TMD Collaboration

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Study of Unpolarized TMDs from HERMES Data

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Overview

- We perform a new phenomenological analysis of unpolarized Transverse Momentum Dependent distribution and fragmentation functions in Gaussian framework with flavor separation
- HERMES data on multiplicities of unpolarized pion and Kaon production differential in transverse momentum is used
- For the first time we implement data selection that maximizes contribution from beam fragmentation region using collinearity parameter *R* of Boglione et al 2017
- Results are compared to existing analyses
- This study gives us information on the intrinsic motion of quarks inside nucleons, which is encoded in TMDs

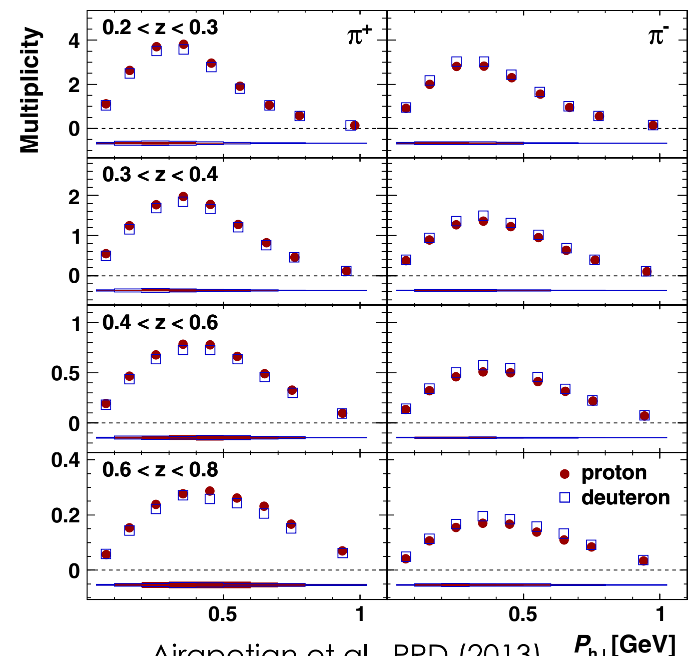
Unpolarized structure functions in generalized parton model

Approximately Gaussian dependence is observed in the data

Schweitzer et al, NPA (2004) & PRD (2010)

We consider Hermes multiplicities data sets.
The observable is defined as

$$M_N^h(x, Q^2, z, P_{hT}) \equiv \frac{\frac{d\sigma}{dx\,dz\,dQ^2\,dP_{hT}^2}}{\frac{d\sigma^{DIS}}{dx\,dQ^2}}$$



Airapetian et al, PRD (2013)

We model the observable using
the standard Gaussian ansatz

$$\frac{dN^h(x, Q^2, z, P_{hT})}{dz\,dP_{hT}^2} = \frac{1}{P_{hT}} M_N^h(x, Q^2, z, P_{hT})$$

$$= \frac{\pi \sum_a e_a^2 f_{a/p}(x) D_{h/a}(z) \frac{e^{-P_{hT}^2/\langle P_{hT}^2\rangle_a}}{\langle P_{hT}^2\rangle_a}}{\sum_a e_a^2\; f_{a/p}(x)}$$

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Unpolarized structure function in TMD parton model

We use the Generalized Parton Model which utilizes a simple Gaussian form of transverse momentum dependence of TMDs

See for instance: M. Anselmino et al. PRD (2005)

Gaussian anzatz with flavor dependence

$$f_{a/p}(x, k_\perp^2) = f_{a/p}(x) \frac{e^{-k_\perp^2/\langle k_\perp^2 \rangle_{a/p}}}{\pi \langle k_\perp^2 \rangle_{a/p}}$$

$$D_{h/a}(z, p_\perp^2) = D_{h/a}(z) \frac{e^{-p_\perp^2/\langle p_\perp^2 \rangle_{h/a}}}{\pi \langle p_\perp^2 \rangle_{h/a}}$$

The result for unpolarized structure functions becomes very simple

$$F_{UU} = x \sum_a e_a^2 f_{a/p}(x) D_{h/a}(z) \frac{e^{-P_{hT}^2/\langle P_{hT}^2 \rangle_a}}{\langle P_{hT}^2 \rangle_a}$$

$$\langle P_{hT}^2 \rangle_a = z^2 \langle k_\perp^2 \rangle_{a/p} + \langle p_\perp^2 \rangle_{h/a}$$

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Previous Extractions of unpolarized TMDs

