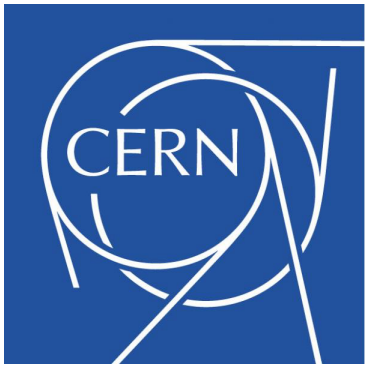


Resummation benchmarking

LHC EW precision group workshop

October 14, 2019

Benchmarking levels

- Benchmarking of resummed $p_T Z$, $p_T W/p_T Z$:
  - Document with specifics attached to the agenda
  - Inputs: https://gitlab.cern.ch/arapyan/pt-comparison

1) Canonical logarithms (as much as possible)
   - Strictly $\ln(Qb_T/b_0)$, $\ln(q_T/Q)$, i.e. $\mu_H = Q_{\rm res} = Q$, $\mu_r = \mu_f = Q$
   - Including b^* or equivalent prescription, but no nonpert. form factor etc.
   - Result in b_T space (if possible)
   - Result in q_T space

2) Nominal, favourite logarithms
   - Including turning off resummation at large q_T, e.g. $Q_{\rm res} = Q/2$, profile scales, $\ln(b_T) \to \ln(1 + b_T)$, etc. ...
   - Result in q_T space

3) Resummation as in 2) plus matching nonsingular FO correction

Resummation codes

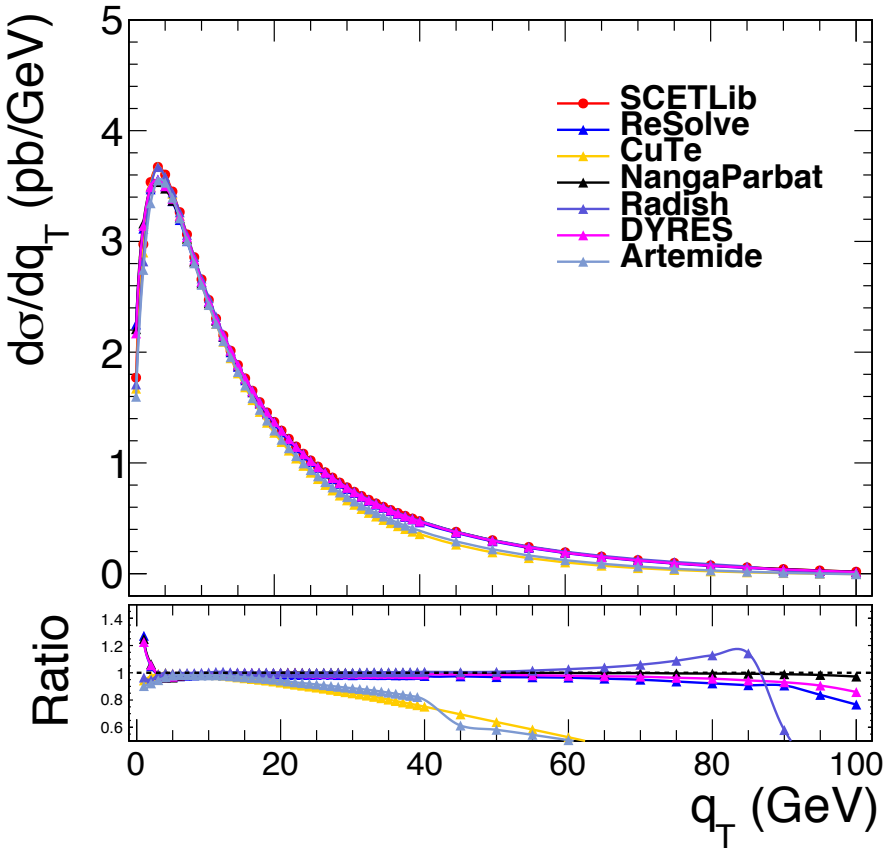
	b-space	k_t-space	add.	mult.	m. logs	profile	trans. fun	NP corr
PB-TMD		✓						✓
CuTe		✓	✓				✓	✓
DYres/DYTURBO	✓		✓		✓			(✓)
NangaParbat	✓		✓		✓			✓
RadISH		✓	(✓)	✓	✓			
ResBos2	✓		✓		✓			✓
Resolve	✓		✓		✓			✓
SCETLib	✓		✓			✓		

