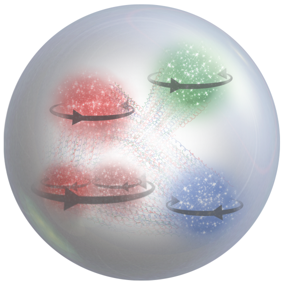
Transverse momentum dependence of sea quark distributions



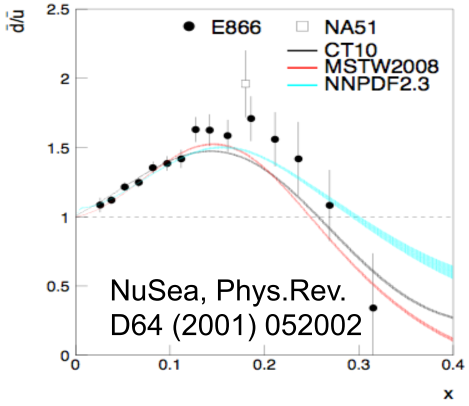
Understanding of the 3D structure of nucleon requires studies of spin and flavor dependence of quark transverse momentum distributions

$$f^a(x, k_T^2; Q^2)$$

TMD PDF for a given combination of parton and nucleon spins

To apply the TMD formalism to data we need to understand the basic properties of the TMDs at a low scale, determined by non-perturbative QCD interactions

Large flavor asymmetry $\bar{d} > \bar{u}$ indicate dynamical mechanisms creating nucleon sea



NuSea, Phys.Rev. D64 (2001) 052002

Non-perturbative sea in nucleon due to chiral symmetry breaking ($q\bar{q}$ vacuum condensate, dynamical mass generation)

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Nucleon could be regarded as a many-body system with short-range correlations induced by the chiral-symmetry breaking interactions.

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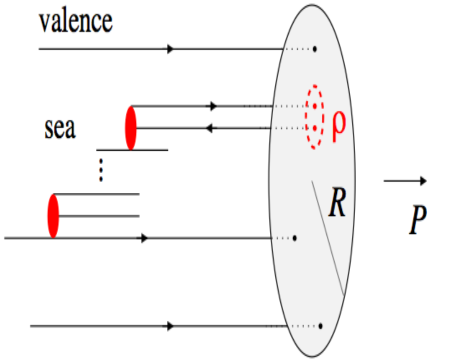


- Short–range interactions $\rho \sim 0.3\,\mathrm{fm}$

New dynamical scale $\rho \ll R$

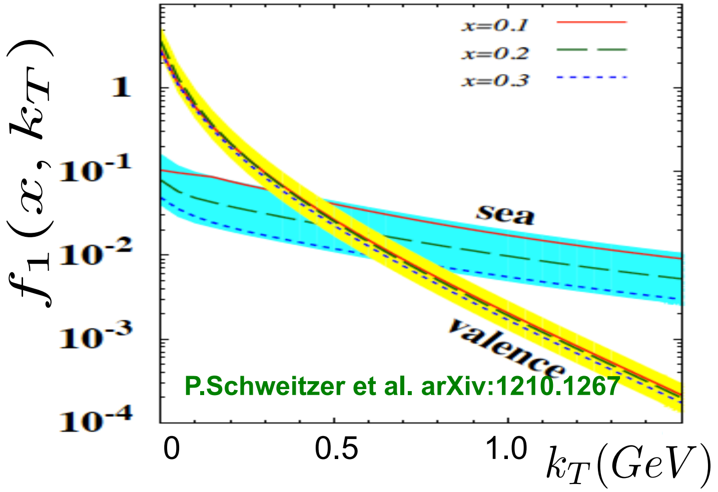
Shuryak; Diakonov, Petrov 80's

Dynamical mechanisms producing intrinsic transverse momentum in the nucleon may be very different for valence and sea quarks

Intrinsic k_T: Valence vs. sea quarks

- Predictions from dynamical model of chiral symmetry breaking [Schweitzer, Strikman, Weiss JHEP 1301 (2013) 163]
  -- short-range correlations between partons (small-size $q\bar{q}$ pairs)
  -- sea k_T~vacuum fluctuations (0.3 fm), with significant contribution from short-range forces
  -- k_T-distributions of valence quarks governed by the overall size of the nucleon of ~1fm (bag, light-front,..)

  k_T (sea) >> k_T (valence)



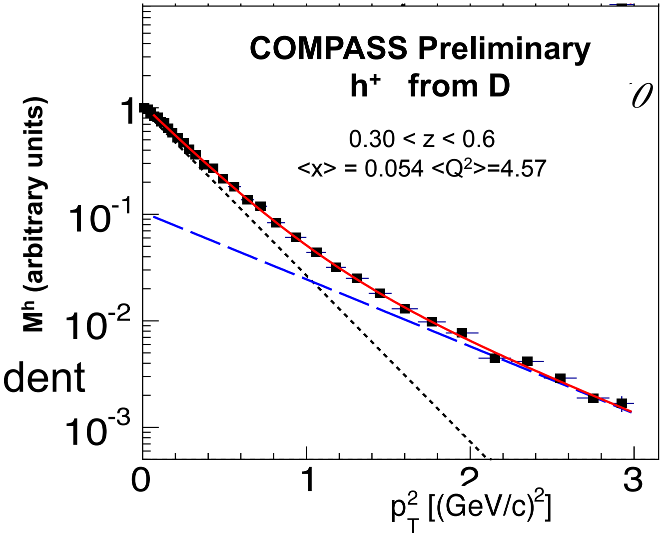
P.Schweitzer et al. arXiv:1210.1267

Higher probability to find more sea quarks at **large k_T**

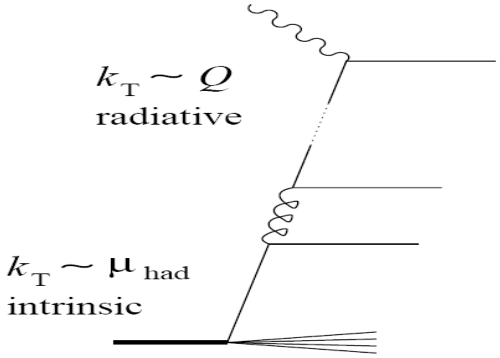
- Effects of short-range correlations may be directly observable in P_T-dependence of hadrons in SIDIS.