Several papers reported results of extraction of unpolarized TMDs

	TMD PDF width	TMD FF width
Anselmino et al. PRD (2005)	$\langle k_\perp^2 \rangle = 0.25\ \mathrm{GeV}^2$	$\langle p_\perp^2 \rangle = 0.2\ \mathrm{GeV}^2$
Anselmino et al. JHEP 2014	$\langle k_\perp^2 \rangle = 0.57 \pm 0.08\ \mathrm{GeV}^2$	$\langle p_\perp^2 \rangle = 0.12 \pm 0.01\ \mathrm{GeV}^2$
Signori et al, JHEP (2013)	$\langle \boldsymbol{k}_{\perp,a}^2 \rangle(x) = \langle \hat{\boldsymbol{k}}_{\perp,a}^2 \rangle \frac{(1-x)^\alpha x^\sigma}{(1-\hat{x})^\alpha \hat{x}^\sigma}$	$\langle \boldsymbol{P}_{\perp,a\to h}^2 \rangle(z) = \langle \hat{\boldsymbol{P}}_{\perp,a\to h}^2 \rangle \frac{(z^\beta + \delta)\ (1-z)^\gamma}{(\hat{z}^\beta + \delta)\ (1-\hat{z})^\gamma}$

See talk of Alessandro Bacchetta

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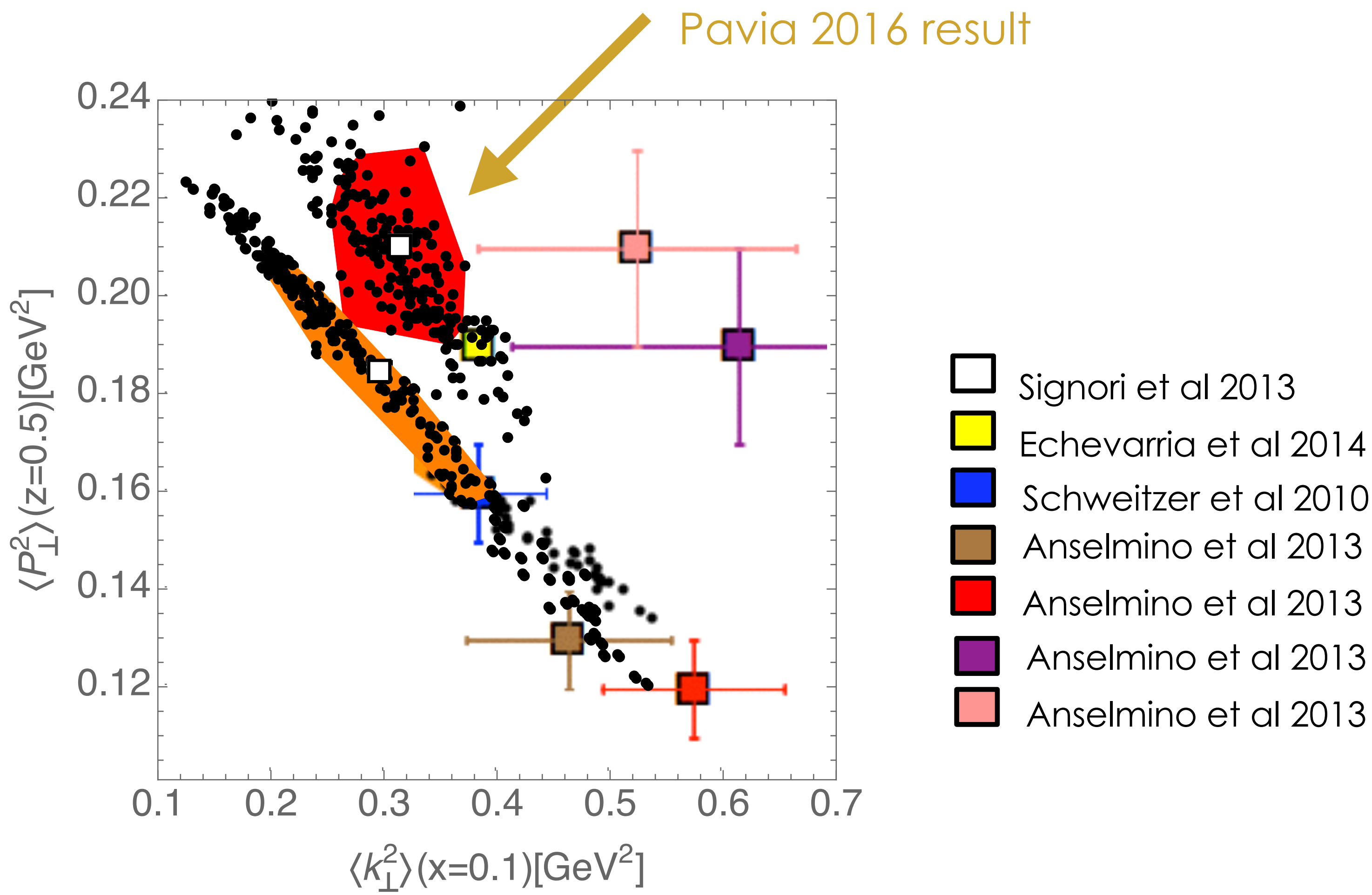
Transverse momentum in FFs

