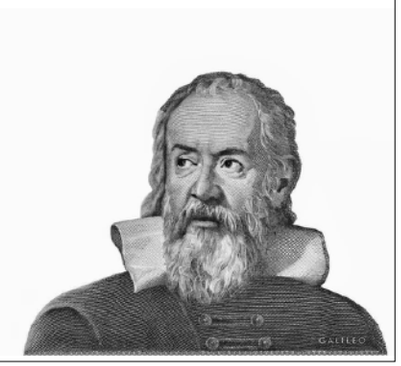
Probes of Dark Sectors

GGI 2019

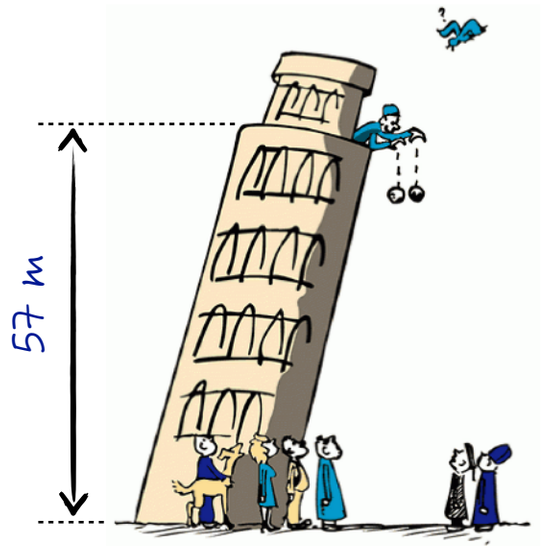
Roni Harnik, Fermilab

Featuring work with Z. Liu and O Palamara.
w/ MAGIS 100, Dark SRF, ArgoNeuT collaborations.



Dark Sector Searches - History

- Though its has become increasingly popular recently, the subject has a long history:



Galileo (around 1590):

Tested what became Equivalence principle at O(1).

Excluded Aristotle's theory of gravity.

Dark Sector Searches - History

This can be recast to a limit on a light B-L !

$$F_{\rm grav} = G_{\rm N}\frac{M_\oplus m_o}{R_\oplus^2} \sim \frac{m_p^2}{M_{\rm pl}}\frac{N_\oplus N_o}{R_\oplus^2}$$

$$F_{\rm B-L} \sim \frac{g_{\rm B-L}^2 N_\oplus N_o}{R_\oplus^2}$$

In fact, rummaging in one of the closets in this villa...

Il mio esperimento PISA 57 ha dimostrato che Aristotele è un pazzo. Inoltre, la nuova interazione B-L è limitata

$$F_{grav} > F_{B\text{-}L}$$

$$\downarrow$$

$$g_{B\text{-}L} \lesssim \frac{M_\rho}{M_{pl}} \sim 10^{-18}$$

La congettura della gravità debole lo afferma in modo interessante:

Follow-ups to PISA:

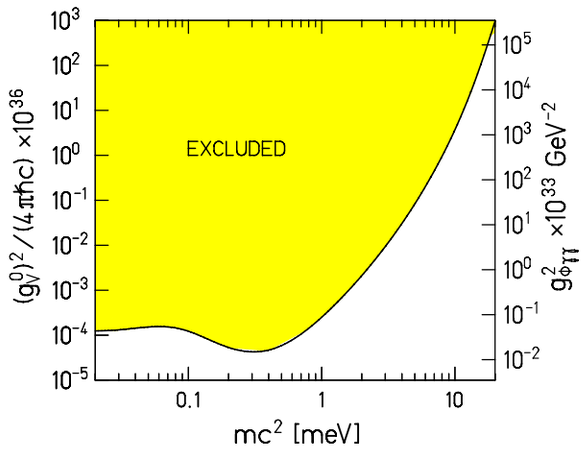
MAGIS 100

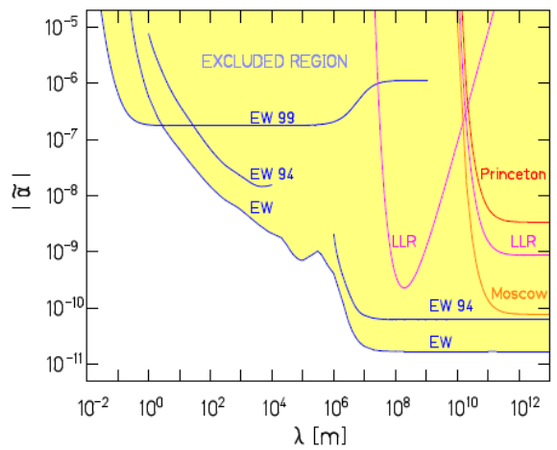
Dark SRF ?

