SCT studies for Run 3 and initial long-lived ALP simulation studies

18TH MAY 2023

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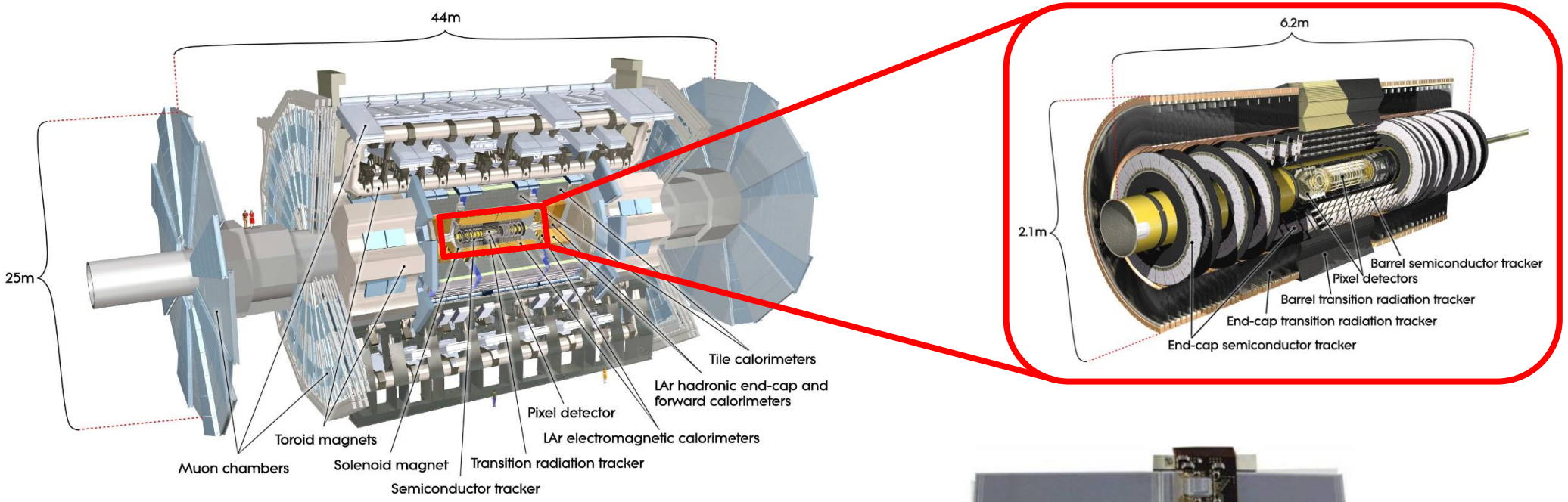
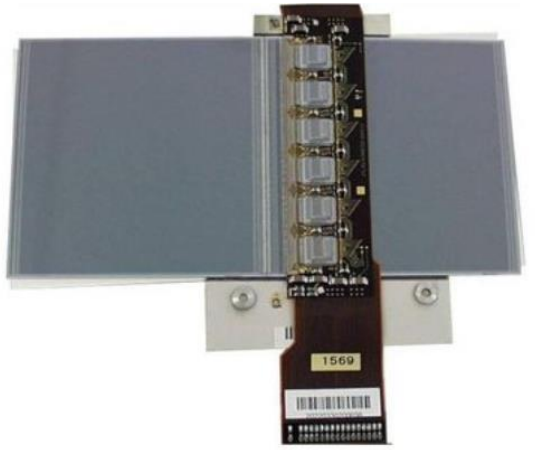
With a lot of help from: Dr Carl Gwilliam and Dr Cristiano Sebastiani

The ATLAS Semiconductor Tracker (SCT)



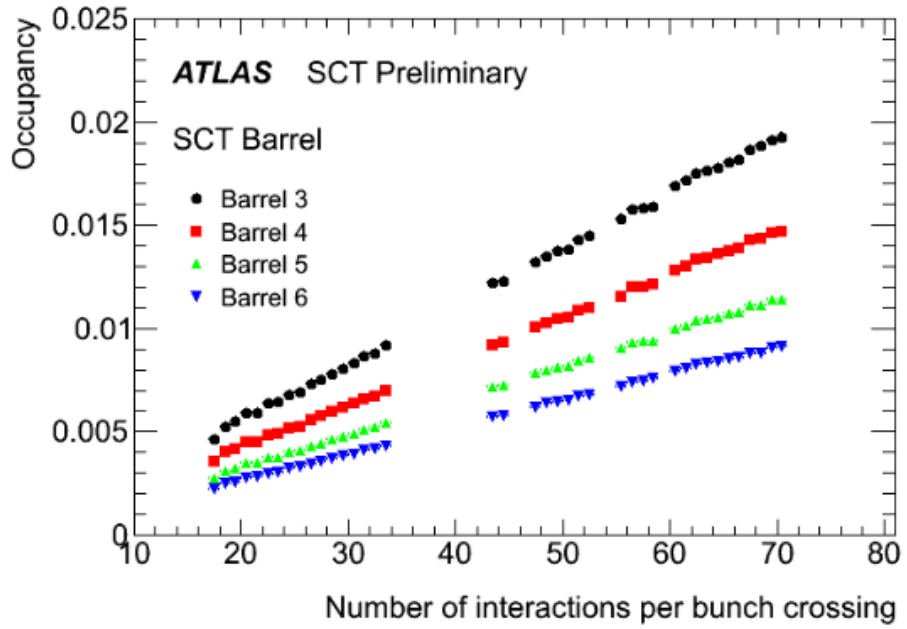
- Located in the ATLAS Inner Detector.
  - Between Pixel and TRT.
- 4 barrel layers and 2 endcaps with 9 disks each.
  - 4088 silicon-strip modules.
- A charged particle produces a hit on each layer which are combined into 3D spacepoints.

