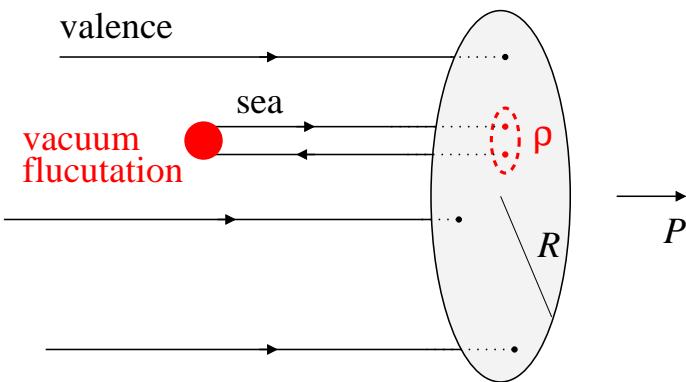# Parton short-range correlations and QCD vacuum structure

P. Schweitzer (UConn), M. Strikman (PSU), C. Weiss (JLab)
High–energy Nuclear Physics and QCD, FIU, Miami, 3–Feb-10

valence

sea

vacuum flucutation

ρ

R

P

- Transverse parton correlations induced by QCD vacuum structure

  Non–perturbative short–distance scale $\rho \ll R_{\mathrm{had}}$ from spontaneous χSB

  k_T distribution of sea quarks $\neq$ valence

- Parton correlations in ep

  p_T distributions in semi-inclusive DIS   in progress

  Higher twist in inclusive DIS $\to \langle k_T^2 \rangle$

- Parton correlations in pp

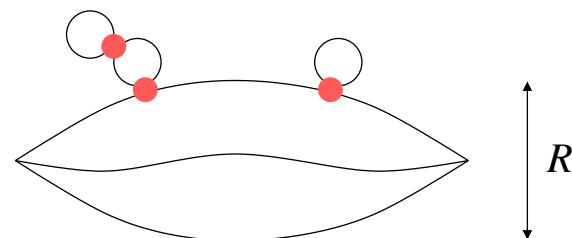 Multiple hard processes @ Tevatron, LHC

  Importance for MC generators

$\to$ New (old) concept!

$\to$ Analogies with NN correlations in nuclei!

QCD vacuum structure and parton correlations

size ρ

R

valence

sea

ρ

R

P

- QCD vacuum: Non–perturbative gluon fields, condensate of $q\bar{q}$ pairs

  Localized with size $\rho \ll R_{\mathrm{had}} \sim 1\,\mathrm{fm}$
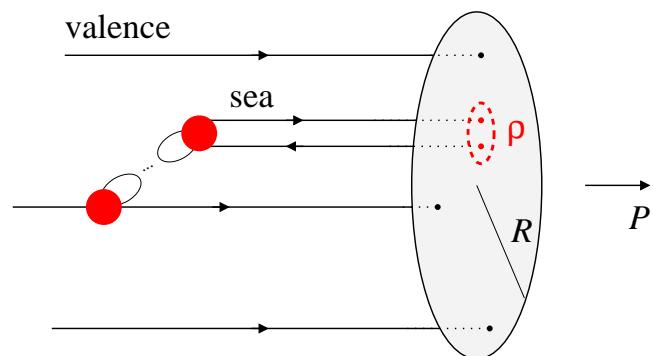 Shuryak; Diakonov, Petrov 80's

  Size measured by average quark virtuality
  $\langle \bar{\psi} \nabla^2 \psi \rangle / \langle \bar{\psi} \psi \rangle > (0.7\,\mathrm{GeV})^2$
  Lattice: Teper 87, Doi 02, Chiu 03

