Status update: impact studies for EIC Sivers function

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Work in progress!
These are preliminary results!

Plan of the talk

- Part 1: Extraction of Sivers function
- Part 2: Impact studies

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Part 1: Extraction of Sivers function based on SV19 unpolarized TMDs using `artemide`

M.Bury, A.Prokudin, AV

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A bit of theory: Sivers asymmetry in TMD factorization

In TMD factorization the Sivers structure function reads

$$F_{UT}^{\sin(\phi_h-\phi_s)} = -M|C_V(-Q^2,\mu^2)|^2 \sum_f e_f^2 \int \frac{db}{2\pi} b^2 J_1(b|q_T|) \overbrace{f_{1T}(x,b;\mu,\zeta_1)}^{\text{Sivers}} \overbrace{D_1(z,b;\mu,\zeta_2)}^{\text{unpol.TMDFF}},$$

$$F_{UU}^{\sin(\phi_h-\phi_s)} = |C_V(-Q^2,\mu^2)|^2 \sum_f e_f^2 \int \frac{db}{2\pi} b J_0(b|q_T|) \underbrace{f_1(x,b;\mu,\zeta_1)}_{\text{unpol.TMDPDF}} \underbrace{D_1(z,b;\mu,\zeta_2)}_{\text{unpol.TMDFF}},$$

with

$$\mu \sim Q, \qquad \zeta_1\zeta_2 = Q^4$$

The Sivers asymmetry is

$$A_{UT}^{\sin(\phi_h-\phi_s)} = -M \frac{\sum_f e_f^2 \int \frac{db}{2\pi} b^2 J_1(b|q_T|) \overbrace{f_{1T}(x,b;Q,Q^2)}^{\text{Sivers}} D_1(z,b;Q,Q^2)}{\sum_f e_f^2 \int \frac{db}{2\pi} b J_0(b|q_T|) f_1(x,b;Q,Q^2) D_1(z,b;Q,Q^2)} \tag{1}$$

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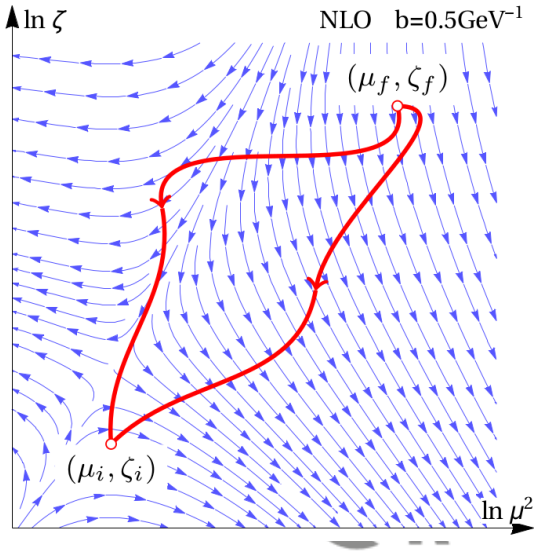
A bit of theory: TMD evolution

$$F(x,b;\mu,\zeta) = R[b;(\mu,\zeta)\leftarrow(\mu_0,\zeta_0)]F(x,b;\mu_0,\zeta_0),$$

where

$$R[b;(\mu_1,\zeta_1)\leftarrow(\mu_0,\zeta_0)] = \exp\left[\int_{(\mu_0,\zeta_0)}^{(\mu_1,\zeta_1)} dt\left(\gamma_F(\mu,\zeta)\frac{d\ln\mu}{dt} - \mathcal{D}(b,\mu)\frac{d\ln\zeta}{dt}\right)\right] \tag{2}$$



A bit of theory: TMD evolution

$$F(x,b;\mu,\zeta) = R[b;(\mu,\zeta)\leftarrow(\mu_0,\zeta_0)]F(x,b;\mu_0,\zeta_0),$$

where

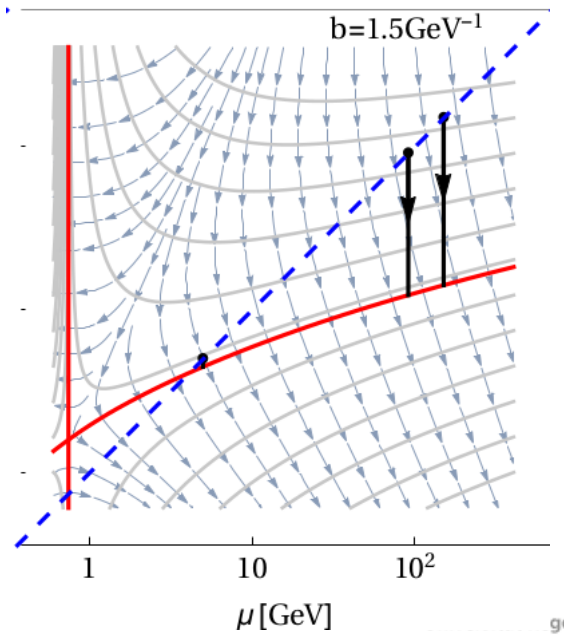
$$R[b;(\mu_1,\zeta_1)\leftarrow(\mu_0,\zeta_0)] = \exp\left[\int_{(\mu_0,\zeta_0)}^{(\mu_1,\zeta_1)} dt\left(\gamma_F(\mu,\zeta)\frac{d\ln\mu}{dt} - \mathcal{D}(b,\mu)\frac{d\ln\zeta}{dt}\right)\right] \tag{2}$$

ζ-prescription

- Evolution along vertical trajectory to the **equi-evolution** curve
- TMD on the **equi-evolution** curve is **Scaleless** ("optimal" TMD [I.Scimemi,AV,1803.11089])

$$F(x,b;\mu,\zeta) = \left(\frac{\zeta}{\zeta_\mu[\mathcal{D}]}\right)^{-\mathcal{D}(b,\mu)} \underbrace{F(x,b)}_{\text{"optimal"}}$$

- The evolution prefactor is a known function of non-perturbative $\mathcal{D}$ (exact transcendental/algebraic) [AV,1907.10356]

