Di-Hadron Status

Chris Dilks (Duke), Anselm Vossen (Duke & Jlab)



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- Physics Interest
- Status of analysis
- Plots for YR
- Detector/Machine requirements
- Current issue/plans

"You think you understand something?---Now add spin...in Hadronization!"

→polarized final states



→di-hadron correlations



- Explore spin-orbit correlation in hadronization
- Additional degrees of freedom in final state make targeted extraction of nucleon structure possible →see h₁(x), e(x)
- New Fragmentation Functions

DI-HADRON FRAGMENTATION FUNCTIONS

Additional Observable:

$$\vec{R} = \overrightarrow{P_1} - \overrightarrow{P_2}$$
 :

The relative momentum of the hadron pair is an additional degree of freedom:

the orientation of the two hadrons w.r.t. each other and the jet direction can be an indicator of the quark transverse spin

arton polarization $ ightarrow$	Spin averaged	longitudinal	transverse
artial wave polarization 🗸			
pin averaged	$D_1^{h/q}(z,M)$	8	$H_1^{\perp h/q}(z, p_T M, (Ph), \theta)$ 'Di-hadron Collins'
longitudinal polarization"			
leeds Interference with p- vave OAM component transverse polarization"	Type equation here.	$G_1^{\perp}(z,M,P_h,\theta)=$ T-odd, chiral-even \rightarrow jet handedness QCD vaccum strucuture	H1 [*] (z,M, (P _h), θ)=. T-odd, chiral-odd Colinear

- Relative momentum of hadrons can carry away angular momentum
 - Partial wave decomposition in $\theta \rightarrow$
 - Needs to be mapped completely!! (no information yet)
 - Energy dependence? (→VM fractions....)
 - Relative and total angular momentum \rightarrow In principle endless tower of FFs
 - Similar to tensor polarized target



c.m.

Some specific points of interest

- Access to aspects of the nucleon structure difficult in single hadrons
 - Examples:
 - <u>Transversity/Tensor charge in collinear picture (global analysis available e^+e^- , <u>SIDIS</u>, <u>pp</u>)</u>
 - Boer-Mulders w/o Cahn, twist3, power corrections
 - e(x) (scalar condensate) \rightarrow New developments using LaMET
- Spin orbit correlations in hadronization (e.g. G_1^{\perp})
 - Interference patterns of different relative partial waves

Additional degrees of freedom → Need large statistics (compared to 1H)

Transversity extraction from global Pavia fit Phys.Rev.Lett. 120 (2018) r

- Need more data over whole x range
- Unpolarized D₁, in particular for gluons→EIC can contribute to flavor separated measurement S







Boer-Mulders through $H_1^<$

- Boer-Mulders couples to TMD version of $H_1^<$
- Unique opportunity since this channel is free of Twist3 contributions, Cahn-effect or power corrections
- Need guidance on Q^2 dependence

e(x) through $H_1^{<}$

- Difficult to access in 1h \rightarrow 2h only half the terms Scalar charge $\sigma_{\psi} = \langle P | \overline{\psi} \psi | P \rangle$, $= \int_{-1}^{1} dx e(x, \mu)$
- e(x) can be interpreted as force exerted by gluon field on q^{\uparrow} after scattering
- e(x) has δ -function at $0 \rightarrow$ might broaden at lower Q^2 and one could compare with LaMET (Xiangdong Ji: arXiv:2003.044)



> Dihadron structure functions:

• twist 2
$$F_{LU,T}^{P_{\ell,m}\sin(m(\phi_h-\phi_{R_{\perp}}))} = -\mathcal{I}\left[2\cos\left(m(\phi_h-\phi_p)\right)f_1G_1^{|\ell,m\rangle}\right] \qquad \mathbf{m} = \mathbf{1} \rightarrow \mathbf{A}_{hR}sin(\phi_h-\phi_R)$$

