



Institut  
Physique de  
l'Univers

Aix\*Marseille Université

# Coordination of the Particle

## Physics Group

### IPhU Days 2022

Aoife Bharucha+  
Lorenzo Feligioni

CPT / CPPM

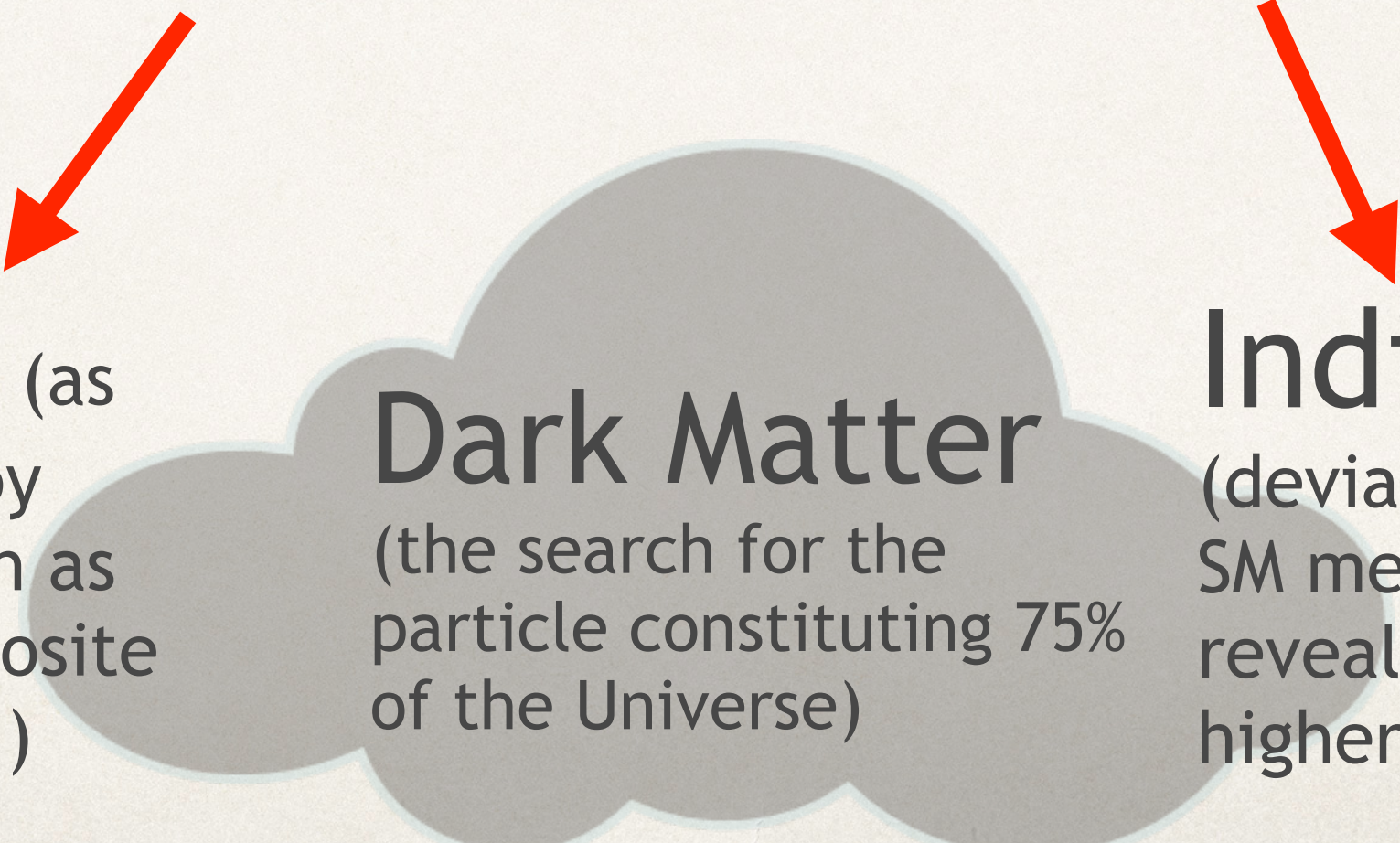




# Introduction to particle physics@IPhU

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*Searching for a better understanding of the Standard Model (SM) and probing physics beyond the SM (BSM).*



**Direct** (as predicted by models such as SUSY, composite Higgs, etc.,)

**Dark Matter**  
(the search for the particle constituting 75% of the Universe)

**Indirect**  
(deviations in precise SM measurements could reveal new physics at higher scale)



# Particle Physics

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## 2021

### June 2021

📅 03 Jun [Interplay of quark and lepton flavour at Belle II and the LHC](#)

### April 2021

📅 23 Apr [Leading hadronic contribution to the muon magnetic moment from lattice QCD](#)

### February 2021

📅 01 Feb [Low Mass Resonance Searches at the LHC](#)

## 2020

### November 2020

📅 02 Nov [Webinar - A physicist's view on pandemic dynamics](#)

### May 2020

📅 11 May [1st Topical Discussion Session: Axions and ALPs](#)

### 🏷️ Managers

👤 Aoife Bharucha

👤 Lorenzo Feligioni

# Low Mass Resonance Searches at the LHC

Monday 1 Feb 2021, 09:00 → 14:00 Europe/Paris

Aoife Bharucha (CPT, Marseille), Lorenzo Feligioni (CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR))

