

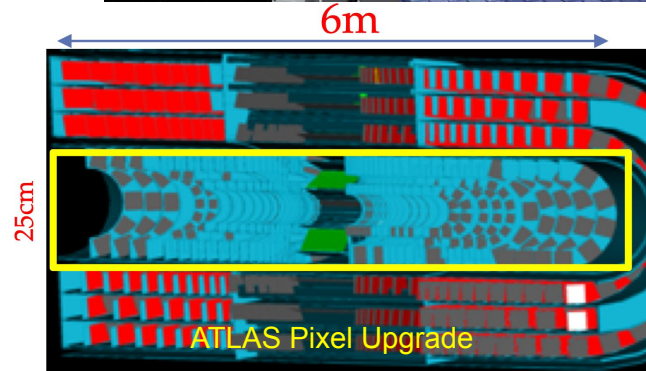
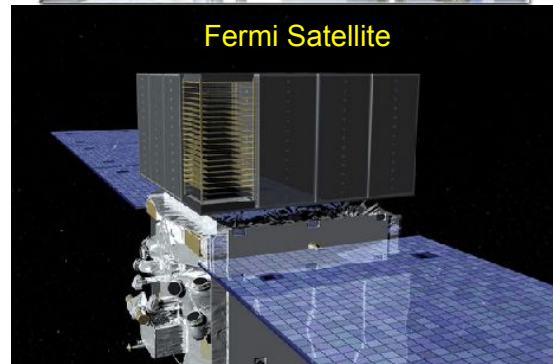
Particle Physics and Particle Astrophysics Experiment

2021 Graduate Student Orientation

Tom Shutt
SLAC, KIPAC
Stanford University

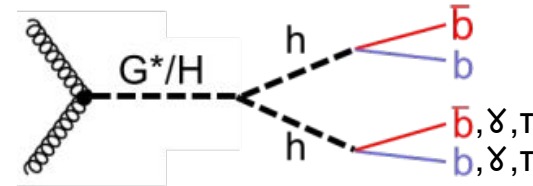
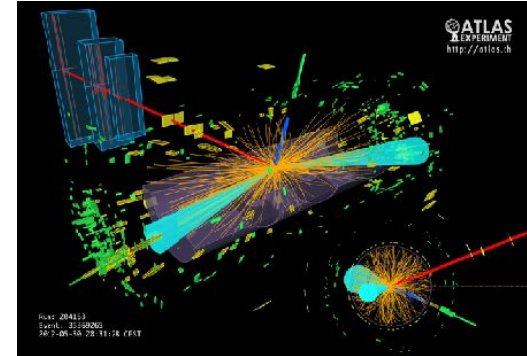
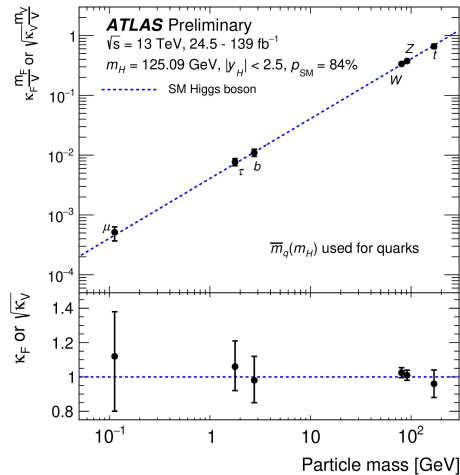
Experimental program at SLAC

- Rich history of discovery at SLAC
- Particle physicists: detector development, data analysis has had big impact on cosmology and astrophysics
- SLAC + Stanford: unique partnership



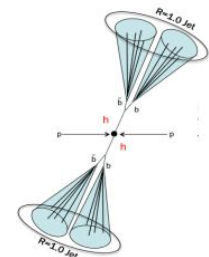
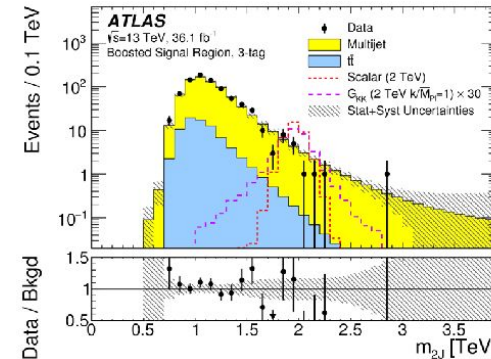
Higgs Portal for New Physics at the LHC

- Di-Higgs production
- Heavy Higgs/ Z' -> bb
- Light scalar a in $h \rightarrow aa$ decays
- BSM Higgs Yukawa couplings



