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

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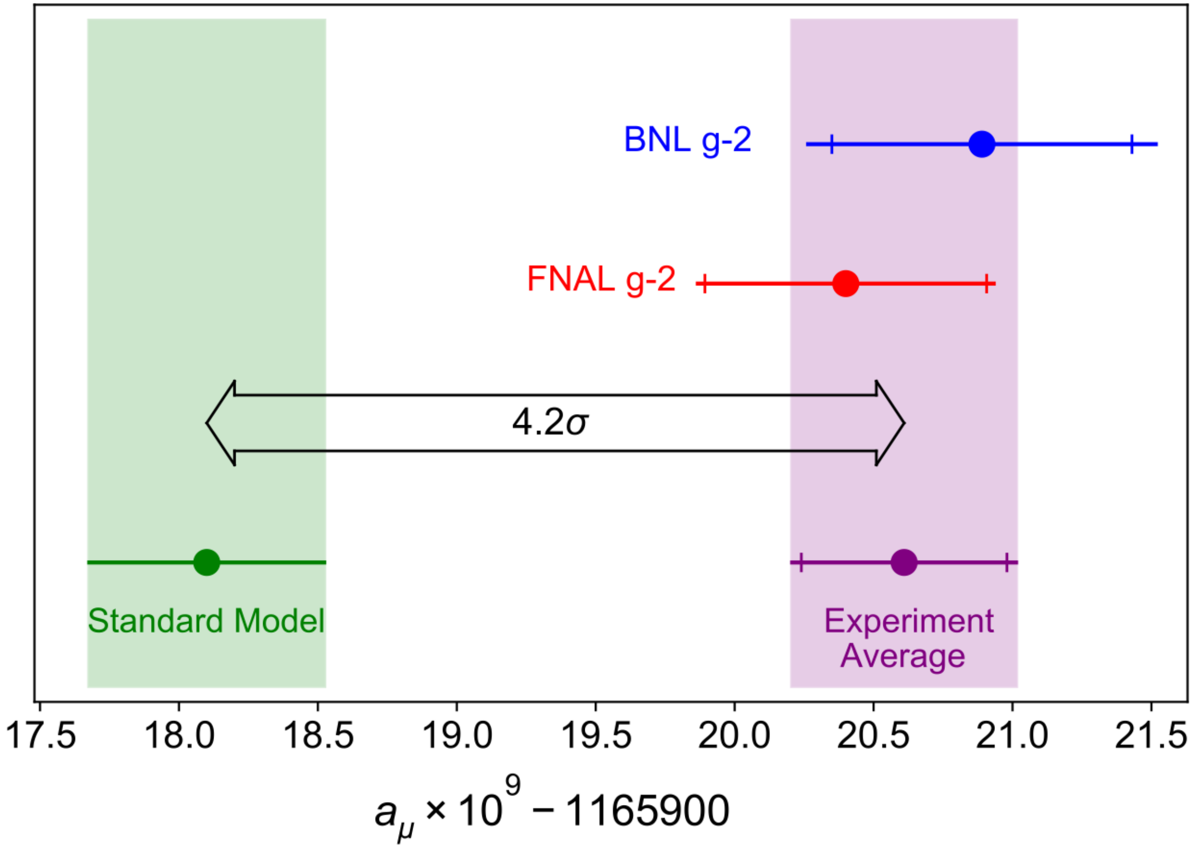
Introduction: muon g-2 anomaly



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

Now the discrepancy between the experimental and theoretical values amounts to

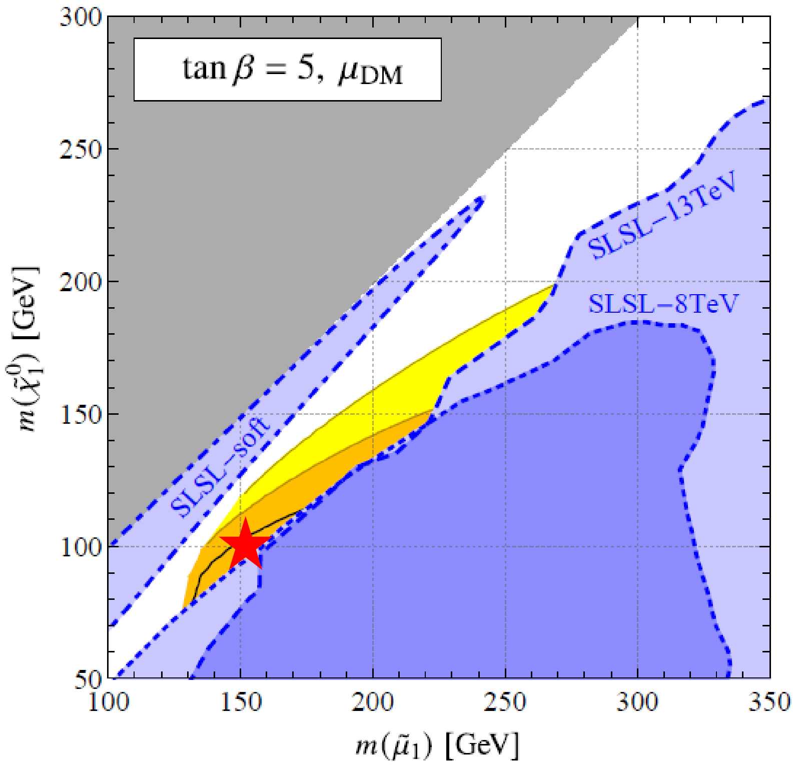
$$\Delta a_\mu \equiv a_\mu^{\mathrm{BNL+FNAL}} - a_\mu^{\mathrm{SM}} = (25.1 \pm 5.9) \times 10^{-10}\,, \qquad (5)$$

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)

	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

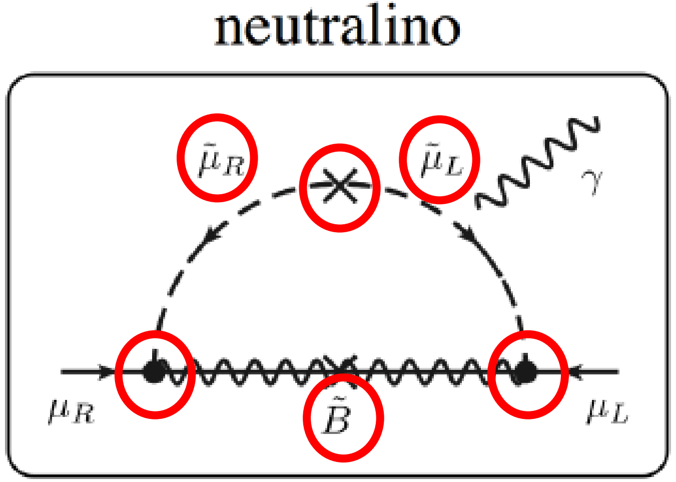


$\tilde{\mu}_1$ mass

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

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

Muon g-2 and ILC



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

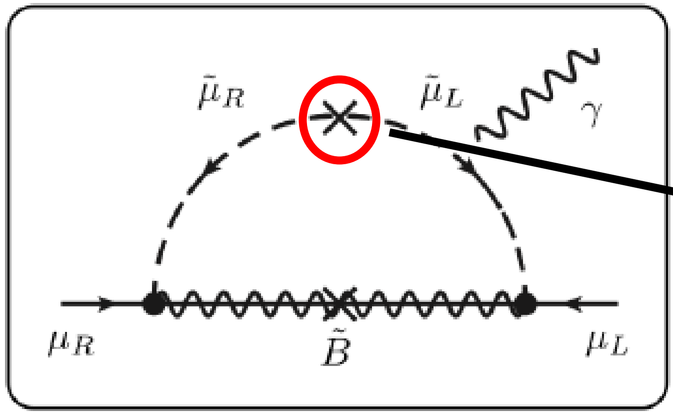
Table 2: Observables necessary for the reconstruction of $a_\mu^{(\mathrm{ILC})}$, and their uncertainties with $\sqrt{s} = 500$ GeV and $\mathcal{L} \sim 500$–$1000\,\mathrm{fb}^{-1}$. Processes relevant to determine each observable are also shown. The second and third rows are the information to determine $m^2_{\tilde{\mu}LR}$. 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

neutralino



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

SUSY contribution to muon g-2

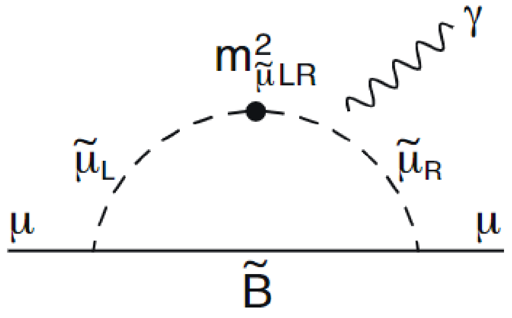


Figure 1: The Bino-smuon loop diagram contributing to $a_\mu^{\rm SUSY}$.

