Baryon Transition Form Factors at Higher Q^2

At E_e=12 GeV

In Hall C with HMS and SHMS

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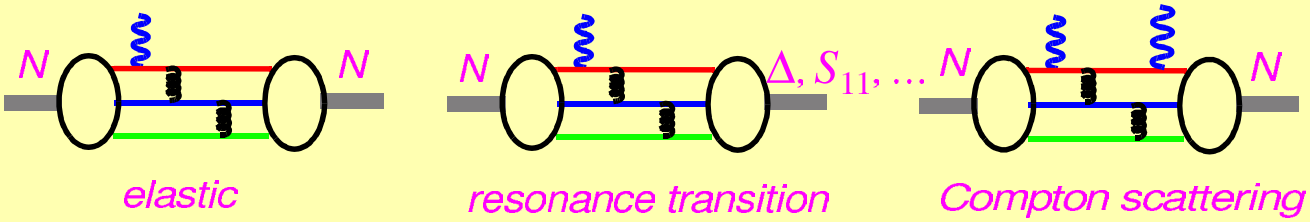
Common Physics Approach

The study of *soft* and *hard* processes in QCD

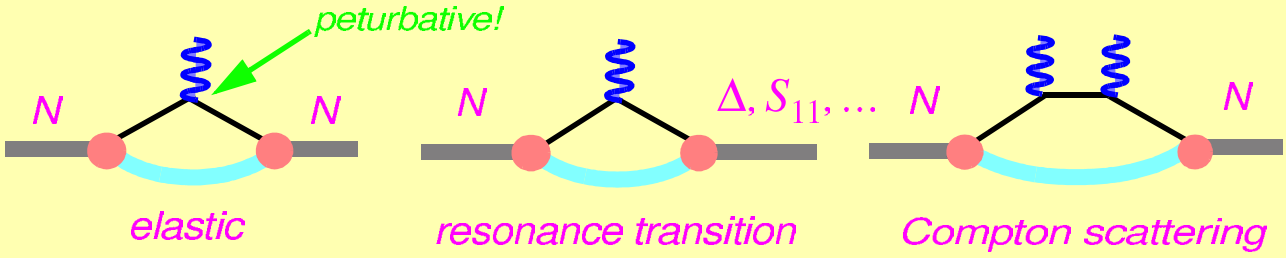
Asymptotically PQCD

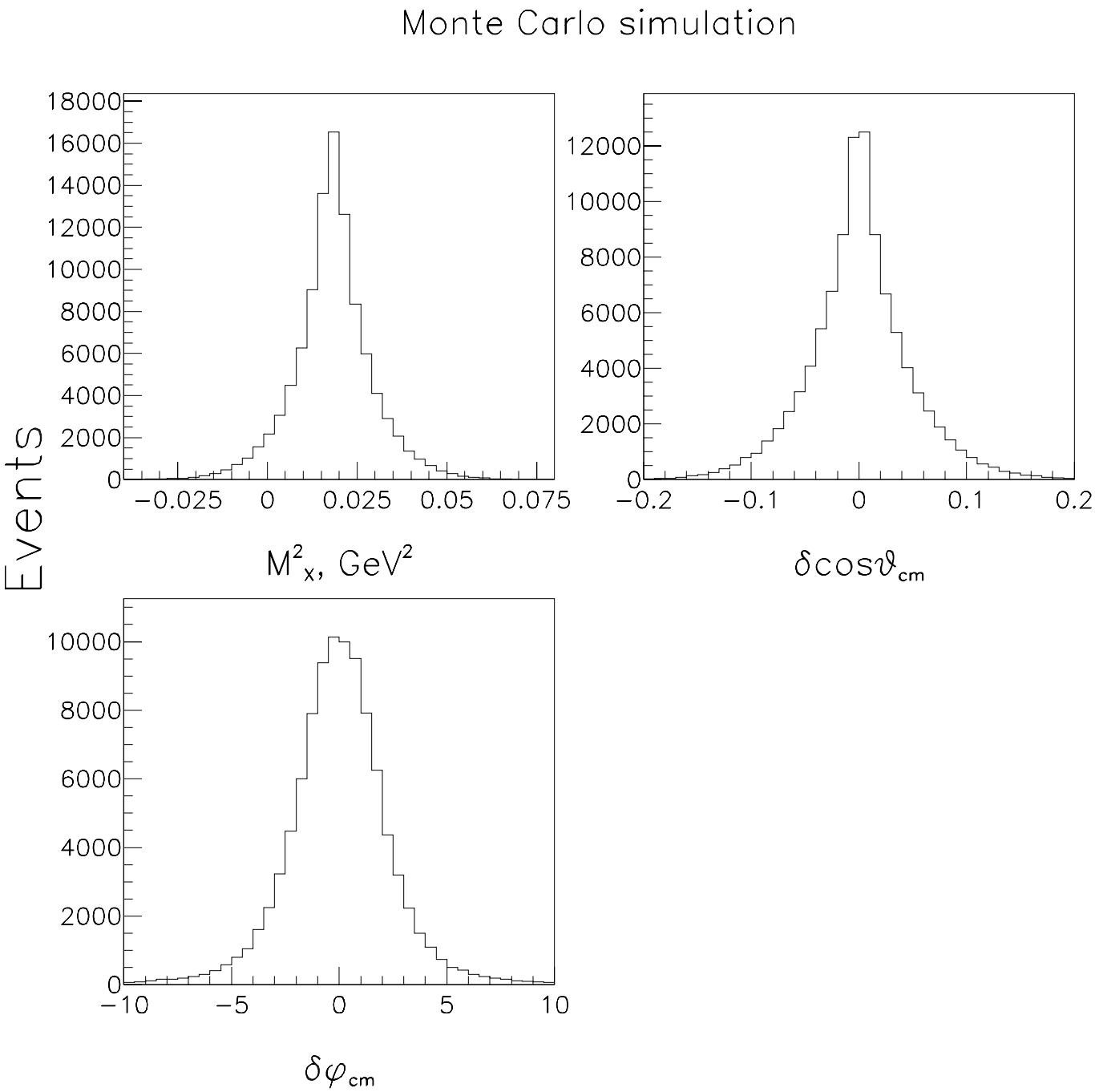
Hard: Leading order Fock states.
Valence pQCD.

