A search for lepton-flavour violating τ→3μ decays with the ATLAS experiment

Conor McPartland

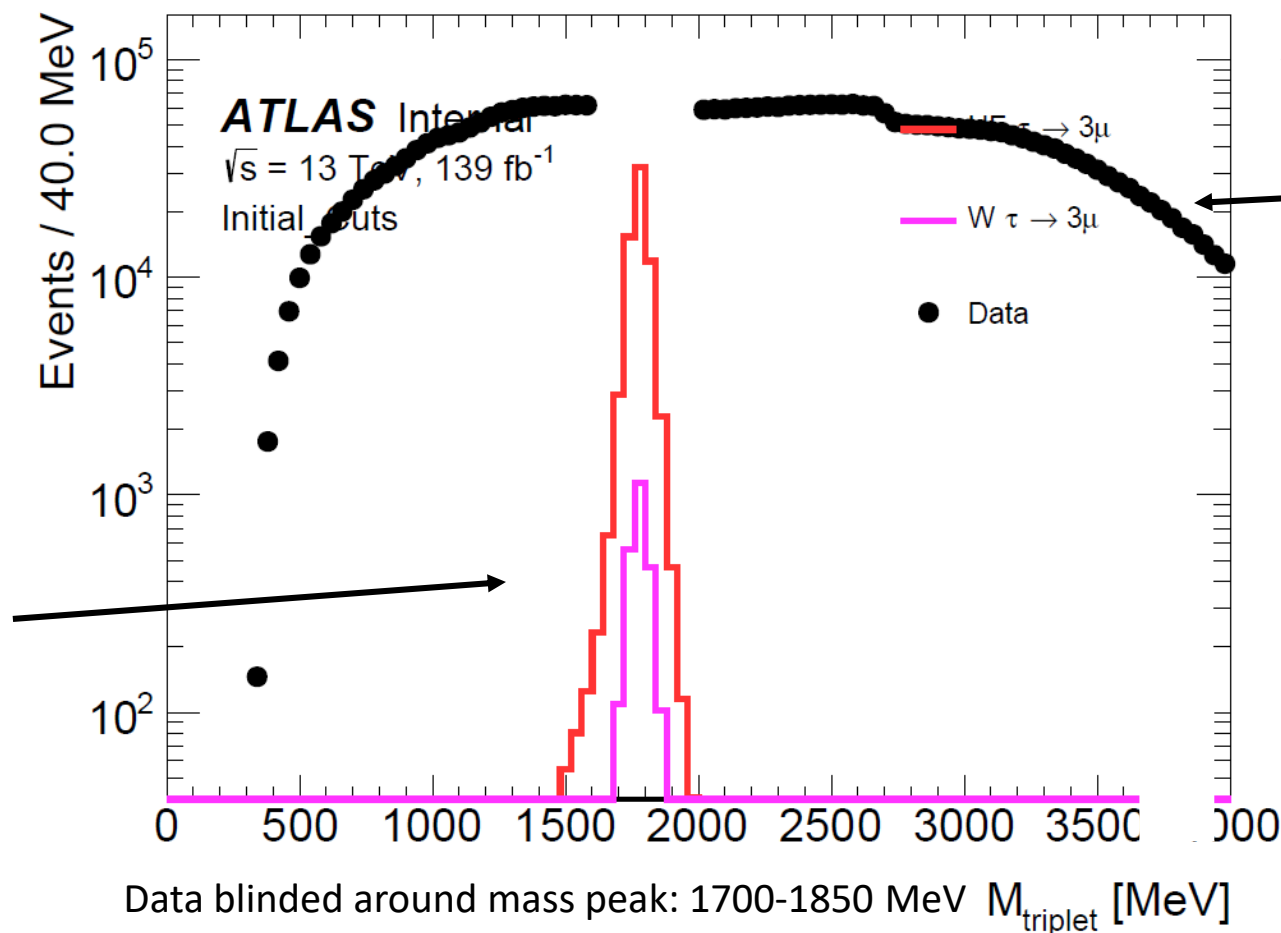Carl Gwilliam, Jan Kretzschmar and Matt Sullivan

Motivation

- Flavour is not a fundamental symmetry, violation observed in neutrinos and quarks
  - Recent intriguing LHCb results on possible violation of lepton universality

- Decay to be analysed at ATLAS $\tau^{\pm} \rightarrow \mu^{\pm}\mu^{\pm}\mu^{\mp}$
  - Standard model BR: $x10^{-55}$-$x10^{-56}$

