Priscilla (Prisca) Cushman
Professor of Physics, University of Minnesota

Graduate student with the hyperon group at FNAL

Postdoc with Rockefeller on CERN UA6

Assistant Prof. at Yale: BNL muon g-2 experiment

SSC Fellowship and R&D on hybrid APDs for SDC

Recruited to University of Minnesota to start an SSC group

SSC cancelled 1 month after I moved

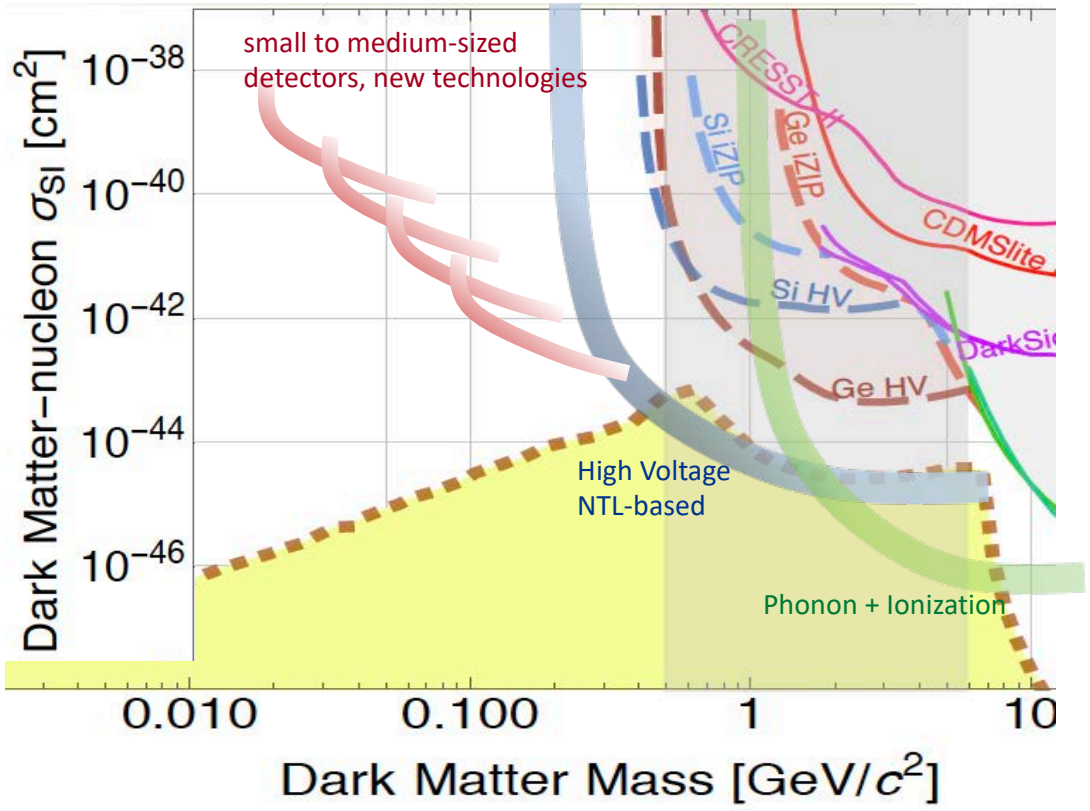
Began work on CMS (HCAL L3 manager)

Joined CDMS and helped install in the Soudan Mine

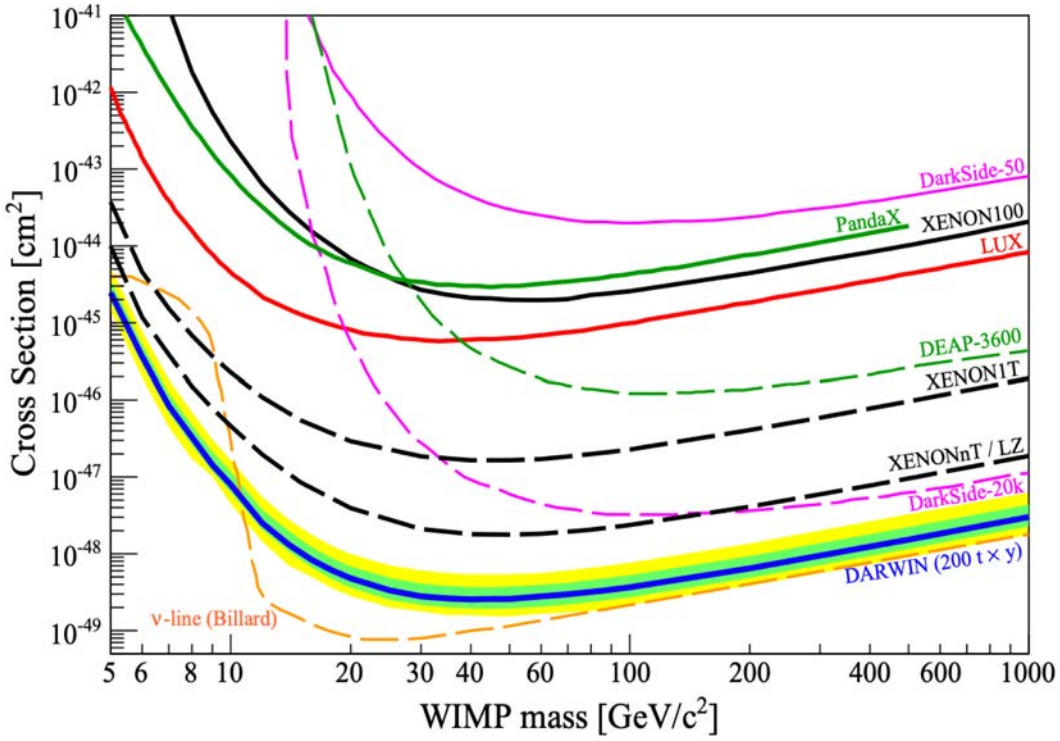
Spokesperson for SuperCDMS SNOLAB

Direct Detection of nuclear-recoiling Dark Matter currently covers two different mass regions with different technologies

