

Constraints on Supersymmetry using LHC data

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Alikhanov Institute for Theoretical and Experimental Physics, Moscow, Russia

Moscow Institute of Physics and Technology, Dolgoprudny, Russia

Two big ideas



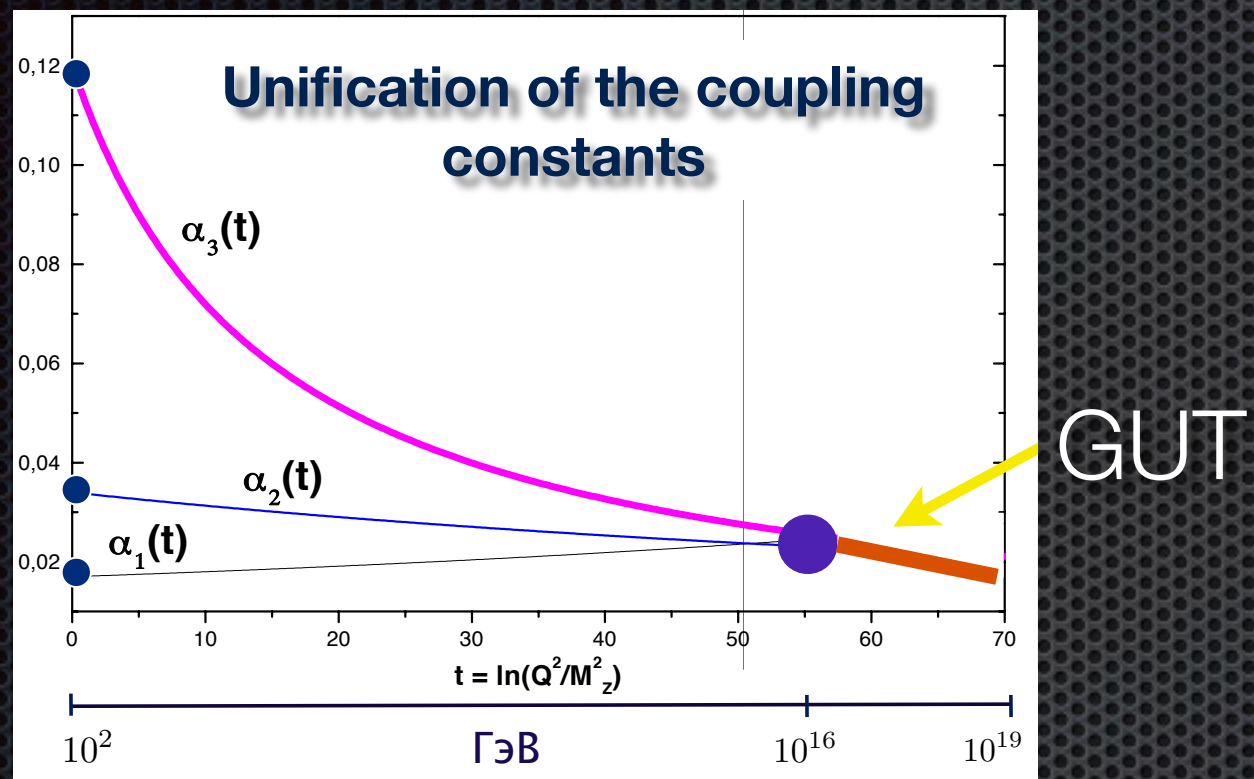
Two big ideas

1. Grand Unification Theory



Two big ideas

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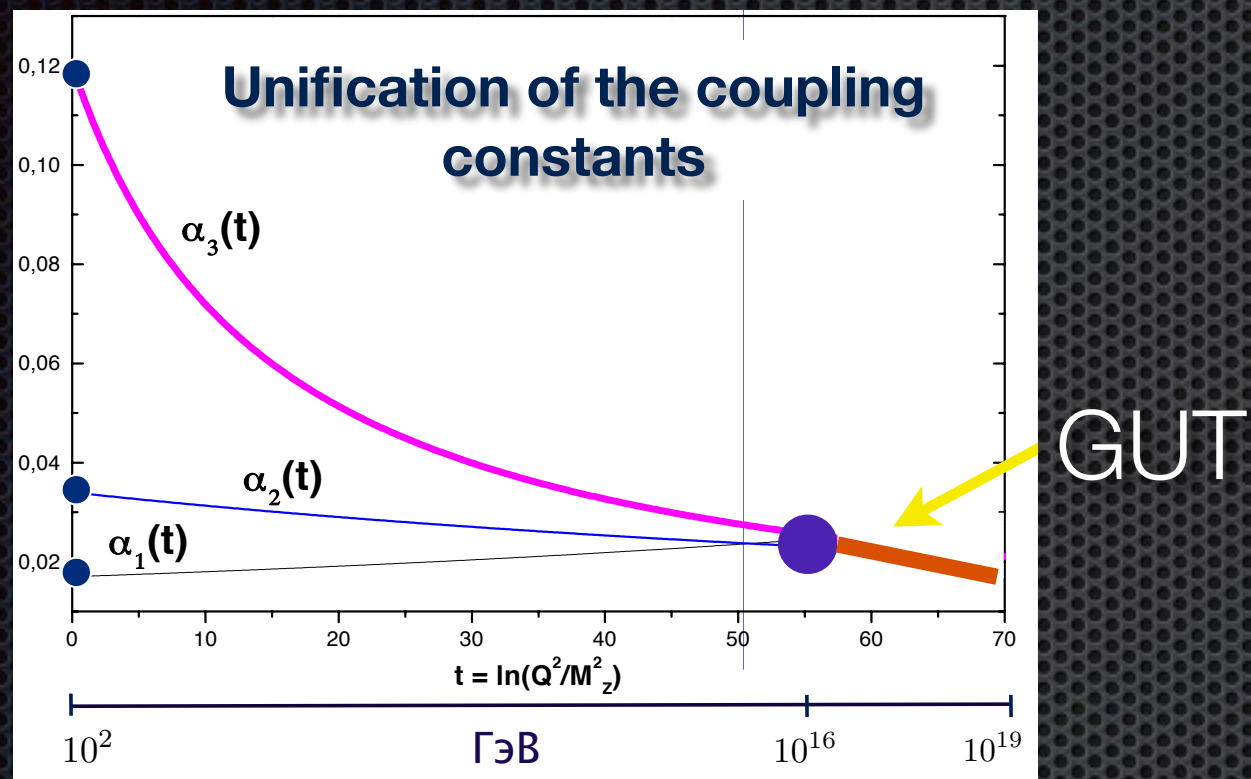
Unification of constants, particles and interactions



Two big ideas

1. Grand Unification Theory

Predictions of GUTs

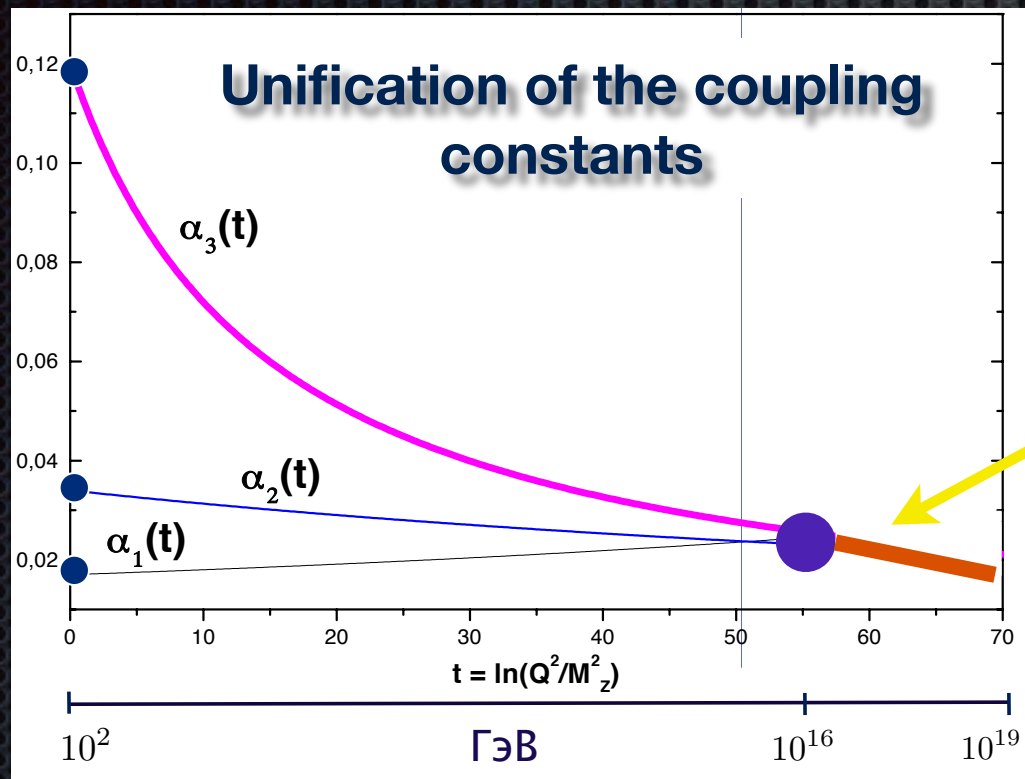


Unification of constants, particles and interactions

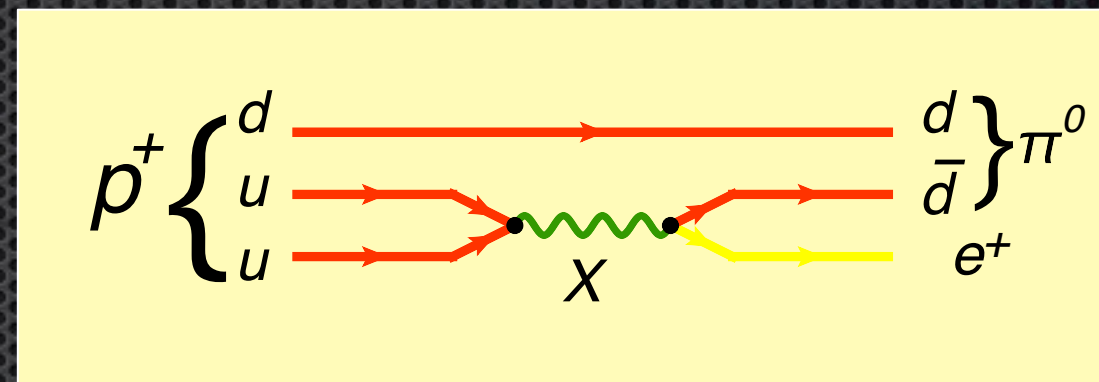


Two big ideas

1. Grand Unification Theory



Predictions of GUTs



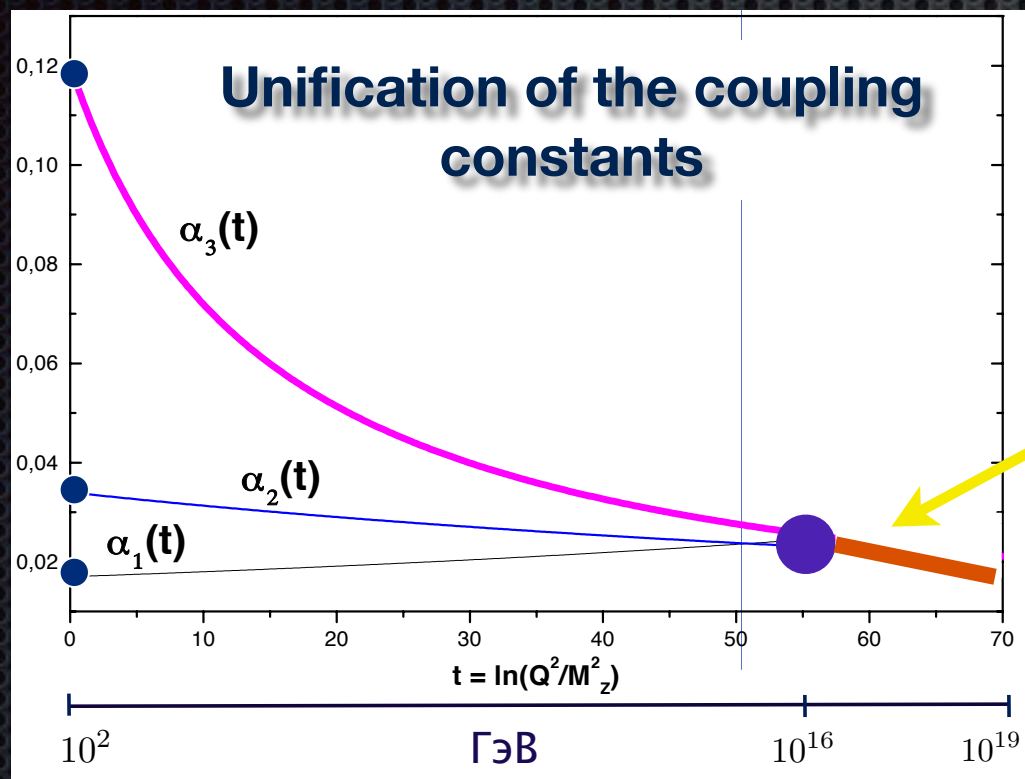
Proton decay

Unification of constants, particles and interactions



Two big ideas

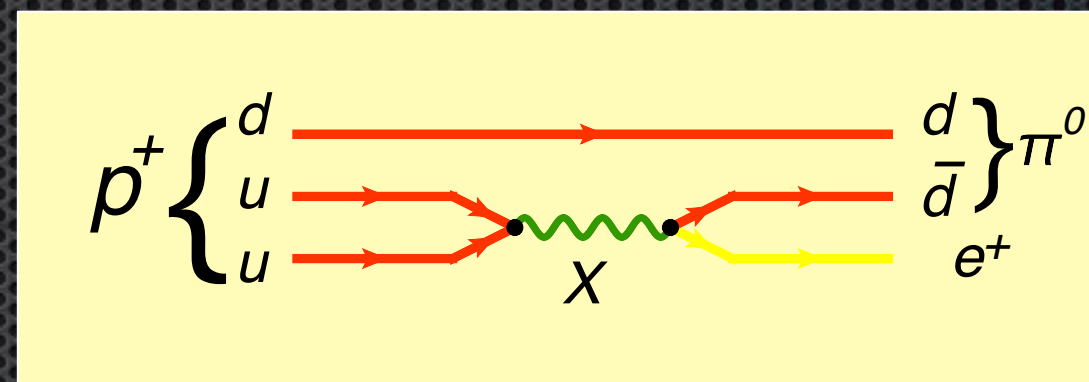
1. Grand Unification Theory



GUT

Unification of constants, particles and interactions

Predictions of GUTs



Proton decay

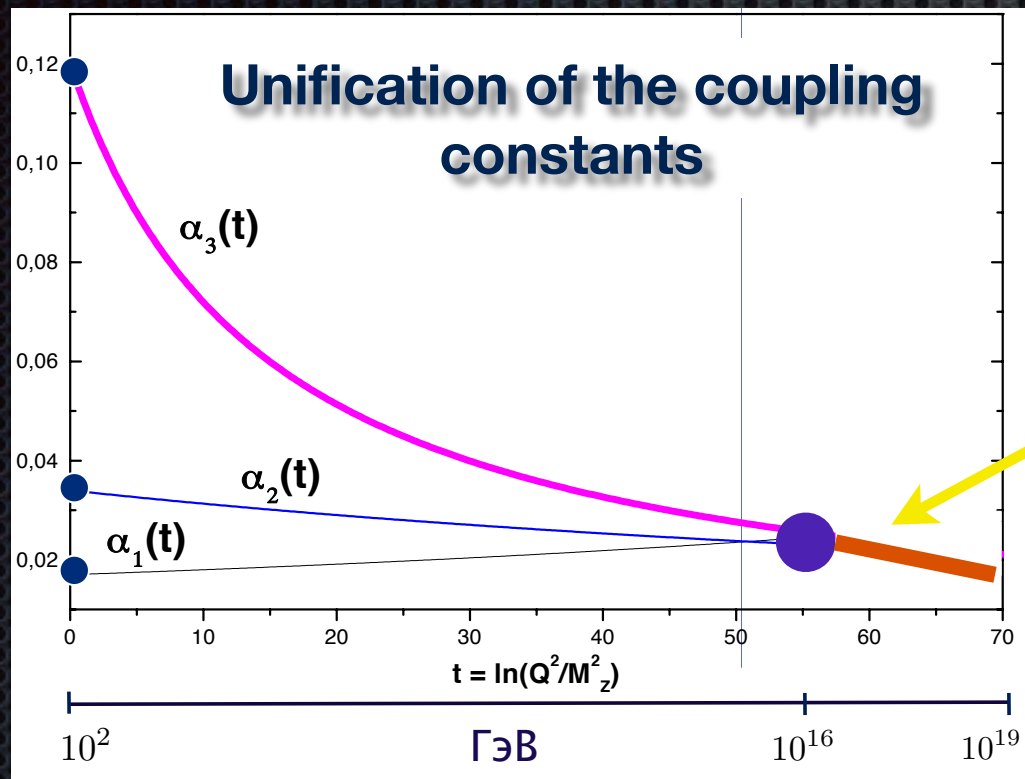
$$\tau_{\text{proton}} \sim 10^{32} \text{ years}$$

$$\tau_{\text{Universe}} \approx 14 \cdot 10^9 \text{ years}$$



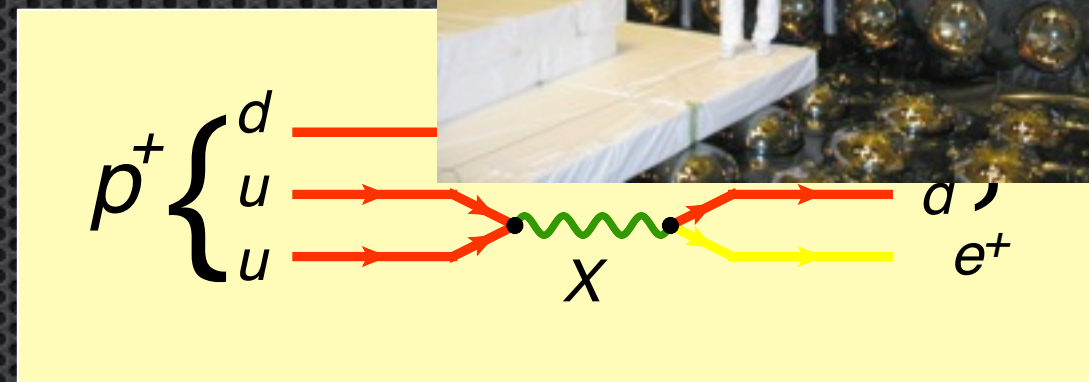
Two big ideas

1. Grand Unification Theory



Unification of constants, particles and interactions

Prediction



Proton decay

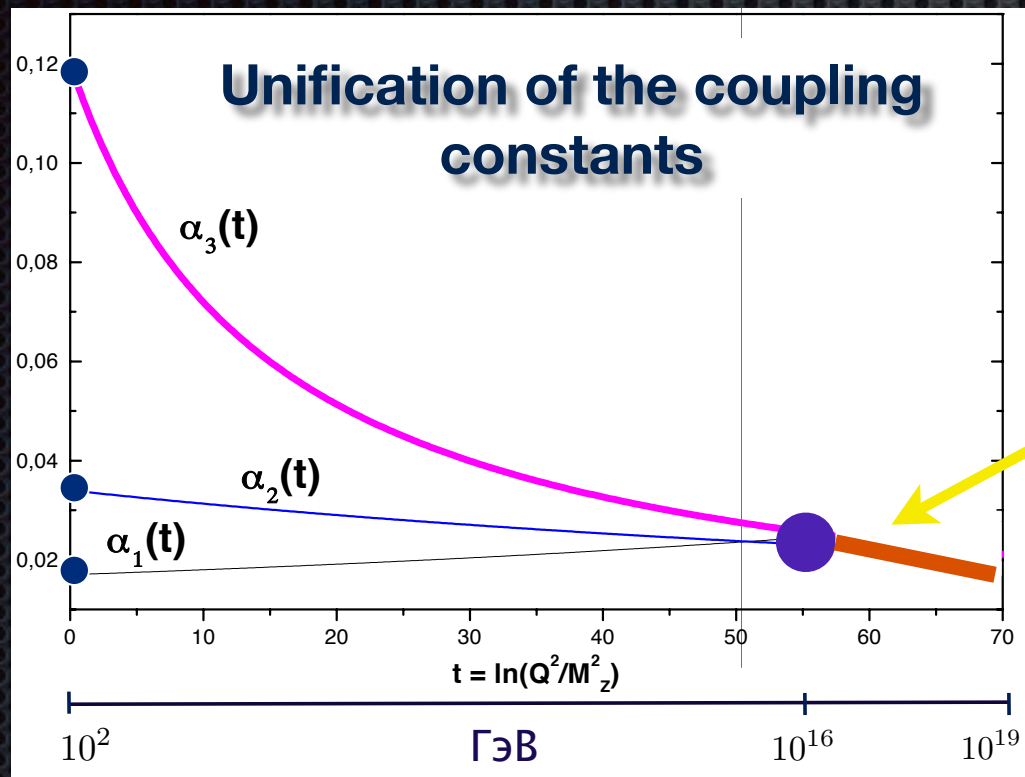
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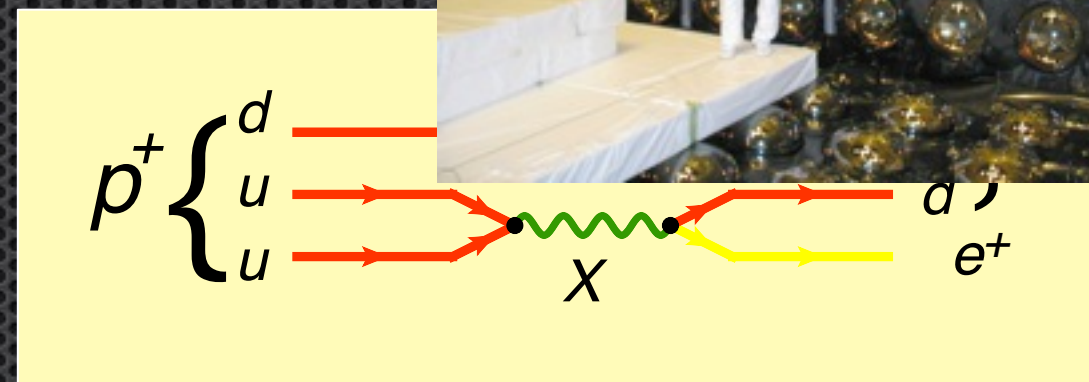
1. Grand Unification Theory



