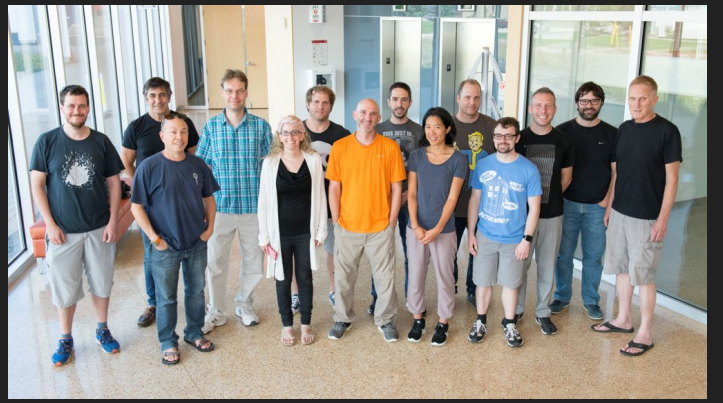
Light Dark Matter Detection with SENSEI

Daniel Gift
On Behalf of the SENSEI Collaboration
Yang Institute for Theoretical Physics
Stony Brook University

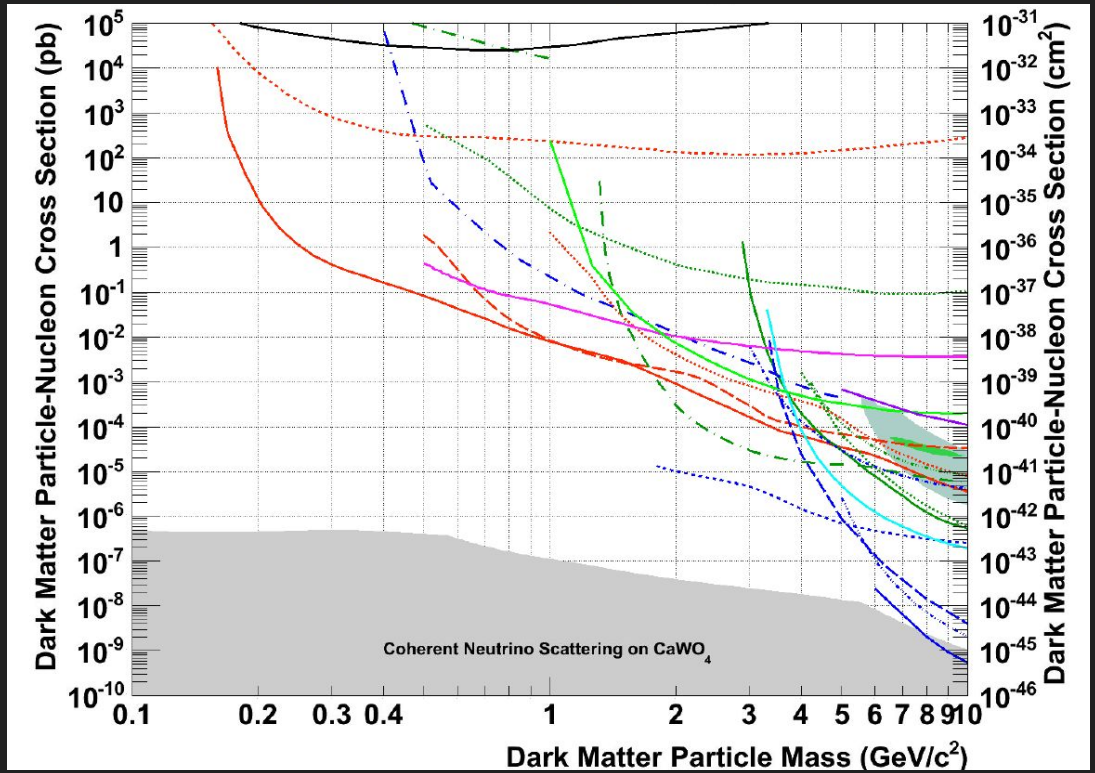
Phenomenology 2019
May 6 2019

SENSEI

- Sub-Electron-Noise Skipper-CCD Experimental Instrument
- Orr Abramoff, Liron Barak, Itay Bloch, Luke Chaplinsky, Michael Crisler, Dawa, Alex Drlica-Wagner, **Rouven Essig**, Juan Estrada, Erez Etzion, Guillermo Fernandez, Daniel Gift, Joseph Taenzer, **Javier Tiffenberg**, Miguel Sofo Haro, **Tomer Volansky**, Tien-Tien Yu
- Fermilab, Stony Brook University, Tel Aviv University, University of Oregon