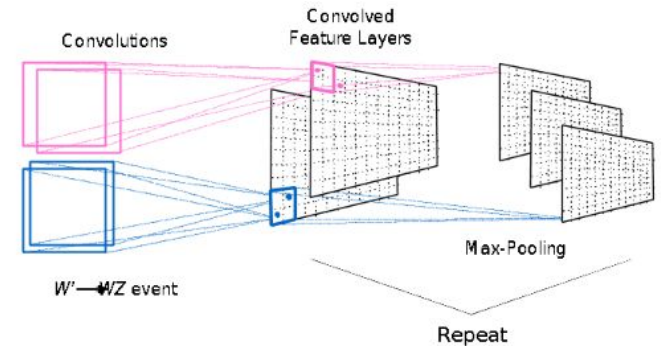
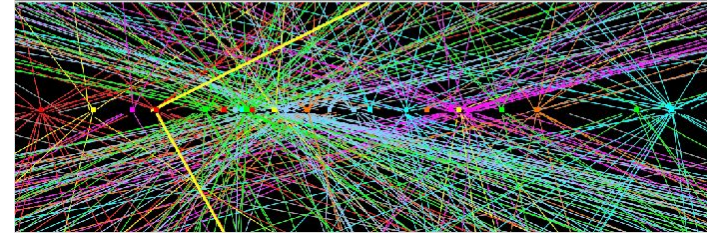
$G^* = \text{KK graviton}$
 in Large Extra
 Dimensions

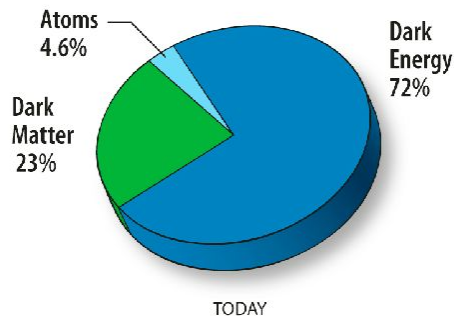
Boosted Higgs



Challenges and Opportunities with ATLAS

- Physics signatures in challenging LHC environment:
 - Advanced b,c quark jet tagging
 - Novel boosted object reconstruction
 - Refined jet property extraction
 - State-of-the-art pileup mitigation
 - Exploring the use of fast timing
- Advanced tools with computer vision, image processing and deep learning
- Detector operations and upgrades
 - HL-LHC Inner pixel assembly at SLAC
 - Trigger & DAQ with modern real time platforms
 - Future detector R&D



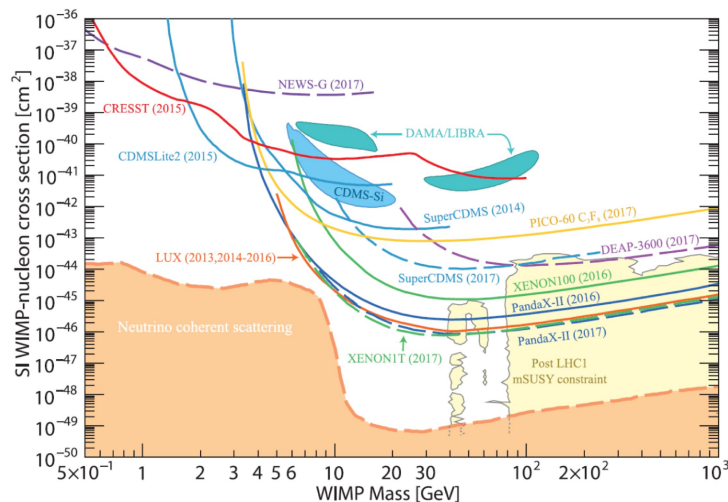
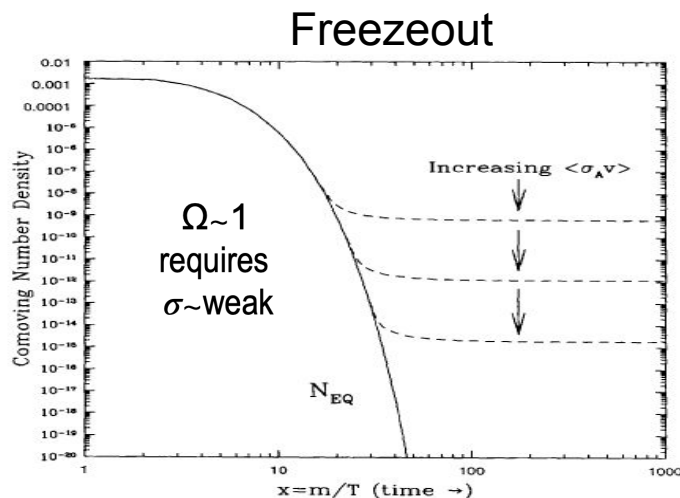


