

T A U P 2 0 2 3

# EARTH-SCATTERING INDUCED MODULATION IN LOW-THRESHOLD DARK MATTER EXPERIMENTS

APPLICATION TO SEARCHES IN THE DARK SECTOR

X. BERTOU, T. EMKEN, R. ESSIG, T. VOLANSKY, T.-T. YU

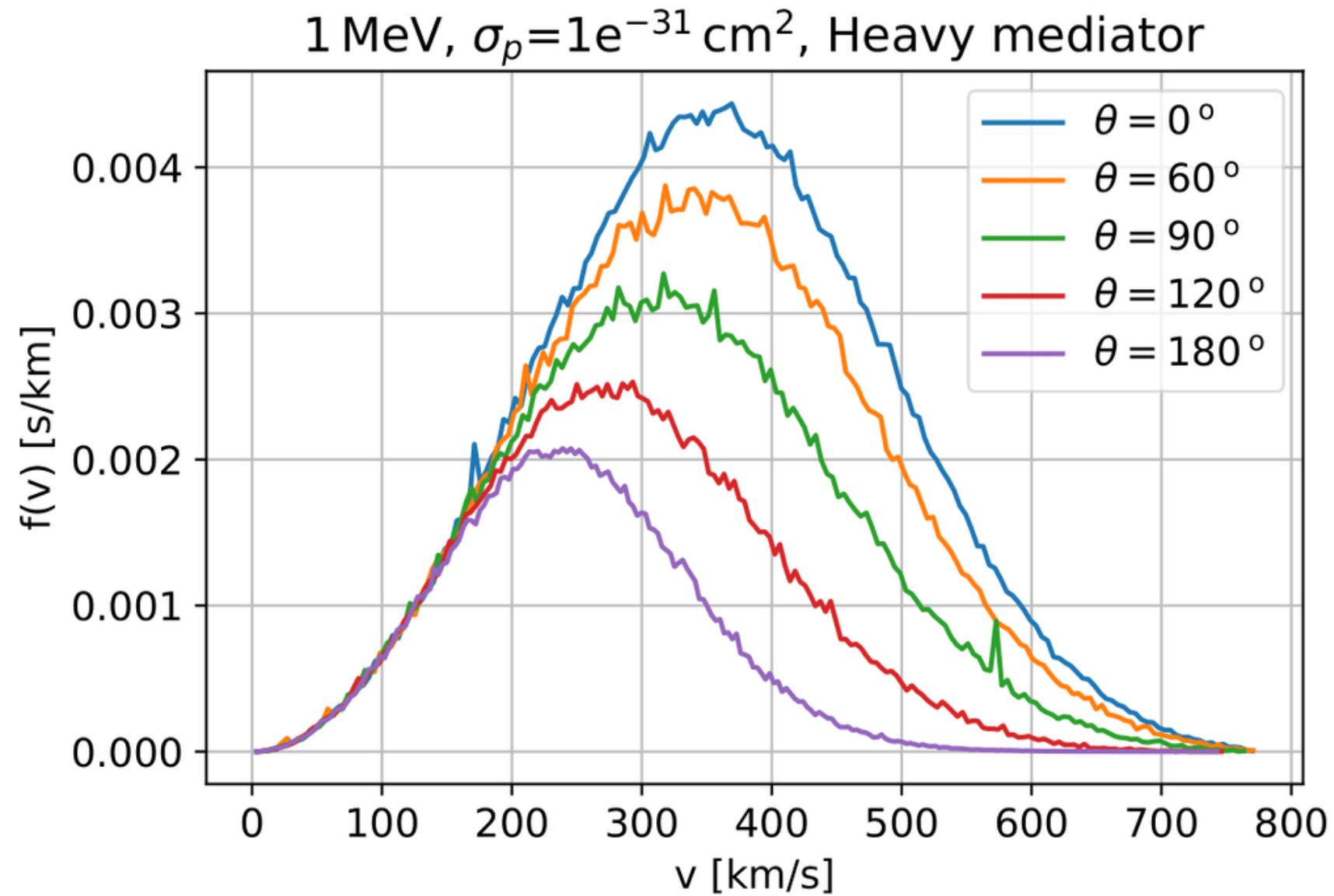
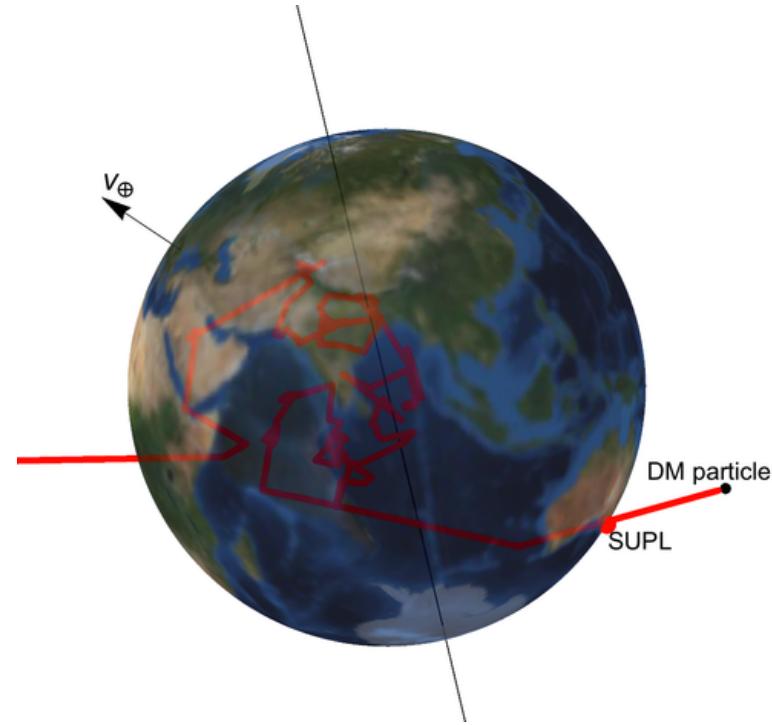
# MOTIVATION

- Skipper CCD are great detectors for Light Dark Matter searches
- They have an ultimate threshold of 1.2 eV!
- But this 1 e- signal bin has a lot of irreducible background (DC)
- Ideal detector for daily modulation experiment: a world leading threshold detector with an irreducible background - let's extract signal from background by looking for the modulation
- Icing on the cake: I live and work in Bariloche, Argentina, 41 deg south latitude, where daily modulations are expected to be maximum

