NCN

Nuclear unintegrated pdfs

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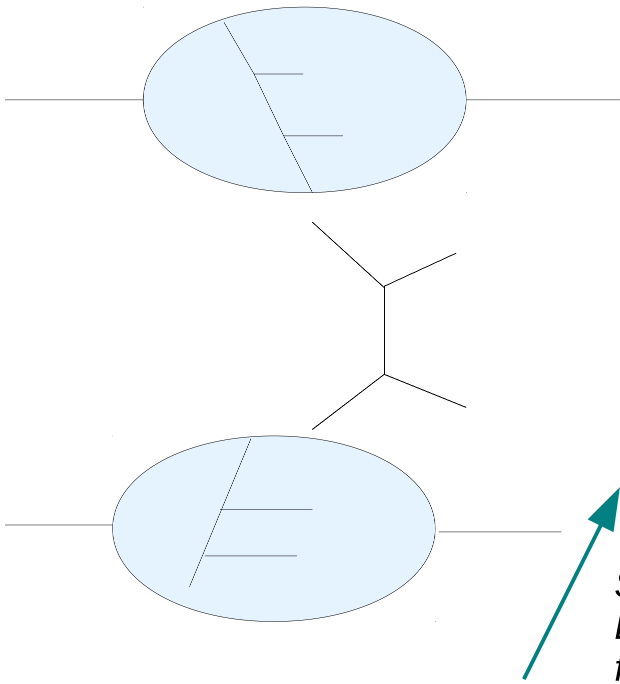
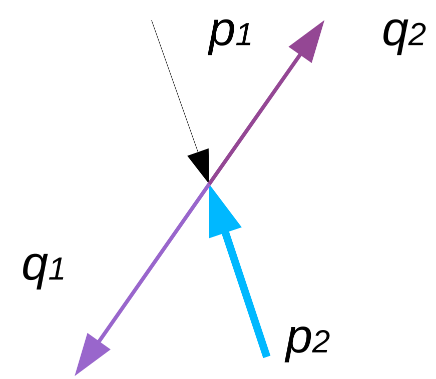
Based on
E. Blanco, A. van Hameren, H. Jung, A. Kusina
Phys. Rev. D 100, 054023 (2019)

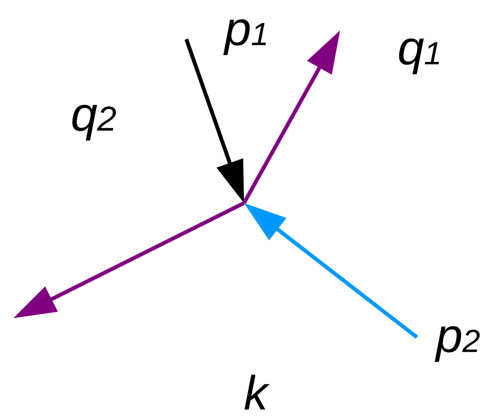
QCD at high energies – k_t factorization



Strongly decreasing
Longitudinal momentum
fractions of off-shell partons



$p_1+p_2=q_1+q_2$



$p_1+p_2=q_1+q_2+k$

$$\frac{d\sigma}{dPS} \propto \mathcal{F}_{a^*}(x_1, k_{\perp\,1}) \otimes \hat{\sigma}_{ab\to cd}(x_1, x_2) \otimes \mathcal{F}_{b^*}(x_2, k_{\perp\,2})$$

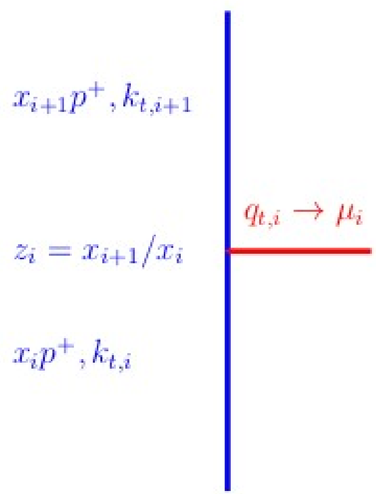
Ciafaloni, Catani, Hautman '93
Collins, Ellis '93

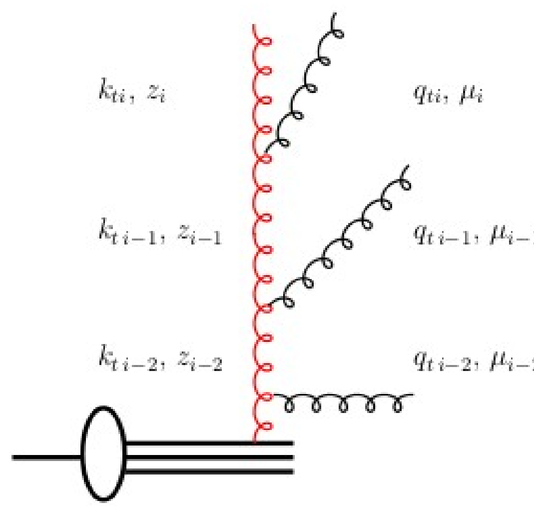
New helicity based methods for ME
Kotko, K.K, van Hameren, '12

Monte Carlo – parton branching method

The idea: construct such parton shower that gives also TMD dependent paton density.
On integrated level the pdf obeys DGLAP equation.

A. Bermudez Martinez, P. Connor, H. Jung, A. Lelek, R. Žlebčík, F. Hautmann, V. Radescu Phys.Rev. D99 (2019) no.7, 074008





$$\mathcal{A}_a(x,\mathbf{k},\mu^2) = \Delta_a(\mu^2)\,\mathcal{A}_a(x,\mathbf{k},\mu_0^2) + \sum_b \int \frac{d^2\mathbf{q}'}{\pi \mathbf{q}'^2}\,\frac{\Delta_a(\mu^2)}{\Delta_a(\mathbf{q}'^2)}\,\Theta(\mu^2-\mathbf{q}'^2)\,\Theta(\mathbf{q}'^2-\mu_0^2) \times \int_x^{z_M} \frac{dz}{z}\,P_{ab}^{(R)}(\alpha_s,z)\,\mathcal{A}_b\left(\frac{x}{z},\mathbf{k}+(1-z)\mathbf{q}',\mathbf{q}'^2\right)$$

The method provides first consistent and complete set of TMD's which are applicable in Monte Carlo simulations and can be generalized to account for small x effects at least in linear regime. Applies in the regime above saturation scale.

