U.S. DEPARTMENT OF ENERGY | Office of Science

DOE Second-Generation Dark Matter Program Status

HEPAP Meeting

Gaithersburg, MD

March 12, 2013

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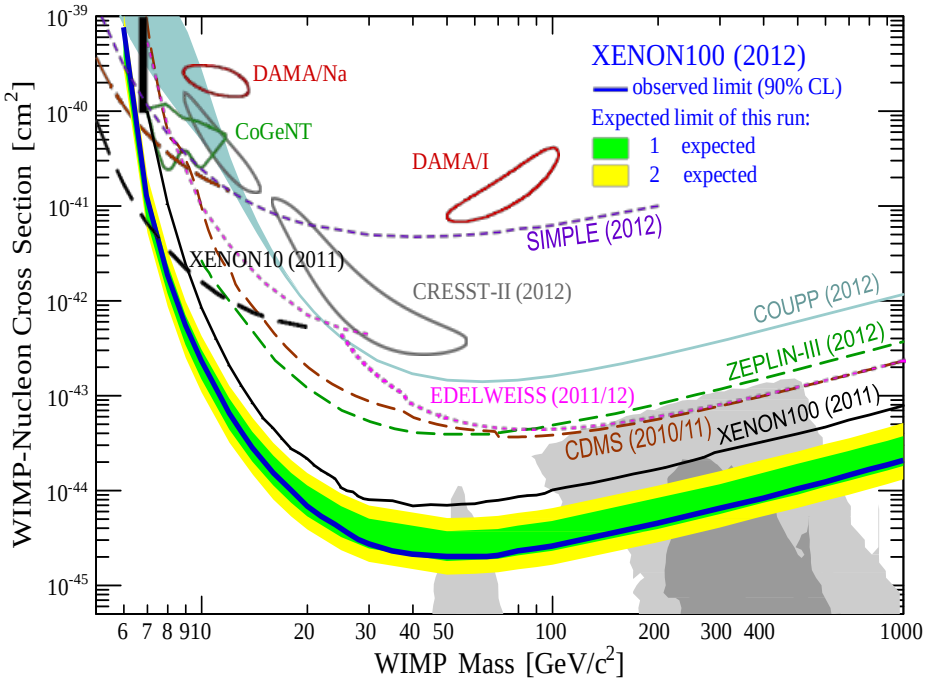
DOE/Office of High Energy Physics

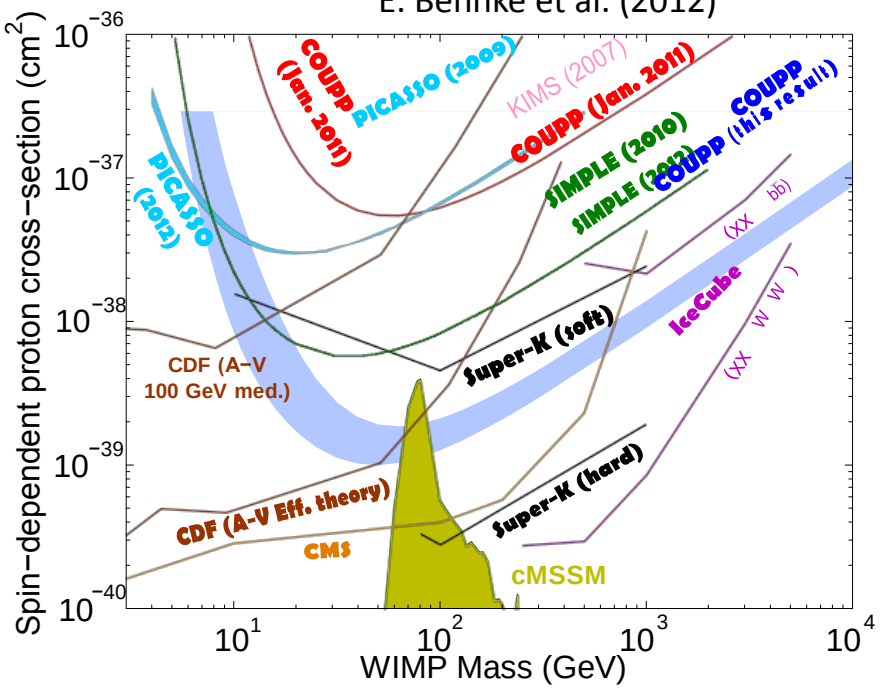
U.S. DEPARTMENT OF ENERGY | Office of Science

DOE Generation-1
Dark Matter Direct Detection Experiments

E. Aprile et al. (2012)



E. Behnke et al. (2012)



PASAG Report (2009)

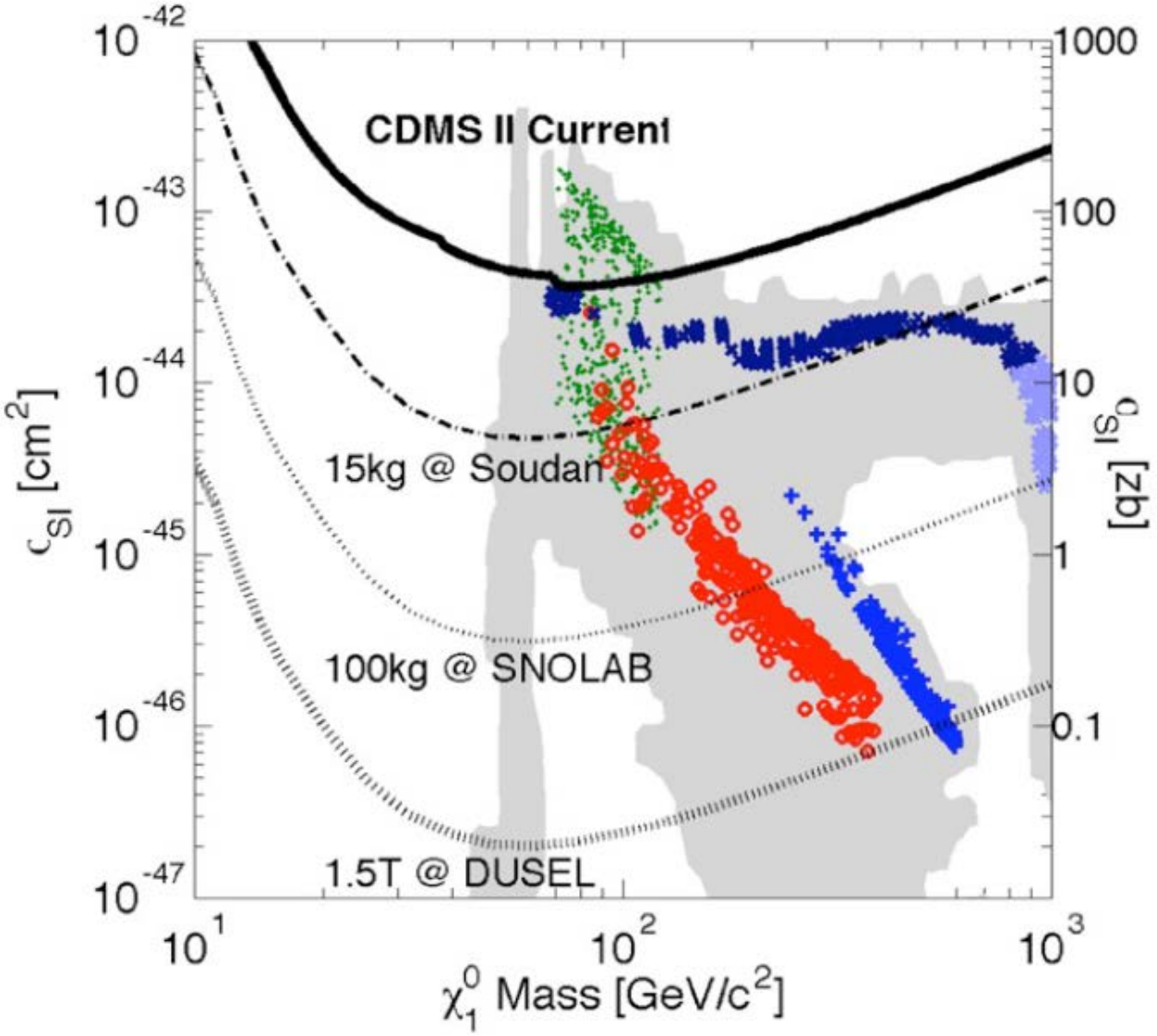
"The panel evaluated the scientific opportunities available under the different budget scenarios. The opportunities include the following:

> For dark matter direct detection, next-generation (G2) facilities capable of reaching sensitivity levels better than 10^{-46} cm^2 (about a factor of 400 better than present-day limits and a factor ~10 better than expected for the experiments already under construction)... Details are different for different technologies. G2 experiments would have typical target masses of approximately one ton, with a construction and operation cost in the range of $15M-$20M."