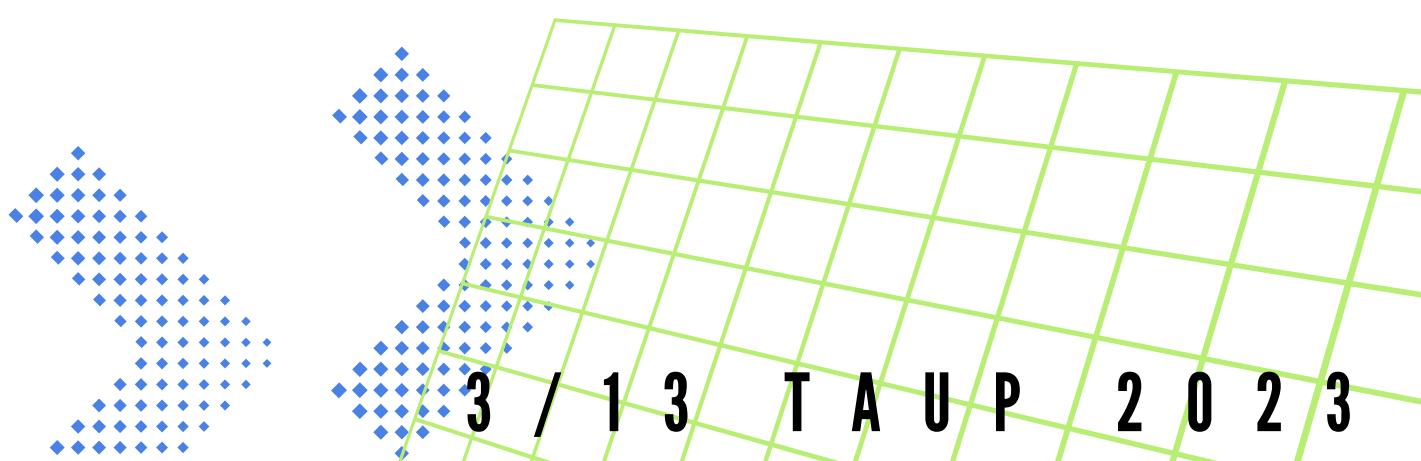


# EARTH PROPAGATION SIMULATION - DAMASCUS

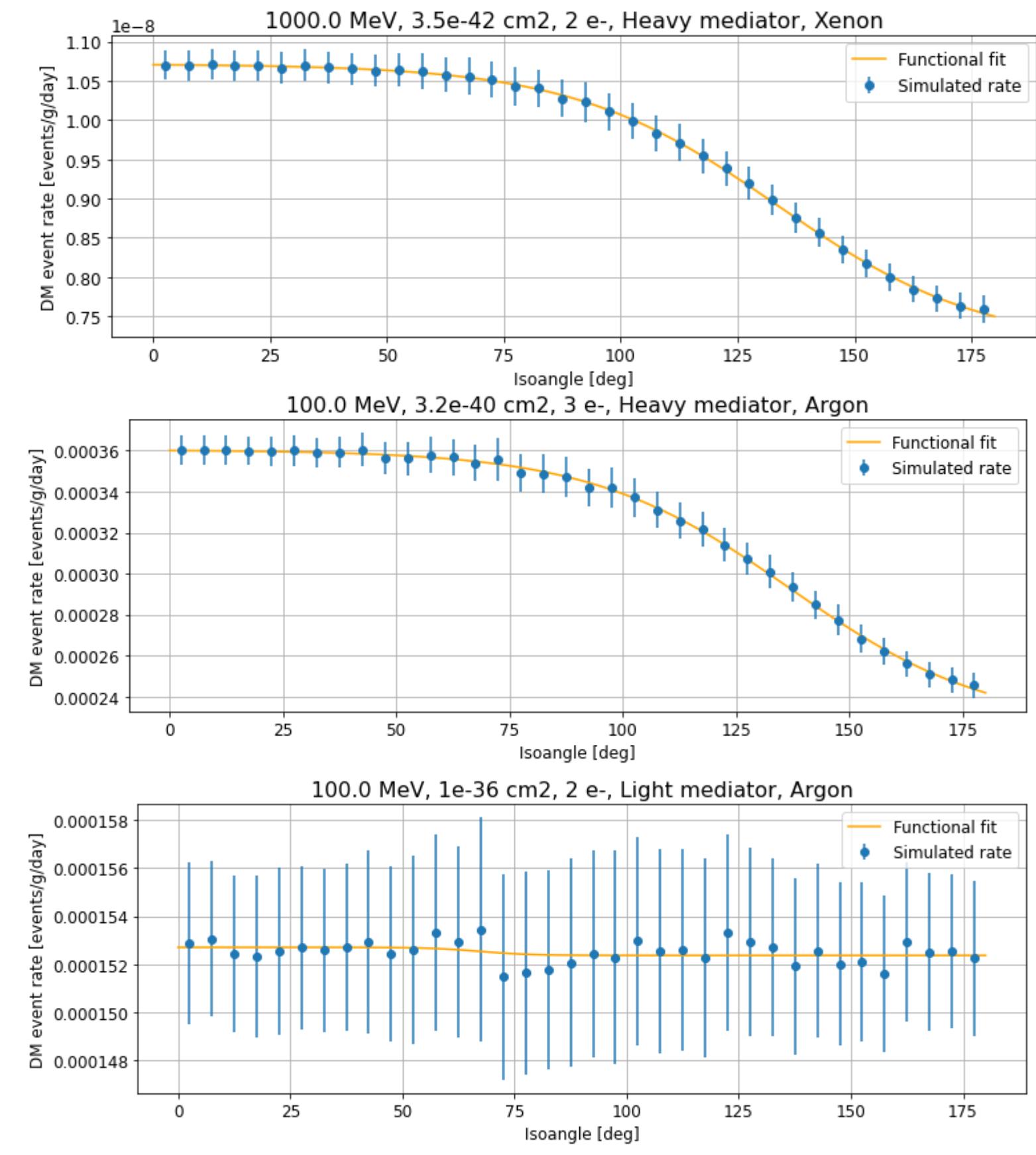
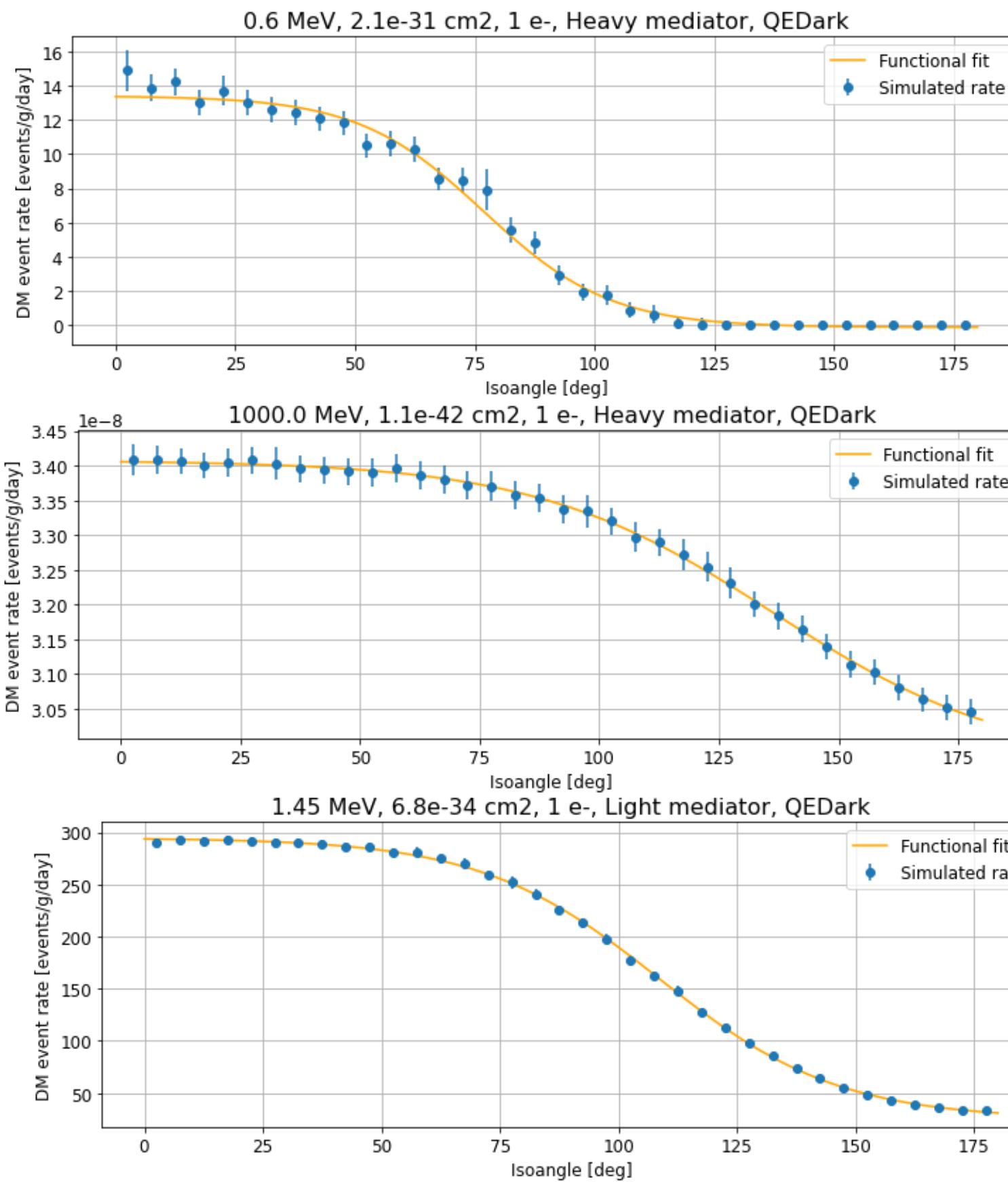
- DaMaSCUS - Dark Matter Simulation Code for Underground Simulations
- Code adapted by Timon Emken for contact interactions  
(heavy/light mediator, screening effects)



- [https://github.com/temken/DaMaSCUS/  
tree/chargescreening](https://github.com/temken/DaMaSCUS/tree/chargescreening) (not main branch)
- Output is DM velocity distribution vs  
isodetection angle:
  - 0: DM wind from above
  - 90: comes from the horizon, ~ SHM
  - 180: DM wind goes through the Earth

