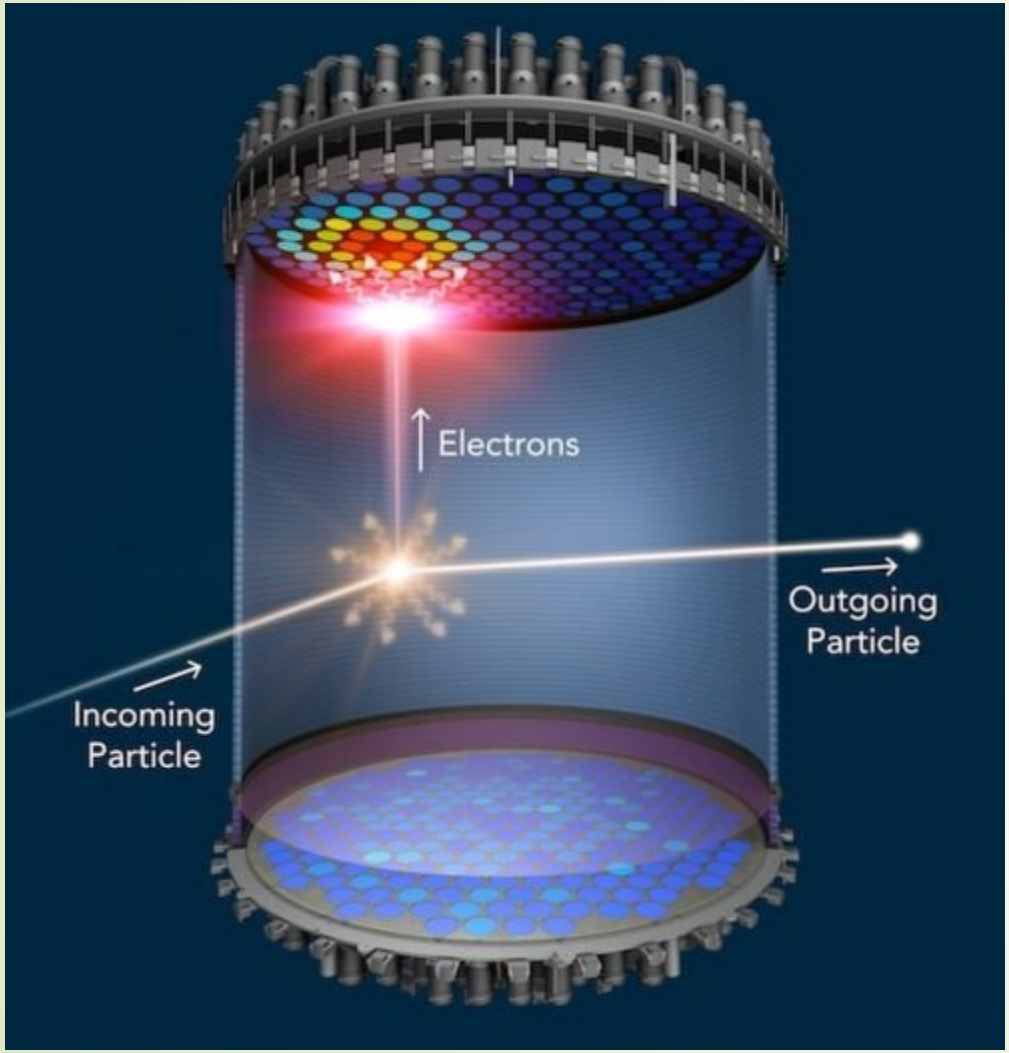
First pilot of a DM Masterclass using Xenon1T S2 Data

Peggy Norris (with help from Charlie Payne and his students) – May 2023

Synopsis

- The Xenon1T collaboration has made data available on the internet and published a sample Google Colaboratory Jupyter Notebook showing how to derive limits on custom dark matter signal models with XENON1T's S2-only data.
- We used this as a basis for a pilot masterclass for advanced high school students who were already familiar with coding using Jupyter notebooks.
- Students were able to:
  - Load detector response functions and binning
  - Generate the nuclear recoil energy spectrum for a particular WIMP mass
  - Convert that to an expected S2 signal in the detector
  - Find a region of interest for the WIMP model and calculate the cross section limit
- We then looked at the full published analysis: Aprile, E. *et al.* (XENON collaboration), Phys. Rev. Lett. 123, 251801 (2019).

