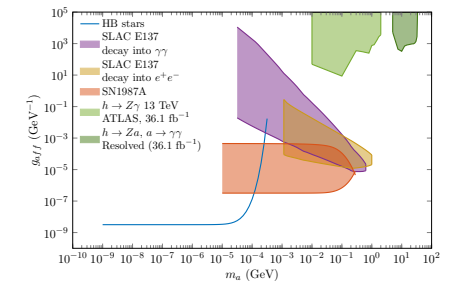
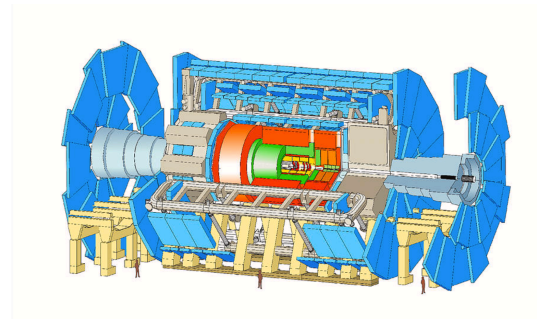
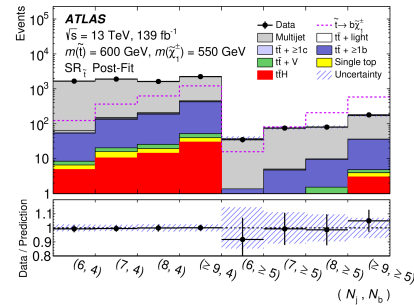


BSM Physics at the Terascale

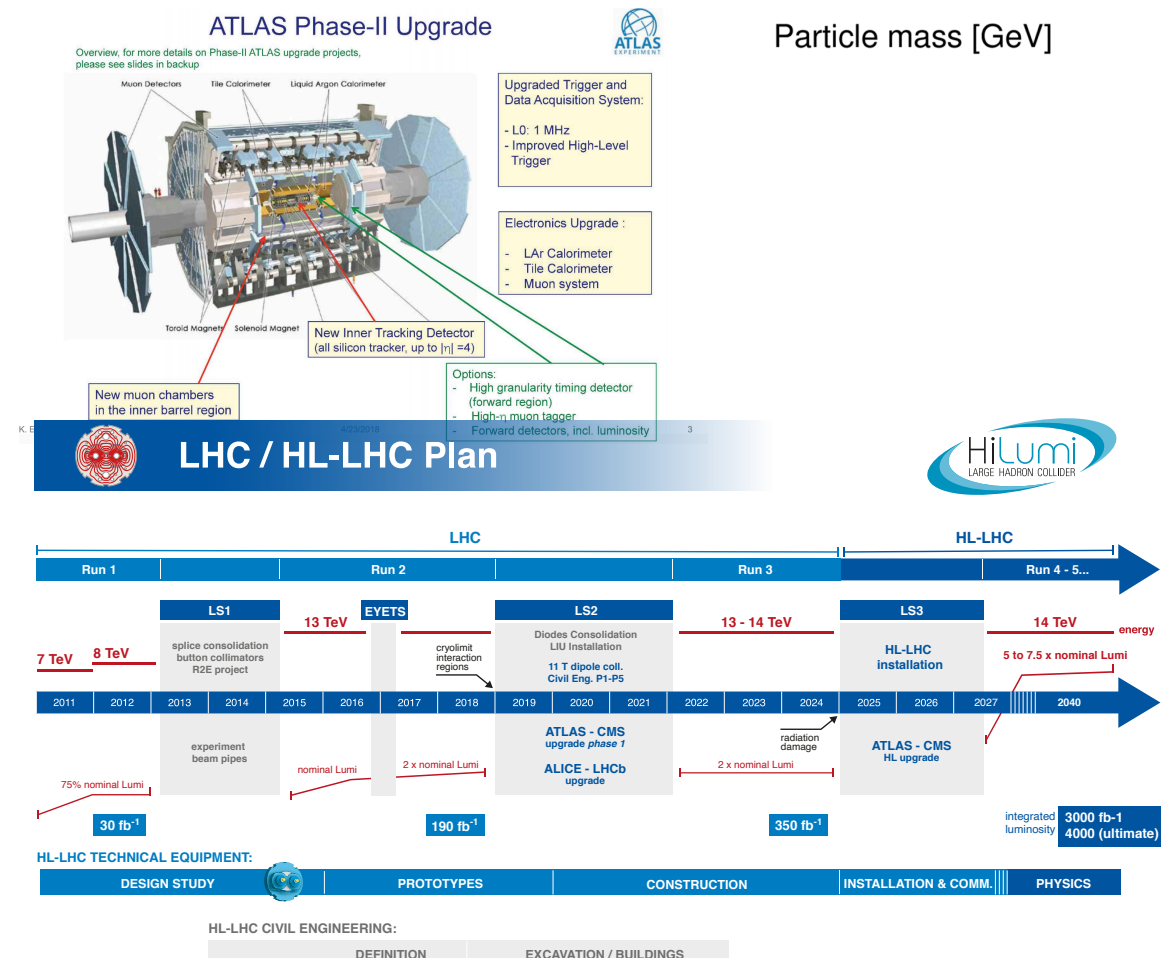
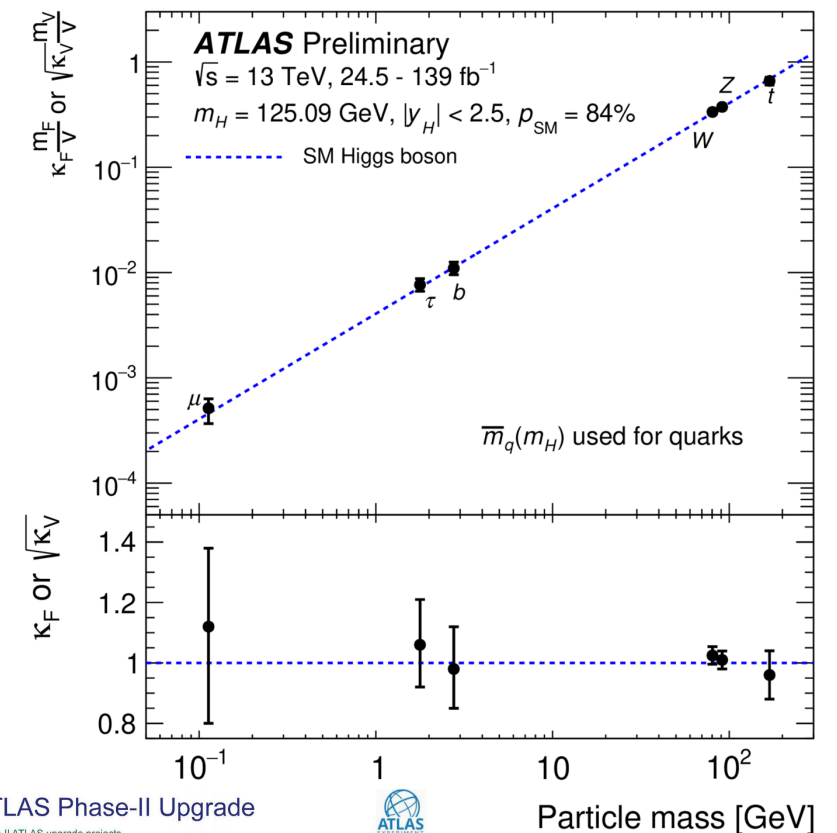


