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Direct Detection of Dark Matter: CDMS and COUPP

Andrew Sonnenschein

CDMS Collaboration at Soudan

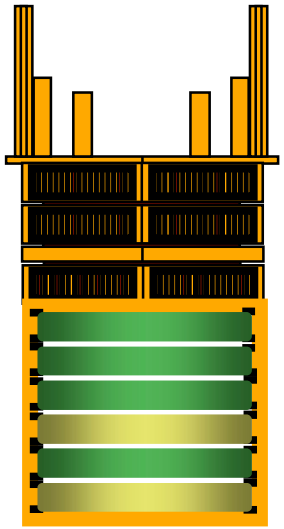
DOE Laboratory
Fermilab
LBNL

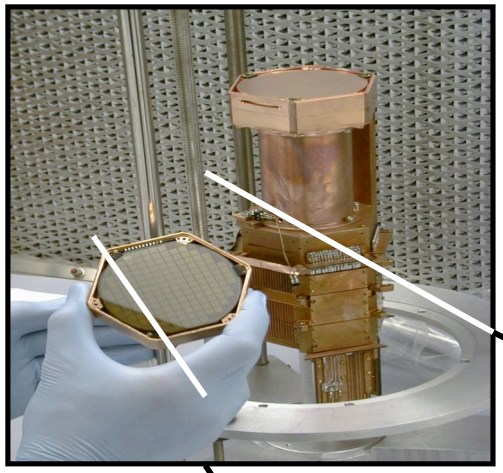
DOE University
Brown
CalTech
Florida
Minnesota
MIT
Stanford
UC Santa Barbara

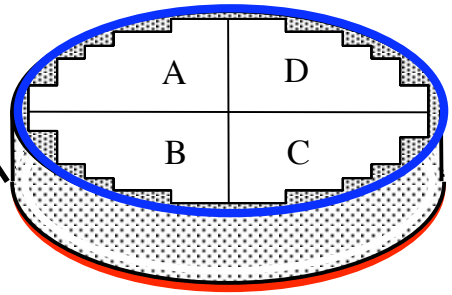
NSF
Case Western Reserve
Colorado (Denver)
Santa Clara
UC Berkeley

