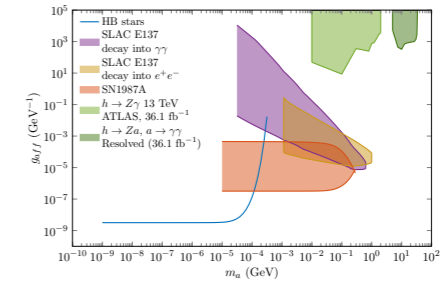
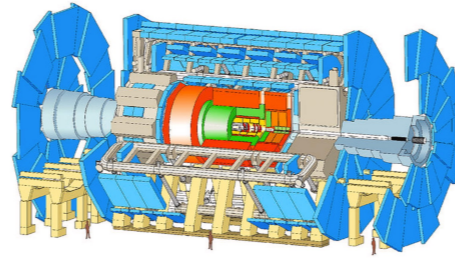
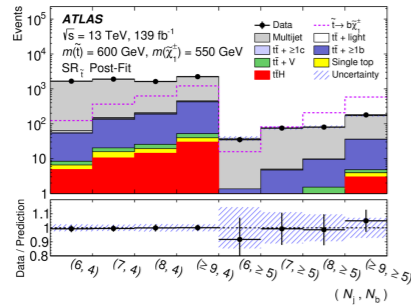


BSM Physics at the Terascale

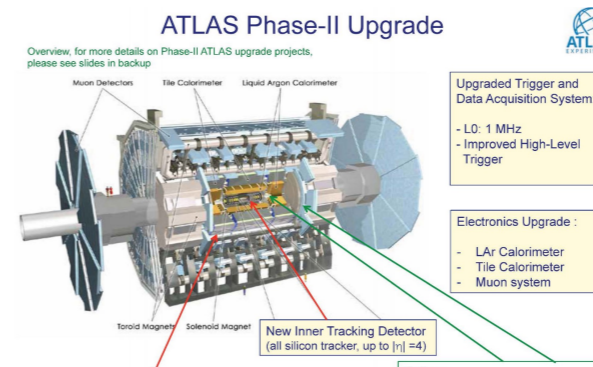
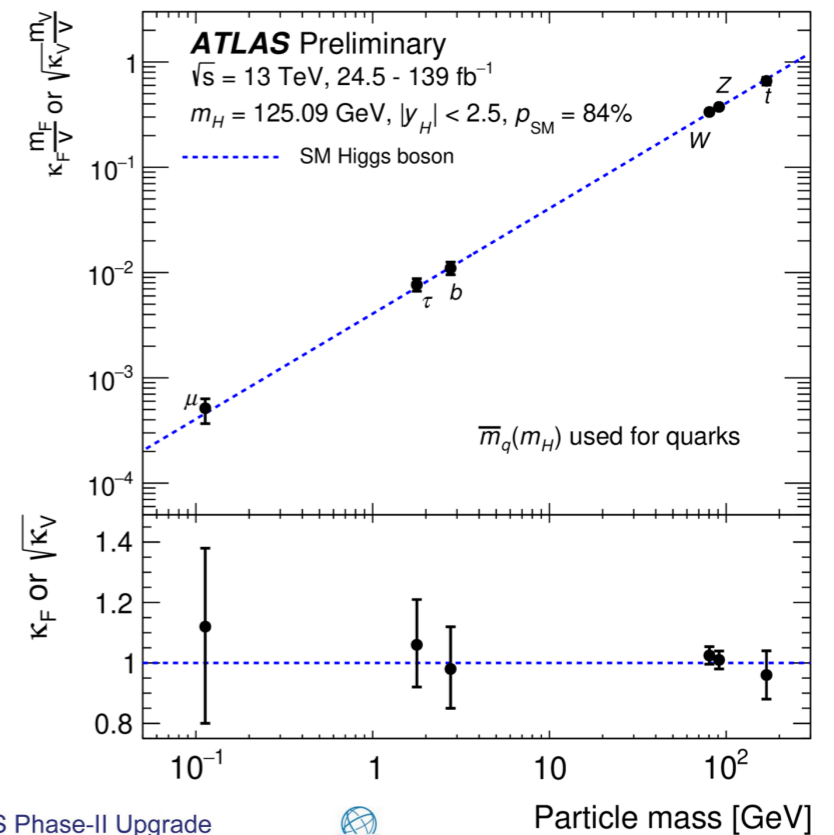


