Liquid Argon Detectors at the Single(ish) Electron Limit

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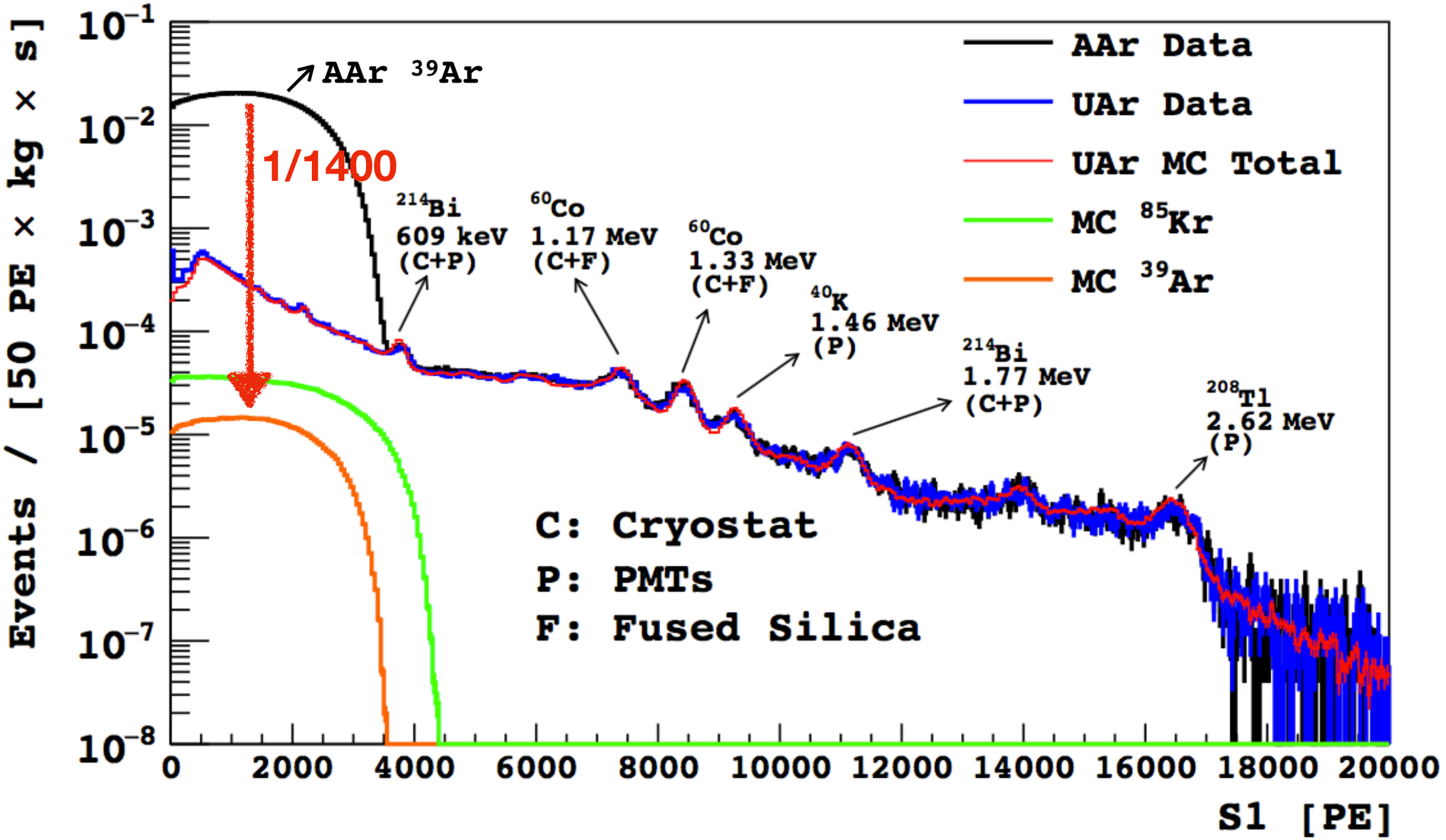
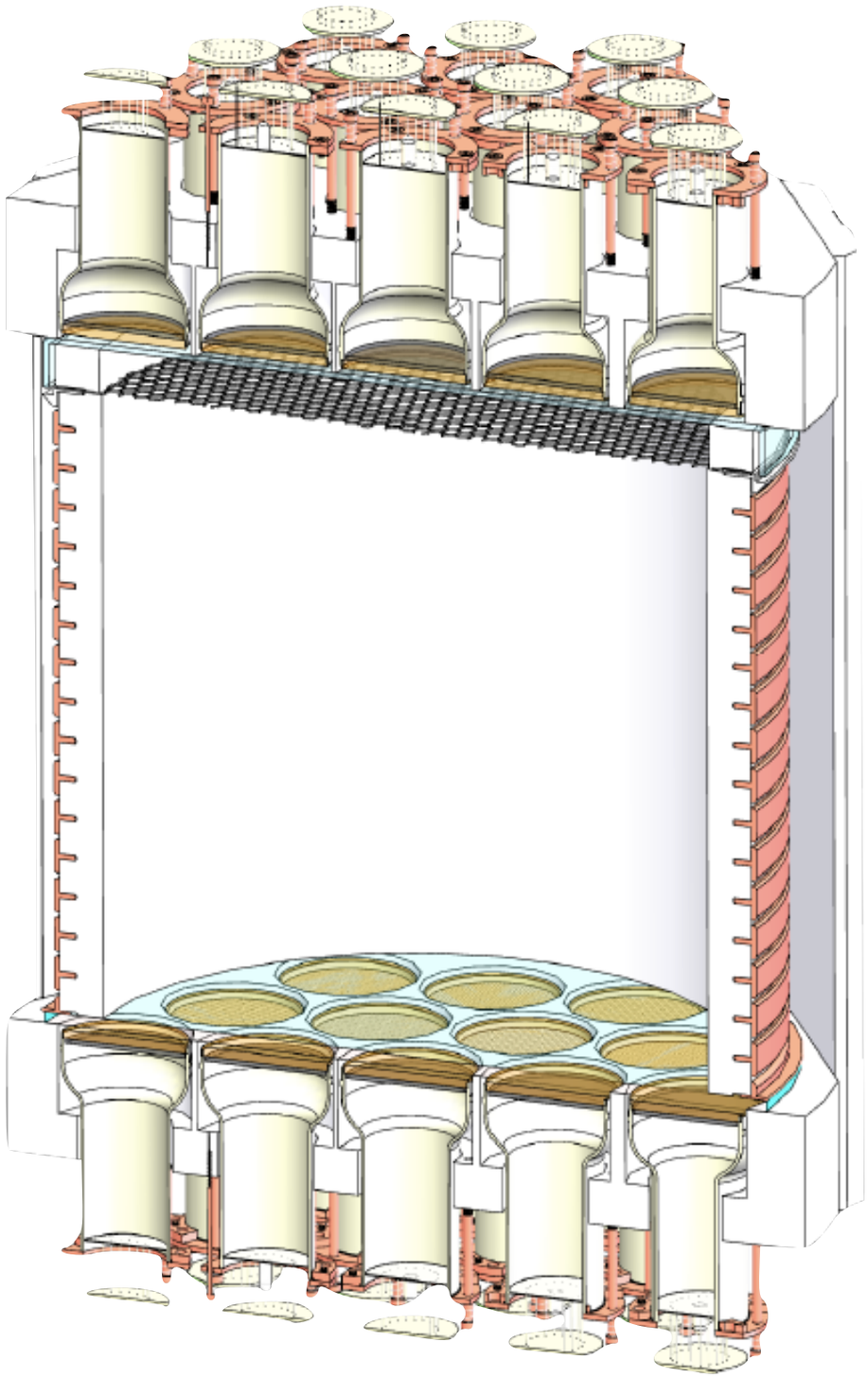
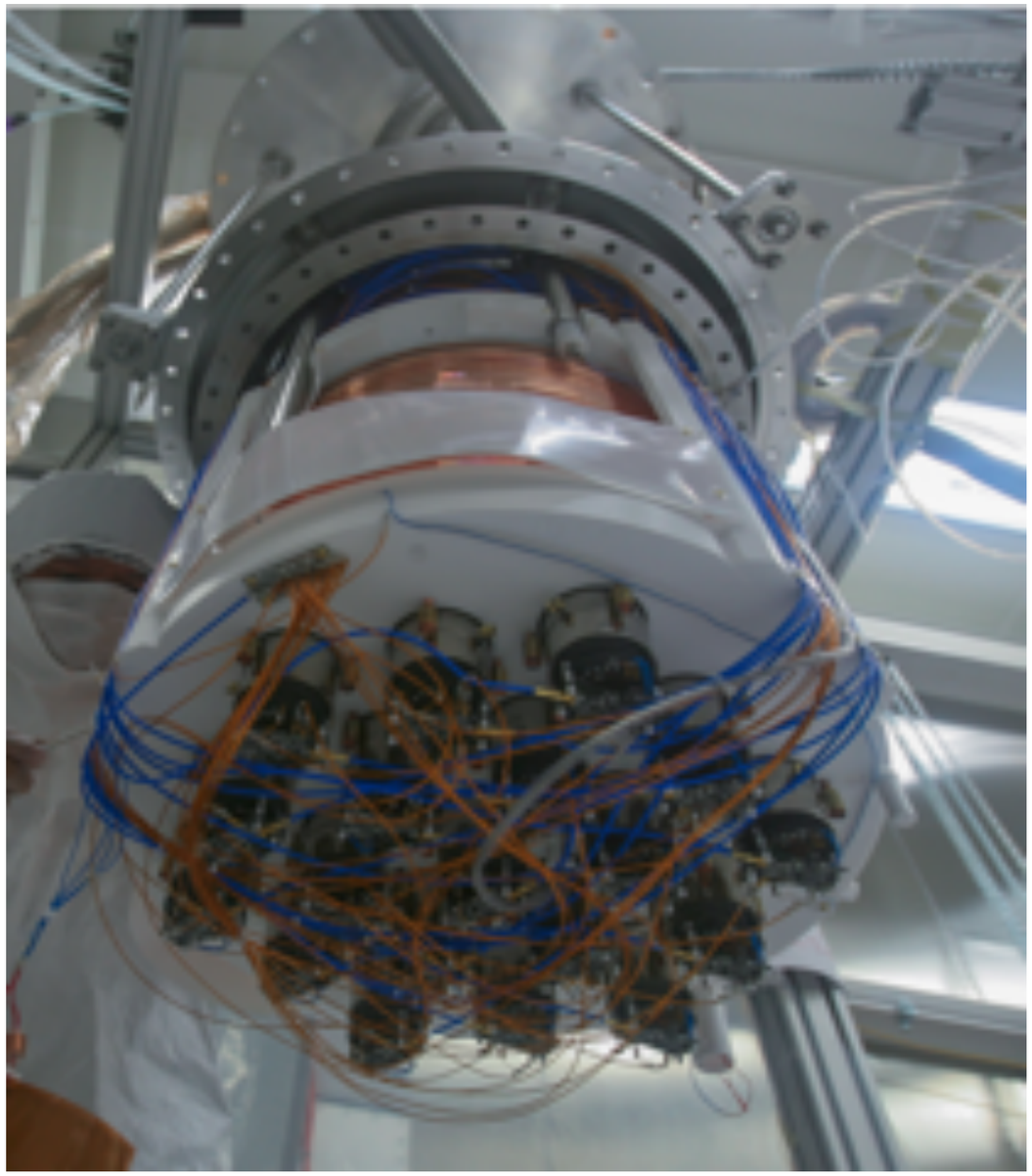
argon has a naturally occurring beta-emitting isotope, ^{39}Ar