Dark Matter

- WIMPs

- Beyond WIMPs

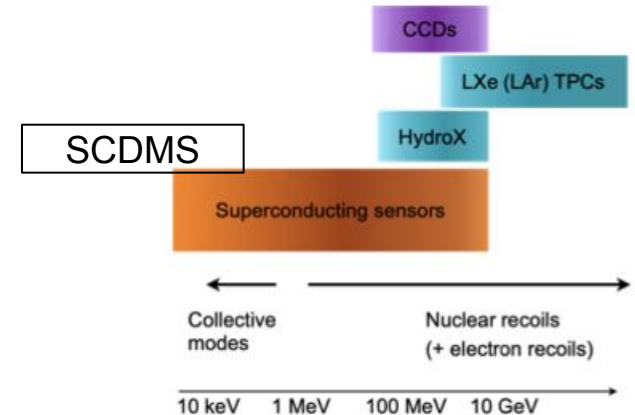
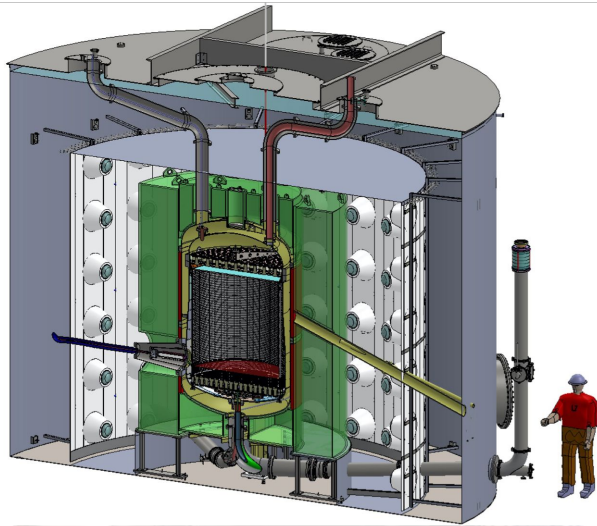
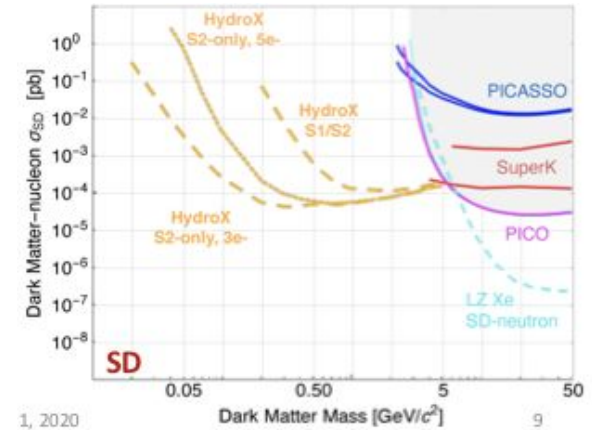
- Sub GeV DM: Assymmetric, other light
- Dark Photon, dark sector
- Axions + strong CP problem
- A new sociology



Dark Matter search with LUX-ZEPLIN

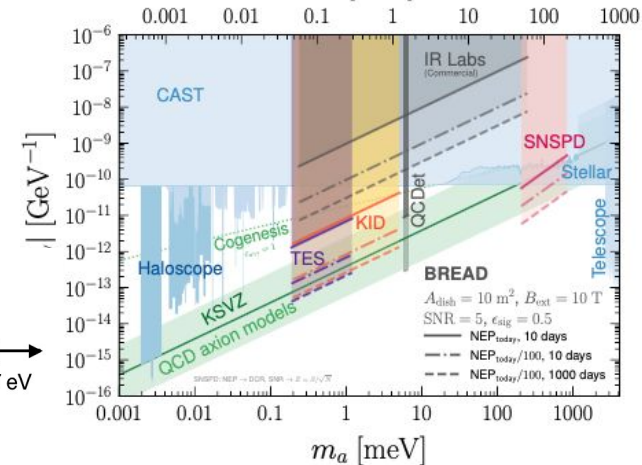
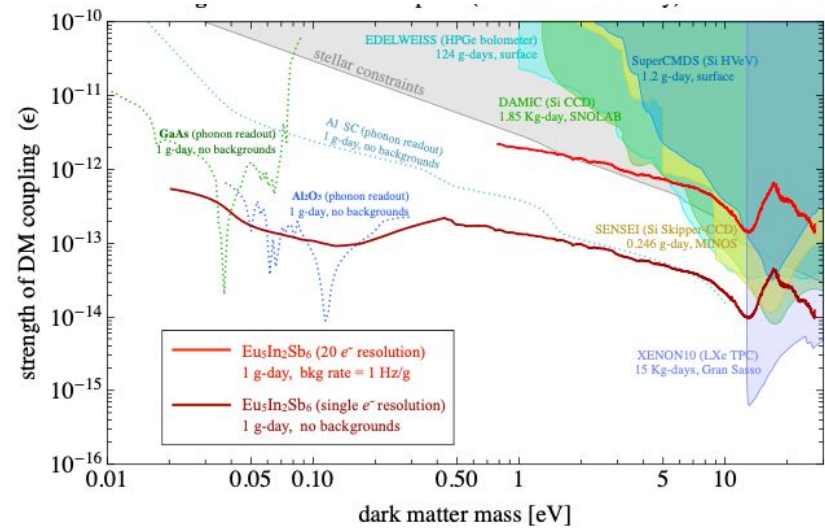
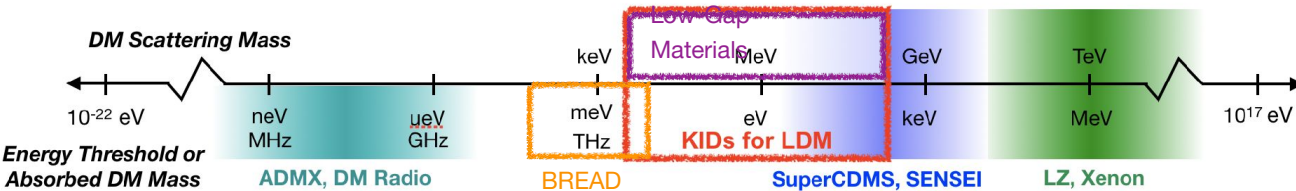
- Data start: this winter
- R&D
 - HydroX low mass search
 - Rn/Kr separation
 - New LAr Gamma Ray instrument