IPhU days Marseille 20 January 2023

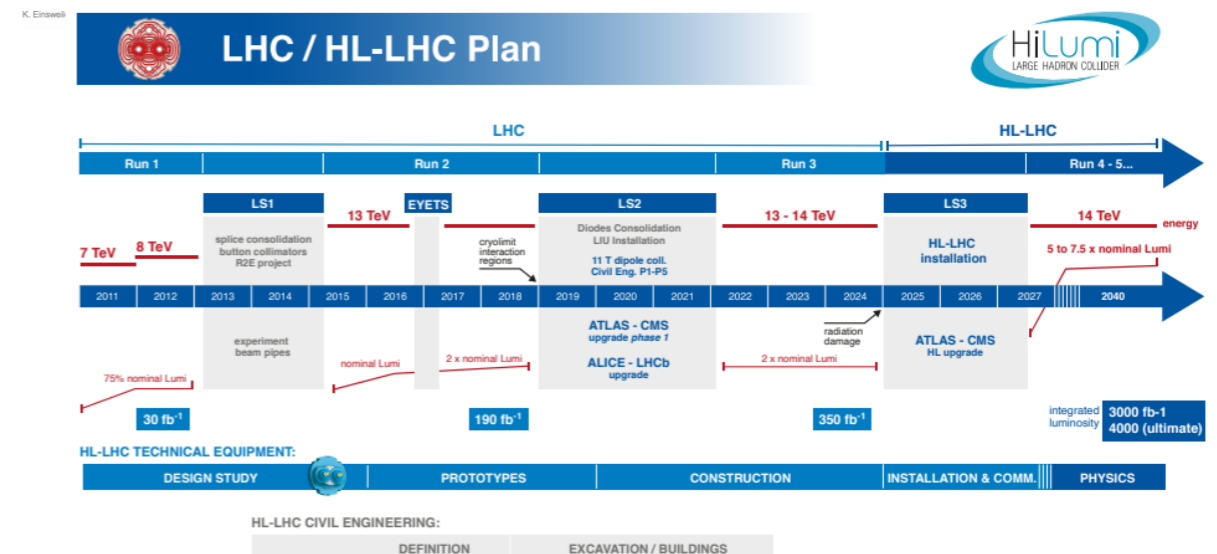
Lorenzo Feligioni obo the group

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.



Upgraded ATLAS for Run 3

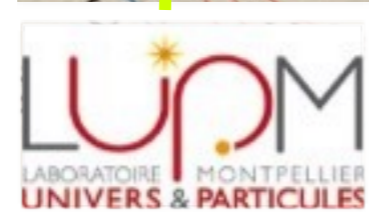


BSM at the Terascale: the constituents

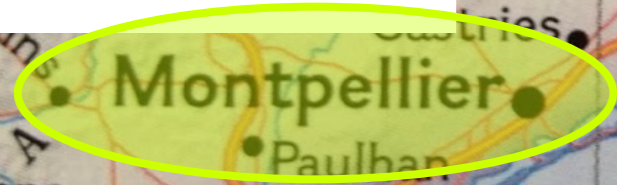
BSM Higgs physics, MSSM, NMSSM (spectrum calculation, couplings, branching ratios,...) Composite Higgs models (new heavy states properties,...) QCD non-perturbative methods, Dark matter (complementary, constraints,...)



Particle phenomenology, flavor physics, low-E precision physics, BSM physics, non-perturbative strong-interaction physics, higher-loop calculations, effective theories, ab-initio lattice QCD calculations

