MSSM confronts the precision electroweak data and muon $g-2$

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I. Introduction
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Introduction

Muon $g-2$:

- ✓ Powerful probe for New Physics at TeV scale.
- ✓ 3.4σ deviation between exp. and theory (SM) reported
  $\Longrightarrow$ Signal of new physics?

Electroweak (EW) precision data:

- ✓ Useful probe for New Physics
- ✓ Only a few years ago final LEP data appeared
  (hep-ex/0509008)

A natural question:

Suppose that the MSSM is responsible for the muon $g-2$ anomaly. **Where is the SUSY parameter region favored by the final LEP EW data?**

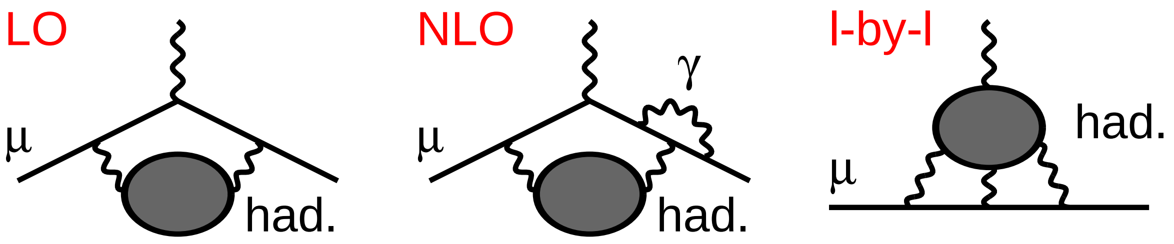
—— **Important question to study BEFORE the LHC**

Standard Model Prediction for Muon $g-2$

QED contribution	11 658 471.809 (0.016) $\times 10^{-10}$	Kinoshita & Nio
EW contrib.	15.4 (0.2) $\times 10^{-10}$	Czarnecki et al
Hadronic contrib.		
LO hadronic	**689.4 (4.5)** $\times 10^{-10}$	HMNT
NLO hadronic	$-$9.8 (0.1) $\times 10^{-10}$	HMNT
light-by-light	13.6 (2.5) $\times 10^{-10}$	Melnikov & Vainshtein
Theory TOTAL	**11 659 180.4 (5.1)** $\times 10^{-10}$	
Experiment	**11 659 208.0 (6.3)** $\times 10^{-10}$	world avg. (2006)

$$\boxed{\delta a_\mu \equiv a_\mu^{\text{exp}} - a_\mu^{\text{SM}} = (27.6 \pm 8.1) \times 10^{-10} : 3.4\sigma \text{ discrepancy}}$$

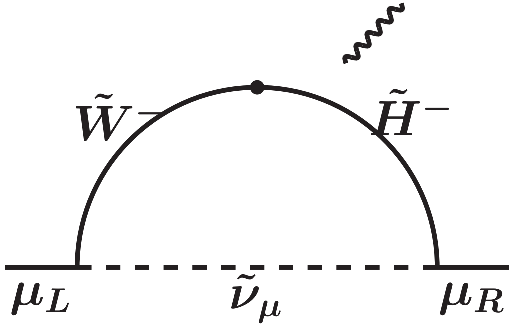
n.b.: hadronic contributions:



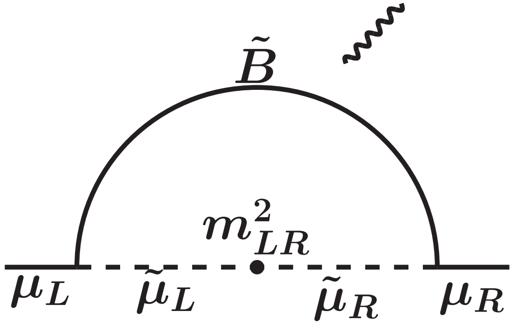
SUSY Contributions to Muon $g-2$

Suppose that the 3.4σ deviation is due to SUSY...

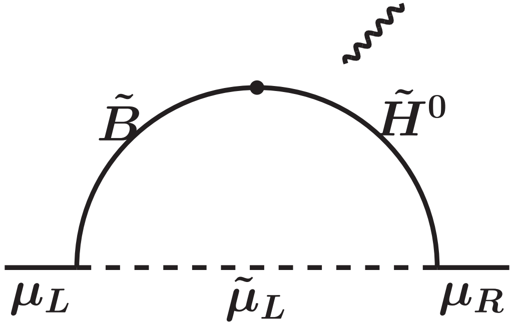
Leading **SUSY contributions** in the $m_Z/m_{\rm SUSY}$ expansion:



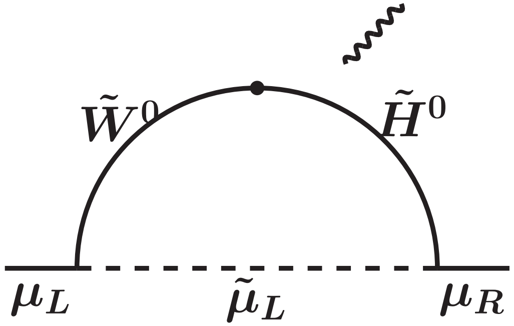
(a)



