

$$H(x, b_\perp) = \int_0^\infty \frac{\mathrm{d}\Delta_\perp}{2\pi} \Delta_\perp J_0(b_\perp \Delta_\perp) H(x, 0, -\Delta_\perp^2)$$

Applying a (model-dependent) "deskewing" factor:

$$\frac{H(\xi, 0, t)}{H(\xi, \xi, t)}$$

and, in a first approach, neglecting the sea contribution

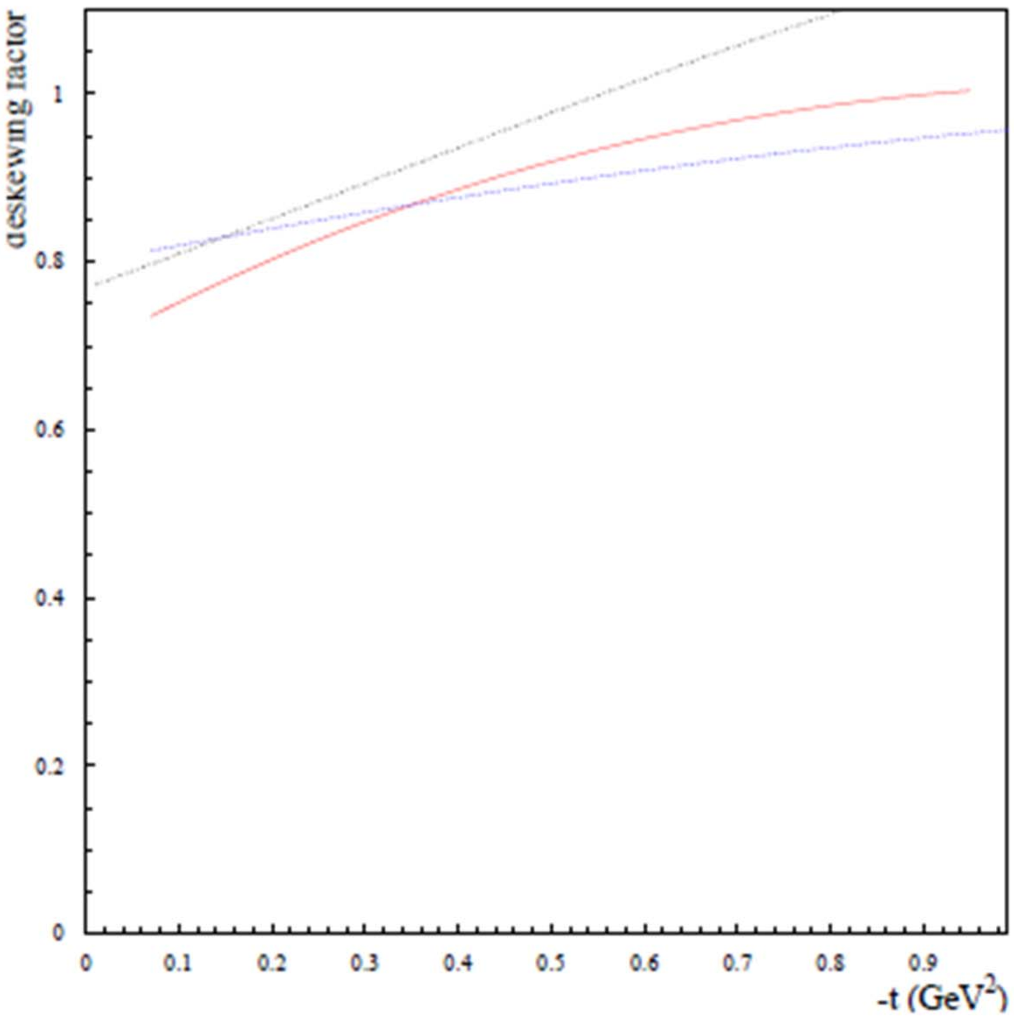
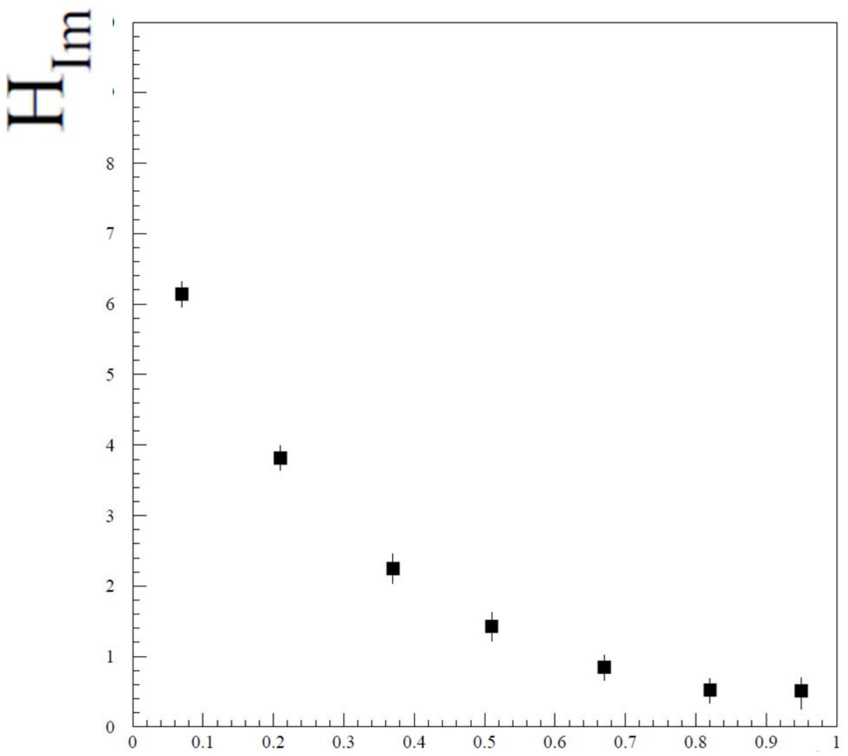


