Higher Order Generators: Which One Where?

"Status, new developments, (some) issues and dusty corners of present higher-order Monte Carlo generators"

Simone Alioli

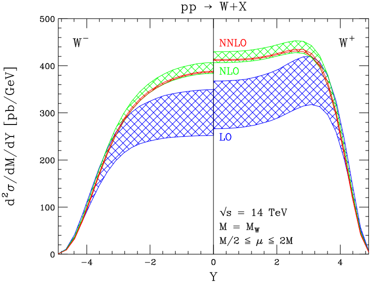
LBNL & UC Berkeley

28 January 2014

US ATLAS Workshop on LHC Searches

What are higher-order generators?

- NLO is the first order at which rates and associated theoretical uncertainties are reliably predicted.
- NLO and NNLO gives non-negligible contributions in several cases (e.g. $gg \to H \approx 100\%$ at NLO and $\approx 30\%$ at NNLO).
- Theoretical uncertainties further reduced by including NLO and NNLO corrections.



[Anastasiou et al., hep-ph/0312266]

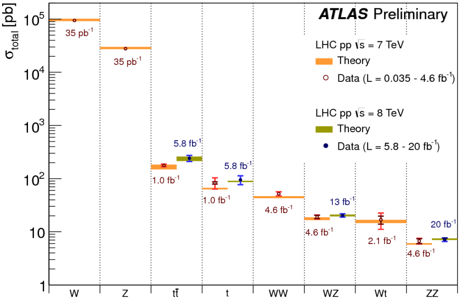
- Shapes are generically better described increasing the parton multiplicity: new channels at NLO, and NNLO, larger K-factors and noticeable shape distorsions.
- Fixed-order results are only at the parton level. No immediate way to estimate detector effects. Singular regions are poorly described.
- Resummation improve sing. region but requires to define the observable in advance, no fully-exclusive events.
- Higher-order generators are tools that aim to incorporate all these effects in a consistent way. Examples:

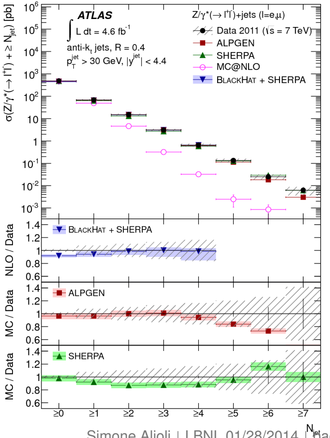
MC@NLO, POWHEG, SHERPA, Geneva, Herwig++, Vincia ...

Which one to use?

- It strongly depends on the obervable under study !
- Multijet shapes are usually ok with CKKW/MLM. Large scale uncertainties.
- Normalizations are given better in NLO+PS, but spectrum is still LO only.

  If normalized, one looses the need for NLO.
- For studying pure shower effects, just use a standard SMC
- In many cases what we really want is higher order resummation.



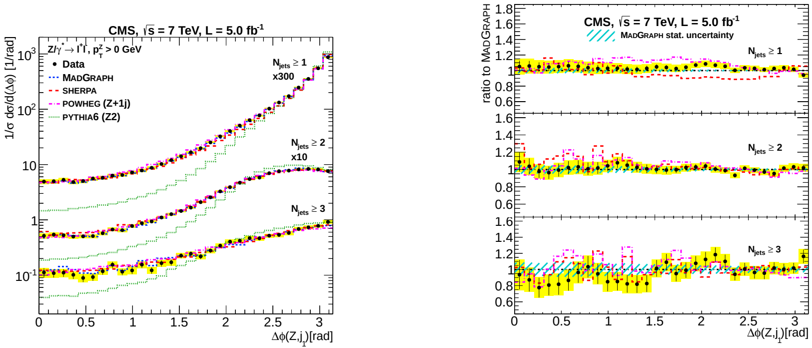


Which one to use?

- It strongly depends on the obervable under study !
- Multijet shapes are usually ok with CKKW/MLM. Large scale uncertainties.
- Normalizations are given better in NLO+PS, but spectrum is still LO only.

If normalized, one looses the need for NLO.

- For studying pure shower effects, just use a standard SMC
- In many cases what we really want is higher order resummation.

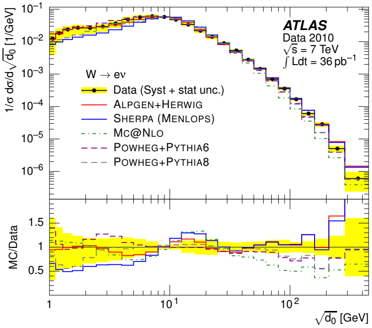


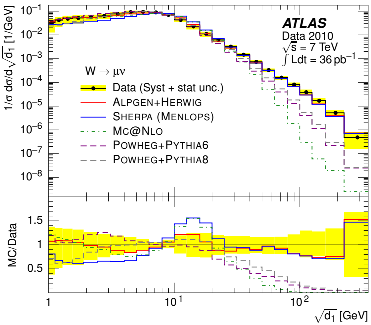
Which one to use?

- It strongly depends on the obervable under study !
- Multijet shapes are usually ok with CKKW/MLM. Large scale uncertainties.
- Normalizations are given better in NLO+PS, but spectrum is still LO only.

If normalized, one looses the need for NLO.

- For studying pure shower effects, just use a standard SMC
- In many cases what we really want is higher order resummation.



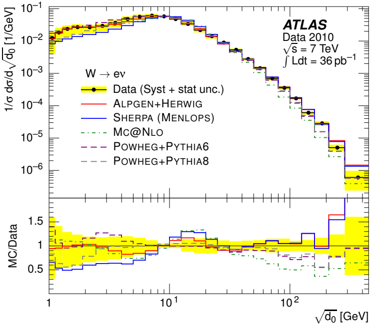


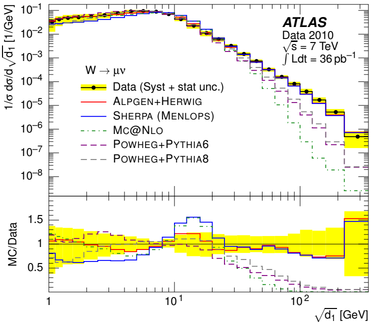
Which one to use?