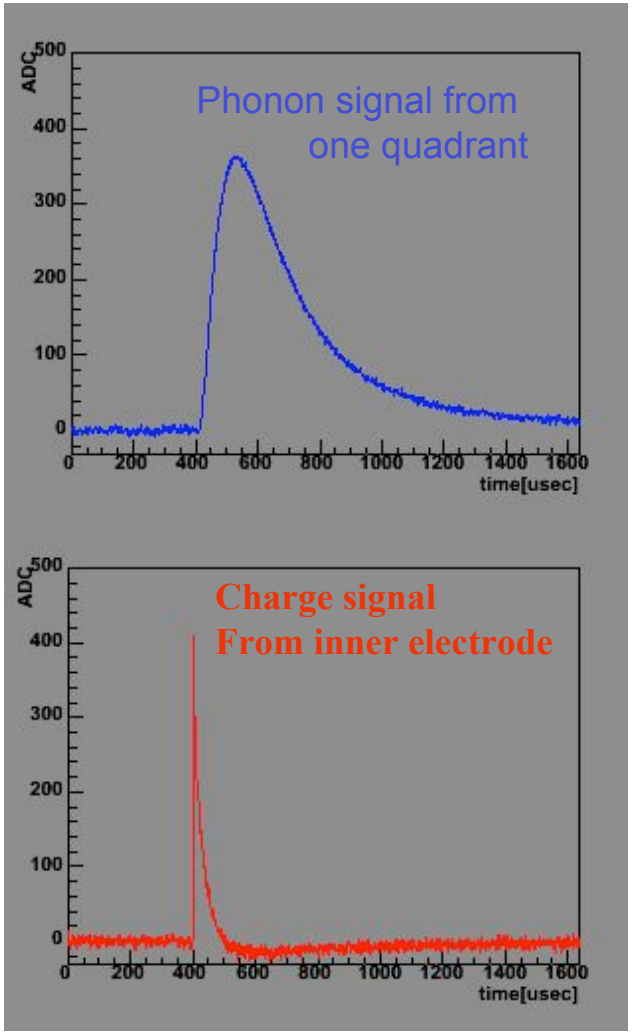
Canada
Queens

CDMS-II Detectors









Direct detection of WIMP signal

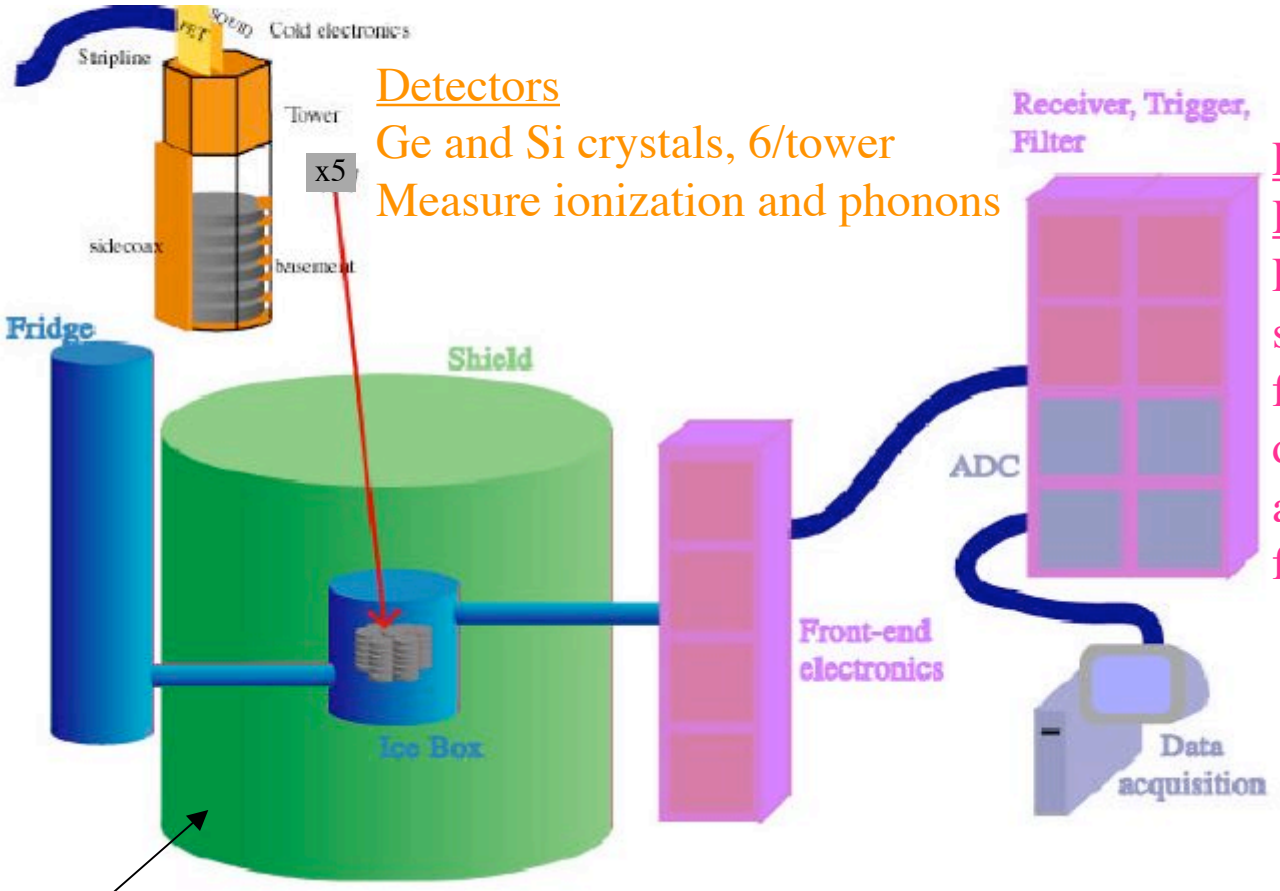
Nuclei recoil by elastic scattering

Read both phonon signal (4 channels) and ionization signal (inner and outer electrode)

1cm thick, 7.8 cm diameter

250g Germanium, 100g Silicon

CDMS Subsystems



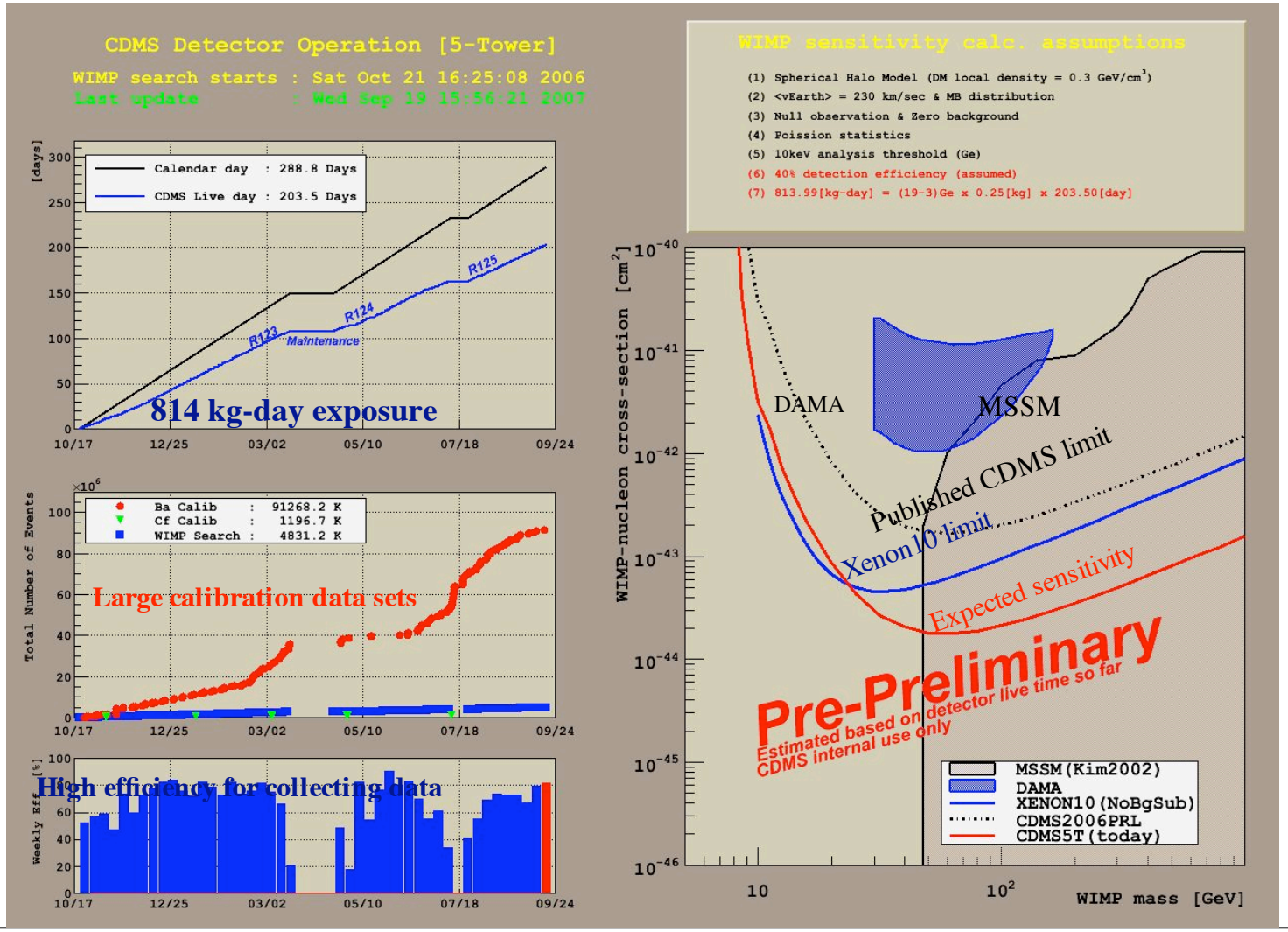
Detectors
Ge and Si crystals, 6/tower
Measure ionization and phonons

Electronics/ DAQ
Record signals from detectors and veto; form trigger

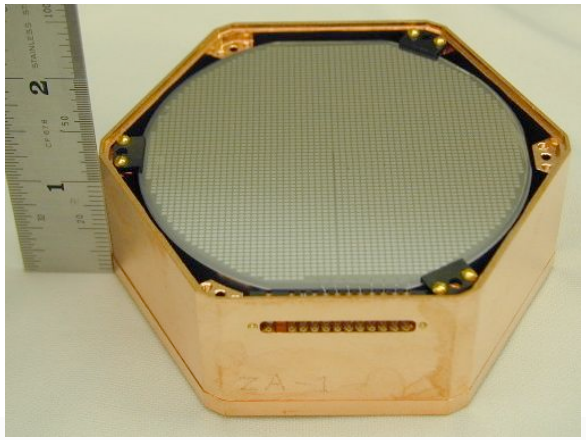
Cryogenics
Maintain detectors at 50 mK

Shielding
Layered shielding (Cu, Pb, polyethylene) reduces radioactive backgrounds and active scintillator veto is >99.9% efficient against cosmic rays.

CDMS II Ongoing Run



SuperCDMS 25 kg



- Proposed 25-kg experiment based on updated 42 x 600-g Ge ZIPs
  - 120x beyond current limits
  - 15x beyond CDMS-II goal
  - Approved for space at SNOLAB
  - Next step towards ton-scale goal
- Detector fabrication and characterization underway
  - Detectors have 3x fiducial volume of CDMS-II design.
  - Cost per kg reduced to ~1/3.

SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

Fermilab responsibilities

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Established roles in CDMS

Project Management

Operations

Lead the Soudan operations

Cryogenics

Design, construction of the cryogenics systems

Electronics, DAQ, Computing

Warm electronics, event builder software, online and offline processing

Infrastructure

Clean rooms, control rooms, computing rooms

Analysis

Independent analysis chain

New roles for SuperCDMS

Backgrounds

Collaborating with COUPP on understanding Radon, alpha screening

Shield/Veto

Do mechanical design and construction together with cryogenics

Detectors

Exploring possibilities for automated inspection and repair at SiDet

May also get involved in bonding our sensors to larger crystals

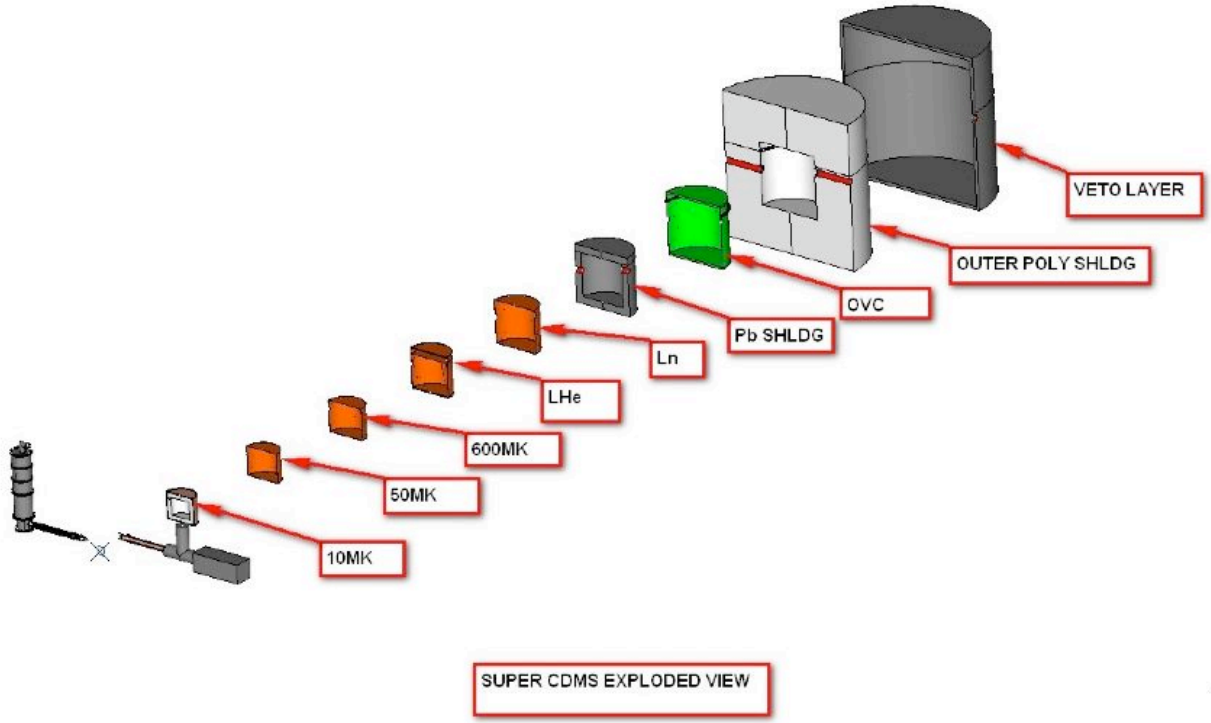
Systems Test

Put everything together at Fermilab and test before taking to SNOLAB

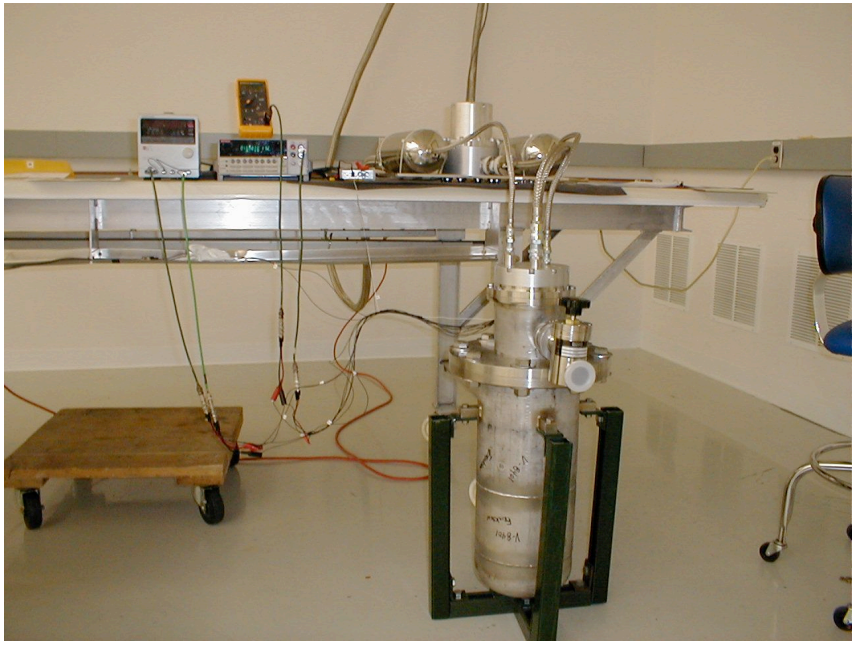
Need more scientist and engineering help to push forward these new areas

SuperCDMS Cryogenics Design

- Cryogen-free dilution refrigerator
  - Much lower operations and maintenance cost
- Larger volume to accommodate more detectors
  - More robust thermal connections than in CDMS II