Description Topic: Low mass resonance at the LHC  
Time: Feb 1, 2021 09:00 AM Paris

Join Zoom Meeting

<https://cern.zoom.us/j/69459552952?pwd=VnQrdzcwXhiQ2hWVEFLYTE1TG5CZz09>

Meeting ID: 694 5955 2952

Passcode: 989071



zoom\_0.mp4

## 1st Topical Discussion Session 2021

### 09:00 → 10:00 Hunting for elusive dark sectors at the LHC

🕒 1h

Hidden sectors that comprise new strong interactions, but interact feebly with the Standard Model, are a broadly motivated possibility for new physics. In particular, a new confining sector at scales between hundreds of MeV and tens of GeV may hold the key to outstanding theoretical questions, such as the naturalness of the weak scale or the dark matter puzzle. The LHC plays a critical role in probing these scenarios, yet the associated signatures generically require targeted strategies, ranging from prompt decays involving low- $p_T$  objects, to long-lived particle signals. Taking as case in point a dark QCD coupled to the visible sector through the Higgs and Z portals, I will discuss several searches where important progress could be achieved, and review some related theoretical developments.

**Speaker:** Ennio Salvioni (CERN/University of Padua)

Talk\_Salvioni\_uploa...

### 10:00 → 11:00 Real-time analysis for low-mass resonances at the LHC

🕒 1h

The Large Hadron Collider collides protons up to 30 million times a second, and provides its experiments with an enormous amount of data. The trigger systems of each experiment quickly analyse and decide whether to retain each of those collision events from the LHC for further analysis, on a timescale of the order of milliseconds. In this seminar, I will present an overview of the tools and real-time analysis techniques employed within these trigger systems, focusing on the ATLAS experiment but also outlining elements of the strategies of the CMS and LHCb experiments. I will also present physics cases that use novel techniques to make the most of LHC data with a sensitivity that would not be achievable with standard techniques. A notable case is that of low-mass resonance searches with physics objects reconstructed and analyzed directly within the trigger system. Finally, I will give an overview of the interconnections of these real-time analysis techniques to other fields of research and industry.

**Speaker:** Caterina Doglioni (University of Geneva)



# IPhU seminar 2021

## Leading hadronic contribution to the muon magnetic moment from lattice QCD

### Leading hadronic contribution to the muon magnetic moment from lattice QCD

Friday 23 Apr 2021, 14:00 → 16:00 Europe/Paris

Aoife Bharucha (CPT, Marseille), Lorenzo Feligioni (CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR)), federico piazza (CPT, Marseille)

#### Description

zoom link: <https://univ-amu-fr.zoom.us/j/91448970216?pwd=SzhmcmRmVmpIY2l0a0JRSUpNdyszd09>



talk.pdf

14:00 → 15:00 **Leading hadronic contribution to the muon magnetic moment from lattice QCD**

🕒 1h

Twenty years ago in an experiment at Brookhaven National Laboratory, physicists measured the muon's anomalous magnetic moment,  $a_\mu = (g_\mu - 2)/2$ , with a remarkable precision of 0.54 parts per million. Ever since that time, the standard model (SM) prediction has exhibited an increasing discrepancy with experiment of over 3 standard deviations. On April 7, a new Fermilab experiment presented its first results, brilliantly confirming Brookhaven's measurement and bringing the discrepancy with the SM to the near discovery level of 4.2 sigmas. To fully leverage this and future measurements, and possibly claim the presence of new fundamental physics, it is imperative to check the SM prediction with independent methods and to reduce its uncertainties. After an introduction and a discussion of the current experimental and theoretical status of  $a_\mu$ , I will present a precise lattice QCD calculation, by the BMW collaboration, of the contribution to this quantity that most limits the precision of its SM prediction. The result of this calculation significantly reduces the gap between the SM and experiment and thus suggests that new physics is not needed to explain the current, experimental world average of  $a_\mu$ .

**Speaker:** Laurent Lellouch (CPT Marseille)



# Interplay of quark and lepton flavour at Belle II and the LHC

Thursday 3 Jun 2021, 09:00 → 14:00 Europe/Paris

Aoife Bharucha (CPT, Marseille), Lorenzo Feligioni (CPPM, Aix-Marseille Université, CNRS/IN2P3 (FR))

## 09:00 → 10:00 Probing new physics solutions to the B-meson anomalies at high-energy colliders

🕒 1h

In the past decade, several experimental collaborations have reported deviations from the SM prediction in semileptonic B meson decays, both in neutral and charged currents. These so-called "B anomalies" point towards new interactions beyond the SM that violate lepton flavor universality. In this talk we discuss some of the ongoing theoretical attempts to solve these anomalies within effective field theories, simplified leptoquark models and beyond. We focus on the phenomenology of such models and show that there is a complementarity between low-energy flavor observables and searches at high-energy colliders. We also discuss the prospects of testing some of these models at the LHC in the near future.

**Speaker:** Dr Darius Faroughy (University of Zurich)


 FLavor\_LHC\_2021.p...

## 10:00 → 11:00 Lepton flavour universality and lepton flavour violation tests at Belle II

🕒 1h

First generation B factories and LHCb measurements on lepton flavour universality in b-hadron decays point to tension with Standard Model predictions. In several new physics models explaining lepton flavour universality violation also lepton flavour violation is expected. The Belle II experiment, operating at the SuperKEKB energy-asymmetric  $e^+e^-$  collider since spring 2019, offers a unique laboratory to study lepton flavour universality and lepton flavour violation in B meson decays. In this talk highlights from the Belle II experiment with a focus on results and perspectives on measurement testing lepton flavour universality and lepton flavour violation will be discussed.

