Status of the Fermilab Cosmic Program

Josh Frieman

Fermilab PAC Meeting

June 29, 2020

Charge & Recommendations

- Charge:
  - We ask the committee to review the status and future perspectives of the Cosmic program at the lab, including expected contributions to LDMX and CMB-S4, and the status of the recommendations made at the January 2020 meeting. ***CMB-S4 and LDMX contributions included below.***
- Recommendations from March PAC Report:
  - If Fermilab is chosen to take on a new role in LSST Operations (leading the data processing), the PAC would like to request a report at the next PAC Meeting about the progress, in particular with regard to the planning for computing support. ***DOE planning call for LSST Data Facility proposals.***
  - The Committee requests an update on CMB-S4 and Fermilab's contributions during the next PAC meeting. Given that by that time, DOE will have made a decision about the Host Laboratory for CMB-S4, Fermilab's role should be more clear by then. ***Lead lab not yet announced. CMB-S4 technical & management roles, R&D ramping up.***
  - The PAC was impressed with the SENSEI results and would like to hear about the project in more detail during the next PAC meeting. ***SENSEI running at MINOS, will install 100g detector at SNOLab next year, R&D toward 10kg Oscura experiment underway.***

Goals of the Cosmic Science Program

- What is the nature of dark matter?
  - Direct detection expts, indirect, colliders, astrophysical (surveys)
- Why is the expansion of the Universe accelerating?
  - Dark energy surveys
- What are the properties of neutrinos?
  - CMB, surveys
- Was there a primordial epoch of inflation and, if so, what physical mechanism drove it?
  - CMB, future surveys
- What are the most effective cosmic probes to address these questions?
  - Detector R&D
- How do we bring the community and data together to best implement & combine these probes?
  - Cosmic Physics Center

Fermilab Cosmic Strategic Plan

- **Cosmic Microwave Background** (inflation, neutrinos)  Grow
  - **SPT 3G lead operations → CMB Stage 4** major roles
- **Dark Matter Detection**  Consolidate
  - **Axions**: lead lab ADMX*, develop Quantum sensors for next-gen expt
  - **Sub-GeV DM**:
    - SuperCDMS construction, operations; R&D at NEXUS
    - Skipper-CCD R&D and deployment: SENSEI → Oscura*
  - Engineering, design, operations & coordination support for DarkSide-20k
  - Concept & trigger/DAQ for LDMX* (accelerator-based expt)
  - ***Dark Matter New Initiatives** (2 led by Fermilab)
- **Cosmic Surveys** (dark energy, dark matter, neutrinos)  Transition
  - **DES → LSST operations** (small but critical role in DESI ops)
  - **R&D toward next-gen spectroscopic survey** (LDRD)
- **Astro Theory program** w/ growing focus on cosmic neutrinos
- **Cosmic Physics Center** to provide connectivity and serve users
- *Cosmic activities flow from P5 drivers and from our core capabilities and synergize with other lab activities (Quantum, Neutrino, Energy...)*

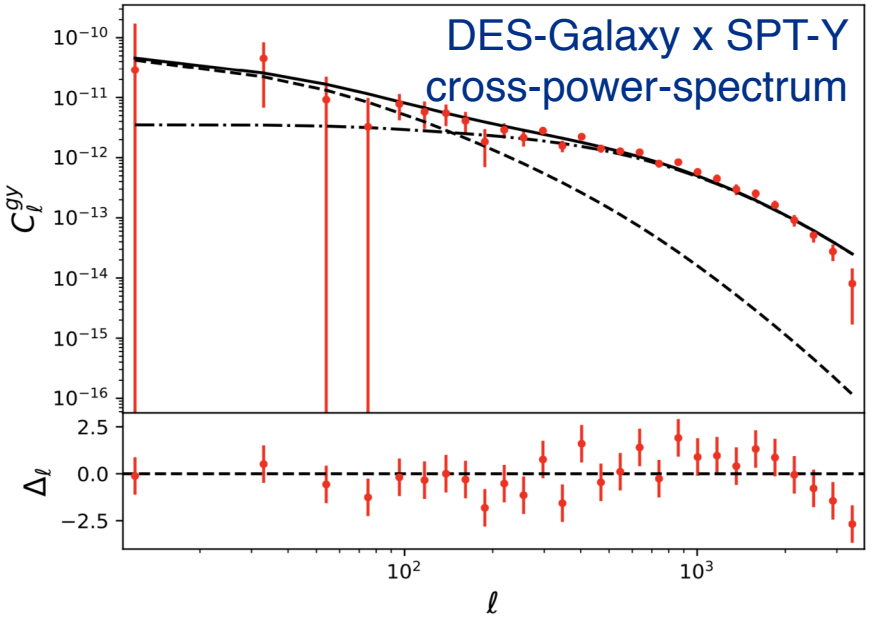
Cosmic Frontier at FNAL

Dark Energy | Dark Matter | CMB

Dark Energy	Fermilab roles	Fermilab Capabilities
DES	Project (DECAM) management, operations management, calibration, science, collaboration leadership, computing, data management	Detector test, assembly & integration at SiDet; survey design & ops, data mgmt.; project mgmt
DESI	Detectors, corrector support, science, online Database, fiber to target translation	Detector test, assembly at SiDet; survey design & ops
LSST	Dark Energy Science framework, survey operations & strategy, data management	Survey ops and computing infrastructure
Dark Matter	**Fermilab roles**	
SuperCDMS	cryogenics, electronics, operations, calibration, data analysis/science, project management	Precision assembly, cryogenic engineering, underground test facility (NEXUS), project mgmt
DarkSide	Ar extraction & purification; proj. coordination	Engineering, proj. management, design
ADMX	RF cavity development, operations management, science	RF engineering test & assembly, quantum sensors, high-field magnets, ops mgmt
Skipper CCD	dark matter search (SENSEI), R&D for applications to dark matter/neutrino expt's & large scale surveys	Expertise in skipper CCD's, detector packaging at SiDet, underground test facility
CMB	**Fermilab roles**	
SPT 3G	Camera design, cryostat fabrication, detector packaging, testing, integration	Detector testing, assembly, integration at SiDet, operations mgmt., detector electronics, project mgmt
CMB S4	R&D, cryostat design, electronics, module assembly/testing, cost/schedule development	

CMB Accomplishments

- SPT-3G survey is continuing nominal operations (insulated from Covid at the South Pole). Survey to continue through 2023. FNAL leading operations.
- In past 12 months, over 43 publications using SPT data.
- FNAL actively participating in science analysis, e.g., cross-correlation from SPT-DES (see figure from postdoc Javi Sanchez)
- In 2020, expect first science results from SPT-3G
- New Wilson Fellow hire: Sara Simon



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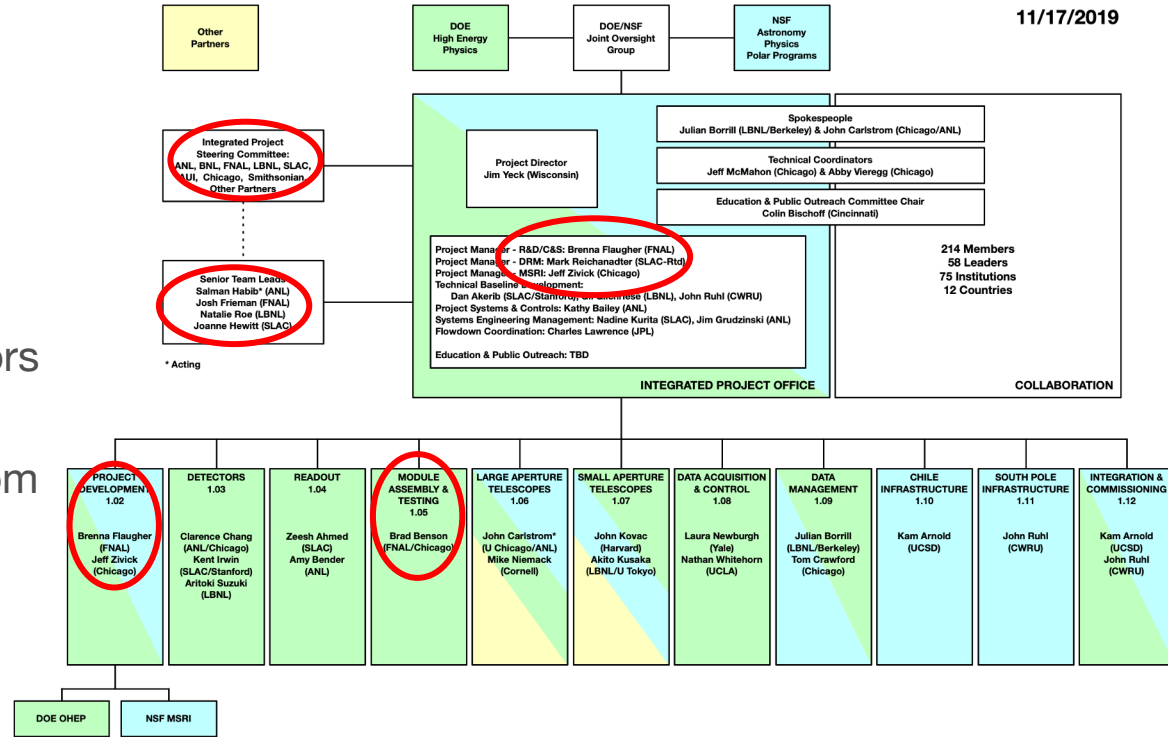
CMB-S4 Status

