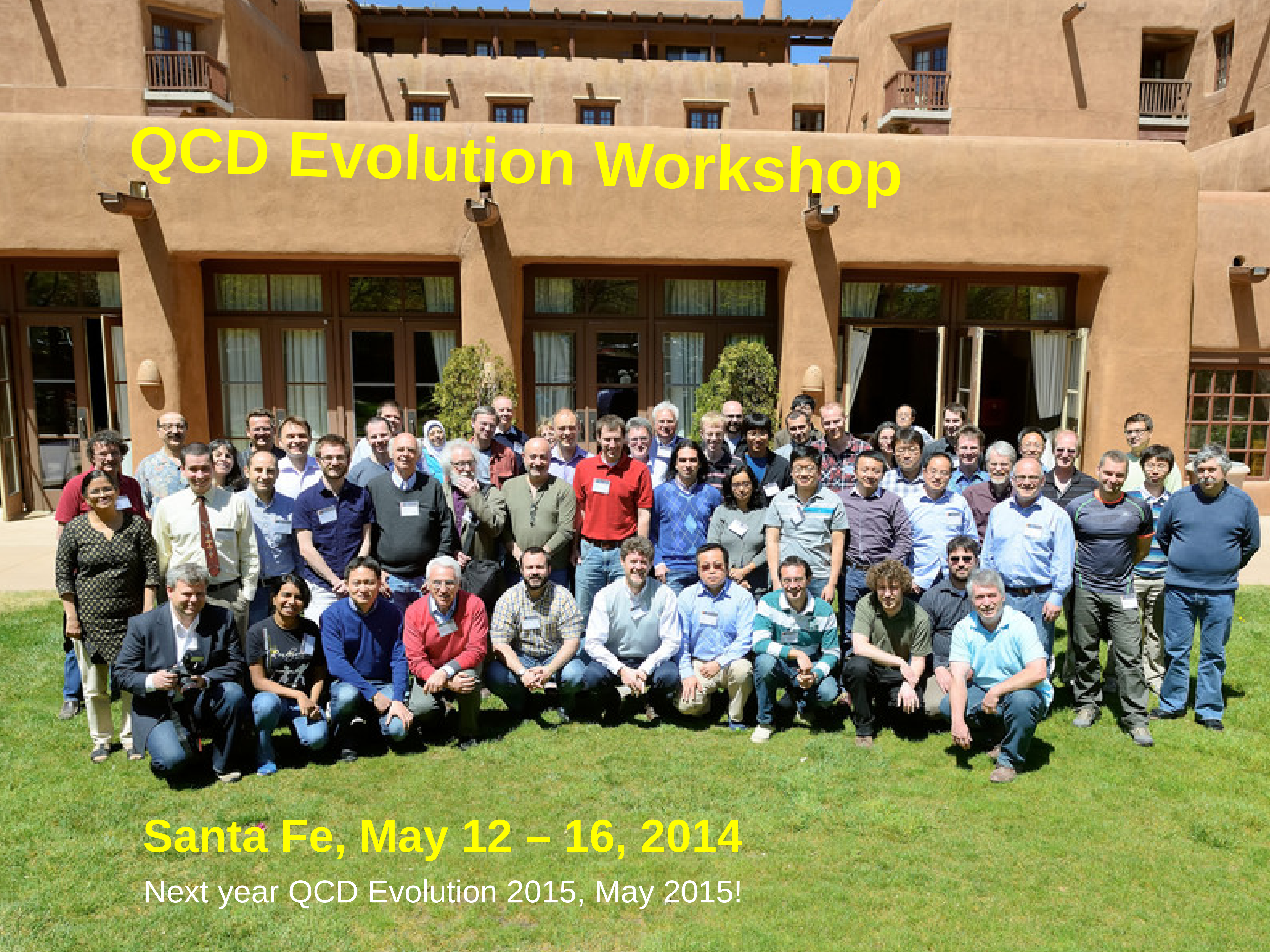
Global fits and impact of TMD evolution: DISCUSSION

Alexei Prokudin

June 10, 2014


QCD Evolution Workshop
Santa Fe, May 12 – 16, 2014
Next year QCD Evolution 2015, May 2015!

