Automatised computations of EW corrections using Sherpa+Recola

Mathieu PELLEN

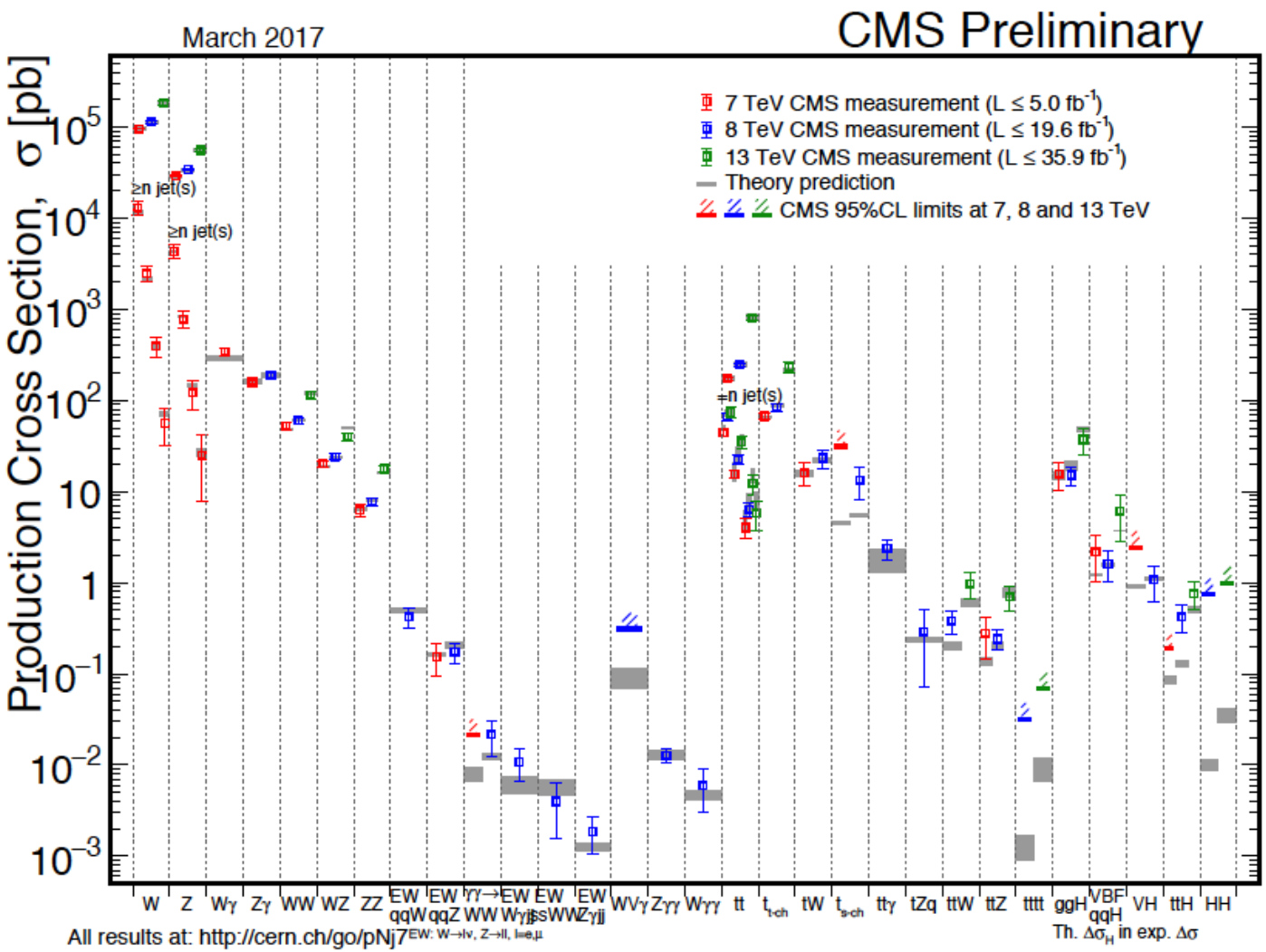
Institute for Theoretical Physics and Astrophysics,
University Würzburg

Based on: **[arXiv:1704.05783]**

In collaboration with:
B. Biedermann, S. Bräuer, A. Denner, S. Schumann, J. M. Thompson

Rencontres de Blois - 2017
Blois, France

30th of Mai 2017



→ Precision physics in both experiment and theory

Many effects to be taken into account ...