Figure 53. "Deskewing" factor $H(\xi,0,t)/H(\xi,\xi,t)$ as a function of $-t$ at x_B=0.1 for the VGG model (red solid line), the GK model (blue dashed line) and the dual model (black dotted line).

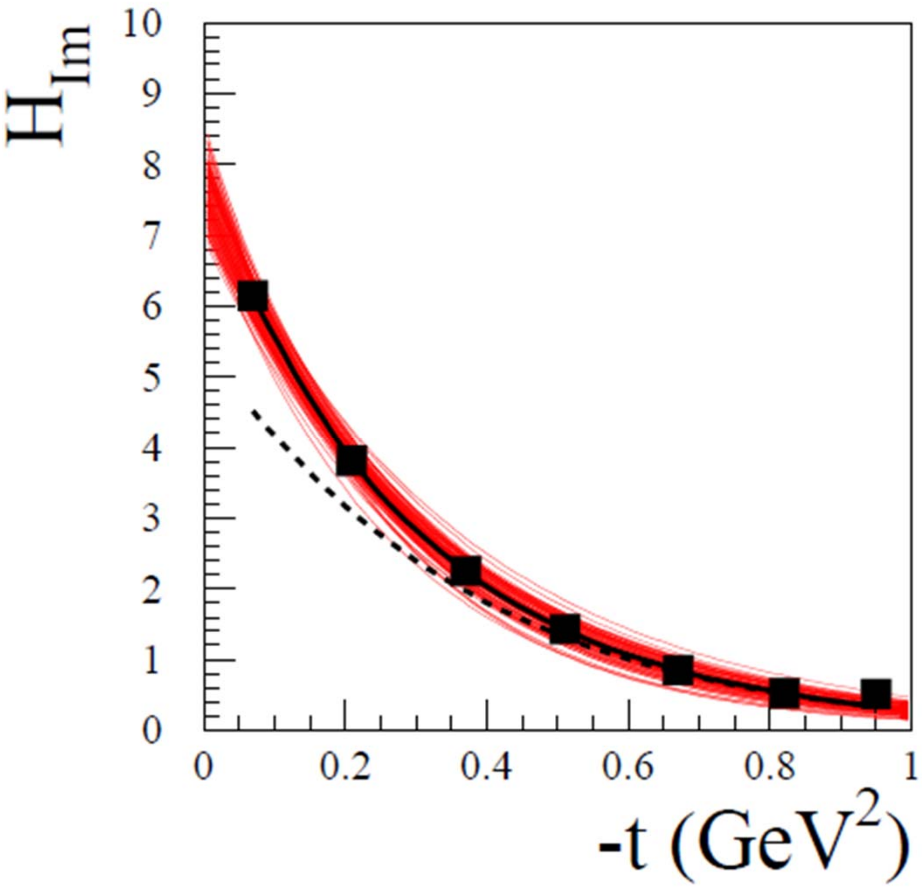
1/Smear the data according to their error bar
2/Fit by Ae^{bt}
3/Fourier transform (analytically)

~1000 times



1/Smear the data according to their error bar
2/Fit by Ae^{bt}
3/Fourier transform (analytically)

