Projects in Heidelberg

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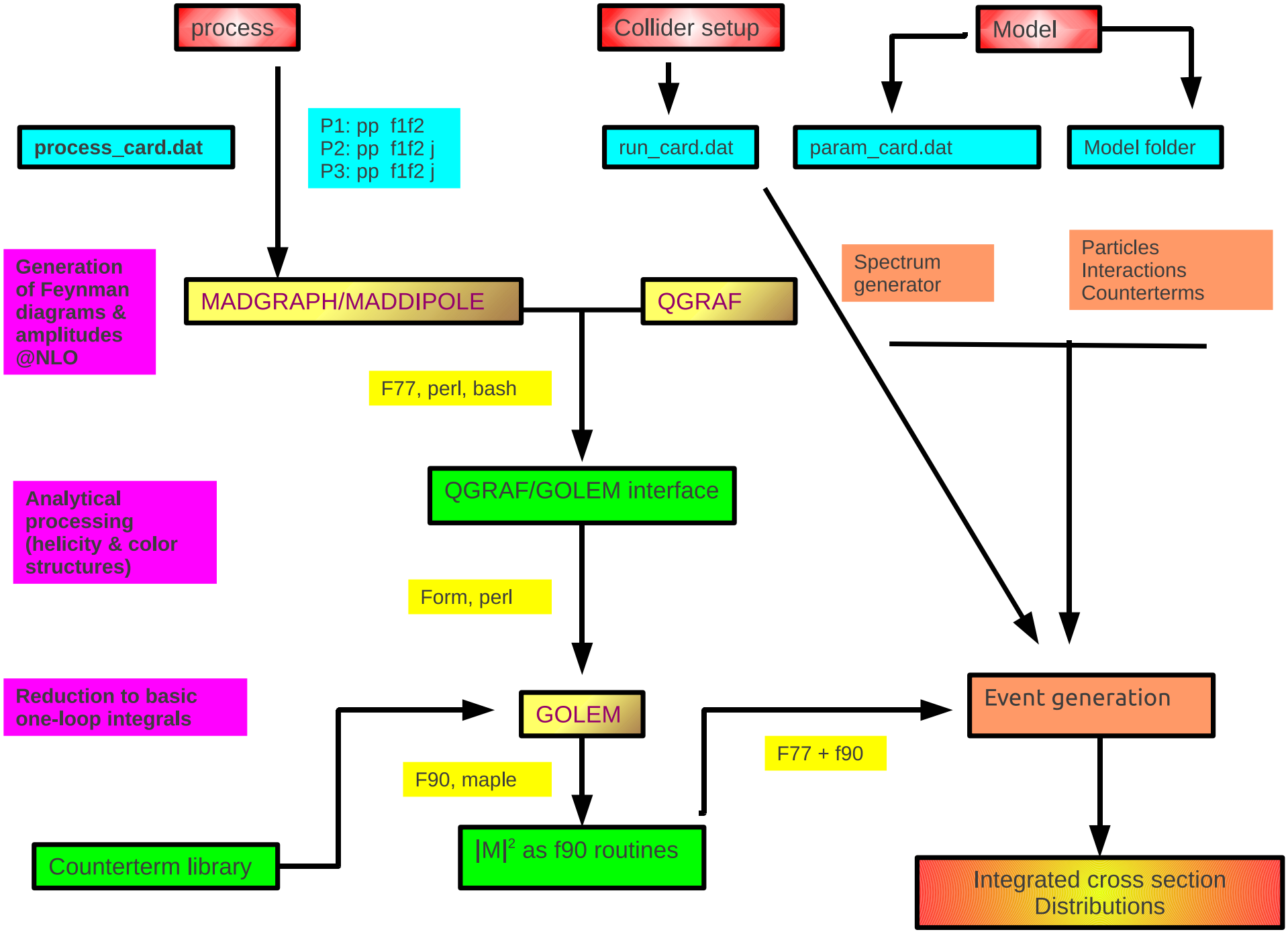
Universität Heidelberg

Terascale Meeting, Karlsruhe 12/2010

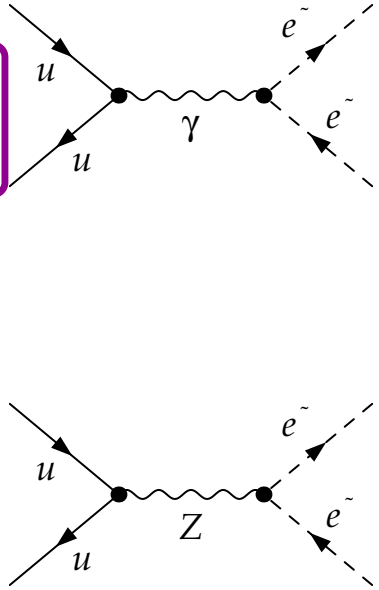
MadGOLEM

Multileg ME generation	modified MADGRAPH	Feynman diagrams + spinor-helicity formalism
One-loop ME generation	QGRAF	graph theory
Reduction to scalar integrals	GOLEM	dim. reg. (UV & IR) Passarino, Veltman ['79]
IR subtraction	modified MADGRAPH own routines	Catani, Seymour ['97]
UV renormalization	modified MADGRAPH own routines	OS field renormalization MSbar α_s SUSY-restoration
OS subtraction	own routines	PROSPINO scheme ['96] applied in MC@NLO ['08]


process
Collider setup
Model
process_card.dat
P1: pp f1f2
P2: pp f1f2 j
P3: pp f1f2 j
run_card.dat
param_card.dat
Model folder
Generation of Feynman diagrams & amplitudes @NLO
MADGRAPH/MADDIPOLE
QGRAF
Spectrum generator
Particles
Interactions
Counterterms
F77, perl, bash
QGRAF/GOLEM interface
Analytical processing (helicity & color structures)
Form, perl
Reduction to basic one-loop integrals
GOLEM
Event generation
F77 + f90
F90, maple
Counterterm library
|M|2 as f90 routines
Integrated cross section
Distributions

