Dark Matter Searches in Rare Higgs Boson Decays at the ATLAS experiment

Adam Ruby
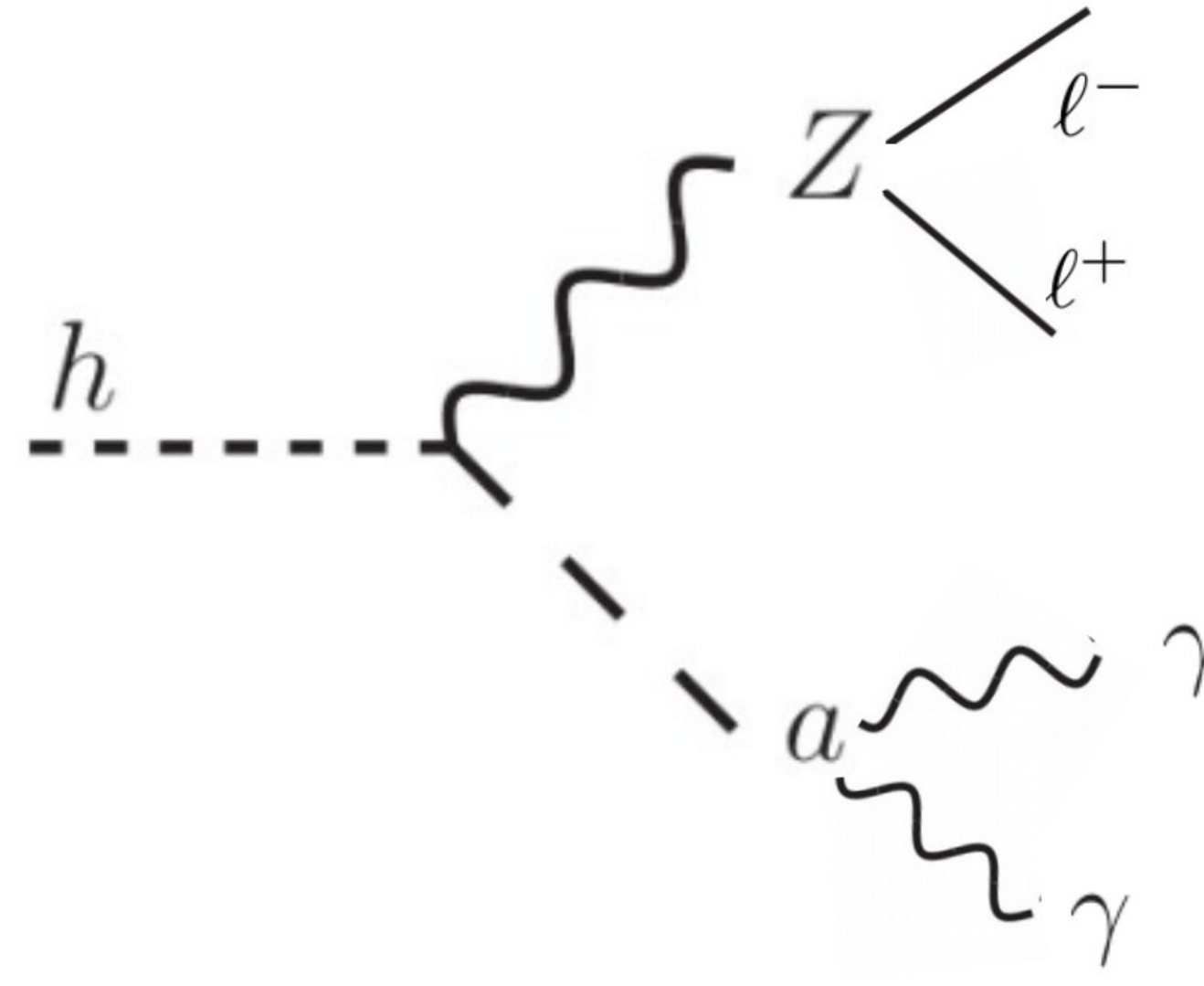linkedin.com/in/adam-james-ruby
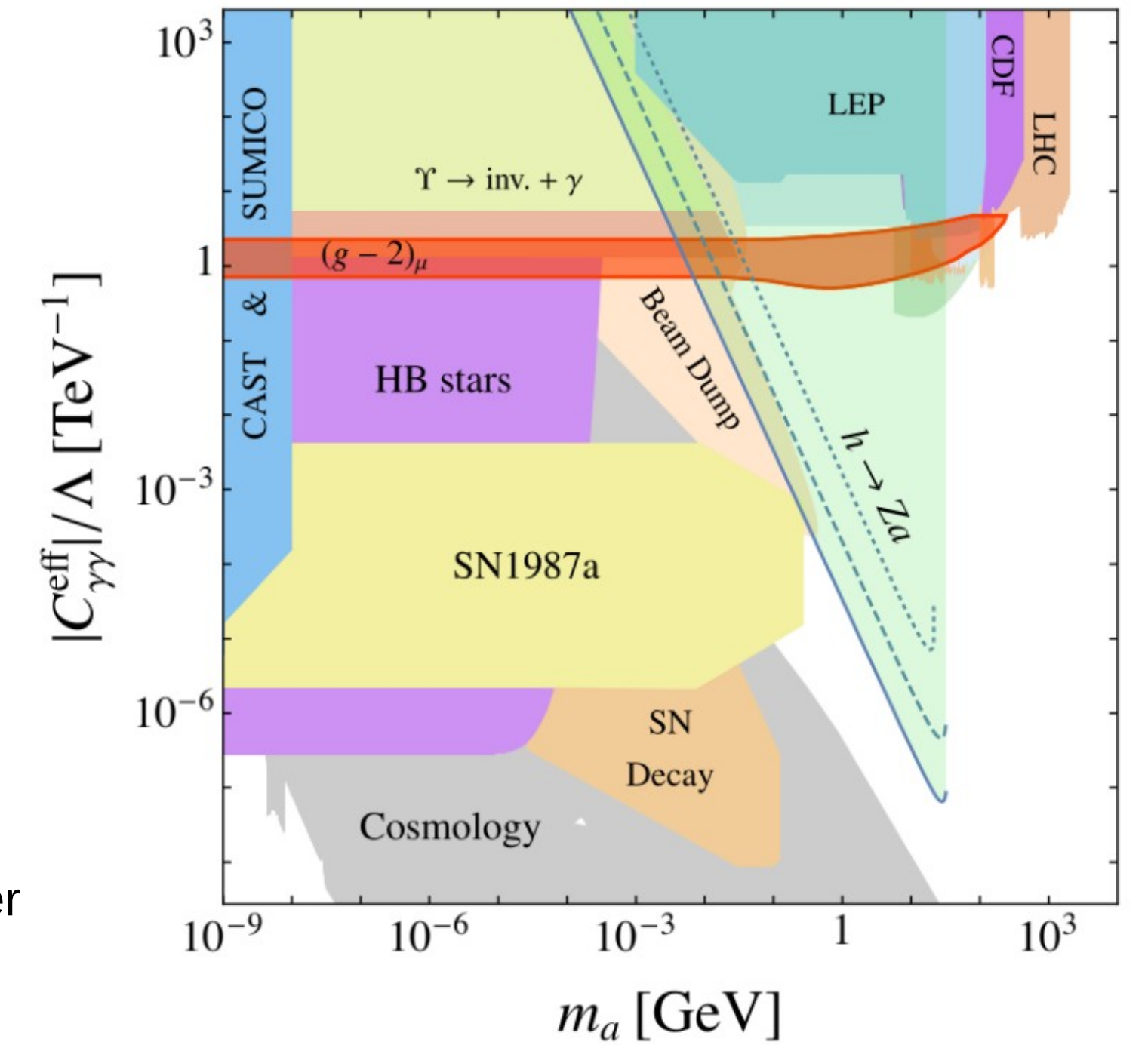
Supervisor: Dr Nikolaos Rompotis

Motivation

It's possible for a dark matter candidate, called an axion or ALP, to couple with the Higgs boson. As such, there is an area of unprobed parameter space that could show evidence for the rare Higgs decay $h \to Za$ by analysing Run-II data using the ATLAS detector at CERN.