- It strongly depends on the obervable under study !
- Multijet shapes are usually ok with CKKW/MLM. Large scale uncertainties.
- Normalizations are given better in NLO+PS, but spectrum is still LO only.

If normalized, one looses the need for NLO.

- For studying pure shower effects, just use a standard SMC
- In many cases what we really want is higher order resummation.





- Lesson: always keep in mind limit of validity of each MC

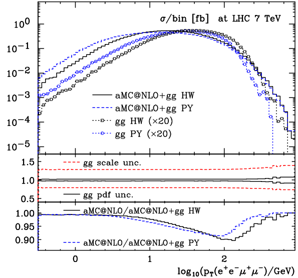
Estimating theoretical uncertainties

- Monte Carlo event distributions are theoretical predictions!
- They should always be accompanied by theoretical uncertainties. If not, demand for them!
- Typical procedure for accuracy of generator = accuracy of the observable, e.g. NLO
  - Independent μ_R, μ_F variations.
  - PDF error set envelope (PDF4LHC recommendation?)
  - Matching to a different parton shower(Herwig vs. Pythia), MPI on/off
  - Caveat: The shower only preserves the total probability. After acceptance cuts, rates and distributions can change drastically.

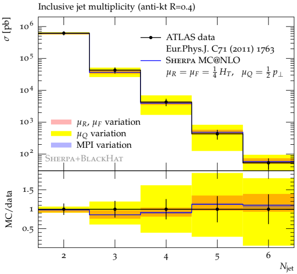
Estimating theoretical uncertainties

- Monte Carlo event distributions are theoretical predictions!
- They should always be accompanied by theoretical uncertainties. If not, demand for them!
- Typical procedure for accuracy of generator = accuracy of the observable, e.g. NLO
  - Independent μ_R, μ_F variations.
  - PDF error set envelope (PDF4LHC recommendation?)
  - Matching to a different parton shower(Herwig vs. Pythia), MPI on/off
  - Caveat: The shower only preserves the total probability. After acceptance cuts, rates and distributions can change drastically.
- Machinery do exist for fast reweighting in many MC. Make use of them!

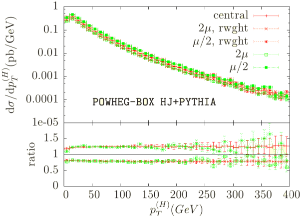
(a)MC@NLO [Frederix et al. 1110.4738]



SHERPA [Schonherr et al. 1212.0386]



POWHEG-BOX [Nason et al.]



Estimating theoretical uncertainties

- Monte Carlo event distributions are theoretical predictions!
- They should always be accompanied by theoretical uncertainties. If not, demand for them!
- Typical procedure for accuracy of generator = accuracy of the observable, e.g. NLO
  - Independent μ_R, μ_F variations.
  - PDF error set envelope (PDF4LHC recommendation?)
  - Matching to a different parton shower(Herwig vs. Pythia), MPI on/off
  - Caveat: The shower only preserves the total probability. After acceptance cuts, rates and distributions can change drastically.
- For process which are already divergent at LO, explicit independence on generation cuts/suppression factors must be enforced. This is not a theoretical unc.
- For observables that don't have NLO accuracy, showers effect are more marked. Different shower starting scales within the same generator can give very different results.

Recent developments and new directions

- POWHEG and MC@NLO methods are by now well established methods for NLO+PS.
- Several implementations by different groups available

POWHEG-BOX, (a)MC@NLO, SHERPA, Herwig++, POWHEL, ...

- Where to move from here ? Three main directions:

Merge NLO samples with different jet multiplicities.	Increase the fixed-order accuracy beyond NLO.	Improve the resummation accuracy beyond (N)LL of parton showers.

Merging NLO Shower Monte Carlo samples

- When merging NLO_N and NLO_{N+1} samples separated by μ_{cut}, the unphysical dependence shows up as $\sigma_{\geq N} \subset \log(\mu_{\text{cut}}/Q)$.

Merging NLO Shower Monte Carlo samples

- When merging NLO$_N$ and NLO$_{N+1}$ samples separated by $\mu_{\rm cut}$, the unphysical dependence shows up as $\sigma_{\geq N} \subset \log(\mu_{\rm cut}/Q)$.
- Resumming this dependence with parton showers (N)LL is usually not enough! If shower approx. does not fully reproduce singularities, left-over dependence is $\mathcal{O}(\alpha_s^2 L^2) \sim \mathcal{O}(\alpha_s) \equiv$ NLO$_N$ in the resumm. region ($\alpha_s L^2 \sim 1$).

Merging NLO Shower Monte Carlo samples

- When merging NLO_N and NLO_{N+1} samples separated by μ_{cut}, the unphysical dependence shows up as $\sigma_{\geq N} \subset \log(\mu_{\text{cut}}/Q)$.
- Resumming this dependence with parton showers (N)LL is usually not enough! If shower approx. does not fully reproduce singularities, left-over dependence is $\mathcal{O}(\alpha_s^2 L^2) \sim \mathcal{O}(\alpha_s) \equiv \text{NLO}_N$ in the resumm. region ($\alpha_s L^2 \sim 1$).
- Merging scale cannot be pushed too low into the resummation region, otherwise the NLO accuracy of inclusive sample is spoiled.

