Event generators and Higgs Physics at LHC

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The project
the goal

- Goal : to build event generators at NLO (Next to Leading Order) accuracy for processes relevant for the Higgs search at the LHC
  this is the continuation of a long term project (started in 2007)
- To build an event generator at NLO accuracy, the main ingredients are :
  - the computation of the virtual corrections
  - the merging of real corrections and parton showers
  it is important to have some automatic tools (so many processes to compute!)

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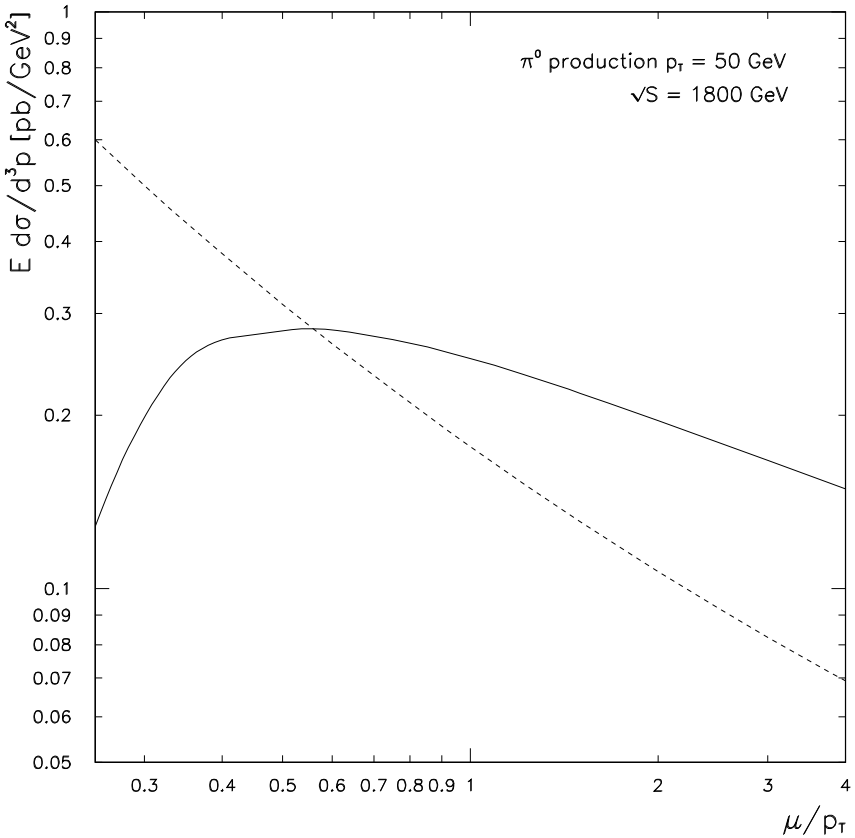
NLO corrections are important to make quantitative predictions



unphysical scales :
renormalisation scale
factorisation scale

Some tools were already developped by our group to compute one loop corrections in QCD :
Golem, Grace
but there are not complete
the first task will be to complete them
Note that this type of computation is very complicated and lengthy, needs to have several tools to cross-check

General One Loop Evaluator of transition Matrix elements

General method to compute one-loop amplitudes

Algorithm for the algebraic reduction of Feynman diagrams into a linear combination of process-dependent tensor structures, weighted by universal form-factors forming a generating set of scalar integrals

Main virtues

- Easy subtraction of infrared singularities
- Explicit absence of inverse Gram determinant

$$
\begin{aligned}
I^{\mu_1 \cdots \mu_k} &= \int \frac{d^n k}{(2\pi)^n} \frac{\prod_k q_k^{\mu_k}}{\prod_{i=1}^N q_i^2} \\
&= \int \frac{d^n k}{(2\pi)^n} \frac{(q_1^{\mu_1} + \sum_{j=1}^N C_{j1}^{\mu_1} q_j^2)}{\prod_{i=1}^N q_i^2} \prod_{k\neq 1} q_k^{\mu_k} \\
&\quad - \sum_{j=1}^N C_{j1}^{\mu_1} \int \frac{d^n k}{(2\pi)^n} \frac{q_j^2 \prod_{k\neq 1} q_k^{\mu_k}}{\prod_{i=1}^N q_i^2}
\end{aligned}
$$

with

$$
C_{jk}^{\mu} = \sum_{i=1}^N S_{ji}^{-1} \Delta_{ik}^{\mu} \qquad \text{with } \Delta_{ij}^{\mu} = r_i^{\mu} - r_j^{\mu}
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golem95