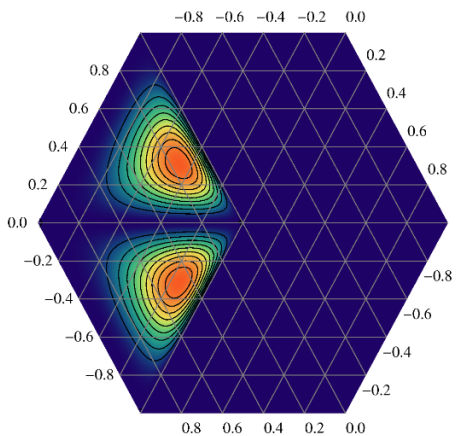


In ζ-prescription Sivers asymmetry is

$$A_{UT}^{\sin(\phi_h-\phi_s)} = -M \frac{\sum_f e_f^2 \int \frac{db}{2\pi} b^2 J_1(b|q_T|) \left(\frac{Q^2}{\zeta_Q[\mathcal{D}]}\right)^{-2\mathcal{D}(b,Q)} f_{1T}^{\perp}(x,b) D_1(z,b)}{\sum_f e_f^2 \int \frac{db}{2\pi} b J_0(b|q_T|) \left(\frac{Q^2}{\zeta_Q[\mathcal{D}]}\right)^{-2\mathcal{D}(b,Q)} f_1(x,b) D_1(z,b)} \tag{3}$$

- All green NP functions are know
  - SV19 global fit, DY+SIDIS [I.Scimemi,AV,1912.06532]
  - + π TMDPDF fit [AV,1907.10356]
  - NNLO or N^{3}LO evolution (with NNLO small-b matching)
- The only unknown is Sivers function
  - Evolution is known (N^{3}LO)
  - Small-b matching is possible but not necessary
  - At small-b Sivers matches twist-3 functions

$$f_{1T}^{\perp}(x,b) = \mp\pi T(-x,0,x) + \alpha_s \underbrace{[T, \Delta T, G^+, G^-]}_{\text{live on hexagon}}$$



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Parameterization of Sivers function

"Model 8.case 2"

$$f_{1T}^{\perp}(x,b) = N_f \frac{(1-x)^{\alpha} x^{\beta_f} (1+\epsilon_f x)}{N(\beta_f, \epsilon_f)} \frac{1}{\cosh((r_0 + r_1 x)b)}$$

- We distinguish only u,d, and sea quarks
- α is common
- $\epsilon_{sea} = 0$
- $N(\beta, \epsilon) = \int_0^1 dx (1-x) x^{\beta} (1+\epsilon x)$

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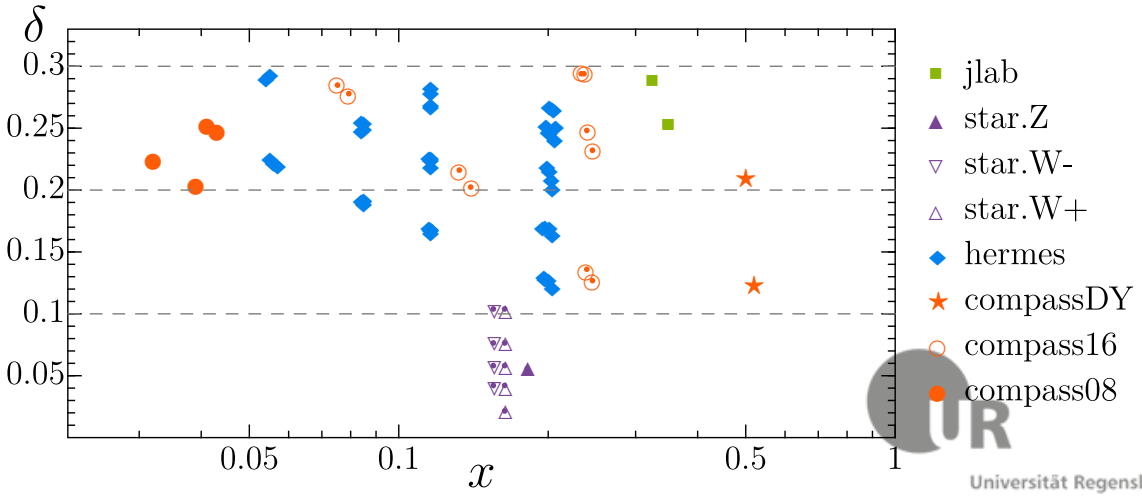
TMD factorization works only for large-Q and small $\delta = q_T/Q$

- THE MOST data points in SIDIS are with $\delta > 1$
- THE MOST data points in SIDIS are with $Q \sim 1$GeV (totally contaminated by mass-corrections)
- We took only q_T differential data
- **We need to apply mild assumptions**

$$\langle Q \rangle > 2\text{GeV}, \qquad \delta < 0.3$$

- Compass→14 points
- Hermes→46 points
- Jlab→3 points
- Compass πDY →2 points
- Star $W^{\pm}$,Z 10 points

Total: 75 points



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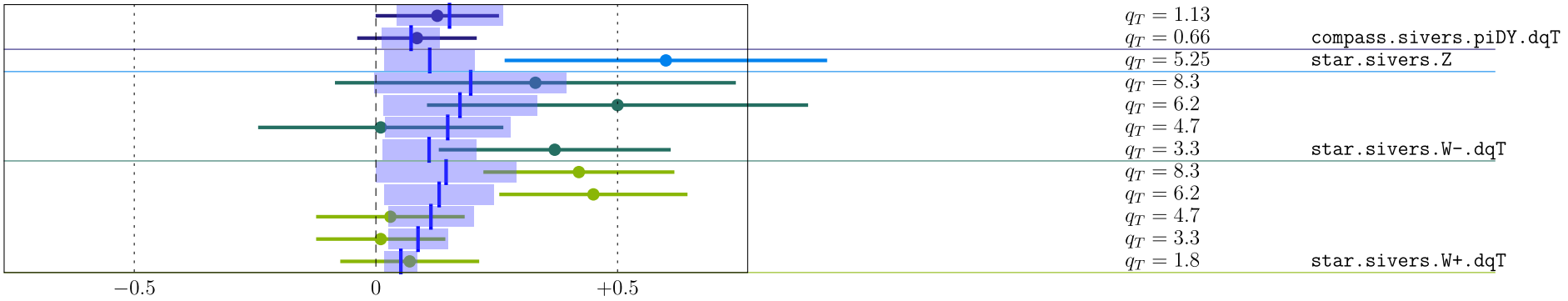
Data is very nicely described!

$$\frac{\chi^2}{\#\text{points}} = 1.03\,(1.02[\text{SIDIS}] + 1.08[\text{DY}])$$

