

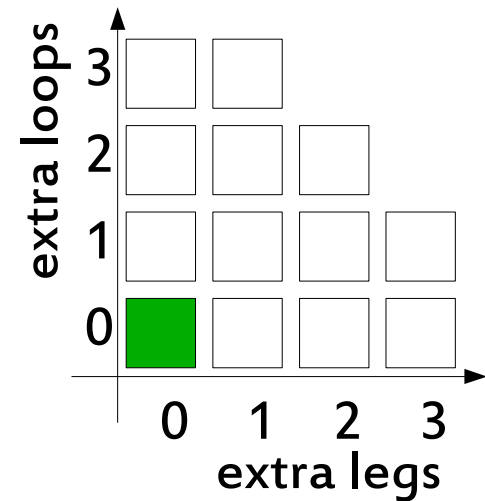
# Slepton Pair Production in the POWHEG BOX

Stephan Thier

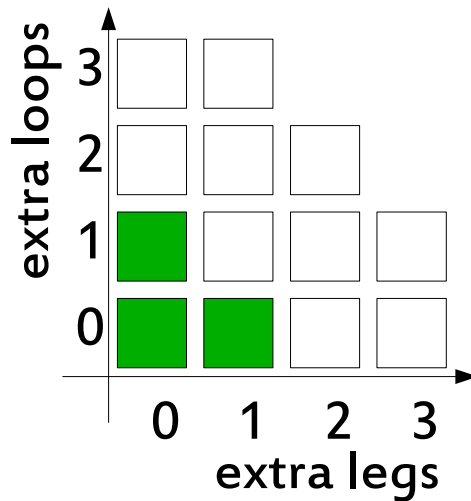


## POWHEG

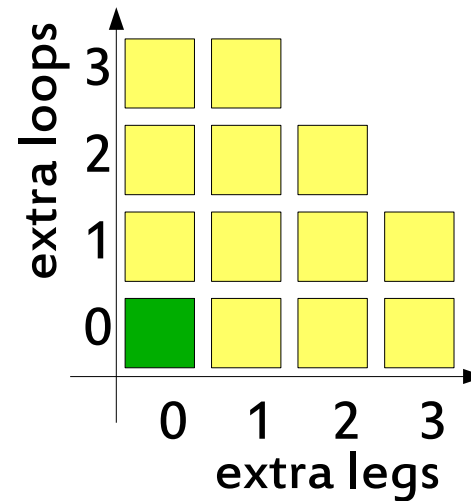
### LO



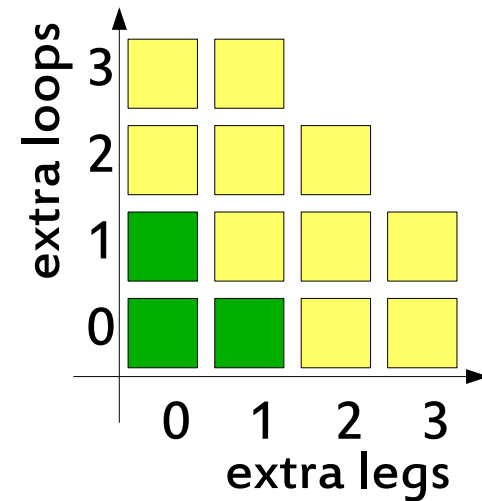
### NLO



### Parton Shower



### POWHEG



completely included



not included



leading logs included

### POWHEG

P. Nason (2004)

S. Frixione, P. Nason and C. Oleari (2007)

### POWHEG BOX

S. Alioli, P. Nason, C. Oleari and E. Re (2010)

# Sleptons meet POWHEG

## POWHEG-BOX/dislepton

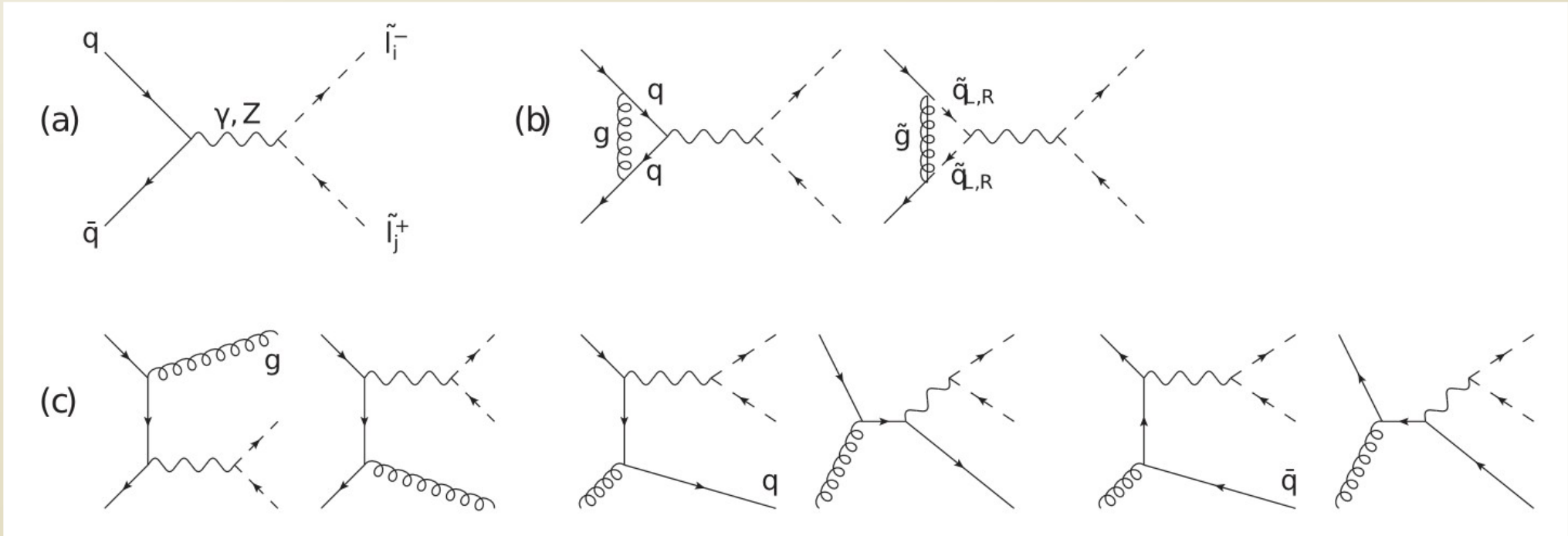
- ◆ Barbara Jäger, Andreas von Manteuffel, ST (2012)
- ◆ MSSM, 4 massless quarks
- ◆ SUSY QCD NLO
- ◆ parton shower & decay (PYTHIA 6)
- ◆ completely configured, easy to modify
  
