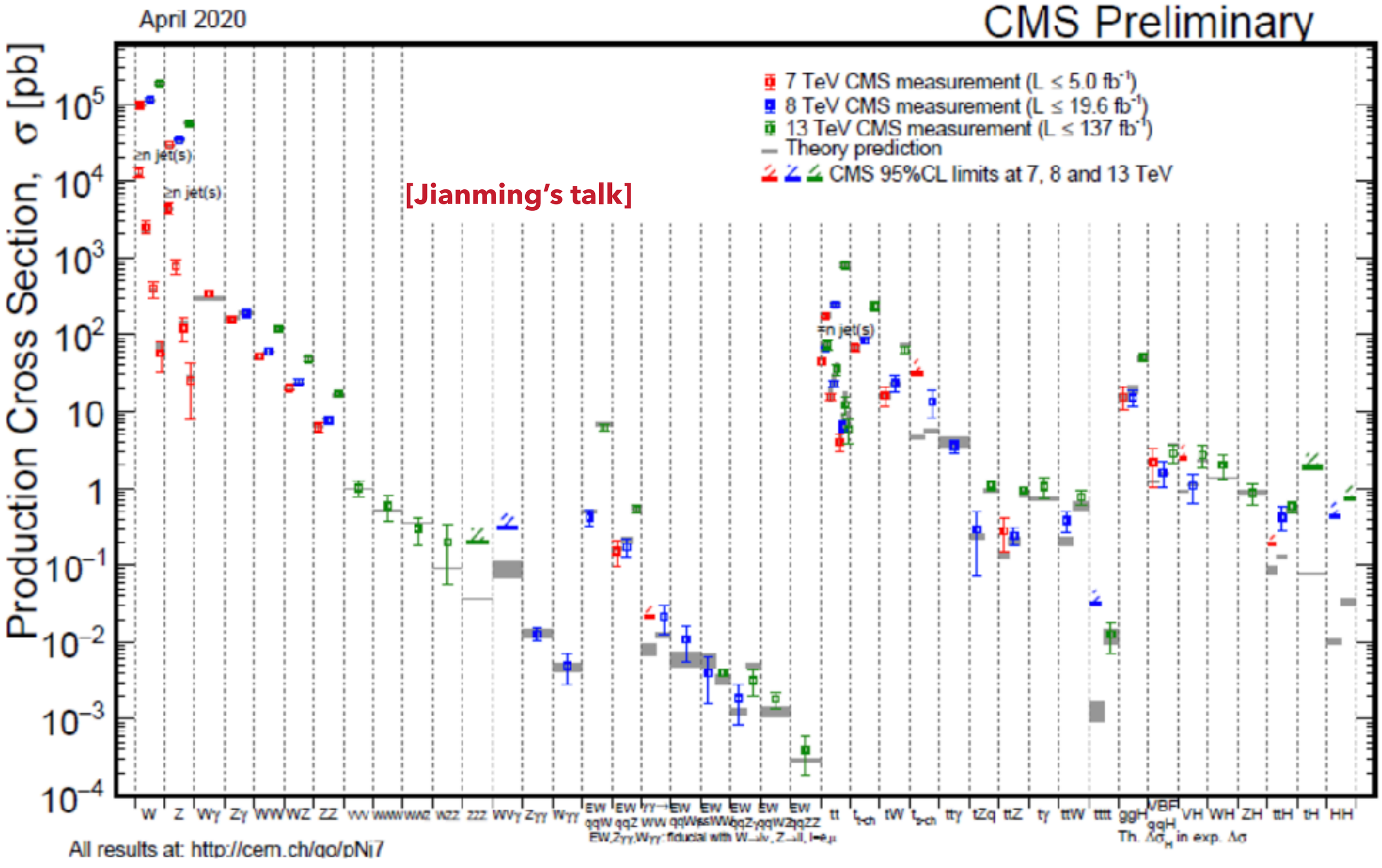
BERNHARD MISTLBERGER

PRECISION PREDICTIONS AT N3LO

SLAC

LHC PROCESSES



The Phenomenology Goal at the LHC

Understand how nature interacts at a fundamental level!

- **A new interaction: Yukawa!**

- **The mechanism of electro-weak symmetry breaking**

- **Generation of fundamental masses**

- **Determine couplings / interactions with established matter** $H \heartsuit \mu$?

$W \heartsuit W \heartsuit W \heartsuit W$?

- **Explore the limitations of the Standard Model of particle physics**

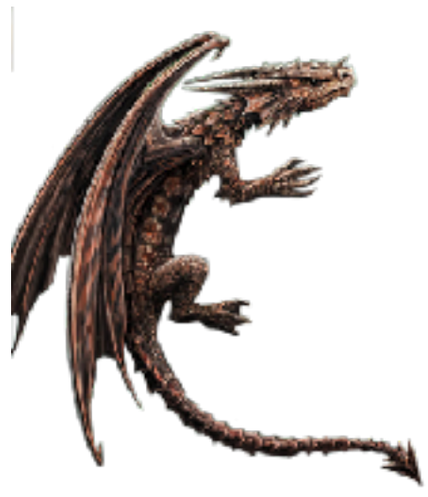
hic svnt dracones

The Phenomenology Goal at the LHC

Understand how nature interacts at a fundamental level!

$H \heartsuit \mu$?

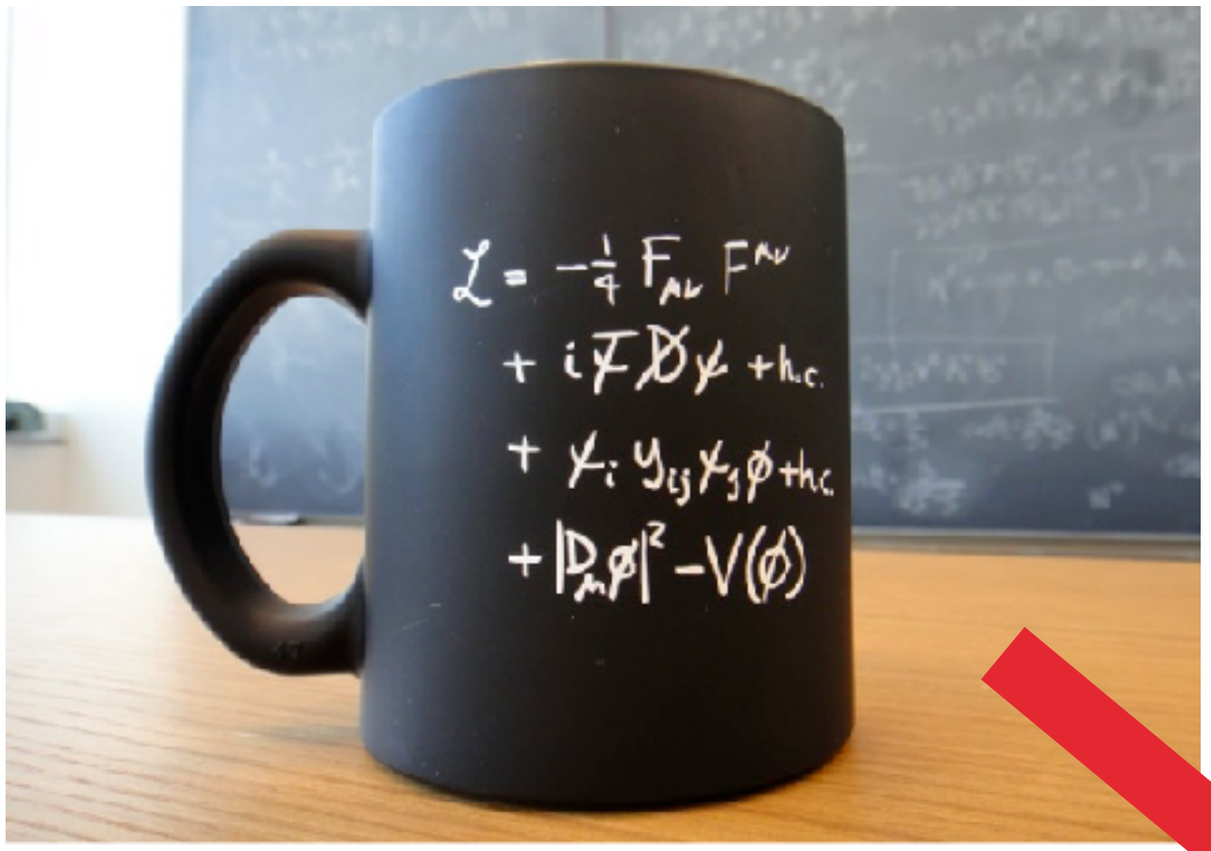
$W \heartsuit W \heartsuit W \heartsuit W$?