We denote this contribution by $a_\mu^{(\tilde{B})}$.
(Bino-smuon diagram)

When we have Higgsino mass parameter $\mu \gg 1$ TeV and
light masses of Binos and smuons (100 - 200 GeV), $a_\mu^{\rm SUSY} \cong a_\mu^{(\tilde{B})} \cong \Delta a_\mu$.
For the reconstruction of $a_\mu^{(\tilde{B})}$, we need the following 4 numbers.
(1) masses of smuons
(2) Bino (i.e. the lightest neutralino) mass
(3) lepton-slepton-Bino couplings
(4) left-right mixing parameter of the smuons $m^2_{\tilde{\mu}LR}$
In our paper, we used old results for (1) - (3). Stau study is necessary to obtain (4).

Workflow

model building
model point decision [2104.03217]

generate MC samples based on the model point
perform physics analysis
provide numbers/plots for final evaluation
(endpoints, cross-sections)

perform final evaluation
(stau masses, mixing parameter, SUSY contribution to muon g-2 a_μ^{SUSY})

	Theory / Model point	First Snowmass deadline (Mar./15)
Used dataset		eRpL 1.6 ab^{-1}
$m_{\widetilde{\tau_1}}$	113.2 GeV	112.8 ± 0.2 GeV
$m_{\widetilde{\tau_2}}$	189.8 GeV	$188.6^{+4.9}_{-3.9}$ GeV
$\cos\theta_{\tilde{\tau}}$	0.703	$0.680^{+0.070}_{-0.051}$
$-m^2_{\tilde{\tau}LR}$	11606 GeV^2	$(1.21^{+0.03}_{-0.12}) \times 10^4$ GeV^2
$-m^2_{\tilde{\mu}LR}$	690 GeV^2	720^{+17}_{-70} GeV^2
$a_\mu^{(\tilde{B})}$	27.5×10^{-10}	$26.4^{+2.1}_{-1.7} \times 10^{-10}$ [-7%, +8%]

※ $m_{\widetilde{\chi_1^0}} = 99.3 \pm 0.1$ GeV is assumed.

	Theory / Model point	First Snowmass deadline (Mar./15)	Final result
Used dataset		eRpL 1.6 ab^{-1}	eLpR 1.6 ab^{-1} + eRpL 1.6 ab^{-1}
$m_{\tilde{\tau}_1}$	113.2 GeV	112.8 ± 0.2 GeV	112.8 ± 0.2 GeV
$m_{\tilde{\tau}_2}$	189.8 GeV	$188.6^{+4.9}_{-3.9}$ GeV	$189.9^{+0.8}_{-0.7}$ GeV
$\cos\theta_{\tilde{\tau}}$	0.703	$0.680^{+0.070}_{-0.051}$	0.703 ± 0.010
$-m^2_{\tilde{\tau}LR}$	11606 GeV^2	$(1.21^{+0.03}_{-0.12}) \times 10^4$ GeV^2	$(1.17 \pm 0.01) \times 10^4$ GeV^2
$-m^2_{\tilde{\mu}LR}$	690 GeV^2	720^{+17}_{-70} GeV^2	693^{+9}_{-8} GeV^2
$a_\mu^{(\tilde{B})}$	27.5×10^{-10}	$26.4^{+2.1}_{-1.7} \times 10^{-10}$ [-7%, +8%]	$(27.5 \pm 0.4) \times 10^{-10}$ [+-1%]

※ $m_{\tilde{\chi}^0_1} = 99.3 \pm 0.1$ GeV is assumed.

Summary & Next step

- Added eLpR numbers/results
- Evaluated final numbers with eLpR dataset
- Significantly improved results! (for BLR1 model point)

- For the full paper:
  - Need new model point [TH work]
  - Fully-simulated samples and physics analysis [EXP work]

BACKUP

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 (~210M 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	$\widetilde{e}_L\widetilde{e}_L$	$\widetilde{e}_R\widetilde{e}_R$	$\widetilde{e}_L\widetilde{e}_R$	$\widetilde{\mu}_L\widetilde{\mu}_L$	$\widetilde{\mu}_R\widetilde{\mu}_R$	$\widetilde{\tau}_1^+\widetilde{\tau}_1^-$	$\widetilde{\tau}_2^+\widetilde{\tau}_2^-$	$\widetilde{\tau}_1\widetilde{\tau}_2$	SM bkg	aa_2f
No cuts	$4.593*10^4$	$8.570*10^4$	$2.205*10^5$	$1.586*10^5$	$4.314*10^4$	$1.488*10^5$	$4.647*10^4$	$2.621*10^4$	$9.663*10^7$	$4.283*10^9$

eRpL	$\widetilde{e}_L\widetilde{e}_L$	$\widetilde{e}_R\widetilde{e}_R$	$\widetilde{e}_L\widetilde{e}_R$	$\widetilde{\mu}_L\widetilde{\mu}_L$	$\widetilde{\mu}_R\widetilde{\mu}_R$	$\widetilde{\tau}_1^+\widetilde{\tau}_1^-$	$\widetilde{\tau}_2^+\widetilde{\tau}_2^-$	$\widetilde{\tau}_1\widetilde{\tau}_2$	SM bkg	aa_2f
No cuts	$3.569*10^4$	$8.751*10^5$	$1.852*10^5$	$4.151*10^4$	$1.480*10^5$	$1.386*10^5$	$4.211*10^4$	$2.075*10^4$	$4.727*10^7$	$4.283*10^9$

O(10^4-10^5) stau events vs O(10^9) SM bkg + aa_2f
Clearly need to design cuts to reject background

Design of precuts

- pre1: N_{tau} == 2
- pre2: E_{tau+} != 0, E_{tau-} != 0 — equivalent to require opposite charged tau
- pre3: N_{e} in taus == 0
- pre4: N_{mu} in taus == 0

reject leptonic events and
apply veto both tau->1-prong+no photon
mainly for rejecting SUSY background

- pre5: N_{photon} in taus >= 1 or $N_{chargedPFO}$ in taus >= 3
- pre6: $N_{chargedPFO}$ except tau <= 1
- pre7: $N_{neutralPFO}$ except tau<= 5

(pre6, pre7) reject high multiplicity events

After precuts (1.6 ab^{-1})

eLpR	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{e_L}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$	SM bkg	aa_2f
No cuts	$4.593*10^4$	$8.570*10^4$	$2.205*10^5$	$1.586*10^5$	$4.314*10^4$	$1.488*10^5$	$4.647*10^4$	$2.621*10^4$	$9.663*10^7$	$4.283*10^9$
precuts	571.2	1081	2703	234.9	62.47	$2.157*10^4$	$1.340*10^4$	5176	$1.209*10^5$	$3.047*10^7$

eRpL	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{e_L}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$	SM bkg	aa_2f
No cuts	$3.569*10^4$	$8.751*10^5$	$1.852*10^5$	$4.151*10^4$	$1.480*10^5$	$1.386*10^5$	$4.211*10^4$	$2.075*10^4$	$4.727*10^7$	$4.283*10^9$
precuts	441.7	$1.081*10^4$	2272	64.01	215.7	$2.004*10^4$	$1.213*10^4$	4128	$7.292*10^4$	$3.047*10^7$

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: $|\cos\theta_{\mathrm{miss}}| < 0.9$
- Cut5: missing P_t > 20 GeV
- Cut6: $|\cos\theta_{\tau^{\pm}}| < 0.9$