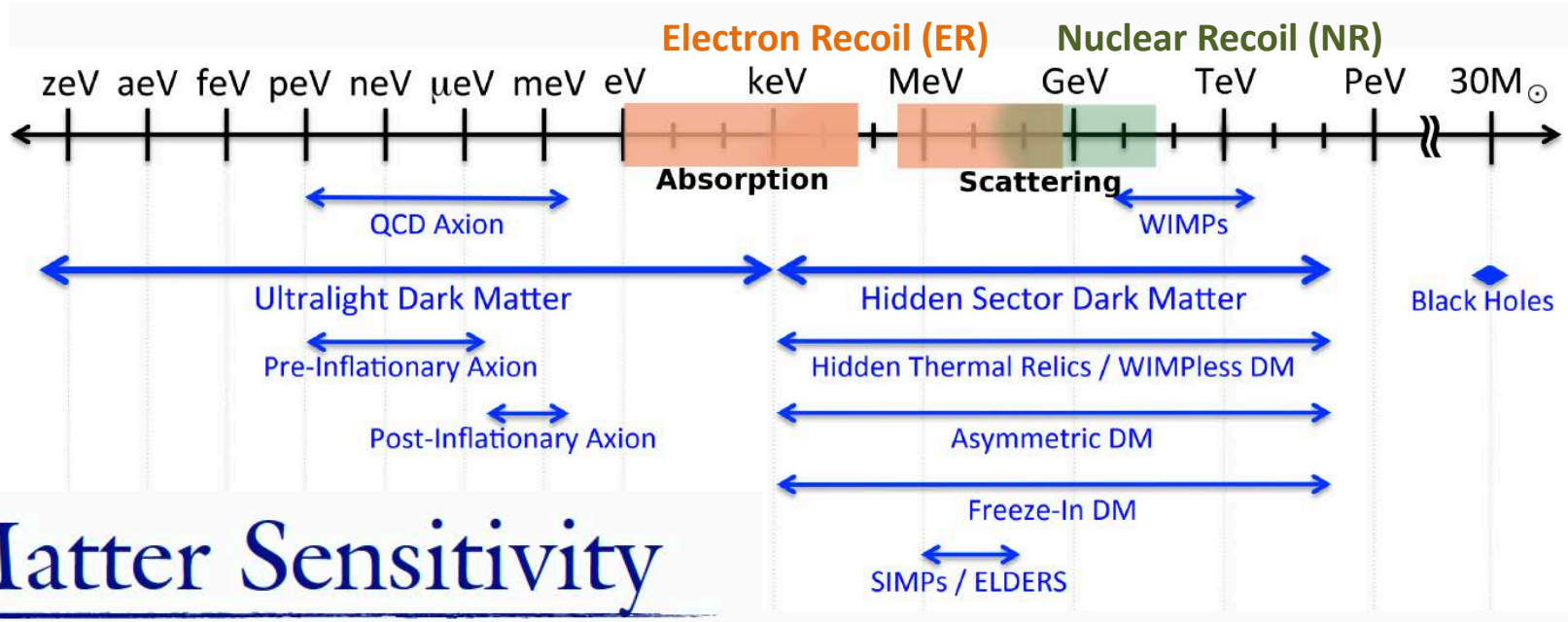
Solid state detectors are struggling with exposure $$, but continue to push lower in mass with smaller detectors and new low-threshold devices



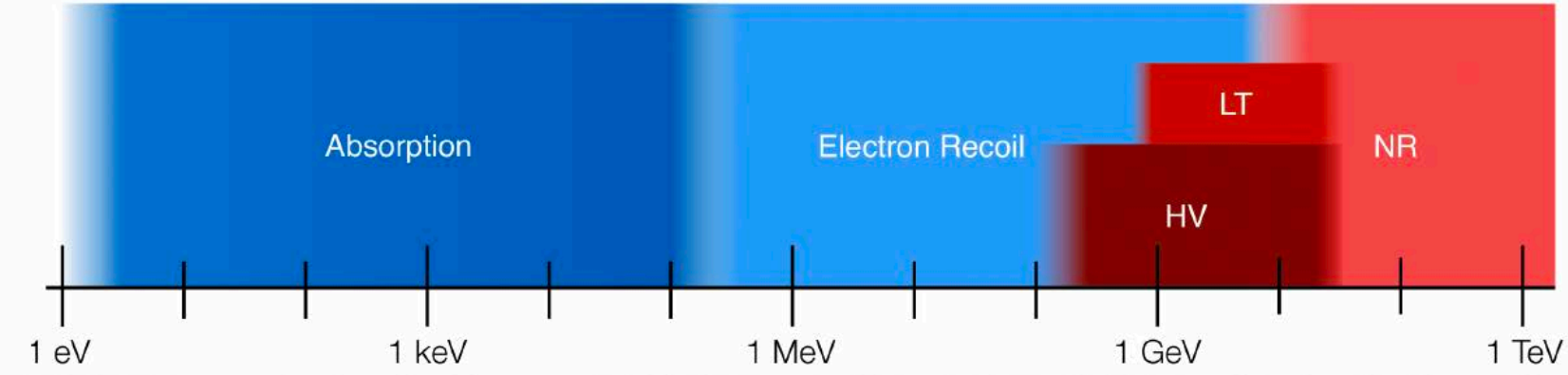
Nobel Liquid TPCs cover the WIMP landscape
They are becoming neutrino detectors.