DarkSide-50





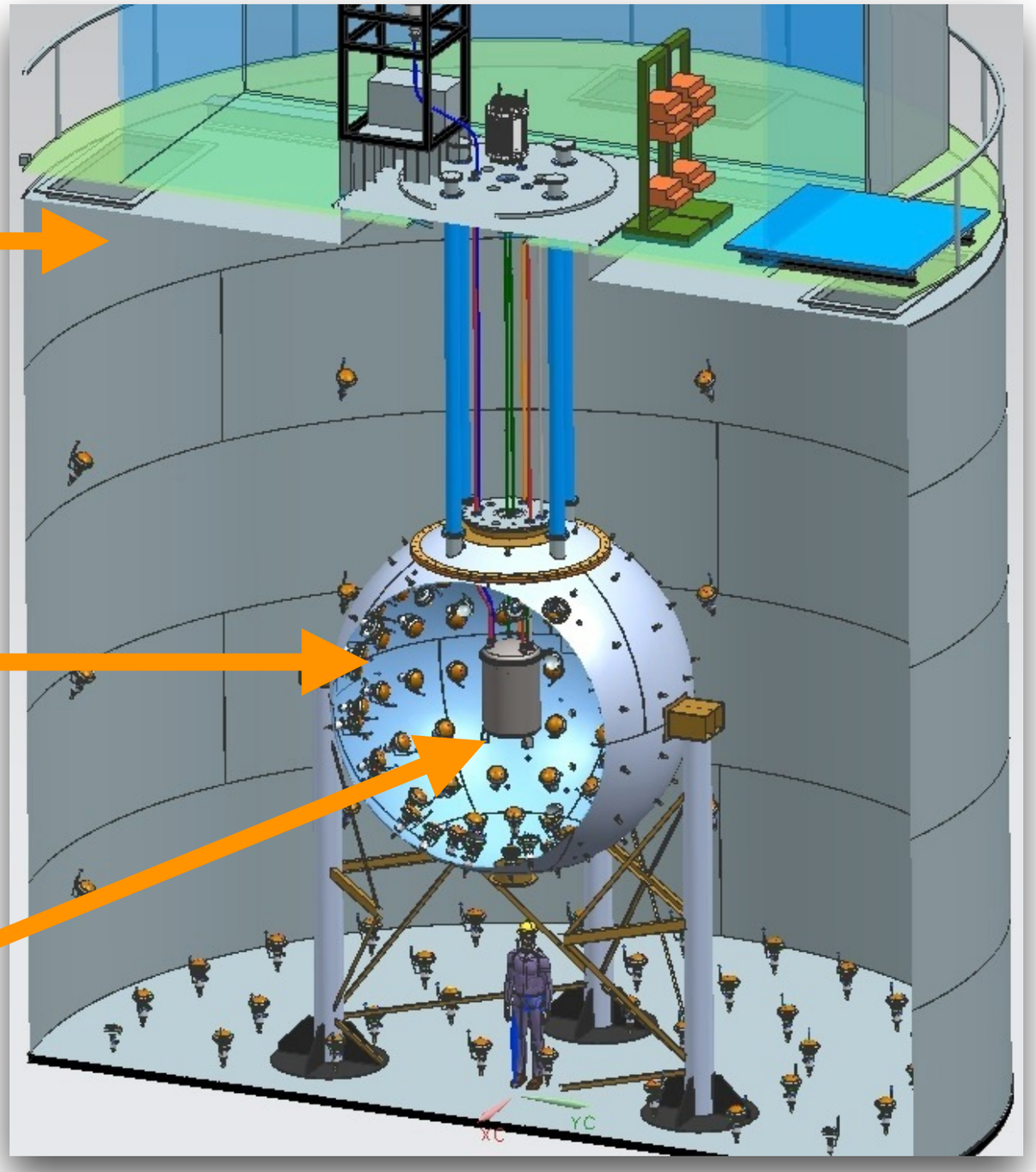
located at LNGS Hall C

and installed in veto detector

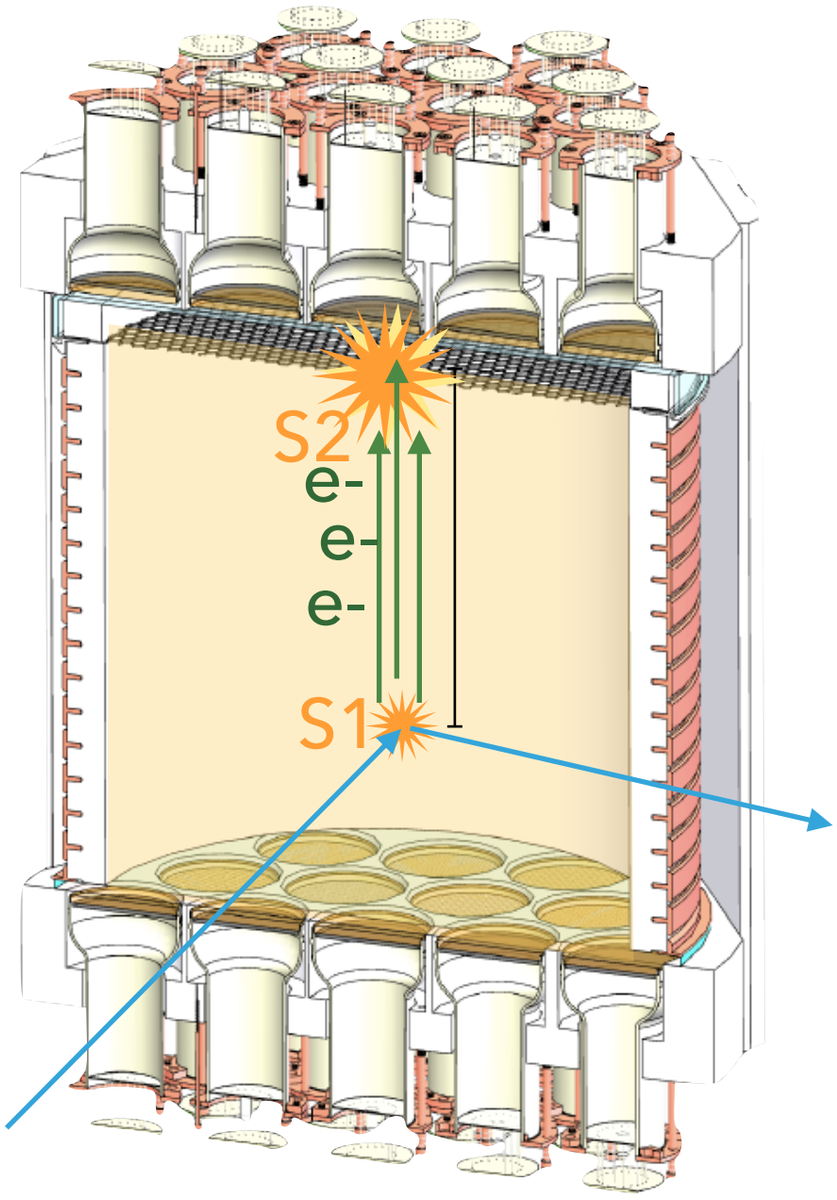
1,000-tonne Water Cherenkov
Cosmic Ray Veto

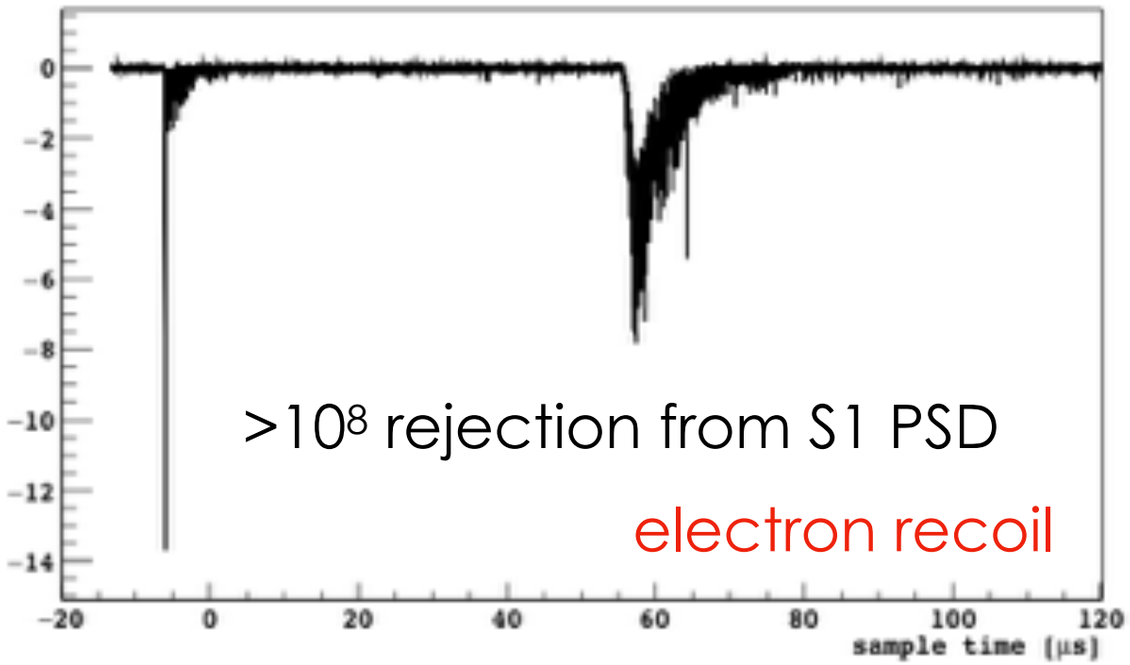
30-tonne Liquid Scintillator
Neutron and γ Veto

inner TPC



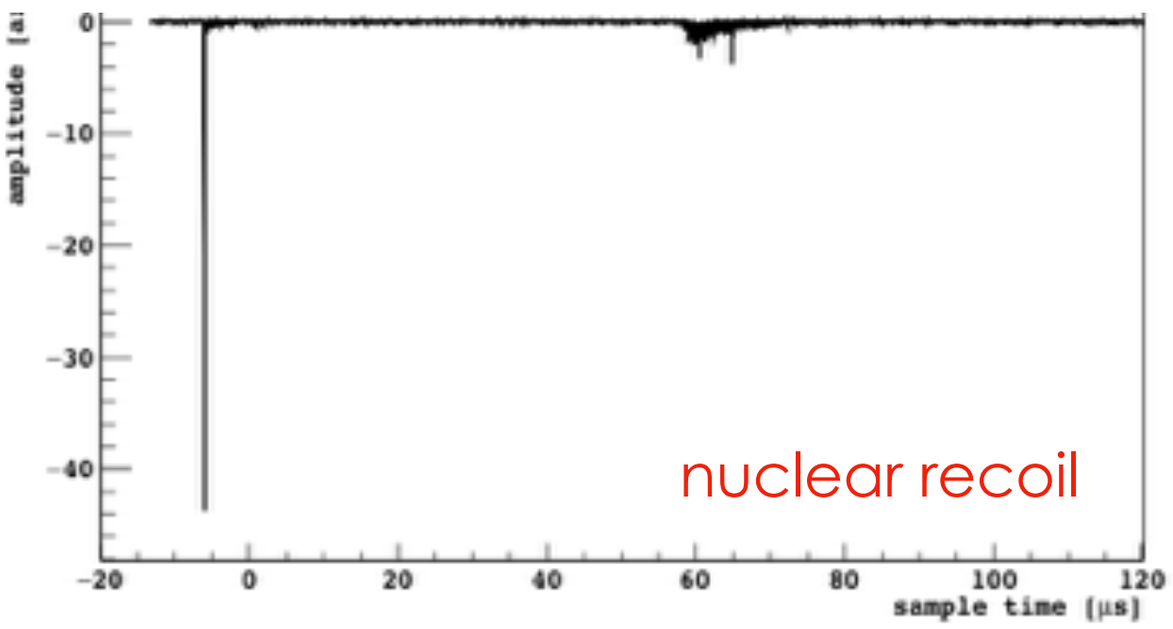
liquid argon TPC concept





>10^8 rejection from S1 PSD

electron recoil



nuclear recoil

can we reduce the energy threshold?

