BSM Theory Summary

GT01 perspectives

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Lyon, 12/03/2020

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Why do we need New Physics?

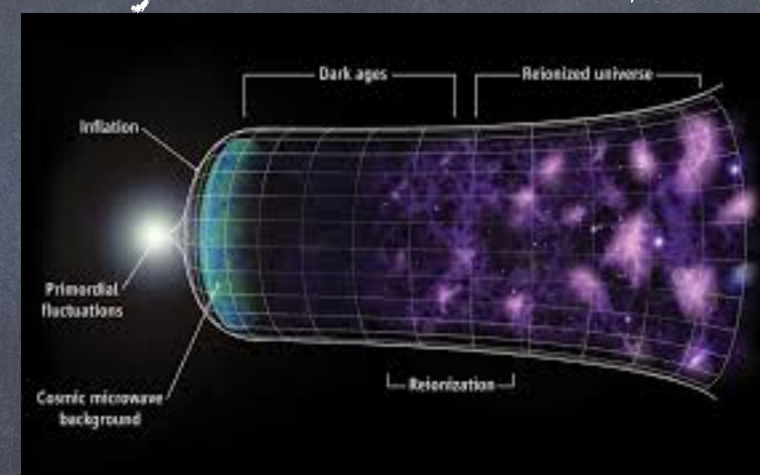
- Several observations in Nature:

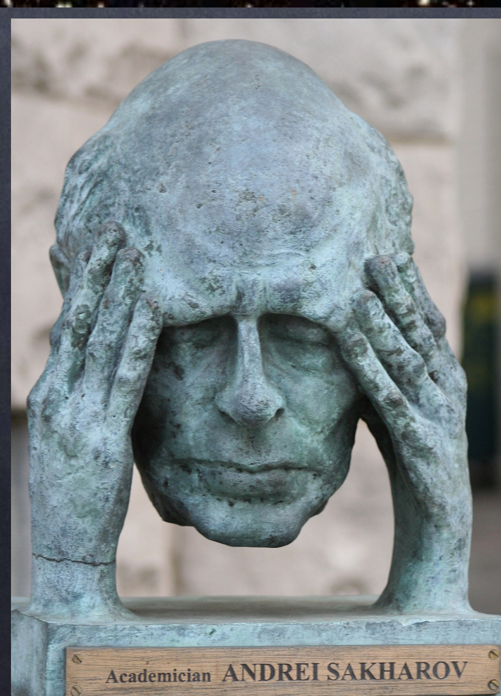
Dark Matter, or...

why is the Universe so heavy?

Inflation, or...

why is the Universe so flat?





Baryogenesis, or...

why is the Universe so interesting?

+ more (to your taste)!

Why do we need New Physics?

- But we have "<u>The Standard Model</u>"!

→ No Dark Matter (primordial Black Holes?),
No Inflation (Higgs Inflation -> non-standard gravity)

→ Two Sakharov condition NOT satisfied!

  - The EW phase transition is not strong enough!
  - CKM CPV is not enough!

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BSM Physics is there!

Why do we need New Physics?

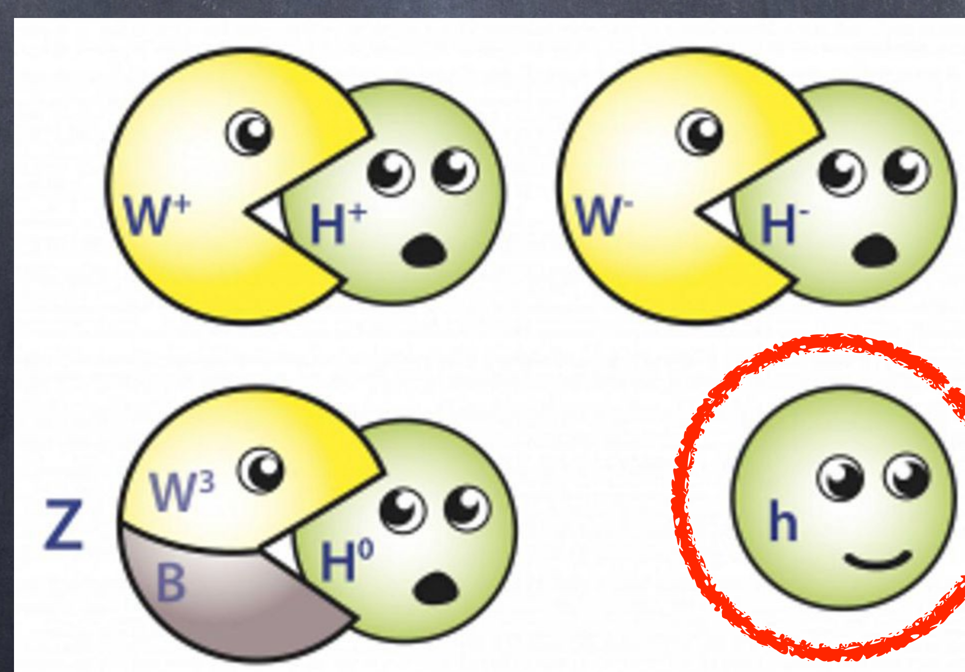
- But we have "The Standard Model"!

→ No Dark Matter (primordial Black Holes?),
No Inflation (Higgs Inflation -> non-standard gravity)

→ Two Sakharov condition NOT satisfied!

- How well do we know the EW sector?

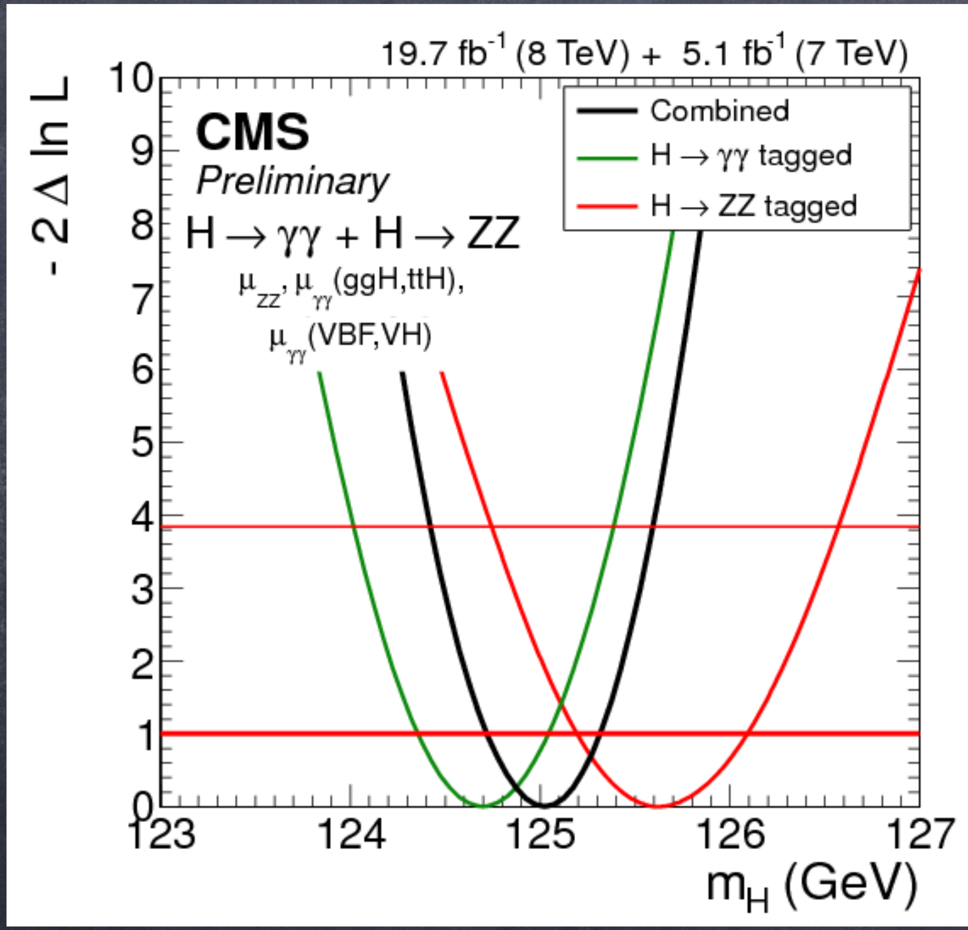
EW precision tests told us a lot on W+, W- and Z physics at per-mille level!