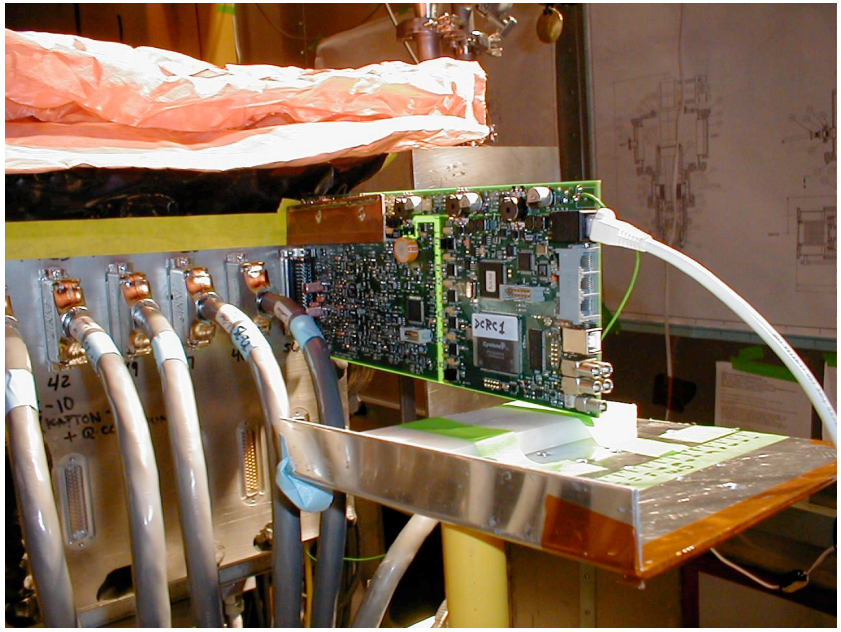


Progress on SuperCDMS

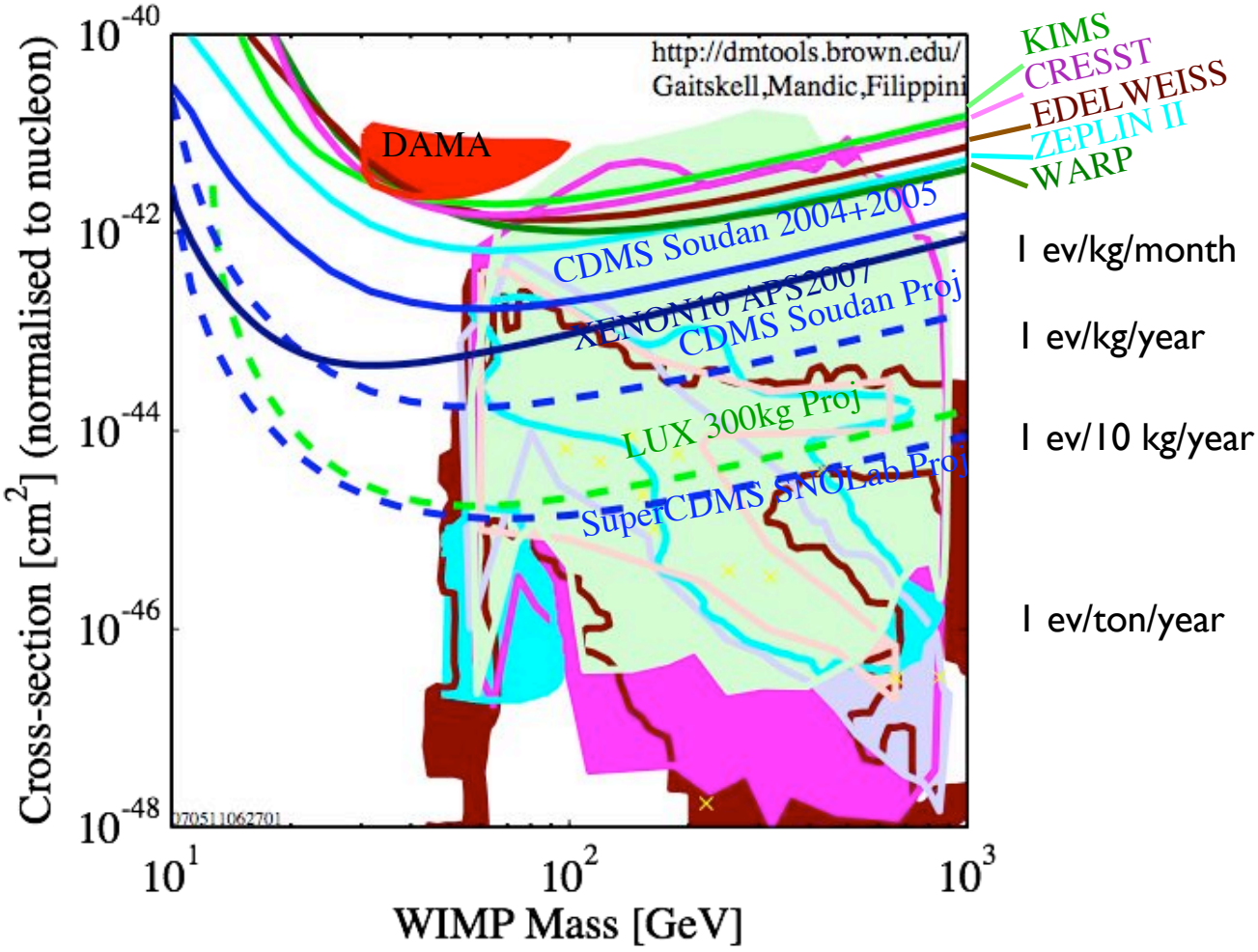


- Pulse tube cryocooler under test in clean room in Lab 3 at Fermilab

- New warm electronics prototype for SuperCDMS
  - Replaces a chain of four 9U-sized boards used for CDMS II
  - Fewer connections, lower power draw => more robust



SuperCDMS Sensitivity



COUPP: Dark Matter Detection with Bubble Chambers

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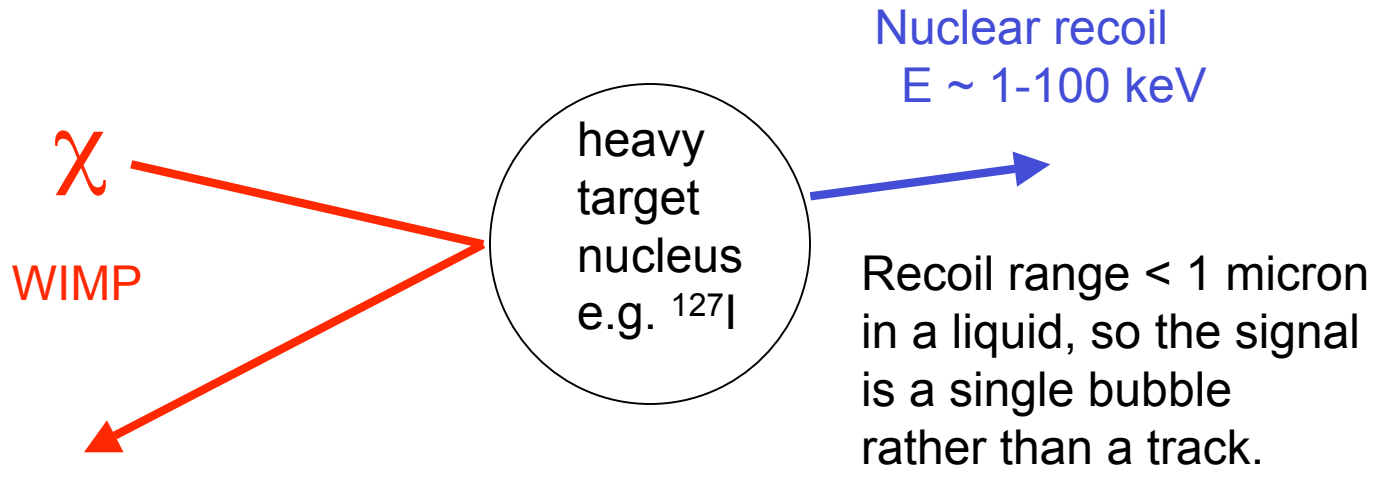
Dark Matter in Bubble Chambers f



Measure the rate at which single bubbles appear

The COUPP Team

THE UNIVERSITY OF CHICAGO

Fermilab

Principal Investigator:
Juan Collar
(spokesperson)

