Characterizing and Reducing the Background on the Athena WFI

IACHEC Detectors and Background WG Meeting, 22 May 2019

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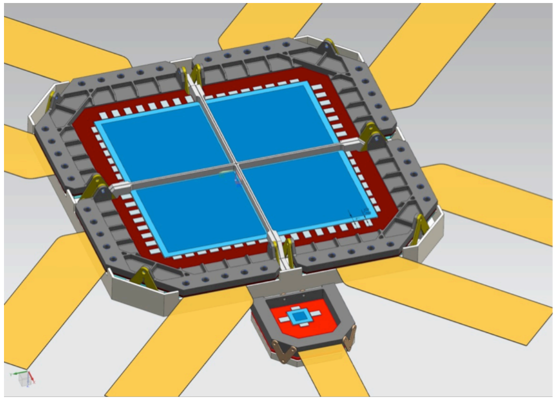
The Problem

- Athena WFI Large Detector Array (LDA) consists of four 512x512 DEPFET arrays
- 130x130x450 μm pixels – big target for particles that produce BG
- 5 ms frame time is not fast enough for full anti-coincidence
- Our goals are to develop algorithms that:
  1. Reduce the unrejected background due to particles
  2. Characterize that background to reduce systematic error

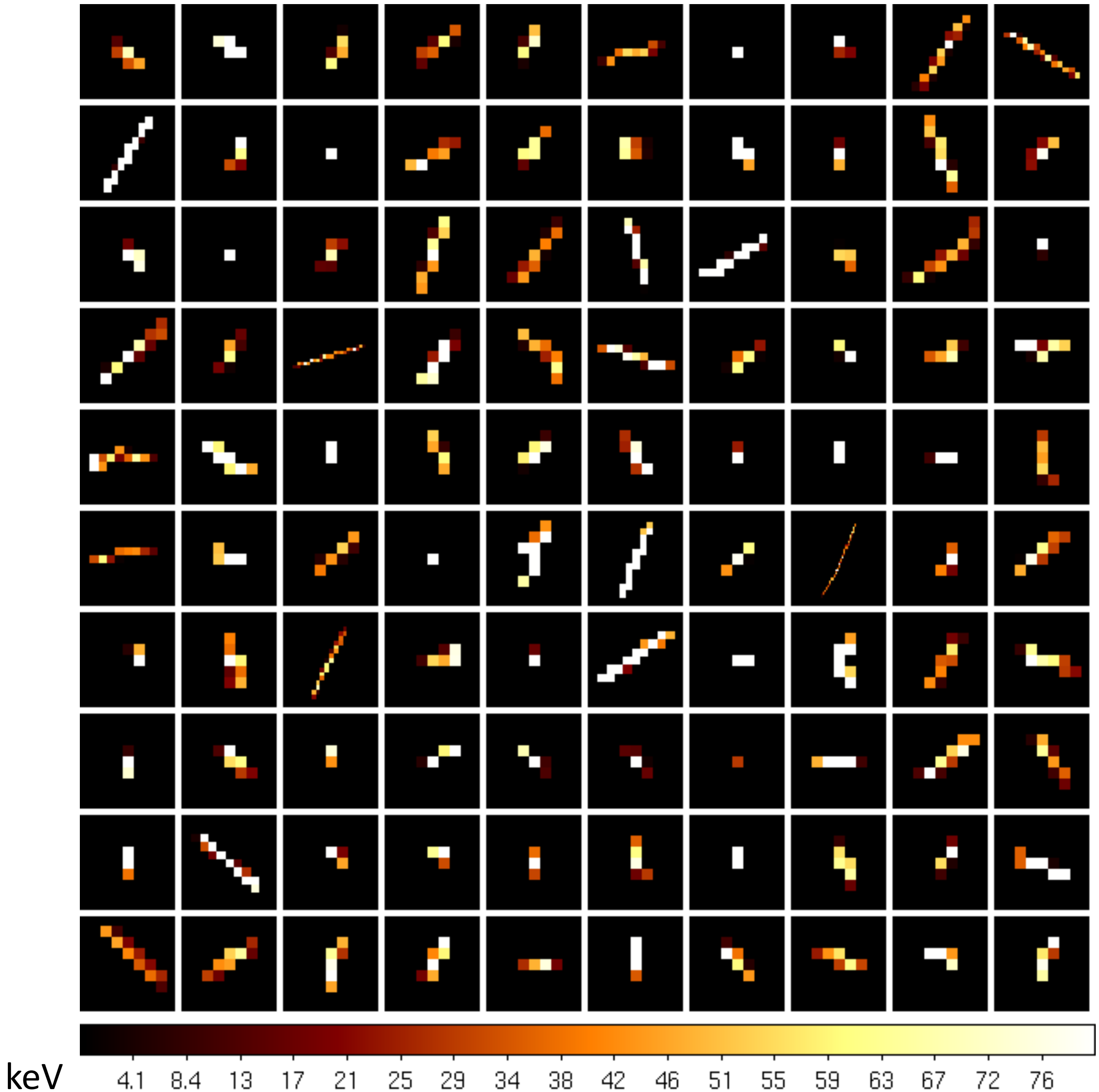


How Can We Predict the WFI Background?

