A few comments on EW settings in QCD generators

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- Review of generator choices and related discrepancies
- Issues at the experimental level
- Requests
In ATLAS, we try to have consistent parameter definitions across our generators
- Couplings, masses and widths set to reference values (PDG), passed to all generators
- Comparing generator distributions nevertheless reveals discrepancies. Taking Pythia as a reference, compare to NLO+PS and Multileg generators:

Generator-level dilepton mass distributions
Comparison of EW input parameters

- Study of generator documentation and code displays a rich variety of default choices
- Assuming we want to stick to PDG values for masses and widths, the colors below are assigned comparing to what is needed to make the dilepton mass distributions consistent with the Z lineshape measurement at LEP1:

<table>
<thead>
<tr>
<th>Generator</th>
<th>alphaEM</th>
<th>Gmu</th>
<th>Mz</th>
<th>Γz</th>
<th>Mw</th>
<th>Γw</th>
<th>BW form</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pythia</td>
<td>Running</td>
<td>Running</td>
<td>91.1876</td>
<td>2.4812</td>
<td>80.399</td>
<td>2.072</td>
<td>Running-width</td>
</tr>
<tr>
<td>Powheg</td>
<td>1/127.9</td>
<td>1.166 \times 10^{-5}</td>
<td>91.1876</td>
<td>2.4952</td>
<td>80.399</td>
<td>2.085</td>
<td>Fixed-width</td>
</tr>
<tr>
<td>Alpgen</td>
<td>1/132.3</td>
<td>1.166 \times 10^{-5}</td>
<td>91.1880</td>
<td>2.4409</td>
<td>80.419</td>
<td>2.047</td>
<td>Fixed-width</td>
</tr>
<tr>
<td>Sherpa</td>
<td>1/128.8</td>
<td>1.166 \times 10^{-5}</td>
<td>91.1876</td>
<td>2.4952</td>
<td>80.399</td>
<td>2.085</td>
<td>Fixed-width</td>
</tr>
<tr>
<td>MC@NLO</td>
<td>Running</td>
<td>1.166 \times 10^{-5}</td>
<td>91.1876</td>
<td>2.4952</td>
<td>80.399</td>
<td>2.085</td>
<td>Fixed-width</td>
</tr>
</tbody>
</table>
Running width vs Fixed width, for physical $M_Z$, $\Gamma_Z$

- LHC → LEP : PDFs → QED ISR
- Semi-analytical calculation assuming the LEP1-recommended Improved Born Approximation (“IBA”, precise to ~0.2%):
  - Either [running width, $M_Z$, $\Gamma_Z$]; or [fixed width, $M_Z/\gamma$, $\Gamma_Z/\gamma$, $\gamma = (1+\Gamma_Z^2/M_Z^2)^{1/2}$]
  - $W,Z$ couplings ~ $G_F$, photon coupling ~ $\alpha_{QED}(M_Z)$

PDG values for $M_Z$ and $\Gamma_Z$, running width
Running width vs Fixed width, for physical $M_Z$, $\Gamma_Z$

- LHC $\rightarrow$ LEP : PDFs $\rightarrow$ QED ISR
- Semi-analytical calculation assuming the LEP1-recommended Improved Born Approximation ("IBA", claimed precision $\sim$0.2% at LEP):
  - Either [ running width, $M_Z$, $\Gamma_Z$]; or [ fixed width, $M_Z/\gamma$, $\Gamma_Z/\gamma$, $\gamma = (1+\Gamma_Z^2/M_Z^2)^{1/2}$]
  - $W,Z$ couplings $\sim G_\mu$, photon coupling $\sim \alpha_{\text{QED}}(M_Z^3)$

![Graph showing running vs fixed width for $M_Z$ and $\Gamma_Z$](image1.png)

![Graph showing PDG values for $M_Z$ and $\Gamma_Z$, fixed width](image2.png)
Experimental issues

- Makes detector calibration (energy and momentum scales, resolution corrections to the simulation) generator dependent – the Z is the primary standard candle
  - Effect $\sim 0.05\%$ - small for most applications except $M_W$

- We are permanently comparing the available generators in many different contexts and distributions. Data/MC comparisons of basic kinematic distributions are polluted by these underlying differences
  - Local effects up to 5% in ratios

- These discrepancies are not reflecting a real uncertainty, so could we remove them?
Temporary / poor man's solution

- Analytically reweighting the various predictions to a common “IBA”, defined for the moment as on slides 4-5
- Plots below: ratios are Generator / IBA (following slide 2 quite closely)
- Only lineshape addressed – does not include any corrections to the couplings
- W & Z processes
Temporary / poor man's solution

- Performance of lineshape reweighting on Pythia / Powheg comparison
Summary

- In the era of N(N)LO QCD + NLO EW event generators, **leading order and multi-leg generators will remain relevant for a long time**
  - The more mature generators are precisely tuned to data, allowing for accurate description of many features (underlying event, isolation, …) that are very relevant in event selections, and hence for efficiency determination, etc. Newer generators will need time to catch up
  - Multi-leg generators are complementary to the NLO generators in the high parton multiplicity regime
  - Many ongoing analyses will stay with current state-of-the-art tools

- However, large diversity in EW settings lead to unnatural discrepancies in some key kinematic distributions.

- Kind request to the theory community:
  - Define a sensible IBA, that mimics the full NLO EW correction to sub-percent accuracy. Was successfully done at LEP times. Precision tag to be re-evaluated in LHC context
  - Harmonize the QCD generators EW settings according to this

- Thanks to all MC authors for discussions in the last months!