Deeply Virtual Compton Scattering at 11GeV with CLAS12

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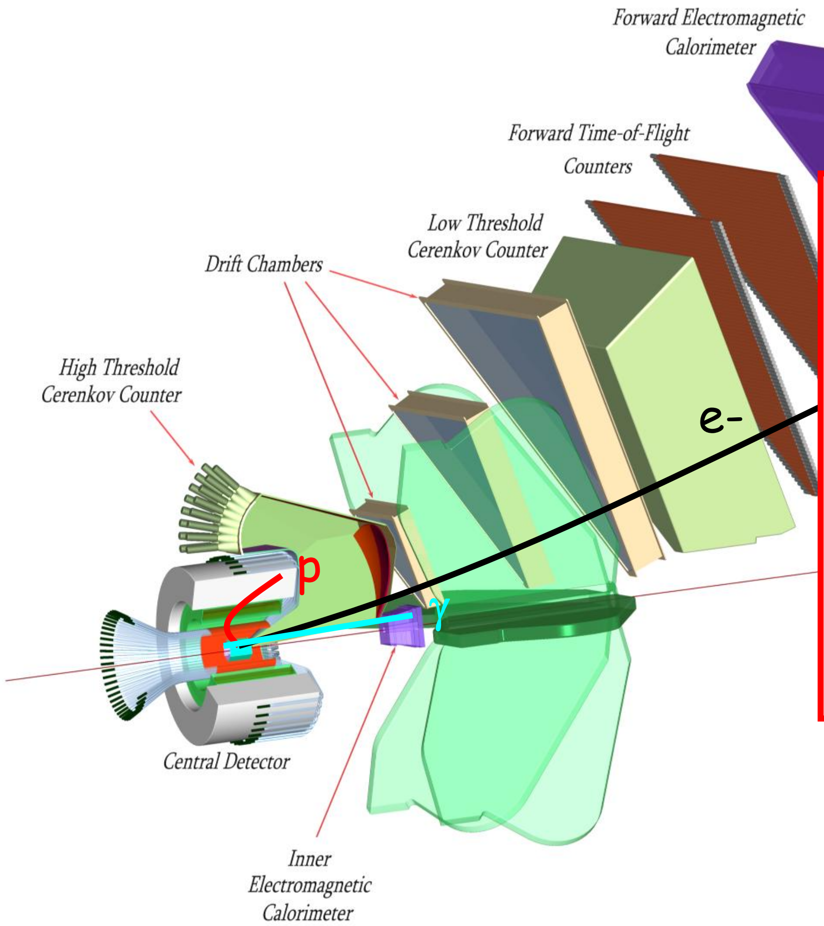
Saclay

JLab PAC30
August 23rd



- Introduction
- Experiment E1-DVCS
- Characteristics of 11 GeV DVCS
- Experimental setup
- Analysis procedure
- Projected results for BSA and TSA

Deeply Virtual Compton Scattering at 11GeV with CLAS12

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Two proposals bundled in one:

1. DVCS Beam Spin Asymmetry
2. DVCS Target Spin Asymmetry

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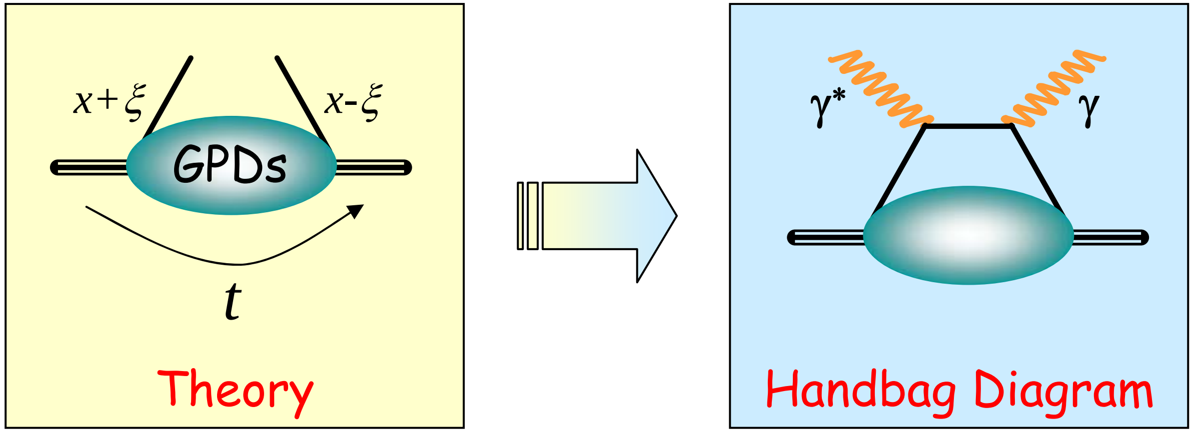
GPDs from Theory to Experiment



<u>2. The GPDs enter the DVCS amplitude as an integral over x:</u>

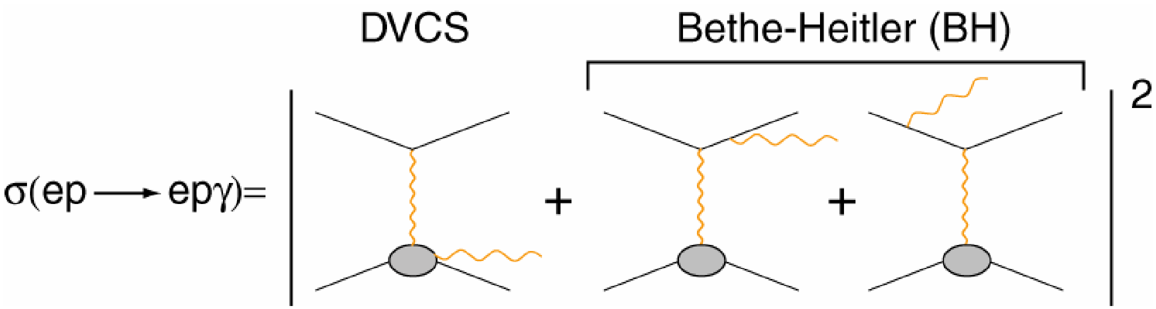
- GPDs appear in the real part through a PP integral over x
- GPDs appear in the imaginary part but at the line x=ξ

$$T^{DVCS} = \int_{-1}^{+1} \frac{GPD(x,\xi,t)}{x-\xi+i\varepsilon} dx \quad + \quad \cdots$$

$$= P\int_{-1}^{+1} \frac{GPD(x,\xi,t)}{x-\xi} dx \quad - \quad i\pi GPD(x=\xi,\xi,t) \quad + \quad \cdots$$

Experimental observables linked to GPDs

3. Experimentally, DVCS is undistinguishable with Bethe-Heitler



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

Using a polarized beam on an unpolarized target or an unpolarized beam on a polarized target, one can access 2 observables:

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

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

At JLab energies, $|T^{DVCS}|^2$ is small… maybe!

Kroll, Guichon, Diehl, Pire, …

Into the harmonic structure of DVCS

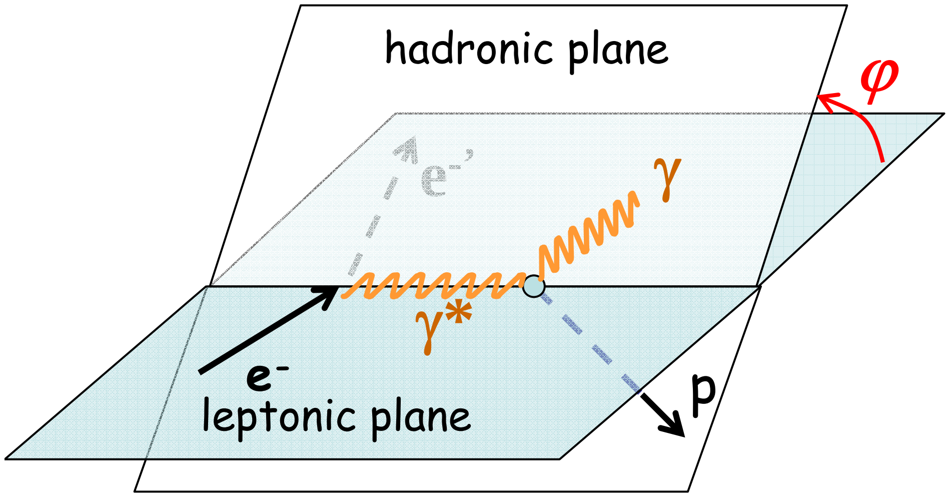
$$\frac{d^4\sigma}{dx_B dQ^2 dt d\varphi} = \frac{1}{P_1(\varphi)P_2(\varphi)}\Gamma_1(x_B,Q^2,t)\left\{c_0^{BH} + c_1^{BH}\cos\varphi + c_2^{BH}\cos 2\varphi\right\}$$

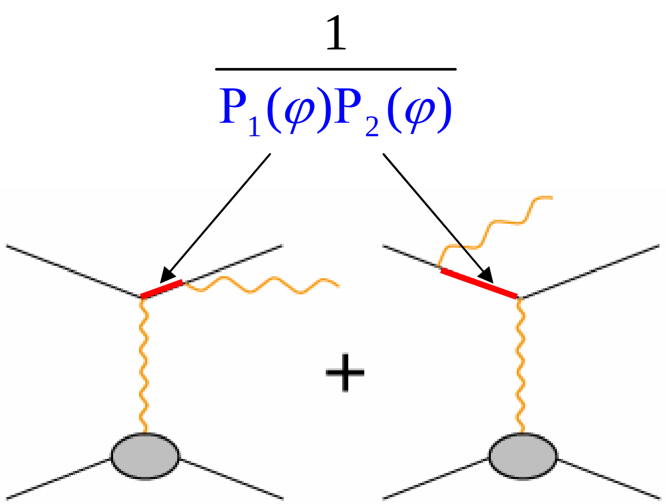
$|T^{BH}|^2$

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

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

Interference term





BH propagators φ dependence

Belitsky, Mueller, Kirchner

Analysis - Extraction of observables (BSA)

Difference of cross-section for polarized beam on unpolarized target:

$$\frac{d^4\overrightarrow{\sigma} - d^4\overleftarrow{\sigma}}{dx_B dQ^2 dt d\varphi} = \frac{\Gamma(x_B, Q^2, t)}{\mathrm{P}_1(\varphi)\mathrm{P}_2(\varphi)}\left\{s_1^I \sin\varphi + s_2^I \sin 2\varphi\right\}$$

$$s_1^I = 8Ky(2-y)\,\mathrm{Im}\,C^I(F)$$

$$C^I(F) = F_1\mathrm{H} + \frac{x_B}{2-x_B}(F_1+F_2)\tilde{\mathrm{H}} - \frac{t}{4M^2}F_2\mathrm{E}$$

$$\mathrm{Im}\,\mathrm{H} = \pi\sum_q e_q^2\left\{H^q(\xi,\xi,t) - H^q(-\xi,\xi,t)\right\}$$

GPD !!!

