BILINEAR R-PARITY VIOLATION IN SUPERSYMMETRY

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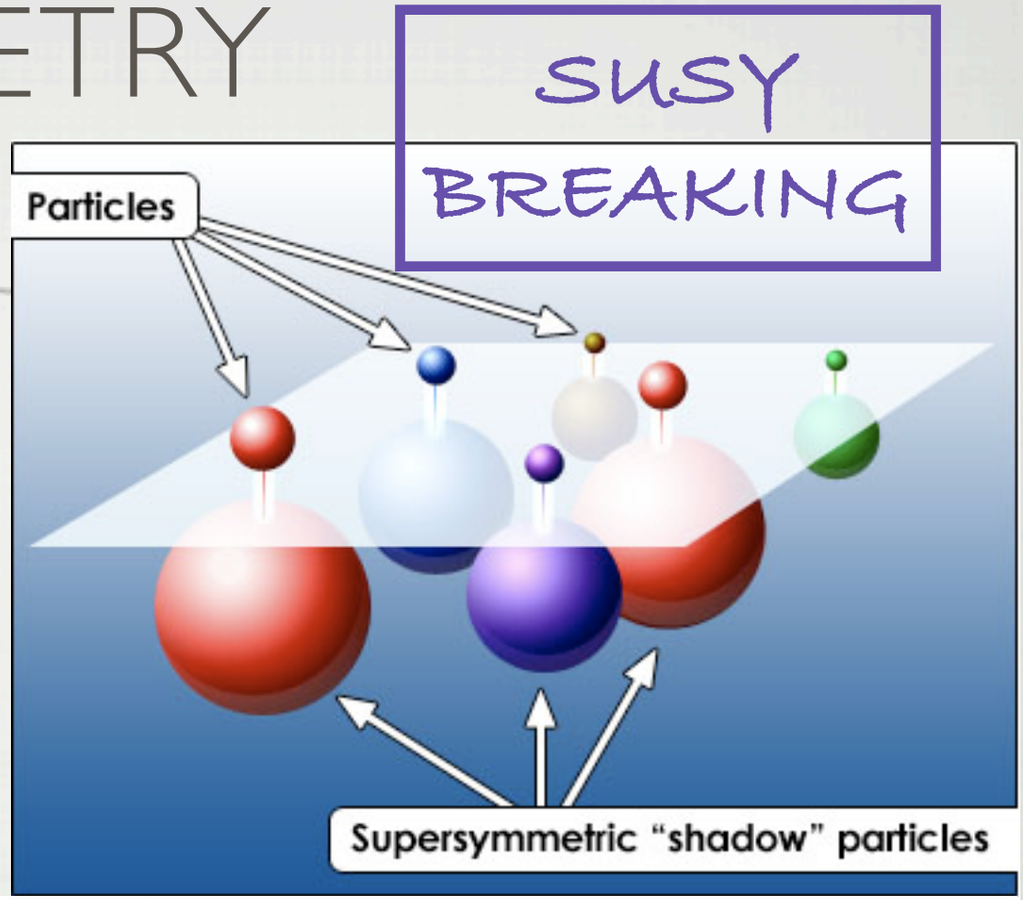
SUPERSYMMETRY

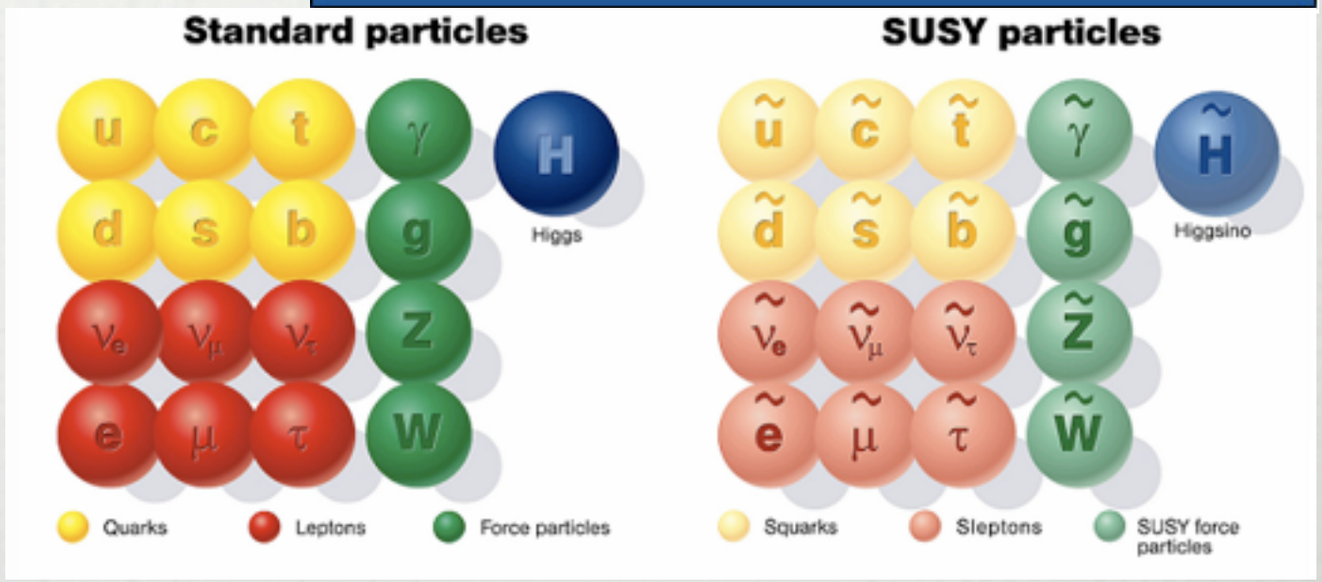
Fermion - boson symmetry

Every SM fermion have a boson susy-partner

Every SM boson have a fermion susy-partner

quarks	q	$\tilde{q}$	squarks
leptons	l	$\tilde{l}$	sleptons
photon	γ	$\tilde{\gamma}$	photino
	Z	$\tilde{Z}$	zino
Higgs	H	$\tilde{H}$	higgsino
	W	$\tilde{W}$	wino
gluon	g	$\tilde{g}$	gluino
graviton	G	$\tilde{G}$	gravitino





LHC: very good chance to observe supersymmetric particles

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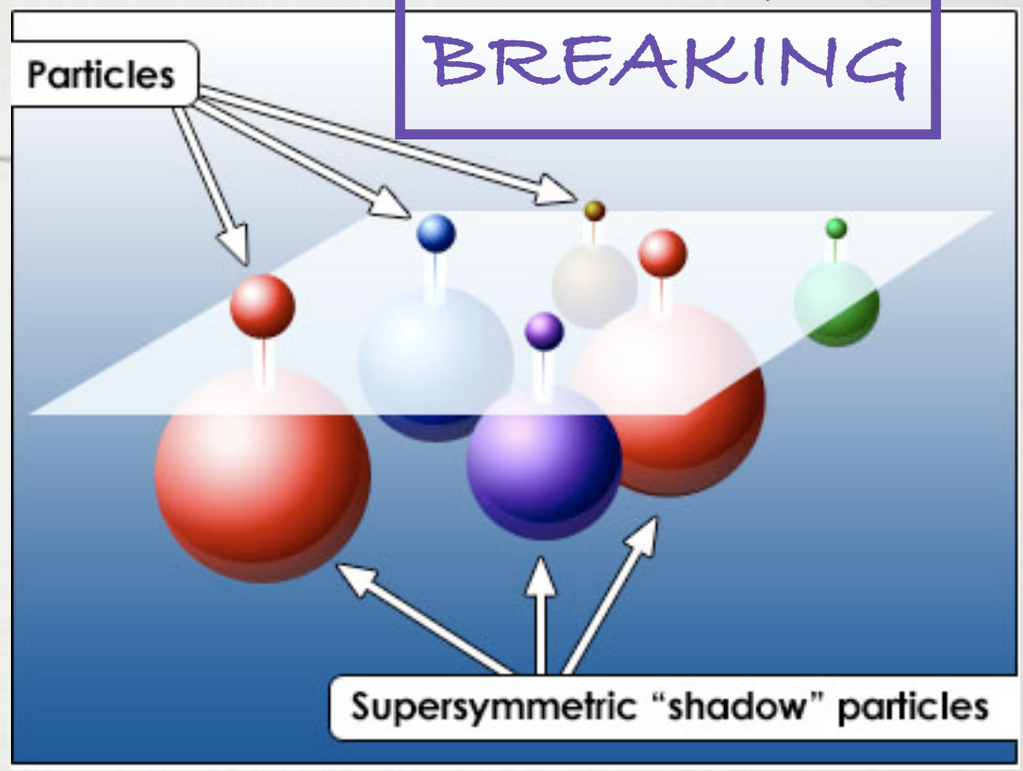
$\tilde{H}$, $\tilde{W}$ → $\tilde{\chi}^0_1, \tilde{\chi}^0_2, \tilde{\chi}^0_3, \tilde{\chi}^0_4$ neutralinos