- Endorsed by P5 and many committees. Received CD-0 July 25, 2019.
- Plan is roughly equal DOE and NSF scope, TPC 600M$ including 30% cont.
- Working toward CD-1 in summer 2021, CD-2 ~'22, CD-3 ~'23, early ops start '27
- Science Case and Project Plan submitted to Astro 2020 Decadal Survey July '19
  - Precursor to MREFC
  - Presentation to Committee Feb. 4, 2020, plus many additional requests for information as part of TRACE process (cost assessment)
- Lead Lab Decision still in progress
  - Letter with Charge and instructions sent to SLAC, LBL and ANL Dec. 2019
    - Proposal submitted Jan. 31.
    - Team visited Germantown mid-Feb.
    - Fermilab, UChicago and ANL comprise the "Argonne CMB Consortium"
      - John Carlstrom, Jim Kerby, Brenna Flaugher are the core leadership team
- Preparing for Directors' review July 14-16 and Agency Review Aug 18-20
  - Preparations organized by team of potential directors: Kerby, Corlett, Kahn
  - DOE said they will have decision by the August Review.

CMB-S4 Project Organization

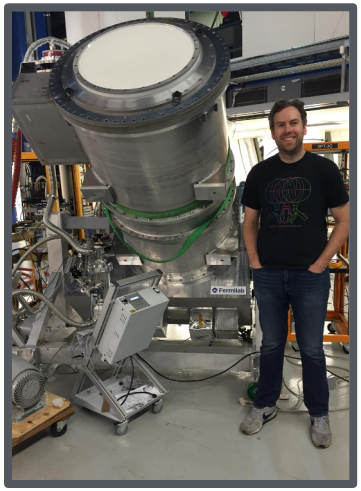
- Jim Yeck has been serving as Director for past ~ 3 years, will transition out after LL decision
- Integrated Project office to jointly manage NSF and DOE Scope
- Steering Committee of Lab Directors
- L2 managers assigned Summer 2019, engage technical experts from across the community
- Fermilab scope: Module Assembly and Testing, Brad Benson L2 manager
  - Recent hire – July 2020: 2nd Wilson Fellow! Sara Simon
  - Schramm postdoc Fellow Kirit Karkare coming in Fall 2021



Brenna Flaugher – R&D and Cost/Schedule, DOE PM if ANL LL
Brad Benson - Vice Chair of Governing board, L2 manager
Adam Anderson - Wilson Fellow 2019 module design, L3
Sara Simon - Wilson Fellow 2020 optical coupling expertise, L3
Jeff McMahon UC Joint Appointment – optics, technical lead
Josh Frieman – FNAL Senior Team Lead

FNAL roles in CMB-S4 capitalize on our strengths

- **Core Capabilities & Experience**
  - Leadership of SPT–3G detector testing, integration, cryostat design, operations
  - Project management expertise and infrastructure
  - Cryogenic Engineering
  - Technical facilities:
    - SiDet – wirebonding, precision assembly, integration and testing
    - IERC cryogenic lab will house multiple dilution fridges for CMB-S4



- **Strong/growing connections with U Chicago and ANL**
  - History of close collaboration on SPT-3G and CMB-S4
  - Combined expertise in project leadership, science, engineering and operations well matched to needs of CMB-S4; working closely to move it forward
  - Joint FNAL/UC positions will provide cost-effective growth to lead this program
- **Strong working relationships with other labs and universities:**
  - Complementary strengths, e.g., detector fab at other labs will feed FNAL testing.
- **DOE-funded R&D program underway at FNAL**
  - Module assembly and LAT cryostat design

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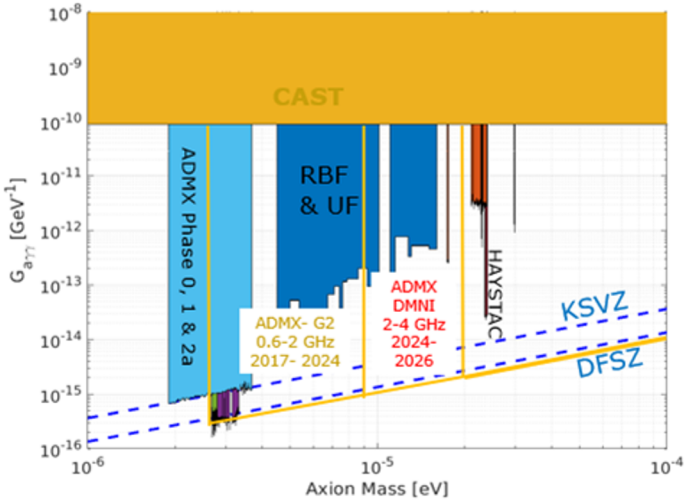
ADMX Status

- Continued data taking at U. Washington during COVID. Remote shifts + weekly site visits by a few essential personnel. Operating in 800-1020 MHz band with sensitivity to DFSZ axions (~20% complete).

- Published results:
  - Run 1A (645-800 MHz). PRL April 2019
  - Run 1B (680-800 MHz). PRL March 2020
- Major current Fermilab hardware responsibility: testing 4-cavity array for Run 2 (1390-2300 MHz) in new cryogenic test stand.
- As lead lab, Fermilab responsible for operations management.
- **Dark Matter New Initiatives** grant in 2020-2021 provides funding for design of next generation experiment (2-4 GHz).

Fermilab Cavity Test Stand



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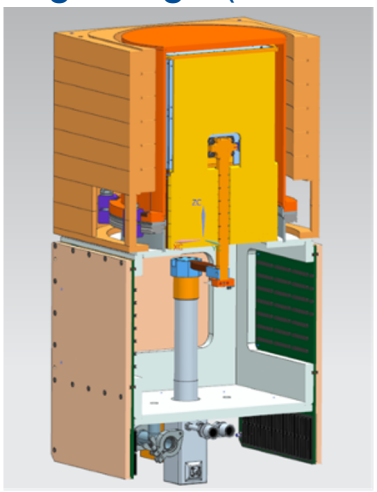
Synergies with DOE quantum program

- Aaron Chou leads 8-institution QuantISED consortium to develop QIS technologies for HEP applications
  - Chou/Hassan/Hollister/Khatiwada (FNAL), Schuster (Chicago), Lehnert (Colorado), McDermott (Wisconsin), Echternach (JPL): **Superconducting qubits for axion searches** Leverages Bowring ECA and FNAL LDRD
  - Maruyama (Yale): **Rydberg atoms for axion searches**
  - Berggren (MIT), Nam (NIST): **Superconducting nanowire single photon detectors for hidden photon dark matter search.**
  - Estrada (FNAL): **SENSEI CCDs for hidden photon search**
- Chou also leads Devices/Sensors thrust for ORNL NQI proposal to apply HEP core capabilities to national priorities in QIS
  - Bauer/Hsu/Lukens: use MINOS underground lab to study solid-state qubits in ultralow ionizing radiation backgrounds (which will soon dominate qubit error rates)
  - Anderson/Benson/Khatiwada/Cancelo: Highly multiplexed testing of arrays of cryogenic qubit sensors and quantum materials, optomechanical force sensors
  - **Engagement of NQI partners from BES (materials science, condensed matter) and ASCR will invigorate sensor development for HEP applications, e.g. ultralow-threshold microcalorimetry using engineered bandgap materials.**

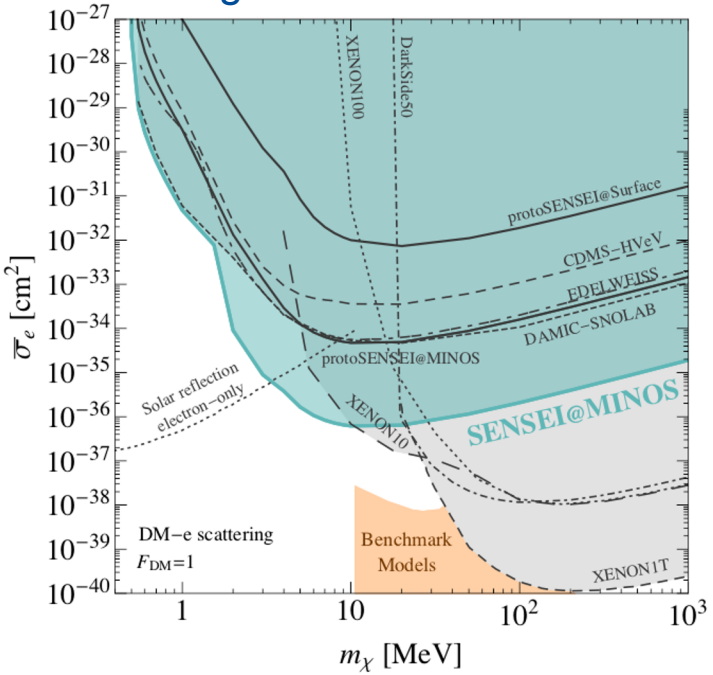
Skipper-CCDs for DM Sensei/Oscura

- SENSEI Collaboration currently running 2.5g skipper-CCD detector at MINOS, producing world leading results.
- Also running 2.5g skipper-CCD engineering detector at SNOLAB, in preparation for 100g experiment to be installed next year.
- Vacuum vessel for 100g experiment being assembled at SiDet.
- Skipper-CCD characterization ongoing at SiDet, production packaging starting in a few weeks.

