Do we need N^{3}LO Parton Distributions?

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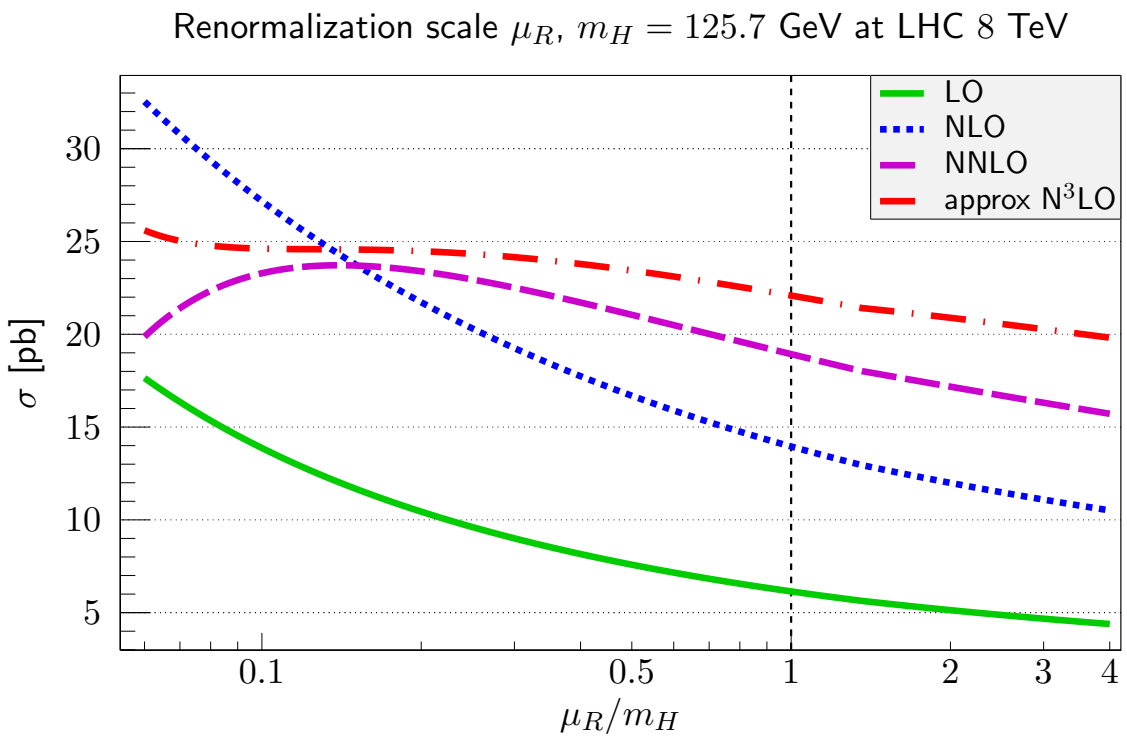
Approx N^{3}LO