IPhU days Marseille 11/12 January 2020

Lorenzo Feligioni

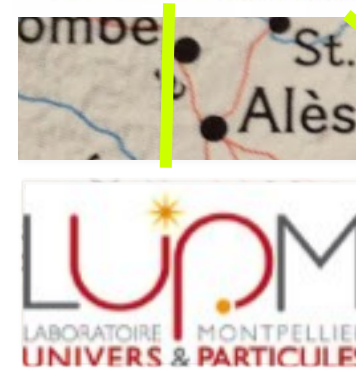
BSM at the Terascale: the constituents

- 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

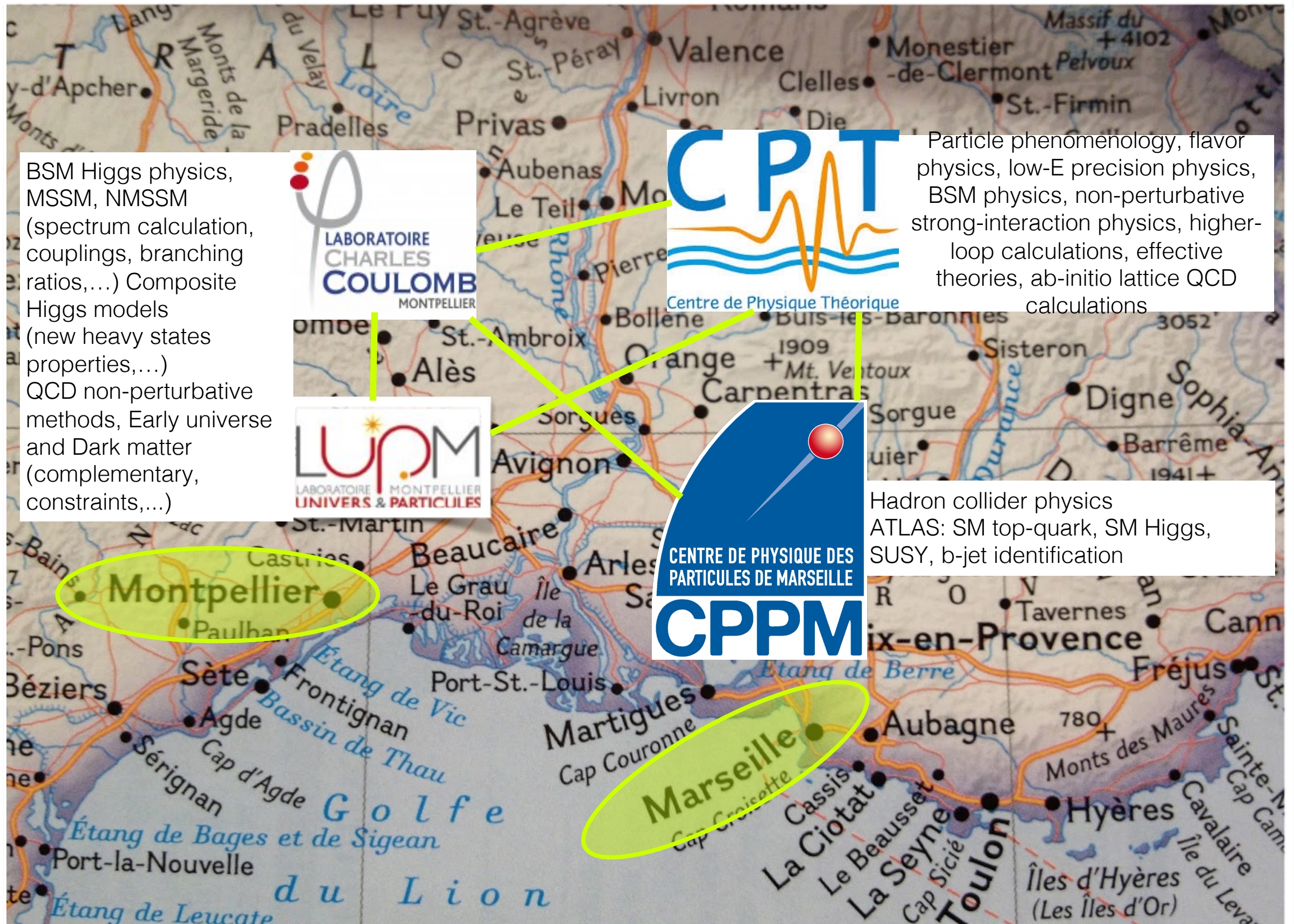
BSM Higgs physics,
MSSM, NMSSM
(spectrum calculation,
couplings, branching
ratios,...) Composite
Higgs models
(new heavy states
properties,...)
QCD non-perturbative
methods, Early universe
and Dark matter
(complementary,
constraints,...)



