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

Daisuke Nomura
(KEK, JSPS Research Fellow)

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In collaboration with **G.-C. Cho** (Ochanomizu), **K. Hagiwara** (KEK/Sokendai) and **Yu Matsumoto** (KEK/Sokendai).

Introduction

Muon $g-2$:

✓ Powerful probe for New Physics at TeV scale.

✓ 3.4σ deviation between exp. and theory (SM) reported (Teubner's and Passera's talks) $\Longrightarrow$ Signal of new physics?

Electroweak (EW) precision data:

✓ Useful probe for New Physics (Heinemeyer's talks)

✓ Only a few years ago final LEP data appeared (hep-ex/0509008)

A natural question everyone thinks of:

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?**

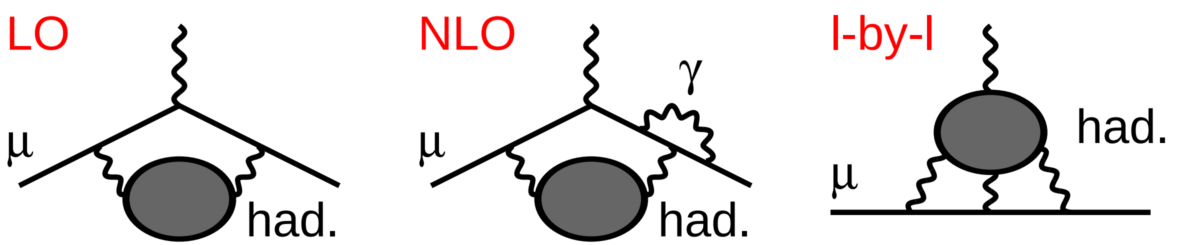
—— **Important question to study BEFORE the LHC**

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)

$$\delta a_\mu \equiv a_\mu^{\rm exp} - a_\mu^{\rm SM} = (27.6 \pm 8.1) \times 10^{-10}$$: **3.4σ discrepancy**

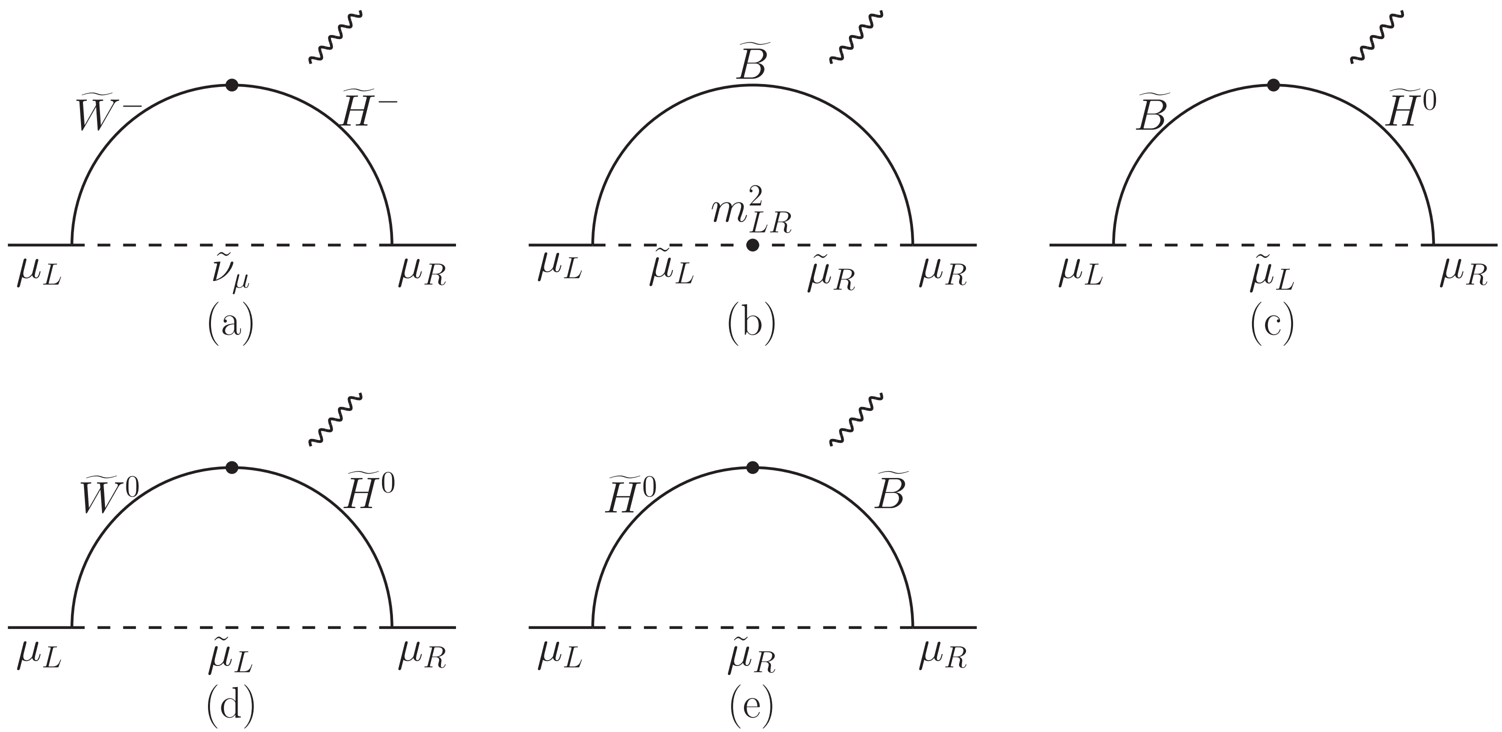
n.b.: hadronic contributions:



SUSY Contributions to Muon $g - 2$

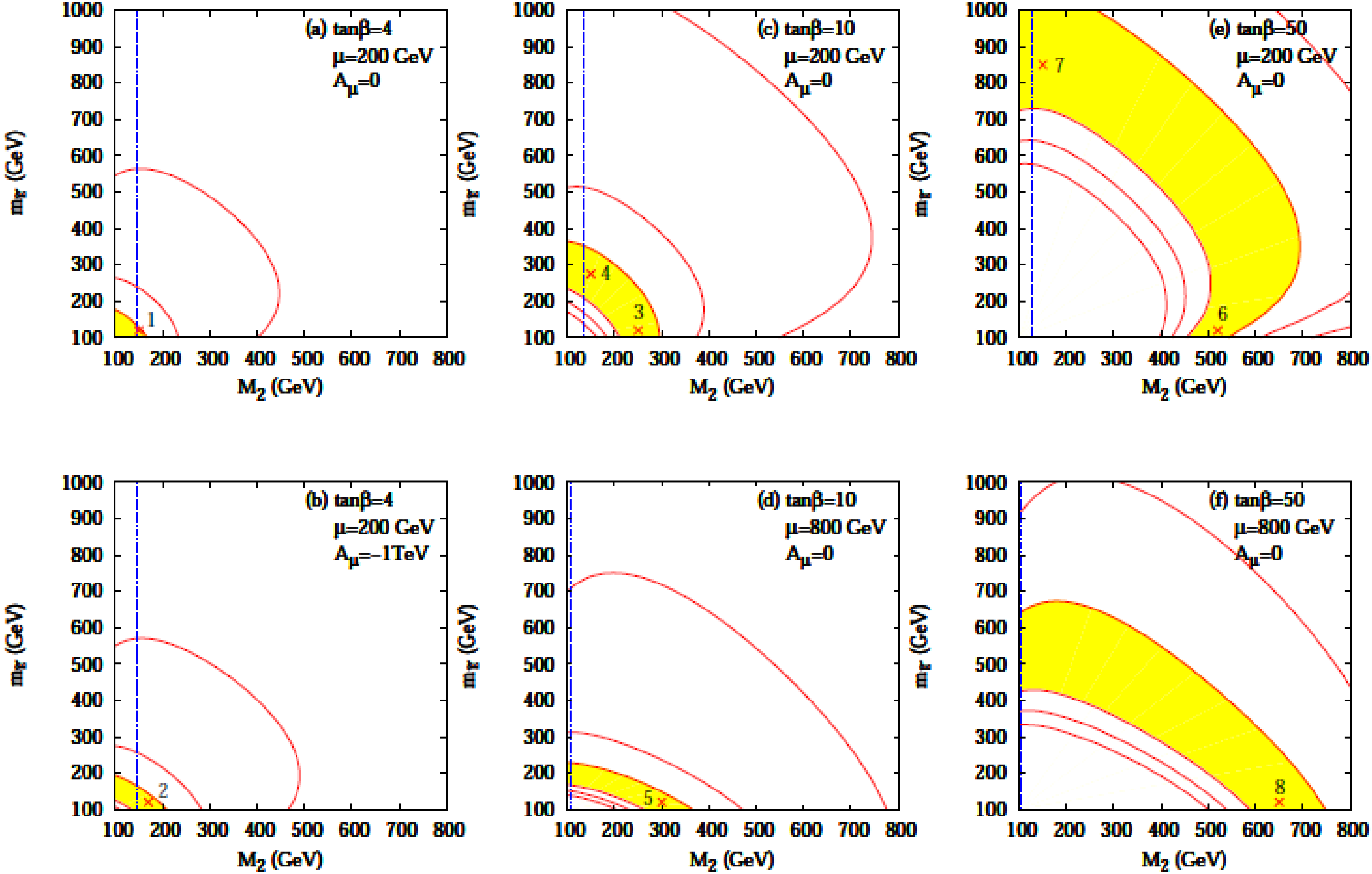
Suppose that the 3.4σ deviation is due to SUSY...

