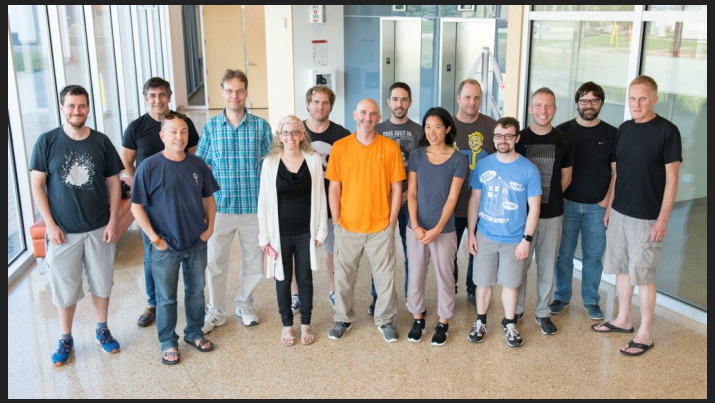
Light Dark Matter Detection with SENSEI

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

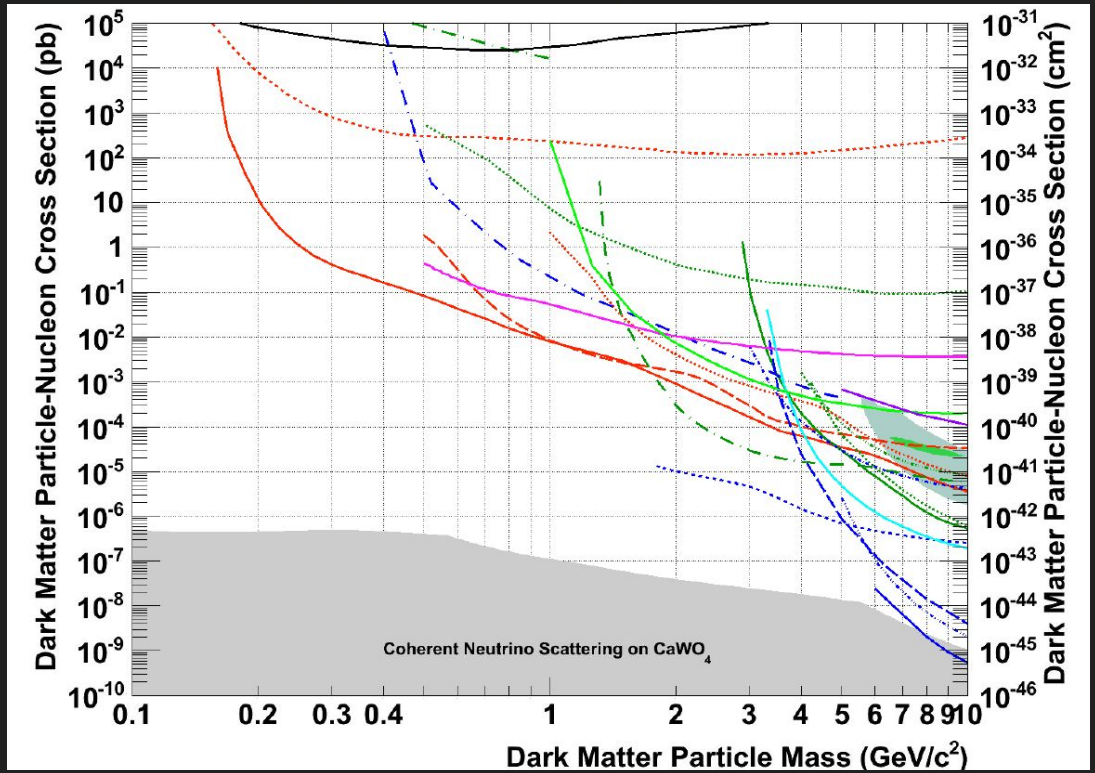
Brookhaven Forum 2019
September 26 2019

SENSEI

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



Nuclear Recoil Bounds



CRESST Collaboration (2019)

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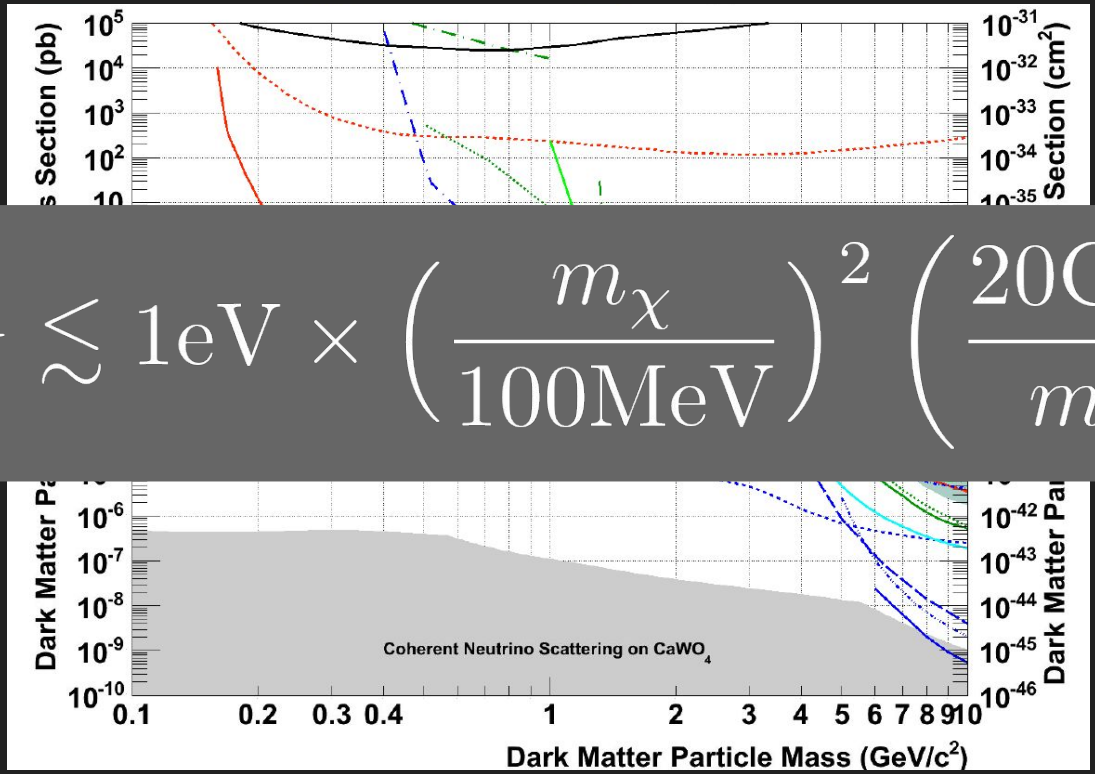


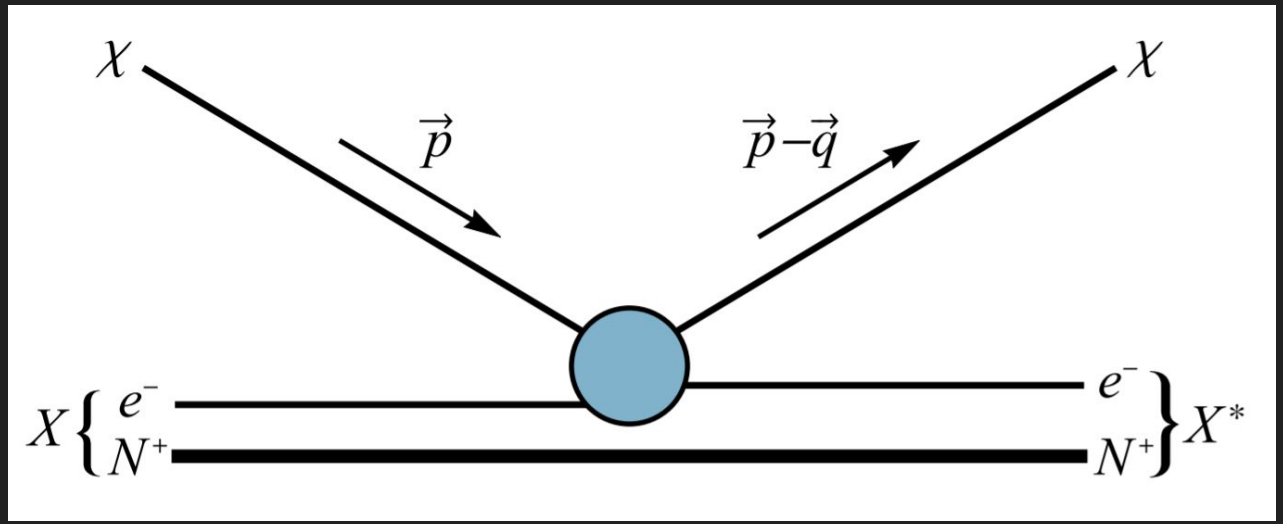
$$E_N \lesssim 1\text{eV} \times \left(\frac{m_\chi}{100\text{MeV}}\right)^2 \left(\frac{20\text{GeV}}{m_N}\right)$$

ration (2019)

Electron Recoil (Arxiv 1108.5383)