After Cuts1-6 (1.6 ab^{-1})

eLpR	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{e}_L\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg	aa_2f
No cuts	$4.593*10^4$	$8.570*10^4$	$2.205*10^5$	$1.586*10^5$	$4.314*10^4$	$1.488*10^5$	$4.647*10^4$	$2.621*10^4$	$9.663*10^7$	$4.283*10^9$
precuts	571.2	1081	2703	234.9	62.47	$2.157*10^4$	$1.340*10^4$	5176	$1.209*10^5$	$3.047*10^7$
Cuts1-6	394.1	736.9	1607	176.1	46.85	4456	9457	3397	7681	1764

eRpL	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{e}_L\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$	SM bkg	aa_2f
No cuts	$3.569*10^4$	$8.751*10^5$	$1.852*10^5$	$4.151*10^4$	$1.480*10^5$	$1.386*10^5$	$4.211*10^4$	$2.075*10^4$	$4.727*10^7$	$4.283*10^9$
precuts	441.7	$1.081*10^4$	2272	64.01	215.7	$2.004*10^4$	$1.213*10^4$	4128	$7.292*10^4$	$3.047*10^7$
Cuts1-6	322.2	7068	1345	47.32	157.4	4091	8564	2706	1001	1764

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

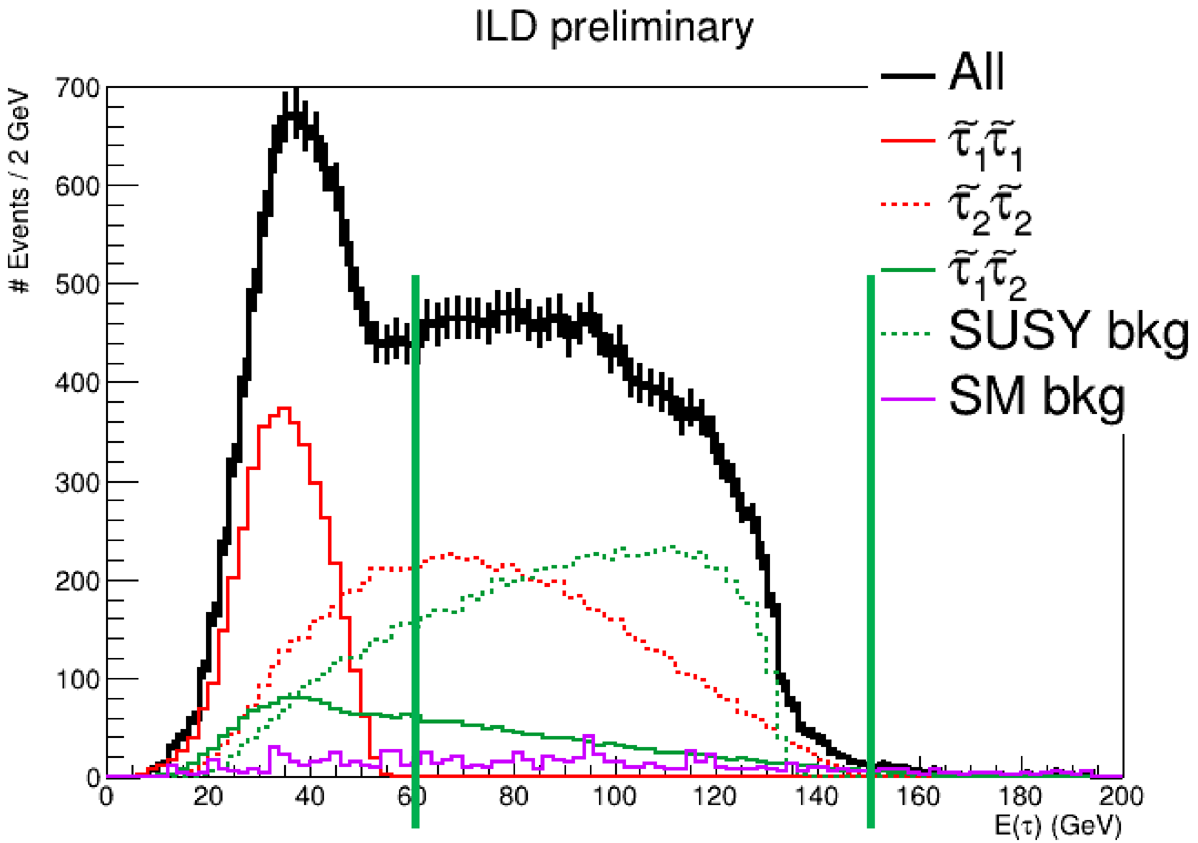
Stau measurement

- We can obtain directly
  - Number of events
  - Endpoint of staus
- We then can calculate/reconstruct
  - Stau masses
  - Production cross-section
  - Mixing angle
  - Muon g-2 contribution

Stau Measurement (eRpL)

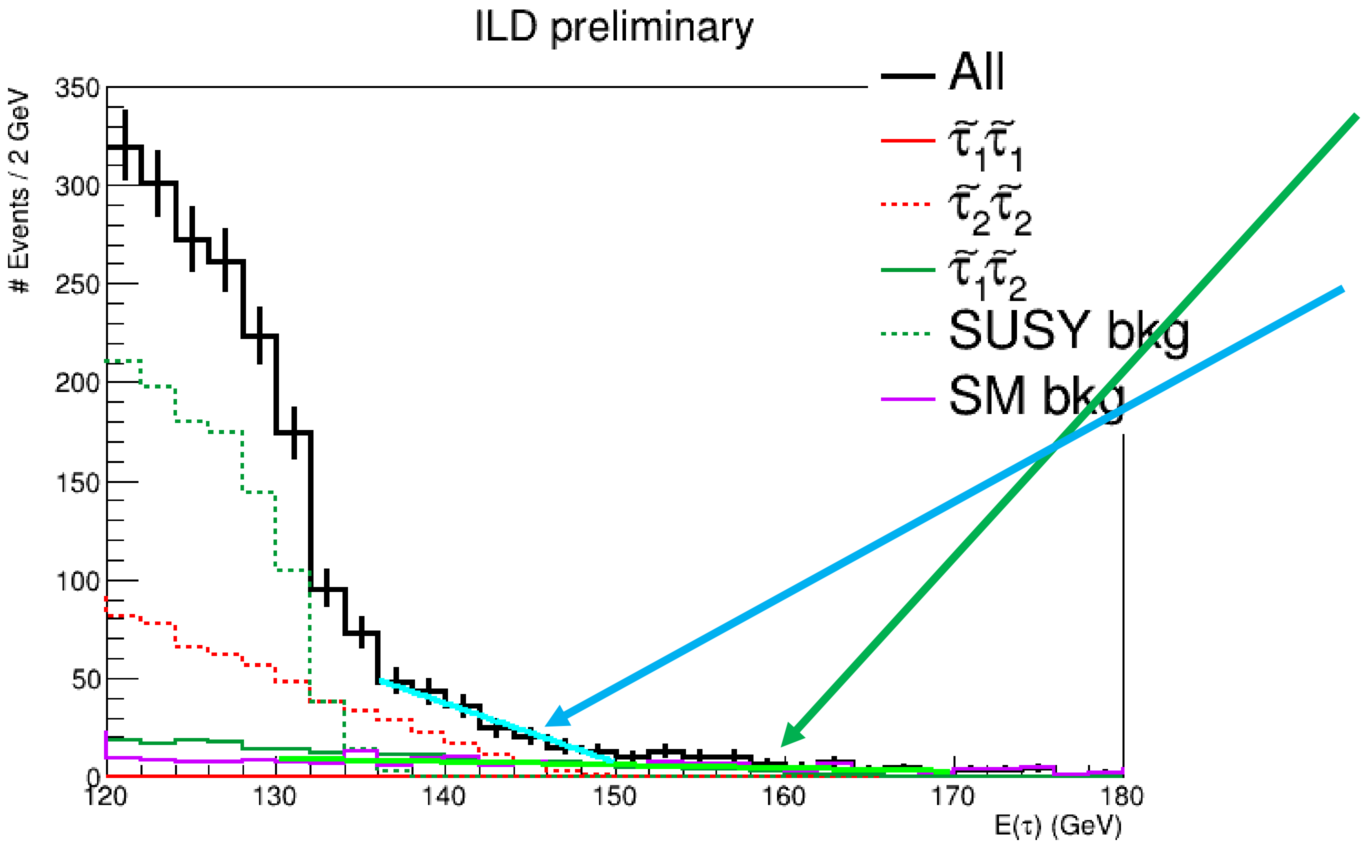
All plots are reconstructed higher tau energy between tau+ and tau- to see the endpoint more clearly.

