Improving the data quality efficiency at the ATLAS Semiconductor Tracker and searching for Long Lived Axion-like Particles

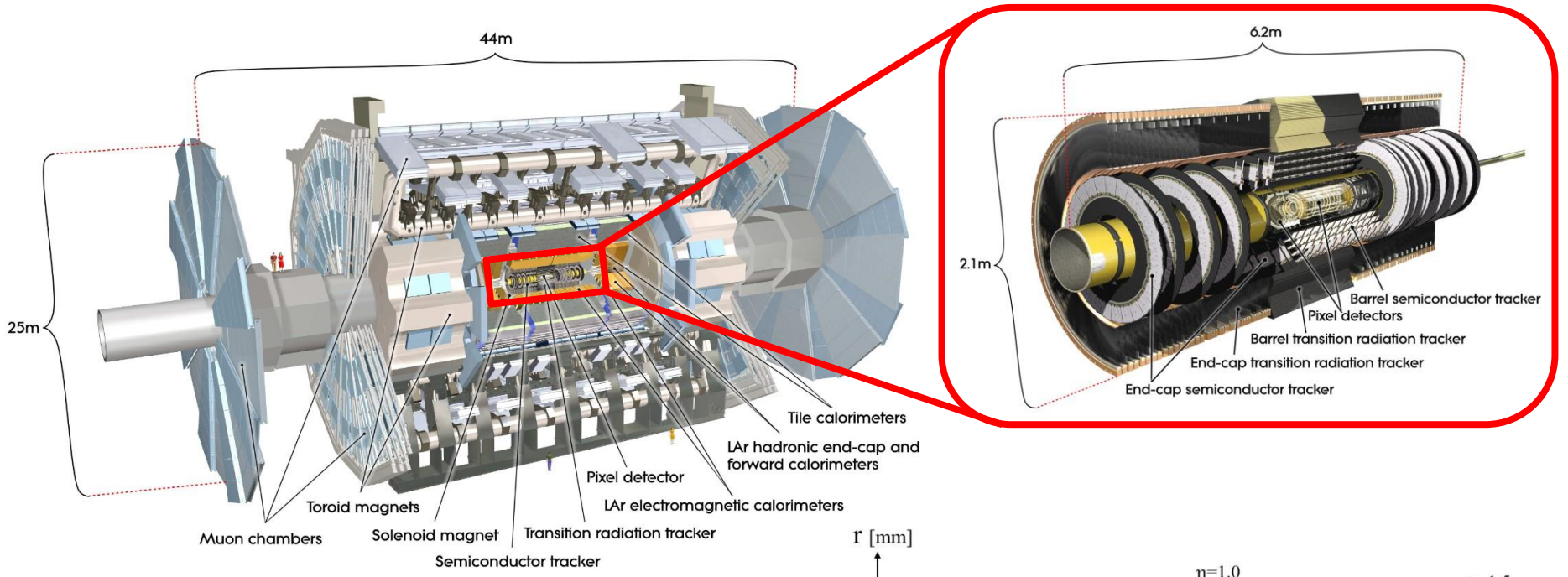
Rebecca Irwin

Supervised by:
Prof. Monica D'Onofrio,
Dr Nikolaos Rompotis,
Dr Carl Gwilliam,
Dr Frederico Meloni
(DESY)

This presentation covers two tasks:

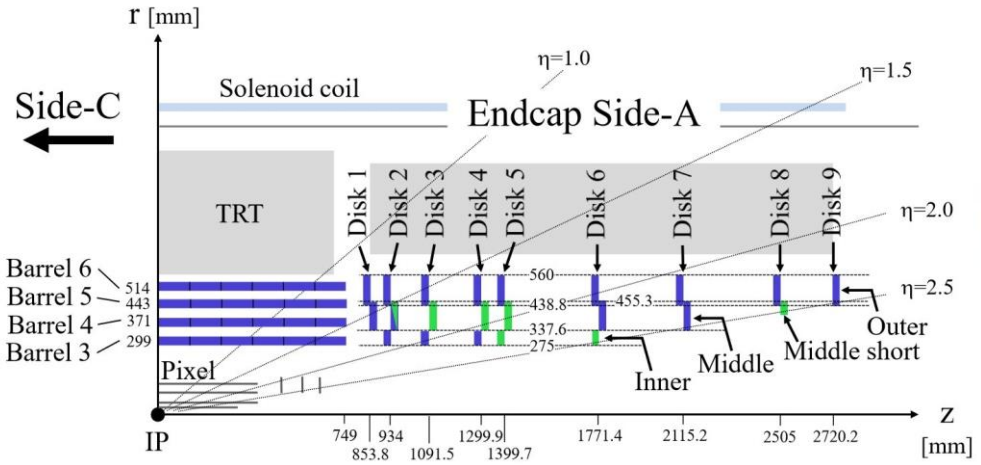
- ATLAS Qualification task studying aging due to radiation damage at the SCT.
- Start-up of physics analysis searching for long lived ALPs.

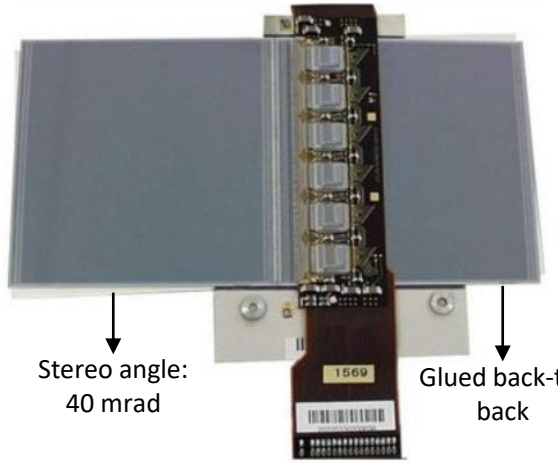
The ATLAS Detector at the LHC



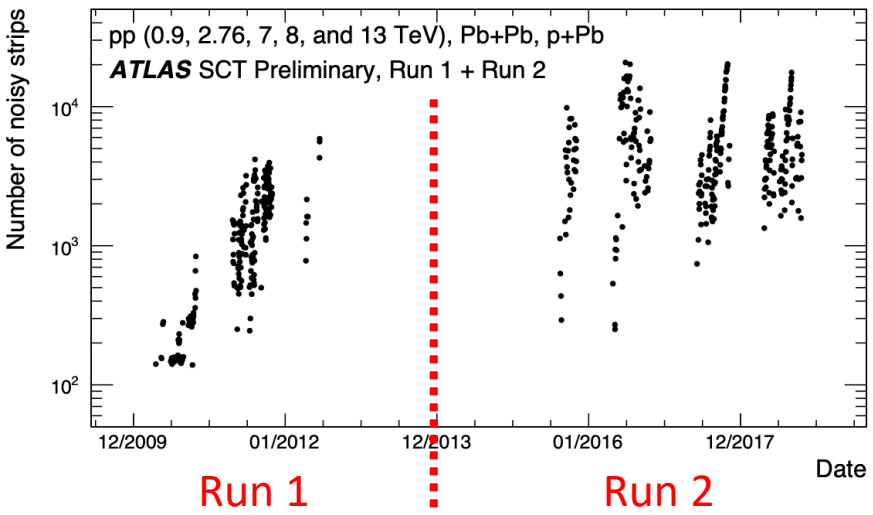
- One of two general-purpose detectors at the LHC.
- In Run 2 the LHC reached 13 TeV centre-of-mass energy ($\sqrt{s}$).
- Run 3 $\sqrt{s}$ = 13.6 TeV