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



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	tanβ	$m_{\tilde{E}}$	M_2	μ	A_μ	(a)	(b)	(c)	(d)	(e)	(a)-(e)	total
1	4	120	150	200	0	21.9	4.6	0.9	−3.4	− 3.1	20.8	20.4
2	4	120	170	200	−1000	19.3	9.3	0.9	−3.0	− 3.2	23.2	22.8
3	10	120	250	200	0	31.1	6.6	1.5	−4.9	− 8.0	26.5	25.9
4	10	275	150	200	0	30.0	1.3	0.7	−2.9	− 1.6	27.4	25.3
5	10	120	300	800	0	8.7	20.3	0.6	−2.1	− 2.8	24.8	24.1
6	50	120	520	200	0	52.6	8.9	2.4	−6.7	−30.9	26.3	26.4
7	50	850	150	200	0	31.8	0.1	0.2	−1.0	− 0.4	30.7	27.8
8	50	120	650	800	0	18.6	21.7	1.3	−4.0	−10.7	26.8	26.5

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	$m_{\tilde{\mu}_L}$	$m_{\tilde{\mu}_R}$	$\mu\tan\beta$	A_μ	M_1	M_2
SPS1a′	10	396.0	181.0	115.7	3960	−445.2	103.3	193.2
SPS4′	50	762.2	585.1	465.0	38110	−145.5	276.7	510.2
SPS7	15	300.0	257.2	119.7	4500	−39.0	168.6	326.8
GM1	42	503.6	440.8	214.0	21151	25.1	180.9	338.8
MAM1	10	429.6	188.2	254.8	4296	−464.8	169.6	258.4
MAM2	10	−572.0	253.1	108.2	−5720	245.1	−98.6	−247.8
MSSM(∗)	10	350	120	120	3500	0	100	600

Muon $g-2$ in selected SUSY models

	(a)	(b)	(c)	(d)	(e)	(a)-(e)	total
SPS1a′	25.7	21.5	1.5	−5.2	−5.4	38.1	37.6
SPS4′	20.0	4.8	1.0	−3.4	−2.8	19.5	19.4
SPS7	27.1	10.6	1.6	−5.0	−9.0	25.3	24.8
GM1	34.6	11.7	1.4	−5.3	−9.2	33.2	33.0
MAM1	19.5	7.2	1.4	−4.5	−1.9	21.7	21.7
MAM2	13.2	18.8	0.7	−2.7	−4.2	25.8	24.7
MSSM(∗)	13.1	28.2	2.8	−4.3	−5.6	34.1	32.9

Introduction to EW Precision Study

LEP-I experiments ('89 - '95): e^+e^- annihilation experiments on the Z pole. The properties of Z bosons were studied in detail (mass, full/partial decay width, angular distributions of the decay products, ...) using 17 millions of Z boson decays collected there. (Final report appeared 'recently': hep-ex/0509008)

To confront the EW precision data with theory, the S, T, U **parameters** gives a useful framework (Peskin & Takeuchi). (One of) their main observations: "In many cases, the most important radiative corrections to the EW observables appear in the gauge boson propagators".

