Exclusive ρ^0 production with the Recoil Detector at HERMES & b-slopes

Avetik Airapetian, Michael Düren,
Roberto Pérez-Benito, Hasko Stenzel , Weilin Yu

II. Physikalisches Institut,
Justus-Liebig-Universität Gießen

On behalf the HERMES Collaboration
74. Annual Meeting and DPG Spring Meeting
Bonn, 15th - 19th of March 2010

JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN

hermes

Outline

- The Spin Structure of the Nucleon

- Generalized Parton Distributions (GPDs)

- Hard meson electroproduction

- Exclusive ρ^0 production at Hermes with the Recoil Detector at Hermes
  - b Slop with & without Recoil Detector

- Outlook

The Spin Structure of the Nucleon

$$S_z = \frac{1}{2} = J_q + J_g = \frac{1}{2}\Delta\Sigma + L_q + J_g$$
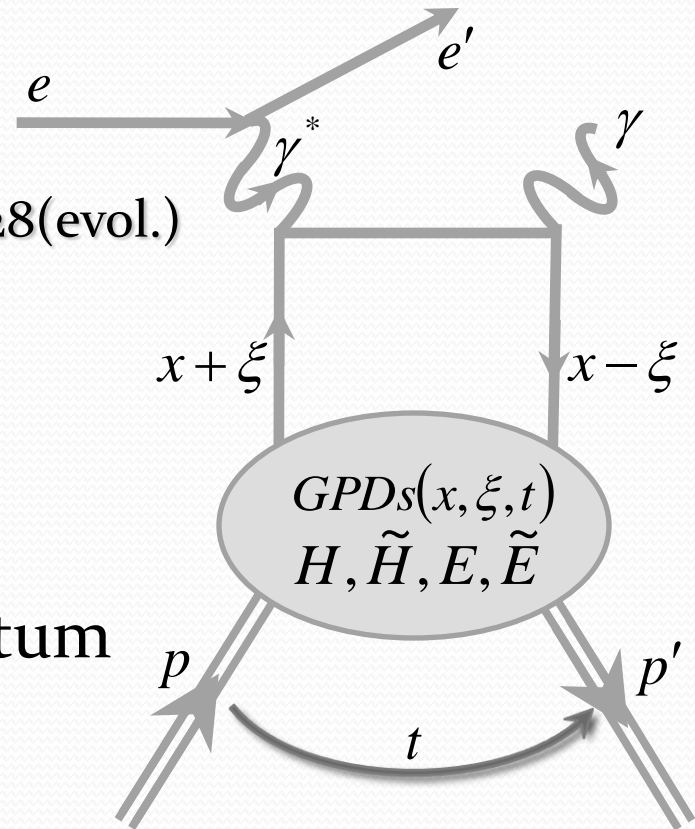
■ $\Delta\Sigma$ Spin of quarks

  ■ $\Delta\Sigma$=0.330±0.011(theo.)±0.025(exp.)±0.028(evol.)

    Airapetian et al. [HERMES Collaboration]

    Phys. Rev. D 75, 012007 (2007)

■ L_q Orbital angular momentum

■ $J_{q,g}$ Total orbital angular momentum

Generalized Parton Distributions

Ji Relation *Ji, Phys. Rev. Lett. 78, 610 - 613 (1997)*

$$J_q = \lim_{t \to 0} \int_{-1}^{1} x\,dx \left\{ H_q(x,\xi,t) + E_q(x,\xi,t) \right\}$$

$$J_g = \lim_{t \to 0} \int_{0}^{1} dx \left\{ H_g(x,\xi,t) + E_g(x,\xi,t) \right\}$$
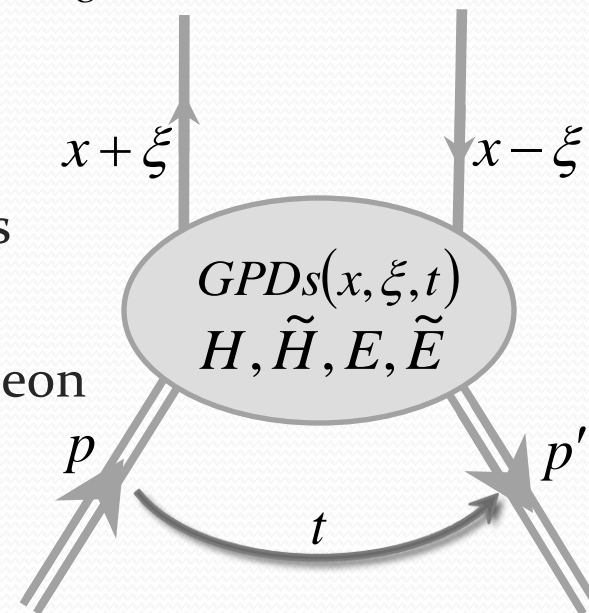
$x \pm \xi$ parton longitudinal momentum fractions

ξ fraction of the momentum transfer

t invariant momentum transfer to the nucleon

$H_q, \tilde{H}_q$ conserve nucleon helicity

$E_q, \tilde{E}_q$ flip nucleon helicity

$x+\xi$ $\quad$ $x-\xi$

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

p $\quad$ p'

t

Hard meson electroproduction

- The quark helicity is conserved in hard scattering process
- The meson acts as a helicity selector:
    - The longitudinally polarized vector meson channels($\rho_L^{0,\pm}$, ω_L, ϕ_L) are sensitive only to the unpolarized GPDs (H and E)
    - The pseudo-scalar channels ($\pi^{0,\pm}$, η, ...) are sensitive only to the polarized GPDs ($\tilde{H}$ and $\tilde{E}$)
- DVCS depends on both, the unpolarized (H and E) and polarized ($\tilde{H}$ and $\tilde{E}$) GPDs.
- Hard meson electroproduction reactions are complementary to the DVCS process, as they provide an additional tool to disentangle the different GPDs.