Analysis - Extraction of observables (TSA)

Difference of cross-section for unpolarized beam on polarized target:

$$\frac{d^4\overrightarrow{\sigma} - d^4\overleftarrow{\sigma}}{dx_B dQ^2 dt d\varphi} = \frac{\Gamma(x_B, Q^2, t)}{\mathrm{P}_1(\varphi)\mathrm{P}_2(\varphi)}\left\{ s_1^I \sin\varphi + s_2^I \sin 2\varphi \right\}$$

$$s_1^I = 8Ky(2-y)\,\mathrm{Im}\,C^I(F)$$

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

Mostly sensitive to H and $\tilde{\mathrm{H}}$

Special case of the asymmetry

Experimentally advantageous, the asymmetry can be written as:

$$\frac{d^4\overrightarrow{\sigma} - d^4\overleftarrow{\sigma}}{d^4\overrightarrow{\sigma} + d^4\overleftarrow{\sigma}} = \Gamma_A(x_B, Q^2, t)\frac{s_1^I \sin\varphi + s_2^I \sin 2\varphi}{c_0^I + c_0^{BH} + (c_1^I + c_1^{BH})\cos\varphi + \ldots}$$

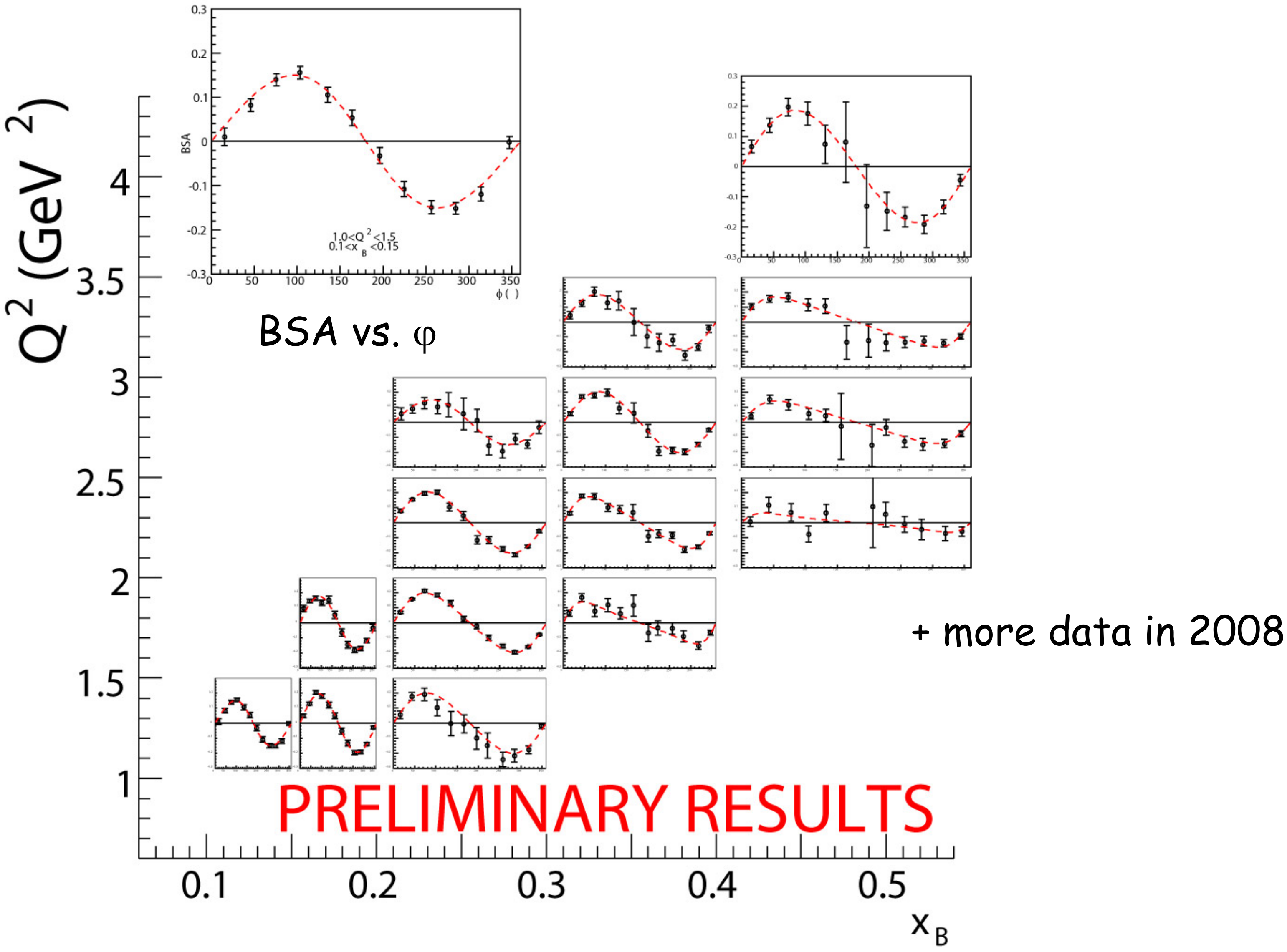
With limited statistics and to give rough estimates, one can consider that the denominator is dominated by c_0^{BH}.

However, high precision experiment will need to take everything into account to extract twist-2 GPDs **without model dependence**. This is foreseen to be achieved using a global fit to parametrized GPDs, just like NLO fits to structure functions yield PDFs.

X. Ji Workshop in October !

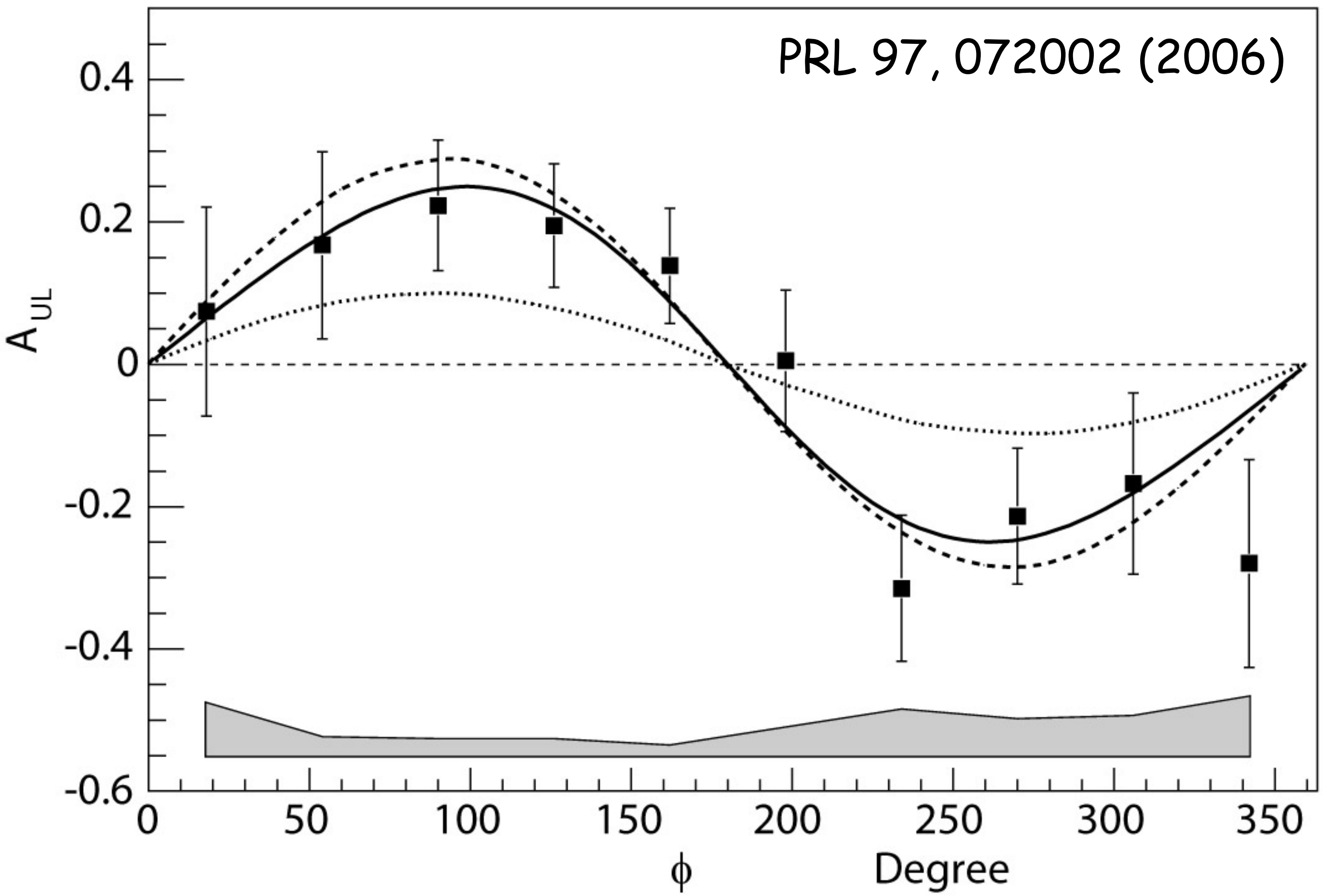
E1-DVCS data and analysis are promising !

