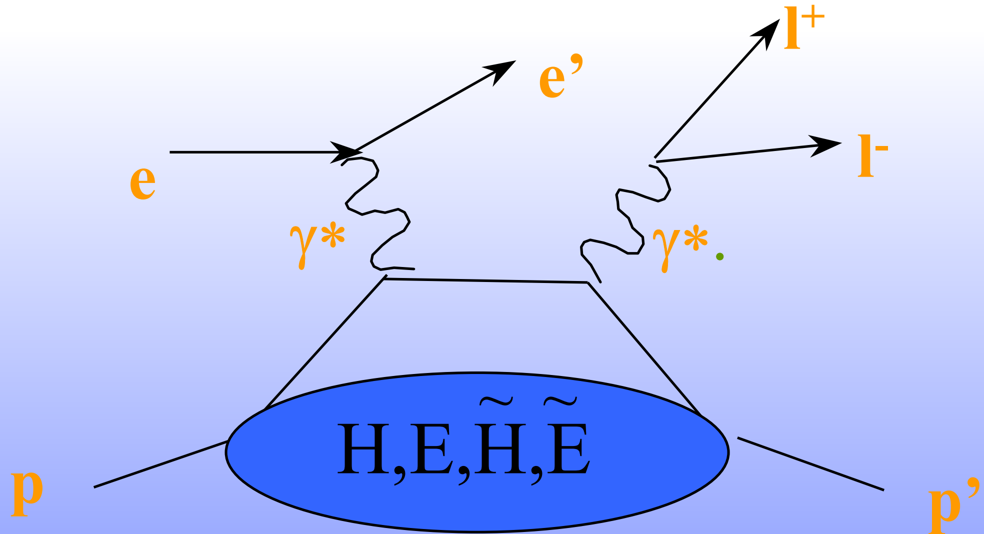
1/ DDVCS

(+ 2/ first study on the (x,t) correlations of the GPDs)



Seattle, 10/07/03

M. Guidal, IPN Orsay

M. G. & M. VdH, PRL 90, 012001 (2003) (also A. Belitsky, D. Mueller)

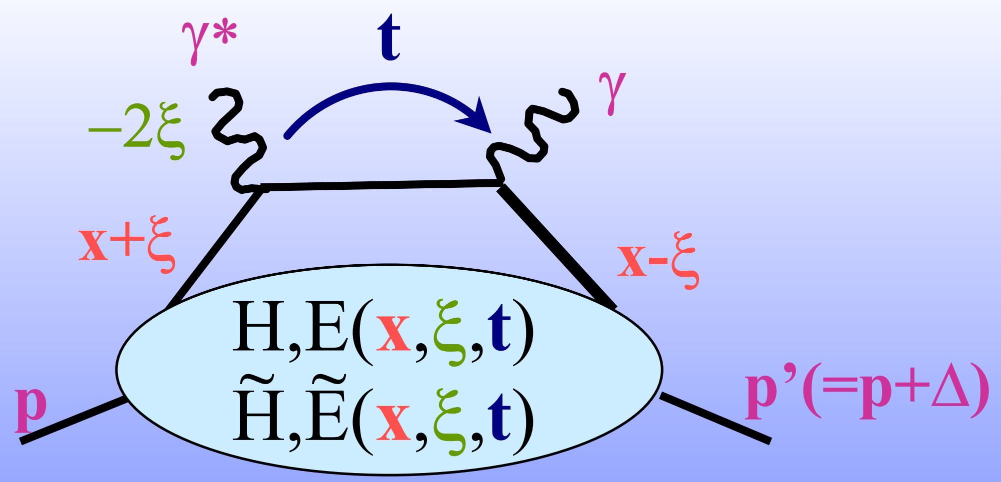
1/ DDVCS

(Double Deeply Virtual Compton Scattering)

Direct access to GPDS
(no deconvolution)

The handbag diagram

(Ji, Radyushkin, Mueller,….)

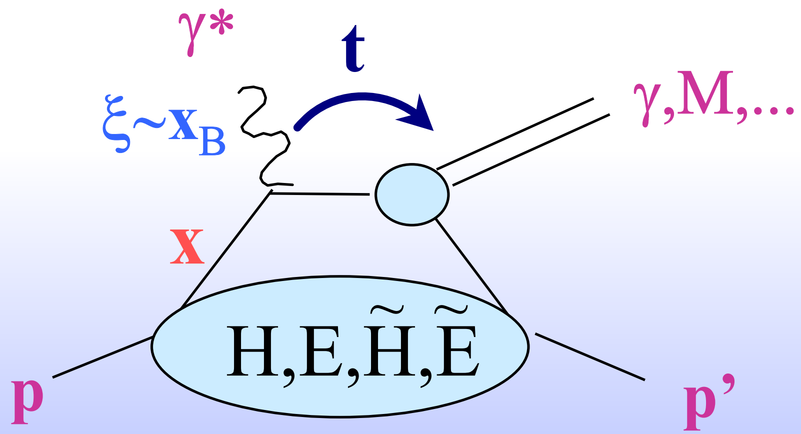


$$\{\gamma^{-}\left[H^{q}(x,\xi,t)\bar{N}(p')\gamma^{+}N(p) + E^{q}(x,\xi,t)\bar{N}(p')i\sigma^{+\kappa}\frac{\Delta_{\kappa}}{2M}N(p)\right] + \gamma^{5}\gamma^{-}\left[\tilde{H}^{q}(x,\xi,t)\bar{N}(p')\gamma^{+}\gamma^{5}N(p) + \tilde{E}^{q}(x,\xi,t)\bar{N}(p')\gamma^{5}\frac{\Delta^{+}}{2M}N(p)\right]\}$$

$H^q(x,\xi,t,Q^2)$ but only ξ , t and Q^2 accessible experimentally

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

$$Q^2=-(e-e')^2$$



$x \neq x_B$!

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

x : mute variable

Deconvolution needed !

$H^q(x,\xi,t)$ *is real but amplitude is complex*

$$\int_{-1}^{1} \frac{H^q(x,\xi,t)}{x-\xi+i\varepsilon}\,dx$$ ⇒ ***Differential cross section***

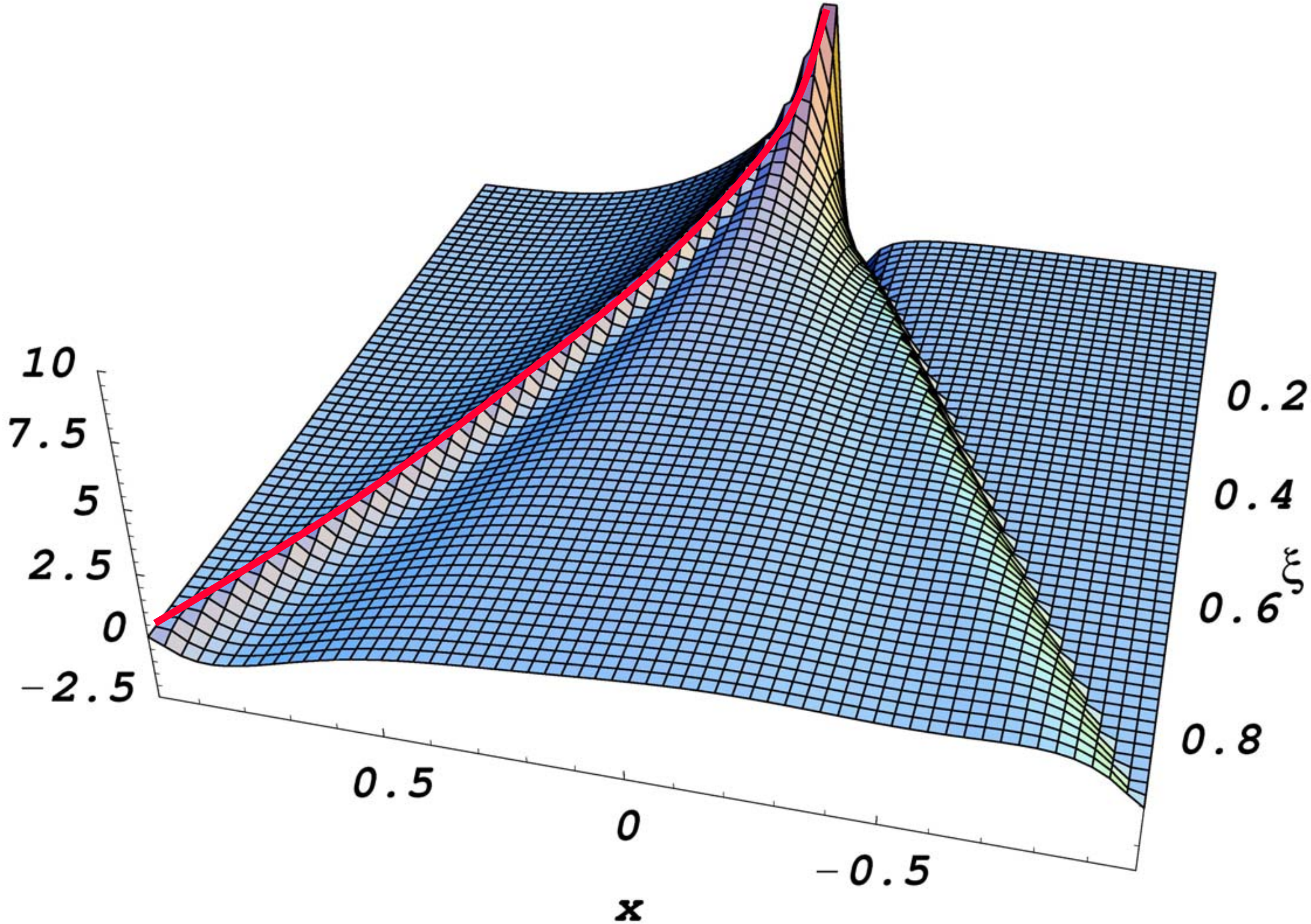
$$= \int_{-1}^{1} \frac{H^q(x,\xi,t)}{x-\xi}\,dx$$ ⇒ ***Real part***

(charge asymmetry)

$$- i\,\pi\,\underbrace{\delta(x-\xi)\,H^q(x,\xi,t)\,dx}_{H^q(\xi,\xi,t)}$$ ⇒ ***Imaginary part***

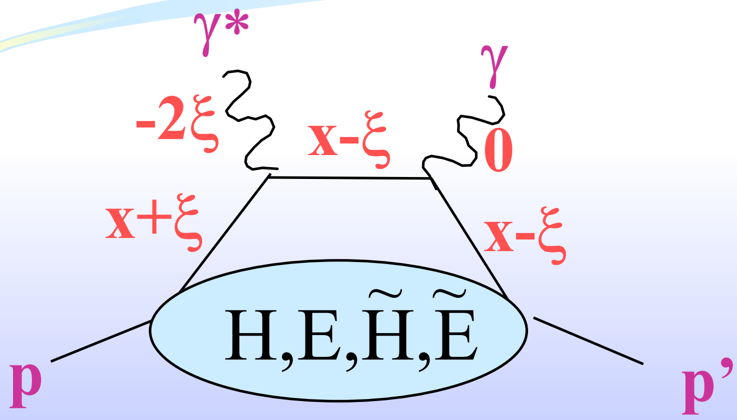
(spin asymmetries)

$H^u(x,\xi,t=0)$



(Goeke,Polyakov,Vanderhaeghen)

