IRFU

cea

saclay

Recent results on **GPD/DVCS** experiments at **CLAS**

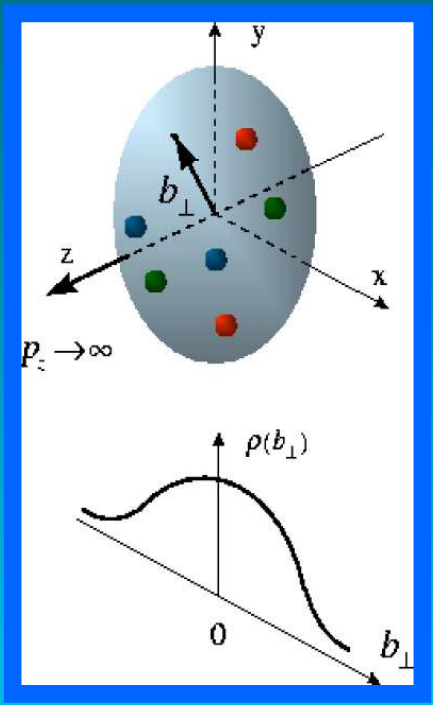
Jacques Ball

(On behalf of the CLAS collaboration)

- GPDs
- DVCS experiments at CLAS
- Results
- Future

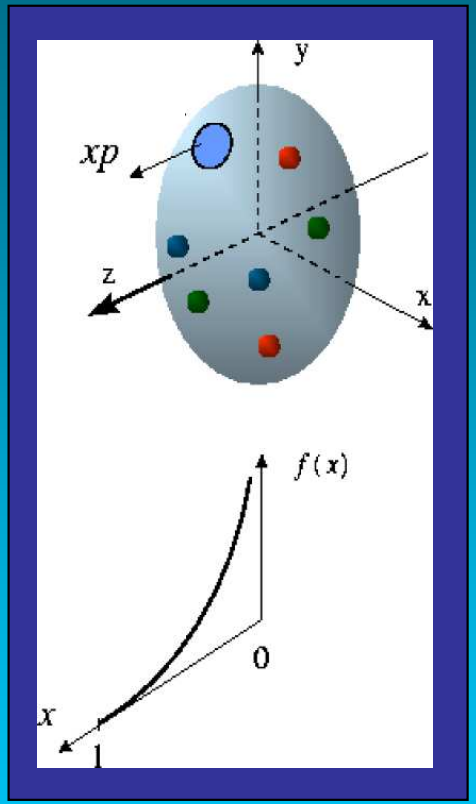
Generalized Parton Distributions (GPDs)

Elastic Scattering



Proton form factors, transverse charge & current densities

DIS



Structure functions, quark longitudinal momentum & helicity distributions

Generalized Parton Distributions (GPDs)

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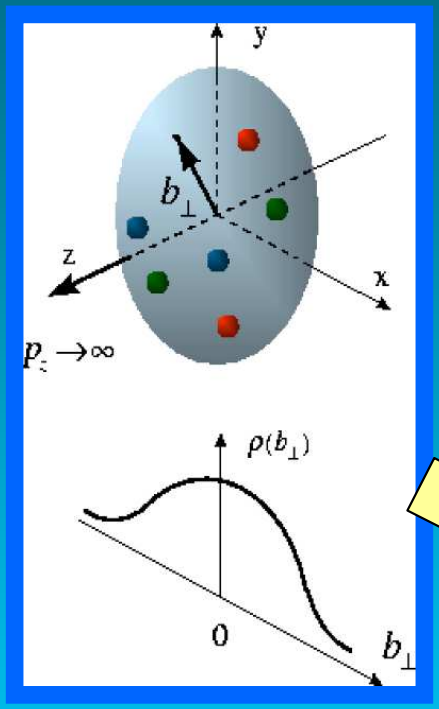

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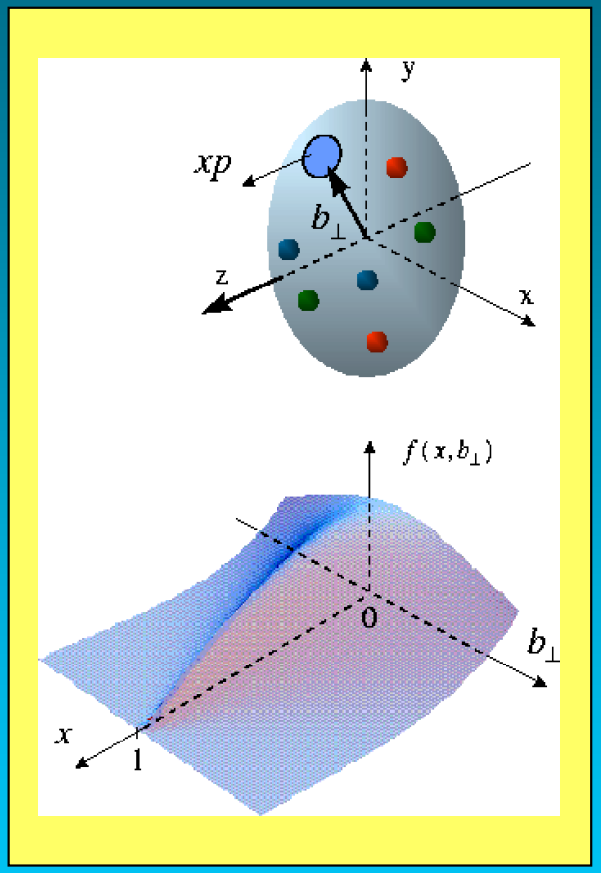
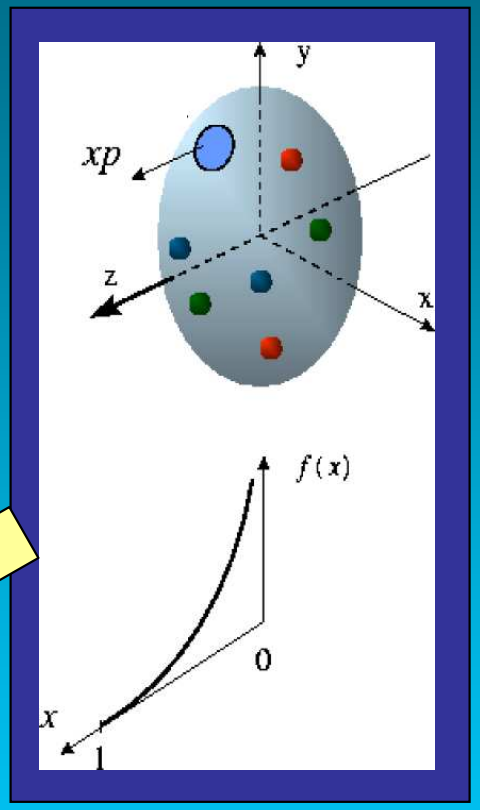
DES



Correlated quark momentum and helicity distributions in transverse space - **GPDs**

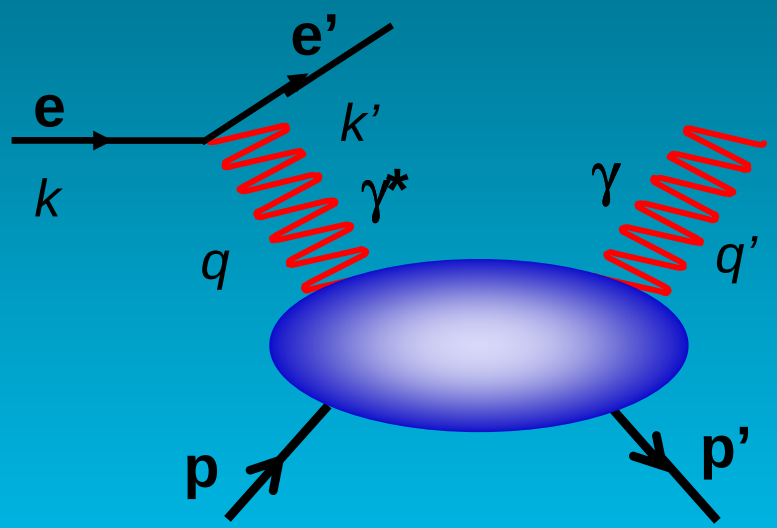
DIS



Structure functions, quark longitudinal momentum & helicity distributions

GPDs
Deeply Virtual Compton Scattering

Exclusive $\vec{e}p \rightarrow e'p\gamma$



$$Q^2 = -q^2 = -(k - k')^2$$

$$t = (p - p')^2$$

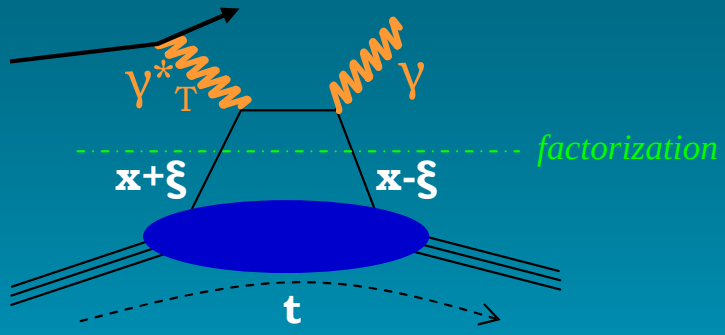
$$x_B = \frac{Q^2}{2p \cdot q}$$

DVCS is one of the keys to access GPDs :

-Simplest process described by GPDs

-Measured Observables would lead to GPDs extraction

DVCS and GPDs



- **x** longitudinal momentum fraction to the quark
- t squared 4-momentum transfer to the target

Observables are integrals, in *x*, of GPDs

$\xi = f(x_B)$ and t fixed by the kinematics

$H, \tilde{H}, E, \tilde{E}\ (x,\xi,t)$

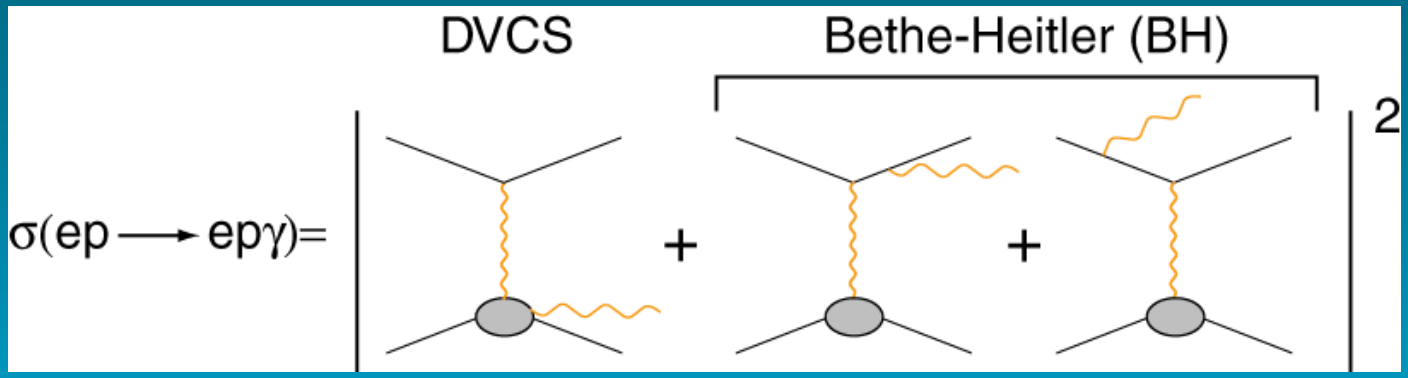
At leading order:

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

H^q: probability amplitude for N to **emit a parton *q* with *x*+ξ** and N' to **absorb it with *x*- ξ.**

Experimental observables linked to GPDs

Experimentally, DVCS is undistinguishable with Bethe-Heitler



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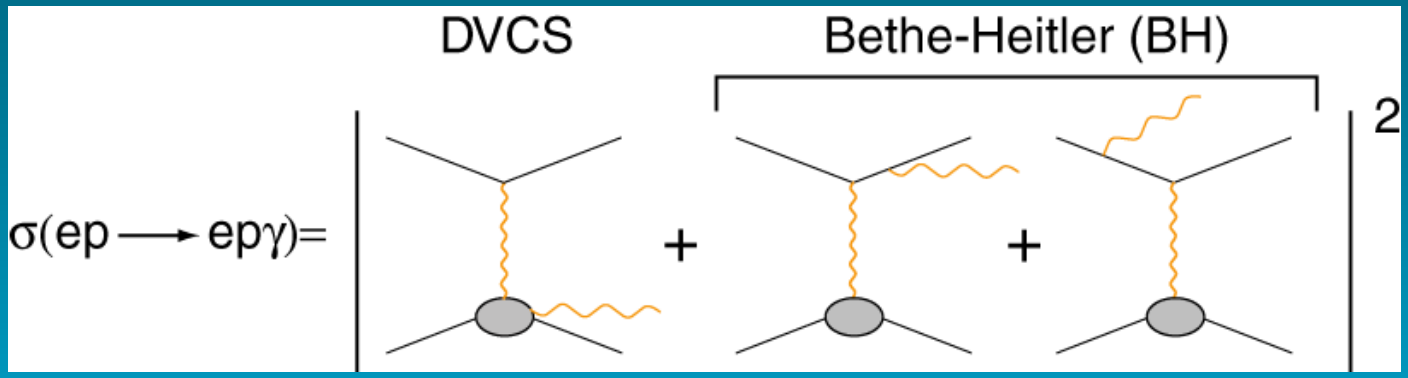

However, we know FF at low t and BH is fully calculable

Using a polarized beam on an unpolarized target, 2 observables can be measured:

$$\frac{d^4\sigma}{dx_B dQ^2 dt d\varphi} \approx \left|T^{BH}\right|^2 + 2T^{BH} \cdot \mathrm{Re}\left(T^{DVCS}\right) + \left|T^{DVCS}\right|^2$$

$$\frac{d^4\vec{\sigma} - d^4\overleftarrow{\sigma}}{dx_B dQ^2 dt d\varphi} \approx 2T^{BH} \cdot \mathrm{Im}\left(T^{DVCS}\right) + \left[\left|T^{\vec{DVCS}}\right|^2 - \left|T^{\overleftarrow{DVCS}}\right|^2\right]$$

Ji, Kroll, Guichon, Diehl, Pire, …

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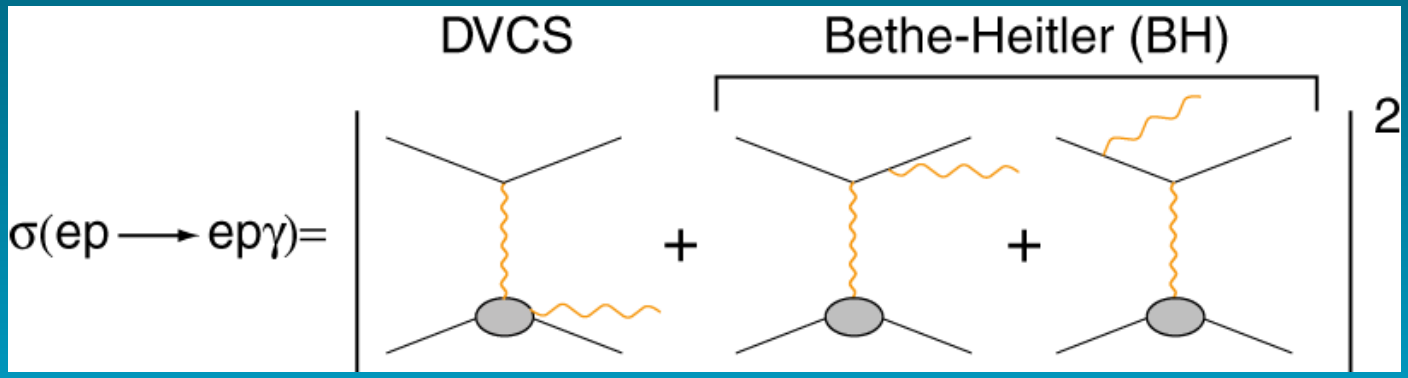

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At low energy, $|T^{DVCS}|^2$ supposed small

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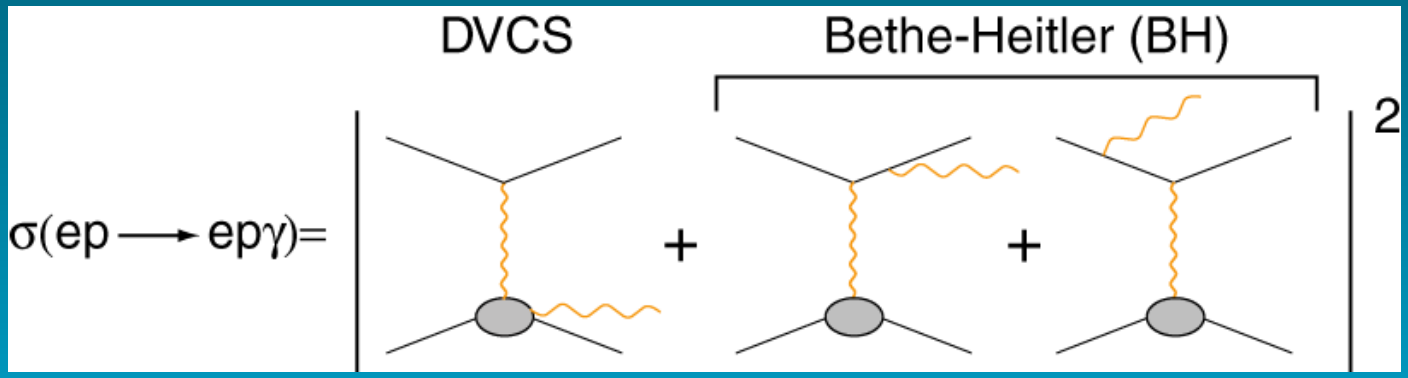

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Ji, Kroll, Guichon, Diehl, Pire, ...

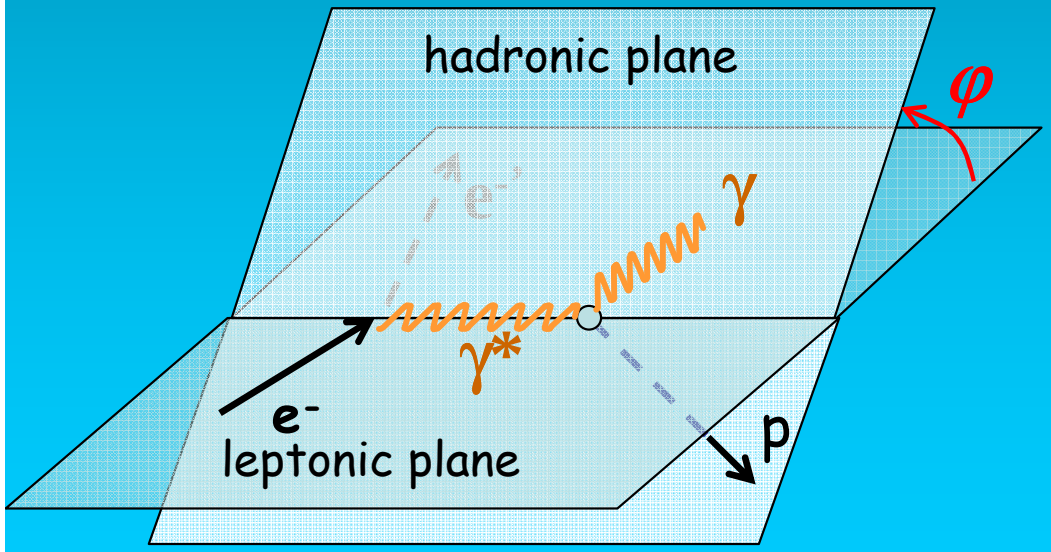
Into the harmonic structure of DVCS

$$\frac{d^4\sigma}{dx_B dQ^2 dt d\varphi} = \frac{1}{P_1(\varphi)P_2(\varphi)}\Gamma_1(x_B,Q^2,t)\left\{c_0^{BH} + c_1^{BH}\cos\varphi + c_2^{BH}\cos 2\varphi\right\} \leftarrow |T^{BH}|^2$$

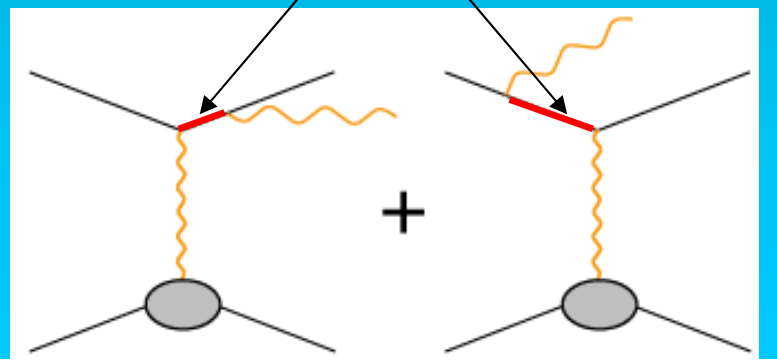
$$+\frac{1}{P_1(\varphi)P_2(\varphi)}\Gamma_2(x_B,Q^2,t)\left\{c_0^{I} + c_1^{I}\cos\varphi + c_2^{I}\cos 2\varphi + c_3^{I}\cos 3\varphi\right\}$$

$$\frac{d^4\vec{\sigma} - d^4\overleftarrow{\sigma}}{dx_B dQ^2 dt d\varphi} = \frac{\Gamma(x_B,Q^2,t)}{P_1(\varphi)P_2(\varphi)}\left\{s_1^{I}\sin\varphi + s_2^{I}\sin 2\varphi\right\}$$

Interference term



$$\frac{1}{P_1(\varphi)P_2(\varphi)}$$



BH propagators φ dependence

Belitsky, Mueller, Kirchner

Separating GPDs through Polarization

Asymmetry : $A = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{\Delta\sigma}{2\sigma}$