Model8 case2



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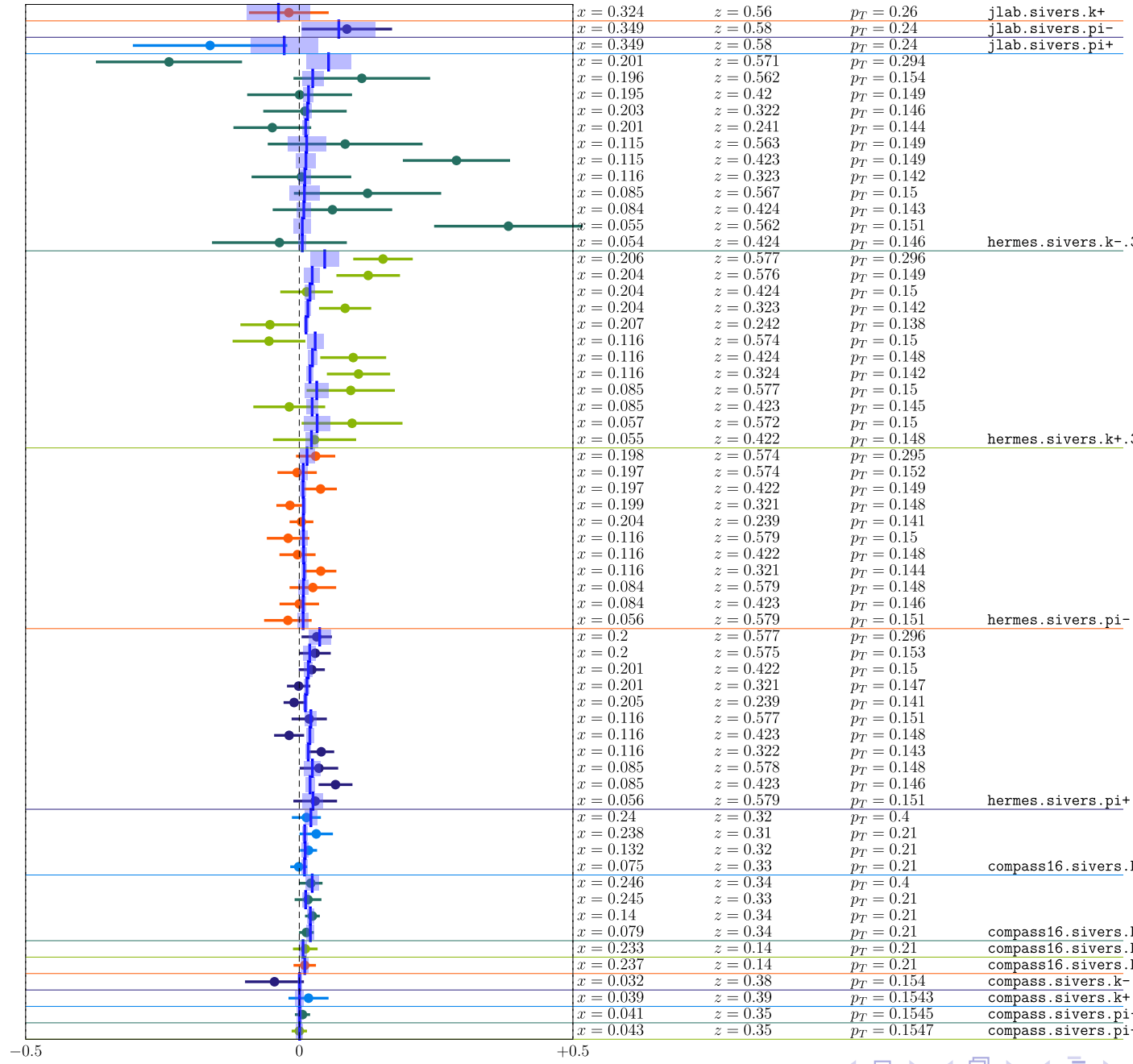
Model8 case2



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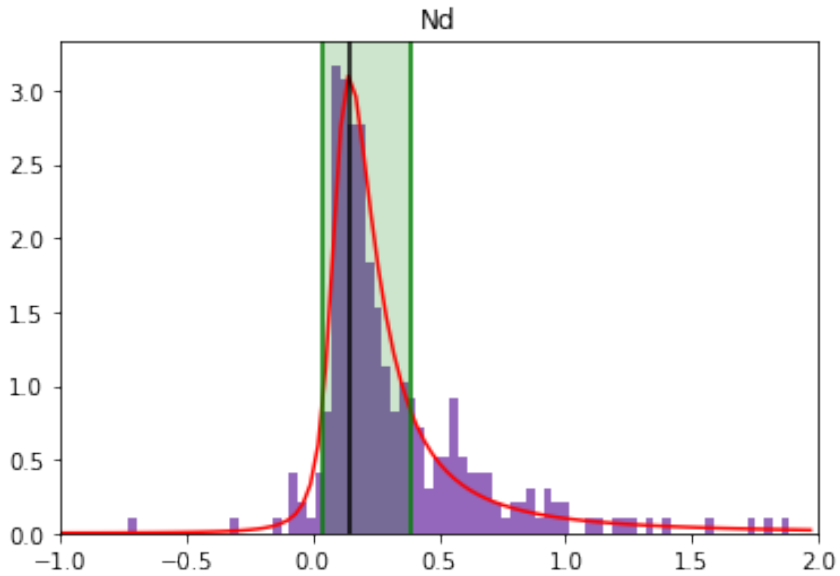
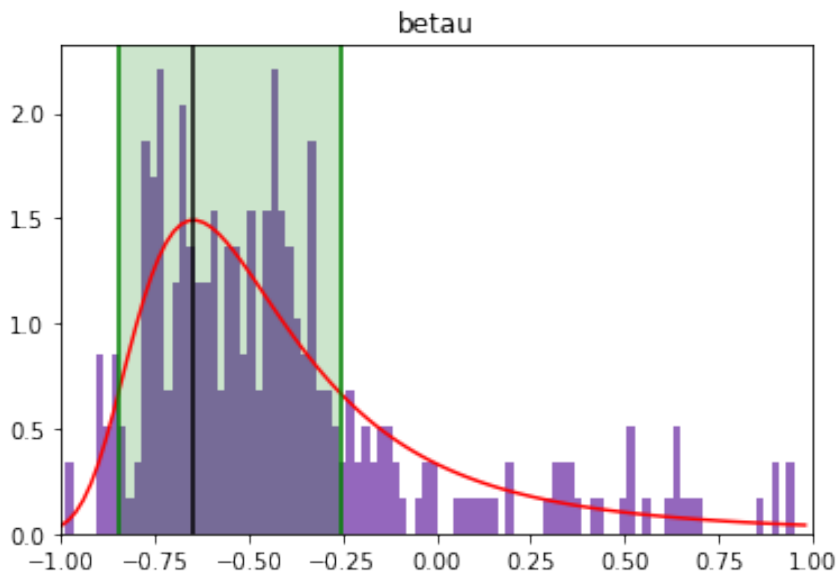
Very asymmetric distribution of parameters
with “long tails”