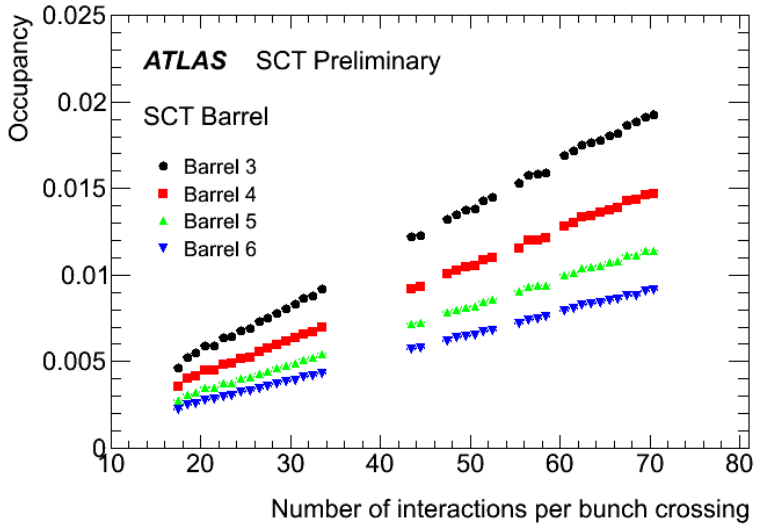
- Made up of 4088 silicon-strip detector modules.
- A binary threshold of around **1 fC** in the detected charge is used to define a ‘hit’ in the SCT.

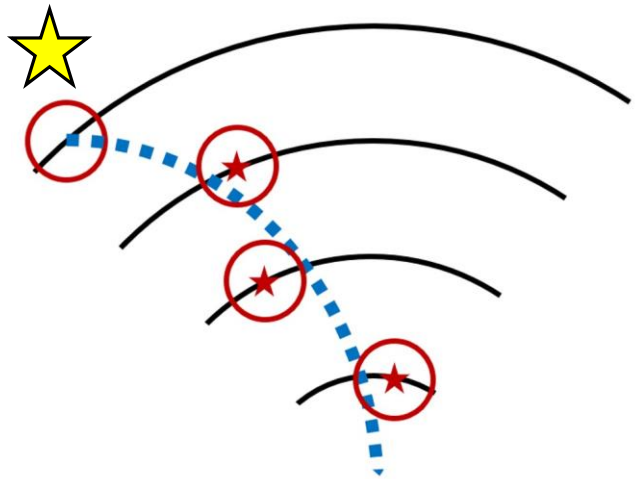




Radiation Damage in the SCT



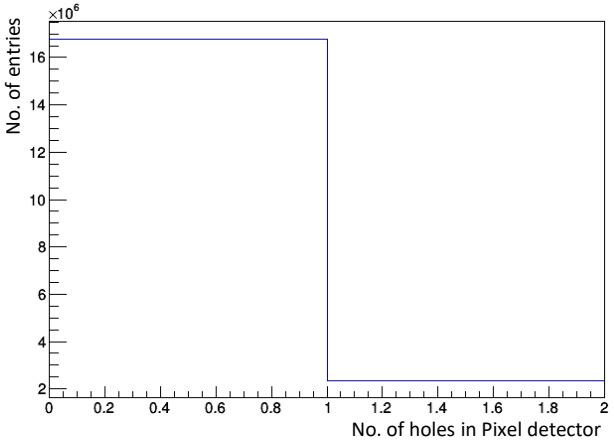


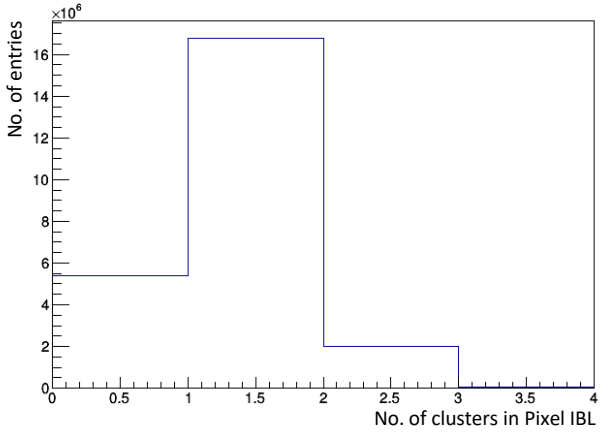


- SCT sensors irradiated by particles with energy ranging from TeV-scale to thermal neutrons in Run 1 and Run 2.
  - Has not been updated, therefore requires optimisation of settings for Run 3.
  - Radiation damage increases number of noisy strips (strip occupancy > 1.5%).
- Readout chip disabled if too many noisy strips.
- Disabling too many readout chips creates ‘holes’ on SCT layer.

