1

Higher twists to xF_3 as the part of the bridge between COMPASS and Neutrino Factory

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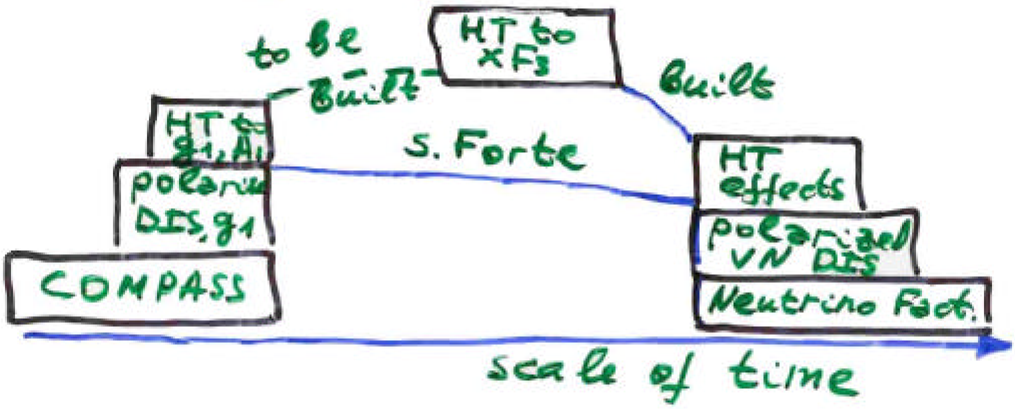


plan

1. What is Neutrino Factory

   M. Mangano et al (01)

2. HT to xF_3: what do we know at NLO, NNLO and Beyond

   Kataev, Kotikov, Parente, Sidorov (98)

   Kataev, Parente, Sidorov (01)

3. HT contributions to $A_1 \simeq (1+\gamma^2)\frac{g_1}{F_1}$; $\gamma^2 = \frac{4M_N}{Q^2}$

   start of the study at NLO

   Leader, Sidorov, Stamenov (00)

   Are there any relations

   2 ⟷ 3

4. Conclusion

3

ECFA STUDIES -> END 2000

A Neutrino Factory Complex

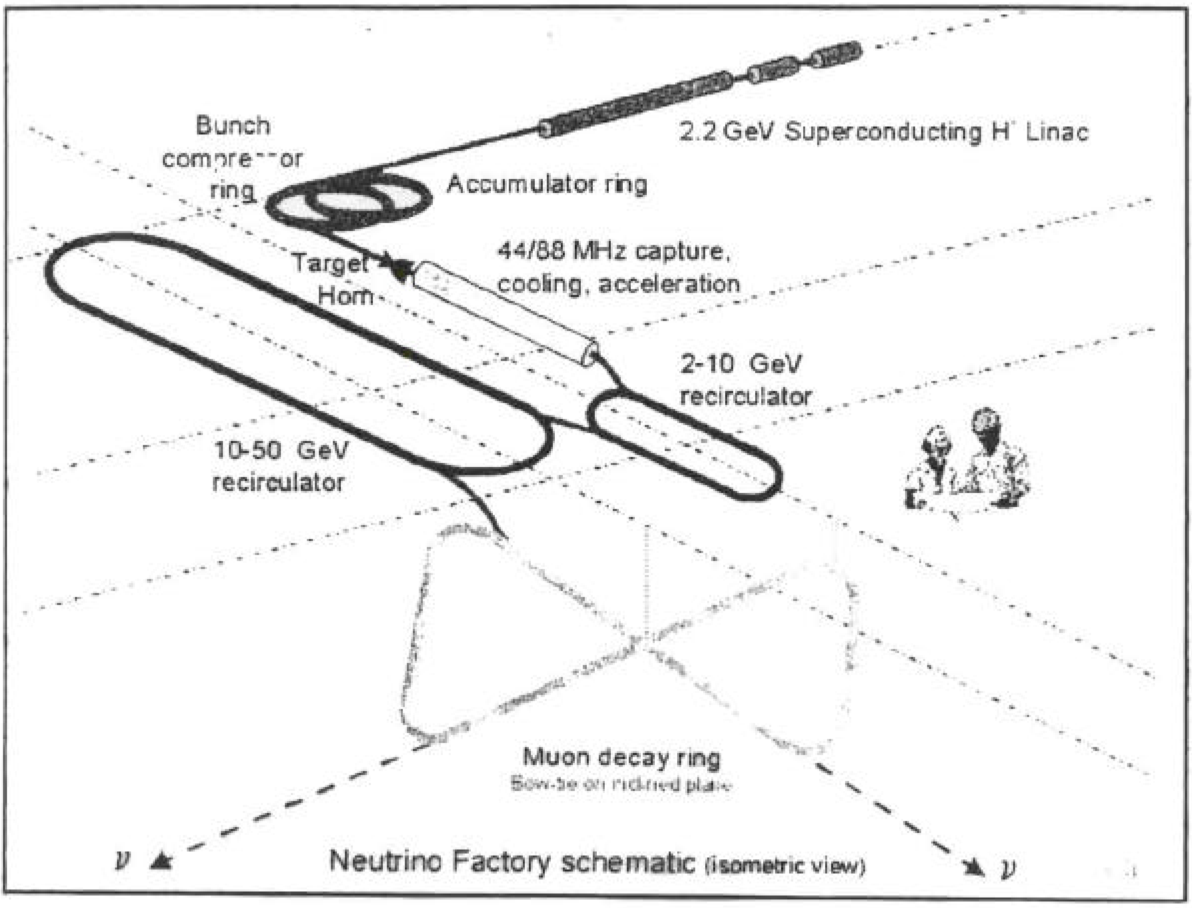
Physics opportunities at the neutrino factory:
A. Neutrino Oscillations (F. Dydak, J.J. Gomez-Cadenas)