**Speaker:** Elisa Manoni (INFN - PG)

 emanoni\_06032021...

## 11:00 → 11:20

Coffee break

🕒 20m

## 11:20 → 12:30 Discussion

🕒 1h 10m

# 2nd Topical Discussion session 2021



# Ongoing projects@IPhU

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- ❖ Semileptonic measurements with excited D mesons at LHCb, e.g.  $R(D^{**})$  - IPhU PhD funding (Anton Poluetkov, Olivier Leroy, Aoife Bharucha, Jérôme Charles)  
See talk by Vlad later this afternoon!
- ❖ Direct search for WIMP Dark Matter (Pascal Pralavorio, Emmanuel Nesri et al)  
See talk by Pascal later this afternoon!
- ❖ BSM Physics at the Terascale - IPhU funding  
See talk by Lorenzo later this morning!
  - Dark Matter Models (Felix Brümmer, Aoife Bharucha)
  - Type II Seesaw Models (Gilbert Moultaqa Emmanuel Monnier, Ana Dumitriu)
  - Supersymmetry (Gilbert Moultaqa, Steve Muanza, Lorenzo Feligioni)
  - Natural electroweak symmetry breaking with a composite Higgs (Marc Knecht, Michele Frigerio, Jean-Loic Kneur)
  - Analysis of Run 3 data and preparation to the HL-LHC phase (Fundamental is the involvement in ATLAS upgrade (calorimeter, pixel, trigger), ANR collaborative presented for the 2021 call (CPPM-L2C))
- ❖ School of Statistics SOS2022 (Yann Coadou) (M. Talby, L. Feligioni, M. Frigerio, G. Moultaqa, E. Petit, F. Bruemmer)
- ❖ Development of artificial intelligence algorithms adapted to big data processing in embedded (FPGAs) trigger and data acquisition systems at the LHC - AIDoc@AMU thesis (started 2020) (Lauri Laatu)



# Direct search for WIMP dark matter

## Project:

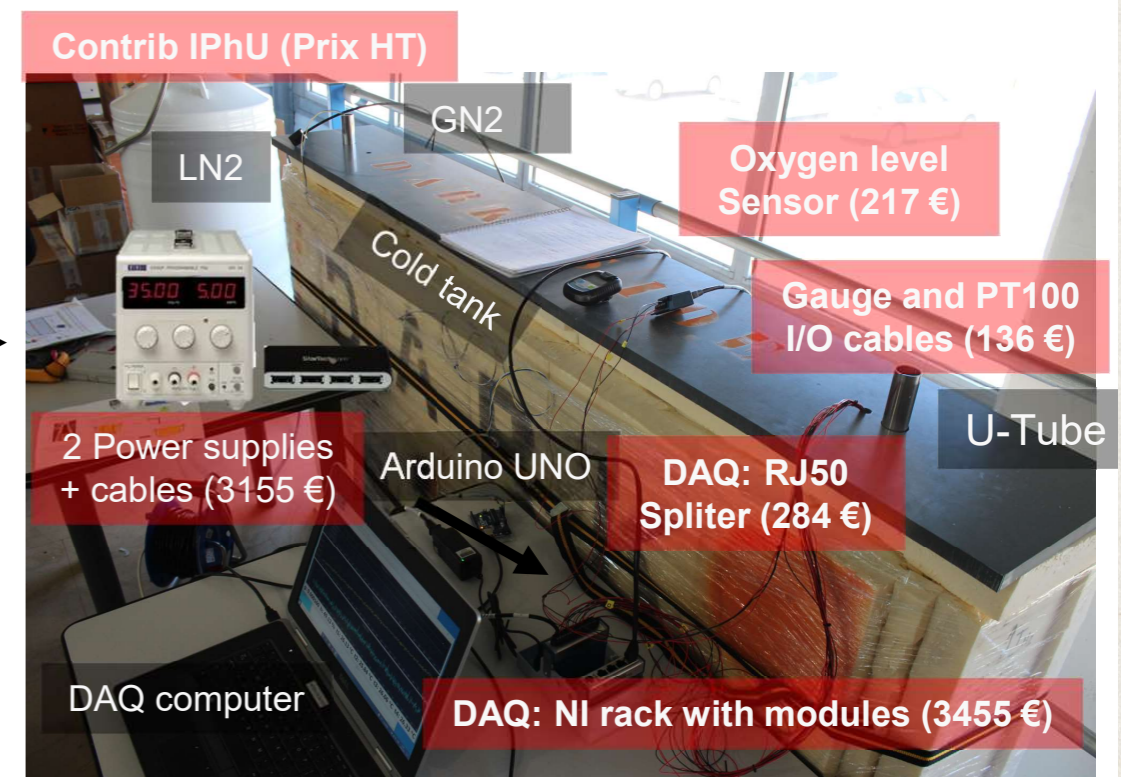
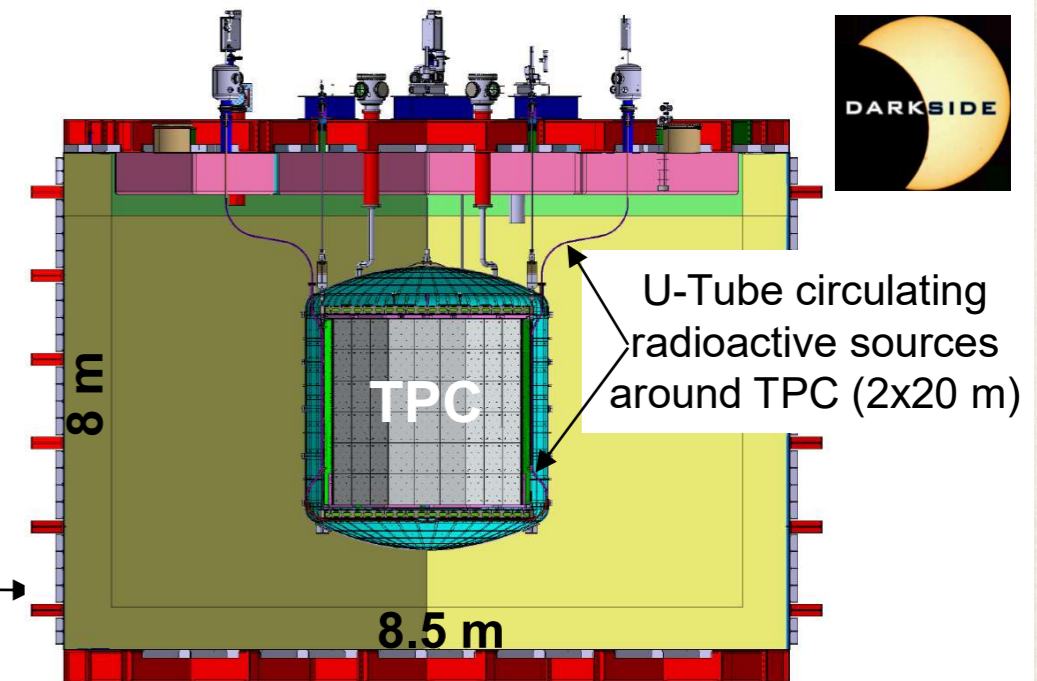
4 years (starting in 2021) between experimentalists and theorists across 3 IPHU science working groups gathering 4 labs (CPPM, CPT, LAM, LUPM)

