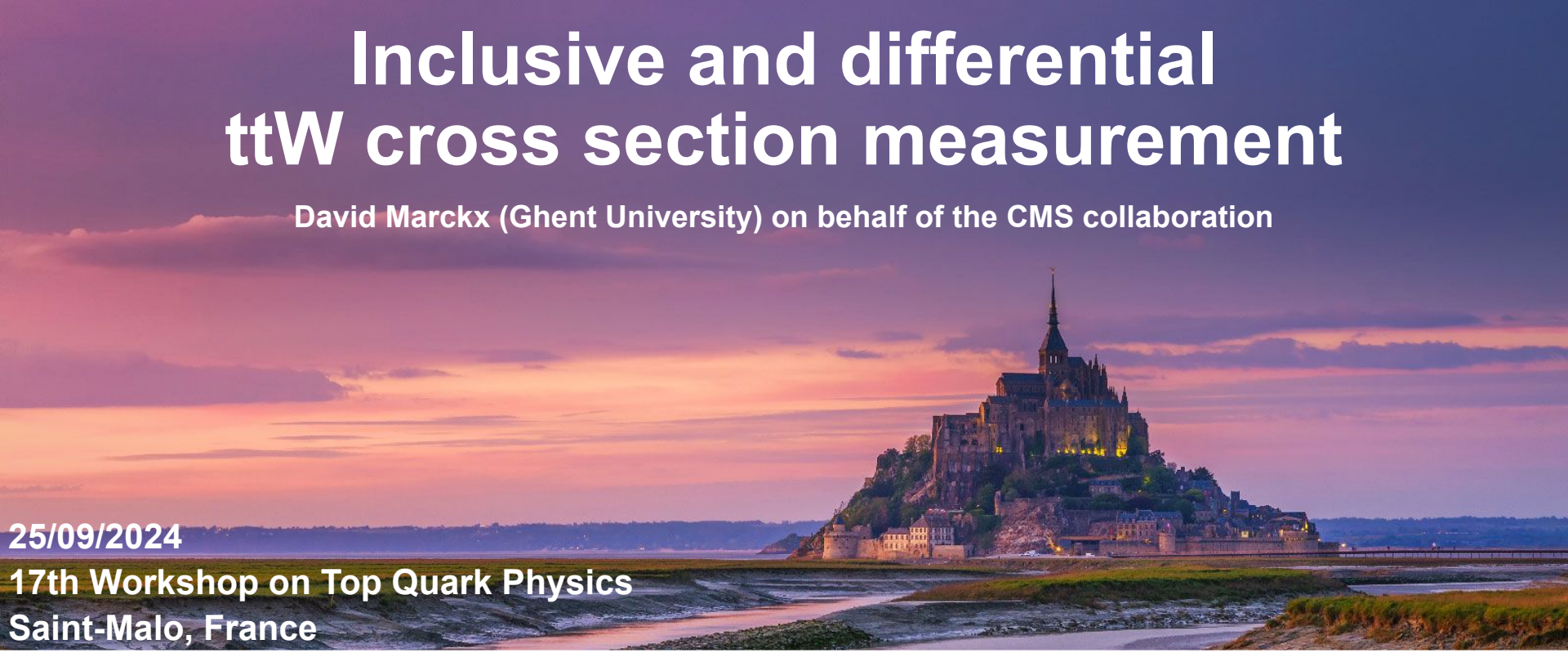
Inclusive and differential ttW cross section measurement

David Marckx (Ghent University) on behalf of the CMS collaboration



25/09/2024

17th Workshop on Top Quark Physics

Saint-Malo, France

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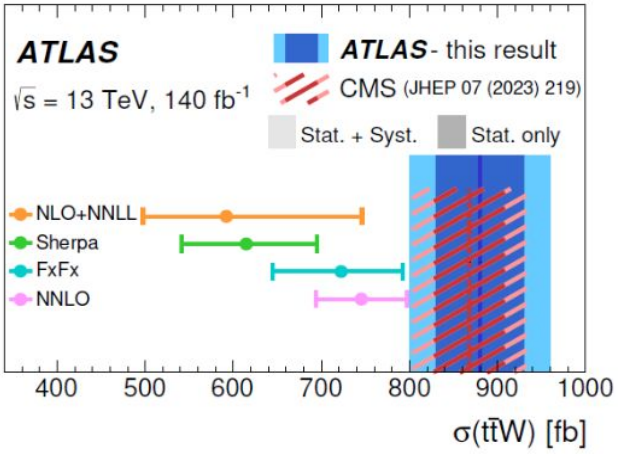
CMS Compact Muon Solenoid

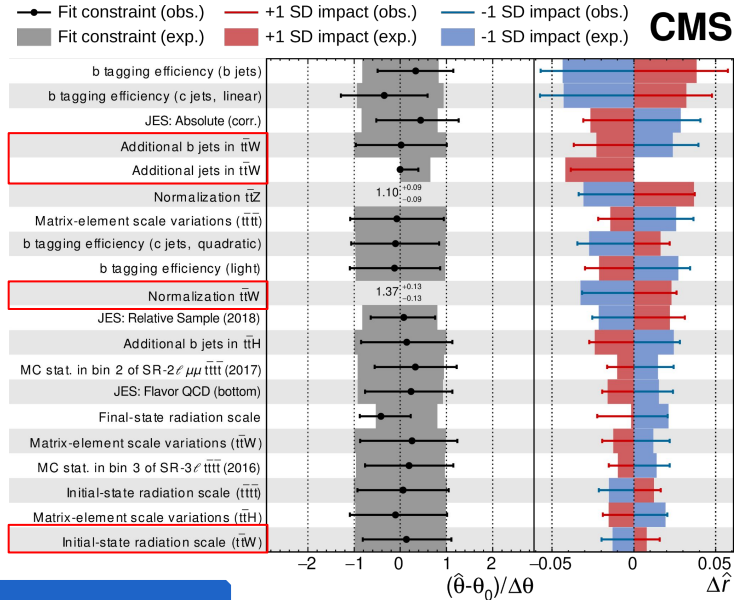
ttW: an intriguing puzzle

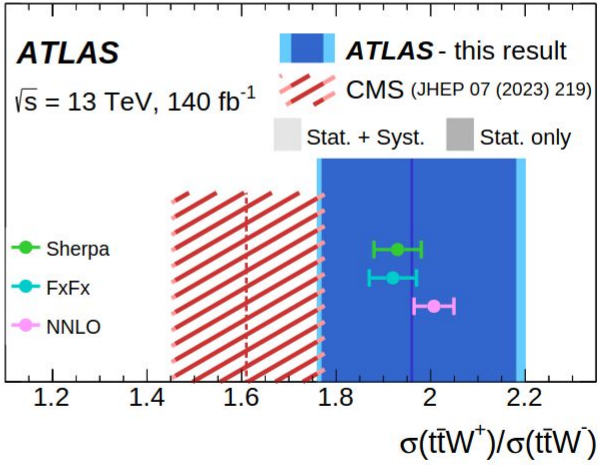
- Both ATLAS and CMS have reported a higher cross-section than the current state-of-the-art MC predictions
- Tension remains, even at NNLO!
- Also the charge asymmetry shows some interesting tension
- ttW is a leading uncertainty in many ongoing TOP efforts

[JHEP 05 (2024) 131]



[PLB 847 (2023), 138290]