Cosmic Visions Workshop Landscape reminded us that it isn't all about nuclear recoils



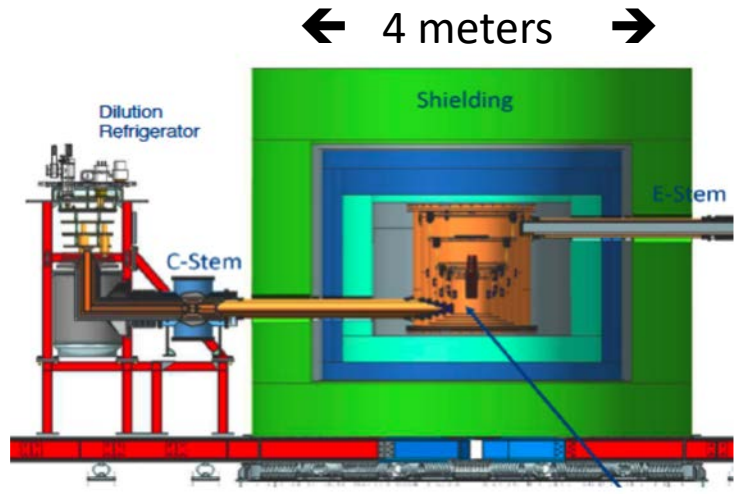
SuperCDMS Dark Matter Sensitivity



Traditional NR:	iZIP, Background free	>5 GeV
Low Threshold NR:	iZIP, limited discrimination	>1 GeV
HV Mode:	HV, no discrimination	~0.3 - 10 GeV
Electron Recoil:	HV, no discrimination	~0.5 MeV - 10 GeV
Absorption (Dark Photons, ALPs)	HV, no discrimintion	~1 eV - 500 keV (peak search)

<u>Mid-size facility needed in this range</u>

smaller than the noble liquid TPC facilities e.g. SuperCDMS will operate 24 detectors in mixed modality. Room for ~200 in the shield



Other cryogenic experiments also targeting this region

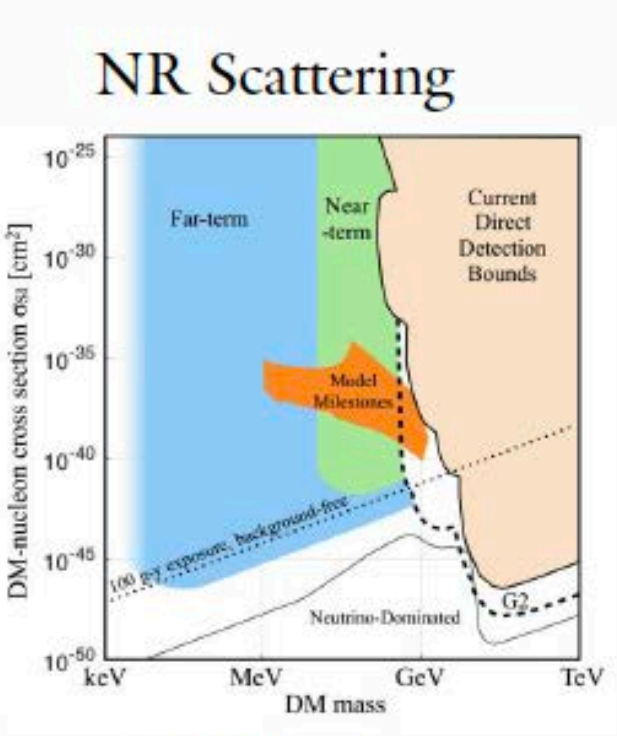
New SuperCDMS R&D
(HVeV and CPD)

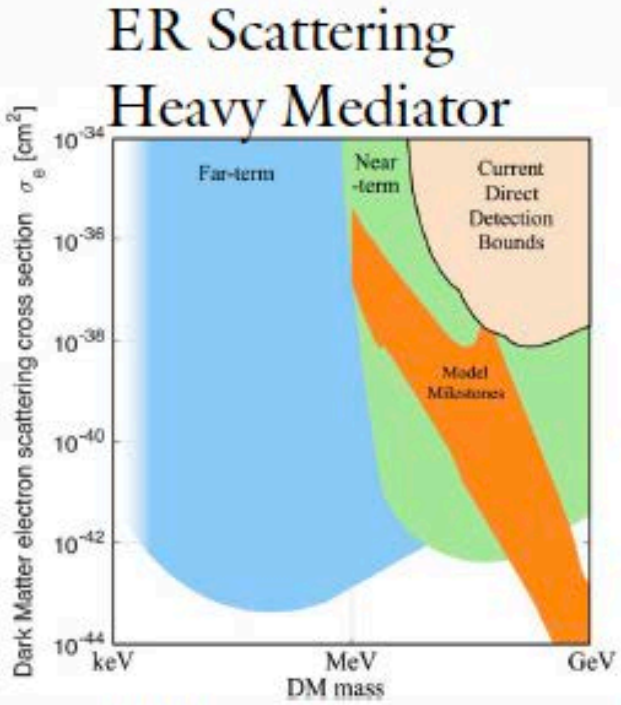
EDELWEISS (bolometers, HV)

