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TOWARDS DIFFERENTIAL HIGGS PRODUCTION AT N3LO

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TOWARDS DIFFERENTIAL N3LO

▸ The basis for testing our understanding of nature is a symbiosis of precise measurements and precise predictions.

▸ Our goal:
Compute differential cross sections for realistic final states to very high precision.

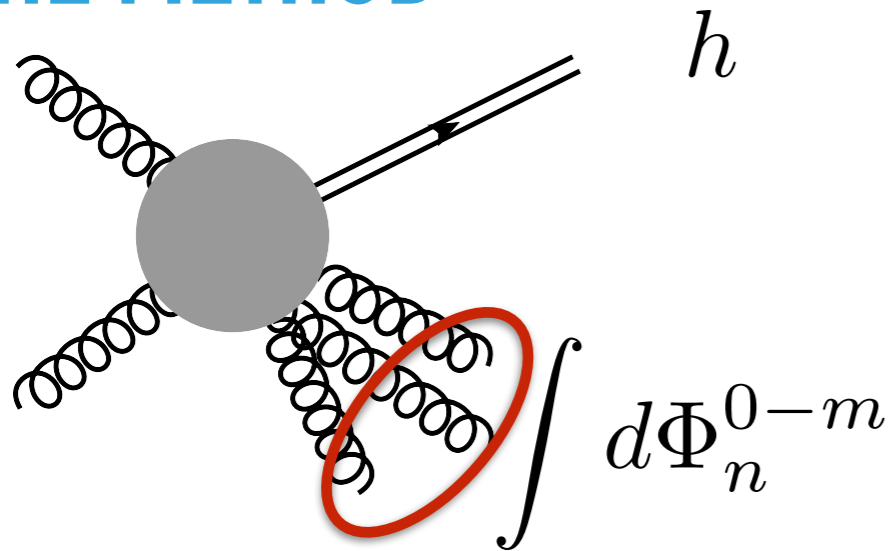**Specifically: Differential Higgs Production at N3LO in QCD**

$$P\,P \to H + X \to \gamma\gamma + X$$

$$P\,P \to H + X \to 4l + X$$

▸ Today: Recent Progress, Obstacles, Method
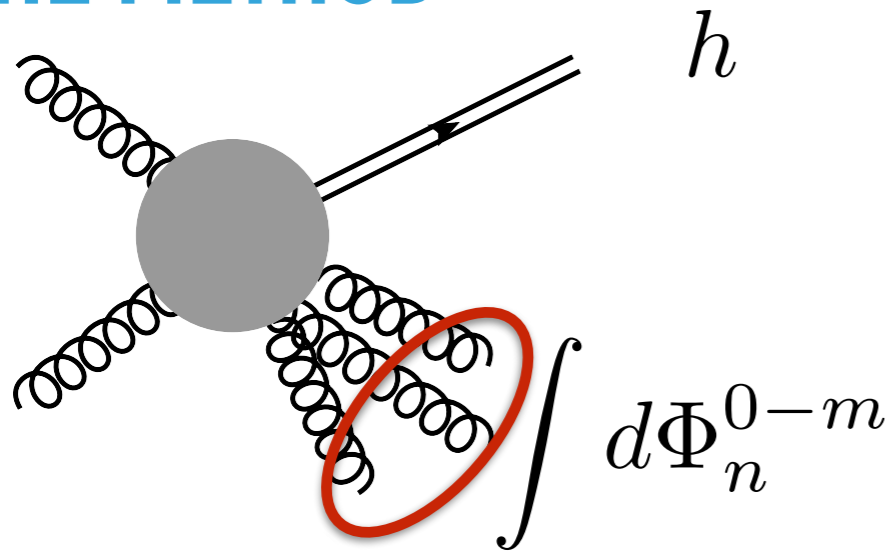
THE METHOD

$$h$$

$$\int d\Phi_n^{0-m}$$

▸ Use a method that is inclusive in all radiation. Effectively covered by H+J @ NNLO

▸ Rely on tools to perform analytic computation learned from inclusive N3LO

▸ Maintain full dependence on the 4-momentum of the Higgs boson.

THE METHOD

h

$\int d\Phi_n^{0-m}$

Y	**Rapidity**
p_T	**Transverse Momentum**
m_h	**Mass / Virtuality**
ϕ	**Azimuthal Angle**

▸ Use a method that is inclusive in all radiation. Effectively covered by H+J @ NNLO