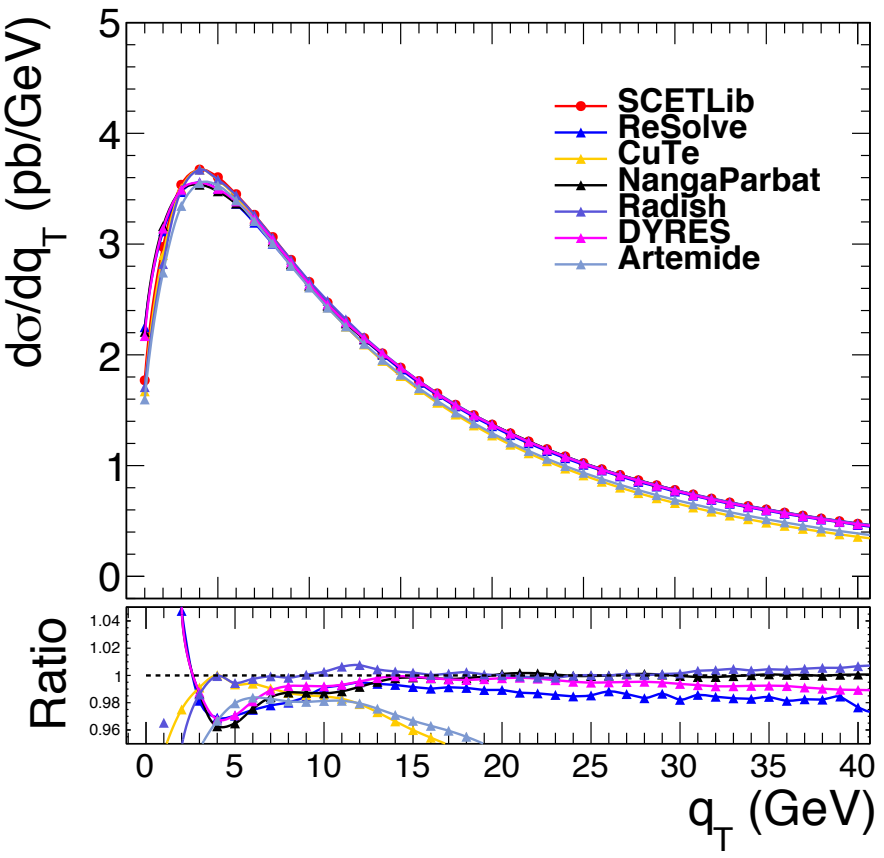
+Artemide

Order	Boundary cond. (FO singular)	Anomalous dimensions γ_i (noncusp)	Anomalous dimensions $\Gamma_{\rm cusp}$, β	FO matching (nonsingular)
LL	1	-	1-loop	-
NLL	1	1-loop	2-loop	-
NLL′ (+NLO$_0$)	α_s	1-loop	2-loop	α_s
NNLL (+NLO$_0$)	α_s	2-loop	3-loop	α_s
NNLL′ (+NNLO$_0$)	α_s^2	2-loop	3-loop	α_s^2
N^{3}LL (+NNLO$_0$)	α_s^2	3-loop	4-loop	α_s^2
N^{3}LL′ (+N^{3}LO$_0$)	α_s^3	3-loop	4-loop	α_s^3
N^{4}LL (+N^{3}LO$_0$)	α_s^3	4-loop	5-loop	α_s^3

Q=MZ, Y=0, level-1, gen=5

- NNNLL comparisons: SCETlib, Resolve(NNLLp), CuTe, NangaParbat, Radish, DYRES (NNLLp?), Artemide
- ReSolve PDF evolution is not through LHAPDF





