

Chiral-odd generalized parton distributions of spin- $\frac{1}{2}$ baryons.

Navpreet Kaur¹, Monika Randhawa² and Harleen Dahiya¹

¹Dr. B. R. Ambedkar National Institute of Technology Jalandhar (144008), Punjab, India

²Punjab University, Chandigarh, India

Nov 13, 2025



1 *Multidimensional picture of a baryon*

2 *Generalized parton distributions*

3 *Results and discussion*

Multidimensional picture of a baryon

BARYONS are composite systems of partons.

Key questions include:

- Spatial distribution of partons,
- Intrinsic motion of partons and
- Contribution of parton momentum (longitudinal and transverse) to the hadron's total momentum.

Insight into these aspects is provided by the study of Distribution Functions (DFs).

- Generalized transverse momentum dependent parton distributions (GTMDs),
- Transverse momentum dependent parton distributions (TMDs) and
- Generalized parton distributions (GPDs).

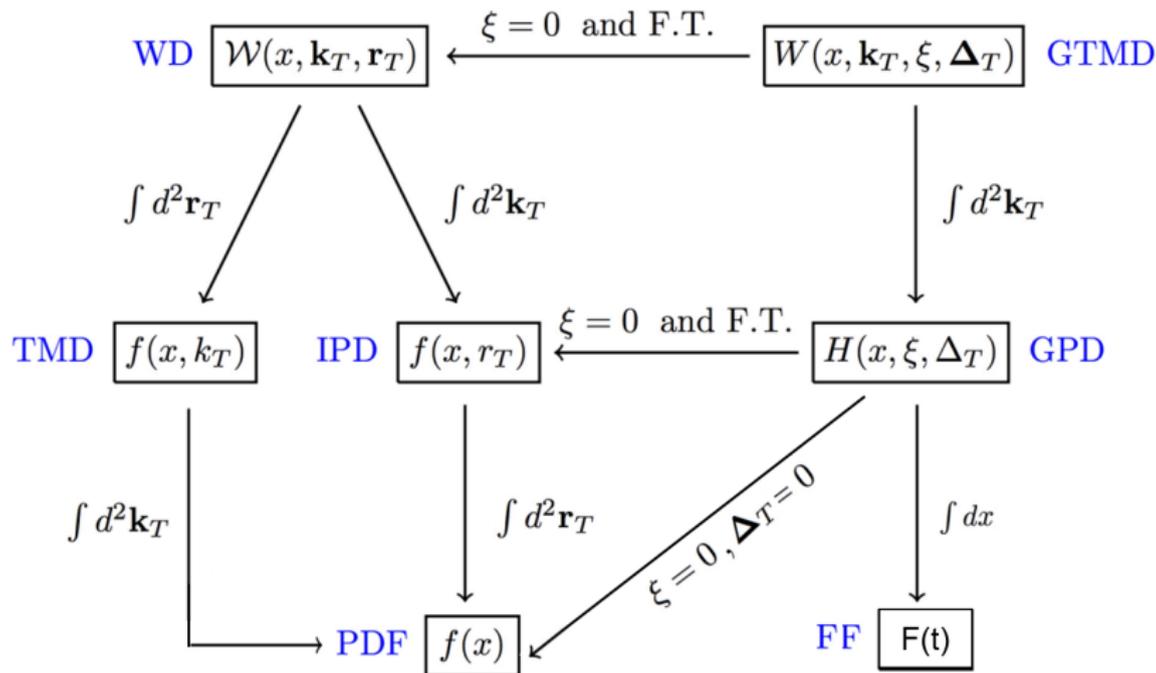
Distribution functions

Distribution functions	GTMDs	TMDs	GPDs
Longitudinal momentum fraction	✓	✓	✓
Transverse momentum	✓	✓	✗
Momentum transfer	✓	✗	✓
Same Initial & final state	✗	✓	✗
Processes	Double Drell-Yan	Deep inelastic scattering	DVCS and DVMP

