

Searches for Dark Matter and BSM physics

Cristiano Sebastiani



UNIVERSITY OF
LIVERPOOL



ATLAS
EXPERIMENT

Past and present activities

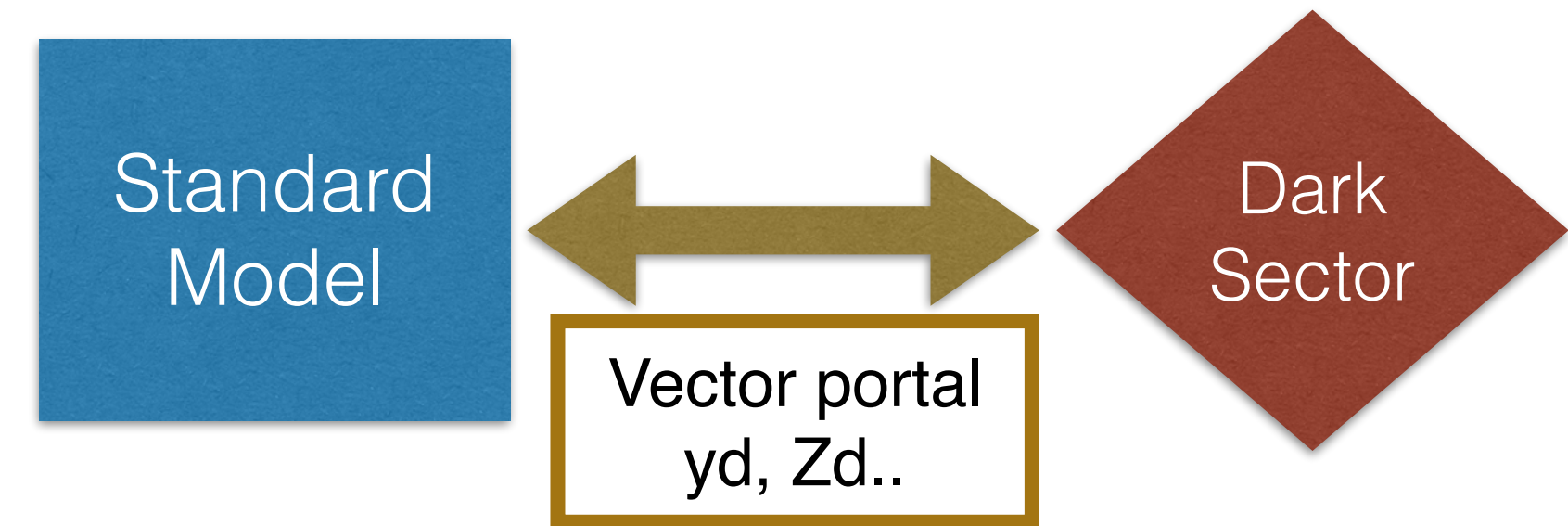
Liverpool leads key areas of the ATLAS BSM physics programme:

- Axions in di-photon channel, prompt [[towards unblinding](#)] and displaced [[ongoing](#)]
- Mono-Z (Higgs invisible) [[published 2022](#)]
- Dark-photon jets, prompt [[ongoing](#)], displaced ggF/WH [[submitted 2022](#)] and VBF [[ongoing](#)]
- Disappearing tracks 1st wave [[submitted 2022](#)], 2nd wave [[ongoing](#)]
- SUSY EWk 2nd wave in bb final state [[towards unblinding](#)]
- High-mass DY resonances [[ongoing](#)]
- BSM Higgs summary plots [[ATL-PHYS-PUB-2021-030](#) [ATL-PHYS-PUB-2022-008](#)]
- LQ (bb $\tau\tau$) 3rd gen LQ [[towards publishing](#)] (**Carl** editor) and combination paper (**Andy** editor) with all LQ analyses
- LQ (ll+b or c-jets or in bb $\tau\tau$) now published or about to be published will be followed up later in Run 3, as well as further studies on HL-LHC prospects

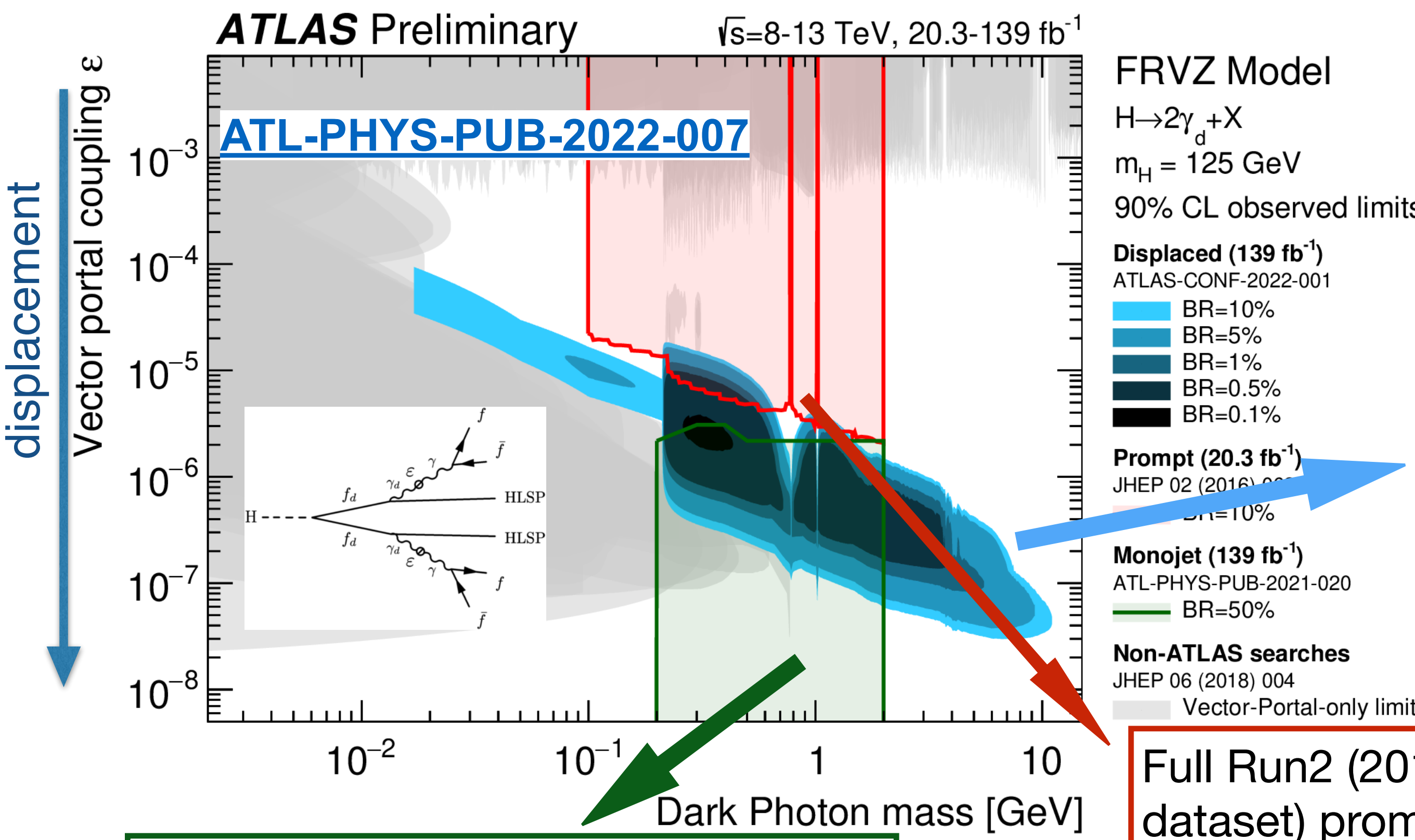
in this talk, a brief summary is given with studies in progress

Dark Sector searches: vector mediators

Search for BSM Higgs decays into (long-lived) light dark photons
 Very unconventional topology: collimated structures of leptons or light hadrons



