Tightening the Gap Between Scattering Amplitudes and Events at the LHC at Higher Orders

18 August – 15 September 2024

Welcome & Introductions — Week 1

Manfred Kraus & Peter Skands

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Wifi Network: ACP-physicists – Password: discovery

Scattering Amplitudes ➤ Events at the LHC

4 communities, each with own specialisations, techniques, & problems

Scattering Amplitudes & Fixed Orders

MC Event Generators & Parton Showers

Resummation & PDFs

LHC Experiments (& Pheno Applications)

Phase-Space Integrations

Speed, Efficiency

Numerical Stability

Accuracy

Codes/Interfaces

Combinations

Uncertainties

…

Focus Weeks

Based on participants, we envision weekly "focus topics"

Not meant to be exclusive!

Week 1: FO Developments and how to make them available?

NNLO computational complexity and how much further we can push the limit?

What is new on the PDF precision frontier?

How do we move towards NNLO for experimentalists? (FO, MC, uncertainties…)

Week 2: (Experimental) Demand for Precision in Showers and Computations: Status, Problems and Outlook.

Week 3: Fixed Order as a proxy to realistic - LHC like observables

Week 4: The path to Higher Shower Accuracy

Week 1 — Scheduled Activities

Monday	Tuesday	Wednesday	Thursday	Friday
10-12am (Flug) Welcome & Self-Introductions			**10-12am (Bethe Library & Breakout Rooms)** Focused Discussions & Tutorials	
3pm (Patio) Lemonade & Cookies Meet & Greet		**2-4pm (Patio)** Focus Topic *Frontier of NNLO computations & how it can reach the experimental program?* — Fabrizio Caola	**3pm** ASC Colloquium (Flug)	
5.15pm Happy Hour (BYOB) at the Gatehouse Snowmass Village	**5pm** Picnic Area Picnic & BBQ (Potluck/BYO)	**5.30pm** Public Lecture: *The Edge of Atom Land: News from the Energy Frontier* — Jon Butterworth		

Tuesday BBQ & Picnic

Tuesday 5-7pm @ ACP Picnic Area

Physicist's BYO Picnic for participants & their families.

You should bring food to grill and beverages.

ACP supplies plates, utensils, grills, condiments, chips, and watermelon.

First time in Aspen?

Beautiful place to hike and explore

But be aware of the **altitude**

Aspen town is at **8,000 feet ~ 2.5km**

(1.5km higher than Les Houches/Chamonix)

Mountains reach 14,000 feet > 4km

Bring and wear **sunscreen** (& appropriate shoes, clothes)

+ First few days until you acclimate:

Stay hydrated: **Drink plenty of water** (& limit alcohol intake)

Take it slow: **Limit physical exercise**


THE BEARS
ARE
HUNGRY

Acknowledging the Aspen Physics Center

Participants should acknowledge NSF grant:

“This work was initiated / performed / performed in part at the Aspen Center for Physics, which is supported by National Science Foundation grant PHY-2210452.”

Recipients of Simons Foundation support:

”This work was initiated / performed / performed in part at the Aspen Center for Physics, which is supported by a grant from the Simons Foundation (1161654,Troyer)”

Recipients of Alfred P Sloan Foundation support:

