
Full Contact QCD: the
Dynamics of Collins
Functions, Polarizing
Fragmentation Functions and
Polarizing Fracture Fu ctions

I. QCD in the Standard Model (& beyond)

QCD "lite" & "full contact" QCD

II. Single-Spin Asymmetries

KPR factorization, confinement, chiral symmetry, spin-orbit

III. ACY Formalism (π) Collins functions

QCD-fluxtubes, spin-directed momentum, Partial waves

IV. KPR-Factorized ACY Calculations

Pseudoscalar & Vector Collins functions ; Vector Polarizing Fragmentation functions ; Baryon polarizing fracture functions + "fractured" Boer-Mulders

V. EXPERIMENTAL SIDIS confronts Chiral Dynamics : a celebration of QCD mechanisms

I. QCD in the Standard Model

Search for new physics at CERN LHC motivated by "naturalness" problem

However, QCD is a richly-structured quantum field theory -- Cleanly separated from other forces in any extension of the standard model -- with <u>no</u> <u>naturalness</u> issues

Confinement / approximate chiral symmetry realized in a Nambu-Goldstone mode & an intriguing complex high-temperature limit

"QCD-lite" describes a very restricted theory that treats hadrons as black boxes that serve as mere sources of quarks & gluons for calculations in renormalization group improved perturbation theory

"Full Contact" QCD includes a variety of calculations aimed at coherent, nonperturbative dynamics in QCD (Lattice regularization, Operator techniques, Classical sol'ns. crossing, analyticity – $\frac{1}{N_c}$).. heavy Q expansion(s) chiral models, AdS-CFT correspondence scaling rules, Fock-basis expansions, "string"-models, sum rules, SU(N) all serve as guidance & tools for nonperturbative QCD

LATTICE SIMULATIONS

play a special role .. lattice p.t, fermion det. approx...

EXPERIMENTAL DATA

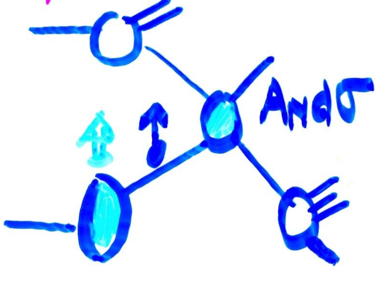
II. Single-Spin Asymmetries

transverse single-spin observables provide a convenient probe of nonperturbative mechaisms in QCD

Kane, Pumplin & Repko (KPR) - 1978

$$A_N \to \alpha_s (m_q/\sqrt{s}) f(\theta)$$

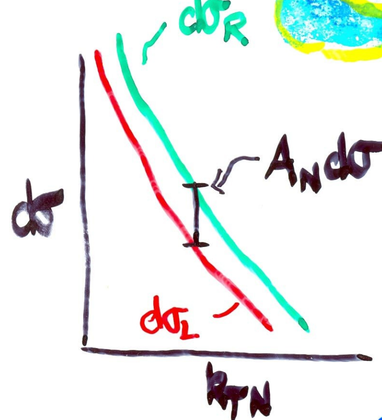
1979-1989 widely quoted as proving single-spin observables would vanish in hard-scattering processes

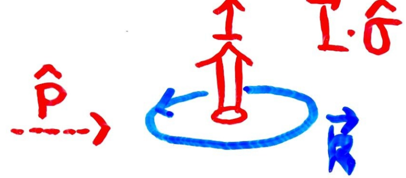


"...observation of significant polarisation in the above reactions would contradict either QCD or its applicability"

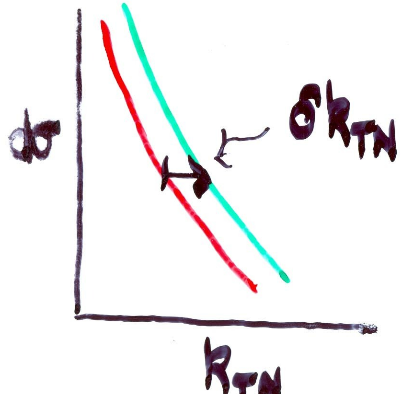
PRL 1978

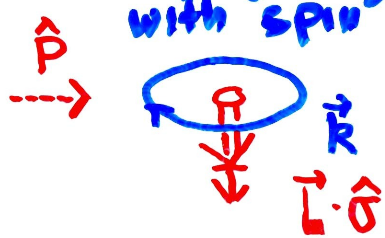
SPIN-DIRECTED MOMENTUM





coherent "boundary conditions" change sign with spin





$$k_{TN} = \vec{k}_T \cdot (\hat{\sigma} \times \hat{P})$$

"It seems convenient to represent the coherent spin-orbit forces in a proton by defining an asymmetry of the transverse momentum distribution of the fundamental constituents"

Phys. Rev. (1990)

KPR calculation ⇒ twist-3 effects can be "factorized" into k_T-dependent dsth's, frag. fcn's.

k_{TN} even under time reversal $T^{-1}(k_{TN})T = ((-\hat{p})\times(-\hat{\sigma}))\cdot(-\vec{k}_T) = k_{TN}$

but odd under a symmetry constructed using the

* (Hodge) operation of differential geometry

$\Theta = *(P^*)$ $\quad \Theta : (\vec{p}_i, \vec{\sigma}_i) \to (\vec{p}_i, -\vec{\sigma}_i)$ $\quad$ snake operator!

$A_\tau = P\Theta$ $\quad A_\tau : (\vec{p}_i, \vec{\sigma}_i) \to (-\vec{p}_i, -\vec{\sigma}_i)$ $\quad$ "naive" time reversal

$$A_\tau^{-1} k_{TN} A_\tau = (-\vec{k}_T)\cdot((-\hat{\sigma})\times(-\hat{p})) = -k_{TN}$$

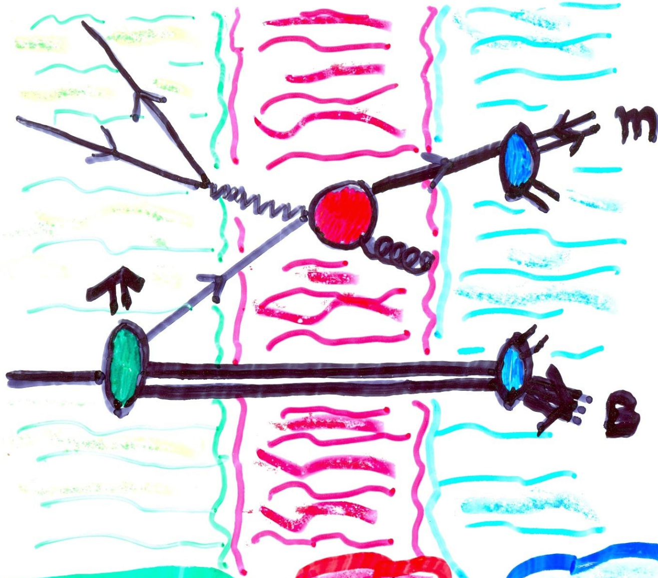
with A_τ we can form idempotent projection operators

$$\boxed{\Pi_A^{\pm} = \left(\frac{1 \pm A_\tau}{2}\right)}$$

that project spin-orbit dynamics both in amplitudes and in $|\text{amp}|^2$

spin-density matrices for single-spin observables diagonal in the transversity basis (Σ_y) diagonal