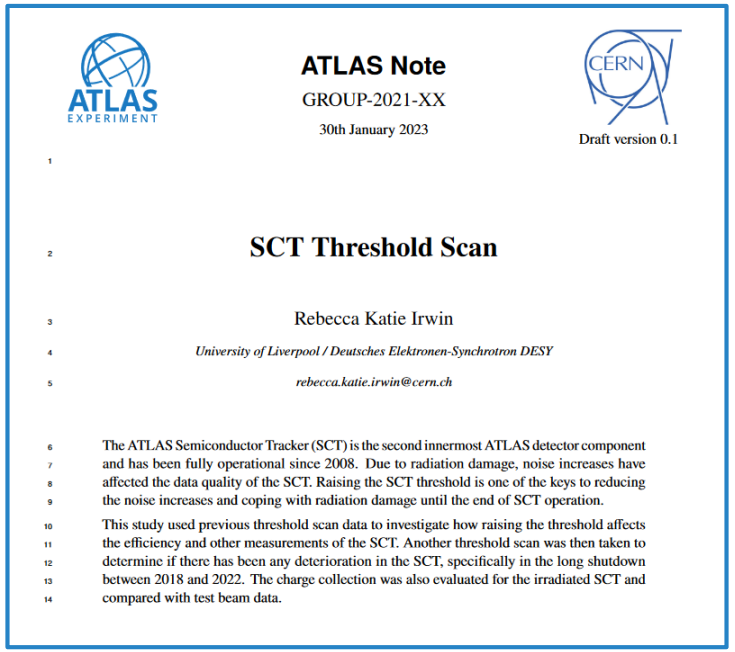


Barrel Module
10.1016

Ageing of the SCT and radiation effects

SCT Public Results





ATLAS EXPERIMENT

ATLAS Note

GROUP-2021-XX

30th January 2023

CERN

Draft version 0.1

SCT Threshold Scan

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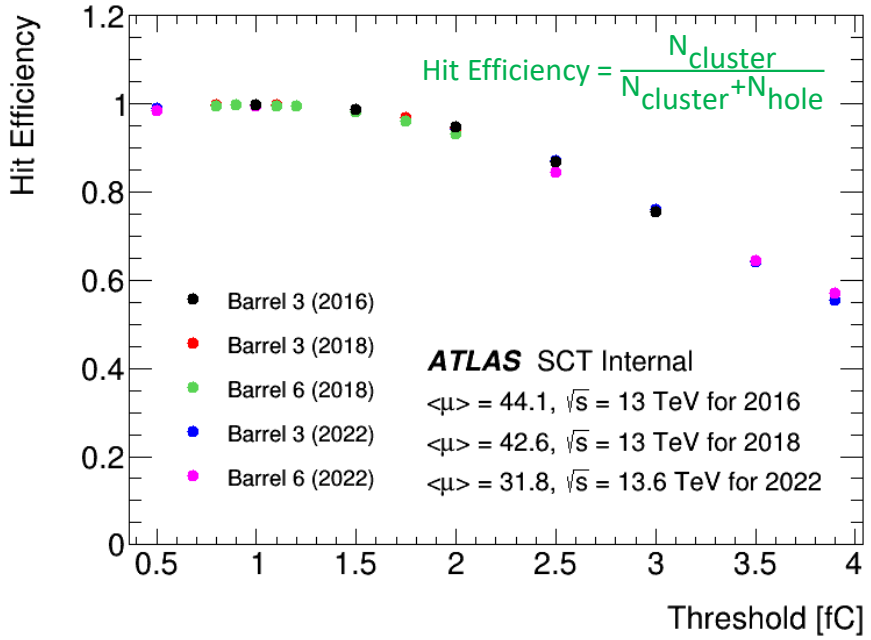
The ATLAS Semiconductor Tracker (SCT) is the second innermost ATLAS detector component and has been fully operational since 2008. Due to radiation damage, noise increases have affected the data quality of the SCT. Raising the SCT threshold is one of the keys to reducing the noise increases and coping with radiation damage until the end of SCT operation.