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THE METHOD

▸ Inclusive Cross Section: Computed as a Threshold Expansion

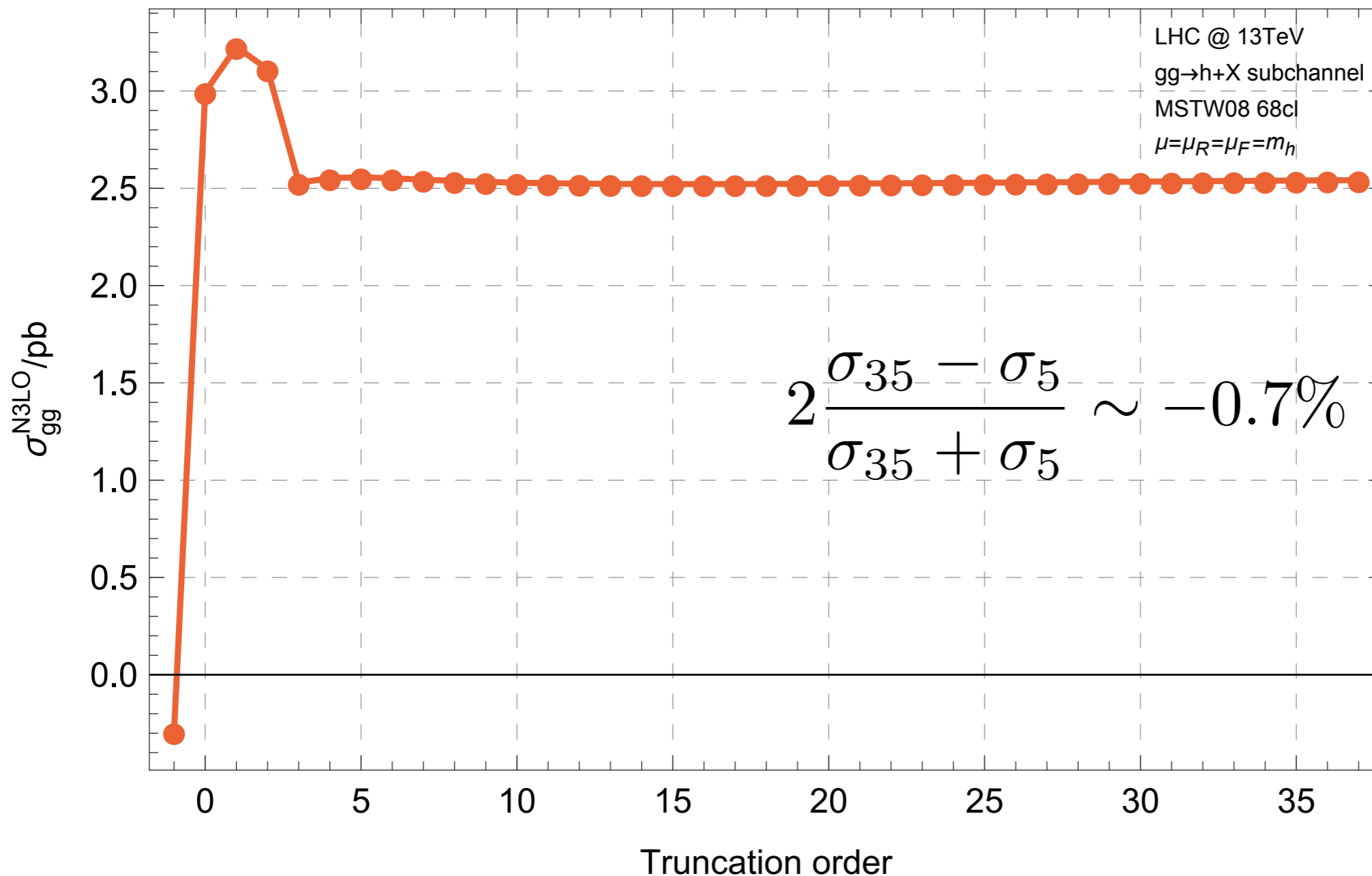$$z = \frac{m_H^2}{\hat{s}} \sim 1$$
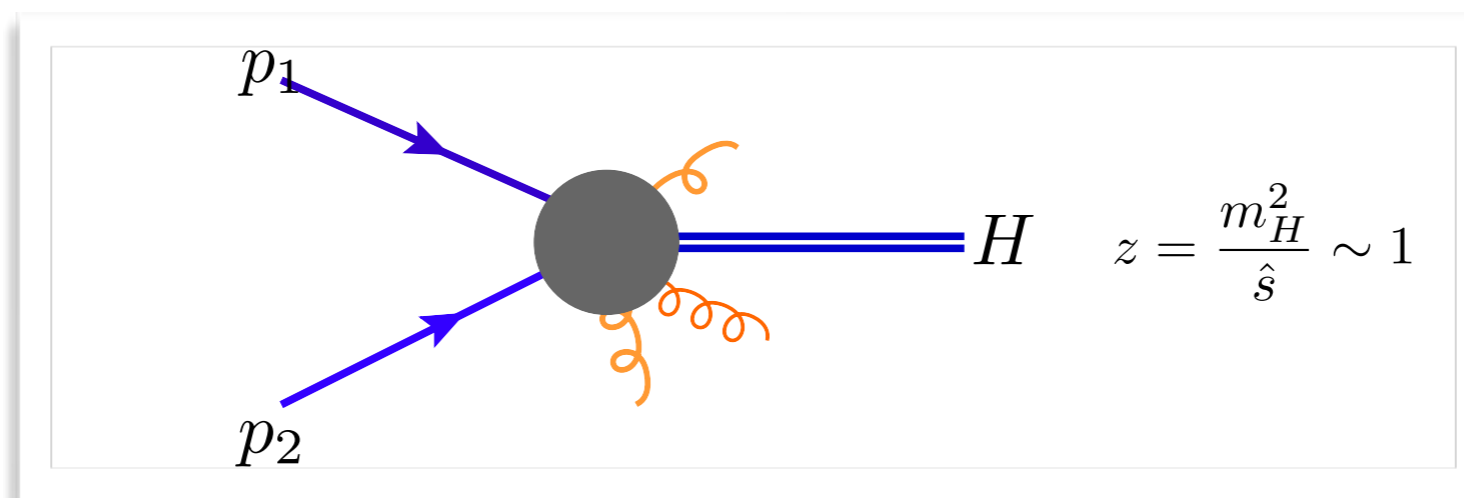
$$\bar{z} = 1 - z \qquad \Longrightarrow \qquad \hat{\sigma}(\bar{z}) = \sigma^{SV} + \sigma^{(0)} + \bar{z}\sigma^{(1)} + \ldots$$

▸ Served as an excellent approximation for inclusive cross section.

▸ Exclusively? Reason Nr.1:
Crucial analytic information a full calculation relies on.
+ checks, testing ground for technology, etc.

▸ Reason Nr. 2: Can we use it for phenomenology?

