MC4MC:

Monte Carlo for a Muon Collider

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$\mu^+\mu^-$ Collider Workshop

Basic Message

- We have the tools to generate the Standard Model cocktail (a "complete" set of high-p_T processes) at a multi-TeV μC
- Sophisticated description of QCD
- Weak on sub-leading and Electroweak effects
- Not yet 1% (NLO) physics description of Standard Model
- Multiple methods to implement (at LO) new Terascale physics

Current State of Event Simulation

Physics simulations provide robust predictions of event properties for known and speculative physics models before the detector simulation

Relative to a few years ago, we have:

- many alternative tools to ask the same questions
  (Cross checks/flexibility/(theory) systematics)
- interfaces between different types of tools
  (basic agreements between practitioners)
- concerted efforts towards tuning and validation
  (MCNet)

Event Generators

Provide fully hadronized events (particles ready for simulation)

Serious implementation of perturbative and non-perturbative QCD

Mostly leading log (most important) physics

- valid for strict orderings (i.e. $p_{T1} \gg p_{T2} \gg p_{T3}$)
- sub-leading logarithms ($p_{T1} \simeq p_{T2}$) may be important for some observables

- `Pythia6` $\longrightarrow$ `Pythia8`
- `Herwig6` $\longrightarrow$ `Herwig++`
- `Ariadne`
- `Sherpa`[1]

[1] PS+ME

Matrix Element Calculators

Automatically calculate code needed for a given HEP partonic process and generate events

- Alpgen@ http://m.home.cern.ch/m/mlm/www/alpgen/
- CompHep@ http://theory.sinp.msu.ru/comphep
- Grace@ http://atlas.kek.jp/physics/nlo-wg/grappa.html
- MadEvent@ http://madgraph.hep.uiuc.edu/index.html
- Sherpa/Amegic++@ http://141.30.17.181/[2]
- WHIZARD@ http://whizard.event-generator.org/

Advantages and disadvantages of each

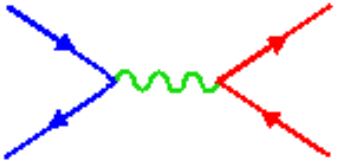
These supplement the event generators

[2] ME+PS

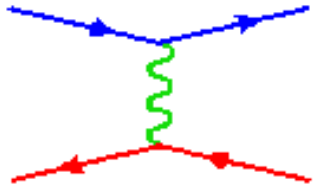
File Edit View Go Bookmarks Tools Window Help

http://madgraph.hep.uiuc.edu/ Search

Home Bookmarks



MadGraph HomePage



by Fabio Maltoni and Tim Stelzer

Generate Process | Calculated Cross Sections | Source Codes | FAQ Developments | Other approaches | Citations