- Current limits on tau are much less stringent than that of muons and electrons by approximately $O(10^4)$
  - If found in charged leptons would be evidence of beyond standard model physics
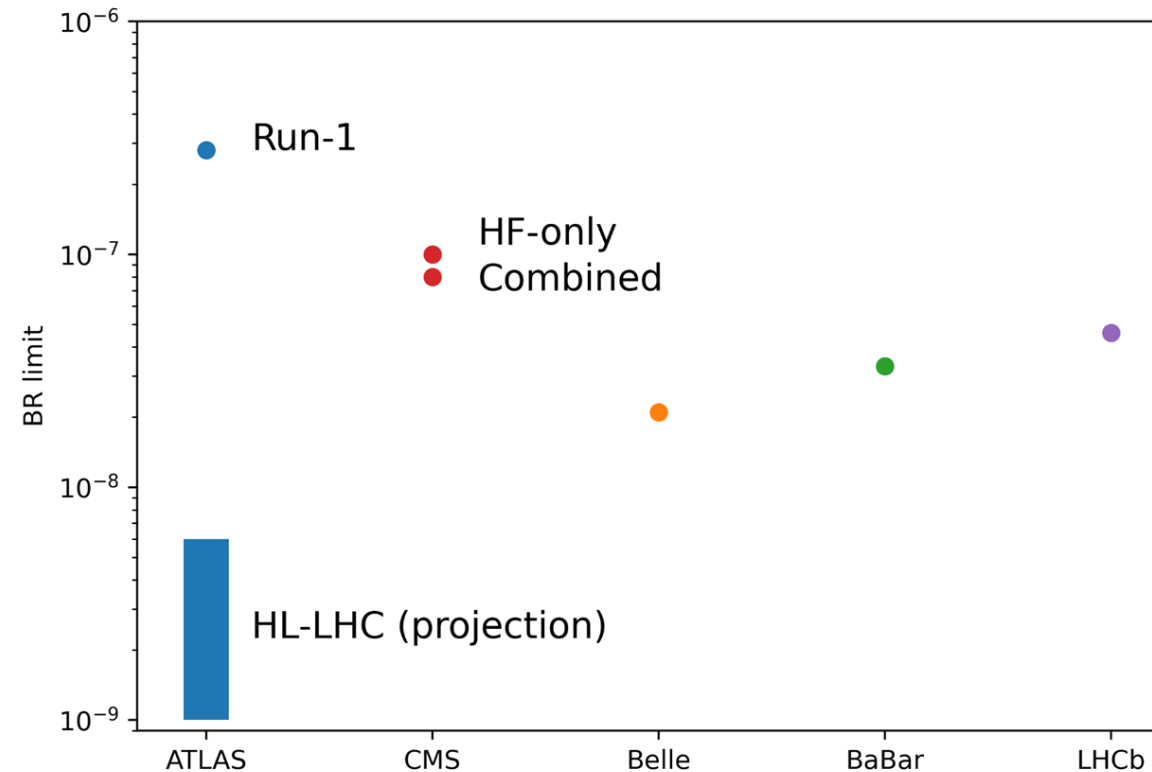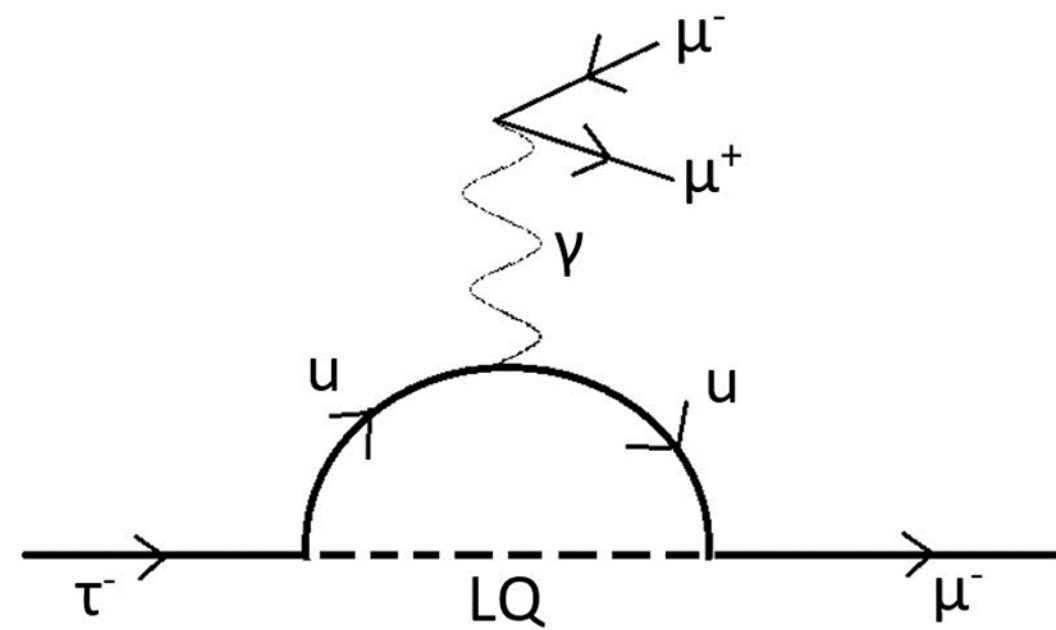
Analysis Strategy

- Taus produced via Ds→ τν and bb→ τν decays (HF) and W→τν (W)

- Current focus HF channel
  - HF has larger acceptance but lower resolution
  - W cleaner signal but lower acceptance

