From the cMSSM Exclusion to Fitting the pMSSM11

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J. Schütte-Engels, T. Keller, J. Tattersal, M. Krämer, H. Dreiner, B. Sarrazin, M. Hamer, et al.

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An Incomplete Overview of the Current Situation

- We need Dark Matter, a stable Higgs mass and an explanation for EWSB . . .

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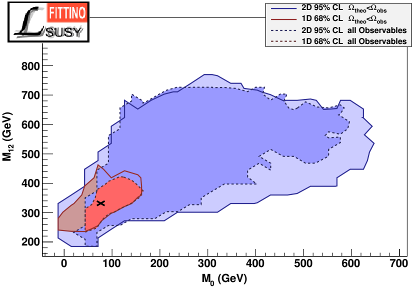
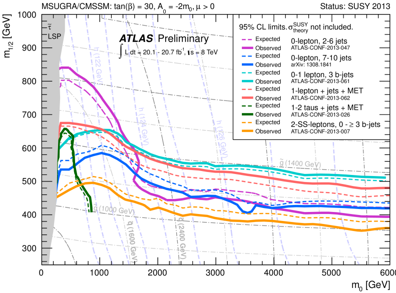




e.g. arXiv:0907.2589 [hep-ph]

- There obviously is a problem.
- We always used $(g-2)_\mu$ as a motivation for SUSY at the TeV scale. But can constrained models still accomodate this?

The status of the CMSSM

healthy?

The status of the CMSSM

healthy?

pretty dull?

The status of the CMSSM

healthy?

pretty dull?

almost dead?

The status of the CMSSM

healthy?

pretty dull?

almost dead?

buried?

Measurements

Measurements

$\mathcal{B}(B_s \to \mu^+\mu^-)$	$(3.20 \pm 1.50 \pm 0.76) \times 10^{-9}$
$\mathcal{B}(B^\pm \to \tau^\pm\nu)$	$(0.72 \pm 0.27 \pm 0.11 \pm 0.07) \times 10^{-4}$
$\mathcal{B}(b \to s\gamma)$	$(3.43 \pm 0.21 \pm 0.07 \pm 0.23) \times 10^{-4}$
Δm_s	$(17.719 \pm 0.043 \pm 4.200)\,\mathrm{ps}^{-1}$
$a_\mu - a_\mu^{\mathrm{SM}}$	$(28.7 \pm 8.0 \pm 2.0) \times 10^{-10}$
Ωh^2	0.1187 ± 0.0017
m_W	$80.385 \pm 0.015 \pm 0.010$
m_t	$(173.18 \pm 0.94)\,\mathrm{GeV}$
$\sin^2\theta_{\mathrm{eff}}$	0.23113 ± 0.00021

$+$ all kinds of limits

$+$ Higgs mass and rate information

Higgs, Searches and Astrophysics

Direct searches for sparticles and Higgs Bosons

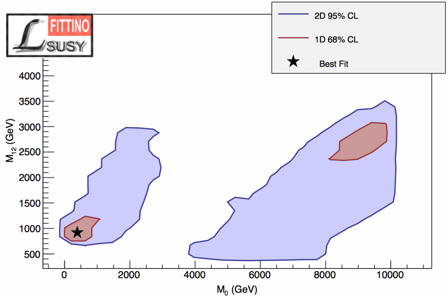
- Higgs limits via HiggsBounds
- Higgs signals via HiggsSignals
- LEP chargino mass limit
- ATLAS MET + jets + 0 lepton search (20fb^{-1})

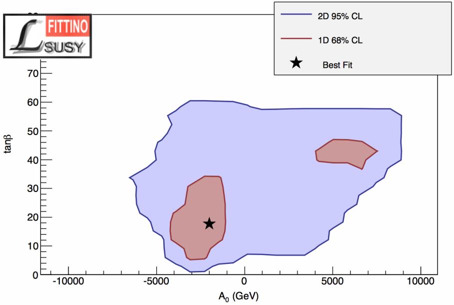
Astrophysical observables

- We require χ_1^0 to be the LSP
- Dark matter relic density:
  $\Omega_{\mathrm{CDM}} h^2 = 0.1187 \pm 0.0017 \pm 0.0119$ (Planck '13)
- Direct detection limit LUX ('13)

“Allowed” Parameter Range in the Fit

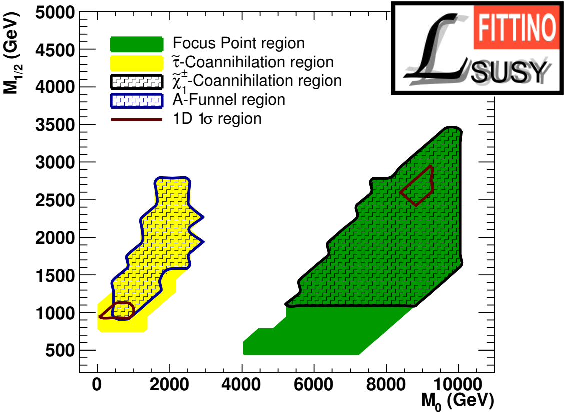
The following results from http://arxiv.org/abs/1508.05951



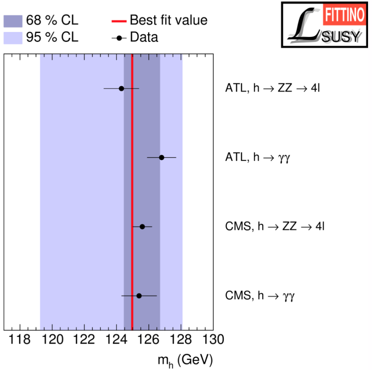


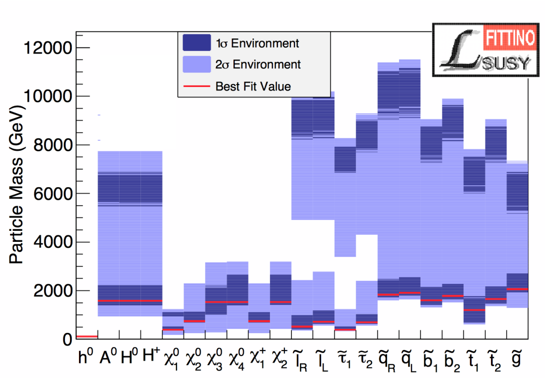
Classifying the “Allowed” Regions

- $\tilde{\tau}_1$ coannihilation: $m_{\tilde{\tau}_1}/m_{\tilde{\chi}_1^0} - 1 < 0.15$
- $\tilde{t}_1$ coannihilation: $m_{\tilde{t}_1}/m_{\tilde{\chi}_1^0} - 1 < 0.2$
- $\tilde{\chi}_1^{\pm}$ coannihilation: $m_{\tilde{\chi}_1^{\pm}}/m_{\tilde{\chi}_1^0} - 1 < 0.1$
- A/H funnel: $|m_A/2m_{\tilde{\chi}_1^0} - 1| < 0.2$
- focus point region: $|\mu/m_{\tilde{\chi}_1^0} - 1| < 0.4$



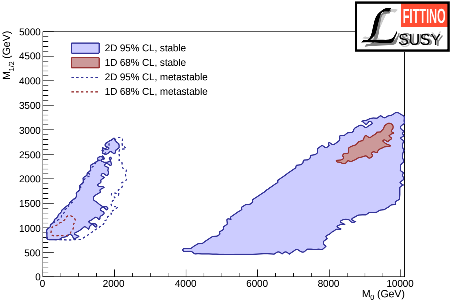
Predicted Ranges of SUSY Particle Masses