100g design (40 CCDs)



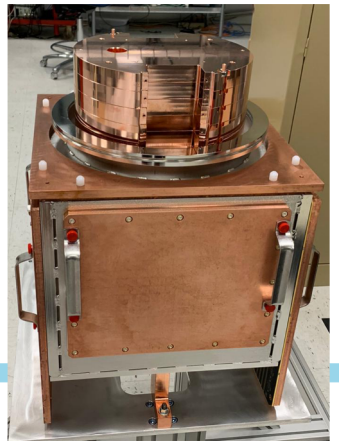
current world leading results arXiv:2004.11378

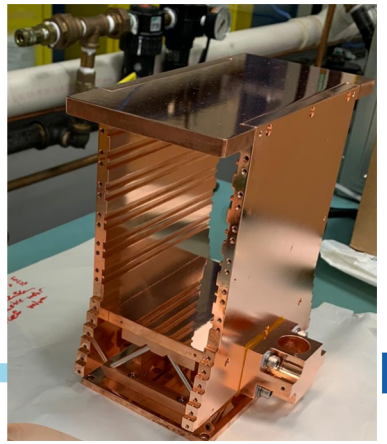


vacuum vessel base

detector housing

ongoing process at SiDet

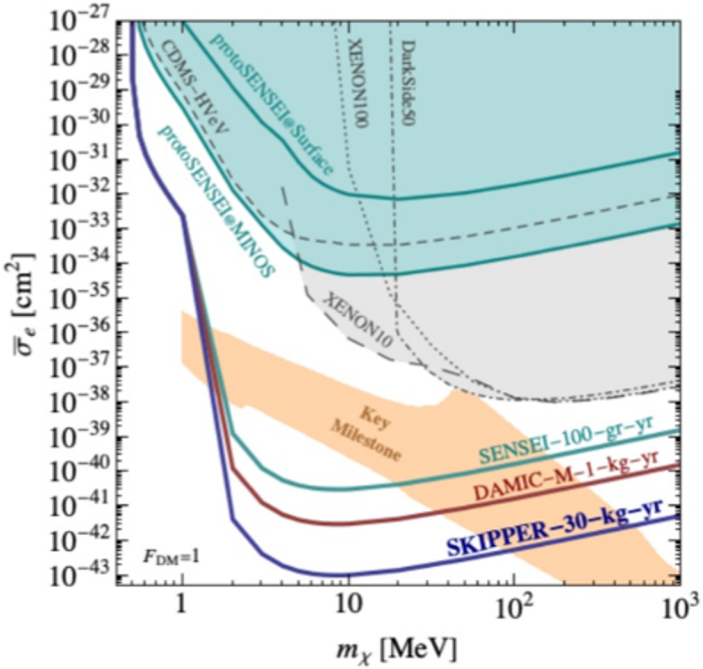


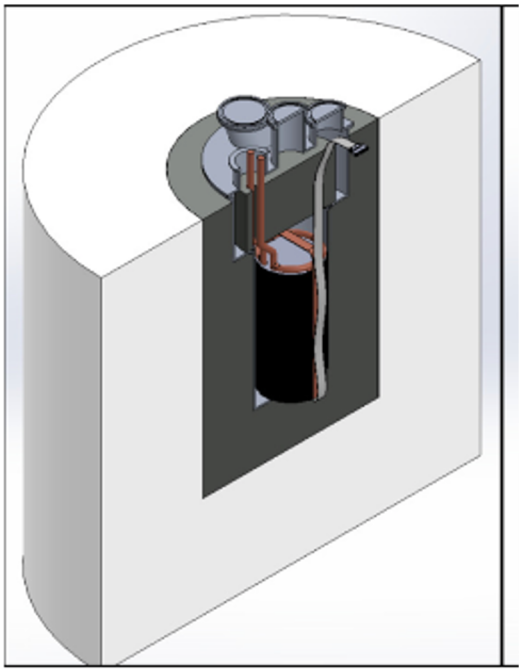


Skipper-CCDs for DM Sensei/Oscura

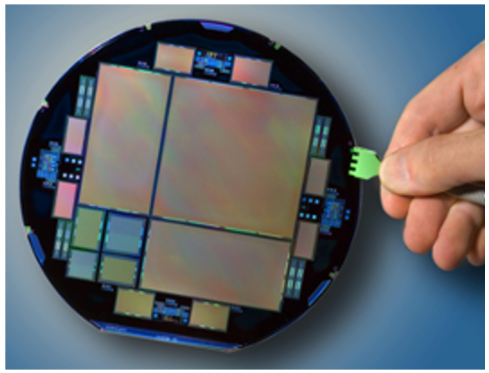
DOE Dark matter New Initiative:

- Oscura 4-year R&D effort (FNAL, LBNL, PNNL, U.Chicago, U.Washington, Stony Brook).
- 10kg experiment, taking skipper-CCDs to full potential





24 Gigapixel digital camera for dark matter! Cooling, readout, packaging and testing of the required 4000 skipper-CCD sensors require engineering solutions not yet available for scientific CCDs. Radiation background required is ~10x lower than state of the art experiments.



Fabrication of skipper-CCDs needs to adapt to changes in the semiconductor industry. Identified new industrial partners and will test over the next year. Good progress in transferring technology to new fabrication facilities (2 options).

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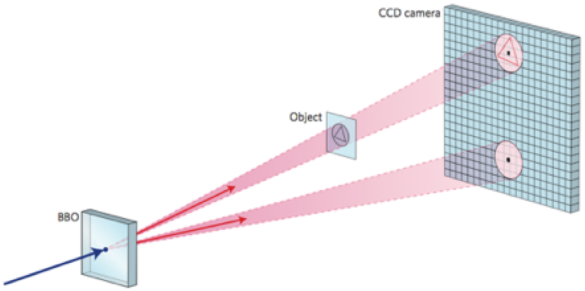
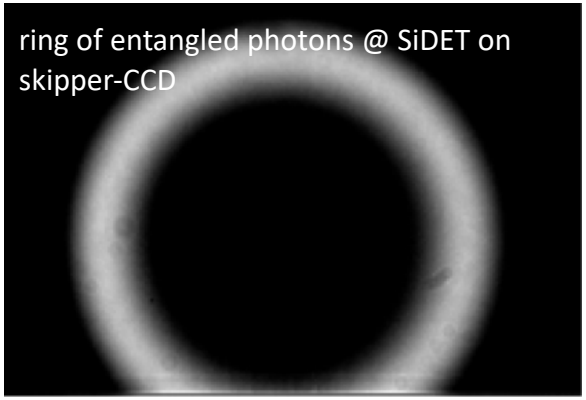
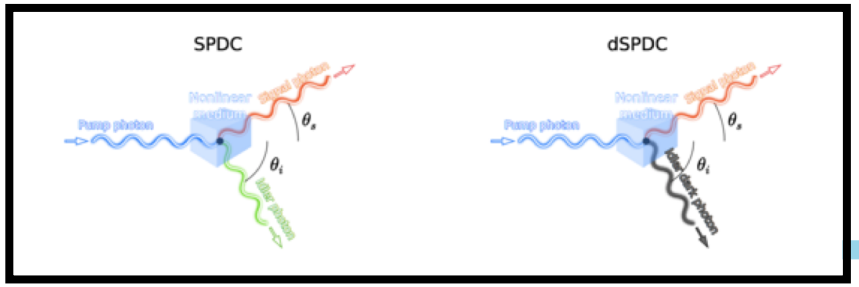
Skipper-CCD beyond DM

quantum imaging



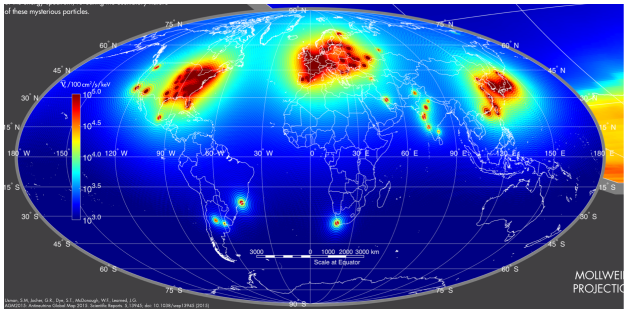


potential new tool to search for the production of dark photons

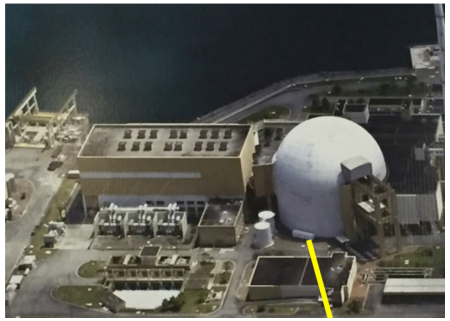


QIS grant funding this.

