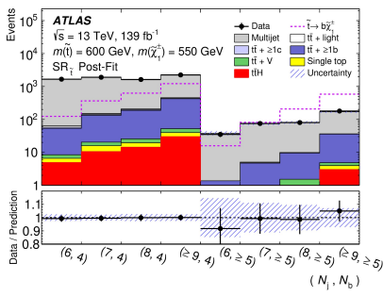
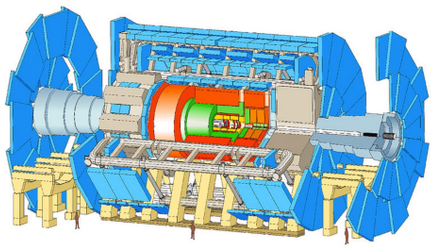
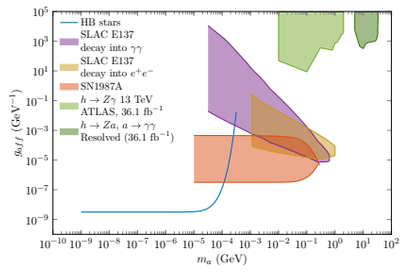
BSM Physics at the Terascale





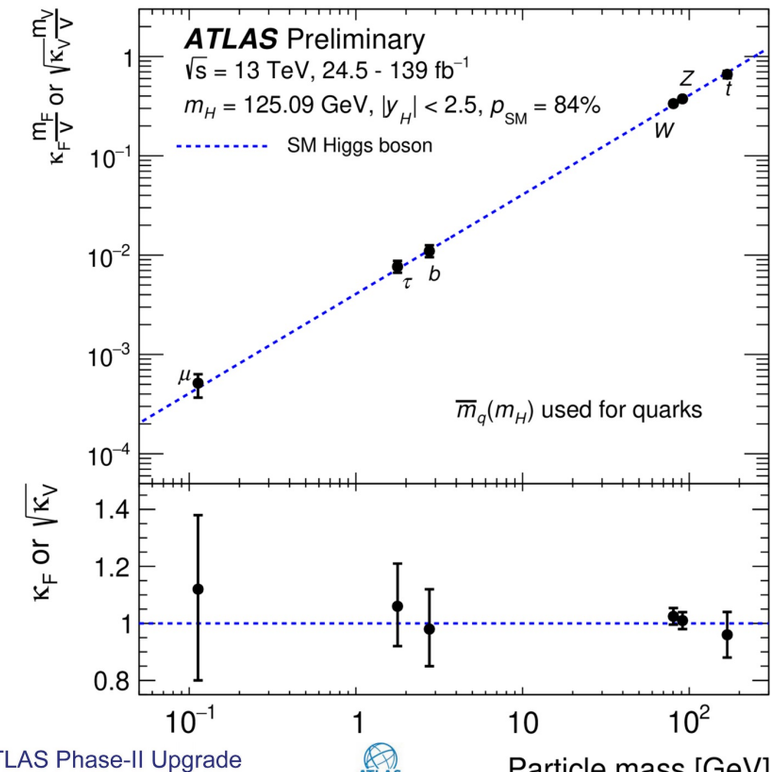


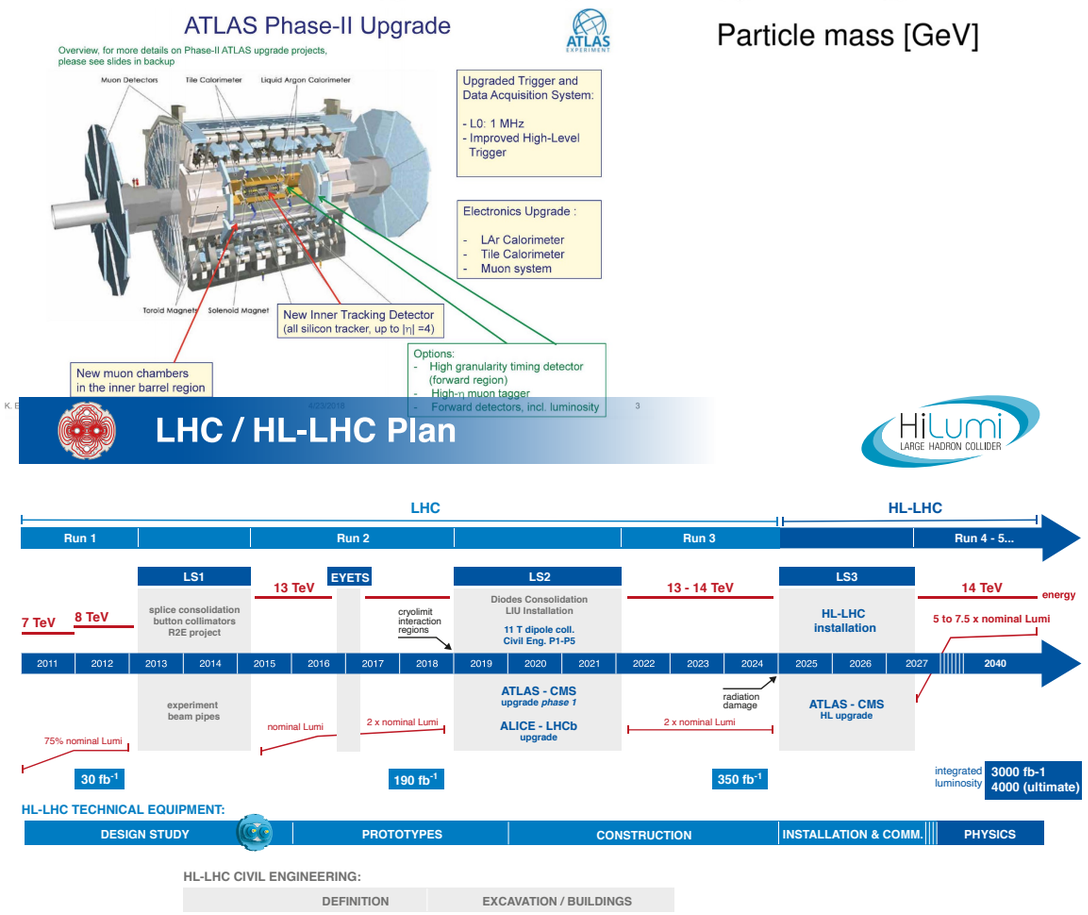
IPhU days Marseille 10/11 February 2022

Lorenzo Feligioni obo the group

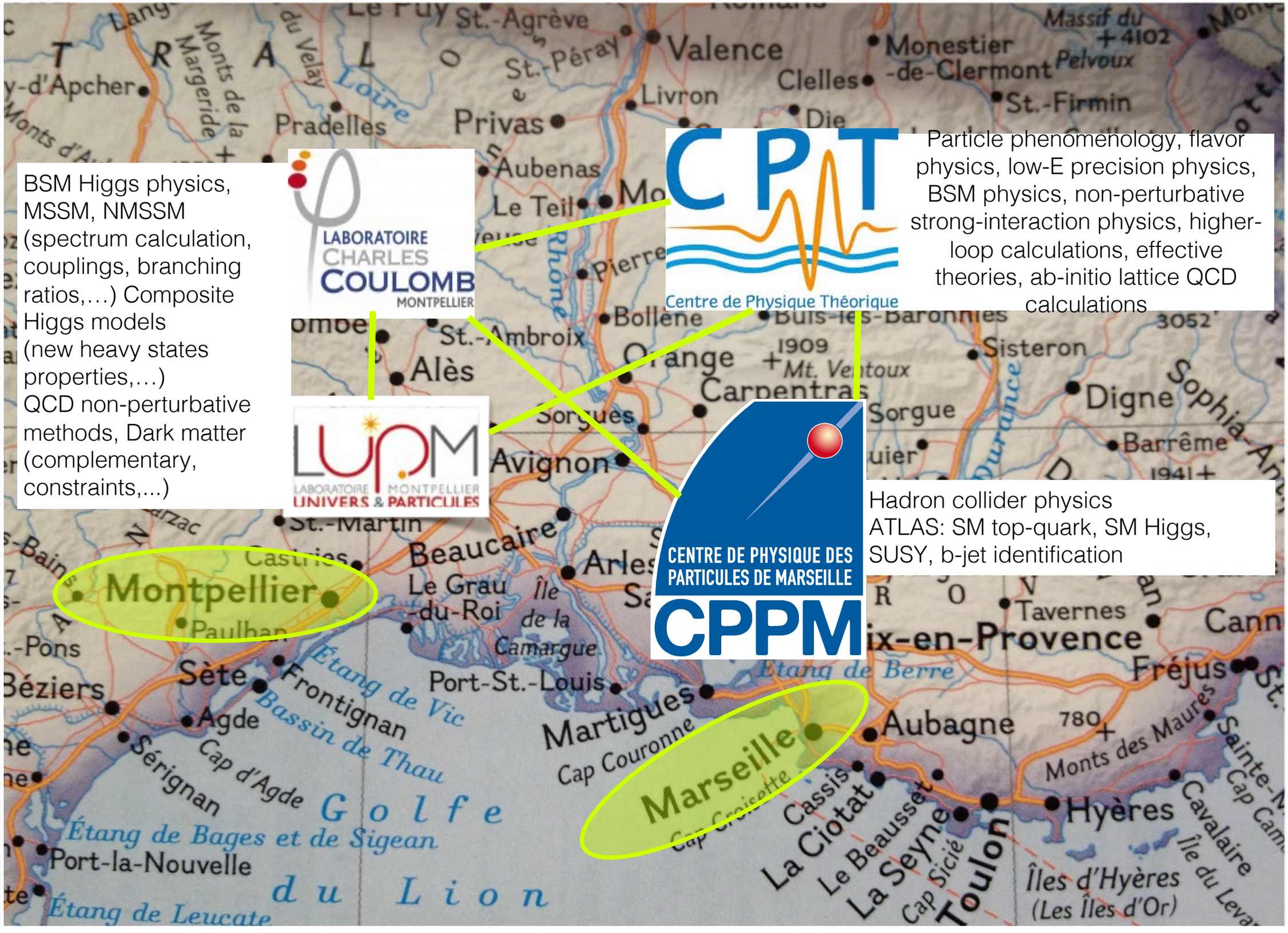
BSM at the Terascale: the constituents

- The measurements of the Higgs boson properties, such as its spin, parity and couplings confirmed its SM-like nature.
- New physics close to the electroweak (EW) scale theoretically well-motivated