TRUNCATION ORDER @ N3LO: INCLUSIVE

▸ How well did it work for N3LO inclusive?

$$\delta\sigma^{N3LO} = \sim 0.5\%$$

$$2\frac{\sigma_{35} - \sigma_5}{\sigma_{35} + \sigma_5} \sim -0.7\%$$

LHC @ 13TeV

gg→h+X subchannel

MSTW08 68cl

$\mu = \mu_R = \mu_F = m_h$
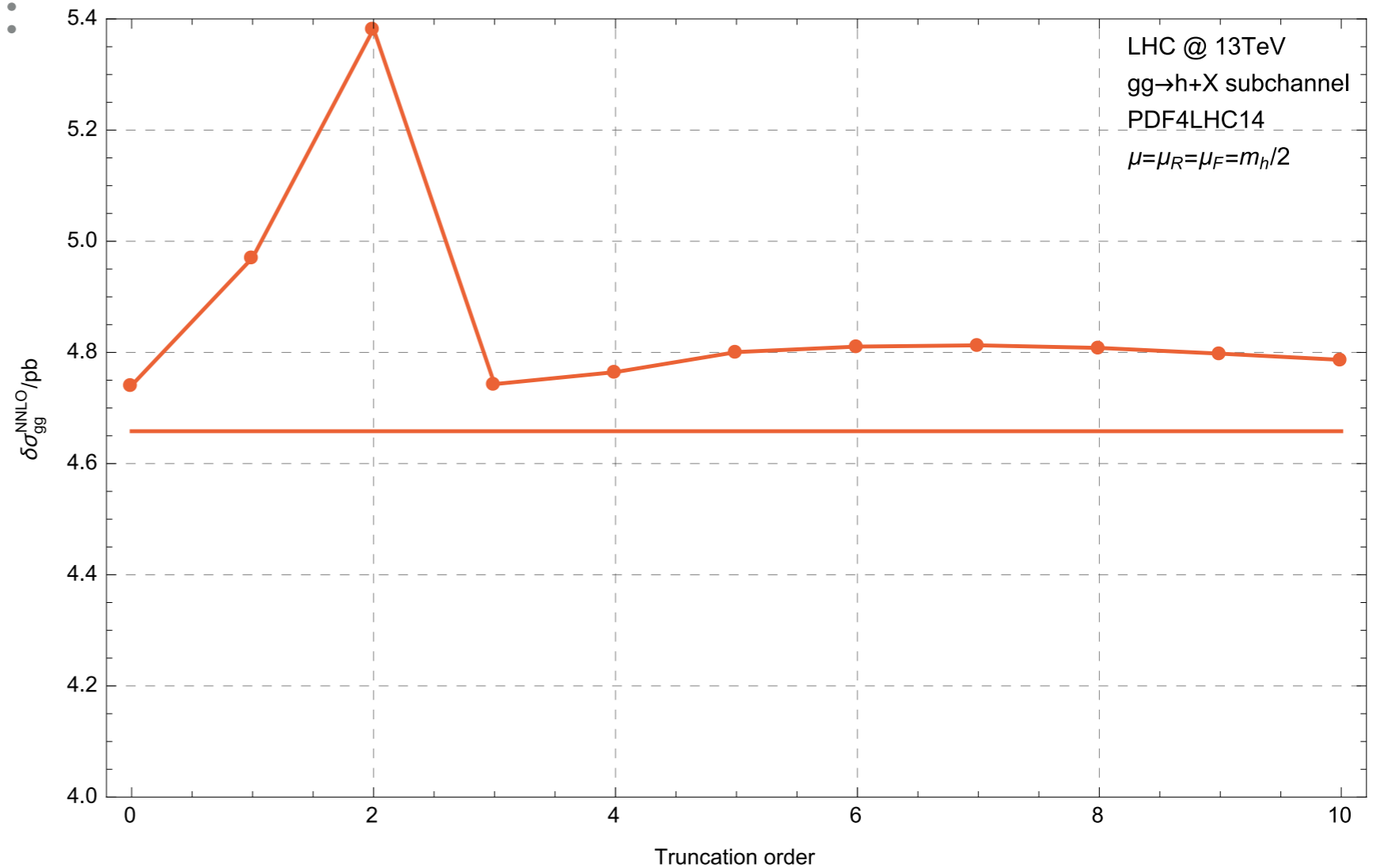
σ_{gg}^{N3LO}/pb