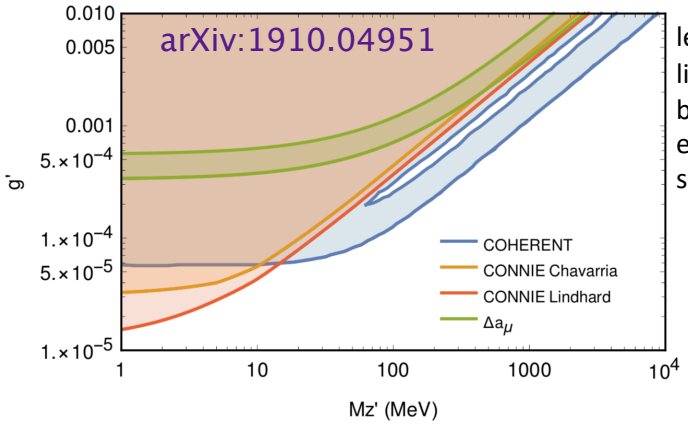
CEvNS and beyond



CCDs next to a nuclear reactor to access new physics in the low-E neutrino sector.



CONNIE (LDRD) has been exploring this at a reactor for a few years with standard CCDs.



leading search for light vector mediator by CONNIE, will get even better with skipper-CCDs.

Large arrays of skipper-CCDs could also be used for safeguard monitoring of nuclear reactors.

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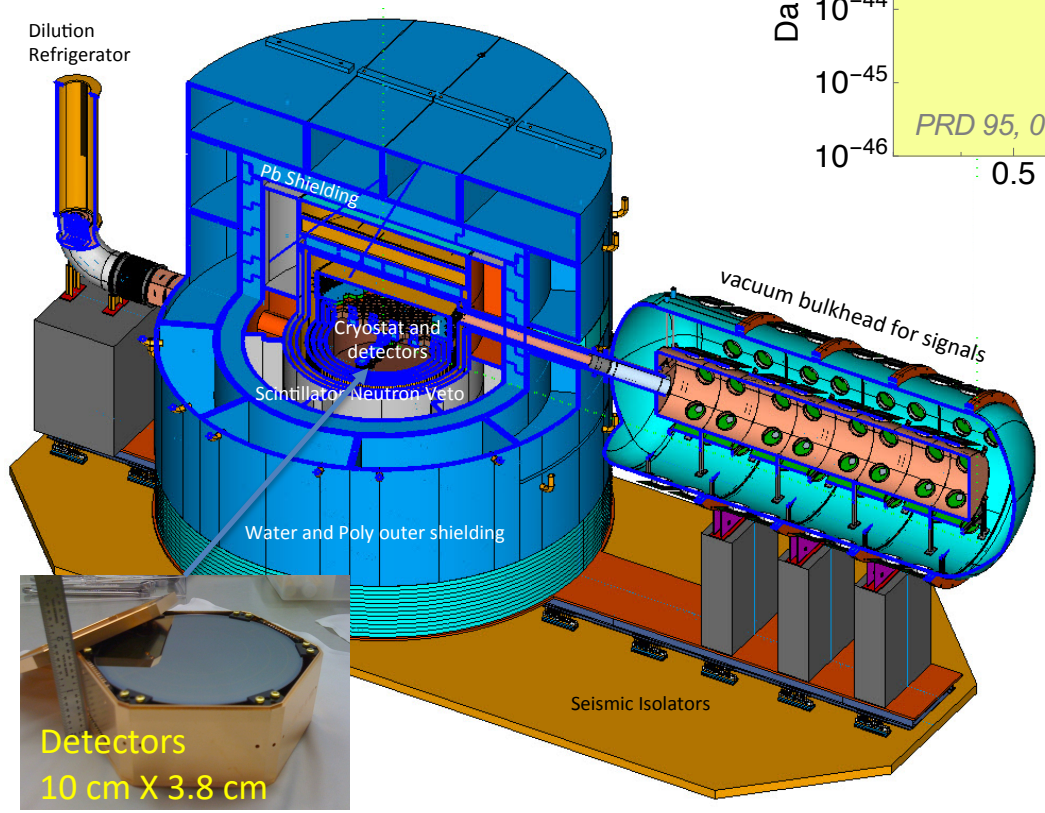
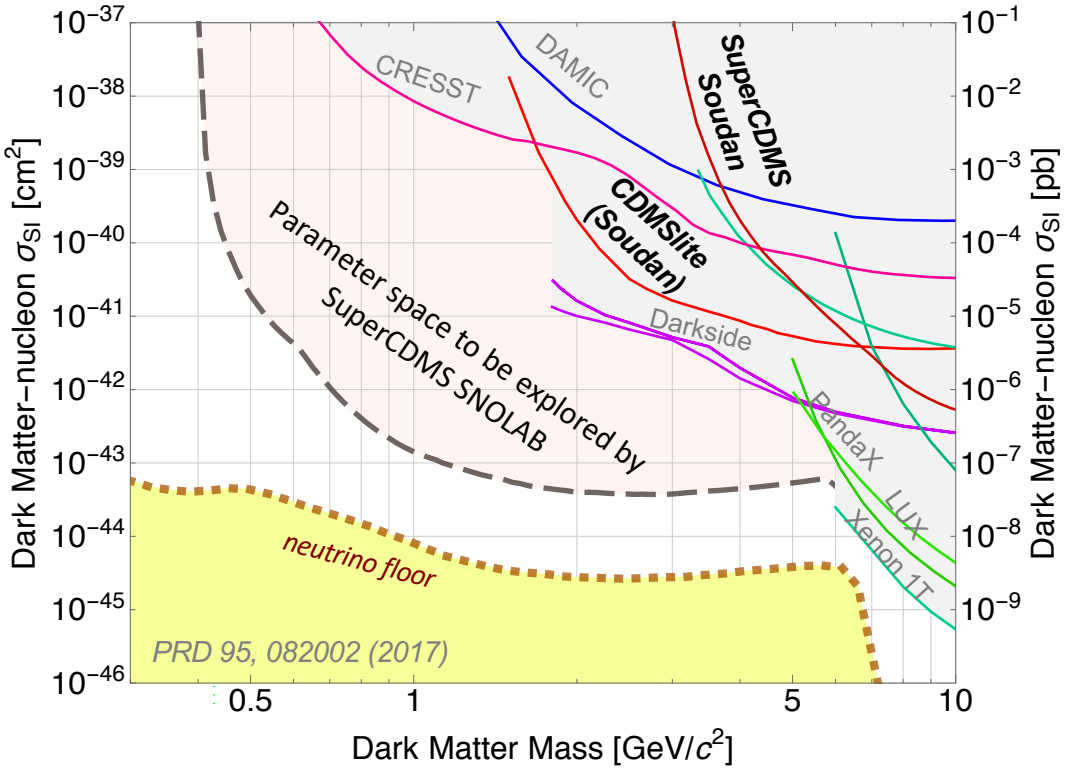
SuperCDMS SNOLAB

Will provide superb sensitivity to dark matter particles with masses in the 0.5-10 GeV/c^2 range with Ge and Si detectors

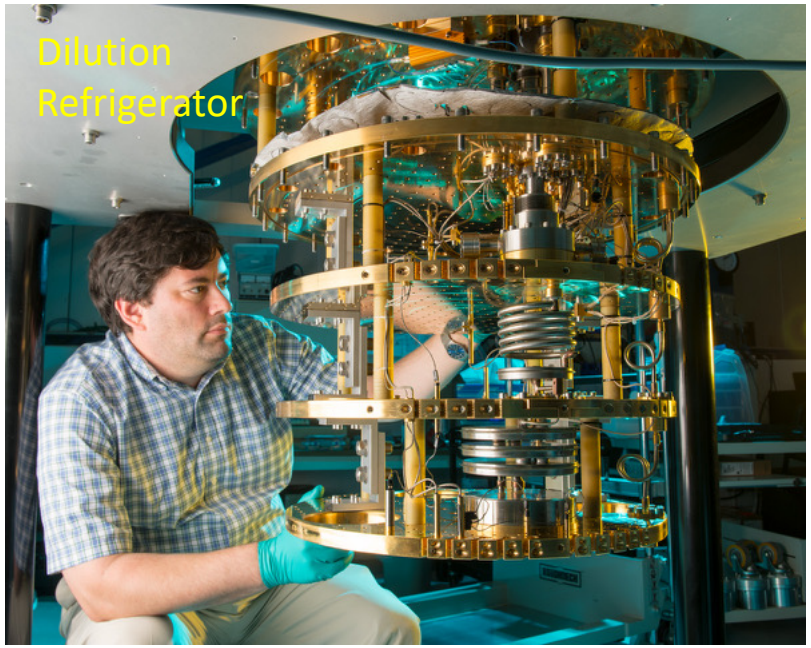


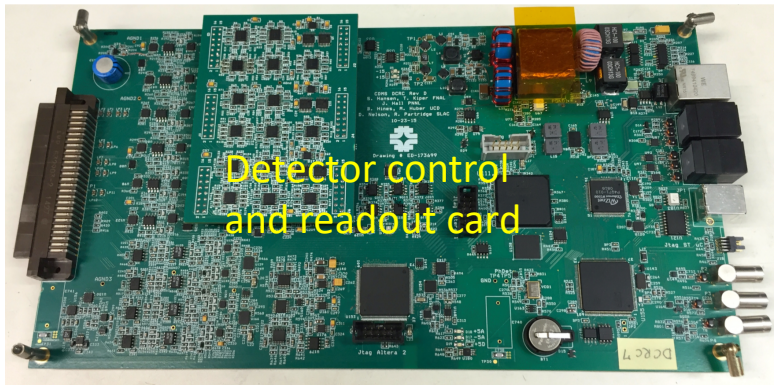


- Project led by SLAC
- Install and commission at SNOLAB in 2021
- First physics run in 2022
- $34M DOE/NSF/Canada Project funding; ~$6M Fermilab scope
- Requesting Operations support of ~$2M/year DOE, ~$1M/year each from NSF and Canada