ATLAS Internal
$\sqrt{s}$ = 13 TeV, 139 fb^{-1}
Initial cuts

HF τ → 3μ

W τ → 3μ

Data

Events / 40.0 MeV

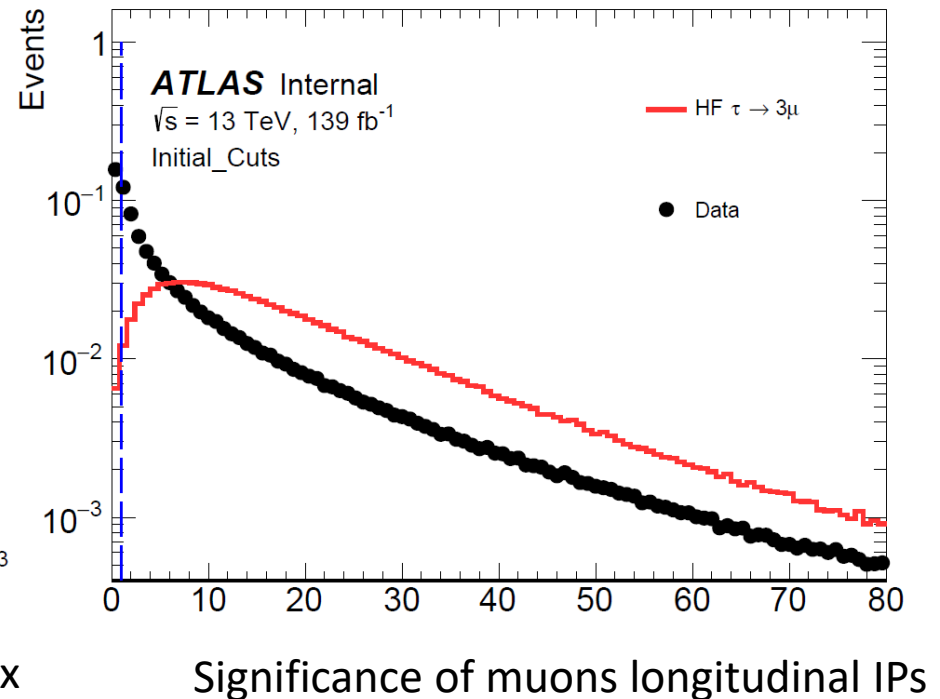