Unification of constants, particles and interactions

The problem: stabilization of the Higgs sector of the SM subjected to radiative corrections due to the heavy particles of a GUT

Prediction



Proton decay

$$\tau_{\text{proton}} \sim 10^{32} \text{ years}$$

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Two big ideas



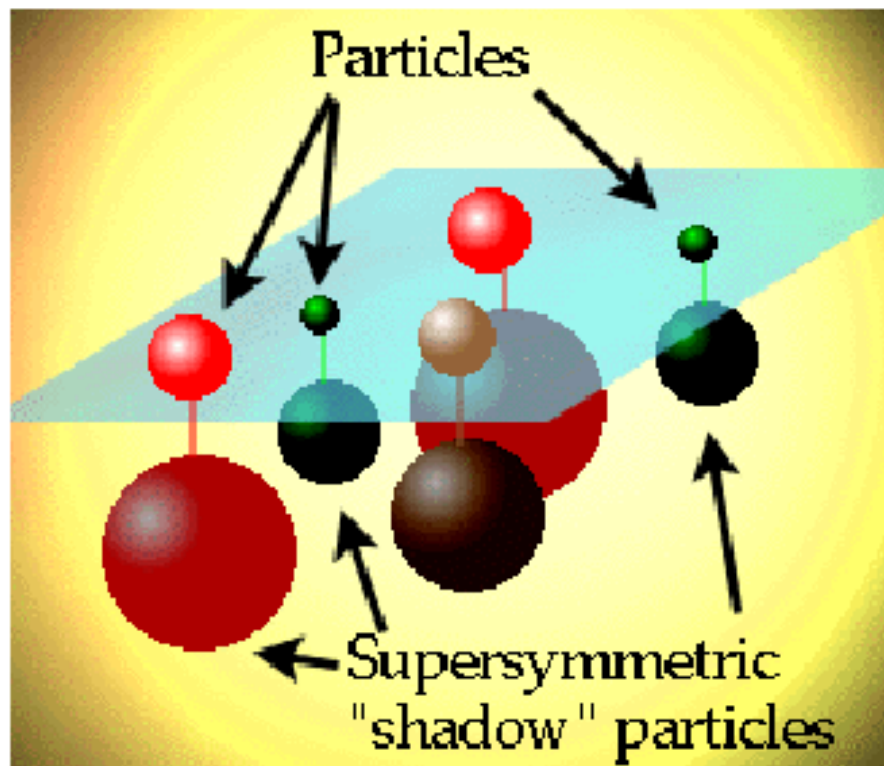
Two big ideas

2. The theory of supersymmetry



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2. The theory of supersymmetry

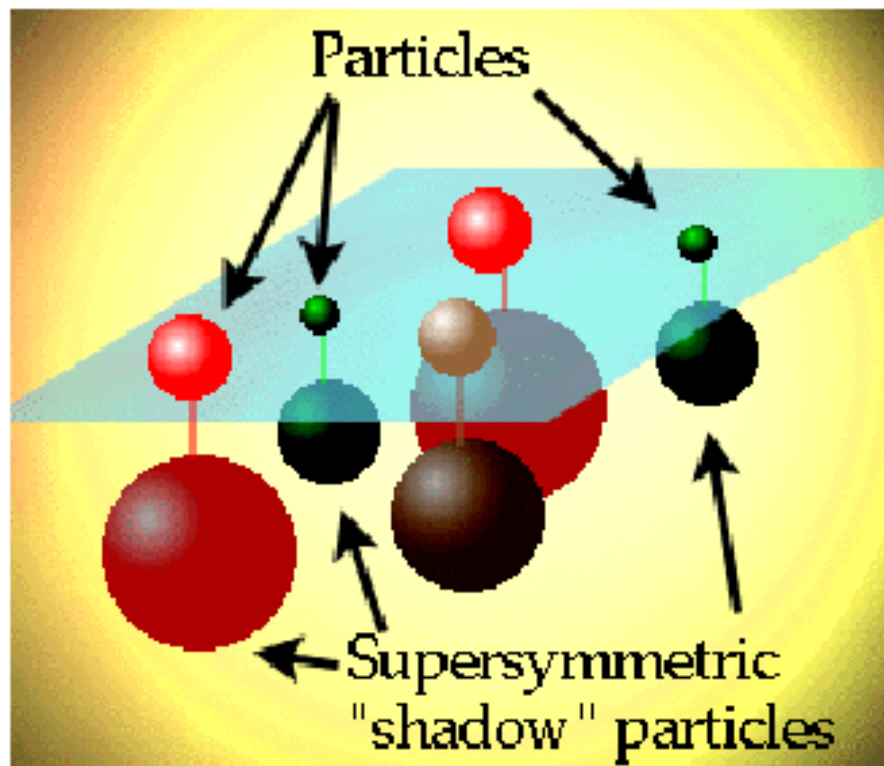




Two big ideas

2. The theory of supersymmetry

Predictions of SUSY

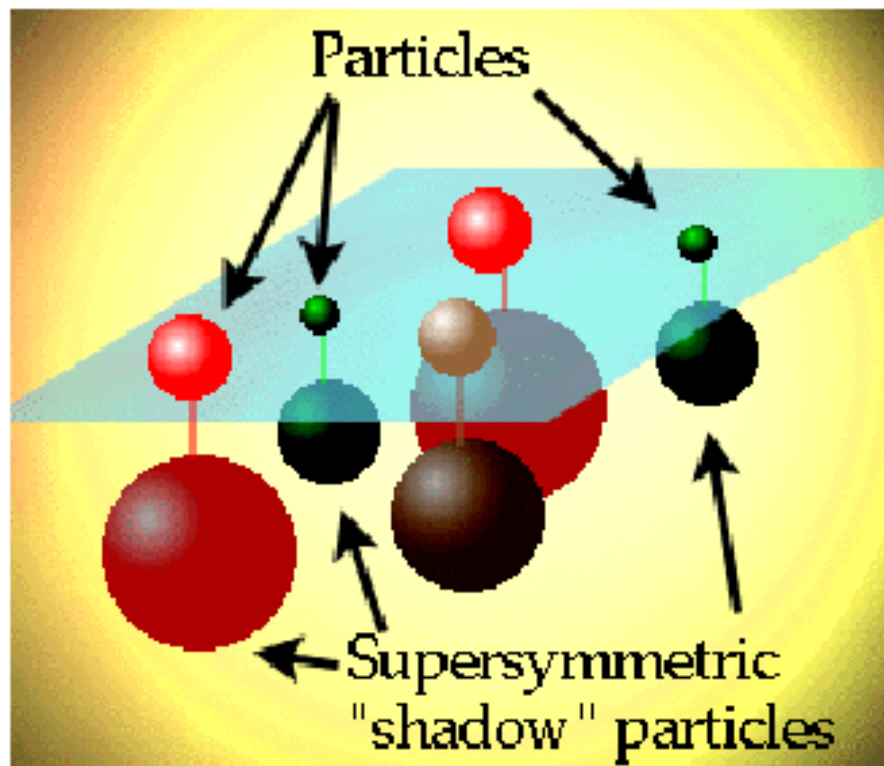




Two big ideas

2. The theory of supersymmetry

Predictions of SUSY



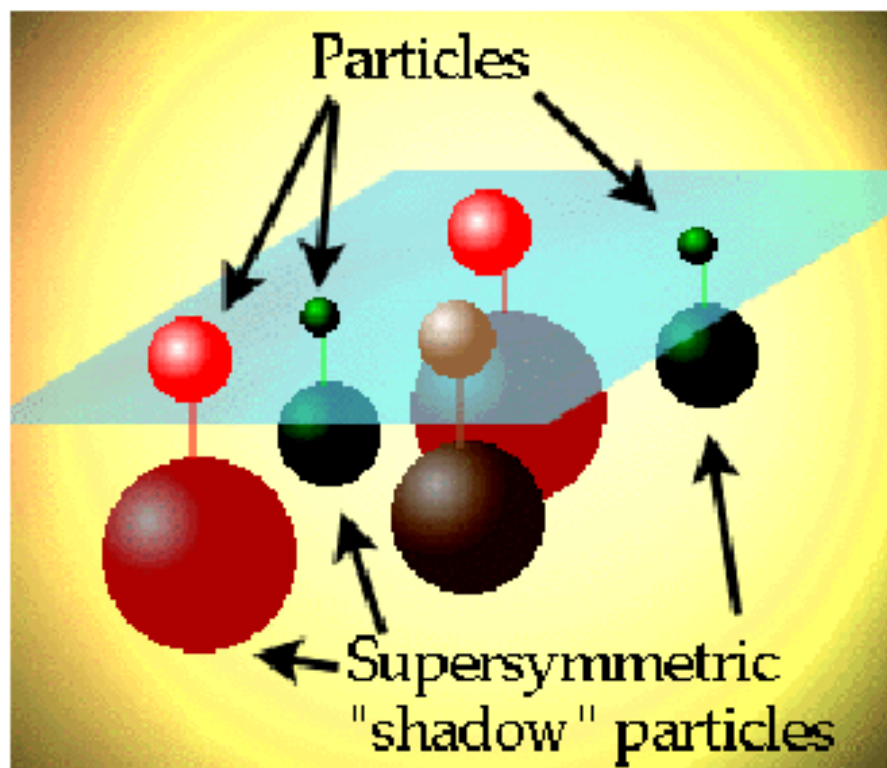
- quark
- lepton
- W-boson
- Z-boson
- gluon
- photon
- Higgs
- graviton



Two big ideas

2. The theory of supersymmetry

Predictions of SUSY



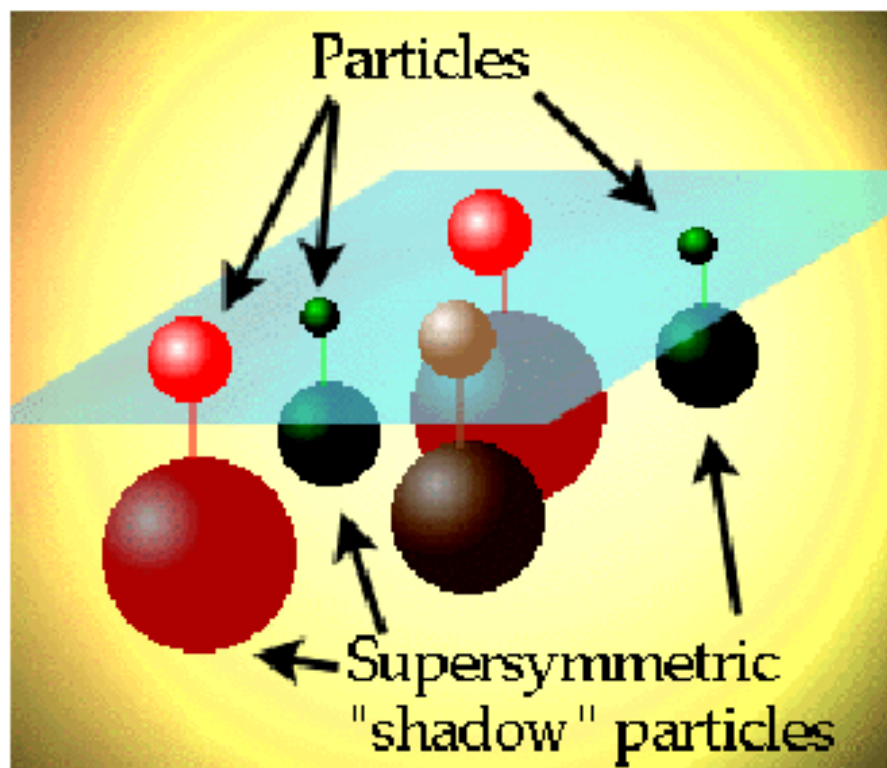
quark	$q \rightarrow \tilde{q}$
lepton	$l \rightarrow \tilde{l}$
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Z-boson	$Z \rightarrow \tilde{Z}$
gluon	$g \rightarrow \tilde{g}$
photon	$\gamma \rightarrow \tilde{\gamma}$
Higgs	$H \rightarrow \tilde{H}$
graviton	$G \rightarrow \tilde{G}$



Two big ideas

2. The theory of supersymmetry

Predictions of SUSY



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lepton
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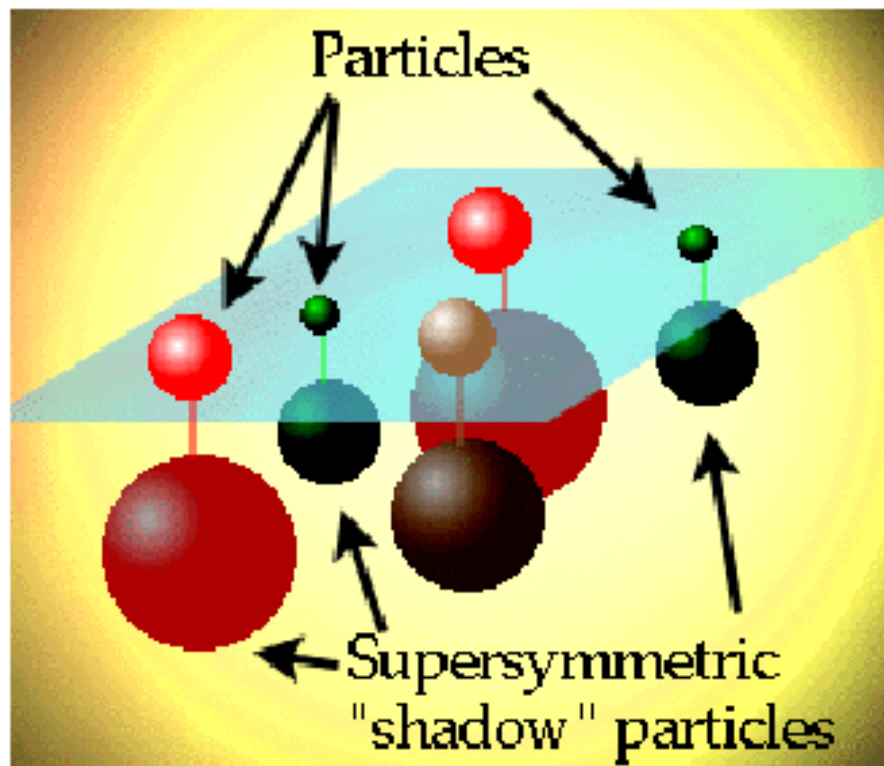
squark
slepton
wino
zino
gluino
photino
Higgsino
gravitino



Two big ideas

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Solves the GUT problems

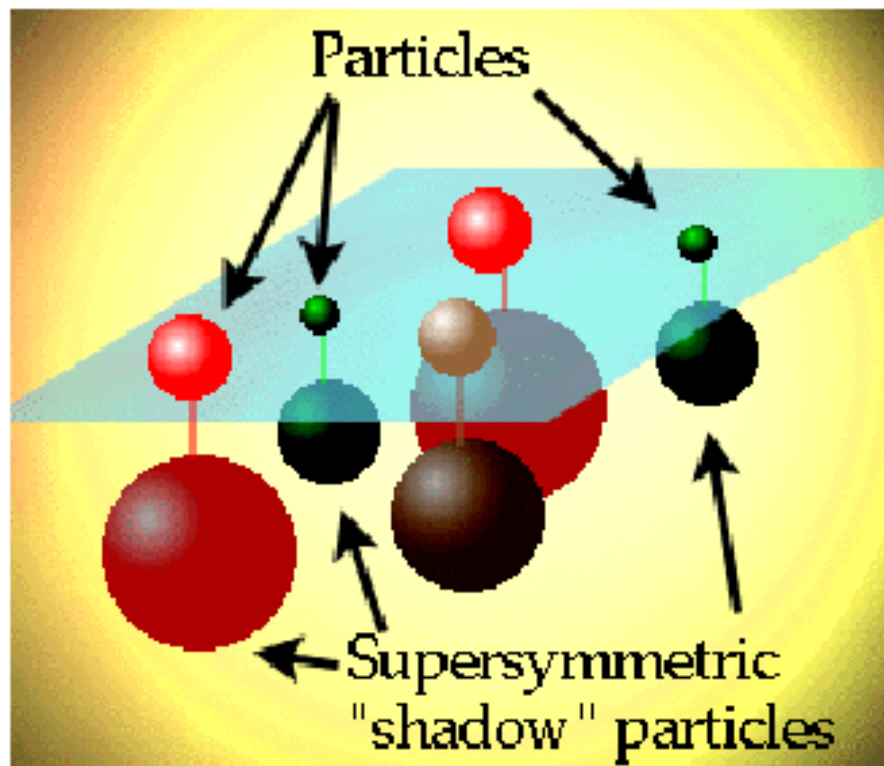
- unification of the couplings
- stabilization of the Higgs sector



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Solves the GUT problems

- unification of the couplings
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The key verification - creation of superpartners at colliders

Search for SUSY manifestation

Search for SUSY manifestation

Particle Phys

Search for SUSY manifestation

Particle Phys



Direct production at colliders at high energies

Search for SUSY manifestation

Particle Phys

 Direct production at colliders at high energies

 Indirect manifestation at low energies

Search for SUSY manifestation

 Direct production at colliders at high energies

 Indirect manifestation at low energies

Rare decays ($B_s \rightarrow s\gamma$, $B_s \rightarrow \mu^+\mu^-$, $B_s \rightarrow \tau\nu$)
g-2 of the muon