- Existing data from similar missions
  - XMM EPIC pn, Chandra ACIS, Suzaku XIS, Swift XRT
  - Real-world, but suffer from insufficient data, dissimilar detectors and particle environment
- Geant4 simulations
  - Athena WFI Background Working Group
  - Being used to model and select the shield design (material, thickness)
  - Can examine the effects of individual cosmic rays, correlation between detected events that we can use

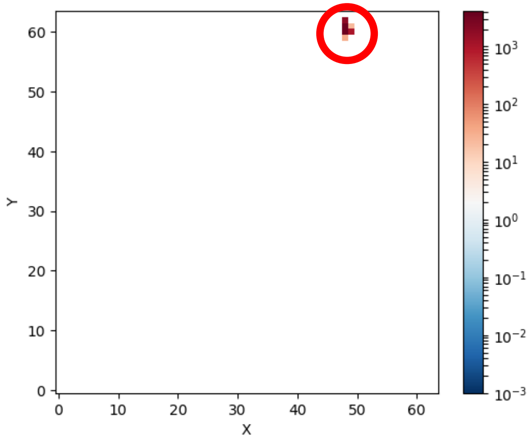
Sample Geant4 Particle Tracks (OU)

- 133 million proton primaries
- 1.04 million particle tracks
- 26,392 valid events < 15 keV
- 8,896 valid events, 2–7 keV



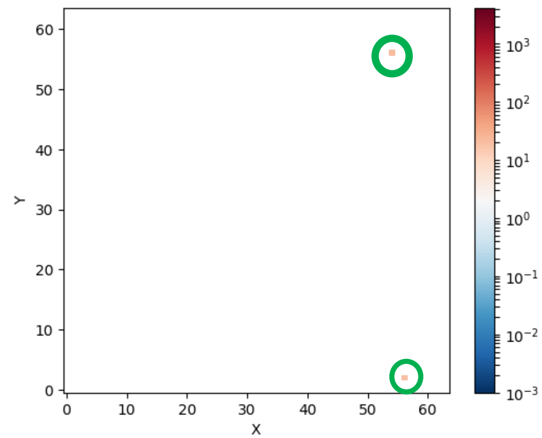
XMM EPIC pn Small Window Mode, Filter Wheel Closed

Case A



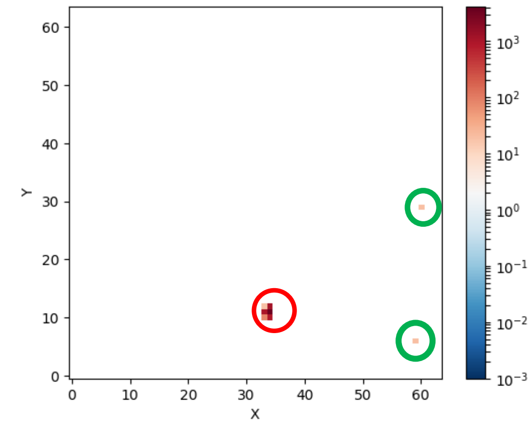
Frame with Just Particle Tracks

Case B



Frame with Just Valid Events

Case C



Frame with Particle Tracks and Valid Events

- "Particle tracks" are contiguous pixels with at least one above 15 keV, or that contain more than 4 pixels above 0.1 keV.
- "Valid events" are 3x3 islands with EPIC pn PATTERN < 13 (singles, doubles, triples, quads).

Case D

Frame with neither

Statistics from Single Geant4 Primaries

Case A	# of primaries producing **particle track** but **no valid event**	909,823	**(97.3%)**
	Fraction of 2–7 keV background	0%	
	# of particle tracks per primary	**1.12**	
Case B	# of primaries producing **valid event** but **no particle track**	16,842	**(1.8%)**
	Fraction of 2–7 keV background	65%	
	# of particle tracks per primary	0.00	
Case C	# of primaries producing **valid event** and **particle track**	8,839	**(0.9%)**
	Fraction of 2–7 keV background	35%	
	# of particle tracks per primary	**1.89**	