The Method: Predict & Compare.

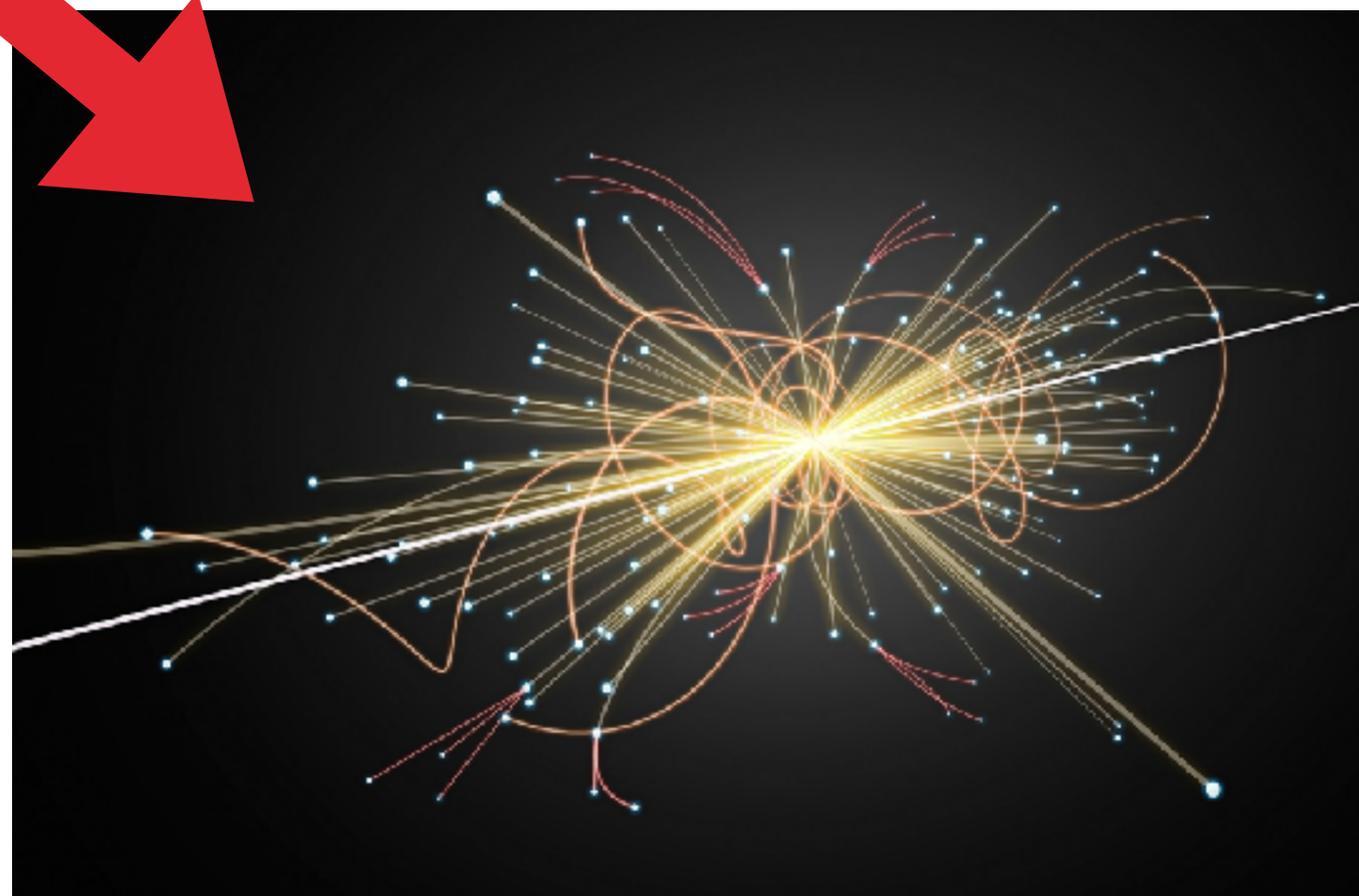
Precision is key!