Event counting



- count number of events with [60 - 150] GeV for SM bkg, SUSY bkg, $\tilde{\tau}_2\tilde{\tau}_2$, and $\tilde{\tau}_1\tilde{\tau}_2$
- N(SMbkg) = 595.2
- N(SUSY) = 7215
- N($\tilde{\tau}_2\tilde{\tau}_2$) = 5803
- N($\tilde{\tau}_1\tilde{\tau}_2$) = 1354

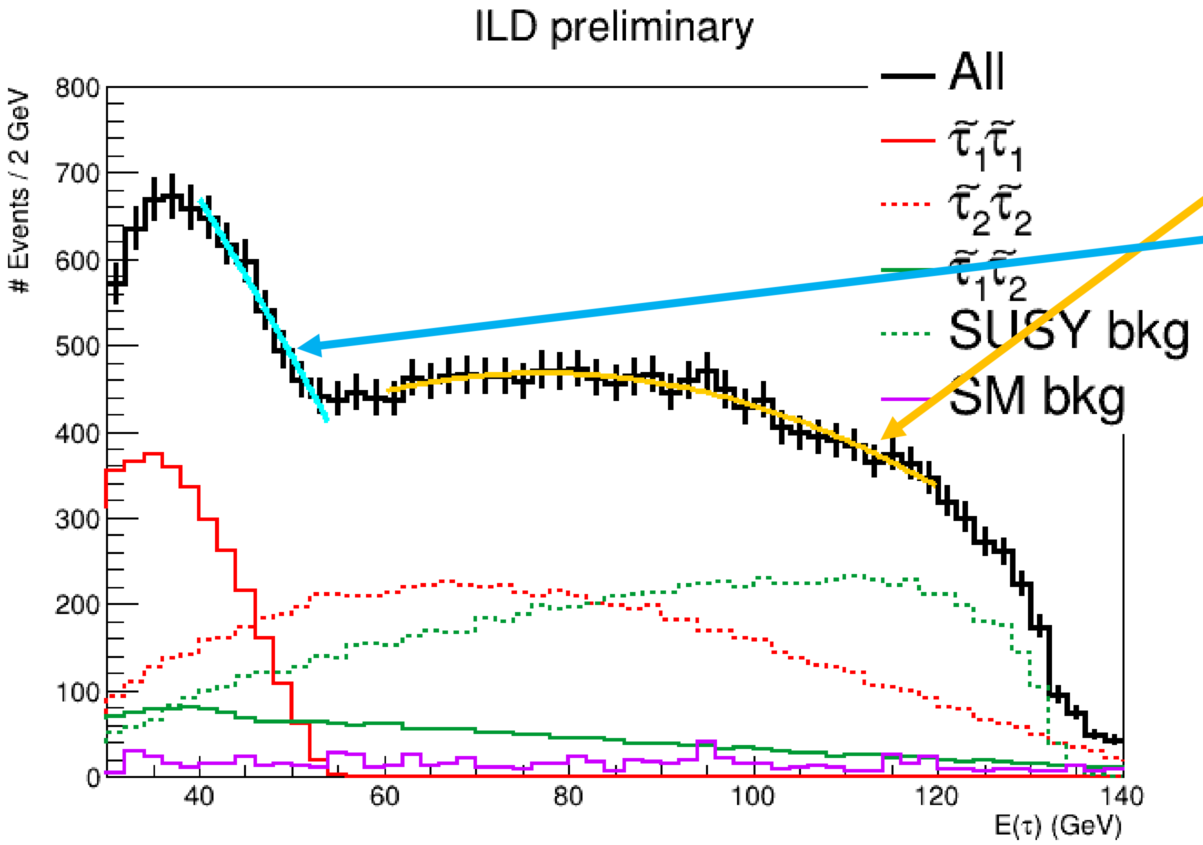
$\widetilde{\tau}_2$ endpoint



- fit SM bkg using straight line [0]*x+[1] with the range 130 - 170 GeV with log-likelihood option (assume we can determine SM bkg nicely)
- fit all using double straight line [0]*x+[1]+[2]*(x-[3]) with the range 136 - 150 GeV
- obtain endpoint [3] from the fit [3] = 150.4 +- 1.2 GeV

$M_{\widetilde{\tau}_2} = XXX \pm XXX$ GeV
(model = 189.8 GeV)

$\widetilde{\tau_1}$ endpoint



- 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 - 54 GeV
- obtain endpoint [4] from the fit
  [4] = 53.19 +- 0.66 GeV

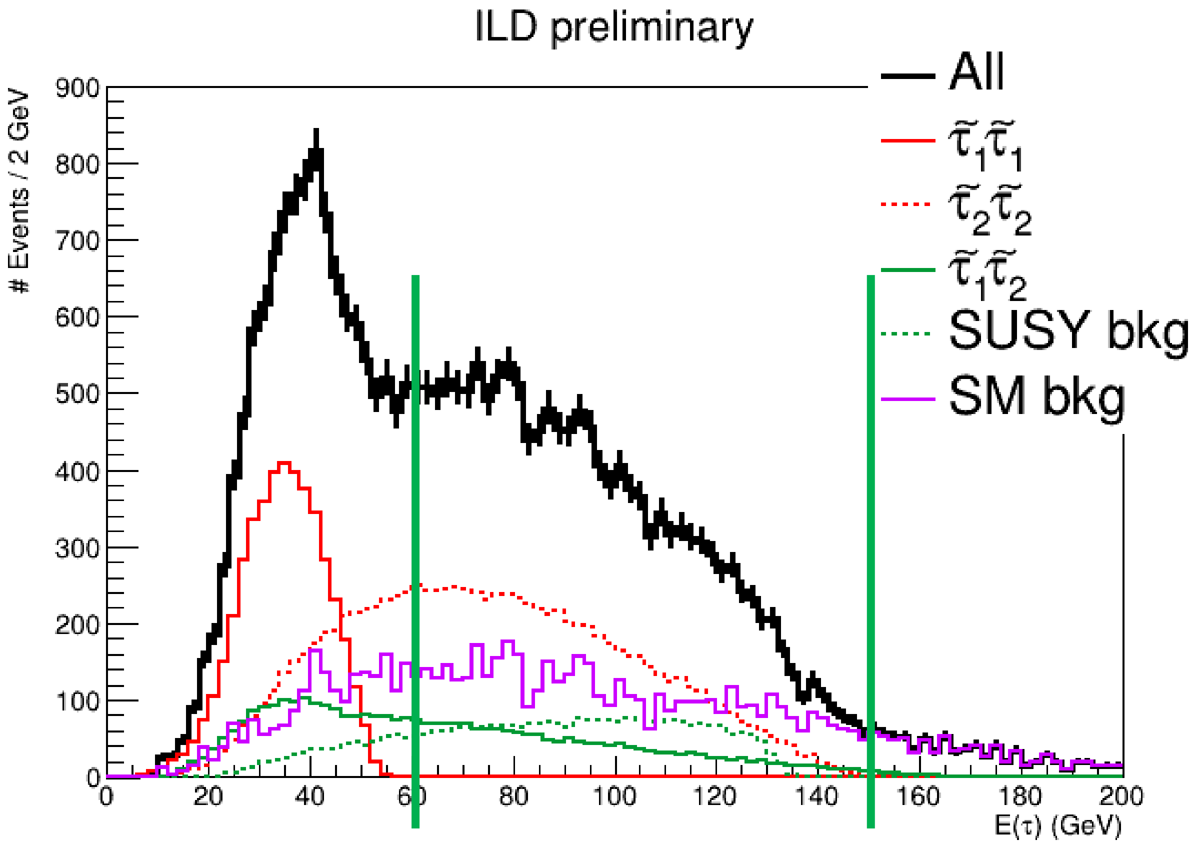
$M_{\widetilde{\tau_1}} = XX \pm XX$ GeV

(model = 113.2 GeV)

Stau Measurement (eLpR)