- Search for New Physics from experimental and theoretical perspectives.
  - Analyze ATLAS Run 2/3 HL-LHC datasets
    - Novel analysis data aimed at unexplored signatures
    - Exploiting updated detector capabilities
  - Underpinning Beyond the SM (BSM) models providing:
    - Dynamical explanation of EWSB
    - Natural EWSB
    - Particle physics solution to the problem of dark matter
    - Explanation of neutrino masses.





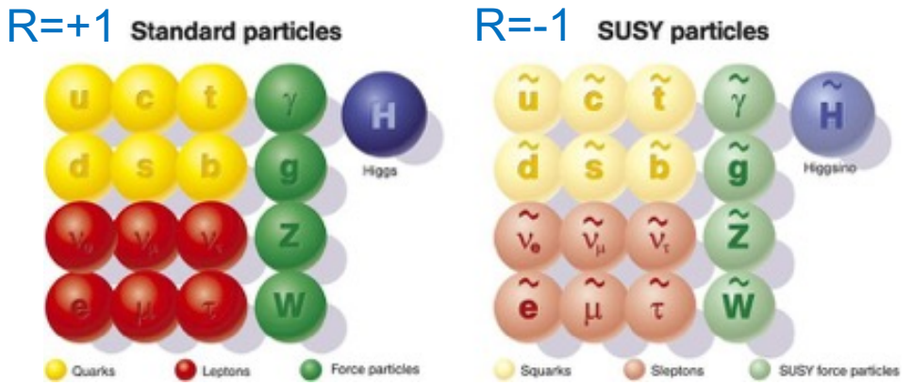
BSM at the Terascale: the constituents



Natural SUSY searches: RPV stop production

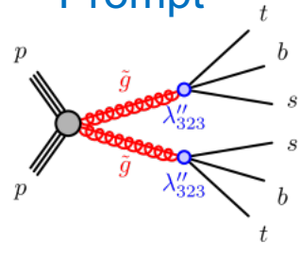
- R-Parity Violating (RPV) SUSY model:
  - Strong **experimental** constraints for many R-Parity conserving models evaporates
- Pheno paper identified uncovered region of phase space with large heavy flavor production
- Run 2 analysis published in 2021
  - Reinterpretation of the analysis for Gtt models

S. Diglio, G.Moultaka, L.Feligioni **Stashing the stops in multijet events at the LHC**, Phys. Rev.D 96 (2017), arXiv:1611.05850 [hep-ph]

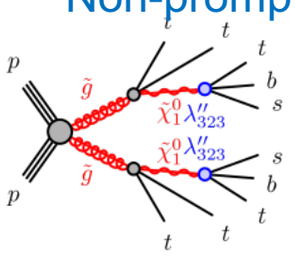


ATLAS Collaboration, **Search for phenomena beyond the Standard Model in events with large b-jet multiplicity using the ATLAS detector at the LHC**. Eur. Phys. J. C 81 (2021) 11