ALP: Axion-like particle

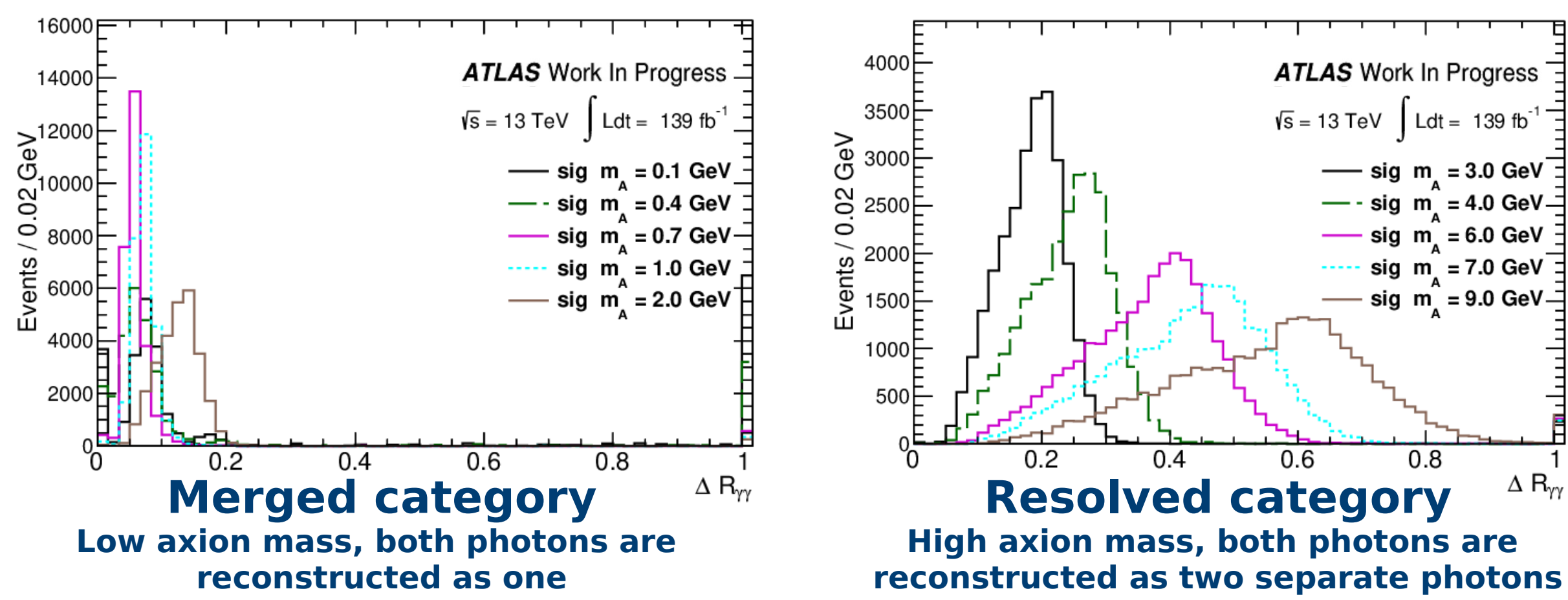$h \to Za$ Feynman diagram (left) and $a \to \gamma\gamma$ coupling parameter space, $|C_{\gamma\gamma}|/\Lambda$, with mass of the a particle, m_a, (right) [1]
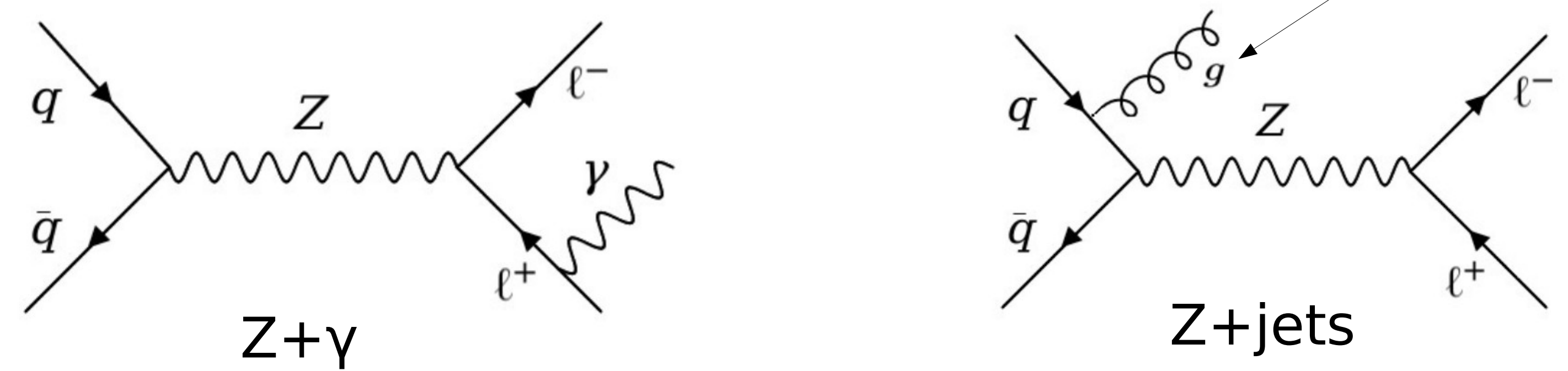
Challenge