MadGOLEM

```
# Begin PROCESS # This is TAG. Do not modify this line
e-e+>ulul~      @1     # for LO
QCD=99                 # Max QCD couplings
QED=99                 # Max QED couplings
end_coup               # End the couplings input
e-e+>ulul~j     @2     # for NLO (virtual+integrated-dipole)
QCD=99                 # Max QCD couplings
QED=99                 # Max QED couplings
end_coup               # End the couplings input
e-e+>ulul~j     @3     # for NLO (unintegrated-dipole)
QCD=99                 # Max QCD couplings
QED=99                 # Max QED couplings
end_coup               # End the couplings input
done                   # this tells MG there are no more procs
```



P1: $pp \to X_1 X_2$

leading order: MadGRAPH

MadGOLEM

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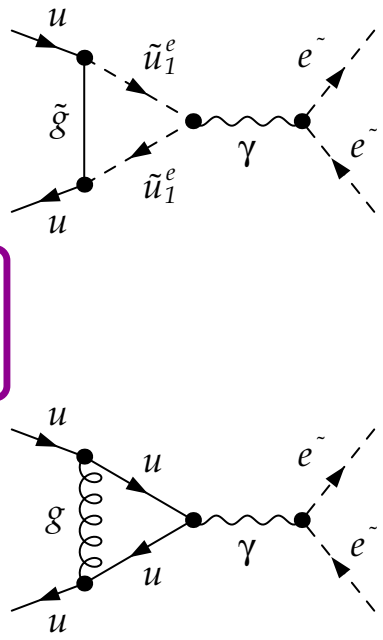

P2: $pp \to X_1 X_2 + j$

NLO - dipoles: MadGOLEM

MadGOLEM

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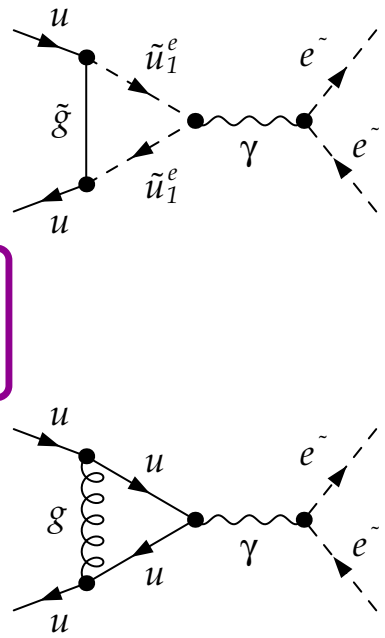