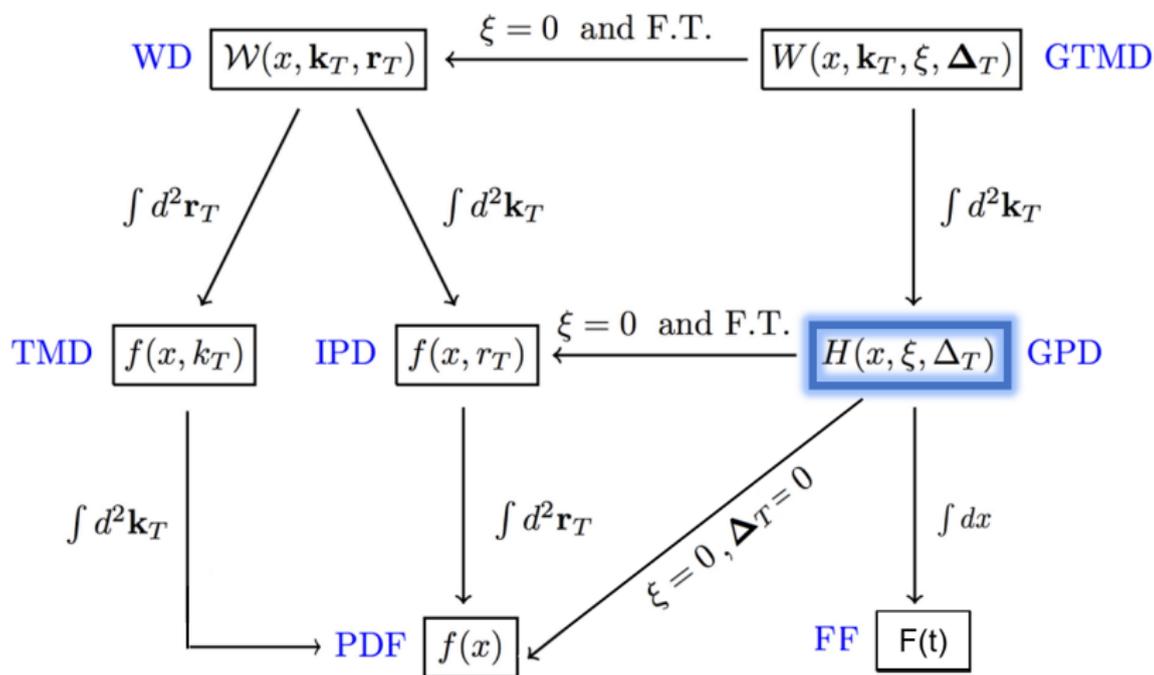
Table 1: Variables on which different distribution functions depend and experimental source of their respective measurement.

JHEP 08, 056 (2009)

Distribution functions



Distribution functions



1 *Multidimensional picture of a baryon*

2 *Generalized parton distributions*

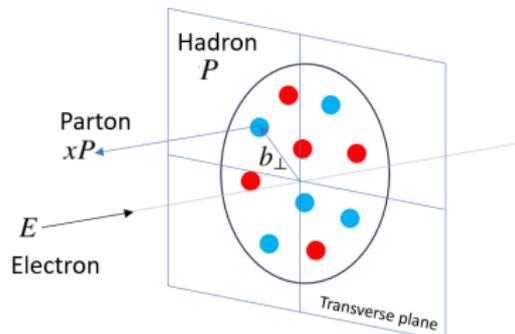
3 *Results and discussion*

Generalized Parton Distributions

$$F_{\lambda\lambda'}^{[\Gamma]} = \frac{1}{2} \int \frac{dz^-}{2\pi} e^{ik \cdot z} \left\langle p', \lambda' \left| \bar{\psi}\left(\frac{-z}{2}\right) \Gamma \psi\left(\frac{z}{2}\right) \right| p, \lambda \right\rangle_{|_{z^+=0, \mathbf{z}_\perp=0}}$$

with

- $\lambda(\lambda')$: Initial (final) state helicity.
- $P = \frac{p+p'}{2}$, average momentum.
- $\Delta = p' - p$, momentum transfer.
- Impact parameter space, $\Delta_\perp \leftrightarrow b_\perp$ via FT.
- Γ basis $[1, \gamma_5, \gamma^\mu, \gamma^\mu \gamma_5, \sigma^{\mu\nu}]$.