## Goal :

Prepare at best the search for WIMP dark matter with the first data of **DarkSide-20k expt** [Gran Sasso, 2025] by reducing the experimental and theory systematics

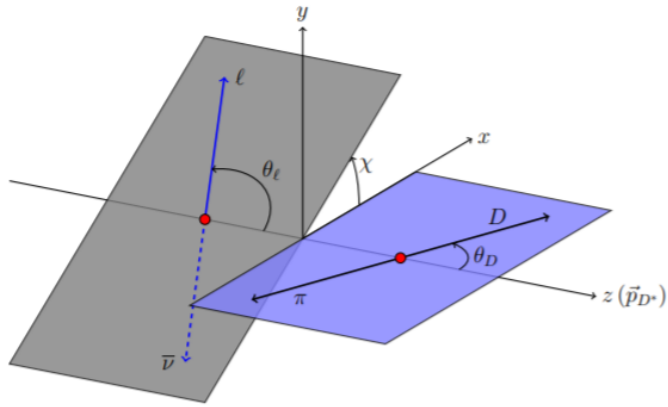
## Progress report in 2021 :

- PhD student, Marie Van Uffelen, started in Oct.
- Equip the mock-up that will validate the **U-tube calibration** system. Cold run at CPPM
- Prepare the calibration program with DarkSide-20k Geant4 simulation
- Started to work on **signal reconstruction** algorithms
- Started to work on **galactic modelling** impact on DarkSide-20k sensitivity





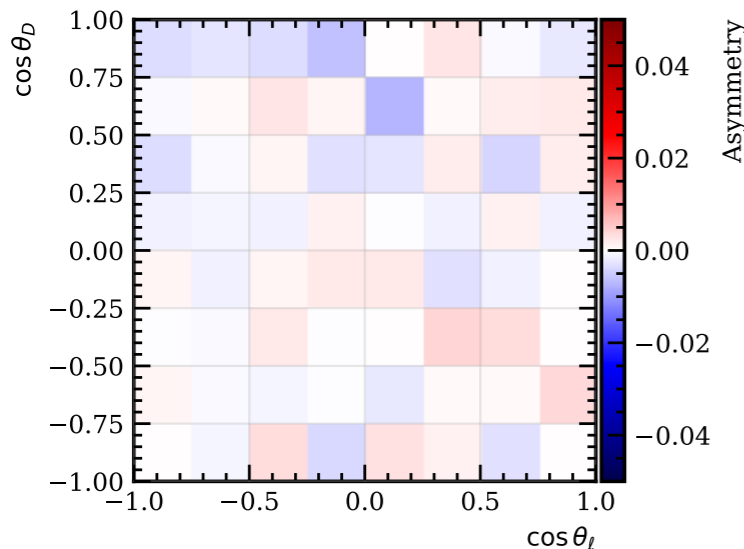
# CP violation in $B \rightarrow D^* \mu \nu$ decays



