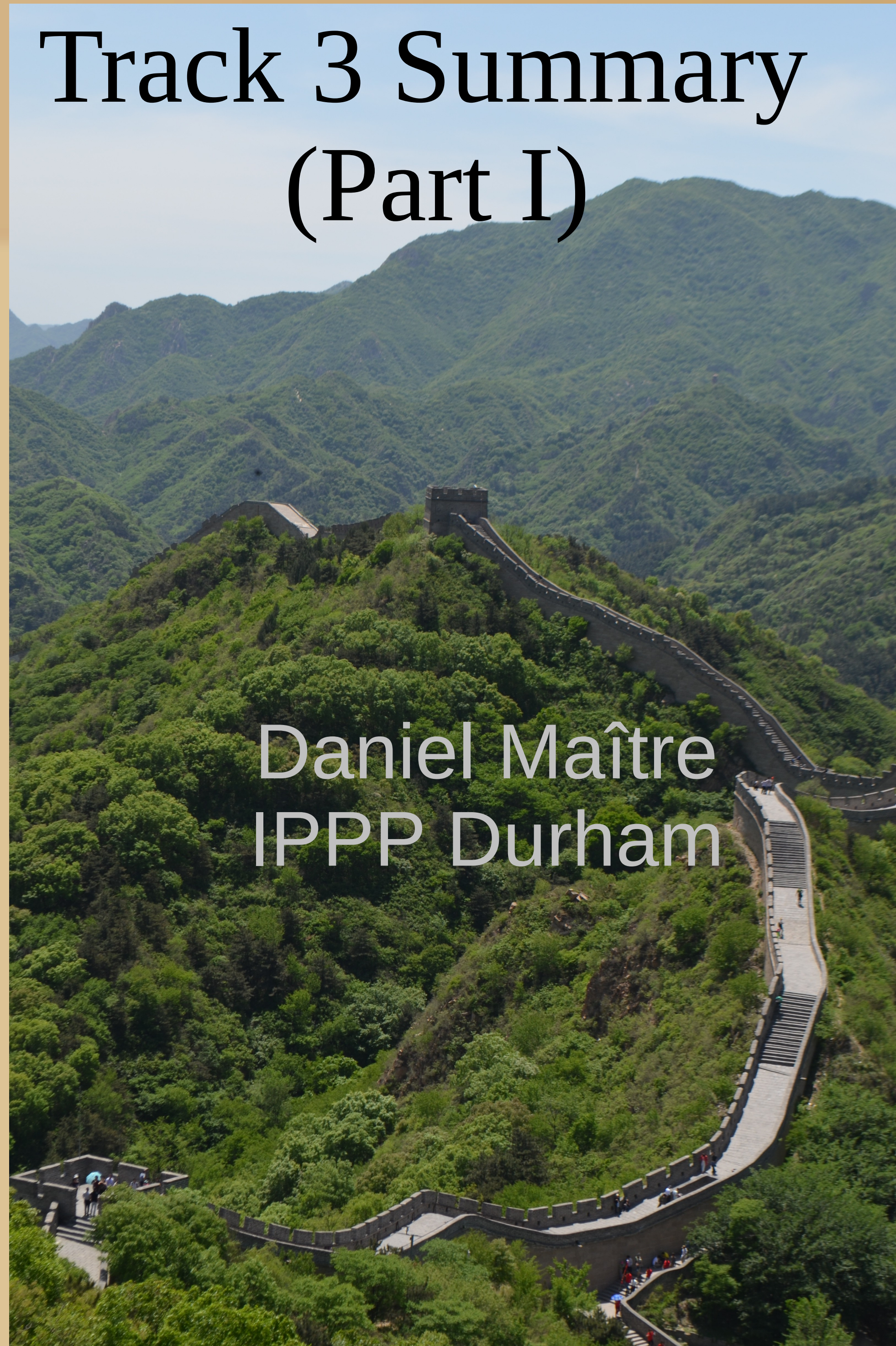
Track 3 Summary (Part I)



Daniel Maître
IPPP Durham

Track 3

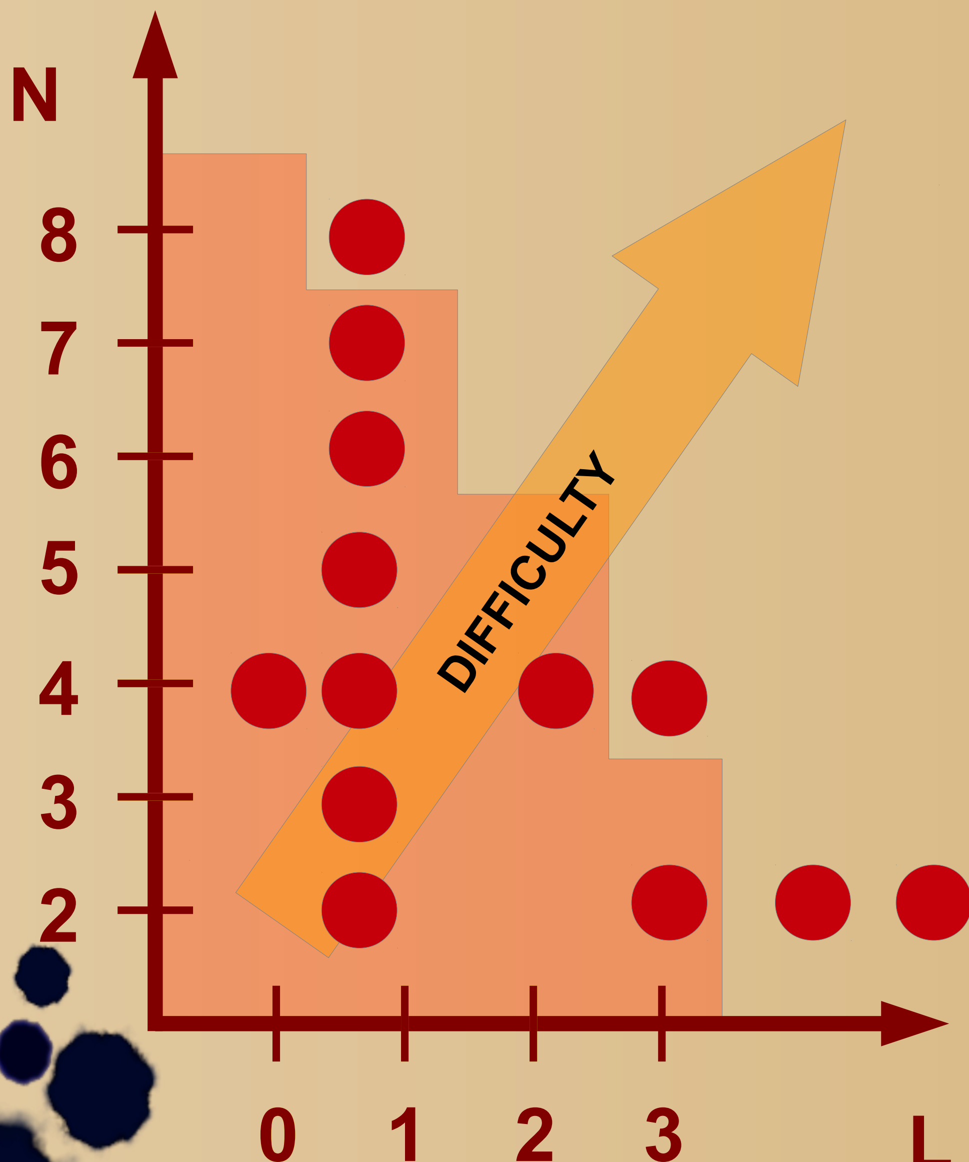
- Conveners
  - Andrej Arbuzov
  - Daniel Maître
  - Wengan Ma
- 6 plenaries
- 24 parallel
- From mathematical aspects to technical applications
- Many very good presentations and a lot of hard work!