HydroX: H-doped Xe



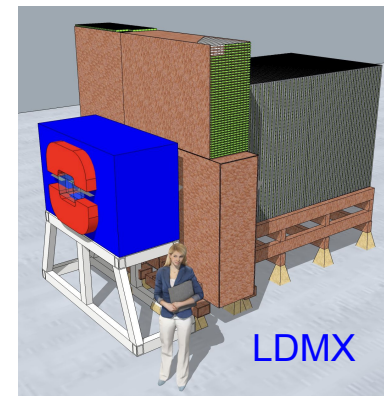
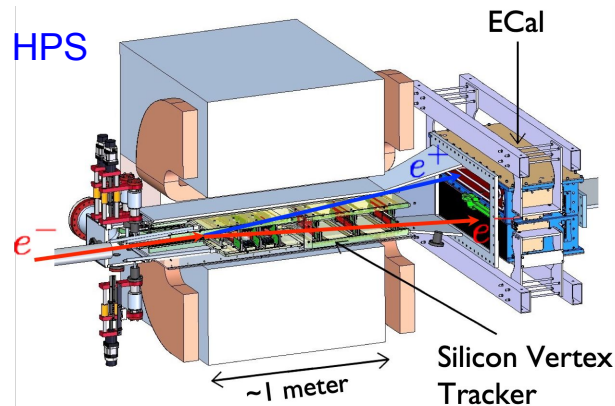
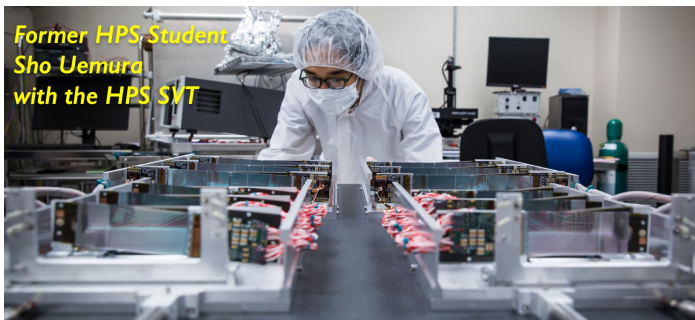
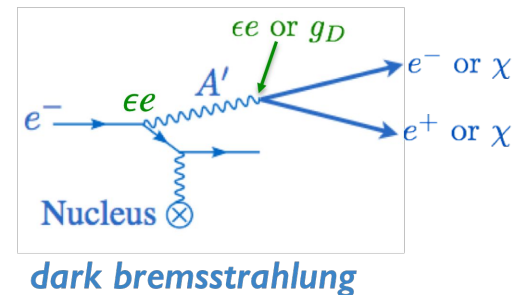
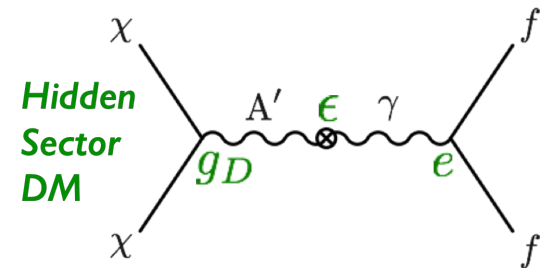
Quantum Sensing for Dark Matter Searches

- Utilize superconducting sensors to search for dark matter in the meV-MeV regime, currently not probed by existing experiments
- KIDs for phonon sensing
- meV-gap materials with single charge readout
- Single THz and IR photon sensors for wide-band axion searches (BREAD)
- Sensors derived from qubit co-design work; heavy overlap with QIS
- Heavy on device R&D and quick science results - demonstrations for larger follow-on experiments
- Smaller scale projects suitable for one student and postdoc and dark matter searches done on site at SLAC!



