LEX results for VCS below threshold at JLab

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Virtual Compton Scattering :
JLab Experiment E93-050

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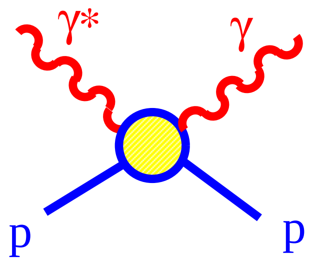
Results of data analysis below Pion Threshold
using the Low Energy Theorem



Trento/ECT, March 31 - April 4, 2003

The JLab VCS Experiment E93050 :

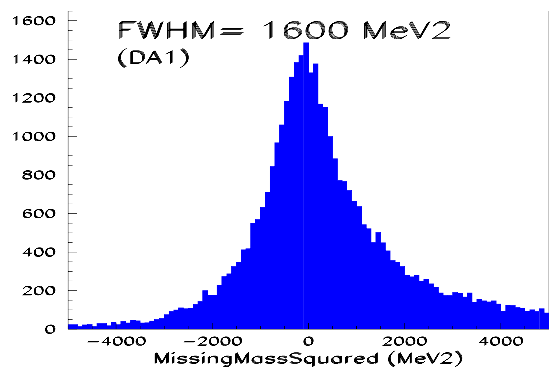
- **Study** $ep \rightarrow ep\gamma$ **in order to extract information on the Generalized Polarizabilities of the proton**
- **One of the commissioning experiments in Hall A (1998)**
- **two High Resolution Spectrometers to detect final** e **and** p
 γ **not detected, but reconstructed as the missing particle**
- **Kinematic range :**

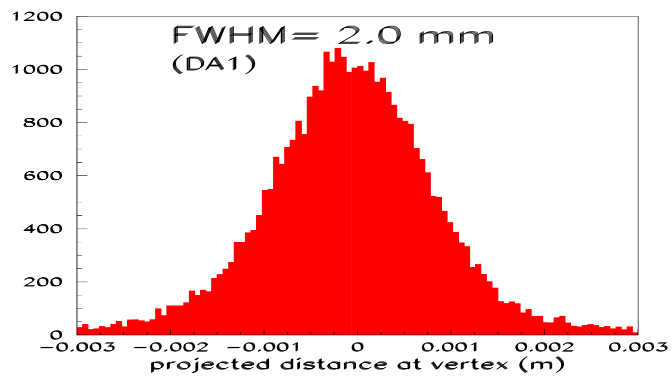
DA1 dataset	RES. dataset	DA2 dataset
$< Q^2 >= 1.0$ GeV^2	$< Q^2 >= 1.0$ GeV^2	$< Q^2 >= 1.9$ GeV^2
$\sim$ below π threshold $W = \sqrt{s_{\gamma^* p}} \leq (m_N + m_\pi)$	resonance region W = 1.2 to 1.9 GeV	$\sim$ below π threshold $W = \sqrt{s_{\gamma^* p}} \leq (m_N + m_\pi)$

To extract Generalized Polarizabilities :

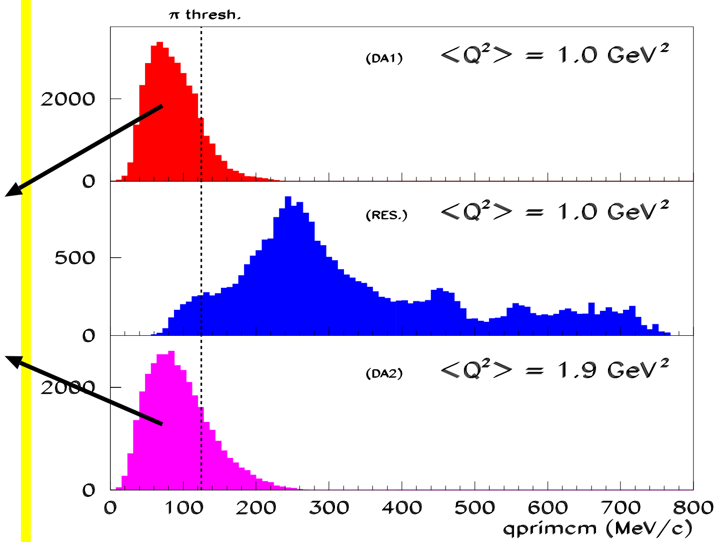
- **need accurate measurement of absolute cross sections** $d^5\sigma(ep\gamma)$
  (effect of GPs is small below π threshold: 0-15 %)
- **accurate Monte-Carlo simulation :** *(L.Van Hoorebeke, gent Univ.)*
  - **realistic input cross section**
  - **resolution and acceptance effects**
  - **radiative effects**
- **careful study of cuts (punchthrough protons)**
- **optimized experimental resolution**

(example: Beam energy = nominal - 12 MeV)





Datasets and Analysis methods



analysis based on the LET (P.Guichon et al.)

VCS Structure functions

PII-Ptt/epsilon and PIt

at a given Q2 and epsilon

analysis based on DR Model (B.Pasquini et al.)

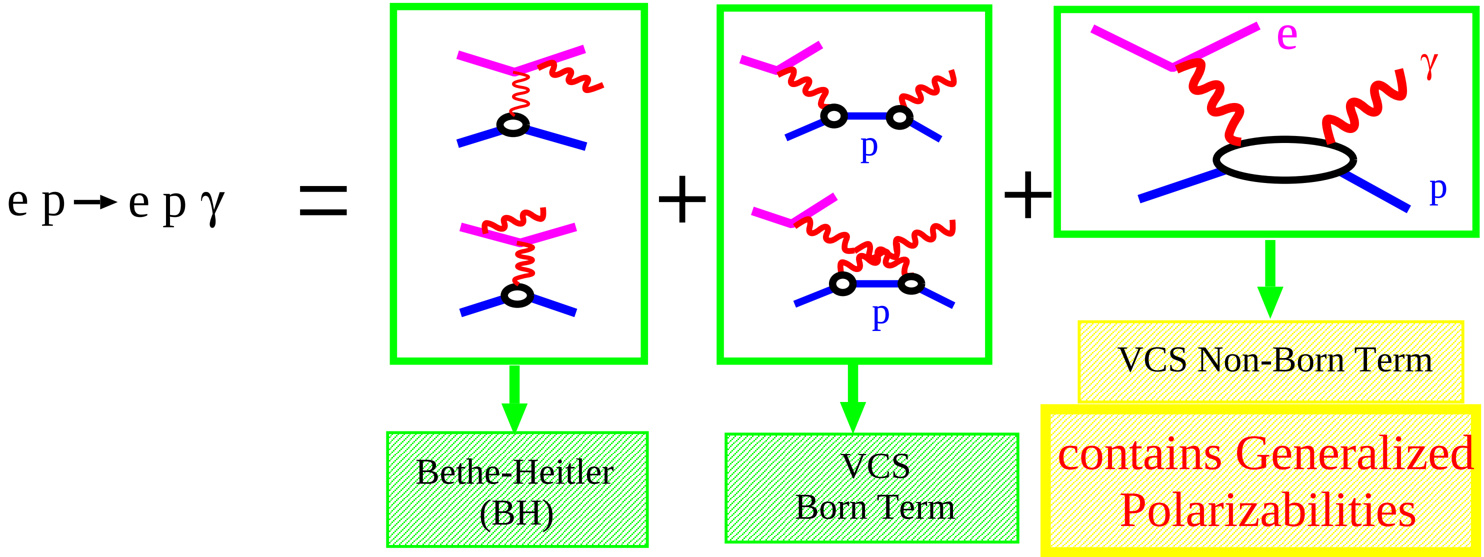
Λ_β , Λ_α parameters

PII, Ptt, PIt structure funct. at a given Q2

PII-Ptt/epsilon and PIt at a given Q2 and epsilon

Formalism

At the amplitude level:



At the cross section level, below pion Threshold:

$$d^5\sigma(ep\gamma) = d^5\sigma(\textbf{BH+Born}) + (\textbf{PhaseSpace Factor}) \times \left([\ \ldots\ ] + O(q'_{cm}) \right)$$

$$[\ \ldots\ ] = v_1 \left[P_{LL}(q_{cm}) - \frac{1}{\epsilon} P_{TT}(q_{cm}) \right] + v_2 \left[P_{LT}(q_{cm}) \right]$$

Low Energy Theorem: P.Guichon et al., Nucl.Phys. A591 (1995) 606.

Principle of extraction of GPs

- measure unpolarized cross sections $d^5\sigma(ep \to ep\gamma)$
  at fixed q_{cm} and fixed ϵ below pion threshold
  in the widest possible range in $(\theta_{\gamma\gamma CM}, \phi_{\gamma\gamma CM})$.

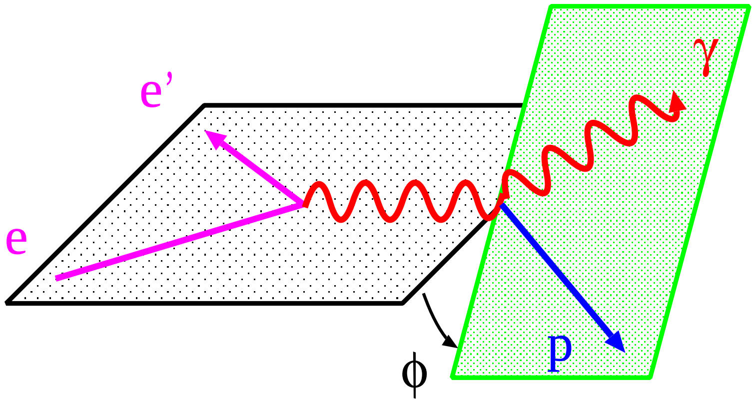
- fit $\Delta M = \frac{d^5\sigma_{measured} - d^5\sigma_{BetheHeitler+Born}}{PhaseSpaceFactor}$ as a linear function
  of the two free parameters: $P_{LL} - \frac{1}{\epsilon}P_{TT}$ and P_{LT}

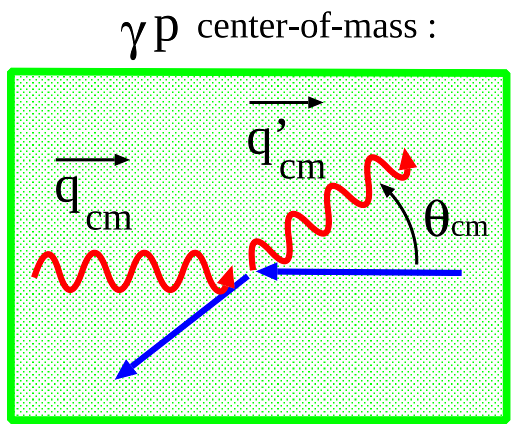
They are combinations of six independent Generalized Polarizabilities of the proton.

$$P_{LL} - \frac{1}{\epsilon}P_{TT} = (\ldots) \ \alpha_E(Q^2) + \text{spin GPs}$$
$$P_{LT} = (\ldots) \ \beta_M(Q^2) + \text{spin GPs}$$

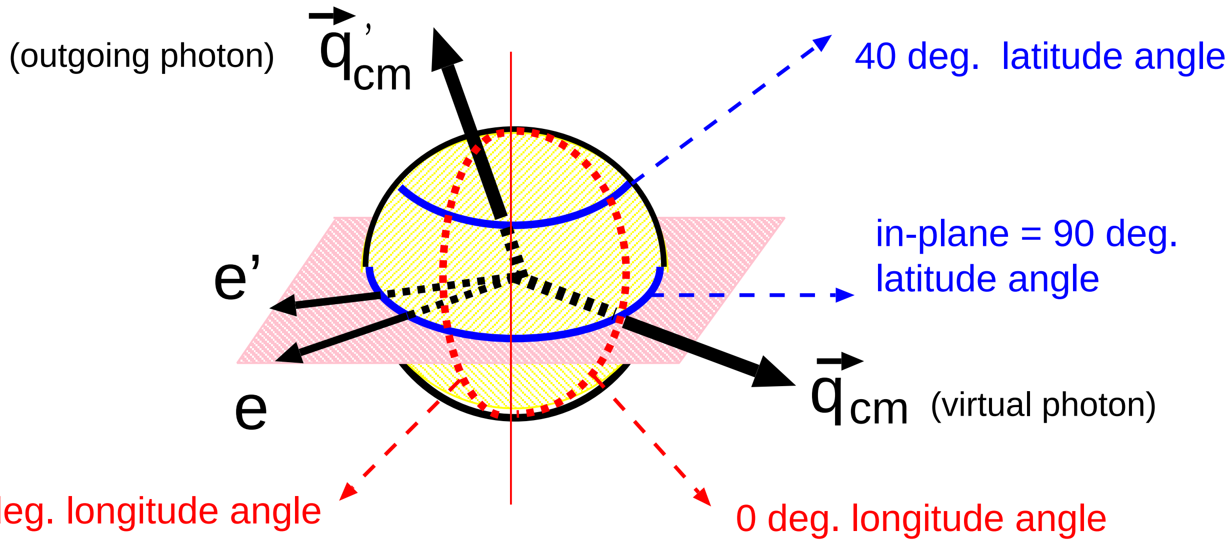
- Choice of proton EM F.F. entering the (BetheHeitler + Born)
  cross section: JLab measurements, E.Brash et al, hep-ex/0111038