• twist 3
$$F_{LU}^{P_{\ell,m}\sin((1-m)\phi_h+m\phi_{R_{\perp}})} = \frac{2M}{Q}\mathcal{I}\left[-\frac{|\boldsymbol{p}_T|}{M_h}\cos\left((1-m)\left(\phi_p-\phi_h\right)\right)\left(xeH_1^{\perp|\ell,m\rangle}+\frac{M_h}{M}f_1\frac{\tilde{G}^{\perp|\ell,m\rangle}}{z}\right) + \frac{|\boldsymbol{k}_T|}{M}\cos\left((m-1)\phi_h+\phi_k-m\phi_p\right)\left(xg^{\perp}D_1^{|\ell,m\rangle}+\frac{M_h}{M}h_1^{\perp}\frac{\tilde{E}^{|\ell,m\rangle}}{z}\right)\right]$$

$m = 1 \rightarrow A_R sin \phi_R$ $m = 0 \rightarrow A_h sin \phi_h$	m = -1 tested, but excluded (~0)
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$$A_{hR}sin(\phi_{h}-\phi_{R}) + A_{R}sin\phi_{R} + A_{h}sin\phi_{h}$$

Gliske, Bacchetta, Radici Phys.Rev. D90 (2014) no.11, 114027



History of wormgear FF G_1^{\perp}

- First suggestion to observe in e⁺e⁻ by Boer, Jakob, Radici, PRD67 (2003) 094003
 - Postulate connection to jet handedness proposed by Efremov and Kharzeev Phys.Lett. B366 (1996) 311-315 (connection to chromomagnetic effects)
- Measurement by Belle \rightarrow No signal
- New model calculations by Matevosyan et al connecting G₁[⊥] with single hadron Collins effect in string fragmentation (a bit like worm gear functions)→Interesting to learn about spin momentum correlations in hadronization: sizable asymmetries contradicted by Belle result??
- Mistake found in Boer et. al: Phys.Rev. D97 (2018) no.7, 074019 → Need weighted asymmetry including dependence on P_{hT}
- Accessible in SIDIS via weighted asymmetries







Matevosyan. , Bacchetta, Boer, Courtoy, Kotzinian, Radici, Thomas: Phys. Rev. D 97, 074019 (2018).



Slide from C. Dilks, see talk from T. Hayward

Note the sign change in $M_{\pi\pi}$! What does this mean in terms of the underlying processes? Looks more 'Jaffe et al' like?



Spectator model: Luo, Sun, Xie, : arXiv:2003.03770





Some example plots to illustrate progress for 10 on 100 GeV, z>0.1, xF>0, $x_{min} = 10^{-3}$, y > 0.2









Money plots

- Transversity/Tensor Charge
 - Impact on Pavia fit
- Boer-Mulders
 - Projections based on reasonable models
 - Needs rework, implementation of evolution in TMDGen
 - Alternatively: use SIDIS DB and weighting (or combination of the two approaches)
- *D*₁:
 - precision of higher partial wave extraction
- G_1^{\perp} :
 - Projections based on models, including evolution
 - Use new spectator model calculations?
- *e*(*x*):
 - projections, impact on extraction (e.g. A. Courtoy might be able to help)
 - Explore comparison's with LaMET

Clearly, this requires more workforce than we have currently available! → probably need to prioritize transversity, BM

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Detector/CMS/lumi requirements

- Similar to single hadrons, jets (most interesting physics for ~central hadrons)
 - PID,
 - Tracking also at low moment for pw extraction
 - Angular resolution
- TMD effects larger at lower energies
- Higher energies explore lower x, Q^2 evolution
 - Need better handle on evolution effects
 - Need more data to make up for smaller asymmetries (and sys under control)
- More degrees of freedom \rightarrow need more statistics than 1h

Current issue/plans

- Need MCEG in SW framework
- Need better understanding of fast simulation
- Need implementation of models in TMDGen or integration of dihadrons in existing SIDIS DB effort
- Workforce...