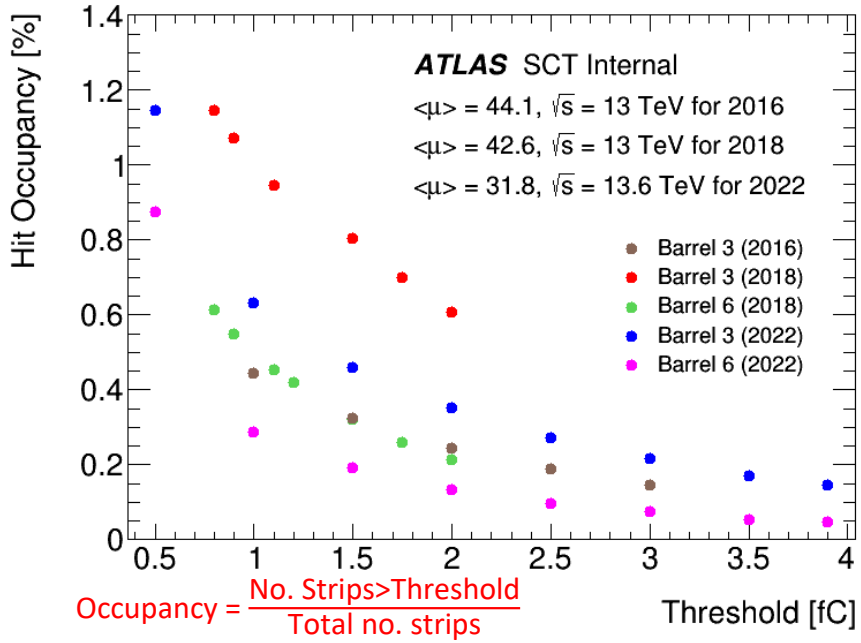
This study used previous threshold scan data to investigate how raising the threshold affects the efficiency and other measurements of the SCT. Another threshold scan was then taken to determine if there has been any deterioration in the SCT, specifically in the long shutdown between 2018 and 2022. The charge collection was also evaluated for the irradiated SCT and compared with test beam data.

- SCT Sensors irradiated by particles with energy ranging from thermal neutrons to the TeV-scale.
- The SCT uses binary readout, where a “hit” is registered if the charge on a strip exceeds a configurable threshold (currently 1fC).
- Raising the SCT threshold from 1fC is one of the keys to reducing occupancy and coping with radiation damage, however it decreases efficiency.
- Optimal threshold maintains efficiency > 99% and occupancy < 1%.
- Full note documenting this study written in January 2023.

Threshold Scan

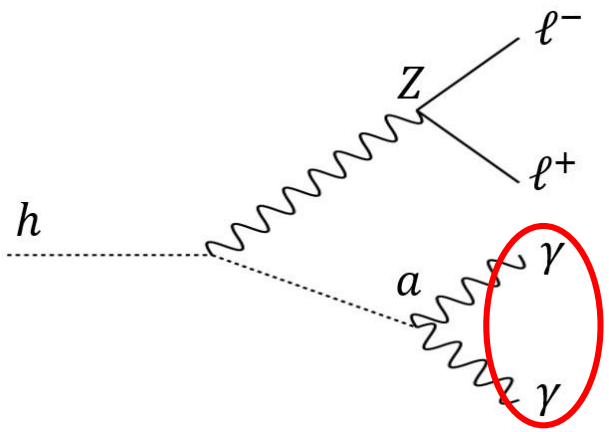
- Special runs have been acquired to scan various thresholds (Threshold scans).
- Three threshold scans were studied to determine if there has been any deterioration in the SCT, specifically in the long shutdown between 2018 and 2022.
- The results from the 2022 threshold scan shows no deterioration in efficiency from the long shutdown, or any increase in occupancy.
- The SCT threshold does not need to be increased from its binary threshold of 1 fC before the end of Run 3.
- An additional scan to be analysed has been taken at higher pile-up in 2023 to understand how much this affects the occupancy.





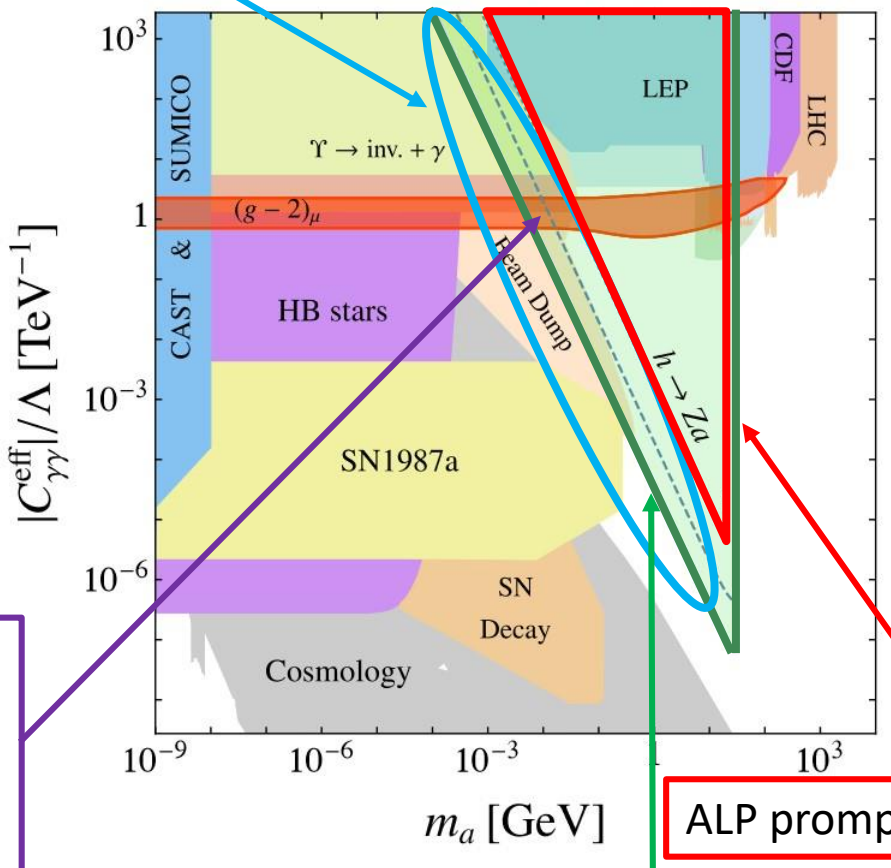
Search for long lived ALPs that decay into diphoton