- Speed ~αc
- Not in momentum eigenstate

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

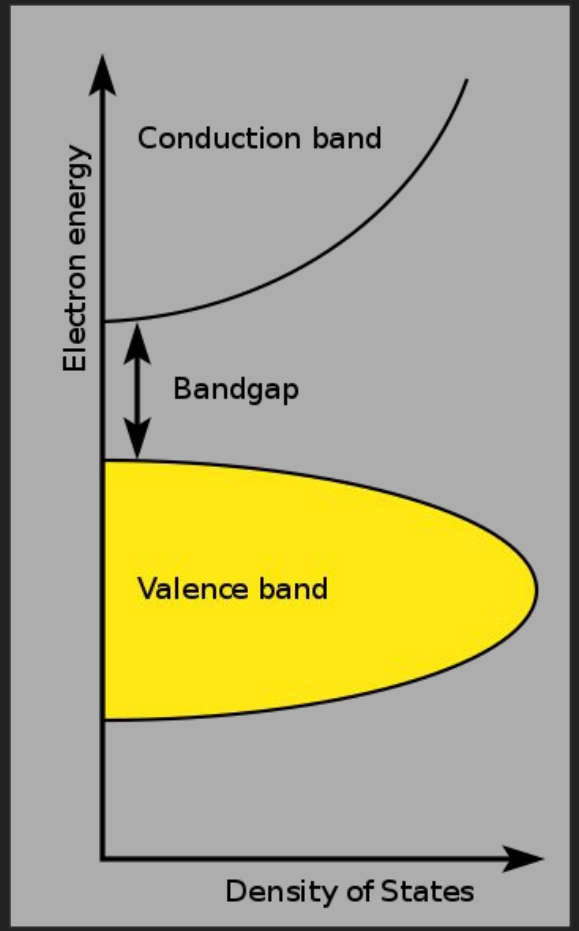


Essig, Fernandez-Serra, Mardon, Soto, Volansky, Yu (2015)

Semiconductor Use

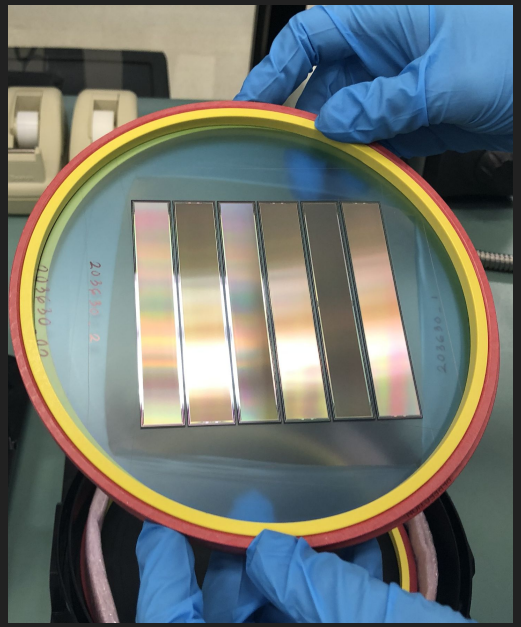
- Detect with silicon
  - Bandgap 1.1 eV

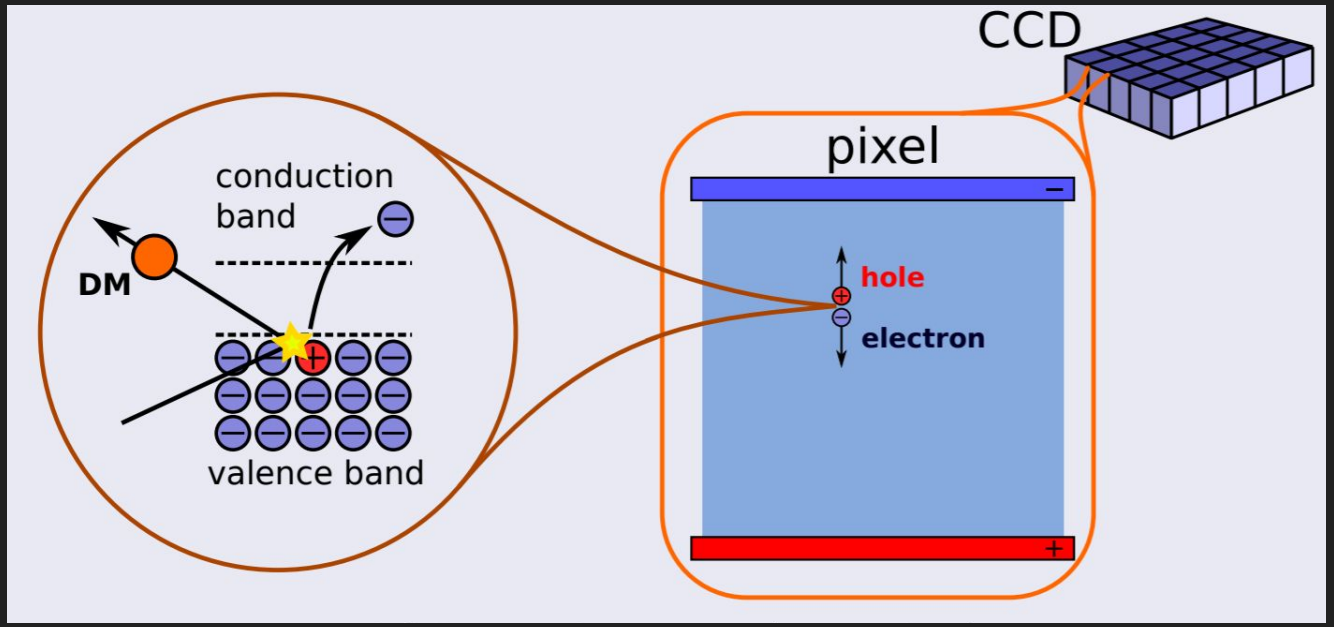
$$E_e \gtrsim \frac{1}{2}\mathrm{eV} \times \left(\frac{m_\chi}{1\mathrm{MeV}}\right)$$



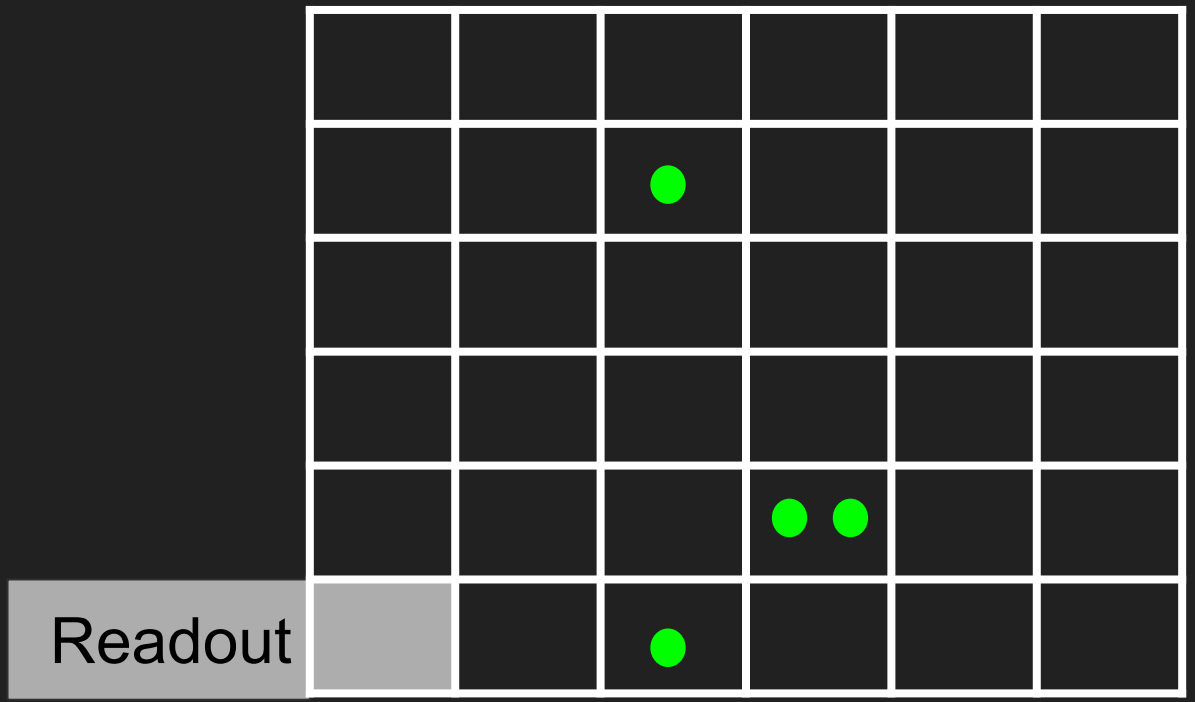
SENSEI

- Sub-Electron-Noise Skipper-CCD Experimental Instrument





Charge Coupled Device



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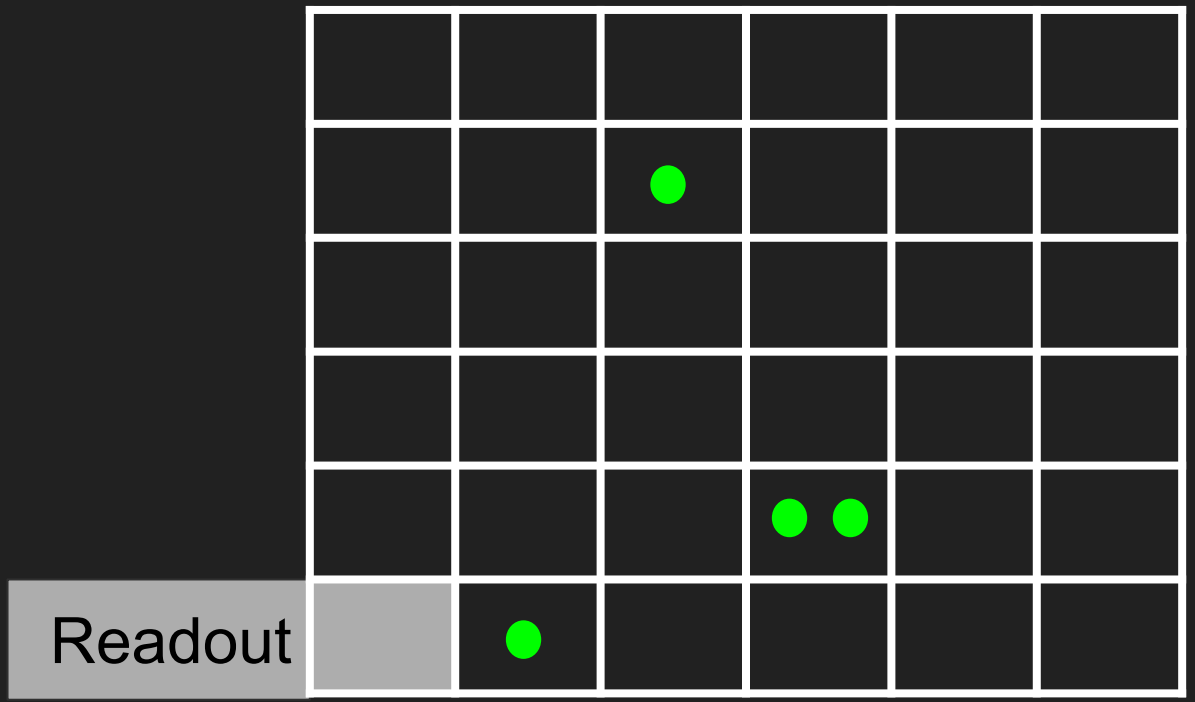