From LZ talk



- Arrives First – Scintillation Light (S1)
  - gammas, betas (background)
- Arrives next – Electrons (S2)
  - drift through electric field of detector
  - Neutron background or WIMP signal

XENON1T Analysis (Aprile et al.)

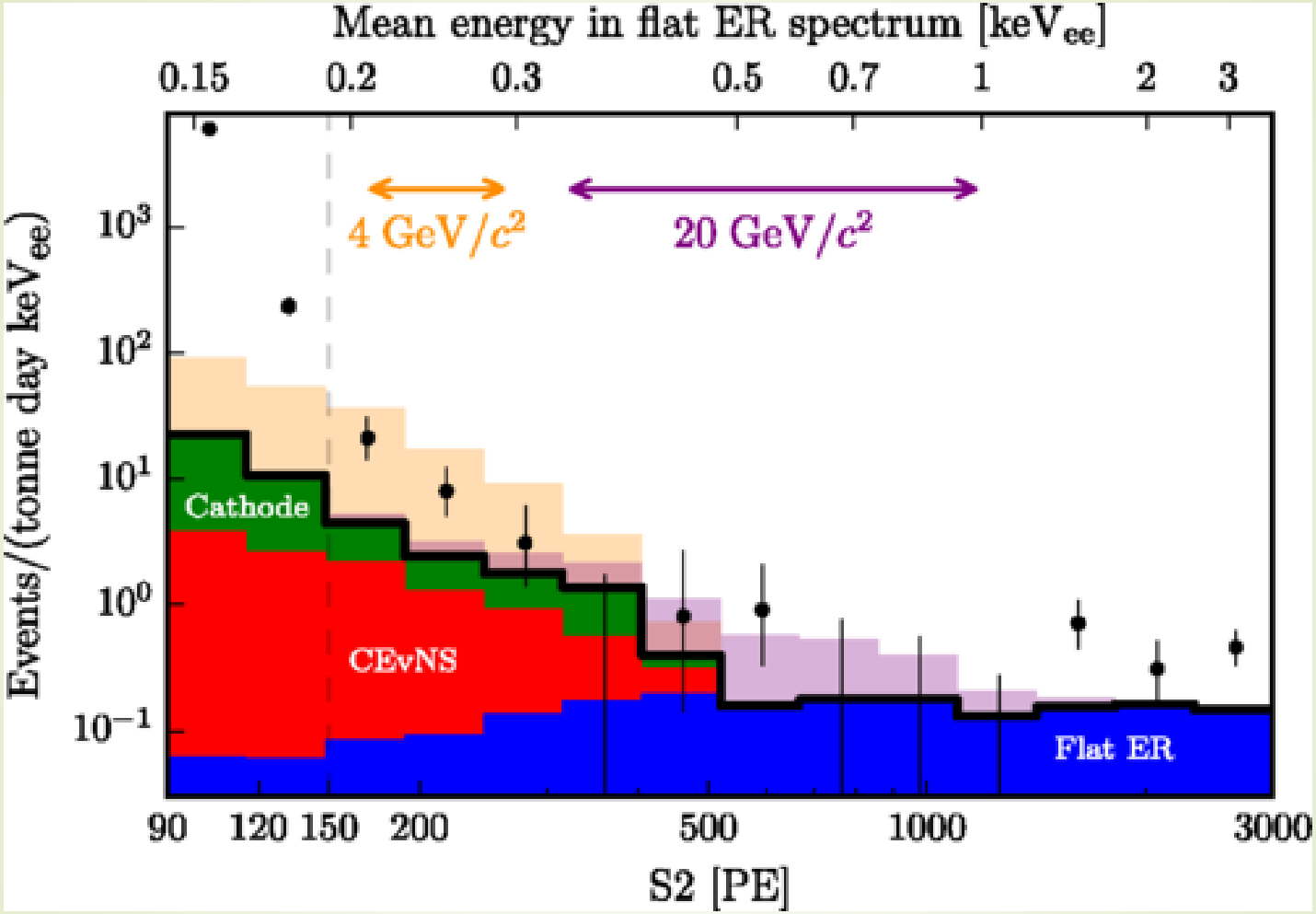
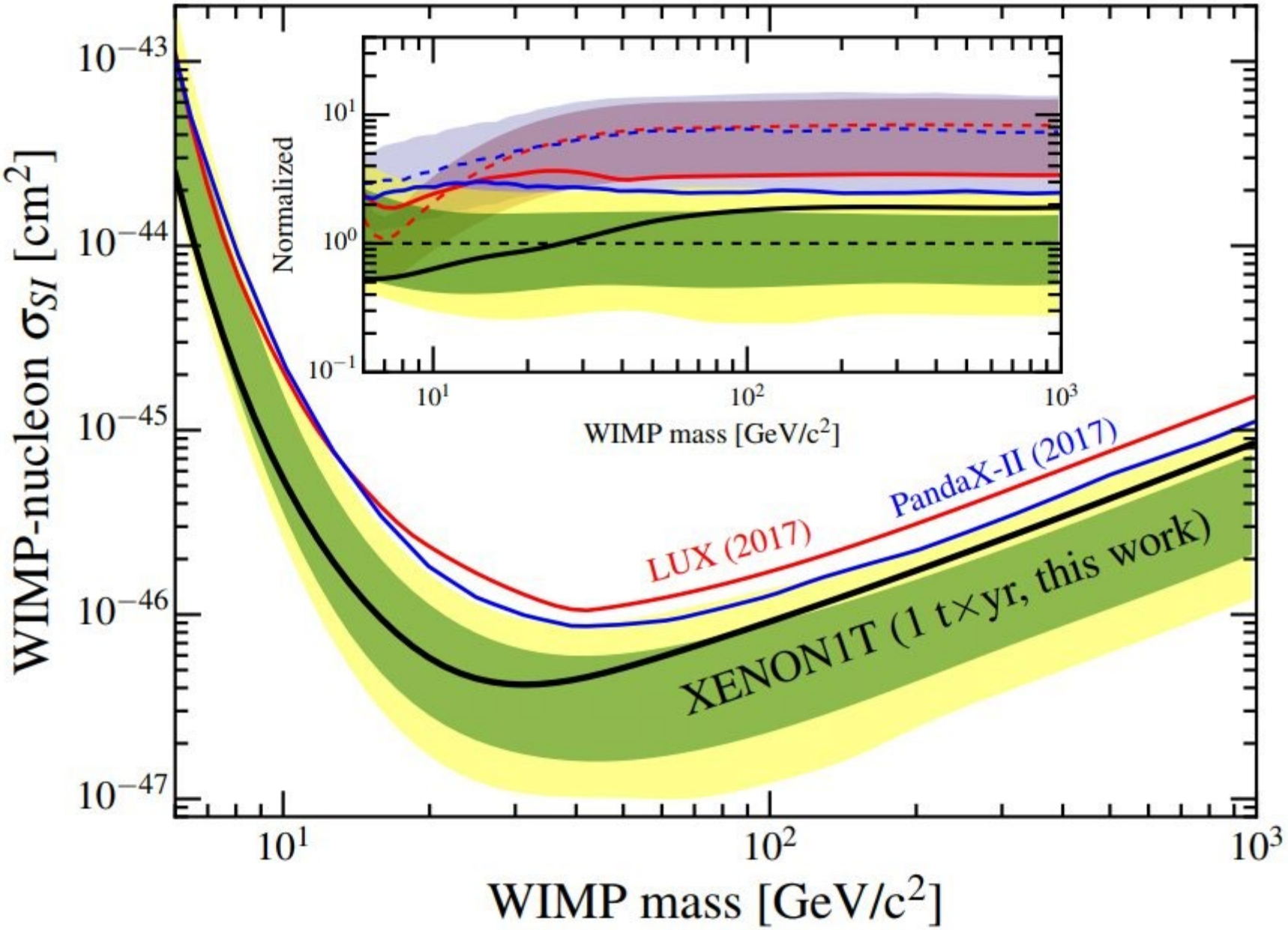


