

# PROSPINO2: AN INTRODUCTION

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- Supersymmetry at the LHC
- Higher order cross sections
- Prospino2

# TeV SCALE SUPERSYMMETRY

## Bright side

- ★ R parity — stable proton yields dark matter
- ★ unification — 3 running couplings meet
- ★ radiative symmetry breaking — 2 Higgs doublets
- ★ local supersymmetry – including gravity?
- ★ rich LHC phenomenology — no nasty surprises

## Dark side

- ★ unknown SUSY breaking
  - masses, scalar couplings, phases...
  - hierarchical spectrum [Split SUSY]
- ★ flavor physics and SUSY breaking
  - CKM and lepton flavor?
- ★ 2 Higgs doublet model
  - $\mu$  parameter and SUSY breaking?

		spin	d.o.f.	
quark	$q_L, q_R$	1/2	1+1	
→ squark	$\tilde{q}_L, \tilde{q}_R$	0	1+1	6 flavors
gluon	$G_\mu$	1	$n - 2$	
→ gluino	$\tilde{g}$	1/2	2	Majorana
gauge bosons	$\gamma, Z$	1	2+3	
Higgs bosons	$h^0, H^0, A^0$	0	3	
→ neutralinos	$\tilde{\chi}_i^0$	1/2	4 · 2	Majorana
gauge bosons	$W^\pm$	1	2 · 3	
Higgs bosons	$H^\pm$	0	2	
→ charginos	$\tilde{\chi}_i^\pm$	1/2	2 · 4	Dirac

⇒ as many as exclusive analyses as possible

# SUSY LES HOUCHES ACCORD

## Problem: Supersymmetric parameter conventions

- link between specialized codes [remember: comparison CompHEP–Pythia–ISAJET]
- implementation of benchmark points [e.g. SPS1a]
  - soft breaking parameters [e.g.  $\pm A_t$ ]
  - scale dependence of couplings, masses [e.g.  $m(q = \text{TeV}, v, m_t)$ ?]
  - definitions of mass matrixes, mixing angles [e.g.  $\tilde{t}_{L,R}$  up or down?]

## SUSY Les Houches Accord [P. Skands et al.]

- spectrum generators: SoftSusy, SPheno, FeynHiggs,...
  - multi-purpose Monte Carlos: Pythia, Herwig, Sherpa
  - matrix element generators: Whizard, SMadGraph
  - NLO cross sections: Prospino2
  - NLO decay rates: Sdecay
  - MSSM parameter extraction: Fittino, Sfitter
  - dark matter calculators: Micromegas
- ⇒ **fixed parameter convention and read-write format**

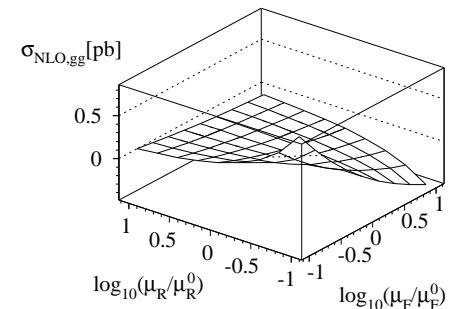
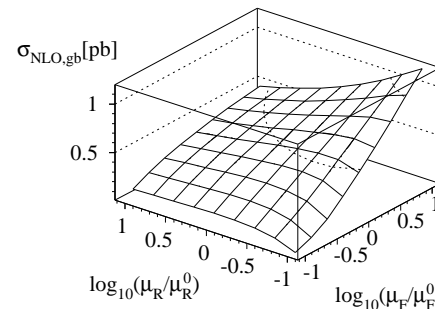
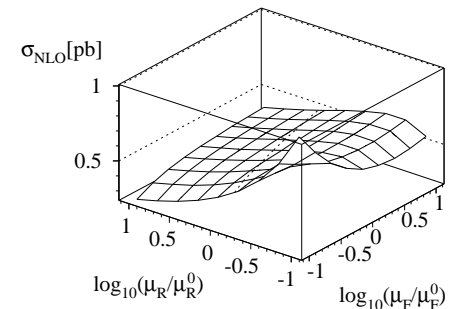
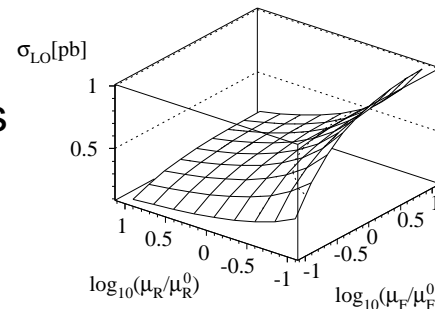
# NEXT-TO-LEADING ORDER CROSS SECTIONS