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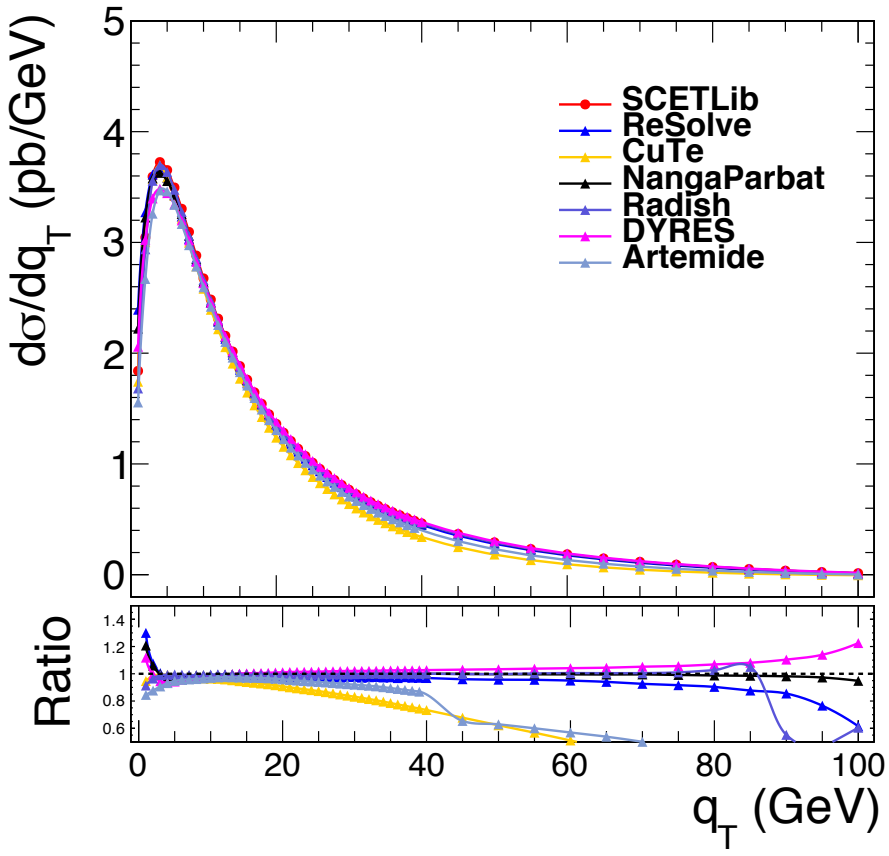