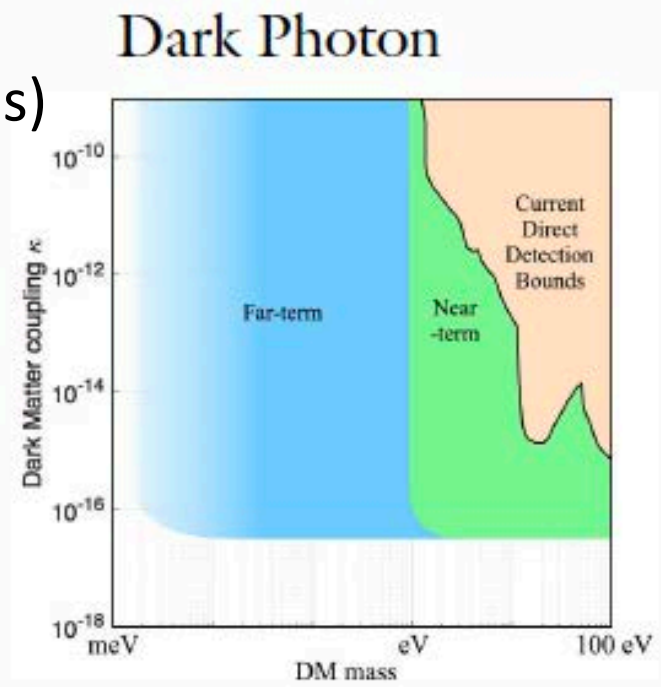
CRESST ($CaWO_4$ - also $LiAlO_2$, Al_2O_3)

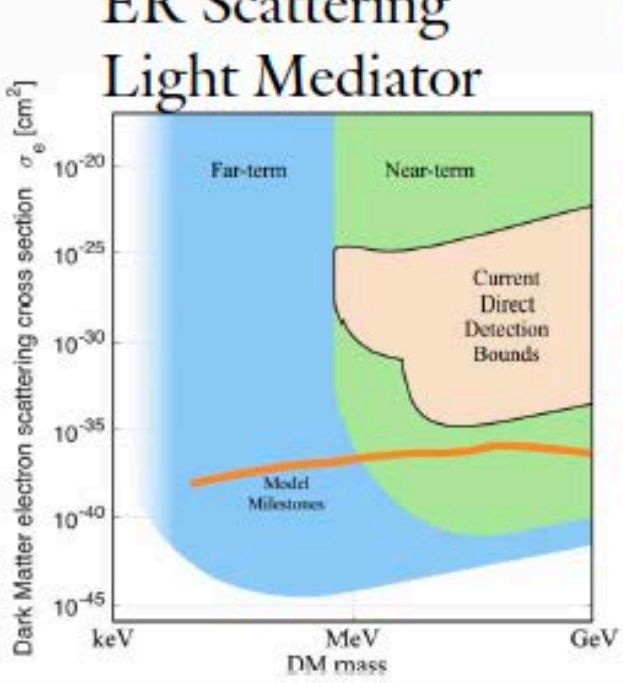
Sensei, DAMIC-M, Oscura (silicon CCDs)

HeRALD (Superfluid He)
SPICE (polar crystals)









DOE BRN Dark Matter New Initiatives

The problem is predicting the next best Dark Matter detector to put in SURF

The problem with dark matter searches is our ignorance! We don't know its mass or how it interacts
Underground needs differ by DM technology and candidate.

It is already true that new technologies are no longer about exposure, but about new parameter space
Many can be done above ground.