Recommendation: In all budget scenarios, "Two G2 experiments and the 100-kg SuperCDMS-SNOLAB experiment are supported."

Recommended G2 construction start in FY13.

The three generations



⟹ a primary selection criterion

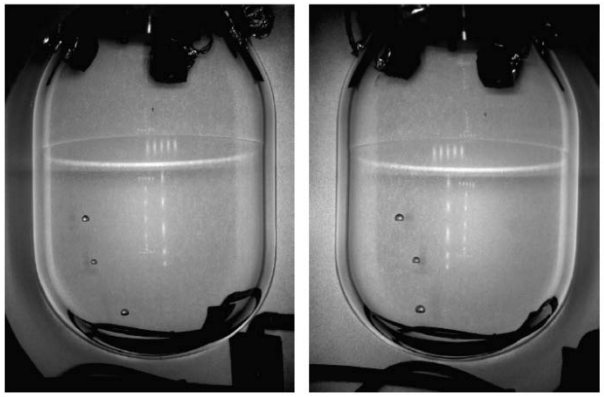
- DOE/HEP Funding Opportunity Announcement (FOA) for G2 DM experiment R&D:
  - *"For the purposes of this FOA, a second-generation experiment is one that, in the absence of detection, improves our current knowledge of a relevant dark matter particle parameter by roughly one order of magnitude or more. For WIMPs, this parameter could be (but is not restricted to) the WIMP-nucleon cross section limit. In the case of axions, the parameter could be (but is not restricted to) a limit on the photon-axion coupling constant…any viable dark matter species may be the object of an investigation."*

Mission Need Statement
(CD-0) Cost Profile
(approved September 2012)

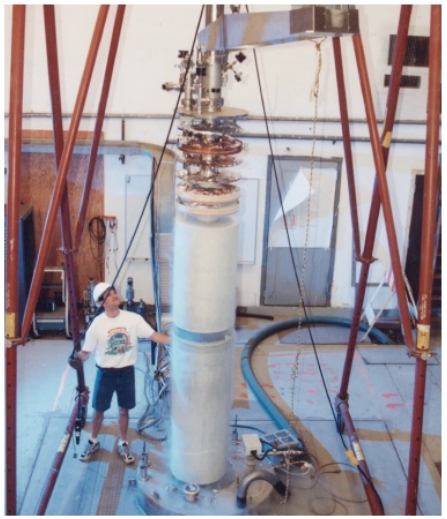
FY13	FY14	FY15	FY16
R&D only	fabrication	fabrication	fab/commission
$7M	$13M	$9M	$9M

R&D: $7M
Fabrication: $31M
Total: $38M

DOE "First Generation" (G1) DM Experiments

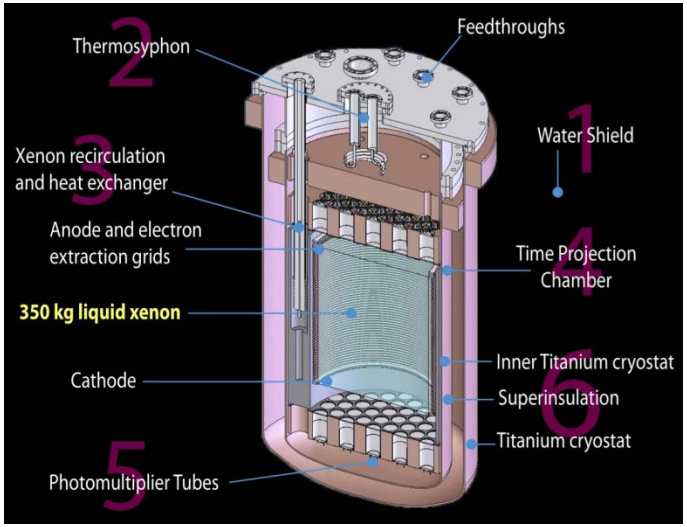


COUPP Bubble Chamber – at SNOLAB
- commissioning



Axion Dark Matter eXperiment (ADMX) Phase-2a at U.Washington
-commissioning; start science run in summer

Cryogenic Dark Matter Search (CDMS) at Soudan mine -
germanium detectors
- operating



Large Underground Xenon (LUX) detector –
Sanford Lab, Homestake mine, commissioning

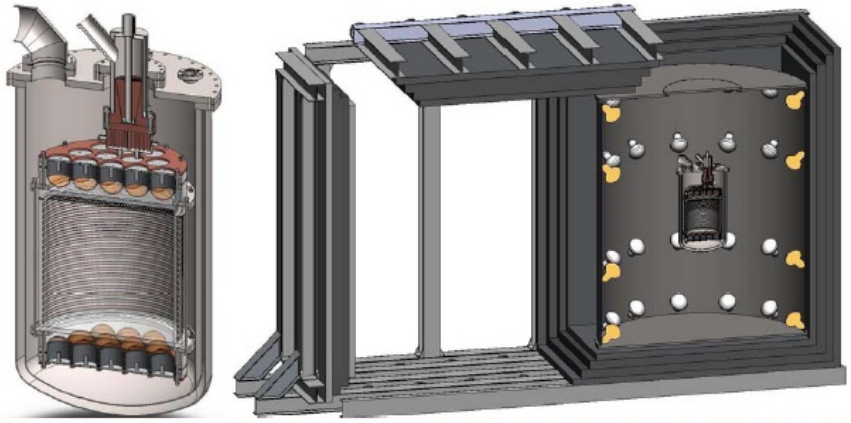


FIG. 5: **(a)** The DarkSide-50 internal detector. **(b)** The DarkSide-50 detector within the active liquid scintillator neutron veto and the passive shield.

DarkSide-50 – Dual-Phase liquid argon TPC at LNGS;
commissioning

Moving forward: the problem

- The DM community wanted to press forward with a G2 program
- However, the various technologies were (are) in differing stages of maturity.
- Some hold great promise, but have yet to fully demonstrate the level of performance required for G2 selection
- Only a few G2 experiments will be selected to become projects, so need to make the most informed selections.

Moving forward: the solution

- Conduct the selection in two phases:
  - First phase (FY13): Selection several experiment proposals for one year of R&D funding only
    - No equipment purchases, fabrication.
    - Pre-conceptual experiment design activities.
    - Activities for the reduction of scientific, technical, cost risk.
    - Experiments with DOE TPC < $5M are exempt from restriction on fabrication (they are below the project threshold)
  - Second phase (FY14-FY16): Have downselection in FY14, selecting 2-3 G2 experiments from the R&D pool to enter into project phase
    - Final R&D report used as basis for downselection.
      - Evaluation based on updated experiment concept, risk reduction.
      - External scientific review; internal technical and cost risk review planned.
    - Each experiment becomes a project within the G2 DM Program, with independent project life cycles (e.g. CD-1, CD-2/3a, etc. gates).
    - Project phase planned to start in FY14/Q2
    - CD-4 is to be reached by end of FY16.
    - ***Final selection of G2 projects done in coordination with NSF.***