ArgoNeuT ?

Improving on Galileo

Torsion balance experiments provide the modern test:
(see Will's talk on Friday.)





α ~ fraction of gravitational strength

[EotWash group]

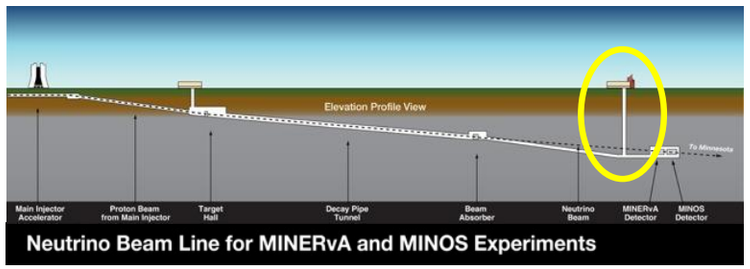
Improving on Galileo

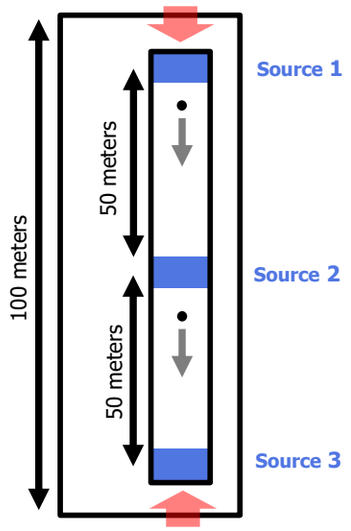
- A new Fermilab-Stanford collaboration will improve on precision test of freely falling objects.

Unfortunately, neither are leaning (yet).

Improving on Galileo

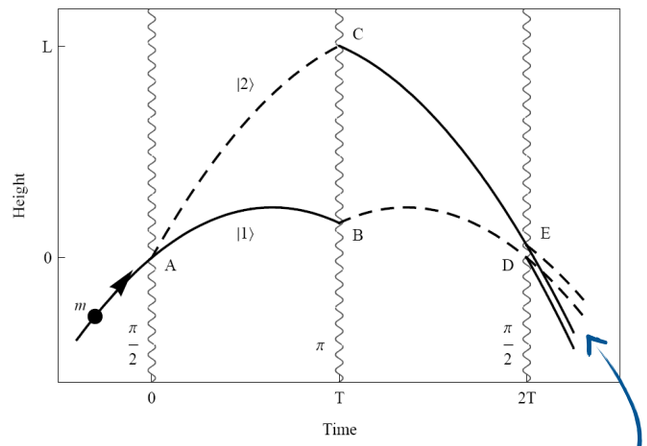
- A new Fermilab-Stanford collaboration will improve on precision test of freely falling objects.





MAGIS 100

- MAGIS 100 vs PISA 57:
  Double the hight.
  Less mass.
  More precision.



Drop atomic clocks!

Measure "fringes" in # of atoms going through two ports.

Design goal: Compare ^{87}Sr to ^{88}Sr with 10^{-16} g precision.

MAGIS 100

- Gee-whiz quantum science.
- Dark Matter and new forces.
- GW demonstrator.