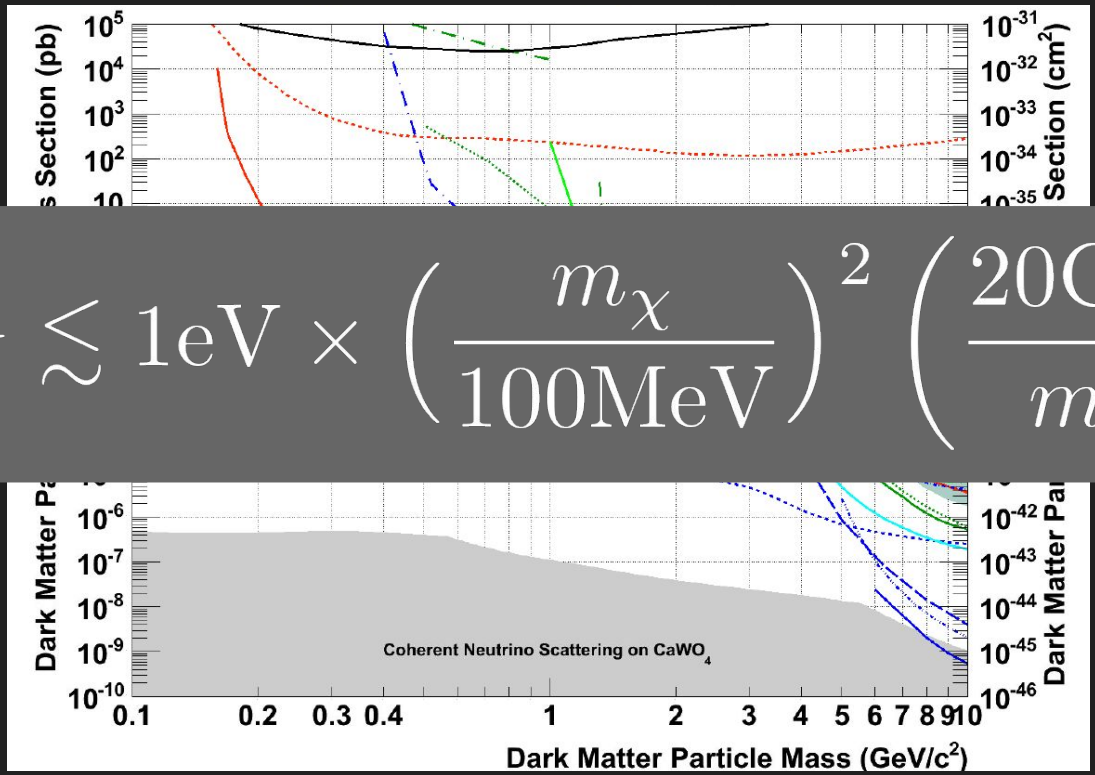


Nuclear Recoil Bounds



CRESST Collaboration (2019)

Nuclear Recoil Bounds



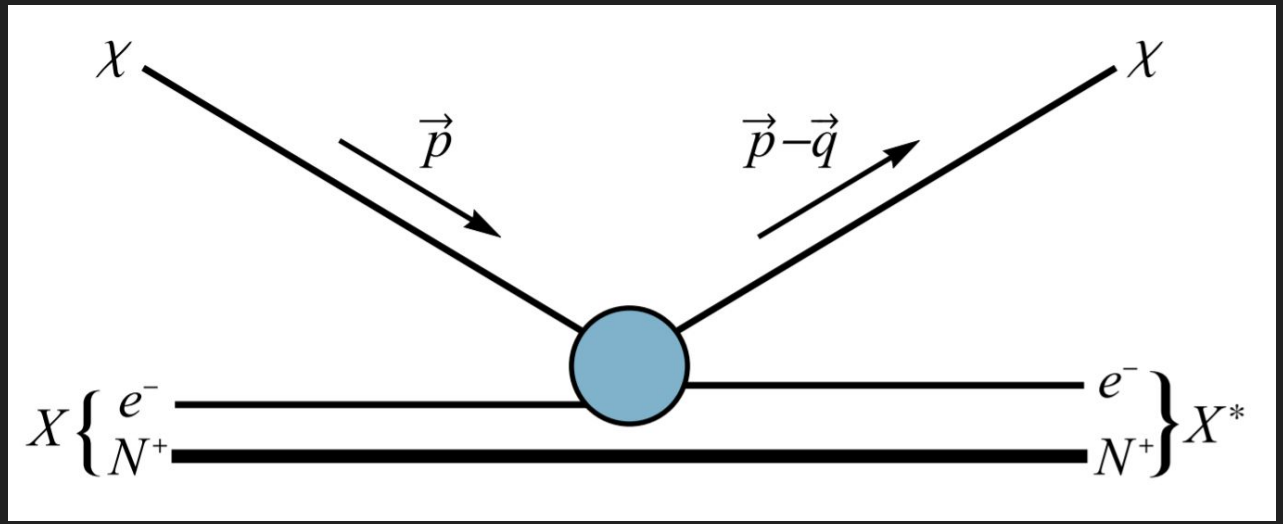
$$E_N \lesssim 1\text{eV} \times \left(\frac{m_\chi}{100\text{MeV}}\right)^2 \left(\frac{20\text{GeV}}{m_N}\right)$$

ration (2019)

Electron Recoil

- Not in momentum eigenstate
- Speed ~αc

$$E_e \lesssim \frac{1}{2}\mathrm{eV} \times \left(\frac{m_\chi}{1\mathrm{MeV}}\right)$$