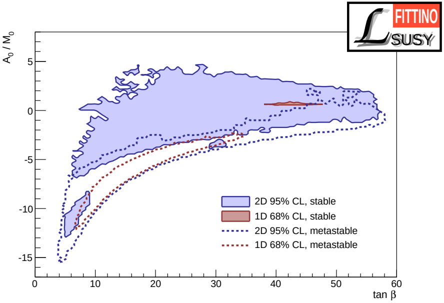




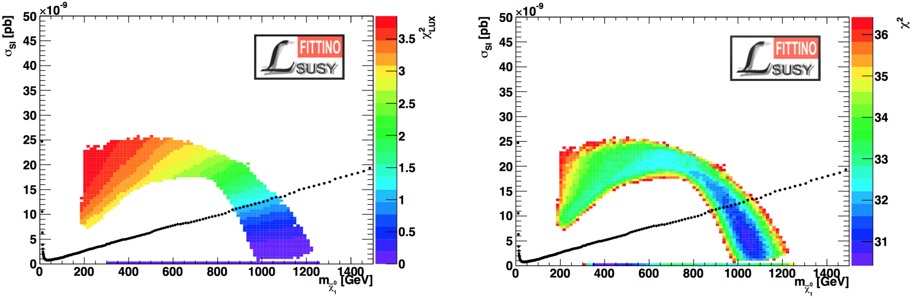
But is that stable on cosmological timescales?

- Using VeVacious arXiv:1307.1477 [hep-ph]
- All minima in stable or metastable (lifetime $\gg$ age of the universe) regions





Sensitivity of Direct Detection Experiments



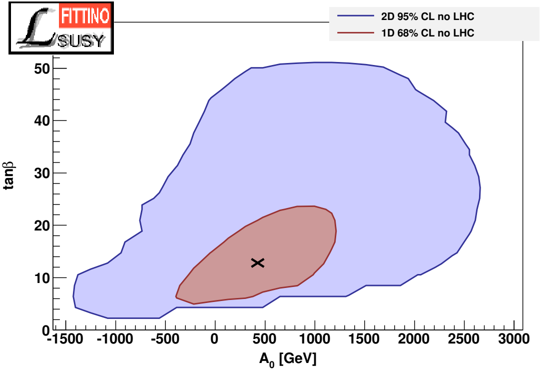
Contributions from Direct Detection

No contributions from Indirect Detection

Why are global fits of SUSY so CPU-consuming?

- ... and impossible with naively employing Minuit?
- This is an old result – just for education!

Looking at any correlations for all other allowed parameters:



Looks OK

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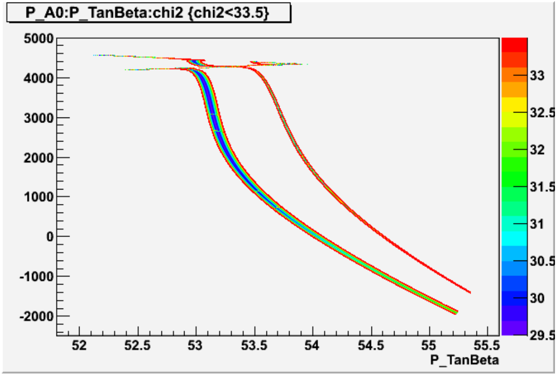
Looking at any correlations for fixed other parameters:

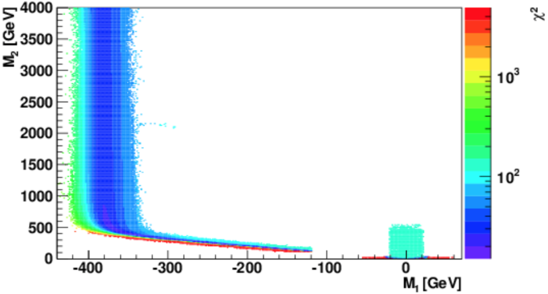


Looks Terrible

Is that a problem of GUT-scale models only?

- ... and impossible with naively employing Minuit?
- This is a work-in-progress result

Testing the pMSSM11 for M_1 and M_2 only:



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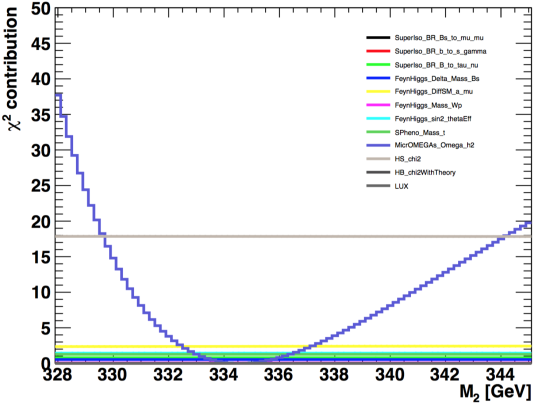
Is that a problem of GUT-scale models only?

- . . . and impossible with naively employing Minuit?
- This is a work-in-progress result

From which observable does that come?



Measuring Ωh^2 precisely makes fits harder

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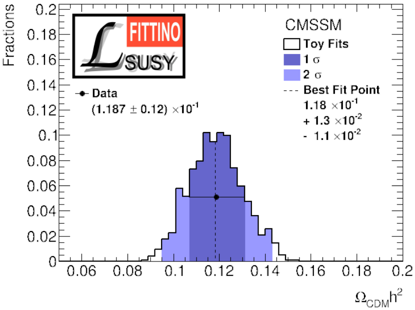
Can we still fit the cMSSM?



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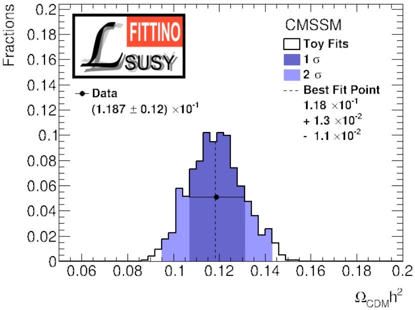
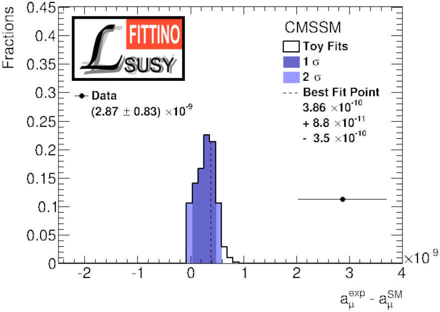
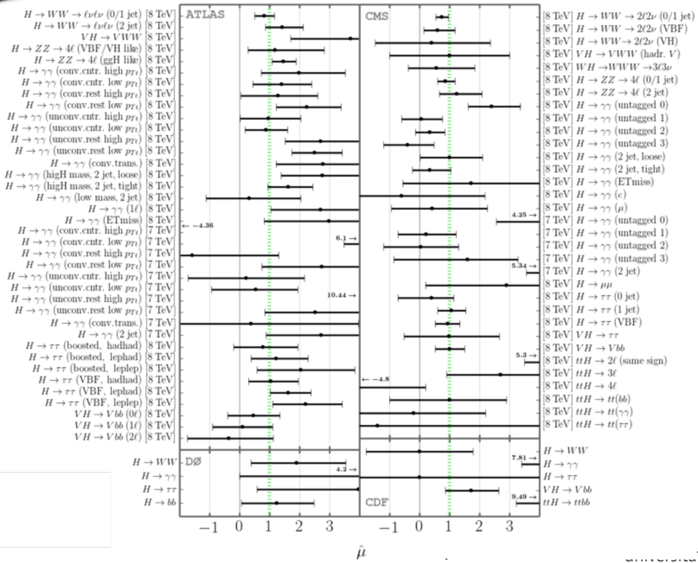




- Most observables are fitted fine in the CMSSM, but not $(g-2)_\mu$

To which Higgs Maesurent Set do we Fit best?