P2: $pp \to X_1 X_2 + j$

NLO - virtual corrections: QGRAF + MadGOLEM

MadGOLEM

```
# Begin PROCESS # This is TAG. Do not modify this line
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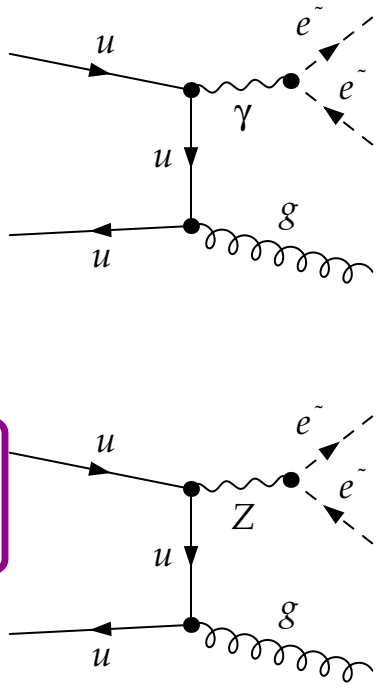
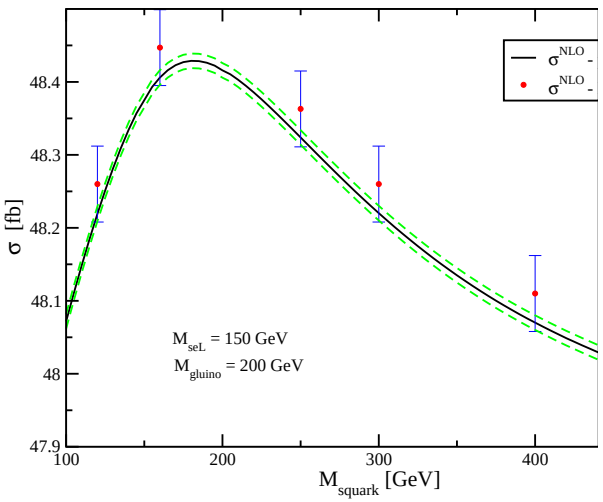


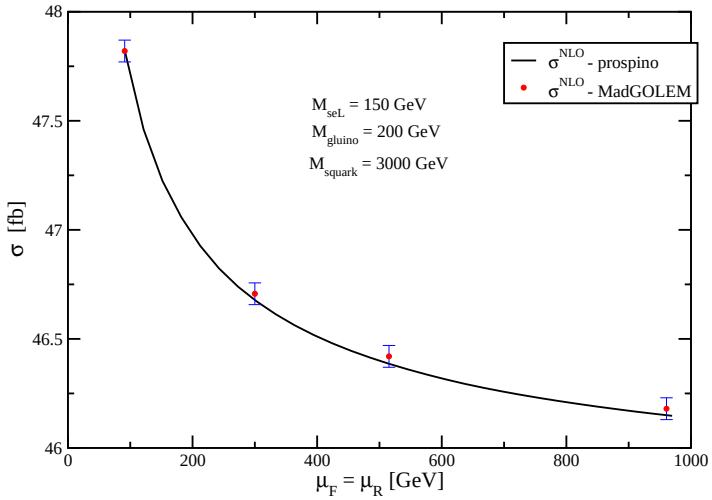
P3: $pp \to X_1 X_2 + j$

NLO - real emission: MadGRAPH

MadGOLEM: tests

$$pp \to \tilde{e}_L \tilde{e}_L^*$$

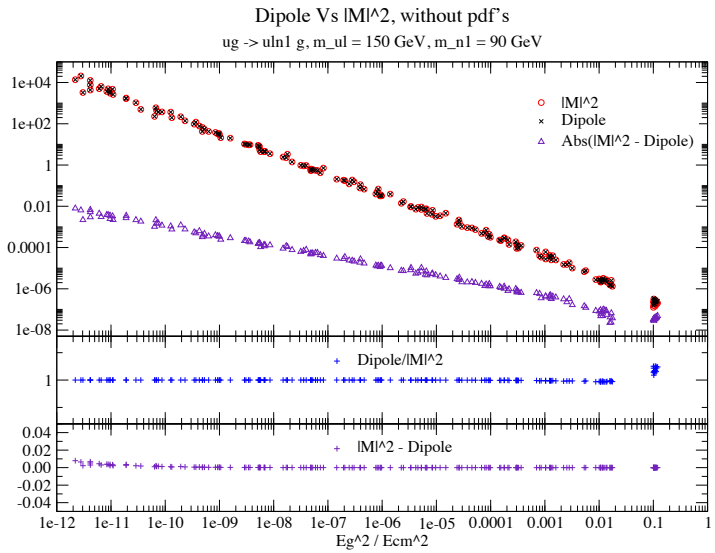




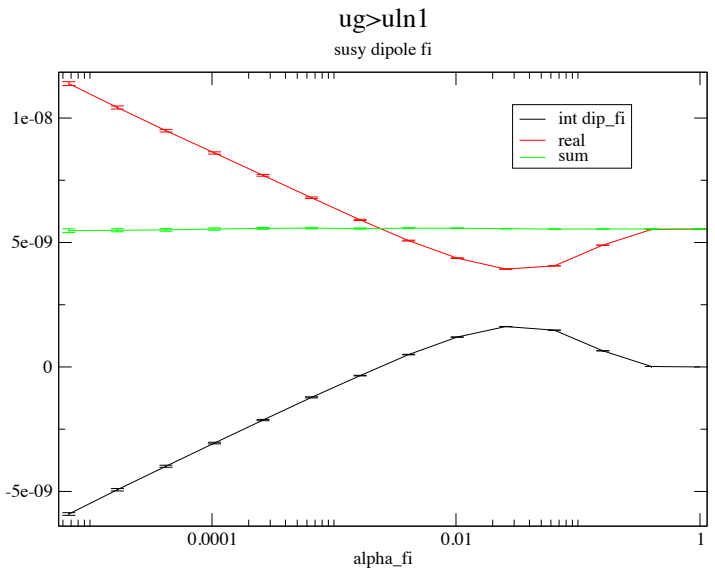
- rate as a function of the squark mass
- rate as a function of the renormalization scale
- red points from MadGOLEM, **black line** from Prospino:

MadGOLEM: tests

$pp \to \tilde{u}\tilde{\chi}$



$e^+e^- \to \tilde{u}\tilde{u}^*$



- SUSY dipoles in $pp \to \tilde{u}\tilde{\chi}$ for soft gluons
- α dependence of the SUSY dipoles in $e^+e^- \to \tilde{u}\tilde{u}^*$

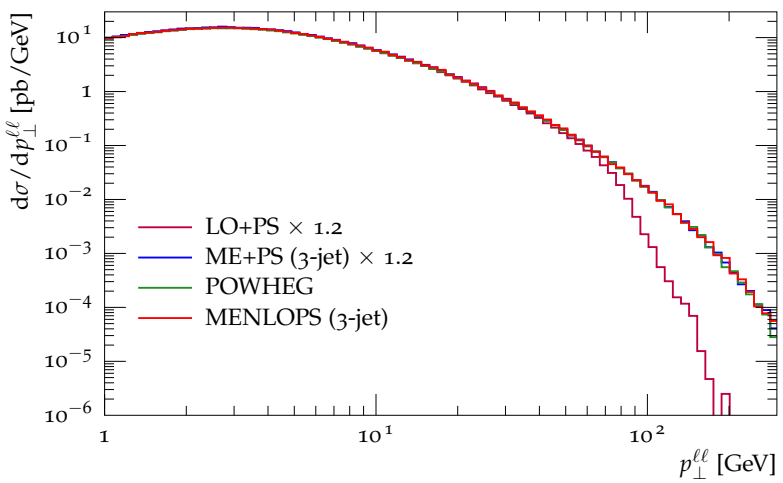