Particle Phys

Search for SUSY manifestation

Particle Phys

📌 Direct production at colliders at high energies

📌 Indirect manifestation at low energies

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📌 Search for long-lived SUSY particles

Search for SUSY manifestation

 Direct production at colliders at high energies

 Indirect manifestation at low energies

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 Search for long-lived SUSY particles

Particle Phys


Astro Phys

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(if SUSY DM)

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📌 Relic abundancy of Dark Matter in the Universe

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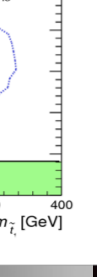
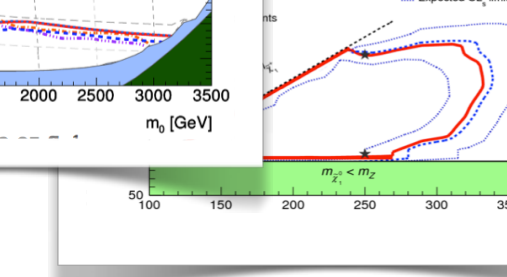
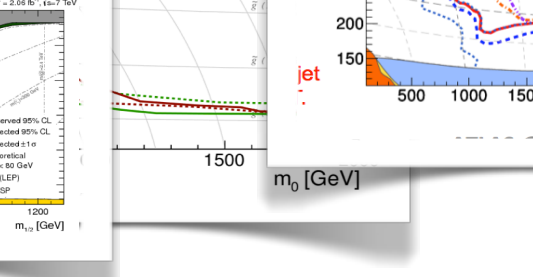
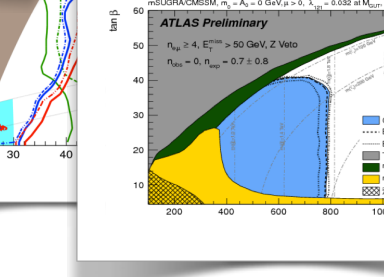
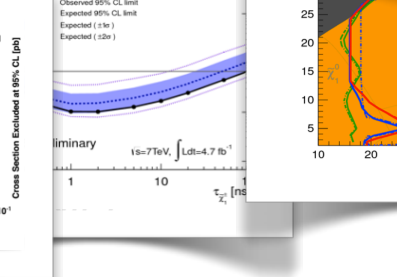
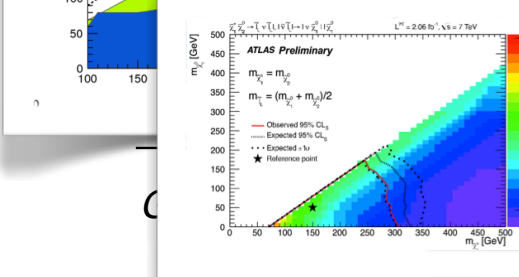
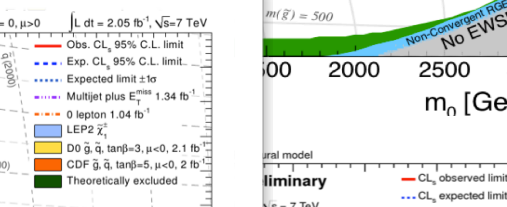
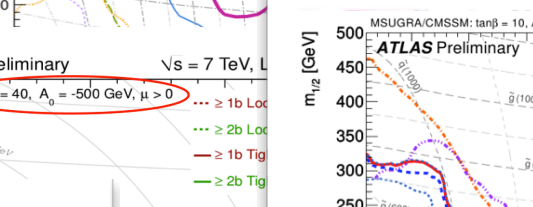
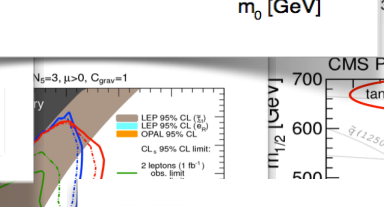
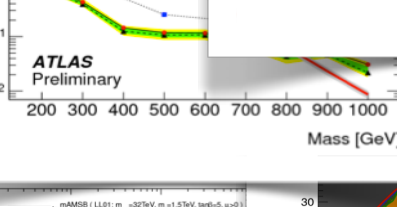
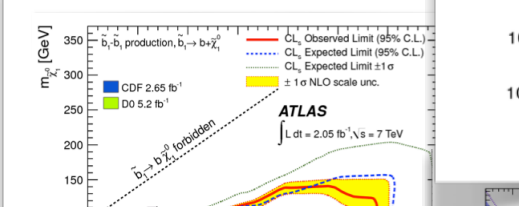
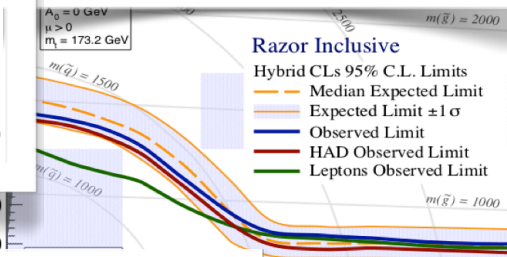
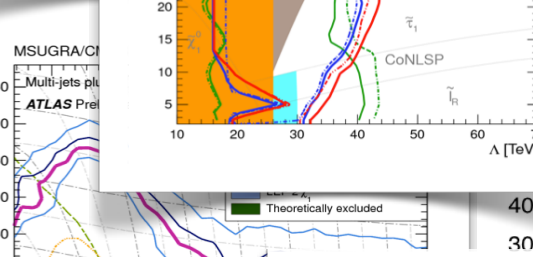
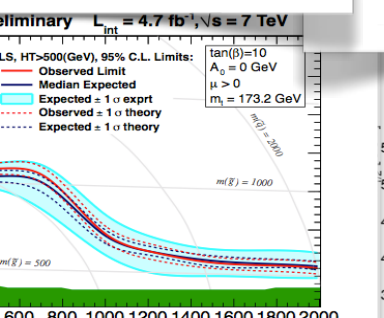
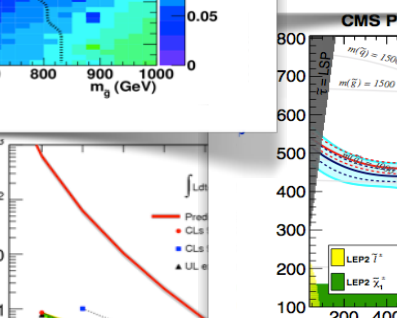
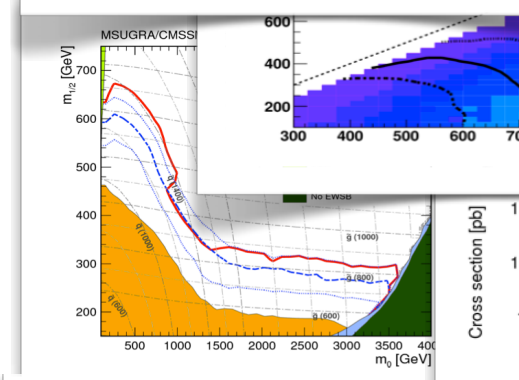
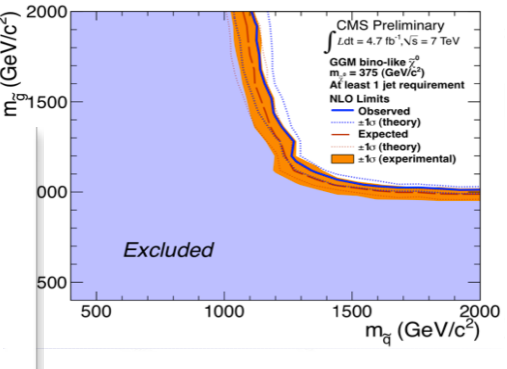
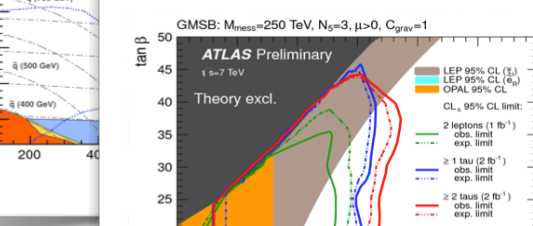
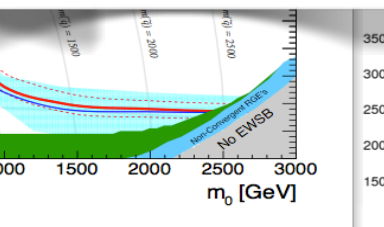
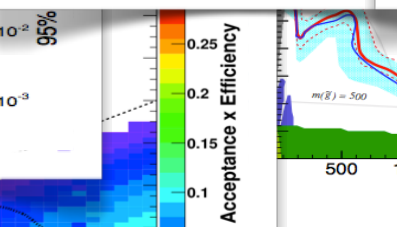
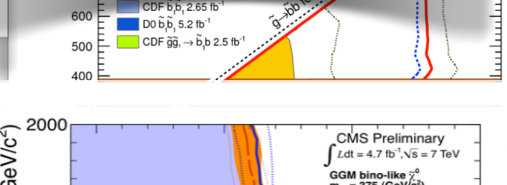
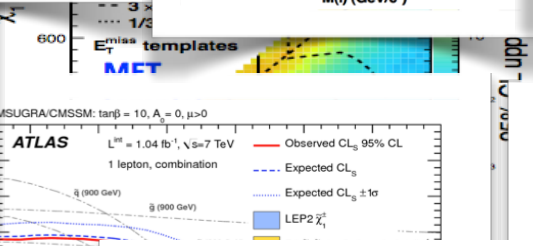
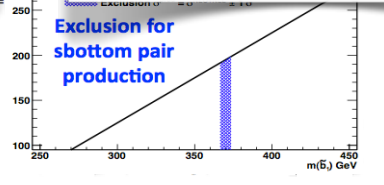
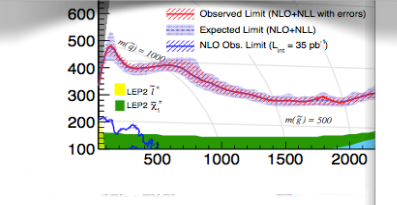
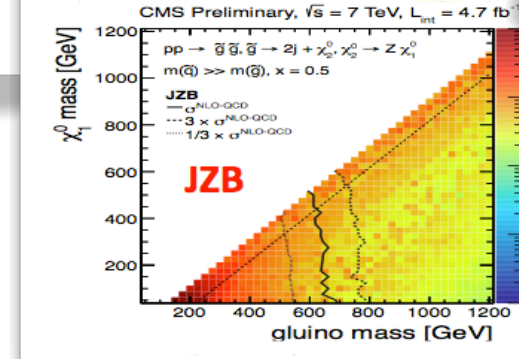
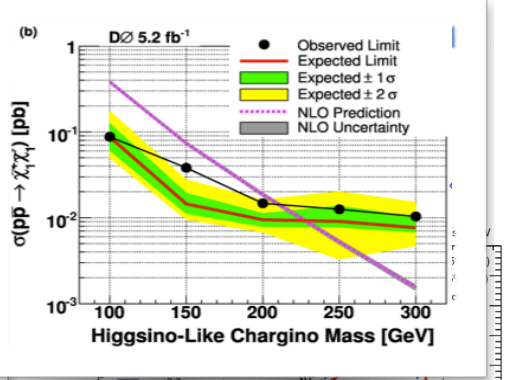
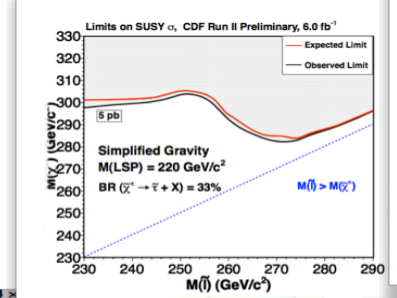
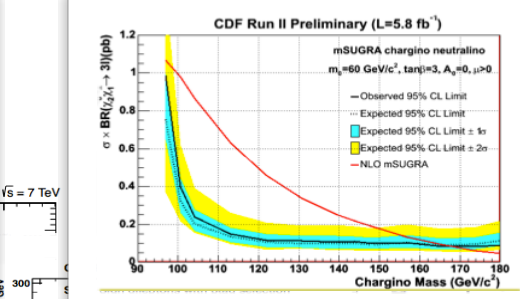
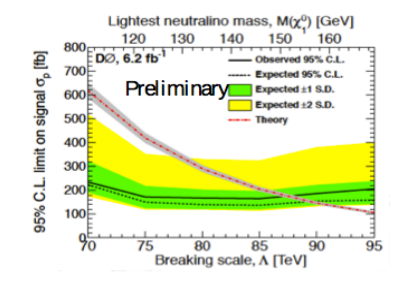
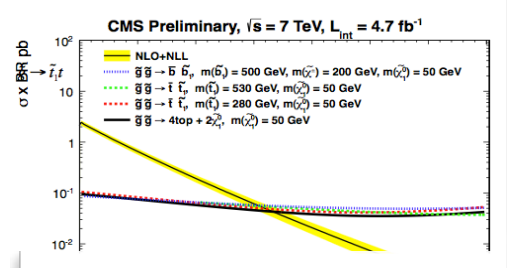
📌 DM annihilation signal in cosmic rays

📌 Direct DM interaction with nucleons

Nothing so far ...

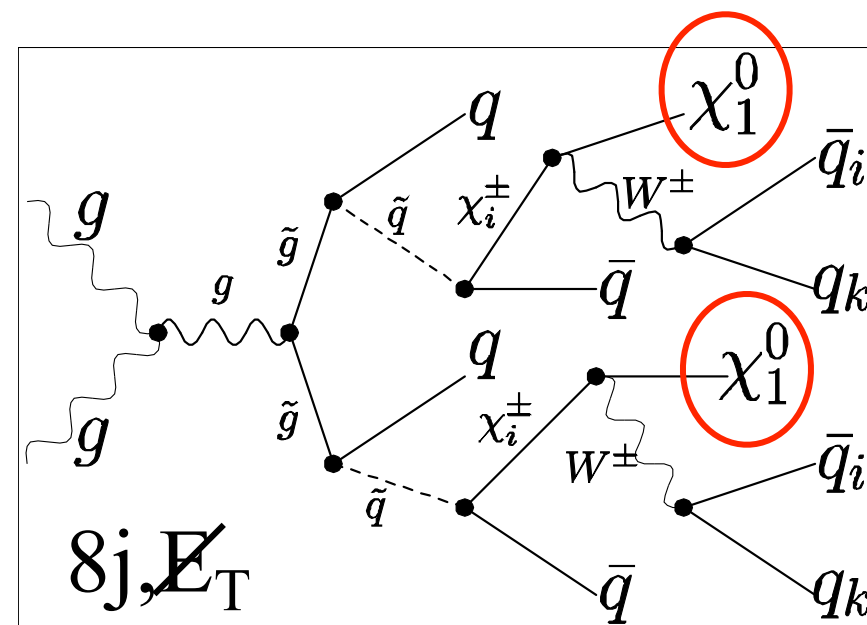
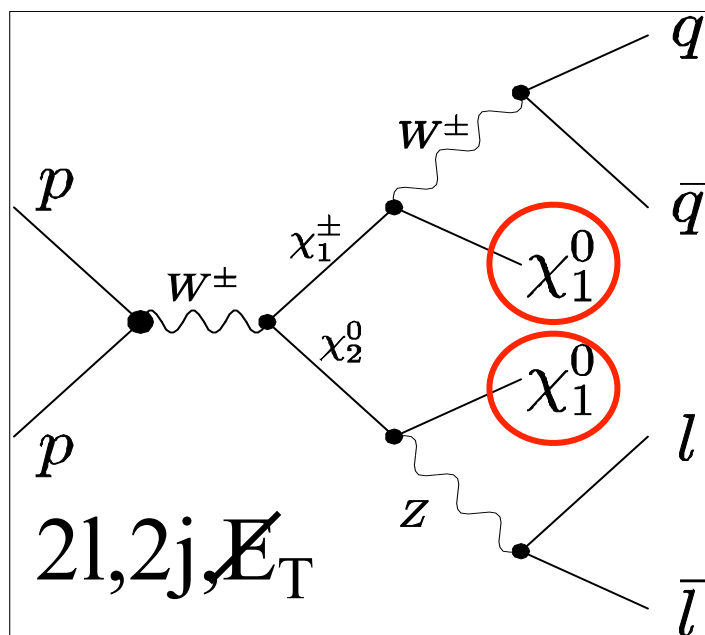
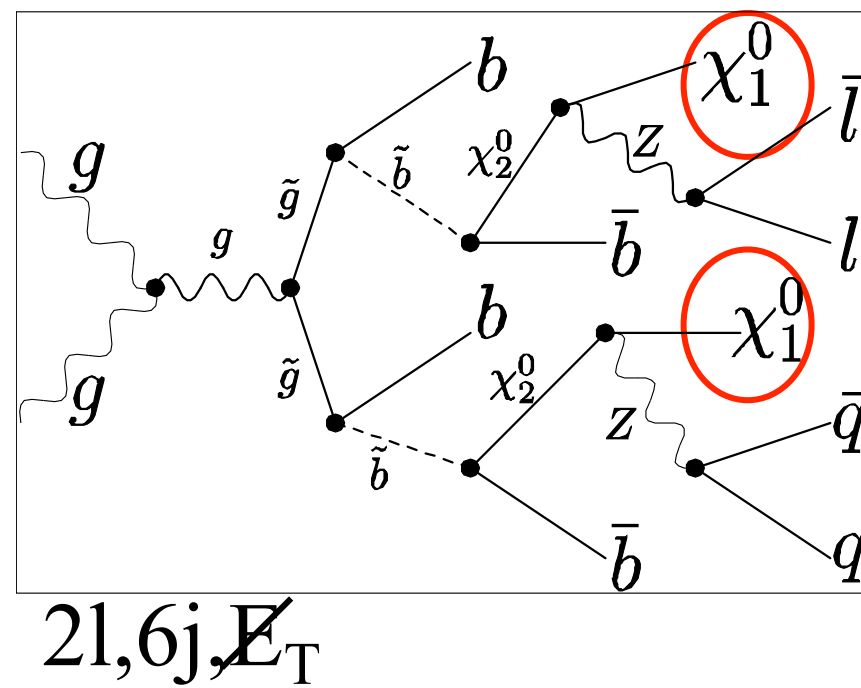
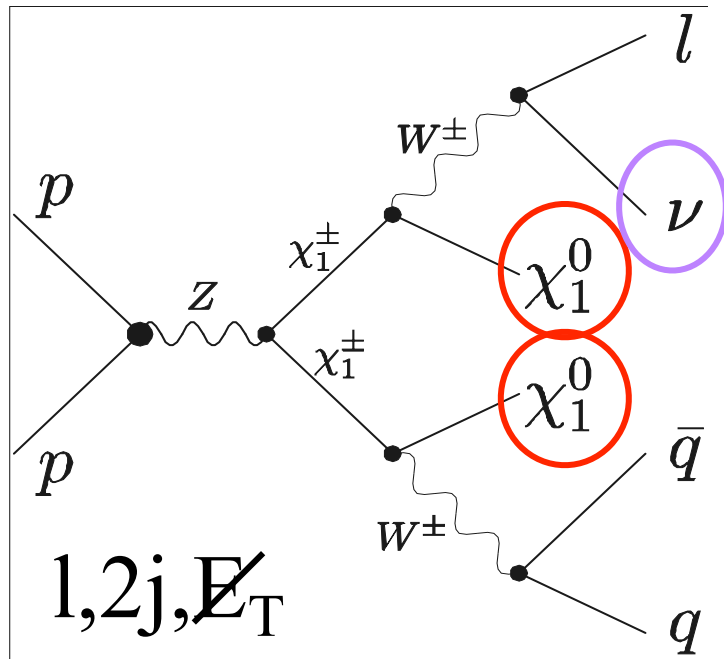


SUSY searches



Cascade processes of SUSY production

Weak interact.