FROM THE STANDARD MODEL TO REAL LIFE OBSERVABLES

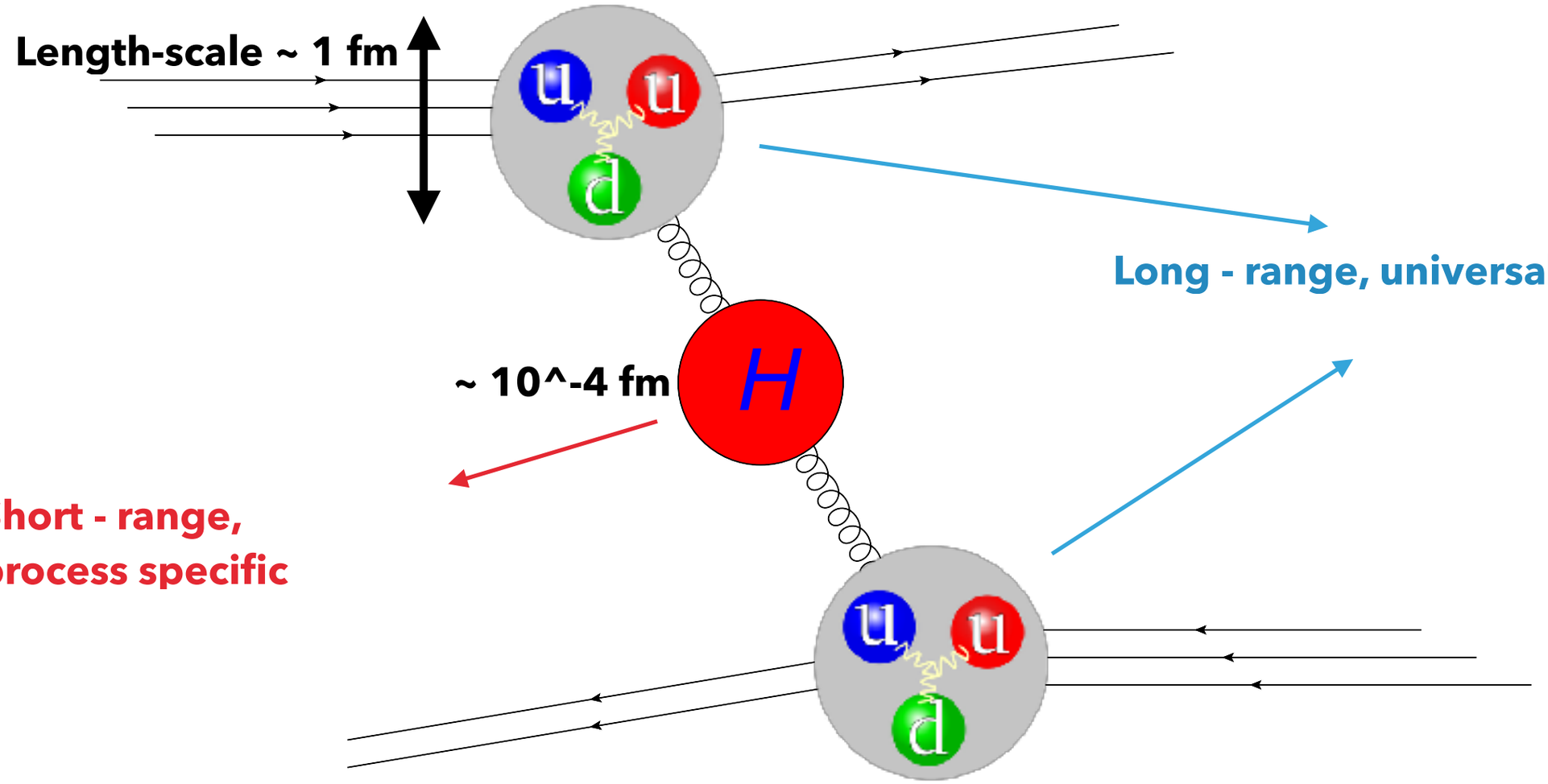


From first principle QFT …

… to real life measurement



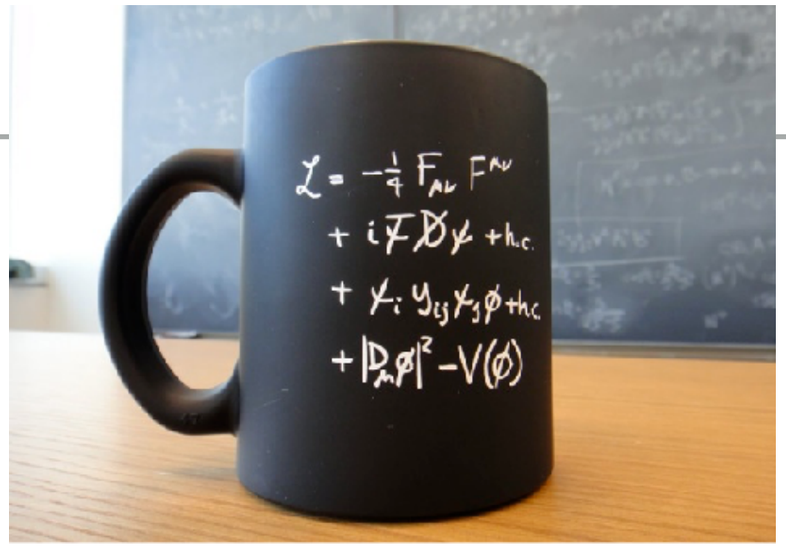
THE WAY TO PRECISION LHC PREDICTIONS



FACTORISATION

$$\sigma \sim \int dx dy f(x) f(y) \hat{\sigma} + \mathcal{O}\left(\frac{\Lambda}{Q}\right)$$

THE WAY TO PRECISION LHC PREDICTIONS



$$\sigma \sim \int dx dy f(x) f(y) \hat{\sigma} + \mathcal{O}\left(\frac{\Lambda}{Q}\right)$$

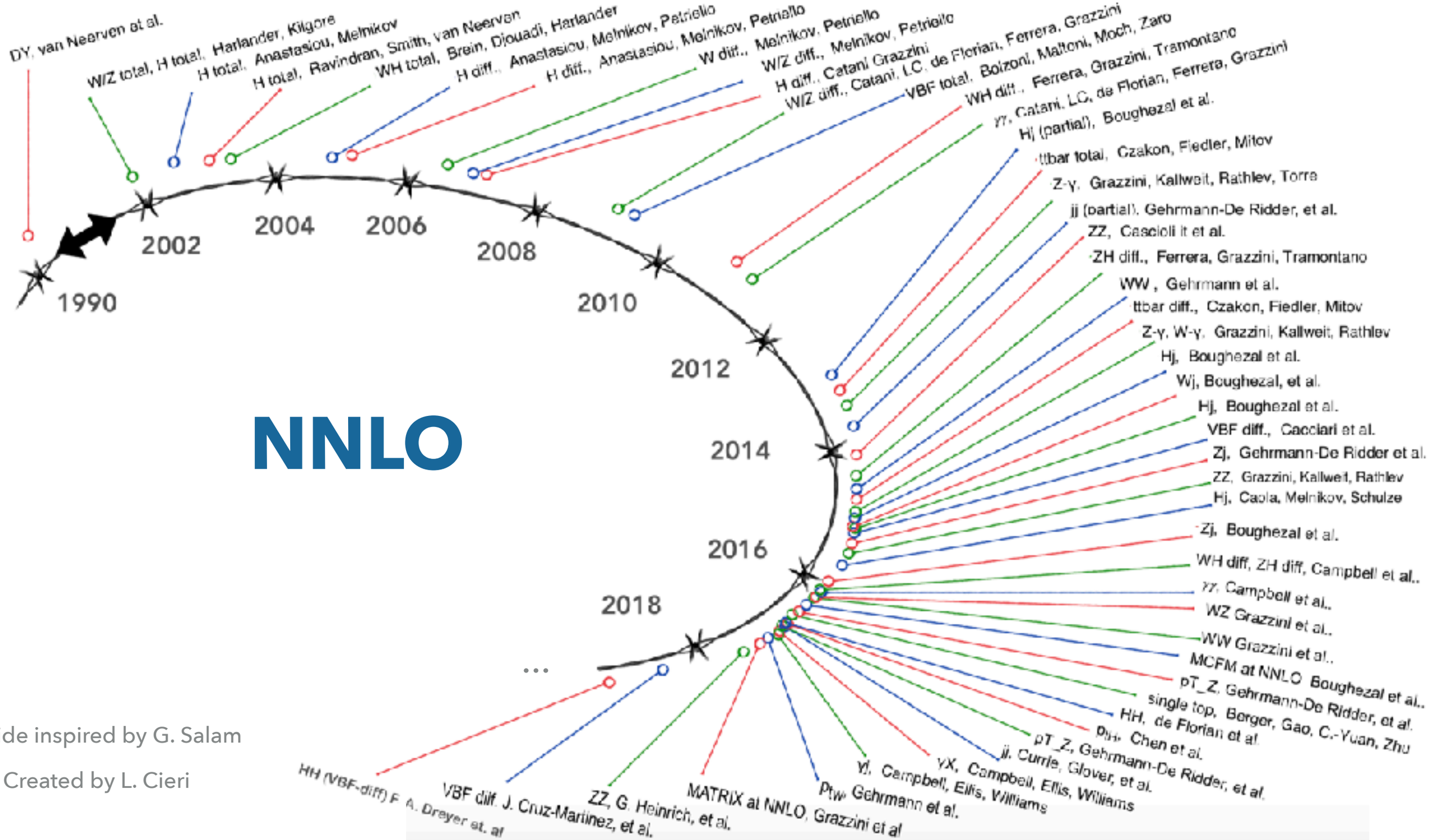
- Perturbative partonic cross sections
- QCD perturbation theory is dominant $\alpha_S = 0.118$
- Naively:

LO **NLO** **NNLO** **N3LO**

$$\hat{\sigma} = \hat{\sigma}^{(0)} + \alpha_S^1 \hat{\sigma}^{(1)} + \alpha_S^2 \hat{\sigma}^{(2)} + \alpha_S^3 \hat{\sigma}^{(3)} + \dots$$

10% 1% 0.1%

NNLO OVER TIME

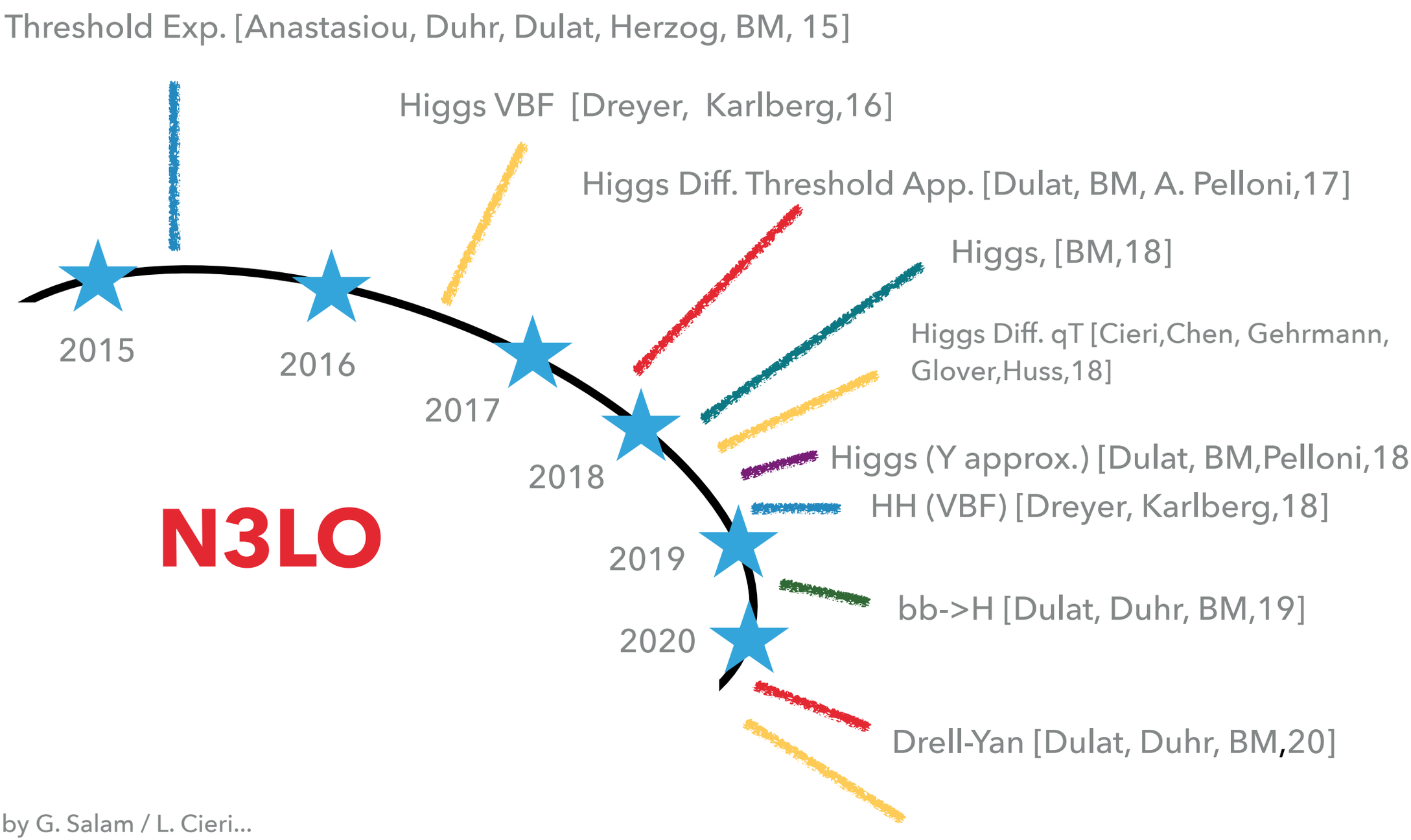


NNLO

Slide inspired by G. Salam

Created by L. Cieri

N3LO OVER TIME

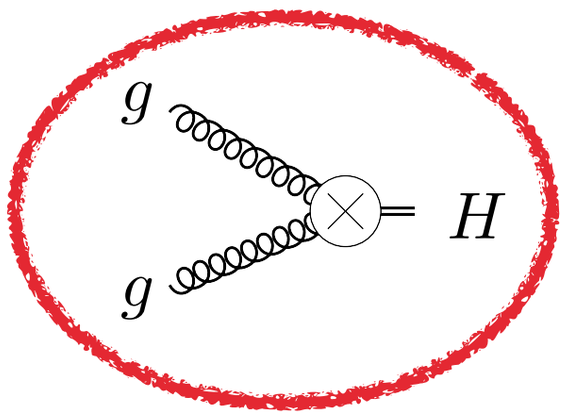


Slide inspired by G. Salam / L. Cieri...

