RPV SUSY Studies

A brief summary of studies into R-Parity violating SUSY models at
ATLAS for both Neutralino and Stau LSPs

ATLAS UK SUSY/Exotics Meeting

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R-Parity Violating (RPV) SUSY

➲ With R-Parity Violation (RPV), SUSY models are no longer constrained by the effects of the conserved global symmetry.

- SUSY particles can decay into purely SM particles
- LSP is no longer stable, meaning a Stau LSP is possible

➲ RPV Couplings:

- λ_{ijk} – violate Lepton Number   (LLE type coupling)*
- λ'_{ijk} – <u>violate Lepton Number</u>   (LQD type coupling)*
- λ''_{ijk} – violate Baryon Number   (UDD type coupling)*
- I have focused on the λ'_{221} coupling in my studies

➲ Combinations of the above couplings are limited by proton decay limits

* L and Q are lepton and quark components of SU(2) doublet superfields, and E,D and U are SU(2) singlet superfields

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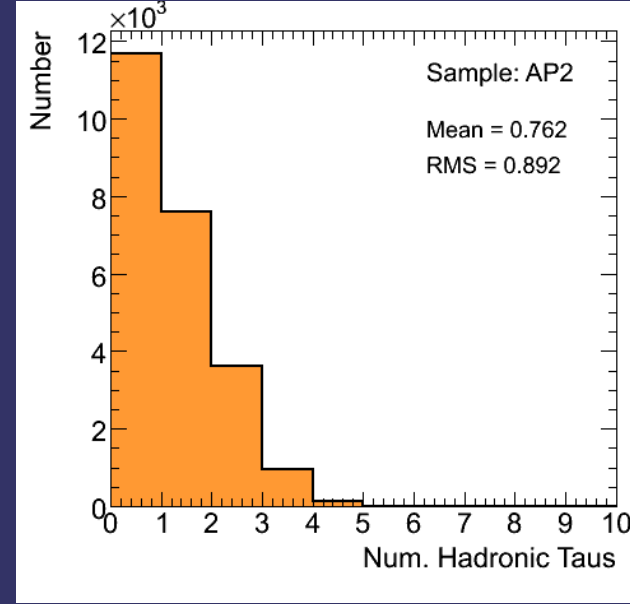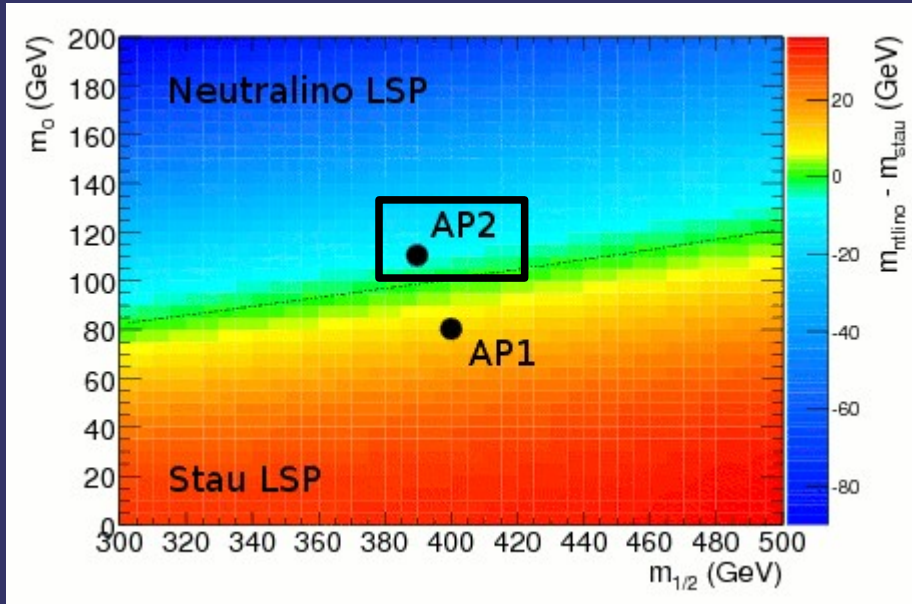# R-Parity Violating (RPV) SUSY
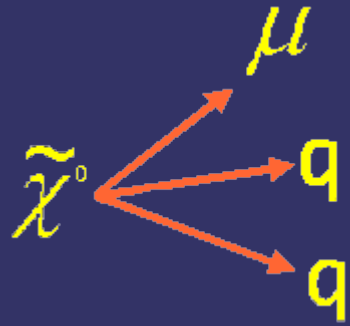
Point "AP2" - Neutralino LSP

