Once upon a time in quarantine - the ending of AmBe saga

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CYGNO Meeting, 4 June 2020

Nuclear recoils paper written

First draft of paper on nuclear recoils identification ready

- exhaustive on CYGNO reconstruction algorithms
  - complements the iDBSCAN paper by Igor Abritta

mentions vaguely the saturation issue, and its calibration procedure

reports on a initial efficiency vs rejection factor for NR vs ER

Identification of nuclear recoils in gas with a sCMOS camera

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May 2020

Abstract.

1. Introduction

The advent of a market of high position resolution and single photon light sensors can open new opportunity to investigate ultra-low rate phenomena as Dark Matter (DM) particle scattering on nuclei in a gaseous target.

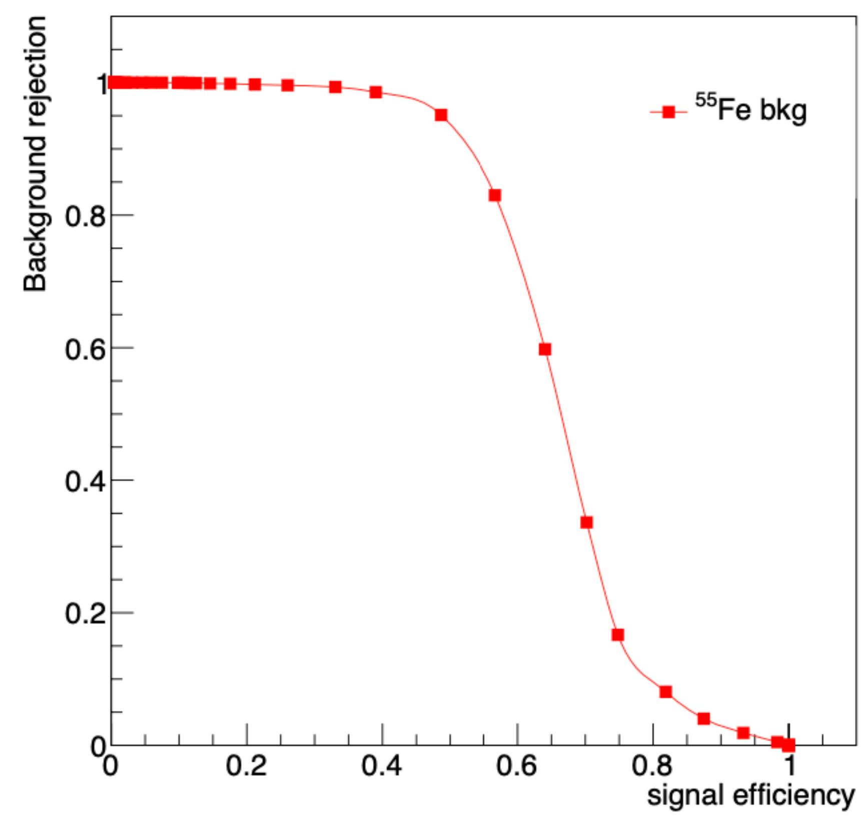
The nature of DM is still one of the key issues to understand our Universe. Different models predicts the existence of neutral particles with a mass of GeV or higher that would fill our Galaxy. They could interact with the nuclei present in ordinary matter producing highly ionizing nuclear recoils but with a kinetic energy as small as few keV. Moreover, given the motion of the Sun in the Milky Way towards the Cygnus constellation such nuclear recoils would exhibit a dipole angular distribution in a terrestrial detector. In this paper we describe the use of a scientific CMOS camera to capture the light emitted by Gas Electron Multipliers (GEMs) in a Time Projection Chamber (TPC) device. The GEMs are located in the TPC gas volume at the anode position and are used to convert the ionization produced in the gas by the nuclear recoils into flashes of visible light. The flash of light and its shape can be located in space adopting a cluster recognition algorithm. Neutron and γ radiation emitted by radioactive sources are used to set in motion atomic electrons and nuclei respectively in the gas volume. Moreover, natural radiation as cosmic rays is leaving a trail of ionization in the gas. They are all producing different patterns of light emission from the GEMs that can be reconstructed and analyzed. Nuclear recoils can then be efficiently identified down to a few keV kinetic energy. The study of the optical readout of TPC has been recently conducted with several small size prototypes (NITEC [1], ORANGE [2, 3], LEMON [4–6]) with various particles sources. In the following, we report the study of nuclear recoils excited by neutron from an AmBe source and electron recoils from a ^{55}Fe source in the gas volume of the LEMON prototype.