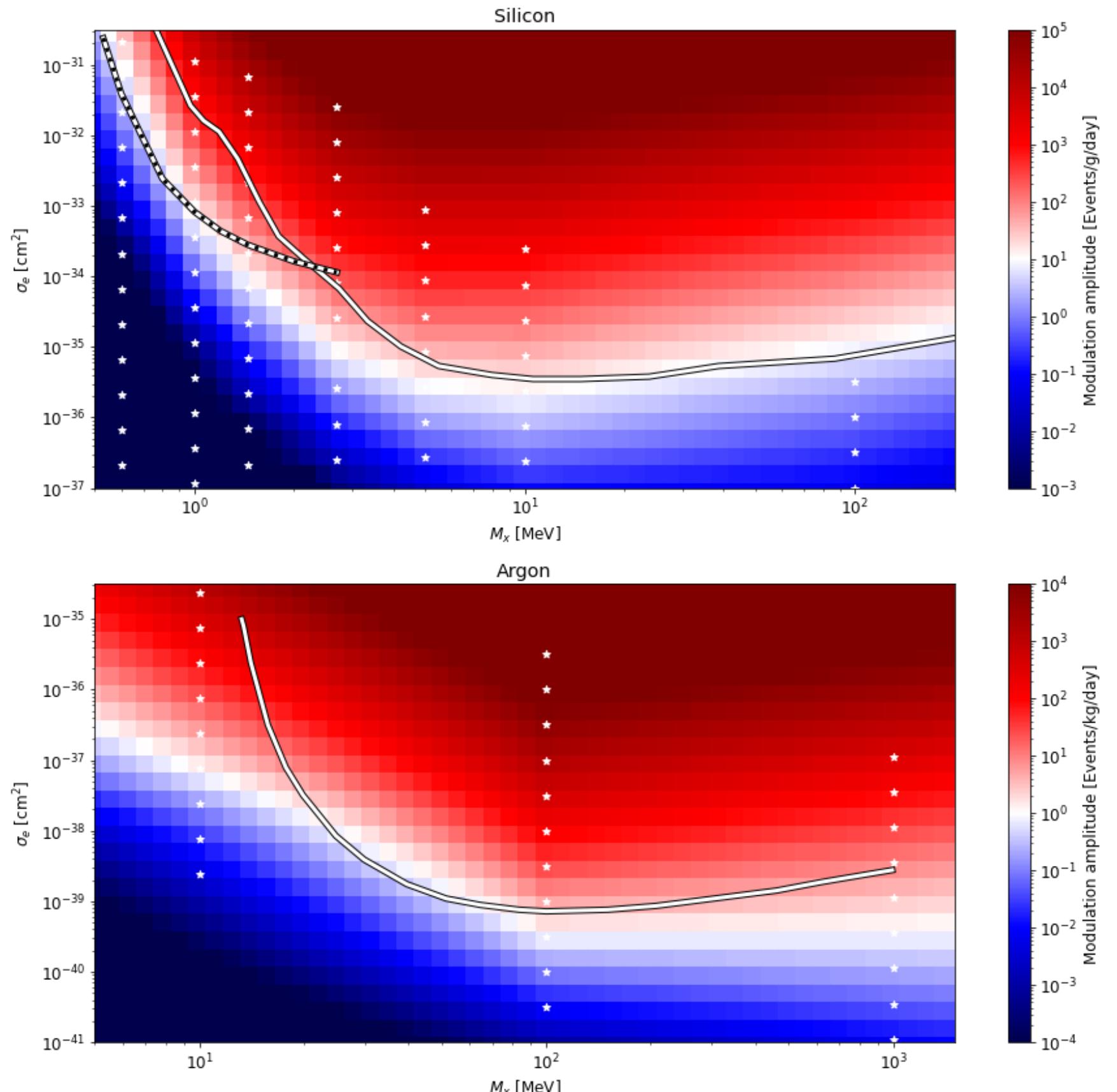


# DETECTOR SIMULATION SI/XE/AR AND FITS



**4 parameter sigmoid fit:**  
amplitude  
inflection  
offset  
slope

# MODULATION AMPLITUDE



Heavy mediator

Modulation amplitude: rate(0 deg) – rate(180 deg)