Generate Process Code On-Line

Quarks: d u s c b t d~ u~ s~ c~ b~ t~

Leptons: e- mu- ta- ve vm vt e+ mu+ ta+ ve~ vm~ vt~

Bosons: A Z W+ W- h g

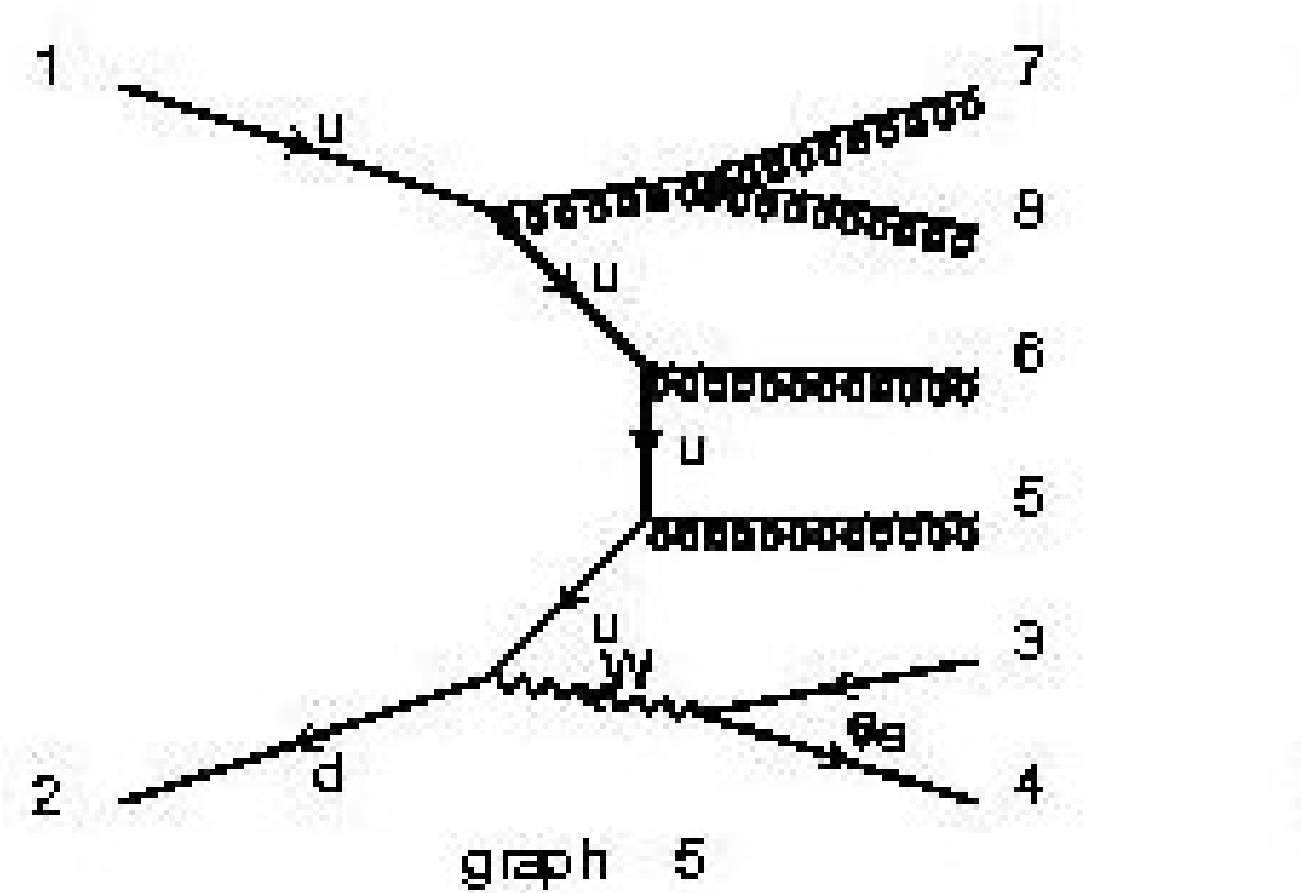
Special: P j (sums over d u s c d~ u~ s~ c~ g)