- ◆ similar: I. Fridman-Rojas, P. Richardson (2012)  
(Herwig++)

# NLO SQCD Matrix Elements

## PROSPINO

W. Beenakker, R. Hopker and M. Spira (1996)

W. Beenakker, M. Klasen, M. Krämer, T. Plehn, M. Spira, P.M. Zerwas (1999)



## QGRAF FORM

P. Nogueira (1993)

J. A. M. Vermaseren (2000)

J. Kuipers, T. Ueda, J. A. M. Vermaseren  
and J. Vollinga (2012)

## Reduze 2

C. Studerus (2010)

A. von Manteuffel and C. Studerus (2012)

## QCDLoop

R. K. Ellis and G. Zanderighi (2008)

## FeynArts FormCalc

T. Hahn (2001)

T. Hahn and M. Perez-Victoria (1999)

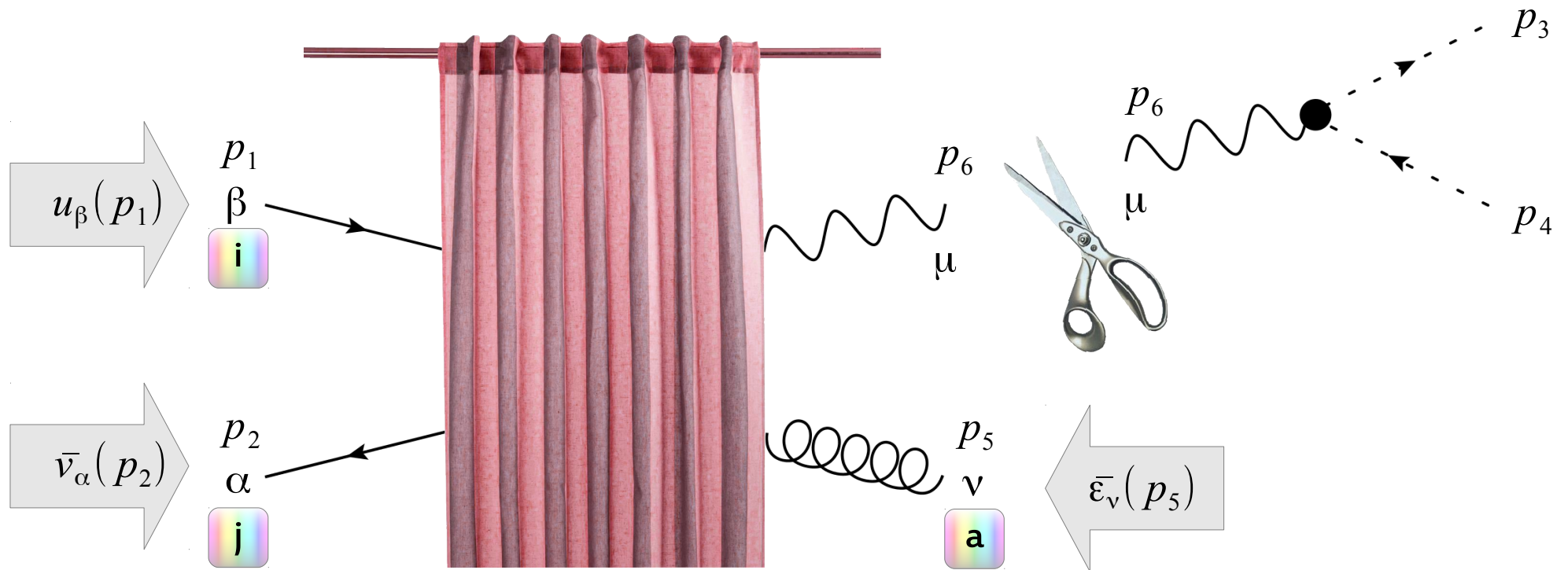
T. Hahn (2008)