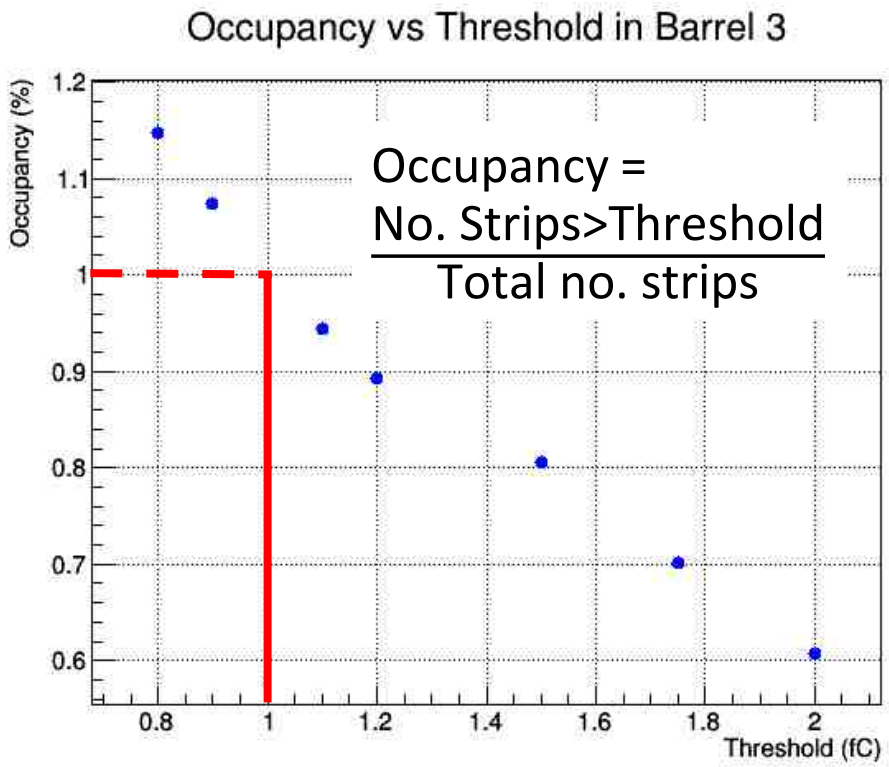
Event Selection

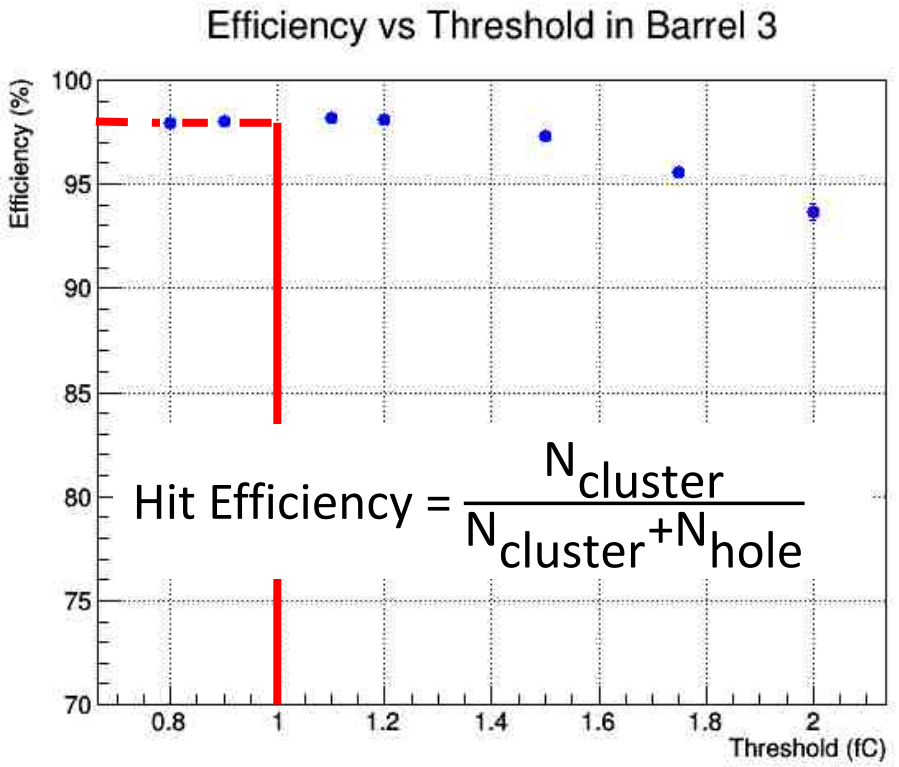
- Threshold scan data from pp collision Run 361635 in 2018 was analysed.
- Tracks found in this scan had to satisfy the following:
  - Transverse momentum $p_T > 1GeV$.
  - $\frac{\chi^2}{N_{dof}} < 3$, where χ^2 is the χ^2 of the track fit to the hits, and N_{dof} = number of degrees of freedom.
  - Transverse impact parameter $|d_0|$ < 10 mm.
  - Number of clusters of SCT sensors, excluding the sensor under consideration, $N_{cluster}^{SCT} \geq 6$.
  - Number of holes in Pixel detector, N_{hole}^{pixel} = 0.
  - Number of clusters in Pixel IBL or B-layer (second innermost Pixel layer), $N_{cluster}^{pixel} \geq 1$.
  - Incident angle with respect to SCT module surface, $|\phi_{inc}| < 40^{\circ}$.





Results using 2018 data



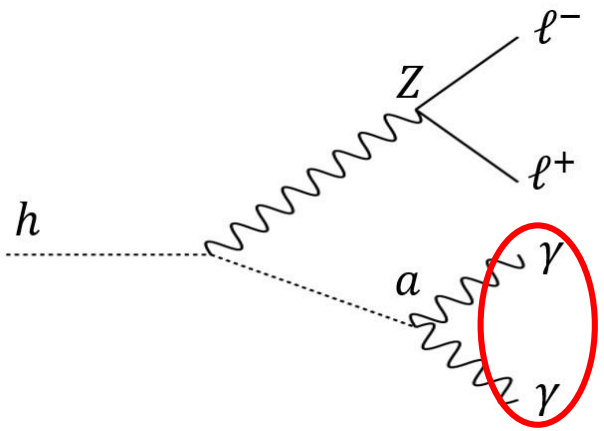


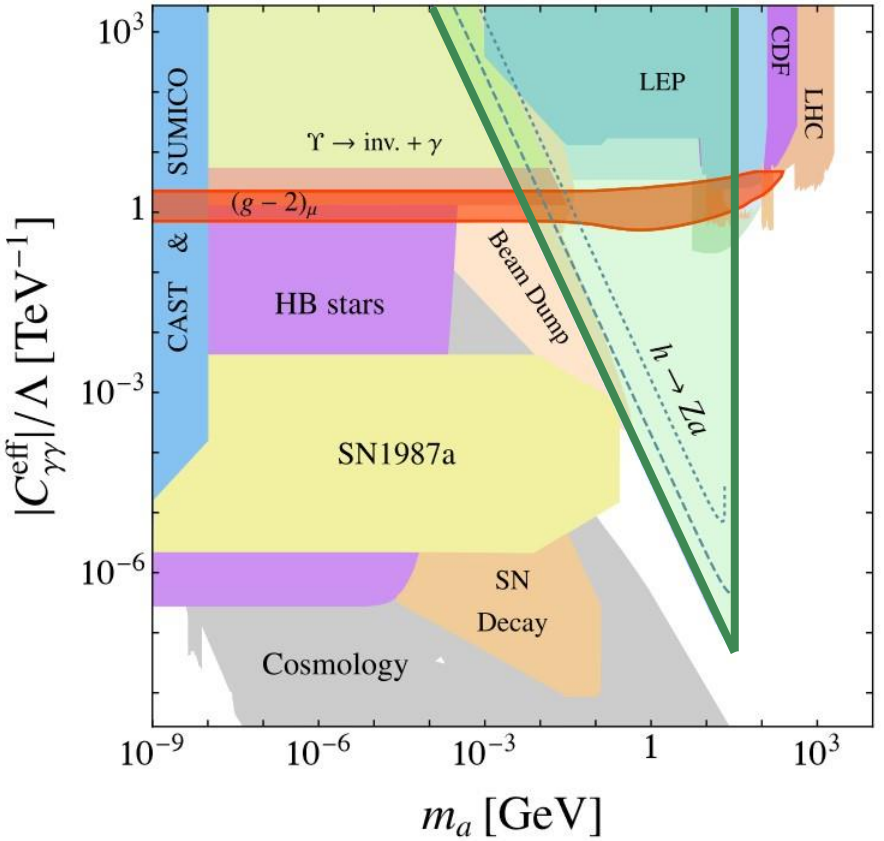
- Optimal threshold maintains efficiency > 99% and occupancy < 1%.
  - Not yet achieved, work in progress to improve selections for efficiency.
- Updating SCT settings will improve quality of data taken in Run 3.

Axion-like Particles

ALPs are hypothetical light particles that may be a component of the dark sector.