Fortran 95 library to compute form-factors up to six external legs, available at:
http://lappweb.in2p3.fr/lapth/Golem/golem95.html

No internal mass up to now (not a matter of principle)

haggies

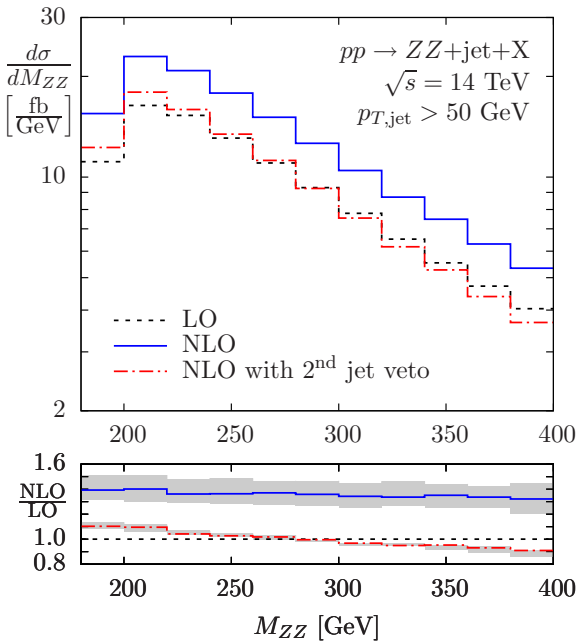
An optimizing code generator
http://www.nikhef.nl/ thomasr/

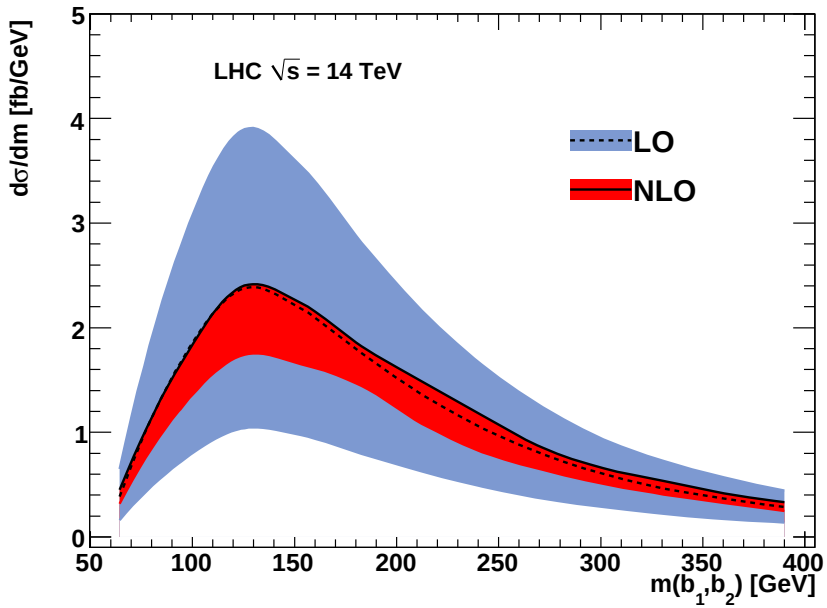
- $p + p \to Z + Z + \text{jet}$

  [T. Binoth, T. Gleisberg, S. Karg, N. Kauer, G. Sanguinetti]

- $p + p \to b + \bar{b} + b + \bar{b}$ ($q\bar{q}$ channel)

  [T. Binoth, N. Greiner, A. Guffanti, J.P. Guillet, T. Reiter, J. Reuter]