Occasionally, photons from the $a \to \gamma\gamma$ decay are too close together and are reconstructed only as one photon.

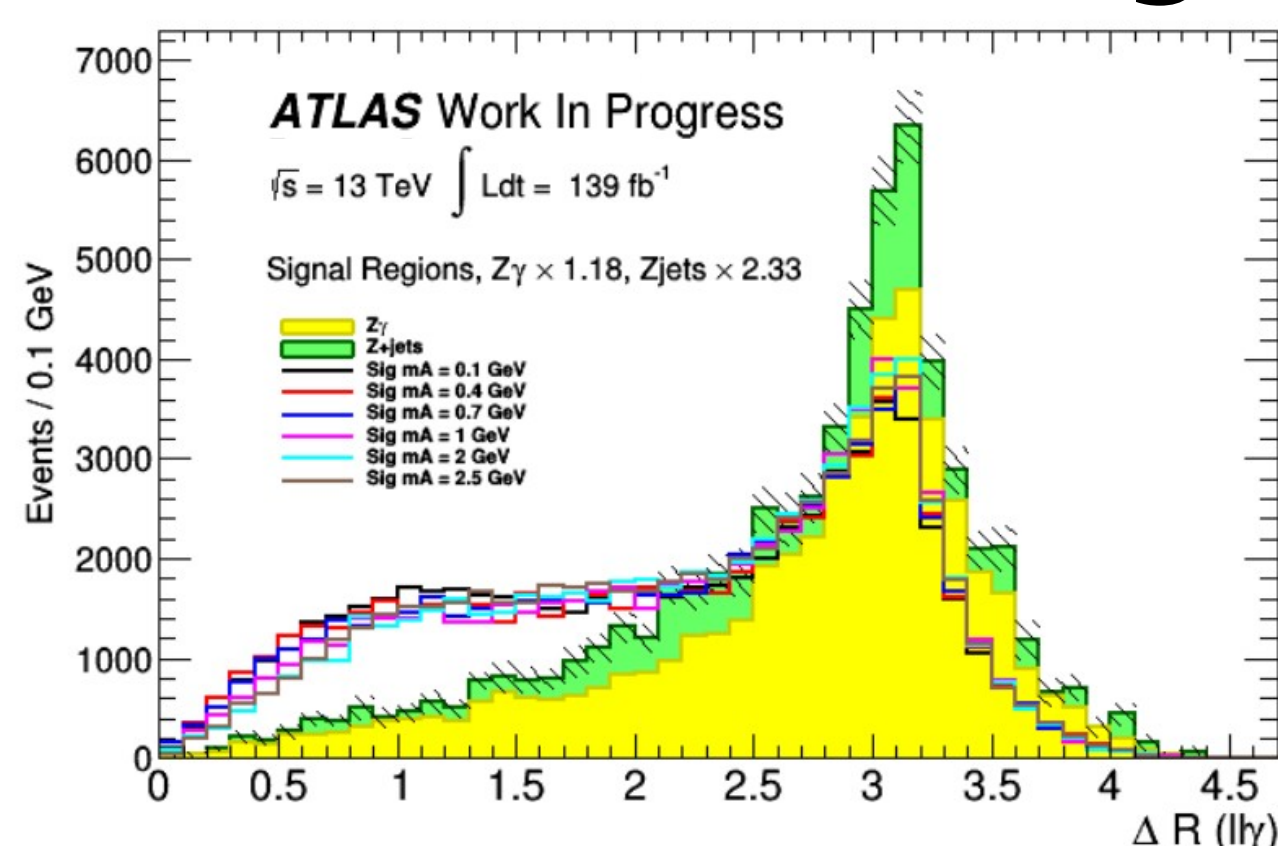**Solution:** Two selection categories based on the number of photons