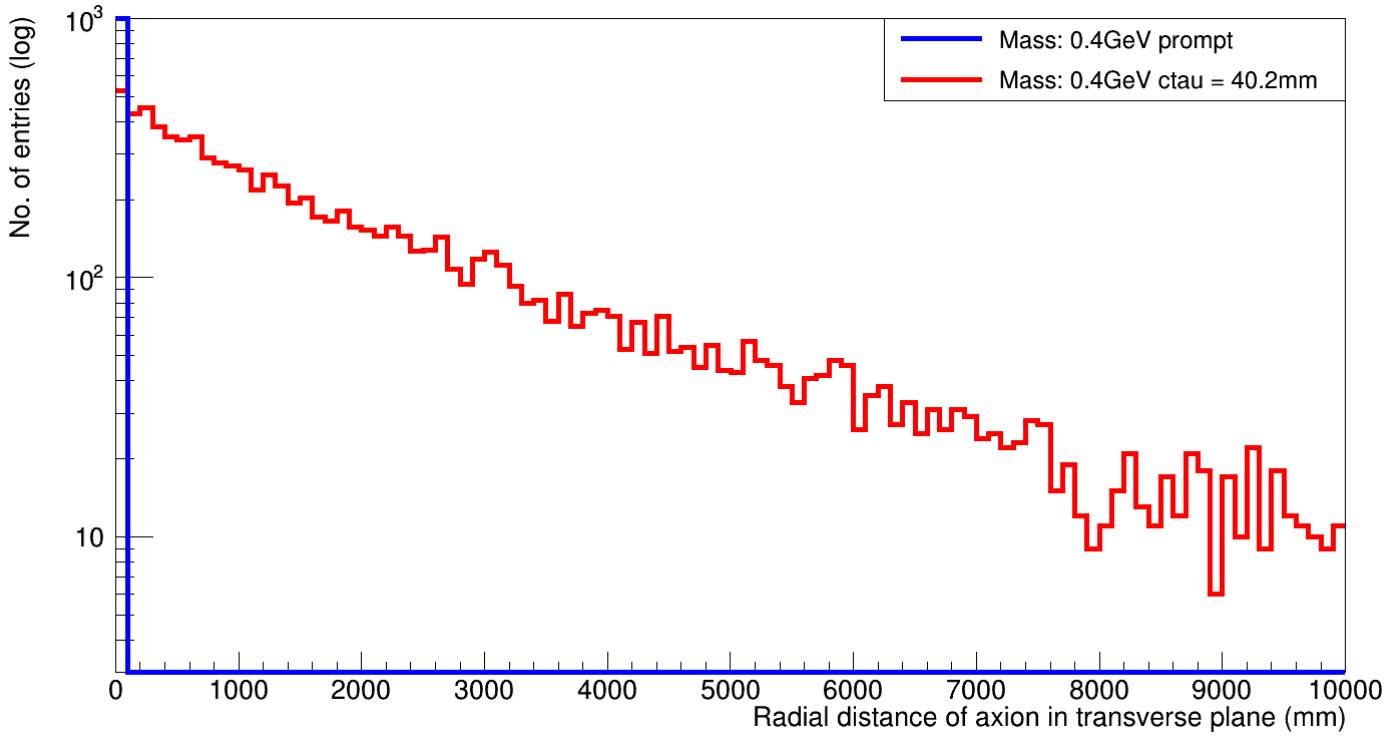
- May be found in Higgs decays.
- Plot shows reach in mass vs coupling to photons for various experiment.
  - γγ coupling denotes lifetime.
  - Dotted lines show coupling to ALP.
- ATLAS can probe $(g\text{-}2)_\mu$ anomaly sensitivity region.
- ALPs can decay prompt or long-lived.





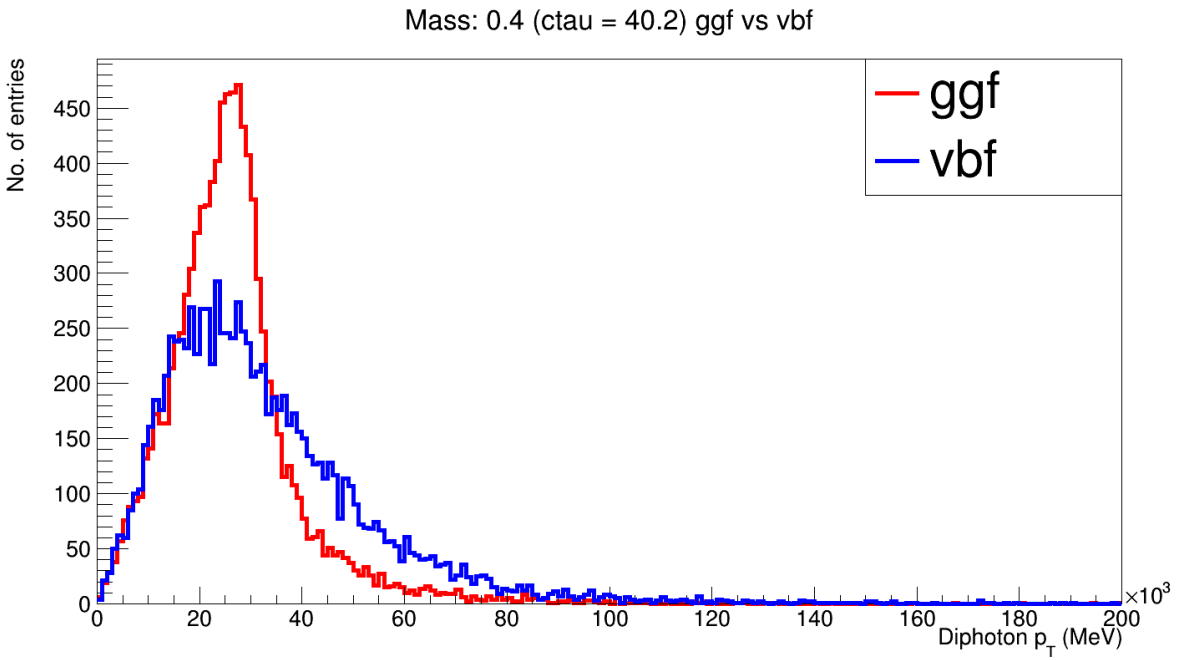
Radial Distance of axion

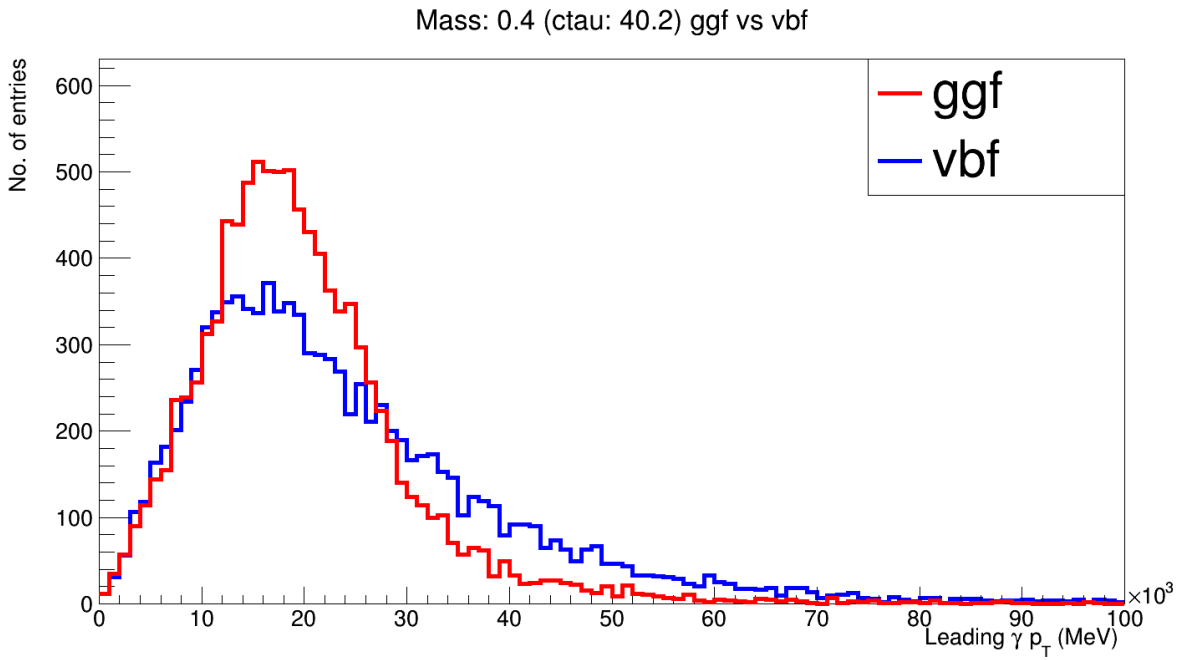
- Events used in preliminary analysis are generator level (no simulated detector).
- Generated samples studied assume mass of 400 MeV.
- ctau = lifetime measured as a distance.