The library golem95

- a library has been written (fortran 95) which enables to compute form factor up to six external legs, phase space regions where $det(G) \simeq 0$ are computed numerically as a one dimensional integrals
  `http://lappweb.in2p3.fr/lapth/Golem/golem95.html`
- initially dedicated to QCD : no internal masses.
  extension to internal masses :
  computation of the infra-red triangle with internal masses (done)
  computation of the 6 dimensional boxes (in progress)
  version with a link to looptools
- extensive comparisons of both libraries (there are so many cases !) with Grace people

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Merging real corrections and parton showers

Among the Higgs backgrounds, we focus on the di-boson production (Z,W,γ)
Several strategies tried
some programs already started : GR@PPA, DiphoxPS
the second task will be to improve them

Towards SMC at NLO accuracy

Goal

Interfacing NLO Matrix Element Generators (MEG) with Shower Monte Carlo's (SMC)

- MEG: Diphox, Jetphox
- SMC: Herwig, Pythia, Sherpa

Method

POWHEG (POsitive Weight Hardest Emission Generator)

[P. Nason 2004]

- Many processes implemented: ZZ, $t\bar{t}$, H, Z+jet, ...

Code

- `Fortran 95` program written for the simplest case:
  - $p\,p \to \gamma\,\gamma\,X$ at leading order
- Structure of the code
  - Generate NLO events using MEG
  - Interface: `xml` format data file based on Les Houches Event File
  - LHEF `xml` file read by the SMC which generate hadronic events

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First results

Sucessful comparison between

- PHOX MEG + Pythia SMC and PYTHIA event generation + SMC
- POWHEG Diphox and “standard” Diphox

Understanding photon fragmentation in SMC

Current issue

- MEG: fragmentation photons are generated through inclusive fragmentation functions
- SMC: generation of exclusive parton showers which produce photons in the final state

Which finite part of NLO matrix elements to be subtracted

to properly match with parton showers which produce photons?

Work in progress. . .

Other developments

- Improving Jetphox
  - LHAPDF implemented
  - modern fragmentation function sets implemented
  - ROOT format output

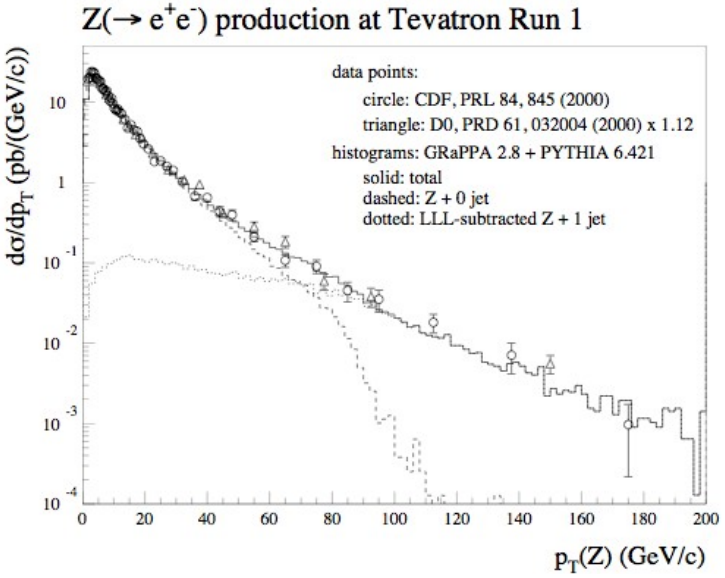
- Isolation studies
  - implementation of a “discretized” Frixione isolation criterion (through nested cones) to reduce fragmentation
  - work in progress with CDF/ATLAS to improve comparison between theory and experiment (e.g. influence of underlying events)

