$\tilde{\tau}$ searches at the ILC

Teresa Núñez - DESY

- Motivation
- Conditions and tools
- Signal characterisation
- Background
- Limits with general cuts
- Detailed study not excluded regions
- Current status and prospects

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Motivation

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

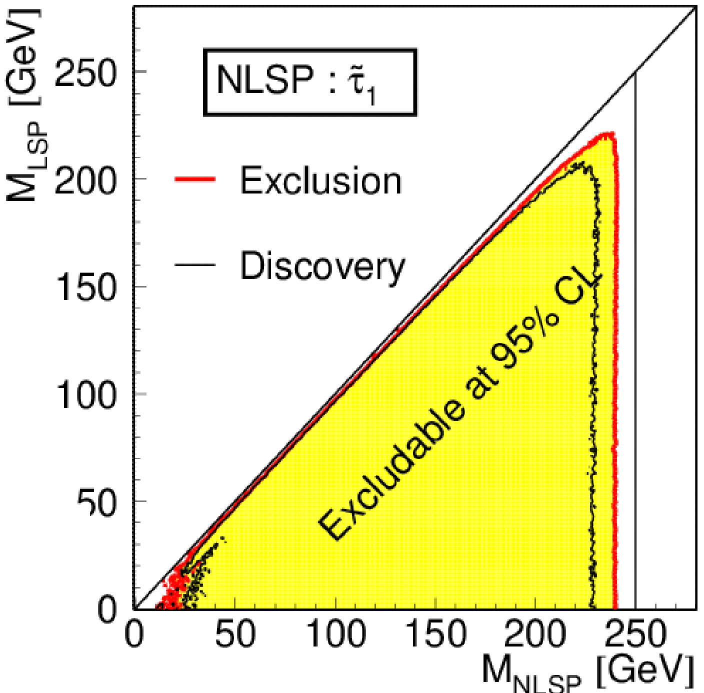
$\tilde{\tau}$ satisfies both conditions

- 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)



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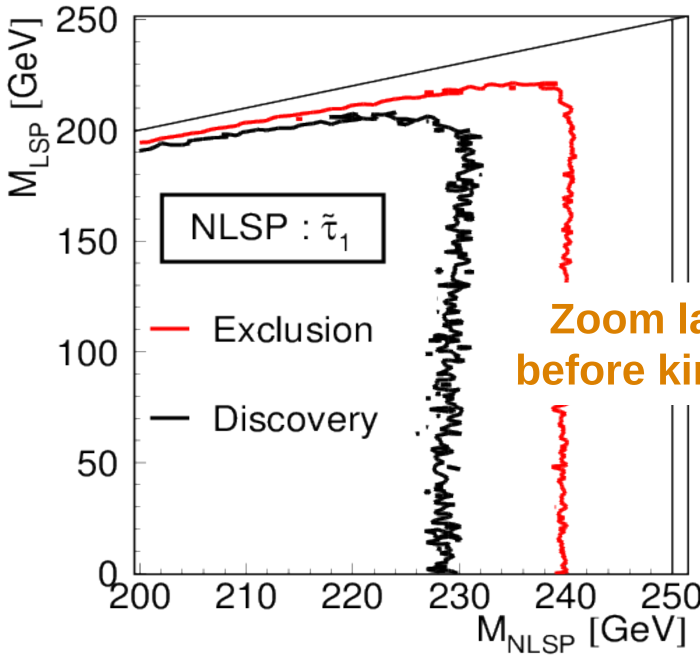

Zoom last 50 GeV before kinematic limit

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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)
- Veto BeamCal as preselection

Root ntuples for analysis

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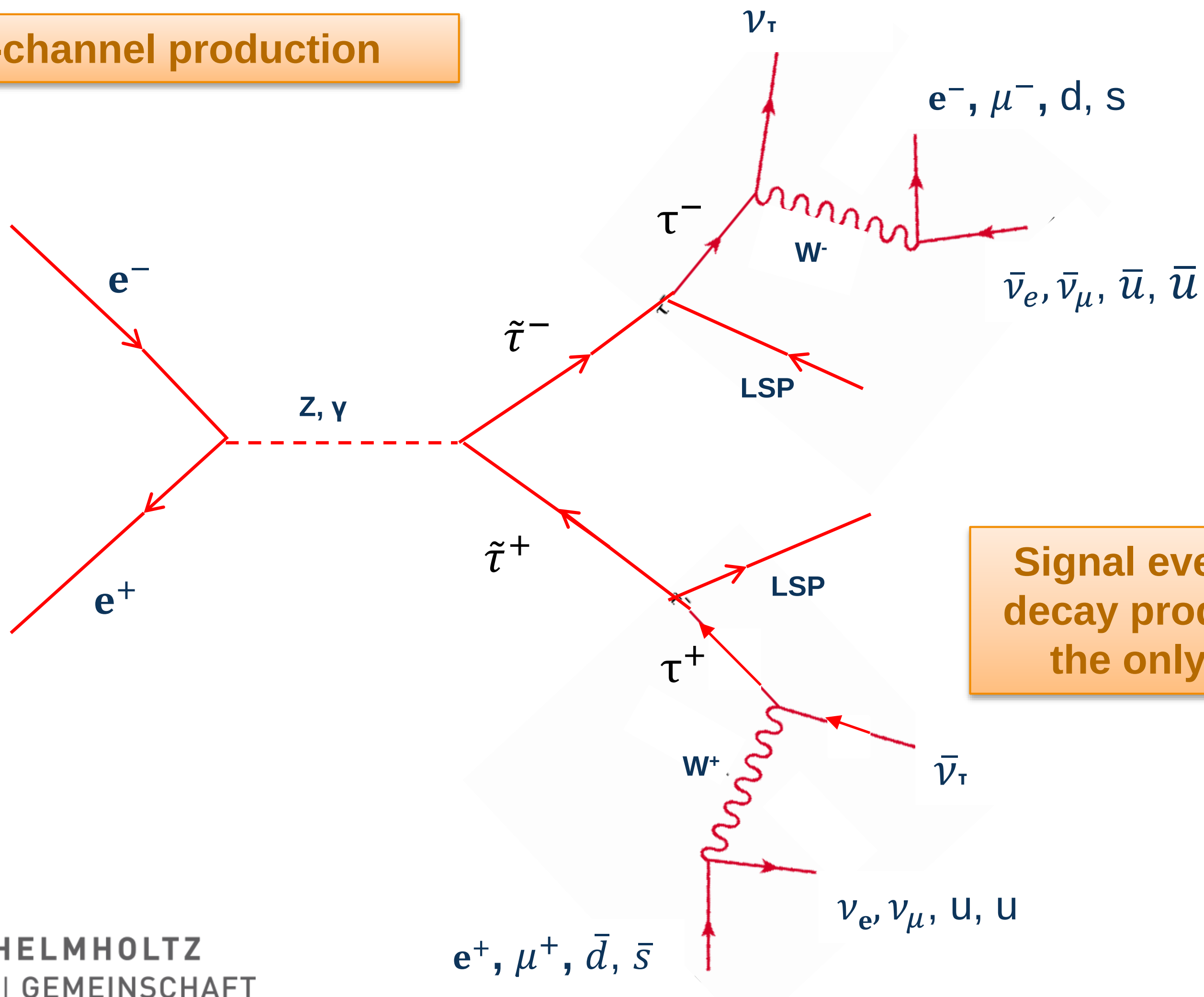
Signal characterisation