Nothing comes for free

Outline

- Tools
- NLO automation
- Loops calculations
- Applications

Perturbative QCD Calculations



- N: Number of external legs
- L: Number of loops
- Bonus points for:
  - Massive particles
  - Moderate use or no approximations
  - Automation
  - Efficiency

Tasks for collider theory prediction

Model

Write amplitude
for example with
Feynman rules

Calculate
Amplitude

Cross section

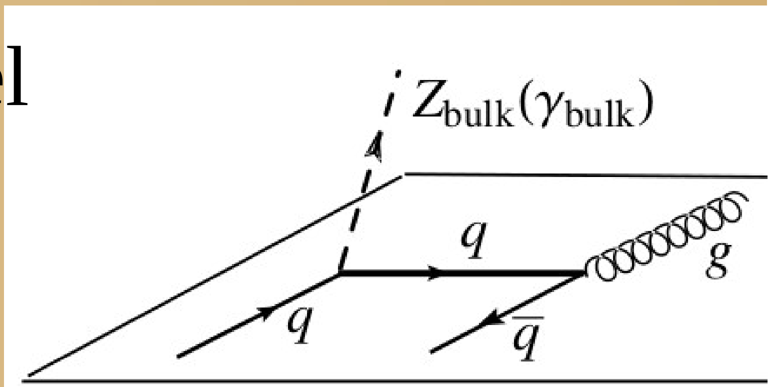
Lattice QCD toolset: Bridge++

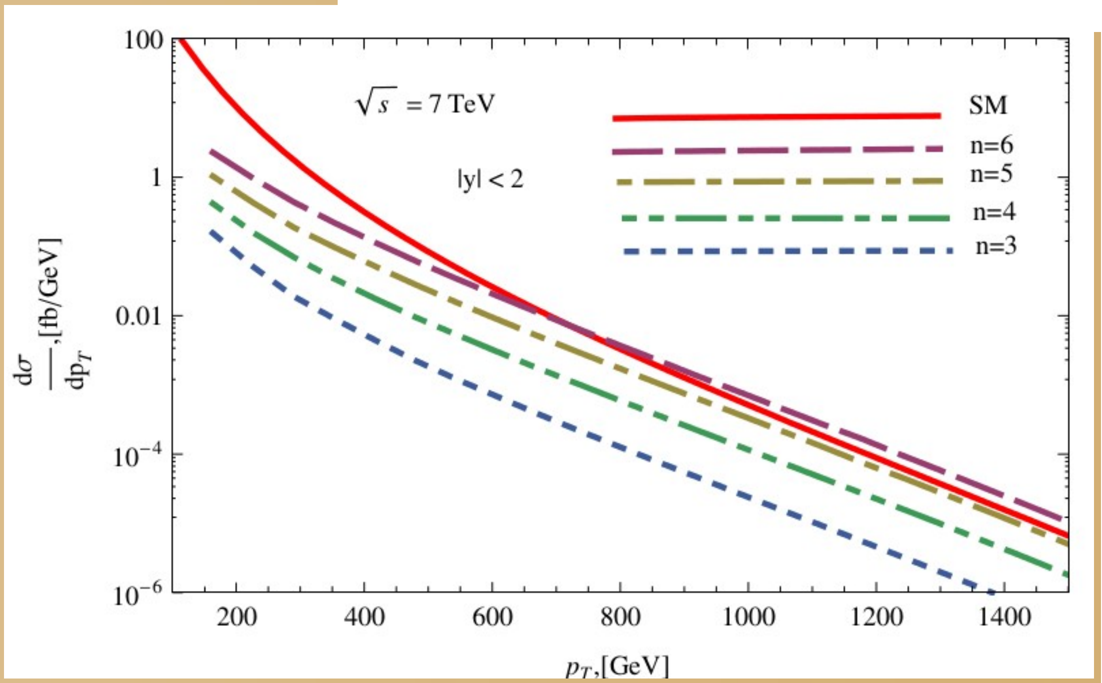
- C++ Codeset for lattice QCD with emphasis on
  - Readability
  - Portability
  - Extensibility
  - High performance

Ueda Satoru

Cross sections in brane world model

- Modified Randall-Sundrum model
- Particles can 'escape' in the bulk dimensions
- Monojet signal
- Detection appears to be hopeless at 7 TeV
- Better chances
  for detection at 14 TeV



