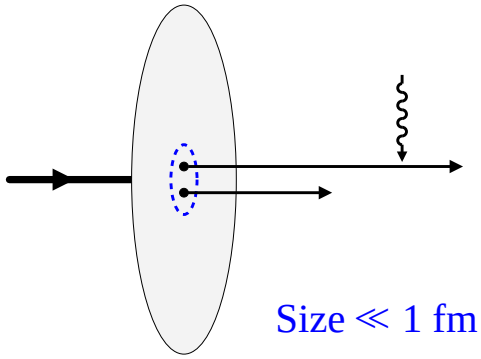
Small–size configurations: Origin and probes

C. Weiss (JLab), Mini–Workshop "Small–size configurations", JLab, 25–Mar–11



High–t photo/electroproduction

Elastic FF, Compton
Meson production, J/ψ
Nuclear transparency
Deuteron breakup

Conceptual framework

Sizes $\leftrightarrow$ dynamics
More general than pQCD!
Analogy with SRC in nuclei

- Elastic form factors pion, nucleon

  Partonic representation

  Effective sizes

  Small–size vs. $x \to 1$ configurations

- Origin of small–size configurations

  Perturbative interactions

  QCD vacuum structure

- Probing small–size configurations with JLab 12 GeV

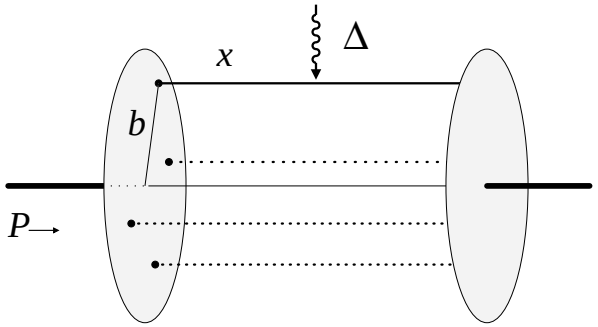
  Wide–angle Compton scattering

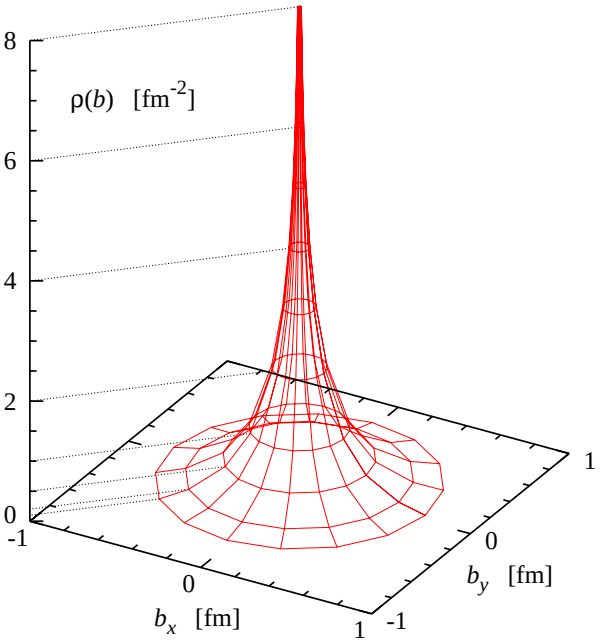
  Meson production at high Q^2, t

  Nuclear transparency

  J/ψ production near threshold

Form factor: Parton picture





- Parton picture $P \to \infty, \boldsymbol{\Delta}$ transverse

  Current cannot produce pairs

  Wave function overlap representation
  $F(t) = \sum_{\rm n} \int dx\ d^2k_T\ \psi_n^*(x, k_{T1}, ..)\psi_n(x, k_{T2}, ..)$

  Configurations with different particle number and transverse size

  Expect that large t "select" small sizes
  How to quantify it?

