LHCPhenoNet Mid-Term Meeting

Xuan Chen

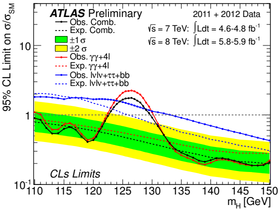
Institute for Particle Physics Phenomenology
University of Durham

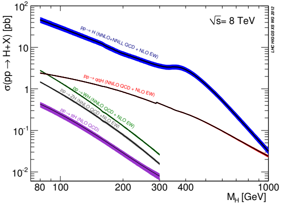
Ravello, September 17-20, 2012

About Me

- ESR of Marie Curie Initial Training Networks (ITN)
  - Start date: 01 DEC 2011
- Home Country: China
- Education:
  - B.S. in Applied Physics, 2006 $\sim$ 2010
    - University of Science and Technology Beijing, China (USTB)
    - B.S. thesis: Magnetic Property of Spin Triplet Superconductor
  - Ph.D. Student in Particle Physic, 2010 $\sim$ 2014
    - Institute for Particle Physics Phenomenology
    - Project: Higgs boson+jet cross sections at NNLO in the large top mass limit.
    - Supervisor: E. W. N. Glover
    - In Collaboration with : S. Wells and J. Currie (ER start in OCT 2012)
    - University: Durham University, UK

Research Project





- Background
  - 1960's Peter Higgs along with five other people proposed a symmetry breaking mechanism to explaining the origin of mass of SM particles
  - 1995 Discovery of Top quark in Fermi Lab left Higgs boson the only undiscovered particle in SM
  - 2012 Atlas and CMS collaborations independently announced the discovery of a new type of boson behaving like the Higgs boson
- Motivation
  - Better understanding of jet vetoes to enhance $H \to b\bar{b}$ signal from background
  - Need event generator for precise cross sections study
  - Study new channel related to gluon fusion to Higgs

Research Project

- Hadron + Hadron → H + Jet
  - At NNLO with Higgs production form gluon fusion
  - Explicit and implicit singularities form NNLO structure
  - Complex factorisation behaviour in subtraction terms

$$d\sigma_{NNLO} = \int_{d\Phi_{H+3}} d\sigma^{RR}_{NNLO} + \int_{d\Phi_{H+2}} d\sigma^{RV}_{NNLO} + \int_{d\Phi_{H+1}} d\sigma^{VV}_{NNLO}$$

  - Each part is divergent thus disallow numerical integration

$$\begin{aligned} d\hat{\sigma}_{NNLO} = & \int_{d\Phi_{H+3}} (d\sigma^{RR}_{NNLO} - d\sigma^{S}_{NNLO}) \\ & + \int_{d\Phi_{H+2}} (d\sigma^{RV}_{NNLO} - d\sigma^{T}_{NNLO}) \\ & + \int_{d\Phi_{H+1}} (d\sigma^{VV}_{NNLO} - d\sigma^{U}_{NNLO}) \end{aligned}$$

  - Each line is finite and each integral for bracketed terms is numerically calculable

MARIE CURIE ACTIONS

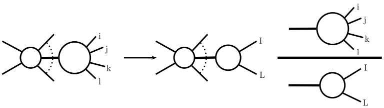
SEVENTH FRAMEWORK PROGRAMME

Research Project

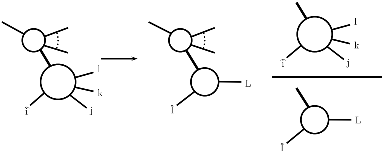
- Antenna Subtraction Method
  - Split phase space and matrix element into singular region and convergent region
  - Analytically integrate antenna function over antenna phase space

$$\int_{d\Phi_{m+2}} d\sigma^{S}_{NNLO} \sim \underbrace{\int_{d\Phi_x} X(\{p_x\})}_{singular\ \epsilon} \underbrace{\int_{d\Phi_n} |\mathcal{M}(\{\widetilde{p_n}\})|^2 \mathcal{J}(\{\widetilde{p_n}\})}_{finite}$$