SPIN ASYMMETRIES IN SIDIS



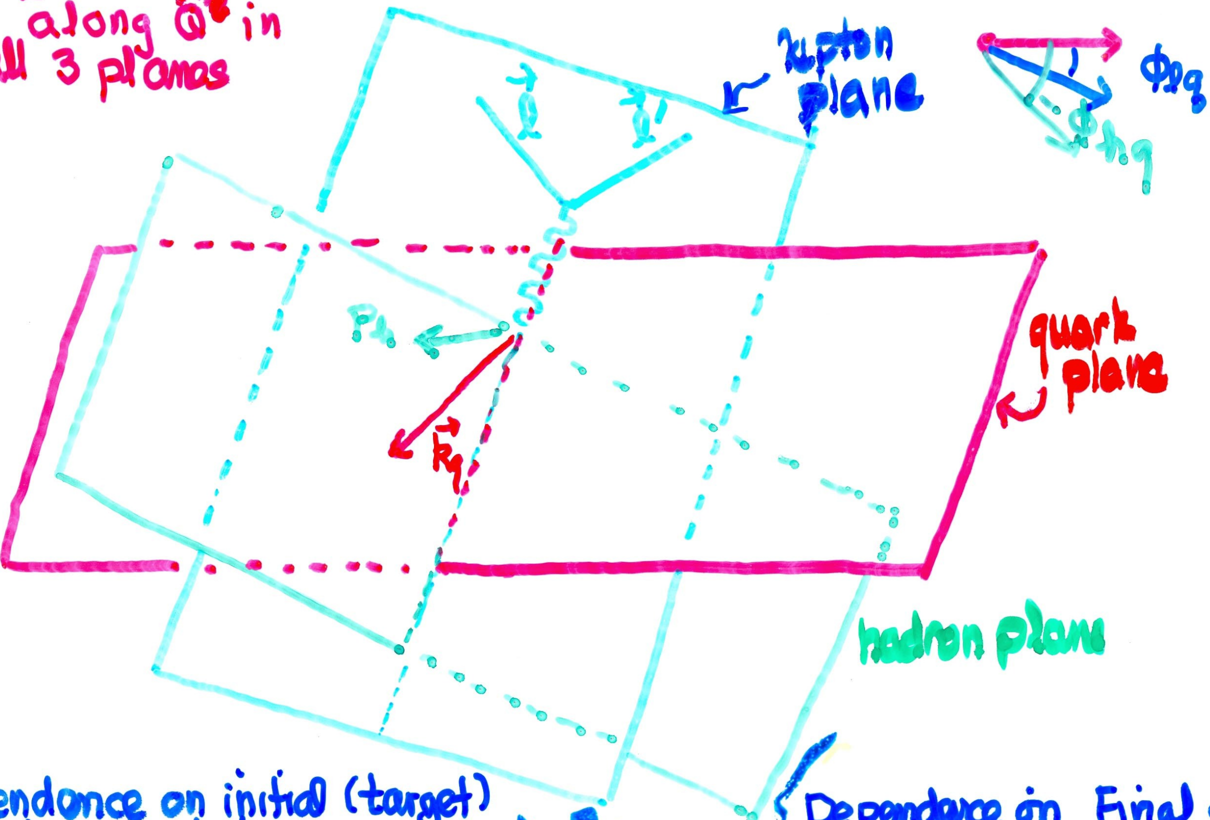
distributións | hard scattering | fragmentatión

flexible boundaries

KPR factorization allows all single-spin dynamics to be associated with distributións or fragmentatión !

Initial-State and Final-State Spin effects SIDIS
KPR Factorization

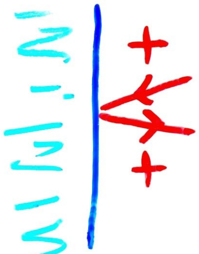
$\hat{Z}$-axis along $\hat{Q}^*$ in all 3 planes



Dependence on initial (target) Spin Orientation			Dependence on Final state Spin Orientation		
Orbital Dstn	odd ϕ_{lq}	even ϕ_{hq}	Fract and BM	odd ϕ_{lq}	even ϕ_{hq}
Collins fcn	even ϕ_{lq}	odd ϕ_{hq}	Polarizing FF	even ϕ_{lq}	odd ϕ_{hq}

SPIN-ORBIT DYNAMICS & QCD

The coherent dynamics probed by single-spin observables play a major role in confined systems of light quarks



$\Delta J_z = 2S$

helicity conservation and angular momentum conservation conflict with rigid confinement

$u\uparrow \to \pi^+ d\Downarrow \quad L = +1$

"constituent" quark resolved into virtual π + "current" quark by $L = \pm 1$ processes

These QCD mechanisms are more transparent in fragmentation functions (Collins functions and Polarizing ff's) than in distribution functions (Boer-Mulders functions and orbital dst'ns). This can be illustrated by a well-known result → Collins Conjugation ←

WILSON OPERATORS RADIAL GAUGE $A^a_i \cdot \hat{r}_i = 0$

$\Uparrow \hat{\sigma}$

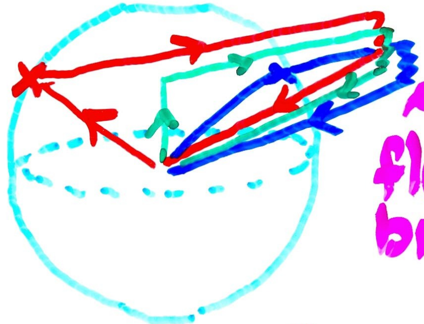
INTRINSIC $\langle \vec{L} \cdot \hat{\sigma} \rangle$