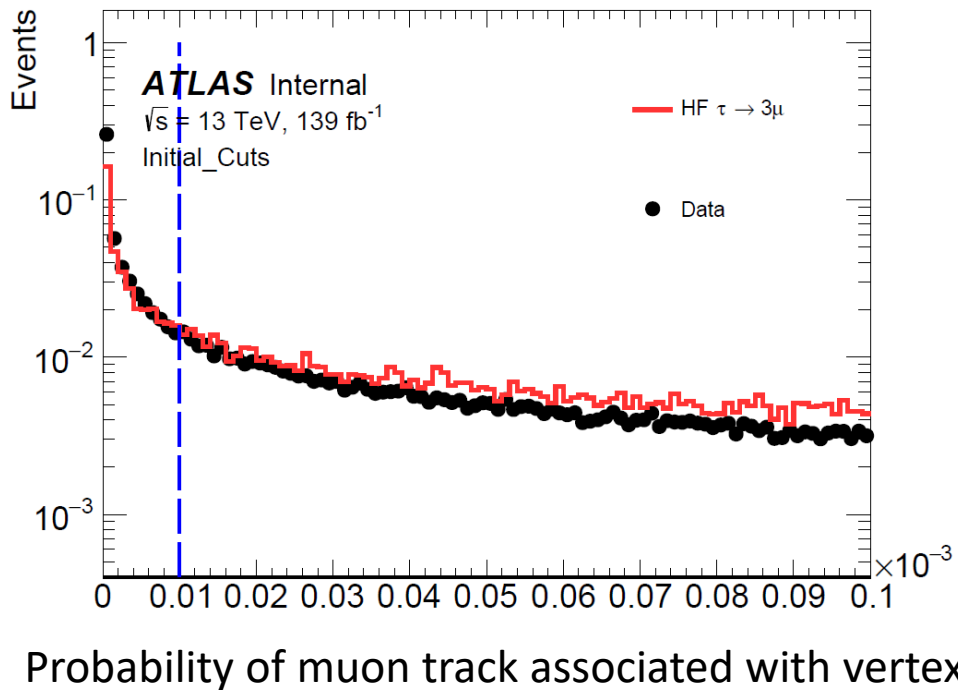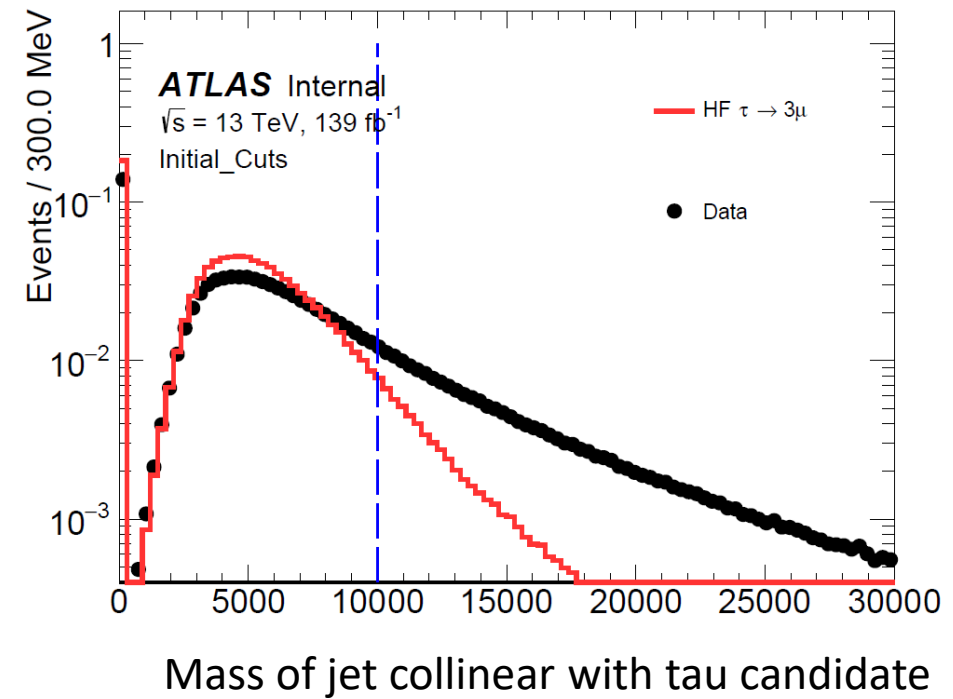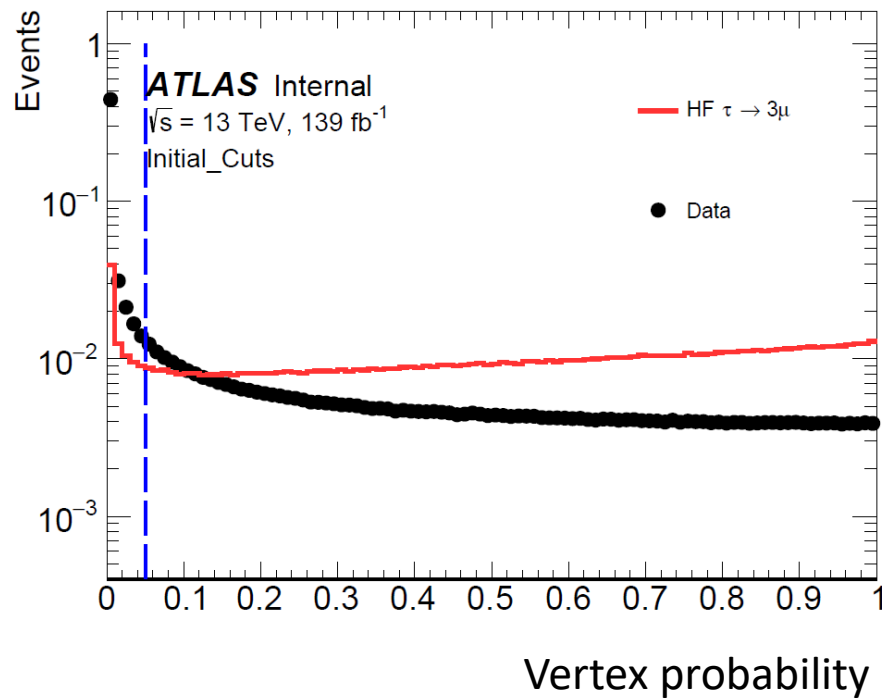$M_{triplet}$ [MeV]