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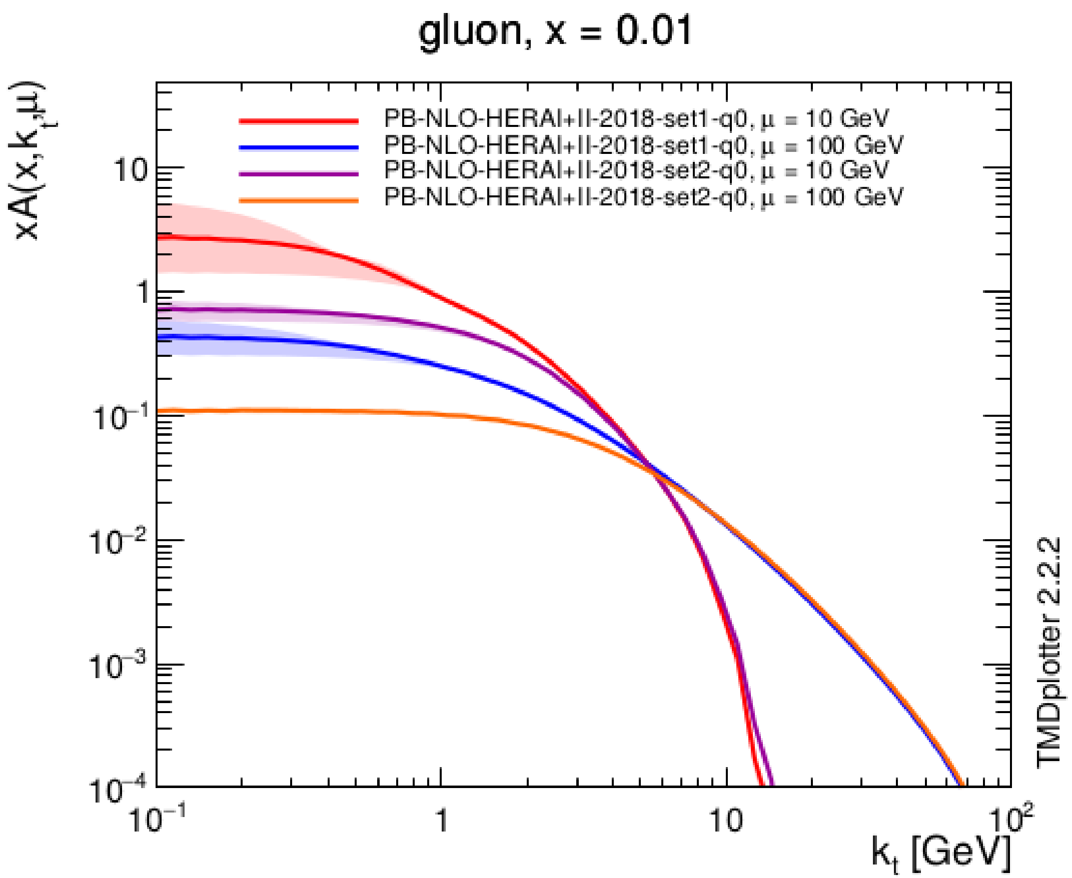
A. Bermudez Martinez, *ev. D99 (2019) no.7, 074008*



$$\mathcal{A}_a(x,\mathbf{k},\mu^2) \quad = \quad \ldots \; - \mu_0^2)$$

$$\times$$

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Monte Carlo – parton branching method

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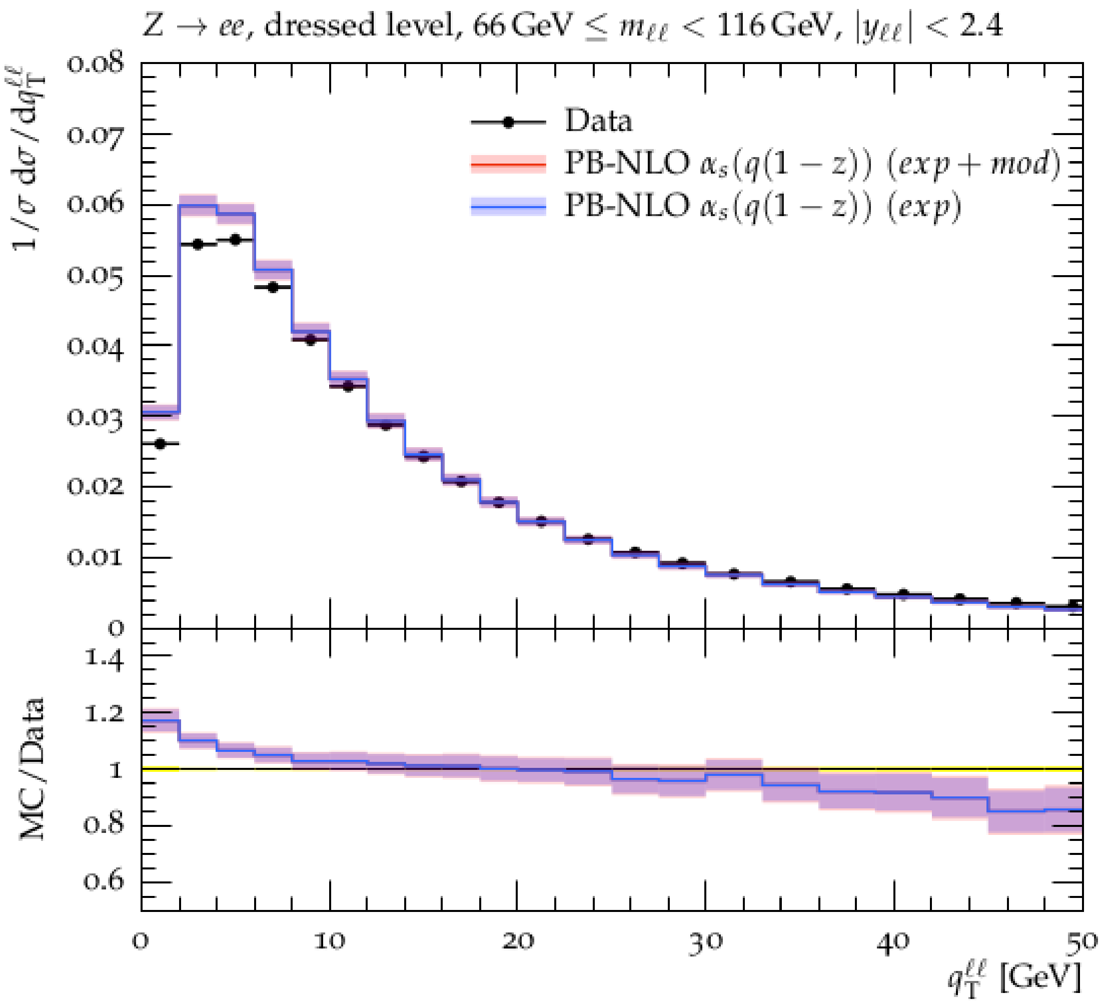
On integrated level i

A. Bermudez Martinez, P



D99 (2019) no.7, 074008

x

z

x

$\mathcal{A}_a(x, \mathbf{k}, \mu^2) \quad =$ … $\mu_0^2)$

$\times$

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Parton branching method for lead unintegrated pdfs

$$x\mathcal{A}_a^{\mathrm{Pb}}(x,k_t^2,\mu^2) = \int dx'\,\mathcal{A}_{0,b}^{\mathrm{Pb}}(x',k_{t,0}^2,\mu_0^2)\,\frac{x}{x'}\;\mathcal{K}_{ba}\left(\frac{x}{x'},k_{t,0}^2,k_t^2,\mu_0^2,\mu^2\right)$$

$$\mathcal{A}_{0,b}^{\mathrm{Pb}}(x,k_{t,0}^2,\mu_0^2) = f_{0,b}^{\mathrm{Pb}}(x,\mu_0^2)\cdot\,\exp(-|k_{t,0}^2|/\sigma^2)$$

$$\sigma^2 = q_0^2/2$$

$$q_0 = 0.5\ \mathrm{GeV}$$

Momentum conservation → exact kinematics

The splitting function → NLO DGLAP

The shower is consistent with the transversal momentum dependent distribution it uses

Available collinear nuclear PDFs

Multiplicative correction factor

$$f_i^{p/A}(x_N, \mu_0) = R_i(x_N, \mu_0, A)\ f_i^{\text{free proton}}(x_N, \mu_0)$$