B. High intensity hadron, muon and neutrino beams (J. Ellis)
B1. ν and μ DIS (M. Mangano)
B2. Rare muon decays and muon physics (G. Giudice)
B3. High intensity Kaon physics (G. Buchalla)

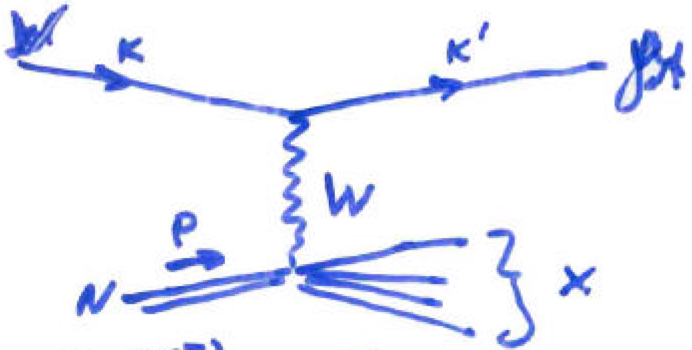
Longer-term opportunities opened by the neutrino factory:
C. muon colliders, (Marcela Carena, Bill Murray)
C'.High Energy Frontier
(coordinated with CLIC studies: J.Ellis/M.Battaglia)

In parallel with machine design studies by the Neutrino Factory working group mandated by CERN (H. Haseroth)

+ High intensity superconducting proton linac(R. Garoby)
+ Rapid cycling synchrotron and accumulator (H. Schonauer)



Neutrino Factory schematic (isometric view)



$$\frac{d^2\sigma^{\nu(\bar\nu)}}{dx\,dy} = \frac{G_F^2 M_N E_\nu}{\pi(1+Q^2/M_W^2)^2}\left[\frac{1}{2}y^2\, 2x F_1^{\nu(\bar\nu)} + \left(1-y-\frac{M_N x y}{2E_\nu}\right)F_2^{\nu(\bar\nu)} \pm \left(y-\frac{1}{2}y^2\right) x F_3^{\nu(\bar\nu)}\right]$$

$$y = \frac{E_{had}}{E_\nu}$$

$$x = \frac{Q^2}{2M_N E_{had}} \qquad 0 < x \le 1$$

$$\frac{1}{1+\frac{x M_N}{2E_\nu}} \ge \boxed{y \ge 0}$$

Both xF_3 and xF_1 ~~may~~ be extracted! ← not small! y

Usually extracted: xF_3, F_2, $R = \frac{\sigma_L}{\sigma_T} = \left(1+\frac{4M_N^2 x}{Q^2}\right) \times \frac{F_2}{2xF_1} - 1$