s-channel production



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

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Signal characterization (ctd.)

Signature:

- large missing energy and momentum
- high acollinearity, 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

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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

General cuts

Properties $\tilde{\tau}$ -events "must" have

- Missing energy (E_{miss}). E_{miss} > 2*MLSP GeV
- Visible mass (mvis). mvis < 2*(M$\tilde{\tau}$ - MLSP) GeV
- Momentum of all jets (pjet). pjet < 70% Beam Momentum (or M$\tilde{\tau}$/MLSP dependent)

- Number of charged particles (ncha). 1< ncha < 6
- Number of clusters identified as τ (nclu). nclu = 2 or 3
- τ-indentification
- Total charge (totcharge). totcharge = 0, +/- 1

- Maximum jet momentum:

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

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

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General cuts (ctd.)

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 background by ~ 94 %

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General cuts (ctd.)

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

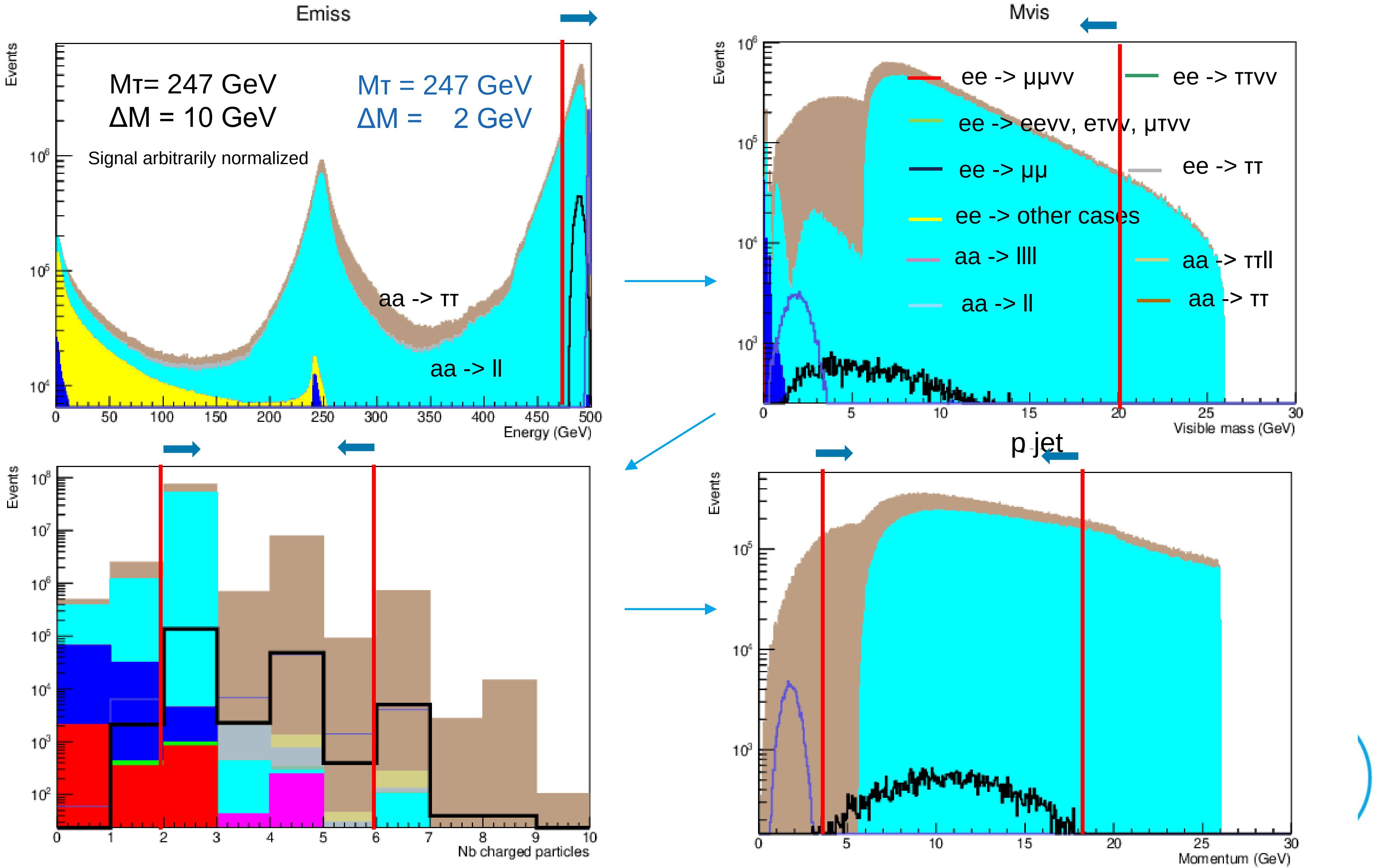
Cuts against properties of some almost irreducible sources of background