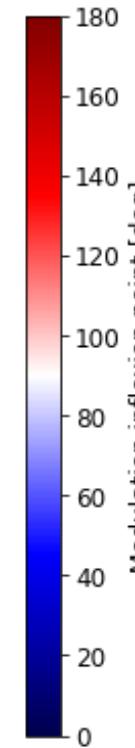
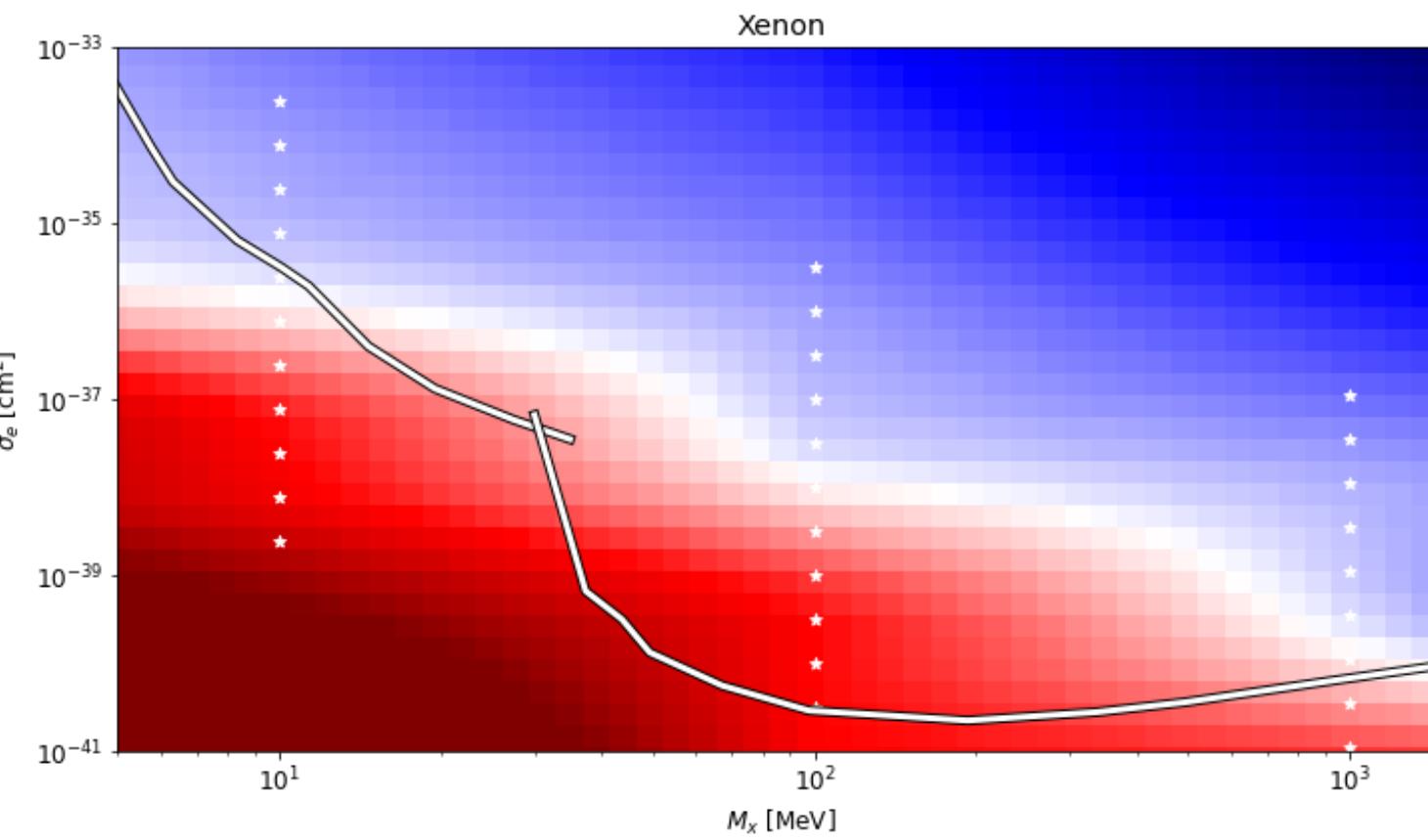
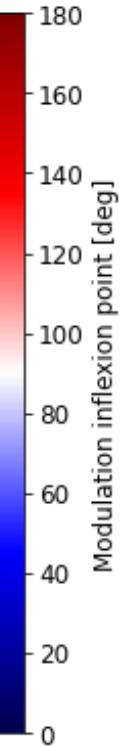
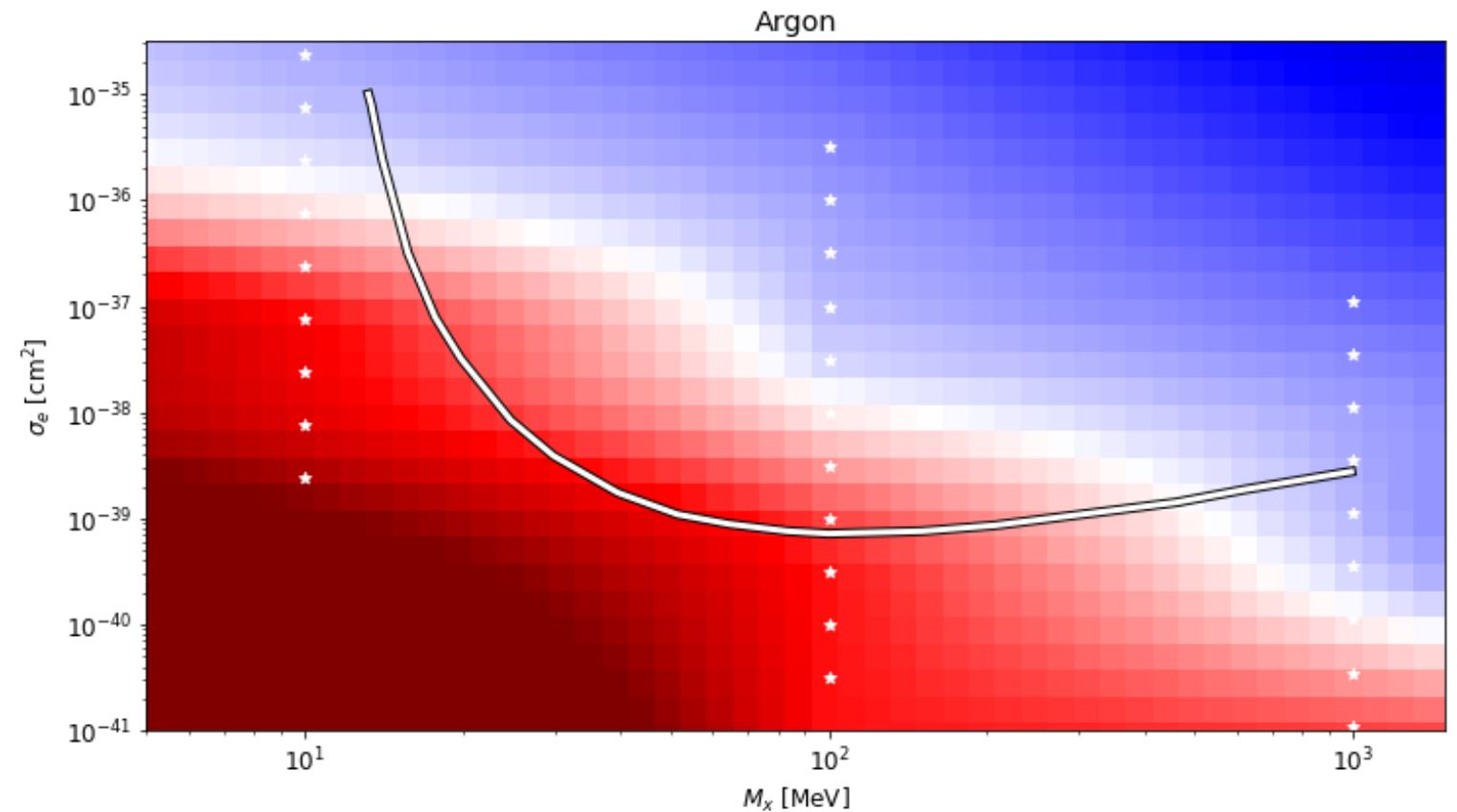
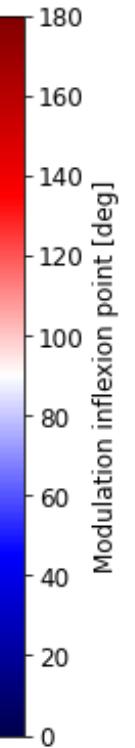
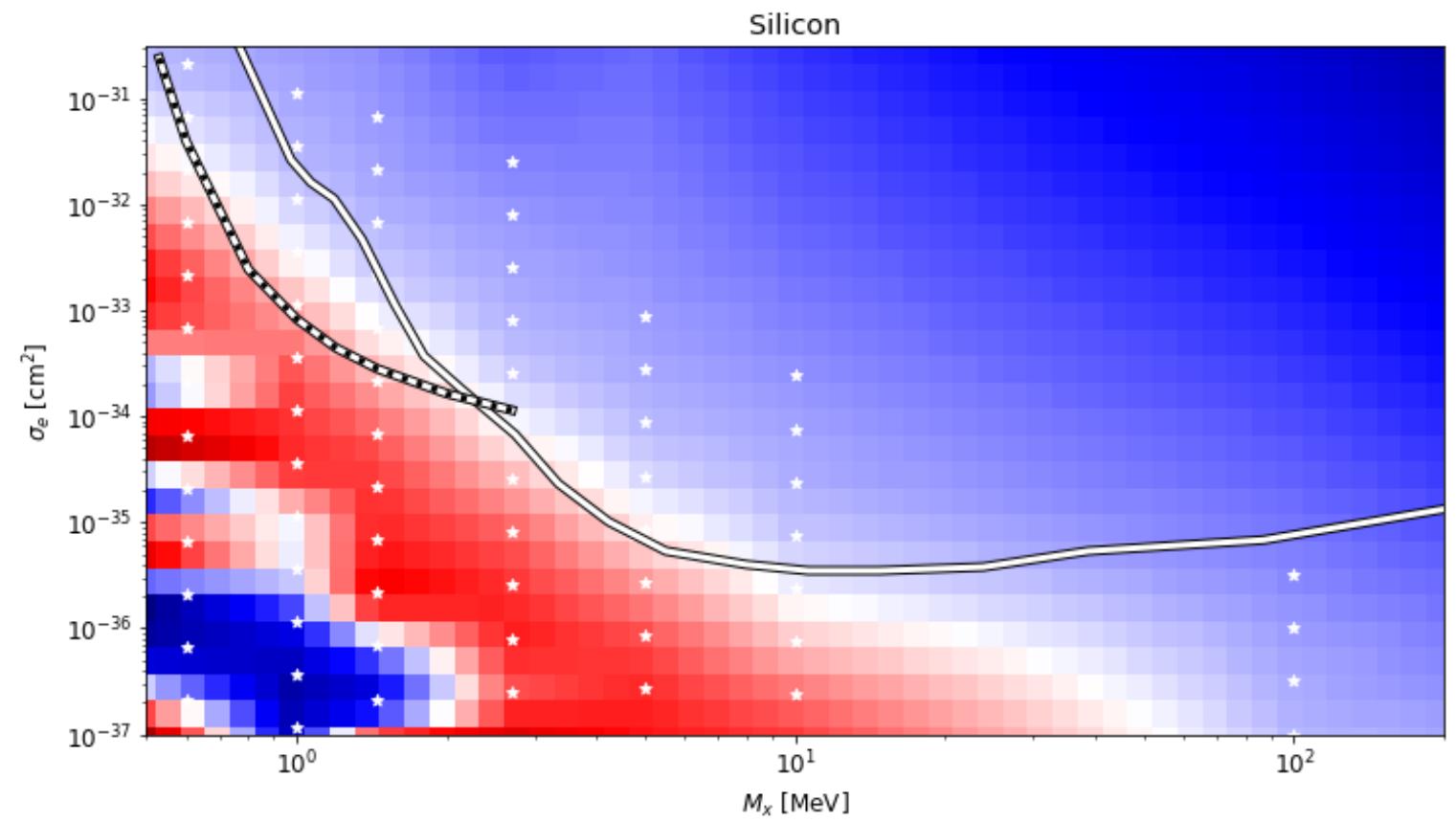
Stars are simulated data points

Fitted parameter interpolated in between simulations

White line: current best limits (Silicon: DAMIC-M;  
Xenon: Xenon1T, PandaX; Argon: DarkSide50)

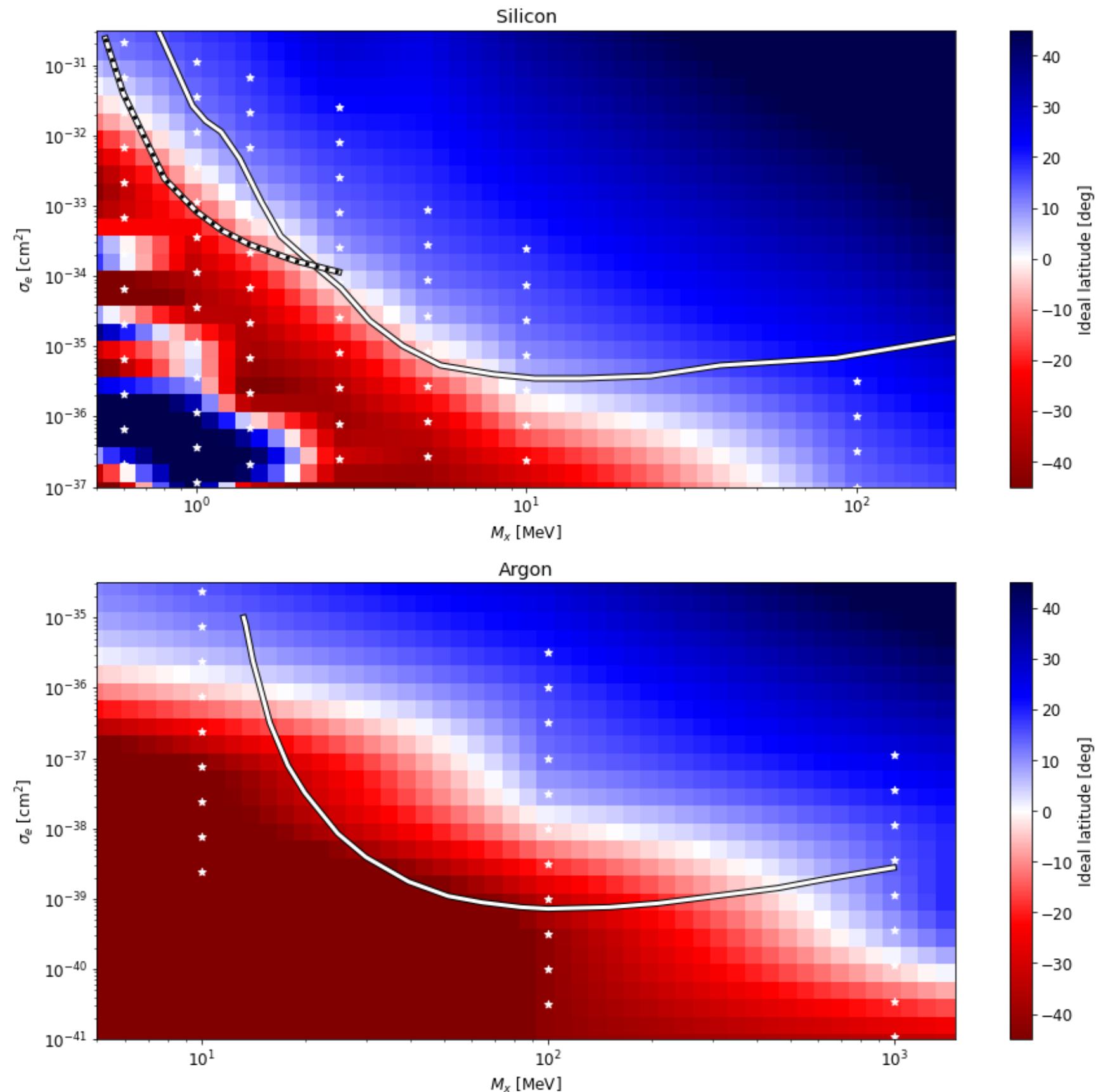
Dotted line: Modulation limit (DAMIC-M)

