π^0 and η electroproduction with CLAS.

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<u>Outlook</u>

- Hard exclusive scattering (large Q^2, small t)
- Large momentum transfer region (large t, small Q^2)
- Exclusive π^0/η electroproduction with CLAS (e1-6)
  - t-dependence of the π^0 and η production
  - Q^2-dependence of the π^0 and η production
- Summary

Hard Exclusive Scattering

The QCD factorization theorem has been generalized to a large group of hard exclusive processes,

$$\gamma^* + N \to (\gamma, \pi, \eta, \rho, \omega, \phi) + N'$$

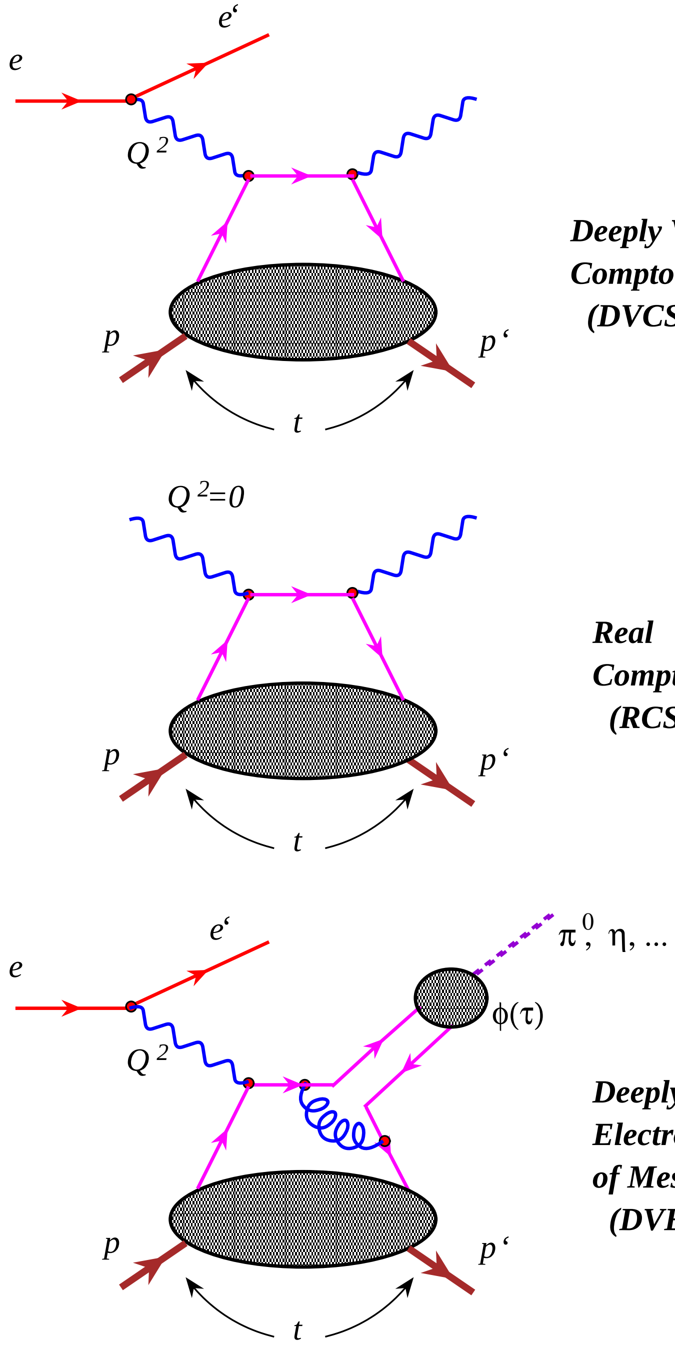
It has been shown that, at large Q^2, and small momentum transfer t, deeply virtual Compton scattering (DVCS) and deeply virtual electroproduction of mesons (DVEM) factorize into hard photon-parton scattering and GPDs describing the soft coupling between partons and hadrons.

DVEM is dominated by longitudinally polarized photons for $Q^2 \to \infty$. The cross section for transversally polarized photons is suppressed by $1/Q^2$ factor.

Vector Meson Electroproduction

- **s-channel helicity conservation. We can access σ_L photon cross section for vector meson production solely by measuring the decay angular distribution of the vector meson.**
- $\sigma_L \sim 1/Q^6$
- $\sigma_T/\sigma_L \sim 1/Q^2$

Factorization of Exclusive Reactions

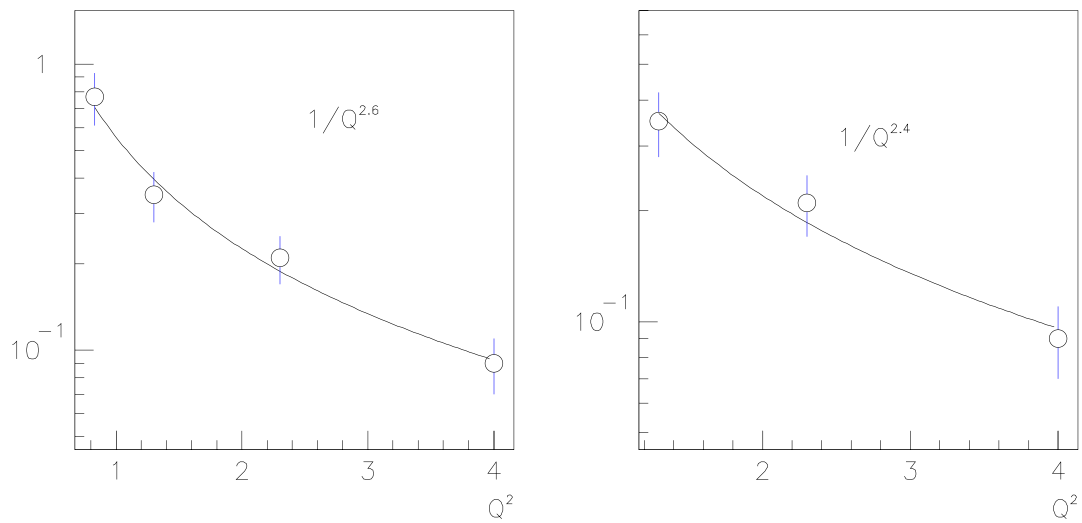


Deeply Virtual Compton Scattering (DVCS)

Real Compton Scattering (RCS)

Deeply Virtual Electroproduction of Mesons (DVEM)