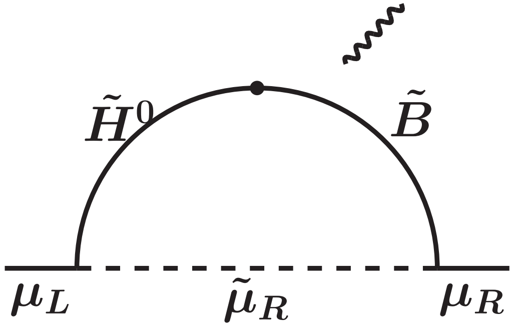
(b)



(c)



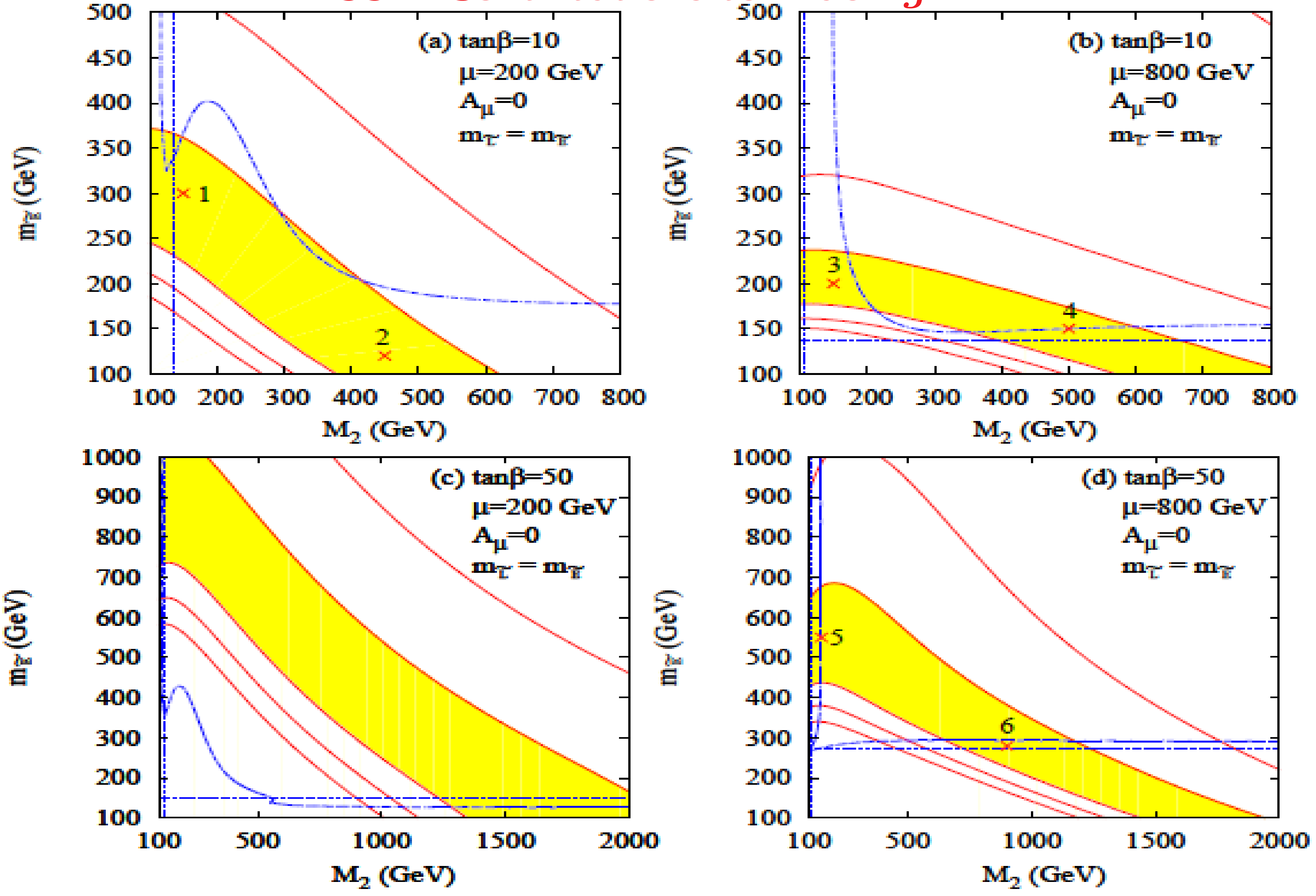
(d)



(e)

In most cases, the $\tilde{\chi}^{\pm}$-$\tilde{\nu}$ diagram (a) and/or the $\widetilde{B}$-$\widetilde{\mu}_{L/R}$ diagram (b) dominate. (Lopez-Nanopoulos-Wang, Chattopadhyay-Nath, Moroi, . . .)

MSSM Contributions to Muon $g-2$



Muon $g-2$ at MSSM sample points

No.	$\tan\beta$	μ	M_2	$m_{\tilde{E}}$	(a)	(b)	(c)	(d)	(e)	(a)-(e)	total	pull
1	10	200	150	300	29.6	1.1	0.7	-2.9	-1.3	27.2	25.0	-0.3
2	10	200	450	120	27.5	8.8	3.3	-7.1	-6.7	25.9	25.9	-0.2
3	10	800	150	200	14.3	16.2	0.6	-2.7	-1.3	27.1	27.1	-0.1
4	10	800	500	150	6.9	21.3	1.0	-2.5	-2.1	24.7	24.3	-0.4
5	50	800	150	550	26.9	2.4	0.5	-2.6	-1.0	26.3	26.0	-0.2
6	50	800	900	280	18.0	18.0	2.5	-5.9	-5.1	27.7	27.6	0.0

The chargino diagram (a) and/or the Bino-smuon$_{L,R}$ diagram (b) dominate in all the sample points.