Same experimental method as the proposed experiment



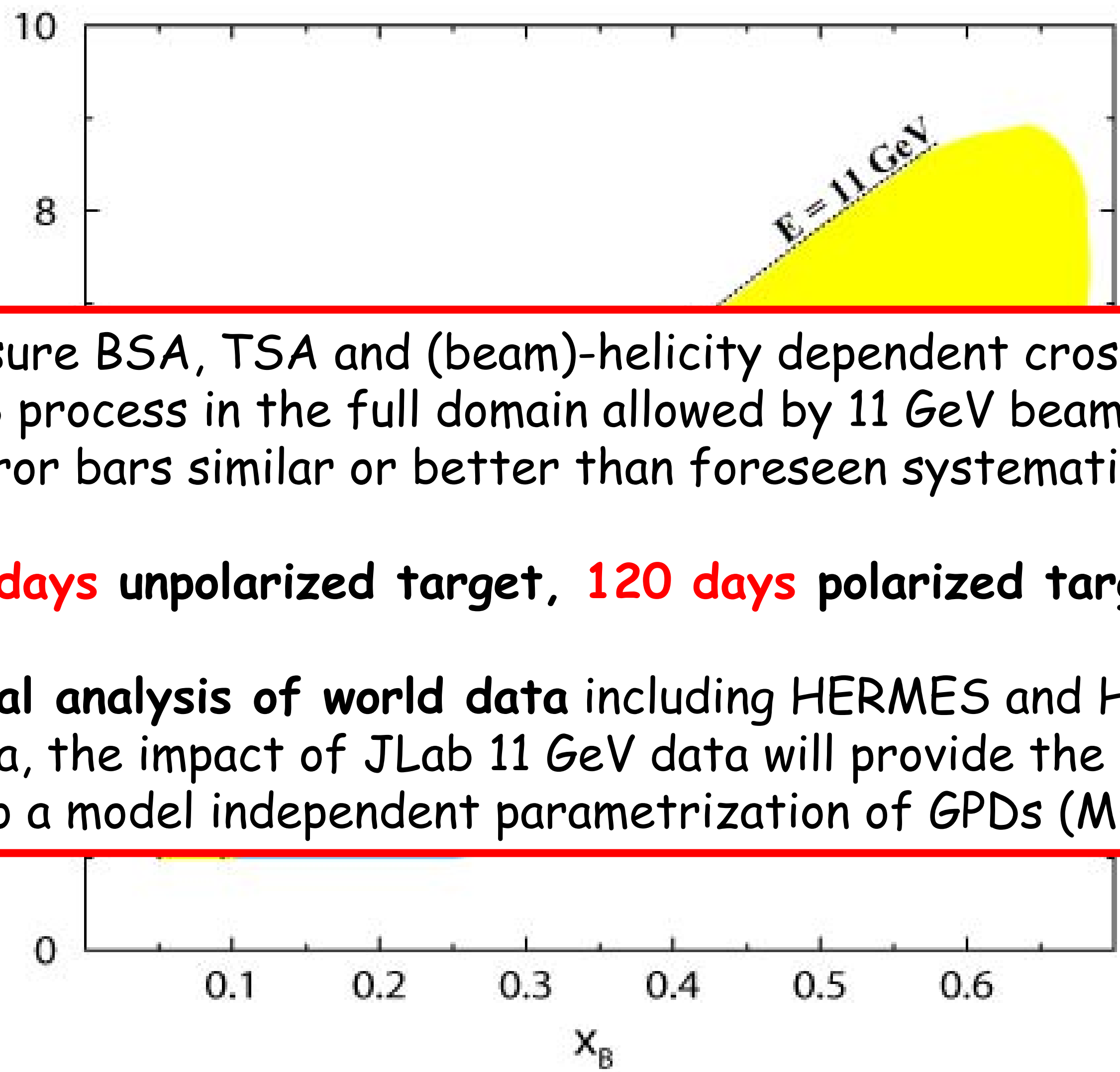
Analysis by F.X. Girod

EG1 data for TSA



+ more data in 2008

From 6 to 11 GeV !



Goal: To measure BSA, TSA and (beam)-helicity dependent cross-sections for the DVCS process in the full domain allowed by 11 GeV beam with statistical error bars similar or better than foreseen systematic errors:

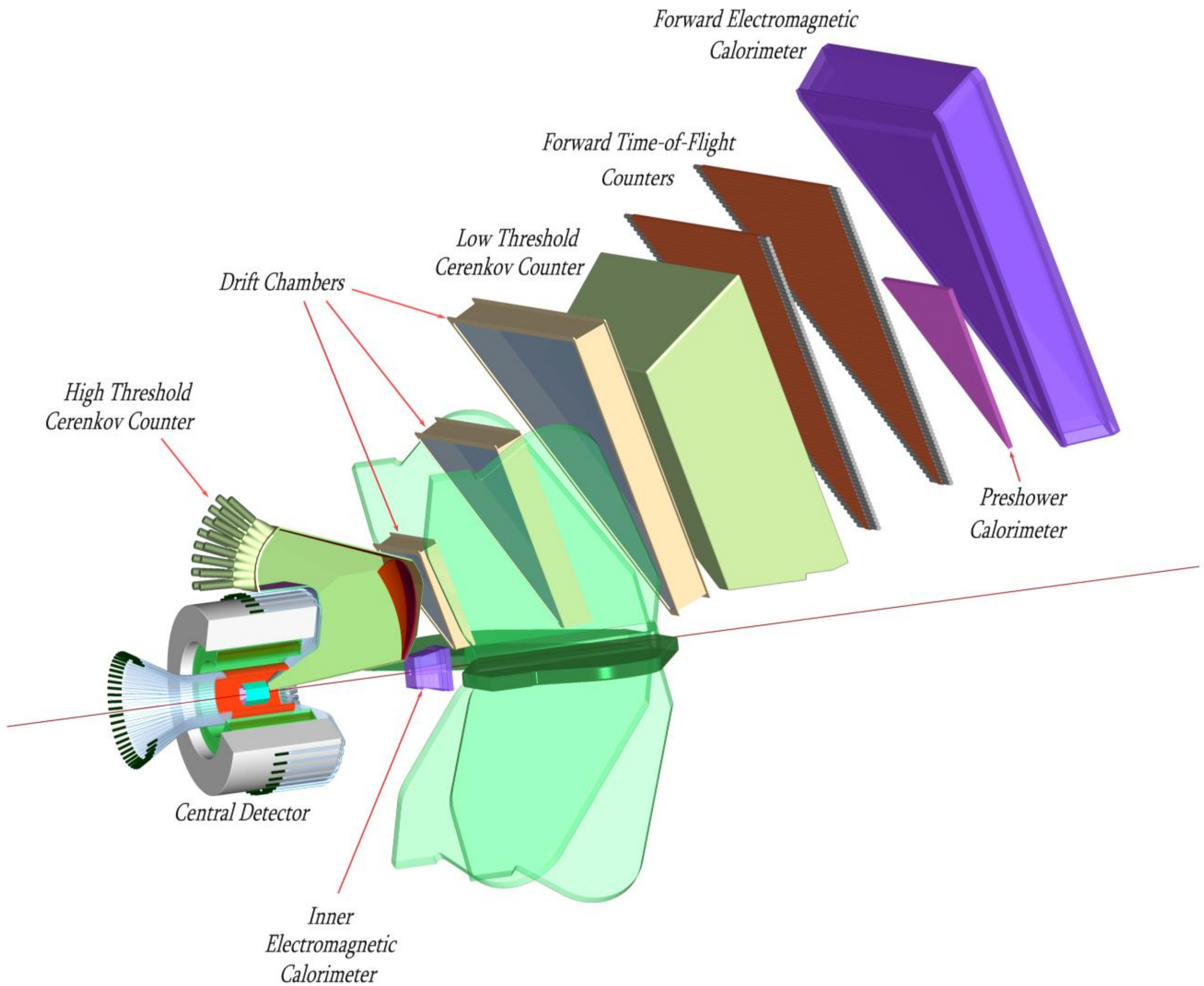
80 days unpolarized target, 120 days polarized target

Within a **global analysis of world data** including HERMES and Hall A Deep Exclusive data, the impact of JLab 11 GeV data will provide the strongest constraints to a model independent parametrization of GPDs (Mueller et al.).

+ increase in luminosity by a factor ~5
+ improved acceptance

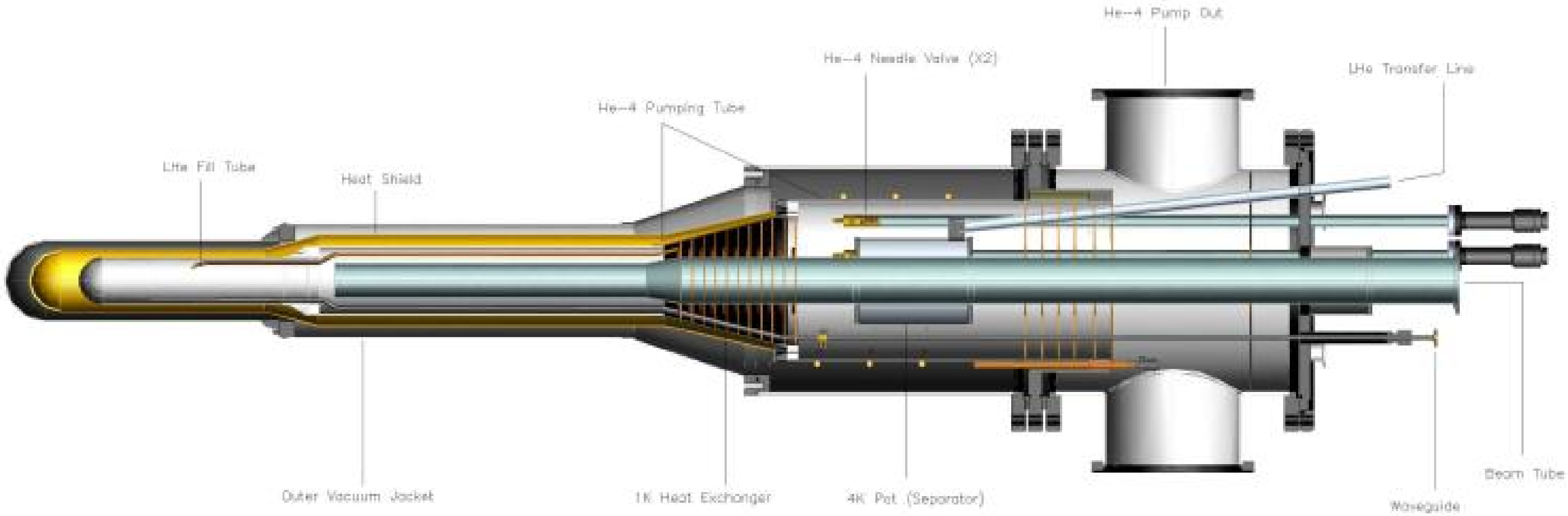
Experimental Setup and proposed experiments at 11 GeV

Use of base CLAS12 equipment, including Inner Calorimeter (IC)