Figure showing Tau Multiplicity for AP2 Events (Neutralino LSP)

Neutralino LSP – 3-body decays e.g

	Mass (GeV)	channel	BR	channel	BR
$\tilde{\chi}_1^0$	157.897	$\nu_\mu\, s\, \bar{d}$	**0.290**	$\bar{\nu}_\mu\, \bar{s}\, d$	**0.290**
		$\mu^-\, c\, \bar{d}$	**0.210**	$\mu^+\, \bar{c}\, d$	**0.210**
$\tilde{\tau}_1^-$	164.568	$\tilde{\chi}_1^0\, \tau^-$	**1.000**		

R-Parity Violating (RPV) SUSY
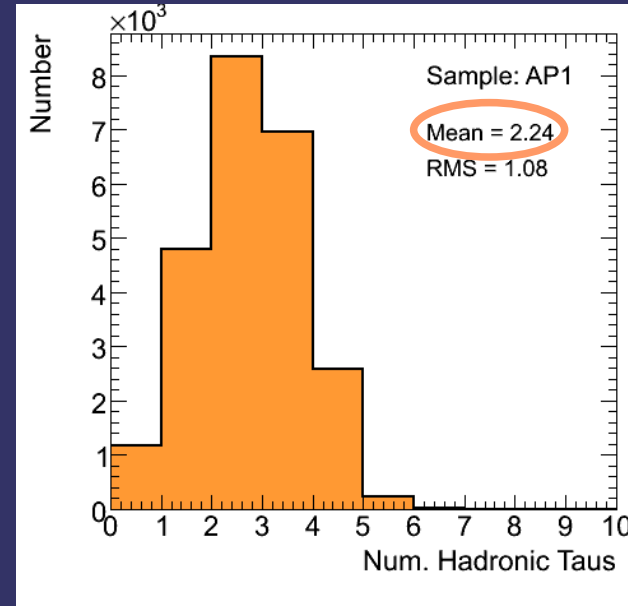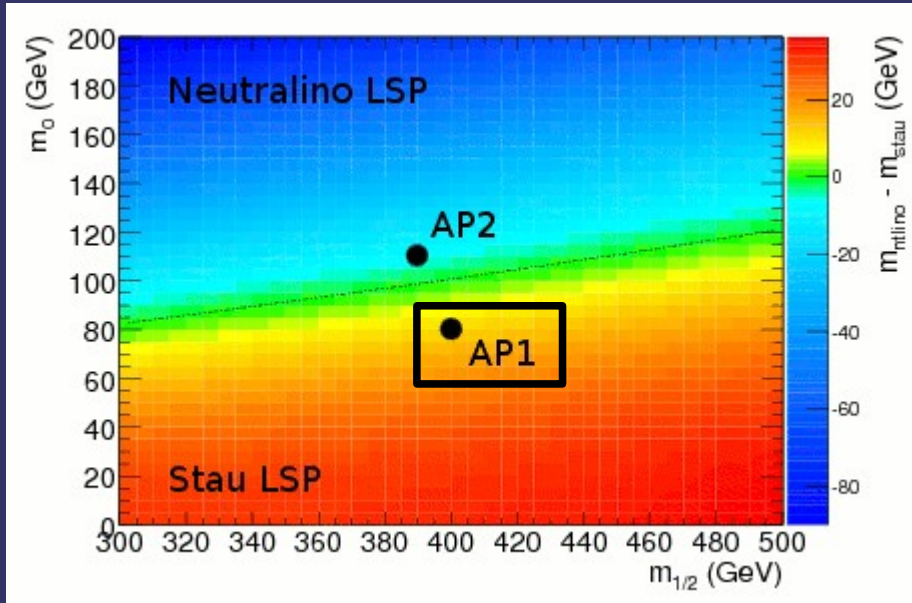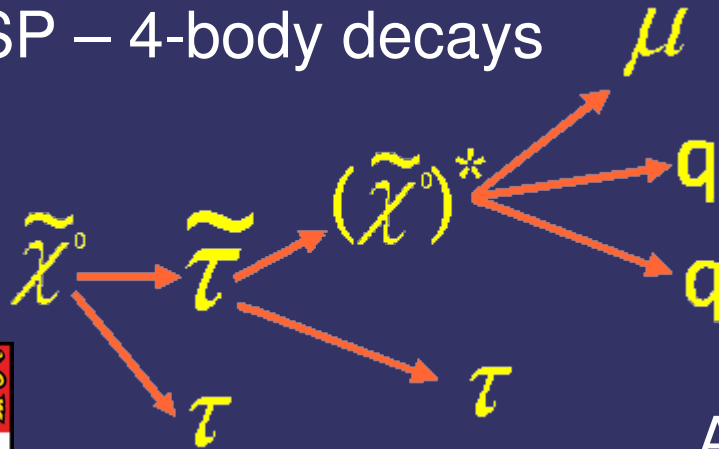
Point "AP1" - Stau LSP