HKN: Hirai, Kumano, Nagai [PRC 76, 065207 (2007)]
DSSZ: de Florian, Sassot, Stratmann, Zurita [PRD 85, 074028 (2012)]
EPS09: Eskola, Paukkunen, Salgado [JHEP 04 (2009) 065]
EPPS16: Eskola, Paakkinen, Paukkunen, Salgado [EPJC 77 (2017) 163]
KT16: Khanpour, Tehrani [PRD 93, 014026 (2016)]

Native nuclear PDFs

$$f_i^{p/A}(x_N, \mu_0) = f_i(x_N, A, \mu_0)$$
$$f_i(x_N, A=1, \mu_0) \equiv f_i^{\text{free proton}}(x_N, \mu_0)$$

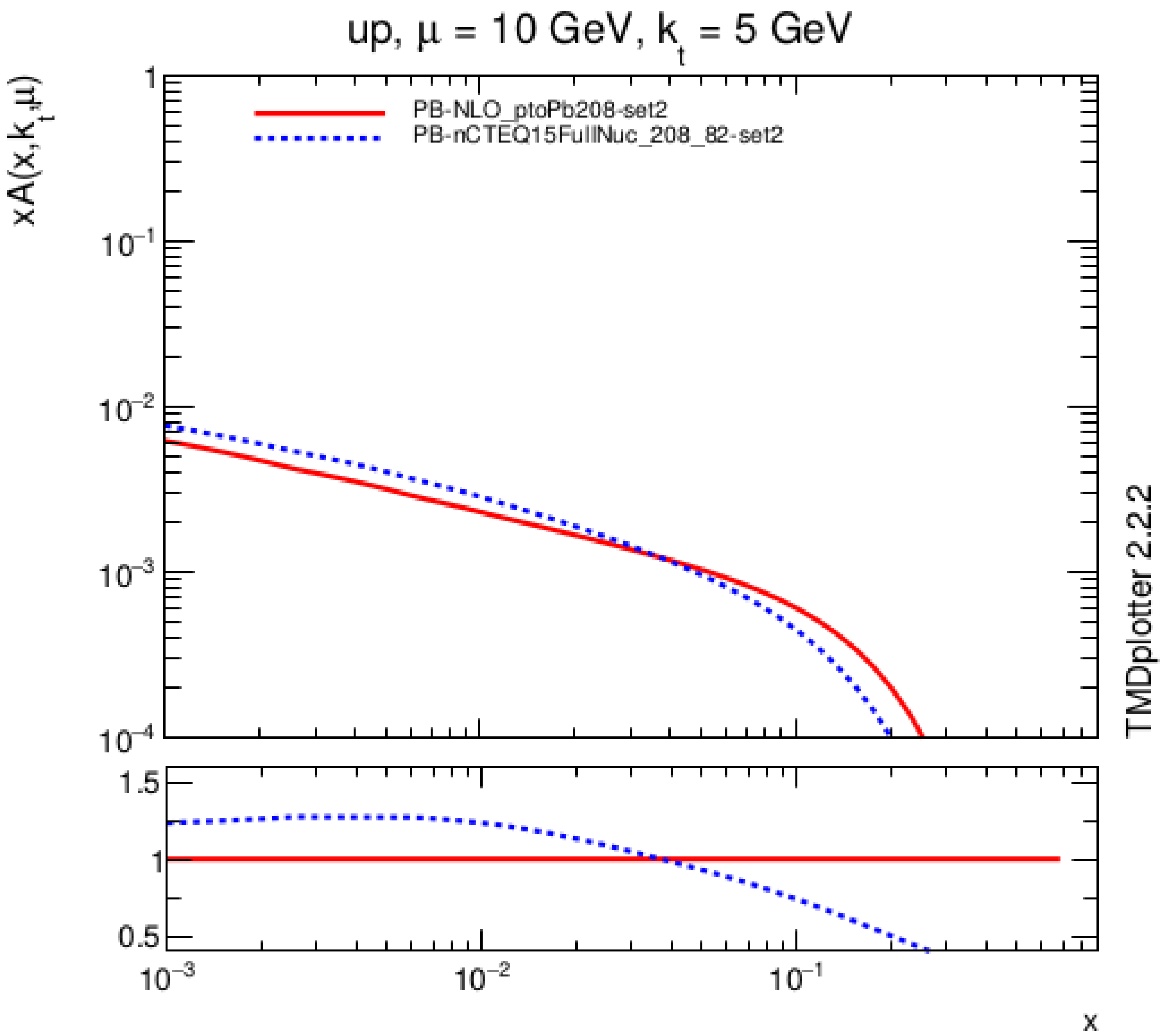
nCTEQ15: Kovarik, Kusina, Jezo, Clark, Keppel, Lyonnet, Morfin, Olness, Owens, Schienbein, Yu [PRD 93, 085037 (2016), arXiv:1509.00792]

NNPDF Khalek, Ethier, Rojo arXiv:1904.00018

WHV Marina Walt, Ilkka Helenius, Werner Vogelsang arXiv:1908.03355

See also talks by
V. Guzey
M. Zurita

Example of our TMD proton vs. lead



To see how the nuclear effects enter we constructed a test lead TMD from free protons. Neutron distribution is obtained assuming isospin symmetry

$f^{Pb}=82/208\ f^{p} + (208-82)/208\ f^{n}$

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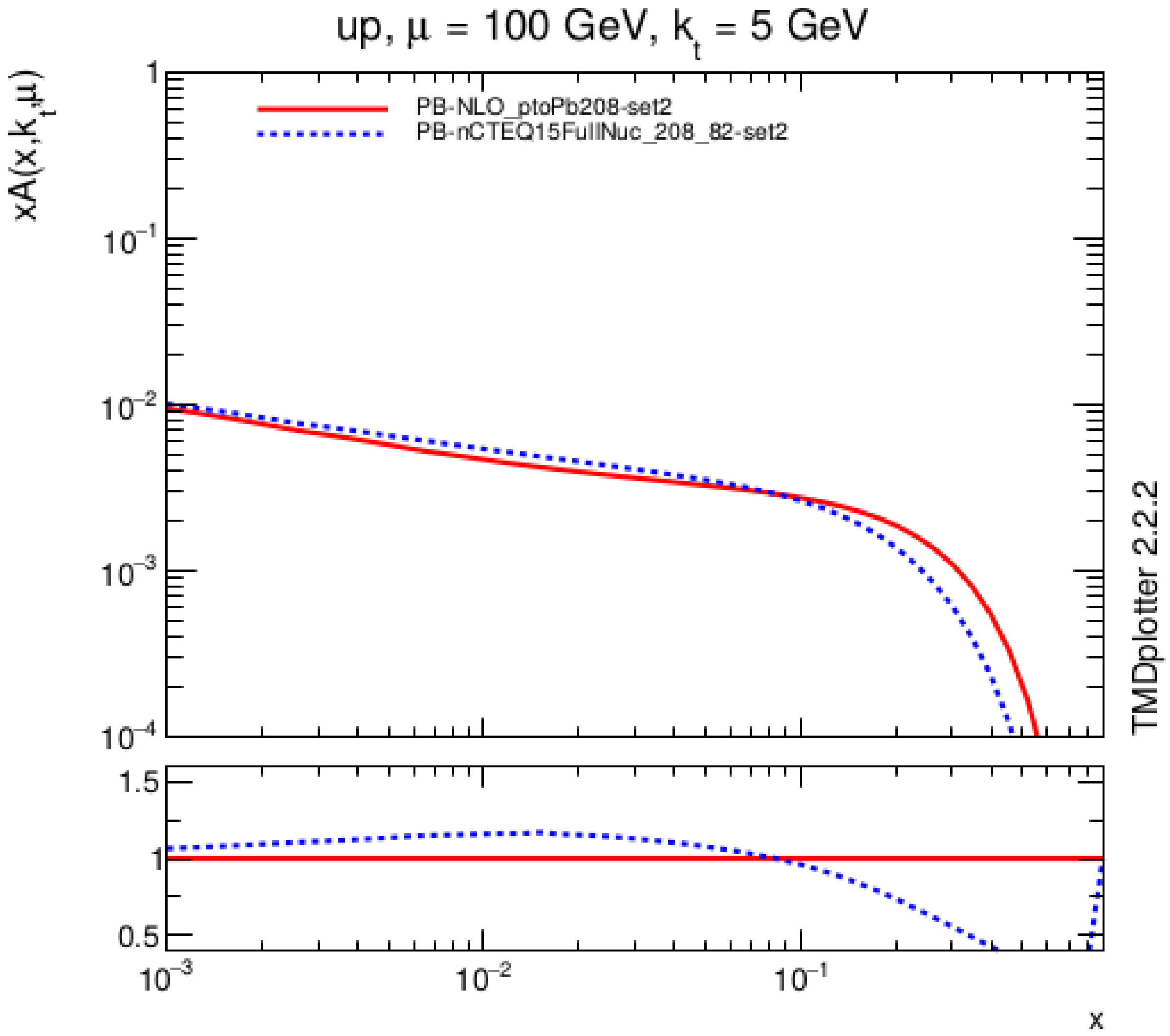

