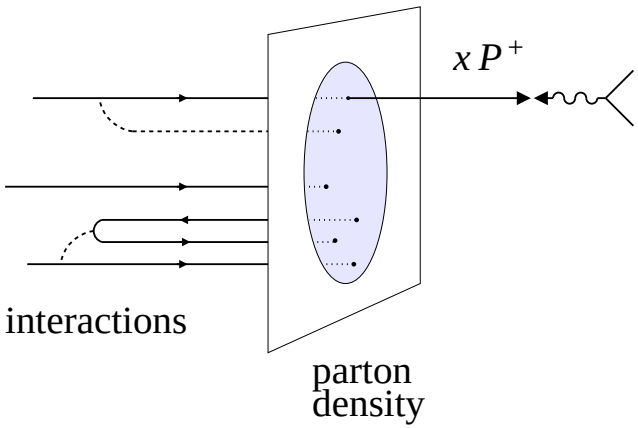
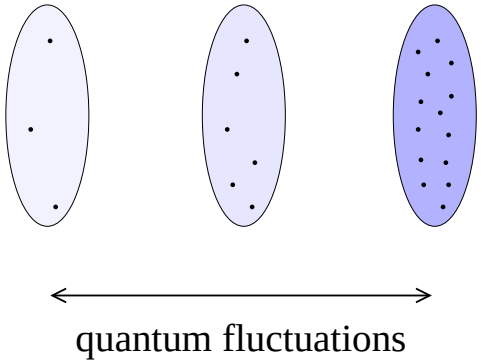
Quantum fluctuations of parton densities in diffractive ep scattering

C. Weiss (JLab), APS April Meeting 2015, Baltimore, 12–Apr–15

Jefferson Lab





- Diffractive vector meson production

$$e + p \to \begin{cases} e' + V + p & \text{elastic} \\ e' + V + X & \text{inelastic} \end{cases}$$

Gluon fluctuations from inelastic diffraction
Frankfurt, Strikman, Treleani, CW, PRL **101**:202003, 2008

- Dynamical origin of fluctuations

Scaling model

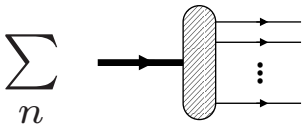
QCD evolution

- Experimental studies

HERA: Diffractive ρ^0 and ϕ

EIC: Quantitative studies of fluctuations

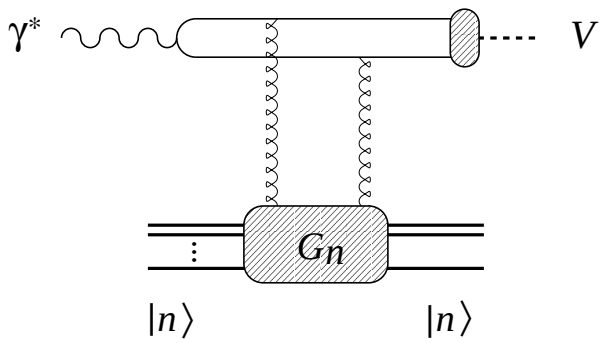
Quantum fluctuations: Inelastic diffraction



- Nucleon quantum many–body system: Partonic wave function has components with different particle number size, etc.

  Usual DIS measures average parton density $\langle f \rangle = \sum_n f_n$

  Can we observe quantum fluctuations?
  Frankfurt, Strikman, Treleani, CW, PRL **101**:202003, 2008



- Hard diffractive processes at small x

  Amplitude diagonal in partonic states $|n\rangle$, proportional to gluon density G_n

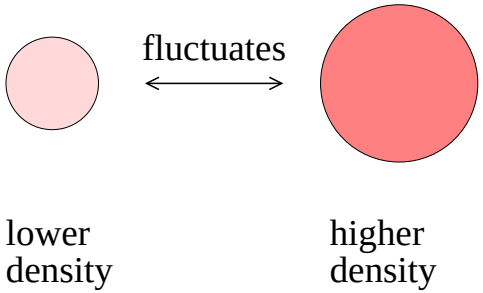
  Fluctuations of G_n lead to dissociation
  cf. soft diffraction: Good, Walker 60, Miettinen, Pumplin 78