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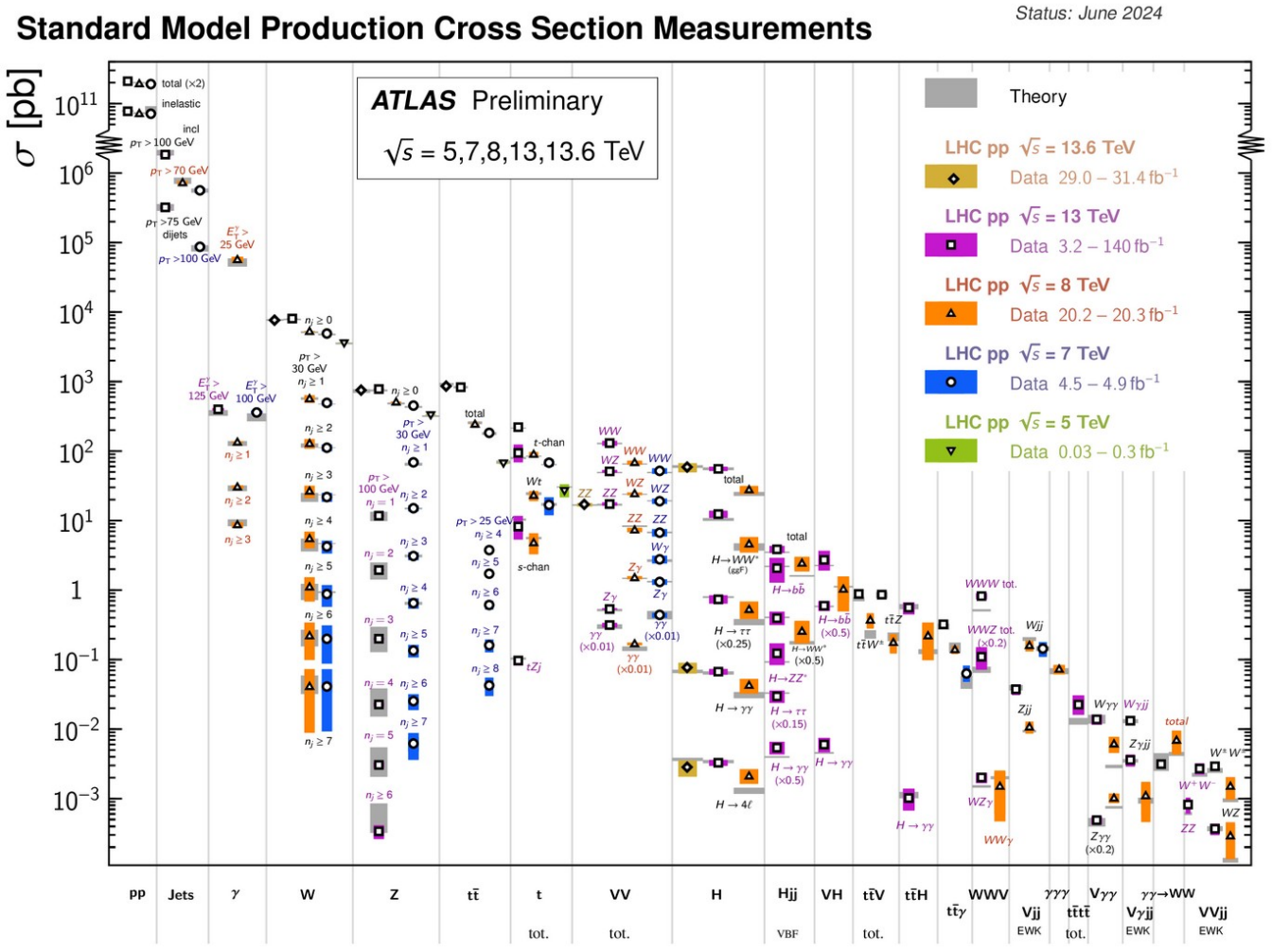
