BSM at future colliders

Veronica Sanz (Sussex)
NExT meeting

UK HEP forum 2014

what this talk is about

Lots of overviews and detailed analysis

FCC-xx, ILC, CLIC physics potential analyses

Snowmass reports

Workshop talks

…lots of theory publications

and a lot more work needed before 2018

This talk is NOT going to be a review of these results

Lots of overviews and detailed analysis

FCC-xx, ILC, CLIC
physics potential analyses

Snowmass reports

Workshop talks

…lots of theory publications

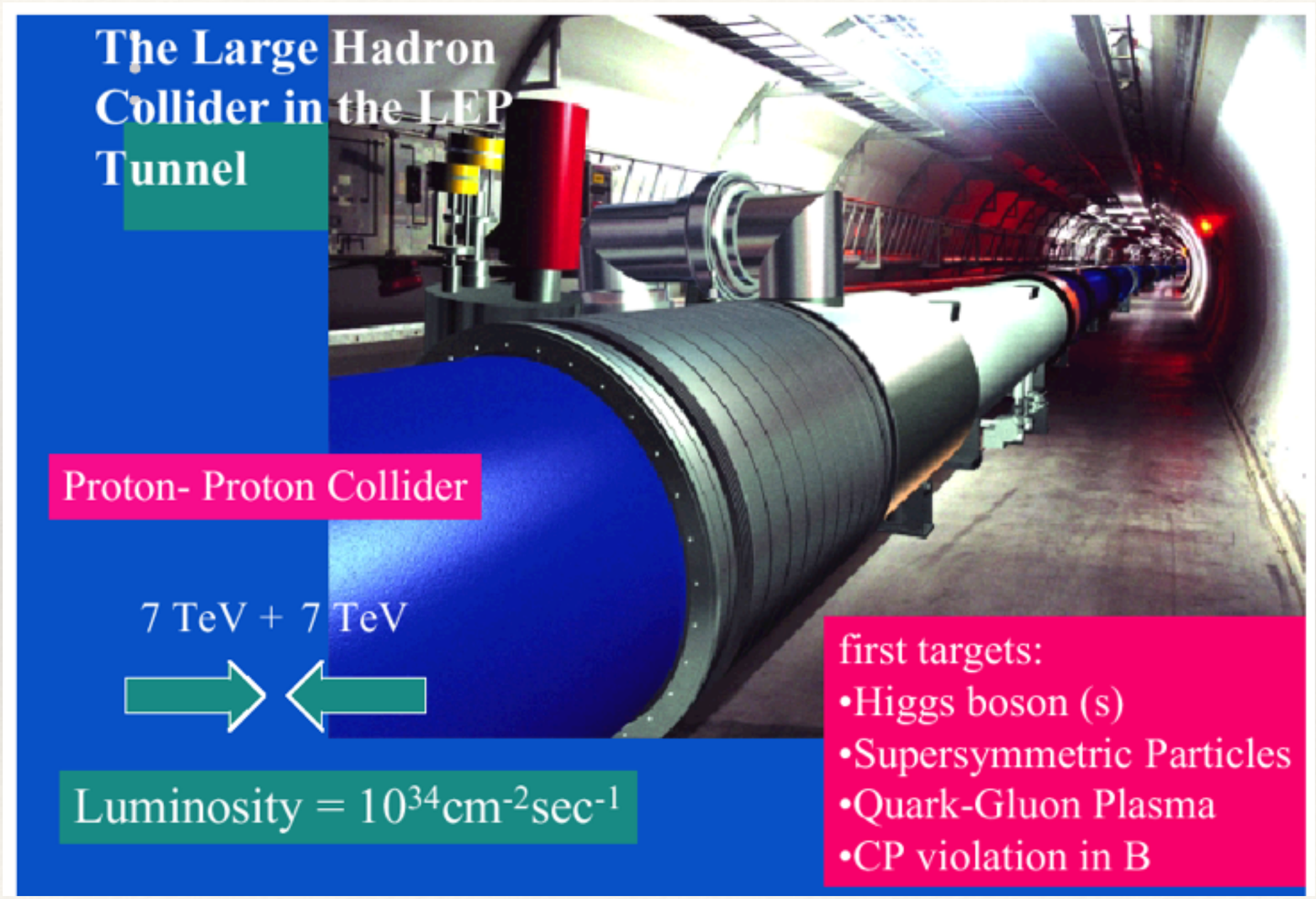
and a lot more work needed before 2018

FORUM
my views as a theorist
BSM models and collider phenomenology

Feel free to add to the discussion

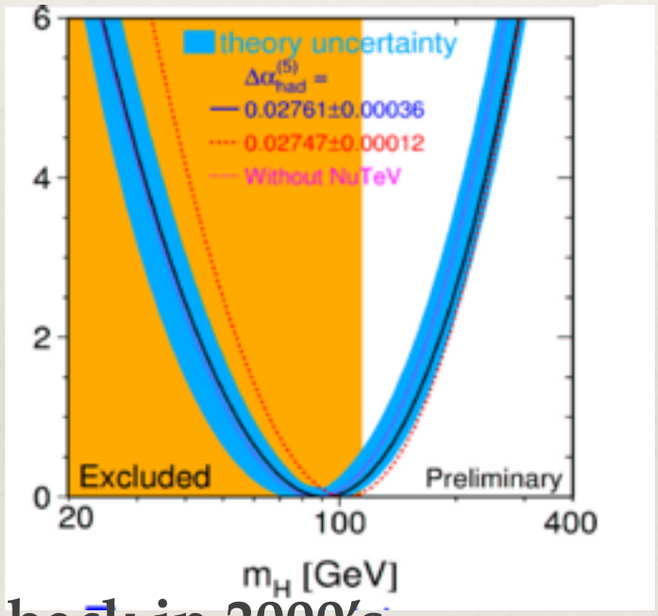
The case for BSM

There was a clear case for the LHC



From CERN's education webpage, back before 2010

There was a clear case for the LHC



back in 2000's

EWSB via Higgs
missing piece

EWPTs: light Higgs or
something rather similar

unitarization of WW scattering
something had to be around the
EW scale

And there is a clear case for BSM

Evidence

Dark Universe, neutrinos, baryogenesis

And there is a clear case for BSM

Evidence

Dark Universe, neutrinos, baryogenesis

but not of where/what BSM is

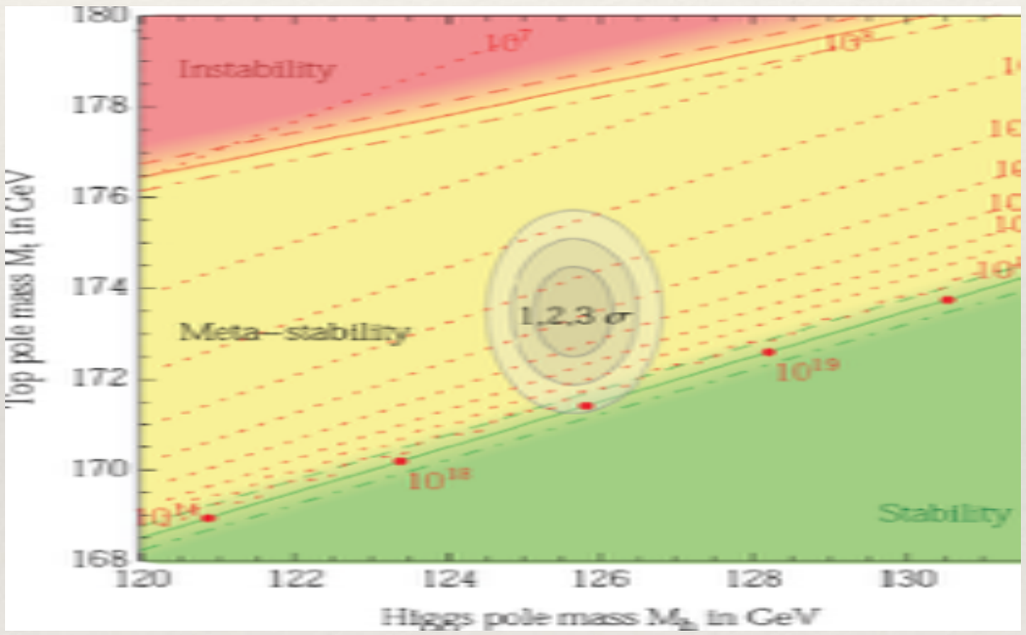
aesthetical arguments as naturalness/tuning are not on the same footing as violation of unitarity

precision tests are perfectly happy with no new physics at the EW scale

BSM models

(Unfortunately)

Higgs is not *evidence* for new physics



but a strong case for it comes from naturalness

Natural theories

No evidence of BSM states

+

naturalness

calls for new symmetries

Supersymmetry

MSSM and the likes

Goldstone

composite Higgs
warped Higgs
gauge-Higgs unification

Conformal

dilaton-like

…???

Natural theories

Supersymmetry

MSSM and the likes

Extended Higgs sectors
scalar top partners
Dark Matter

Goldstone

composite Higgs
warped Higgs
gauge-Higgs unification

Conformal

dilaton-like

…???

Natural theories

Supersymmetry	Goldstone	Conformal	…???
MSSM and the likes	composite Higgs warped Higgs gauge-Higgs unification	dilaton-like	

non-linear realization of the Higgs mechanism
fermionic top partners
Dark Matter ?

