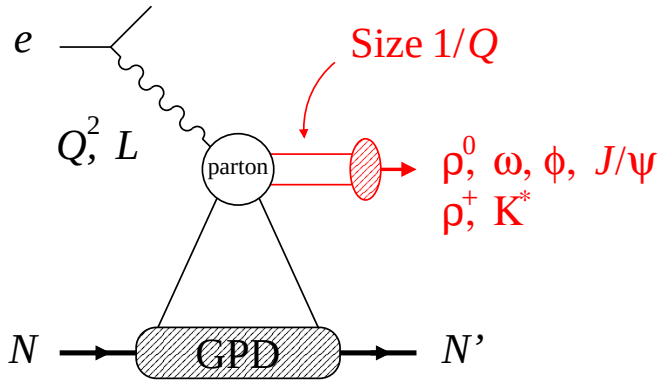
Hard exclusive vector meson production: Mechanism and GPD description

C. Weiss (JLab), MENU2010, Williamsburg, 02–Jun–10



→ Transverse quark/gluon imaging of nucleon

→ Spin/flavor structure of GPDs

→ Meson structure

- Mechanism of high–Q^2 meson production

  Small–size configurations ↔ color transparency

  Challenges in quantitative implementation

  Tests of reaction mechanism

- Gluon–dominated region $W > 10\,\text{GeV}$
  HERA, COMPASS, EIC

  Reaction mechanism: t–slopes, universality, α'

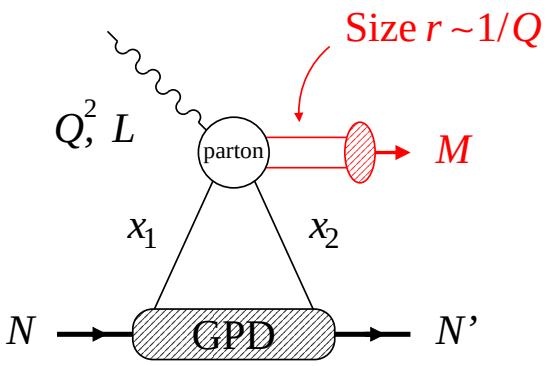
  GPD–based description

- Quark exchange region $W \sim$ few GeV
  JLab 6/12 GeV, EIC

  Comparison $\rho^+ \leftrightarrow \rho^0, \omega \leftrightarrow \phi$ CLAS data: Fradi

  Missing strength from scalar $q\bar{q}$ exchange: Chiral symmetry breaking

Mechanism of high–Q^2 meson production



- Partonic mechanism at high Q^2

  $Q^2 \gg$ hadronic scale: Meson produced predominantly in $q\bar{q}$ configuration of transverse size $r \sim 1/Q$

  $Q^2 \to \infty$: pQCD interaction, factorization theorem
  Brodsky et al. 94; Collins, Frankfurt, Strikman 96

  Target structure in GPDs: Universal, process–independent

- Quantitative questions

  Distribution of sizes/configurations for given Q^2?
  Effective QCD scale, finite–size corrections

  Role of different partons/exchanges?
  Quark vs. gluon GPDs in ρ^0

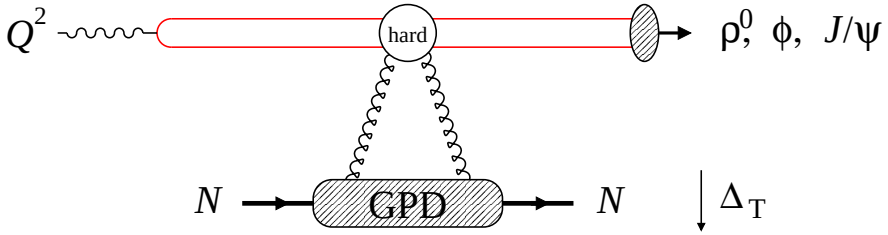
  Partonic kinematics $x_{1,2}$: Scattering from quarks vs. $q\bar{q}$ pair knockout? Re/Im of amplitude