S1 scintillation signal threshold at 2 keVee = 10 keVnr

S2 ionization signal threshold at <0.1 keVee = 0.4 keVnr

- PMTs have negligible dark rate at 88 K
- center PMT sees ~23 photoelectrons per electron
  - high trigger efficiency
  - single electron sensitivity
- lose PSD, Z-reconstruction, and S2/S1

1 keVee ~ 5 keVnr ~ 25 e^- ~ 10 S1 PE ~ 600 S2 PE

NB: very rough comparison, these don't scale linearly

Phys. Rev. Lett., vol. 121, 081307 (2018)

Phys. Rev. Lett., vol. 121, 111303 (2018)

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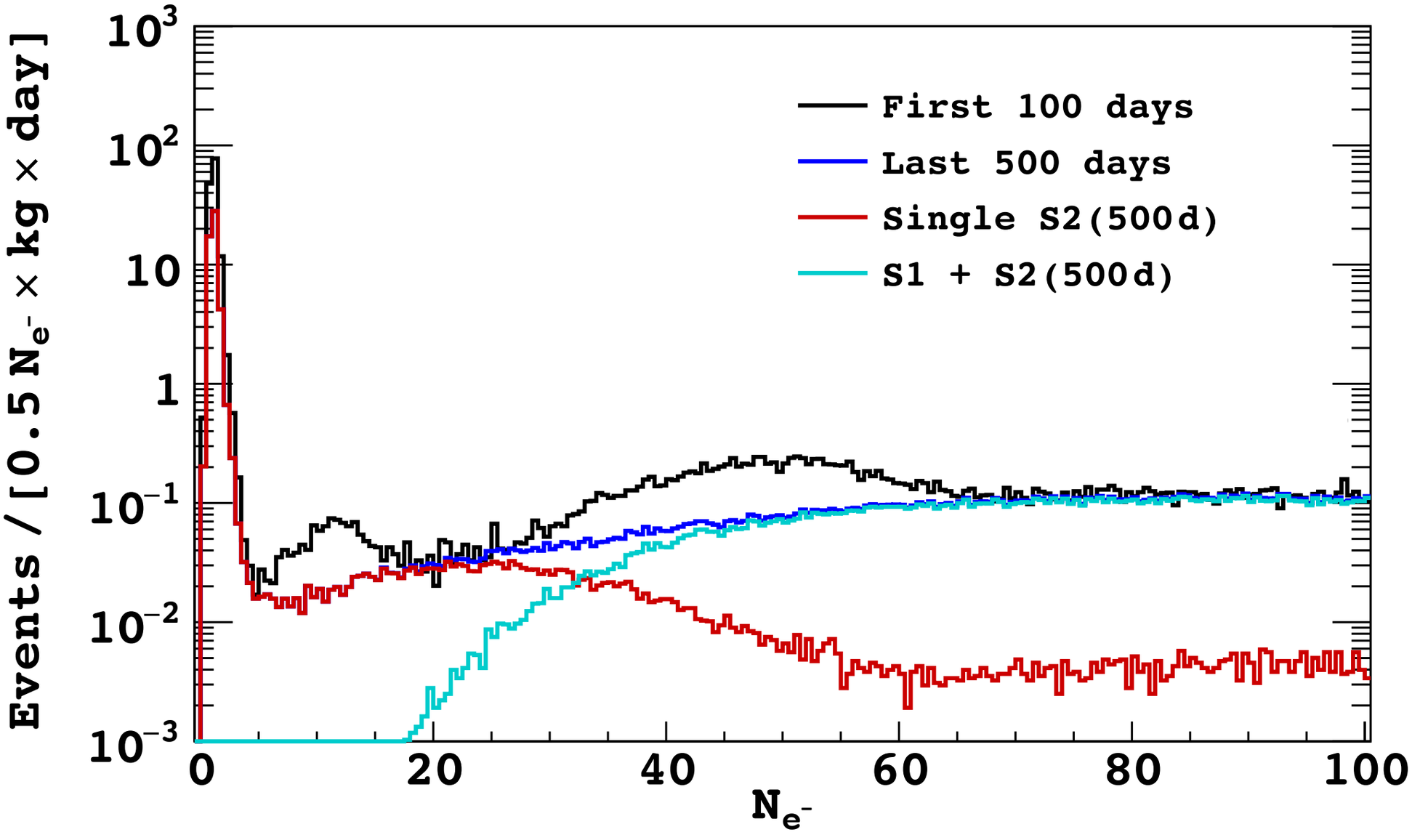

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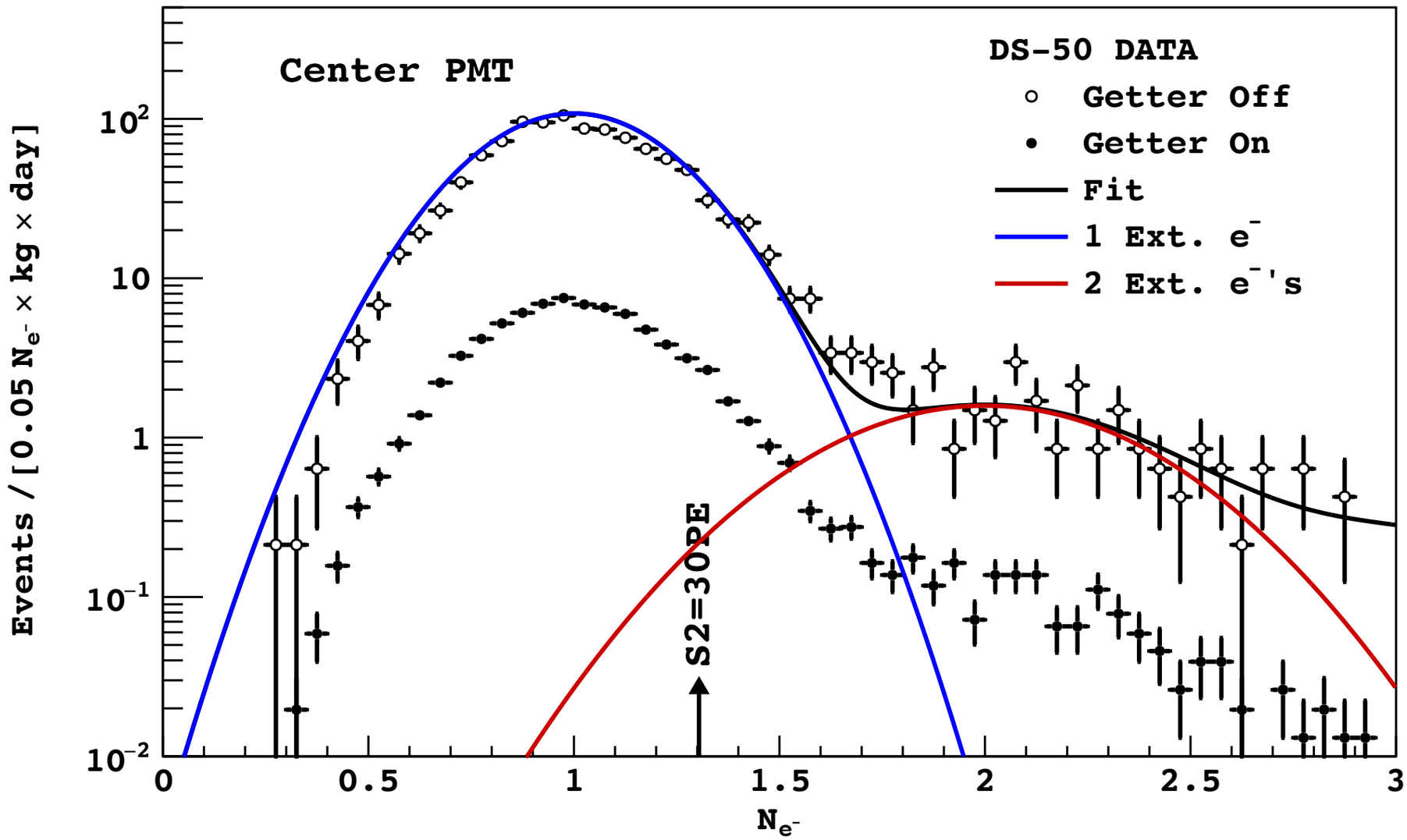
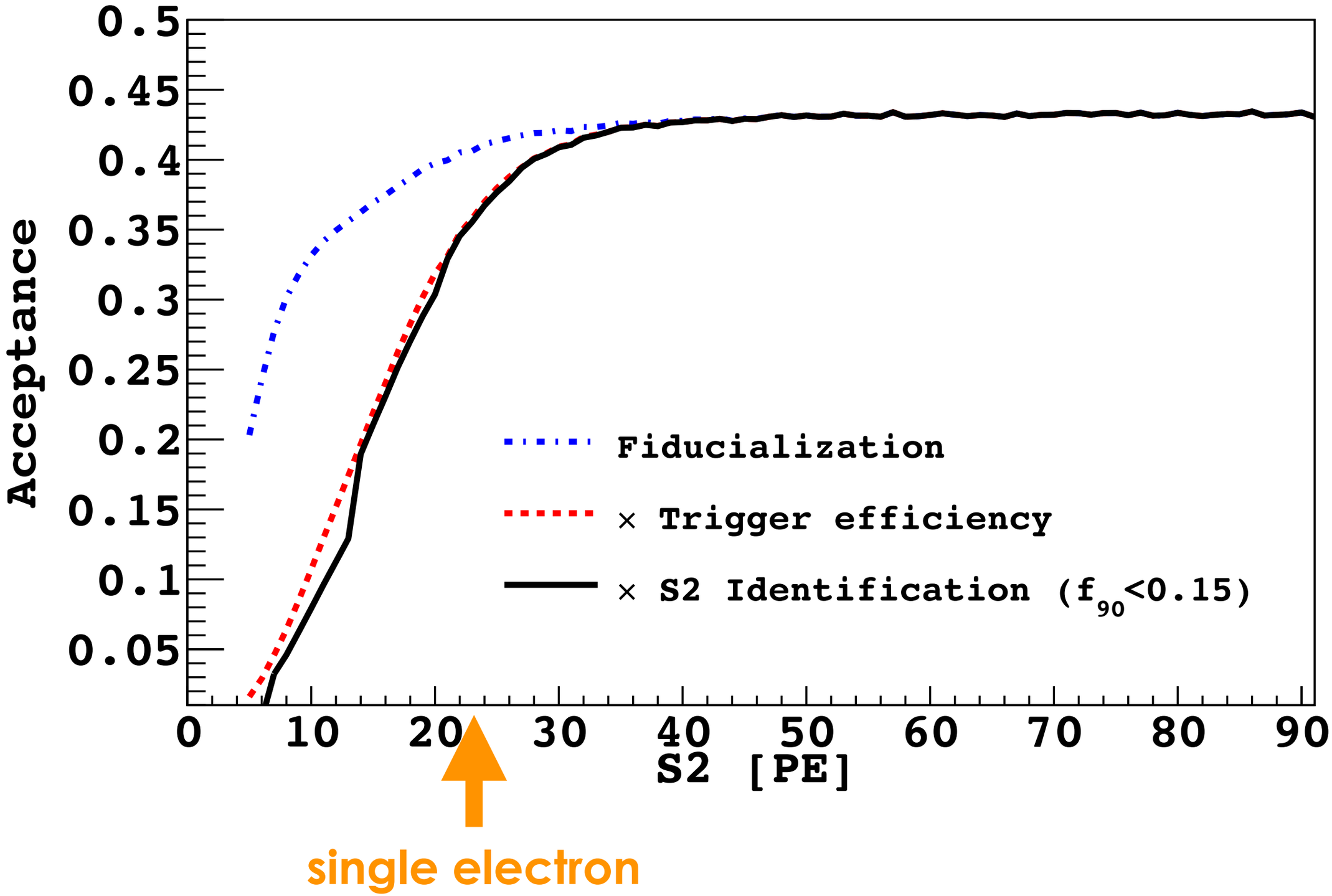
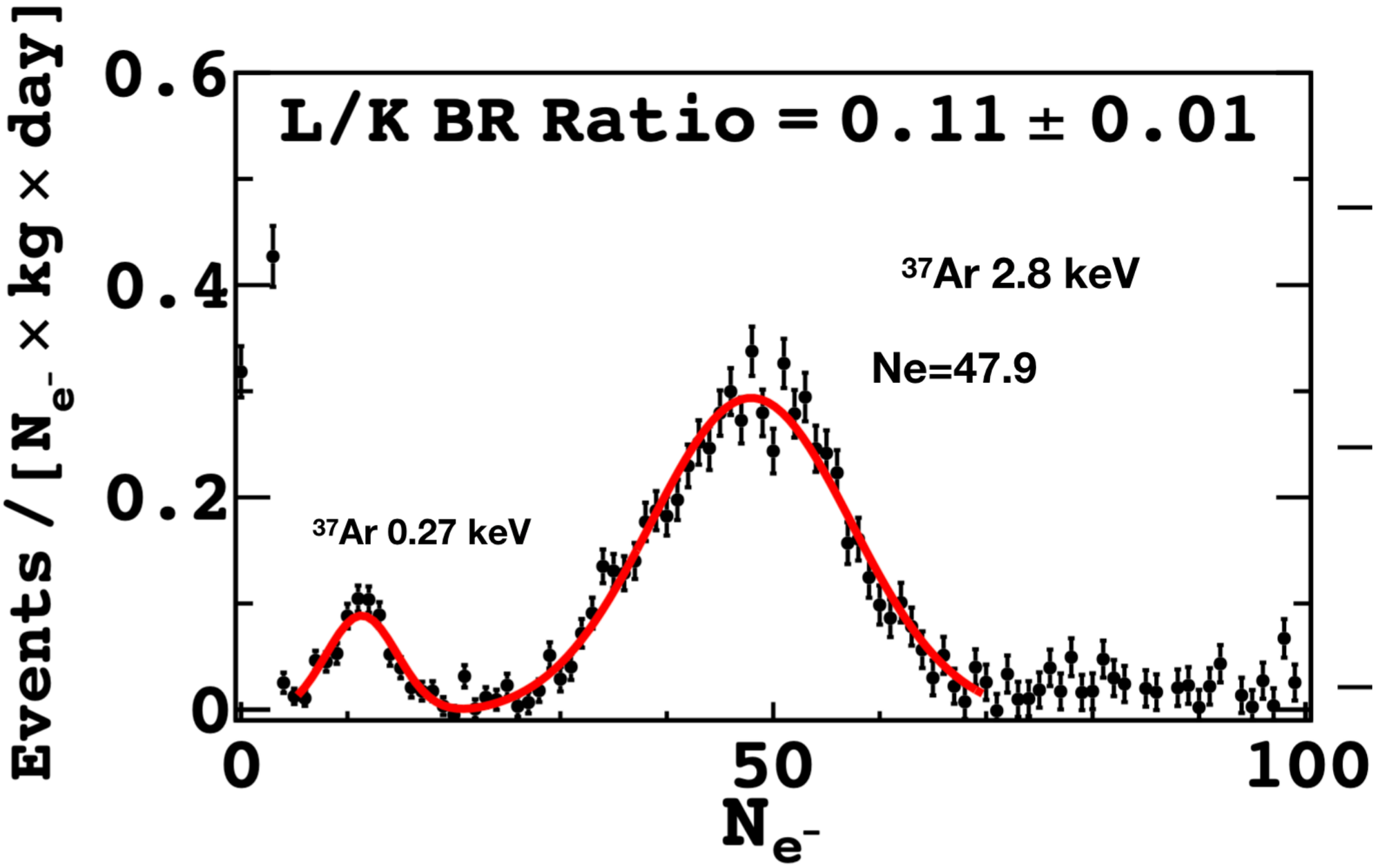