Correlation: Valid Events and Particle Tracks

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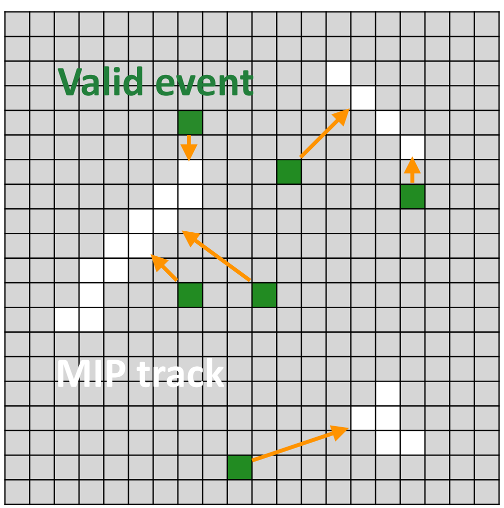
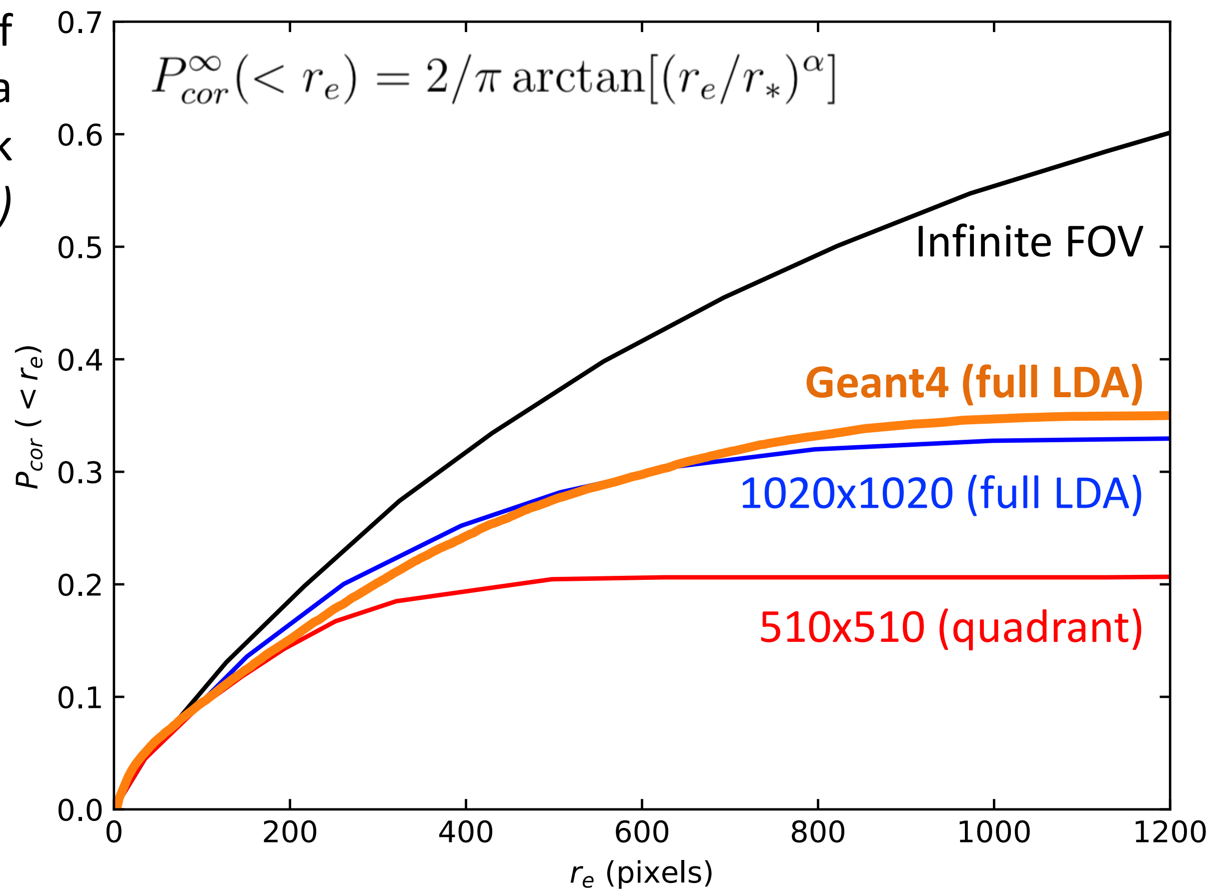
Correlation: Valid Events and Particle Tracks

P_{cor} = cumulative probability of valid event within r_e of a MIP track

(Molendi, Gastaldello, Rau)