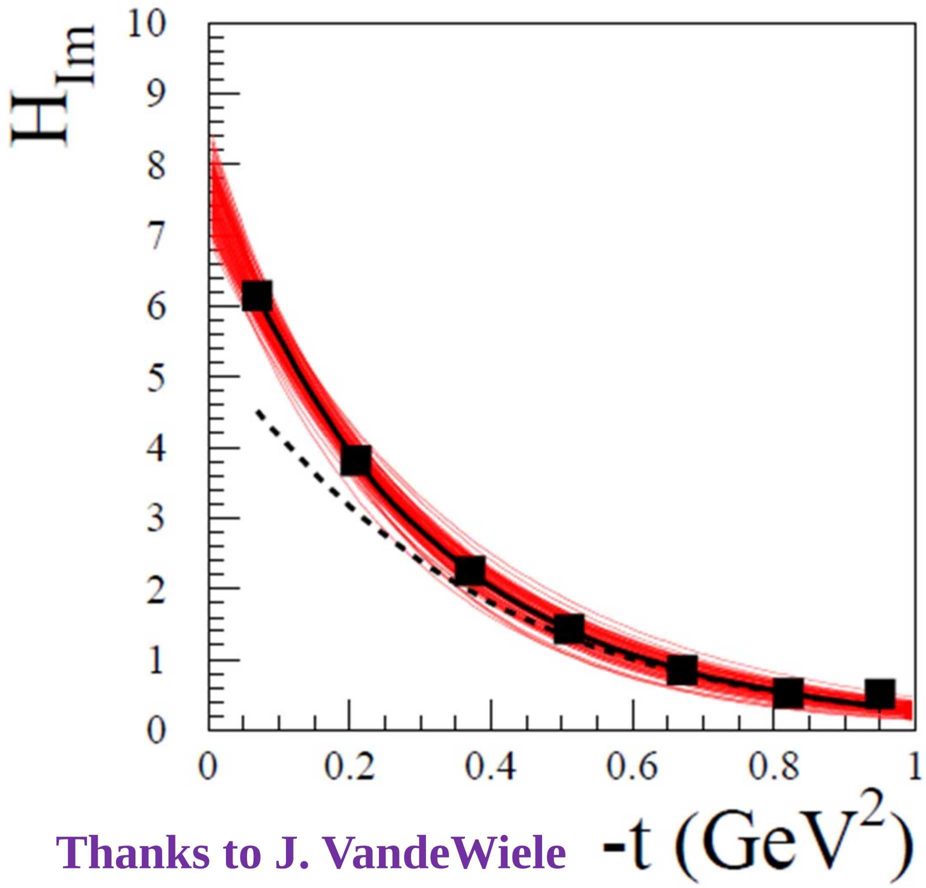
} ~1000 times



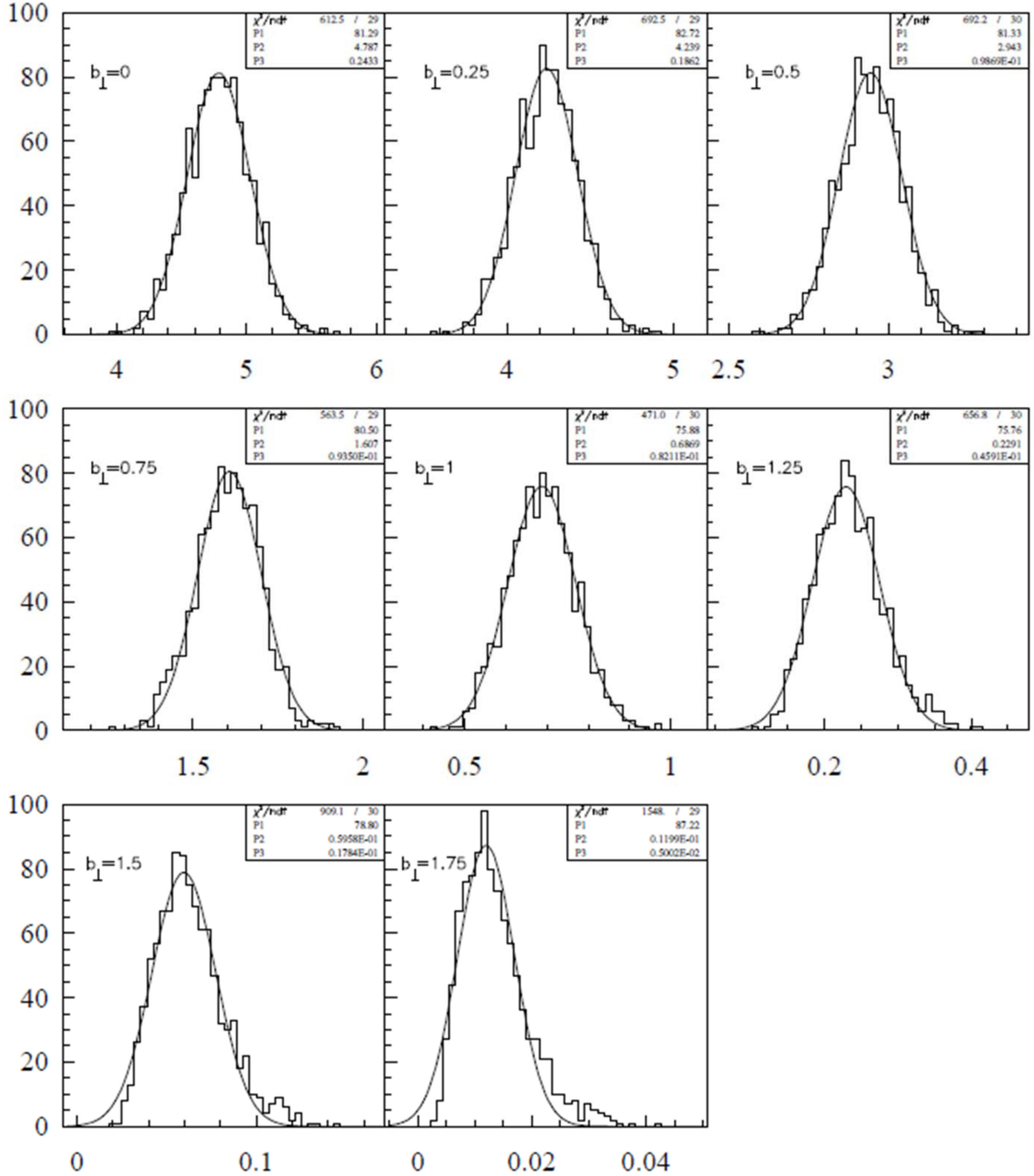
1/Smear the data according to their error bar
2/Fit by Ae^{bt}
3/Fourier transform (analytically)