SCDMS: Fermilab Roles & Status

- FNAL continuing 20 years of involvement in SuperCDMS, with leadership roles in:
  - Cryogenic design and operation
  - Warm electronics design and fabrication
  - Calibration system design and ops
  - Infrastructure and Integration
- Cryogenics:
  - Dilution Refrigerator tested at Fermilab
  - Copper cryostat (SNOBOX) vendor bid exceeded project budget/schedule
    - Redesigning affordable cryostat requires reducing payload capacity from 31 detector towers to 7
    - Delays project completion by ~12 months
  - Overruns due to detector towers, cryostat and COVID-19 make it likely that the project will be re-baselined
- Electronics and Calibration on schedule
- Infrastructure being installed at SNOLAB





SCDMS: Fermilab working closely with SLAC/Project

- Redesign of cryostat by FNAL/SLAC task force nearing completion
- Must deliver on DOE/OHEP PEMP Notables:
  - Present Project-vetted plan to OHEP for completion of Fermilab project scope
  - Supported Project in developing and presenting an installation and commissioning plan to OHEP
  - Developed Lessons Learned report for cost overruns associated with Fermilab scope of work
  - Completed (re)design of the SNOBOX (Cryostat for detectors)
- Chief Project Office and Divisions have provided increased oversight of Fermilab performance and strengthened liason with SLAC/Project.
- PPD, APS-TD have provided priority for key FNAL technical personnel to SuperCDMS SNOLAB
- Fermilab agreed to remove $390K costs from the Project to help re-build Project contingency

LDMX: Fermilab Roles

- **LDMX Collaboration Positions**
  - **Tran/Krnjaic** are Fermilab's institutional representatives on the collaboration and members of senior collaborators committee.
  - **Tran** is also a member of the collaboration board.

- **Collaboration Activities**
  - BSM studies of model discrimination strategies **(Blinov/Krnjaic)**
  - Fermilab is leading the trigger and DAQ effort, **Tran** is the TDAQ subsystem coordinator; including trigger design and firmware.
  - We are contributing to the HCal backend electronics design and firmware.
  - We have $150k of Dark Matter New Initiatives funding (mostly engineering labor and M&S).
  - LDRD funding including some postdoc funding and summer students to contribute to LDMX Snowmass studies (among other hidden sector initiatives)
  - **Tran** is the point-of-contact for Snowmass LDMX electronuclear measurements for DUNE white paper

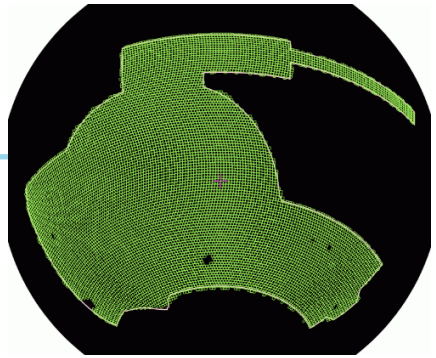
LDMX: Fermilab Contributions

- **Upcoming LDMX-related theory papers**
  - Using signal kinematics to distinguish BSM models (**Blinov, Krnjaic** - June 2020)
  - Thermal relic targets for scalar mediated dark matter (**Blinov, Krnjaic** - Fall 2020)
  - Proton beam missing momentum possibilities (**Krnjaic, Tran** 2020-2021)
- **Upcoming LDMX Collaboration papers**
  - Multi-electron events at LDMX (**Krnjaic, Tran** w. LDMX Collaboration)
  - Backgrounds study with 8 GeV beam (**Krnjaic, Tran** w. LDMX Collaboration)
- **LDMX Collaboration Activity (FNAL people)**
  - BSM model discrimination studies (**Blinov, Krnjaic**), HCAL development (**Tran**)
  - Presentations at LDMX physics workshop June, 2020 (**Krnjaic, Tran**)
- **LDRD: Accelerator-based Dark Matter Initiatives at Fermilab**
  - feasibility studies for various experimental possibilities (**Blinov, Kelly, Krnjaic, Toups, Tran**)
- **Snowmass LOI/Papers (Summer 2020)**
  - LDMX electron beam w/ collaboration
  - M3 muon beam based on Kahn, **Krnjaic,** Whitbeck, **Tran** arXiv:1804.03144
  - LDMX and lepton-nucleon interactions to improve ν-N modeling — based on Ankowski, Friedland, **Li,** Moreno, Schuster, Toro, **Tran** 1912.06140
- **Broad FNAL/CPC Accelerator Based Dark Sector Efforts**
  - Dark/Long Quest, DUNE DM, FerMINI (**Blinov, Kelly, Tsai, Toups, Tran**)

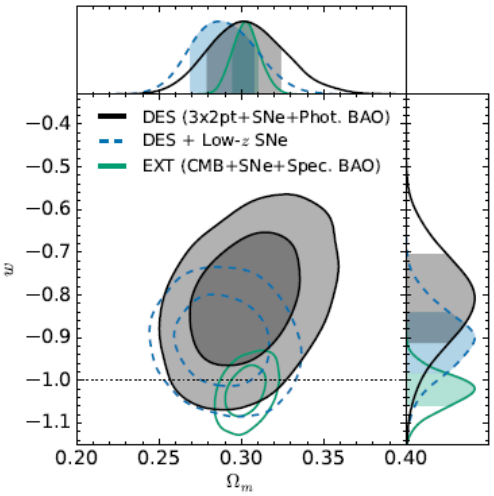
DarkSide-20k

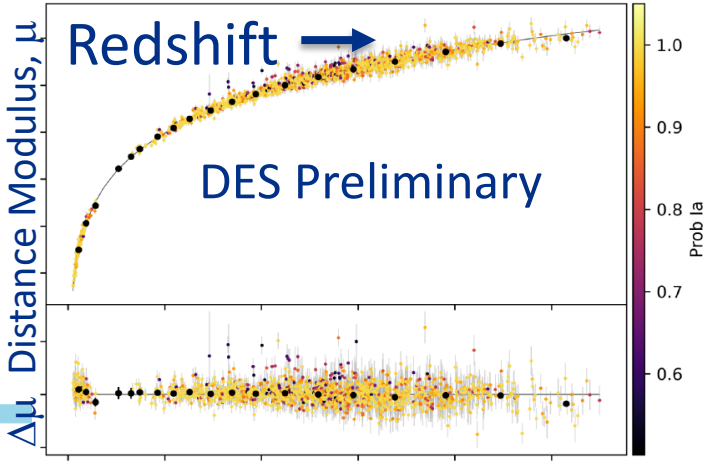
- ~$130M INFN-led experiment to search for dark matter using dual-phase LAr TPC (protoDUNE-like cryostat) at Gran Sasso National Laboratory. Project and collaboration include significant NSF support.
- Procurement & purification of low-radioactivity argon is a key requirement:
  - Extract underground Ar, which has reduced amounts of radioactive ^{39}Ar
  - Separate ^{39}Ar via cryogenic distillation; Fermilab developed this for DS-50
- Construction of *Urania* underground Ar extraction plant from CO_2 gas mine near Cortez, Colorado funded by INFN, NSF.
- Purification via *Aria* cryo distillation column in Sardinia (INFN).
- At request of INFN and NSF, DOE will support FNAL ($9.5M over 4 years) to provide engineering support for *Aria* and *Urania*, contributions to DS-20k detector design, DS-20k project coordination, and operation of the *Urania* facility. No support provided for scientific role (DS-20k is not one of the G2-approved DM projects).