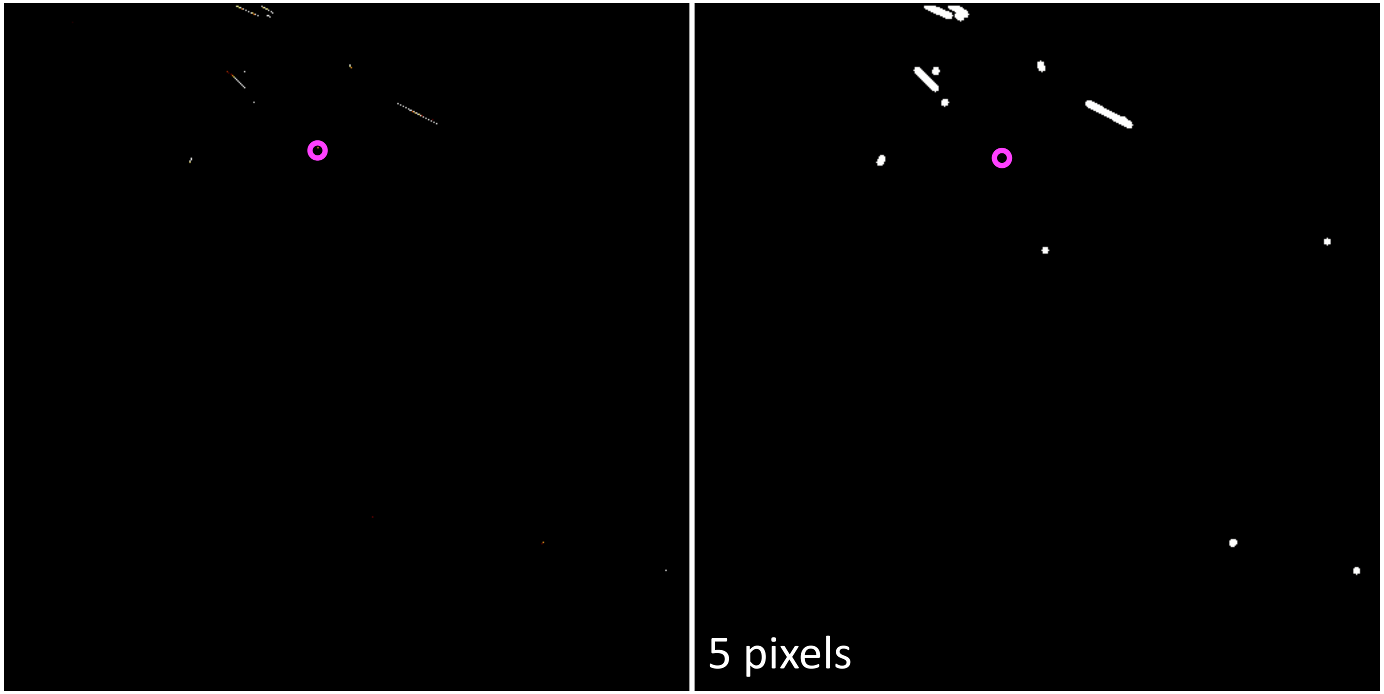




Exploiting the Correlation: Self Anti-Coincidence

- Eliminate valid events within certain distance around each particle track pixel
- Removes both background events and celestial X-rays
  - Reduces systematic error at the expense of statistical precision
- Exclusion distance can be tuned depending on the science goal
  - Long observations of low-surface-brightness targets
- Can be done on the ground if all particle track pixels can be telemetered; otherwise must be done on board

Masking Around Particle Tracks



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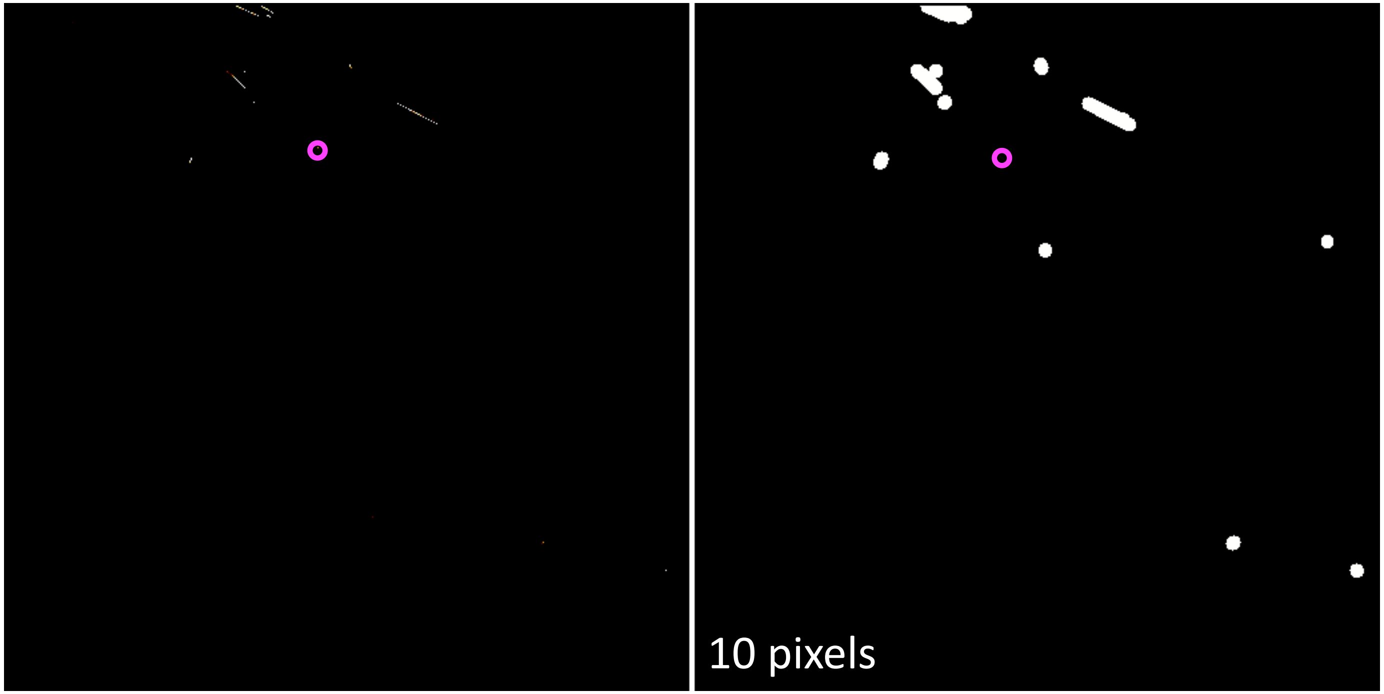