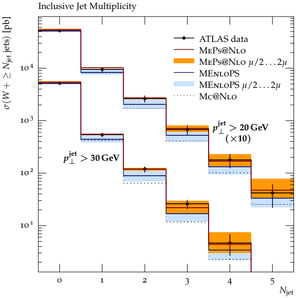
Merging NLO Shower Monte Carlo samples

- When merging NLO$_N$ and NLO$_{N+1}$ samples separated by μ_{cut}, the unphysical dependence shows up as $\sigma_{\geq N} \subset \log(\mu_{\mathrm{cut}}/Q)$.
- Resumming this dependence with parton showers (N)LL is usually not enough! If shower approx. does not fully reproduce singularities, left-over dependence is $\mathcal{O}(\alpha_s^2 L^2) \sim \mathcal{O}(\alpha_s) \equiv$ NLO$_N$ in the resumm. region ($\alpha_s L^2 \sim 1$).
- Merging scale cannot be pushed too low into the resummation region, otherwise the NLO accuracy of inclusive sample is spoiled.
- Picking an high scale means that one is forced to describe relatively hard jets only at the lower accuracy (LO).

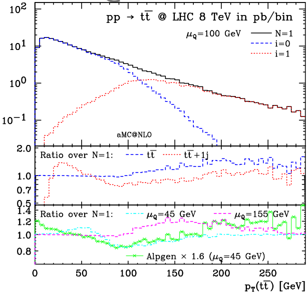
Merging NLO Shower Monte Carlo samples

- When merging NLO_N and NLO_{N+1} samples separated by μ_{cut}, the unphysical dependence shows up as $\sigma_{\geq N} \subset \log(\mu_{\text{cut}}/Q)$.
- Resumming this dependence with parton showers (N)LL is usually not enough! If shower approx. does not fully reproduce singularities, left-over dependence is $\mathcal{O}(\alpha_s^2 L^2) \sim \mathcal{O}(\alpha_s) \equiv \text{NLO}_N$ in the resumm. region ($\alpha_s L^2 \sim 1$).
- Merging scale cannot be pushed too low into the resummation region, otherwise the NLO accuracy of inclusive sample is spoiled.
- Picking an high scale means that one is forced to describe relatively hard jets only at the lower accuracy (LO).

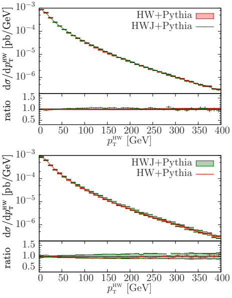
SHERPA/MENLOPS



MC@NLO/FxFx

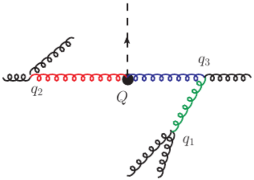


POWHEG/MiNLO



Multiscale Improved NLO.

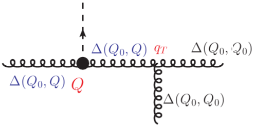
- MiNLO is CKKW-inspired recipe to set *a priori* the scales of a NLO calculation involving multiple scales. [Hamilton et al. 1206.3572]



Multiscale Improved NLO.

- MiNLO is CKKW-inspired recipe to set *a priori* the scales of a NLO calculation involving multiple scales. [Hamilton et al. 1206.3572]

- Like CKKW, it also includes LL Sudakovs factors, that regulate IR divergencies (e.g. H+1 jets finite $p_T^j \to 0$)



Multiscale Improved NLO.

- MiNLO is CKKW-inspired recipe to set *a priori* the scales of a NLO calculation involving multiple scales. [Hamilton et al. 1206.3572]
- Like CKKW, it also includes LL Sudakovs factors, that regulate IR divergencies (e.g. H+1 jets finite $p_{\mathrm{T}}^{j} \to 0$)
- NLO accuracy for inclusive sample not achieved in MiNLO (LL Sudakov)

Multiscale Improved NLO.

- MiNLO is CKKW-inspired recipe to set *a priori* the scales of a NLO calculation involving multiple scales. [Hamilton et al. 1206.3572]
- Like CKKW, it also includes LL Sudakovs factors, that regulate IR divergencies (e.g. H+1 jets finite $p_{\mathrm{T}}^{j} \to 0$)
- NLO accuracy for inclusive sample not achieved in MiNLO (LL Sudakov)
- Including NLL terms (B_2) in MiNLO Sudakovs, NLO accuracy for inclusive sample can be restored . [Hamilton et al. 1212.4504]

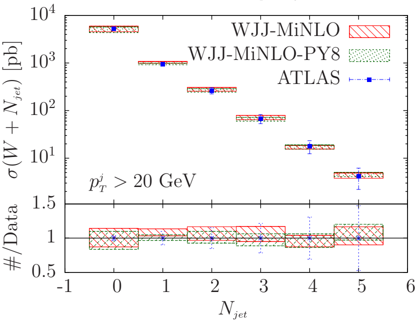
Multiscale Improved NLO.

- MiNLO is CKKW-inspired recipe to set *a priori* the scales of a NLO calculation involving multiple scales. [Hamilton et al. 1206.3572]
- Like CKKW, it also includes LL Sudakovs factors, that regulate IR divergencies (e.g. H+1 jets finite $p_T^j \to 0$)
- NLO accuracy for inclusive sample not achieved in MiNLO (LL Sudakov)
- Including NLL terms (B_2) in MiNLO Sudakovs, NLO accuracy for inclusive sample can be restored . [Hamilton et al. 1212.4504]
- Achieves NLO merging without merging scale (H+0 jets is never present)

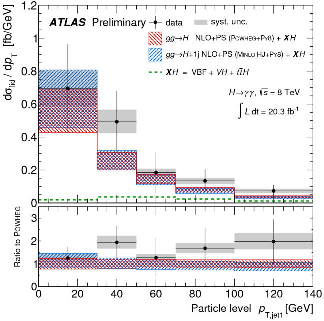
Multiscale Improved NLO.

- MiNLO is CKKW-inspired recipe to set *a priori* the scales of a NLO calculation involving multiple scales. [Hamilton et al. 1206.3572]
- Like CKKW, it also includes LL Sudakovs factors, that regulate IR divergencies (e.g. H+1 jets finite $p_{\mathrm{T}}^{j} \to 0$)
- NLO accuracy for inclusive sample not achieved in MiNLO (LL Sudakov)
- Including NLL terms (B_2) in MiNLO Sudakovs, NLO accuracy for inclusive sample can be restored . [Hamilton et al. 1212.4504]
- Achieves NLO merging without merging scale (H+0 jets is never present)

[Campbell et al. 1303.5447]



[ATLAS-CONF-2013-072]



POWHEG/MiNLO as a path to NNLO+PS.