- Transverse density Soper 76, Miller 07

  $F(t) = \int d^2b\ e^{i\boldsymbol{\Delta b}}\ \rho(b)$ 2D Fourier

  Cumulative charge/current of constituents at transverse position b

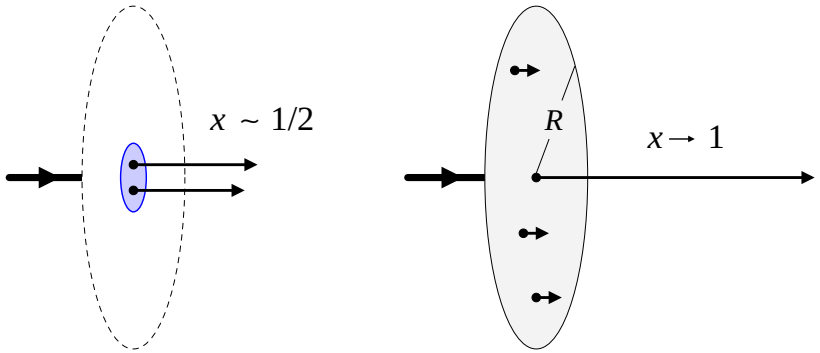
  Reduction of GPD $\rho(b) = \int dx f_{q-\bar{q}}(x, \boldsymbol{b})$

- Empirical charge density in pion

  Dispersion integral over timelike FF e^+e^- data

  High density at $b \to 0$: Small–size configurations?

Form factor: Small–size configurations



small−size end−point

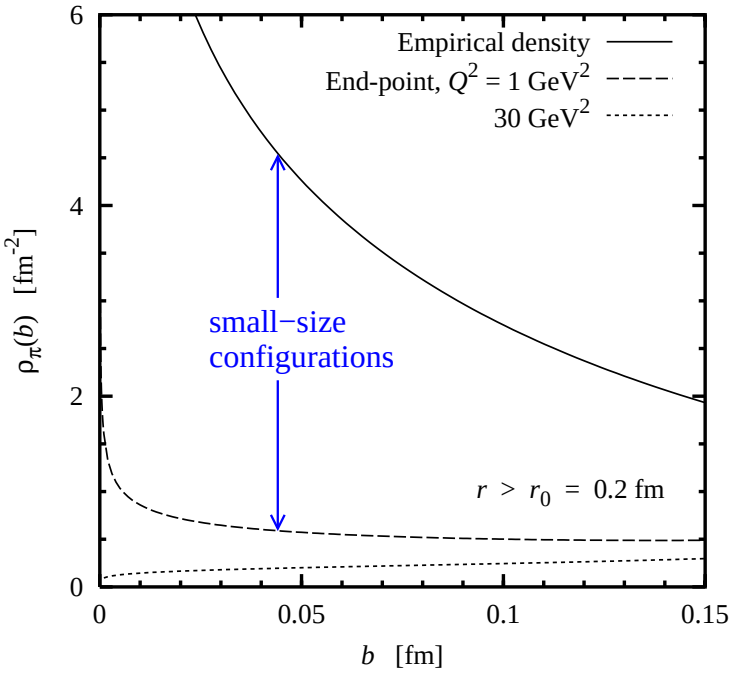
- Two sources of small–b density

$x \sim 1/2$	size $\ll R$	small–size	mostly $q\bar{q}$
$x \to 1$	size $\sim R$	end–point	multiparticle, soft gluons

  Dynamical question!

- Density in center of pion mostly from small–size configurations

  End–point contribution constrained by quark density in pion at $x \to 1$
  Miller, Strikman, CW 10. πA Drell–Yan data

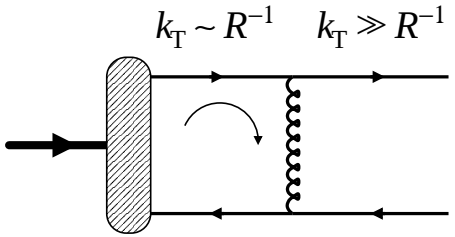


- Alt. picture: Breit frame

  Photon reverses quark with $x \to 1$
  Feynman mechanism

Model–independent statement on small–size configurations!