Monica, Alessandro (PhD yr4), Cristiano

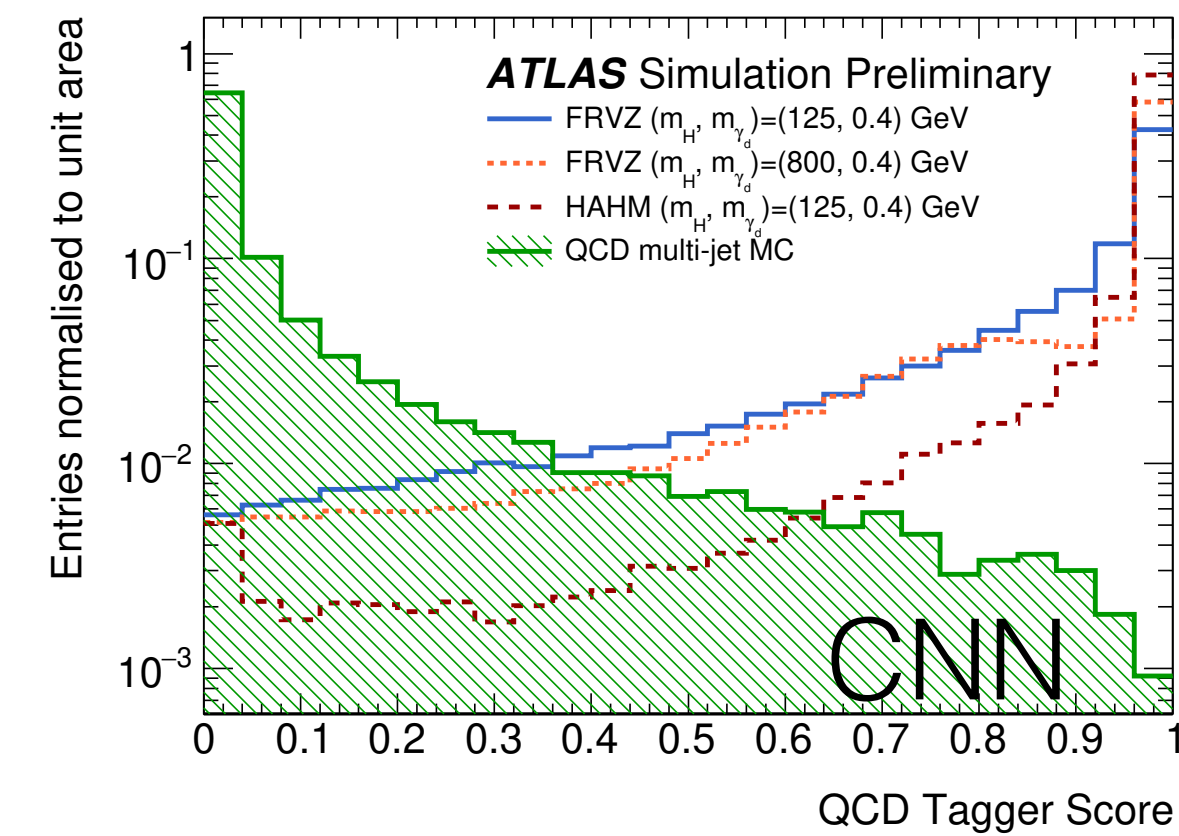


Full Run2 displaced analysis soon to be submitted to JHEP ([ATLAS-CONF-2022-001](#)):

- Focus on ggF/WH production, VBF analysis ongoing
- First exclusion of fully electronic displaced decays

Monica, Joe, Cristiano

Testing state of the art graph NN to further improve the results within the MUCCA CHIST-ERA project



Very displaced region: mono-jet search reinterpretation
[ATL-PHYS-PUB-2021-020](#)

Full Run2 (2015-2018 dataset) prompt analysis just started

Convolutional NN jet image tagger

Extended Higgs sectors searches

Nikos, Adam R. (PhD yr4), Cristiano

NEW ANALYSIS IN ATLAS

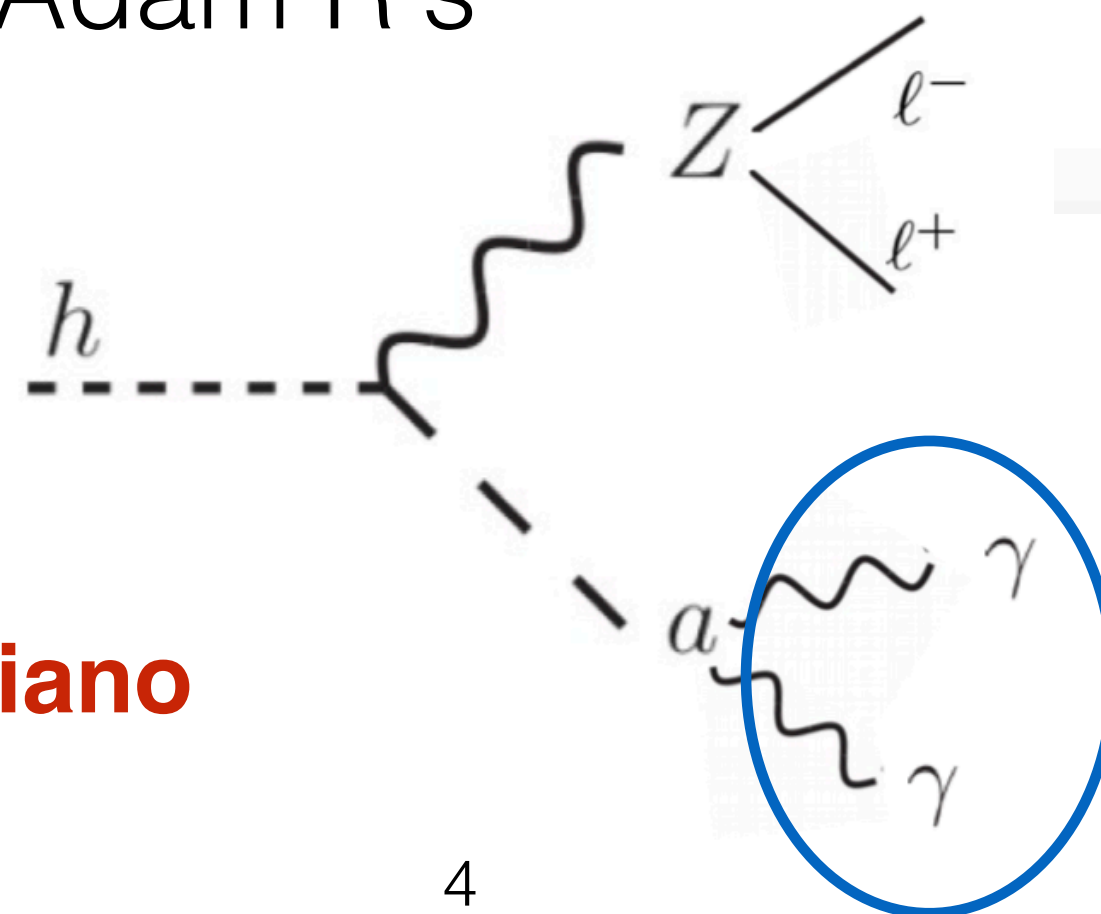
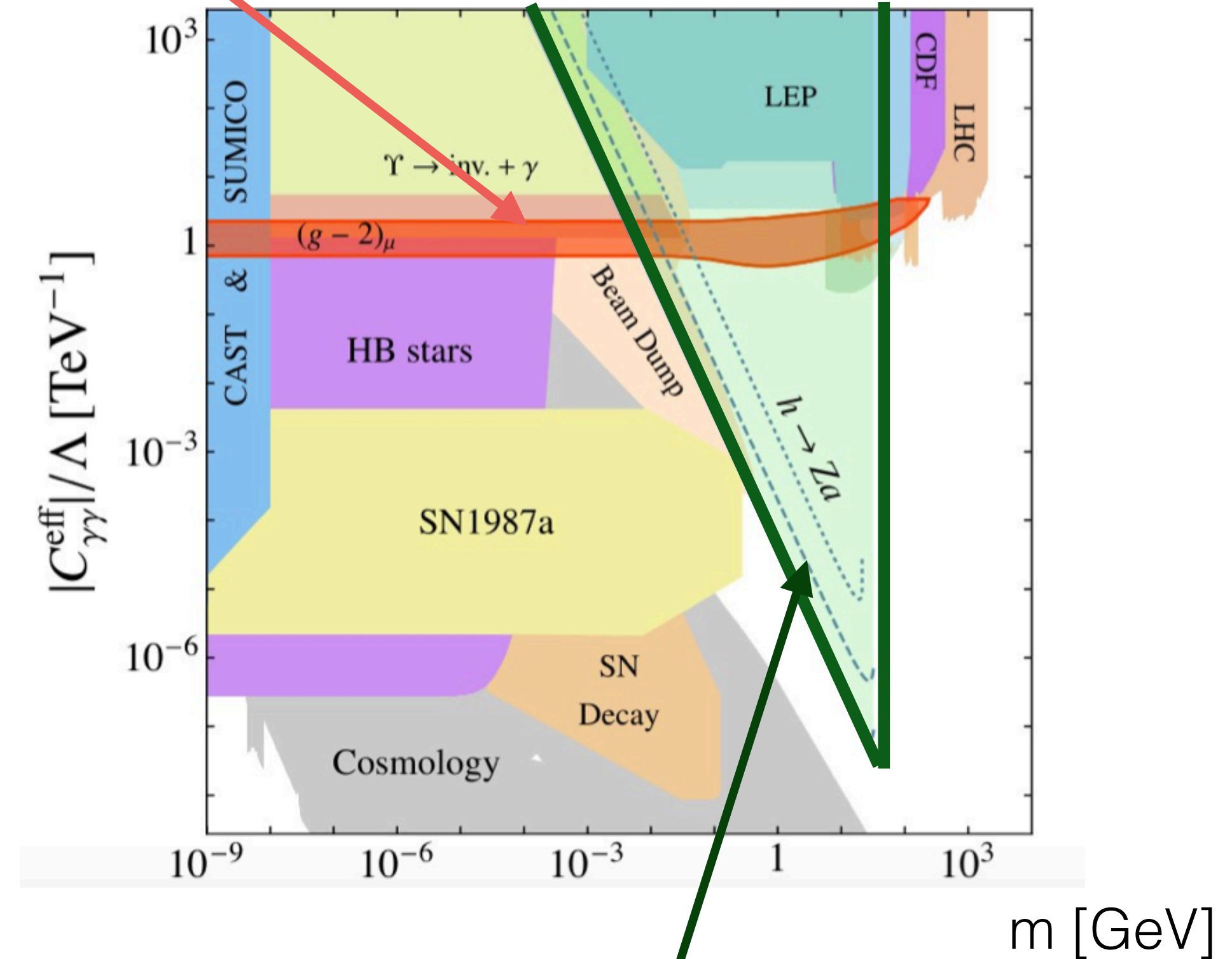
- Full Run2 search for two leptons and two collimated photons (one if signal photons are collimated)
- Main backgrounds Z+jet are Zy
- For axion masses below ~ 1 GeV \rightarrow sizeable lifetime
- Publication expected this year! Visit Adam R's poster for more details :)