- 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

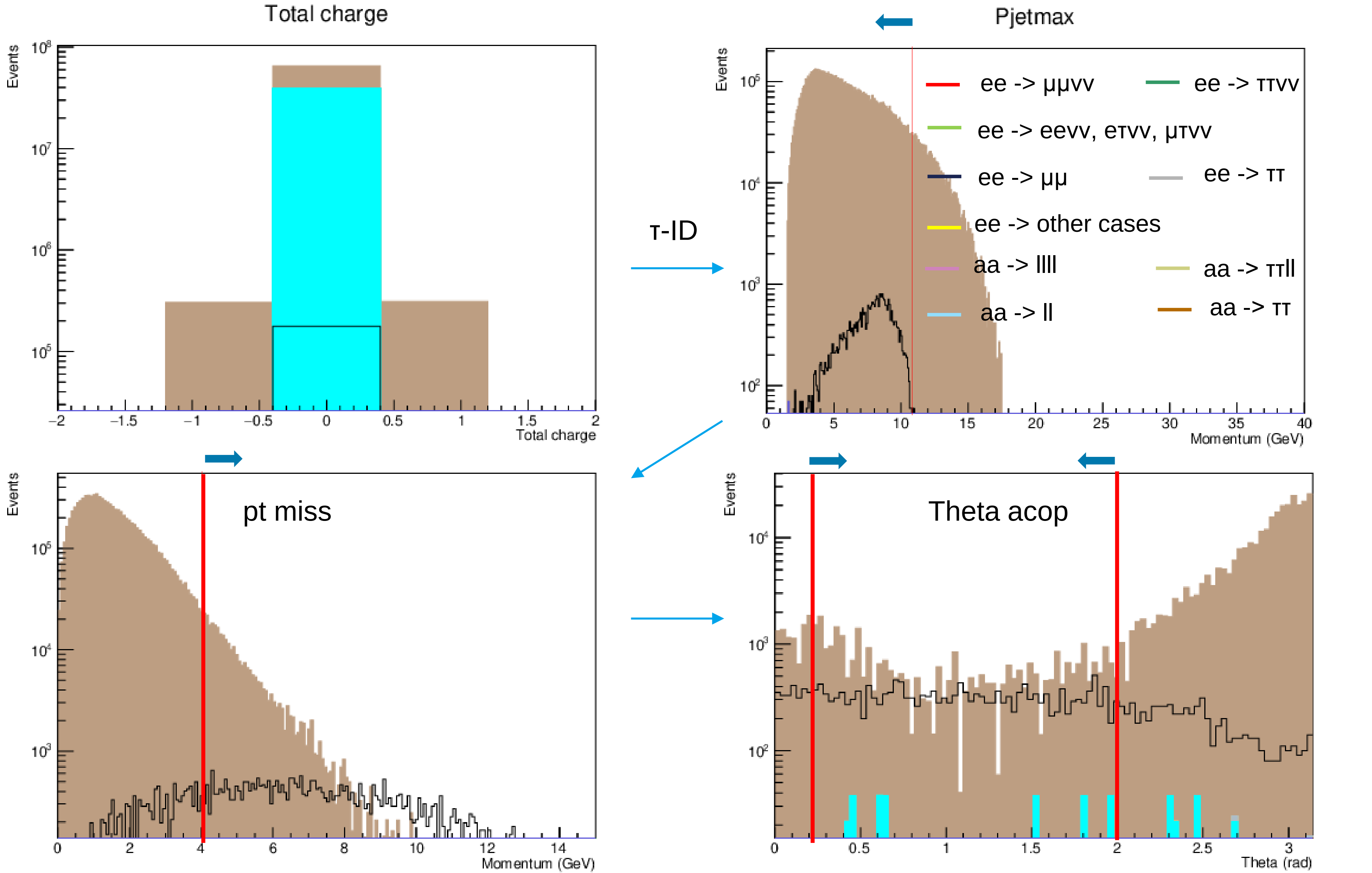
Properties that the background often “does not” have