Results 1: ER rejection

- Preselection:
  - cluster properties selection
  - after studies by D. Piccolo, PMT selection used to reject additional 20% of cosmics in the Fe sample (i.e., split tracks which are “spot-like”, but still have a “long” PMT signal)
- Selection: 1D cut on cluster density
- Identified 2 example Working Points: 50% and 40% eff on signal. Correspond to 3.5% and 0.8% efficiency on ER with E=5.9 keV

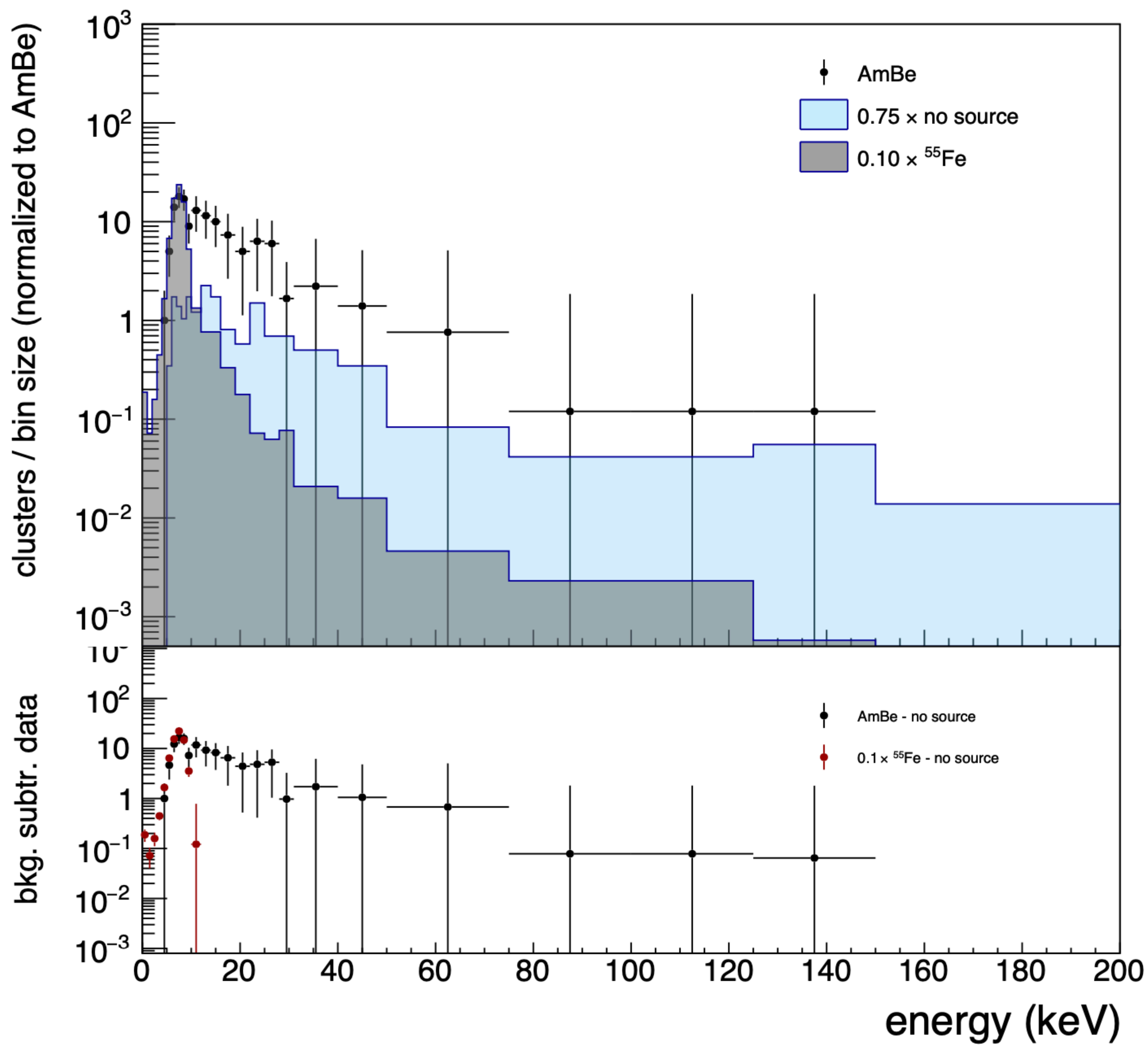
Table 1. Signal (nuclear recoils) and background (electron recoils) effi
different selections on δ.