$\xi = x_B/(2-x_B)$

$k = t/4M^2$

Polarized beam, unpolarized target:

$\Delta\sigma_{LU} \sim \sin\phi\{F_1 H + \xi(F_1+F_2)\tilde{H} + kF_2 E\}d\phi$

Kinematically suppressed

$H, \tilde{H}, E$

Unpolarized beam, longitudinal target:

$\Delta\sigma_{UL} \sim \sin\phi\{F_1\tilde{H} + \xi(F_1+F_2)(H + \ldots)\}d\phi$

$H, \tilde{H}$

Unpolarized beam, transverse target:

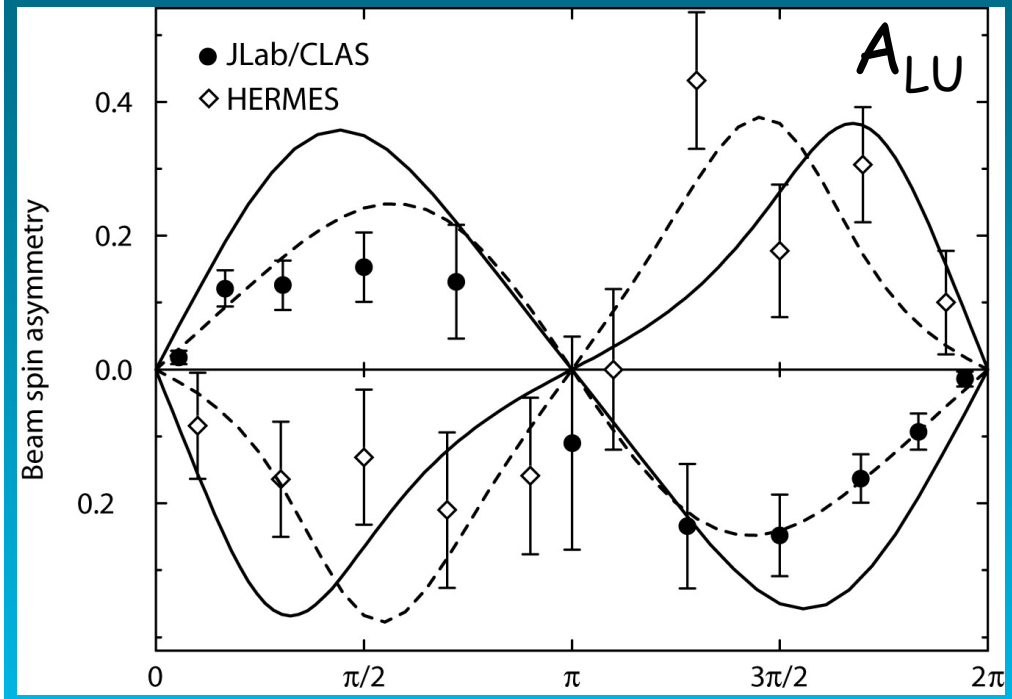
$\Delta\sigma_{UT} \sim \sin\phi\{k(F_2 H - F_1 E) + \ldots..\}d\phi$

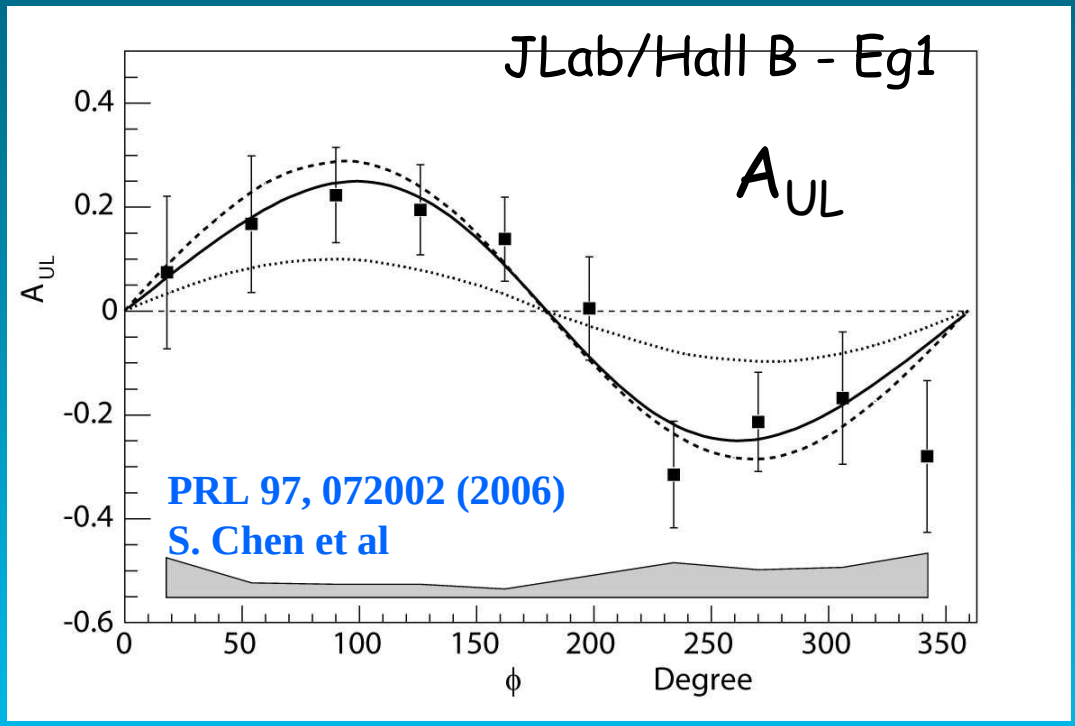
H, E

Global analysis of polarized and unpolarized data needed for GPD separation

Published non-dedicated results on A_{LU} and A_{UL}

JLab/Hall B - E1 & HERMES





CLAS: PRL 87, 182002 (2001)
HERMES: PRL 87, 182001 (2001)

Both results show, with a limited statistics, a sinφ behavior (necessary condition for handbag dominance)

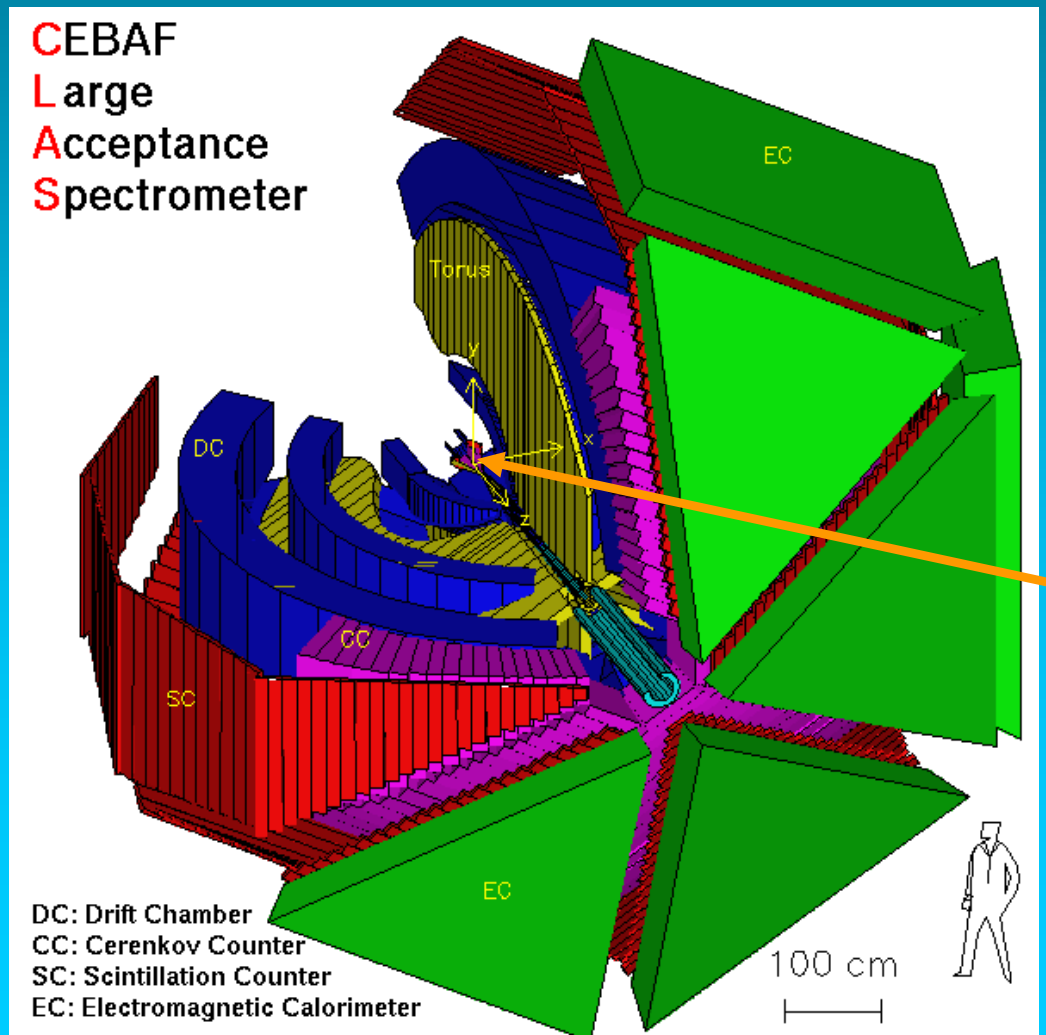
In the A_{LU} result, DD models (VGG) tend to over-estimate the data

The perfect tools

The perfect tools

E1-DVCS with CLAS

Beam energy: ~5.8 GeV
Beam Polarization: 75-85%
Integ. Luminosity: 45 fb^{-1}
2nd half of data under analysis



e^- identified in EC and ČC

p through TOF, track length, momentum.

