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

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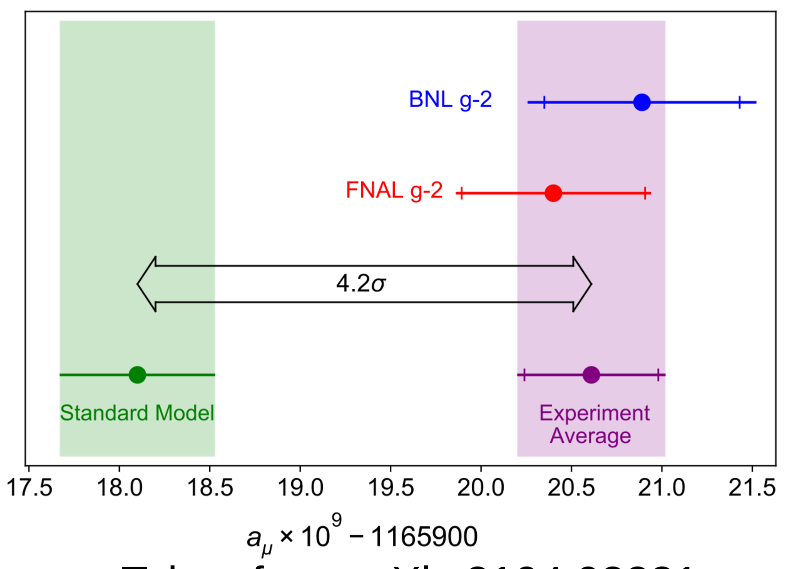
Introduction: muon g-2 anomaly



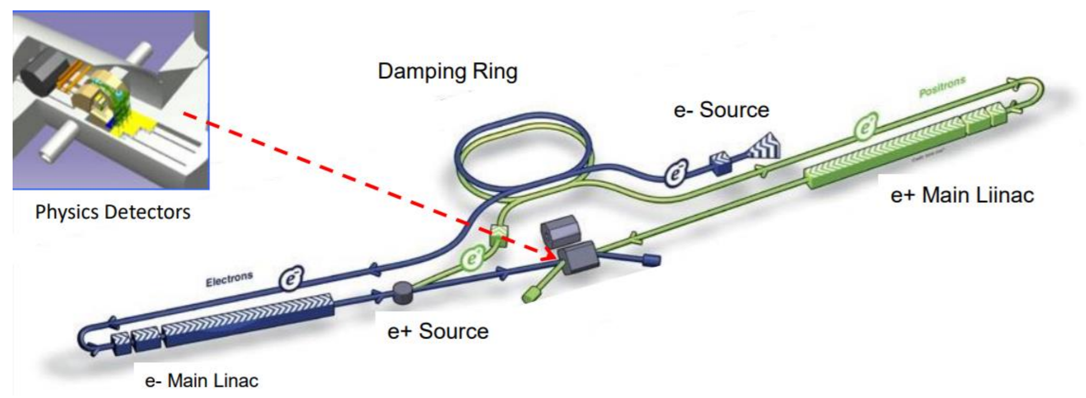
Taken from arXiv:2104.03281

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

Many models proposed to explain. In this contribution, we pick up the interpretation of [2104.03217]: SUSY interpretation (pure-Bino-contribution scenario, or "BLR" scenario)

International Linear Collider (ILC)

