Constraints on SUSY Higgs Sector Parameters from Higgs Mass and Branching Fractions at the LHC and LC

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Implications of LHC Results for TeV-scale Physics
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If a 125 GeV Higgs boson exists which are the constraints on SUSY parameter space ?

Which are the SUSY scenarios most interesting for the LHC program ?

Which are the implications of measurements of the Higgs properties at the LHC ?

How will a lepton collider complement the LHC data ?

This talk is part of a study which attempts to answer these questions, at least in part:

Use pMSSM flat scans, apply flavour and DM constraints, verify observability of points in LHC MET and Higgs analyses, impose Higgs mass range and study fraction of viable pMSSM points as function of pMSSM parameters;

Here, study range of viable values of pMSSM variables and constraints (predictivity) from measurements at LHC and LC.

For previous results see EPJ C72 (2012) 1847, EPJ C72 (2012) 1906, PLB 708 (2012) 162.

pMSSM Scans

Flat scan of 19 pMSSM parameters:
60M pMSSM points generated

Parameter	Range
$\tan\beta$	$[1, 60]$
M_A	$[50, 2000]$
M_1	$[-2500, 2500]$
M_2	$[-2500, 2500]$
M_3	$[50, 2500]$
$A_d = A_s = A_b$	$[-10000, 10000]$
$A_u = A_c = A_t$	$[-10000, 10000]$
$A_e = A_\mu = A_\tau$	$[-10000, 10000]$
μ	$[-3000, 3000]$
$M_{\tilde{e}_L} = M_{\tilde{\mu}_L}$	$[50, 2500]$
$M_{\tilde{e}_R} = M_{\tilde{\mu}_R}$	$[50, 2500]$
$M_{\tilde{\tau}_L}$	$[50, 2500]$
$M_{\tilde{\tau}_R}$	$[50, 2500]$
$M_{\tilde{q}_{1L}} = M_{\tilde{q}_{2L}}$	$[50, 2500]$
$M_{\tilde{q}_{3L}}$	$[50, 2500]$
$M_{\tilde{u}_R} = M_{\tilde{c}_R}$	$[50, 2500]$
$M_{\tilde{t}_R}$	$[50, 2500]$
$M_{\tilde{d}_R} = M_{\tilde{s}_R}$	$[50, 2500]$
$M_{\tilde{b}_R}$	$[50, 2500]$

Constraints

$$2.16 \times 10^{-4} < \mathrm{BR}(B \to X_s\gamma) < 4.93 \times 10^{-4}$$

$$\longrightarrow \quad \mathrm{BR}(B_s \to \mu^+\mu^-) < 1.08 \times 10^{-8}$$

$$0.56 < \frac{\mathrm{BR}(B \to \tau\nu)}{\mathrm{BR}_{SM}(B \to \tau\nu)} < 2.70 \,,$$

$$4.7 \times 10^{-2} < \mathrm{BR}(D_s \to \tau\nu) < 6.1 \times 10^{-2} \,,$$

$$2.9 \times 10^{-3} < \mathrm{BR}(B \to D^0\tau\nu) < 14.2 \times 10^{-3} \,,$$

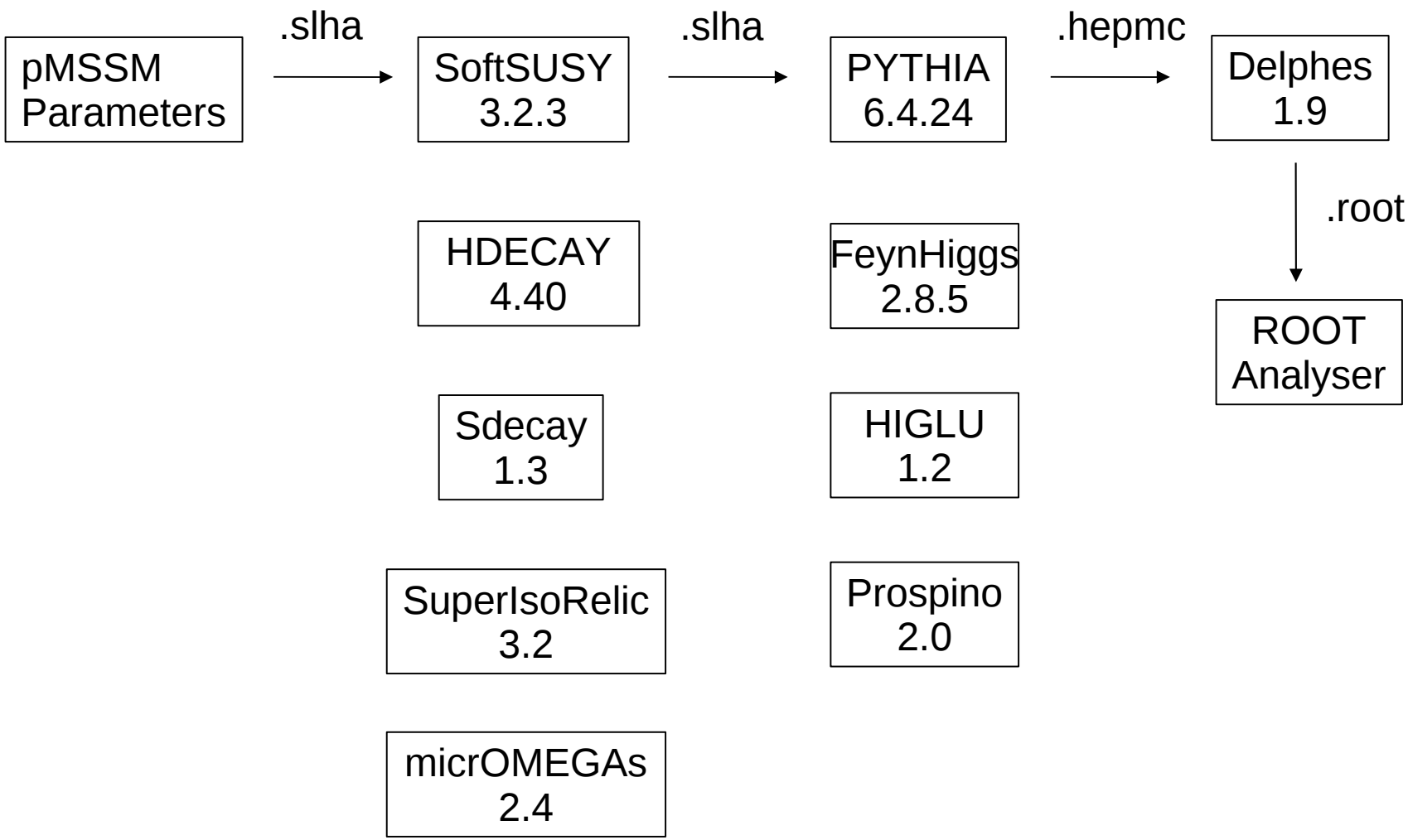
$$0.985 < \mathrm{R}_{\ell 23}(K \to \mu\nu) < 1.013 \,.$$