Displaced search has also started by Rebecca for her PhD thesis!

Nikos, Monica, Carl, Rebecca (PhD yr1), Cristiano

Preferred parameter space where $g-2$ anomaly can be explained

[arXiv:1708.00443](https://arxiv.org/abs/1708.00443)



2 close-by photons

ALPs pseudo-scalar particles: mass range up to ~ 34 GeV.

Dark Sector searches: (pseudo)scalar mediators

Search for heavy Higgs boson decaying into a Z boson and another heavy Higgs boson

Nikos (llbb/llWW), Alan PhD (llbb) [published]

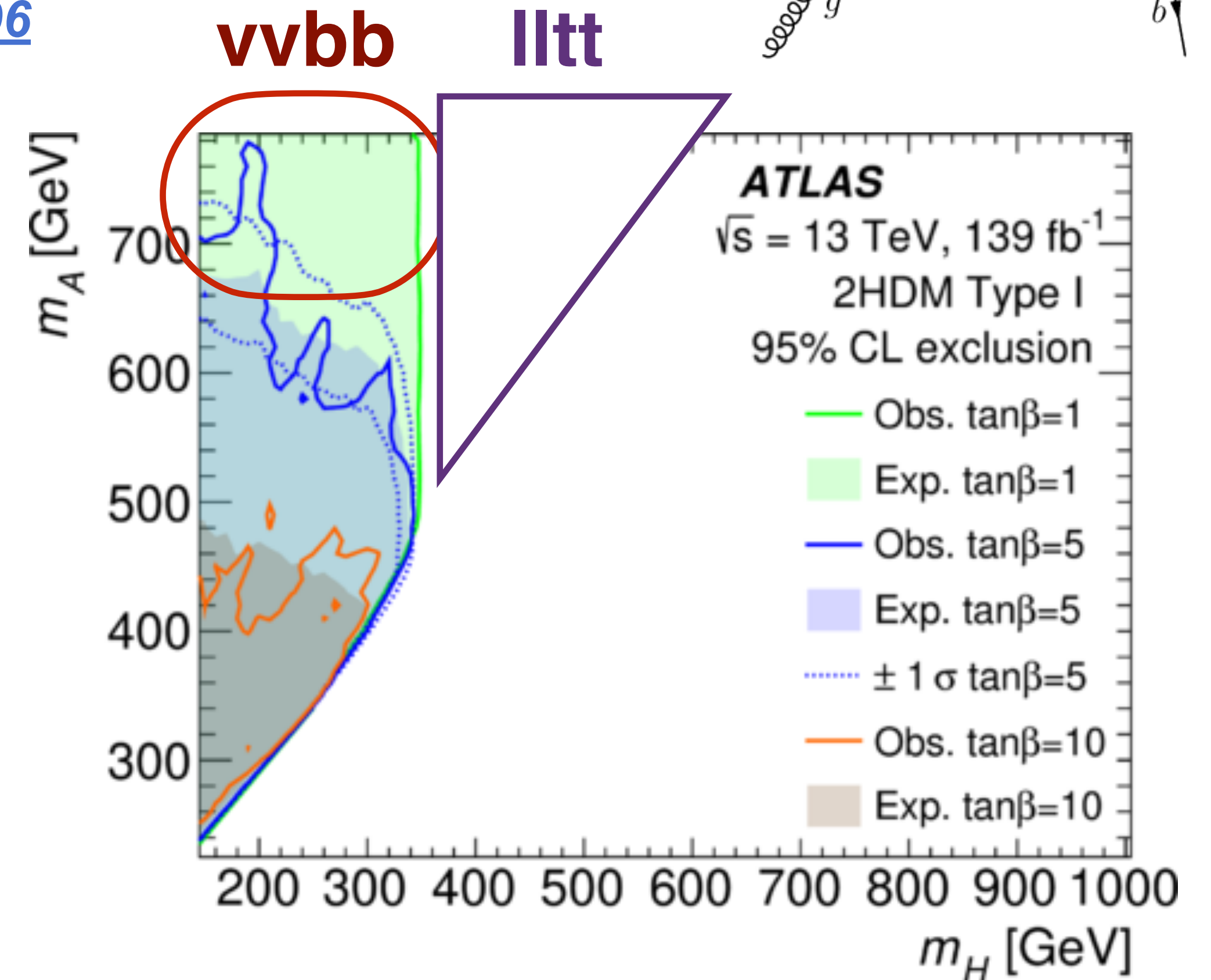
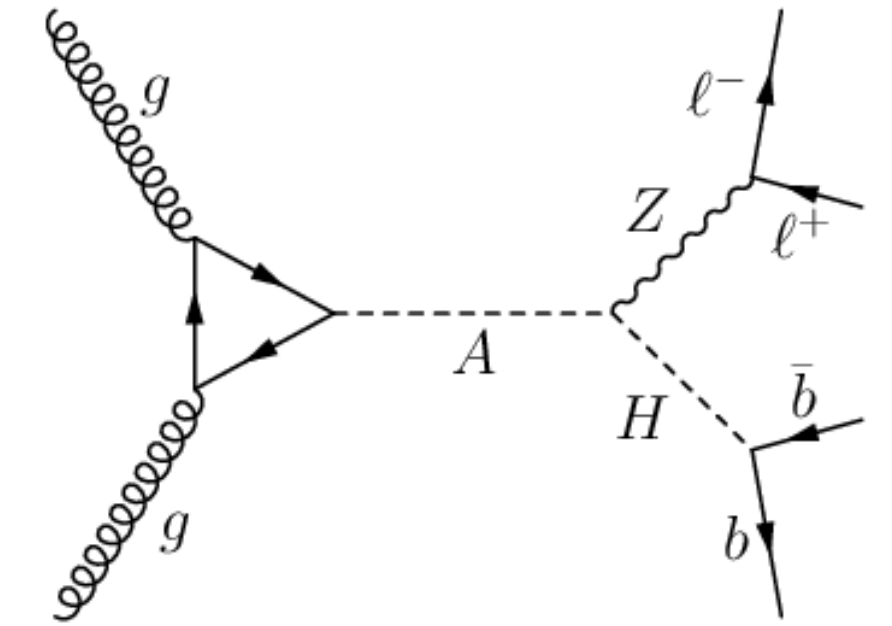
Nikos (lltt) [NEW]

- Full Run2 paper in the llbb and llWW final states recently published! [Eur. Phys. J. C. 81 \(2021\) 396](#)
- New search in the lltt final state recently started: [first ttZ resonance search in ATLAS](#)
- Main backgrounds: Z+jets and ttbar
- Results interpreted in the context of different 2HDM models

Nikos as ATLAS Higgs BSM combination contact, coordinated many ATLAS summary papers.