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

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

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

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

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

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

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

S-T Plane Analysis

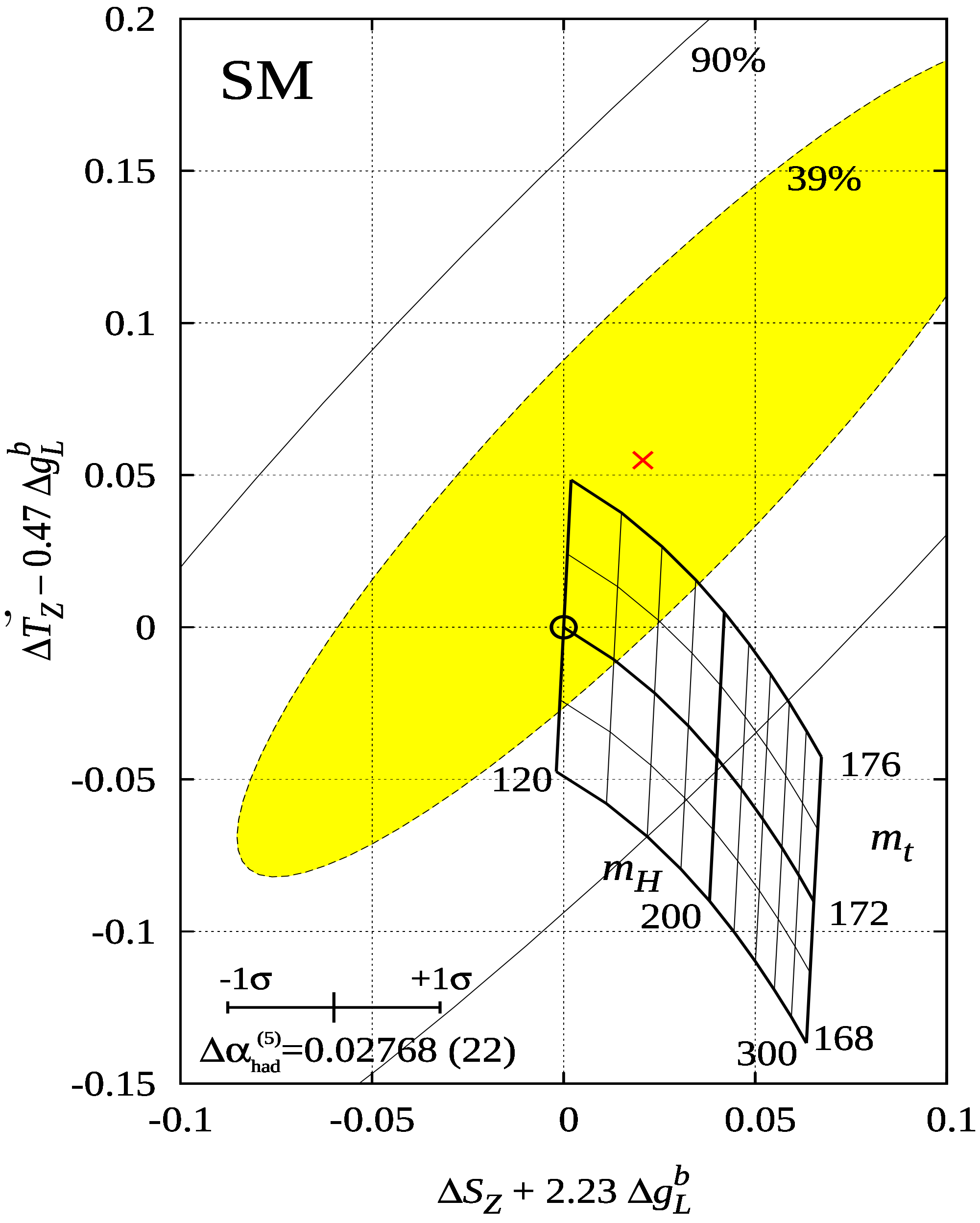
1. Calculate $\mathcal{O}_i^{\rm th}(\Delta S, \Delta T, \ldots)$, where $\mathcal{O}_i$ are EW precision observables $(\Gamma_Z, \sigma_h^0, A_f, \ldots)$.