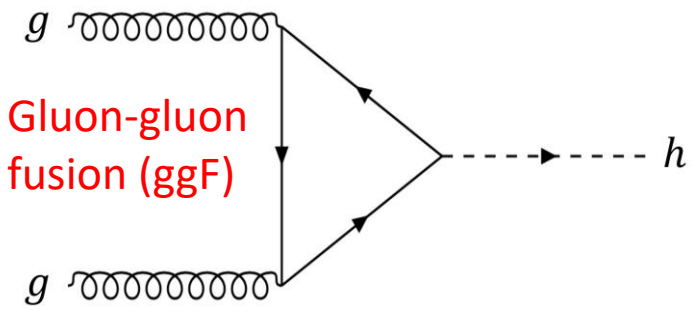


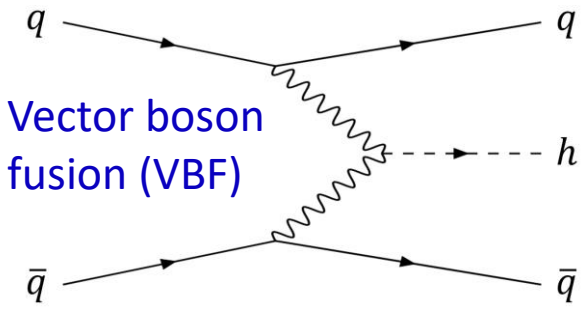
- The lifetime follows an exponential decay.
- This plot tails at 100 cm as everything is plotted within the tracker volume.
- Long-lived ALP travels quite a distance before decaying, whereas the prompt ALP does not.

Transverse momentum (p_T)



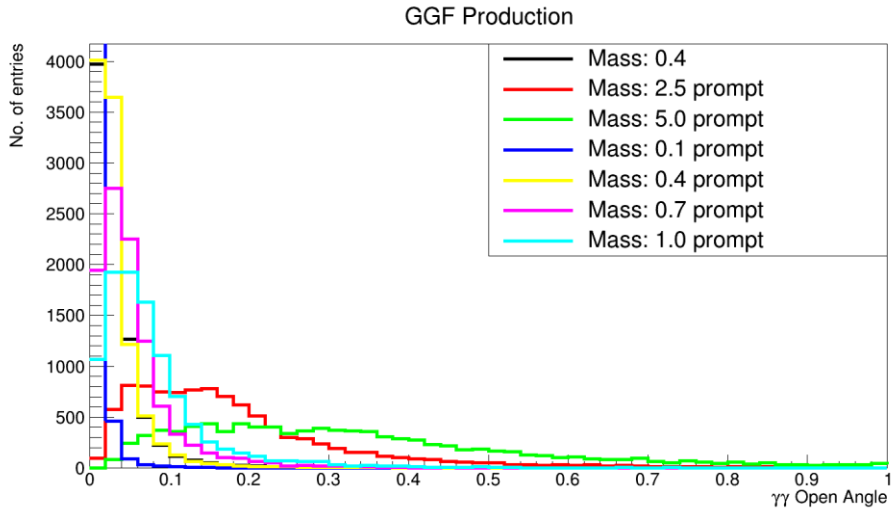


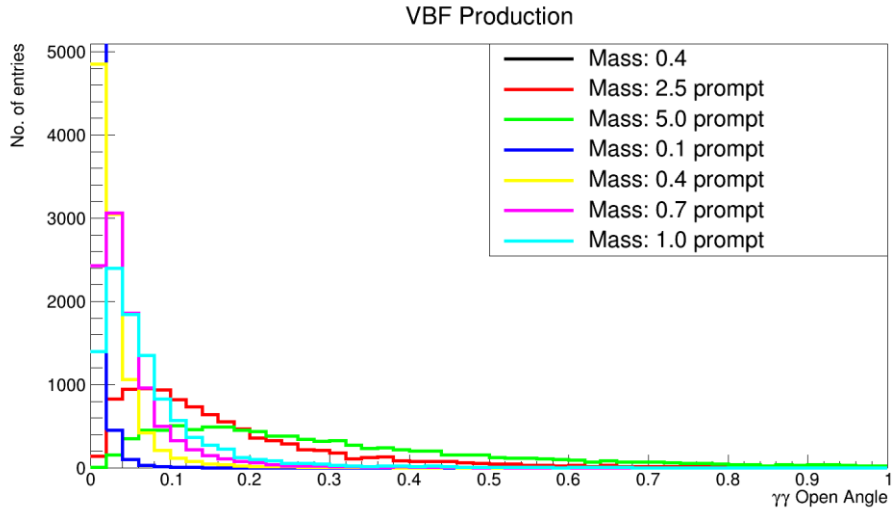


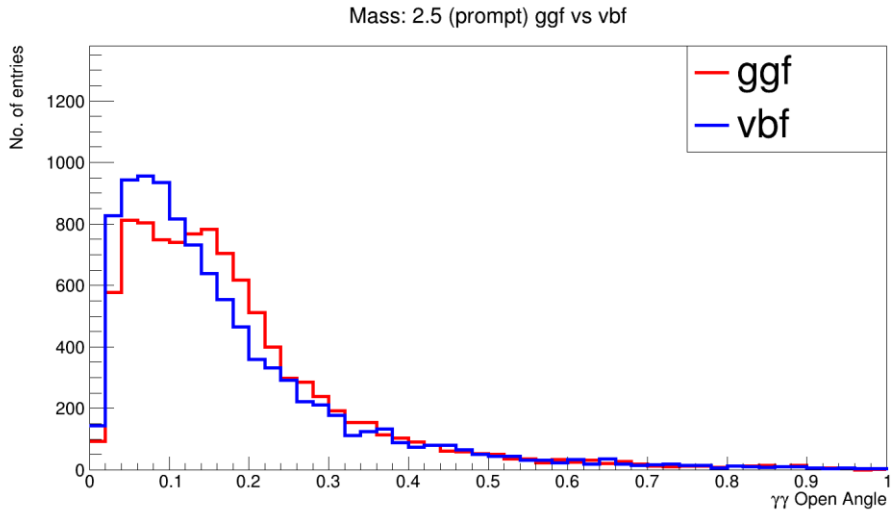


The photons from ggF Higgs production have a sharper peak, this is from VBF Higgs production being more boosted than ggF production.

Di-photon open angle







- ALP mass range studied from 0.1 – 5.0 GeV.
  - Only one sample with assumed lifetime distribution ctau = 40.2 mm.
- Angle between two photons analysed.
- Increases as ALP mass increases as momentum would be smaller.