$\gamma^* p \to \rho_L + p$



$\sigma_L(\gamma^* p \to \rho_L + p)$ **vs** Q^2
HERMES
$W = 4.6$ **GeV**

Hard electroproduction of mesons

at large Q^2, with t and x_B fixes

M.I. Eides, L.L. Frankfurt, M.I. Strikman

It seems likely that a precocious factorization into three blocks could be valid already at relatively low Q^2 leading to a precocious scaling of the ratios of the xros sections as a function of Q^2

For the π^0, η ratio on proton we have:

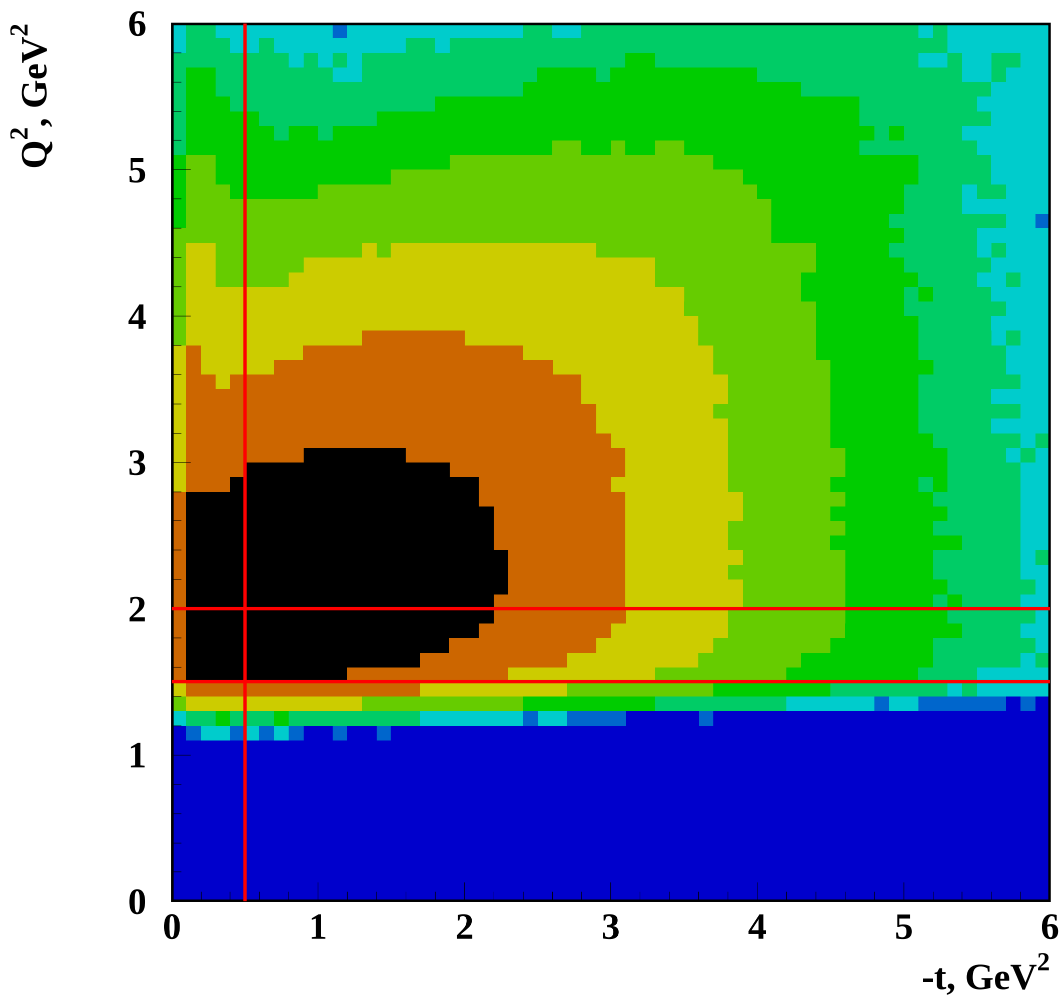
$$\pi^0 : \eta = \frac{1}{2}\left(\frac{2}{3}\Delta u + \frac{1}{3}\Delta d\right)^2 : \frac{1}{6}\left(\frac{2}{3}\Delta u - \frac{1}{3}\Delta d + \frac{2}{3}\Delta s\right)^2$$

Large Momentum Transfer Region

Complementary to the large Q^2 region is the large momentum transfer region $-t \gg 1$ (and $Q^2 < -t$). In this kinematical region Compton scattering of protons factorizes into a hard parton-level subprocesses and a soft proton matrix elements that is described by new formfactors $R(t)$. These formfactors represent $1/x$–moments of GPDs at large momentum transfer.

The same mechanism can be applied to electroproduction of flavor-neutral pseudoscaler ($P = \pi^0,\ \eta,\ \eta'$) and longitudinally polarized vector ($V = \rho^0,\ \omega,\ \phi$) mesons. It factorizes into meson electroproduction off partons and soft proton matrix elements described by the same type of formfactors as appears in Compton scattering. It was shown that that, at large momentum transfer, there is one parton with a large virtuality that couples to the meson and forces the exchange of at least one hard gluon.

e1-6: Q^2 vs $-t$



High t Electroproduction of Mesons

H.W. Huang, P. Kroll

$$\frac{d^4\sigma}{dsdQ^2dtd\phi} \sim \left(\frac{\sigma_T}{dt} + \epsilon\frac{d\sigma_L}{dt} + 2\epsilon cos2\phi\frac{d_{TT}}{dt} + 2(1+\epsilon)cos\phi\frac{d\sigma_{LT}}{dt}\right)$$

$$\frac{d\sigma_L^{\pi^0}}{dt} \sim \left(R_A^{\pi^0}(t)\int_0^1 d\tau\phi_M(\tau)f_0^{(q)}(\tau, s, Q^2, t)\right)^2$$

where $\phi_M(\tau)$ **is the distribution amplitude,** τ **is the fraction of the meson's momentum the valence quark in the meson carries,** $f_0^{(q)} = f(\tau, s, t, u)$ **is parton–level amplitude,** $R(t)$ **is formfactor.**

$$R_A^{\pi^0}(t) \sim (e_u R_A^u - e_d R_A^d)$$

$$R_A^a(t) = \int_o^1 \frac{dx}{x} e^{\hat{a}t\frac{1-x}{2x}}[\Delta q_a(x) - \Delta\overline{q}_a(x)]$$