2. Construct the χ^2 function as

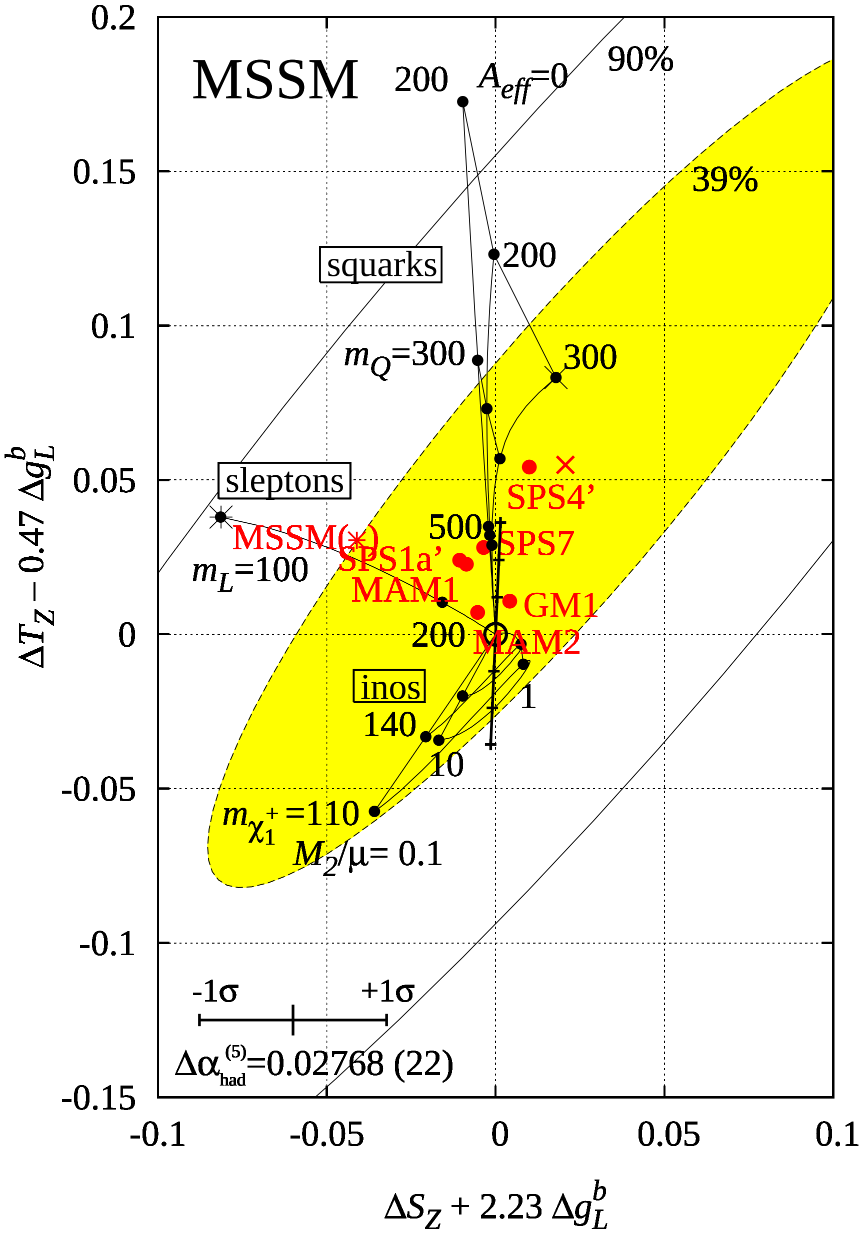
$$\chi^2 = \sum_{i,j} \left(\mathcal{O}_i^{\rm th}(\Delta S, \Delta T, \ldots) - \mathcal{O}_i^{\rm exp}\right) \times \left(V^{-1}\right)_{ij} \left(\mathcal{O}_j^{\rm th}(\Delta S, \Delta T, \ldots) - \mathcal{O}_j^{\rm exp}\right),$$

where V is the covariance matrix (which can be constructed from the correlation matrix and the error, given by the LEP EW Working Group), $V_{ij} = (\delta\mathcal{O}_i^{\rm exp})(\delta\mathcal{O}_j^{\rm exp})\rho_{ij}$.