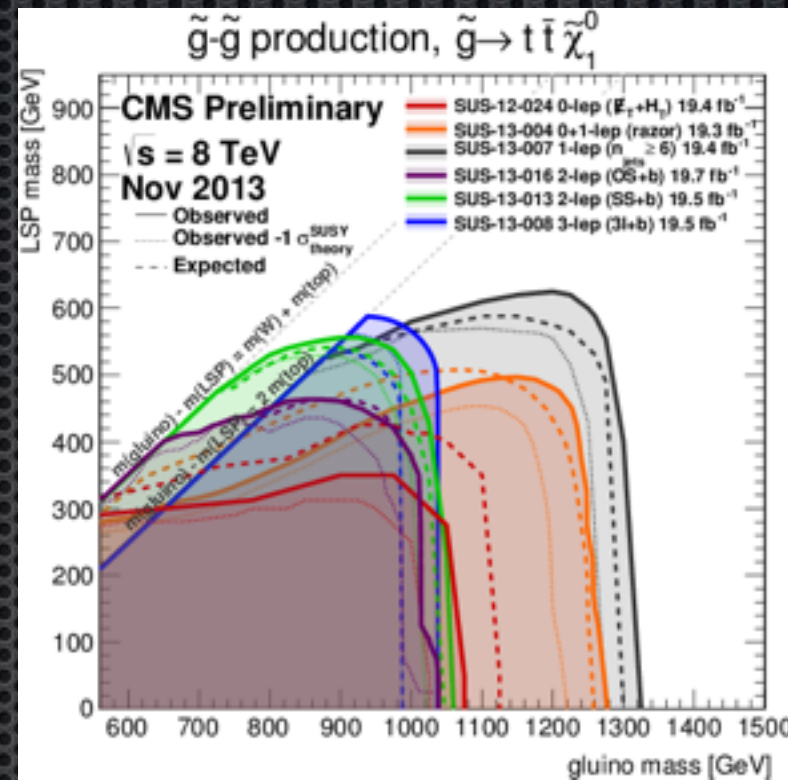
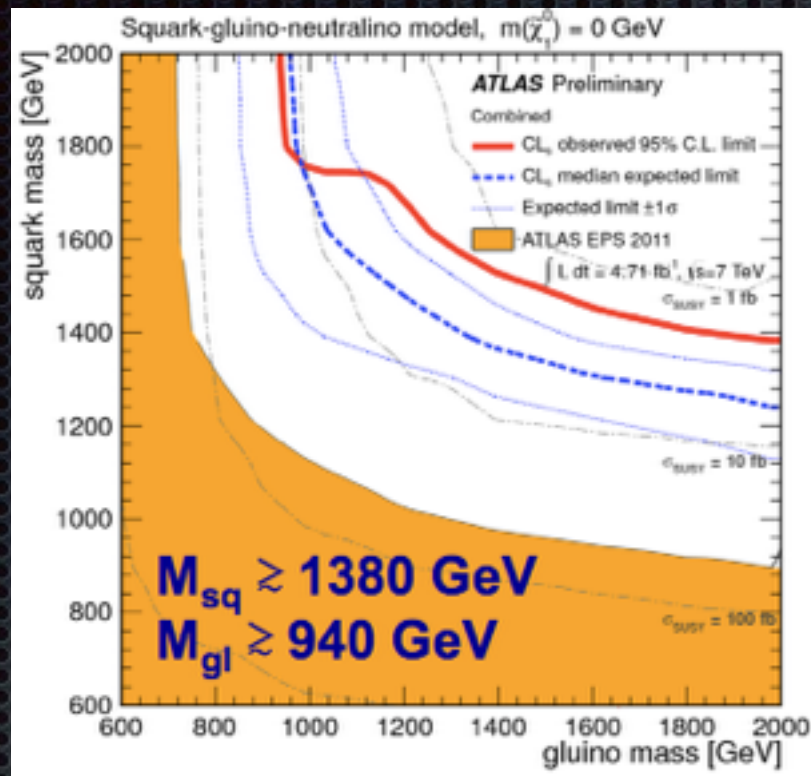


Strong interact.

Missing energy and transverse momentum!

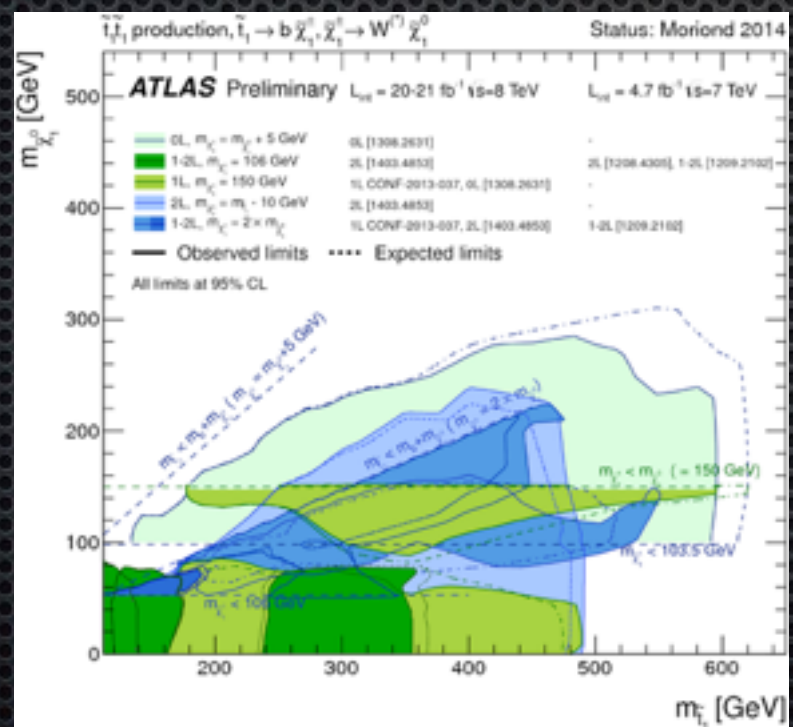
Search for SUSY at colliders

$\tilde{g} \tilde{q}$

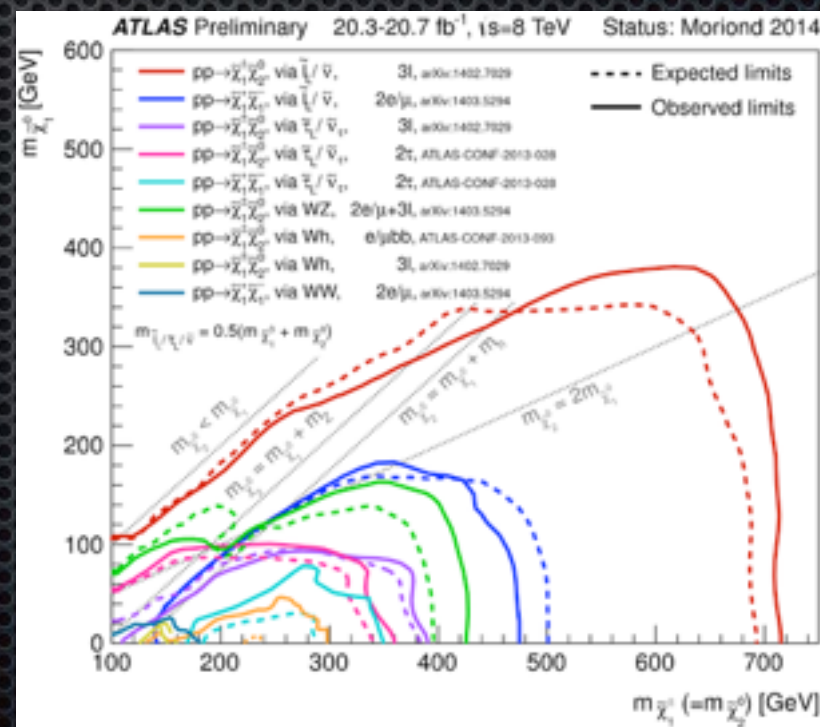


$\tilde{g} \tilde{\chi}^0$

$\tilde{t} \tilde{\chi}^0$



$\tilde{\chi}^+ \tilde{\chi}^0$



The third generation is lighter

The see-saw mechanism

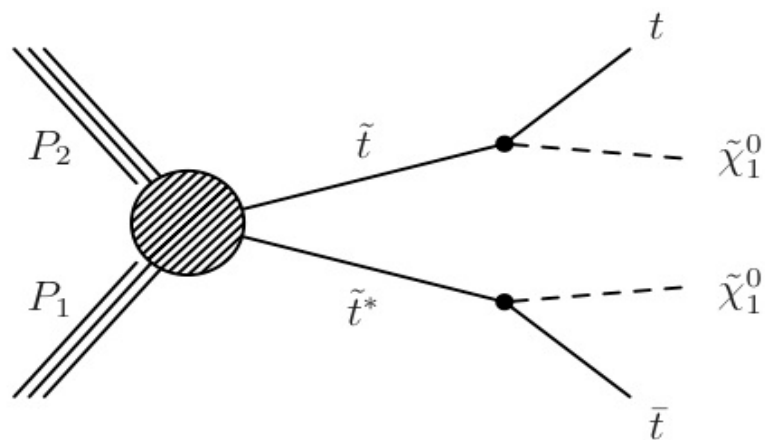
$$m_{\tilde{q}}^2 = \begin{array}{c} \tilde{q}_L \\ \tilde{q}_R \end{array} \begin{array}{c} \tilde{q}_L \\ \tilde{q}_R \end{array} \left(\begin{array}{cc} \tilde{m}_L^2 & m_q X_q \\ m_q X_q & \tilde{m}_R^2 \end{array} \right), \quad X_q = A_q - \mu \cot \beta$$

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Di-stop production resulting in 2 top quarks +MET final states

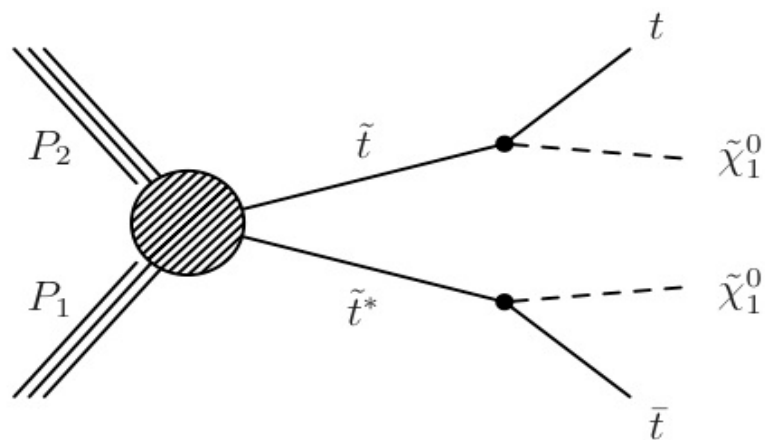


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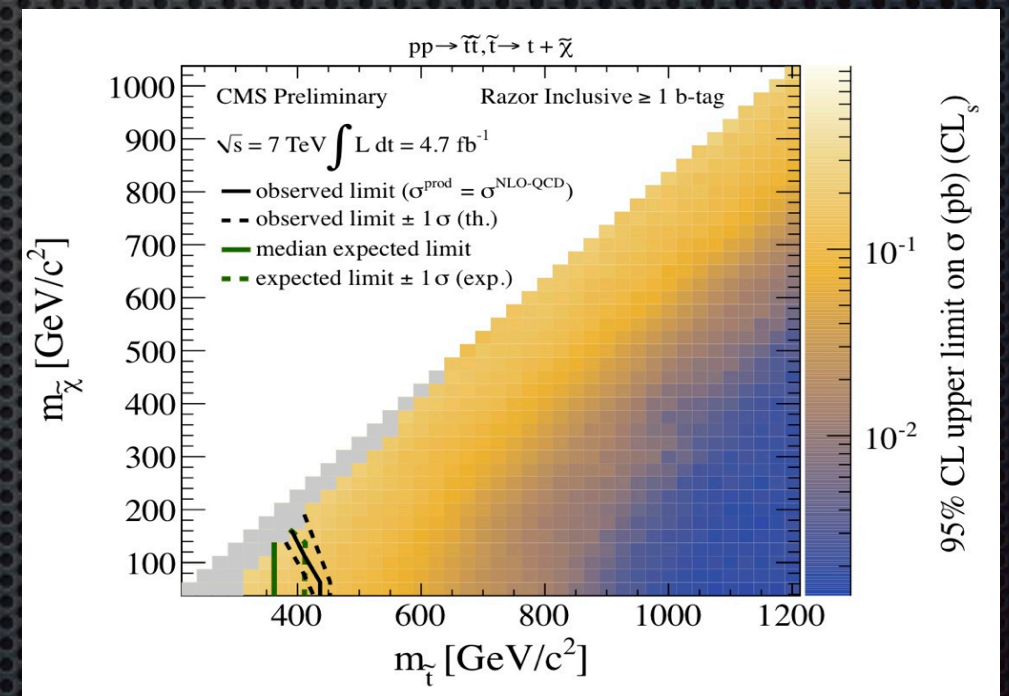
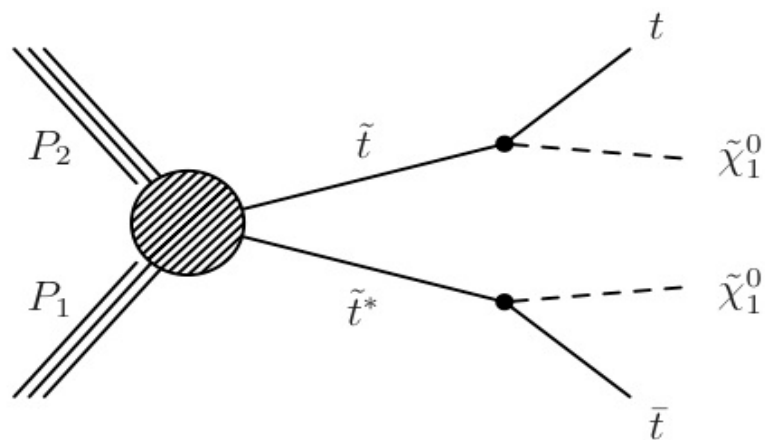
Small phase space - small branching

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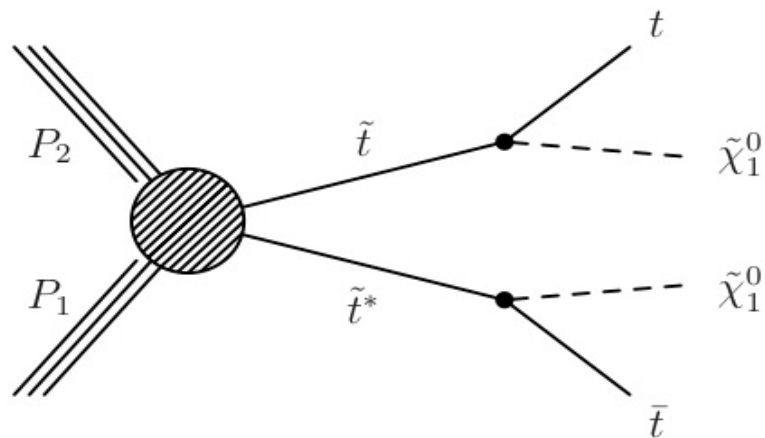
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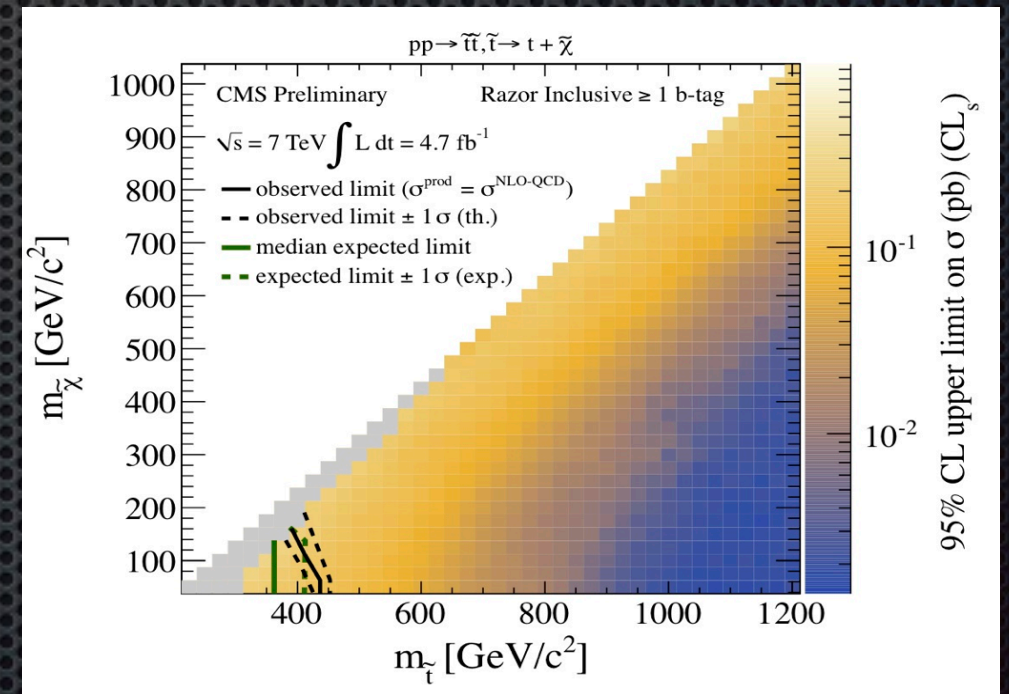
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Di-stop production resulting in 2 top quarks +MET final states



Small phase space - small branching



There is still large unexplored space of possibilities

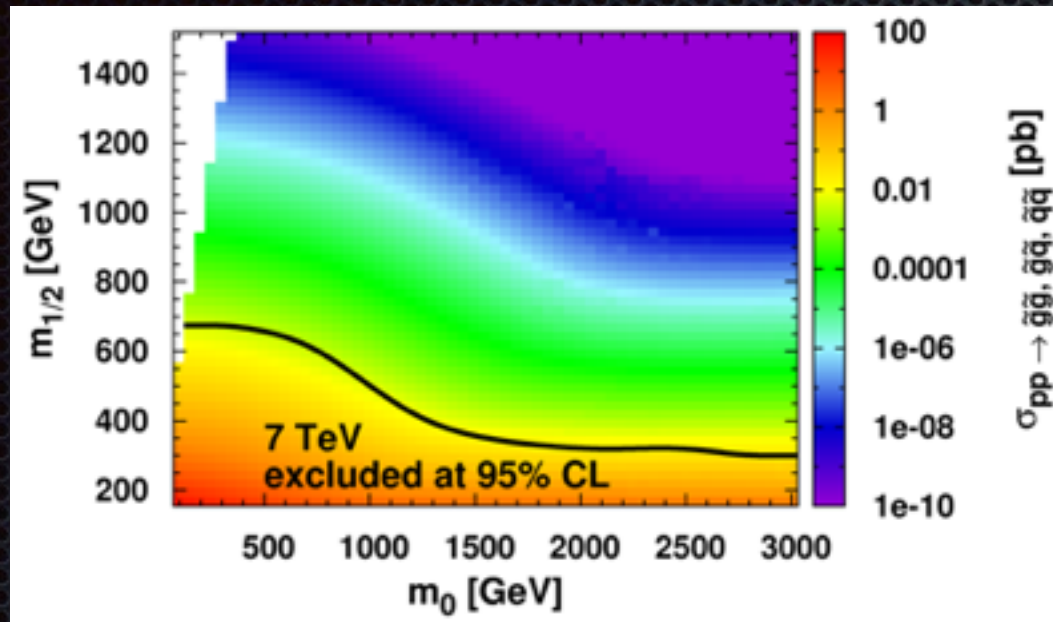
What is the LHC reach?