- NLO QCD: $\mathcal{O}(\alpha_s)$, NNLO QCD: $\mathcal{O}(\alpha_s^2)$ ...
- Resummation: $\mathcal{O}(\alpha_s^n \log^n)$
- Matching to parton shower: $\mathcal{O}(\alpha_s \log)$
- Merging
- Off-shell effects: $\mathcal{O}(\Gamma/m)$
- NLO EW: $\mathcal{O}(\alpha) \rightarrow \alpha \sim \alpha_s^2$

$\rightarrow$ Automatisation of NLO EW corrections ...
... in publicly available Monte Carlo (MC) programs
$\rightarrow$ example: SHERPA+RECOLA

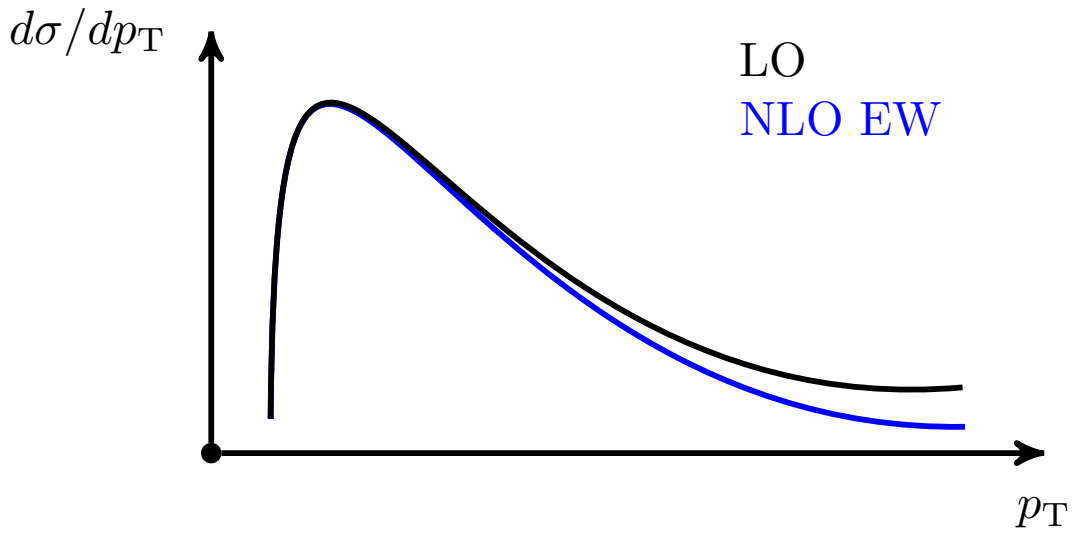
Disclaimer: no review of the recent progresses @ NLO EW
→ Going towards full off-shell computation or all NLO orders

- ZZ [Biedermann et al.; 1611.05338, 1601.07787]
- WW [Biedermann et al.; 1605.03419], [Kallweit et al.; 1705.00598]
- tt [Pagani et al.; 1606.01915], [MP et al.; 1607.05571], [Czakon et al.; 1705.04105]
- tt+V [Frixione et al.; 1504.03446]
- tth [Zhang et al.; 1407.1110], [MP et al.; 1612.07138]
- VBS [MP et al.; 1611.02951]
- WWW [Dittmaier et al.; 1705.03722]
- V+γ [Denner et al.; 1412.7421, 1510.08742]
- V+jets [Denner et al.; 1411.0916], [Chiesa et al.; 1507.08579], [Kallweit et al.; 1412.5157, 1511.08692]
- dijet [Frederix et al.; 1612.06548]

- EW corrections:

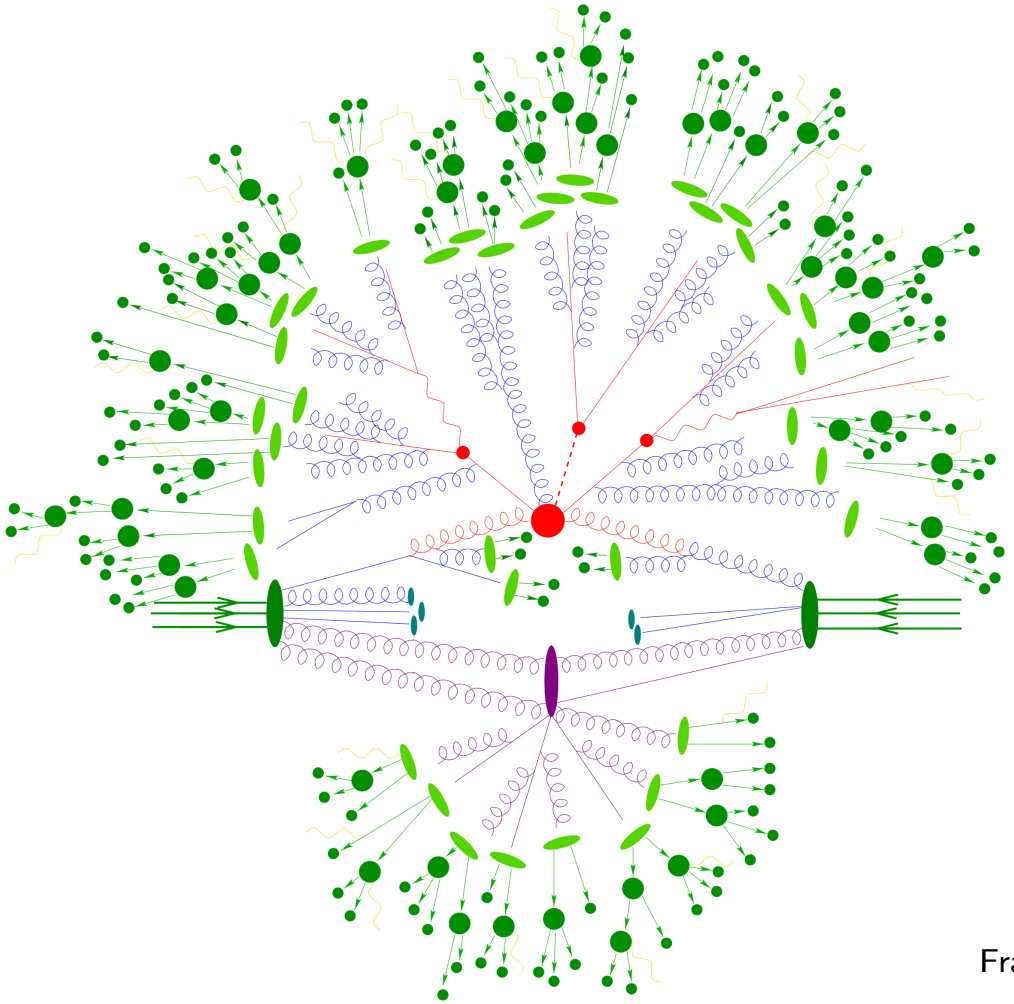
  → large in high energy region

  → Sudakov logarithms: $-\frac{\alpha}{4\pi}\log^2\left(s_{ij}/M_{\mathrm{W}}^2\right)$



→ During run II, the tail of the distributions will be probed

→ New physics contributions?



Frank Krauss

→ Monte Carlo: matrix element, parton shower, hadronisation, ...
→ Tree/one-loop matrix element generator

Tools for automatised NLO EW computations

- GoSam: not public
- MadLoop: `launchpad.net/mg5amcnlo`
  → obtained in MadGraph5_aMC@NLO (MG5)
- OpenLoops: `openloops.hepforge.org`
- Recola: `recola.hepforge.org`

Generator	Monte Carlo	Processes	Availability
GoSam	private MC	generated	?
MadLoop	MG5	generated	soon
OpenLoops	Sherpa, private MC	libraries	soon
Recola	Sherpa, private MC	dynamical	soon