Truncation order

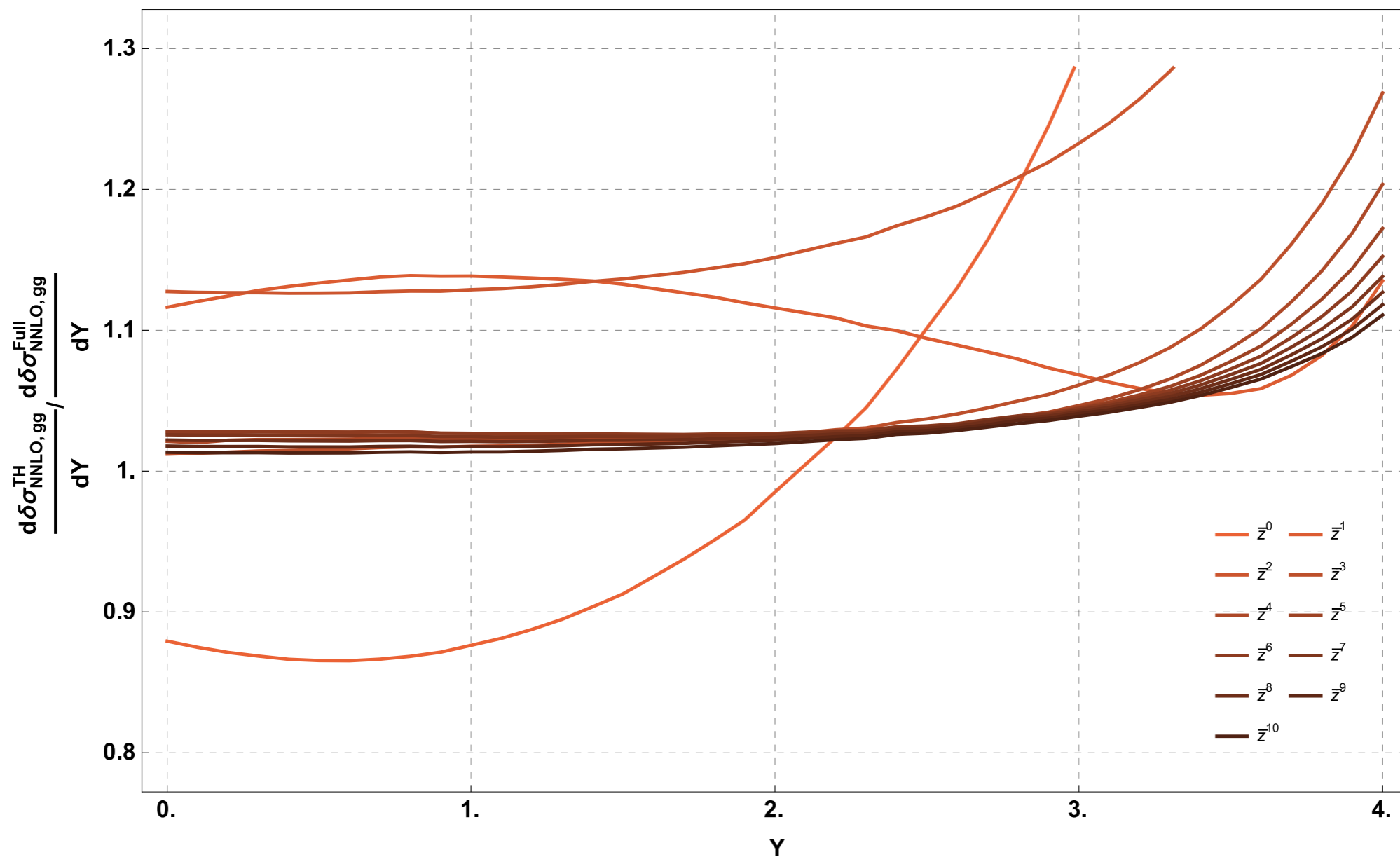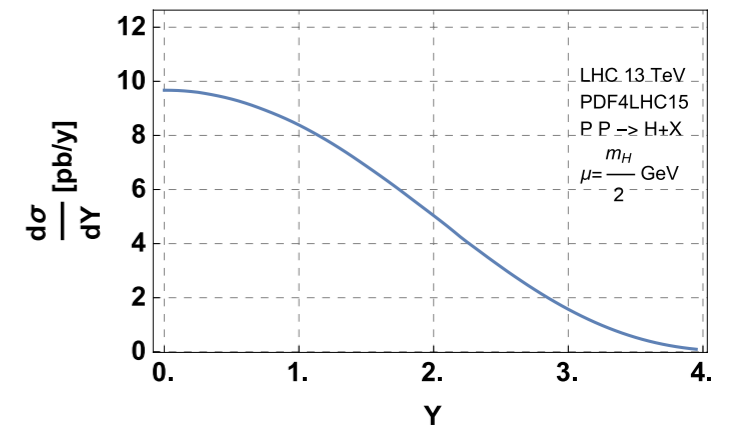# TRUNCATION ORDER @ NNLO: INCLUSIVE

▶ Let's test at NNLO:

▶ Good approximation
   reached with only
   5-10 terms

▶ ~3% off-set from full result
   for the NNLO correction -
   > ~0.5 % on the total

LHC @ 13TeV
gg→h+X subchannel
PDF4LHC14
$\mu=\mu_R=\mu_F=m_h/2$

y-axis: $\delta\sigma_{gg}^{NNLO}/pb$

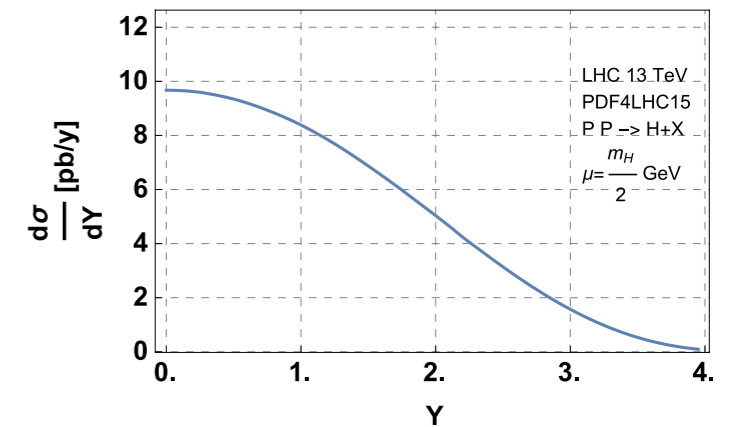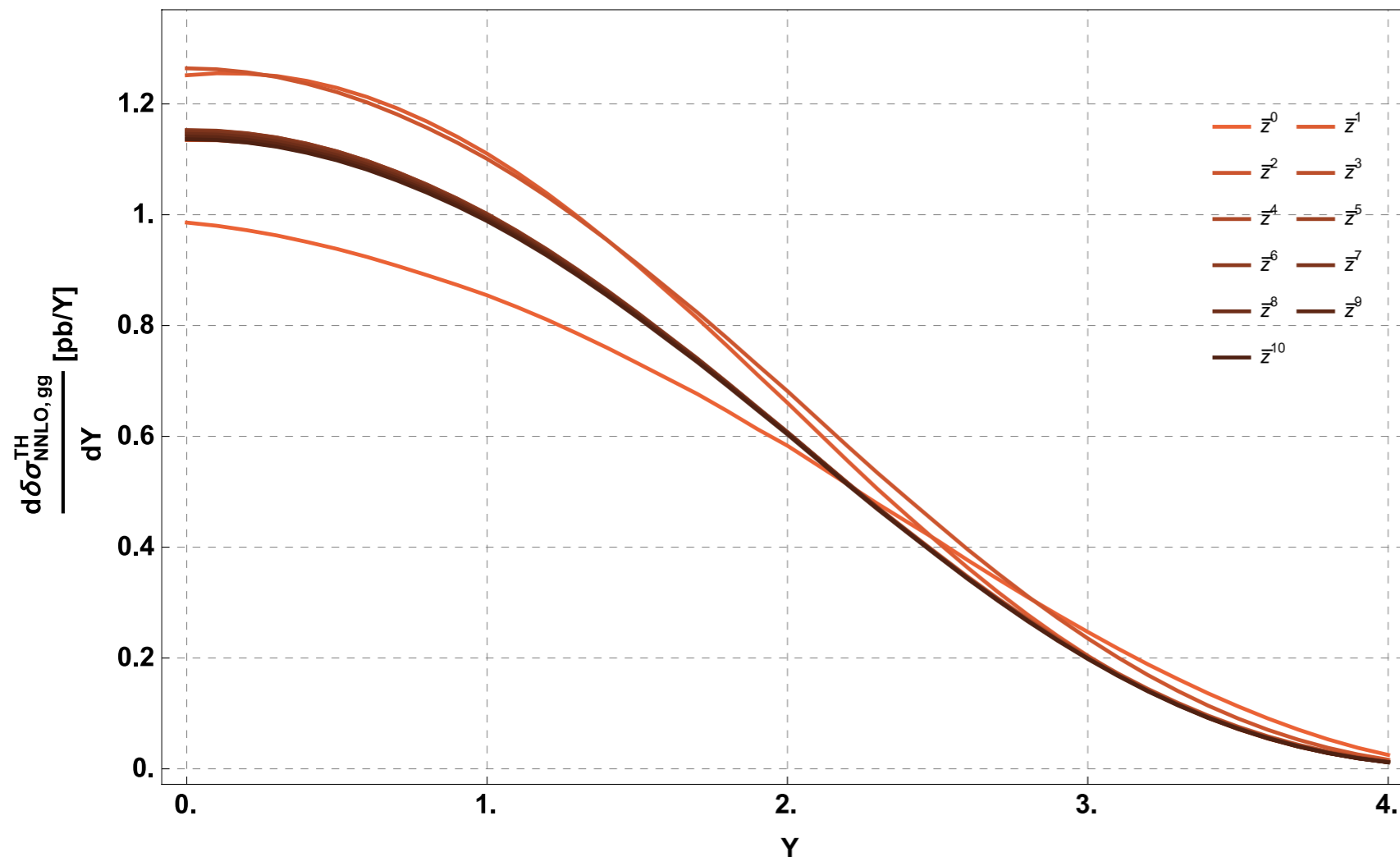x-axis: Truncation order