Quantitative nonperturbative calculations required

J. Collins

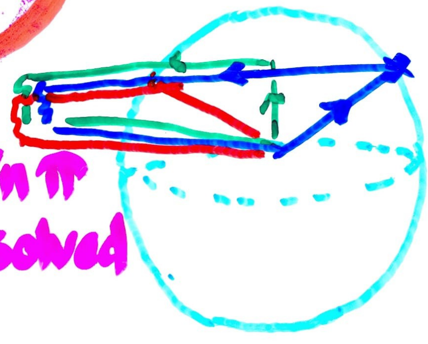
$$\frac{\langle \delta_{RTN} \rangle^{SIDIS}}{\langle \delta_{RTN} \rangle_{DY}} = -1$$

$\Uparrow \hat{\sigma}$



flux tube breaks

$\Uparrow \hat{\sigma}$



$\vec{q}$ in π resolved

SIDIS $A_N(\gamma^* p T \to \pi)$

DY $A_N(\pi p T \to \gamma^*)$

// Conjecture ISI & FSI same for Boer-Mulders fn's as for orbital distn's

Parallelism Conjecture & Collins Conjugation

$$\frac{\Delta^N f_{qT/p}(x, k_{TN}; Q^2)}{\Delta^N f_{q/pT}(x, k_{TN}; Q^2)} = \frac{\langle \vec{L}_q \cdot \hat{\sigma}_q \rangle}{\langle \vec{L}_q \cdot \hat{S}_p \rangle}$$

process independent

soft interactions given by gauge theory (Wilson Loops) even when quarks & gluons are <u>not</u> dominant degrees of freedom

$$\frac{\Delta^N f_{qT/p}(\mathrm{DIS})}{\Delta^N f_{qT/p}(\mathrm{DY})} = -1$$

nonAbelian Bohm-Aharonov effect (Pijlman)

Ratio for Boer-Mulders functions same as that of orbital distributions!

conveniently,

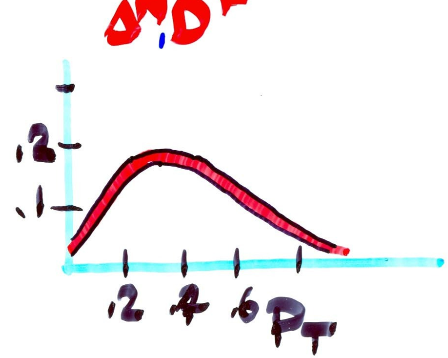
the spin-directed momentum measured in Collins functions is directly connected to $\vec{L}\cdot\hat{\sigma}$ and the dynamics are the same that give the intrinsic $\langle \vec{L}_q \cdot \hat{\sigma}_p \rangle$ in the proton!

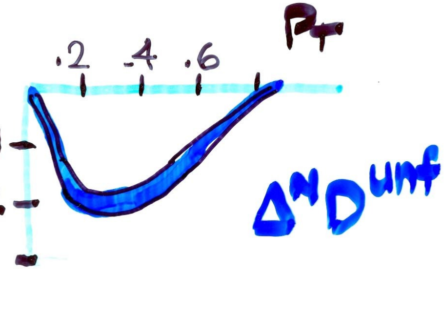
Artru, Czyzewski and Yabuki

ACY

III. The ACY FORMALISM for Collins FUNCTIONS

Artru, Czyzewski, and Yabuki formulated a very successful approach (ACY) to Collins functions with a nonintutive prediction $\frac{\Delta^N D_{\pi^-/u}}{\Delta^N D_{\pi^+/u}} \leq -1$ that was subsequently supported!





← Anselmino et. al

orignally presented in terms of a "string" model

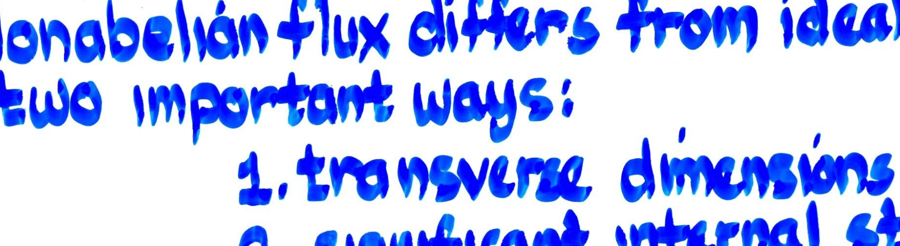
For the purpose of illustrating the underlying dynamics, it is instructive to reconsider the ACY approach using SU_3 "flux tubes"

Nonabelian flux differs from idealized strings in two important ways:

1. transverse dimensions of hadronic size
2. significant internal structure

that significantly modify how they break.

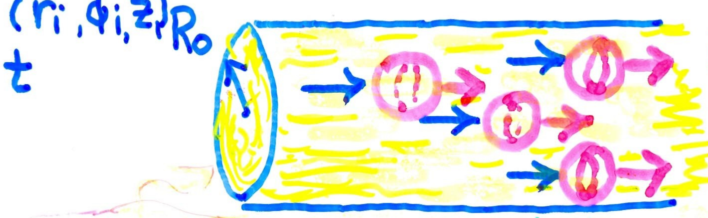
color charge in flux → interactions involving flux lines merging, twining, splitting, knotting



most local fluctuations self healing ...

CLASSICAL non-Abelian fields

$U_1 \in SU_2 \in SU_3$ $\quad U_1$



$\hat{\xi}_a$

Confined fields with cylindrical symmetry

$$\hat{\xi}_a = \hat{z}_a \qquad \xi_{ia} = \hat{z}_i \hat{z}_a$$

$$D_j^{ab}\hat{z}_b = a(r,z,t)\, e^{(+)}_{ja}(\omega(z,t))$$

$$-i[\hat{z}, D_j \hat{z}]^a = a(r,z,t)\, e^{(-)}_{ja}(\omega(z,t))$$

a gauge transformation that leaves ξ_a unchanged can be compensated by spatial rotation around z axis $\quad i = 1,3 \quad a = 1,3$ $(4,8)$

$$gA_0^a = A_0 \hat{\xi}_a$$

$$gA_i^a = A_1 \xi_{ia} + a\left[e^{(-)}_{ia}(\omega) - e^{(-)}_{ia}(0) \right]$$

vector potential ansatz

$$\boxed{A_0 = A_0(r,z,t) \quad A_1 = A_1(r,z,t) \quad a = a(r,z,t) \quad \omega = \omega(z,t)}$$

no r dependence

FIELD Strengths

$$E_L = (\partial A_0/\partial z - \partial A_1/\partial t) \qquad B_L = (a^2 - 1)$$

$$E^{(+)} = -a(\partial \omega/\partial t - A_0) \qquad B^{(+)} = -\partial a/\partial r$$

$$E^{(-)} = -\partial a/\partial t \qquad B^{(-)} = -a(\partial \omega/\partial z - A_1)$$