- 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

Background evolution after cuts



Background evolution after cuts



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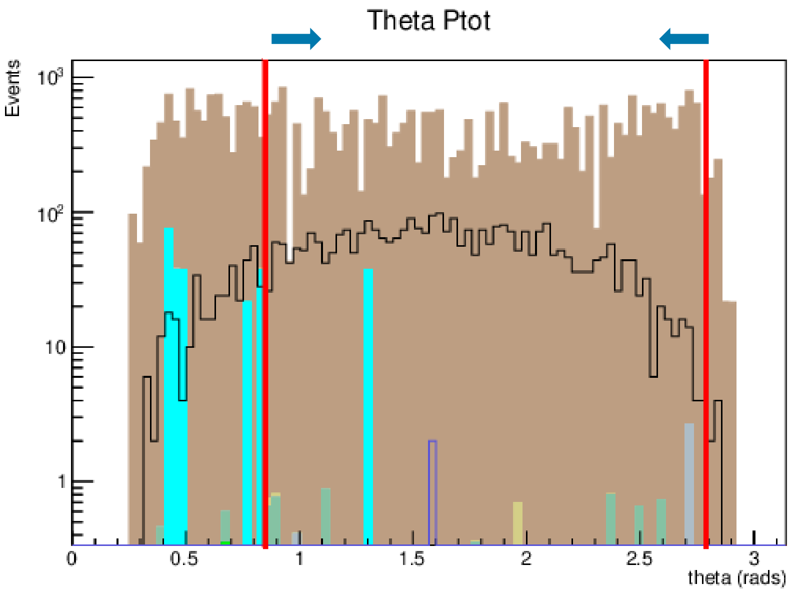

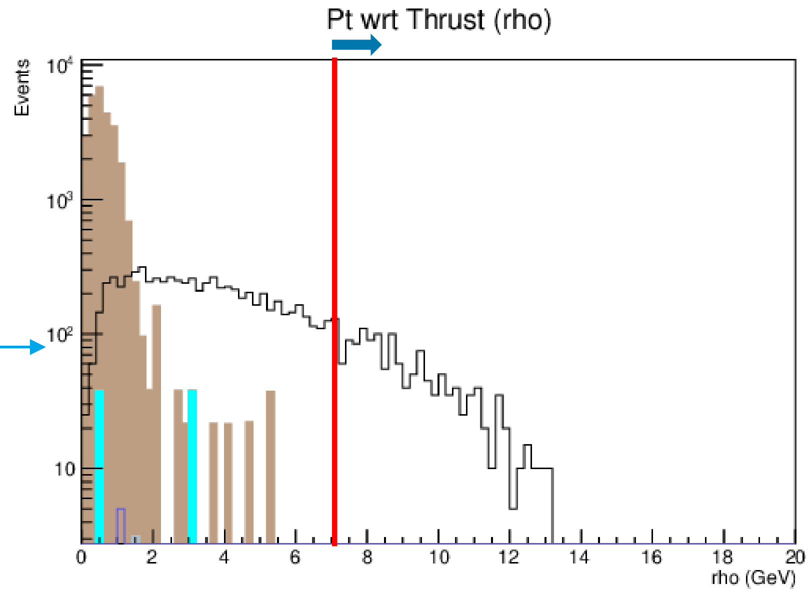

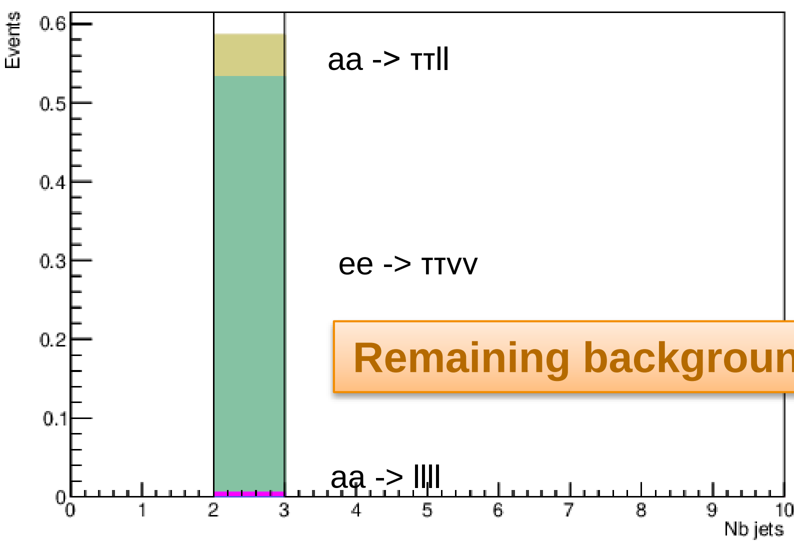

Remaining background

- ee -> μμνν
- ee -> ττνν
- ee -> eeνν, eτνν, μτνν
- ee -> μμ
- ee -> ττ
- ee -> other cases
- aa -> llll
- aa -> ττll
- aa -> ll
- aa -> ττ

Background evolution after cuts

Signal/Background reduction P(e⁻,e⁺)=(+80%,-30%), Mτ=247GeV, ΔM=10GeV

	Signal	ee -> ττνν	ee-> ττ	aa->ττll	aa->ττ	ee->μμνν,ll´νν	ee->μμ	ee->others	aa->llll	aa->ll
Total	265	44191	2051799	25944	157254000	586930	2325654	13383974	37096	322692096
Missed E	265	1347	89206	3474	109269880	11516	318367	24	1698	178861408
Visible Mass	264	1298	88297	2647	108400824	11369	317781	14	1044	171774796
Nb ch part	255	995	20815	2136	101468816	3206	11020	8.1	1028	167016624
Pjet	242	639	12931	1188	84502640	1975	5982	0	406	123845000
Tau ID	94	161	2448	17	31606836	21	0	0	1.4	1947
Maximum Pjet	94	140	2066	13	29692016	16	0	0	1.0	1469
Missed Pt	73	85	337	6.6	1048857	10	0	0	0.6	1162
ϴacop	50	56	9.4	4.8	113049	5	0	0	0.3	785
ϴptot	46	48	8.8	4.3	86407	2	0	0	0.3	239
Rho	8.0	1.7	0	0.2	0	0	0	0	0.02	0
Low angle E	8.0	1.7	0	0.2	0	0	0	0	0.02	0
WW/Z	7.4	1.7	0	0.2	0	0	0	0	0.02	0