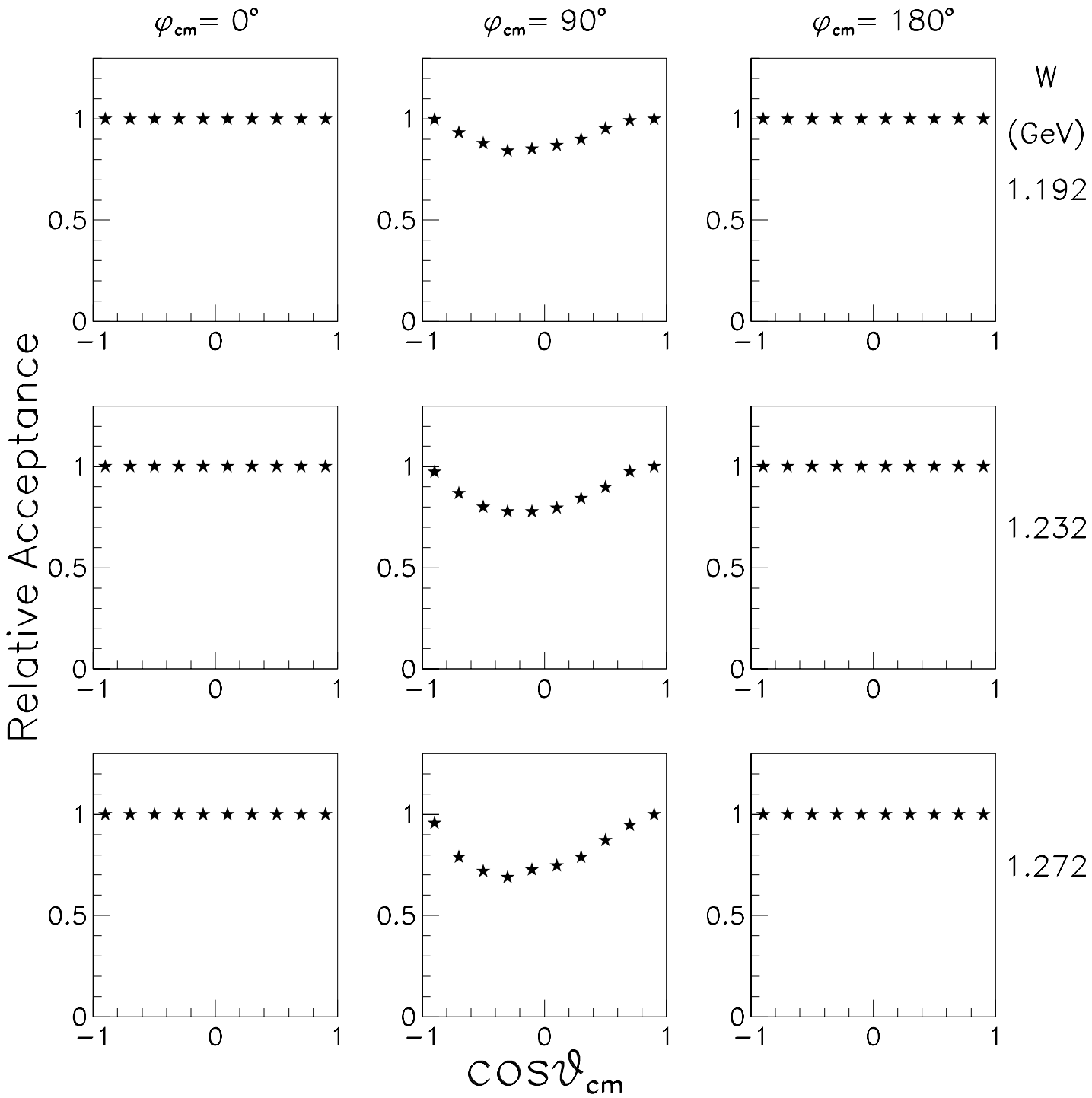


Pre -asymptotically GPD

Soft: Fully complex Fock states states.
Feynman mechanism.




Monte Carlo simulation
Events
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
−0.025
0
0.025
0.05
0.075
M²x, GeV²
12000
10000
8000
6000
4000
2000
0
−0.2
−0.1
0
0.1
0.2
δcosϑcm