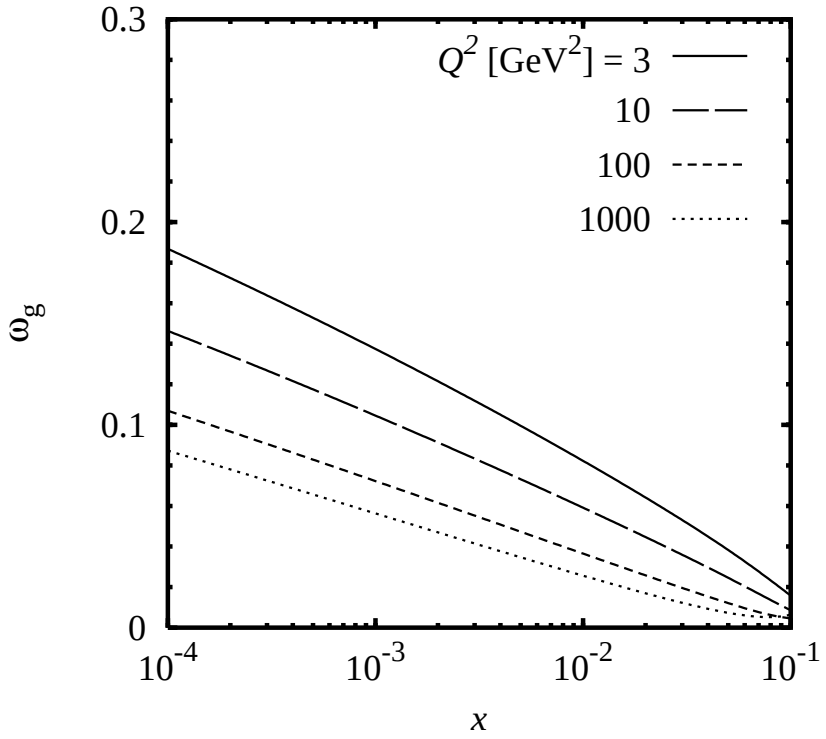
$N \xrightarrow{G_n \text{ const.}} N$

$N \xrightarrow{\text{fluctuating}} X$

$$\omega_g \equiv \frac{\langle G^2 \rangle - \langle G \rangle^2}{\langle G \rangle^2} = \left. \frac{d\sigma/dt\ (\gamma^* N \to V X)}{d\sigma/dt\ (\gamma^* N \to V N)} \right|_{t=0}$$

Quantum fluctuations: Dynamical origin





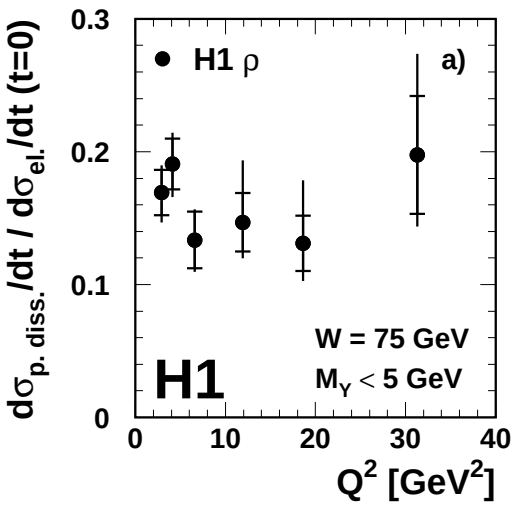
- Fluctuations challenge our understanding of nucleon structure and non-perturbative dynamics
- First estimate: Scaling model
  Close, Roberts, Ross 83: EMC effect

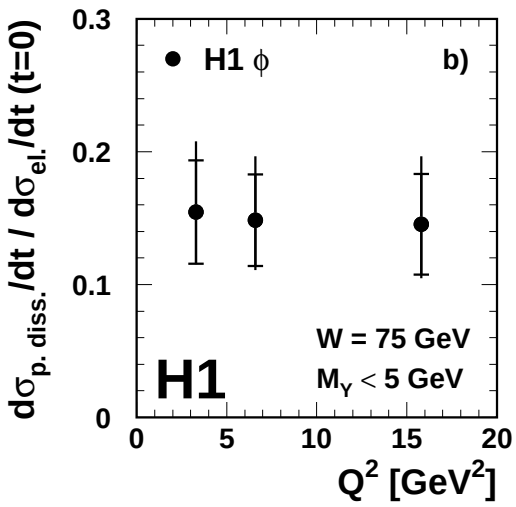
  Fluctuations of nucleon size change normalization scale of non-perturbative gluon density
  μ^2(gluon density) $\propto R^{-2}$

  DGLAP evolution: Dispersion of gluon density changes with x, Q^2
- Fluctuations arise also from DGLAP evolution itself

  Parton at given x and Q^2 can arise from lower scale partons through emission or no emission

Quantum fluctuations: Experimental studies





HERA H1 2009
exclusive vector mesons

- Experimental requirements

  Forward detection of elastic protons and low–mass diffractive states at $x < 0.01$

  Accurate t measurements (coverage, resolution) for extrapolation $t \to 0$

- HERA: Diffractive ρ^0 and ϕ

  Inelastic/elastic ratio comparable with scaling model prediction, but kinematic dependences not reproduced. . . likely needs fluctuations from DGLAP evolution

- EIC: Detailed studies of quantum fluctuations

  Dedicated forward detectors also for DVCS, meson production

  High luminosity permits fully differential measurements in x, Q^2, t

Summary and outlook

- Nucleon in QCD as quantum many–body system:
  Quantum fluctuations of parton densities

- Challenge understanding of non-perturbative QCD and nucleon structure

- Explore as next step after one-body densities (PDFs, GPDs)

- EIC will enable fully quantitative studies: Forward detection, luminosity

- Interesting theoretical questions: Formal operator definition,
  fluctuations from DGLAP evolution, . . .

- Fluctuations of parton densities affect other high-energy processes,
  e.g. rapidity gap survival probability in diffractive pp scattering
  Frankfurt, Strikman, Treleani, CW, PRL **101**:202003, 2008; Frankfurt, Hyde, Strikman, Weiss, PRD **75**:054009, 2007