Figure showing Tau Multiplicity for AP2 Events (Neutralino LSP)

High Tau Multiplicity:
- *~4 taus/event*
- *>2 hadronic tau decays/event*

Stau LSP – 4-body decays e.g.

	Mass (GeV)	channel	BR	channel	BR
$\widetilde{\tau}_1^-$	151.022	$\overline{\nu}_\mu\,\overline{s}\,d\,\tau^-$	**0.351**	$\mu^+\,\overline{c}\,d\,\tau^-$	**0.255**
		$\nu_\mu\,s\,\overline{d}\,\tau^-$	**0.200**	$\mu^-\,c\,\overline{d}\,\tau^-$	**0.145**
		$\mu^-\,s\,\overline{d}\,\nu_\tau$	**0.045**	$\overline{\nu}_\mu\,\overline{c}\,d\,\nu_\tau$	**0.005**
$\widetilde{\chi}_1^0$	162.149	$\widetilde{\tau}_1^+\,\tau^-$	0.500	$\widetilde{\tau}_1^-\,\tau^+$	0.500

A Stau LSP is allowed with RPV SUSY

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RPV SUSY Samples

➥ Define RPV SUSY points using SoftSUSY, for a λ'_{221} coupling

- **AP1** – Stau LSP (m_0=80 GeV, $m_{1/2}$=400 GeV, tan β=20, μ=+, A_0=0, λ'_{221}=0.01)

- **AP2** – Neutralino LSP (m_0=110 GeV, $m_{1/2}$=390 GeV, tan β=20, μ=+, A_0=0, λ'_{221}=0.01)

➥ Generation: Herwig (modified for 4-Body Stau Decays) + Jimmy

➥ Full Sim: Athena v12.0.6.5 (using Ganga AthenaMC)

➥ Recon: Athena v12.0.6.5 (using Ganga AthenaMC)

➥ Ntuples made using EventView: ~ 24k events each for AP1 and AP2

Particle Definitions:

Muons:	Staco, pT > 10 GeV.
	Isolation: etcone20 < 10 GeV + 0.3×ET, ΔR > 0.4 nearest Jet
Electrons:	pT > 10 GeV
	Isolation: etcone20 < 10 GeV, ΔR > 0.4 nearest Jet
Jets:	Cone4 Jets
Taus:	Require Ntrack = 1 or 3; and |charge| = 1
taurec	Likelihood > 4
tau1p3p	discNN > 0.5 (0.85) 1-prong (3-prong)

