Stau study at the ILC and its implication for the muon g-2 anomaly

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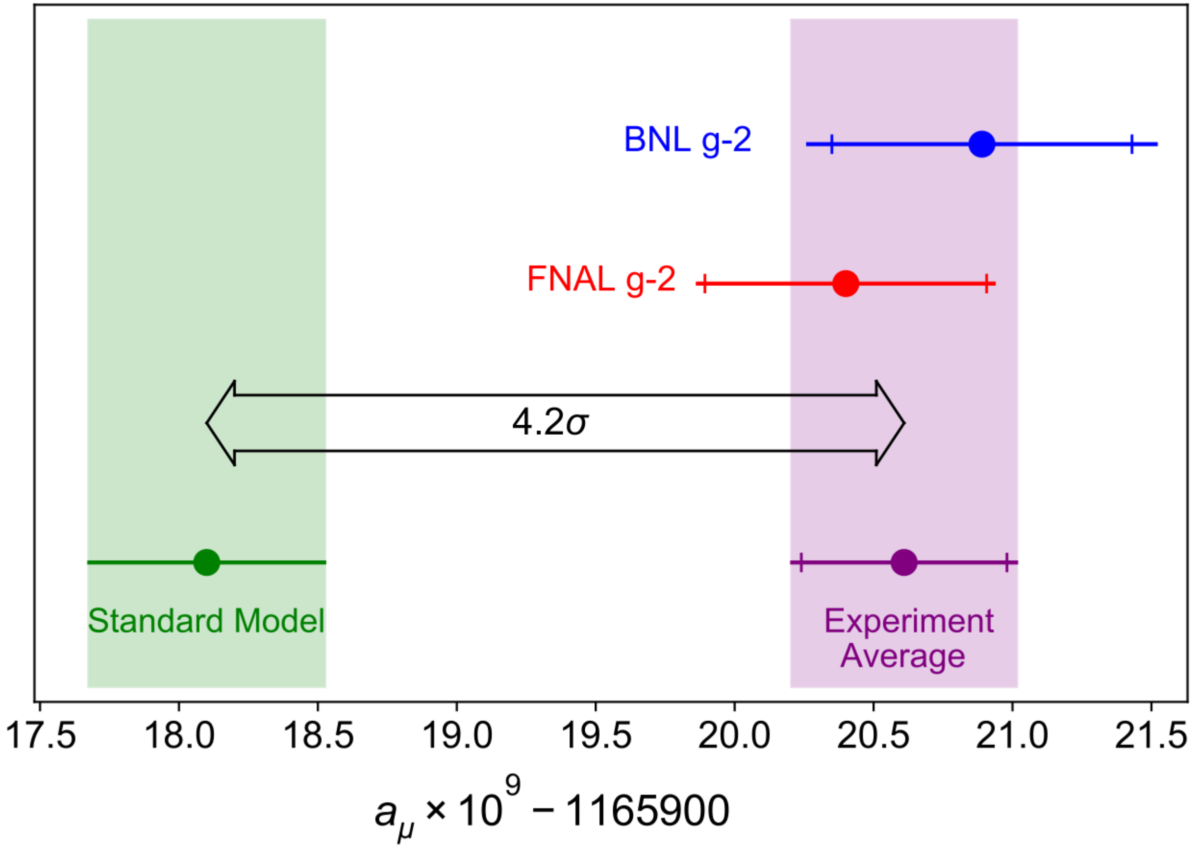
Introduction: muon g-2 anomaly



4.2σ discrepancy from the SM prediction
---> New physics?

Now the discrepancy between the experimental and theoretical values amounts to

$$\Delta a_\mu \equiv a_\mu^{\mathrm{BNL+FNAL}} - a_\mu^{\mathrm{SM}} = (25.1 \pm 5.9) \times 10^{-10}\,, \tag{5}$$

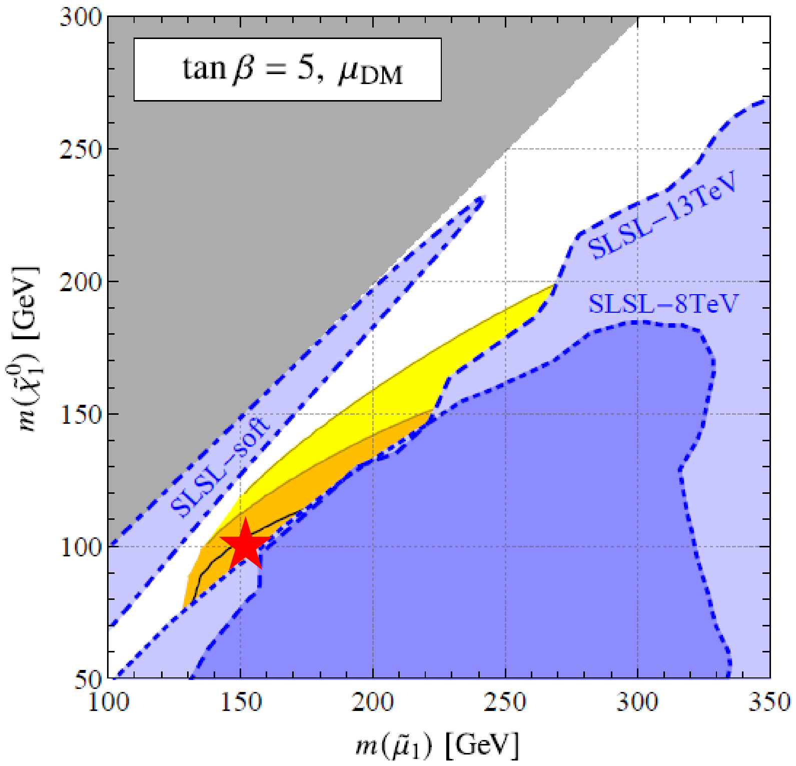
whose significance is equivalent to 4.2σ level, and the muon $g-2$ anomaly is reconfirmed.[#3]

Many models proposed to explain.
This talk will pick up the interpretation of [2104.03217]: SUSY interpretation (pure-Bino-contribution scenario)

arXiv:2104.03217

	BLR1	BLR2	BLR3	BLR4
M_1	100	100	150	150
$m_L = m_R$	150	150	200	200
$\tan\beta$	5	10	5	10
μ	1323	678	1922	973
$m_{\tilde{\mu}_1}$	154	154	202	202
$m_{\tilde{\mu}_2}$	159	159	207	208
$m_{\tilde{\tau}_1}$	113	113	159	158
$m_{\tilde{\tau}_2}$	190	191	242	243
$m_{\tilde{\nu}_{\mu,\tau}}$	137	136	190	190
$m_{\tilde{\chi}_1^0}$	99	99	150	149
$m_{\tilde{\chi}_2^0}, m_{\tilde{\chi}_3^0}, m_{\tilde{\chi}_1^\pm}$	1323–1324	678–680	1922–1923	973–975
$a_\mu^{\rm SUSY} \times 10^{10}$	27	27	17	17
$\Omega_{\rm DM} h^2$	0.120	0.120	0.120	0.120
$\sigma_p^{\rm SI} \times 10^{47}$ [cm^2]	1.7	3.7	0.8	1.9
$\mu_{\gamma\gamma}$	1.01	1.01	1.01	1.01

$\tilde{\chi}_1^0$ mass

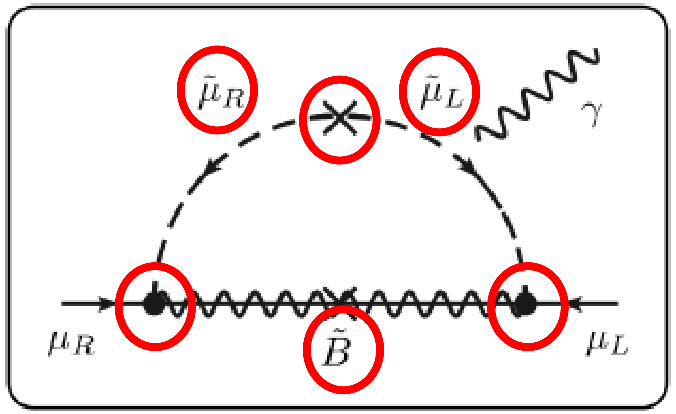


$\tilde{\mu}_1$ mass

Can explain muon g-2 with $1\sigma(2\sigma)$

+ $\Omega_{\chi_1^0} = \Omega_{\text{dark matter}}$

Muon g-2 and ILC



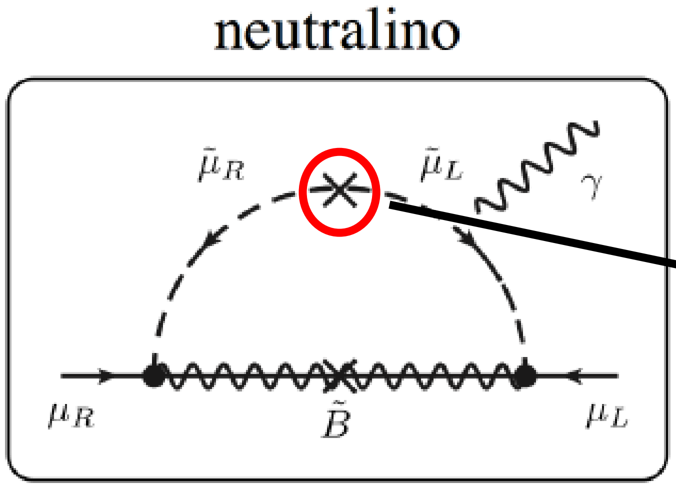
At ILC500 (or even at ILC250), we can reconstruct the contribution of this loop-diagram.

Table 2: Observables necessary for the reconstruction of $a_\mu^{(\mathrm{ILC})}$, and their uncertainties with $\sqrt{s} = 500$ GeV and $\mathcal{L} \sim 500$–$1000\,\mathrm{fb}^{-1}$. Processes relevant to determine each observable are also shown. The second and third rows are the information to determine $m^2_{\tilde{\mu}LR}$. For the determination of $m_{\tilde{\chi}^0_1}$, analyses of the productions of selectrons and smuons are combined. The uncertainties in $\tilde{g}^{(\mathrm{eff})}_{1,L}$ are those from the experiment and theory, respectively.

X	δX	$\delta_X a_\mu^{(\mathrm{ILC})}$	Process	
$m^2_{\tilde{\mu}LR}$	12 %	13 %	$e^+e^- \to \tilde{\tau}^+\tilde{\tau}^-$	(cross section, endpoint)
$(\sin 2\theta_{\tilde{\tau}})$	(9 %)	–	$e^+e^- \to \tilde{\tau}_1^+\tilde{\tau}_1^-$	(cross section)
$(m_{\tilde{\tau}2})$	(3 %)	–	$e^+e^- \to \tilde{\tau}_2^+\tilde{\tau}_2^-$	(endpoint)
$m_{\tilde{\mu}1}$, $m_{\tilde{\mu}2}$	200 MeV	0.3 %	$e^+e^- \to \tilde{\mu}^+\tilde{\mu}^-$	(endpoint)
$m_{\tilde{\chi}^0_1}$	100 MeV	< 0.1 %	$e^+e^- \to \tilde{\mu}^+\tilde{\mu}^- / \tilde{e}^+\tilde{e}^-$	(endpoint)
$\tilde{g}^{(\mathrm{eff})}_{1,L}$	a few+1 %	a few+1 %	$e^+e^- \to \tilde{e}^+_L\tilde{e}^-_R$	(cross section)
$\tilde{g}^{(\mathrm{eff})}_{1,R}$	1 %	0.9 %	$e^+e^- \to \tilde{e}^+_R\tilde{e}^-_R$	(cross section)

ALL measurable

This study: Stau measurement at the ILC



Approximately $\Delta a_\mu^{(\tilde{B})} \propto m^2_{\tilde{\mu}LR}$

Need smuon left-right mixing measurement
Generally, it is difficult to measure directly,
but we also have: $m^2_{\tilde{\mu}LR} = \frac{m_\mu}{m_\tau} m^2_{\tilde{\tau}LR}$