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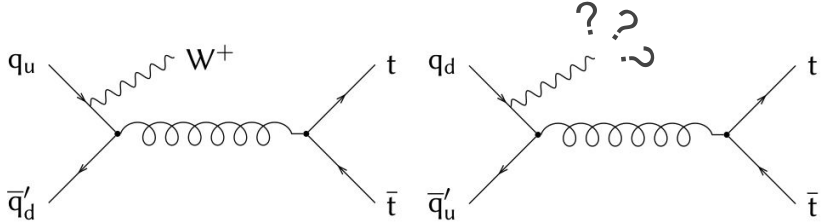
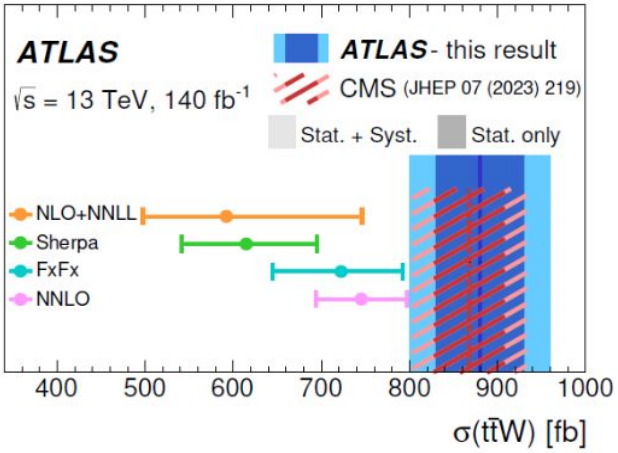
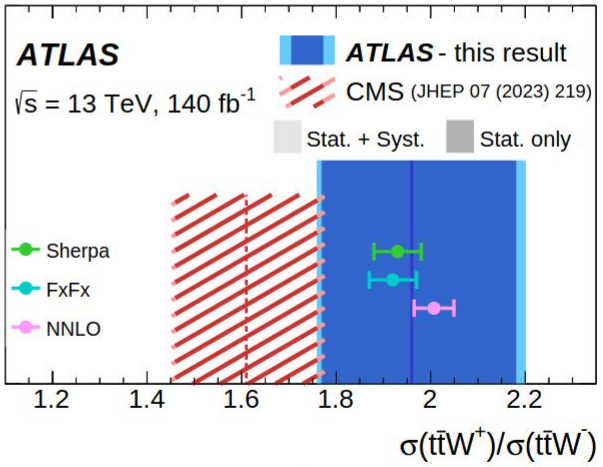
- Both ATLAS and CMS have reported a higher cross-section than the current state-of-the-art MC predictions
- Tension remains, even at NNLO!
- Also the charge asymmetry shows some interesting tension
- ttW is a leading uncertainty in many ongoing TOP efforts

a seemingly simple process that produces a lot of question marks…



[JHEP 05 (2024) 131]





[talk Jan Van der Linden]

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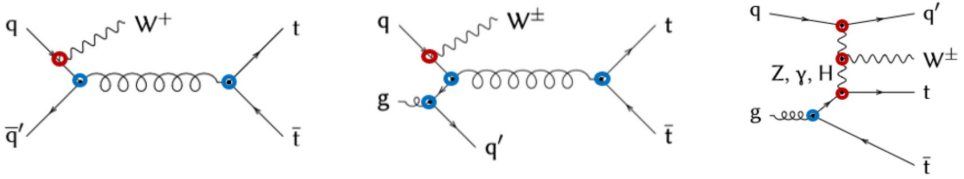
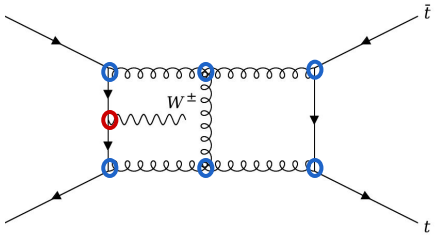
Challenges from the theory perspective

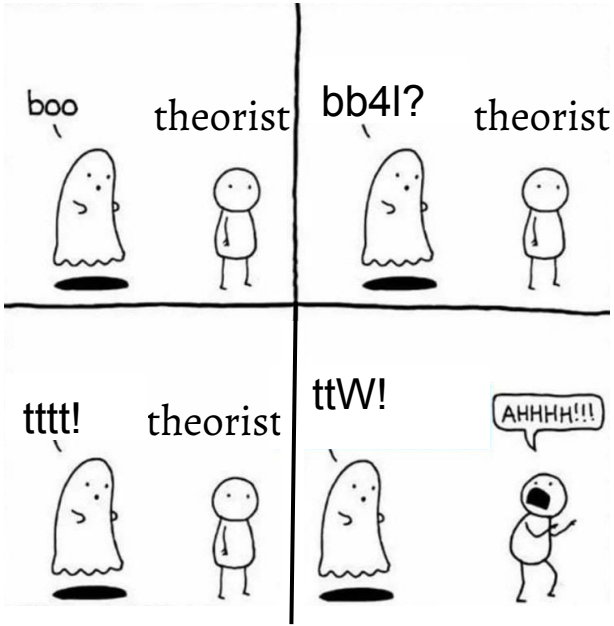
- significant higher order and EWK corrections
  - only quark induced at leading order
  - EWK t-W scattering corrections are surprisingly large



- complex loop diagrams with massive, charged and coloured objects
  - double loop diagrams



- Not clear what is to be found beyond going to NNLO
  - experimental input is needed!



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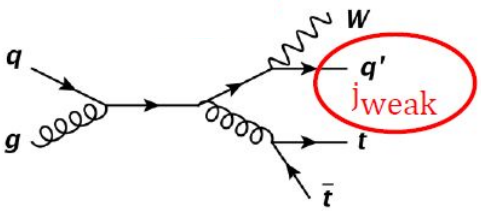
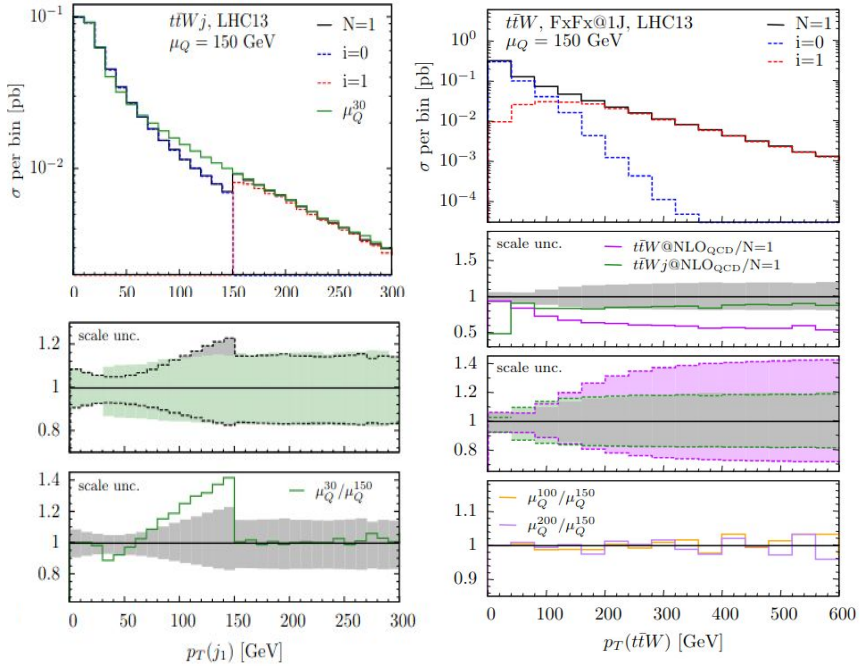
State-of-the-art MC: improved FxFx merging