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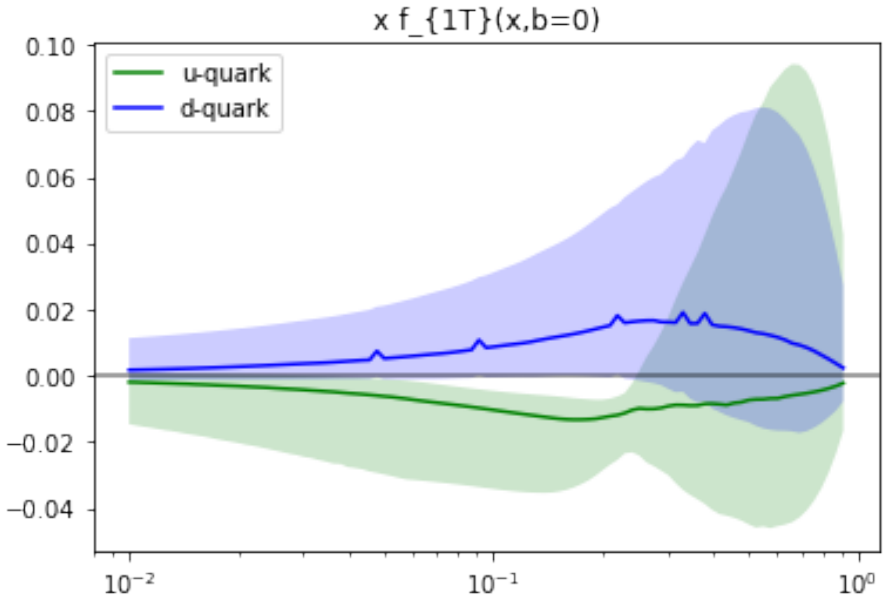
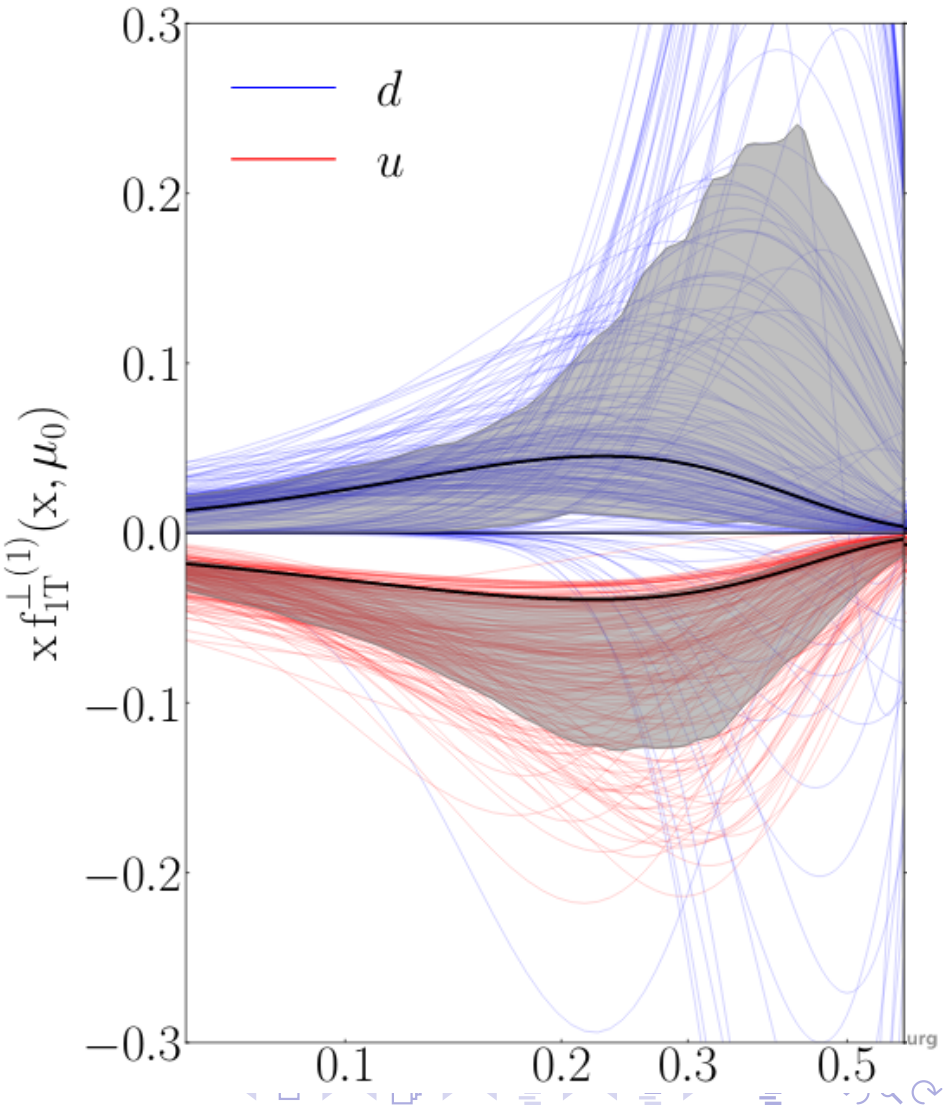
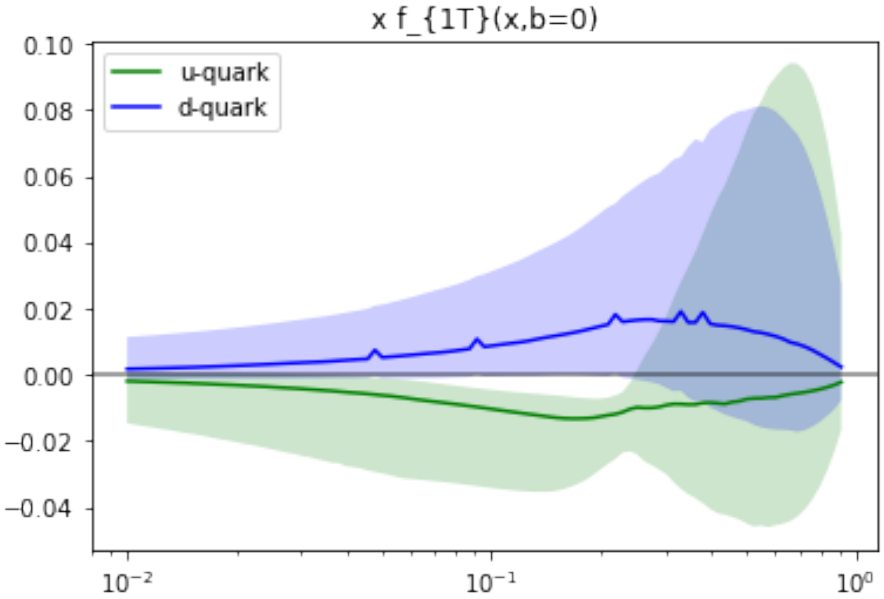
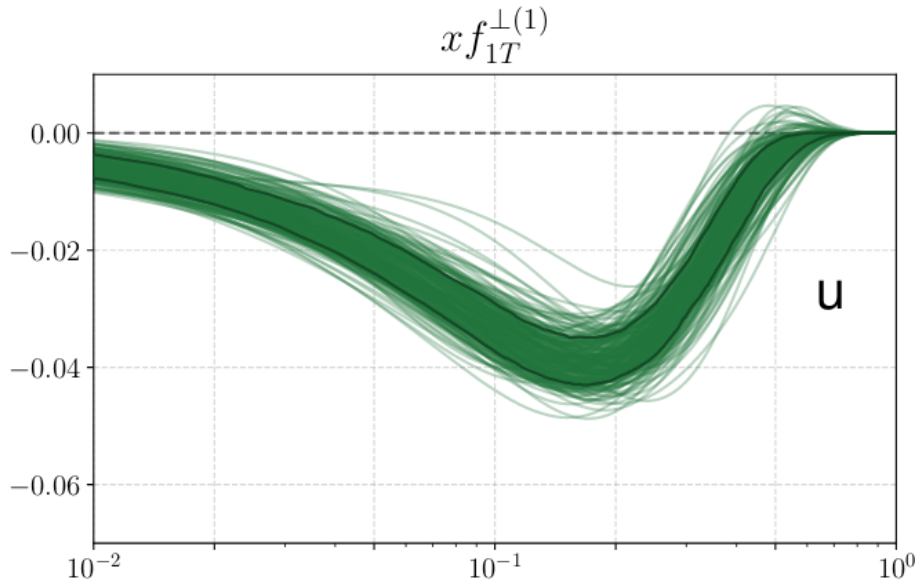
Comparison to M.Echevarria, Z.-B.Kang, J.Terry [2009.10710] relative factor $(2M)^{-1} \simeq 1.8$