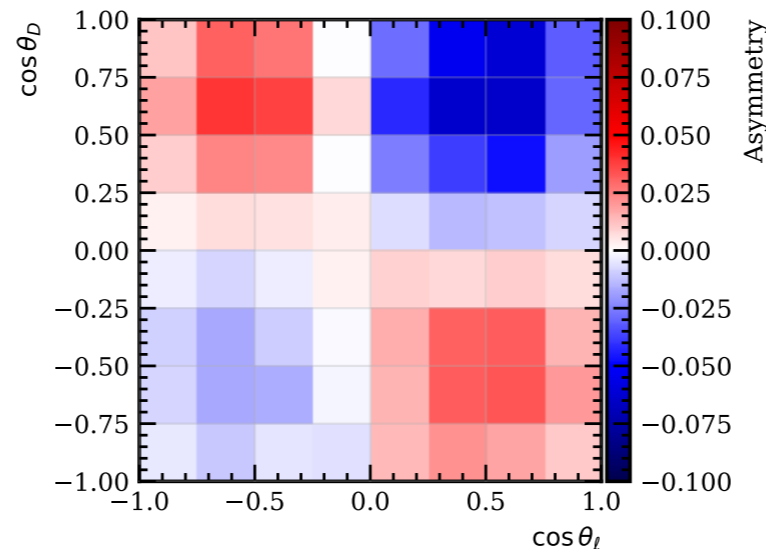
Search for “**twists**” (parity-odd terms) in the  $B \rightarrow D^* \mu \nu$  angular distribution at LHCb.

Distribution may have *chirality* in the SM, but it **must** be the same for  $B$  and  $\bar{B}$  ( $CP$  conservation).

$CP$ -violating terms  $\Rightarrow$  New physics (e.g. RH vector, pseudoscalar, tensor currents)