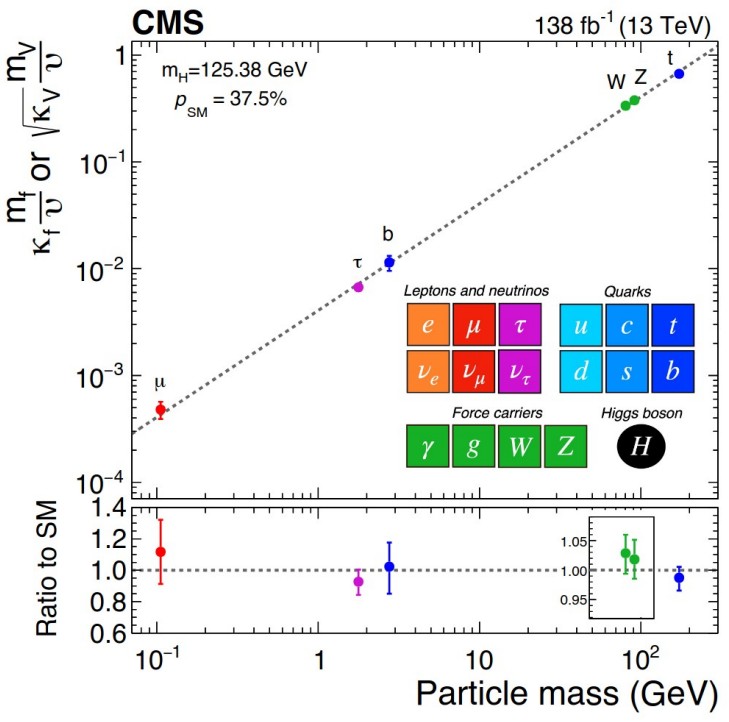
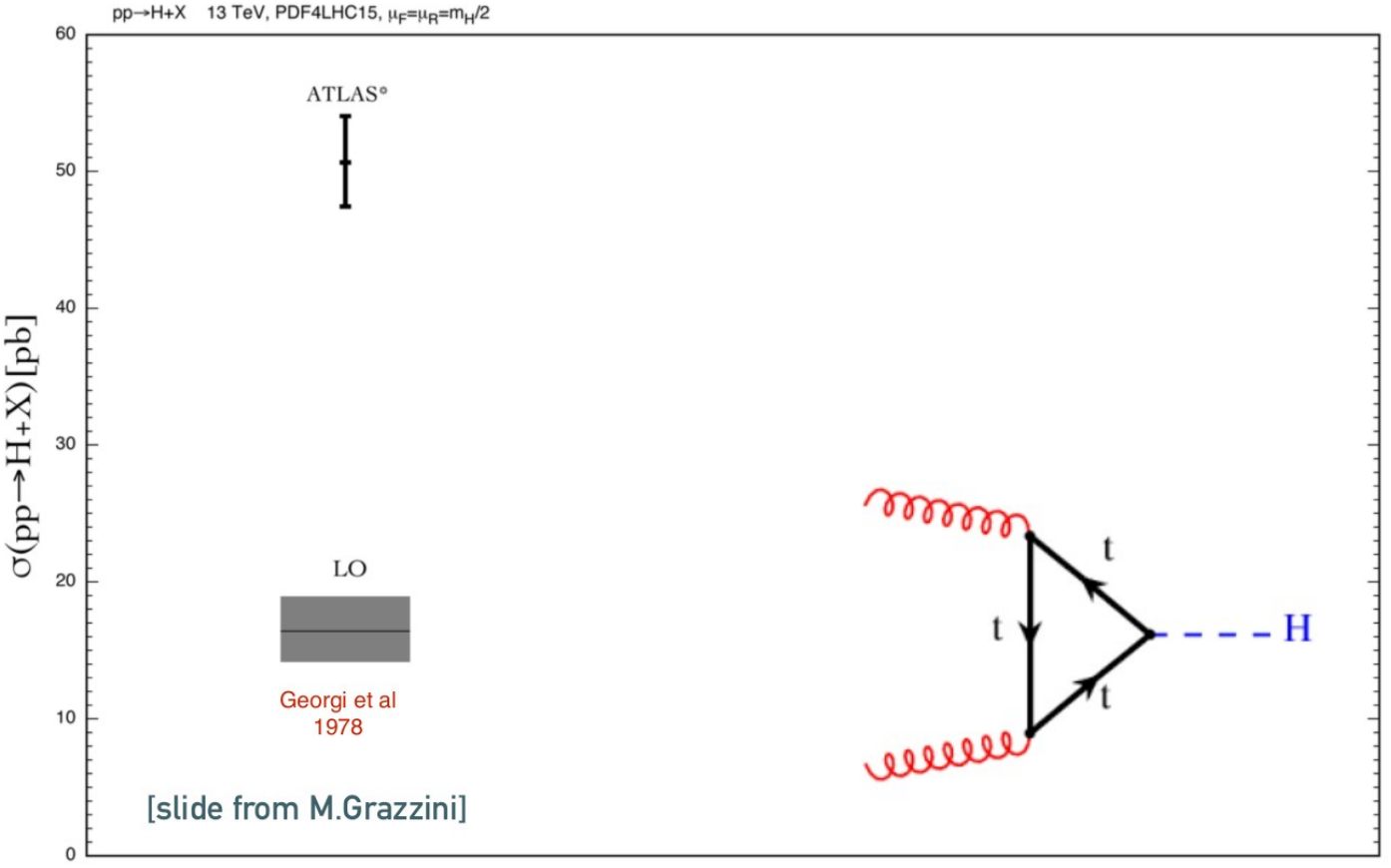
Precision Demands at the LHC: An Example