SOFT EXPANSION @ NNLO DIFFERENTIAL

▶ NNLO Corrections to the Rapidity distribution

SOFT EXPANSION @ NNLO

▸ NNLO Corrections to the Rapidity distribution

▸ Bulk of XS is described well with a couple of terms

▸ Changes from observable to observable. (soft radiation dominance, …)

SOFT EXPANSION

▸ Systematically improvable approximation.

▸ Soft expansion gives the opportunity to study differential distribution

▸ Doing phenomenology in this approximation requires careful case by case analysis to see if the approximation is valid!

▸ Ambiguity of higher order terms has to be controlled.
Example:
Inclusive N3LO:
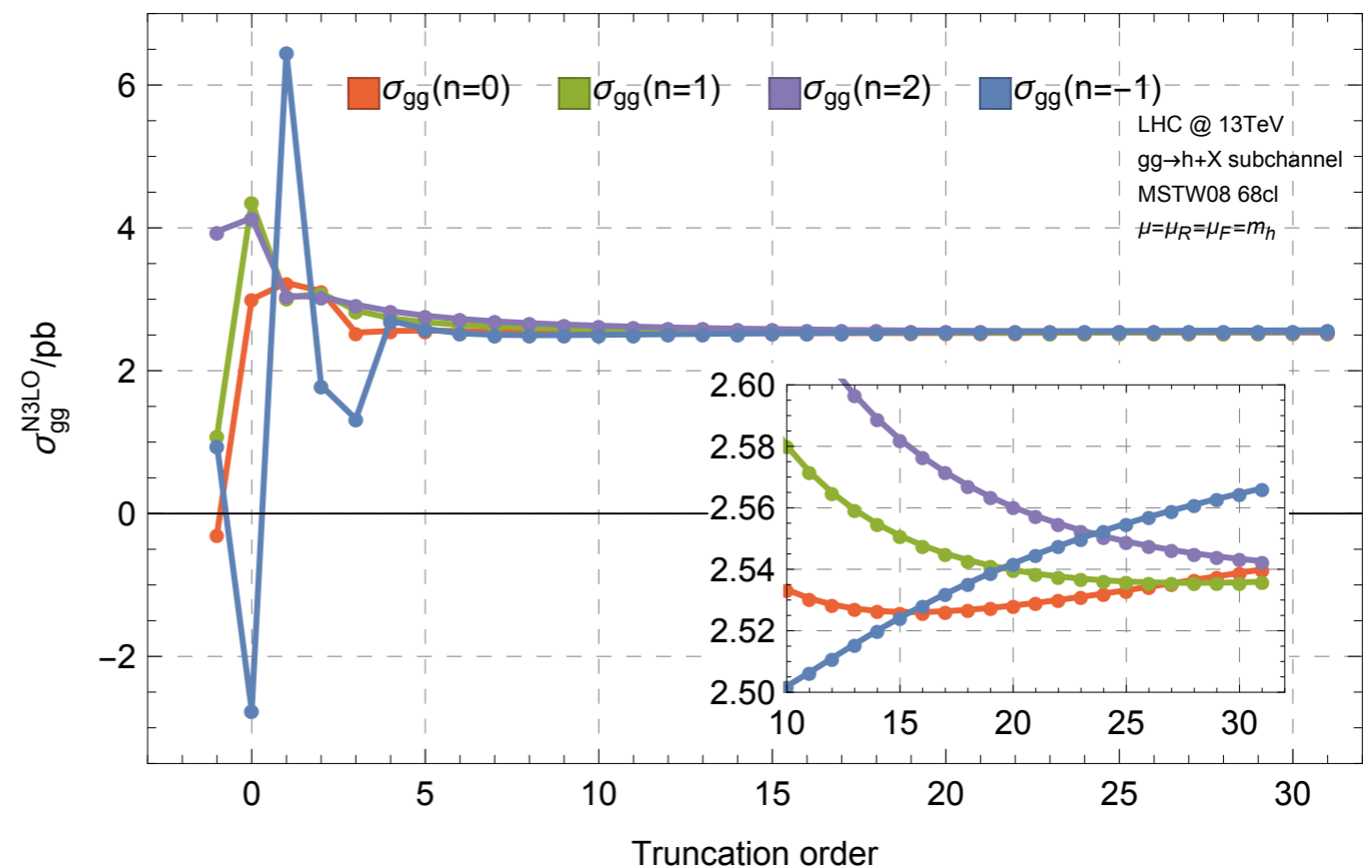
THE ROCKY ROAD TO N3LO

▸ Extend analytic techniques
for automatic soft amplitude expansions.