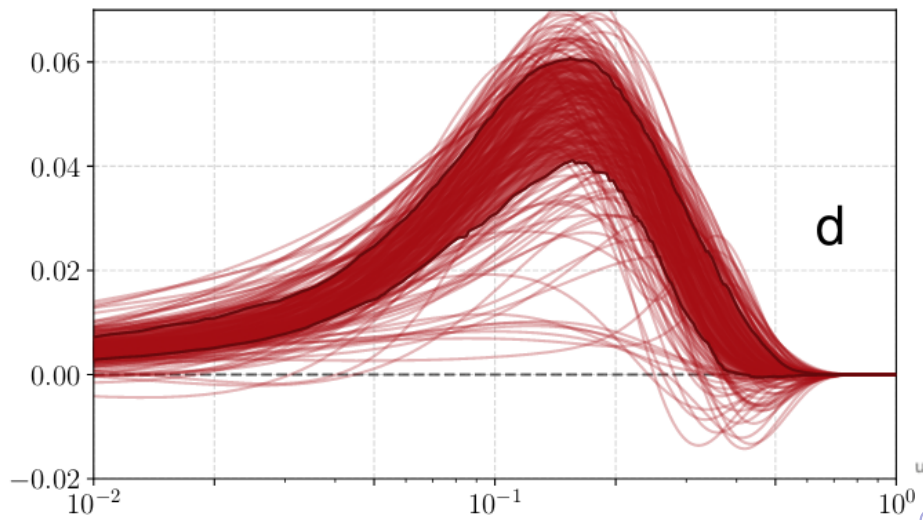




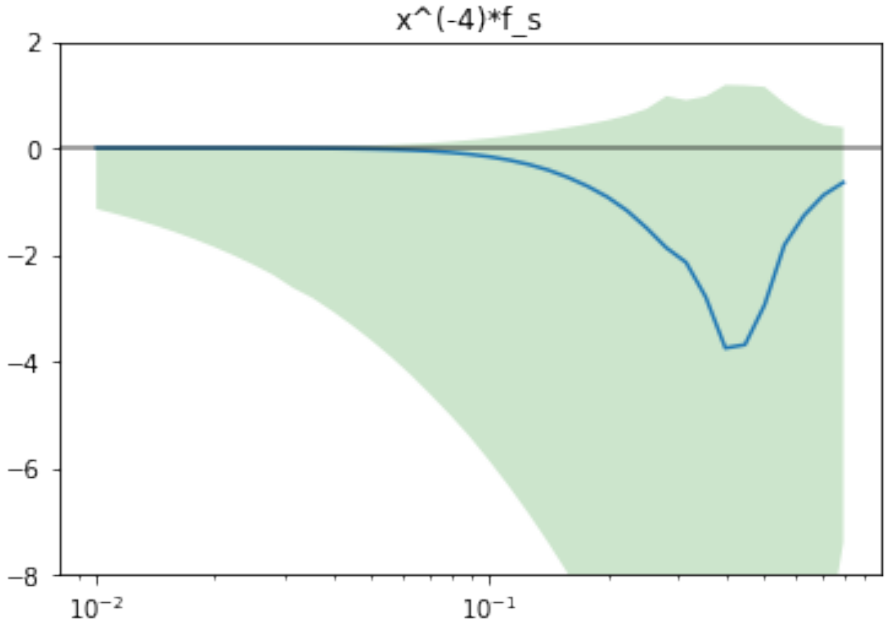
Comparison to A.Bacchetta, F. Delcarro, C.Pisano, M.Radici, [2004.14278]

