

Particle-Astrophysics Experiments at SLAC: *Fall 2016 Graduate Student Orientation*

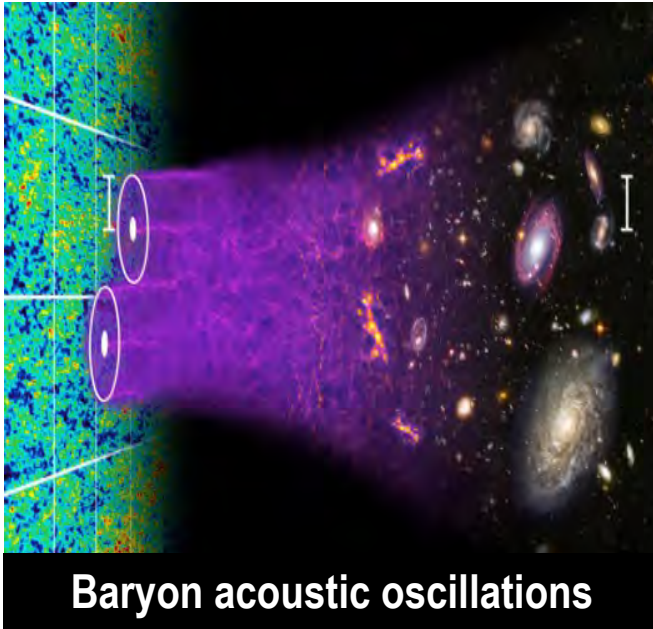
Tom Shutt

SLAC National Accelerator Laboratory
Kavli Institute for Particle Astrophysics & Cosmology
Stanford University

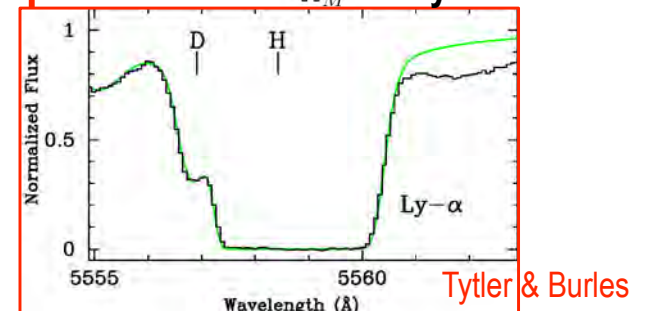
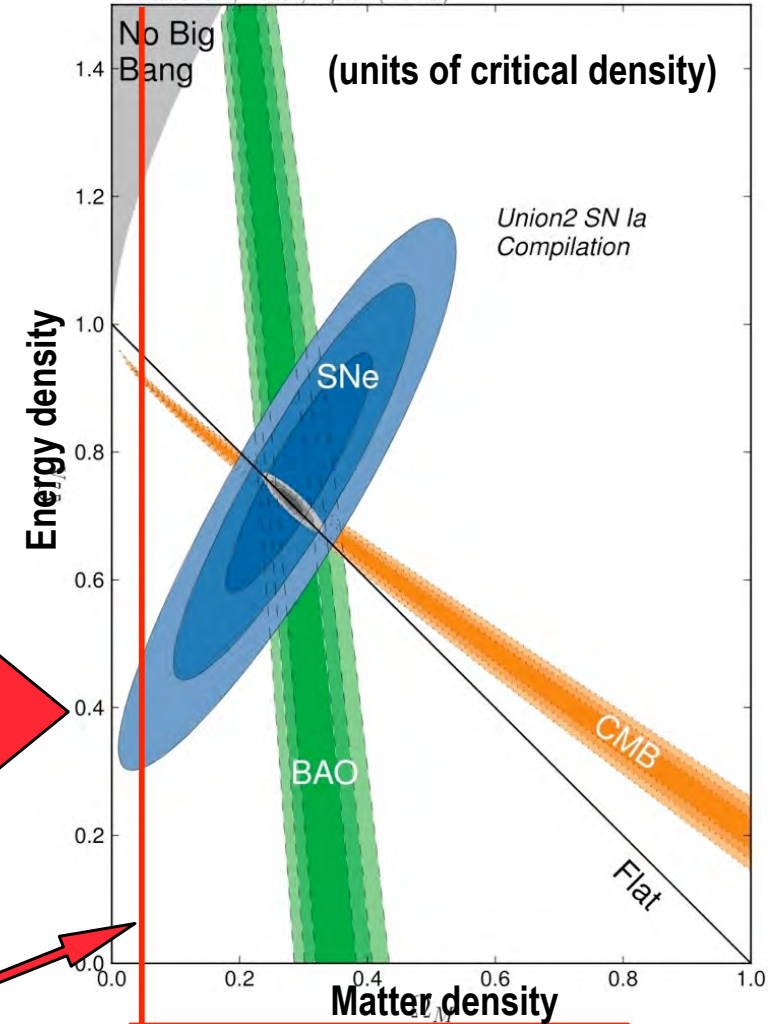
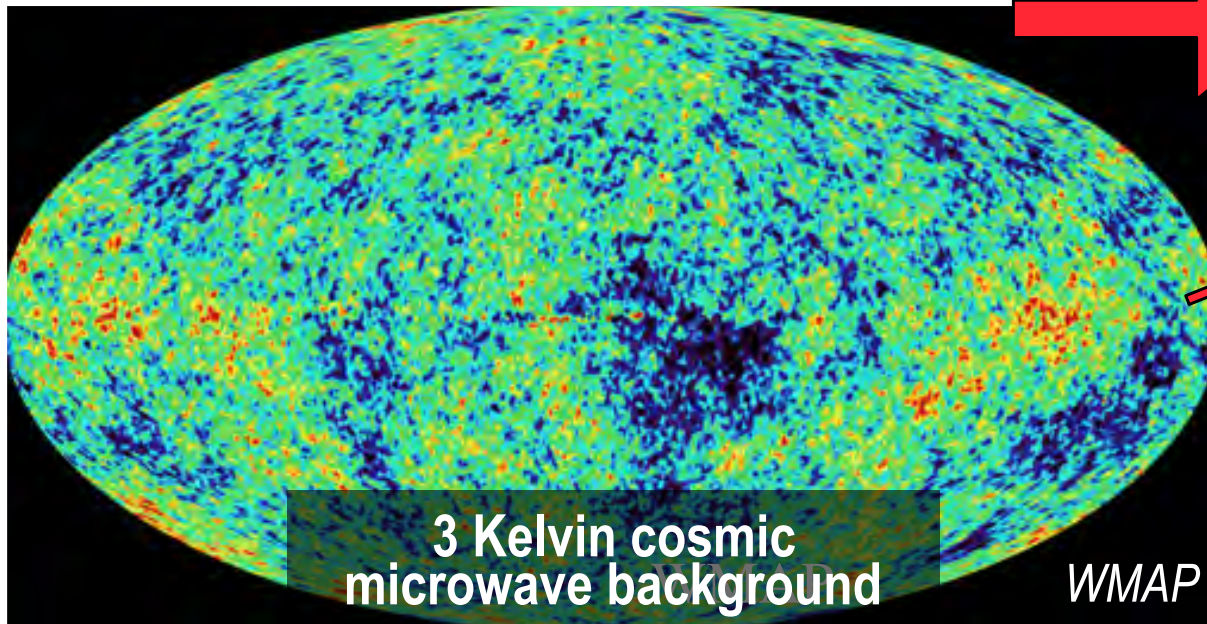
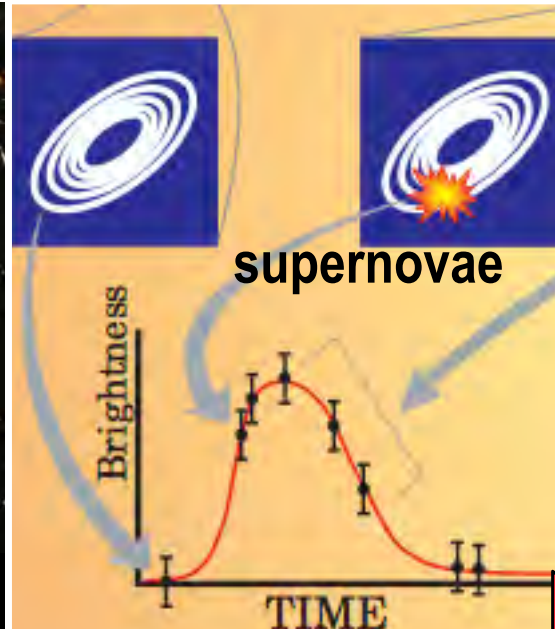
Standard cosmology: An inventory of the universe

Supernova Cosmology Project
Amanullah, et al., *Ap.J.* (2010)

SDSS-III / BOSS

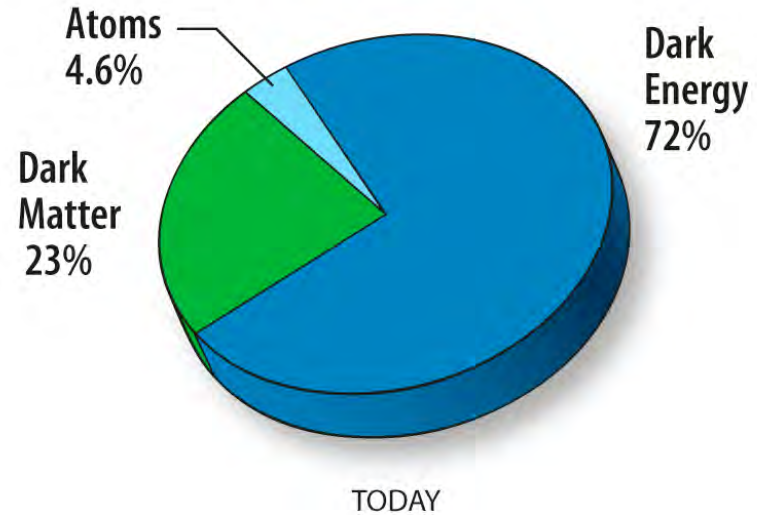


from Perlmutter, *Phys. Today*



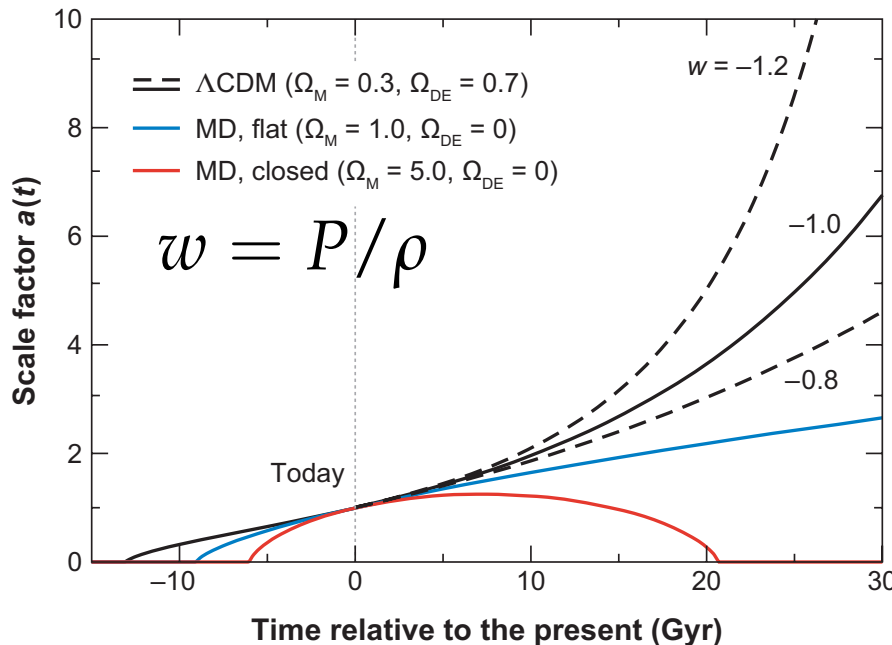
Physical theories of dark energy

Fate of the Universe?



