Towards universal fit of parton distributions and fragmentation functions

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Jefferson Lab Angular Momentum Collaboration

Jefferson Lab
EXPLORING THE NATURE OF MATTER

Motivations

- SIDIS data from JLab 12 brings new challenges to understand the microscopic nature of $e + P$ reactions
  - It demands to know the limits in x and Q^2 where factorization theorems are applicable $\rightarrow$ opens up the possibility to extend, modify existing approximations
  - Tests on universality of non perturbative objects associated with nucleon structure and hadronization
- To study the data one needs to have self consistent tools
  - A framework that analyzes the data with the same theoretical assumptions $\rightarrow$ simultaneous extraction of all non perturbative functions
  - A framework that integrates collinear physics and TMDs is needed to reliably understand SIDIS
- As a first step we explore a combined unpolarized PDF and fragmentation function analysis

Setup

- Data sets
  - All inclusive DIS with $Q^2 > m_c^2$ and $W^2 > 10\text{GeV}^2$
  - pp and pd DY data from E866
  - SIDIS $\pi^\pm$ and $K^\pm$ multiplicities
  - All inclusive SIA $(e^+e- \to h + X)$ data + HQ tagged data
- Theory assumptions
  - All observables computed at NLO in pQCD
  - We work in Mellin space with truncated DGLAP evolution and numerically solved α_S
  - DIS structure functions computed at leading twist
  - Nuclear smearing for deuterium DIS
  - We use ZMVF
  - To describe SIA tagged data we fit HQ FFs
- Likelihood analysis
  - For the results presented here we use maximum likelihood and resampling
  - Final analysis will be done using Nested Sampling

Setup

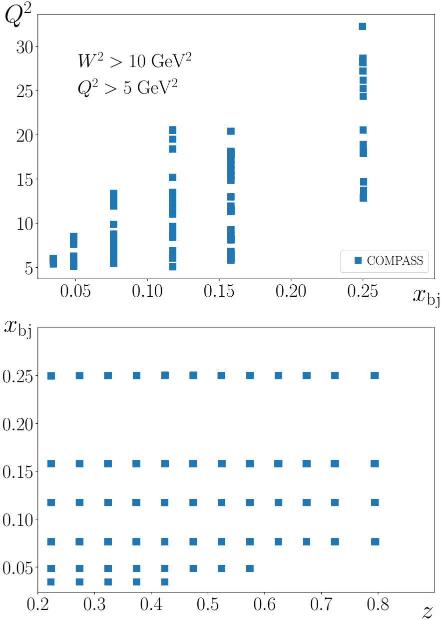
- Parametrization $\rightarrow$ generic template functions

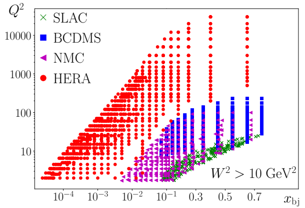
$$T(\xi;\boldsymbol{a}) = N\frac{\xi^a(1-\xi)^b(1+c\sqrt{\xi}+d\xi)}{B(2+a,b+1)+cB(5/2+a,b+1)+dB(3+a,b+1)}$$

- For PDFs 13 parameters
  - g, u_v, d_v, $\bar{u}$, $\bar{d}$, $s=\bar{s}$
  - momentum sum rules and quark number sum rule
- For FFs π^+ 16 parameters
  - g, u(fav.), d (ufav.), c, b
  - $u=\bar{d}$, $d=\bar{u}=s=\bar{s}$
- For FFs K^+ 15 parameters
  - g, u (fav.), d (unf.), $\bar{s}$ (fav.), c, b
  - $d=\bar{d}=\bar{u}=s$

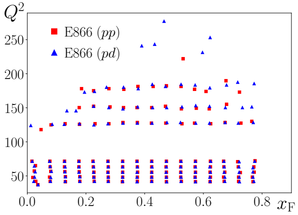
Data Kinematics

SIDIS (COMPASS)