Another way:

$$F_1^{\nu N} = \frac{F_2^{\nu N}}{2x} + \frac{F_L^{\nu N}}{2x}$$

So instead of fits of R, $F_2^{\nu(\bar\nu)}$, $xF_3^{\nu(\bar\nu)}$

6-parameters: $2xF_1^{\nu}$, $2xF_1^{\bar\nu}$, $F_2^{\bar\nu}$, F_2^{ν}, xF_3^{ν}, $xF_3^{\bar\nu}$

All available preliminary results:

CCFR (Iron)

CHORUS (R. Oldeman, Thesis).
Lead

EW-corrections D. Bardin, Dokuchaeva. (86)

NUDIS1 – $\frac{d\sigma}{dx}$

NUDIS2 → $\frac{d\sigma}{dx\,dy}$

5

Theoretical QCD Kitchen

DGLAP equation

$$Q^2 \frac{d}{dQ^2} F_3(x,Q^2) = \frac{1}{2} \int_x^1 \frac{dy}{y} \left[V_{F_3}(y,A_s) + \beta(A_s) \frac{\partial \ln C_{F_3}(A_s)}{\partial A_s} \right] F_3\left(\frac{x}{y}, Q^2\right)$$

$$Q^2 \frac{\partial A_s}{\partial Q^2} = \beta(A_s) = -\sum_{i=0}^{2} \beta_i A_s^{i+2}; \quad A_s = \frac{\alpha_s}{4\pi}$$

$\beta(A_s)$ is calculated at 4-loops - N^3LO

Ritbergen, Vermaseren, Larin (97)

$$C_{F_3}(y, A_s) = \sum_{n=0}^{2} C_{F_3,n} A_s^n$$

calculated to A_s^2 van Neerven, Zijlstra (91)

$$V_{F_3}(z,\alpha_s) = \sum_{n=0}^{2} V_n(z) A_s^{n+1},$$ calculated at A_s^2

$V_3(z)$ - model - new

van Neerven, Vogt (01)

Moments

$$\int_0^1 z^{n-1} V_{F_3}(z, A_s) = \sum_{i=0}^{2} \gamma_{F_3}^{(i)}(n) A_s^{i+1}$$

$\gamma_{F_3}^{(2)}(n)$ - 3 loops calculated analytically at $n = 3, 5, 7, 9, 11, 13 \Rightarrow$ NNLO

Retey, Vermaseren (00)

$$\int_0^1 z^n F_3(z, A_s) = \sum_{i=0}^{3} C^{(i)}(n) A_s^i$$

NNLO $C^{(2)}(n)$ - calculated analytically at any n.

N^3LO $C^{(3)}(n)$ - calculated analytically at $n = 1, 3, 5, 7, 9, 11, 13$

Retey, Vermaseren (00)

Method of the fits.

Jacobi polynomial technique

$$F_3(x_{exp}, Q^2_{exp}) = x^{\alpha}(1-x)^{\beta} \sum_{n=0}^{N_{max}} \Theta_n^{\alpha,\beta}(x) \sum_j c_j^{(n)}(\alpha,\beta) \times M_{j+2,xF_3}(Q^2)$$