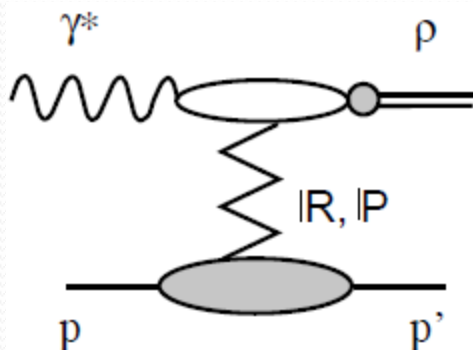*K. Goeke, M V. Polyakov, M. Vanderhaeghen, Prog.Part.Nucl.Phys.47,401-515(2001)*

Advantage of exclusive ρ⁰ production

- the only process where the gluon contribution enters in LO
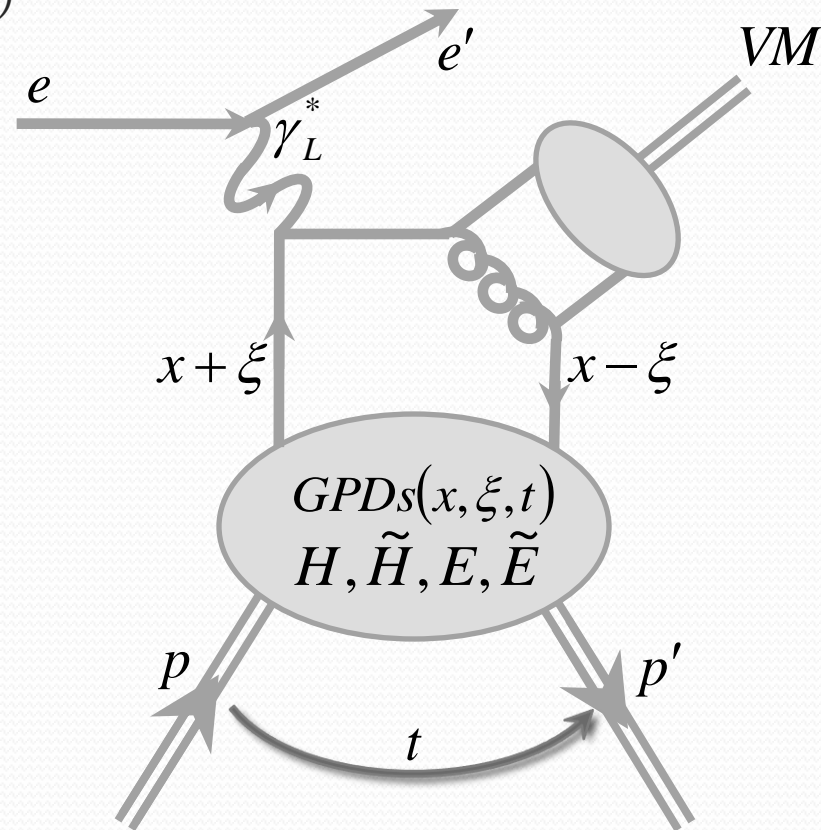- exclusive ρ⁰ sensitive to $H_{q,g}$ and $E_{q,g}$ at the same order in α_s

M. Diehl, A.V. Vinnikov, Phys.Lett.B609,286-290,(2005)
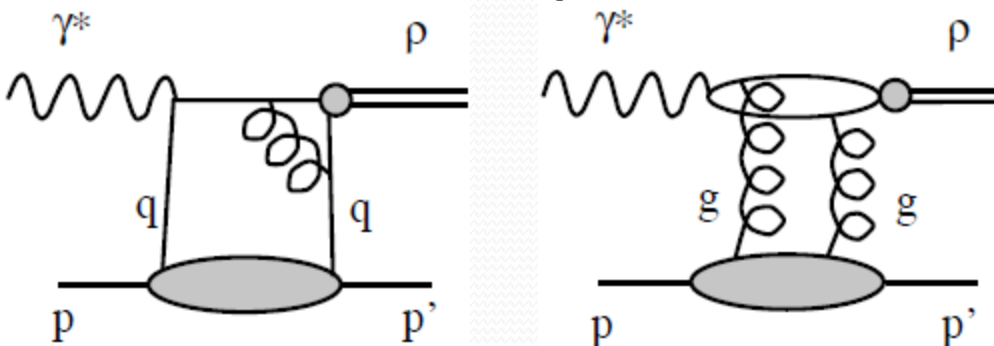
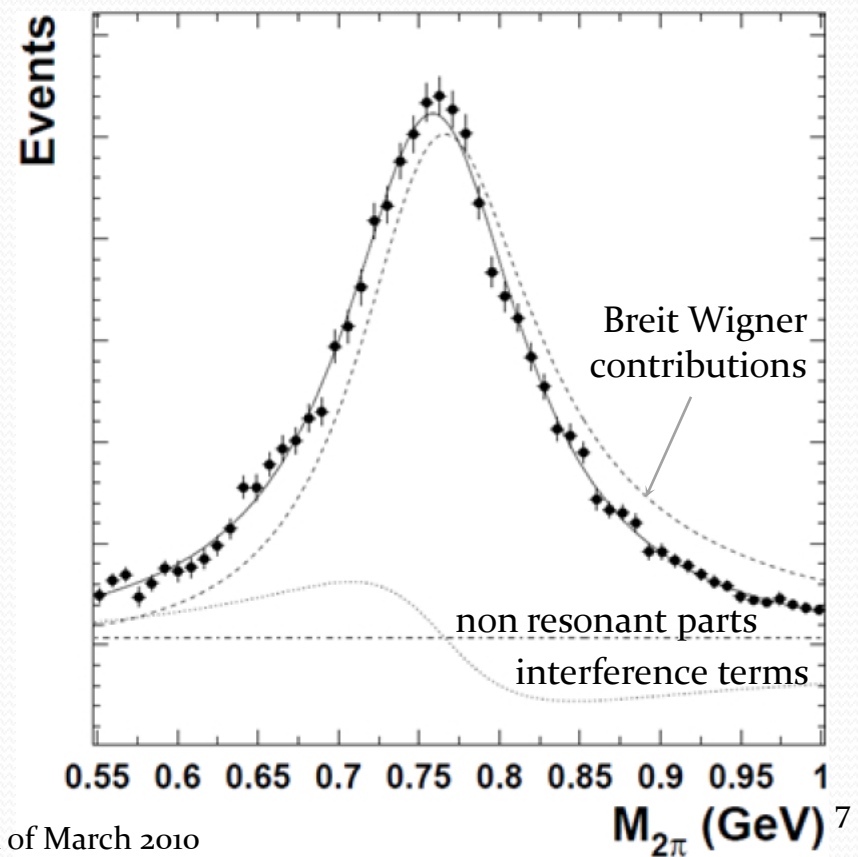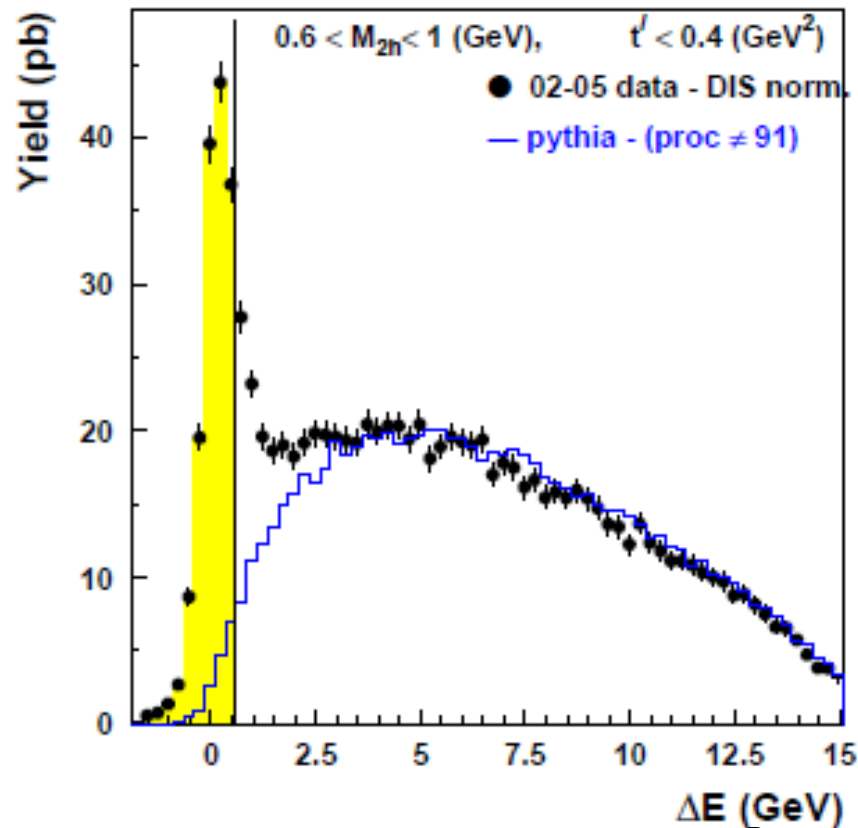quark exchange   two-gluon exchange
models inspired by perturbative QCD