- NLO QCD FxFx@2j + NLO EWK
- MadGraph with new FxFx merging [JHEP11 (2023) 029)]





- treats EWK jets by ME below merging scale.
- better description of low p_T jets
- Many other ongoing efforts

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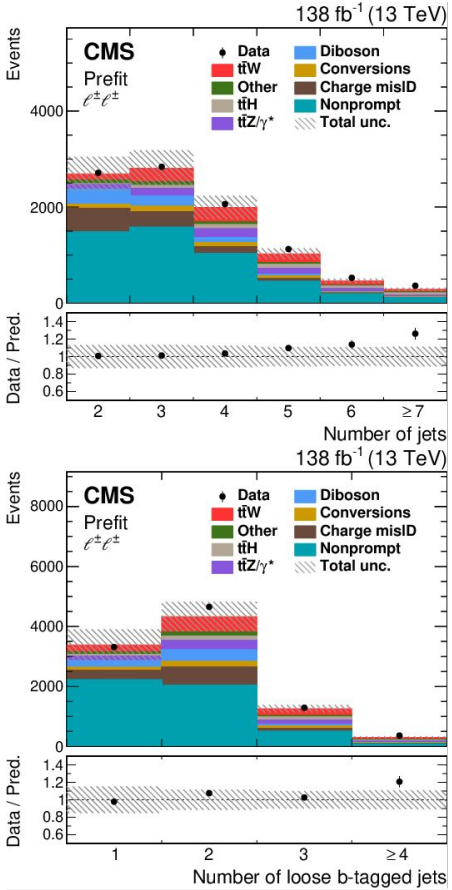
Challenges from the experimental perspective

- most sensitivity can be reached in the 2L SS region
  - reduce tt, ttZ, ttH, …
  - require (b-)jets

- still swamped with other background processes
  - Reducible backgrounds
    - Nonprompt leptons
    - Photon conversions
    - Charge misidentified electrons

  - Irreducible backgrounds
    - ttH, ttZ, t(t)X, Multiboson
    - large modelling uncertainty in this phase space

[JHEP 07 (2023) 219]



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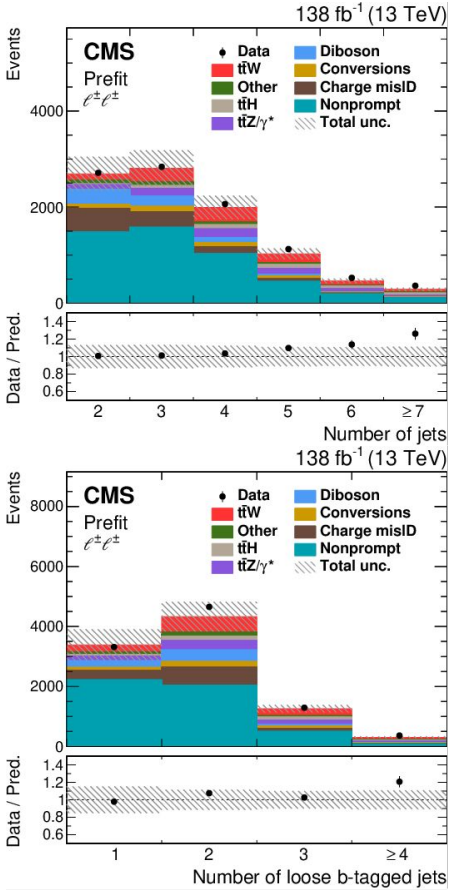
    - large modelling uncertainty in this phase space

We have to rely on a few tools from our toolbox:

1. good lepton ID
2. good b-tagging
3. data-driven methods to model reducible components
4. control regions adapted to the phase space to calibrate normalization of backgrounds

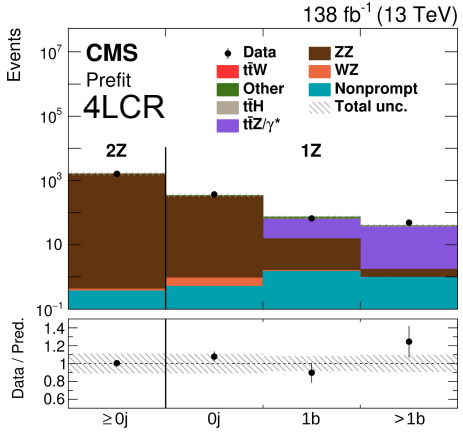
[JHEP 07 (2023) 219]

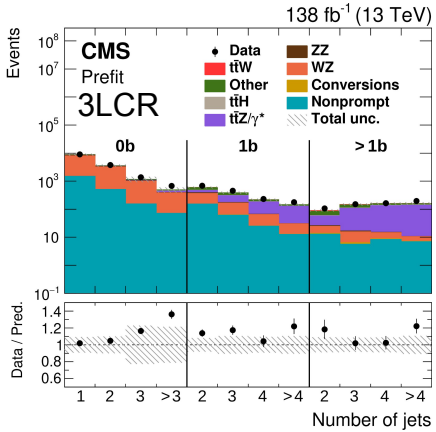


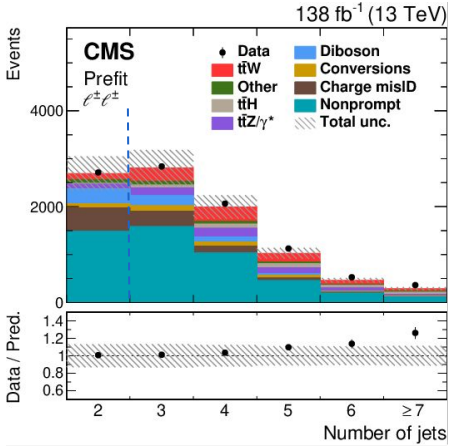
Inclusive measurement strategy

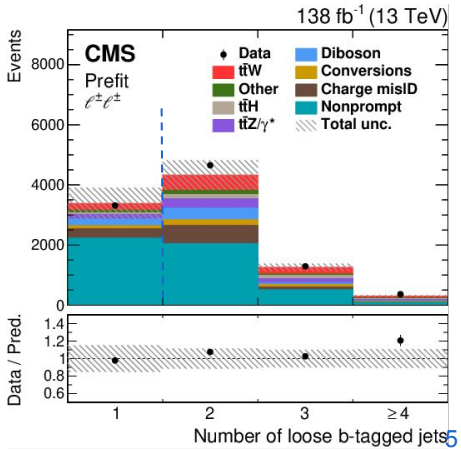
[JHEP 07 (2023) 219]

- Inclusive cross section extraction strategy:
  - add control regions to calibrate normalization of backgrounds
  - charge flips and nonprompt leptons estimated from data
  - focus on good acceptance
    - loose b-tagging requirements
    - loose lepton ID requirements









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Inclusive measurement strategy