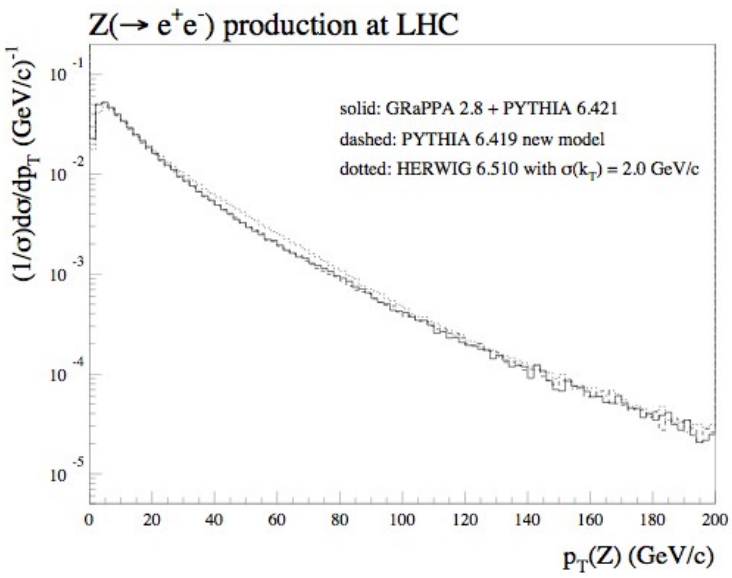
GR@PPA 2.8

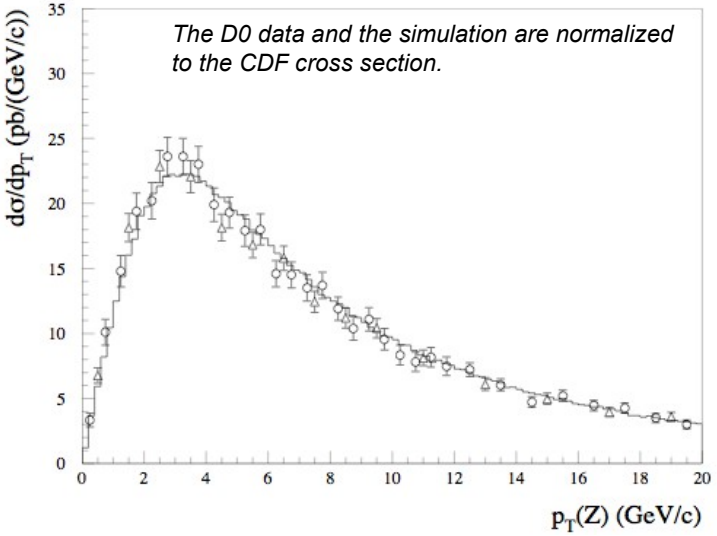
A new version of the GR@PPA event-generator package

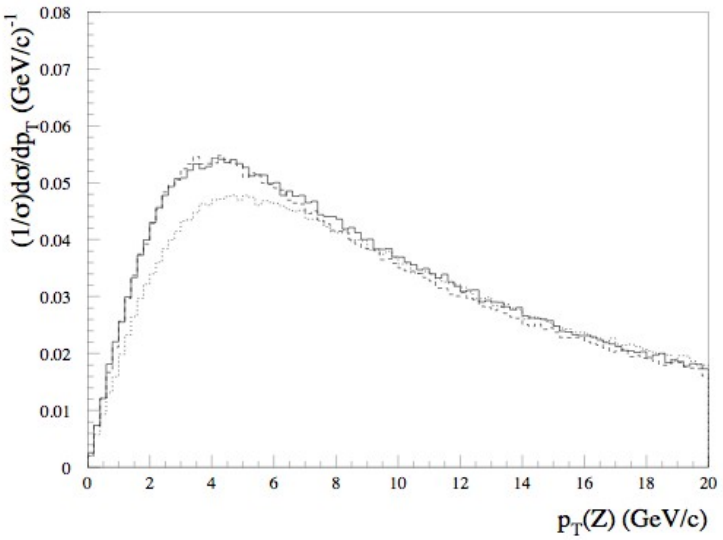
- ME-PS matching in the generation of *W*, *Z*, W^+W^-, *ZW*, *ZZ* production processes at hadron collisions
  - LLL subtraction & custom LL PS
    - Forward evolution PS in the initial state (QCDPS)
    - Backward evolution PS (QCDPSb) available as well
    - Final-state PS (QCDPSf) also implemented
      - Can also be applied to initial-state radiations.
  - Still at LO; *i.e.*, no loop yet
- Additional features
  - *W* and *Z* decays in the matrix elements
    - Exact spin, phase-space and off-shell effects at the tree level
  - PDG values for the decay widths and branching ratios of *W* and *Z*
  - Generated events can be passed to PYTHIA to proceed the simulation; i.e., hadronization and decays.
- Release candidate version can be downloaded from:
  - http://atlas.kek.jp/physics/nlo-wg/grappa.html.