DVCS

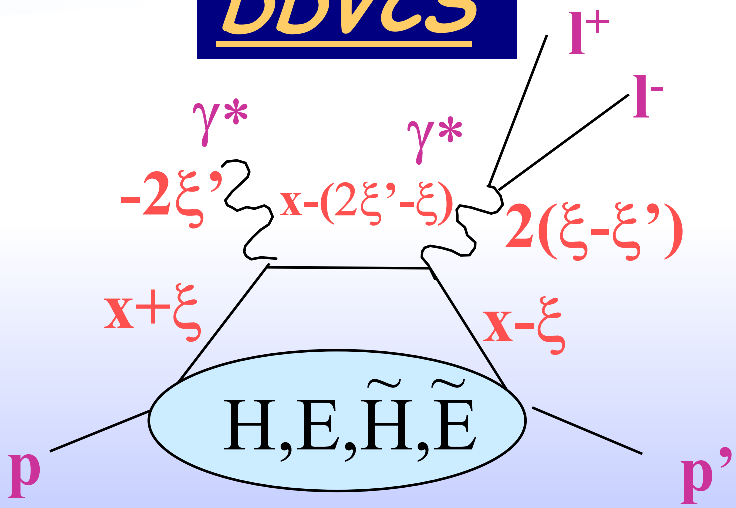


$$\sigma \sim \left| \int_{-1}^{1} \frac{H^{q}(x,\xi,t)}{x-\xi+i\varepsilon} dx \right|^{2}$$

$$\mathrm{Im} \sim H^{q}(\xi,\xi,t)$$

$$\mathrm{Re} \sim \left| \int_{-1}^{1} \frac{H^{q}(x,\xi,t)}{x-\xi} dx \right|^{2}$$

DDVCS



$$\sigma \sim \left| \int_{-1}^{1} \frac{H^{q}(x,\xi,t)\; dx}{x-(2\xi'-\xi)+i\varepsilon} \right|^{2}$$

$$\mathrm{Im} \sim H^{q}(2\xi'-\xi,\xi,t)$$

$$\mathrm{Re} \sim \left| \int_{-1}^{1} \frac{H^{q}(x,\xi,t)}{x-(2\xi'-\xi)} dx \right|^{2}$$

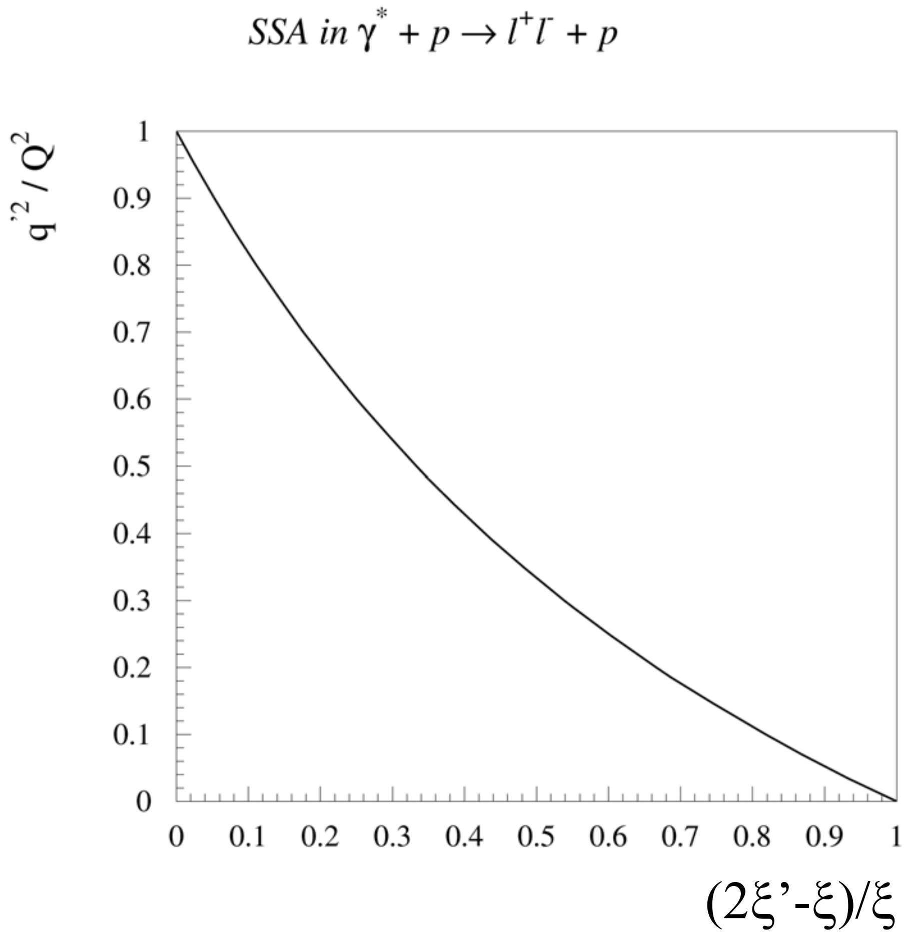
$q'^2 = 0\ GeV^2$ $q'^2 = Q^2$

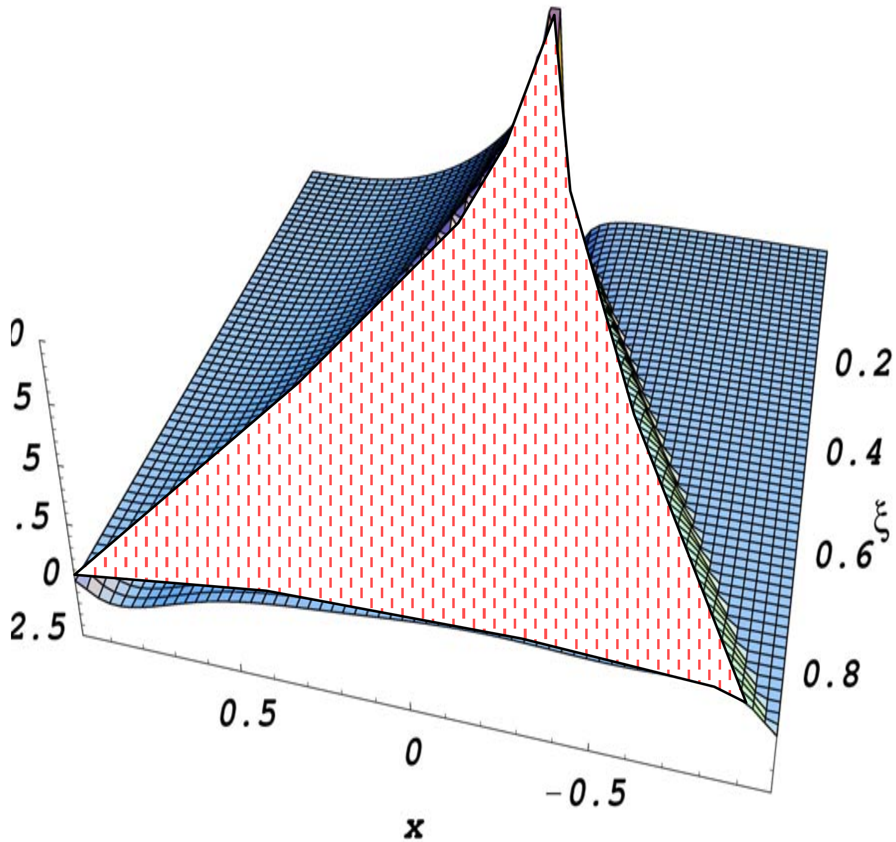
$0 < 2\xi' - \xi < \xi$

Numerical example :

