Precision theory for colliders and beyond

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The need for precision theory

- Lack of direct discoveries forces us to test the Standard Model with increasing precision
- Some future measurements will be limited by the theoretical accuracy
- Energy and Intensity frontiers are becoming now the **Precision Frontier** and strongly rely on the theoretical input

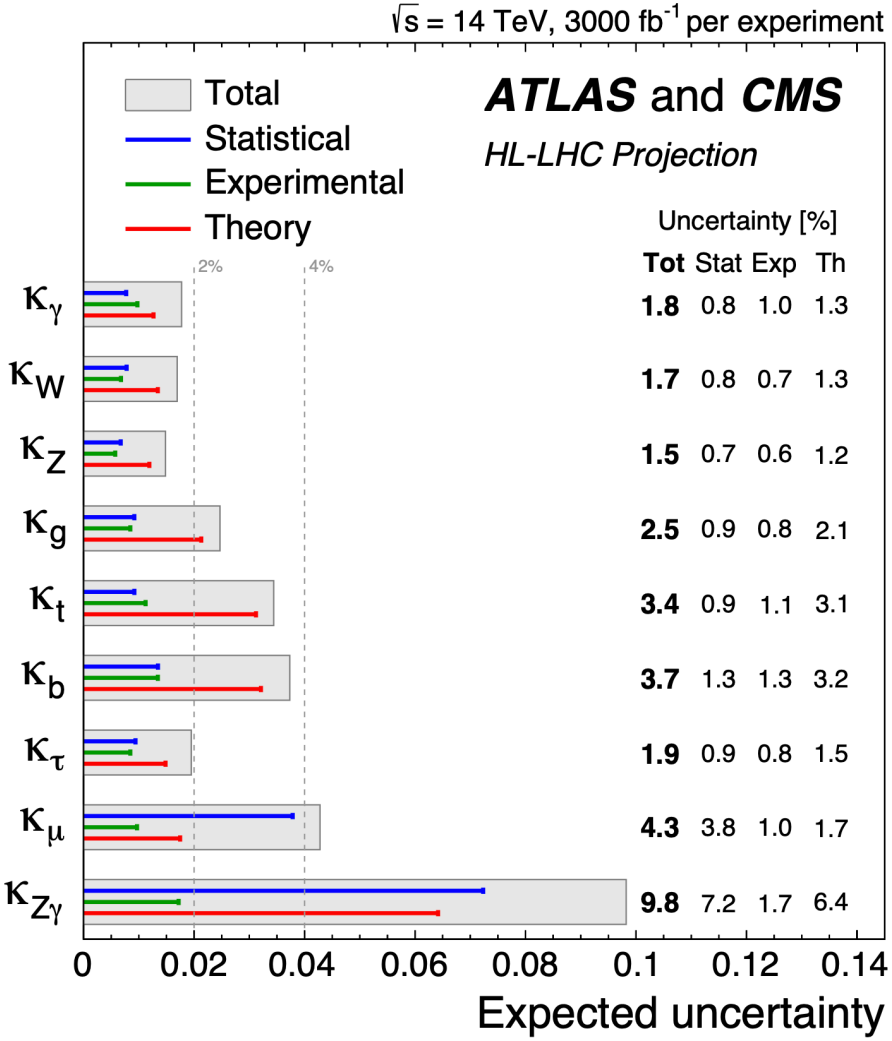
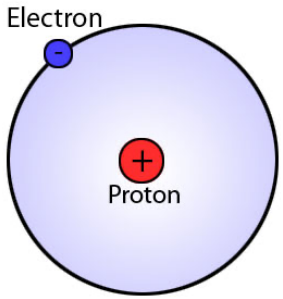
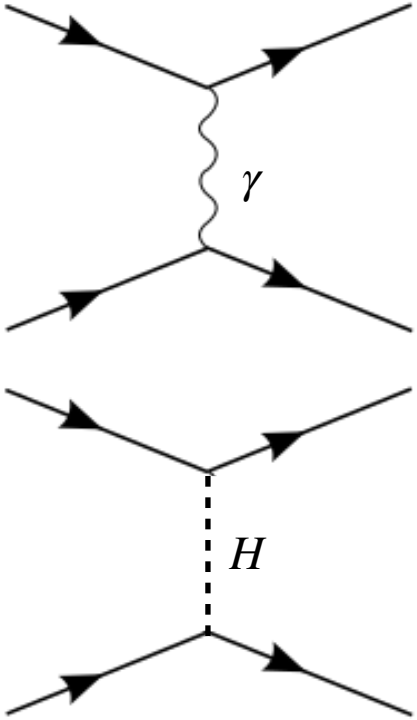