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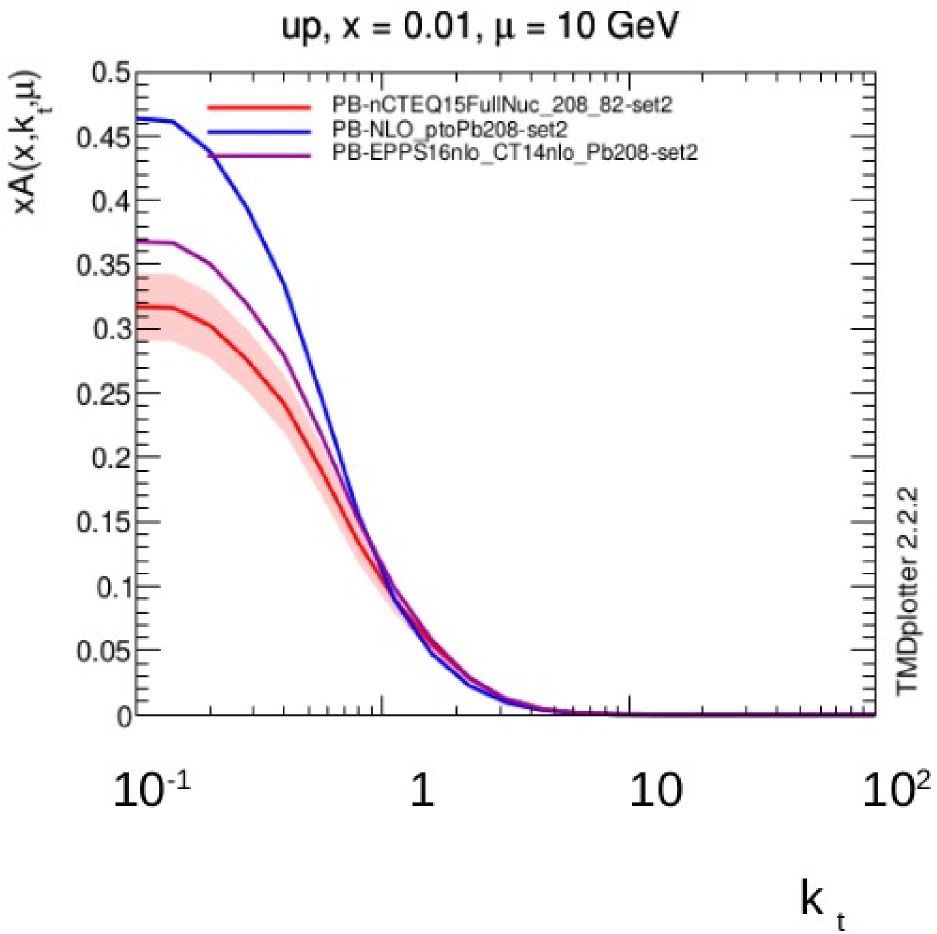
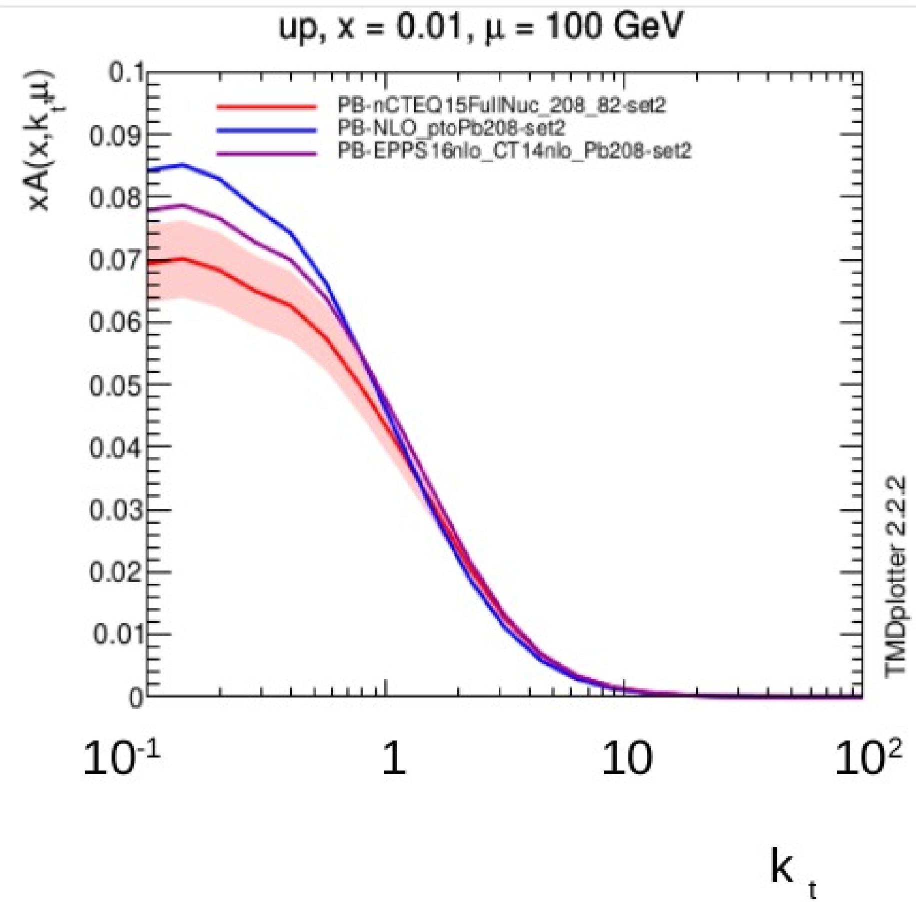
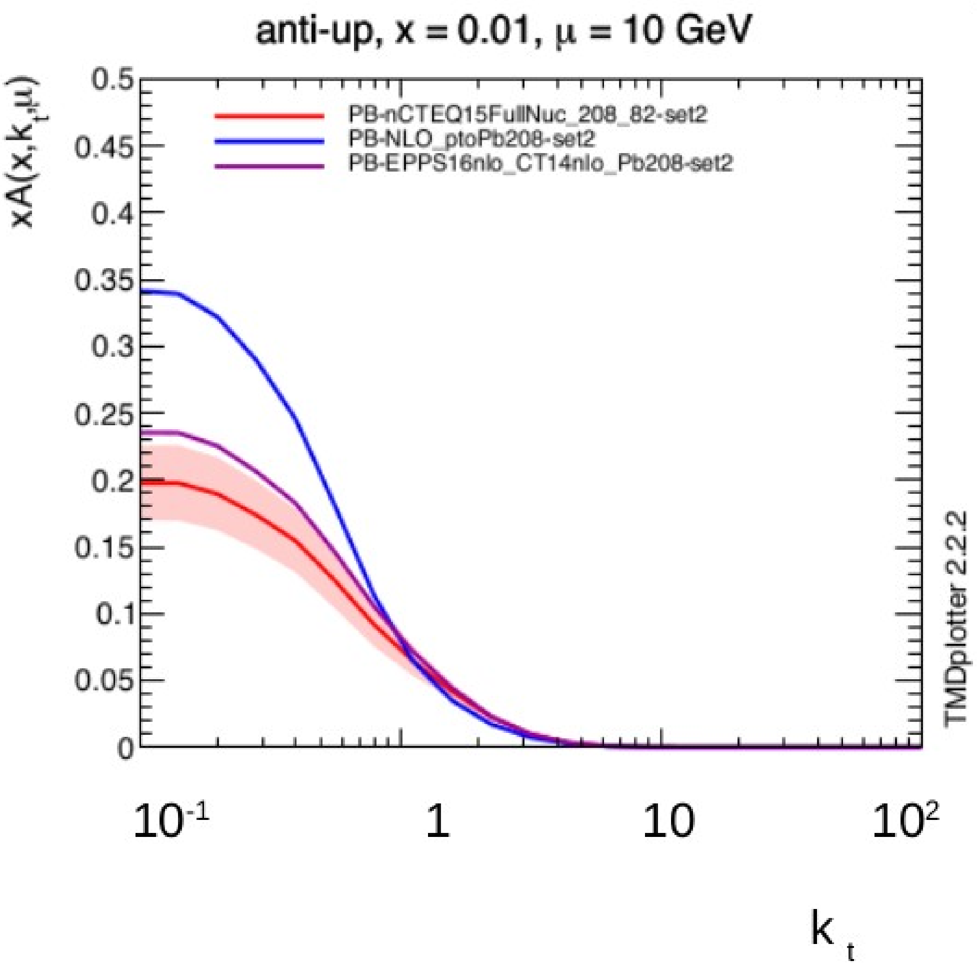
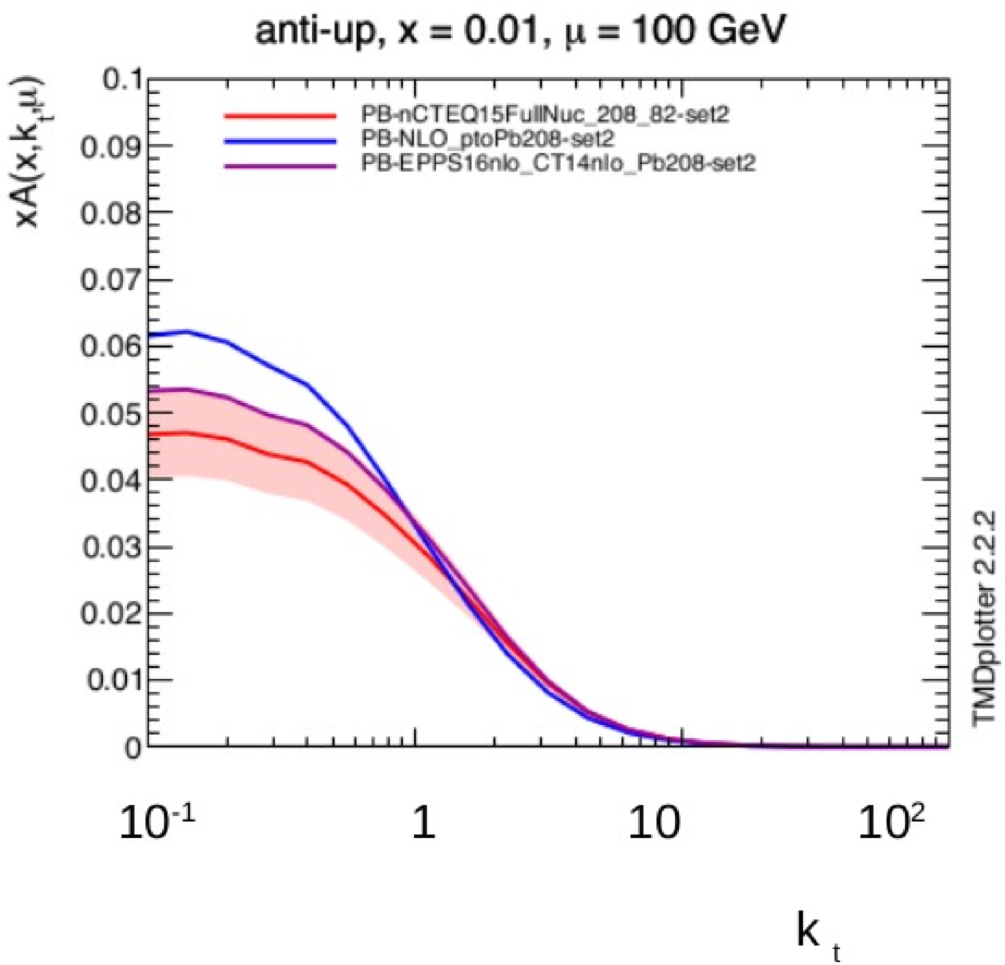
Transverse momentum dependence