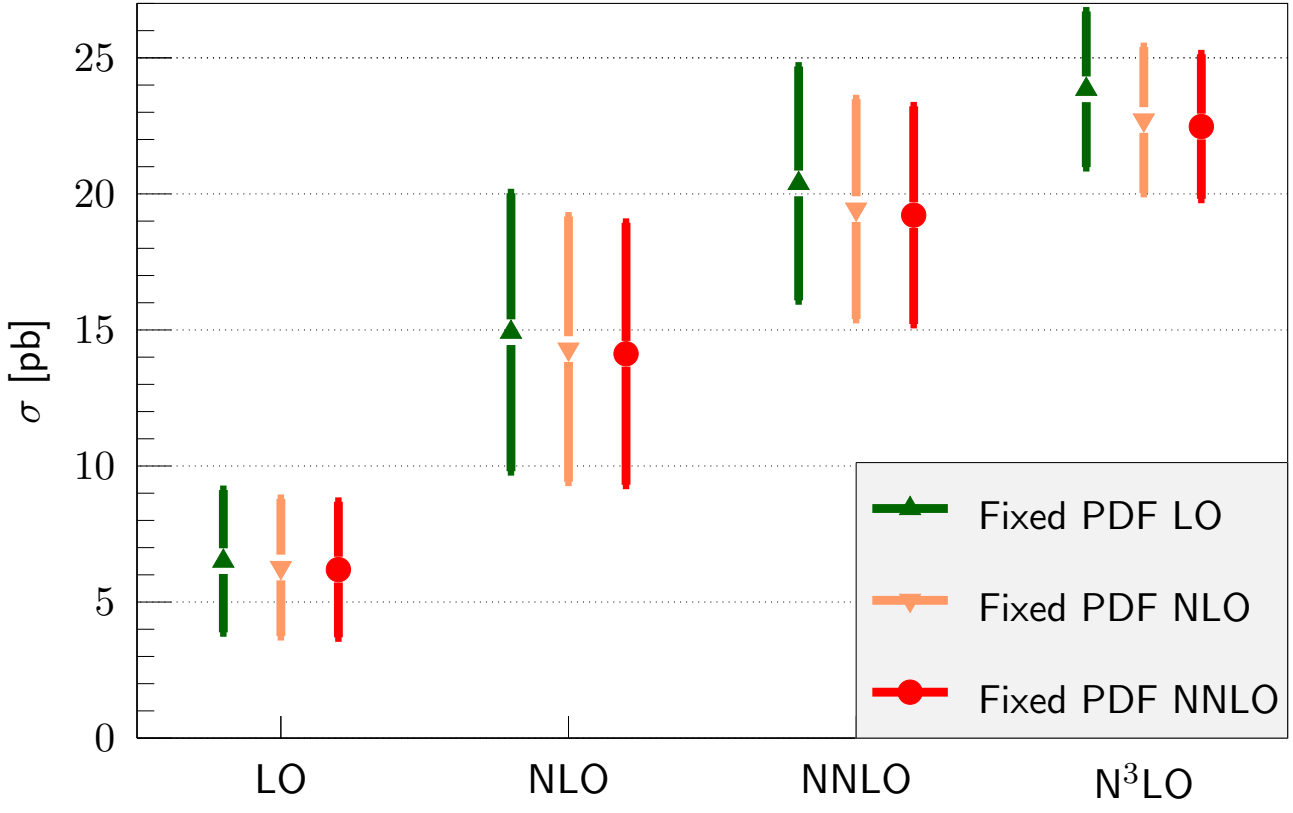
- perturbative expansion of Higgs XS $gg \to H$ slowly convergent
- exact **N^{3}LO XS** currently being computed (Anastasiou et al)
- approx version already avaliable (Ball, Bonvini, Forte, Marzani, Ridolfi)
- flat dependence on factorization scale μ_F



Can we make use of this N^{3}LO cross section without N^{3}LO PDFs?