- Search for axion like particle (ALP) produced in association with a Z boson from Higgs decay.
- ALPs are hypothetical light particles that may be a component of the dark sector.
- Prompt search is finished, new idea on performing the long-lived search.
- Signature with two leptons and two collimated photons (one if signal photons are collimated enough).



ALP displaced region

arXiv:1708.00443

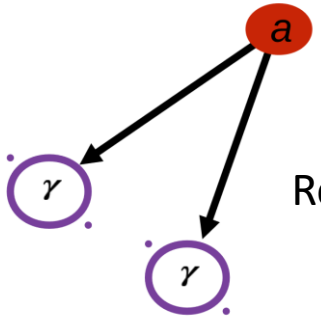


ATLAS can probe region where $(g\text{-}2)_\mu$ anomaly can be explained

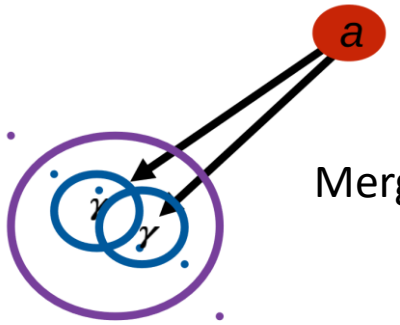
ALP prompt region

ALPs mass range: 0.1-35 GeV

Reconstructed photons



Resolved

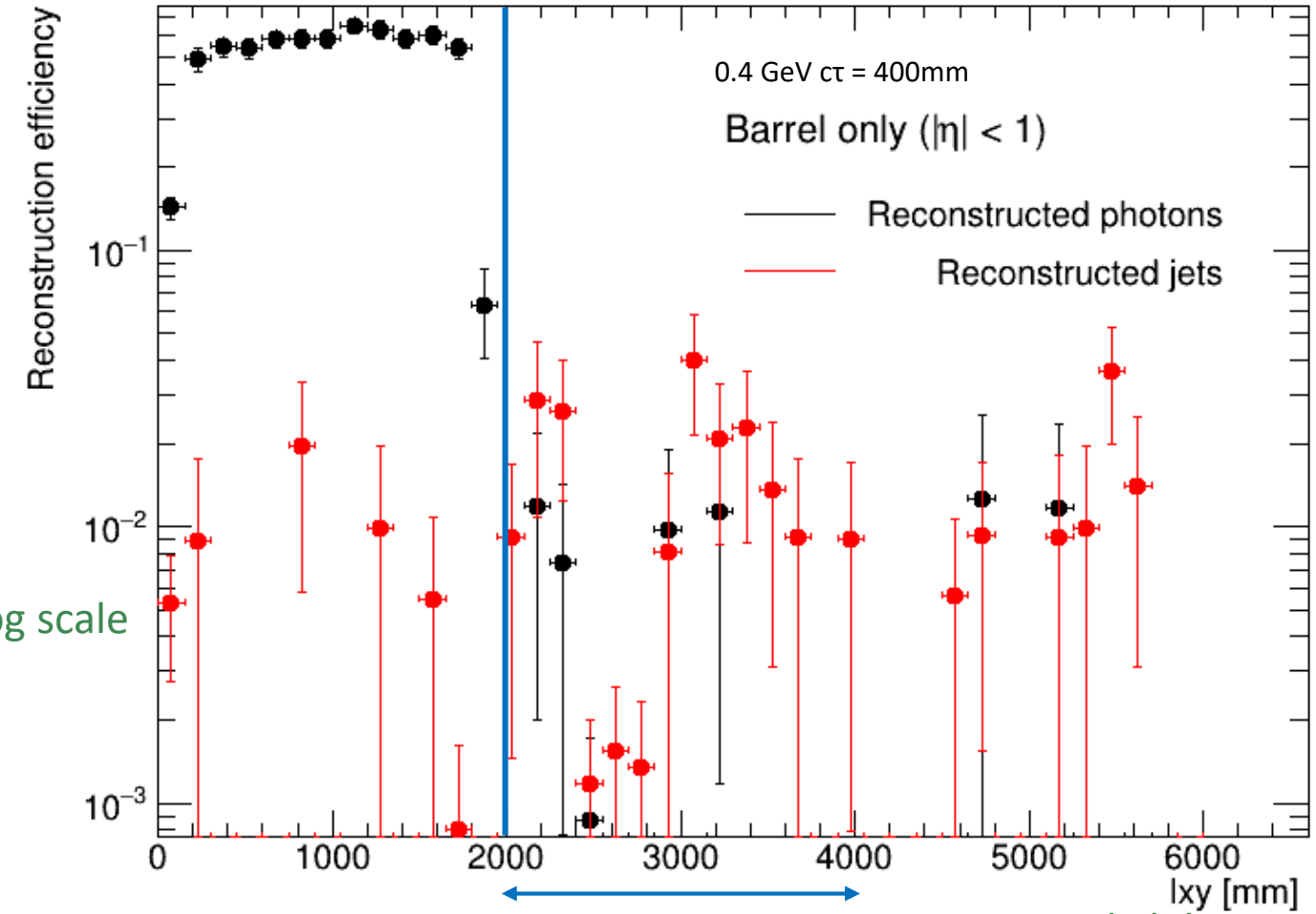


Merged

	Very displaced		Displaced		Prompt	
Sample	**0.4 GeV (cτ = 400 mm)**	**Fraction**	**0.4 GeV (cτ = 40.2 mm)**	**Fraction**	**0.4 GeV**	**Fraction**
Total Events	234576.7	1.000	199264.0	1.000	194209.4	1.000
Resolved	851.7	0.004	658.5	0.003	1062.7	0.005
Merged	128287.5	0.547	110636.4	0.555	108244.1	0.557
Merged with pT > 20 GeV	7332.7	0.031	29967.7	0.150	62055.5	0.320
No cat	226392.2	0.965	168637.8	0.846	131091.2	0.675

