$\tilde{\tau}$ searches at the ILC (WIP)

Teresa Núñez - DESY

- Motivation
- Conditions and tools
- Signal characterisation
- Background
- Signal efficiency
- Analysis main background sources
- Current status and prospects

HELMHOLTZ GEMEINSCHAFT

ILD Analysis/Software Meeting, 15-07-20

CLUSTER OF EXCELLENCE QUANTUM UNIVERSE

DESY.

Motivation

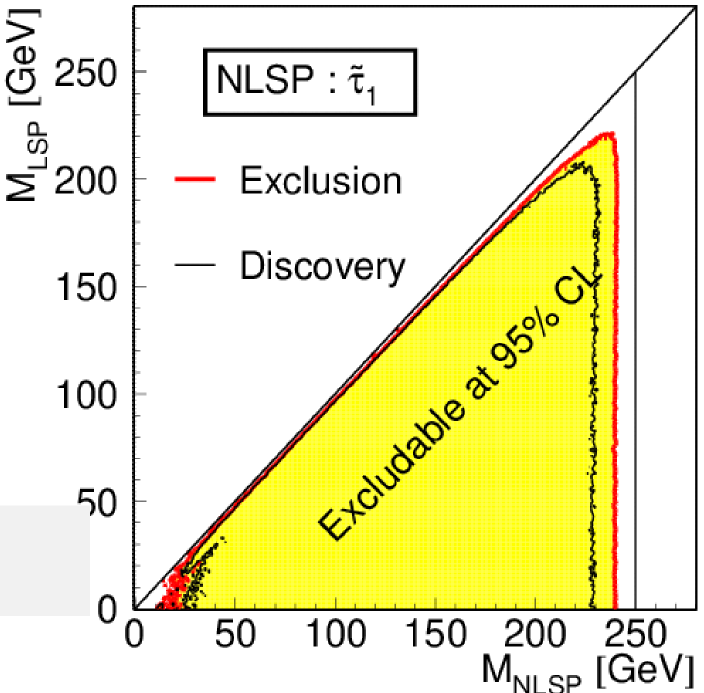
Searching SUSY focused on best motivated NLSP candidates and most difficult scenarios

$\tilde{\tau}$ satisfies both conditions

- High probability to be the lightest sfermion (stronger trilinear couplings)
- More difficult signal identification than the other sfermions (decay to τ's)

Previous studies do not cover small ΔM = (M$\tilde{\tau}$ - MLSP)

500 fb^{-1} at $\sqrt{s}$ = 500 GeV
with P(e^-,e^+)=(+80%,-30%)



Limits only valid up to ΔM 3-4 GeV
(not dedicate low ΔM analysis)

Motivation

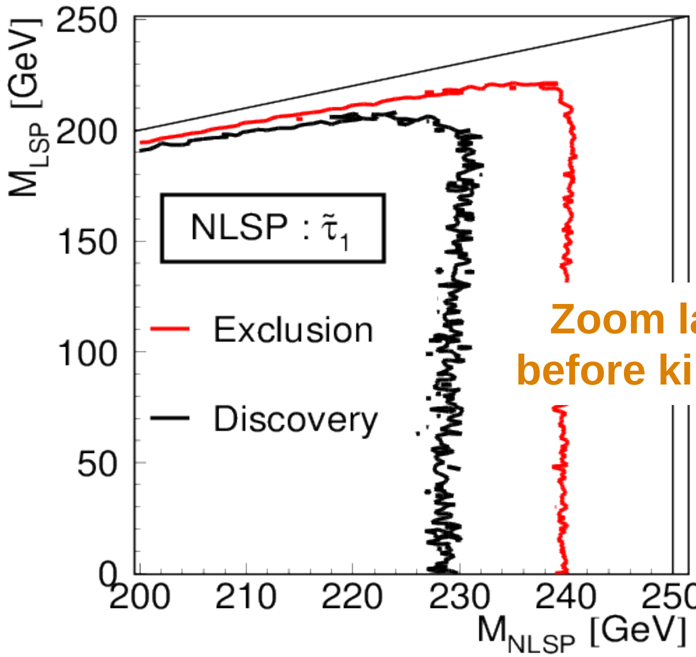
Searching SUSY focused on best motivated NLSP candidates and most difficult scenarios

$\tilde{\tau}$ satisfies both conditions

- High probability to be the lightest sfermion (stronger trilinear couplings)
- More difficult signal identification than the other sfermions (decay to τ's)

Previous studies do not cover small ΔM = (M$\tilde{\tau}$ - MLSP)

500 fb^{-1} at $\sqrt{s}$ = 500 GeV
with P(e$^-$,e$^+$)=(+80%,-30%)



Zoom last 50 GeV before kinematic limit

HELMHOLTZ
GEMEINSCHAFT

DESY.