$\tilde{H}$, $\tilde{W}$ → $\tilde{\chi}^\pm_1, \tilde{\chi}^\pm_2$ charginos

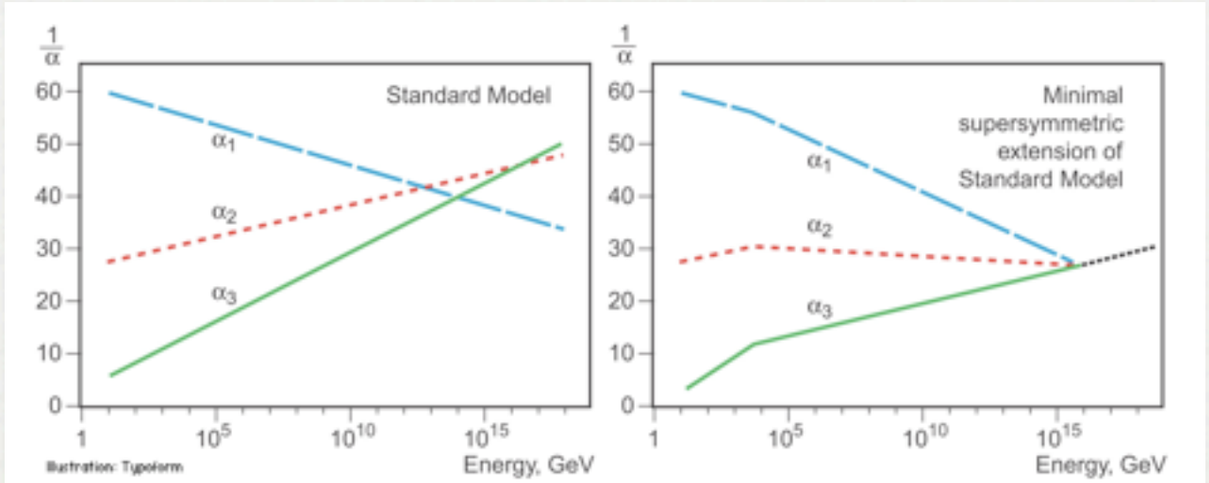


LHC: very good chance to observe supersymmetric particles

MOTIVATION FOR SUSY

Avoids Fine-Tunning for the Higgs mass

Grand Unification EW + strong interactions



If R-Parity is conserved:

the Lightest Supersymmetric Particle (LSP) has to be stable, neutral and not strong-interacting: candidate to DM

R-PARITY

$$R = (-1)^{3B + L + 2S} = \begin{cases} +1 \text{ for SM particles} \\ -1 \text{ for SUSY particles} \end{cases}$$

- Constructing a theory: { renormalizable; conserving symmetries of the system (Gauge, Lorentz...)

- There is not a fundamental reason to conserve L, B.

- A hard violation of B and L $\longrightarrow$ p fast decay BUT soft violation of B OR L keeps p lifetime ok.

L_{MSSM}: no ~~L~~, no ~~B~~ $\longrightarrow$ RPC $\longrightarrow$ implies LSP and p stable

RPC VS. RPV

RPC

→ susy particles generation in pairs

→ Stable LSP

Interacting Massive Stable particle would form part of atoms. Their mass would be different!!

↓

no em charge
no strong interaction

→ undetectable ⇒large E_T^{miss}

RPV

→ susy single particles

→ LSP decay

↓

new signals
new background

no need to be em neutral
can have strong int

→ not so large E_T^{miss}

BILINEAR R-PARITY VIOLATION

L-number violating terms

$$W^{MSSM}_{\not{RP}} = \lambda_{ijk}\,\hat{L}_i\,\hat{L}_j\,\hat{E}_k + \lambda_{ijk}\,\hat{L}_i\,\hat{Q}_j\,\hat{D}_k + \varepsilon_i\,\hat{L}_i\,\hat{H}_u + \lambda_{ijk}\,\hat{U}^c_i\,\hat{D}^c_j\,\hat{D}^c_k$$

bilinear terms

B-number violating terms

- 3 parameters ε_i in bilinear terms $\varepsilon_i L_i H_u$
- 3 "alignment" parameters: $\Lambda_i = \varepsilon_i v_d + \mu v_i$

v_i : sneutrino vev's

v_d : vev of H_d

but

fixing:
- ew symmetry breaking and
- neutrino oscilation data

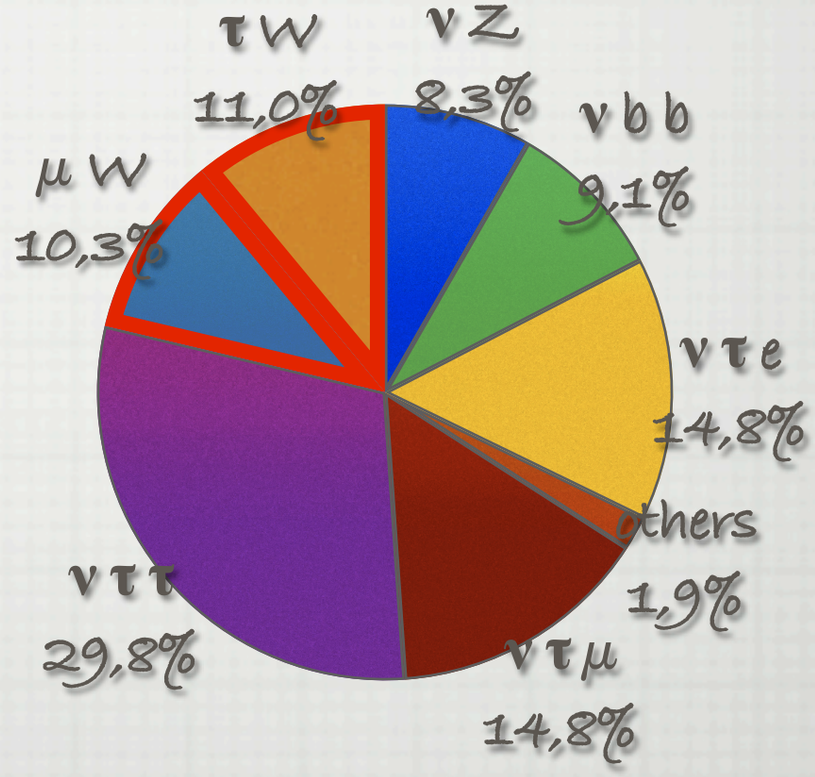
1 remaining free parameter

BILINEAR RPV & NEUTRINO MIXING

- RPV through bilinear terms ($\varepsilon_i \neq 0$) in the super-potential and the SUSY-breaking potential: [c.f. M. Hirsch et al., JHEP 0805:048,2008 and references therein]

- LSP = LIGHTEST NEUTRALINO: $\tilde{\chi}_1^0$

$$\tan^2 \theta_{atm} \simeq \frac{BR(\tilde{\chi}_1^0 \to \mu^{\pm} W)}{BR(\tilde{\chi}_1^0 \to \tau^{\pm} W)} \to \bar{q}q'$$



10 TeV, 2 fb^{-1}, SU3 mSUGRA point

$M(\tilde{\chi}_1^0) = 118$ GeV

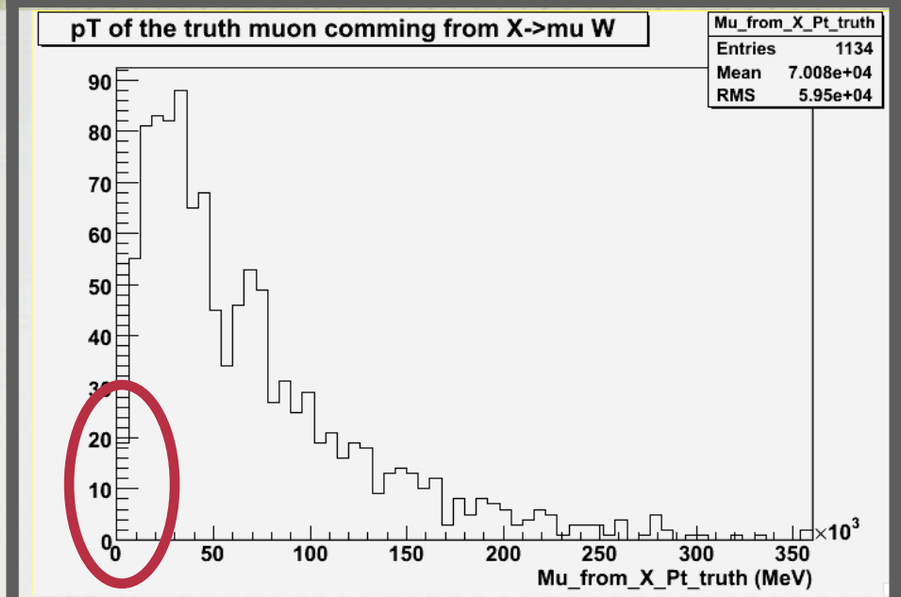
$\tilde{\chi}_1^0$ lifetime: $c\tau = 290\ \mu m$