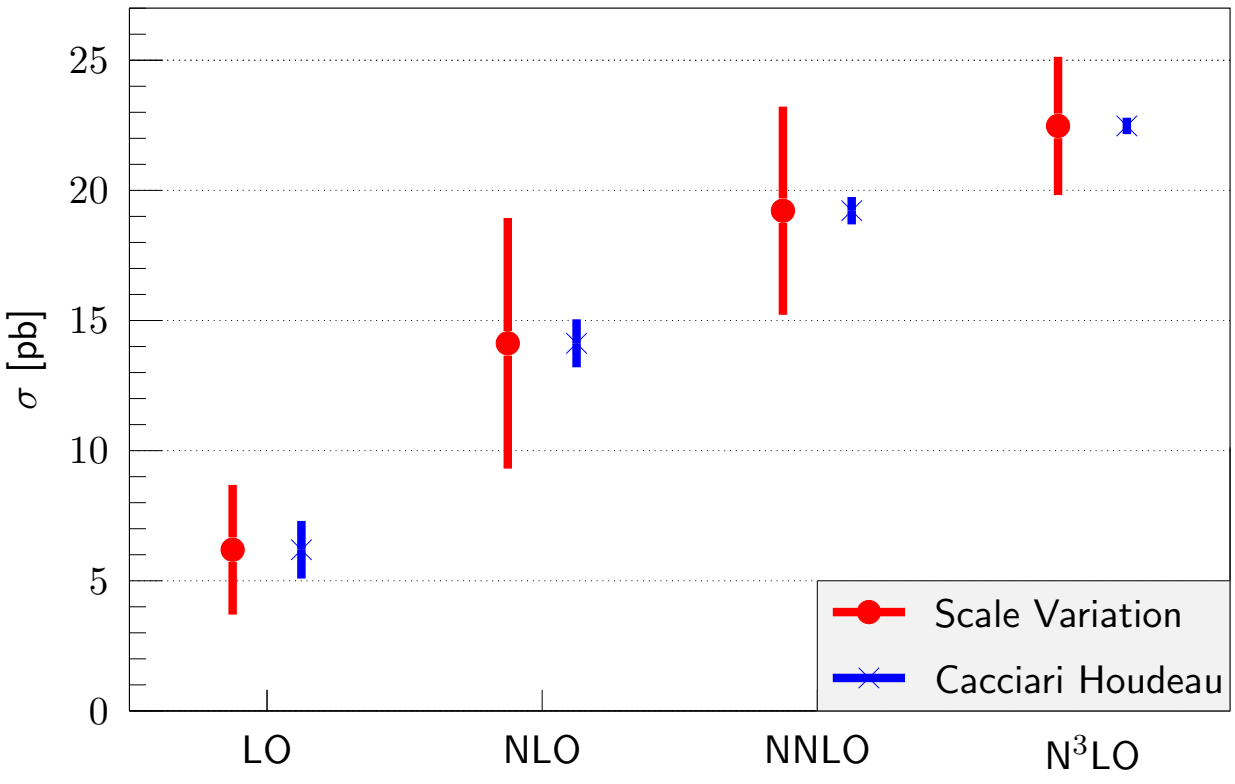
Quick answer

- compute the **total** cross section at fixed PDF orders
- Theor Unc: scale variation $\mu_R \in [\mu_0/2, 2\,\mu_0]$, $\mu_0 = m_H$
- similar results for $\mu_0 = m_H/2$
- first glance: PDF dependence is much weaker
- unified methodology to give error bars?