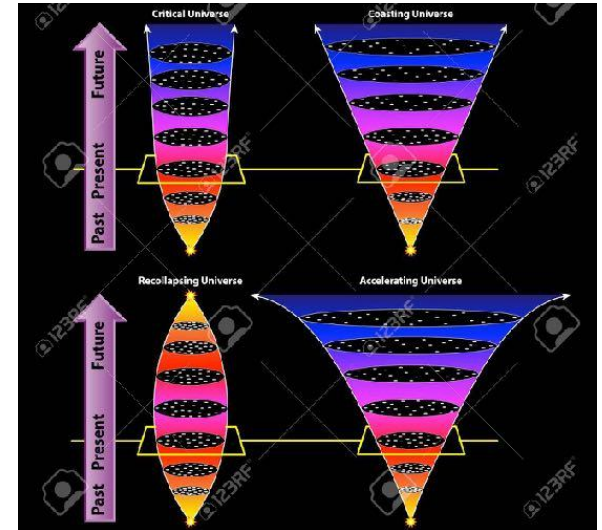
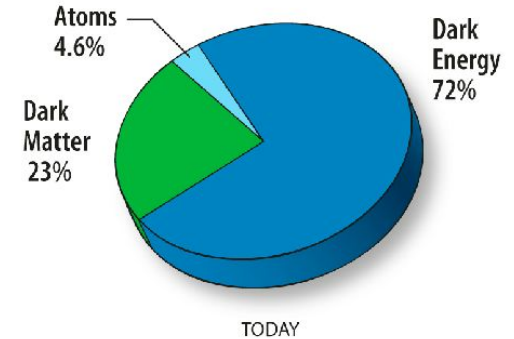
Hidden Sector Dark Matter

- Dark matter couples only through hidden sector to standard model particles.
- Benchmark case: dark photon, A'
- Search for hidden sectors at accelerators
 - A' decaying to SM particles: HPS @ JLab
 - Production of hidden sector Dark Matter: LDMX @ SLAC
- Unique theory/experiment collaboration at SLAC



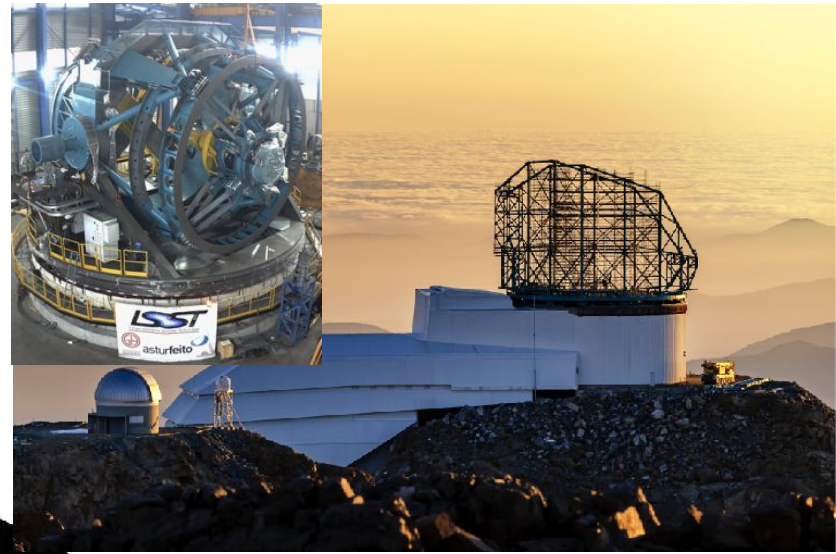
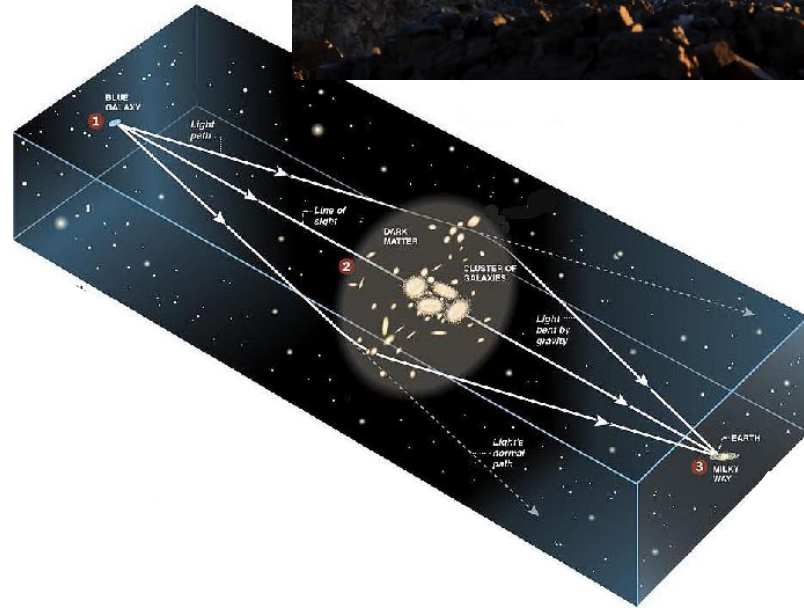
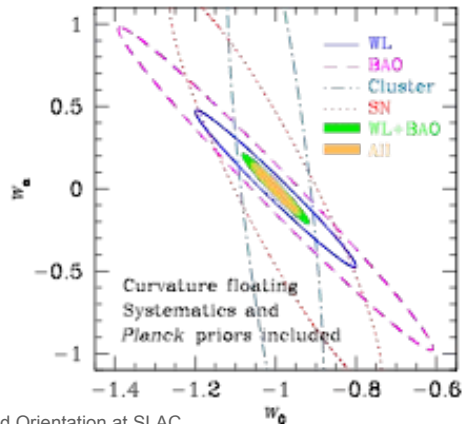
Dark Energy and Cosmology