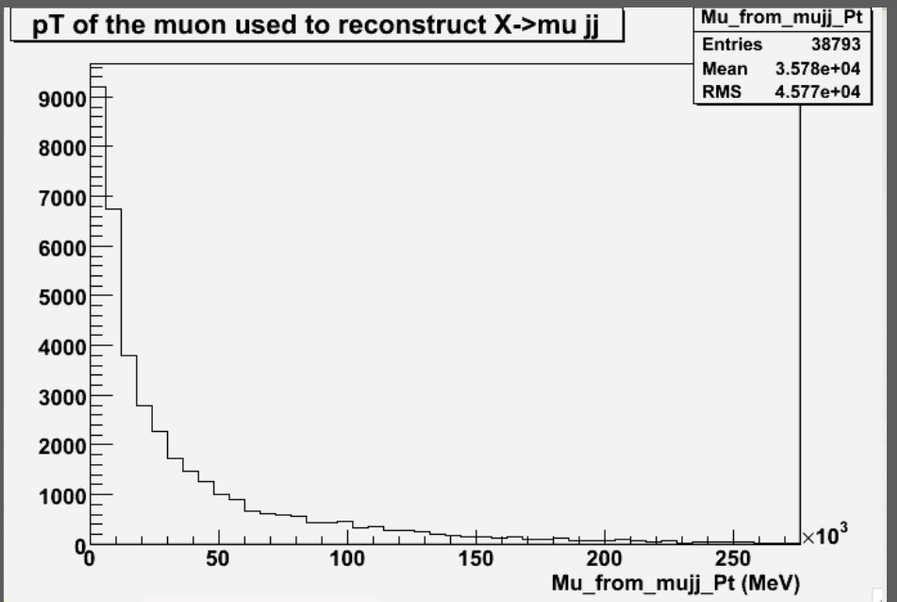
other mSUGRA points $\lambda \in (0.1\ ,\ 100)$ mm