Need stau mass and mixing measurement

Analysis setup

- ILC500 with BLR1 parametrization (p3)
- eLpR (P(e-,e+) = (-0.8,+0.3)) and eRpL (P(e-,e+) = (+0.8,-0.3)): 1.6 ab^{-1} both
- SUSY MC sample production: DELPHES + ILC generic detector card
- SM background (~200M MC events in total)
  - aa_2f (2-photon process): SGV sample due to huge cross-section but old (~8 years)
  - others: ALL ILD-IDR 500 GeV full simulation samples
- Tau reconstruction: TaJetClustering with default settings

Statistics (no cuts, 1.6 ab^{-1})

eLpR	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg
No cuts	$4.59*10^4$	$8.57*10^4$	$1.59*10^5$	$4.31*10^4$	$1.49*10^5$	$4.65*10^4$	$2.62*10^4$	$4.39*10^9$

eRpL	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg
No cuts	$3.57*10^4$	$8.75*10^4$	$4.15*10^4$	$1.48*10^5$	$1.39*10^5$	$4.21*10^4$	$2.08*10^4$	$4.34*10^9$

O(10^4-10^5) stau events vs O(10^9) SM bkg
Clearly need to design cuts to reject SM bkg

Design of precuts

- pre1: N_{tau} == 2
- pre2: E_{tau+} != 0, E_{tau-} != 0
- pre3: $N_{e\text{-}PFO}$ <=1
- pre4: $N_{(tau\text{--->}e)}$ <= 1
- pre5: $N_{mu\text{-}PFO}$ <= 1
- pre6: $N_{(tau\text{--->}mu)}$ <= 1
- pre7: $N_{chargedPFO}$ except tau <= 1
- pre8: $N_{neutralPFO}$ except tau<= 5

equivalent to require opposite charged tau (pre2)

sacrifice same flavor lepton events
~6% stau events will be rejected
can reject more backgrounds
(pre3–pre6)

reject high multiplicity events (pre7–pre8)

After precuts (1.6 ab^{-1})

eLpR	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg
No cuts	$4.59*10^4$	$8.57*10^4$	$1.59*10^5$	$4.31*10^4$	$1.49*10^5$	$4.65*10^4$	$2.62*10^4$	$4.39*10^9$
precuts	0	0	0	0	$5.37*10^4$	$3.04*10^4$	$1.24*10^4$	$1.14*10^9$

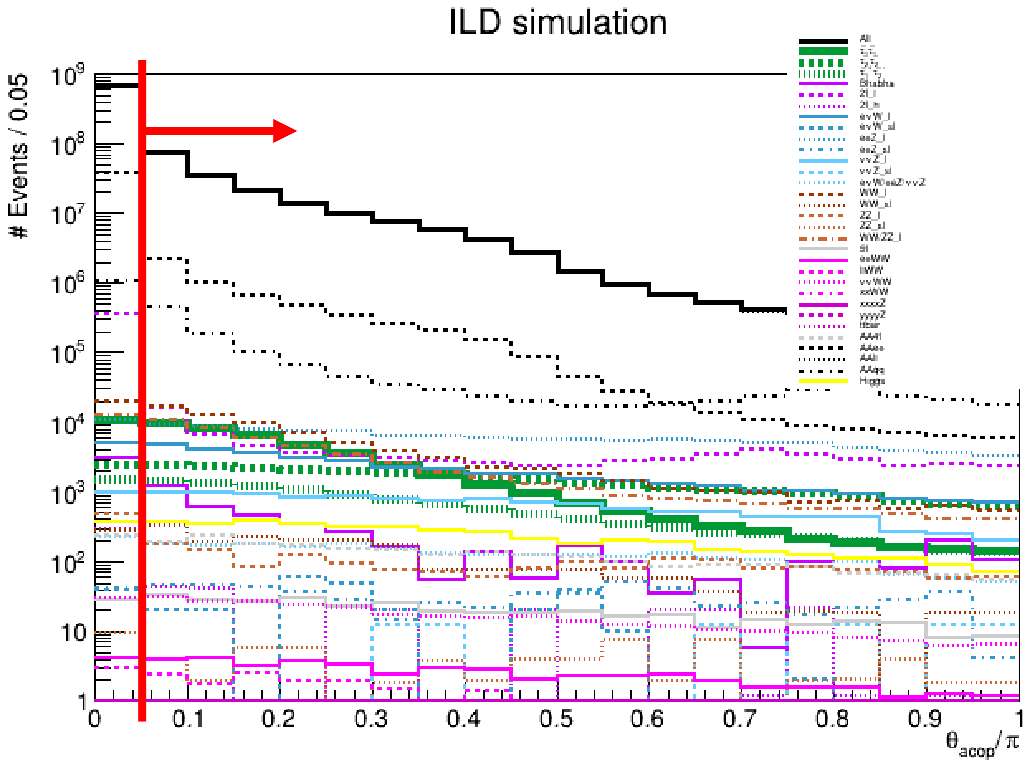
eRpL	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg
No cuts	$3.57*10^4$	$8.75*10^4$	$4.15*10^4$	$1.48*10^5$	$1.39*10^5$	$4.21*10^4$	$2.08*10^4$	$4.34*10^9$
precuts	0	0	0	0	$5.00*10^4$	$2.76*10^4$	$9.82*10^3$	$1.14*10^9$

O(10^4) stau events vs O(10^9) SM bkg
Still lots of SM bkg, especially aa_ll

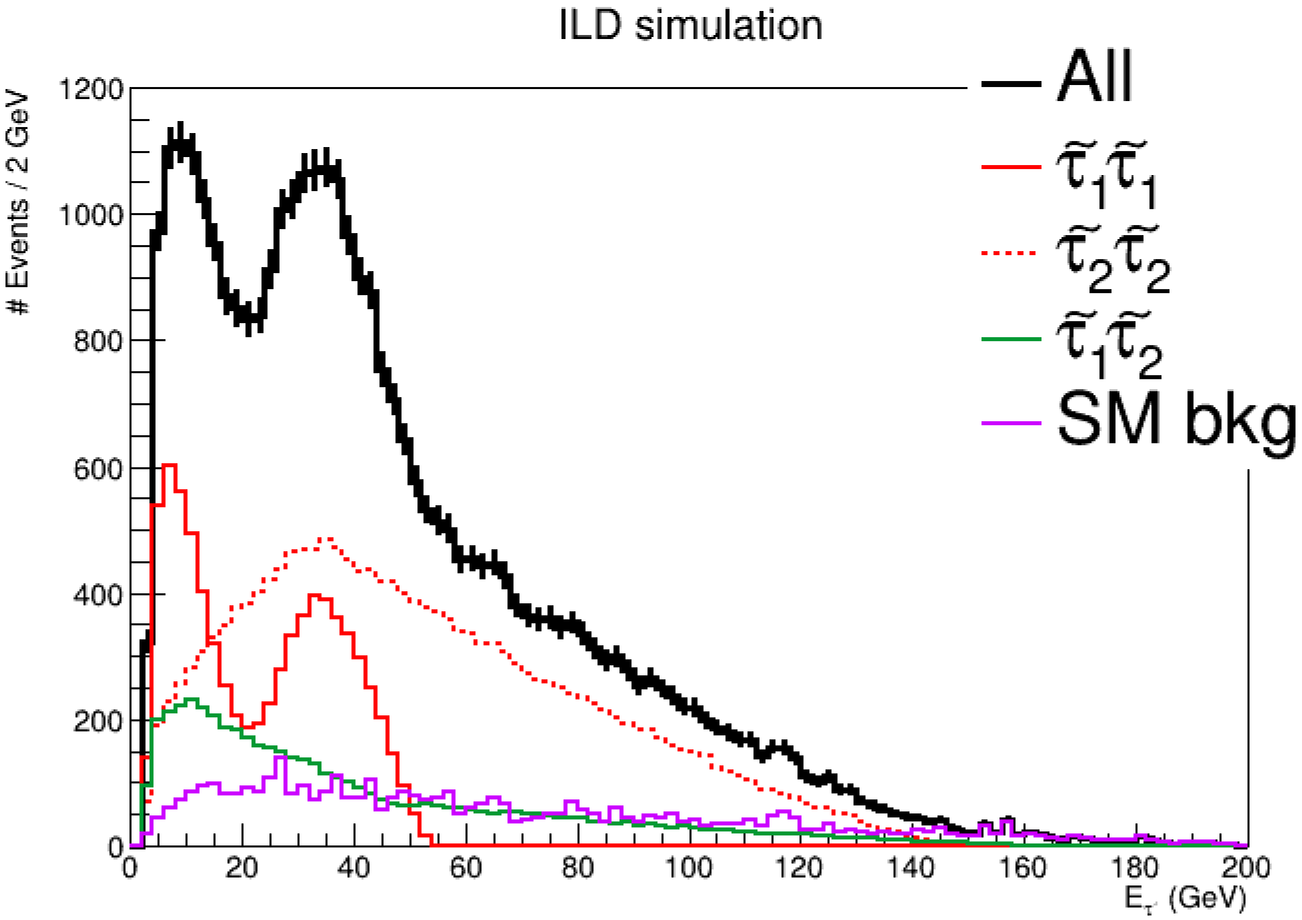
Cut design

- Cut1: $\frac{\theta_{\mathrm{acop}}}{\pi} > 0.05$
- Cut2: $20 < E_{\mathrm{vis}} < 300$ GeV
- Cut3: $M_{\mathrm{inv}} > 200$ GeV
- Cut4: $|\cos\theta_{\mathrm{miss}}| < 0.85$
- Cut5: missing P_t > 20 GeV
- Cut6: $M_{\tau\tau} > 20$ GeV
- Cut7: $\left|\cos\theta_{\tau^\pm}\right| < 0.9$

Example plot



$\theta_{\mathrm{acop}}/\pi$: mainly for background rejection (eLpR)
otherwise we can see nothing



E_{τ^-} after all cuts (eRpL)
now it is possible to see stau event distribution

After Cuts1-7 (1.6 ab^{-1})

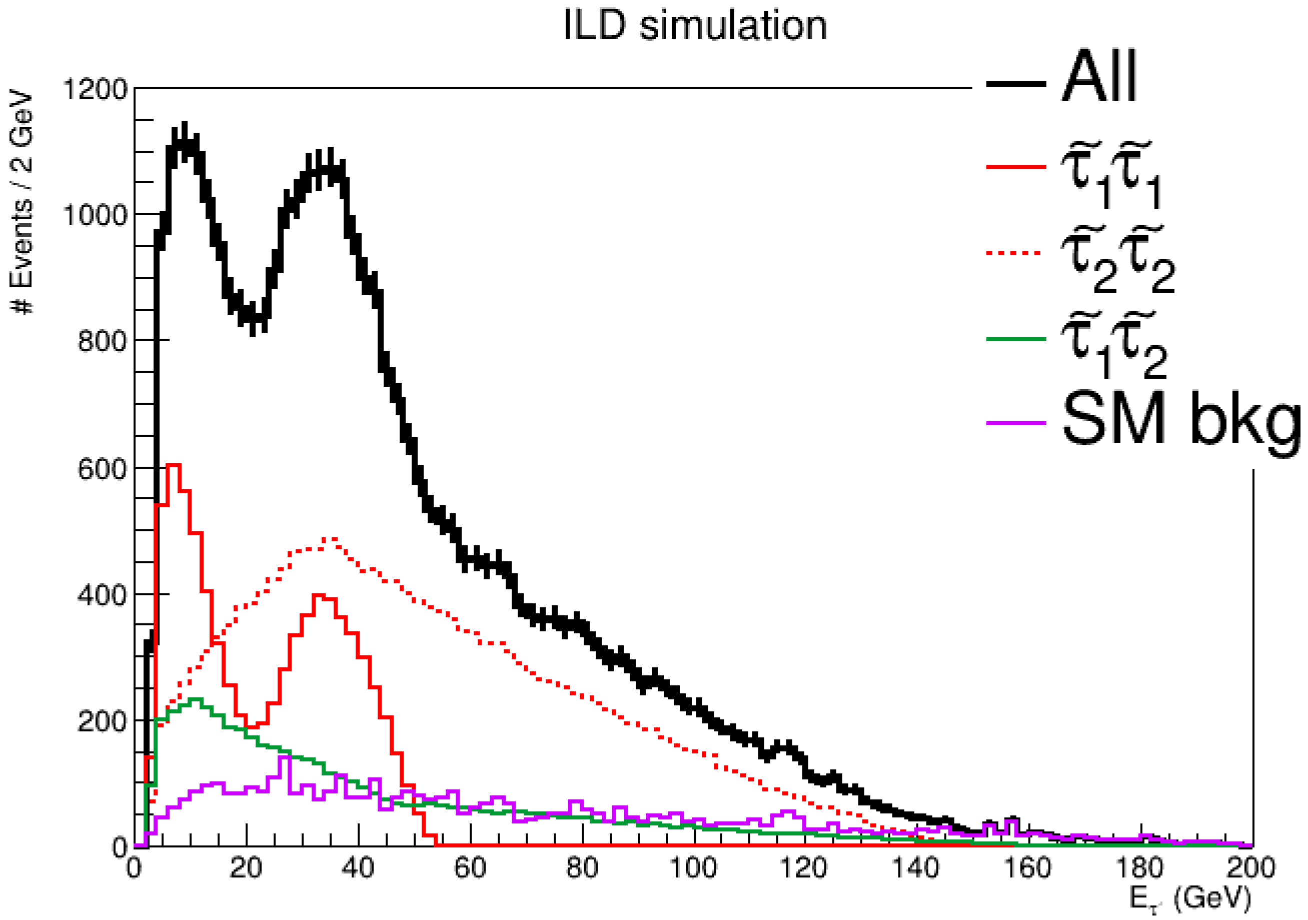
eLpR	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg
No cuts	$4.59*10^4$	$8.57*10^4$	$1.59*10^5$	$4.31*10^4$	$1.49*10^5$	$4.65*10^4$	$2.62*10^4$	$4.39*10^9$
precuts	0	0	0	0	$5.37*10^4$	$3.04*10^4$	$1.24*10^4$	$1.14*10^9$
Cuts1-7	0	0	0	0	$8.28*10^3$	$1.89*10^4$	$6.45*10^3$	$4.56*10^4$