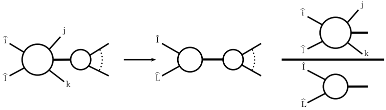
  - Three possible phase space configuration



(a) Final-Final



(b) Initial-FInal



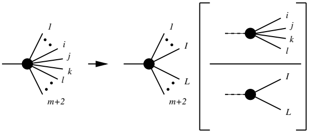
(c) Initial-Initial

Research Project

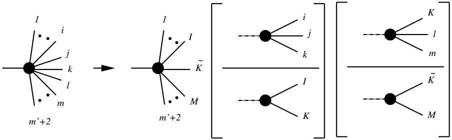
- Double unresolved subtraction structure

$$d\sigma_{NNLO}^{RR,S} = d\sigma_{NNLO}^{S,a} + d\sigma_{NNLO}^{S,b} + d\sigma_{NNLO}^{S,c} + d\sigma_{NNLO}^{S,d}$$

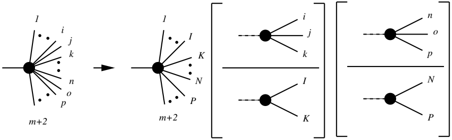
  - $d\sigma_{NNLO}^{S,a}$ one unresolved parton with Jet function missing additional parton



(a) S^b colour connect $X_4^0 \otimes A_m^0$



(b) S^c colour almost connect $X_3^0 \otimes X_3^0 \otimes A_m^0$



(c) S^d colour not connect $X_3^0 \otimes X_3^0 \otimes A_m^0$

Research Project

- $q\bar{q} \to gggH$ Process (only $\mathbb{X}$ topology)

$$d\sigma^{RR,\mathbb{X}}_{NNLO} = \mathcal{N}^{RR}_{NNLO}\, d\Phi_4(p_3,\cdots,p_H;p_1,p_2)\frac{1}{3!}\sum_{(i,j,k)} A^0_{5H}(1_q,i,j,k,2_{\bar{q}},H)\,\mathcal{J}^{(4)}_2(p_3,\cdots,p_H)$$

$$d\sigma^{S^b}_{NNLO} = \mathcal{N}^{RR}_{NNLO}\, d\Phi_4(p_3,\cdots,p_H;p_1,p_2)\frac{1}{3!}\sum_{P_c(i,j,k)} \Bigg[$$

$$\left\{\begin{array}{l} +D^0_4(1_q,i,j,k)\,B^0_{3H}(\bar{1}_q,\widetilde{(ijk)},2_{\bar{q}},H)\,\mathcal{J}^{(2)}_2(p_{(i,j,k)},p_H) \\ +D^0_4(2_{\bar{q}},k,j,i)\,B^0_{3H}(1_q,\widetilde{(ijk)},\bar{2}_{\bar{q}},H)\,\mathcal{J}^{(2)}_2(p_{(i,j,k)},p_H) \\ -\widetilde{A}^0_4(1_q,k,i,2_{\bar{q}})\,B^0_{3H}(\bar{1}_q,\widetilde{j},\bar{2}_{\bar{q}},H)\,\mathcal{J}^{(2)}_2(p_{\widetilde{j}},p_H) \end{array}\right.$$

$$\left\{\begin{array}{l} -\big(d^0_3(1_q,i,j)\,D^0_3(\bar{1},\widetilde{(ij)},k) + f^0_3(i,j,k)\,D^0_3(1_q,\widetilde{(ij)},\widetilde{(jk)}) + d^0_3(1_q,k,j)\,D^0_3(\bar{1}_q,i,\widetilde{(jk)})\big) \\ B^0_{3H}(\bar{1}_q,\widetilde{(i,j,k)},2_{\bar{q}},H)\,\mathcal{J}^{(2)}_2(p_{(i,j,k)},p_H) \end{array}\right.$$