$$-2.4 \times 10^{-9} < \delta a_\mu < 4.5 \times 10^{-9}$$

$$10^{-4} < \Omega_{DM} h^2 < 0.135$$

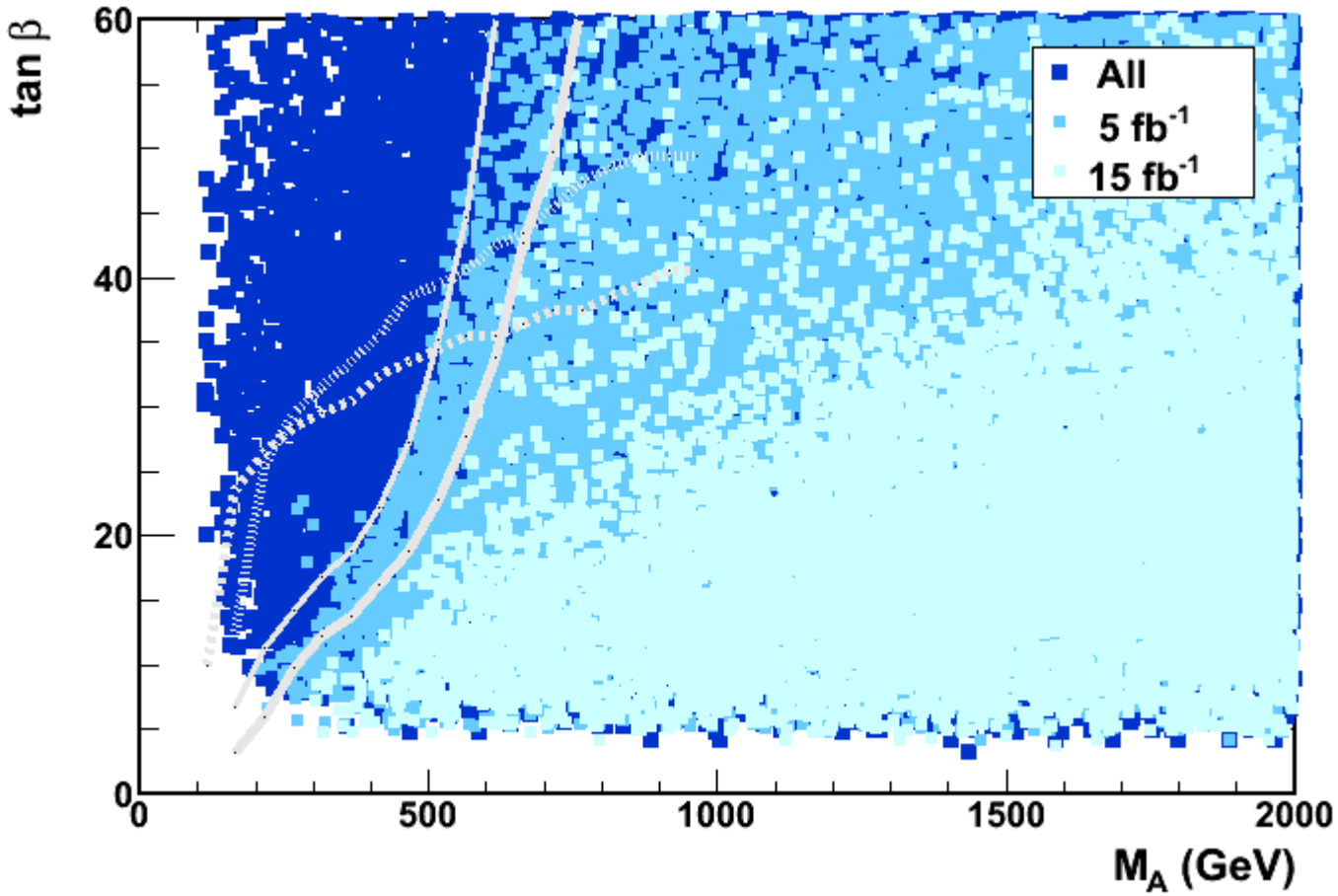
Parameter	Value
$\alpha_s(M_Z)$	0.1184
$\bar{m}_b(\bar{m}_b)$	4.19 GeV
m_t^{pole}	172.9 GeV