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



Electroweak Precision Data vs MSSM, (I) S-T plane analysis



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

Our Results:

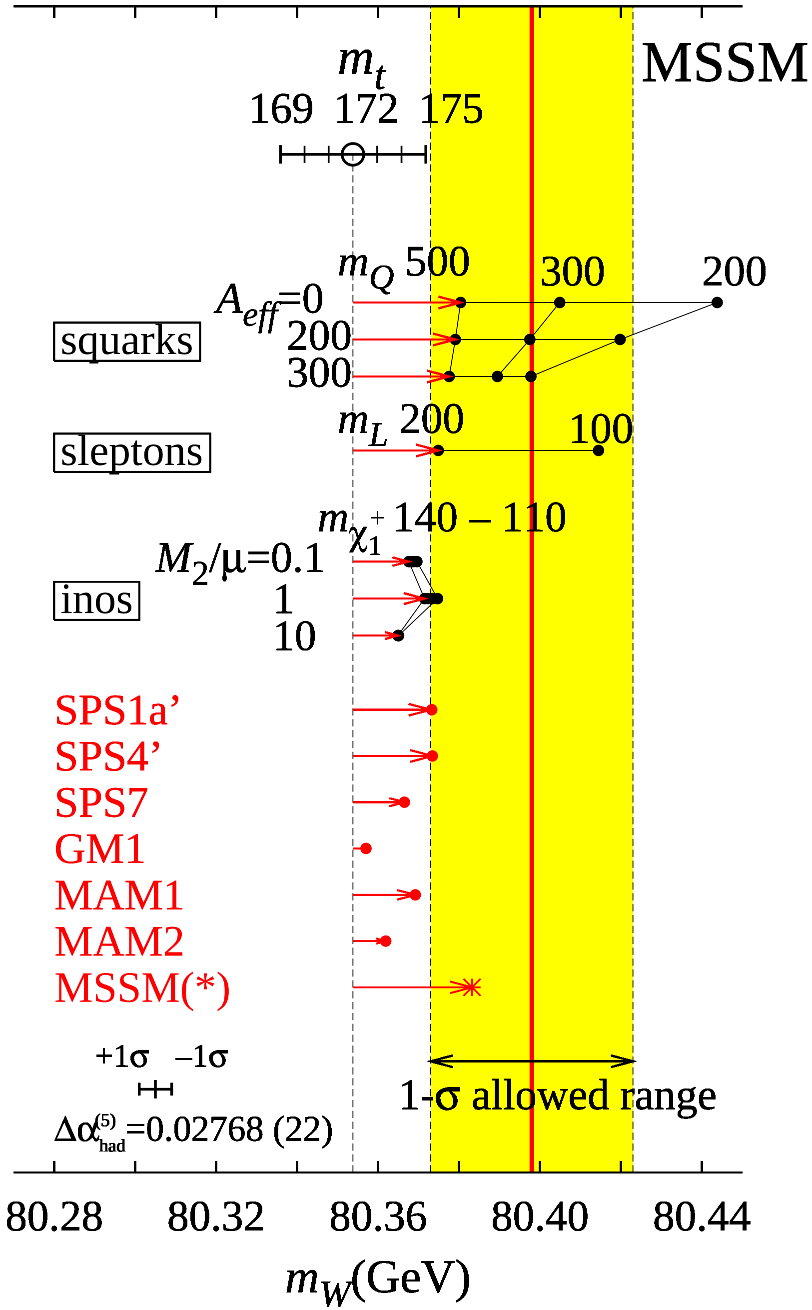
✓ The SM with $m_H \sim 100$ GeV gives a good description.

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

✓ The MSSM sample points studied here, SPS1a′, SPS4′, SPS7, . . . are within the favored region.