- RECOLA [Actis, Denner, Hofer, Lang, Scharf, Uccirati; 1605.01090]:
  → tree and one-loop matrix element generator for QCD and EW
  → based on COLLIER library [Denner, Dittmaier, Hofer; 1604.06792]
  → NLO QCD and EW for high multiplicity processes (up to $2 \to 7$)
- SHERPA [Bothmann, Hoeche, Krauss, Kuttimalai, Schönherr, Schulz, Schumann, Siegert, Zapp]:
  → multi-purpose Monte Carlo, hard ME → hadronisation
  → `sherpa.hepforge.org`
- SHERPA+RECOLA [Biedermann, Bräuer, Denner, MP, Schumann, Thompson; 1704.05783]:
  → any process at NLO QCD and EW accuracy
  → any loop induced process
  → arbitrary flavour scheme

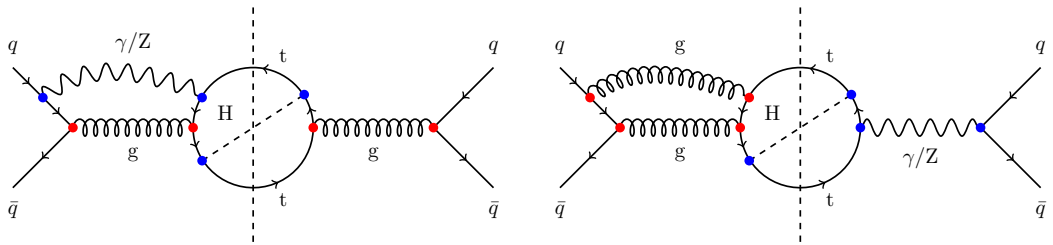
SHERPA+RECOLA [Biedermann, Bräuer, Denner, MP, Schumann, Thompson; 1704.05783]

- Phase-space point comparison vs. OPENLOOPS at NLO QCD for virtual+integrated dipole (62 processes) and for QCD loop-induced process (13 processes)
- Matching to Parton Shower for Drell-Yan+jets at NLO QCD
  → All capabilities of SHERPA can be used with RECOLA
- NLO QCD and EW corrections to:

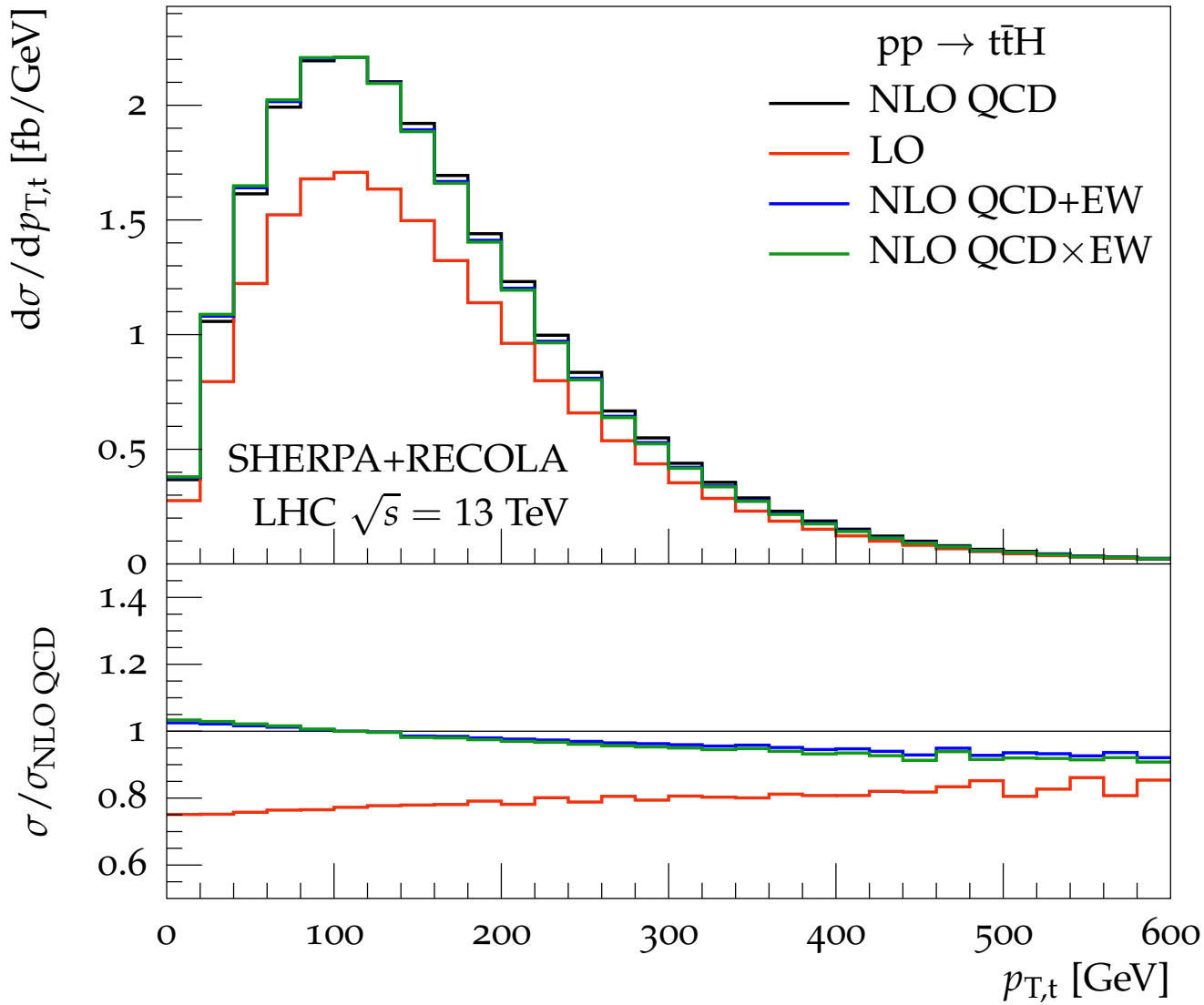
→ $pp \to V + \text{jets}$
→ $pp \to t\bar{t}H$
→ $pp \to e^+e^-\mu^+\mu^-$