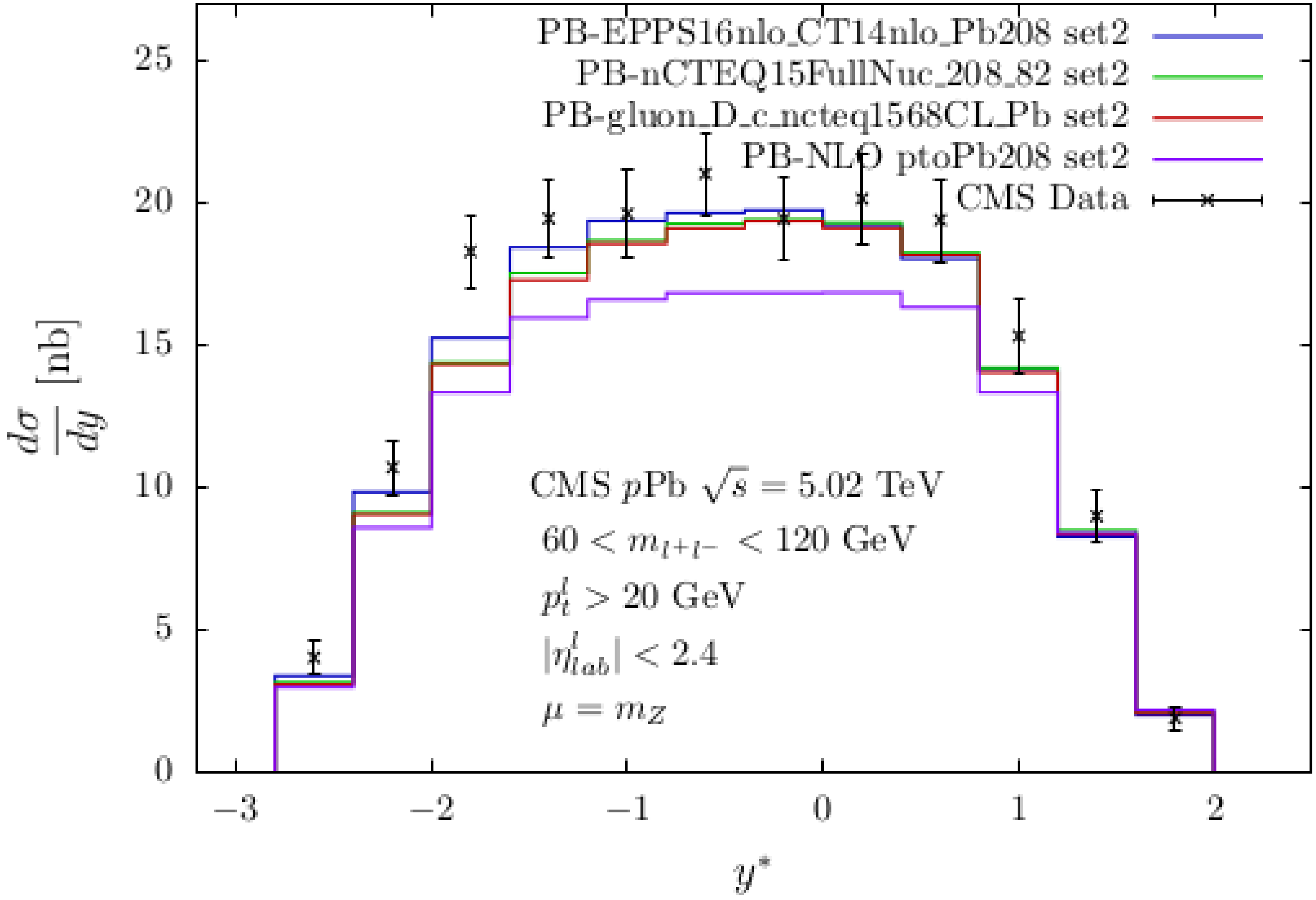
Transverse momentum dependence





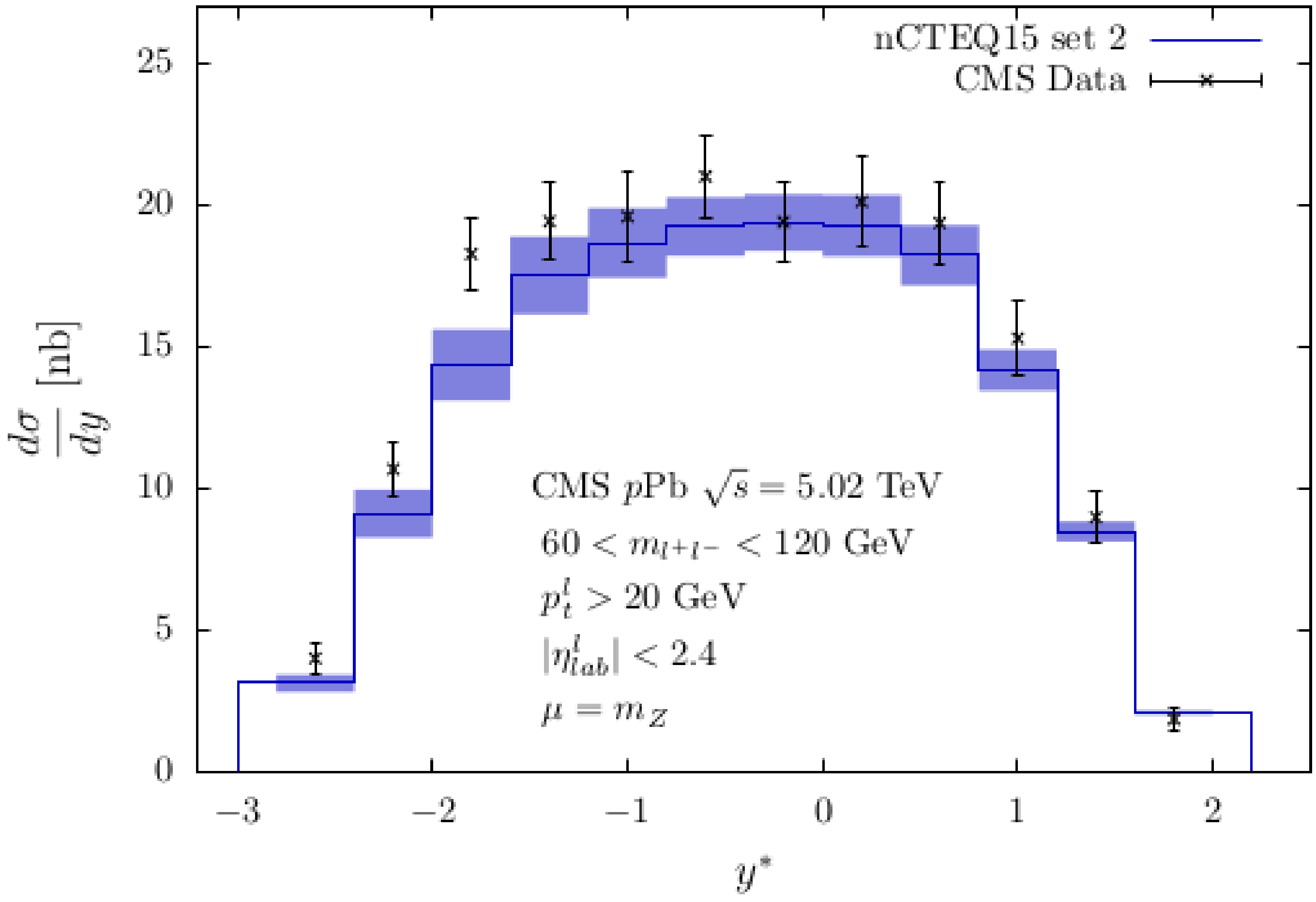
Drell-Yan – rapidity distribution