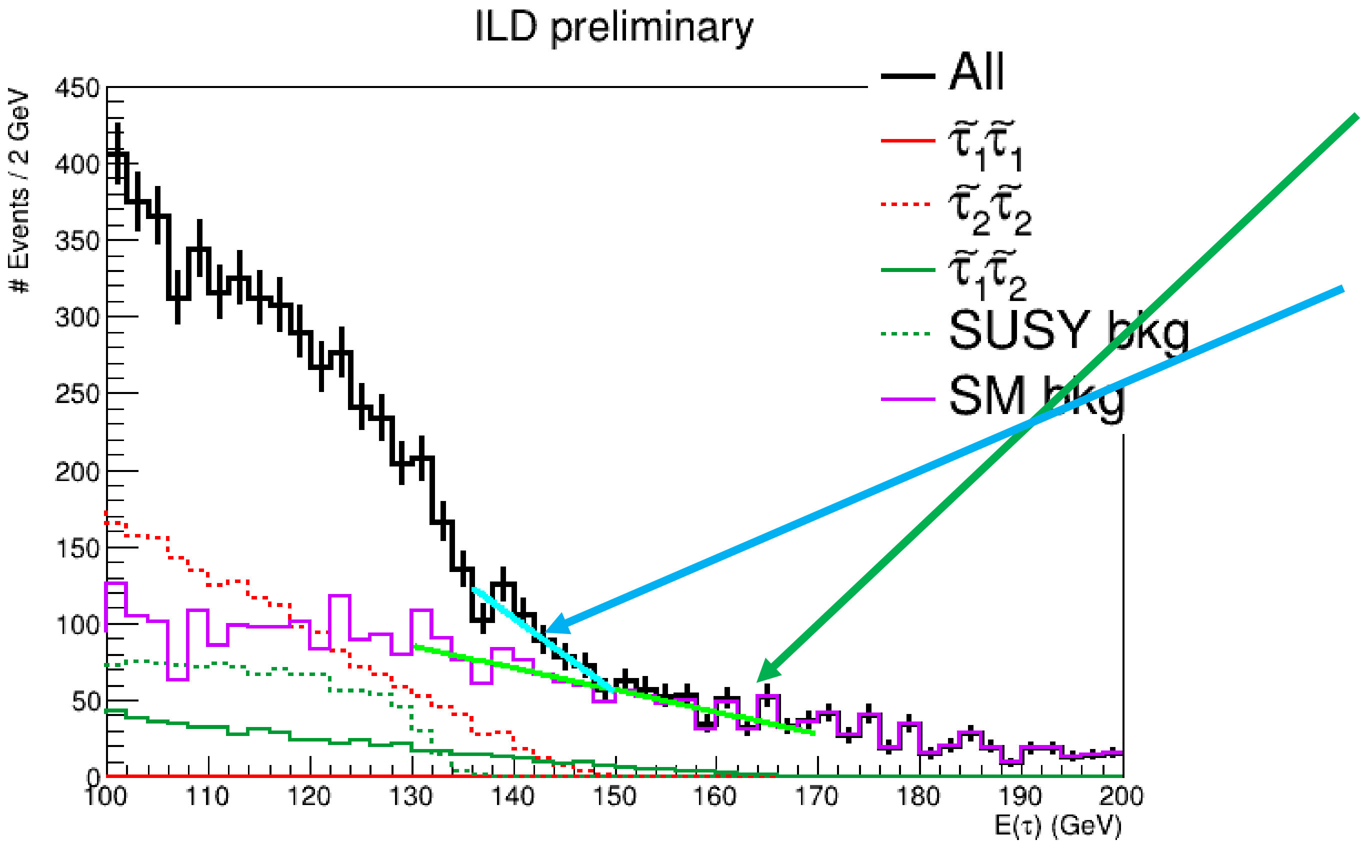
All plots are reconstructed higher tau energy between tau+ and tau- to see the endpoint more clearly.

Event counting



- count number of events with [60 - 150] GeV for SM bkg, SUSY bkg, $\tilde{\tau}_2\tilde{\tau}_2$, and $\tilde{\tau}_1\tilde{\tau}_2$
- N(SMbkg) = 4873
- N(SUSY) = 2365
- N($\tilde{\tau}_2\tilde{\tau}_2$) = 6413
- N($\tilde{\tau}_1\tilde{\tau}_2$) = 1705

$\widetilde{\tau_2}$ endpoint

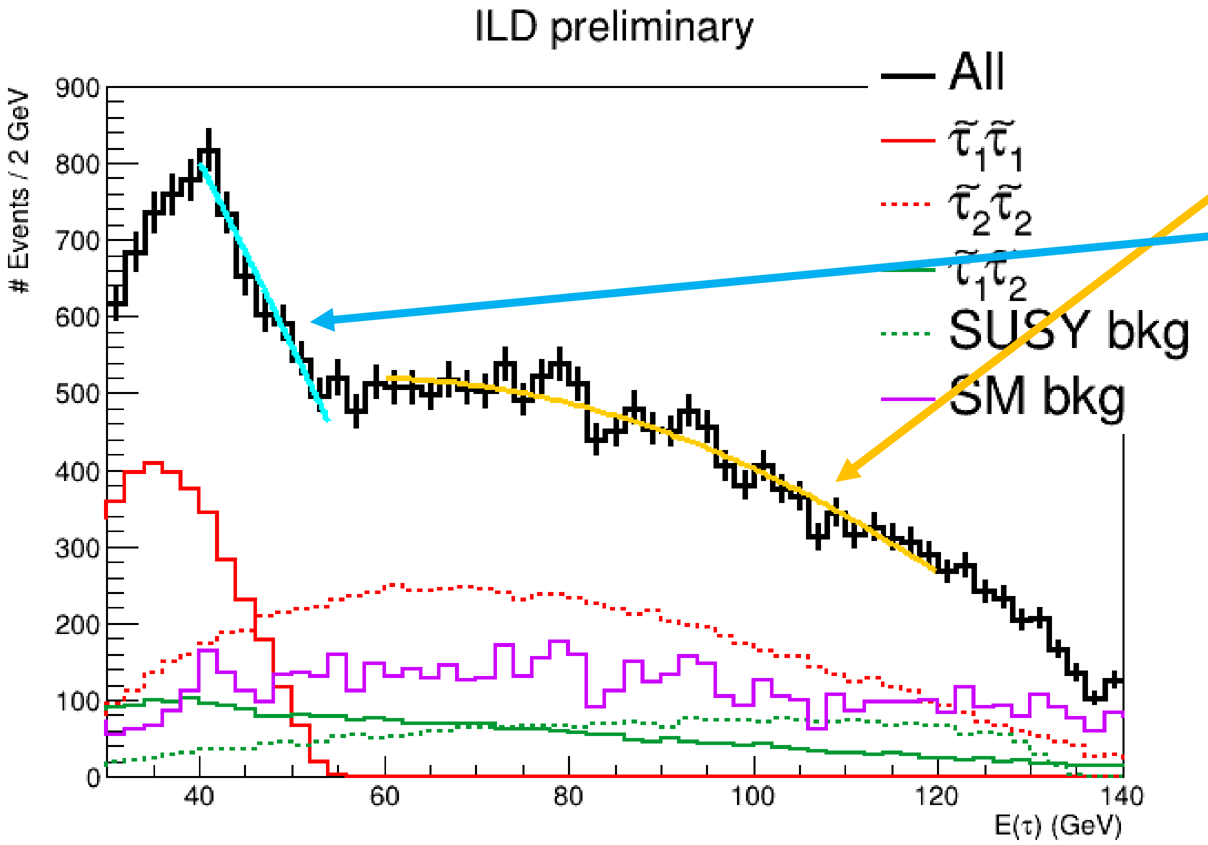


- fit SM bkg using straight line [0]*x+[1] with the range 130 - 170 GeV (assume we can determine SM bkg nicely)
- fit all using double straight line [0]*x+[1]+[2]*(x-[3]) with the range 136 - 150 GeV
- obtain endpoint [3] from the fit [3] = 149.5 +- 1.7 GeV

$$M_{\widetilde{\tau_2}} = XXX \pm XXX \text{ GeV}$$

(model = 189.8 GeV)