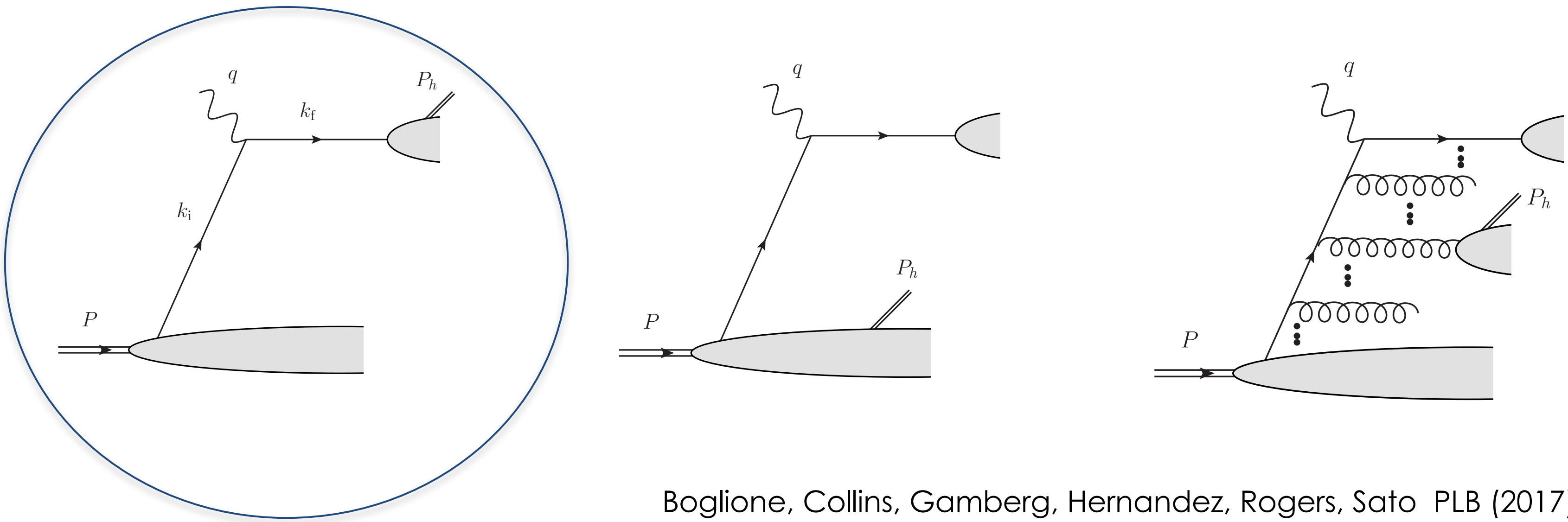


Transverse momentum in PDFs

From Alessandro Bacchetta's talk

New extraction of unpolarized TMDs

We revisit the HERMES data and attempt to isolate the current fragmentation data based on R criterion in SIDIS to see how this affects the determination of flavor dependence of widths



Boglione, Collins, Gamberg, Hernandez, Rogers, Sato PLB (2017)