$$M_{j+2,xF_3}(Q^2) = \int_0^1 x^{N-1} F_3(x,Q^2)\,dx$$

In the process of

NNLO fits : NNLO $\beta(\alpha_s)$, $\gamma_{F_3}(\alpha_s)$, $C^{(2)}_{F_3}(n)$

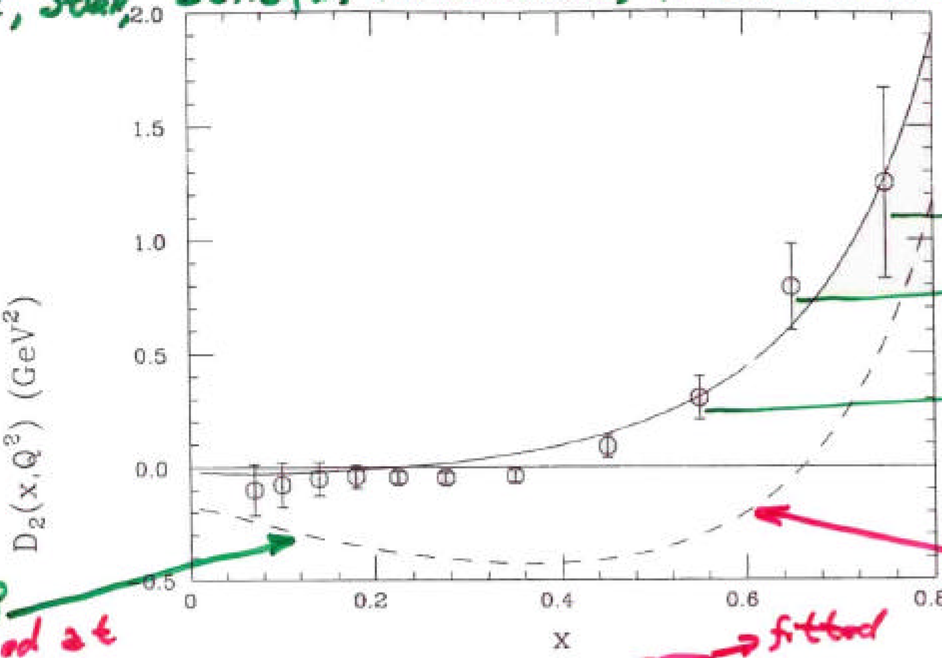
N^3LO fits : N^3LO $\beta(\alpha_s)$, $C^{(3)}_{F_3}(n)$, $\underline{\gamma_{F_3}\text{ - Padé}}$ $\to$ weak sensitivity

Determination : $\Lambda^{(4)}_{\overline{MS}} \to \alpha_s(Q^2) \to \alpha_s(M_Z)$

(7)

Why extraction of xF_3 is interesting?

Dasgupta, Webber, PL B382 (1996) 273
Maul, Stein, Schäfer, Mankiewicz, PL B401 (97) 100



BCDMS + SLAC F_2 data

predicted

KKPS'98 confirmed at NLO from CCFR'97 fits

fitted

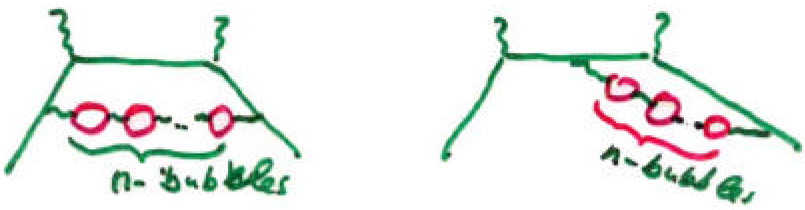
Figure 1: Coefficients of $1/Q^2$ contributions to F_2 (solid), and to F_1 and F_3 (dashed).

For F_1 and F_3 $D_i(x)$ is the same!

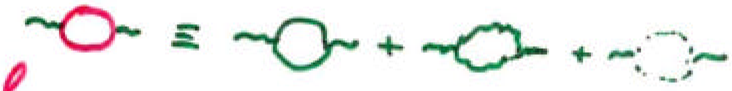
$$F_i(x,Q^2) = F_i^{\text{pert+TMC}}(x,Q^2)\left[1 + \frac{D_2^{(i)}(x)}{Q^2} + O\left(\frac{1}{Q^4}\right)\right]$$

$$D_2^{(2)}(x) \sim \frac{A_2'}{q(x,Q^2)} \int_x^1 \frac{dz}{z} C_2(z)\, \underbrace{q(x/z, Q^2)}_{\text{parton distribution}}$$