$\widetilde{\tau_1}$ endpoint



- 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 - 54 GeV
- obtain endpoint [4] from the fit
  [4] = 51.73 +- 0.53 GeV

$M_{\widetilde{\tau_1}} = XX \pm XX$ 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 ~XXX%/XXX% 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]

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

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

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

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

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 $e^+e^- \rightarrow$	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	546.909 +- 0.022	2187636	875054	10M	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

Produced events (3)

Process $e^{+}e^{-} \rightarrow$	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
$\widetilde{e_L}^{+}\widetilde{e_R}^{-}$	-80/+30	23.5750 +- 0.0011	94300	37720	500K	17
$\widetilde{e_L}^{+}\widetilde{e_R}^{-}$	+80/-30	114.248 +- 0.0051	456992	182797	1.5M	18
$\widetilde{e_R}^{+}\widetilde{e_L}^{-}$	-80/+30	114.248 +- 0.0051	456992	182797	1.5M	19
$\widetilde{e_R}^{+}\widetilde{e_L}^{-}$	+80/-30	23.575 +- 0.0011	94300	37720	500K	20

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 ~210M 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 $\tilde{\tau}_1$
  - 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	$\widetilde{e}_L\widetilde{e}_L$	$\widetilde{e}_R\widetilde{e}_R$	$\widetilde{e}_L\widetilde{e}_R$	$\widetilde{\mu}_L\widetilde{\mu}_L$	$\widetilde{\mu}_R\widetilde{\mu}_R$	$\widetilde{\tau}_1^+\widetilde{\tau}_1^-$	$\widetilde{\tau}_2^+\widetilde{\tau}_2^-$	$\widetilde{\tau}_1\widetilde{\tau}_2$
No cuts	$4.593*10^4$	$8.570*10^4$	$2.205*10^5$	$1.586*10^5$	$4.314*10^4$	$1.488*10^5$	$4.647*10^4$	$2.621*10^4$

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	$5.401*10^6$	$5.436*10^6$	$3.140*10^7$	$2.593*10^6$	$7.765*10^6$	$1.144*10^7$	$3.012*10^6$	$2.618*10^5$	$8.941*10^5$	$1.043*10^6$

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	$7.191*10^6$	$7.403*10^5$	$8.915*10^6$	$6.519*10^5$	$5.824*10^4$	$5.858*10^5$	$5.995*10^6$	$7.684*10^5$	$1.237*10^5$	$4.612*10^4$	$1.943*10^4$

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$3.227*10^4$	$3.650*10^4$	1293	2803	$1.470*10^6$	$3.356*10^5$	$1.146*10^9$	$2.246*10^9$	$8.909*10^8$	$4.123*10^5$

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	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{e_L}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$4.593*10^4$	$8.570*10^4$	$2.205*10^5$	$1.586*10^5$	$4.314*10^4$	$1.488*10^5$	$4.647*10^4$	$2.621*10^4$
pre1	$4.308*10^4$	$8.028*10^4$	$2.038*10^5$	$1.492*10^5$	$4.068*10^4$	$5.892*10^4$	$3.282*10^4$	$1.350*10^4$
pre2	$4.308*10^4$	$8.028*10^4$	$2.038*10^5$	$1.492*10^5$	$4.068*10^4$	$5.866*10^4$	$3.281*10^4$	$1.346*10^4$
pre3	641.0	1205	3011	$1.492*10^5$	$4.068*10^4$	$3.960*10^4$	$2.273*10^4$	9164
pre4	641.0	1205	3011	433.4	118.2	$2.318*10^4$	$1.400*10^4$	5474
pre5	571.2	1081	2703	234.9	62.47	$2.158*10^4$	$1.341*10^4$	5178
pre6	571.2	1081	2703	234.9	62.47	$2.158*10^4$	$1.340*10^4$	5176
pre7	571.2	1081	2703	234.9	62.47	$2.157*10^4$	$1.340*10^4$	5176

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	$5.401*10^6$	$5.436*10^6$	$3.140*10^7$	$2.593*10^6$	$7.765*10^6$	$1.144*10^7$	$3.012*10^6$	$2.618*10^5$	$8.941*10^5$	$1.043*10^6$
pre1	$2.605*10^6$	$3.092*10^6$	$8.230*10^4$	$1.495*10^6$	$3.721*10^5$	$1.857*10^6$	$2.549*10^5$	$7.508*10^4$	4212	$6.027*10^5$
pre2	$2.581*10^6$	$3.063*10^6$	$5.775*10^4$	$1.477*10^6$	$2.659*10^5$	$1.624*10^6$	$2.313*10^5$	$7.404*10^4$	2838	$5.948*10^5$
pre3	1665	$1.151*10^6$	2010	$2.451*10^4$	1249	$2.978*10^5$	810	$2.999*10^4$	222.9	668.5
pre4	1382	$1.513*10^5$	750.5	5789	399.1	$1.654*10^4$	316.2	3955	86.74	508.8
pre5	772.5	$1.185*10^5$	460.8	4360	289.7	$1.201*10^4$	228.8	3483	49.66	293.0
pre6	614.9	$1.015*10^5$	0	3733	0	$1.021*10^4$	129.5	2967	12.36	237.2
pre7	546.0	$8.984*10^4$	0	3457	0	6840	50.41	2665	12.36	209.2

2f_l, 4f_singleW_l, 4f_singleZee_l, 4f_singleZnunu_l: $O(10^3\text{-}10^4)$
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	$7.191*10^6$	$7.403*10^5$	$8.915*10^6$	$6.519*10^5$	$5.824*10^4$	$5.858*10^5$	$5.995*10^6$	$7.684*10^5$	$1.237*10^5$	$4.612*10^4$	$1.943*10^4$
pre1	$2.850*10^4$	$4.455*10^5$	$4.122*10^5$	2504	$2.155*10^4$	$1.072*10^5$	$2.457*10^4$	$4.682*10^5$	$3.048*10^4$	$1.352*10^4$	5487
pre2	$1.670*10^4$	$4.413*10^5$	$2.915*10^5$	1472	$2.051*10^4$	$1.048*10^5$	$1.477*10^4$	$4.644*10^5$	$2.033*10^4$	9312	4263
pre3	439.8	$1.514*10^5$	$2.758*10^4$	16.53	6990	7648	422.5	$1.766*10^5$	587.5	61.65	217.5
pre4	76.48	1622	3271	16.53	696.2	465.4	115.7	$2.134*10^4$	39.35	5.995	7.175
pre5	76.48	1187	2617	16.53	616.5	401.9	96.54	$1.846*10^4$	30.68	5.215	5.639
pre6	0	1007	18.68	0	510.4	3.744	0	$1.579*10^4$	20.15	3.247	0.8555
pre7	0	928.4	18.68	0	443.1	0	0	$1.456*10^4$	15.54	1.955	0.5277

4f_WW_l, 4f_ZZ_l, 4f_ZZWW_l: $O(10^3\text{-}10^4)$
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	$3.227*10^4$	$3.650*10^4$	1293	2803	$1.470*10^6$	$3.356*10^5$	$1.146*10^9$	$2.246*10^9$	$8.909*10^8$	$4.123*10^5$
pre1	3849	4200	59.39	500.1	$1.415*10^5$	$7.629*10^4$	$8.937*10^8$	$1.116*10^9$	$5.456*10^6$	$4.070*10^4$
pre2	3510	3612	54.16	400.9	$1.266*10^5$	$5.738*10^4$	$8.923*10^8$	$1.109*10^9$	$3.643*10^6$	$3.875*10^4$
pre3	514.3	123.4	0.9239	16.87	2700	4958	$6.863*10^5$	$1.063*10^9$	$2.529*10^6$	4813
pre4	52.38	4.970	0.1071	0.9115	65.30	280.3	$1.017*10^5$	$1.059*10^9$	$1.473*10^6$	1765
pre5	44.88	4.399	0.05906	0.7031	52.64	230.1	850.5	$3.040*10^7$	$1.123*10^6$	1600
pre6	34.65	0	0	0.2749	0	133.3	850.5	$3.026*10^7$	$3.119*10^5$	1284
pre7	32.39	0	0	0.1283	0	114.2	850.5	$3.021*10^7$	$2.561*10^5$	1150

aa_ll: $O(10^7)$
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.
- 209M ---> 1.35M MC events