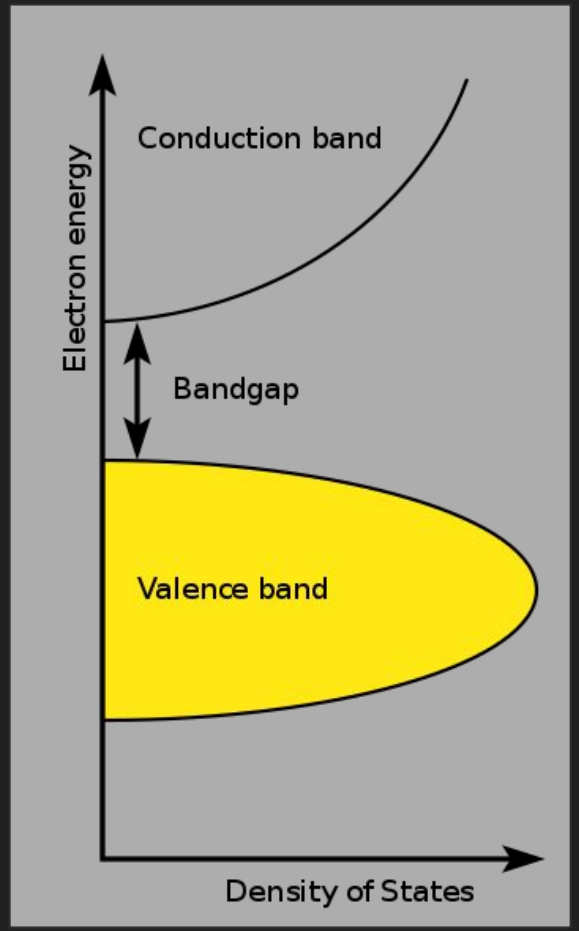


Essig, Fernandez-Serra, Mardon, Soto, Volansky, Yu (2016)

Semiconductor Use

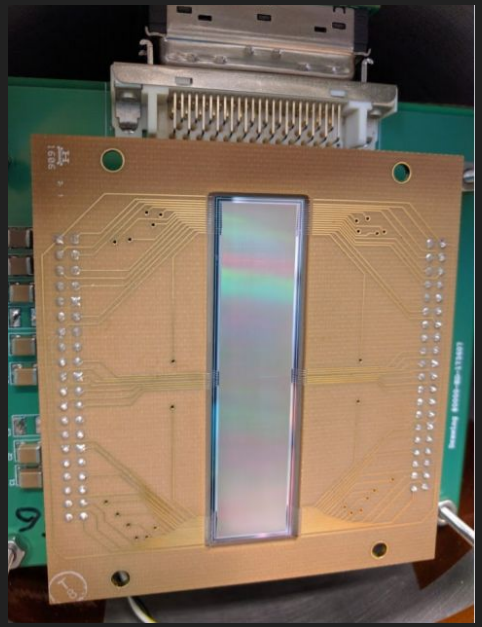
- Detect with silicon
  - Bandgap 1.1 eV

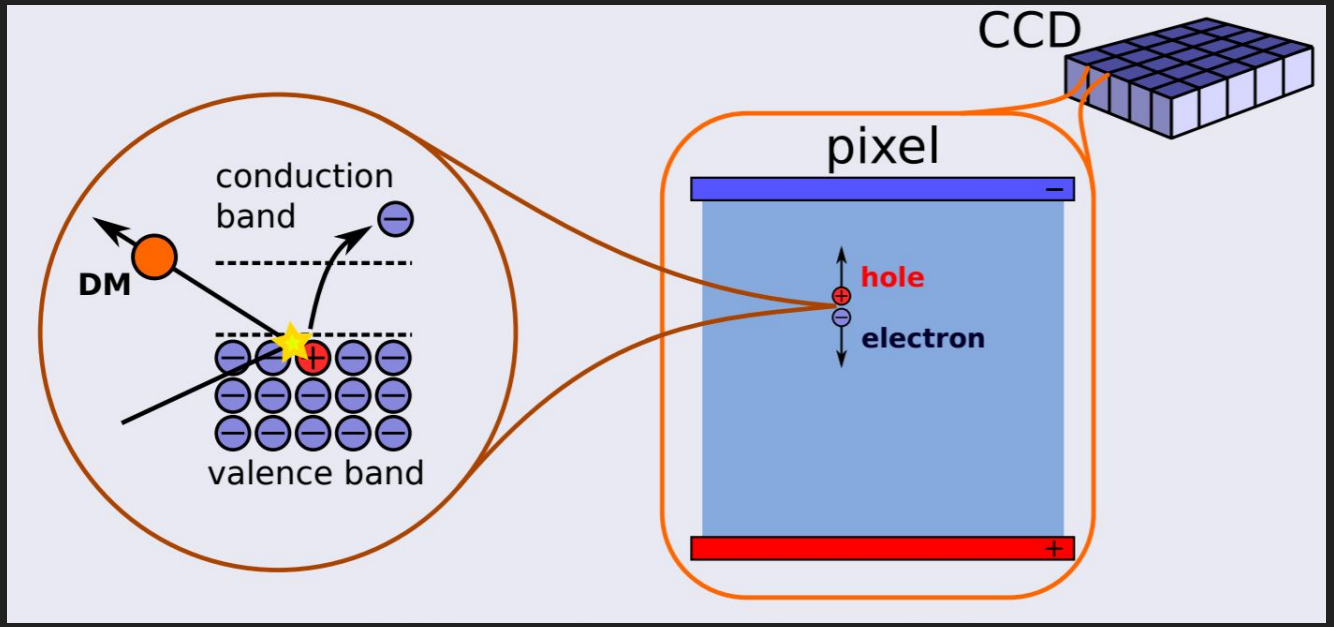
$$E_e \gtrsim \frac{1}{2}\mathrm{eV} \times \left(\frac{m_\chi}{1\mathrm{MeV}}\right)$$