G2 DM FOA

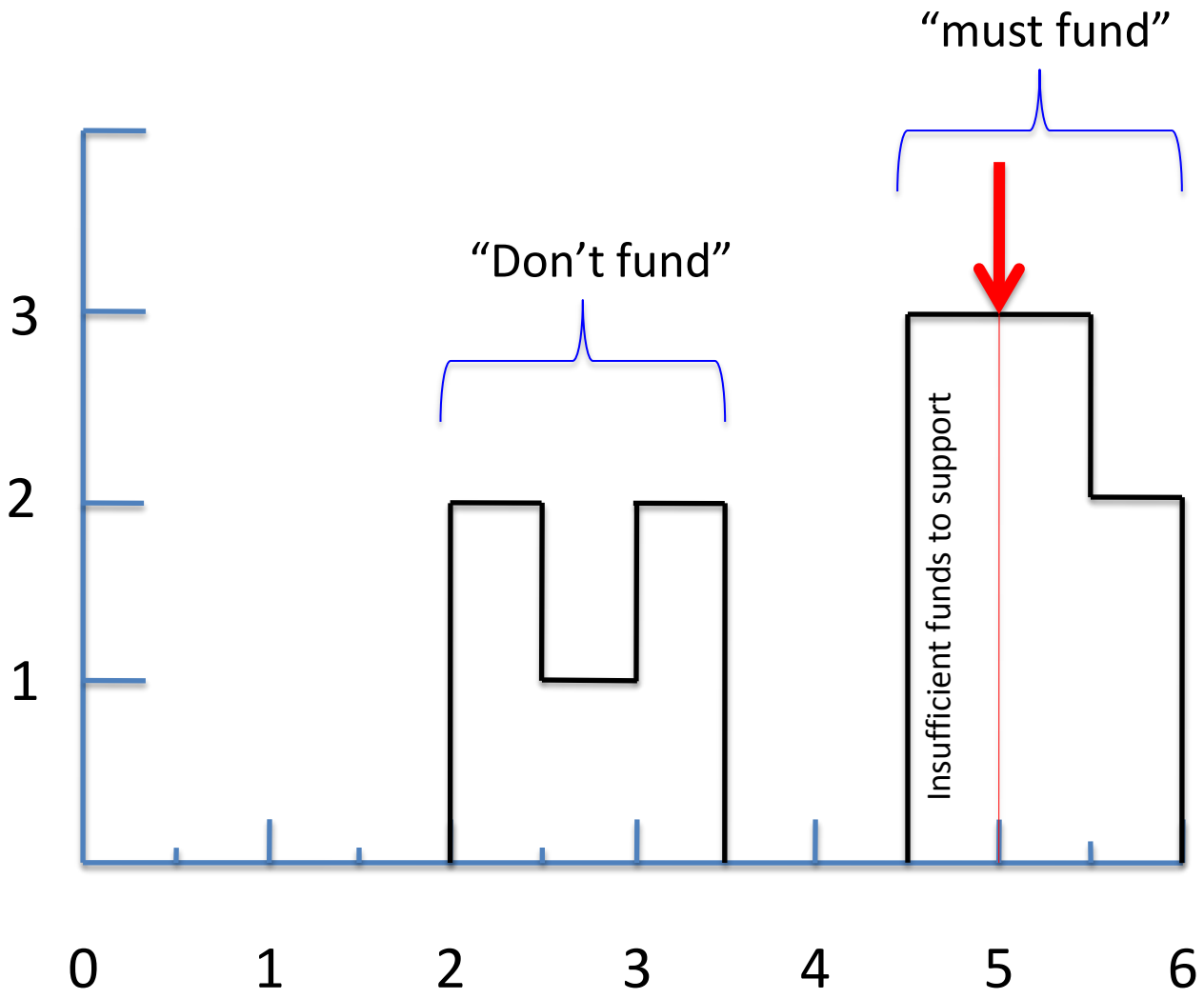
- The recent G2 DM solicitation provides one year (FY13) of R&D funding only
- Application requirements in the FOA:
  - Statement of science goals and justification of G2 status
  - Description of experiment performance requirements
  - Technical description of experiment that documents how it will meet its performance requirements
  - An estimate (not budget) of total costs of experiment, inlcuding design, equipment, fabrication, management.
  - Project schedule estimate
  - List of current technical risks with a plan for mitigation.
  - A detailed description of the proposed research and concept development work, including scientific, technical and cost risk reduction to be conducted during the one year of R&D support.

- Received 13 proposals in July 2012.
- R&D final reports due FY14/Q1.

Panel Review

- 13 proposals received: 10 for WIMPs, 3 for axions
- 14 panelists (one being Chair), each panelist writing a review for 3 proposals.
    - 5 of the 13 panelists were from outside the U.S. (Nearly all the members of the U.S. direct-detection DM community were on one or more proposals.)
- Each proposal also 2 mail-in written reviews, → 5 reviews/proposal
- Panel met for 3 days in Gaithersburg in mid-September 2012
- Made strong recommendation that all "must-fund" proposals be funded, even if it required significant reductions to all the selected proposals' budgets.
- Such deep cuts could not be made without compromising the R&D programs of the topped ranked proposals, so only the highest ranked of the "must-funds" were selected.

Proposal Scoring by Panel

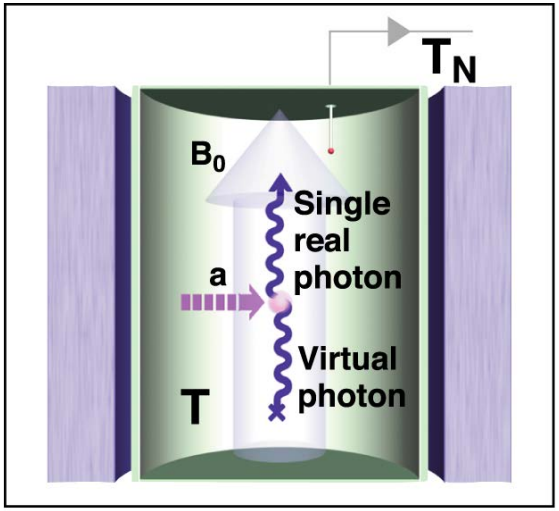


Selected Proposals

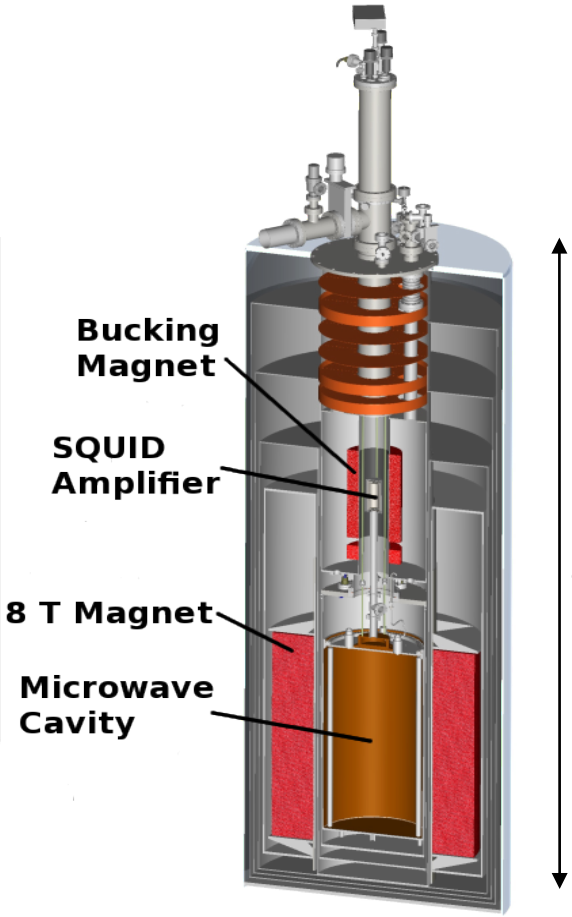
- **ADMX-Gen 2** (Axion Dark Matter Experiment)
  - Axion detection via the Primakov process
  - Planned location = U. Washington surface lab
  - DOE G1 expt: ADMX-IIa
- **LZ**
  - LXe TPC – scintillation + ionization
  - Planned location = SURF/Davis Campus 4850L
  - DOE G1 expt: LUX
- **SuperCDMS-SNOLAB**
  - Ge crystals – phonon + ionization
  - Planned location = SNOLAB
  - DOE G1 expt: SuperCDMS-Soudan
- **DarkSide-G2**
  - LAr TPC -- scintillation + ionization
  - Planned location = LNGS
  - DOE G1 expt: DarkSide-50
- **COUPP-500** (Chicagoland Observatory for Underground Particle Physics)
  - CF_3I (spin-independent) and C_3F_8 (spin-dependent) bubble chamber – visual + acoustic
  - Planned location = SNOLAB
  - DOE G1 Expt: COUPP-60