$$\left\{\begin{array}{l} -\big(d^0_3(2_{\bar{q}},k,j)\,D^0_3(\bar{2}_{\bar{q}},\widetilde{(kj)},i) + f^0_3(k,j,i)\,D^0_3(2_{\bar{q}},\widetilde{(kj)},\widetilde{(ji)}) + d^0_3(2_{\bar{q}},i,j)\,D^0_3(\bar{2}_{\bar{q}},k,\widetilde{(ij)})\big) \\ B^0_{3H}(1,\widetilde{(i,j,k)},\bar{2}_{\bar{q}},H)\,\mathcal{J}^{(2)}_2(p_{(i,j,k)},p_H) \end{array}\right.$$

$$\left\{\begin{array}{l} +\big(A^0_3(1,i,2)\,A^0_3(\bar{1},\widetilde{k},\bar{2}) + A^0_3(1,k,2)\,A^0_3(\bar{1},\widetilde{i},\bar{2})\big) \\ B^0_{3H}(\bar{\bar{1}},\widetilde{\widetilde{j}},\bar{\bar{2}},H)\,\mathcal{J}^{(2)}_2(p_{\widetilde{\widetilde{(j)}}},p_H)\Bigg] \end{array}\right.$$

Overview of Training

- Conference attend
  - Young Theorists' Forum 2011, Durham
  - Annual Theory Meeting 2011, Durham
  - LHCPhenoNet Winter School 2012, Ascona
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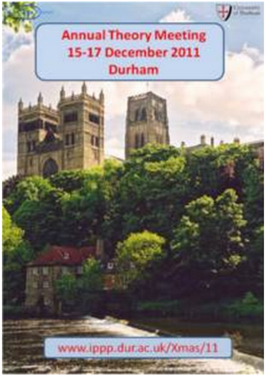

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Durham University · University of Glasgow · Lancaster University

Higgs Maxwell Workshop

Particle Physics at the Crossroads

MARIE CURIE ACTIONS · SEVENTH FRAMEWORK PROGRAMME

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- Training courses at Ascona
  - QCD and jet physics, M. Cacciari
  - Parton Distribution Functions, M. Ubiali
  - BSM physics, A. Romanino
  - Monte Carlo event generators, R. Frederix
  - Methods for higher order calculations, L. Dixon
  - Results from the Tevatron, T. Junk
  - Results from the LHC, G. Dissertori
- Organisation of the Annual Meeting at Durham
  - Drafting scientific program
  - Discussion with A-level school children

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SEVENTH FRAMEWORK PROGRAMME

Overview of Training

- Scheduled seminars
  - Seminars each Thursday afternoon during term time in Durham
  - QCD journal club every two weeks on recent papers
- Language Skills
  - Presentation skills from Durham University
  - Preparing slides in LaTex and speech
  - Improvement in both formal and oral English
- Internship with Maple Soft
  - Interview and preparing with Dr. Dave Hare
  - Preparing for Canada VISA
    - Tried in person application with Canada Embassy in London for temporary visiting visa
    - Working permit would only be applied in home country (3 month in China)

Milestones and Plans

- Presentations
  - Talk at LHCPhenoNet Annual Meeting 2012
    - Higgs plus multi-gluon helicity amplitudes
  - Talk at LHCPhenoNet Mid-Term Meeting 2012
    - Progress in NNLO Process Involving Higgs plus Jets
- Fortran code
  - Analytical calculation of Higgs + (up to) 5 parton helicity amplitudes
    - Compact analytical result from application of BCFW method
  - Numerical testing the code with Madgraph5 (MG5)
    - Tested all channels for $2 \to 2$, $2 \to 3$, $2 \to 4$ process
    - About 10 times average faster than MG5 speed (using traditional Feynman Rules)
- Analytical double unresolved subtractions terms

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