Figure from arXiv:1902.00134

EFTs - factorization

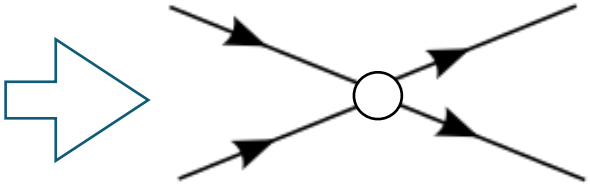
To calculate Hydrogen energy levels we don't need to know about the Higgs boson





$$V \sim \frac{\alpha}{r}$$

$$V \sim \frac{y_e y_q e^{-m_H r}}{r}$$



$$V \sim \frac{y_e y_q}{m_H^2}\delta^{(3)}(r)$$

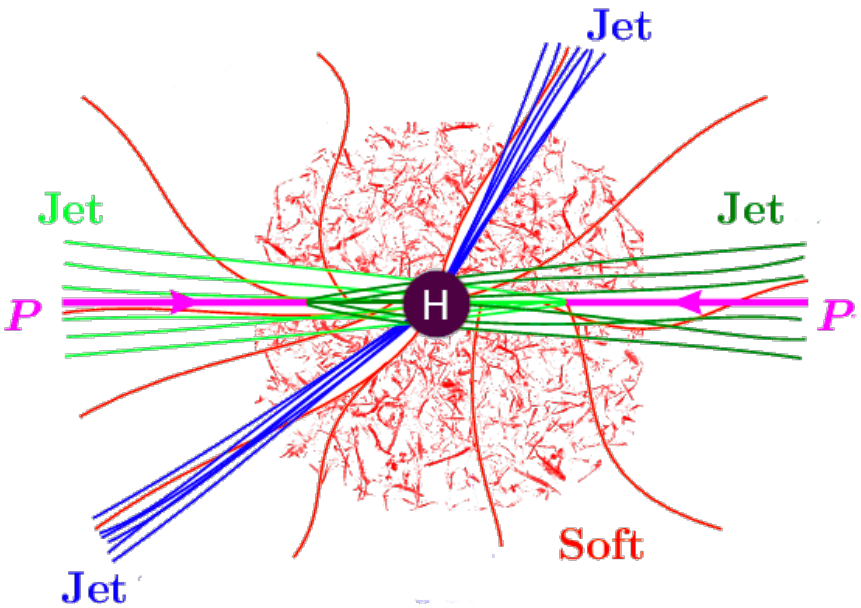
$$\Delta E \sim \frac{\alpha^3 y_e y_q m_e^2}{m_H^2} m_e$$

Short and long distance physics naturally factorize in the Effective Field Theory framework

Precision at the LHC

Modern EFTs allow us to factorize complicated processes at the LHC into simpler objects

$$d\sigma \sim H \otimes J \otimes J \otimes f_P \otimes f_P \otimes S$$



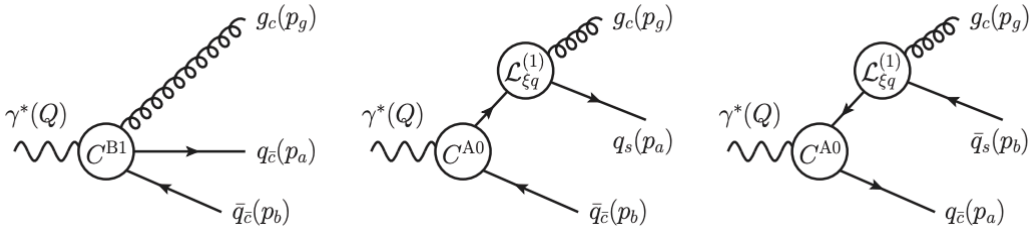
My work is focused on

Theoretical developments of the factorization framework to improve our understanding of it