## LoopTools

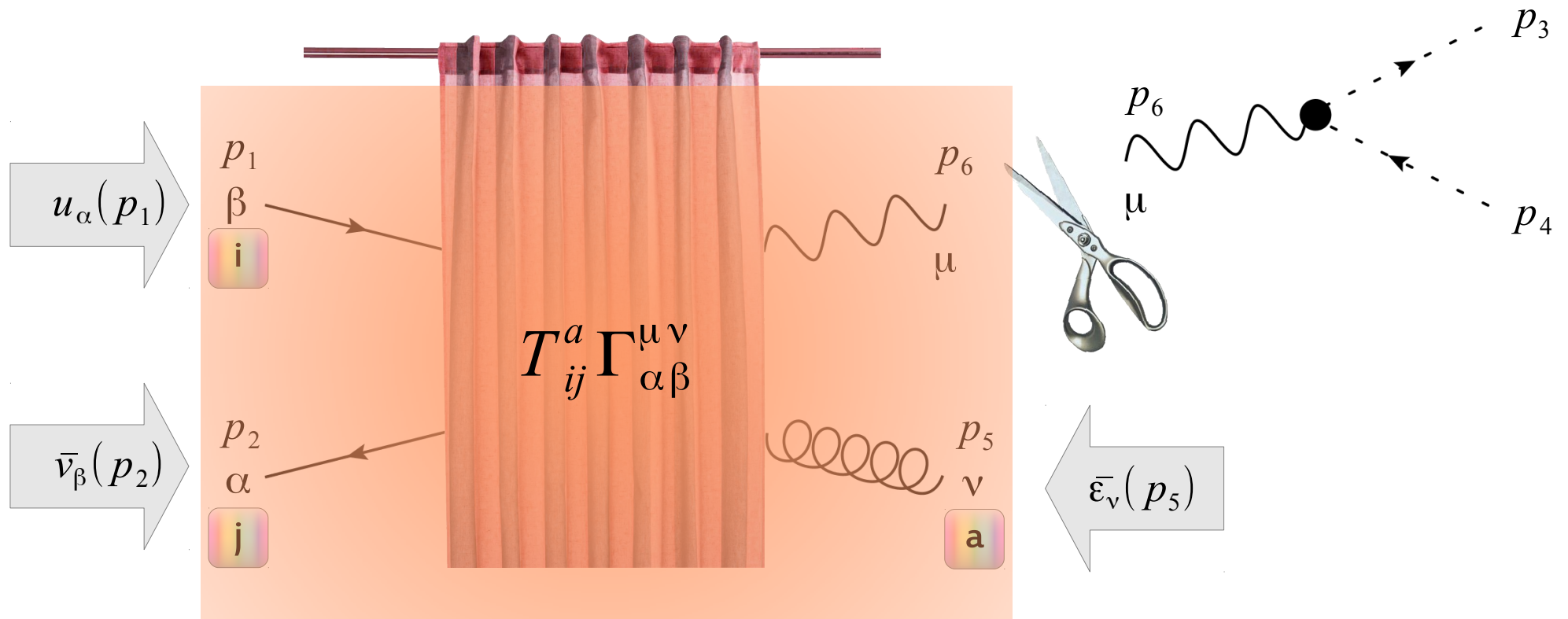
G. J. van Oldenborgh (1991)

T. Hahn and M. Perez-Victoria (1999)

# Structural Decomposition

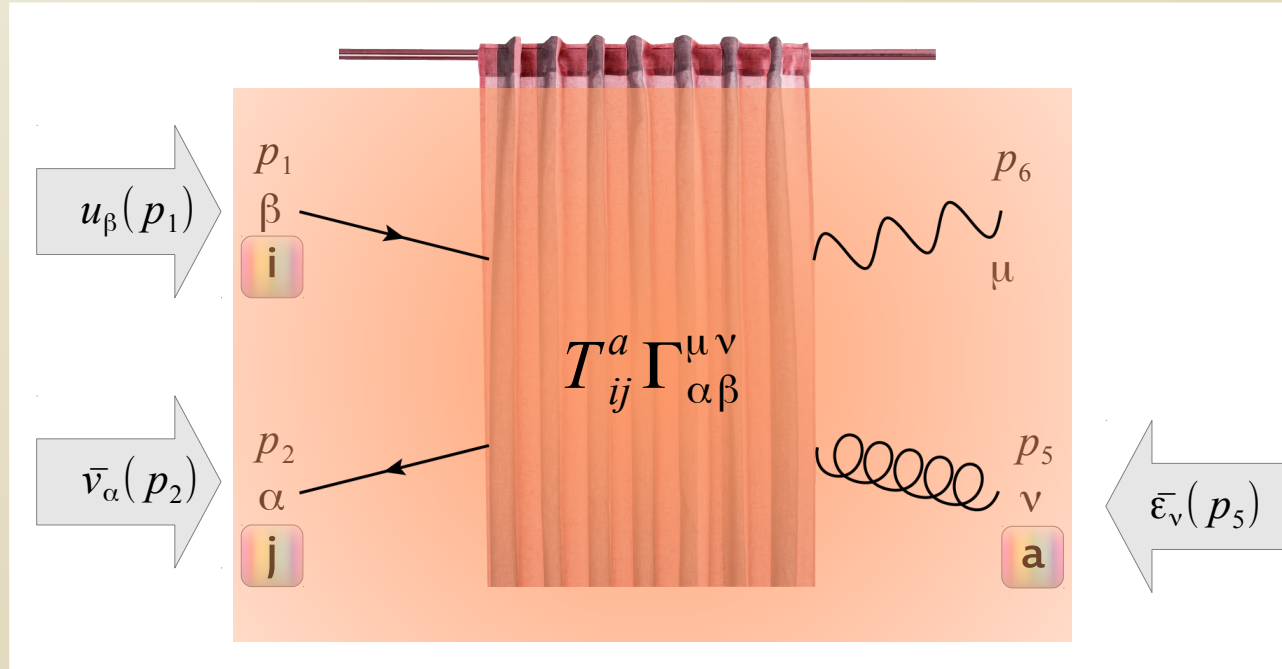


# Structural Decomposition



# Structural Decomposition

- possible parts of  $\Gamma_{\alpha\beta}^{\mu\nu}$   
 $p_1^\eta, p_2^\eta, p_5^\eta, \gamma_{\delta\varepsilon}^\eta, g^{\eta\sigma}$
- free indices,  
 legs 1,2,5 on-shell  
 & massless, ...  
 → 34 combinations