LargeObsSet



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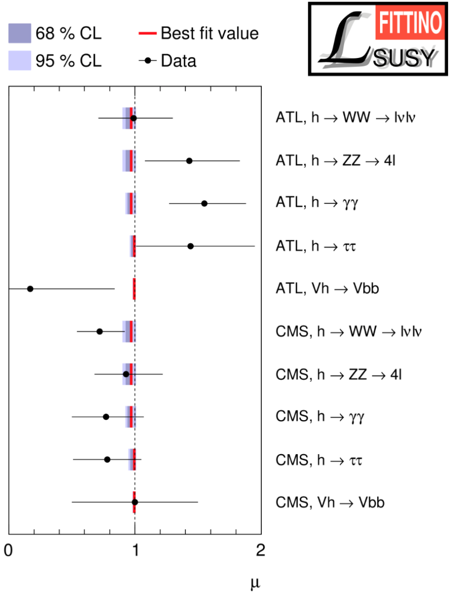
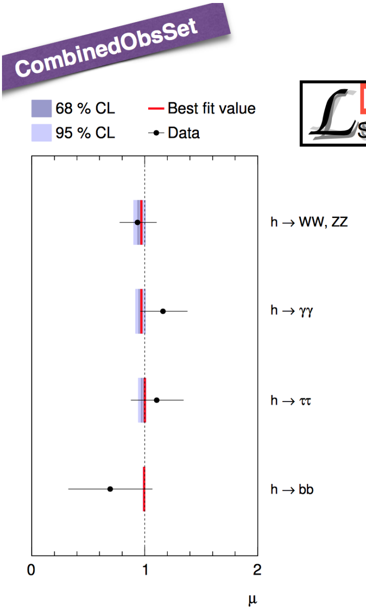
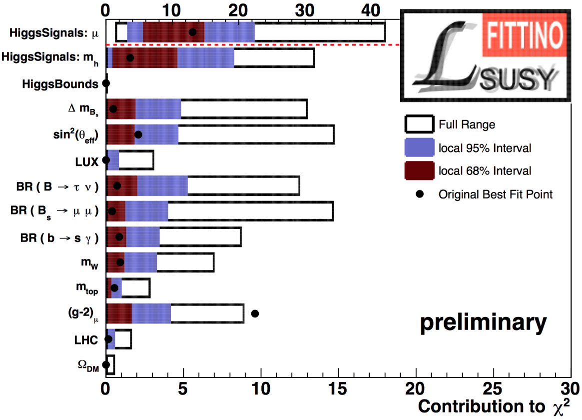


To which Higgs Maesurent Set do we Fit best?



So does the Higgs do anything?



- This plot shows the variation of the χ^2 contributions for all toy fits, calculated with respect to the smeared values
- If the colored band is small: Observable has no effect on the fit
- m_h obviously has an effect, μ's a bit.

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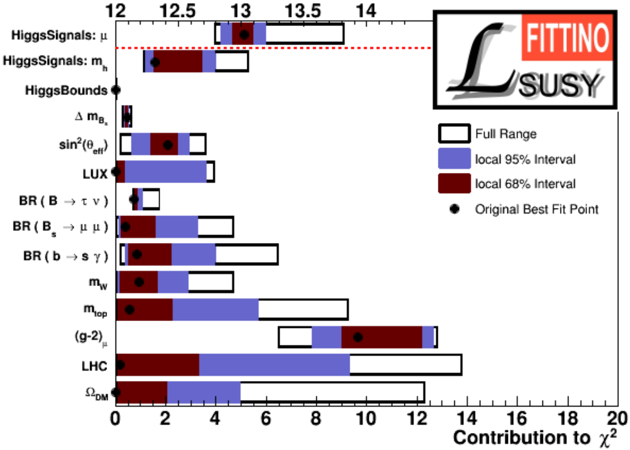

- This plot shows the variation of the χ^2 contributions for all toy fits, calculated with respect to the measured values
- If the colored band is small: Observable has no effect on the fit
- m_h obviously has an effect, μ's a bit.

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Effect of the Combination on the $\mathcal{P}$-value

Measurements $(x_i, \sigma_i), i = 1..N$

$$\chi^2_{\text{data}} = \sum_{i=n}^{N} \left(\frac{x_i - \bar{x}}{\sigma_i} \right)^2$$

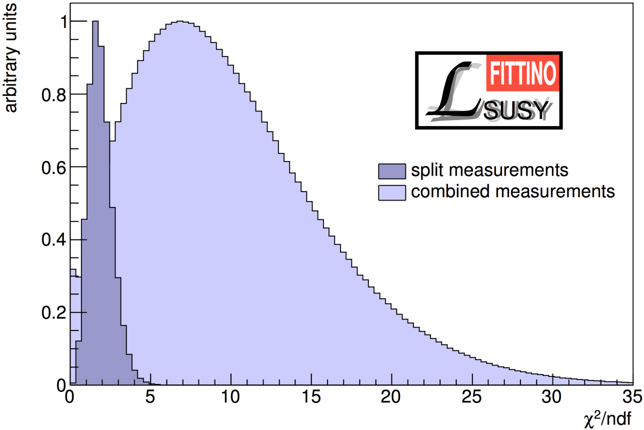
$$\chi^2_{\text{split}} = \sum_{i=1}^{N} \left(\frac{x_i - a_i}{\sigma_i} \right)^2$$

Combination $(\bar{x}, \sigma)$

$$\chi^2_{\text{combined}} = \sum_{i=1}^{n-1} \left(\frac{x_i - a_i}{\sigma_i} \right)^2 + \left(\frac{\bar{x} - a_n}{\sigma} \right)$$

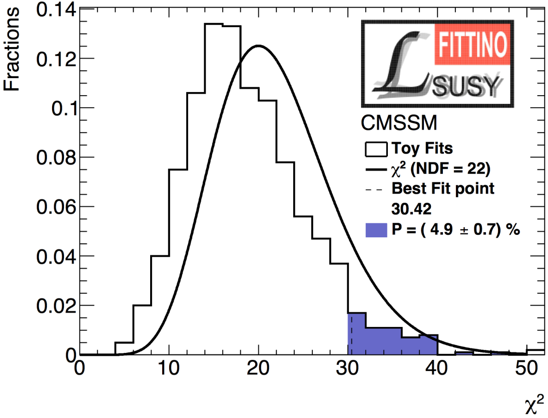
Model predictions $a_i(\mathbf{P}), i = 1..N \quad a_n \equiv \cdots \equiv a_N$

Effect of the Combination on the $\mathcal{P}$-value



$$n = 1, \quad N = 10, \quad 3\,\sigma \text{ devition}$$

What is the $\mathcal{P}$-value of the CMSSM?