electron detection efficiency



electron recoil energy scale



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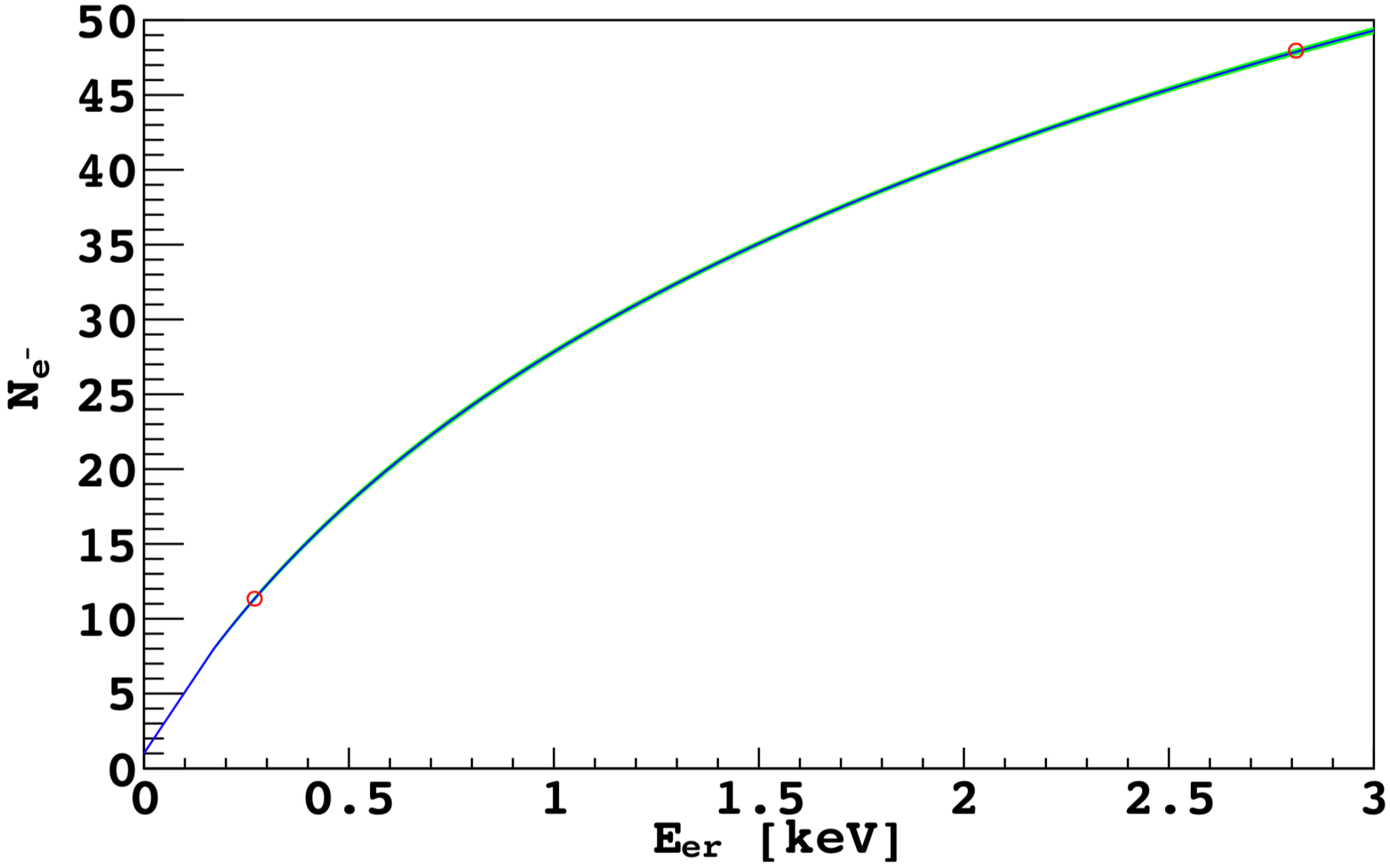
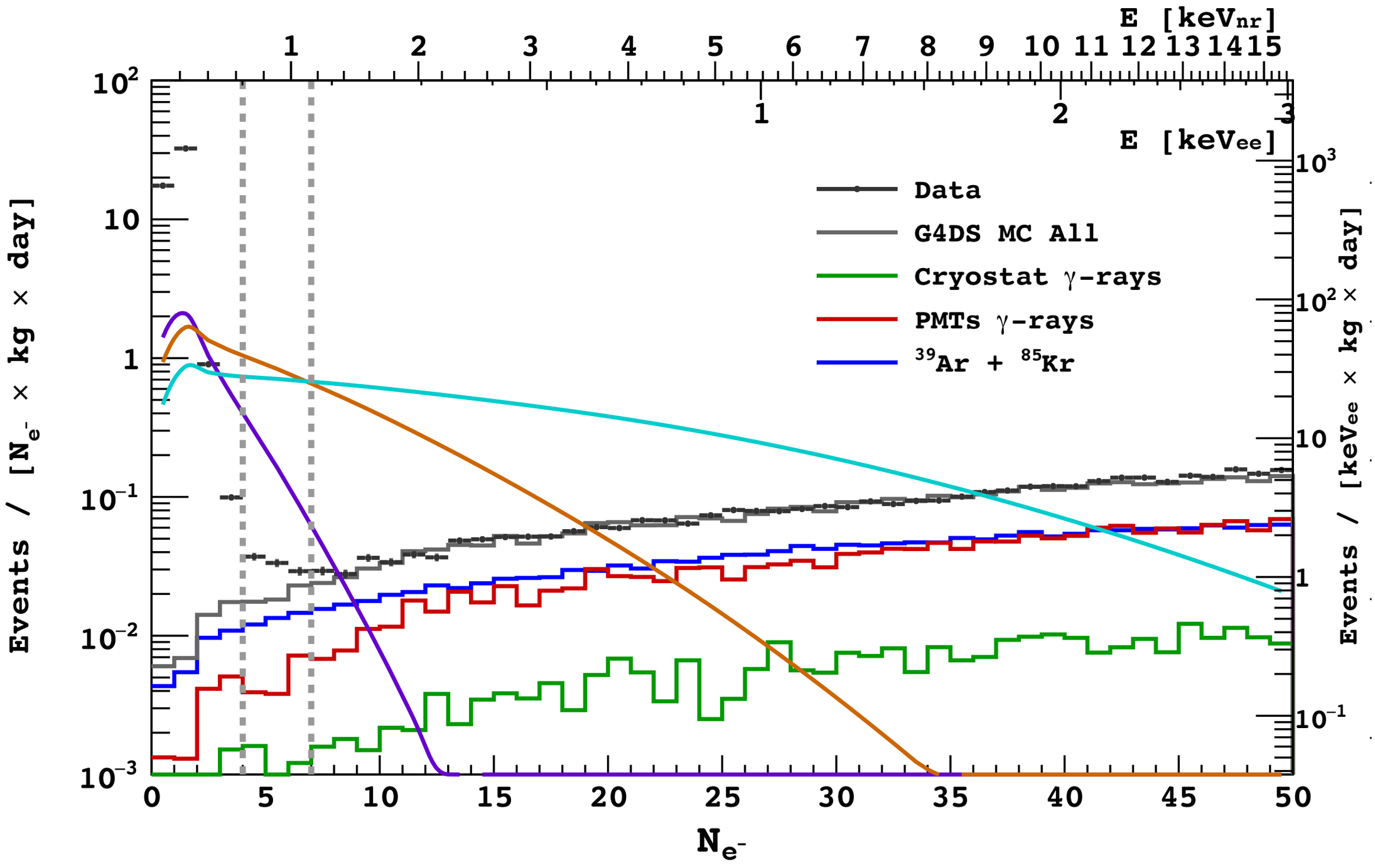