Natural theories

Supersymmetry

MSSM and the likes

Goldstone

composite Higgs
warped Higgs
gauge-Higgs unification

Conformal

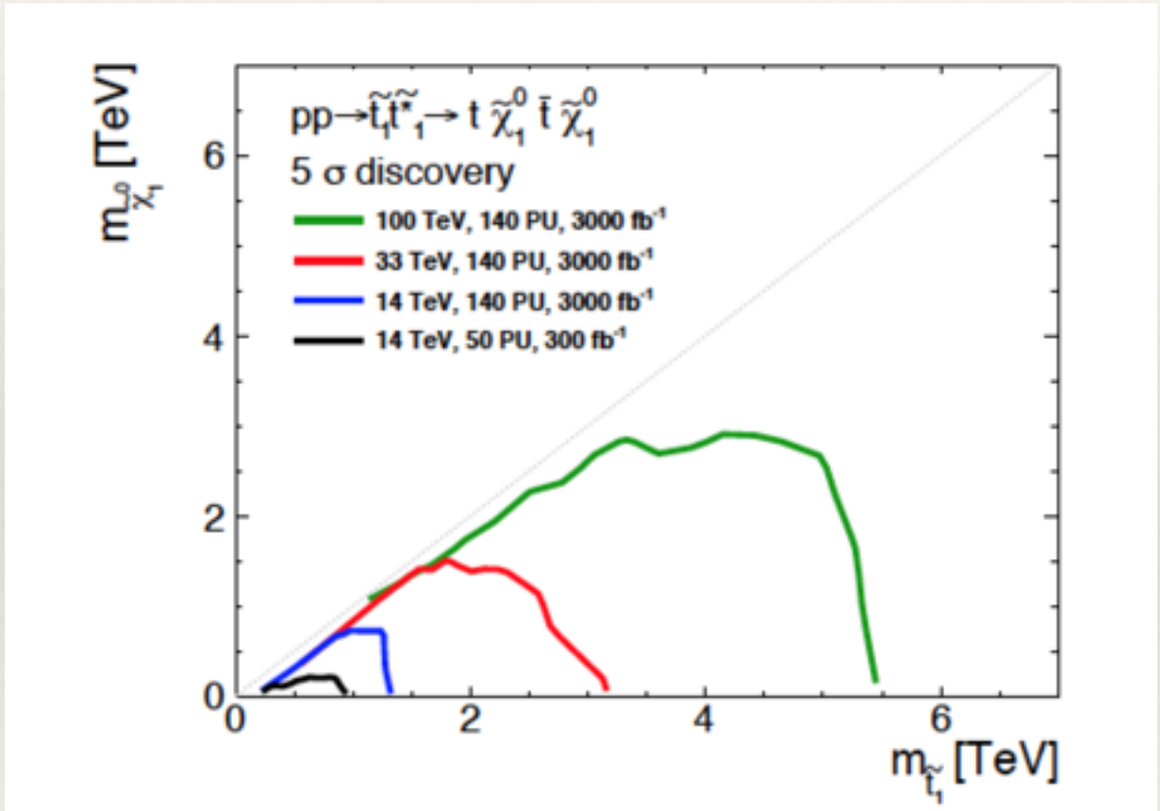
dilaton-like

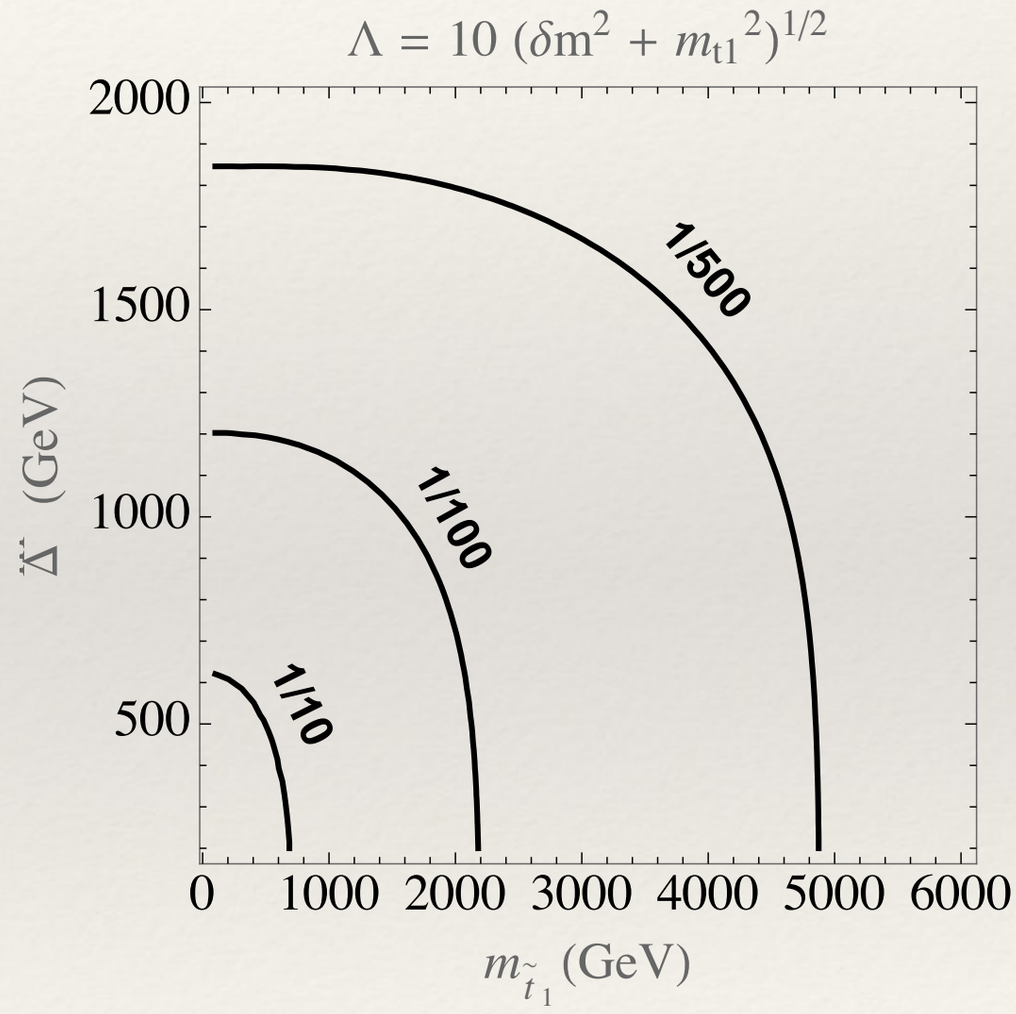
less understood, could be:
large mass gaps
new physics could be non-resonant
(tails vs resonances)
dark matter?

…???

Natural theories

yet, naturalness is a guiding principle



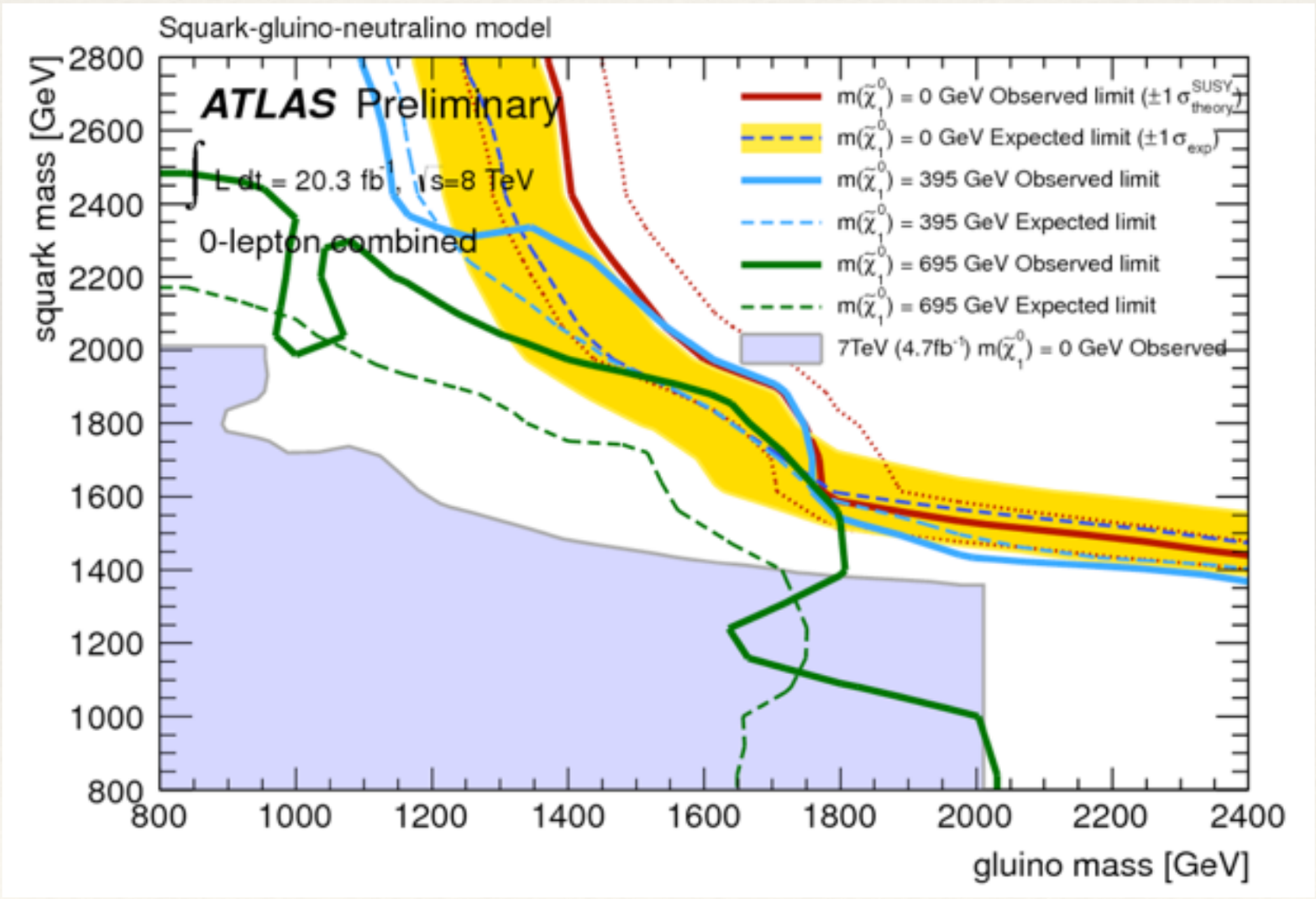


… and not more than that

which BSM?

Which BSM?

Highest bet, SUSY-like around the corner



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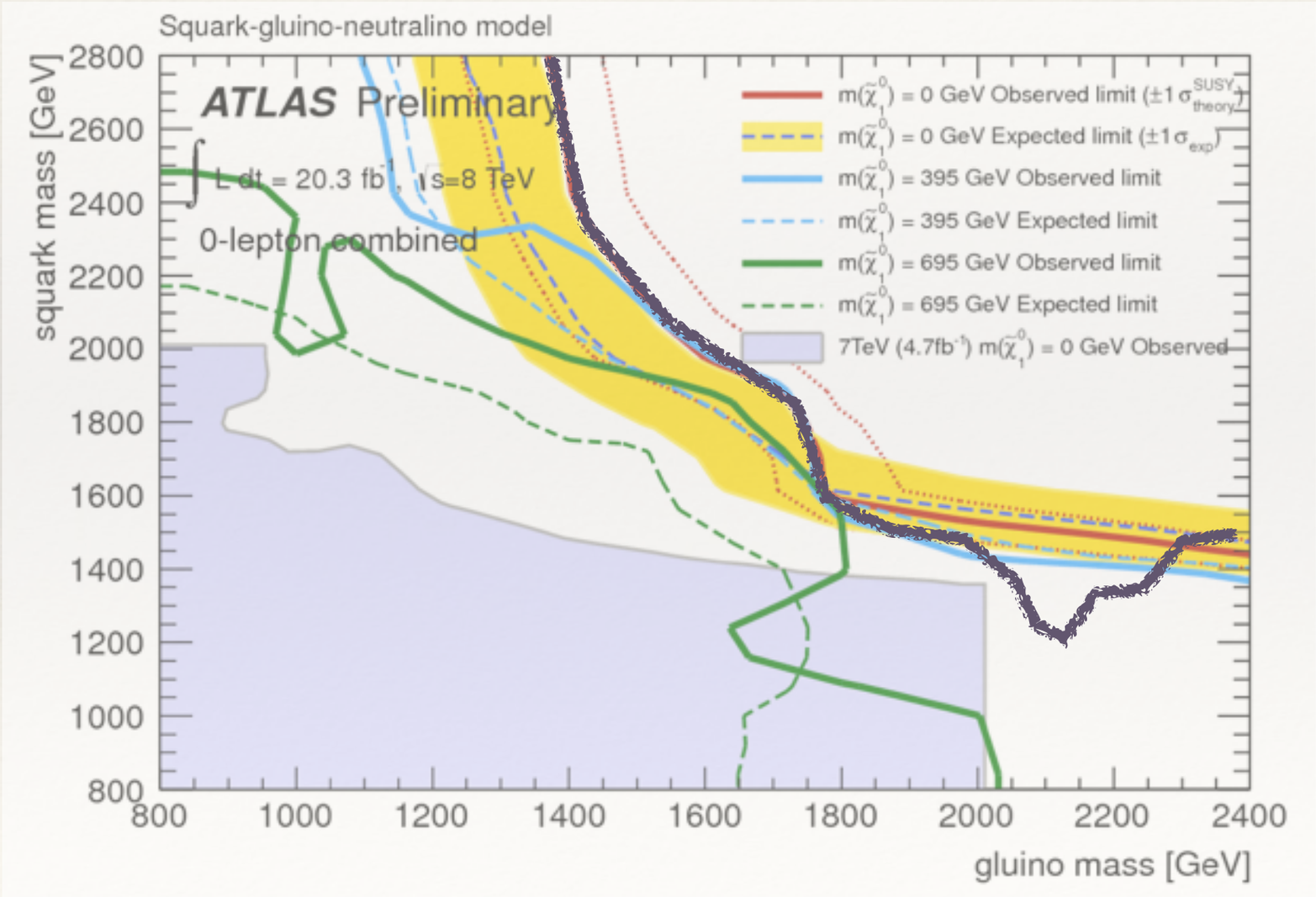
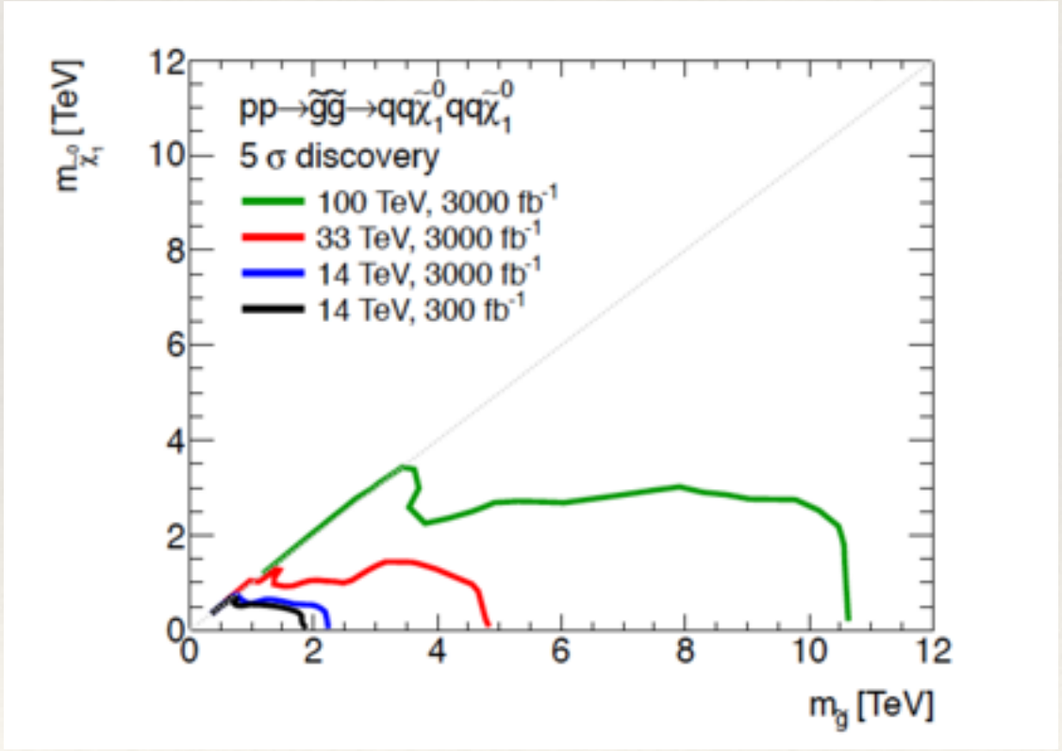