Our model describes current fragmentation

N.B. boundary between regions is not sharp

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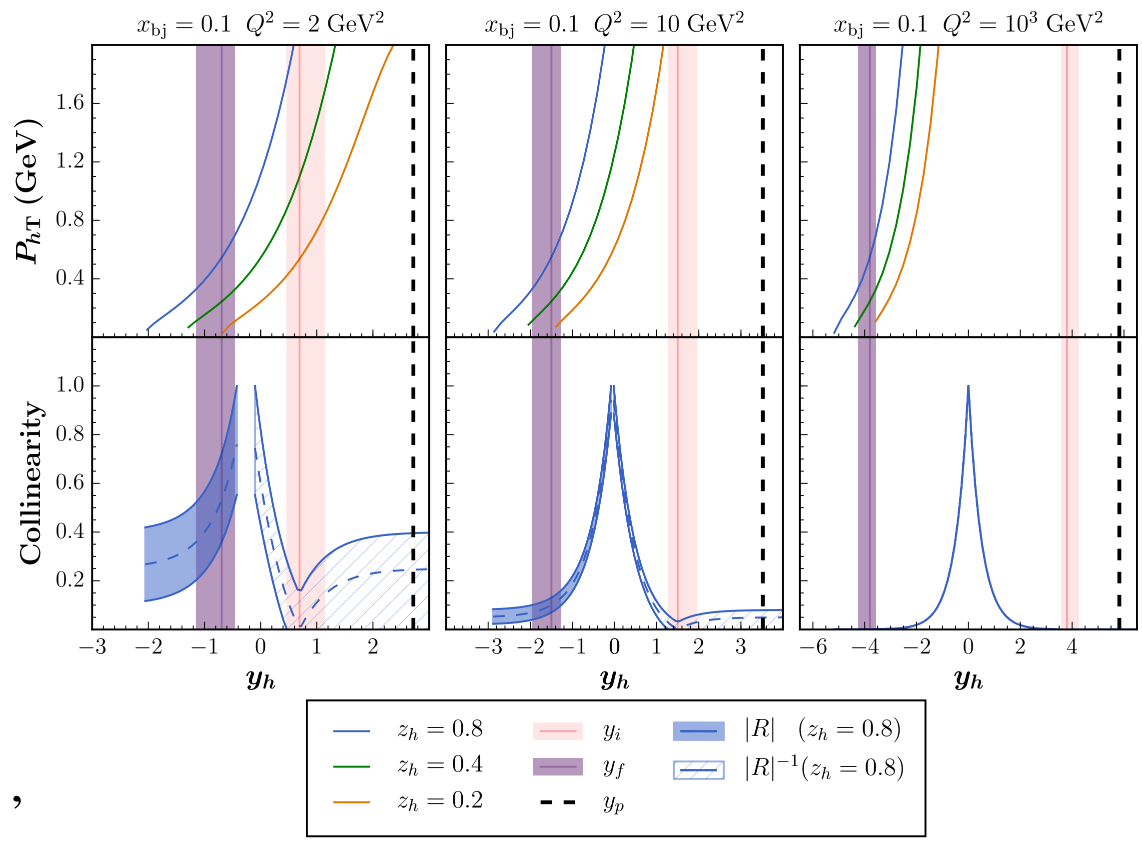
See talk by Elena Boglone

The Collinearity Parameter & improved cuts



$$R(y_h, z_h, x_{bj}, Q) \equiv \frac{P_h \cdot k_f}{P_h \cdot k_i},$$

We impose a stronger cut of R< 0.3 in order to get data samples that are more consistent with TMD factorization

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See talk by Elena Boglone

- We assume different widths for TMD PDF light valence u_v, d_v and sea quarks (the same width for all sea quarks): 3 parameters.

- We assume different widths favored and unfavored for TMD FFs: 2 parameters.