# INFLECTION POINT



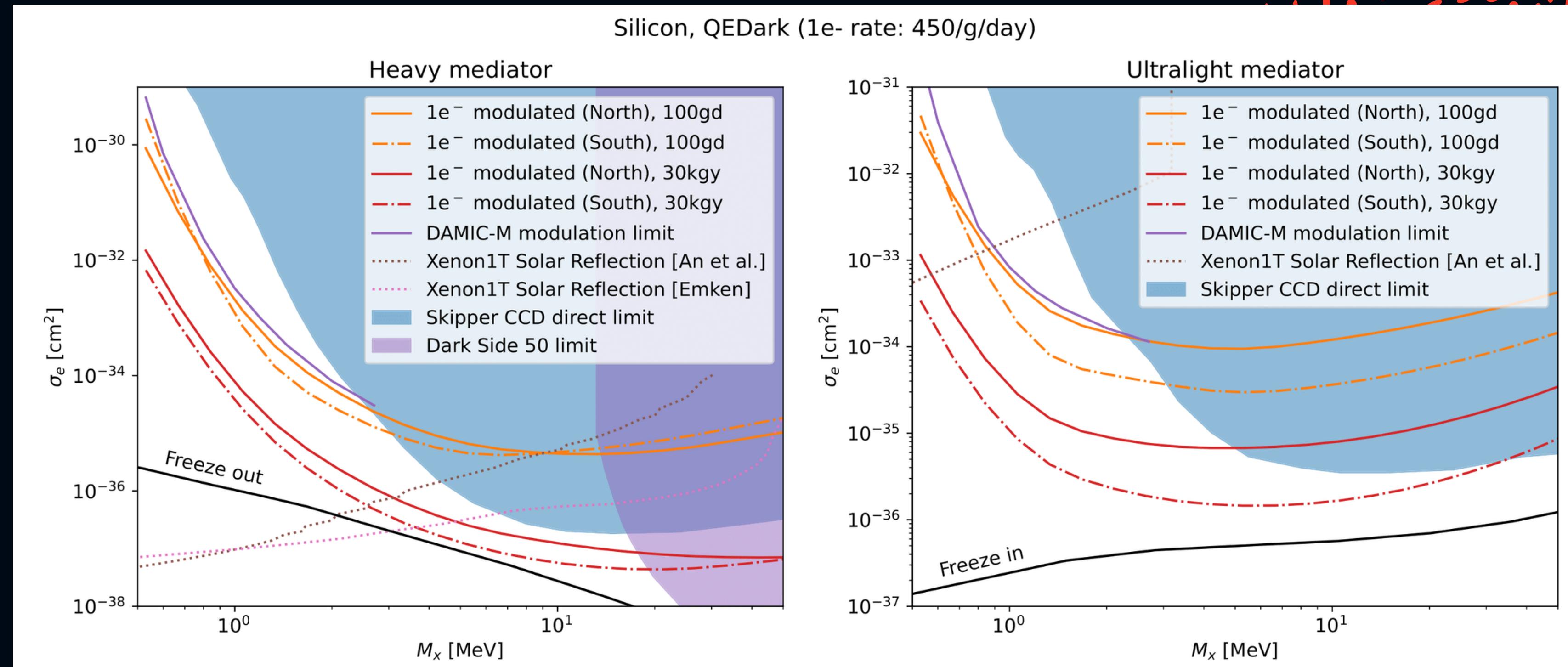
Heavy mediator  
Inflection point  
Stars are simulated data points  
Fitted parameter interpolated in between simulations  
White line: current best limits (Silicon: DAMIC-M;  
Xenon: Xenon1T, PandaX; Argon: DarkSide50)  
Dotted line: Modulation limit (DAMIC-M)