Data blinded around mass peak: 1700-1850 MeV

- Two main background sources:
  - Incorrectly identified vertices and misidentified muons
  - Resonant meson background processes e.g. Ds → ϕμν

| Preselection	MVA	Resonant background cut	Fit to three muon mass

Pre-selection cuts

- Before using MVA perform pre-selection cuts to reduce background to signal ratio for triplet muon mass

Vertex probability

Mass of jet collinear with tau candidate

Probability of muon track associated with vertex

Significance of muons longitudinal IPs

MVA

- Several MVA types tried and optimised
  - Using XGBoost BDT to improve signal to background ratio
- Trained with signal (Ds) vs sideband data
  - Training sample composed of two equal halves
- 16 inputs features, some examples shown in slide 4
  - Vertex quality, tau displacement, tau kinematics and isolation variables
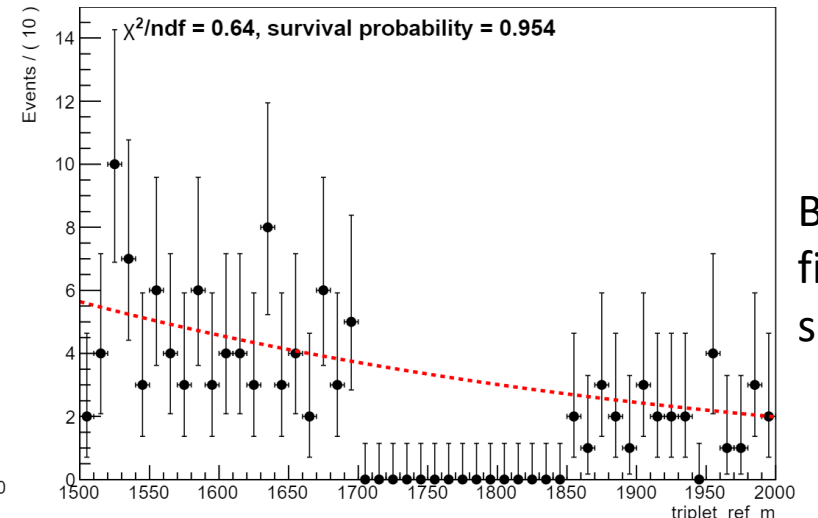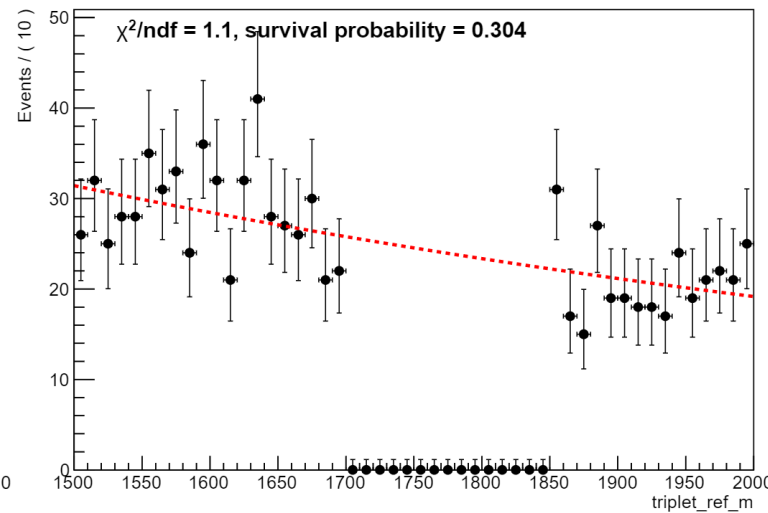 - Variables are not correlated with triplet mass
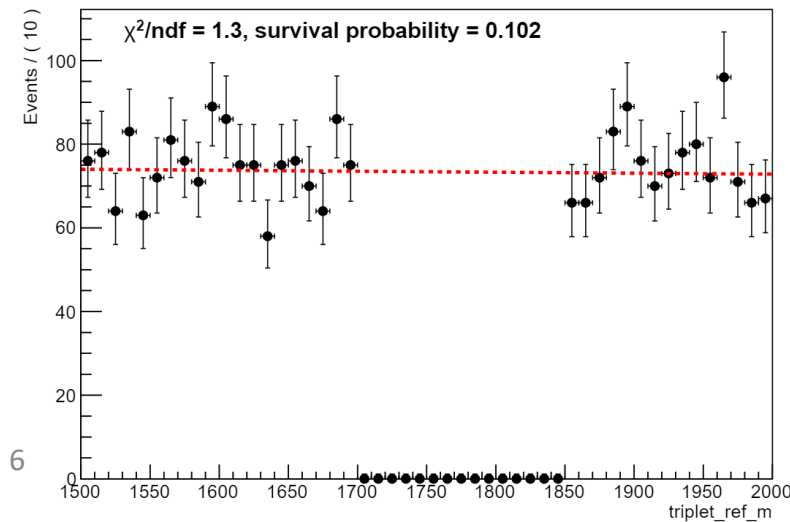