background rates



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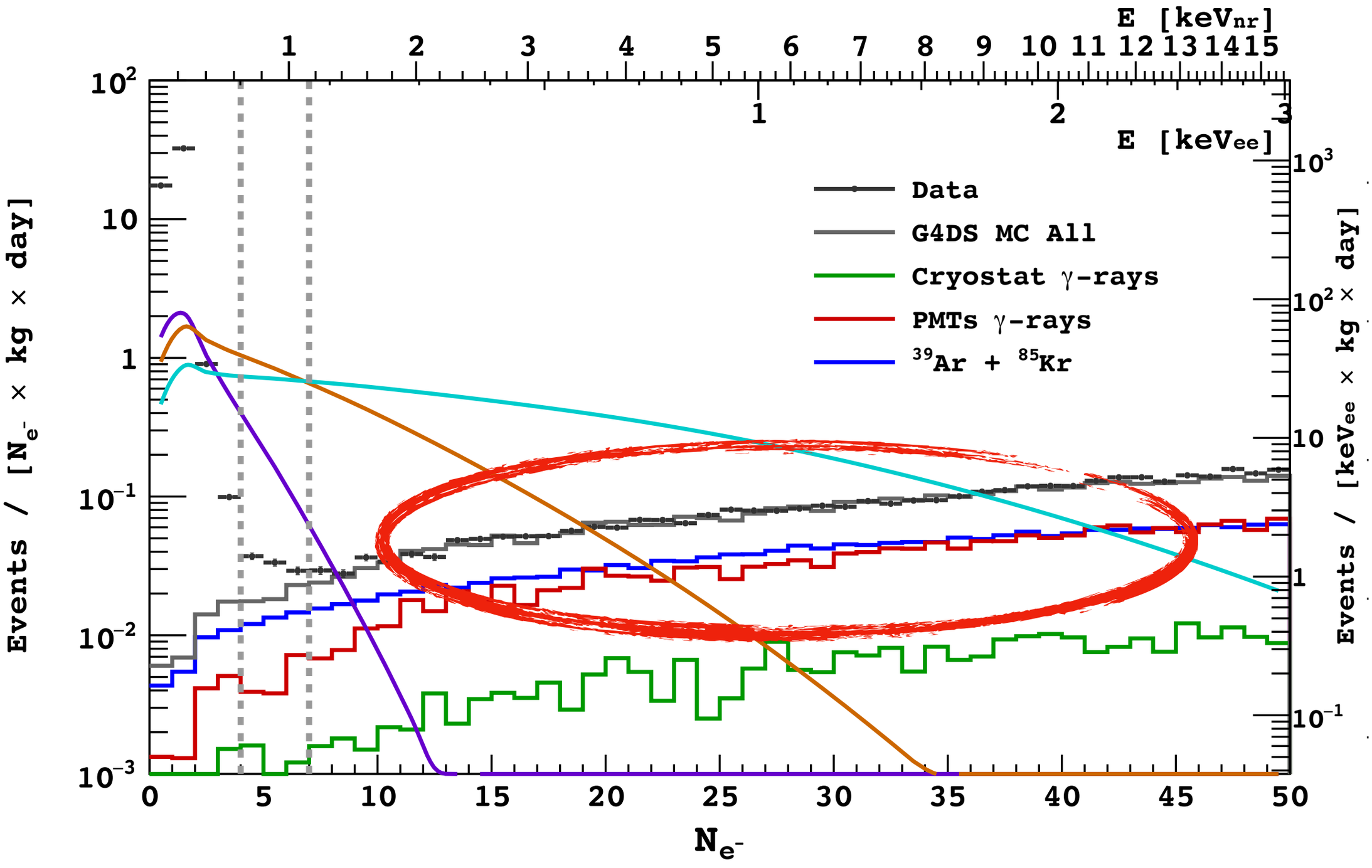
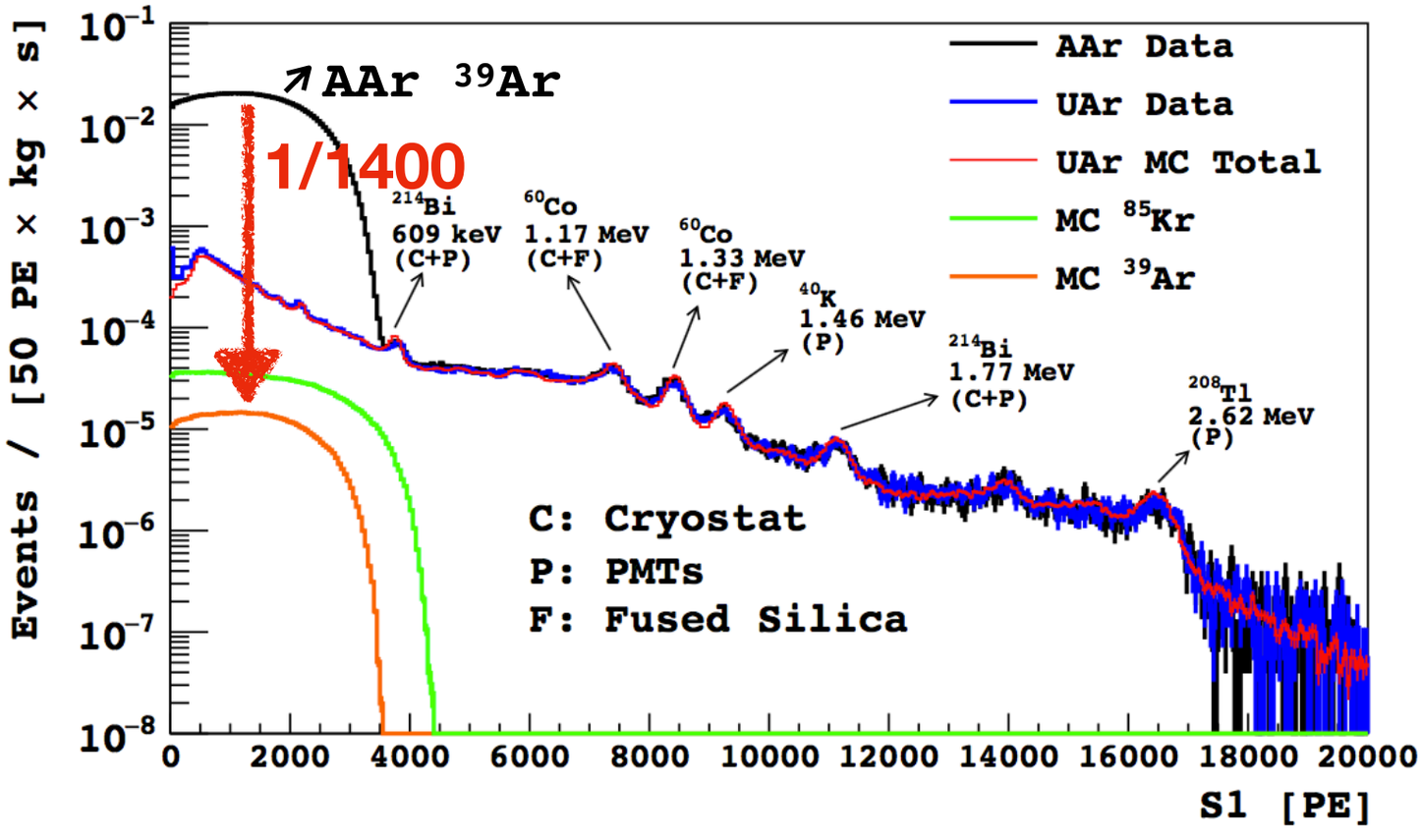
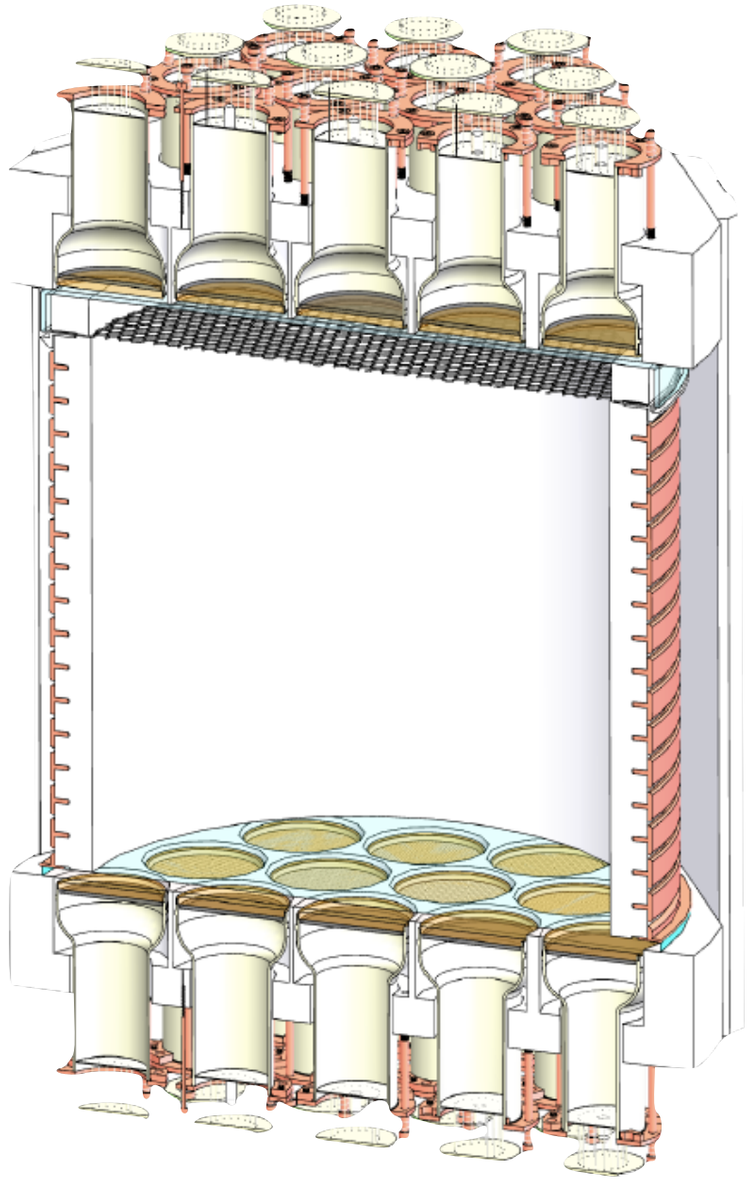