10000
8000
6000
4000
2000
0
−10
−5
0
5
10
δφcm


φ_{cm}= 0°
φ_{cm}= 90°
φ_{cm}= 180°
W
(GeV)
1.192
1.232
1.272
Relative Acceptance
$\cos\vartheta_{cm}$
0
0.5
1
−1
0
1

Extrapolation for JLAB at Higher Energies.

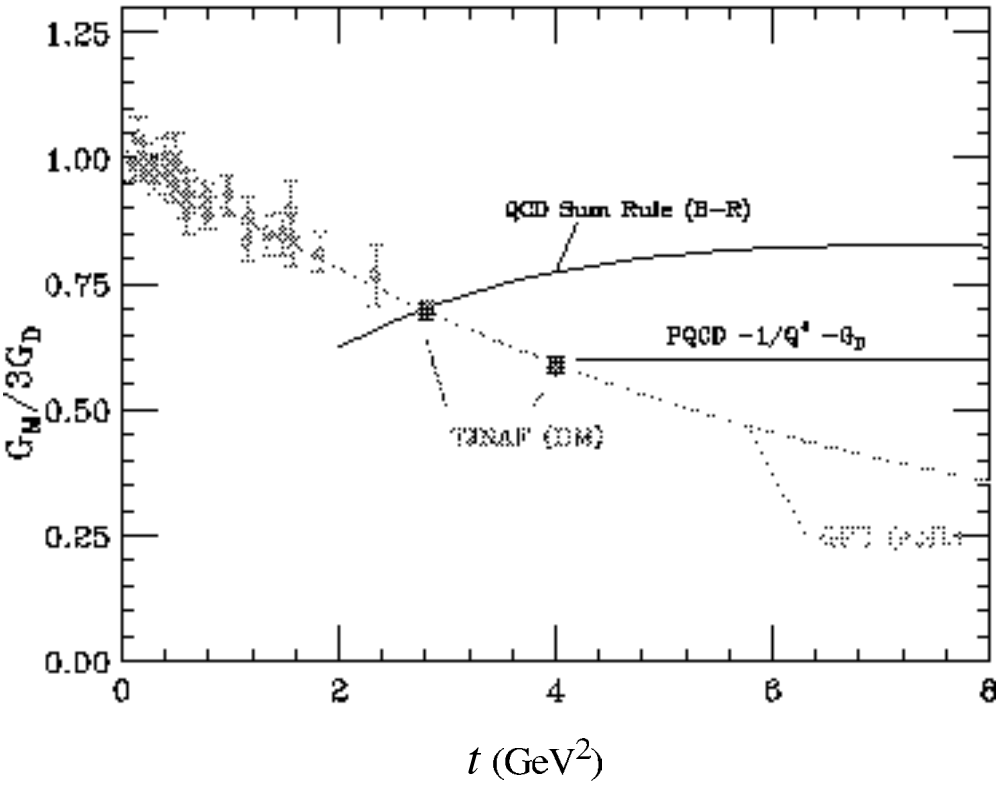
$\Delta(1232)$ $p(e,e'p)\pi^0$ $Q^2 \sim 10$ GeV^2/c^2