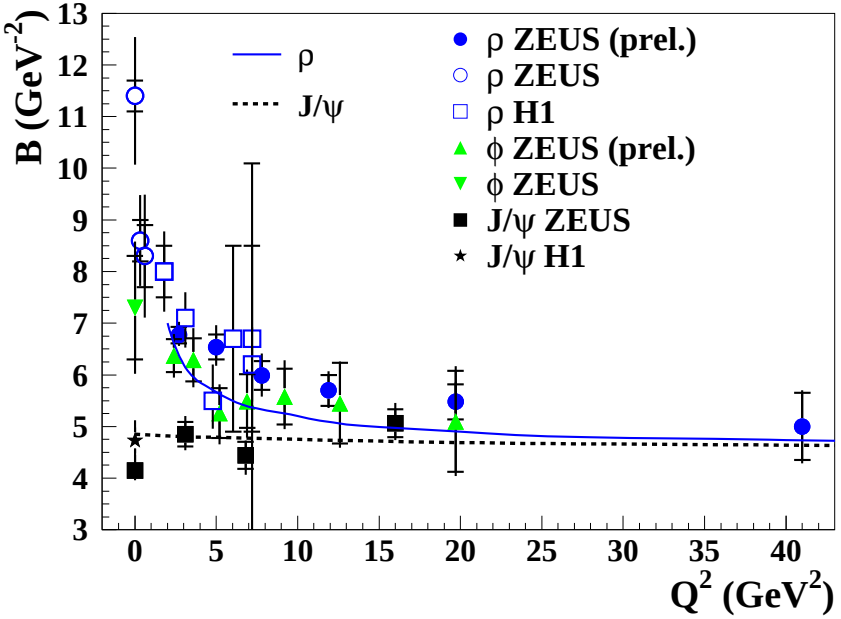
$\to$ Need experimental input: Kinematic dependences, comparison of channels

$\to$ Model–independent tests of reaction mechanism

. . . should be addressed before detailed modeling!

Gluon–dominated region: Mechanism I





- Simplifications at $W > 10\,\text{GeV}$

  Gluon exchange dominant in $\rho^0 \leftrightarrow \phi, J/\psi$

  Coherence length $\gg 1$ fm:
  Dipole picture in nucleon rest frame

  Im A $\gg$ Re A: DGLAP region of gluon GPD

- Test approach to small–size regime

  Δ_T^2 slope measures transverse size of interaction region: Decreases at large Q^2, becomes universal

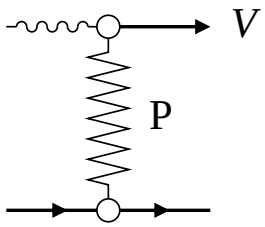
  Seen in HERA data!

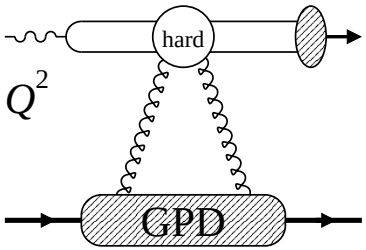
- Further tests

  Q^2 dependence, σ_L dominance

  $\phi : \rho^0 = 2 : 9$ from SU(3)

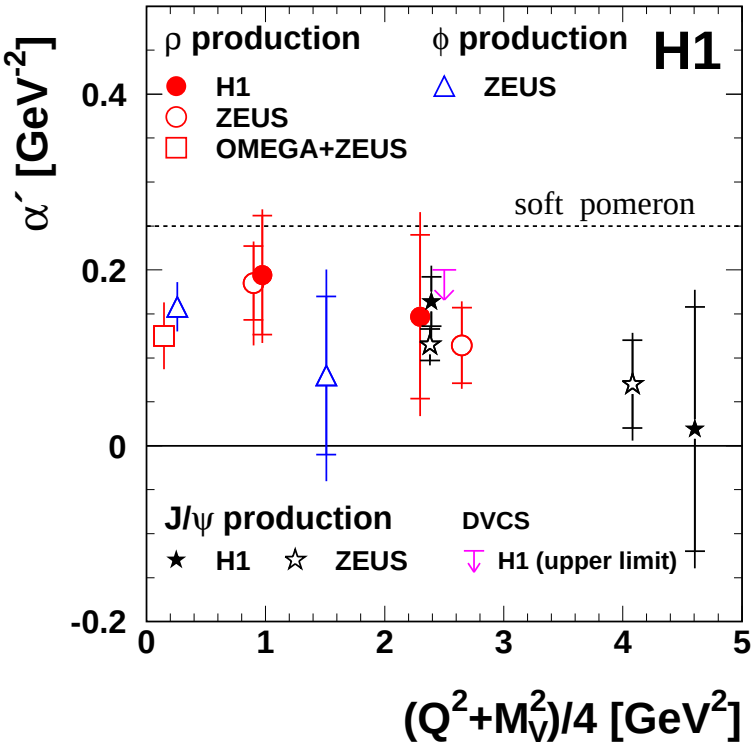
Gluon–dominated region: Mechanism II





$\sigma \sim W^{4\alpha'_{\rm soft}t}$

$\alpha'(Q^2) \ll \alpha'_{\rm soft}$



- Test reaction mechanism through W–dependence: Changes with t through effective Regge slope α'

  Soft process: Pomeron trajectory

  Hard processes: $\alpha'(Q^2) \ll \alpha'_{\rm soft}$, drops with Q^2,

  Seen in HERA data!