working point	Signal efficiency			Background efficiency		
	ε_S^{presel}	ε_S^{δ}	ε_S^{total}	ε_B^{presel}	ε_B^{δ}	ε_B^{total}
WP_{50}	0.98	0.51	0.50	0.70	0.050	0.035
WP_{40}	0.98	0.41	0.40	0.70	0.012	0.008



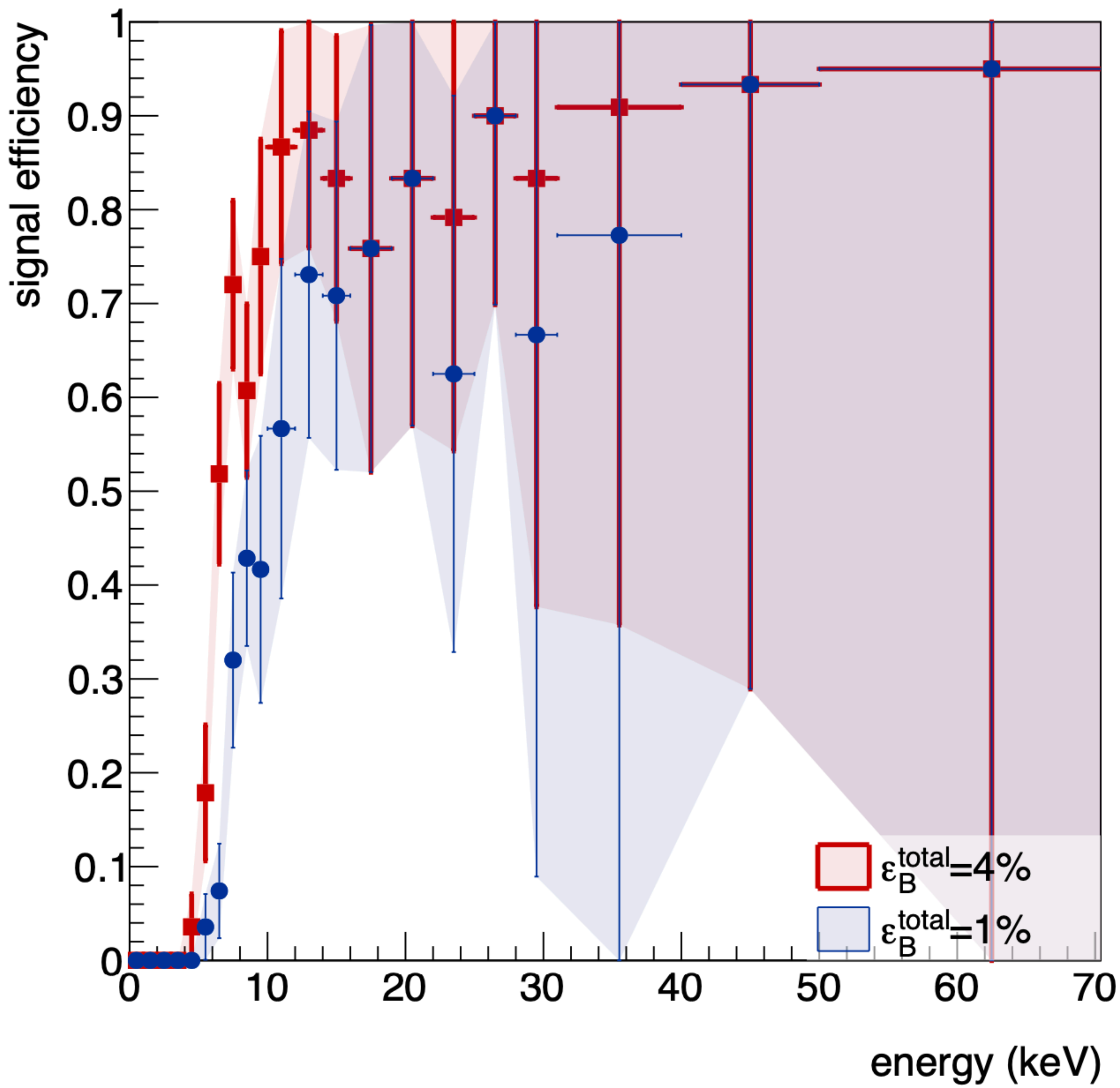
Results 2: NR spectrum

- analysis provides the background-subtracgted spectrum of NR, with, e.g, the WP50 selection