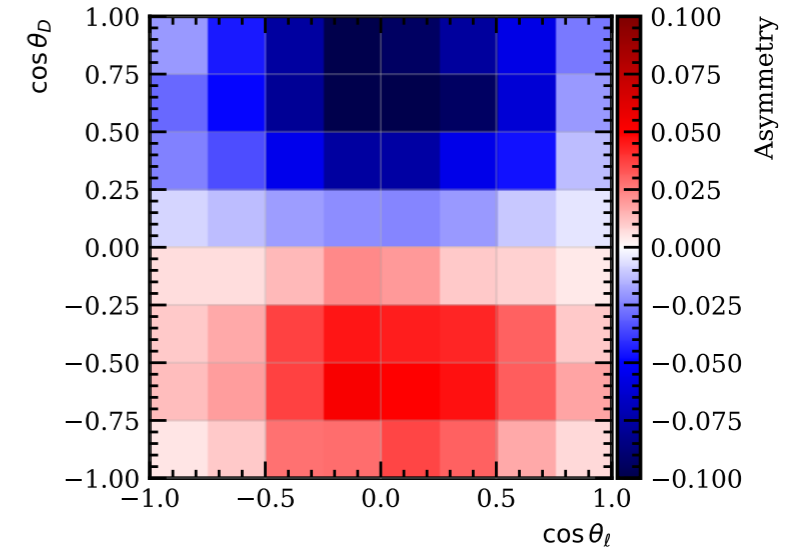


SM only



+RH vector current

$$g_R = 0.3i$$



+ $P \times T$  interference

$$g_P g_T^* = 0.1i$$

Current dataset:  $\sim 0.1\%$  precision for CPV terms

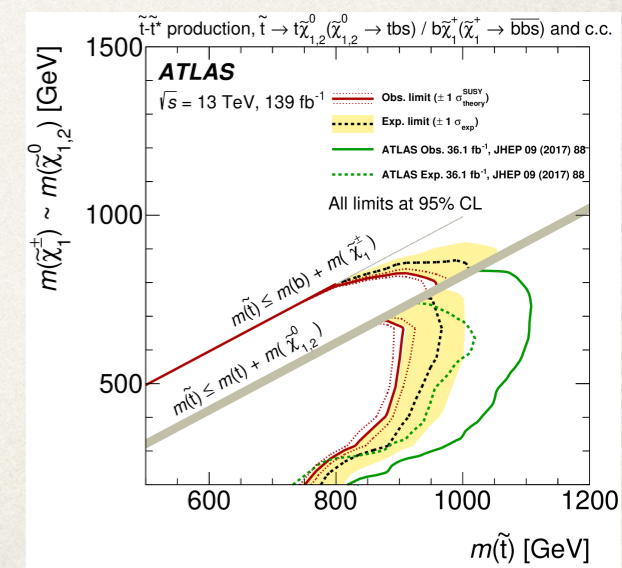
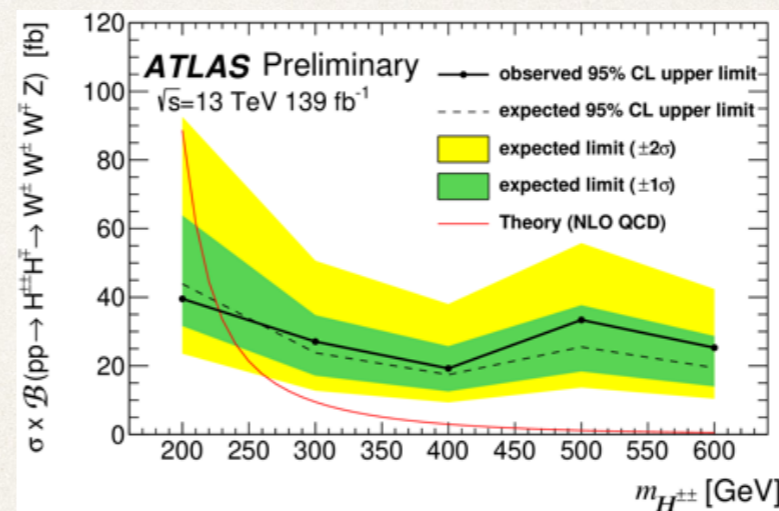
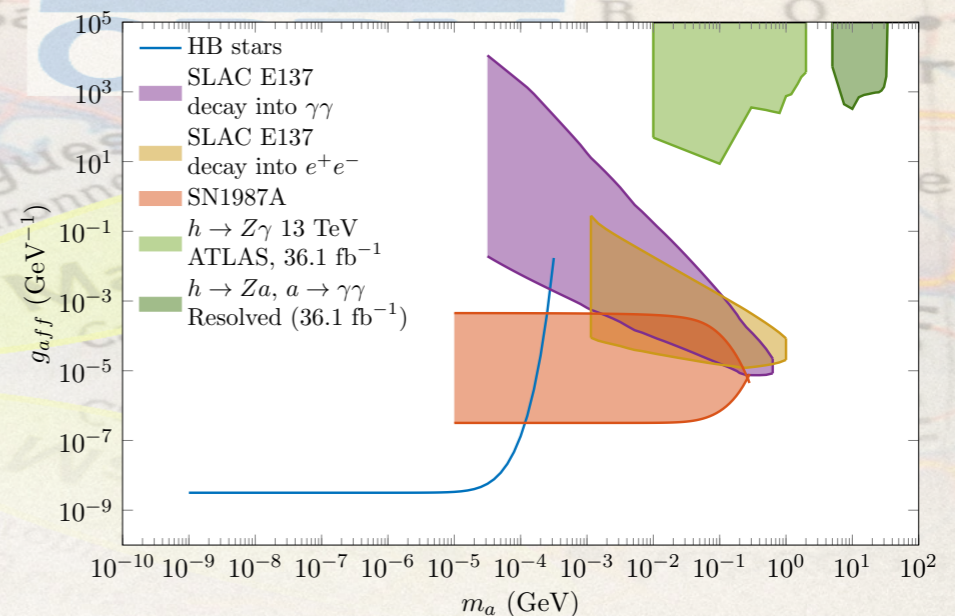
Main difficulty: distinguish “twists in reality” and “twists in perception” (parity-odd detector effects and backgrounds).



# BSM Physics at Terascale

Aoife Bharucha, Felix Brümmer, Ana Dumitriu, Lorenzo Feligioni, Michele Frigerio, Marc Knecht, Jean-Loic Kneur, Emmanuel Monnier, Gilbert Moultaika and Steve Muanza

- ❖ Collaborative experimental (ATLAS-CPPM) theoretical (CPT,L2C,LUPM) project
- ❖ phenomenology work addressing dynamical explanation of EWSB, particle physics solution dark matter problem, explanation of neutrino masses.
  - ❖ From model building to interpretation of ATLAS results
- ❖ Novel data analysis data focused on unexplored signatures
  - ❖ Two new ATLAS results appeared in 2020, from original ideas developed within the collaboration



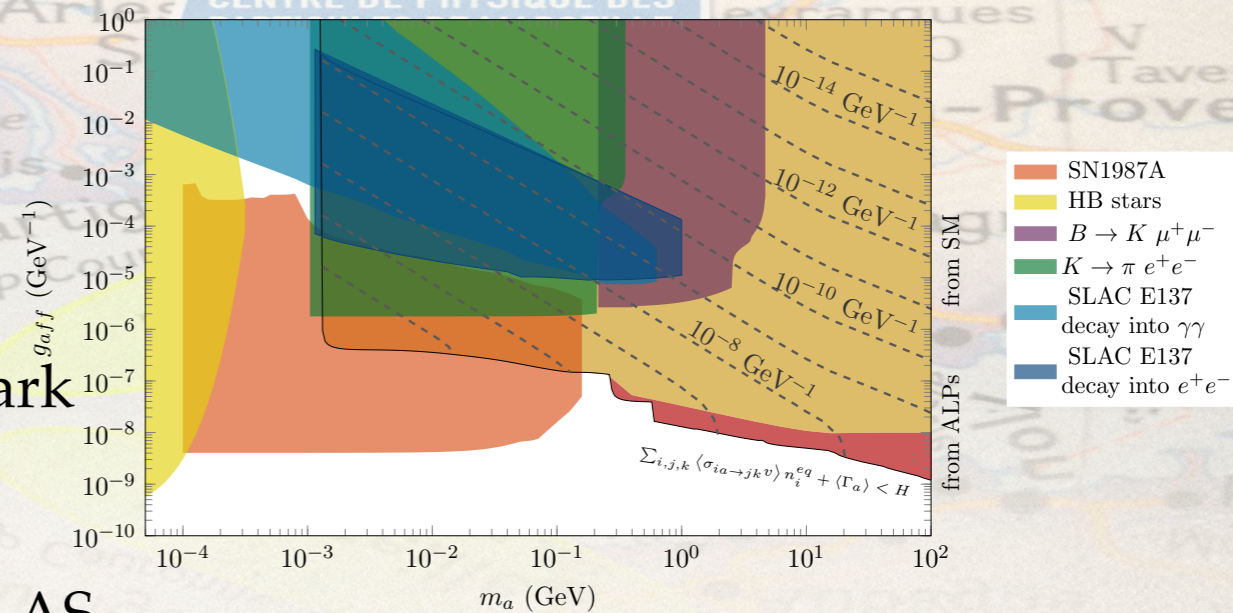
See talk by Lorenzo Feligioni later this afternoon!