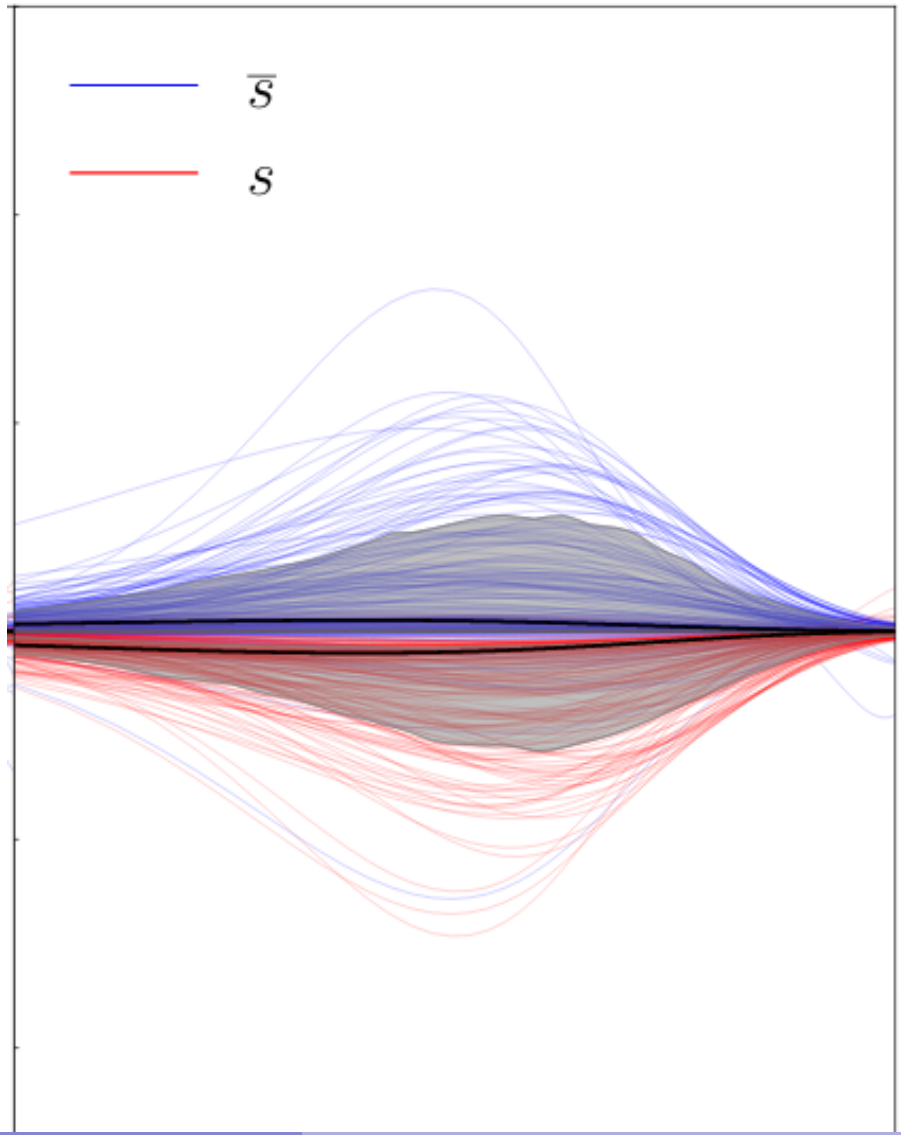




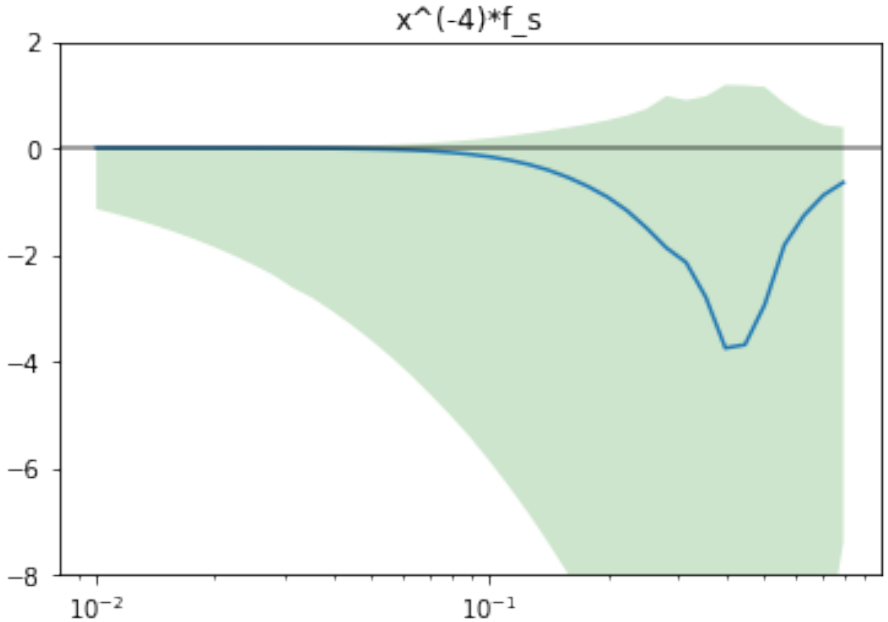


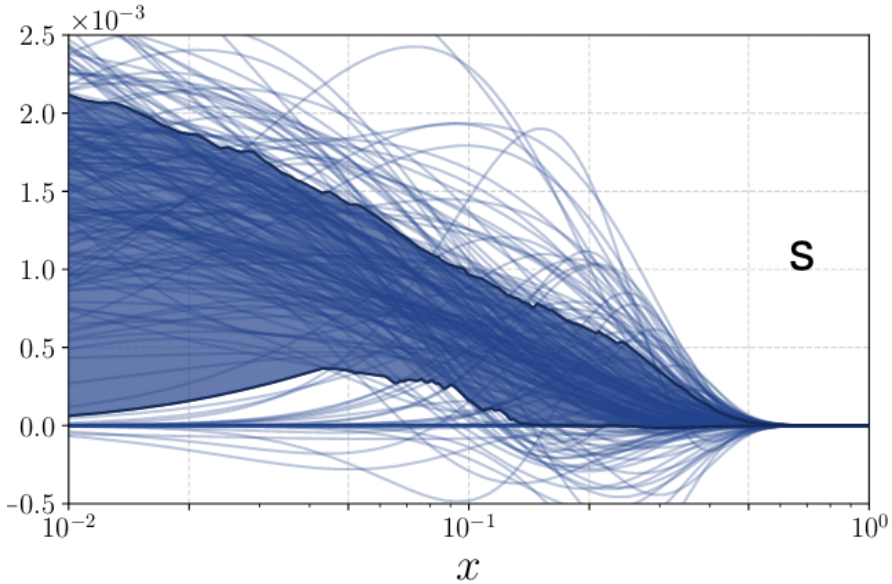
Comparison to M.Echevarria, Z.-B.Kang, J.Terry [2009.10710]
sea-quarks





Comparison to A.Bacchetta, F. Delcarro, C.Pisano, M.Radici, [2004.14278]
sea-quark





Part 2:
Impact of EIC
In Progress!