# IDEAL LATITUDE FOR OBSERVATION



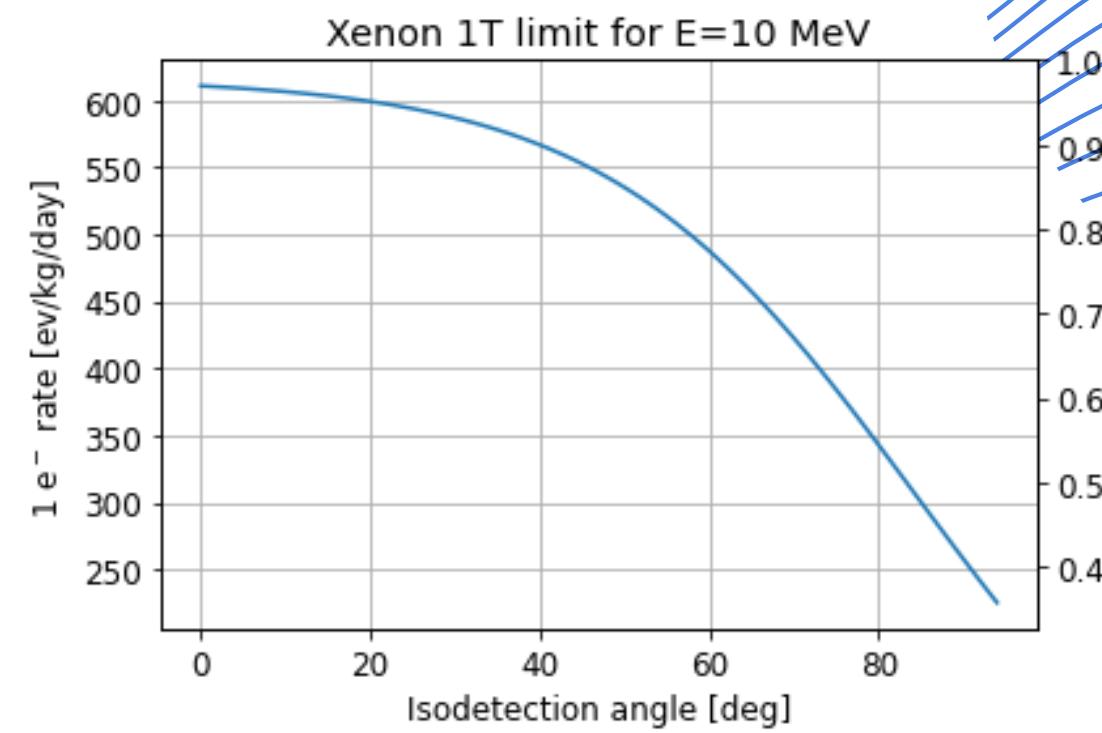
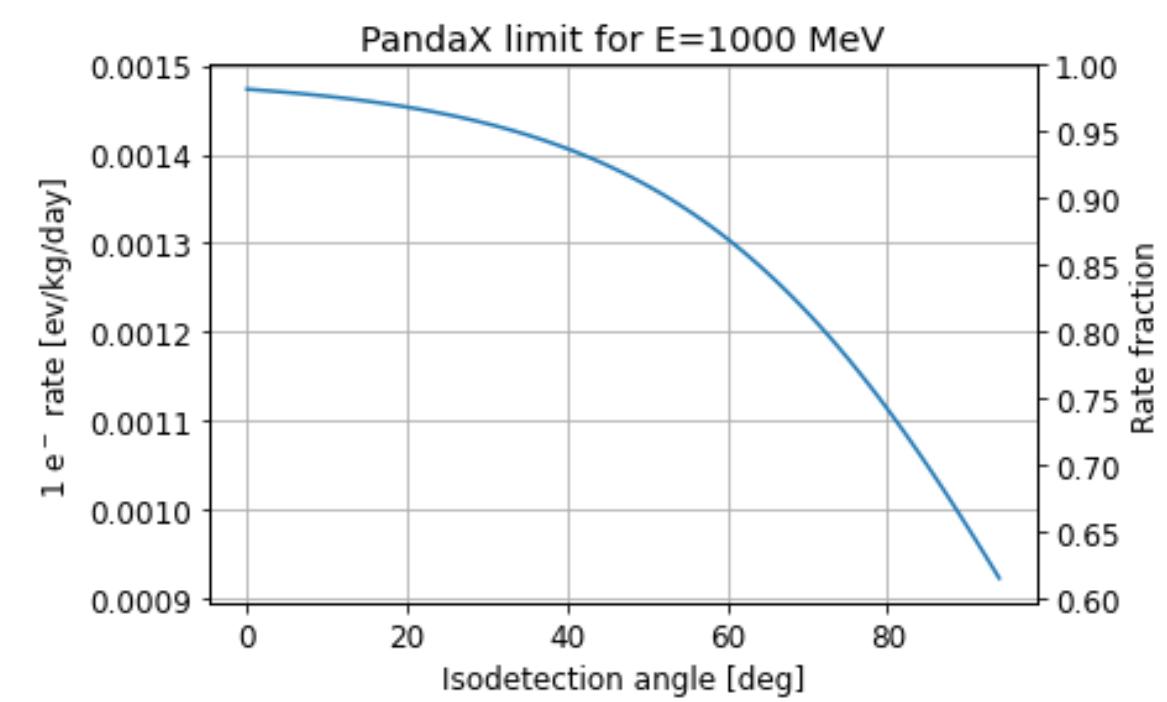
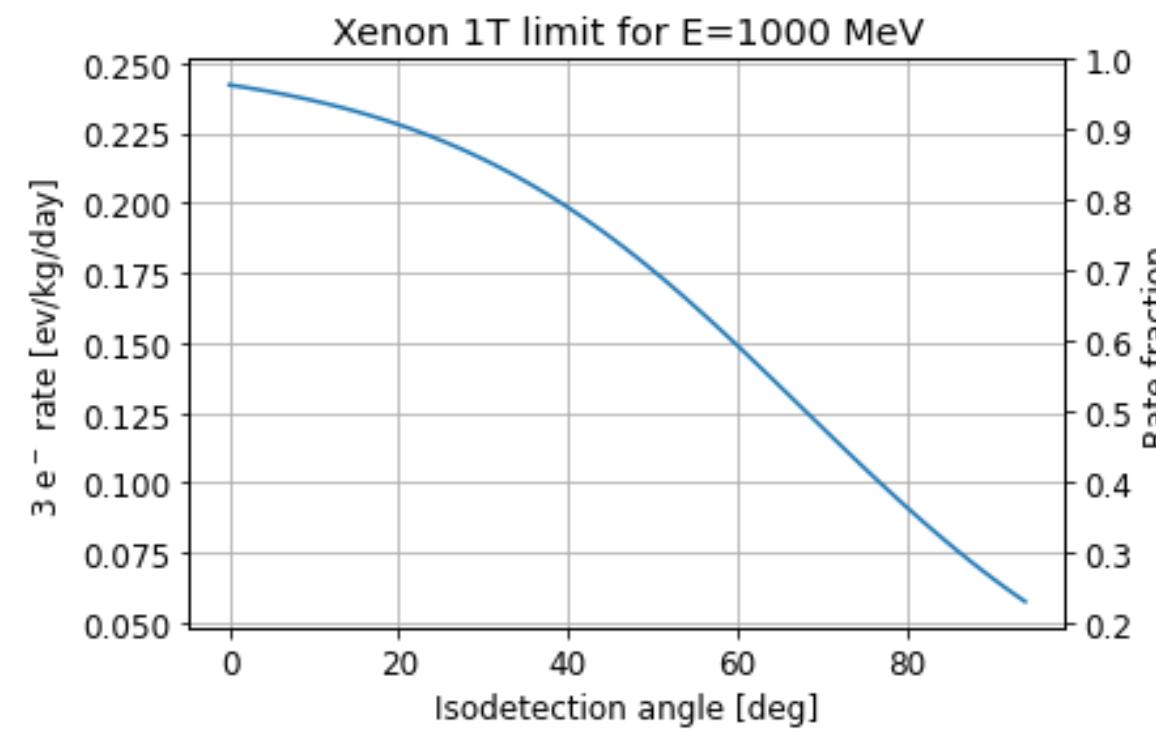
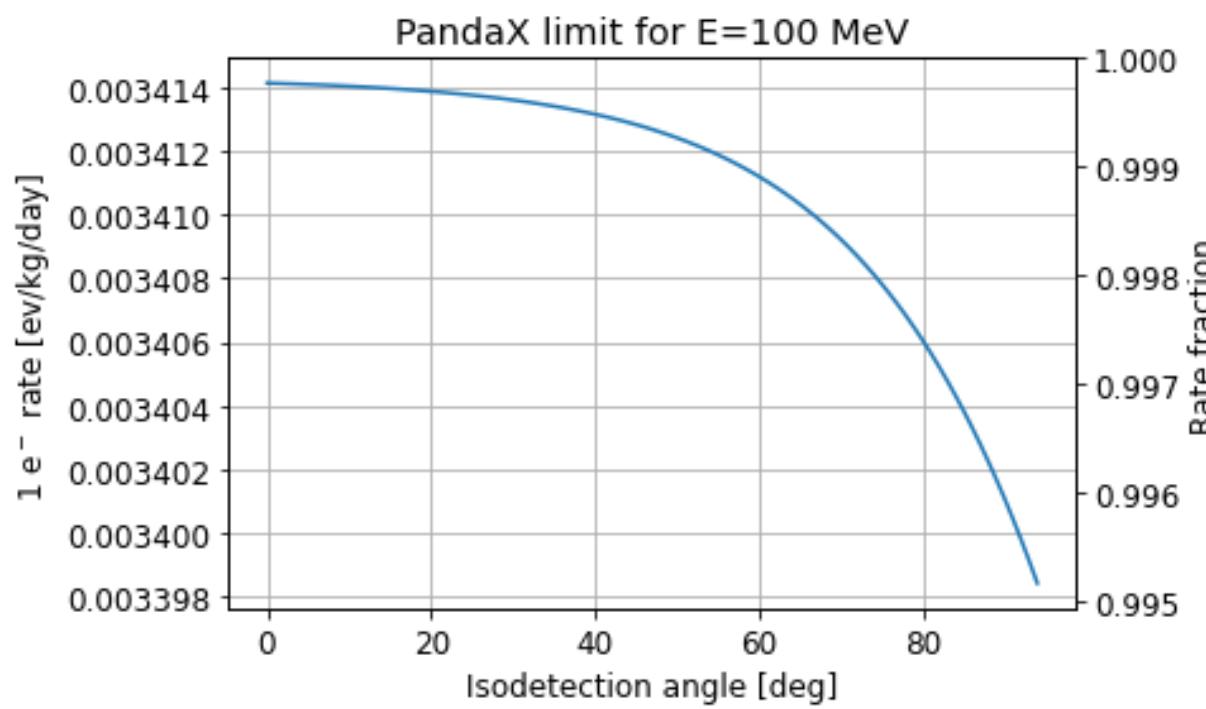
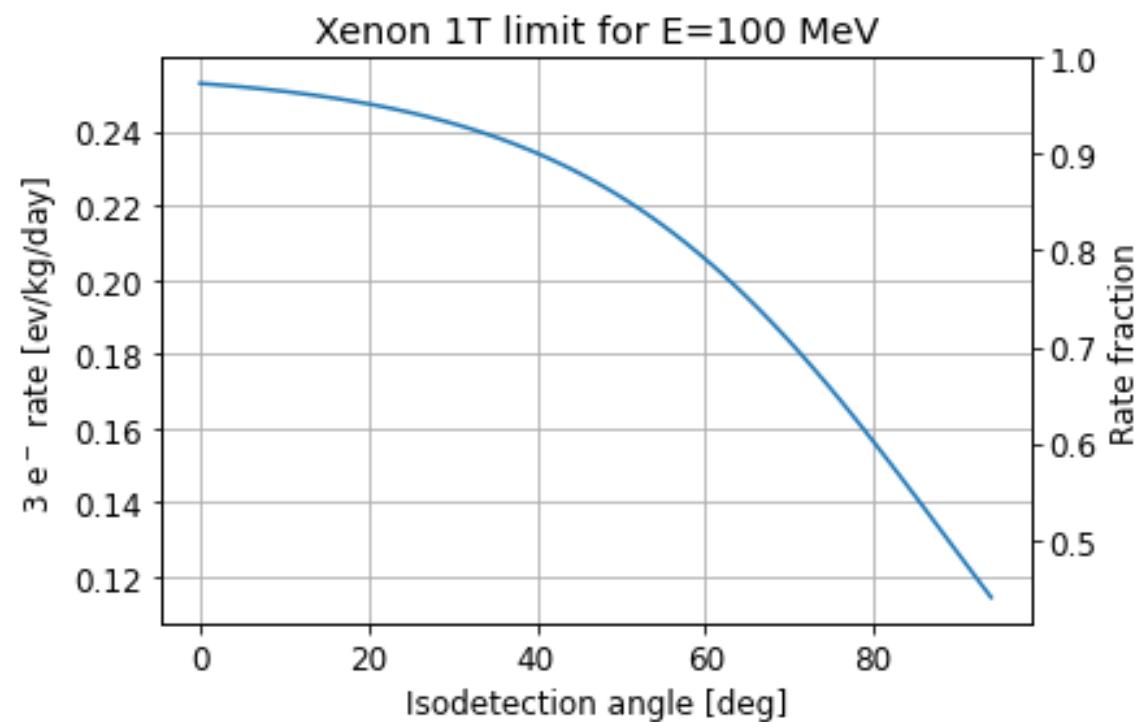
Heavy mediator  
Best latitude (90 deg – inflection point)  
Stars are simulated data points  
Fitted parameter interpolated in between simulations  
White line: current best limits (Silicon: DAMIC-M;  
Xenon: Xenon1T, PandaX; Argon: DarkSide50)  
Dotted line: Modulation limit (DAMIC-M)

