Electron Trains in LXe TPCs

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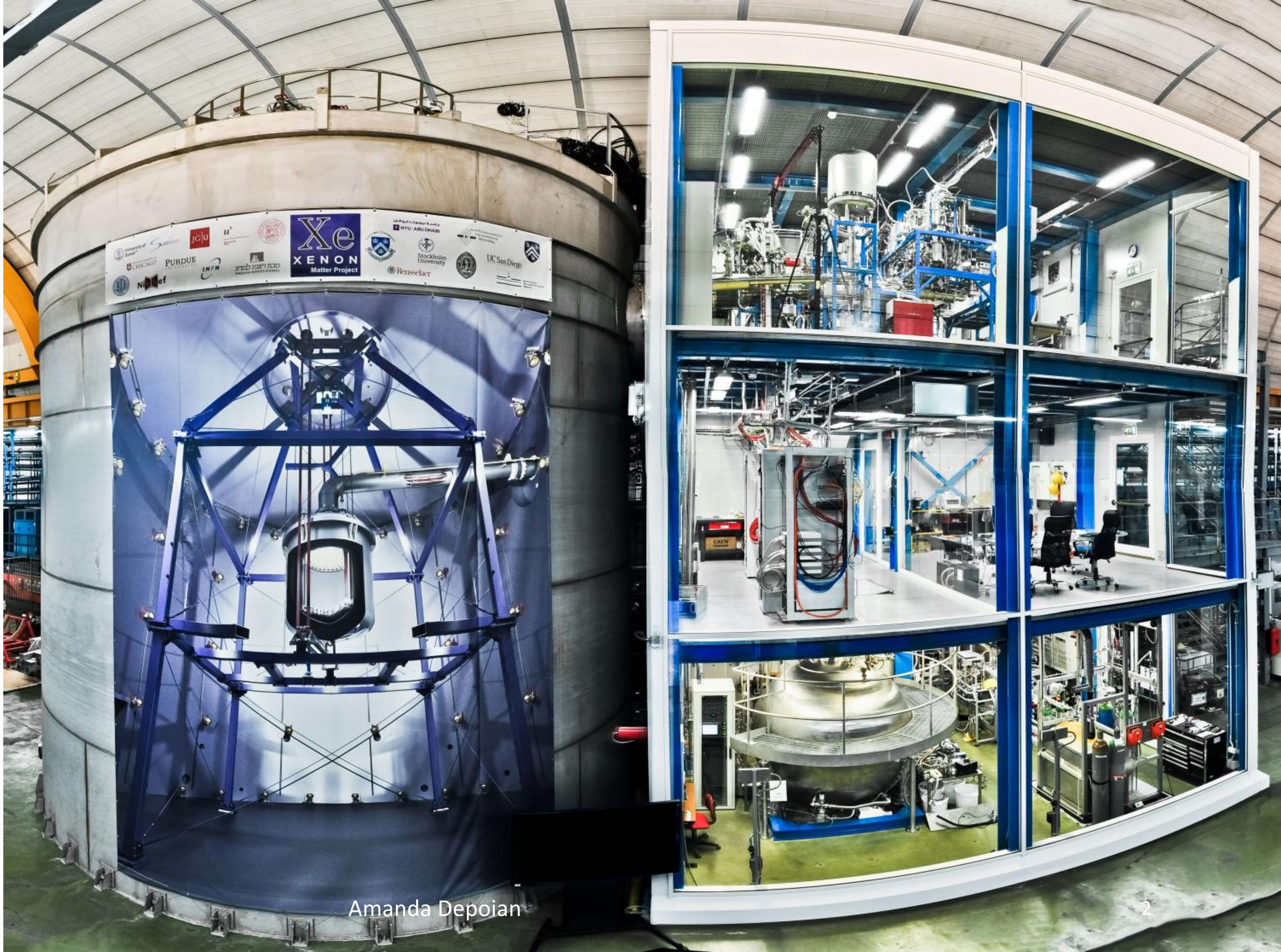
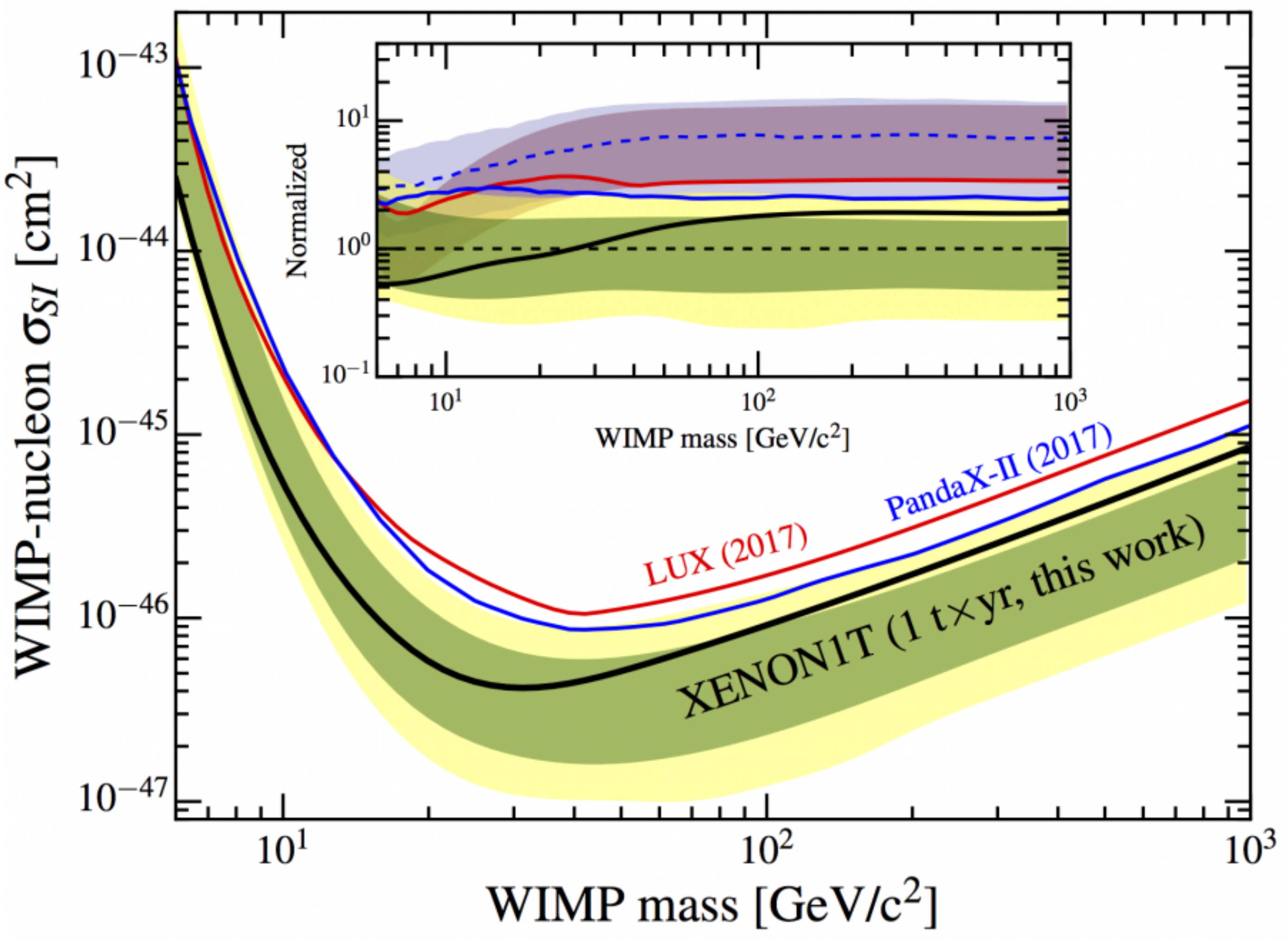
XENON1T