Software and Tools



Higgs Mass and the M_A – tan β Plane

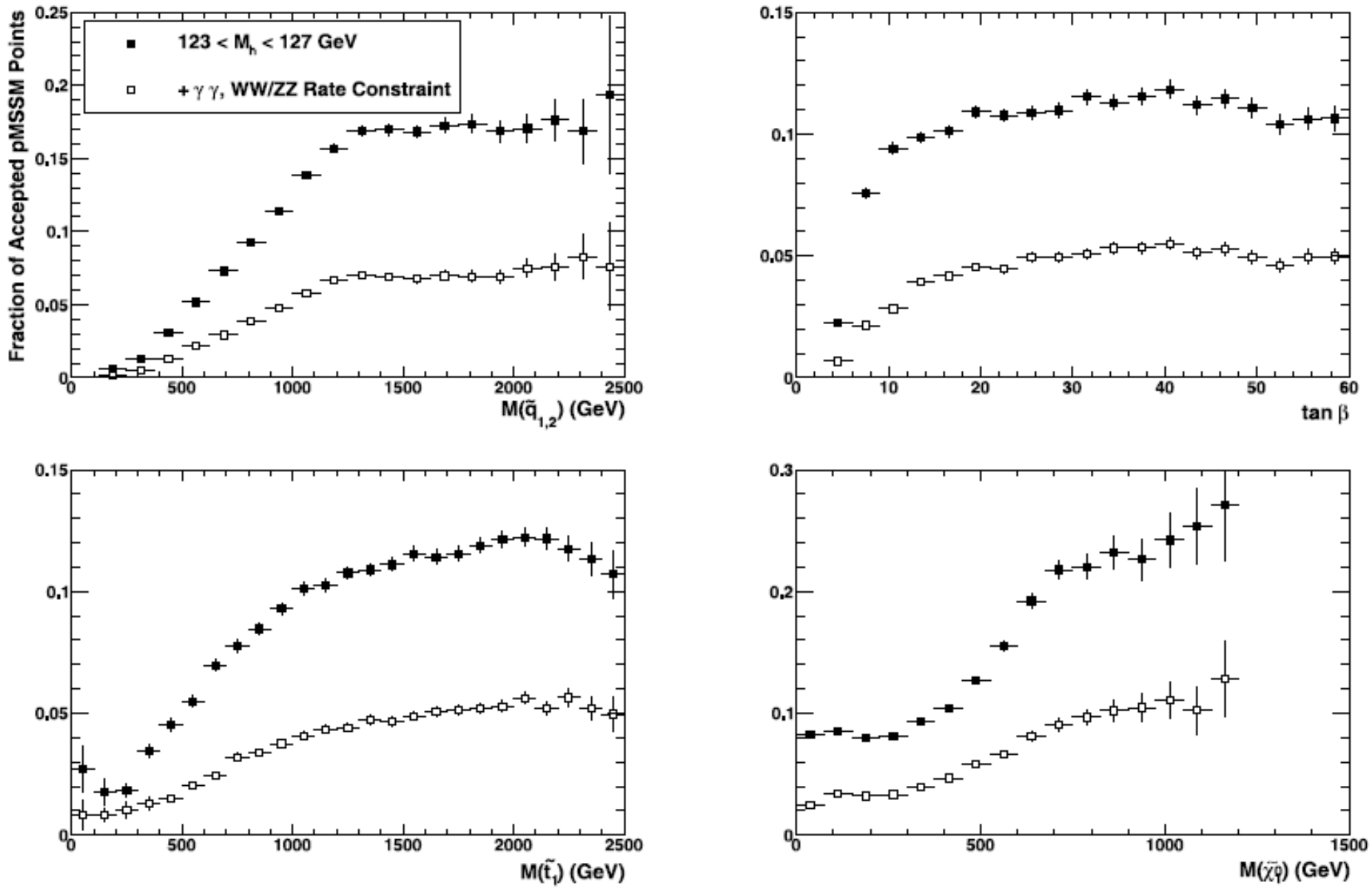
pMSSM points: $123 < M_h < 127$ GeV



updated from EPJ C72 (2012) 1906

Higgs Mass, Rates and SUSY Parameters

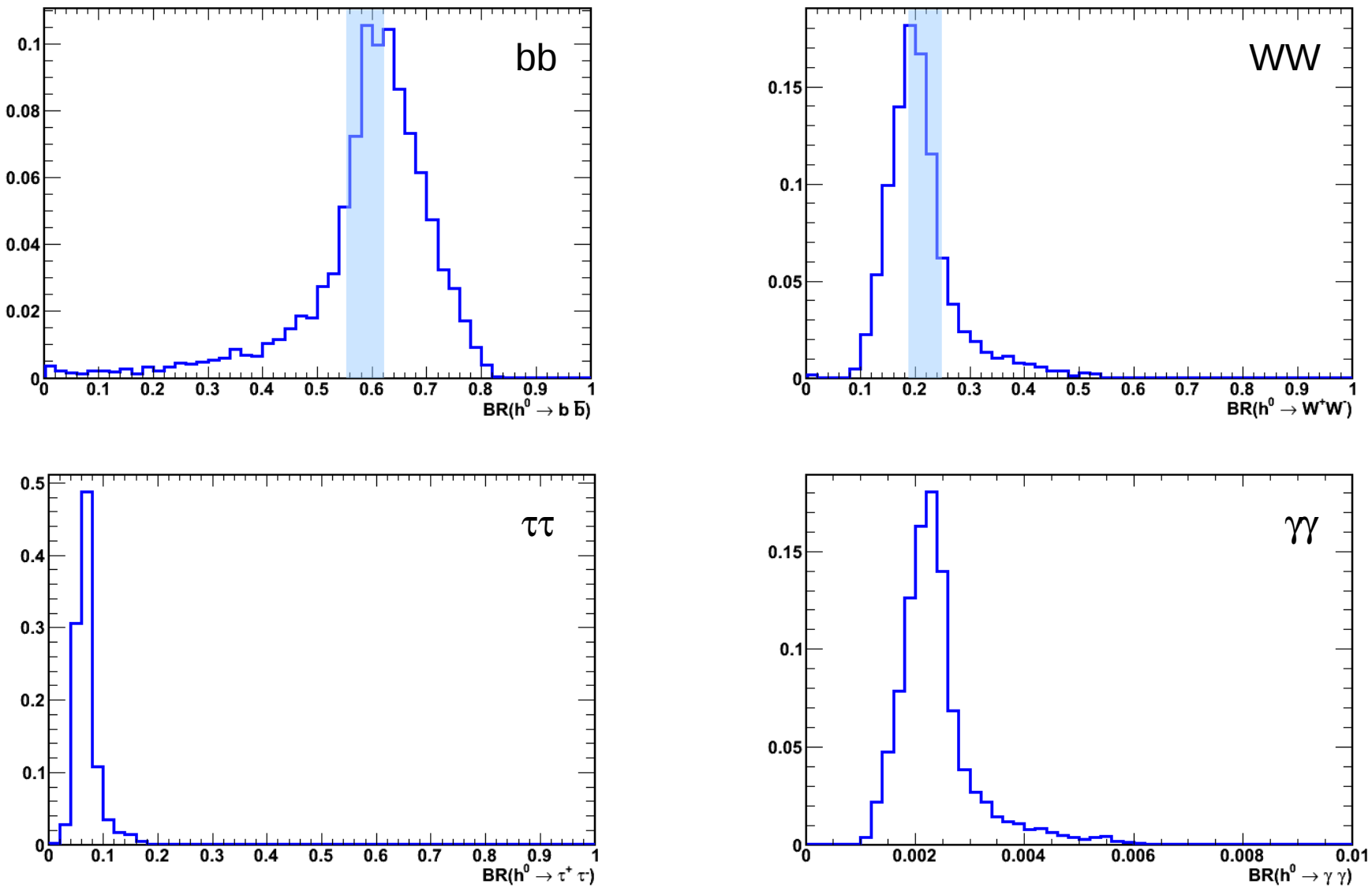
$$123 < M_{h^0} < 127 \text{ GeV} \; ; \quad 1 \leq R_{\gamma\gamma} < 3 \; ; \quad 0.3 < R_{W^+W^-/Z^0Z^0} < 2.5$$