Graduate Students:
Nathan Riley
Matthew Szydagis

Undergraduates:
Luke Goetzke
Hannes
Schimmelpfennig

KICP Fellows:
Brian Odom

University of Chicago

Wilson Fellows:
Andrew Sonnenschein

Staff Scientists:
Peter Cooper
Mike Crisler
Martin Hu
Erik Ramberg
Bob Tschirhart

Fermi National Accelerator Laboratory

Principal Investigator:
Ilan Levine

Undergraduates:
Earl Neeley
Tina Marie Shepherd

Engineers:
Ed Behnke

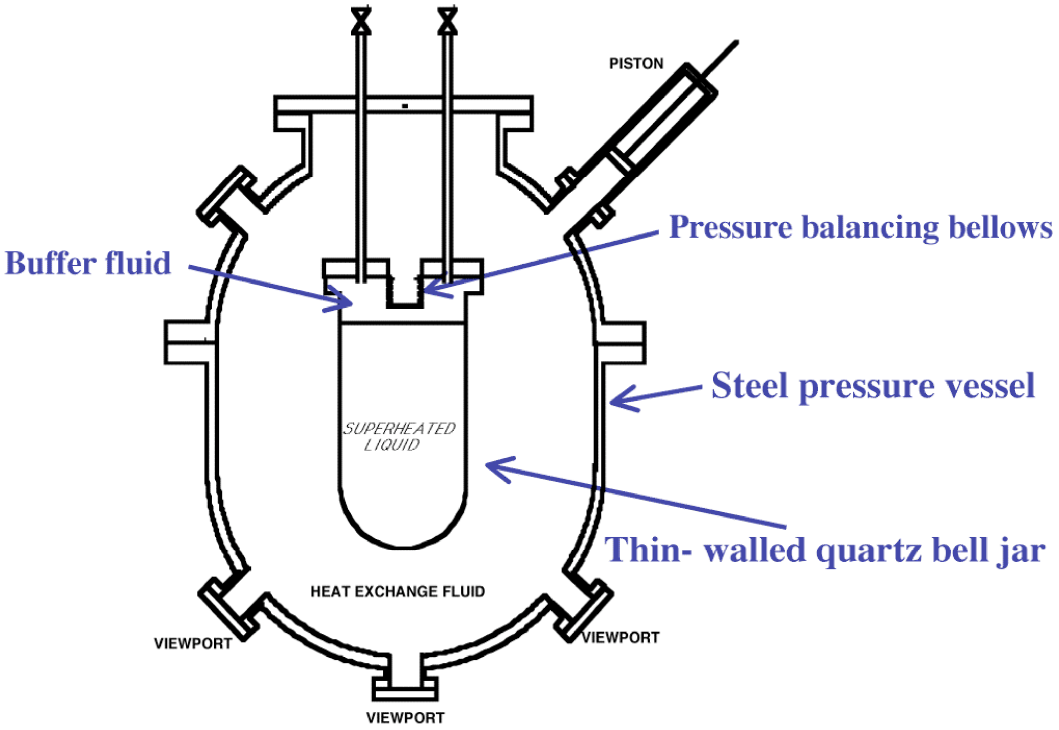
Indiana University South Bend

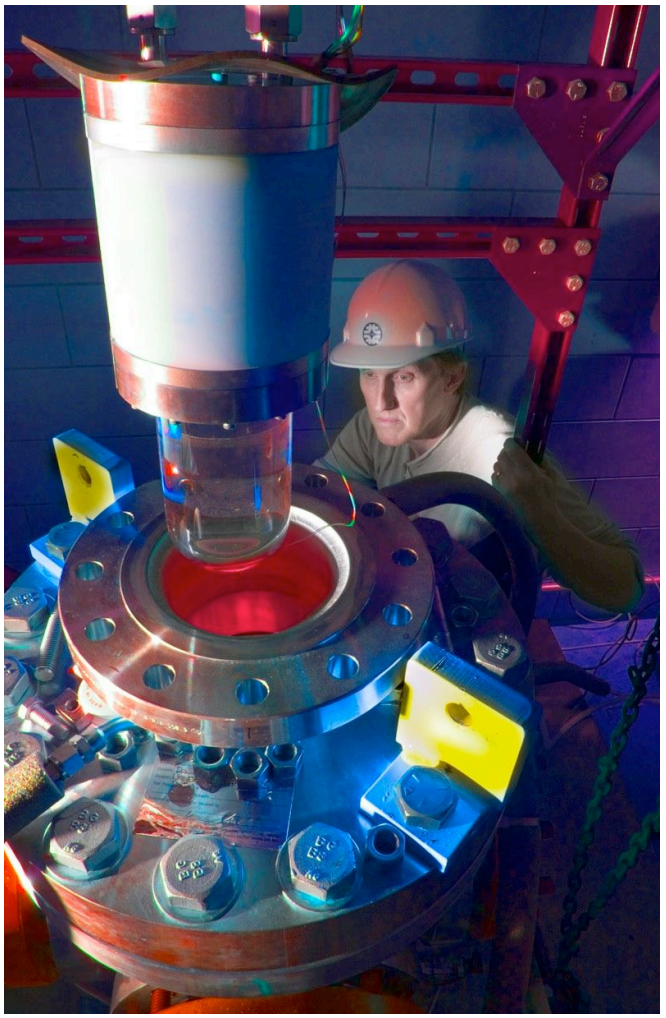
Funding

National Science Foundation
Kavli Institute for Cosmological Physics
Department of Energy