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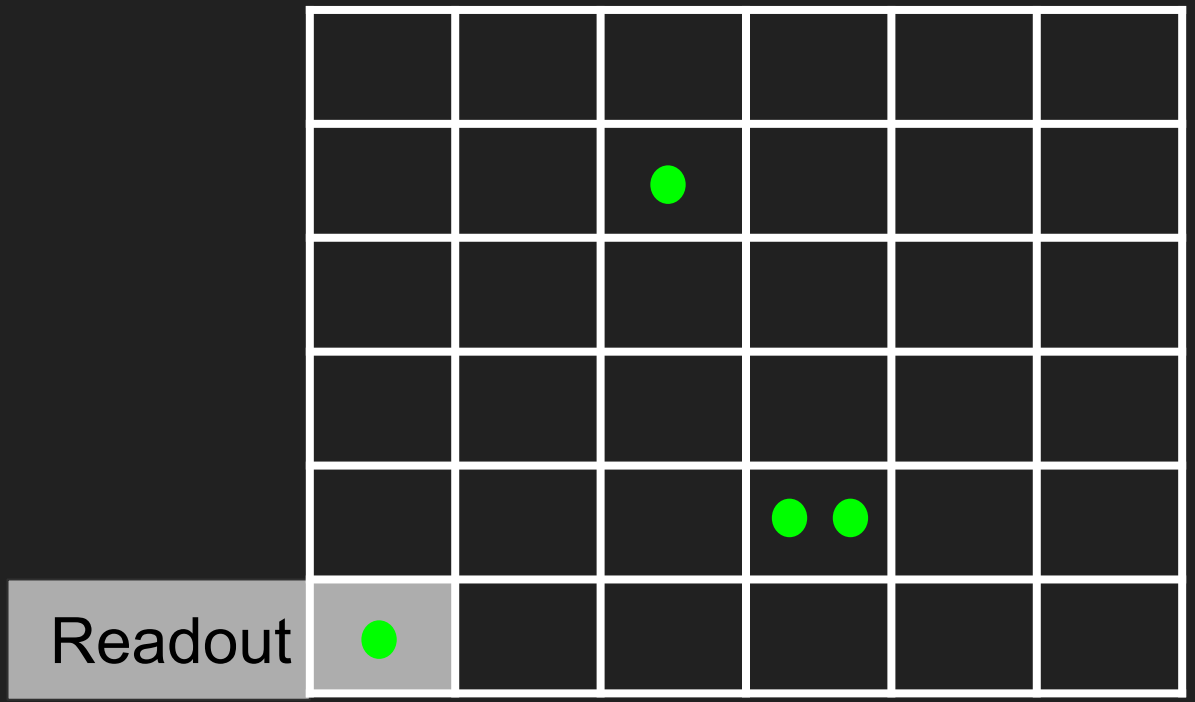
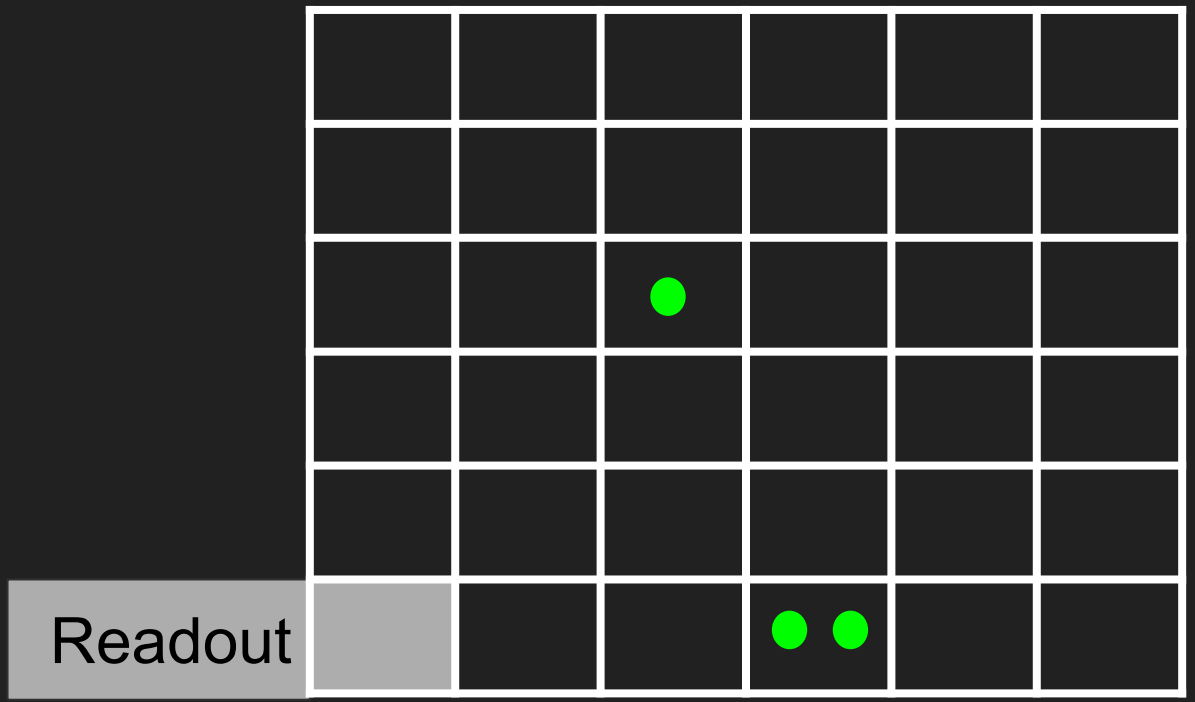
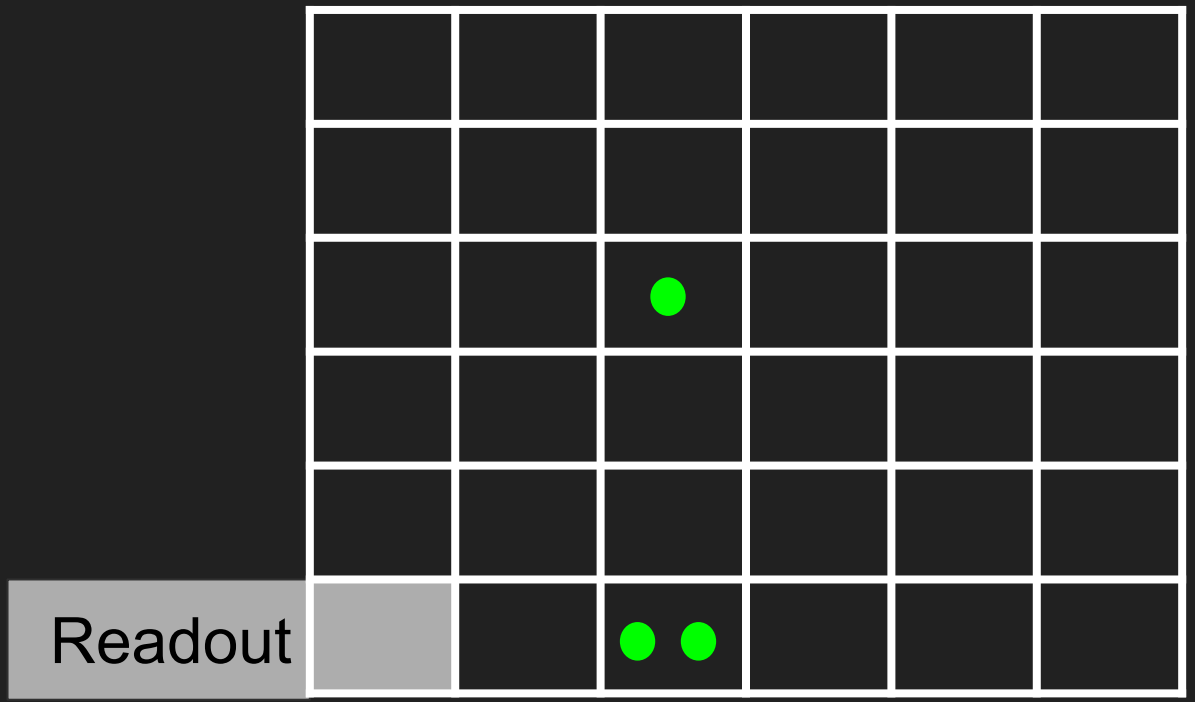