E_{beam}	I_{max}	Target	beam time	proton detector	electron detector
10 GeV	100 μA	4cm LH	30 days	HMS I	HMS II

Assumptions:

- $L = 1 \times 10^{38}$ cm^{-2}s^{-1}
- $\Delta E_p \Delta\Omega_p = \Delta E_e \Delta\Omega_e = 0.03$ GeV $\times 0.7$ msr
- Resolutions $\delta p/p \approx 1 \times 10^{-3}$ $\delta\theta = \delta\varphi = 1$mr
- 10 settings for proton arm
- Overall acceptance (MC) = 0.93
- $\frac{d\sigma}{d\Omega_p}^{*} = 2.5\ \mu b \left(\frac{G_D(4)}{G_D(10)}\right) f(Q^2)$
- $\dot{n} \approx 5 \times 10^{-2}$ ev/sec $\approx 1 \times 10^{4}$ ev/ 600 hrs

$$G^*_M(N-\Delta)$$



$$F_{n\Delta}(t) = \sum_q e_q \int_0^1 H^3_{n\Delta}(\xi, x, t)dx$$

$$\Psi_p(x, k_\perp) = \Phi_p(x) e^{-k_\perp{}^2/2x\bar{x}\lambda_p^2} \qquad \Psi_\Delta(x, k_\perp) = \Phi_\Delta(x) e^{-k_\perp{}^2/2x\bar{x}\lambda_\Delta^2}$$

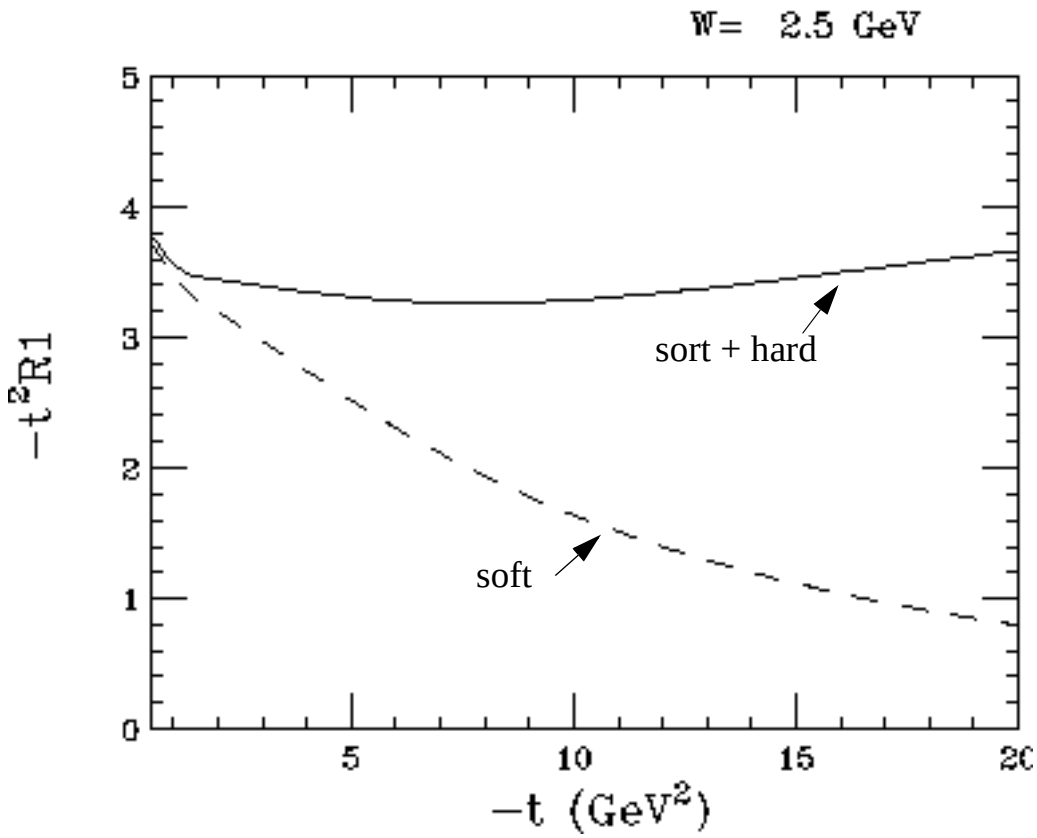
$$H^3_{n\Delta}(x, t) \sim \int \Psi_P(x, k_\perp)\Psi_\Delta(x, k_\perp)dk_\perp = f_{n\Delta}(x) e^{-\bar{x}t^2/4x\lambda^2_{n\Delta}}$$