JHEP 08, 056 (2009)

Generalized Parton Distributions

$$F_{\lambda\lambda'}^{[i\sigma^{+i}\gamma^5]} = \frac{1}{2P_X^+} \bar{U}(P', \lambda') \left[H_T(x, \xi, -t) \sigma^{+i} \gamma_5 + \tilde{H}_T(x, \xi, -t) \frac{\epsilon^{+j\alpha\beta} \Delta_\alpha P_\beta}{M^2} \right. \\ \left. + E_T(x, \xi, -t) \frac{\epsilon^{+j\alpha\beta} \Delta_\alpha \gamma_\beta}{2M} + \tilde{E}_T(x, \xi, -t) \frac{\epsilon^{+j\alpha\beta} P_\alpha \gamma_\beta}{M} \right] U(P, \lambda)$$

Eur. Phys. J. A 52 (2016) 163.

quark pol.

	U	L	T	
nucleon pol.	U	H	$E_T + 2\tilde{H}_T$	
	L		\tilde{E}_T	
	T	<i>E</i>	\tilde{E}	H_T \tilde{H}_T

$\Gamma = \gamma^+ : H \ \& \ E$
unpolarized

$\Gamma = \gamma^+ \gamma^5 : \tilde{H} \ \& \ \tilde{E}$
longitudinal polarized

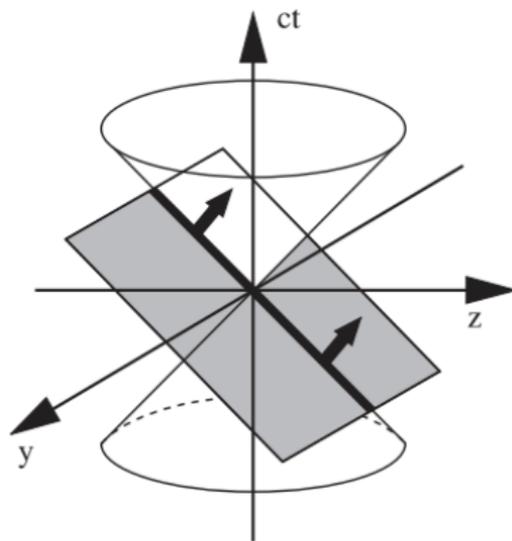
$\Gamma = i\sigma^{+i}\gamma^5 : H_T, E_T, \tilde{H}_T \ \& \ \tilde{E}_T$
transversely polarized

Partonic interpretation

A generic four Vector x^μ in light-cone coordinates is describe as $x^\mu = (x^-, x^+, x_\perp)$.

- $x^+ = x^0 + x^3$ is called as **light-front time**.
- $x^- = x^0 - x^3$ is called as **light-front longitudinal space variable**.
- $x^\perp = (x^1, x^2)$ is the **transverse variable**.

Similarly, we can define the longitudinal momentum $p^+ = p^0 + p^3$ and light-front energy $p^- = p^0 - p^3$.



The front form

[arXiv:hep-ph/9612244](https://arxiv.org/abs/hep-ph/9612244) [hep-ph]

Spectator diquark model

The instant form wave function of proton

$$|p\rangle^{\uparrow,\downarrow} = \frac{1}{\sqrt{2}}|u\ s(ud)\rangle^{\uparrow,\downarrow} - \frac{1}{\sqrt{6}}|u\ a(ud)\rangle^{\uparrow,\downarrow} + \frac{1}{\sqrt{3}}|d\ a(uu)\rangle^{\uparrow,\downarrow}$$

Probabilistic weight among

- scalar isoscalar $s(ud)$
- axial-vector isoscalar $a(ud)$
- axial-vector isovector $a(uu)$ comes out to be 3:1:2.