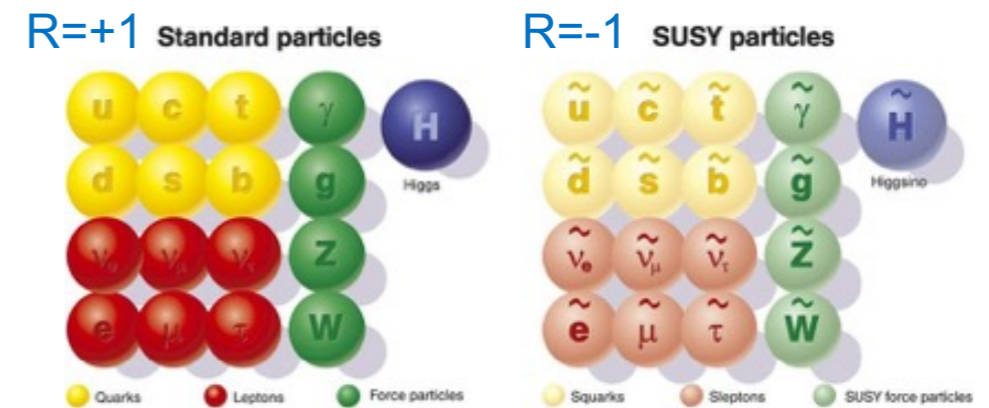


Hadron collider physics ATLAS: SM top-quark, SM Higgs, SUSY, b-jet identification

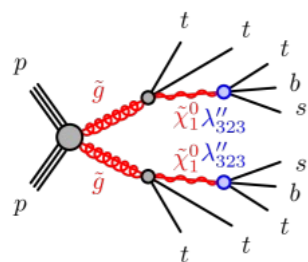


Natural SUSY searches: RPV stop production

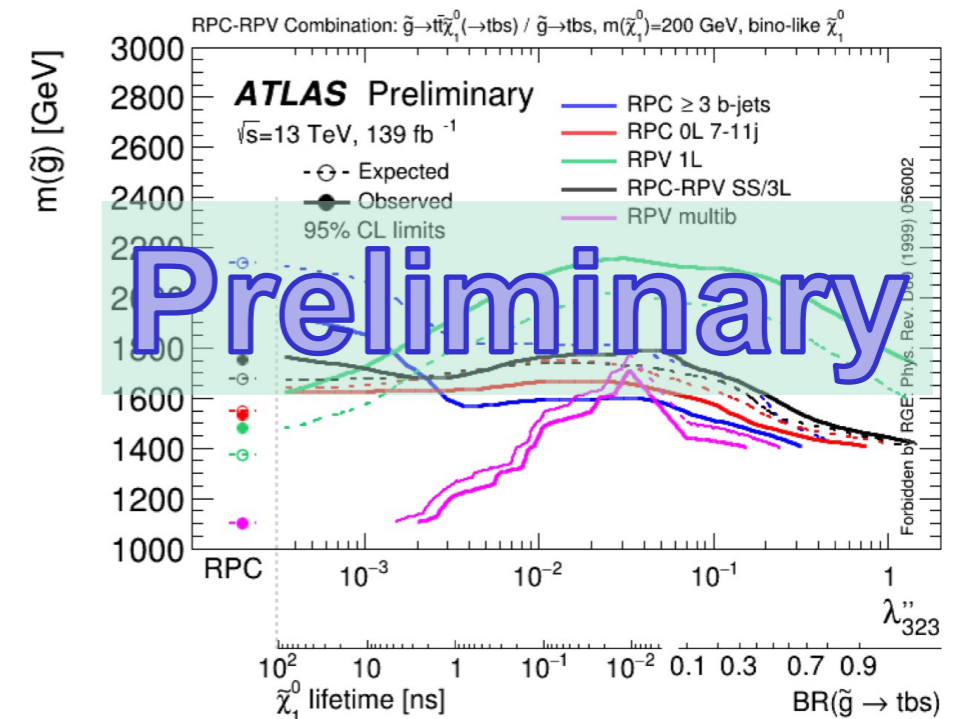
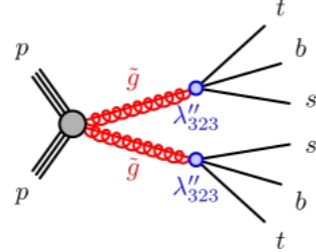
- R-Parity Violating (RPV) SUSY model:
 - Strong experimental constraints for many R-Parity conserving models evaporates
- Pheno paper identified uncovered region of phase space with large heavy flavor production
- Run 2 analysis published in 2021
 - Reinterpretation of the analysis for Gtt models