Which BSM?

Nightmare, BSM beyond the reach of future colliders

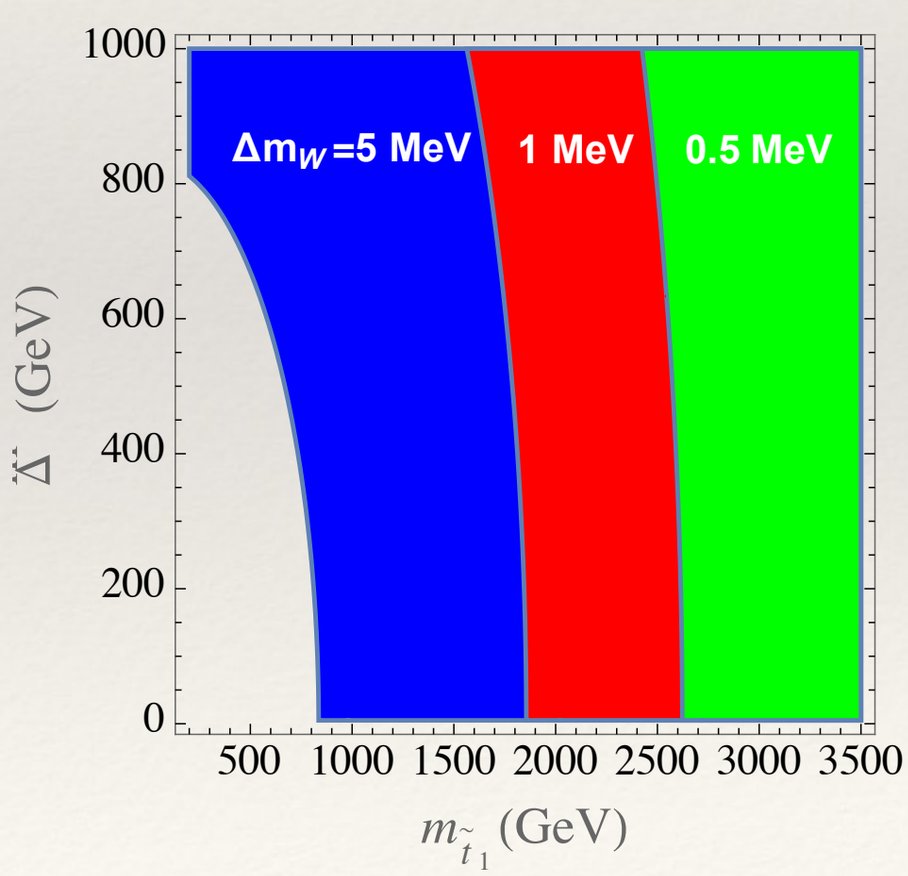
e.g. SUSY spectrum at about 5 TeV

direct



simplified models team, snowmass rept

indirect



Which BSM?

Buried BSM

e.g. stealth SUSY

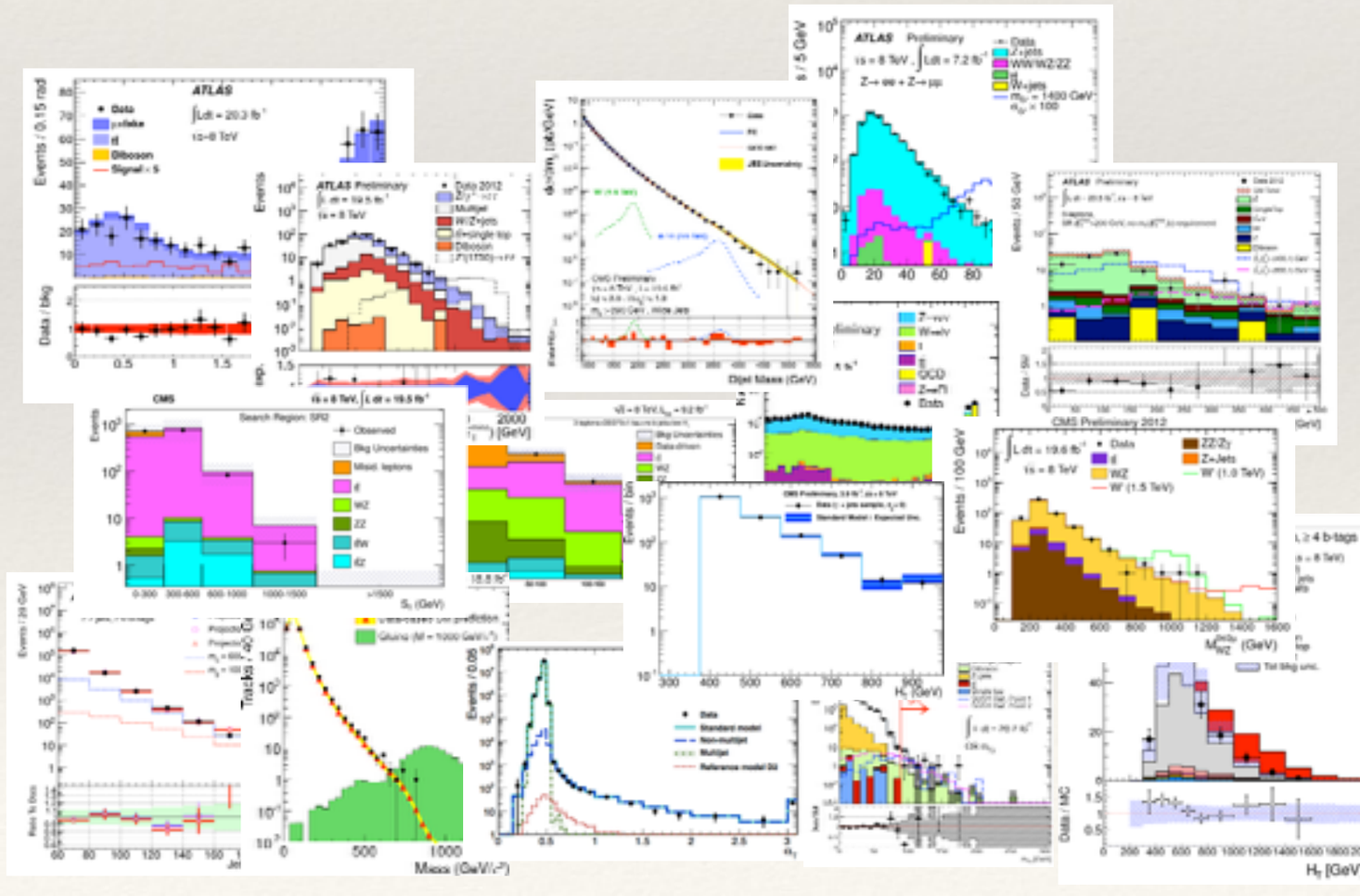
As a theorist, quite difficult, as analyses keep increasing sensitivity to kinematic corners

Trickier in the low-invariant mass, and hadronic channels

experimentalists' grit

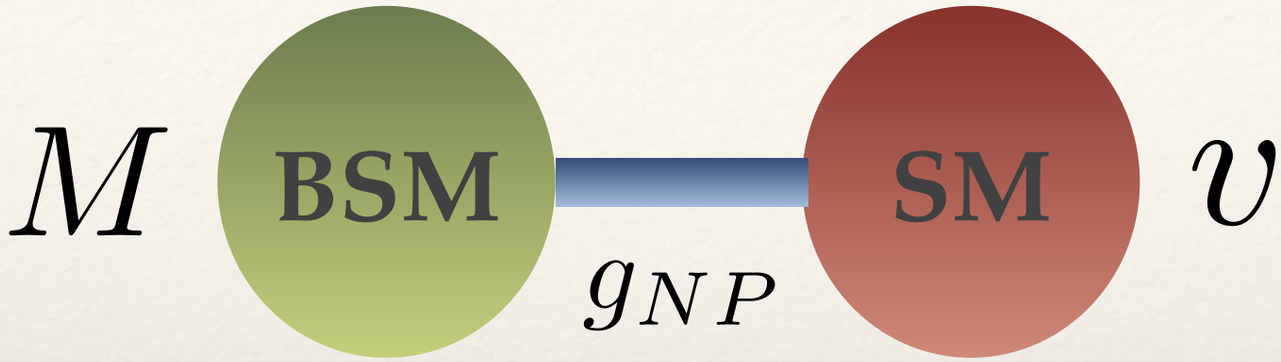
no stone unturned

wo/ theoretical bias

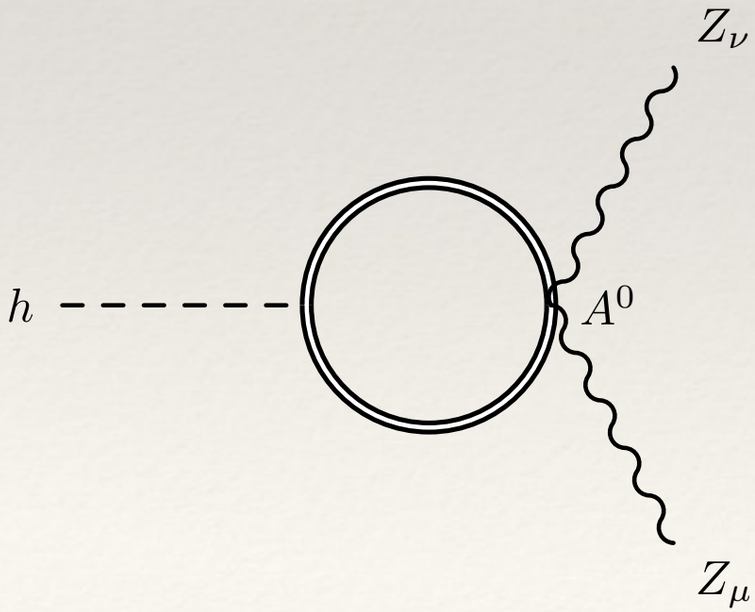


precision or energy?

