mSUSY

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No observation of SUSY thus far.

If none after the upgrade, what next (if anything) for SUSY research?

A partial cancellation of quadratic sensitivity is better than nothing. SUSY may still live at a higher scale.

What is the scale?

Necessarily imprecise business. Few “theorems.”

Much discussion already. Arguments exist for a variety of scales.

$10 \text{ TeV} \quad 100 \text{ TeV} \quad >1000 \text{ TeV}$

Better understanding informs:
- interpretation of results from future experiments
- decisions about what experiments to build
$m_h = 125\text{GeV}$ in the MSSM for $\tan \beta > 6$ and A-terms of order $m_{\text{SUSY}}$ or smaller.

structure still necessary in the soft sector to suppress FCNC, EDM

Any moduli need to be $> 30\text{TeV}$ for cosmological reasons

Experimental prospects:

LHC14 with $3\text{ab}^{-1}$ will pair-produce less than 10 stop pairs if the stops are heavier than about 2.5 TeV.

100 TeV VHE-LHC may reach $\sim 14\text{TeV}$ stops.

K. Howe, Brookhaven Snowmass workshop

[If the -inos are all parametrically lighter and observable, how well can we measure $\tan \beta$ in their mixing?]
**100 TeV**

Scale appears in the context of the moduli problem

May exist very weakly-interacting scalars with masses small compared to $M_p$ (e.g. string moduli). Some moduli candidates naturally have masses of order or less than the SUSY-breaking scale (e.g. saxion, inflaton). 

When moduli decay in the early universe they may destroy the light elements. Reheating temperature sufficiently high for masses of order 30-100 TeV.

Virtue: may produce wino dark matter ($m_{\text{wino}} \sim 200$ GeV) nonthermally. 

However:

- 100 TeV may not be high enough to avoid overproduction of nonthermal wino DM in tension with indirect detection (HESS, Fermi)

Might imagine avoiding LSP DM problems; e.g., RPV + axion DM.

For given $\theta_0 f_a$, preventing axion domination before $T=1$ eV limits $T_{\text{Reheat}} (m_{\phi})$

$$m=100 \text{ TeV}, \quad f_a=M_p/16\pi^2 \Rightarrow \theta_0 \sim 10^{-2}$$
10^3-10^9 \text{TeV} \text{ ("PeV-ZeV")}

Tuning > part in 10^8, m_h obtained for \tan \beta < 2-3

FCNCs and EDMs sufficiently decoupled at the PeV scale. ⇒ less structure needed for PeV SUSY?

But without flavor symmetry, may have proton decay from dim 5 operators

Above \sim 10^9 \text{GeV}, protons ok; tension with both Higgs mass and unification

Anomaly-mediated (mini-split) spectrum can give \sim 3 \text{TeV} wino: thermal DM

Also in tension with absence of signals in indirect detection
Figuring out the distinguishing properties of different possible SUSY scales is an important problem.

Examples exist of arguments for and against various possibilities.

Goal is to infer the scale on theoretical grounds. Probably impossible, but we may narrow down the most plausible candidates.