- For simple processes (e.g. $gg \to H$), using HNNLO [Catani et al. 0801.3232] for event-by-event reweighting results in a NNLO+PS

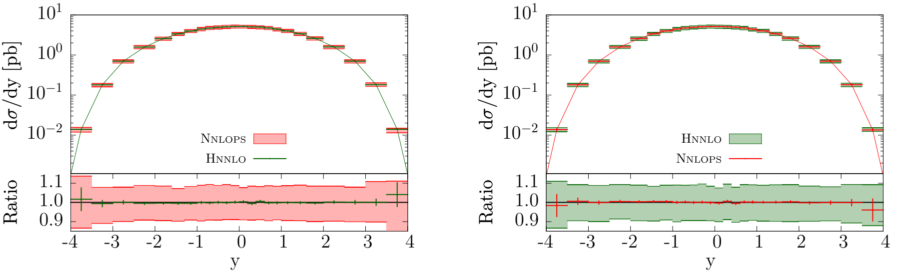
$$\mathcal{W}(y) = \frac{\left(\frac{d\sigma}{dy}\right)_{\rm HNNLO}}{\left(\frac{d\sigma}{dy}\right)_{\rm HJ-MiNLO}} = \frac{c_2\alpha_S^2 + c_3\alpha_S^3 + c_4\alpha_S^4}{c_2\alpha_S^2 + c_3\alpha_S^3 + c_4'\alpha_S^4 + \ldots} = 1 + \frac{c_4 - c_4'}{c_2}\alpha_S^2 + \ldots$$

✓ Integrates back to NNLO cross-section by construction

✓ NLO accuracy of Hj is maintained. Corrections start at $\mathcal{O}(\alpha_s^5)$.

? Need to reweight after generation, for each independent LO variable

- Hj-MiNLO NNLO+PS results [Hamilton,Nason,Re,Zanderighi 1309.0017]



POWHEG/MiNLO as a path to NNLO+PS.

- For simple processes (e.g. $gg \to H$), using HNNLO [Catani et al. 0801.3232] for event-by-event reweighting results in a NNLO+PS

$$\mathcal{W}(y) = \frac{\left(\frac{d\sigma}{dy}\right)_{\rm HNNLO}}{\left(\frac{d\sigma}{dy}\right)_{\rm HJ-MiNLO}} = \frac{c_2\alpha_S^2 + c_3\alpha_S^3 + c_4\alpha_S^4}{c_2\alpha_S^2 + c_3\alpha_S^3 + c_4'\alpha_S^4 + \ldots} = 1 + \frac{c_4 - c_4'}{c_2}\alpha_S^2 + \ldots$$

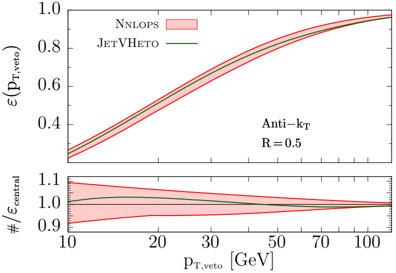
✓ Integrates back to NNLO cross-section by construction

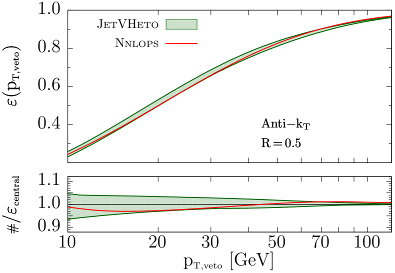
✓ NLO accuracy of Hj is maintained. Corrections start at $\mathcal{O}(\alpha_s^5)$.

? Need to reweight after generation, for each independent LO variable

- Hj-MiNLO NNLO+PS results

[Hamilton,Nason,Re,Zanderighi 1309.0017]





POWHEG/MiNLO as a path to NNLO+PS.

- For simple processes (e.g. $gg \to H$), using HNNLO [Catani et al. 0801.3232] for event-by-event reweighting results in a NNLO+PS

$$\mathcal{W}(y) = \frac{\left(\frac{d\sigma}{dy}\right)_{\mathrm{HNNLO}}}{\left(\frac{d\sigma}{dy}\right)_{\mathrm{HJ-MiNLO}}} = \frac{c_2\alpha_S^2 + c_3\alpha_S^3 + c_4\alpha_S^4}{c_2\alpha_S^2 + c_3\alpha_S^3 + c_4'\alpha_S^4 + \ldots} = 1 + \frac{c_4 - c_4'}{c_2}\alpha_S^2 + \ldots$$

✓ Integrates back to NNLO cross-section by construction

✓ NLO accuracy of $\boldsymbol{Hj}$ is maintained. Corrections start at $\mathcal{O}\left(\alpha_s^5\right)$.

? Need to reweight after generation, for each independent LO variable

Is this the only way to NNLO+PS ?

See Christian's talk next . . .

Interplay between NLO QCD and NLO QED corrections

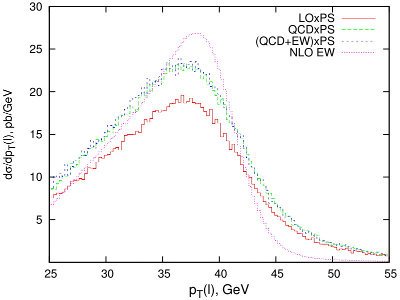
- First examples in single vector boson production

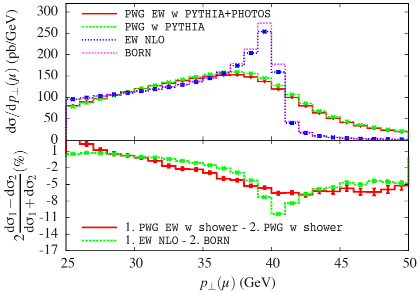
[Bernaciak, Wackeroth, arXiv:1201.4804]

- Two separate implementations for $W^{\pm}$:

[Barzé et al., arXiv:1202.0465]

  - NLO QCD + NLO EW, only 1st QCD emission by POWHEG. Interfaced to QCD parton shower (PYTHIA / HERWIG). No photon-induced nor multiple photon radiation.
  - Simultaneous NLO QCD and QED correction on first emission by POWHEG, interfaced to QCD (PYTHIA) and QED (PHOTOS) parton showers. POWHEG-BOX handles quasi-collinear QED radiation from massive legs.