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

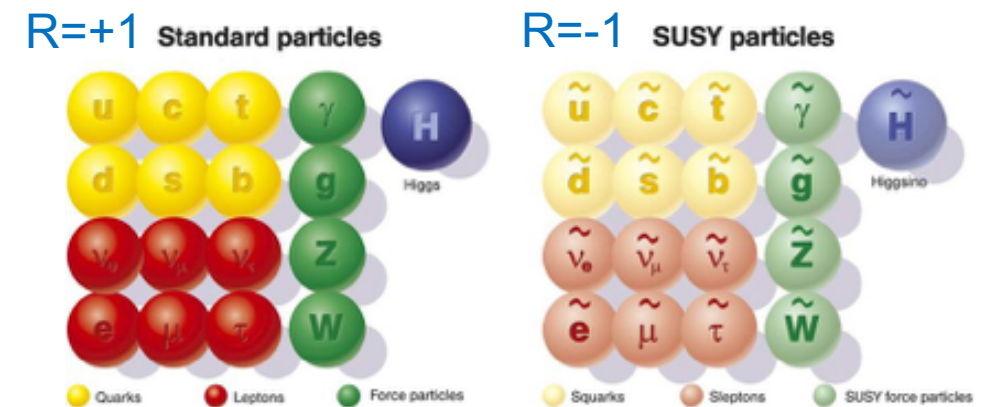


Natural SUSY searches: RPV stop production

- R-Parity Violating (RPV) SUSY model:
 - Light top squark favored scenario by natural SUSY
 - Strong experimental constraints for many R-Parity conserving models
- Pheno paper identified uncovered region of phase space with large heavy flavor production