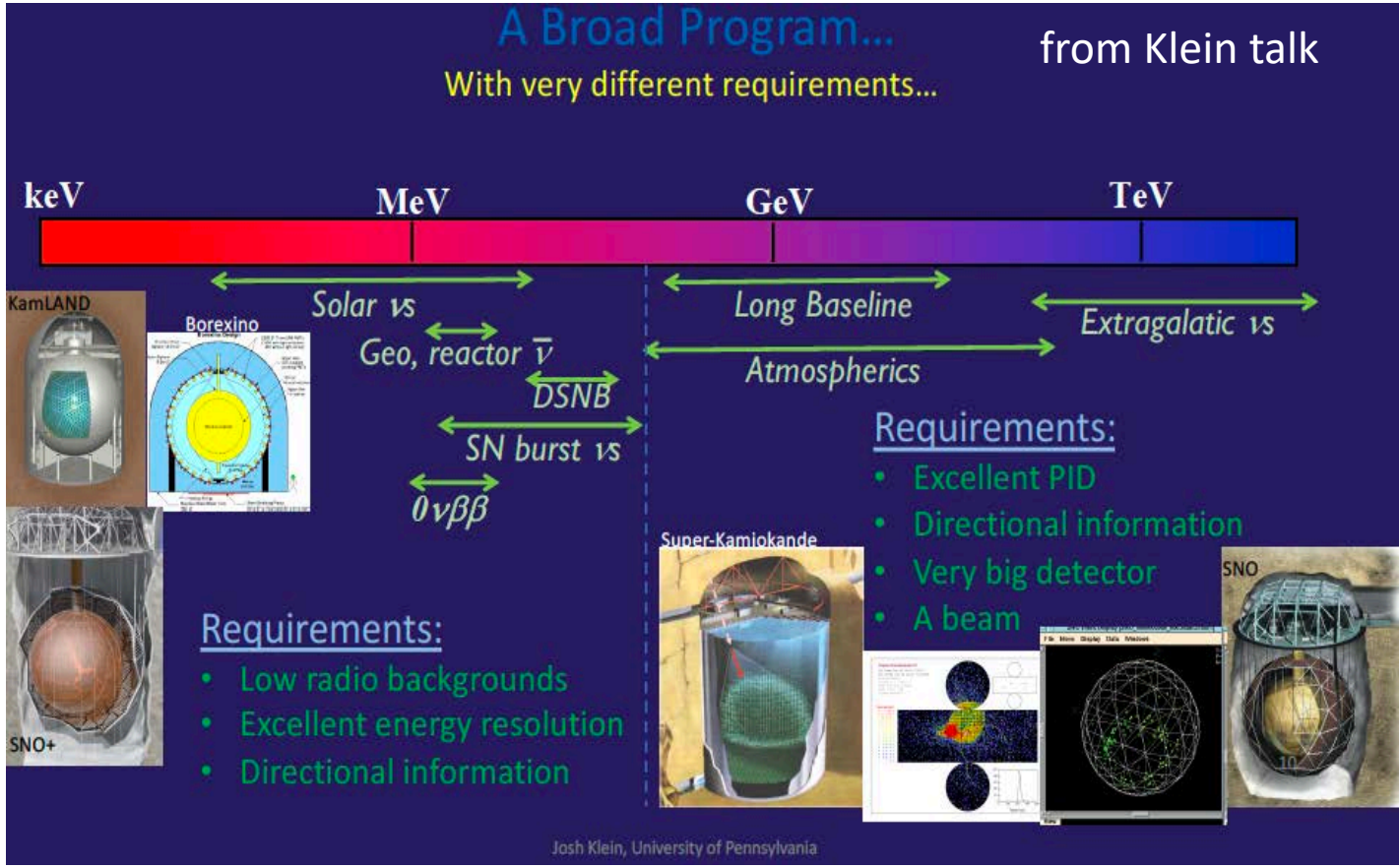
➔ Accelerator and beam dump searches
➔ Axions and wave-like DM
➔ Even Low mass DM with solid state and/or superfluid He: R&D starts at the surface.
Modest space requirements underground

Future Noble Liquid TPCs need BIG cavern installations, many are already spoken for. After LZ, what?

Paradigm shift coming up. If no WIMP-like DM found down to the neutrino floor, attention will shift to
Annual modulation (crystals) - Multiple northern and southern locations
Moderate Depth, Excellent purification techniques
Directional detection (wire chambers/TPCs etc.) large installations still needed for full exposure

AND different candidates ➔ less need for large underground space

SURF should brand itself as the premiere neutrino laboratory
Build on your strengths to create an "ecosystem" of international underground labs with complementary expertise



Strengths

Large caverns (engineering expertise)
Multiple campuses and room for expansion
DUSEL legacy and Low bkgd counting infrastructure
Surface sites at local institutions

A neutrino beam!!
A flagship neutrino experiment (DUNE)
Space for more exciting BIG neutrino installations
Neutrinoless double beta decay (Majorana)
CASPAR - upgrades? new location?
Sell new experiments on the neutrino physics and related infrastructure.
Maybe the next noble liquid TPC is a neutrino experiment and dark matter is a background *(just kidding….?)*

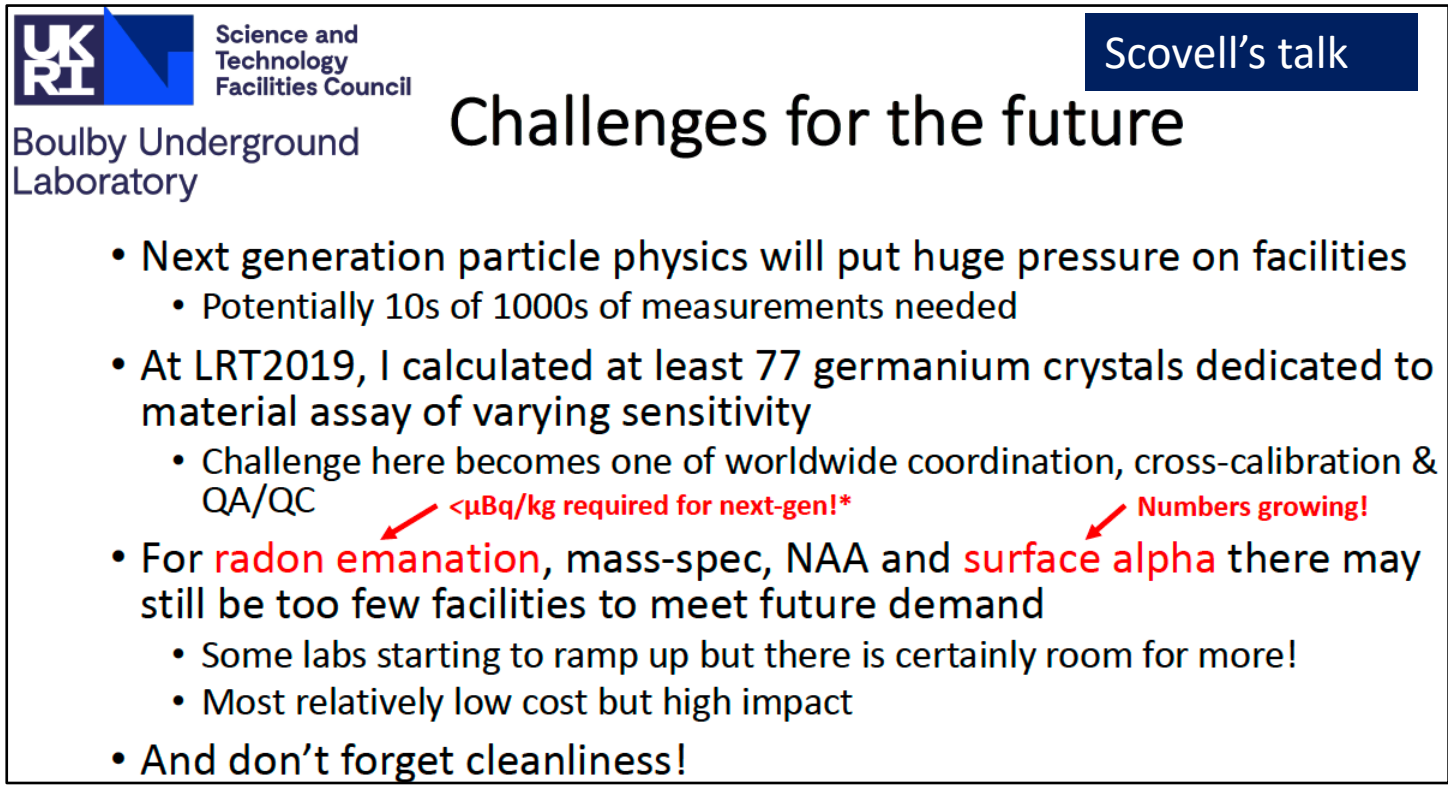
Another strength to capitalize on is Low Background Infrastructure and assay techniques