Selected SUSY models and muon $g-2$

Selected SUSY Models

	$\tan\beta$	μ	$m_{\tilde{\mu}_L}$	$m_{\tilde{\mu}_R}$	A_μ	M_1	M_2
S G 1 (mSUGRA, $\tan\beta = 10$)	10	396	181	116	-445	103	193
S G 2 (mSUGRA, high $\tan\beta$)	50	762	585	465	-145	277	510
GM 1 (Gauge Med., high $\tan\beta$)	42	504	441	214	25	181	339
GM 2 (Gauge Med., $\tan\beta \sim 10$)	15	300	257	120	-39	169	327
MM1 (Mirage Med., $\alpha > 0$)	10	430	188	255	-465	170	258
MM2 (Mirage Med., $\alpha < 0$)	10	-572	253	108	245	-99	-248
MM3 (Mirage Med., $M_2 < M_1$)	10	534	200	237	509	224	173

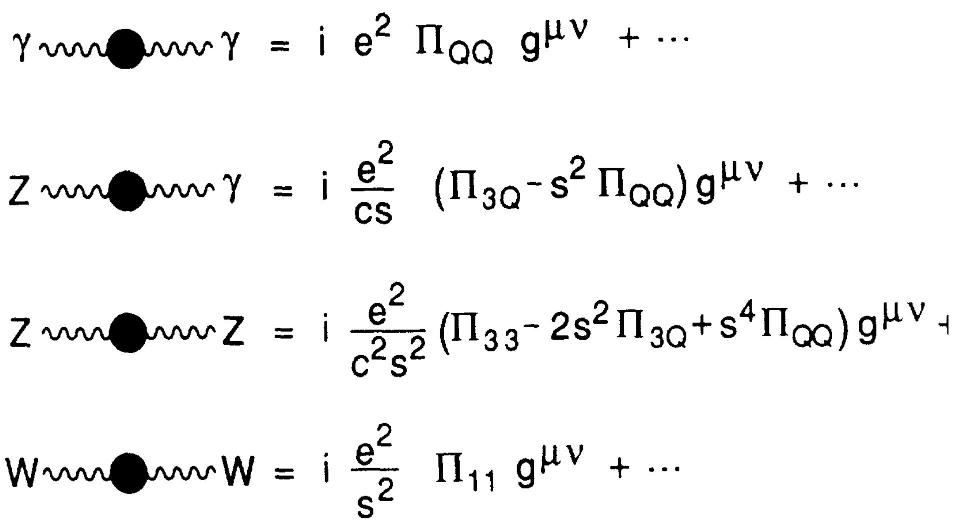
Muon $g-2$ in the Selected SUSY Models

	(a)	(b)	(c)	(d)	(e)	(a)-(e)	total	pull
S G 1	25.7	21.5	1.5	-5.2	-5.4	38.1	37.6	1.2
S G 2	20.0	4.8	1.0	-3.4	-2.8	19.5	19.4	-1.0
GM 1	34.6	11.7	1.4	-5.3	-9.2	33.2	33.0	0.7
GM 2	27.1	10.6	1.6	-5.0	-9.0	25.3	24.8	-0.3
MM1	19.4	7.2	1.4	-4.5	-1.9	21.7	21.7	-0.7
MM2	13.2	18.8	0.7	-2.7	-4.2	25.8	24.7	-0.4
MM3	19.6	7.9	1.1	-3.8	-1.8	23.0	23.1	-0.5

Introduction to EW Precision Study

LEP-I experiments ('89 - '95): The Z-boson properties were studied in great detail using 17 millions of Z boson decays. (Final report appeared 'recently': `hep-ex/0509008`)

To confront the EW precision data with theory, the S, T, U **parameters** are useful (Peskin & Takeuchi).



$$= i\, e^2\, \Pi_{QQ}\, g^{\mu\nu} + \cdots$$

$$= i\, \frac{e^2}{cs}\, (\Pi_{3Q} - s^2 \Pi_{QQ})\, g^{\mu\nu} + \cdots$$

$$= i\, \frac{e^2}{c^2 s^2} (\Pi_{33} - 2s^2 \Pi_{3Q} + s^4 \Pi_{QQ})\, g^{\mu\nu} +$$

$$= i\, \frac{e^2}{s^2}\, \Pi_{11}\, g^{\mu\nu} + \cdots$$

$$\alpha S \equiv 4e^2 [\Pi'_{33}(0) - \Pi'_{3Q}(0)] \,,$$

$$\alpha T \equiv \frac{e^2}{s^2 c^2 m_Z^2} [\Pi_{11}(0) - \Pi_{33}(0)] \,,$$

$$\alpha U \equiv 4e^2 [\Pi'_{11}(0) - \Pi'_{33}(0)] \,.$$

In this talk, we use an improved version, S_Z, T_Z **and** M_W (Hagiwara, Haidt, Kim & Matsumoto).