Conditions and tools

$\tilde{\tau}$ searches in worst scenario using SGV fast simulation

- Mixing angle set to 53 degrees (lowest cross sections)
- Small mass difference with LSP (ΔM < 11 GeV)

ILC experimental conditions

- Polarization P(e^-,e^+)=(+80%,-30%)
- $\sqrt{s}$ = 500 GeV with 1.6 ab^{-1} integrated luminosity (H-20, I-20 ILC500)

Event reconstruction using SGV adapted to the ILD detector concept at ILC

- Signal: Phytia 6.422
- Background: Whizard 1.95 (standard DBD background samples)

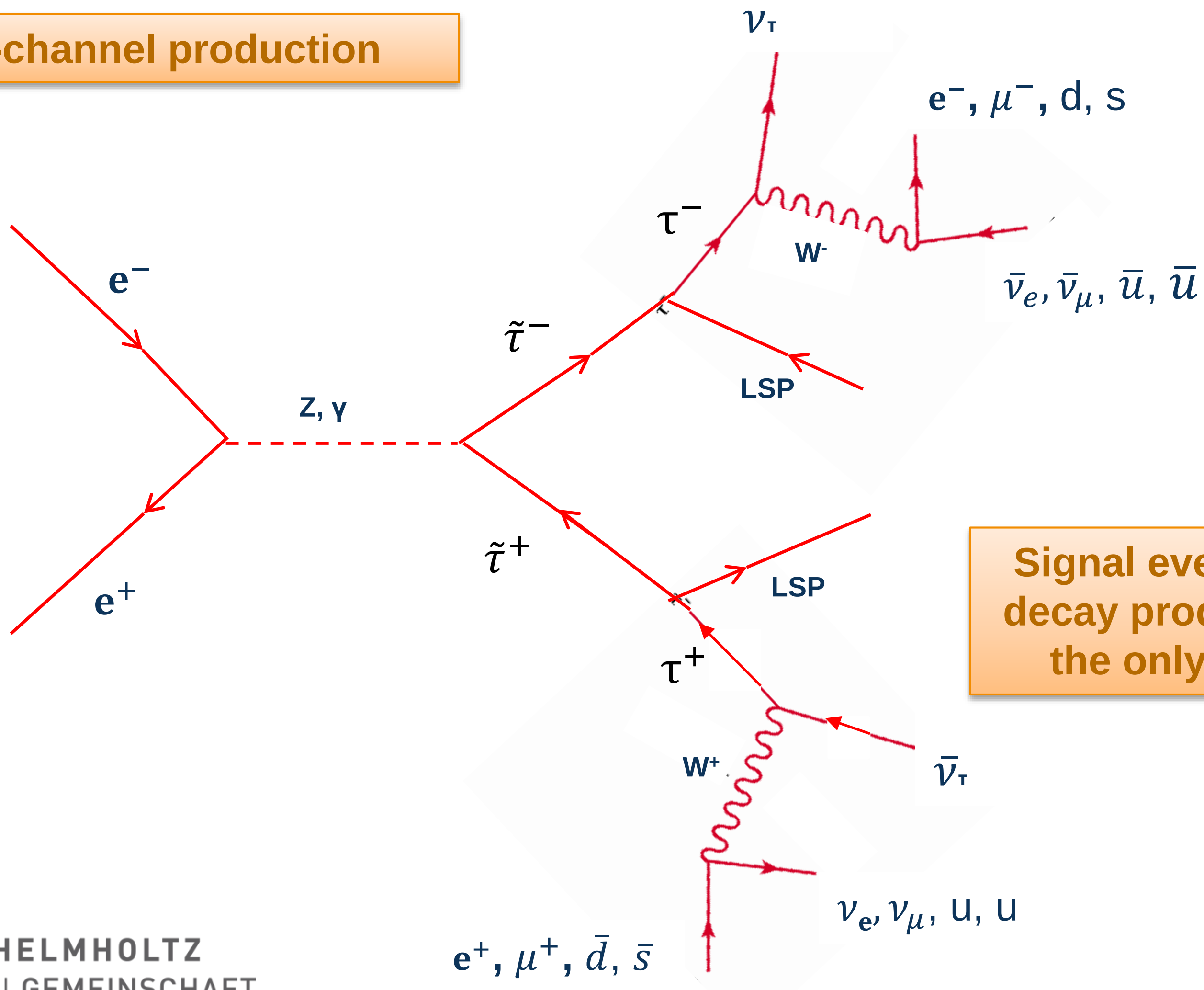
Root ntuples for analysis

HELMHOLTZ GEMEINSCHAFT

DESY.