# EXAMPLE APPLICATION: SKIPPER CCD



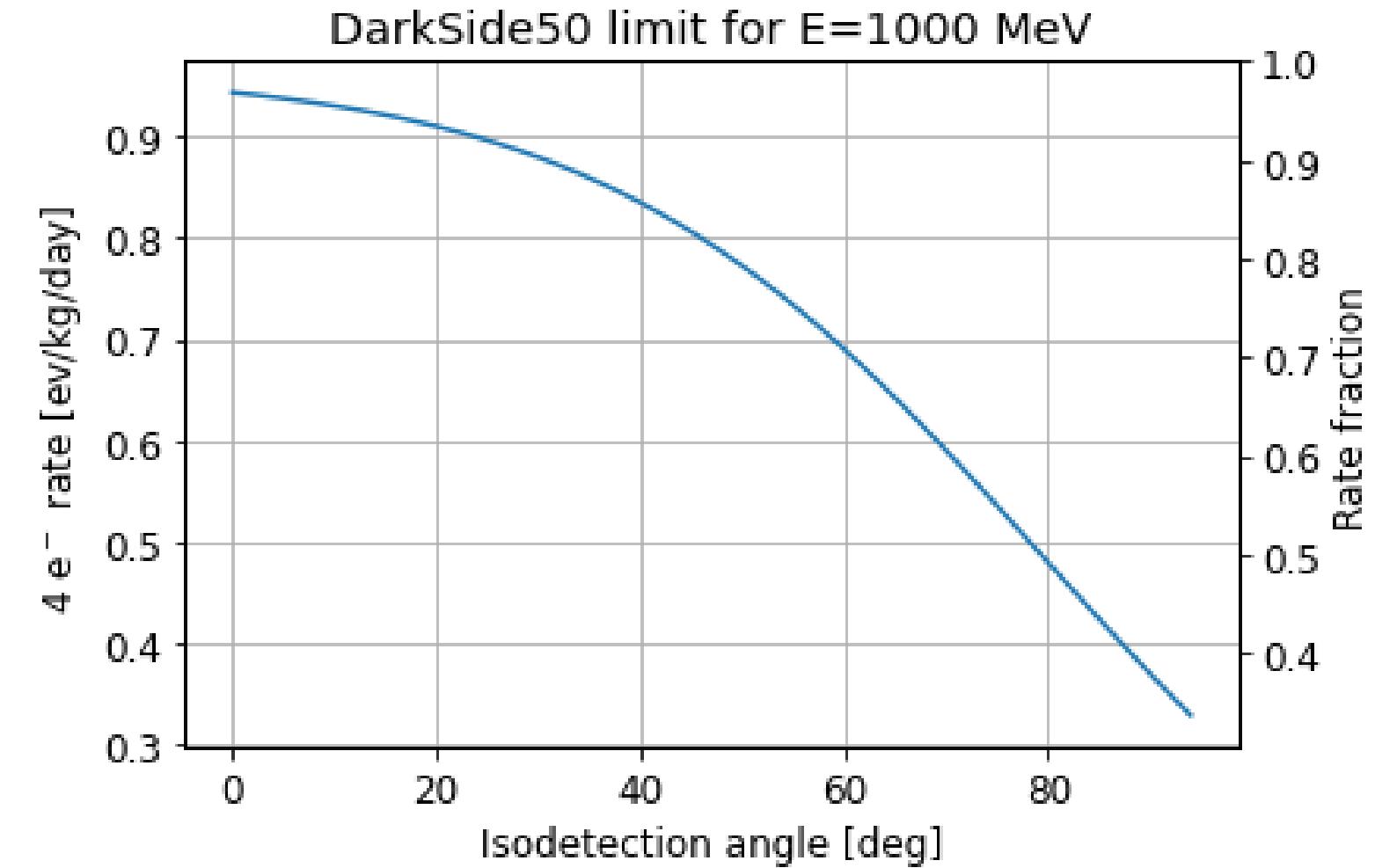
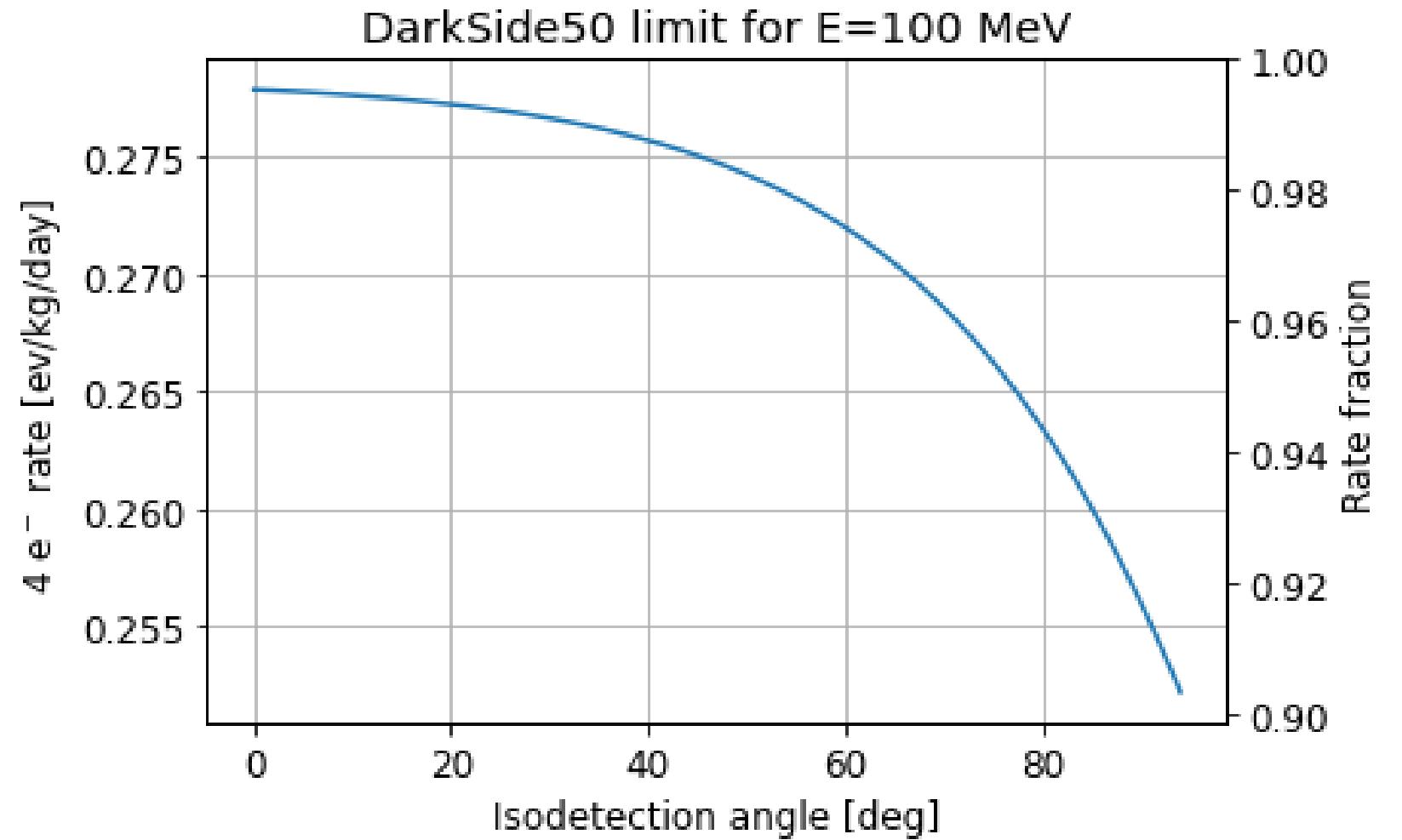
See "Search for Daily Modulation of MeV Dark Matter Signals with DAMIC-M", arXiv:2307.07251