- Q^2–dependence of α' explained by DGLAP evolution

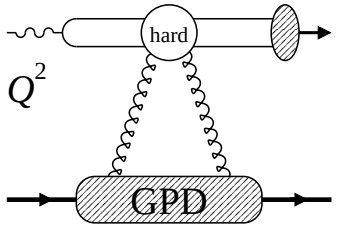
  Frankfurt, Strikman, CW 04; Müller at al. 04

Gluon–dominated region: GPD description

- Successful GPD–based phenomenology including finite–size effects

  Dipole picture with size distribution Frankfurt, Strikman, Koepf 95

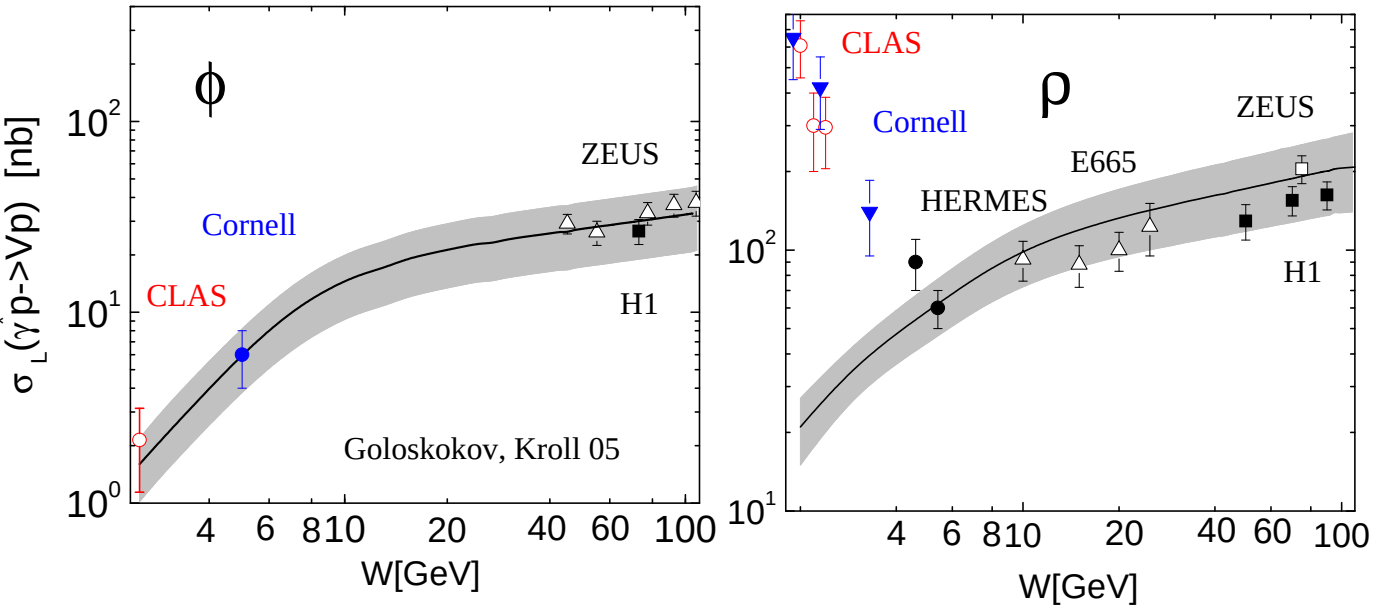
  Hard scattering with intrinsic k_T VGG 98; Kroll, Goloskokov 05+