Signal characterisation

s-channel production



Signal events with the (visible) decay products of two τ's being the only detectable activity

Signal characterization (ctd.)

Signature:

- large missing energy and momentum
- high acolinearity, with little correlation to the energy of the decay products
- large fraction of detected activity in central detector (isotropic production of scalar particles)
- unbalanced transverse momentum
- no forward-backward asymmetry

HELMHOLTZ GEMEINSCHAFT

DESY.

Background

SM processes with real or fake missing energy

Irreducible

4-fermion production with two of the fermions being neutrinos and two leptons

- ZZ -> ννττ, WW -> τν τν

Almost irreducible

2-τ production partially escaping detection

- ee -> ττ, ZZ -> ννll, WW -> lν lν (l = e or μ)
- ee -> ττ + ISR, ee -> ττ ee, γγ -> ττ

γγ interactions

HELMHOLTZ GEMEINSCHAFT

DESY.

Cuts

Properties $\tilde{\tau}$ -events “must” have

- Missing energy (emiss). emiss > 2*MLSP GeV (preselection)
- Visible mass (mvis). mvis < 2*(M$\tilde{\tau}$ - MLSP) GeV (preselection)
- Number of charged particles (ncha). 2 <= ncha < 6 (preselection)

- Momentum of all jets (pjet). pjet < 70% Beam Momentum

- Number of clusters identified as τ (nclu). nclu = 2 or 3
- τ-indentification
- Total charge (totcharge). totcharge = 0, +/- 1

Above 95 % signal efficiency for each of these cuts (excluding for the τ-identification)

- Maximum jet momentum:

$$P_{max} = \frac{\sqrt{s}}{4}(1 - (MLSP - M\tilde{\tau})^2 (1 + \sqrt{1 - \frac{4M\tilde{\tau}^2}{s}})$$

Cuts

Tau identification

- Pattern of charged tracks from τ-decay:
  - Exactly two jets with charged particles
  - 1 or 3 charged particles in each charged jet, with total charge +/-1
  - Two jets with opposite charge
- Reduction of background from sources with leptons not from τ-decays
  - Two charged jets not made by single leptons with same flavor
  - None of the jets made by single positron (RL beam polarization)
  - Most energetic jet should not be a single electron

Signal efficiency ~ 40% but reduce the WW background up to 94 %

Cuts

Properties $\tilde{\tau}$ -events "might" have but background "rarely" has

- Missing transverse momentum (ptmiss). ptmiss > 2-4 GeV (depending on mass difference)
- Large acoplanarity (thetaacop). 0.2 rad < thetaacop < 2. rad
- Large transverse momentum wrt. thrust-axis (rho). rho > 2-4 GeV(depending on mass difference)
- High angles to beam (thetaptot). 0.79 rad < thetaptot < 2.84 rad

Cuts against properties of some almost irreducible sources of background

- Charge asymmetry (cha_asym: $\Sigma charge * \cos(polar\_angle)$). char_asym > -1
- Difference between visible mass and Z mass (Z_peak). Z_peak > 4 GeV

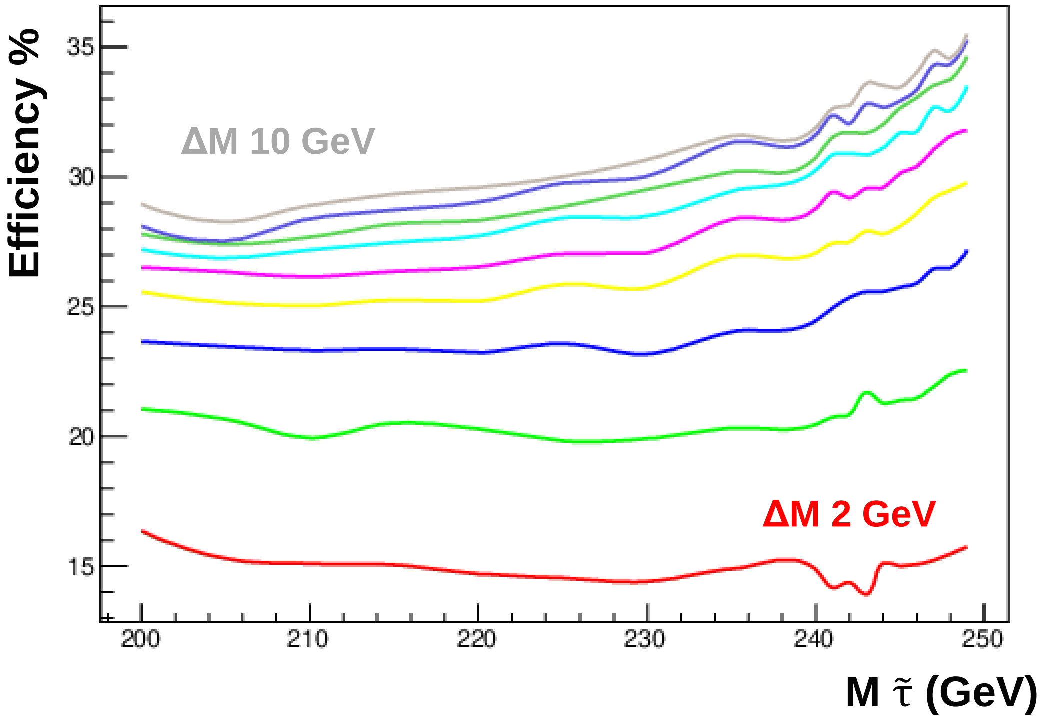
Properties that the background often "does not" have