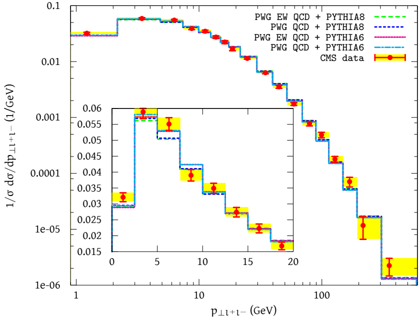
Interplay between NLO QCD and NLO QED corrections

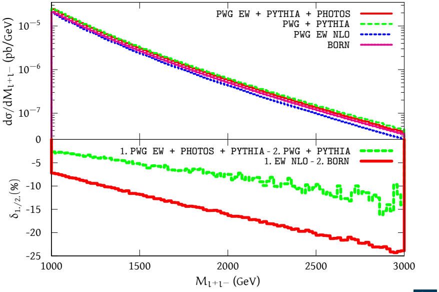
- First examples in single vector boson production
- Two separate implementations for $W^{\pm}$:

  [Bernaciak, Wackeroth, arXiv:1201.4804]

  [Barzé et al., arXiv:1202.0465]

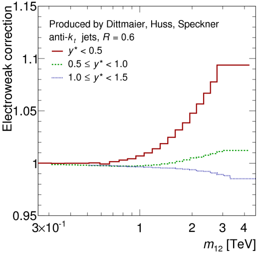
  - NLO QCD + NLO EW, only 1st QCD emission by POWHEG. Interfaced to QCD parton shower (PYTHIA / HERWIG). No photon-induced nor multiple photon radiation.
  - Simultaneous NLO QCD and QED correction on first emission by POWHEG, interfaced to QCD (PYTHIA) and QED (PHOTOS) parton showers. POWHEG-BOX handles quasi-collinear QED radiation from massive legs.
- Simultaneous NLO QCD and QED also available for DY [Barzé et al., arXiv:1302.4606]



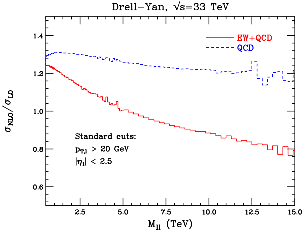


EW Sudakov logs and weak emissions in PS

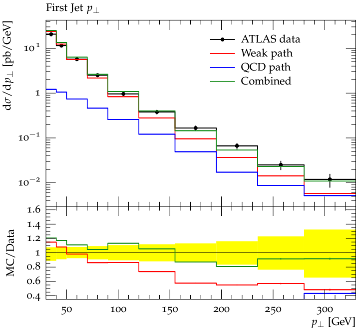
- EW logs don't cancel as QCD, partonic processes are not EW singlets
- Sizeable effects at LHC [1312.3524]



- Huge at future colliders [1308.1430]



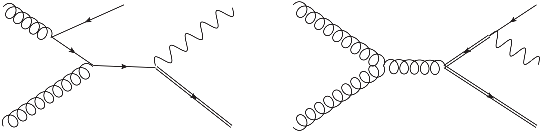
- Machinery started for EW showers in Pythia [1401.5238]
- Interleaved QCD-EW evolution, matched to QCD and EW ME, better agreement with data



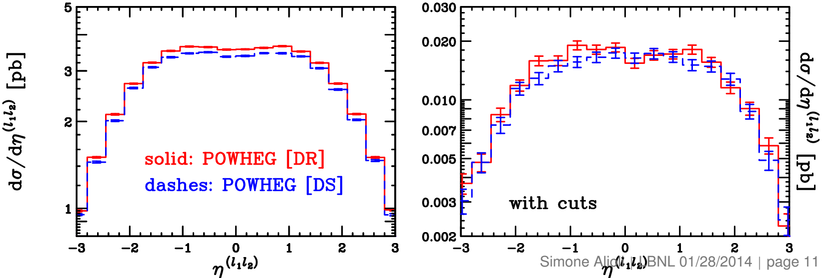
- Possible to take advantage of this for EW-improved ME merging ?

Interference issues in the SM: single top Wt-channel

- In general, LO QCD + NLO EW must be treated as LO EW + NLO QCD
- In the SM, a prime example is $gg \to W^+ b\bar{t}$ vs. $gg \to t\bar{t} \to W^+ b\bar{t}$ at NLO

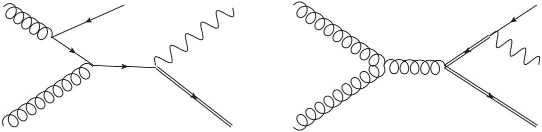


- Contributions from doubly resonant seem to spoil perturbative convergence.
- DR removes $|\mathcal{M}_r|^2$ $(\pm 2\mathcal{R}e\{\mathcal{M}_r\ \mathcal{M}^*_{nr}\})$. Not gauge invariant (but violations numerically small)
- DS cancels the resonant contribution near the doubly-resonant region in a (almost) gauge-invariant way $|\mathcal{M}_r + \mathcal{M}_{nr}|^2 - \mathcal{C}_{sub}$.
- The difference is a measure of the interference, provided $|\mathcal{M}_r|^2\ - \mathcal{C}_{sub} \approx 0$