Process: PP > W+ > e+ ve jjj Submit EXAMPLES

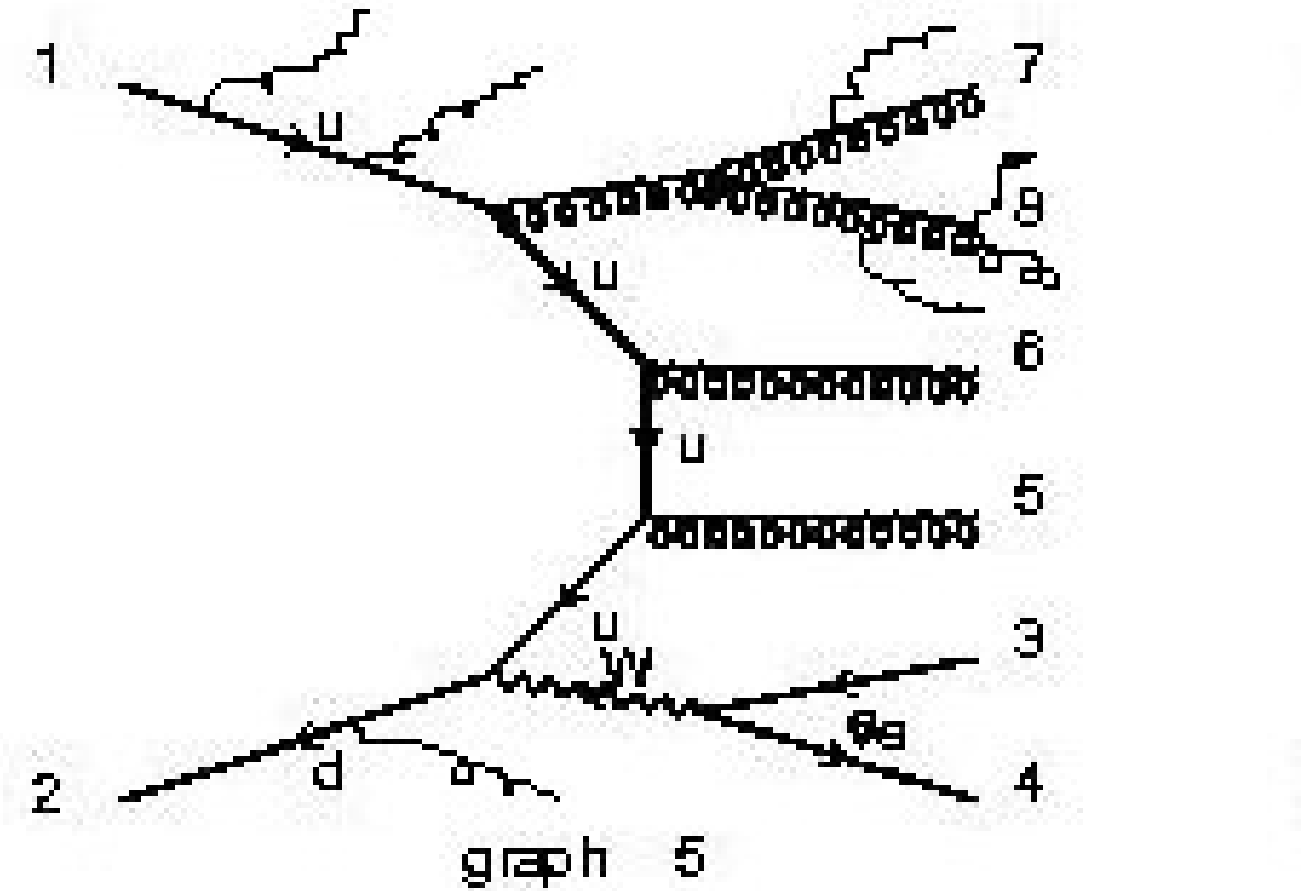
Max QCD Order: 4

Max QED Order: 2

Tree Graph with Hard Partons



Tree Graph + Parton Shower



External Tools

SM tools

`EvtGen`	B decays beyond phase space
`Tauola`	τ decays with polarization
`Photos`	photons in τ and hadron decays

BSM tools

- Susy/Higgs spectrum tools
- Lagrangian generator tools
- SLHA interface to `Pythia/Herwig` *etc.*

“NLO” Event Generators

NLO is not the problem

- decomposition of loop integrals is known
- human intervention is decreasing
- tree level (i.e. `MadGraph`) calculations are the most time-consuming