Standard Model Production Cross Section Measurements
Status: June 2024
ATLAS Preliminary
√s = 5,7,8,13,13.6 TeV
Theory
LHC pp √s = 13.6 TeV
Data 29.0 – 31.4 fb⁻¹
LHC pp √s = 13 TeV
Data 3.2 – 140 fb⁻¹
LHC pp √s = 8 TeV
Data 20.2 – 20.3 fb⁻¹
LHC pp √s = 7 TeV
Data 4.5 – 4.9 fb⁻¹
LHC pp √s = 5 TeV
Data 0.03 – 0.3 fb⁻¹
σ [pb]
pp
Jets
γ
W
Z
tt̄
t
VV
H
Hjj
VH
tt̄V
tt̄H
tt̄γ
WWV
Vjj
EWK
γγγ
tt̄tt̄
Vγγ
Vγjj
EWK
γγ→WW
VVjj
EWK
tot.
VBF

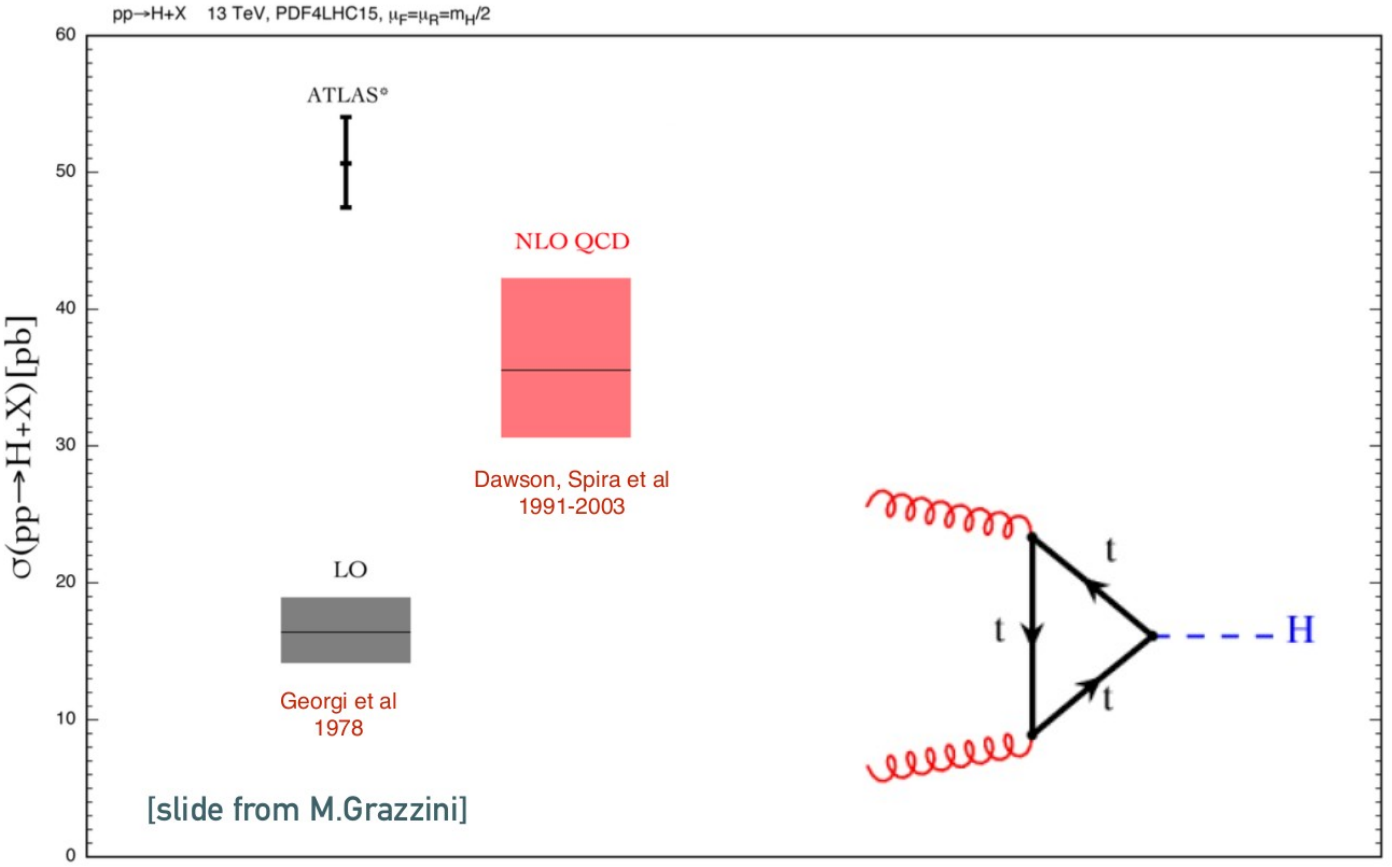

CMS
138 fb⁻¹ (13 TeV)
m_H=125.38 GeV
p_SM = 37.5%
Leptons and neutrinos
Quarks
Force carriers
Higgs boson
Ratio to SM
Particle mass (GeV)