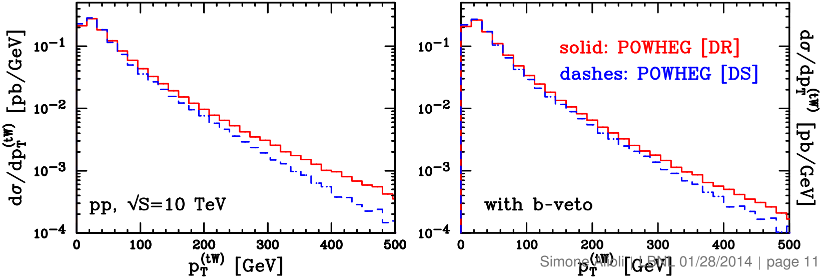


Interference issues in the SM: single top Wt-channel

- In general, LO QCD + NLO EW must be treated as LO EW + NLO QCD
- In the SM, a prime example is $gg \to W^+ b\bar{t}$ vs. $gg \to t\bar{t} \to W^+ b\bar{t}$ at NLO

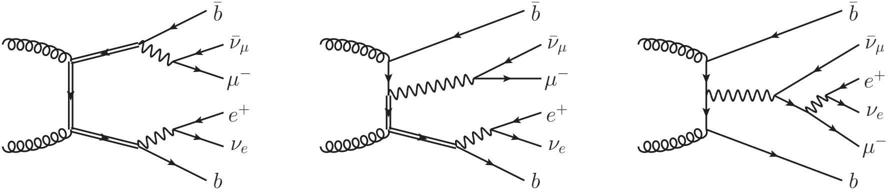


- Contributions from doubly resonant seem to spoil perturbative convergence.
- DR removes $|\mathcal{M}_r|^2$ $(\pm 2\mathcal{R}e\{\mathcal{M}_r\ \mathcal{M}^*_{nr}\})$. Not gauge invariant (but violations numerically small)
- DS cancels the resonant contribution near the doubly-resonant region in a (almost) gauge-invariant way $|\mathcal{M}_r + \mathcal{M}_{nr}|^2 - \mathcal{C}_{sub}$.
- The difference is a measure of the interference, provided $|\mathcal{M}_r|^2\ - \mathcal{C}_{sub} \approx 0$



Interference issues in the SM: single top Wt-channel

- Recent aMC@NLO calculation provides better approach [Frederix 1311.4893]
- Complete $pp \to e^+ \nu_e \mu^- \nu_\mu b\bar{b} + X$ at NLO in 4F scheme ($m_b \neq 0$)

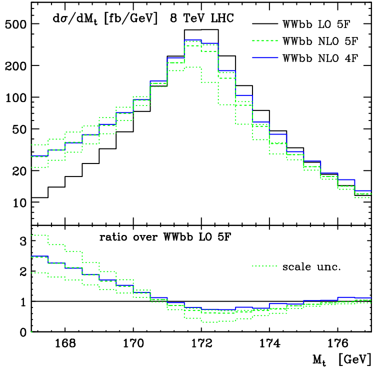


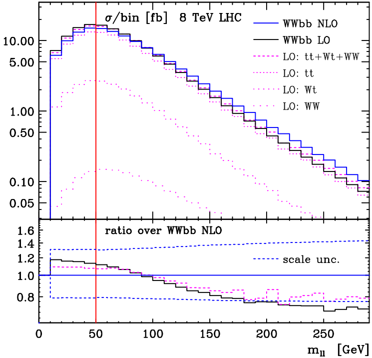
- Includes SR,DR, and NR contributions, off-shell effects and interferences

Interference issues in the SM: single top Wt-channel

- Recent aMC@NLO calculation provides better approach [Frederix 1311.4893]
- Complete $pp \to e^+\nu_e\mu^-\nu_\mu b\bar{b} + X$ at NLO in 4F scheme $(m_b \neq 0)$
- Includes SR,DR, and NR contributions, off-shell effects and interferences

- Results show moderate NLO corrections and scale unc. $(\pm 20 - 30\%)$.

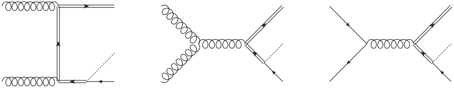




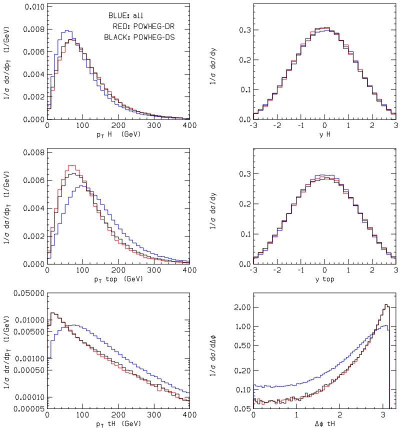
- Extremely challenging calculation, NLO only for now. Shower Matching?

Interference issues beyond the SM: $H^{\pm}t$

- Same issue present in $H^{\pm}t$ associate production with $m_H^{\pm} < m_t$

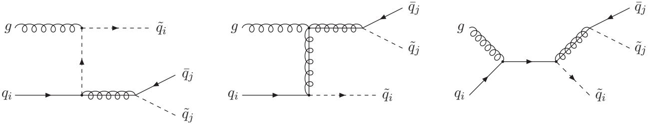


- Implemented in both POWHEG and MC@NLO [Klasen et al. 1203.1341] [Weydert et al. 0912.3430]
- DR vs. DS differences seems smaller in his case, compared to doubly resonant contributions

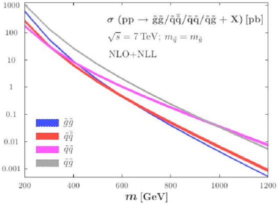


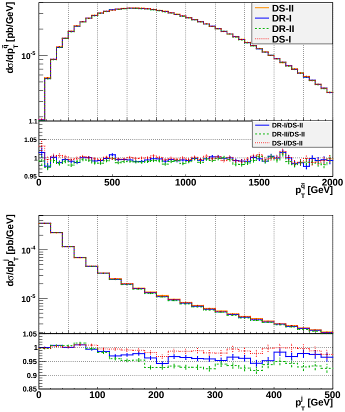
Interference issues beyond the SM: $\tilde{q}\tilde{q}$