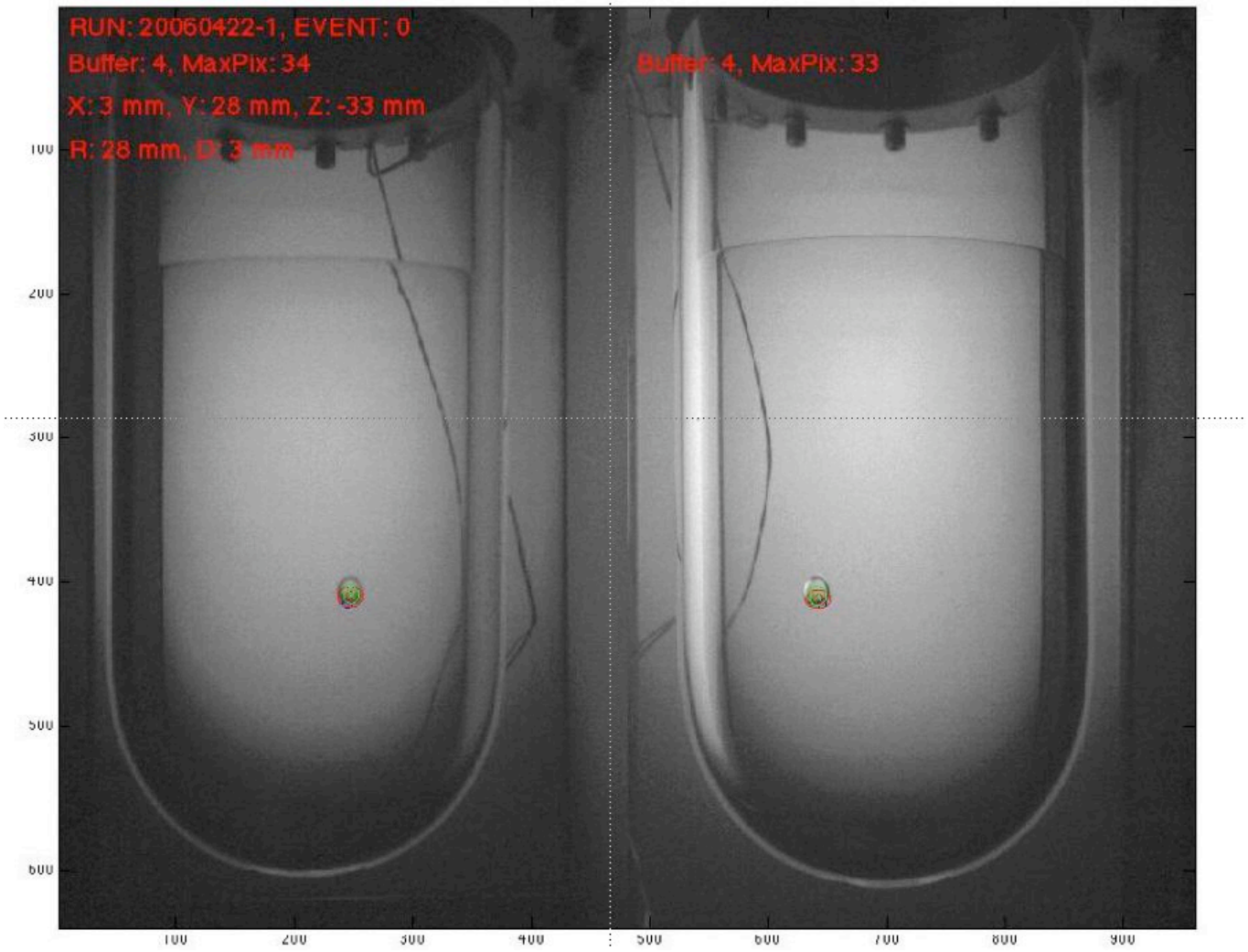
1-Liter Chamber in NuMi Tunnel

Design concept:





A Typical COUPP Event



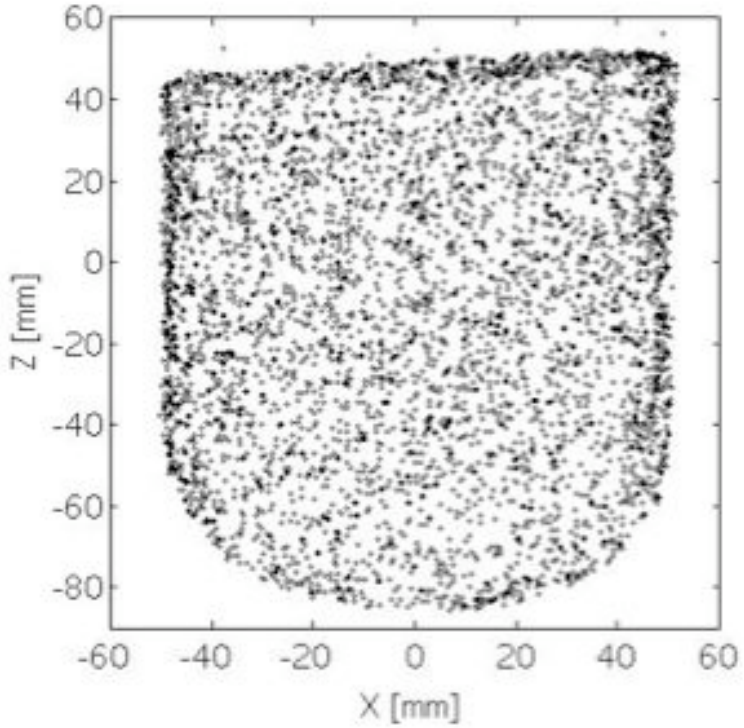
Appearance of a bubble causes the chamber to be triggered.

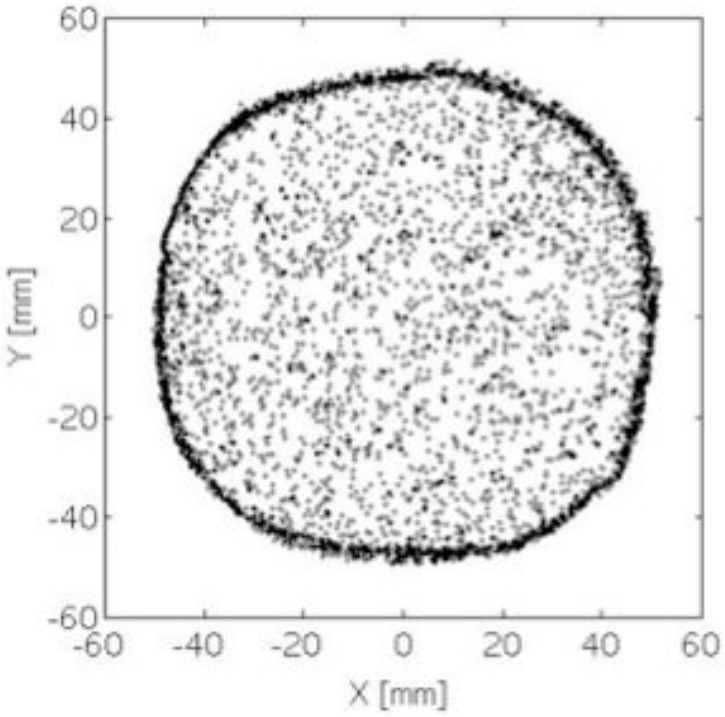
Bubble positions are measured in three dimensions from stereo camera views

Spatial Distribution of Bubbles

Two populations:

- Walls: apparently from radium contamination of quartz.
- Bulk: radon dissolved in chamber liquid