INCLUSIVE CROSS SECTIONS

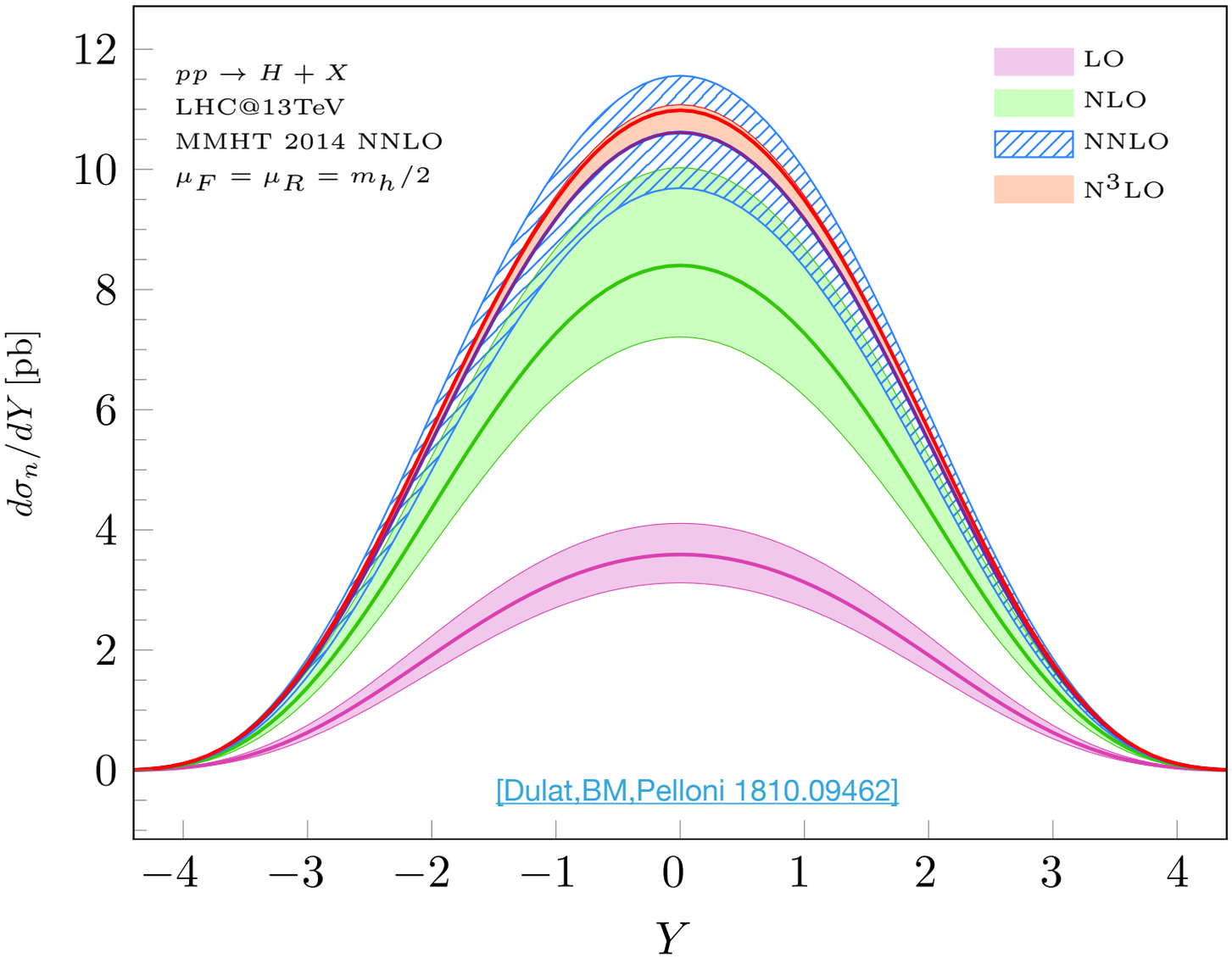
- First steps at a new perturbative order!
- Learn about the impact of perturbative corrections.
- Make use of them to improve our predictions, e.g. via K-Factors

Example: Producing a Higgs boson in Gluon Fusion



RAPIDITY DISTRIBUTION OF THE HIGGS BOSON

- First LHC cross section to be computed at N3LO.
- Notoriously large perturbative corrections.
- N3LO allows for state of the art comparisons with current LHC measurements.

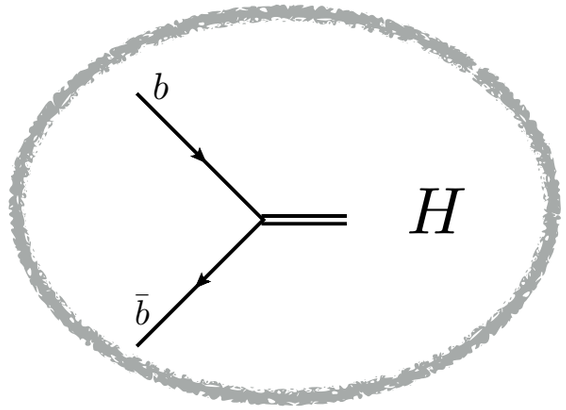


- N3LO stabilises perturbative expansion
- Relative size of the correction: $\delta\sigma_{N3LO} = +3.5\% \times \sigma_{NNLO}$

PRODUCING A HIGGS IN BOTTOM QUARK FUSION

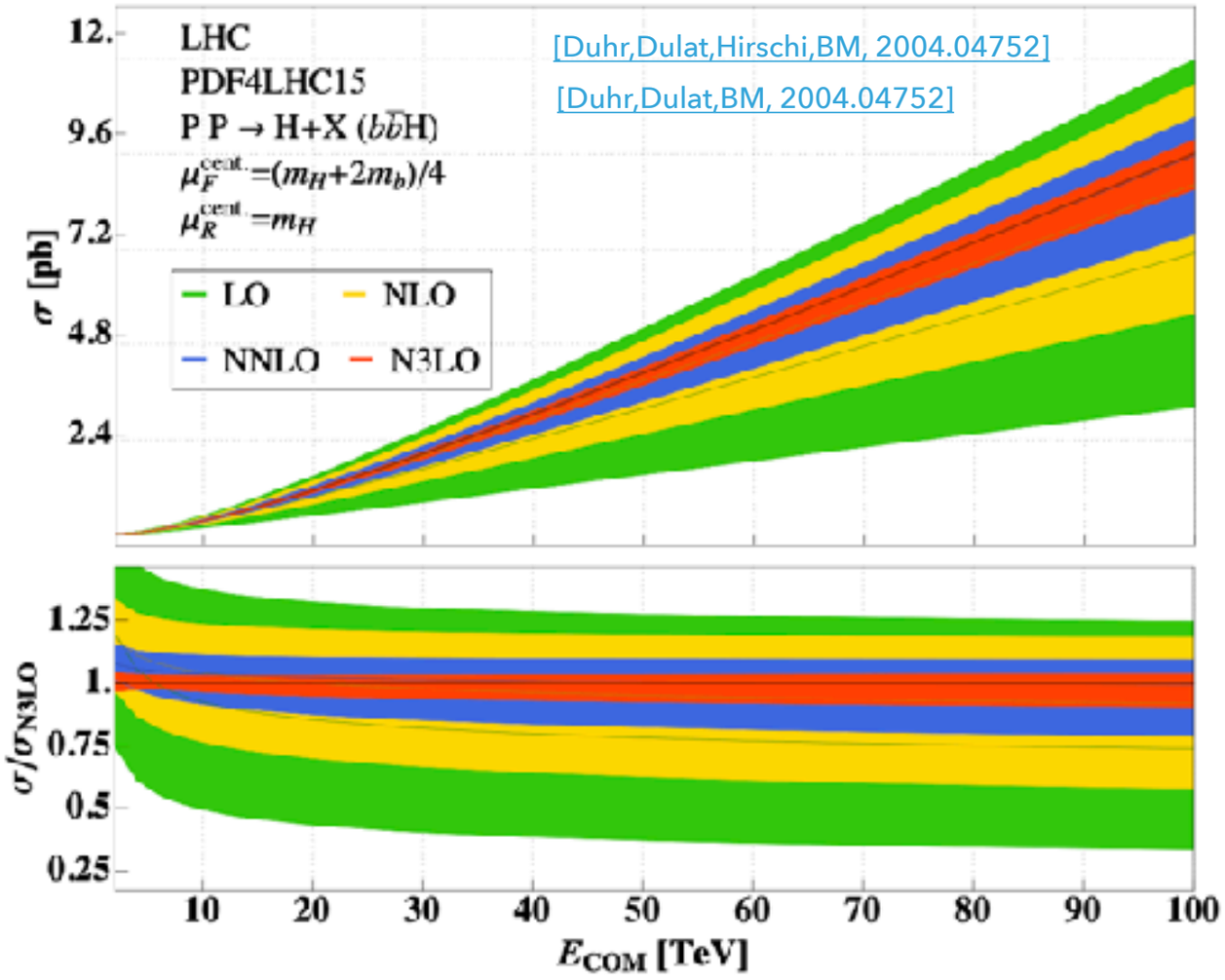
- Another example: Bottom Quark Fusion

Coupling the Higgs to the third generation!