Notes: Tau ID includes nb clusters + total charge

Signal excluded at 95% CL ($S > 2\sqrt{S+B}$)

Remaining events for inverse polarization (LR) and not polarized (NP) beams

LR	5.7	28	0	0.2	0	0	0	0	0.02	0
NP	6	12	0	0.2	0	0	0	0	0.02	0

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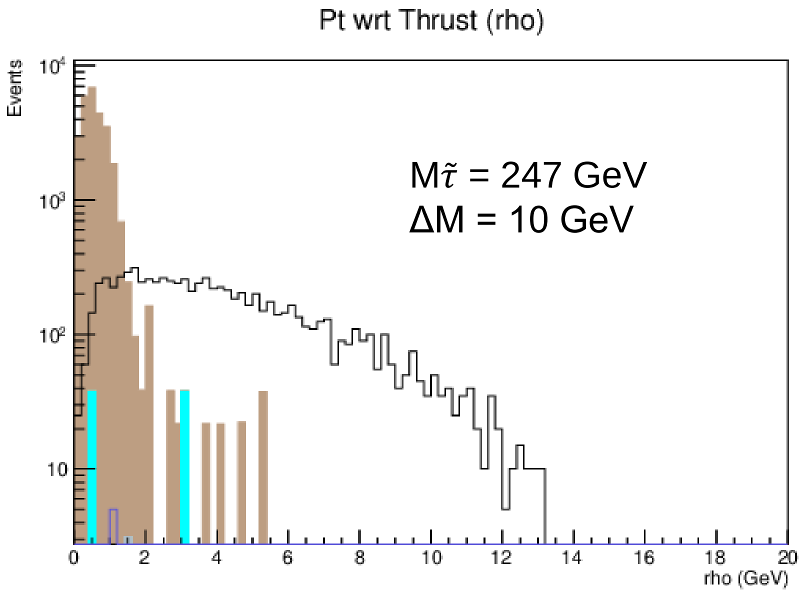
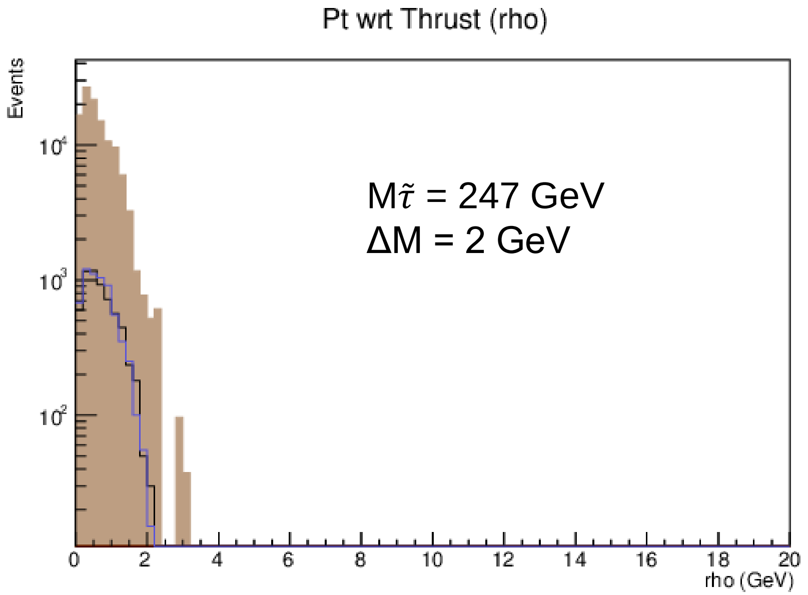
Not exclusion for LR or NP beams

Comparison DM = 10 GeV vs DM = 2 GeV





Cut in Rho does not allow to cut the γγ background for ΔM = 2 GeV

ee -> eeνν, eτνν, μτνν

Limits with general cuts

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

For luminosity 500 fb^{-1}

- ΔM = 10 GeV -> exclusion limit up to $M_{\tilde{\tau}}$ = ~247 GeV
- ΔM = 5 GeV -> exclusion limit up to $M_{\tilde{\tau}}$ = ~240-245 GeV
- ΔM = 4 GeV -> exclusion limit up to $M_{\tilde{\tau}}$ = ~235-240 GeV
- ΔM = 3 GeV -> exclusion limit up to $M_{\tilde{\tau}}$ = ~220 GeV

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Detailed study not excluded regions

Further analysis done:

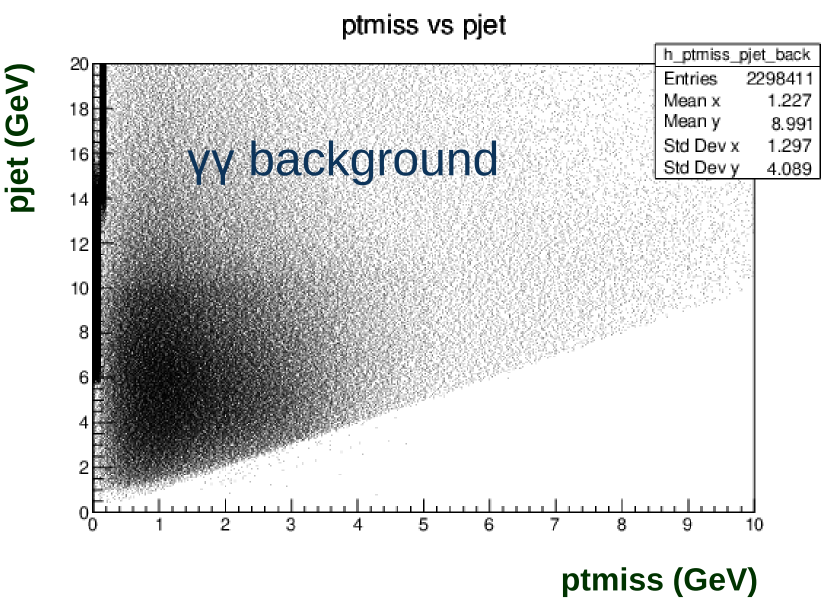
- Impact parameter -> does not help since remaining background comes from τ´s
- ISR photons -> improves limits for ΔM = 2 and 3 GeV