Charge Coupled Device



Charge Coupled Device



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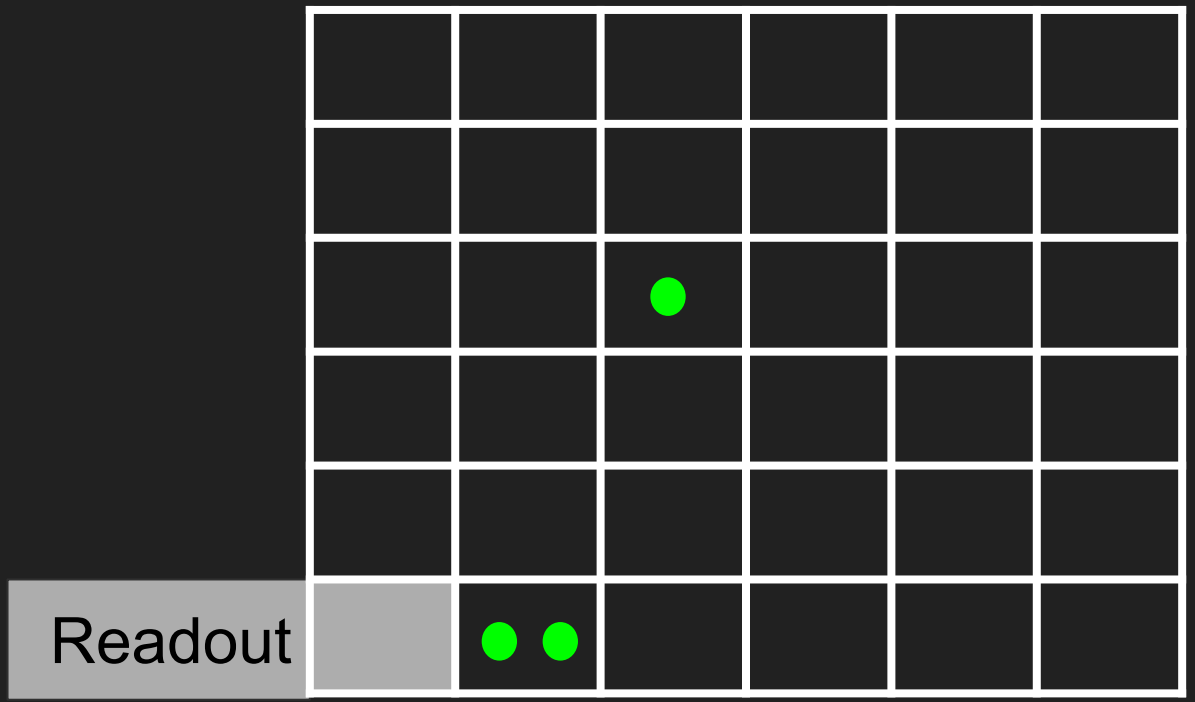

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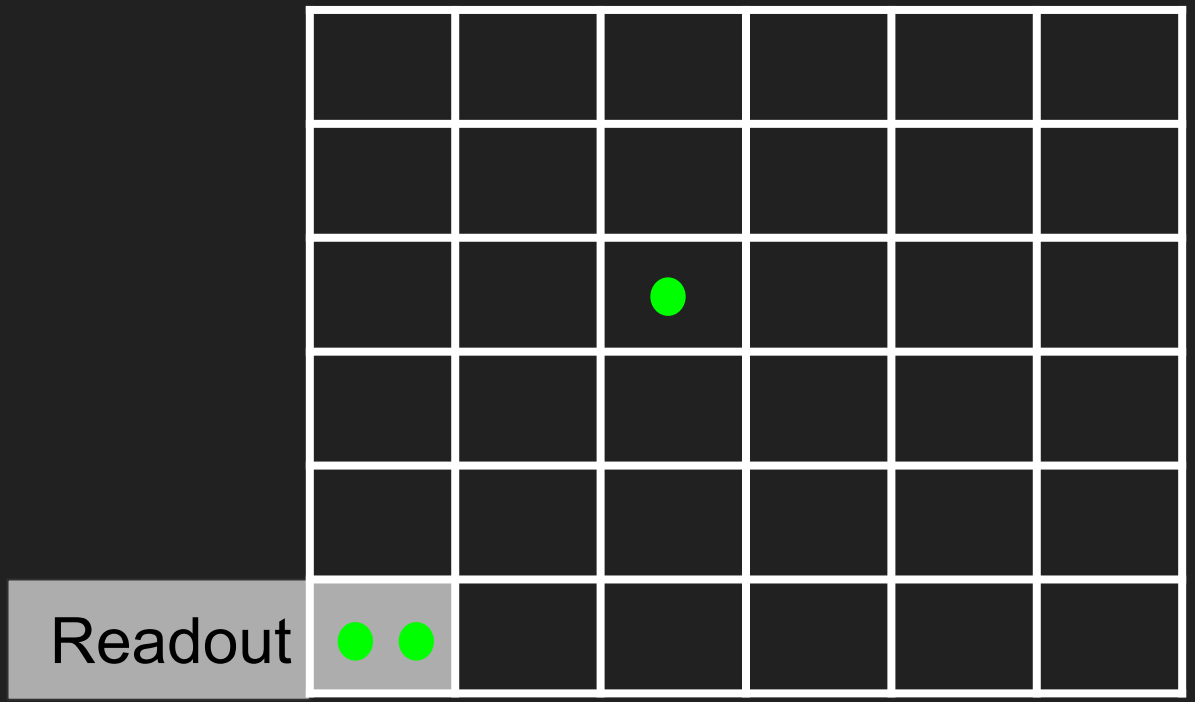
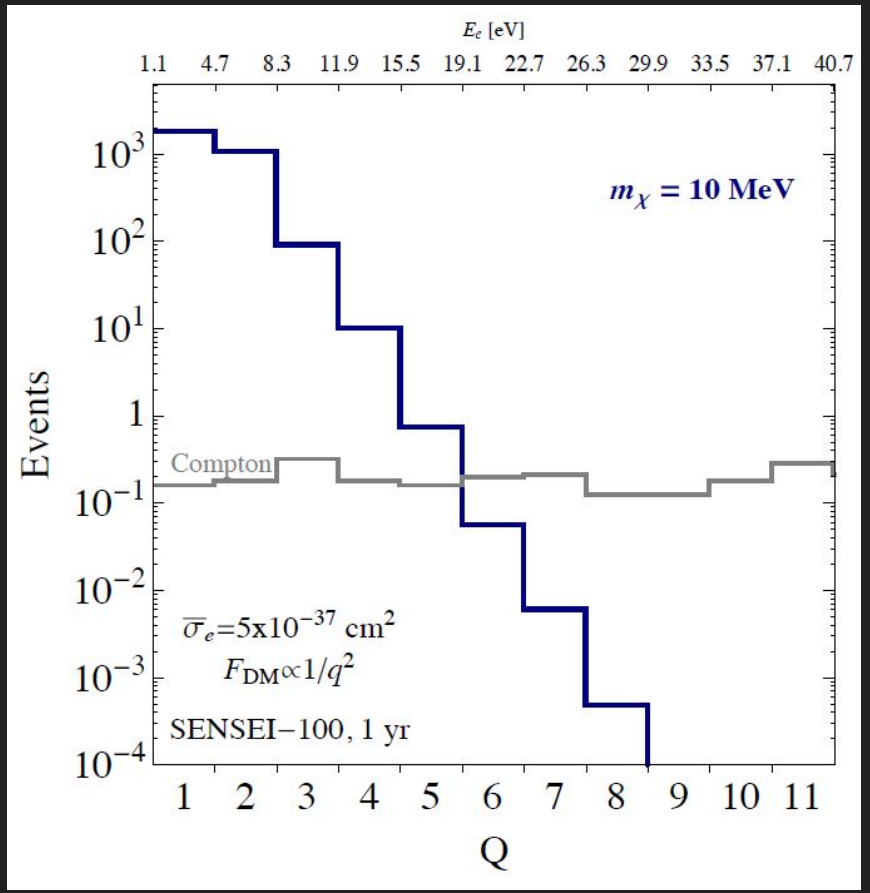
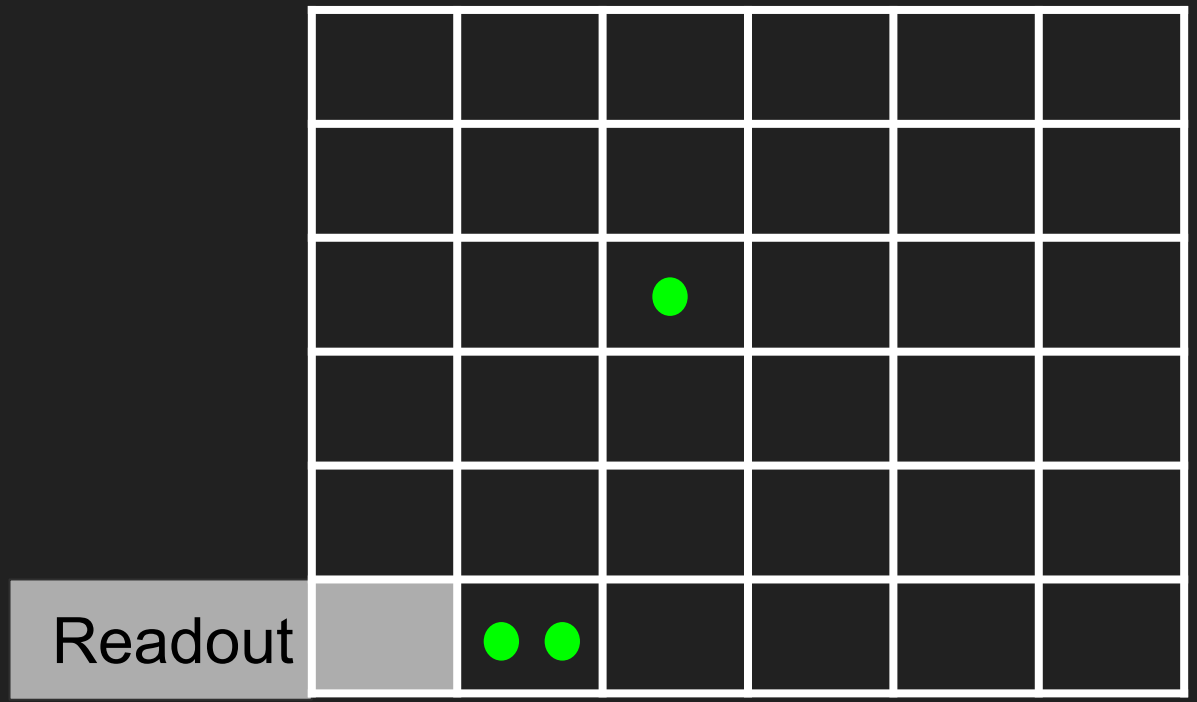