Non-prompt



Prompt

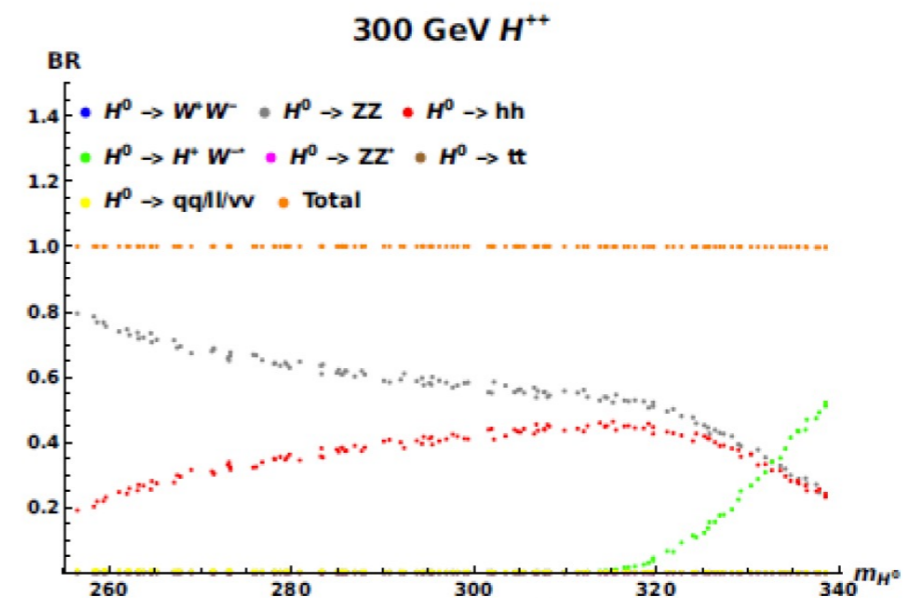


- L. Feligioni A. Dumitriu coordinate ATLAS RPC-RPV reinterpretation effort

LHC Higgsology with the Type II seesaw model

- A search for neutral (new!), singly- and doubly-charged BSM Higgs bosons – WIP
 - Guided by a type II seesaw model that extends the SM scalar sector with a scalar triplet
 - The analysis performed using the full Run-2 published last year [1]
- This year the work focused on:
 - Studying production modes involving **neutral BSM Higgs bosons**
 - Studying additional decay modes
 - Revising the model parameters (!)
 - Framework improvements, and updates to include one lepton final states (new!)
 - Signal region re-optimization
- This new analysis including also Run-3 aim at public in spring 2024

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



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) 182 [arXiv:2011.03003]

2. **Fermionic sector** JHEP 05 (2022) 066 [arXiv:2112.14740]

Holography: strongly-coupled 4-dim gauge theory (CFT) dual to weakly-coupled 5-dim gravity theory (AdS): correlation functions can be computed in 5-dim, by taking the classical limit

Composite-Higgs models in Veneziano limit: large number of colours N_C and flavours N_F

→ deformation of the minimal AdS/CFT duality (flavour fields back-react on the geometry)

→ computation of the spectrum of **bosonic and fermionic resonances**

→ renormalisation-group evolution of the coupling between the SM and composite fermions

Possible future directions:

→ computation of the Higgs potential

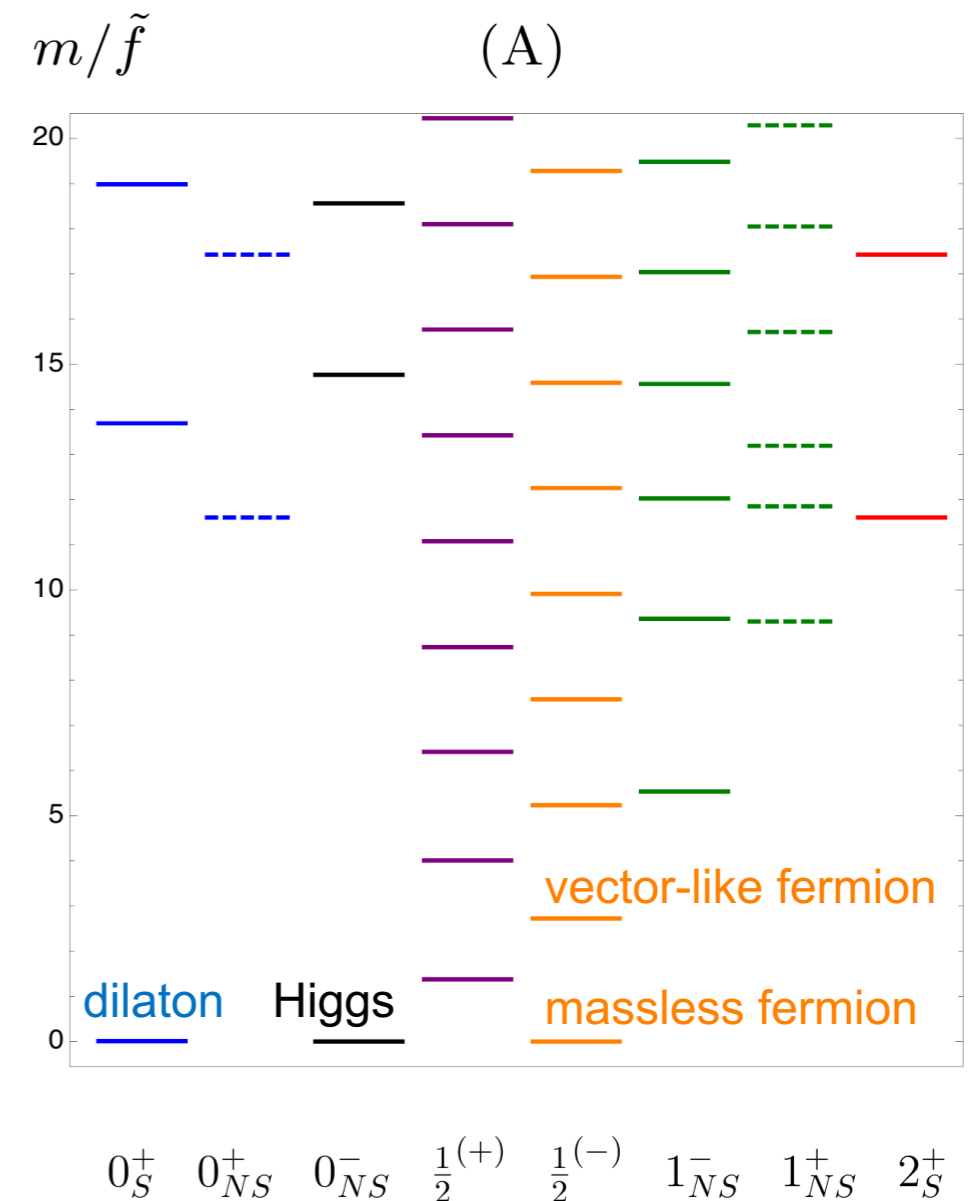
→ **LHC signatures** of the various resonances

→ anomalous dimension of strongly-coupled operators

→ AdS description of CFT anomalies

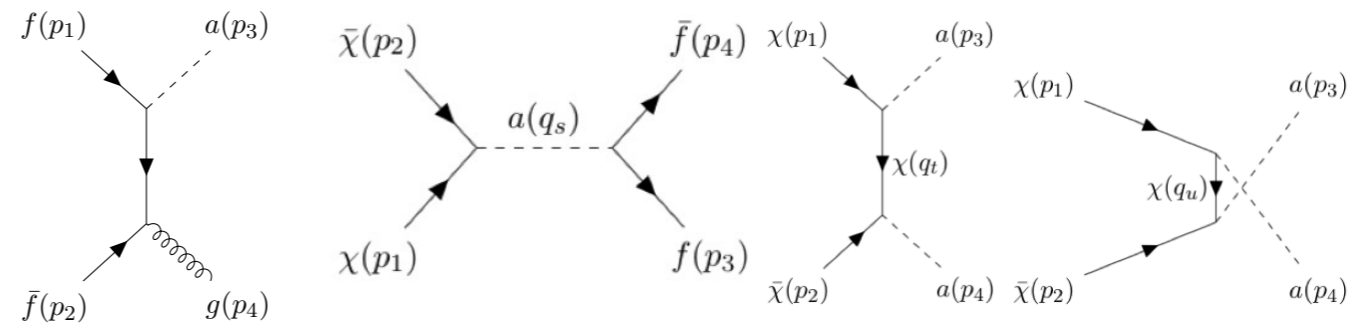
→ confinement in **chiral gauge theories**

