Search for the slepton cascade decays motivated by the muon g-2 anomaly

(ANA-SUSY-2023-11)

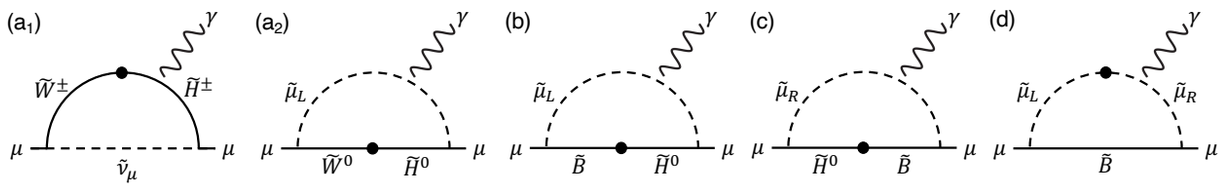
① Introduction

- The anomalous magnetic moment of the muon (muon g-2) is one of the most precisely measured quantities of the particle physics field.
- The latest result [1] shows a 4.2σ discrepancy from the SM calculation based on $e^+e^- \rightarrow$ hadrons data.
  $\Delta a_\mu^{\mathrm{exp}} \equiv a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}} = (25.1 \pm 5.9) \times 10^{-10}$.

- **Minimal Supersymmetric Standard Model (MSSM) with low mass smuon, gauginos and higgsinos could explain the muon g-2 anomaly.**
  MSSM with *R*-parity conservation can also naturally provide a dark matter (DM) candidate.

② Muon g-2 anomaly and MSSM

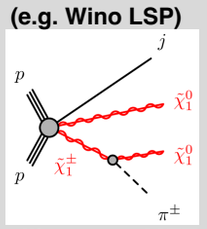
- One loop diagrams which mainly contribute to muon g-2.



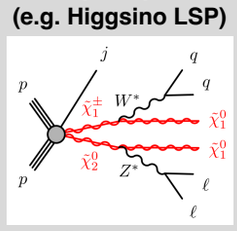
- If only one type of the loop dominates the contribution there are 24 (= 4 × 3!) possible mass hierarchies.
- When SUSY particles in the loop are **$\mathcal{O}$(100) GeV** and $\tan\beta$ is $\mathcal{O}(10)$, muon g-2 anomaly can be explained by MSSM.
- **Constraints on the presence of Dark Matter**
  (a) Snuetrino LSP -> disfavored by DM direct detection (DD) searches ×
  (b) Right-handed smuon LSP -> charged LSP ×
  (c) Wino / Higgsino LSP -> underabundant △
  (d) Bino LSP, smuon NLSP -> can avoid overabundance with coannihilation ◯
  (e) Bino LSP, Higgsino NLSP -> overabundant or excluded by DM DD ×
- **Signatures @ Collider with (c)(d) DM** -> can be grouped into six categories

Direct decay signatures

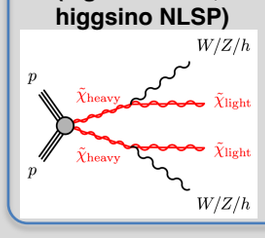
disappearing track (e.g. Wino LSP)



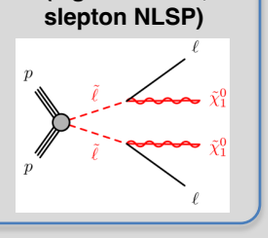
low pT lepton (e.g. Higgsino LSP)



diboson + MET (e.g. Bino LSP, higgsino NLSP)

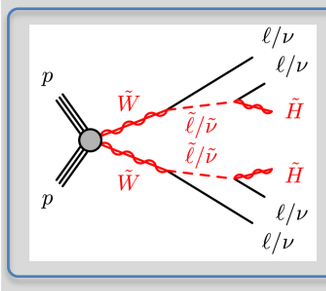


2L + MET (e.g. Bino LSP, slepton NLSP)