$a = 1$

$$E_L = (A_0' - A_1') \quad B_L = 0$$

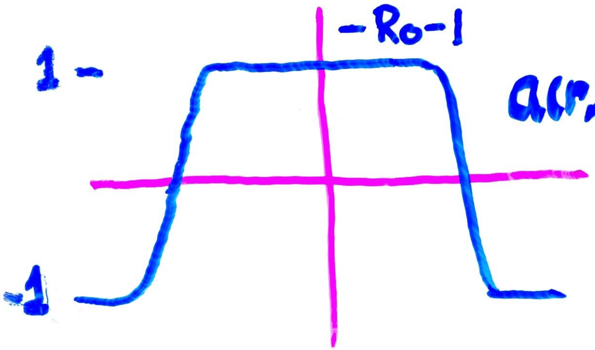
$$E^{(+)} = K_0 - A_0 \quad B^{+} = 0$$

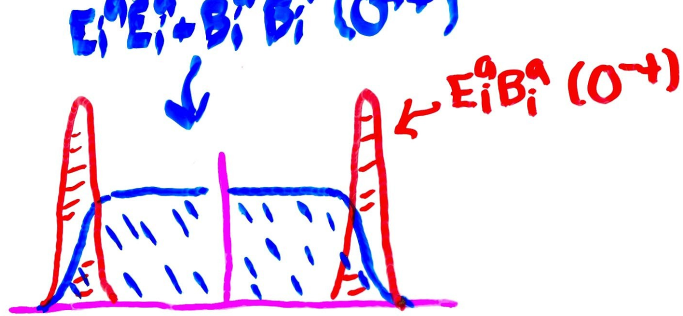
$$E^{(-)} = 0 \quad B^{-} = A_1 - K_1$$

topological current $\quad \frac{1}{2}{}^*G^a_{\mu\nu} G^{a\mu\nu} = E^a_i B^a_i = \partial^\ell K_\ell \quad \ell = 0, 1$

$$K_0 = (a^2 - 1)A_1 - a^2(\partial \omega/\partial t)$$

$$K_1 = -(a^2 - 1)A_0 + a^2(\partial \omega/\partial z)$$

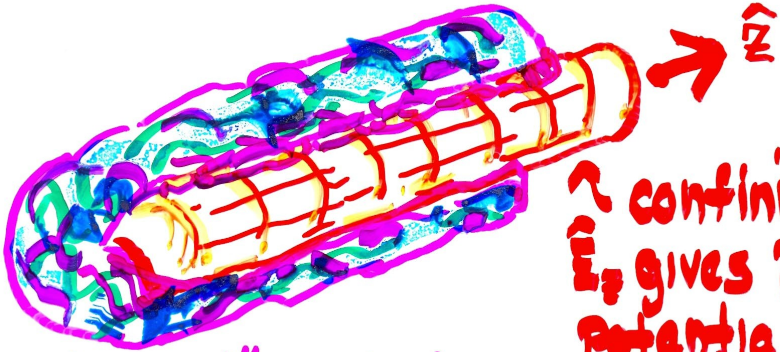




cylinder cross section

"CLASSICAL" PICTURE

$ep \to e'qX$ Monojet event



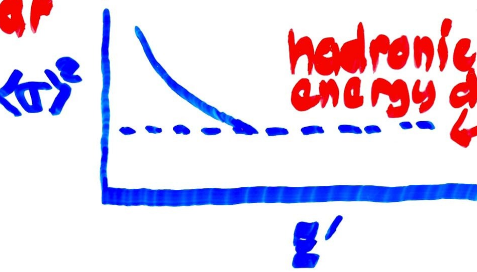
confining $\hat{E}_z$ gives linear potential

"topological" shell gives Adler zeros for π emission

Light-Cone momentum densities

$p^+(r,z^+,z^-) = \sigma(r,z^+,z^-)e^{\eta}$

$p^-(r,z^+,z^-) = \sigma(r,z^+,z^-)e^{-\eta}$



Local $\bar{q}q$ fluctuations $J^P = 0^- \ 1^+ \ldots$

$0^+ \ 1^- \ldots$

s-wave fluctuations give "clumps" that stick to topological shell

p-wave fluctuations ($0^{++} = {}^3P_0$) break tube and relieve expansion pressure

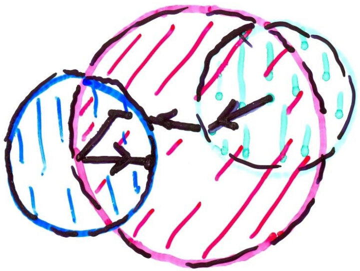
To understand dynamics of Quantum Flux attention must be directed to local symmetry properties

Local 0^{-+} fluctuation does not generate a string break!

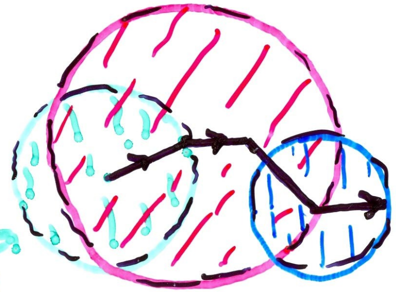
Internal motion of $^3P_0$ 0^{++} pair creates flux gap via "weedeater" effect $\Rightarrow$ local vacuum

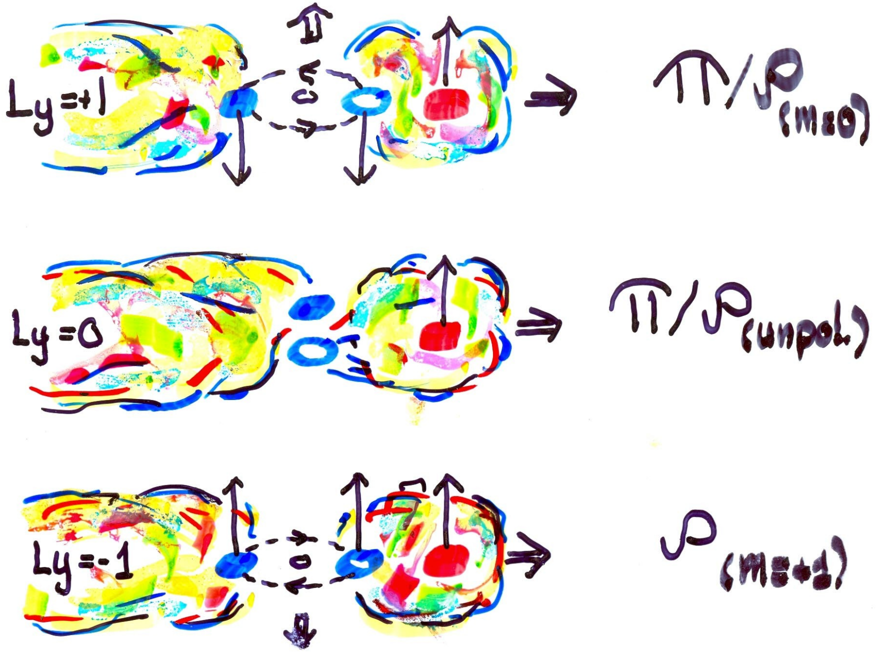
Energy released then Generates R_{TN} !!