ROC curve
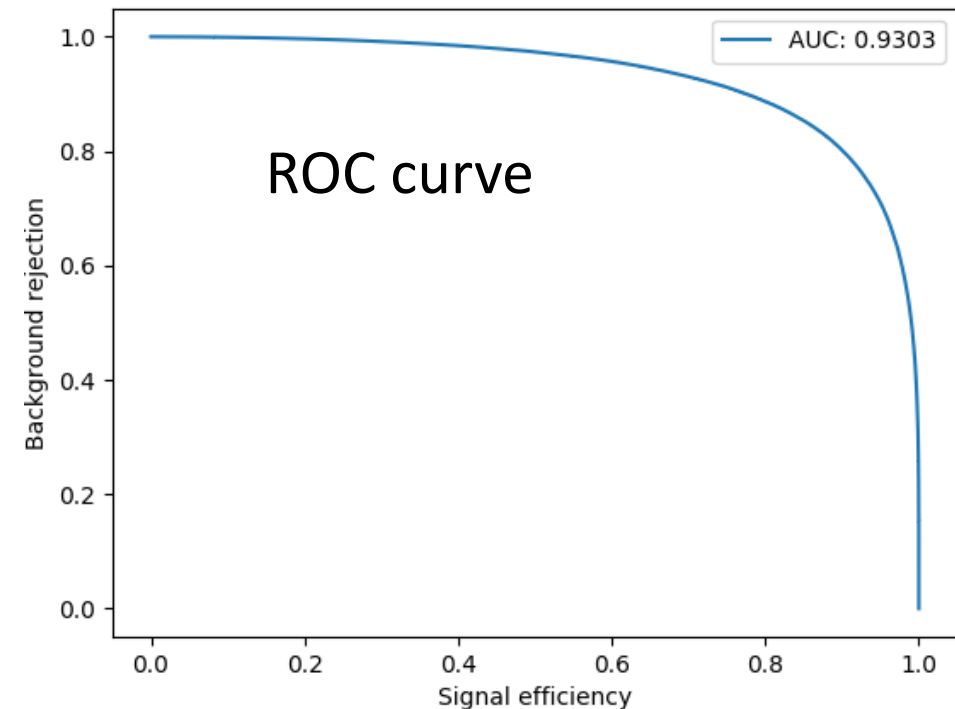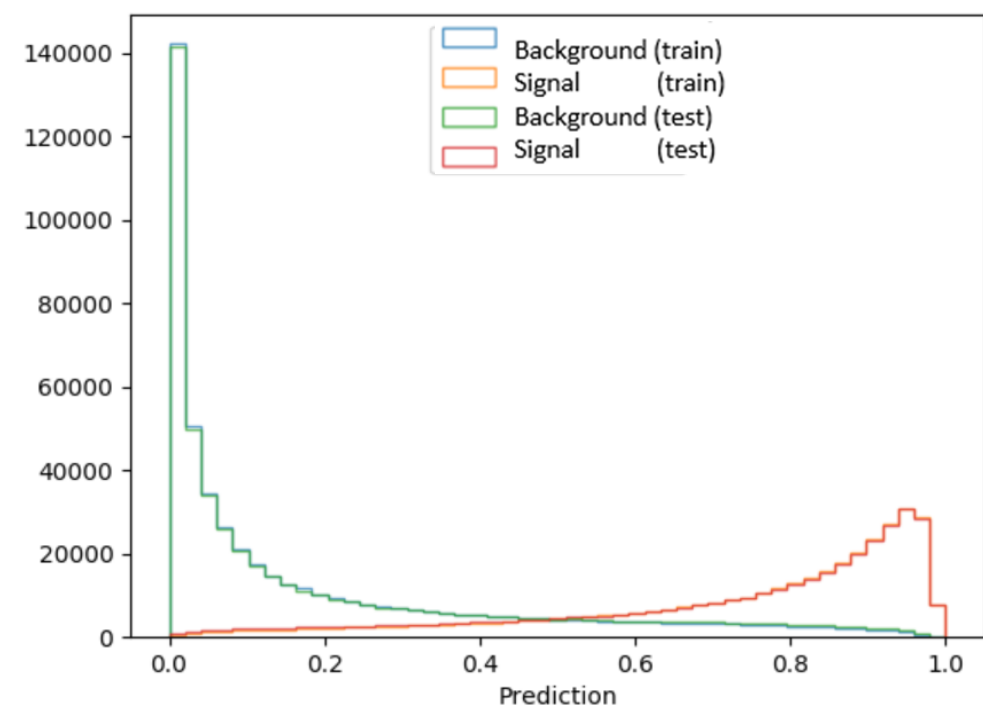
Fitting

- Simultaneous fit performed in 6 regions
 - 3 BDT bins
 - 2 eta split (low and high)
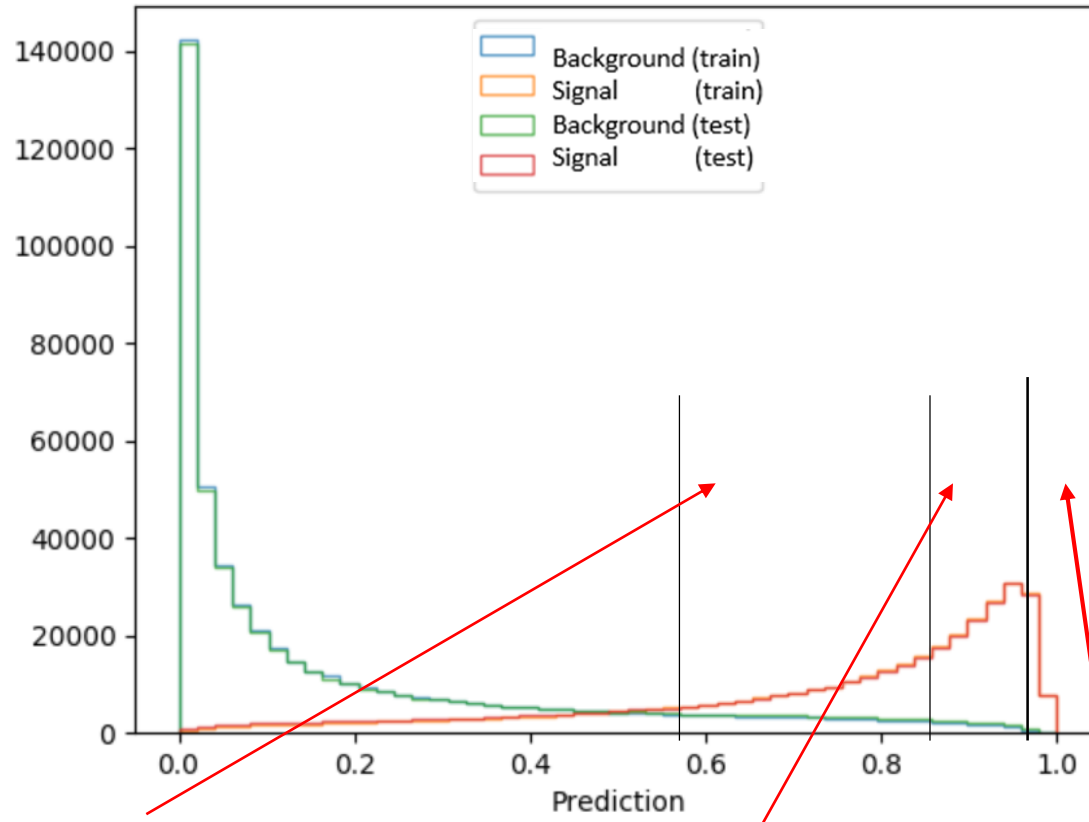
- Fit signal MC with double sided crystal ball
- Fit background with exponential
- Test combined fit by injecting a known signal