$pp \to t\bar{t}H$

- Evidence Run-I at $\sqrt{s} = 7$ and 8 TeV [ATLAS+CMS, 1606.02266]
  $\to$ Yukawa coupling, new physics contributions, ...
- State-of-the art @ NLO EW: [Frixione et al.; 1504.03446], [Zhang et al.; 1407.1110], [Denner, Lang, MP, Uccirati; 1612.07138]
- Massive coloured final state
- Interference of EW and QCD processes at $\mathcal{O}\left(\alpha_s^2\alpha^2\right)$



- Validation: Les Houches report [1605.04692], comparison of OpenLoops and MG5
- Fully inclusive



→ Typical behaviour of Sudakov logarithms

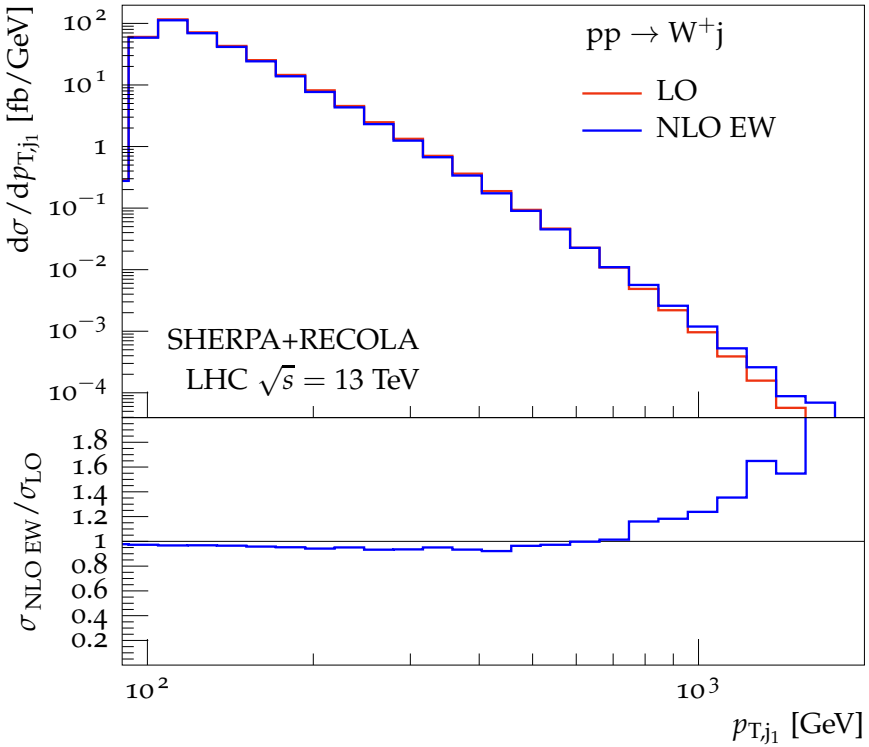
$pp \to V + \text{jets}$

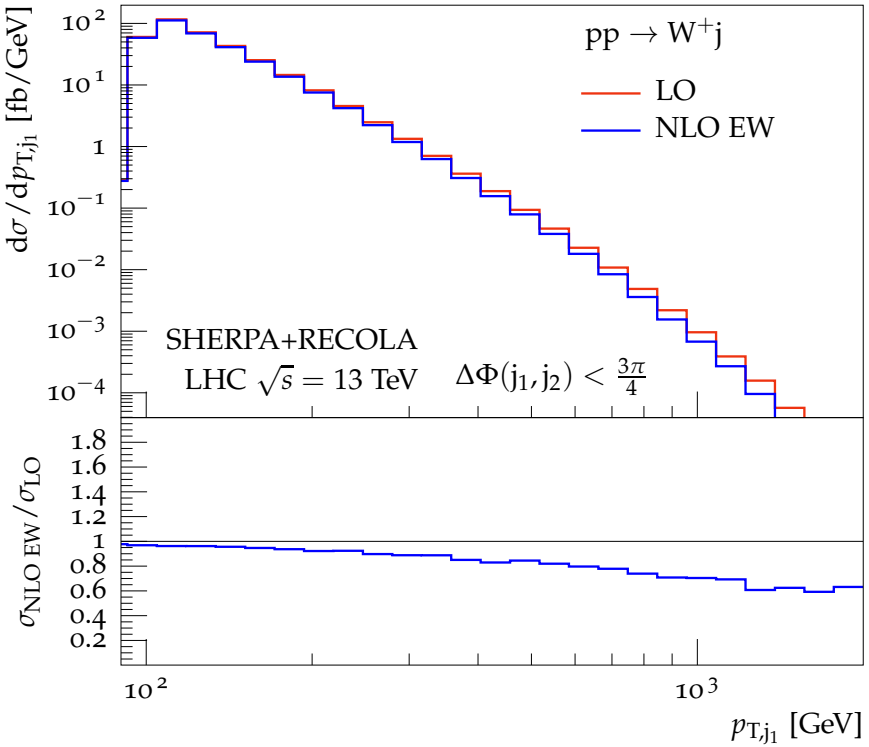
- Background for new physics searches [Lindert at al.; 1705.04664]
- State-of-the art @ NLO EW: [Denner et al.; 1411.0916], [Kallweit et al.; 1412.5157, 1511.08692]
- Computed with SHERPA+RECOLA:

$pp \to W^+ + 1/2j$ with both on- and off-shell W
$pp \to Z + 1/2j$ with both on- and off-shell Z

- Mixture of EW and QCD final states, Interferences
- Many partonic channels
- Validation vs. [Kallweit et al.; 1412.5157, 1511.08692]