Yields

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



Skipping



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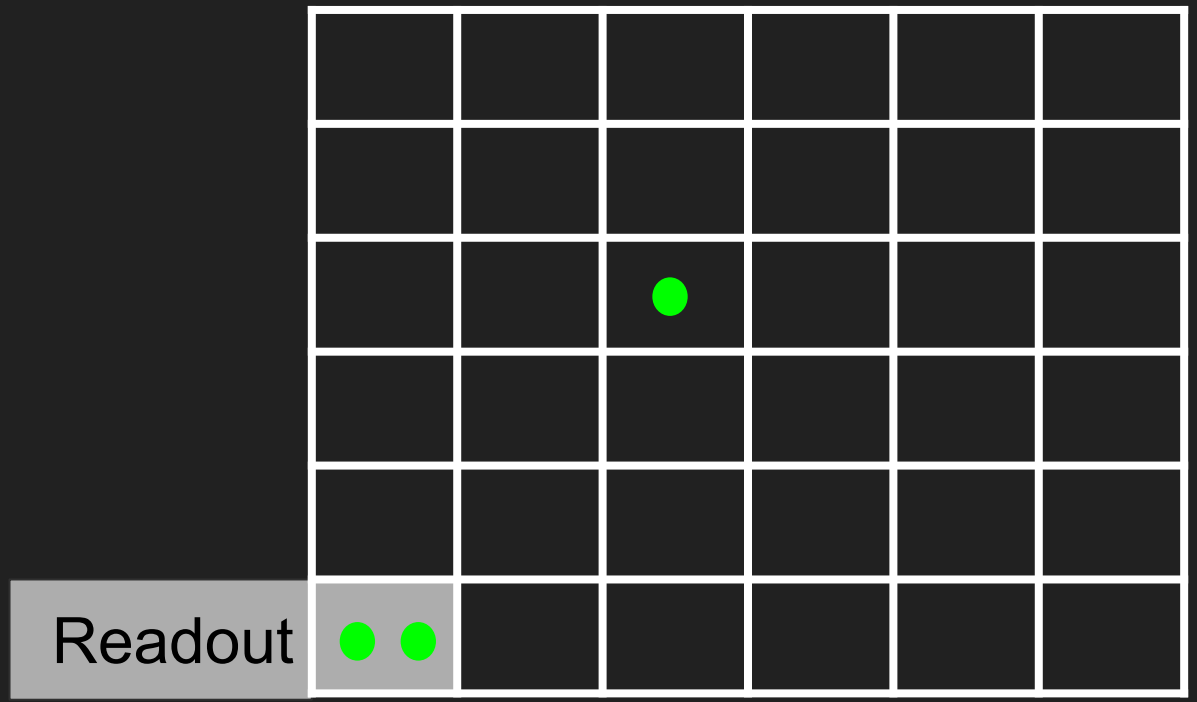

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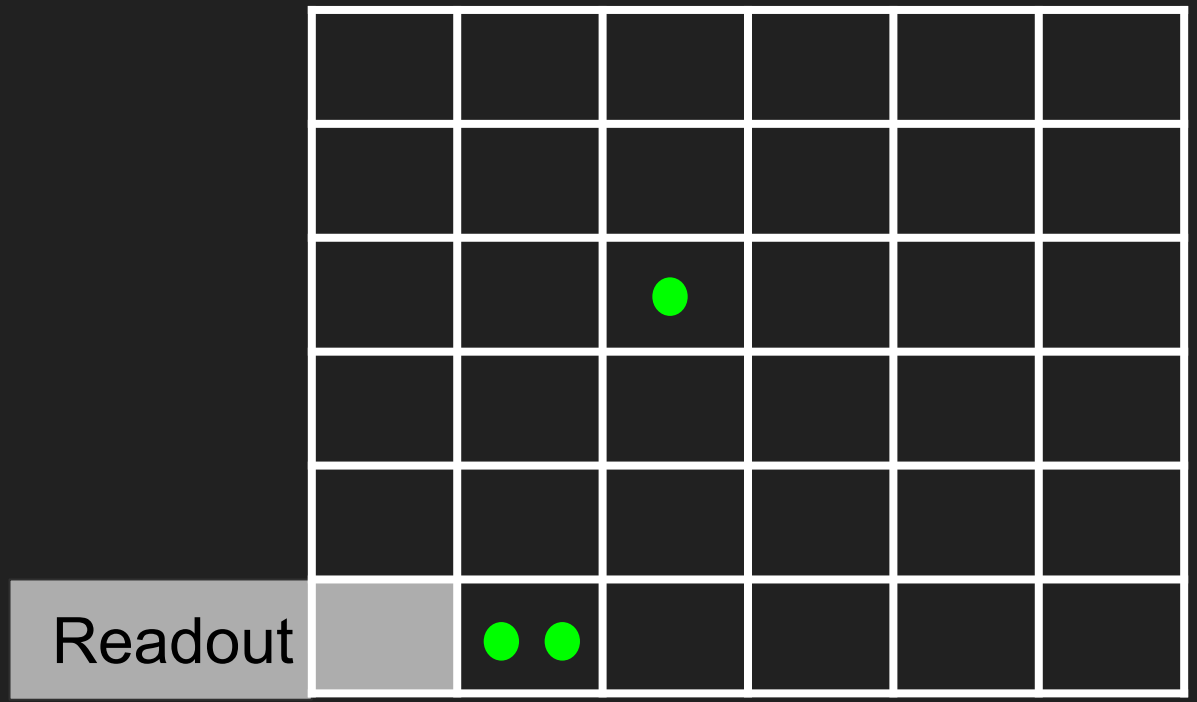

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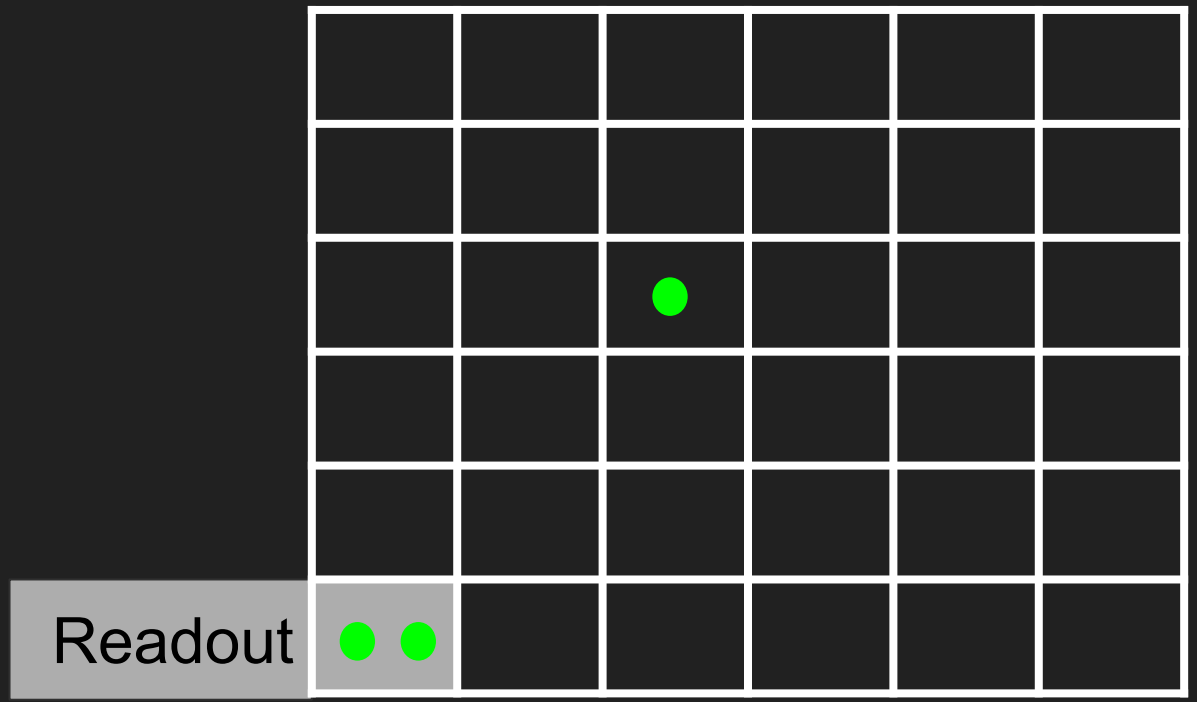