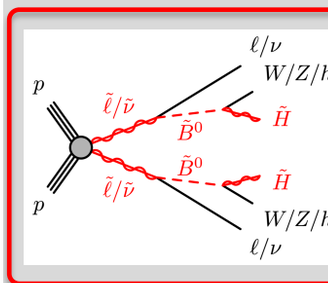


well-studied signatures

One-step decay signatures



Not a typical target however well covered by the existing searches



Has not been covered by Run2 analyses

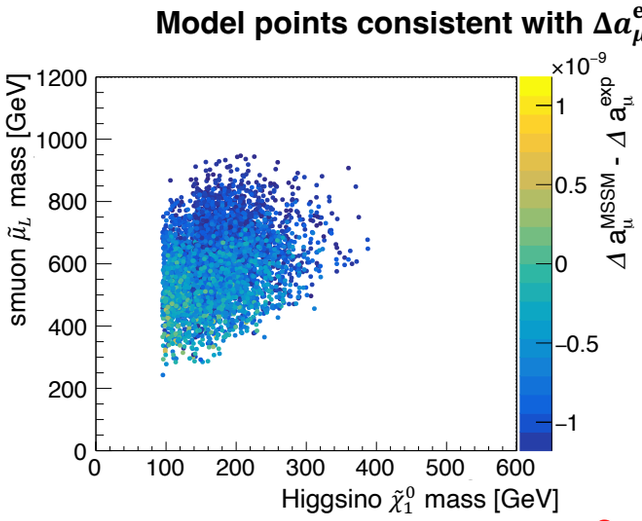
- xsec(left-handed smuon) > 10 × xsec(right-handed smuon)
- Focus on **L**eft-handed smuon -> **B**ino -> **H**iggsino scenario **(LBH scenario)**

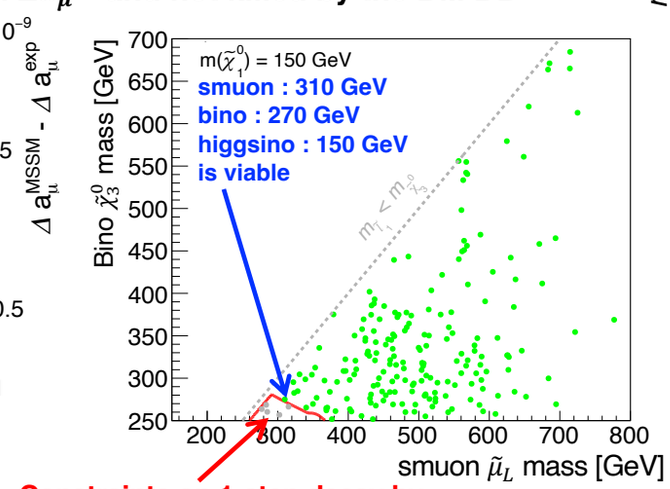
③ Current constraints on the LBH scenario

- **Favored by muon g-2 anomaly**
  - Light SUSY particles : left-handed smuon < 950 GeV, higgsino < 400 GeV
- **DM DD constraint** (LZ result [2])
  - Δm (bino, higgsino) > 100 GeV
- **ATLAS SUSY search constraints**
  (1) Higgsino search -> constraints only up to 200 GeV LSP
  (2) EWK multi-lepton search -> exclude a tiny bit of the low mass region [3]

-> Only a very weak constraint is imposed to the LBH scenario.

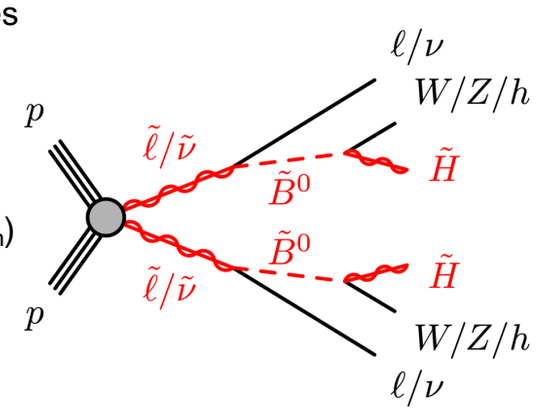
Model points consistent with $\Delta a_\mu^{\mathrm{exp}}$ and not killed by the DM DD