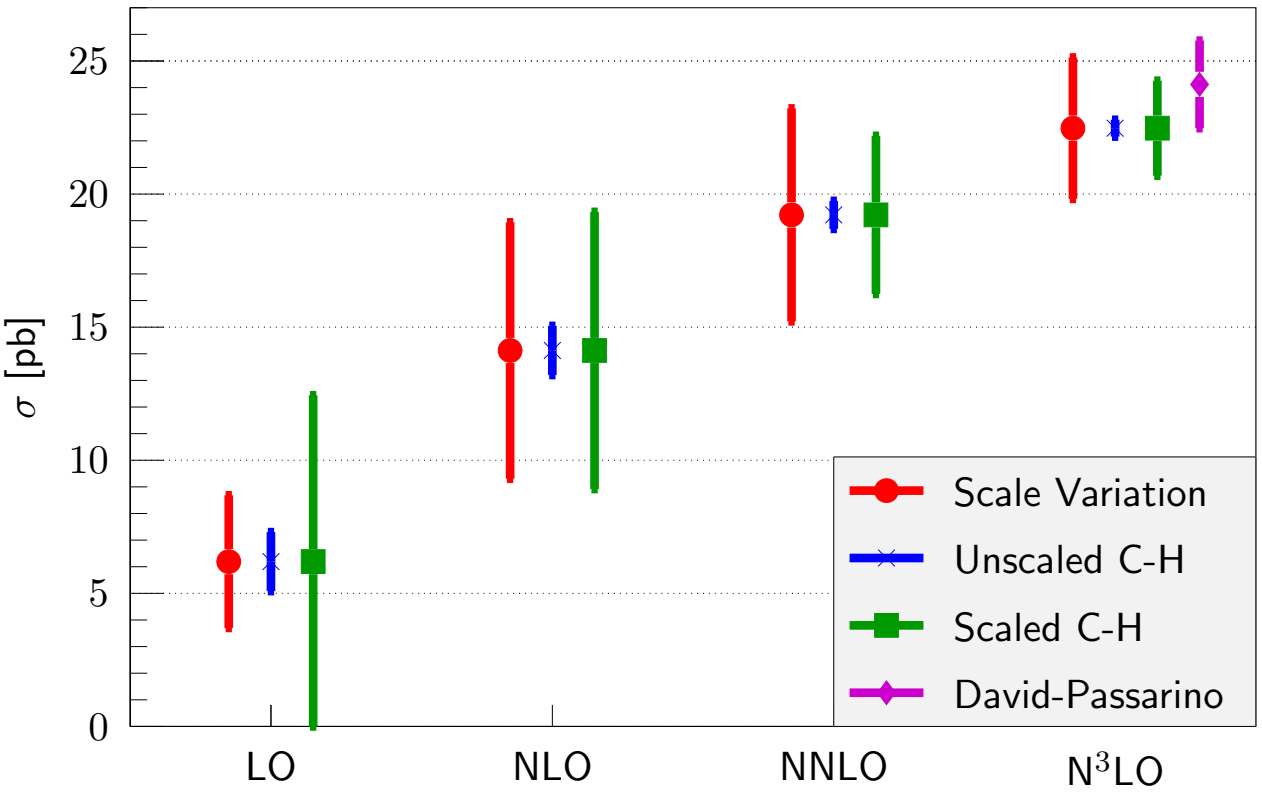
Cacciari-Houdeau method

- $\sigma = \alpha_S^2 \left(\sigma_0 + \alpha_S \sigma_1 + \alpha_S^2 \sigma_2 + \alpha_S^3 \sigma_3 + \dots\right)$ (simple minded)
- Bayesian confidence interval based on known σ_i, $i \in [0, 3]$
- check known orders: $\neq$ Scale Variation, smaller than shift
- hypothesis: σ_i all of the **same size**, but **rapid growth**!
- scaled parameter, $\frac{\alpha_S}{4\pi}$? $C_A \alpha_S$? We do not know



Scaled parameter

- $\sigma = \alpha_S^2 \, \sigma_0 \left(1 + \bar{\alpha}_S c_1^\lambda + \bar{\alpha}_S^2 c_2^\lambda + \dots\right)$, $\bar{\alpha}_S \equiv \lambda \, \alpha_S$, $c_n^\lambda \equiv \frac{c_n}{\lambda^n}$
- lack of theoretical motivation, λ is fitted asking $c_n^\lambda = \kappa$
- NNLO PDF, $\mu_R = m_H$, $\lambda \approx 5.6$, similar if σ_0 included
- λ: stable with PDF order, moderate dependence on μ_R
- works for $i < 3$, consistent with Scale Var and David-Passarino