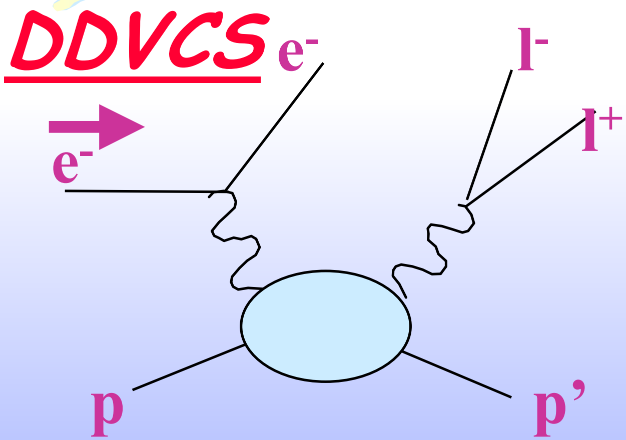
$Q^2 = 5\ GeV^2$, $q'^2 = 2\ GeV^2$

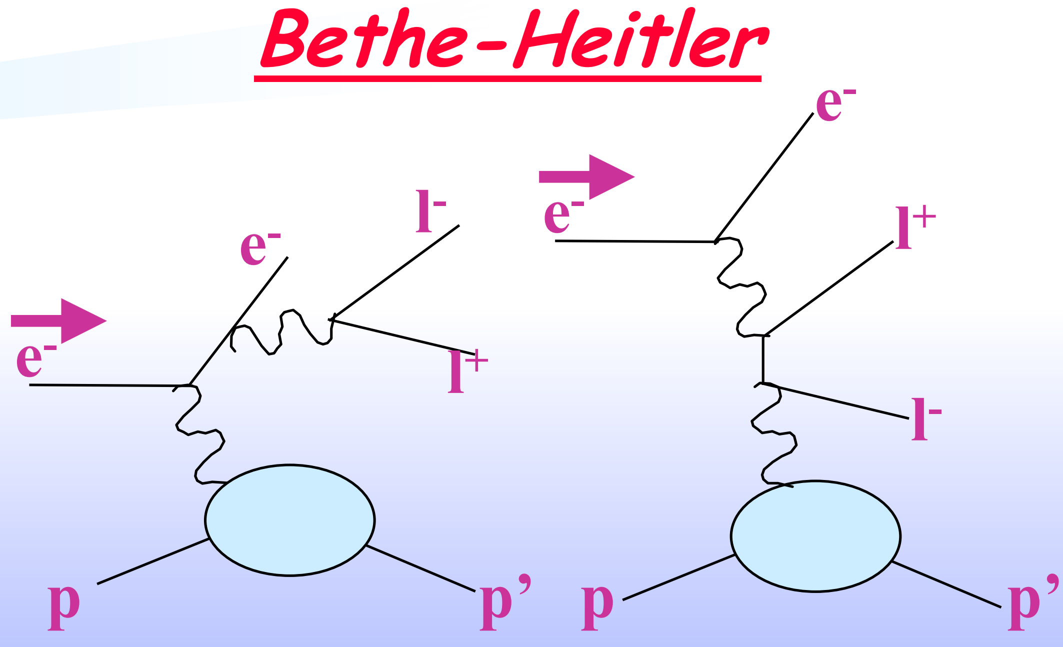
$(2\xi' - \xi) = .43\xi$

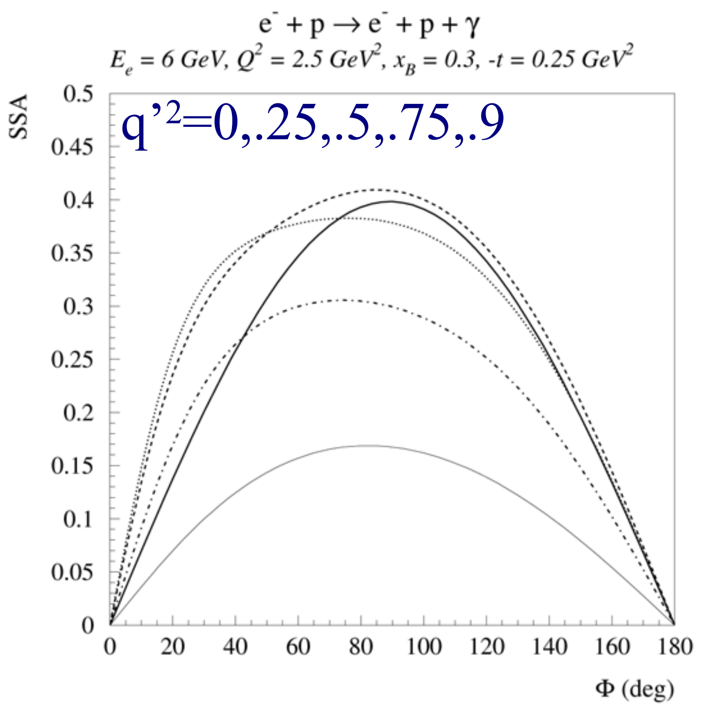


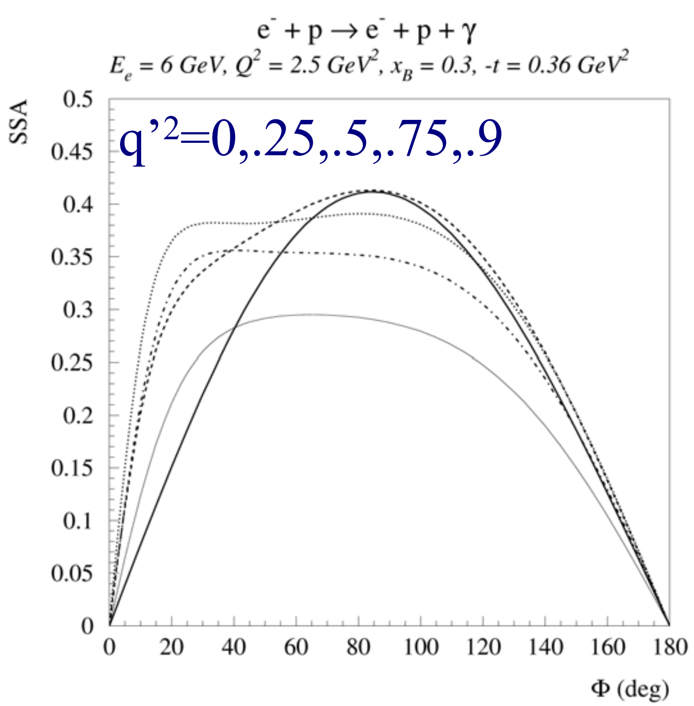


Beam Spin asymmetry for ep ⇨ ep γ^* ↳ l^+l^-



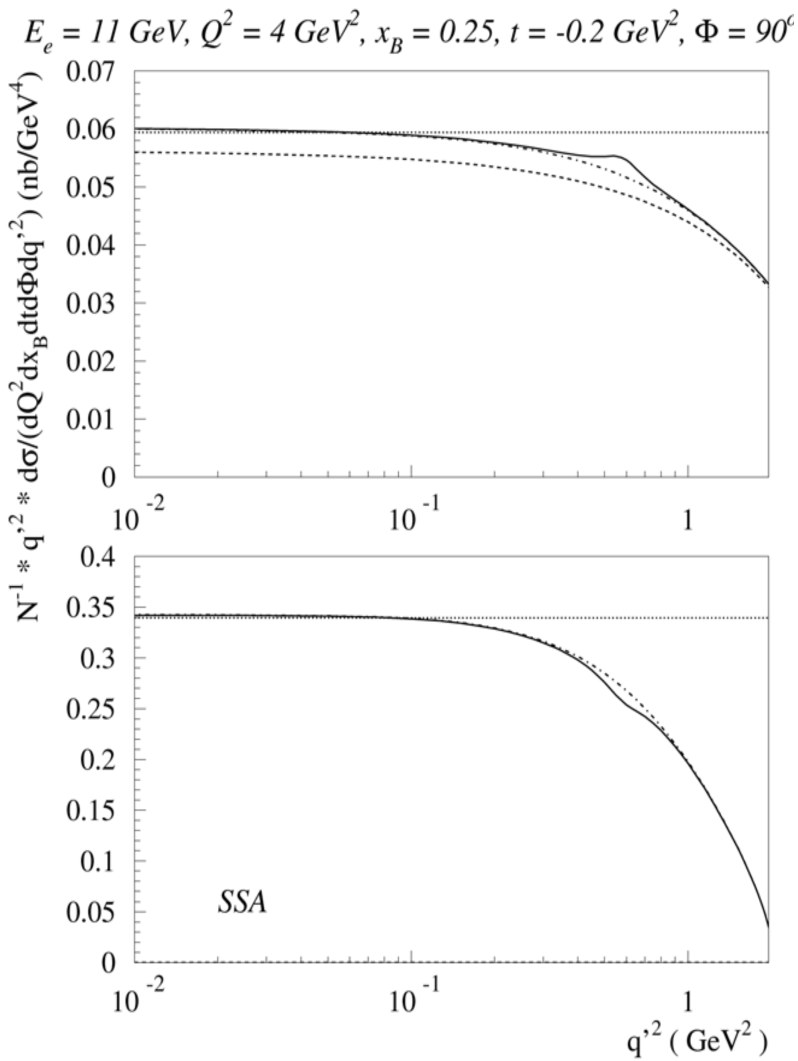


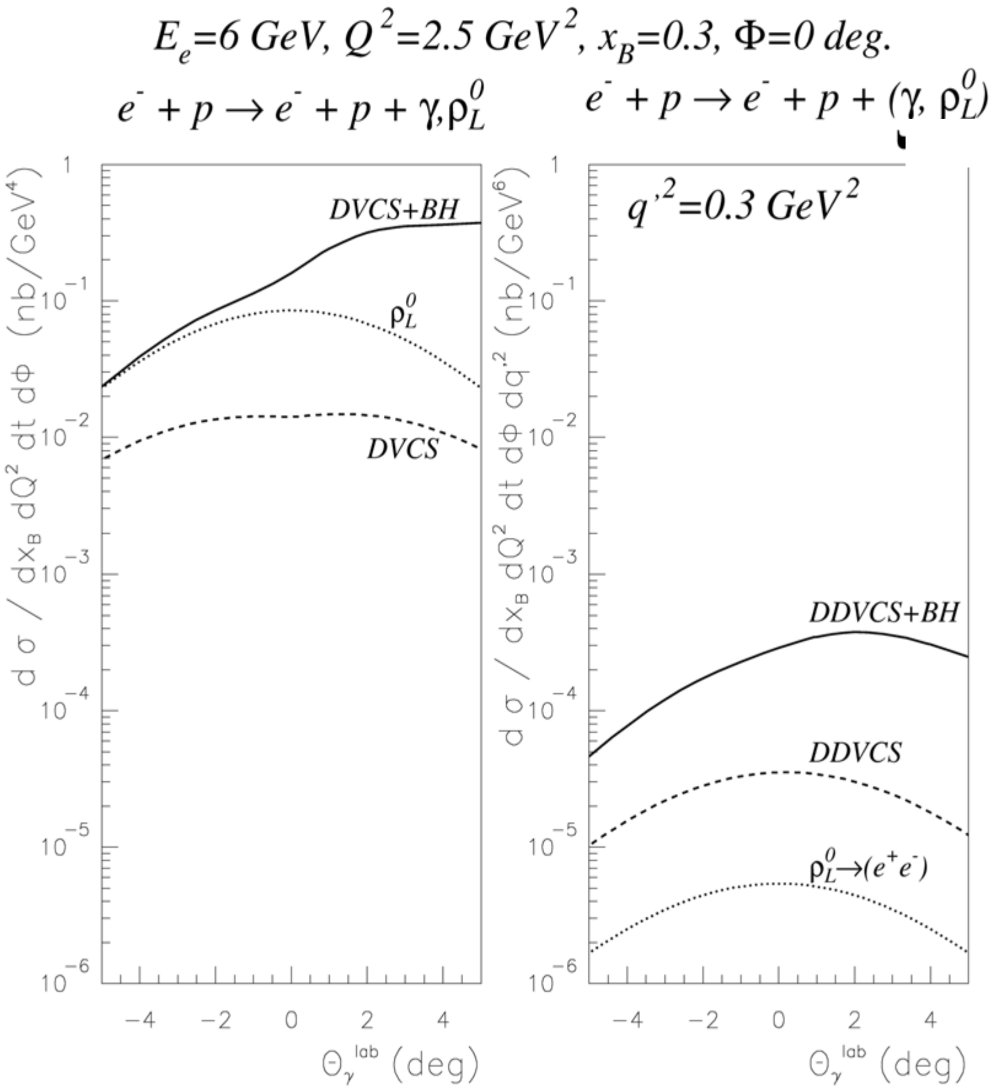




ρ influence

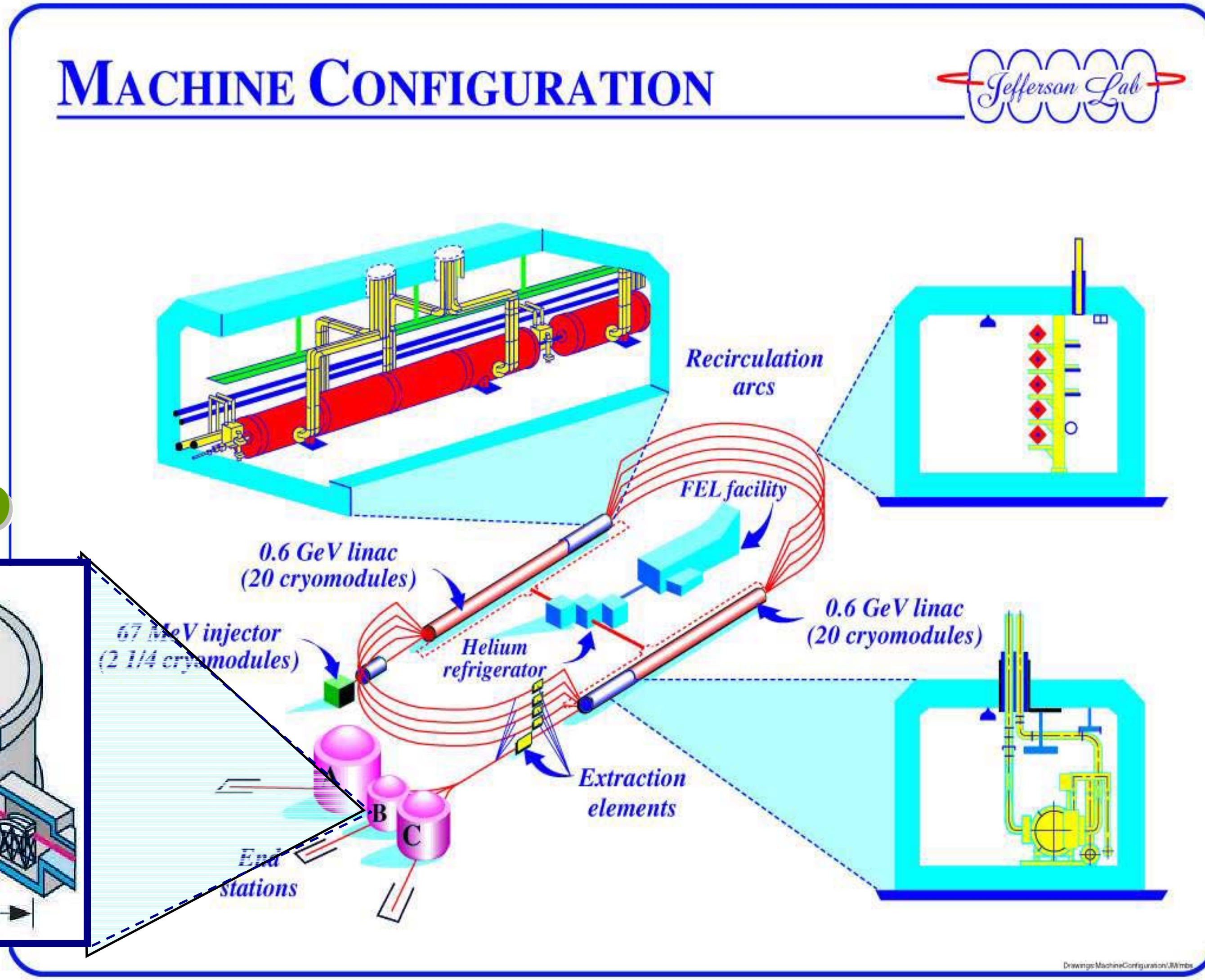
ep ⇒ ep ρ ↳ l^+l^-

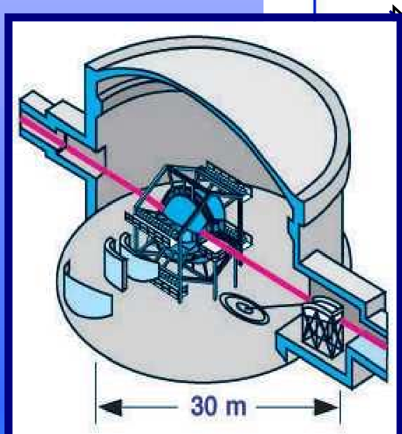