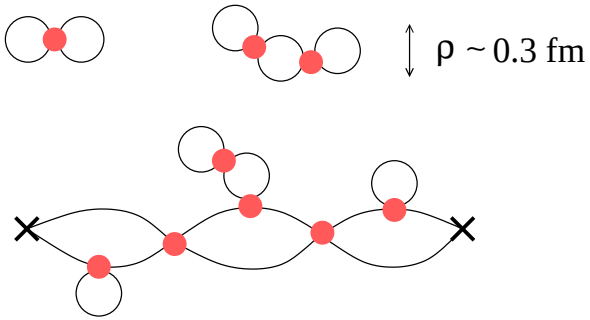
Small–size configurations: Dynamical origin



- Perturbative interactions

  High–momentum component of wave function $k_T \sim R^{-1}$ wave function as source, $\int d^2k_T$

  Responsible for leading $|t| \to \infty$ asymptotics of pion FF Efremov, Radyushkin 77+; Brodsky Lepage 80



- QCD vacuum structure

  Strong non–perturbative gluon fields of size $\rho \sim 0.2$–0.3 fm

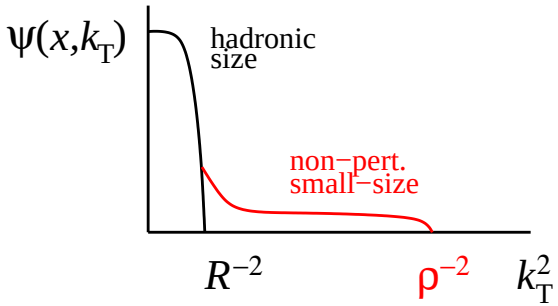
  Objective measure: Average quark virtuality $\langle\bar\psi\nabla^2\psi\rangle/\langle\bar\psi\psi\rangle > (0.7\,\text{GeV})^2$

  Lattice: Teper 87, Doi 02, Chiu 03

  Non–perturbative semi–hard component of WF

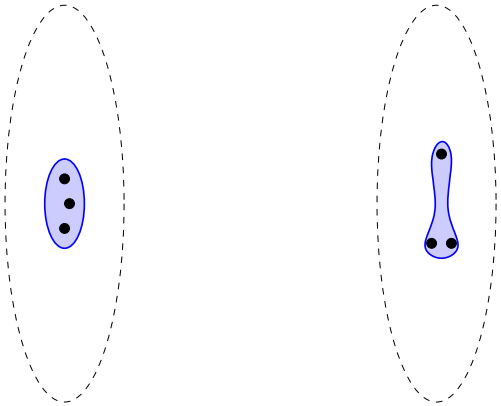
  Cf. short–range correlations in nuclei

  Chiral anomaly? $\gamma^*\gamma \to \pi^0$ puzzle



Evidence for non-perturbative small–size configurations!

Small–size configurations: Nucleon

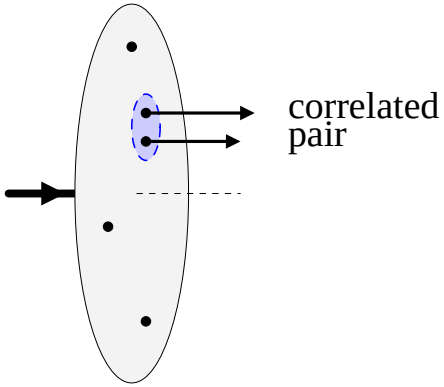


- Nucleon more complex, more possibilities

  Uniform squeezing or diquark–like configurations?

  End-point configurations $x \to 1$?
  Related to large–x parton densities JLab 12 GeV

  Mean–field picture generally successful:
  Quark model, chiral soliton $N_c \to \infty$
  Nature of dynamical correlations?