Merged category
Low axion mass, both photons are reconstructed as one

Resolved category
High axion mass, both photons are reconstructed as two separate photons

Backgrounds

Gluons can produce quark-antiquark pairs that hadronise to pions and two close photons that aere reconstructed as one
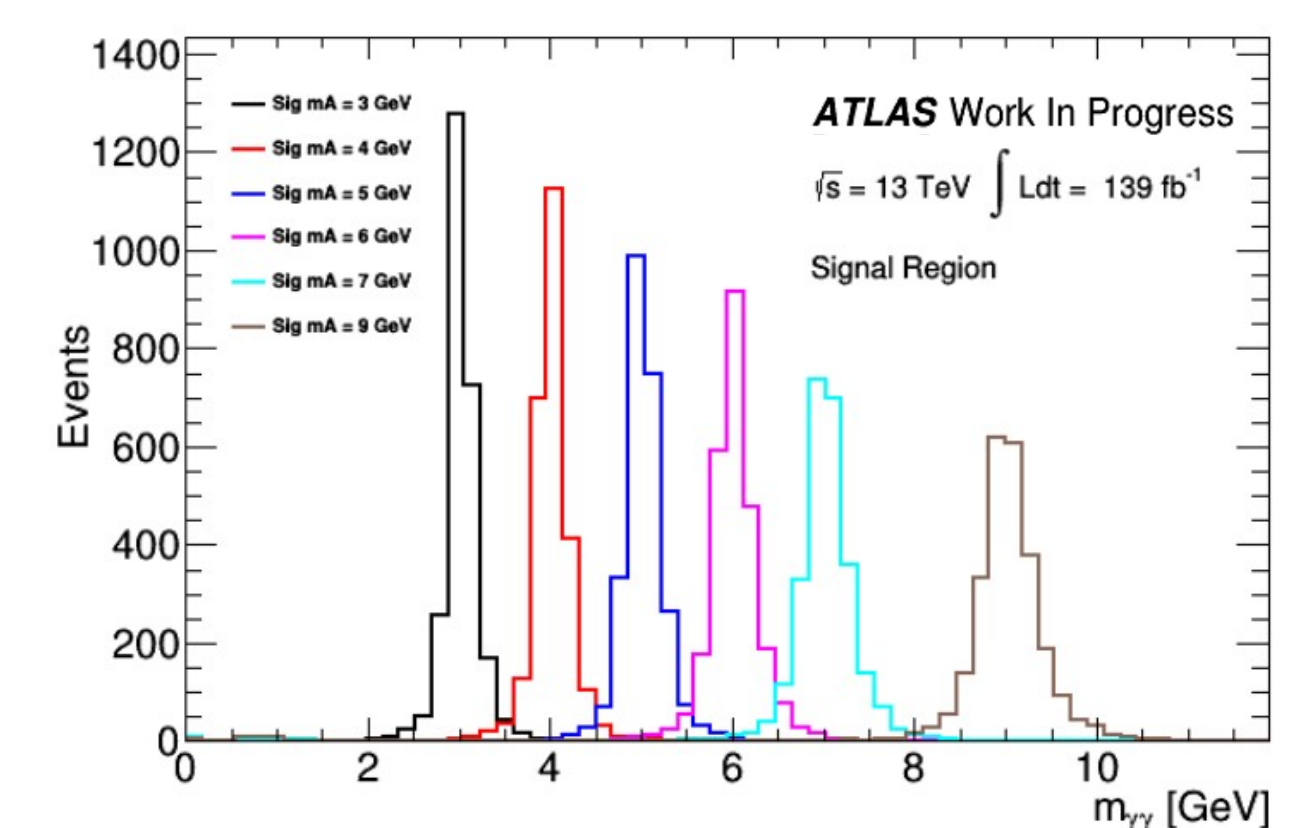