$$p + Pb \rightarrow Z^* \rightarrow \mu^+ + \mu^-$$



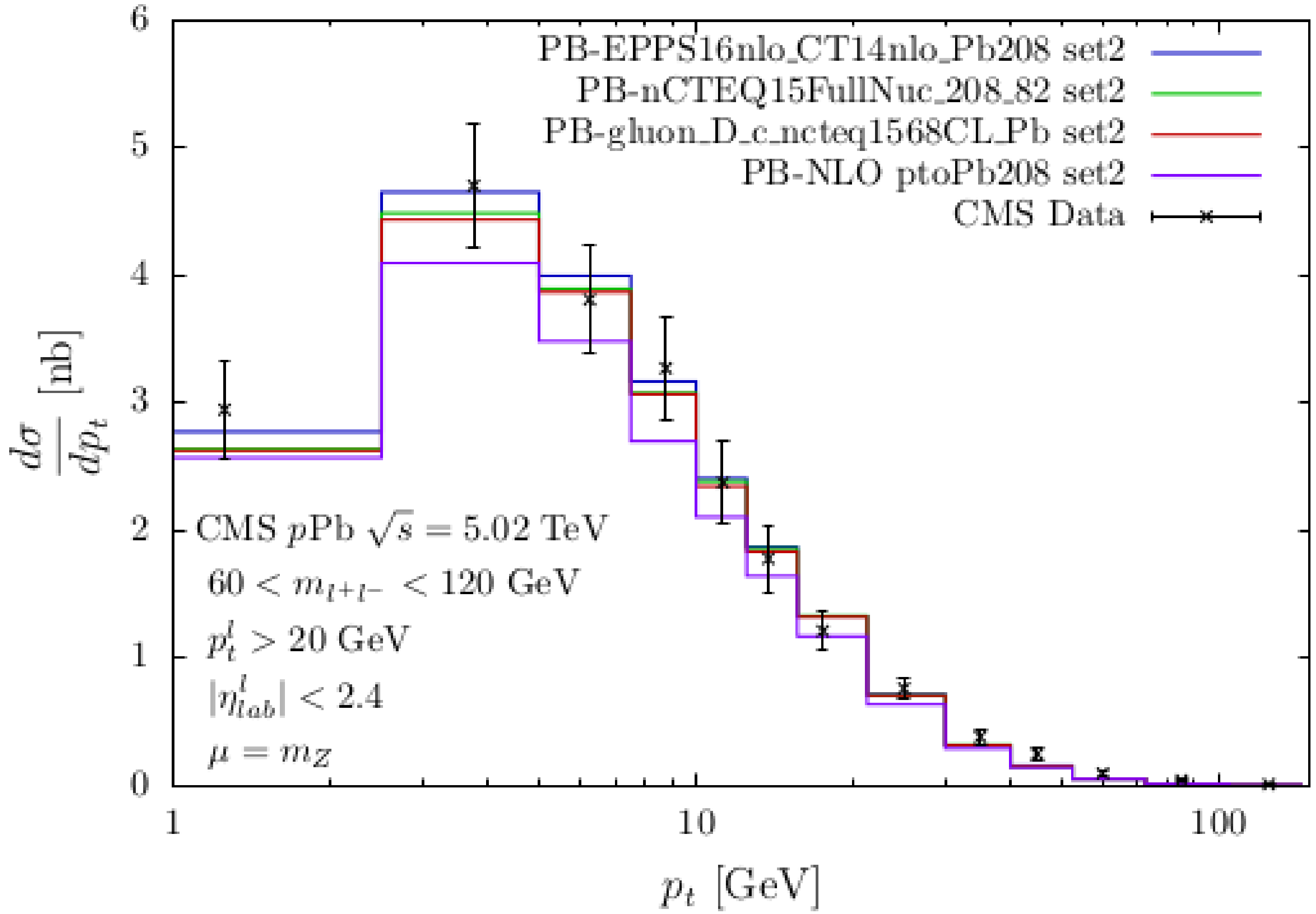
Drell-Yan – rapidity distribution – with PDF uncertainty

