Overview of Future CMB at Fermilab

- **CMB-S4** - 21 telescopes/cryostats in Atacama + South Pole, 500k TES detectors
  - R&D phase (now - 2023)
  - Production phase (2023 - 2028) - Ideally at IERC

- **SPT-SLIM** - Intensity mapping of CO, CII with MKID spectrometers on South Pole Telescope (pending LDRD funding)
  - Integration (2021 - 2022) - Small ADR + 1 detector wafer + readout
  - Deployment (Nov 2022) - Move to South Pole

- **SPT-4** - CMB at 220, 270, 350 GHz with MKIDs (pending NSF funding)
  - Integration (2021 - 2023)
  - Deployment (Nov 2023)
CMB-S4 Overview at Fermilab

- Fermilab leading “Modules and Testing” for CMB-S4

- Plan to design, build, and test (at 100mK) 500 modules (10x more than SPT-3G) consisting of 6-inch Si wafers of superconducting TES bolometers + SQUID-based multiplexing readout electronics

- Assembly and testing to be split between several labs, including Fermilab

- Current R&D phase focused on design work and testing of prototypes

- Production phase will require many technicians + 8 DRs operating continuously for years, split between FNAL + another site
# CMB-S4 Overview at Fermilab

## Detector Readout Module Schedule Overview

<table>
<thead>
<tr>
<th>Year</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
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<td>Agency Approval</td>
<td>CD-1 Approval</td>
<td>NSF Final Design (FD)</td>
<td>NSF Final Design Review FDR</td>
<td>CD-2 Approval</td>
<td>CD-3 Approval</td>
<td>NSF MBEFC Construction Award</td>
<td>CD-4 Approval</td>
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### Project Milestone

- Readout Prototype Complete
- Module Assembly Prototype Complete
- Detector Wafer Prototype Complete
- Prototype DRM Review Complete

### SiDet needed

- Preproduction
  - Readout Preproduction Complete
  - Detector Wafer Preproduction Complete
  - Module Assembly Preproduction Complete
  - Preproduction DRM Review Complete

- 1st Batch Complete
  - Detector Wafers - 1st Batch Complete
  - 1st Batch of 100mK Assembly and Test Complete
  - Module Assembly 1st Batch Complete

- Production
  - Readout Production Complete
  - Detector Wafers Production Complete
  - Module Assembly Production Complete

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Move these activities to IERC
CMB-S4 Activities at SiDet

- R&D focused on:
  - Designing module assembly process (existing Lab D space)
  - Refining detector wire bonding (existing Lab D space)
  - Integrated detector + readout testing in Lab A cryostats
  - Prototyping and characterization of feedhorns with VNA + test bench (10ft x 10ft setup in Lab A)
- Peak throughput during R&D comparable to peak SPT-3G (few modules / week)
- Current spaces probably adequate: Lab D assembly space, bonding, and cryostats and general lab space in Lab A
- Uptime is critical: cannot have wirebonders offline for long during move to IERC
- Want full access to Lab A after Mu2e completion
• Funds procured (last week!)

• Expect delivery between Feb and Jun 2021 from Bluefors or Oxford

• Want to install in Lab A, then move to IERC when available

• Lab A chilled water maxed out, plan to take one of our HPD cryostats offline temporarily until move to IERC

• Nominal footprint is very roughly 2m x 3m
SPT-SLIM

- Pending LDRD (commission at Fermilab) or NSF/ATI funding (commission at U. Chicago)
- Involves very small ADR to fit in small space in SPT cabin
- Expect delivery at start of CY 2022, commission in Lab A during 2022
- Use PTC or GM cooler; will have to juggle chilled water with S4 DR and other cryostats
- Commissioning will primarily involve running cryostat, characterizing resonator properties, optical calibration measurements

HPD Model 102 ADR similar to SPT-SLIM needs
SPT-4

- In proposal stage, similar scale to SPT-3G
- NSF project with some Fermilab involvement
- Fermilab role is TBD, though likely to involve readout electronics and detector calibration and testing
- Cryostat construction at U. Chicago likely, due to NSF funding and interference with S4 at Fermilab
Block Diagrams
Lab A: pre-Mu2e

- Pre-Mu2e storage
- Lab benches
- Desks
- Dilution refrigerator
- ADR
- Compressors (2)
- (offline) HPD cryostat
- Sonicator
- Mu2e clean area
- Mu2e clean area
- CMB storage (mezzanine north corner room)
- Storage + lab benches
Lab A: post-Mu2e

- CMB storage (mezzanine north corner room)
- Clean-ish testing and assembly (feedhorns + RF electronics)
- Cryostat assembly area (NO enclosure)
- (offline) HPD cryostat
- Sonicator
- Desks
- Dilution refrigerator
- ADR compressors (2)
Lab D

storage cabinets + desk

microscope + benches

wire-bonding