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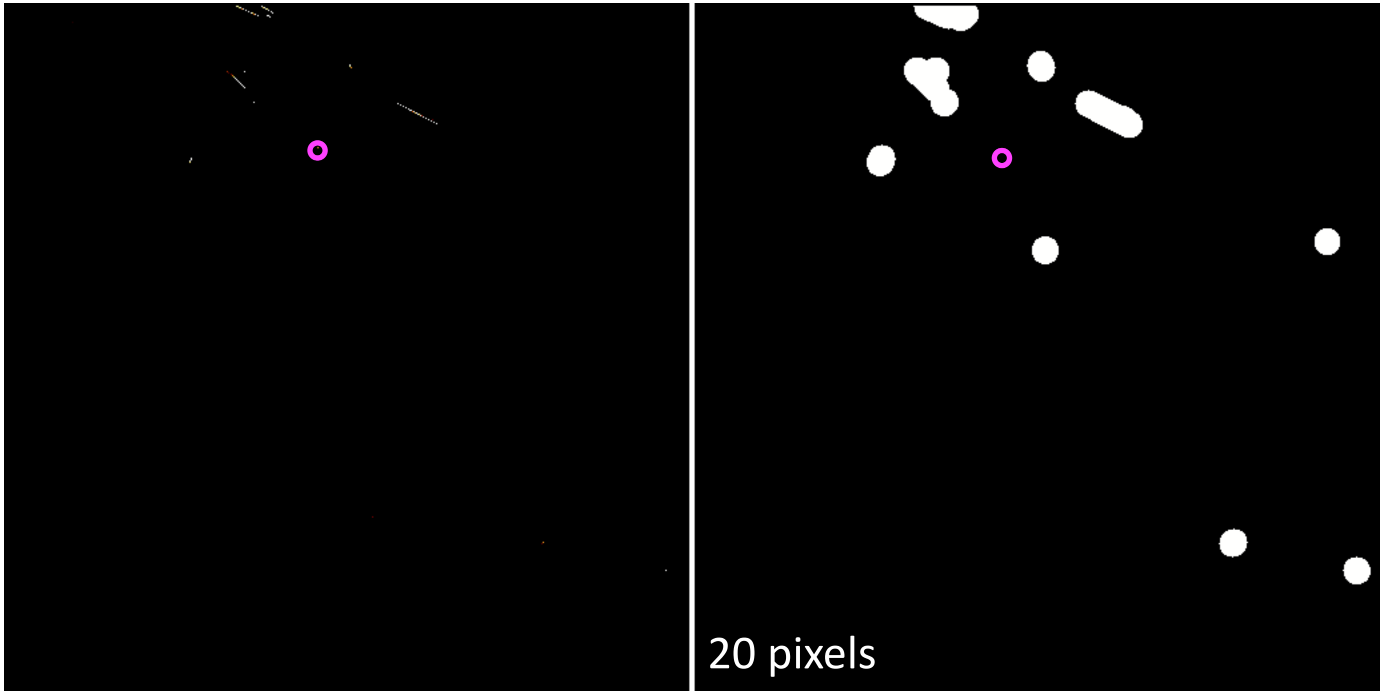

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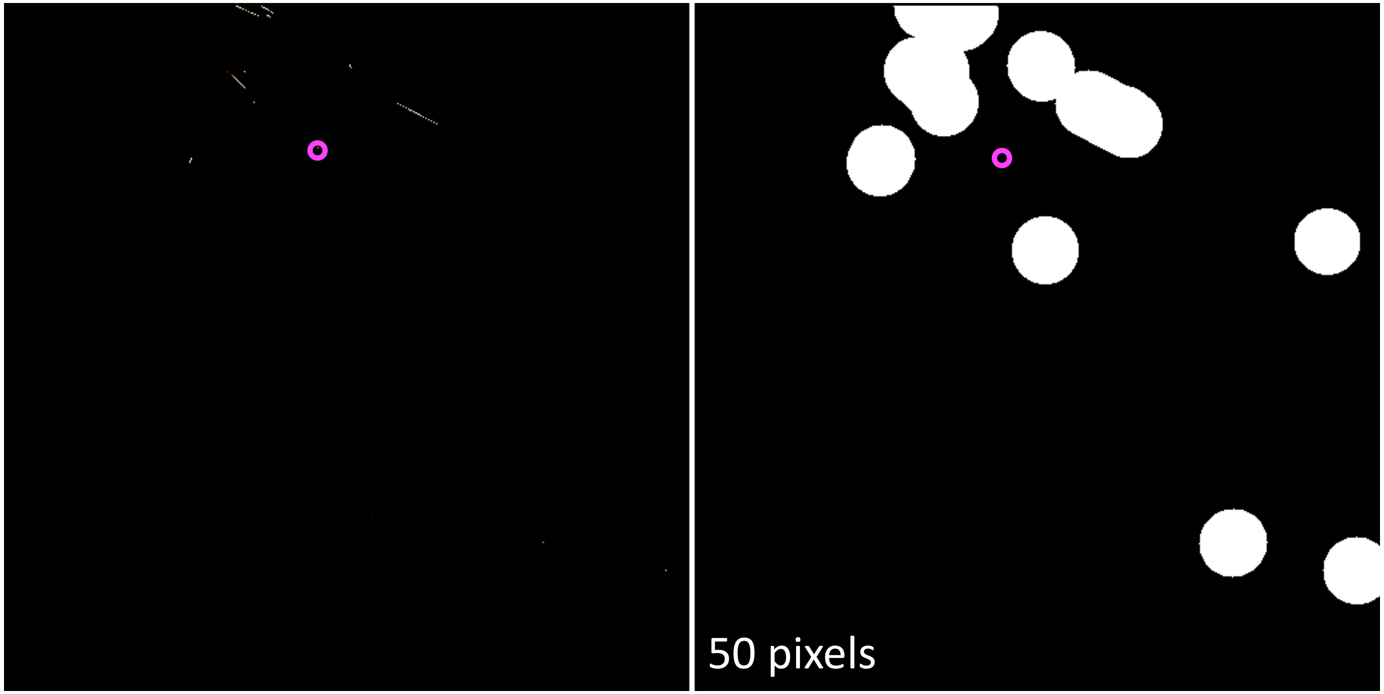