Barrel fits shown

Result

- Overall normalisation of signal template is treated as parameter of interest in fit
  - POI is interpreted as branching ratio

- Use confidence limit scan method

- An expected limit of: 9.13×10^{-8} was obtained

- CMS (HF) 10.0×10^{-8} (33.2 fb^{-1})

- Plan to combine with W result- initial studies started by MPHYS student
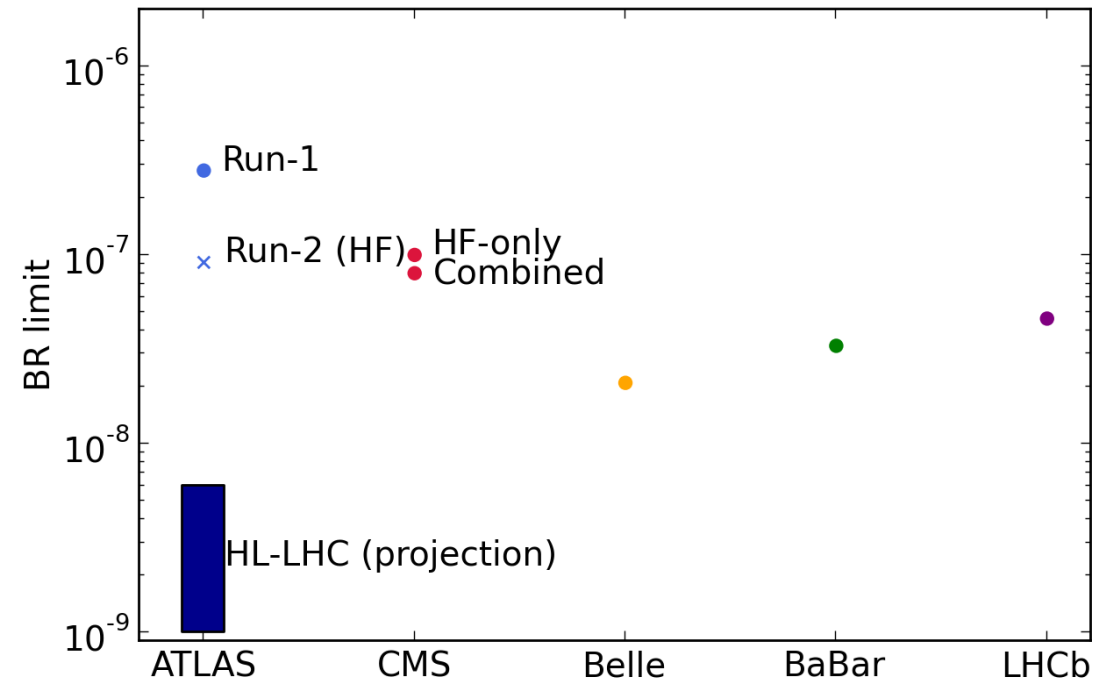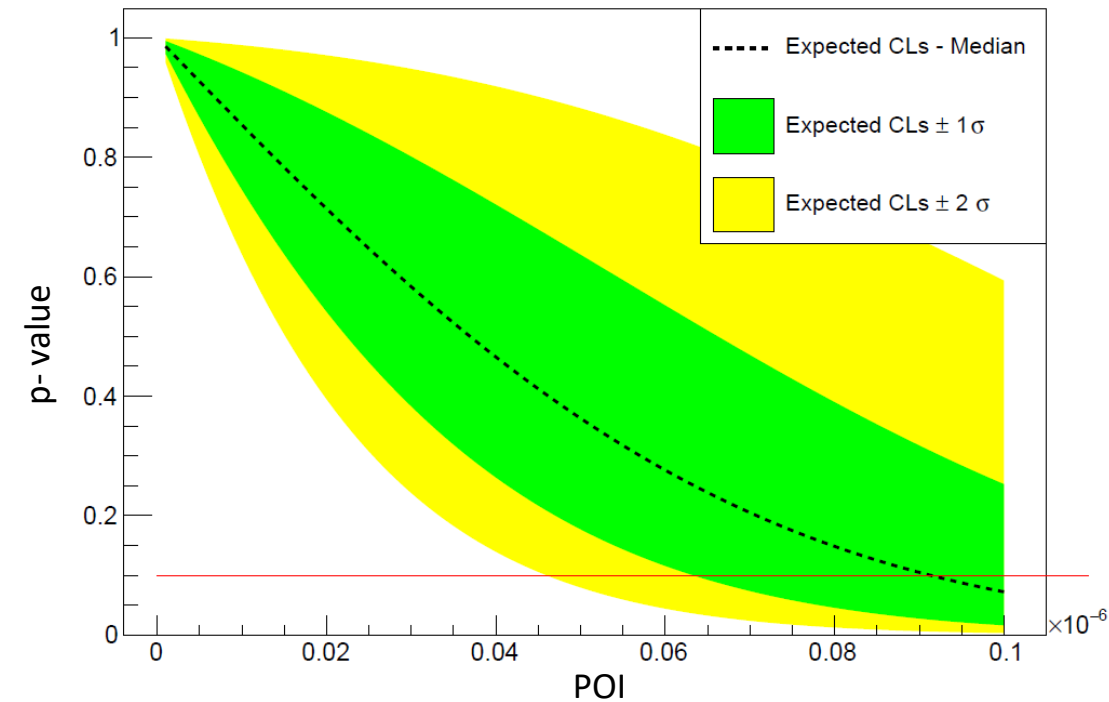
Qualification Task