Z+γ

Z+jets

Merged Category

• Two photons from ALP decay reconstructed as a single photon

• Background Monte Carlo template

• Distribution for photon identification used to normalise and correct backgrounds

• Angular distance between Z boson and photon ($\Delta R_{ll\gamma}$) used to extract the signal

Resolved Category

• Both photons from ALP decay reconstructed as two photons

• Background estimation: Data driven

• Axion mass distribution used in final fit

• Signal parametrisation using Double Sided Crystal-Ball to generate non-Monte Carlo mass points.

Centre for Doctoral Training

Since 2017, 35 physics postgraduate students at UoL and LJMU had the opportunity to undergo unique training approaches that focused on wider Data Science and Big Data analysis skill-sets beyond the scope of that expected in the nominal PhD programme structure.

Funded by STFC, as well as comprehensive training, the LIV.DAT CDT offered the freedom to share one's expertise gained from the centre with an extensive cohort of researchers, not limited to only physics or academia but also industry and international partners.
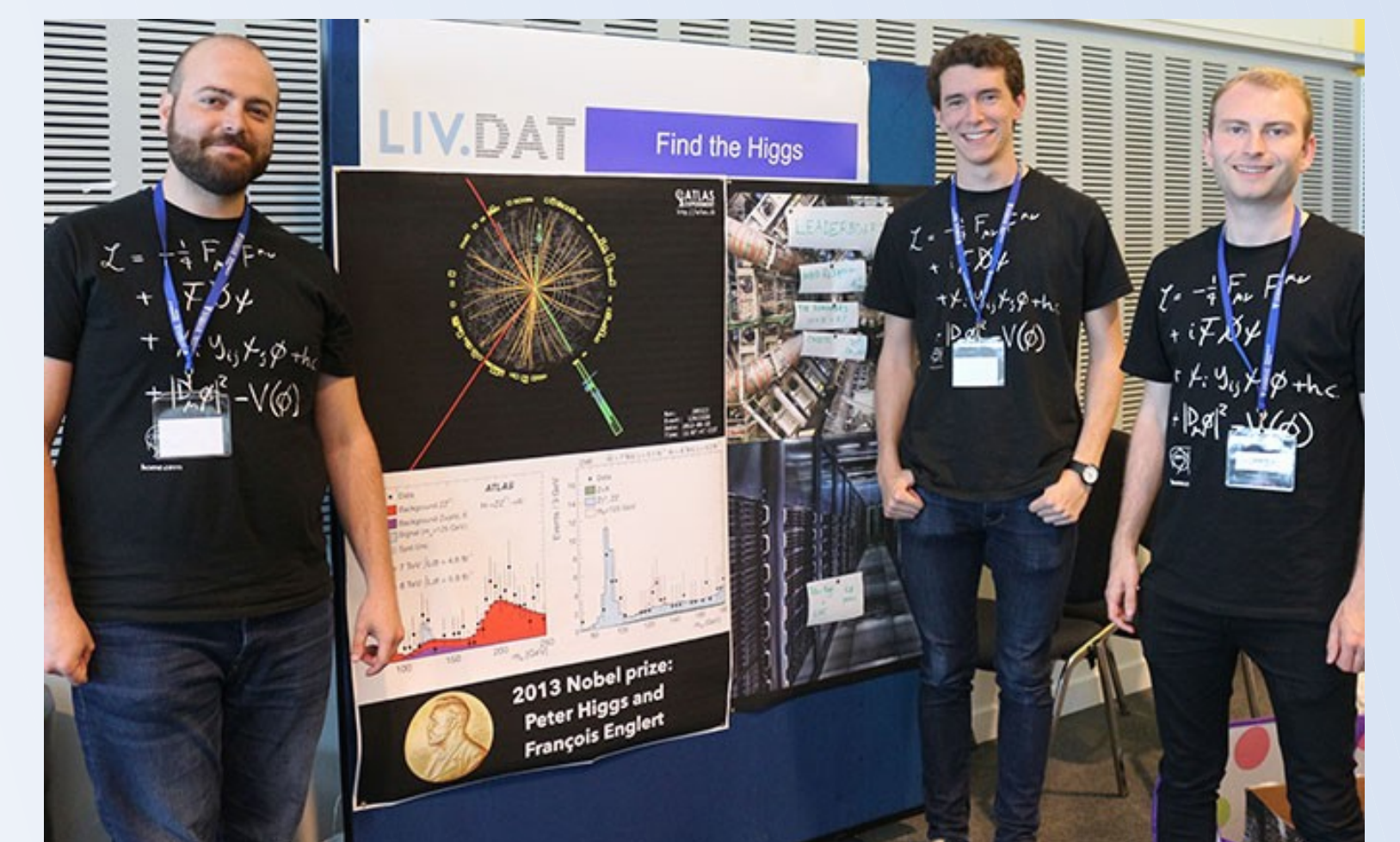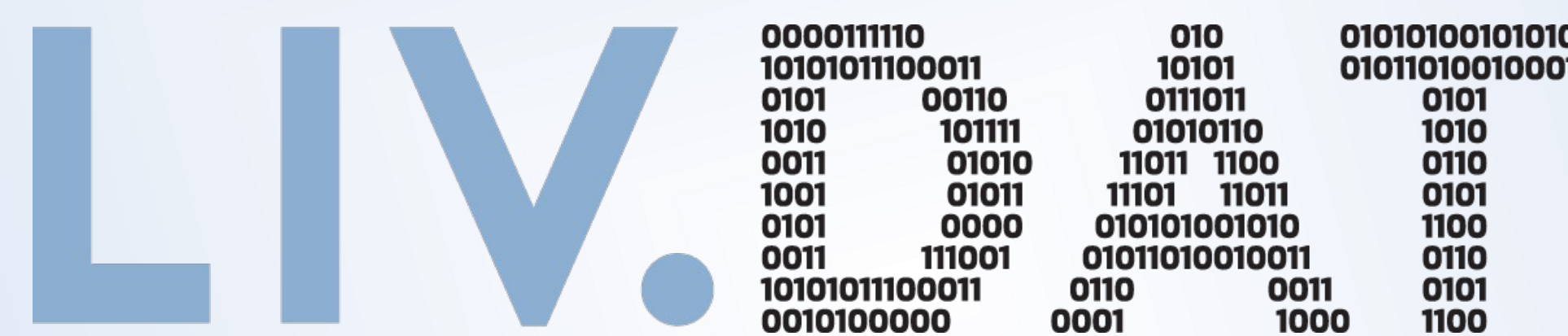