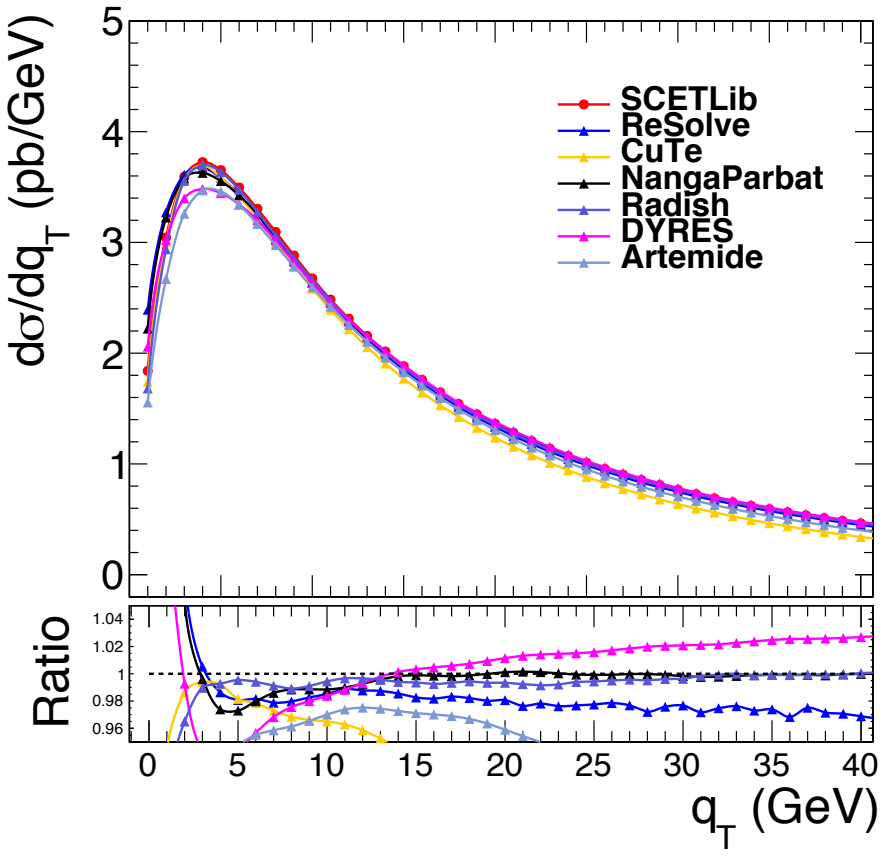
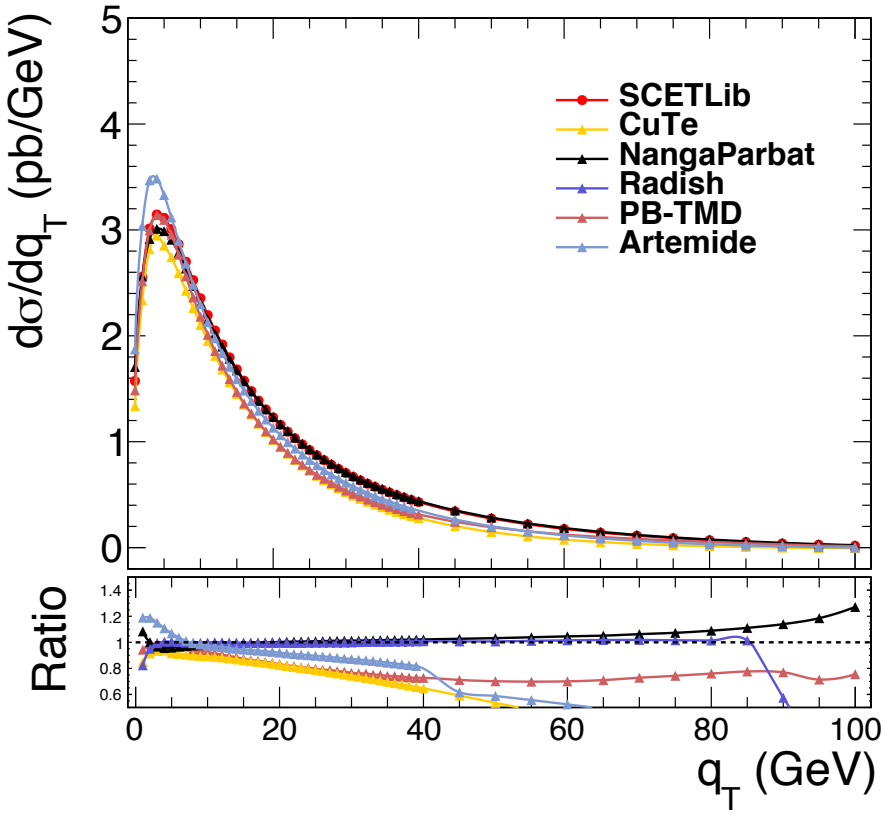
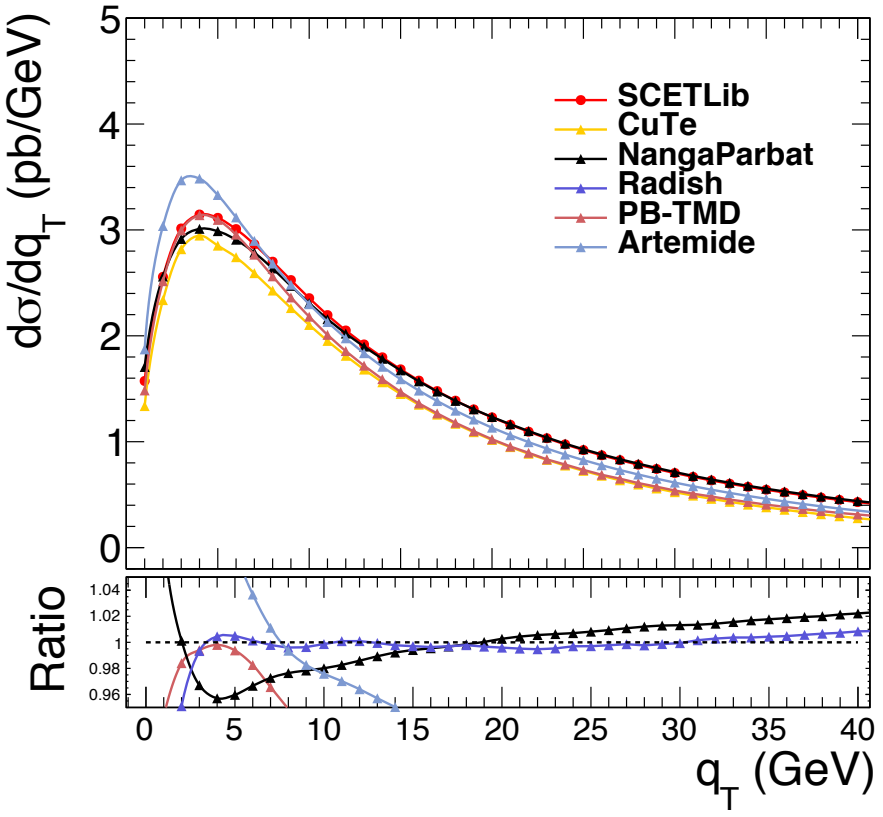