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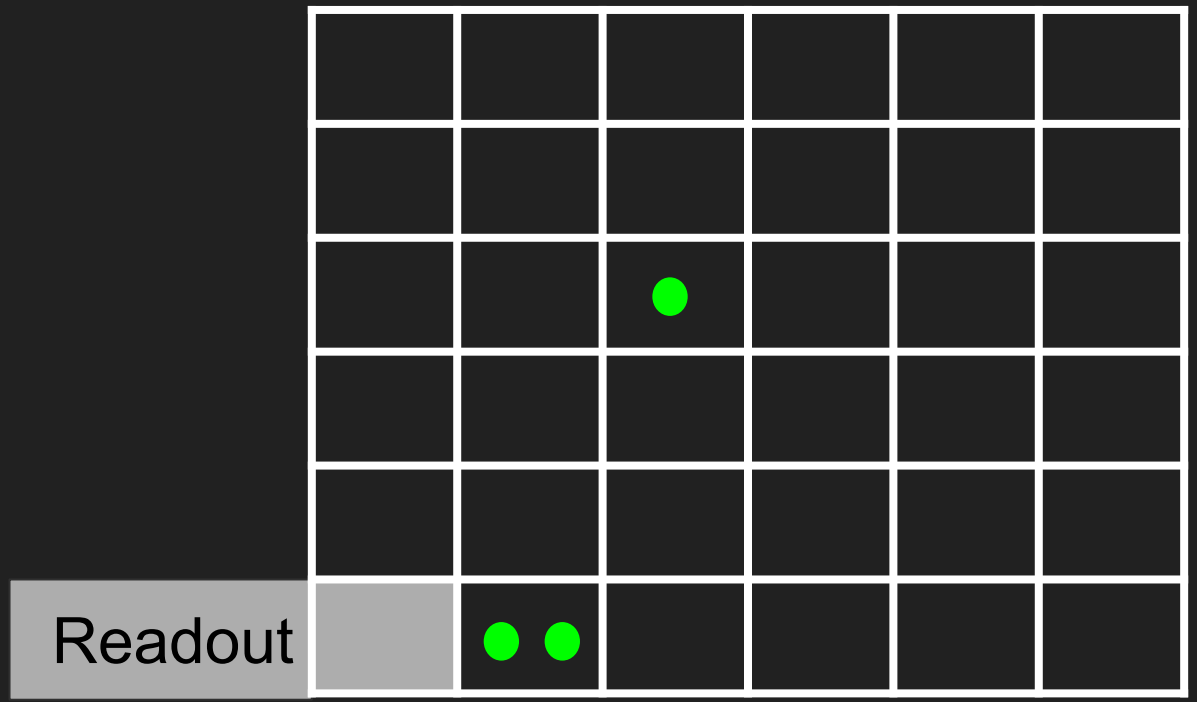

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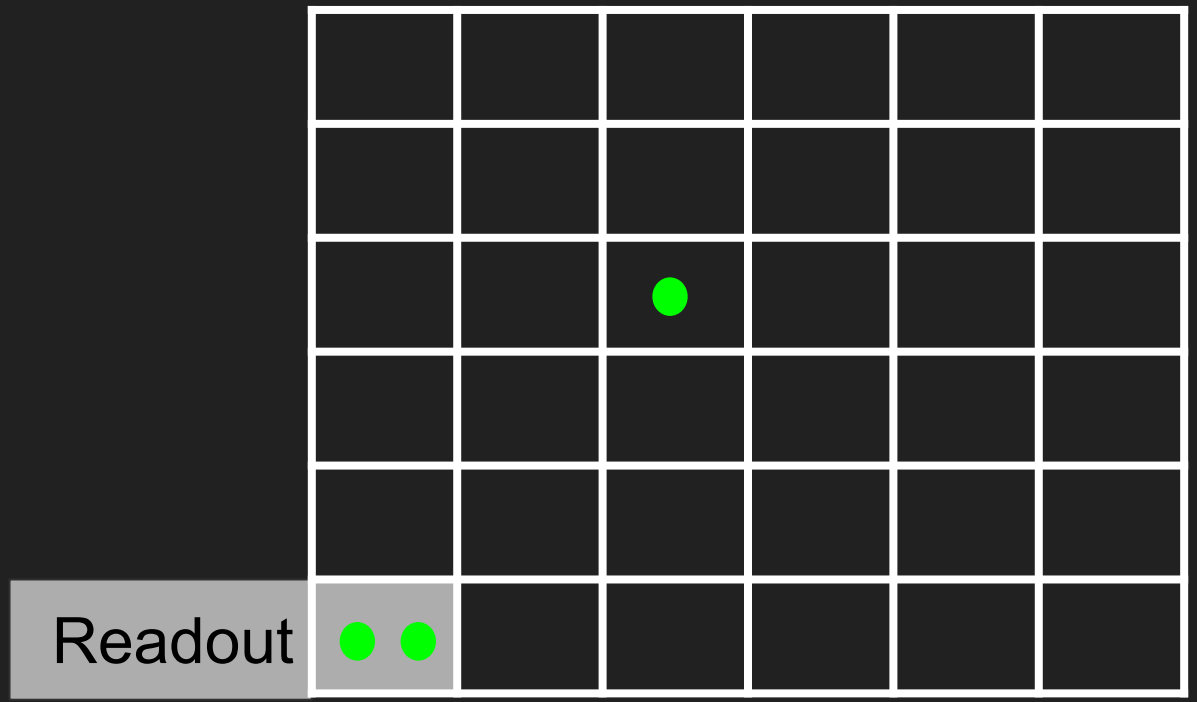
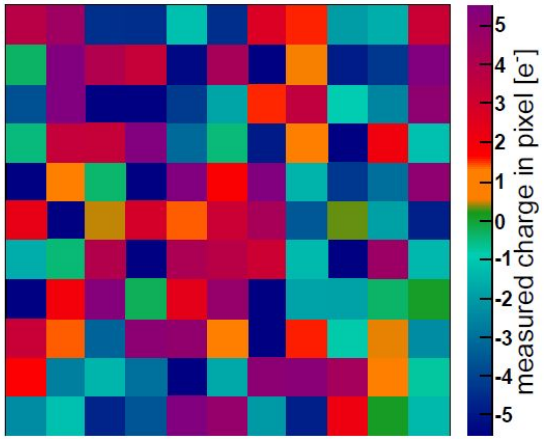


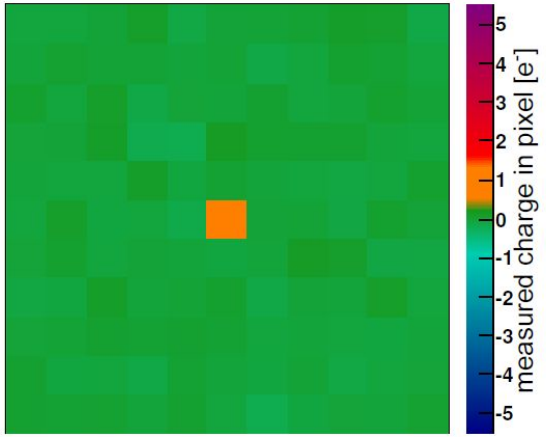
Sub-Electron Noise

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

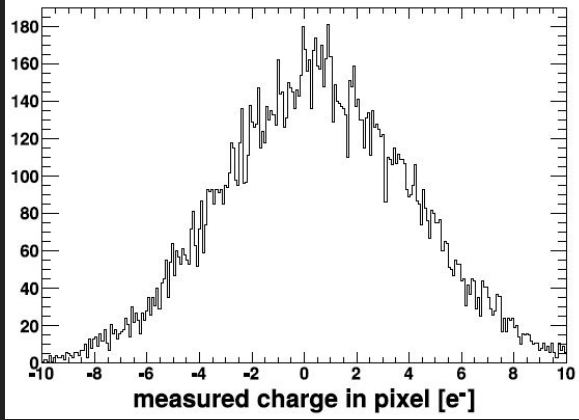
Standard CCD mode: charge in each pixel is measured once



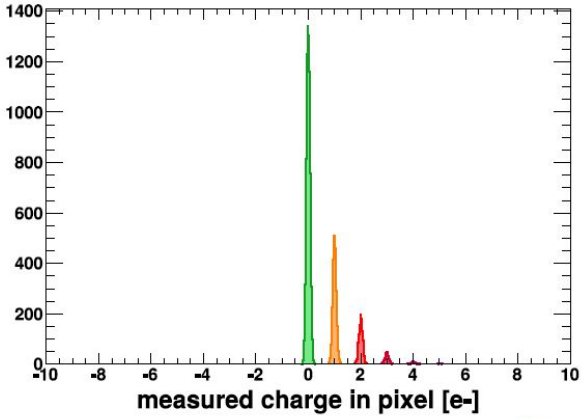
New Skipper CCD: charge in each pixel is measured multiple times