Matrix Element dependence vs PDF dependence

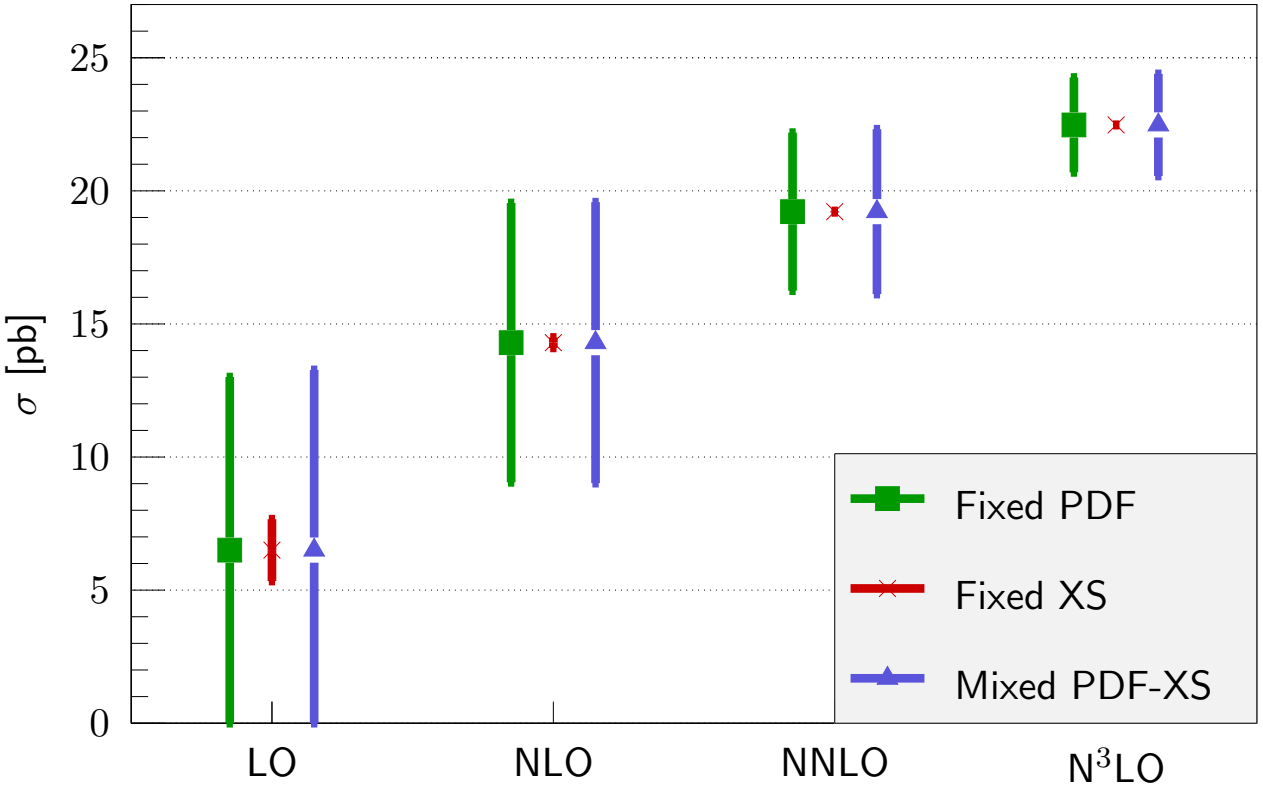
Matrix Element dependence

- series at **Fixed PDF** order
- **scaled** Cacciari-Houdeau

PDF dependence

- series at **Fixed XS** order
- **unscaled** Cacciari-Houdeau

Mixed: LO PDF – LO XS, NLO PDF – NLO XS, etc. (scaled)