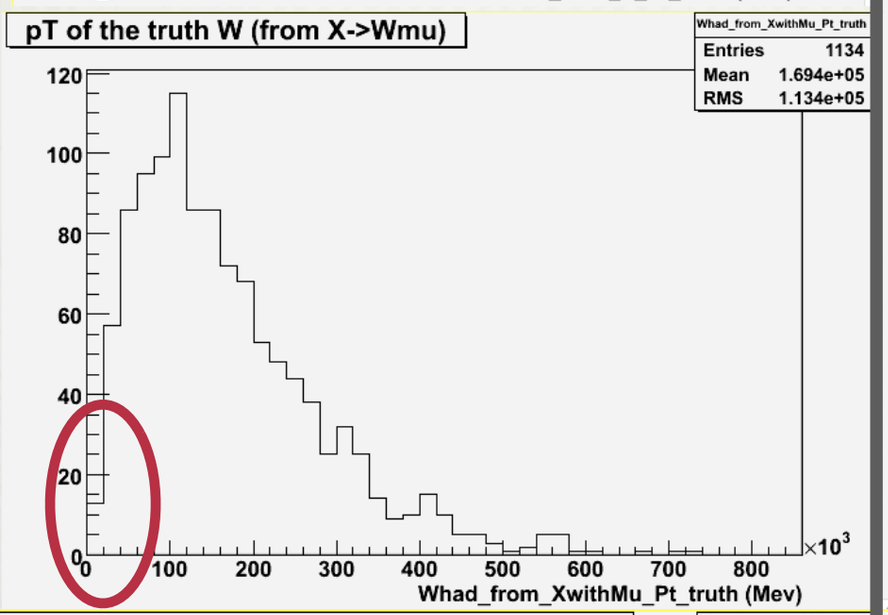
SIGNAL

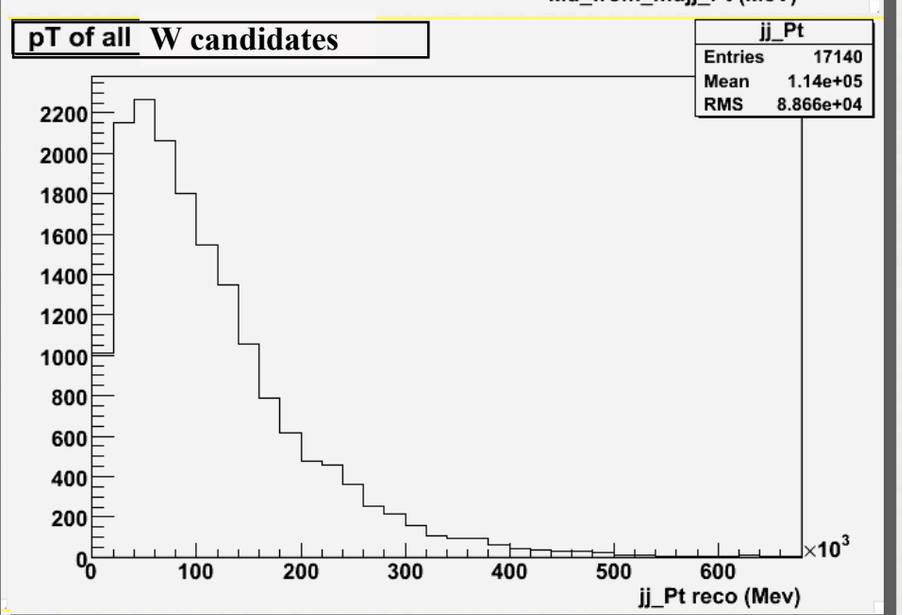
TRUTH

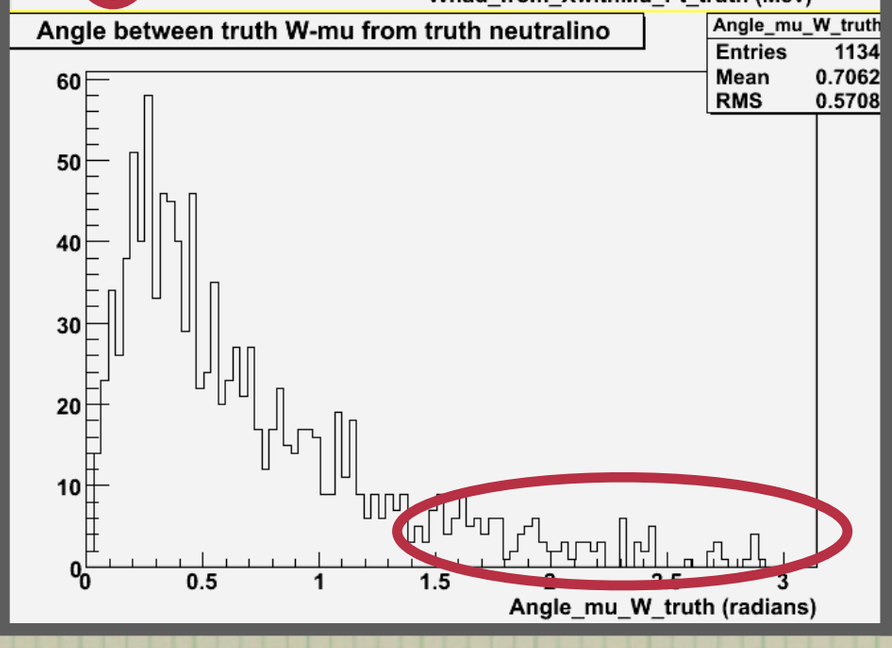
RECO

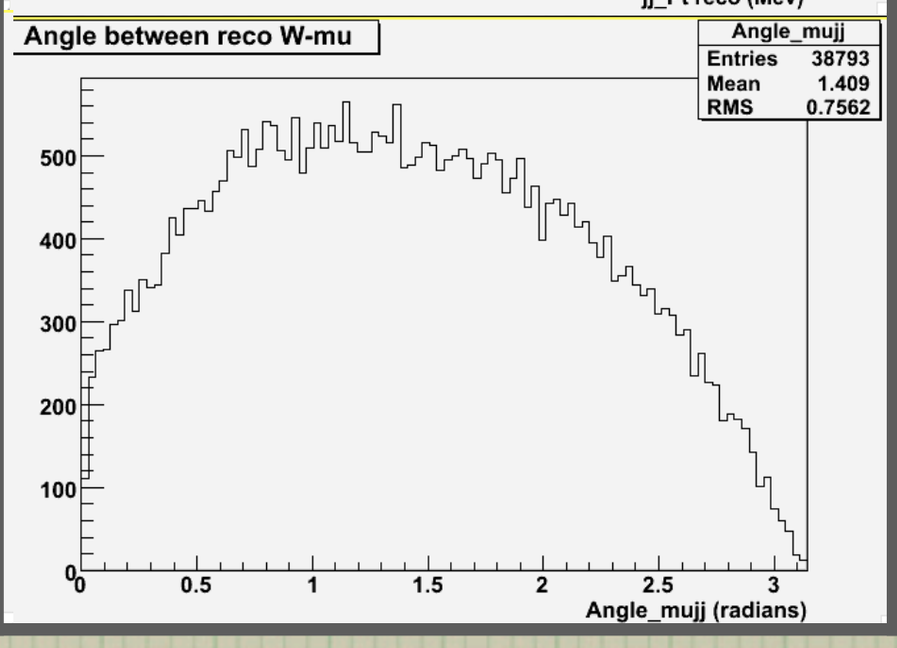












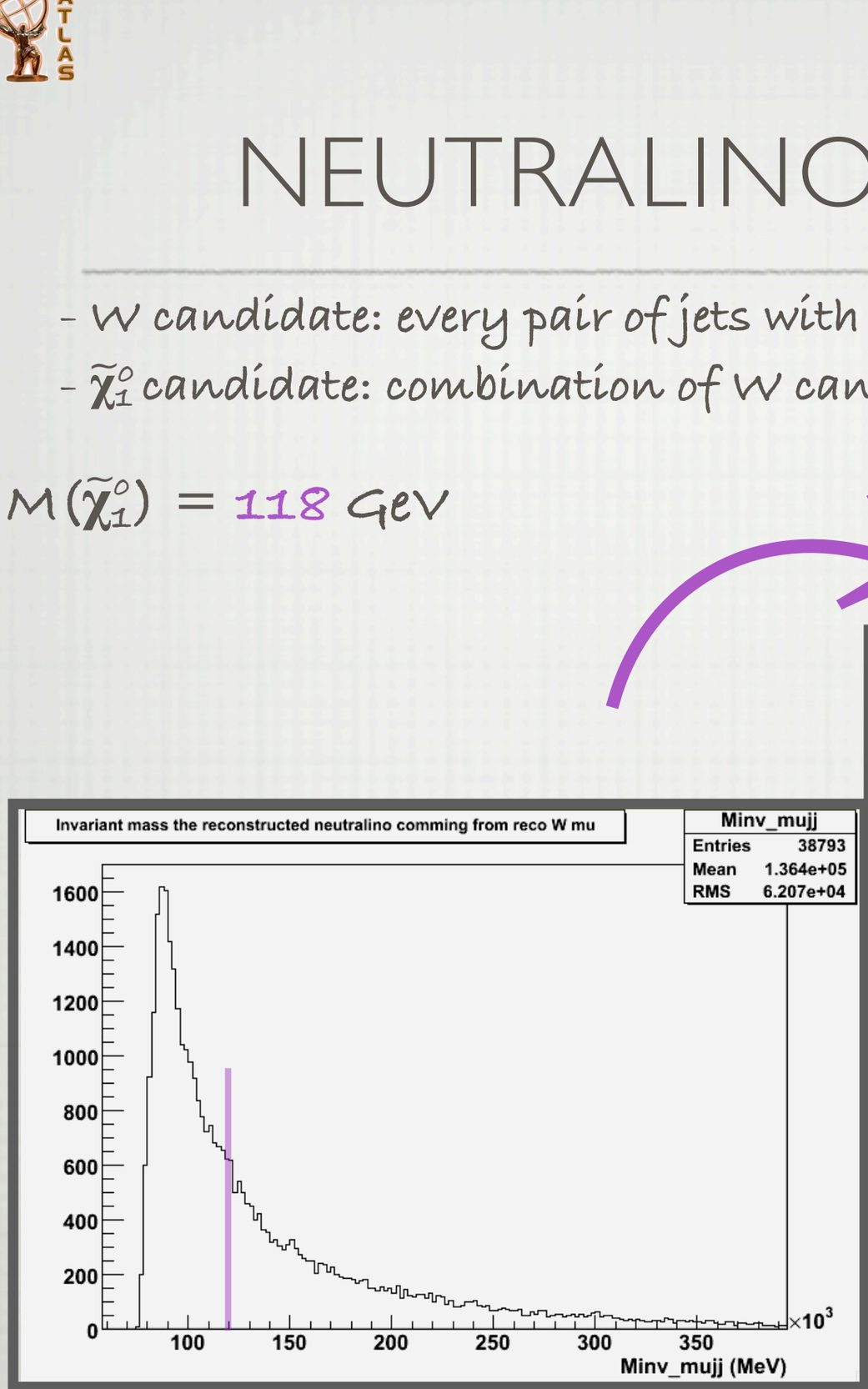
NEUTRALINO INVARIANT MASS

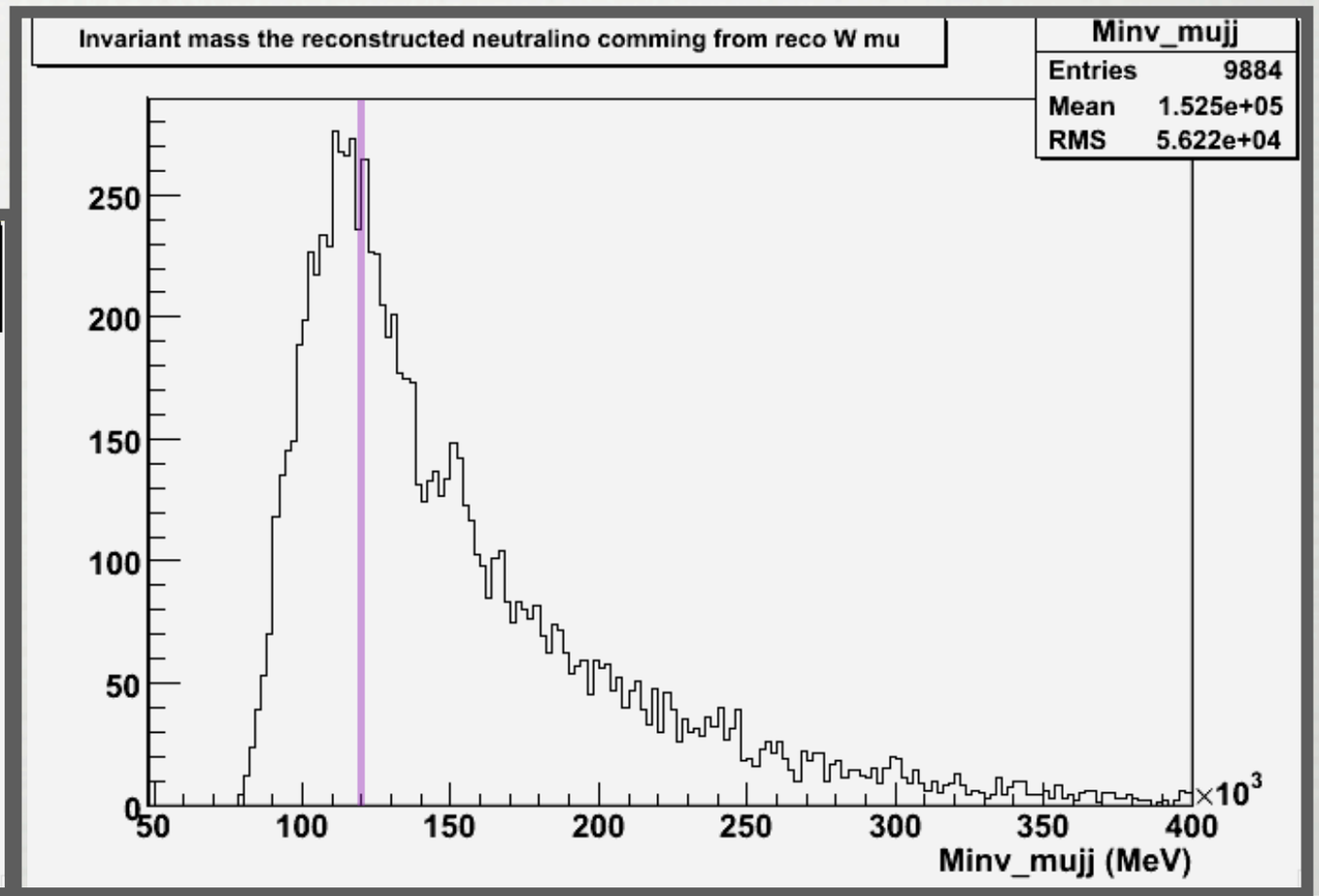
- W candidate: every pair of jets with inv mass = $M_W \pm 5$ GeV.
- $\tilde{\chi}_1^0$ candidate: combination of W candidates with all μ or τ in the event.