■ What is Dark Energy?

- a Cosmological Constant?
- a Quantum Field?
- Or does General Relativity need to be modified?



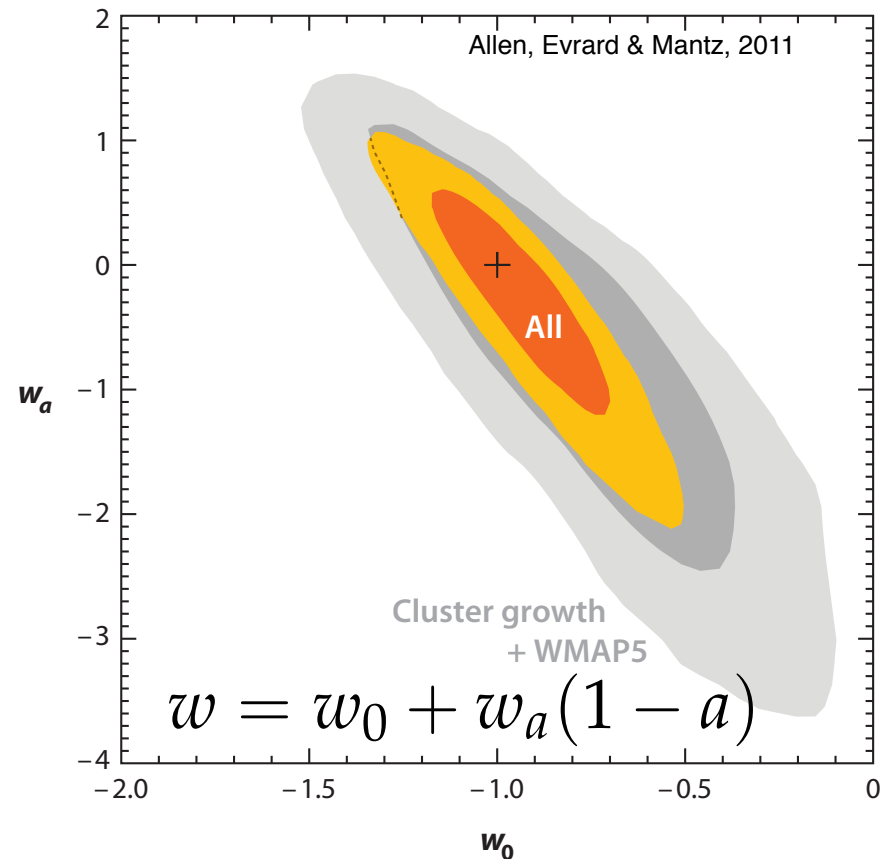
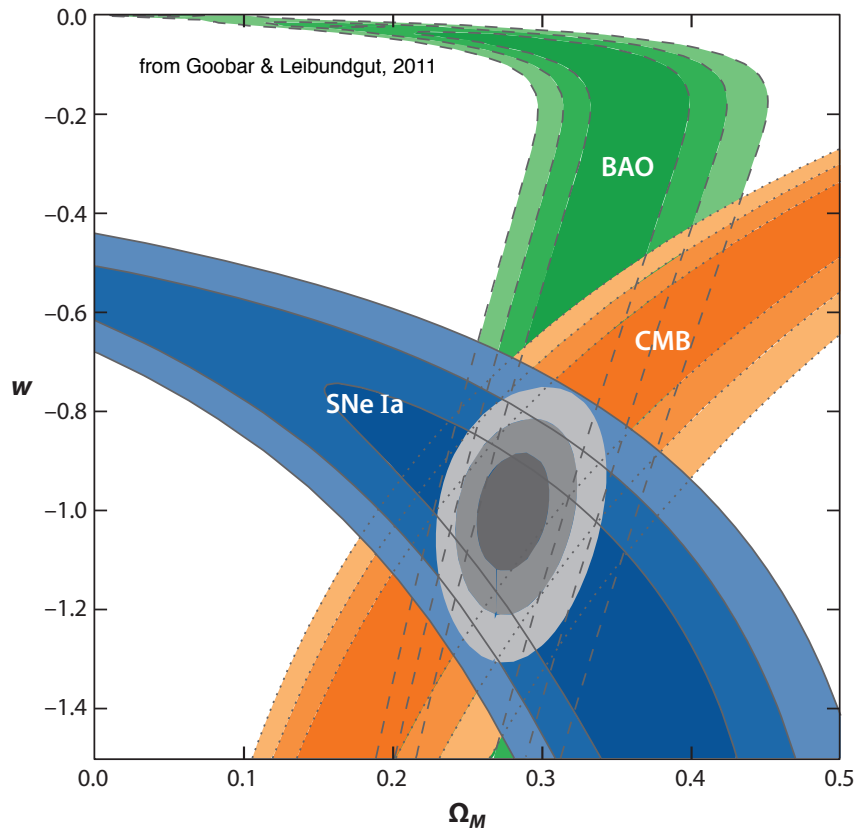
Rip Apart Space-Time

Expand Forever

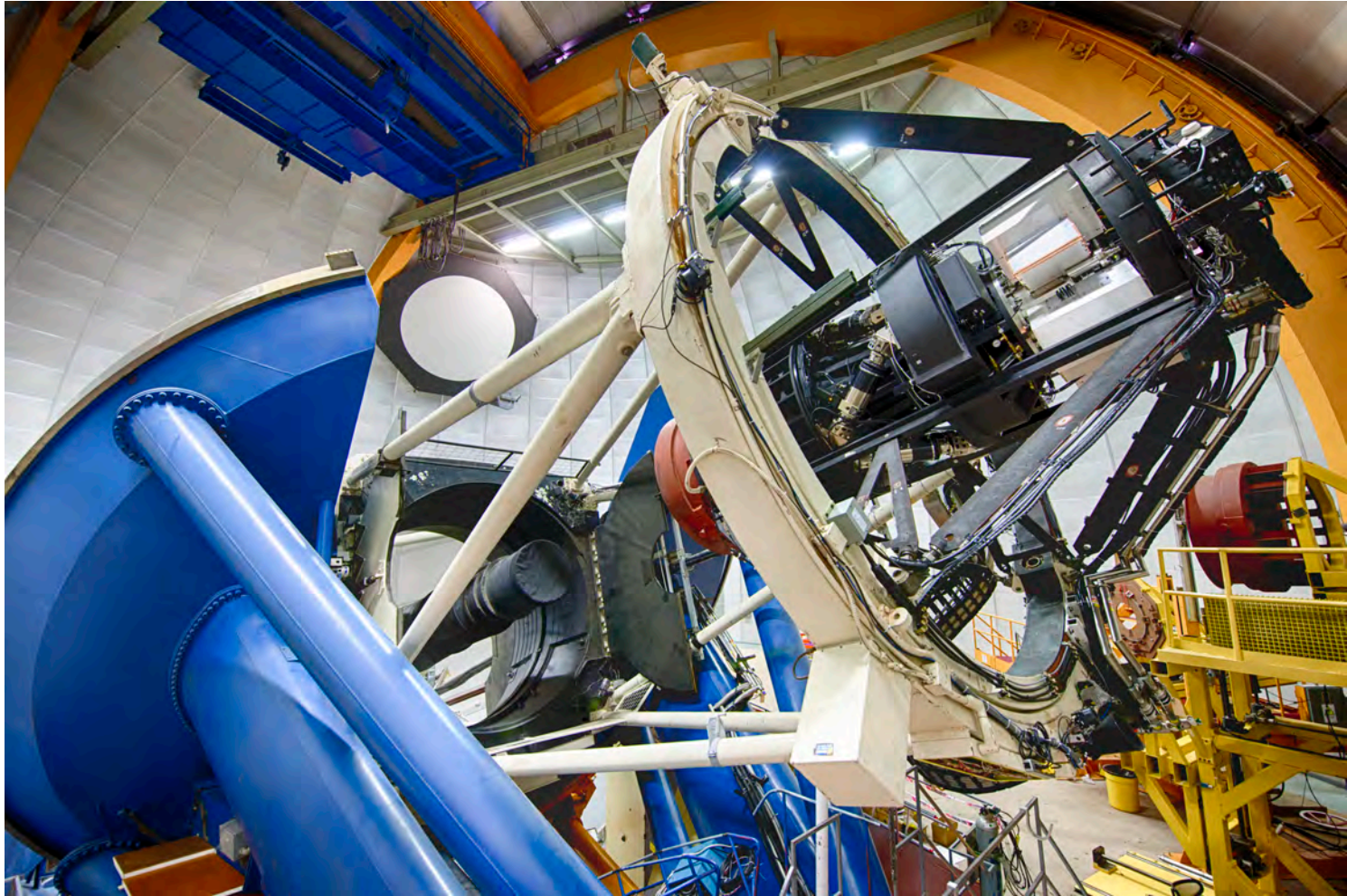
Study Dark Energy with Multiple Methods

Complementary techniques, including:

- The mass function and clustering of **Galaxy Clusters**
- The power spectrum of **Weak Gravitational Lensing** shear
- The statistical distance scale in the galaxy distribution, the **Baryon Acoustic Oscillations**
- The distance-brightness relation of **Type Ia Supernovae**