Gen 2 ADMX: Ultrasensitive Search for Dark-Matter Axions

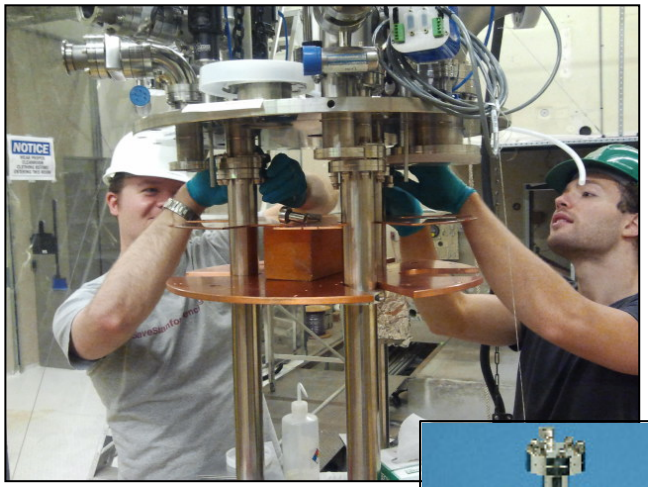
Halo axions convert into microwave photons inside a RF cavity threaded by a strong magnetic field



ADMX is sensitive to sub-yoctowatts of microwave power



New experimental insert fabricated and being assembled

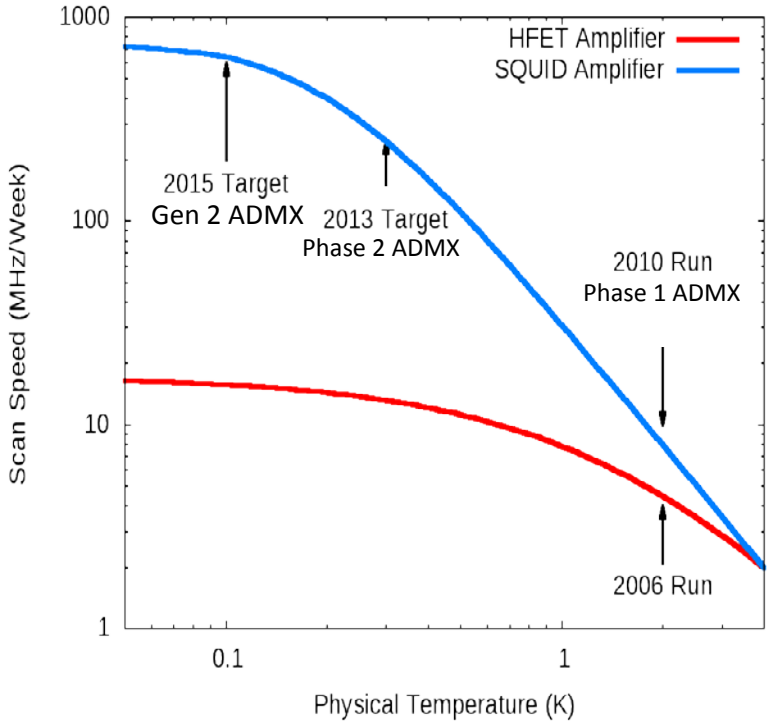


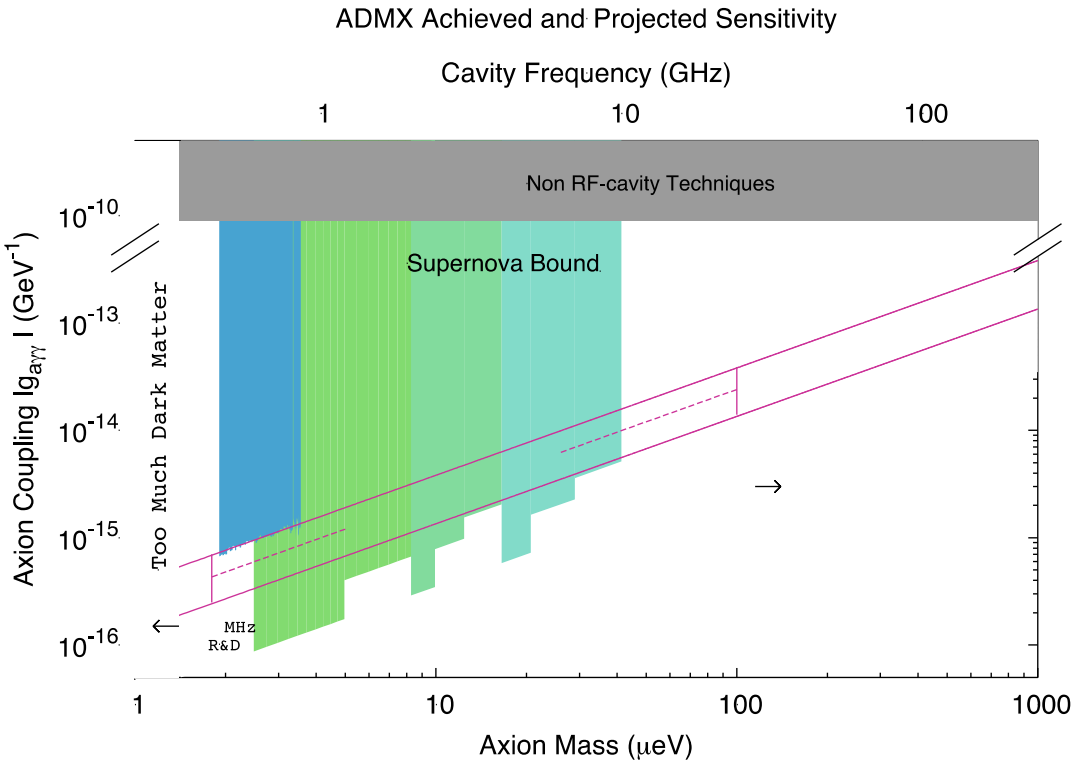
Dilution refrigerator provides the low temperature for the Gen 2 ADMX "Definitive Search"

Gen 2 ADMX: Ultrasensitive Search for Dark-Matter Axions

The dilution refrigerator in Gen 2 ADMX significantly speeds the dark-matter search, so that …

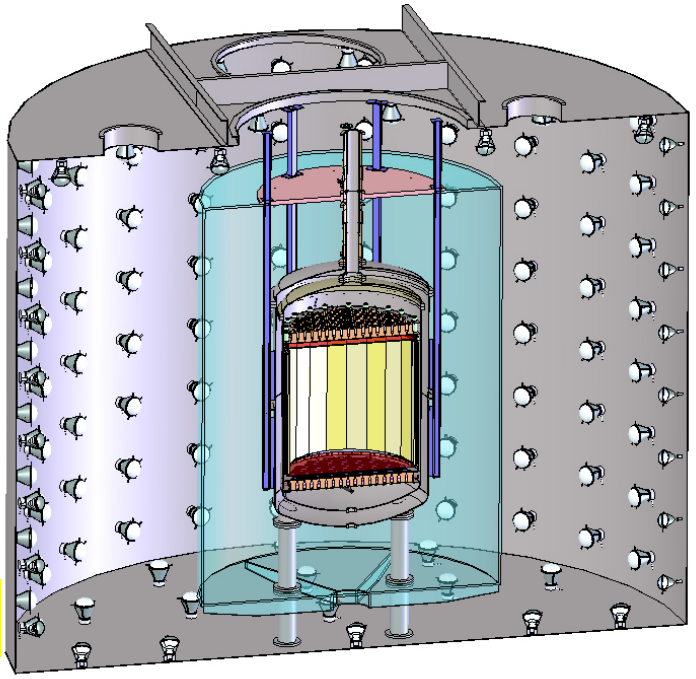
… Gen 2 ADMX has the sensitivity to either detect the dark-matter QCD axion or reject the hypothesis at high confidence. This is called the "Definitive Search".