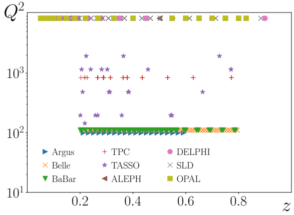




DIS

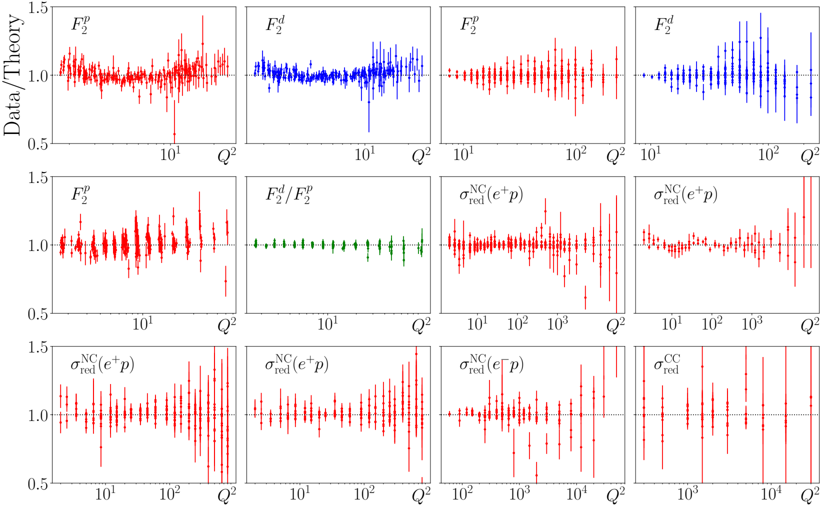


DY



SIA

Inclusive DIS: $l + (p, d) \to l' + X$

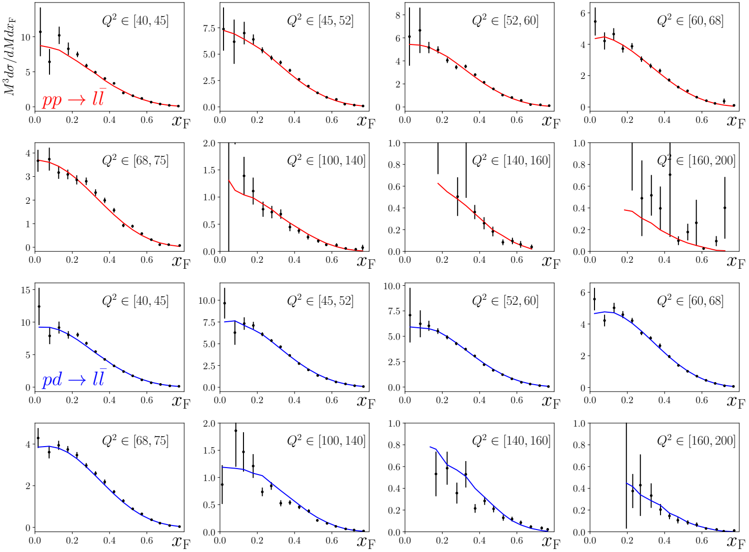


tar	col	npts	χ^2	χ^2/npts	χ^2-npts
p	BCDMS	348	375	1.1	27
d	BCDMS	254	280	1.1	26
p	NMC	273	499	1.8	226
d/p	NMC	174	172	1.0	−2
p	SLAC	218	300	1.4	82
d	SLAC	228	231	1.0	3

tar	col	npts	χ^2	χ^2/npts	χ^2-npts
p	HERA	402	627	1.6	225
p	HERA	75	93	1.2	18
p	HERA	259	265	1.0	6
p	HERA	209	231	1.1	22
p	HERA	159	261	1.6	102

tar	col	npts	χ^2	χ^2/npts	χ^2-npts
p	HERA	39	44	1.1	5
p	HERA	42	48	1.1	6

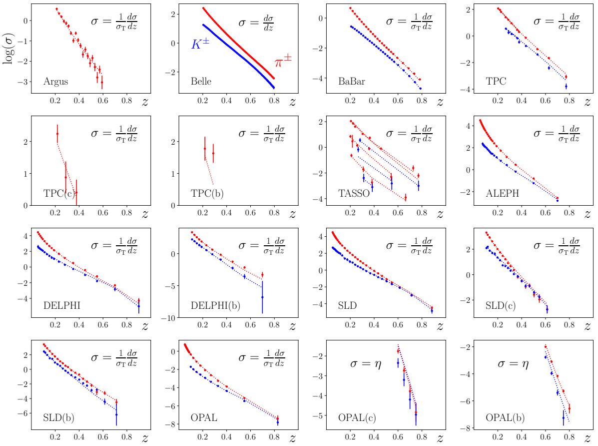
Lepton pair production: $p + (p, d) \rightarrow l\bar{l} + X$