$C_2^{(2,3,1)}(x) \rightarrow$ calculated from set of diagrams



Infrared renormalon model



generate $\frac{1}{Q^2}$ - correction after resummation

(8) Fits to CCFR'97 with HT included

order/N_{max}	$Q_0^2 =$	5 Gev^2	20 GeV^2	100 GeV^2
NLO/9 (KPS'01= KPS'00)	$\Lambda^{(4)}_{\overline{MS}}$/[MeV] χ^2/nep A_2'/[GeV^2]	379±41 78.6/86 −0.125±0.053	376±39 79.5/86 −0.125±0.053	374±42 79.0 −0.124±0.053
NNLO/6 (KPS'01)	$\Lambda^{(4)}_{\overline{MS}}$/[MeV] χ^2/nep A_2'/[GeV^2]	297±30 77.9/86 −0.007±0.051	**328±36** **76.8/86** **−0.017±0.051**	328±35 79.5 −0.015±0.051
NNLO/6 (KPS'00)	$\Lambda^{(4)}_{\overline{MS}}$/[MeV] χ^2/nep A_2'/[GeV^2]	– – –	326±35 76.9/86 −0.01±0.05	— – –
NNLO/9 (KPS'01)	$\Lambda^{(4)}_{\overline{MS}}$ χ^2/nep A_2'/[GeV^2]	**331±33** **73.1/86** **−0.013±0.051**	**332±35** **75.7/86** **−0.015±0.051**	**331±35** **76.9/86** **−0.016±0.051**
N^{3}LO/6 (KPS'01)	$\Lambda^{(4)}_{\overline{MS}}$/[MeV] χ^2/nep A_2'/[GeV^2]	305±29 76.0/86 0.036±0.051	**327±34** **76.2/86** **0.033±0.052**	326±34 78.5 0.029±0.052
Padé/6 (KPS'00)	$\Lambda^{(4)}_{\overline{MS}}$/[MeV] χ^2/nep A_2'	– – –	340±37 77.2/86 - 0.004±0.05	– – –
N^{3}LO/9 (KPS'01)	$\Lambda^{(4)}_{\overline{MS}}$/[MeV] χ^2/nep A_2'/[GeV^2]	**333±34** **73.8/86** **0.038±0.052**	**328±33** **75.9/86** **0.035±0.052**	**328±38** **76.4/86** **0.034±0.052**

At $N_{max} = 9 \Rightarrow$ Stability to Q_0^2 !! χ^2 is minimized

$$\frac{h(x)}{Q^2} = x^{\alpha}(1-x)^{\beta} \sum_{n=0}^{N_{max}} \Theta_n^{\alpha,\beta}(x) \sum_{j=0}^{n} c_j^{(n)}(\alpha,\beta)\, M^{IRR}_{j+2,xF_3}(Q^2)$$

$$M^{IRR}_{n,xF_3}(Q^2) = \tilde{C}(n)\, M_n^{F_3}(Q^2)\, \frac{A_2'}{Q^2}$$

$$\tilde{C}(n) = -n - 4 + \frac{2}{n+1} + \frac{4}{n+2} + 4\sum_{j=1}^{n}\frac{1}{j}$$

- At NLO $\Rightarrow$ one can extract A_2' and $\Lambda^{(4)}_{\overline{MS}}$
- Starting from NNLO $\rightarrow$ A_2' is "screened" by higher order terms

May be CCFR'97 data are not so precise? $\rightarrow$ or general feature?

Notice, that interplay of HT and NNLO order corrections exist in the case of another model

SY'01 used (Santiago, Ynduraín)

$$\boxed{M^{HT}_{n,xF_3}(Q^2) = n\frac{B_2'}{Q^2}M_n^{F_3}(Q^2) \;, \text{ with } B_2' = a(\Lambda^{(4)}_{\overline{MS}})^2}$$

only in the NNLO fits

KPS'01 results: (Jacobi)

Order	$\Lambda^{(4)}_{\overline{MS}}$	χ^2/nep	B_2'	a	$\alpha_s(M_Z)$
LO	433±89	88/74	-0.330±0.126	-1.76±0.37	0.1471±0.0075
NLO	371±72	75/74	-0.135±0.113	-0.98±0.57	0.1231±0.0041
NNLO	316±51	64/74	-0.031±0.088	-0.31±0.80	0.1196±0.026

in agreement with SY'01

We noticed, that the observed feature of HT-duality (or interplay between NNLO and HT/Q^2 - corrections is model independ