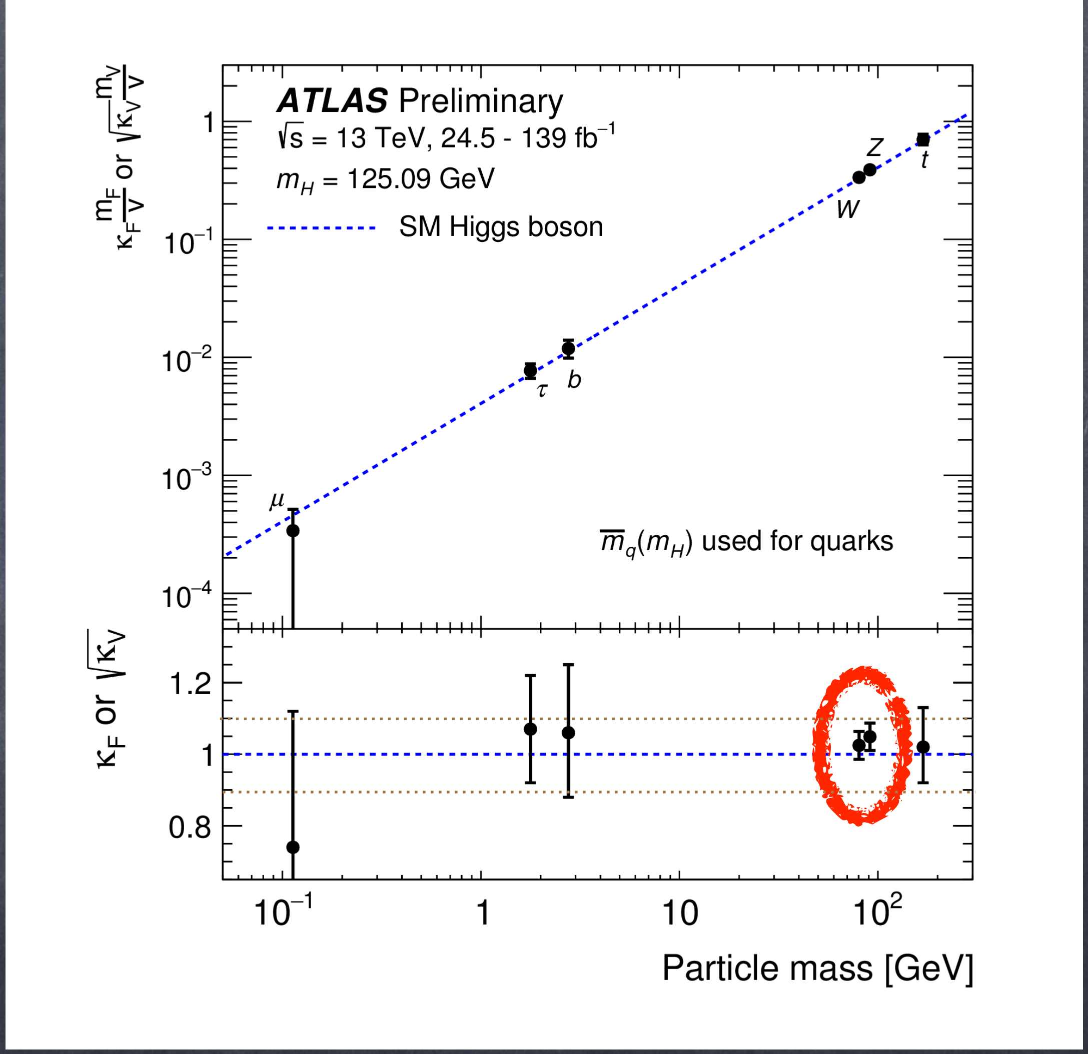


How well do we know this guy?

LHC 2020: an appraisal

- Higgs discovered! It's SM-like (within 10%)