Higgs Production: gg -> H

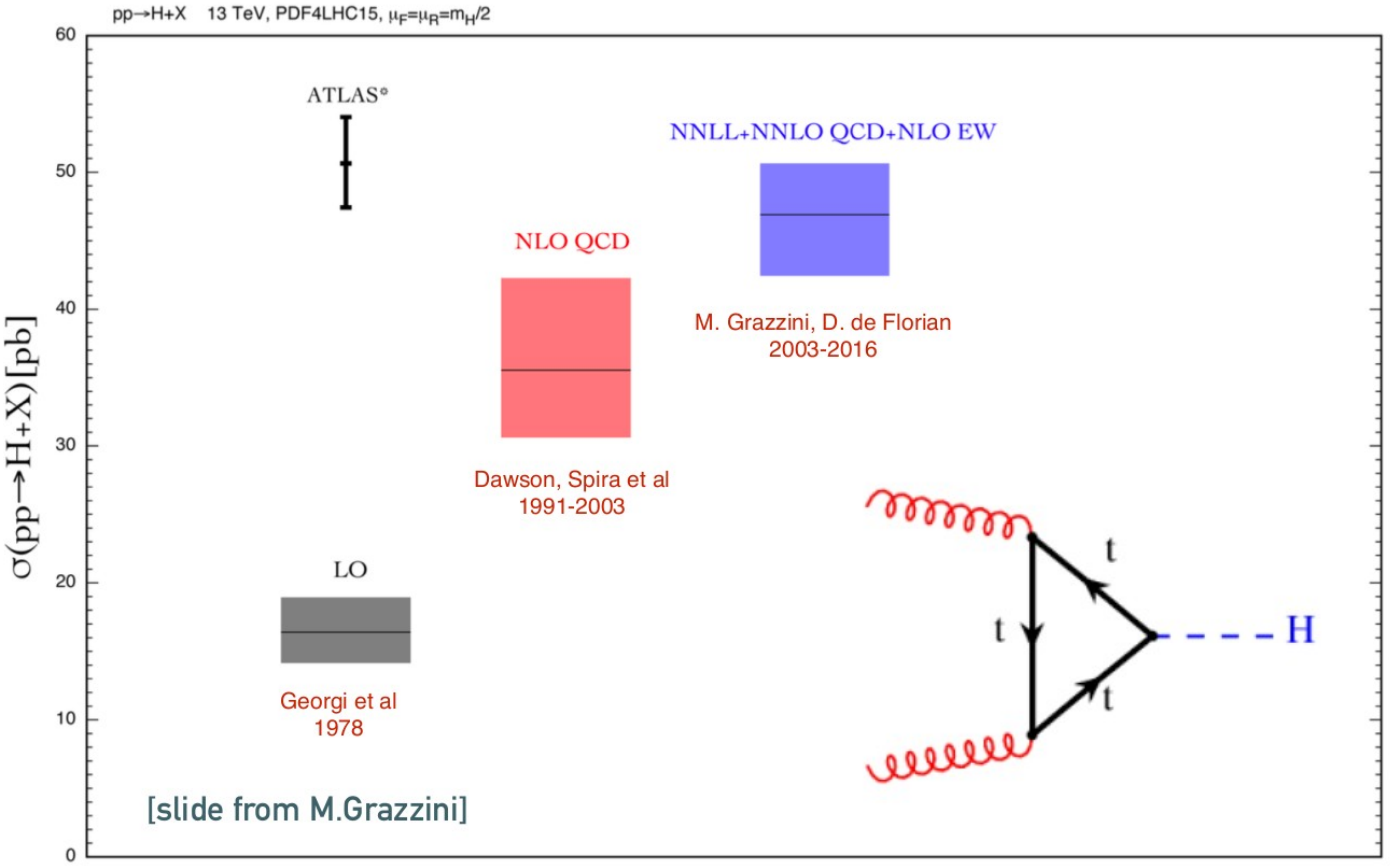


[slide from M.Grazzini]

