Weak boson scattering at the LHC

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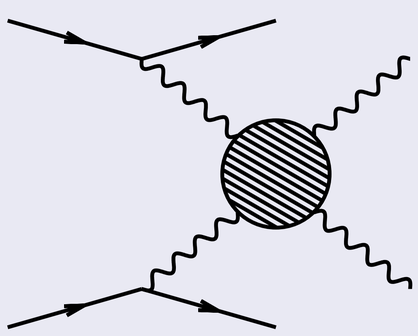
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

motivation

weak boson scattering processes . . .



- . . . exhibit striking kinematic features: suppressed color exchange in the t-channel $\Longrightarrow$ little jet activity in central-rapidity region
- . . . are crucial to distinguish signatures of a standard-model type Higgs mechnism from other scenarios of electroweak symmetry breaking (e.g., strong interactions in the weak sector, extra dimensional models, etc.)

aim: tool development

develop stable, fast & flexible Monte Carlo programs allowing for

- computation of various jet observables for electroweak W^+W^-jj, $ZZjj$, $W^\pm Zjj$, and $W^\pm W^\pm jj$ production at the next-to-leading order (NLO) of QCD
- full consideration of leptonic decay correlations
- straightforward implementation of cuts
- implementation of new physics models
- embedding in more general framework of the `vbfnlo` code for various gauge-boson production processes

ingredients of the calculation

- Born amplitude squared:

$$|\mathcal{M}_B|^2 = \left| \quad + \quad + \quad + \ldots \right|^2$$

large number of Feynman diagrams requires efficient set-up of the calculation:

- employ amplitude techniques to evaluate $\mathcal{M}$ first (numerically) for specific helicities of the external particles, then square
- avoid multiple evaluation of recurring building blocks

- real-emission amplitude squared:

$$|\mathcal{M}_R|^2 = \left| \quad + \quad + \quad + \ldots \right|^2$$

real-emission contribution diverges as unobserved parton becomes soft or collinear

$\Longrightarrow$ apply dipole subtraction formalism to absorb these divergencies in auxiliary counterterms $d\sigma^A$, which are then added back to virtual corrections:

$$\sigma^{NLO} = \int_{m+1} \left[d\sigma^R_{\varepsilon=0} - d\sigma^A_{\varepsilon=0} \right] + \int_m \left[d\sigma^V + \int_1 d\sigma^A \right]_{\varepsilon=0}$$

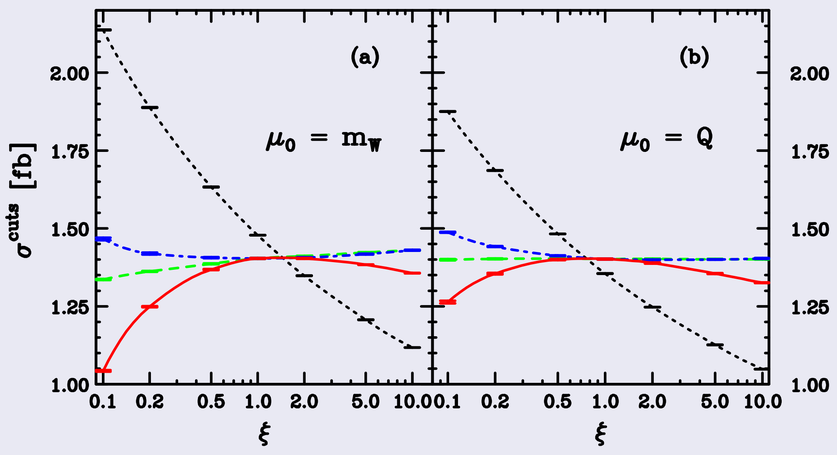
- interference of $\mathcal{M}_B$ with virtual corrections:

$$\mathcal{M}_V = \quad + \quad + \quad + \ldots$$

- need to compute vertex-, box-, and pentagon-loop diagrams
- singularities are extracted analytically in $d = 4 - 2\varepsilon$ dimensions and cancel with respective counterterms
- finite contributions are evaluated numerically

results for the LHC

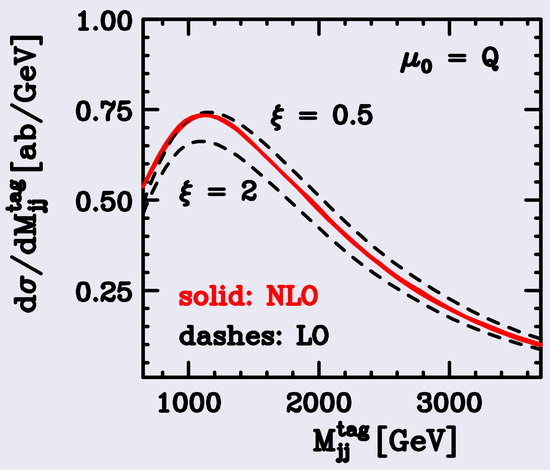
scale dependence of the W^+W^+jj cross section:



$\mu_R = \xi_R \mu_0$ and $\mu_F = \xi_F \mu_0$ with variable ξ

dependence on unphysical renormalization and factorization scales is significantly reduced at NLO

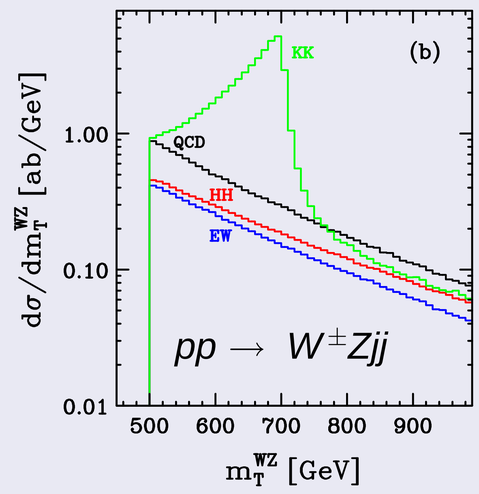
invariant dijet mass:



shape of kinematic distributions changes after inclusion of radiative corrections

signatures of new physics

transverse gauge boson mass:



. . . exhibits pronounced sensitivity to Warped Higgsless model with extra vector resonances

publications

- Jäger, Oleari, Zeppenfeld, Phys. Rev. **D80**, 034022 (2009).
- Englert, Jäger, Worek, Zeppenfeld, arXiv: 0904.1229 (hep-ph).
- Englert, Jäger, Zeppenfeld, JHEP **0903**, 060 (2009).
- Arnold et al., Comput. Phys. Commun. **180**, 1661 (2009).
- Englert, Jäger, Worek, Zeppenfeld, Phys. Rev. **D80**, 035027 (2009).

conclusions

- explicit calculations revealed that weak boson scattering reactions are perturbatively well-behaved:
  moderate NLO QCD and EW corrections,
  negligible higher order and interference effects
- various background processes are well under control

$\Longrightarrow$ weak boson scattering is crucial for understanding the mechanism of electroweak symmetry breaking

$\Longrightarrow$ signatures of new physics in the gauge boson sector should be observable at the LHC