Talks

Talks related to TMD evolution up to Tuesday:

- Mauro Anselmino
- Stefano Melis
- John Collins
- Werner Vogelsang
- Leonard Gamberg
- Ignazio Scimemmi
- Frederik Van der Veken
- Miguel Echevarria
- Marc Schlegel
- Dennis Sivers
- Oleg Teryaev
- ... many more talks later this week

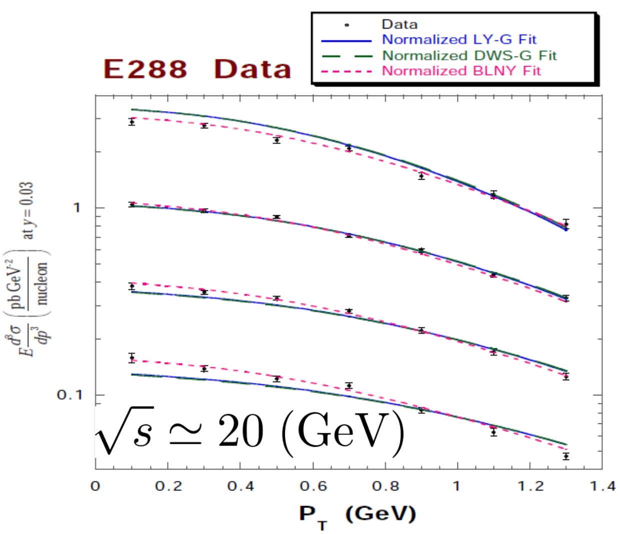
TMD evolution: promise

TMD evolution connects both different values of Q^2 and *different values of energy*.

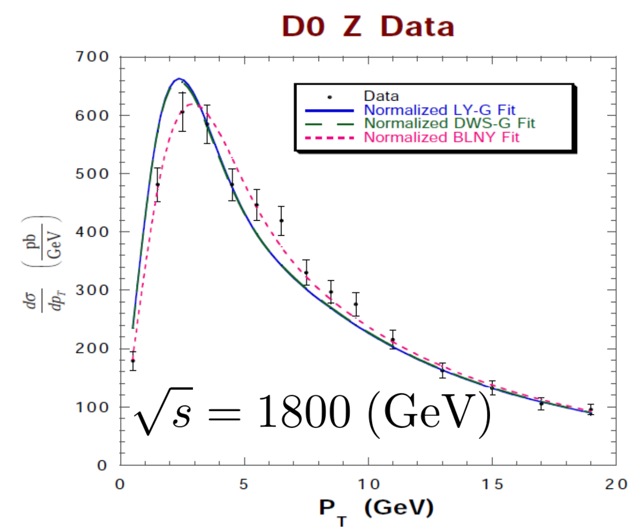
TMD evolution = CSS evolution and is well developed since 80s.

TMD formalism smoothly matches to collinear formalism.

Part of evolution is universal in all processes.



$Q \simeq 5 \div 13$ (GeV)



$Q \simeq 91$ (GeV)

Landry, Brock, Nadolsky, Yuan (2002)

TMD evolution details

- CSS evolution

Stefano Melis

$$\frac{1}{\sigma_0}\frac{d\sigma}{dQ^2dydq_T^2} = \int \frac{d^2\boldsymbol{b}_T e^{i\boldsymbol{q}_T\cdot\boldsymbol{b}_T}}{(2\pi)^2}\sum_j e_j^2 W_j(x_1,x_2,b_T,Q) + Y(x_1,x_2,q_T,Q)$$