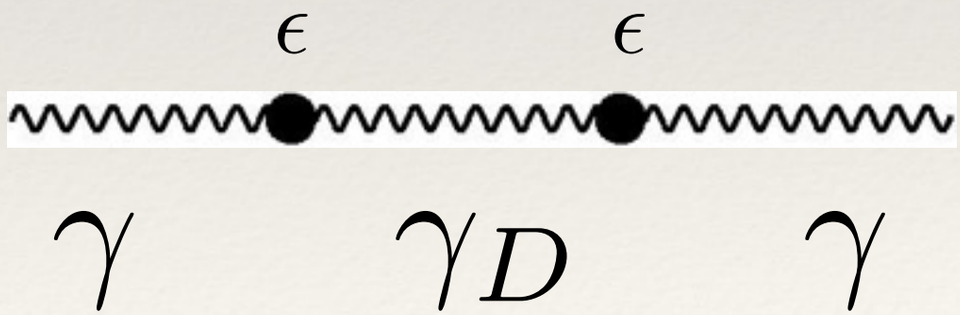
BSM effects



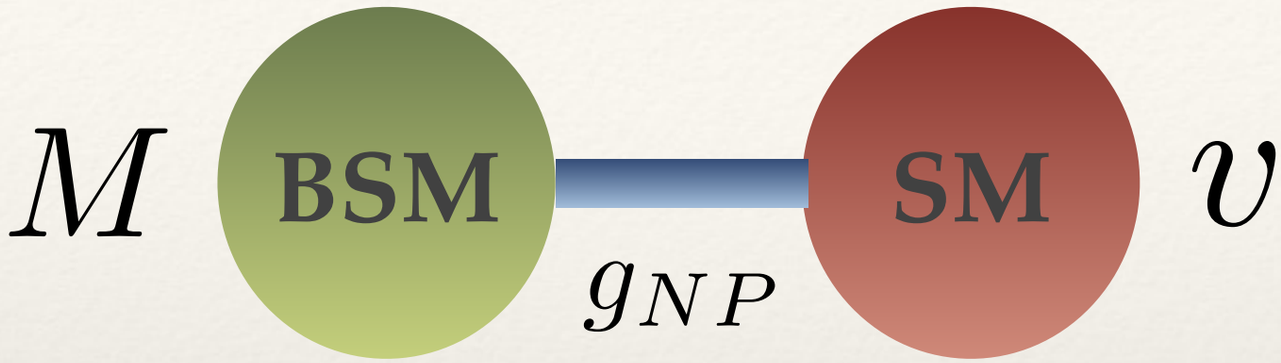
e.g. extended Higgs sectors



e.g. dark photon



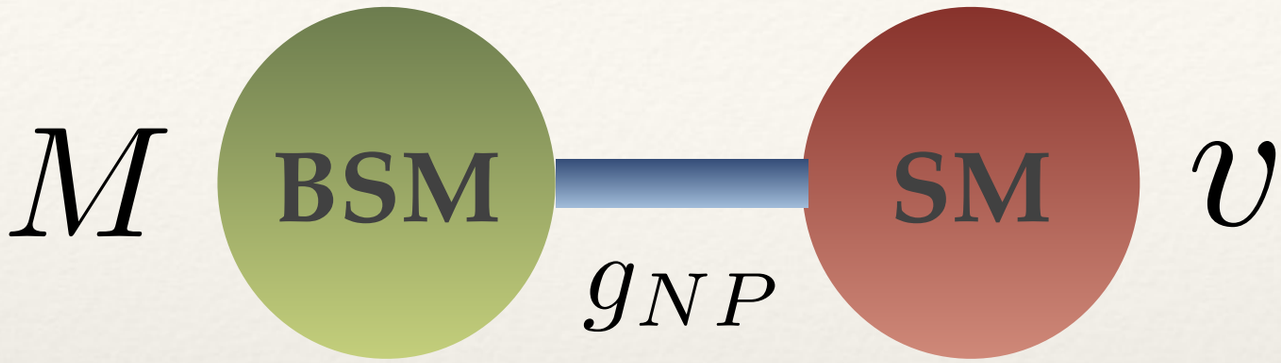
BSM effects

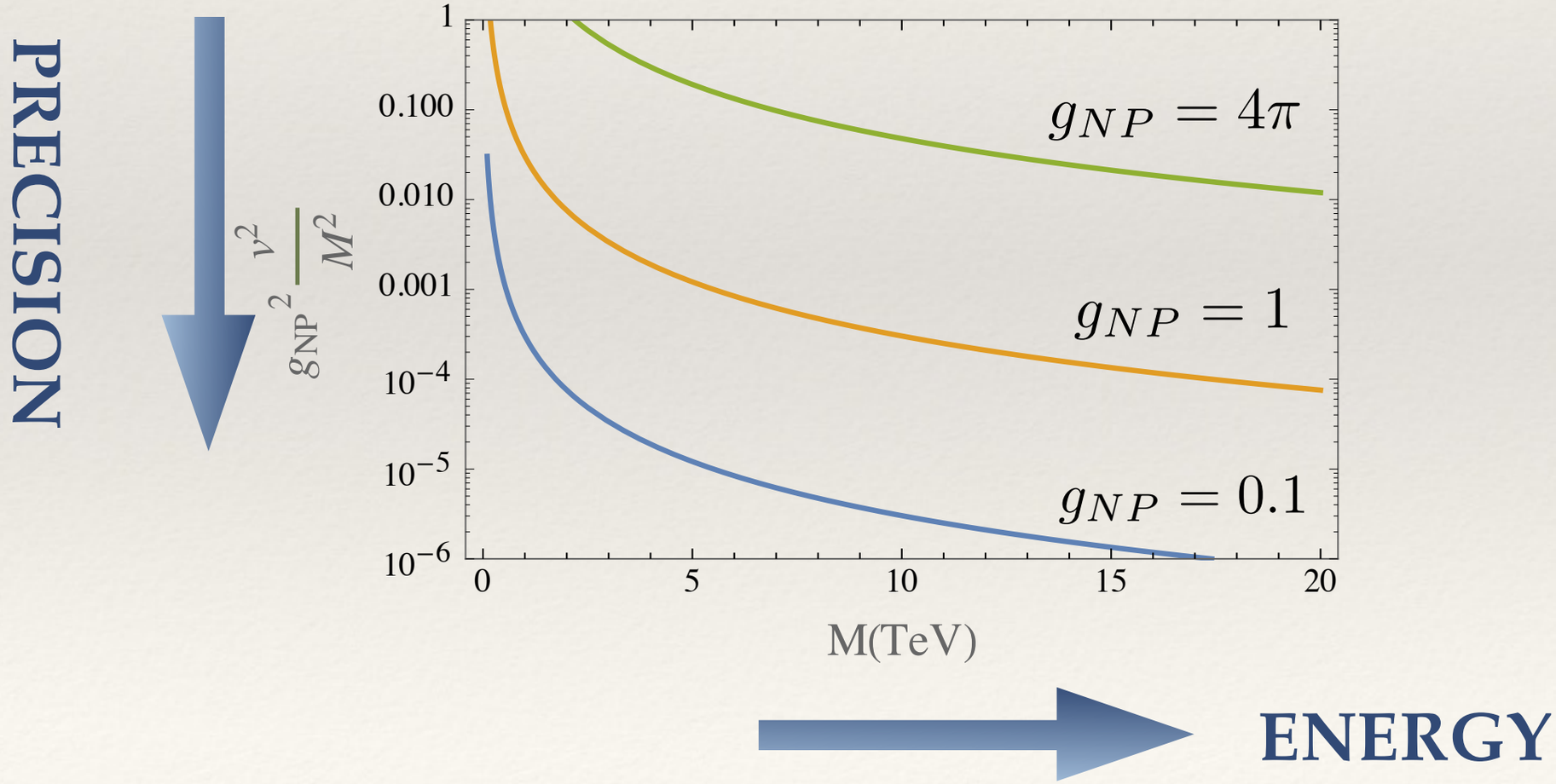


g_{NP} : tree-level or loop-suppressed coupling

Indirect searches limited by precision	$g_{NP}^2 \, \dfrac{v^2}{M^2}$
Direct searches kinematic reach	M

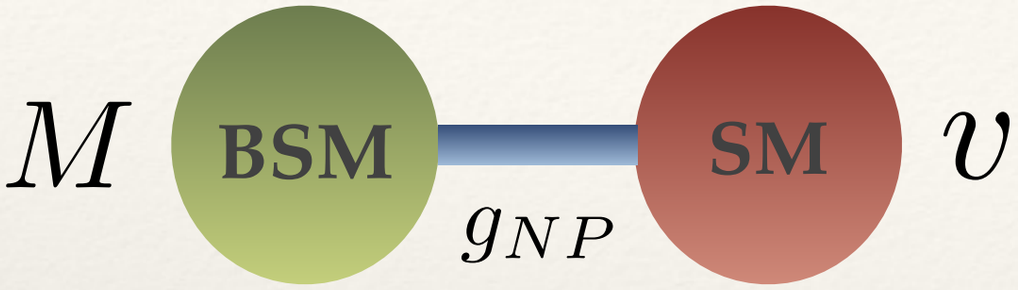
BSM effects


M
BSM
SM
v
g_{NP}


PRECISION
$g_{NP}^2 \frac{v^2}{M^2}$
1
0.100
0.010
0.001
10^{-4}
10^{-5}
10^{-6}
0
5
10
15
20
M(TeV)
$g_{NP} = 4\pi$
$g_{NP} = 1$
$g_{NP} = 0.1$
ENERGY

BSM effects

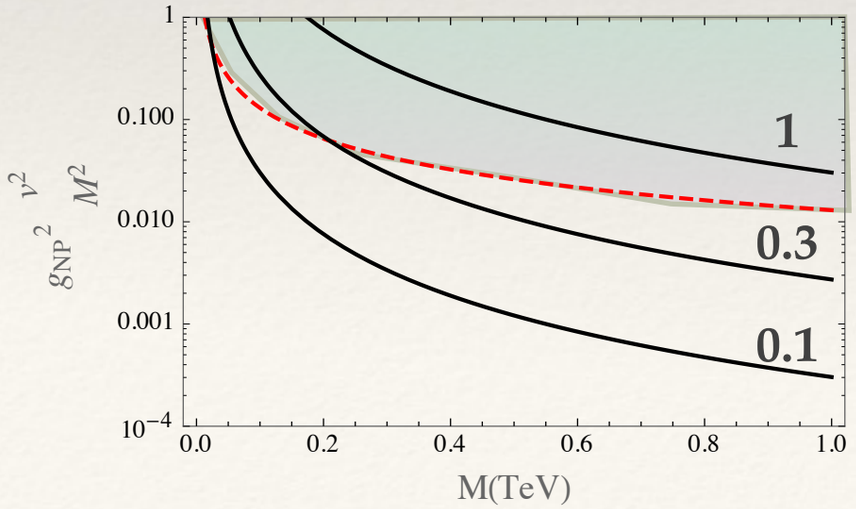
assuming direct coupling
and/or light mediator
and thermal production