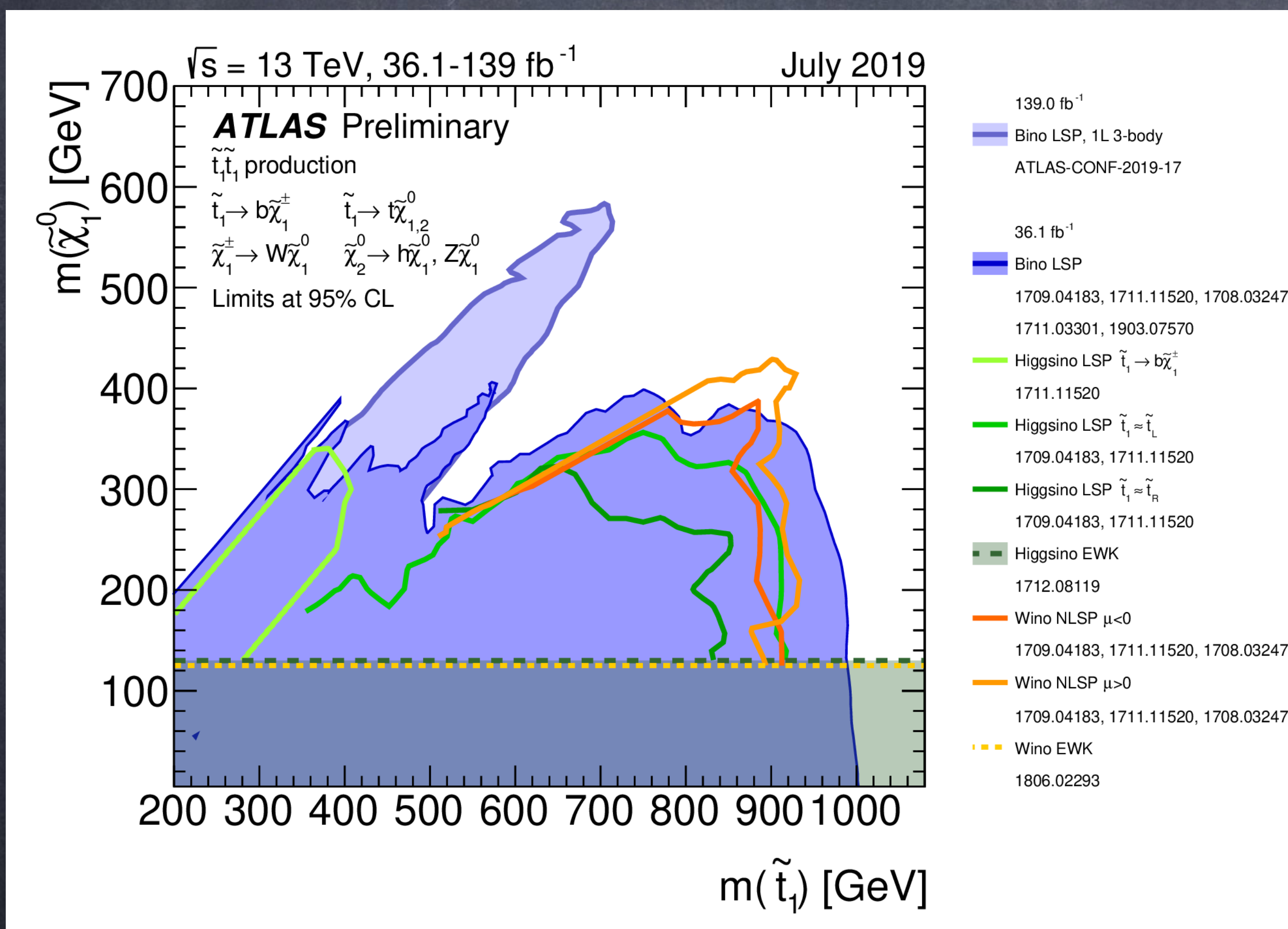
Consistency check requires measuring h-self couplings!

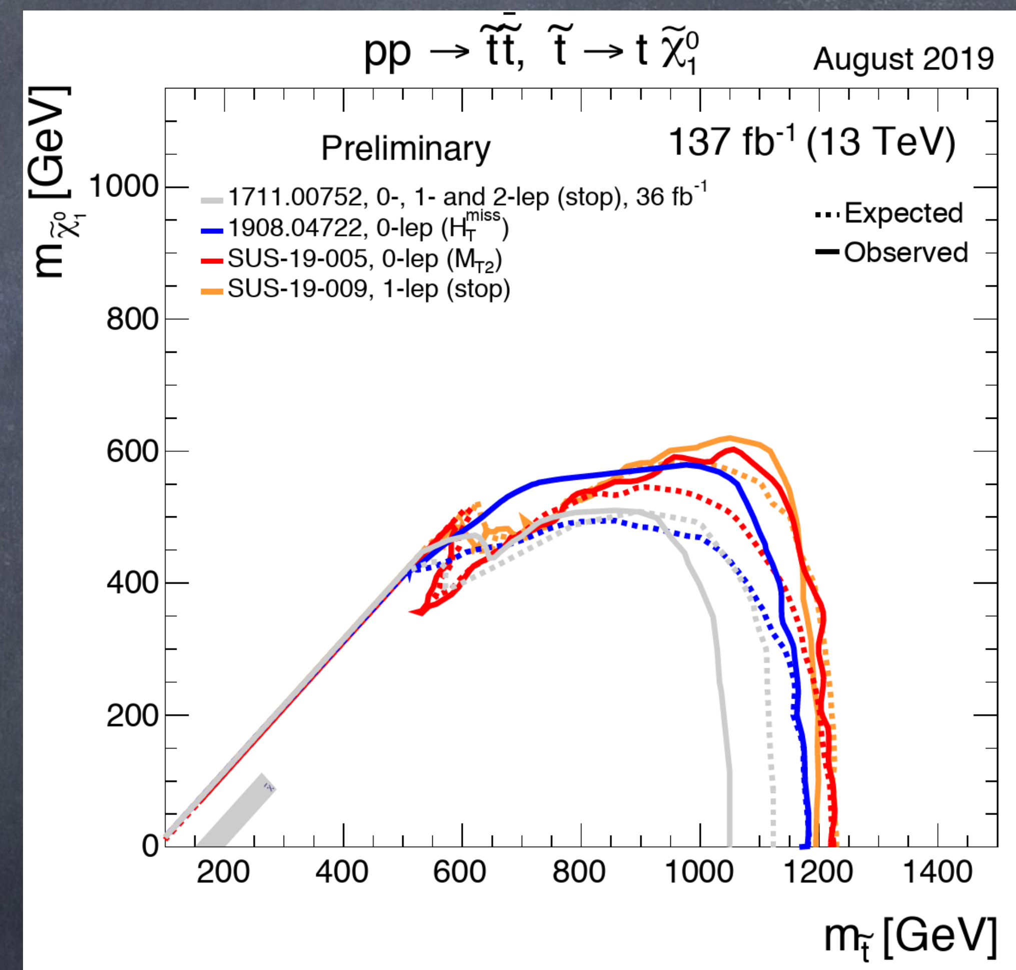
Compare with 0.1% of EWPTs!!!

LHC 2020: an appraisal

- No "expected New Physics" has been found!

Examples from SUSY stop searches.