https://phys.org/news/2017-05-xenon1t-sensitive-detector-earth-wimp.html



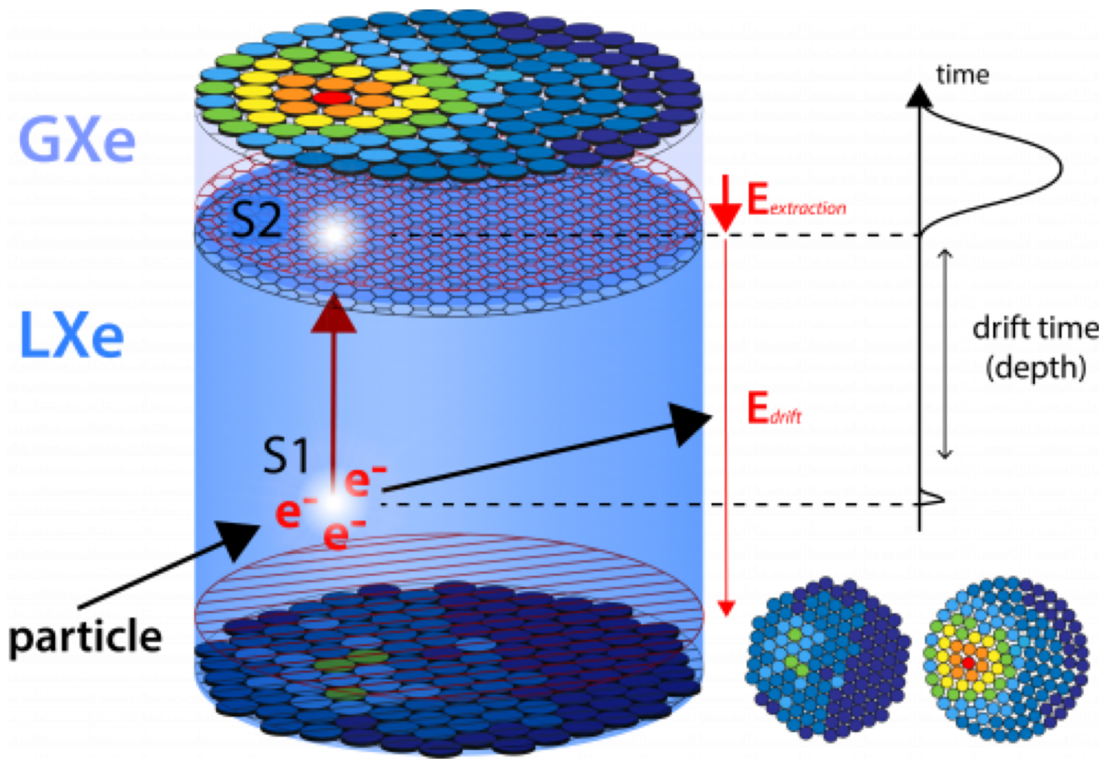
XENON1T recent results

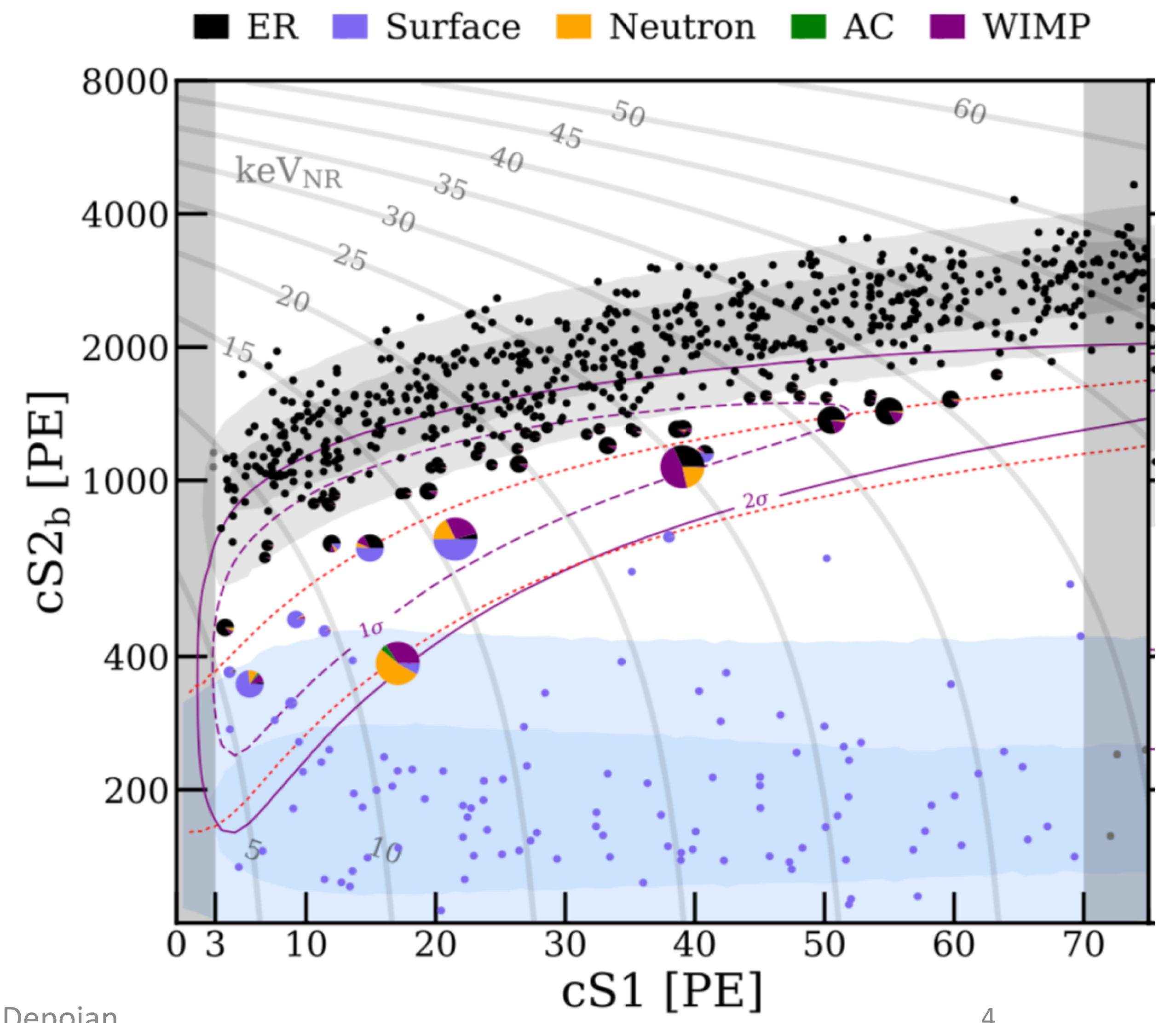
$\sigma_{SI} < 4.1 \times 10^{-47}\ cm^2$ at 30 GeV/c^2