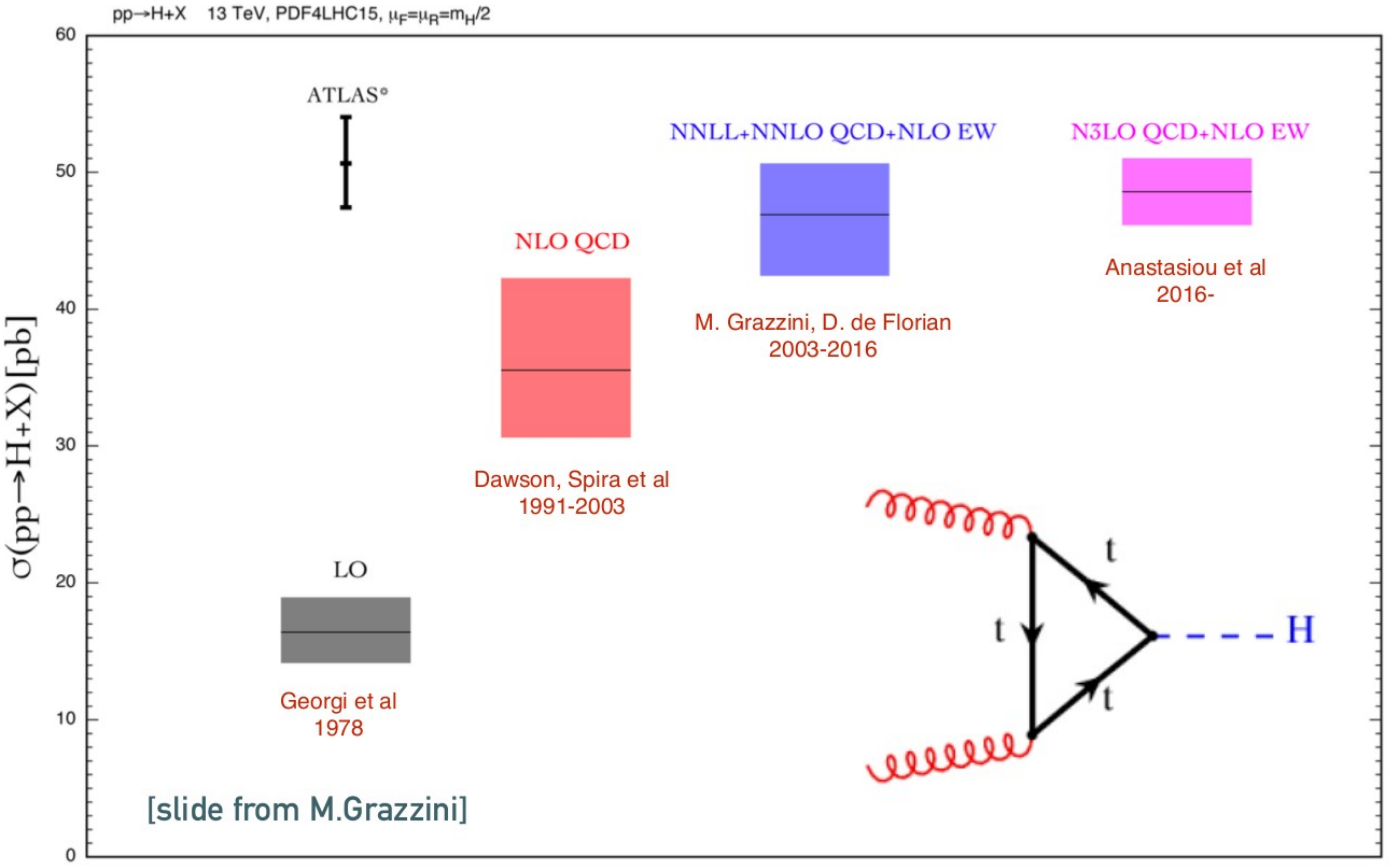
Higgs Production: gg -> H



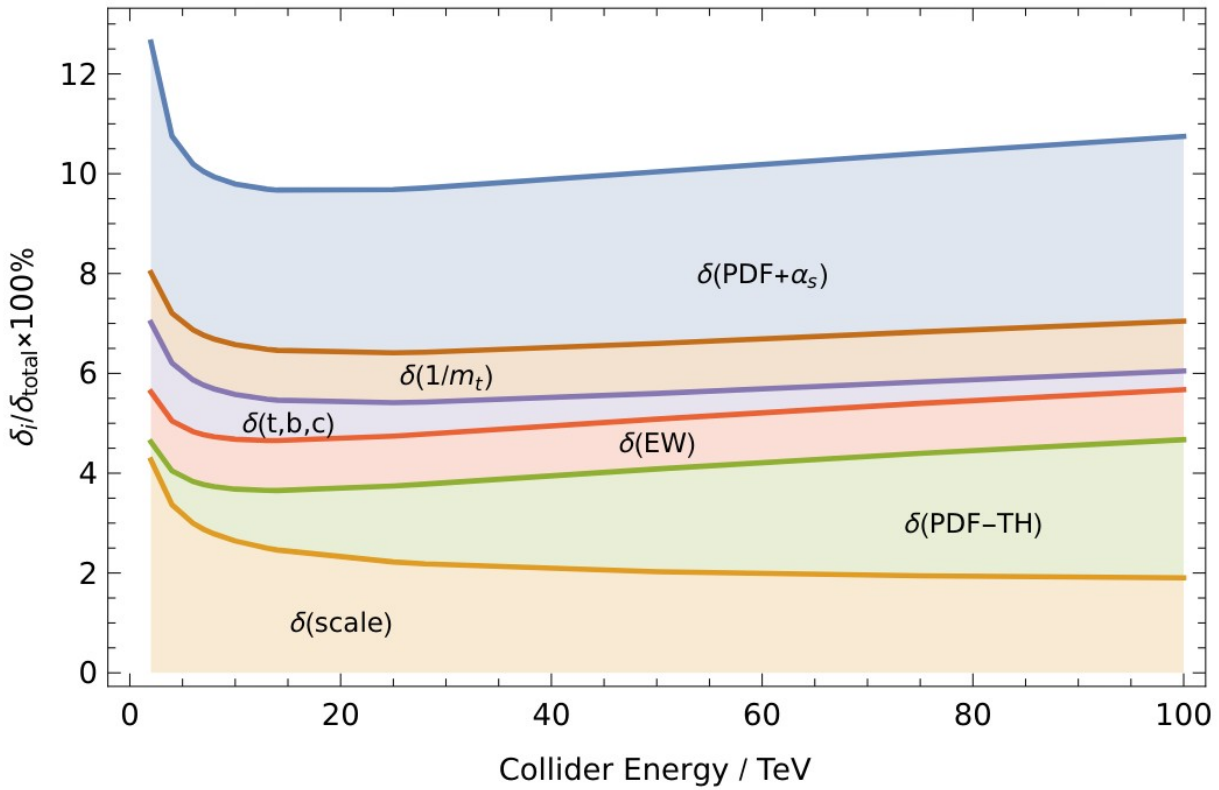
Higgs Production: gg -> H



Higgs Production: gg -> H



Higgs Production: gg -> H



[Dulat, Lazopoulos, Mistlberger arXiv:1802.00827]