SPIN-DIRECTED MOMENTUM IN FRAGMENTATION



multiple sources of k_T





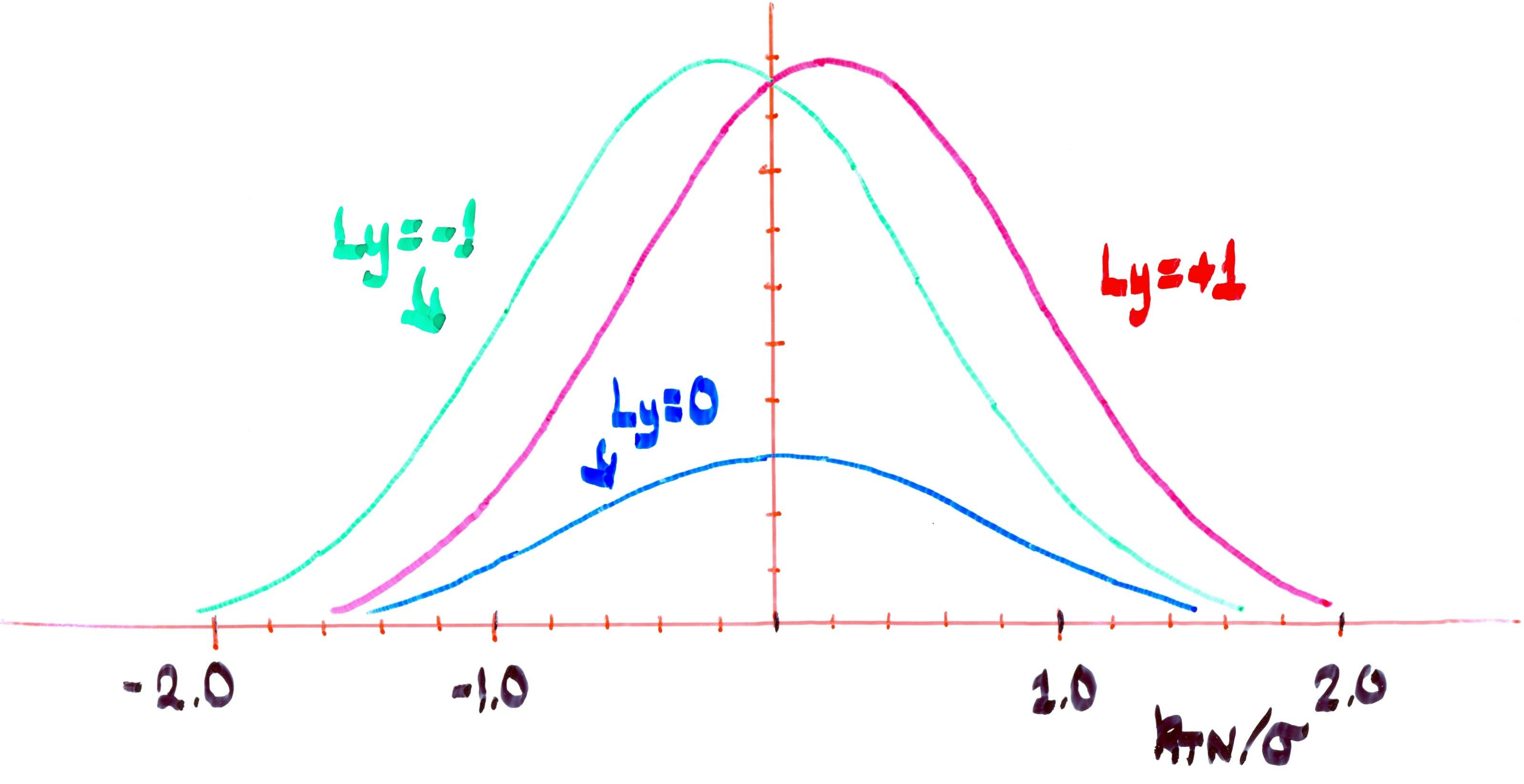
Partial Wave expansión for the Fragmentation Dynamics