Prompt

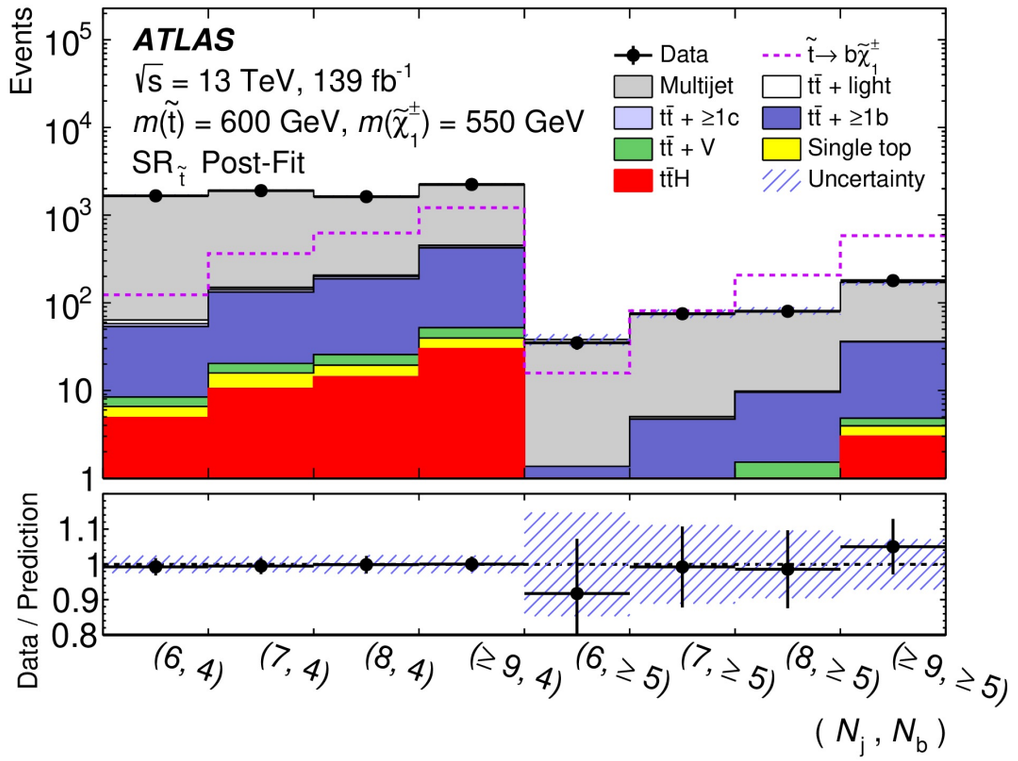


Non-prompt

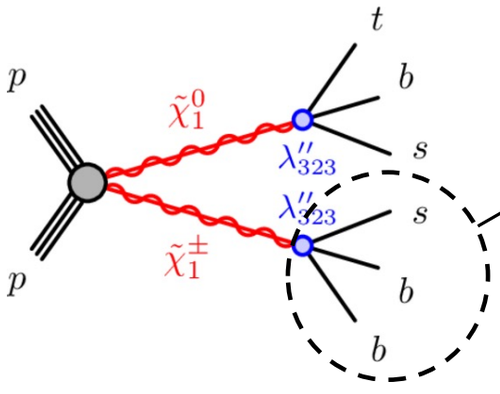


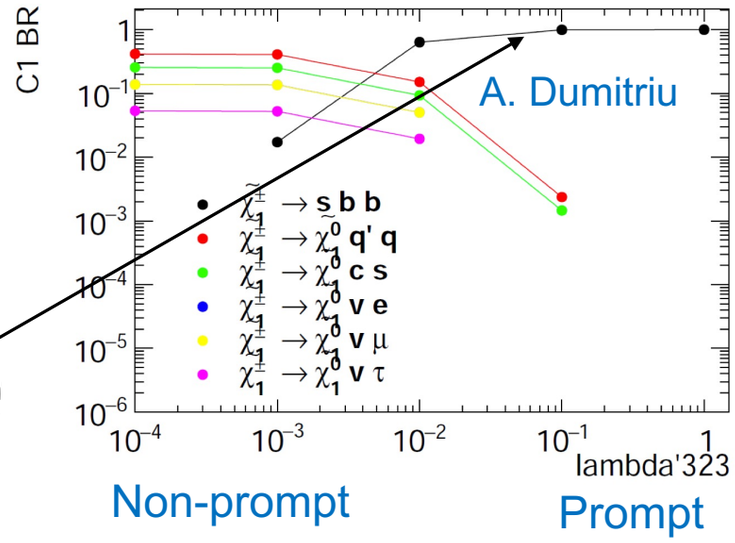
reinterpretation

G. Bartolini, L. Feligioni, G. Moultaka, N. Nguyen, E. Nagy, M. Talby



- Investigation of new possible reinterpretation of EW analysis
  - model scans





LHC Higgsology with the Type II seesaw model

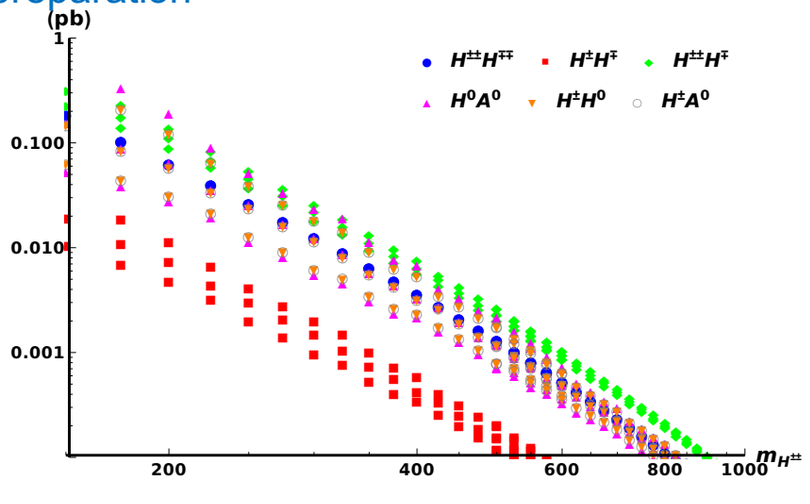
- A model for neutrino masses implying naturally a SM-like Higgs (despite the extension).
  - A rich scalar sector: 7 massive physical Higgses

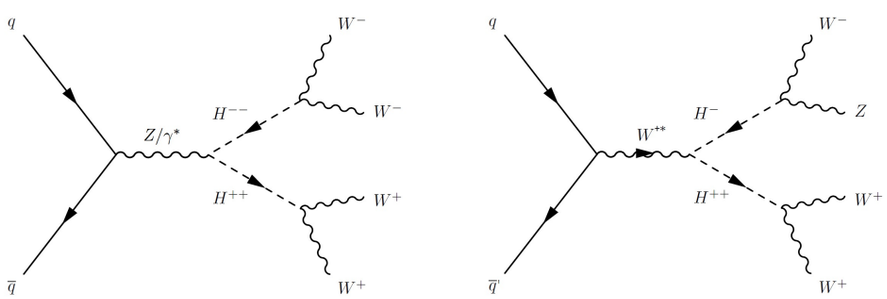
Collaboration theory-experimental

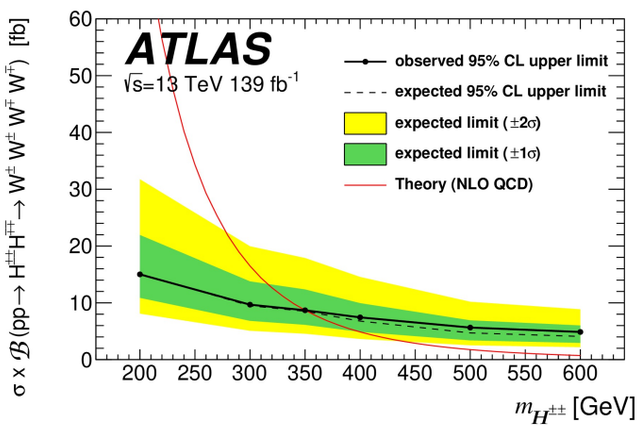
  - Implementation of the model in MadGraph and Delphes, scan of the parameter space, generation of events, extension of the study to associate production and others, including neutral states.