Q=MZ, Y=0, level-1, gen=5

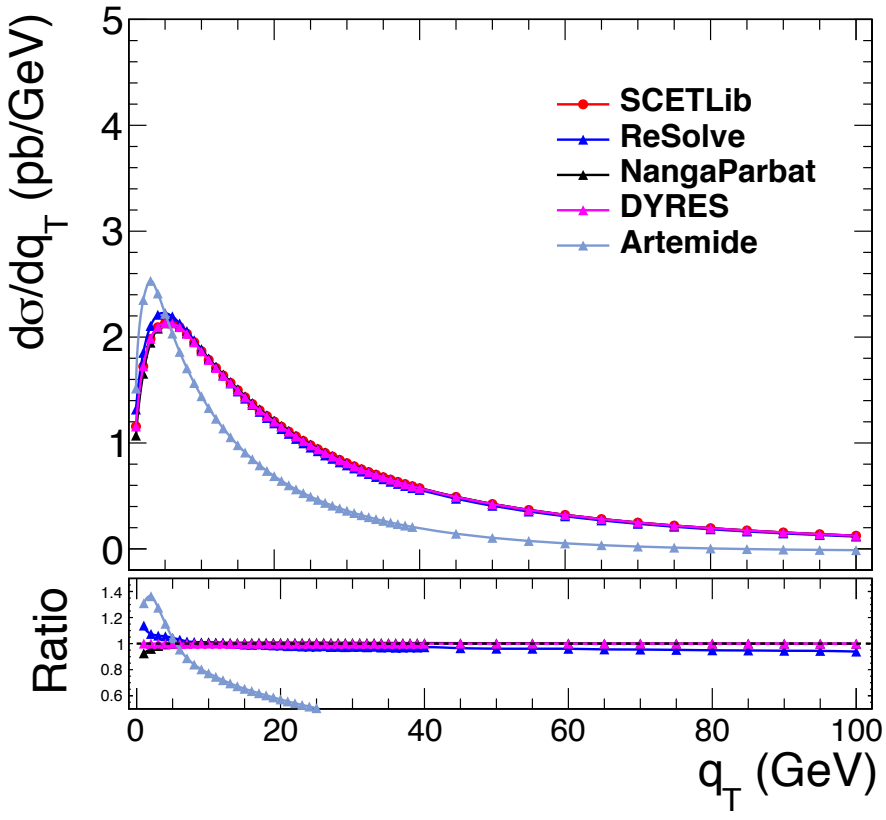
- NLL comparisons: SCETlib, CuTe, NangaParbat, Radish, PB-TMD, Artemide
- ReSolve PDF evolution is not through LHAPDF

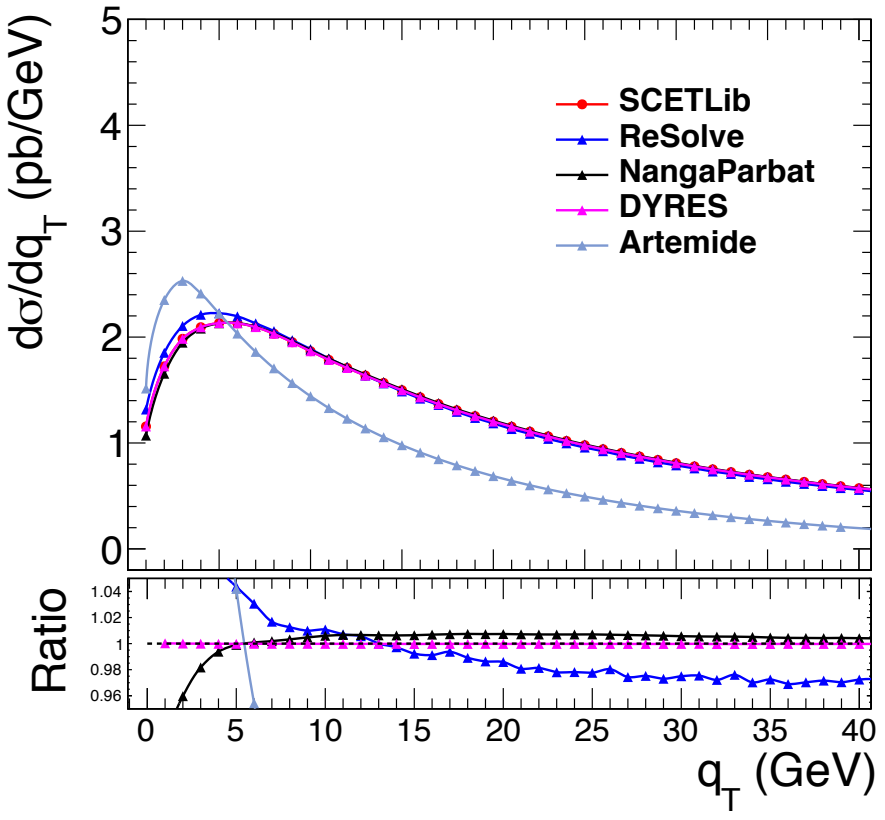




Q=MZ, Y=0, level-1, gen=5

- LL comparisons: SCETlib, Resolve, NangaParbat, DYRES, Artemide
- ReSolve PDF evolution is not through LHAPDF