EPJ C72 (2012) 1906

Higgs Branching Fractions

pMSSM points: $123 < M_h < 127$ GeV



Higgs Branching Fractions

pMSSM points:
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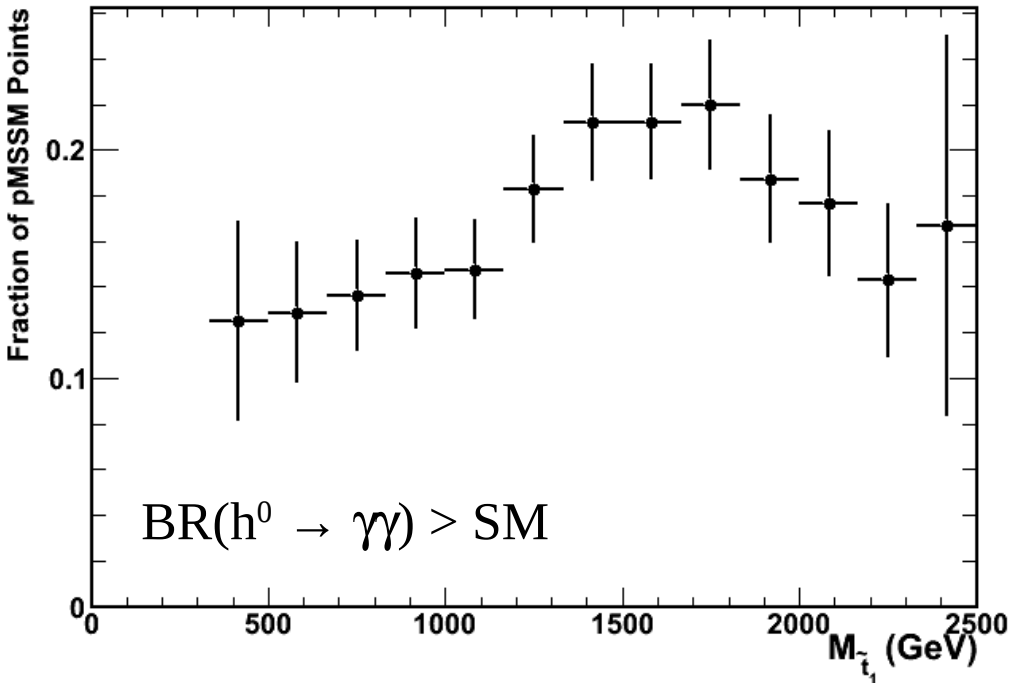
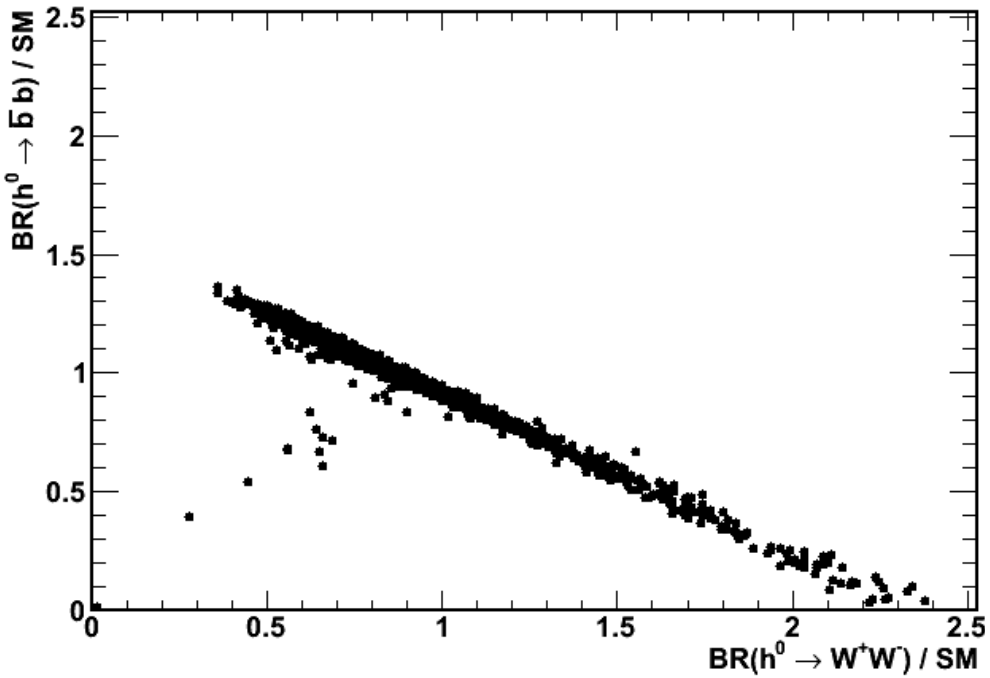
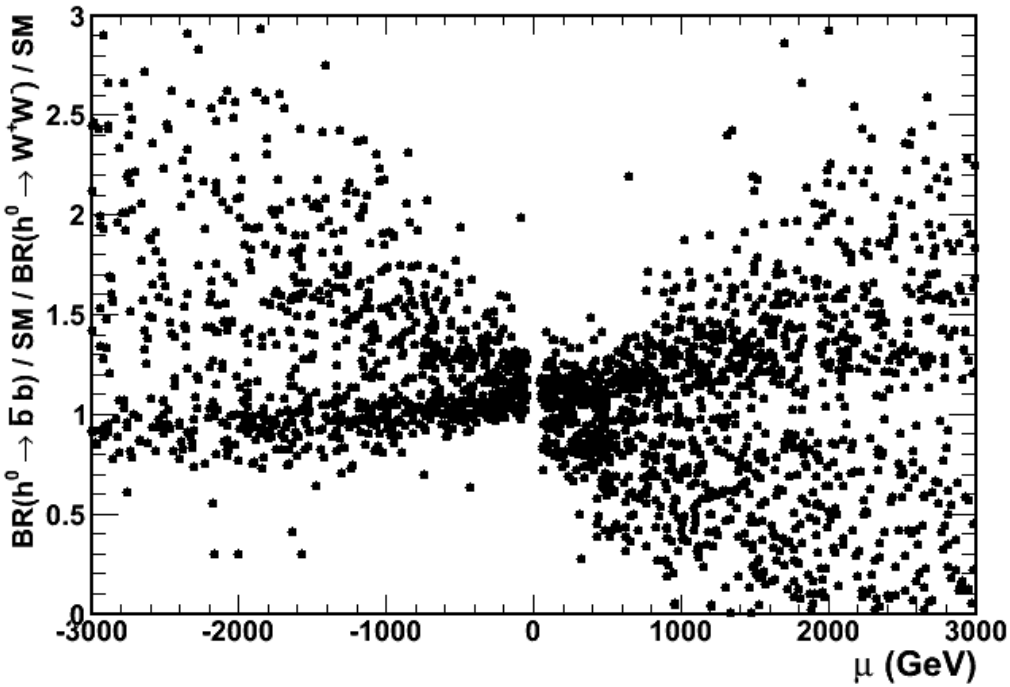






Reference pMSSM Points

Choose a set of reference pMSSM points:

Points not excluded by current LHC and flavour data, M_A < 900 GeV to retain sensitivity through BRs
Specific scenarios tested: light M_A at low tan β, low and high M_{SUSY} and μ values

Point	M_h (GeV)	M_A (GeV)	$\tan\beta$	μ (GeV)	M_{SUSY} (GeV)
1	124.6	402.8	17.4	-961	1898
2	125.8	705.8	28.4	1334	1928
3	124.2	846.9	35.9	1869	1547
4	125.5	773.3	13.0	-2022	940
5	125.3	585.3	31.0	2666	1703
6	125.8	519.0	16.2	-166	1714
7	125.9	728.9	11.7	114	2096
8	125.9	440.5	44.9	758	2385
9	125.6	336.2	10.1	197	1030
10	125.7	432.5	21.2	-249	1140
11	124.6	877.5	45.2	102	1402
12	124.4	255.7	5.6	-1125	1804

Define accuracies for measurements at LHC and LC

Channel	$\frac{\delta BR}{BR}$
$h^0 \to W^+W^-$	0.20
$h^0 \to b\bar{b}$	0.40
$h^0 \to c\bar{c}$	-
$h^0 \to \tau^+\tau^-$	0.25
$h^0 \to \gamma\gamma$	0.15

ATLAS TDR & PRD70 (2004) 113009

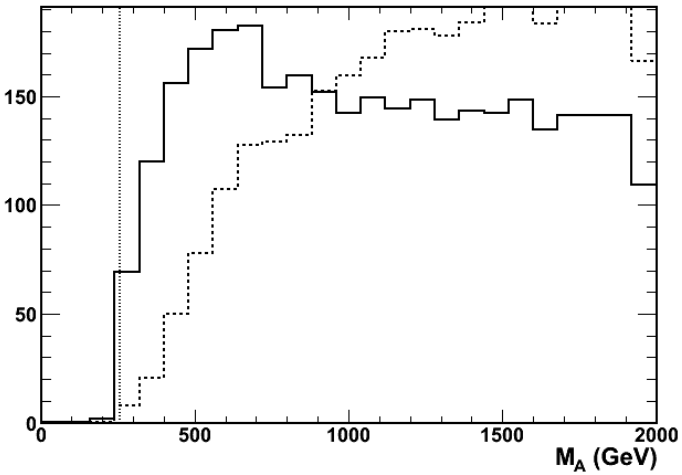
Channel	$\frac{\delta BR}{BR}$
$h^0 \to W^+W^-$	0.05
$h^0 \to b\bar{b}$	0.02
$h^0 \to c\bar{c}$	0.12
$h^0 \to \tau^+\tau^-$	0.05
$h^0 \to \gamma\gamma$	0.20

TESLA TDR, LC-PHSM-2007-001 & ILD LoI

Build probability density function of SUSY variables by weighting pMSSM points by the χ^2 prob that their corresponding M_h and h^0 Brs are compatible to those of the selected pMSSM point within their uncertainties, compare to distribution of accepted pMSSM points with M_h within σ_M from point.