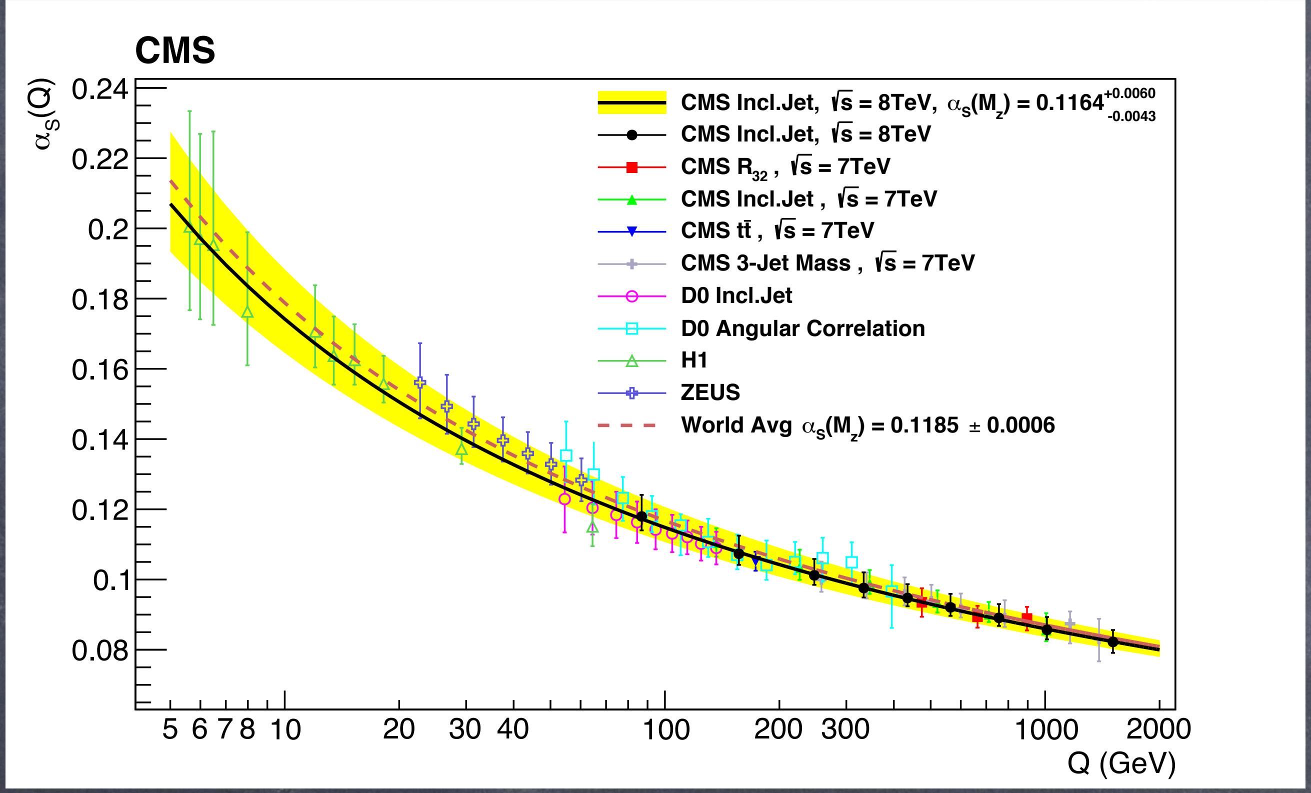




There are still poorly constrained New Physics scenarios!

LHC 2020: an appraisal

- The SM is valid up to E = TeV-ish



Randomly generated example:
strong coupling running measured
up to 1.5 TeV

LHC 2020: an appraisal

- No "expected New Physics" has been found!
- The SM is valid up to E = TeV-ish

Do we need to give-up naturalness?

No BSM guiding principle?

$$\delta m_h^2 = -\frac{3y_t^2}{8\pi} M_{\rm BSM}^2$$

$$M_{\rm BMS} \approx \mathcal{O}(1\ \text{TeV})$$

i.e.

$$0.1 \div 10\ \text{TeV}$$

Just starting to pull the carrots!

LHC 2020: an appraisal

- No "expected New Physics" has been found!
- The SM is valid up to E = TeV-ish

Do we need to give-up naturalness?

No BSM guiding principle?

Un-naturalness implies:

Where do the carrots come from?

Planck scale meadows?

GUT scale terrains?

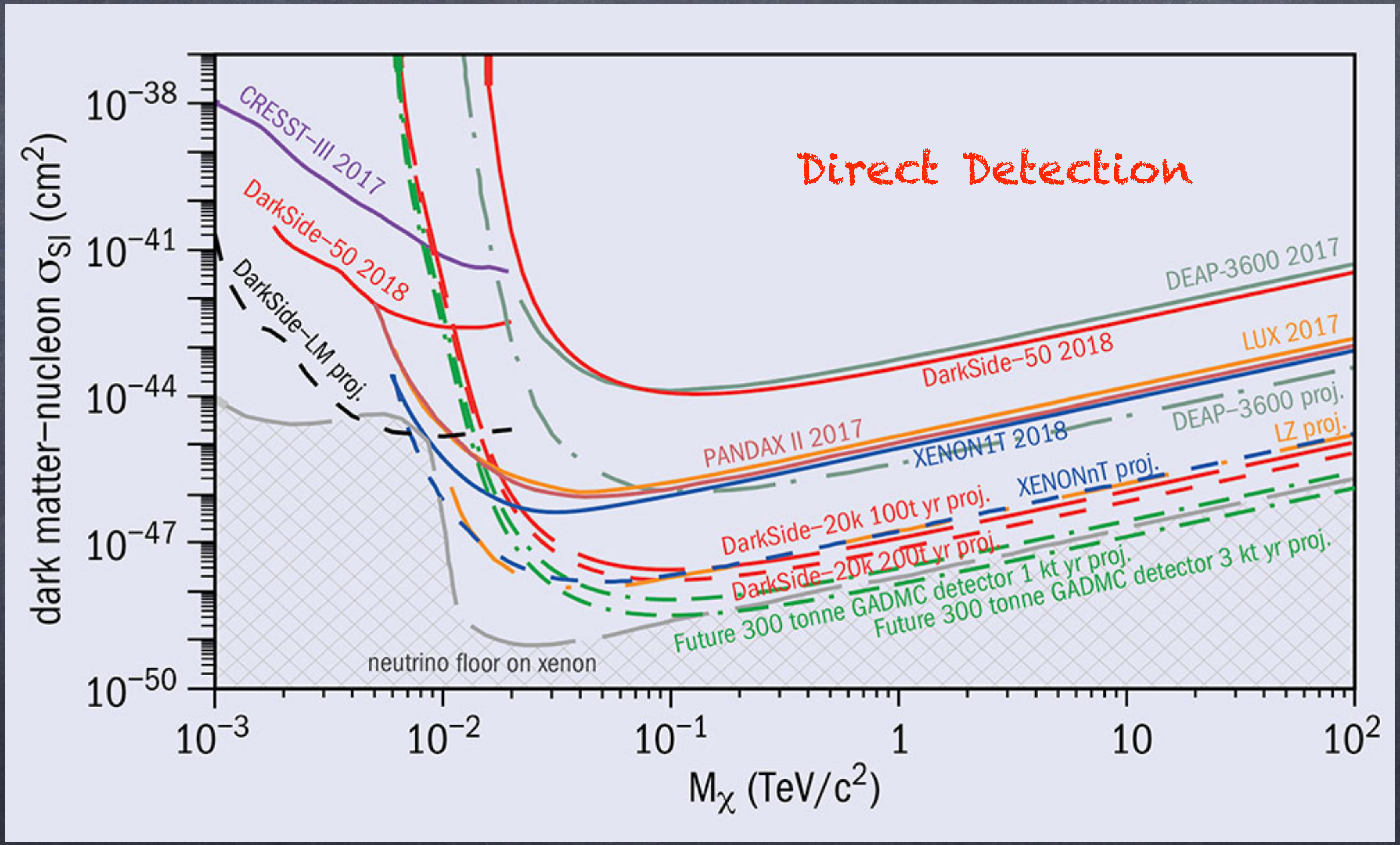
The LHC orchards?