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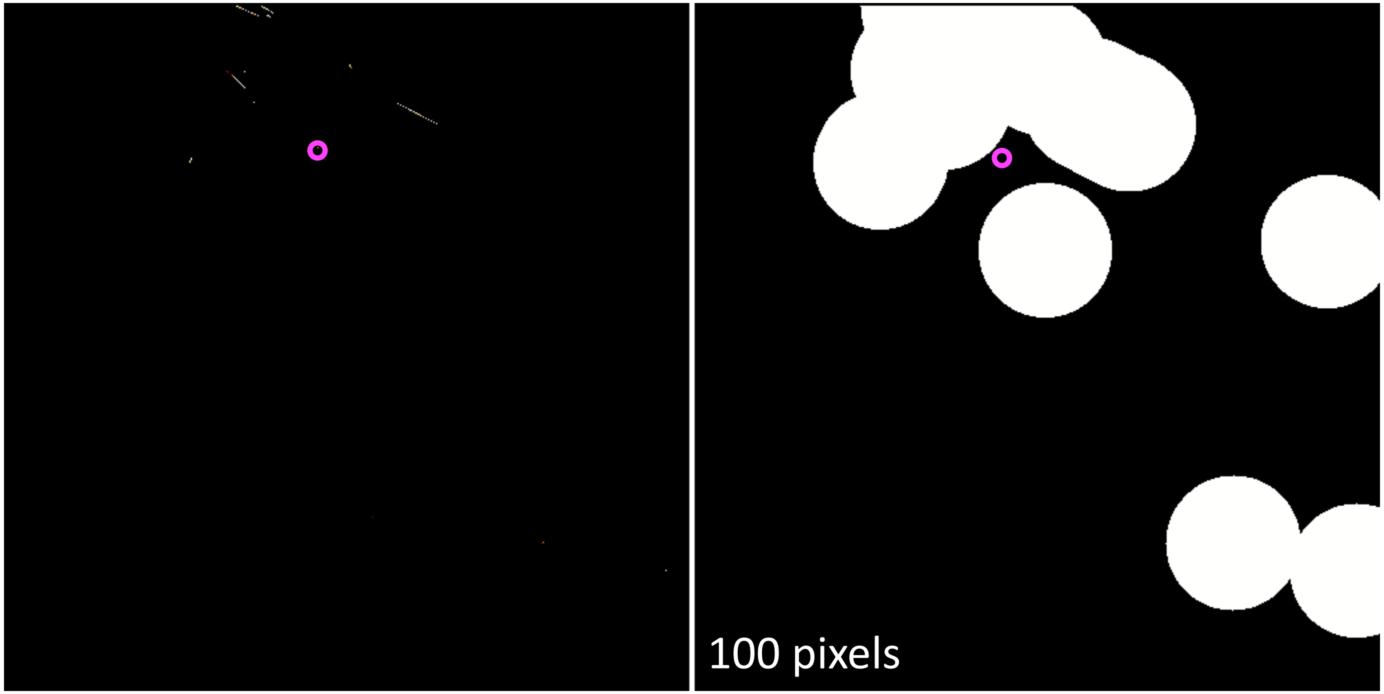

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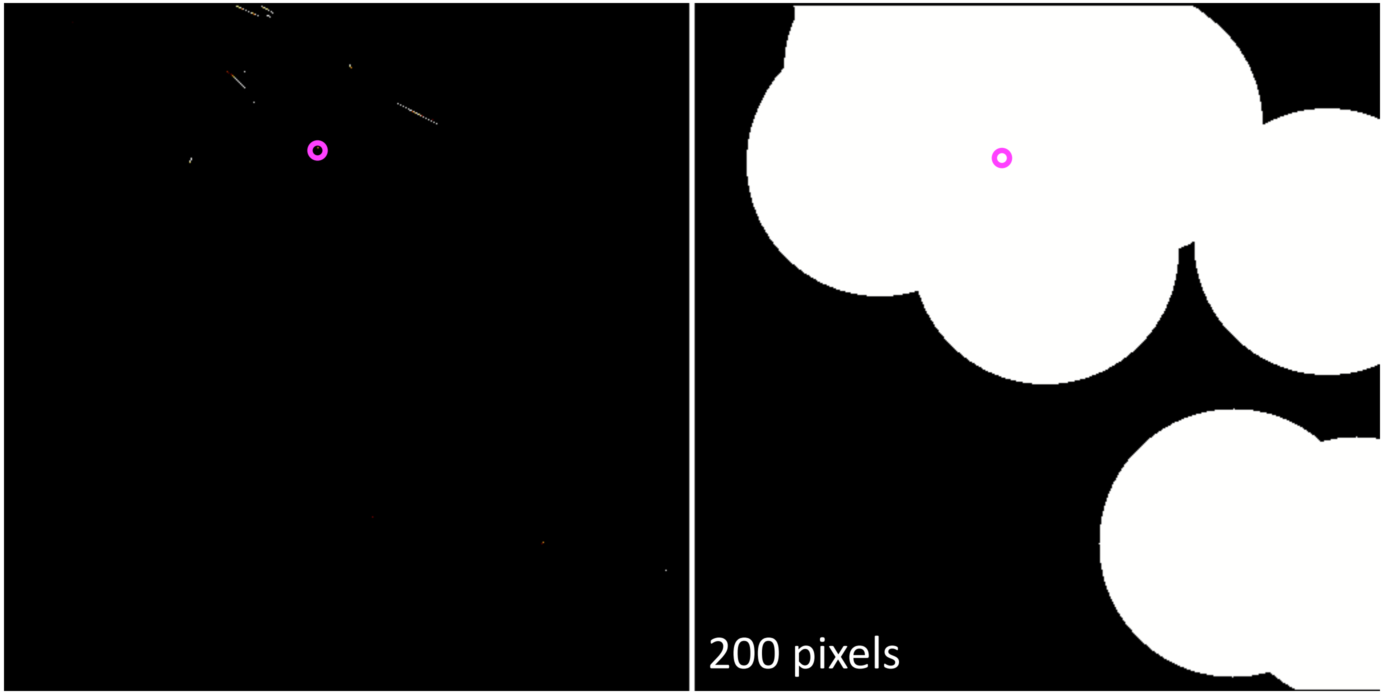