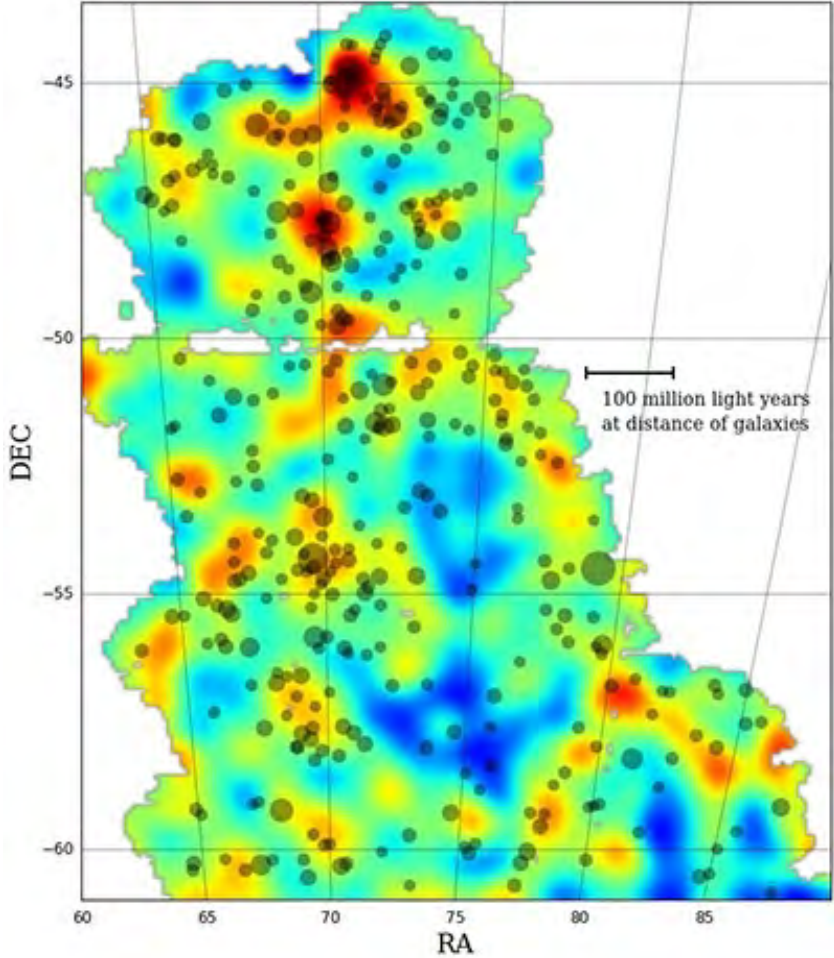
Dark Energy Survey



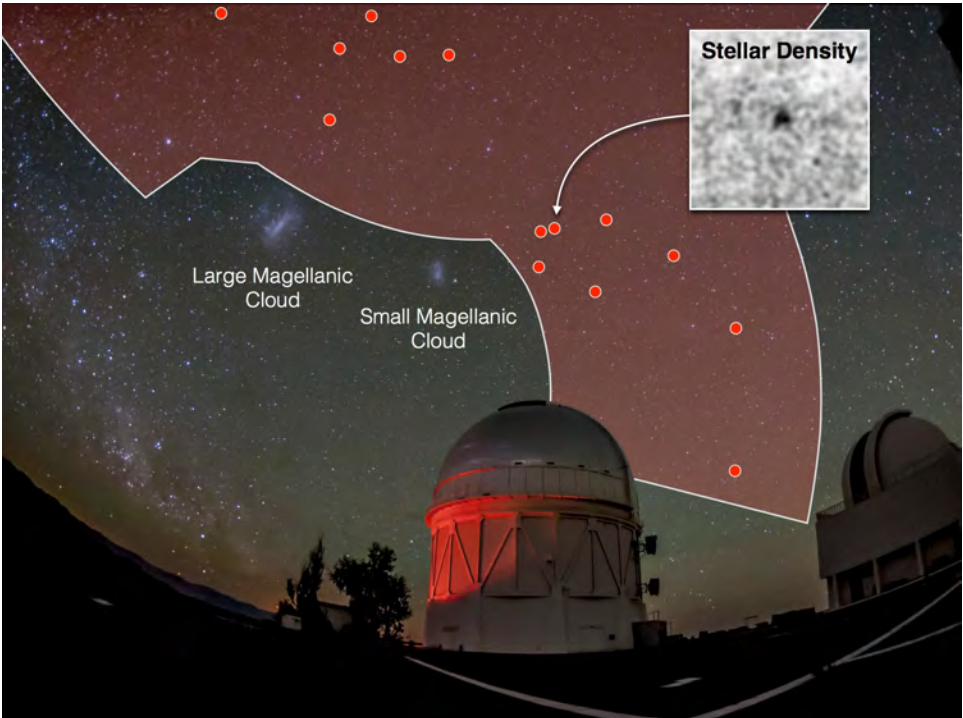
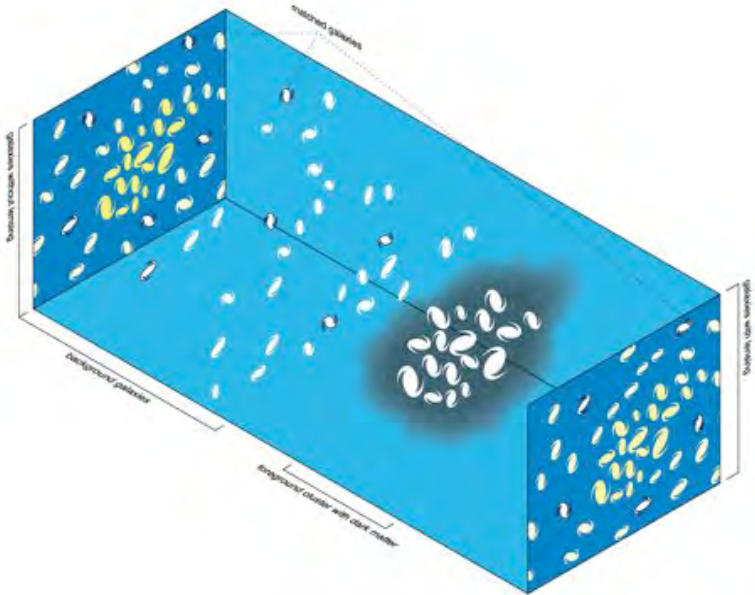
570-megapixel imaging device

in 3rd Year of 5 Yr Survey

Dark Energy Survey



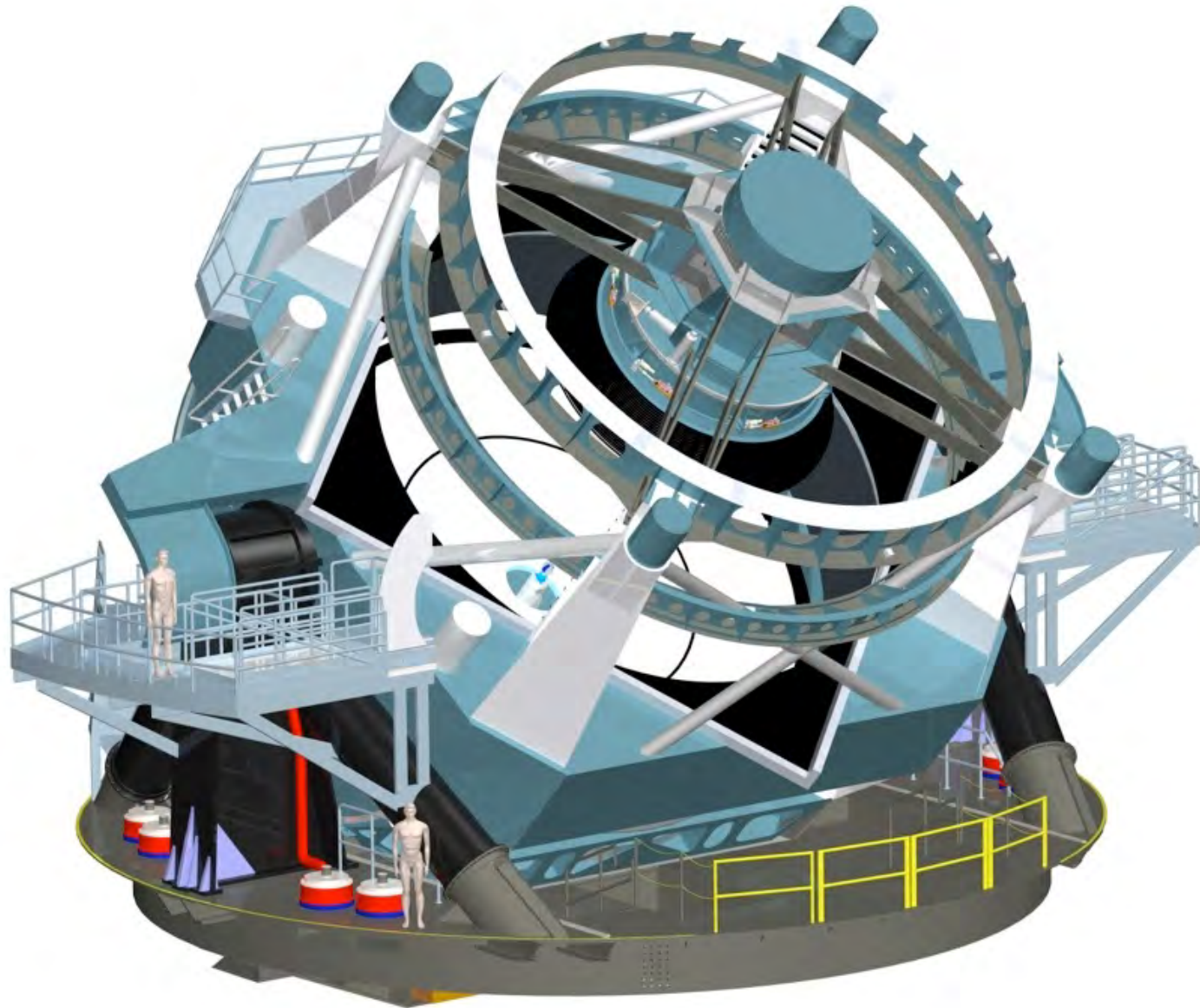
dark matter maps



dwarf galaxy candidates

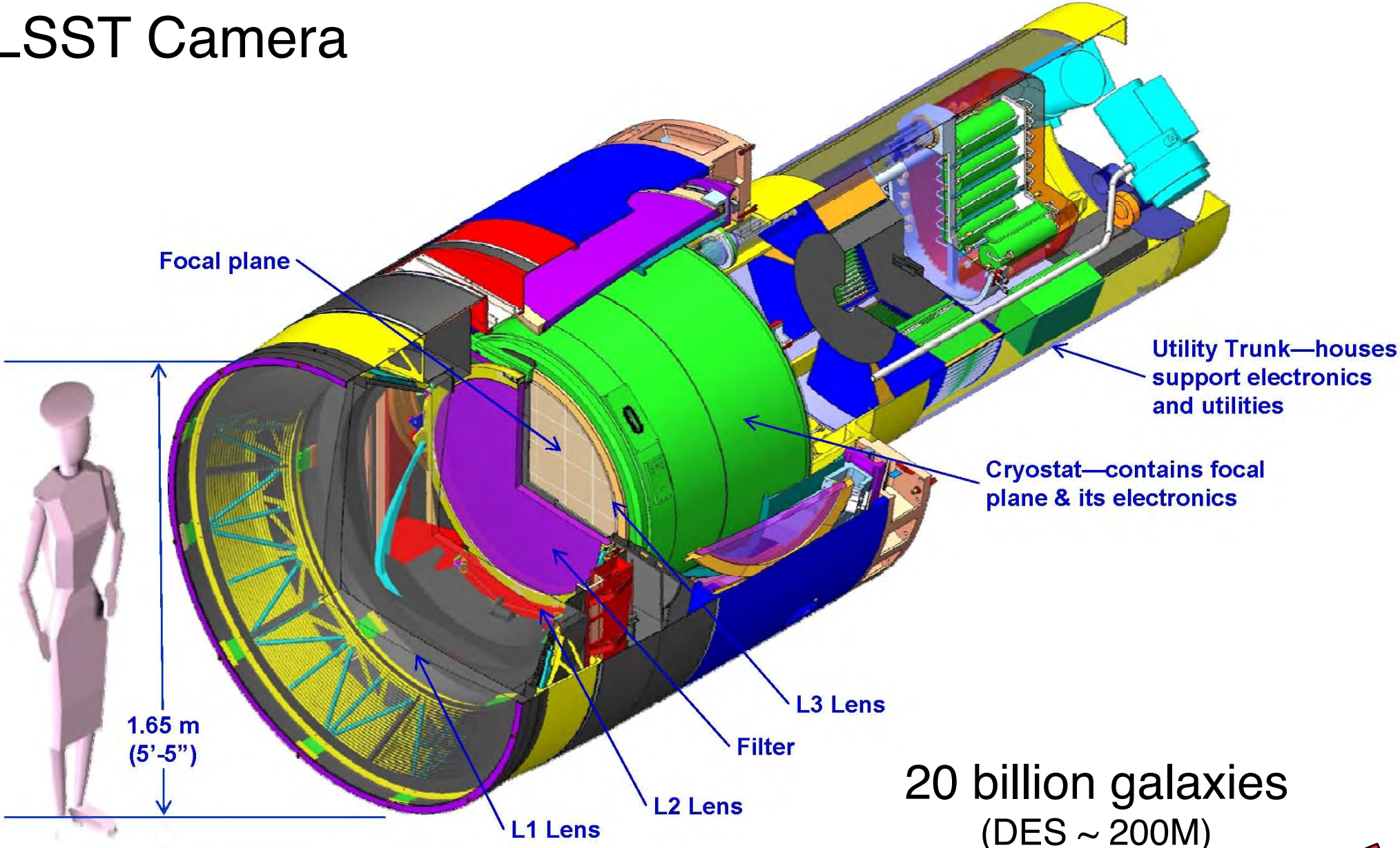
Year 3 of 5 Yr Survey

Large Synoptic Survey Telescope



Construction now underway!