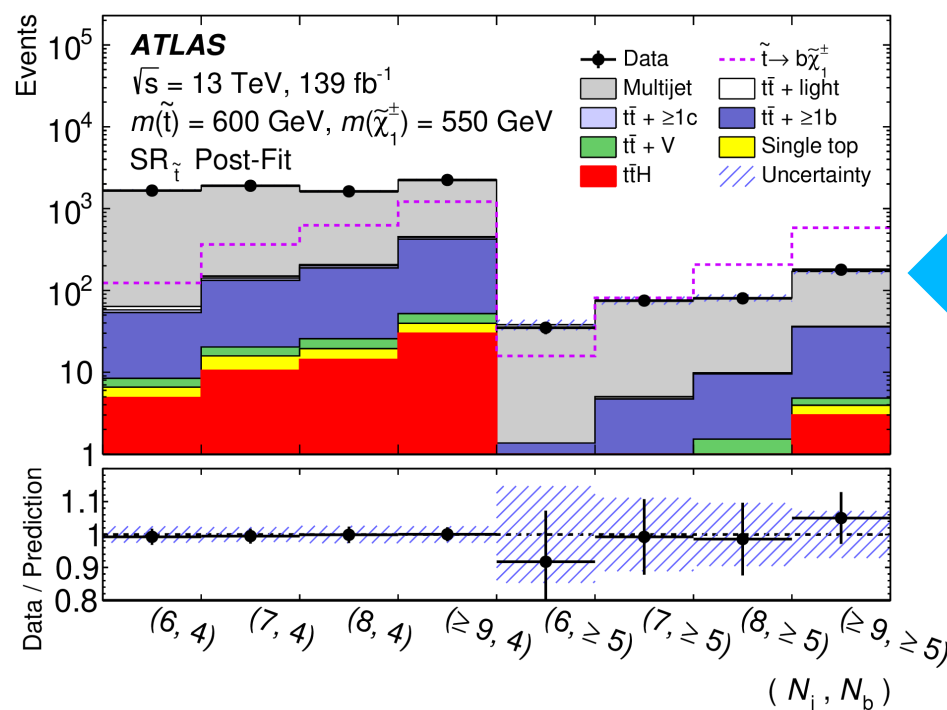
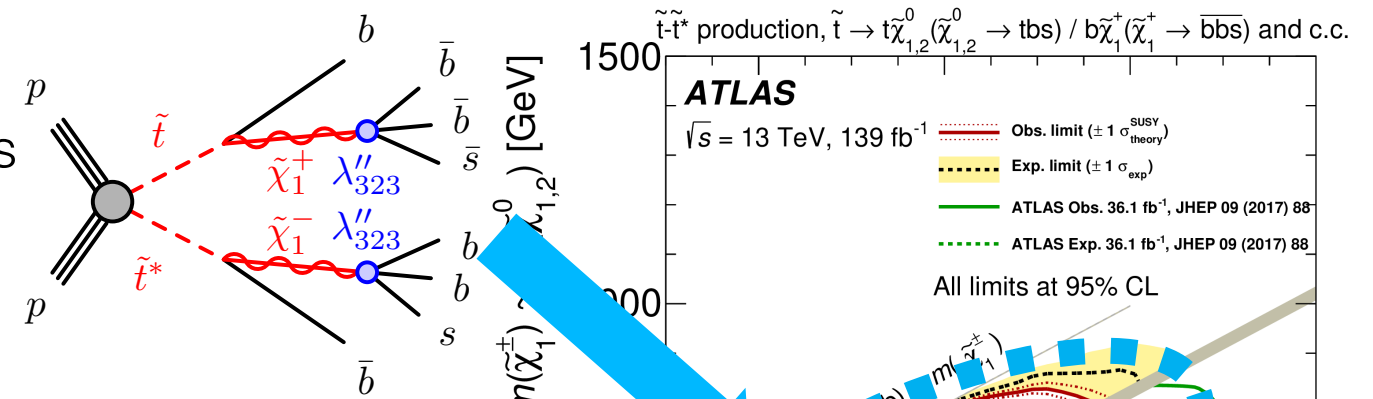
S. Diglio, G. Moutaka, L. Feligioni **Stashing the stops in multijet events at the LHC**, Phys. Rev.D 96 (2017), arXiv:1611.05850 [hep-ph]

- Run 2 analysis finalized in 2020
 - CPPM leading role in fully hadronic final states
→ complementarity with ttH analysis

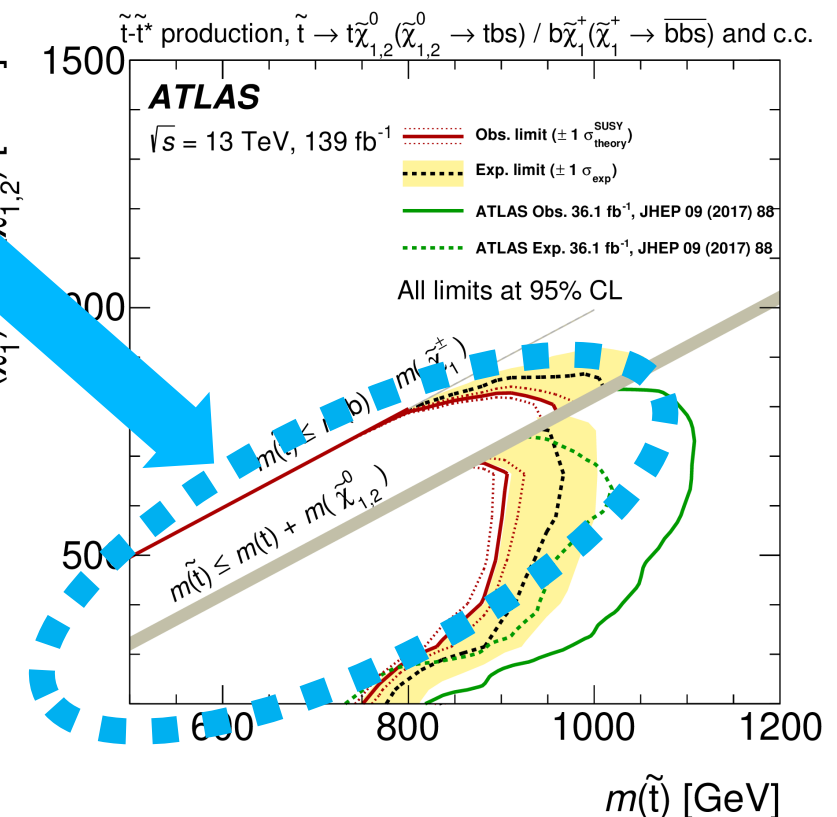


Stabilization of the Higgs mass

$$\delta m_{H_u}^2 = -\frac{6y_t^2}{16\pi^2}\Lambda^2 + \frac{6y_t^2}{16\pi^2}\Lambda^2 - \frac{3y_t^2}{4\pi^2}m_{\tilde{t}}^2 \ln(\Lambda/m_{\tilde{t}}) + \dots$$