Dark Matter relic
abundance condition $g_{NP}^2 \frac{v^2}{M^2} \propto \frac{1}{M}$

Heavy mediators with coupling gNP lead to
large deviations (outside this plot)

zoom in the region < 1 TeV



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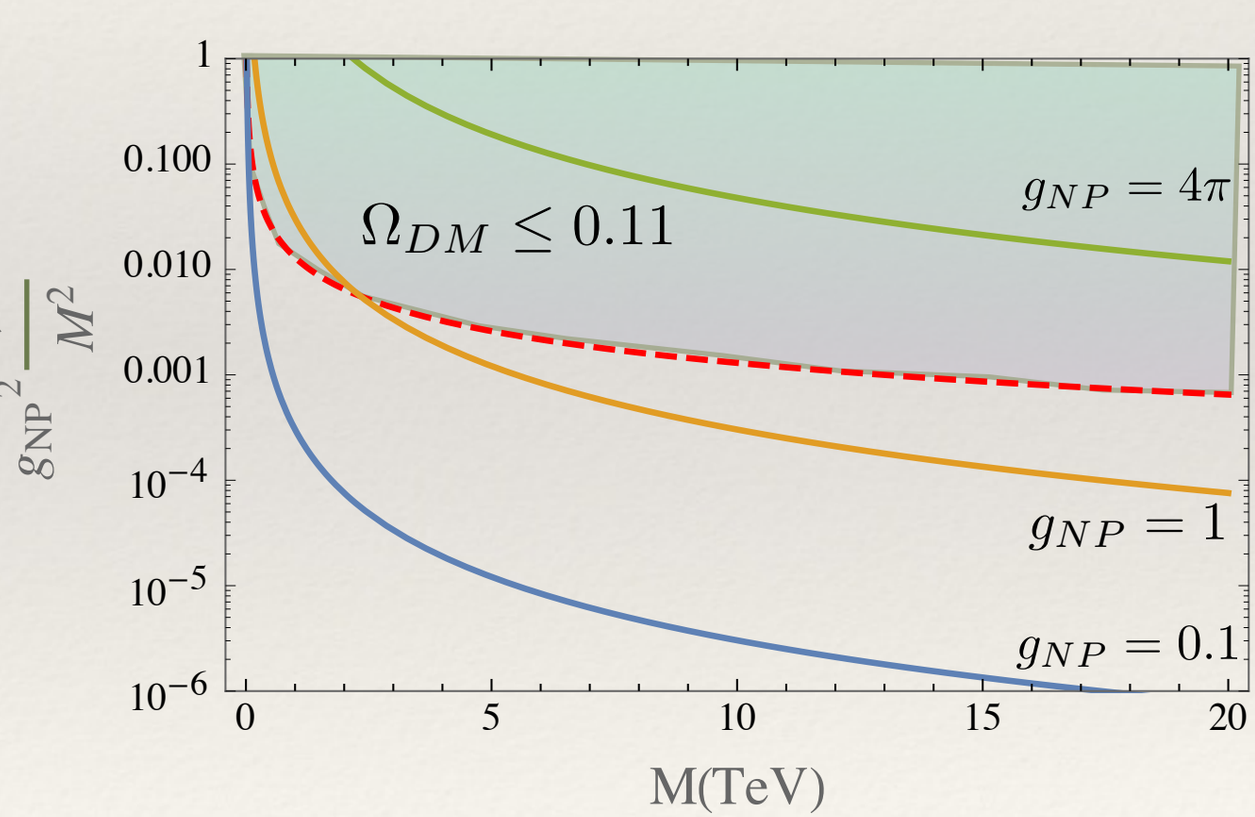
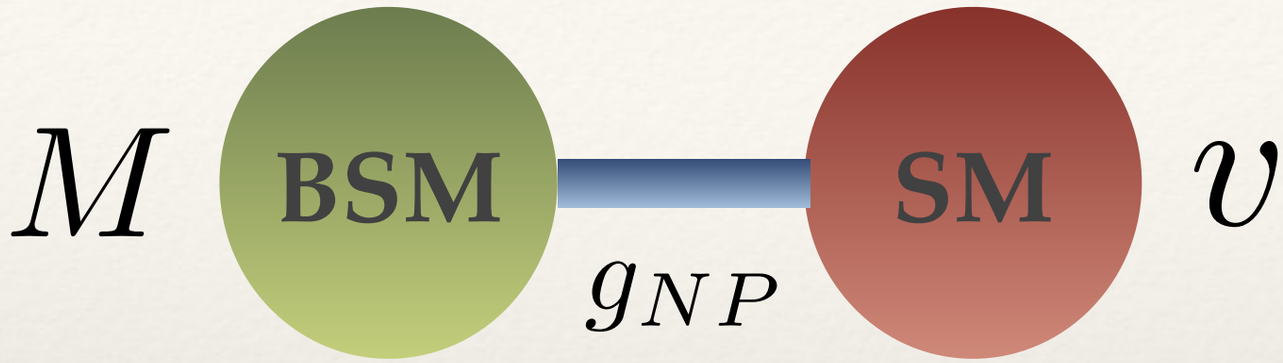
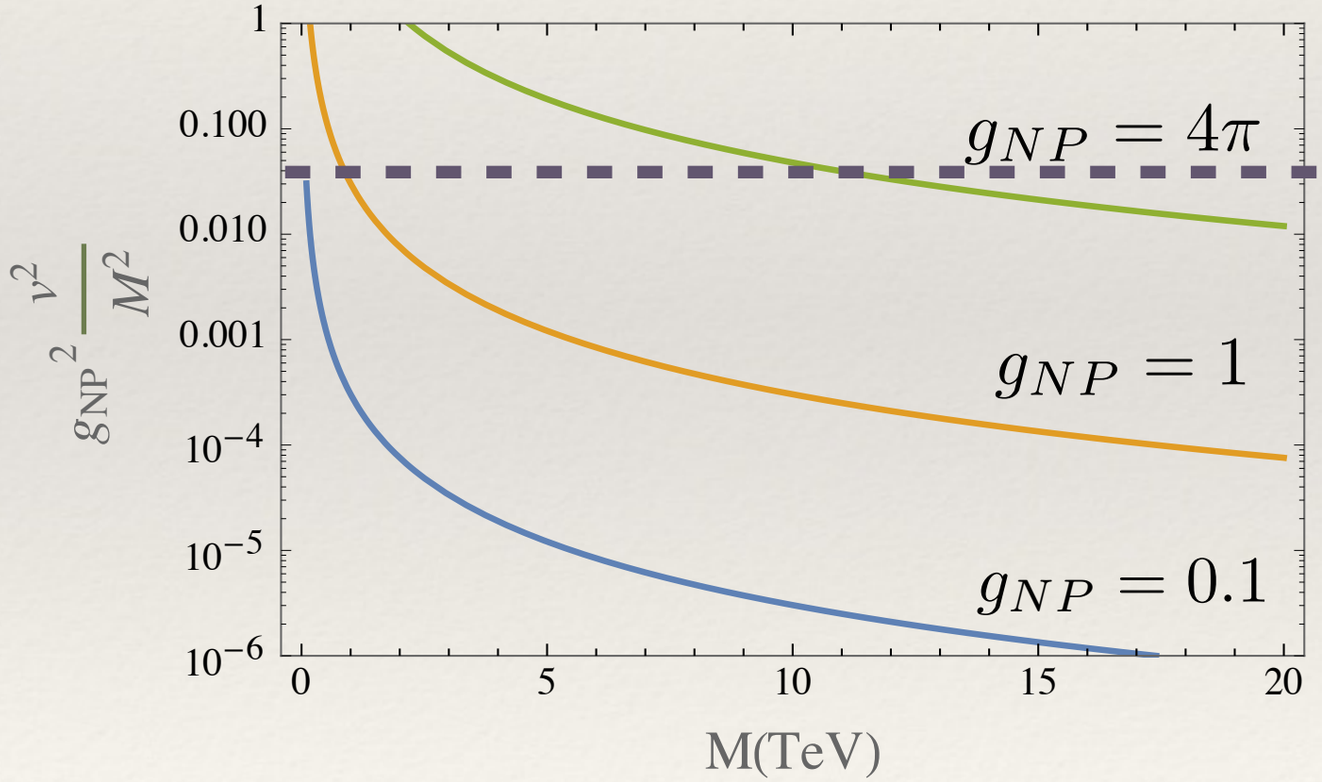