Mass of composite bosons and fermions in units of $\text{TeV} / N_C^{1/2}$



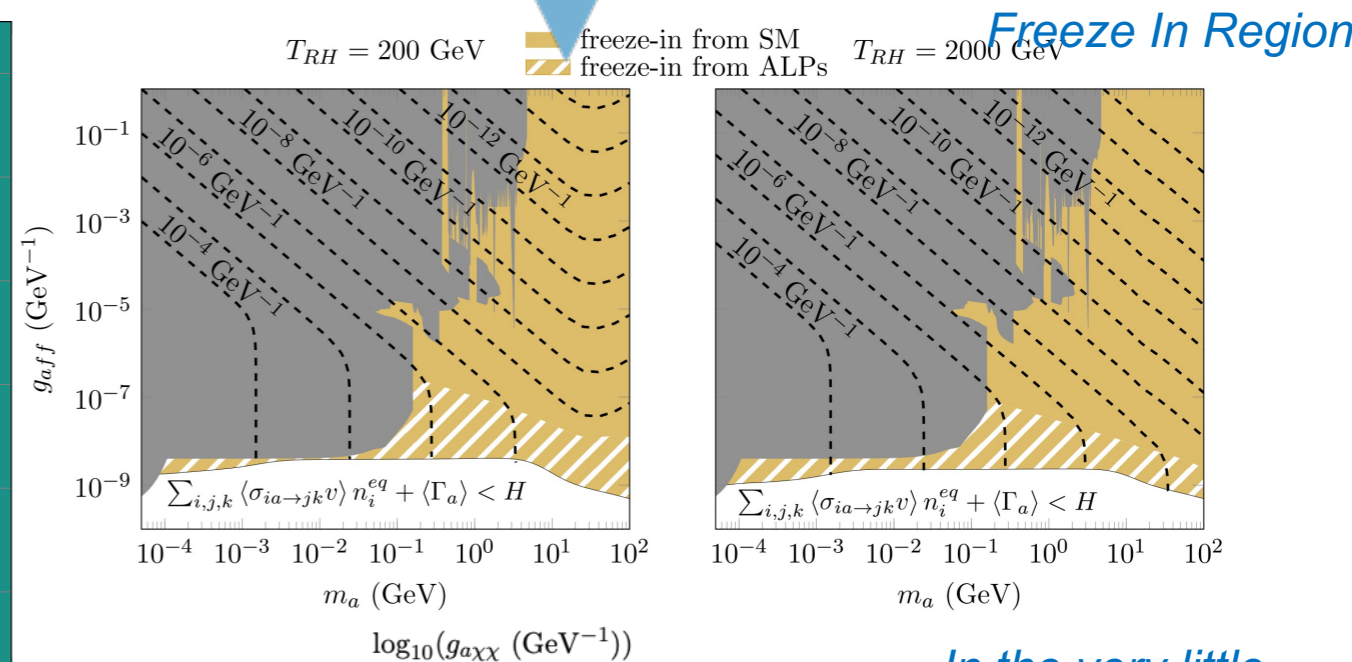
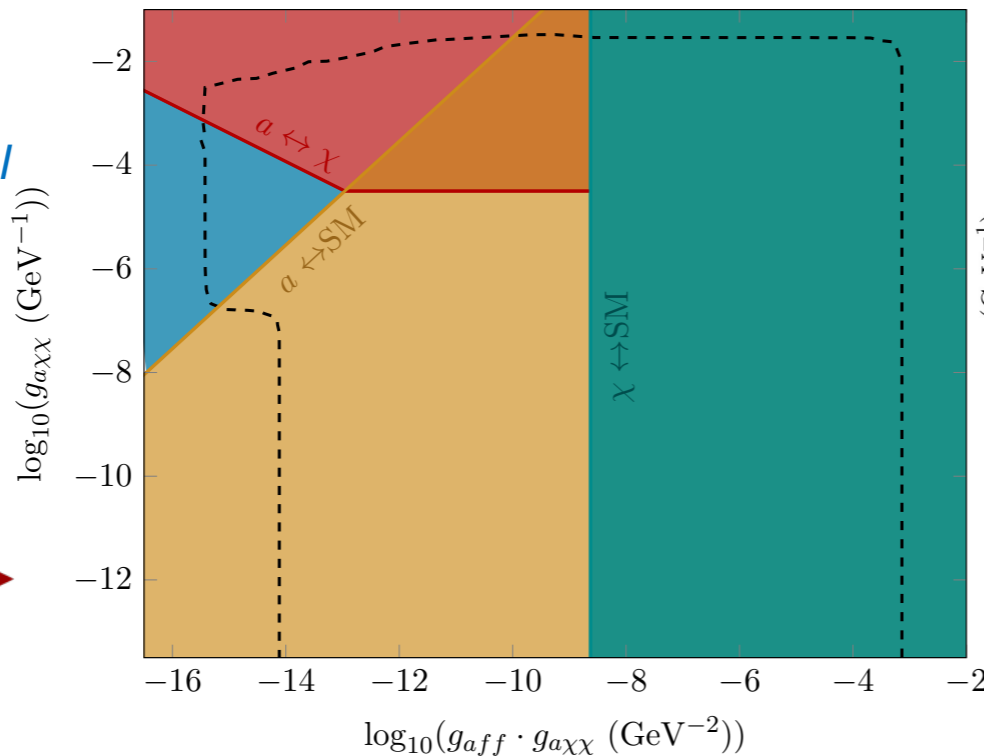
ALPs as Dark Matter (DM) mediators