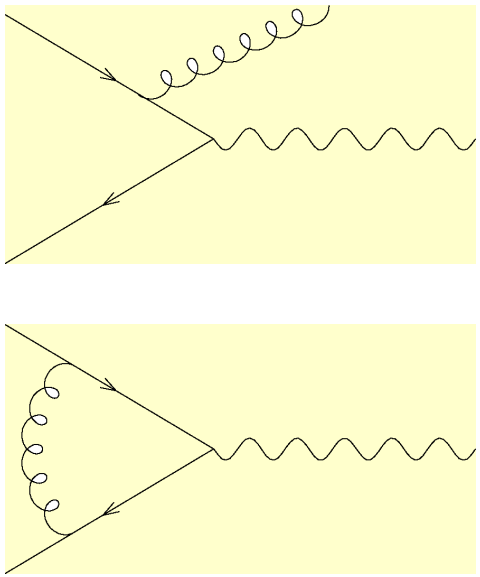
Addition of parton showering (for hadronization) is the thorny problem

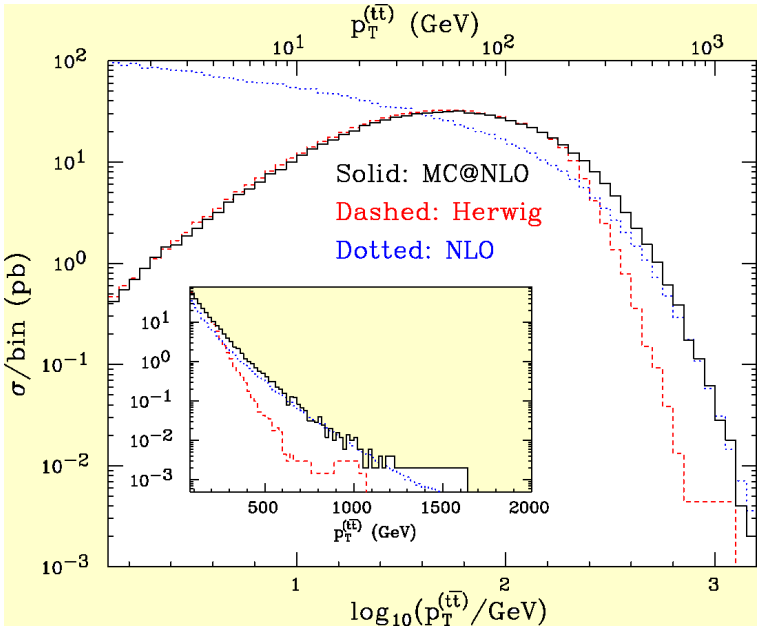
- partial solutions (*e.g.* `MC@NLO/Powheg/Pythia-Herwig` ME correction)
- must be worked out case-by-case
- most work for hadron collisions
- `Vincia` (antenna showers) project very promising for MC

Still no Next-to-Leading-Log showers

Event Generation At NLO

- NLO Calculations give an improved description of the hard kinematics and cross sections, but are inclusive, i.e. **not** (exclusive) event generators
- Solution (`MC@NLO`): Remove divergences by adding and subtracting the Monte Carlo result for one emission





What is different about a multi-TeV MC?

μ beams

- handled by main-stream generators
- handles for beam structure (machine physics)
- photon radiation implemented

multi-TeV

- QCD should be under better control
- physics of loop effects is trouble

  SM must be implemented to high precision
  raises the whole “NLO” event generator issue