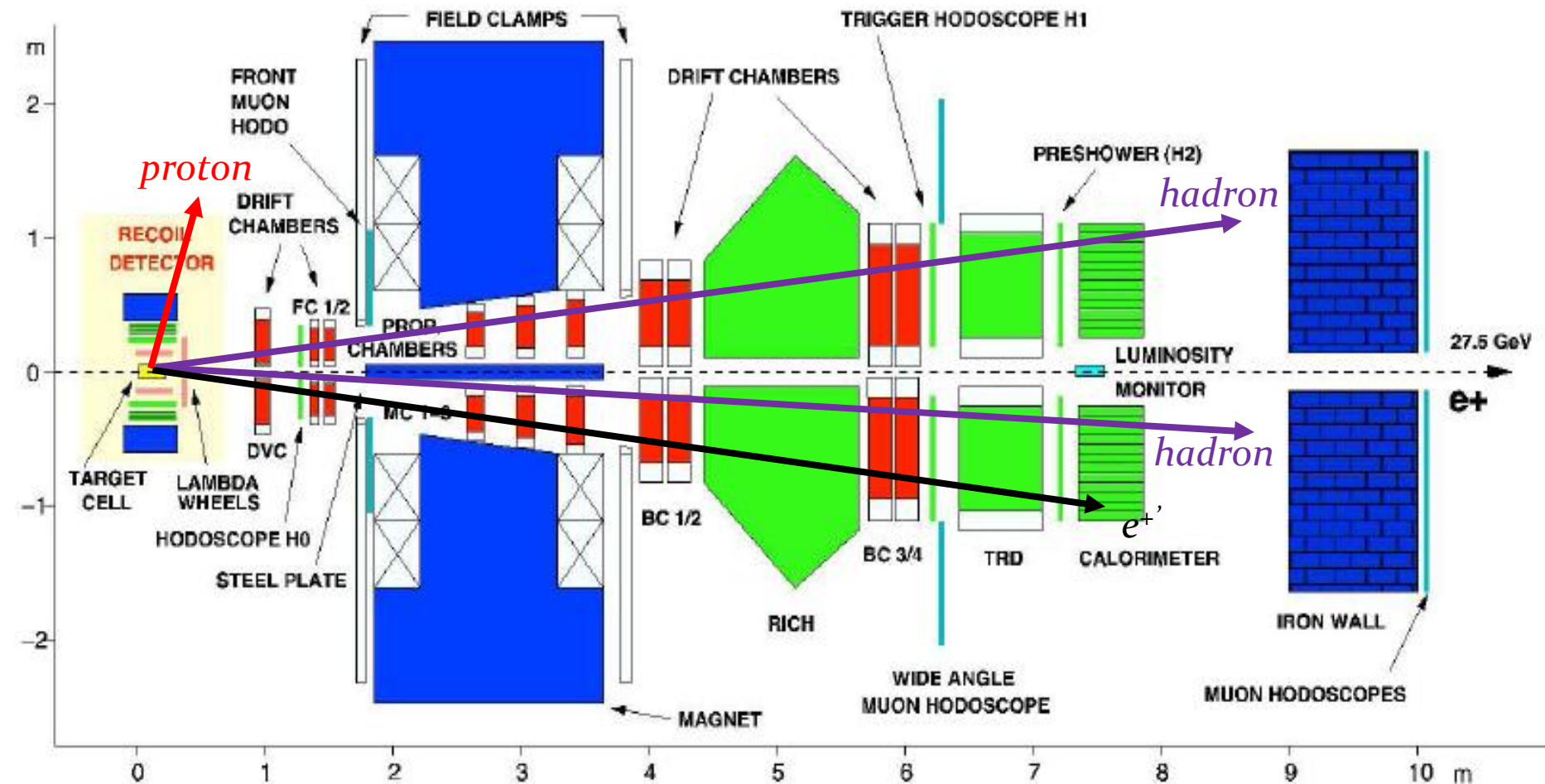Reggeon or Pomeron exchange in
models based on Regge theory