No measured excess found
In events with at large jet and
b-jet multiplicity



ATLAS Collaboration, **Search for phenomena beyond the Standard Model in events with large b-jet multiplicity using the ATLAS detector at the LHC.**
2010.01015 [hep-ex]

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

New Physics from a natural electroweak symmetry breaking

N. Bizot, M. Frigerio, M. Knecht, J.-L. Kneur, **Non-perturbative analysis of the spectrum of meson resonances in an ultraviolet-complete composite-Higgs model**, arXiv:1610.09293 [hep-ph], Phys.Rev.D95 (2017)

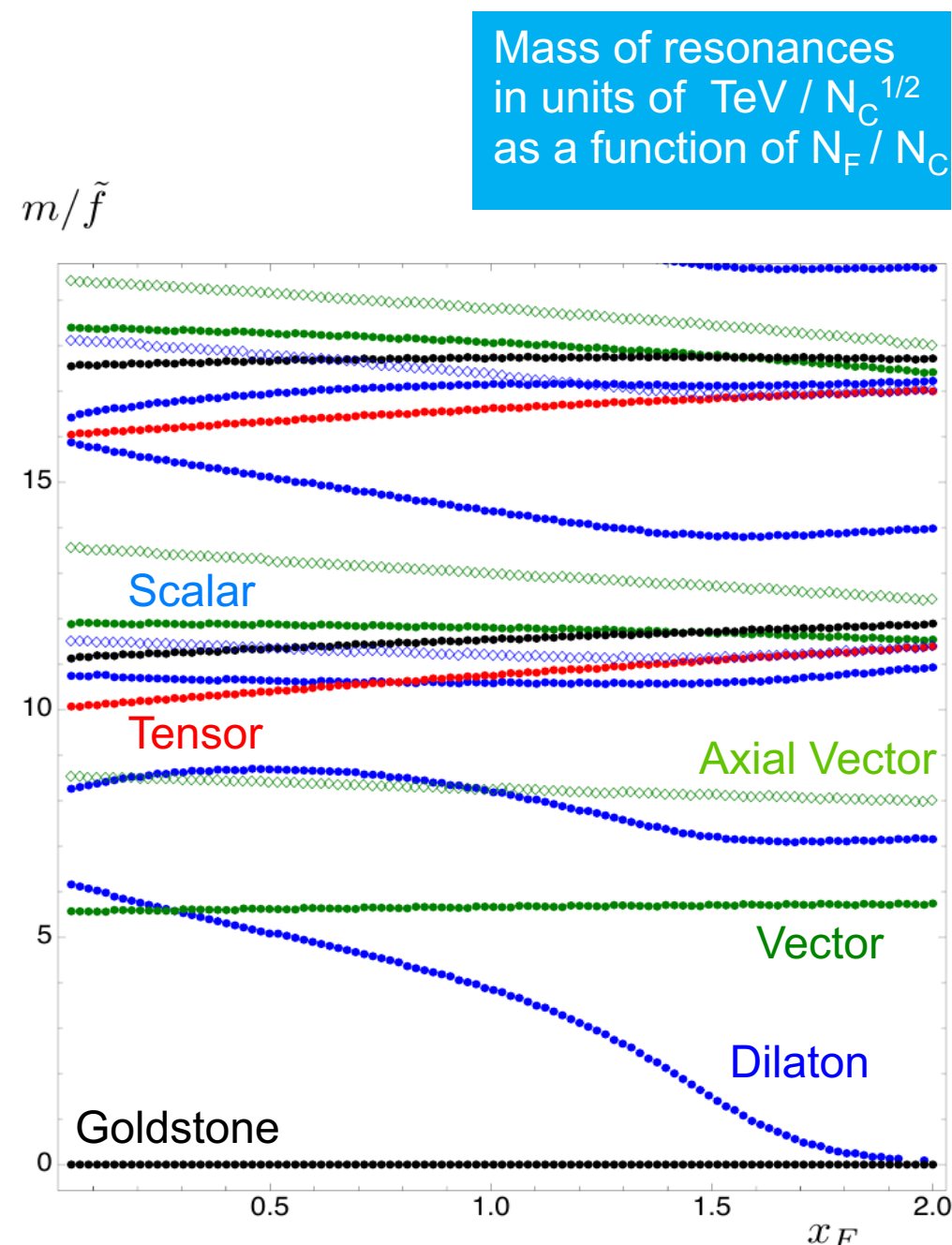
- **Holography**: strongly-coupled 4-dim gauge theory dual to weakly-coupled 5-dim gravity theory: correlation functions can be computed in the classical limit
- **Holographic models of composite Higgs in the Veneziano limit**: large number of colours N_C and flavours N_F

→ deformation of the minimal AdS/CFT duality

→ computation of the spectrum of bosonic resonances

D. Elander, M. Frigerio, M. Knecht, J.-L. Kneur, **Holographic models of composite Higgs in the Veneziano limit: 1. Bosonic sector** arXiv:2011.03003, to appear in JHEP]

- Future directions: fermionic resonances [soon to appear], Higgs potential, **LHC signatures**, renormalisation of strongly-coupled operators, dual description of anomalies, ...