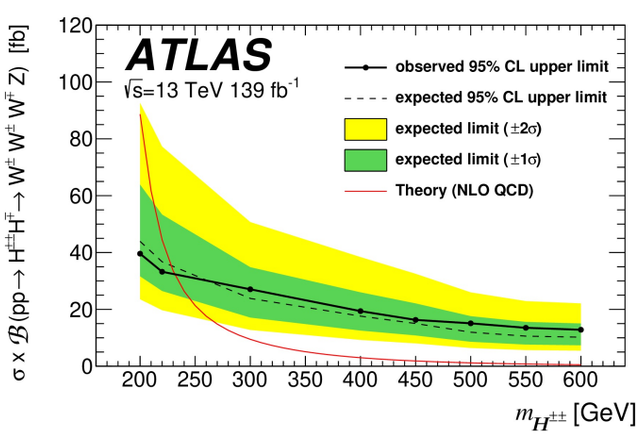
- Data analysis using final state already exploited at CPPM
  - First result on full 2015+2016 data 37 fb-1 analysis (Eur. Phys. J. C 78, (2018) arXiv:1710.09748)
  - New result with full Run 2 data result includes pair and associated production

A. E. Dumitriu, Y. Liu, E. Monnier, G. Moultaka, H. Xu, **Type II seesaw Higgs triplet production and decays at the LHC**, In preparation









*New Run2 data including extension of phase + Run3 first period aimed at global analysis H++ adding **new neutral channels***

ATLAS Collaboration, **Search for doubly- and singly-charged Higgs bosons decaying into vector bosons in multi-leptons final states with the ATLAS detector using proton-proton collisions at √s = 13 TeV**. JHEP 06 (2021) 146,