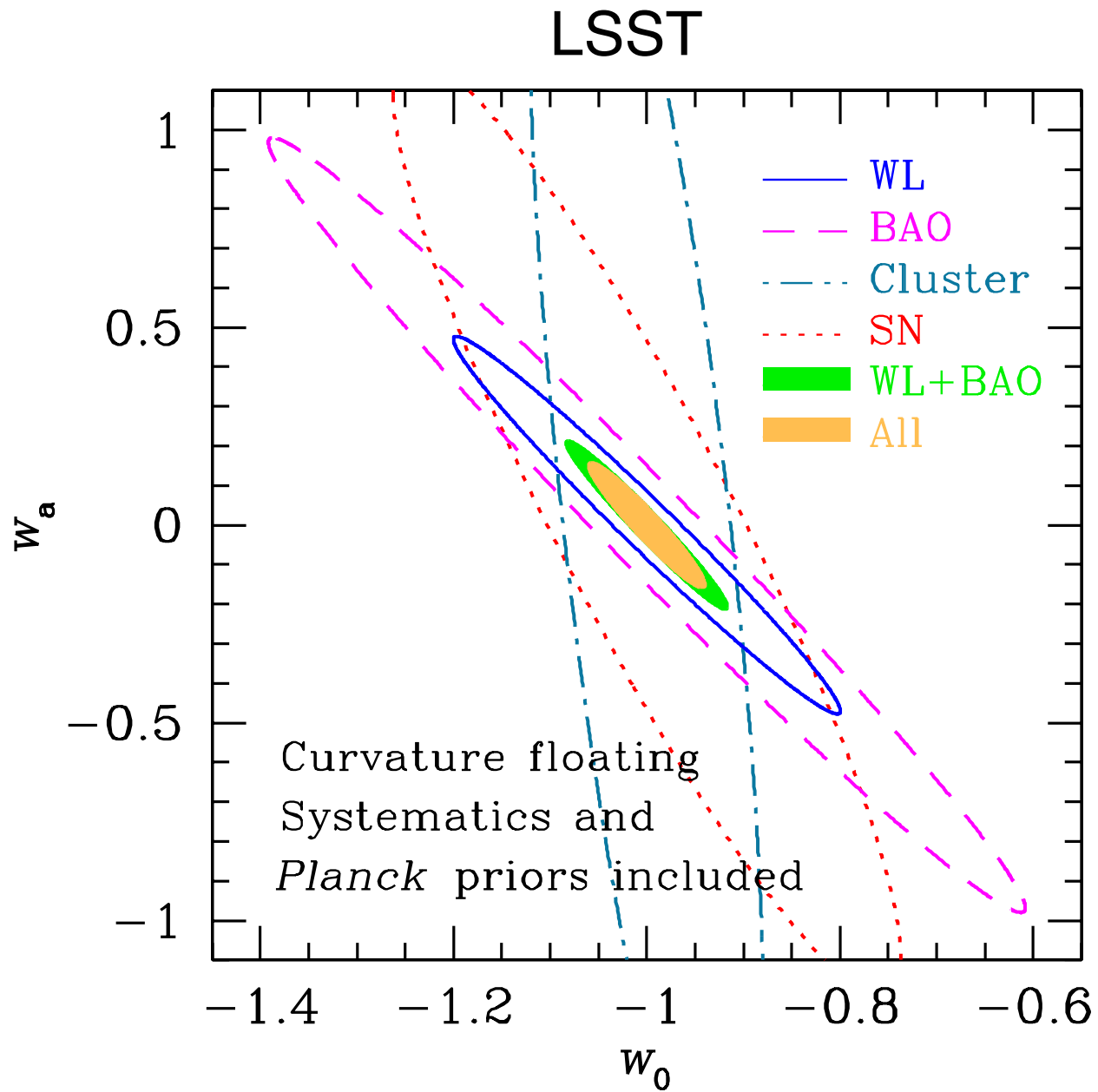
LSST Camera



Camera construction in new SLAC clean room

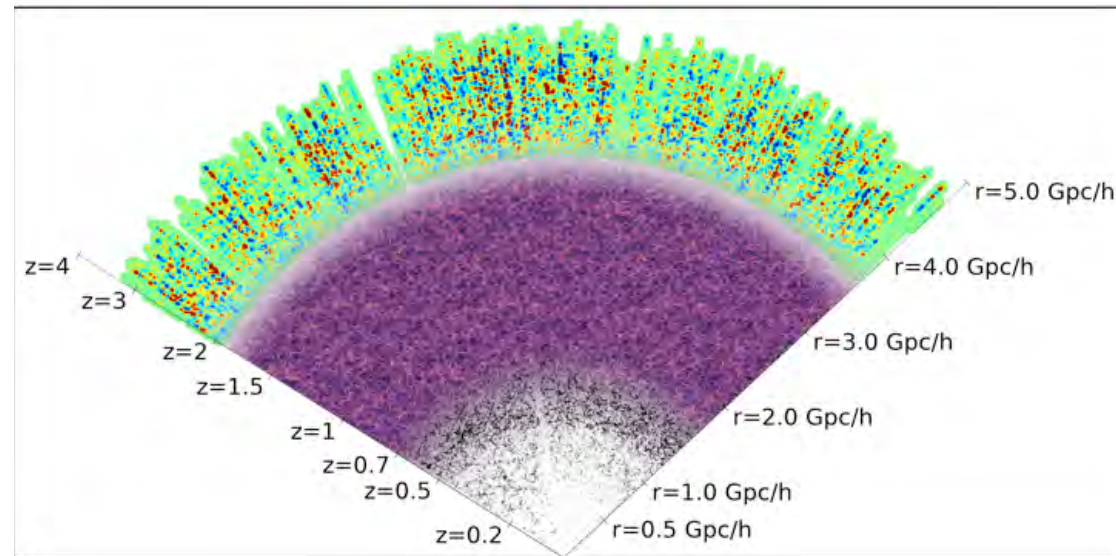
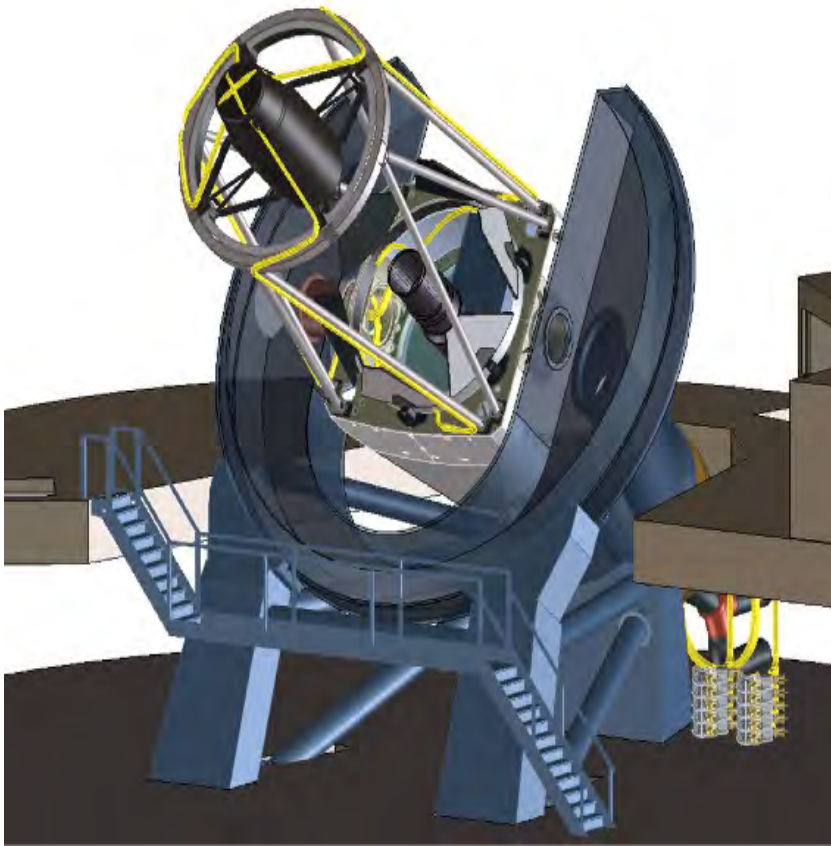
Lab tour 4-5 pm