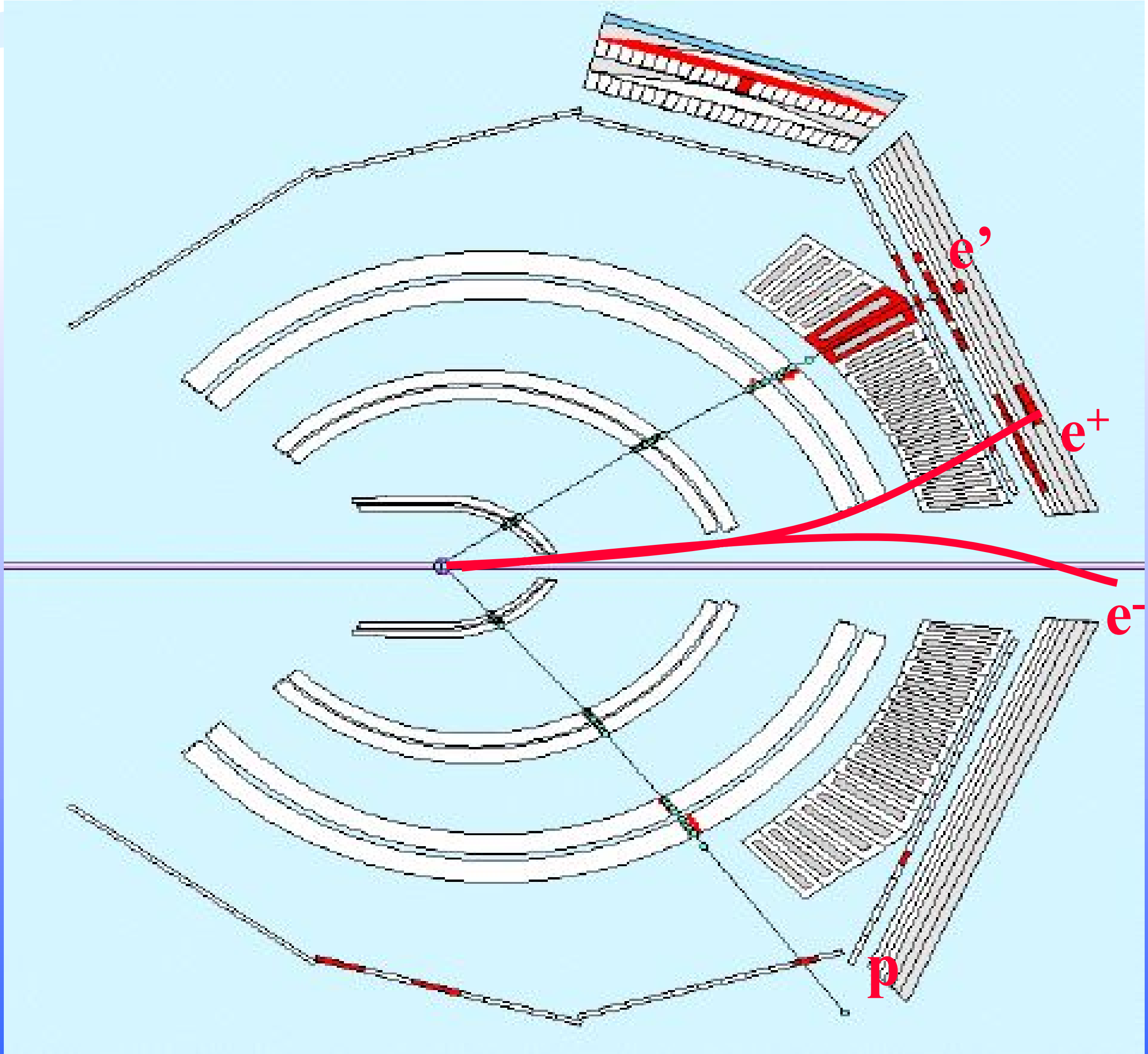
First experimental look

CLAS, JLab





Any **DDVCS** event in CLAS ?

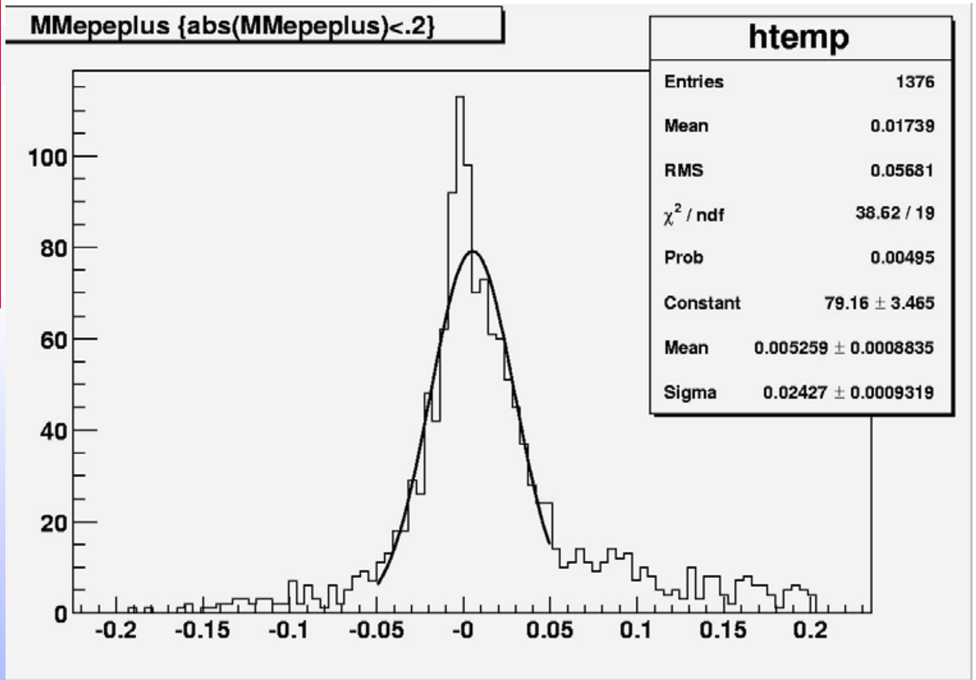


Detect e’, e^+ and p ⇨ missing e^-

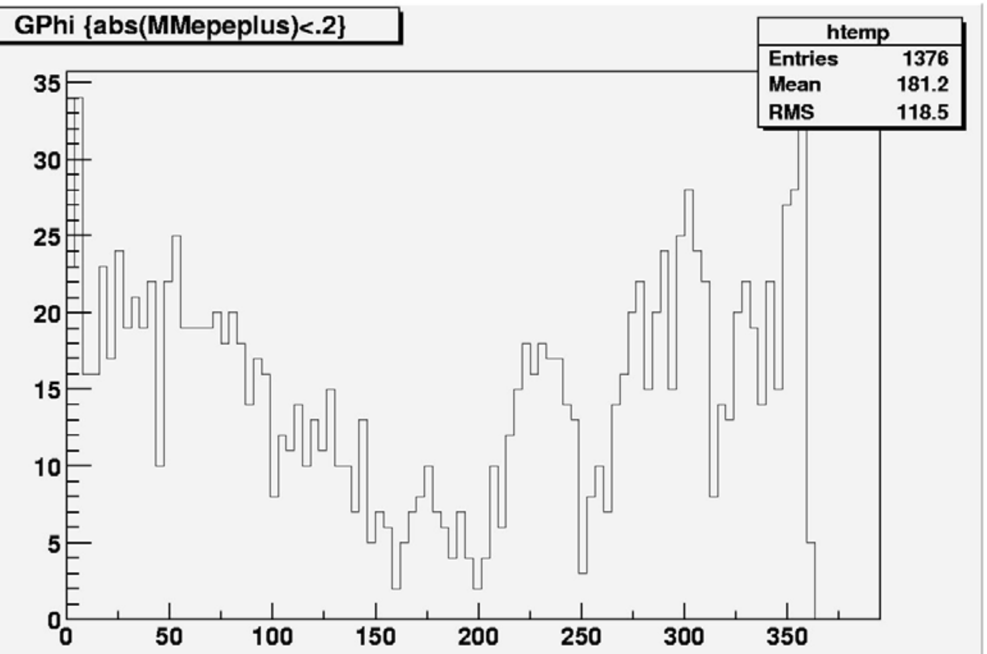
First experimental investigations

CLAS, 30 days beam time, 1/3 statistics, Ee=5.75 GeV

Detect $e'pe^+$ ⇨ missing e^-

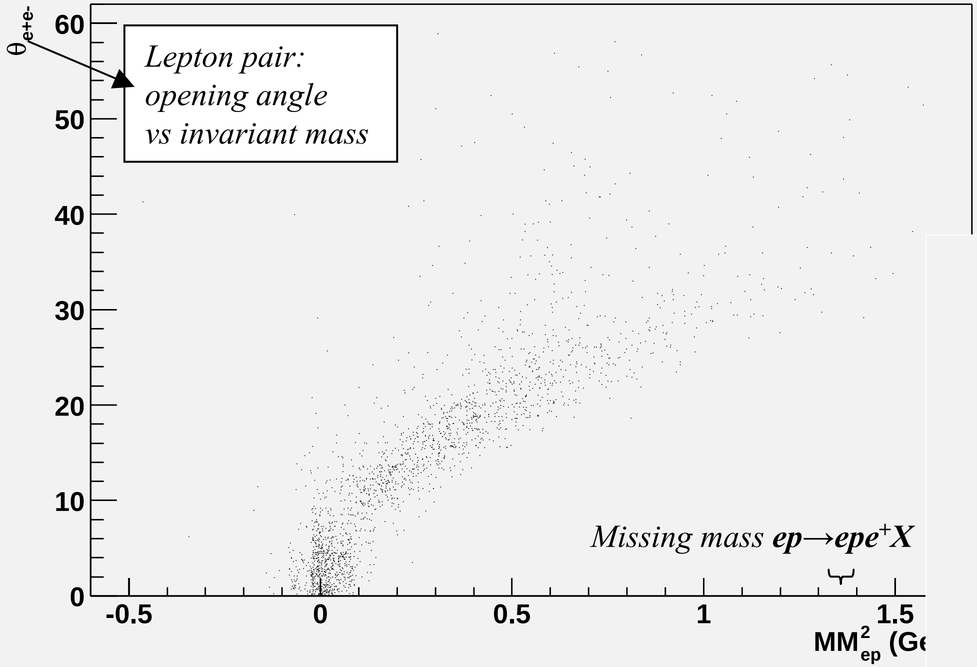


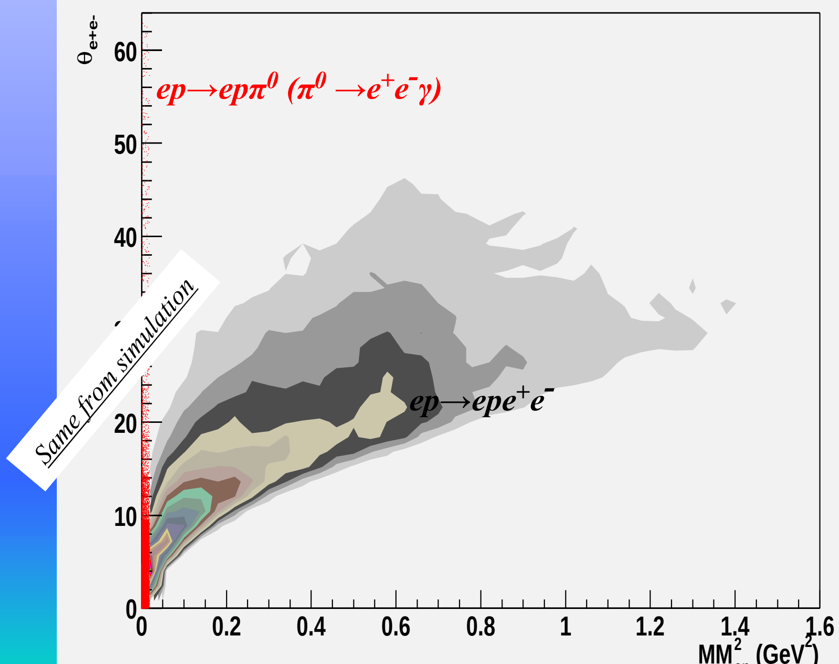
Missing Mass² ($e'pe^+$ X) (GeV²)