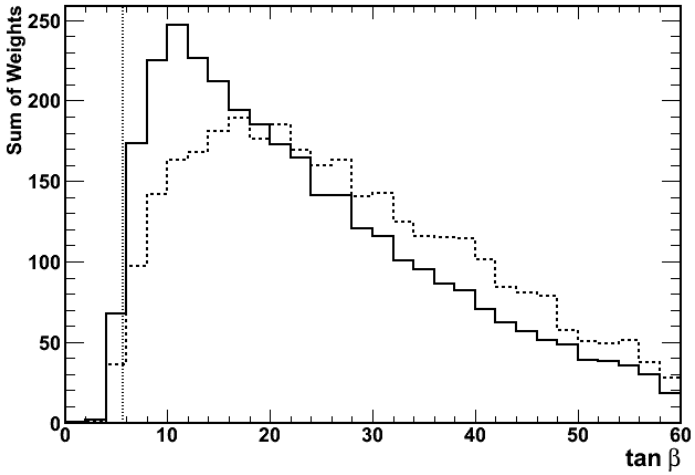
Pdf from BRs at LHC

256 GeV



LHC
Set 12

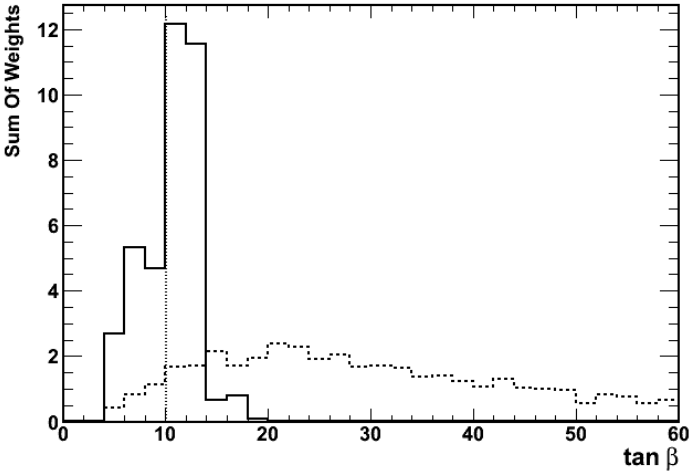
No
Constraints



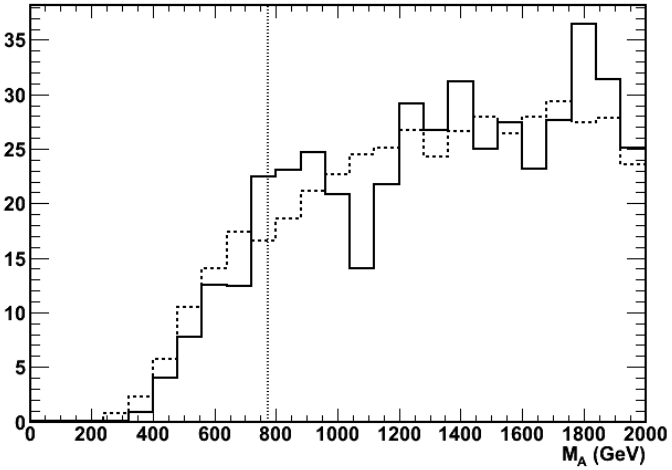
339 GeV

LHC
Set 09

$M_A \pm 20$

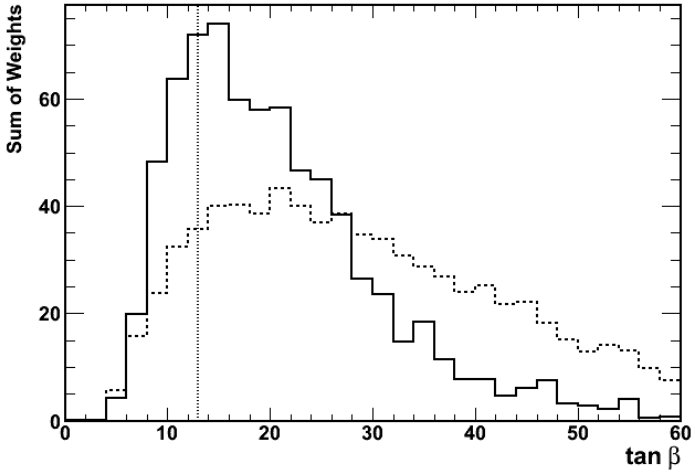


773 GeV



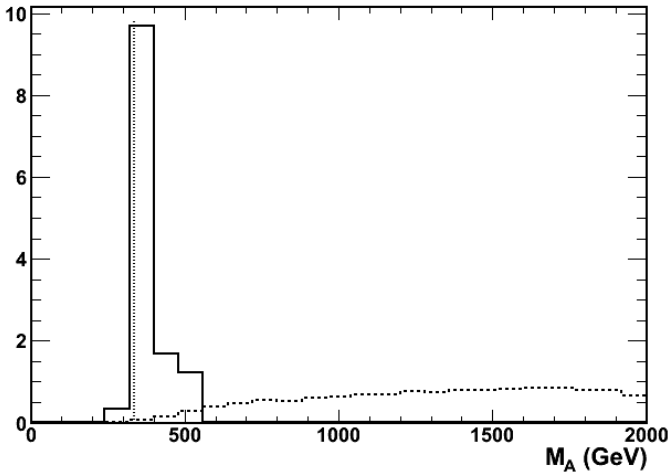
LHC
Set 04

$M_{SUSY} \pm 50$