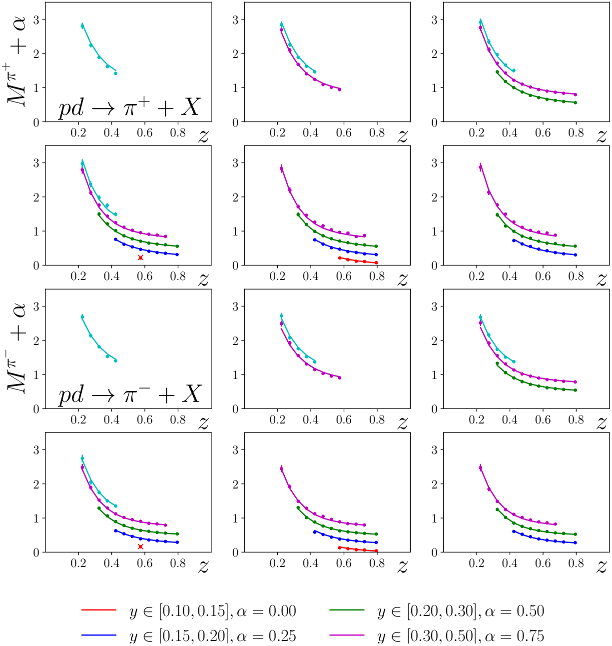
tar	col	npts	chi2	chi/npts	chi2-npts
pp	E866	121	169	1.4	48.07
pd	E866	129	169	1.3	40.07

SIA: $e^+e^- \to (\pi^\pm, K^\pm) + X$

rs	col	had	npts	χ^2	χ^2/npts	χ^2-npts
12	TASSO	pion	1	0.8	0.8	−0.2
14	TASSO	pion	4	12.3	3.1	8.3
22	TASSO	pion	4	2.9	0.7	−1.1
34	TASSO	pion	5	7.6	1.5	2.6
44	TASSO	pion	3	5.4	1.8	2.4
29	TPC	pion	3	0.9	0.3	−2.1
29	TPC	pion	9	4.8	0.5	−4.2
29	TPC(c)	pion	3	1.5	0.5	−1.5
29	TPC(b)	pion	2	4.8	2.4	2.8
58	TOPAZ	pion	1	0.1	0.1	−0.9
91	SLD	pion	29	31.2	1.1	2.2
91	SLD(c)	pion	19	63.8	3.4	44.8
91	SLD(b)	pion	20	19.8	1.0	−0.3
91	ALEPH	pion	22	40.6	1.8	18.6
91	OPAL	pion	22	46.5	2.1	24.5
91	OPAL(c)	pion	4	15.3	3.8	11.3
91	OPAL(b)	pion	5	11.0	2.2	6.0
91	DELPHI	pion	17	25.9	1.5	8.9
91	DELPHI(b)	pion	11	15.4	1.4	4.4
11	BABAR	pion	25	20.1	0.8	−5.0
11	BELLE	pion	60	25.9	0.4	−34.1
10	ARGUS	pion	20	37.3	1.9	17.3
14	TASSO	kaon	2	4.1	2.1	2.1
22	TASSO	kaon	2	0.2	0.1	−1.9
34	TASSO	kaon	2	0.1	0.1	−1.9
29	TPC	kaon	2	7.3	3.7	5.3
29	TPC	kaon	7	13.9	2.0	6.9
58	TOPAZ	kaon	1	0.2	0.2	−0.8
91	SLD	kaon	29	20.1	0.7	−8.9
91	SLD(c)	kaon	19	46.1	2.4	27.1
91	SLD(b)	kaon	20	54.8	2.7	34.8
91	ALEPH	kaon	18	7.7	0.4	−10.3
91	OPAL	kaon	10	6.0	0.6	−4.0
91	OPAL(c)	kaon	4	55.3	13.8	51.3
91	OPAL(b)	kaon	5	39.8	8.0	34.8
91	DELPHI	kaon	17	20.6	1.2	3.6
91	DELPHI(b)	kaon	11	4.4	0.4	−6.6
11	BABAR	kaon	26	10.7	0.4	−15.3
11	BELLE	kaon	60	14.9	0.3	−45.2