C. Diaconu, O. A. Ducu, A. Dumitriu, Y. Liu, E. Monnier, M. Rotaru, S. Su, H. Xu

New Physics from a natural electroweak symmetry breaking

D. Elander, M. Frigerio, M .Knecht, J.-L. Kneur, **Holographic models of composite Higgs in the Veneziano limit:**
1. Bosonic sector JHEP 03 (2021) [arXiv:2011.03003]
2. Fermionic sector arXiv:2112.14740, submitted to JHEP

Holography: strongly-coupled 4-dim gauge theory dual to weakly-coupled 5-dim gravity theory: correlation functions can be computed in the classical limit

Holographic models of composite Higgs in the Veneziano limit: large number of colours N_C and flavours N_F

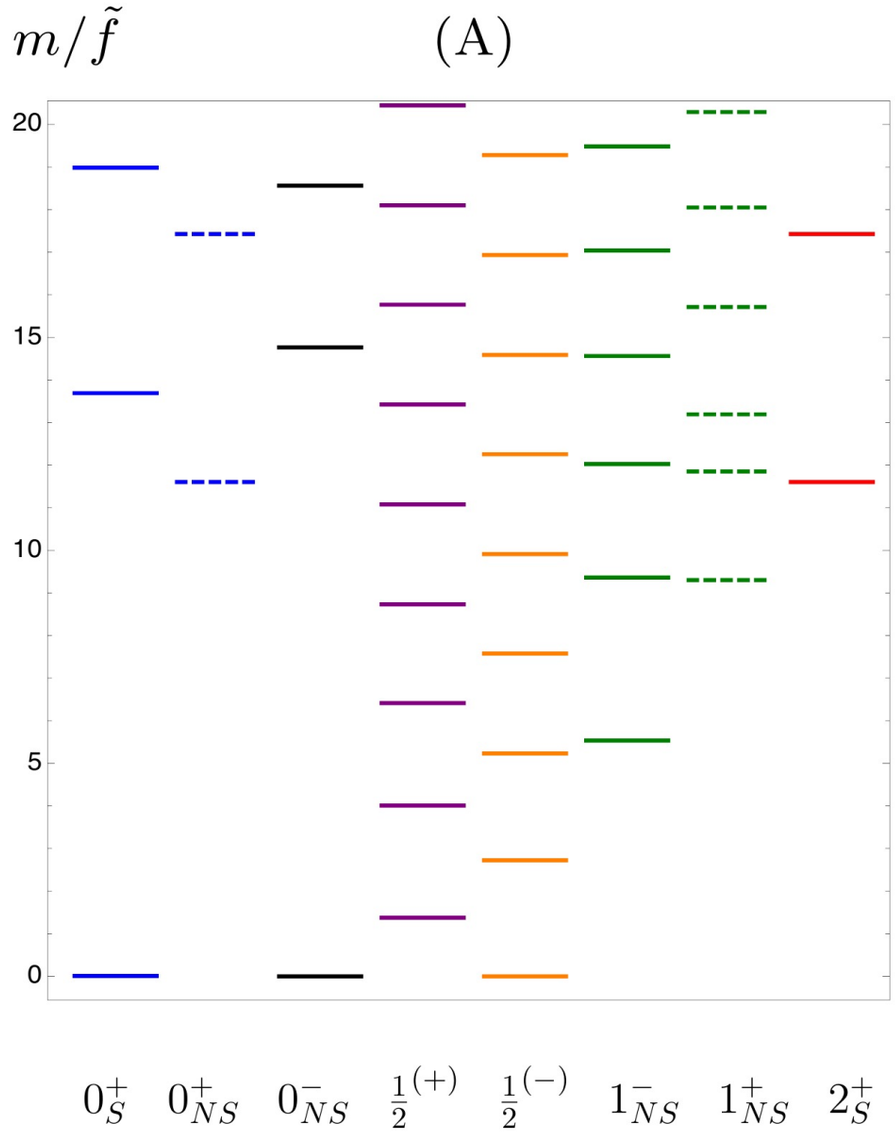
→ deformation of the minimal AdS/CFT duality (flavour backreaction on the geometry)

→ computation of the spectrum of bosonic and fermionic resonances

→ non-perturbative RG evolution of coupling between elementary and composite fermions