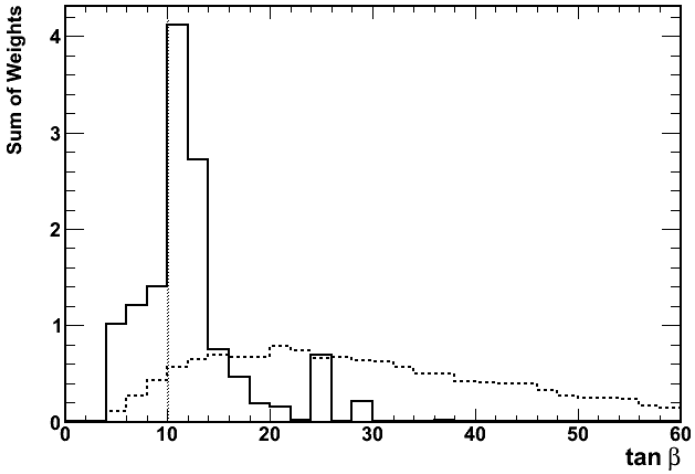


Pdf from BRs at LC

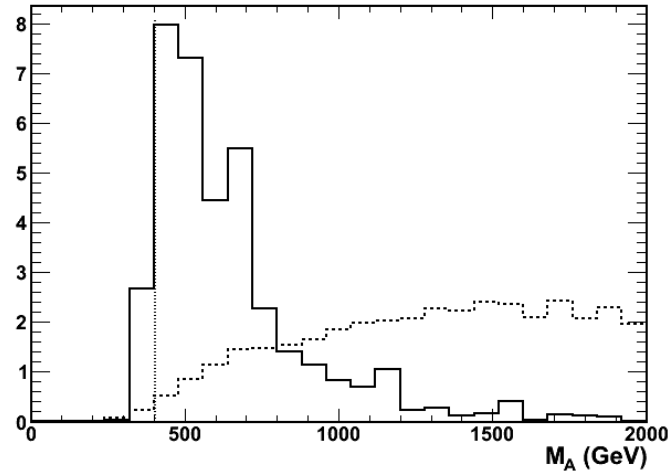
339 GeV



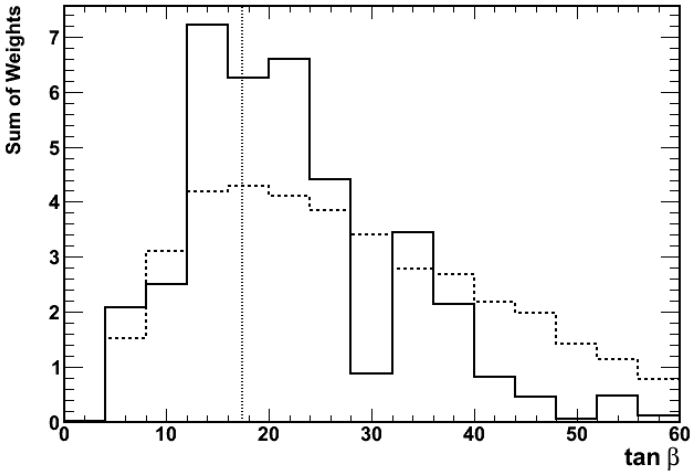
LC
Set 09



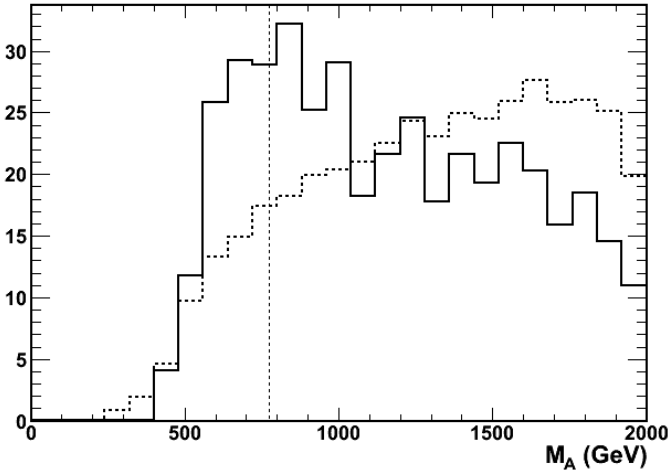
403 GeV



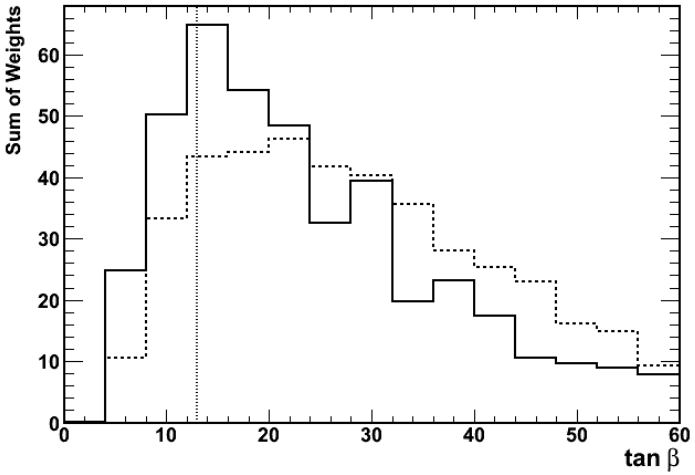
LC
Set 01



773 GeV



LC
Set 04



Fits to Pdfs

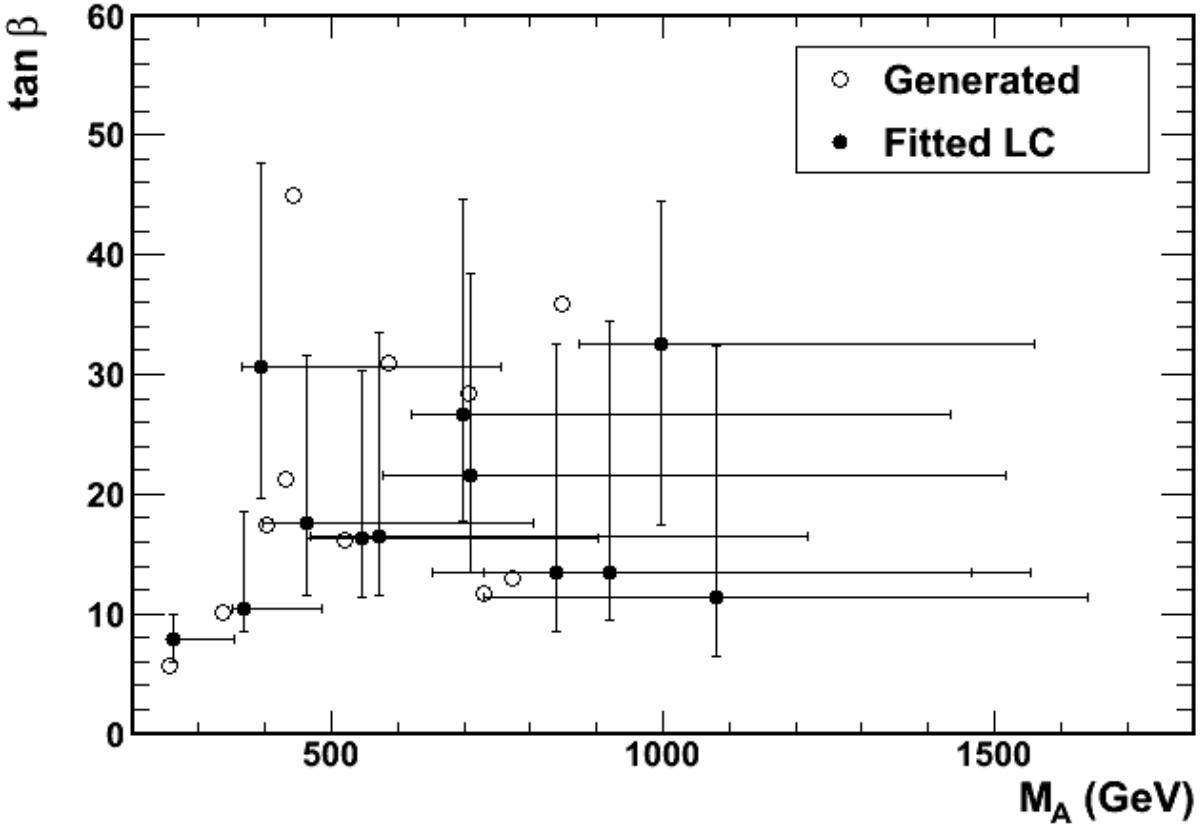
Four main observables:

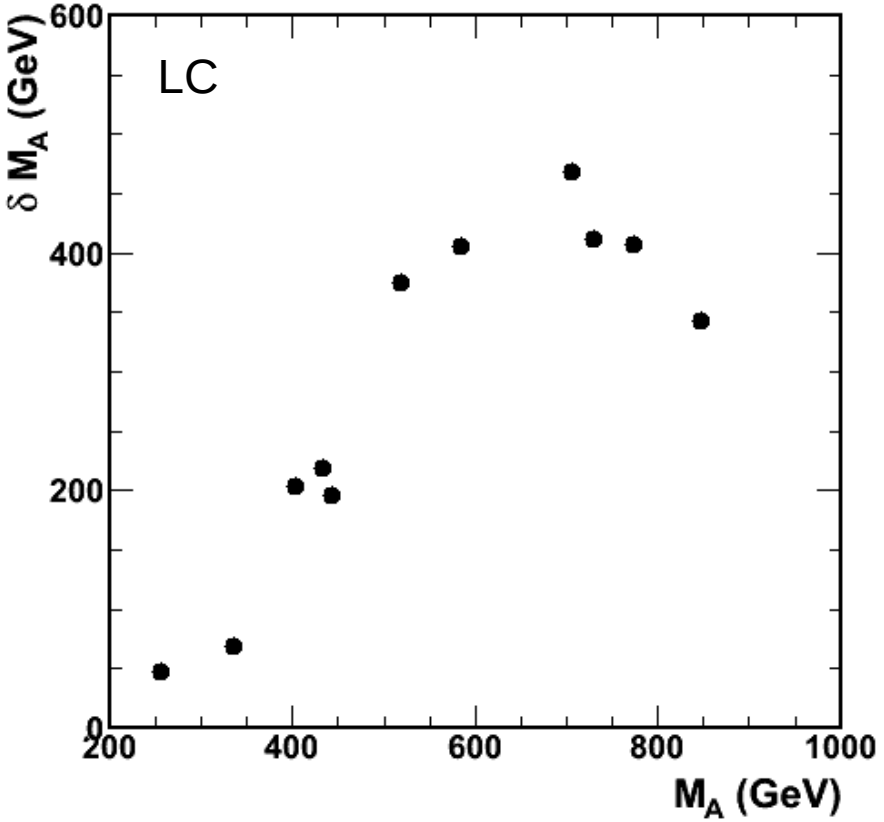
- M_A
- tan β
- M_{SUSY}
- μ

Determine central value and 68%C.L. range from binned pdf distributions

	M_A (GeV)	$\tan\beta$	M_{SUSY} (GeV)	μ (GeV)
Point 1	403	17.4	1898	- 961
LC	463^{+341}_{-65}	17.6^{+14}_{-6}	1809^{+298}_{-515}	- 133±1600
Point 2	705	28.4	1928	1334
LC	710^{+806}_{-132}	21.5^{+17}_{-8}	1930^{+280}_{-390}	1266^{+840}_{-600}
Point 3	847	35.9	1547.2	1869
LC	997^{+564}_{-123}	32.5^{+12}_{-15}	1778^{+384}_{-428}	463^{+1185}_{-2190}
Point 4	773	13.0	940	-2022
LHC	–	20.5^{+19}_{-9}		-101^{+1230}_{-1310}
LHC	925^{+660}_{-280}	15.4^{+13}_{-5}	*940±50*	
LC	838^{+625}_{-185}	13.5^{+19}_{-5}	1670±340	-121^{+625}_{-905}
Point 5	585	31.0	1704	2667
LC	697^{+737}_{-75}	26.7^{+18}_{-9}	1777^{+353}_{-430}	-420^{+2310}_{-1315}
Point 6	519	16.2	1714	- 166
LC	571^{+647}_{-103}	16.5^{+17}_{-5}	1772±380	160^{+1080}_{-830}
Point 7	729	11.7	2097	114
LC	920^{+635}_{-190}	13.4^{+21}_{-4}	1832^{+310}_{-410}	-136±650
Point 8	441	44.9	2385	757
LC	394^{+161}_{-26}	30.7^{+17}_{-11}	2134^{+310}_{-420}	328^{+850}_{-2115}
Point 9	336	19.1	1030	197
LHC	*336±20*	12.6^{+2}_{-4}	1810±400	250^{+1600}_{-1200}
LC	369^{+118}_{-7}	10.5^{+8}_{-2}	1710±430	1808^{+1000}_{-1750}
Point 10	433	21.3	1140	-249
LC	547^{+354}_{-84}	16.3^{+14}_{-5}	1637^{+430}_{-350}	-70^{+760}_{-865}
Point 11	878	45.2	1402	102
LC	1080^{+560}_{-350}	11.4^{+21}_{-5}	1590^{+420}_{-360}	-300^{+720}_{-1060}
Point 12	256	5.6	1804	-1125
LC	263^{+90}_{-3}	7.9±2	1810±415	180±1600
LHC	510^{+750}_{-250}	11.0^{+22}_{-5}	–	–