continuum background





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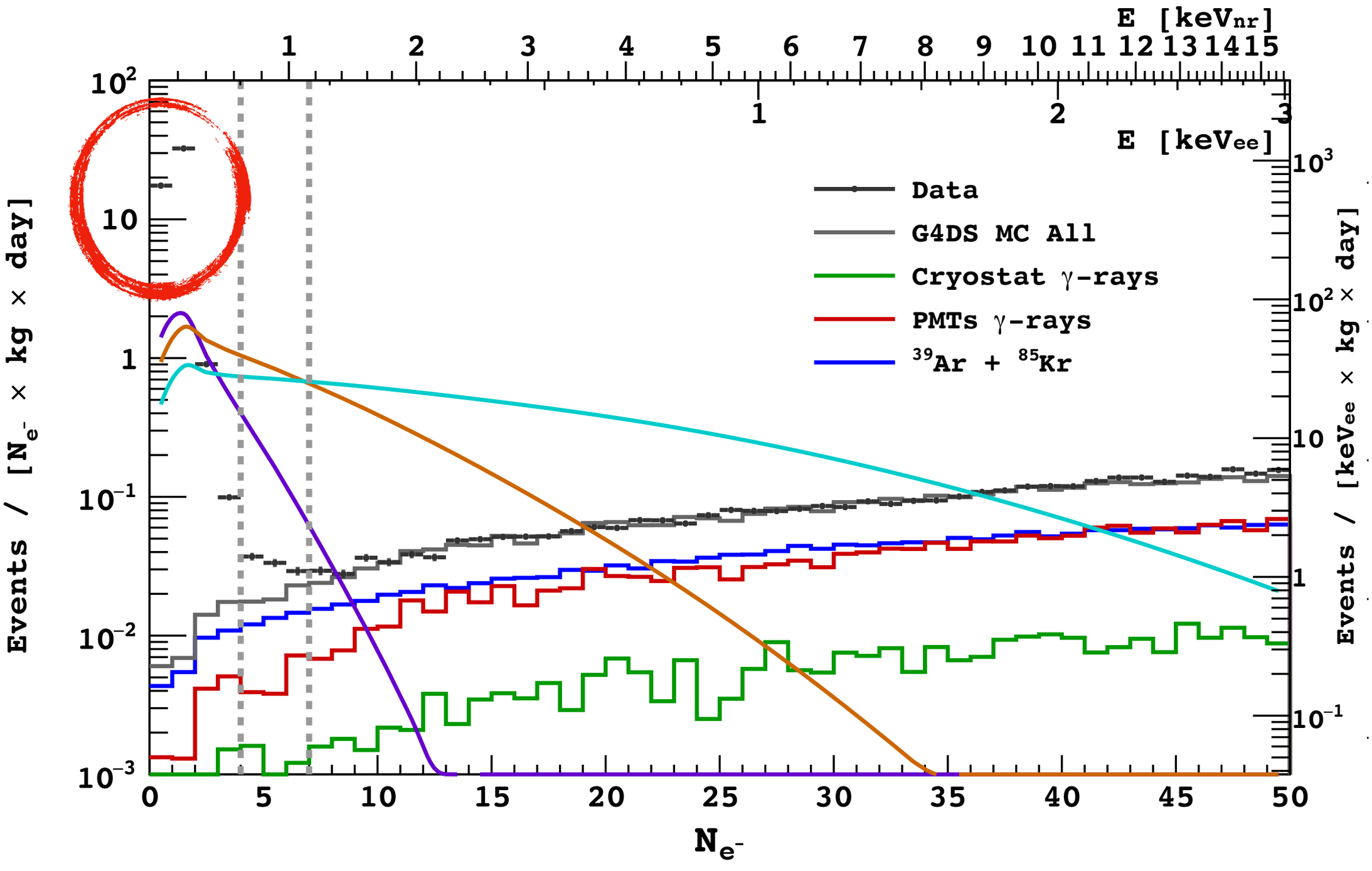
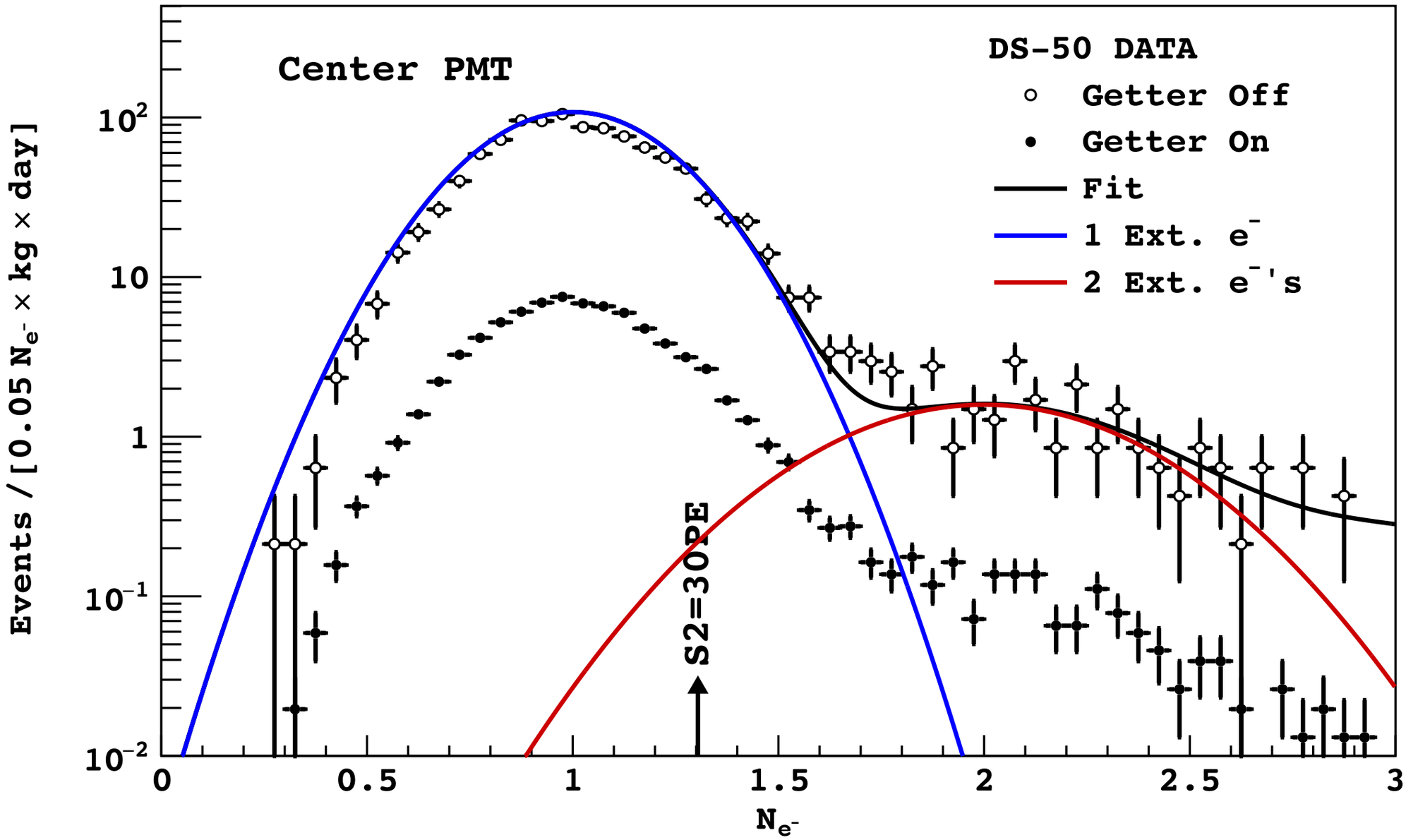
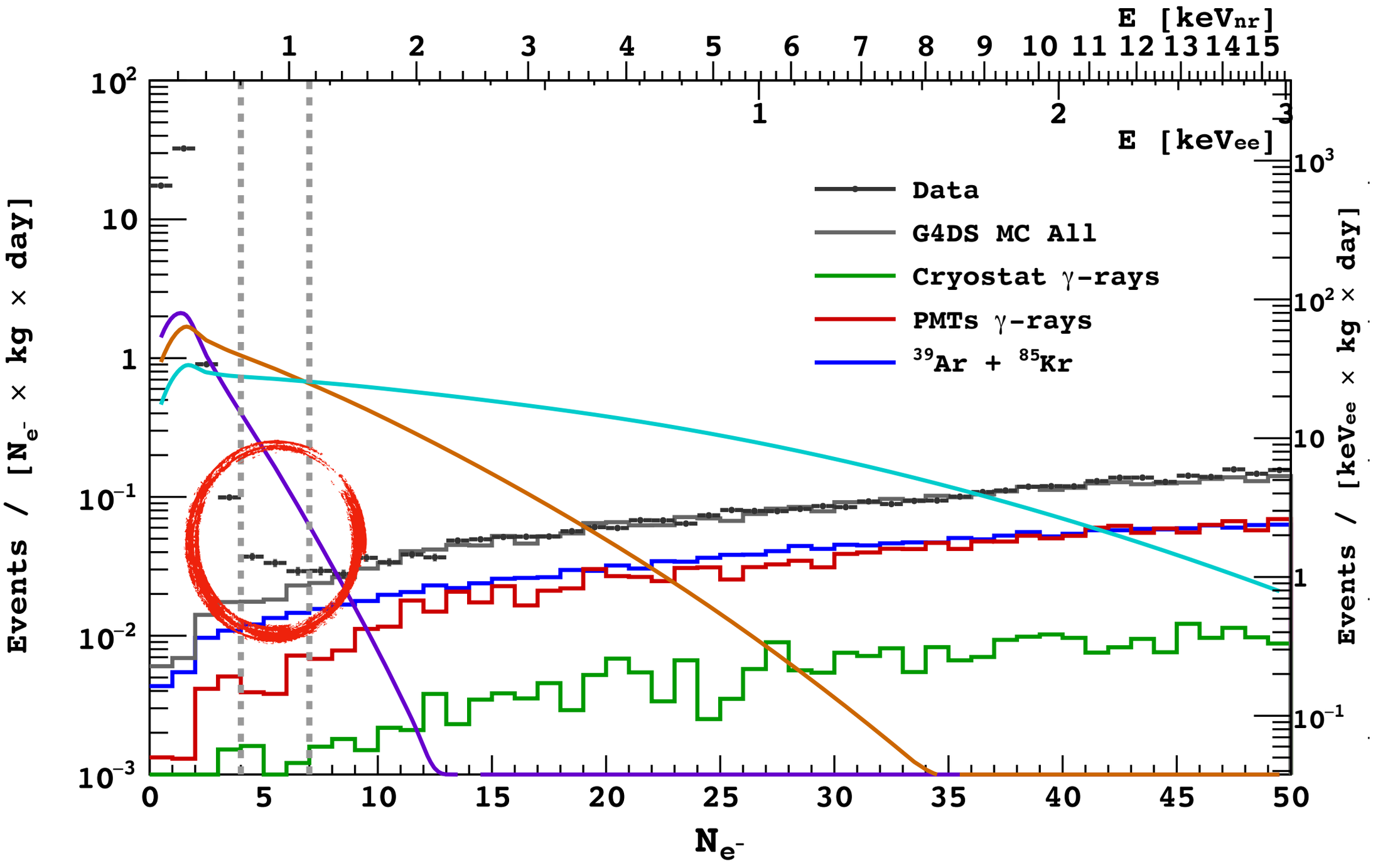