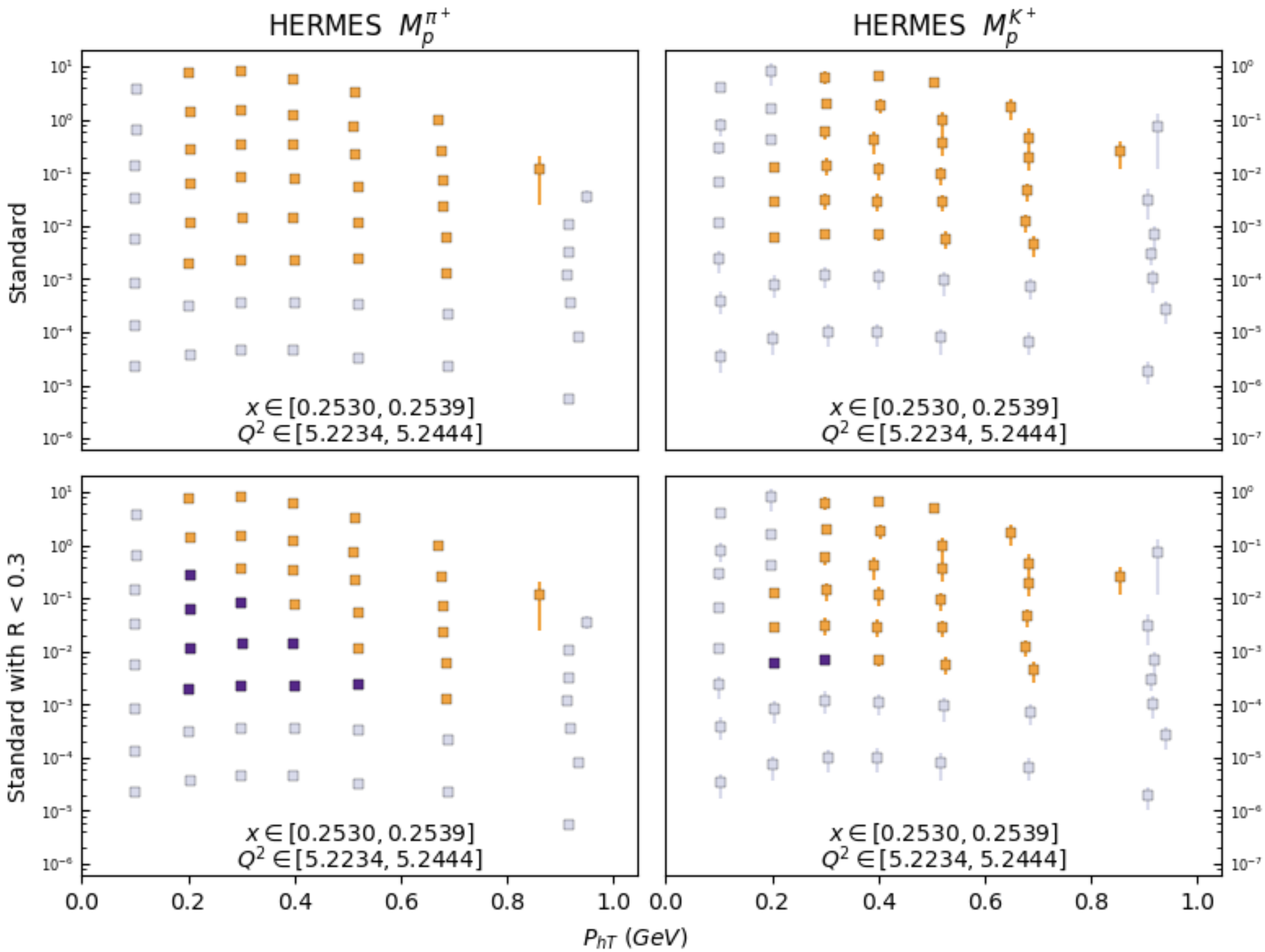
- We perform two types of fits

  1) Standard Cuts: $z < 0.6 \quad 0.2 < P_{hT} < 0.9 \text{ GeV}$

  2) More restrictive: Standard + R < 0.3
- Use CJ15LO pdfs and DSS LO collinear FFs

Accardi, Brady, Melnitchouk, Owens, Sato Phys. Rev. D 93, 114017
de Florian, Sassot,Stratmann Phys. Rev. D75 (2007)