$\Delta q_a(x)$ **and** $\Delta\overline{q}_a(x)$ **are polarized parton distributions for qurk** a **(**$a = u, d, s$**),** $\hat{a} \sim 1\ GeV^{-1}$

Physics Goals

In exclusive pseudoscalar meson production with high momentum transfer we can probe:

- **the distribution amplitude $\phi_M(\tau)$ of mesons**
- **the parton–level amplitude $f_0^{(q)}$**
- **formfactors $R(t)$ and quark helicity distributions $\Delta q(x)$**

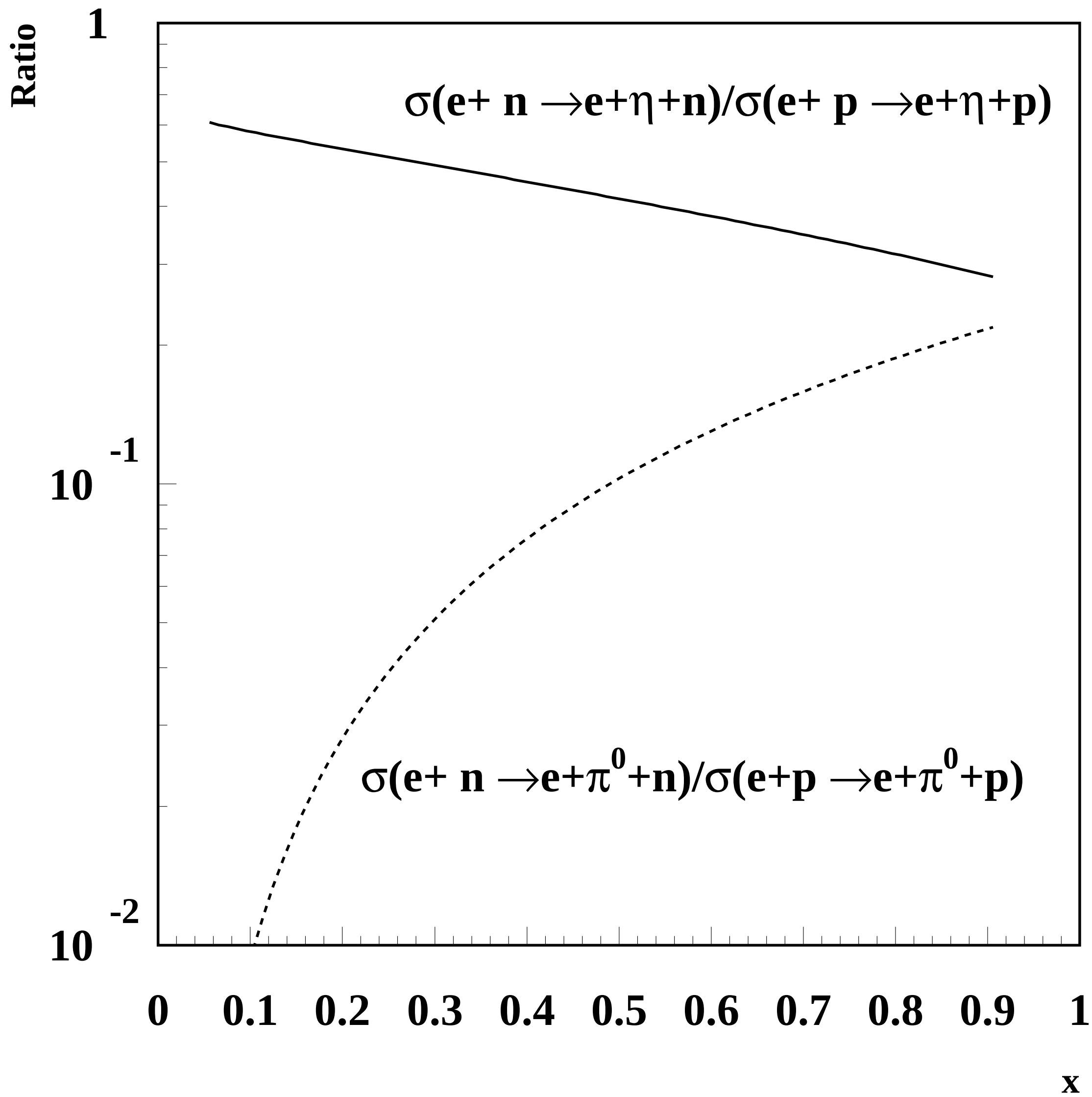
The theory predicts σ_L, σ_T and interference terms. In the kinematical region high Q^2 and low t only σ_L can be predicted.