Soft gluon emissions resummed in b-space

Matching to LO, NLO QCD

$$W_j(x_1,x_2,b_T,Q) = \exp\left[S_j(b_T,Q)\right]\sum_{i,k} C_{ji}\otimes f_i(x_1,C_1^2/b_T^2)\; C_{\bar{j}k}\otimes f_k(x_2,C_1^2/b_T^2)$$

Sudakov factor $S_j(b_T,Q) = \int_{C_1^2/b_T^2}^{Q^2}\frac{d\kappa^2}{\kappa^2}\left[A_j(\alpha_s(\kappa))\ln\left(\frac{Q^2}{\kappa^2}\right) + B_j(\alpha_s(\kappa))\right]$

$$C_1 = 2\exp(-\gamma_E)$$

$$A_j(\alpha(\mu)) = \sum_{n=1}^{\infty}\left(\frac{\alpha_s}{2\pi}\right)^n A_j^{(n)}$$

$$B_j(\alpha(\mu)) = \sum_{n=1}^{\infty}\left(\frac{\alpha_s}{2\pi}\right)^n B_j^{(n)}$$

Leading Log (LL)	:	$A^{(1)}$;
Next to LL (NLL)	:	$A^{(2)}, B^{(1)}, C^{(1)}$;
Next to NLL (NNLL)	:	$A^{(3)}, B^{(2)}, C^{(2)}$;
Fixed order $\alpha_s(FXO)$	:	$A^{(1)}, B^{(1)}, C^{(1)}$;

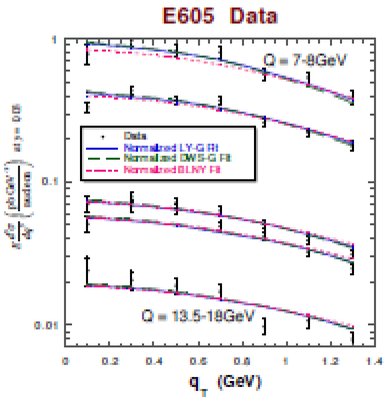
Jefferson Lab

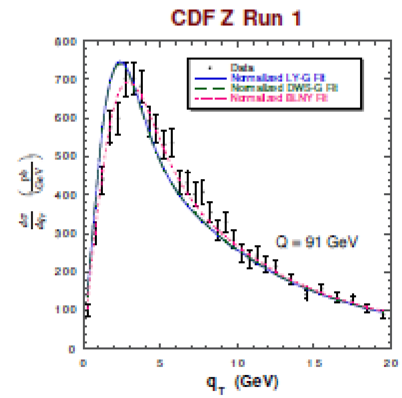
TMD evolution details

John Collins

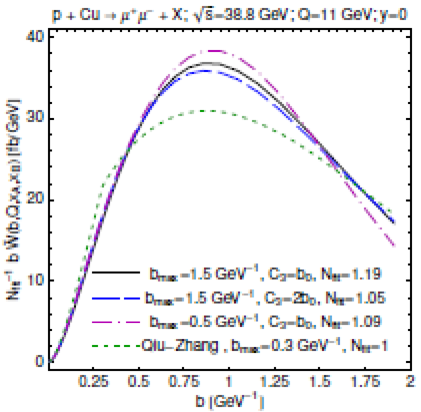
Geography of evolution of cross section

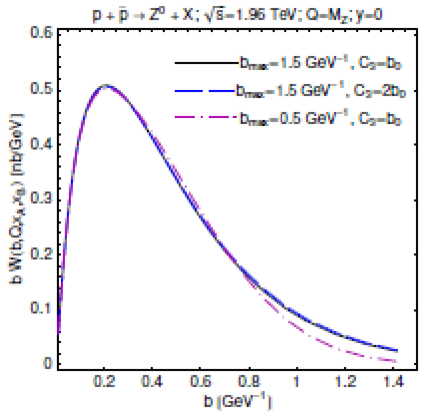
q_T





b_T





Q	Typical b_T
$2\,\mathrm{GeV}$	$3\,\mathrm{GeV}^{-1}$
$10\,\mathrm{GeV}$	$1.2\,\mathrm{GeV}^{-1}$
m_Z	$0.5\,\mathrm{GeV}^{-1}$