- Low energy in small angles (e30: energy in 30 degrees cone around the beam axis). e30 < 10 GeV
- Maximum energy of isolated neutral clusters (pmaxneuc). pmaxneuc < 10% beam momentum

Signal efficiencies (example behaviour)

All cuts applied …

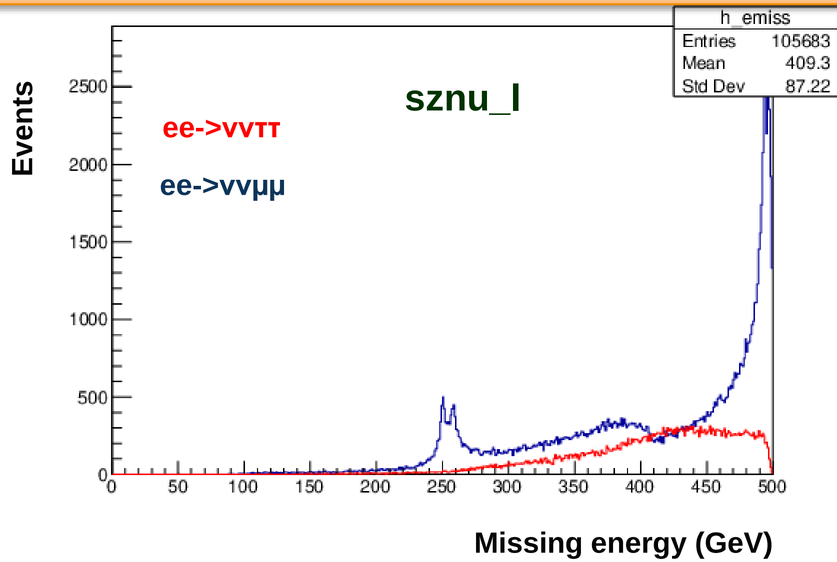
… but ptmiss relaxed to > 0.1 GeV and rho to > 0.7 GeV



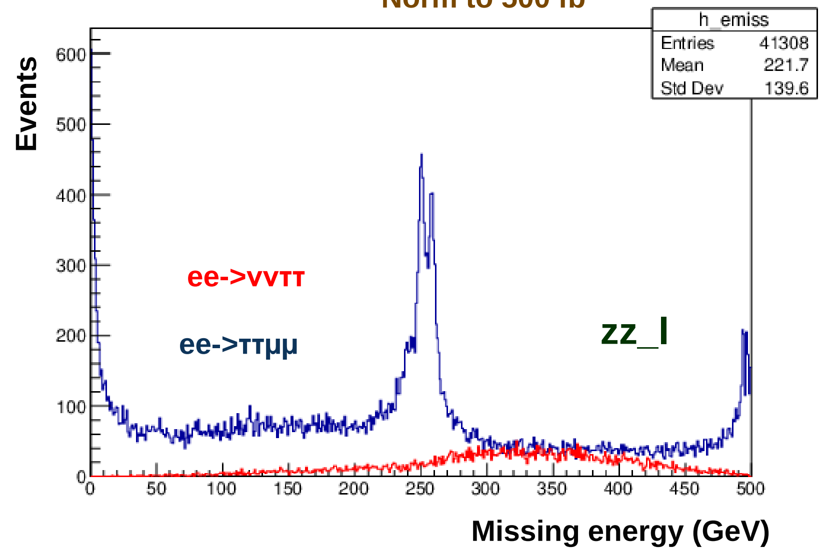
Efficiency strongly depends on ΔM and slighlty on M τ̃