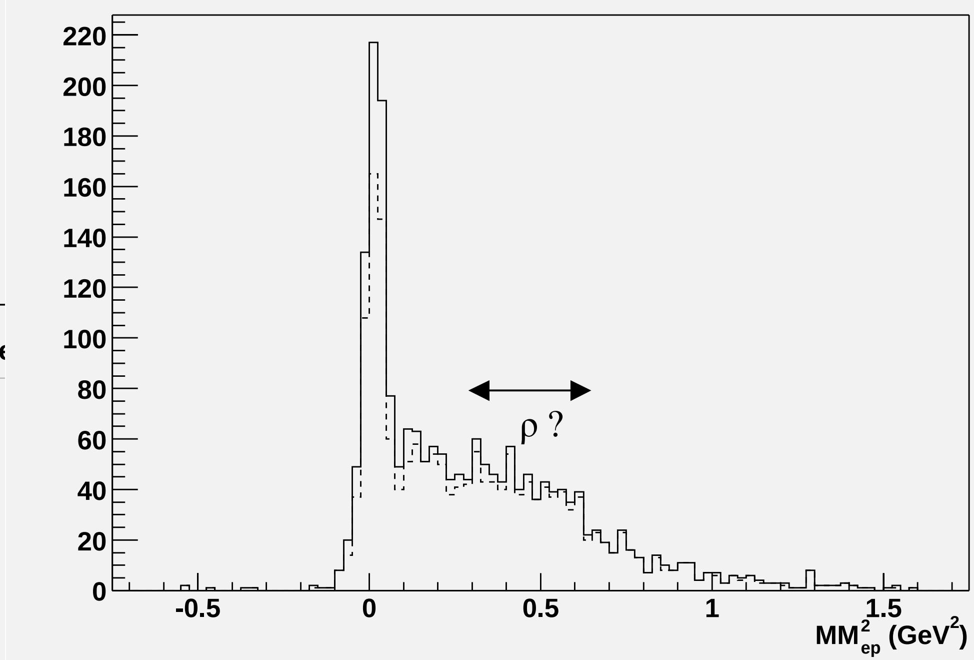
Φ distribution

Analysis S. Morrow (Saclay)





Distributions of counts
(not corrected from acceptance)



($q^{2\prime}$)

***Next step*: extract**

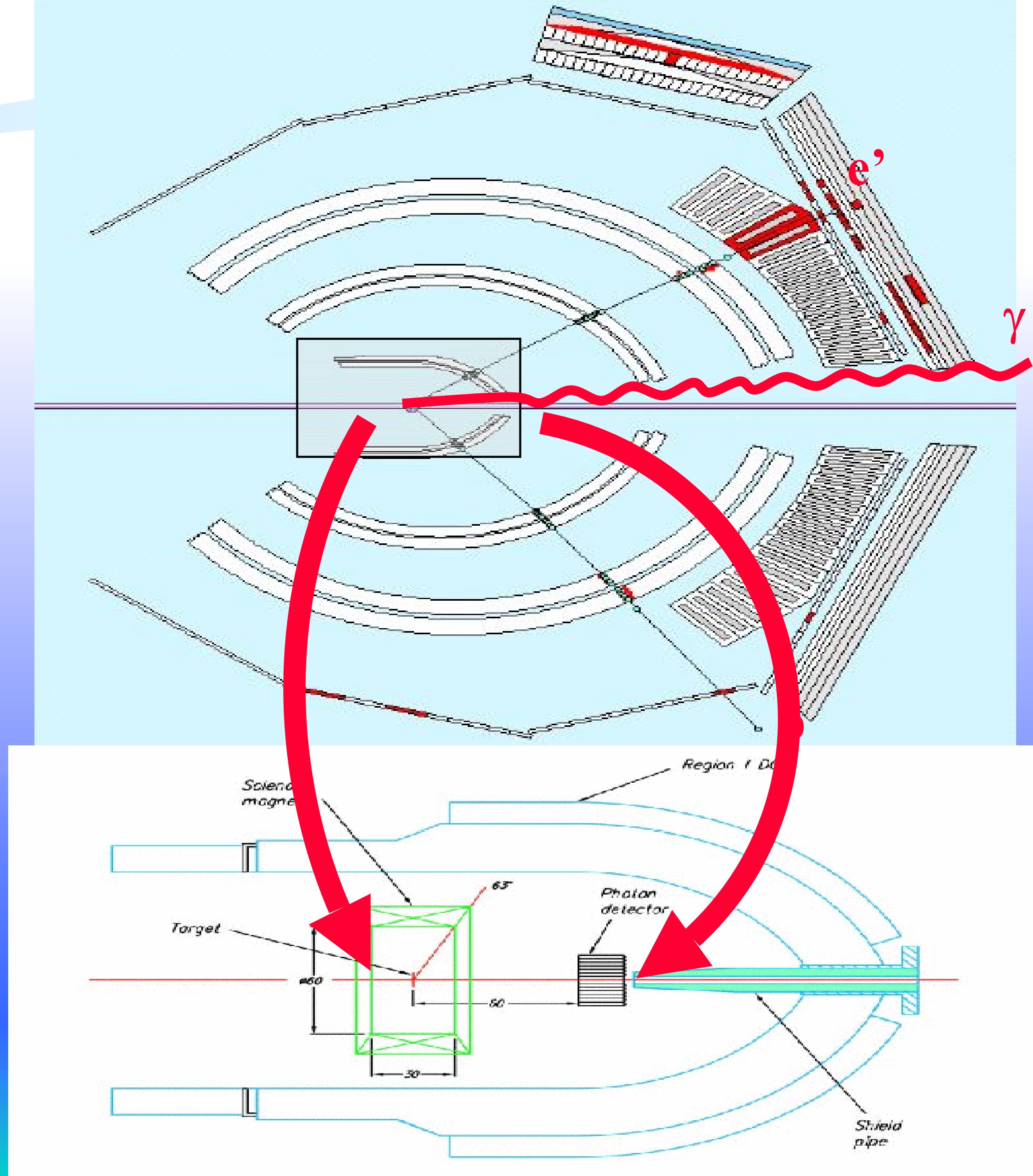
beam polarization asymmetry

Figures, courtesy of M. Garcon & S. Morrow (Saclay)

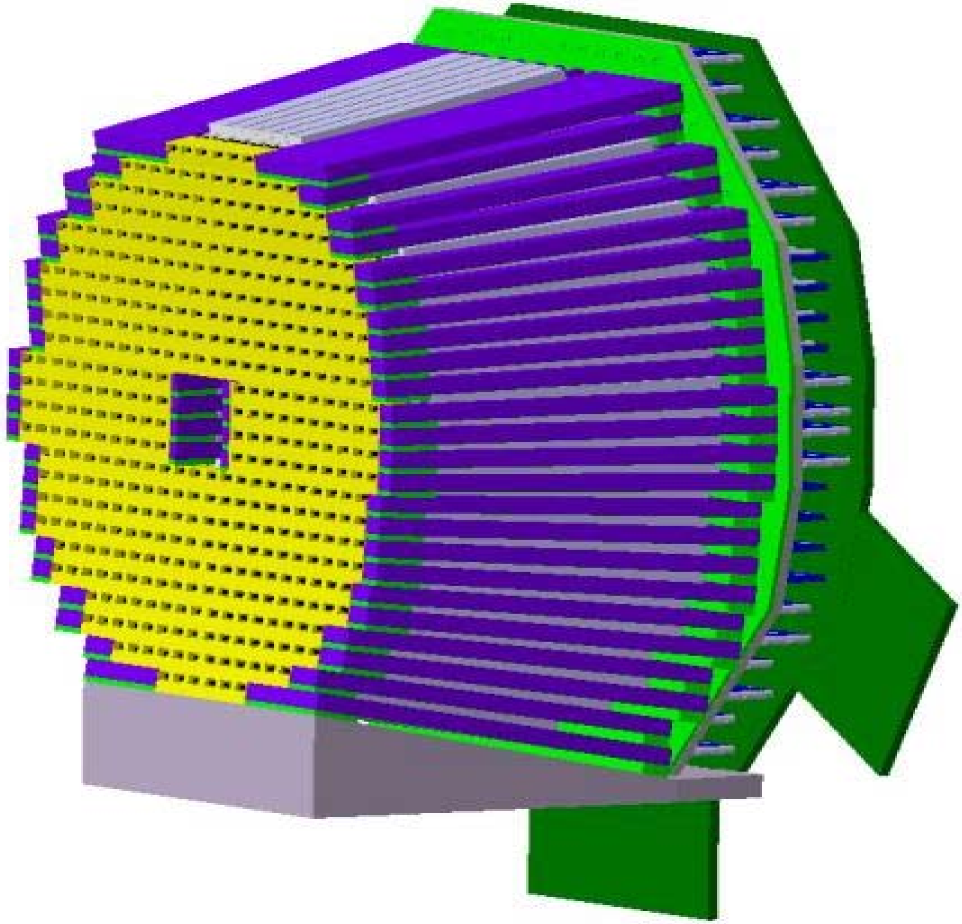
A typical ep⇨ epγ event in CLAS

Add EM calorimeter at forward angles

Add solenoid Moller shield around target



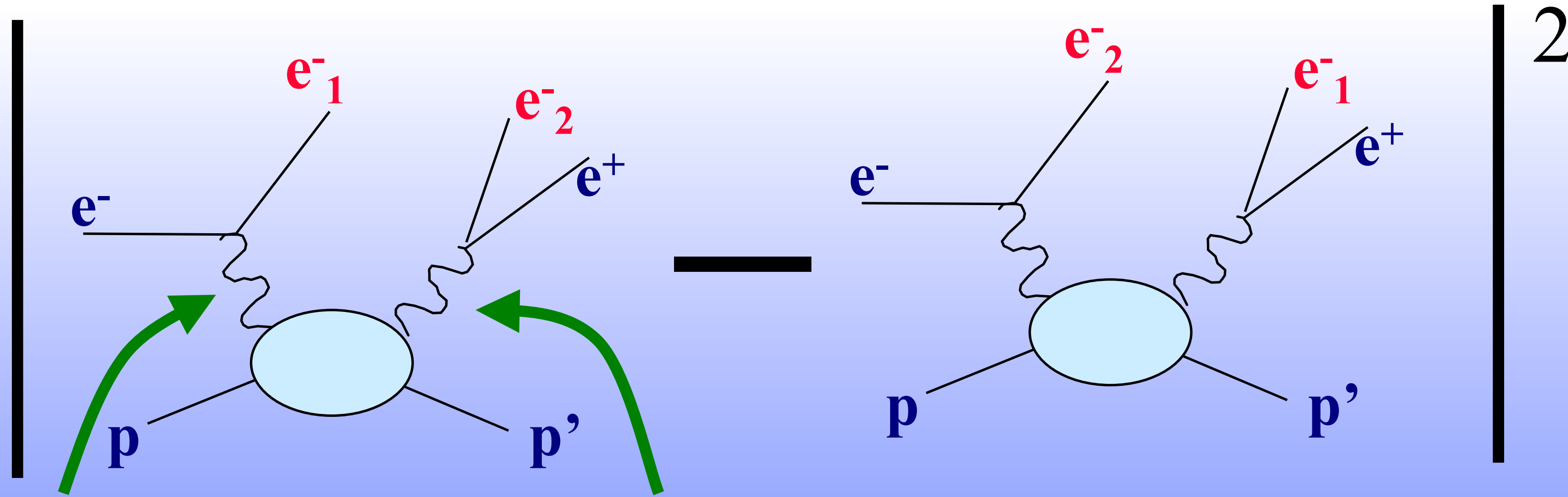
JLab/ITEP/ Orsay/Saclay/ UVA collaboration