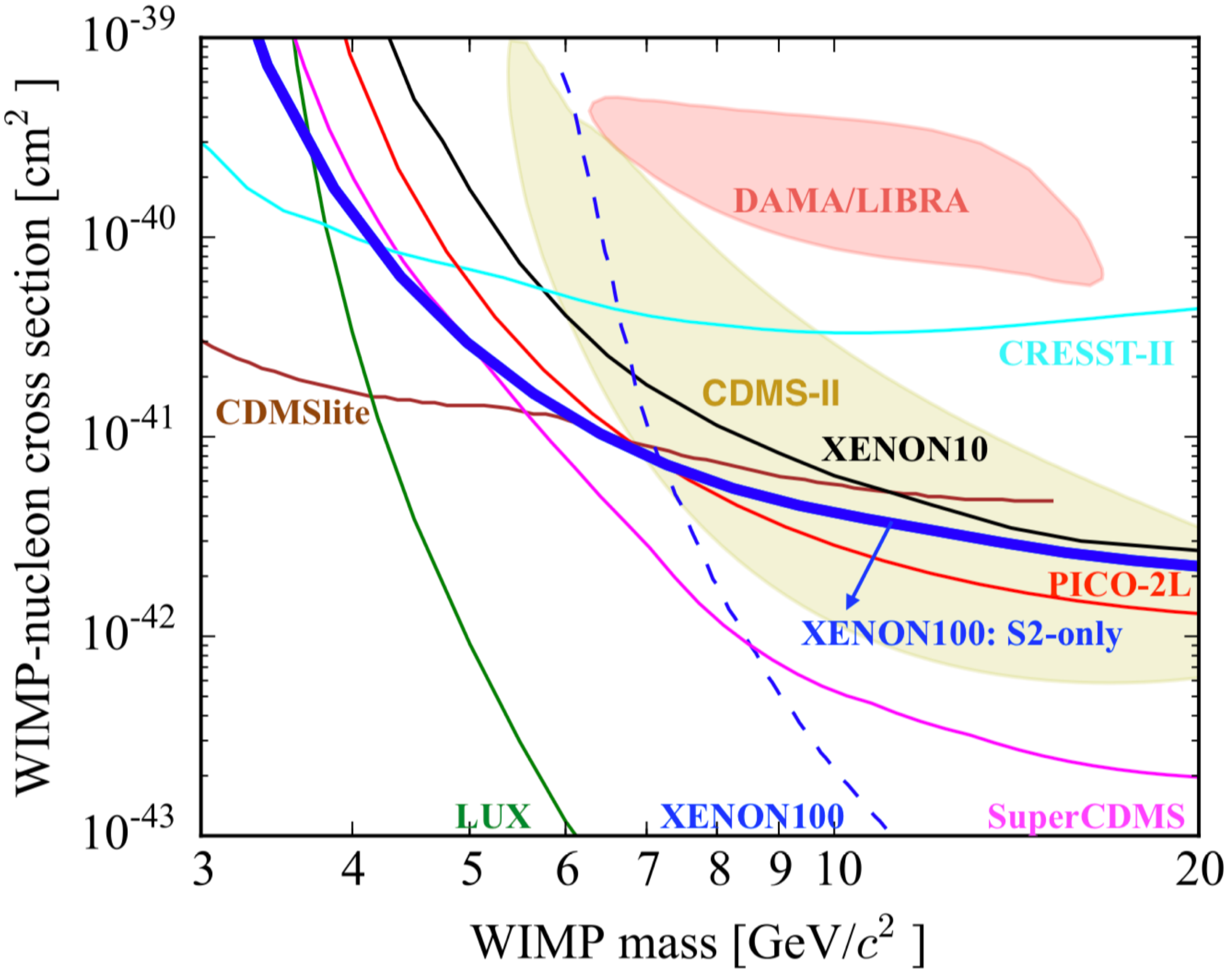
https://arxiv.org/pdf/1805.12562.pdf

Probing lower S2 energies



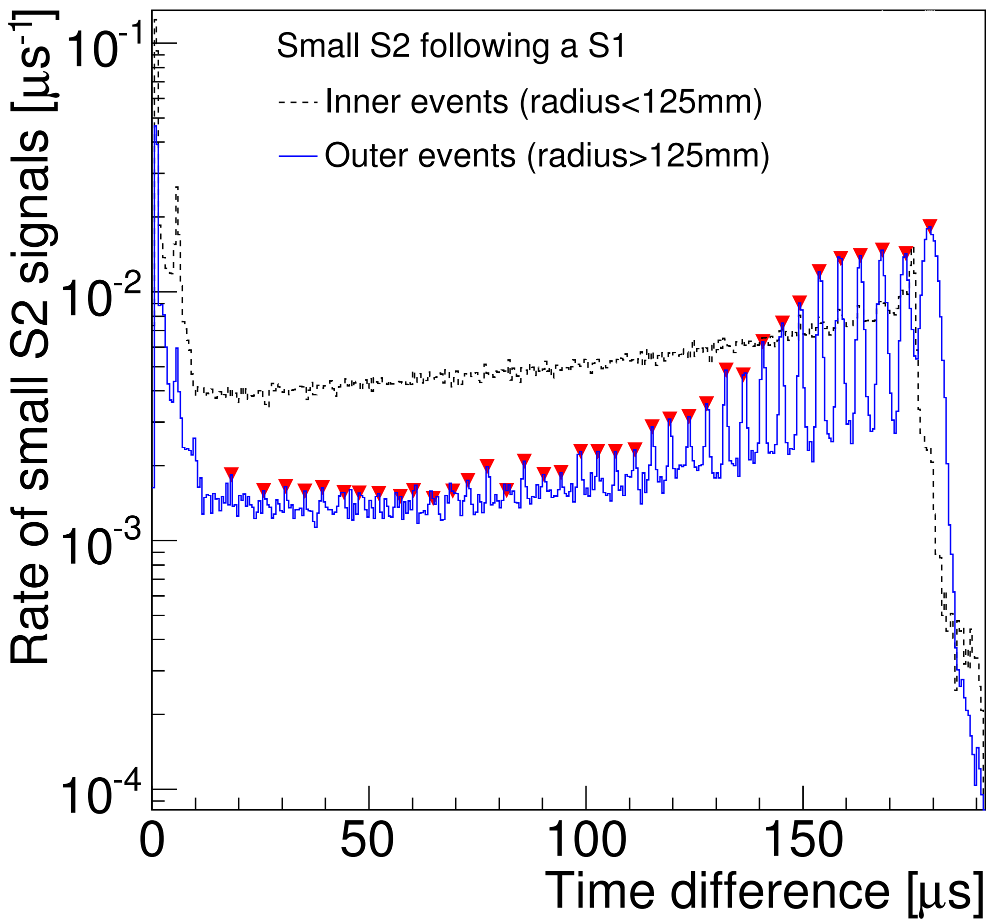