  Couple to valence quarks in
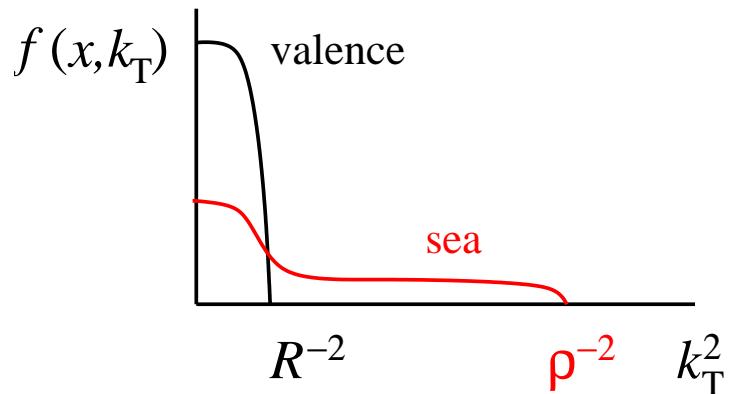 Euclidean correlation functions

- Partonic picture $P \gg \rho^{-1}$:
  Short–range correlations in wave function

  Sea quarks in correlated pairs of size ρ

  Transverse gluon fields correlated with quarks

  Here: Heuristic approach based on
  partonic wave function   Feynman, Gribov 70's

Parton correlations: k_T distributions

$f(x, k_T)$

valence

sea

R^{-2} ρ^{-2} k_T^2

valence

sea

ρ

R

P

- Intrinsic k_T distributions

  Bulk at $k_T \sim R^{-1}$ "mean field"

  Sea quarks have tail   "correlations"
  up to $k_T \sim \rho^{-1}$

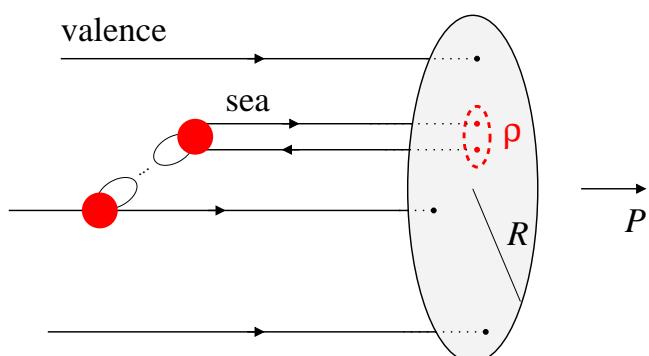- Example: Chiral quark–soliton model
  Diakonov, Petrov, Pobylitsa 88
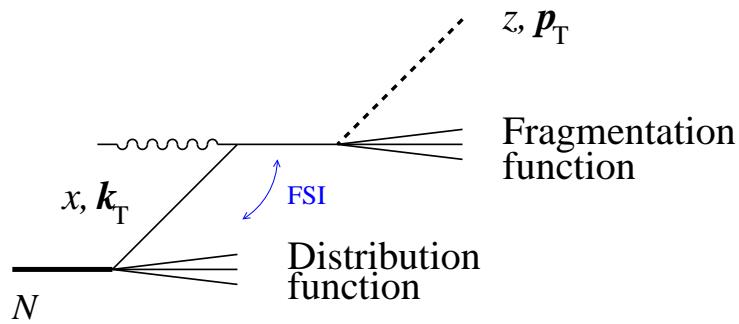
  Field–theoretical: Completeness, positivity

  Power–like tail of k_T distribution
  in region $R^{-2} \ll k_T^2 < \rho^{-2}$

  $$f_1^{u+d}(x, k_T) \sim \frac{N_c M_{\text{const}}^2}{4\pi^3 F_\pi^2} \times \frac{f_1^{u+d}(x)}{k_T^2}$$

- Average transverse momentum determined
  by size of correlation $\langle k_T^2 \rangle \sim \rho^{-2}$