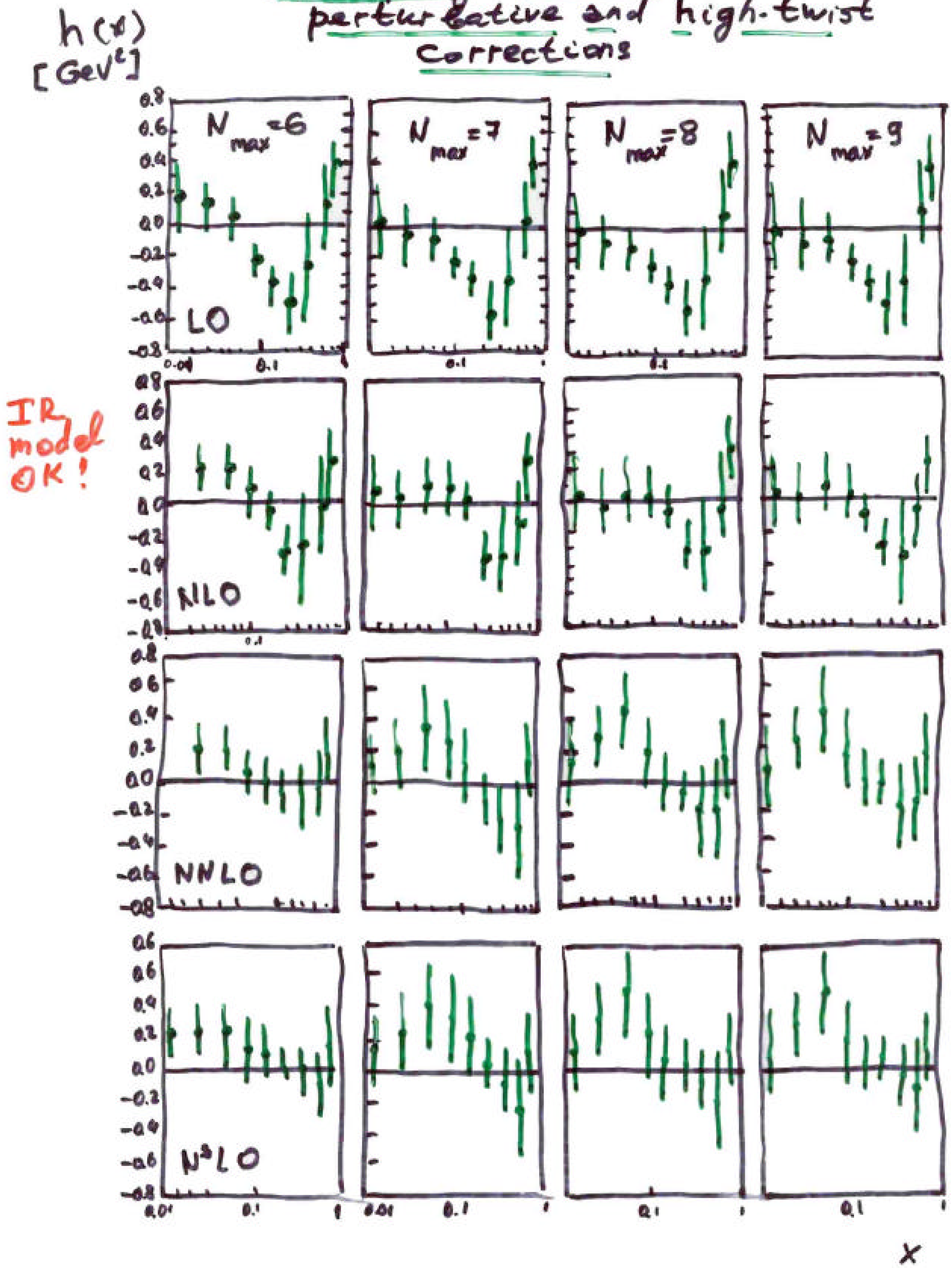
$$|B_2'|_{LO} > |B_2|_{NLO} > |B_2|_{NNLO} \approx 0$$

In agreement with original observation -

KKPS'98; KPS'01

(10)