- Dark Energy: a mystery wrapped in a riddle
 - Cosmological Constant?
 - Quantum Field?
 - General Relativity wrong?
- Determines ultimate fate of universe
- Galaxy surveys
 - Imaging
 - Spectroscopic
- Supernova
- CMB



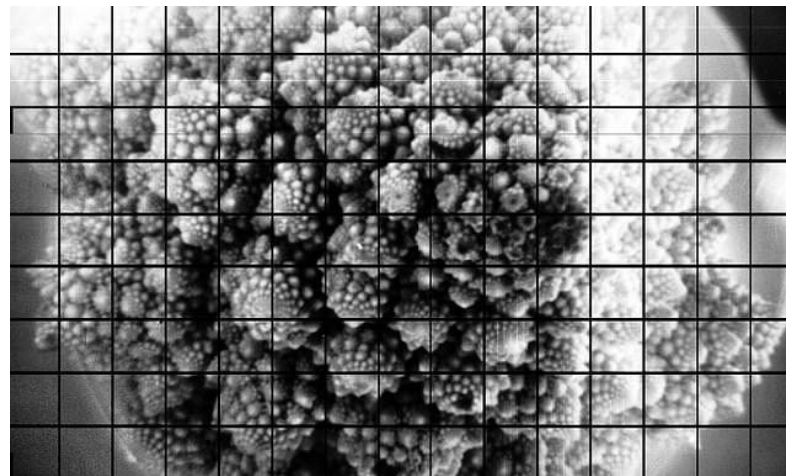
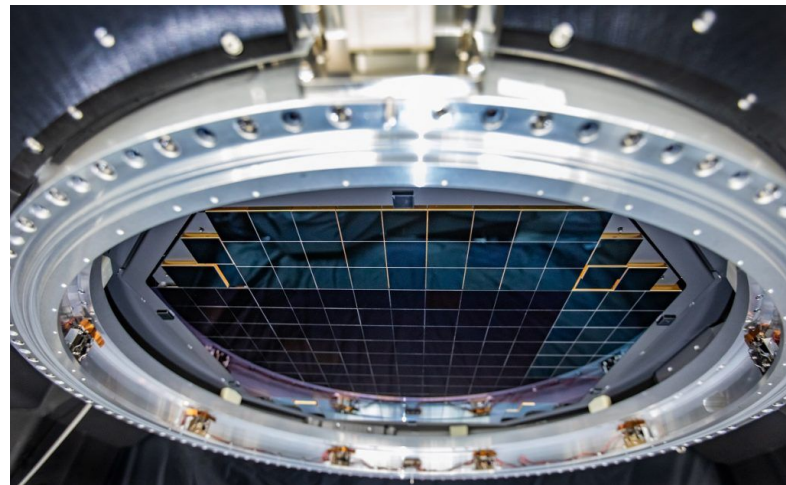
LSST

- Wide field survey with massive camera
- Dark energy
 - Independent measures of structure evolution
 - 1 million supernovae
- First light in 2022



LSST - Camera

- Camera assembled and tested at SLAC
 - Large effort to characterize and minimize systematics
- Wealth of other astrophysics topics
 - Dark matter from weak lensing
 - Extensive map of Milky Way
 - Time domain: transients and variable objects
 - etc...