Sheer amount of screening needed ➔ MORE dedicated space for ultra-sensitive screening
Make connections to other screening facilities and unify the process
This does not easily happen from the top down – Progress tends to driven by the experiments
e.g. LZ and the UK collaborators ➔ Boulby
But that leaves out smaller players and non-physics applications needed to build up a multi-disciplinary bio/geo presence.

Large space needed for

- Crystal growth and fabrication
- Copper Electroforming
- Stockpile of cosmogenically-sensitive materials
- Water shielded ultra-sensitive screening space

The ultimate low background facility
was explored in the context of DUSEL
and all the engineering still exists.



A DUSEL vision of a world-class Low Background Facility

Entire facility is class 10,000 clean room, < 20 Bq/m^3

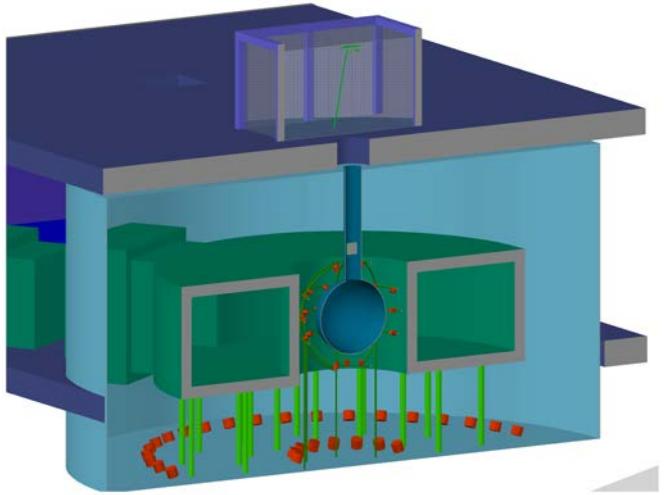
- Radon-mitigated zones (<1 Bq/m^3) and assembly areas (<0.1 Bq/m^3)
- Radon-free storage and unified LN system
- Wet benches, clean machining, hoods, Several class 1000 clean rooms

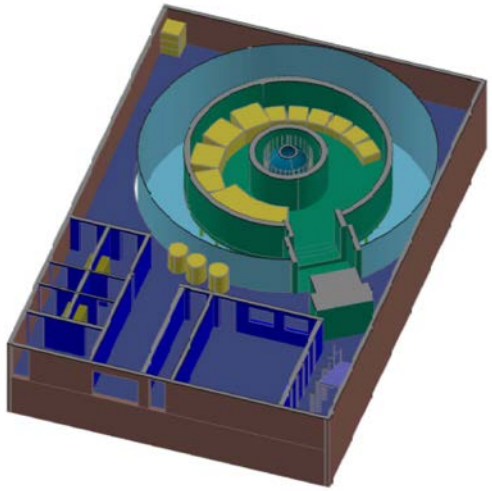
Instrumented Water Shield with toroidal interior acrylic room