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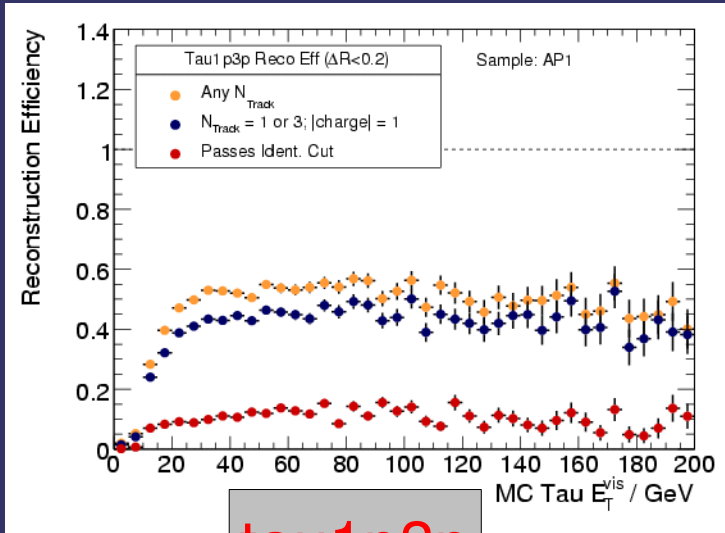# Tau Reconstruction Performance in Stau LSP Events (AP1)
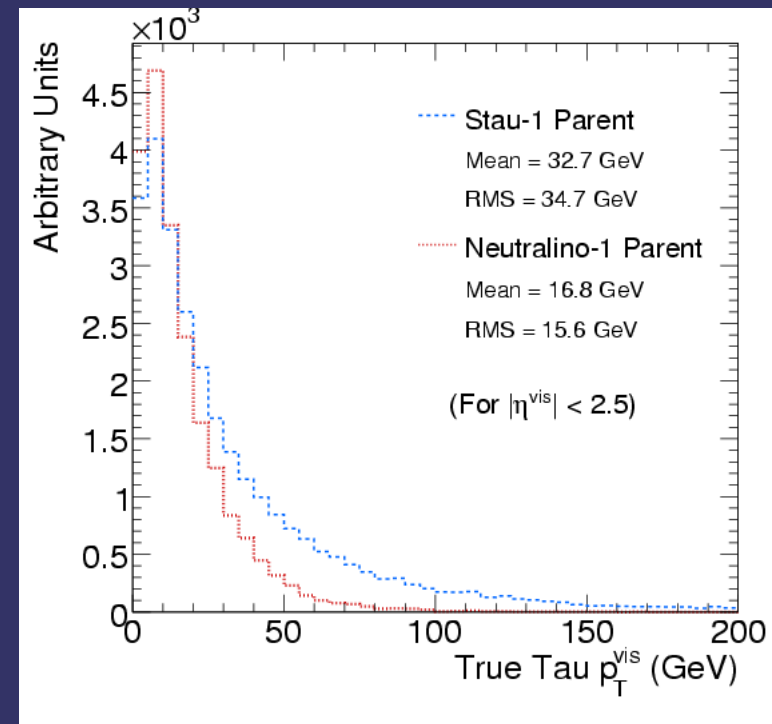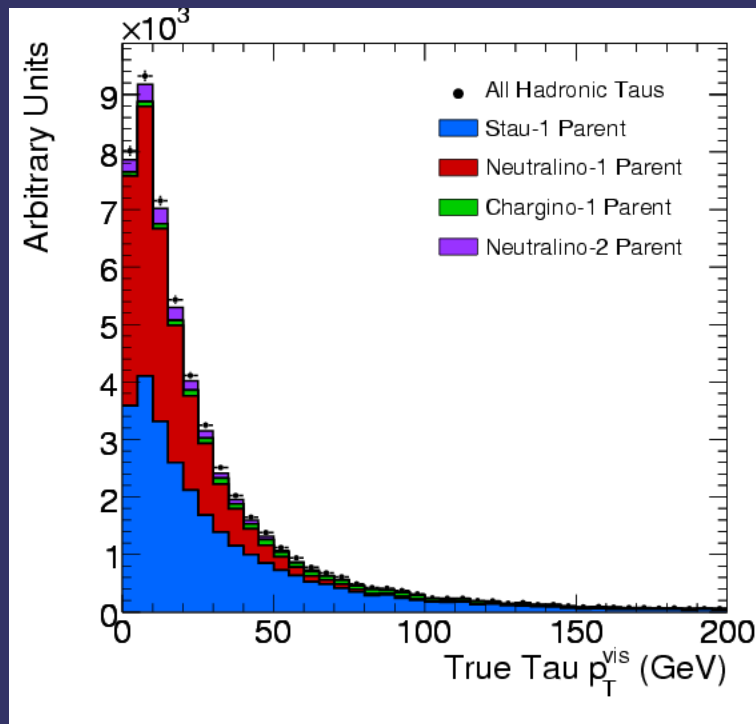
As mentioned, a high tau multiplicity is expected for RPV SUSY points with a Stau LSP – unfortunately, taus are often v.soft (particularly for small NLSP-LSP ΔM).
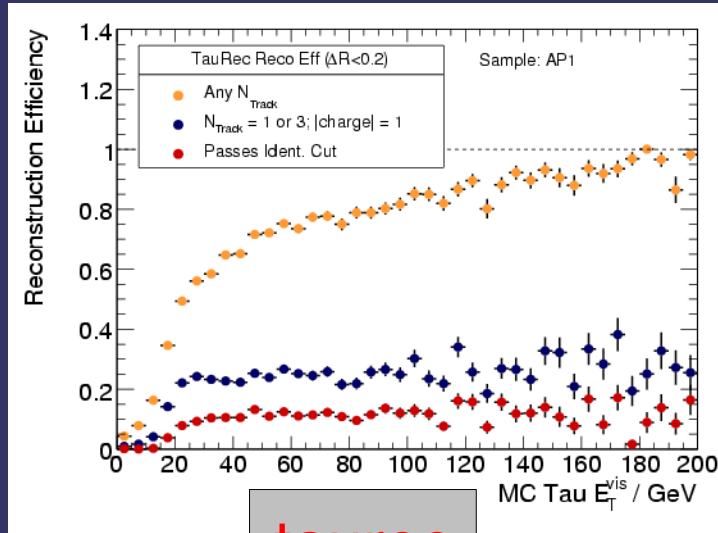
Also, the high multiplicity environment makes reconstruction difficult (overlap with jets etc...)
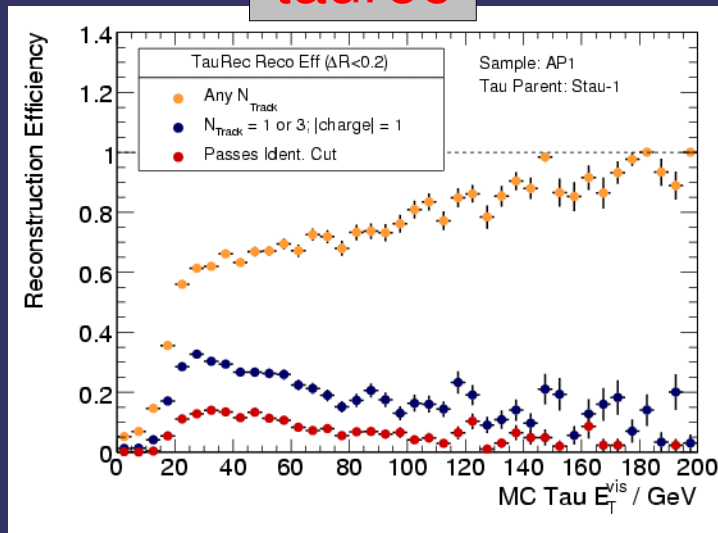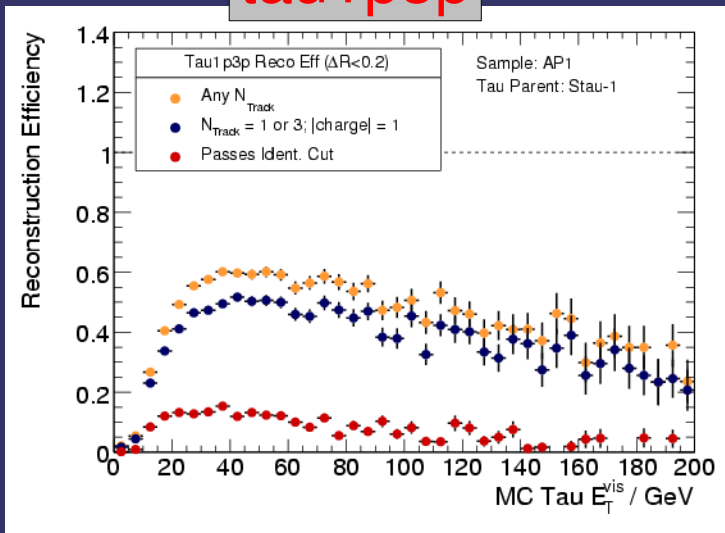
Tau Reco Performance... continued