Next steps for inputs

- So far seems ReSolve, NangaParbat, DYRES, Radish, SCETlib are within ~1% in qT>10 GeV and qT<80 GeV region
  - Cute, Artemide, and PB-TMD show larger differences (similar trend?)
- As discussed during the last meeting please upload the other Q points for level 1
  - Q=1TeV is a must
  - Q=66, 116, and 300 GeV points as many as possible
  - For example: NangaParbat already has all the Q and Y points
- Status of inputs for level 2 benchmarking
  - ReSolve and PB-TMD have already provided

Timelines and documentation

- We agreed early this year to proceed in successive steps fo the benchmarking from pure resummation benchmarking to “full resummation+fixed order (FO)” benchmarking
  - Levels 1, 2, and 3
- From the Precision EW group the 3 steps will converge for the Yellow Report. it was also tentatively agreed:
  - There will be real added value in publishing the results of these comparisons (one can include a suitable version of such a publication in a Yellow Report). This would be jointly signed by all participating resummation groups.
- Possible timeline?
  - Digest steps 1 and 2 by the end of the year. We can also document these results by the end of the year.
  - Can we produce the step-3 (matched to FO) results early next year?
  - Try to wrap up by Summer of next year!

Theory uncertainties

- Discussion by Pier during the last meeting. Here re-iterating some of the discussion points for further discussion
  - Quantify systematic uncertainties in all-order calculations
    - **perturbative**: μ_R/μ_F scales, resummation scales, (difference in *resummation method* must be encoded too)
    - **unitarity constraint**: modified logarithms, profile functions, …
    - **matching**: matching scheme, additional damping factors
    - **Non-perturbative corrections**: cutoffs (PDFs, α_S), NP models
    - **Heavy flavours & mass thresholds**: impact of bottom quark, thresholds in α_S and DGLAP evolution
- First 3 are the main/default objective of the benchmarking exercise. 4 and 5 are desirable but we have to see if there is time
- Theory uncertainties enter at L2 and L3. Of course provided that the differences in central values at L1 are understood

The objective

- The benchmarking exercise and W mass measurement
  - We benchmark Z, W, and W/Z ratio analytic resummed predictions
  - Has never been done before and there is already much to be learned

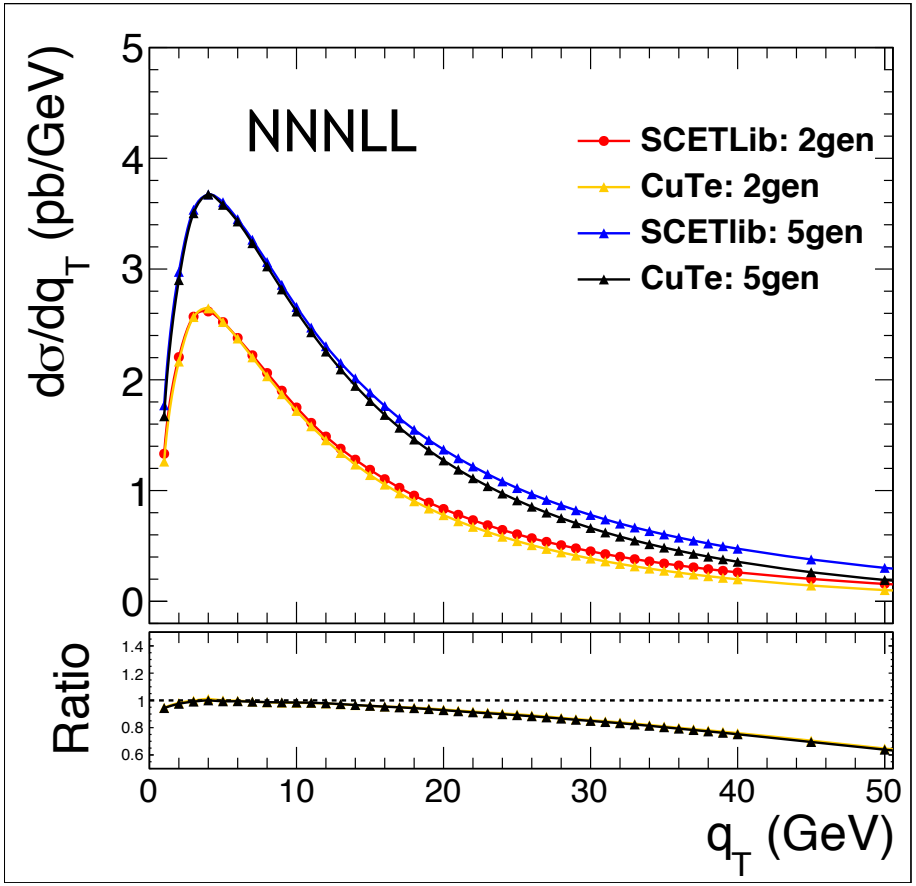
- Detailed study of how each of the uncertainty sources defined above impacts the W/Z ratio
- Final Goal: a list of uncertainties > what must be improved in the future