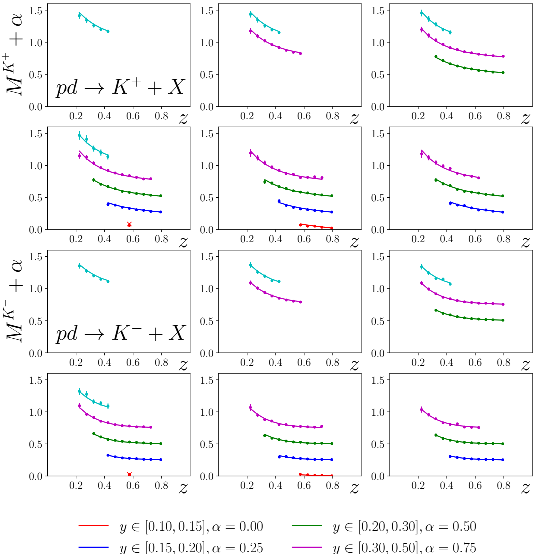
SIDIS: $l + d \to l' + \pi^{\pm} + X$



tar	had	col	npts	χ^2	χ^2-npts	χ^2/npts
d	π^-	COMPASS	142	175	33	1.23
d	π^+	COMPASS	142	158	16	1.11
d	K^-	COMPASS	141	67	-74	0.48
d	K^+	COMPASS	141	70	-71	0.5

- α is use to offset the data
- Difficulty in fitting all the low Q^2 data. Only $Q^2 > 5\text{GeV}^2$ included

SIDIS: $l + d \to l' + K^{\pm} + X$



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d	π^+	COMPASS	142	158	16	1.11
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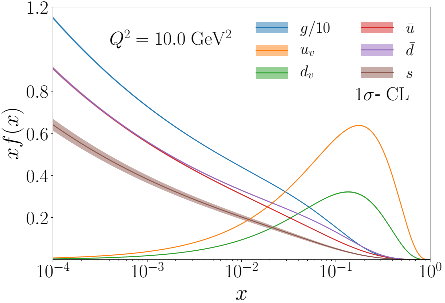
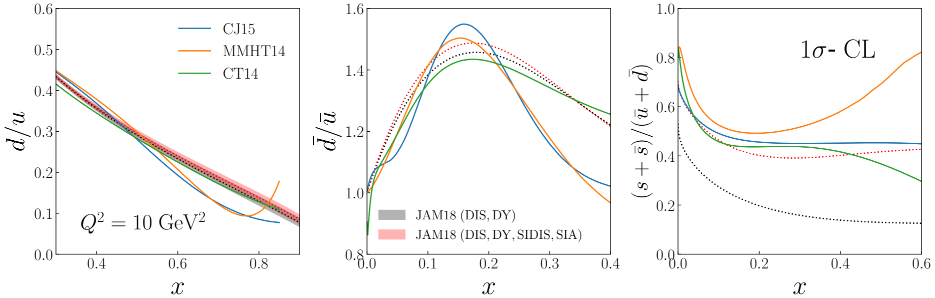
d	K^+	COMPASS	141	70	-71	0.5

PDFs (preliminary)

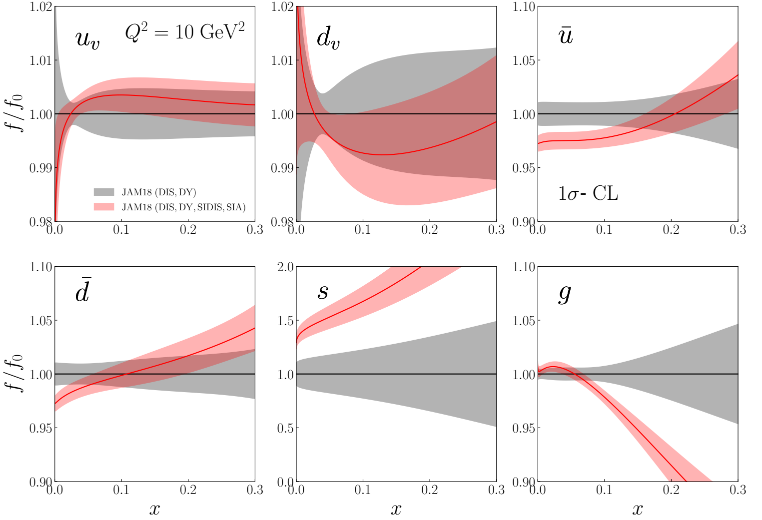


- consistent with previous analyses $\bar{d} - \bar{u}$ except at large x JAM18 predicts large asymmetry at large x to be tested by SeaQuest data
- SIDIS data supports the strange suppression