## Supersymmetry at the LHC

- (1) **discovery** — signals for new physics, possibly SUSY, exclusion of parameter space
  - (2) **measurements** — masses, cross sections, decays
  - (3) **parameter studies** — MSSM Lagrangean, SUSY breaking
- ⇒ at least 10% precision to be matched at LHC

## Hadron collider observables

- renormalization scale from  $\alpha_s, y_{b,t}$
- factorization scale from parton densities  
[scale dependence minimum error]
- perturbative series  $N_c \alpha_s / \pi \sim 10\%$   
[fixed order naive error]
- finite terms  
[LO-NLO-NNLO: Drell-Yan, Higgs]



# PROSPINO2: THE IDEA

## NLO cross sections for Tevatron and LHC

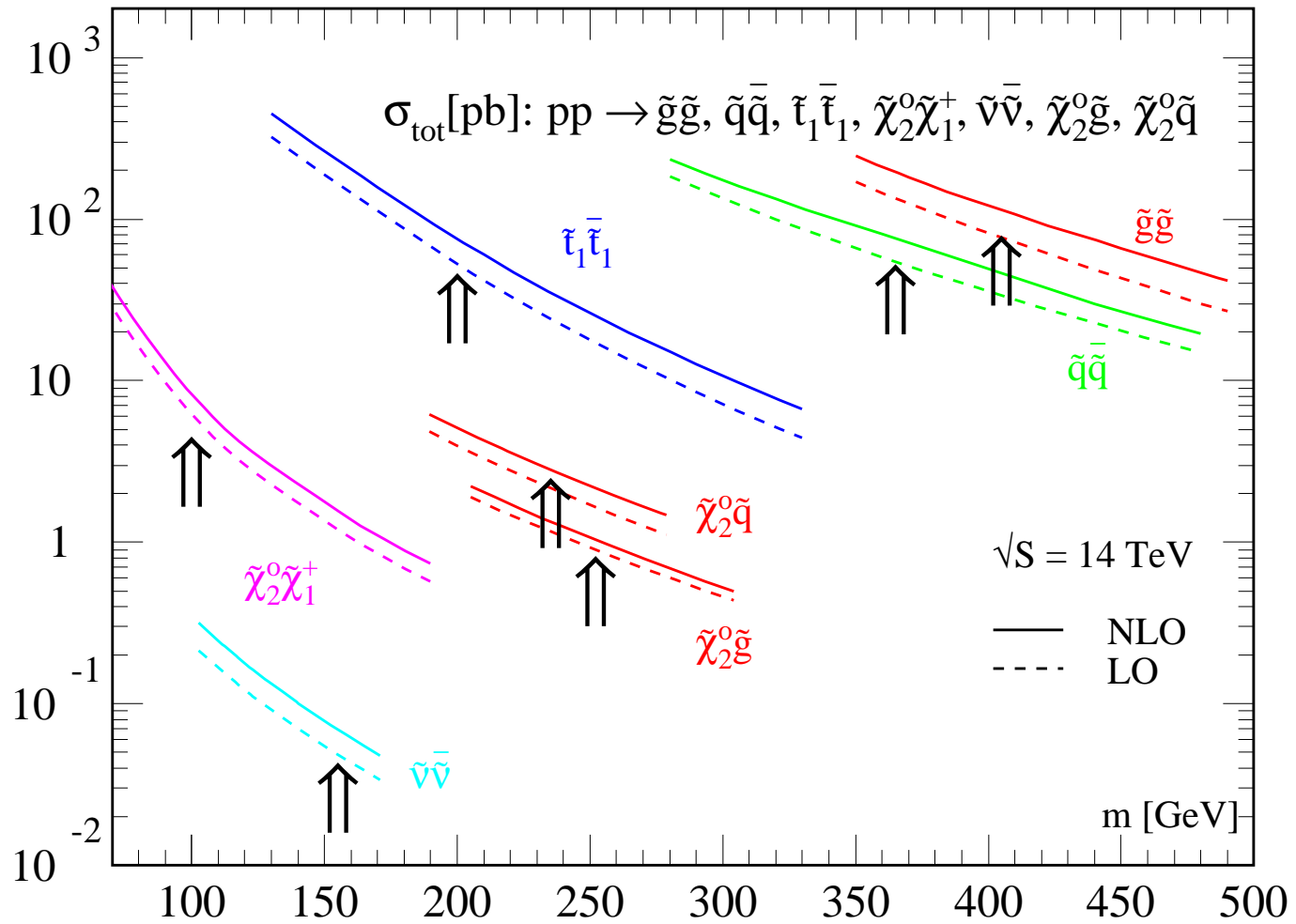
- compute total cross sections for heavy particles [distributions on demand]
- all two-particle SUSY production channels included
- extended version beyond Prospino2:  $pp \rightarrow SS^*, tH^- \dots$
- public Website and continuously maintained Fortran program
- thanks to: W. Beenakker, R.Höpker, M. Krämer, M. Spira, P. Zerwas