Conclusion

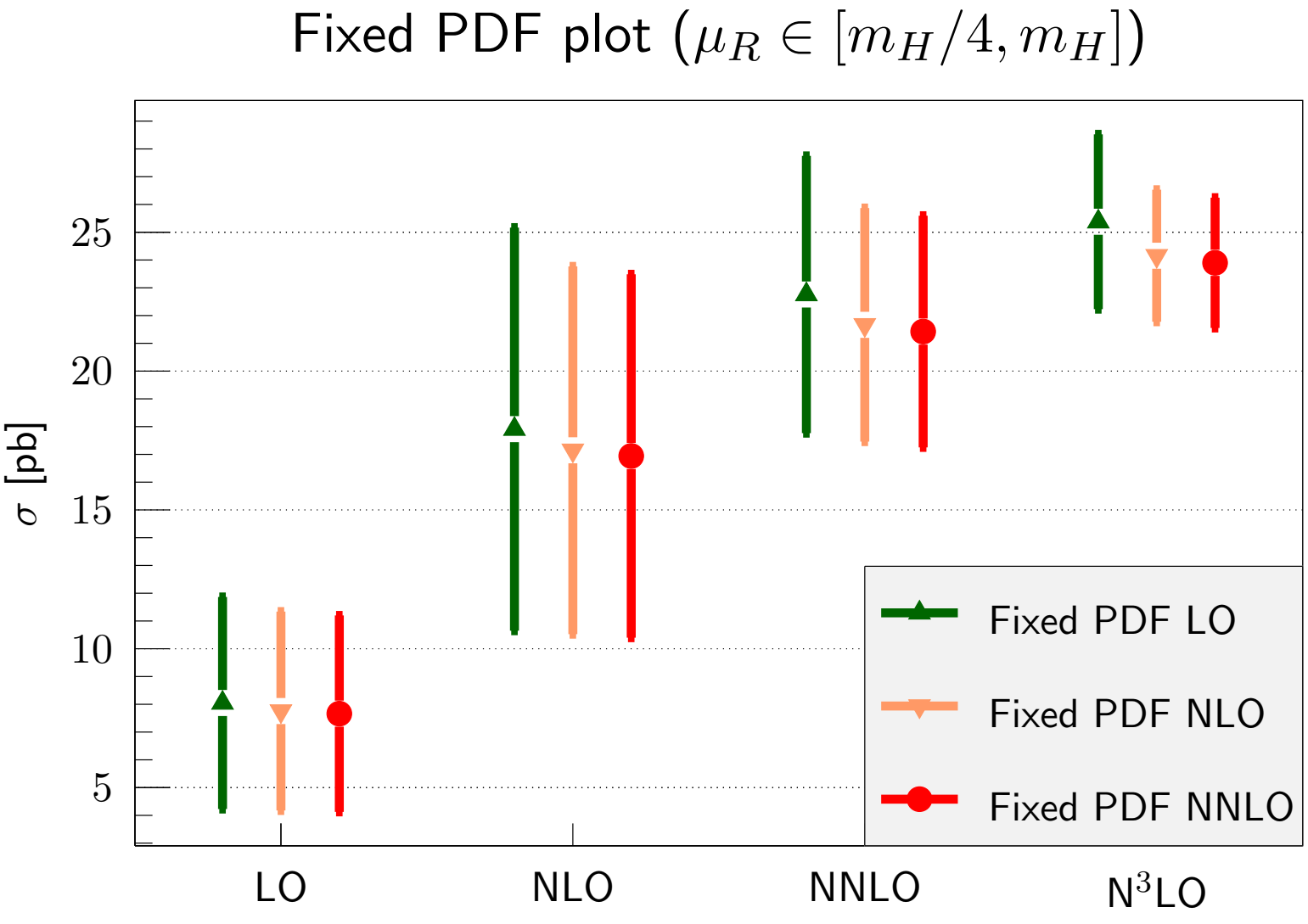
Higgs in gluon fusion

- Theor Unc on Fixed XS series much smaller than Fixed PDF
- N^3LO XS expected to be almost unchanged with N^3LO PDF
- N^3LO PDFs not really needed