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

Exclusive ρ⁰ production at Hermes

$$ep \rightarrow e'p\rho^0, \rho^0 \rightarrow \pi^+\pi^-$$

- exclusive events: main contribution at small values of
$$\Delta E = E_e + E_p - E_{e'} - E_\rho - E_{p'} \quad \text{and} \quad t' = t - t_0$$
- non-exclusive events ($\Delta E > 0$) contribute due to the experimental resolution and restricted acceptance
- Event produced in non-exclusive processes as an estimate of background size: **11%**
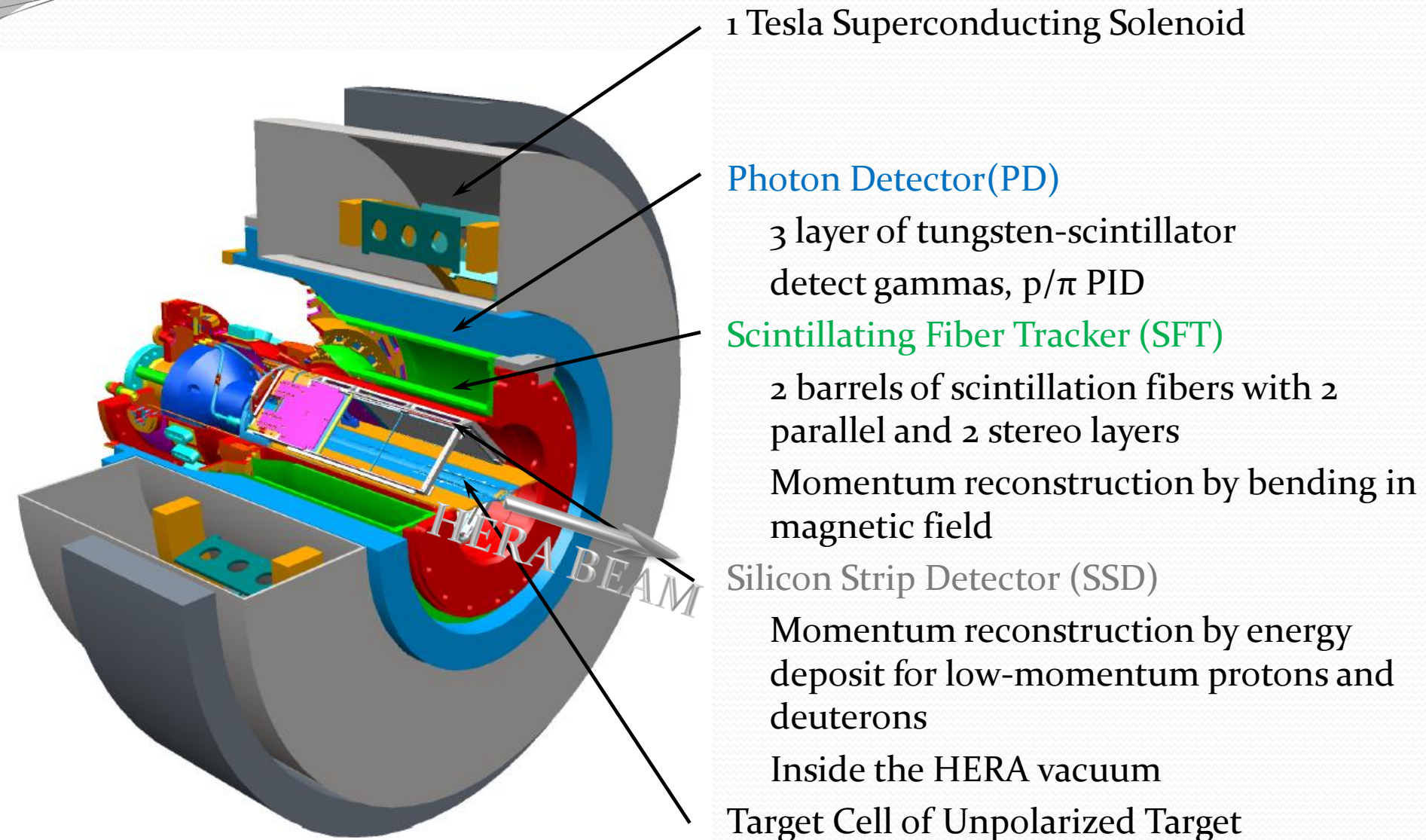

Left plot labels: Yield (pb), $0.6 < M_{2h} < 1$ (GeV), $t' < 0.4$ (GeV^2), 02-05 data - DIS norm., pythia - (proc ≠ 91), ΔE (GeV)

Right plot labels: Events, Breit Wigner contributions, non resonant parts, interference terms, $M_{2\pi}$ (GeV)

Hermes with Recoil Detector

- Unpolarized hydrogen target: **38**Mio DIS
- Unpolarized deuterium target: **10**Mio DIS
- Two beam helicities, electron and positron beam

Recoil Detector at Hermes

1 Tesla Superconducting Solenoid

Photon Detector(PD)

3 layer of tungsten-scintillator

detect gammas, p/π PID

Scintillating Fiber Tracker (SFT)

2 barrels of scintillation fibers with 2 parallel and 2 stereo layers

Momentum reconstruction by bending in magnetic field

Silicon Strip Detector (SSD)

Momentum reconstruction by energy deposit for low-momentum protons and deuterons

Inside the HERA vacuum

Target Cell of Unpolarized Target

ΔE distributions with only Forward Spectrometer

0.6 < M($\pi^+ \pi^-$)< 1.0

1.04 < M(KK)
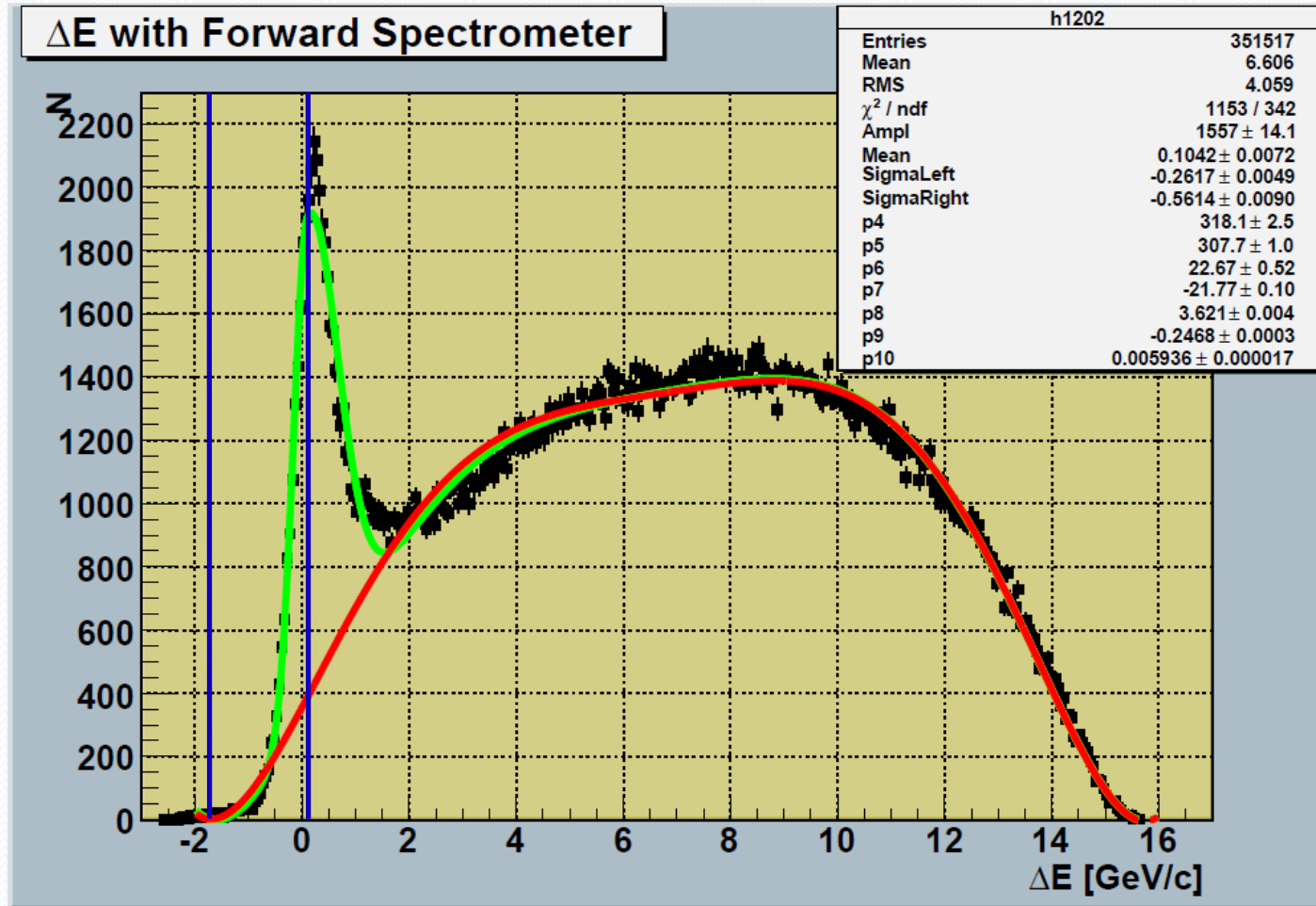
7.0 < Energy of vector meson