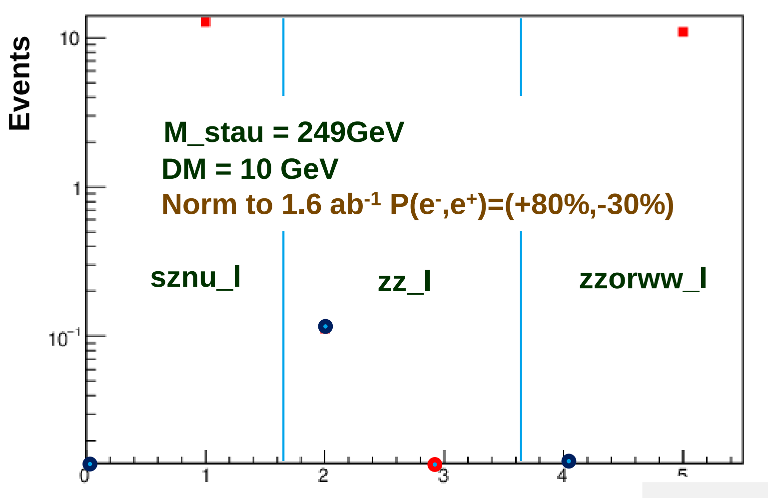
Background analysis

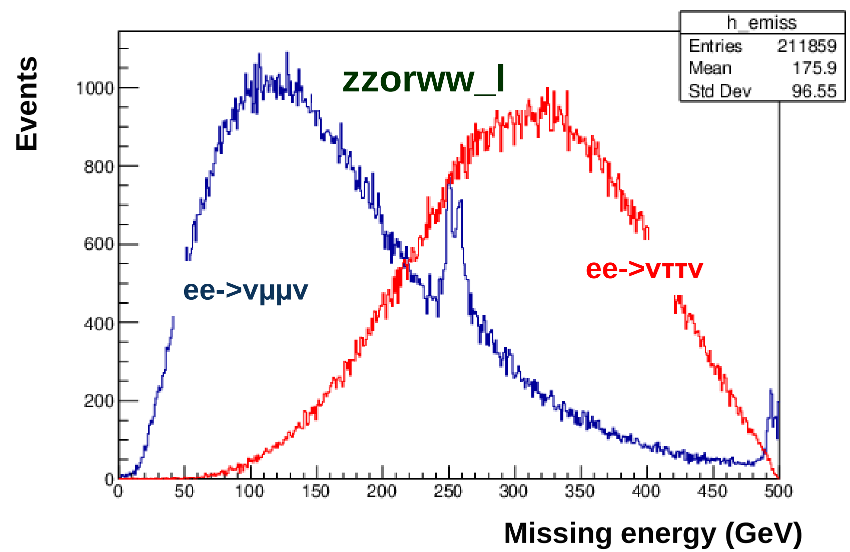
Remaining background in ee->llvv files



Norm to 500 fb^{-1}



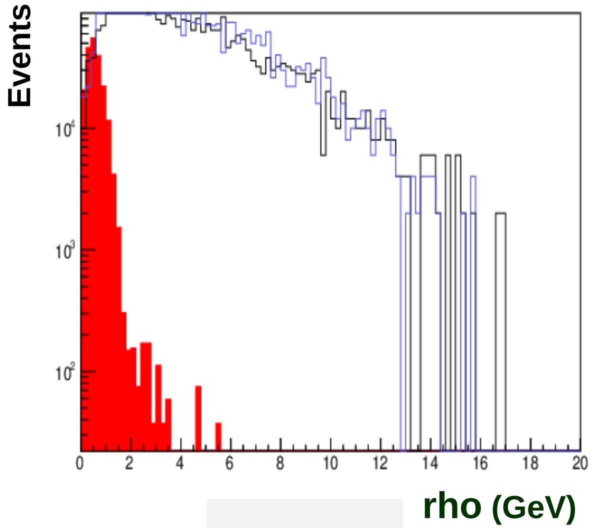