$1.5\,\mathrm{GeV}^{-1} = 0.3\,\mathrm{fm}$

Q: 7–$18\,\mathrm{GeV}$, $\sqrt{s} = 38.8\,\mathrm{GeV}$ $\quad$ $Q = m_Z$, $\sqrt{s} = 1800\,\mathrm{GeV}$

(Adapted from Landry et al., PRD 67,073016 (2003), Konychev & Nadolsky, PLB 633, 710 (2006))

TMD evolution non-perturbative input

Stefano Melis

- Non-perturbative Sudakov form factor

CSS

$F_{NP}(x_1, x_2, b_T, Q)$

Brock-Landry-Nadolsky-Yuan (BLNY): $\exp\left[-g_1 - g_2 \ln\left(\frac{Q}{2Q_0}\right) - g_1 g_3 \ln(100 x_1 x_2)\right] b^2$

Ladinsky-Yuan (LY): $\exp\left\{\left[-g_1 - g_2 \ln\left(\frac{Q}{2Q_0}\right)\right] b^2 - [g_1 g_3 \ln(100 x_1 x_2)] b\right\};$

TMD

Aidala-Field-Gamberg-Rogers: $g_K(b_T; b_{\max}) = \frac{g_2(b_{\max}) b_{\rm NP}^2}{2} \ln\left(1 + \frac{b_T^2}{b_{\rm NP}^2}\right)$

Sun-Yuan: $g_2 \ln(b_T / b^*)$

- Non-perturbative input for TMDs

$$F_{NP}(b_T, Q)^{\rm pdf} = \exp\left[-b_T^2 \left(g_1^{\rm pdf} + \frac{g_2}{2} \ln(Q/Q_0)\right)\right]$$

$$F_{NP}(b_T, Q)^{\rm ff} = \exp\left[-b_T^2 \left(g_1^{\rm ff} + \frac{g_2}{2} \ln(Q/Q_0)\right)\right]$$

Gaussian ansatz works very well. Justified theoretically?

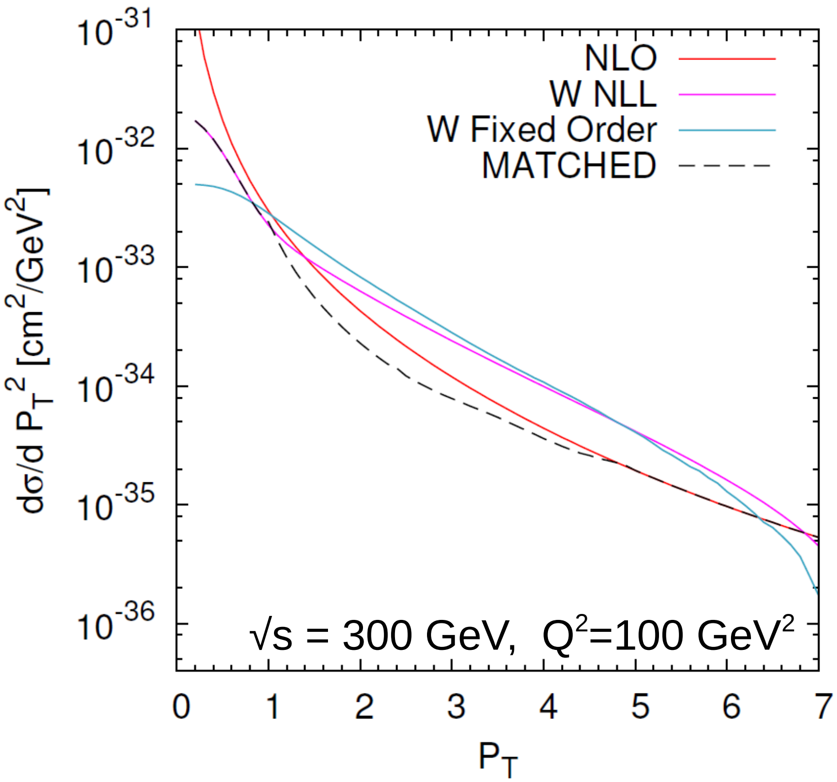
A case when matching works ...