SENSEI

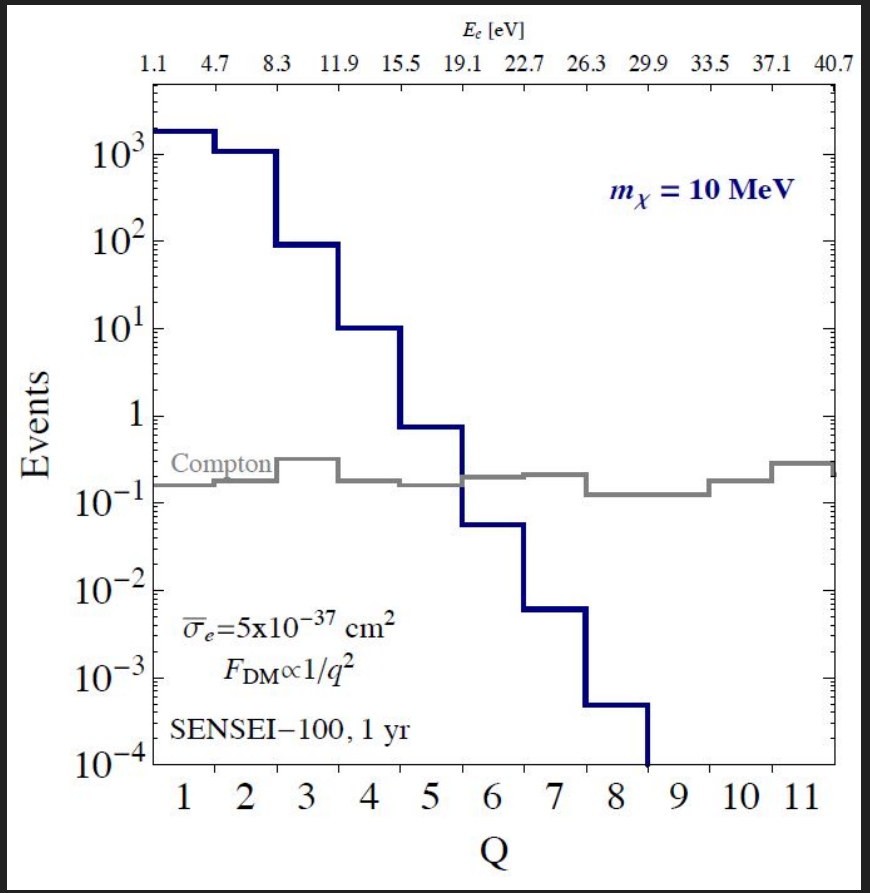
- Sub-Electron-Noise Skipper-CCD Experimental Instrument