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Universal scenario

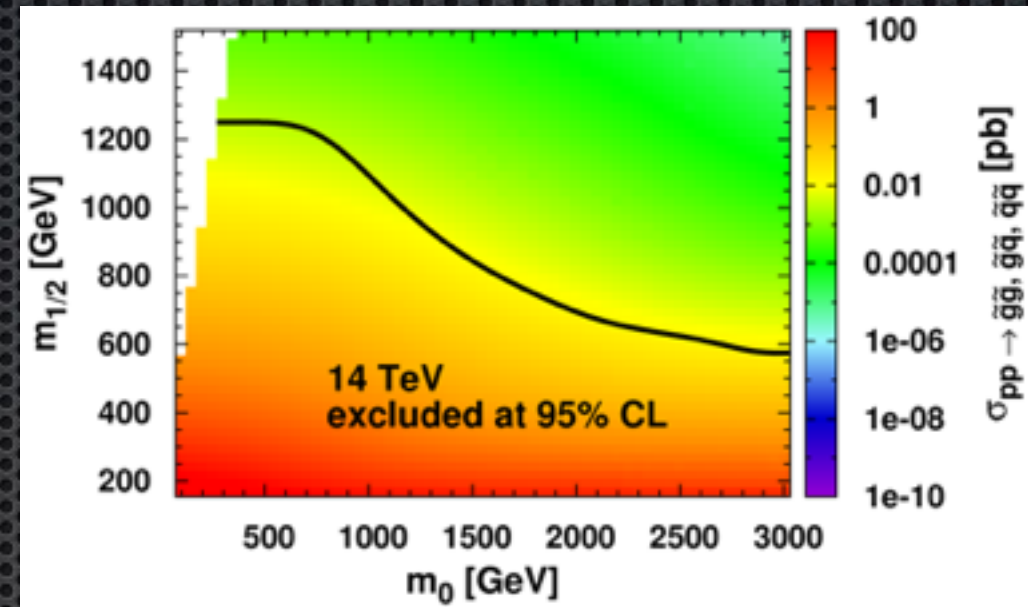
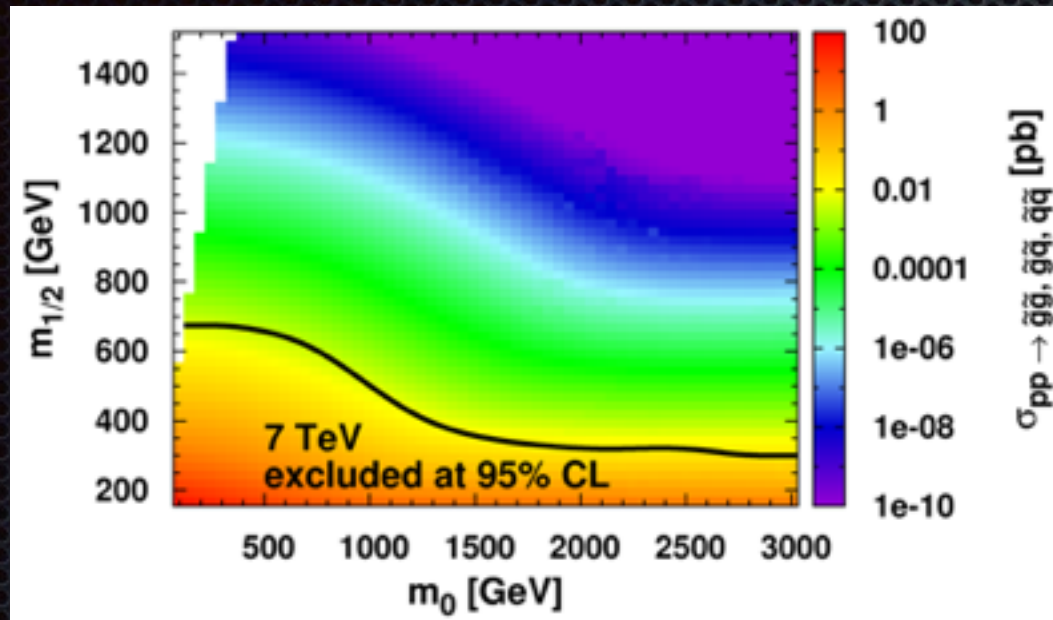
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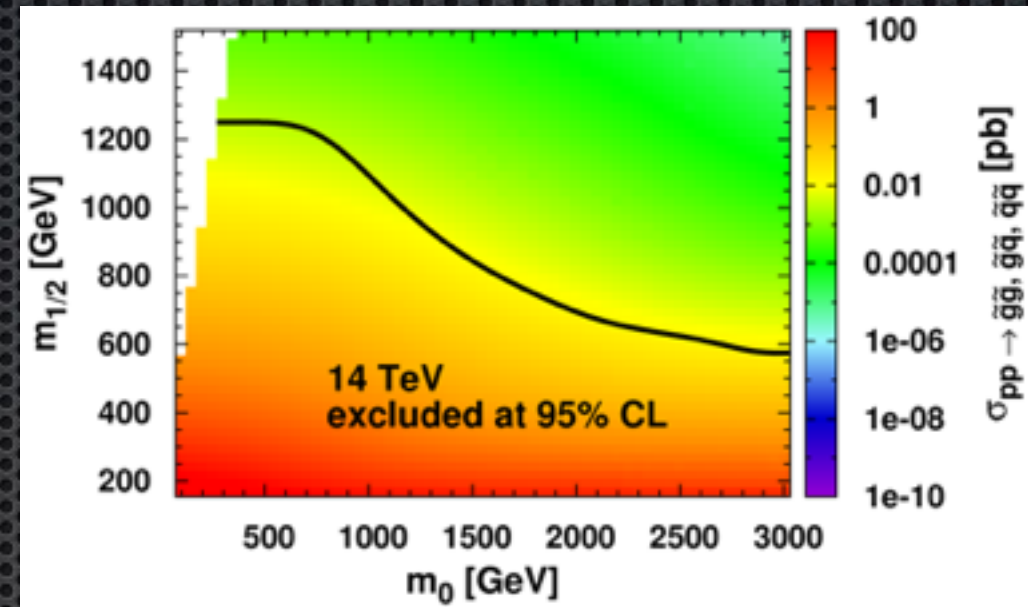
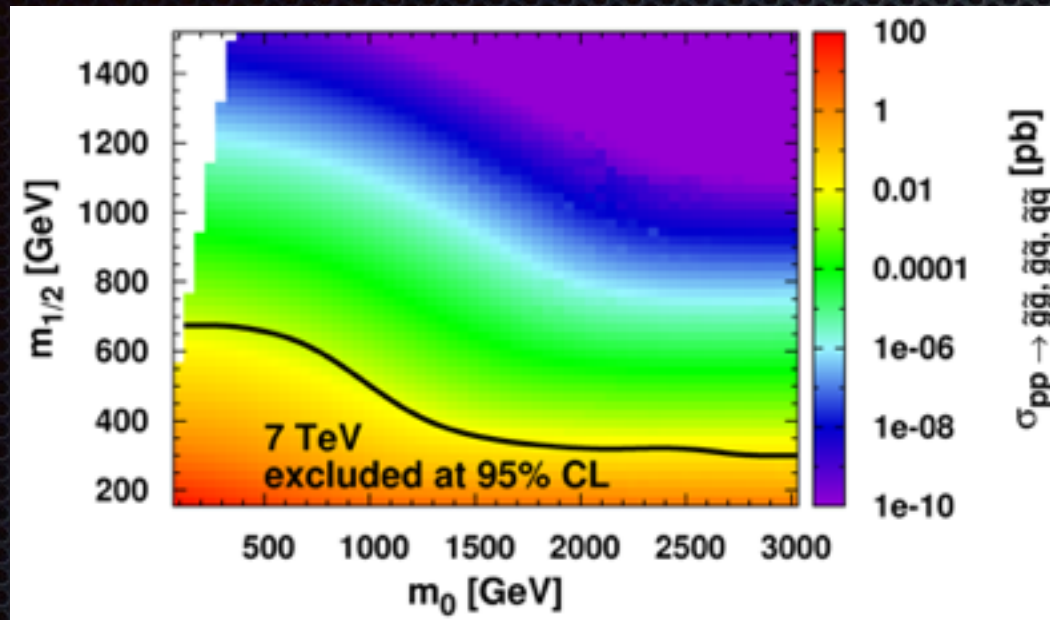
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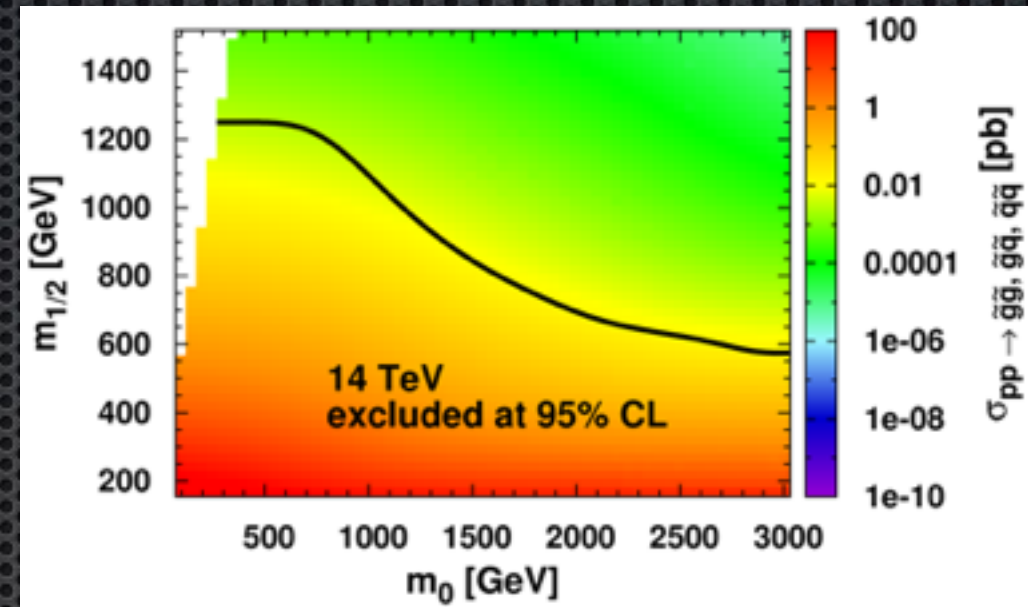
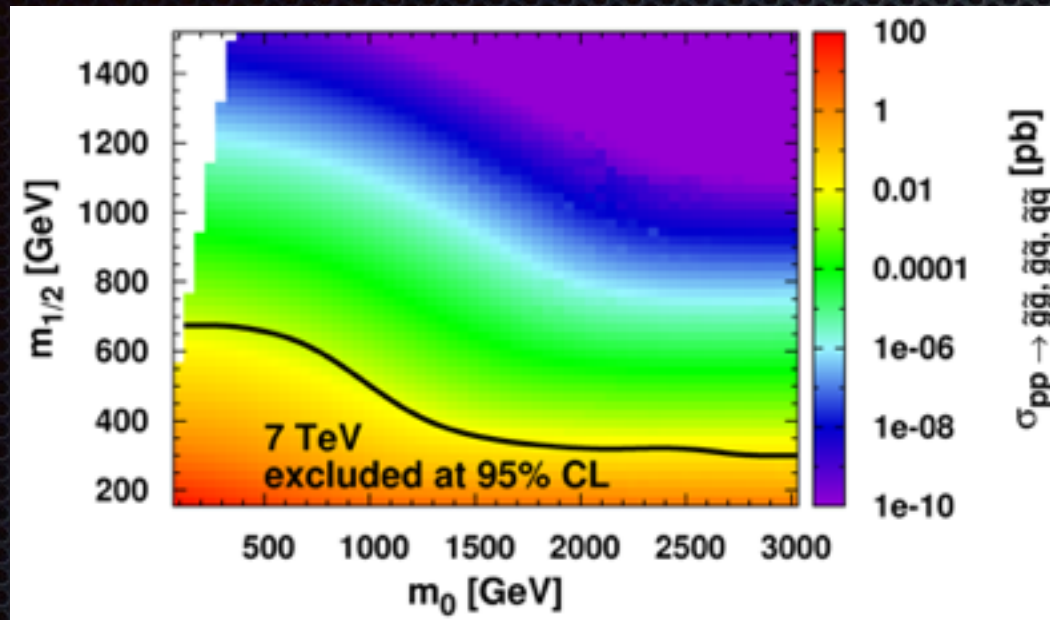
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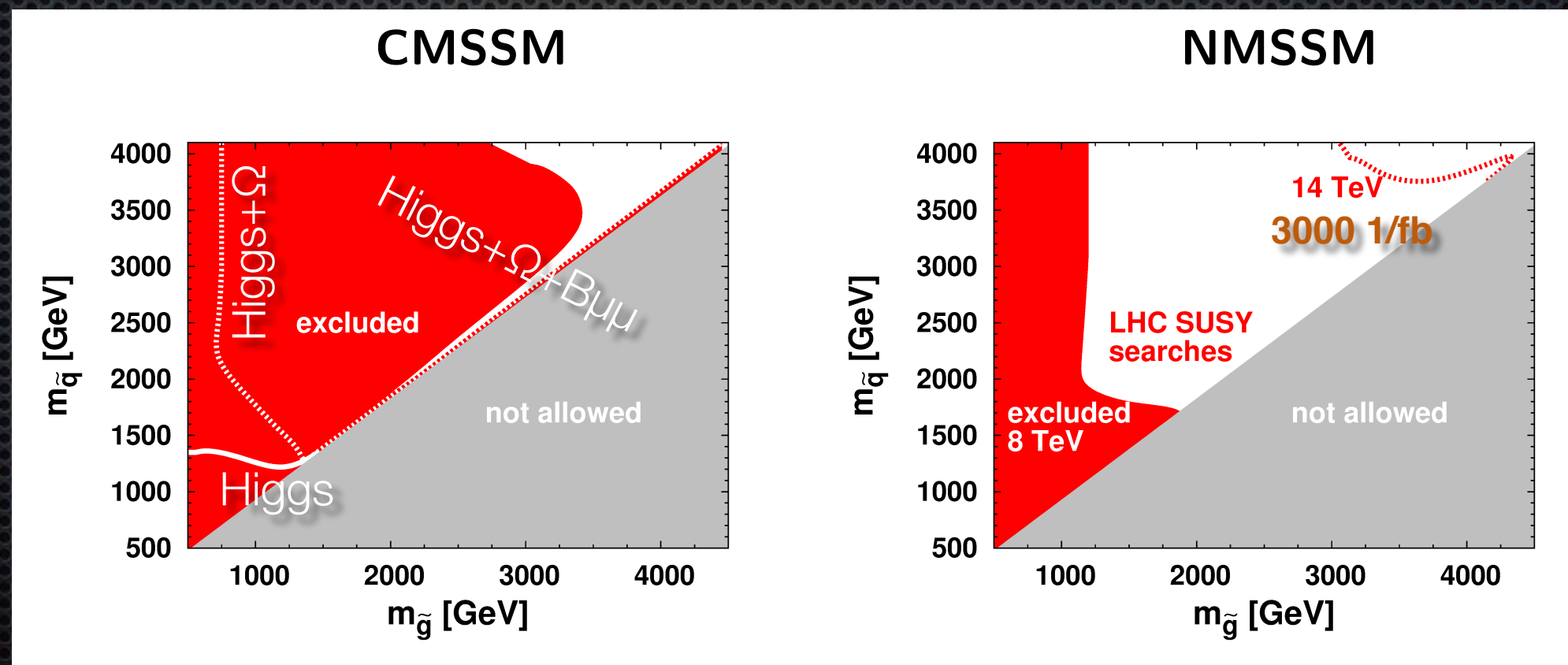
Masses of superpartners

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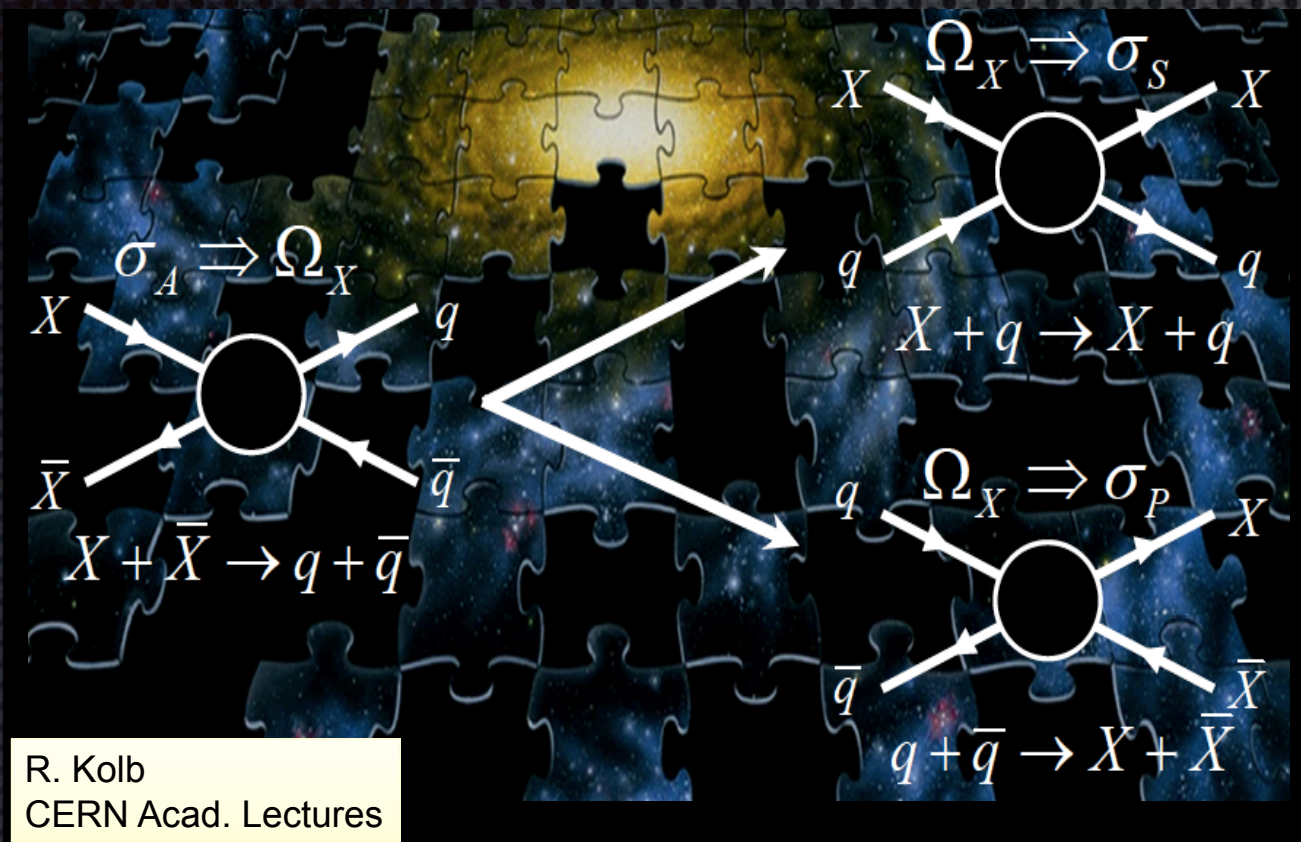