pp → W⁺j





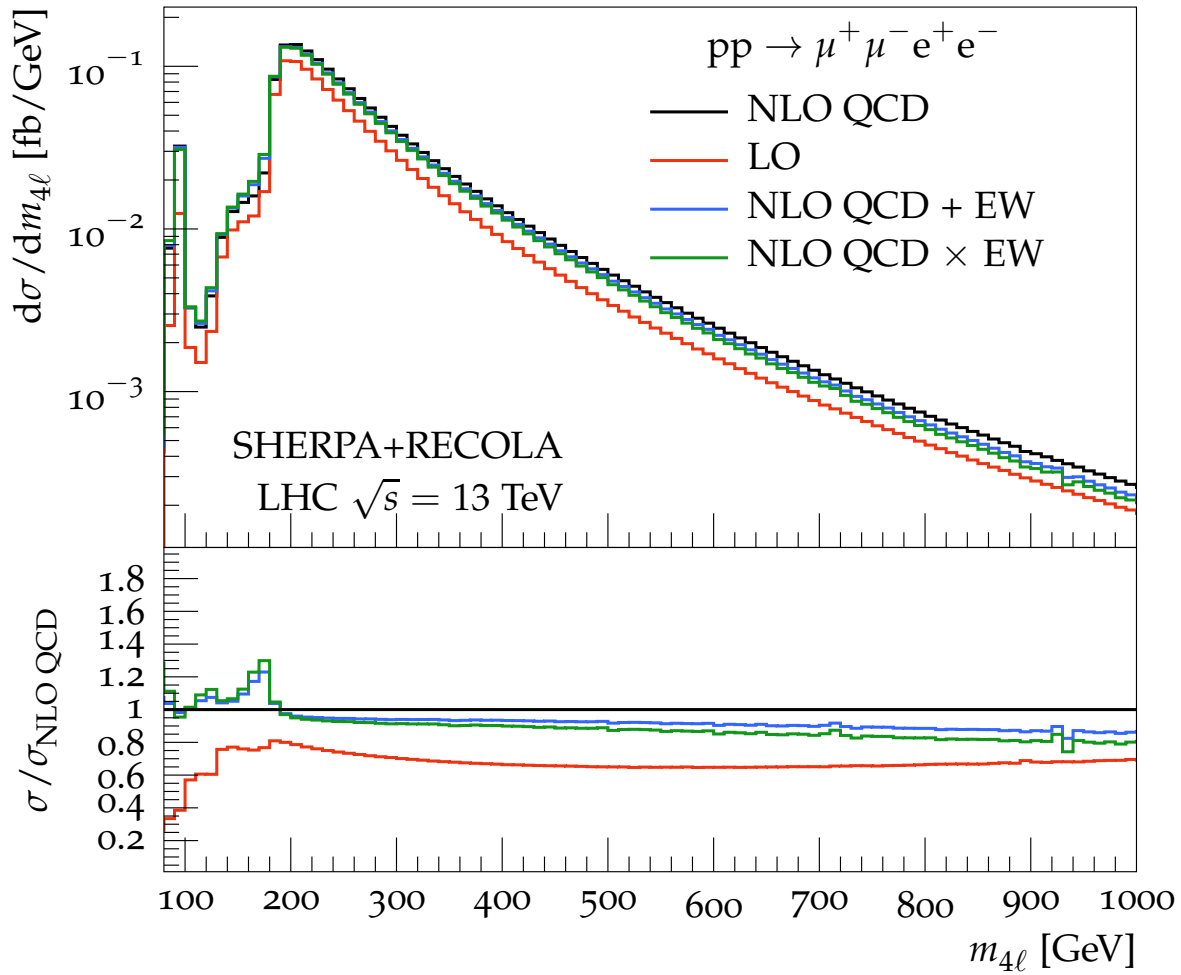
→ $\Delta\Phi\,(j_1 j_2) < 3\pi/4$ removes back-to-back topologies

→ Typical behaviour of Sudakov logarithms recovered

$pp \to e^+e^-\mu^+\mu^-$

- Final state dominated by ZZ pair production:
  $pp \to Z^\star Z^\star \to e^+e^-\mu^+\mu^-$
- Background for Higgs searches, triple gauge coupling, ...
- State-of-the art at NLO EW: [Biedermann et al.; 1601.07787, 1611.05338], [Kallweit et al.; 1705.00598]
- Complicated purely EW process
- Validation vs. [Biedermann et al.; 1611.05338]

$pp \to e^+e^-\mu^+\mu^-$



→ Non-trivial kinematic edges

Summary

- Automatisation of NLO EW corrections soon publicly available
  $\rightarrow$ Allows for systematic study of EW corrections
- SHERPA+RECOLA [MP et al.; 1704.05783]
  $\rightarrow$ any process at NLO QCD and EW accuracy
  $\rightarrow$ any loop induced process
  $\rightarrow$ examples: $pp \rightarrow V + \text{jets}$, $pp \rightarrow t\bar{t}H$, $pp \rightarrow e^+e^-\mu^+\mu^-$

These corrections are particularly relevant for ...
... SM measurements as well as BSM searches

Back-up slides

BACK-UP