eRpL	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg
No cuts	$3.57*10^4$	$8.75*10^4$	$4.15*10^4$	$1.48*10^5$	$1.39*10^5$	$4.21*10^4$	$2.08*10^4$	$4.34*10^9$
precuts	0	0	0	0	$5.00*10^4$	$2.76*10^4$	$9.82*10^3$	$1.14*10^9$
Cuts1-7	0	0	0	0	$7.65*10^3$	$1.71*10^4$	$5.09*10^3$	$1.45*10^4$

O(10^3-10^4) stau events vs O(10^4) SM bkg
Less backgrounds in eRpL

Stau Measurement (eRpL) (Work in progress, results are preliminary)

E_{τ^-} distribution

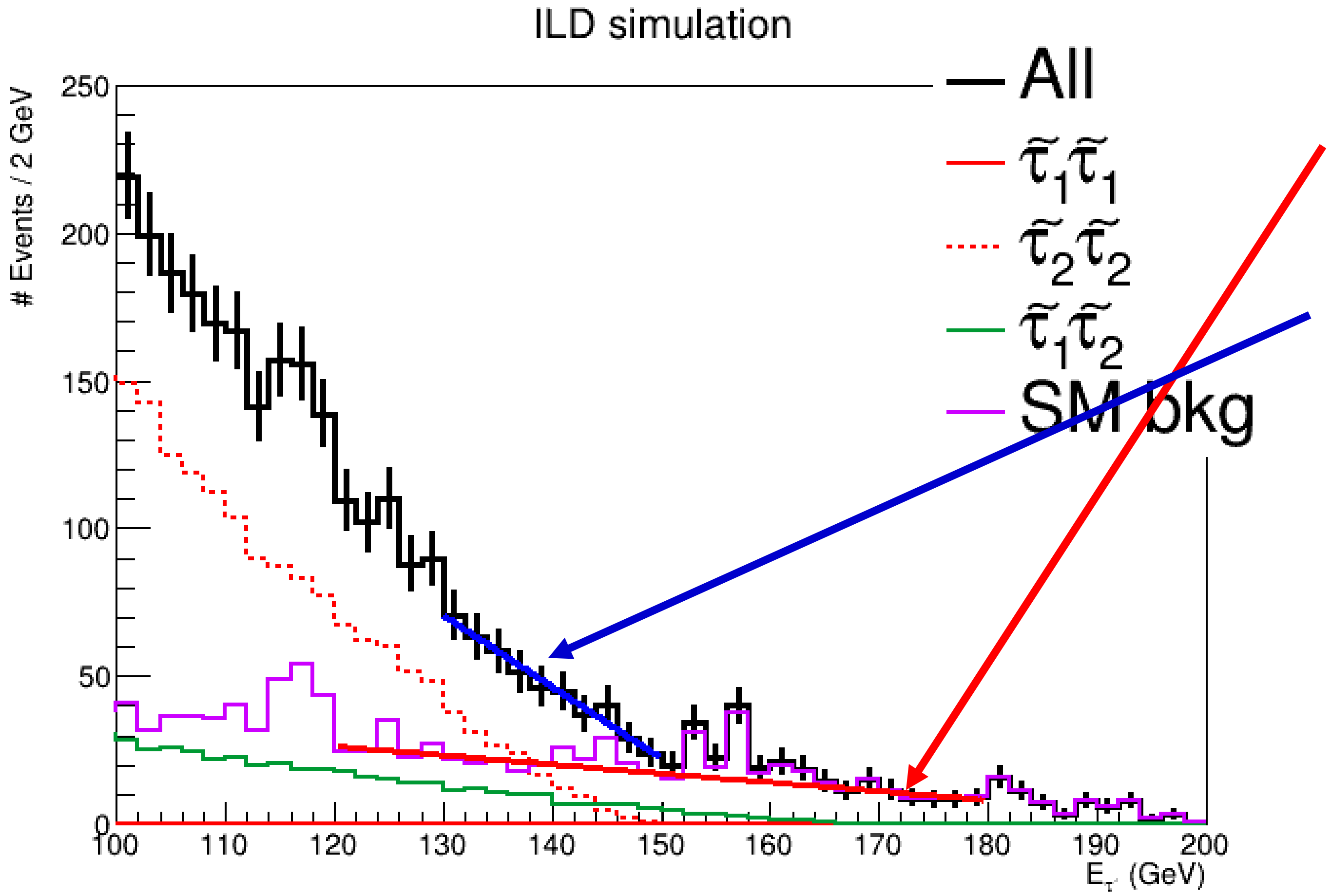


Need to get from the analysis:
- $\tilde{\tau}_2$-pair production endpoint (theory: 150.2 GeV)
- $\tilde{\tau}_1$-pair production endpoint (theory: 55.0 GeV)
- $\tilde{\tau}_1\tilde{\tau}_2$ production event count

Can obtain:
- $M_{\tilde{\tau}_2}$ and $M_{\tilde{\tau}_1}$
- $\sigma(\tilde{\tau}_2\tilde{\tau}_2)$ and $\sigma(\tilde{\tau}_1\tilde{\tau}_2)$
- mixing angle $\sin 2\theta_{\tilde{\tau}}$

Assumption:
- mass of neutralino can determine from other SUSY particle measurement (= 99 GeV)
- aa_2f backgrounds can be vetoed using BeamCal

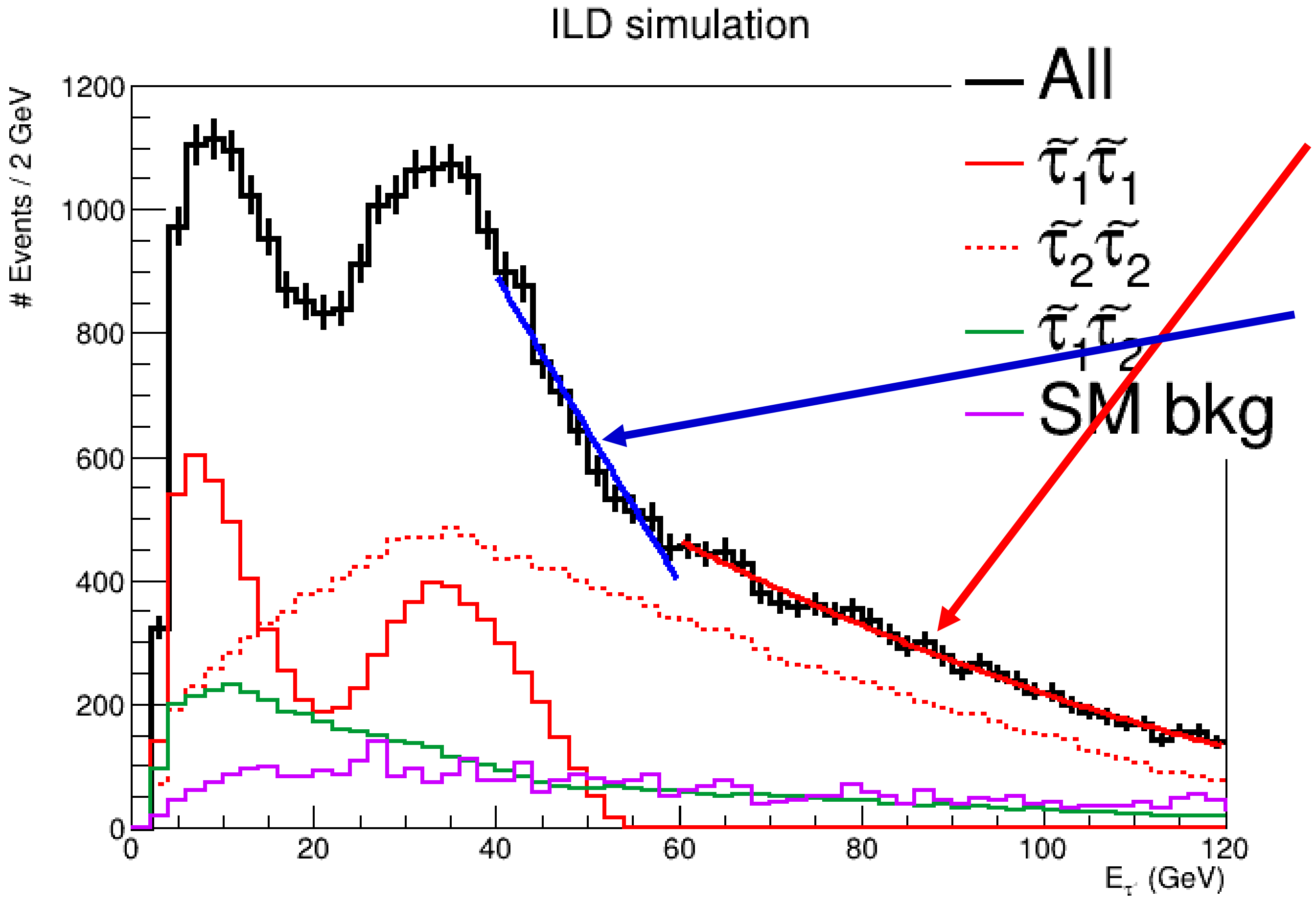
$\widetilde{\tau_2}$ endpoint measurement



- fit SM bkg using straight line [0]*x+[1] with the range 120 - 180 GeV (assume we can determine SM bkg nicely)
- fit all using double straight line [0]*x+[1]+[2]*(x-[3]) with the range 130 - 150 GeV
- obtain endpoint [3] from the fit [3] = 152.0 +- 2.0 GeV

$M_{\widetilde{\tau_2}} = 188.9 \pm 5.1$ GeV
(model = 189.8 GeV)

$\widetilde{\tau}_1$ endpoint measurement



- fit all using 2nd order polynomial
  [0]*x^2+[1]*x +[2] with the range 60 - 120 GeV
- fit all using 2nd order polynomial + straight line
  [0]*x^2+[1]*x +[2]+[3]*(x-[4]) with the range 40 - 60 GeV
- obtain endpoint [4] from the fit
  [4] = 55.89 +- 0.61 GeV

$M_{\widetilde{\tau_1}} = 113.6 \pm 0.2$ GeV
(model = 113.2 GeV)