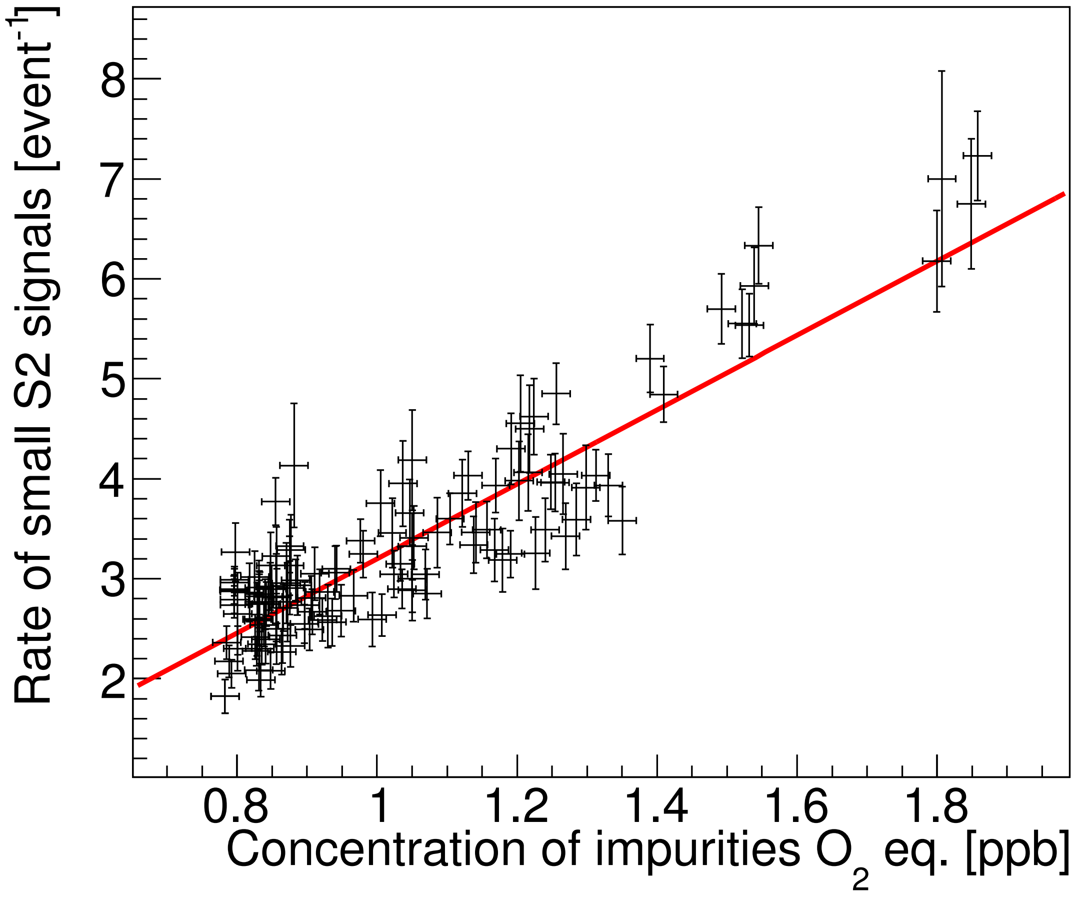
Hitting a wall



https://arxiv.org/pdf/1605.06262.pdf

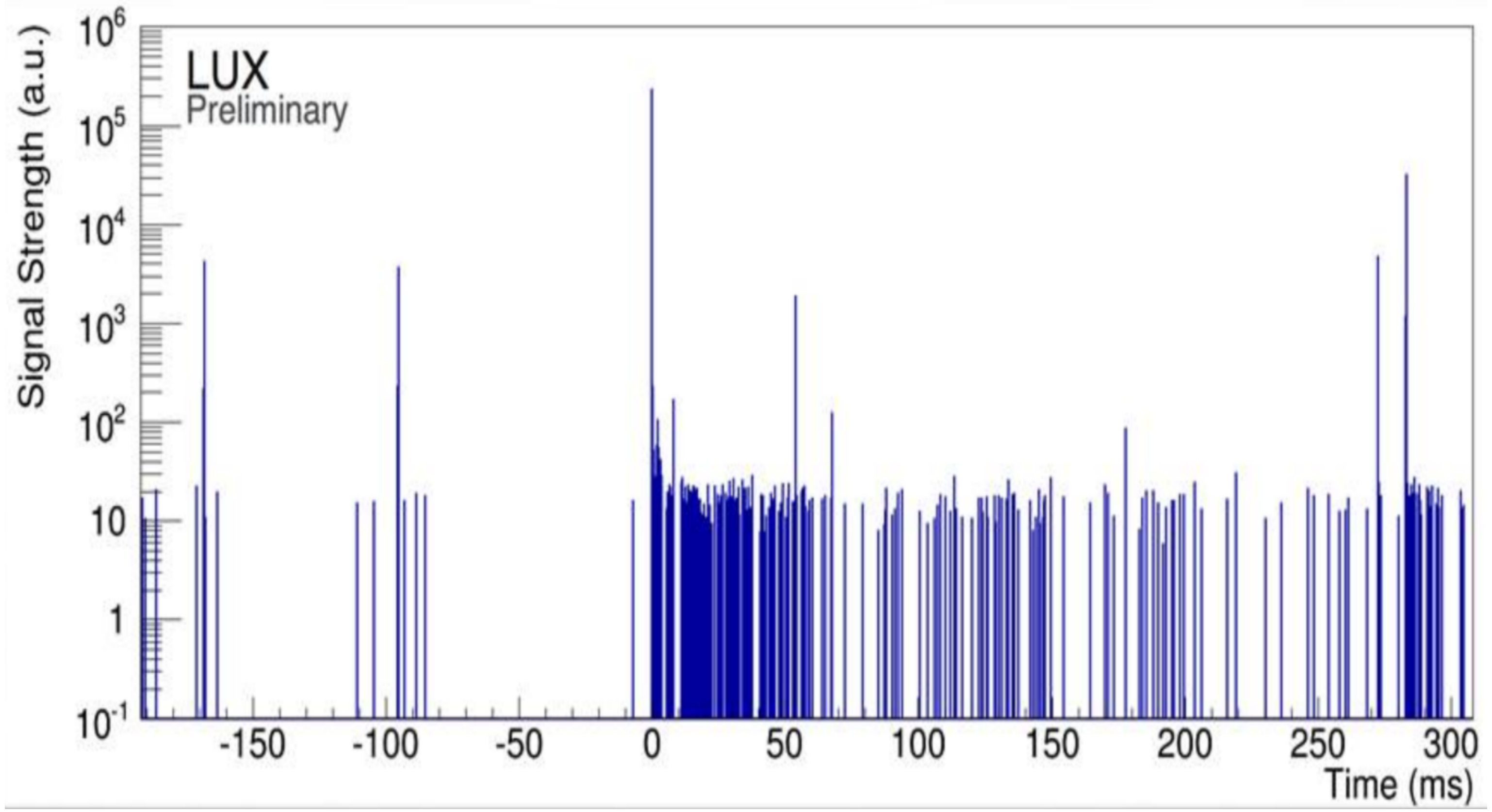
Photoionization

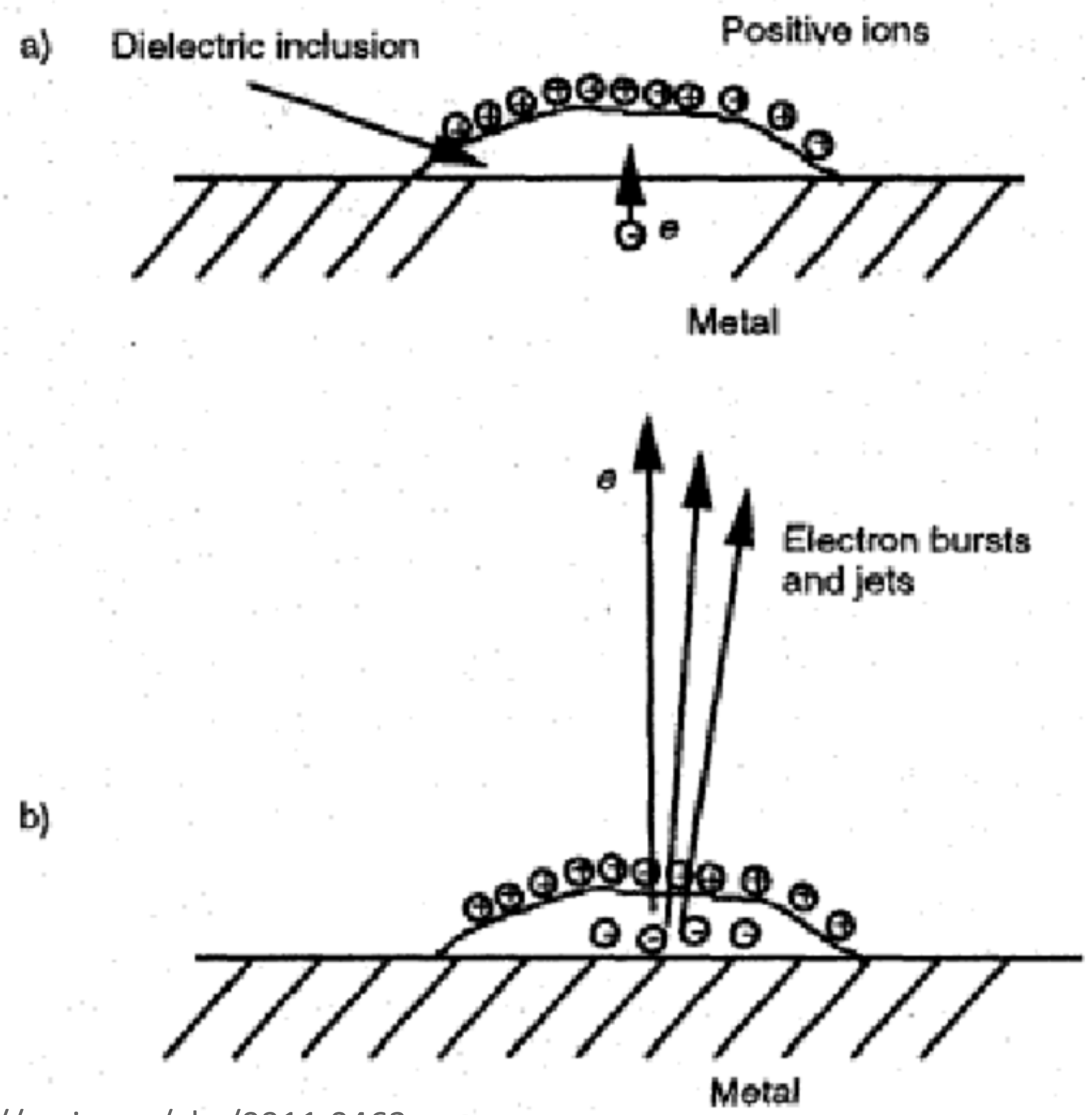