tau1p3p

taurec

Efficiency for recon./identifying for __ALL__ taus in RPV SUSY events

Efficiency for recon./identifying only those taus originating from Stau decays

Higher pT taus from Stau decays are boosted with other decay products – merge in with jets, lowering efficiency

Low Tau identification efficiency – inclusive tau signature v.difficult

Mass Reconstruction in Neutralino LSP Events (AP2)

Event Selection Cuts

SumET:	**SumET > 1000 GeV**
Jets:	**N_jet≥6** (with pT> 20 GeV, |eta|<2.5);
	Jet[0] pT > 200 GeV;
	Jet[1] pT > 100 GeV
Muons:	**N_mu≥1** (isolated with pT>20 GeV)
Z-Veto:	Exclude if **86 GeV < $M_{\mu\mu}$ < 96 GeV**
W-Veto:	Exclude if **$M_T(\mu,$ETmiss) < 90 GeV**

	AP1	AP2
Total	24125	24000
SumET Selection	19813 (**82.1%**)	20055 (**83.6%**)
Jet Selection	15720 (**65.2%**)	16092 (**67%**)
Lepton Selection	5694 (**23.6%**)	5399 (**22.5%**)
Z Veto	5559 (**23%**)	5294 (**22.1%**)
W Veto	3220 (**13.3%**)	3246 (**13.5%**)
$\mathcal{L} = 5fb^{-1}$	2.54e+03	2.57e+03

	J4	J5	J6	$t\bar{t}$ lep.	$W \rightarrow \mu\nu + 5j$	$Z \rightarrow \mu\mu + 5j$
Total	368650	239000	387050	435624	9750	11200
SumET Selection	1392 (**0.378%**)	50381 (**21.1%**)	386293 (**99.8%**)	6779 (**1.56%**)	499 (**5.12%**)	605 (**5.4%**)
Jet Selection	558 (**0.151%**)	12169 (**5.09%**)	53822 (**13.9%**)	2311 (**0.531%**)	167 (**1.71%**)	239 (**2.13%**)
Lepton Selection	0 (**0%**)	4 (**0.00167%**)	11 (**0.00284%**)	295 (**0.0677%**)	88 (**0.903%**)	175 (**1.56%**)
Z Veto	0 (**0%**)	4 (**0.00167%**)	11 (**0.00284%**)	291 (**0.0668%**)	87 (**0.892%**)	85 (**0.759%**)
W Veto	0 (**0%**)	0 (**0%**)	1 (**0.000258%**)	67 (**0.0154%**)	20 (**0.205%**)	42 (**0.375%**)
$\mathcal{L} = 5fb^{-1}$	<9.61e+03 (**90% C.L.**)	<601 (**90% C.L.**)	4.65	371	188	31.5