Yields

- Need to be sensitive to few electrons
- Skipper-CCD achieves low enough noise

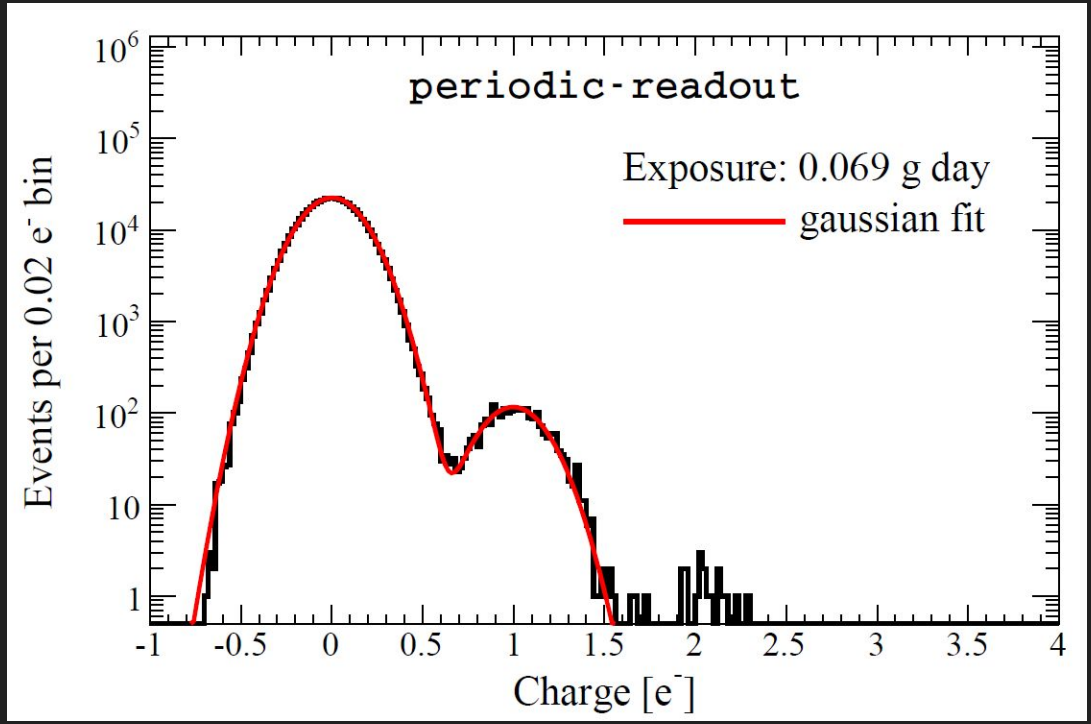


Current status of SENSEI

- Readout technology successful in 2017
- Initial surface run 2017, paper 2018 (arXiv 1804.00088)
- Prototype run with 0.1 g silicon in 2018 (arXiv 1901.10478)
  - MINOS cavern at Fermilab
  - Publication in PRL accepted April 2019

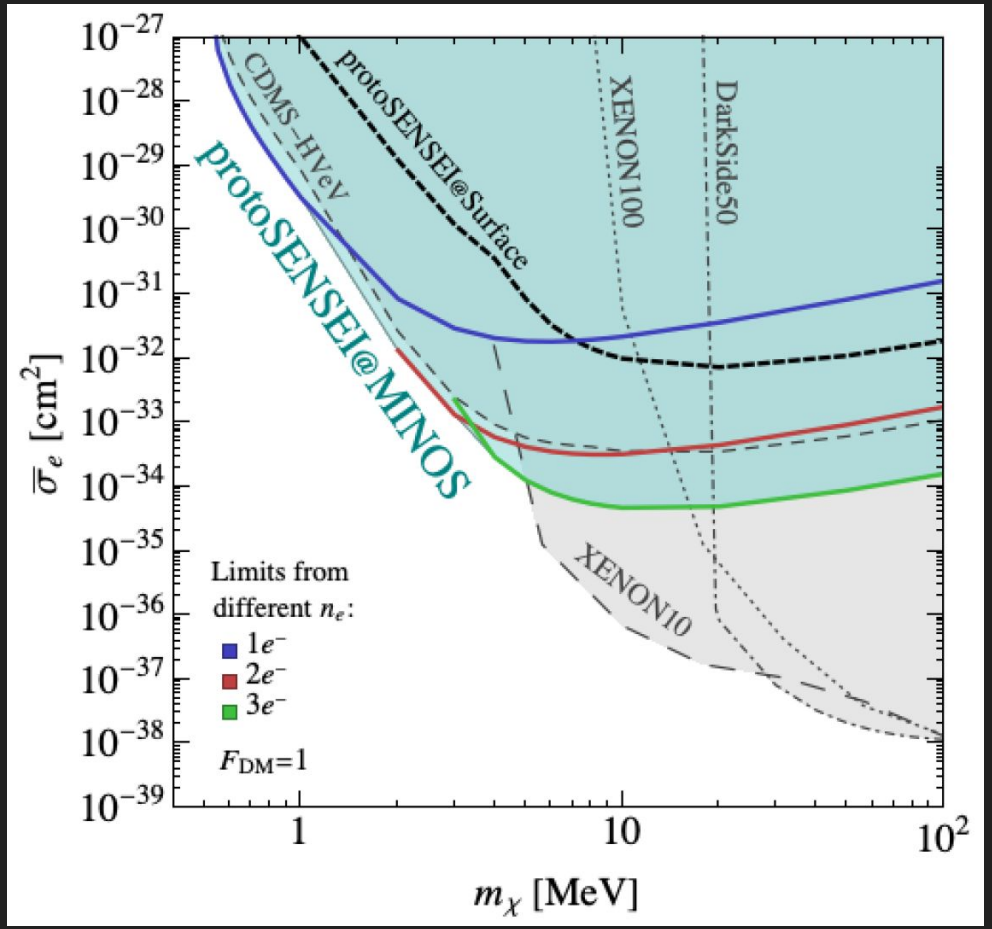
ProtoSENSEI

- 2 readout strategies
- Periodic: 0.07 g-days
- 5x 120 ks



Abramoff, Barak, Bloch, Chaplinsky, Crisler, Dawa, Drlica-Wagner, Essig, Estrada, Etzion, Fernandez, **DG**, Taenzer, Tiffenberg, Sofo Haro, Volansky, Yu (2019)