S_Z-T_Z Plane Analysis

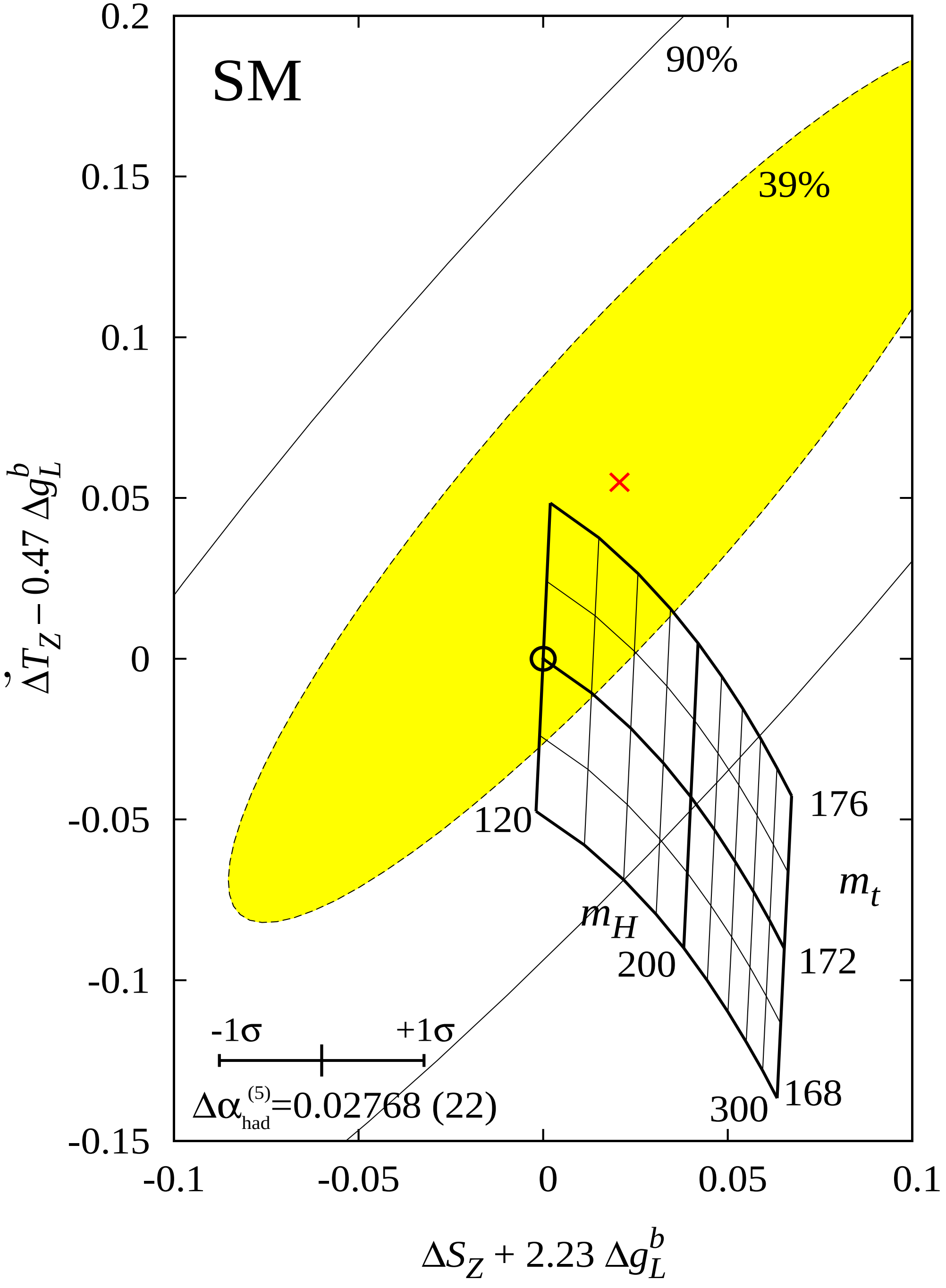
1. Calculate $\mathcal{O}_i^{\rm th}(\Delta S_Z, \Delta T_Z, \ldots)$, where $\mathcal{O}_i$ are EW precision observables $(\Gamma_Z, \sigma_h^0, A_f, \ldots)$.