Precision of strong coupling

Exact top-mass dependence

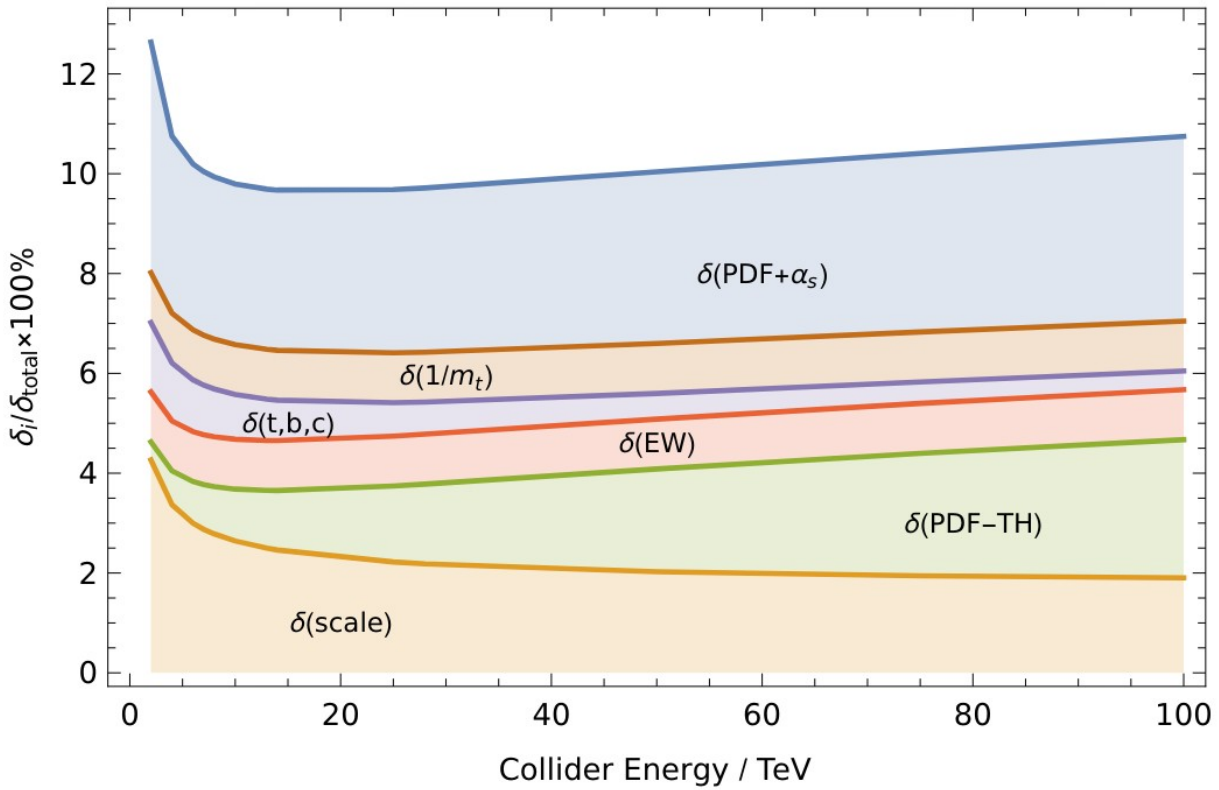
Interference with other heavy quarks

Electroweak corrections

Unknown N3LO PDFs

Scale uncertainty at N3LO

Higgs Production: gg -> H



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[Czakon et al., 2021-2024]

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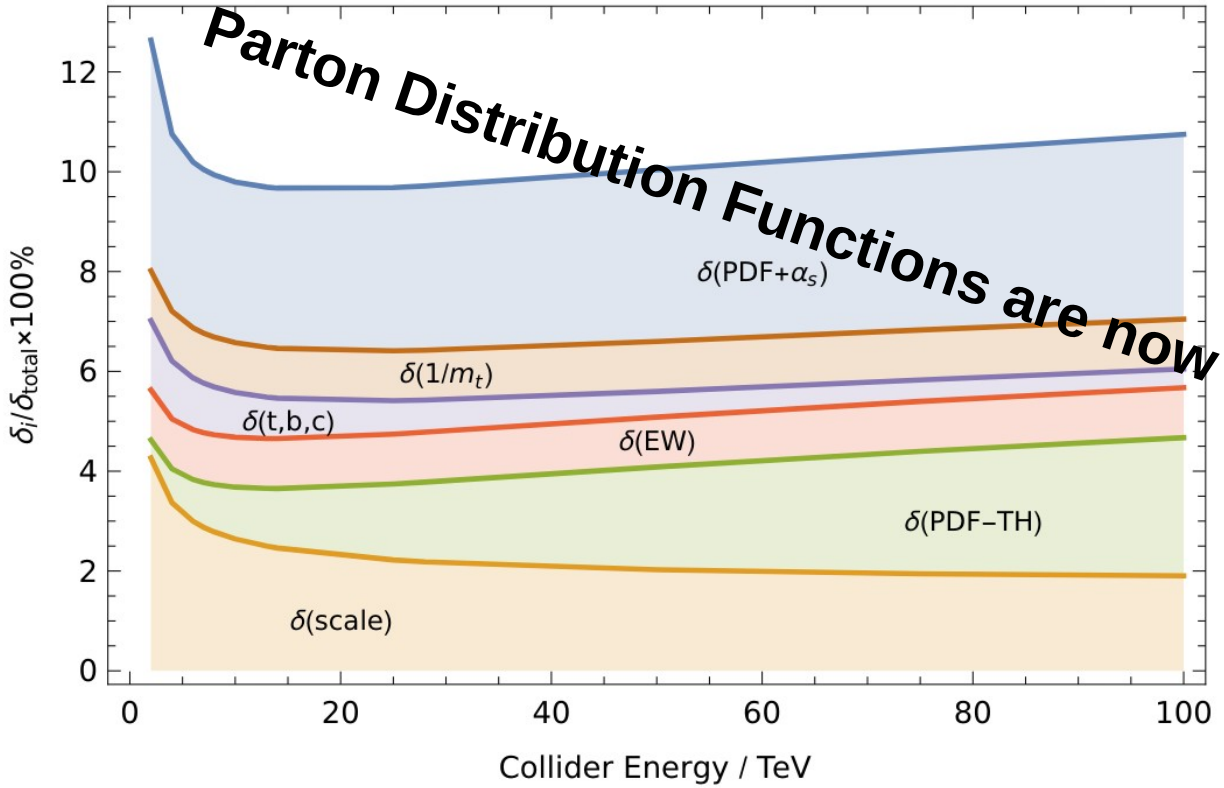