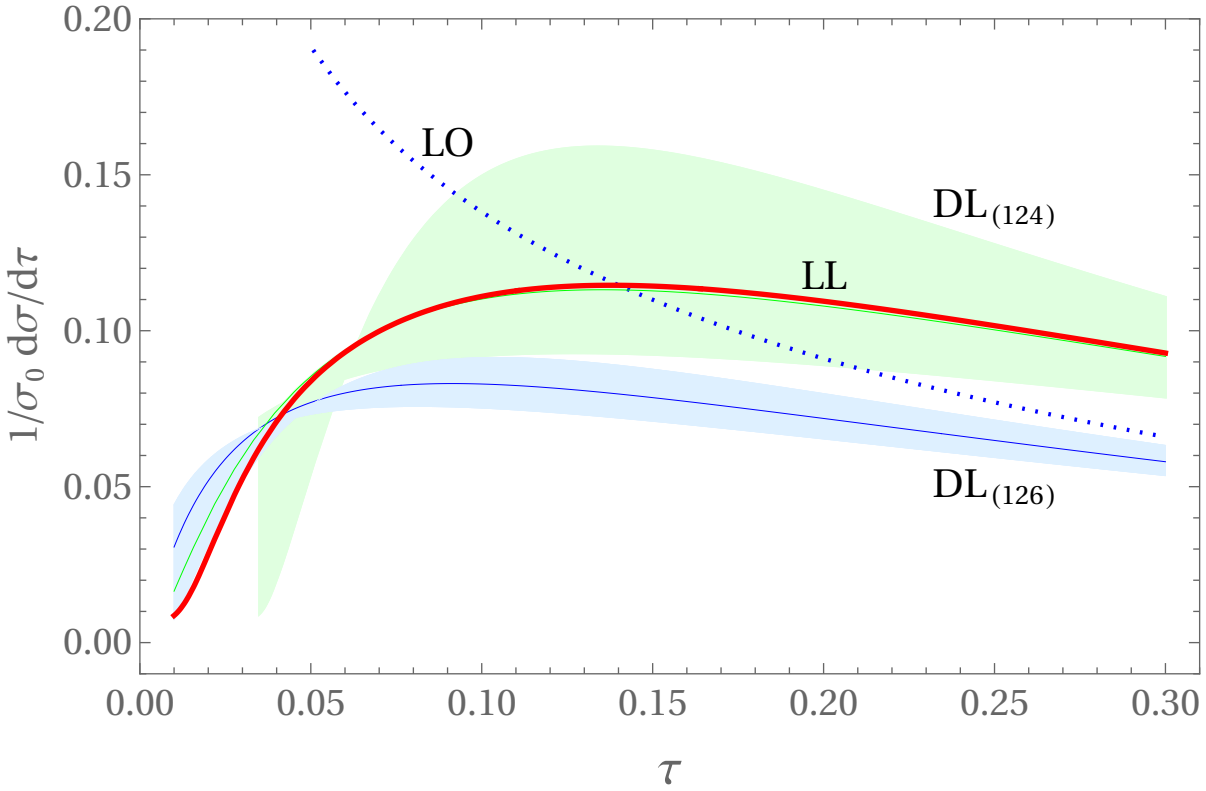
Higher order calculations of the objects needed to improve theoretical precision