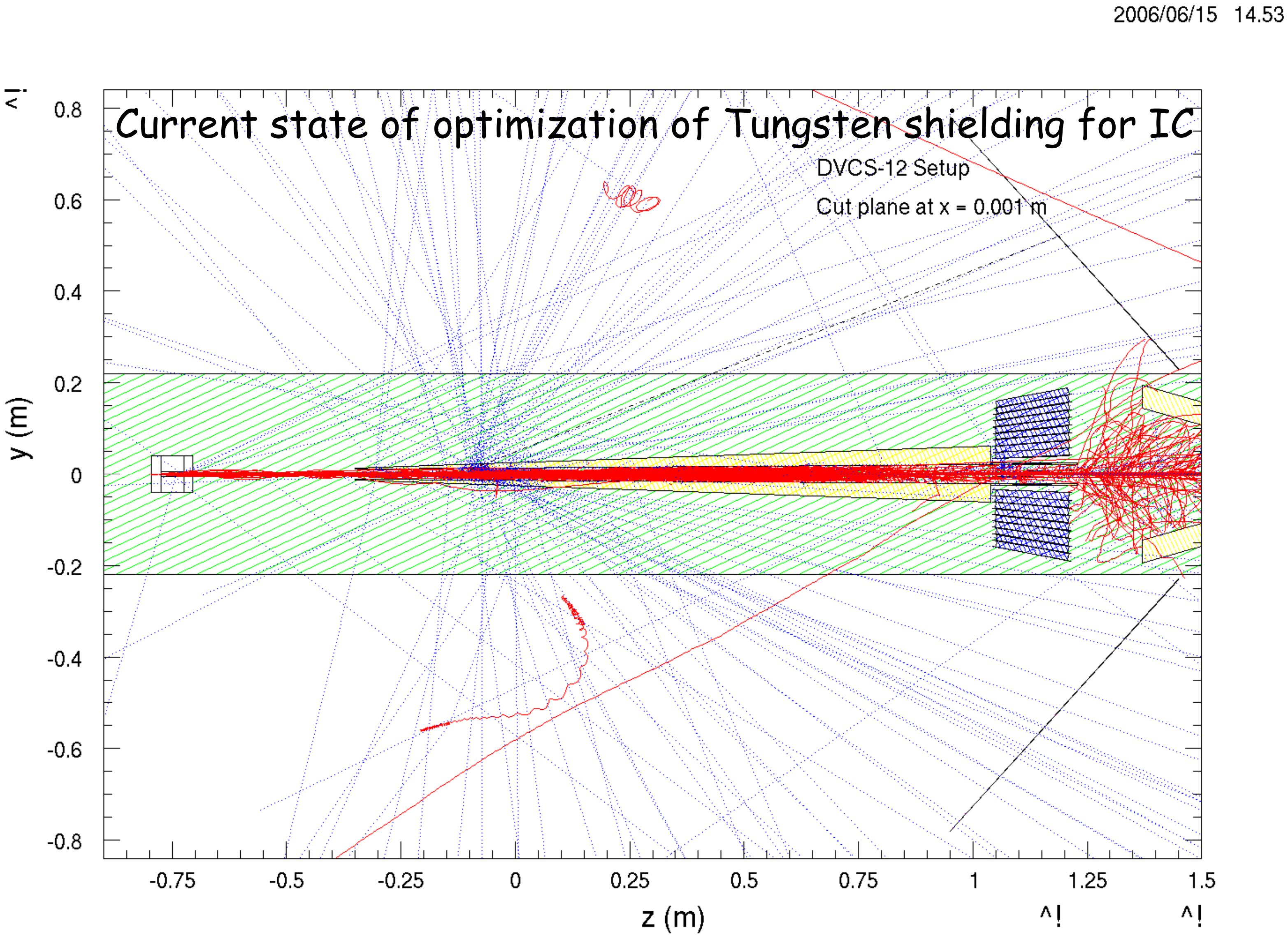


Longitudinally polarized NH3 target

Polarization:	85%
Dilution factor:	1/6
Length:	up to 100 mm
Diameter:	up to 30 mm
Luminosity:	up to 2x10^35 /cm^2/s
Pol. Meas.:	NMR + physics



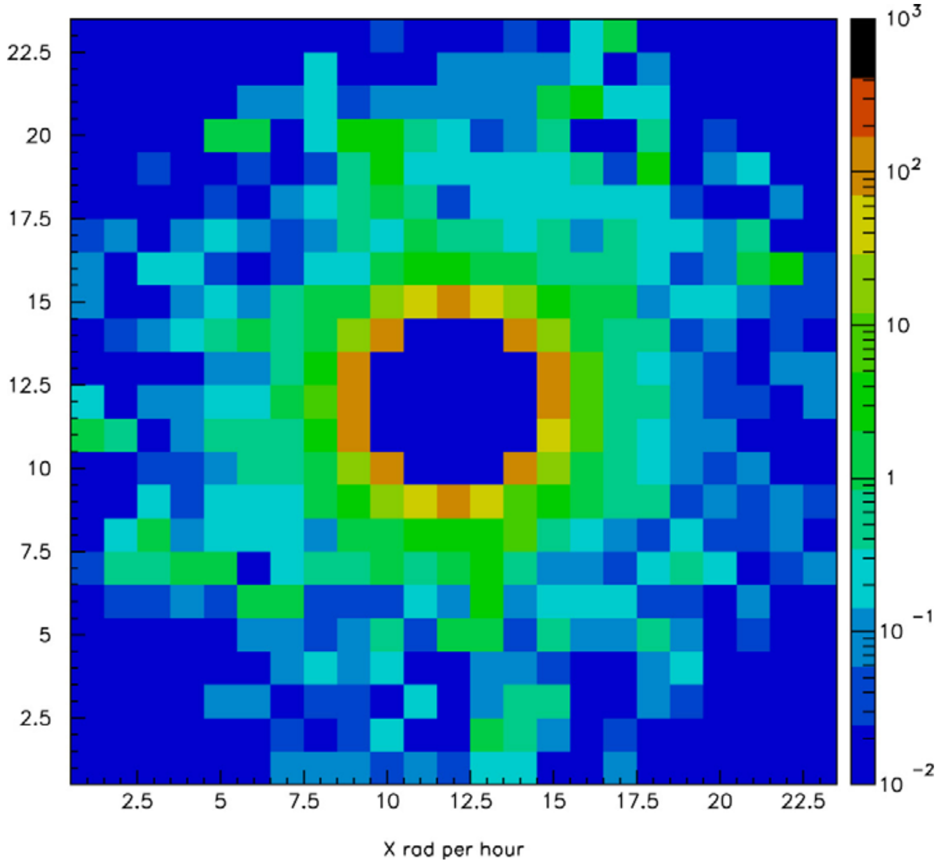
IC radiation study



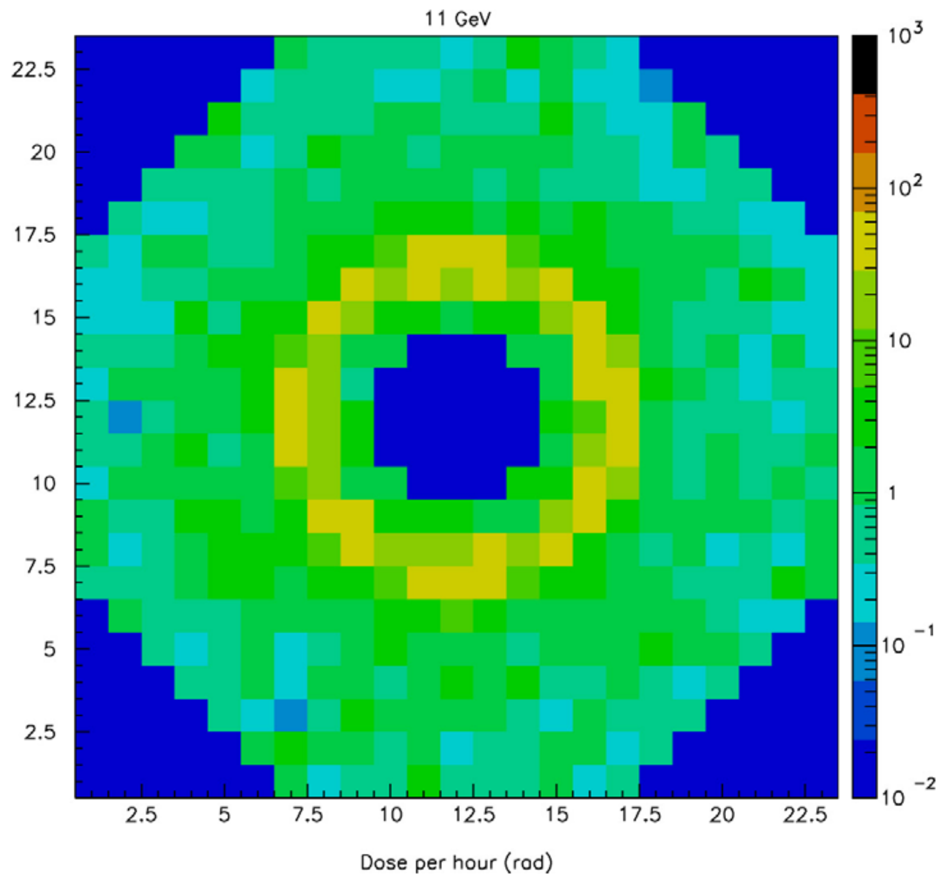
Study by L. Elouadrhiri and A. Vlassov

IC radiation study

E1-DVCS configuration
[compatible with data study]