Data from 2006 Run

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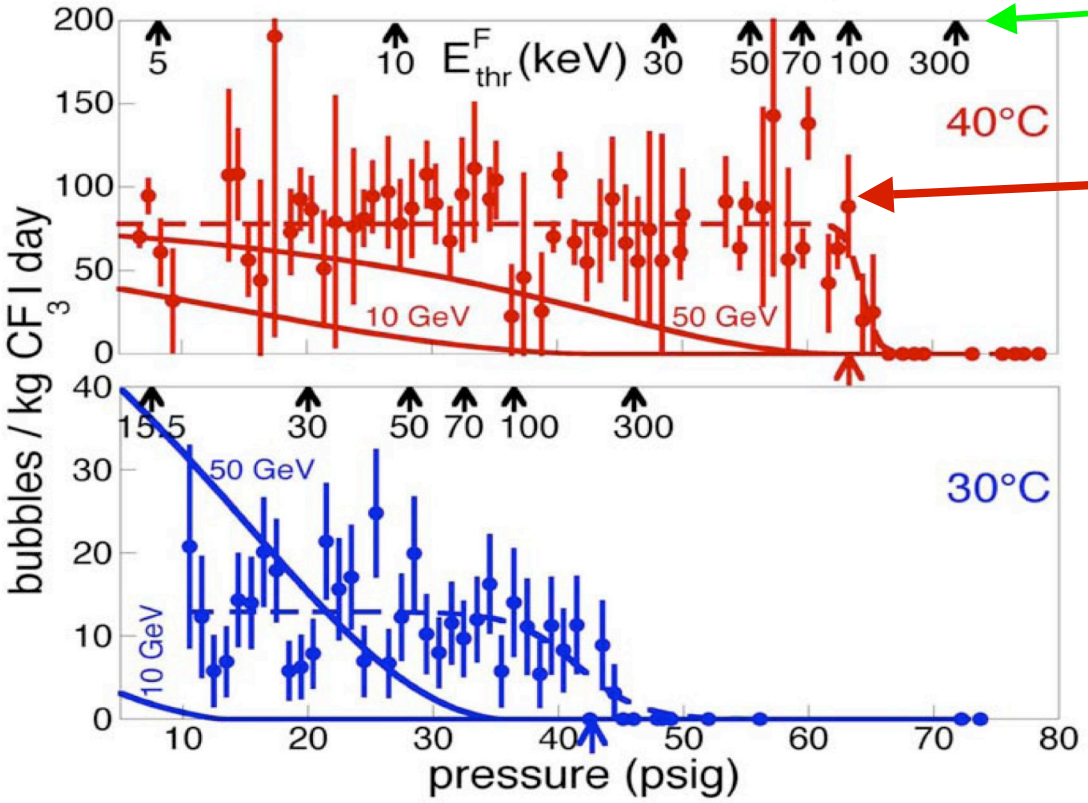
- First physics results were shown at Fermilab last week.
- Data from pressure scan at two temperatures:



Energy Threshold In KeV

Radon background

Solid lines:
Expected WIMP response for

$\sigma^{SD(p)}$=3 pb

Results from 2006 Run

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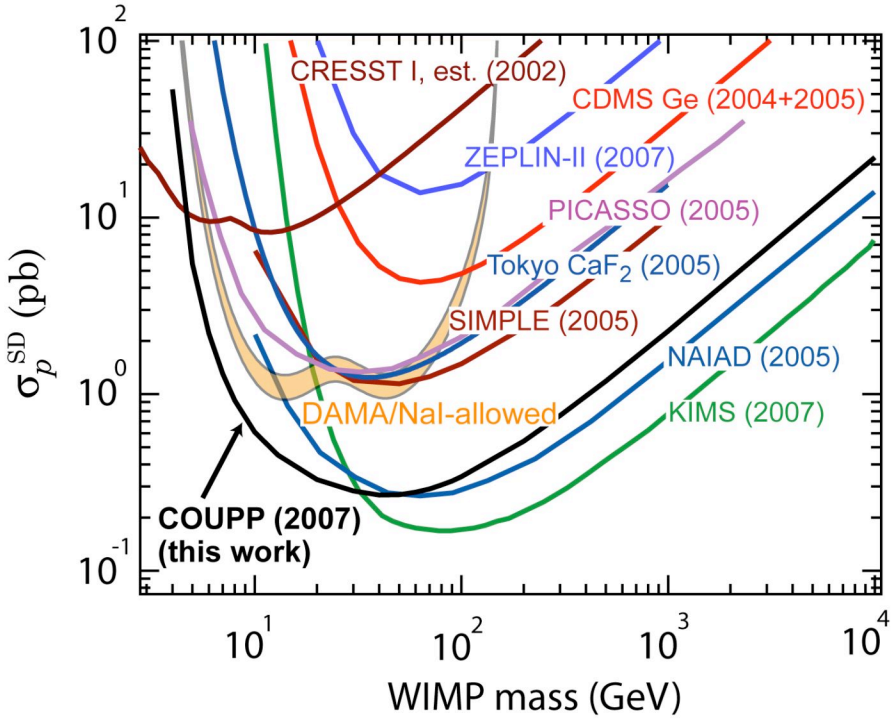
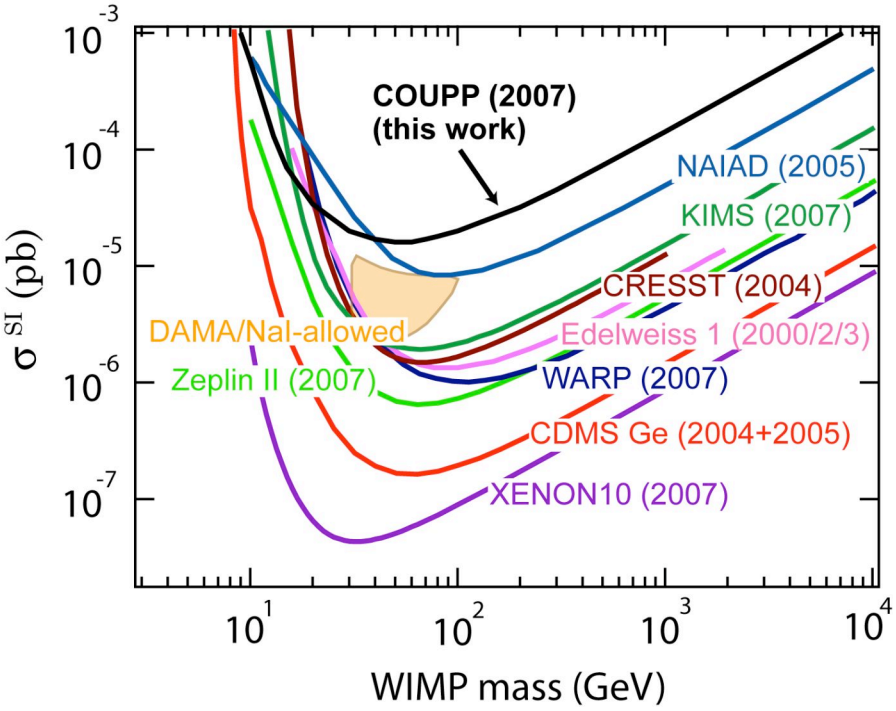
- We have competitive sensitivity for spin-dependent scattering, despite high radon background