Dark Energy Survey



- DES:
  - Six-year survey of 5100 sq-deg completed in early 2019 using 570-Megapixel Camera built at Fermilab for DES
  - DR1 based on Y1-Y3 observations is public. DR2 in Jan 2021
- Science Production
  - Over 280 science publications to date
  - World-leading constraints on dark energy. Examples:
    - Constraints on Extended cosmological models from DES Y1 Weak Lensing and Galaxy Clustering (WL) and galaxy cluster abundances/masses.
    - Cross Correlation of DES WL signal w/ Planck & SPT
    - Cosmology from 207 DES Y1-Y3 spect.-typed SN1a
    - Combined DES Y1 WL & Y1 LSS & SN1a cosmology
    - H_0 from strongly-lensed time-varying quasars and from binary neutron star and black hole collisions.
    - Y3 WL/LSS results are imminent. Y5 SN1a with photometric redshifts in a few months





FNAL Group DES Highlights since January 2020

*Nord et al., "Discovery of Nine Strong Lensing Systems"

*Buckley-Geer et al., "STRIDES: Spectroscopic and photometric characterization of the environment and effects of mass along the line of sight to the gravitational lenses DES J0408–5354 and WGD 2038–4008"

***Zhang** et al, "Discovery of Diffuse Light in Galaxy Clusters"

*DES Collaboration, "Cosmology from cluster abundance and weak lensing data using DES Y1 data"

Pereira, ***Palmese** et al., "Weak Lensing Calibration of the Dark Energy Survey Year 1 redMaPPer Clusters using Stellar Masses"

Leung**, *Zhang** et al., "The faint diffuse light halo around Y1 Luminous Red Galaxies"

*Sampio-Santos, ***Zhang** et al., "Is Intra-cluster light a good tracer of the galaxy cluster mass distribution?"

***Palmese** et al., "A statistical standard siren measurement of the Hubble constant with a LIGO/Virgo gravitational wave neutron star-black hole and the Dark Energy Survey galaxies" ("Dark Sirens")

Garcia, Morgan, *Herner, ***Palmese** et al., "A DES GW search for the Electromagnetic Counterpart to the probable LIGO/Virgo gravitational wave binary neutron star merger S190510g"

*Herner, *Annis et al. "Optical follow-up of gravitational wave triggers with DECam during the first two LIGO/VIRGO observing runs"

Morgan, Soares-Santos, *Annis, *Herner et al., "Constraints on the Physical Properties of S190814bv through Simulations based on DECam Follow-up Observations by the Dark Energy Survey"

*Drlica-Wagner et al., "Constraints on dark matter particle physics from observations of dwarf galaxies

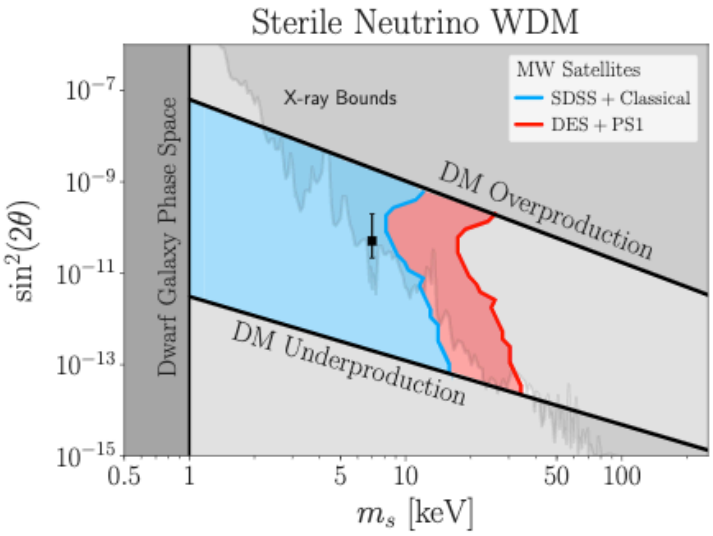
*Tanoglidis, *Drlica-Wagner et al, "Low-Surface-Brightness Galaxies Discovered in the First Three Years of the Dark Energy Survey"

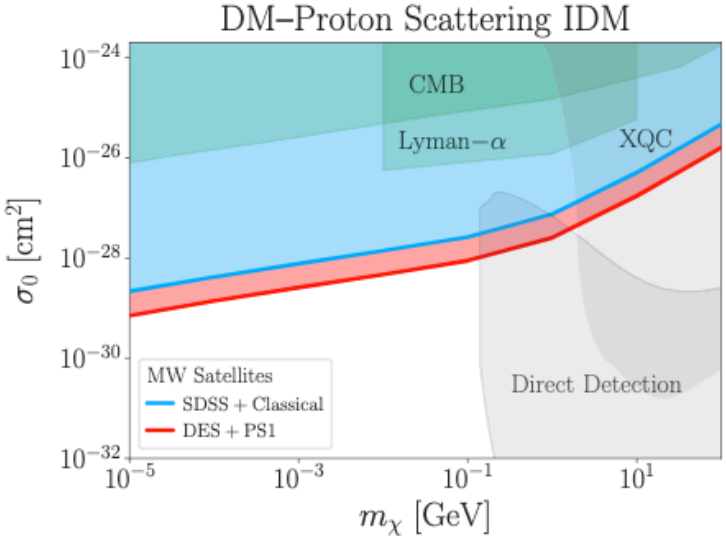
And many coming up soon on Y3 cosmology

*Denotes Fermilab, **Bold** font are FNAL postdocs

Dark Energy Survey: Recent Dark Matter Highlights

- **Constraints on dark matter particle physics from observations of dwarf galaxies** (Drlica-Wagner* et al. [1912.03302], Nadler et al. [1912.03303], Nadler, Drlica-Wagner* et al. in prep)





- **Largest catalog of low-surface-brightness galaxies** (Tanoglidis, Drlica-Wagner*, et al 1812.04004)
- **Leadership in Snowmass2021 CF3 - Dark Matter: Cosmic Probes**

Ramping up with the Rubin Observatory/LSST

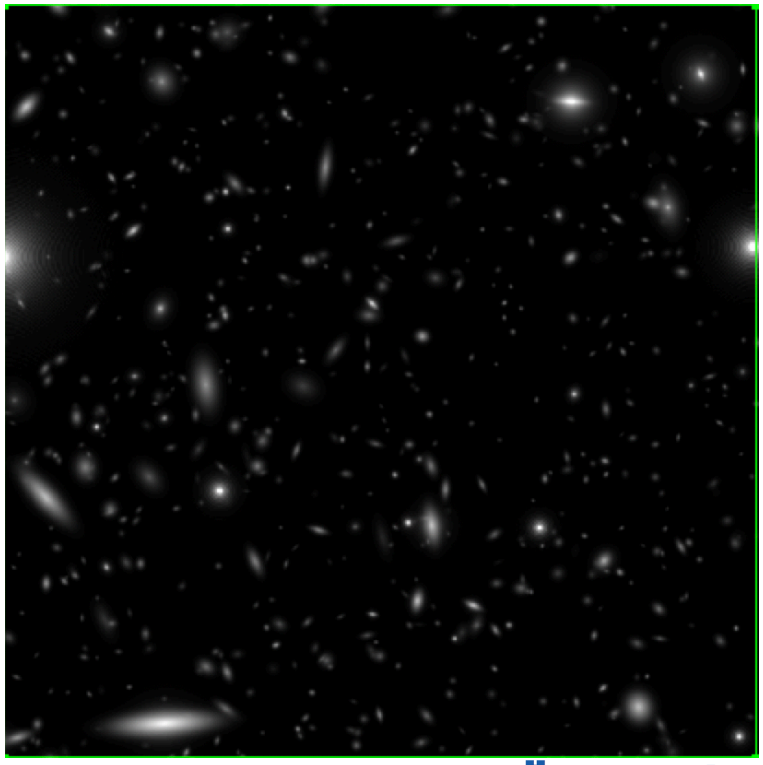
- Leveraging DES expertise to ramp up in Rubin/LSST operations & science
- Operations:
  - Roles in Observatory Operations, Data Production, & System Performance
    - Production Scientist, Computation Facility Scientist, QA Scientist for Data Releases, Scheduler Scientist, Data Release Systematics Scientist, Community Engagement Scientists
    - Core networking roles
  - Data Production team is helping set up the Rubin Interim Data Facility
    - Commercial cloud platform
    - DESC simulated images & catalogs
    - Rubin data access and science platform tools
    - Exploring contributing SCD tools (e.g., Rucio, Big Data Express, HEPCloud)
- DESC Science and Operations:
  - Science: Survey Simulations co-convener, Dark Matter co-convener, blending and LSS.
  - Operations: Operations Committee, Publication Database, proposed pipeline scientists
- Exploring responding to an expected DOE FOA for Data Facility
  - On order of $10 million/year for a decade

Ramping up with the Rubin Observatory/LSST

- Validation of LSST DESC survey simulations, with a specific emphasis on deblending.
- Investigating how space-based imaging could help LSST science

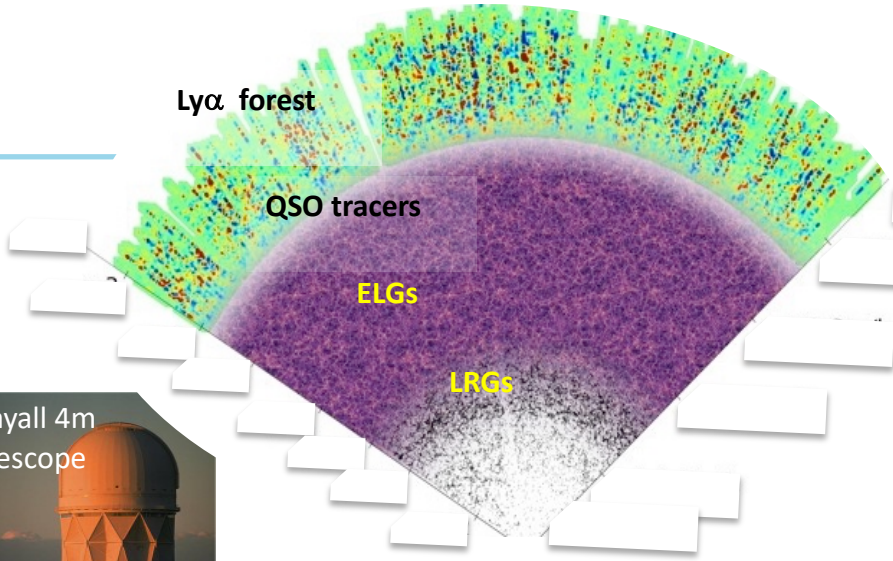
r-band noiseless full-depth Rubin image.