④ Features of the LBH scenario one-step decay signals

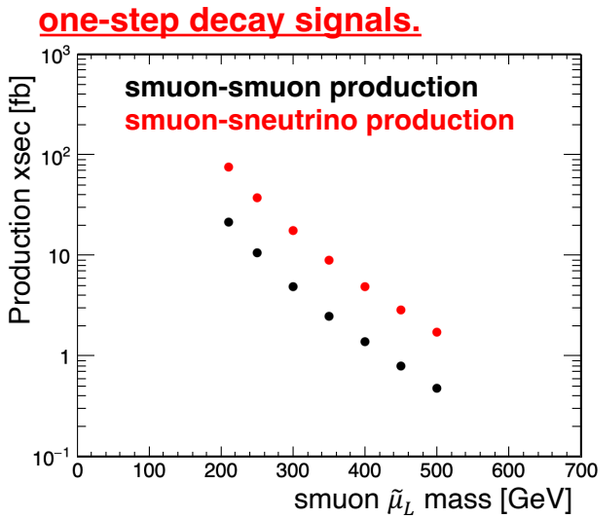
- **Production processes**
  - smuon-smuon / smuon-sneutrino / sneutrino-sneutrino
  - smuon-sneutrino production xsec is 3-4 times larger than smuon-smuon production.
- **one-step decay BR ~ 90 %**
  - due to small Yukawa coupling
- **Bino BR**
  - W ~50 %, Z ~25 %, h ~25 % ($\Delta m(\tilde{B}, \tilde{H}) > m_h$)
  - W ~50 %, Z ~50 % ($\Delta m(\tilde{B}, \tilde{H}) < m_h$)

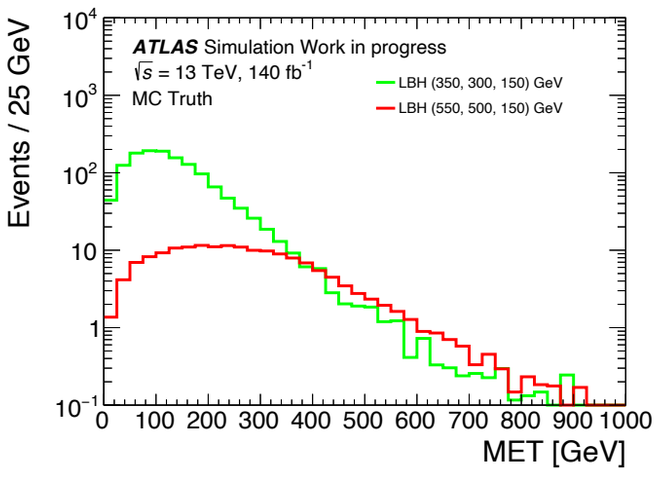


- Jets from hadronically decaying bosons
- Relatively low MET due to moderate smuon mass and mass splitting

Makes the usual EWK multi-lepton searches which have **jet veto** and strong searches with **tight MET cut** (typically > 300 GeV) sub-optimal to LBH scenario.

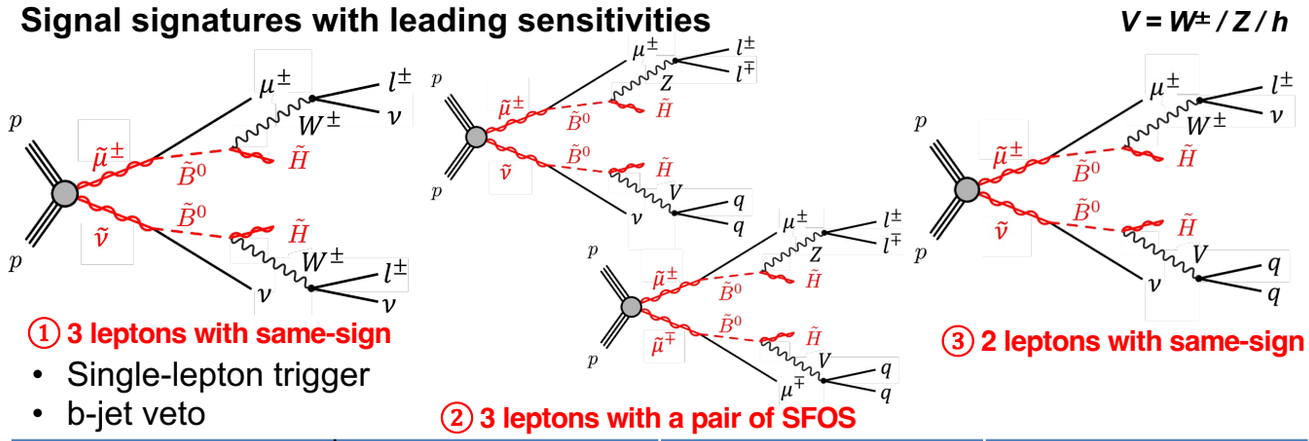
-> Need to design a new dedicated search to target the LBH scenario one-step decay signals.