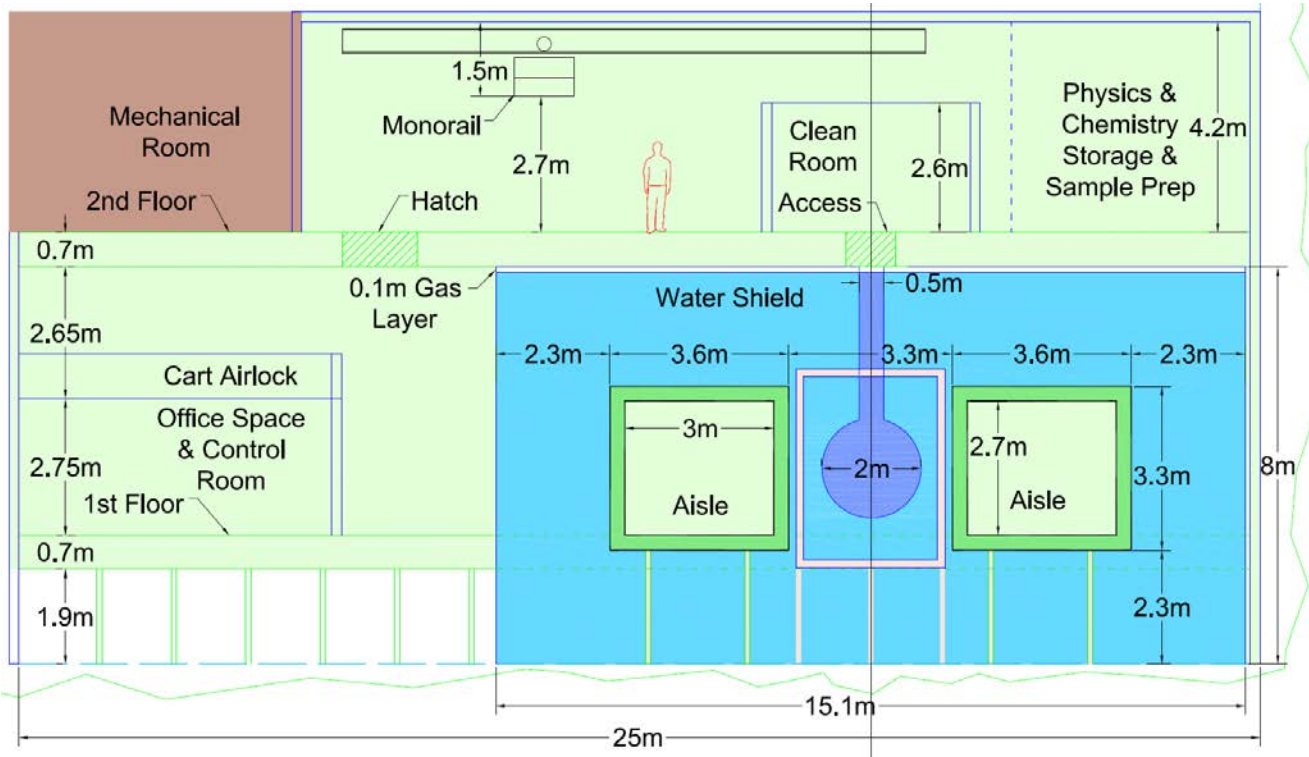
- Much cheaper than individual lead castles. Instrumented water shield provides veto capacity, bkgd monitoring.
- Houses ultra-sensitive screeners, staging space for experiments & R&D Prototypes
- Serves as the outer shield of the Immersion Tank