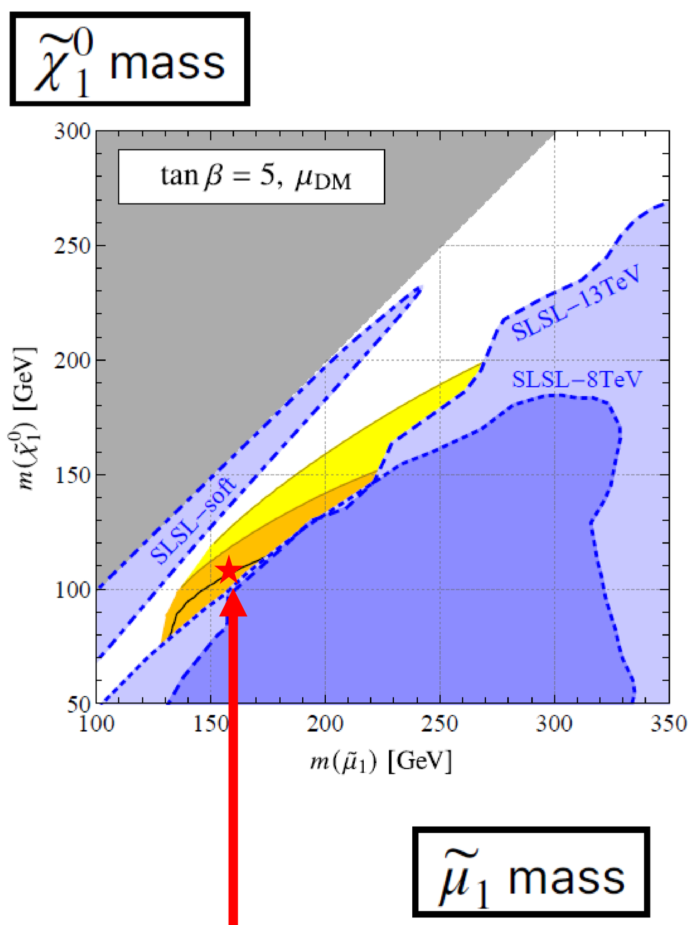
- Proposed future e^+e^- linear collider
- $\sqrt{s}$ = 250 GeV (upgradable to 500 GeV, 1 TeV)
- Polarized beams ($|P_{e^-}|$ = 80%, $|P_{e^+}|$ = 30%)
- Clean environment, well-defined initial state



We study the case at ILC 500 GeV and 2 beam polarization cases.
eLpR: (P_{e^-}, P_{e^+}) = (-80%, +30%), eRpL: (P_{e^-}, P_{e^+}) = (+80%, -30%)

Model point

	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



We study BLR1 model point.
This model can explain the muon g-2 anomaly with $1\sigma(2\sigma)$ and dark matter relic density ($\Omega_{\chi_1^0} = \Omega_{\text{dark matter}}$).

Bino-smuon diagram

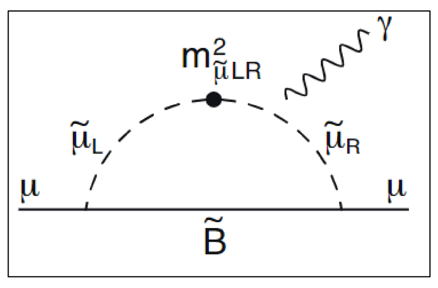


Figure: Bino-smuon loop diagram contributing to $a_\mu^{\rm SUSY}$.
We denote this contribution by $a_\mu^{(\tilde{B})}$.

When we have Higgsino mass parameter $\mu \gtrsim 1$ 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 (both left- and right-handed)
(2) Bino (= 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 the previous results for (1) - (3).
For (4), it is difficult to get $m^2_{\tilde{\mu}LR}$, but we can expect an equation $m^2_{\tilde{\mu}LR} = \frac{m_\mu}{m_\tau} m^2_{\tilde{\tau}LR}$ by assuming a flavor universality.
Therefore, we need stau mixing measurement.

Physics analysis

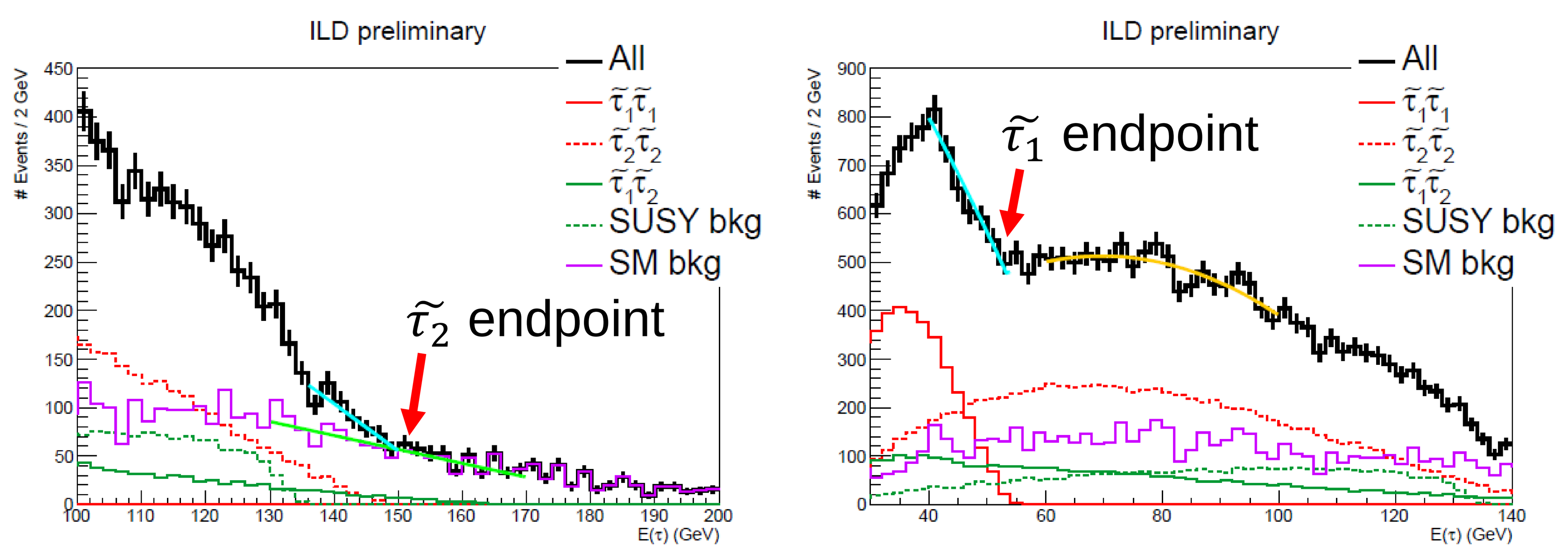
SUSY MC sample: DELPHES + ILC generic detector card
SM backgrounds (in total ~210M MC events)
- $\gamma\gamma \to$ 2f (2-photon scattering process): SGV fast simulation
- all other: full detector simulation with ILD model