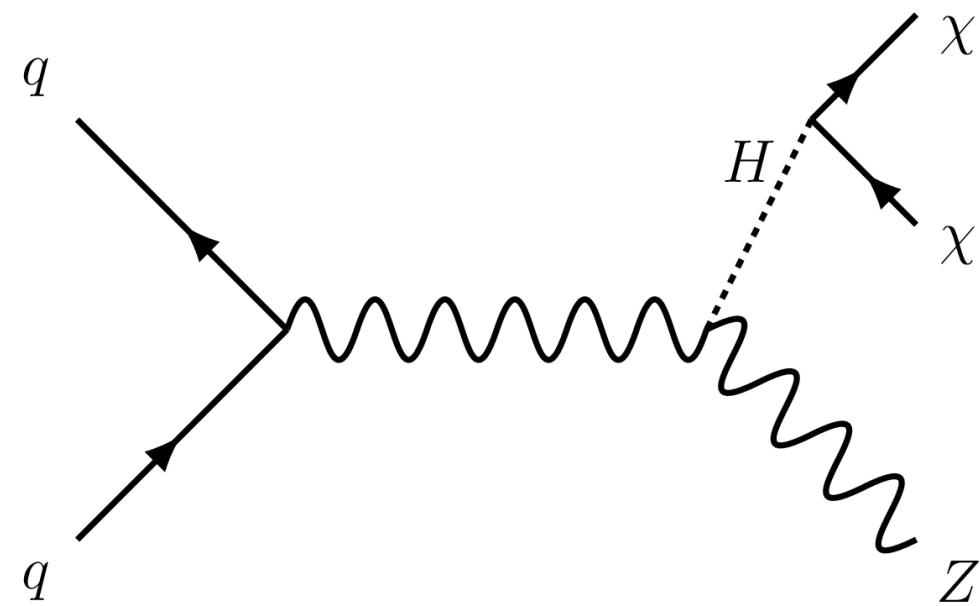
Latest ones: [ATL-PHYS-PUB-2022-008](#) and [ATL-PHYS-PUB-2021-030](#)

Complementarity with current ATLAS exclusion



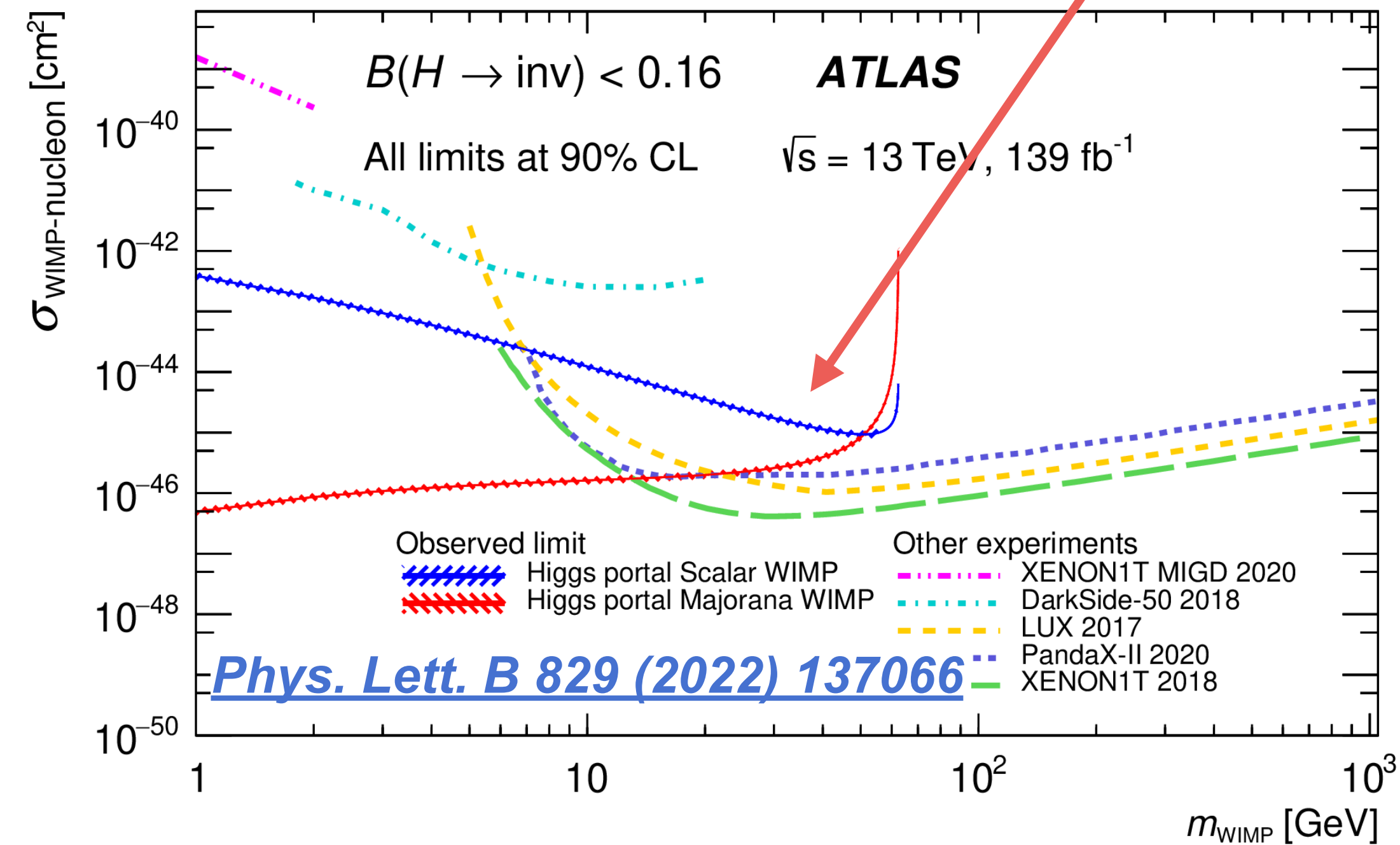
Higgs to invisible

Search for associated production of a Z boson with an invisibly decaying Higgs boson or dark matter candidates

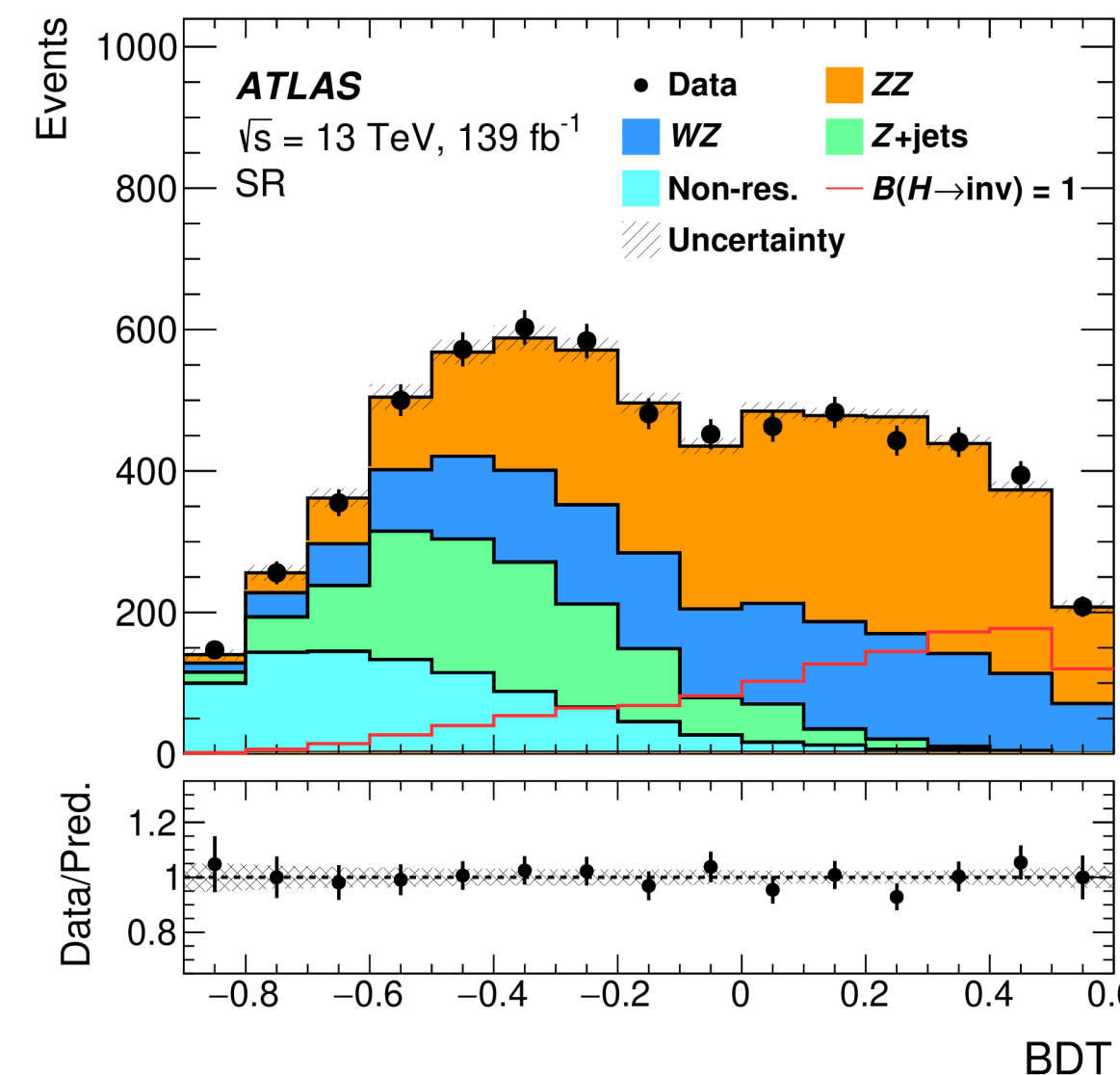


Nice interplay with direct detection experiments on $\sigma(\text{WIMP-nucleon})$