Photon detected in EC

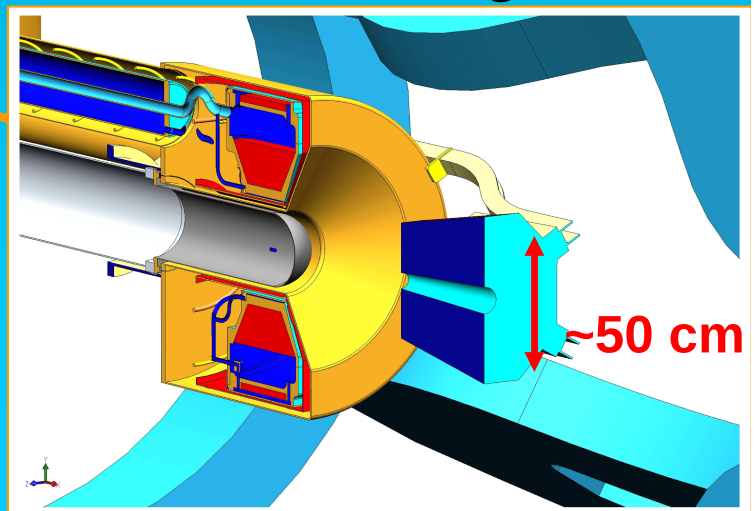
Or in IC (4.5 to 15˚ for γ 1 to 5 GeV)

Q^2 from 1 to 4.8 GeV^2

x_B from 0.11 to 0.58

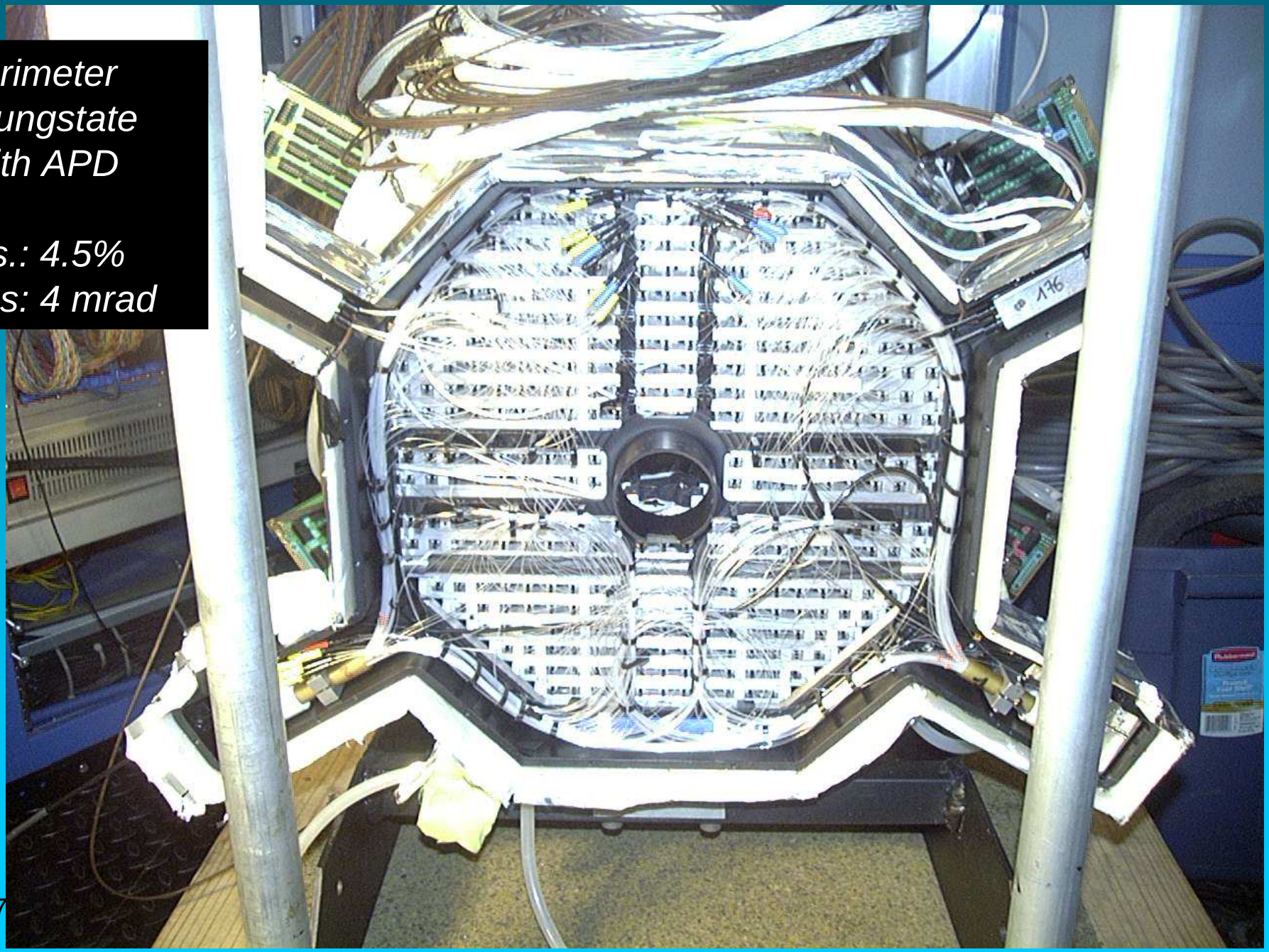
-t from 0.09 to 1.8 GeV^2

Inner Calorimeter
+ Moller shielding solenoid



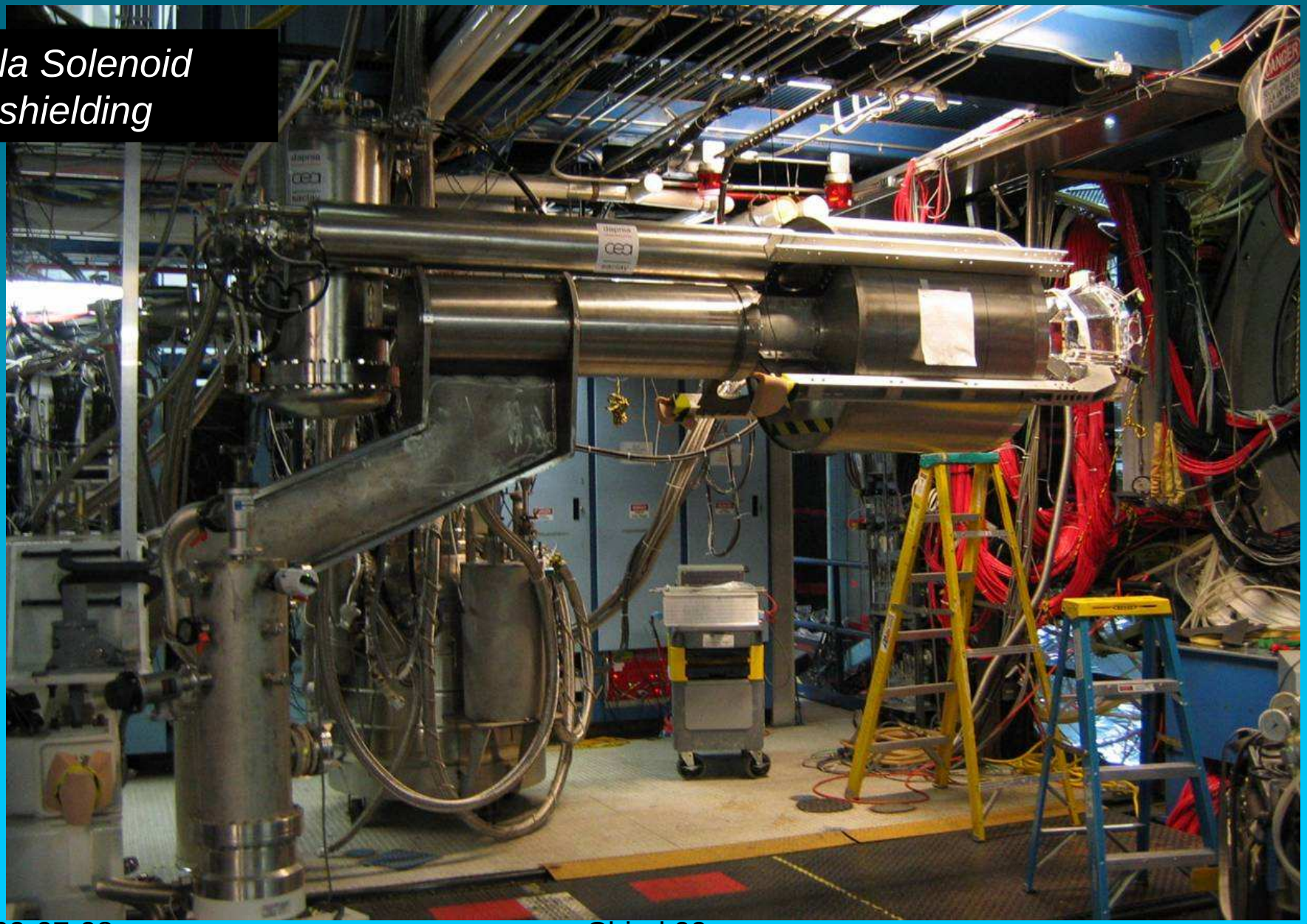
Additional Equipment for E1-DVCS

Inner Calorimeter
424 lead-tungstate crystals with APD readout.
Energy res.: 4.5%
Angular res: 4 mrad