## Getting started on Prospino2.0

- (1) download prospino.tar.gz from Prospino2 page: <http://pheno.physics.wisc.edu/~plehn>
- (2) edit path and compiler in Makefile [any F90 compiler will do]
- (3) make, run executable
- (4) find results in file prospino.dat

```
nn 1 1 0.00 0.00 1.00 96.27 96.27 0.00 0.908E-02 0.165E-03 0.118E-01 0.265E-02 1.3020
nn 1 2 0.00 0.00 1.00 96.27 179.38 0.00 0.101E-02 0.179E-03 0.136E-02 0.181E-02 1.3477
nn 1 3 0.00 0.00 1.00 96.27 -364.09 0.00 0.204E-02 0.154E-03 0.260E-02 0.144E-03 1.2763
nn 1 4 0.00 0.00 1.00 96.27 382.63 0.00 0.443E-03 0.164E-03 0.565E-03 0.301E-03 1.2747

i1 i2          scafac  m1      m2  angle      LO[pb] rel-error  NLO[pb] rel-error  K
```



# PROSPINO2: THE STRUCTURE

## Structure of Prospino2 code

- driver file: `prospino_main.f90`
- user subdirectories:
  - Pro2\_doc: getting started, documentation, reference output
  - Pro2\_interface: interface for SUSY spectrum and for parton densities [default: SLHA, Cteq6]
- global parameters: `Xvital.f90` [e.g.  $m_W$ ,  $m_t$ ,  $G_F$ ]
- advanced user: `Xprospino_subroutine.f90`
  - collider energy
  - input-output file initialization
- professional user: `Xinitialize.f90`
  - SUSY spectrum initialization
  - numerical cutoff parameters
  - number of points and iteration for integration
- directories not to be touched:
  - Pro2\_integrals: routines for angular integrals and loop integrals
  - Pro2\_matrix: matrix elements squared
  - Pro2\_sq-gl: old Prospino for squark and gluino production
  - Pro2\_subroutines: all subroutines

# PROSPINO2: THE CODE

```
program main
use xx_kinds                                ! defines integer and real variables
use xx_prospino_subroutine                  ! links the actual prospino code

integer :: nlo,icoll,ipart1,ipart2
character(len=2) :: final_state

!-----
nlo = 1 ! specify LO only[0] or complete NLO (slower)[1]
!-----
!-----
icoll = 1 ! specify the collider :  tevatron[0] , lhc[1]
!-----
!-----
! final_state = ng neutralino/chargino + gluino
!               ns neutralino/chargino + squark
!               nn neutralino/chargino pair combinations
!               ll slepton pair combinations
!               sb squark-antisquark
!               ss squark-squark
!               tb stop-antistop
!               gg gluino pair
!               sg squark + gluino
!               lq leptoquark pairs (using stop1 mass)
!-----
final_state = 'ng'

!-----
! final_state = ng,ns,nn
! ipart1 = 1,2,3,4 neutralinos
...
!-----
ipart1 = 1
ipart2 = 1

call PROSPINO_OPEN_CLOSE(0)                ! open all input/output files
call PROSPINO(nlo,icoll,final_state,ipart1,ipart2) ! actual prospino call
call PROSPINO_OPEN_CLOSE(1)                ! close all input/output files

end program main
```



# OUTLOOK

## Theory tools for supersymmetry at LHC

- spectrum generators → LHC cross sections all available with SLHA
- major progress on improved errors for LHC
- many tools in testing phase or beyond, e.g. Prospino2

## Prospino2

- LO production cross sections clearly insufficient
- NLO cross sections computed, published, checked
- Prospino2.0 code and news availables from <http://pheno.physics.wisc.edu/~plehn>
- continuous updates, e.g. Split Supersymmetry, Leptoquarks, SUSY-Higgs
- feedback crucial for further developments