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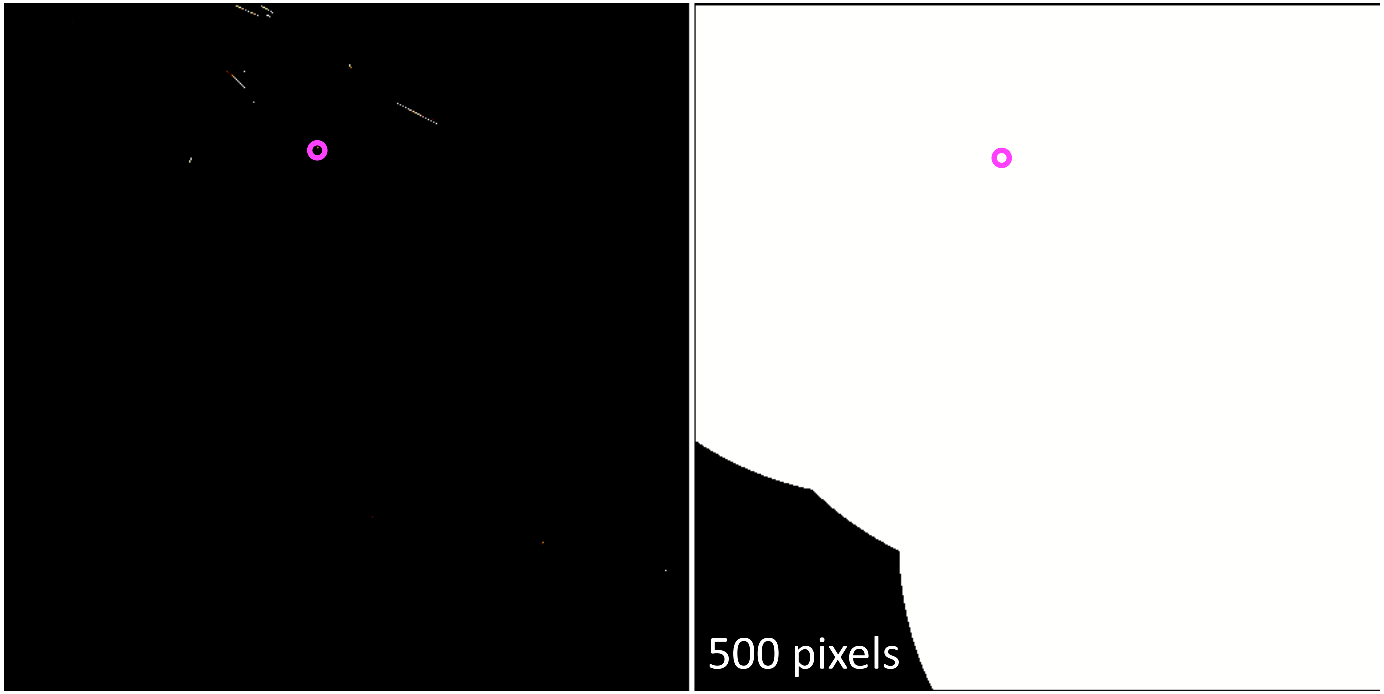
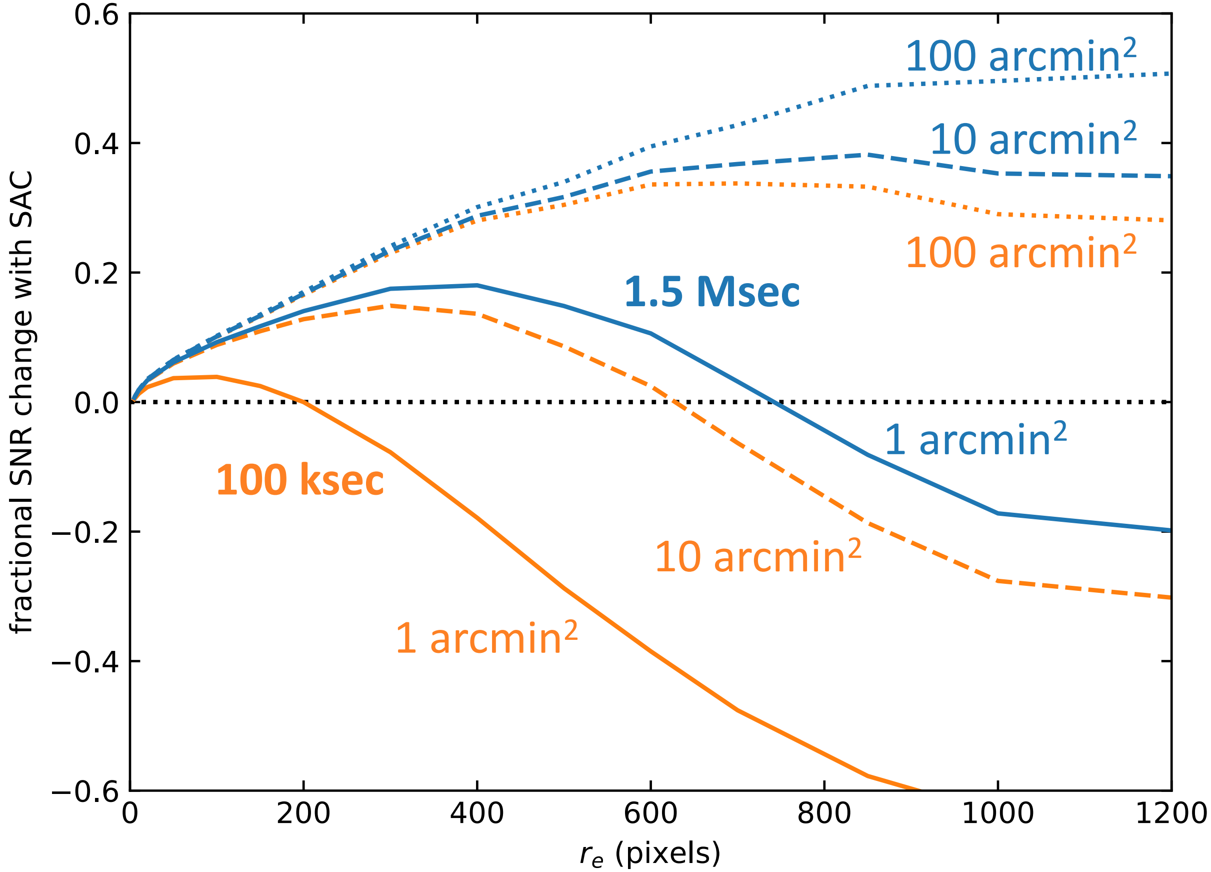