$$p + Pb \to Z^* \to \mu^+ + \mu^-$$



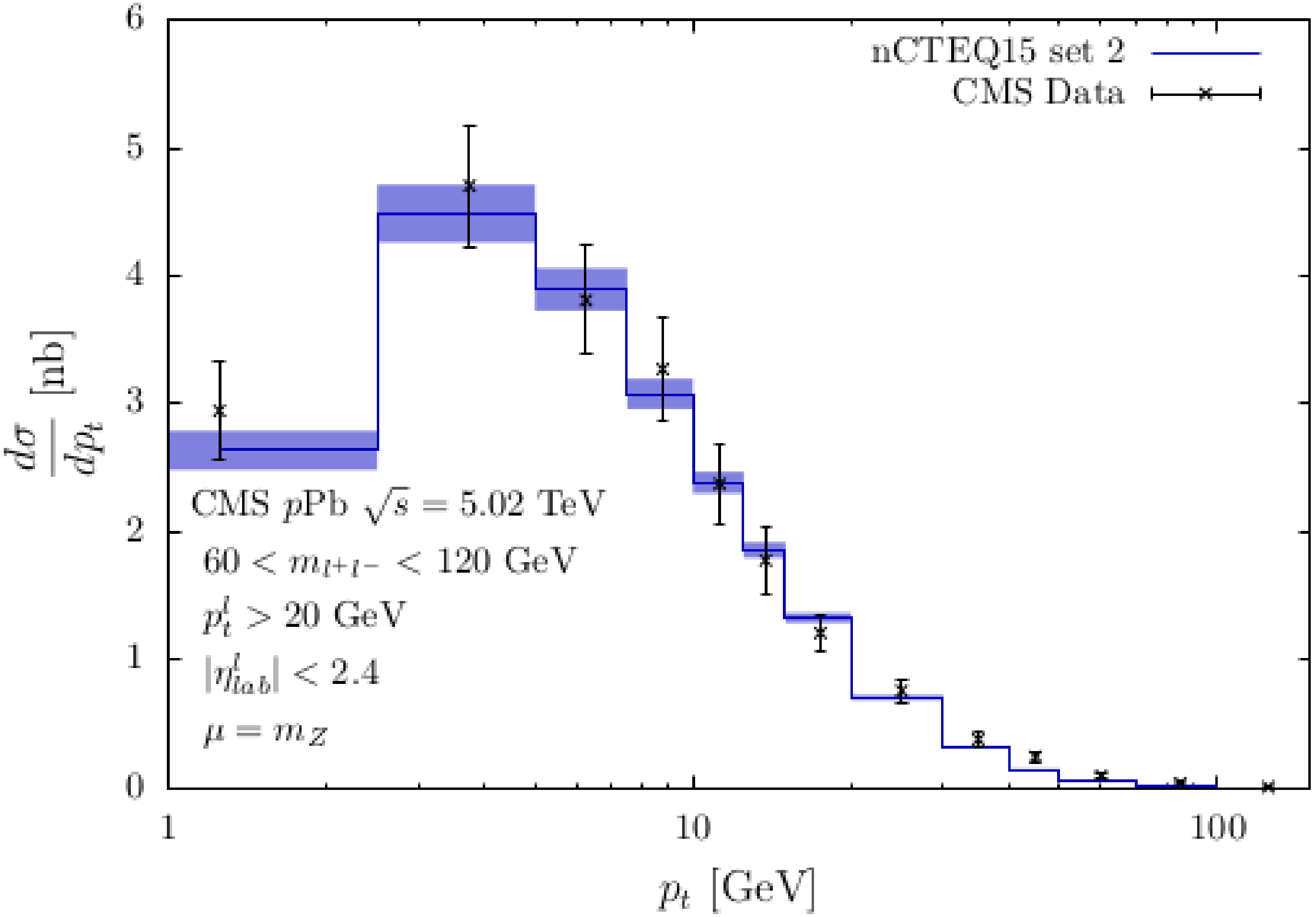
Drell-Yan – distribution in p_t

$$p + Pb \rightarrow Z^* \rightarrow \mu^+ + \mu^-$$

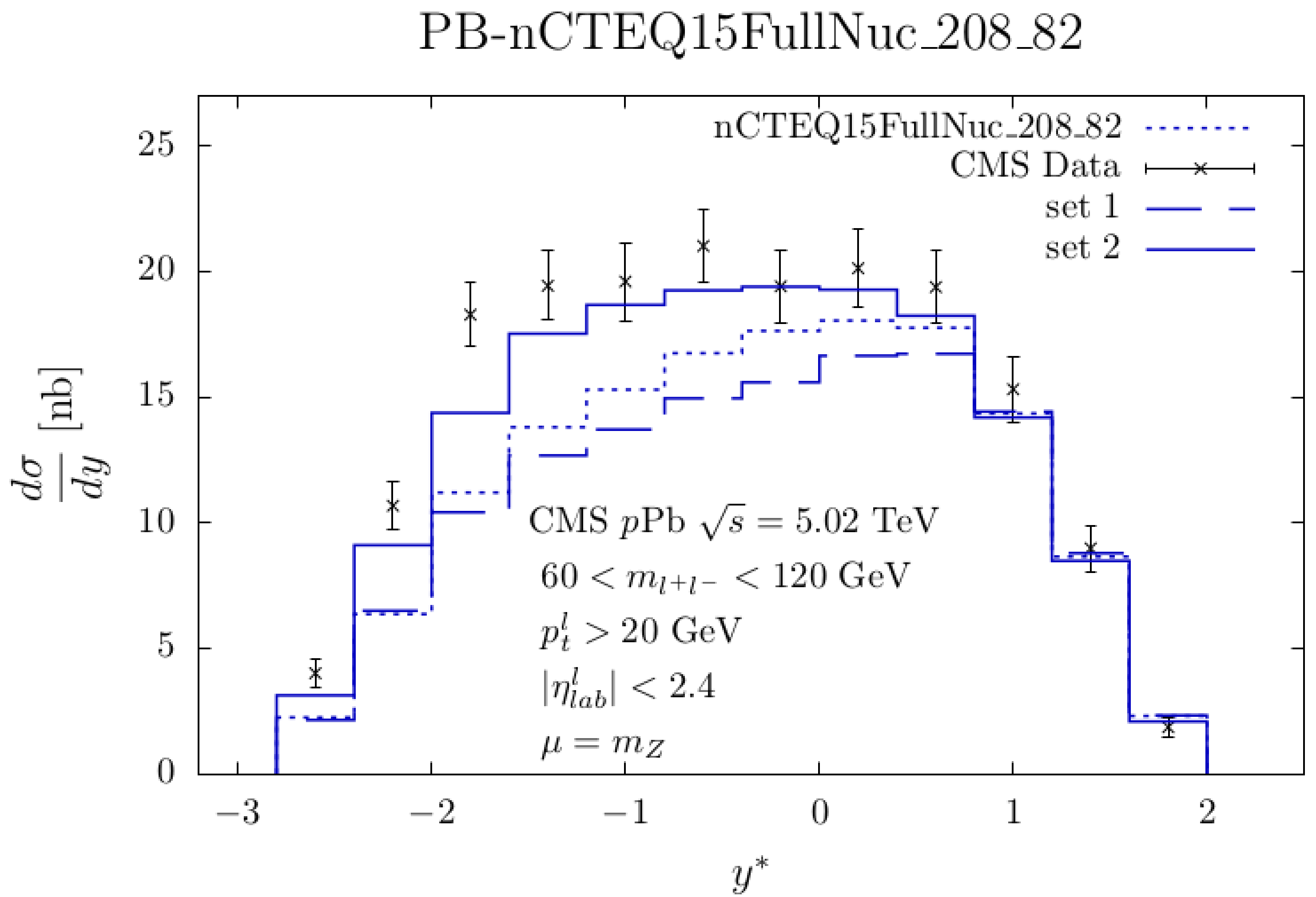


Drell-Yan – distribution in p_t – with PDF uncertainity

$$p + Pb \to Z^* \to \mu^+ + \mu^-$$



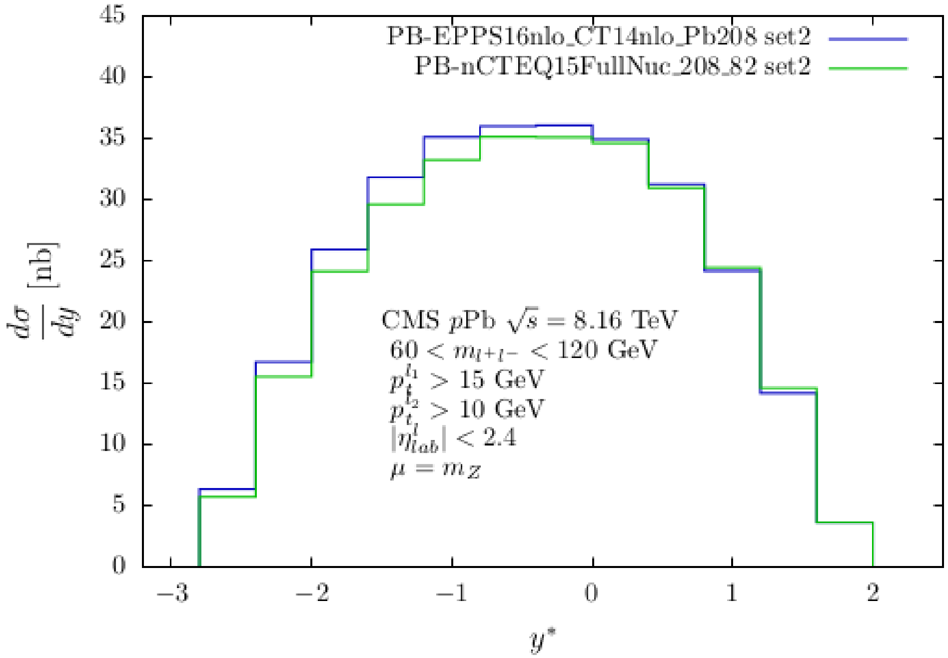
Comparison to collinear factorization based calculation