Similarly,

$$|\Sigma^+\rangle^{\uparrow,\downarrow} = \frac{1}{\sqrt{2}}|u\ s(us)\rangle^{\uparrow,\downarrow} - \frac{1}{\sqrt{6}}|u\ a(us)\rangle^{\uparrow,\downarrow} + \frac{1}{\sqrt{3}}|s\ a(uu)\rangle^{\uparrow,\downarrow},$$
$$|\Xi^0\rangle^{\uparrow,\downarrow} = \frac{1}{\sqrt{2}}|s\ s(us)\rangle^{\uparrow,\downarrow} + \frac{1}{\sqrt{6}}|s\ a(us)\rangle^{\uparrow,\downarrow} - \frac{1}{\sqrt{3}}|u\ a(ss)\rangle^{\uparrow,\downarrow}.$$

Phys. Rev. C **93**, 065209 (2016)

Spectator diquark model

Light-cone wave function for **scalar diquark**

$$\psi_{\lambda_q}^{\lambda}(x, \mathbf{k}_{\perp}) = \sqrt{\frac{k^+}{(P-k)^+} \frac{1}{k^2 - m_q^2}} \bar{u}(k, \lambda_q) \mathcal{Y}_s U(P, \lambda),$$

Light-cone wave function for **axial-vector diquark**

$$\psi_{\lambda_q \lambda_a}^{\lambda}(x, \mathbf{k}_{\perp}) = \sqrt{\frac{k^+}{(P-k)^+} \frac{1}{k^2 - m_q^2}} \bar{u}(k, \lambda_q) \epsilon_{\mu}^*(P-k, \lambda_a) \cdot \mathcal{Y}_a^{\mu} U(P, \lambda).$$

- \mathcal{Y}_s - contribution of scalar vertex
- \mathcal{Y}_a^{μ} - contribution of axial-vector vertex
- λ - baryon helicity
- λ_q - quark helicity
- λ_a - axial-vector diquark helicity
- $\epsilon_{\mu}^*(P-k, \lambda_a)$ - four-vector polarization of spin-1 diquark
- $u(k, \lambda_q)$ - spin $-\frac{1}{2}$ Dirac spinor of active quark with momentum k
- $U(P, \lambda_q)$ - spin $-\frac{1}{2}$ Dirac spinor of baryon with momentum P

Phys. Rev. D **78**, 074010 (2008), Phys. Rev. D **112**, 074024 (2025)

1 *Multidimensional picture of a baryon*

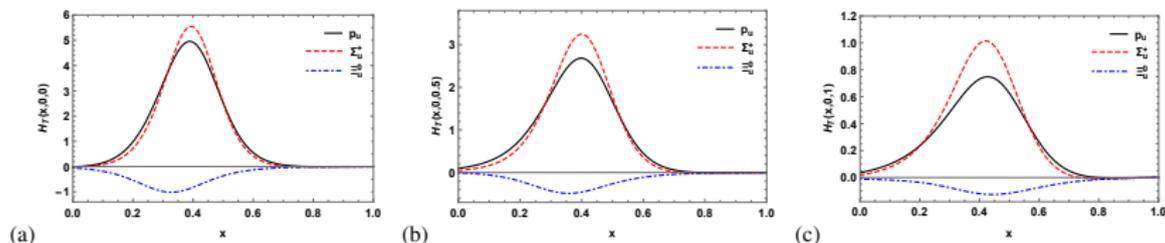
2 *Generalized parton distributions*

3 *Results and discussion*

Chiral-odd GPD $H_T(x, 0, t)$

In terms of helicity basis,

$$H_T(x, \xi, t) = A_{\uparrow\uparrow, \downarrow\downarrow} + A_{\downarrow\uparrow, \uparrow\downarrow}$$



- Transversity distribution, $h_1(x) = H_T(x, 0, 0)$.
- Ξ_u^0 has peak at smaller x than p_u and Σ_u^+ .
- **Spin-flavor dynamics:** For a transversely polarized Ξ^0 , measured u quark is more likely to find with anti-aligned spin wrt Ξ^0 .
- With increasing t (GeV), peak shifts more faster for Ξ^0 .