Readout-noise: 3.5 e RMS



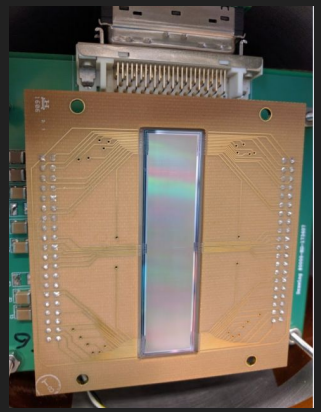
Readout-noise: 0.06 e RMS

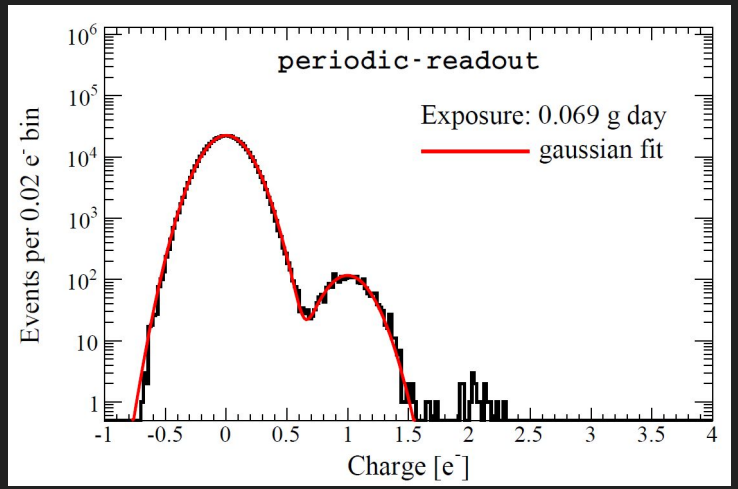


Tiffenberg 2018 https://conferences.pa.ucla.edu/pacific-2018/talks/tiffenberg.pdf

SENSEI Milestones

- Readout technology successful in 2017
- Prototype on surface, run 2017, paper 2018 (PRL 121, 061803)
- Underground run with 0.1 g silicon in 2018 (PRL 122, 161801)
  - “ProtoSENSEI”
  - MINOS cavern at Fermilab

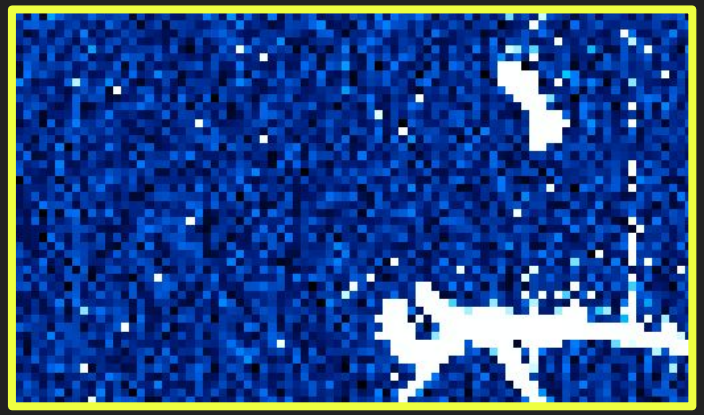


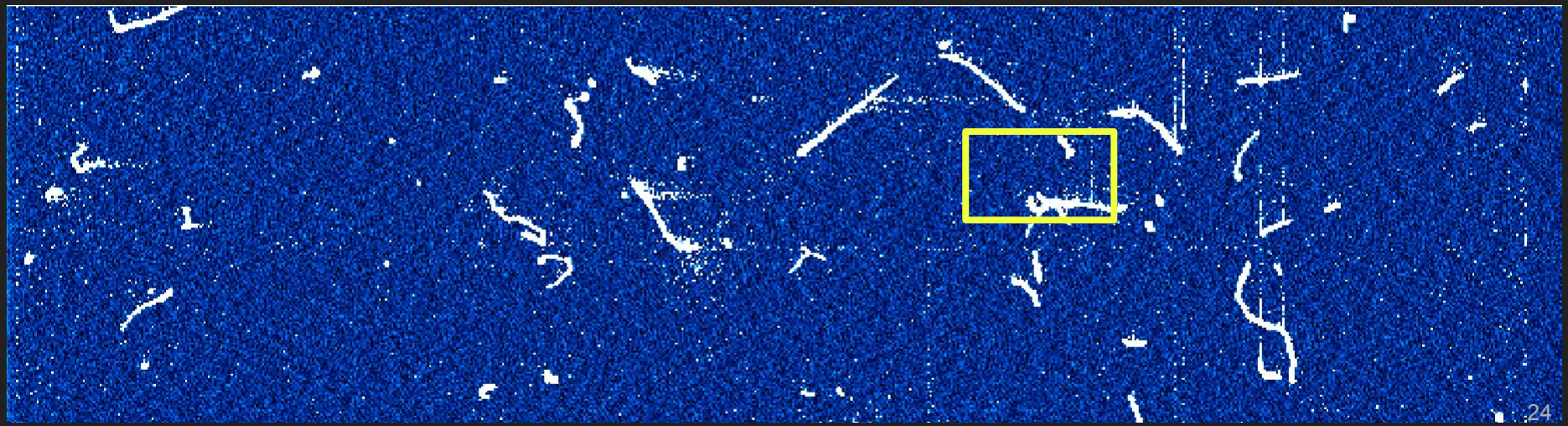


SENSEI Collaboration (2019), including DG

Backgrounds

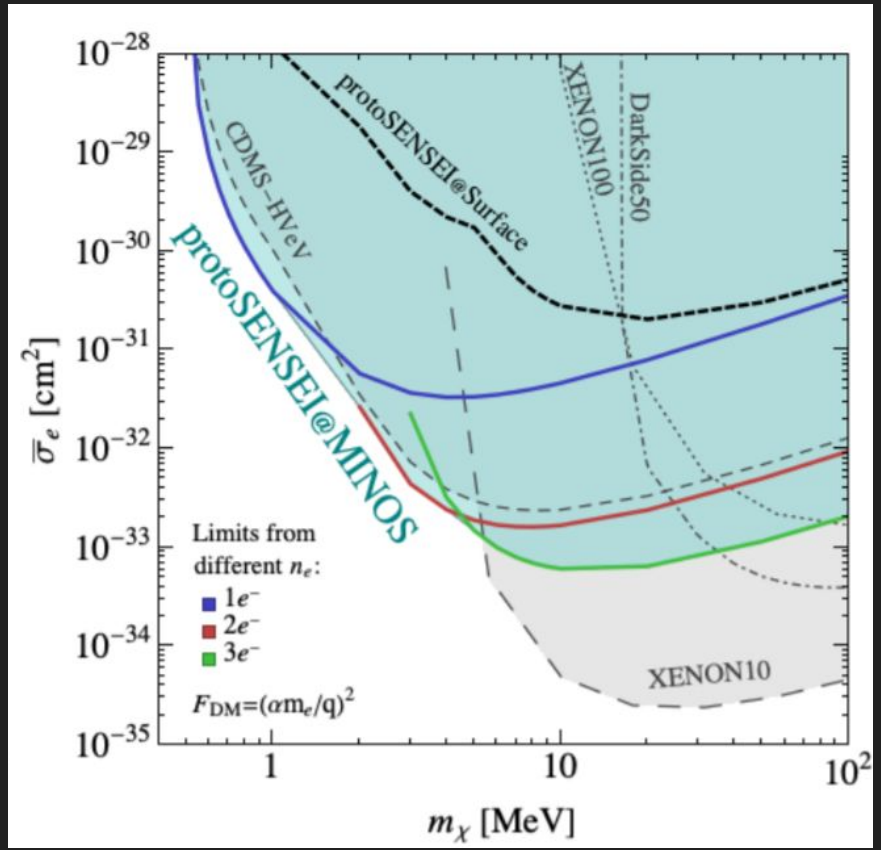
- Gamma Rays
- Bleeding
- Dark Current





Limits

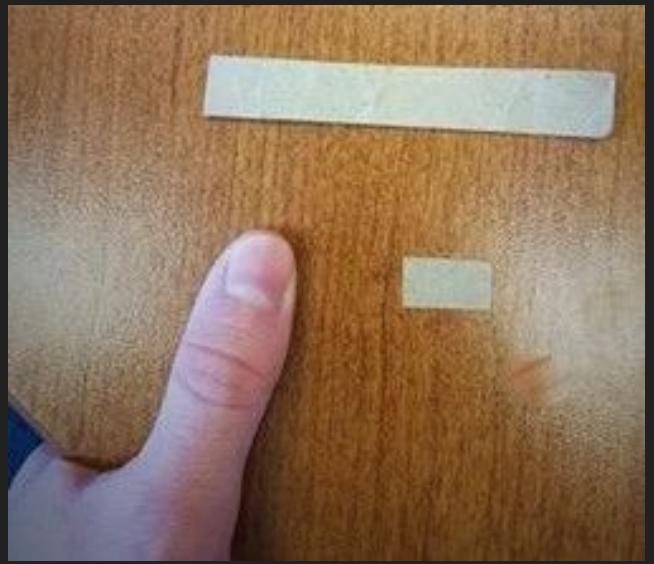
- New limits from DAMIC not shown



SENSEI Collaboration (2019), including DG

Currently

- Development of SENSEI-10g
  - Improved Si quality
  - Thicker, bigger detectors
  - Better analysis
  - MINOS @ Fermilab -> SNOLAB