$$\langle L_y \rangle = \langle z k_x - x k_z \rangle$$

PARTIAL WAVES

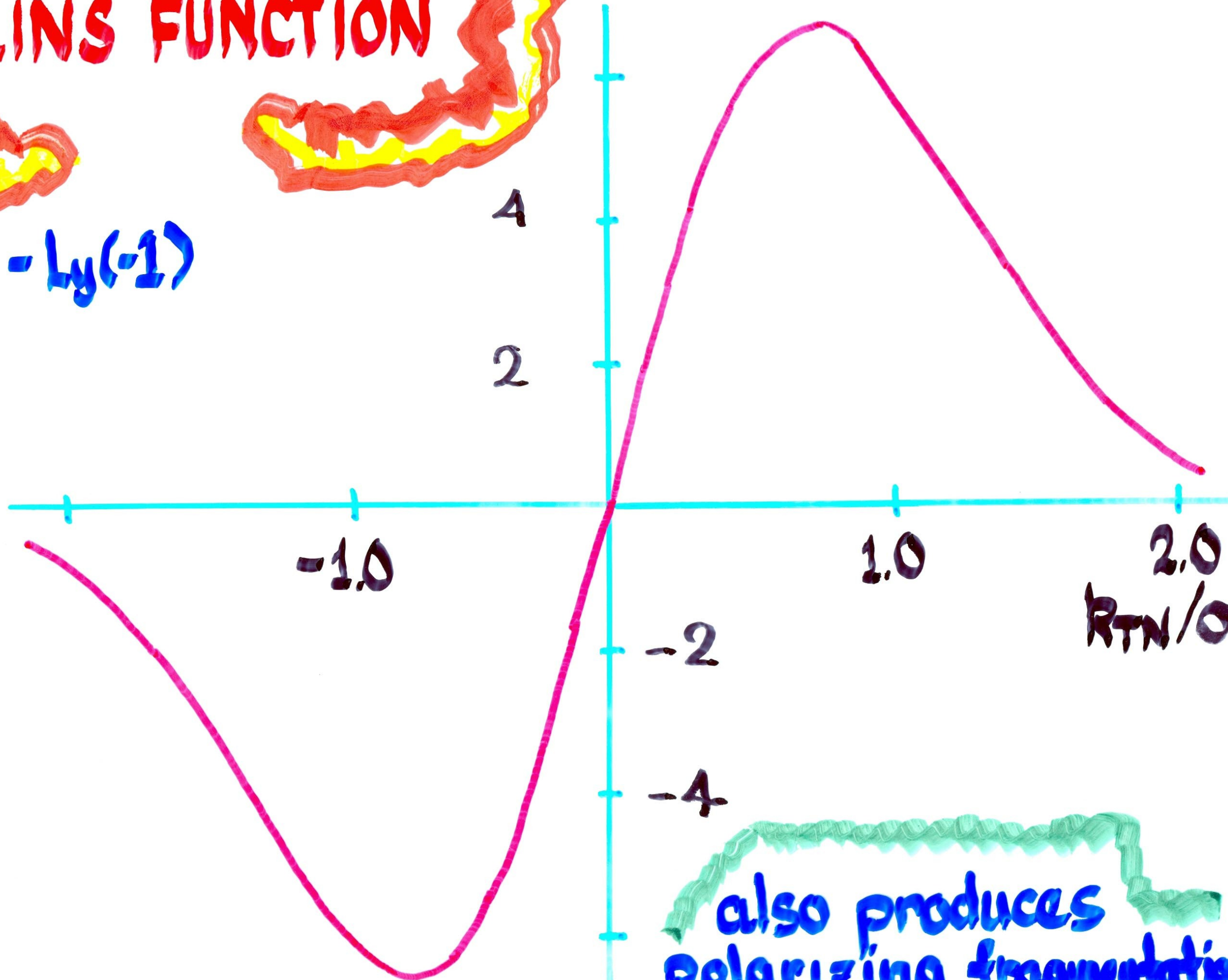
$\delta k_{TN}/\sigma = 0.2$

gaussian approx.



COLLINS FUNCTION

Ly(+1) - Ly(-1)



also produces polarizing fragmentation & polarizing fracture functions

IV. KPR- FACTORIZED ACY CALCULATION

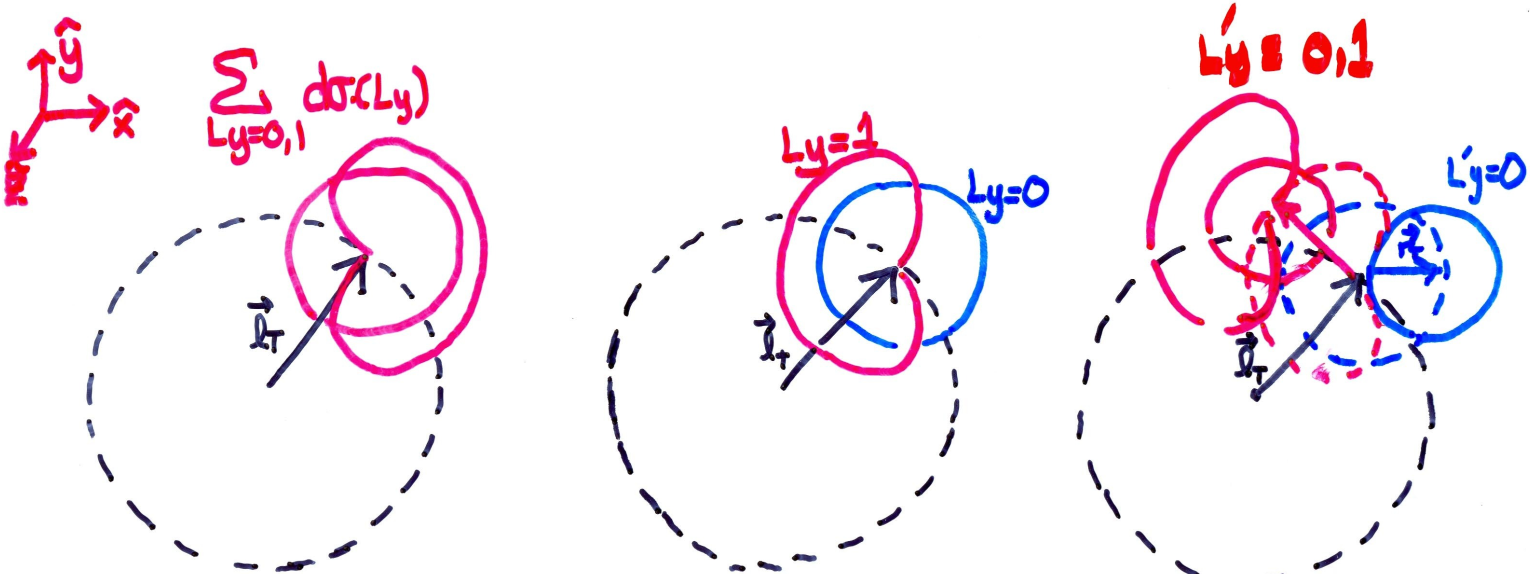
Pseudoscalar meson Collins functions

Issues:

1) Favored & Disfavored
2) The cost of $\bar{s}$
3) Strangeness Disfavored

Putting the QCD tools to work

Favored and Unfavored Collins Functions



$u\uparrow(\vec{l}_T) \to \pi^+(\vec{k}_T)$

$L_y = 0,1$

$u\uparrow(\vec{l}_T) \to d(\vec{k}_T)$

$(L_y=0)$

$u\uparrow(\vec{l}_T) \to d\downarrow(\vec{k}_T)$

$(L_y=+1)$

$d(\vec{l}_T + \vec{r}_T) \to \pi^-(\vec{k}_T)$

$L'_y = 0$

$d\downarrow(\vec{l}_T + \vec{r}'_T) \to \pi^-(\vec{k}_T)$

$L'_y = 0,-1$

Provide Sensitive Measure of $L_y = 0$ Component !!