Interplay between perturbative and high-twist corrections



Kataev, Parente, Sidorov (01)

11'

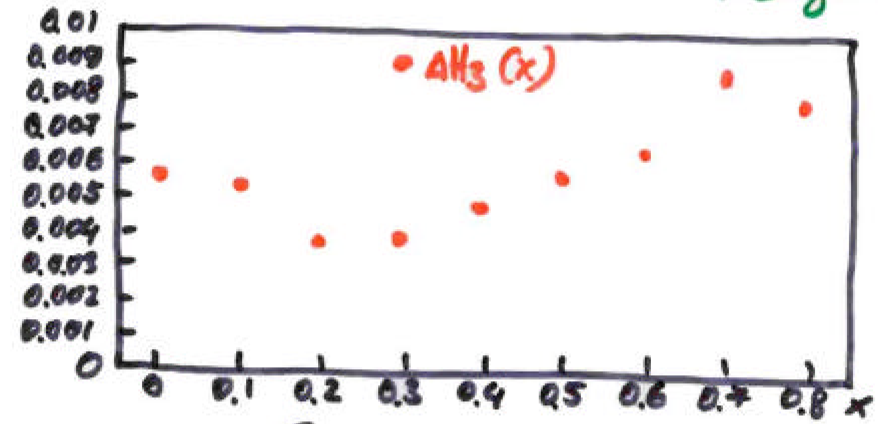
At NNLO and N^3LO effects of HT less vivid

(•) Interplay between HO perturbative corrections or (••) lack of precision of CCFR'97 Tevatron data for xF_3 ?

At Neutrino factory this problem can be clarified: increase of presision of xF_3 data

$$F_3(x,Q^2) = F^{LT}(x,Q^2) + \frac{H(x)}{Q^2}$$

Mangano et al (01)



Comperison

IRR-model parameter

$$H(x) = -\frac{2C_F}{\beta_0}\Lambda^2\int_x^1 dz\, C(z) F^{LT}(x/z, Q)$$

Experiment	Λ_3^2 [GeV^2]
IHEP-JINR	0.69 ± 0.37
CCFR	0.36 ± 0.22
νF-	± 0.007

NLO fits.