- define  $H^\mu = \bar{v}_\alpha(p_2) \Gamma_{\alpha\beta}^{\mu\nu} u_\beta(p_1) \bar{\epsilon}_\nu(p_5)$
- transverse gluon polarization → 26 terms remain
- QCD Ward identity, hadron current conservation  
 → 14 free coefficients

# Structural Decomposition

$$H_{explicit}^{\mu} = H^{\mu} = \sum_{i=1}^{14} \text{coeff}[i] \text{struct}[i]^{\mu}$$

- ◆ construct projectors

$$\begin{aligned} & \sum_{pol, hel} H_{explicit}^{\mu} \text{struct}[j]_{\mu} \\ = & \sum_{i=1}^{14} \text{coeff}[i] \underbrace{\sum_{pol, hel} \text{struct}[i]^{\mu} \text{struct}[j]_{\mu}}_{M[i, j]} \end{aligned}$$





# Structural Decomposition

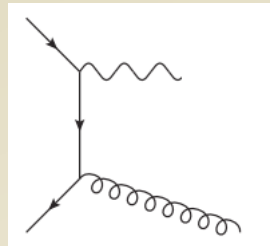
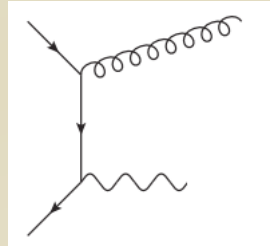
- ♦ only one coefficient non-zero for tree diagrams

- ♦ coeff

$$-g_s g_{em} \frac{2i}{r_{15} r_{25} s_{125}^2} (hP_{r1} hP_{l2} gqr + hP_{l1} hP_{r2} gql)$$

- ♦ struct

$$\begin{aligned} & \frac{1}{2} (s_{15} + s_{25}) \bar{v}(p_2) \gamma^\mu \bar{\not{\epsilon}}_5 \not{p}_5 u(p_1) \\ & + s_{15} p_5^\mu \bar{v}(p_2) \bar{\not{\epsilon}}_5 u(p_1) \\ & - s_{15} \bar{\epsilon}_5^\mu \bar{v}(p_2) \not{p}_5 u(p_1) \\ & - s_{15} p_2 \cdot \bar{\epsilon}_5 \bar{v}(p_2) \gamma^\mu u(p_1) \\ & + s_{25} p_1 \cdot \bar{\epsilon}_5 \bar{v}(p_2) \gamma^\mu u(p_1) \end{aligned}$$



## Features

- ◆ read in Supersymmetry Les Houches Accord (SLHA) files
  - ◆ produced by spectrum generators
  - ◆ masses, mixing parameters, ...
- ◆ create Les Houches event files
  - ◆ contain hard events
  - ◆ input for Parton-Shower Monte-Carlo programs
- ◆ full range of PYTHIA options

**SLHALib2**  
T. Hahn (2009)

**PYTHIA 6.4**  
T. Sjostrand, S. Mrenna,  
P. Z. Skands (2006)

## Features

- ◆ decays
  - ◆ according to mass spectrum
  - ◆ generated by PYTHIA
- ◆ full event output in HEPEVT standard
  - ◆ list of all particles and their momenta
  - ◆ freedom to generate arbitrary distributions
  - ◆ apply selection cuts
  - ◆ use analysis software