- Displaced -> photons are reconstructed at a higher radial distance from collision point.
- At low mass points, the ALP is more boosted, therefore the photons are more merged.
- Most of the photons in the displaced “merged” category have very low pT (< 20 GeV) which cannot be calibrated.
- The number of merged reconstructed truth matched photons decreases as they are more displaced.

Reconstruction efficiency



Log scale

Hadronic Calorimeter

Radial distance from interaction point

- The majority of reconstructed photons are loss when decay length passes the electromagnetic calorimeter.
- From these events lost I checked if the photons were being reconstructed as jets, but, as seen, they are not.
- Reconstructed photons (jets) are the photons (jets) with the smallest ΔR with respect to Truth photons.
- Dedicated study is needed to reconstruct displaced photons which will be the work of my thesis.

Summary

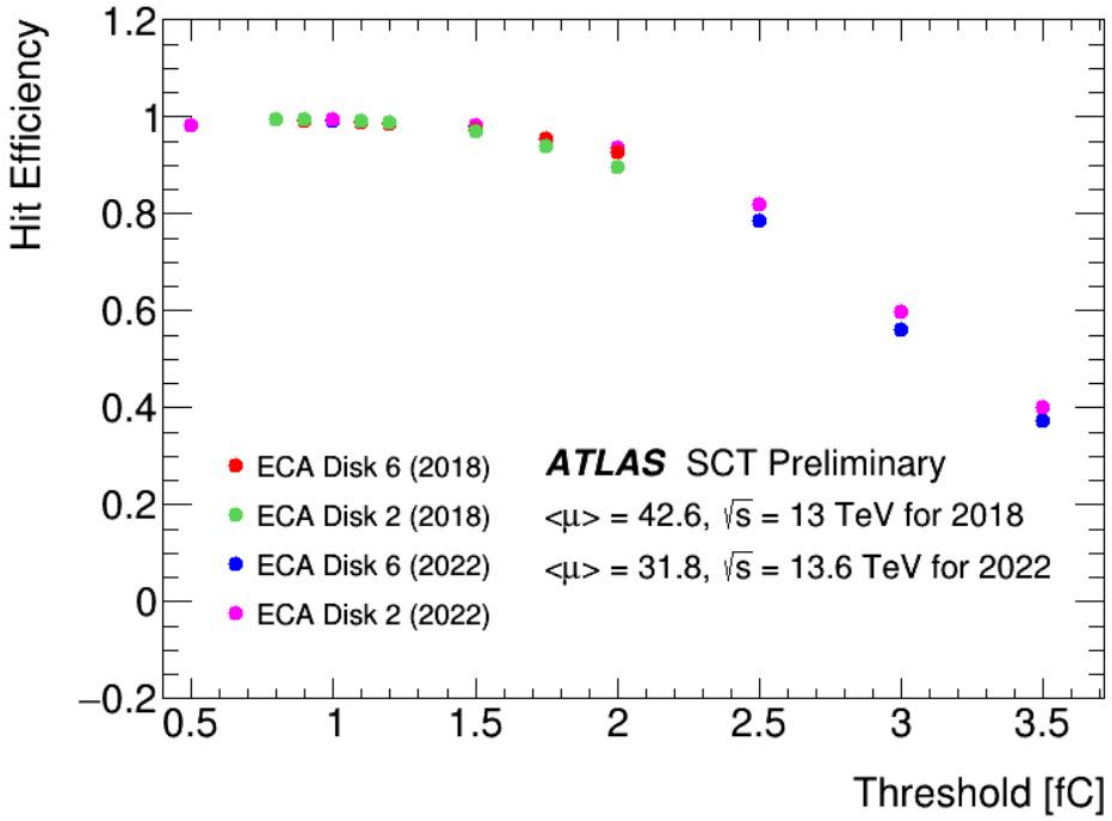
- The slides summarised worked carried out for ATLAS in the detector (SCT) and analysis, which will be the work of my thesis.