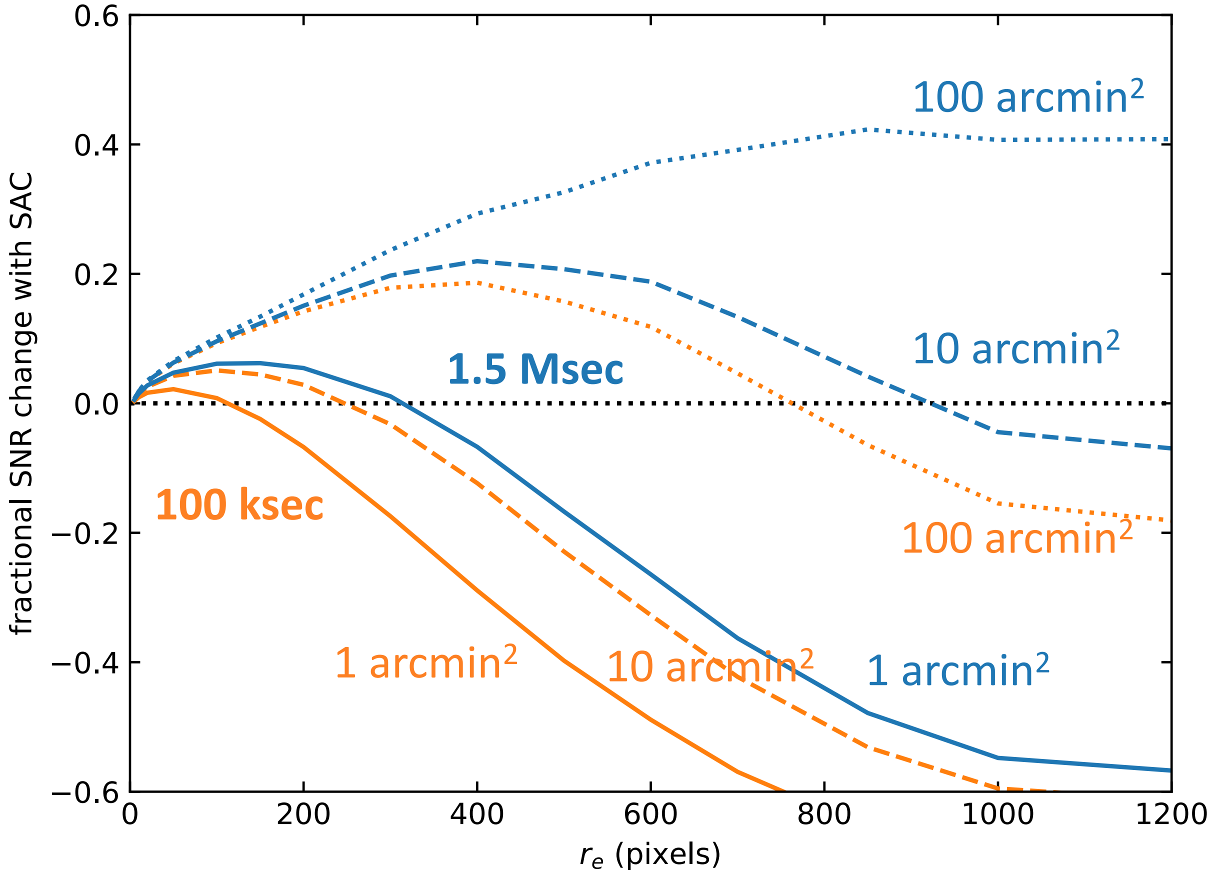
SNR Improvement with SAC

$$SNR = \frac{S_0}{(S_0 + B_0 + \sigma^2 B_0^2)^{1/2}},$$ BG uncertainty **σ = 5%**



SNR Improvement with SAC

$$SNR = \frac{S_0}{(S_0 + B_0 + \sigma^2 B_0^2)^{1/2}},$$ BG uncertainty **σ = 2%**



Summary

- Geant4 simulations predict a strong spatial correlation between particle tracks and valid events in the WFI background
- The correlation can be exploited to reduce the WFI background
- Self-anticoincidence (SAC, or partial veto) can reduce the systematic error due to background, at a cost to statistical error
- Tuning of masking radius depends on science goals, but should be user-selectable
- Work is ongoing