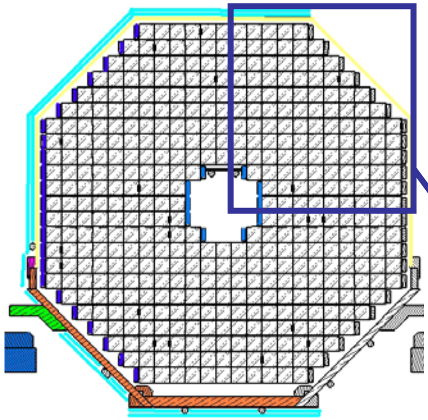


Clas12 configuration
With IC shielding

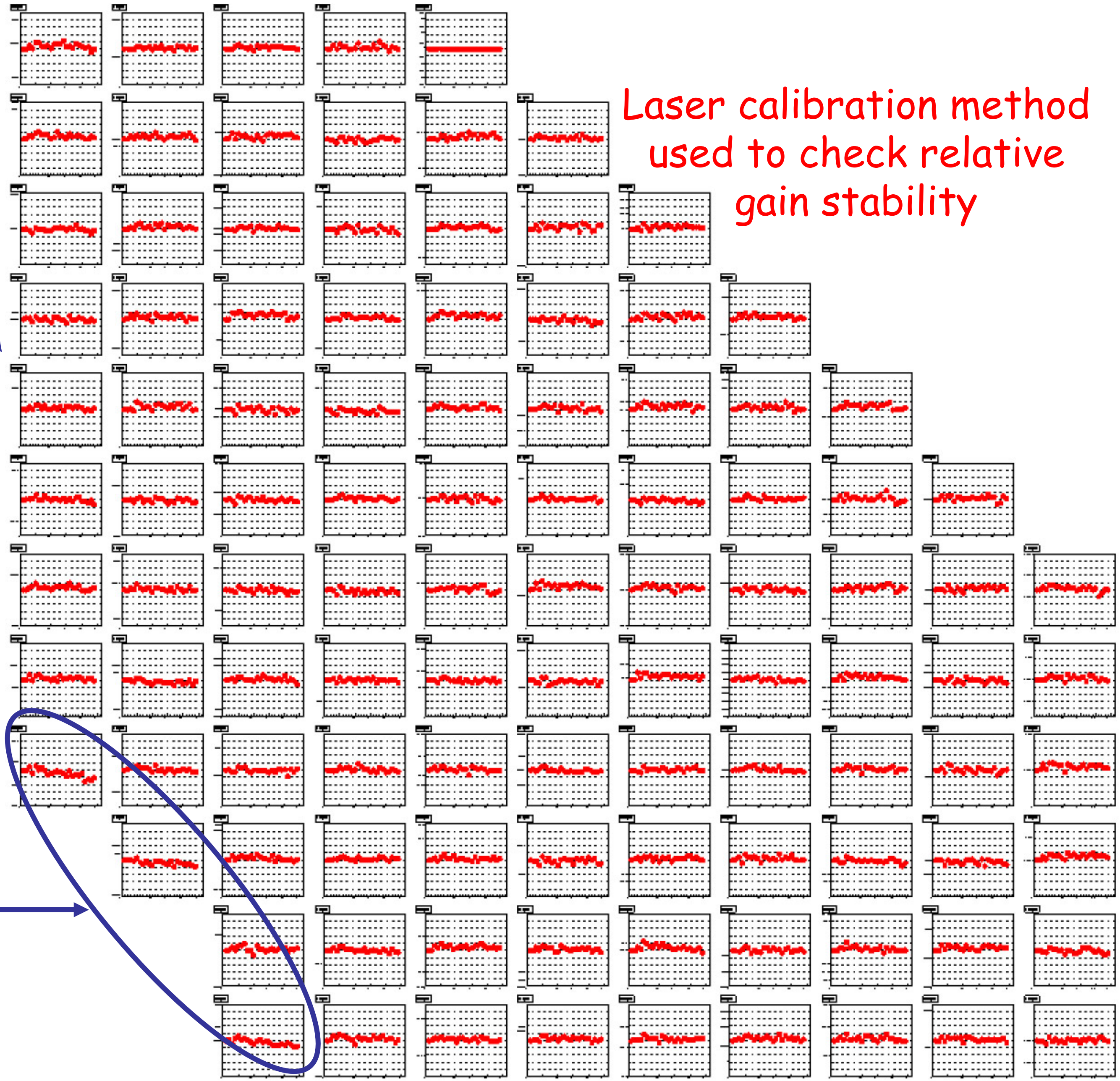


The IC radiation is not worse with CLAS12 configuration than during E1-DVCS

IC block gain variation during E1-DVCS running



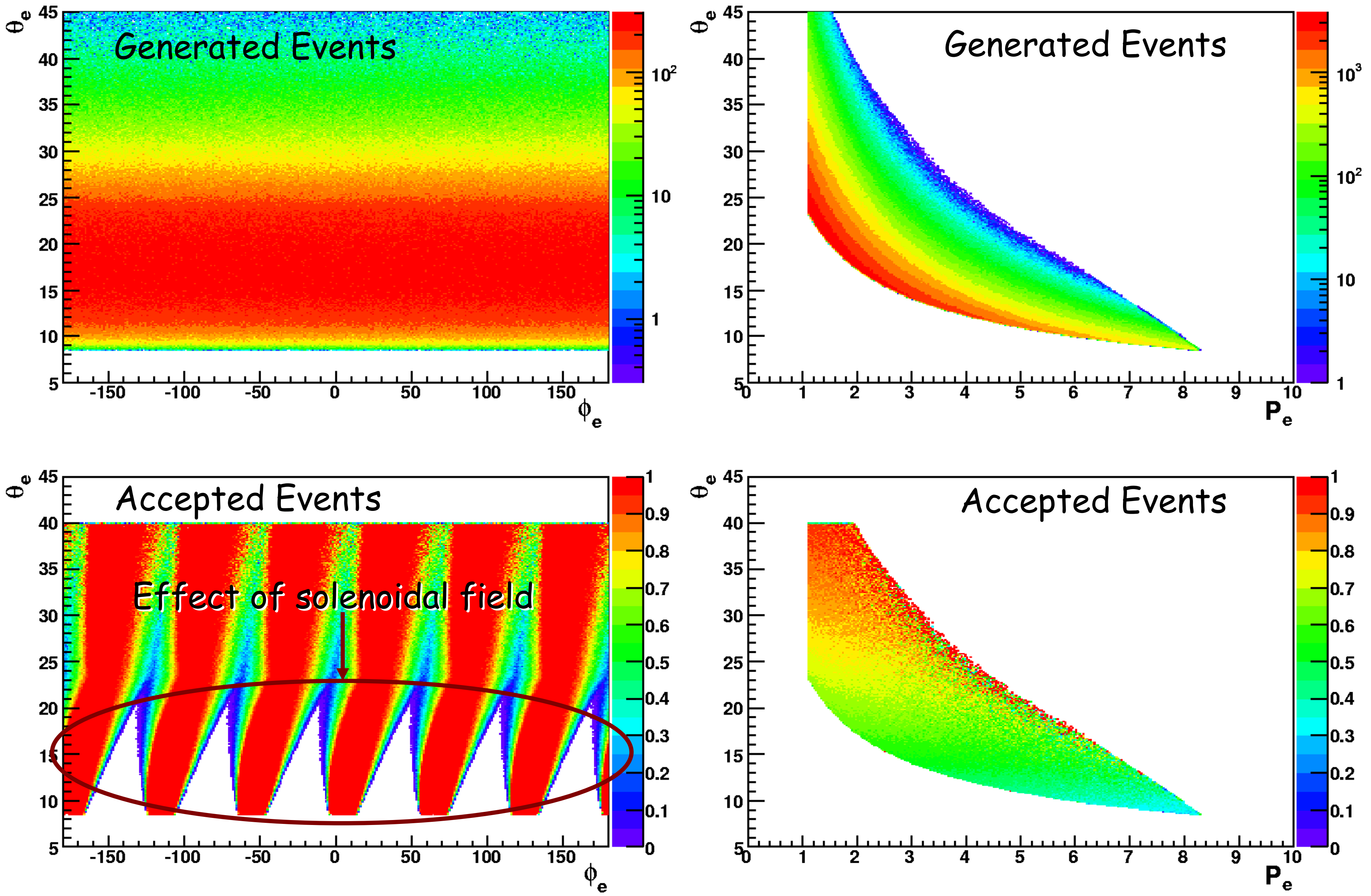
Front View



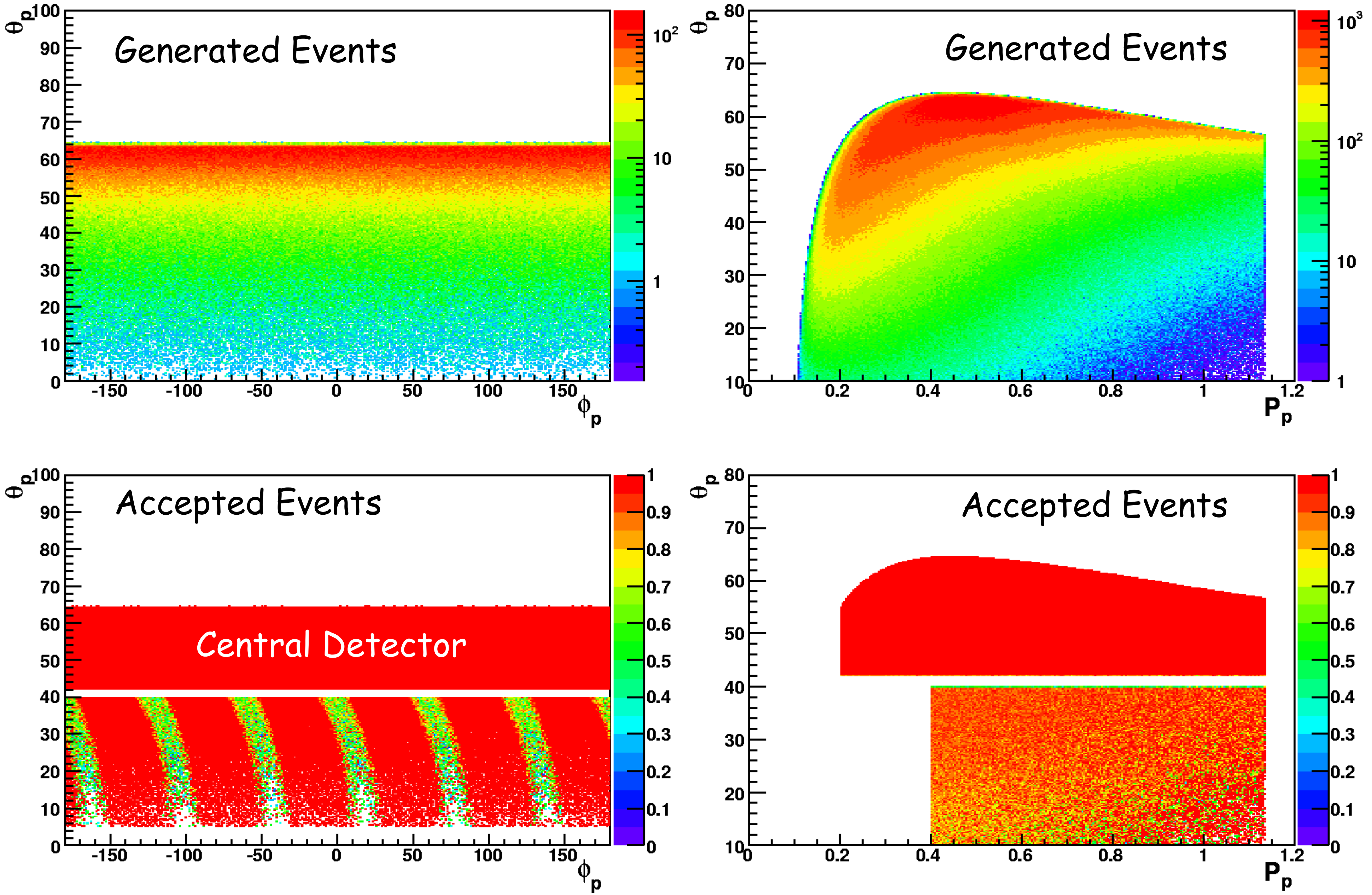
Laser calibration method used to check relative gain stability

Slight gain decrease of blocks closest to the beam line.