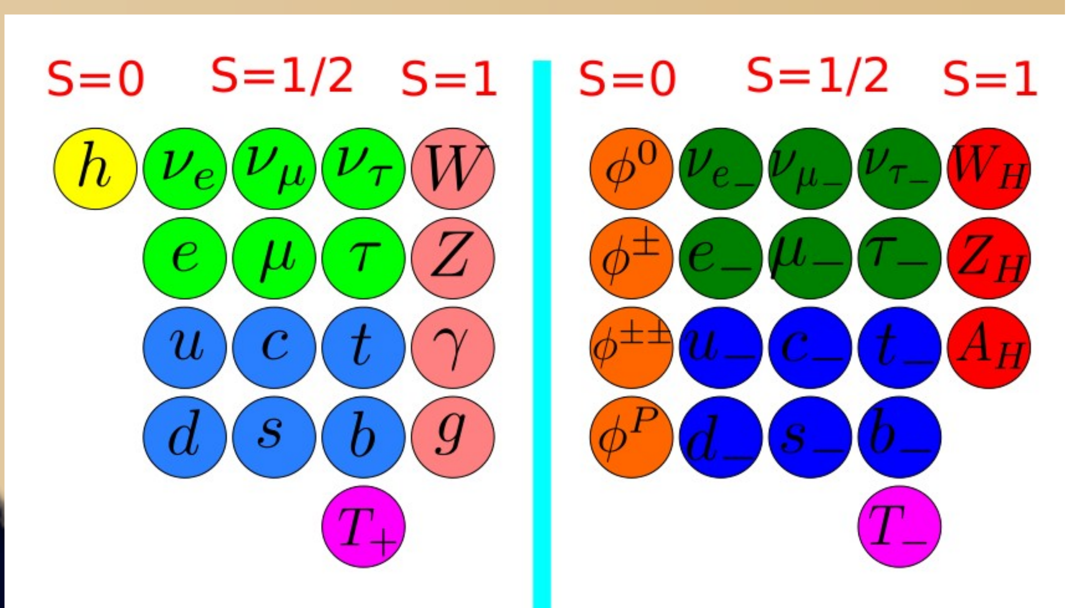


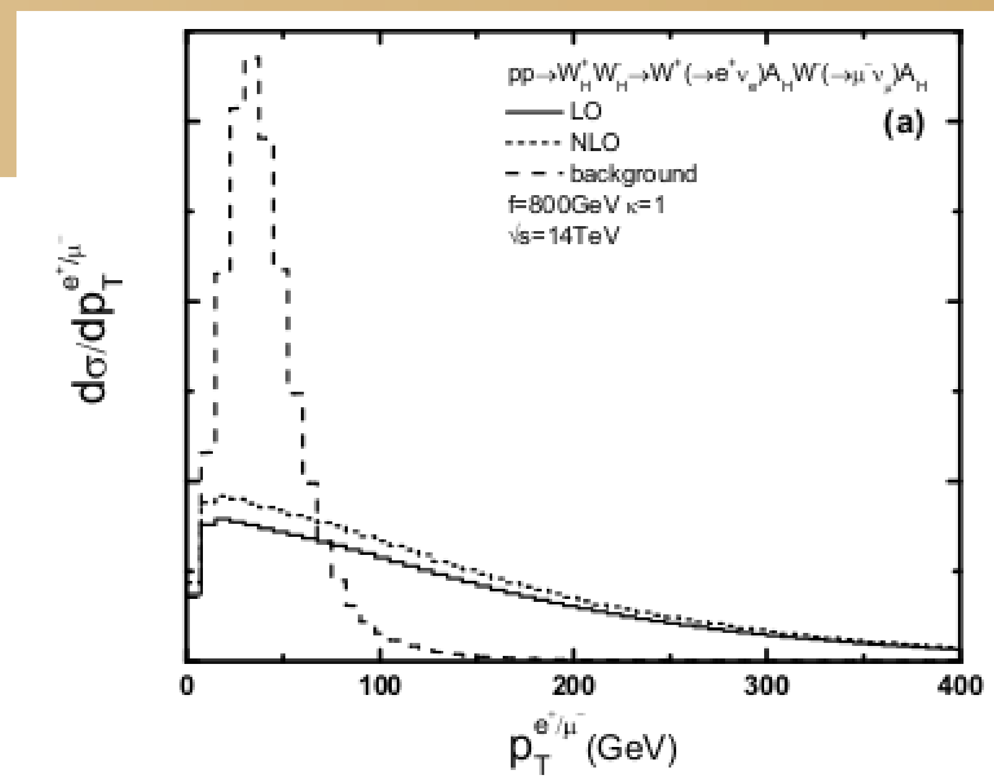
Dmitry Kirpichnikov

Heavy gauge boson production in the LHT model

- Little Higgs model with T parity
- Computed NLO corrections (they are important)
- Shape is different from background

Guo Lei





Tools

- FeynRules 1.8 beta
- FormCalc improvements
- Form 4.1
- SecDec 2.1

FeynRules

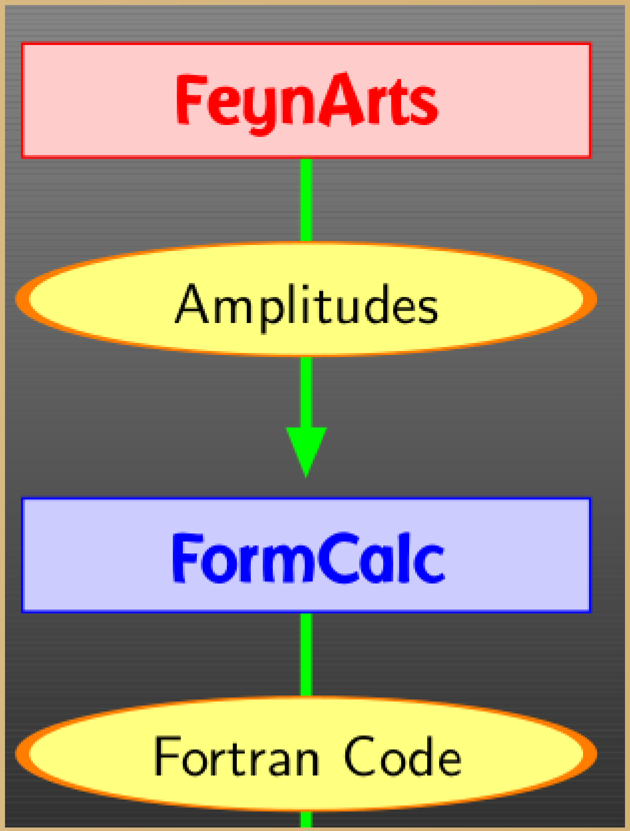
- Mathematica package
- Takes a Lagrangian and generates the Feynman rules needed by other programs.
- Improvents:
  - Spin-3/2 fields
  - Decay package
  - ASperGe is a C++ package for spectrum generation
- Future: UFO@NLO (automatic UV counterterms and diagramatic part of the rational part of the virtual part)

```
M$GaugeGroups = {
  SU3C == {
   Abelian -> False,
   CouplingConstant -> gs,
   GaugeBoson -> G,
   StructureConstant -> f,
   Representations -> {T,Colour},
   SymmetricTensor -> dSUN }}
```