Somewhere in between?

eV lowlands?

LHC 2020: an appraisal

- Dark Matter: still no idea what it is!



Ici, on tâtonne dans le noir...

Theory directions

- ## Supersymmetry

  Compressed spectra (LLP), Dark Matter, synergy between colliders/Dark matter experiments/Cosmology

- ## Compositeness (and extra dimensions)

  Compressed spectra (LLP), Dark Matter, heavy states (need for FCC), synergy with BSM Lattice, connection to Cosmology poorly developed

- ## Dark Matter

  WIMP miracle points towards EW scale but it's in crisis, where and what is Dark Matter? We are groping in the dark.
  New ideas are needed! Unusual signatures possible.

Contribution to Prospectives 2020 – GT01

Phénoménologie des recherches de Nouvelle Physique aux collisionneurs

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The quest for New Physics remains central for Particle Physics!

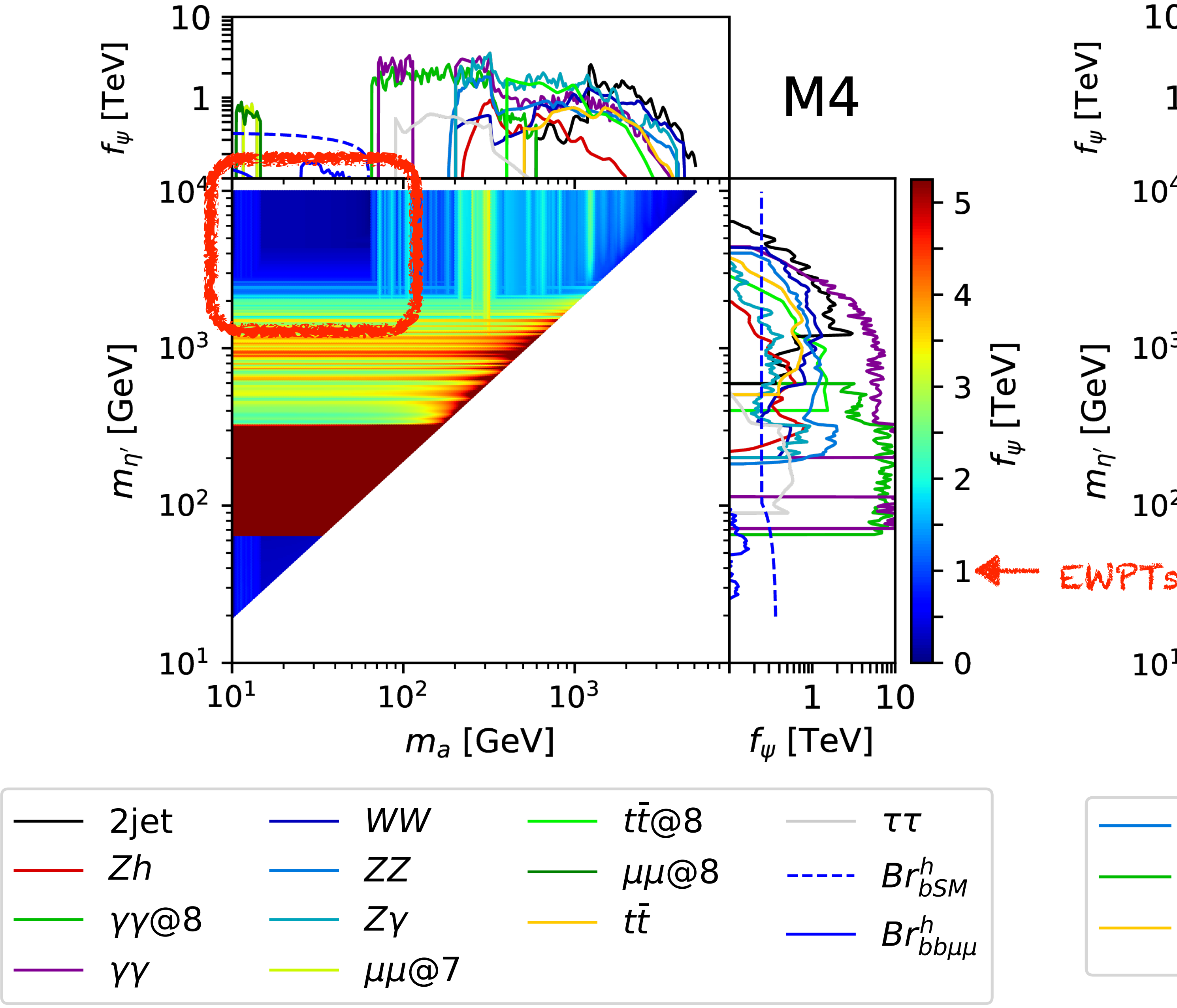
Several scenarios are still accessible to the LHC:

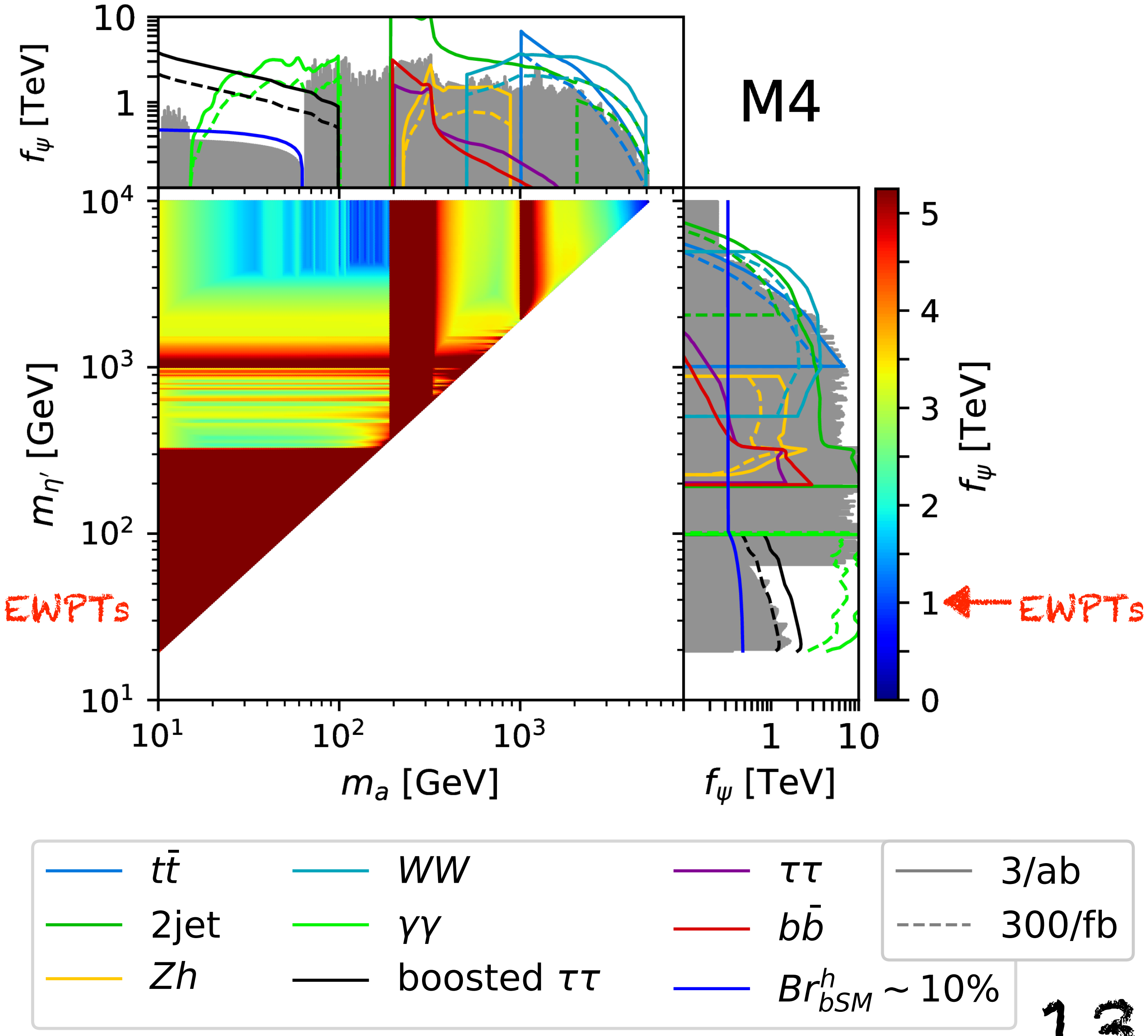
- Compressed spectra, leading to soft physics and/or LLPs -> new triggers, new exp (MATUSLA, e+e-), Dark searches or Cosmology
- Only EW physics is affected -> poor direct access, indirect probes (precision), or heavy stuff (compositeness). HH measurements!
- Small couplings, g<<1 -> indirect effects + high luminosity
- New Physics only in couplings modifications -> Higgs coupling determination, CPV, precision physics
- Non-standard physics -> indirect probes or case-specific

Example 1:
light composite pseudo-scalars

Ubiquitous in gauge-fermion underlying theories

Produced via gluon fusion at LHC





Example 1:
light composite pseudo-scalars

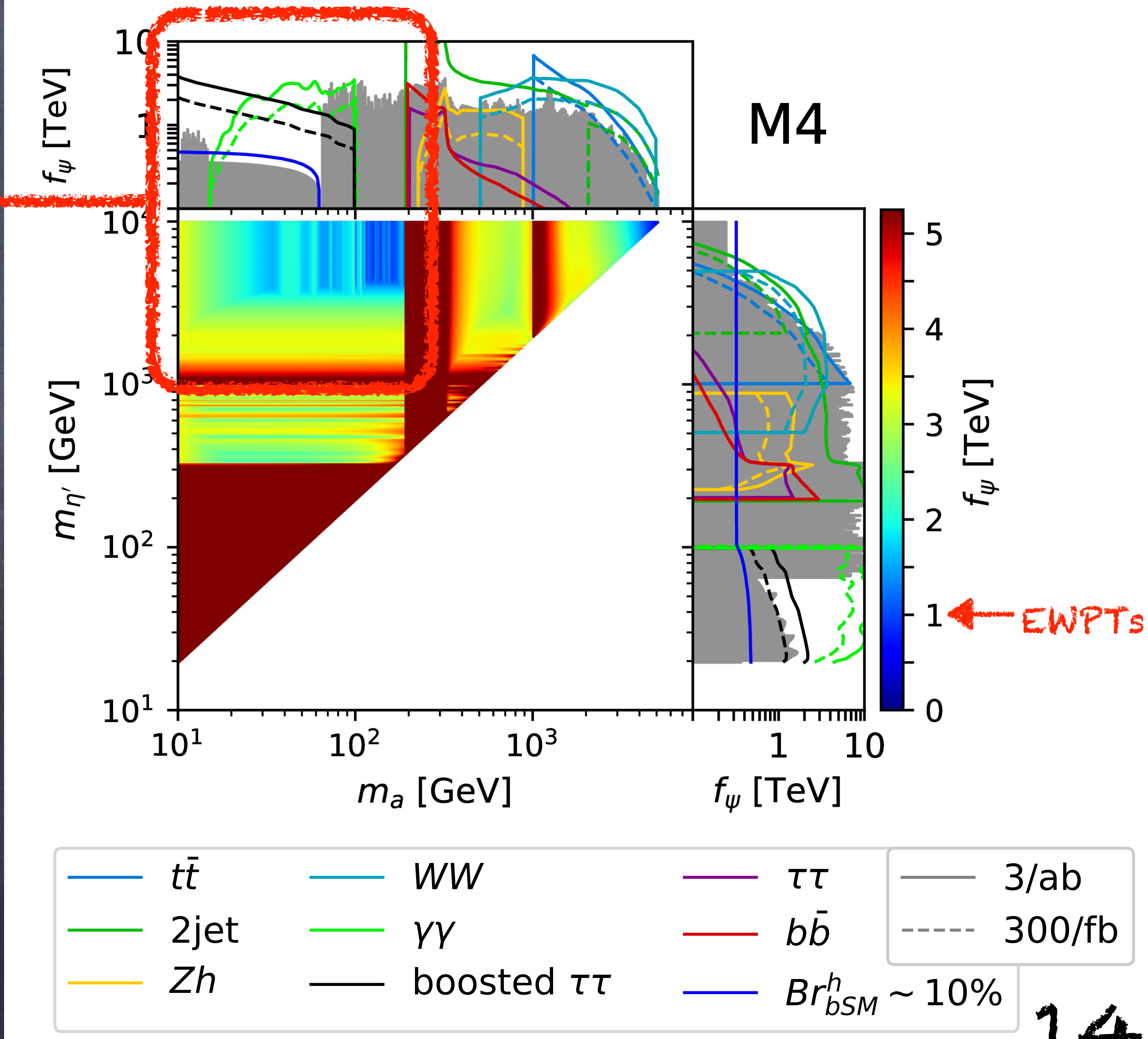
Ubiquitous in gauge-fermion underlying theories