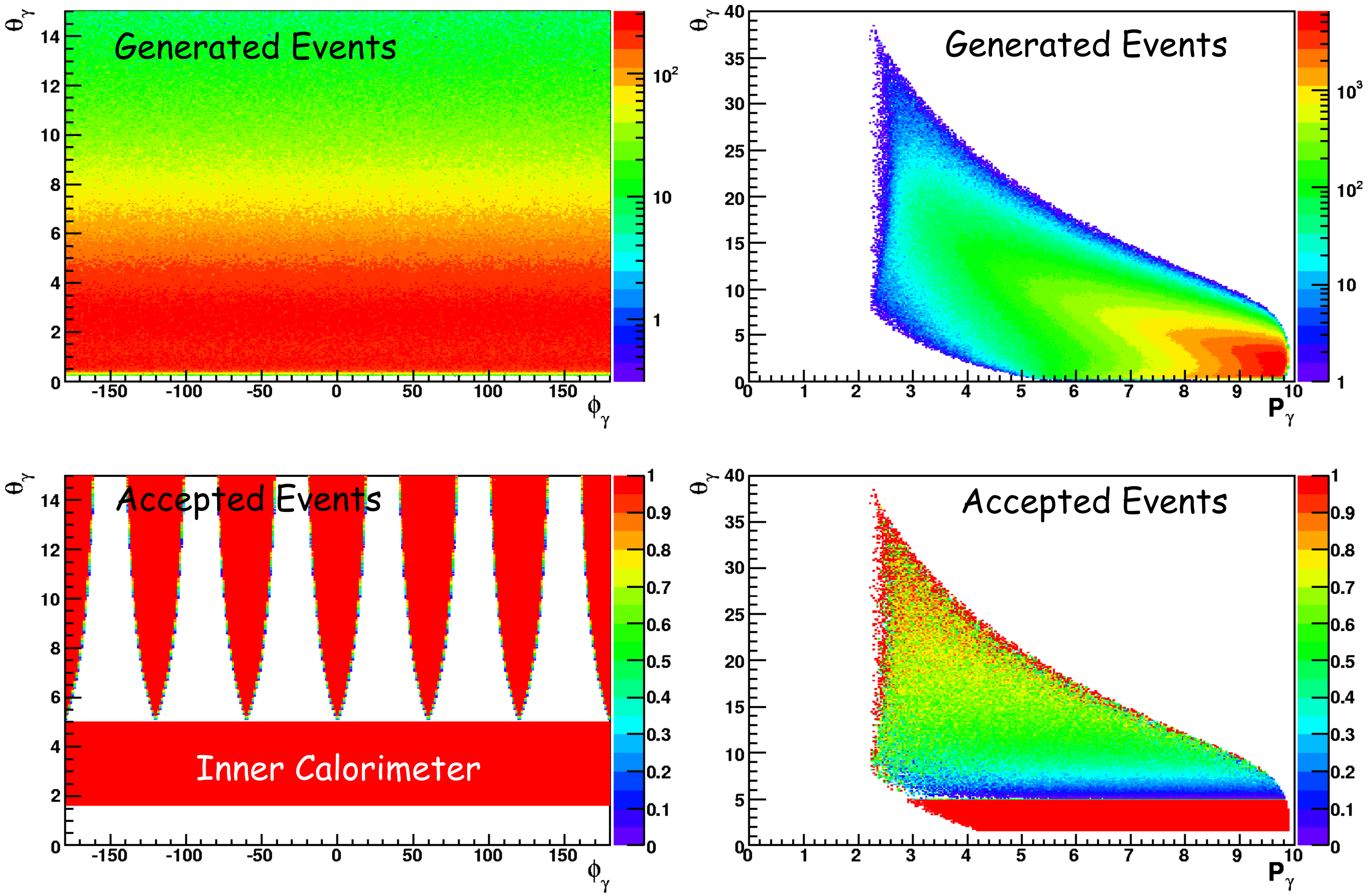
Electron acceptance for DVCS



Proton acceptance for DVCS



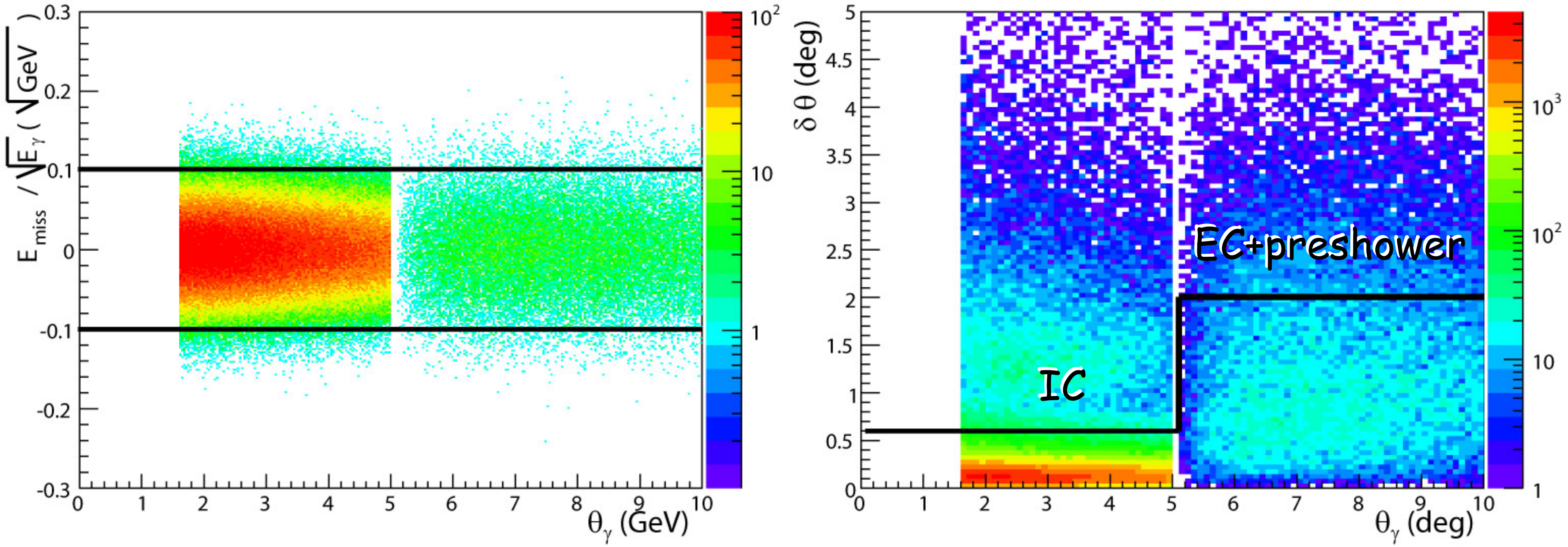
Photon acceptance for DVCS



Selection of events - exclusivity

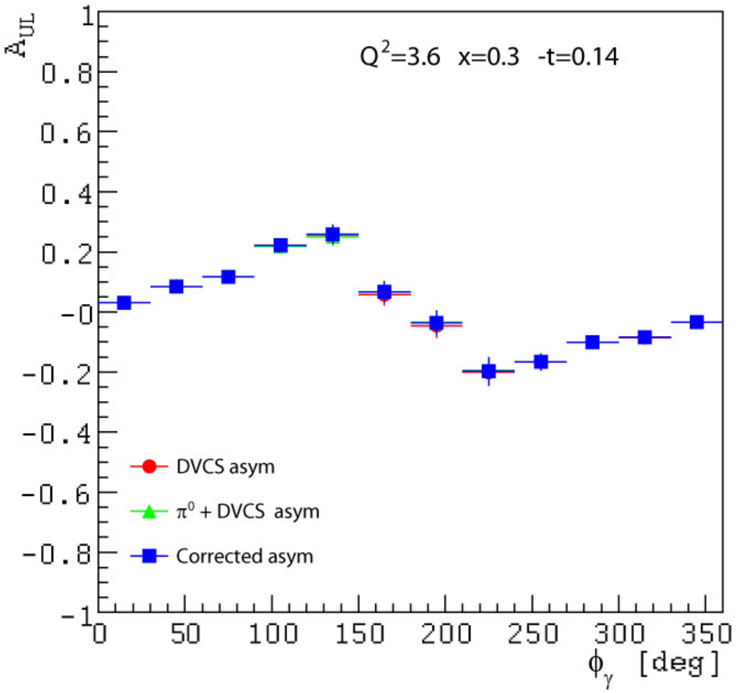
Clean exclusive (e,p,γ) final state is selected the usual way.

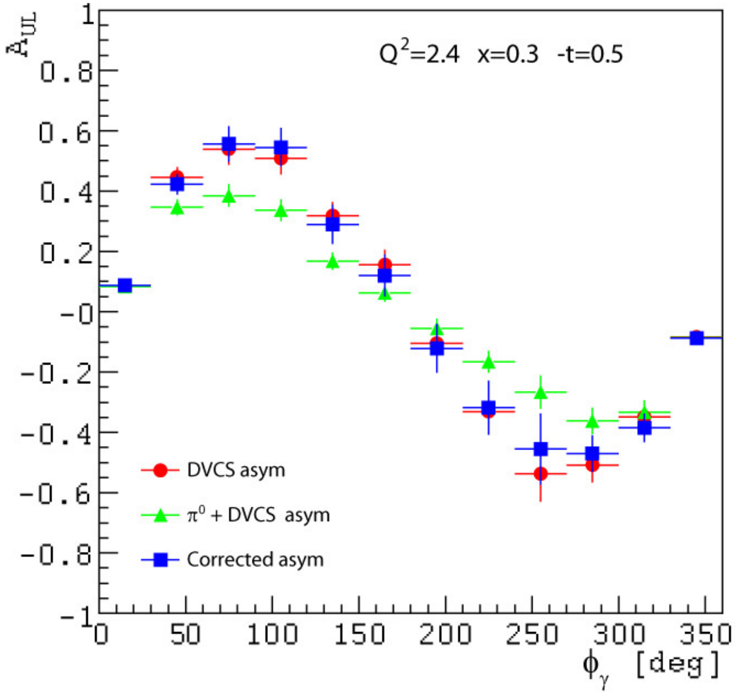
The remaining contribution comes from π° electroproduction asymetric decays (only 1 photon detected), which can be reduced by performing cuts on Emiss and $\delta\theta$, the angle between the expected and measured photons.



Reduction in pion contamination by up to a factor 10 !