https://arxiv.org/pdf/1311.1088.pdf

Electron Train Background



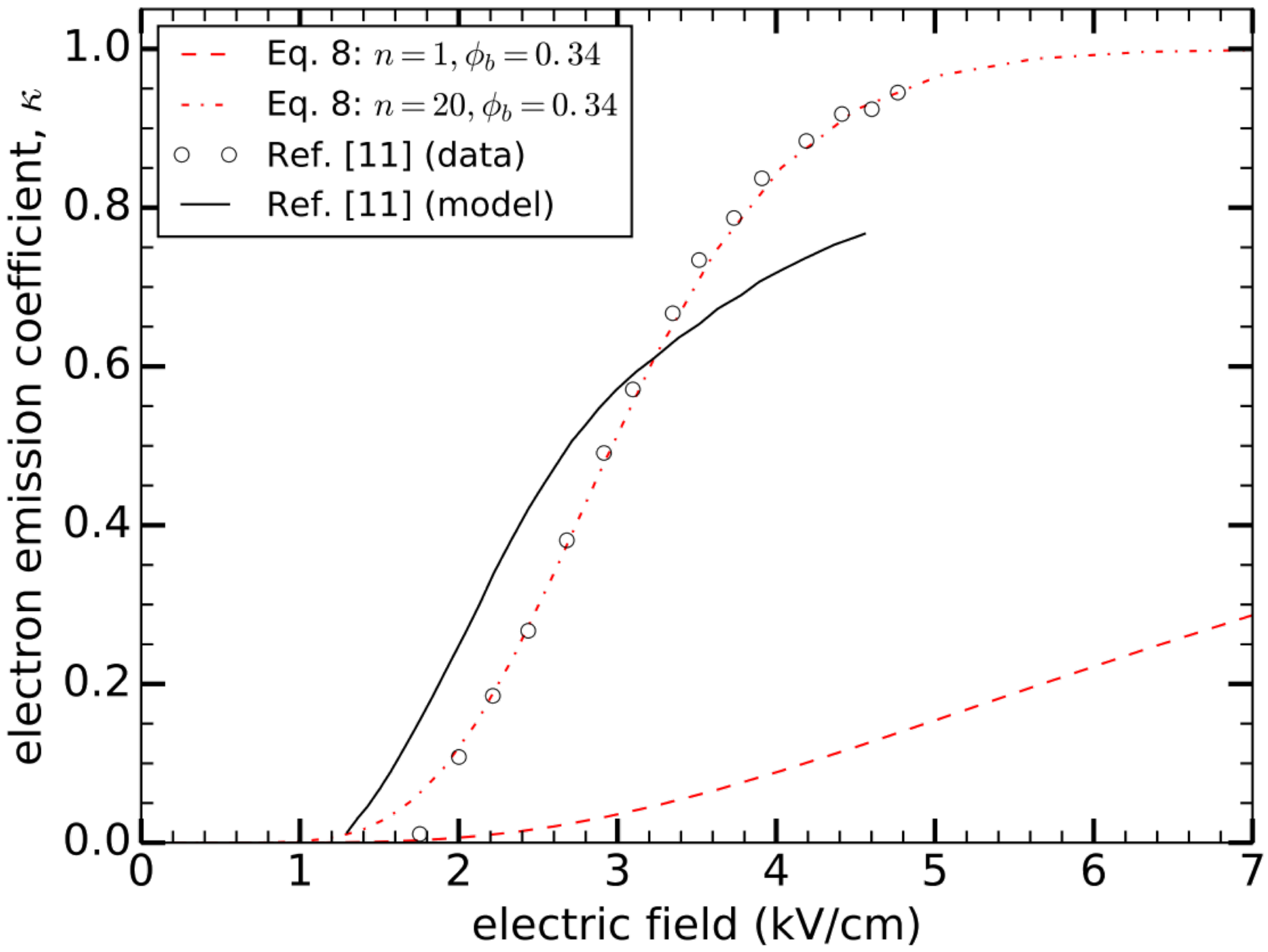


https://arxiv.org/abs/0911.0463

Malter effect

Trapped positive ions on the cathode can lower the work function of the metal, making it easier to emit electrons. This may lead to few-electron bursts.