single electron events

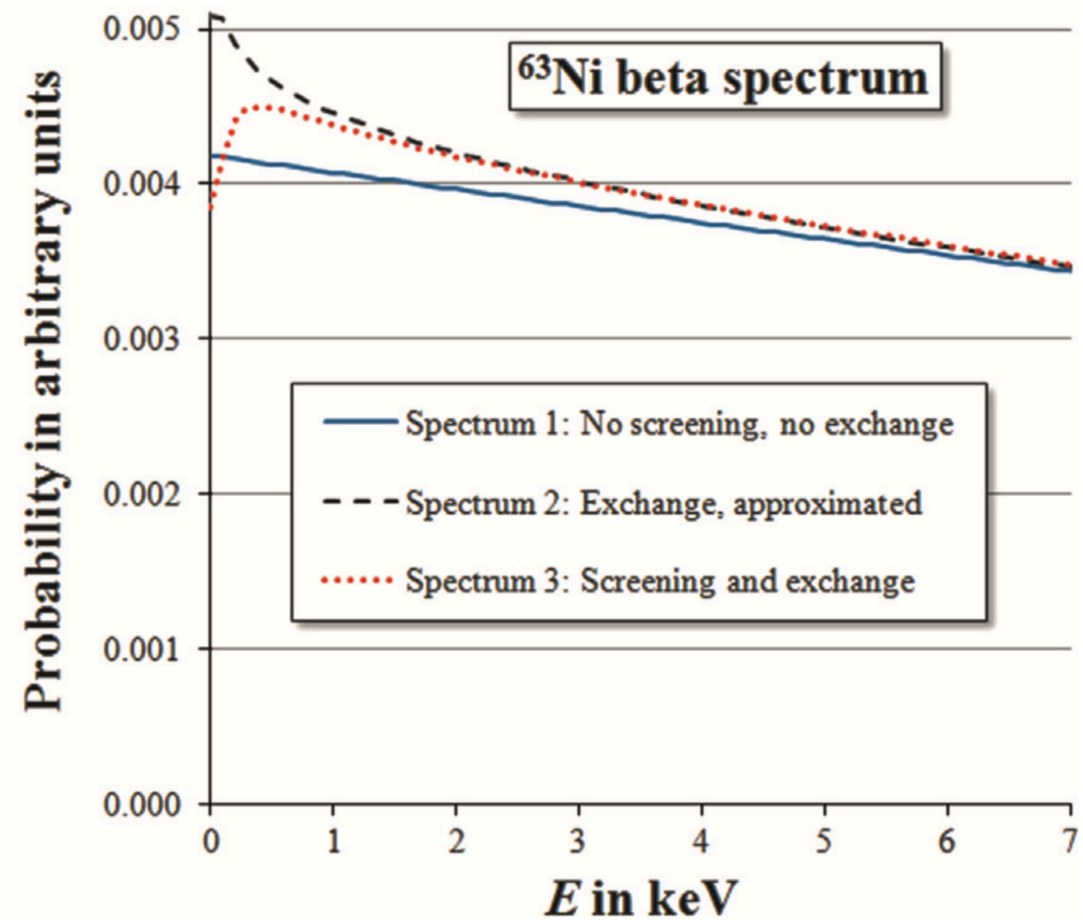


background rates



4-7 e^- excess

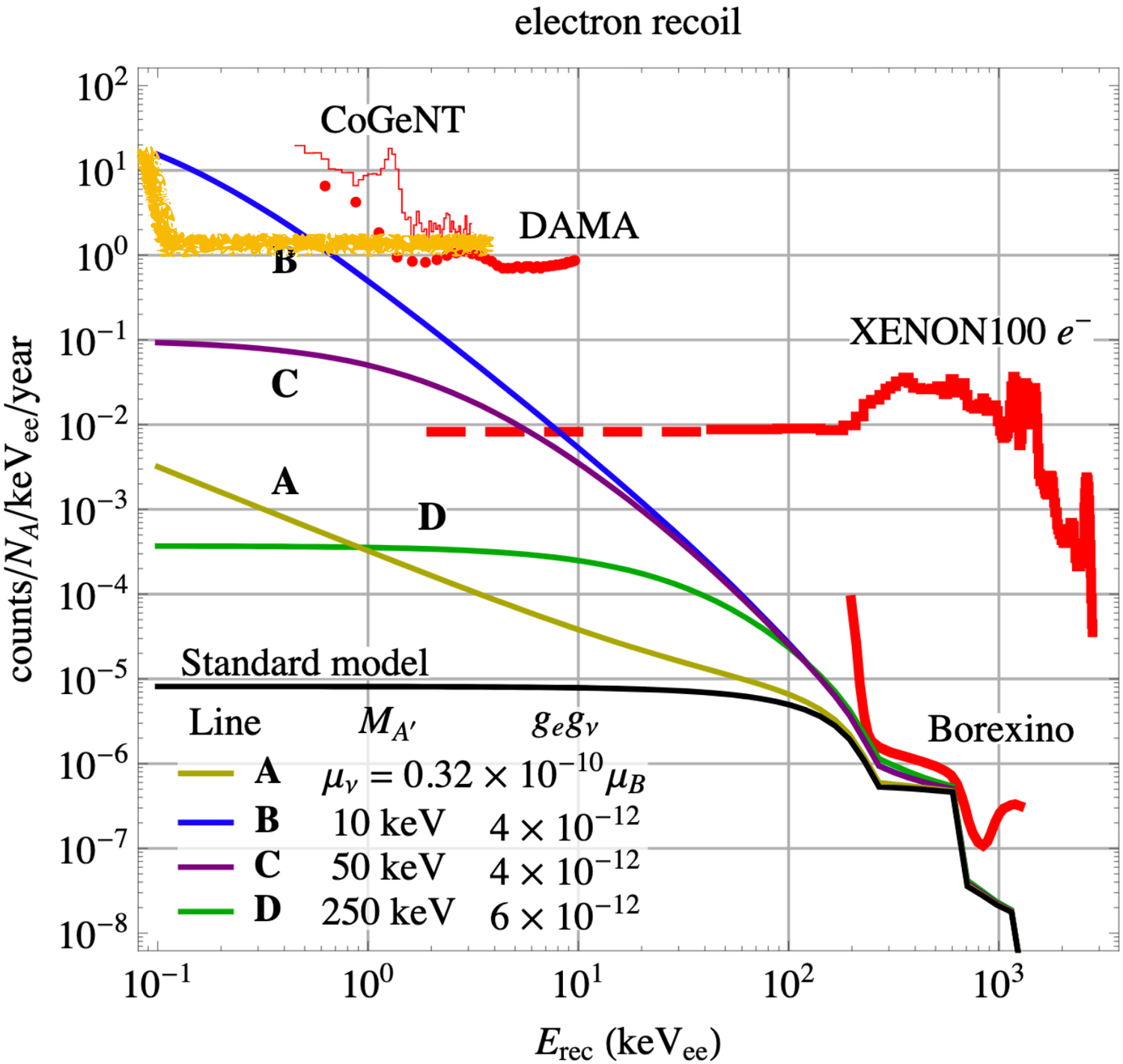
- incorrectly modeled beta spectrum?
- tritium?
- other



Kossert & Mougeot, Appl. Radiat. Isot., Vol. 101 (2015)

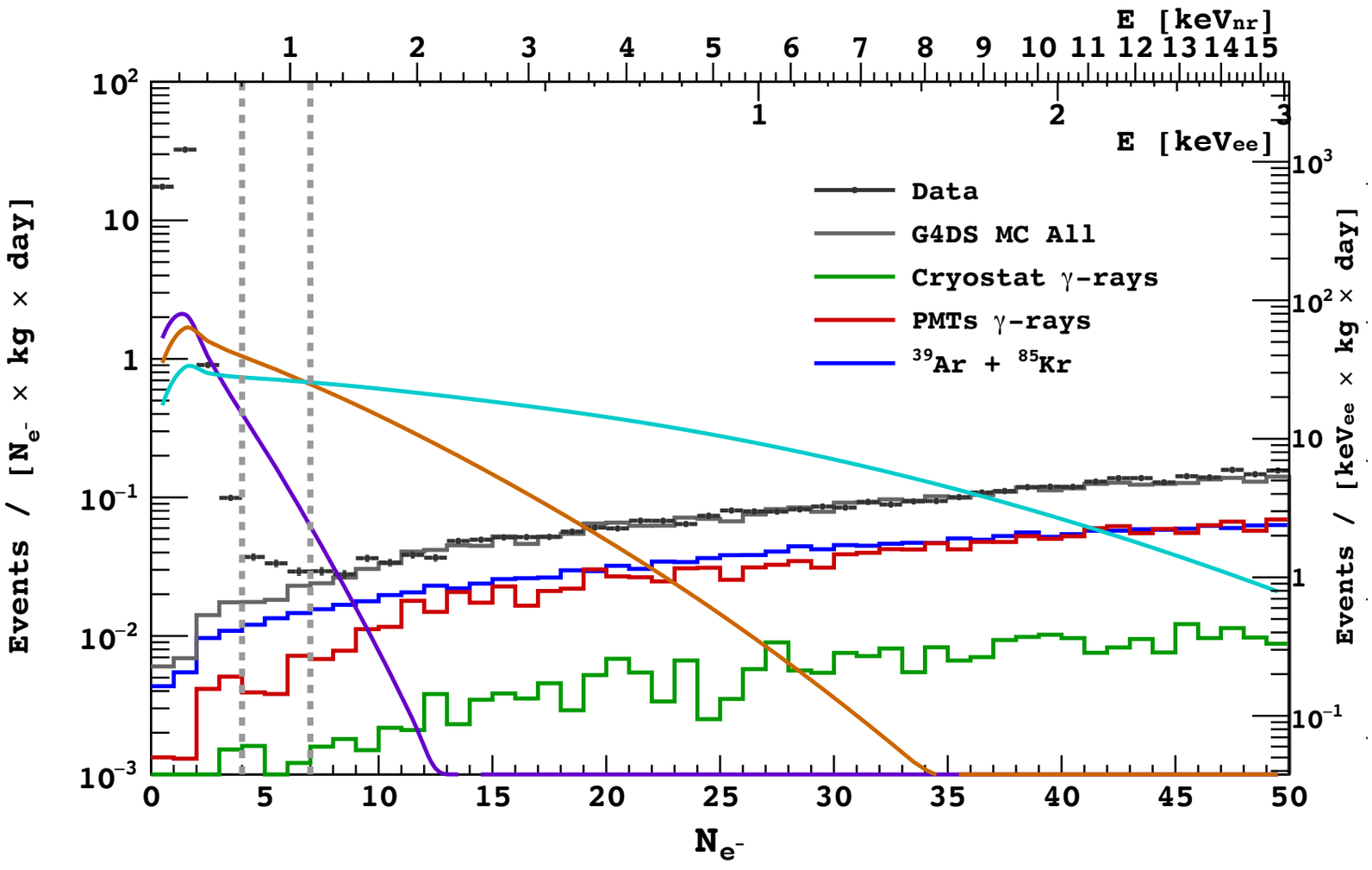
background rate in DarkSide-50

arXiv:1202.6073, see Scott's introductory talk



what about a future detector?