- **Dynamical range : 50 MeV < E_γ < 5 GeV (σ~5%/sqrt(E_γ))**
  Counting rates ~ 1 MHz
  Magnetic field environment : B~ 1 T

⇨ **~400 $PbWO_4$ crystals : ~10x10 mm^2, l=160 mm (18 λ's)**
Read-out : APDs +preamps

The particular case of e-/e+ pairs

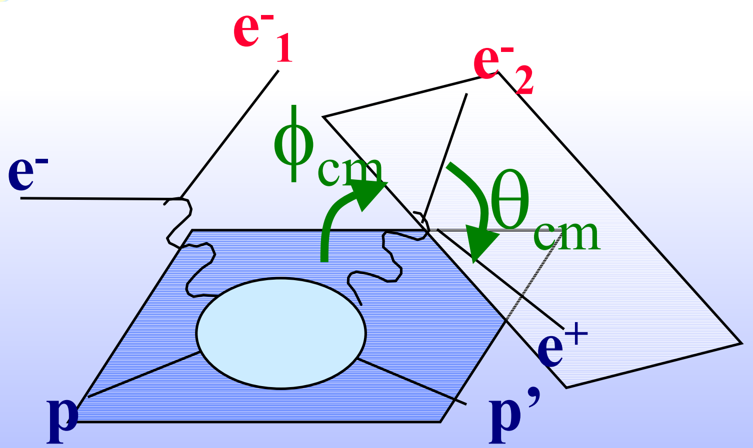


$Q^2=(e^- - e_2)^2$ $q^{2'}=(e_2+e^+)^2$

1/ Theoretically, one has to anti-symmetrize

2/ Experimentally, ambiguity on defining Q^2, $q^{2'}$,…

A bit of kinematics

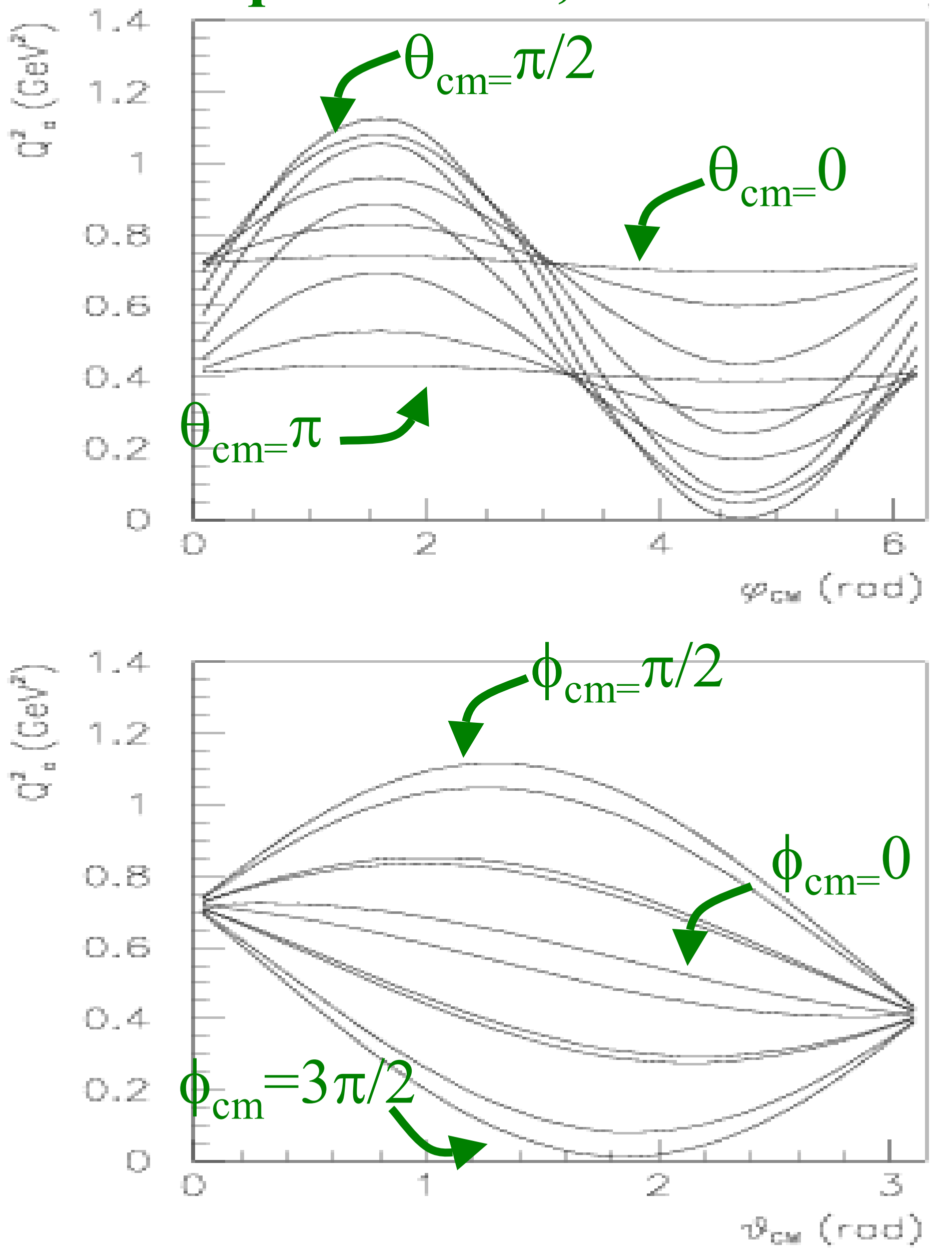


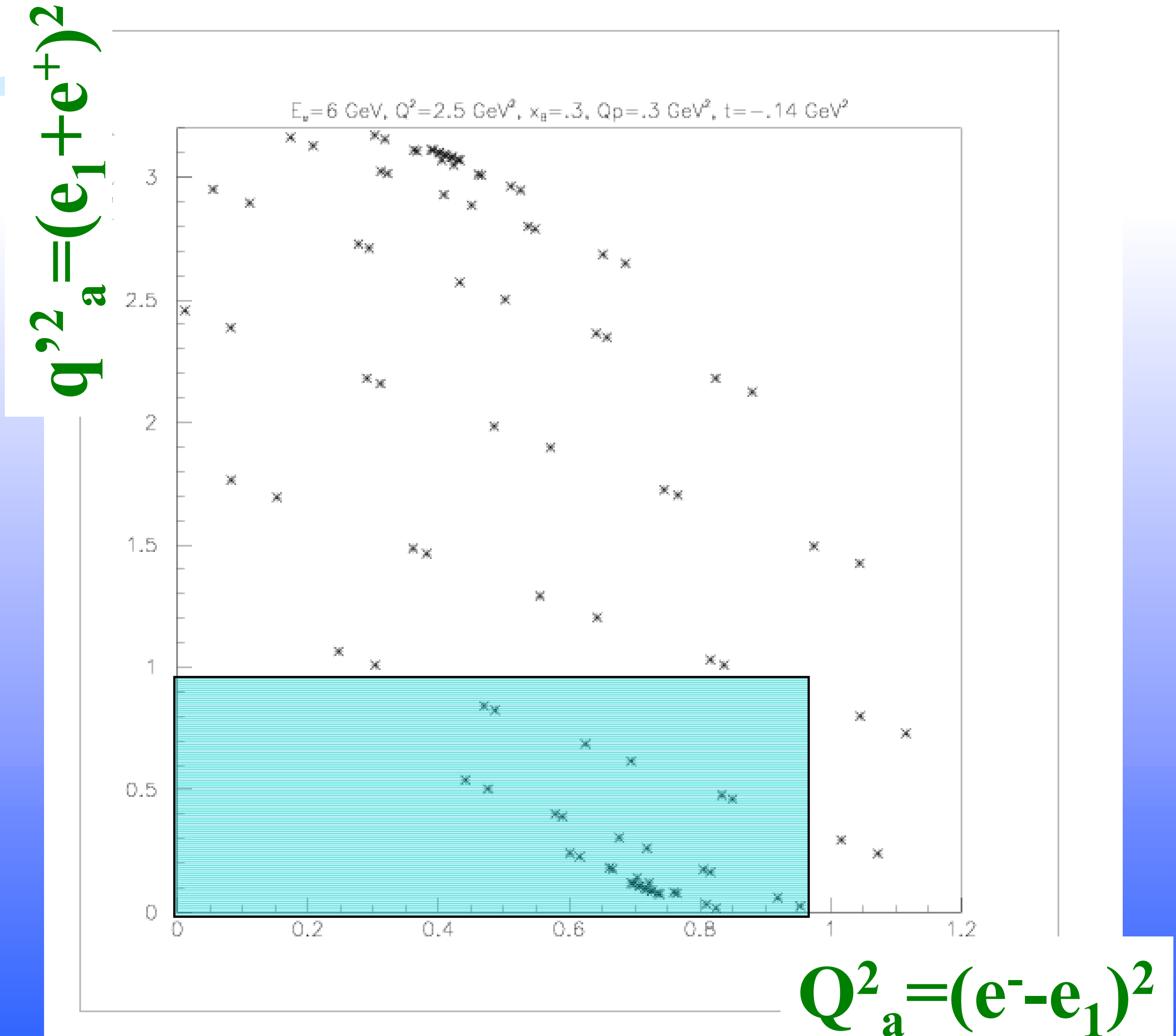
2 possibilities :

$Q^2=(e-e_1)^2$
$q'^2=(e_2+e^+)^2$

$Q^2_a=(e^--e_1)^2$
$q'^2_a=(e_1+e^+)^2$

E_e=6 GeV, Q^2=2.5 GeV^2, q'^2=.3 GeV^2, t=-.14 GeV^2





<u>At least, one virtuality > 1 GeV^2</u>

2/ Study on the (x,t) correlation of the GPDs

(in coll. with M. VdH & M. Polyakov)

Link between GPDs & FFs

$$F_1^q = \int_{-1}^{1} H^q(x,\xi,t)dx \qquad F_2^q = \int_{-1}^{1} E^q(x,\xi,t)dx$$

Low t (-t<1 GeV2) : Regge ansatz **(Goeke, Poliakov, VdH)**

$$F_1^u(t) = \int_0^1 u_v(x) 1/(x^{\alpha'_1 t})dx \qquad F_1^d(t) = \int_0^1 d_v(x) 1/(x^{\alpha'_2 t})dx$$

$$\mathbf{F_1^p} = e_u F_1^u(t) + e_d F_1^d(t) \qquad \mathbf{F_1^n} = e_u F_1^d(t) + e_d F_1^u(t)$$