Z-boson production





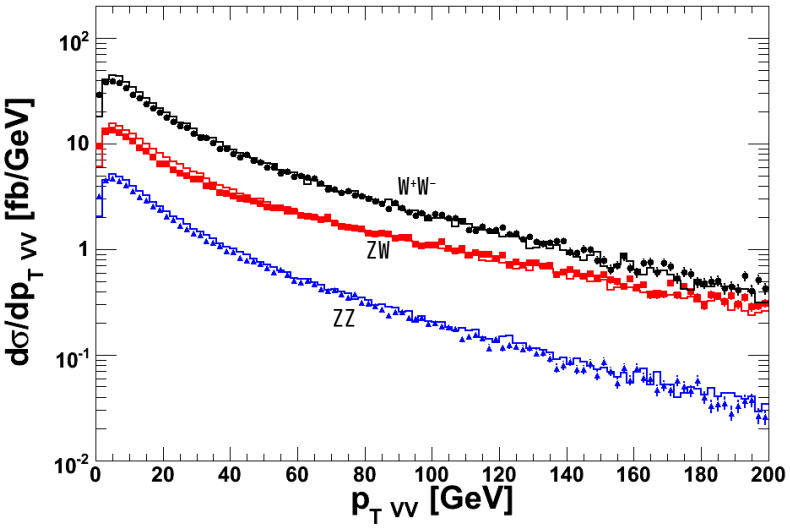


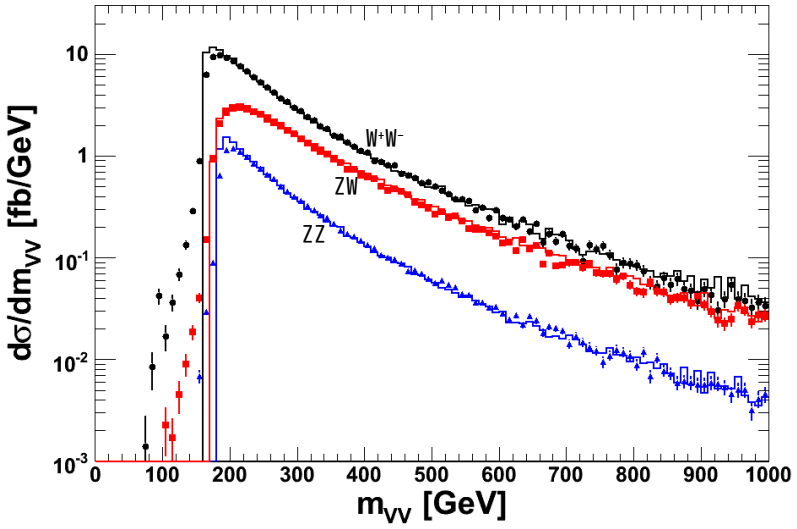


Di-boson production @LHC

GR@PPA v.s. MC@NLO

Plots: GR@PPA 2.8 + PYTHIA 6.419
Solid lines : MC@NLO3.31+Herwig6.510.3+Jimmy4.31.3





Reasonable agreement

GR@PPA simulations are still at LO.