$$\lambda^2_{n\Delta} = \lambda^2_n + \lambda^2_\Delta \approx 0.4 \text{ GeV2} \Rightarrow (k_{\perp n\Delta})_{RMS} \approx 180 \text{ MeV}$$

power law (hard)

Wide Angle Compton Scattering

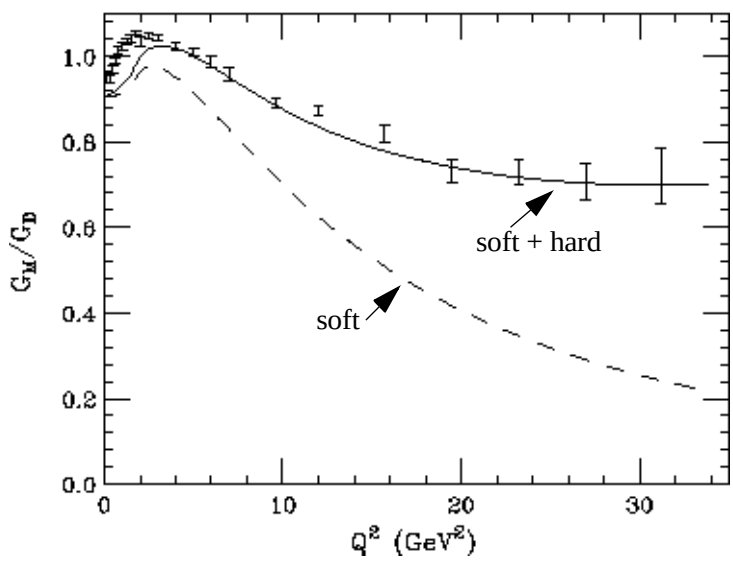
$$R_1(t) = \sum_q e^2 q \int_{-1}^{1} H^q(\xi, x, t) \frac{dx}{x}$$

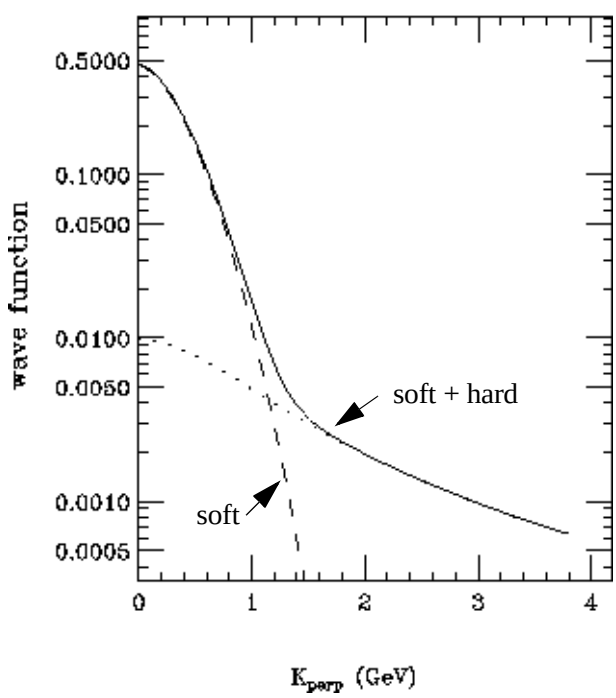


$$\Psi = A\phi(x)\left(e^{-k_\perp^2/(2x\bar{x}\lambda^2)} + A_H \frac{x\bar{x}}{k_\perp^2/\Lambda^2 + 1}\right)$$