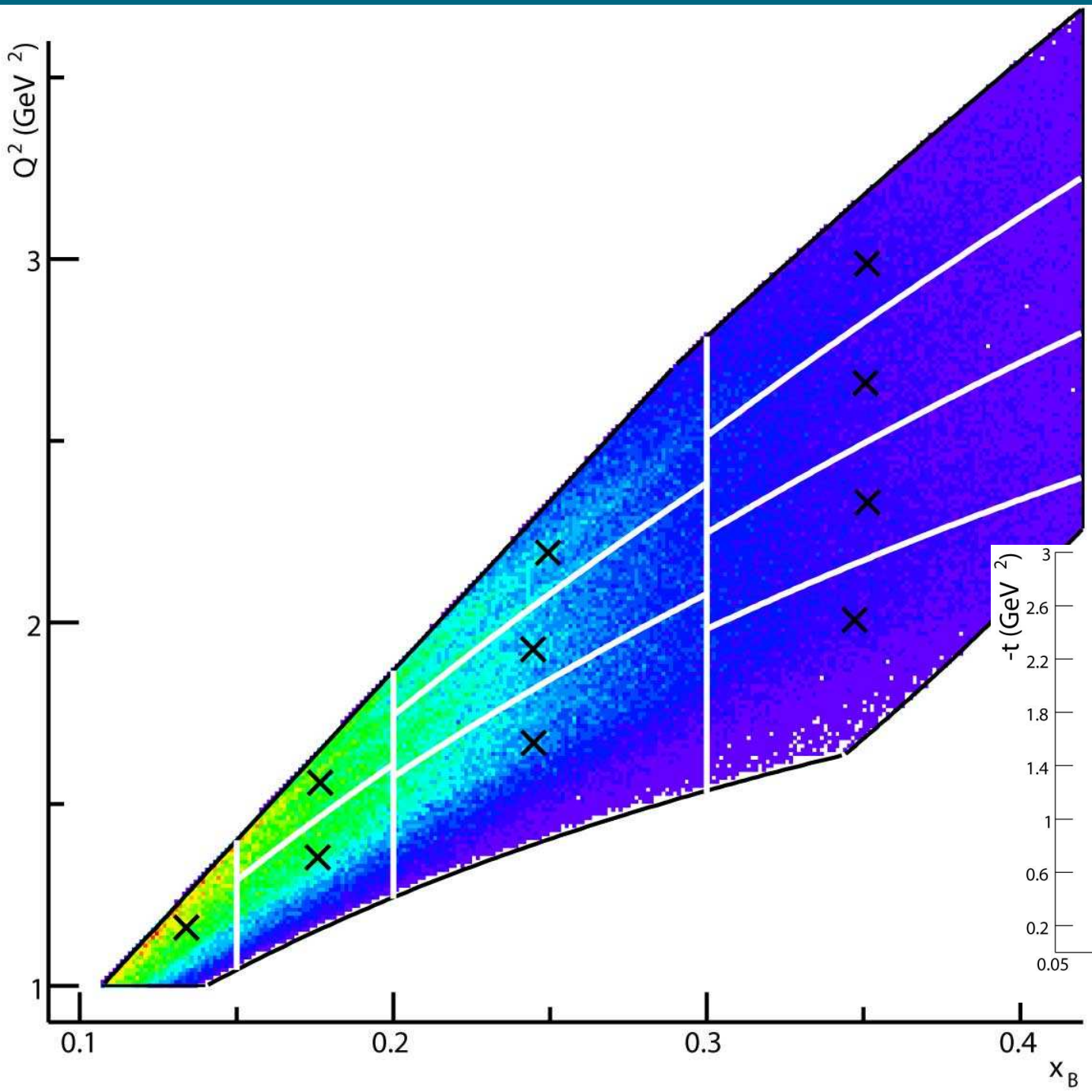
Additional Equipment for E1-DVCS

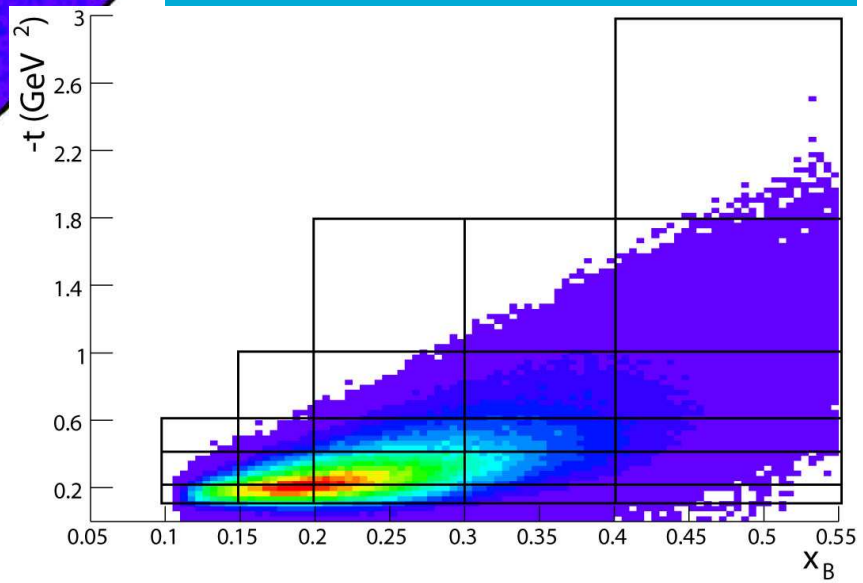
4.7 tesla Solenoid
Active shielding



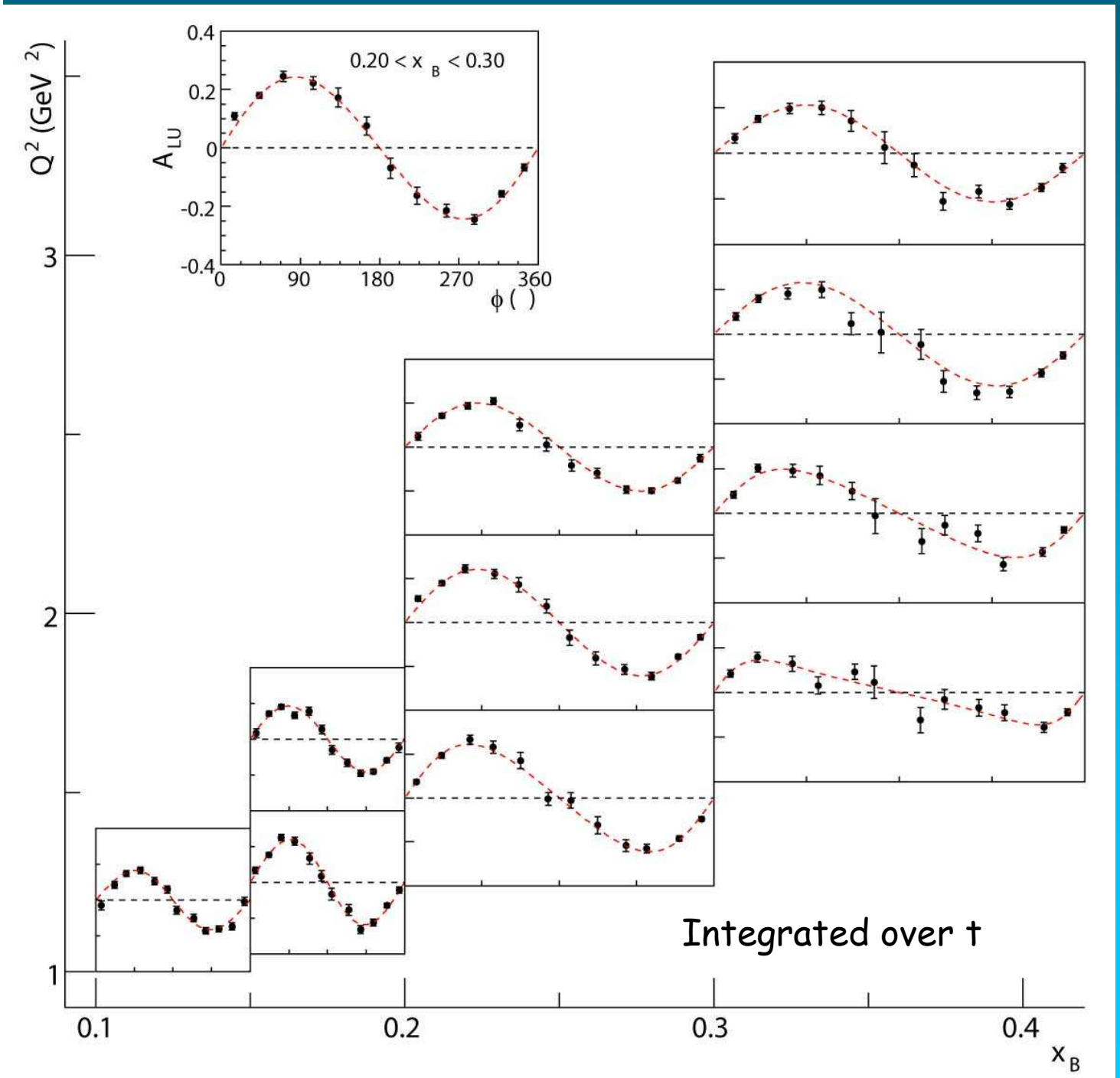
E1-DVCS kinematical coverage and binning