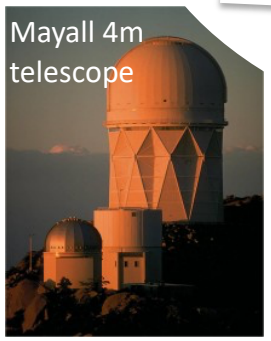
Euclid VIS noiseless full-depth image

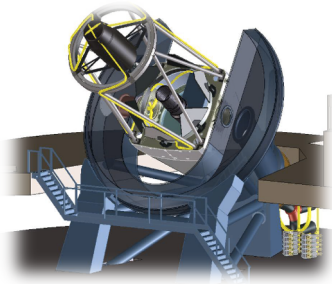


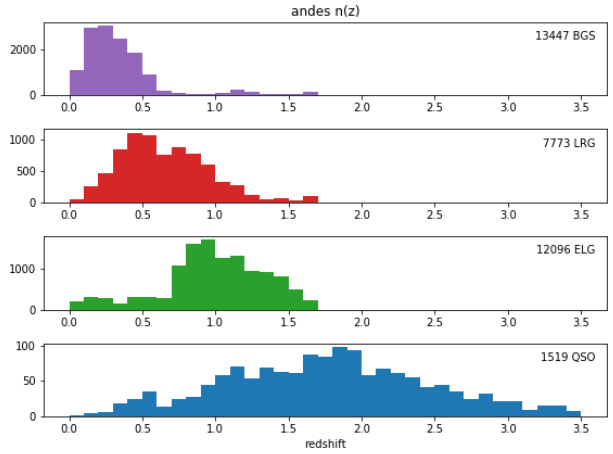
DESI

- DESI: Stage-IV dark energy survey
- Commissioning operations through March 15, 2020, now suspended
- Passed CD4 April 2, 2020
  - Commissioning confirmed that the instrument met design requirements
- Science verification will resume in fall 2020, and the 5-year survey early 2021 (all dates tentative)
- May 7: ANDES – first internal data release
  - 34.2 K redshifts for all target classes
- Fermilab contributions
  - Construction: Corrector cage/barrel, ADC; CCD testing; fiber location software; databases; project scientist; donut software
  - Operations: Lead observer
  - Science: Time Domain working group co-chair



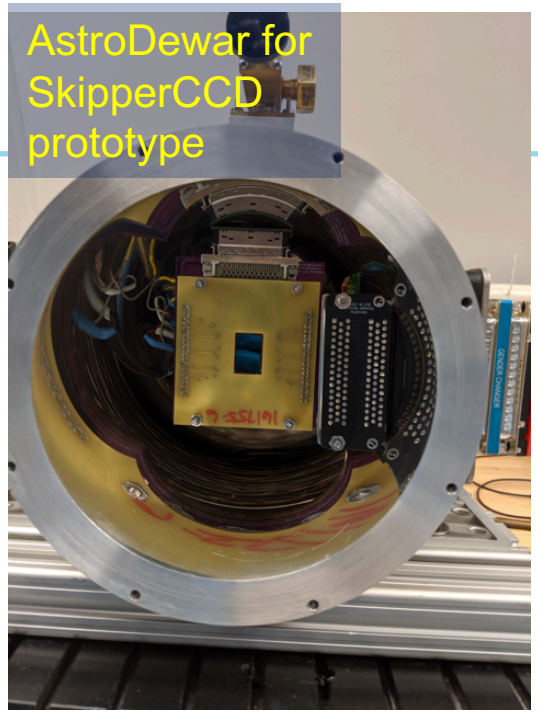


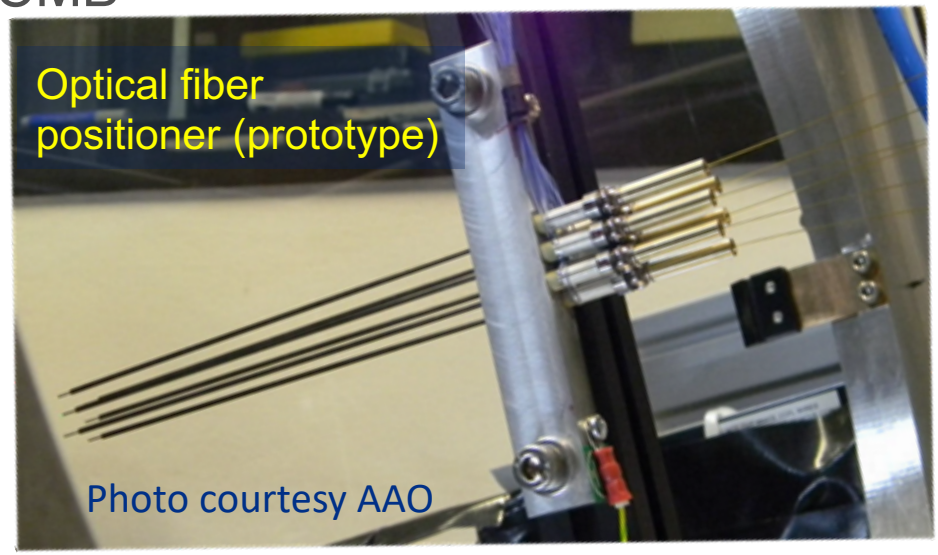


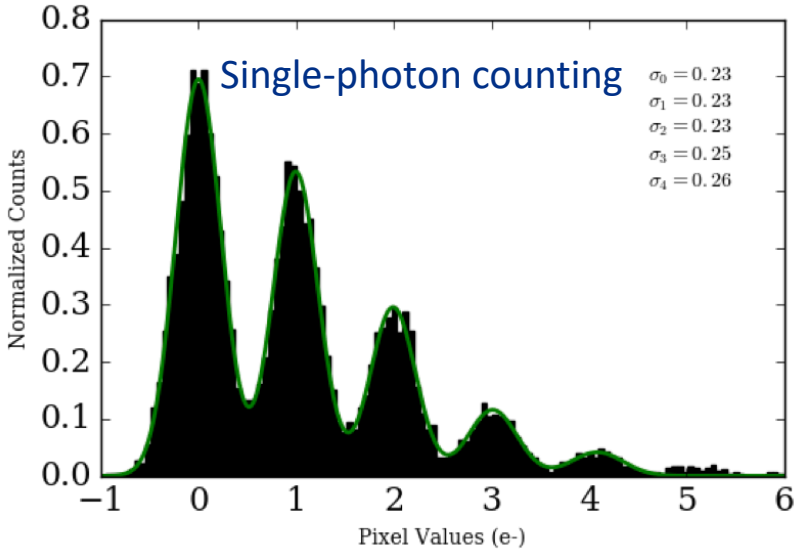


Detector R&D for Dark Energy

- Advance R&D on new technologies for future large cosmic surveys (LDRD):
  - Optical fiber positioners for Massively Parallel Spectroscopy (Stage V DE experiment)
  - Skipper CCDs for low-noise spectroscopy
- Leverages advanced detector and readout technologies developed for dark matter and CMB