▸ Apply reverse unitarity, differential equations,
Multiple PolyLog, IBP, DiffEq techniques ….

▸ Compute 110 new double differential soft master integrals.

▸ Compute the first terms (Soft-Virtual SV) at N3LO

▸ Put into code and look at the N3LO corrections to the rapidity
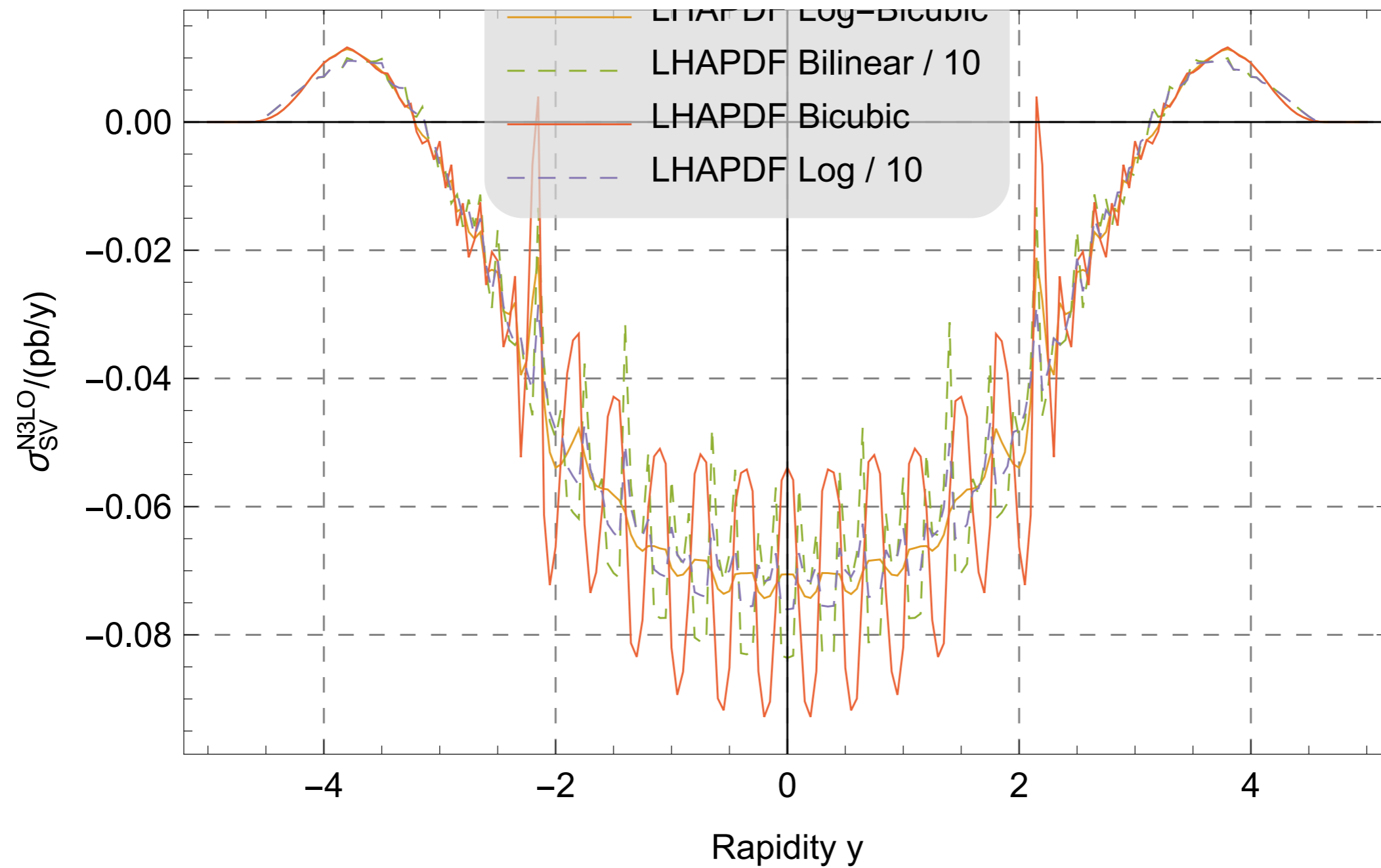distribution and …