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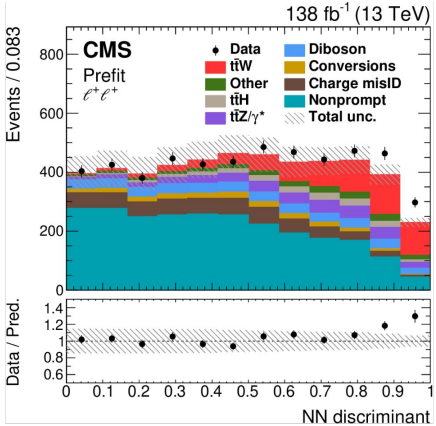
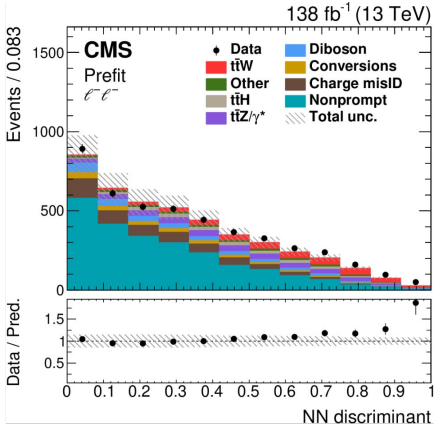
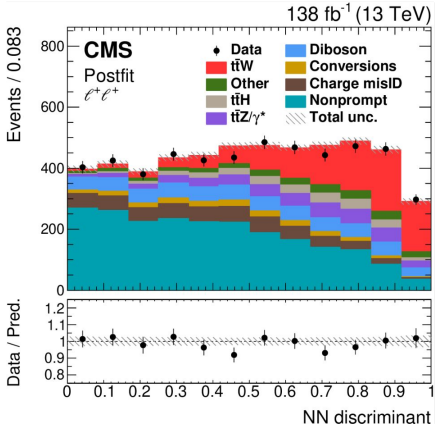
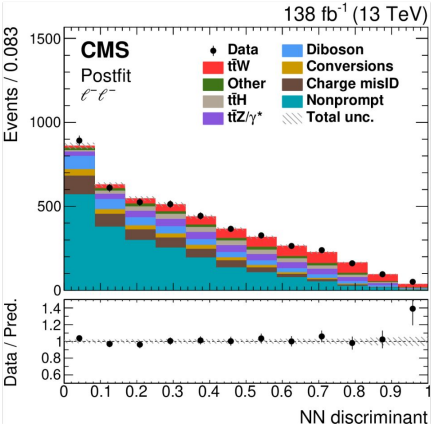
  - charge flips and nonprompt leptons estimated from data
  - focus on good acceptance
    - loose b-tagging requirements
    - loose lepton ID requirements
  - use a DNN to separate signal from background
  - split the signal regions in lepton charge

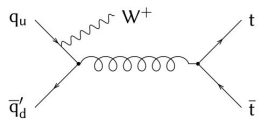
    use charge asymmetry to our advantage











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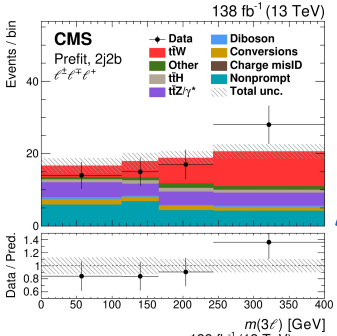
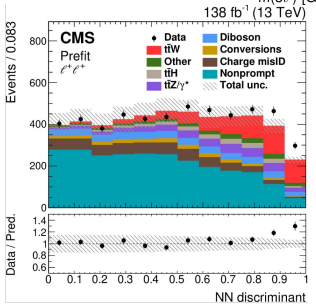
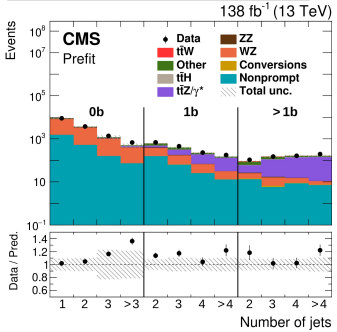
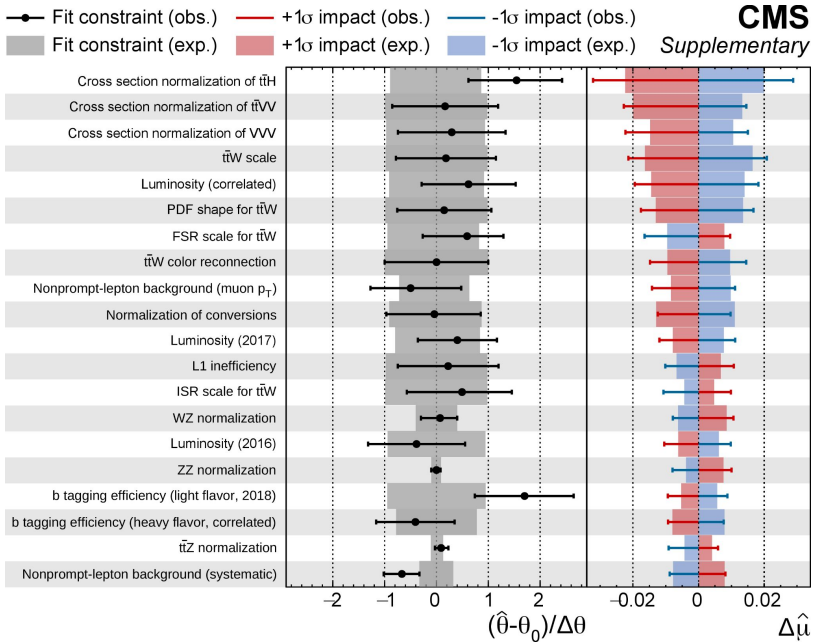
Inclusive measurement strategy

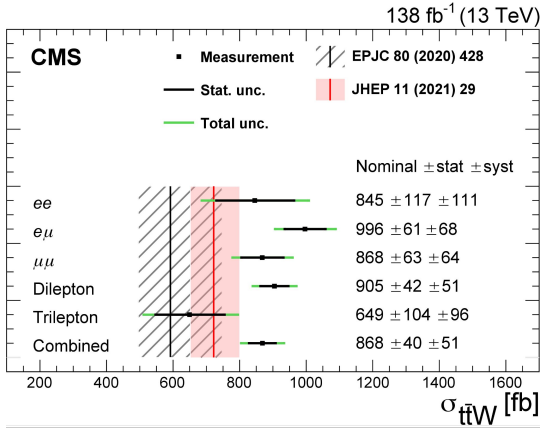
[JHEP 07 (2023) 219]