Observables

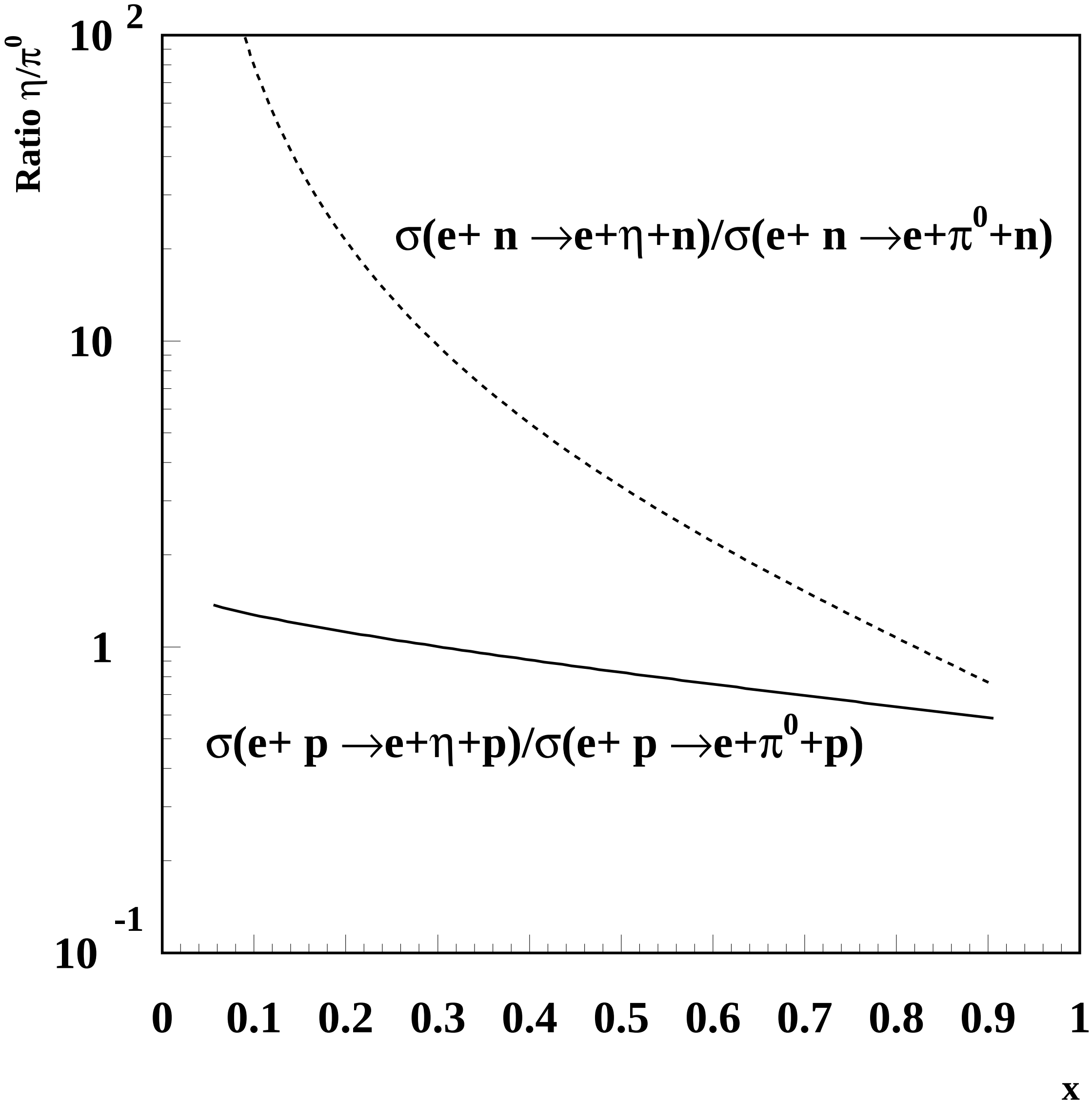
Probe hard exclusive processes in electroproduction of pseudoscalar mesons off the proton and the neutron in a wide kinematical range of Q^2 and t

- **ratios of π^0, η of the deuteron, proton, and neutron.**
- **the t dependence of the π^0 and η production for different Q^2 bins**
- **the Q^2 dependence of the π^0 and η production for different t bins**