- Correlated $q\bar{q}$ pairs

  Size $\rho \ll R$, induced by QCD vacuum structure
  Cf. Short–range correlations in nuclei

  Important in meson production processes!
  Strikman, CW, in progress

Small–size configurations: Other processes

- Get more information: x–dependence, quantum numbers, . . .

- Test universality!

- Details depend on channel

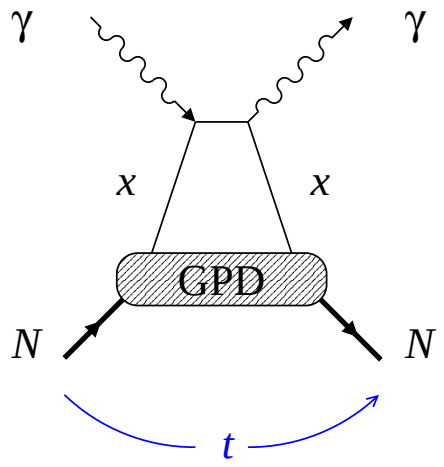
  Meson production: $\phi \leftrightarrow \rho^0, \quad \rho^+, K^* \leftrightarrow \pi, K, \quad \pi^+ \leftrightarrow \pi^0, \quad$ etc.

- Space–time picture needs to be developed

  Transverse frame $\quad \longleftrightarrow \quad$ Center–of–mass frame

This presentation: Comments, suggestions, no definitive answers!

Processes: Wide–angle Compton scattering



- Compton process at $s, |t|, |u| \gg R^{-2}$

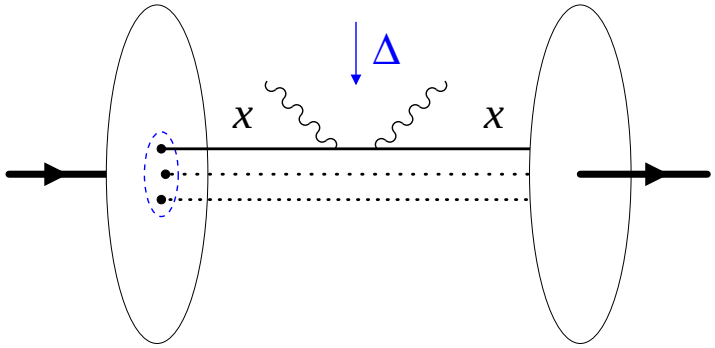
  Scattering from single quark:
  "Handbag" diagram

  Closely related to elastic FF at high $|t|$

  $$R(t) \sim \int \frac{dx}{x} \, \mathrm{GPD}(x_1 = x_2 = x, t)$$

  → Talk Radyushkin

  Constituent quark model: Wave functions,
  quark helicity flip → Talk Miller



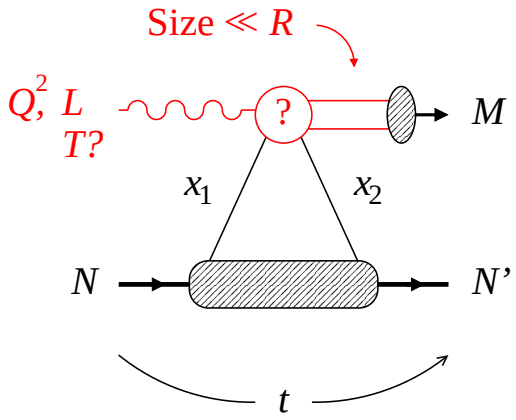
- Test reaction mechanism

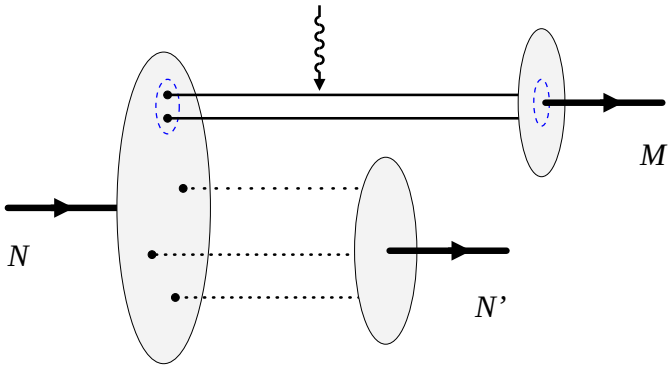
  Polarization observables A_{LL}, K_{LL}
  → Talk Wojtsekhowski