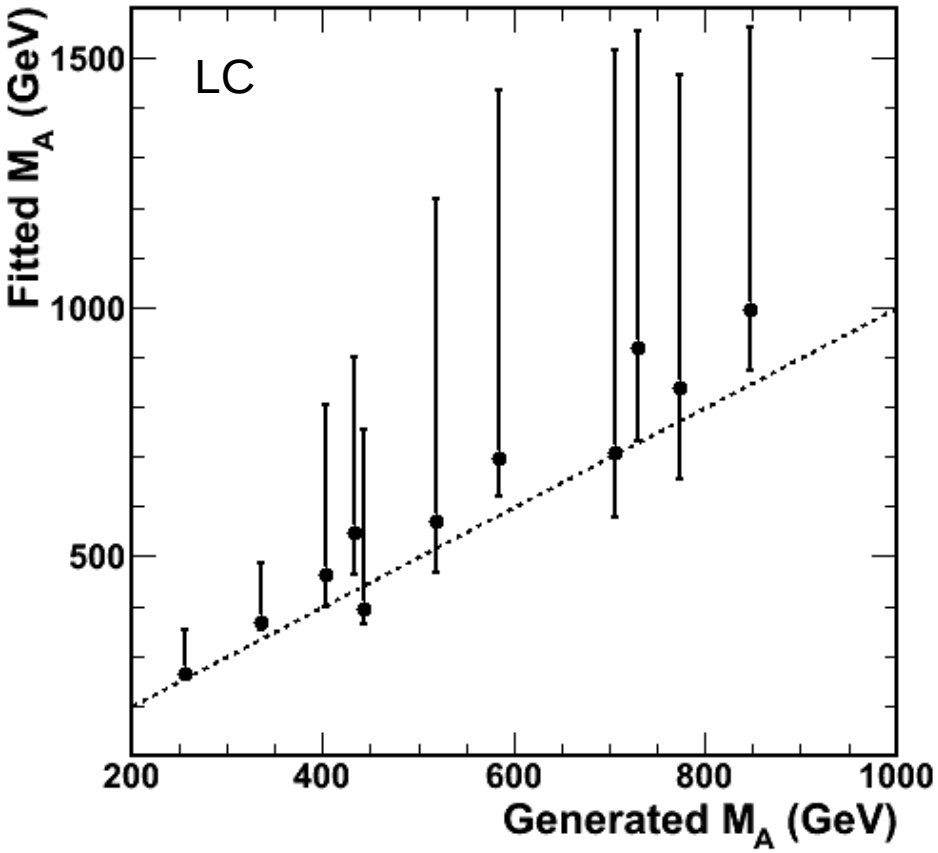
Fit Results

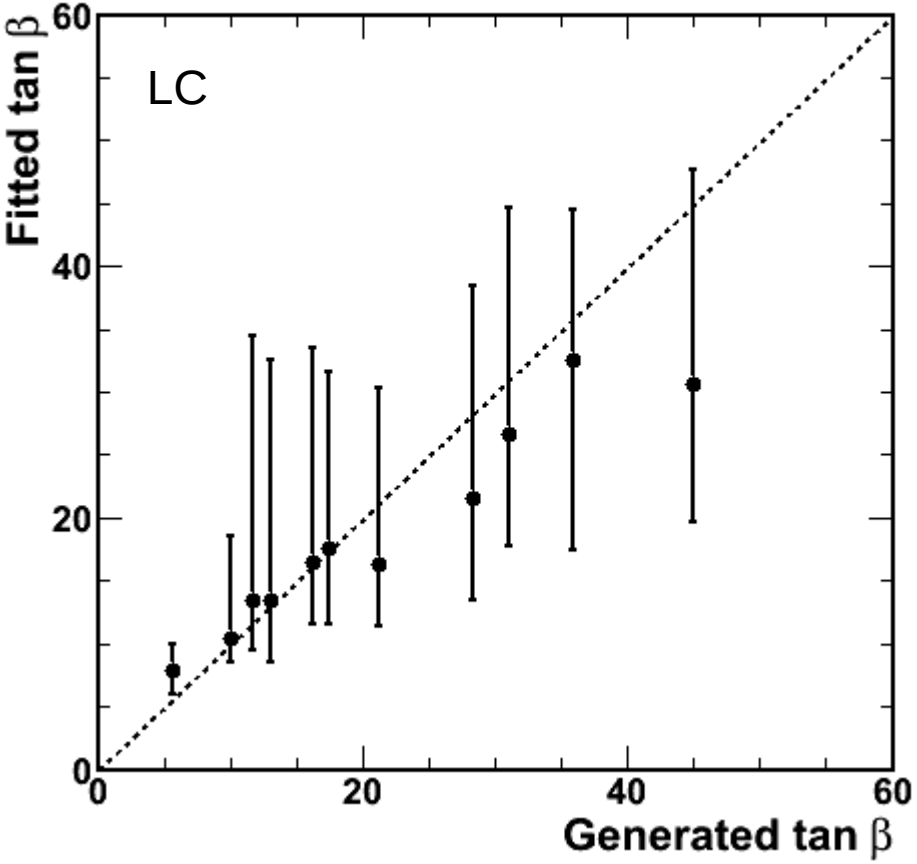




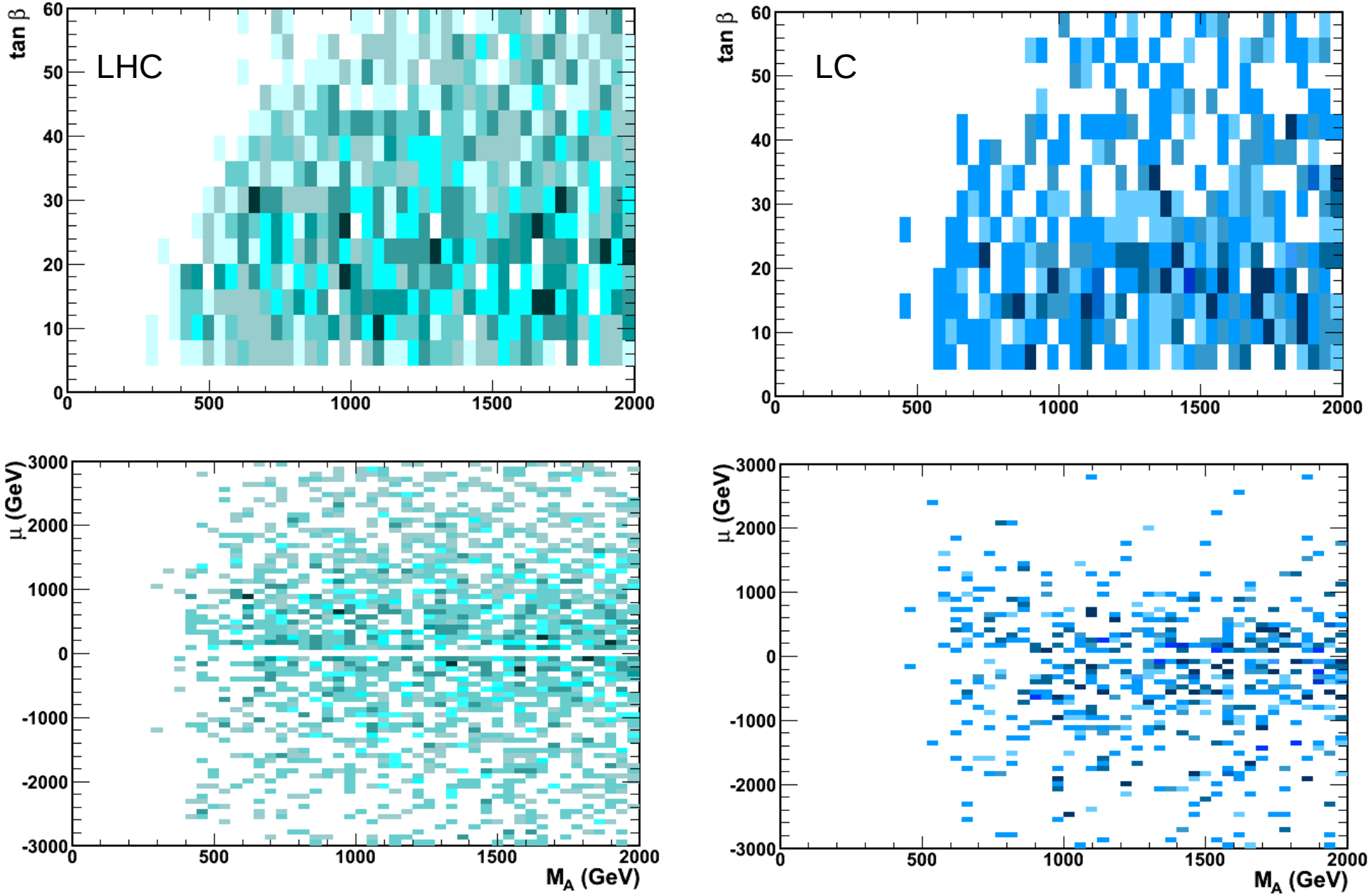
M_A symmetrised uncertainties vs. M_A

Fit Results


LC
Fitted M_A (GeV)
Generated M_A (GeV)
500
1000
1500
200
400
600
800
1000


LC
Fitted tan β
Generated tan β
0
20
40
60
0
20
40
60

SM-like BRs and the MSSM Phase Space



Conclusions

Study implications of Higgs mass and branching fraction measurements on SUSY Higgs parameters through pMSSM flat scans;

LHC rate measurements already provide important information which restricts the parameter space, using extra inputs from squark or $A^0/H^0/H^+$ mass measurements can estimate other parameters;

LC 1-10% level of accuracy on most of the decay rates provides independent information on M_A and tan β , some hints on M_{SUSY} and m up to M_A ~ 700 GeV;

SM-like values provide significant bound on M_A and μ;

Study offers us an interesting platform to evaluate precision needs and value of LC data complementing LHC results in a realistic scenario;

Need to continue the study with larger samples and realistic LHC accuracy estimates.