- For the first time, it has conclusively been shown that the most constrained popular SUSY model can be excluded
- Without $(g-2)_\mu$, the $\mathcal{P}$-value with the given observable set is $51 \pm 3\,\%$
- But the $\mathcal{P}$-value without $(g-2)_\mu$ is meaningless. We only quoyte it because some people suddenly don't like the result anymore.

The cMSSM is kind of dead. Conventional wisdom is that the pMSSM is boring.

The cMSSM is kind of dead. Conventional wisdom is that the pMSSM is boring.

But is the MSSM Higgs Sector really boring?

[P. Bechtle, H. Haber, S. Heinemeyer, O. Stål, T. Stefaniak, G. Weiglein, L. Zeune, arXiv:1608.00638]

Obtaining a light Higgs with SM-like couplings

[J. Gunion, H. Haber, hep-ph/0207010]

Look at CP conserving 2HDM in the Higgs basis $(\langle H_1^0 \rangle = v/\sqrt{2},\ \langle H_2^0 \rangle = 0)$:

$$\mathcal{V} \ni \ldots \tfrac{1}{2} Z_1 (H_1^\dagger H_1)^2 + \cdots + \left[\tfrac{1}{2} Z_5 (H_1^\dagger H_2)^2 + Z_6 (H_1^\dagger H_1)(H_1^\dagger H_2) + \mathrm{h.c.} \right] + \ldots$$

The CP-even neutral Higgs squared-mass matrix is

$$\mathcal{M}^2 = \begin{pmatrix} Z_1 v^2 & Z_6 v^2 \\ Z_6 v^2 & M_A^2 + Z_5 v^2 \end{pmatrix},$$

with mixing angle $c_{\beta-\alpha} \equiv \cos(\beta - \alpha)$.

- If $Z_1 < Z_5 + M_A^2/v^2$ and $Z_6 = 0$, then $c_{\beta-\alpha} = 0$ and h is identical to SM Higgs boson (*alignment limit*).
- If $M_A^2 \gg Z_i v^2$, then $m_h^2 \simeq Z_1 v^2$ and $|c_{\beta-\alpha}| \ll 1 \Rightarrow h$ becomes SM-like (*decoupling limit*).

The pMSSM8 Parameter Scan

	Light Higgs case		Heavy Higgs case	
Parameter	Minimum	Maximum	Minimum	Maximum
M_A [GeV]	90	1000	90	200
$\tan\beta$	1	60	1	20
$M_{\tilde{q}_3}$ [GeV]	200	5000	200	1500
$M_{\tilde{\ell}_3}$ [GeV]	200	1000	200	1000
$M_{\tilde{\ell}_{1,2}}$ [GeV]	200	1000	200	1000
μ [GeV]	$-3\,M_{\tilde{q}_3}$	$3\,M_{\tilde{q}_3}$	-5000	5000
A_f [GeV]	$-3\,M_{\tilde{q}_3}$	$3\,M_{\tilde{q}_3}$	$-3\,M_{\tilde{q}_3}$	$3\,M_{\tilde{q}_3}$
M_2 [GeV]	200	500	200	500

Fix $M_{\tilde{q}_{1,2}} = 5\,\mathrm{TeV}$ and leave M_1 free

External Constraints

Observable	Experimental value	SM value	MSSM uncertainty
$\mathrm{BR}(B \to X_s \gamma)$	$(3.43 \pm 0.21 \pm 0.07) \times 10^{-4}$ [94]	$(3.40 \pm 0.22) \times 10^{-4}$	$\pm\, 0.15 \times 10^{-4}$
$\mathrm{BR}(B_s \to \mu^+\mu^-)$	$(2.8 \pm 0.7) \times 10^{-9}$ [97, 98]	$(3.54 \pm 0.2) \times 10^{-9}$	–
$\mathrm{BR}(B^+ \to \tau^+\nu_\tau)$	$(9.1 \pm 1.9 \pm 1.1) \times 10^{-5}$ [100, 101]	$(8.09 \pm 0.7) \times 10^{-5}$	–
δa_μ	$(30.2 \pm 9.0) \times 10^{-10}$ [117–119]	–	–
M_W	(80.385 ± 0.015) GeV [111, 112]	(80.358 ± 0.007) GeV	$\pm\, 0.003$ GeV

Table 2: The experimental values and SM theory predictions for the low-energy observables (LEOs) that are used in the pMSSM 8 scan. The last column lists additional uncertainties intrinsic to the MSSM predictions.

Leave out Ωh^2 and leave M_1 free in turn

So can we fit the h and the H?

Case	full fit			fit without a_μ			fit without all LEOs		
	χ^2/ν	χ^2_ν	p	χ^2/ν	χ^2_ν	p	χ^2/ν	χ^2_ν	p
SM	83.7/91	0.92	0.69	72.4/90	0.80	0.91	70.2/86	0.82	0.89
h	68.5/84	0.82	0.89	68.2/83	0.82	0.88	67.9/79	0.86	0.81
H	73.7/85	0.87	0.80	71.9/84	0.86	0.82	70.0/80	0.88	0.78

Table 3: Global χ^2 results with ν degrees of freedom from the fits of the SM and the MSSM with either h or H as the LHC signal, the reduced $\chi^2_\nu \equiv \chi^2/\nu$, and the corresponding p-values. The number of degrees of freedom, ν, are estimated by subtracting the number of free model parameters from the number of observables.

Pulls and Best Fit Parameters

Observable	Light Higgs case Prediction	Light Higgs case Pull	Heavy Higgs case Prediction	Heavy Higgs case Pull
$M_{h/H}$ [GeV]	125.20	+0.034	124.15	−0.29
$\mathrm{BR}(B \to X_s \gamma)$	3.55×10^{-4}	+0.185	4.17×10^{-4}	+1.138
$\mathrm{BR}(B_s \to \mu^+\mu^-)$	3.03×10^{-9}	+0.247	3.48×10^{-9}	+0.731
$\mathrm{BR}(B^+ \to \tau^+ \nu)$	7.53×10^{-5}	−0.424	7.38×10^{-5}	−0.465
δa_μ	28.8×10^{-10}	−0.151	27.6×10^{-10}	−0.289
M_W [GeV]	80.383	−0.080	80.373	−0.480

Table 4: Pull table for the best-fit (BF) points of the two MSSM Higgs interpretations.

Case	M_A (GeV)	$\tan\beta$	μ (GeV)	A_t (GeV)	$M_{\tilde{q}_3}$ (GeV)	$M_{\tilde{\ell}_3}$ (GeV)	$M_{\tilde{\ell}_{1,2}}$ (GeV)	M_2 (GeV)
h	929	21.0	7155	4138	2957	698	436	358
H	172	6.6	4503	−71	564	953	262	293

Table 5: MSSM parameters for the BF points found for the light Higgs (h) and heavy Higgs (H) interpretation in the full fit.