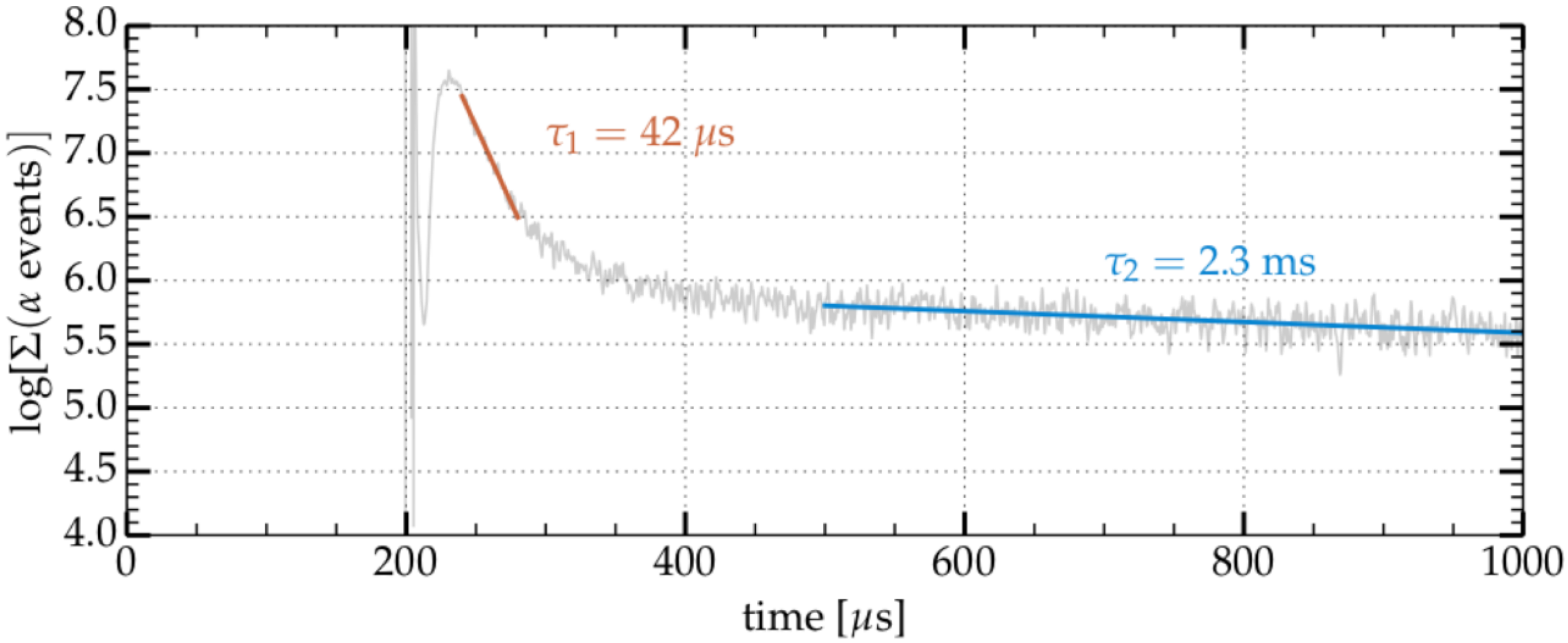
Trapped Electrons



http://www.jetp.ac.ru/cgi-bin/dn/e_055_05_0860.pdf (Ref. 11)

https://arxiv.org/pdf/1702.04805.pdf

Long lived excited states



https://arxiv.org/pdf/1711.07025.pdf

My Work

1

Determining the decay constant(s) of the electron trains

2

Determining electron efficiency by analyzing data with different electric fields

Conclusion

- Electron trains could be caused by:
  - Photoionization
  - Trapped electrons
  - Malter effect
  - Long lived excited states
- By eliminating these electron trains we can use noble element detectors to probe for sub GeV/c^2 dark matter particles!

Back up slides

Equations to slide 9

$$\phi_b = \frac{e^2}{8\pi\epsilon_0 z}\frac{\epsilon - 1}{\epsilon + 1}.$$

Schottky barrier – aka work function. As an electron approaches a dielectric boundary that is held at a constant potential, the force due to it's image charge results in an energy barrier.
epislon => dielectric constant of boundary (1.5-2 for xenon)
z => characteristic dimension of the order of the lattice constant (~5 angstrom)

$$\Delta\phi_b = e\left(\frac{eE}{4\pi\epsilon_0 z}\frac{\epsilon - 1}{\epsilon + 1}\right)^{1/2}$$

The external field E does two things with respect to electron emission: it increases the energy of the drifting electrons, and it lowers the height of the barrier by an amount equal to

$$\kappa = \int_{\phi_b - \Delta\phi_b}^{\infty} \varepsilon^{1/2} f_0(\varepsilon) d\varepsilon \Big/ \int_0^{\infty} \varepsilon^{1/2} f_0(\varepsilon) d\varepsilon,$$

Electron emission efficiency. the factor ε1/2 serves to select electrons whose velocity has a component directed toward the barrier.
f_0 is the electron energy distribution
ε → energy

$$\kappa_n = 1 - (1 - \kappa)^n.$$

Electron emission efficiency after n tries