} ~1000 times

4/Obtain a series of Fourier transforms as a function of b
5/For each slice in b, obtain a (Gaussian) distribution which is fitted so as to extract the mean and the standard deviation



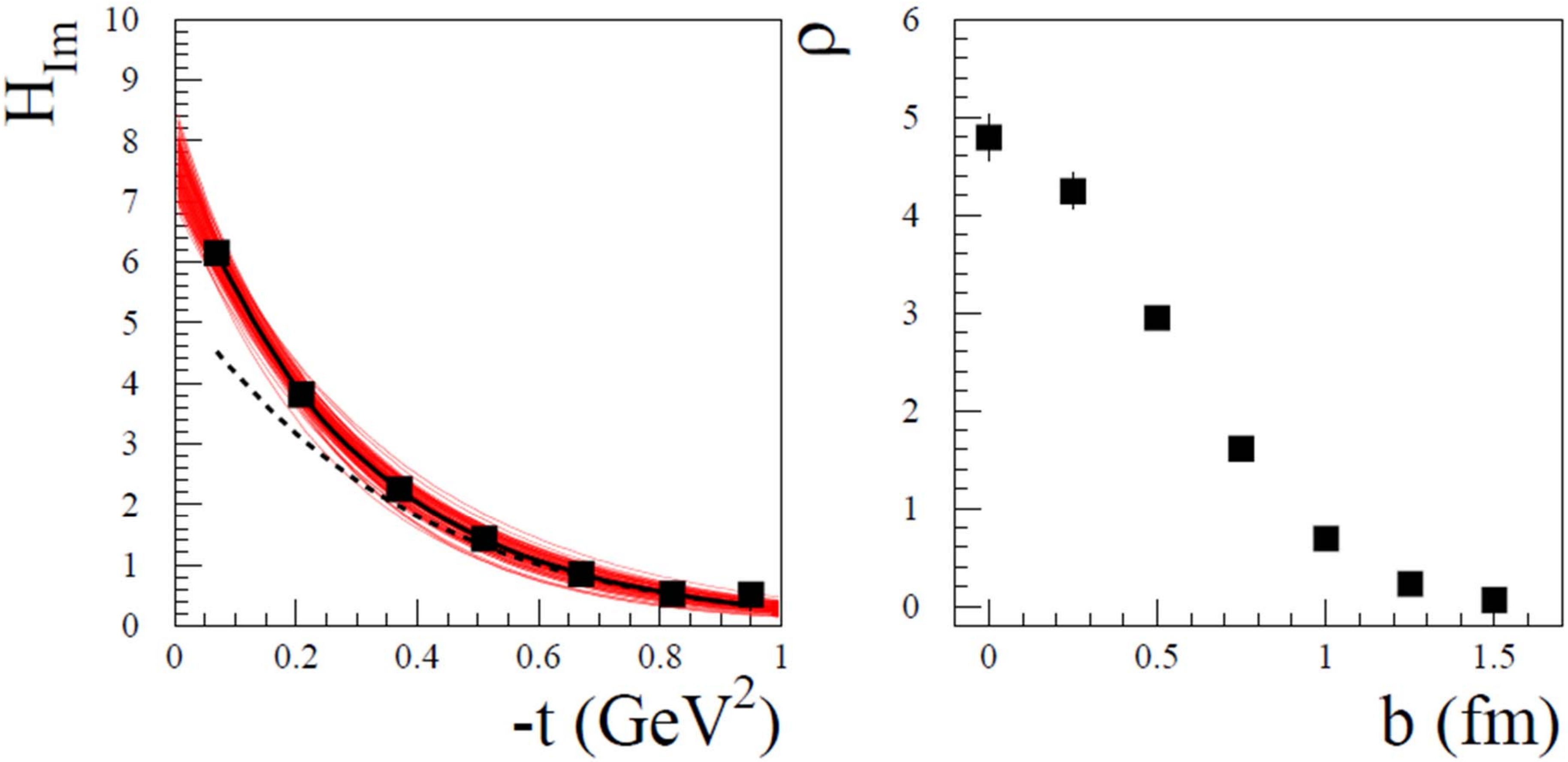
Thanks to J. VandeWiele



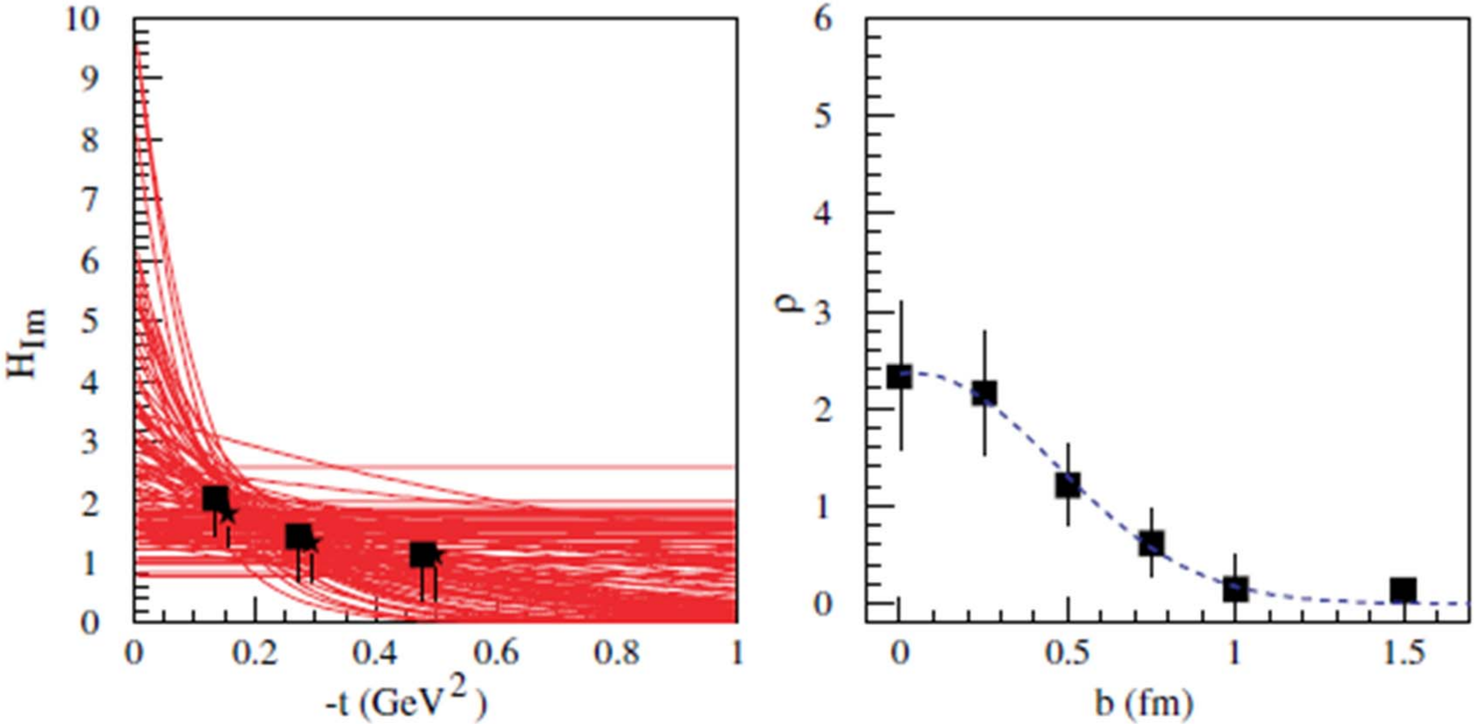
b⊥=0
χ²/ndf 612.5 / 29
P1 81.29
P2 4.787
P3 0.2433
b⊥=0.25
χ²/ndf 692.5 / 29
P1 82.72
P2 4.239
P3 0.1862
b⊥=0.5
χ²/ndf 692.2 / 30
P1 81.33
P2 2.943
P3 0.9869E-01
b⊥=0.75
χ²/ndf 563.5 / 29
P1 80.50
P2 1.607
P3 0.9350E-01
b⊥=1
χ²/ndf 471.0 / 30
P1 75.88
P2 0.6869
P3 0.8211E-01
b⊥=1.25
χ²/ndf 656.8 / 30
P1 75.76
P2 0.2291
P3 0.4591E-01
b⊥=1.5
χ²/ndf 909.1 / 30
P1 78.80
P2 0.5958E-01
P3 0.1784E-01
b⊥=1.75
χ²/ndf 1548. / 29
P1 87.22
P2 0.1199E-01
P3 0.5002E-02

1/Smear the data according to their error bar
2/Fit by Ae^{bt}
3/Fourier transform (analytically)
4/Obtain a series of Fourier transform as a function of b
5/For each slice in b, obtain a (Gaussian) distribution which is fitted so as to extract the mean and the standard deviation

} ~1000 times (steps 1–3)



CLAS data (x_B=0.25)