$W^2 > 4\ GeV^2$
$Q^2 > 1\ GeV^2$



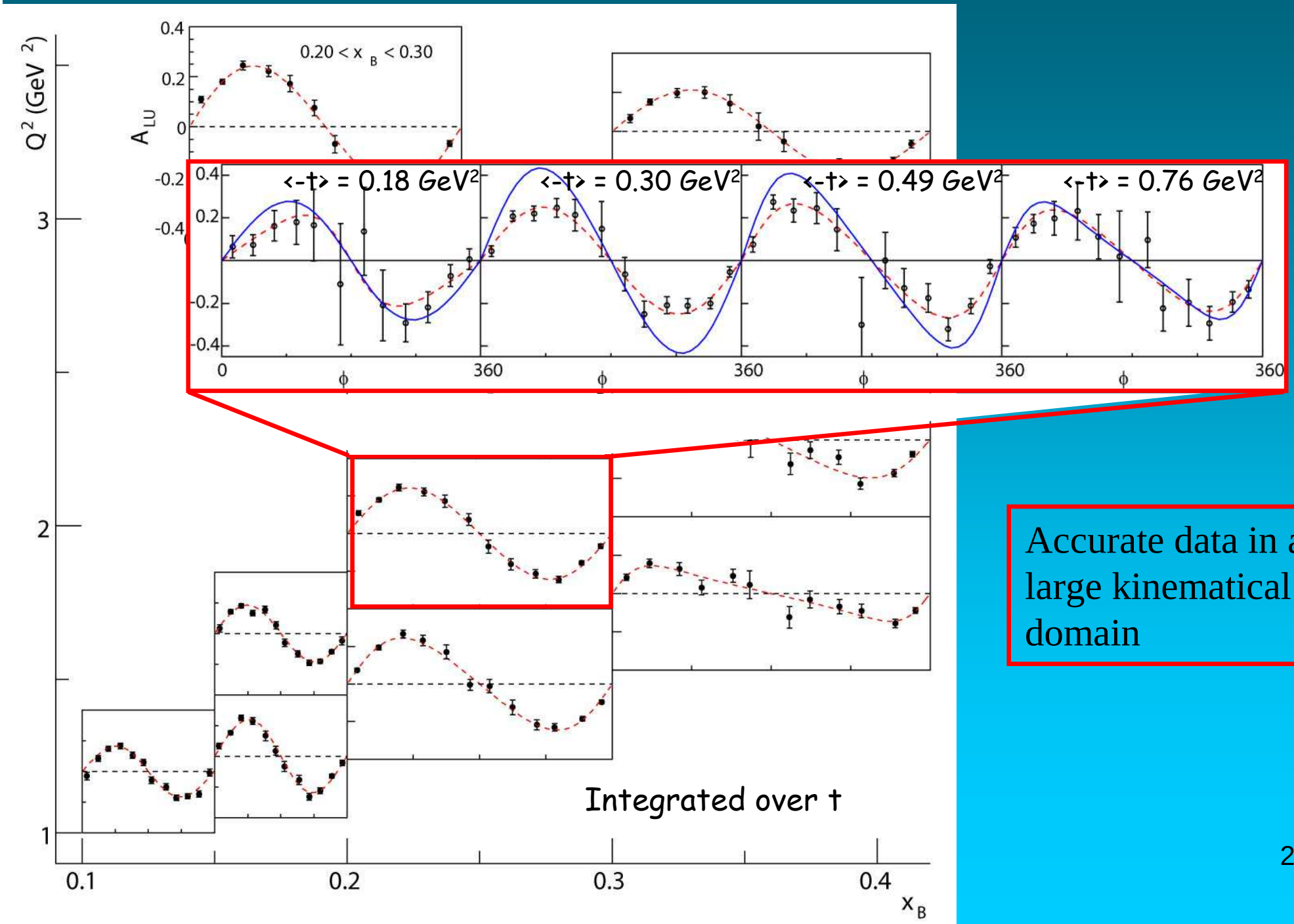


E1-DVCS : Asymmetry as a function of x_B and Q^2



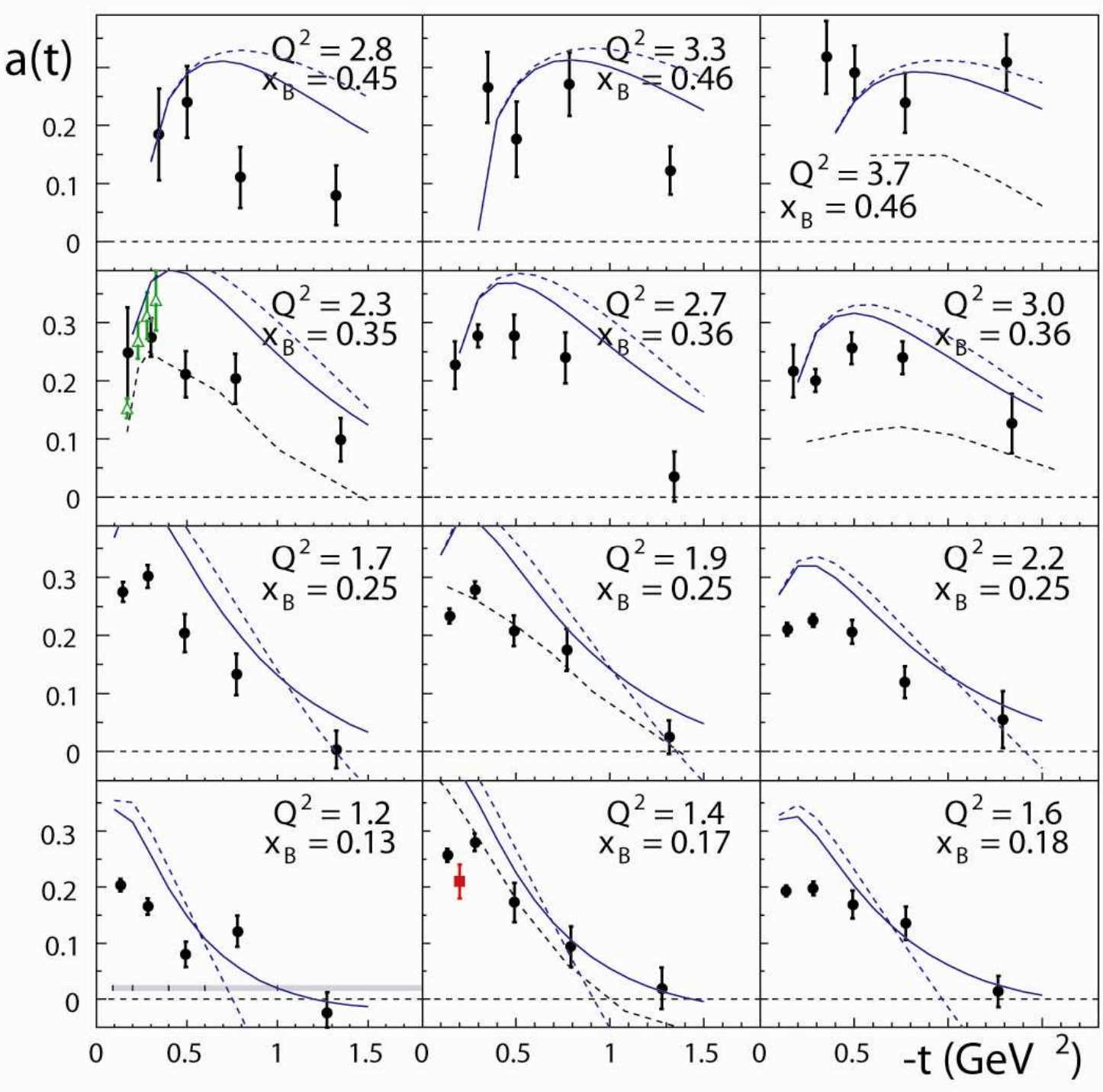
Accurate data in a large kinematical domain

E1-DVCS : Asymmetry as a function of x_B and Q^2



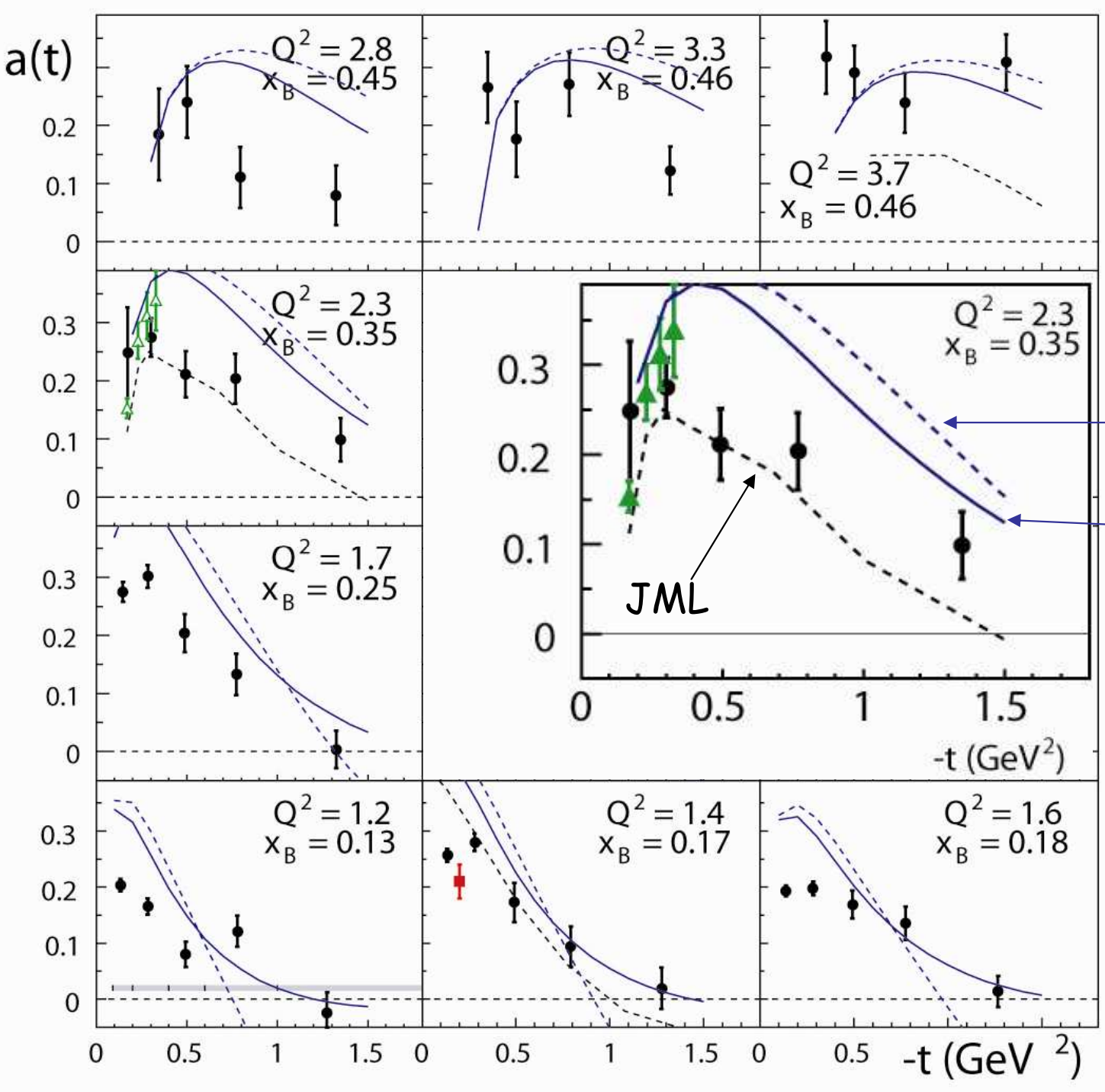
Accurate data in a large kinematical domain

E1-DVCS : $A_{LU}(90°)$ as a function of $-t$ + models



F.X. Girod et al
PRL100 162002, 2008

E1-DVCS : $A_{LU}(90°)$ as a function of $-t$ + models



F.X. Girod et al
PRL100 162002, 2008

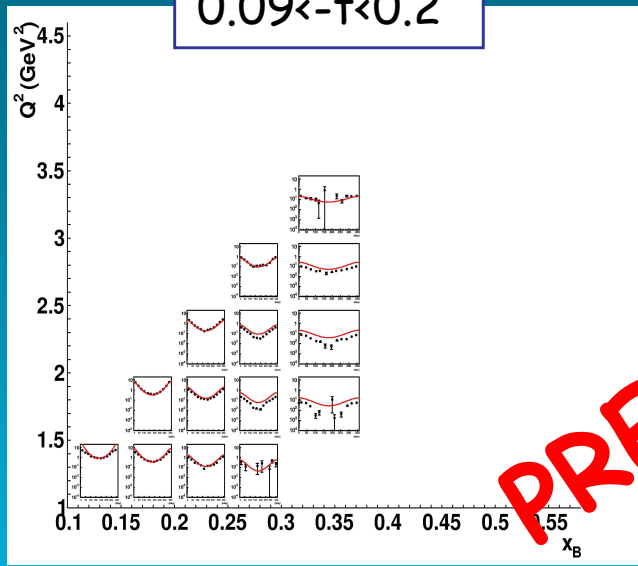
VGG twist-2+3

VGG twist-2

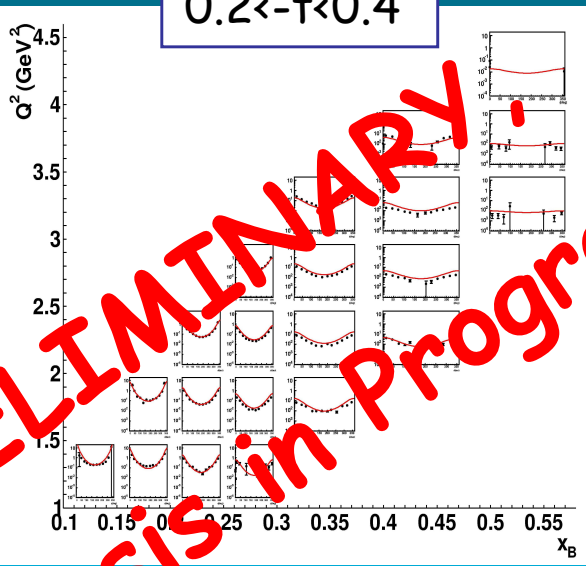
E1-DVCS : Cross-sections over a wide kinematical range