ENERGY

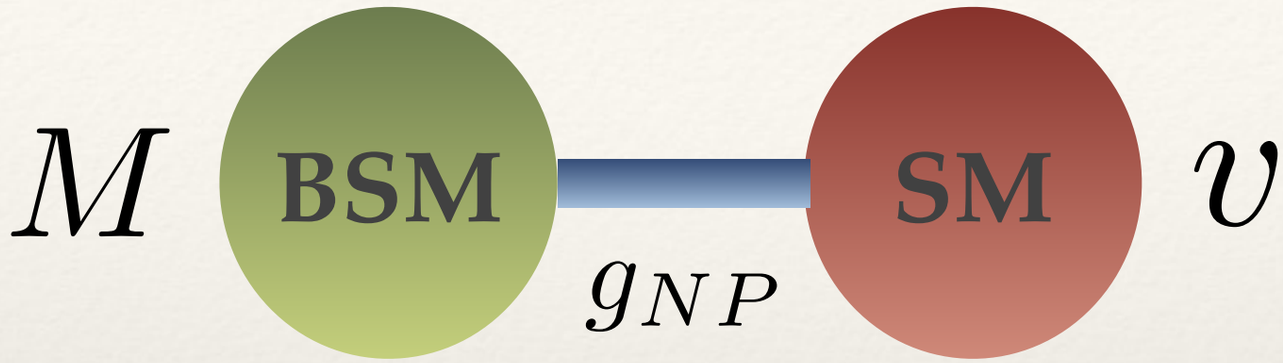
BSM effects



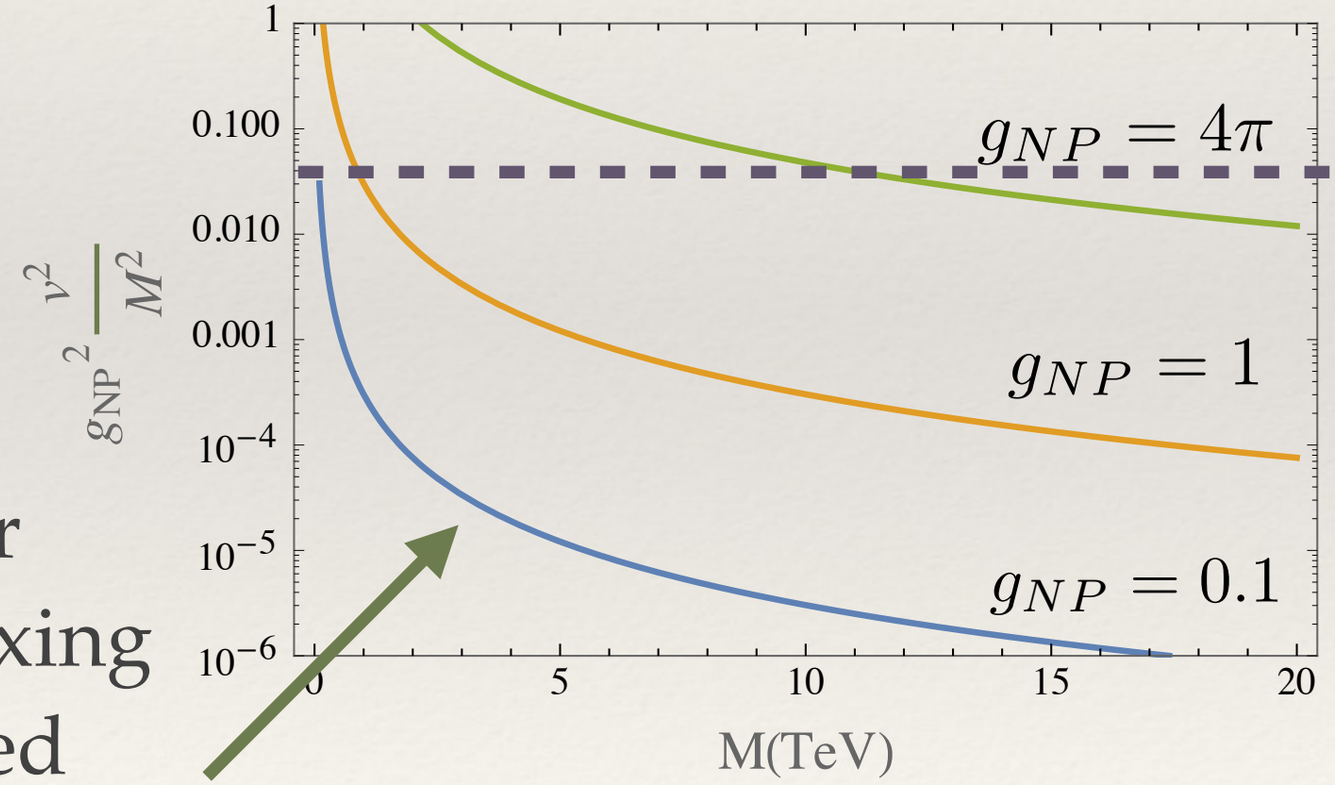


LHC limits

BSM effects



hidden sector
mass/kinetic mixing
or loop-induced
e.g. dark photon



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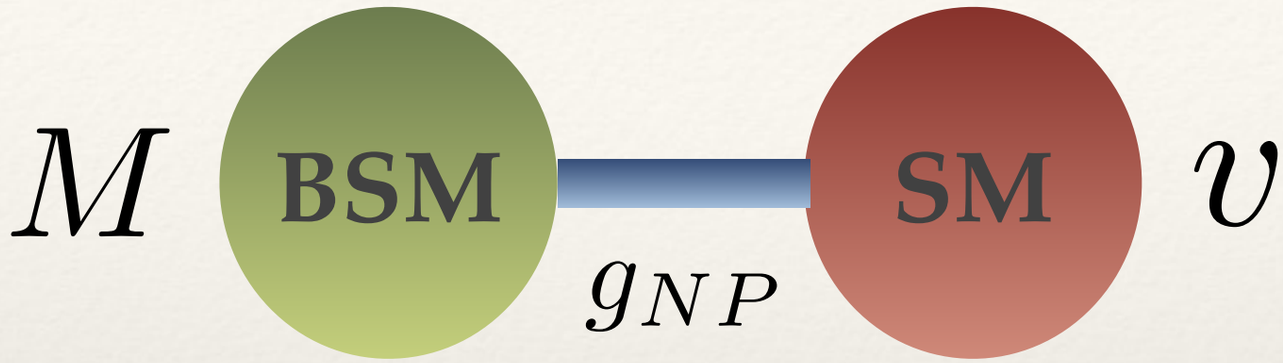
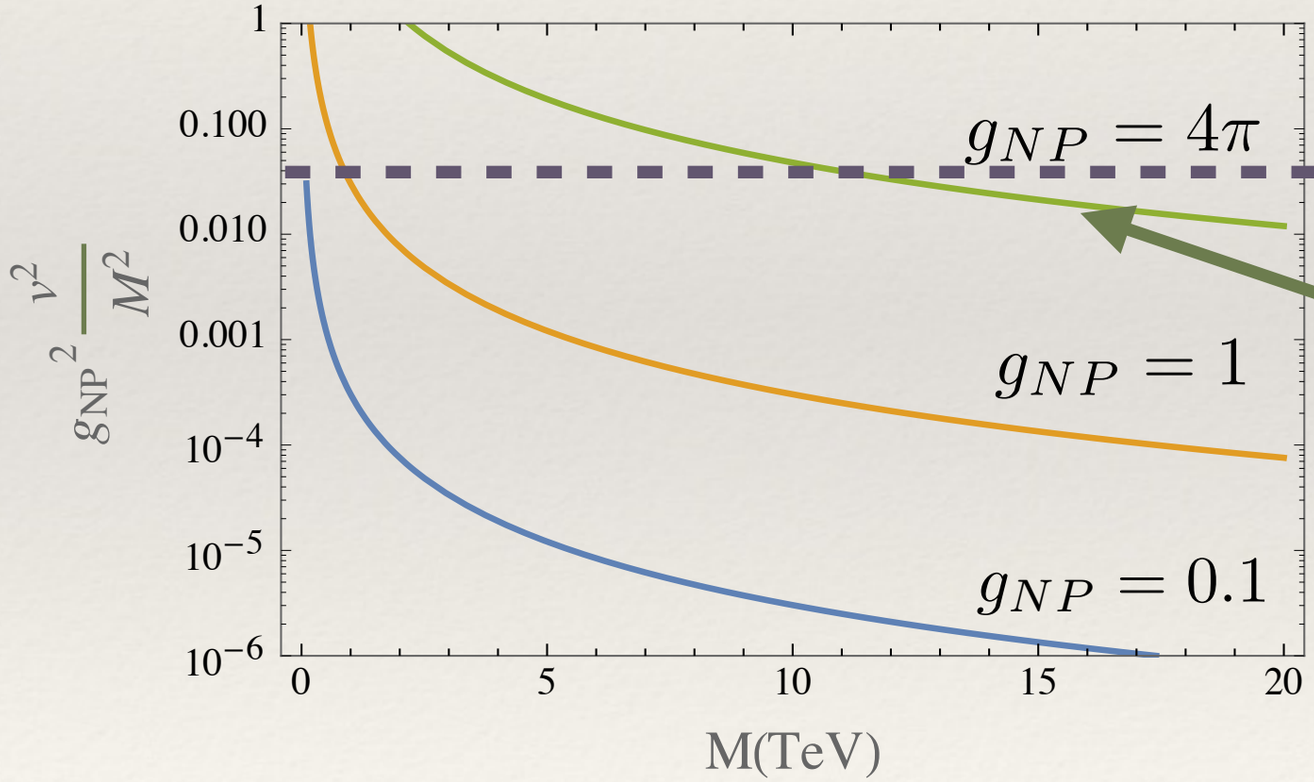
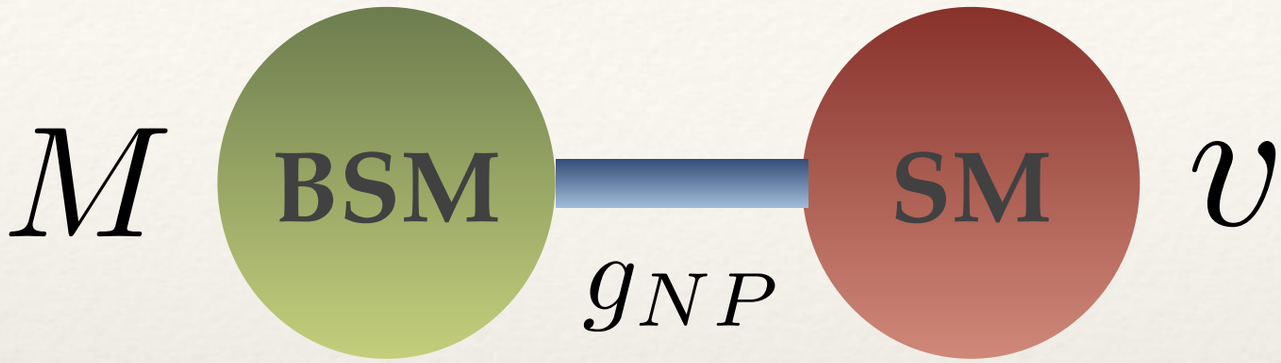