- As part of ATLAS a qualification task (QT) is needed in order to contribute to experiment

- ATLAS Inner Tracker (ITk) is being produced for HL-LHC which requires major increase in detector area

- Significant numbers of individual pixel modules are being produced, shipped and tested

- My QT involved producing a page in the pixels webapp to produce summary plots and tables that show production worldwide and at country and institute level
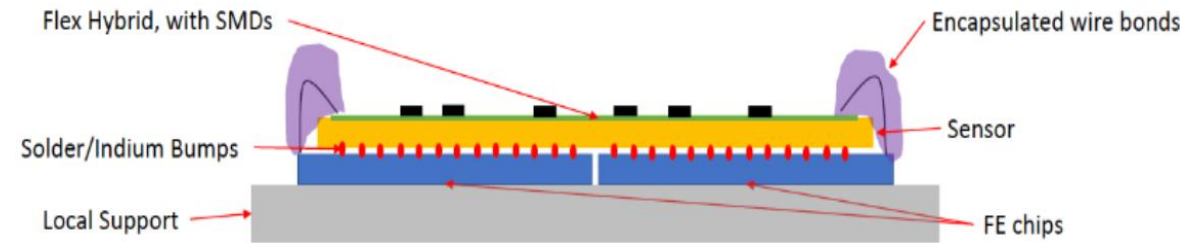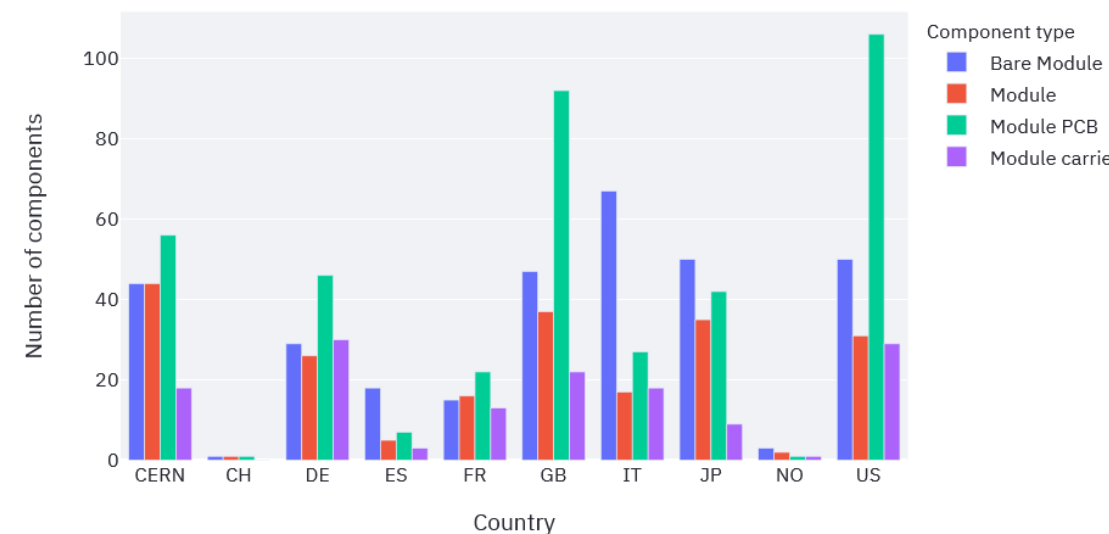
Summary

- All main analysis tools in place to find limit
- Obtained an expected limit
- Before systematics expected limit looks to be competitive with CMS
- Current focus:
  - Trigger efficiency studies
  - Trigger scale factor calculation
- Short/medium term:
  - Fit optimisation
  - Systematics
- Long term
  - W channel- MVA studies have been started by MPHYS student
  - Plan for paper at next winter conferences
  - LIV.DAT work placement
- Qualified as ATLAS author and hope to continue working on ITK reporting tools