- Same effect studied also in squark-squark production [Gavin et al. 1305.4061]
- Interference with $\tilde{q}\tilde{g}$ when gluino is resonant



- Dominant channel in the high mass region

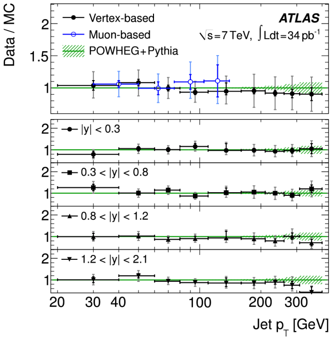




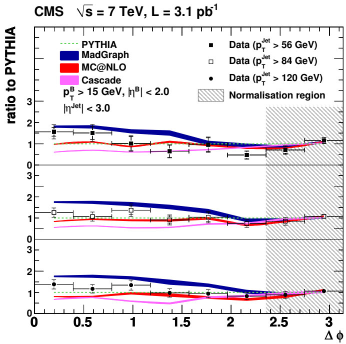
- Inclusive effects small, again more pronounced in particular distributions

Heavy quarks in the final state

[Eur.Phys.J.C 71 (2011)]

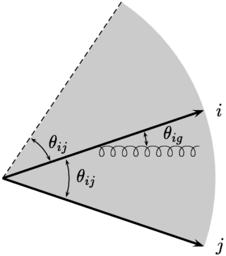


[JHEP 1103:136 (2011)]



- Inclusive b-jets cross sections in good agreement with MC
- As the two b-jets become closer MC start to show disagreements. Disagreement grows with $\boldsymbol{p_T}$, where $\boldsymbol{g \to b\bar{b}}$ dominates.
- Use Heavy Quark Fragmenting Jet Functions for simultaneous resummation of jet resolution and quark mass logs [Bauer, Mereghetti 1312.5605]
- How to include these resummations into a fully exclusive Montecarlo ? Geneva . . .

Color coherence



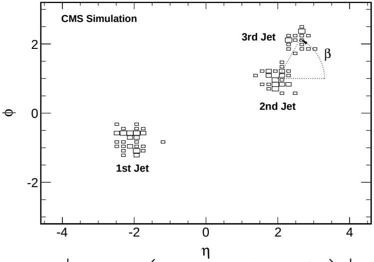
$\theta_{ig} < \theta_{ij}$

$\phi_{ig} = 0$
(w.r.t. i-j plane)

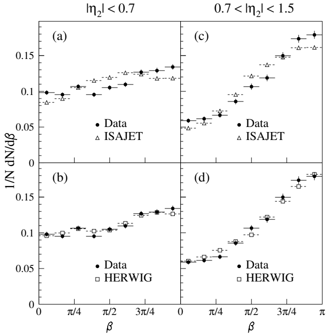
- At Tevatron collinear approx. + angular-ordering provided good modeling of color-coherence effects.

Color coherence

[D0 Phys. Lett. B 414 419 (1997)]



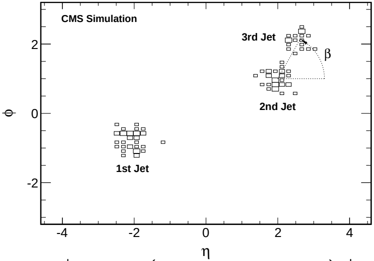
$$\beta = \left| \tan^{-1}\left(\text{sign}(\eta_2)\frac{\phi_3 - \phi_2}{\eta_3 - \eta_2} \right) \right|$$



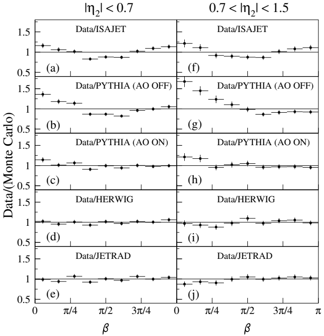
- At Tevatron collinear approx. + angular-ordering provided good modeling of color-coherence effects.
- Shower Monte Carlo needed to take angular-ordering into account.

Color coherence

[D0 Phys. Lett. B 414 419 (1997)]

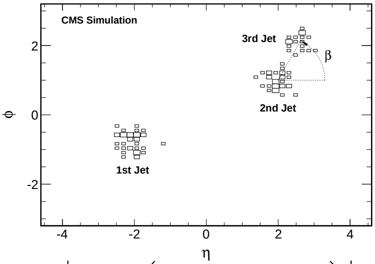


$$\beta = \left| \tan^{-1}\left(\text{sign}(\eta_2) \frac{\phi_3 - \phi_2}{\eta_3 - \eta_2} \right) \right|$$

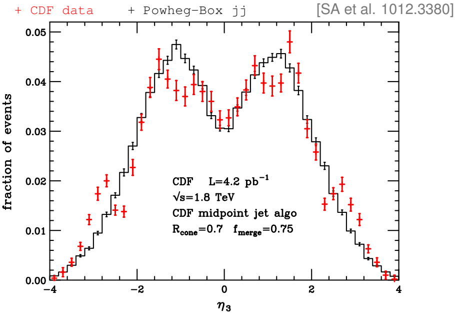


- At Tevatron collinear approx. + angular-ordering provided good modeling of color-coherence effects.
- Shower Monte Carlo needed to take angular-ordering into account.

Color coherence

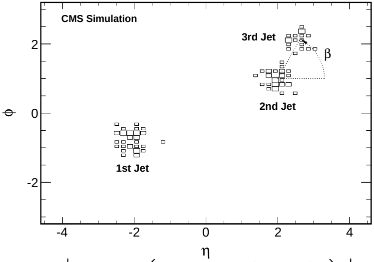


$$\beta = \left| \tan^{-1}\left(\mathrm{sign}(\eta_2) \frac{\phi_3 - \phi_2}{\eta_3 - \eta_2} \right) \right|$$



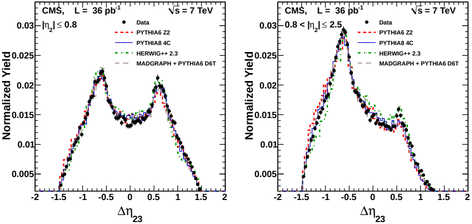
- At Tevatron collinear approx. + angular-ordering provided good modeling of color-coherence effects.
- Shower Monte Carlo needed to take angular-ordering into account.