VCS Kinematics





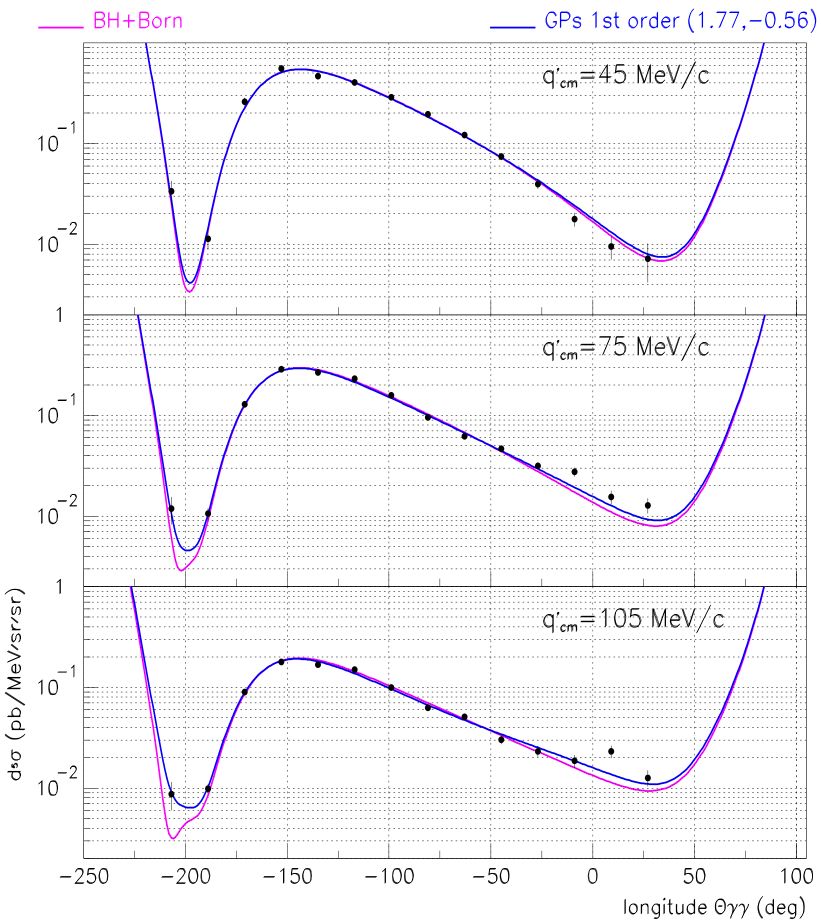
In (γp) center-of-mass: instead of CM angles, polar $\theta_{\gamma\gamma CM}$ and azimuthal $\phi_{\gamma\gamma CM}$, we use longitude angle θ_{INP} and latitude angle θ_{OOP} :



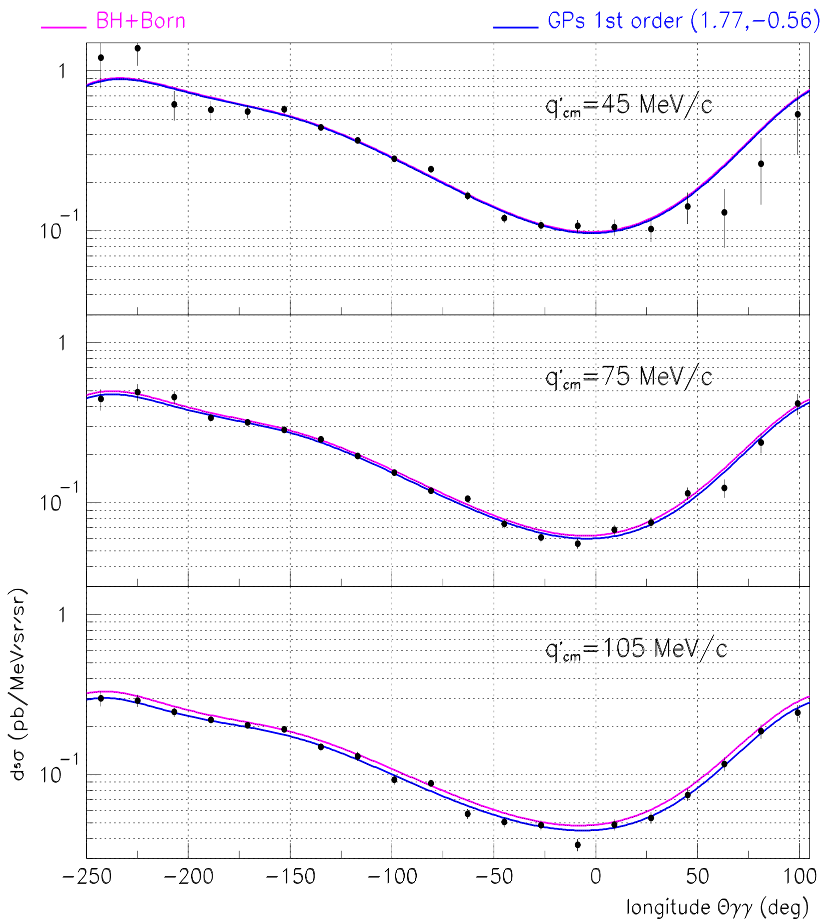
$(ep \to ep\gamma)$ Cross sections. Dataset at $< Q^2 > = 1.0$ GeV^2