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Data

Repository: https://github.com/VladimirovAlexey/EIC_YR_TMD

Data by Ralf: `/Data1` PID and PID+HB
based on reweighed MC by Torino08

Usual TMD cut: $p_T < 0.25zQ$, $Q > 2$ (and $z > 0.05$ for technical reasons)

	#points	#points after cut
(5×41)	$\sim 3 \cdot 10^3$	$\sim 1 \cdot 10^3$
(5×100)	$\sim 3.5 \cdot 10^3$	$\sim 1.3 \cdot 10^3$
(10×100)	$\sim 3.5 \cdot 10^3$	$\sim 1.6 \cdot 10^3$
(18×100)	$\sim 4. \cdot 10^3$	$\sim 1.9 \cdot 10^3$
(18×285)	$\sim 4. \cdot 10^3$	$\sim 2.2 \cdot 10^3$
		$\sim (7. - 7.5) \cdot 10^3$ $\times\{\pi^{\pm}\}$

- (compare to global analysis) $\sim$75

Some points has huge error (pseudodata, or theory, or more then 100% disagreement (theory-pseudo data) [$\sim$ 3% of data points, mainly on the edges of phase-space]. These are thrown away

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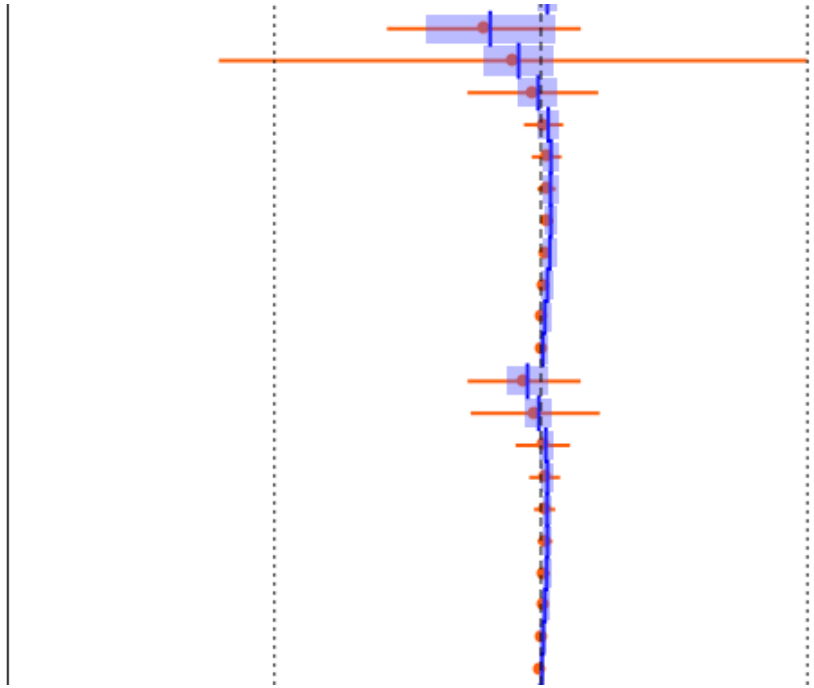
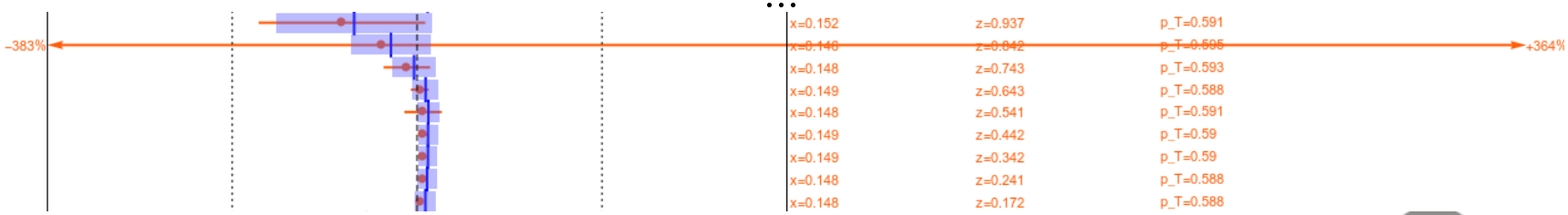


x=0.15	z=0.94	p_T=0.255
x=0.147	z=0.842	p_T=0.249
x=0.151	z=0.741	p_T=0.252
x=0.149	z=0.642	p_T=0.249
x=0.148	z=0.541	p_T=0.249
x=0.149	z=0.44	p_T=0.248
x=0.149	z=0.34	p_T=0.25
x=0.15	z=0.24	p_T=0.249
x=0.148	z=0.172	p_T=0.249
x=0.148	z=0.121	p_T=0.248
x=0.148	z=0.07	p_T=0.248
x=0.144	z=0.841	p_T=0.147
x=0.15	z=0.746	p_T=0.154
x=0.146	z=0.64	p_T=0.153
x=0.148	z=0.541	p_T=0.153
x=0.149	z=0.442	p_T=0.151
x=0.149	z=0.341	p_T=0.153
x=0.149	z=0.24	p_T=0.152
x=0.149	z=0.171	p_T=0.152
x=0.148	z=0.121	p_T=0.152
x=0.148	z=0.0696	p_T=0.151

...

...

...



x=0.152	z=0.937	p_T=0.591
x=0.146	z=0.842	p_T=0.595
x=0.148	z=0.743	p_T=0.593
x=0.149	z=0.643	p_T=0.588
x=0.148	z=0.541	p_T=0.591
x=0.149	z=0.442	p_T=0.59
x=0.149	z=0.342	p_T=0.59
x=0.148	z=0.241	p_T=0.588
x=0.148	z=0.172	p_T=0.588