Data Selection



Upper plots: standard cuts, bottom plots: R < 0.3 cuts

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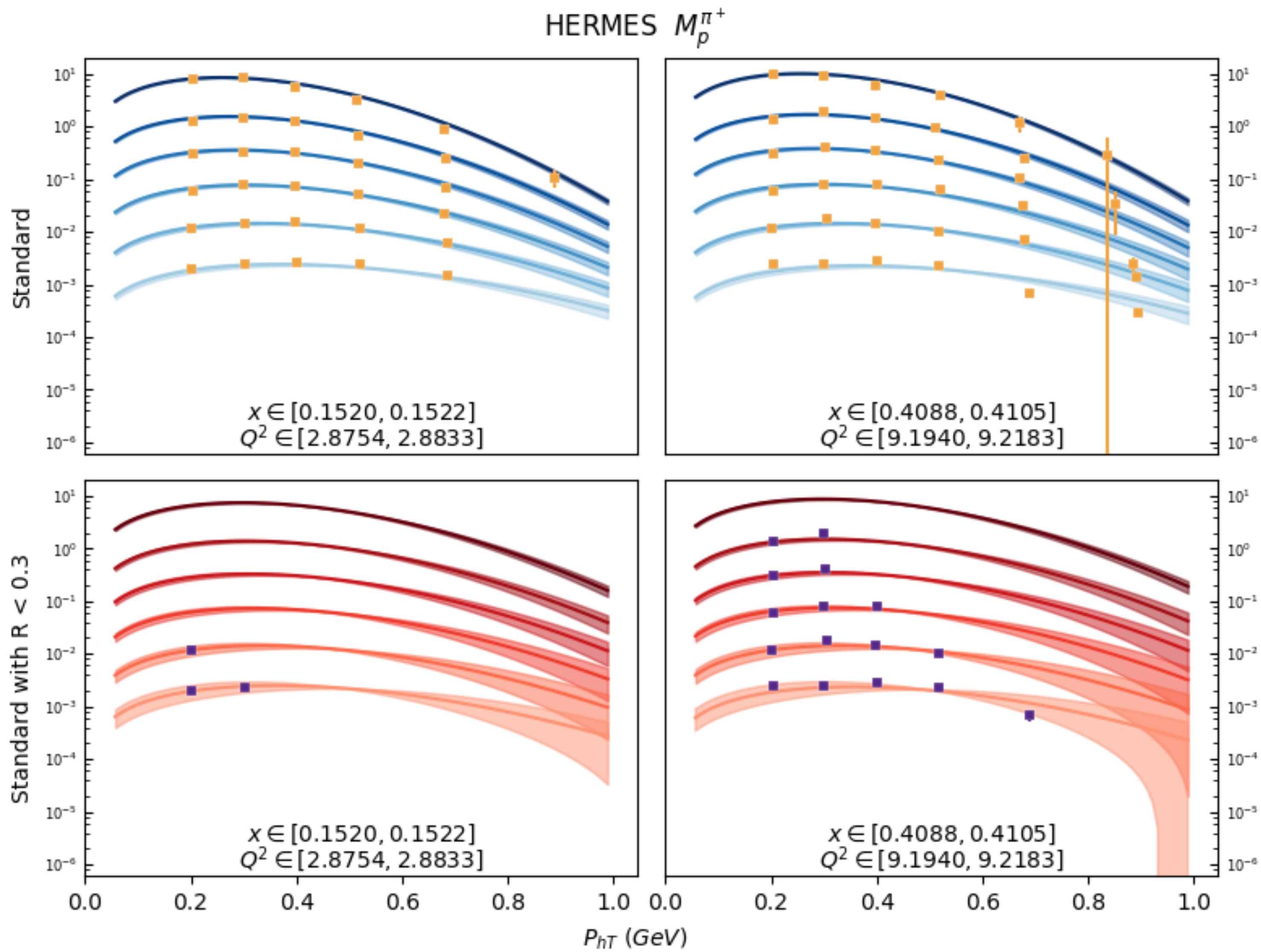
New extraction of unpolarized TMDs: proton-charged pion



Upper plots: standard cuts, bottom plots: R < 0.3 cuts

Standard Cuts

$$\chi^2/d.o.f. = 1.16$$

Number of points 978

$$\langle k_\perp^2 \rangle_{u_v} = 0.54 \pm 0.02 \text{ GeV}^2$$

$$\langle k_\perp^2 \rangle_{d_v} = 0.55 \pm 0.06 \text{ GeV}^2$$

$$\langle k_\perp^2 \rangle_{sea} = 0.69 \pm 0.05 \text{ GeV}^2$$

$$\langle p_\perp^2 \rangle_{fav} = 0.12 \pm 0.01 \text{ GeV}^2$$

$$\langle p_\perp^2 \rangle_{unfav} = 0.14 \pm 0.02 \text{ GeV}^2$$

Standard + R < 0.3 Cuts

$$\chi^2/d.o.f. = 0.91$$

Number of points 152

$$\langle k_\perp^2 \rangle_{u_v} = 0.28 \pm 0.05 \text{ GeV}^2$$

$$\langle k_\perp^2 \rangle_{d_v} = 0.32 \pm 0.14 \text{ GeV}^2$$

$$\langle k_\perp^2 \rangle_{sea} = 0.55 \pm 0.17 \text{ GeV}^2$$

$$\langle p_\perp^2 \rangle_{fav} = 0.17 \pm 0.01 \text{ GeV}^2$$

$$\langle p_\perp^2 \rangle_{unfav} = 0.15 \pm 0.02 \text{ GeV}^2$$

Extraction of unpolarized TMDs

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The new entry!