⑤ Potential of the new analyses

Signal signatures with leading sensitivities $V = W^\pm / Z / h$

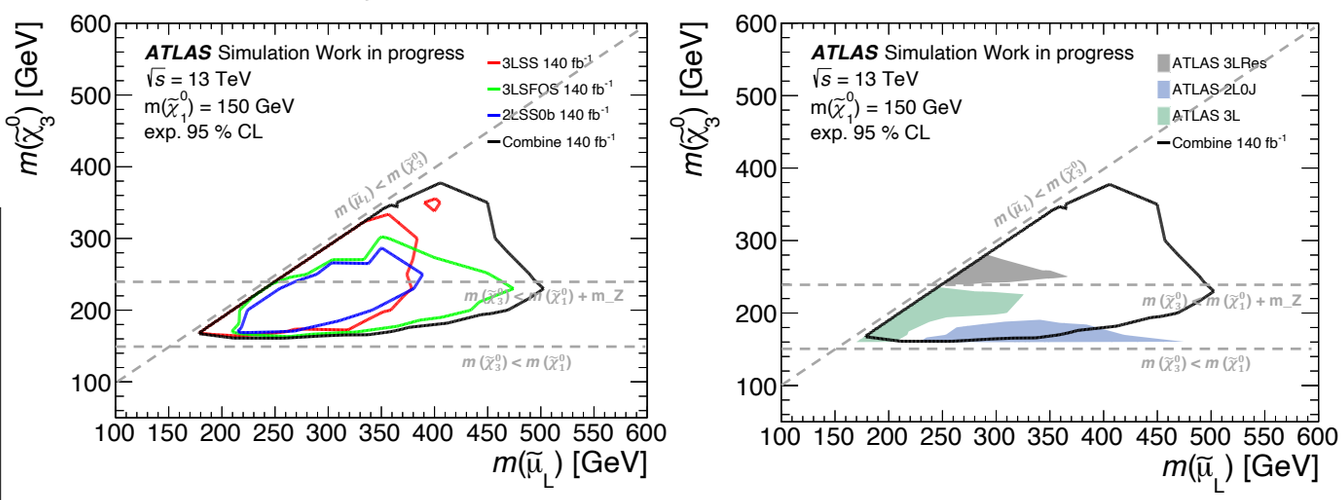


① **3 leptons with same-sign**
- Single-lepton trigger
- b-jet veto

② **3 leptons with a pair of SFOS**

③ **2 leptons with same-sign**

Variable	3LSS SR	3LSFOS SR	2LSS SR
# leptons	≥ 3	≥ 3	= 2
Lepton pT	> 28 GeV, > 20 GeV, > 10 GeV		> 28 GeV, > 20 GeV
# jets (> 20 GeV)	N/A		≥ 1
Charge	Same-sign	Contain SFOS pair	Same-sign
ECIDS	Veto events with charge-flip-tagged electron		
MET	> 50 GeV	> 150 GeV	> 50 GeV
mTmin	N/A	> 125 GeV	N/A
mT2	N/A	N/A	> 100 GeV
Final discriminant	Leading electron pT	Tri-lepton mass	Di-lepton mass
Main backgrounds	WZ (charge-flip), fakes	WZ	Z+jets (charge-flip), WZ



- **Newly defined SRs can significantly improve the sensitivity for the LBH scenario.**
- **Able to extend the sensitivity to the region which is not killed by DM DD.** (Δm (bino, higgsino) > 100 GeV)
- Aiming to publish with Full Run-2 + Early Run-3 (2022, 2023) data.

Takumi Aoki (UTokyo/ICEPP)

ATLAS Week 2023 Vancouver, Canada

[1] Phys. Lett. B 126 (2021) 141801 [2] arXiv:2207.03764
[3] Phys. Rev. D 103 (2021) 112003

More information and detailed plots here!

ICEPP The University of Tokyo

ATLAS EXPERIMENT