$Q^2 = 0.923$ **GeV^2**, $q_{cm} = 1080$ **MeV**, $\epsilon = 0.950$

LEPTON PLANE



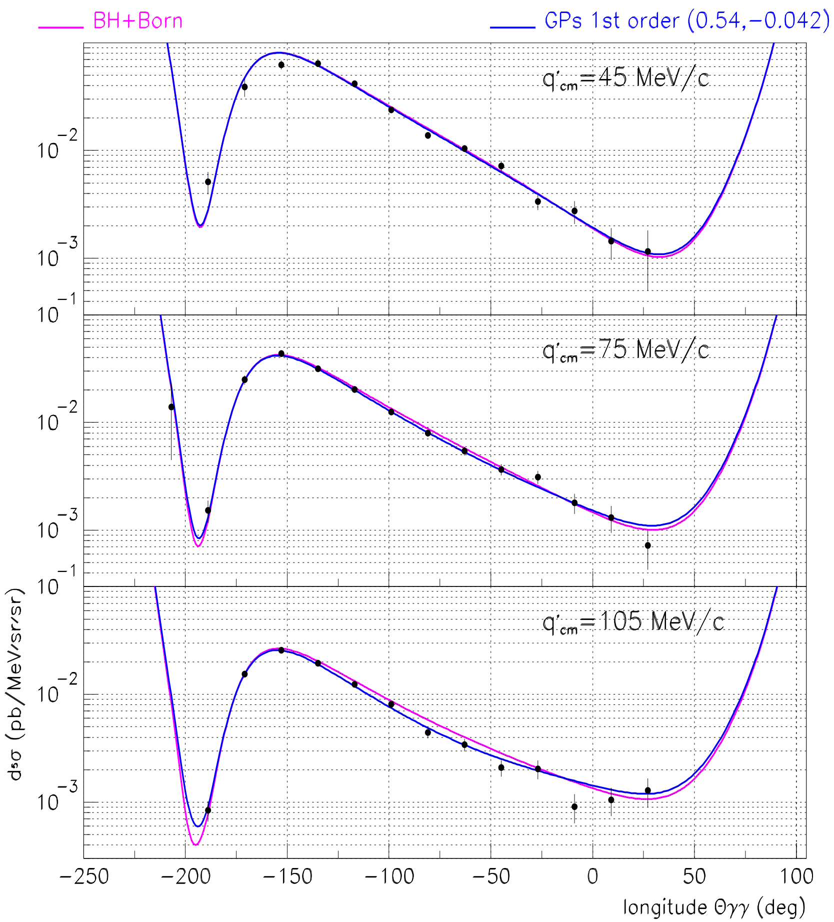
40° OUT-OF-PLANE



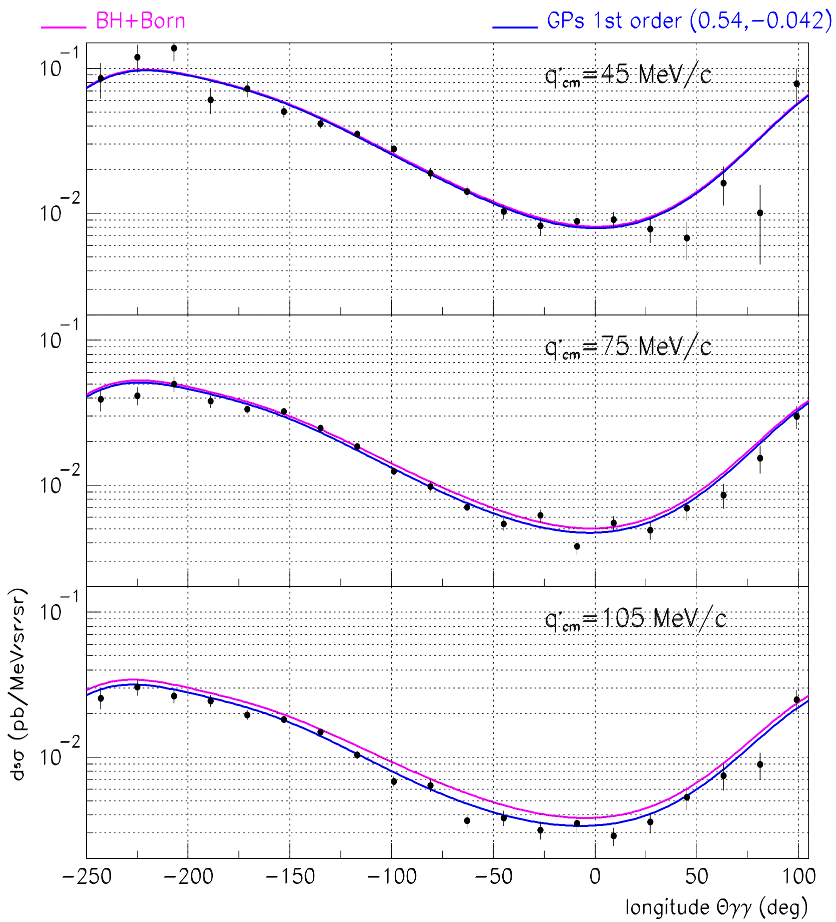
$(ep \to ep\gamma)$ Cross sections. Dataset at $< Q^2 >$ = 1.9 GeV^2

$Q^2 = 1.76$ **GeV^2**, $q_{cm} = 1625$ **MeV**, $\epsilon = 0.879$

LEPTON PLANE



40° OUT-OF-PLANE



absolute normalization

- **To obtain absolute cross sections, exp. rates are corrected for:**

  - luminosity (beam charge + target density)
  - inefficiencies and dead times (acquisition, electronics, scintillators, ...)
  - radiative effects not in the Monte-Carlo (constant part)
  - ...

  $\rightarrow$ **global uncertainty = $\pm$ 2-3 %**

- **How to test the absolute normalization:**

at the lowest value of q'_{cm} we compare ($d^5\sigma_{EXP} \times F$) with (BetheHeitler + Born + GPs 1st order), **where the GP effect is the smallest ($\sim$ 2 %). $\Rightarrow F$ given by a χ^2 minimization.**

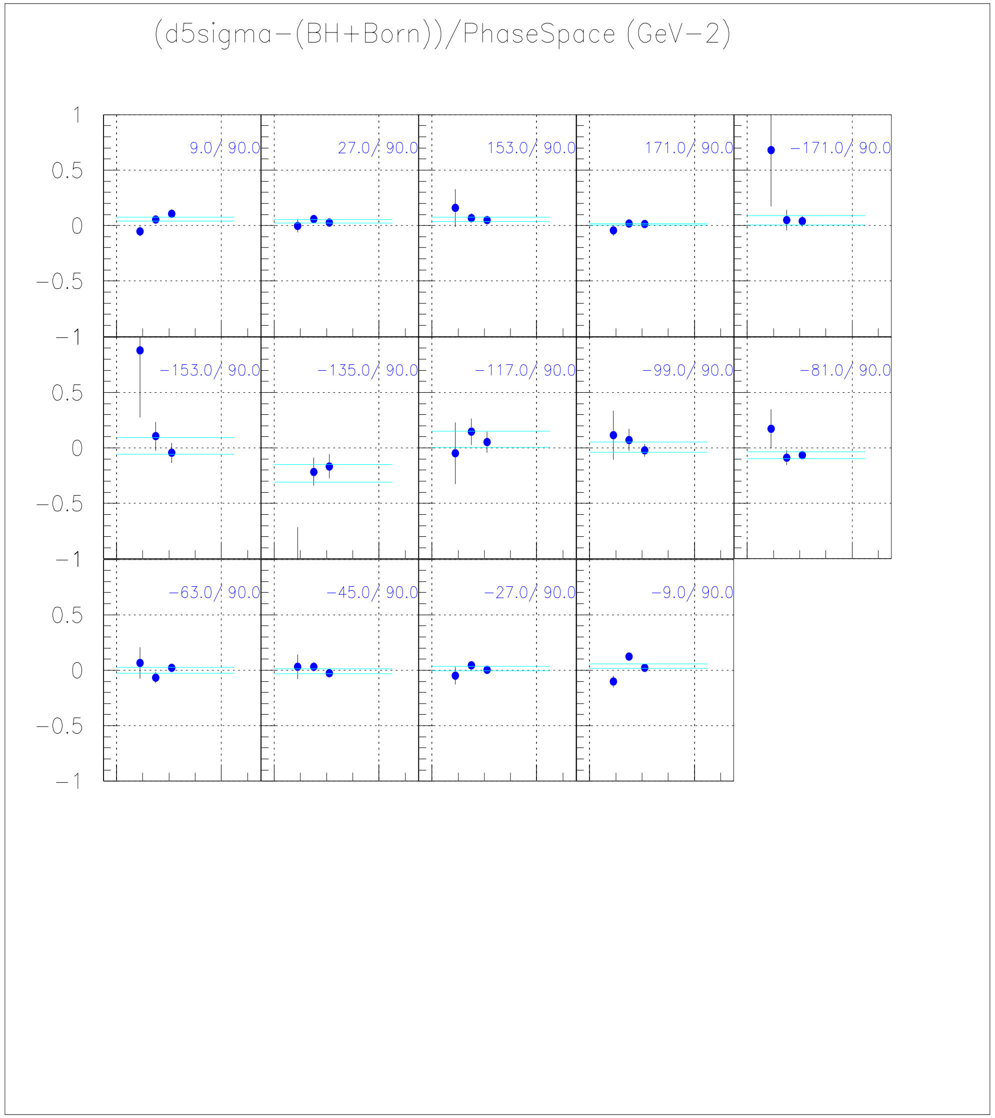
All analyses give F in the range: 0.995 to 1.015 (i.e. agreement with *BH+Born* to better than $\pm$ 2 %).