Summary

- Muon g-2 anomaly is a window to new physics
- SUSY model [2104.03217] can explain this anomaly
- Generated MC samples for realistic estimation at the ILC500
- Designed cuts to reject huge amount of SM background
- (preliminary) can determine ~0.2%/2.5% for stau1/stau2 masses
- Will determine cross-section and mixing angle
- Will write a white paper as Snowmass contribution

BACKUP

Muon g-2 anomaly + SUSY interpretation

The SUSY contributions to the muon $g-2$ can be sizable when at least *three* SUSY multiplets are as light as $\mathcal{O}(100)$ GeV. They are classified into four types: "WHL", "BHL", "BHR", and "BLR", where W, B, H, L, and R stand for wino, bino, higgsino, left-handed and right-handed smuons, respectively. Under the mass-insertion approximation, these four types are given as [23][#4]

$$a_\mu^{\rm WHL} = \frac{\alpha_2}{4\pi}\frac{m_\mu^2}{M_2\mu}\tan\beta\cdot f_C\left(\frac{M_2^2}{m_{\tilde\nu_\mu}^2},\frac{\mu^2}{m_{\tilde\nu_\mu}^2}\right) - \frac{\alpha_2}{8\pi}\frac{m_\mu^2}{M_2\mu}\tan\beta\cdot f_N\left(\frac{M_2^2}{m_{\tilde\mu_{\rm L}}^2},\frac{\mu^2}{m_{\tilde\mu_{\rm L}}^2}\right), \quad (6)$$

$$a_\mu^{\rm BHL} = \frac{\alpha_Y}{8\pi}\frac{m_\mu^2}{M_1\mu}\tan\beta\cdot f_N\left(\frac{M_1^2}{m_{\tilde\mu_{\rm L}}^2},\frac{\mu^2}{m_{\tilde\mu_{\rm L}}^2}\right), \quad (7)$$

$$a_\mu^{\rm BHR} = -\frac{\alpha_Y}{4\pi}\frac{m_\mu^2}{M_1\mu}\tan\beta\cdot f_N\left(\frac{M_1^2}{m_{\tilde\mu_{\rm R}}^2},\frac{\mu^2}{m_{\tilde\mu_{\rm R}}^2}\right), \quad (8)$$

$$a_\mu^{\rm BLR} = \frac{\alpha_Y}{4\pi}\frac{m_\mu^2 M_1\mu}{m_{\tilde\mu_{\rm L}}^2 m_{\tilde\mu_{\rm R}}^2}\tan\beta\cdot f_N\left(\frac{m_{\tilde\mu_{\rm L}}^2}{M_1^2},\frac{m_{\tilde\mu_{\rm R}}^2}{M_1^2}\right), \quad (9)$$

Two-body decay kinematics (1)

- In the end, we have
  - $E^+ = \frac{\sqrt{s}}{4}\left[1-\left(\frac{m_\chi}{m_{\mathrm{SUSY}}}\right)^2\right]\left[1+\sqrt{1-4\left(\frac{m_{\mathrm{SUSY}}}{\sqrt{s}}\right)^2}\right]$
  - $E^- = \frac{\sqrt{s}}{4}\left[1-\left(\frac{m_\chi}{m_{\mathrm{SUSY}}}\right)^2\right]\left[1-\sqrt{1-4\left(\frac{m_{\mathrm{SUSY}}}{\sqrt{s}}\right)^2}\right]$
  - where E^+/E^- is the maximum/minimum energy of lepton (electron/positron/muon/tau), m_{SUSY} is the mass of SUSY particle (selectron/smuon/stau), $\sqrt{s}$ = 500 GeV in this analysis, and m_χ is the neutralino mass and equals to 99 GeV on BLR1 parametrization
  - Ignored lepton masses

Two-body decay kinematics (2)

$\sqrt{s}$ = 500 GeV, $\widetilde{\chi_1^0}$ = 99 GeV, ignored lepton masses

SUSY particle	mass (GeV)	E^+ (GeV)	E^- (GeV)
$\widetilde{e}_L$	157	133.9	16.7
$\widetilde{e_R}$	156	133.0	16.3
$\widetilde{\mu_L}$	158	134.8	17.1
$\widetilde{\mu_R}$	154	131.1	15.6
$\widetilde{\tau}_1$	113	55.0	3.1
$\widetilde{\tau}_2$	190	150.2	31.9

Produced events (1)

Process $e^+e^- \to$	Pol (e-, e+) (%)	Xsec (fb)	N = L*Xsec (Assume L = 4 ab^{-1})	N = L*Xsec (Assume L = 1.6 ab^{-1})	N_generated	process ID
$\tilde{e}_L^+ \tilde{e}_L^-$	-80/+30	28.7091 +- 0.0012	114836	45935	500K	1
$\tilde{e}_L^+ \tilde{e}_L^-$	+80/-30	22.30497 +- 0.00071	89220	35688	500K	2
$\tilde{e}_R^+ \tilde{e}_R^-$	-80/+30	53.5626 +- 0.0019	214250	85700	1M	3
$\tilde{e}_R^+ \tilde{e}_R^-$	+80/-30	54.6909 +- 0.022	218764	87505	1M	4
$\tilde{\mu}_L^+ \tilde{\mu}_L^-$	-80/+30	99.1388 +- 0.0079	396555	158622	1.5M	5
$\tilde{\mu}_L^+ \tilde{\mu}_L^-$	+80/-30	25.9426 +- 0.0021	103770	41508	500K	6
$\tilde{\mu}_R^+ \tilde{\mu}_R^-$	-80/+30	26.9622 +- 0.0021	107849	43140	500K	7
$\tilde{\mu}_R^+ \tilde{\mu}_R^-$	+80/-30	92.4999 +- 0.0072	370000	148000	1.5M	8

1.6 ab^{-1} is the integrated luminosity of ILC500 with -80/+30 and +80/-30

Produced events (2)

Process $e^+e^- \to$	Pol (e-, e+) (%)	Xsec (fb)	N = L*Xsec (Assume L = 4 ab^{-1})	N = L*Xsec (Assume L = 1.6 ab^{-1})	N_generated	process ID
$\tilde{\tau}_1^+\tilde{\tau}_1^-$	-80/+30	92.9890 +- 0.0063	371956	148782	1.5M	9
$\tilde{\tau}_1^+\tilde{\tau}_1^-$	+80/-30	86.6444 +- 0.0059	346578	138631	1.5M	10
$\tilde{\tau}_2^+\tilde{\tau}_2^-$	-80/+30	29.0410 +- 0.0033	116164	46466	500K	11
$\tilde{\tau}_2^+\tilde{\tau}_2^-$	+80/-30	26.3214 +- 0.0029	105286	42114	500K	12
$\tilde{\tau}_1^+\tilde{\tau}_2^-$	-80/+30	8.18989 +- 0.00062	32760	13104	200K	13
$\tilde{\tau}_1^+\tilde{\tau}_2^-$	+80/-30	6.48573 +- 0.00050	25943	10377	200K	14
$\tilde{\tau}_2^+\tilde{\tau}_1^-$	-80/+30	8.19128 +- 0.00062	32765	13106	200K	15
$\tilde{\tau}_2^+\tilde{\tau}_1^-$	+80/-30	6.48553 +- 0.00050	25942	10377	200K	16

1.6 ab^{-1} is the integrated luminosity of ILC500 with -80/+30 and +80/-30

Potential problem

- The spin information is not stored in stau events
  - This might affect to the decay products of tau
  - It is OK for SM world (e.g.: Keita's study)
  - So far, no special treatment applied

Physics analysis

- Made everything luminosity-weighted
  - Considered MC statistics
  - eLpR/eRpL for (e-, e+) = (-80%, +30%)/(+80%, -30%)
  - 1.6 ab^{-1} for both polarization (ILC500 full statistics)
- Included **ALL** available SM background MC samples: in total ~200M MC samples

SM background (1)

- Added **ALL** available IDR samples
  - /gpfs/group/ilc/soft/samples/mc-opt-3/ild/dst-merged/500-TDR_ws/PROCESS/ILD_l5_o1_v02/v02-00-01/~~~~~.slcio
  - processes (h = hadronic, l = leptonic, sl = semileptonic)
    - all 2f (bhabha, h, l)
    - all 4f (singleW_l/sl, singleZee_l/sl, singleZnunu_l/sl, singleZsingleWMix_l, WW_h/l/sl, ZZ_h/l/sl, ZZWWMix_h/l)
    - all 5f
    - all 6f (eeWW, llWW, ttbar, vvWW, xxWW, xxxxZ, yyyyZ)
    - all aa_4f
    - all higgs_ffh (qqh/llh/nnh, no specific decays)

SM background (2)

- Also added **ALL** aa_2f created by SGV
  - /ghi/fs02/orig_root_fs02/ilc/grid/storm/users/berggren/mc-dbd/sgv-dst_6/500-TDR_ws/aa_2f/~~~~~.slcio
  - ~8 years old samples (even used in my PhD thesis)
  - 4 types of processes: aa_ee, aa_ll, aa_xx, aa_yy
- Since the cross-section is huge, there are no full simulation samples of aa_2f @ 500 GeV.
- SGV is pretty much faster, but not enough MC samples (event weight ~ 20, which means 1 MC event corresponds to > 20 real events)

Tau clustering: TaJetClustering

- Originally developed for tau reconstruction under the jet environment
- Treat inclusively, no special treatments for different tau decay
- Used with all default values
  - MinimumJetEnergy = 3 GeV: minimum energy for reconstructed tau
  - MinimumTrackEnergy = 2 GeV: minimum energy for tau seed
  - MinimumTrackEnergyAssoc = 2 GeV: minimum energy for associate particle for tau seed
- This setting might be problematic for $\widetilde{\tau}_1$
  - Theoretical E+ = 55.0 GeV, E- = 3.1 GeV for τ. Its decay products have even lower energy.

PID information

- Now using getParticleIDs instead of getType
- In analysis, DELPHES and full simulation samples information are changed to PID information, not getType information anymore.
  - DELPHES only have 2 algorithms, picked up higher probability one
  - Full simulation: pick up LikelihoodPID
- SGV can only use PID information (due to old?), but performance of PID maybe not so good.
  - e.g.: 2muons + missing in MC truth, 2pions in PID
  - Only one PID is available

Statistics (eLpR)

SUSY	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$4.59*10^4$	$8.57*10^4$	$1.59*10^5$	$4.31*10^4$	$1.49*10^5$	$4.65*10^4$	$2.62*10^4$

SM bkg (1)	Bhabha	2f_l	2f_h	4f_sw_l	4f_sw_sl	4f_sze_l	4f_sze_sl	4f_szn_l	4f_szn_sl	4f_szsw_l
No cuts	$5.40*10^6$	$5.44*10^6$	$3.14*10^7$	$2.59*10^6$	$7.76*10^6$	$1.14*10^7$	$3.01*10^6$	$2.62*10^5$	$8.94*10^5$	$1.04*10^6$

SM bkg (2)	4f_WW_h	4f_WW_l	4f_WW_sl	4f_ZZ_h	4f_ZZ_l	4f_ZZ_sl	4f_ZZWW_h	4f_ZZWW_l	5f	eeWW	llWW
No cuts	$7.91*10^6$	$7.40*10^5$	$8.91*10^6$	$6.52*10^5$	$5.82*10^4$	$5.86*10^5$	$5.99*10^6$	$7.68*10^5$	$1.24*10^5$	$4.61*10^4$	$1.94*10^4$

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$3.23*10^4$	$3.65*10^4$	$1.29*10^3$	$2.80*10^3$	$1.47*10^6$	$3.36*10^5$	$1.15*10^9$	$2.25*10^9$	$8.91*10^8$	$4.12*10^5$

stau events: $O(10^4\text{-}10^5)$
SUSY background: $O(10^4\text{-}10^5)$
SM background: $O(10^7)$
aa_2f: $O(10^9)$

Precuts (eLpR)