Adam Alloul

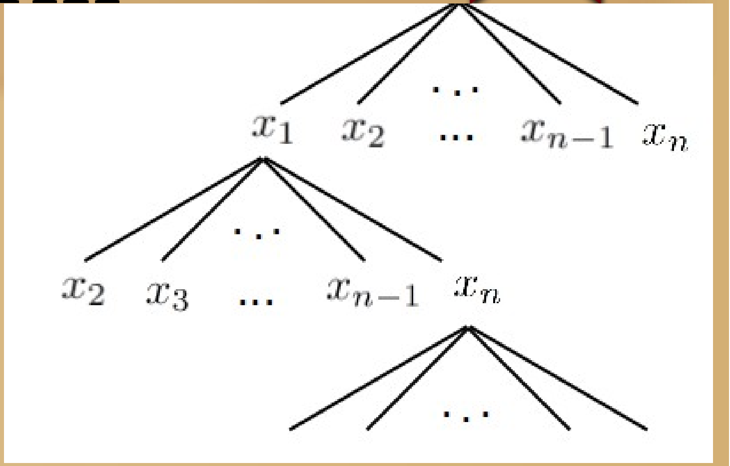
FormCalc

- FormCalc processes amplitudes produced by FeynArts
- Efficiency improvements using new features of Form 4
- Optimisations
  - Vectorisation of helicity loop in the generated code
  - OPP optimisation

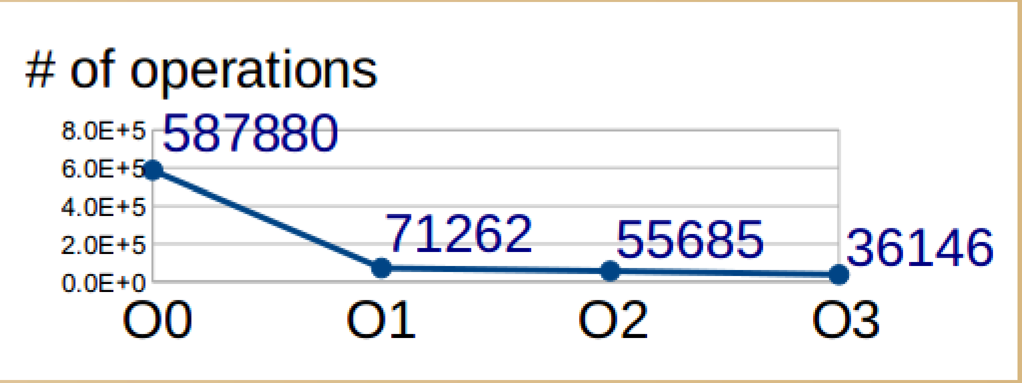


Thomas Hahn

Developments in Form



- New feature presented (for 4.1):
  - More optimised code generation
    Format -O0 / -O1 / -O2 / -O3
  - Uses Horner scheme for multivariate polynomials
  - Uses Monte Carlo tree search to determine to order of the variable for which the Horner scheme is applied
  - They find that the performance is better than anything in the literature



Takahiro Ueda

SecDec 2.1

- Can compute numerically integrals of the form

$$G = \frac{(-1)^N}{\prod_{j=1}^N \Gamma(\nu_j)} \int_0^\infty \prod_{j=1}^N dx_j \; x_j^{\nu_j - 1} \, \delta(1 - \sum_{l=1}^N x_l) \; \frac{\mathcal{U}(x)^{N-(L+1)D/2}}{\mathcal{F}(x)^{N-LD/2}}$$

$$\mathcal{F} = -s\,(x_2 x_3 x_{4567} + x_5 x_6 x_{1234} + x_2 x_4 x_6 + x_3 x_4 x_5) \qquad \mathcal{U} = x_{123} x_{567} + x_4 x_{123567}$$

$$-t\, x_1 x_4 x_7 - p_4^2\, x_7 (x_2 x_4 + x_5 x_{1234}) + \mathcal{U} \sum_i x_i\, m_i^2 - i\,\delta \qquad x_{ijk\ldots} = x_i + x_j + x_k + \ldots$$

Gudrun Heinrich

that have divergent when integrated in 4 dimension as an expansion around 4 dimensions.

- New in version 2: No restriction on the positive definiteness of the denominator (i.e the kinematics)

DCM

- 'Direct computation method'

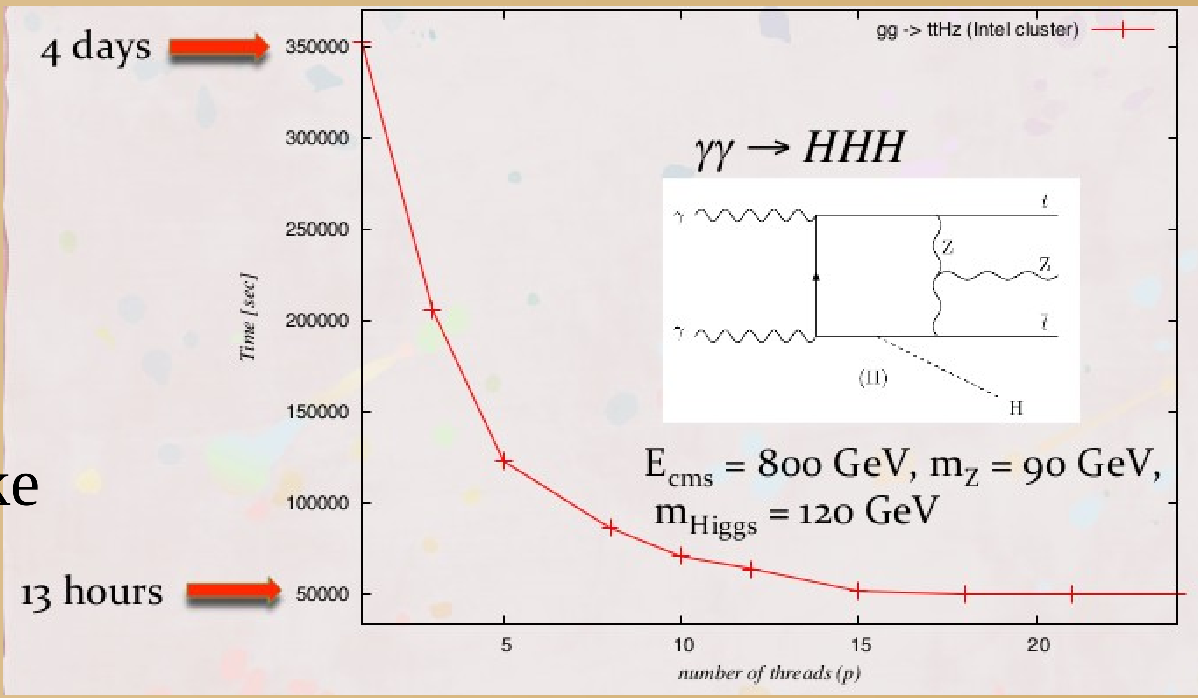
$$(-1)^N \left(\frac{1}{4\pi}\right)^{nL/2} \Gamma(N - nL/2) \int_0^1 \prod_{i=1}^{N} dx_i \delta(1 - x_1 \cdots - x_N) \frac{C^{N-n(L+1)/2}}{(D - i\varepsilon C)^{N-nL/2}}$$