Factorization for jet productions

arXiv:2205.04479

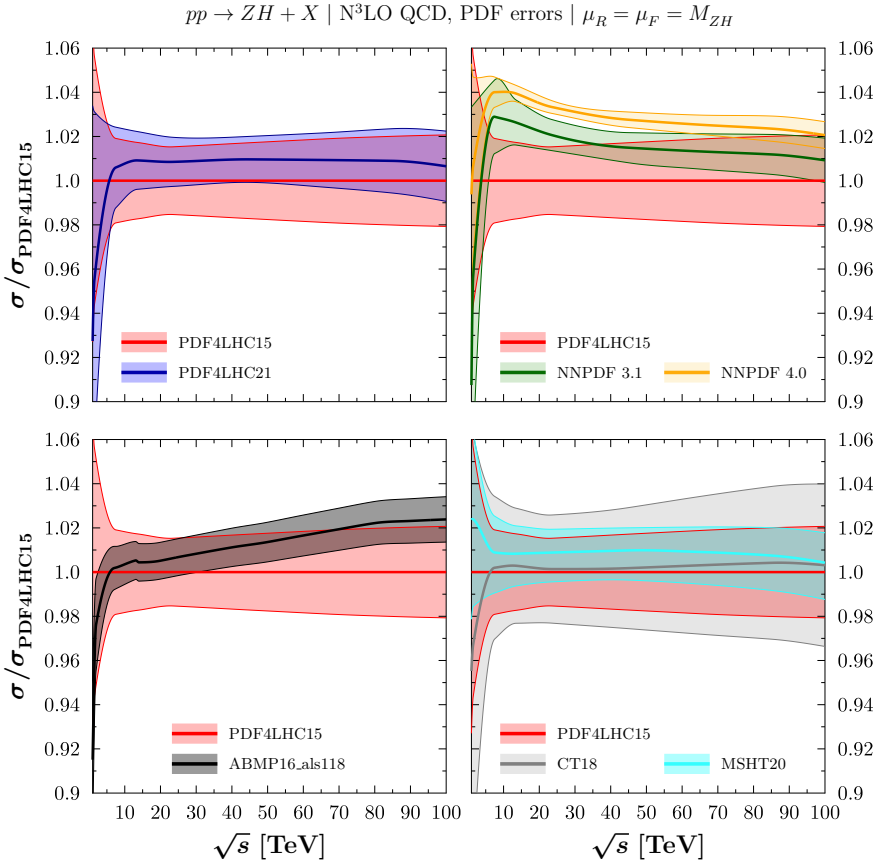


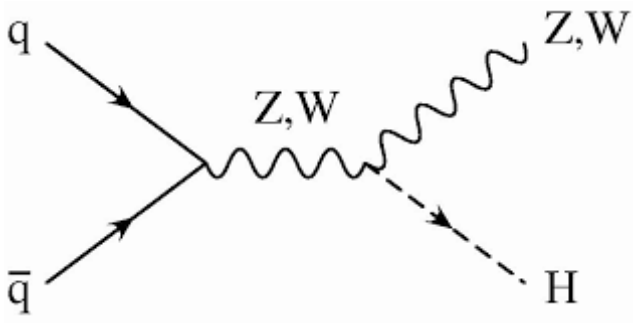
Gluon jet recoiling against $q\bar{q}$ jet:
New factorization theorem valid at the next-to-leading power



Z H production at N3LO

Process	σ^{LO} [pb]	σ^{NLO} [pb]	$\mathrm{K}^{\mathrm{NLO}}$	σ^{NNLO} [pb]	$\mathrm{K}^{\mathrm{NNLO}}$	$\sigma^{\mathrm{N^3LO}}$ [pb]	$\mathrm{K}^{\mathrm{N^3LO}}$
W^+H	$0.758^{+2.43\%}_{-3.13\%}$	$0.883^{+1.38\%}_{-1.20\%}$	1.16	$0.891^{+0.28\%}_{-0.34\%}$	1.18	$0.884^{+0.27\%}_{-0.30\%}$	1.17
W^-H	$0.484^{+2.50\%}_{-3.26\%}$	$0.560^{+1.34\%}_{-1.23\%}$	1.16	$0.564^{+0.27\%}_{-0.34\%}$	1.17	$0.559^{+0.30\%}_{-0.33\%}$	1.16
ZH	$0.678^{+2.40\%}_{-3.11\%}$	$0.786^{+1.33\%}_{-1.16\%}$	1.16	$0.792^{+0.25\%}_{-0.32\%}$	1.17	$0.786^{+0.26\%}_{-0.29\%}$	1.16