Cho-Hagiwara-Matsumoto-DN, in preparation

Electroweak Precision Data vs MSSM (II), M_W

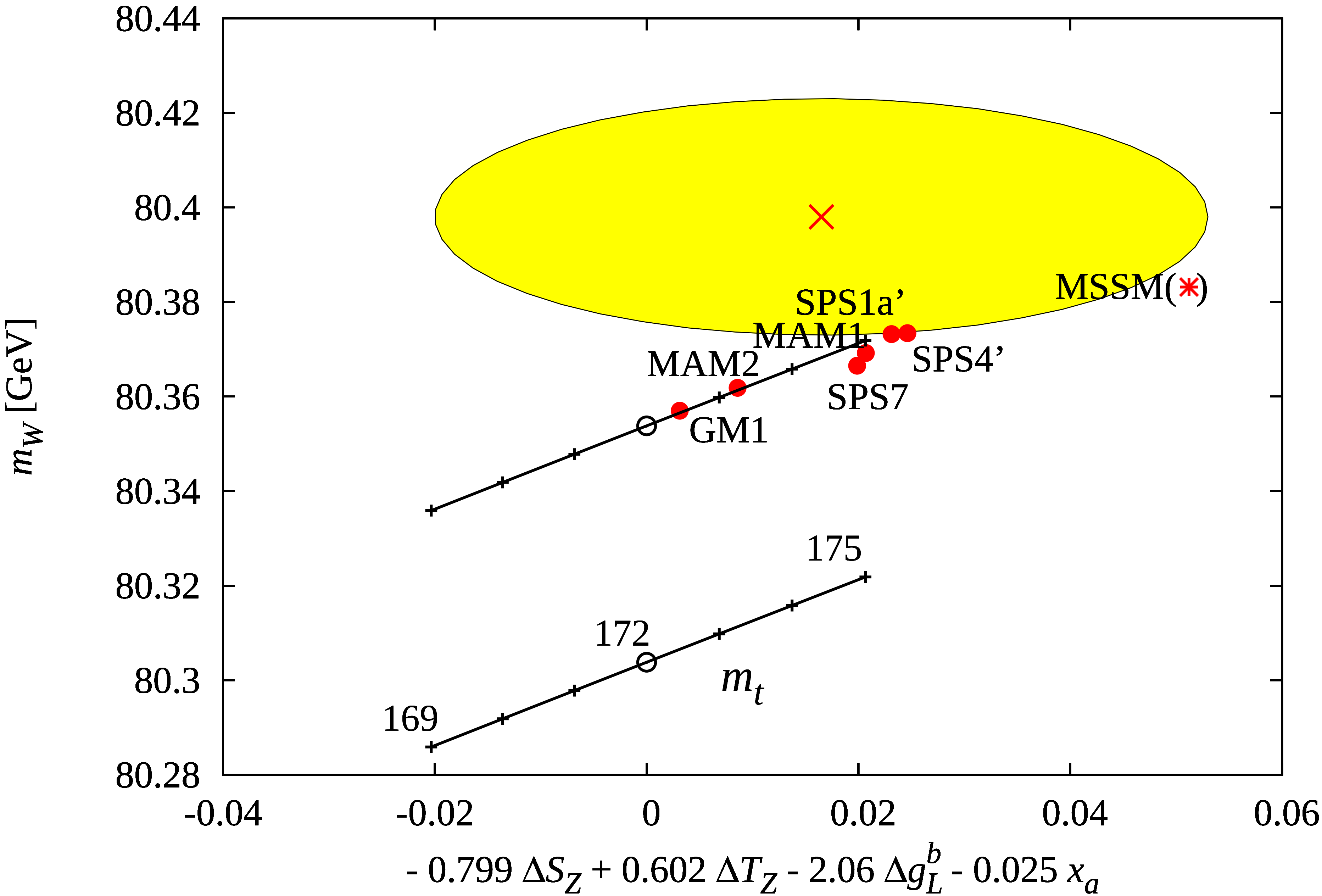


Our Results:

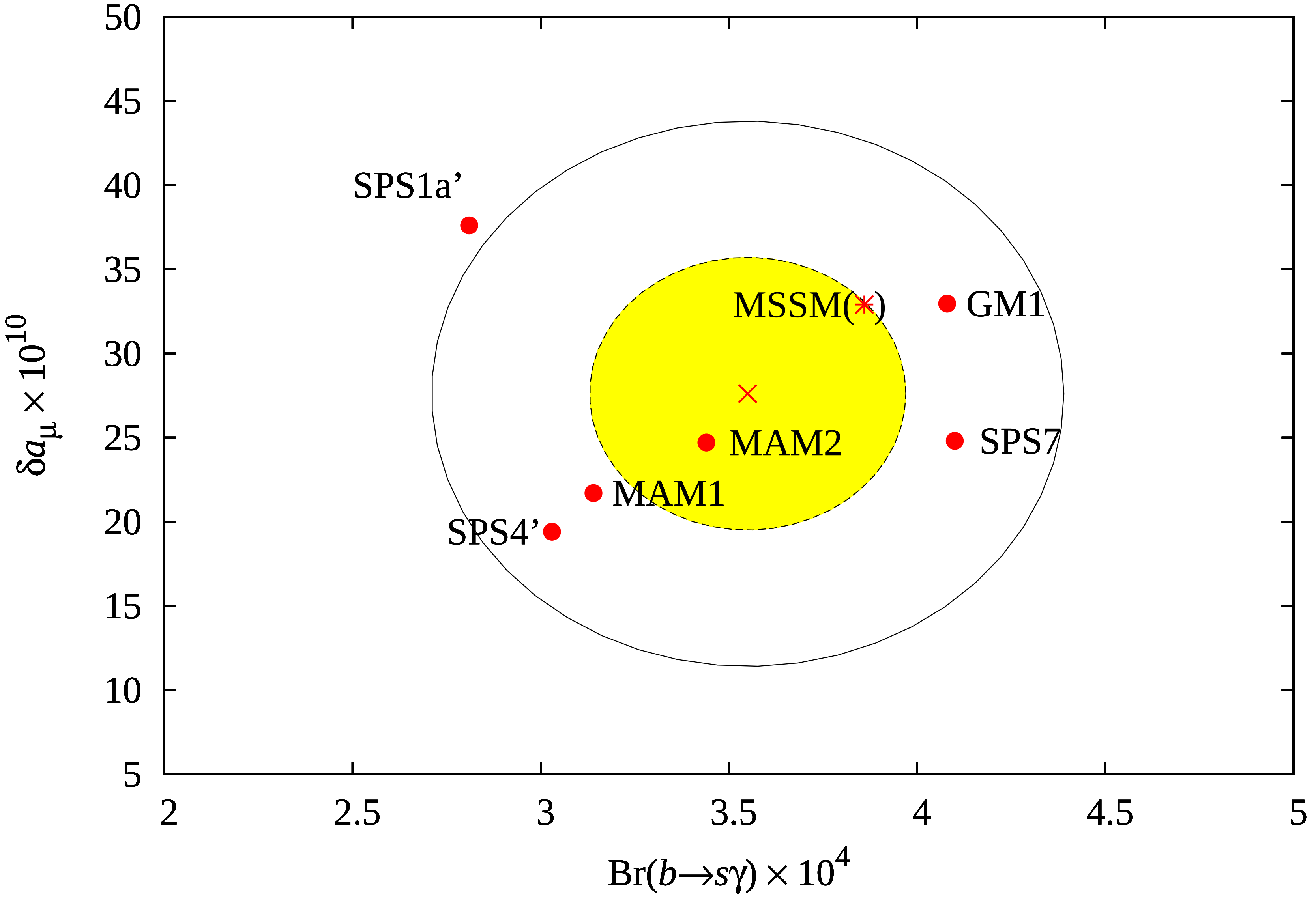
✓ The MSSM with $\mathcal{O}(100)$ GeV SUSY masses gives a good description.

Cho-Hagiwara-Matsumoto-DN, in preparation

EW Constraints vs selected SUSY points



Constraints from muon $g-2$ and $\mathrm{Br}(b \to s\gamma)$



Summary

We studied the favored parameter region of MSSM using the results of 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 popular models like mSUGRA, GMSB and MMAM, there still be some parameter region favored from muon $g-2$ and EW precision data, as well as $b \to s\gamma$.