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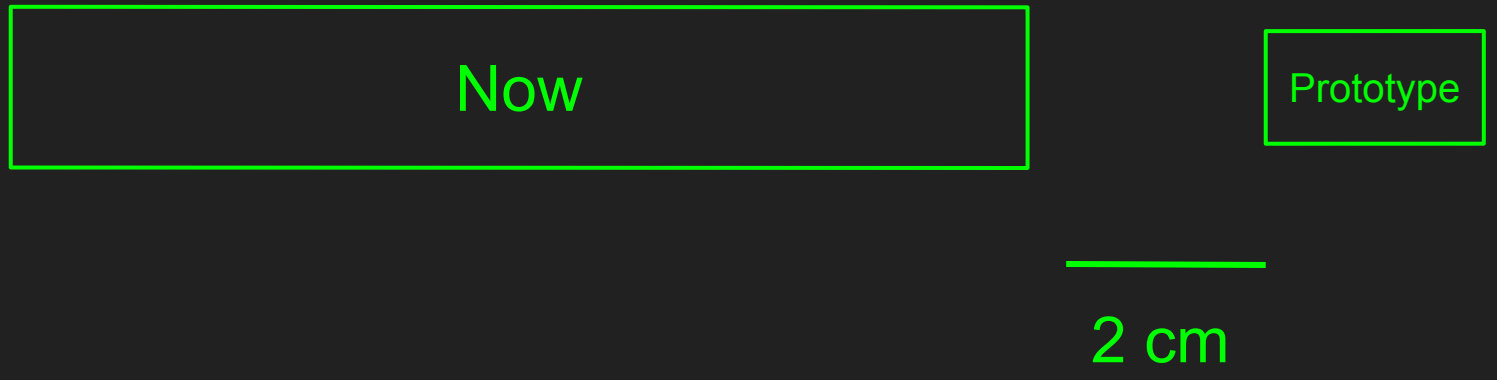
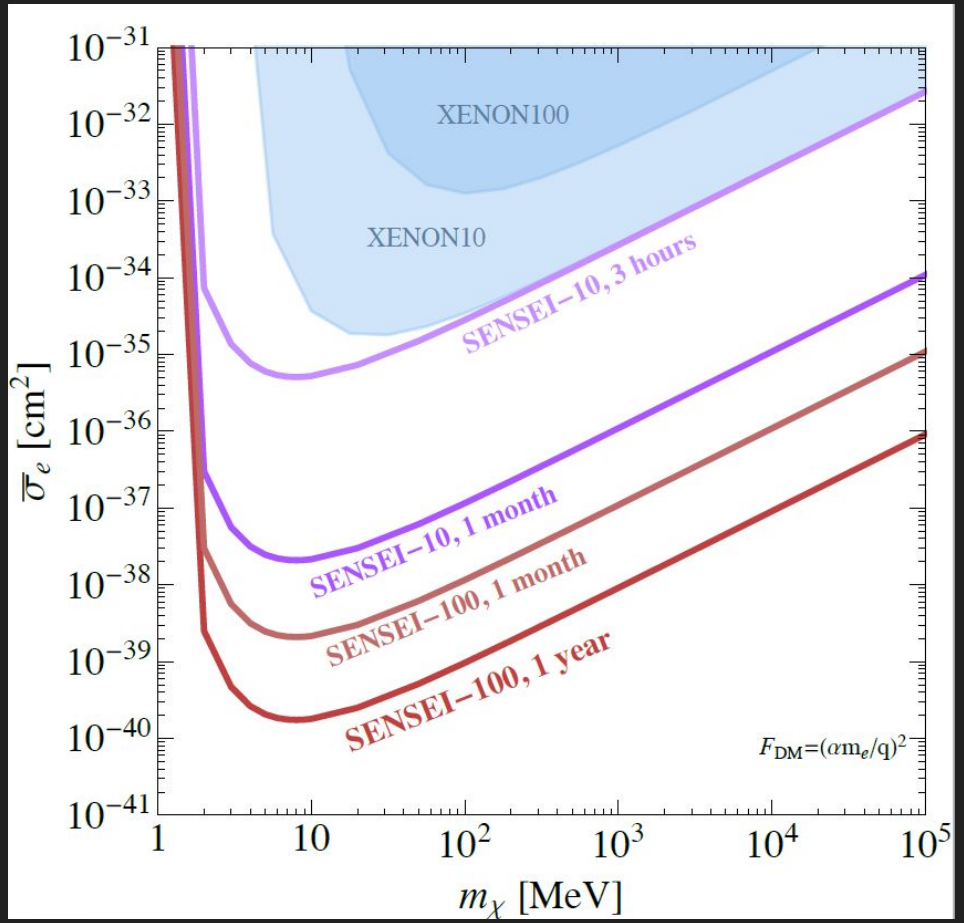


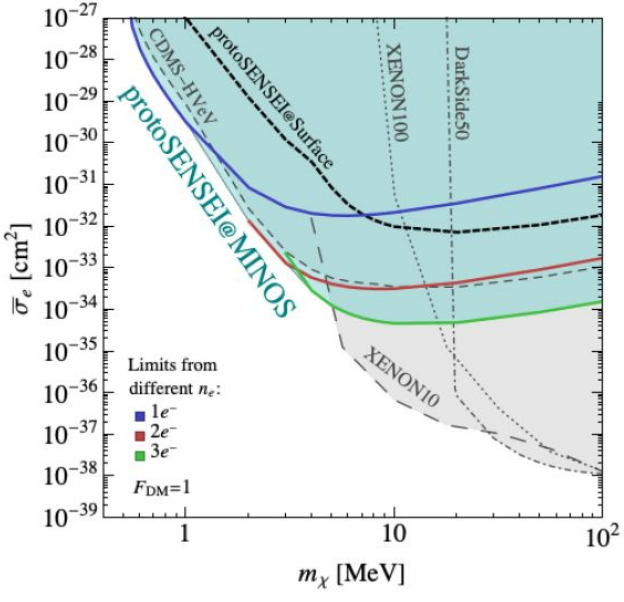
Future of SENSEI

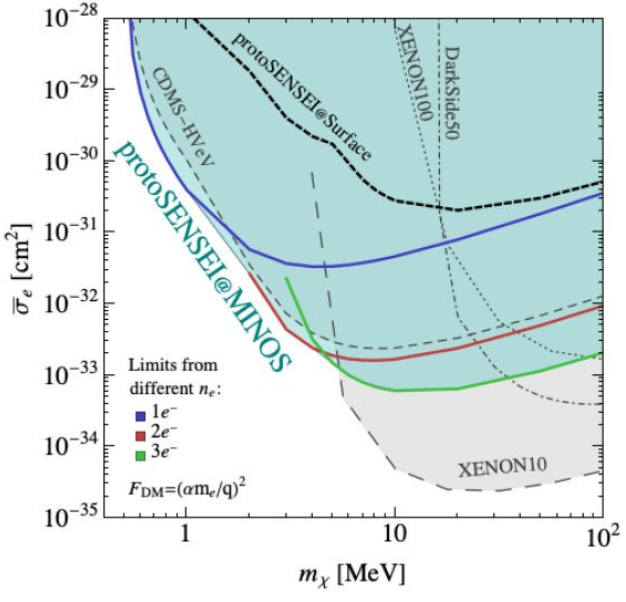
- Prototype: 0.1g Silicon
- Now: work on SENSEI 10 g
- 2020: 100g

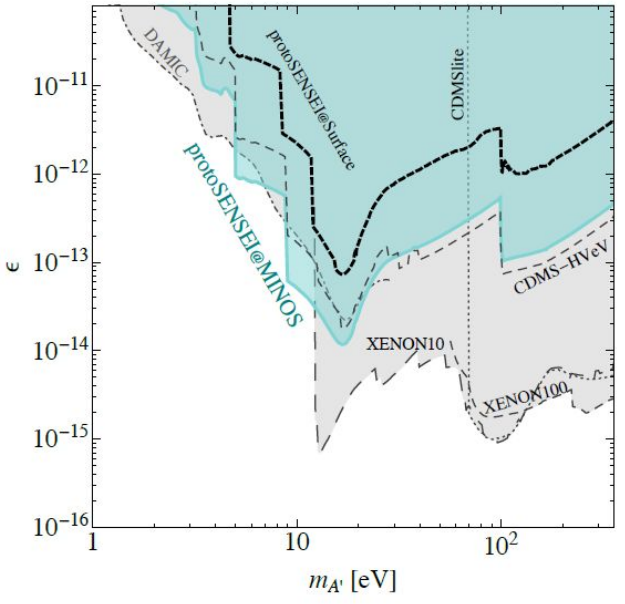


Thank You!

Backup: More Limits

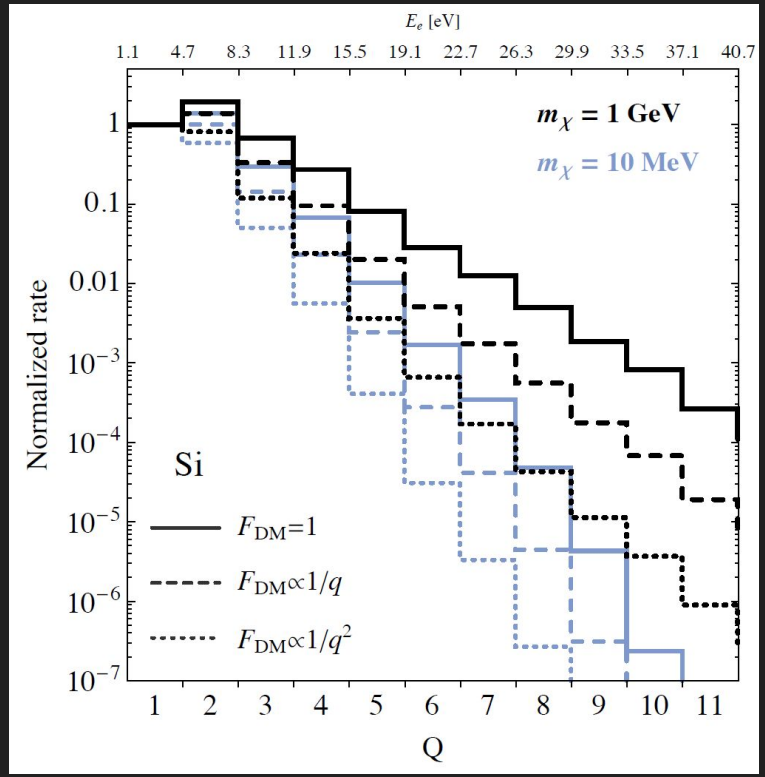






SENSEI Collaboration (2019)

Backup: More Yields



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

Backup: Absorption Expectations for SENSEI