$M(\tilde{\chi}_1^0) = 118$ GeV

Combining all the previous cuts, the best option is:

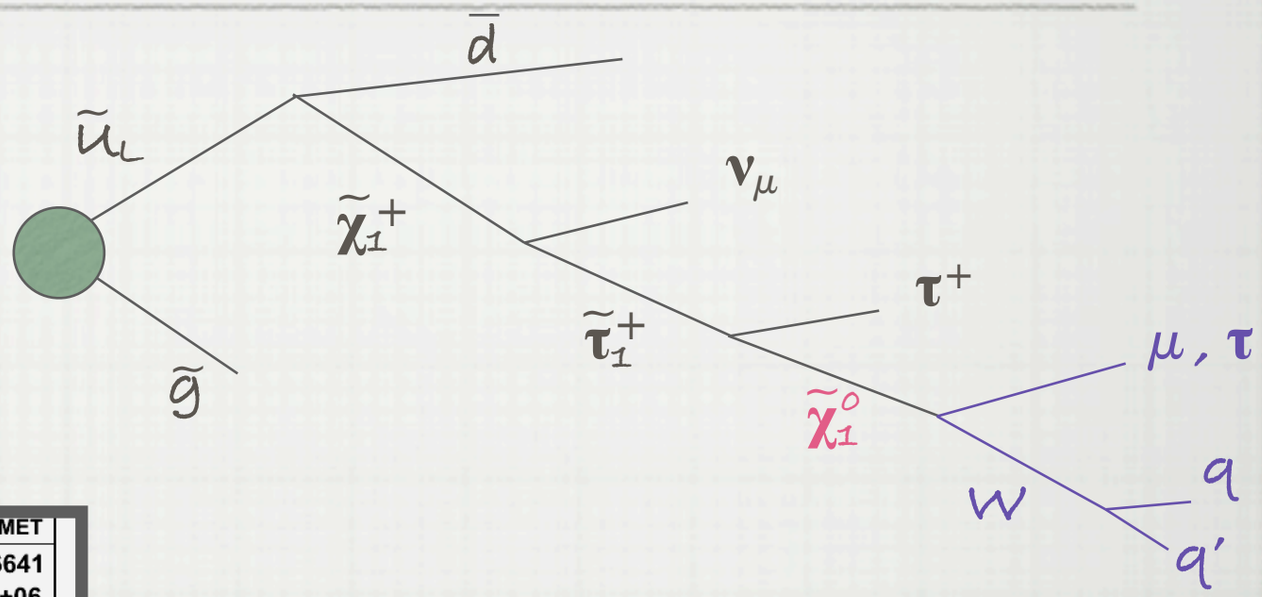
- $\mu_{pT} > 20$ GeV
- no cut on W_{pT}
- $\theta_{\mu W} < 1.5$
- no cut on θ_{jj}

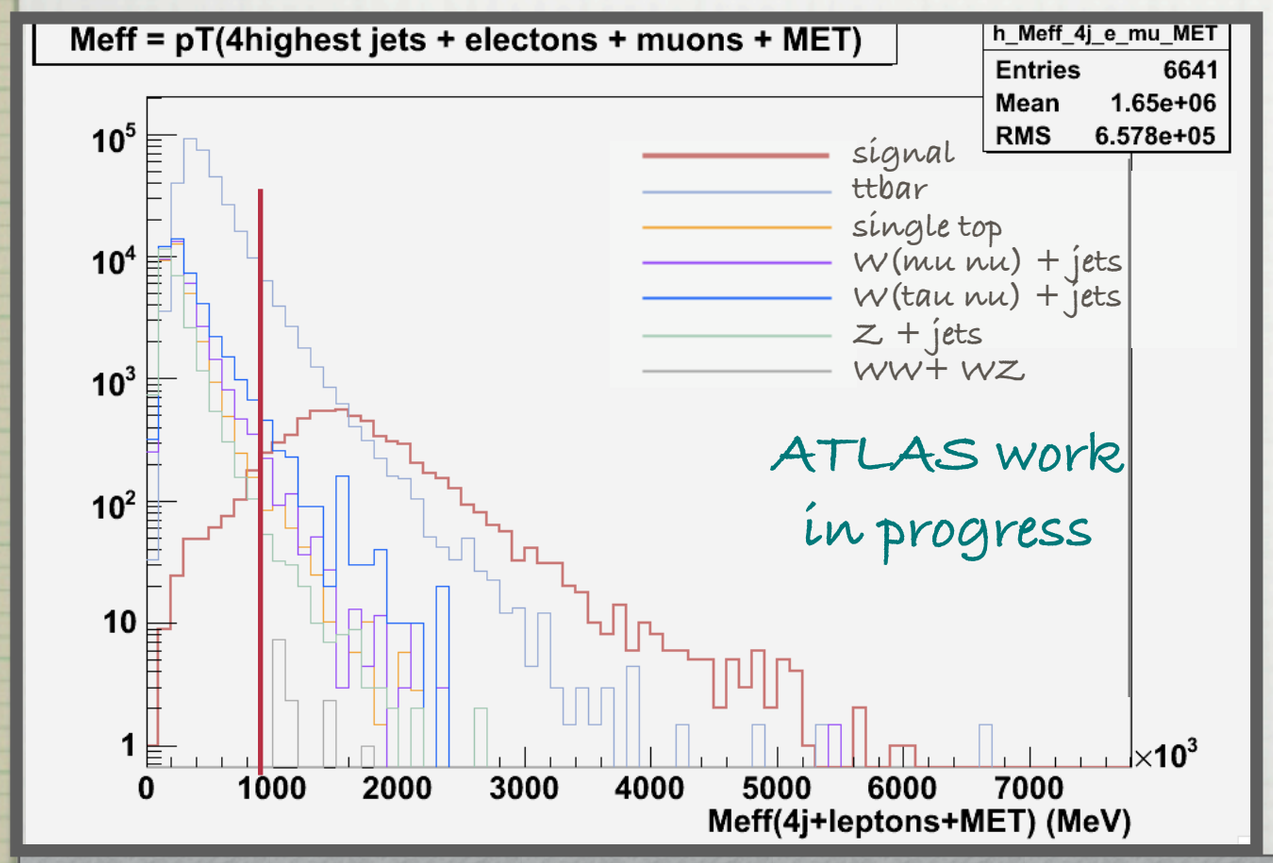




MAIN BACKGROUNDS

- main SM backgrounds: ttbar
  sinlge top
  W + jets
  Z + jets
  WW, WZ, ZZ
  QCD
  (easy to remove requiring 1 μ or τ)





$$Meff = \Sigma\, p_T(\text{electrons, muons, 4highest jets}) + MET$$

EFFICIENCIES FOR SM BACKGROUND

	trigg mu10 jet18	Meff >1000, MeffTau >1600, tveto > 30, $\mu(p_T) > 20$, $\theta_{W,\mu} < 1.5$
signal	70%	47%
ttbar	45%	1%
single top	41%	0,08%
W + jets	43%	0,05%
Z + jets	15%	0,04%
WW, WZ, ZZ	1%	0,1%
S/B	0,02	0,85
$S/\sqrt{B}$	10,5	61,5

- Meff = Σ p_T(electrons, muons, 4highest jets) + MET
- MeffTau= Σ p_T(electrons, muons, taus, 4highest jets) + MET
- 'tveto' $\forall$ W candidate, if $|M_{inv}(W,\text{highest jet}) - M_{top}| < 30$ GeV → reject event