Neutron to Proton Ratios for π^0 and η



η to π^0 ratios for Neutron and Proton

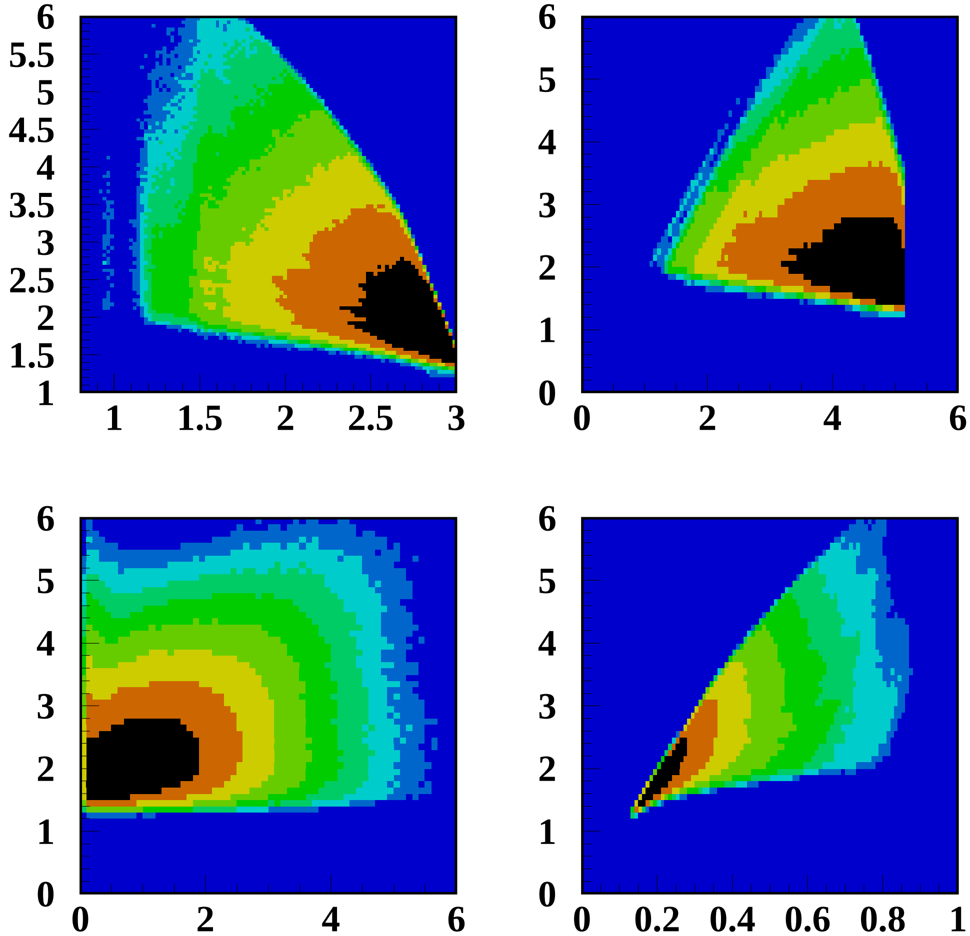


e1-6 Statistics

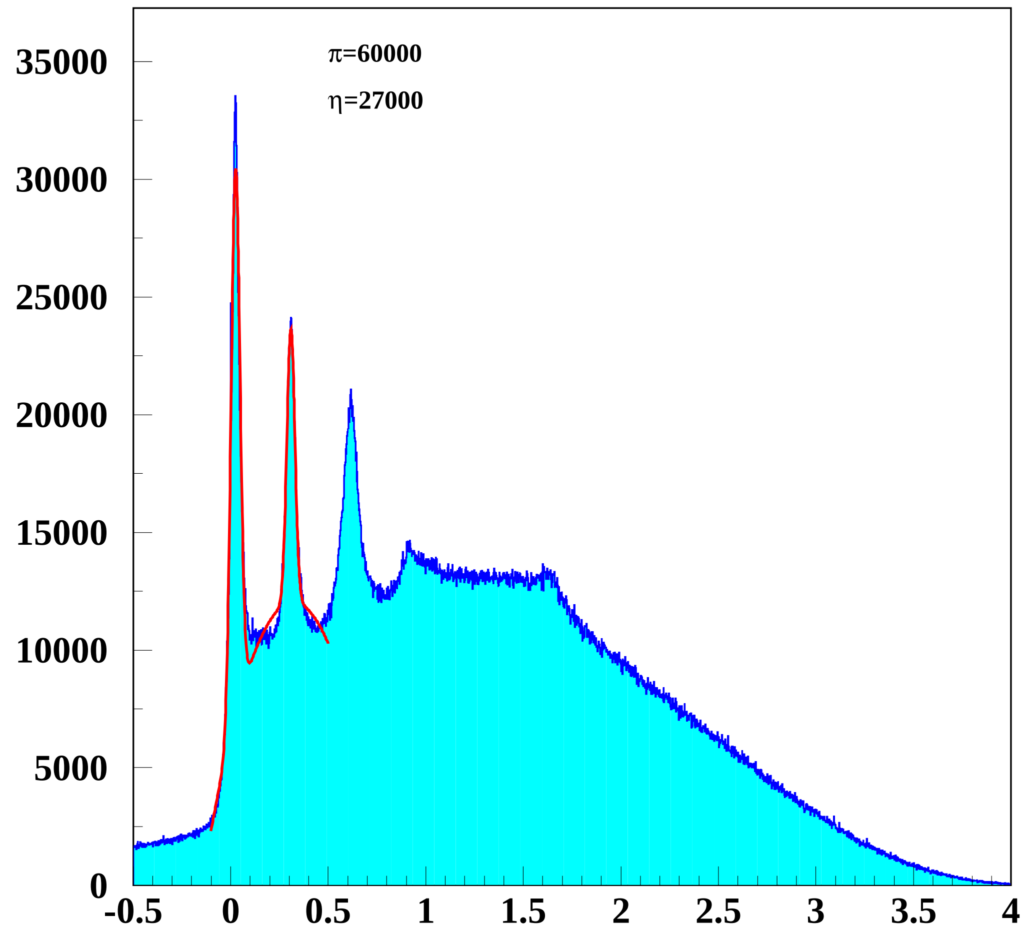
Electron energy	**5.7542**	**GeV**
Total number of files	**9400**	
Total number of events	**3.7**	**billions**

95% of data were analyzed VERY PRELIMINARY
Full GEANT simulation using GSIM.