- we'll imagine an optimized electron recoil detector spun-off of DarkSide-20k (next-gen DarkSide TPC)
- ~200 kg fiducial mass

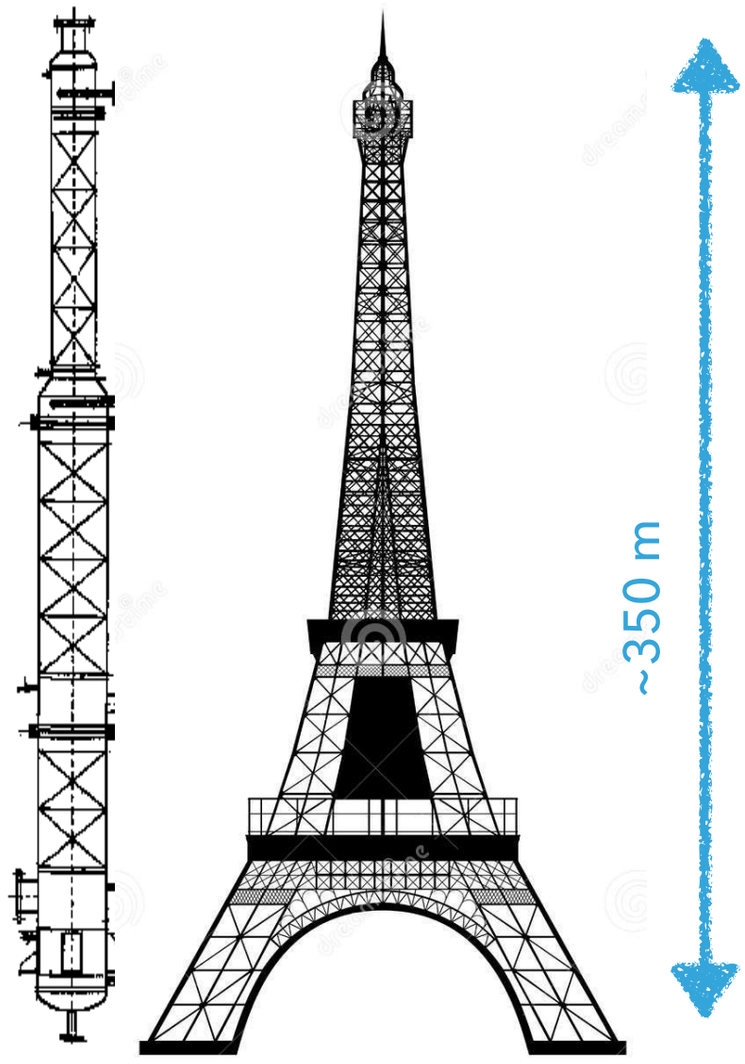


assume no ^{85}Kr and 100x reduction in ^{39}Ar

- better handling at URANIA (UAr extraction in Colorado)
- and/or cryogenic distillation at ARIA

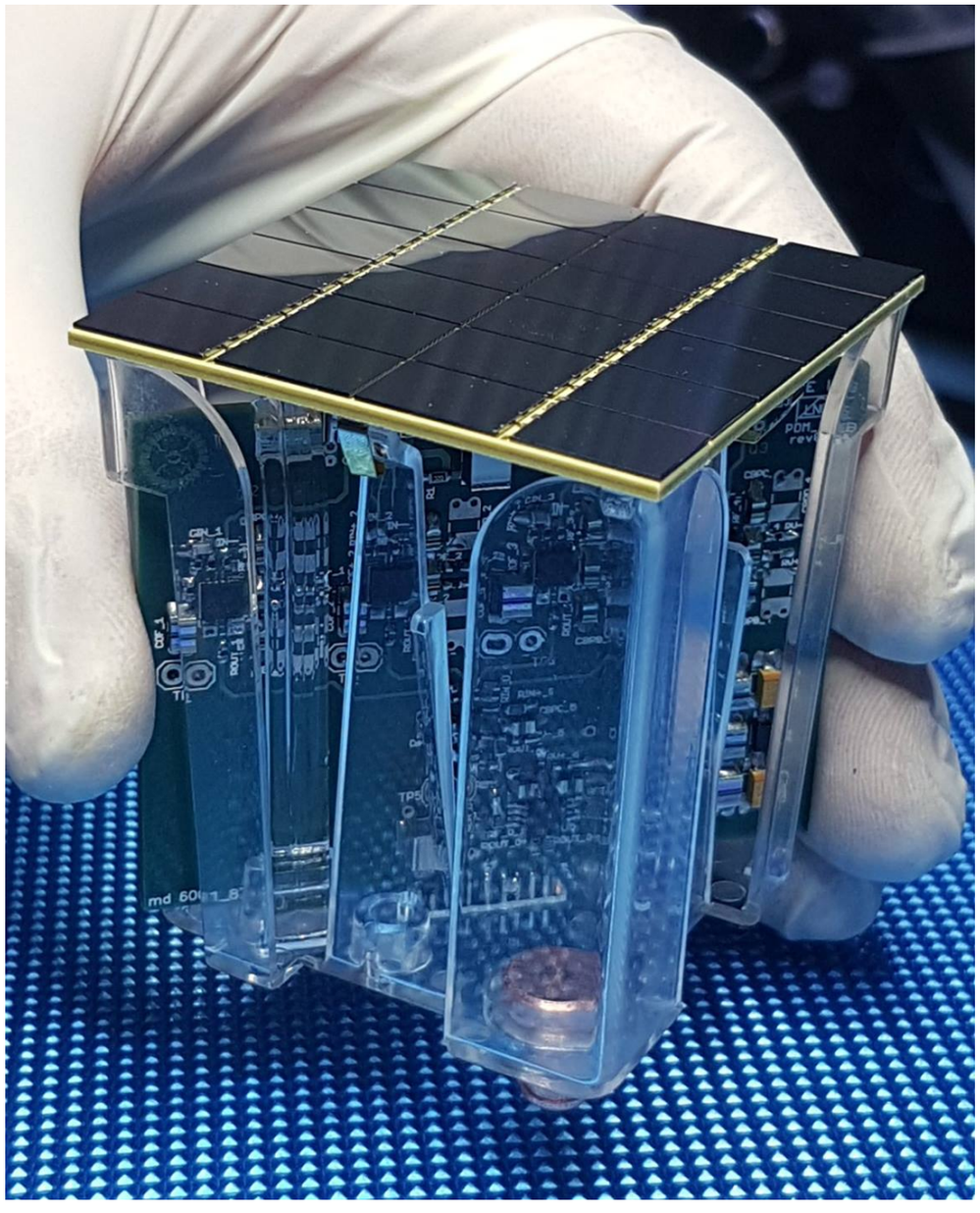
25 M

SERUCI-0 pilot plant

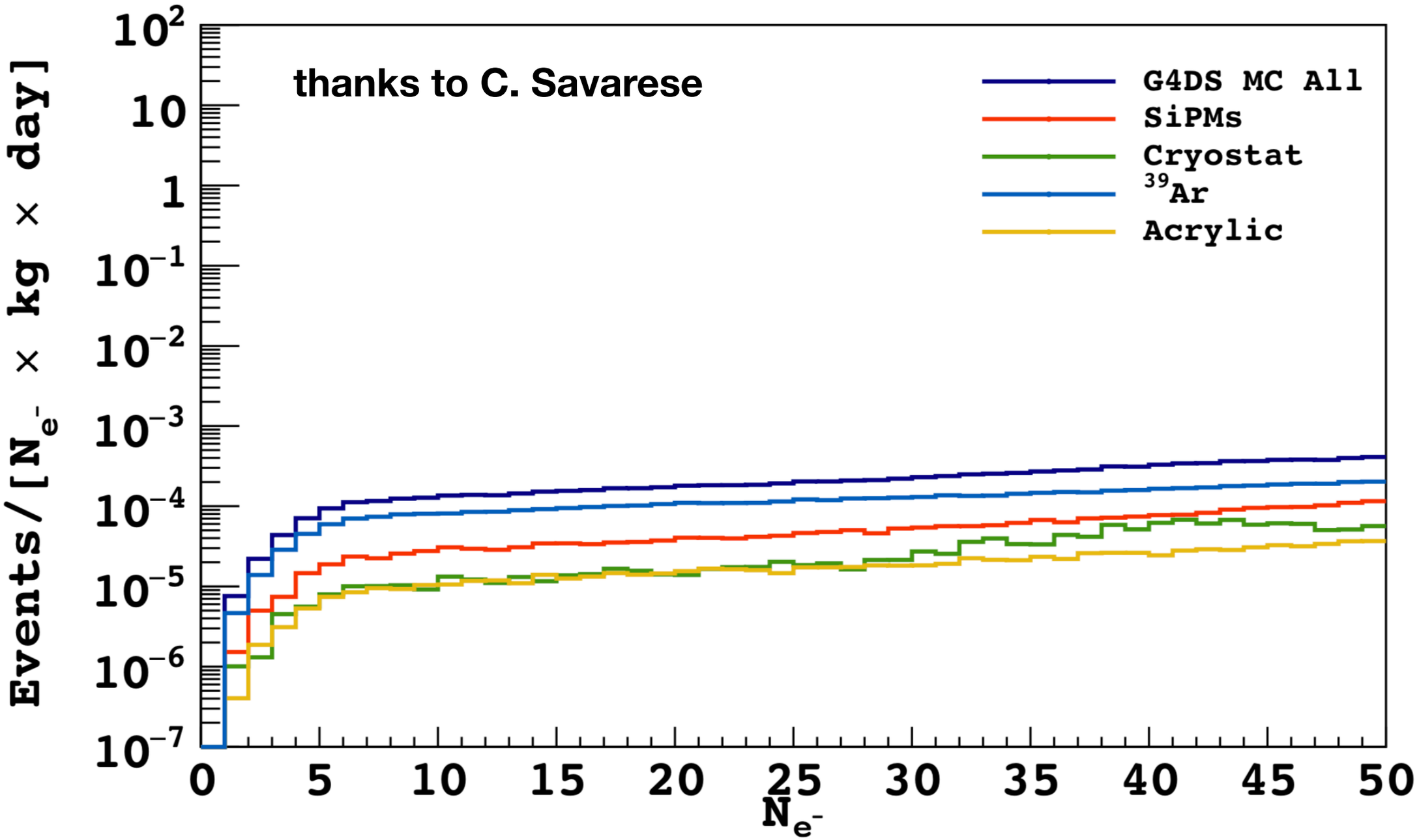


reduce other internal backgrounds below ^{39}Ar

- larger volume improves fiducialization
- switch from PMTs to SiPMs
- optimize geometry to minimize number of SiPMs
- eliminate TPC cryostat and use a large argon buffer volume



ignore single e^- and 4-7 e^- excess



approximate bkg rate in new experiment

arXiv:1202.6073, see Scott's introductory talk