- Consistent with experimental data (increasing $<k_T^2>$ with energy, shifts from single Gauss already at P_T~0.6-0.7GeV), but require more detailed studies.

- Extraction will require detailed understanding of p_T-dependent distributions of fragmentation functions (BELLE, BABAR).



Intrinsic k_T: SIDIS observables



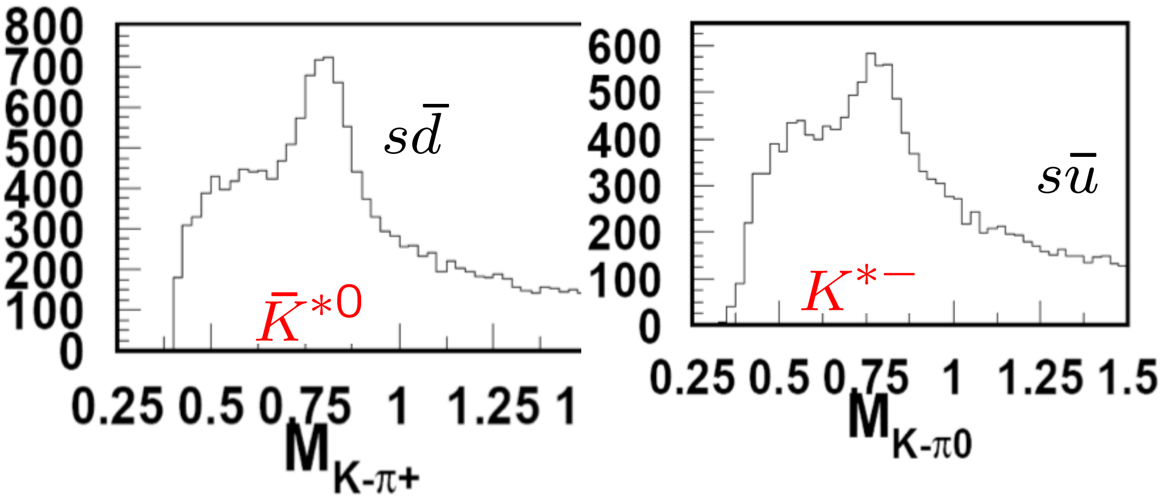
Separate valence and sea in K* SIDIS

$$N(K^{*-} - \bar{K}^{*0}) \propto (\bar{u} - \bar{d}) * FF$$

$$N(\rho^{+} + \rho^{-}) \propto (u_{val} - d_{val}) * FF)$$

- Aim: Observe intrinsic k_T of sea quarks due to QCD vacuum fluctuations
- Challenge: Separate intrinsic k_T from perturbatively generated k_T (DGLAP evolution)
- Tool: hadron production in SIDIS

<x>=0.1, <Q²>=4



$\sigma(p) = 0.05 + 0.06*p$ [GeV] %

Separate valence and sea
(charge separation with pions)

$$N(\pi^{+} - \pi^{-}) \propto e_u^2(u_{val}) - e_d^2(d_{val})$$

$$N(\pi^{+} + \pi^{-}) \propto e_u^2(u + \bar{u}) + e_d^2(d + \bar{d})$$

EIC can measure the widths of sea quark distributions in π, ρ, K and K* production in SIDIS

Support slides….

TMD factorization and analysis framework

TMD factorization theorem separates a transversely differential cross section into a perturbatively calculable part and several well-defined universal factors

$$d\sigma_{\text{SIDIS}} = \sum_f \mathcal{H}_{f,\text{SIDIS}}(\alpha_s(\mu), \mu/Q) \otimes F_{f/H_1}(x, k_{1T}; \mu, \zeta_1) \otimes D_{H_2/f}(z, k_{2T}; \mu, \zeta_2) \; + Y_{\text{SIDIS}}$$

corrections for the region of large $k_T \sim Q$

TMDs may in general contain a mixture of both perturbative and non-perturbative contributions

$$\boldsymbol{b}_*(\boldsymbol{b}_T) \equiv \frac{\boldsymbol{b}_T}{\sqrt{1 + b_T^2/b_{\max}^2}}.$$

Aybat,Collins,Qiu,Rogers 2012

non perturbative

$$\tilde{F}_{H_1}(x, b_T; Q, Q^2) = \tilde{F}_{H_1}(x, b_*; \mu_b, \mu_b^2) \exp\left\{ \boxed{-g_1(x, b_T; b_{\max})} - g_K(b_T; b_{\max}) \ln\left(\frac{Q}{Q_0}\right) + \ln\left(\frac{Q}{\mu_b}\right) \tilde{K}(b_*; \mu_b) + \int_{\mu_b}^{Q} \frac{d\mu'}{\mu'} \left[\gamma_{\text{PDF}}(\alpha_s(\mu'); 1) - \ln\left(\frac{Q}{\mu'}\right) \gamma_K(\alpha_s(\mu')) \right] \right\}$$

perturbatively calculable