Probability densities involve 2-dim mom. space Convolutions (can be done in gaussian approx.) Mean Spin/directed momentum shifts are easier to calculate

Let $\xi_0(k_{TN}, z)$ = fraction of $L_y=0$ events / fraction $L_y=+1$

Start with $u\uparrow$ & neglect $n(\rho^+)/n(\pi^+) \propto e^{-b(m_\rho - m_\pi)}$

$\langle \delta k_{TN}(\pi^+) \rangle = \dfrac{+\delta}{1+\xi_0}$ $\quad \langle \delta k_{TN}(d\downarrow) \rangle = -\delta \quad \langle n(d\downarrow) \rangle = \dfrac{1}{1+\xi_0}$

$\langle \delta k_{TN}(d_u) \rangle = 0 \quad \langle n(d_u) \rangle = \dfrac{\xi}{1+\xi_0}$

$\langle \delta k_{TN}(\pi^-) \rangle = \langle \delta k_{TN}(u\uparrow \to d\downarrow \to \pi^-) \rangle \langle n(d\downarrow) \rangle + \langle \delta k_{TN}(u\uparrow \overset{0}{\to} d_u \to \pi^-) \rangle \langle n(d_u) \rangle$

$= \dfrac{1}{(1+\xi_0)} \left(\dfrac{-2\delta}{1+\xi_0} - \delta \dfrac{\xi_0}{1+\xi_0} \right) = \dfrac{-2\delta}{(1+\xi_0)^2} (1+\xi_0/2)$

$$\boxed{\frac{\langle \delta k_{TN}(\pi^-) \rangle}{\langle \delta k_{TN}(\pi^+) \rangle} = -2 \left(\frac{1+\xi_0/2}{1+\xi_0} \right)}$$

$\langle \delta k_{TN}(\pi^0) \rangle = \frac{1}{2}(\langle \delta k_{TN}(\pi^+) \rangle + \langle \delta k_{TN}(\pi^-) \rangle)$

Strange & Strangeness-Disfavored Collins Functions

The shape & Relative magnitude of Partial Waves Can change as u,d → s in flux tube breakup

$u\uparrow$ $$\frac{\langle \delta k_{TN}(K^+)\rangle}{\langle \delta k_{TN}(\pi^+)\rangle} = \frac{\delta_K}{\delta}\,\frac{1+\xi_0}{1+\xi_{0K}}$$ $$\frac{n(K_+)}{n(\pi^+)} = b e^{-H(m_K - m_\pi)}$$

guess $\delta_K > \delta$

$\xi_{0K} > \xi_0$

$u\uparrow \to d\downarrow \to K_0$ $$\frac{\langle \delta k_{TN}(K^0)\rangle}{\langle \delta k_{TN}(K^+)\rangle} = \frac{-\delta - \delta_K - \delta\xi_{0K}}{\delta_K(1+\xi_0)}$$

$u\uparrow \to s\downarrow \to K-$ $$\frac{\langle \delta k_{TN}(K^-)\rangle}{\langle \delta k_{TN}(K^+)\rangle} = \frac{-\delta - \delta_K - \delta_K\xi_0}{\delta_K(1+\xi_{0K})}$$ strangeness disfavored

Vector Meson Collins Functions

$u\uparrow \to \rho^{+}\uparrow d\uparrow \quad (L_y = -1) \qquad [-\delta]$

$u\uparrow \to \frac{1}{2}\rho^{+} d_u \quad (L_y = 0) \qquad [\,0\,]$

$u\uparrow \to \frac{1}{2}\rho_{M=0}\, d\downarrow \quad (L_y = +1) \qquad [+\delta]$

$$\to \frac{\langle \delta k_{TN}(\rho^{+})\rangle}{\langle \delta k_{TN}(\pi^{+})\rangle} = -\frac{(1+\xi_0)}{(3+\xi_0)}$$

$$\langle \delta k_{TN}(\rho^{+})\rangle = \frac{-\delta}{3+\xi_0}$$

$$\frac{\langle \delta k_{TN}(\rho^{-})\rangle}{\langle \delta k_{TN}(\rho^{+})\rangle} = \frac{(2+\xi_0)}{(1+\xi_0)}$$

$$\langle \delta k_{TN}(K^{*+})\rangle = \frac{-\delta_K}{3+\xi_{0K}}$$

$$\frac{\langle \delta k_{TN}(\rho^{0})\rangle}{\langle \delta k_{TN}(\rho^{+})\rangle} = \frac{3+2\xi_0}{2(1+\xi_0)}$$

many more ....

Let's turn attention to polarizing fragment.

$(q \to \rho\uparrow X)$

POLARIZING FRAGMENTATION

$L_y = +1$

$V \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1/2 & 0 \\ 0 & 0 & 0 \end{pmatrix}$

$V \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

$L_y = 0$

$V \xi \begin{pmatrix} 1/2 & 0 & 0 \\ 0 & 1/4 & 0 \\ 0 & 0 & 0 \end{pmatrix}$

$V \xi \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1/4 & 0 \\ 0 & 1/2 & 0 \end{pmatrix}$ ← mistake

$L_y = -1$

$V \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$

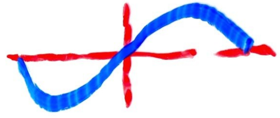
$V \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1/2 & 0 \\ 0 & 0 & 0 \end{pmatrix}$

diagonal spin density matrices

$\frac{1}{2} \Sigma \left(L(+1) - L(-1) \right) = \frac{1}{2} \begin{pmatrix} -1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$ $\quad V\uparrow = \rho\uparrow, \omega\uparrow, K^*\uparrow \ldots$

Vector Meson Polarization: L_y produces separation in k_{TN}

$D_{V\uparrow/q}(z, k_{TN})$



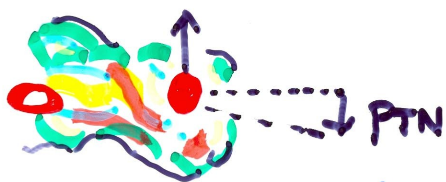
FINAL-STATE POLARIZATION COURTESY of BOER-MULDERS

Boer-Mulders odd (p_{TN}) even ($\hat{p}_T \cdot \hat{k}_T$)

⊗ transverse frag

Sign & Magnitude in DIS sensitive to final-state interactions

Parallelism Conjecture for single-spin observables: QCD ISI / FSI same for Boer-Mulders as for orbital dstn.



fragmentation even in $(\hat{p}_T \cdot \hat{k}_T)$ leads to k_{TN} separation

polarizing fragmentation

$f_q(x, p_T^2)\,\Delta^N D_{V\uparrow/q}(z, p_{TN})$

$\Delta^N f_{q\uparrow}(x, p_{TN}) \cdot D_{V\uparrow/q\uparrow}(z, (\hat{p}_T \cdot \hat{k}_T))$

selected a la Collins v. Orbital distribution

to be continued!

NEED ANALYZING POWER

to study final-state polarizations

TOUGH for vector mesons so let's

study Baryons in the target fragmentation region !!