- **we renormalize $d^5\sigma_{EXP}$ by F.**

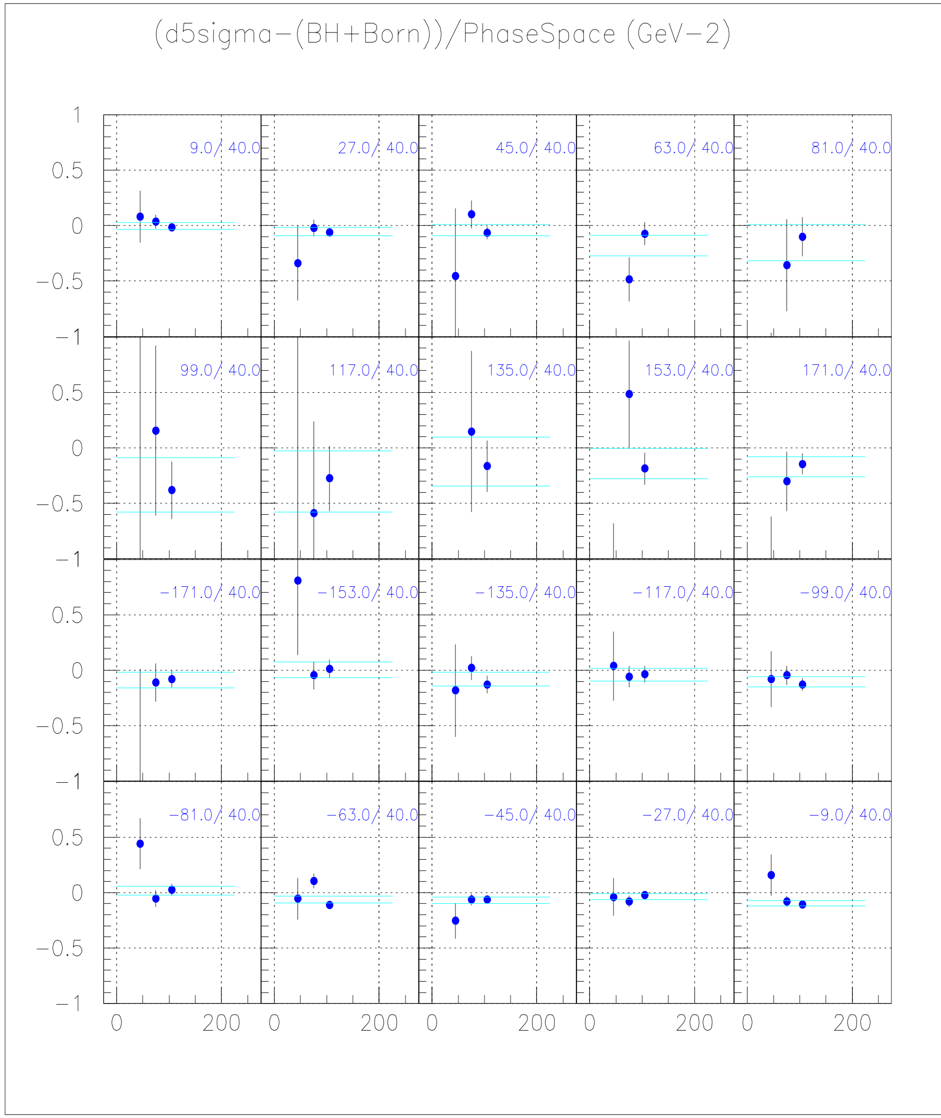
- **the $\sim$ 2-3 % syst.error due to absolute normalization can also be seen as the uncertainty on the (BH+Born) cross section, due to the knowledge of proton EM Form factors ($\sim$ 1-1.5 % in the Brash parametrization).**