Event selection: 2 τ-jets + no isolated leptons + kinematical cuts

eLpR 1.6 ab^{-1}	$\tilde{\tau}_1\tilde{\tau}_1$	$\tilde{\tau}_2\tilde{\tau}_2$	$\tilde{\tau}_1\tilde{\tau}_2$	SUSY bkg	SM bkg	$\gamma\gamma \to$ 2f
No cuts	1.488*10^5	4.647*10^4	2.621*10^4	5.539*10^5	8.770*10^7	4.283*10^9
After cuts	4456	9457	3397	2961	7681	1764

eRpL 1.6 ab^{-1}	$\tilde{\tau}_1\tilde{\tau}_1$	$\tilde{\tau}_2\tilde{\tau}_2$	$\tilde{\tau}_1\tilde{\tau}_2$	SUSY bkg	SM bkg	$\gamma\gamma \to$ 2f
No cuts	1.386*10^5	4.211*10^4	2.075*10^4	1.286*10^6	4.727*10^7	4.283*10^9
After cuts	4091	8564	2706	8940	1001	1764

Endpoint extraction



(a) $\tilde{\tau}_2\tilde{\tau}_2$ endpoint fit (b) $\tilde{\tau}_1\tilde{\tau}_1$ endpoint fit

Figure: Endpoint fit of the stau energy distribution (eLpR)

	Fit	True
$\tilde{\tau}_1$ endpoint, eLpR	53.31 ± 0.55 GeV	54.5 GeV
$\tilde{\tau}_1$ endpoint, eRpL	53.17 ± 0.67 GeV	54.5 GeV
$\tilde{\tau}_2$ endpoint, eLpR	149.5 ± 1.7 GeV	149.9 GeV
$\tilde{\tau}_2$ endpoint, eRpL	150.4 ± 1.2 GeV	149.9 GeV

Results of likelihood analysis

Inputs:
- stau endpoints
- cross-sections of each process
- $M_{\chi_1^0} = 99.3 \pm 0.1$ GeV (taken from earlier analysis)

	Fit	True
$M_{\tilde{\tau}_1}$	112.8 ± 0.2 GeV	113.2 GeV
$M_{\tilde{\tau}_2}$	$189.9^{+0.8}_{-0.7}$ GeV	189.8 GeV
$\cos\theta_{\tilde{\tau}}$	0.703 ± 0.010	0.703
$-m^2_{\tilde{\tau}LR}$	$(1.17 \pm 0.01) \times 10^4$ GeV^2	11606 GeV^2
$-m^2_{\tilde{\mu}LR}$	693^{+9}_{-8} GeV^2	690 GeV^2
$a_\mu^{(\tilde{B})}$	$(27.5 \pm 0.4) \times 10^{-10}$	27.5 * 10^{-10}

Summary

- The muon g-2 anomaly can be explained with SUSY interpretation
- Studied the feasibility of SUSY measurement at ILC 500 GeV
- Performed realistic detector simulation and physics analysis
- Can reconstruct the SUSY contribution to muon g-2 anomaly with 1% precision at our model point

References

- Snowmass White Paper: 2203.07056
- 2104.03217
- PLB **728** (2014) (1310.4496)