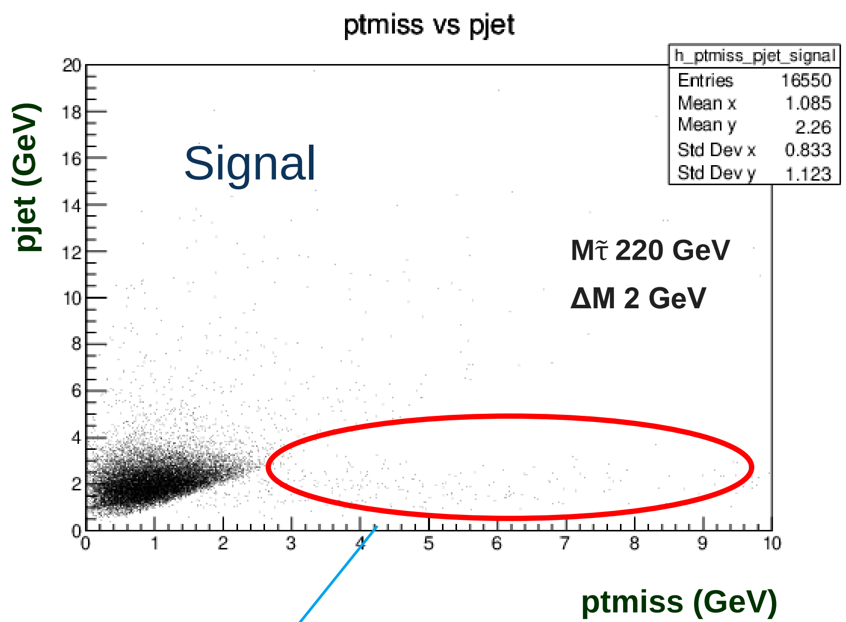
  - select events with high transversal momentum and isolated photons

Detailed study not excluded regions

ΔM=2 GeV

Use the relation ptmiss vs pjet





Contribution to pt from isolated photons

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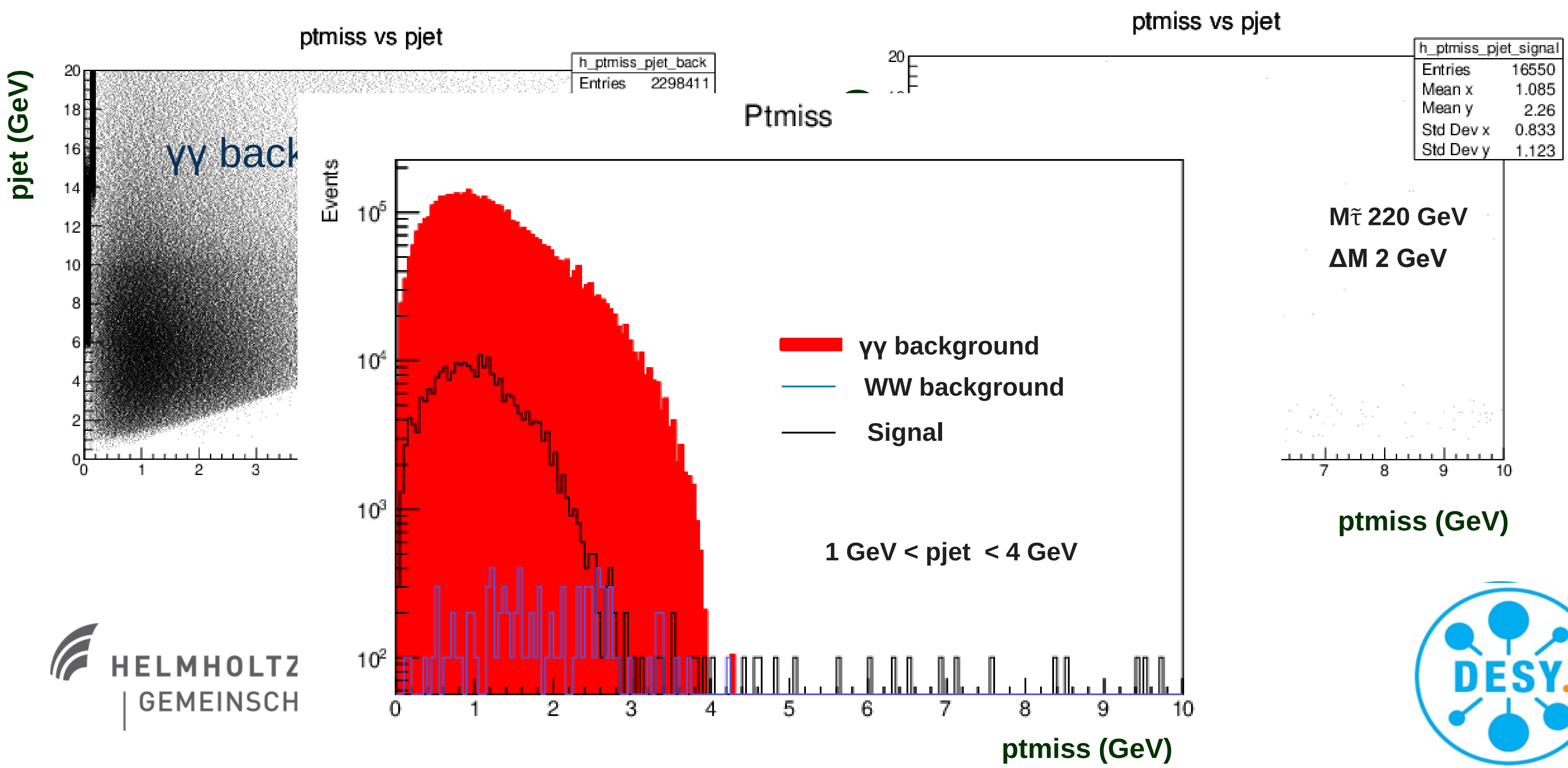
Detailed study not excluded regions