q'_{cm} - dependence. Dataset at $< Q^2 >$ = 1.0 GeV^2

LEPTON PLANE

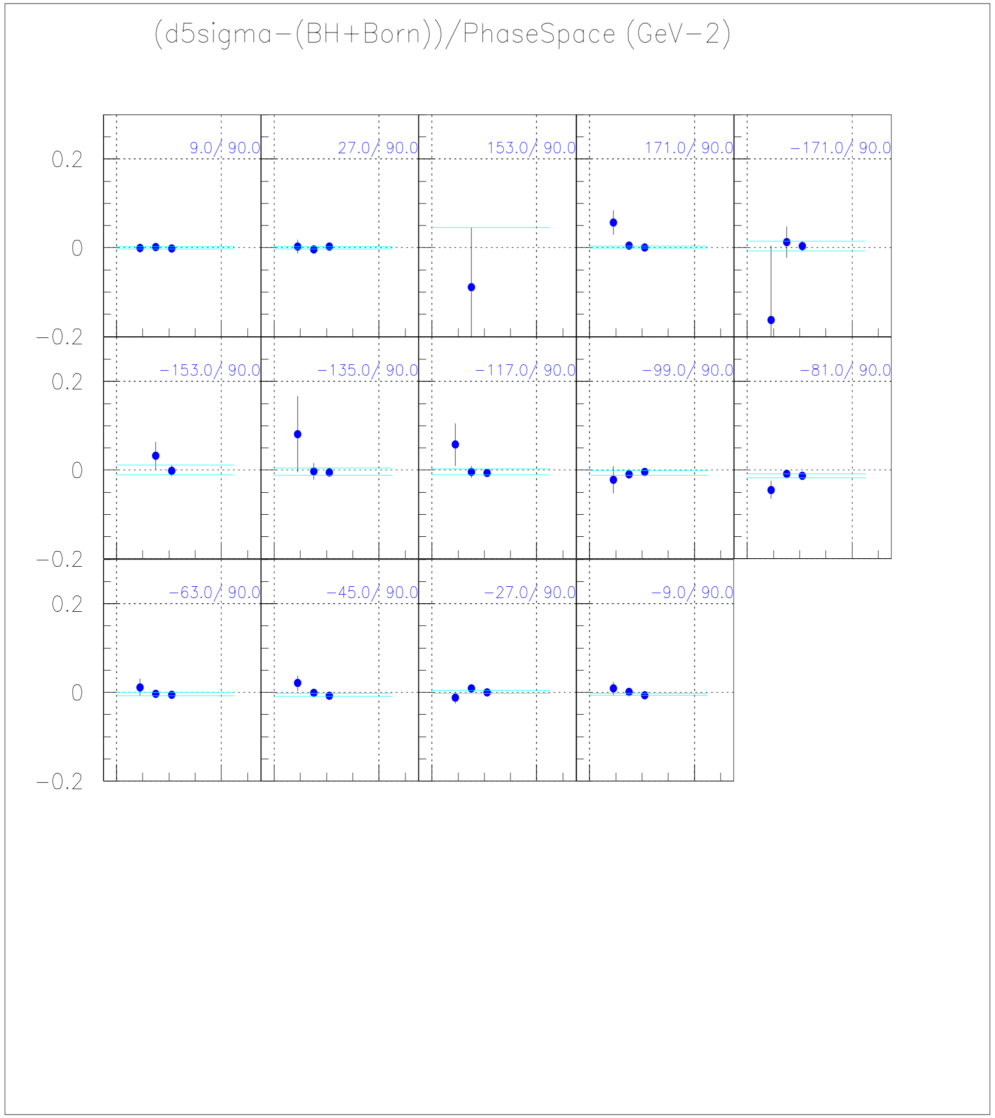


40° OUT-OF-PLANE

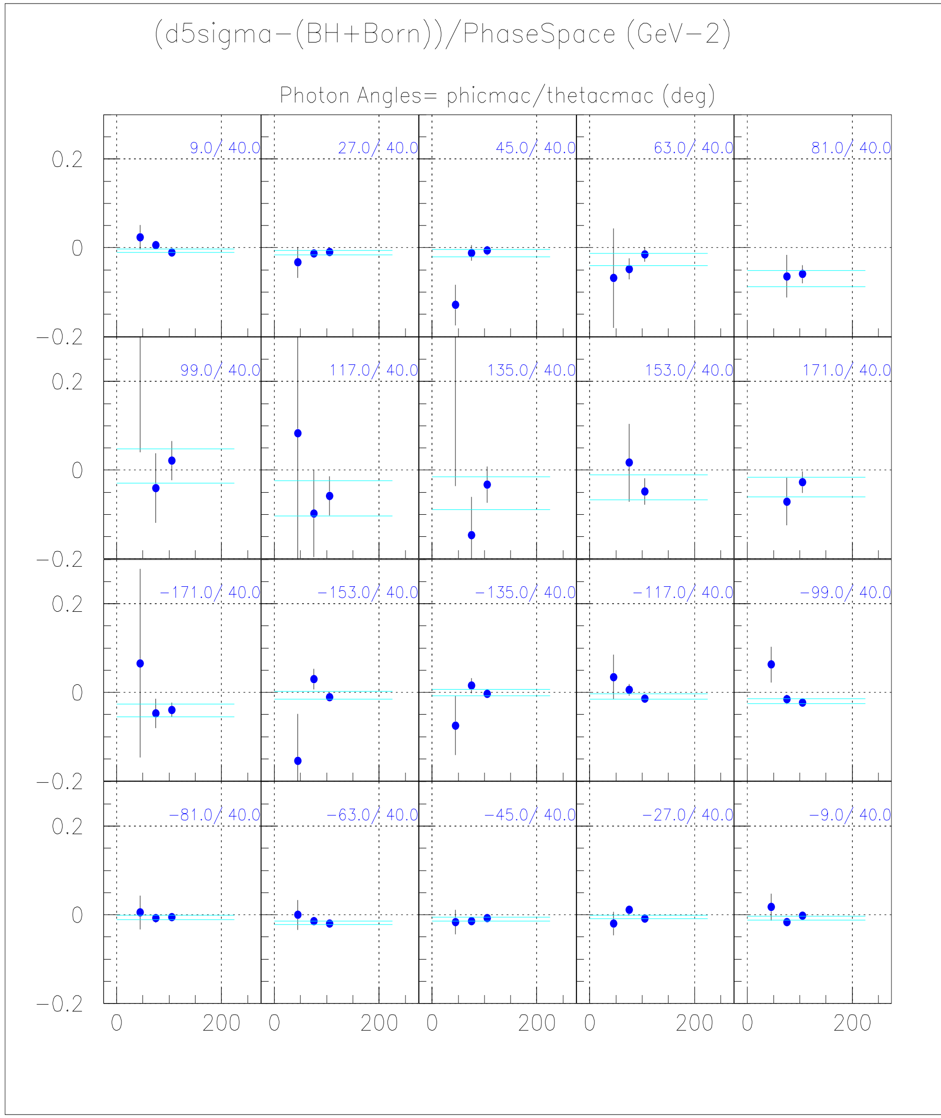


q'_{cm} - dependence. Dataset at $< Q^2 > = 1.9$ GeV^2

LEPTON PLANE

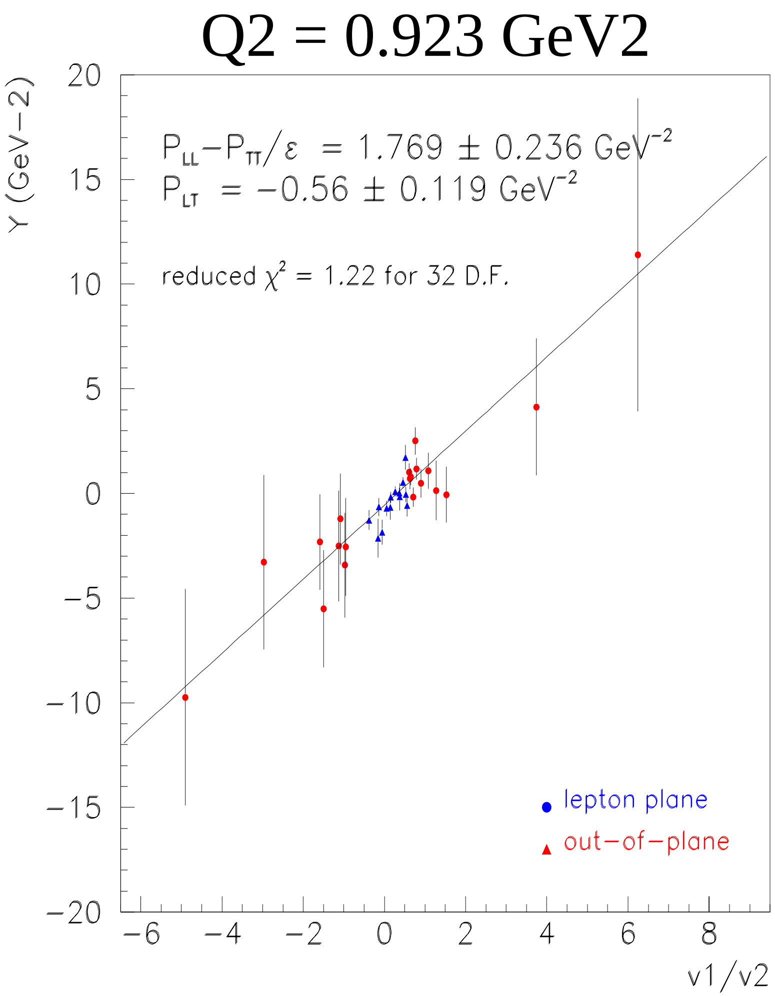


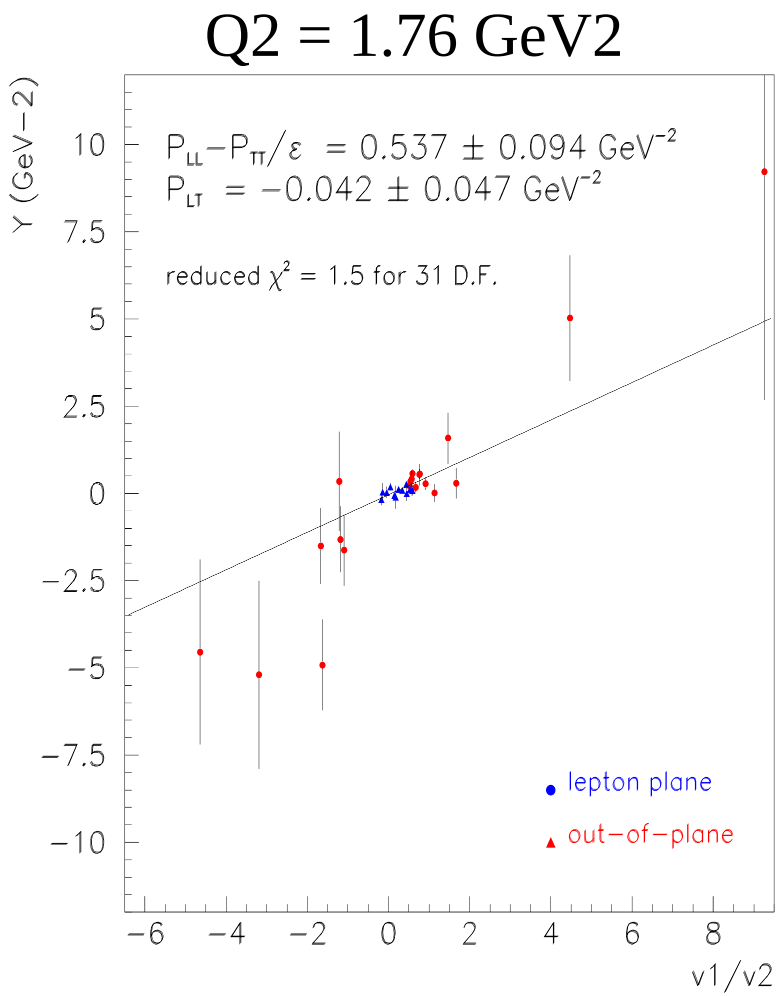
40° OUT-OF-PLANE



Polarizability fit

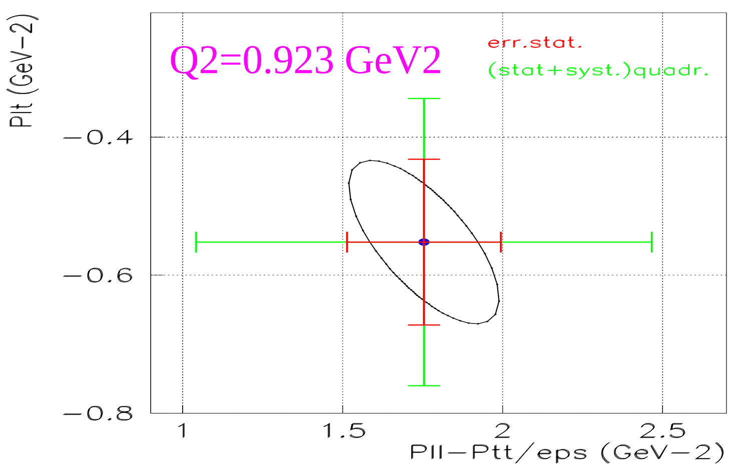
in ordinate : $Y = (d\sigma_{EXP} - d\sigma_{BHB})/\textbf{PhaseSpaceFactor}\,/v_2 \;=\; P_{LT} + \frac{v_1}{v_2}(P_{LL} - P_{TT}/\epsilon)$

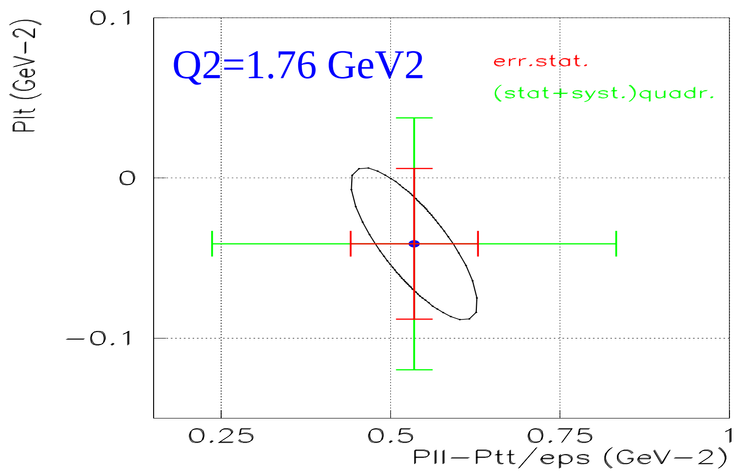




Error bars and results