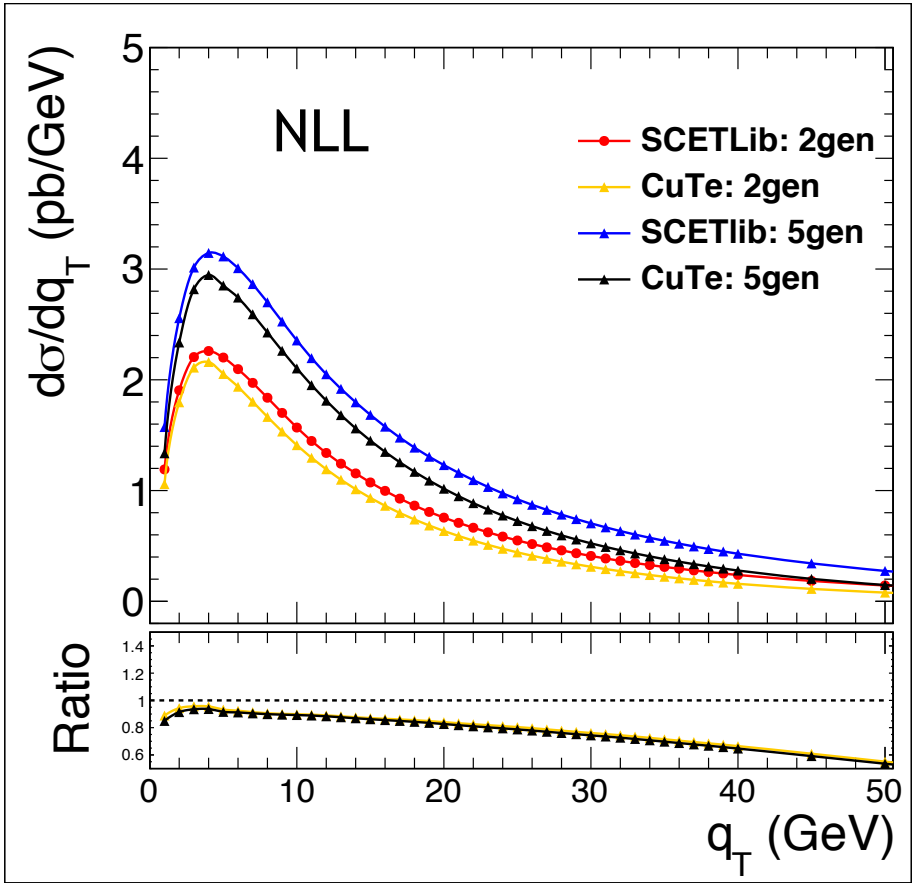
- As discussed during the last meeting the modeling of the correlations of the uncertainties in the pT W/Z ratio is outside of the scope of this first benchmarking result and documentation
  - This will be studied beyond Summer of 2020 within the LHC EW group