Cosmology Measurements



Spectroscopic Survey

Dark Energy Spectroscopic Instrument



Passed 2nd of 3 Critical reviews

Complements LSST - fewer objects (20M) / better *redshift*

Dark matter searches

Scattering experiment

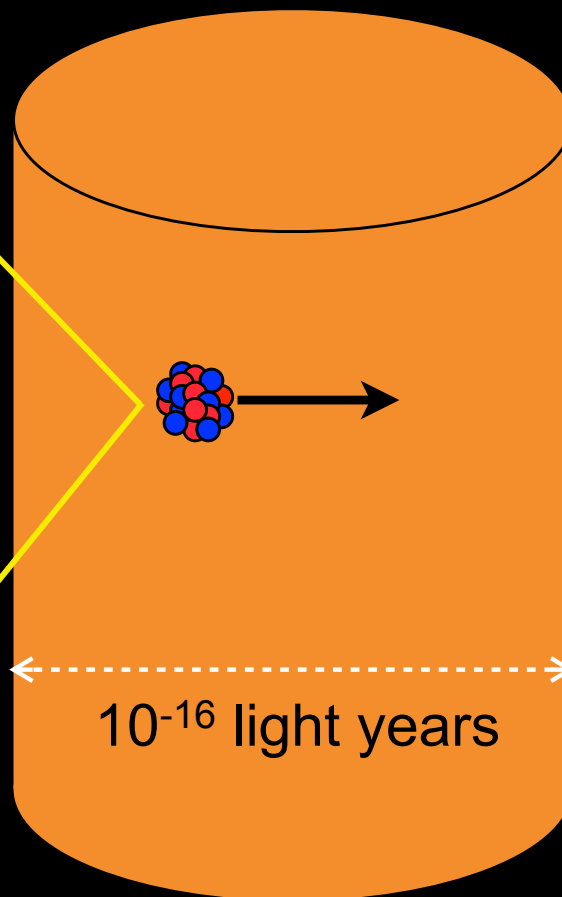
WIMP



density, speed

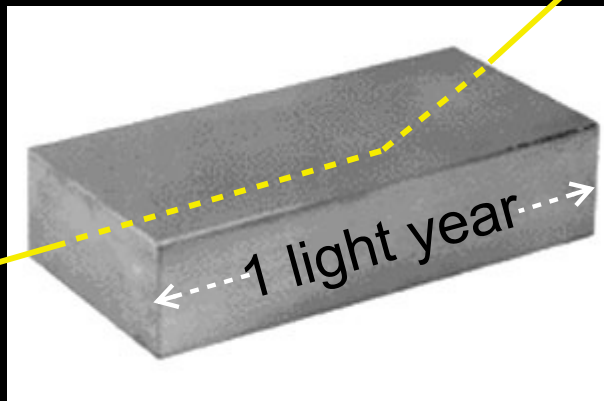
dark matter halo

10^{16} WIMPs/year



10^{-16} light years

detector



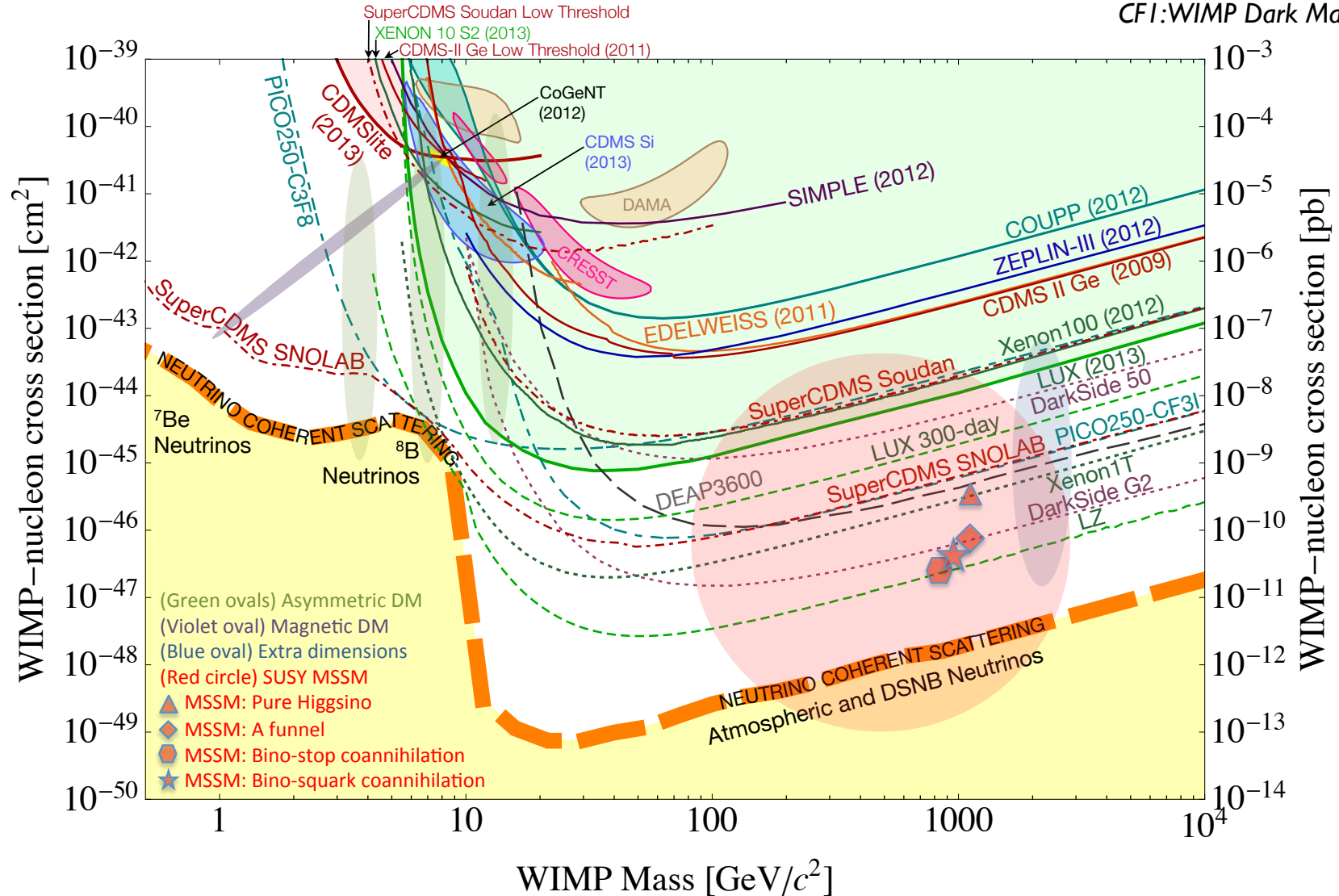
1 light year

Cross section: WIMP scatters
once in a light year of lead

Rate ~ few events / year

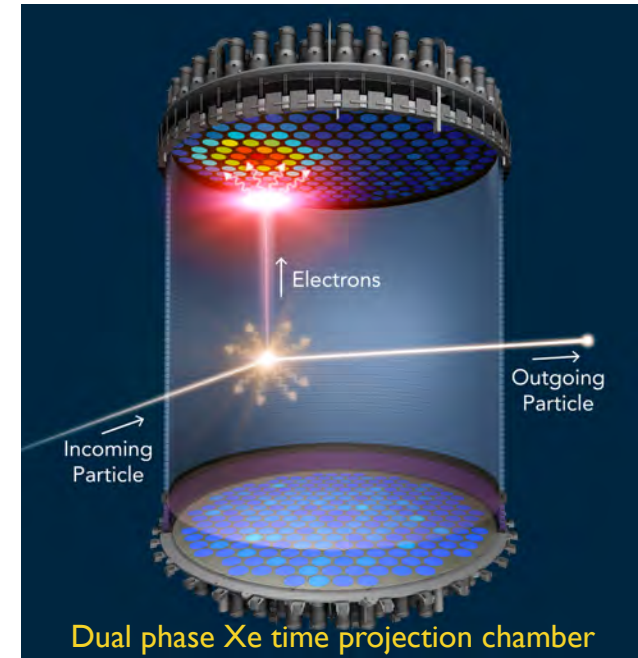
SuperCDMS and LZ

Updated from
Snowmass Community Summer Study 2013
CFI:WIMP Dark Matter Detection

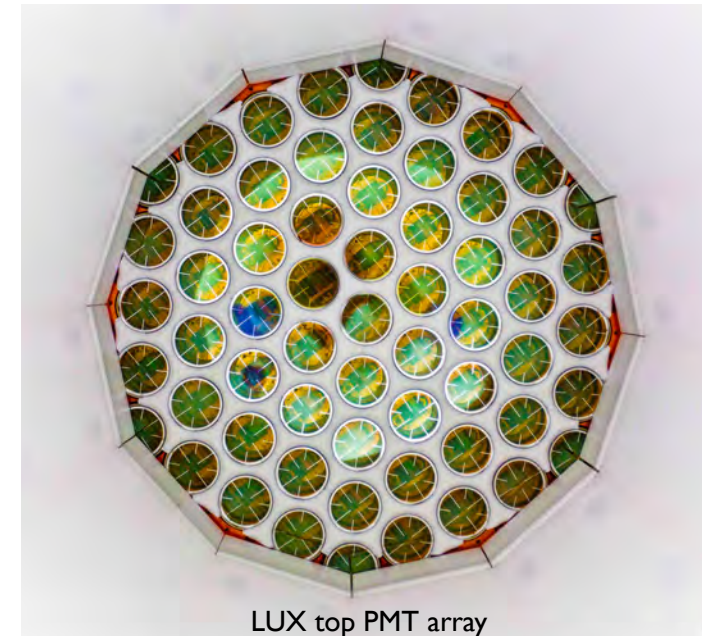


limited by nuclear scatter background? reach to 10⁻⁴⁹ cm²
neutrino floor depends on rejecting pp solar

Akerib/Shutt (SLAC): Dark Matter with LUX and LZ



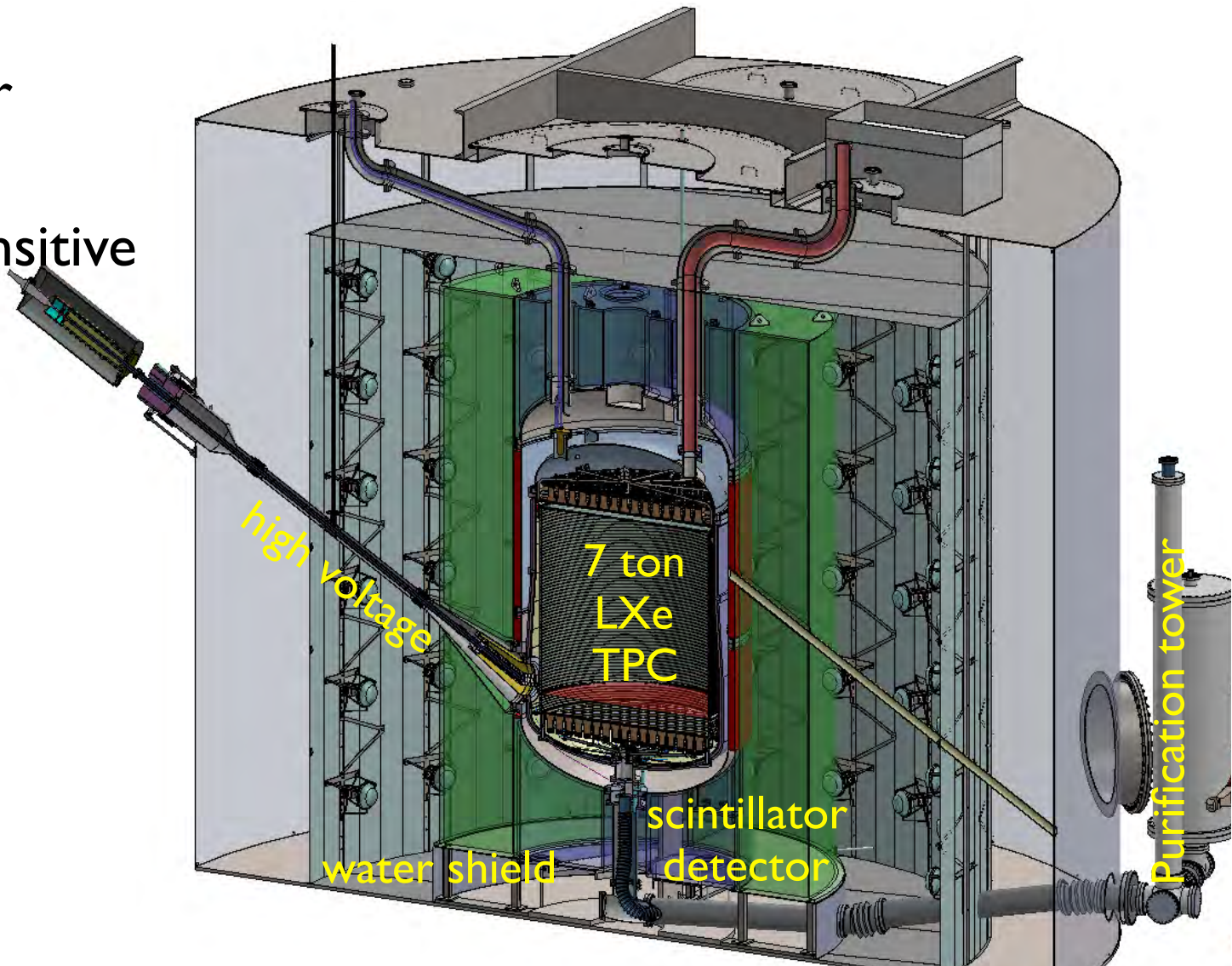
LUX: world-leading search experiment,
4850 ft underground at SURF, South Dakota