- Normally epsilon infinitesimal, just to say which way around the poles one has to go
- Compute numerically for finite values of epsilon and extrapolate to epsilon ->0

Fukuko Yuasa

DCM

- Up to 2 loops with 4 external legs
- Many difficulties
  - Long time (parallel computing helps)
  - Infrared divergences make convergence slower
  - Doesn't appear to be competitive for one-loop amplitudes
  - Very general method, any masses, any loops



Fukuko Yuasa

QCD One-loop amplitudes

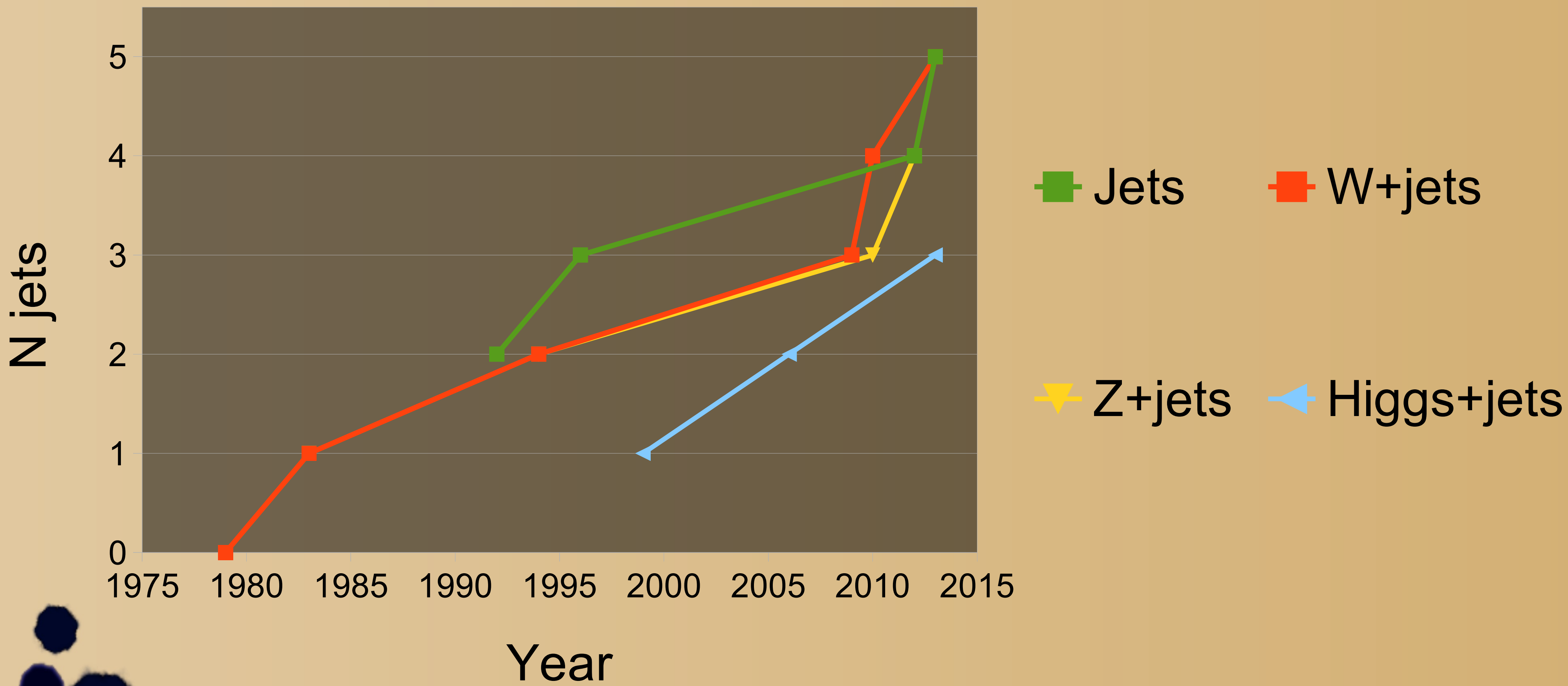
- Ingrediens of a NLO prediction

$$\sigma_n^{NLO} = \int_n \sigma_n^{tree} + \int_n \left(\sigma_n^{virt} + \Sigma_n^{sub}\right) + \int_{n+1} \left(\sigma_{n+1}^{real} - \sigma_{n+1}^{sub}\right)$$

- Focus on virtual part for track 3
- Rest is handled by other programs

Recent progress

- Number of jets in addition to the vector boson



At ACAT 2013

- Four of the major players in the field
  - Usually quite large collaborations (for theorist standards)
- Talks
  - BlackHat [Kosower]
  - GoSam [Heinrich]
  - Njets [Yundin]
  - OpenLoops [Maierhöfer]