3.5 < momentum of lepton

-t' < 0.4

7.0 > q^2 > 0.5

w^2 > 7

y_{bjorn} > 0.85

5cm < Z Vertex < 20 cm

ΔE with Forward Spectrometer

h1202	
Entries	351517
Mean	6.606
RMS	4.059
χ^2 / ndf	1153 / 342
Ampl	1557 ± 14.1
Mean	0.1042 ± 0.0072
SigmaLeft	-0.2617 ± 0.0049
SigmaRight	-0.5614 ± 0.0090
p4	318.1 ± 2.5
p5	307.7 ± 1.0
p6	22.67 ± 0.52
p7	-21.77 ± 0.10
p8	3.621 ± 0.004
p9	-0.2468 ± 0.0003
p10	0.005936 ± 0.000017

ΔE [GeV/c]

-1 < ΔE < 0.6

Bonn, 15th - 19th of March 2010

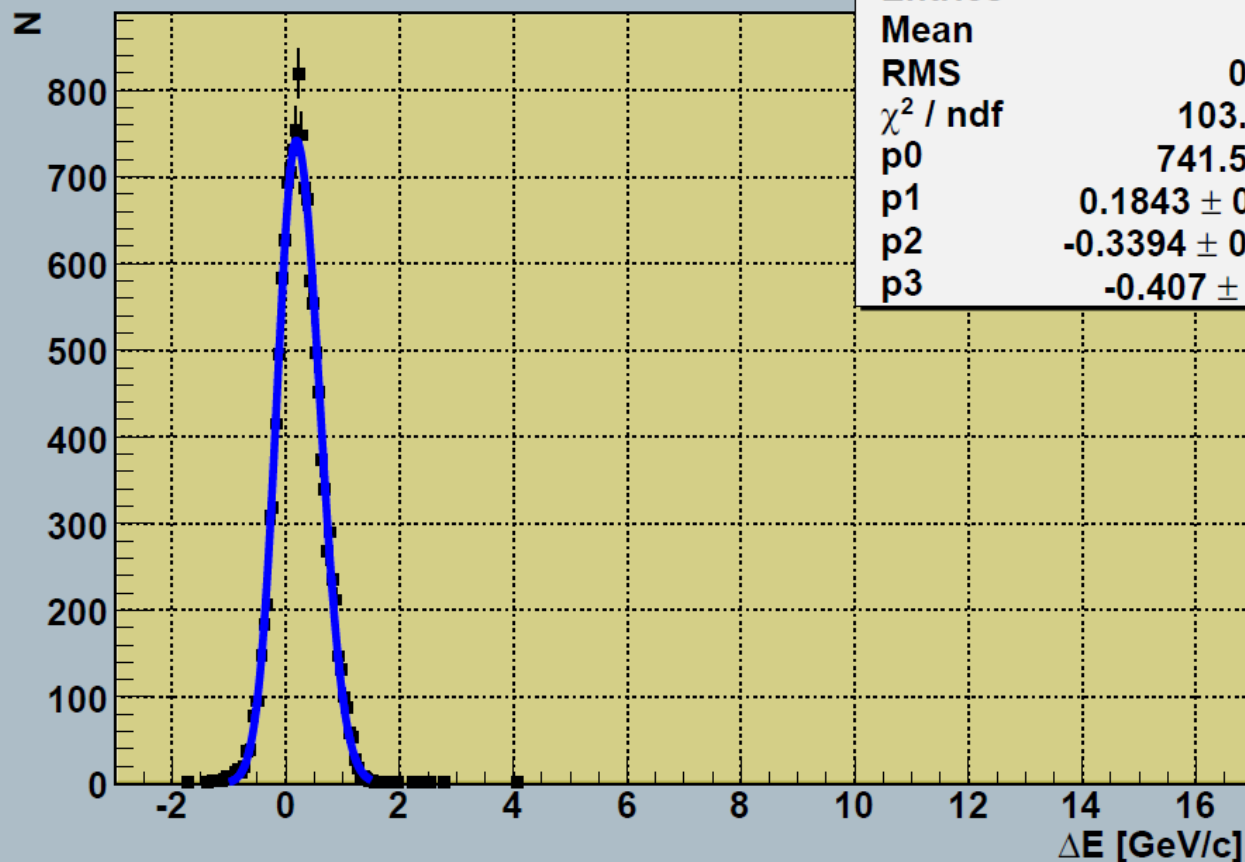# ΔE distributions with cuts on Recoil Protons

0.6 < M(π^+ π^-) < 1.0

1.04 < M(KK)

7.0 < Energy of vector meson

3.5 < momentum of lepton

-t' < 0.4
7.0 > q^2 > 0.5
w^2 > 7
y_{bjorn} > 0.85

5cm < Z Vertex < 20 cm
5cm < Z Vertex Recoil < 20 cm

ΔE with Proton on Recoil Detector	h1201	
Entries		14005
Mean		0.238
RMS		0.3865
χ^2 / ndf		103.2 / 46
p0		741.5 ± 7.8
p1		0.1843 ± 0.0081
p2		-0.3394 ± 0.0055
p3		-0.407 ± 0.005