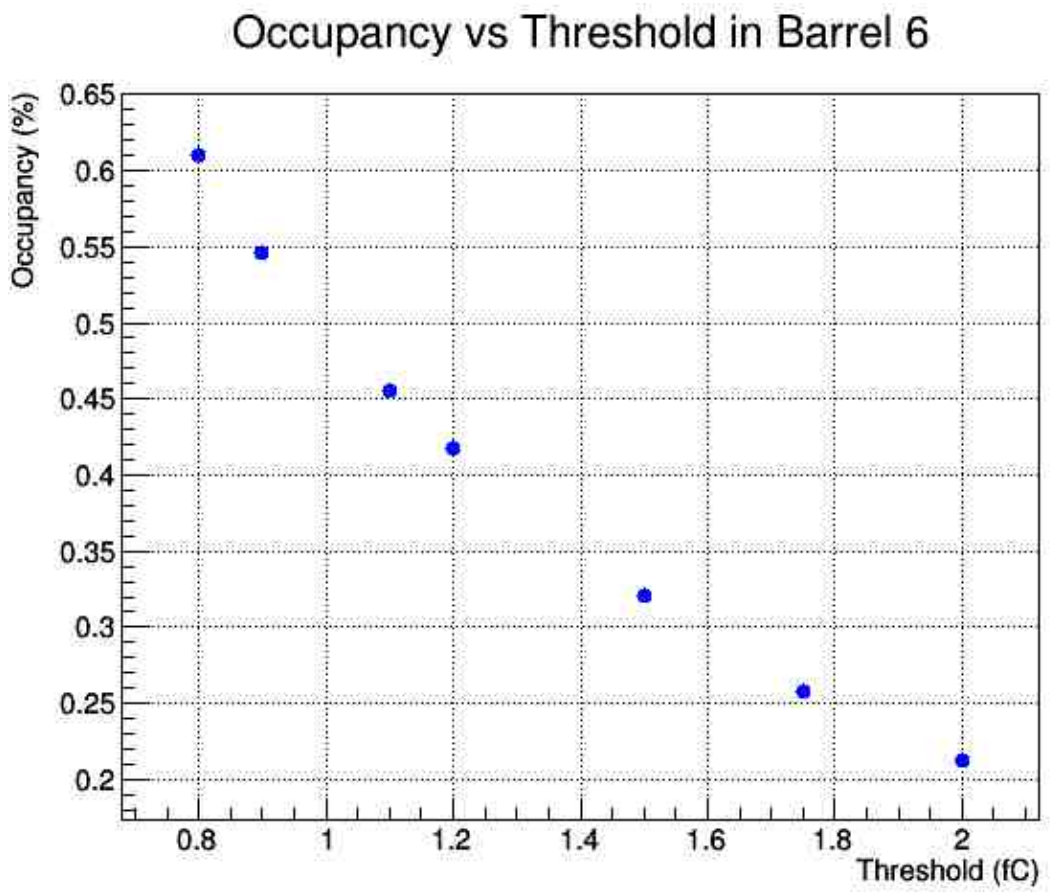
Conclusion

- Two projects have been undertaken this year:
  - Improving the data quality efficiency of the SCT in preparation for Run 3.
  - Preliminary study to search for long lived ALPs.
- The immediate next steps for these analyses are:
  - Finalise optimisation of SCT in preparation for Run 3.
  - Start physics analysis studying ALP events passed through a simulated detector.
    - Understand the kinematic of the signal with respect to the background.

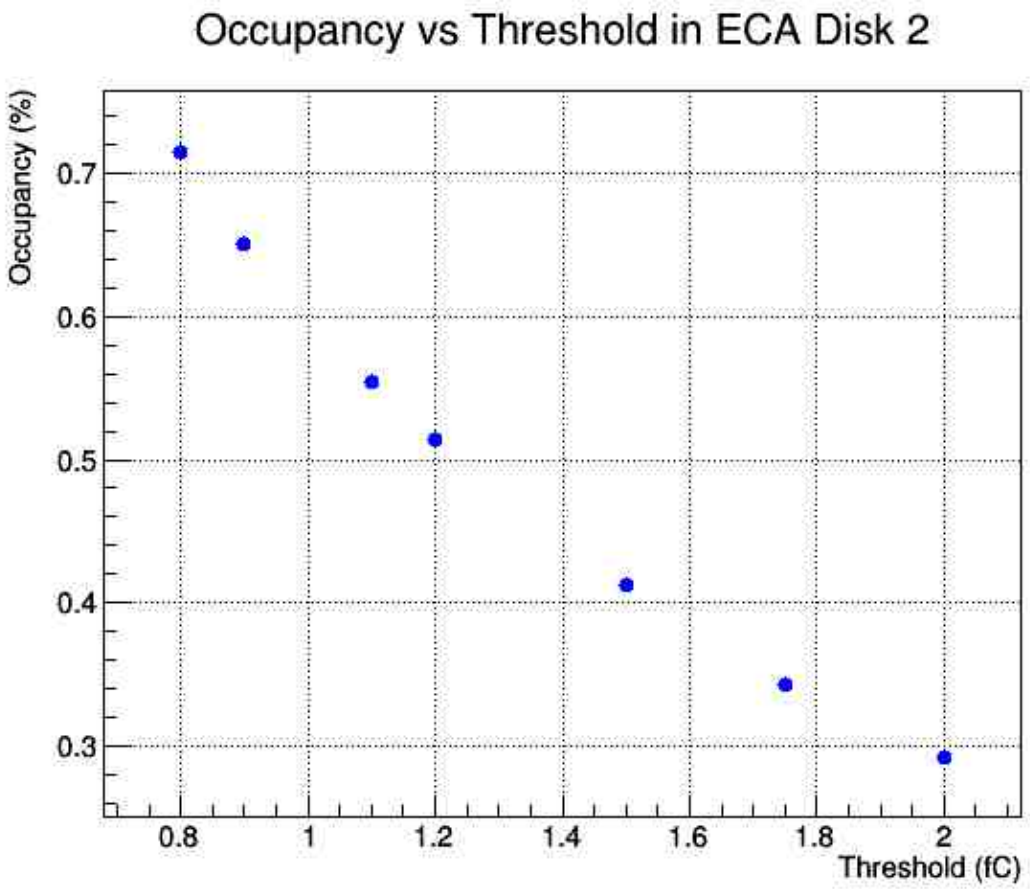
- Attended Warwick week, Liverpool HEP meeting (presented), HEP UK graduate lectures (RAL).
- Will be attending ATLAS Software Tutorial, going to DESY in October this year.

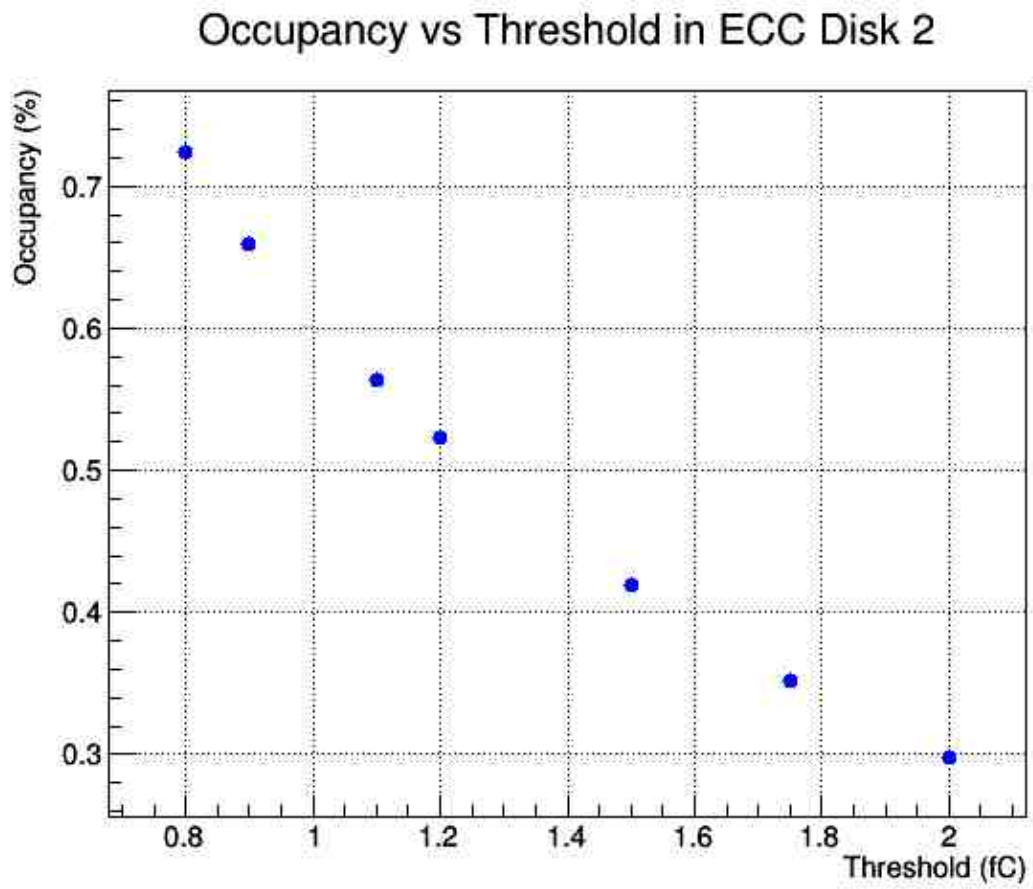
Backup

Other 2018 Occupancy Plots (1/3)