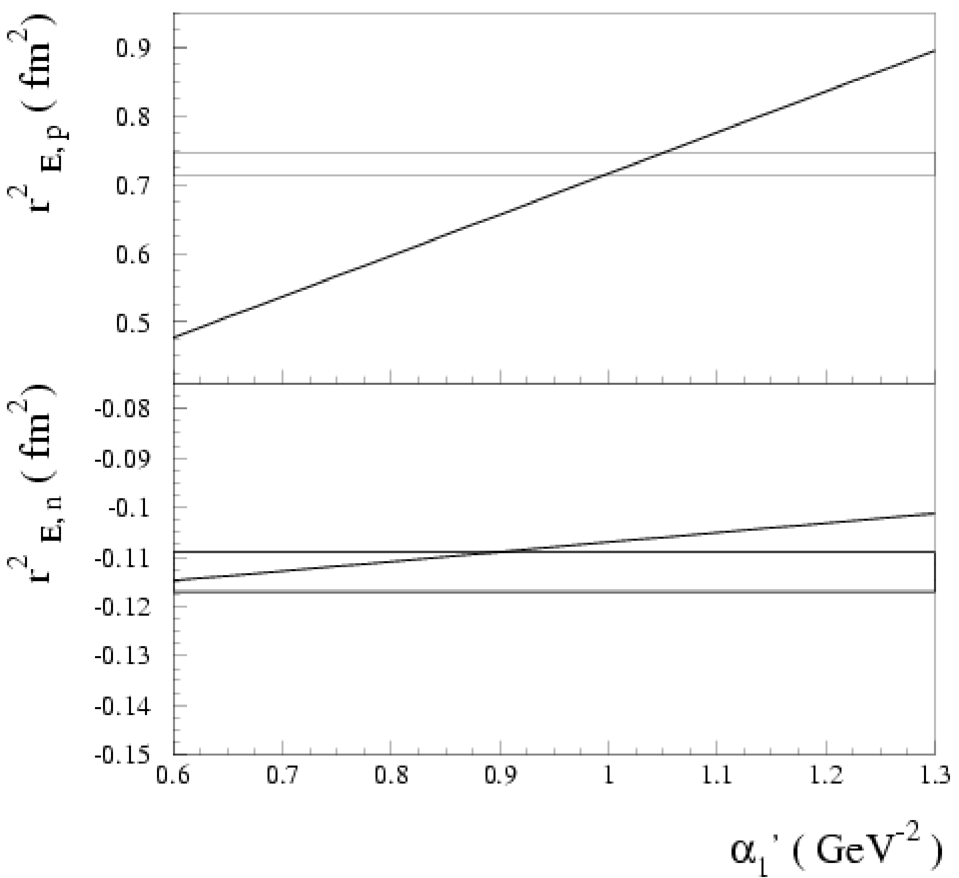
Similarly $F_2^q(t) = \int_0^1 \kappa_v\, q_v(x) 1/(x^{\alpha'_2 t})dx$

- 2 free parameters : α'_1, α'_2 **(constrained by Regge)**
- Fit 4 form factors : $G_{E,M}^{p,n}$

Proton & neutron electric charge radii

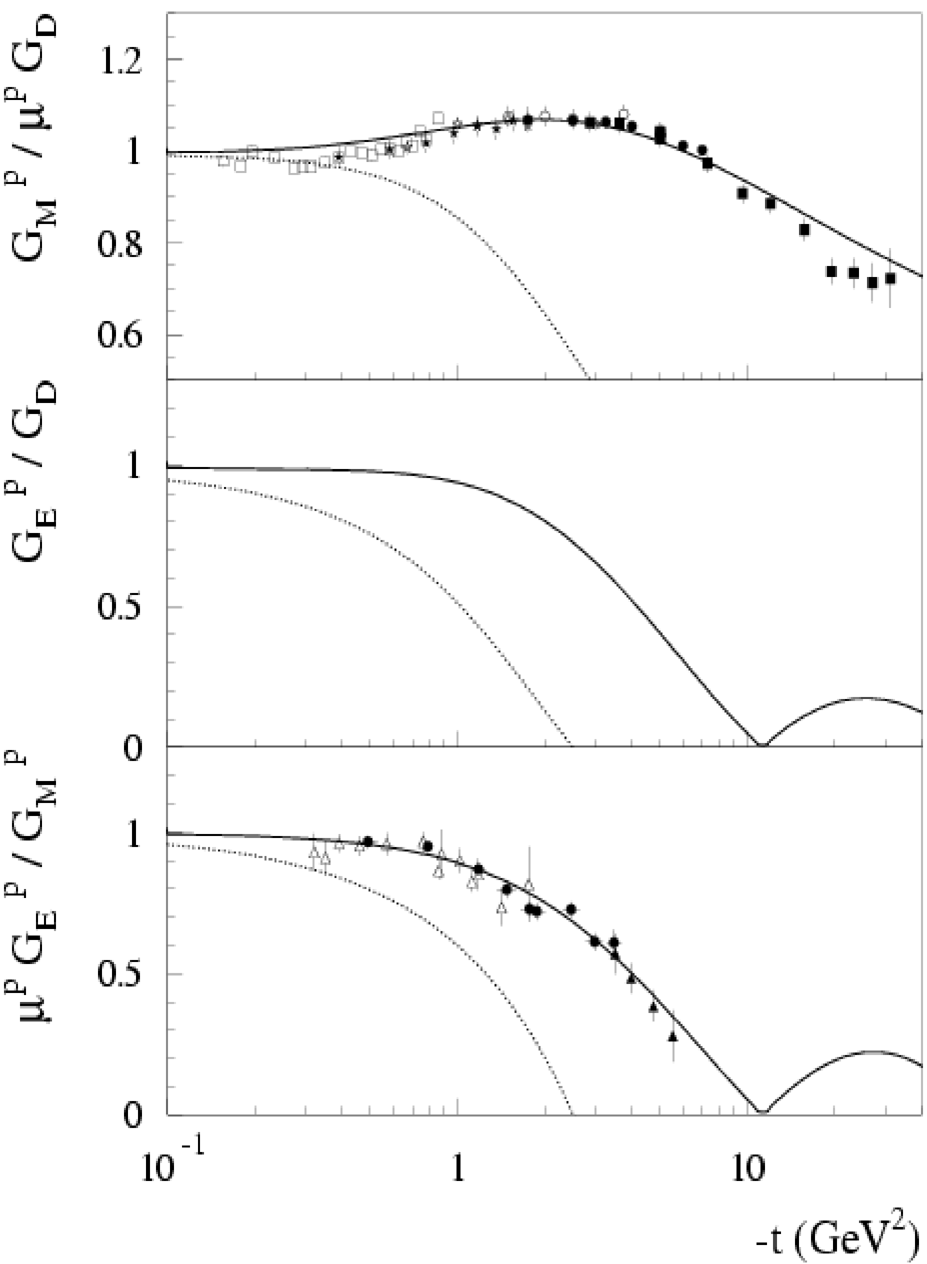
$$F_1^u = \int_0^1 u_v(x) 1/(x^{\alpha'_1 t}) dx \Rightarrow r^2_{1,p} = -6\alpha'_1 \ln x (e_u u_v + e_d d_v) dx$$

$$r^2_{E,N} = r^2_{1,N} + 3/2 \kappa_N / m^2_N$$

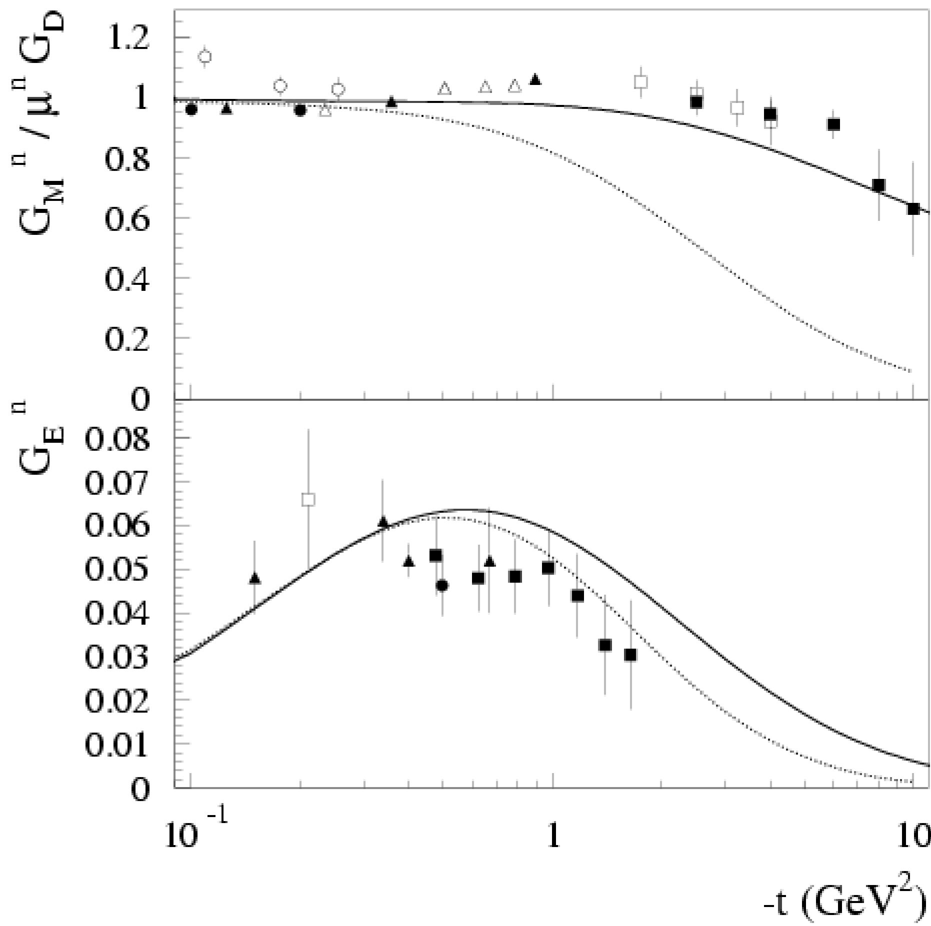


$\Rightarrow$ $\alpha'_1 \sim 1$ GeV^{-2}

PROTON electric and magnetic form factors



NEUTRON electric and magnetic form facto



Extending the t domain

pQCD : $F_1(t) \sim 1/t^2$ at large t ($F_2 \sim 1/t^3$)

1/ Introduce non-linear Regge trajectories :

$$\alpha(t)=\alpha(0)+\alpha' 2T[1-\mathrm{sqrt}(1-t/T)]$$

(Brisudova, Burakovsky, Goldman)

