The Power of Automated Numerics: Application of HELAC-NLO in pp → ttbb

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Research Interests

- Phenomenology of the Standard Model at present and future colliders and Monte Carlo simulations of the physical processes
- Fixed order multi-leg automatic LO and NLO calculations
- Development of system based on **HELAC-PHEGAS**, **HELAC-1LOOP**, **CUTTOOLS, ONELOOP, HELAC-DIPOLES**

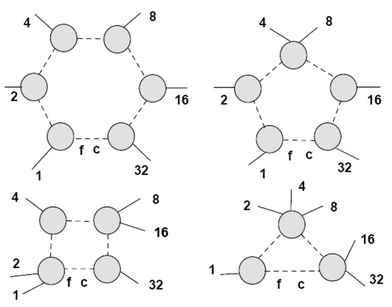
Virtual Corrections

- One-loop n particle amplitude
- Amplitude can be expressed in basis of known integrals such as 4-, 3-, 2-, 1-point scalar integrals

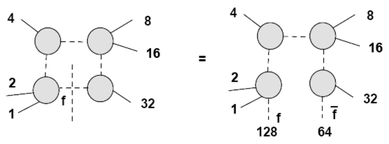
$$A = \sum_{I\in\{1,2,\dots,n\}} \int \frac{\mu^{4-d} d^d \bar{q}}{(2\pi)^d} \frac{\bar{N}_I(\bar{q})}{\prod_{i\in I} \bar{D}_i(\bar{q})} \qquad \bar{D}_i(\bar{q}) = (\bar{q}+p_i)^2 - m_i^2, \quad i = 1,2,\dots,n$$

$$A = \sum_i d_i\ Box_i + \sum_i c_i\ Triangle_i + \sum_i b_i\ Bubble_i + \sum_i a_i\ Tadpole_i + R$$

- In order to calculate one loop amplitude three main building blocks are needed
- Evaluation of numerator function N(q) - **HELAC-1LOOP**
- Determination of coefficients via reduction method – **OPP** and **CUTTOOLS**
- Evaluation of scalar functions – **ONELOOP**

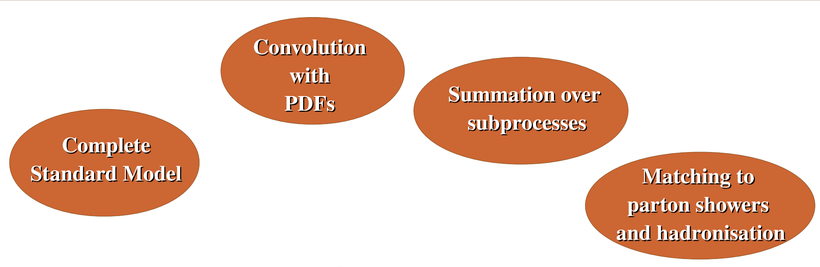


Collection of possible contributions



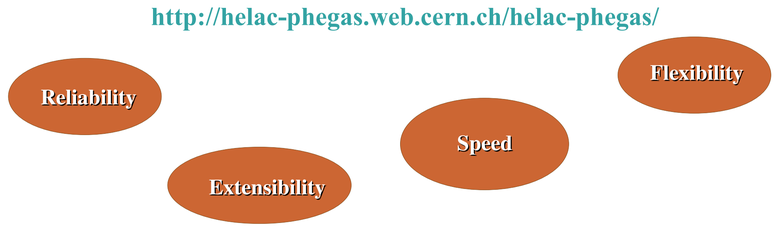
- Possibility to use tree level amplitudes
- Collecting all contributions with given loop propagator
- Calculated as part of tree level amplitude with n+2 particles in 4 dimensions