PROPOSAL: P-1101
Matter-wave Atomic Gradiometer Interferometric Sensor
(MAGIS-100)

Phil Adamson[1], Swapan Chattopadhyay[1,2], Jonathon Coleman[5], Peter Graham[3], Steve Geer[1], Roni Harnik[1], Steve Hahn[1], Jason Hogan[13], Mark Kasevich[3], Tim Kovachy[6], Jeremiah Mitchell[2], Rob Plunkett[1], Surjeet Rajendran[4], Linda Valerio[1] and Arvydas Vasonis[1]

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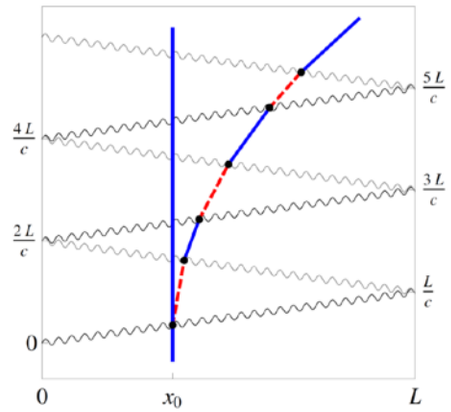
Funded by Moore foundation and DOE.

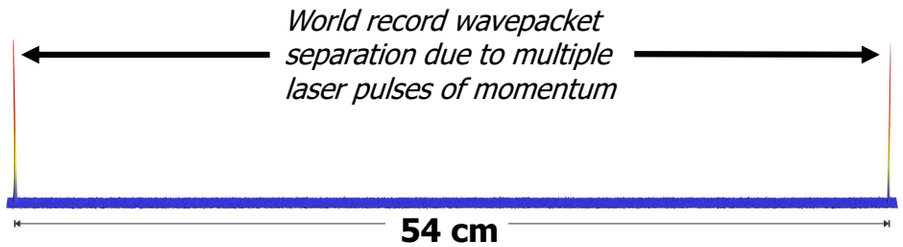
MAGIS 100 - Quantum

- Quantum mechanics: mid blown.

Large momentum transfer:

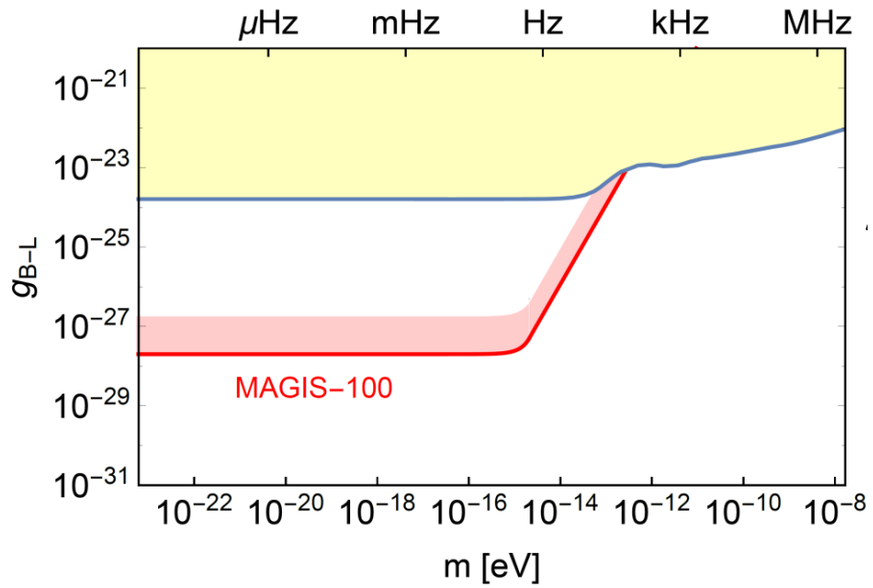


World record wavepacket separation due to multiple laser pulses of momentum



EP Violating DM

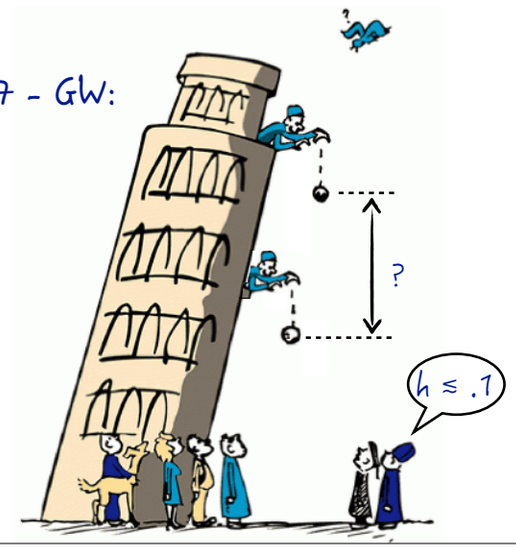
- Sensitivity to B-L Dark Matter:



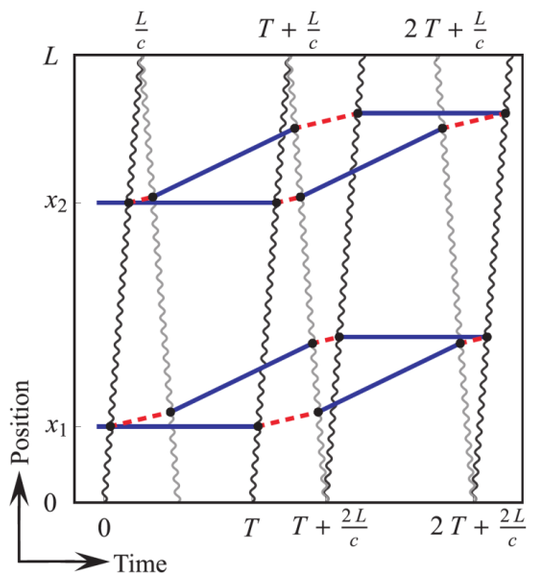
Differential measurement

- Gee-whiz quantum science.
- Dark Matter and new forces.
- GW demonstrator.

PISA 57 - GW:

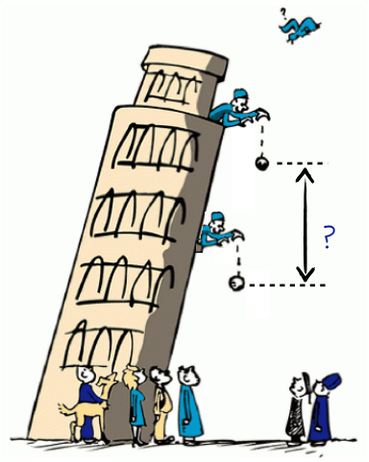


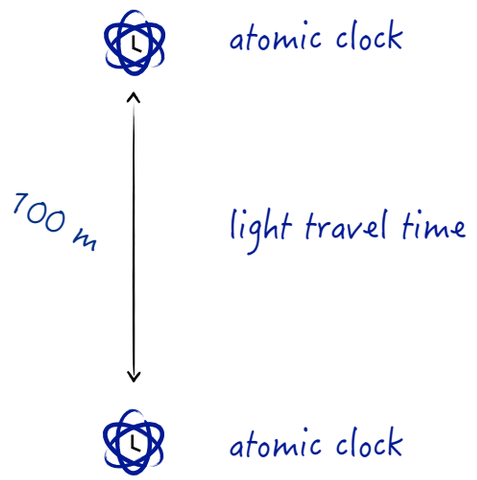
MAGIS 100 - GW:



Clock Comparison

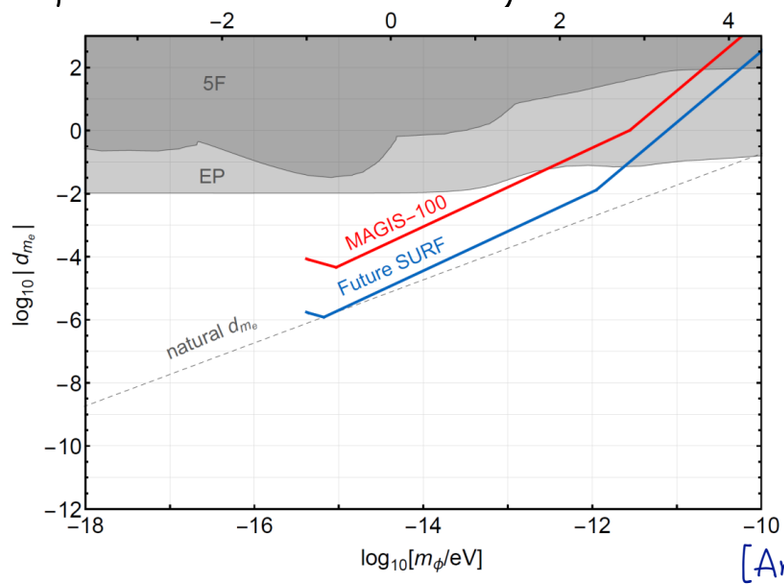
- There are two types of precise clocks here