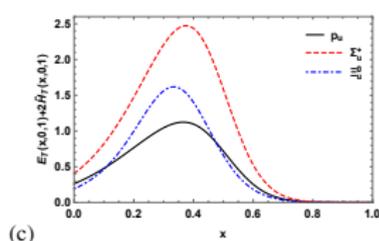
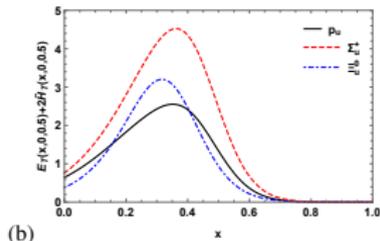
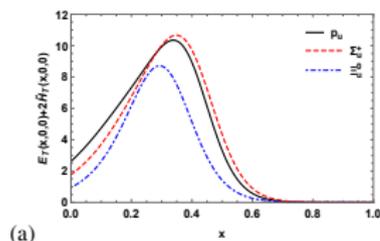
Chiral-odd GPD $E_T(x, 0, t) + 2\tilde{H}_T(x, 0, t)$

In terms of helicity basis,

$$E_T(x, \zeta, t) = \frac{2M}{\epsilon \sqrt{t_0 - t}} T_4 - \frac{4M^2}{(t_0 - t)} (T_2 - T_1),$$

$$\tilde{H}_T(x, \xi, t) = \frac{2M^2}{(t_0 - t)} (T_2 - T_1).$$

where $T_{1(2)} = A_{\uparrow\uparrow, \downarrow\downarrow} \pm A_{\downarrow\uparrow, \uparrow\downarrow}$, $T_{3(4)} = A_{\uparrow\uparrow, \uparrow\downarrow} \mp A_{\downarrow\uparrow, \downarrow\downarrow}$

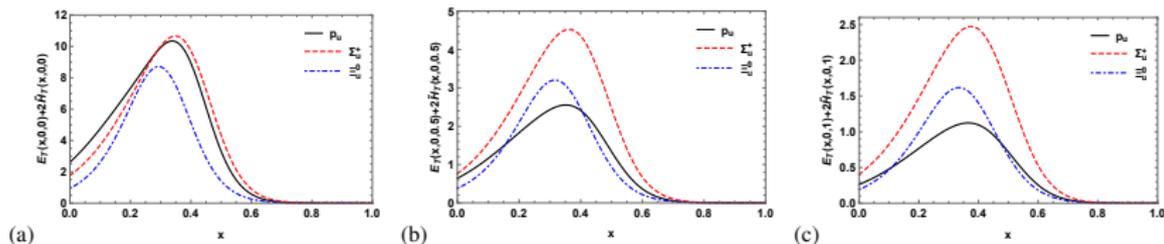


Chiral-odd GPD $E_T(x, 0, t) + 2\tilde{H}_T(x, 0, t)$

The combination $E_T + 2\tilde{H}_T$ is more fundamental than E_T itself when discussing spin densities in the transverse plane.

For u quark distribution,

- at zero momentum transfer, the amplitude follows $\Sigma^+ > p > \Xi^0$,
- for a finite value of t (GeV), p is found to decrease slowly than hyperons,
- with increase in the value of t (GeV), heavier the baryon, more slowly its amplitude decreases.



Summary

- Studied the
 - chiral-odd GPDs
 - in spectator diquark model
 - with light-front dynamics.
- With increase in the value of t (GeV), the generic trend of
 - decrease in the amplitude of quark distributions and
 - shifting of peak value on higher x value is same.
 - But hyperons decreases much slower.
- u quark flavor of Ξ^0 is found with anti-aligned spin with respect to Ξ^0 hyperon.

Thank You!