SUSY	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$
No cuts	$4.59*10^4$	$8.57*10^4$	$1.59*10^5$	$4.31*10^4$	$1.49*10^5$	$4.65*10^4$	$2.62*10^4$
pre1	$4.31*10^4$	$8.03*10^4$	$1.49*10^5$	$4.07*10^4$	$5.89*10^4$	$3.28*10^4$	$1.35*10^4$
pre2	$4.31*10^4$	$8.03*10^4$	$1.49*10^5$	$4.07*10^4$	$5.86*10^4$	$3.28*10^4$	$1.35*10^4$
pre3	$9.59*10^3$	$1.78*10^3$	$1.49*10^5$	$4.07*10^4$	$5.68*10^4$	$3.19*10^4$	$1.31*10^4$
pre4	0	0	$1.49*10^5$	$4.07*10^4$	$5.62*10^4$	$3.16*10^4$	$1.30*10^4$
pre5	0	0	$1.36*10^4$	$3.75*10^3$	$5.40*10^4$	$3.06*10^4$	$1.25*10^4$
pre6	0	0	0	0	$5.38*10^4$	$3.04*10^4$	$1.24*10^4$
pre7	0	0	0	0	$5.37*10^4$	$3.04*10^4$	$1.24*10^4$
pre8	0	0	0	0	$5.37*10^4$	$3.04*10^4$	$1.24*10^4$

Precuts (eLpR)

SM bkg (1)	Bhabha	2f_l	2f_h	4f_sw_l	4f_sw_sl	4f_sze_l	4f_sze_sl	4f_szn_l	4f_szn_sl	4f_szsw_l
No cuts	$5.40*10^6$	$5.44*10^6$	$3.14*10^7$	$2.59*10^6$	$7.76*10^6$	$1.14*10^7$	$3.01*10^6$	$2.62*10^5$	$8.94*10^5$	$1.04*10^6$
pre1	$2.61*10^6$	$3.09*10^6$	$8.23*10^4$	$1.49*10^6$	$3.72*10^5$	$1.86*10^6$	$2.55*10^5$	$7.51*10^4$	$4.21*10^3$	$6.03*10^5$
pre2	$2.58*10^6$	$3.06*10^6$	$5.78*10^4$	$1.48*10^6$	$2.66*10^4$	$1.62*10^6$	$2.31*10^5$	$7.40*10^4$	$2.84*10^3$	$5.95*10^5$
pre3	$9.41*10^4$	$2.01*10^6$	$6.64*10^3$	$6.31*10^5$	$3.38*10^4$	$5.67*10^5$	$5.60*10^3$	$5.01*10^4$	619	$2.62*10^4$
pre4	$8.44*10^3$	$1.82*10^6$	$5.41*10^3$	$6.44*10^4$	$4.75*10^3$	$4.85*10^5$	$2.11*10^3$	$4.75*10^4$	570	$2.96*10^3$
pre5	$8.04*10^3$	$5.42*10^5$	$3.24*10^3$	$5.54*10^4$	$2.96*10^3$	$1.48*10^5$	$1.39*10^3$	$1.49*10^4$	384	$2.82*10^3$
pre6	$7.75*10^3$	$4.58*10^5$	$2.99*10^3$	$4.31*10^4$	$2.88*10^3$	$1.28*10^5$	$1.31*10^3$	$1.36*10^4$	359	$2.69*10^3$
pre7	$5.62*10^3$	$3.30*10^5$	144	$3.32*10^4$	0	$9.80*10^4$	197	$9.88*10^3$	12.4	$2.01*10^3$
pre8	$4.76*10^3$	$2.94*10^5$	21.4	$3.10*10^4$	0	$7.18*10^4$	66.4	$8.94*10^3$	12.4	$1.86*10^3$

2f_l, 4f_singleW_l, 4f_singleZee_l, 4f_singleZnunu_l: $O(10^3\text{-}10^5)$
semileptonic events: < $O(10^2)$

Precuts (eLpR)

SM bkg (2)	4f_WW_h	4f_WW_l	4f_WW_sl	4f_ZZ_h	4f_ZZ_l	4f_ZZ_sl	4f_ZZWW_h	4f_ZZWW_l	5f	eeWW	llWW
No cuts	$7.91*10^6$	$7.40*10^5$	$8.91*10^6$	$6.52*10^5$	$5.82*10^4$	$5.86*10^5$	$5.99*10^6$	$7.68*10^5$	$1.24*10^5$	$4.61*10^4$	$1.94*10^4$
pre1	$2.85*10^4$	$4.46*10^5$	$4.12*10^5$	$2.50*10^3$	$2.15*10^4$	$1.07*10^5$	$2.46*10^4$	$4.68*10^5$	$3.05*10^4$	$1.35*10^4$	$5.49*10^3$
pre2	$1.67*10^4$	$4.41*10^5$	$2.92*10^5$	$1.47*10^3$	$2.05*10^4$	$1.05*10^5$	$1.48*10^4$	$4.64*10^5$	$2.03*10^4$	$9.31*10^3$	$4.26*10^3$
pre3	$1.70*10^3$	$2.90*10^5$	$7.79*10^4$	82.6	$1.27*10^4$	$2.23*10^4$	$1.59*10^3$	$3.08*10^5$	$2.38*10^3$	378	727
pre4	$1.63*10^3$	$2.43*10^5$	$7.14*10^4$	66.1	$1.17*10^4$	$2.15*10^4$	$1.44*10^3$	$2.79*10^5$	$1.48*10^3$	180	614
pre5	765	$1.53*10^5$	$3.30*10^4$	33.1	$2.73*10^3$	$3.40*10^3$	595	$7.42*10^4$	571	87.8	90.1
pre6	746	$9.42*10^4$	$2.59*10^4$	16.5	$2.40*10^3$	$3.17*10^3$	595	$6.31*10^4$	524	75.8	77.2
pre7	0	$7.33*10^4$	131	0	$1.57*10^3$	23.0	0	$4.63*10^4$	251	34.5	6.49
pre8	0	$6.86*10^4$	56.1	0	$1.38*10^3$	1.87	0	$4.28*10^4$	190	21.7	3.76

4f_WW_l, 4f_ZZWW_l: $O(10^4)$
semileptonic events: $< O(10^2)$
hadronic events: 0

Precuts (eLpR)

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$3.23*10^4$	$3.65*10^4$	$1.29*10^3$	$2.80*10^3$	$1.47*10^6$	$3.36*10^5$	$1.15*10^9$	$2.25*10^9$	$8.91*10^8$	$4.12*10^5$
pre1	$3.85*10^3$	$4.20*10^3$	59.4	500	$1.42*10^5$	$7.63*10^4$	$8.94*10^8$	$1.12*10^9$	$5.46*10^6$	$4.07*10^4$
pre2	$3.51*10^3$	$3.61*10^3$	54.2	401	$1.27*10^5$	$5.74*10^4$	$8.92*10^8$	$1.11*10^9$	$3.64*10^6$	$3.87*10^4$
pre3	$1.50*10^3$	509	3.04	49.3	$1.23*10^4$	$1.38*10^4$	$4.39*10^7$	$1.10*10^9$	$3.16*10^6$	$1.14*10^4$
pre4	936	372	2.88	43.5	$9.68*10^3$	$1.11*10^4$	$4.39*10^7$	$1.10*10^9$	$3.16*10^6$	$9.38*10^3$
pre5	474	81.9	0.312	9.67	$1.48*10^3$	$3.36*10^3$	$4.36*10^7$	$1.10*10^9$	$2.73*10^6$	$6.08*10^3$
pre6	391	68.0	0.312	8.74	$1.28*10^3$	$3.03*10^3$	$4.36*10^7$	$1.10*10^9$	$2.73*10^6$	$5.65*10^3$
pre7	250	0.562	0.0478	2.51	0	$1.43*10^3$	$4.36*10^7$	$1.10*10^9$	$5.03*10^5$	$3.47*10^3$
pre8	232	0.0624	0.0477	0.908	0	$1.18*10^3$	$4.36*10^7$	$1.10*10^9$	$4.16*10^5$	$3.16*10^3$

aa_ll: $O(10^9)$
aa_ee: $O(10^7)$
aa_qq: $O(10^5)$
6f high multiplicity events: negligible

Summary of precuts

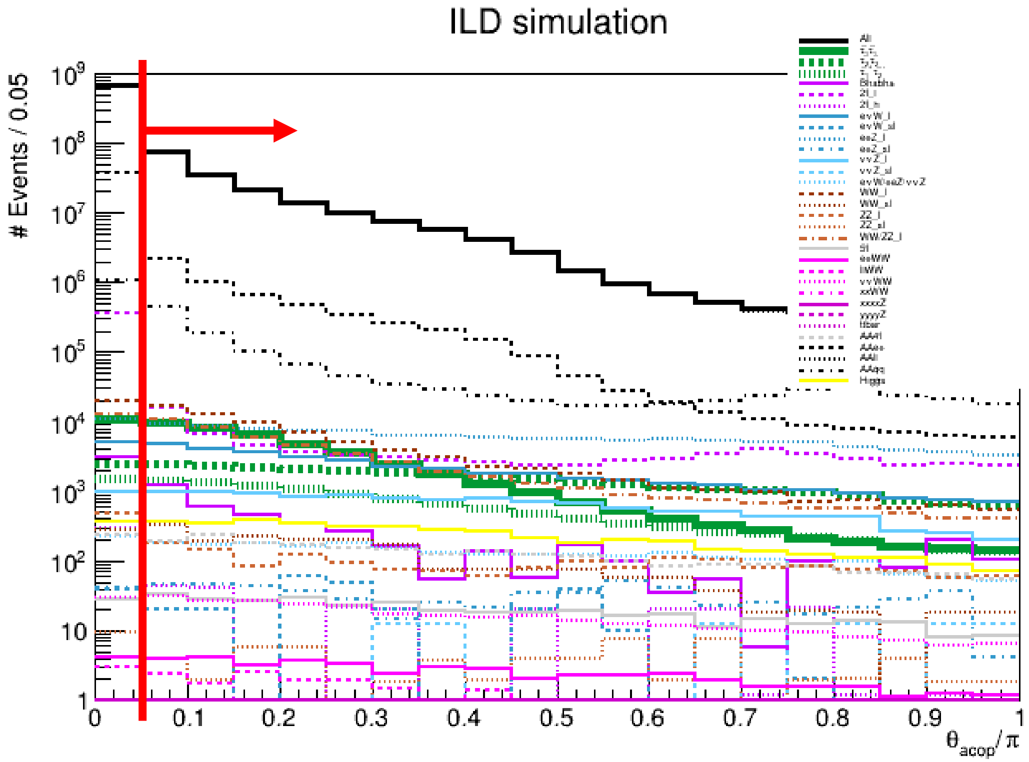
- Already stau1-pair process is rejected by 64%, still order of $O(10^4)$ statistics.
  - Due to default setting of TaJetClustering and its lower energy of decay products
- High multiplicity events are now almost negligible.
- SGV-based samples cannot reject by requiring $N_{(e/mu\text{-}PFO)}$ because such information is not stored in reconstructed PFO. This is maybe due to the performance of PID.
- 198M ---> 29M MC events

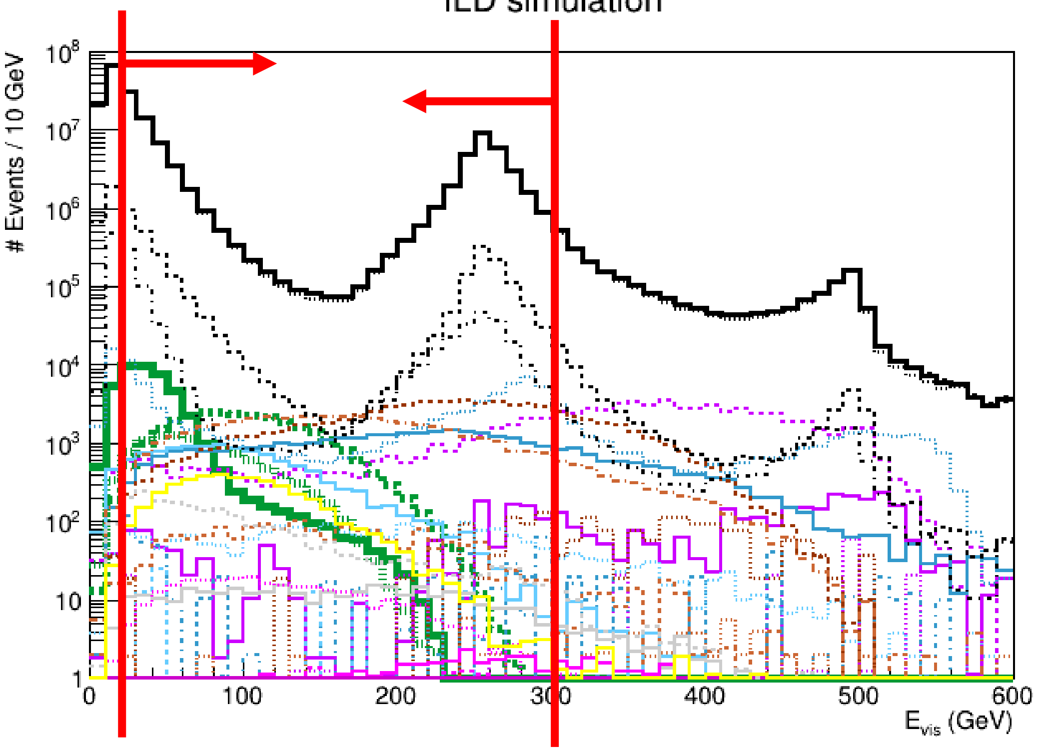
Reject more aa_2f and save stau events

- Stau events: $O(10^4)$ for all channels
- aa_2f: $O(10^9)$ at maximum
- Need to design some cuts to reduce the background level