ADDITIONAL MATERIAL

gen=2 vs. gen=5, mZ, Y=0

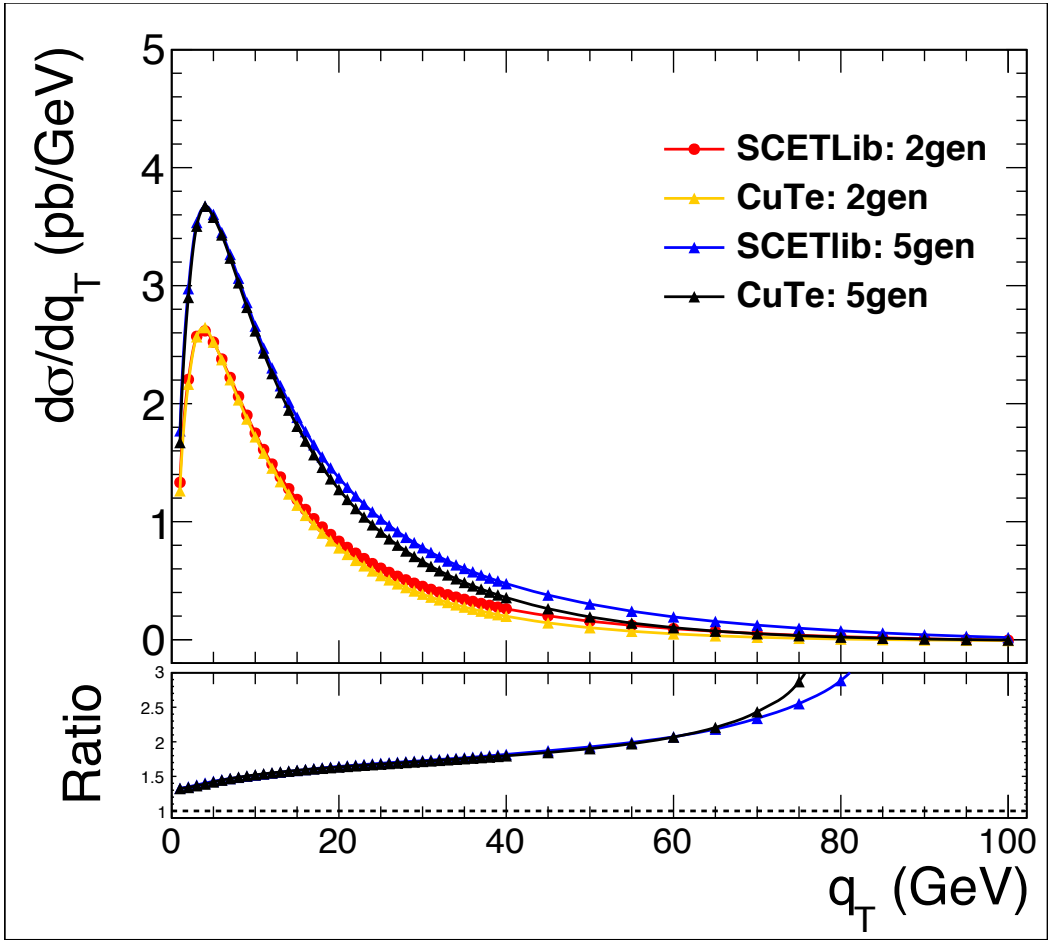
- The CuTe/SCETLib ratio appears to be the same for 2gen and 5gen in all orders. Probably no need to generate 2gen inputs.





gen=2 vs. gen=5, mZ, Y=0

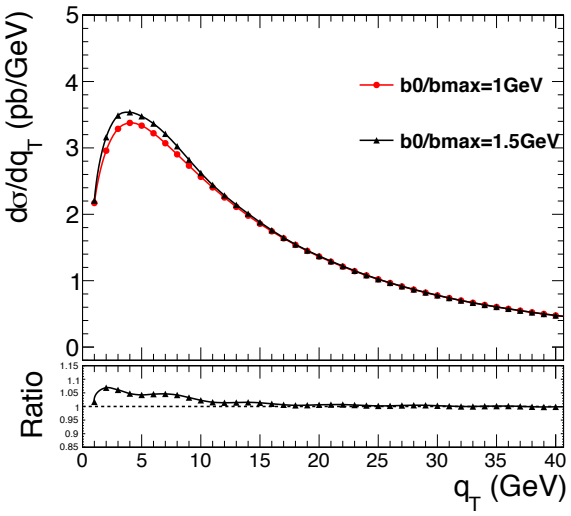
- Ratio plot: 5gen/2gen ratio (blue: scetlib, black: CuTe)



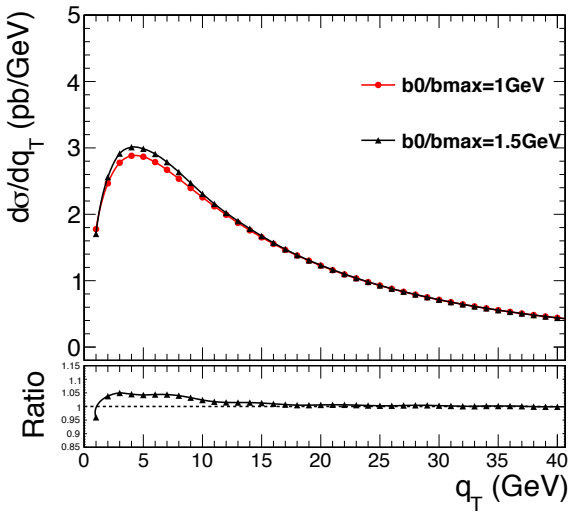
Non-perturbative cutoff

- NangaParbat had 1.65 GeV cut-off last round and has updated to 1.0 GeV
  - ~5% effect below 10GeV. What is happening with LL?

NNNLL



NLL



LL