Figure 4. Distribution of events that pass all cuts (black dots); error bars show statistical uncertainties (1σ Poisson). The thick black line shows the predetermined summed background model, below which its three components are indicated, with colors as in Fig. 3. The lightly shaded orange (purple) histogram, stacked on the total background, shows the signal model for 4 GeV/c2 (20 GeV/c2) SI DM models excluded at exactly 90% confidence level.


WIMP-nucleon σ_{SI} [cm^2]
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^1
10^2
10^3
WIMP mass [GeV/c^2]
LUX (2017)
PandaX-II (2017)
XENON1T (1 t×yr, this work)
Normalized
10^1
10^0
10^{-1}
10^1
10^2
10^3
WIMP mass [GeV/c^2]

Our MC Pilot

9:30 - 9:45	Assess prior knowledge - What have you heard or read about Dark Matter?	https://jamboard.google.com/d/1gjI5PVT9i26rowWJFT3lpa4oiJCK5e1hT1-LxGE0jmY/edit?usp=sharing
9:45-10:15	Evidence for Dark Matter, Part I	Peggy Powerpoint
10:15-10:35	Activity using DM Galaxy Simulator	https://foothillastrosims.github.io/dark-matter/ Student sheet
10:35-10:45	Break	
10:45-11:10	Evidence for DM, Part 2	Peggy Powerpoint
11:10 - 11:30	DM Detection and detectors	Peggy Powerpoint
11:30 - 12:00	Summary article	https/physics.aps.org/articles/v12/s145
12-1:30	Lunch Break	
1:30 - 3:00	DM analysis by students	https://colab.research.google.com/drive/1ilKV73kuK72o8kK_FNdcNwc6BBq_twl6
3:00 - 3:20	Discussion	https://journals.aps.org/prl/pdf/10.1103/PhysRevLett.123.251801
3:20 - 3:30	Post assessment - What have you learned today?	https://jamboard.google.com/d/1pUKU0k2ITnXrtnQ20zZjujaiNhxV8crYIoPAVyOlfb0/edit?usp=sharing

Student Activities

1. Galaxy Simulator with dark matter (https://foothillastrosims.github.io/dark-matter/)
2. Synopsis of analysis paper –student jigsaw (https://physics.aps.org/articles/v12/s145)
3. Analysis activity (https://colab.research.google.com/drive/1ilKV73kuK72o8kK_FNdcNwc6BBq_twl6)

Pre/Post Assessments

- PRE-Assessment Jamboard (working with a partner)
  - What have you heard or read about dark matter?
- POST-Assessment Jamboard (working individually)
  - What is something you learned today about evidence for dark matter?
  - What is something you learned today about candidates for dark matter?
  - What is something you learned today about how scientists are trying to detect dark matter?
  - What is something that surprised you today?

Next steps

- Clean up the code and finish annotations.
- Generate a spreadsheet of region of interests for different WIMP masses for the use of teachers (to check student work).
- Contact XENON1T collaboration about providing speakers for videoconferences.
- Better slides illustrating Nuclear versus Electronic recoils and their importance in understanding whether or not there is a viable dark matter candidate.