### **FASTJET**

M. Cacciari, G. P. Salam  
(2006)

M. Cacciari, G. P. Salam  
and G. Soyez (2011)

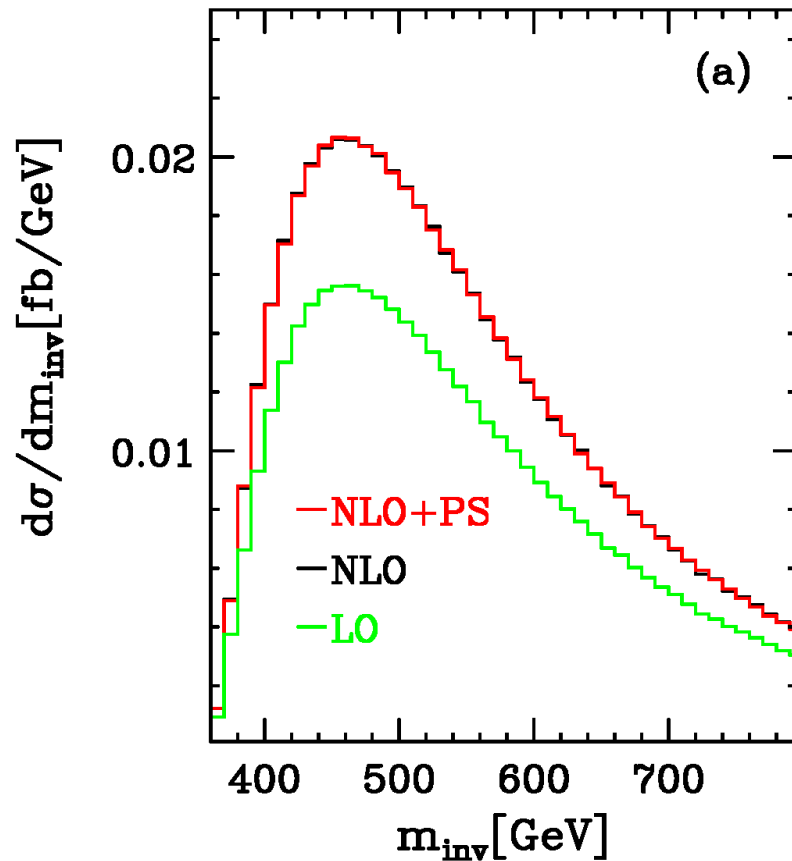
# Phenomenology

- ♦ right-handed sleptons
- ♦ LHC at 8TeV
- ♦ factorization and renormalization scale: invariant mass of the slepton pair

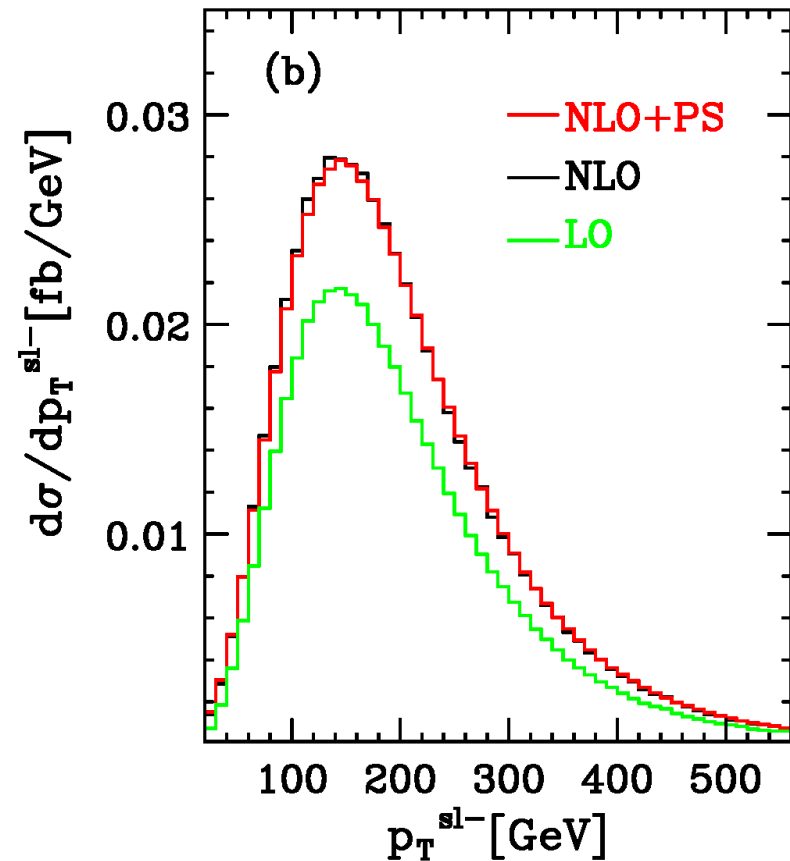
	mass [GeV]
slepton	180
neutralino 1	80
squark	1500
gluino	2000