LHC Higgsology with the Type II seesaw model

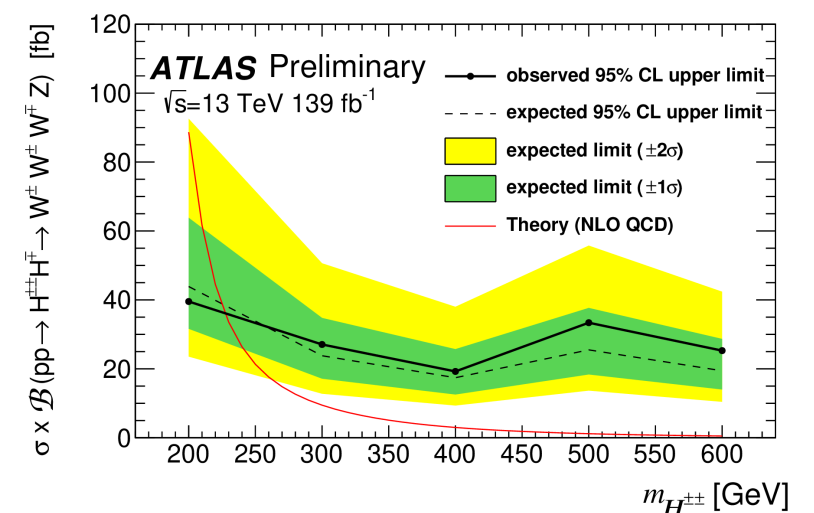
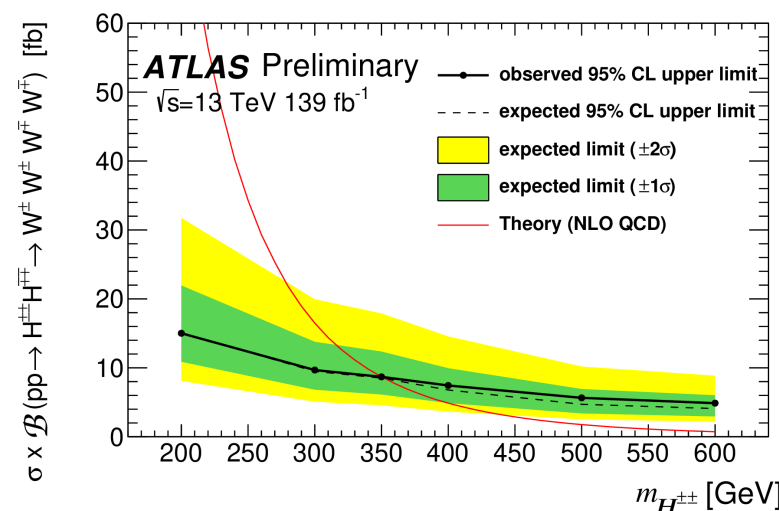
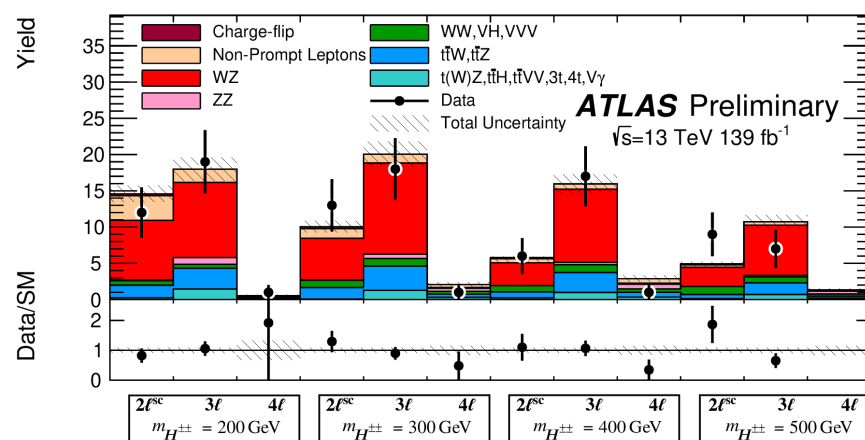
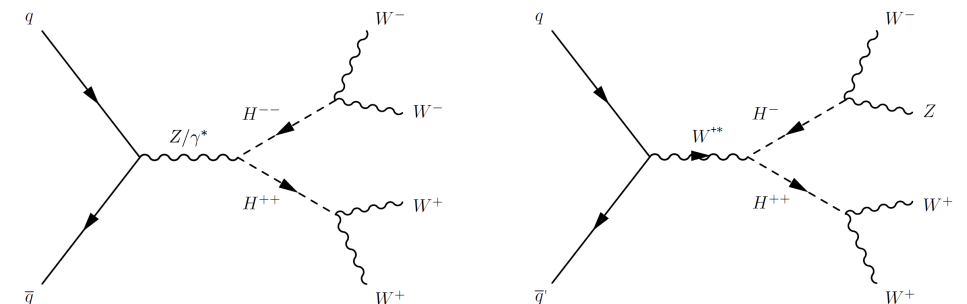
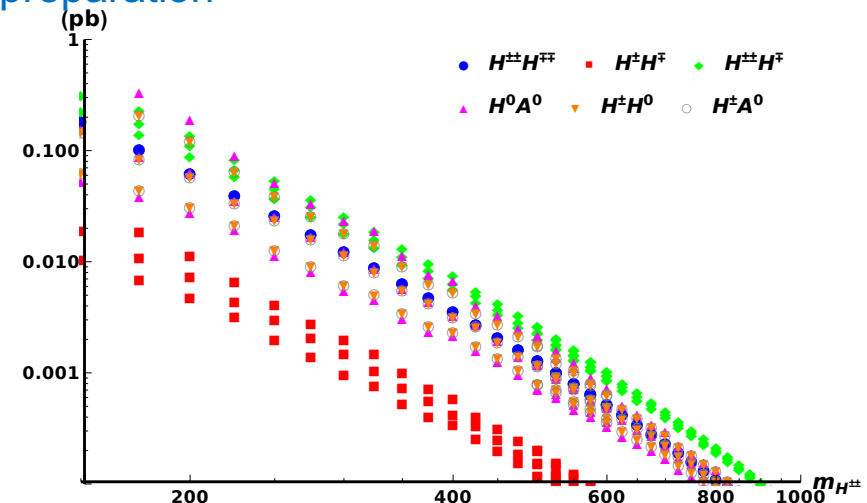
- A model for neutrino masses implying naturally a SM-like Higgs (despite the extension).