- Full Run2 paper recently published!
- Dilepton + missing transverse energy signature
- 19% upper limit @95%CL on SM xsec for Higgs boson to invisible particles. SM BR(H→ZZ→4ν) ~ 0.1%
- Many BSM interpretations on simplified dark matter models and 2HDM+a models



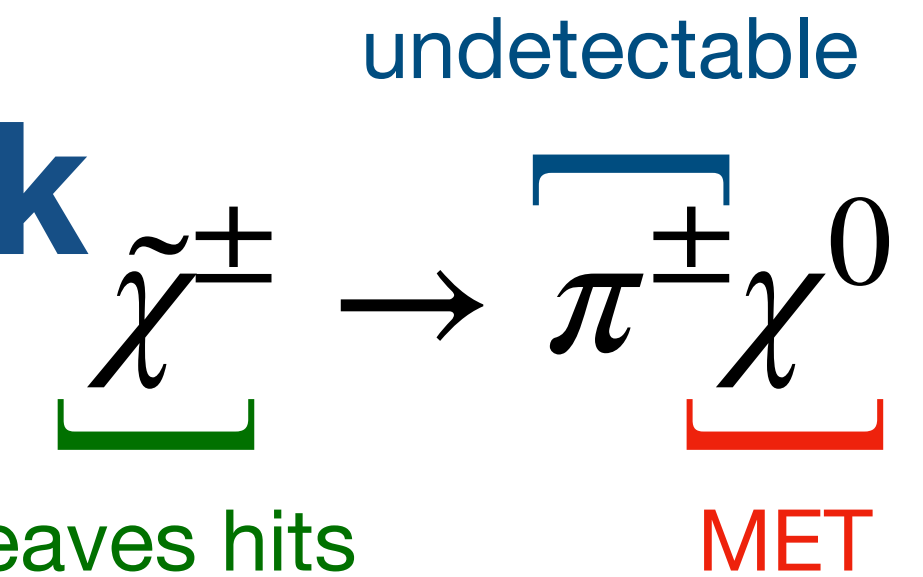
N.B. ATLAS model assumes a Higgs portal



BDT introduced to optimise the SR, trained on MC high-level variables

SUSY prompt and disappearing track

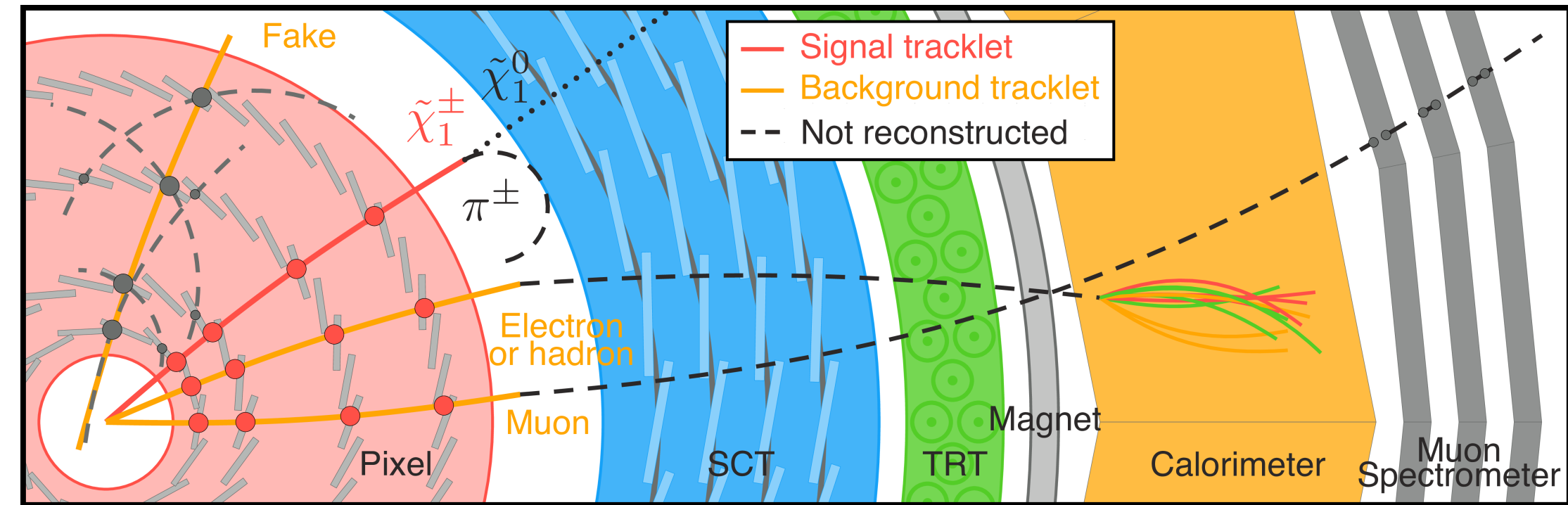
Search for prompt (EWk legacy) and long-lived charginos (disappearing tracks)