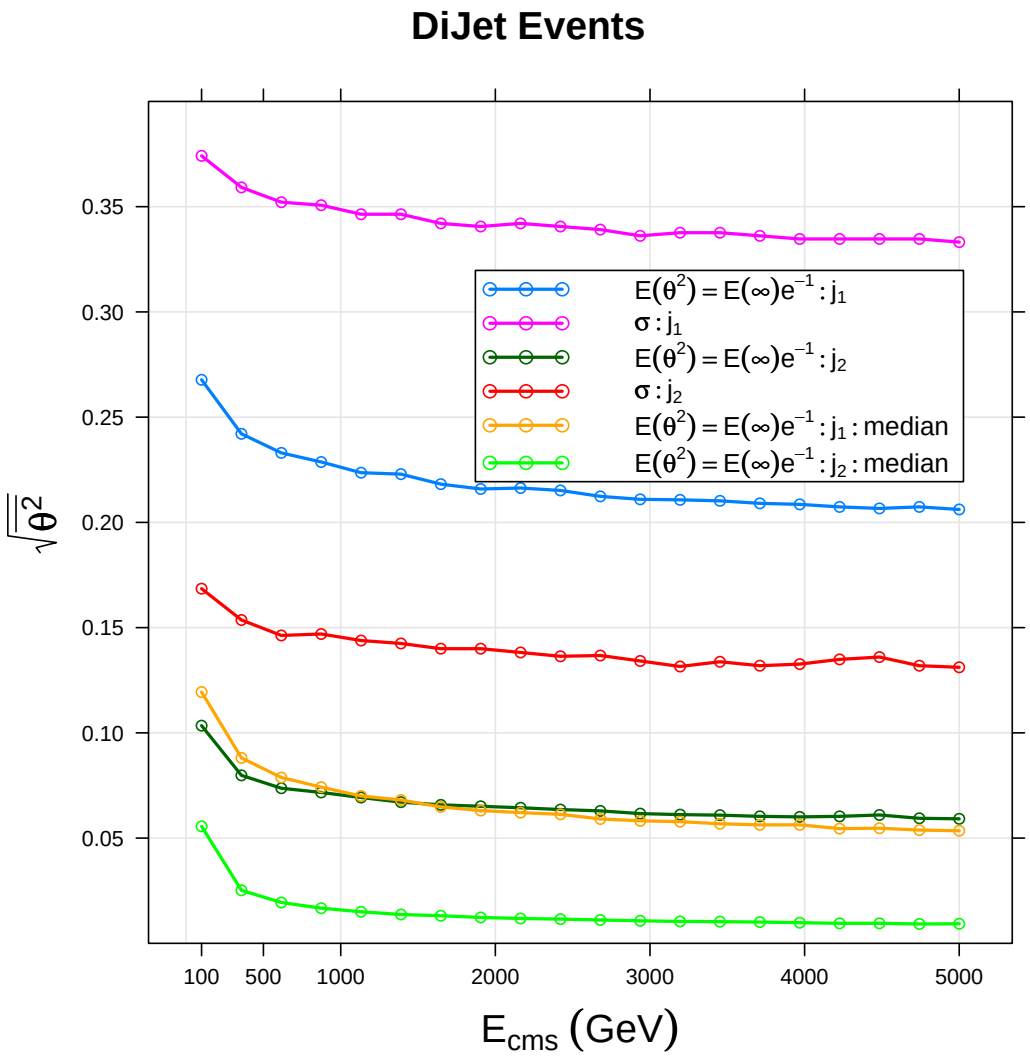
Accuracy driven by physics goals

We don't know what new Terascale physics to prepare for

At least, I expect we will want QCD to an accuracy where we can distinguish a W from a Z

- What does a TeV jet look like?

Jet Size


DiJet Events
0.35
0.30
0.25
0.20
0.15
0.10
0.05
$\sqrt{\overline{\theta^2}}$
$E(\theta^2) = E(\infty)e^{-1} : j_1$
$\sigma : j_1$
$E(\theta^2) = E(\infty)e^{-1} : j_2$
$\sigma : j_2$
$E(\theta^2) = E(\infty)e^{-1} : j_1 : \text{median}$
$E(\theta^2) = E(\infty)e^{-1} : j_2 : \text{median}$
100
500
1000
2000
3000
4000
5000
E_{cms} (GeV)

Message

- We have necessary tools to generate a high statistics sample of the Standard Model cocktail at a multi-TeV muon collider
- It contains a sophisticated description of QCD, including leading logarithms and matrix elements
  - this is its main virtue
  - lacking in Electroweak and higher-order QCD effects
- There are many tools to cross check our predictions, but there has to be a benchmark
- More work is needed to do $< 1\%$ physics