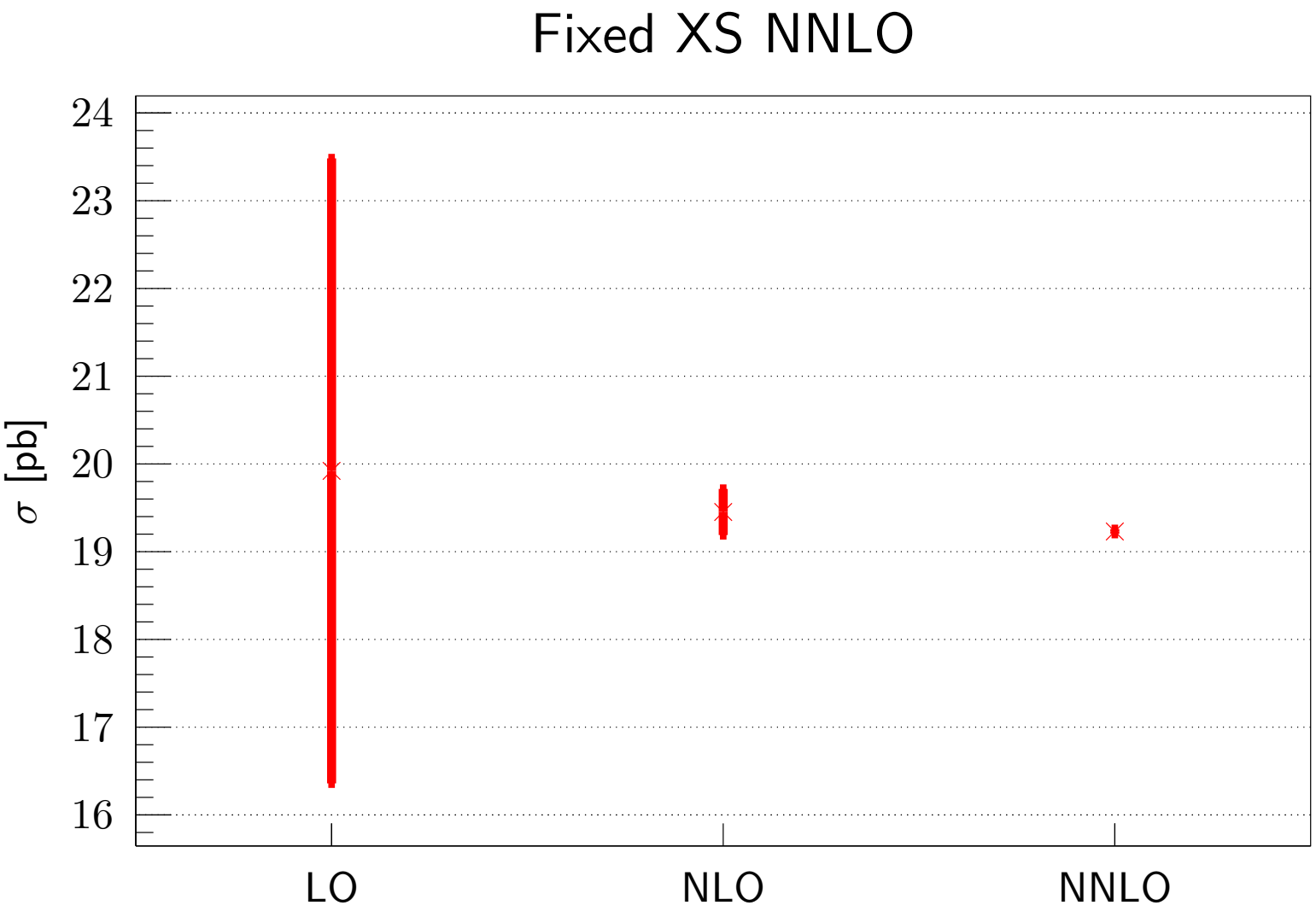
What did we find out?

- Cacciari Houdeau works well if we scale parameter
- we need to analyze case by case
- **N^3LO** correction might still be important in other processes

Backup slide 1: $\mu_R = m_H/2$



Backup slide 2: Fixed XS



Backup slide 3: λ dependence on μ_R

- slower convergence $\Longrightarrow$ higher μ_R $\Longrightarrow$ higher λ
- faster convergence $\Longrightarrow$ smaller μ_R $\Longrightarrow$ smaller λ