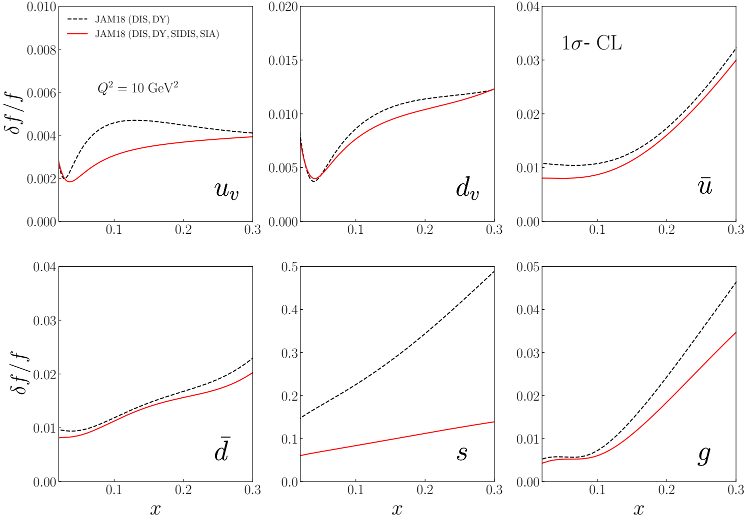
PDFs: impact of SIDIS (preliminary)

f_0: central JAM18 DIS+DY PDFs



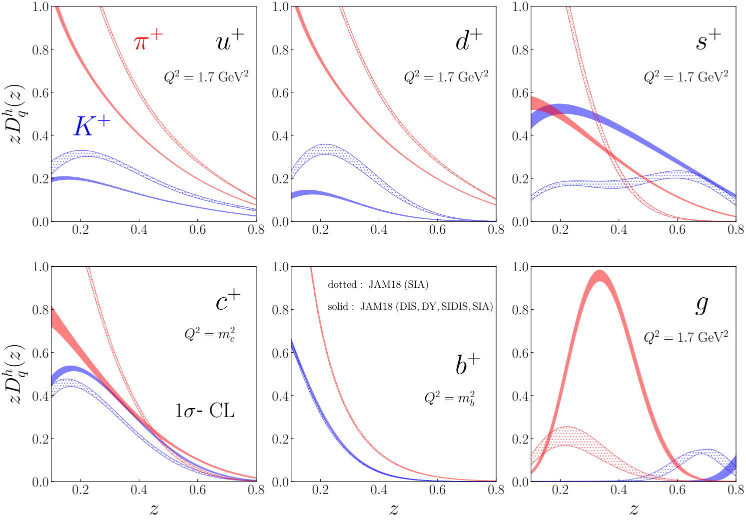
+ The gluon distribution seems to change significantly with the inclusion of SIDIS

PDFs: uncertainties after SIDIS (preliminary)



- As expected, inclusion of K data decreases significantly uncertainties on the strange distribution

FFs: impact of SIDIS (preliminary)



- Flavor decomposition of FFs changes significantly if SIDIS data is included

Summary and outlook

- Preliminary analysis of combined DIS, SIDIS and SIA
  - It is possible to fit simultaneously PDFs and FFs using DIS, SIDIS and SIA
  - SIDIS Kaon data provides significant constraints on the strange distribution $\rightarrow$ It support the strange suppression for PDFs
  - Flavor decomposition of FFs is significantly affected by SIDIS data in comparison with SIA only analysis
  - Difficulties in incorporating low $Q^2 < 5\mathrm{GeV}^2$ data $\rightarrow$ it suggests that power corrections in SIDIS shows up at higher Q^2 values than in DIS
- To do list:
  - Inclusion of HQ treatment especially for low Q^2 and low x HERA data
  - Release the $s = \bar{s}$ constraint since SIDIS K can discriminate s from $\bar{s}\rightarrow$ needs to be done using MC approach
  - Inclusion of polarized DIS and SIDIS and extract ΔPDFs in addition to PDFs and FFs $\rightarrow$ unpolarized SIDIS can affect polarized SIDIS asymmetries