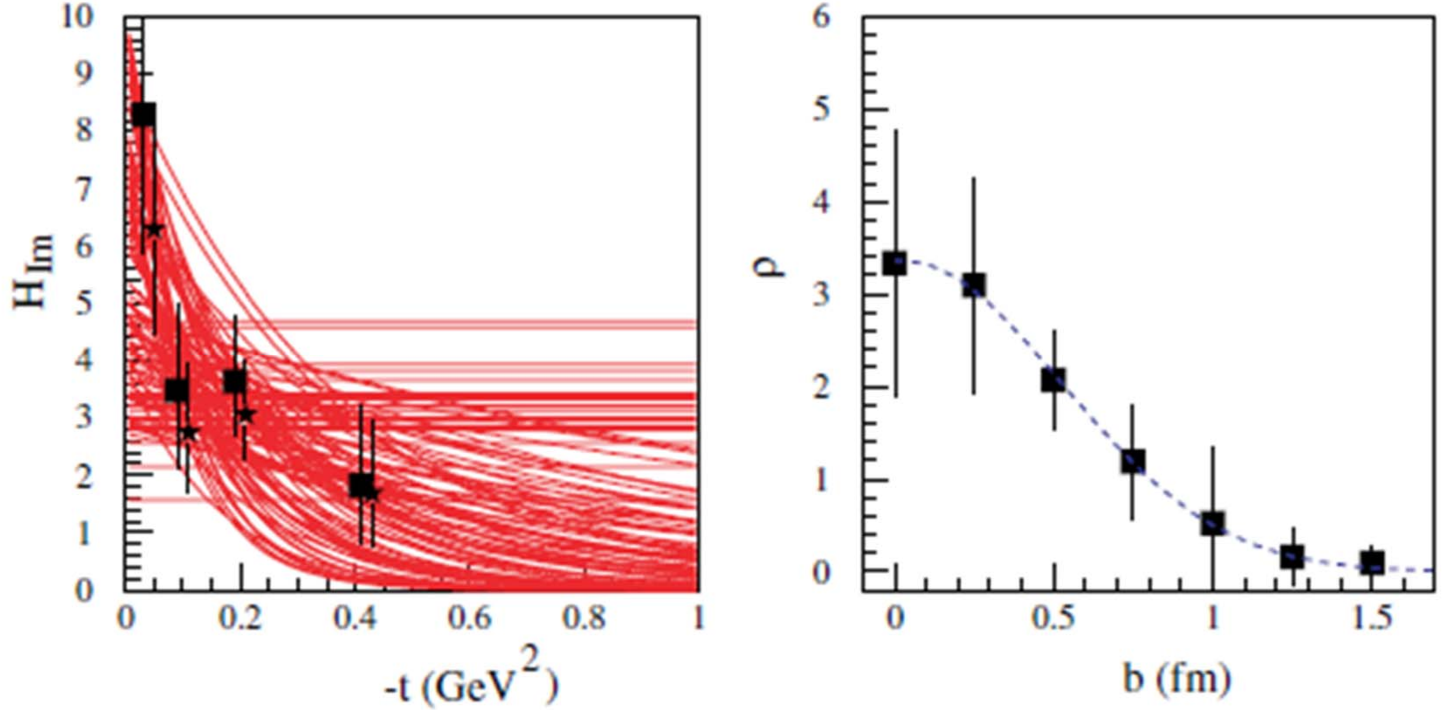


■ "skewed" H_{Im}

★ "deskewed" H_{Im}

(fits applied to « deskewed » data)