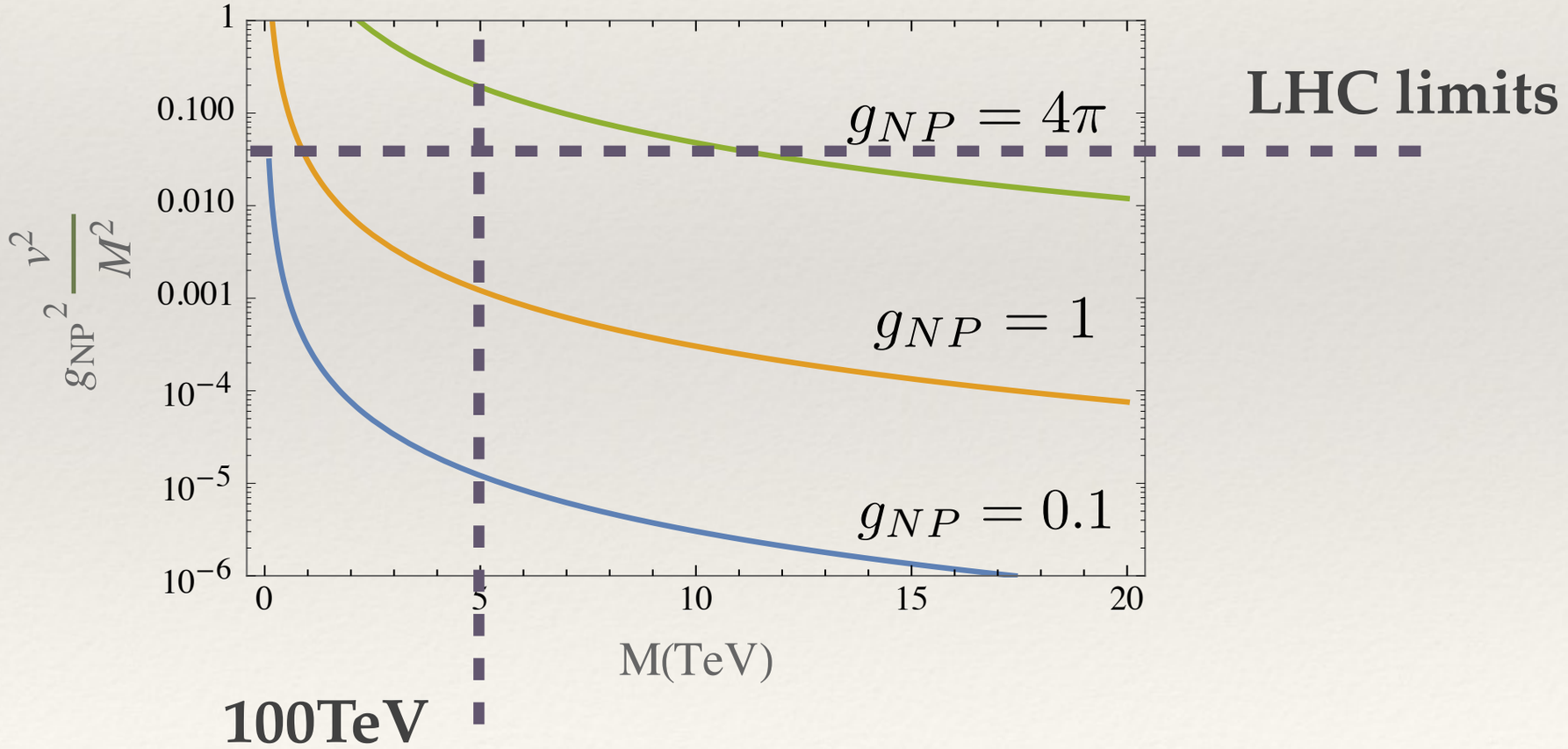


LHC limits

strongly coupled
e.g.
composite Higgs
warped xdims

BSM effects


M
BSM
SM
v
g_{NP}


LHC limits
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0.100
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0
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10
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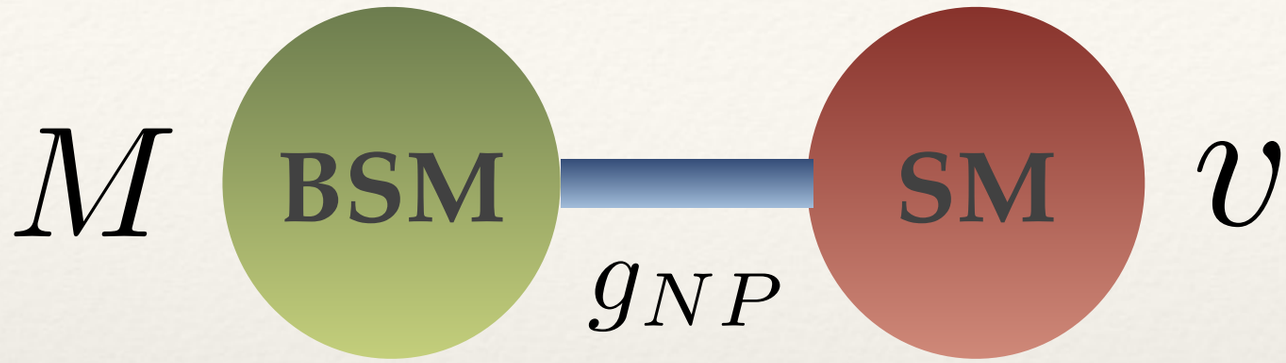
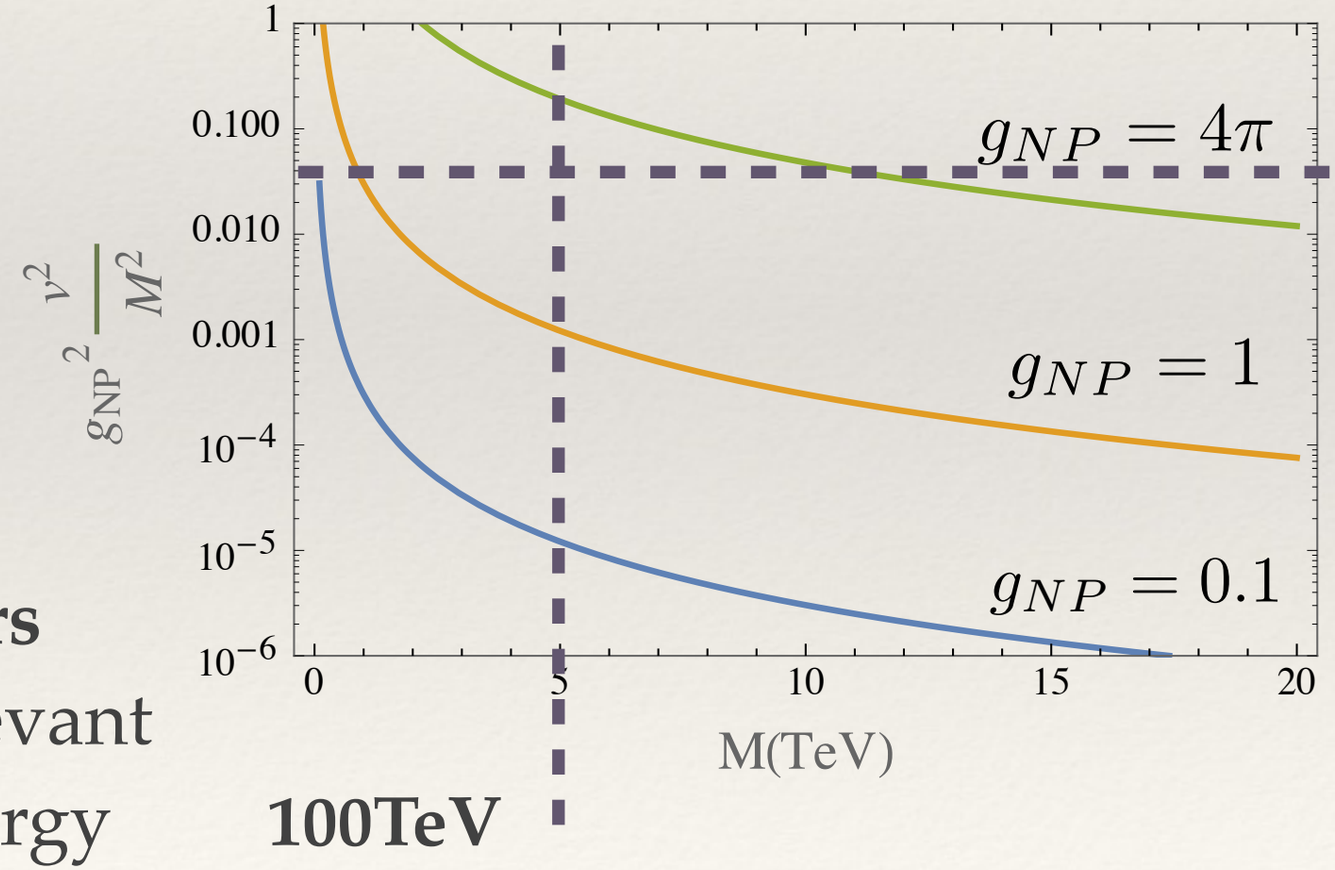
20
M(TeV)
100TeV