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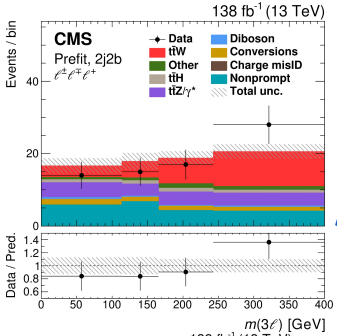
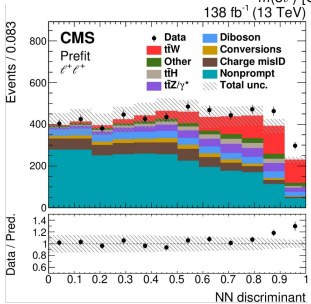
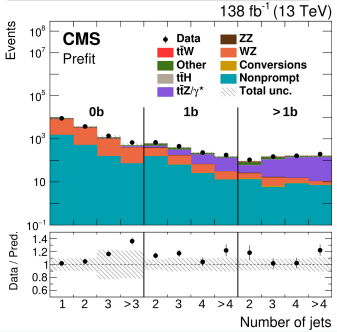
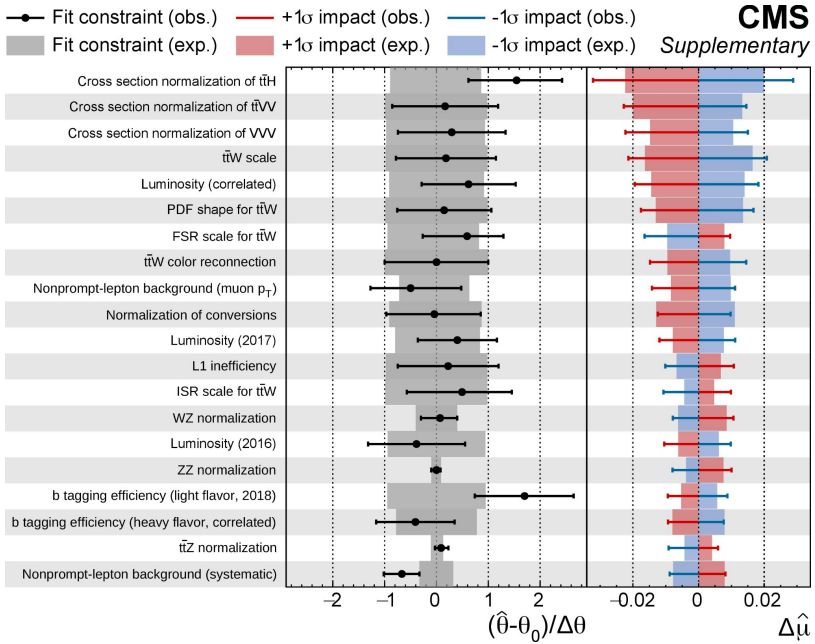
Inclusive measurement strategy

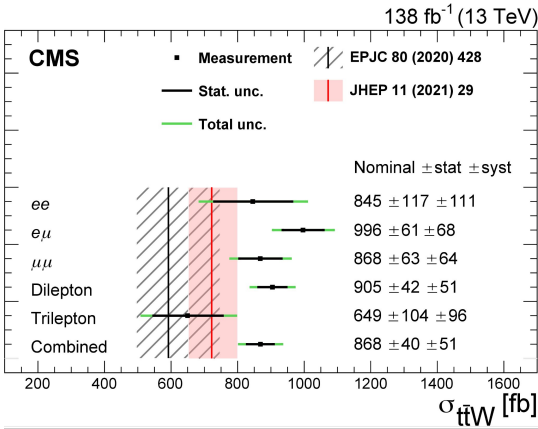
[JHEP 07 (2023) 219]











how to do this for differential results?

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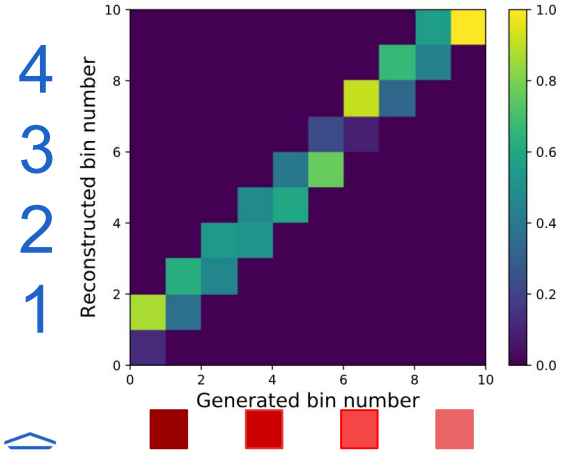
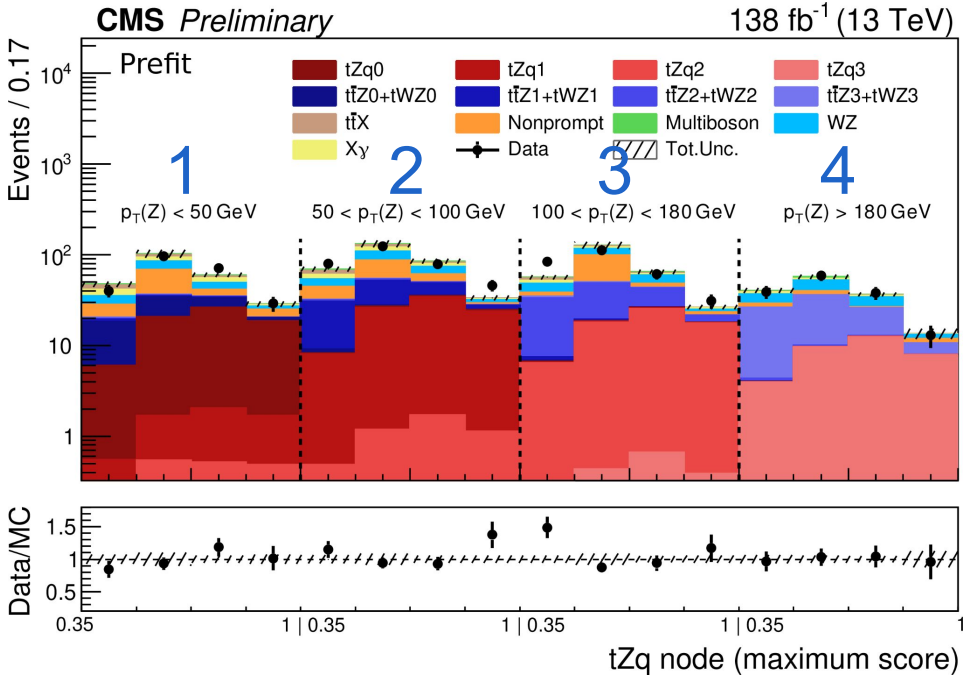
towards a differential measurement

- given the many backgrounds and uncertainties, can we encode our response matrix into our systematic framework?

- example from PAS-TOP-23-004





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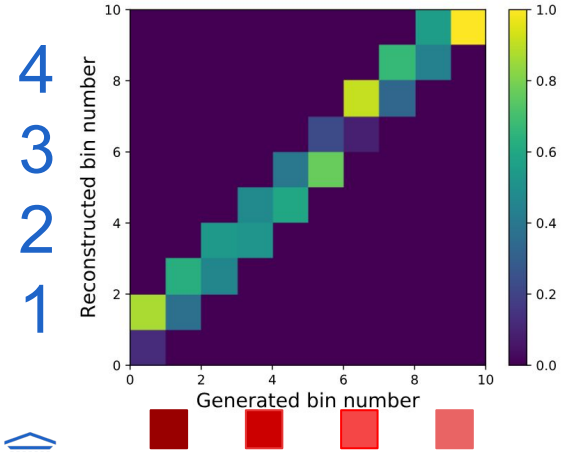