Current Sherpa-1.2.3 (Dec 7th)

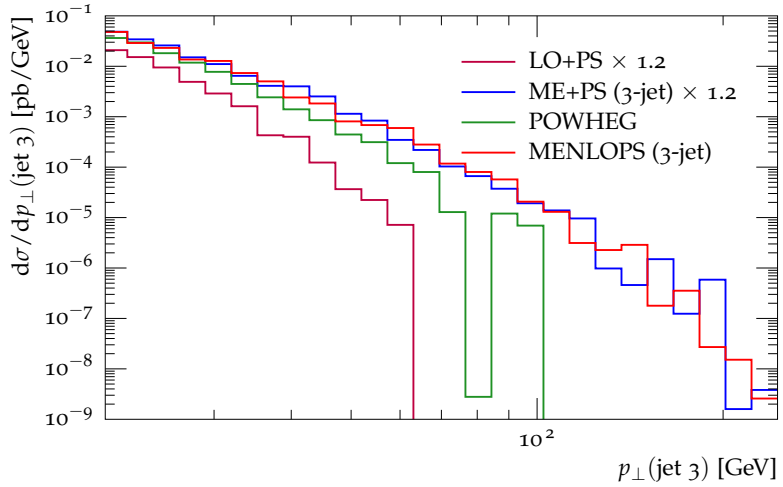
- POWHEG & MENLOPS [arXiv:1008.5399 & arXiv:1009.1127]
  - DY & W production, WW dibosons
  - Higgs production in gluon fusion
- PROFESSOR tuning
  - hadron data from Tevatron & LHC
    $\rightsquigarrow$ only tuned to minbias/UE, *not* to DY, W, ...
  - different PDF sets: CTEQ6L1 & CTEQ66 (default)
    $\rightsquigarrow$ LO* planned
- LHE output for MEs
- various bugfixes

`http://www.sherpa-mc.de/`

POWHEG vs. MEPS vs. MENLOPS

example: Drell-Yan at 14 TeV LHC



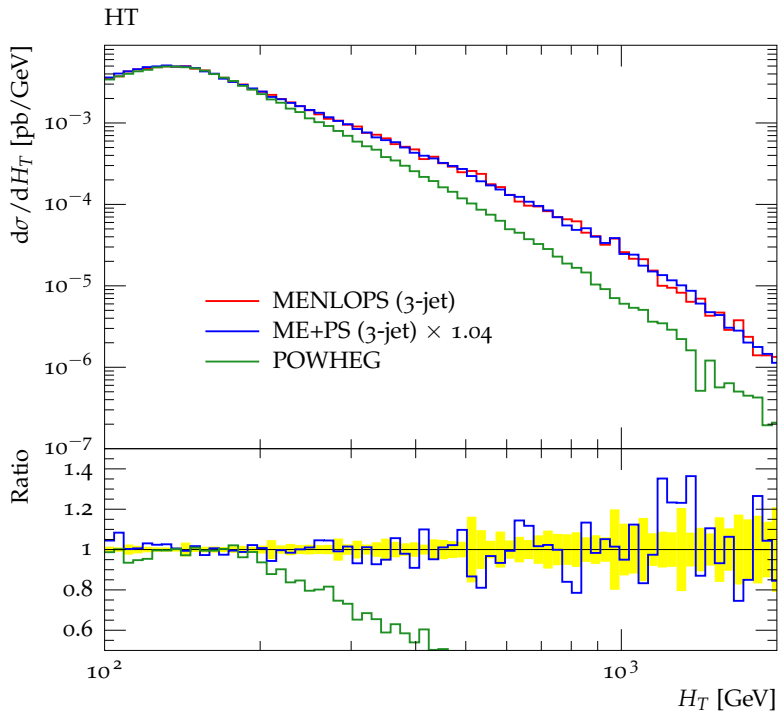


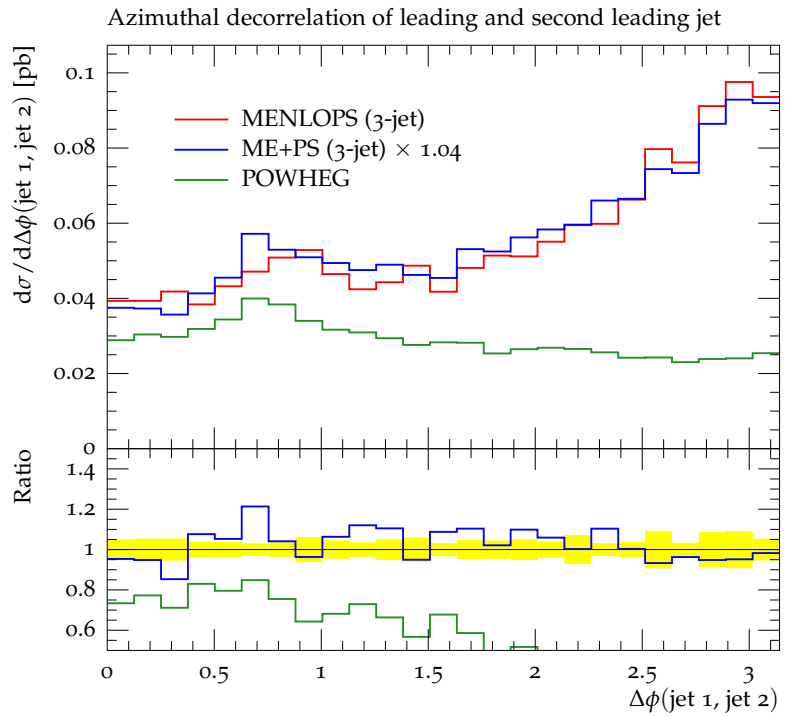
MENLOPS:

- inclusive cross section at NLO
- multiple hard emissions through tree level MEs

POWHEG vs. MEPS vs. MENLOPS

example: WW production at 14 TeV LHC

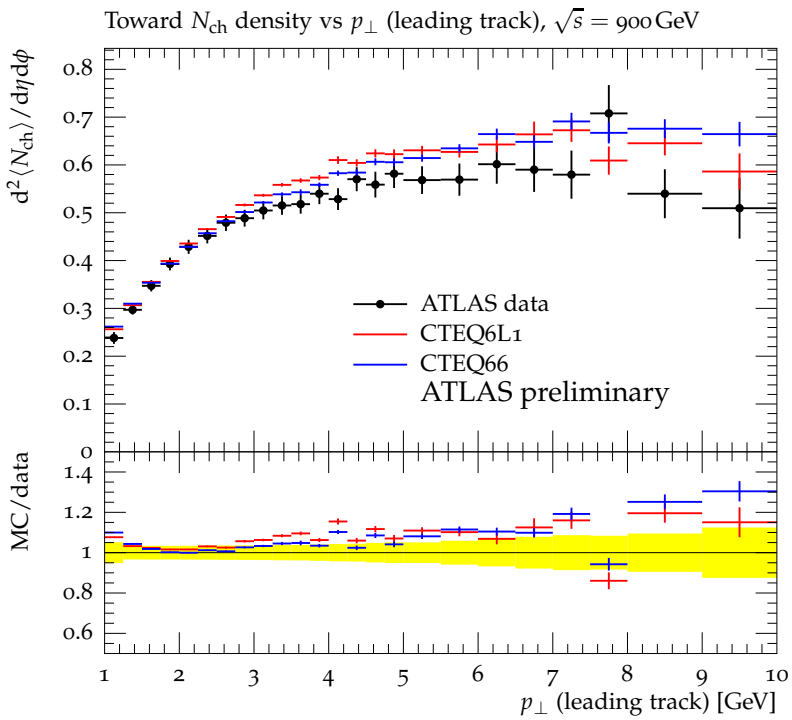


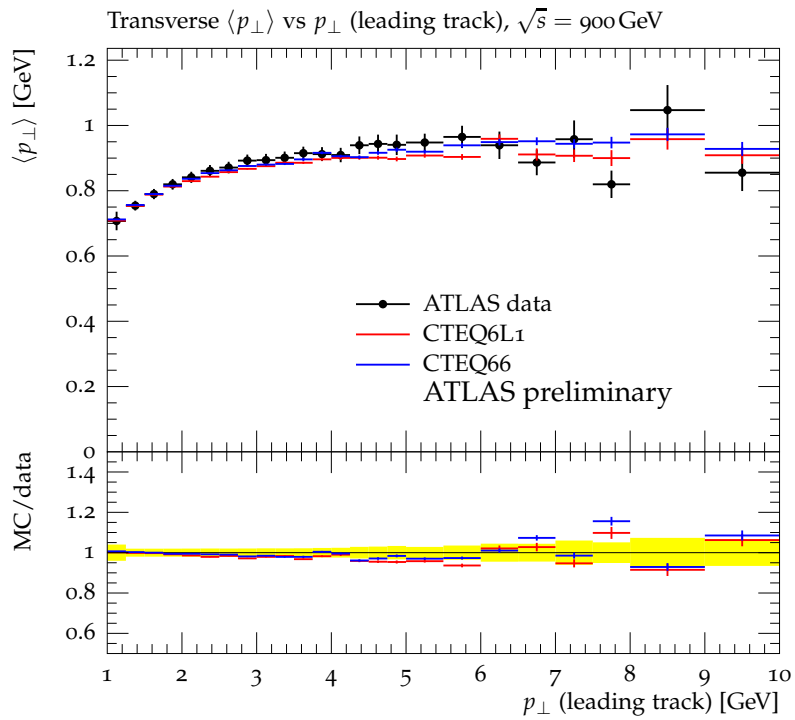


$$H_T = \not{E}_T + \sum_{i=l,j} p_{T,i}$$