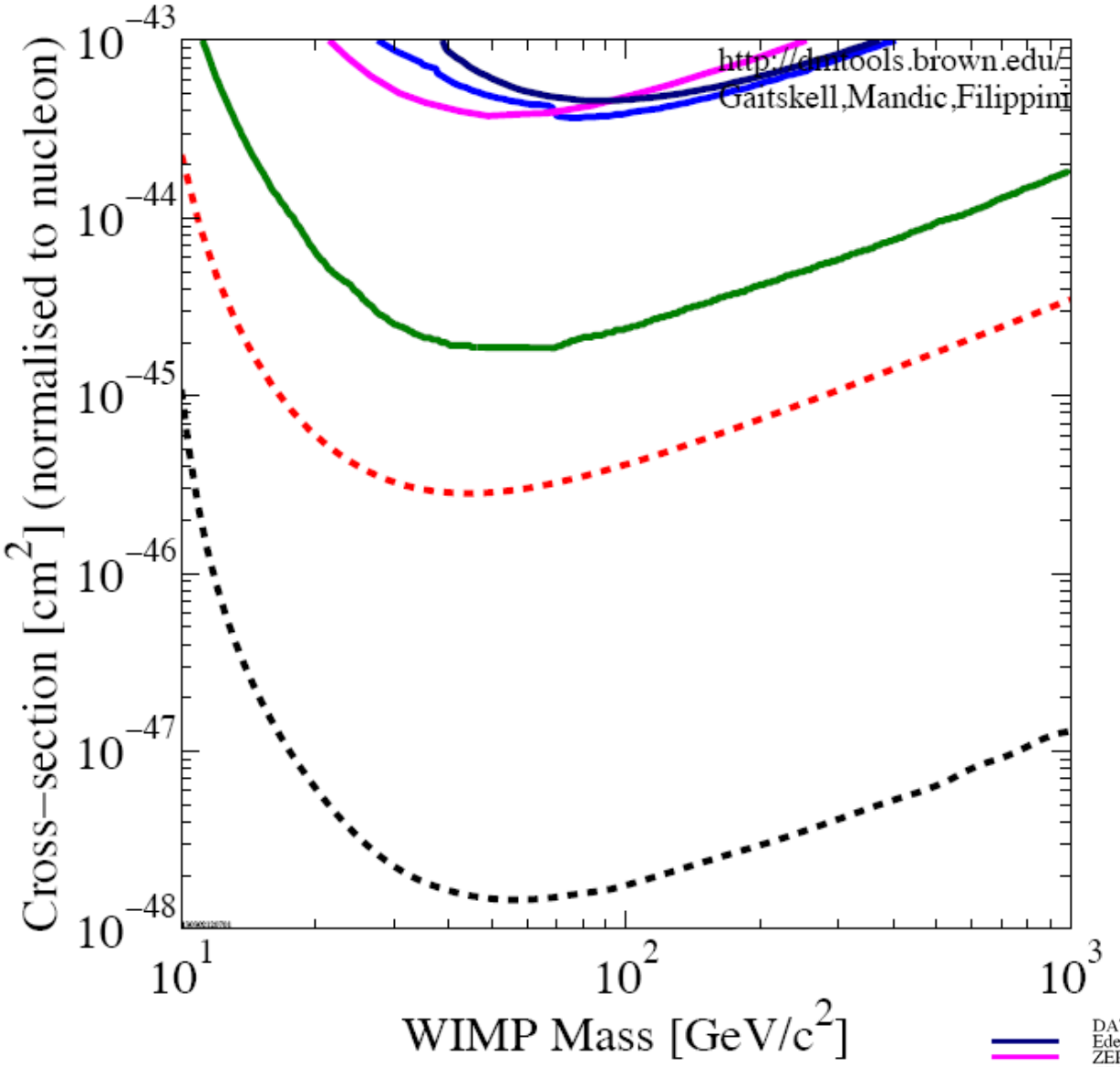
LZ Experiment

- Builds upon the experience from the Large Underground Xenon (LUX) detector
  - Dual-phase, ~ 350 kg of liquid Xenon
  - Installed at the Sanford Underground Research Facility (SURF)
  - Full of Xenon since early February, commissioning underway
- LZ Collaboration and Detector
  - Collaboration of 20 institutions from United States, United Kingdom and Portugal
  - Collaboration growing beyond LUX
  - Can utilize SURF infrastructure, water tank
  - Much increased Xenon volume ~ 8 tonnes
  - Powerful active scintillator veto
  - Conceptual design and key R&D underway
  - Goal: CD-1 quality design by end 2013.



LZ Experiment in SURF Water Tank

LZ Experiment Reach



XENON100(2012)