N3LO CORRECTIONS TO THE RAPIDITY DISTRIBUTION
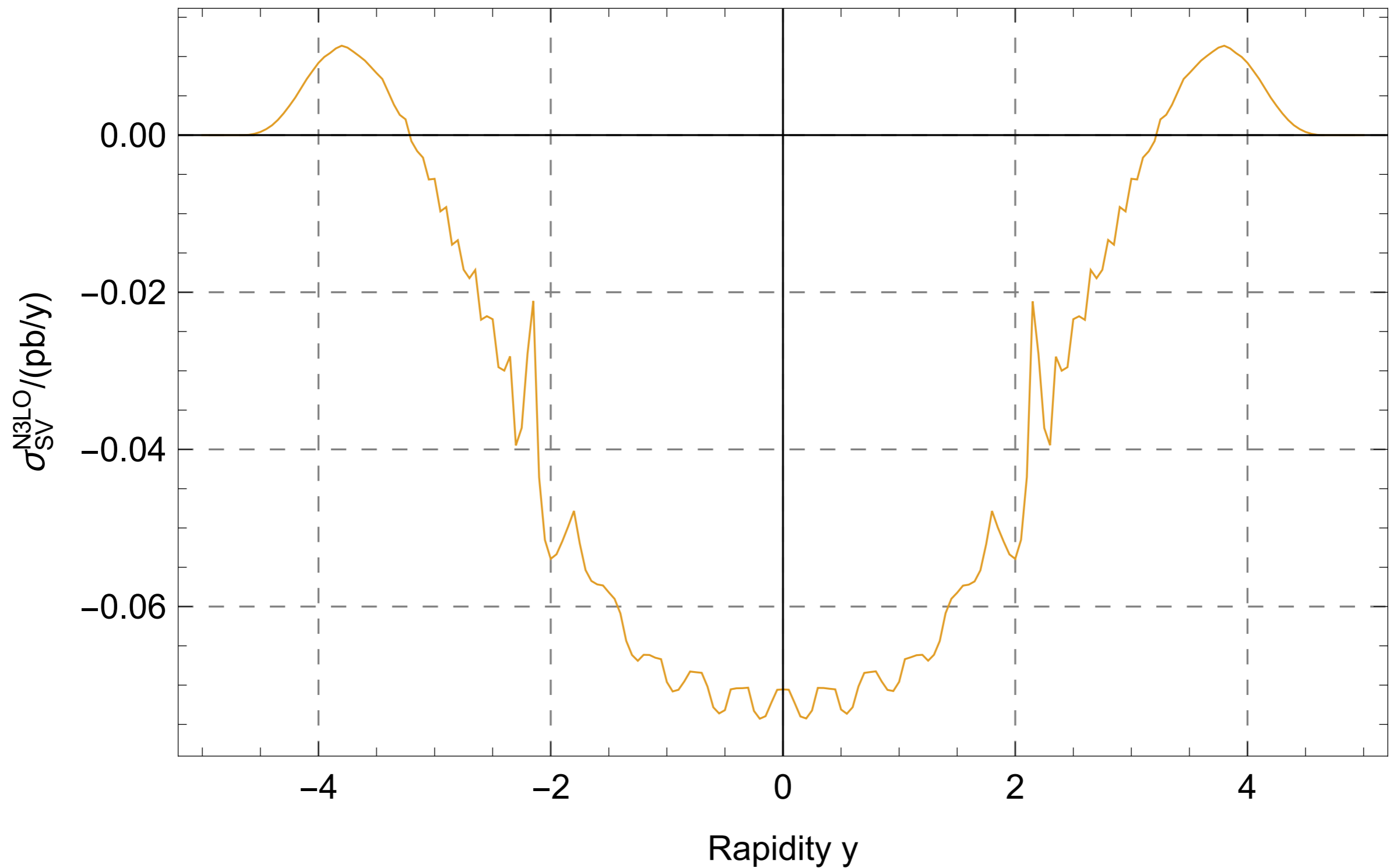
BE CAREFUL WHEN YOU DO SOMETHING NEW

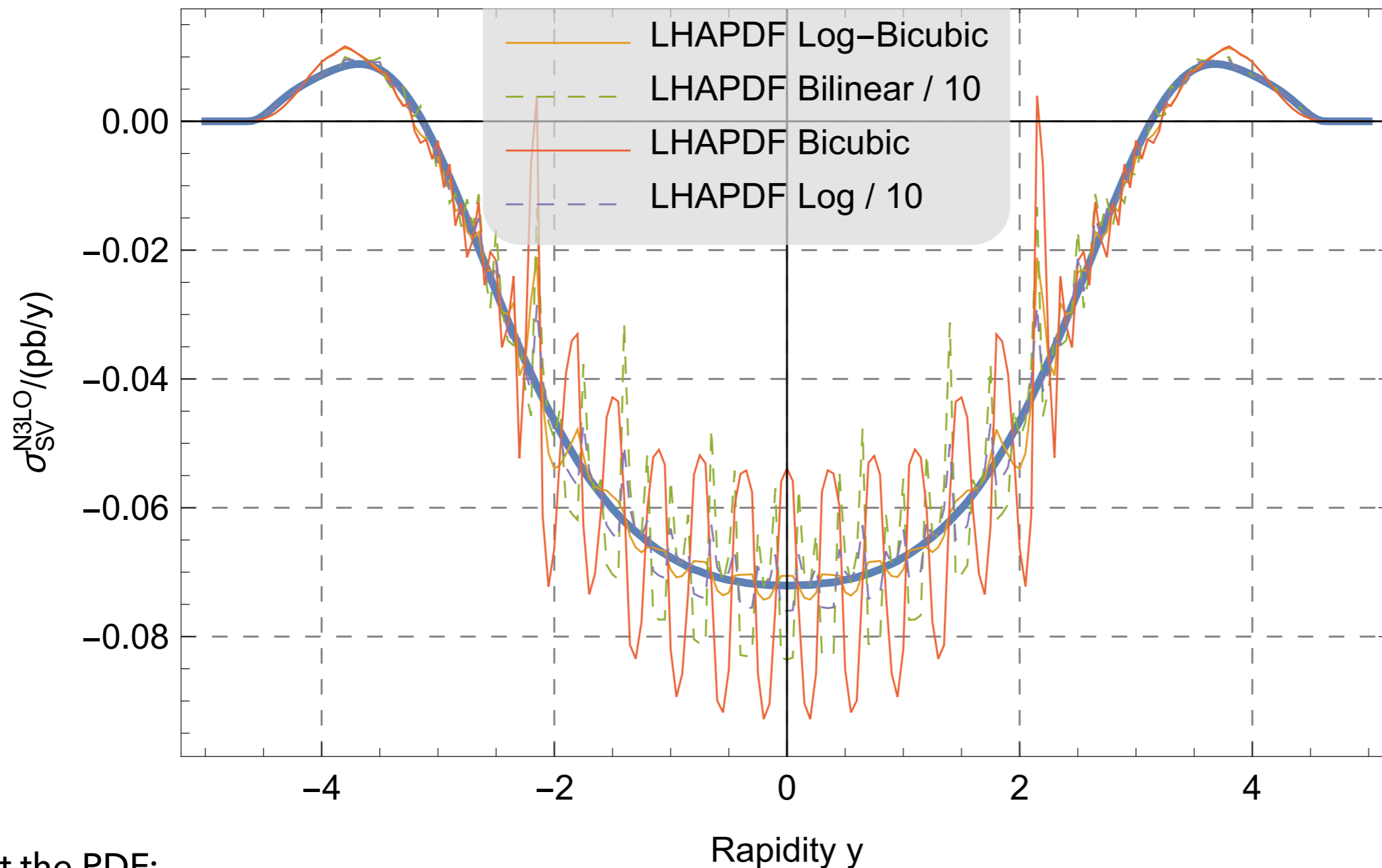$$\sigma \sim \int dz \mathcal{L}_{gg}(z) \left[\frac{log^5(1-z)}{1-z} \right]_+$$