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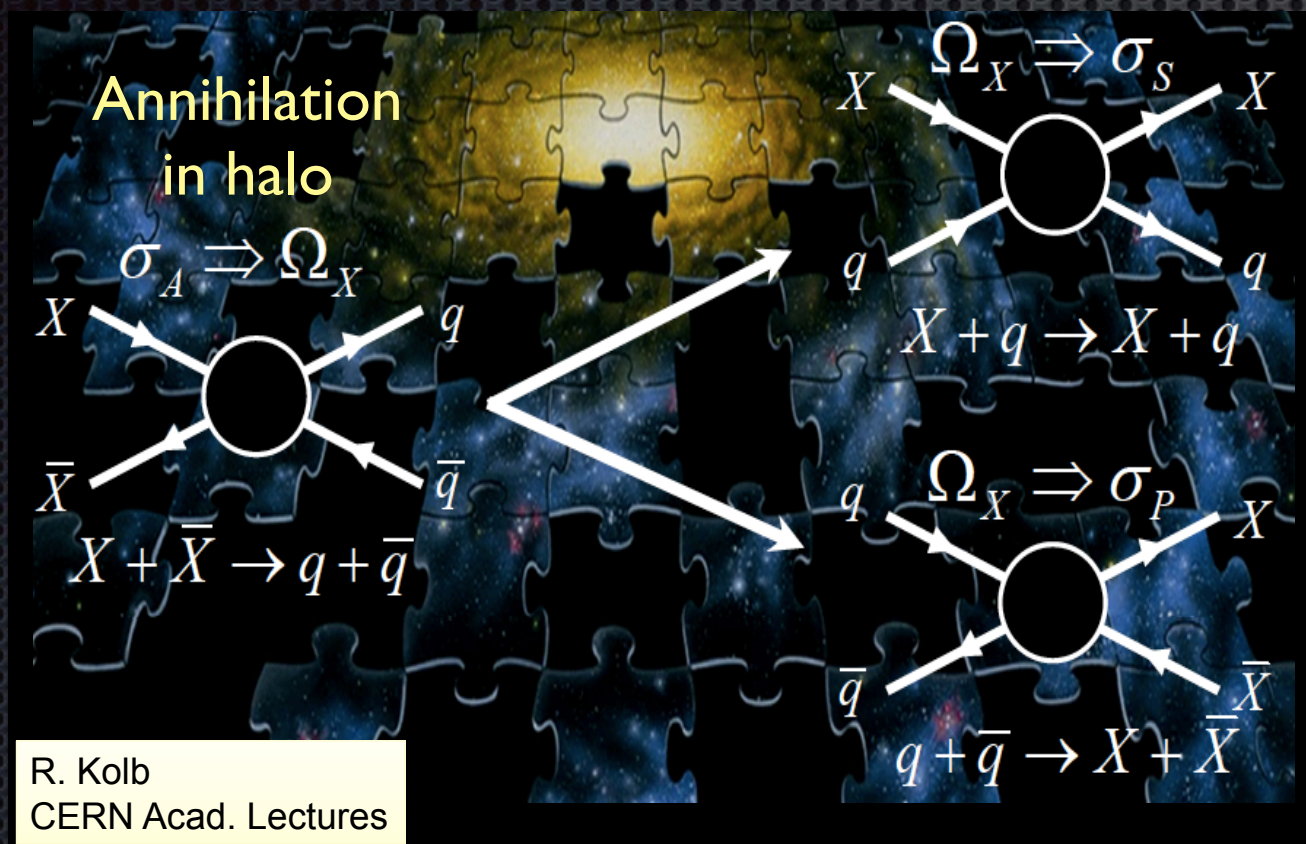
The Dark Matter:
three reactions in one

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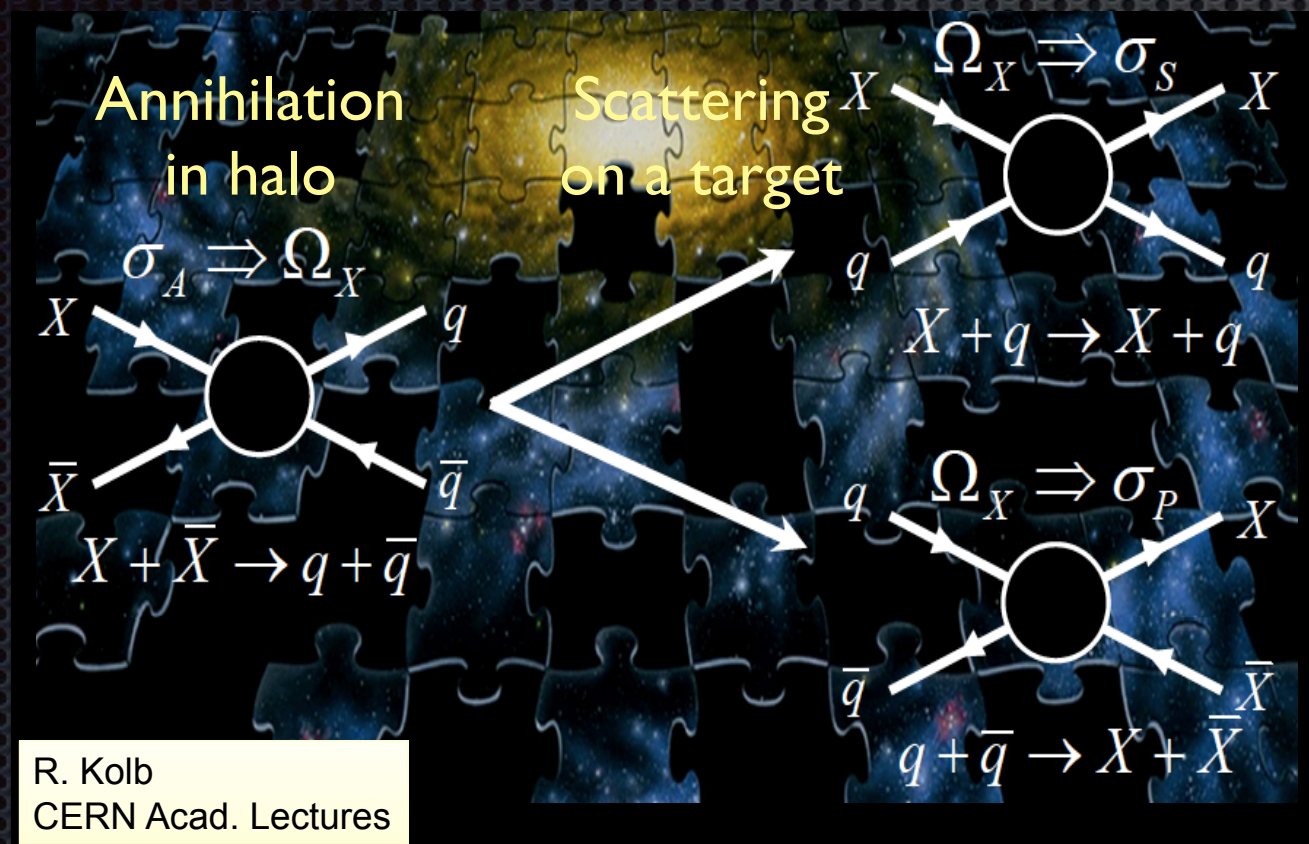


R. Kolb
CERN Acad. Lectures

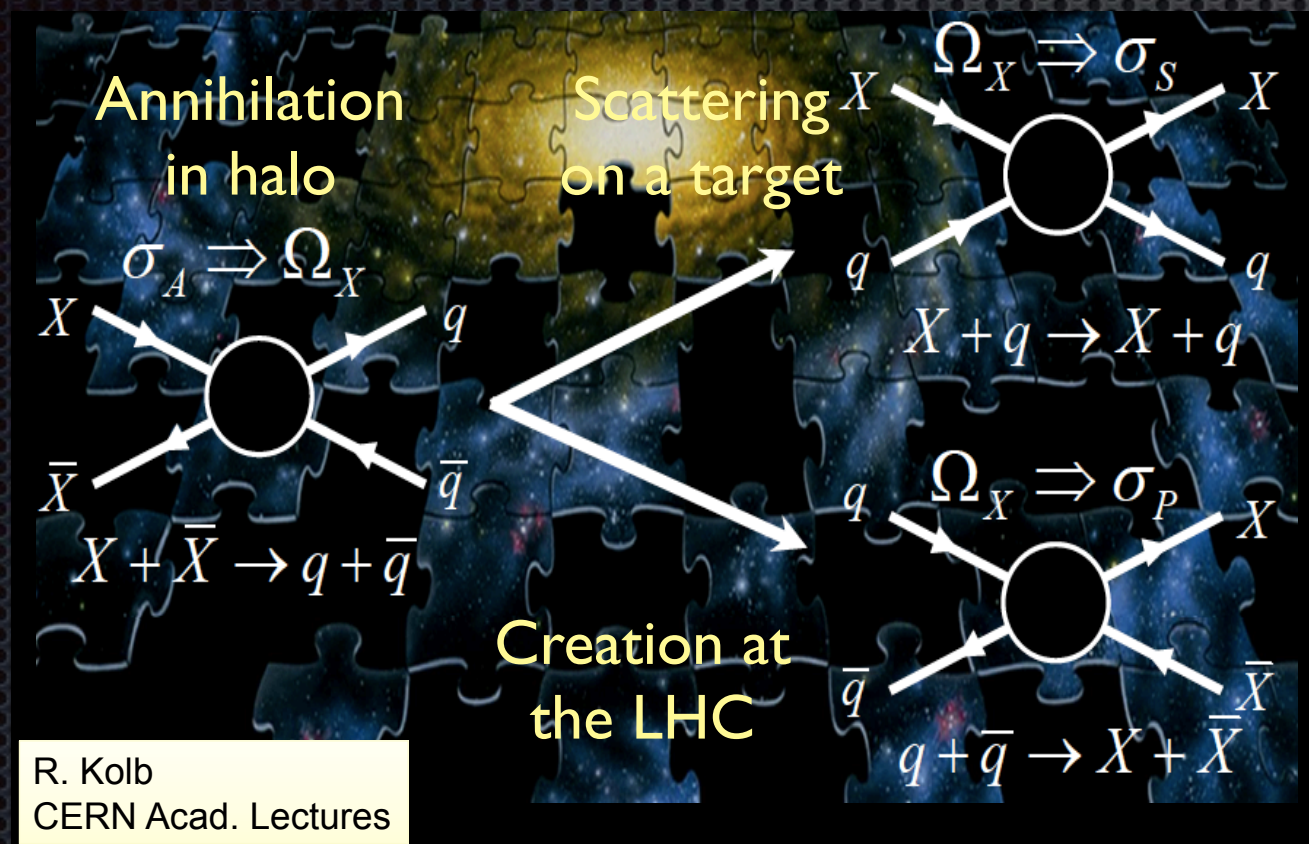
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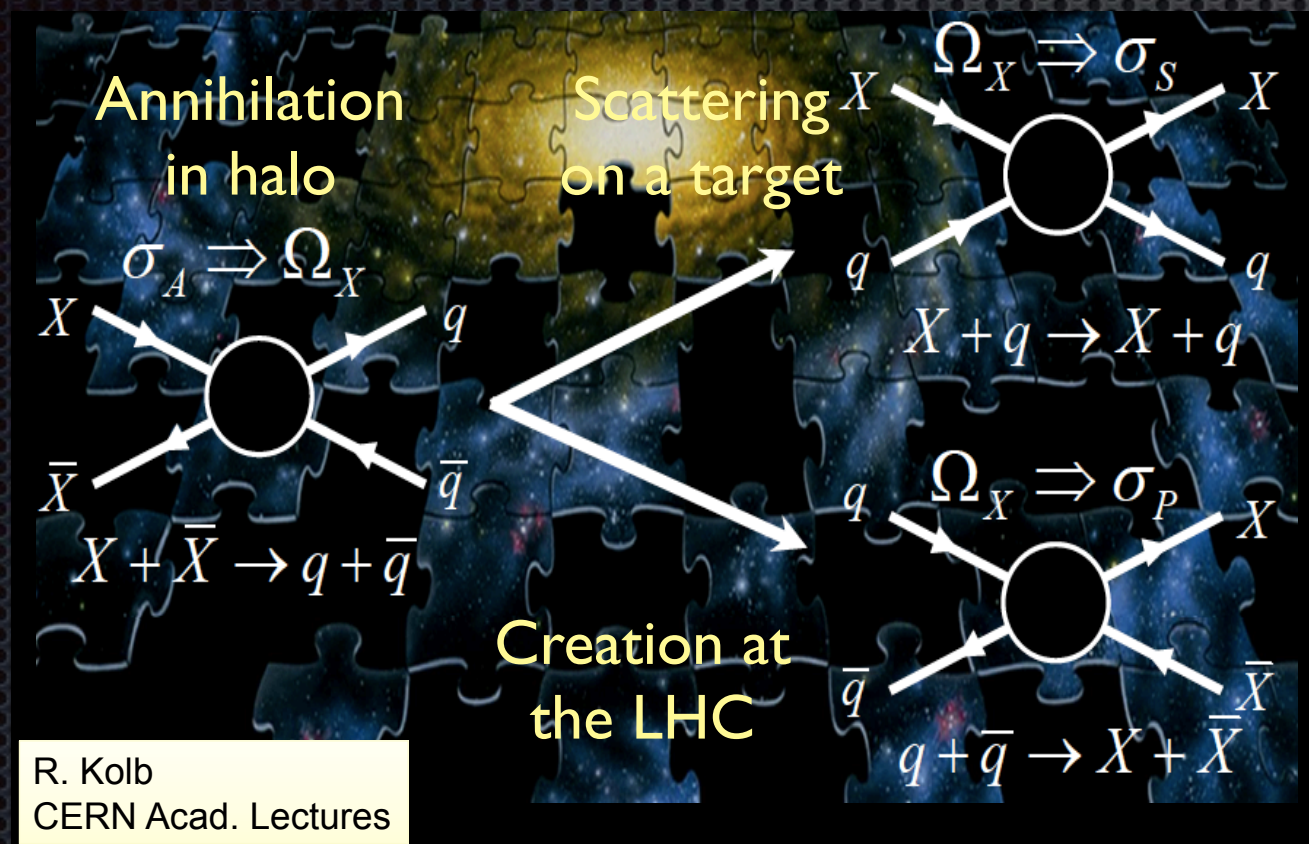
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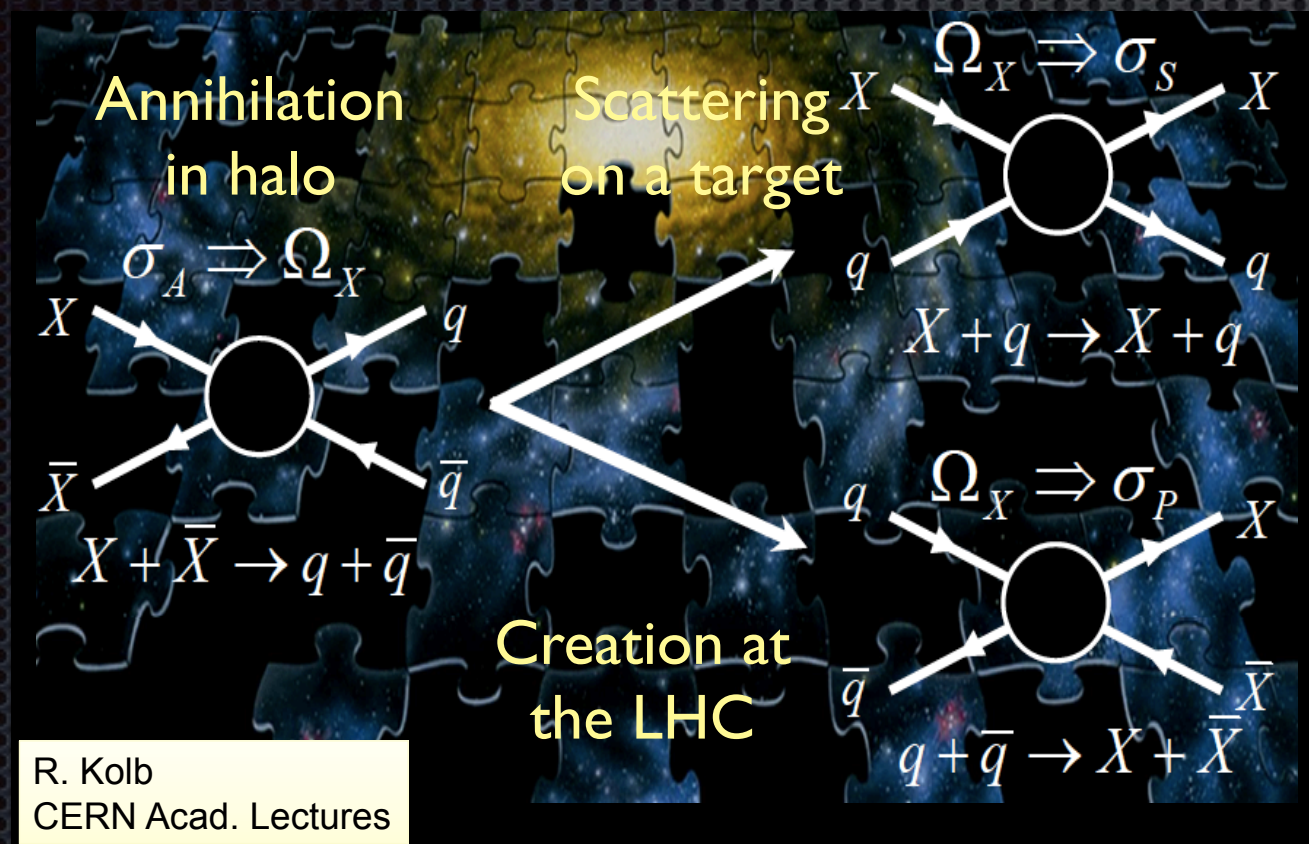


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D.Heuer: «There should be something beyond the SM like supersymmetry. I dream that at the LHC we can find some trace of the Dark matter particles»
April,2 CERN