- A rich scalar sector: 7 massive physical Higgses

Collaboration theory-experimental

- Implementation of the model in MadGraph and CalcHEP, 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 Preliminary result with full Run 2 data result includes pair and associated production

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



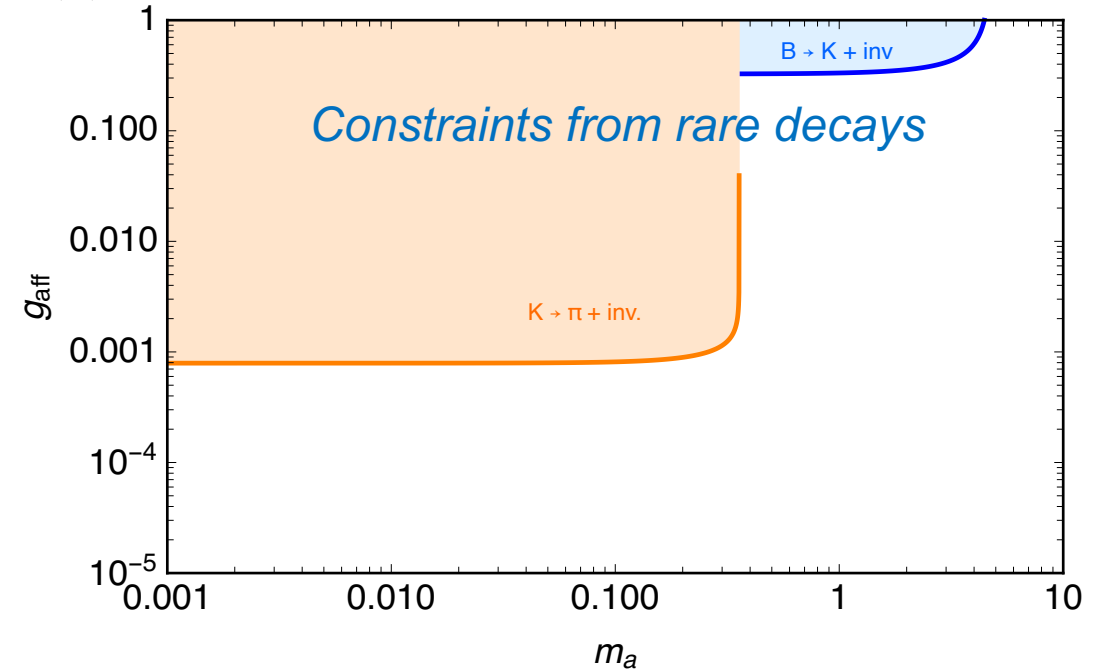
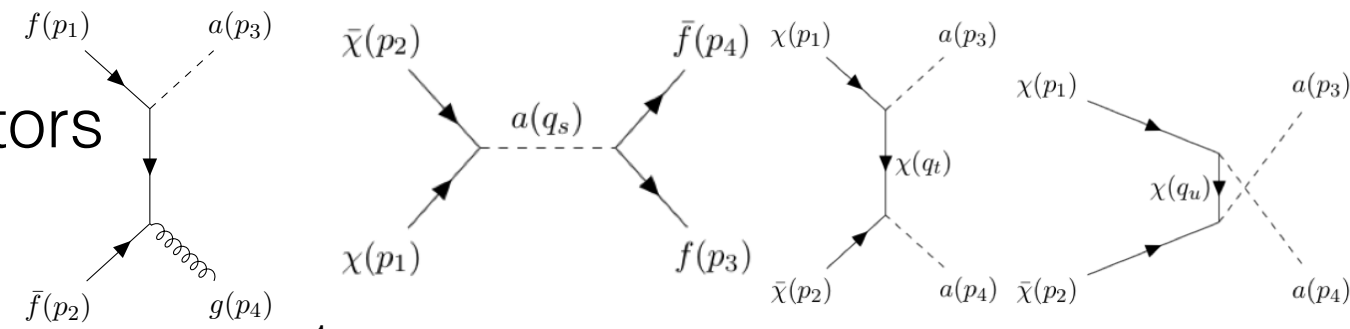
ATLAS Collaboration, **Search for doubly- and singly-charged Higgs bosons decaying into vector bosons in multi-leptons final states with the ATLAS detector using proton-proton collisions at $\sqrt{s} = 13$ TeV**. ATLAS-CONF-2020-056,