Electron mass varying DM

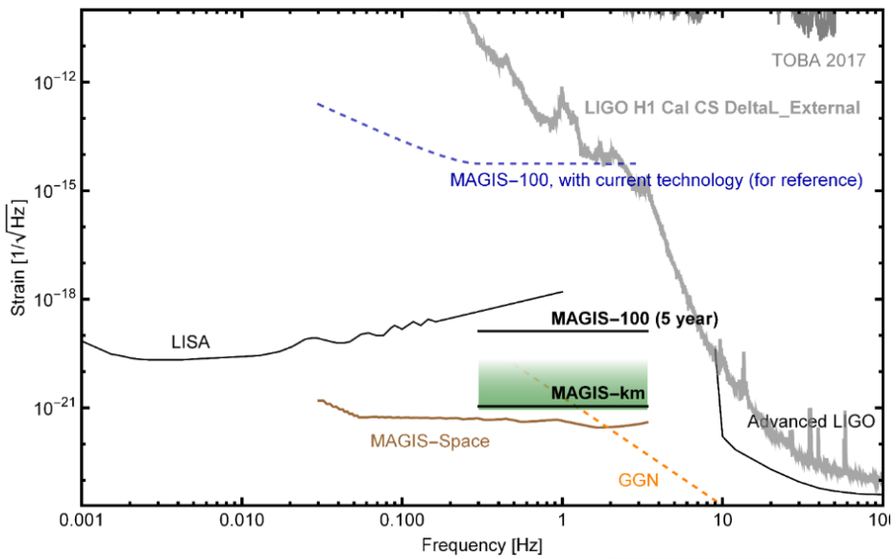
- If m_e oscilates, so will atomic clock tick rate.
- Compare Atomic clock to light travel time:



[Arvanitaki et al]

Gravity Waves

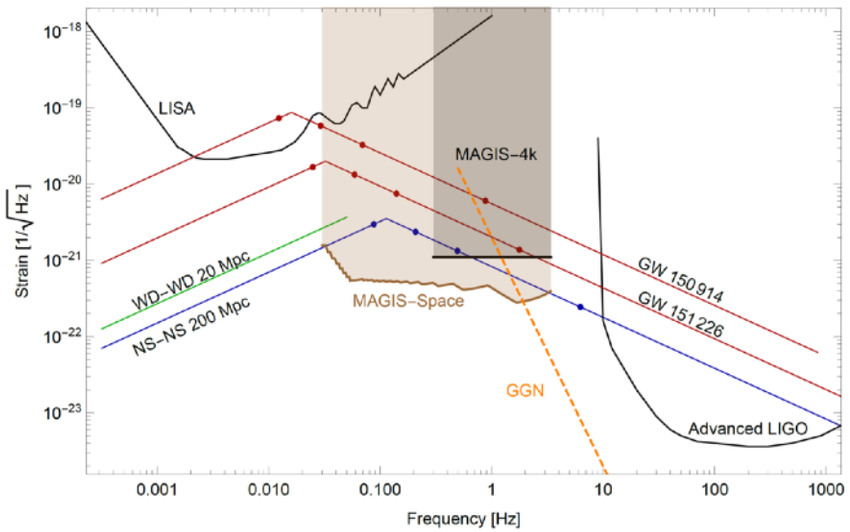
Compare light travel time to atomic clock:



	MAGIS-100 (current)	MAGIS-100 (5 year)	MAGIS-km
Baseline	100 m	100 m	2 km
Phase noise	$10^{-3}/\sqrt{\text{Hz}}$	$10^{-5}/\sqrt{\text{Hz}}$	$0.3 \times 10^{-5}/\sqrt{\text{Hz}}$
LMT	100	4e4	4e4
Atom sources	3	3	30