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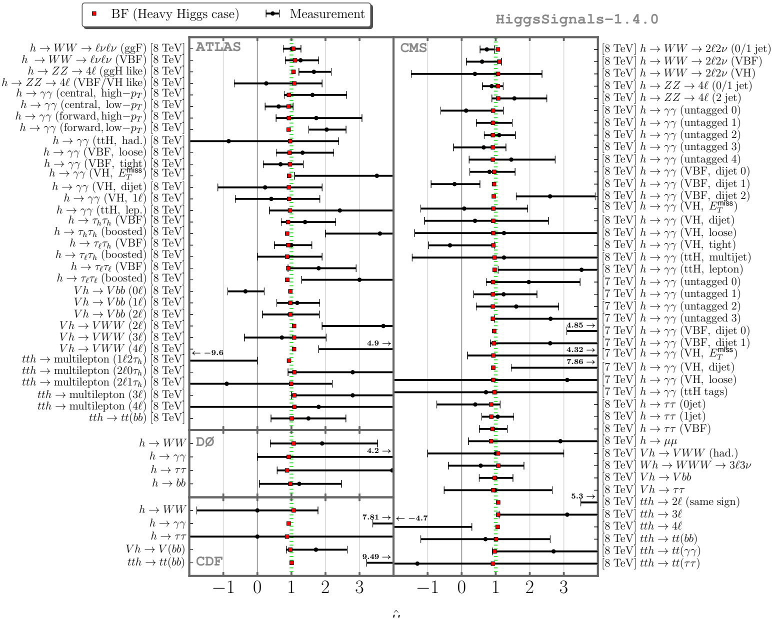
Best-Fit (heavy Higgs case) – Higgs signal rates



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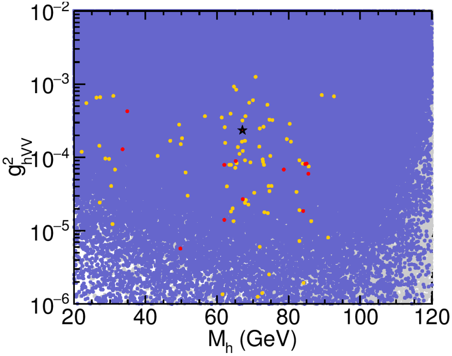
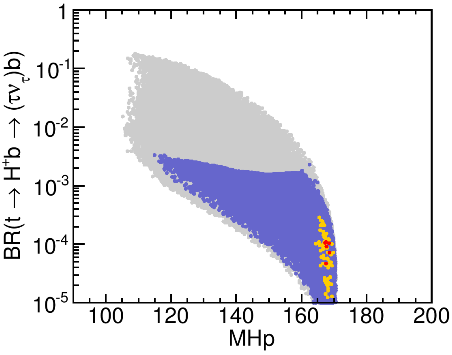
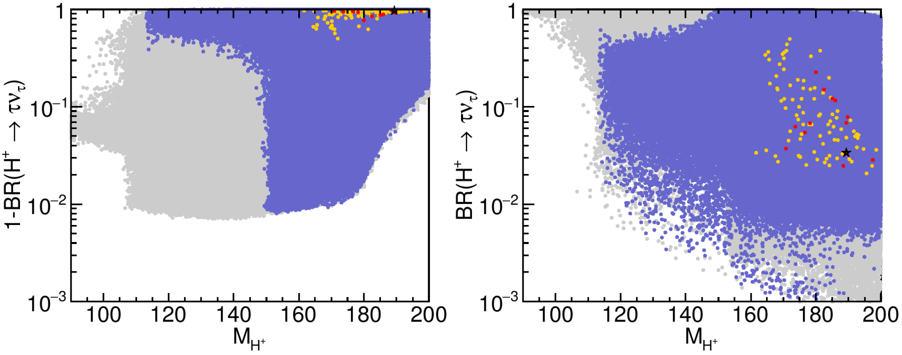
Where are the other Higgs states?



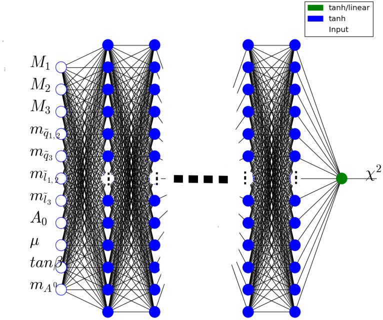


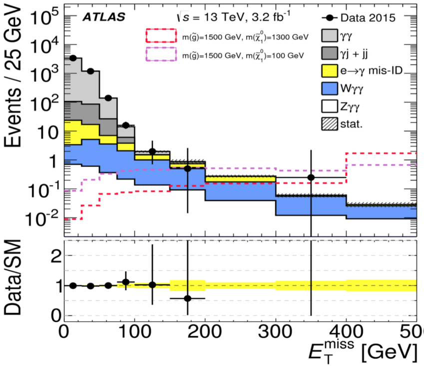
- Light Higgs h with mass $m_h \sim (60 - 100)\ \mathrm{GeV}$ has extremely reduced coupling to vector bosons $\Rightarrow$ beyond LEP reach!
- LHC searches for $gg \to h \to \gamma\gamma$ are also not (yet) sensitive.
- Charged Higgs $H^\pm$ lies at kinematic threshold of $t \to H^\pm b$. $H^\pm \to \tau\nu_\tau$ decay rate suppressed by competing decay $H^\pm \to hW^\pm$.

Heavy Higgs case: Charged Higgs Decays



Options for the LHC Parametrization

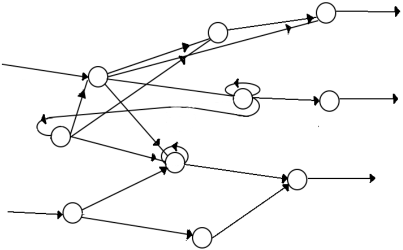




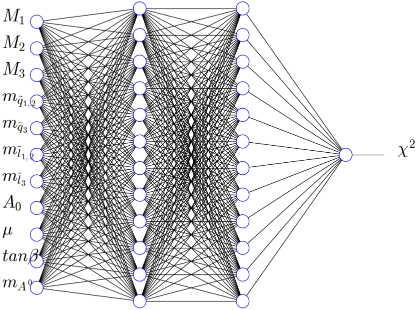
- For the cMSSM it was rather easy to parametrize the LHC results. We had only 4 dimensions, and for the largest part of the parameter space, only $M_{1/2}$ and M_0 were relevant

Building up a neural network

Recurrent neural networks not considered

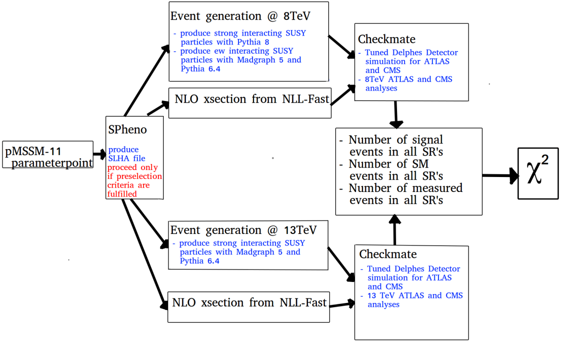


Example of pMSSM-11 network



- A lot free parameters in net $\rightarrow$ hyperparameter optimization
- neural network: highly nonlinear interpolator
- All neural nets implemented with TensorFlow

Generating Events at Random Parameter Points



Preselection criteria:

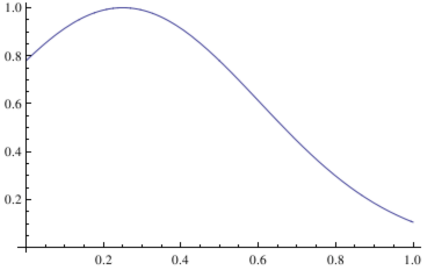
- No tachyons in spectrum.
- χ_1^0 is the LSP
- Both Higgses (h^0, H^0) have mass above 110 GeV
- $m_{\chi_1^\pm}$ >103.5 GeV (from LEP)
- For m_W, Δm_s, $\mathcal{B}(B_s \to \mu\mu)$, $\mathcal{B}(b \to s\gamma)$, $\mathcal{B}(B_u \to \tau\nu)$ require

$$5 \times \sqrt{\sigma^2_{\text{experiment}} + \sigma^2_{\text{theory}}} > |\text{theory value- experimental value}|.$$