Produced via gluon fusion at LHC

High-Luminosity is needed:

black: boosted di-tau proposal (also di-muon) @ CMS and LHCb

green: use of SM measurement of di-photon differential xsec



Example 2:
Goldstone Dark Matter

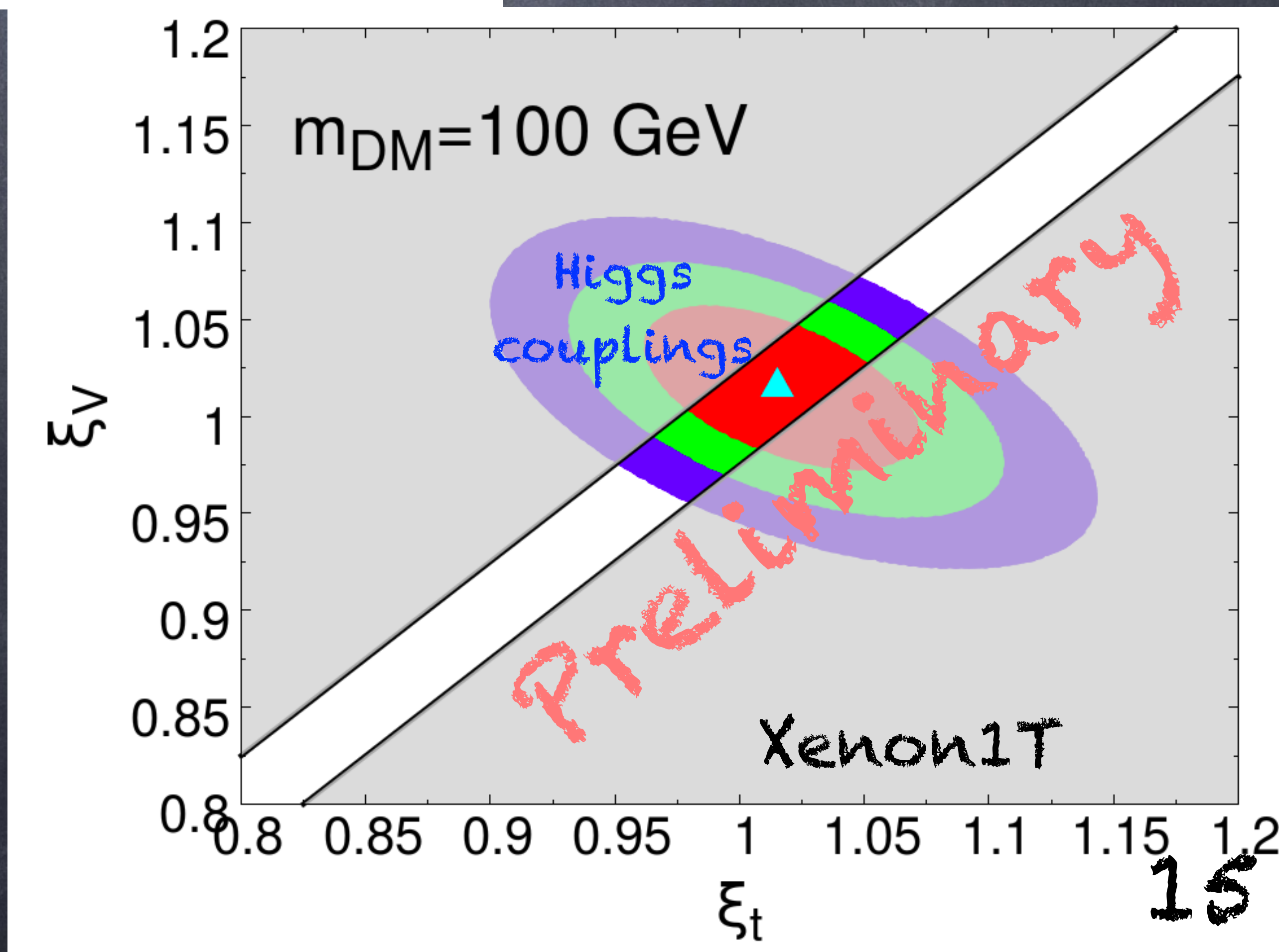
$$\mathcal{L} = \frac{1}{2}(\partial_\mu H)^2 - \frac{1}{2}\kappa_M(H)\ M^2\ H^2 + \kappa_G(H)\ \frac{f^2}{8}\ \mathrm{Tr}[(D_\mu\Sigma)^\dagger \cdot D^\mu\Sigma] + \ \ldots$$

Higgs

Contains
EW Goldstone
+ DM Goldstone

$$\mathcal{L}_{H\varphi\varphi} = -\frac{\xi_V}{v}\ (\partial_\mu H)\varphi_i(\partial^\mu\varphi_i) - \frac{H}{v}\ [\xi_V\varphi_i\partial^2\varphi + \xi_t m^2_{\varphi_i}\varphi_i^2 + (\xi_t - \xi_V)\delta m^2_{G,i}\varphi_i^2]$$

Higgs coupling
modifiers (kappa's)



Nice complementarity between Higgs precision and Dark Matter Direct Detection!

IN2P3 Prospects 2020

GT05, Physique de l'inflation et énergie noire

GT01, Physique des particules

SUSY Cosmic Inflation
or when cosmology meets particle physics

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on behalf of: Laurent Duflot[b], Sophie Henrot-Versillé[b], Nikola Makovec[b], Ludovic Montier[c], Baptiste Mot[c], Matthieu Tristam[b], Vincent Vennin[a], and Dirk Zerwas[b]

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[d]L2C

Motivation:

- LHC discovery of the Higgs, and nothing beyond (so far)... BUT we need BSM!
- Planck results strongly support inflation hypothesis... BUT we have no embedding theory

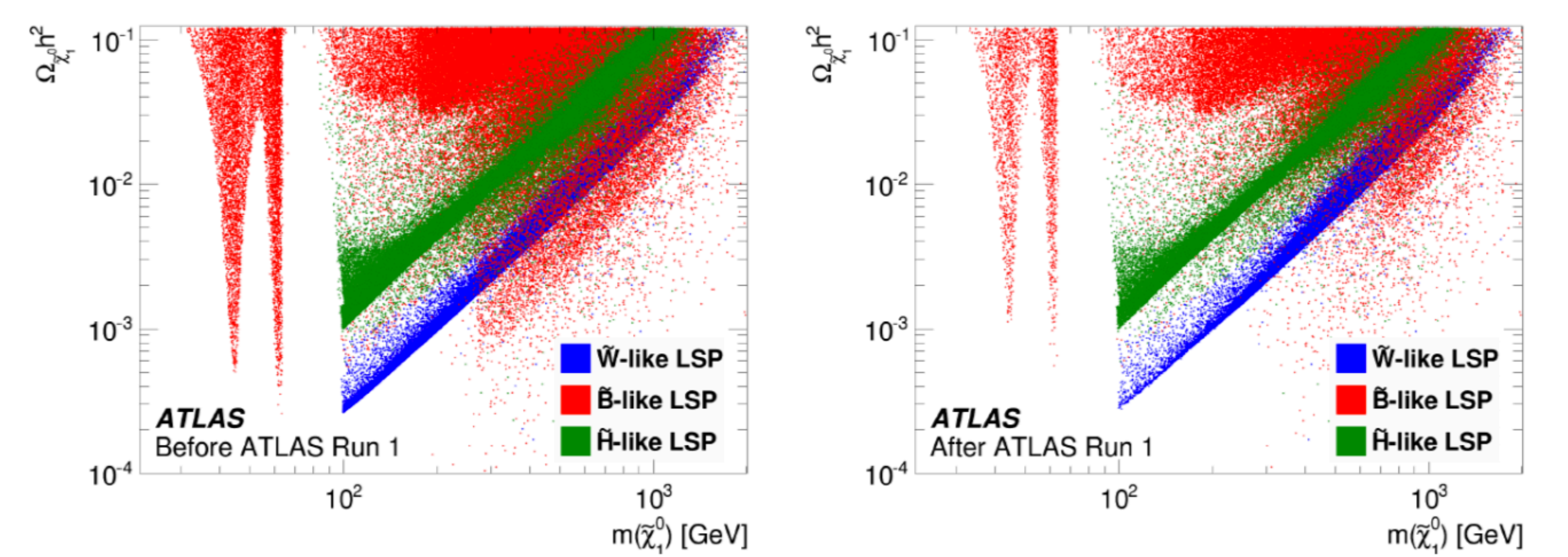
Any common traits?