Reject more aa_2f and save stau events

- Stau events: O(10^3-10^4) for all channels
- aa_2f: O(10^7) at maximum
- Need to design some cuts to reduce the background level

After Cut6 (eLpR)

SUSY	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{e_L}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$4.593*10^4$	$8.570*10^4$	$2.205*10^5$	$1.586*10^5$	$4.314*10^4$	$1.488*10^5$	$4.647*10^4$	$2.621*10^4$
precuts	571.2	1081	2703	234.9	62.47	$2.157*10^4$	$1.340*10^4$	5176
Cut1	518.3	982.0	2514	212.8	56.69	$1.703*10^4$	$1.230*10^4$	4536
Cut2	518.3	982.0	2514	212.8	56.69	$1.608*10^4$	$1.229*10^4$	4499
Cut3	518.3	982.0	2514	212.8	56.69	$1.608*10^4$	$1.229*10^4$	4499
Cut4	482.1	909.3	2236	202.2	52.46	$1.475*10^4$	$1.141*10^4$	4141
Cut5	470.1	882.5	2158	198.1	51.51	4798	$1.091*10^4$	3675
Cut6	394.1	736.9	1607	176.1	46.85	4456	9457	3397

After Cut6 (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	$5.401*10^6$	$5.436*10^6$	$3.140*10^7$	$2.593*10^6$	$7.765*10^6$	$1.144*10^7$	$3.012*10^6$	$2.618*10^5$	$8.941*10^5$	$1.043*10^6$
precuts	546.0	$8.984*10^4$	0	3457	0	6840	50.41	2665	12.36	209.2
Cut1	189.5	$1.577*10^4$	0	3053	0	5752	50.41	2455	12.36	192.3
Cut2	33.87	3833	0	2454	0	3940	25.69	2438	12.36	154.5
Cut3	3.605	2164	0	1822	0	1986	25.69	2405	12.36	104.0
Cut4	0	778.1	0	1193	0	466.5	0	1892	12.36	48.22
Cut5	0	615.2	0	1125	0	15.85	0	1673	12.36	40.74
Cut6	0	403.9	0	783.2	0	12.94	0	1456	12.36	24.34

hadronic and semileptonic events are now negligible
4f_singleZnunu_leptonic: 1456
4f_singleW_leptonic: 783.2
2f_leptonic: 403.9

After Cut6 (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	$7.191*10^6$	$7.403*10^5$	$8.915*10^6$	$6.519*10^5$	$5.824*10^4$	$5.858*10^5$	$5.995*10^6$	$7.684*10^5$	$1.237*10^5$	$4.612*10^4$	$1.943*10^4$
precuts	0	928.4	18.68	0	443.1	0	0	$1.456*10^4$	15.54	1.955	0.5277
Cut1	0	757.4	18.68	0	346.8	0	0	$1.153*10^4$	13.98	1.878	0.3952
Cut2	0	542.5	0	0	344.9	0	0	$1.090*10^4$	12.25	1.482	0.3952
Cut3	0	444.8	0	0	323.1	0	0	$1.035*10^4$	11.05	1.359	0.3952
Cut4	0	342.2	0	0	190.1	0	0	7790	5.581	0.5022	0.1360
Cut5	0	332.5	0	0	186.1	0	0	6622	4.350	0.4617	0.06906
Cut6	0	210.4	0	0	147.9	0	0	3859	3.879	0.3587	0.06906

hadronic and semileptonic events are now negligible
4f_ZZWW_leptonic: 3859

After Cut6 (eLpR)

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	$3.227*10^4$	$3.650*10^4$	1293	2803	$1.470*10^6$	$3.356*10^5$	$1.146*10^9$	$2.246*10^9$	$8.909*10^8$	$4.123*10^5$
precuts	32.39	0	0	0.1283	0	114.2	850.5	$3.021*10^7$	$2.561*10^5$	1150
Cut1	29.57	0	0	0.1240	0	104.9	277.1	$1.303*10^7$	$7.263*10^4$	1036
Cut2	29.39	0	0	0.1025	0	99.68	259.5	$7.011*10^6$	$4.625*10^4$	1032
Cut3	29.26	0	0	0.1025	0	96.82	216.0	$6.029*10^6$	$3.953*10^4$	1016
Cut4	24.18	0	0	0.02483	0	64.46	35.09	$5.950*10^5$	1242	867.8
Cut5	21.06	0	0	0	0	56.68	0	2788	0	809.4
Cut6	17.30	0	0	0	0	46.03	0	1764	0	703.6

hadronic and semileptonic events are now negligible
AA_ll: 1764

Statistics (eRpL)

SUSY	$\tilde{e}_L\tilde{e}_L$	$\tilde{e}_R\tilde{e}_R$	$\tilde{e}_L\tilde{e}_R$	$\tilde{\mu}_L\tilde{\mu}_L$	$\tilde{\mu}_R\tilde{\mu}_R$	$\tilde{\tau}_1^+\tilde{\tau}_1^-$	$\tilde{\tau}_2^+\tilde{\tau}_2^-$	$\tilde{\tau}_1\tilde{\tau}_2$
No cuts	$3.569*10^4$	$8.751*10^5$	$1.852*10^5$	$4.151*10^4$	$1.480*10^5$	$1.386*10^5$	$4.211*10^4$	$2.075*10^4$

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	$5.159*10^6$	$4.377*10^6$	$1.866*10^7$	$3.070*10^5$	$9.148*10^5$	$1.131*10^7$	$2.807*10^6$	$2.951*10^4$	$1.085*10^5$	$1.787*10^5$

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	$4.615*10^5$	$4.818*10^4$	$5.759*10^5$	$2.926*10^5$	$3.784*10^4$	$3.040*10^5$	$4.321*10^5$	$6.372*10^4$	$7.201*10^4$	$1.932*10^4$	1634

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	2489	2947	308.6	1591	$6.372*10^5$	$3.356*10^5$	$1.146*10^9$	$2.246*10^9$	$8.909*10^8$	$1.303*10^5$

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

Precuts (eRpL)

SUSY	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{e_L}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$3.569*10^4$	$8.751*10^5$	$1.852*10^5$	$4.151*10^4$	$1.480*10^5$	$1.386*10^5$	$4.211*10^4$	$2.075*10^4$
pre1	$3.358*10^4$	$8.173*10^5$	$1.712*10^5$	$3.906*10^4$	$1.395*10^5$	$5.485*10^4$	$2.970*10^4$	$1.071*10^4$
pre2	$3.358*10^4$	$8.173*10^5$	$1.712*10^5$	$3.906*10^4$	$1.395*10^5$	$5.460*10^4$	$2.970*10^4$	$1.068*10^4$
pre3	495.1	$1.207*10^4$	2530	$3.906*10^4$	$1.395*10^5$	$3.687*10^4$	$2.060*10^4$	7289
pre4	495.1	$1.207*10^4$	2530	113.7	381.0	$2.155*10^4$	$1.268*10^4$	4367
pre5	441.7	$1.081*10^4$	2272	64.01	215.7	$2.005*10^4$	$1.214*10^4$	4129
pre6	441.7	$1.081*10^4$	2272	64.01	215.7	$2.004*10^4$	$1.213*10^4$	4128
pre7	441.7	$1.081*10^4$	2272	64.01	215.7	$2.004*10^4$	$1.213*10^4$	4128

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	$5.159*10^6$	$4.377*10^6$	$1.866*10^7$	$3.070*10^5$	$9.148*10^5$	$1.131*10^7$	$2.807*10^6$	$2.951*10^4$	$1.085*10^5$	$1.787*10^5$
pre1	$2.464*10^6$	$2.396*10^6$	$4.863*10^4$	$1.368*10^5$	$3.526*10^4$	$1.827*10^6$	$1.900*10^5$	8974	418.0	$7.211*10^4$
pre2	$2.440*10^6$	$2.373*10^6$	$3.410*10^4$	$1.340*10^5$	$2.526*10^4$	$1.598*10^6$	$1.697*10^5$	8873	289.2	$7.028*10^4$
pre3	1721	$8.750*10^5$	993.1	2618	185.4	$2.968*10^5$	763.4	3432	20.80	97.60
pre4	1366	$1.112*10^5$	441.7	621.7	40.66	$1.594*10^4$	352.6	445.5	8.920	75.17
pre5	797.0	$8.347*10^4$	305.3	487.1	30.75	$1.133*10^4$	235.5	378.1	6.702	39.55
pre6	745.5	$7.164*10^4$	0	409.6	0	9728	81.06	330.5	0.7395	32.91
pre7	590.8	$6.333*10^4$	0	379.0	0	6578	33.15	301.2	0.7395	31.23