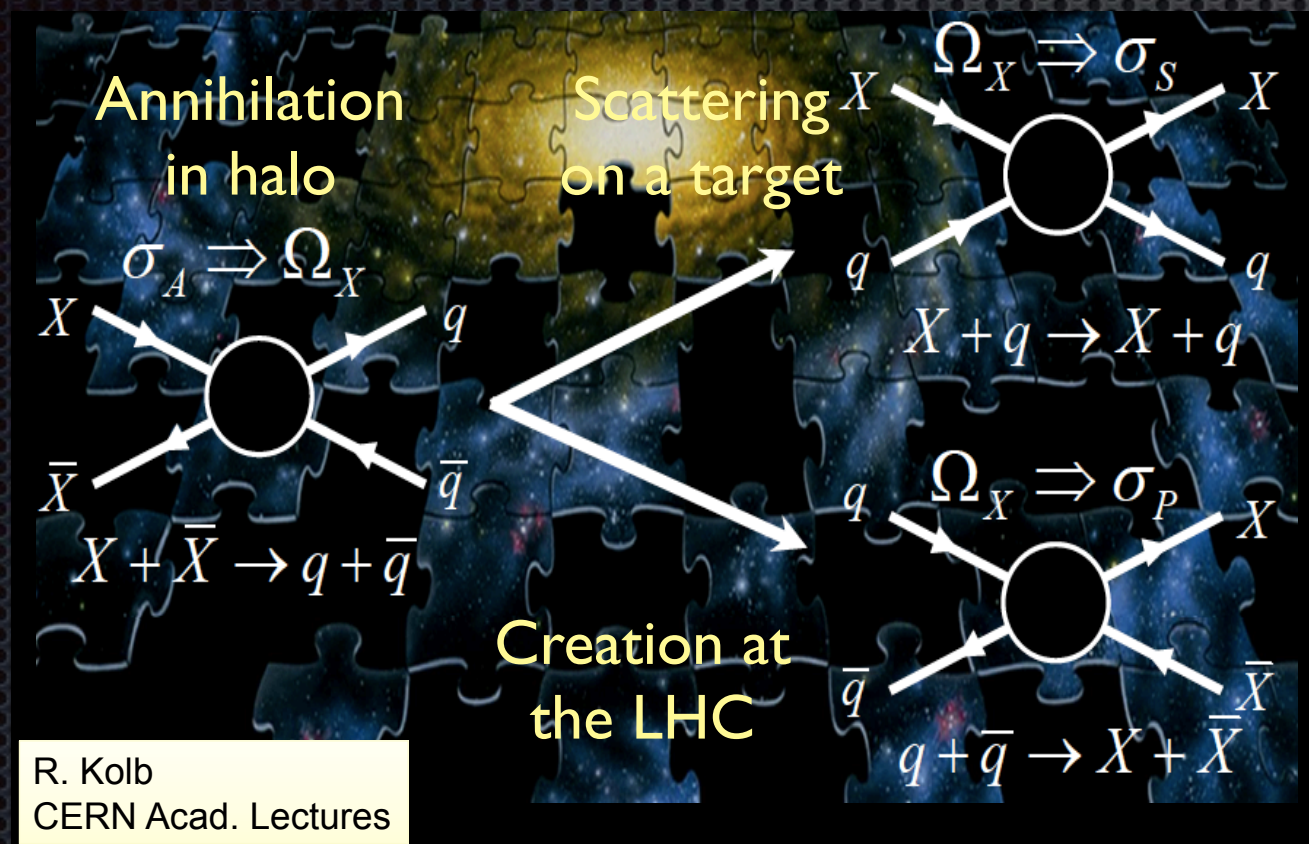
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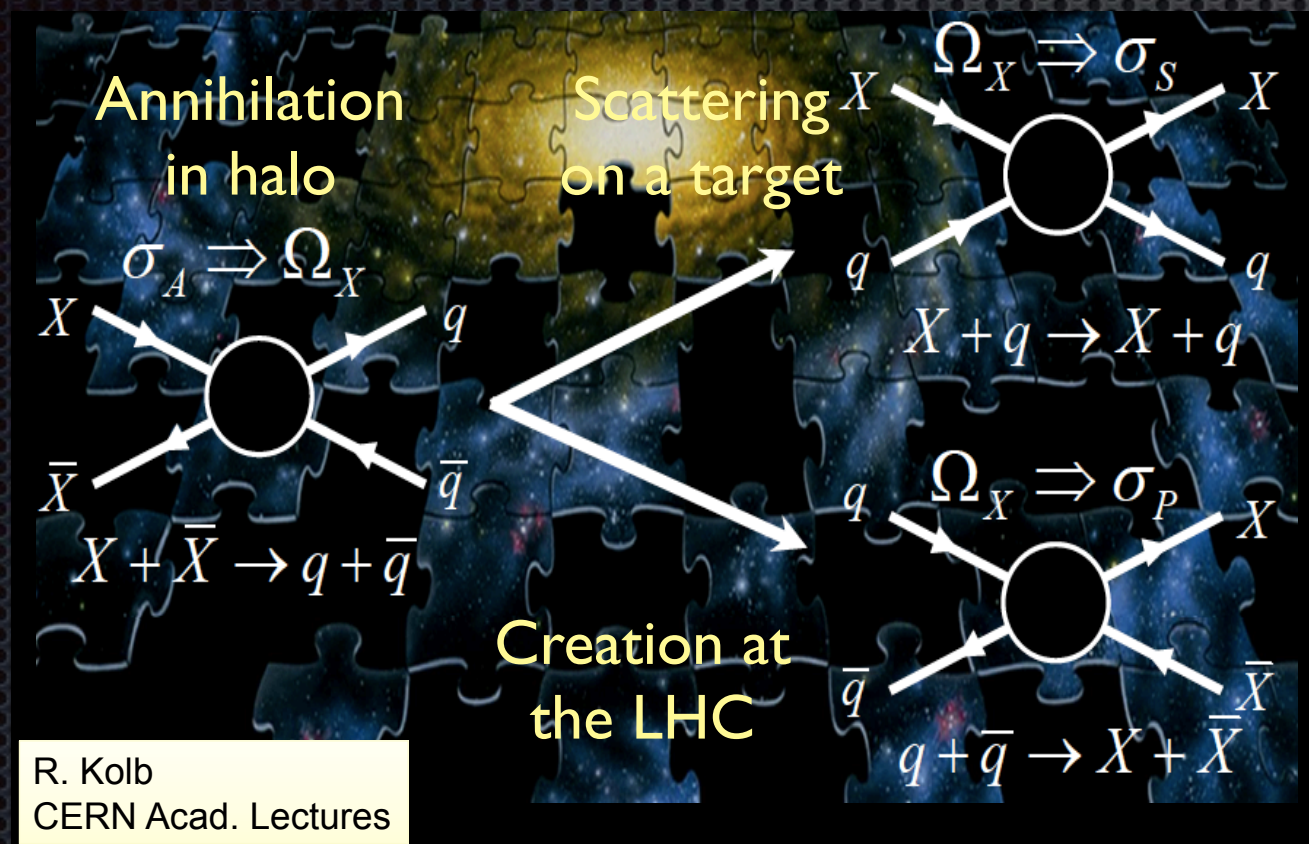


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The signal is absent so far!

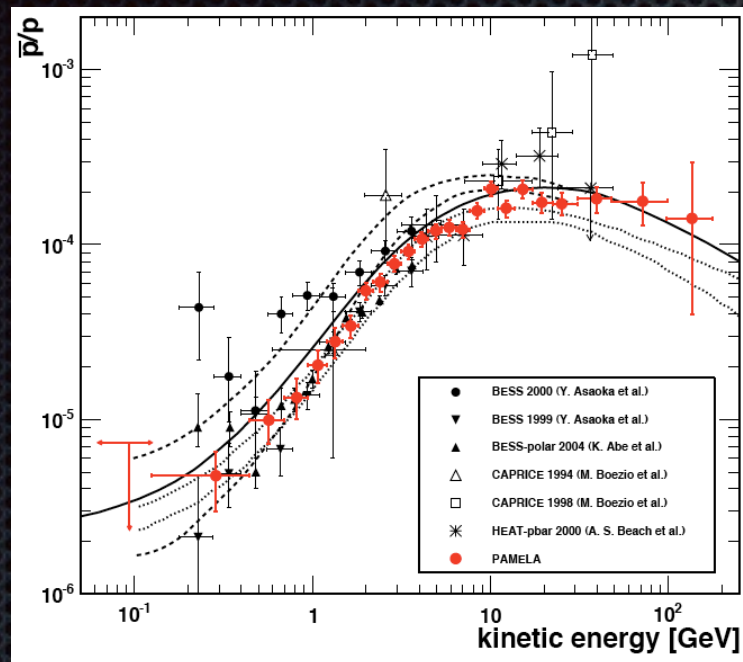
Search for the Dark Matter

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Annihilation in halo

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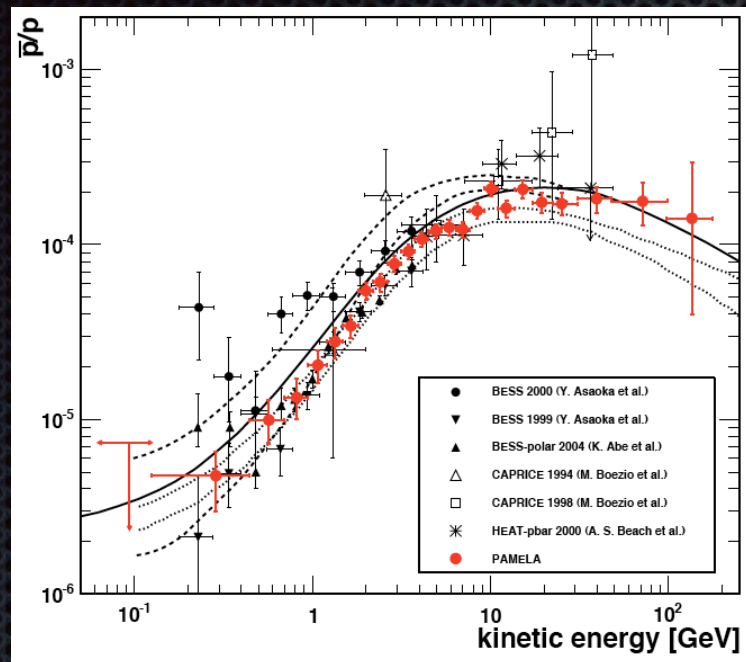
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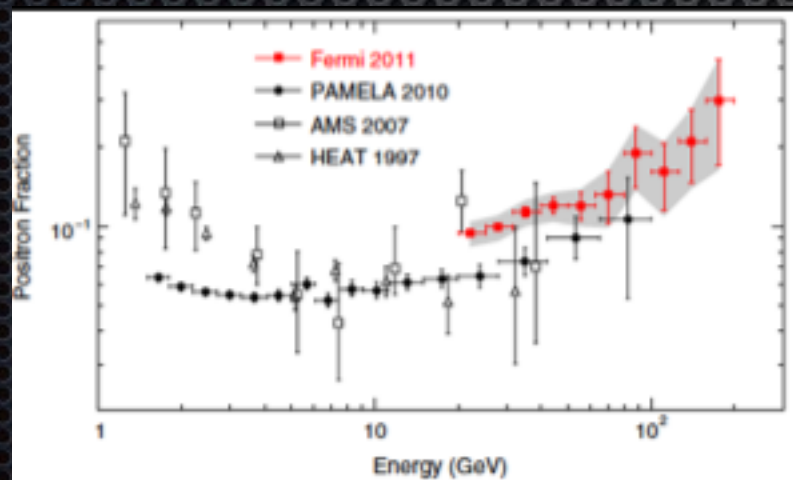
Antiprotons

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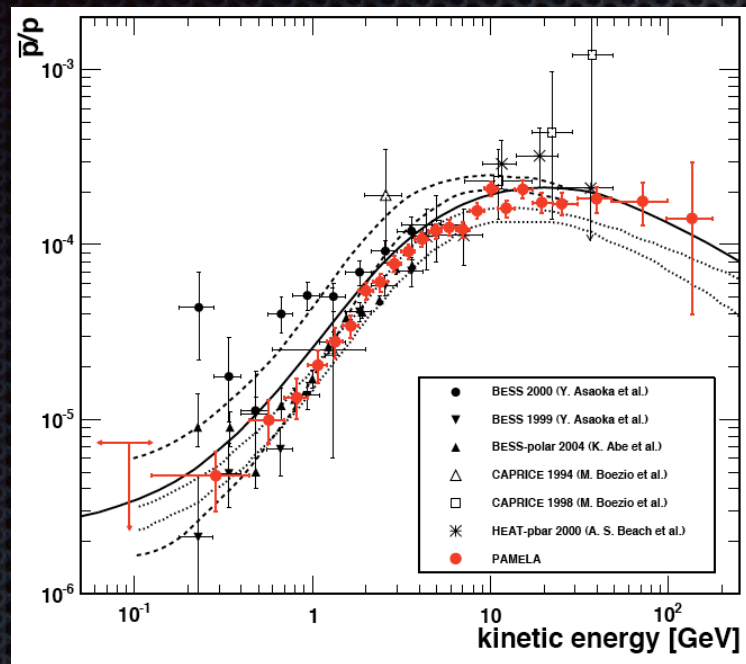


A confirmed positron "excess"

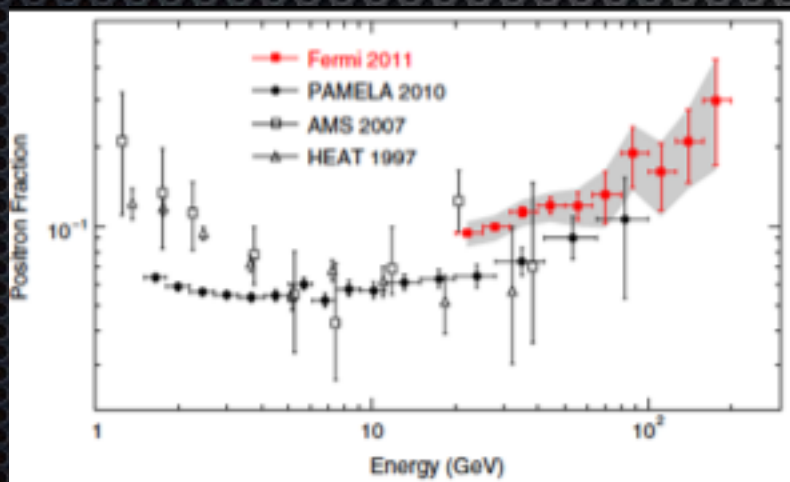
Positrons

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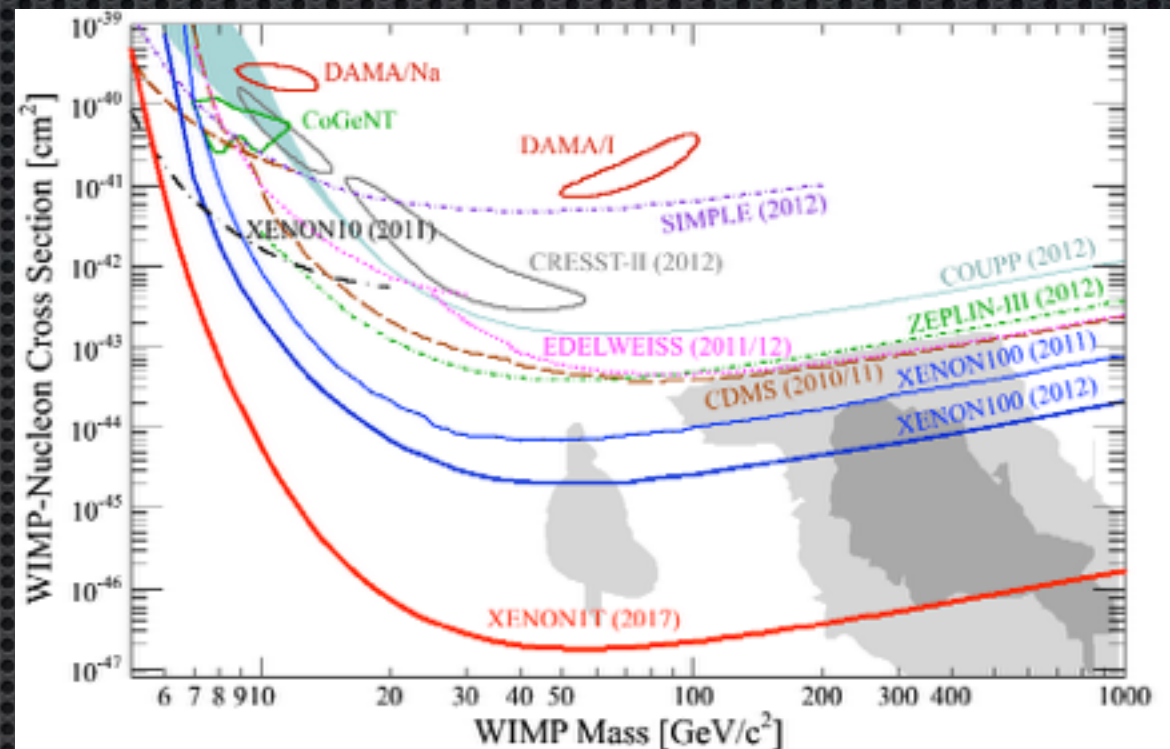
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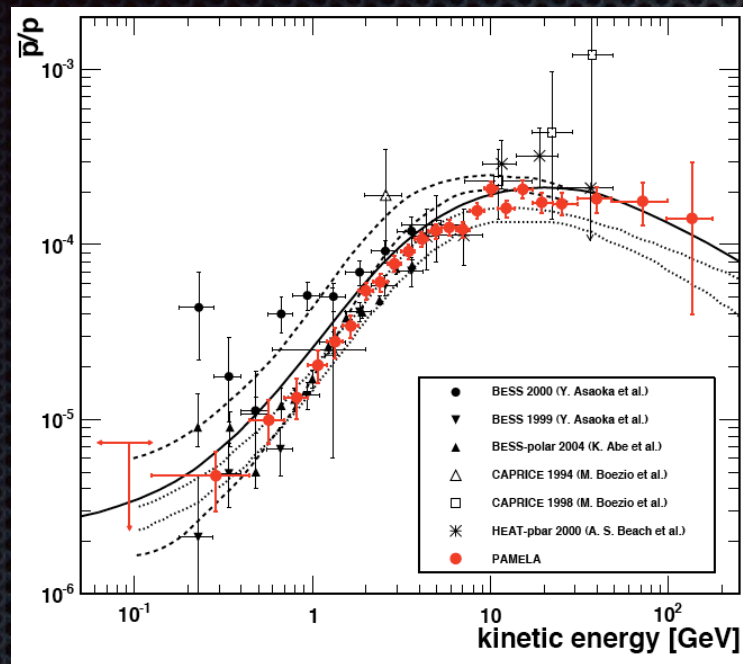
Positrons