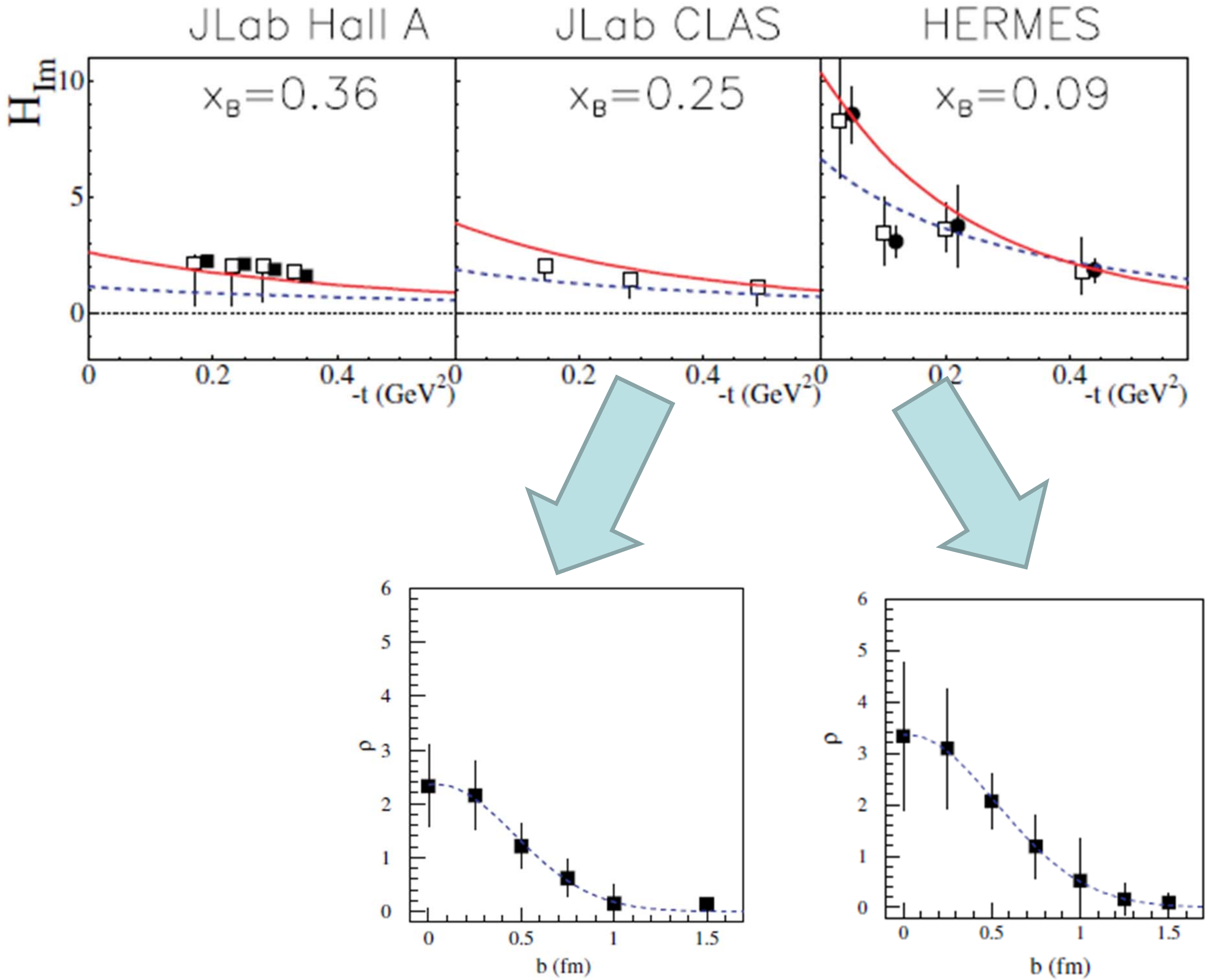
HERMES data (x_B=0.09)



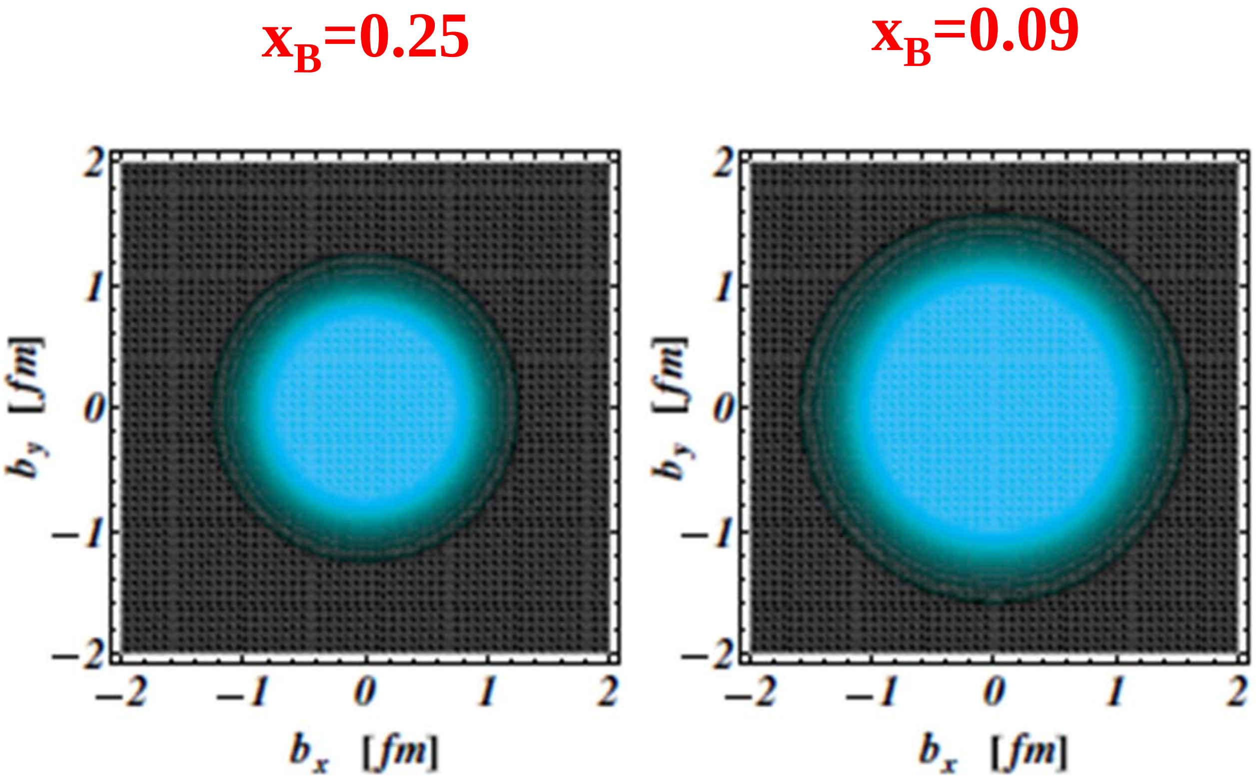
■ “skewed” H_{Im}

★ “deskewed” H_{Im}

(fits applied to « deskewed » data)