LHAPDF

▸ LHAPDF: Grid of points for PDFs in x and Q

▸ Interpolation between points with certain precision

▸ Not meant to be precise enough for N3LO plus distributions yet ....

▸ Improvements required: New interpolator, evolve from smooth PDF .... ?
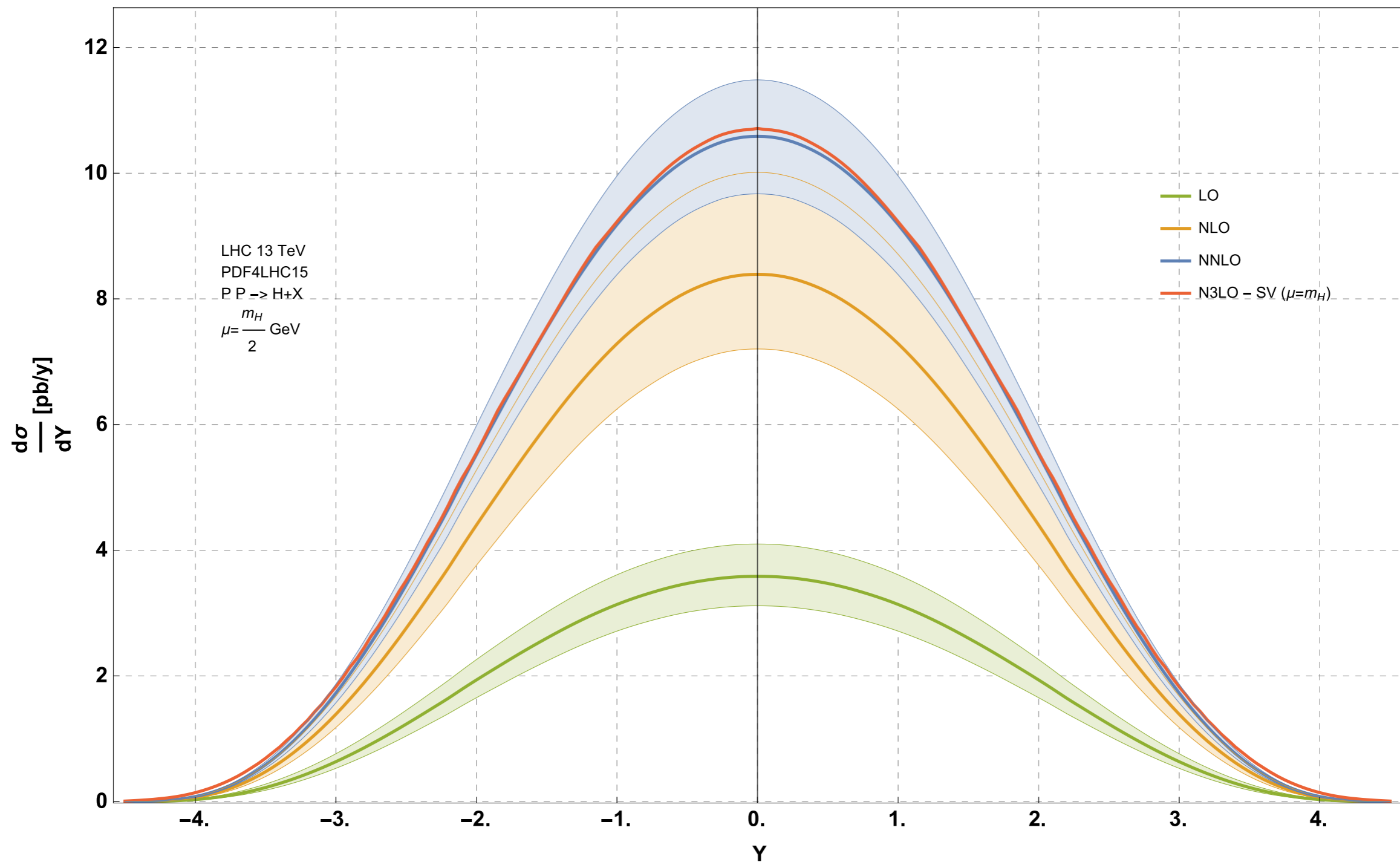
N3LO CORRECTIONS TO THE RAPIDITY DISTRIBUTION

N3LO CORRECTIONS TO THE RAPIDITY DISTRIBUTION

Fit the PDF:

$$f(x, Q = 125) = c_1(1 - x)^{e_1} x^{e_2} + c_2(1 - x)^{e_3}(1 - c_3\sqrt{x}) + c_4 x + c_5 \log^2(x) + c_6 \log^4(x) + c_7 \log^4(x)$$

SV CORRECTIONS TO RAPIDITY AT N3LO

CONCLUSIONS

▸ Progress towards differential N3LO

▸ Double differential framework for realistic final states looks promising

▸ Threshold expansions provide a key ingredient for analytic computation

▸ Threshold expansion can be used at the differential level to approximate precisely differential cross section predictions

▸ Many interesting things to be encountered when going to higher order.

Thank you!