  Finite virtuality $Q^2 \neq 0$ → Talk Hyde

x–distribution of small–size configs,
nucleon helicity structure

Processes: Exclusive meson production





- $Q^2 \gg R^{-2}$: Meson produced in small–size configuration

  Exp. test: t–slope becomes independent of Q^2
  Seen in HERA VM data; some signs at CLAS 6 GeV

  $Q^2 \to \infty$: QCD factorization theorem with pQCD interaction and GPDs
  Collins, Frankfurt, Strikman 96

  Small–size regime $\neq$ pQCD dominance

- Quantitative description based on non–perturbative interactions?

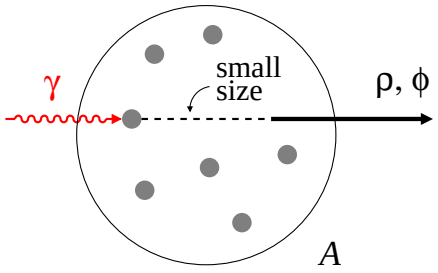
  Knockout of small–size $q\bar{q}$ pair, may explain CLAS ρ^0, ρ^+ data
  Cf. ERBL region of GPD

  Also scattering from uncorrelated quarks
  Cf. DGLAP region of GPD. Related by crossing, dispersion relations

- What about high–t photoproduction?
  → Talks Ilieva, Strikman, discussion

  Timelike Compton: Talk Stepanyan

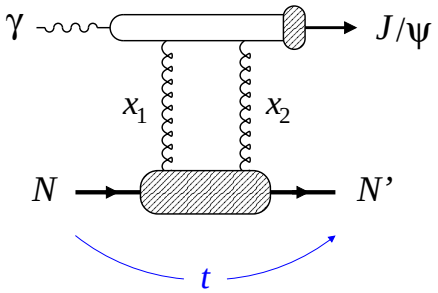
Processes: Small–size configurations with 12 GeV



- Nuclear transparency → Talks Cosyn, Horn, Gao, Gilman

  Small–size configurations experience reduced interaction with nuclear medium: Color transparency

  ϕ, ρ photoproduction on nuclei



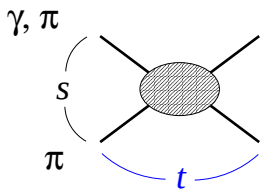
- J/ψ photo/electroproduction → Talks Strikman, Fuchey, Chudakov

  "Naturally" small size even in photoproduction

  Clean probe of gluon field even at JLab energies

  Near–threshold $|t_{\rm min}| \sim 1\,{\rm GeV} \leftrightarrow$ high–t form factors

  Reaction mechanism poorly understood near threshold: GPD for large longitudinal momentum transfer $x_1 \neq x_2$? Re/Im ratio?



- High-energy deuteron breakup → Talk Sargsian

  Small–size configurations in NN system

- Hadronic $2 \to 2$ processes at high t → Talk Strikman

Summary

- Small–size configurations key concept of hadron structure

  More primary than specific interaction models

  Contains, but is not limited to, pQCD interactions

  Small–size configurations from non–perturbative interactions:
  Chiral symmetry–breaking forces in QCD vacuum

- Learn to discuss/describe high–momentum–transfer processes in terms of small–size configurations

  Detailed modeling required: Space–time picture, effective interactions

  Experiments should answer quantitative questions:
  Effective size distribution, shrinkage, . . .

- Many interesting options to probe small–size configurations with 12 GeV

  Collider energies: Small–size configurations in photon's $q\bar{q}$ wave function,
  diffractive scattering, nuclear shadowing EIC