Generating Events at Random Parameter Points

PMSSM11 Parameter	Range
$M1$ (Bino mass)	$\pm 0 - 4000$ GeV
$M2$ (Wino mass)	$100 - 4000$ GeV
$M3$ (gluino Mass)	$\pm 400 - 4000$ GeV
M_{sq1} (1st and 2nd gen. scalar squark mass)	$300 - 5000$ GeV
M_{sq3} (3rd gen. scalar squark mass)	$100 - 5000$ GeV
M_{sl1} (1st and 2nd gen. scalar slepton mass)	$100 - 3000$ GeV
M_{sl3} (3rd gen. scalar slepton mass)	$100 - 4000$ GeV
M_A (Pseudoscalar Higgs pole mass)	$0 - 4000$ GeV
A (Third generation trilinear coupling)	$\pm 0 - 5000$ GeV
μ (Higgsino mass parameter)	$\pm 100 - 5000$ GeV
$tan(\beta)$ (Higgs doublet vacuum expectation value)	$1 - 60$ GeV

pMSSM11 Parameter PDF used for Training



- If we used a flat pdf, almost all points would be on the edge

Number of Parameter Points

scanned points:

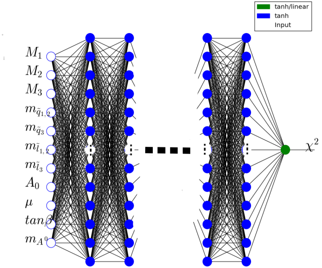
$\sqrt{s}$	**scanned points**
8 TeV	700000
13 TeV	140000

Disjoint signal regions:

$\sqrt{s}$	**disjoint SRs**
8 TeV	47
13 TeV	65

LHC χ^2 for 8 TeV

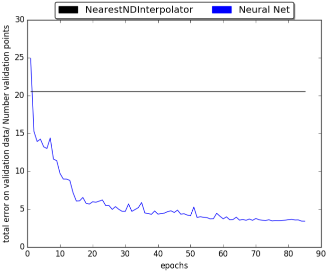
hyperparameter	scanned values
number of hidden layers	2,3,4,5
number neurons in hidden layers	50, 150, 450
cost function	quadratic,cross
exponential damping	on / of
batch size	80 ,500, 3000
λ	0.001 , 0.0001, 0.00001,0.000001
learning rate	0.1, 0.01, 0.001, 0.0001
dropout probability 1	0.9,0.95, 1.0
dropout probability 2	0.9,0.95, 1.0
activation in last layer	tanh / linear

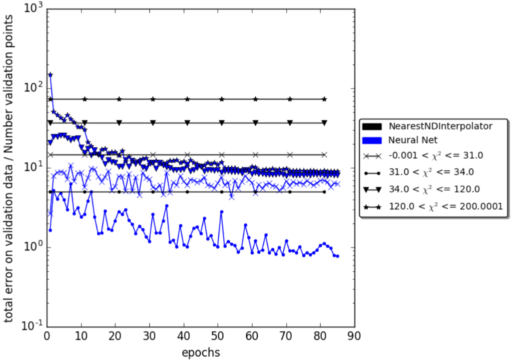


best found hyperparameter configurations:

# h. layer	#neurons	cost	damp.	batch size	λ	learn. rate	dropout 1/2	activation
4	150	quadratic	1.0	500	10^{-5}	0.001	1.0/1.0	tanh
4	150	quadratic	0.0	500	10^{-5}	0.001	1.0/1.0	tanh
4	50	quadratic	1.0	500	10^{-6}	0.001	1.0/1.0	tanh
5	450	quadratic	0.0	80	10^{-5}	0.0001	1.0/1.0	tanh
4	50	quadratic	0.0	500	10^{-4}	0.001	1.0/1.0	tanh

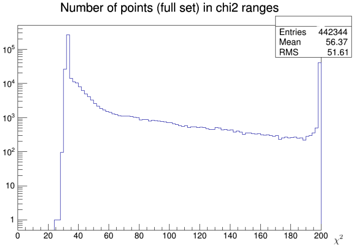
LHC χ^2 for 8 TeV:

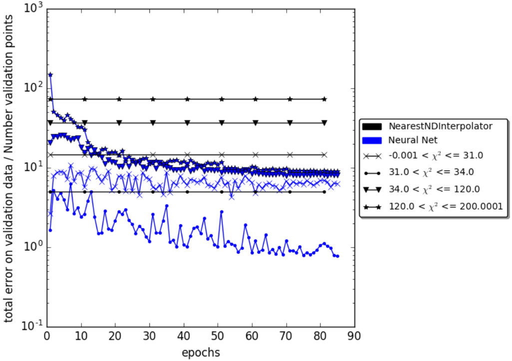




$0 < \chi^2 \leq 200$	$0 < \chi^2 \leq 31$	$31 < \chi 2 \leq 34$	$34 < \chi 2 \leq 120$	$120 < \chi 2 \leq 200$
3.4 (0.05)	6.3 (0.21)	0.77 (0.024)	8.1 (0.14)	9.1 (0.055)

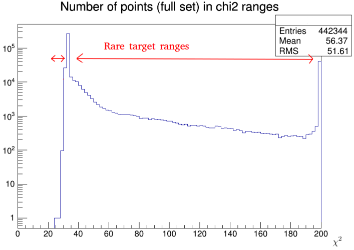
LHC χ^2 for 8 TeV:

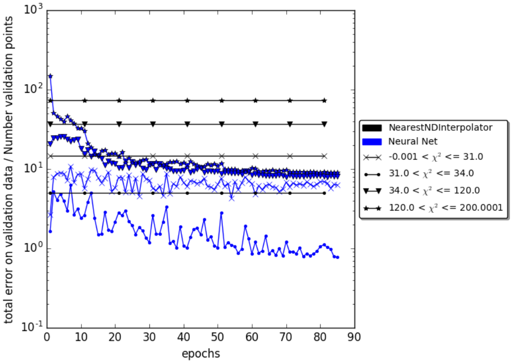




$0 < \chi^2 \leq 200$	$0 < \chi^2 \leq 31$	$31 < \chi2 \leq 34$	$34 < \chi2 \leq 120$	$120 < \chi2 \leq 200$
3.4 (0.05)	6.3 (0.21)	0.77 (0.024)	8.1 (0.14)	9.1 (0.055)

LHC χ^2 for 8 TeV:





$0 < \chi^2 \leq 200$	$0 < \chi^2 \leq 31$	$31 < \chi2 \leq 34$	$34 < \chi2 \leq 120$	$120 < \chi2 \leq 200$
3.4 (0.05)	6.3 (0.21)	0.77 (0.024)	8.1 (0.14)	9.1 (0.055)

Rare Target Learning Problem (RTLP):
solution strategies:

- sample in the rare target areas
- artificial extension
- sequence learning

LHC χ^2 for 8 TeV

Second hyperparameterscan:

hyperparameter	scanned values
use data sampled in rare target areas	yes/no
extend data artificially	yes/no
use sequence learning	yes/no
multiply number of neurons in first hidden layer by (x_1)	1.0 , 1.5, 2.0
multiply number of neurons in hidden layer 2,3,4 by (x_2)	1.0, 1.5, 2.0
multiply batch size by (x_3)	1.0, 1.5