Central Top-loading Immersion Tank

- modeled on the Borexino CTF – whole body counting

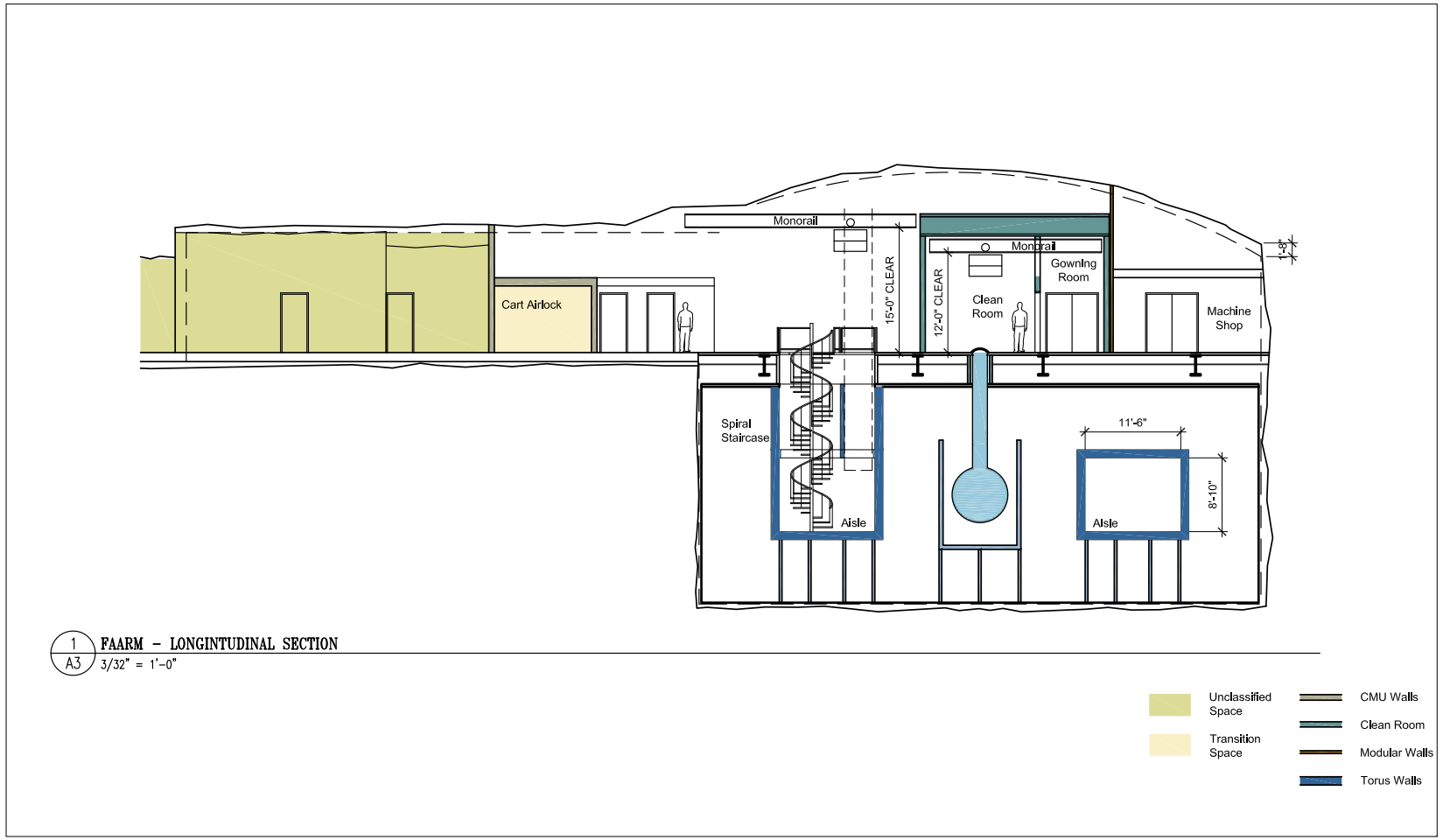






A DUSEL vision of a world-class Low Background Facility

Original Design fit into “Lab Module 2” in DUSEL plans at Homestake.
A fully engineered, smaller, non-site specific design also exists



Inner Tunnel Lab

γ-flux	7.974×10^{-5}	$cm^{-2}\ s^{-1}$
n-flux	4.817×10^{-10}	$cm^{-2}\ s^{-1}$

4 < ppt (GeMPI, arrays)
6 < ppb (well, clover, coax)
2 Beta Cages
Prototyping Space
(DM or $0\nu\beta\beta$ or novel assay)

Radon Mitigation
Common cryogen plumbing and
LN boil-off for screeners

Central Pool

0.1 counts/day, E > 250 keV
sensitivity of 10^{-14} g/g U/Th 10^{-12} g/g K
modeled on Borexino CTF
2m diam nylon vessel filled with LS
Observed by low rad QUPIDs
Top-loading from dedicated Clean Room

Reconsider many DUSEL goals in the next decade.

For example, no one has successfully created a true multi-disciplinary underground lab.
Smaller projects are not self-supporting; they need to be subsidized until they mature
The DUNE project can provide this.

They also need a unifying theme and an Institute: ***Climate Change is this century's challenge***
This theme already shares many of the established geo/bio/engineering science goals.
An Institute at SURF would also promote work at other sites, unified by the theme and led by geo/bio/engineering

Examples

Energy production
geothermal energy
understanding fracking

Changes to the water cycle
Climate and the critical zone
CO_2 sequestration
Vulcanism, subduction, CO_2 cycles
Biogeochemical cycles,
New microbes for digestion/waste

Attributes of SURF for BG&E Grand Challenges

Pro

Large Spatial Scale – Access to heterogeneous/opaque block at km-scale

Large Depth – Elevated stress and temperature

Long Term Occupancy – Continuity

Low Background Noise – Seismically

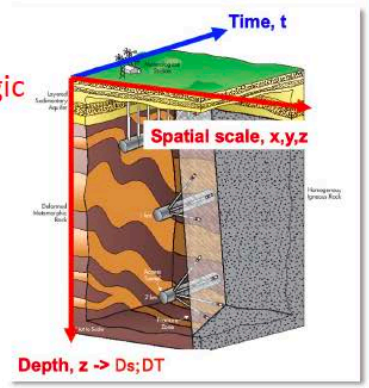
Proximal Access – To processes/expts. At depth

Active Experimentation – Ameliorates constraints of the (very specific) geologic environment

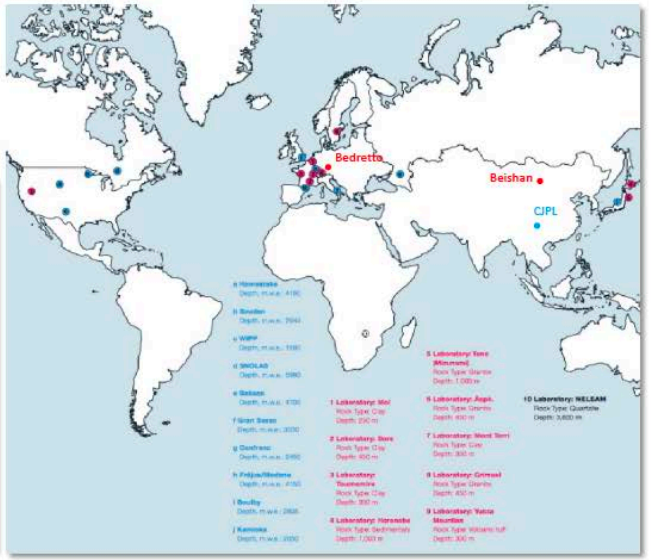
Con

Merely One Environment – Rock type/non-sedimentary

Many Competing Locations – Some with more-favorable/specific attributes



Elsworth Slide



UNDERGROUND FACILITIES

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Advertisement: A robust Snowmass White Paper on a unified plan for complementary strengths of Underground Labs worldwide would help SURF.

Explore the ecosystem! Define it.