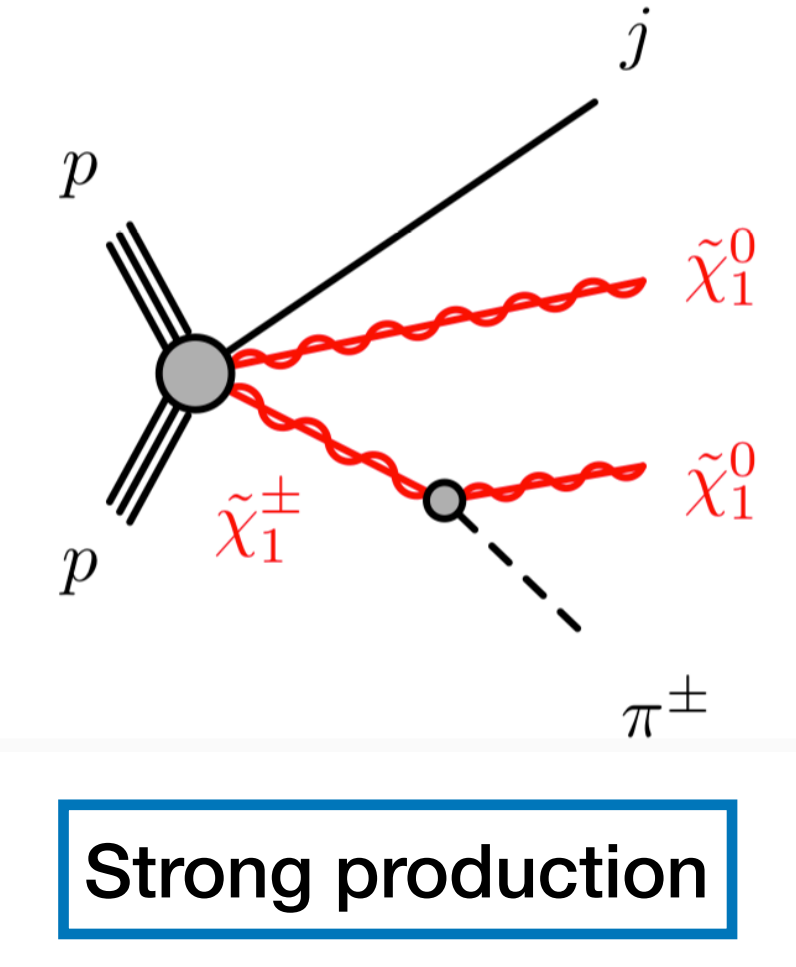
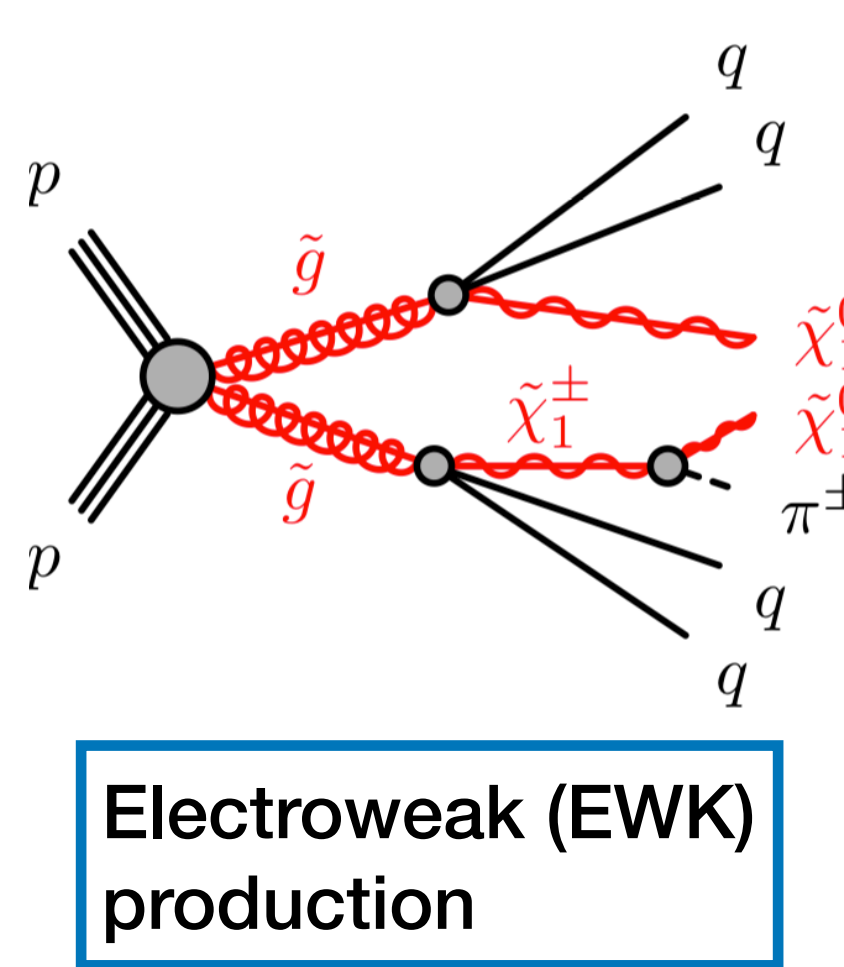
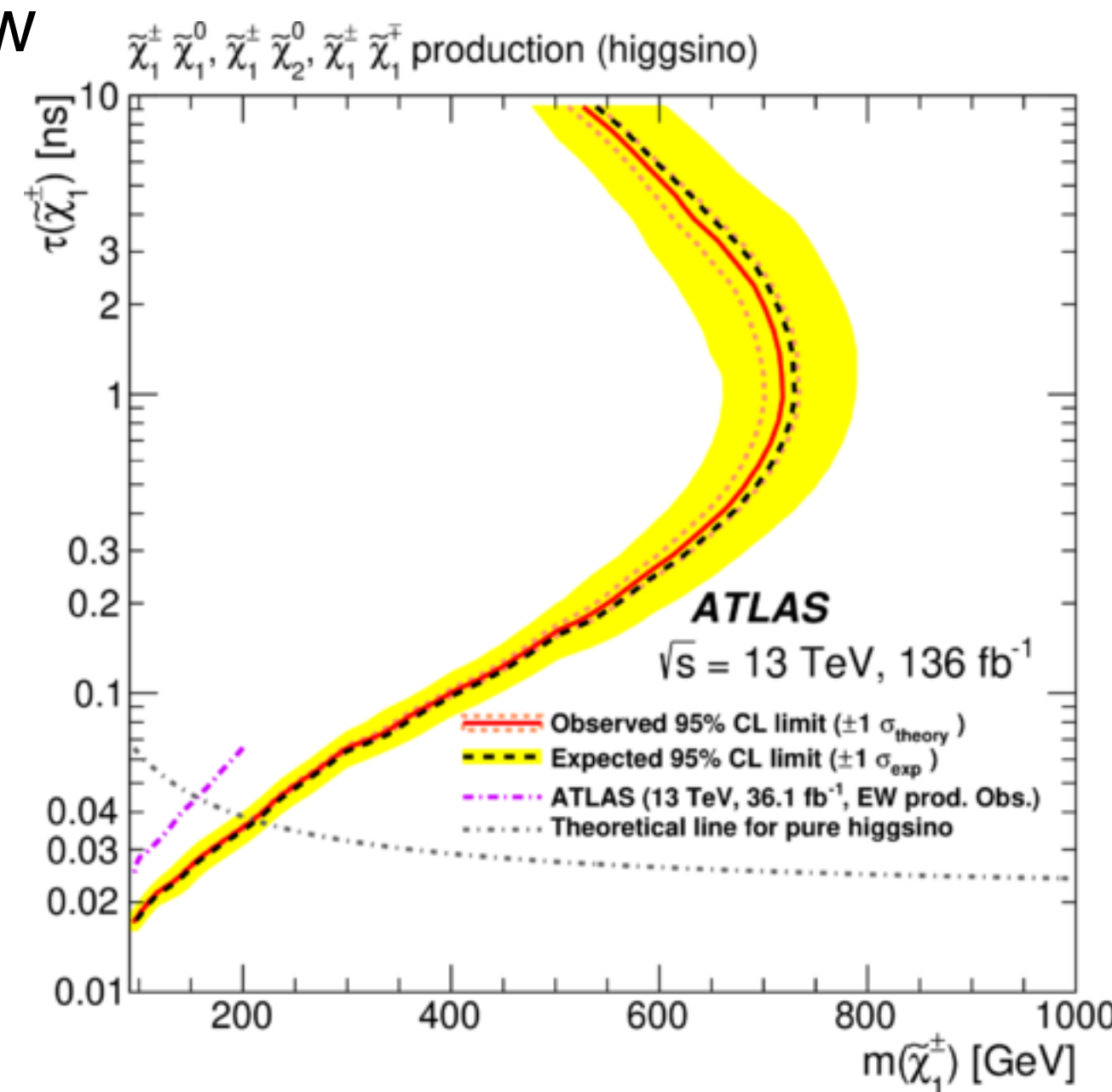
**Monica, Hamish
(recently Dr) and
now Joe**

**Monica, Helen,
James S. (PhD yr 3)**

- Finalising EWk SUSY search in Wh(bb) channel
 - Will be used as test bench for new machine learning techniques within MUCCA CHIST-ERA
- Disappearing track paper submitted to EPJC ([arXiv:2201.02472](https://arxiv.org/abs/2201.02472))
 - 2nd wave effort already started! With many new improvements in tracking and vertexing techniques ([ATL-PHYS-PUB-2019-011](https://arxiv.org/abs/1907.01141))
 - Search for events with jets and ‘disappearing tracks’ (due to suppressed interaction or low-pT)
 - Rare SM backgrounds from charged lepton scattering and combinatorial fakes



Targets very compressed SUSY scenarios (...and various DM models)

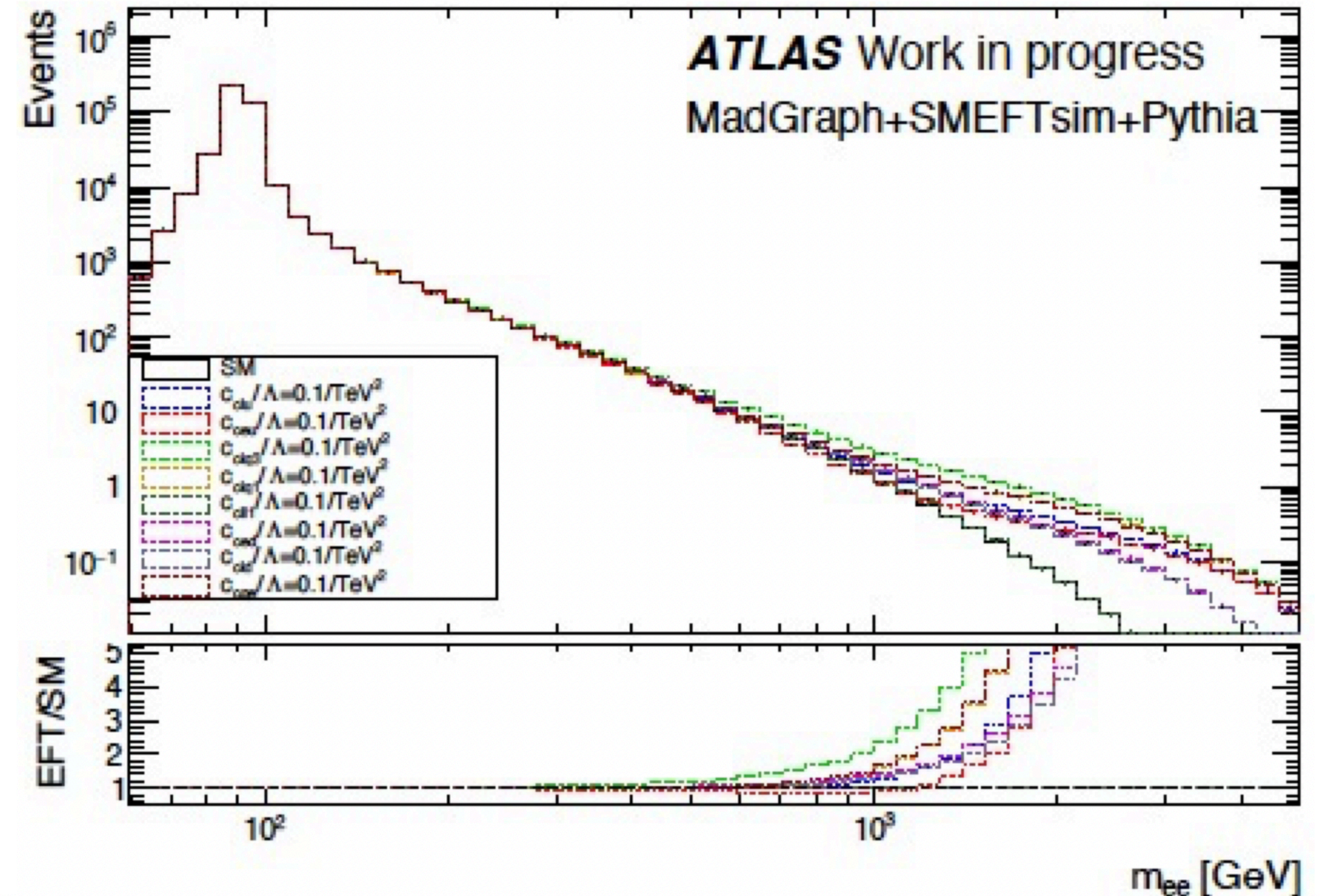


High-mass DY: EFT interpretations

Differential cross section measurement in the high mass neutral current Drell-Yan ($m_{ll} > 116 \text{ GeV}$)