Differences/Similarities

<table>
<tr><td colspan="2">Unitarity</td><td>Feynman diagrams</td></tr>
<tr><td colspan="2">BlackHat, NJets</td><td>GoSam, OpenLoop</td></tr>
<tr><td colspan="2">Generality</td><td>multiplicity</td></tr>
<tr><td>GoSam</td><td>OpenLoops</td><td>BlackHat, NJets</td></tr>
<tr><td colspan="2">Standard reduction</td><td>OPP reduction [see Ossola]</td></tr>
<tr><td colspan="2">GoSam, OpenLoops</td><td>GoSam,BlackHat, Njets, OpenLoops</td></tr>
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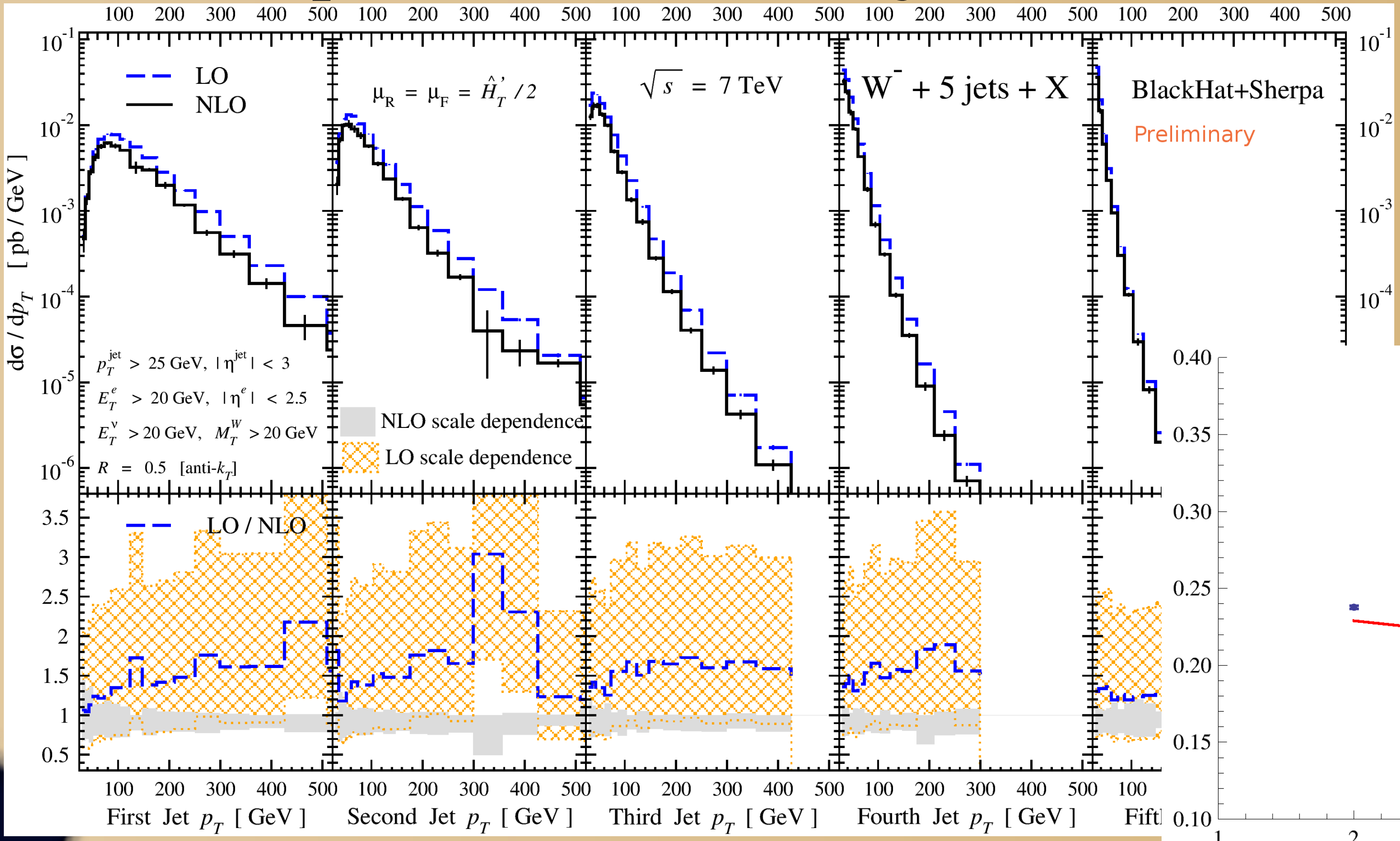
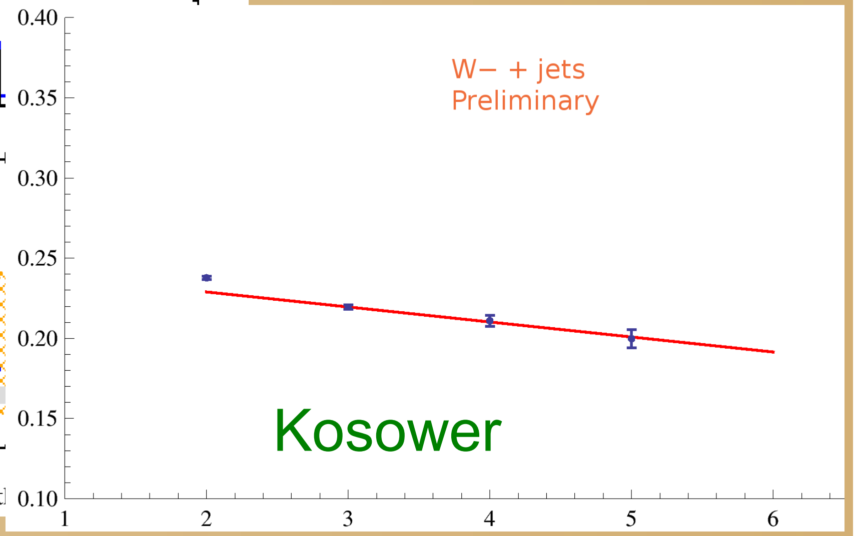
BlackHat (黑帽)

- Presented results for W+5 jets (first 2 ->6 process for LHC @ NLO)
- Extrapolation for W+6 jets