Event Selection Cut Flow. Final numbers weighted for a luminosity of 5 fb-1. Top Right: RPV SUSY Points. Bottom: Selected BG Samples. ttbar (and possibly QCD dijets) probably largest background.
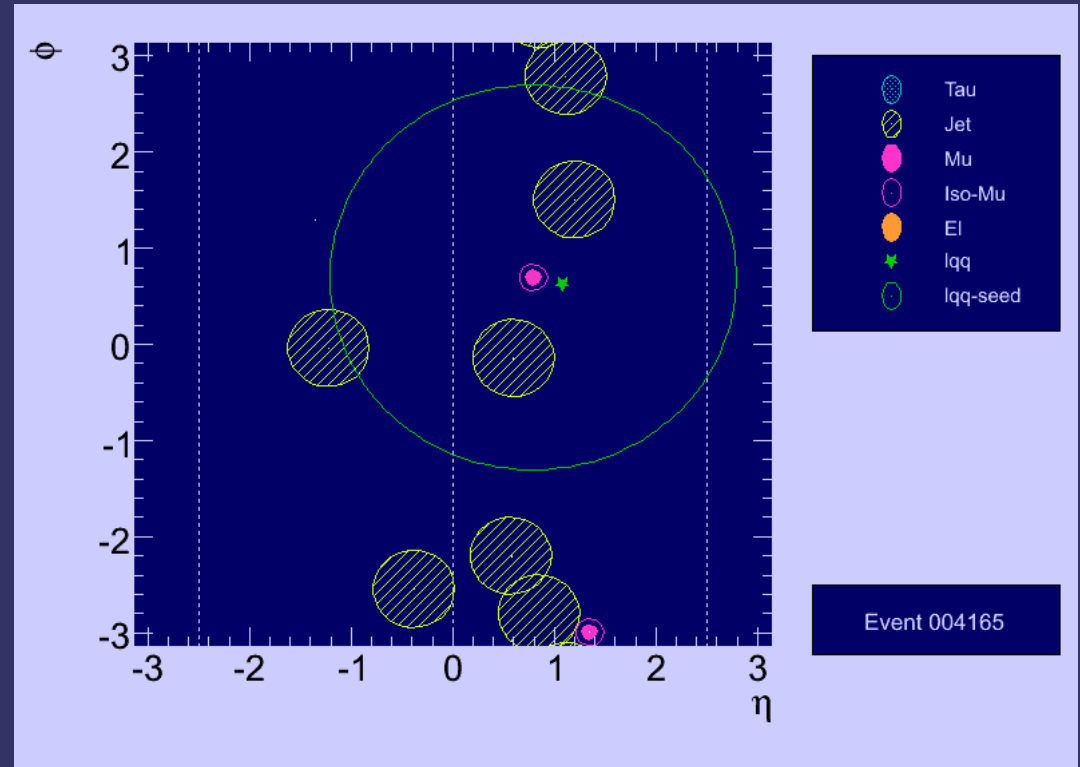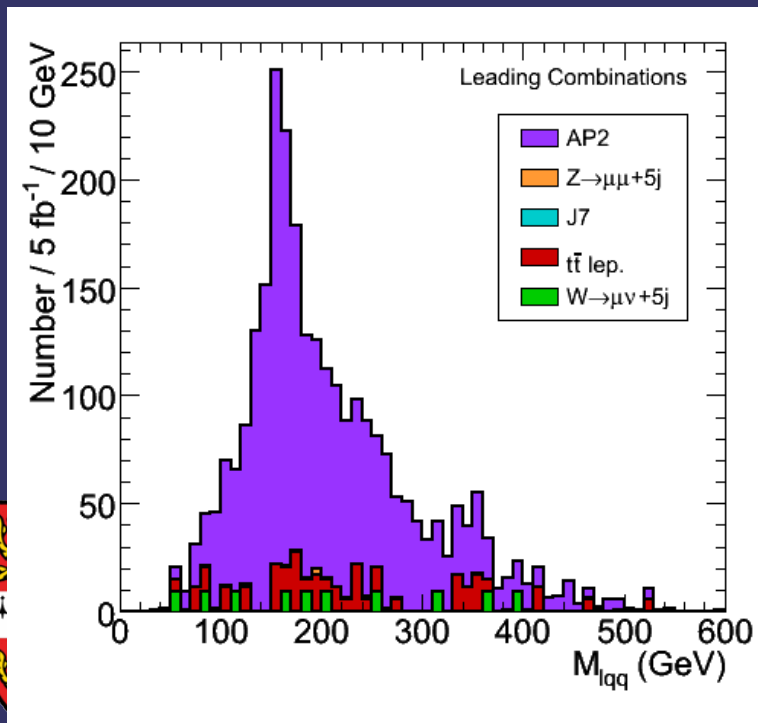
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Mass Reconstruction in Neutralino LSP Events (AP2)

The aim of this analysis is to reconstruct the mass of the neutralino LSP by making invariant mass combinations of muons & 2×jets.

μjj mass Combination Cuts:

Muon Seed: $pT > 20$ GeV & isolated

Reco Cone: $\Delta R < 2.0$ around seed muon

Jet-1: 20 GeV $< pT < 250$ GeV

Jet-2: 20 GeV $< pT < 150$ GeV

(ignoring 2 hardest jets in event)

Event 004165

Above: eta-phi map showing position of objects in a given event. The green circle shows a reconstruction cone around a seed muon.

Left: Invariant mass plot for muon-jet-jet combinations satisfying the above list of cuts for all events passing event selection criteria. The RPV SUSY contribution is shown in purple. Dominant BG is SUSY combinatoric BG. Numbers weighted for a luminosity of 5 fb-1.