CMB-S4

Next Generation CMB Experiment

CMB-S4 @ SLAC:

- Inflation science
- Cryogenic cameras
- Superconducting detectors
- Readout technology
- and more...

CMB-S4 in a nutshell:

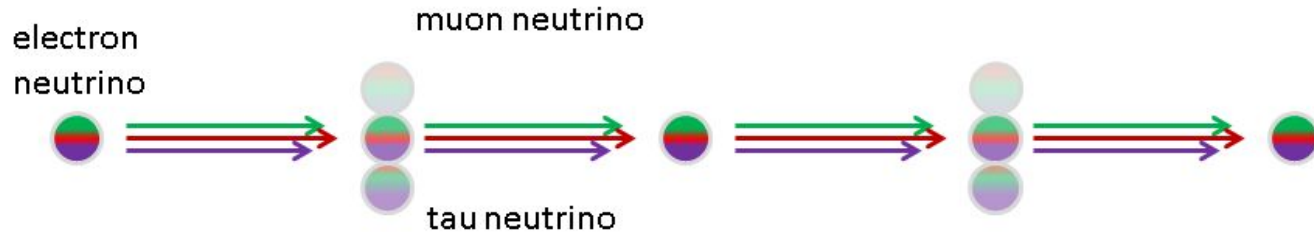
- Telescopes at Chile Atacama Desert and the South Pole
- $O(500,000)$ detectors
- PBs of data
- First light c.2027

Key science themes: CMB-S4 Science Book [arXiv:1610.02743](https://arxiv.org/abs/1610.02743)

- Inflation/primordial gravitational waves
- Early universe light relics/nature of dark matter
- Mapping masses in the observable universe
- Multi-messenger astronomy

Neutrinos

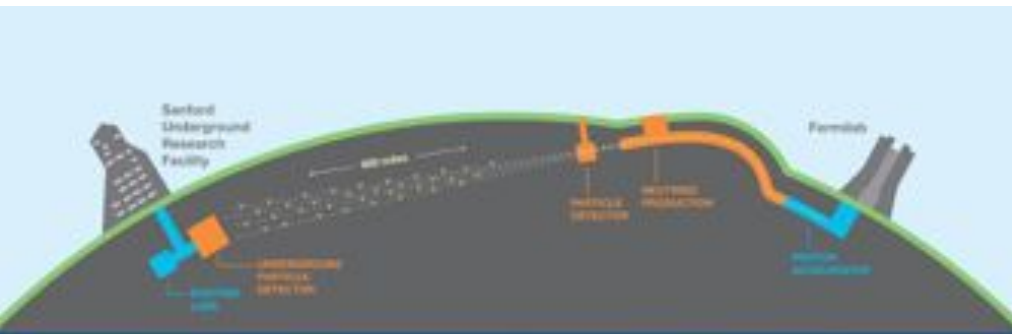
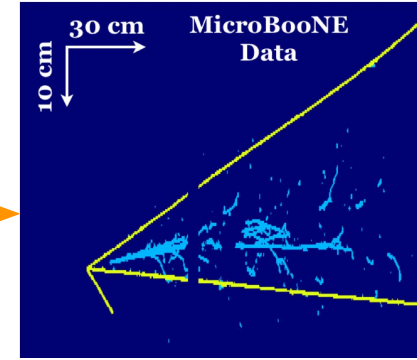
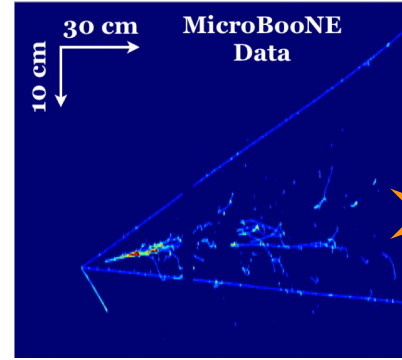
- Neutrinos oscillate and have mass
 - First direct physics beyond the standard model
- But much not yet known
 - Neutrino masses
 - CP violation? Is this the origin of mass in the universe?



M. Strassler 2011

Accelerator neutrino program

- Ongoing short baseline at Fermilab: MicroBooNE, ICARUS
- DUNE - near detector
- Event reconstruction: machine learning
- Electronics
- TPC design + testing



nEXO - Neutrinoless Double Beta Decay

Are neutrinos Majorana or Dirac like?