Scattering on a target

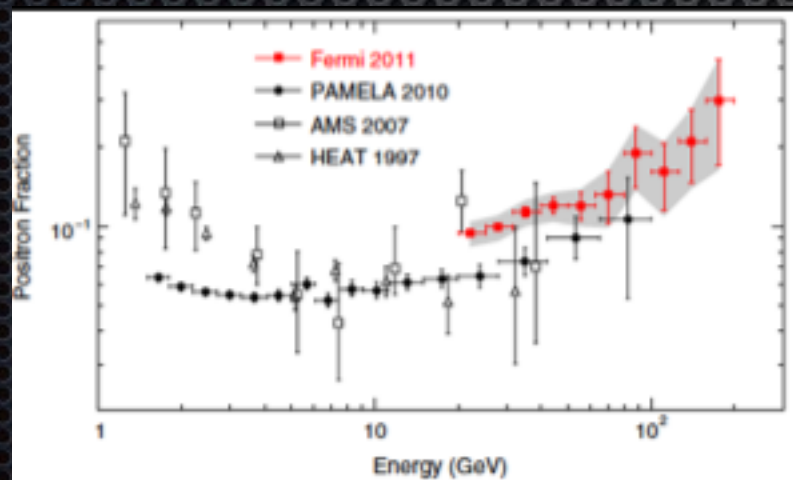


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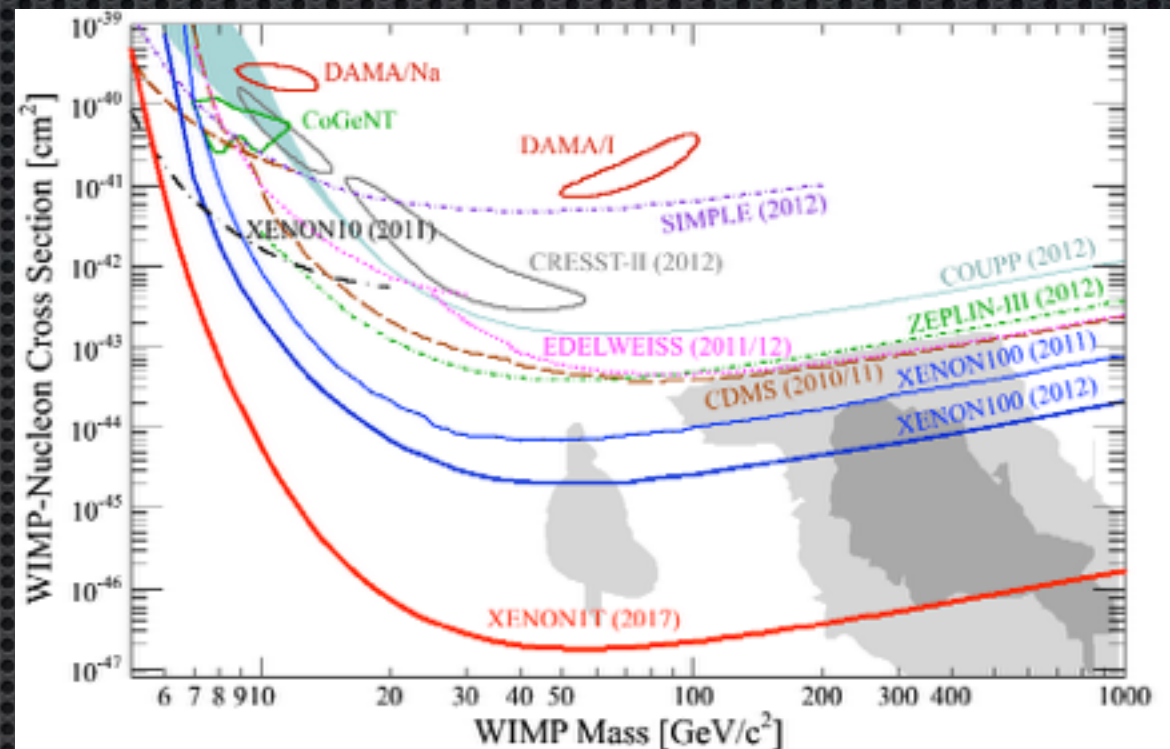
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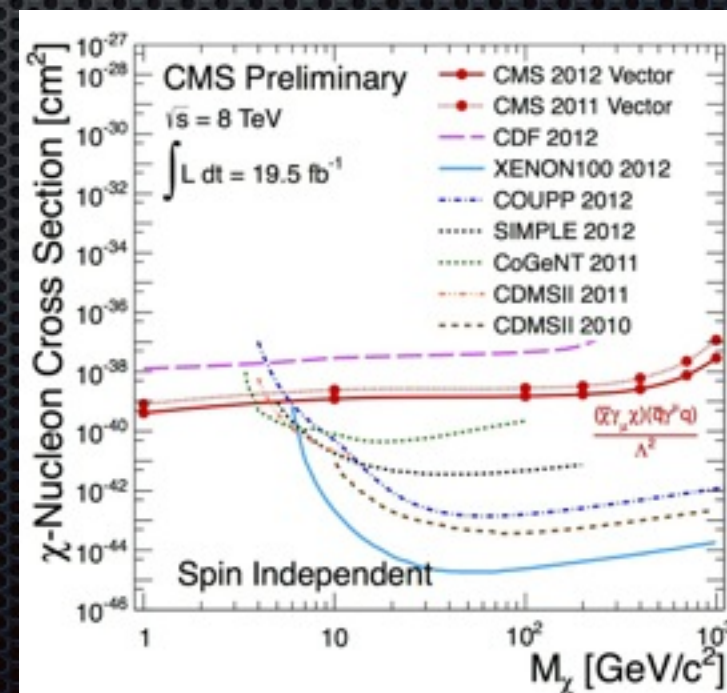
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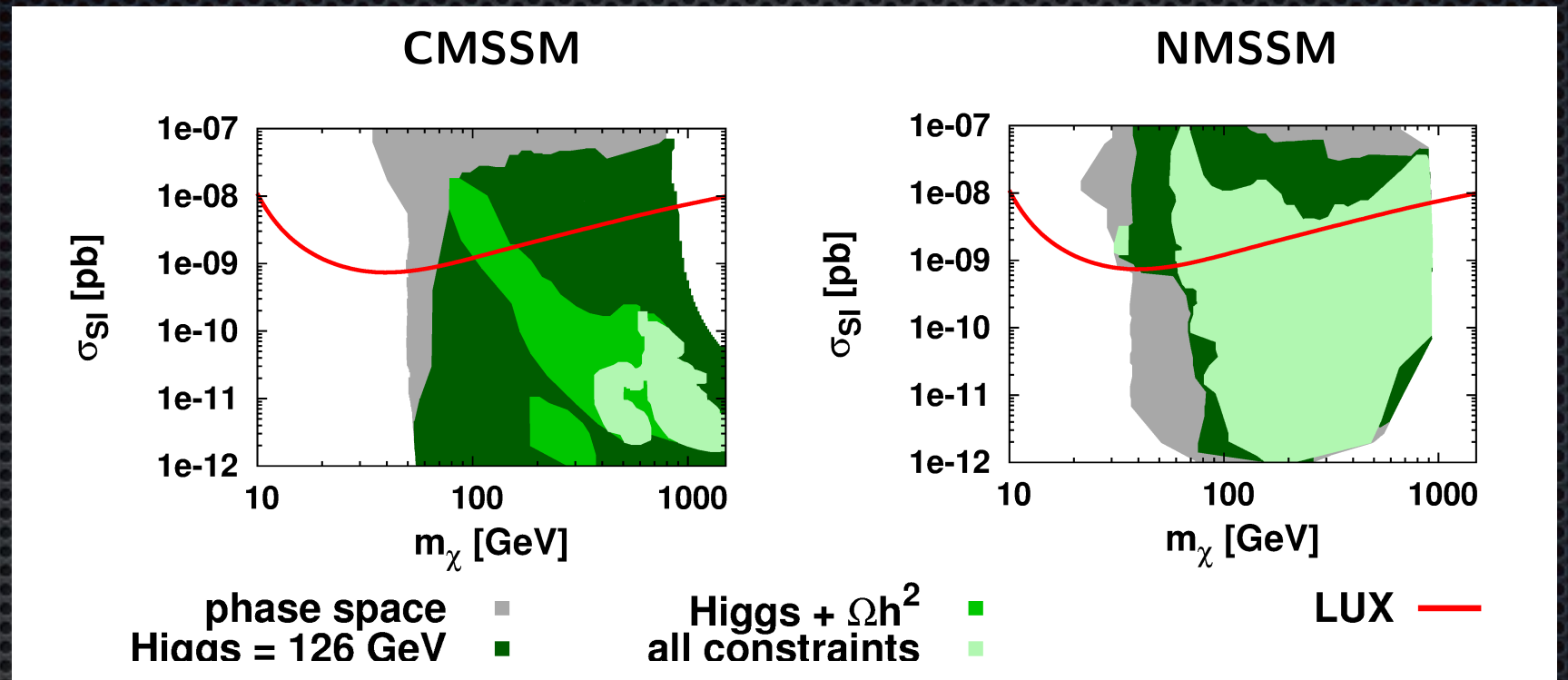


Creation at the LHC



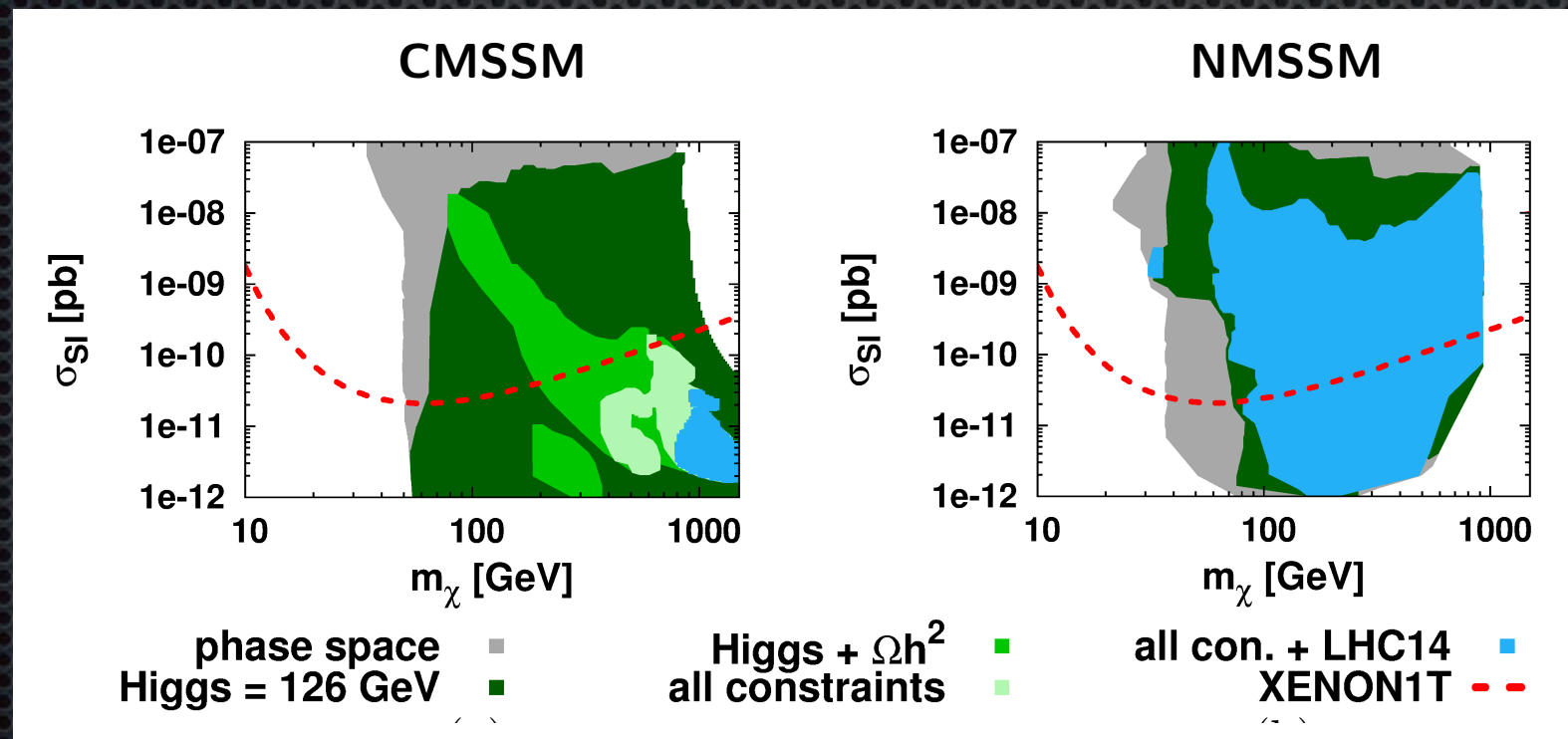
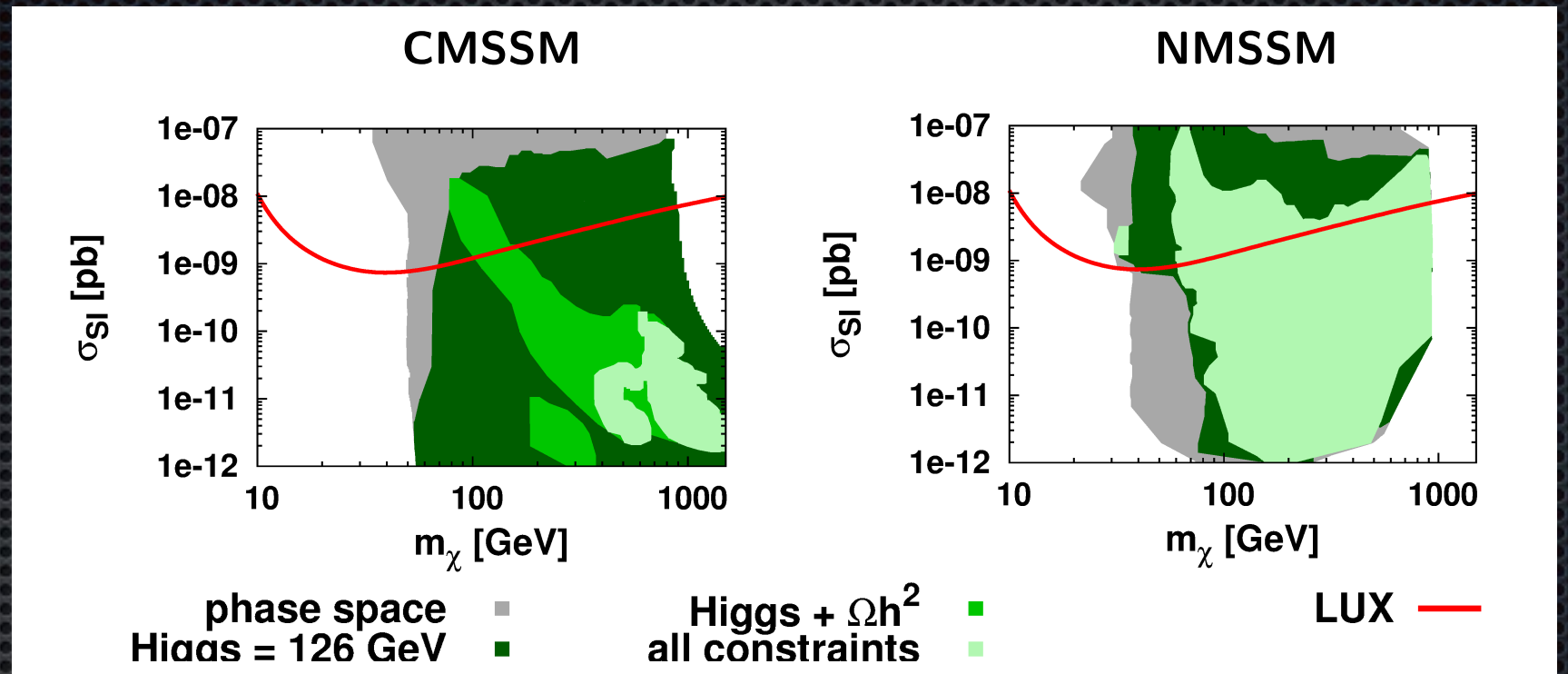
Direct search limits in SUSY Models

Today



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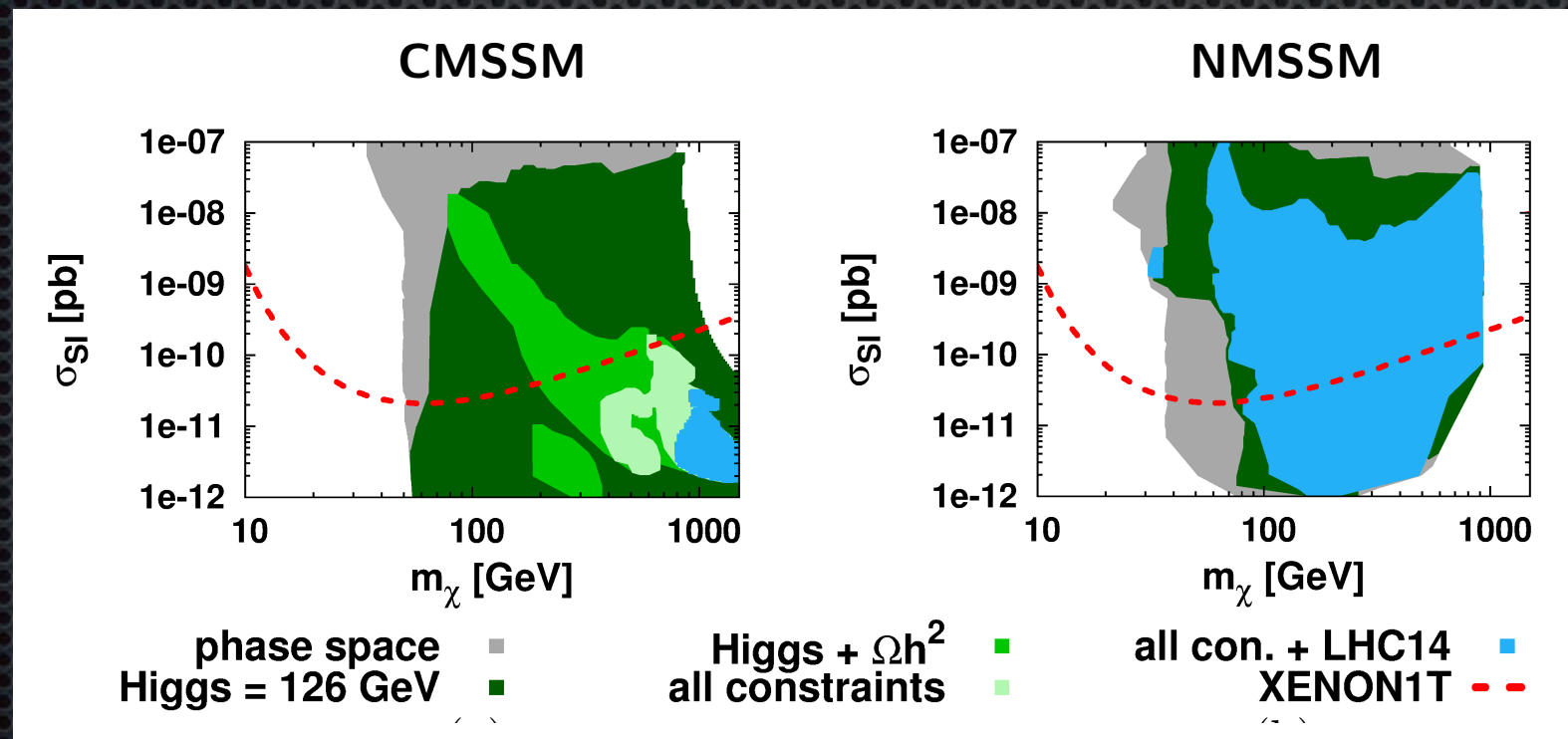
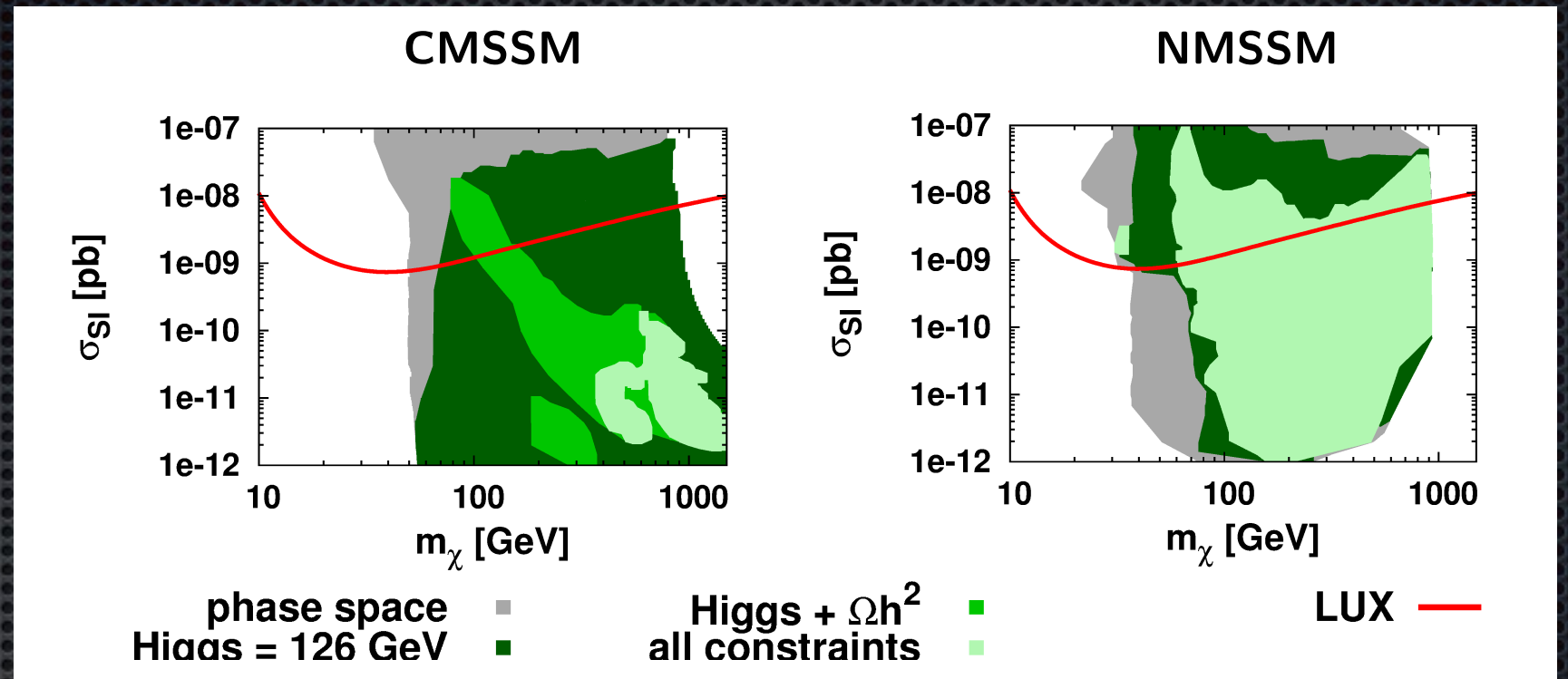
Today



In few
years

Direct search limits in SUSY Models

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In few
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The blue regions will not be accessible to future LHC SUSY searches at 14 TeV and 3000fb^{-1} (LHC14).

If $S\bar{Y}S\bar{Y}$ is not found at the
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If SUSY is not found at the LHC then what?

Paris Sphicas Parting word on SUSY

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