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

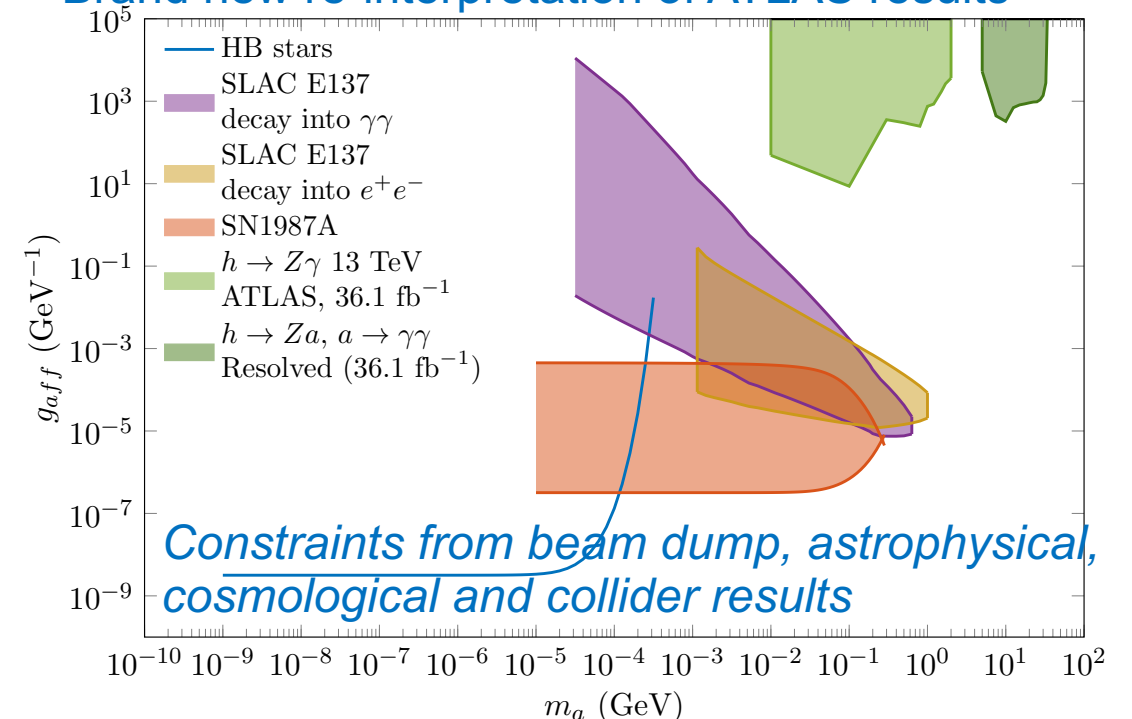
ALPs as Dark Matter (DM) mediators

- Axion-like particles could act as mediators between the SM and DM
- We have collected/re-calculated all flavour/cosmological and astrophysical bounds on such 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 **reannihilation**
- In the very little-studied reannihilation region the Boltzmann equations are complex, and the evolutions of the number density of the dark matter and axions non-trivial.
- Currently finalising the regions of parameter space $(g_{aff}, g_{a\chi\chi}, m_a, m_\chi)$ where the correct relic density is obtained

- F. Brümmer (LUPM), A. Bharucha, S. Mutzel (CPT) and N. Desai (TIFR, India), **Paper in prepration**



Brand new re-interpretation of ATLAS results



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**
 - Two new results appeared in 2020, 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
 - I.e. Lectures in Montpellier + Seminar in Marseille by Daniel Elander
- Next...continue a successful interface between theory and experiment
 - Keep exploiting Run 2 data: finalizing current analysis, recasting in terms of new searches, reinterpretation of ATLAS results
 - 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)
 - Finalize ongoing pheno papers (DM, Strong dynamics, Type II seesaw)
- We ask to keep support for travel, workshop organization and visiting scientist/students in 2021