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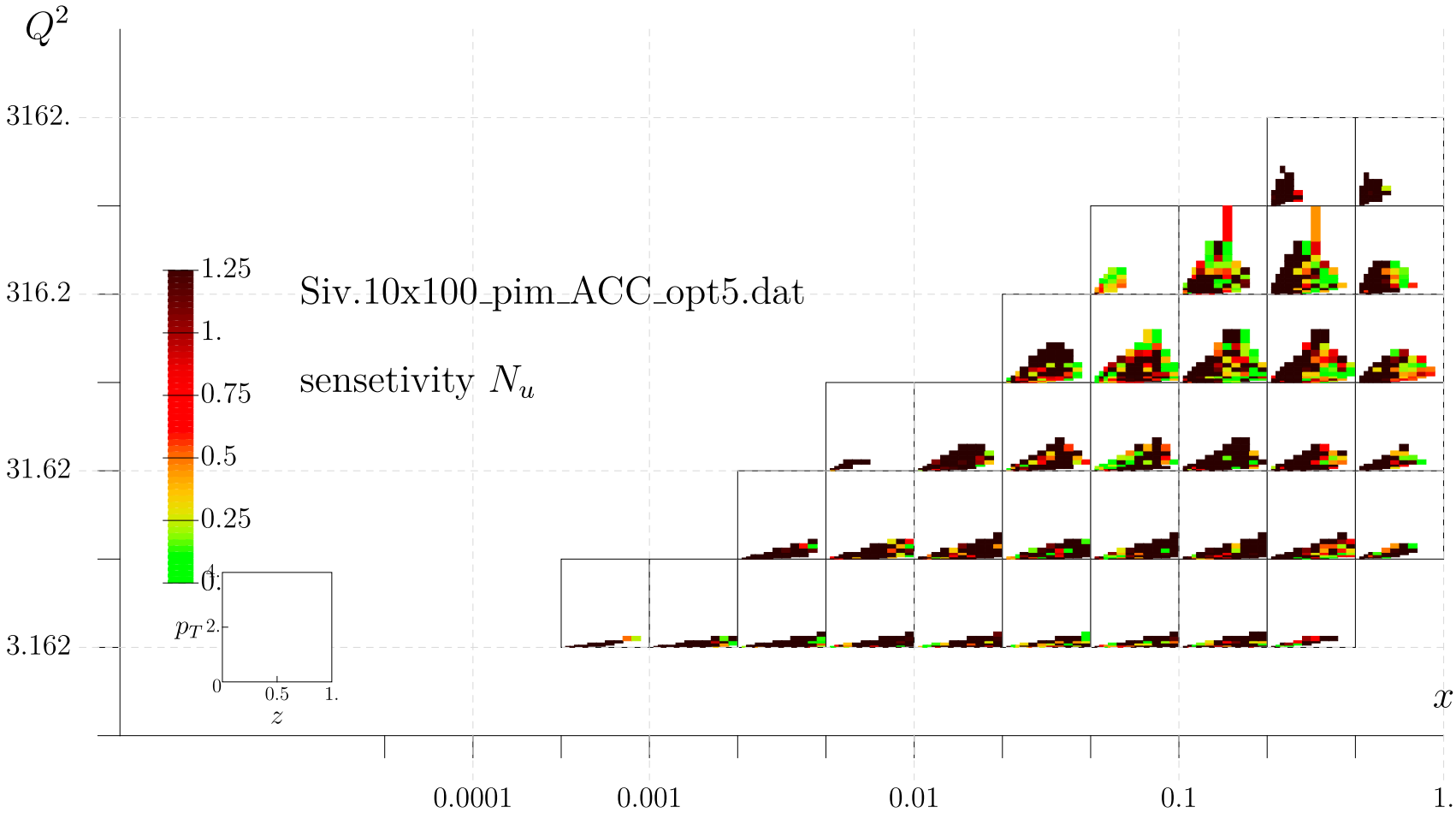

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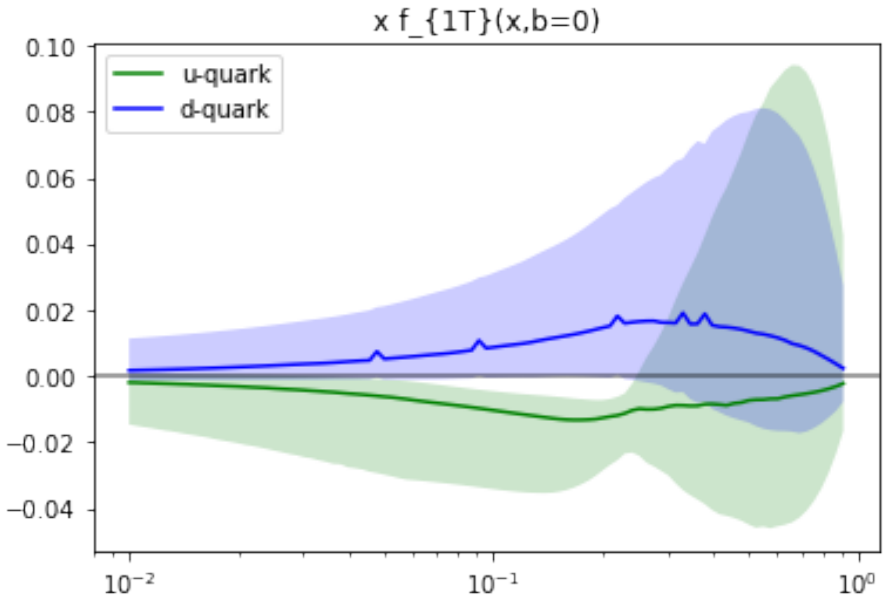
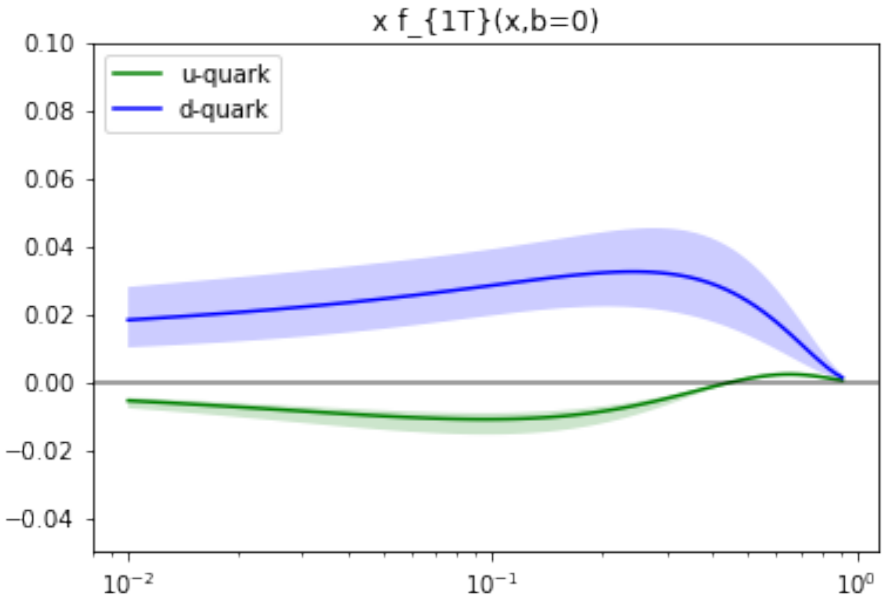
Impact studies just started (takes some time to evaluate points)
Some "morning results" 80 replicas
Siv.18x275_pip_ACC_opt5

Model8 case2



After EIC



Soon, more to come!

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