π^o subtraction: removing the remaining contribution





<u>π^0 subtraction relies on:</u>

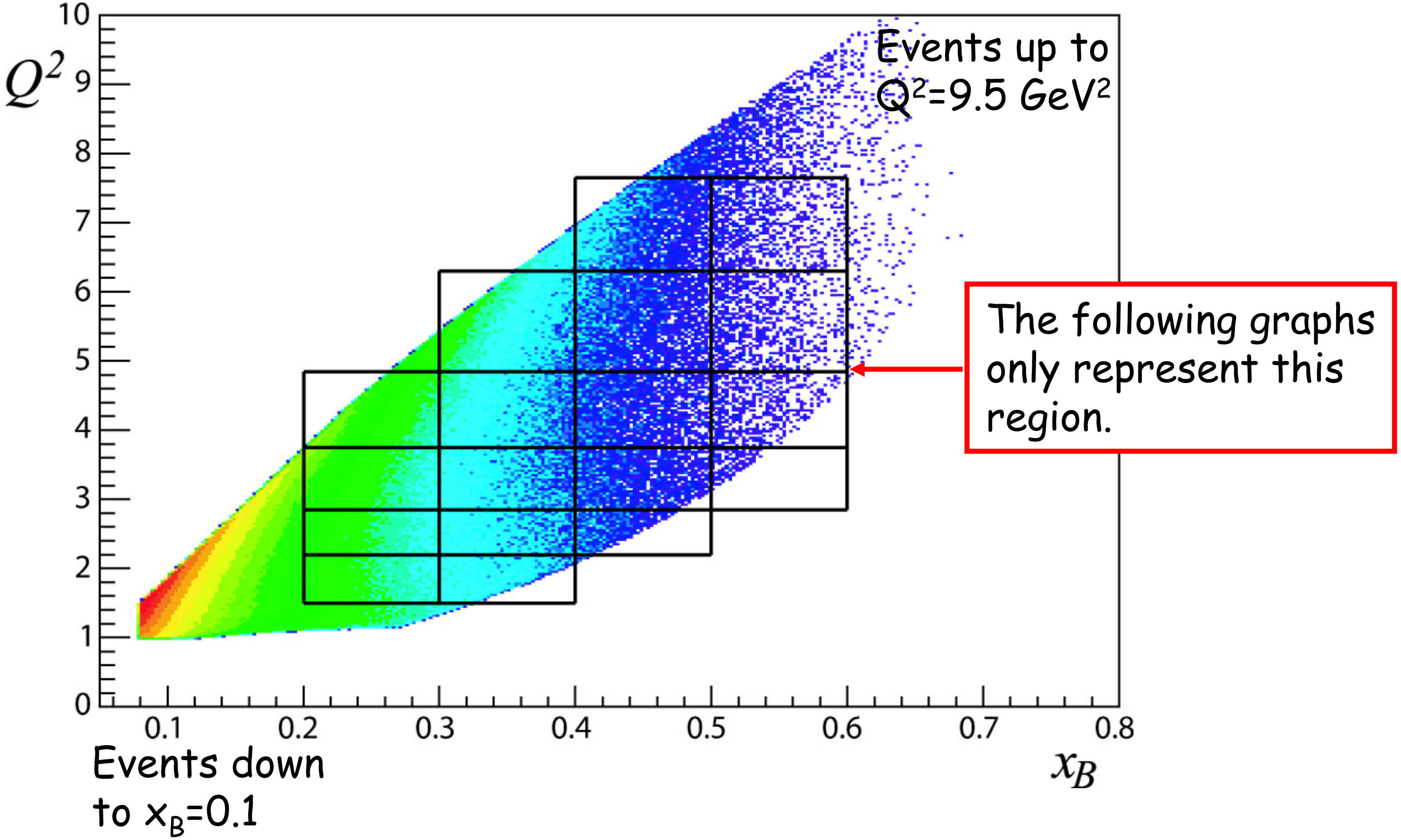
-Determination of 1-γ to 2-γ photon acceptance ratio from Monte-Carlo

-Measurement of π^0 yield (2-γ detected) and asymmetry

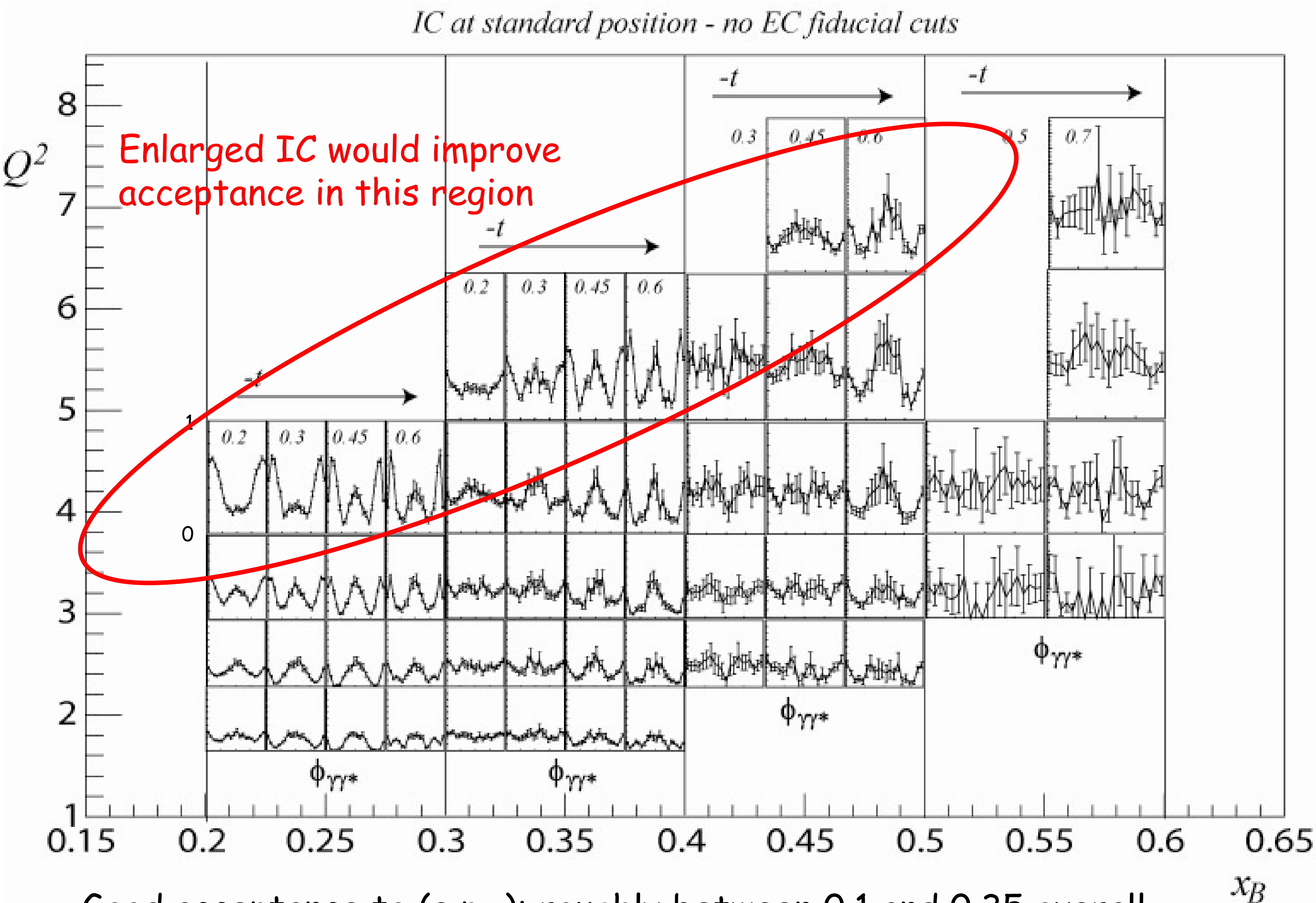
[Method already used for analysis of EG1 data (PRL 97, 072002 (2006))]

Study by. A. Biselli

Statistical error bar estimates – Arbitrary binning choice



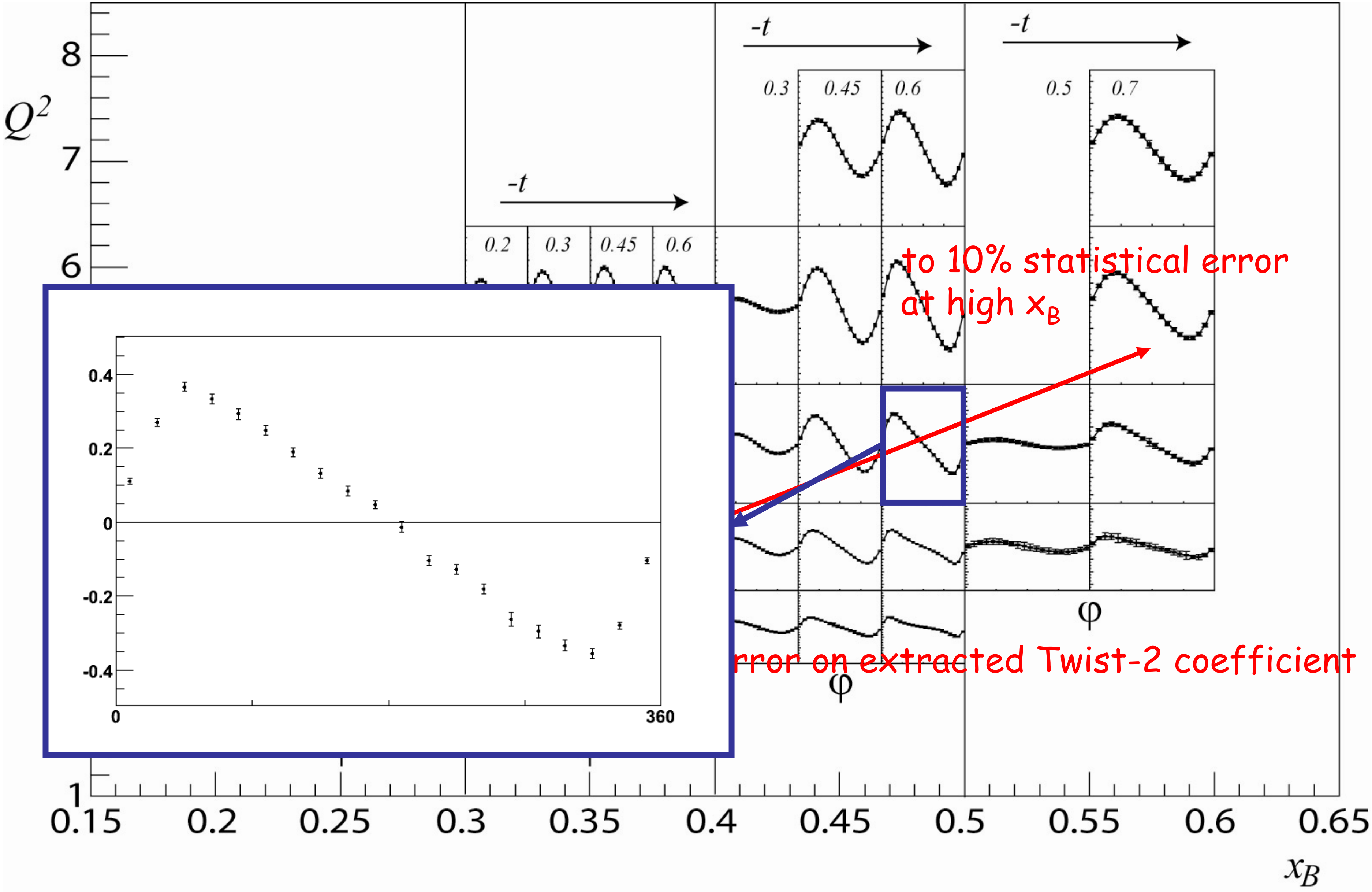
Acceptance for DVCS events in (x,Q^2,t)