PhD Thesis H.S. Jo

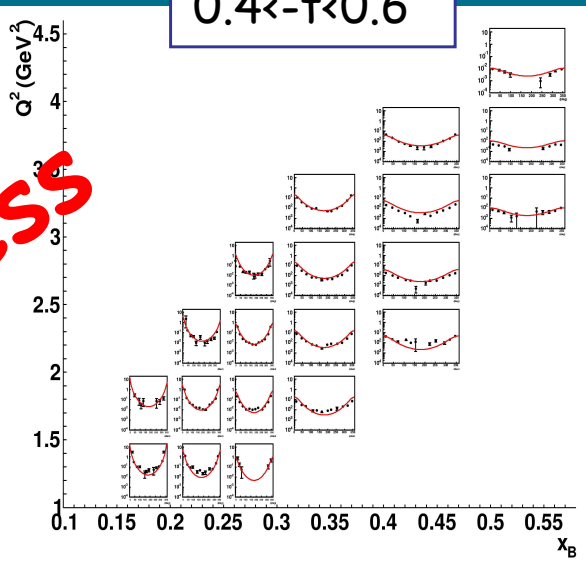
0.09<-t<0.2



0.2<-t<0.4

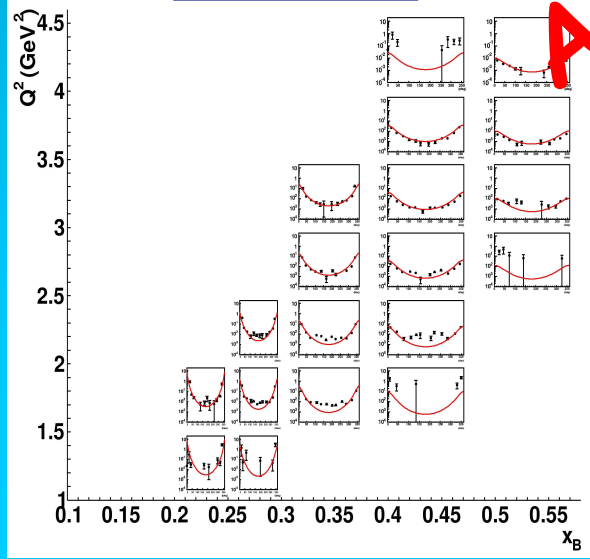


0.4<-t<0.6

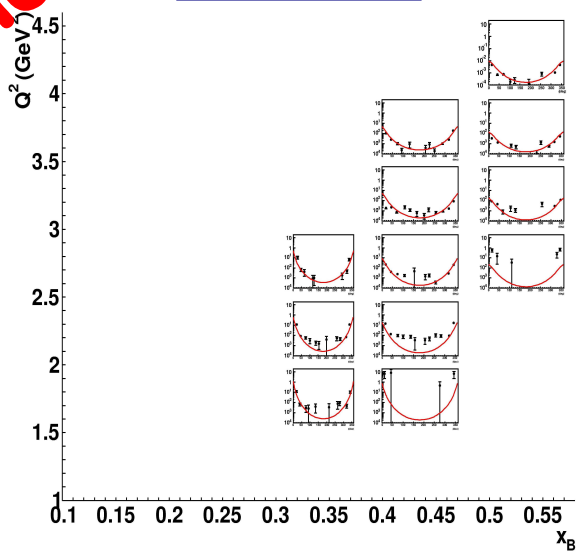


PRELIMINARY - Analysis in Progress

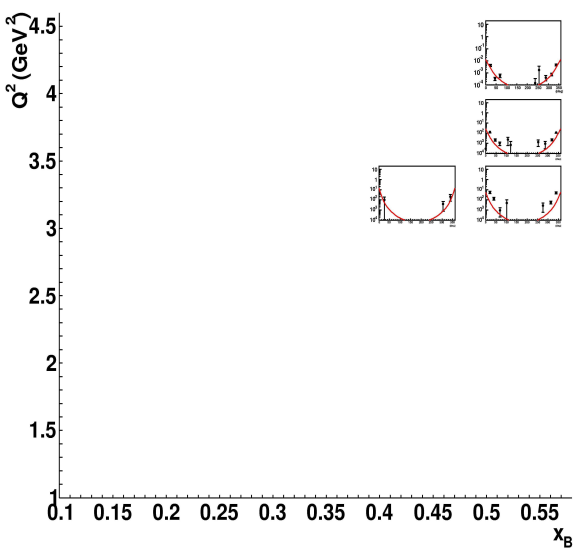
0.6<-t<1



1<-t<1.5

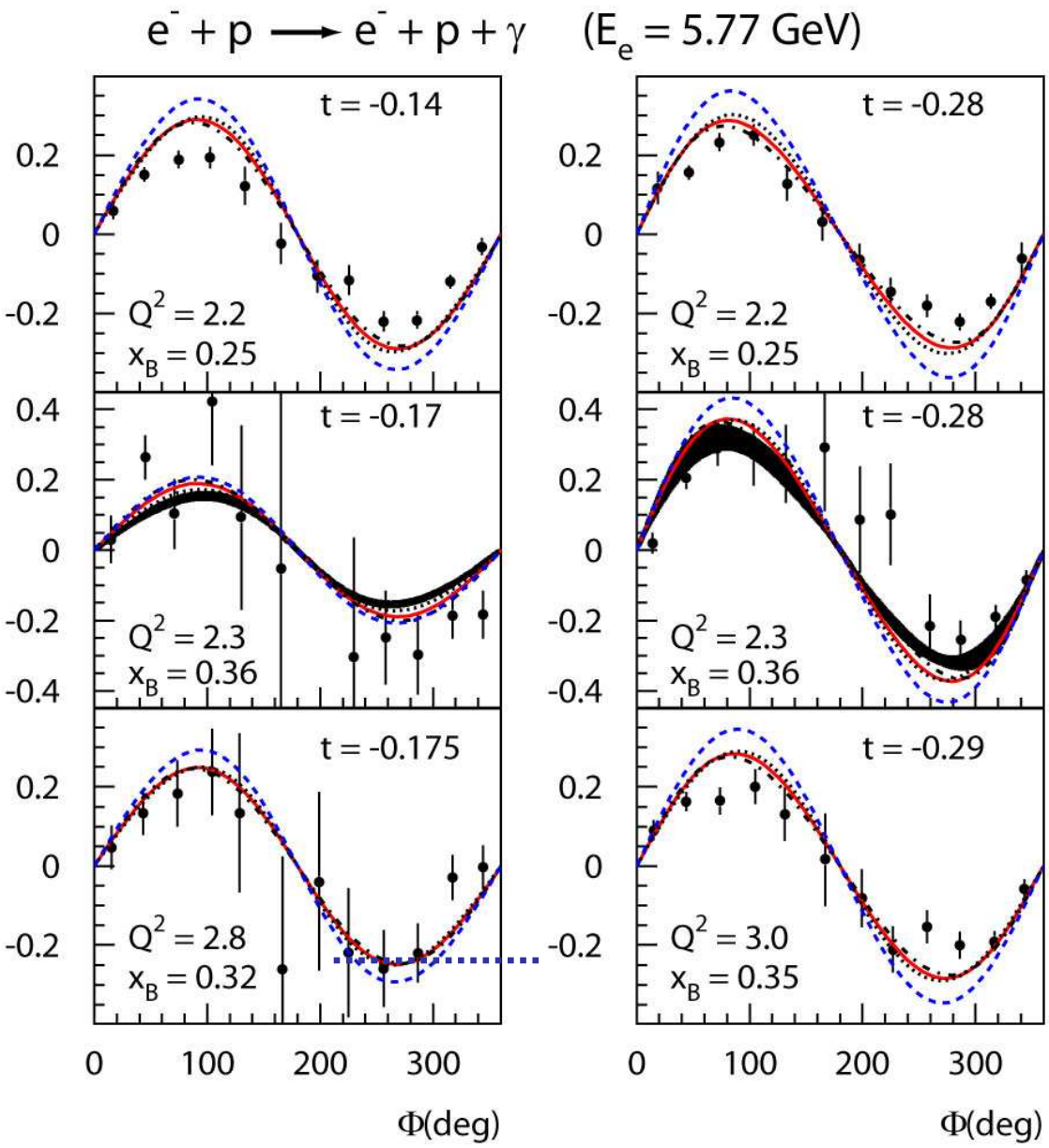


1.5<-t<2



Minimal dual model (*i.e.* forward model) of DVCS data

Beam Spin Asymmetries
(Hall B data)

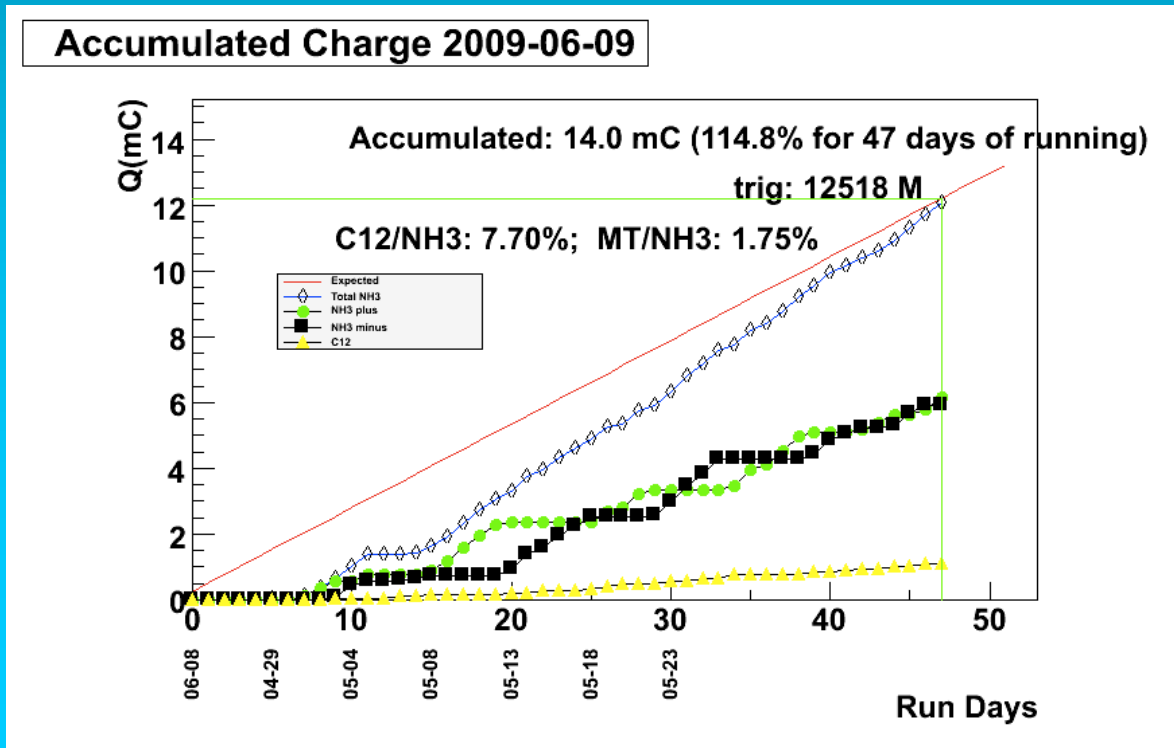


DD Model (VGG)

Minimal Dual Model
(M. Polyakov, M. Vanderhaeghen
arXiv:0803.1271)

EG1- DVCS

- First dedicated DVCS experiment with the polarized target
- Approved for 60 PAC days @ 5.9 GeV
- Feb 4th – Mar 15th - 7 mC
- Apr 23rd – Jun 14th – 14 mC so far
- Aug 21st – Sept 20th
- Running at 7.5 nA
- Target polarization 80%