Jan, Uta, Ricardo (PhD yr 4), Sam (PhD yr2)

- Searches for high mass DY resonances and for non resonant effects in NC DY - published
 - Now new effort to search for NO effects in the SMEFT framework
- Incredible SM probe: measurements can be used to extract (photon) PDF, test lepton universality. First time in ATLAS
- Also sensitive to new physics! The first EFT interpretation in this mass range
- 95%CL limit setting on Wilson coefficients from unfolded data. Public results very soon... stay tuned!



$$\underbrace{|\mathcal{A}_{\text{SM}} + \sum_i c_i \mathcal{A}_i|^2}_{\text{SM+EFT}} = \underbrace{|\mathcal{A}_{\text{SM}}|^2}_{\text{SM}} + \underbrace{\sum_i c_i 2\text{Re}(\mathcal{A}_{\text{SM}}^* \mathcal{A}_i)}_{\text{linear term } \propto c_i} + \underbrace{\sum_i c_i^2 |\mathcal{A}_i|^2}_{\text{quadratic term } \propto c_i^2} + \underbrace{\sum_{i \neq j} c_i c_j 2\text{Re}(\mathcal{A}_i^* \mathcal{A}_j)}_{\text{cross terms not considered}}$$

More details on DY measurement in Matt's talk

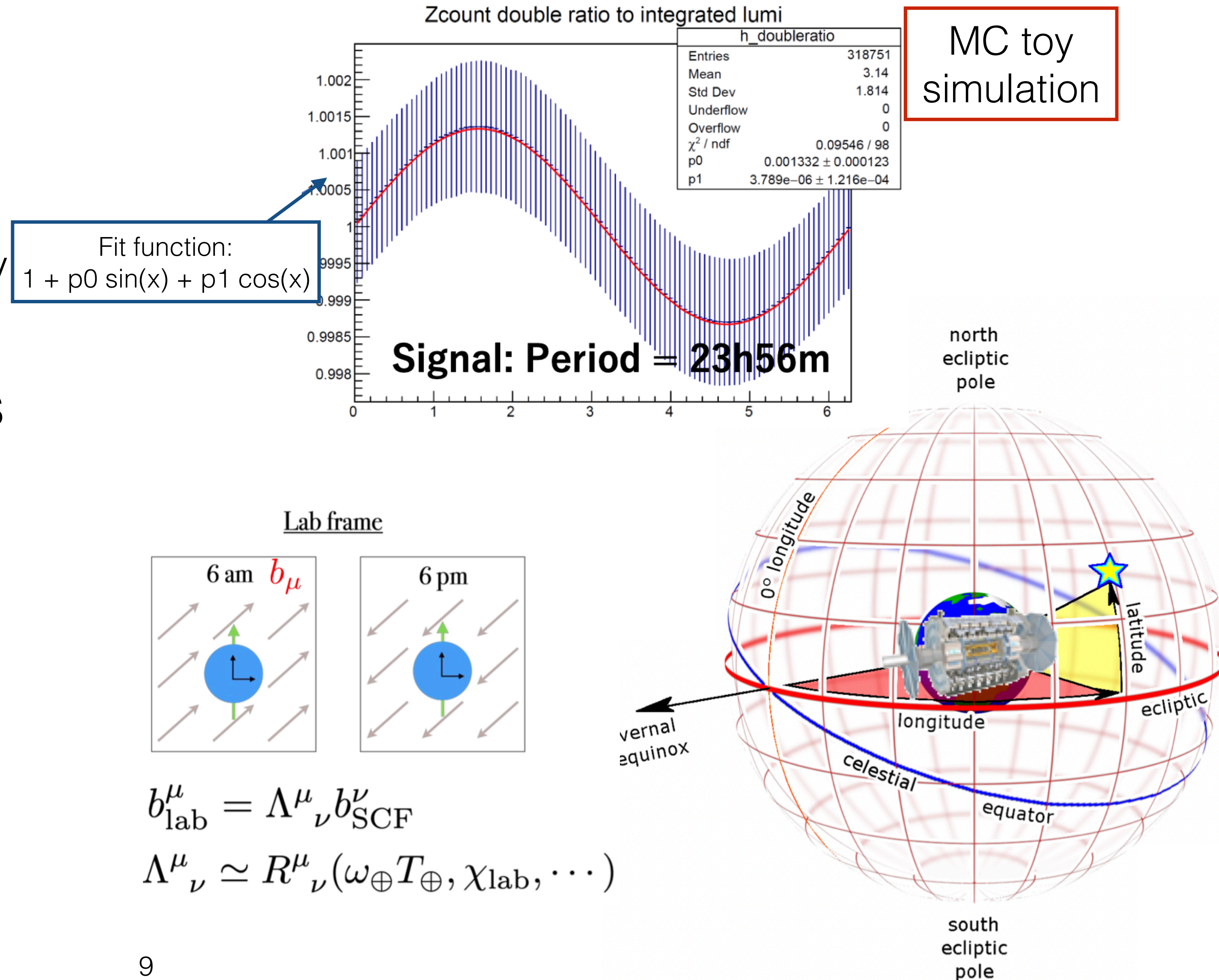
Lorentz-invariance signatures

Search for Lorentz- and CPT invariance violating signatures: measure physics observables over phase of periodic intervals

Uta, Michael (recently Dr), Ricardo (PhD yr4)

This new effort (Liverpool led) in ATLAS has just started:

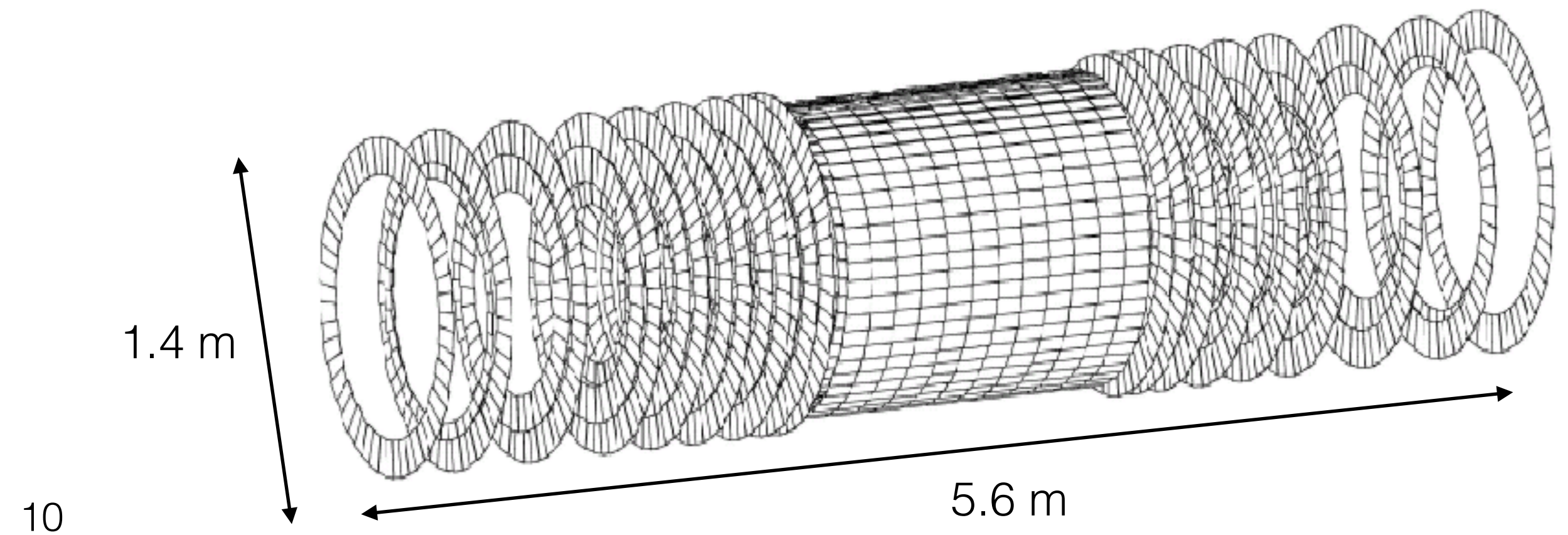
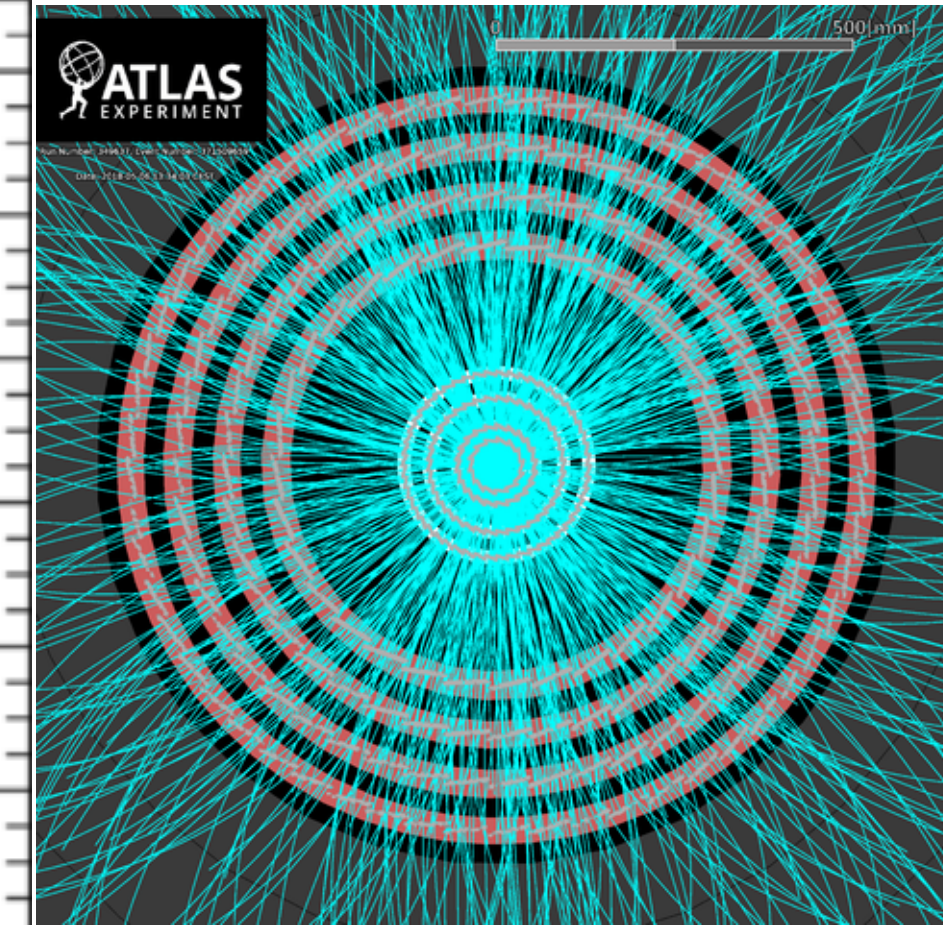
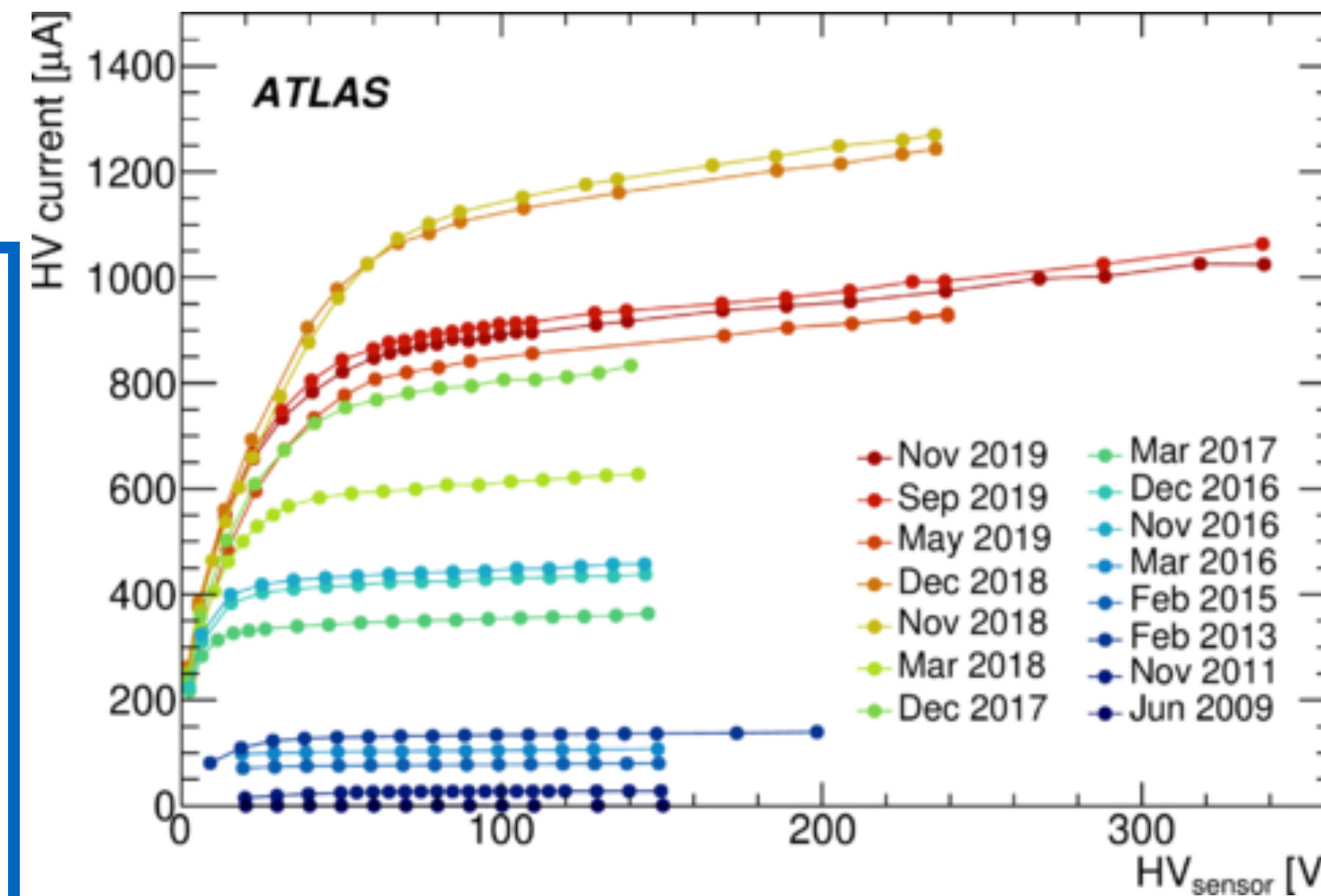
- Exploit the team leading role in ATLAS luminosity measurement (more in Matt's talk) from Z boson counting
 - Real time luminosity check (on top of ATLAS baseline luminosity measurement)
- Study the time-dependent number of Z-bosons decaying to electron or muon pairs
- Sidereal time dependent effects due to a non-isotropic background field
- Expected sensitivity (from preliminary toy MC studies): 3 sigma for 300 fb LIV effect



Extra: SCT LS2 operations

The Liverpool ATLAS group was involved in the construction, testing, installation and commissioning of the ATLAS SCT... now during Long Shutdown 2 is involved in the maintenance, monitoring and calibration of the system toward Run3 operations (SCT will survive until the end of Run 3) **Carl, Cristiano, Rebecca (PhD yr1)**

- The semiconductor tracker (SCT) consists of 4088 silicon strip sensor modules
- SCT operated stably throughout Run2 with a data quality efficiency of 99.85%!
- Run2 performance summary paper recently published: [JINST 17 \(2022\) P01013](#)
- Evaluation of the radiation damage and operational conditions expected for Run3
- Software improvements ([Liv coordinates the SCT software](#)): reconstruction, simulation, DAQ and DQ tools



Conclusions

- New searches for NP at ATLAS using the full Run-2 dataset have been presented, showing an expansion of the BSM physics programme of the Liverpool team:
 - New efforts for LLPs and Dark Sectors searches
 - Exploitation of the high statistics of the dataset for small and challenging measurement, like sidereal timing effects
- Great effort in developing new tools and strategies to improve identification and reconstruction of reconstructed object, pushing the detectors beyond their limits
- Fast approaching Run3 (and HL-LHC) programme offers a unique opportunity to plan, innovate and create new searches yet to be pursued

First pilot beam after LS2
in ATLAS Control Room



Liv team actively participate
in detector operations!