	$\sigma$ [fb]	scale uncertainty [%]
LO	4.52	8
NLO	5.93	4

# Phenomenology

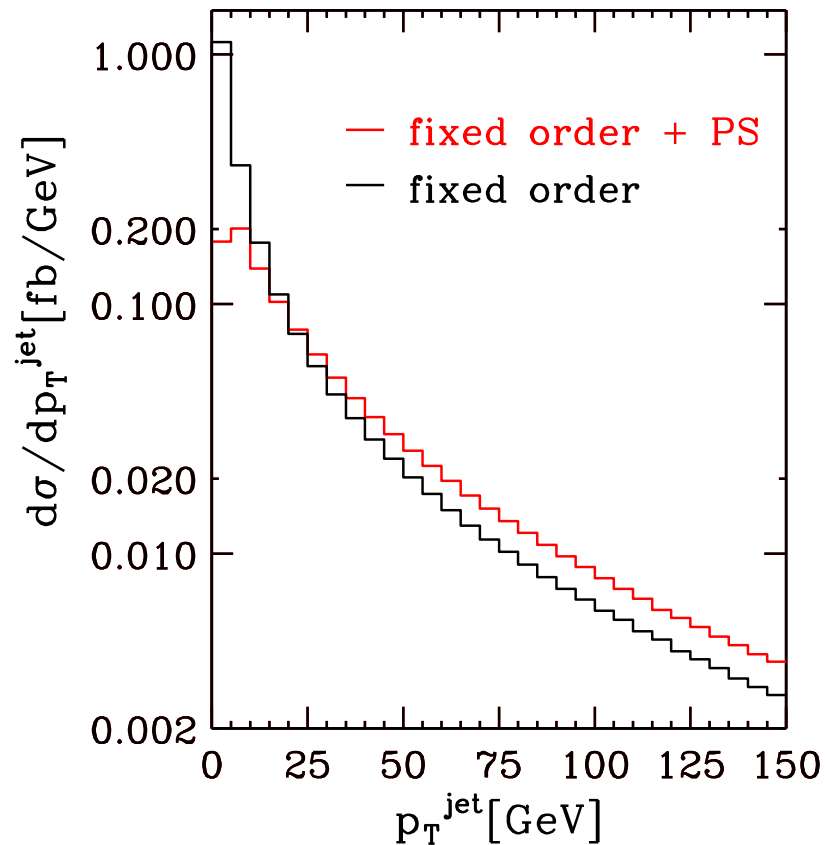


invariant mass  
of the slepton pair

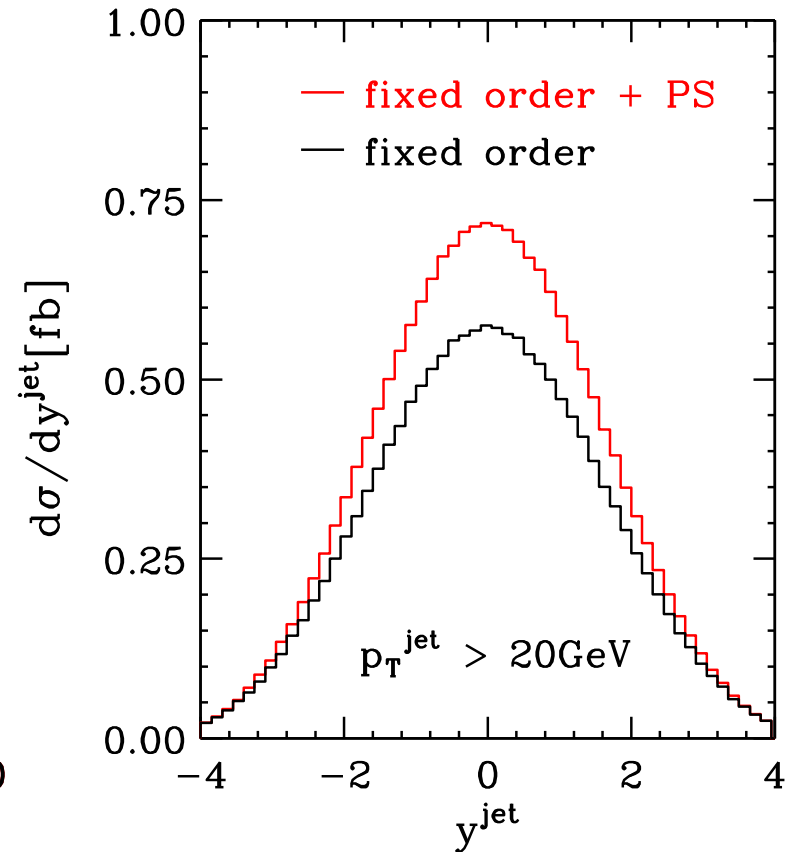


transverse momentum  
of one slepton

# Phenomenology

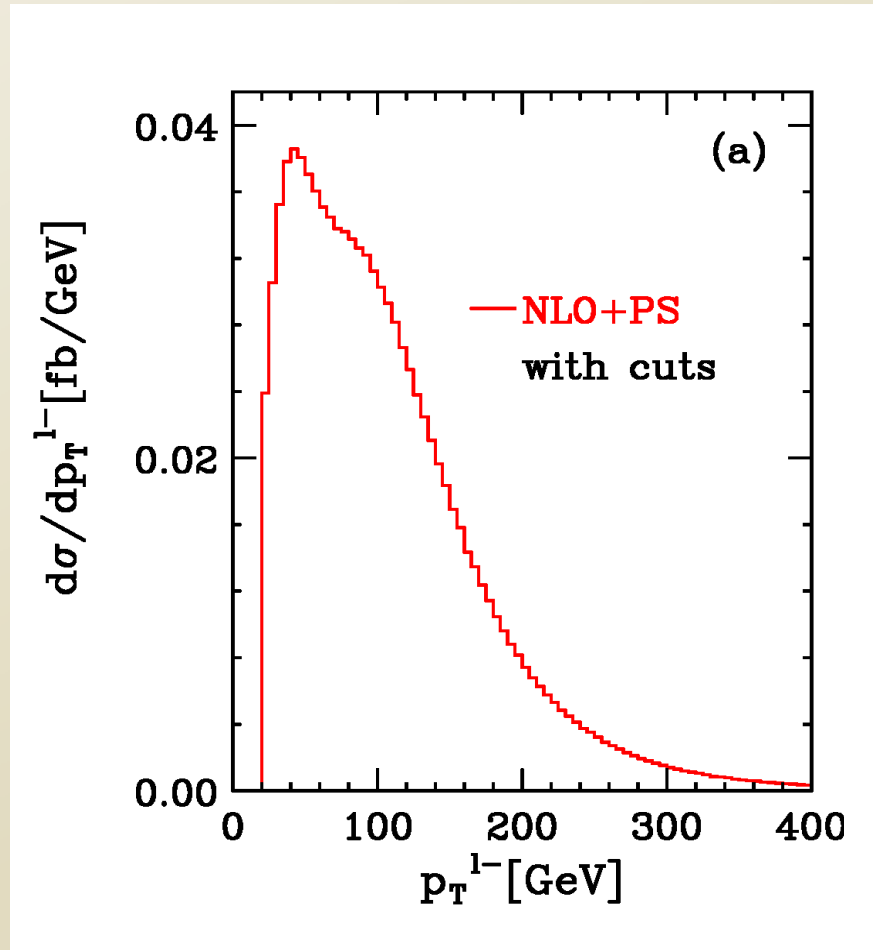


transverse momentum  
hardest jet



rapidity  
hardest jet

# Phenomenology



transverse momentum  
hardest lepton

$$\tilde{l} \rightarrow l + \tilde{\chi}_1$$

cuts:

$$p_t^l > 20 \text{ GeV}$$

$$|\eta^l| < 2.5$$

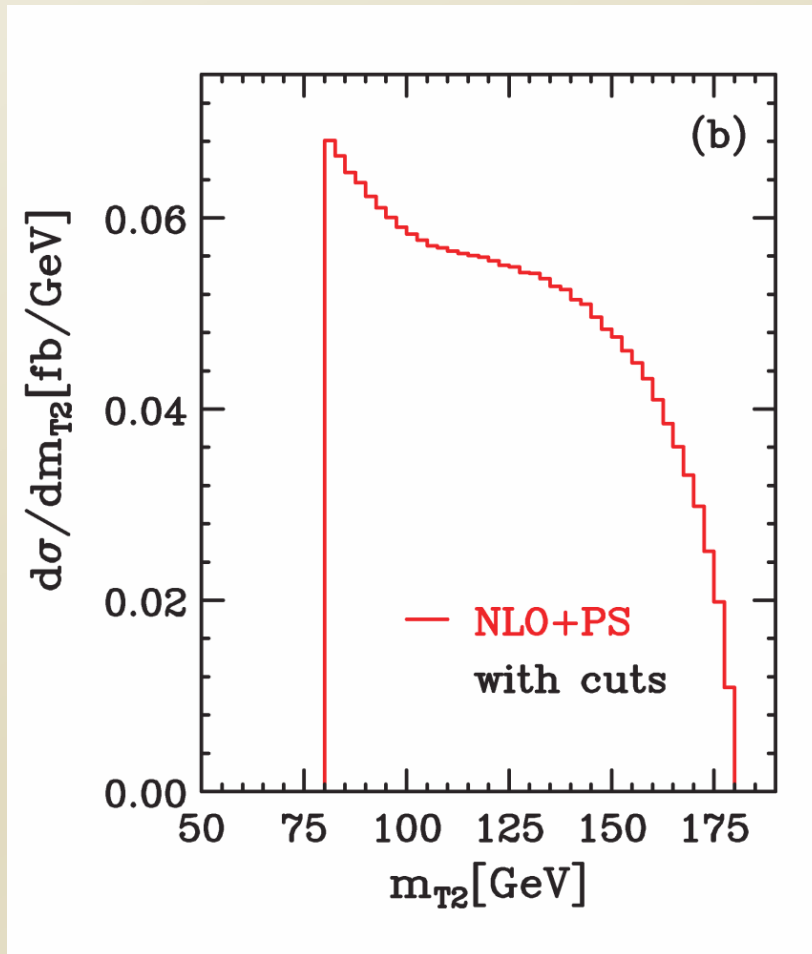
# Phenomenology

$$\tilde{l} \rightarrow l + \tilde{\chi}_1$$

cuts:

$$p_t^l > 20 \text{ GeV}$$

$$|\eta^l| < 2.5$$



	mass [GeV]
slepton	180
neutralino 1	80

$m_{T2}$

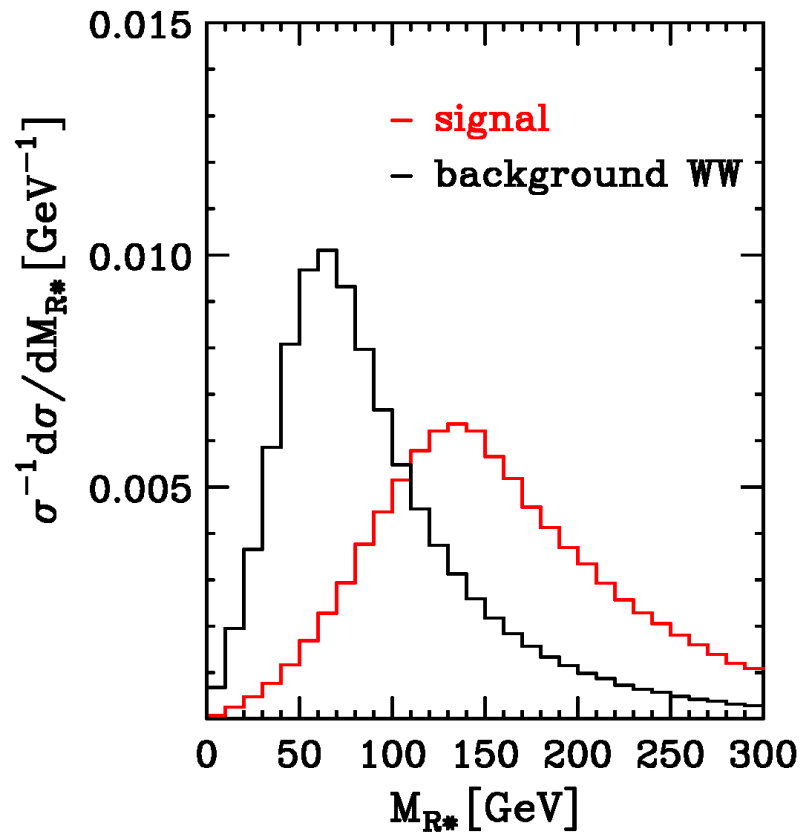
C. G. Lester and  
D. J. Summers  
(1999)

$$m_{\tilde{l}}^2 \geq M_{T2}^2 \equiv \min_{\mathbf{p}_1 + \mathbf{p}_2 = \mathbf{p}_T} \left[ \max \{ m_T^2(\mathbf{p}_{Tl-}, \mathbf{p}_1), m_T^2(\mathbf{p}_{Tl+}, \mathbf{p}_2) \} \right]$$