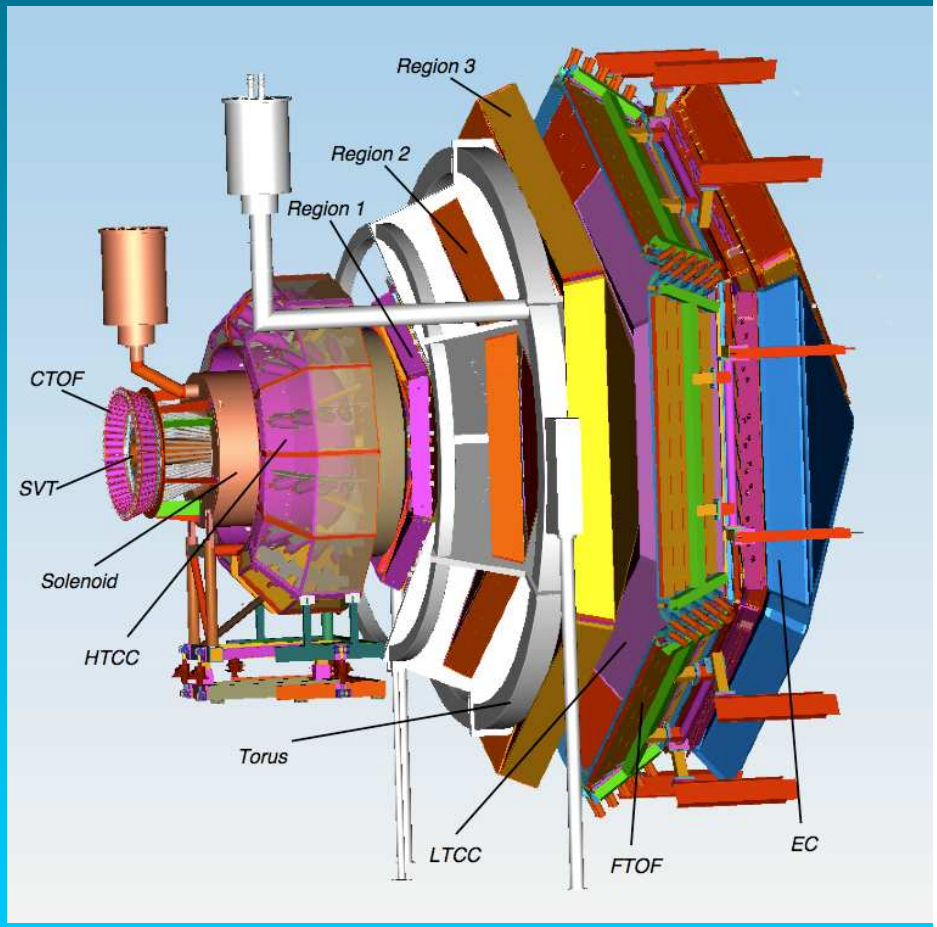
Conclusion

Asymmetry measured in a large kinematical range &
Cross section measured both accurately, badly described by DD models, and H-only models: suggests genuine off-forward contribution, other GPD contricution and/or higher twist at work.

More data coming soon

JLab 6 GeV cross section data in large kinematical range
JLab 6 GeV L and T polarized target data (2009+)
JLab 12 GeV data (all configurations) in 2014+

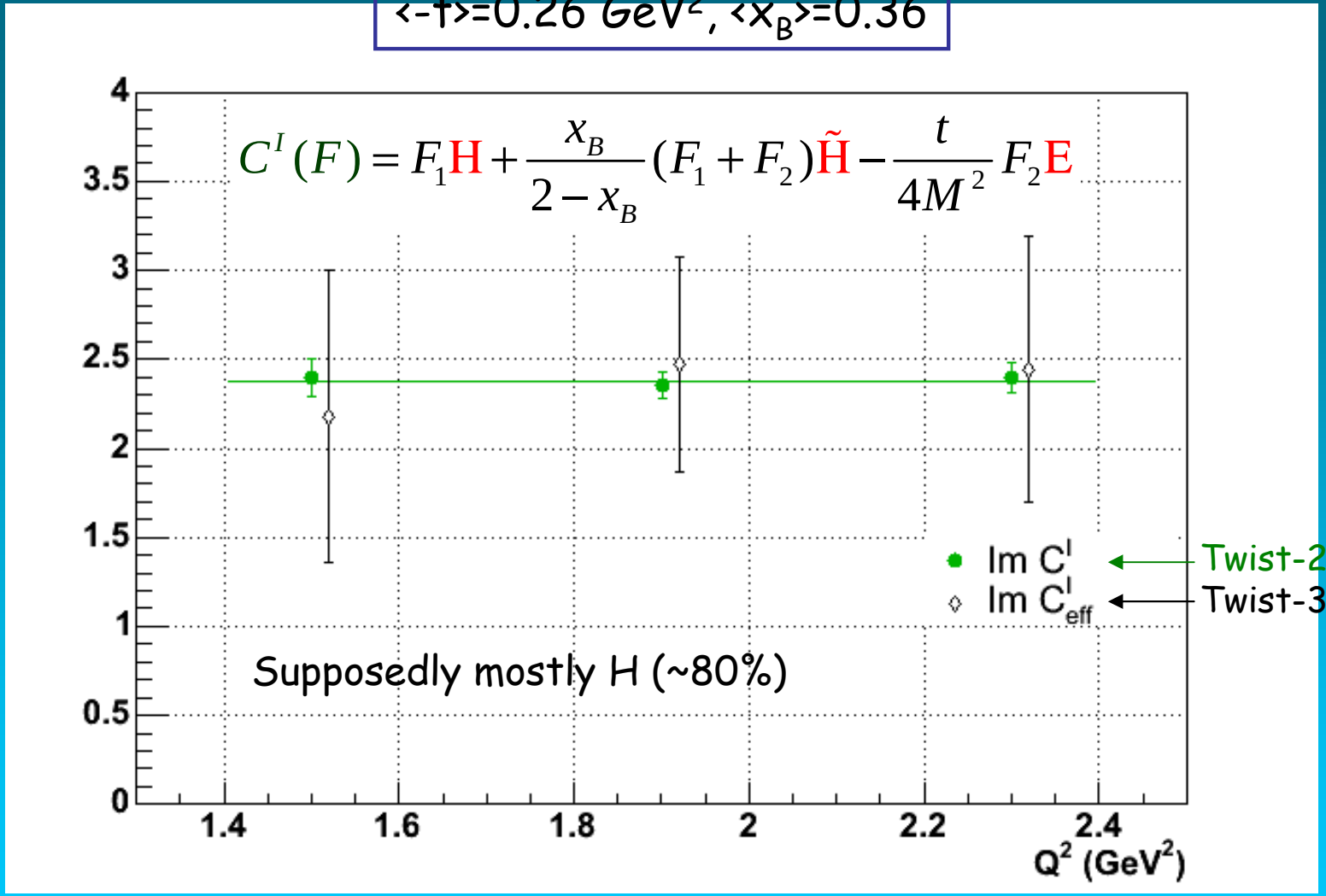
Fitting procedures will be more mature by then



Q^2 dependence and test of scaling

PRL97, 262002 (2006)

$\langle -t \rangle = 0.26\ GeV^2$, $\langle x_B \rangle = 0.36$

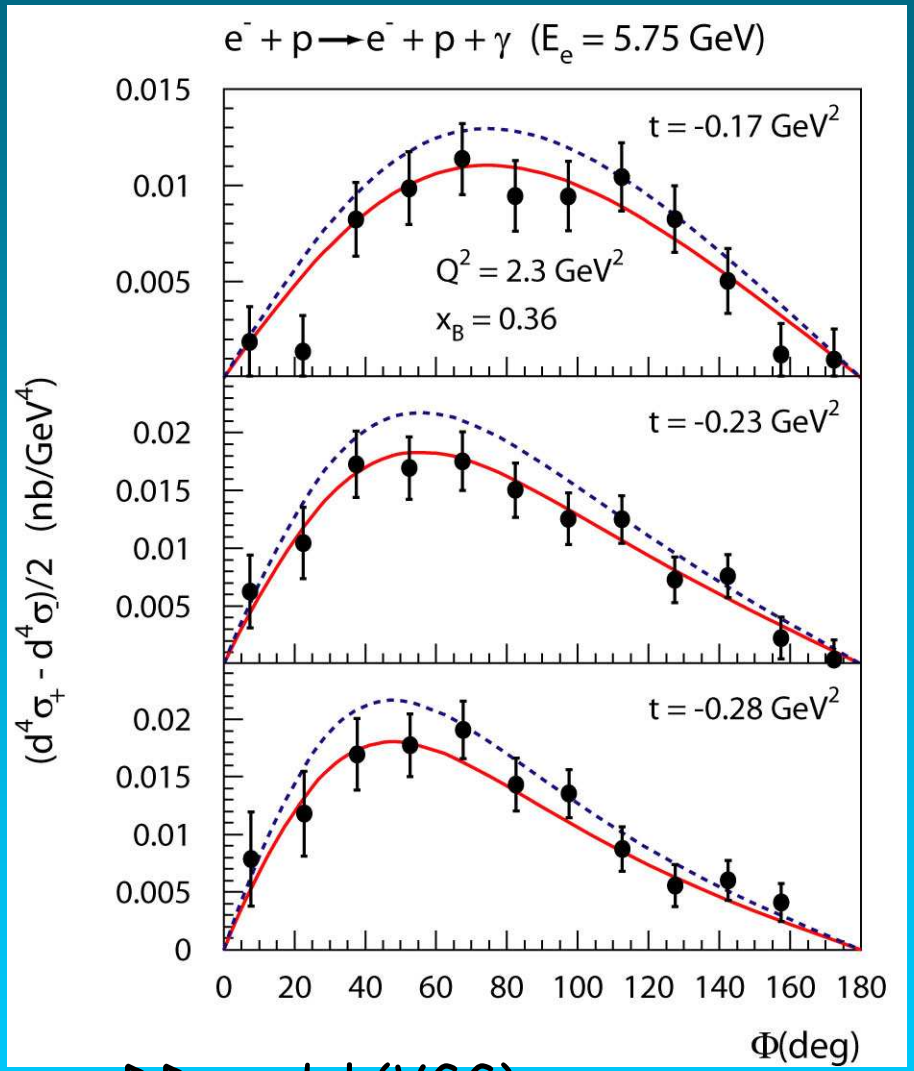


No Q^2 dependence using BMK separation:
strong indication for scaling behavior and handbag dominance

Twist 4+ contributions are smaller than 10%

Minimal dual model (*i.e.* forward model) of DVCS data

Difference of cross sections (imaginary part of interference term)



M. Polyakov,
M. Vanderhaeghen
arXiv:0803.1271

DD model (VGG)

Minimal dual model

Data are perfectly described by minimal dual model

Data: Hall A polarized cross section data at Q^2=2.3 GeV²

Deeply Virtual Exclusive Processes - Kinematics Coverage of the 12 GeV Upgrade