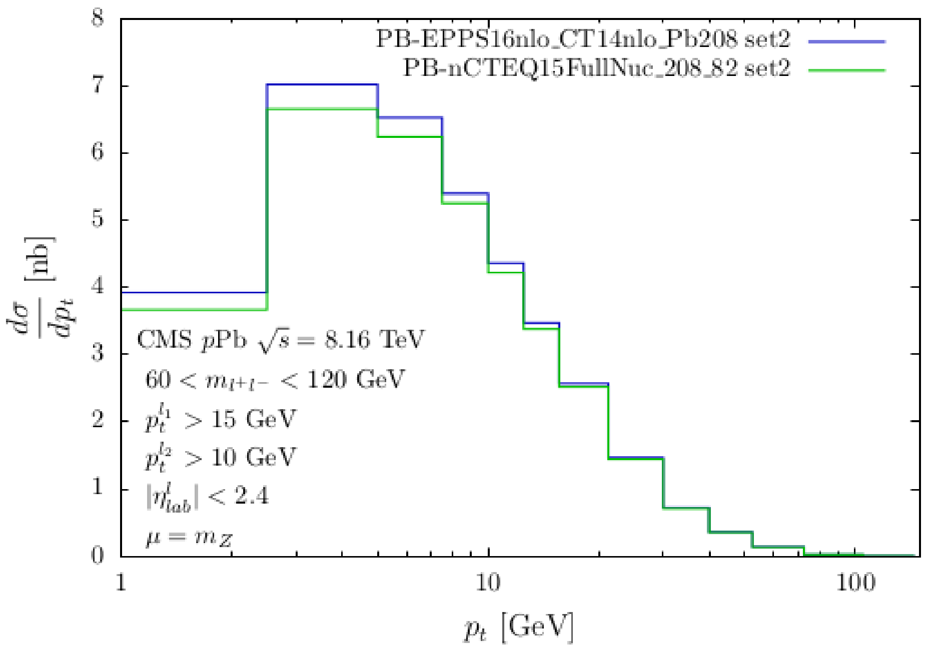


Set 1 uses evolution variable as a scale

Set 2 uses $|q_t^2|$ as evolution variable i.e. momentum of emitted gluon

Predictions for 8.16 TeV





Conclusions and outlook

New TMD introduced: i.e. nTMD's using PB method

The set does well describing Drell-Yan data

Application to other processes involving heavy ions

New fit of the initial distribution using off-shell coefficient function