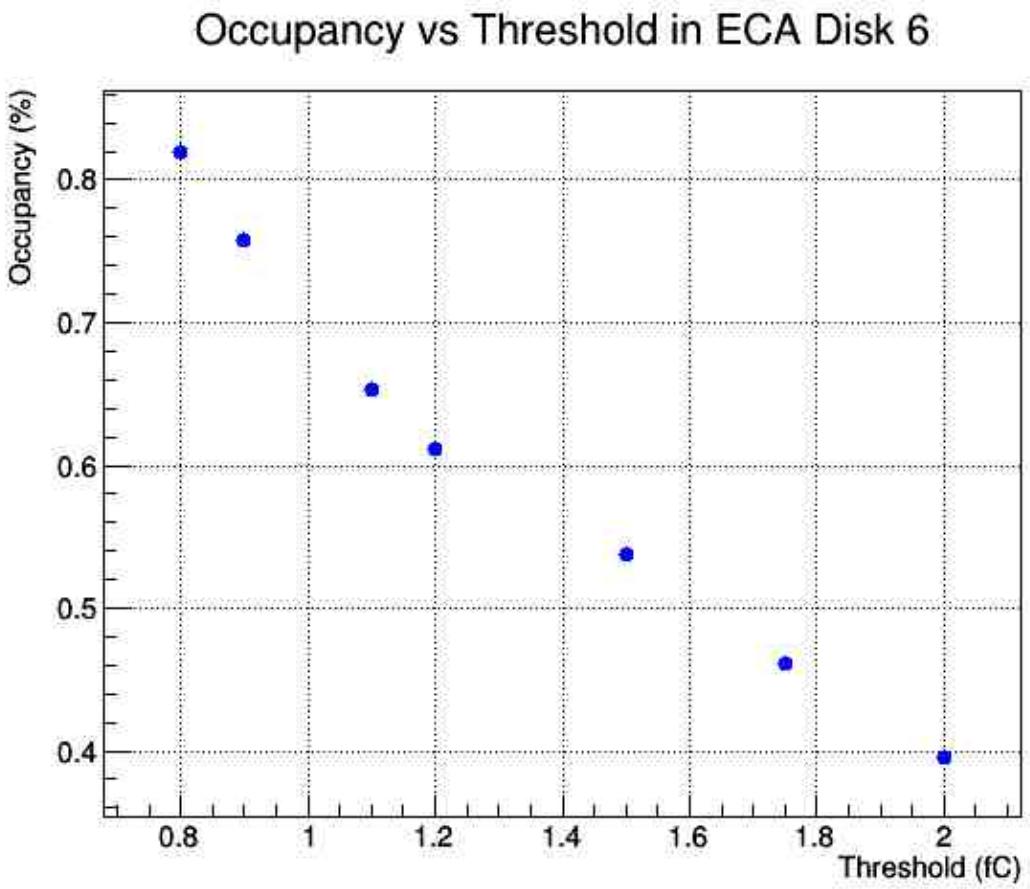


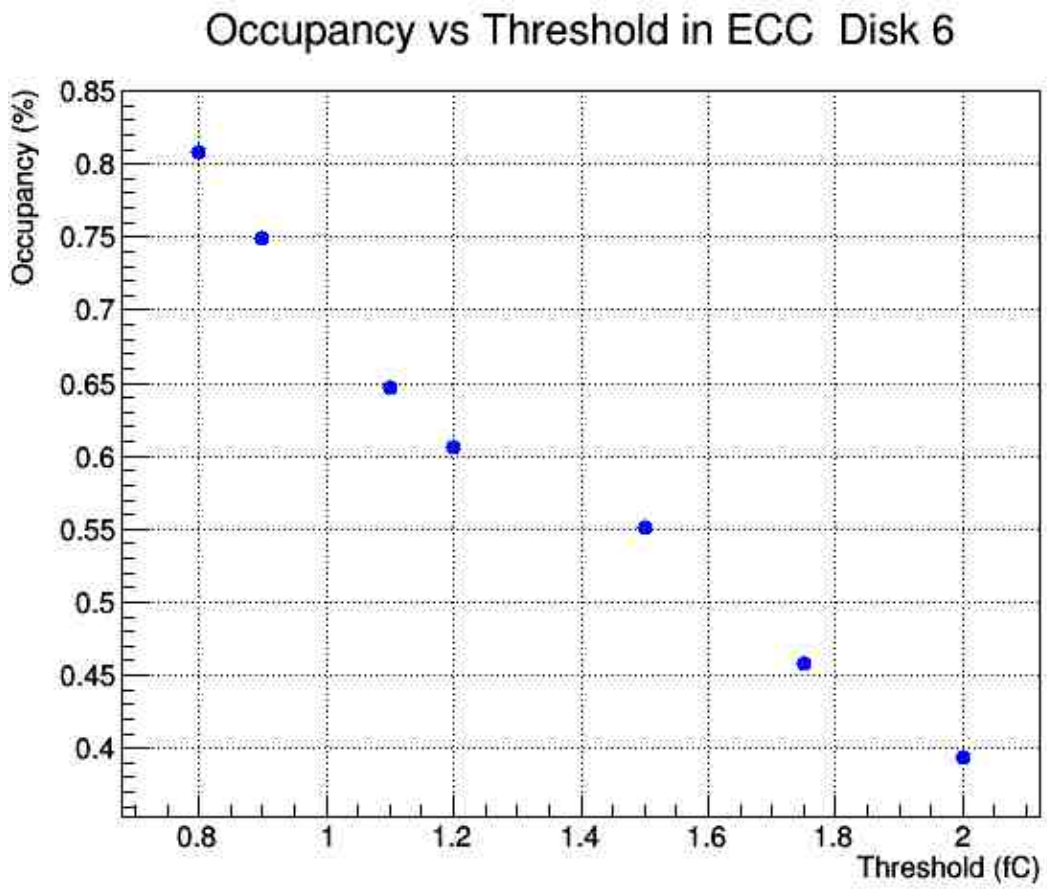
Other 2018 Occupancy Plots (2/3)