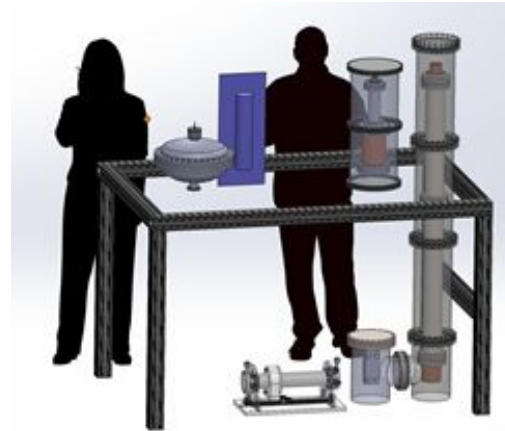
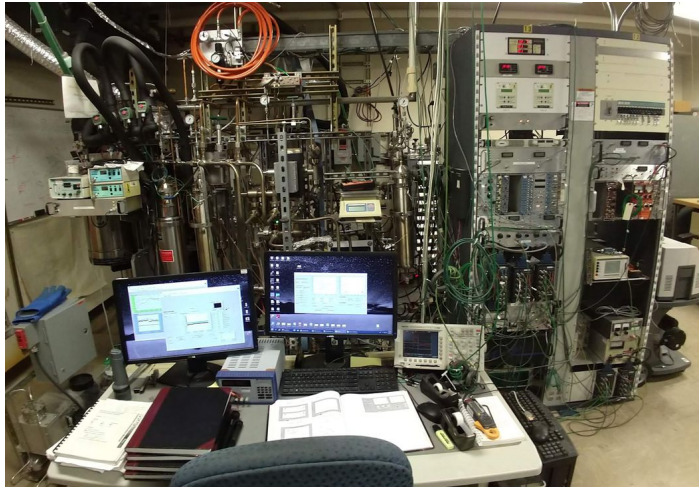
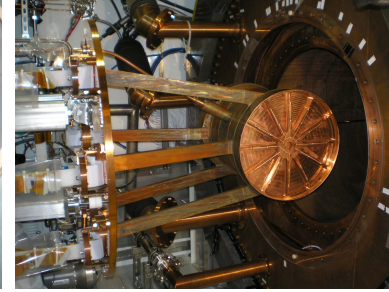
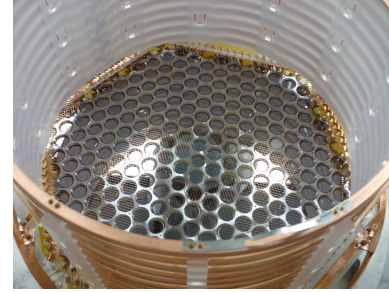
Is Lepton Number Violated?

Follows successful EXO-200 experiment

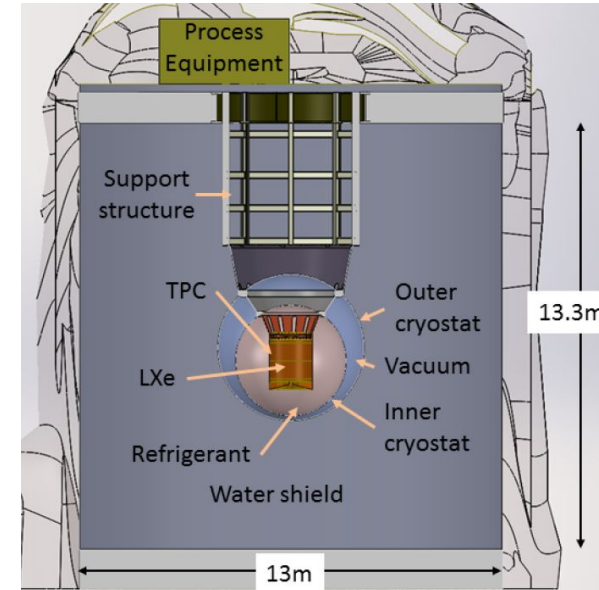
200 kg enriched Liquid Xenon TPC

nEXO is in the R&D and design phase

5000 kg eLXe TPC



LDRD award for radon removal beginning FY21



At SLAC

- ATLAS
- LZ, HydroX
- SuperCDMS
- Fermi-LAT
- HPS + LDMX
- LSST
- DES
- LSST
- MicroBooNE, ICARUS
- Dune, T2K
- nEXO
- CMB S4
- DM Radio

Talk to poster presenters about office / lab visits this afternoon

backup

(new slides start here)

- Cosmology and the subatomic world
 - Dark matter
 - Dark energy
 - Inflation
 - Neutrinos mass, number
 - Origin of matter vs anti-matter
- Other basic questions
 - What lies beyond standard model?
 - Mass hierarchy in SM
 - Neutrino vs anti-neutrinos
 - others ...