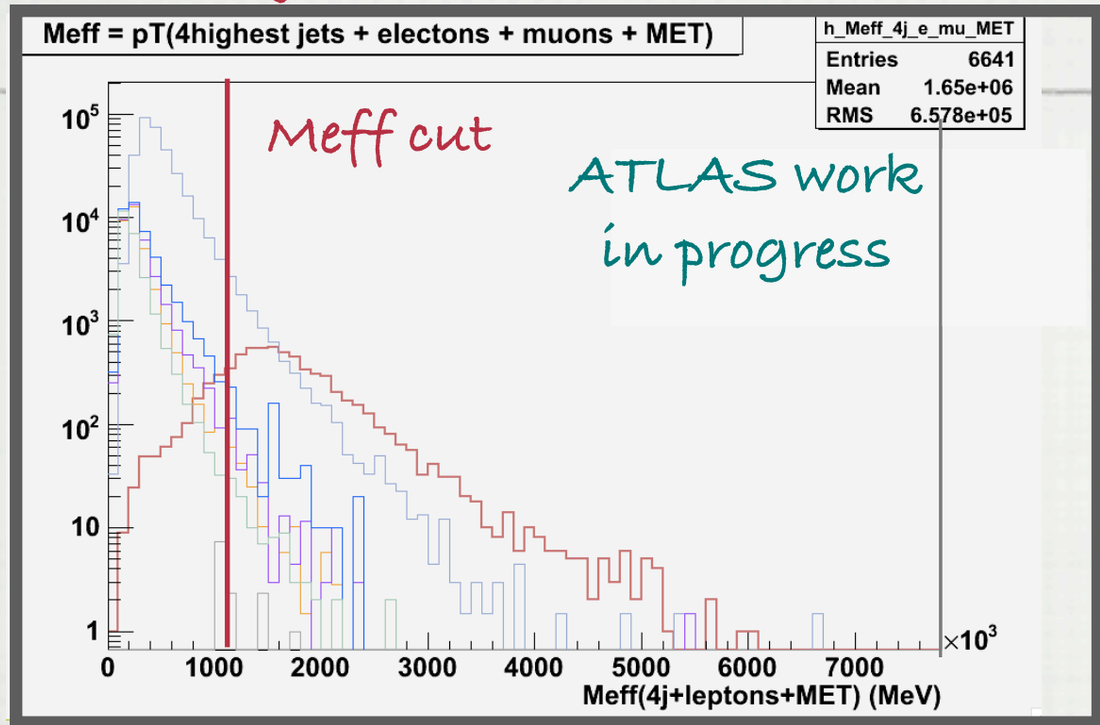
2 fb^{-1}

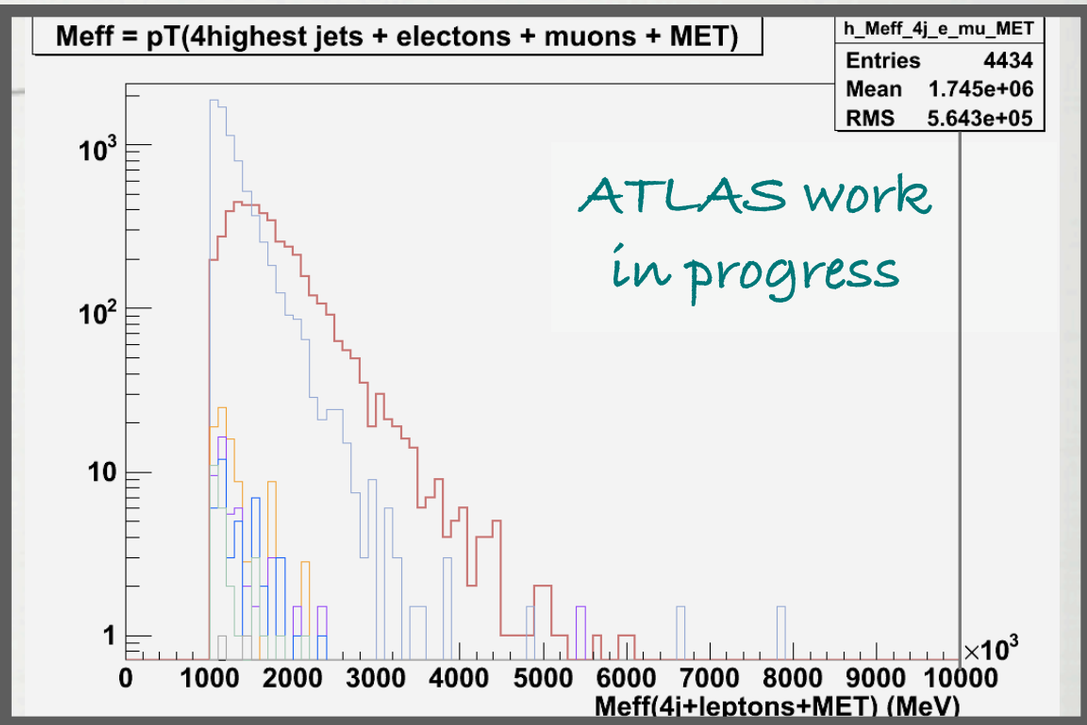
signal
ttbar
single top
W(mu nu) + jets
W(tau nu) + jets
Z + jets
WW+ WZ

mu10 jet18 trigger

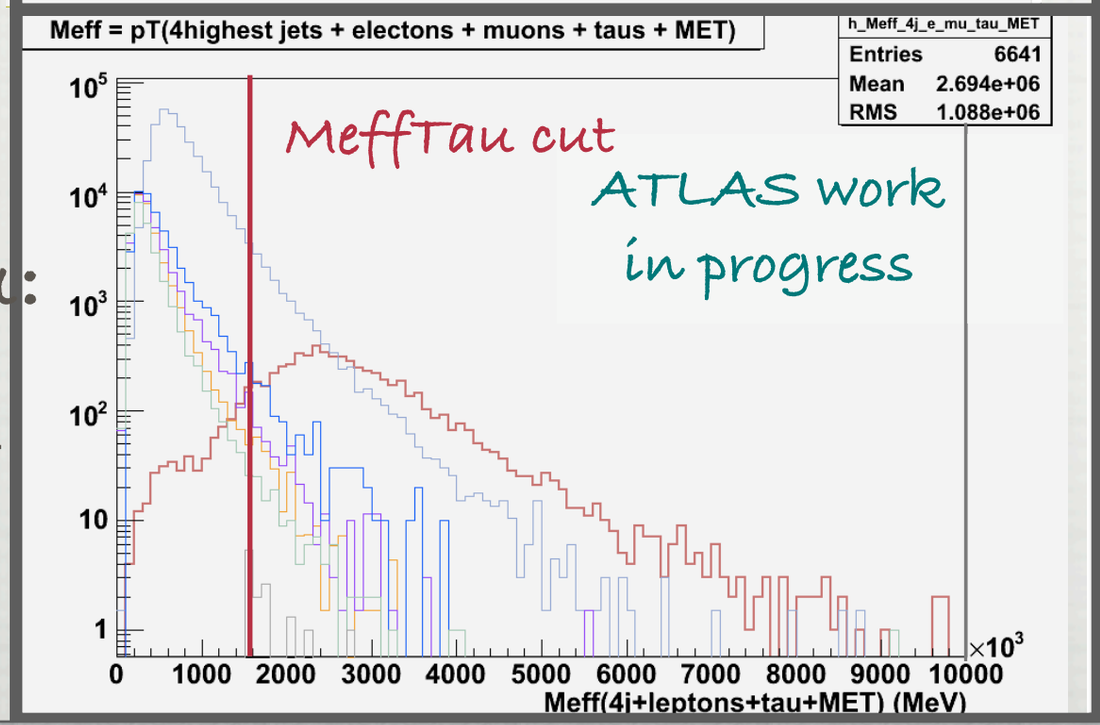
mu10 jet18 trigger+
Meff >1000, MeffTau >1600, tveto > 30,
$\mu(p_T) > 20$, $\theta_{W,\mu} < 1.5$ cuts