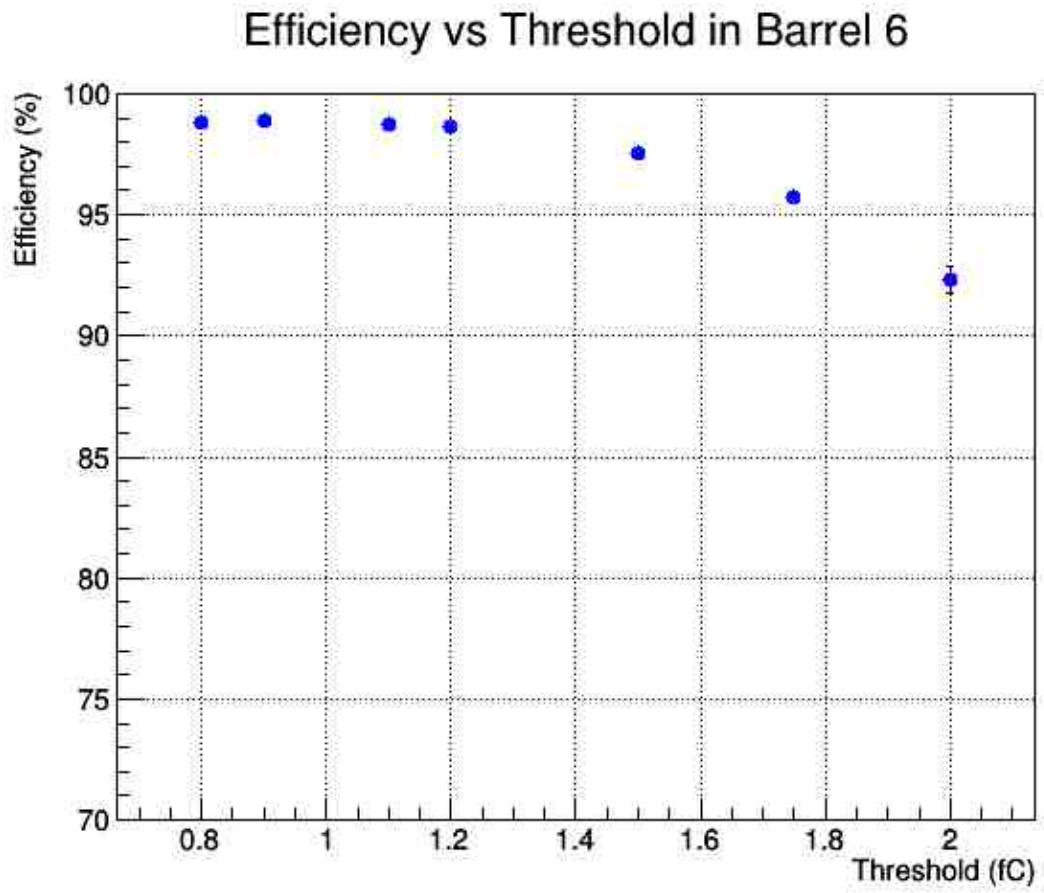


Other 2018 Occupancy Plots (3/3)

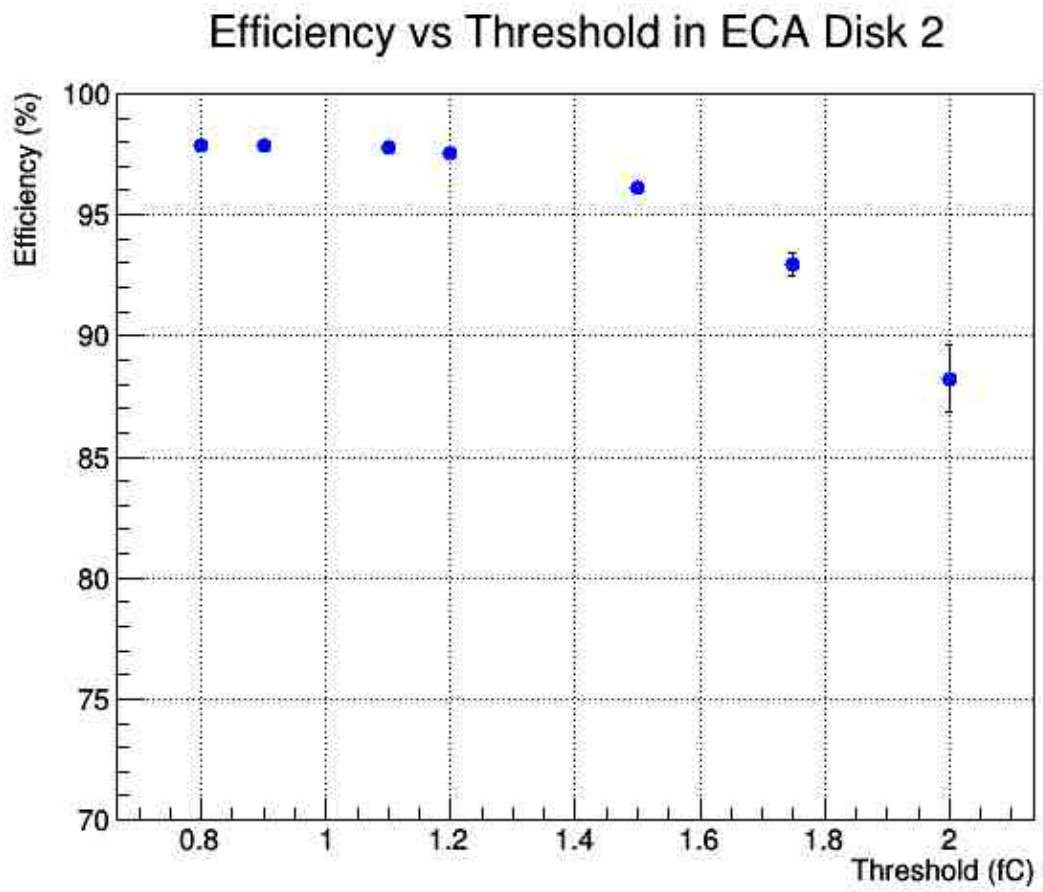


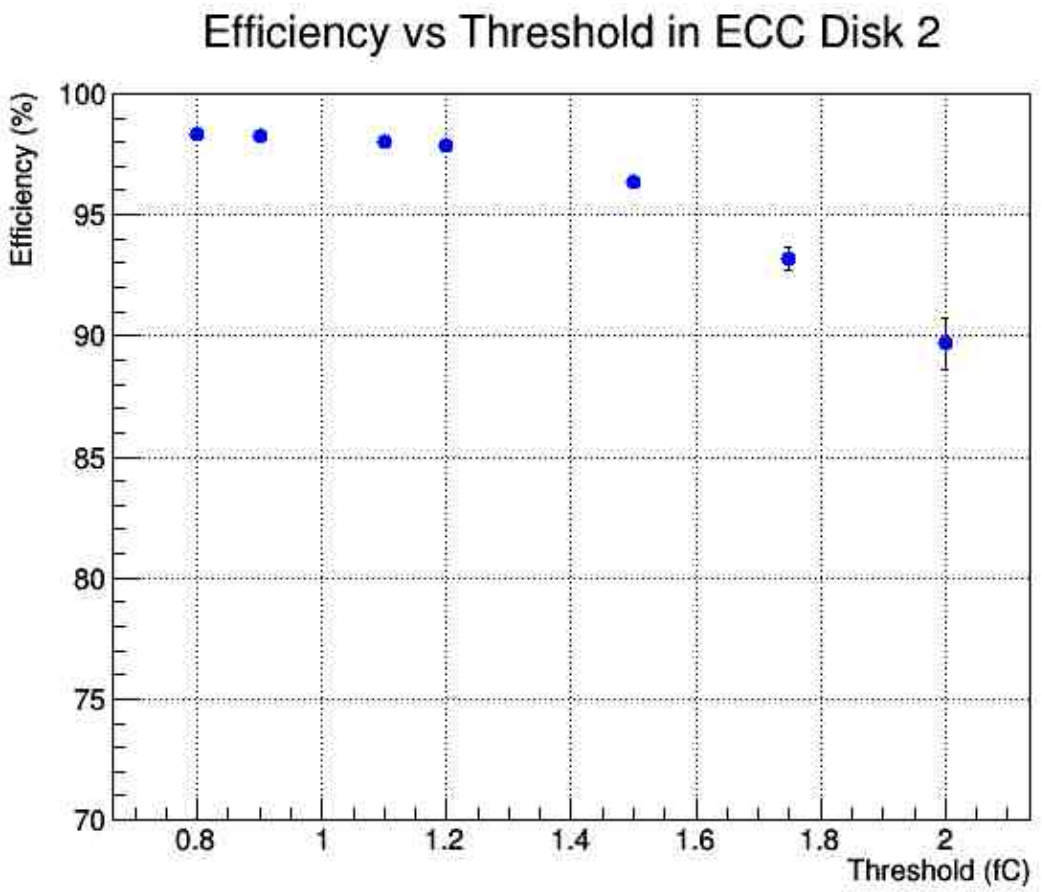


Other 2018 Efficiency Plots (1/3)



Other 2018 Efficiency Plots (2/3)





Other 2018 Efficiency Plots (3/3)