LUX ZEPLIN



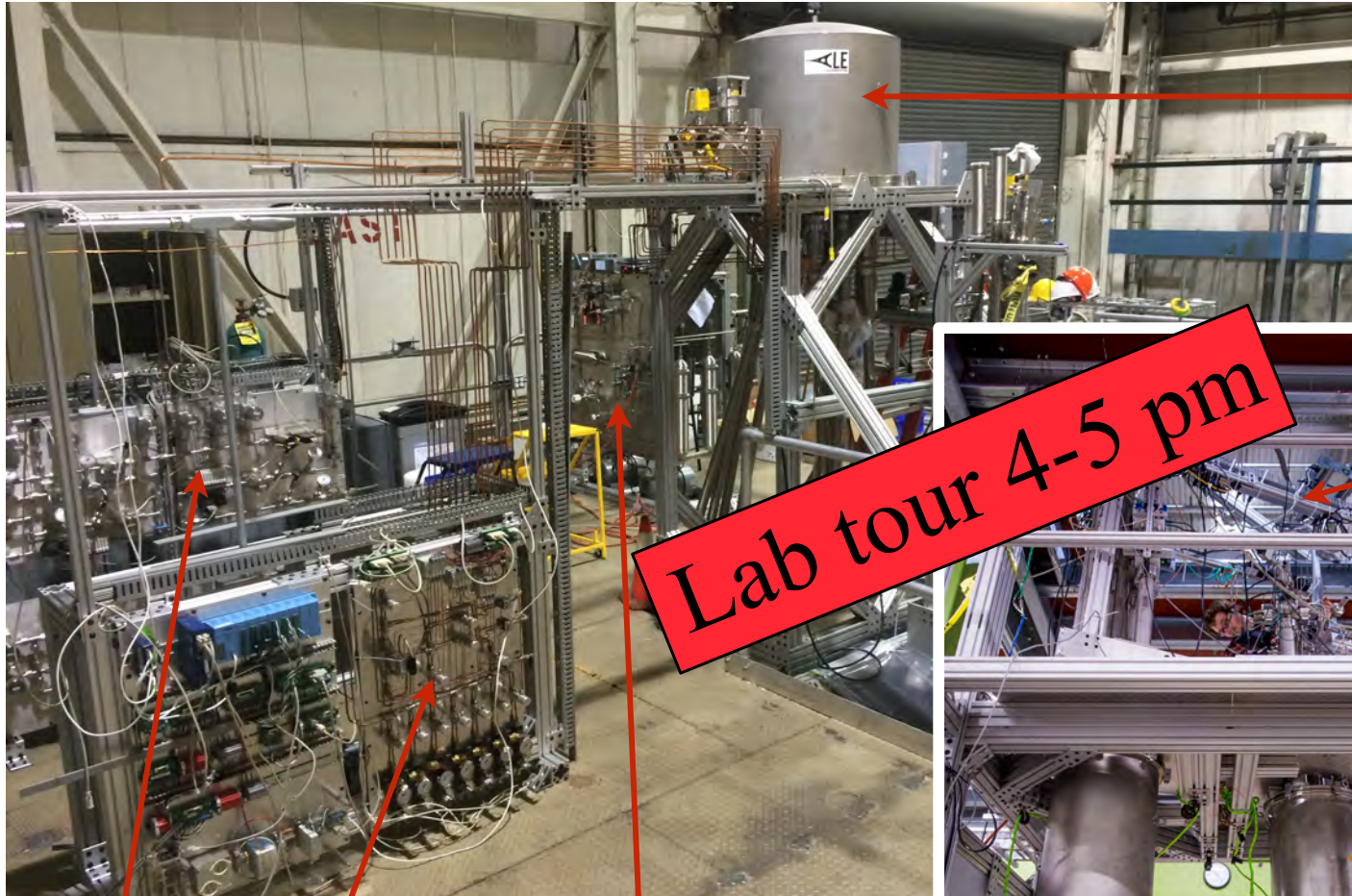
- Funded. In design phase. Expected turn on in 2019.
- Largest dark matter experiment.
- 300 times more sensitive than LUX.
- As-yet unmeasured Astrophysical neutrinos should be limiting background to dark matter signal



LZ at SLAC

- SLAC group has major role in LZ
 - Central Xe detector
 - LXe purification systems
 - Removal of Kr from Xe to 10^{-14} g/g
 - Data processing and simulations
 - Control systems
- System Test Platform
 - Design and testing of LZ detector components
 - Fundamental studies, advanced electronics development, blue-sky detector R&D
- Graduate opportunities in all these areas
- LZ dark matter data starting in 2019.

SLAC LZ System Test Platform



Thermosyphon
Dewar

Lab tour 4-5 pm

Breakout system /
Thermosyphon lines

Clean-tented area
for detector
assembly



RGA+ Cold-trap
sampling system
(U. Maryland)

Detector test
volume - COLD -
xenon condensed.

Purification Tower



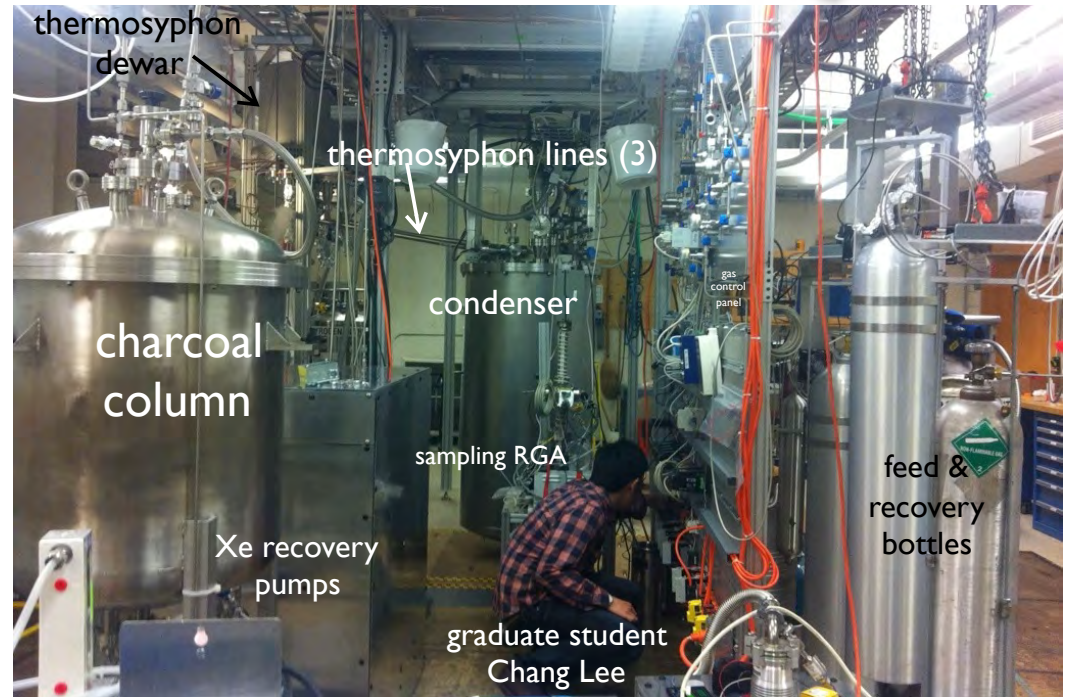
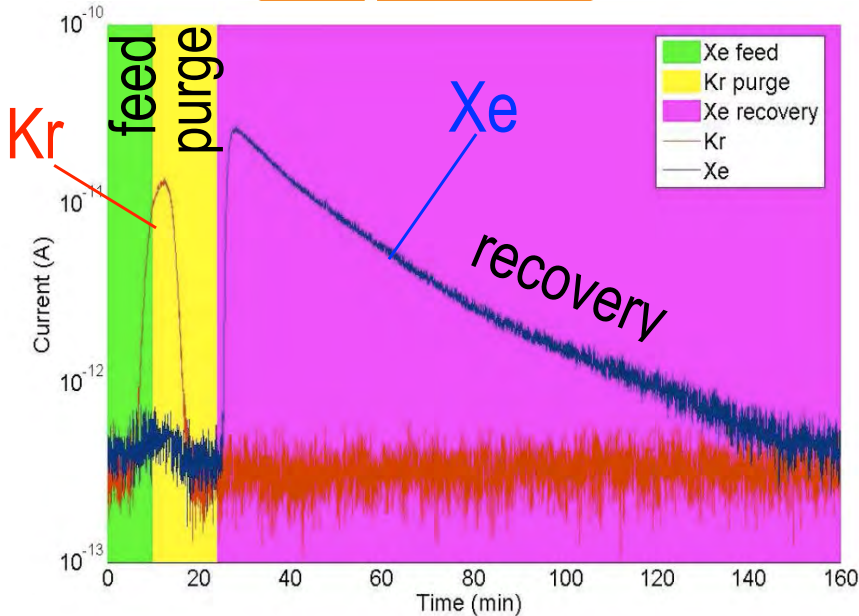
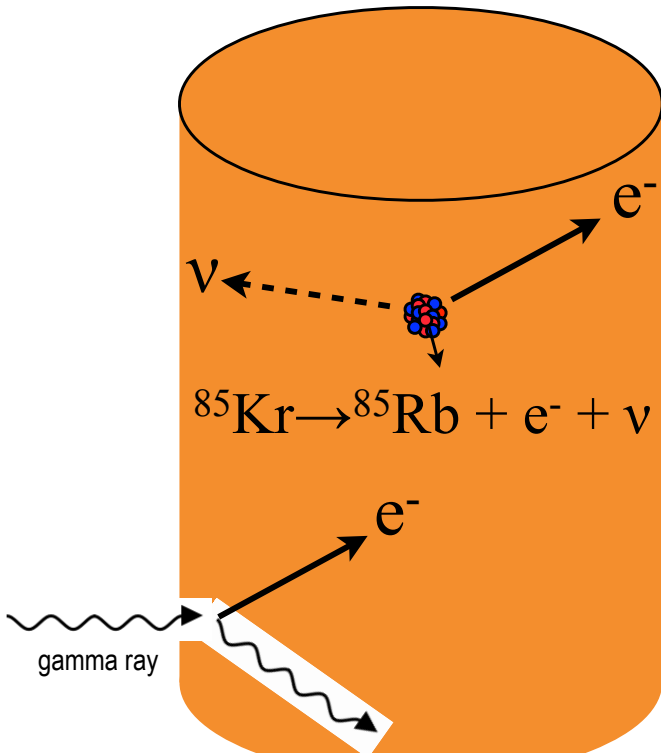
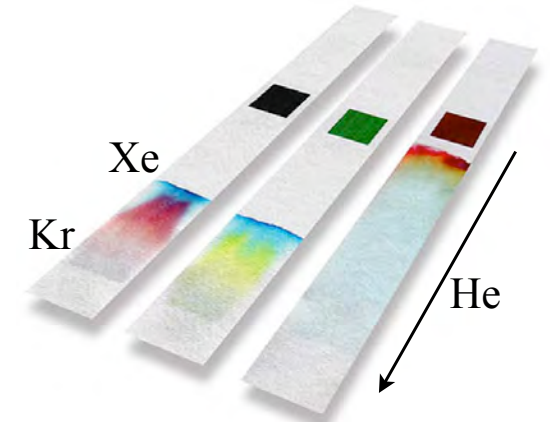
Thermosyphon
gas system

Xe purification
gas system

Internal dangers: radioactive krypton

Krypton:

- 10-y $T_{1/2}$ beta decay
- can't self-shield
- ~100 ppb in purchased Xe
 - 20 ppt ~ 122 PMTs
- noble gas: non-reactive