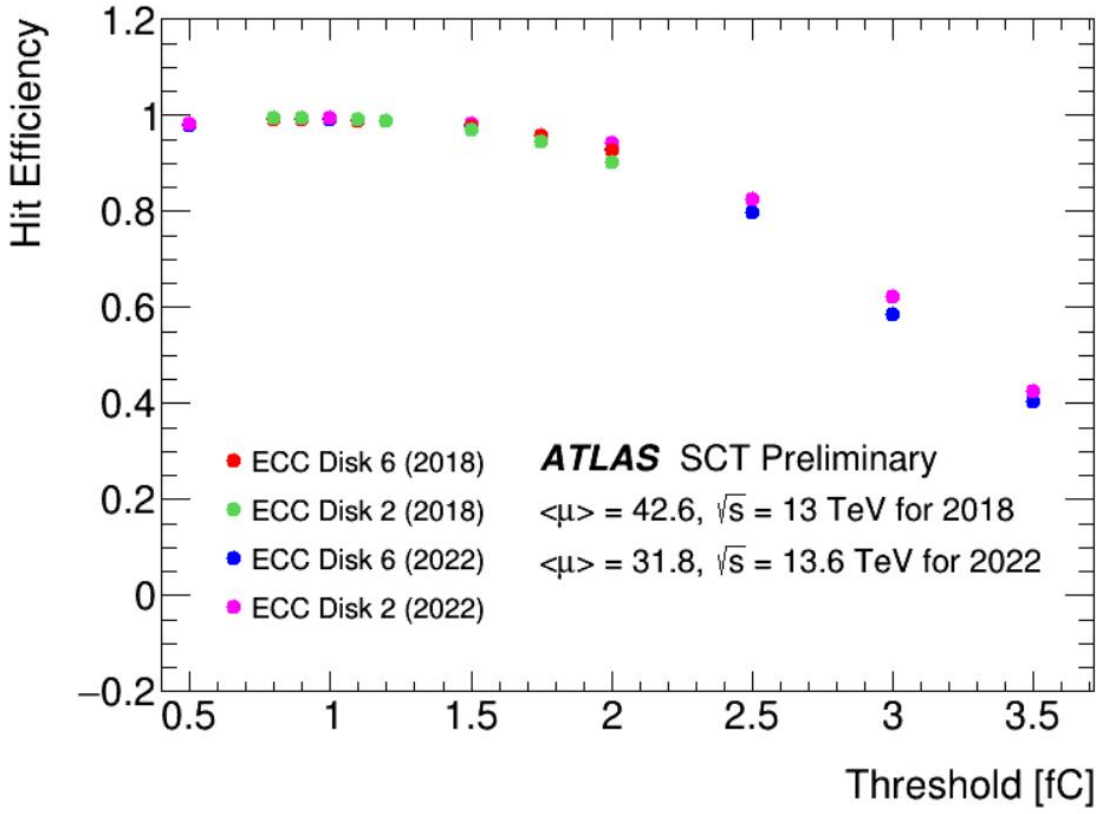
- The SCT threshold does not currently need to be increased from 1 fC, however an additional scan to be analysed will find the effect pile-up has on occupancy.
- Reported on the full status of the SCT at ATLAS UK in January.

- Initial long lived ALP study shows that displaced samples poorly reconstruct standard objects.
- A dedicated study is needed to identify low pT photons arising from displaced ALP decays which is the next step of this analysis.