2. Construct the χ^2 function as

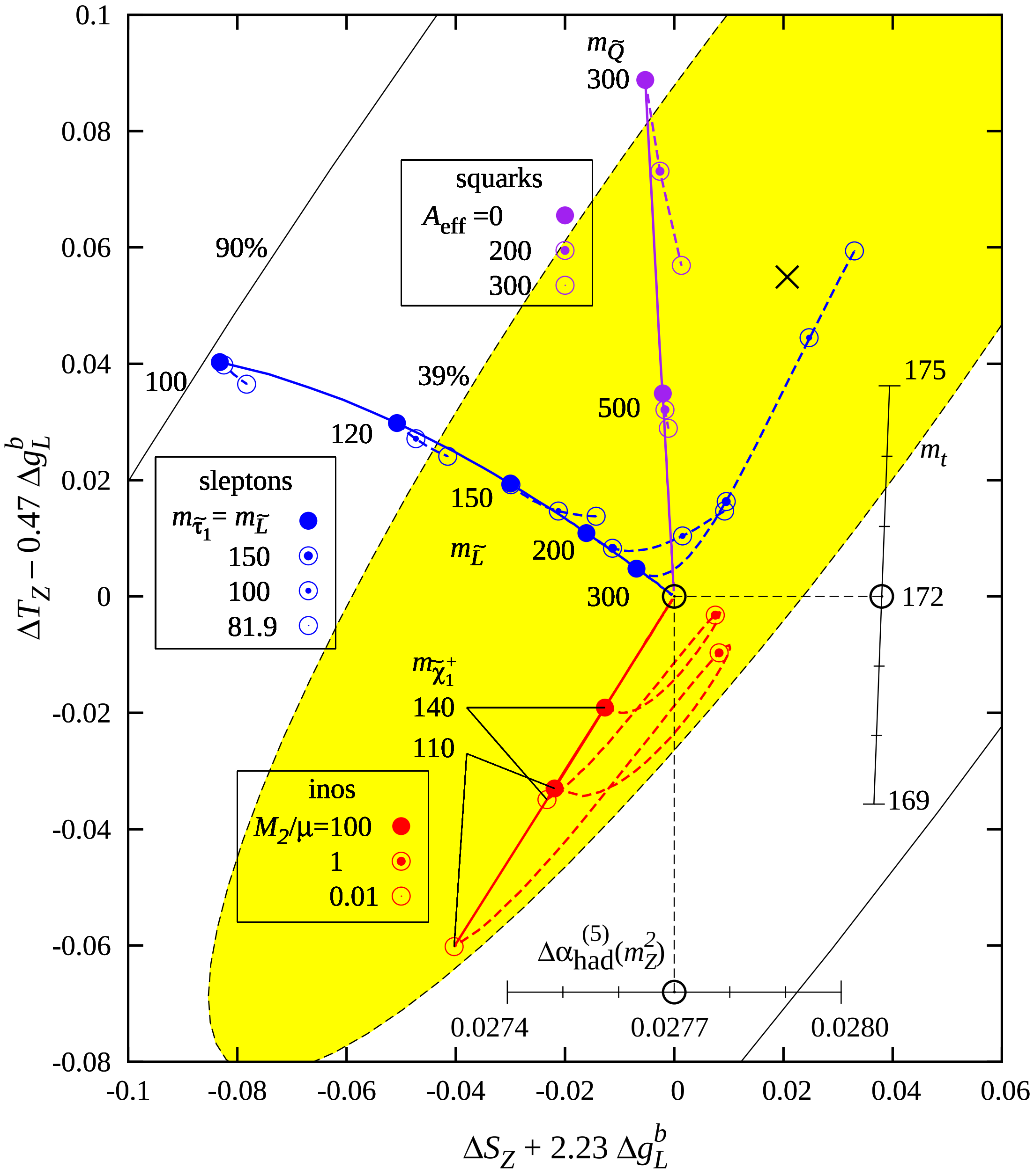
$$\chi^2 = \sum_{i,j} \left(\mathcal{O}_i^{\rm th}(\Delta S_Z, \Delta T_Z, \ldots) - \mathcal{O}_i^{\rm exp}\right) \times \left(V^{-1}\right)_{ij} \left(\mathcal{O}_j^{\rm th}(\Delta S_Z, \Delta T_Z, \ldots) - \mathcal{O}_j^{\rm exp}\right),$$

where V is the covariance matrix, $V_{ij} = (\delta\mathcal{O}_i^{\rm exp})(\delta\mathcal{O}_j^{\rm exp})\rho_{ij}$.

3. Find the minimum of χ^2 with respect to ΔS_Z, ΔT_Z etc. Draw the contours $\chi^2 - \chi^2_{\rm min} = {\rm const}$ if necessary.



Electroweak Precision Data vs MSSM, (I) S_Z-T_Z plane analysis



Using the final LEP EW precision data, we can give a constraint on MSSM contributions to S_Z and T_Z.