	$P_{LL} - \frac{1}{\epsilon}P_{TT}$ (GeV^{-2})		P_{LT} (GeV^{-2})	
SYST.ERR.	$Q^2 = 0.923$ GeV^2	$Q^2 = 1.76$ GeV^2	$Q^2 = 0.923$ GeV^2	$Q^2 = 1.76$ GeV^2
nor. ($\pm$ 3 %)	+0.505 -0.506	+0.142 -0.142	+0.047 -0.047	+0.004 -0.004
E_0 ($\pm$ 2 MeV)	+0.391 -0.354	+0.139 - 0.074	+0.132 -0.024	+0.017 - 0.005
θ_{hrs}($\pm$ 0.5 mr)	+0.283 -0.167	+0.159 -0.283	+0.185 -0.094	+0.090 -0.033 -0.283
sym. + ( )^2	$\pm$ 0.667	$\pm$ 0.283	$\pm$ 0.167	$\pm$ 0.063
RESULT	+1.77 $\pm$ 0.24 (stat) $\pm$ 0.67 (syst)	+0.537 $\pm$ 0.094 (stat) $\pm$ 0.283 (syst)	-0.56 $\pm$ 0.12 (stat) $\pm$ 0.17 (syst)	-0.042 $\pm$ 0.047 (stat) $\pm$ 0.063 (syst)