UE at LHC 900 GeV – included in tuning

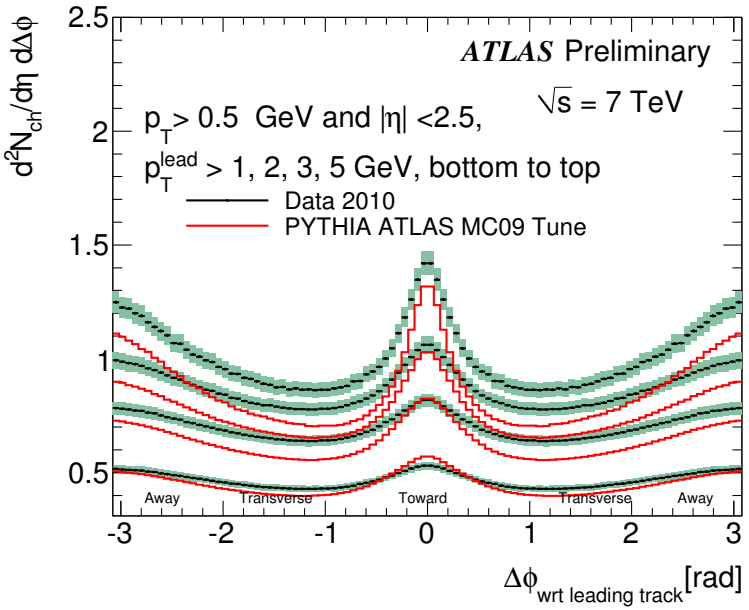
ATLAS-CONF-2010-081

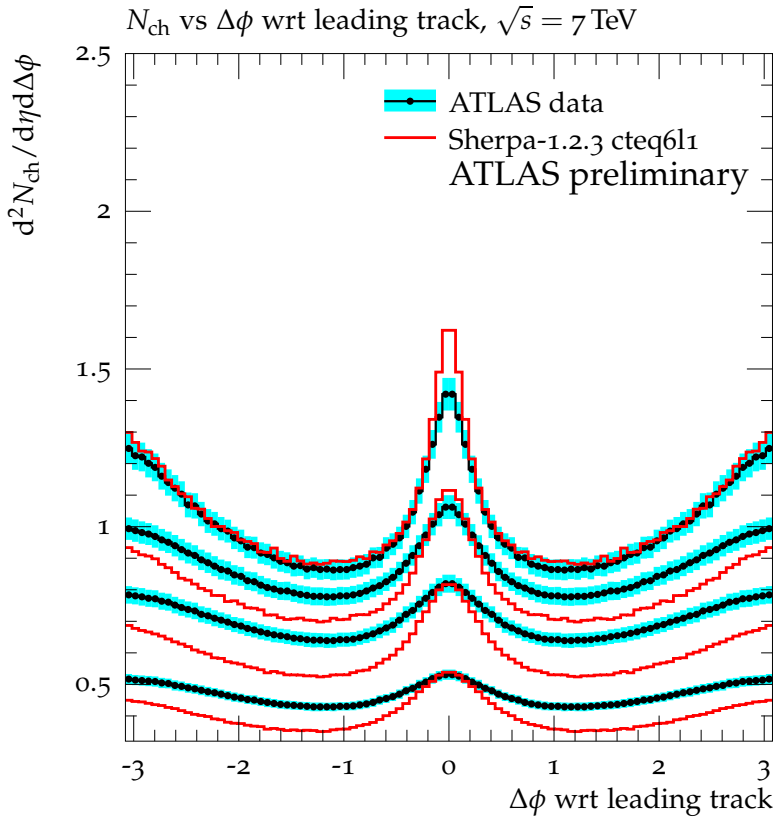




UE at LHC 7 TeV – included in tuning

ATLAS-CONF-2010-081





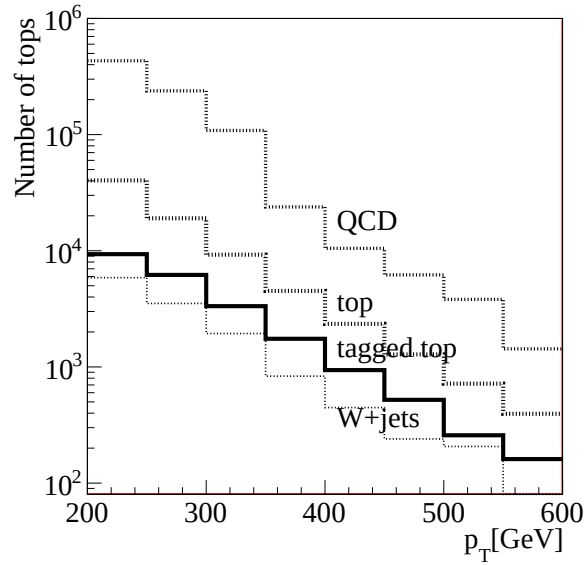
HEPTopTagger

Boosted top quarks [Kaplan, Rehermann, Schwartz, Tweedie; Princeton, Seattle...]

- hadronic tops with $p_T \gtrsim 800$ GeV
  isolation and b tagging challenging
- C/A algorithm with p_T drop criterion
  all top decay jets identified
  3 kinematic constraints: $m_W, m_t, \cos\theta_{\text{hel}}$ [no b tag]
- top mass included, no sidebins

HEPTopTagger [TP, Salam, Spannowsky, Takeuchi]

- extend to lower $p_T \gtrsim 250$ GeV
  realistic for $t\bar{t}$ in Standard Model



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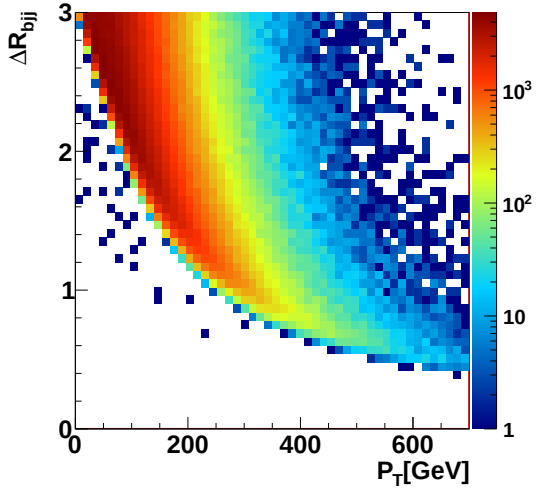

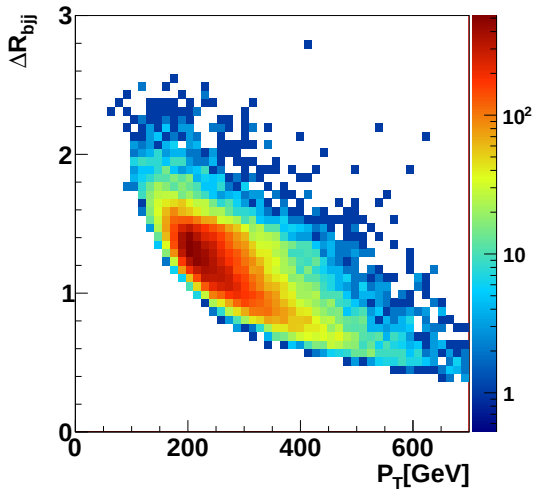

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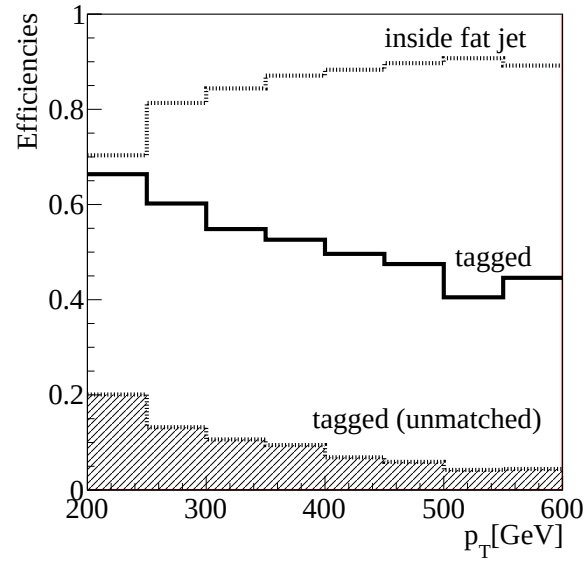