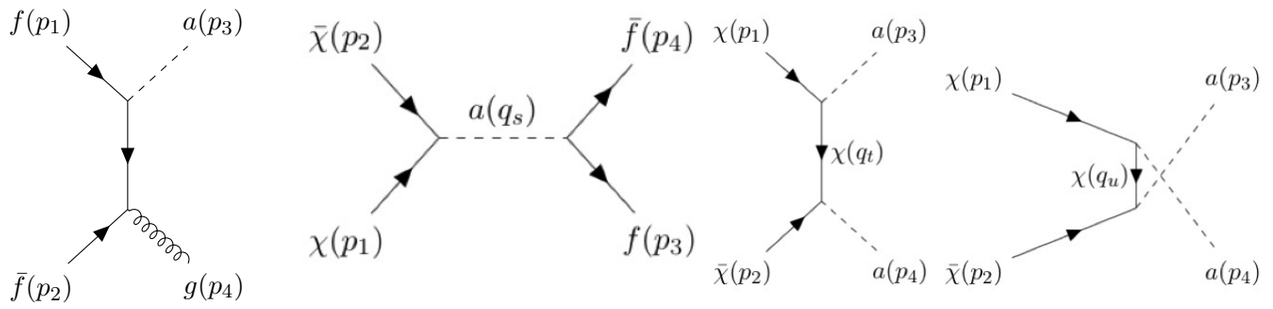
- Future directions: Higgs potential, **LHC signatures**, renormalisation of strongly-coupled operators, dual description of anomalies, ...

Mass of bosonic and fermionic states in units of TeV / $N_C^{1/2}$



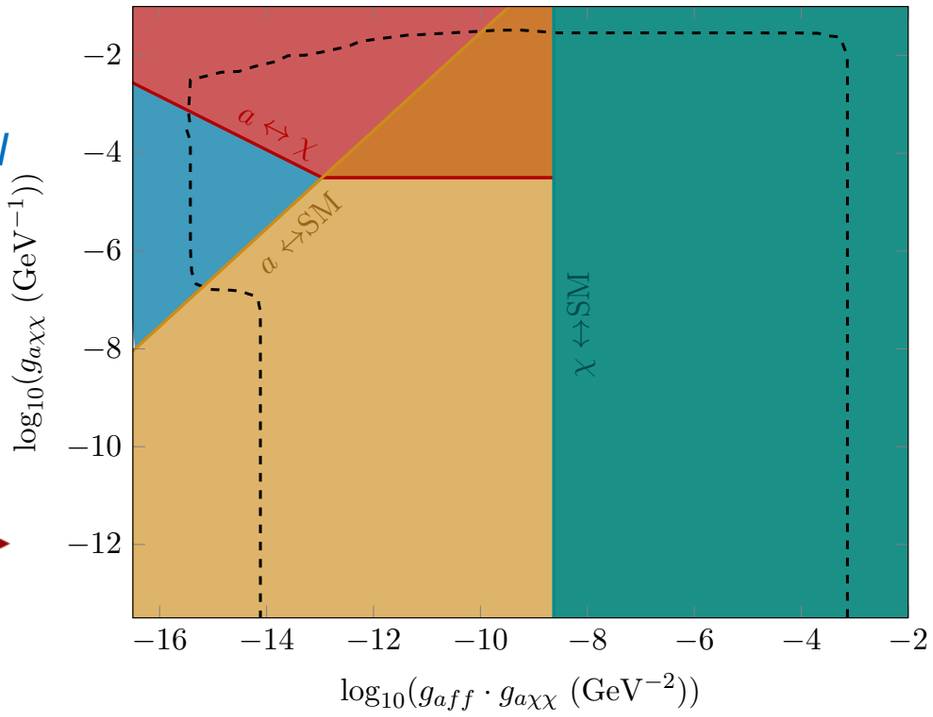
ALPs as Dark Matter (DM) mediators

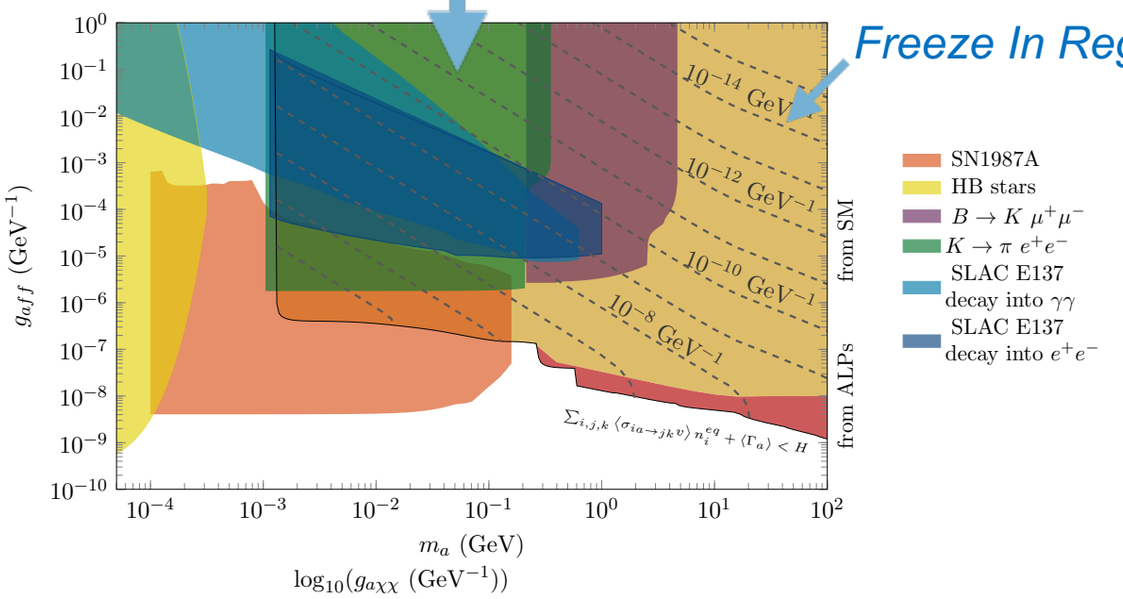
- Starting from an initial number density of zero, the ALPs and DM are generated via SM annihilations, and depending on g_{aff} and $g_{a\chi\chi}$ they might freeze in, or undergo Freeze Out in a Dark Decoupled Sector (FODDS)