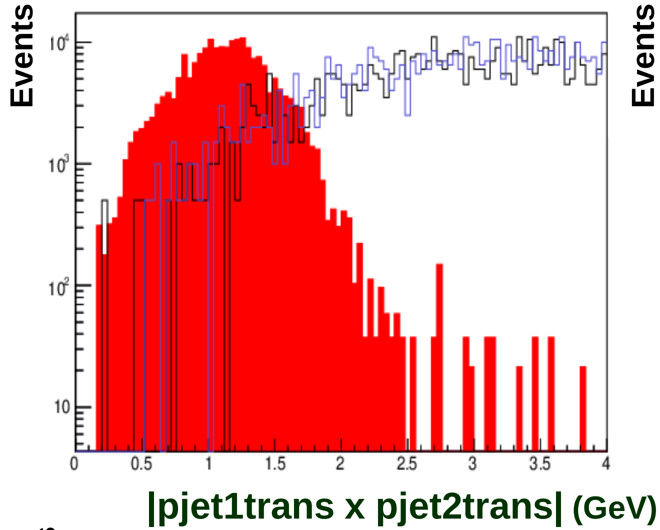


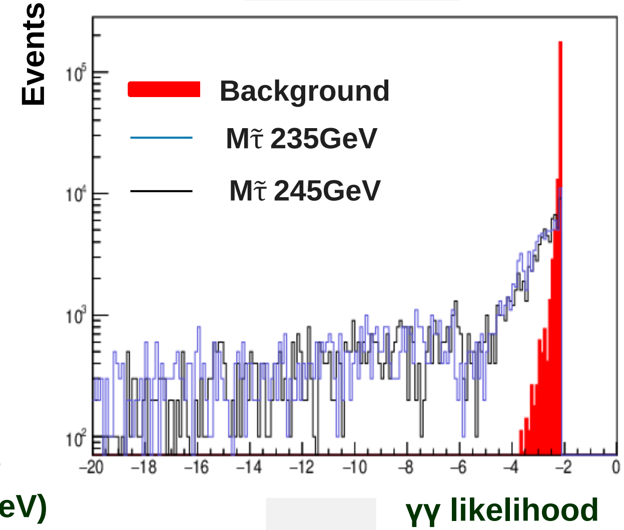
Background analysis

Fine tuning γγ background rejection

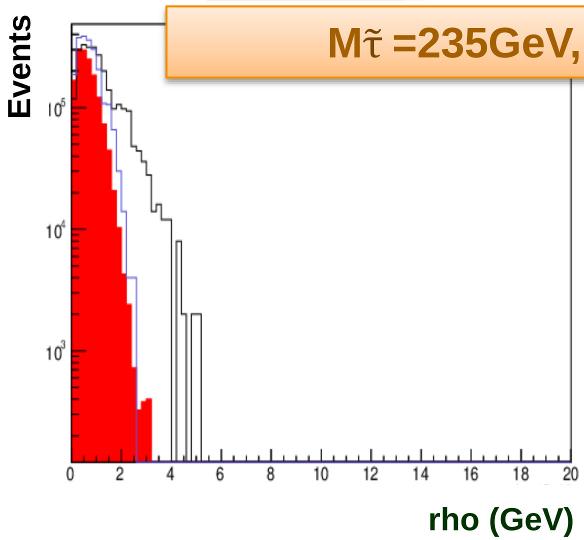
M$\tilde{\tau}$ 235GeV vs 245GeV, ΔM=10GeV