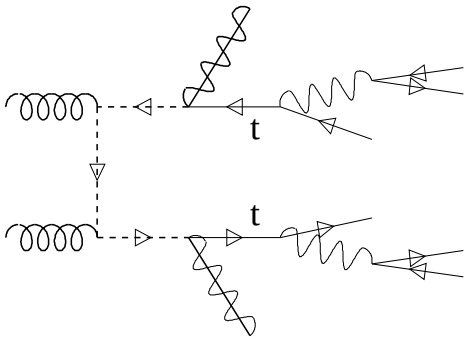
HEPTopTagger [TP, Salam, Spannowsky, Takeuchi]

- extend to lower $p_T \gtrsim 250$ GeV
  realistic for $t\bar{t}$ in Standard Model
- top reconstruction possible
- tested and implemented by ATLAS [Kasieczka & Schätzel]
- hadronic top like tagged b



Stops

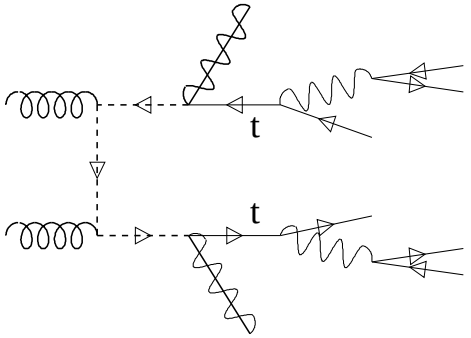


Stop pairs [TP, Spannowsky, Takeuchi, Zerwas]

- stop most important for hierarchy problem
  comparison to other top partners [Meade & Reece]
- difficult semi-leptonic channel
- purely hadronic: $\tilde{t}\tilde{t}^* \to t\tilde{\chi}_1^0\, \bar{t}\tilde{\chi}_1^0$ [CMS TDR: leptons as spontaneous life guards]

events in 1 fb^{-1}	$\tilde{t}_1\tilde{t}_1^*$						$t\bar{t}$	QCD	W+jets	Z+jets	S/B	$S/\sqrt{B}_{10\ \text{fb}^{-1}}$
$m_{\tilde{t}}$[GeV]	340	390	440	490	540	640					340	
$p_{T,j} > 200$ GeV, ℓ veto	728	447	292	187	124	46	87850	$2.4 \cdot 10^7$	$1.6 \cdot 10^5$	n/a	$3.0 \cdot 10^{-5}$	