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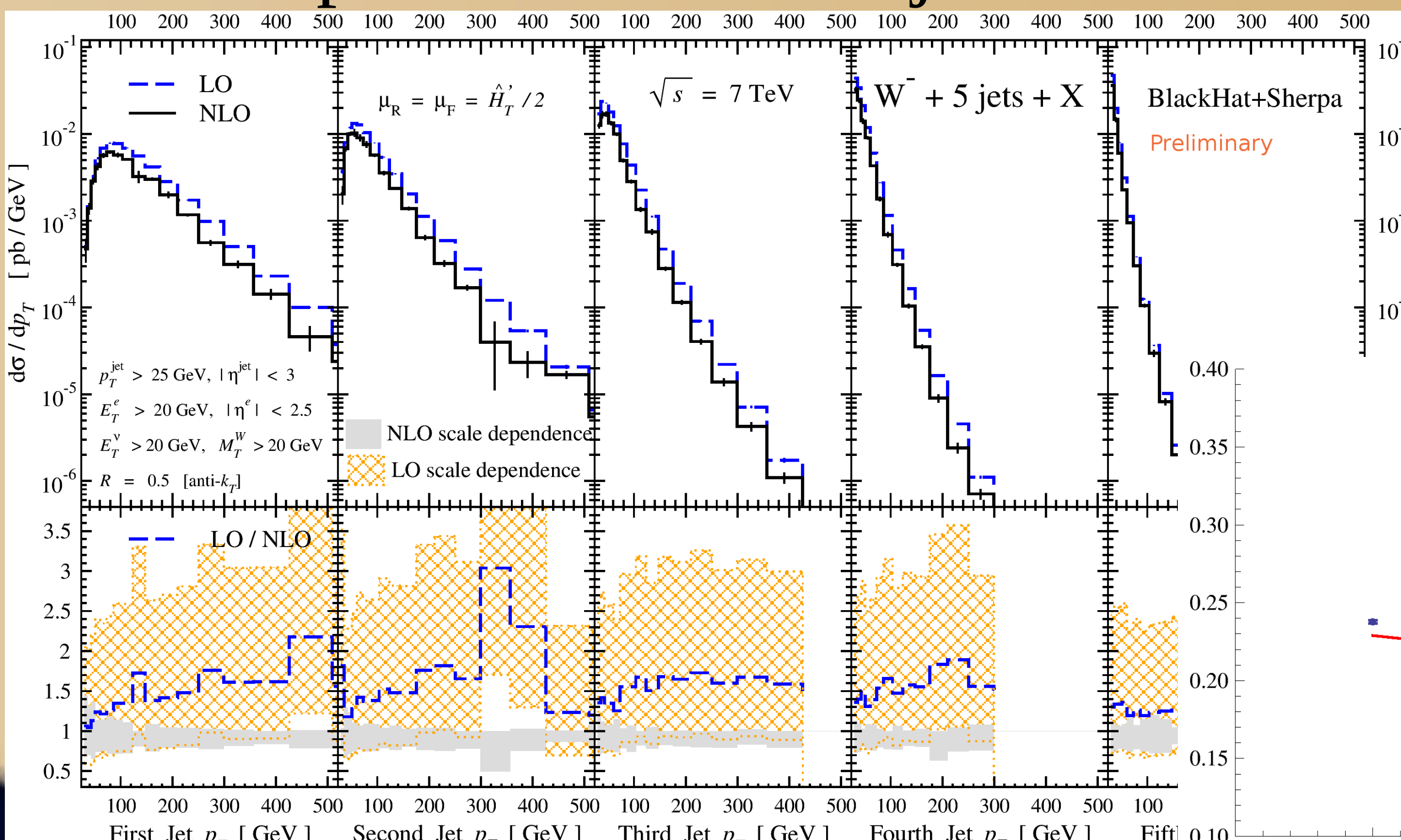
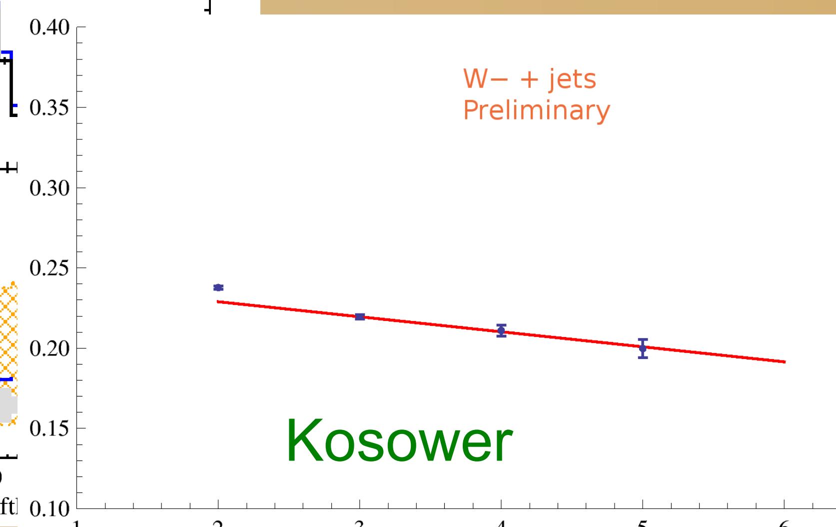
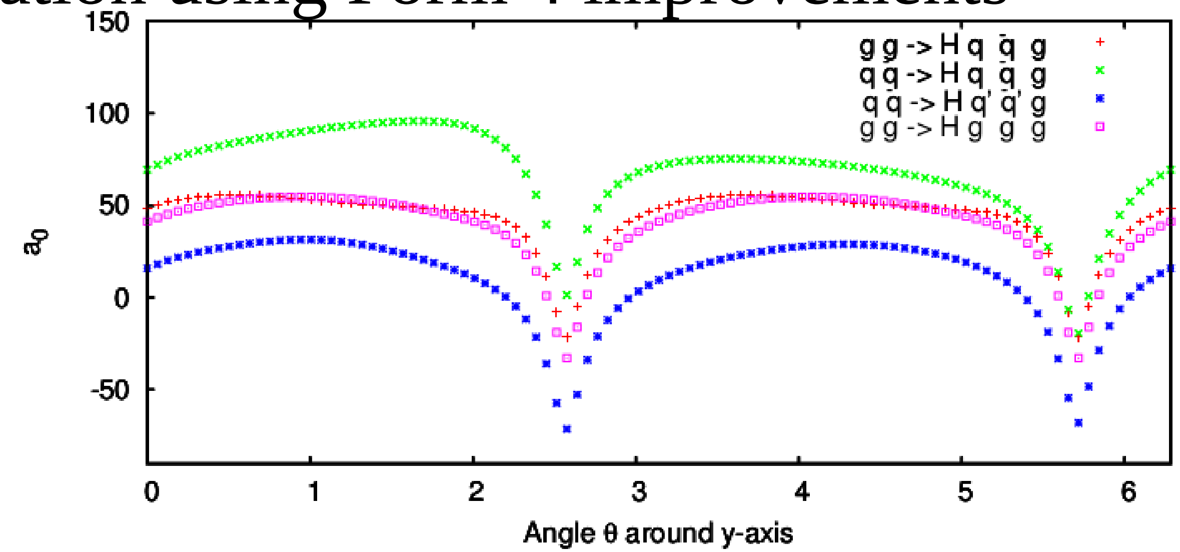