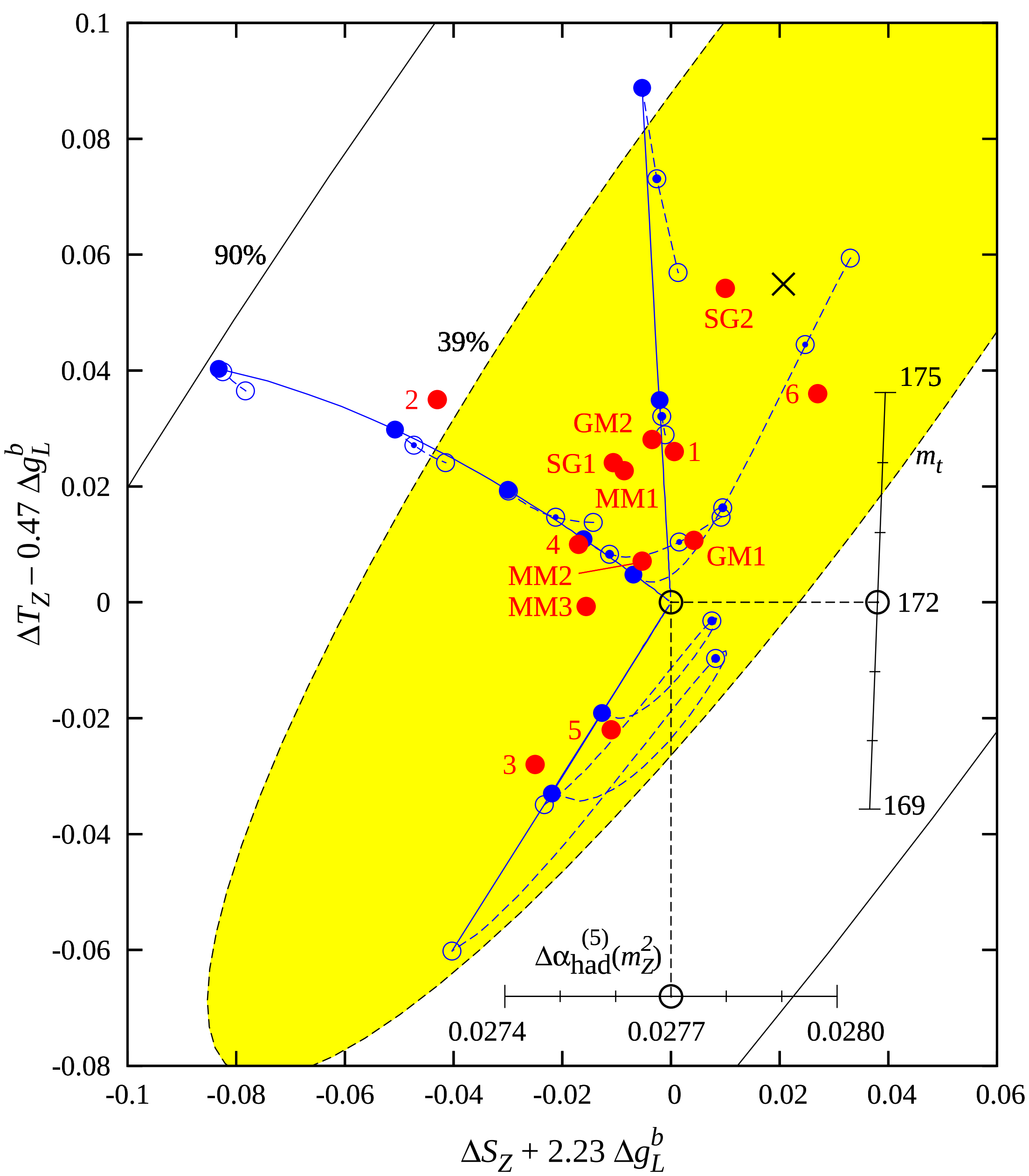
Our Results:

✓ The SM with $\boldsymbol{m_H \sim 100}$ GeV gives a good description.

✓ In the MSSM, light sfermions tend to be disfavored.

Cho-Hagiwara-Matsumoto-DN, in preparation

EW Precision Data vs MSSM, (II) S_Z-T_Z plane analysis



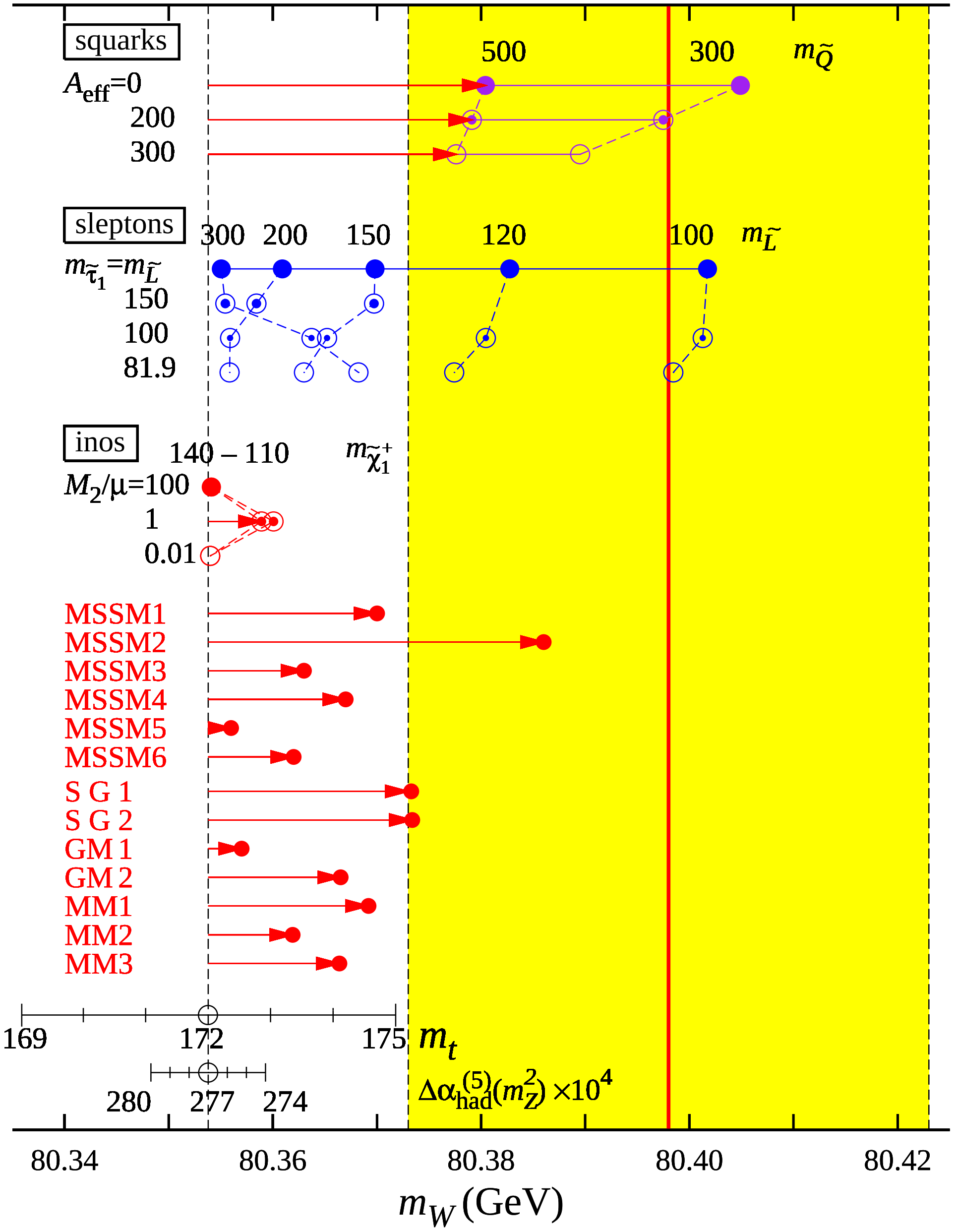
Using the final LEP EW precision data, we can give a constraint on MSSM contributions to S_Z and T_Z.