The Mid-Band

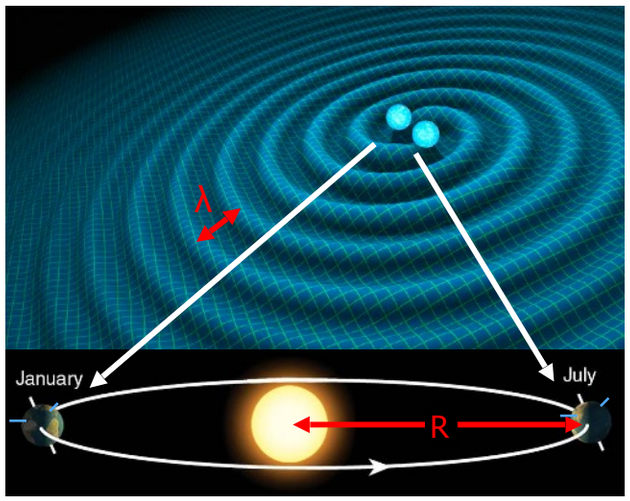
- LIGO sources will spend days to months in the 0.1-1 Hz band (mid-band).



dots: hour, week, 3 months, year

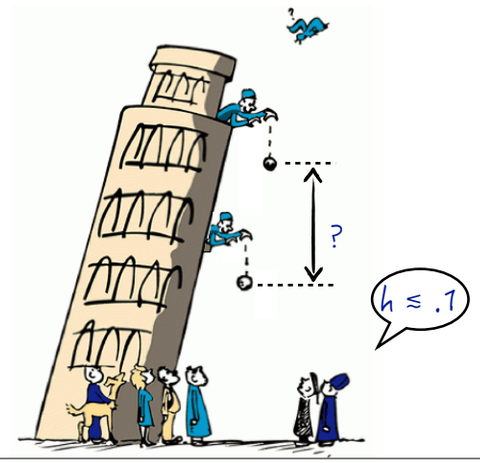
Localization

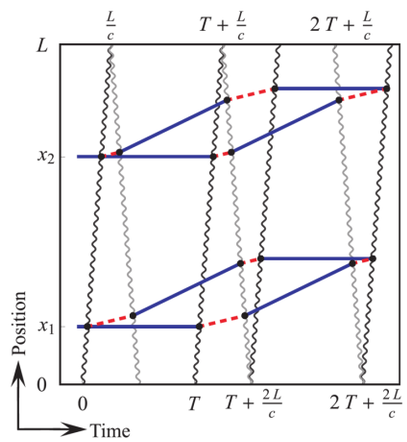
- Sources can be localized in the sky, b/c of relative angle to source (Graham et al 2015)



Conclusion

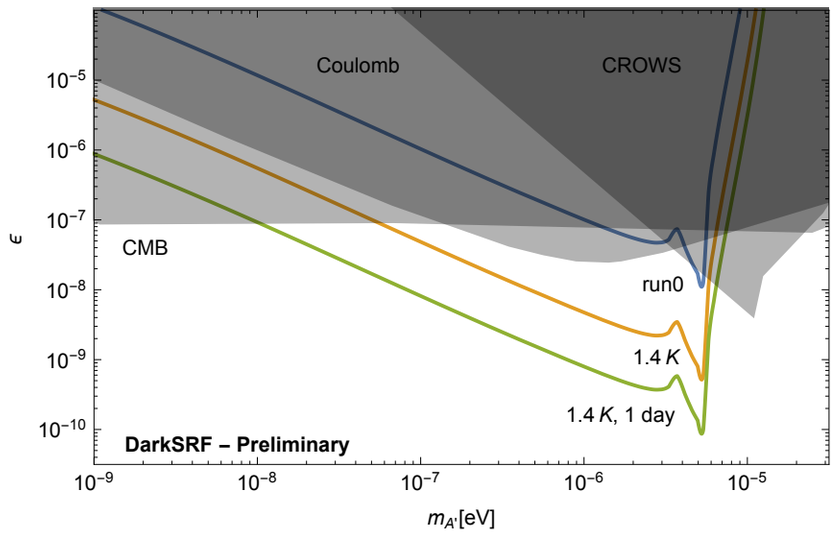
- The search for news forces and sectors is on for ≥ 400 years...
- But it has intensified recently!