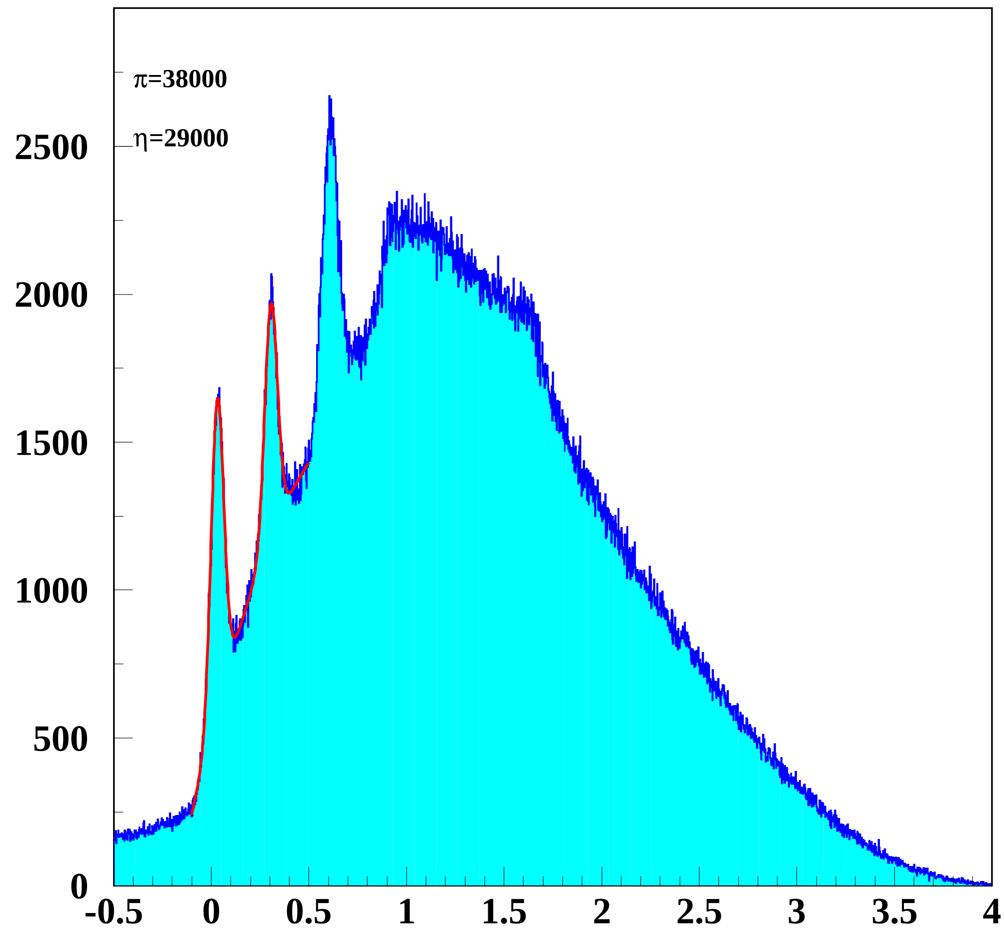
e1-6: Kinematics at 5.76 GeV



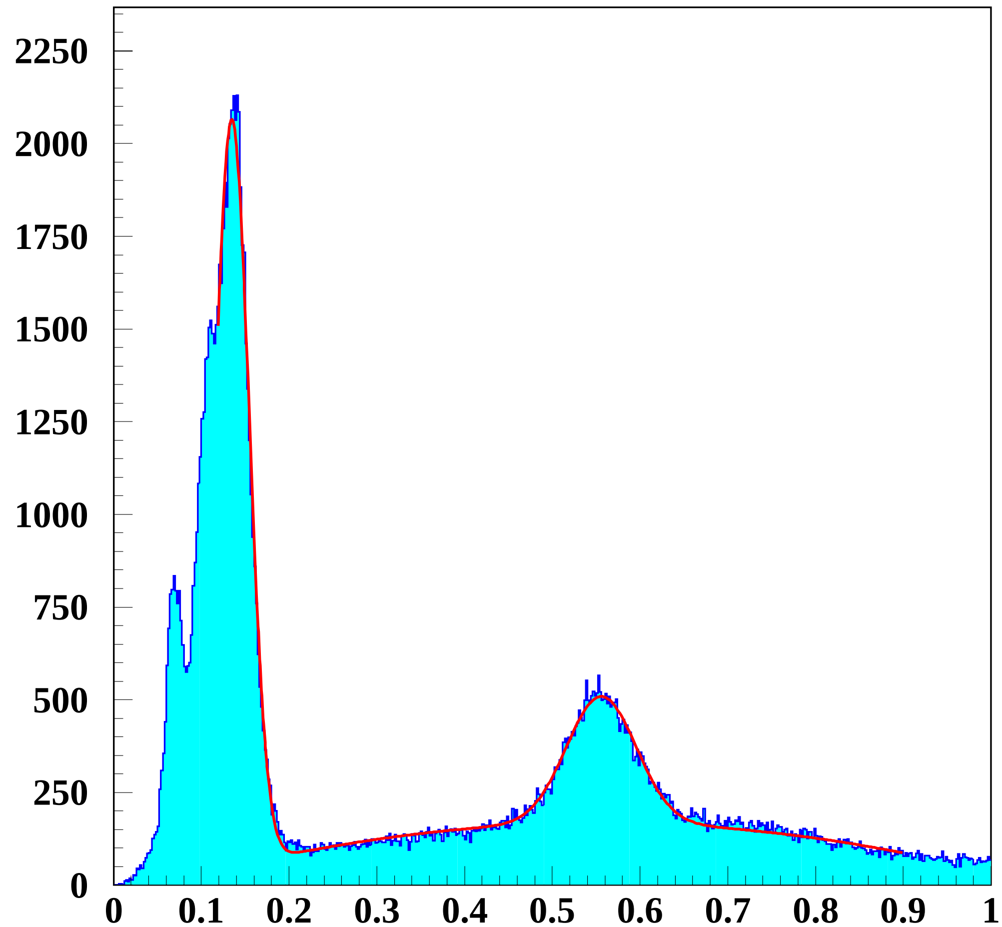
e1-6: M_x^2 spectrum



e1-6: M_x^2 spectrum $W > 2$ GeV

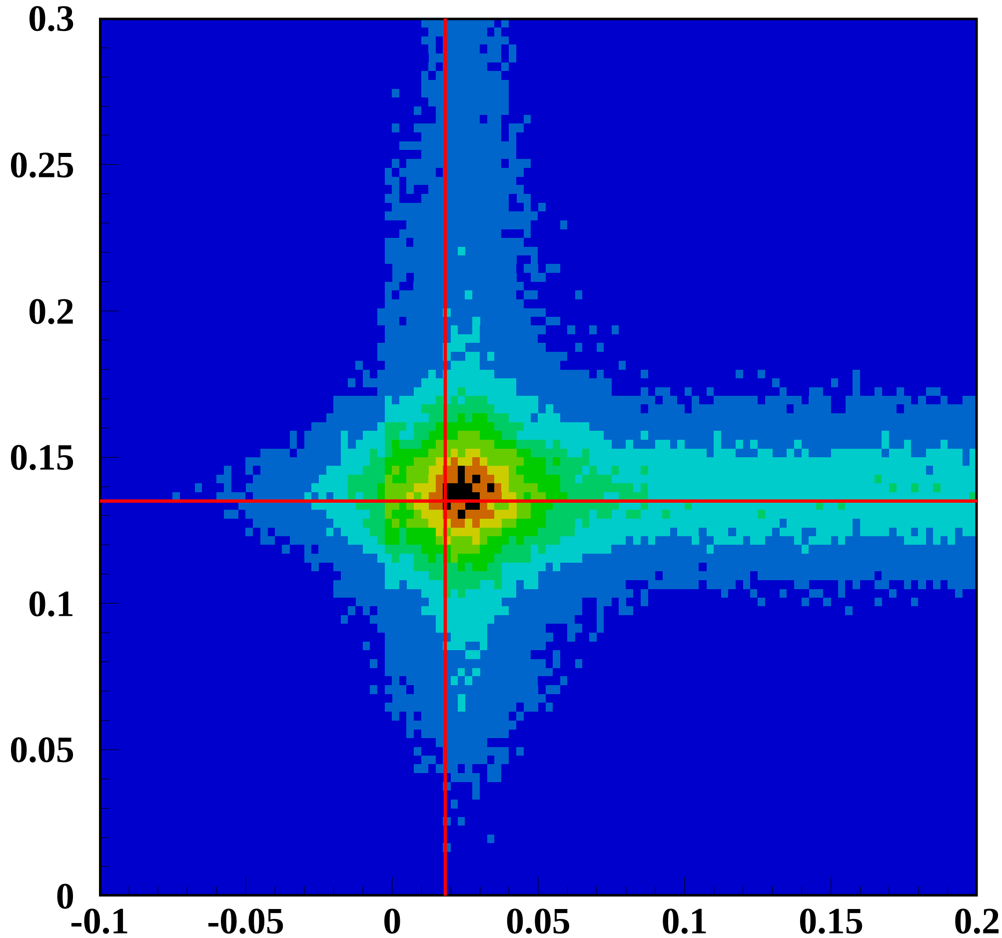


e1-6: $M\gamma\gamma for W > 2GeV$



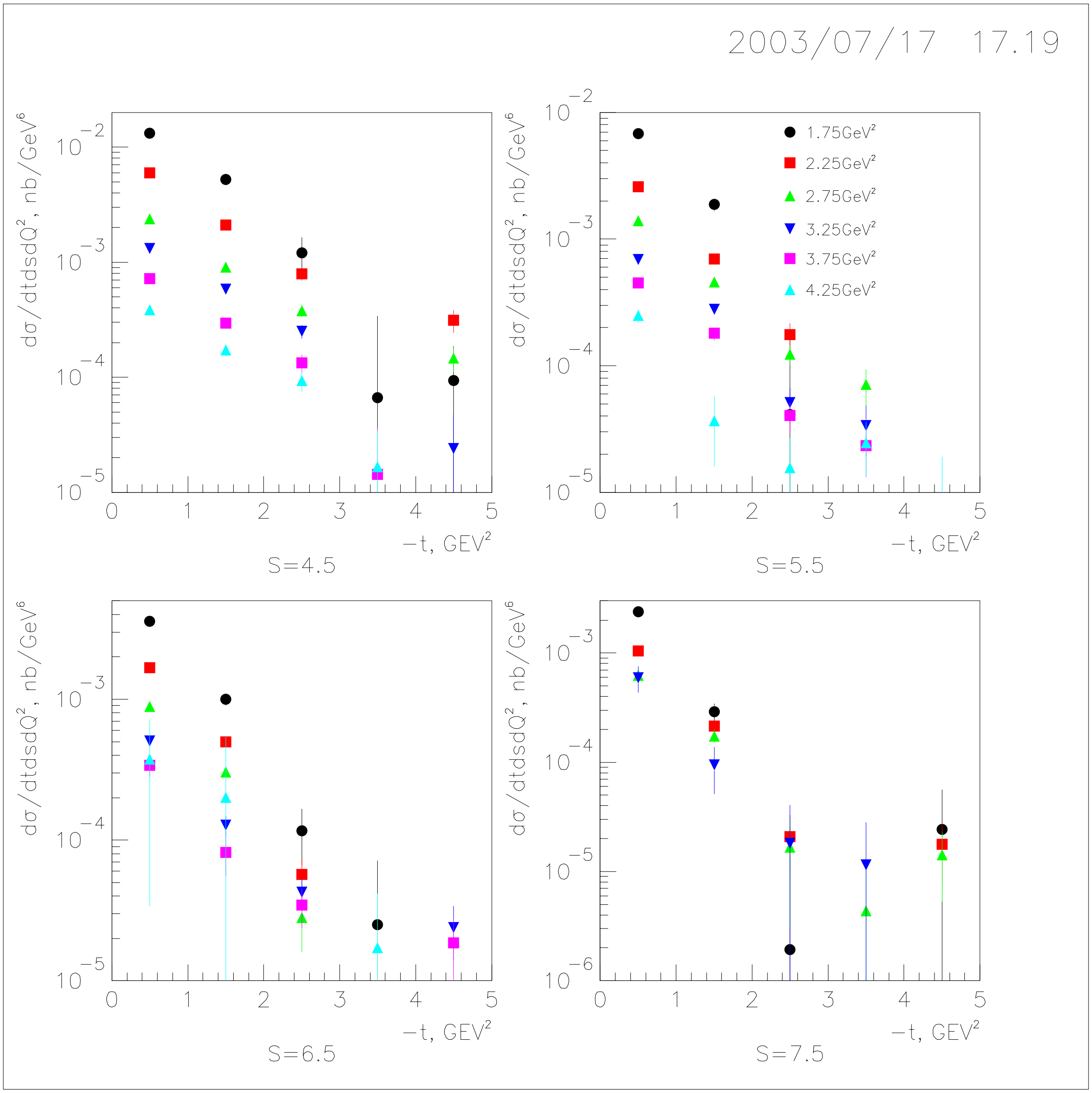
Cuts: $W > 2GeV$
Bethe-Heitler kinematics
Missing energy $<$ 500 **MeV**

$M\gamma\gamma$ vs Mx^2



Cuts: $W > 2GeV$
Bethe-Heitler kinematics
Missing energy $<$ **500 MeV**

$d\sigma^\eta/dtdsdQ^2$



Differential cros section $d\sigma^\eta/dtdsdQ^2$ **for the reaction** $ep \to ep\eta$ **as a function of** $-t$