Limits



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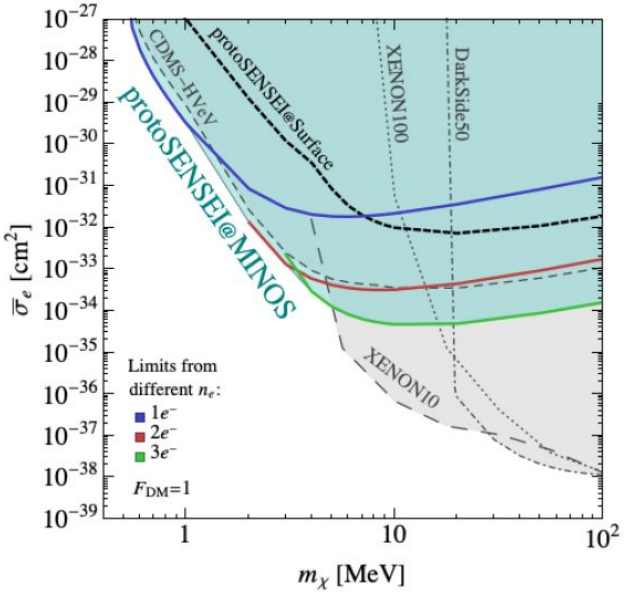

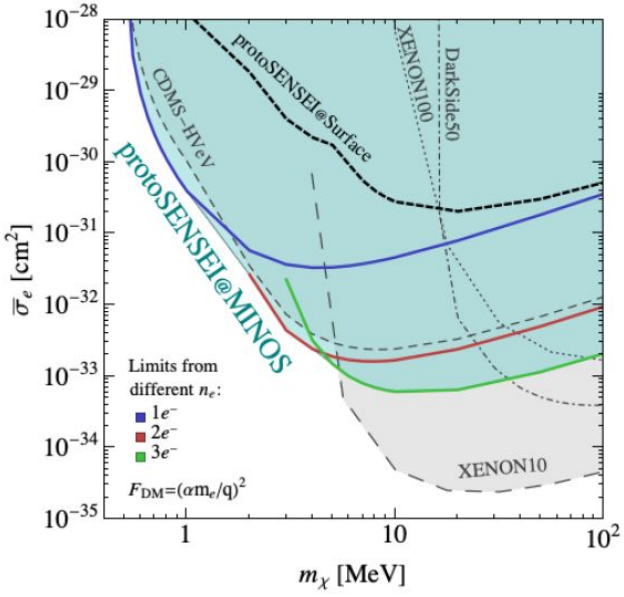

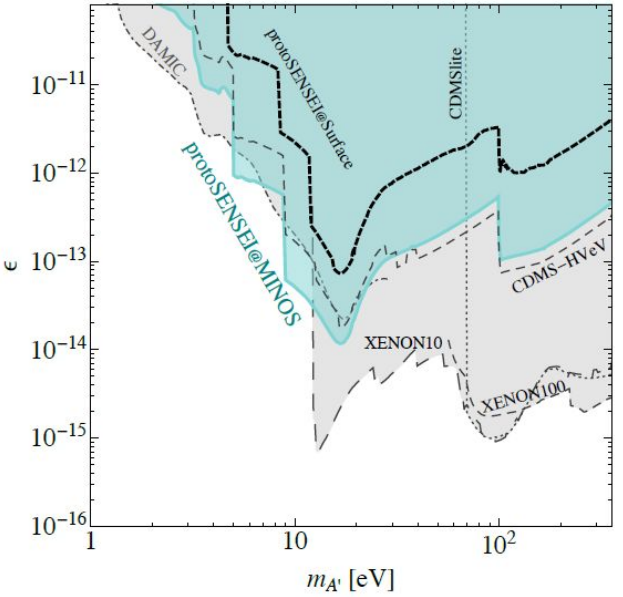

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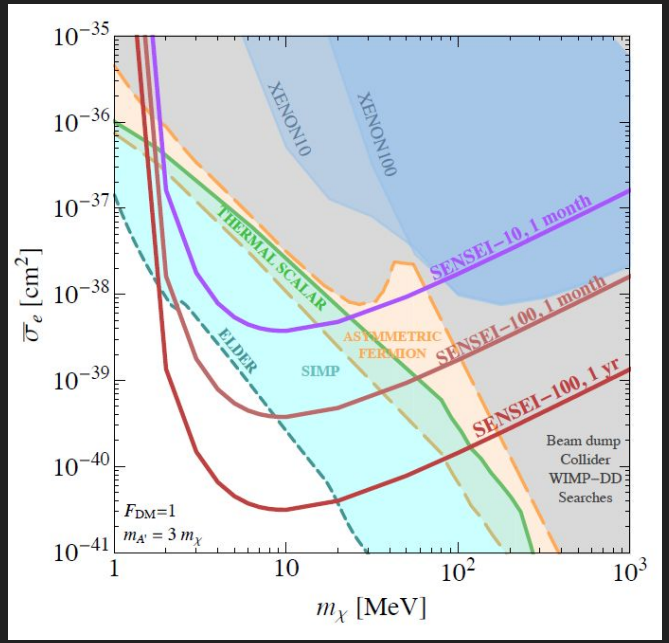
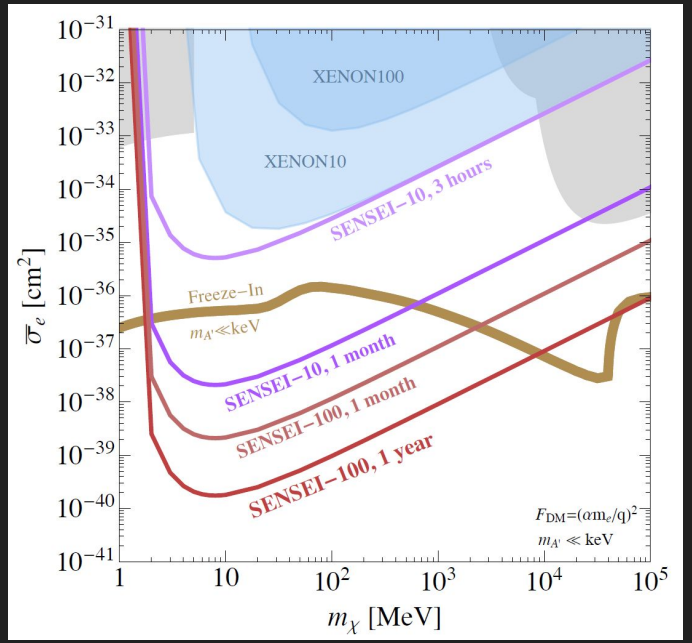
Future of SENSEI