Albright et al, (2017) in preparation

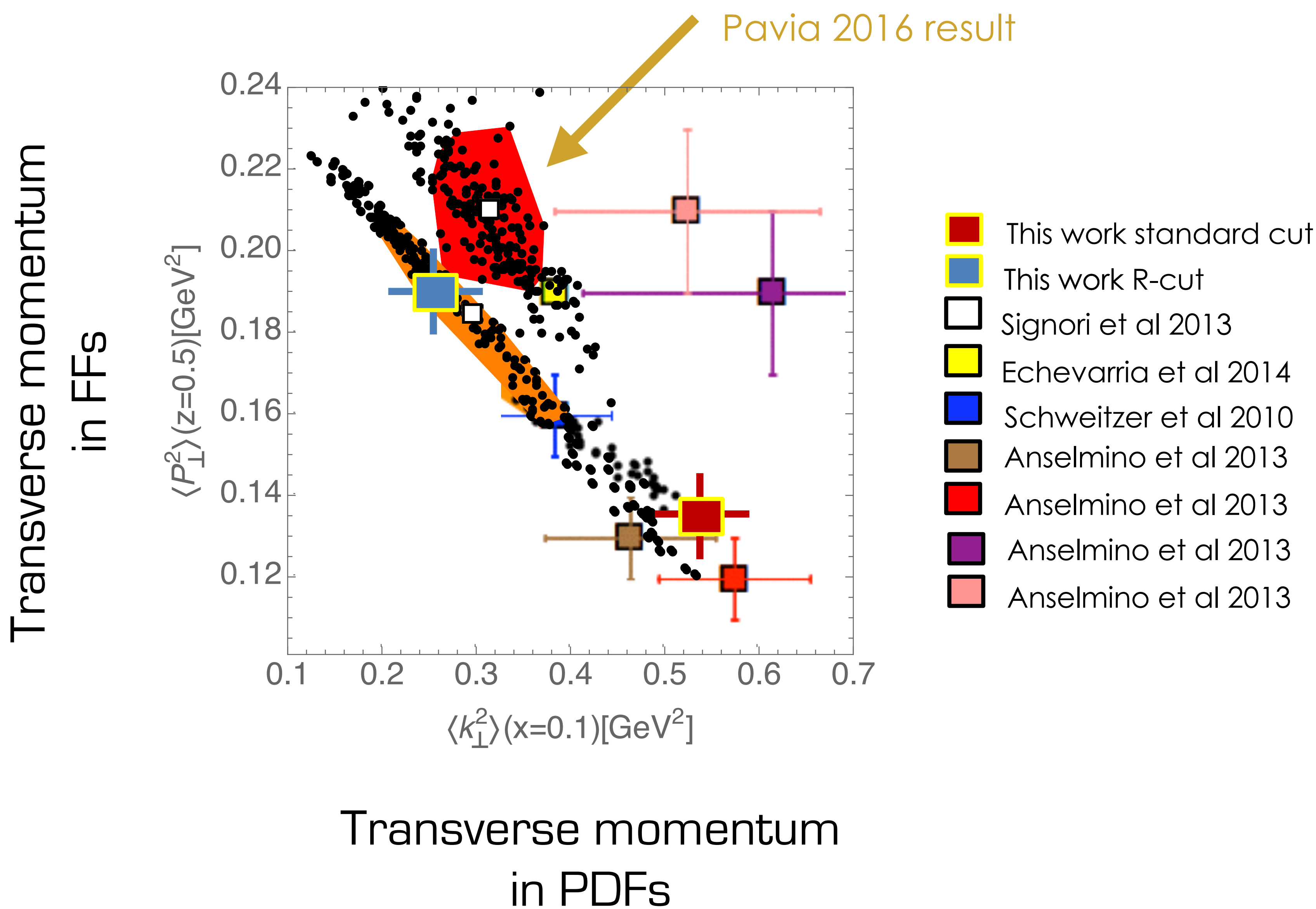
Standard cuts

$\langle k_\perp^2 \rangle_{u_v} = 0.54 \pm 0.02\ \mathrm{GeV}^2$ $\quad \langle p_\perp^2 \rangle_{fav} = 0.12 \pm 0.01\ \mathrm{GeV}^2$

Standard + R cuts

$\langle k_\perp^2 \rangle_{u_v} = 0.28 \pm 0.05\ \mathrm{GeV}^2$ $\quad \langle p_\perp^2 \rangle_{fav} = 0.17 \pm 0.01\ \mathrm{GeV}^2$