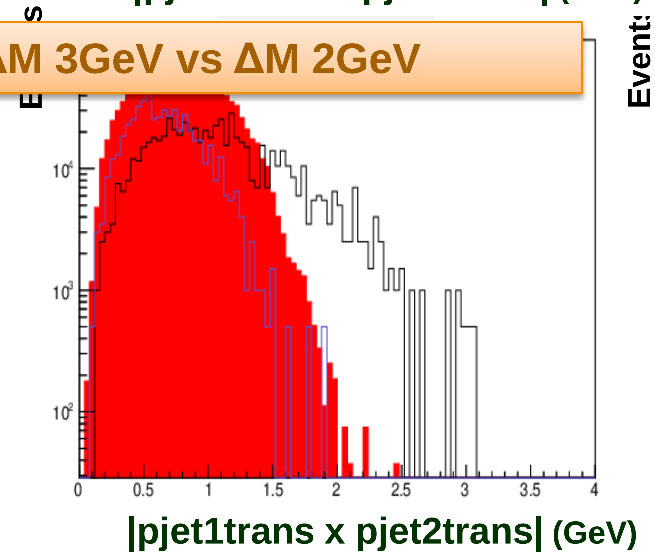


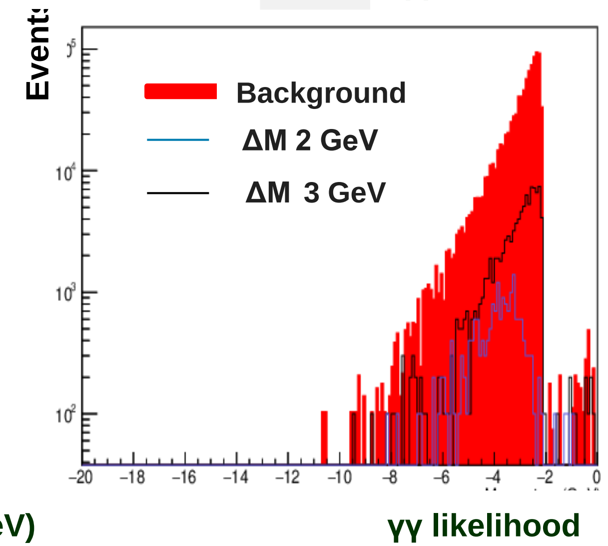




M$\tilde{\tau}$ =235GeV, ΔM 3GeV vs ΔM 2GeV

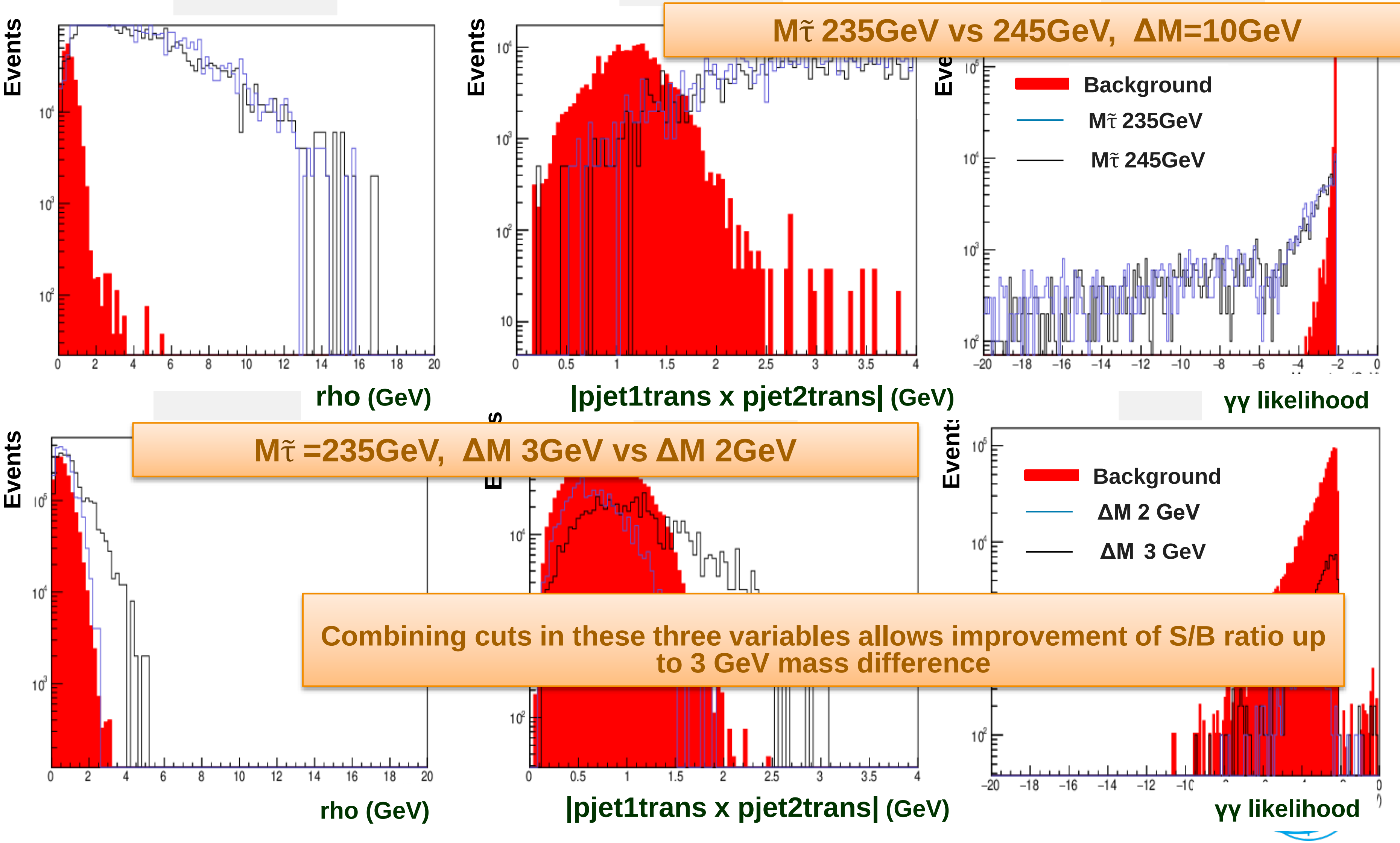






Background analysis

Fine tuning γγ background rejection



M$\tilde{\tau}$ 235GeV vs 245GeV, ΔM=10GeV

M$\tilde{\tau}$ =235GeV, ΔM 3GeV vs ΔM 2GeV

Combining cuts in these three variables allows improvement of S/B ratio up to 3 GeV mass difference

Current status and prospects

Two main effects

- WW background decreases with decreasing ΔM (kinematic cut in pjetmax)
- γγ background very similar to the signal for small ΔM

Where are we (preliminary)?

