## TMDs studies with RFseparated beams

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## TMDs /beams

- TMDs of various (unpolarized) hadrons
- ----//----- of valence antiquarks
- Universality of TMDs of (polarized) target
- Flavour separation


## TMDs vs GPDs

- Theoretically: Sivers $f(x) \sim L(x) E(x)-$ Lensing function
- $\Sigma<x \mathrm{E}(\mathrm{x})>=0$-> Ji's SR's (=Equivalence principle: AGM=0; Kobzarev, Okun'62)
- $\Sigma<x f(x)\rangle=0$-Burkardt SR
- Conjecture(OT'06): <x f(x)>~<x E(x)>
- L(x)??


## - TMDs vs FFs?

- Large x?!


## Exclusive limit : DIS and spacelike (transitional and elastic) FFs

- Small invariant mass

- BG duality and DYW relation
- Relation between x ->1 and large $Q^{2}$
- pdf ~ (FF) ${ }^{2}$


## Exclusive limit of DY and timelike FFs (OT'14)

- (Proton-antiproton) DY at small s - Q ${ }^{2}$

(pdf) $)^{2} \sim($ Dirac $)(F F)^{2}$
- Other beams - baryon number conservation - time-like transition FFs


## Comparing space-like and time-like FFs

- "Duality intervals" - from mass to $x$-space
- DIS: $\left.(P+q)^{2}=\left(P_{f}+\delta P_{D I S}\right)\right)^{2}=\left(M+\mu_{D I S}\right)^{2} \mu_{D I S} \sim$ pion related scale
- Deviation of $\quad x_{B}\left(\equiv 1-\delta_{D I S}\right) \quad$ from 1

$$
\delta_{D I S} \sim 2 M \mu_{D I S} / Q^{2} .
$$

- DY: $\left(P_{1}+P_{2}\right)^{2}=\left(q+\delta P_{D Y}\right)^{2}$
- Deviation of $\tau=Q^{2} / s\left(\equiv 1-\delta_{D Y}\right)$ from 1

$$
\delta_{D Y} \sim 2 \mu_{D Y} / Q
$$

## DR: FFs from duality intervals

- DIS: $\quad F_{S L}^{2} \sim \int_{0}^{\delta_{0 I S}} d \bar{x} f(\bar{x}) \quad x=1-\bar{x}$
- DY: $\quad F_{T L}^{2} \sim \int_{0}^{\delta_{D Y}} d \bar{x}_{1} d \bar{x}_{2} f\left(\bar{x}_{1}\right) f\left(\bar{x}_{2}\right) \delta\left(\delta_{D Y}-\bar{x}_{1}-\bar{x}_{2}\right)$
- Proton-antiproton DY -same parton distributions $f(\bar{x})=C \bar{x}^{a}$

$$
F_{S L}^{2}\left(Q^{2}\right) \sim \frac{C}{a+1}\left(\frac{2 M \mu_{D I S}}{Q^{2}}\right)^{a+1} ; F_{T L}^{2}\left(Q^{2}\right) \sim \frac{C^{2}}{2(a+1)}\left(\frac{4 \mu_{D Y}^{2}}{Q^{2}}\right)^{a+1}
$$

- Pion: a=1 ('effective' pdf) supported !


## SL vs TL

- Same Q-dependence
- Normalization -defined by distribution scale ( $\sim 5$ ) and duality intervals
- Asymptotically coincide - scales close to QCDSR pion duality interval (rather than pion mass) similar (equal?!) for DIS and DY)!?


## Sivers function and formfactors

- Relation between Sivers function and AMM known on the level of matrix elements (Brodsky, Schmidt, Burkardt)
- Phase?
- Duality for observables?


## BG/DYW type duality for DY SSA in exclusive limit

- Proton-antiproton DY - valence annihilation analyticity - cross section is described by Dirac FF squared
- The SSA similar to Sivers one- due to interference of Dirac and Pauli FF's with a phase shift (Rekalo,Brodsky)
- Exclusive large energy limit; $x$-> 1 : $f(x) / q(x)$-> Im F2/F1( $\left.Q^{2} \sim M^{2}(1-x)\right)$
- Both directions - estimate of Sivers at large $x$ and explanation of phases in FF's