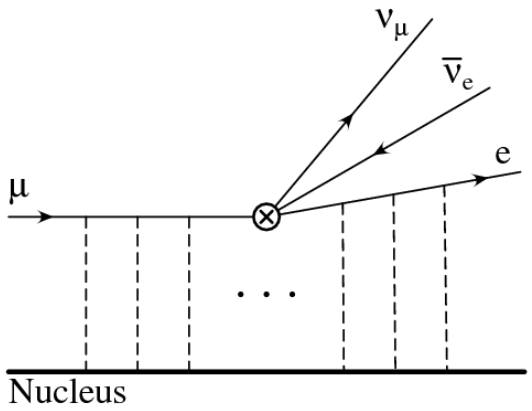


Differences between parton distributions sets are larger than the claimed uncertainties!

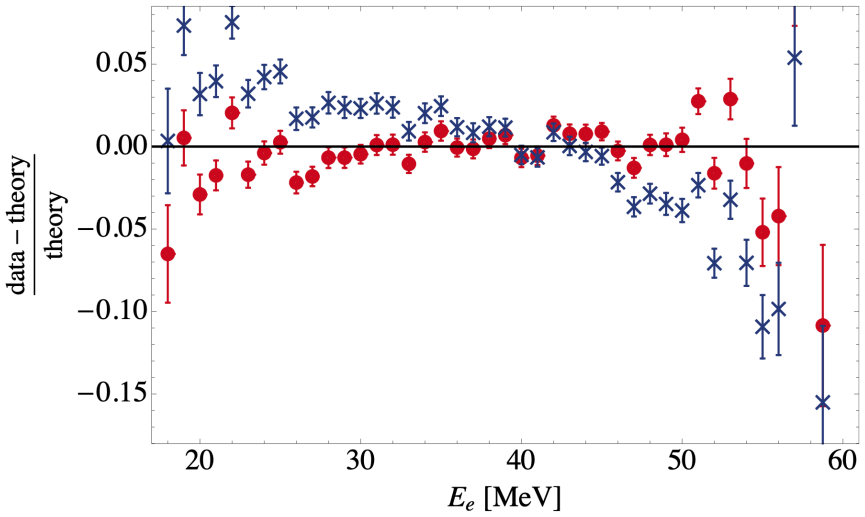
Precision beyond the colliders

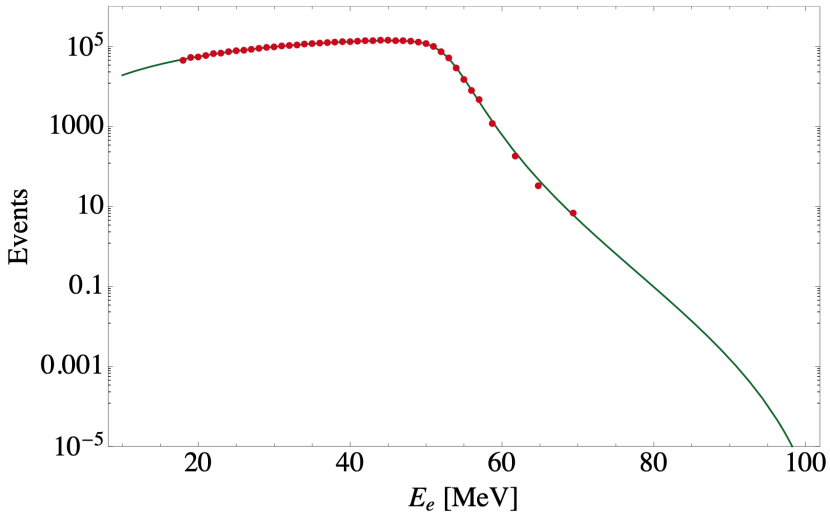
The same EFT tools can be used to improve theoretical predictions for low energy experiments

Bound muon decay spectrum relevant for the Mu2e experiment



arXiv: 1608.05447





Summary

- ☑ Developments in theory: new factorization theorems
- ☑ More precise calculations: higher order corrections

The precise theory is now more than ever crucial for the success of the experimental program in High Energy Physics

Questions?