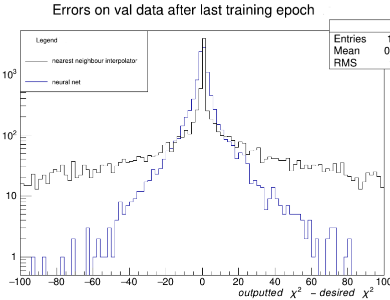
best hyperparameters:

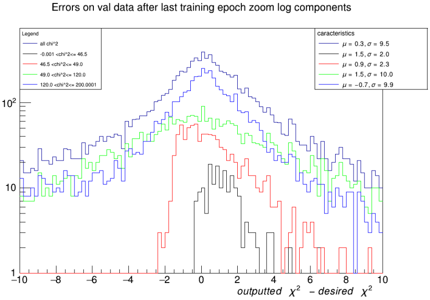
extra sampling	artificial extension	seq. learning	x_1	x_2	x_3
yes	no	yes	2.0	2.0	1.5
yes	no	yes	2.0	1.0	1.0

Results:

$0 < \chi^2 \leq 200$	$0 < \chi^2 \leq 31$	$31 < \chi 2 \leq 34$	$34 < \chi 2 \leq 120$	$120 < \chi 2 \leq 200$
3.25 (0.049)	5.7 (0.18)	0.81 (0.024)	7.94 (0.13)	8.57 (0.052)
3.4 (0.05)	6.3 (0.21)	0.77 (0.024)	8.1 (0.14)	9.1 (0.055)

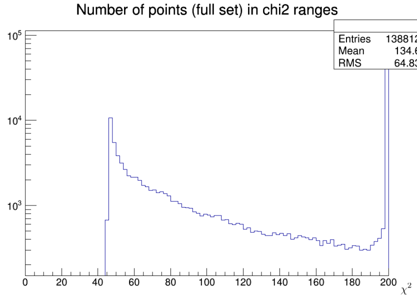
LHC χ^2 for 13 TeV

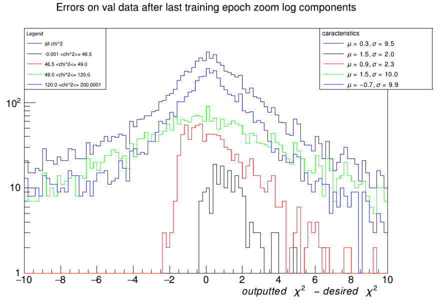




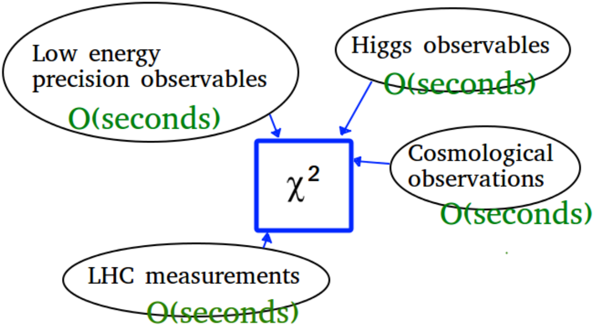
$0 < \chi^2 \leq 200$	$0 < \chi^2 \leq 46.5$	$46.5 < \chi2 \leq 49$	$49 < \chi2 \leq 120$	$120 < \chi2 \leq 200$
4.9 (0.046)	1.53 (0.033)	1.55 (0.032)	5.87 (0.075)	4.94 (0.029)

LHC χ^2 for 13 TeV





$0 < \chi^2 \leq 200$	$0 < \chi^2 \leq 46.5$	$46.5 < \chi2 \leq 49$	$49 < \chi2 \leq 120$	$120 < \chi2 \leq 200$
4.9 (0.046)	1.53 (0.033)	1.55 (0.032)	5.87 (0.075)	4.94 (0.029)



$$\chi^2 = (\mathcal{O}_{\text{meas}} - \mathcal{O}_{\text{pred}})^T cov^{-1} (\mathcal{O}_{\text{meas}} - \mathcal{O}_{\text{pred}}) + \chi^2_{\text{limits}},$$

Best fit point

Total scanned 2.6 million points. Only 1.4 million points have $\chi^2_{\mathrm{LO}} < 1000$.

M_1	M_2	M_3	$m_{\tilde{Q}_{12}}$	$m_{\tilde{Q}_3}$	$m_{\tilde{L}_{12}}$	$m_{\tilde{L}_3}$	m_{A^0}	A_0	μ	$\tan\beta$
-196	3739	2396	2512	5083	361	709	3145	275	-4163	15.4

Table: All quantities are given in GeV (except $\tan\beta$).

Preliminary!

- Need to scan more points
- pMSSM-11 parameters for neural nets defined at 1 TeV, but all other pMSSM-11 parameters are defined at 1.5 TeV.

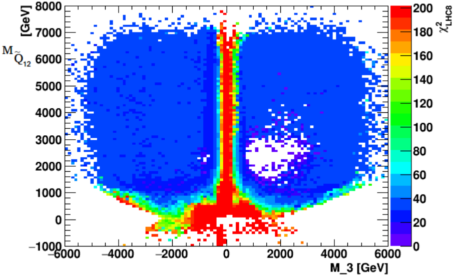
SUSY spectrum at best fit point

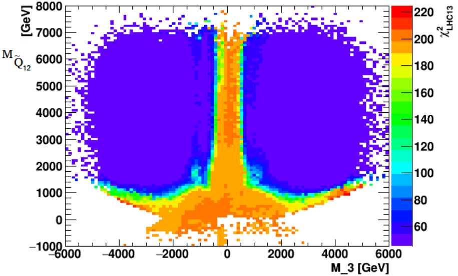
mass in GeV	particle
2557	$\tilde{d}_L$
2559	$\tilde{d}_R$
2556	$\tilde{u}_L$
2560	$\tilde{u}_R$
2557	$\tilde{s}_L$
2559	$\tilde{s}_R$
2556	$\tilde{c}_L$
2560	$\tilde{c}_R$
5105	$\tilde{b}_1$
5142	$\tilde{b}_2$
5135	$\tilde{t}_1$
5164	$\tilde{t}_2$
2587	$\tilde{g}$

mass in GeV	particle
217	$\tilde{e}_L-$
358	$\tilde{e}_R-$
203	$\tilde{\nu}_{e,L}$
216	$\tilde{\mu}_L$
359	$\tilde{\mu}_R$
203	$\tilde{\nu}_{\mu,L}$
569	$\tilde{\tau}_1$
748	$\tilde{\tau}_2$
637	$\tilde{\nu}_{\tau,L}$

mass in GeV	particle
126	h^0
3145	H^0
3145	A^0
3146	H^+
195	$\tilde{\chi}_1^0$
3738	$\tilde{\chi}_2^0$
4202	$\tilde{\chi}_3^0$
4207	$\tilde{\chi}_4^0$
3738	$\tilde{\chi}_1^+$
4207	$\tilde{\chi}_2^+$

LHC χ^2 in the global fit





Profile plots of all scanned points.