Our Results:

✓ All the sample points are within or close to the 1-σ favored region.

Cho-Hagiwara-Matsumoto-DN, in preparation

EW Precision Data vs MSSM (III), M_W



In our framework, M_W is a calculable quantity, which can be compared to the data.

Our Results:

✓ Light squarks and sleptons tend to make the fit better.

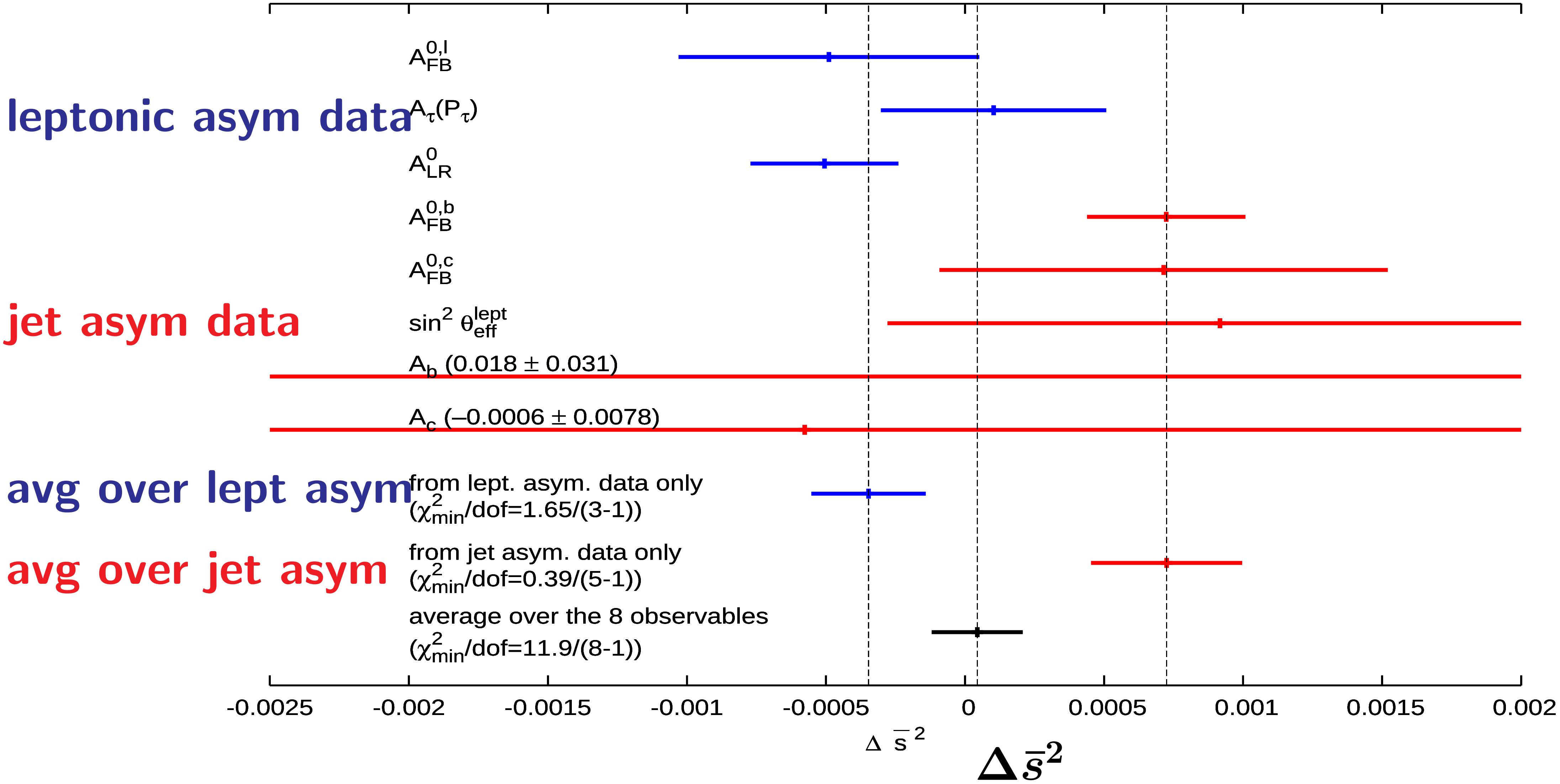
✓ Inos do not give contributions to Δm_W very much.