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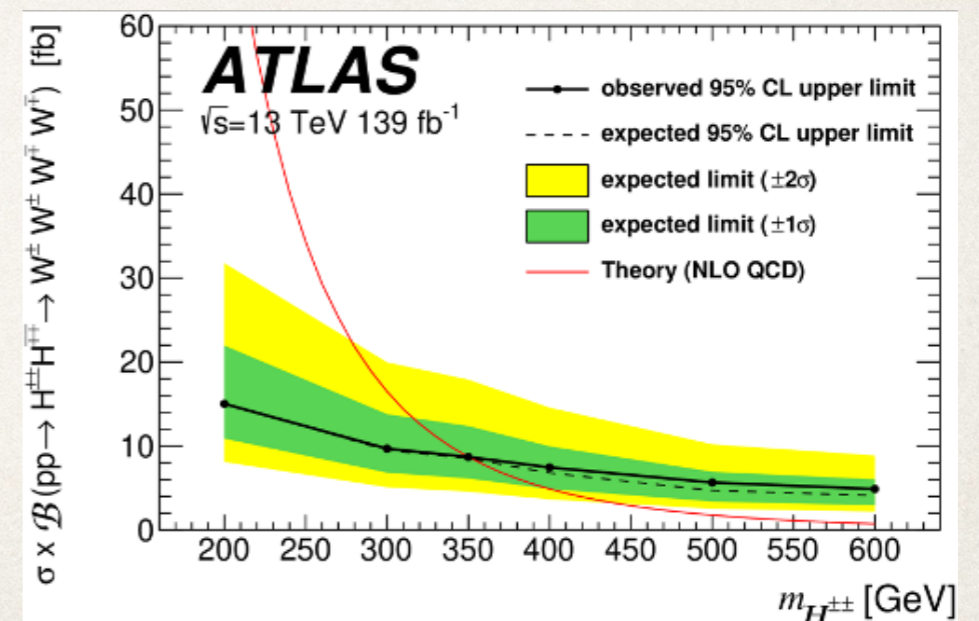
- ❖ Collaborative experimental (ATLAS-CPPM) theoretical (CPT,L2C,LUPM) project
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- ❖ From model building to interpretation of ATLAS results

- ❖ Novel data analysis data focused on unexplored signatures

- ❖ One ATLAS result appeared in 2021, from original ideas developed within the collaboration



See talk by Lorenzo Feligioni later this morning!