Spin-dependent



Spin-independent



New Low-Background Vessel

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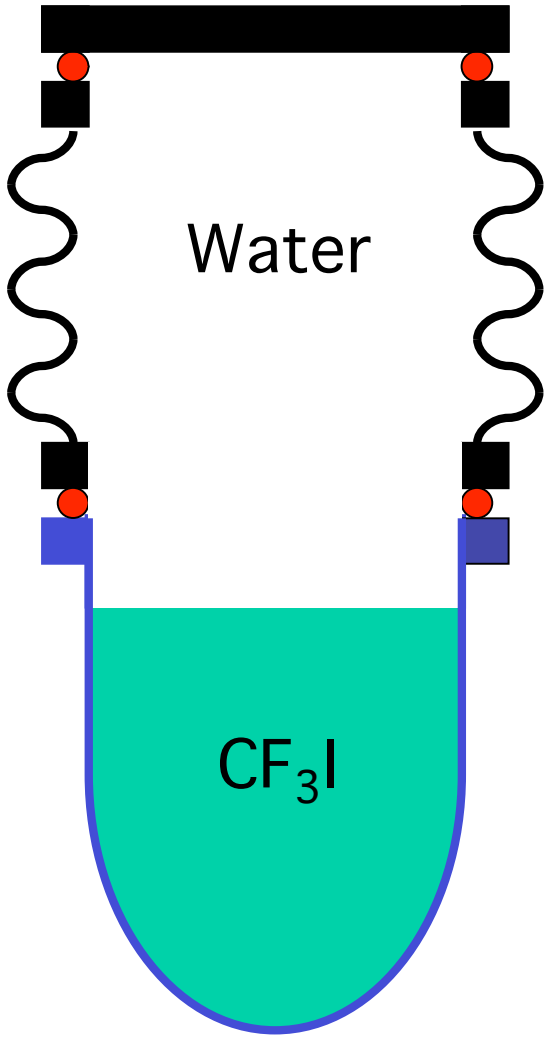

- Teflon-coated inconel seals replace Viton.
  Radon emanation <1% of previous design

- Quartz etched with HF acid by vendor to remove implanted radon daughters.

- All parts cleaned and assembled in Accelerator Division RF cavity cleaning facility.

- Very high purity, well-studied water from Sudbury Neutrino Observatory.

- Bellows made using non-thoriated welding electrodes.

New Run of 1-liter Chamber

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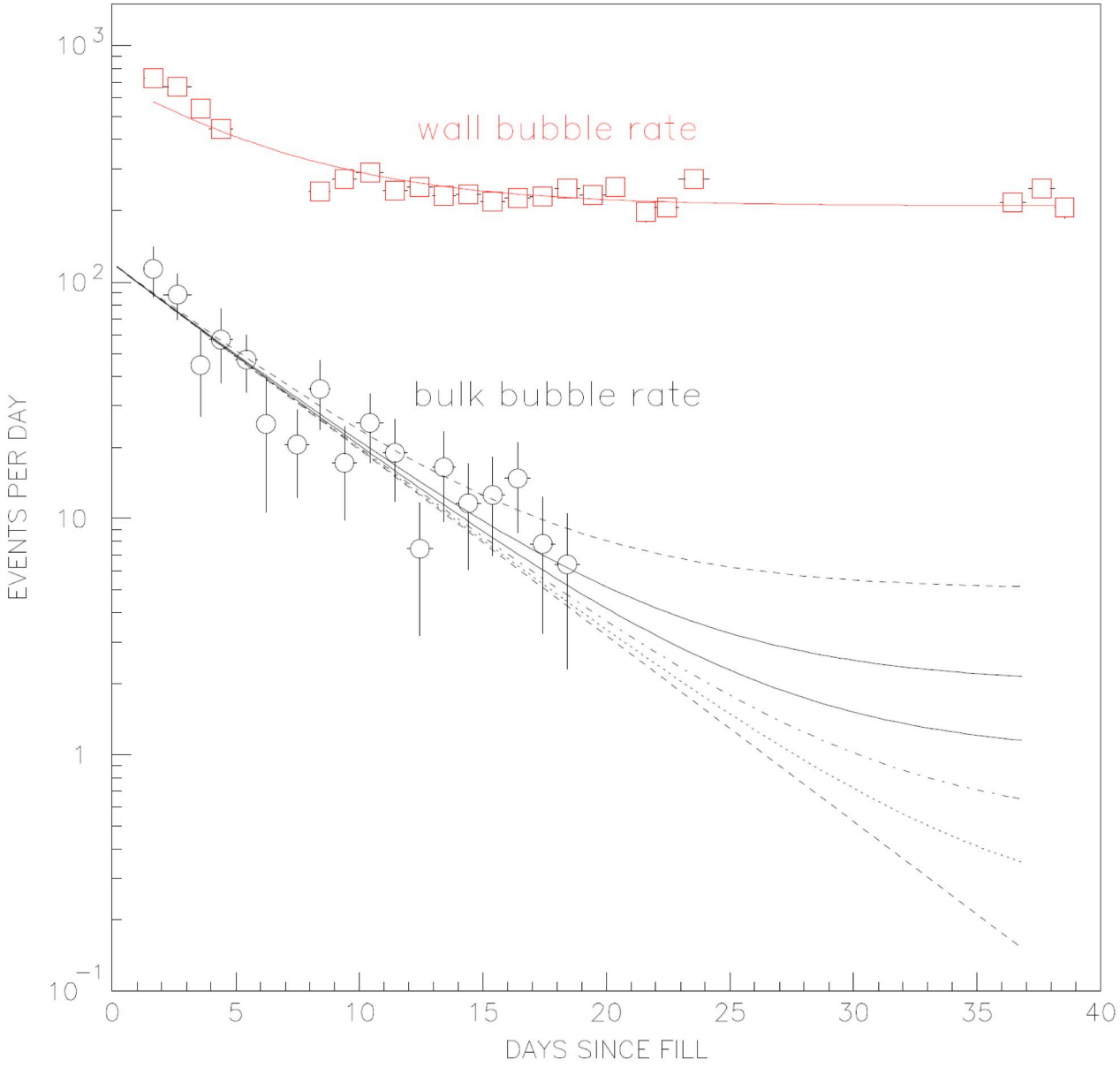
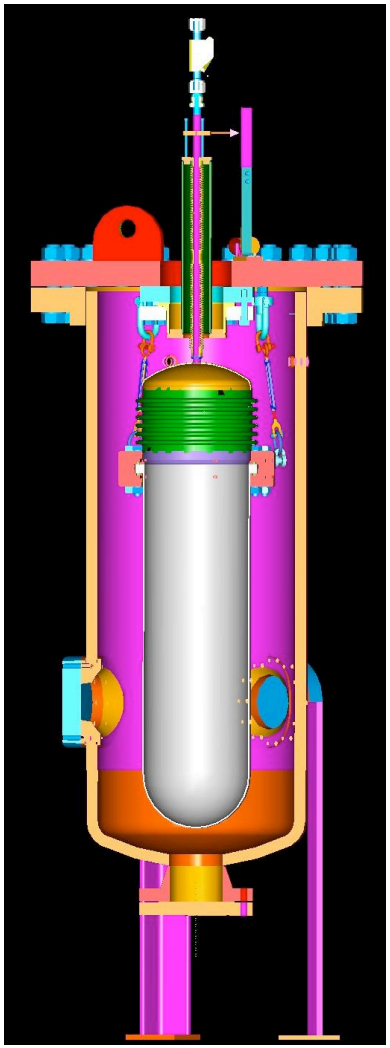


- Inner vessel has been entirely rebuilt with materials believed to have lower radioactivity.
- New run started July 30, 2007.
- Some radon introduced during f lling, now decaying to equilibrium.

COUPP 60 Kg Chamber



· Construction of 60 kg chamber approved by the PAC and director in Fall, 2006. Now being built.