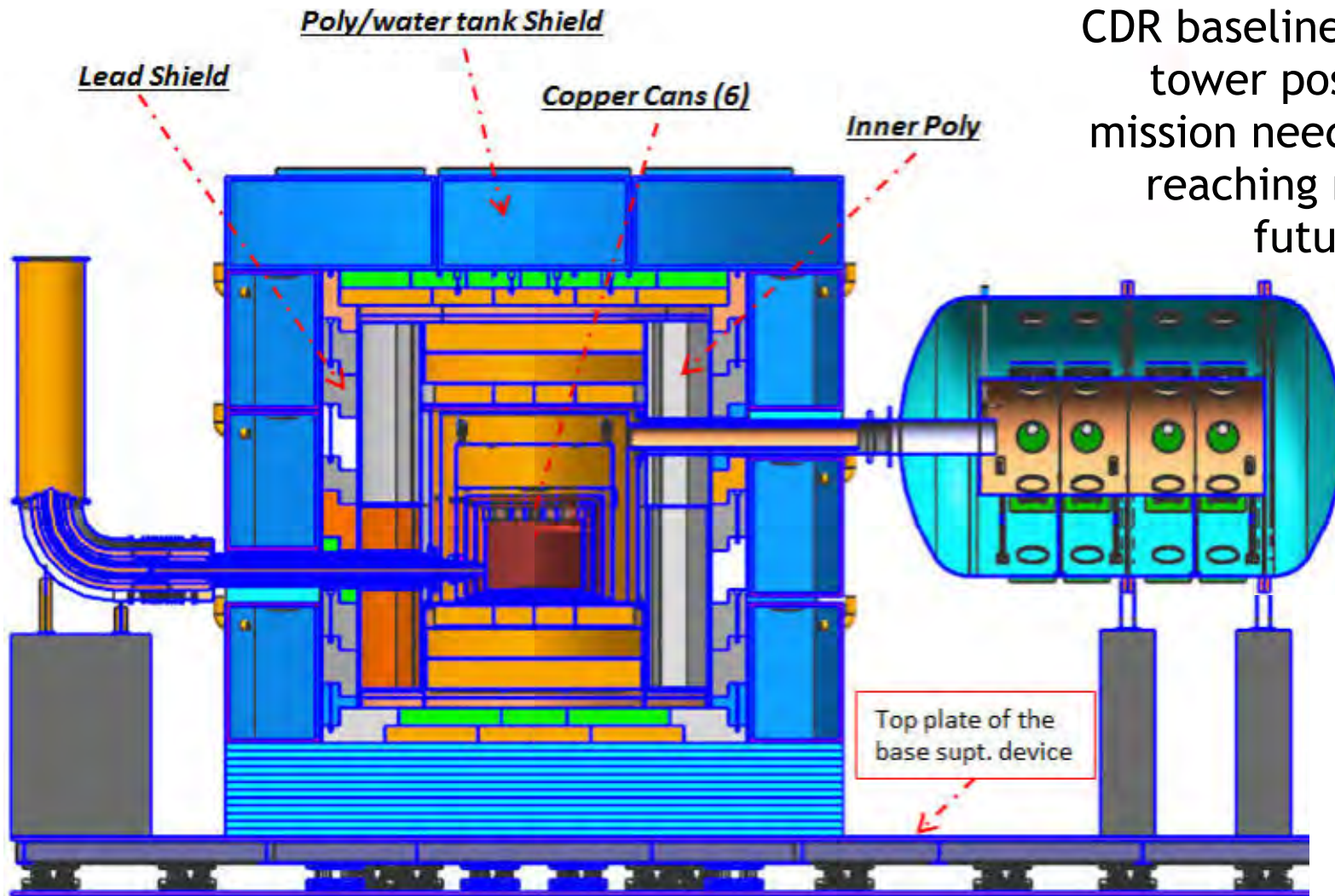
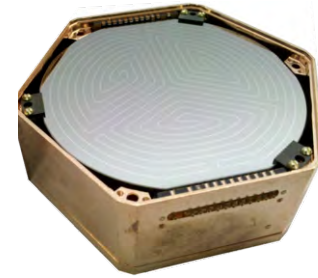


Charcoal chromatography removal system @ Case

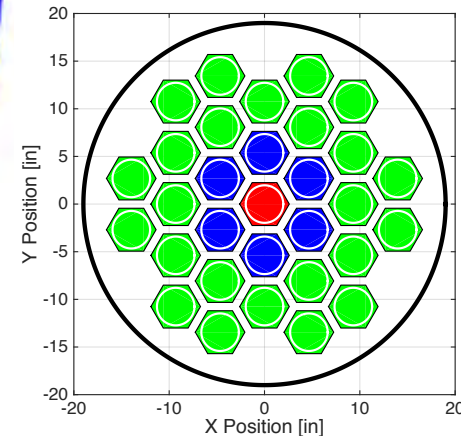
- processed 400 kg LUX xenon from 150 ppb to 4 ppt
- cold-trap leak-valve analytics - C. Hall / UMd.



Conceptual Design for SuperCDMS SNOLAB

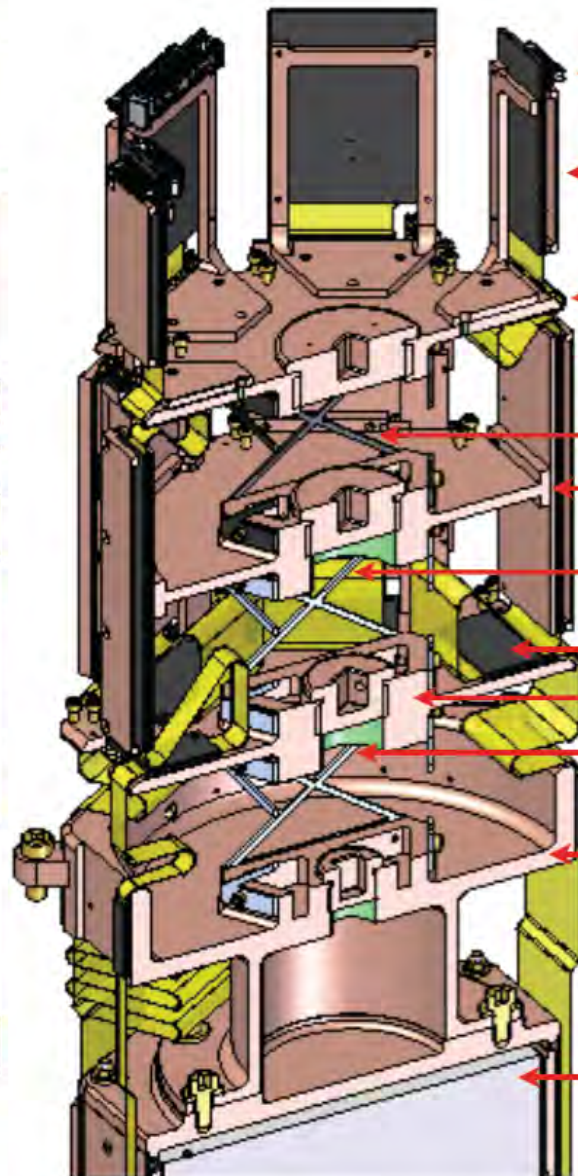
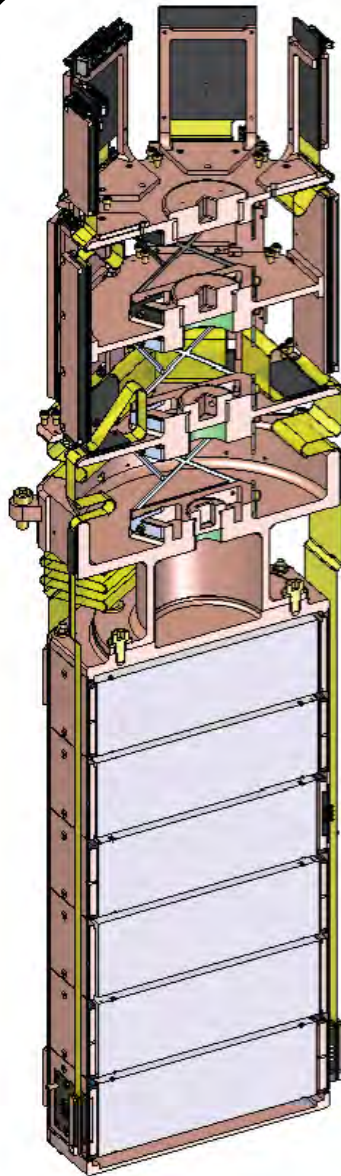
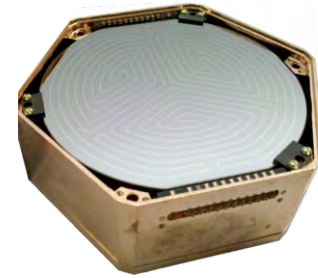


CDR baseline design contains 31 tower positions, fulfilling mission need with capability of reaching neutrino floor in future upgrade