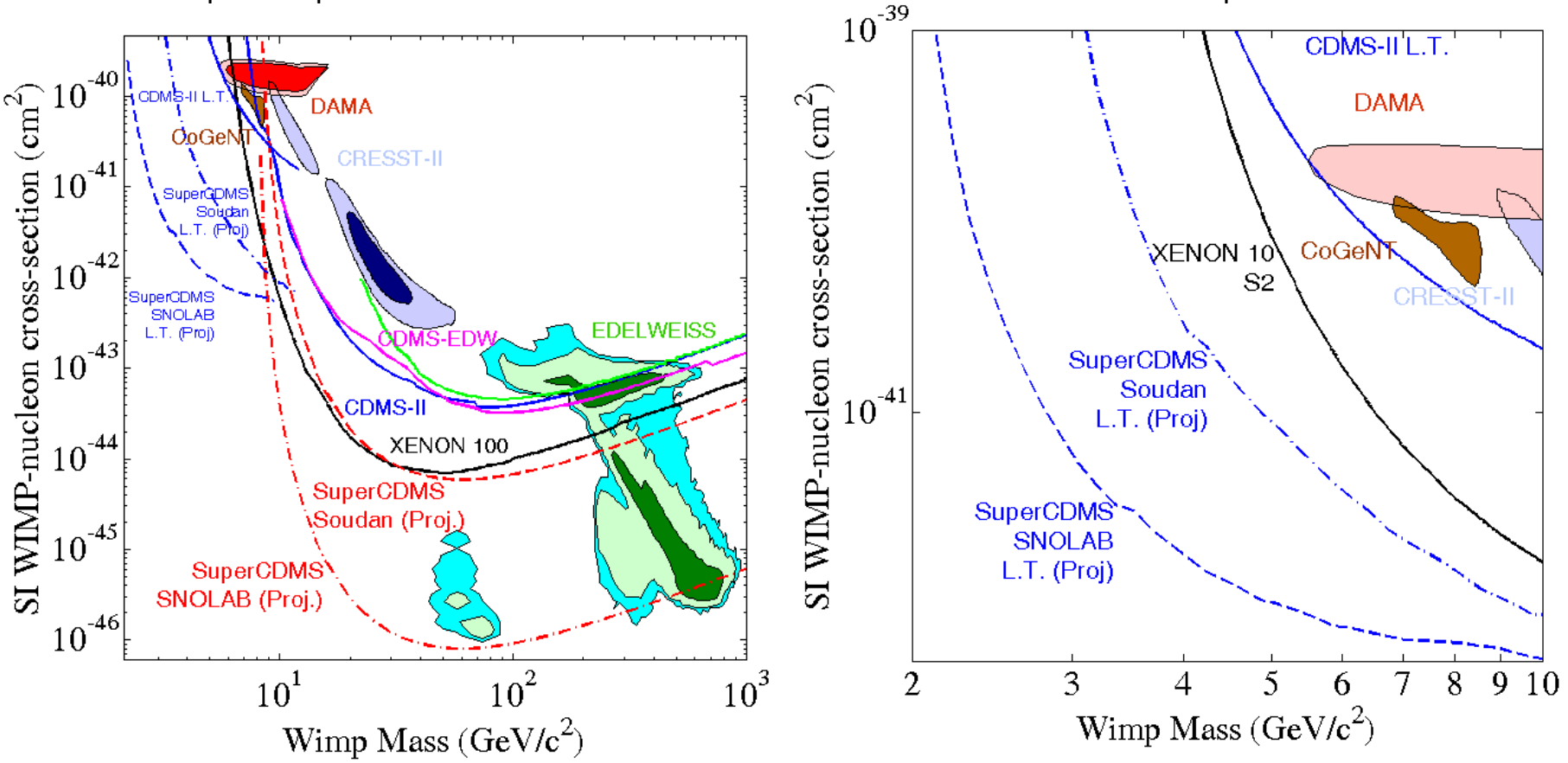
LUX Goal

LZ Goal

SuperCDMS SNOLAB

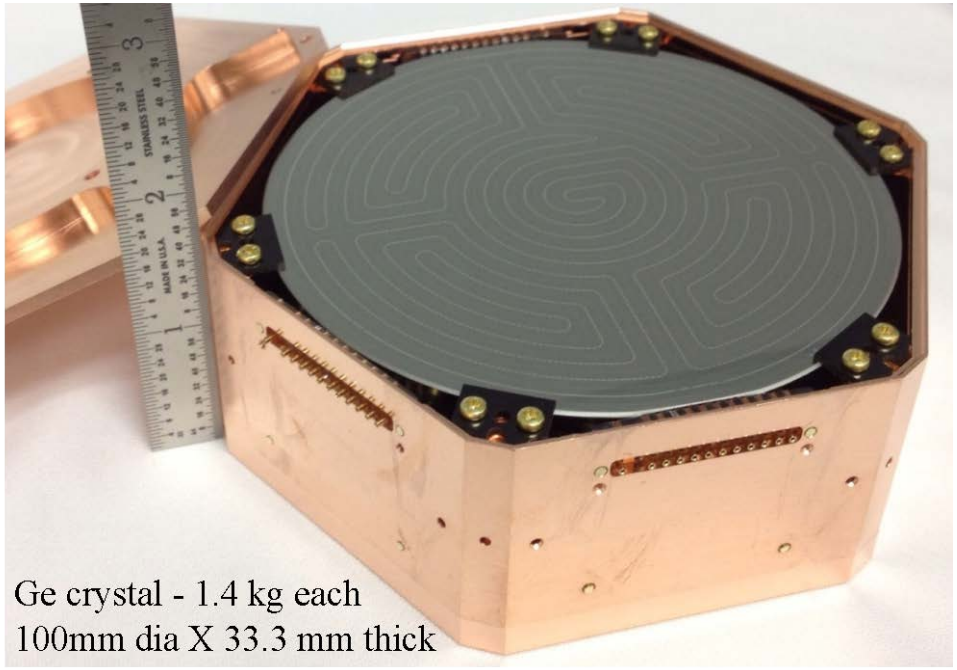
- Next-generation (G2) dark matter direct detection experiment designed for background-free, competitive sensitivity for 100 GeV WIMPS
- Will also provide world-leading sensitivity to low-mass (3-10 GeV) and high mass (>1 TeV) WIMPs

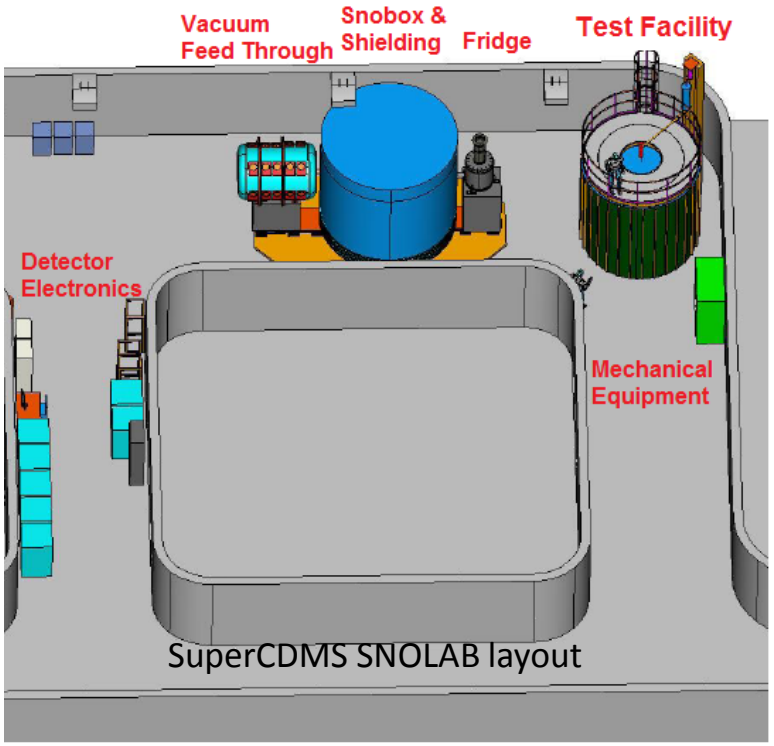
Spin-independent WIMP-nucleon cross section versus WIMP mass reach for SuperCDMS



SuperCDMS SNOLAB

- 200 kg Ge target mass with interleaved charge and phonon sensors to reject surface events (iZIPs)
- Cryogenics system designed to hold up to 400 kg at <40 mK
- State-of-the-art passive and active shielding against backgrounds
- Location at SNOLAB, the deepest, cleanest underground lab





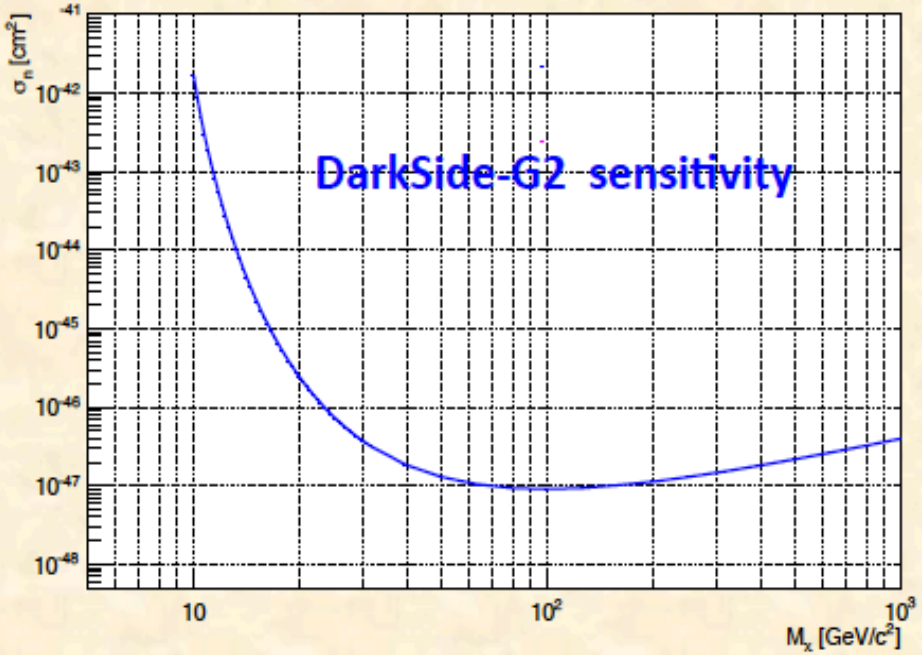
DarkSide – G2 summary

Two-phase liquid argon TPC ~ argon mass 5 tonnes, fiducial mass 2.8 tonnes

Successor to DarkSide-10 and DarkSide-50; planned for operation at L.N.G.S. in Italy

TPC surrounded by **existing veto system** of 4 meter diameter active liquid scintillator veto inside a 10 meter high, 11 meter diameter, active water tank.