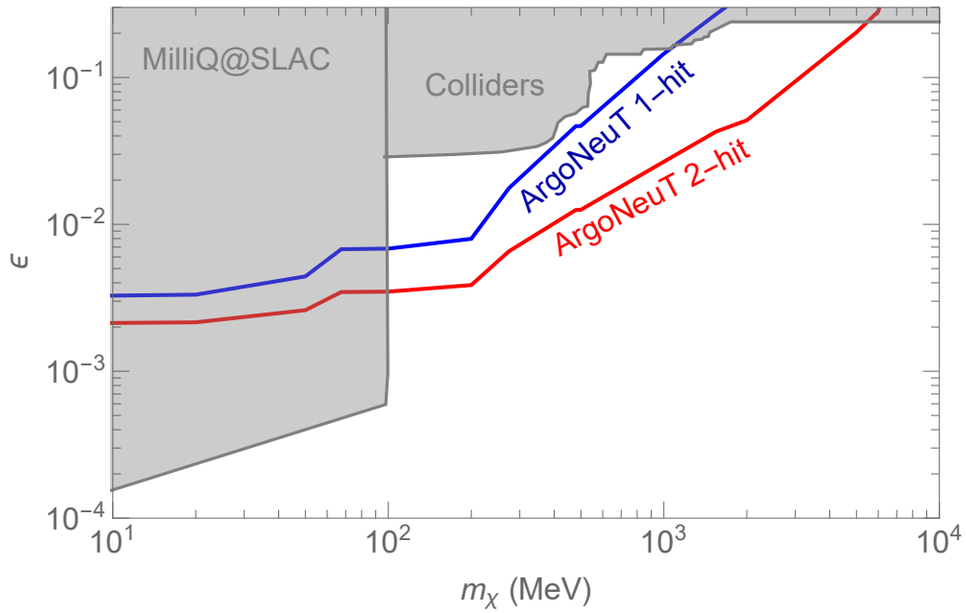


Dark SRF near-term progress (potentially in run1)

If cross-talk can be eliminated in run1, powerful new limits can be set. Thermal noise, at 1.4 Kelvin, will dominate (or a signal :-). Bellow reaches are shown for running one coherence time (1 sec!) and for a day.



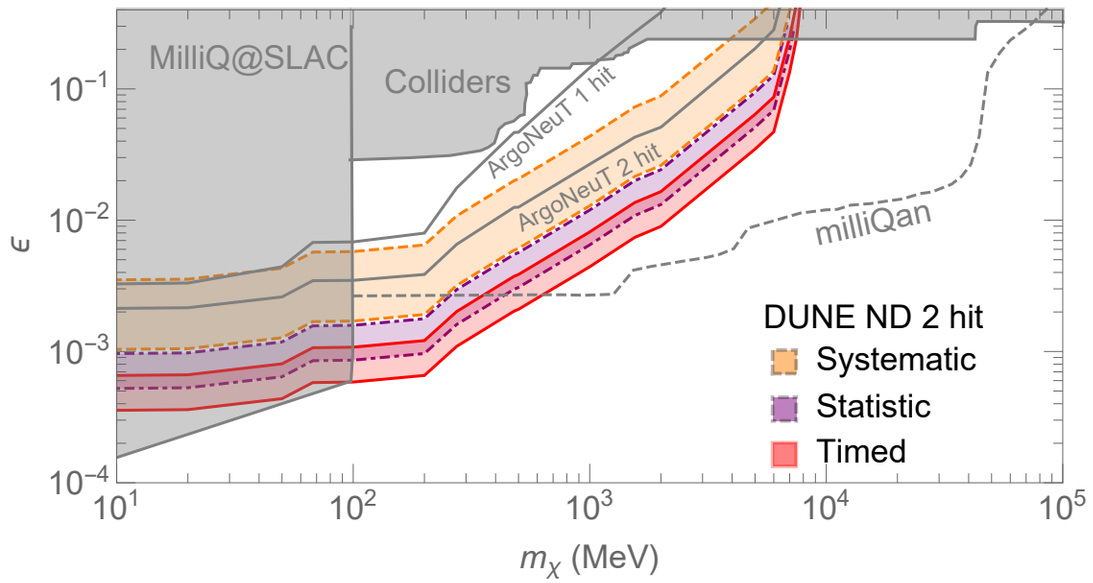
ArgoNeuT Sensitivity



A data driven ArgoNeuT analysis is underway.

Results soon!

Prospects for DUNE



Promising! but ultimately depends on BG level.
(see Yu-Dai's talk for more options)