Parton correlations: ep scattering

$z, \boldsymbol{p}_{\mathrm{T}}$

Fragmentation function

$x, \boldsymbol{k}_{\mathrm{T}}$

FSI

Distribution function

N

- Semi-inclusive DIS

  Tail in p_T distribution from intrinsic $k_T \sim \rho^{-1}$
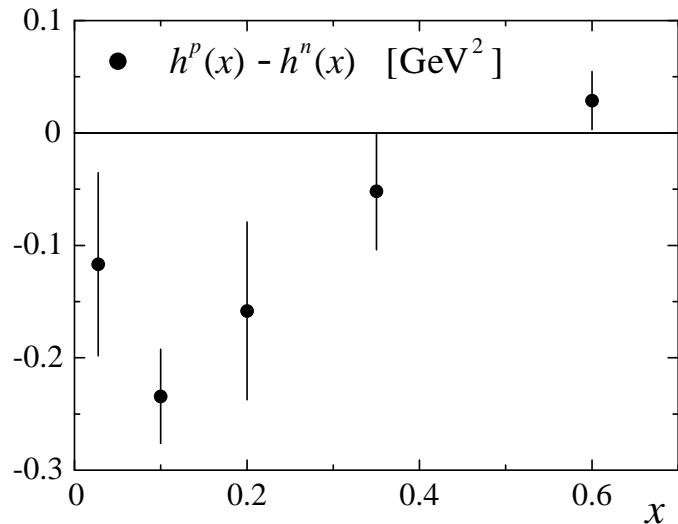
  Collinear approximation? FSI?

  Different p_T distributions of hadrons produced from quarks and antiquarks

$h^p(x) - h^n(x)$ $[\mathrm{GeV}^2]$

$1/Q^2$ correction to g_1^{p-n} from global QCD fit

Leader, Stamenov, Sidorov 05

- Inclusive DIS

  Power corrections governed by scale $\langle k_T^2 \rangle \sim \rho^{-2} \gg R^{-2}$

  QCD operator–based calculation in instanton vacuum model, includes gluon field, agrees with empirical power corrections

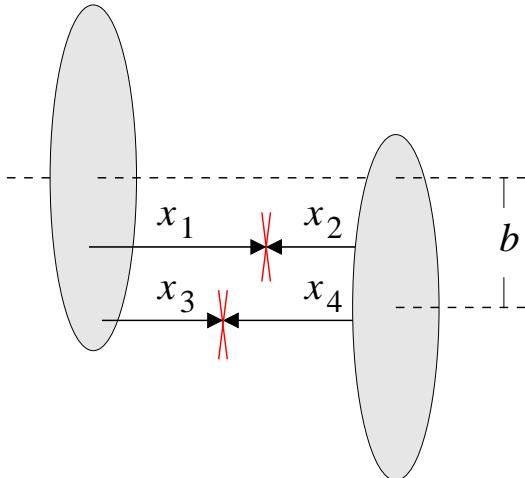 Balla, Polyakov, CW 97; Maul et al 00; Sidorov, CW 05

  Dominant higher twist not related to hadronic size $R \leftrightarrow$ Duality?

  x–dependence of higher twist follows sea quark distribution $\rightarrow$ lower x

Parton correlations: Hard processes in pp

$$\frac{\sigma(12;34)}{\sigma(12)\sigma(34)} = \frac{1}{\sigma_{\text{eff}}}$$

$$\times \frac{f(x_1, x_3) f(x_2, x_4)}{f(x_1) f(x_2) f(x_3) f(x_4)}$$

- Transverse correlations increase probability of multiple hard processes

  FNAL CDF σ_{eff} two times larger than mean field with $R^2(x \sim 0.1)$

  Consistent with transverse correlations of size $\rho \sim 0.2 - 0.3\,\text{fm}$
  Frankfurt, Strikman CW 04

- High probability of multiple hard processes in pp@LHC

  Detailed studies of parton correlations

  Needed in MC generators for pedestal of new physics signals

  Correlations reduce rapidity gap survival in central diffraction $pp \to p + H + p$
  Frankfurt, Strikman CW 06+

Parton correlations: Summary and outlook

- Many analogies with short–range NN correlations in nuclei

- Different k_T distribution of valence and sea quarks, important for semi-inclusive processes at JLab, EIC

- Interesting new connection $ep \leftrightarrow pp$

- Future studies needed/in progress

  Quantitative studies of k_T distributions and implications for semi-inclusive DIS

  Role of gauge fields?

  Correspondence with QCD operator formulation? Higher twist $\leftrightarrow$ $\langle N | \bar{\psi} \nabla_T \ldots \psi | N \rangle$ Ellis, Furmanski, Petronzio 84

  Applications to exclusive meson production