GoSam

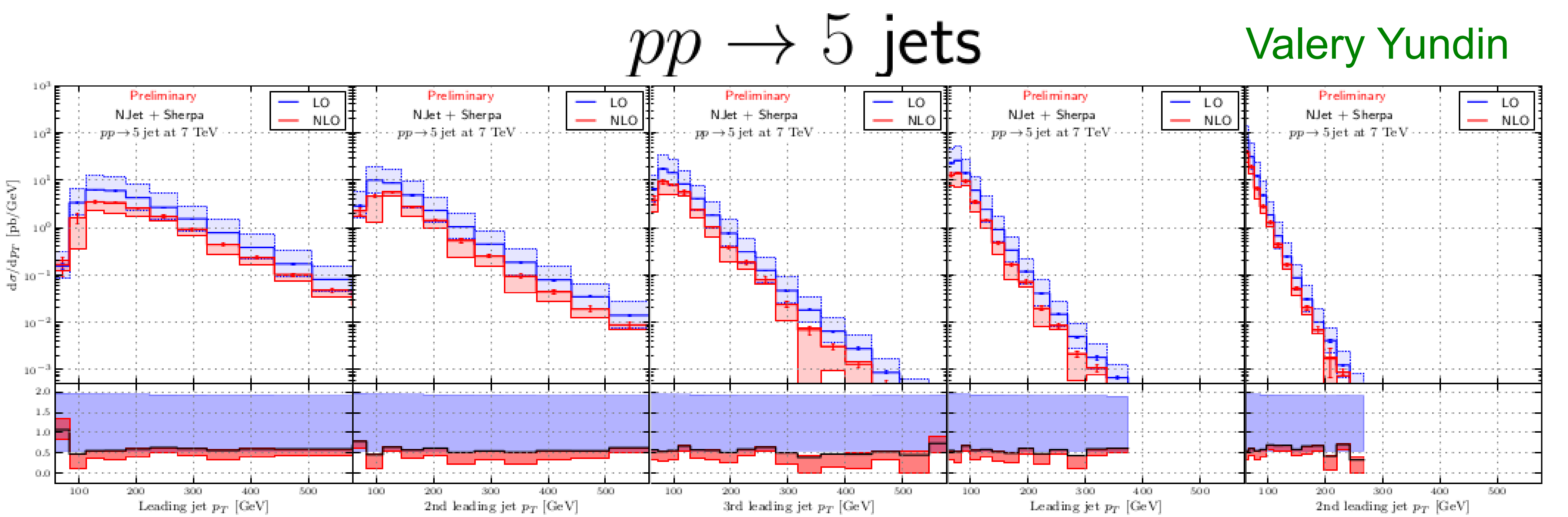
- Not limited to SM model processes
- Presented new Higgs + 2/3 jets and BSM applications
- Improvements for GoSam 2.0
  - Use UFO input (renormalisation not automated)
  - Support for effective vertices
  - Better code generation using Form 4 improvements
  - ...



Gudrun Heinrich

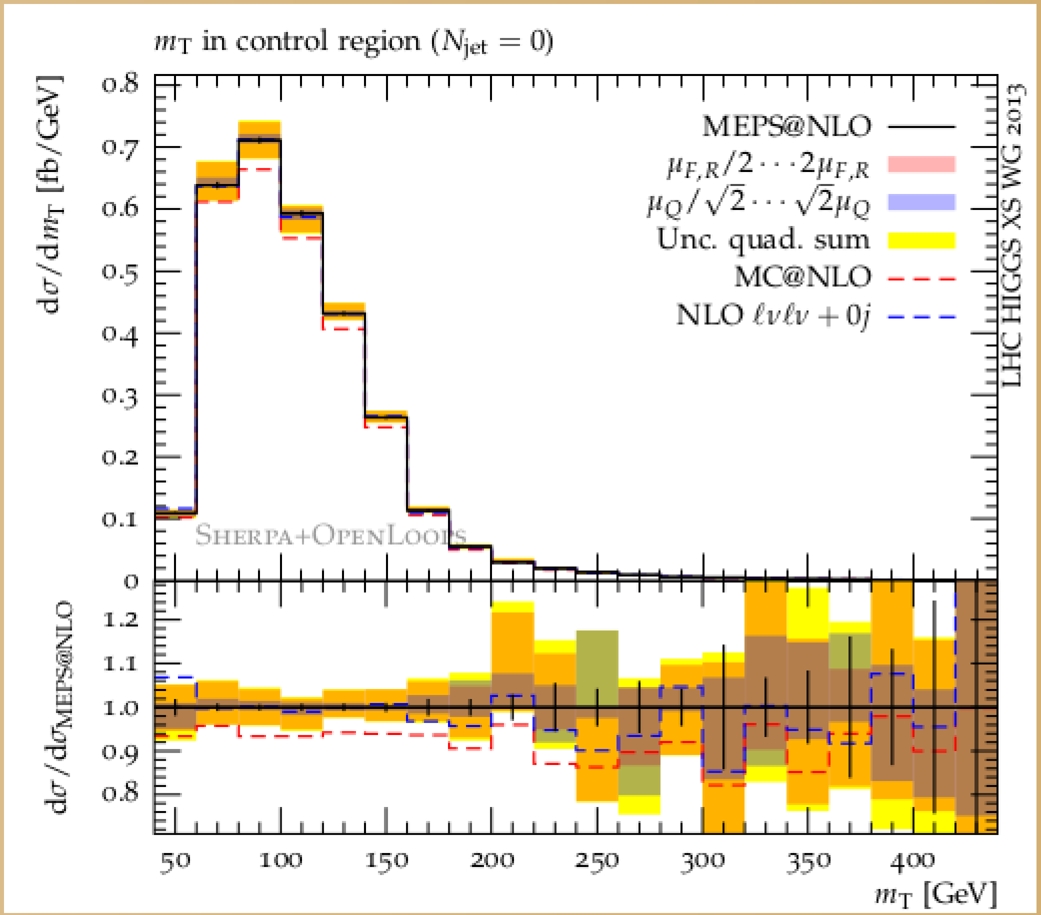
NJets

- Calculates numerically one-loop virtual amplitudes
- Computes with Sherpa pure jet observables for up to 4 jets
- Presented preliminary results for 5 jets



OpenLoops

- Uses OPP reduction with a recursive approach to construct the numerator function
- Presented WW+0,1 jet comparison between NLO, MC@NLO and MEPS@NLO



Maierhöfer


游人止步
TOURIST STOPS