$\not{E}_T > 150$ GeV	283	234	184	133	93	35	2245	$2.4 \cdot 10^5$	1710	2240	$1.2 \cdot 10^{-3}$	
first top tag	100	91	75	57	42	15	743	7590	90	114	$1.2 \cdot 10^{-2}$	
second top tag	15	12.4	11	8.4	6.3	2.3	32	129	5.7	1.4	$8.3 \cdot 10^{-2}$	
b tag	8.7	7.4	6.3	5.0	3.8	1.4	19	2.6	$\lesssim 0.2$	$\lesssim 0.05$	0.40	5. 9
$m_{T2} > 250$ GeV	4.3	5.0	4.9	4.2	3.2	1.2	4.2	$\lesssim 0.6$	$\lesssim 0.1$	$\lesssim 0.03$	0.88	6. 1

Stops



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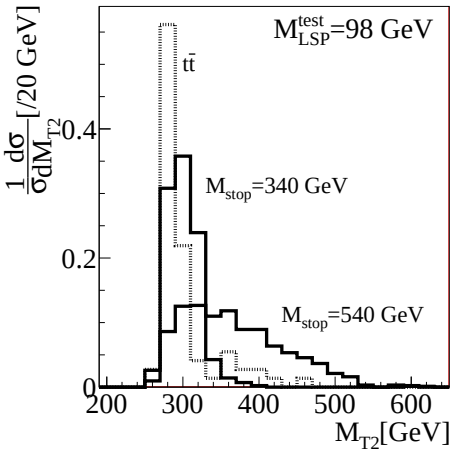
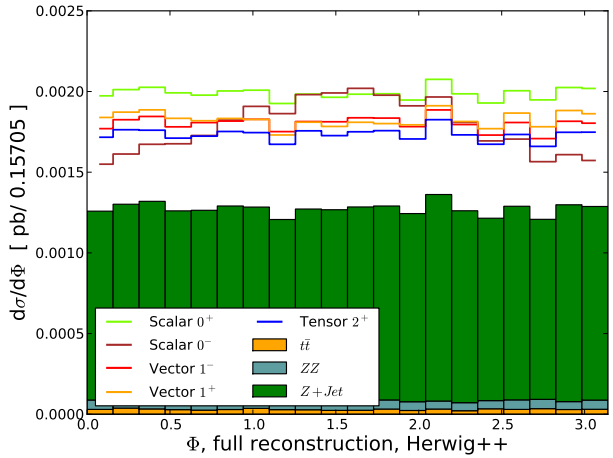
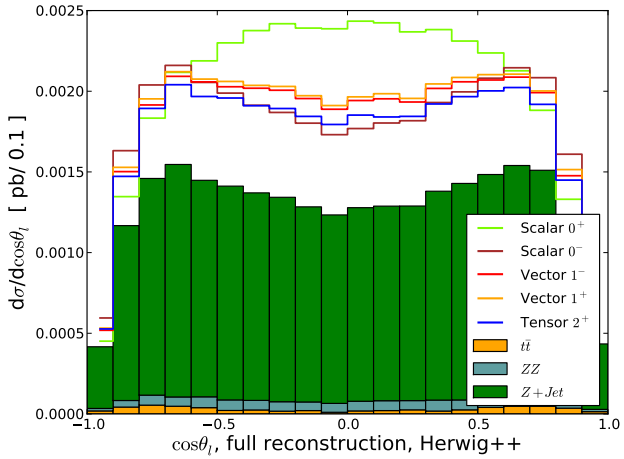
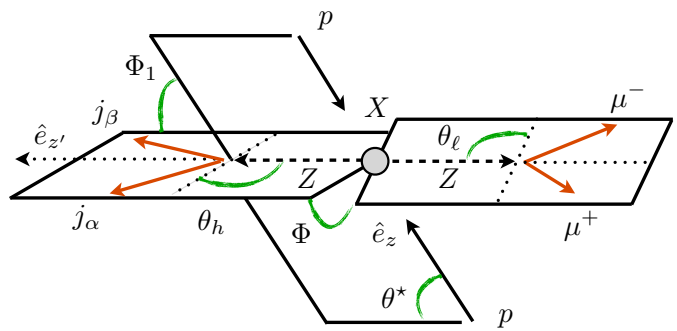
- difficult semi-leptonic channel
- purely hadronic: $\tilde{t}\tilde{t}^* \to t\tilde{\chi}_1^0\ \bar{t}\tilde{\chi}_1^0$ [CMS TDR: leptons as spontaneous life guards]
- stop mass from m_{T2} endpoint [like sleptons or sbottoms]
- not even a hard analysis



Measuring J^{CP} using jet substructure







[Cabibbo, Maksymowicz '65] [Dell'Aquila, Nelson '85]
[Buszello, Fleck, Marquard, van der Bij '04] ...

- sub-jets plus spin analysis
  semi-hadronic $X \to ZZ \to \mu^+\mu^- jj$
- price for boosted signatures
  (many angles lost)
- discriminative power
  singly-produced $0^\pm$ "Higgs lookalikes"

[Englert, Hackstein, Spannowsky '10]

Outlook

MC development and LHC applications

- MadGOLEM
- SHERPA
- misc tools: SFitter, HEPTopTagger, FeynRulez, MC@NLO,...

- NLO/matching/merging for new physics
- bottom partons
- Higgs plus QCD
- SUSY Higgs predictions
- stop searches
- jets plus missing energy,...

thank you to:

Christoph Englert, Steffen Schumann, Michihisa Takeuchi, David Lopez Val,
Erik Gerwick, Dorival Netto, Ioan Wigmore,
Fabian Gross, Thomas Lübbert, Peter Schichtel,
Kentarou Mawatari, Michael Rauch, Michael Spannowsky, Carole Weydert,...