BSM effects



hidden sectors
BGs at low-E relevant precision or energy depends on model



LHC limits

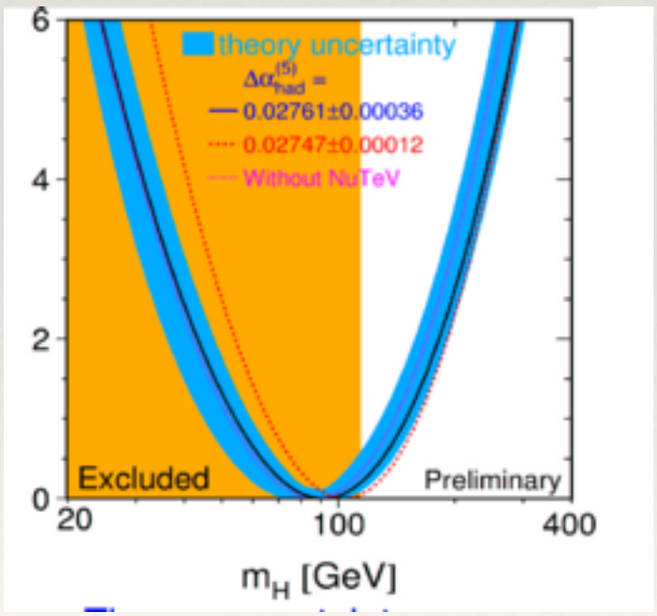
strongly-coupled precision way

Scenarios for future colliders

My prior

If no hint of new physics shows up in the 2017 data

no clear case for a new machine



why? BSM models have more structure than the SM

evade constraints in many ways

e.g. MSSM, Composite Higgs

interpretation in terms of simplified models

but simple models are not the typical BSM

My prior

If no hint of new physics shows up in the 2017 data

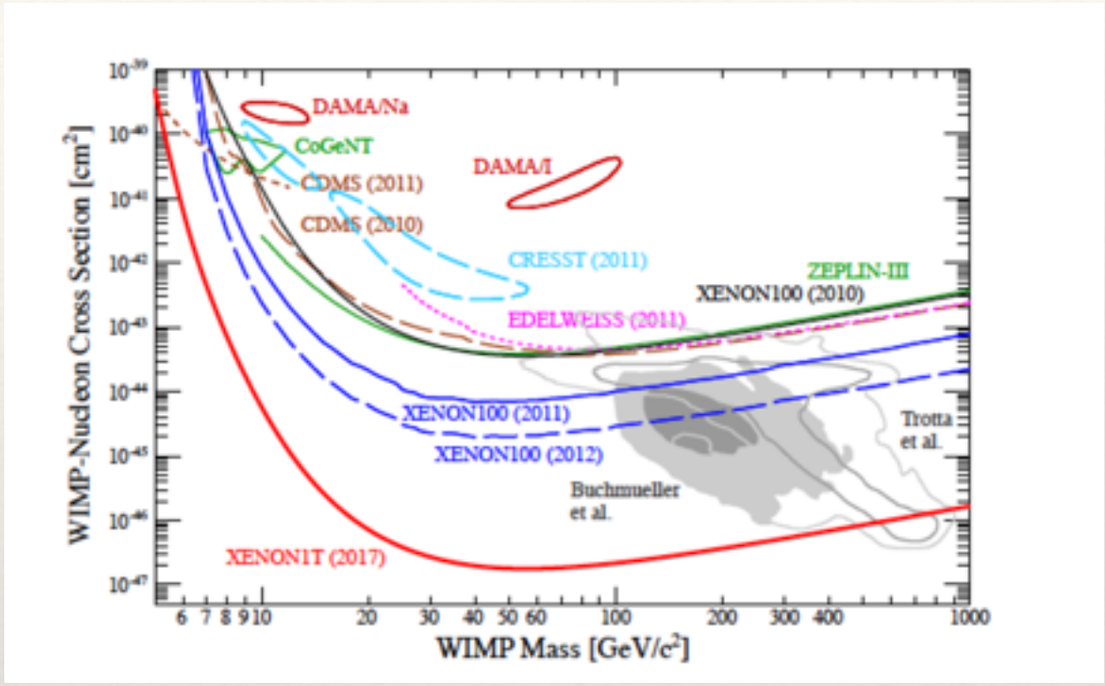
no clear case for a new machine

Discuss possible

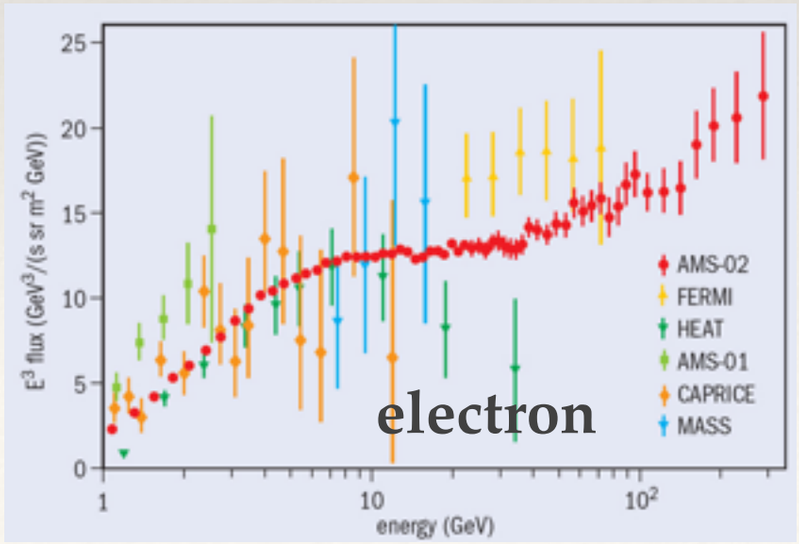
scenarios for discovery

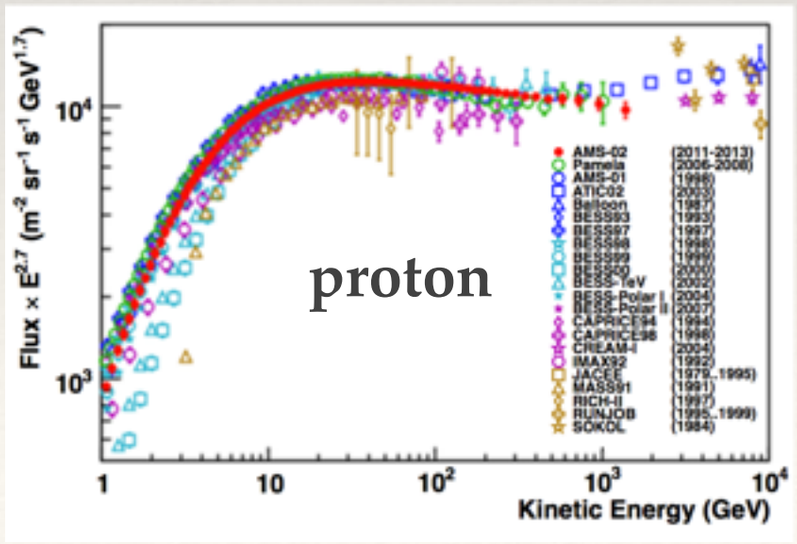
The Dark Matter connection

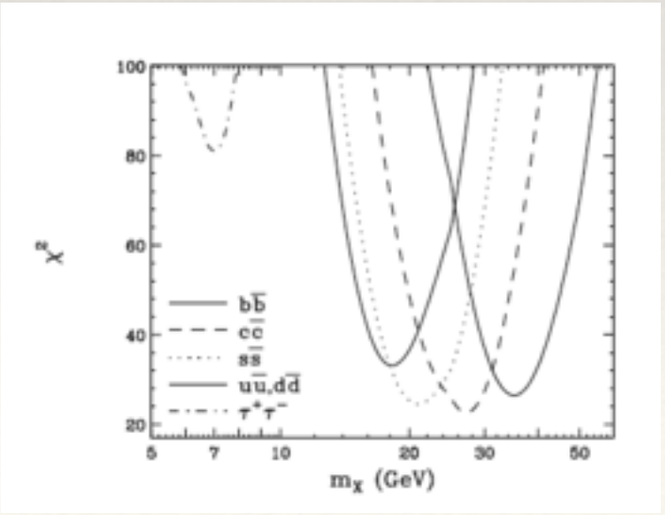
Direct detection



Indirect detection



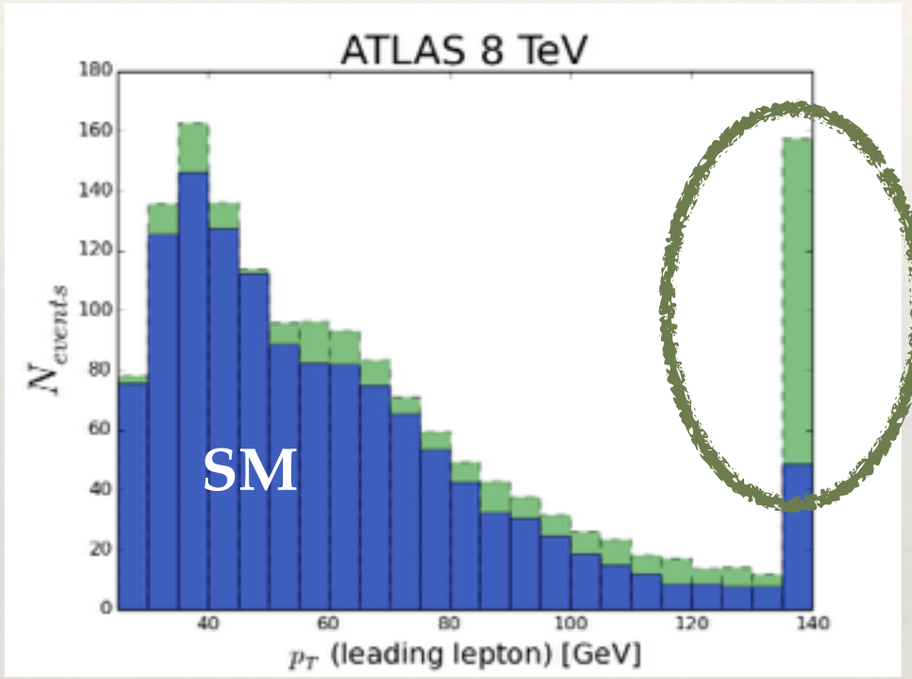




1402.6703

An excess in a tail: EFT analysis

E.g. a non-resonant excess in diboson production



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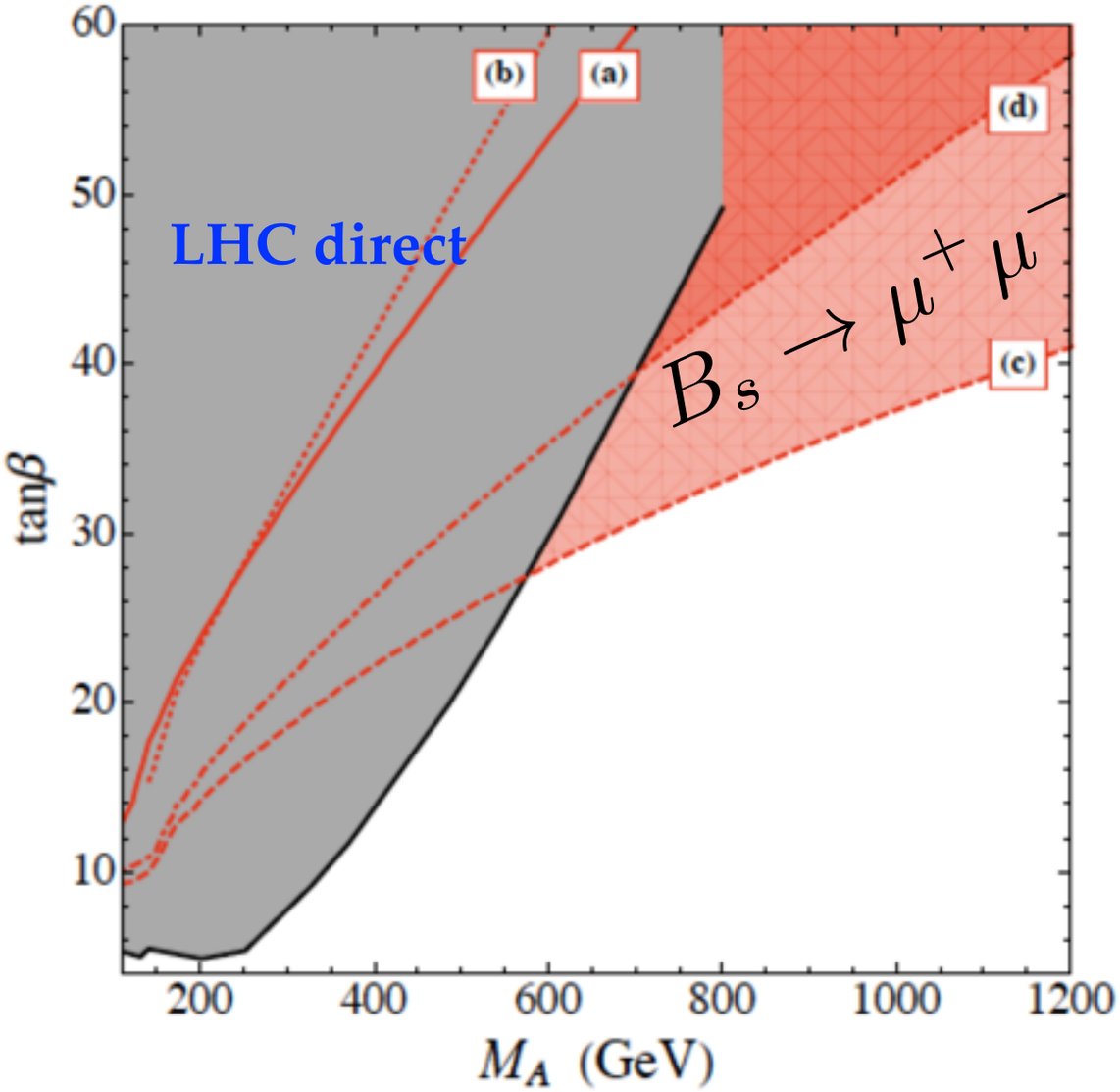
EFT -> UV models

correlations with other signals

could point a specific scale

The flavour connection

Excess in LHCb/CMS/ATLAS



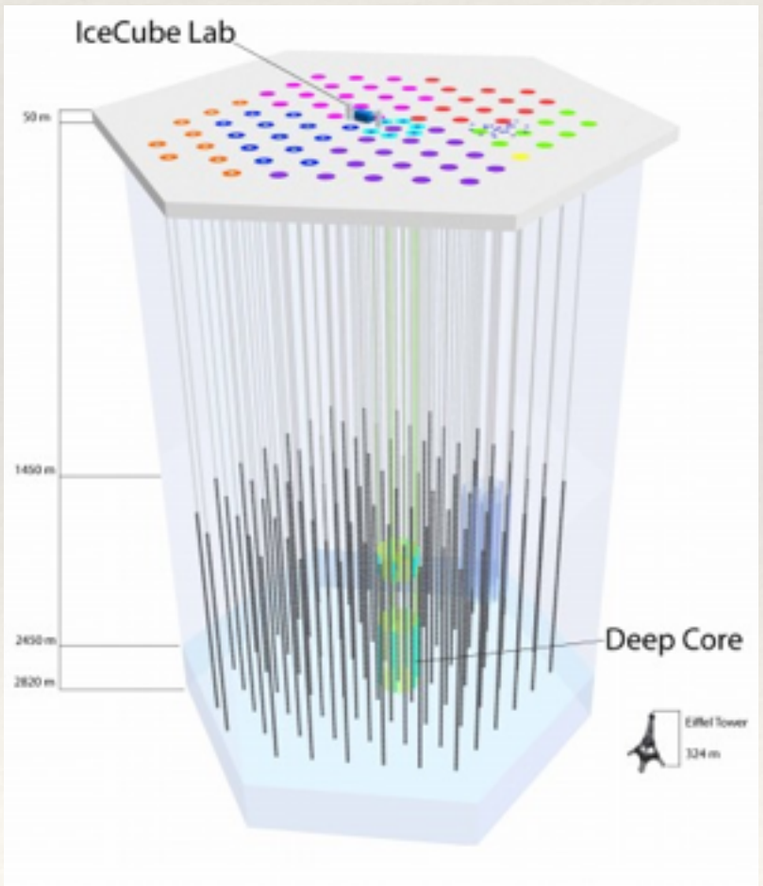
1211.1976

correlations with other signals could point a specific scale

And others

Hint of an EW scale/neutrino connection

Axion-like searches pointing at a scale within collider reach



1409.4792

Conclusions

- Strong case for BSM close to the electroweak scale
- Precision: Higgs, top. Risk is interpretation of an excess may not indicate the scale of NP
- Energy: hadron machines. Direct detection. Discovery
- Precision vs Energy: depends on the model
- No unique benchmark to follow: Exciting but difficult to make long-term decisions. To attract enthusiasm, and a clear-cut objective could be necessary
- Beginning of 2018: now or never? release and maximize output of this dataset seems crucial