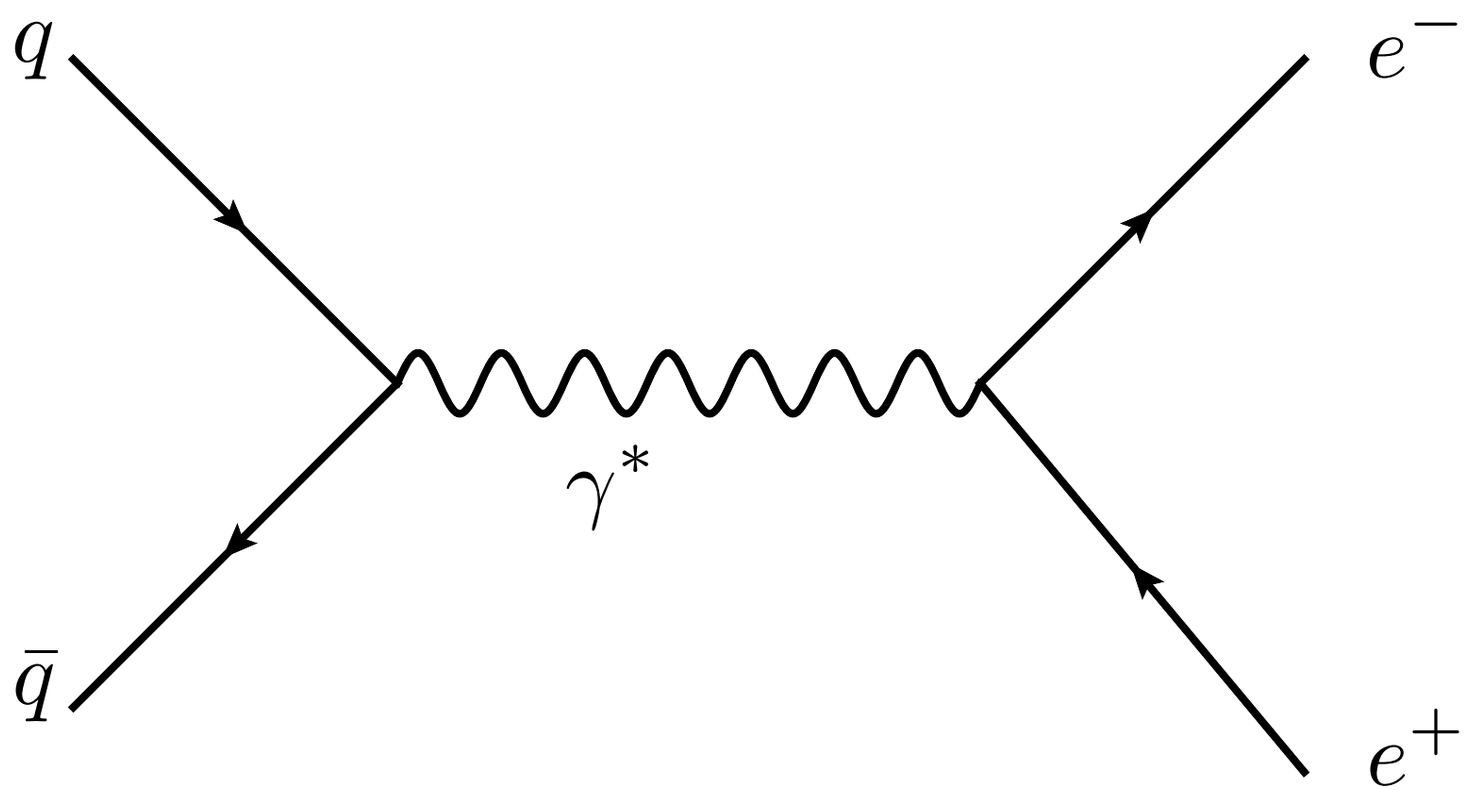
- Very nice perturbative behaviour.
- N3LO reduced uncertainty due to missing higher orders.