Back-up

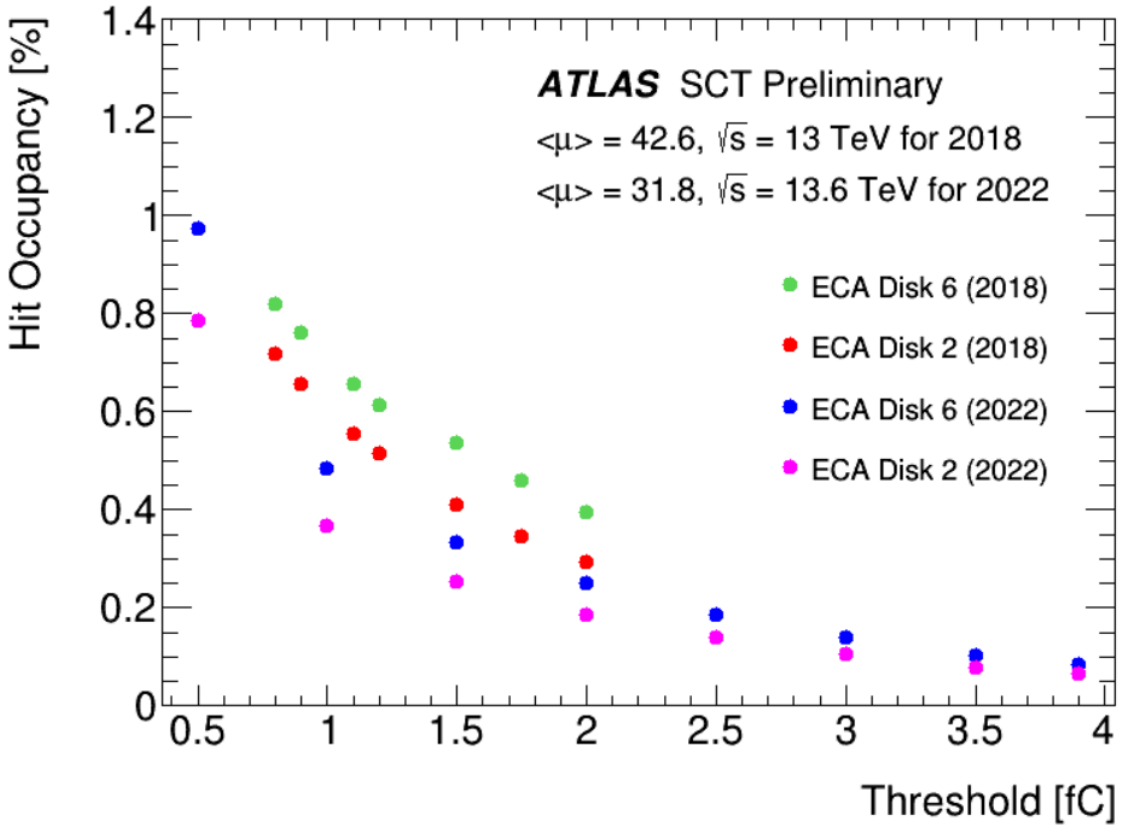
Hit Efficiency end-cap layers

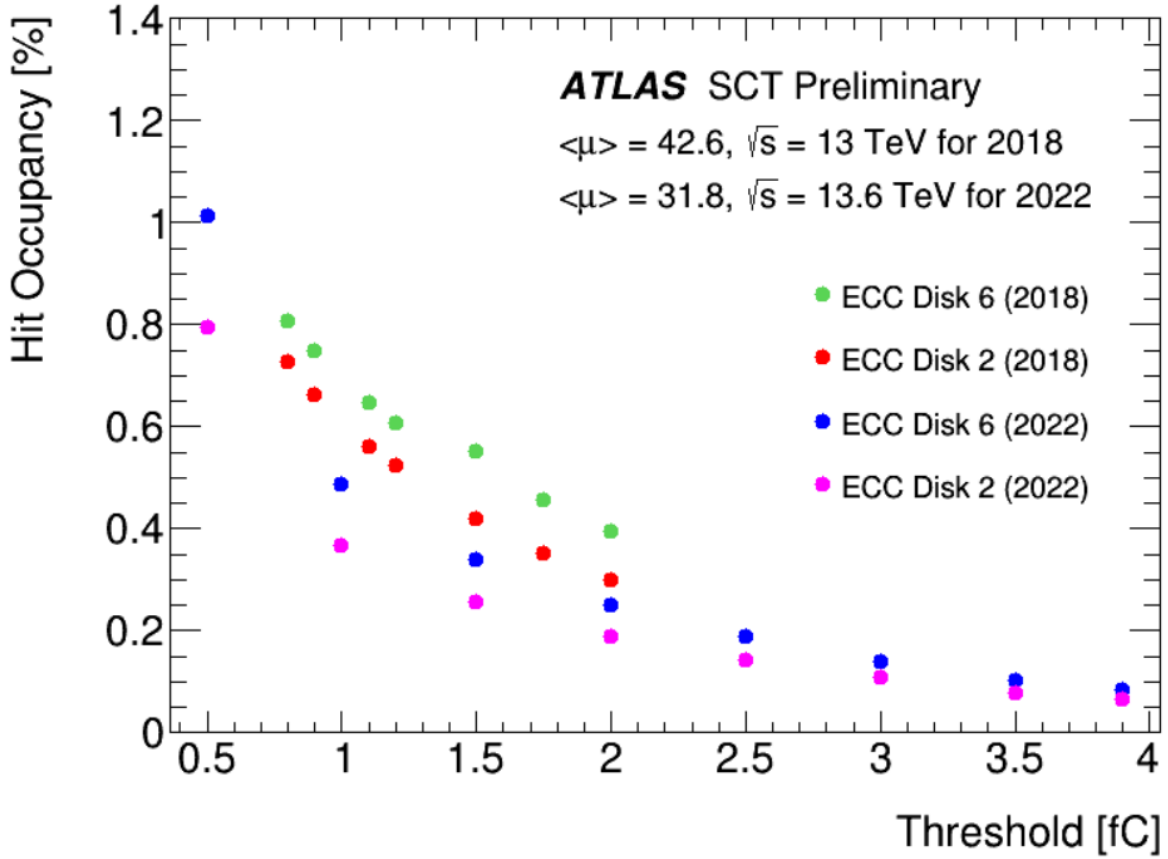




- The end-cap layers were also plotted for the same plots as the barrel layers and were consistent with barrel layers.
- The 2016 Threshold scan was only for Barrel 3 so there was no end-cap information.