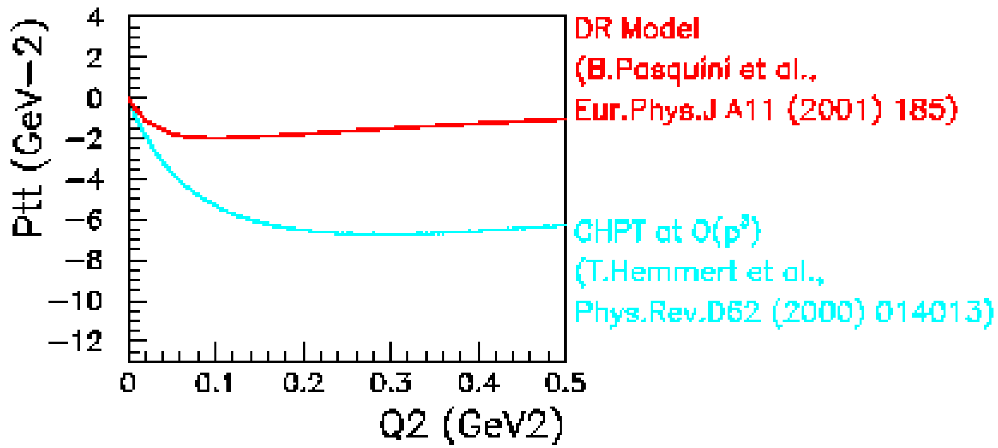
VCS Structure Functions (LEX Results). 1

EXPT	Q^2 (GeV^2)	ϵ	$P_{LL} - \frac{1}{\epsilon}P_{TT}$ (GeV^{-2})	P_{LT} (GeV^{-2})
TAPS (Mainz)	0		81.3 $\pm$ 2.00 $\pm$ 3.36	-5.38 $\pm$ 1.34 $\pm$ 1.90
VCS (Mainz)	0.33	0.62	23.7 $\pm$ 2.2 $\pm$ 4.3	-5.0 $\pm$ 0.8 $\pm$ 1.8
VCS (JLab) (E93050)	0.92	0.95	1.77 $\pm$ 0.24 $\pm$ 0.67	-0.56 $\pm$ 0.12 $\pm$ 0.17
VCS (JLab) (E93050)	1.76	0.88	0.54 $\pm$ 0.09 $\pm$ 0.28	-0.042 $\pm$ 0.047 $\pm$ 0.63

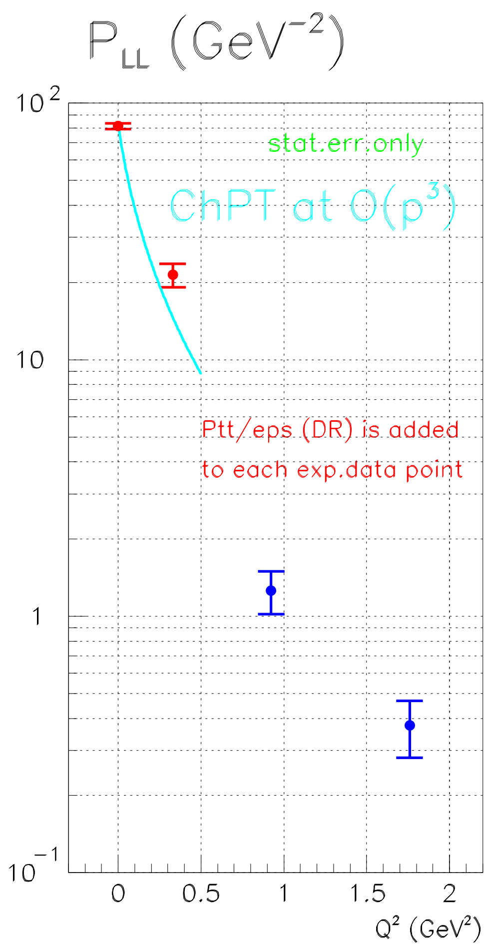
$\downarrow$
different ϵ !
add P_{TT}/ϵ from a model
(see below) & plot $P_{LL}(Q^2)$

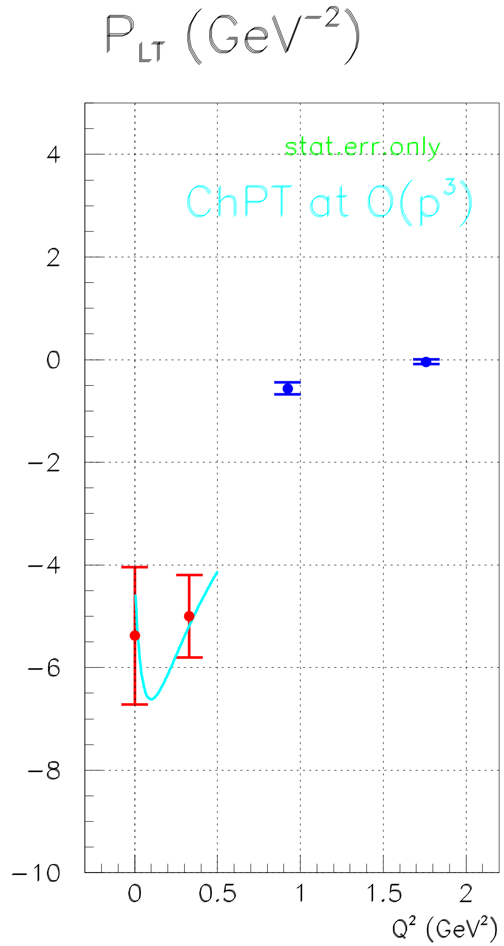
$\downarrow$
ok

plot $P_{LT}(Q^2)$



VCS Structure Functions (LEX Results). 2





proton EM Form factors = parametrization of Brash et al.

exp. point at Q^2=0.00 / (RCS) V.Olmos de Leon et al., Eur.Phys.J.A10 (2001) 207
exp. point at Q^2=0.33 / VCS (Mami) J.Roche et al, Phys.Rev.Lett.85 (2000) 798
exp. point at Q^2=0.92 and 1.76 / VCS JLab E93050 LEX analysis