# Phenomenology

$$\tilde{l} \rightarrow l + \tilde{\chi}_1$$



	$\sigma$ [fb]
signal	5.93
backgr.	600.9

## background WW

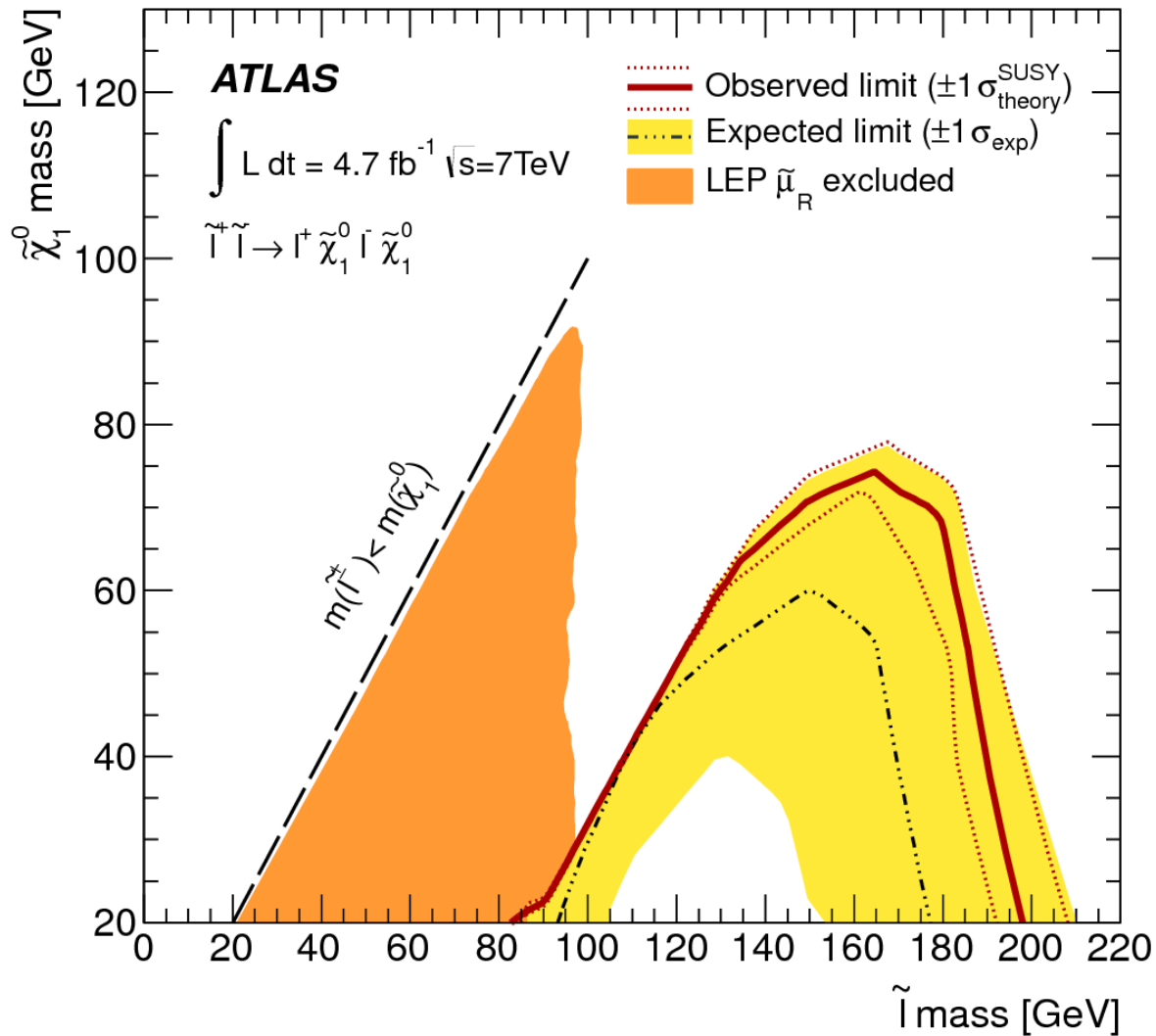
T. Melia, P. Nason, R. Rontsch,  
G. Zanderighi (2011)

$$m_{peak} \approx \frac{m_{parent}^2 - m_{invisible}^2}{m_{parent}}$$

$M_{R^*}$   
C. Rogan (2010)

$$M_{R^*} = \sqrt{(q_{10}^l + q_{20}^l)^2 - (q_{1z}^l + q_{2z}^l)^2 - \frac{(|\vec{q}_{1T}^l|^2 - |\vec{q}_{2T}^l|^2)^2}{|\vec{q}_{1T}^l + \vec{q}_{2T}^l|^2}}$$

# Search Status



pMSSM

ATLAS  
(2013)

# Conclusions

- ◆ new process in the POWHEG BOX:  
slepton pair production
- ◆ flexible input and output following  
common standards
- ◆ many possibilities for phenomenology at  
high precision

**Thank you  
for your attention!**