FRACTURE FUNCTIONS

$M^{q}_{B/p}(x, \vec{p}_T, z, \vec{k}_T ; Q^2)$

conjoint probability for finding $q\{x, \vec{p}_T\}$ on $B\{z, \vec{k}_T\}$ in DIS event

Veneziano-Trentadue

Fracture Functions for Baryon Production
SIDIS/DY Target frag. region

chiral obs.

$\Delta^N M^{q\uparrow}_{B/p\uparrow}$ — $\Delta^N M^{q}_{B\uparrow/p}$

Fractured Collins Functions — Polarizing Fracture functions

KPR
Factorial

$\Delta^N M^{q\uparrow}_{B\uparrow/p}$ — $\Delta^N M^{q}_{B/p\uparrow}$

Fractured Boer-Mulders functions — Fractured Orbital Distributions

hadronic

Formalism of Veneziano-Trentadue applied to study of spin observables in inclusive baryon production

Initial state Spins

polarised $p\uparrow$ $d\uparrow$ targets

FCF - FOD

Final state Spins $\Lambda\uparrow, \Sigma\uparrow \ldots$

self analyzing hyperon pol's.

PFF - FBM

Polarizing Fracture Functions & Diquarks

d. sivers
arXiv 0811.2388

Two kinds of color $\bar{3}$ diquarks

$[q,q]$ SU$_3$ flavor $\bar{3}$ $J_P = 0^+$

$\{q,q\}$ SU$_3$ flavor 6 $J_P = 1^+$

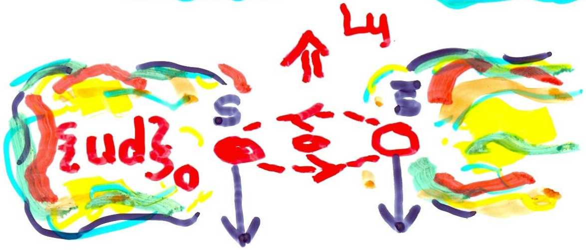
$\Delta^N M^u_{\Lambda\uparrow/[ud]}(x, z, k_{TN}; Q^2)$ asymmetry in production of $\Lambda\uparrow$ from $[ud]$ diquark

$\Delta^N M^d_{\Sigma^+\uparrow/\{uu\}}(x, z, k_{TN}; Q^2)$ asymmetry in production of $\Sigma^+\uparrow$ from $\{uu\}$ diquark

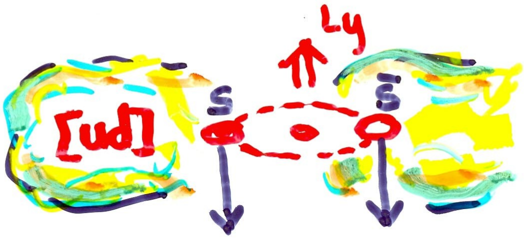
$\Delta^N M^u_{\Sigma^0\uparrow/\{ud\}}(x, z, k_{TN}; Q^2)$ asymmetry in production of $\Sigma^0\uparrow$ from $\{ud\}$ diquark

These, and many others, calculable in KPR-factorized ACY formalism !!

The target end of the Color Flux



$$|\Sigma_0^*\rangle\langle\Sigma_0^*|\begin{pmatrix}0&0&0&0\\0&1/6&0&0\\0&0&1/3&0\\0&0&0&1/2\end{pmatrix}+|\Sigma_0\rangle\langle\Sigma_0|\begin{pmatrix}2/3&0\\0&1/3\end{pmatrix}$$



$$|\Lambda_0\rangle\langle\Lambda_0|\begin{pmatrix}0&0\\0&1\end{pmatrix}$$

$$\Delta^N M^u_{\Sigma\uparrow/\{ud\}_S}(x,z,k_{TN},Q^2)=C^u_{\{ud\}}(x,z,Q^2)\,\delta G_S(x,z,k_{TN};M_\Sigma^2)\begin{pmatrix}-1/3&0\\0&1/3\end{pmatrix}$$

$$\Delta^N M^u_{\Lambda^0/[ud]}(x,z,k_{TN};Q^2)=C^u_{[ud]}(x,z,Q^2)\,\delta G_S(x,z,k_{TN};M_\Lambda^2)\begin{pmatrix}1&0\\0&-1\end{pmatrix}$$

Different x dependence & different Polarization

Can be Separated Experimentally from Fractured Boer-Mulders

Fractured Boer-Mulders Effect

Correlation between transverse-momentum and Polarization of **Diquarks** in an unpolarized ensemble of nucleons.

Leads to much different polarization for Λ's vs. Σ's !!

Spin-Polarized I=1 diquarks {uu}, {ud}, {dd} can lead to polarized $\Sigma\uparrow$ but not $\Lambda\uparrow$!!!

Intrinsic strangeness {us}, {ds} in diquarks contributes equally to $\Lambda\uparrow$, $\Sigma\uparrow$

Explores the same final state interactions as fractured orbital distribution.

(work in progress...)

V EXPERIMENTAL SIDIS

The exploration of nucleon structure in deep-inelastic lepton scattering has a venerated history

Semi-Inclusive production uses flavor & spin quantum numbers to isolate specific nonperturbative mechanisms

COLLINS FUNCTIONS use quark jets to help us understand Constituent quarks!

Separation based on KPR factorization allows study

transversity $\otimes$ Collins fcns v. orbital dstn's,

combined with Belle $\rightarrow$ transversity dstn $\delta f(x, Q^2)$

This can be just the beginning!

Vector Meson Collins functions

Strange & strangeness-disfavored Collins fcns.

The concept of spin-directed momentum provides an organizing principle that allows quantitative nonperturbative QCD calculations for Single Spin asymmetries

Semi-Classical understanding of QCD flux

⇒ Extend the ABY formalism →

Polarizing fragmentation

Grabbing onto the "other" end of the flux tube (the target end) ⇒ Polarizing Fracture functions

$p^{\uparrow} \to \Lambda\, \Sigma$	$p \to \Lambda^{\uparrow}\, \Sigma^{\uparrow}$
fractured orbital	polarizing fragmentation
fractured Collins	fractured Boer-Mulders

self-calibrating in DIS & can be extended to DY! ($BM_{DY} \to -BM_{SIDIS}$; $OD_{DY} \to -OD_{SIDIS}$)

The topics discussed here are already

PART OF JEFFERSON LAB

EXPERIMENTAL

PROGRAM

and I hope to learn more from

REAL DATA

as soon as it is

AVAILABLE


The Importance of
an Organizing
Principle