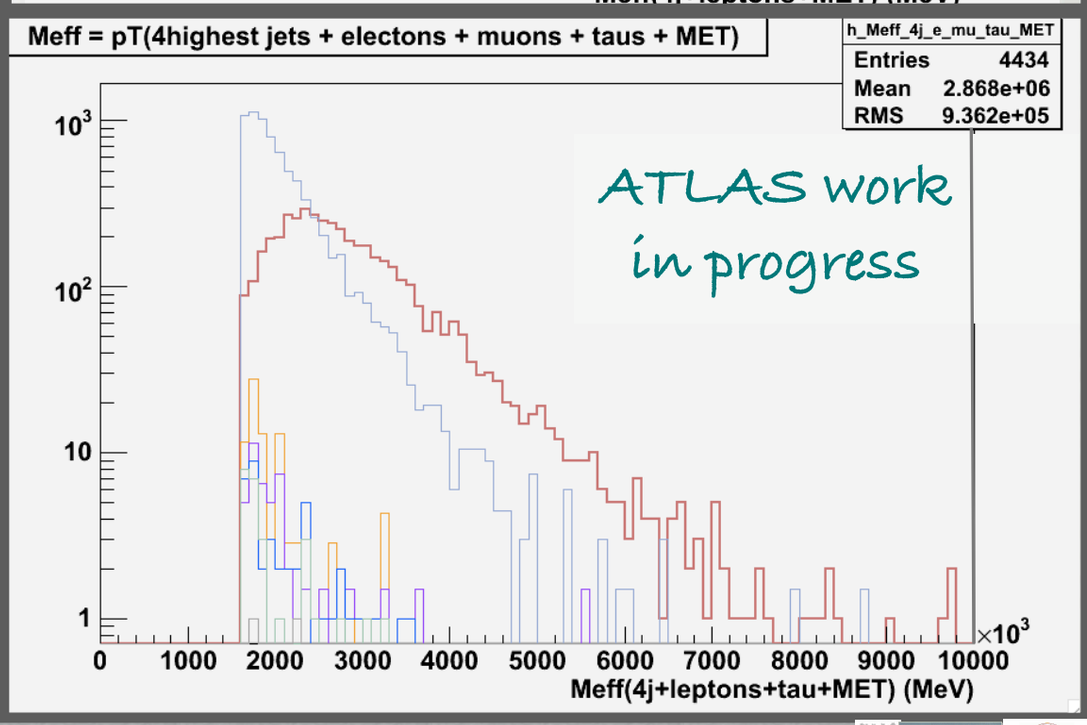
Meff: 4jets + leptons + MET





MeffTau: 4jets + leptons + taus + MET





EFFICIENCY IN THE MASS WINDOW

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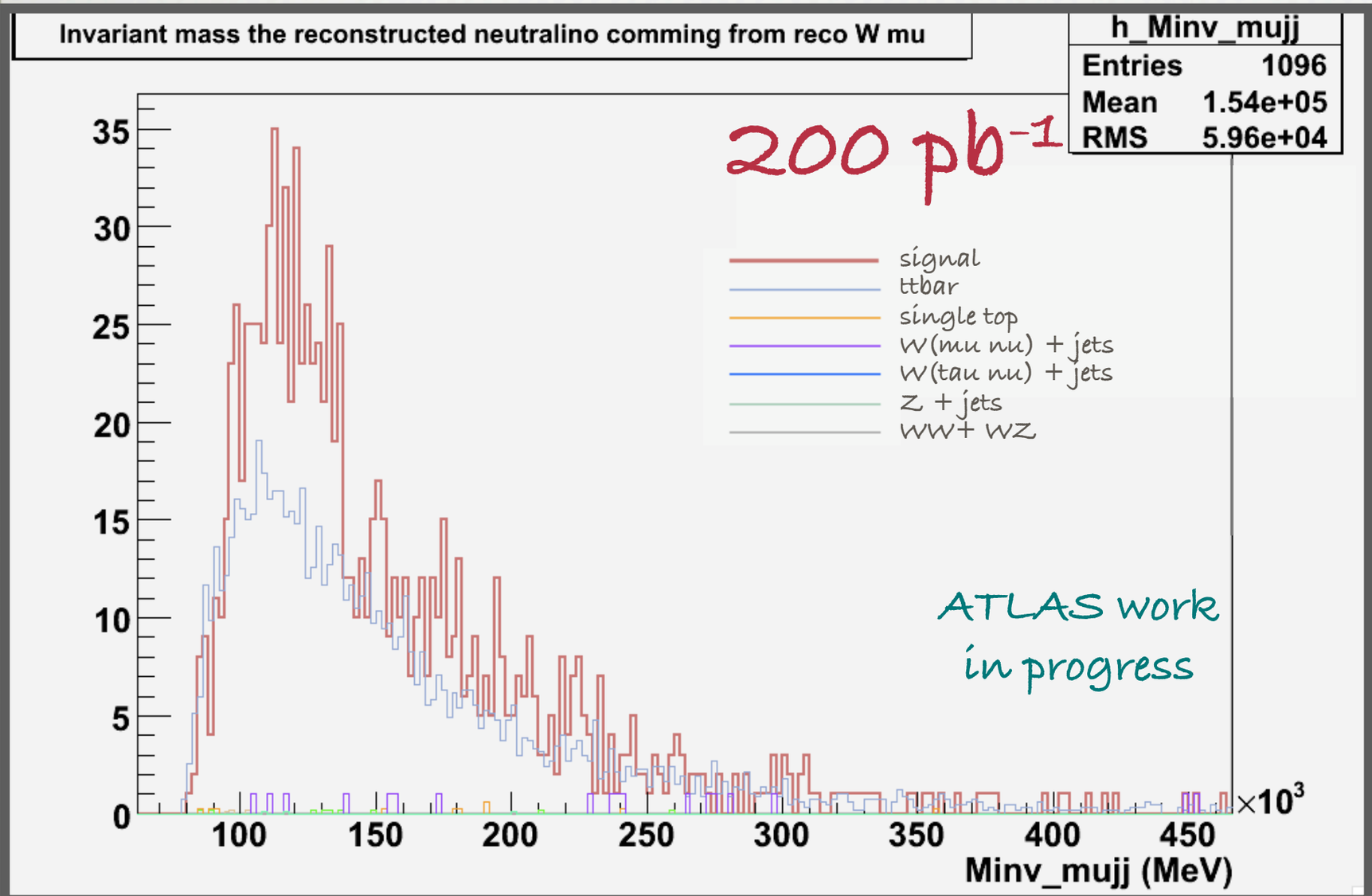


Efficiency in the peak

$M(\tilde{\chi}_1^0) \pm 20$ GeV

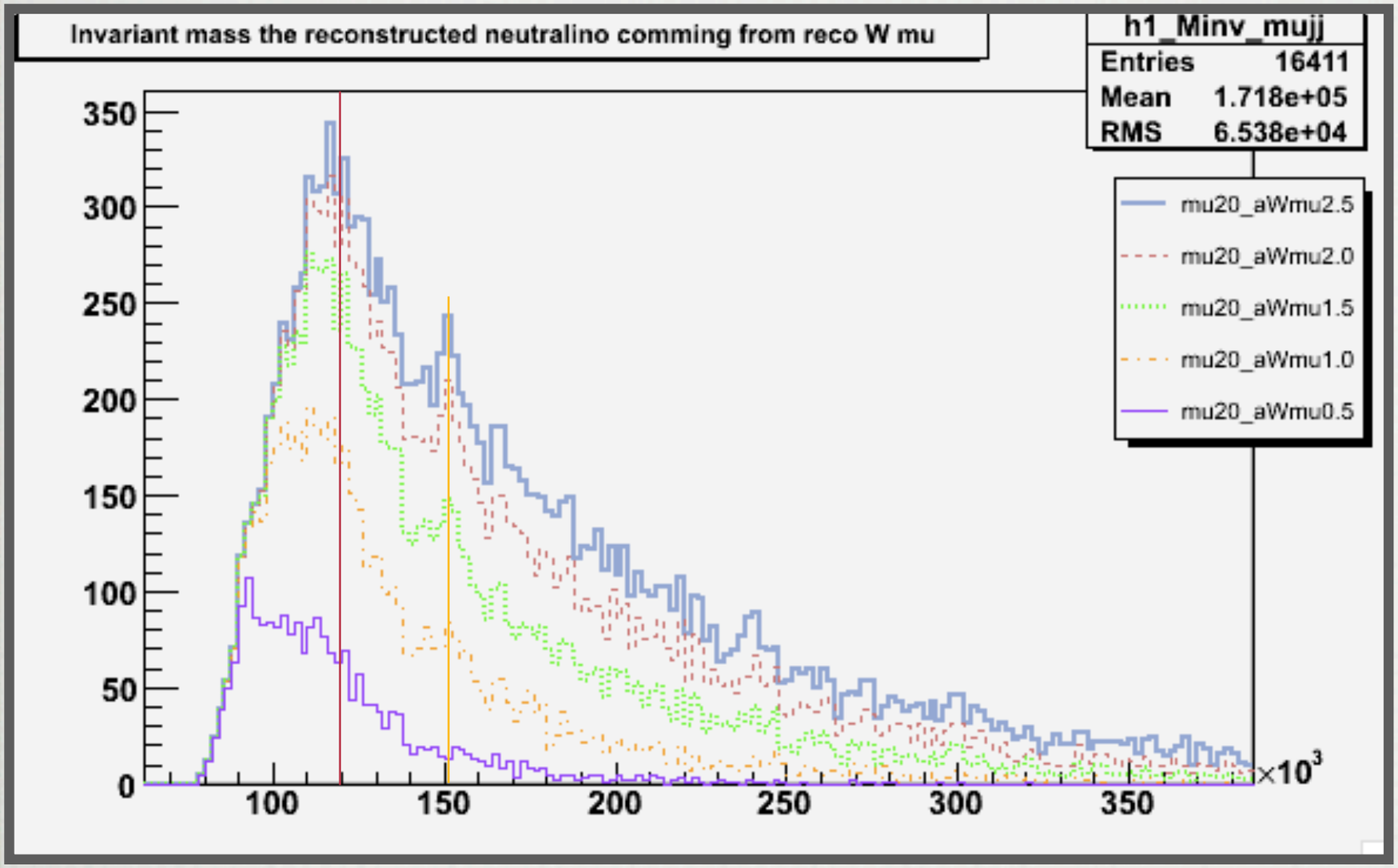
	trigg	trigg + cuts
S/B	0,05	1,65
S/√B	25,3	93,1