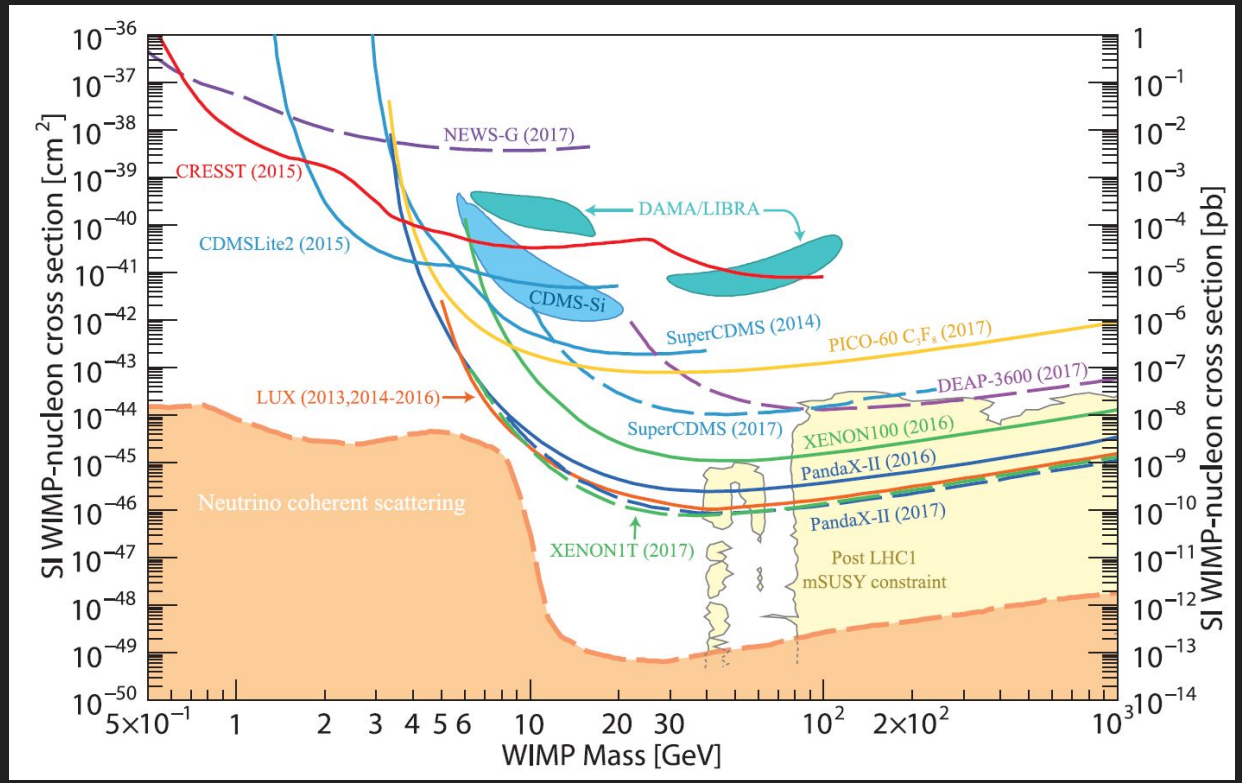
- Prototype: 0.1g Silicon
- 2019: 10g
- 2020: 100g
  - SNOLAB