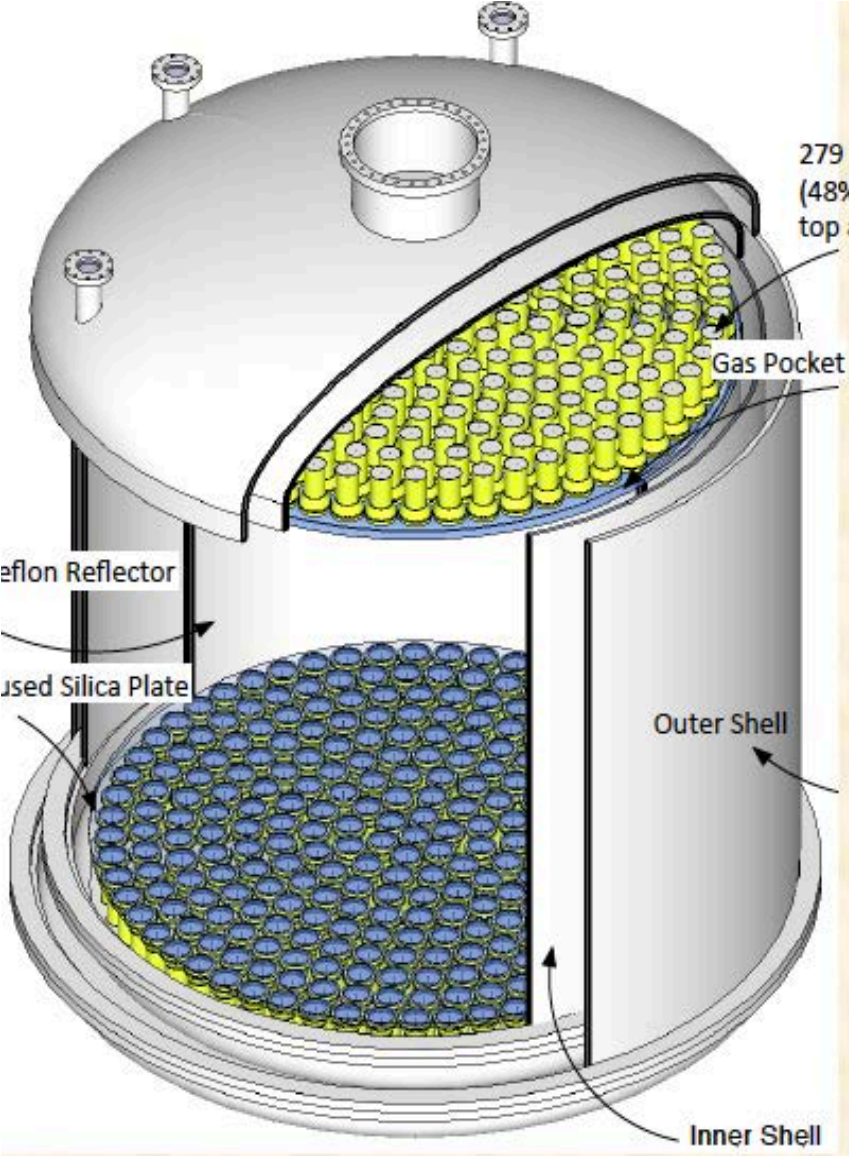
TPC design features: low radioactivity argon (< 0.65% atmospheric argon),
minimum radioactivity detector – in particular PMTs,
high light yield,
low noise electronics,
powerful data-acquisition



DarkSide-G2 predicted sensitivity for 14 tonne-yrs with <0.1 background event.

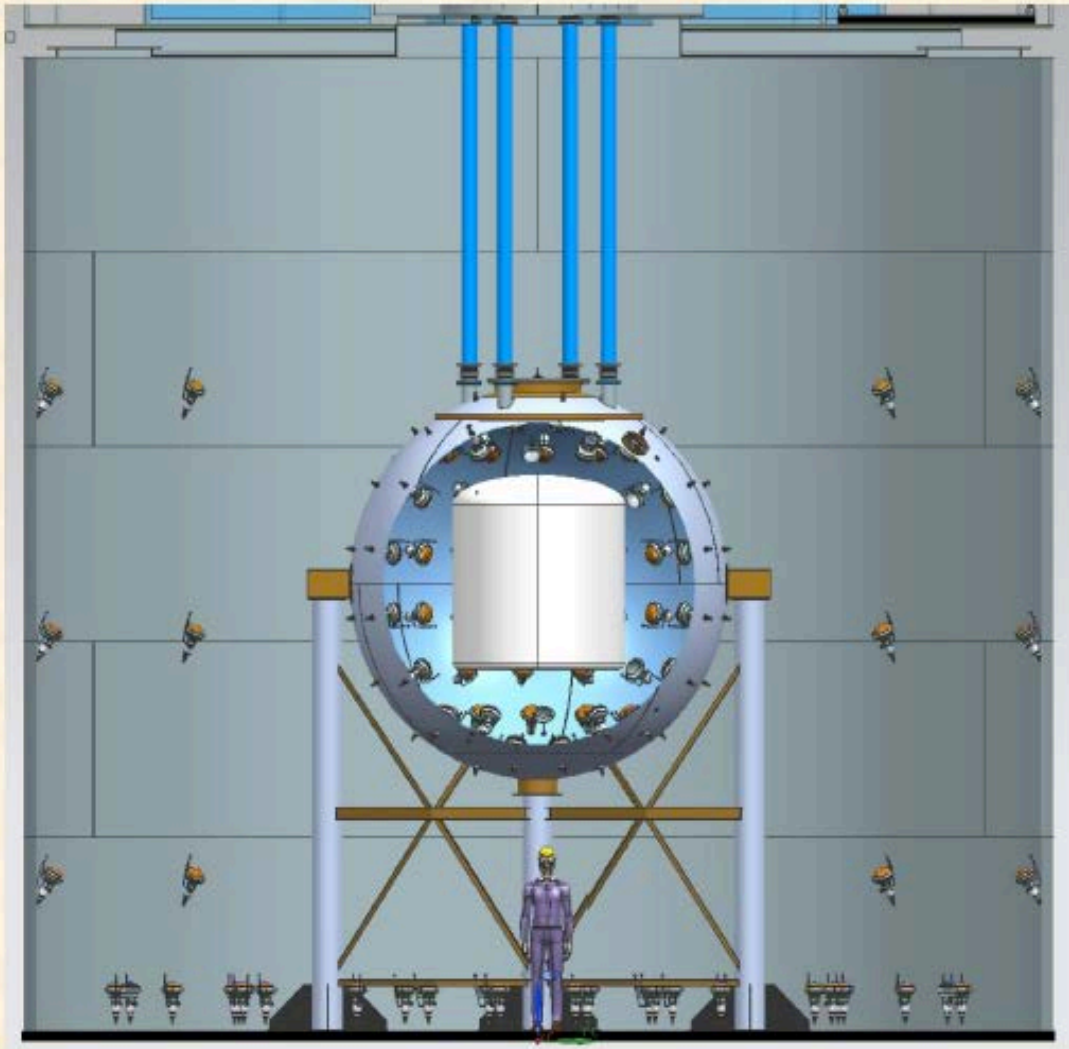
(extrapolation based on DS-10 data)

DarkSide – G2 conceptual design



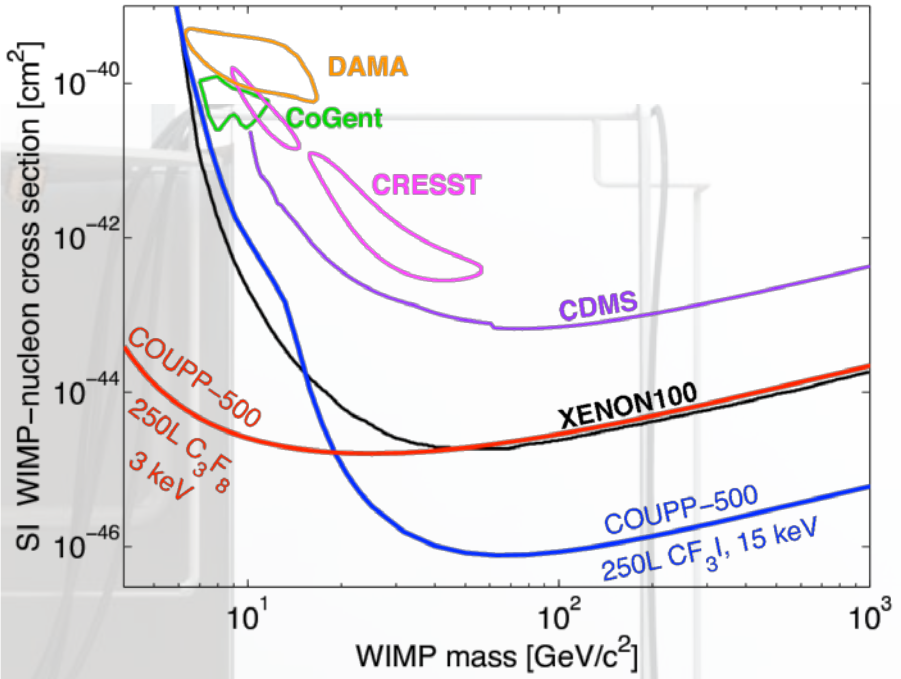
Concept of TPC for DarkSide – G2
based on 3 inch PMTs