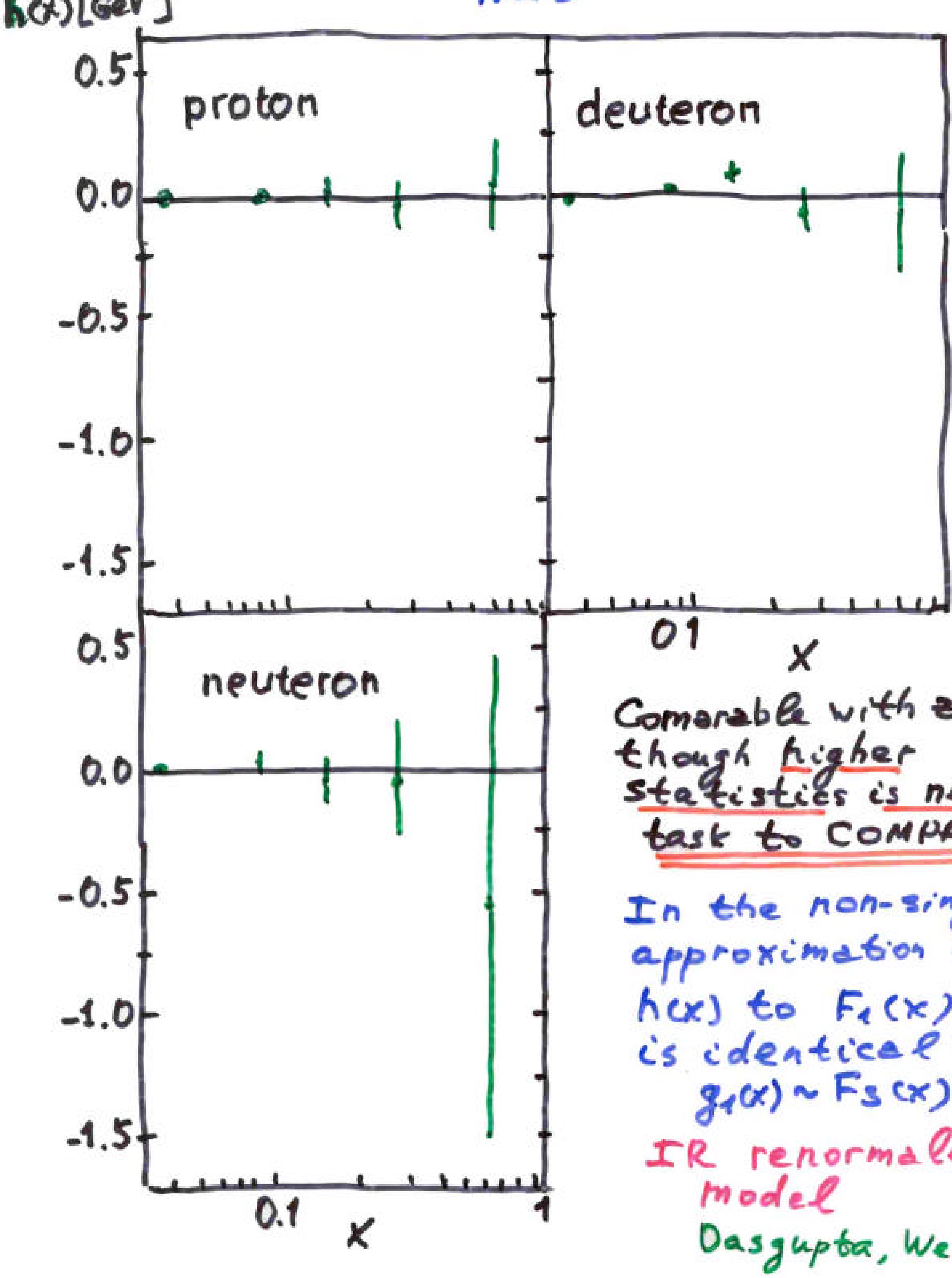
At Neutrino Factory data expected drastically more precis

12

HT corrections to $A_1 = (1+\gamma^2)\frac{g_1}{F_1} + \frac{h(x)}{Q^2}$

Leader, Sidorov, Stamenov(a)

NLO



Comarable with zero, though higher statistics is needed task to COMPASS

In the non-singlet approximation $x > 0.2$ $h(x)$ to $F_1(x)$ is identical to $g_1(x) \sim F_3(x)$

IR renormalon model

Dasgupta, Webber

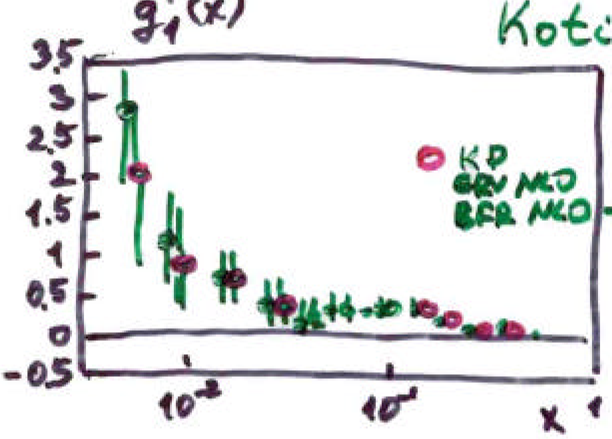
13

Limitation to $g_1(x)$ analysis at NLO

1. NS approximation

$g_1(x) \simeq F_3(x)$; NLO evolution is identical to xF_3

Kotikov, Peshekhonov (01)



→ Ball, Forte, Ridolfi

Good agreement

However, no information on SI contribution to $g_1(x)$ (KP)

2. xF_3 and $g_1(x)$

Coefficient functions are known at NNLO

van Neerven, Zijlstra (92)

DGLAP Kernal

NNLO mode exist for xF_3

No $g_1(x)$

3. Precision of $g_1(x)$ experimentally not so good, in particular at small x → COMPASS

More precise data at moderate Q^2 – Neutrino Factory

[These possible new data provide possibility to study HT effects to $g_1(x)$ and xF_3]