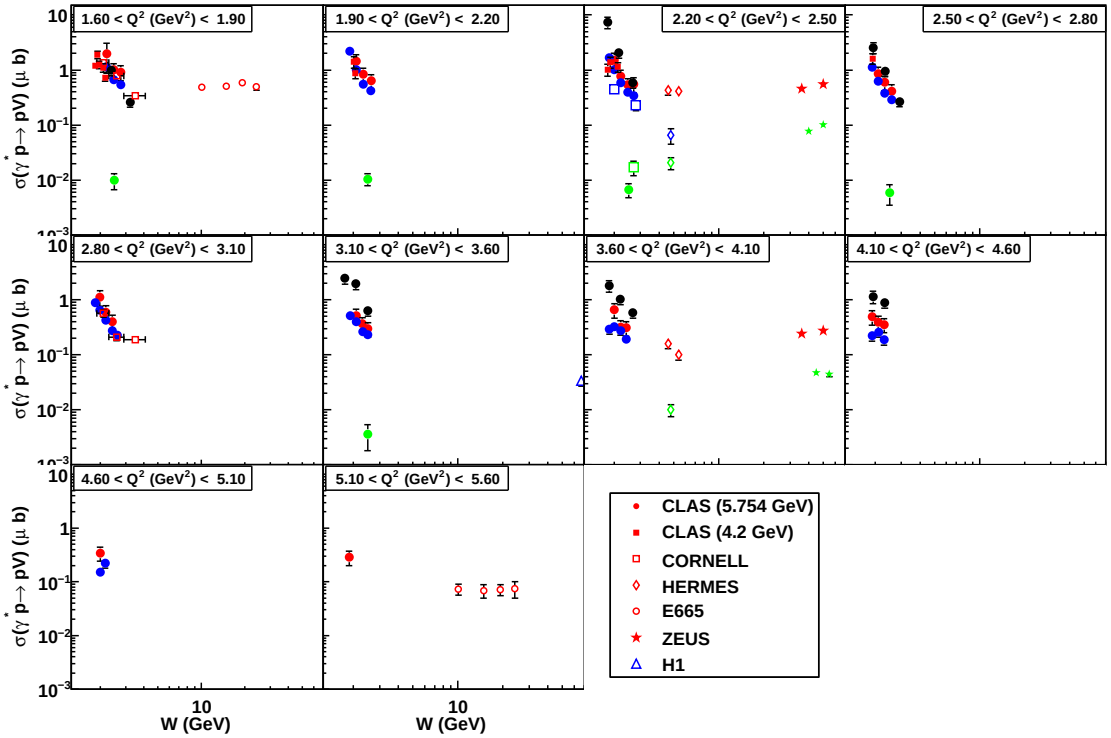
- Lower energies

  ϕ still gluon–dominated at JLab energies
  Nucleon gluonic consistent with HERA Frankfurt, Strikman 02

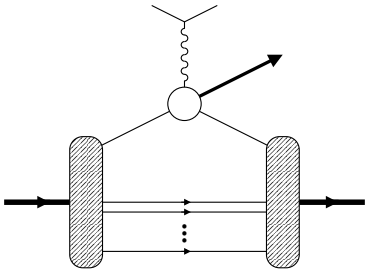
  ρ^0: Quark exchange – new challenges!



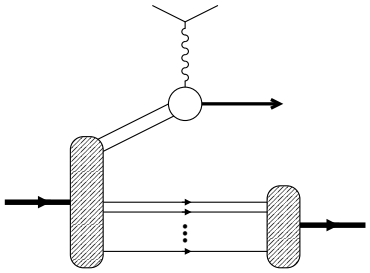
Quark exchange region: Mechanism



CLAS 09 Fradi et al. **Black** ρ^+, **Red** ρ^0 **Blue** ω **Green** ϕ



Scattering from quark



Knockout of $q\bar{q}$ pair

- Comparison $\rho^+ \leftrightarrow \rho^0 \leftrightarrow \phi$: Quark exchange!

  Approximate u–quark dominance
  $\rho^0 : \omega : \rho^+ \sim 1 : 1 : 2$

- Valence quarks or $q\bar{q}$ pair?