Cuts on the recoil proton
-1GeV<ΔP< 1GeV
-0.1 rad<Δϕ< 0.1 rad

ρ⁰ mass distributions with cut on Recoil Protons

$0.3 < M(\pi^+ \pi^-) < 1.2$

$1.04 < M(KK)$

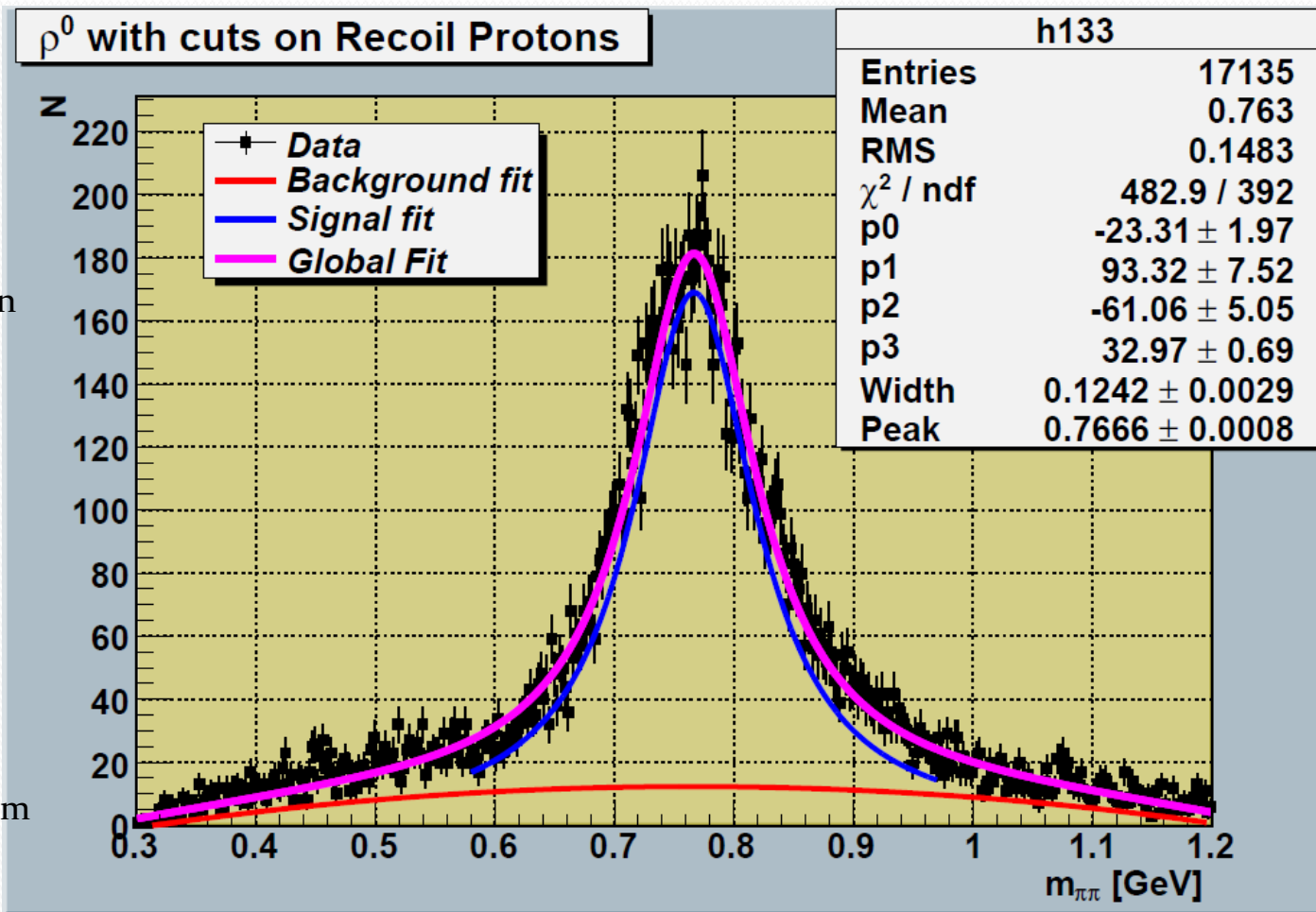$7.0 <$ Energy of vector meson

$3.5 <$ momentum of lepton

$-t' < 0.4$
$7.0 > q^2 > 0.5$
$w^2 > 7$
$y_{bjorn} > 0.85$

$5cm < Z$ Vertex < 20 cm
$5cm < Z$ Vertex Recoil < 20 cm

ρ⁰ with cuts on Recoil Protons

- **Data**
- **Background fit**
- **Signal fit**
- **Global Fit**

h133	
Entries	17135
Mean	0.763
RMS	0.1483
χ^2 / ndf	482.9 / 392
p0	-23.31 ± 1.97
p1	93.32 ± 7.52
p2	-61.06 ± 5.05
p3	32.97 ± 0.69
Width	0.1242 ± 0.0029
Peak	0.7666 ± 0.0008

$m_{\pi\pi}$ [GeV]

Cuts on the recoil proton
$-1GeV < \Delta P < 1GeV$
-0.1 rad $< \Delta < 0.1$ rad