ΔM=2 GeV

Use the relation ptmiss vs pjet



Current status and prospects

Improvements in analysis

- Use of relation between ptmiss and pjet for ΔM = 2 GeV
- Use sum of photon energy and number of photons for ΔM = 3 GeV

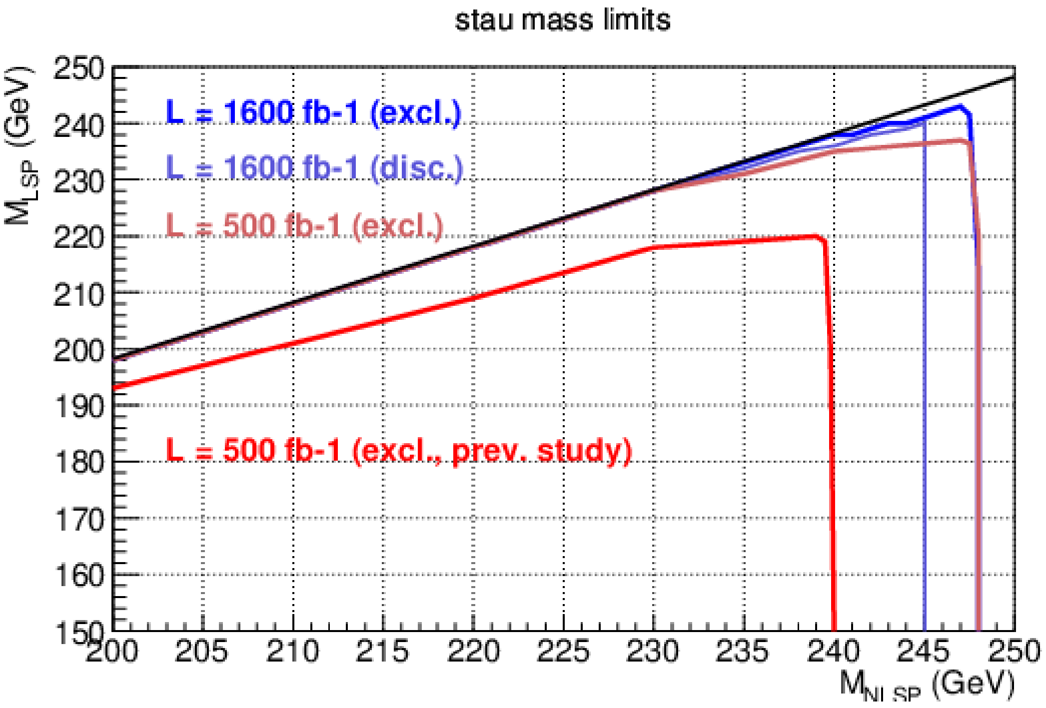
Limits for 1.6 ab^{-1}

- ΔM = 10 to 4 GeV -> exclusion limit up to $M\tilde{\tau}$ = ~247 GeV
- ΔM = 3 GeV -> exclusion limit up to $M\tilde{\tau}$ = ~243 GeV
- ΔM = 2 GeV -> exclusion limit up to $M\tilde{\tau}$ = ~240 GeV

For luminosity 500 fb^{-1}

- ΔM = 10 GeV -> exclusion limit up to $M\tilde{\tau}$ = ~247 GeV
- ΔM = 5 GeV -> exclusion limit up to $M\tilde{\tau}$ = ~240-245 GeV
- ΔM = 4 GeV -> exclusion limit up to $M\tilde{\tau}$ = ~235-240 GeV
- ΔM = 2 GeV -> exclusion limit up to $M\tilde{\tau}$ = ~230 GeV