$$\delta\sigma_{N3LO} = -2.3\% \times \sigma_{NNLO}$$



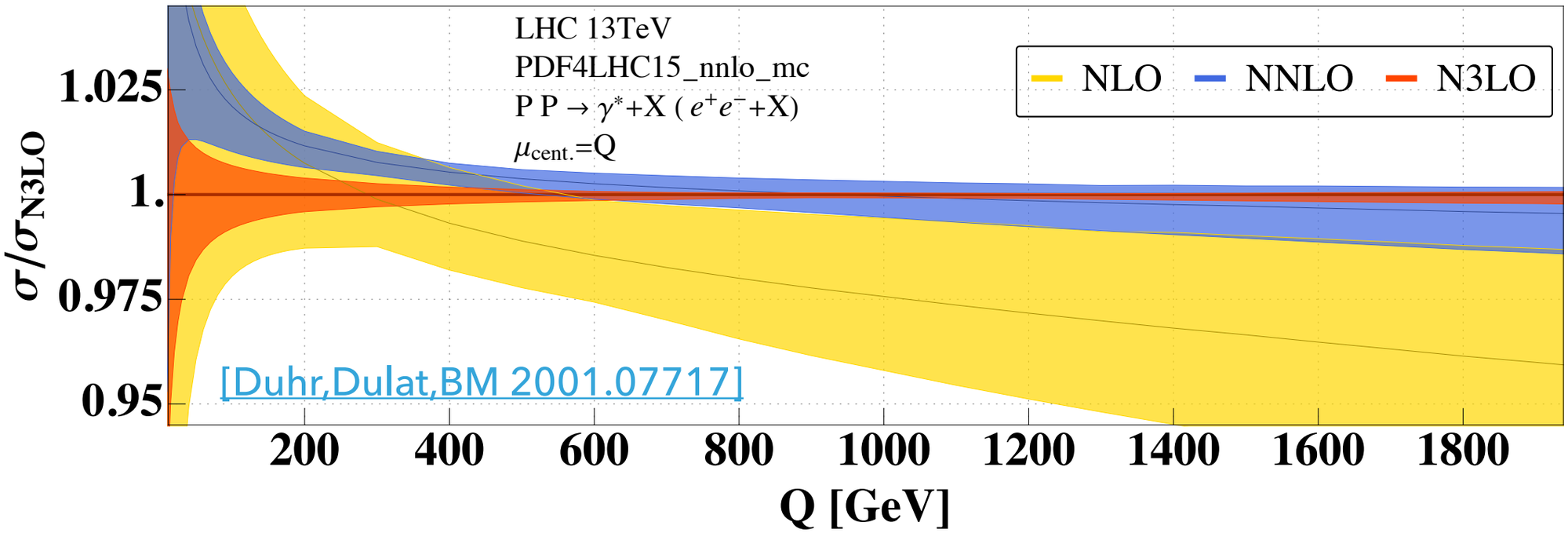
$P\,P \to \gamma^*$

The probability to produce a $e^+\,e^-$ pair



DRELL-YAN PRODUCTION

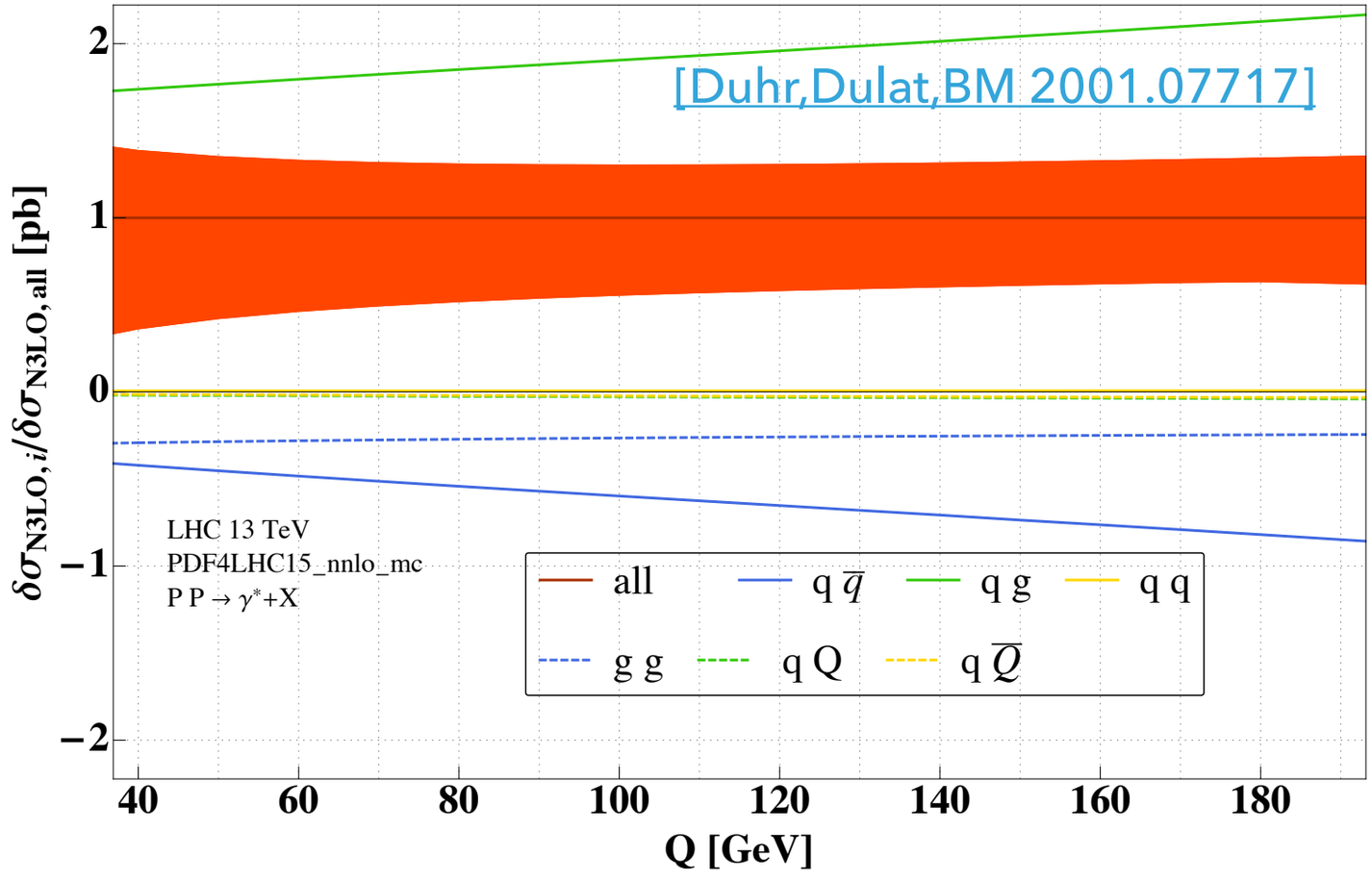
The probability to produce a $e^+ e^-$ pair



- N3LO corrections to THE LHC precision process.
- Interesting perturbative development: N3LO outside of NNLO scale band.

The probability to produce a $e^+ e^-$ pair

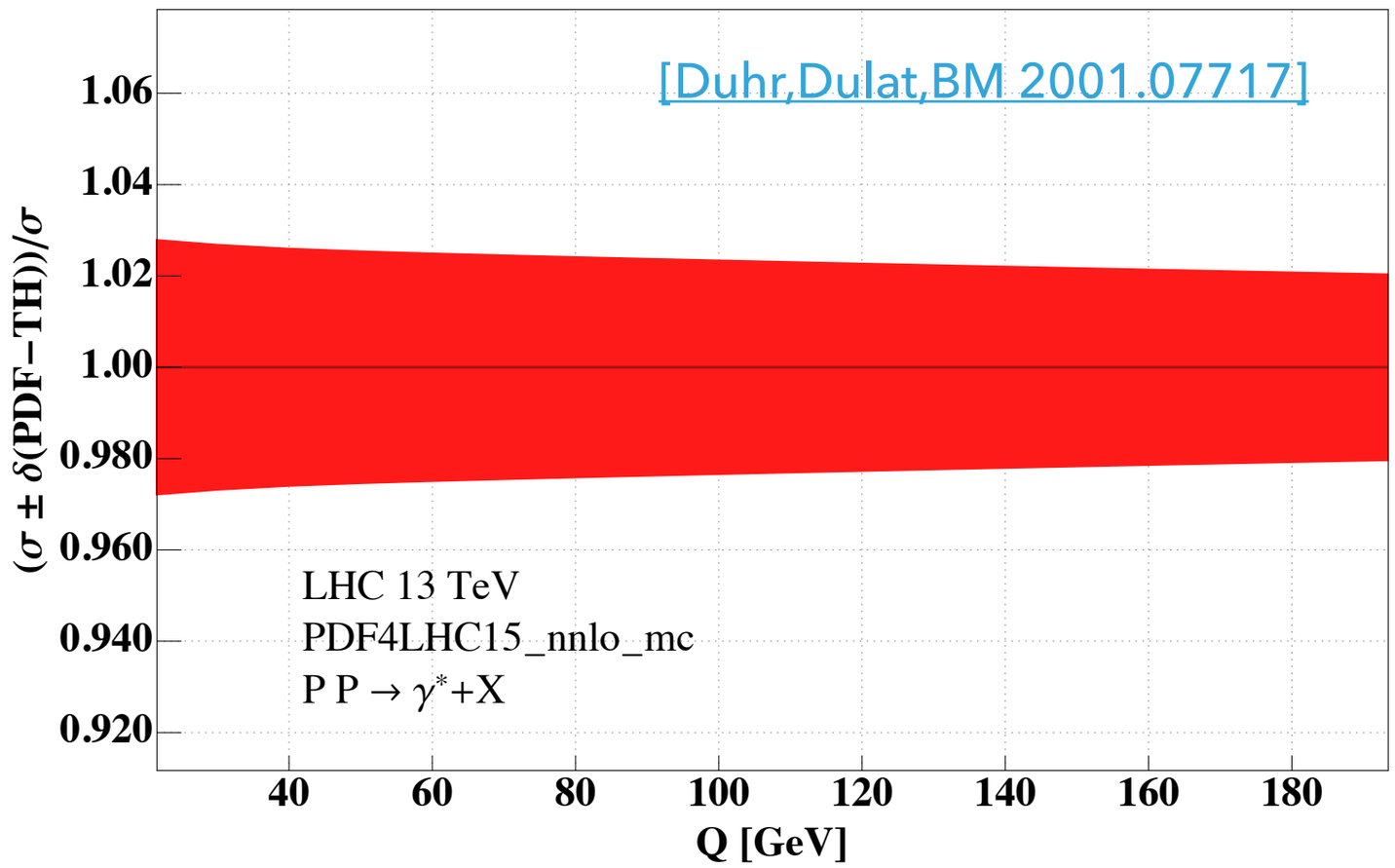
- Fairly large cancellations between different channels lead to small bands.
- Already present at NNLO.
- This is NOT a breakdown of pQCD but an encouragement to think about the way we assess uncertainties.