mass ρ(770) = 775.49±0.34 MeV

C. Amsler *et al.* (Particle Data Group), PL B667, 1 (2008)

Bonn, 15th - 19th of March 2010

The slope parameter b is a measure of the transverse size of the $\rho°$ vector meson ($b = 1/3$ ($<r\rho°^2>+<rp^2>$), where $<rp^2>$ is a measure of the transverse size of the proton.
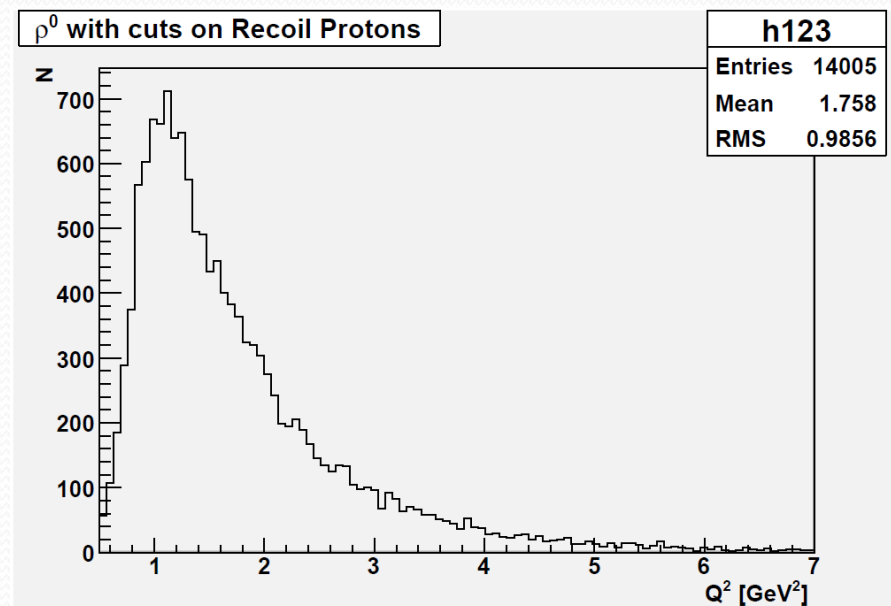
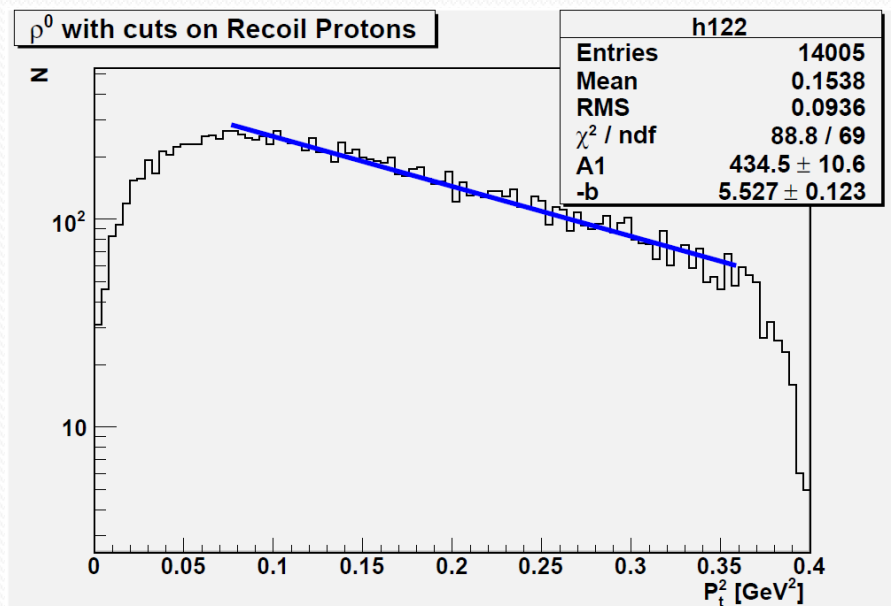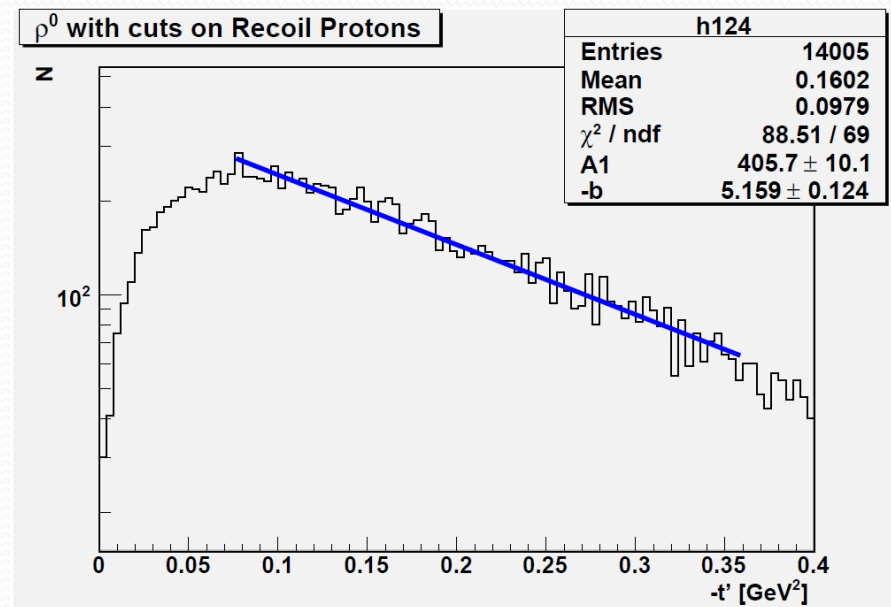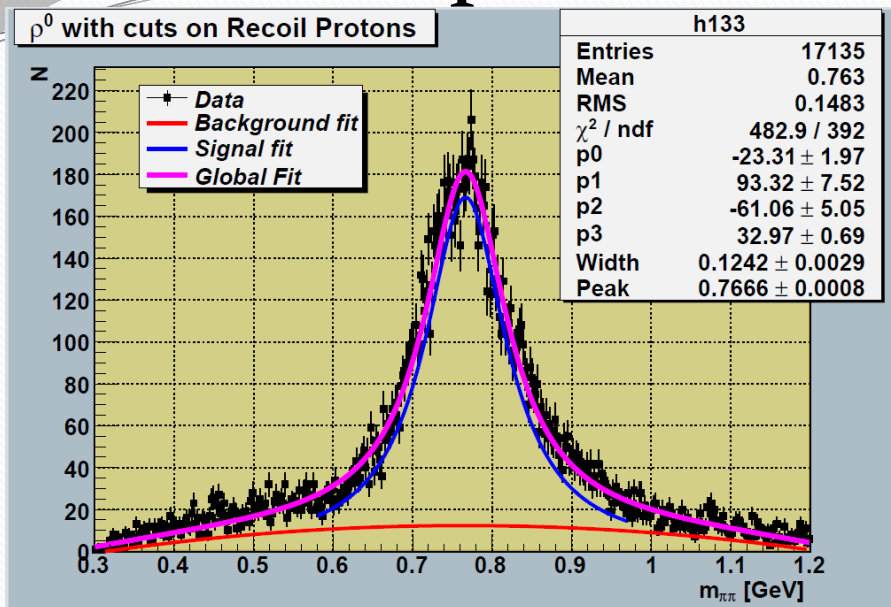*In certain theoretical models, $b(Q^2)$ is needed to check the $-t'$ dependence of GPDsSlope*

