

Five Reasons

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Status

Parameters

WIMP model

Simplified models

DMEFT

Precision

Five Reasons to Study Supersymmetry

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Where we stand

Experiment

- squarks and gluinos at best heavy
 - stops not much lighter
 - no unexplained missing energy
 - $(g - 2)_\mu$ on the way out? [only SUSY-relevant anomaly, flavor anomalies not SUSY-like]
- ⇒ Looking pretty dead to me

Theory

- light Higgs, no sign of compositeness
hierarchy problem ... too hard for me ...
- stop mass not small
little hierarchy problem ... not worth my time ...

Phenomenology

- LHC model building practically dead
 - dark matter still attractive
 - new, data driven approaches to BSM physics?
- ⇒ I am not interested in SM precision measurements!



Why we are optimistic

Physics

- perturbative QFT appropriate framework
- Higgs physics now window to BSM physics
- working description through SMEFT
- case for (WIMP) dark matter not weakened [watch out for DD]

Simulation

- jets and QCD no longer scare us
- precision predictions automatized
- Monte Carlo increasingly first-principle
- simple signal-background studies no longer worth a paper

Analysis

- communication with experimentalists work
 - jets being deconstructed for 10 years
 - big data tools from outside
- ⇒ LHC being turned into a multi-purpose precision machine ...



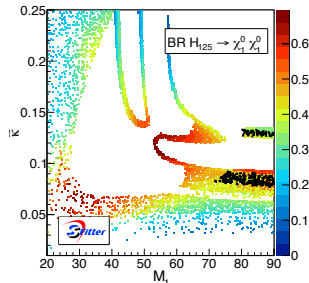
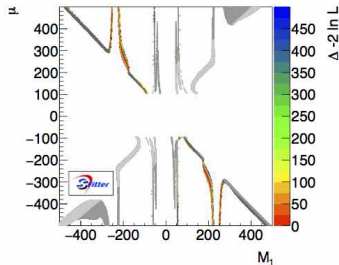
1– Parameter space patterns

Anomalies driving parameter studies

- observables $m_h, \Omega_\chi h^2$
add Hooperon for fun
decouple strongly interacting particles
 - analysis of parameter volumes pointless(?)
 - check DM-related MSSM patterns
 - annihilation $\tilde{\chi}\tilde{\chi} \rightarrow b\bar{b}, WW, t\bar{t}$ possible
- ⇒ XENON1T really just a SUSY hater?

Old link to invisible Higgs decays

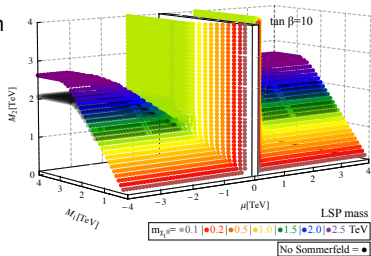
- possible in the MSSM
 - linked to Hooperon only in NMSSM
 - minimal vs non-minimal SUSY realizations
 - ‘generic’ is not the question
 - ????? [insert your best idea here]
 - by now ruled out by DD
- ⇒ extrapolation to high scales still the theme



2– WIMP model

Electroweakinos only

- define DM through $SU(2)_L$ representation singlet, doublet, triplet
 - allow for general mixing
 - add co-annihilation partners, if needed
 - ignore squarks, gluinos
- ⇒ relic neutralino surface



Majorana neutralino, different mediators

- SM Z-boson $\chi\chi \rightarrow Z \rightarrow$ jets
 - SM-like Higgs $\chi\chi \rightarrow h \rightarrow b\bar{b}$
 - heavy Higgs $H, A \rightarrow b\bar{b}, t\bar{t}$
 - t -channel chargino $\chi\chi \rightarrow WW \rightarrow$ jets
 - chargino co-annihilation $\chi^0\chi^\pm \rightarrow W$
 - stau co-annihilation $\tilde{\tau}\chi \rightarrow \tau + X$
- ⇒ Leading to signatures and analyses



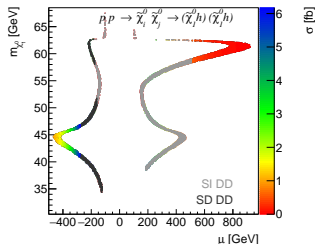
3– Sanity check for simplified models

DM and Mono-X

- ISR only interesting for mono-jet
 - large rates only from intermediate resonances
 - light pseudoscalar: Zah giving mono- Z [Bauer etal]
 - heavy pseudoscalar: Aah giving mono-Higgs
 - charged Higgs: $H^\pm aW$ giving mono- W
- ⇒ intermediate particles as we go

Looking a lot like SUSY

- search for well-defined scalar sectors
 - compute relic density
 - relate different hypotheses
 - include intermediate electroweakinos
 - mono- W -pairs and mono-Higgs-pairs expected
- ⇒ add sense of coherence/systematic



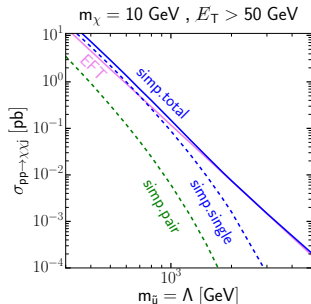
4– Sanity check for DMEFT

DMEFT

- SM particles plus DM agent
 - ‘mediator’ integrated out, D6 Lagrangian
 - useful for DD and ID, low momentum exchange
 - LHC fine for heavy mediator
 - freeze-out relic density tough: $(m_\chi, \Lambda) = (10, 100)$ GeV
- ⇒ not the problem people usually quote

Make it work

- remove freeze-out assumption [the one measurement]
 - start with a proper BSM model
 - integrate out heavy mediators
 - possibly even combine with SM mediators
 - example: t-channel ‘squark’ mediator
- ⇒ kinda interesting...



5– Benchmark for precision BSM physics

When signatures get tough

- SUSY in low rates
 - SUSY in tails or rotten phase space
 - SUSY in loops
- ⇒ whatever makes our lives hard

New approach to BSM Physics

- it's not going to be easy
 - it might not be tree-level
 - it might be hidden in the backgrounds
 - it might not show up in resonance searches
 - it might not show up in generic signatures
 - it should be a decent QFT
 - it has to fit into the history of the Universe
- ⇒ proper theory foundation very helpful



Finally

Supersymmetry is...

...maybe related to nature

...not ruled out

...an inspiration

...not to be taken literally

...great to play with

...an actual QFT model!!



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