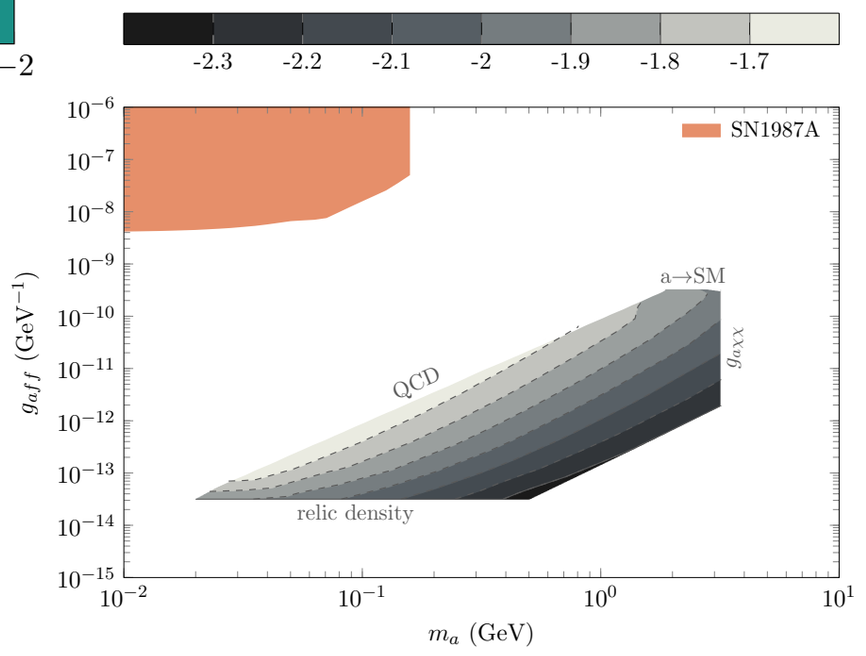


We have collected/re-calculated all flavour/cosmological and astrophysical bounds on such mediators

Newly developed Fortran code, by solving differential equations obtained full phase diagram where relic density can be obtained via different DM generation mechanisms.







In the very little-studied FODDS region a system of three stiff coupled differential equations has to be solved numerically in order to obtain the correct DM relic density.

- Incorporated thermal corrections (including temperature dependent masses for fermions and gauge bosons and temperature dependent couplings).
- F. Brümmer (LUPM), A. Bharucha, S. Mutzel (CPT) and N. Desai (TIFR, India), **Paper in last stage of finalization**

Conclusions

- The SM-like properties of the 125 GeV Higgs boson and the absence of direct signs of TeV physics beyond the SM go hand in hand
  - New physics at EW scale theoretically well-motivated, may still be hidden if sufficiently weakly coupled to the SM.
- BSM Physics at the Terascale is a collaborative experimental-theoretical project: **phenomenological investigations ⇔ ATLAS data analysis**
  - A new experimental results appeared in 2021, from original ideas developed within OCEVU
  - Many phenomenology papers produced addressing dynamical explanation of EWSB, particle physics solution to the problem of dark matter, explanation of neutrino masses.
  - Strong link built between different labs
- Next…continue a successful interface between theory and experiment
  - Keep exploiting Run 2 data: recasting in terms of new searches (multi-b RPV), reinterpretation of ATLAS results (DM) including Run 3 first data for extended analysis (H++)
  - Take advantage of CPPM involvement for ATLAS upgrade (calorimeter, pixel, trigger) for Run 3/HL-LHC future analysis
    - ANR collaborative project presented for the 2021 call (CPPM-L2C)
    - Answered to AMU Interdisciplinarity AAP (low mass resonances at LHC)
  - Finalize ongoing pheno papers (DM, Type II seesaw)
- We ask to keep supporting our travels, workshop organization and visiting scientist/students in 2021