$$\phi^2(x) = \frac{2}{3} f_u(x) + \frac{1}{3} f_d(x)$$

A_S=1 A_H=0.08 Λ = 0.35 GeV λ^2 = 0.62 GeV^2



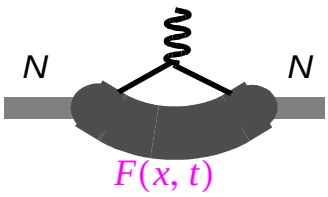


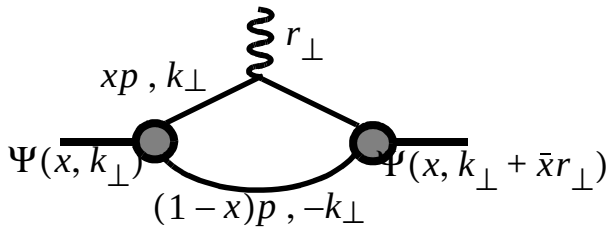
$$\Psi = A\phi(x)\left(e^{-k_\perp^2/(2x\bar{x}\lambda^2)} + x\bar{x}A_H\frac{1}{k_\perp^2+m^2}\right)$$

$$\phi^2(x) = \frac{2}{3}f_u(x) + \frac{1}{3}f_d(x)$$

A=.22 A_H=0.3A m=0.35 GeV $\lambda^2 = 0.7$ GeV^2

Two body model (A. Radyushkin)





Dirac form factor: $$F_1(t) = \sum_q e_q \int_0^1 F(x, t)\, dx$$

Generalized Parton Distribution: $$F(x, t) \sim \int \Psi(x, k_{\perp i}) \Psi(x, k_{\perp f})\, dk_\perp$$

Soft wave function: $$\Psi(x, k_\perp) = \Phi(x) e^{-k_\perp{}^2 / 2x\bar{x}\lambda^2}$$

Soft plus hard $$\Psi = A\phi(x) \left(e^{-k_\perp^2 / (2x\bar{x}\lambda^2)} + x\bar{x} A_H \frac{1}{1 + k_\perp^2 / \Lambda^2} \right)$$

What can we learn?

Wave function of nucleon $\psi(x, k_\perp)$

Observables:

$$DIS \rightarrow |\psi(x)|^2 \quad \text{probability distributions.}$$

$$Exclusive \rightarrow \psi^*(x, k_\perp) \bullet \psi'(x-\zeta, k_\perp) \leftarrow GPD$$

- Map out *transverse* and *longitudinal* parton distributions and model wave functions
- Correlations of quark gluonic matter vs increasing $k_\perp$

Form Factors and GPD's ?

-GPD's are the best hope for modeling parton distributions at accessible kinematic regions

-Form factors are simply related to GPD moments

-Form factors are related to parton k_perp distributions

Nucleon Elastic scattering:
Wide angle Compton scattering:

$$F_1,\ F_2 \text{ or } G_M,\ G_E \longleftrightarrow H,\ E$$

Delta Resonance:

(isovector components)

$$G^*_M,\ G^*_E \longleftrightarrow H_{T3},\ E_{T3}$$

$N \to \Delta$ Resonance Form Factors

$$G_M^*(t) = \sum_q e_q \int F_M^{(3)q}(x, t)\, dx$$

$$G_E^*(t) = \sum_q e_q \int F_E^{(3)q}(x, t)\, dx$$

$$G_C^*(t) = \sum_q e_q \int F_E^{(3)q}(x, t)\, dx$$

Large Nc limit:

$$F_M^{(3)q} = \frac{2}{\sqrt{3}} K_M{}^{(3)q} = \frac{2}{\sqrt{3}} \left(K_p^q - K_n^q \right)$$

Form Factors and GPD's

Elastic Form Factors

$$F_1(t) = \sum_q e_q \int \mathcal{F}^q(x,t)\,dx \qquad F_2(t) = \sum_q e_q \int \mathcal{K}^q(x,t)\,dx$$

Wide Angle Compton Scattering

$$R_1(t) = \sum_q e_q^2 \int \mathcal{F}^q(x,t)\frac{dx}{x} \qquad R_2(t) = \sum_q e_q^2 \int \mathcal{K}^q(x,t)\frac{dx}{x}$$