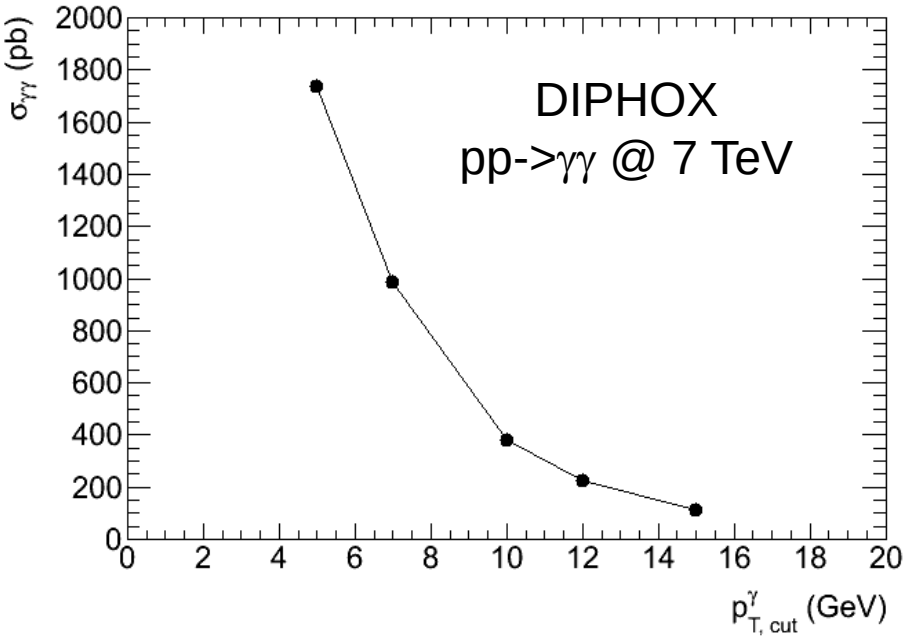
Zero decay widths in these MC@NLO simulations.

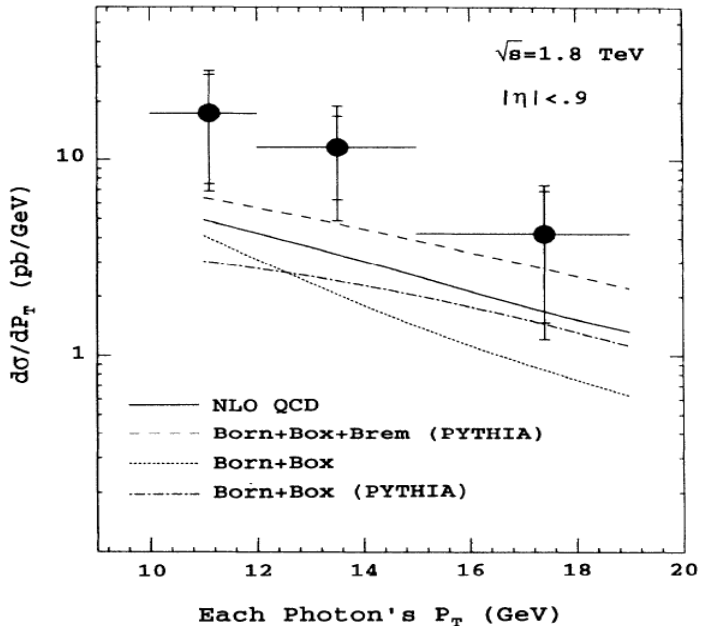
Di-photon activities

- First measurement of prompt photon production for ICHEP
- Next step: diphoton production.

- Short-term goal (this Fall) : reproduce early TeVatron analyses
  - Should have few 100's of nb^{-1} by end of Summer
  - Cross-section (DiPhox) : ~400 pb for p_T>10 GeV => O(100) events ?
  - Use robust methods
  - Challenge: understand photon selection, isolation, etc.
- Longer term (2011): results competitive with recent TeVatron measurements
- First studies using Sherpa to model signal at NLO.

- H->γγ sensitivity numbers have also been updated recently towards the 2010-2011 dataset (1 fb^{-1} @ 7 TeV). Results not public yet, but should be very soon.





summary

thanks to fjppl, we organised informal meetings (3 per year) $\rightarrow$ fruitful exchanges of ideas and comparisons between the different codes

- completion of the loop libraries (golem95, Grace)
- improvements of GR@PPA and Diphox(PS)