Elena Boglione
QCD Evolution
Santa Fe

W^{NLL}	W^{NLL} - W^{FXO} + NLO	NLO

$W^{FXO} \sim$ NLO $\qquad$ $W^{NLL} \sim W^{FXO}$

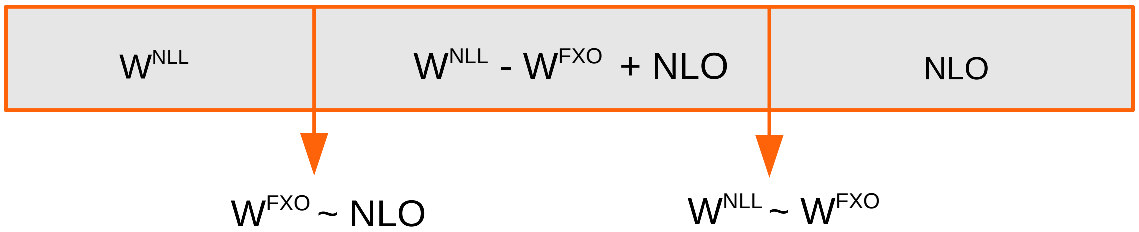
Matching OK !



- At "low" P_T there is a region where $W^{NLL} \sim W^{FXO}$
- At "large" P_T there is a region where $W^{FXO} \sim$ NLO

COMPASS … a case matching does not work

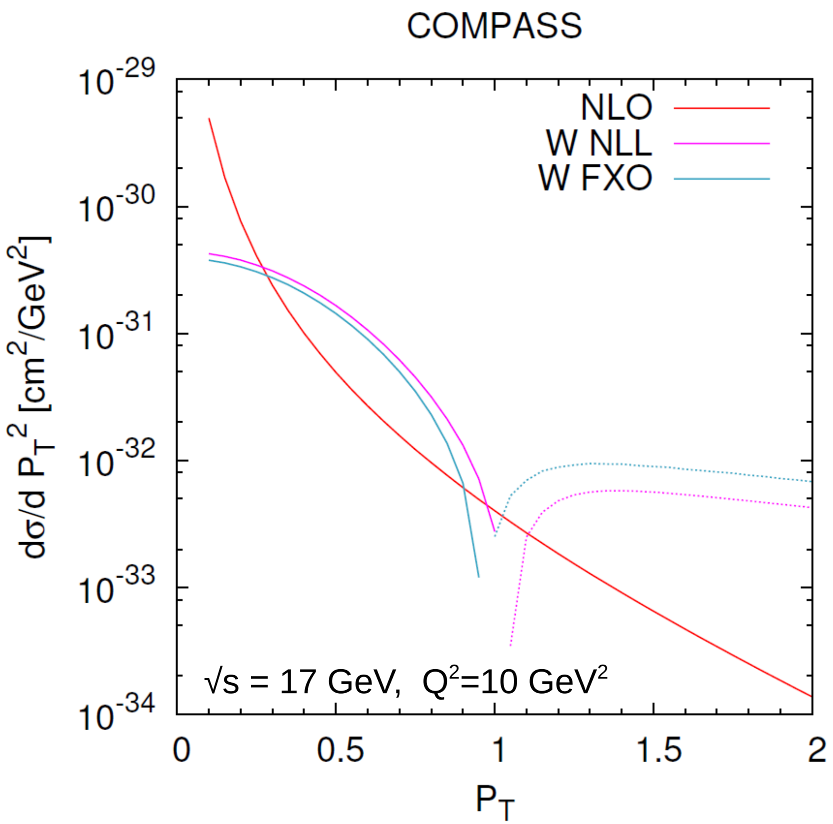
Elena Boglione
QCD Evolution
Santa Fe



See talk
Werner Vogelsang

Why it happens?