OUTLOOK - SUMMARY

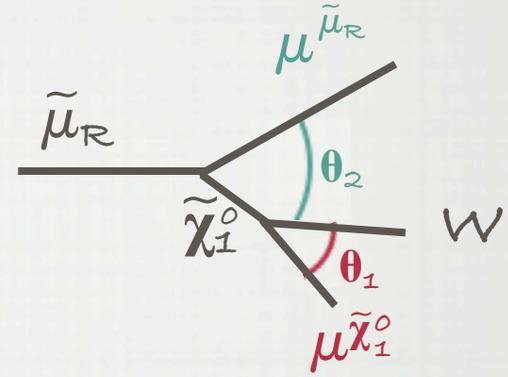
- A search for Supersymmetry with bilineal R-Parity Violation in the detector ATLAS of LHC is being done.
- Most of SM background is under control after some cuts using simple variables.
- An excess of events in the distribution of Meff and MeffTau would be visible.
- Thinking in an early analysis, it is possible to distinguish this excess of events with 200 pb^{-1} and a peak in the invariant mass of the neutralino appears.
- For a more detailed analysis and more statistics we are trying b-tagging to remove more ttbar.
- τ analysis in progress.

BACKUP

THE PEAK IN 150 GeV



$M(\tilde{\mu}_R) \approx 157$ GeV



- if $W_p \sim \tilde{\chi}_{1p}^0$, the $\tilde{\mu}_R$ can be reconstructed by the W and the $\mu^{\tilde{\mu}_R}$
- As in general $\theta_2 > \theta_1$, when the restriction on $\theta_{\mu W}$ is tighter, there are less $\tilde{\mu}_R$ candidates reconstructed and the peak in ~150 GeV becomes smaller.

- Given a fixed cut on μ_{pT}, the peak in ~150 GeV decreases as the angle between the muon and the W is more restricted. This seems to confirm our hypothesis about the muon coming from a $\tilde{\mu}_R$.

mSUGRA / RPV parameters

SU3, 10 TeV

mSUGRA point SU3:

m_0 = 100 GeV, $m_{1/2}$= 300 GeV

tanβ = 6, A_0 = -300 GeV, sgn μ = +1

RPV parameters:

ε_1 = 102 MeV, ε_2 = -102 MeV, ε_3 = 102 MeV

V_1 = - 8.8 MeV, V_2 = 9.0 MeV, V_3 = - 8.6 MeV

Neutrino mixing parameters:

$\Delta m_{atm}^2 = 2.2 \cdot 10^{-3}$ eV^2, $\Delta m_{sol}^2 = 2.8 \cdot 10^{-5}$ eV^2

$\tan^2\theta_{atm} = 0.96$, $\tan^2\theta_{sol} = 0.64$

LSP ($\tilde{\chi}_1^0$) lifetime: $c\tau = 290\ \mu m$

$M_{\tilde{\chi}_1^0} \sim 118.5$ GeV

Total SUSY cross-section: ~ 4.8 pb

Luminosity ~ 2 fb^{-1}

9.5k events (Full simulation!!)

SPARTICLES MIXINGS

•There are 4 neutral fermions in the MSSM: partners of neutral U(1) and SU(2) gauge bosons, B^0, W^0 (or γ , Z) and the partners of the two neutral Higgs scalars, H_u and H_d. They mix to form the 4 mass eigenstates called neutralinos:

$$\begin{pmatrix} \tilde{\chi}_1^0 \\ \tilde{\chi}_2^0 \\ \tilde{\chi}_3^0 \\ \tilde{\chi}_4^0 \end{pmatrix} = N \begin{pmatrix} -i\tilde{\gamma} \\ -i\tilde{Z} \\ \tilde{H}_u^0 \\ \tilde{H}_d^0 \end{pmatrix}$$

•The charged Winos and Higgsinos mix to form two doublets of charginos:

$$\begin{pmatrix} \tilde{\chi}_1^+ \\ \tilde{\chi}_2^+ \end{pmatrix} = V \begin{pmatrix} -i\tilde{W}^+ \\ \tilde{H}_u^+ \end{pmatrix}$$

$$\begin{pmatrix} \tilde{\chi}_1^- \\ \tilde{\chi}_2^- \end{pmatrix} = U \begin{pmatrix} -i\tilde{W}^- \\ \tilde{H}_d^- \end{pmatrix}$$

SPHERICITY

$$S^{\alpha\beta} = \frac{\sum_i p_i^{\alpha} p_i^{\beta}}{\sum_i |\vec{p_i}|^2}$$

$\alpha, \beta = 1,2,3$

i = all particles in the event

$$VSV^{\dagger} = \begin{pmatrix} \lambda_1 & 0 & 0 \\ 0 & \lambda_2 & 0 \\ 0 & 0 & \lambda_3 \end{pmatrix}$$

$\lambda_1 > \lambda_2 > \lambda_3$

$\lambda_1 + \lambda_2 + \lambda_3 = 1$

$$V = \begin{pmatrix} |v_1\rangle \\ |v_2\rangle \\ |v_3\rangle \end{pmatrix}$$

$S = 3/2\ (\lambda_2 + \lambda_3)$

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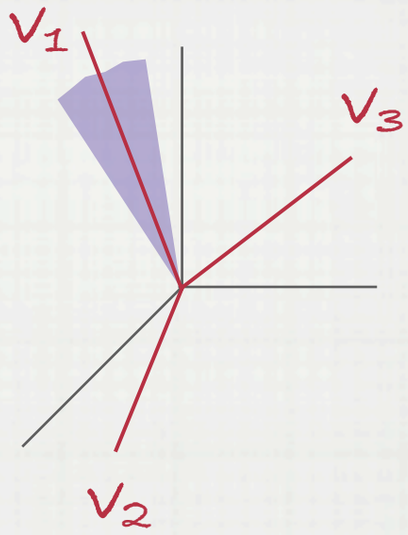

$\lambda_1 = 1;$

$\lambda_2 = \lambda_3 = 0;$

$S = 0$

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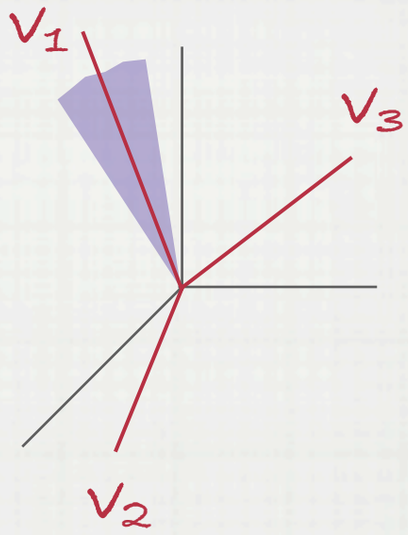

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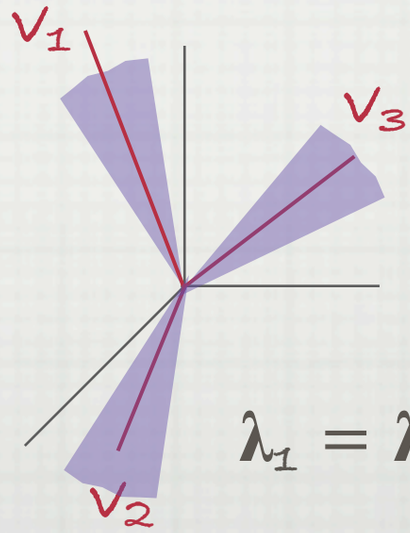

$\lambda_1 = \lambda_2 = \lambda_3 = 1/3;$

$S = 1$