- 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 (DFO)



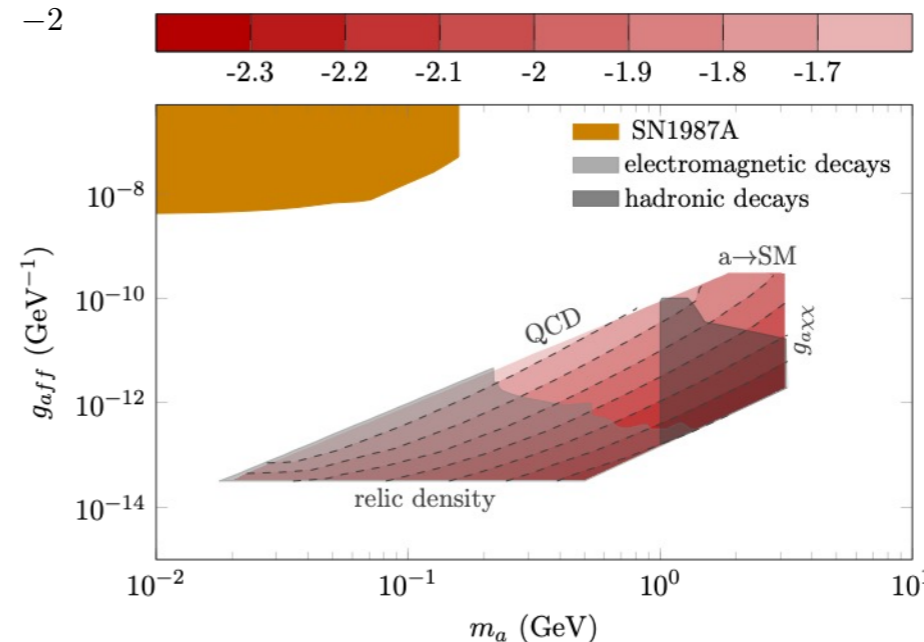
We have collected/re-calculated all flavour/cosmological and astrophysical bounds on such mediators

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



- Updated to include contributions from 5-dimensional operators, DFO region unaffected but induces UV freeze-in effects depends on reheating temperature.

- Axion-like particles as mediators for dark matter: beyond freeze-out** by A. Bharucha (CPT), F. Brummer (LUPM), N. Desai (TIFR, Mumbai), S. Mutzel (CPT), 2209.03932 [hep-ph], accepted by JHEP



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

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 \Leftrightarrow ATLAS data analysis**
 - Strong link built between different labs
 - Several experimental and pheno results produced
- Next...continue the 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++)
 - Finalize ongoing pheno papers on Type II seesaw
 - Fostering new ideas that allow us to answer AAP
 - AMU Interdisciplinarity AAP (low mass resonances at LHC) ✓
 - One month visiting scientist AMU Lidija Zivkovic ✓
 - Answered AMU AAP blanc (low mass resonances)
- Ask to keep supporting our travels, workshop organization and visiting scientist/students in 2023