Non-perturbative input becomes crucial



- ✗ The matching should be done over a very small P_T region
- ✗ No way to realize a smooth matching, without "cusps".

Phenomenology

Stefano Melis

	SIDIS	DY
➢Anselmino et al: Gaussian	Yes	
➢SBRS*: Gaussian	Yes	
➢Sun-Yuan: TMD EVO I/O+ Modified Sudakov	Yes	Yes
➢EIKV**: TMD Evo a la CSS+ C at LO	Yes	Yes
➢AEMS***: TMD Evo a la CSS		Yes
➢AFGR****: TMD Evo	Yes?	

*Signori-Bacchetta-Radici-Schnell

**Echivarria-Idilbi-Kang-Vitev

***D'Alesio-Echevarria-Melis-Scimemi

****Aidala-Field-Gamberg-Rogers

Unpolarized phenomenology Sivers

Stefano Melis

	Can describe unpolarized SIDIS	DY
➤Aybat-Roger-Prokudin: TMD EVO I/O	No	No
➤Anselmino-Boglione-Melis: Gaussian	Maybe	Maybe No High energy
➤Anselmino-Boglione-Melis: TMD EVO I/O	No	No
➤Sun-Yuan: TMD EVO IO+ Modified Sudakov	No Hermes YES/Maybe COMPASS	Yes low energy No High energy
➤EIKV*: TMD Evo a la CSS+ C at LO	No Hermes YES/Maybe COMPASS	YES

*Echivarria-Idilbi-Kang-Vitev

TMD evolution: some open questions

… for phenomenology

What is the optimal shape for non-perturbative input?

What is the shape of non-perturbative Sudakov form factor?

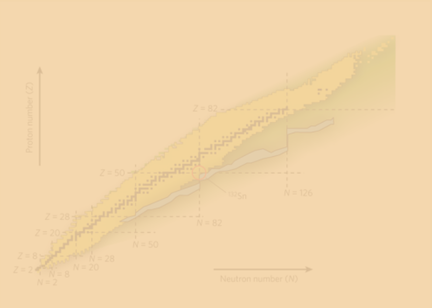
What is the best way to avoid Landau pole? b*, complex b, etc

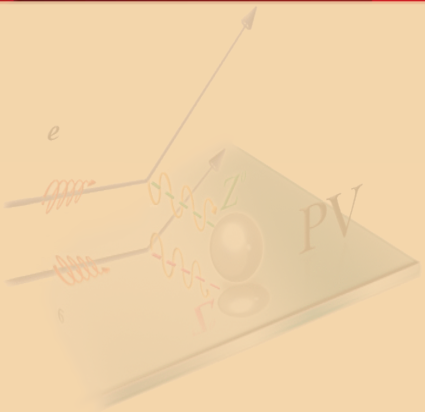
What about matching?

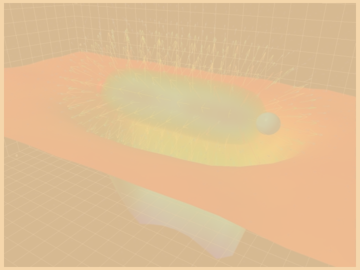
What data can we actually use in our analysis?

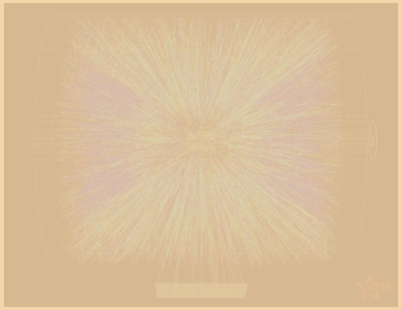
...etc

Conclusions









~~Conclusions~~

DISCUSSION