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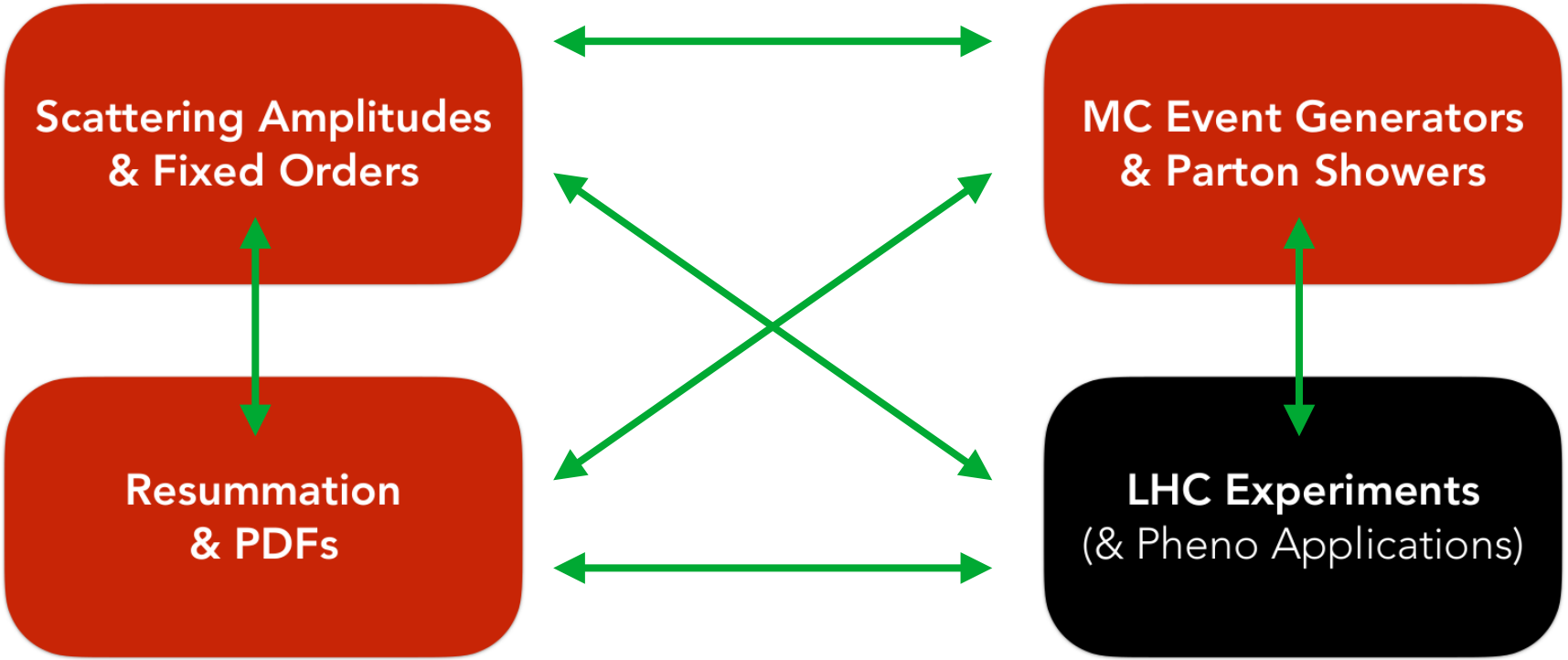

Proposed Topics from Questionaire

- Reliable estimation of theory uncertainties
- Resummation of super-leading logarithms
- Efficiency of NNLO calculations
- Non-perturbative and power corrections
- Parton shower matching at NNLO
- Accuracy of Parton distribution functions
- Event Generators
- Automation of two-loop amplitueds
- ….