2f_l, 4f_singleZee_l: $O(10^3\text{-}10^4)$
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	$4.615*10^5$	$4.818*10^4$	$5.759*10^5$	$2.926*10^5$	$3.784*10^4$	$3.040*10^5$	$4.321*10^5$	$6.372*10^4$	$7.201*10^4$	$1.932*10^4$	1634
pre1	1849	$2.961*10^4$	$2.739*10^4$	845.0	$1.338*10^4$	$5.363*10^4$	1796	$3.540*10^4$	$1.628*10^4$	4868	465.1
pre2	1085	$2.934*10^4$	$1.928*10^4$	384.2	$1.266*10^4$	$5.233*10^4$	1099	$3.510*10^4$	$1.113*10^4$	3169	367.7
pre3	26.31	$1.014*10^4$	1895	0.9889	4371	3811	50.03	$1.338*10^4$	509.6	52.43	19.82
pre4	4.576	108.2	231.1	0.9889	380.9	233.3	21.07	1639	30.66	6.164	0.7124
pre5	4.576	78.50	184.5	0.9889	338.7	200.7	19.92	1419	25.90	5.382	0.5849
pre6	0	65.81	1.118	0	275.1	0.2240	0	1212	16.98	3.716	0.1119
pre7	0	61.14	1.118	0	245.4	0	0	1106	13.65	2.519	0.06642

4f_ZZ_l, 4f_ZZWW_l: $O(10^2\text{-}10^3)$
semileptonic events: < O(10)
hadronic events: 0

Precuts (eRpL)

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	2489	2947	308.6	1591	$6.372*10^5$	$3.356*10^5$	$1.146*10^9$	$2.246*10^9$	$8.909*10^8$	$1.303*10^5$
pre1	296.3	354.3	26.18	358.1	$6.172*10^4$	$7.629*10^4$	$8.937*10^8$	$1.116*10^9$	$5.456*10^6$	$1.771*10^4$
pre2	271.3	308.3	24.18	279.2	$5.536*10^4$	$5.738*10^4$	$8.923*10^8$	$1.109*10^9$	$3.643*10^6$	$1.699*10^4$
pre3	38.72	10.69	0.3570	13.18	1223	4958	$6.863*10^5$	$1.063*10^9$	$2.529*10^6$	1095
pre4	4.170	0.4392	0.02543	0.6309	34.88	280.3	$1.017*10^5$	$1.059*10^9$	$1.473*10^6$	269.6
pre5	3.585	0.3783	0.01577	0.4996	28.96	230.1	850.5	$3.040*10^7$	$1.123*10^6$	227.9
pre6	2.724	0	0	0.1851	0	133.3	850.5	$3.026*10^7$	$3.119*10^5$	153.1
pre7	2.524	0	0	0.09603	0	114.2	850.5	$3.021*10^7$	$2.561*10^5$	133.6

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

After Cut6 (eRpL)

SUSY	$\widetilde{e_L}\widetilde{e_L}$	$\widetilde{e_R}\widetilde{e_R}$	$\widetilde{e_L}\widetilde{e_R}$	$\widetilde{\mu_L}\widetilde{\mu_L}$	$\widetilde{\mu_R}\widetilde{\mu_R}$	$\widetilde{\tau_1^+}\widetilde{\tau_1^-}$	$\widetilde{\tau_2^+}\widetilde{\tau_2^-}$	$\widetilde{\tau_1}\widetilde{\tau_2}$
No cuts	$3.569*10^4$	$8.751*10^5$	$1.852*10^5$	$4.151*10^4$	$1.480*10^5$	$1.386*10^5$	$4.211*10^4$	$2.075*10^4$
precuts	441.7	$1.081*10^4$	2272	64.01	215.7	$2.004*10^4$	$1.213*10^4$	4128
Cut1	397.7	9912	2114	57.53	194.7	$1.581*10^4$	$1.113*10^4$	3616
Cut2	397.7	9912	2114	57.53	194.7	$1.493*10^4$	$1.112*10^4$	3584
Cut3	397.7	9912	2114	57.53	194.7	$1.493*10^4$	$1.112*10^4$	3584
Cut4	374.9	9058	1874	55.04	182.9	$1.369*10^4$	$1.032*10^4$	3301
Cut5	365.3	8764	1806	53.71	178.8	4396	9868	2930
Cut6	322.2	7068	1345	47.32	157.4	4091	8564	2706

After Cut6 (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	$5.159*10^6$	$4.377*10^6$	$1.866*10^7$	$3.070*10^5$	$9.148*10^5$	$1.131*10^7$	$2.807*10^6$	$2.951*10^4$	$1.085*10^5$	$1.787*10^5$
precuts	590.8	$6.333*10^4$	0	379.0	0	6578	33.15	301.2	0.7395	31.23
Cut1	342.2	$1.113*10^4$	0	341.0	0	5624	33.15	277.4	0.7395	30.22
Cut2	68.73	2239	0	288.1	0	3813	12.69	274.5	0.7395	22.54
Cut3	17.47	1259	0	217.0	0	1949	12.69	252.1	0.7395	11.66
Cut4	0	396.5	0	111.9	0	509.6	0	171.0	0.7395	5.024
Cut5	0	341.6	0	106.4	0	11.95	0	156.1	0.7395	4.576
Cut6	0	204.8	0	62.70	0	8.851	0	135.6	0.7395	1.456

hadronic and semileptonic events are now negligible
2f_leptonic: 204.8
4f_singleZnunu_leptonic: 135.6

After Cut6 (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	$4.615*10^5$	$4.818*10^4$	$5.759*10^5$	$2.926*10^5$	$3.784*10^4$	$3.040*10^5$	$4.321*10^5$	$6.372*10^4$	$7.201*10^4$	$1.932*10^4$	1634
precuts	0	61.14	1.118	0	245.4	0	0	1106	13.65	2.519	0.06642
Cut1	0	50.91	1.118	0	184.5	0	0	894.7	12.35	2.356	0.05850
Cut2	0	38.05	0	0	184.3	0	0	851.7	11.01	1.752	0.05850
Cut3	0	32.21	0	0	175.1	0	0	804.0	9.474	1.538	0.05850
Cut4	0	26.07	0	0	113.9	0	0	604.1	4.952	0.5664	0.03403
Cut5	0	25.49	0	0	111.7	0	0	512.2	4.299	0.5259	0.02680
Cut6	0	18.18	0	0	85.77	0	0	339.1	3.764	0.4816	0.02680

hadronic and semileptonic events are now negligible
4f_ZZWW_leptonic: 339.1

After Cut6 (eRpL)

SM bkg (3)	vvWW	xxWW	xxxxZ	yyyyZ	ttbar	AA4f	AAee	AAll	AAqq	higgs
No cuts	2489	2947	308.6	1591	$6.372*10^5$	$3.356*10^5$	$1.146*10^9$	$2.246*10^9$	$8.909*10^8$	$1.303*10^5$
precuts	2.524	0	0	0.09603	0	114.2	850.5	$3.021*10^7$	$2.561*10^5$	133.6
Cut1	2.317	0	0	0.04830	0	104.9	277.1	$1.303*10^7$	$7.263*10^4$	125.8
Cut2	2.301	0	0	0.03463	0	99.68	259.5	$7.011*10^6$	$4.625*10^4$	123.6
Cut3	2.287	0	0	0.03463	0	96.82	216.0	$6.029*10^6$	$3.953*10^4$	119.9
Cut4	1.901	0	0	0.001486	0	64.46	35.09	$5.950*10^5$	1242	108.2
Cut5	1.692	0	0	0	0	56.68	0	2788	0	104.7
Cut6	1.415	0	0	0	0	46.03	0	1764	0	91.87

hadronic and semileptonic events are now negligible
AA_ll: 1764