Results



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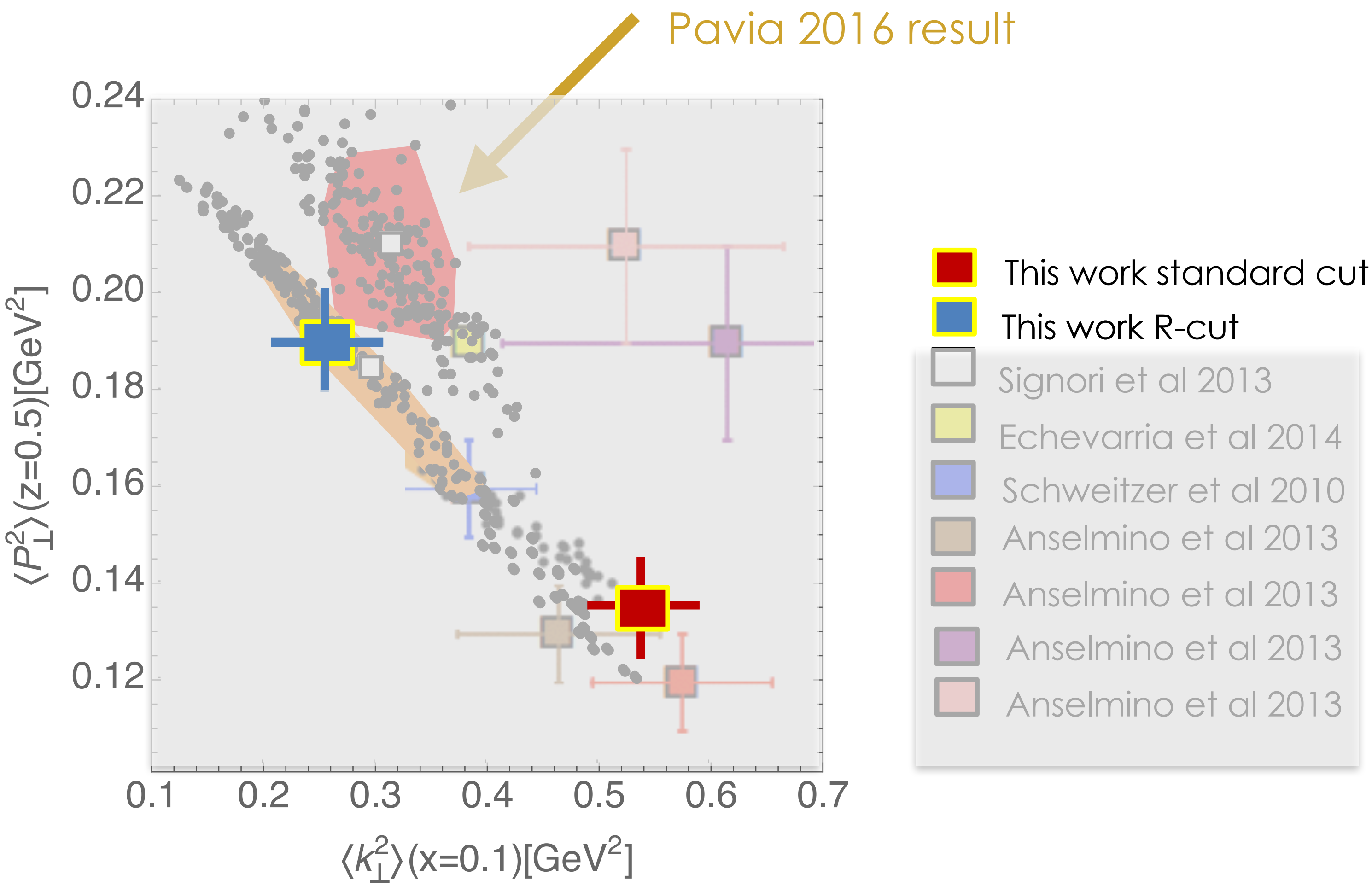
Results



Transverse momentum in FFs

Transverse momentum in PDFs

CONLCUSIONS

- New analysis of unpolarized TMD widths has been performed
- We have used for the first time ever the collineality parameter as a discriminator for the current region
- We find that value s of parameters are very sensitive to the R-cut and thus its future exploration is very important for understanding of TMDs and low Q
- Future directions of our research will include Hybrid Monte Carlo fits in order to reliably estimate parameters. We plan to include COMPASS data as well.