Current status and prospects



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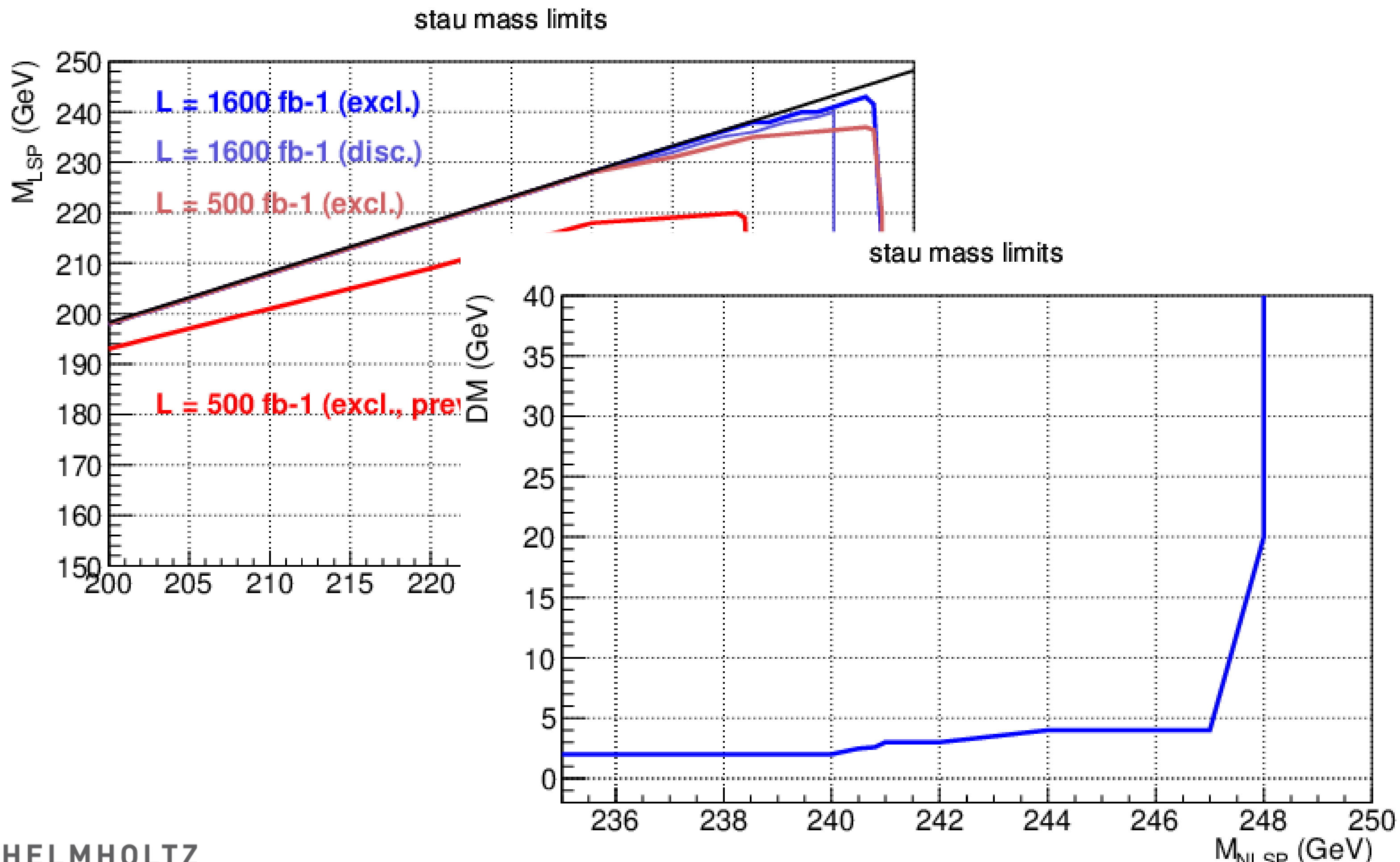

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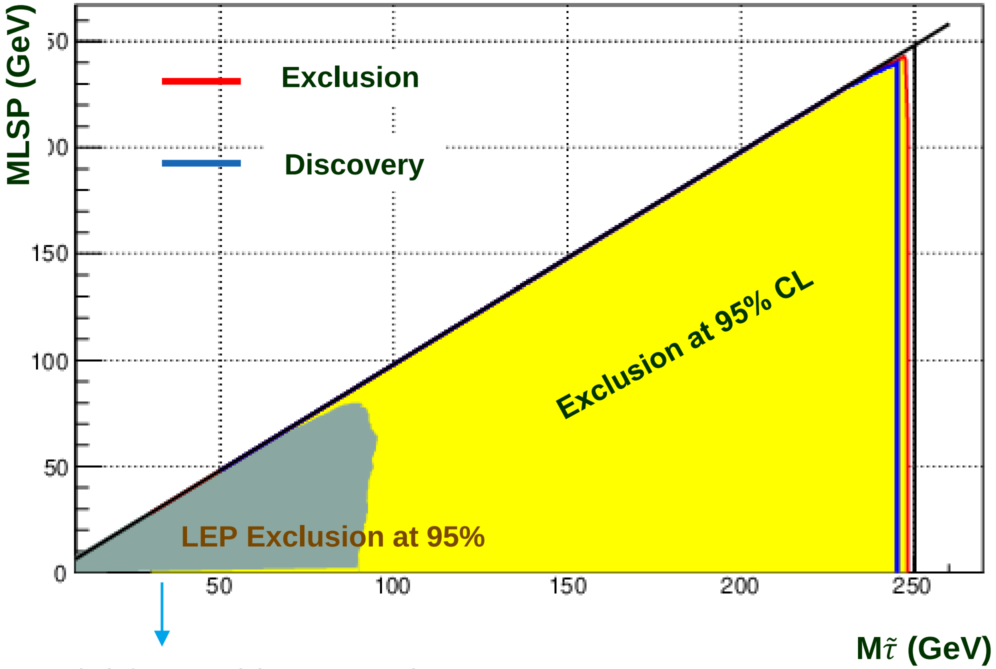
Current status and prospects

Next steps

- Study the region with $\Delta M < M_\tau$
- Study effects of tau polarization from stau decays
- Use full reconstructed background samples
- Cross-check with previous studies
- Increase statistics

Current status and prospects



26.3 GeV: limit for any mixing angle and
any mass difference above τ mass

No LHC limit for $\tilde{\tau}$

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