- ΔM = 10 to 5 GeV -> exclusion limit up to $M_{\tilde{\tau}}$ = ~247 GeV
- ΔM = 4 GeV -> exclusion limit up to $M_{\tilde{\tau}}$ = ~240 GeV
- ΔM = 3 GeV -> exclusion limit up to $M_{\tilde{\tau}}$ = ~230 GeV
- ΔM = 2 GeV -> fine tuning is needed due to γγ background

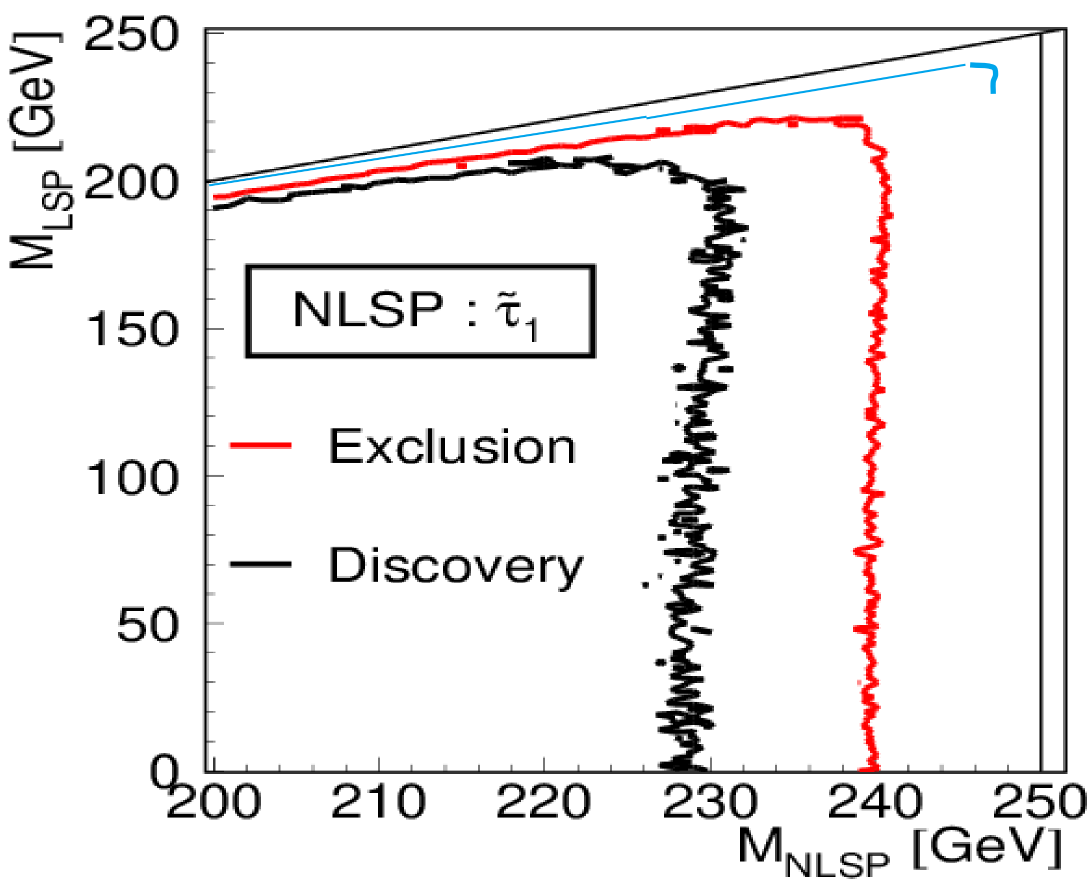
HELMHOLTZ GEMEINSCHAFT

DESY.

Current status and prospects

Comparison to previous limits

Exclusion. New study (preliminary)



HELMHOLTZ GEMEINSCHAFT

Current status and prospects

Still to be analyzed

- Fine tuning current cuts
- Requirement of ISR photon
- Vertex reconstruction for ΔM = 2 GeV ?

General comments

- First analysis of the cuts have been done
- Further refinements are needed
- Use of full MC reconstructed events as background input for SGV is planned
- Results are still very preliminary

HELMHOLTZ GEMEINSCHAFT

DESY.