T : (free) non-linearity parameter → $F_1(t) \sim 1/t^2$

2/ a/ x-dependence of Eq is not constrained

b/ Large t power behavior is fixed by large x behavior

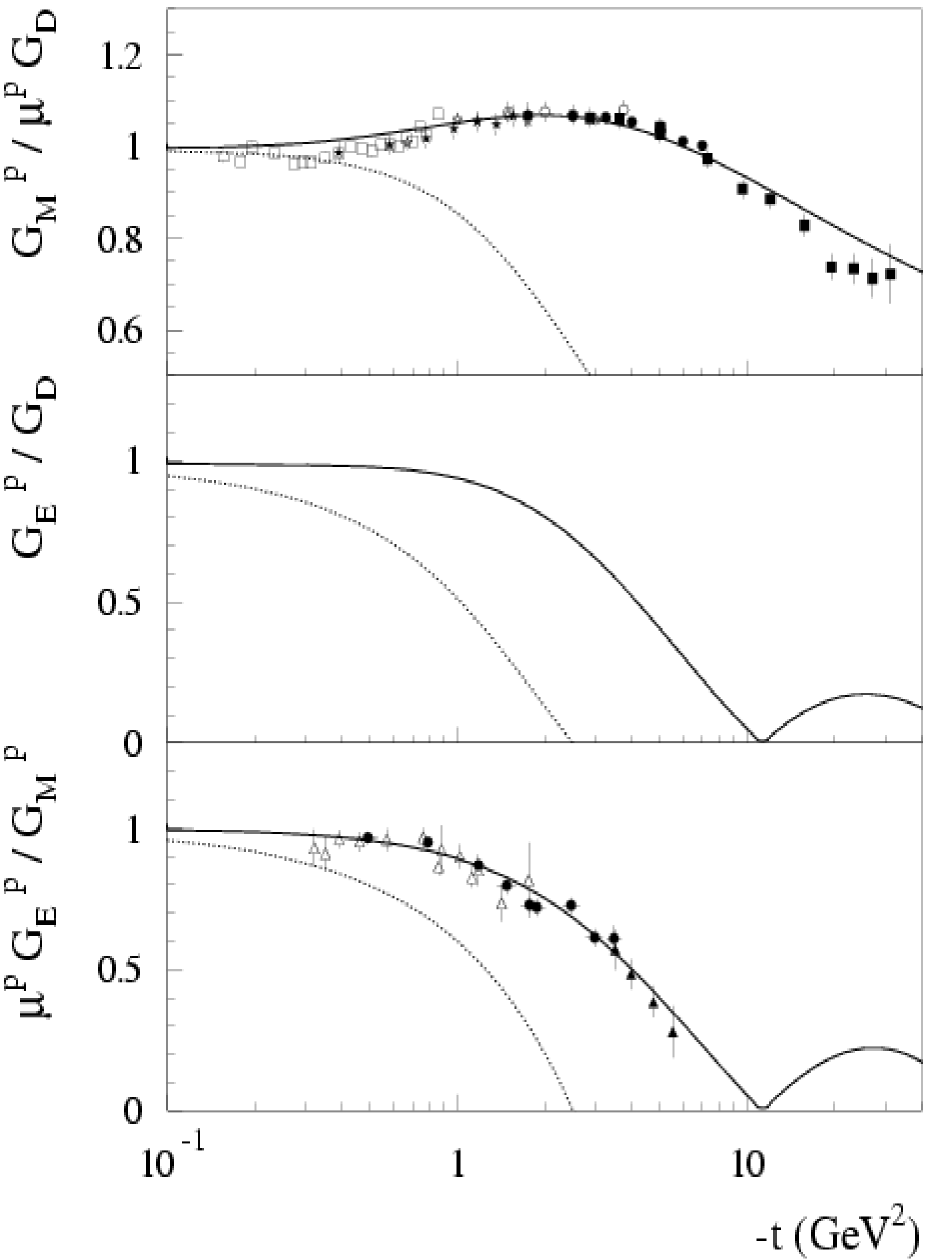
⇒ Large x behavior of E should be different from H

$$F_2^q(t)= \int_0^1 \kappa_v (1-x)^{\eta q} q_V(x)/(x^{\alpha'_2 t})dx$$

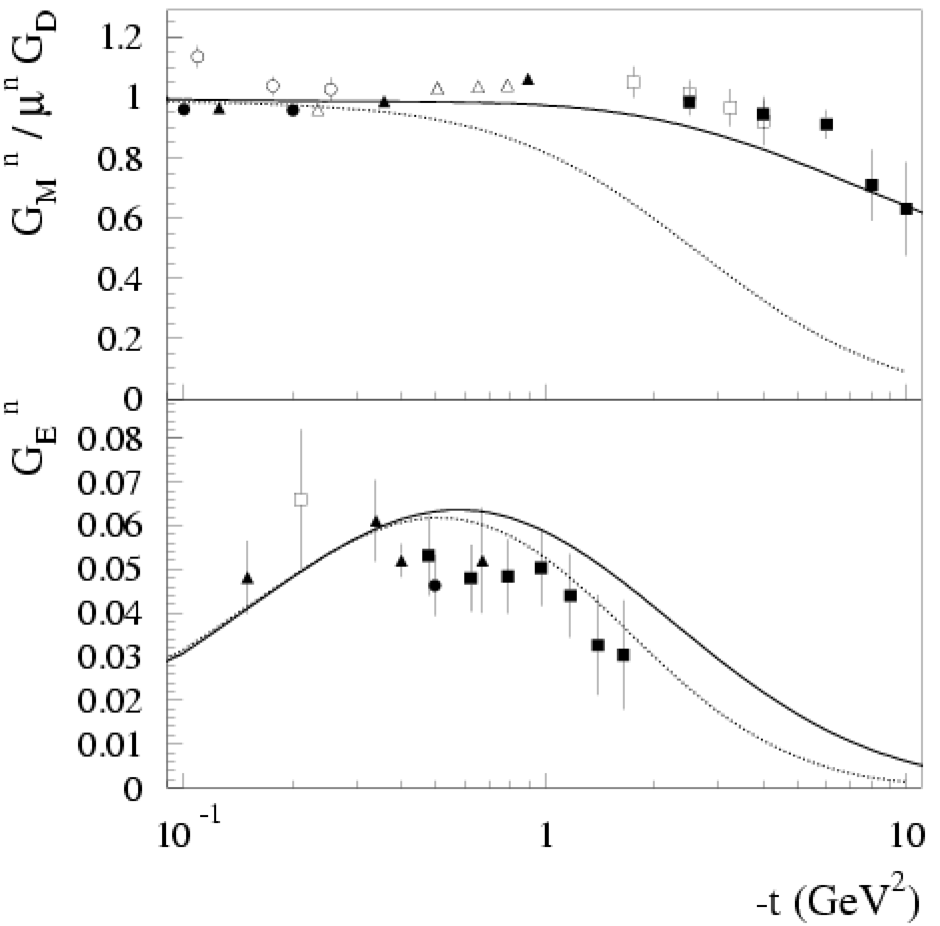
⇒ 6 parameters : $\alpha'_1, \alpha'_2, \eta^u, \eta^d, T_1, T_2,$

⇒ Fit 4 form factors : $G_{E,M}^{p,n}$ **on whole t domain** !

PROTON electric and magnetic form factors



NEUTRON electric and magnetic form factors



Nucleon strangeness : F_1^s

$$\int_{-1}^{1} [s(x)-\bar{s}(x)]dx=0$$

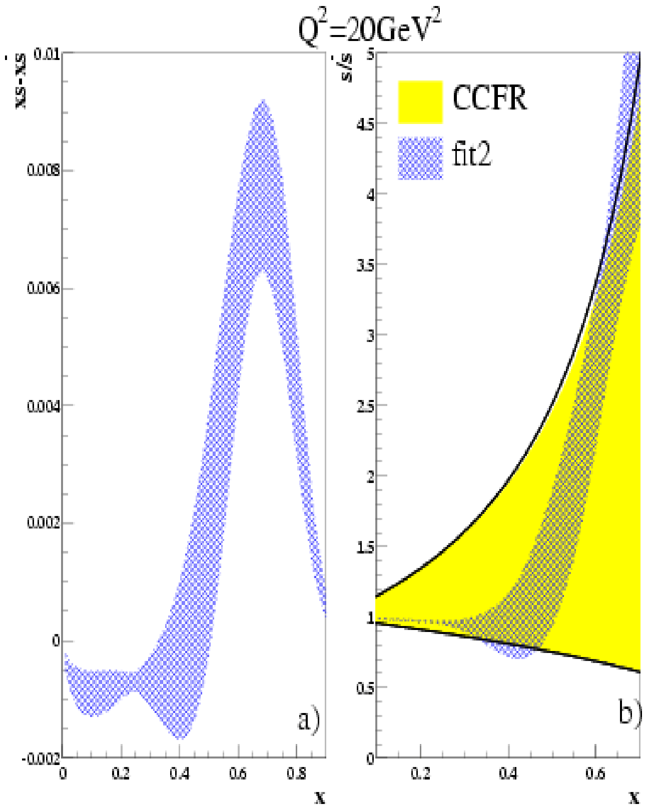
But : $F_1^s(t) = \int_{-1}^{1} [s(x)-\bar{s}(x)]/(x^{\alpha' t})dx \neq 0$

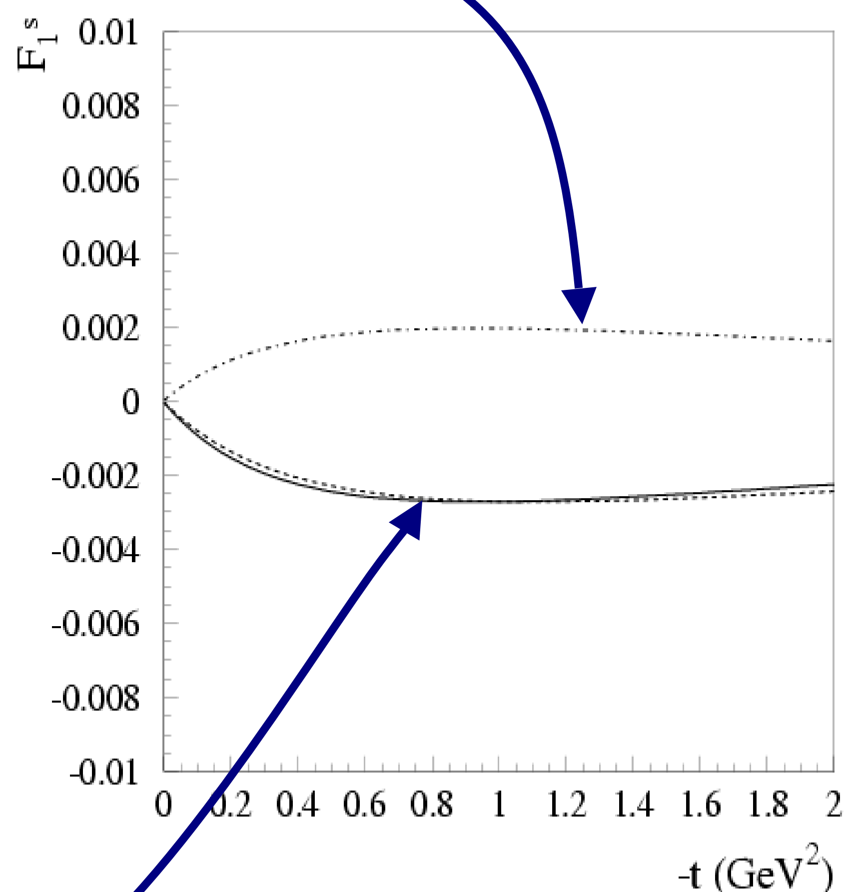
$s(x) - \bar{s}(x)$ distribution in the proton

NUCLEON STRANGENESS F_1 form factor

- extracted from ν, $\bar{\nu}$ data
- DIS fit performed by Barone, Pascaud, Zomer (2000)

  fit $s \neq \bar{s}$ (CDHS data) : $< xs > - < x\bar{s} > \simeq +2 \cdot 10^{-3}$





- fit based on ν, $\bar{\nu}$ CCFR + NuTeV (2001) data :

  $< xs > - < x\bar{s} > \simeq -(2.7 \pm 1.3) \cdot 10^{-3}$

SUMMARY

1/DDVCS

- The (continously) varying virtuality of the outgoing photon allows to "tune" the kinematical point (x,ξ,t) at which the GPDs are sampled
- Currently working out the anti-symmetrisation issues
- Experimental feasibility : maybe not so far away….

2/(x,t) dep. of GPDs

- α' should depend on Q^2 to match evolution of PDF/GPDs