Extraction and Separation of Exclusive $\rho_L°$and $\rho_T°$
B.Ball, A. Airapetian, W. Lorenzon, December 13, 2007

b Slop with only Forward Spectrometer
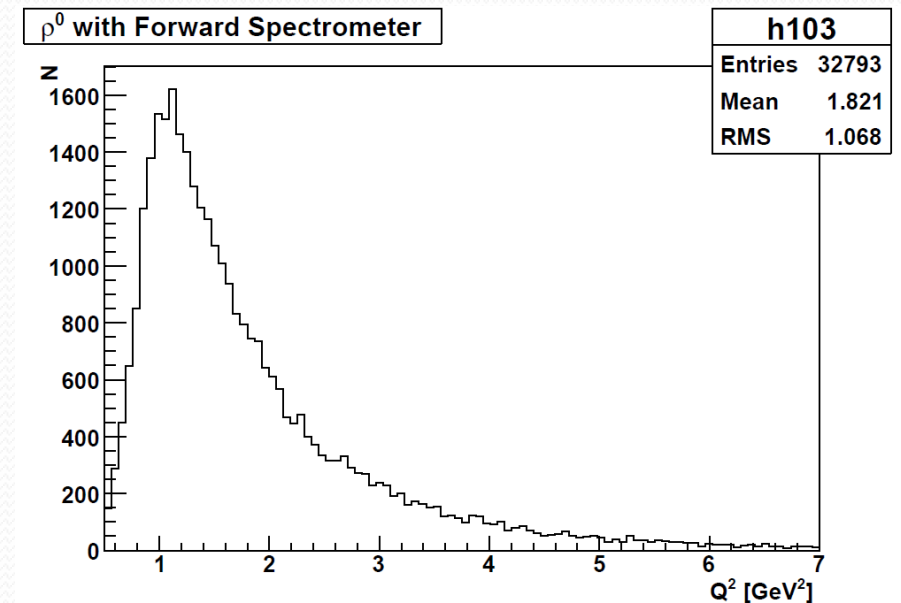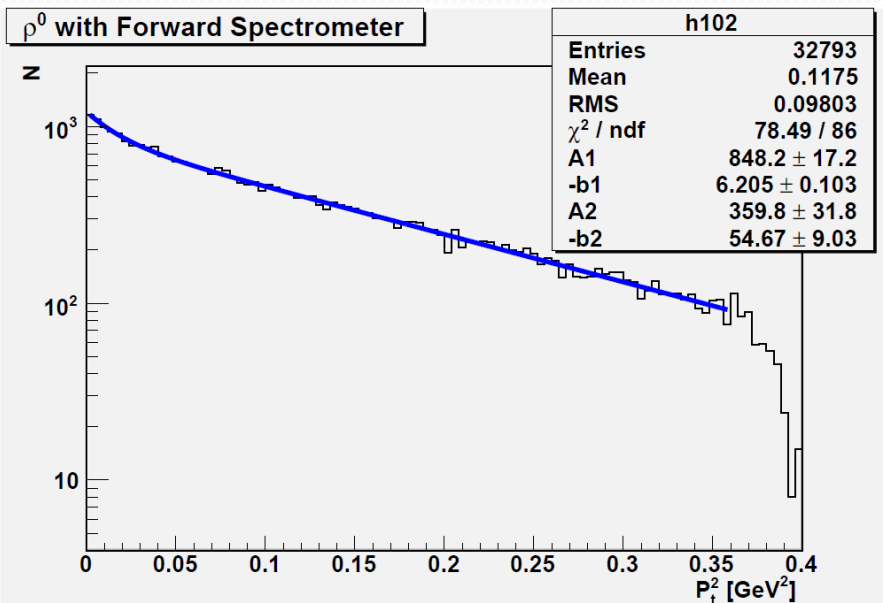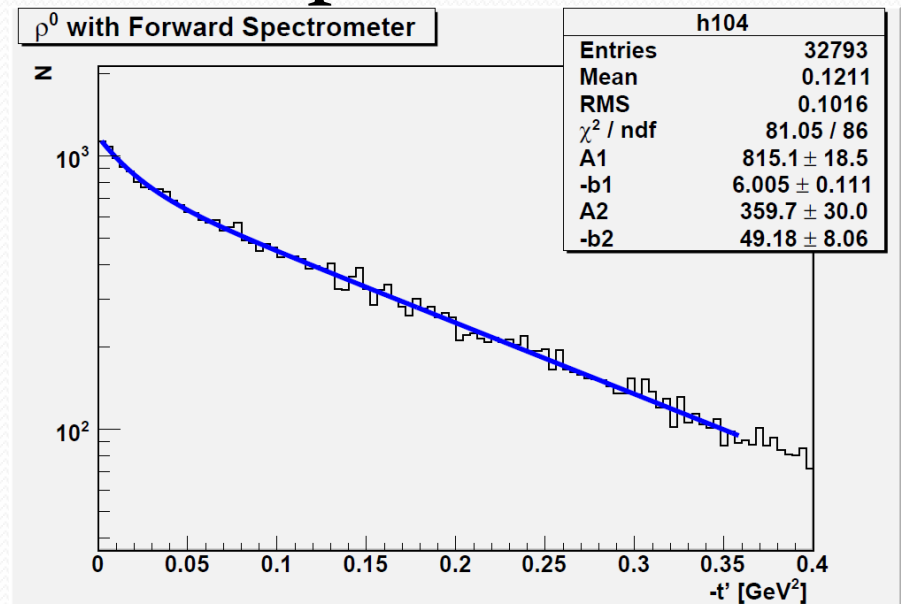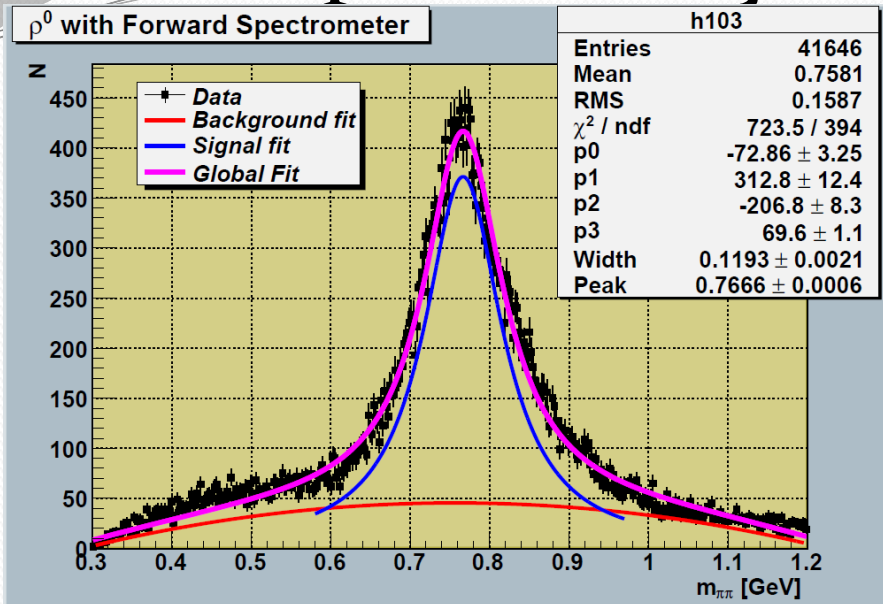
b Slop with cut on Recoil Protons

Summary and Outlook

- New data from Hermes using the Recoil Detector are ready for physics analysis

- Exclusive ρ^0 production with the Recoil Detector

- b slope analysis of exclusive ρ^0 production