Occupancy end-cap layers

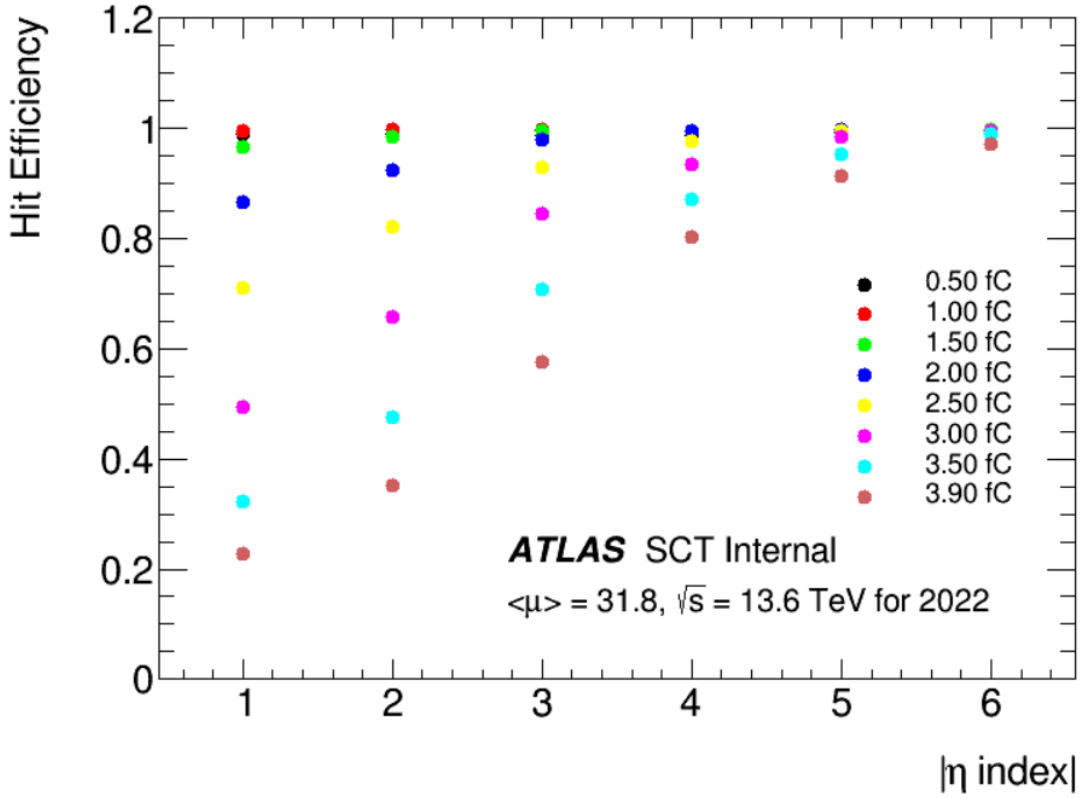


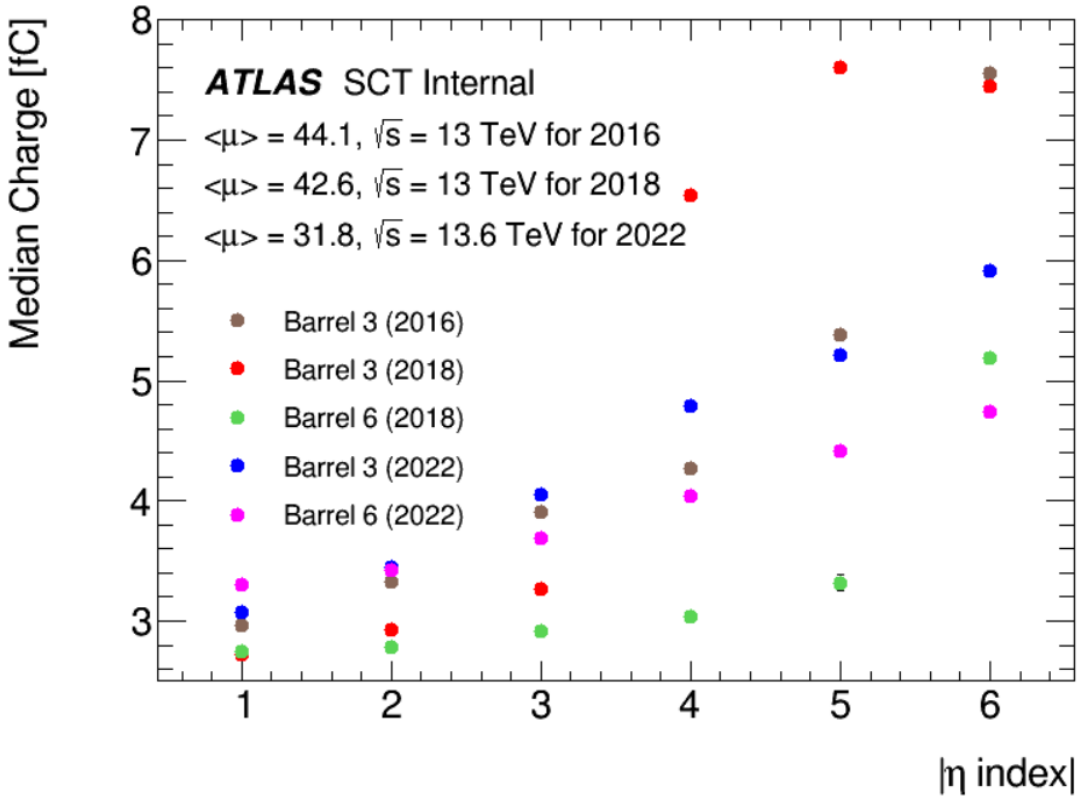


- Consistent with the barrel layer plot, the end-caps have higher occupancy in 2018.

Threshold Scan η dependence

- At higher η index particles pass through a longer distance in the silicon and have more charge deposited in the SCT, making them more likely to pass the threshold value.





The median charge is equivalent to the threshold value at 50% Hit Efficiency.