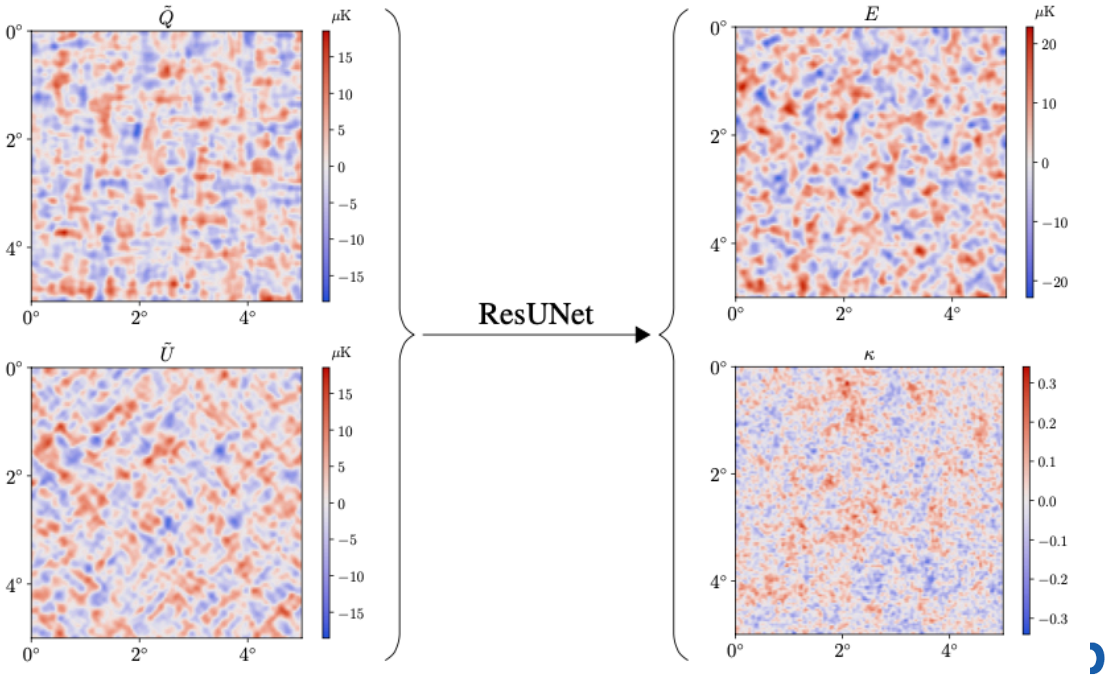






Cosmic Frontier AI/ML

- AI/ML in cosmic surveys
  - Detection, modeling, and classification of faint galaxies [1911.06259, 2004.11981, 2006.04294]
  - Neural networks for strong lensing identification and modeling [1911.06341]
  - Machine learning to deblend galaxies in future surveys
  - Self-supervision for blinded de-noising of astronomical images (LDRD)
  - Reinforcement learning AI to develop “self-driving” telescopes (LDRD)
- AI/ML in CMB
  - Using neural networks to de-lense CMB [1810.01483]



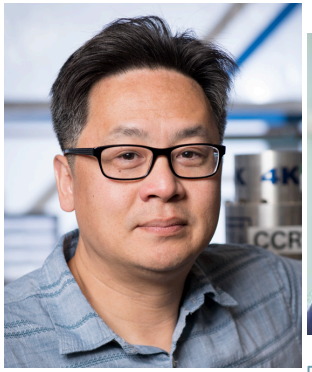
Caldeira et al. (2019)

Cosmic LDRD & Other Related Grants (plus private)

- **LDRD Efforts:**
  - Scintillating Bubble Chambers: superheated argon for low-mass WIMP and CEvNS detection
  - Pixel-configurable CCD's for cosmological applications
  - Development of Microwave Readout Electronics for Massively Multiplexed Arrays of TES
  - Cryogenic photon sensors for the low mass frontier
  - 10 kg skipper-CCD development for next gen dark matter/neutrino experiments
  - MKIDs sensors for optical and near-IR
  - Dark Matter as Sterile Neutrino Search Satellite: Cubesat to look for the 3.5 keV line
  - Deep Learning Algorithms
  - Dark Sector studies
- **QuantiSED/Dark Matter New Initiatives:**
  - Qubit single photon detection for axion searches (QuantiSED)
  - Skipper CCD's for quantum imaging (QuantiSED)
  - Design of next phase of ADMX to search for axions in 2-4 GHz range (DM New Initiatives)
  - Design of OSCURA, a 10-kg Skipper CCD dark matter experiment (DM New Initiatives)
  - Trigger/DAQ for ADMX (DM New Initiatives)
- **DOE R&D Grant** for CMB-S4 detectors and readout development
- **DOE Early Career:**
  - Microwave Single-Photon Sensors for DM Searches and Precision Neutrino Measurements (2018)
  - Towards table-top neutrino detectors: A 10 kg Skipper-CCD experiment (2018)
- **DOE Late Career:** Office of Science Distinguished Scientist Fellow Award

Fermilab leadership roles in Snowmass Cosmic Frontier

- Cosmic Frontier co-convenors:
  - **Aaron Chou,** Marcelle Soares-Santos (FNAL alumnus), Tim Tait (alumnus)
- Topical groups co-convenors:
  - CF1. Dark Matter: Particle-like
    - High Lippincott (alumnus)
  - CF3. Dark Matter: Cosmic Probes
    - **Alex Drlica-Wagner**
  - CF6. Dark Energy and Cosmic Acceleration: Complementarity of Probes and New Facilities
    - **Brenna Flaugher**
- Fermilab to host November Snowmass kick-off meeting






Cosmic Physics Center (CPC)

Cosmic Science

- The CPC aims to serve the growing cosmic user community, following the successful Fermilab models of the LHC Physics Center and the Neutrino Physics Center:
  - roughly 100 annual on-site Cosmic users
  - over 700 Cosmic users of Fermilab computing facilities
- Host and modestly support visiting scientists and students to
  - formalize and expand hands-on training opportunities in hardware and detector development
  - enable joint analysis and cross-correlation of cosmic experiments
- Host targeted workshops to accelerate the pace of research
- Develop and strengthen the cosmic synergies between Fermilab and local institutions to realize the tremendous potential of the Chicagoland cosmic community
- Provide platform for coordination of Snowmass Cosmic Frontier efforts
- Post-COVID Shutdown: Seminars, Journal Club and Chalk talks have continued with Zoom. Many requests from across the lab and from broader community to join the seminars remotely.
- Not funded as explicit task under Cosmic Research: rebranding visitor & seminar funds

Cosmic Physics Center https://astro.fnal.gov

Cosmic Physics Center

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Upcoming Seminars

- Particle Astrophysics Seminar: Optical Cosmic Survey at the Low Surface Brightness limit: Detection of Diffuse Light in Galaxies and Galaxy Clusters on June 29, 2020 2:00 PM
- Particle Astrophysics Seminar: New Avenues of Thermal Dark Matter on July 6, 2020 2:00 PM

See all upcoming seminars »

Upcoming Chalk talks

- No Events

See all upcoming chalk talk »

Highlights

Dark Matter May Lurk at Low-Energy Frontiers

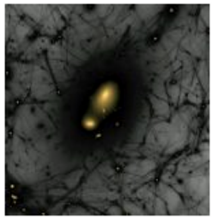
June 13, 2020 | Gordan Krnjaic and Noah Kurinsky

In an article submitted to Physical Review D, CPC members Noah Kurinsky and Gordan Krnjaic collaborate with Dan Baxter (KICP) and Yoni Kahn (UIUC) to present a novel interpretation of excess events observed at various low-threshold dark matter searches. They found that the anomalous results across various detectors operating in dramatically different experimental conditions could... More »

SPT-3G Begins 2020 Winter Observing Season!

April 7, 2020 | Bradford Benson and Alexandra Rahlin

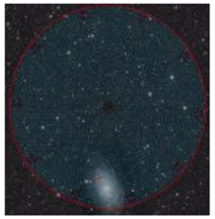
The SPT-3G experiment began its 2020 winter observing season on March 23, 2020. The SPT-3G camera on the South Pole Telescope (SPT) is undertaking a 1500 square degree survey of the cosmic microwave background, the light left over from the Big Bang. SPT is located at the geographic South Pole, and takes some of its... More »



The Milky Way's satellites help reveal link between dark matter halos and galaxy formation

April 6, 2020 | Nathan Collins

Over the past five years, the Dark Energy Survey, a DOE-funded project led by Fermilab, has revolutionized our view of small satellite galaxies. DES discovered a large number of tiny galaxies close to the Milky Way's largest satellites, the Magellanic Clouds, suggesting that multiple galaxies may have been captured by the Milky Way at the... More »



DESI opens its 5,000 eyes to capture the colors of the cosmos

October 28, 2019 | Gaston Gutierrez and Andre Salles

The Dark Energy Spectroscopic Instrument seeks to further our cosmic understanding by creating the largest 3-D map of galaxies to date. Below is a press release issued by Lawrence Berkeley National Laboratory announcing first light for this extraordinary instrument. The U.S. Department of Energy's Fermi National Accelerator Laboratory is a key player in the construction of... More »

Conclusion

- Cosmic Frontier Strategic Plan delivered Feb. 2019, implementation underway, satisfied 2019 FNAL PEMP Notable.
- FNAL growing its technical expertise and management roles in CMB-S4, building from SPT-3G experience and the lab's core capabilities. Working with other labs and universities to make it a success.
- Sub-GeV Dark matter program progressing well with DM New Initiatives. Laser focus on making SuperCDMS a success.
- DES entering the heart of its cosmology analyses; small roles in transition to DESI operations; growing roles in LSST operations.
- Cosmic Physics Center did a soft launch last year, amalgamating visitor & seminar programs, initiating targeted workshops, with plans to expand the efforts in coming years based on community and agency feedback.