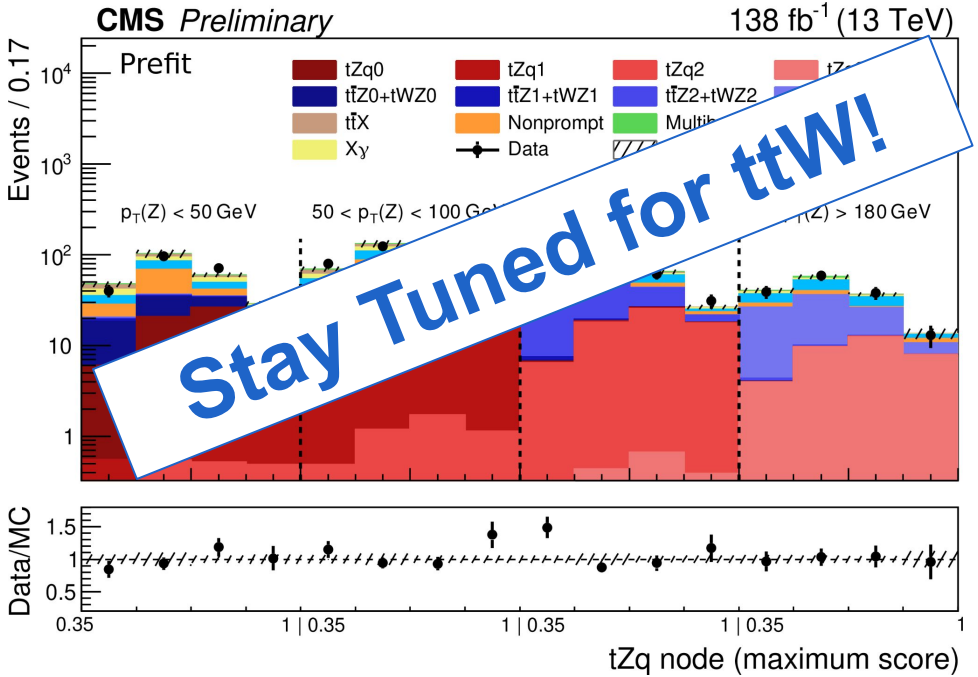

Stay Tuned for ttW!

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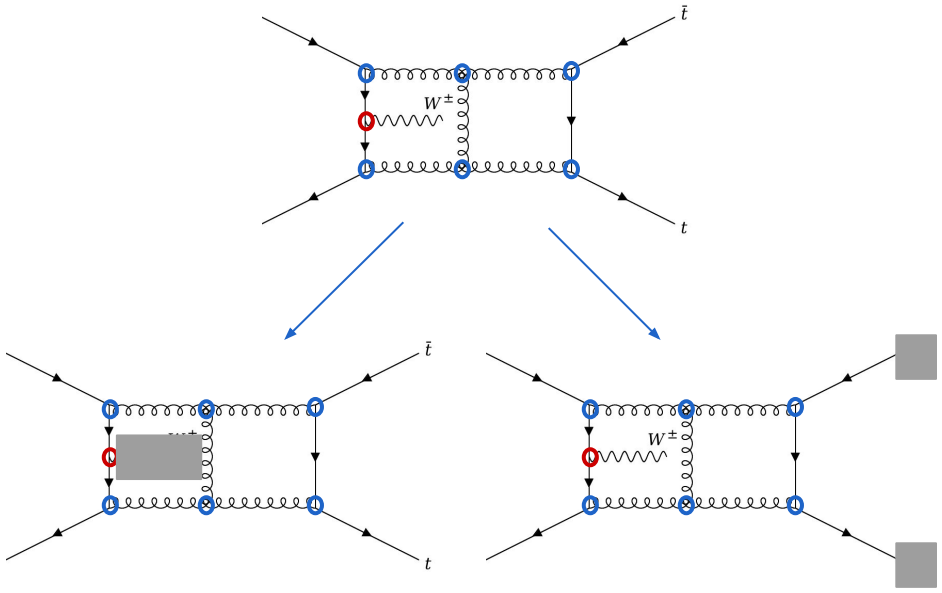
Conclusions

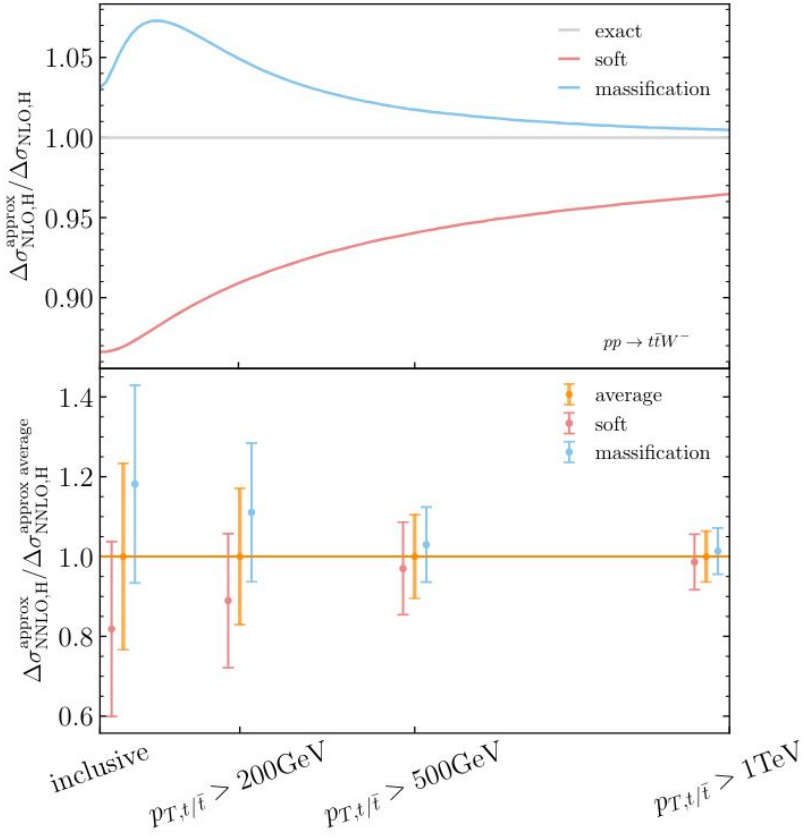
- We discussed the many challenges facing us in the pursuit of a better understanding of ttW
- We present the methodology for a differential ttW measurement
- Stay tuned and let’s have an interesting discussion!

ttW@NNLO: the 2-loop approximation

arxiv2306.16311



soft W massification



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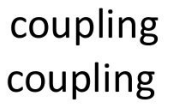
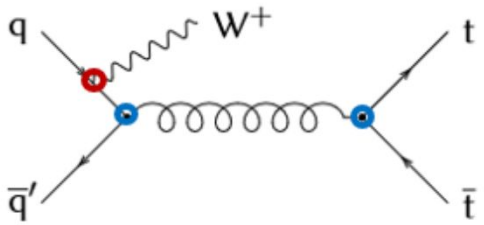
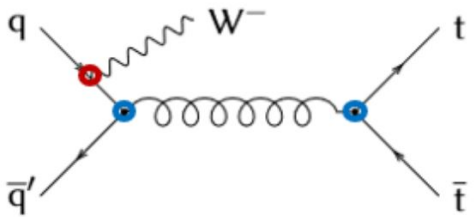
The modeling challenges