Detector Tower payload



connector to
cable to 300K

4K stiffener
w/HEMTs

4K stage

ST stiffener
w/SQUIDs

CFRP truss

ST stage

CFRP truss

CP stiffener w/ R_{sh}

CP stage

Ti 15-3-3-3 truss

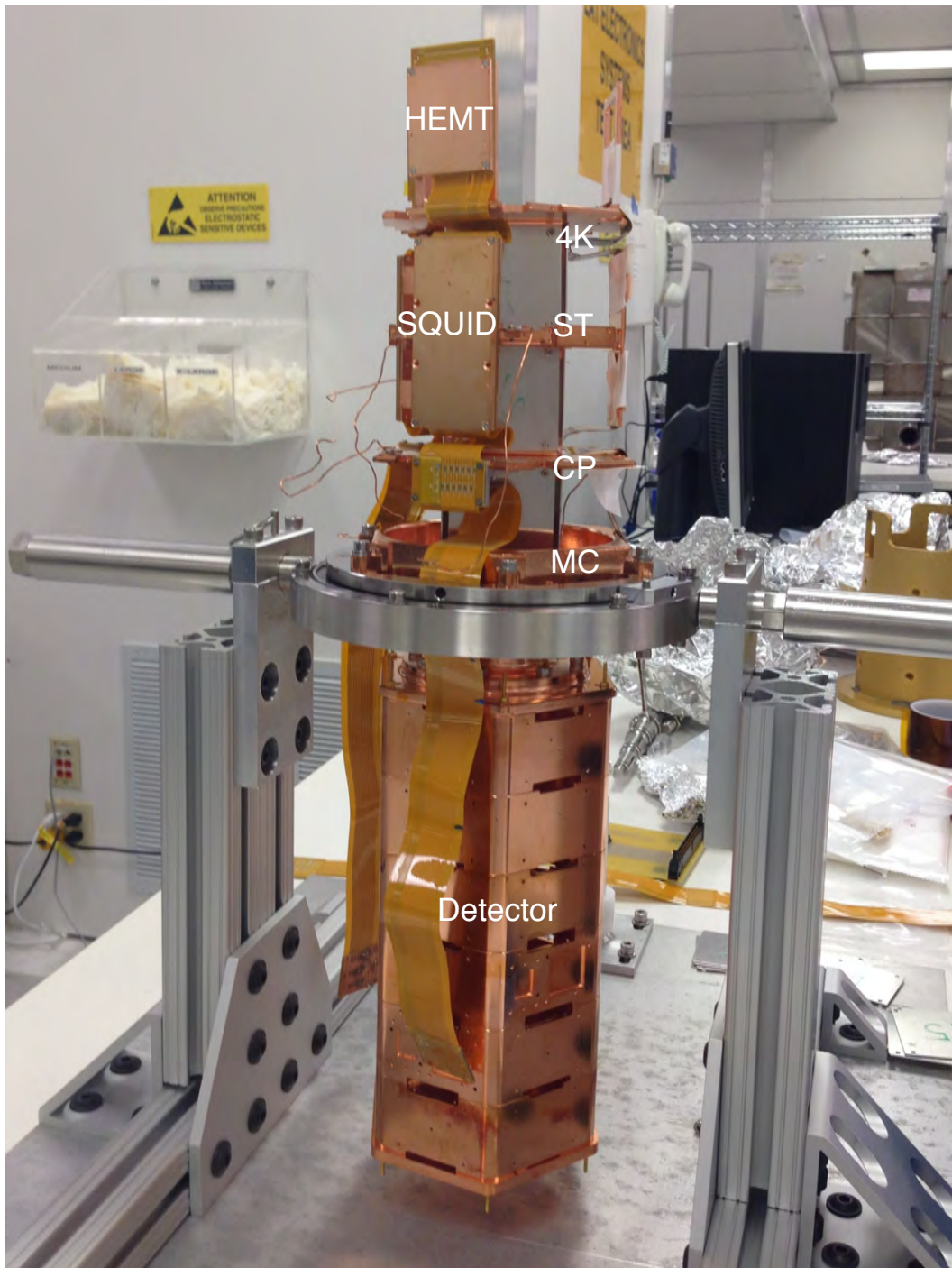
MC stiffener/heat sink

MC stage

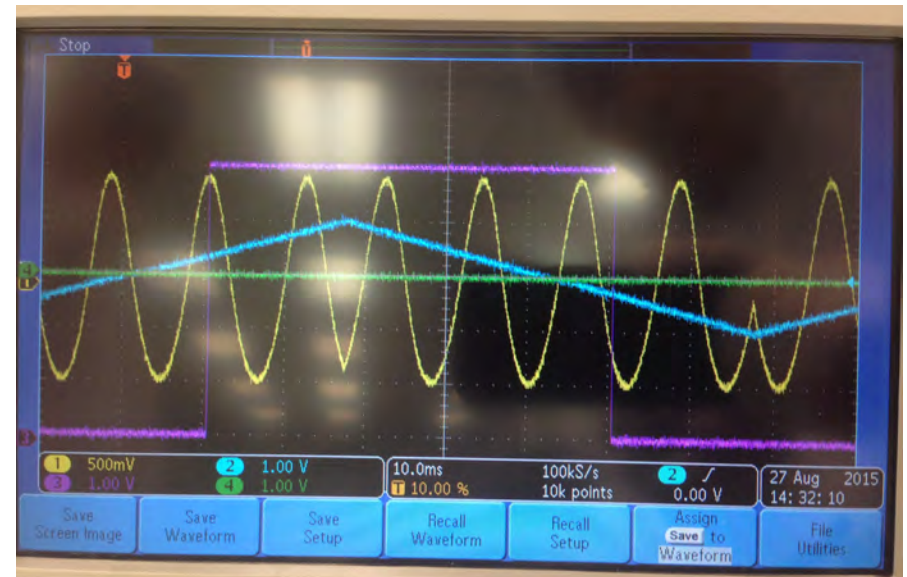
tower flex
cable

detector
packages

Tower Assembly Stand



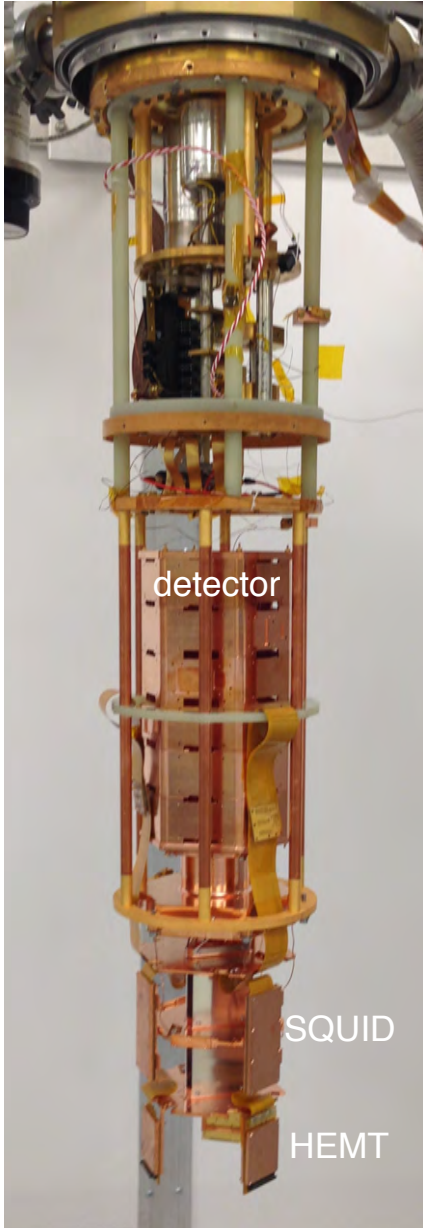
SQUID Modulation Curve



CDMS Tower Test Stand in Cleanroom



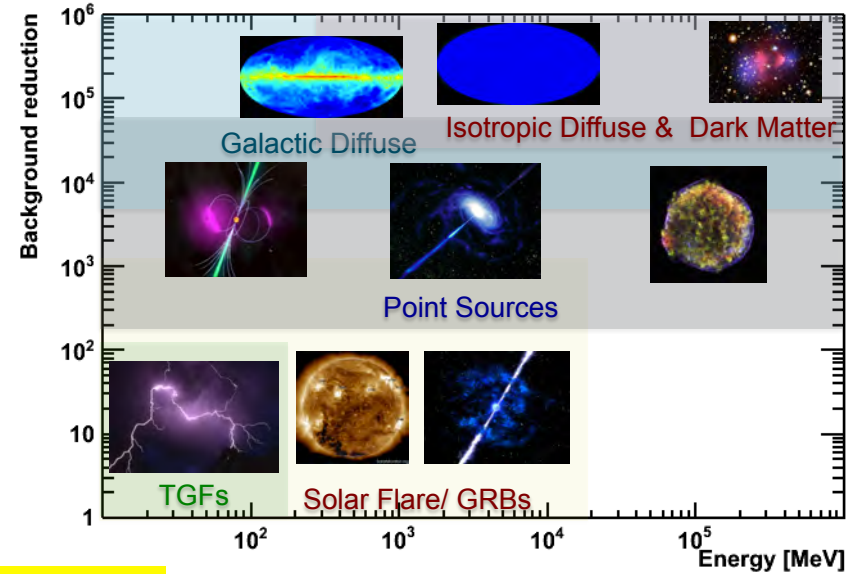
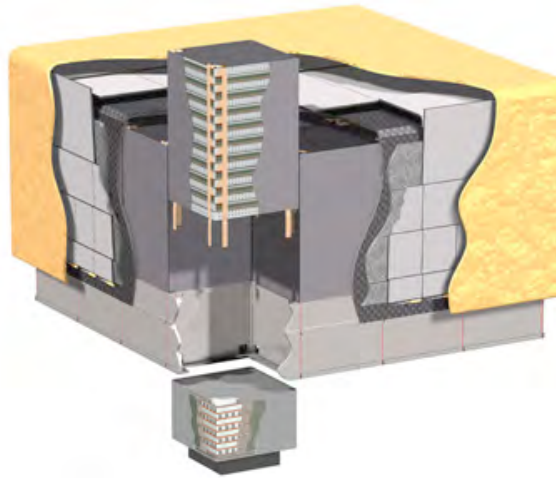
CDMS Tower in ^3He Fridge



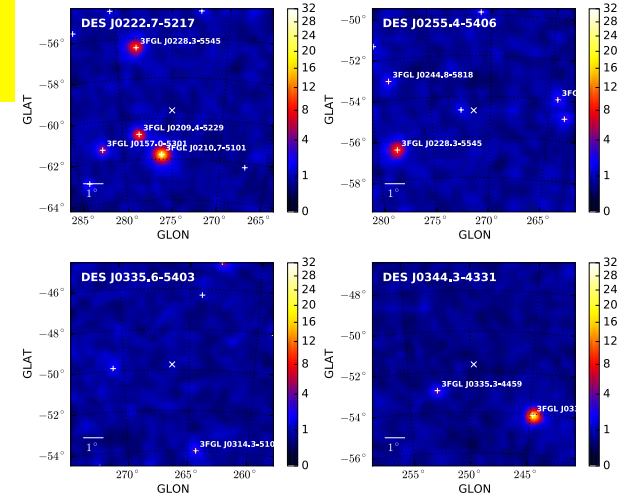
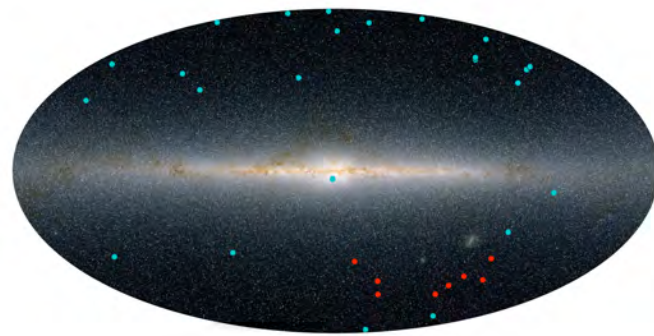
Fermi Gamma Ray Space Telescope

Constructed at SLAC

Advanced reconstruction analysis: "Pass 8"

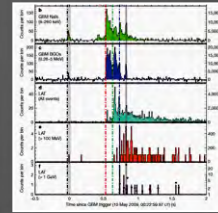
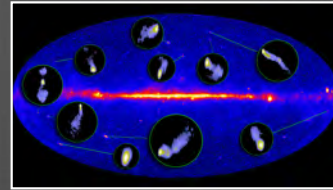
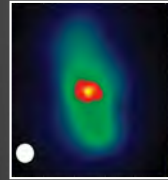
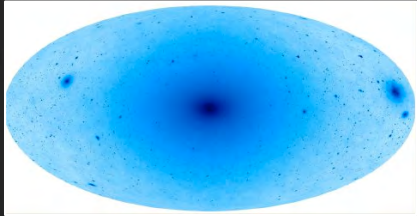


DES & Fermi: Dwarf Galaxies



Fermi Highlights and Discoveries

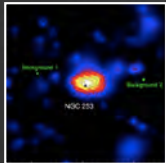
Dark Matter searches



GRBs

Blazars

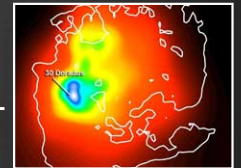
Radio Galaxies



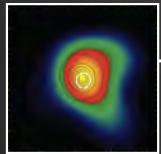
Starburst Galaxies

Extragalactic

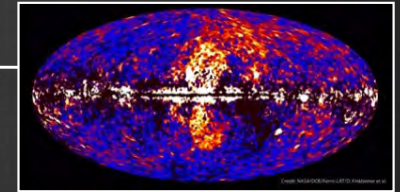
LMC & SMC



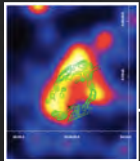
Globular Clusters



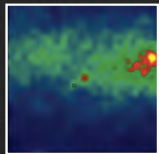
Fermi Bubbles



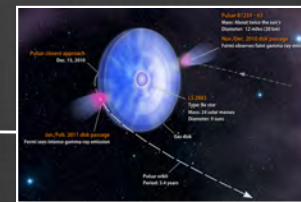
SNRs & PWN



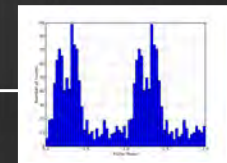
Novae



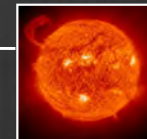
γ -ray Binaries



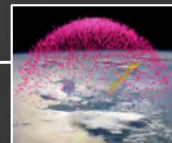
Pulsars: isolated, binaries, & MSPs



Sun: flares & CR interactions

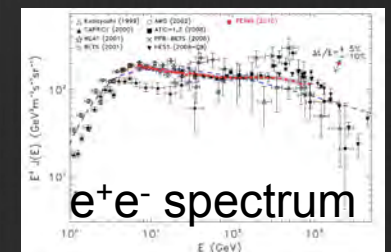


Terrestrial γ -ray Flashes



Unidentified Sources

Galactic



Particle-Astro Experiments at SLAC

- SLAC history of particle physics experimentation & experiment development
- Large scale facilities & technical support
 - Complements campus
- Dark Energy Survey
 - Profs. Allen, Burke, Roodman, Weschler,
- Large Synoptic Survey Telescope
 - Profs. Kahn, Roodman, Burchat, Allen, Schindler, Weschler
- Dark Energy Spectroscopic Instrument
 - Profs. Weschler, Roodman
- SuperCDMS
 - Prof. Cabrera, Dr. Partridge (SLAC Sr. Scientist)
- Fermi-LAT
 - Dr. Madejski (SLAC Sr. Scientist)
- LUX / LZ
 - Profs. Akerib, Shutt

Three tours today

- 2-3 SuperCDMS
- 3-4 Visualization Lab
- 4-5 IR2 - LZ and LSST