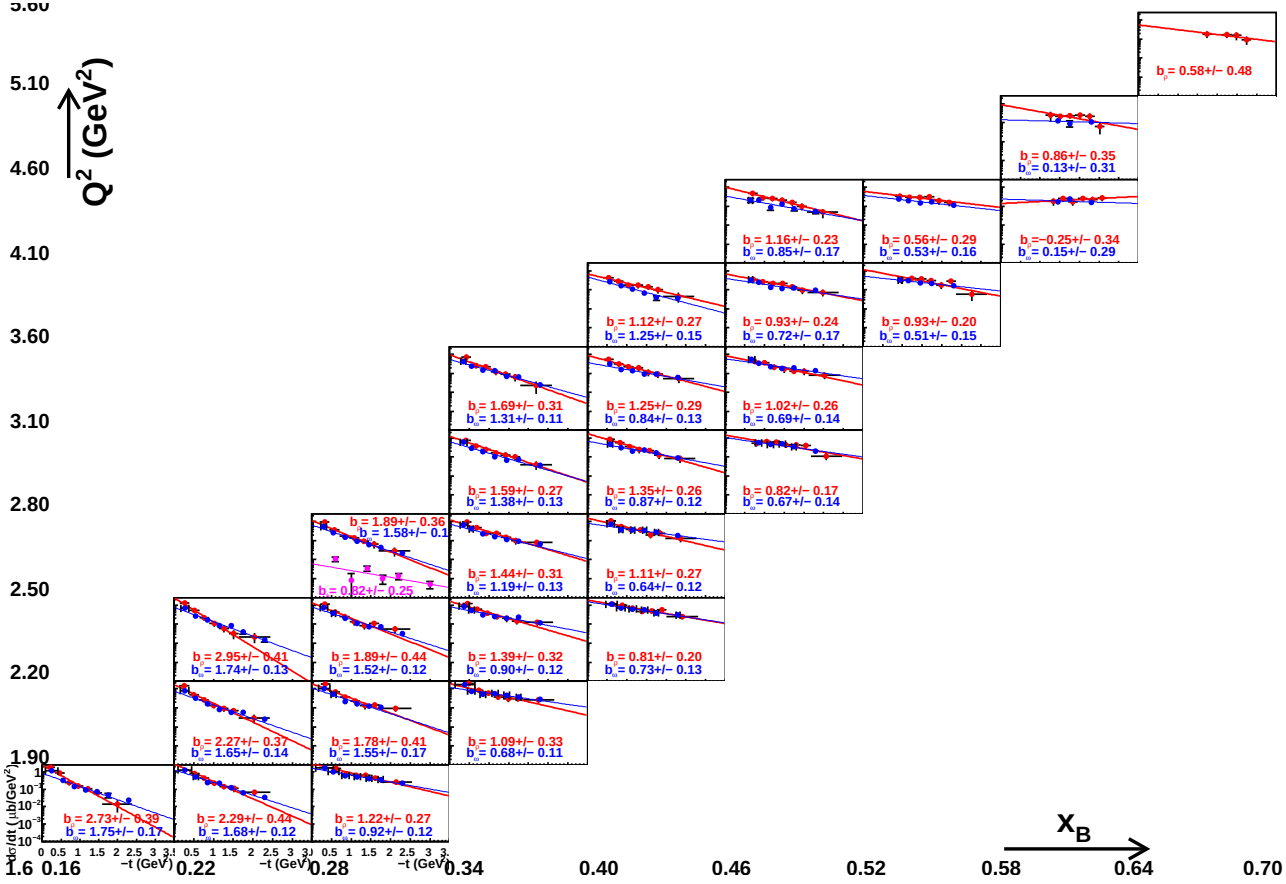
  W dependence at $W < 4$ GeV suggest spin–0 exchange

  Guidal, Morrow: Modified D–term in GPD?

  Chiral symmetry breaking: Correlated spin–0 pairs in nucleon

  Most likely $q\bar{q}$ exchange with non-perturb. interactions ("soft mechanism")

Quark exchange region: Mechanism



CLAS 09 Fradi et al.

- t–slopes and their Q^2 dependence

  Interpretation more difficult: exponential fits dominated by large $|t| \sim 1 - 2\,\mathrm{GeV}^2$

  Possibly factors $\sqrt{-t}$ from nucleon helicity flip

  Approach to small-size regime at large Q^2? . . . Need also low–Q^2 data!

Summary

- Experimental input essential for understanding reaction mechanism of exclusive meson production

  Not "GPDs or not GPDs," but quantitative questions

  Kinematic dependences more important than pushing for highest Q^2

- Successful GPD–based phenomenology in gluon–dominated region

  Substantial finite–size effects at $Q^2 \sim$ few GeV^2, physically motivated

  No reason why it should not work at lower energies!

- New insights into reaction mechanism from CLAS $\rho^+/\rho^0/\omega/\phi$ data

  Likely $q\bar{q}$ exchange with non-perturbative interactions

  Toward a partonic description of meson production at JLab 6 and 12 GeV!