- Why is ttW such a challenging process?
  - @LO
    only qq







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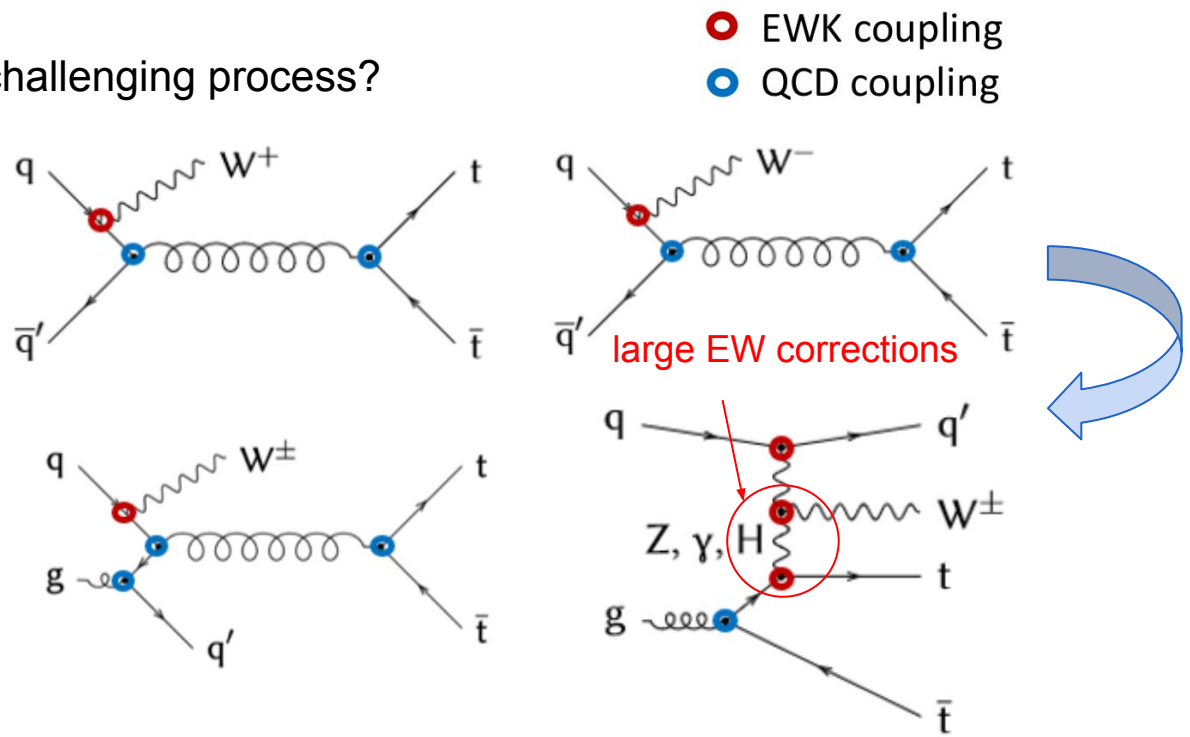

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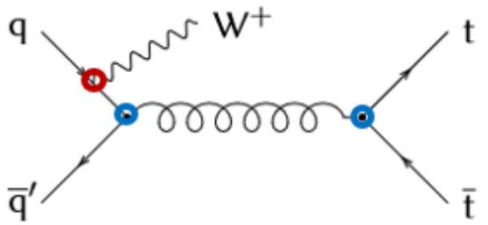

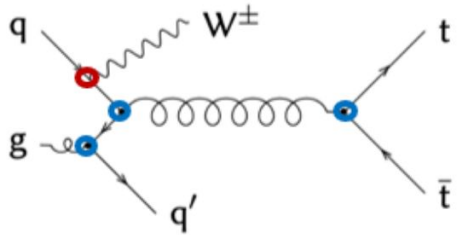

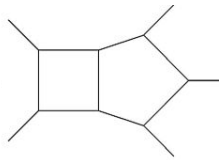

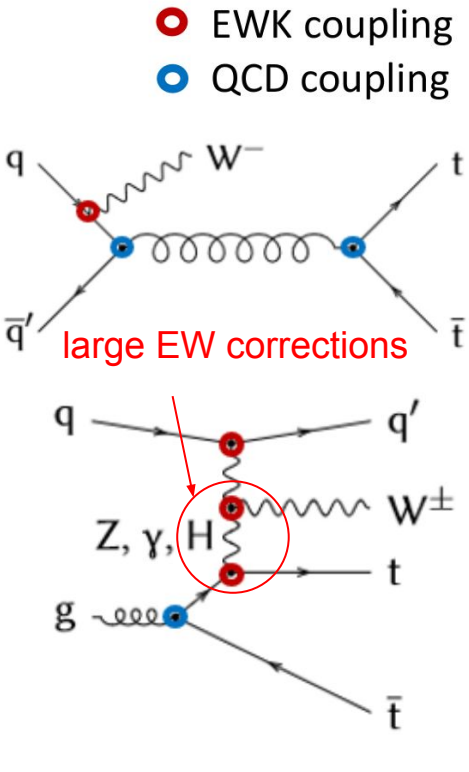

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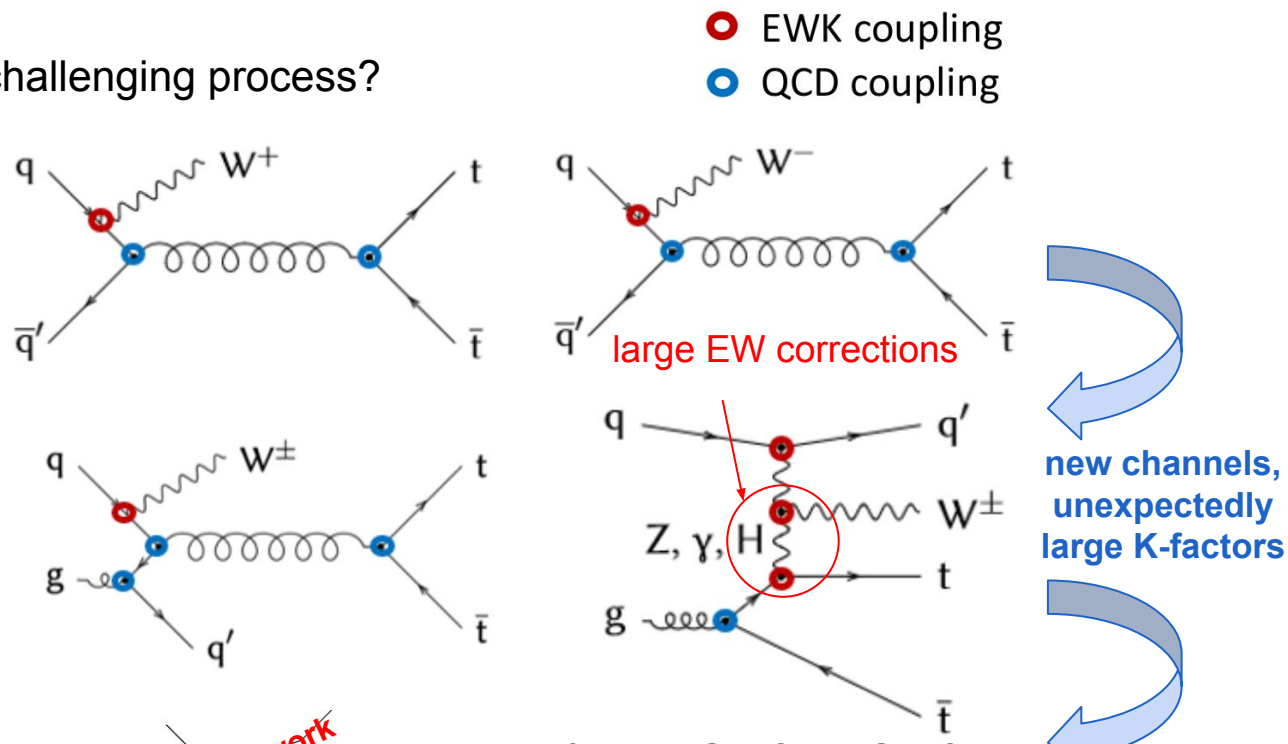