$N \to \Delta$ Resonance Form Factors

$$G_M^*(t) = \sum_q e_q \int \mathcal{F}_M^{(3)q}(x,t)\,dx$$

$$G_E^*(t) = \sum_q e_q \int \mathcal{F}_E^{(3)q}(x,t)\,dx$$

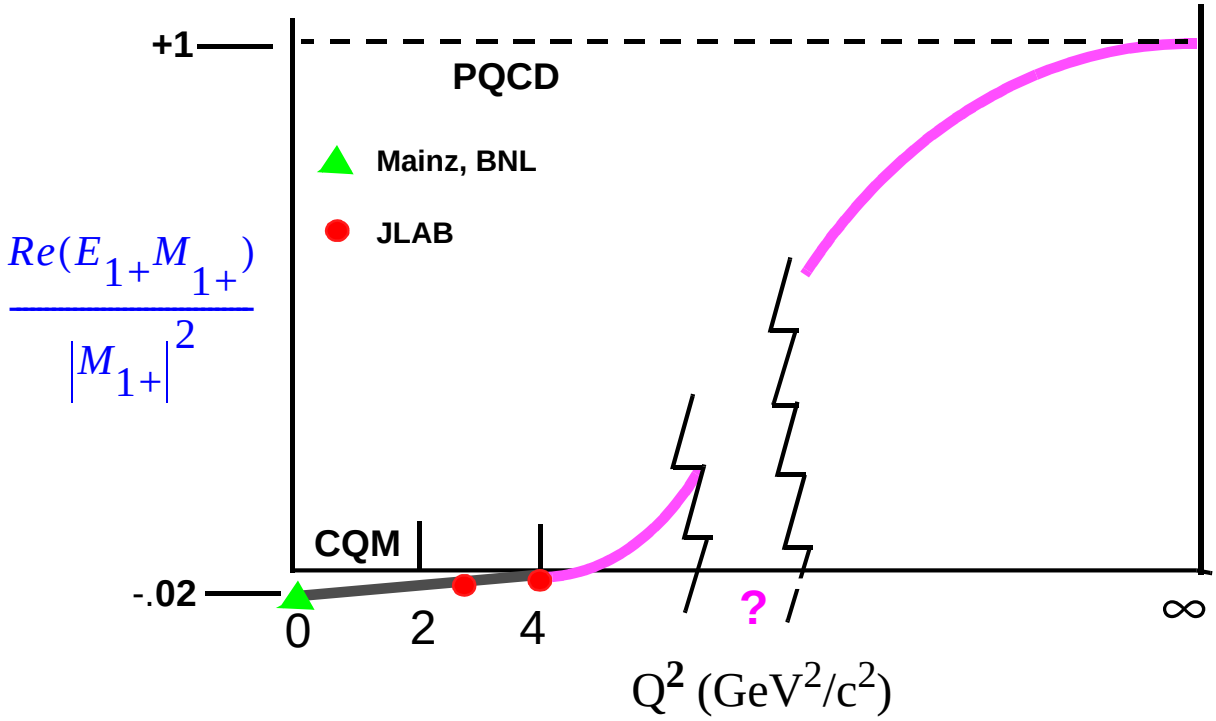
$$G_C^*(t) = \sum_q e_q \int \mathcal{F}_E^{(3)q}(x,t)\,dx$$

$$e + p \rightarrow \Delta(1232) \rightarrow \pi^0 + p$$

CQM ⟶ GPD ⟶ PQCD

$$A_{1/2} \propto 1/Q^3 \qquad Q^4 G_M^* \rightarrow const$$

$$E_2/M_1 \rightarrow 1$$



Example

Hall C with E_e = 12 GeV

$$e + p \rightarrow \Delta(1232) \rightarrow e + p + \pi^0$$

$$L = 1 \times 10^{38} \ cm^{-1} s^{-1} \qquad T = 30 \ days$$

$$\delta W = 0.1 \ GeV$$

Table 1:

Q^2	***Inclusive Yield***	ϕ_{cone}	***Exclusive fraction out of plane***	***Net Yield***
4	3.5×10^8	95 mr	0.6	2×10^7
5	8×10^7	80 mr	0.75	6×10^6
6	2.5×10^7	70 mr	0.85	2×10^6
7	9×10^6	61 mr	0.9	9×10^5
8	3×10^6	56 mr	1.0	3×10^5
9	1×10^6	51 mr	1.0	1×10^5
10	7×10^5	45 mr	1.0	7×10^4