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The G2 Direct Detection Program in a Broader Scientific Context

The Nature of Dark Matter:

Current understanding: observations/theoretical ideas

The Generation 2 Direct Detection Dark Matter Program

ADMX, LZ, CDMS: Plans and Challenges
Complementarity with other US and international efforts
Timeliness

Preparing for the Generation 3

Be ready for a breakthrough

Not for presentation: Appendix: submission by collaborations (51 slides!).

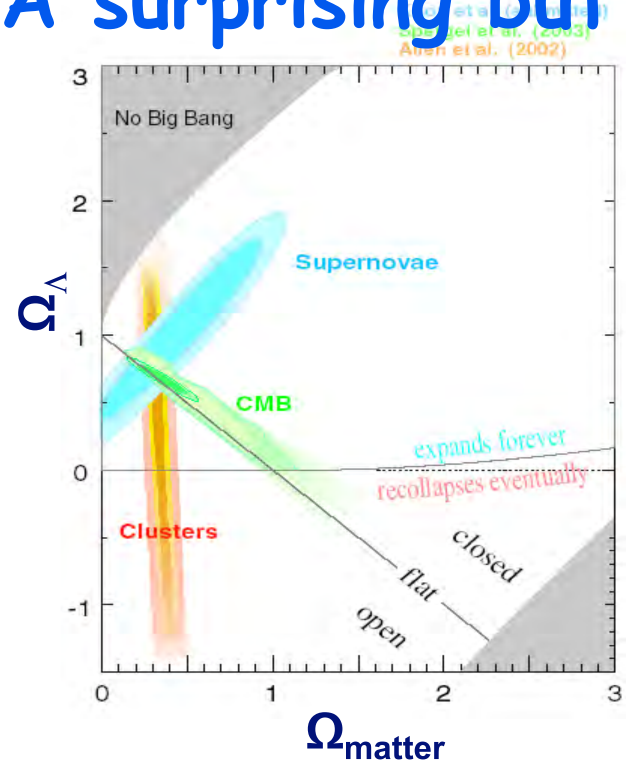
A useful snapshot of Direct Detection in the world
Many thanks to my colleagues, but opinions/errors are mine!

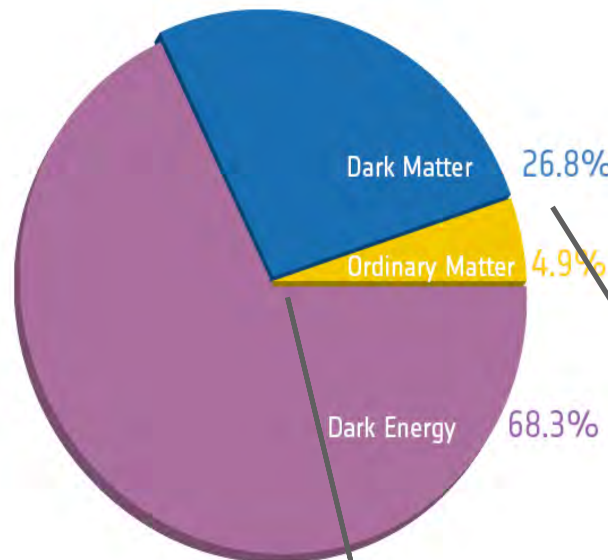
The Nature of Dark Matter

Current understanding: observations/paradigms

Standard Model of Cosmology

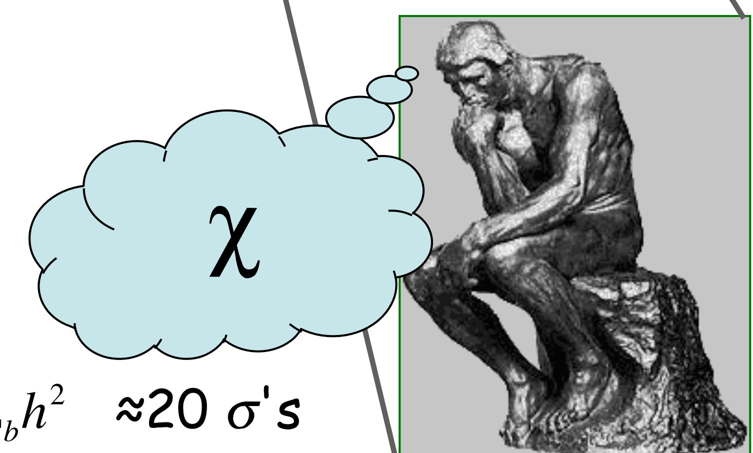
A surprising but consistent picture





Not ordinary matter (Baryons)