Good acceptance to (e,p,γ): roughly between 0.1 and 0.35 overall

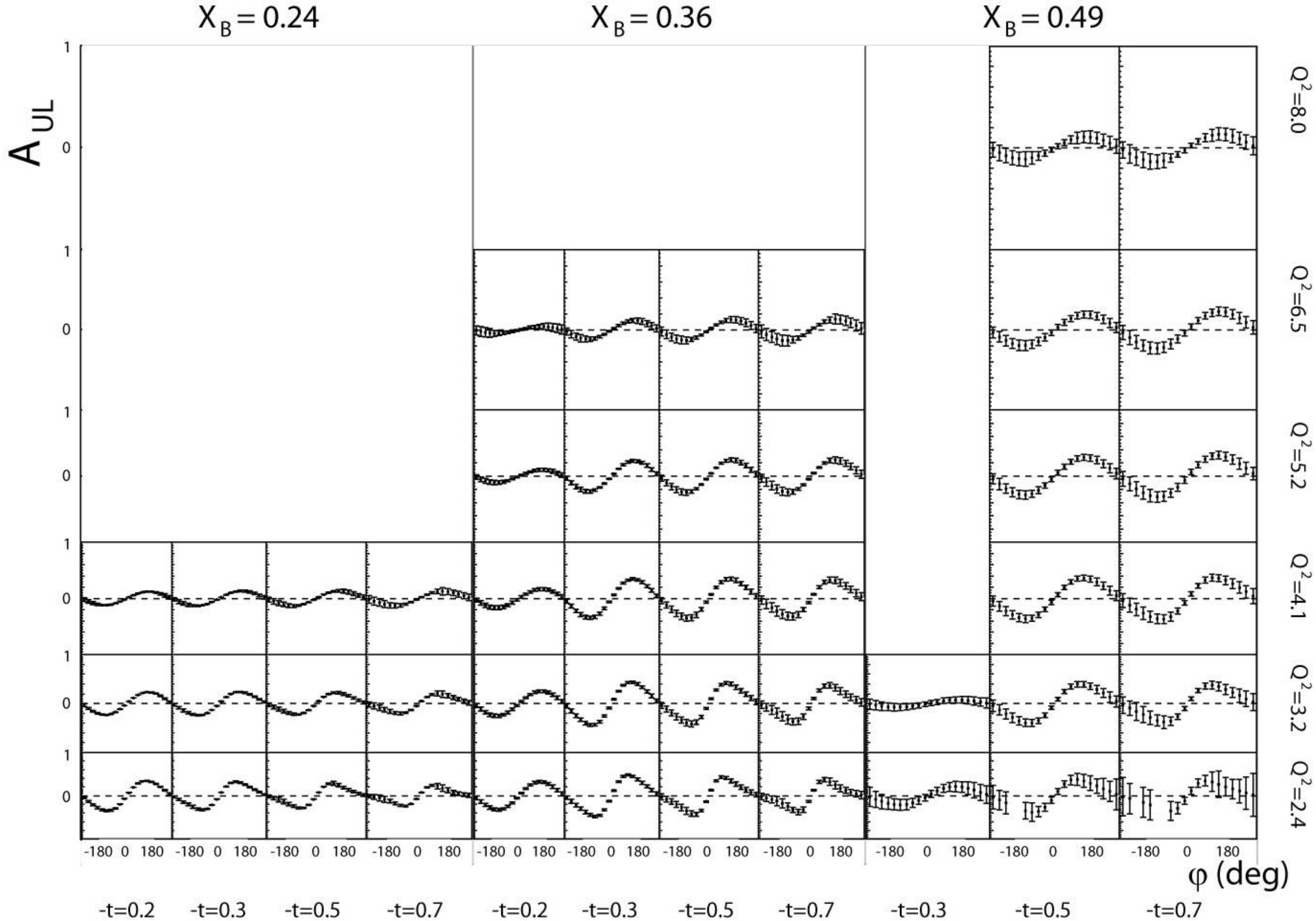
Beam Spin Asymmetry

*IC in standard position - **80 days** - 10^35 Lum - VGG model*



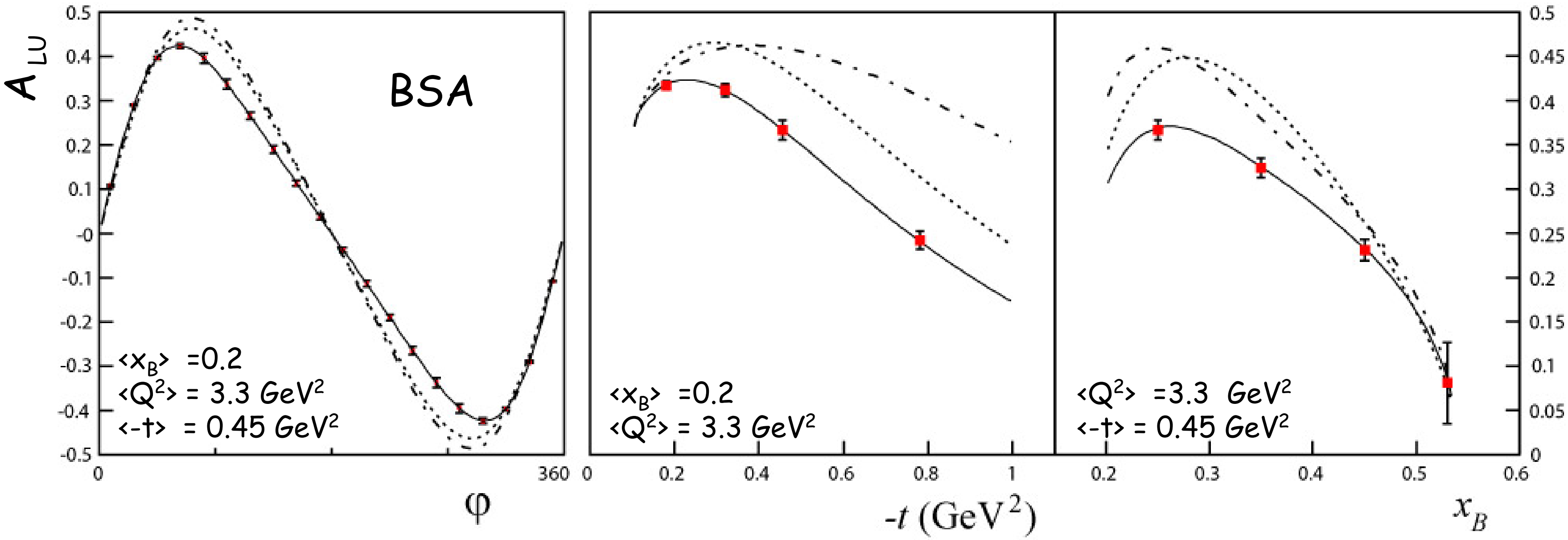
Target Spin Asymmetry

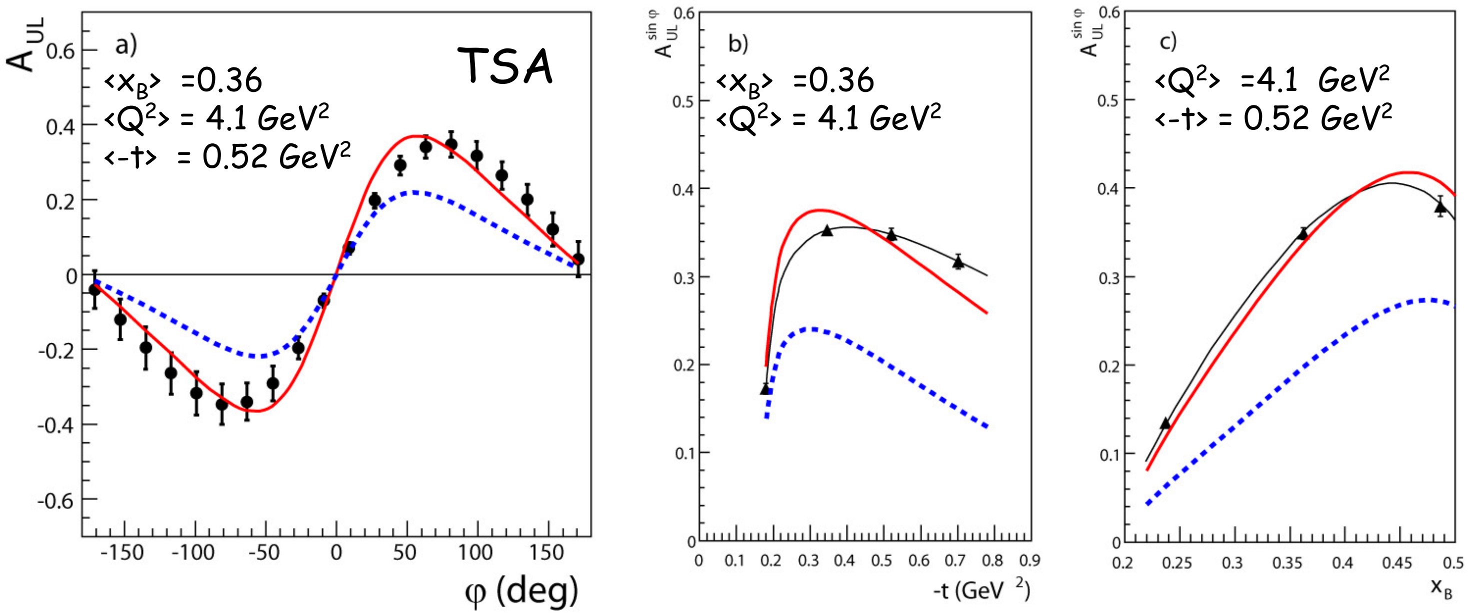
*IC in standard position – **200 days** – 2x10^35 Lum – VGG model*



Study by H. Egiyan

Sensitivity to GPD models – sample of data points





Systematic Errors (all relative)

Unpolarized Target

Source	BSA	$\Delta\sigma$	σ
Luminosity	-	2%	2%
Pe determination	2%	2%	-
π° contamination	1%-5%	1%-5%	3-8%
Acceptance	3%	8%	8%
Radiative Corr.	1%	3%	3%
Total	4%-7%	9%-10%	8%-12%

Polarized Target

Source	TSA
Nuclear Material	4%
Pt determination	3%
π° contamination	1%-5%
Acceptance	3%
Accidentals	1%
Radiative Corr.	1%
Total	6%-8%

Summary

- Deeply Virtual Compton Scattering remains the best understood tool in order to access GPDs at moderate energies.

- Beam and Target spin asymmetries will allow access to observables linked to GPDs (different kinds and combinations).

- Experimentally, the previous analysis have proven the feasibility of these type of experiments. The potential issue of radiation damage to the IC is under control with proper shielding.

- An essential aspect of the GPD study for 12 GeV is to collect a large statistical sample in order to give constraints on GPD parametrizations. Precision data is the key to the understanding of the nucleon structure with this study.