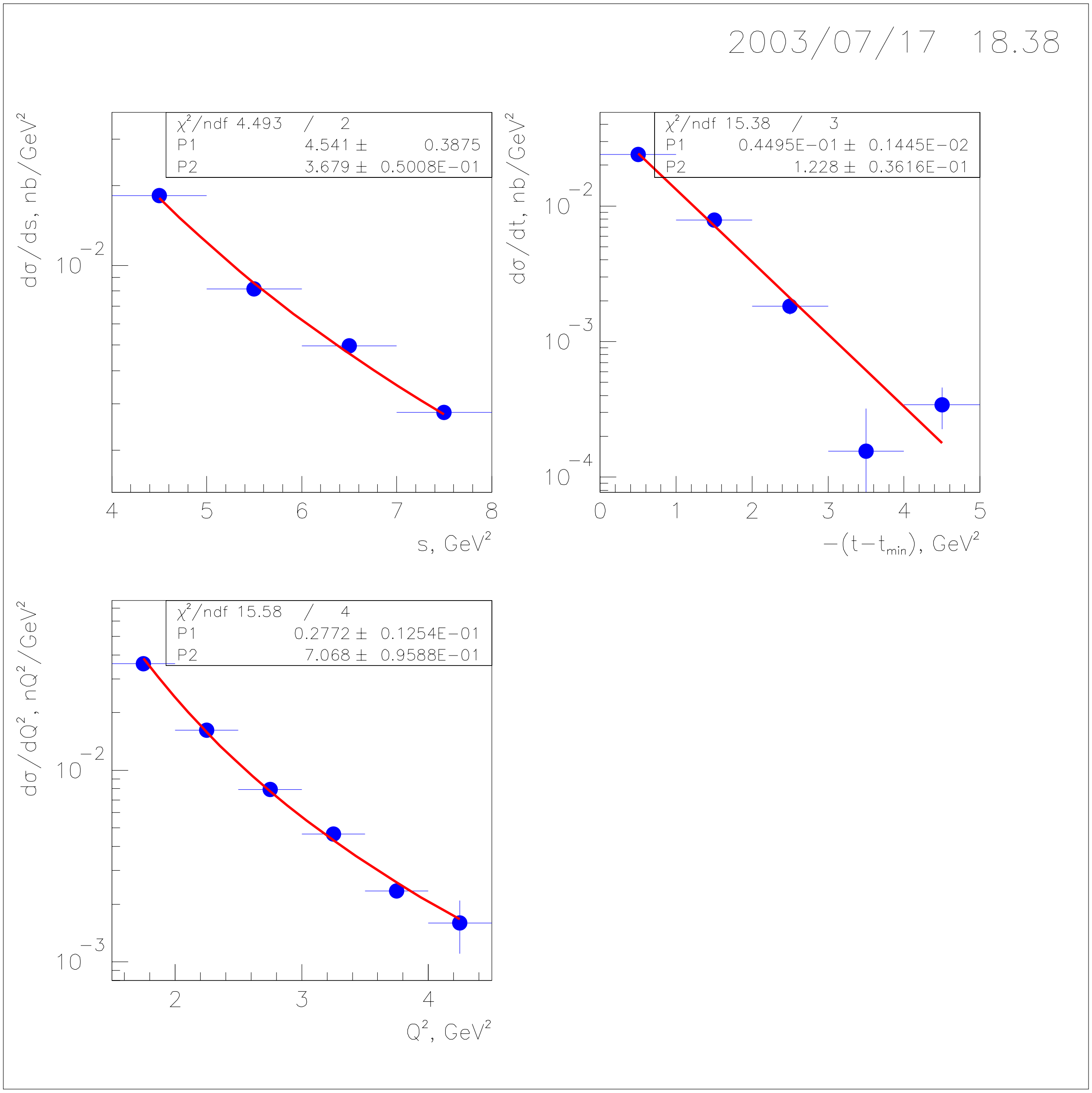
a. $s = W^2 = 4.5\ GeV^2$

b. $s = W^2 = 5.5\ GeV^2$

c. $s = W^2 = 6.5\ GeV^2$

d. $s = W^2 = 7.5\ GeV^2$

Reaction $ep \to ep\eta$

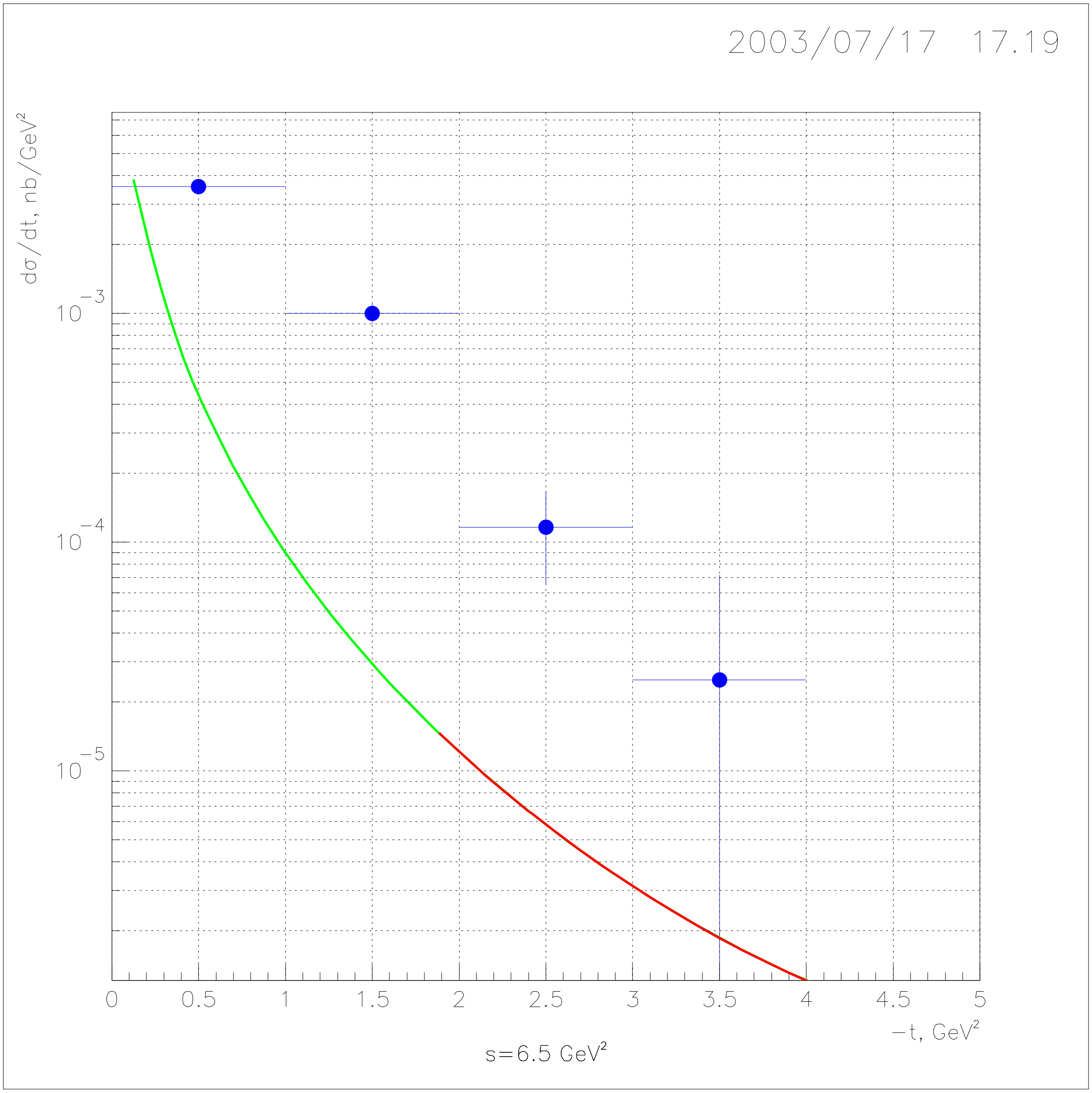


1. $d\sigma/ds \sim 1/s^{3.7}$

2. $d\sigma/dt \sim e^{-1.22|t|}$ $\quad (\sim 1/t^{1.6})$

3. $d\sigma/dQ^2 \sim 1/Q^{7.1}$

Reaction $ep \to ep\eta$



$d\sigma/dsdtdQ^2$ **for the** $s = 6.5\ GeV^2$ **and** $Q^2 = 1.75\ GeV^2$
Theory: Huang, Kroll.

Conclusion

- **e1-6 Data are available for analysis**
- **Direct comparison with theory predictions in the two kinematics regimes for application of GPD's.**
  - **High Q^2, low t - ρ_L production**
  - **Low Q^2, high t - σ_L and σ_T for $\pi^0/\eta/\rho^0$ mesons**
- **The main goal for a moment is to test factorization theorem**
  - **Q^2 and t dependence**
  - **absolute cross sections**
  - **the ratios of cross sections for different particles**

Experimental test of the onset of scaling regime in a broad range of the kinematical variables what can be definitely done at 12 GeV machine.