Mass Reconstruction in Neutralino LSP Events (AP2)
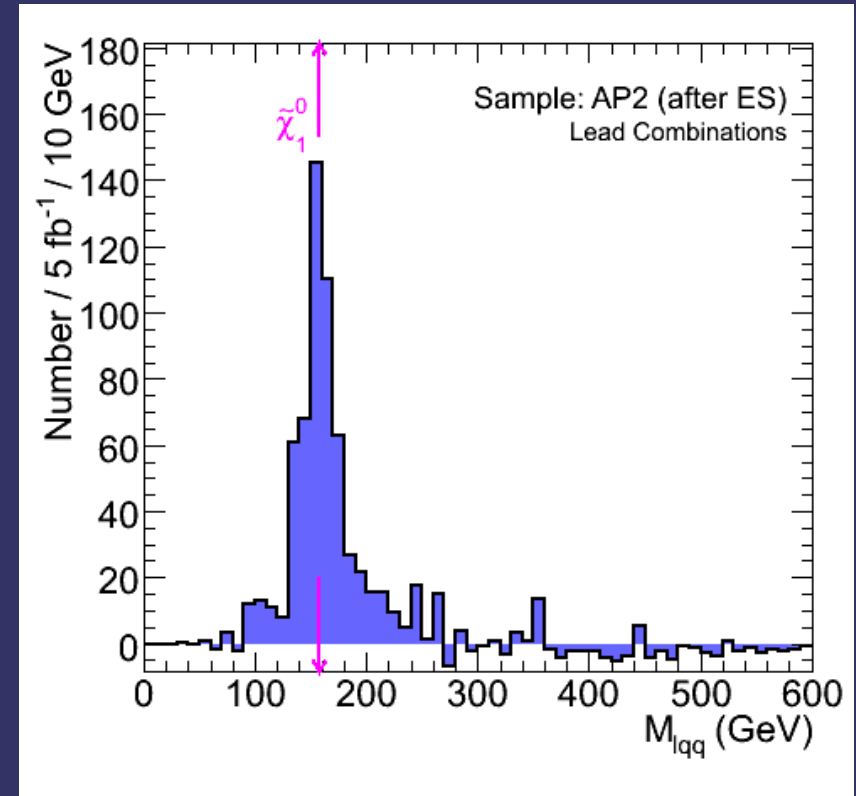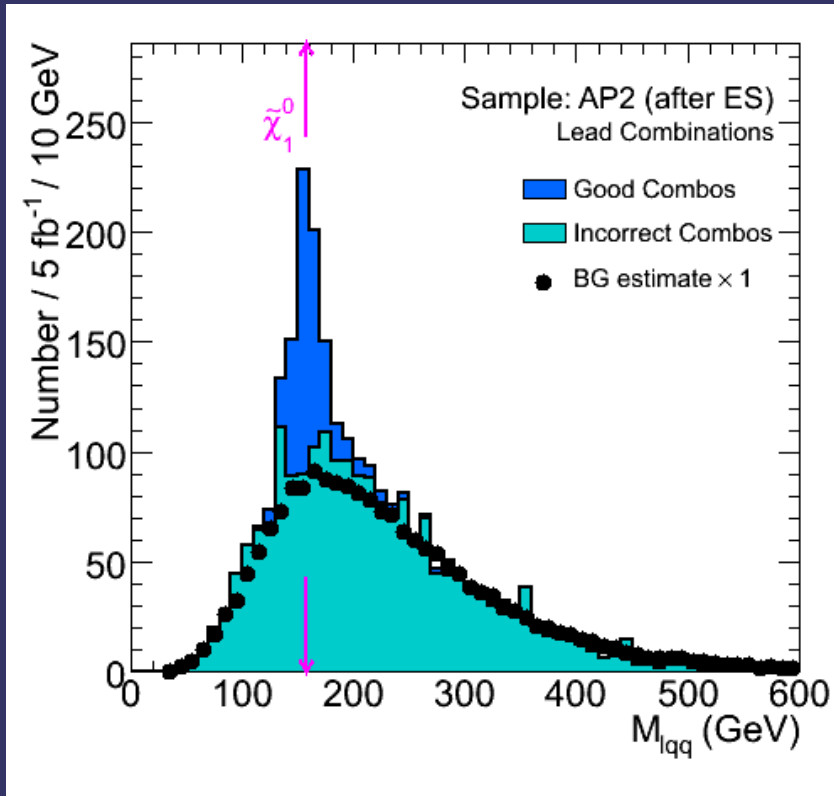
Left: Estimation of combinatoric background (SUSY sample only – no SM included here yet). BG estimate made by looking at combinations of muons from one event and jets from a different event (that also passes Event Selection). Right: After subtraction of BG estimate.

True Neutralino mass shown in pink.
Numbers weighted for a luminosity of 5 fb-1.