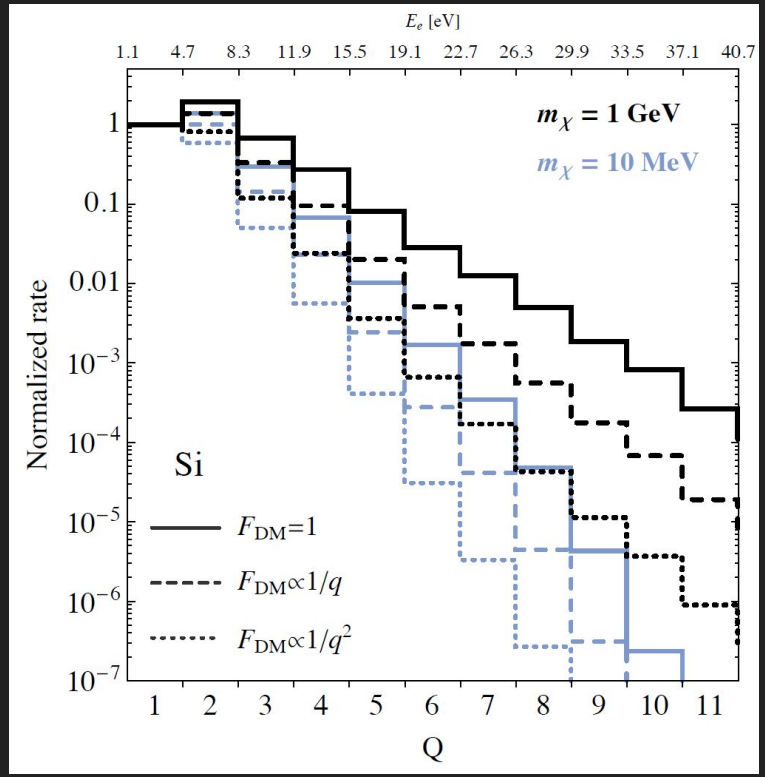
Thank You!

Backup: More Exclusion Curves



PDG 2018 http://pdg.lbl.gov/2018/reviews/rpp2018-rev-dark-matter.pdf

Backup: More Yields

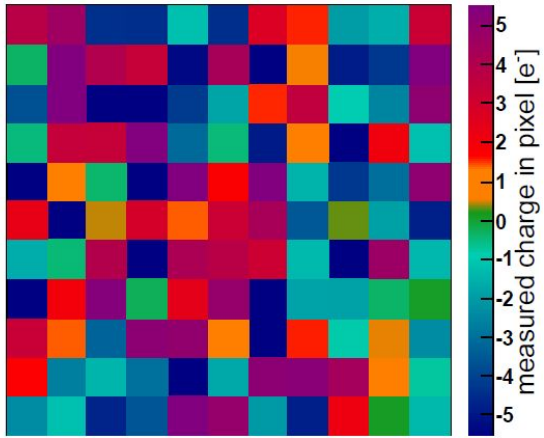


Essig, Fernandez-Serra, Mardon, Soto, Volansky, Yu (2016)

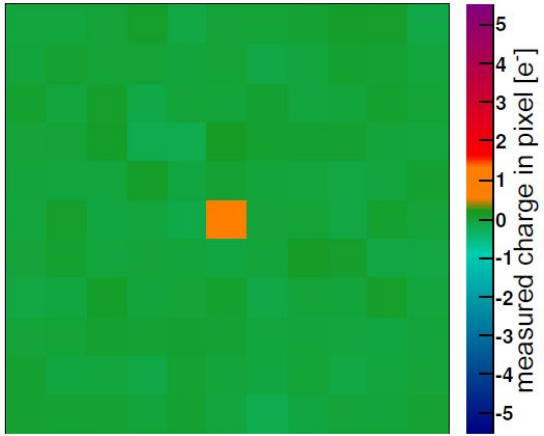
Backup: Sub-Electron Noise

$$\sigma \propto \frac{1}{\sqrt{N}}$$

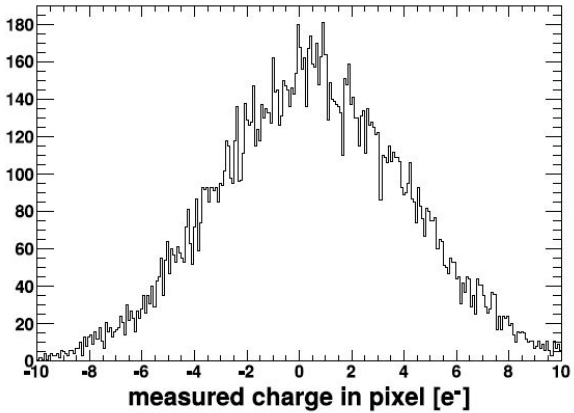
Standard CCD mode: charge in each pixel is measured once



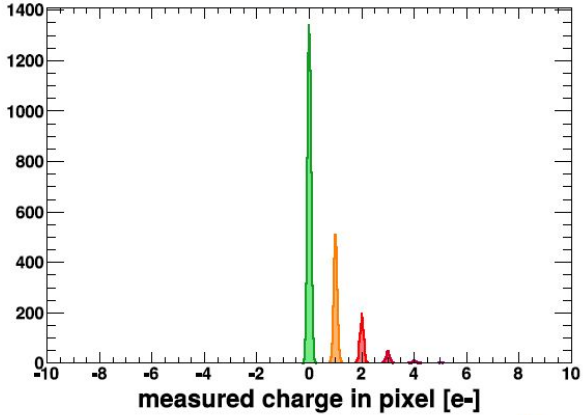
New Skipper CCD: charge in each pixel is measured multiple times



Readout-noise: 3.5 e RMS



Readout-noise: 0.06 e RMS



Tiffenberg 2018 https://conferences.pa.ucla.edu/pacific-2018/talks/tiffenberg.pdf

Backup: Absorption Expectations for SENSEI