pMSSM-11 neural network to predict pMSSM-19 χ^2

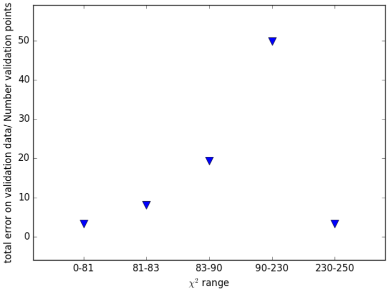
$$m_{\tilde{Q}_{12}} = \frac{m_{\tilde{Q}_{L,12}} + m_{\tilde{u}_{R,12}} + m_{\tilde{d}_{R,12}}}{3}$$

$$m_{\tilde{Q}_3} = \frac{m_{\tilde{Q}_{L,3}} + m_{\tilde{u}_{R,3}} + m_{\tilde{d}_{R,3}}}{3}$$

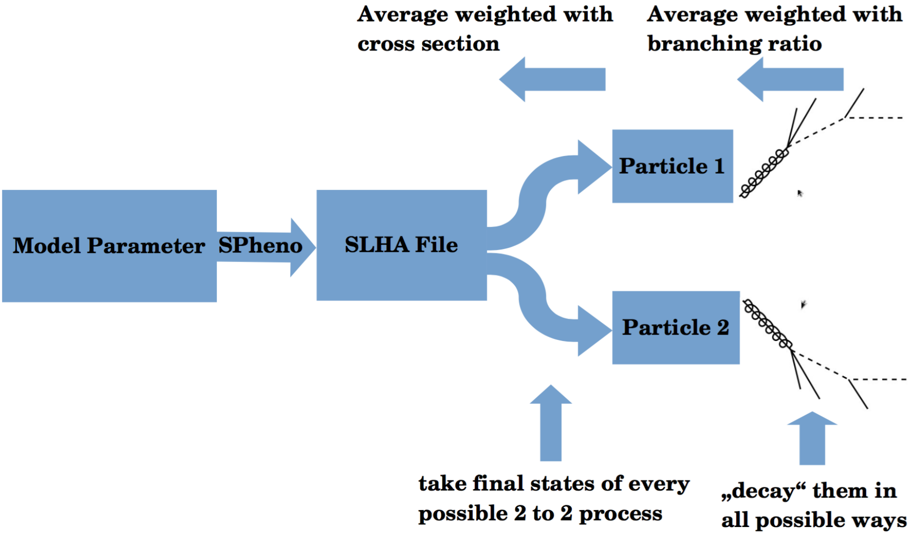
$$m_{\tilde{L}_{12}} = \frac{m_{\tilde{L}_{L,12}} + m_{\tilde{l}_{R,12}}}{2}$$

$$m_{\tilde{L}_3} = \frac{m_{\tilde{L}_{L,3}} + m_{\tilde{l}_{R,3}}}{2}$$

$$A_0 = \frac{A_t + A_b + A_\tau}{3}$$

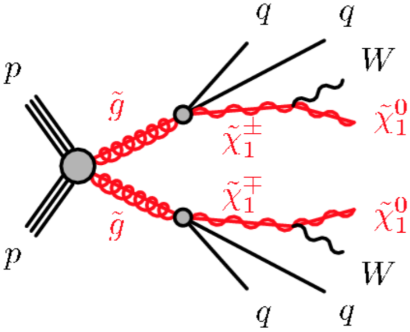


Finding more generic Pseudo-Observables



Finding more generic Pseudo-Observables

- $<< N_X >_D >_P$ (9 total)
- $< \sigma(N_X)_D >_P$ (9 total)
- $<< N_\mathrm{R} >_D >_P$ (5 total)
- $< \sigma(N_\mathrm{R})_D >_P$ (5 total)
- $<< \sum_i \frac{1}{N_{X_i}} max(E_{X_i}) >_D >_P$ (9 total)
- $< \sigma(\sum_i \frac{1}{N_{X_i}} max(E_{X_i}))_D >_P$ (9 total)
- $<< \sum_i \frac{1}{N_{R_i}} max(E_{R_i}) >_D >_P$ (5 total)
- $< \sigma(\sum_i \frac{1}{N_{R_i}} max(E_{R_i}))_D >_P$ (5 total)



X=jets, b-jets, $e^\pm$, $\mu^\pm$, $\tau^\pm$, any E^T_{Miss} particle

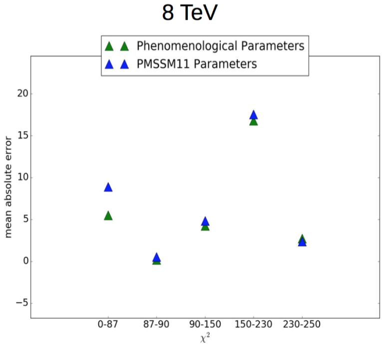
R=Intermediate t,W,Z

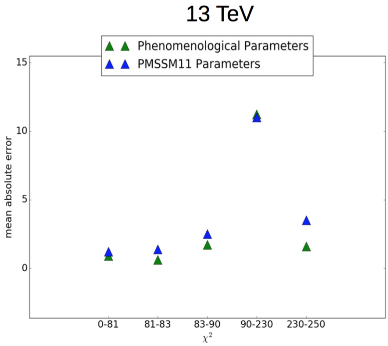
D=Average over decay chains

P=Average over production processes

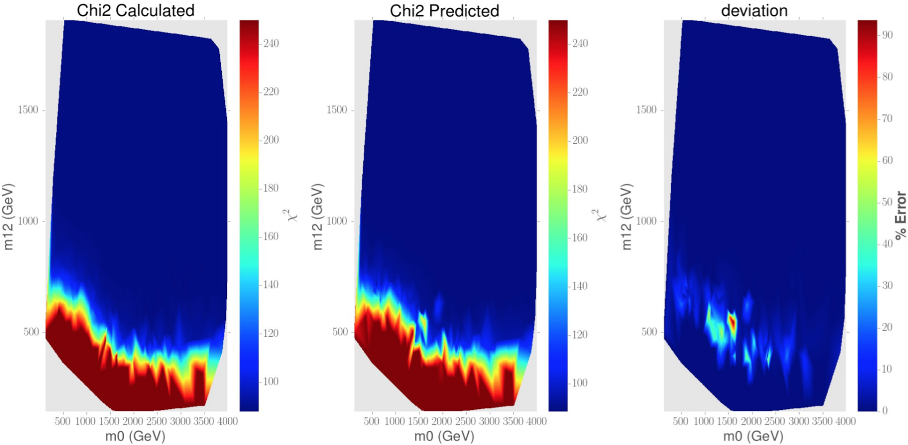
The Present Performance on the pMSSM11

mean absolute error(mean % error)	pheno. parameters	PMSSM11 parameters
8 TeV	2.68(1.75 %)	2.89(2.0 %)
13 TeV	4.54(3.0 %)	5.70(3.5 %)





The Performance on the cMSSM



Conclusions

- We sold SUSY to the world using $(g-2)_\mu$ – so we cannot drop $(g-2)_\mu$ now that we don't like the exact same result anymore.
- We now established that the combination of m_h, SUSY limits at the LHC and $(g-2)_\mu$ kills the cMSSM
- We want to be able to play those games also for more complex models, but this requires to understand the LHC limit for them
- NN regressions are a promising tool to parametrize them
- Need to strongly improve on the rare details learning problem
  - Restrict the parametrized $\chi 2$ range even further
  - Generate many more points using a narrow pdf around the RDLP points and iterate

Backup Slides