Color coherence



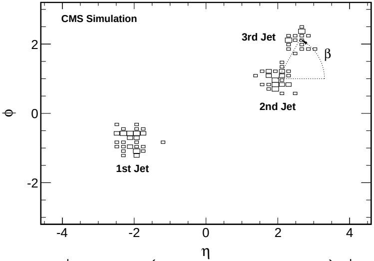
$$\beta = \left| \tan^{-1}\left(\text{sign}(\eta_2)\frac{\phi_3 - \phi_2}{\eta_3 - \eta_2} \right) \right|$$

[CMS Phys. Lett. B 414 419 (1997)]

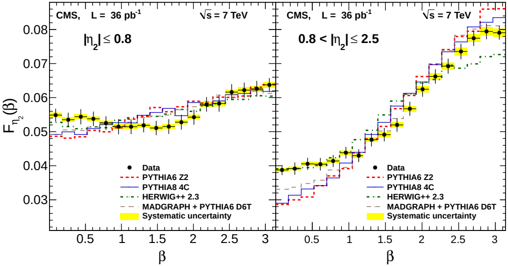


- At Tevatron collinear approx. + angular-ordering provided good modeling of color-coherence effects.
- Shower Monte Carlo needed to take angular-ordering into account.
- At LHC, general features are still described fairly

Color coherence



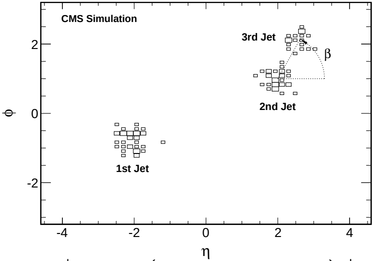
[CMS Phys. Lett. B 414 419 (1997)]



$$\beta = \left| \tan^{-1} \left(\mathrm{sign}(\eta_2) \frac{\phi_3 - \phi_2}{\eta_3 - \eta_2} \right) \right|$$

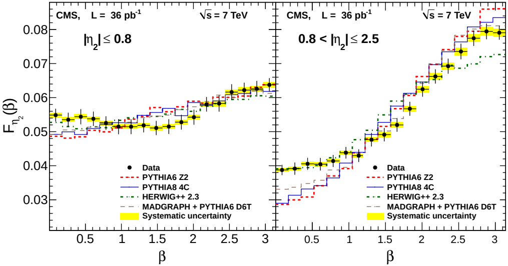
- At Tevatron collinear approx. + angular-ordering provided good modeling of color-coherence effects.
- Shower Monte Carlo needed to take angular-ordering into account.
- At LHC, general features are still described fairly
- But larger coherence effects start to show up in angular correlation between 2nd and 3rd jet

Color coherence



$$\beta = \left| \tan^{-1}\left(\mathrm{sign}(\eta_2)\frac{\phi_3 - \phi_2}{\eta_3 - \eta_2} \right) \right|$$

[CMS Phys. Lett. B 414 419 (1997)]

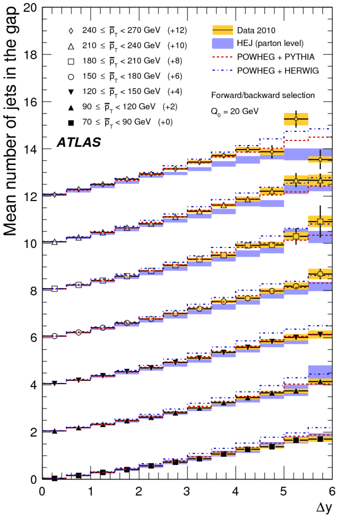


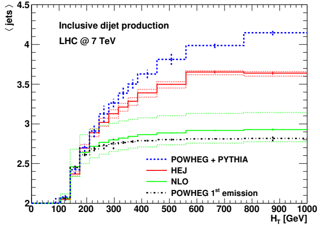
- At Tevatron collinear approx. + angular-ordering provided good modeling of color-coherence effects.
- Shower Monte Carlo needed to take angular-ordering into account.
- At LHC, general features are still described fairly
- But larger coherence effects start to show up in angular correlation between 2nd and 3rd jet
- Can we learn something from 3-jets at NLO ?

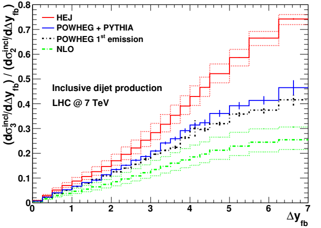
Njet+SHERPA [Badger et al., 1309.6585]

Jets gap and BFKL dynamics

- Study of effects beyond NLO at large rapidity separations, comparison between POWHEG+SMC and HEJ [SA et al., 1202.1475]
- Indentified few other observables with larger difference in radiation patterns







Conclusions and outlook

- Monte Carlo's have been tested across a wide range of energies and phase spaces.
- In general, NLO SMC's are performing remarkably well to describe LHC data.
- When looking into extreme areas of phase space or in high multiplicity regions, we start seeing (expected) disagreements.
- NLO+PS automation is now mature and helpful for new analysises.
- Care must still be taken for selected processes: interference effects, new regimes, BSM physics ...
- New developments and theoretical ideas are pushing MC forward in three main directions
  - Merge NLO sample with different NLO multiplicities.
  - Increase the fixed-order accuracy beyond NLO.
  - Increase the resummation accuracy beyond parton showers.
- Many other interesting subjects that have not been covered: MPI, soft-QCD, MC tunes ...

Thank you for your attention!