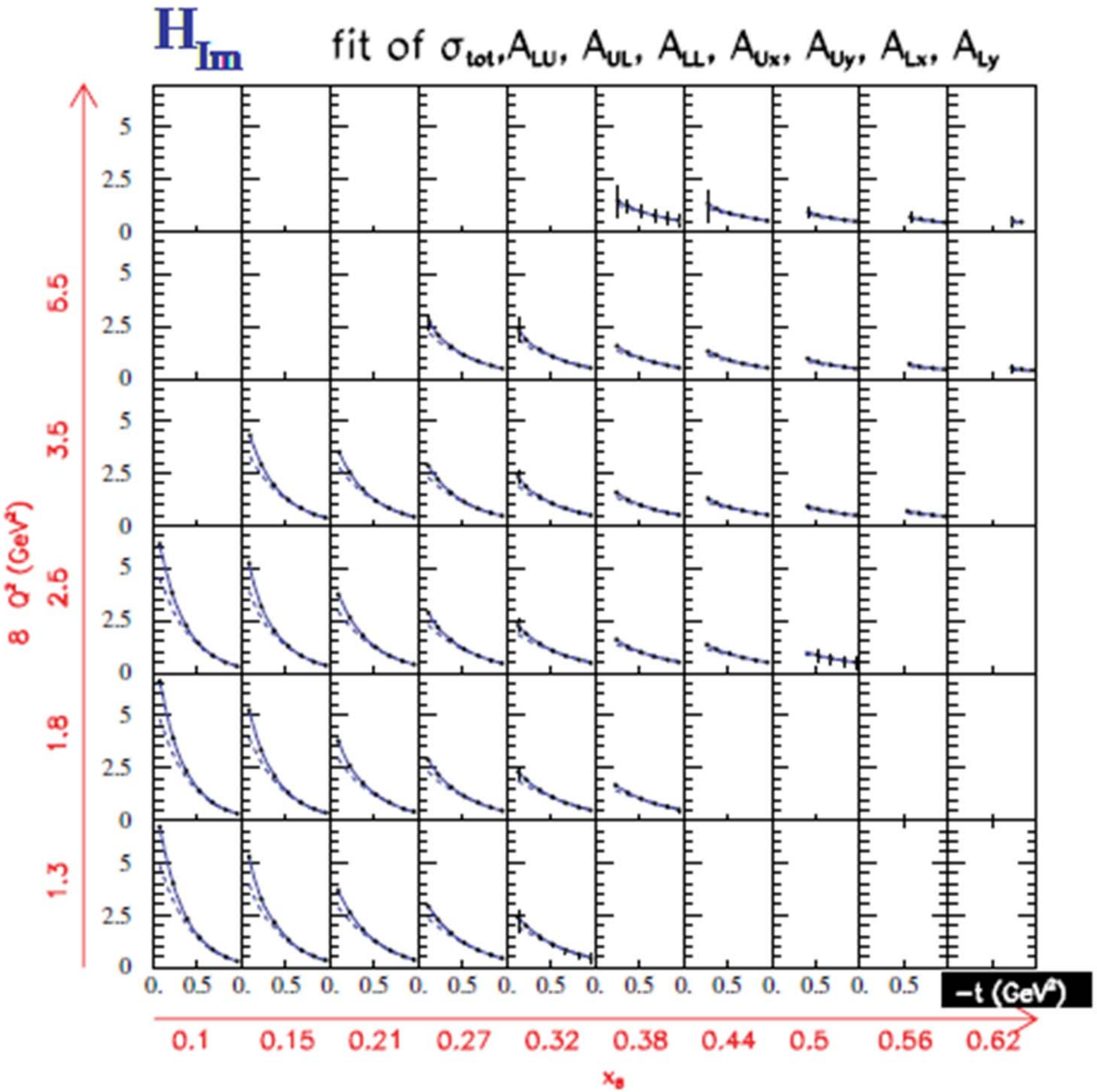


JLab Hall A
JLab CLAS
HERMES
H_{Im}
x_B=0.36
x_B=0.25
x_B=0.09
-t (GeV^2)
ρ
b (fm)



x_B=0.25
x_B=0.09
2
1
0
−1
−2
b_y [fm]
−2
−1
0
1
2
b_x [fm]

Projections for CLAS12 for H_{Im}



Corresponding spatial densities