Cut1 & Cut2

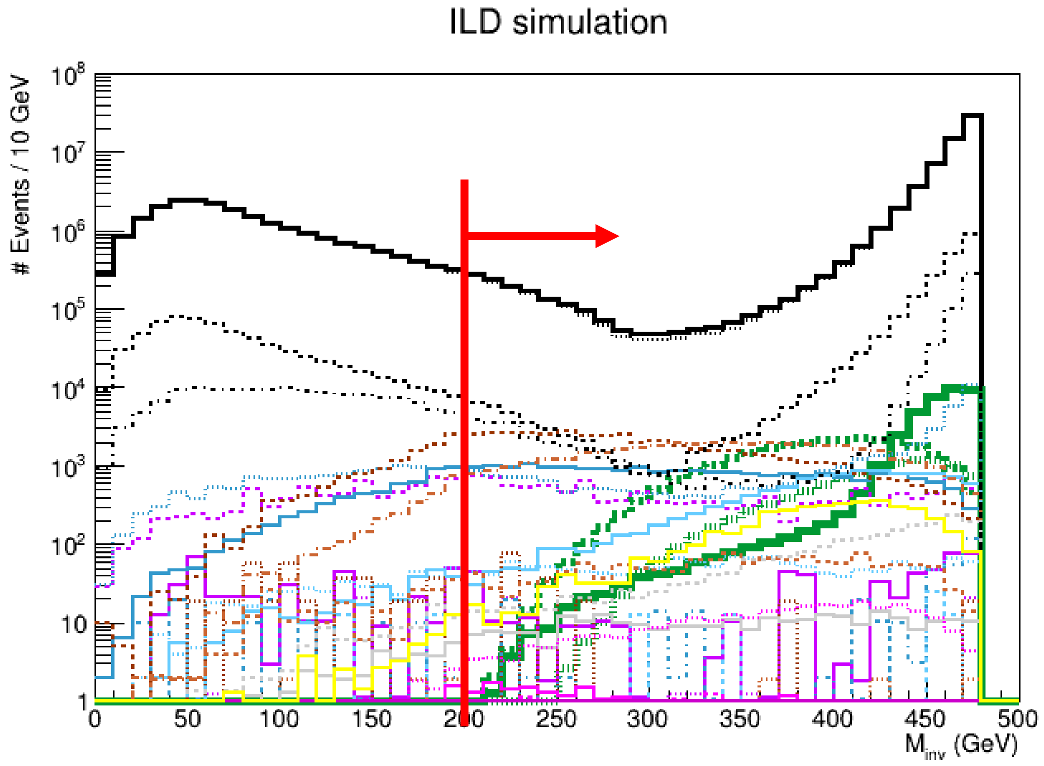
solid black on top: all events summed up
solid/dotted blue: seL/seR
solid/dotted red: smuL/smuR
solid/dotted/thin-dotted green: stau11/stau22/stau12
dotted/thin-dotted black: aa_ee/aa_ll
other colors: other SM background

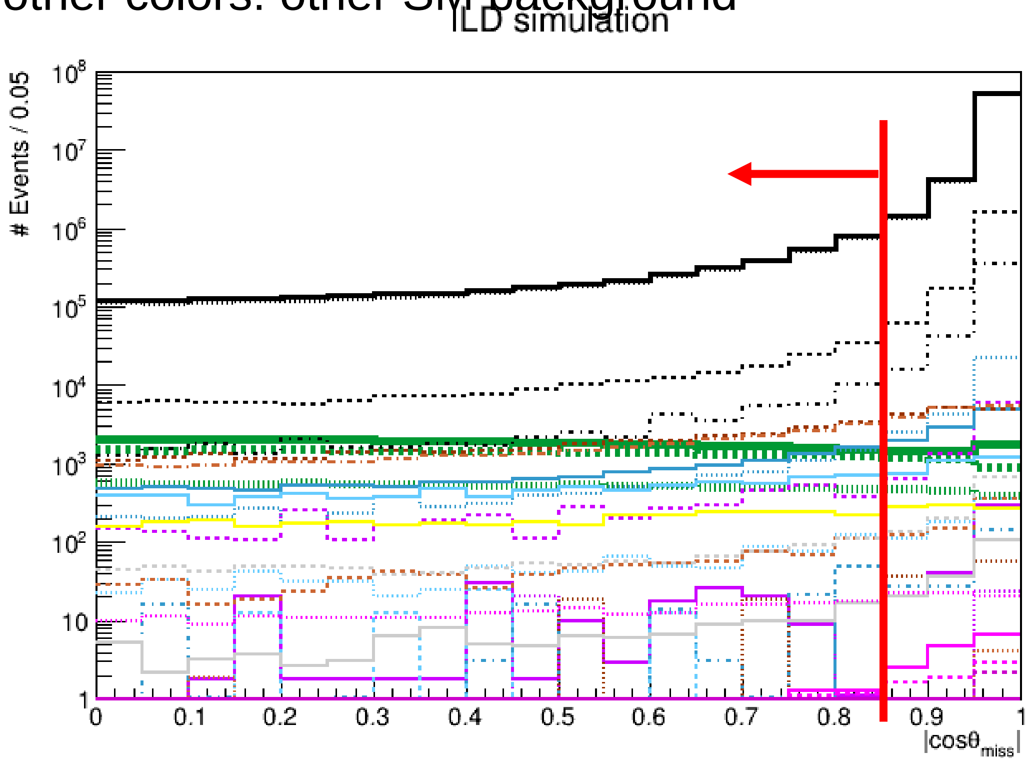




Cut3 & Cut4

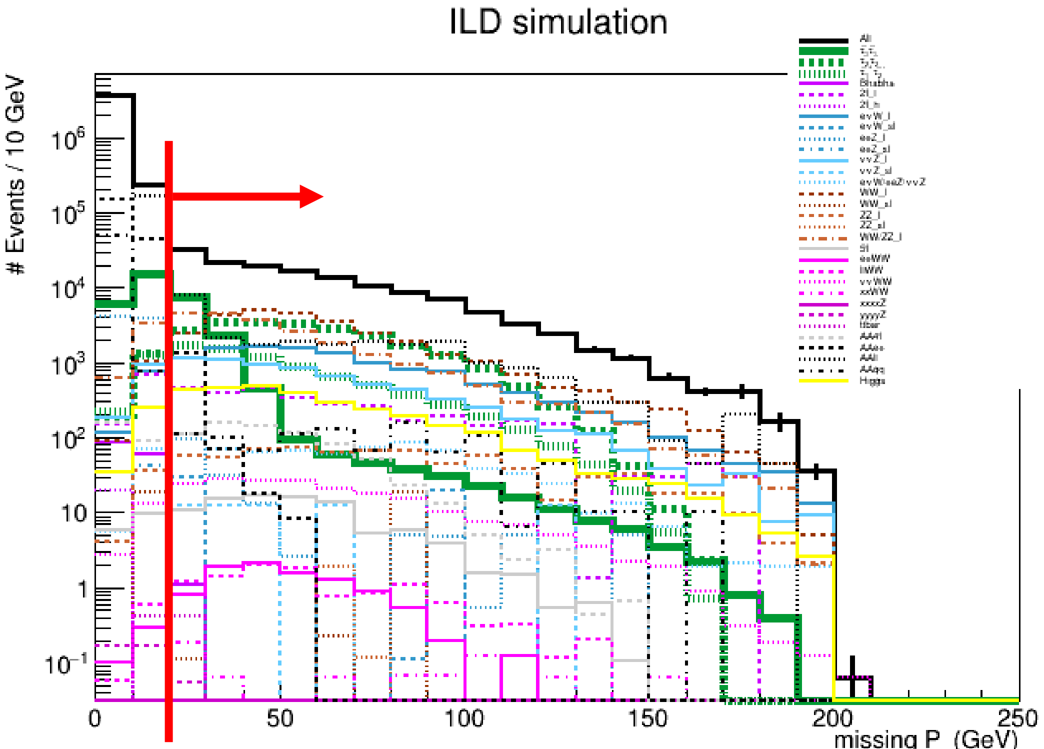
solid black on top: all events summed up
solid/dotted blue: seL/seR
solid/dotted red: smuL/smuR
solid/dotted/thin-dotted green: stau11/stau22/stau12
dotted/thin-dotted black: aa_ee/aa_ll
other colors: other SM background