Leading Order Part



Features of HELAC-PHEGAS Monte Carlo generator

http://helac-phegas.web.cern.ch/helac-phegas/

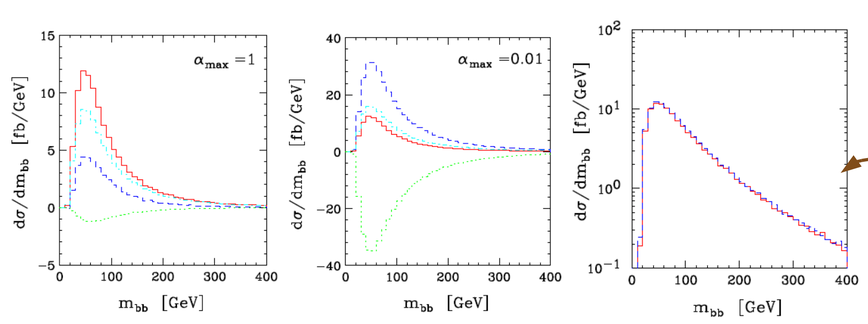


Real Emission Part

HELAC-DIPOLES

http://helac-phegas.web.cern.ch/helac-phegas/

- Complete, publicly available automatic implementation of Catani-Seymour dipole subtraction
- Phase space integration of subtracted real radiation and integrated dipoles
- Massless and massive cases included
- Extended for arbitrary polarizations. Monte Carlo over polarization states of external particles
- Phase space restriction on the dipole phase space $\alpha_{max} \in]0,1]$

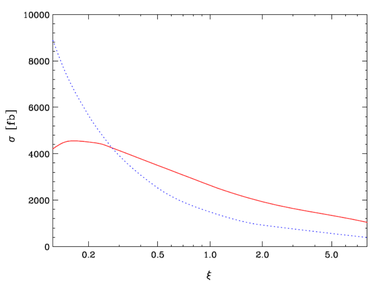


- Cutoff independence
- Distributions level

Full Result • Subtracted Real Emission • K+P insertion operators • I insertion operator

First Application: NLO QCD corrections to pp → ttbb

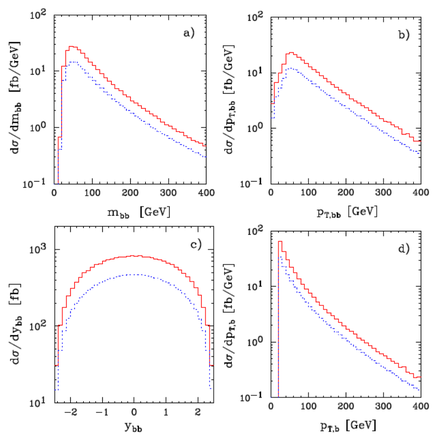
- Irreducible background to **ttH** production where Higgs boson decays into a bb pair
- NLO corrections to 2 → 4 processes current technical frontier



- Differential cross sections at the LHC for pp → ttbb
- Invariant mass distribution, transverse momentum and rapidity distribution of bb pair. Transverse momentum of b quark
- **K = 1.77**

Varying renormalization and factorization scale up or down by a factor 2 changes cross section by **70%** in LO and **33%** in NLO

LO • NLO



Mini-workshop on fixed order multi-leg automatic NLO calculations

- Organizer of the Helmholtz Alliance workshop
- 2nd – 3th of June 2009, Wuppertal University
- 33 Participants. Experts in the field !
- Physicists from Belgium, France, Germany, Greece, Netherlands, Poland, Spain, Switzerland,United Kingdom and United States

Publications

- Helac-Phegas: A Generator for all parton level processes, A. Cafarella, C.G. Papadopoulos, **M. Worek**, Comput. Phys. Commun. 180 (2009) 1941.
- Polarizing the Dipoles, M. Czakon, C.G. Papadopoulos, **M. Worek**, JHEP 0908 (2009) 085.
- Assault on the NLO Wishlist: pp -> t anti-t b anti-b, G. Bevilacqua, M. Czakon, C.G. Papadopoulos, R. Pittau, **M. Worek**, JHEP 0909 (2009) 109.