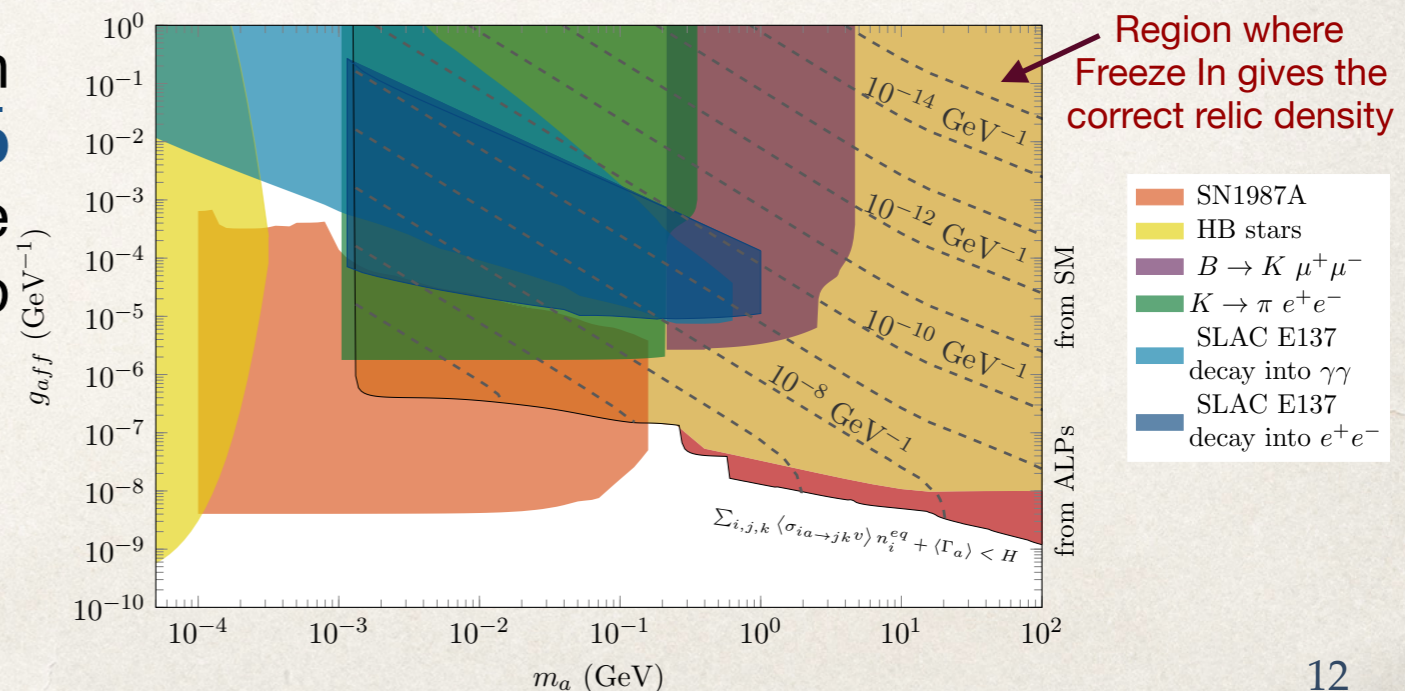
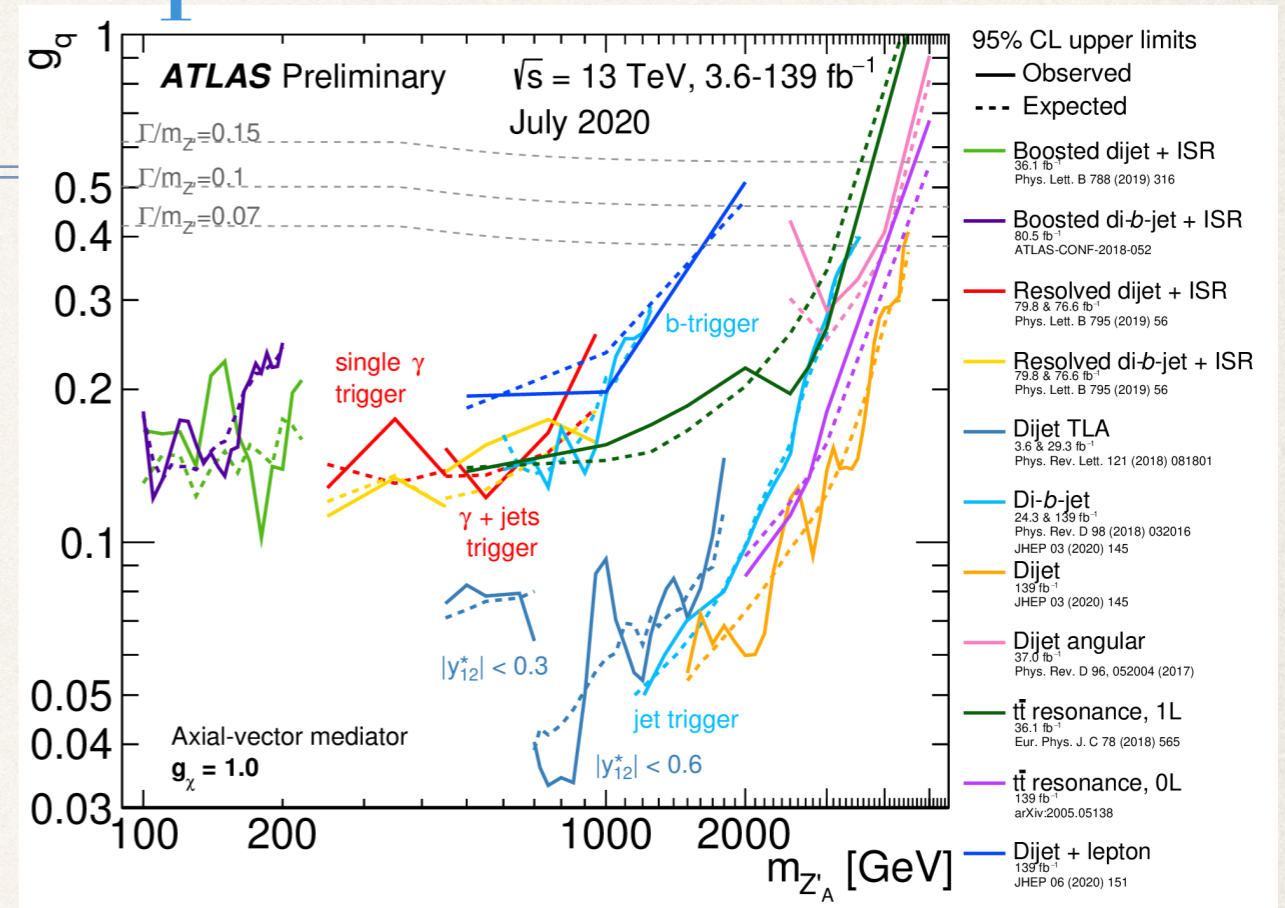


# Low mass resonances:

**NEW!!**

## AAP A\*MIDEX “Interdisciplinarité 2022”

- So far the LHC experiments have succeeded in excluding large regions of parameter space of possible BSM models
- However, resonance searches@LHC leave **area of opportunity for low mass resonances below EW scale**
- Such light states are ubiquitous in model of BSM physics, for example as **mediators to DM** as studied by phenomenologists@CPT
- ATLAS team@CPPM proposes a new Run 3 analysis to probe this region via the  **$b\bar{b}$  final state**. Expertise in b jets. Propose triggering on the muons found in b-jets to probe lower masses.





# IPhU Doctoral Lectures: Particle Physics

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- ❖ Standard Model — Aoife Bharucha
- ❖ Introduction to theories beyond the Standard Model of particle physics — Michele Frigerio
- ❖ Advanced statistical methods for high energy physics — Lorenzo Feligioni and Yann Coadou
- ❖ Quantum Chromodynamics — Antoine Gerardin



# Particle Physics

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### 👤 Managers

👤 Aoife Bharucha

👤 Lorenzo Feligioni

Looking forward to constructing an exciting programme in 2022!!

Topical discussion session: Run3 SUSY!