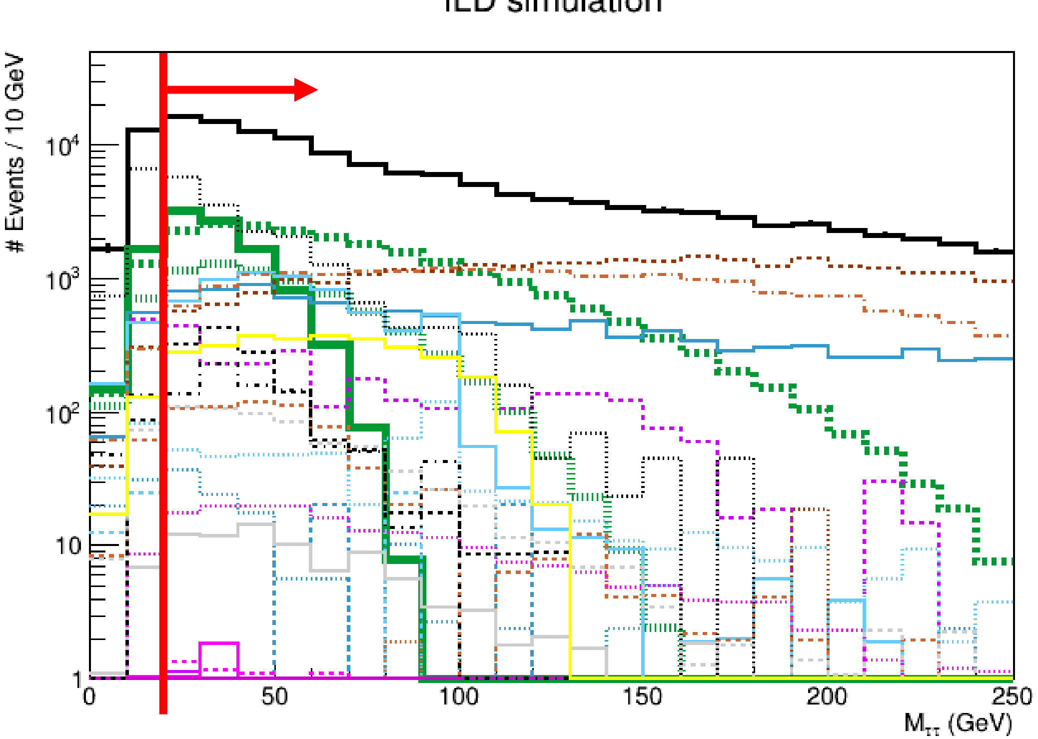




Cut5 & Cut6

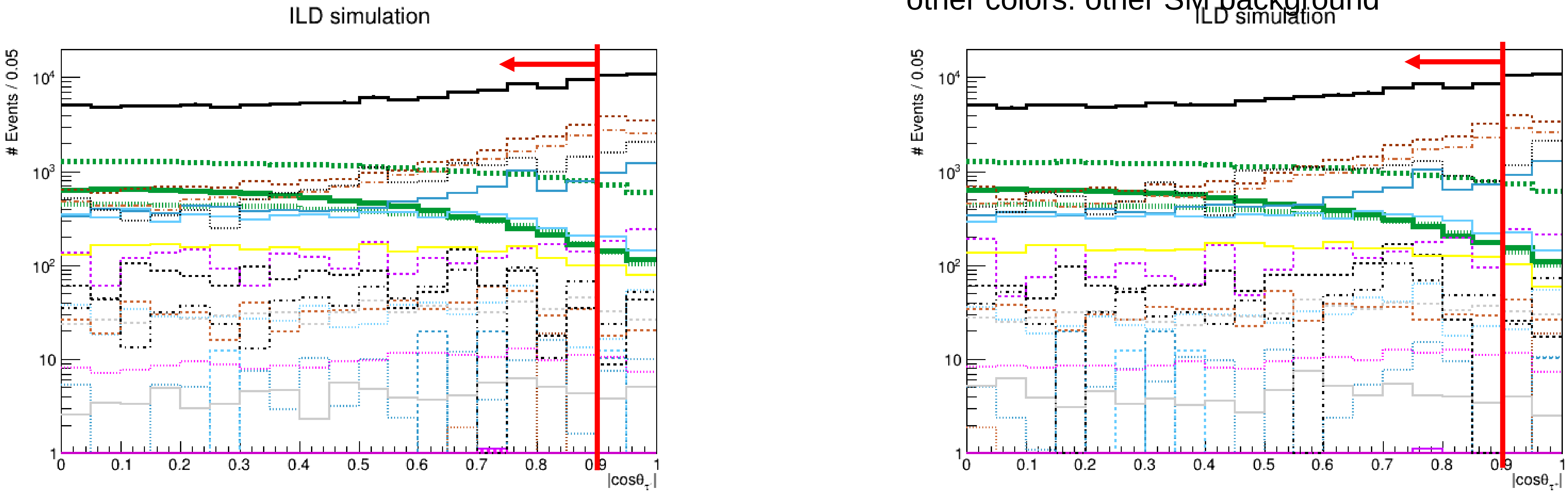
solid black on top: all events summed up
solid/dotted blue: seL/seR
solid/dotted red: smuL/smuR
solid/dotted/thin-dotted green: stau11/stau22/stau12
dotted/thin-dotted black: aa_ee/aa_ll
other colors: other SM background





Cut7

solid black on top: all events summed up
solid/dotted blue: seL/seR
solid/dotted red: smuL/smuR
solid/dotted/thin-dotted green: stau11/stau22/stau12
dotted/thin-dotted black: aa_ee/aa_ll
other colors: other SM background



After Cut7 (eLpR)

SUSY	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$4.59*10^4$	$8.57*10^4$	$1.59*10^5$	$4.31*10^4$	$1.49*10^5$	$4.65*10^4$	$2.62*10^4$
precuts	0	0	0	0	$5.37*10^4$	$3.04*10^4$	$1.24*10^4$
Cut1	0	0	0	0	$4.29*10^4$	$2.79*10^4$	$1.09*10^4$
Cut2	0	0	0	0	$3.69*10^4$	$2.77*10^4$	$1.06*10^4$
Cut3	0	0	0	0	$3.69*10^4$	$2.77*10^4$	$1.06*10^4$
Cut4	0	0	0	0	$3.22*10^4$	$2.45*10^4$	$9.23*10^3$
Cut5	0	0	0	0	$1.06*10^4$	$2.30*10^4$	$7.76*10^3$
Cut6	0	0	0	0	$8.80*10^3$	$2.16*10^4$	$6.93*10^3$
Cut7	0	0	0	0	$8.28*10^3$	$1.89*10^4$	$6.45*10^3$

After Cut7 (eLpR)

SM bkg (1)	Bhabha	2f_l	2f_h	4f_sw_l	4f_sw_sl	4f_sze_l	4f_sze_sl	4f_szn_l	4f_szn_sl	4f_szsw_l
No cuts	$5.40*10^6$	$5.44*10^6$	$3.14*10^7$	$2.59*10^6$	$7.76*10^6$	$1.14*10^7$	$3.01*10^6$	$2.62*10^5$	$8.94*10^5$	$1.04*10^6$
precuts	$4.76*10^3$	$2.94*10^5$	21.4	$3.10*10^4$	0	$7.18*10^4$	66.4	$8.94*10^3$	12.4	$1.86*10^3$
Cut1	$2.74*10^3$	$4.86*10^4$	0	$2.74*10^4$	0	$6.55*10^4$	66.4	$8.29*10^3$	12.4	$1.70*10^3$
Cut2	873	$1.40*10^4$	0	$2.14*10^4$	0	$4.10*10^4$	41.7	$7.82*10^3$	12.4	$1.41*10^3$
Cut3	327	$8.08*10^3$	0	$1.69*10^4$	0	$2.14*10^4$	41.7	$7.61*10^3$	12.4	$1.08*10^3$
Cut4	83.4	$2.57*10^3$	0	$9.41*10^3$	0	$4.62*10^3$	1.05	$5.46*10^3$	12.4	606
Cut5	0	$2.07*10^3$	0	$8.80*10^3$	0	55.5	0	$4.72*10^3$	12.4	557
Cut6	0	$1.75*10^3$	0	$8.34*10^3$	0	39.6	0	$4.27*10^3$	0	475
Cut7	0	$1.29*10^3$	0	$5.47*10^3$	0	31.7	0	$3.78*10^3$	0	366

hadronic and semileptonic events are now negligible
4f_singleW_leptonic: $5.47*10^3$
2f_leptonic: $1.29*10^3$
4f_singleZnunu_leptonic: $3.78*10^3$

After Cut7 (eLpR)

SM bkg (2)	4f_WW_h	4f_WW_l	4f_WW_sl	4f_ZZ_h	4f_ZZ_l	4f_ZZ_sl	4f_ZZWW_h	4f_ZZWW_l	5f	eeWW	llWW
No cuts	$7.91*10^6$	$7.40*10^5$	$8.91*10^6$	$6.52*10^5$	$5.82*10^4$	$5.86*10^5$	$5.99*10^6$	$7.68*10^5$	$1.24*10^5$	$4.61*10^4$	$1.94*10^4$
precuts	0	$6.86*10^4$	56.1	0	$1.38*10^3$	1.87	0	$4.28*10^4$	190	21.7	3.76
Cut1	0	$5.42*10^4$	56.1	0	$1.10*10^3$	1.87	0	$3.40*10^4$	178	19.8	3.17
Cut2	0	$4.26*10^4$	0.112	0	$1.07*10^3$	1.87	0	$3.10*10^4$	159	13.4	3.05
Cut3	0	$3.37*10^4$	0.112	0	930	0	0	$2.93*10^4$	141	10.7	2.49
Cut4	0	$2.24*10^4$	0.112	0	511	0	0	$1.85*10^4$	60.4	4.58	1.35
Cut5	0	$2.15*10^4$	0.112	0	490	0	0	$1.55*10^4$	53.9	4.43	1.03
Cut6	0	$2.13*10^4$	0	0	443	0	0	$1.53*10^4$	49.8	3.71	1.03
Cut7	0	$1.26*10^4$	0	0	373	0	0	$9.34*10^3$	41.3	3.26	0.833

hadronic and semileptonic events are now negligible
4f_WW_leptonic: $1.26*10^4$
4f_ZZWW_leptonic: $9.34*10^3$

After Cut7 (eLpR)

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$3.23*10^4$	$3.65*10^4$	$1.29*10^3$	$2.80*10^3$	$1.47*10^6$	$3.36*10^5$	$1.15*10^9$	$2.25*10^9$	$8.91*10^8$	$4.12*10^5$
precuts	232	0.0624	0.0477	0.908	0	$1.18*10^3$	$4.36*10^7$	$1.10*10^9$	$4.16*10^5$	$3.16*10^3$
Cut1	211	0	0.0477	0.813	0	$1.09*10^3$	$5.53*10^6$	$1.74*10^8$	$1.18*10^5$	$2.90*10^3$
Cut2	208	0	0.0477	0.641	0	$1.02*10^3$	$2.98*10^6$	$8.66*10^7$	$6.95*10^4$	$2.87*10^3$
Cut3	202	0	0.0477	0.543	0	972	$2.03*10^6$	$5.92*10^7$	$5.76*10^4$	$2.84*10^3$
Cut4	155	0	0	0.0552	0	585	$1.92*10^5$	$3.75*10^6$	$1.08*10^3$	$2.24*10^3$
Cut5	143	0	0	~0	0	511	$1.43*10^3$	$2.16*10^4$	3.20	$2.04*10^3$
Cut6	137	0	0	~0	0	453	$1.34*10^3$	$1.47*10^4$	3.20	$1.95*10^3$
Cut7	111	0	0	0	0	368	$1.25*10^3$	$8.85*10^3$	3.20	$1.71*10^3$

hadronic and semileptonic events are now negligible
AA_ee: $1.25*10^3$
AA_ll: $8.85*10^3$

Statistics (eRpL)

SUSY	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$
No cuts	$3.57*10^4$	$8.75*10^4$	$4.15*10^4$	$1.48*10^5$	$1.39*10^5$	$4.21*10^4$	$2.08*10^4$

SM bkg (1)	Bhabha	2f_l	2f_h	4f_sw_l	4f_sw_sl	4f_sze_l	4f_sze_sl	4f_szn_l	4f_szn_sl	4f_szsw_l
No cuts	$5.16*10^6$	$4.38*10^6$	$1.87*10^7$	$3.07*10^5$	$9.15*10^5$	$1.13*10^7$	$2.81*10^6$	$2.95*10^4$	$1.09*10^5$	$1.79*10^5$

SM bkg (2)	4f_WW_h	4f_WW_l	4f_WW_sl	4f_ZZ_h	4f_ZZ_l	4f_ZZ_sl	4f_ZZWW_h	4f_ZZWW_l	5f	eeWW	llWW
No cuts	$4.61*10^5$	$4.82*10^4$	$5.76*10^5$	$2.93*10^5$	$3.78*10^4$	$3.04*10^5$	$4.32*10^5$	$6.37*10^4$	$7.20*10^4$	$1.93*10^4$	$1.63*10^3$

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$2.49*10^3$	$2.95*10^3$	309	$1.59*10^3$	$6.37*10^5$	$3.36*10^5$	$1.15*10^9$	$2.25*10^9$	$8.91*10^8$	$1.30*10^5$

stau events: $O(10^4\text{-}10^5)$
SUSY background: $O(10^4\text{-}10^5)$
SM background: $O(10^7)$
aa_2f: $O(10^9)$

Precuts (eRpL)

SUSY	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$3.57*10^4$	$8.75*10^4$	$4.15*10^4$	$1.48*10^5$	$1.39*10^5$	$4.21*10^4$	$2.08*10^4$
pre1	$3.36*10^4$	$8.18*10^4$	$3.91*10^4$	$1.40*10^5$	$5.49*10^4$	$2.97*10^4$	$1.07*10^4$
pre2	$3.36*10^4$	$8.18*10^4$	$3.91*10^4$	$1.40*10^5$	$5.46*10^4$	$2.97*10^4$	$1.07*10^4$
pre3	$7.48*10^3$	$1.83*10^4$	$3.91*10^4$	$1.40*10^5$	$5.29*10^4$	$2.89*10^4$	$1.03*10^4$
pre4	0	0	$3.91*10^4$	$1.40*10^5$	$5.23*10^4$	$2.86*10^4$	$1.02*10^4$
pre5	0	0	$3.58*10^3$	$1.28*10^4$	$5.03*10^4$	$2.77*10^4$	$9.87*10^3$
pre6	0	0	0	0	$5.00*10^4$	$2.76*10^4$	$9.83*10^3$
pre7	0	0	0	0	$5.00*10^4$	$2.76*10^4$	$9.82*10^3$
pre8	0	0	0	0	$5.00*10^4$	$2.76*10^4$	$9.82*10^3$