The probability to produce a $e^+ e^-$ pair

- Currently we only have NNLO parton distribution functions.
- How large is the mismatch?
- DIS is known at N3LO and several LHC processes become available. N3LO PDFs?

Uncertainty due to missing N3LO PDFs



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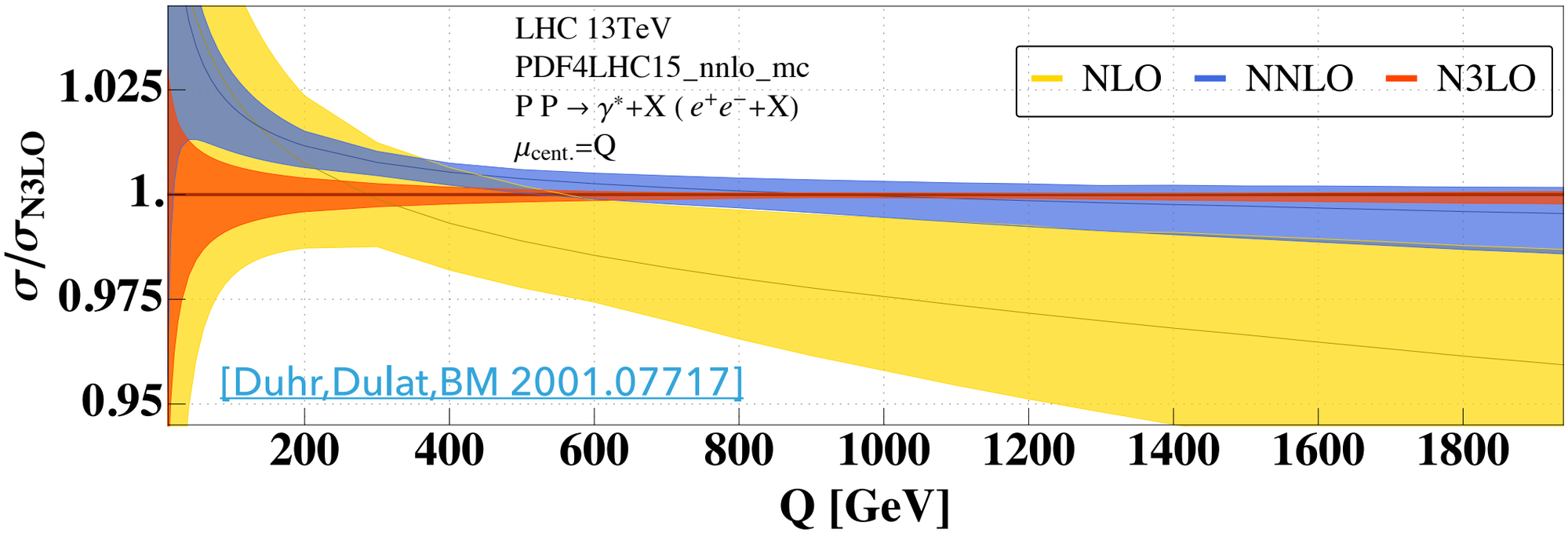


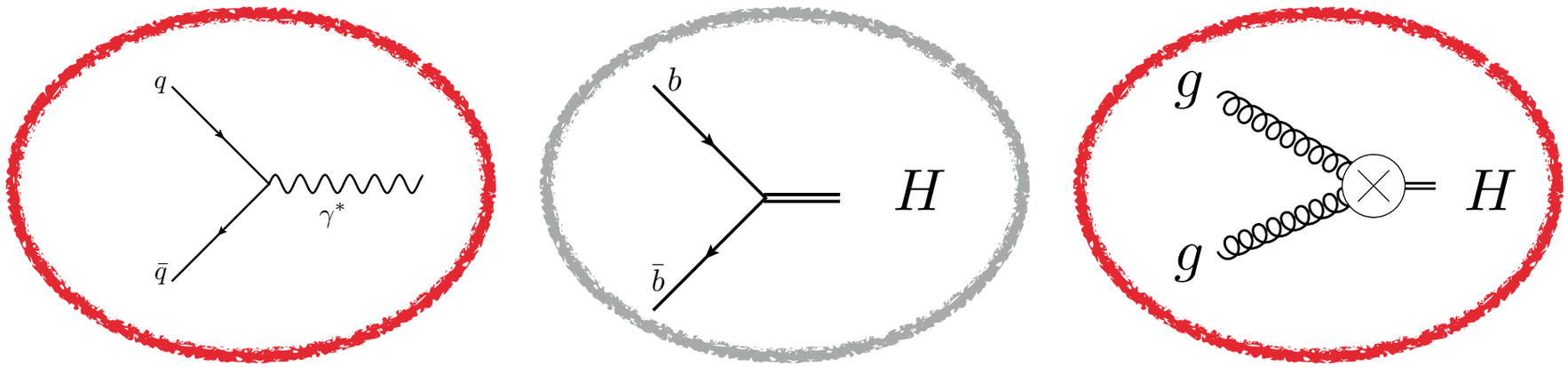
Q=60 GeV

- N3LO predictions improve the perturbative precision.

$$\delta\sigma_{N3LO} = -1.4\% \times \sigma_{NNLO}{}^{0.16\%}_{-2.6\%}$$

THE EMERGING N3LO PICTURE

We know several processes at **N3LO**:



$\frac{\delta\sigma_{N3LO}}{\sigma_{NNLO}}$ -1.4% -2.3% 3.5%

- Corrections are at the order of a few percent.
- Perturbative Uncertainty only one source of uncertainties: PDFs, EWK, Masses, Coupling Constants, …
- Same as precision target of LHC phenomenology.
- We are at the **beginning** of the age of wide-spread N3LO phenomenology.

PRECISION PREDICTIONS AT N3LO

- **Precise** predictions are key to reaching our phenomenology goals
  - **N3LO** is the precision frontier
- Now several processes available: DY, Higgs
  - The future: Widespread **N3LO** phenomenology

THANK YOU!