Electroweak Corrections to Vector-Boson + b-jet Production

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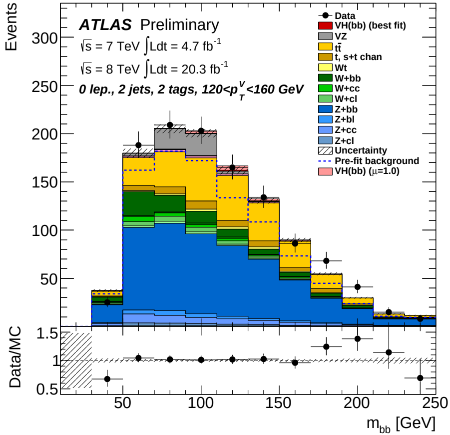
Pheno 2015

May 5, 2015

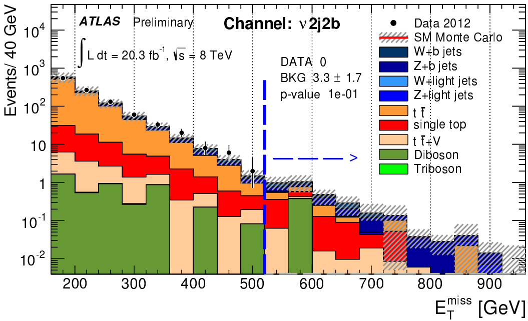
Importance of vector-boson + heavy-jet production

- Processes of interest include ($V = Z, \gamma, W^{\pm}$)
  - $gg, q\overline{q}^{(\prime)} \to Vb\overline{b}$
  - $bg \to Zb, \gamma b$
  - $qb \to Wbq'$
- Backgrounds for measurement of Higgs-boson couplings
- Backgrounds for new physics searches
- Clean vector boson signals enable precision measurements of heavy-quark PDFs.



(*ATLAS-CONF-2013-079*)

Why study b-initiated processes?



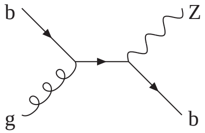
(*ATLAS-CONF-2014-006*)

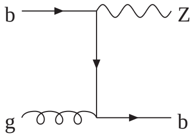
- $Z/W + b$-jets are a significant background at large values of missing transverse energy (due to neutrinos).
- Processes in this regime are well beyond the 4FNS $\to$ 5FNS threshold.
- A more accurate b PDF would improve background predictions.

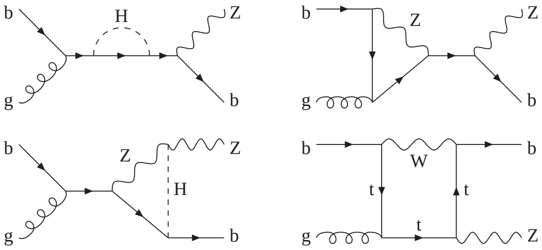
Achieving greater accuracy

- We choose first to study the b-initiated process $bg \to Zb$.
- $\mathcal{O}(\alpha_s)$ QCD corrections have already been calculated for each of the $V+$ heavy jet processes including $bg \to Zb$.
- $\mathcal{O}(\alpha)$ electroweak (EW) corrections are the next step and are presented in this talk.
- Mass effects are expected to be of the same order as $\mathcal{O}(\alpha)$ EW corrections (a few percent), and thus the b-quark mass must be retained.
- Implementing mass effects consistently at all levels (both initial- and final-state, PDF, etc.) takes some care.
- Important for NLO parton-shower Monte Carlo event generators

- 2 Born-level diagrams corresponding to s- and t- channels
- $m_b \neq 0$
- $\sigma = \sigma_0 + \sigma_{1-loop} + \sigma_{real}$
  - $\mathcal{O}(\alpha\alpha_s) + \mathcal{O}(\alpha\alpha_s^2) + \mathcal{O}(\alpha^2\alpha_s) + \cdots$
- UV and IR divergences regulated using dimensional regularization
- QED and weak corrections can be separated since we do not encounter the vertex which mixes γ and $W^{\pm}$.

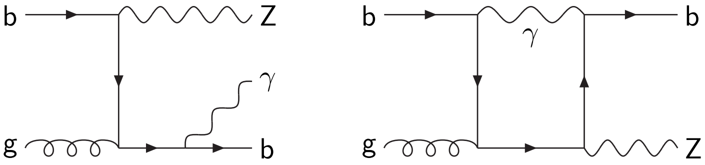






- 36 unique weak diagrams (not counting *s*- and *t*- channels separately) in the 't Hooft-Feynman gauge
- Renormalization conditions following A. Denner (*Fortschritte der Physik, 41(4):307420, 1993*)
- Z and H real emission diagrams are not needed to cancel divergences and can be treated as separate processes.
  - $bg \to Zb + (Z/H)$

QED Corrections



- Photon loop diagrams contain IR divergences which cancel the IR divergences arising from soft photon emission diagrams
- The IR poles are extracted using phase-space slicing (only soft divergences → only one cutoff)
  - Used to study the implementation of massive dipoles in the simplest case (soft divergence only) (*S.Dittmaier, arXiv:hep-ph/9904440*)
  - Very useful for future MC improvements

Tools

- NLOX
  - Automated calculation of 1-loop QCD corrections using Feynman diagrams and advanced reduction techniques
  - Started by T. Schutzmeier (*JHEP 1209 (2012) 119*)
  - Maintained and completed by S. Quackenbush (release in preparation)
  - Added EW 1-loop corrections (by S. Quackenbush)
- Compared to two in-house codes (written using FORM, public C++/Fortran libraries, Maple, and custom code)

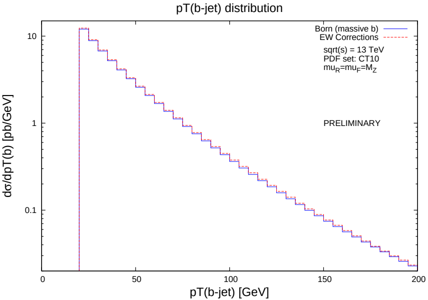
Results (Preliminary)

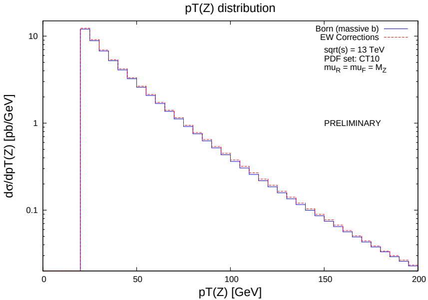
Order	LO	NLO (EW only)	% shift
σ (pb)	273.31 ± 0.02	281.17 ± 0.04	2.97%

Table: Total cross sections, 20 GeV $<$ b-jet $p_T < 200$ GeV, $\sqrt{s} = 13$ TeV

- PDF set used is CT10
- Renormalization and factorization scales were set equal to M_Z.
- Only error displayed is statistical (due to the Monte Carlo integration)
  - Other sources of error (i.e. scale variation) will be explored later.
- For comparison, QCD corrections are around 20% (Campbell et al., arXiv:hep-ph/0312024)

p_T distributions (EW corrections)





- Small impact (1-2%)
- No “heavy radiation” (W/Z/H) included
- Need to carefully study how much is a mass effect and how much is a pure EW effect

- EW corrections to $bg \to Zb$ have been calculated.
    - Study mass effect in QCD corrections
- EW 1-loop automation implemented in NLOX
- Heavy quark mass must be retained
    - Requires a consistent implementation of PDFs with massive initial states
- Explore other vector-boson + heavy-jet processes