- Heavy or difficult SUSY scenarios at the LHC!
- SUSY flat direction inflation
- or SUSY Higgs inflation, e.g. SUGRA-MSSM

The proposal:

Put together experimental and theoretical expertise on SUSY searches & parameter exploration, CMS analyses and Cosmo parameter exploration, to constrain/improve SUSY inflation models from present and future experiments

Participants: members of collaborations (LHC, Planck...) theoreticians (Inflation, SUSY) and co-authors of analysis codes (ASPIC, SFitter, SuSpect).



(a) Before ATLAS Run 1 (b) After ATLAS Run 1

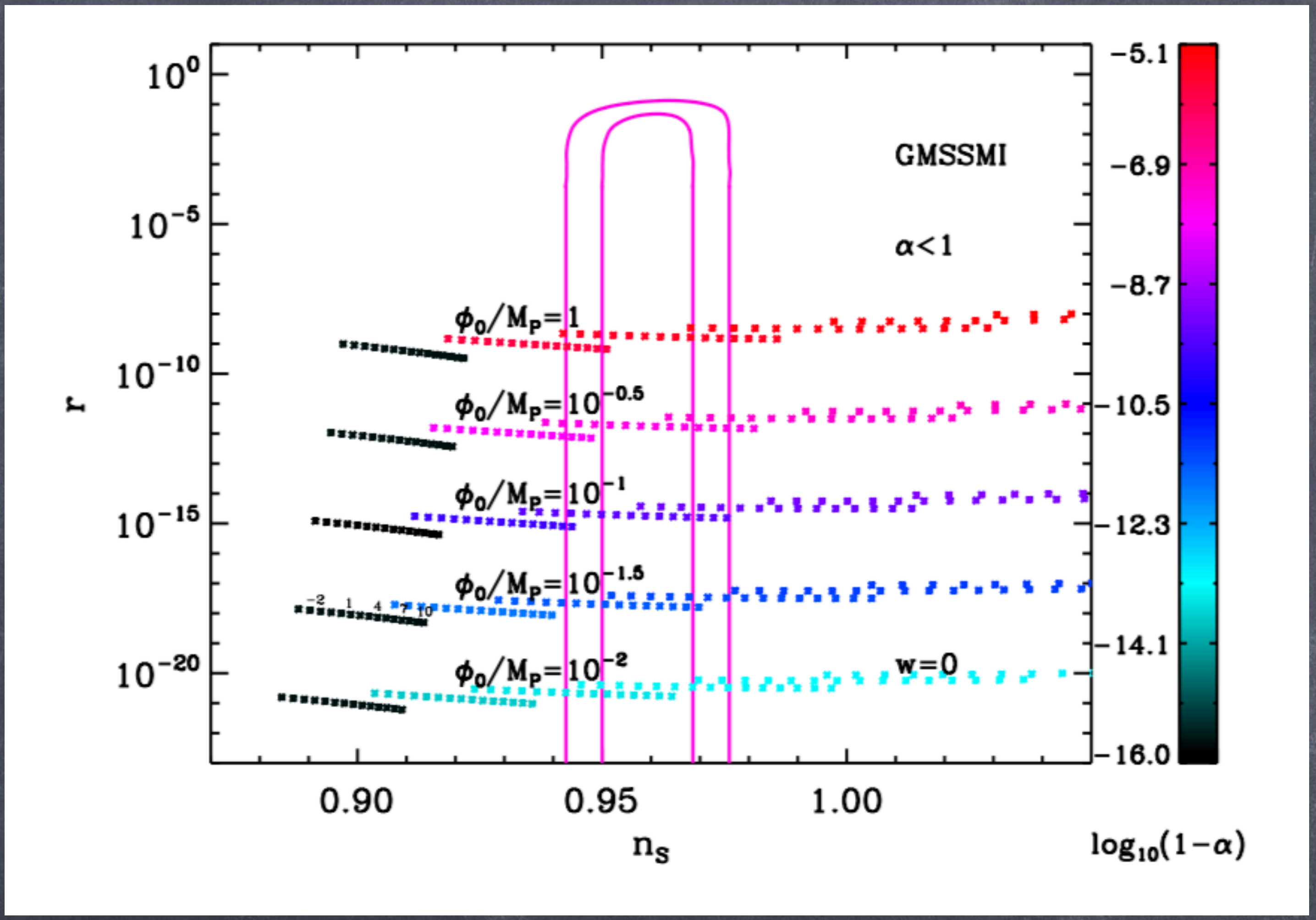
pMSSM points

LOW ENERGY (TeV):

Example of constraints from DM relic density and collider searches.

Participants: members of collaborations (LHC, Planck...) theoreticians (Inflation, SUSY) and co-authors of analysis codes (ASPIC, SFitter, SuSpect).

Tensor-scalar ratio



Spectral index

HIGH ENERGY (Planck):

Constraints from Planck measurements on the inflationary potential.

Interface SFitter/SuSpect with ASPIC

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Relate high-scale (Cosmo) and low scale (Particle Phys.) features of a SUSY-inflation model

Compare predictions with data (Cosmo + HEP): SUSY collider searches, Dark Matte relic, (in)direct detection, low energy observables, CMS, spectral index, tensor-to-scalar ratio...

↓

Constraints!

- First (ongoing) application: inflection point MSSM inflation: LLE and UDD flat directions lifted by non-ren. operators. Implementation of RG flow relating the inflationary scale to the LHC scale; soft SUSY scalar masses -> inflation mass; other soft breaking masses SUGRA-mediated scenarios -> effective inflation potential. In principle fully calculable!

Summary:

- BMS physics is there!
- Many scenarios to be tested (HL-LHC, future colliders are needed)
- Precision physics: HH measurement crucial! EFT analyses complementary to direct searches.
- Synergy: Colliders/Cosmology/Gravitational waves/Dark Matter/Flavour...
- Systematic characterisation of models: consistent DM models, compositeness...

Outlook:

- Lots of New Physics still to probe/understand!
- The french theory (and experimental) community is fully engaged in this quest!