✓ The MSSM with $\mathcal{O}(100)$ GeV SUSY masses gives a good description.

Cho-Hagiwara-Matsumoto-DN, in preparation

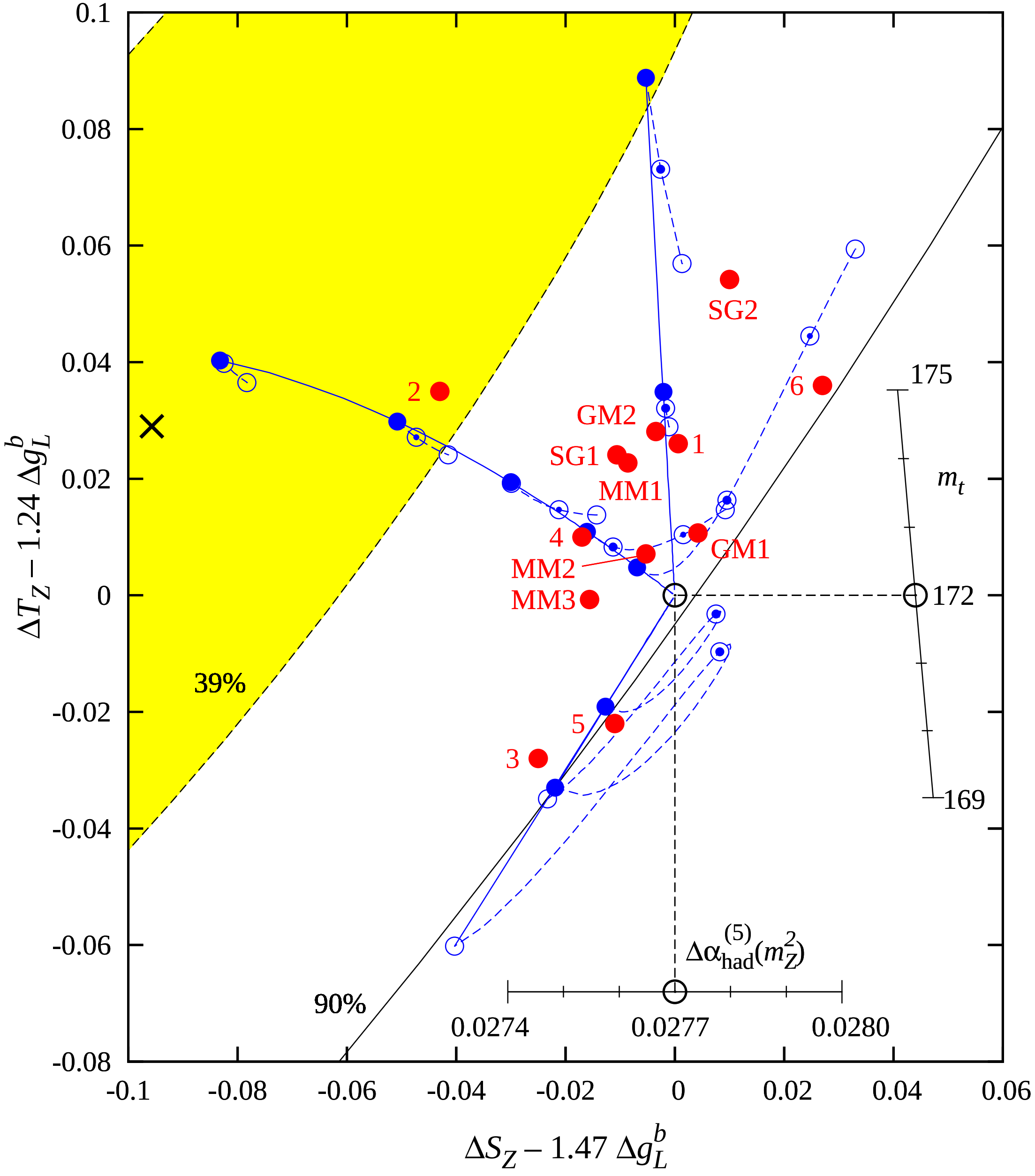
But this is not the full story...

Problem in Jet Asymmetry Data?



The value of the effective mixing angle $\bar{s}^2$ determined only from leptonic asymmetry data and that determined only from jet asym. data do not agree very well $\Longrightarrow$ **problem in jet asym. data (or in the analysis of them)?**

EW Precision Data vs MSSM, (IV) fit without jet asymm. data



If we do not use the jet asymmetry data, the favored range shifts to the left. (Negative ΔS_Z is favored.)

✓ Light sleptons are favored.

Cho-Hagiwara-Matsumoto-DN, in preparation

Summary

We have studied the favored parameter region of MSSM using the results of the muon $g-2$ and the EW precision data.

From muon $g-2$: when $\tan\beta = 10$, the slepton mass of a few hundred GeV is favored. When $\tan\beta = 50$, the sleptons as heavy as 1 TeV are allowed within 1-σ.

From EW precision data: SUSY particles of a few hundred GeV are OK.

In well-studied models like mSUGRA, Gauge Med. and Mirage Med. there still is some parameter region favored from muon $g-2$ and EW precision data.

If we leave out the jet asymmetry data, light sleptons become more favored, which is favored from muon $g-2$ as well.