Poster presentation @ SIAM 2019

Outreach

Students present outreach activities to inspire the next cohort of ambitious students:

• Accelerators for Science & Society Symposium @ ACC

• Physics of Star Wars @ UoL

• European Week of Astronomy and Space Science @ ACC
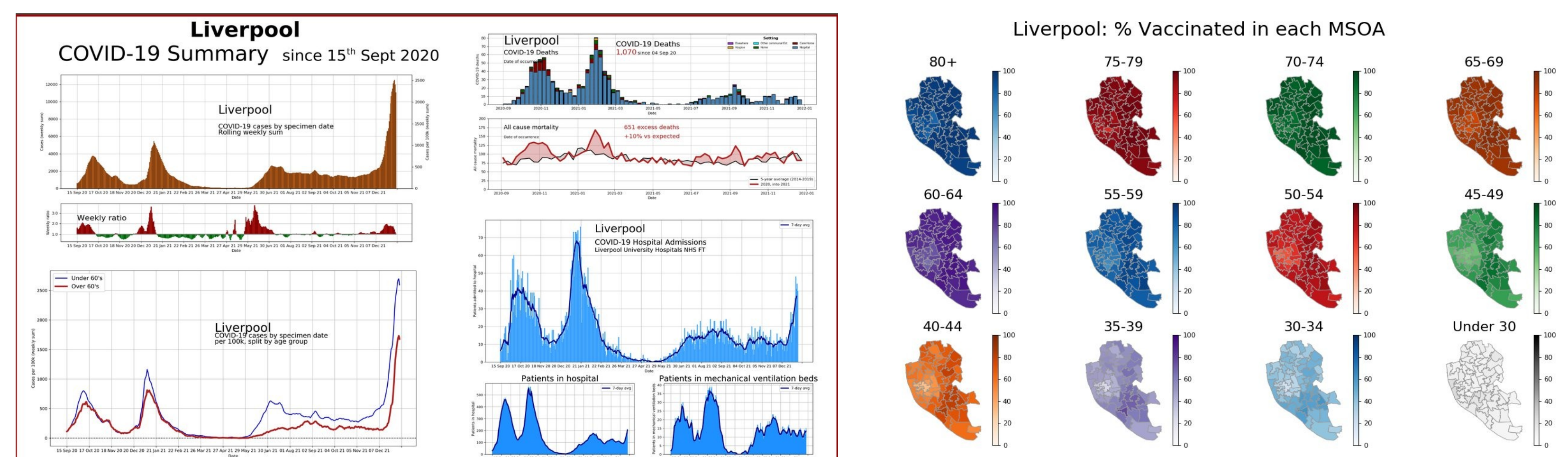
• CDT Summer school @UoL

"Finding Higgs" activity - Accelerators for Science Symposium

How the CDT aided my PhD experience

LIV.DAT gave a plethora of benefits during the PhD experience that helped with project work and beyond:

• Courses improving analysis techniques (e.g. machine learning, big data analysis, Git)

• Better computing resources

• Networking with non-ATLAS researchers (e.g. at summer schools and data science conferences)

• Opportunities of working outside academia

• Workshops to improve interpersonal skills and CV writing

COVID-19 Data Science Voluntary work

Volunteering work as part of the wider data science community for Cheshire & Merseyside's COVID-19 response (CIPHA). Collated local information from open sourced government and council COVID-19 data sources to produce plots/dashboards during the pandemic which was shared publicly via social media and local journalists.

References: [1] M.Bauer, M.Neubert, and A.Thamm, "Collider Probes of Axion-Like Particles," JHEP **12** (2017) 044, arXiv:1708.00443 [hep-ph].