Result 3: NR efficiency vs E

- For the two WPs, show the efficiency of NR signal versus (calibrated) energy

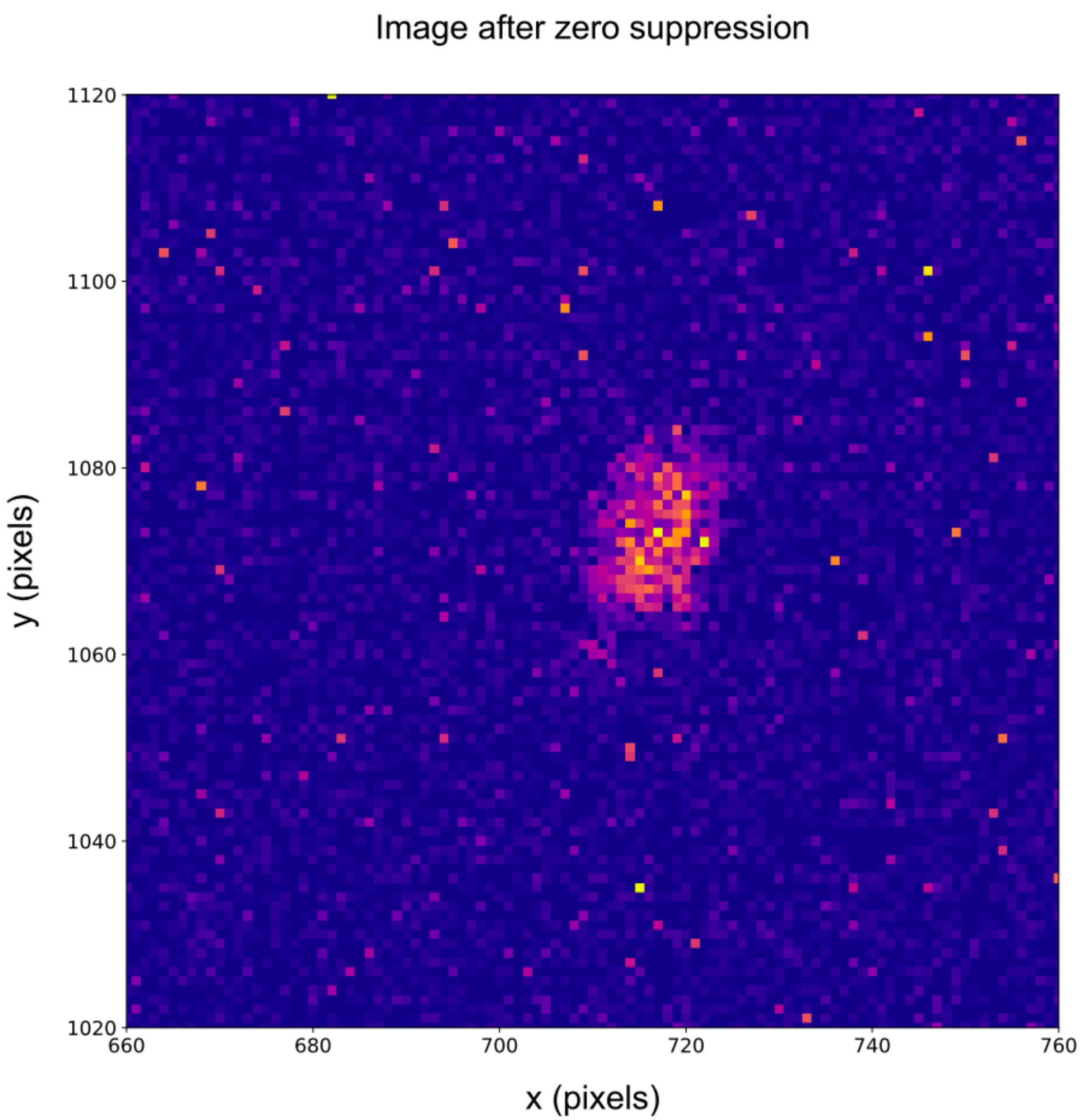


The signal efficiency for the WP with 4% bkg efficiency has:

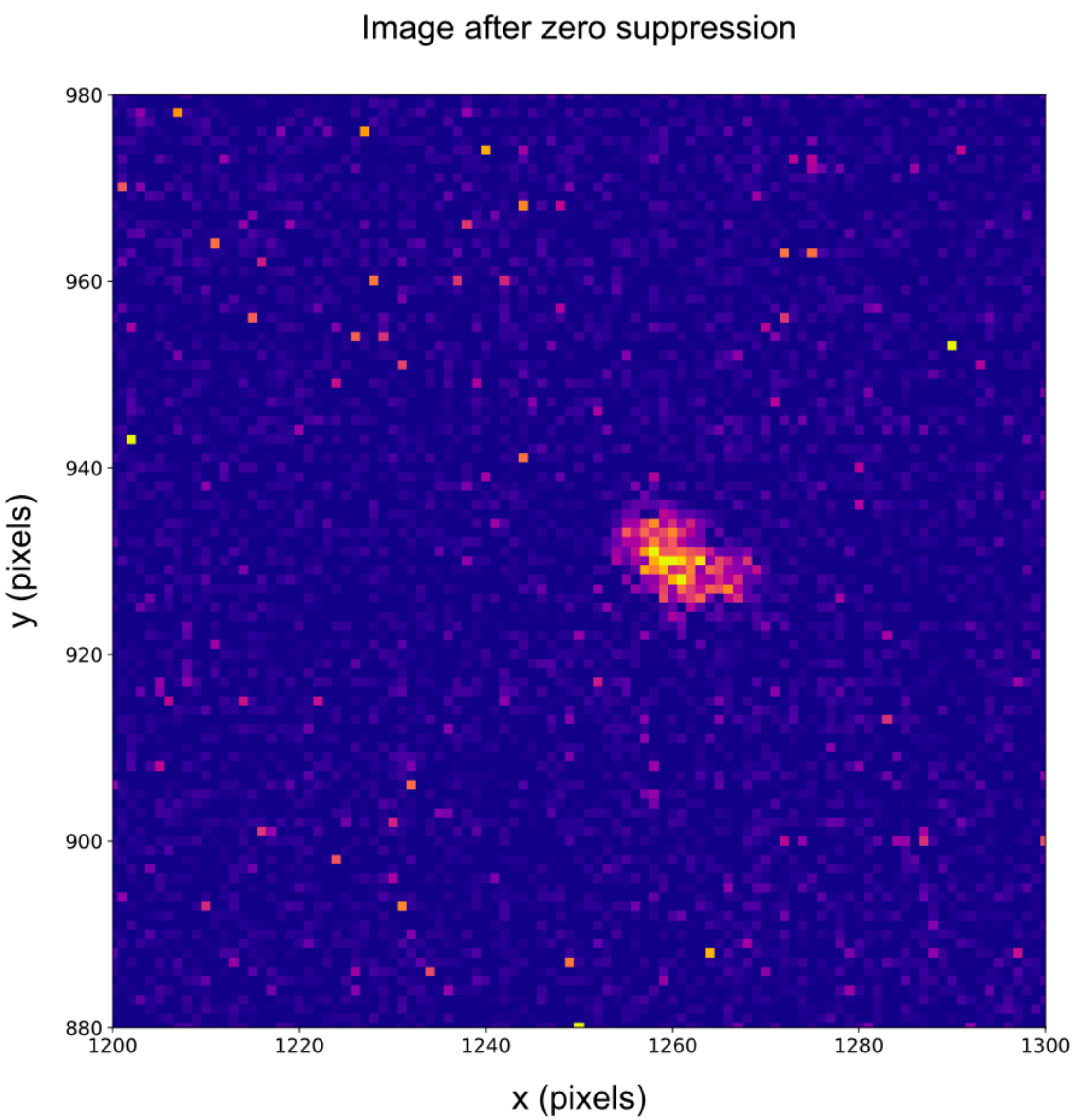
$\varepsilon_S^{total} \approx$ 18% at E=6 keV

Examples of 2 low-E NRs

- Two selected NR candidates with E<6 keV



E=5.2 keV



E=6.0 keV

Paper status

- First version written, currently under editors review
- E.T.A. for PubCom review: end of this week
- Current version of the paper available:
  - in git at this link
  - PDF at this link
- Target journal:
  - 1st choice: Nature
  - backup solution: Measurement Science and Technology

- Side notes for PubCom from this experience:
  - propose to PubCom to store every paper source (including figures) in github
  - can make “tags” (e.g. “preliminary”, “referee”, “published”) and can be used to access the figures for talks, etc
  - Overleaf can push to github easily
  - Now github allows free private repositories (the ambe paper one is such)

The End