# EXAMPLE XENON1T/PANDAX CURRENT BEST LIMITS



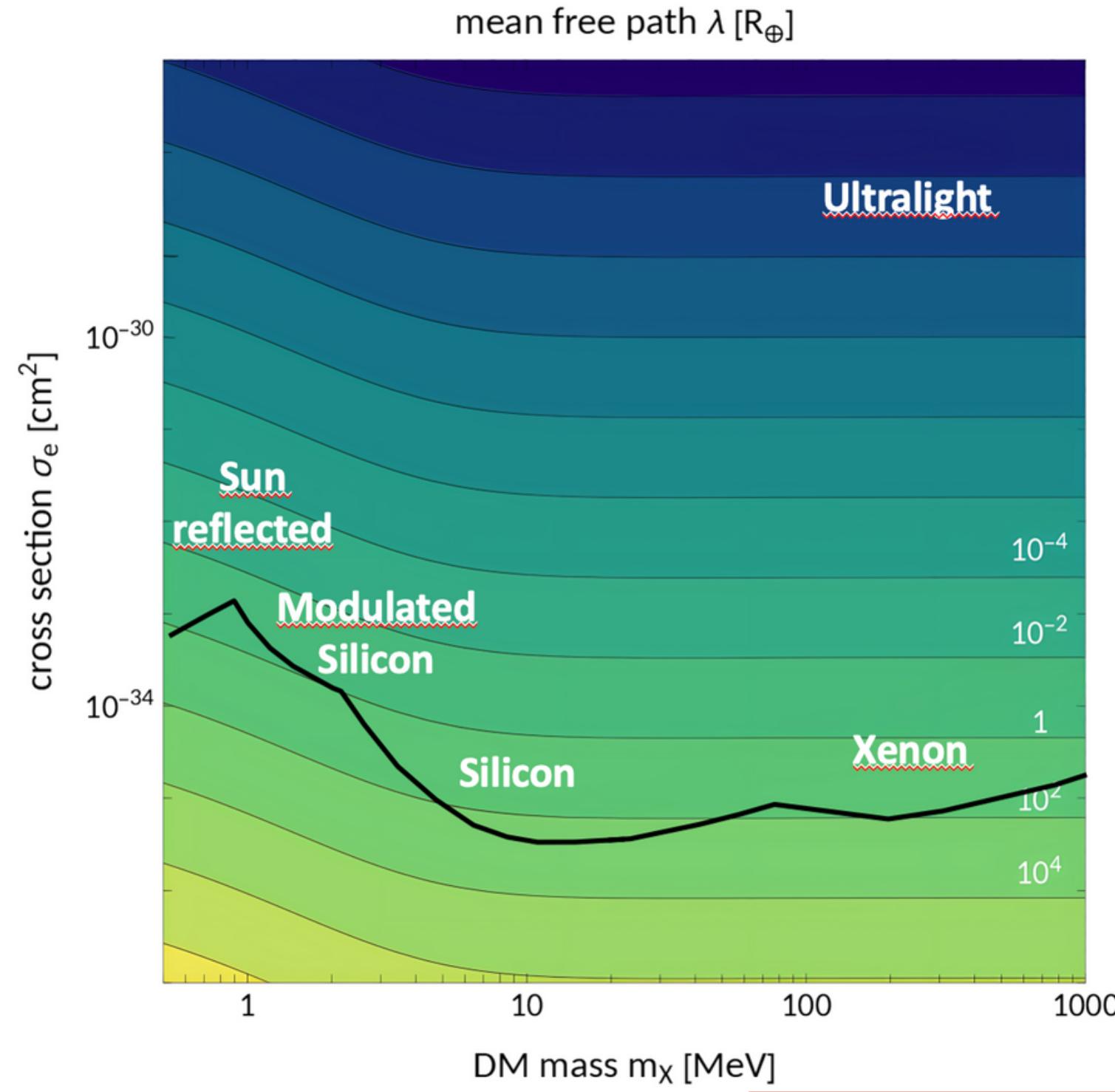
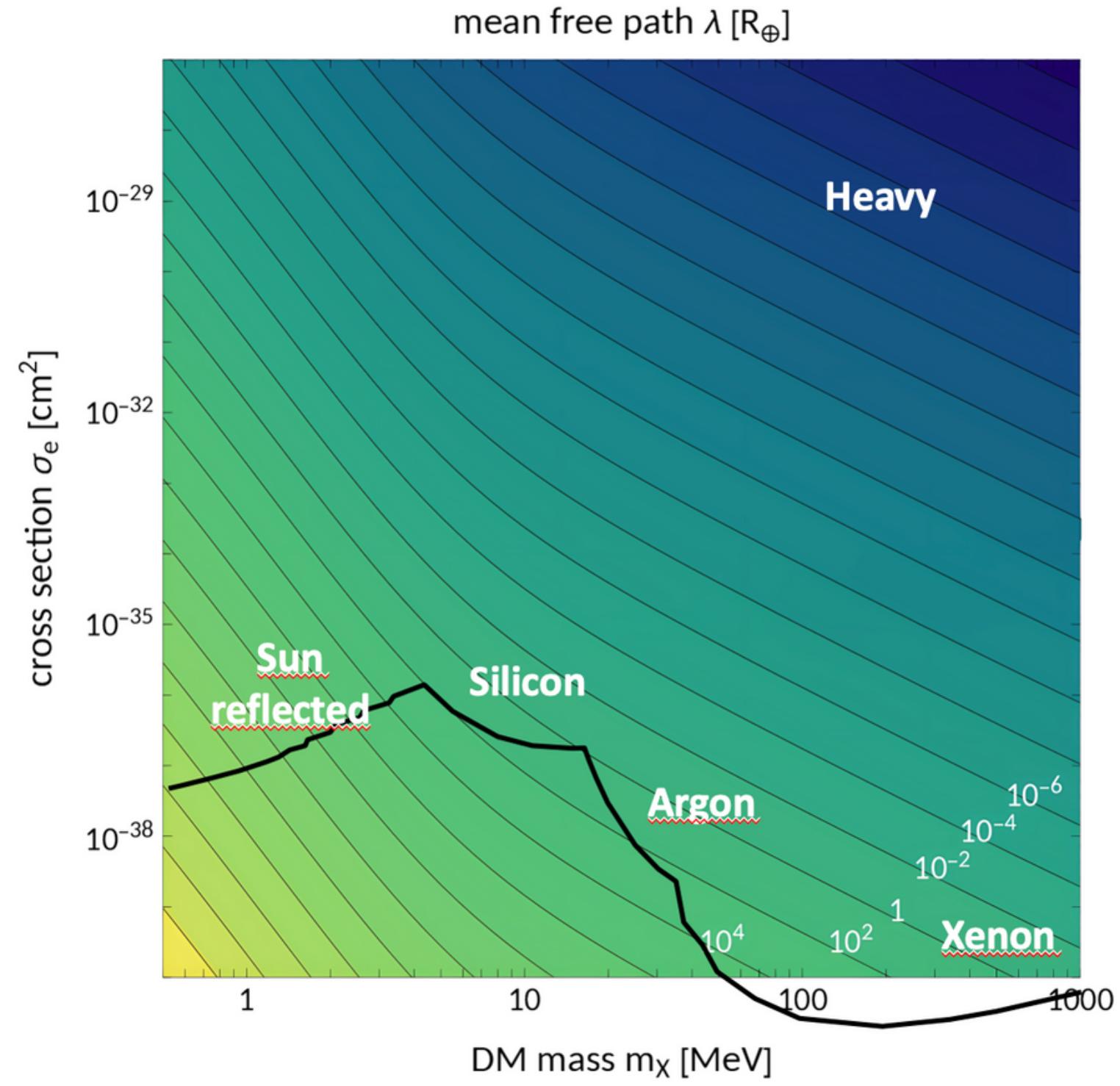
Using limits from "Emission of single and few electrons in XENON1T and limits on light dark matter" (Phys. Rev. D 106, 022001) and "Search for Light Dark Matter with Ionization Signals in the PandaX-4T Experiment" (Phys. Rev. Lett. 130, 261001)

# EXAMPLE DARKSIDE50 CURRENT BEST LIMIT



Using limits from "Search for Dark Matter Particle Interactions with Electron Final States with DarkSide-50" (Phys. Rev. Lett. 130, 101002)

# TAKE HOME MESSAGE: MEAN FREE PATH IN EARTH



# CONCLUSION AND PERSPECTIVES

- Earth propagation induces a daily modulation that provides a tool to improve limits for dark sector searches, especially close to threshold, for any detector currently in operation
- It provides the best limit for ultra light mediator in the 1 - 2.5 MeV (DAMIC-M)
- There is an interesting parameter space to explore with that method
- Current parameter space is better explored in the southern hemisphere
- If/once dark sector dark matter is observed (and is in the relevant mass/cross-section parameter space), daily modulation can be a smoking gun to discriminate it from unexpected background



# THANK YOU

X. BERTOU (HE/HIS)  
(CNEA/CONICET)