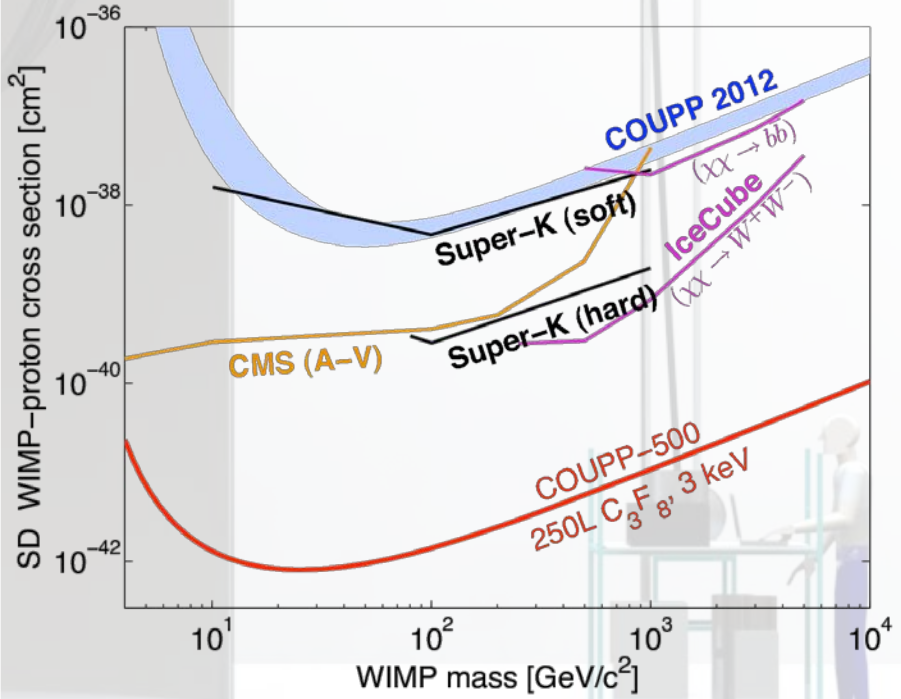
G2 TPC inside **existing** scintillator and water veto



COUPP–500

- >10^{10} γ/β insensitivity
- >99.3% acoustic α-discrimination
- Multi-target Capability
  - SD- and SI-coupling
  - High- and low-mass WIMPs
- Easily scalable, Inexpensive to replicate
- COUPP-60 turning on March 2013
- Growing Collaboration Newly merged with PICASSO

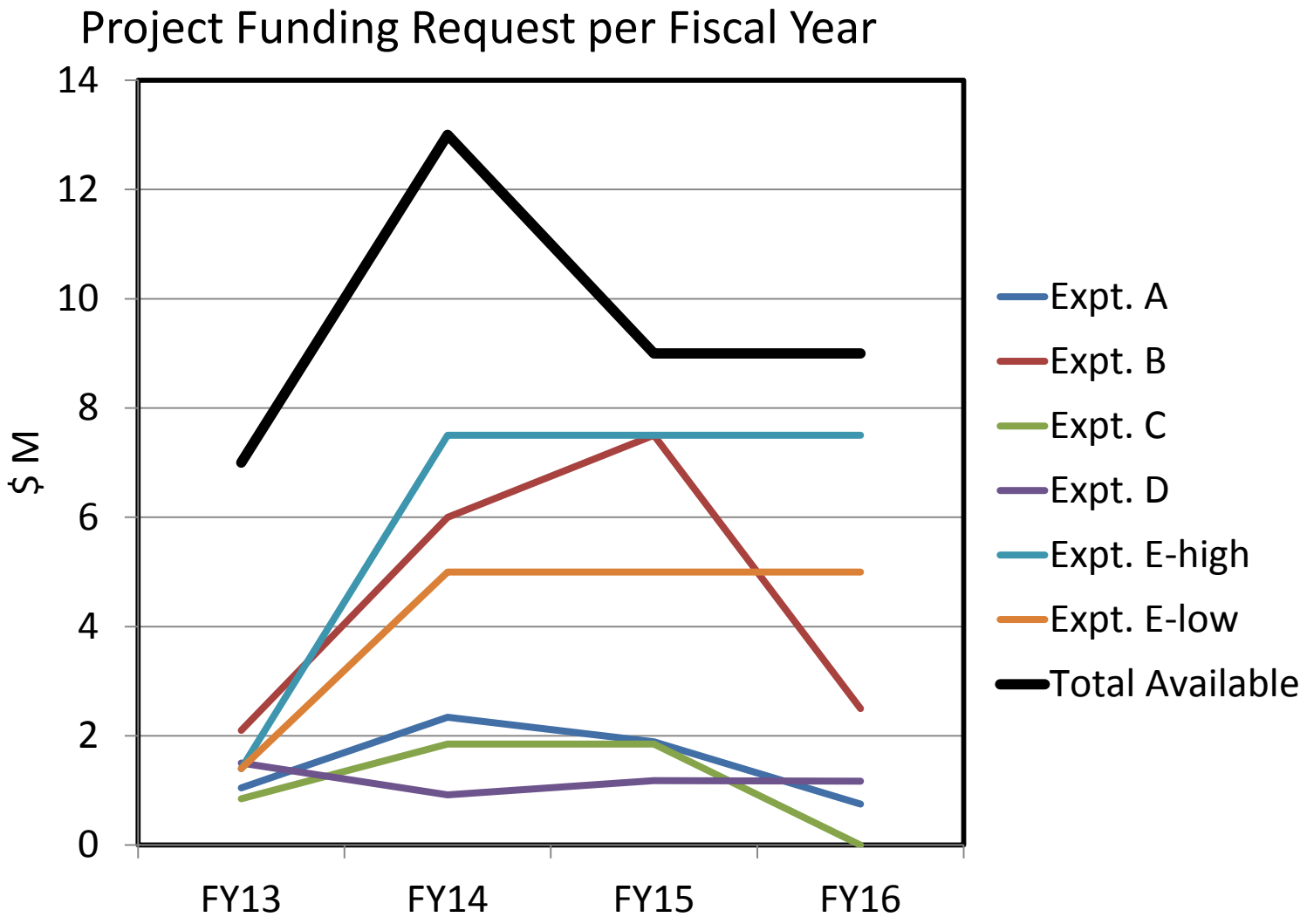




G2 Funding

Funding: DOE Available *vs.* DOE Request

Total planned DOE G2 DM funds summed over FY14-FY15 = $31M



Funding Issues

- Most of the selected G2 candidates also will ask for NSF funding after the current R&D phase.
- Some of the “low cost” experiments, those under $5M total, plan to submit a much larger request to NSF.
- The number of R&D proposals selected was based on the funds available for R&D in FY13, not on the total estimated project cost of the project candidates.
- There is a significant gap between the total available funding and potential need.

G2 DM Program Timeline

- Past:
  - "DOE Funding Opportunity Announcement for Second Generation Dark Matter Experiments" issued March 2012.
  - Proposals submitted in July 2012
  - Panel review held in Gaithersburg, MD in mid-September 2012.
  - DOE G2 DM CD-0 in September 2012
  - Most selections made in December 2012, some funding out in January 2013.
- Present:
  - Formal announcement of selections at this HEPAP meeting.
- Future:
  - R&D reports due in FY14/Q1 (exact date to be fixed soon)
  - Downselection in FY14/Q1, coordinated with NSF
  - Funding starts for fabrication in FY14/Q2, assuming we are not in a Continuing Resolution
  - Fabrication complete, commissioning near end of FY16.
  - Funding problem?