- state-of-the-art: @NLO+2j +@NLO$_{EWK}$
- missing virtual double loop (important)
- only inclusive cross section can be given at the moment [arXiv:2306.16311]

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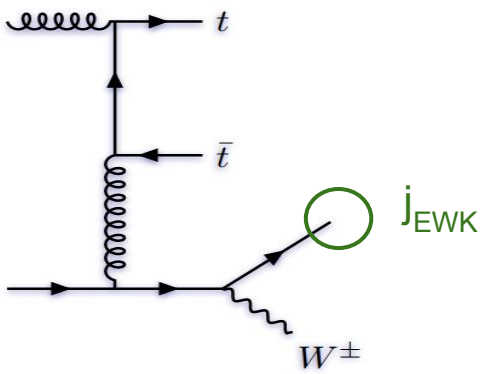
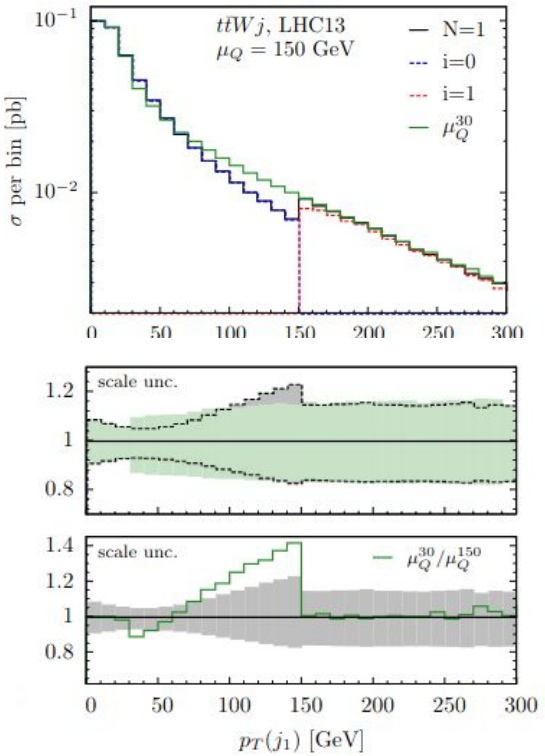
Improved FxFx simulation

Improved FxFx@2J scheme for aMC@NLO, reported in [JHEP11 (2023) 029]

- looked at these diagrams:



- badly modeled, especially at higher pt, by the PS
- results in high merging scale dependence and discontinuity in spectrum



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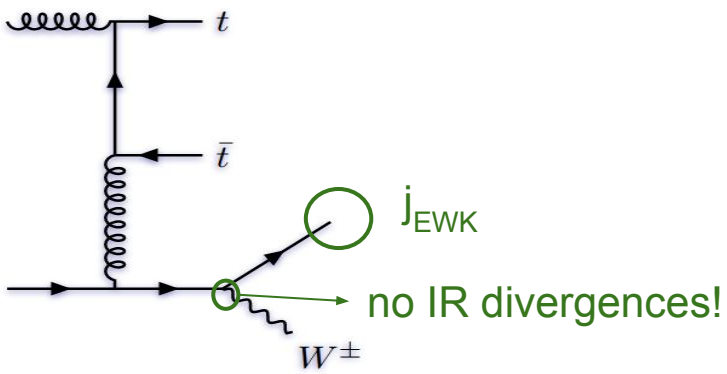
Improved FxFx simulation

Improved FxFx@2J scheme for aMC@NLO, reported in [JHEP11 (2023) 029]

- looked at these diagrams:



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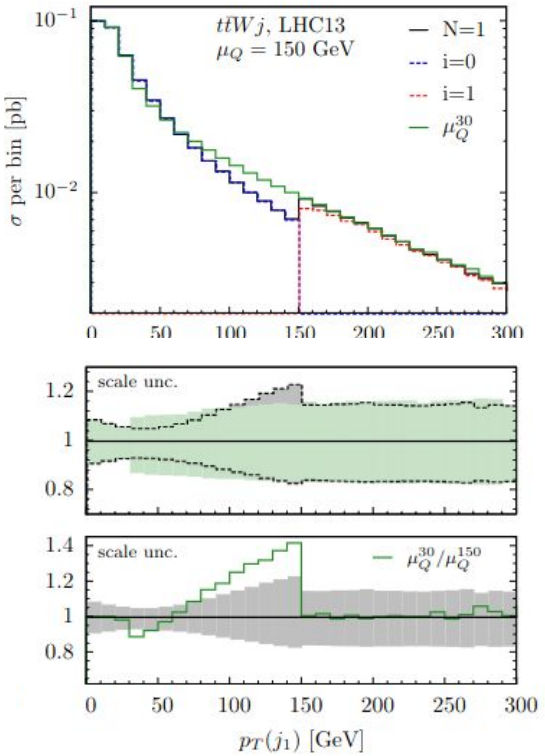

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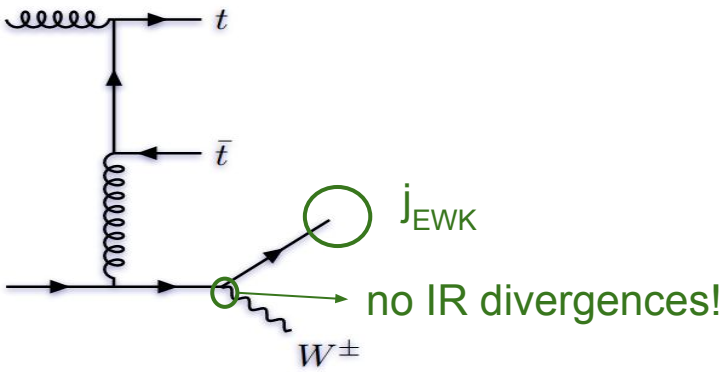
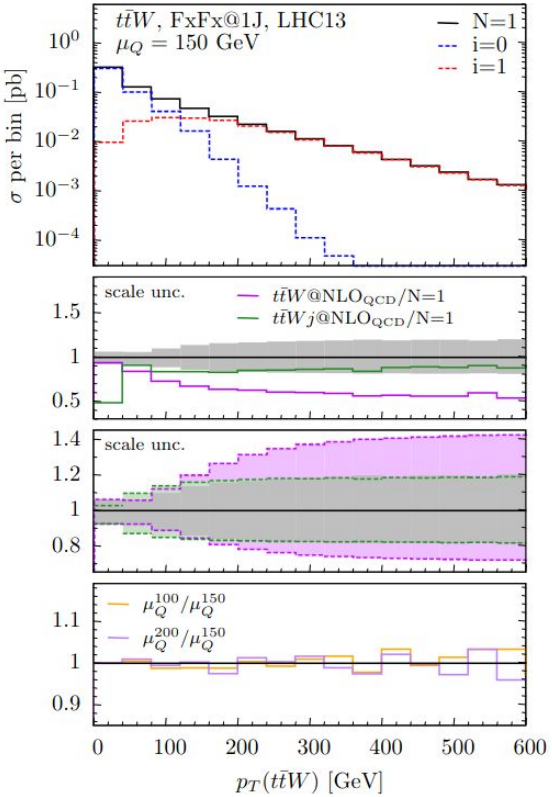


- badly modeled, especially at higher pt, by the PS
- results in high merging scale dependence and discontinuity in spectrum
- exclude from PS merging and take from ME, even below Merging scale!
  - much improved modeling of the extra radiation



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