Precuts (eRpL)

SM bkg (1)	Bhabha	2f_l	2f_h	4f_sw_l	4f_sw_sl	4f_sze_l	4f_sze_sl	4f_szn_l	4f_szn_sl	4f_szsw_l
No cuts	$5.16*10^6$	$4.38*10^6$	$1.87*10^7$	$3.07*10^5$	$9.15*10^5$	$1.13*10^7$	$2.81*10^6$	$2.95*10^4$	$1.09*10^5$	$1.79*10^5$
pre1	$2.46*10^6$	$2.40*10^6$	$4.86*10^4$	$1.37*10^5$	$3.53*10^4$	$1.83*10^6$	$1.90*10^5$	$8.97*10^3$	418	$7.21*10^4$
pre2	$2.44*10^6$	$2.37*10^6$	$3.41*10^4$	$1.34*10^5$	$2.53*10^4$	$1.60*10^6$	$1.70*10^5$	$8.87*10^3$	289	$7.03*10^4$
pre3	$8.90*10^4$	$1.54*10^6$	$3.67*10^3$	$5.79*10^4$	$3.39*10^3$	$5.65*10^5$	$4.70*10^3$	$5.92*10^3$	55.7	$3.43*10^3$
pre4	$8.05*10^3$	$1.40*10^6$	$3.08*10^3$	$7.04*10^3$	547	$4.84*10^5$	$2.02*10^3$	$5.54*10^3$	50.9	407
pre5	$7.65*10^3$	$4.15*10^5$	$1.78*10^3$	$6.01*10^3$	344	$1.47*10^5$	$1.52*10^3$	$1.69*10^3$	32.3	395
pre6	$7.47*10^3$	$3.51*10^5$	$1.63*10^3$	$4.78*10^3$	317	$1.27*10^5$	$1.45*10^3$	$1.50*10^3$	30.8	377
pre7	$5.79*10^3$	$2.53*10^5$	48.3	$3.71*10^3$	0	$9.70*10^4$	189	$1.11*10^3$	0.739	274
pre8	$4.84*10^3$	$2.25*10^5$	21.1	$3.45*10^3$	0	$7.10*10^4$	90.1	$1.02*10^3$	0.739	253

2f_l, 4f_singleZee_l: $O(10^4\text{-}10^5)$
semileptonic events: $< O(10^2)$

Precuts (eRpL)

SM bkg (2)	4f_WW_h	4f_WW_l	4f_WW_sl	4f_ZZ_h	4f_ZZ_l	4f_ZZ_sl	4f_ZZWW_h	4f_ZZWW_l	5f	eeWW	llWW
No cuts	$4.61*10^5$	$4.82*10^4$	$5.76*10^5$	$2.93*10^5$	$3.78*10^4$	$3.04*10^5$	$4.32*10^5$	$6.37*10^4$	$7.20*10^4$	$1.93*10^4$	$1.63*10^3$
pre1	$1.85*10^3$	$2.96*10^4$	$2.74*10^4$	845	$1.34*10^4$	$5.36*10^4$	$1.80*10^3$	$3.54*10^4$	$1.63*10^4$	$4.87*10^3$	465
pre2	$1.08*10^3$	$2.93*10^4$	$1.93*10^4$	384	$1.27*10^4$	$5.23*10^4$	$1.10*10^3$	$3.51*10^4$	$1.11*10^4$	$3.17*10^3$	368
pre3	109	$1.93*10^4$	$5.29*10^3$	4.94	$7.87*10^3$	$1.13*10^4$	141	$2.32*10^4$	$1.72*10^3$	244	65.2
pre4	105	$1.63*10^4$	$4.85*10^3$	3.96	$7.29*10^3$	$1.08*10^4$	132	$2.11*10^4$	$1.20*10^3$	125	55.7
pre5	51.4	$1.03*10^4$	$2.27*10^3$	1.98	$1.53*10^3$	$1.84*10^3$	71.0	$5.84*10^3$	426	61.7	8.27
pre6	50.2	$6.48*10^3$	$1.79*10^3$	0.989	$1.33*10^3$	$1.68*10^3$	71.0	$5.03*10^3$	389	52.9	7.17
pre7	0	$4.99*10^3$	9.69	0	804	11.0	0	$3.69*10^3$	200	28.8	0.722
pre8	0	$4.67*10^3$	5.22	0	706	0.112	0	$3.42*10^3$	153	18.5	0.426

4f_WW_l, 4f_ZZ_l, 4f_ZZWW_l: $O(10^3)$
semileptonic events: < O(10)
hadronic events: 0

Precuts (eRpL)

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$2.49*10^3$	$2.95*10^3$	309	$1.59*10^3$	$6.37*10^5$	$3.36*10^5$	$1.15*10^9$	$2.25*10^9$	$8.91*10^8$	$1.30*10^5$
pre1	296	354	26.2	358	$6.17*10^4$	$7.63*10^4$	$8.94*10^8$	$1.12*10^9$	$5.46*10^6$	$1.77*10^4$
pre2	271	308	24.2	279	$5.54*10^4$	$5.74*10^4$	$8.92*10^8$	$1.11*10^9$	$3.64*10^6$	$1.70*10^4$
pre3	114	43.2	1.24	39.4	$5.51*10^3$	$1.38*10^4$	$4.39*10^7$	$1.10*10^9$	$3.16*10^6$	$3.01*10^3$
pre4	70.5	31.6	1.14	34.4	$4.29*10^3$	$1.11*10^4$	$4.39*10^7$	$1.10*10^9$	$3.16*10^6$	$2.55*10^3$
pre5	35.7	6.85	0.117	8.15	633	$3.36*10^3$	$4.36*10^7$	$1.10*10^9$	$2.73*10^6$	$1.17*10^3$
pre6	29.6	5.80	0.117	7.22	556	$3.03*10^3$	$4.36*10^7$	$1.10*10^9$	$2.73*10^6$	$1.09*10^3$
pre7	19.2	0.0346	0.00558	2.28	0	$1.43*10^3$	$4.36*10^7$	$1.10*10^9$	$5.03*10^5$	445
pre8	17.7	0.00373	0.00285	0.814	0	$1.18*10^3$	$4.36*10^7$	$1.10*10^9$	$4.16*10^5$	401

aa_ll: $O(10^9)$
aa_ee: $O(10^7)$
aa_qq: $O(10^5)$
6f high multiplicity events: negligible

After Cut7 (eRpL)

SUSY	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$3.57*10^4$	$8.75*10^4$	$4.15*10^4$	$1.48*10^5$	$1.39*10^5$	$4.21*10^4$	$2.08*10^4$
precuts	0	0	0	0	$5.00*10^4$	$2.76*10^4$	$9.82*10^3$
Cut1	0	0	0	0	$4.00*10^4$	$2.53*10^4$	$8.63*10^3$
Cut2	0	0	0	0	$3.44*10^4$	$2.51*10^4$	$8.34*10^3$
Cut3	0	0	0	0	$3.44*10^4$	$2.51*10^4$	$8.34*10^3$
Cut4	0	0	0	0	$2.99*10^4$	$2.21*10^4$	$7.29*10^3$
Cut5	0	0	0	0	$9.82*10^3$	$2.08*10^4$	$6.12*10^3$
Cut6	0	0	0	0	$8.13*10^3$	$1.95*10^4$	$5.47*10^3$
Cut7	0	0	0	0	$7.65*10^3$	$1.71*10^4$	$5.09*10^3$

After Cut7 (eRpL)

SM bkg (1)	Bhabha	2f_l	2f_h	4f_sw_l	4f_sw_sl	4f_sze_l	4f_sze_sl	4f_szn_l	4f_szn_sl	4f_szsw_l
No cuts	$5.16*10^6$	$4.38*10^6$	$1.87*10^7$	$3.07*10^5$	$9.15*10^5$	$1.13*10^7$	$2.81*10^6$	$2.95*10^4$	$1.09*10^5$	$1.79*10^5$
precuts	$4.84*10^3$	$2.25*10^5$	21.1	$3.45*10^3$	0	$7.10*10^4$	90.1	$1.02*10^3$	0.739	253
Cut1	$2.95*10^3$	$3.60*10^4$	0	$3.12*10^3$	0	$6.49*10^4$	90.1	943	0.739	235
Cut2	769	$9.61*10^3$	0	$2.64*10^3$	0	$4.05*10^4$	69.6	905	0.739	189
Cut3	289	$5.56*10^3$	0	$1.99*10^3$	0	$2.11*10^4$	69.6	821	0.739	122
Cut4	63.1	$1.66*10^3$	0	934	0	$4.74*10^3$	17.6	526	0.739	59.8
Cut5	0	$1.31*10^3$	0	881	0	48.0	0	473	0.739	56.9
Cut6	0	$1.06*10^3$	0	822	0	40.0	0	429	0	48.0
Cut7	0	709	0	493	0	31.4	0	375	0	28.9

hadronic and semileptonic events are now negligible
2f_leptonic: 709
4f_singleW_leptonic: 493
4f_singleZnunu_leptonic: 375

After Cut7 (eRpL)

SM bkg (2)	4f_WW_h	4f_WW_l	4f_WW_sl	4f_ZZ_h	4f_ZZ_l	4f_ZZ_sl	4f_ZZWW_h	4f_ZZWW_l	5f	eeWW	llWW
No cuts	$4.61*10^5$	$4.82*10^4$	$5.76*10^5$	$2.93*10^5$	$3.78*10^4$	$3.04*10^5$	$4.32*10^5$	$6.37*10^4$	$7.20*10^4$	$1.93*10^4$	$1.63*10^3$
precuts	0	$4.67*10^3$	5.22	0	706	0.112	0	$3.42*10^3$	153	18.5	0.426
Cut1	0	$3.68*10^3$	5.22	0	519	0.112	0	$2.79*10^3$	142	17.3	0.380
Cut2	0	$2.96*10^3$	1.87	0	508	0.112	0	$2.60*10^3$	127	12.2	0.360
Cut3	0	$2.40*10^3$	1.87	0	452	0	0	$2.42*10^3$	108	10.1	0.304
Cut4	0	$1.67*10^3$	1.87	0	226	0	0	$1.55*10^3$	47.2	4.31	0.161
Cut5	0	$1.60*10^3$	1.87	0	223	0	0	$1.33*10^3$	41.2	4.07	0.135
Cut6	0	$1.59*10^3$	0	0	204	0	0	$1.30*10^3$	37.9	3.74	0.127
Cut7	0	$1.06*10^3$	0	0	168	0	0	912	31.4	3.30	0.105

hadronic and semileptonic events are now negligible
4f_WW_leptonic: $1.06*10^3$
4f_ZZWW_leptonic: 912

After Cut7 (eRpL)

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$2.49*10^3$	$2.95*10^3$	309	$1.59*10^3$	$6.37*10^5$	$3.36*10^5$	$1.15*10^9$	$2.25*10^9$	$8.91*10^8$	$1.30*10^5$
precuts	17.7	0.00373	0.00285	0.814	0	$1.18*10^3$	$4.36*10^7$	$1.10*10^9$	$4.16*10^5$	401
Cut1	16.2	0	0.00285	0.700	0	$1.09*10^3$	$5.53*10^6$	$1.74*10^8$	$1.18*10^5$	382
Cut2	15.9	0	0.00285	0.601	0	$1.02*10^3$	$2.98*10^6$	$8.66*10^7$	$6.95*10^4$	376
Cut3	15.6	0	0.00285	0.542	0	972	$2.03*10^6$	$5.92*10^7$	$5.76*10^4$	366
Cut4	11.9	0	0	0.0585	0	585	$1.92*10^5$	$3.75*10^6$	$1.08*10^3$	311
Cut5	11.1	0	0	~0	0	511	$1.43*10^3$	$2.16*10^4$	3.20	296
Cut6	10.5	0	0	~0	0	453	$1.34*10^3$	$1.47*10^4$	3.20	281
Cut7	8.55	0	0	0	0	368	$1.25*10^3$	$8.85*10^3$	3.20	244

hadronic and semileptonic events are now negligible
AA_ee: $1.25*10^3$
AA_ll: $8.85*10^3$