$\Omega_m >> \Omega_b = 0.049 \pm 0.001$ from | Nucleosynthesis / WMAP/Planck



+ internally to WMAP/Planck $\Omega_m h^2 \neq \Omega_b h^2$ ≈20 σ's

Mostly cold: Not light neutrinos ≠ small scale structure

Particle Physics:Favorite Possibilities

Axions <= Strong CP problem $10^{-6\ -3}$ eV

Peccei Quinn solution: dynamic restoration of CP

Weak scale WIMPs <= hierarchy problem 10^{11-12} eV

Freeze out when annihilation rate ≈ expansion rate

$$\Rightarrow \Omega_x h^2 = \frac{3\cdot 10^{-27} cm^3/s}{\langle \sigma_A v \rangle} \Rightarrow \sigma_A \approx \frac{\alpha^2}{M_{EW}^2} \equiv \text{Weak scale}$$

coincidence between Cosmology and Particle Physics

Dark Matter Hidden Sector: not necessarily weak scale

e.g., Asymmetric Dark Matter (Zurek) <-> Baryon-Antibaryon asymmetry

$$\frac{\rho_{\text{dark matter}}}{\rho_{\text{baryon}}} \approx 6 \Rightarrow M_{\text{dark matter}} \approx 6\ \text{GeV}/c^2$$

Dark Photon (Arkani Hamed-Finkbeiner-Weiner), atomic DM, Self Interacting

Intriguing but less predictive 10^{6-13} eV

Sterile neutrino in keV range ≈10^3 eV

with very small mixing angle (≠1 eV)

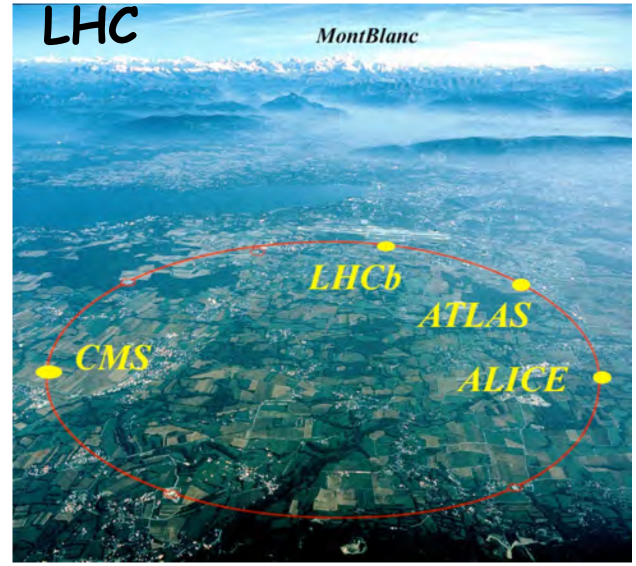
4 Complementary Approaches

Cosmological Observations

Planck

Keck telescopes

Dark Matter
Galactic Halo (simulation)



WIMP production on Earth

VERITAS, also HESS, Magic + IceCube (ν)

WIMP annihilation in the cosmos

Fermi/GLAST

CDMS

WIMP scattering on Earth:e.g. CDMS, Xenon 100,etc.

Recent inputs from Cosmology

Remarkable success of Lambda CDM

Cosmic Microwave Background
Large scale structure

Potential Problems at small scale

Observe Core instead of NFW cusp
Do not observe enough large satellites "which should too big to fail"

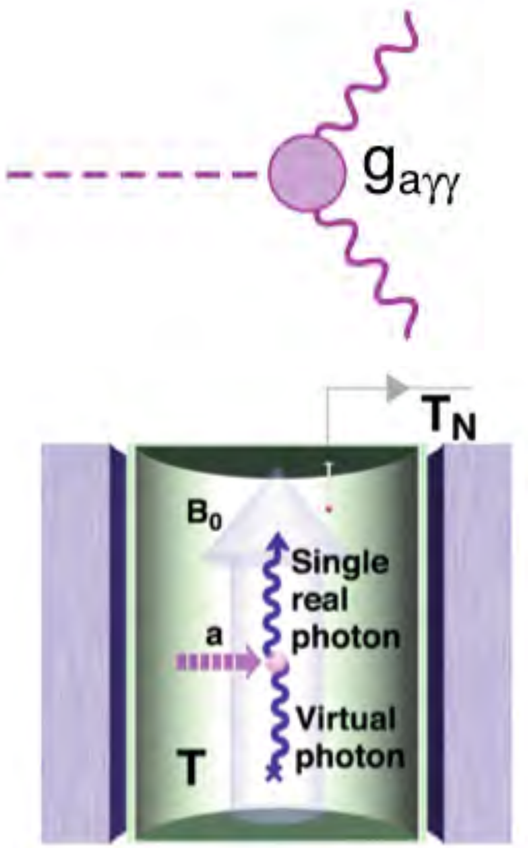
Debate on whether this is a sign of

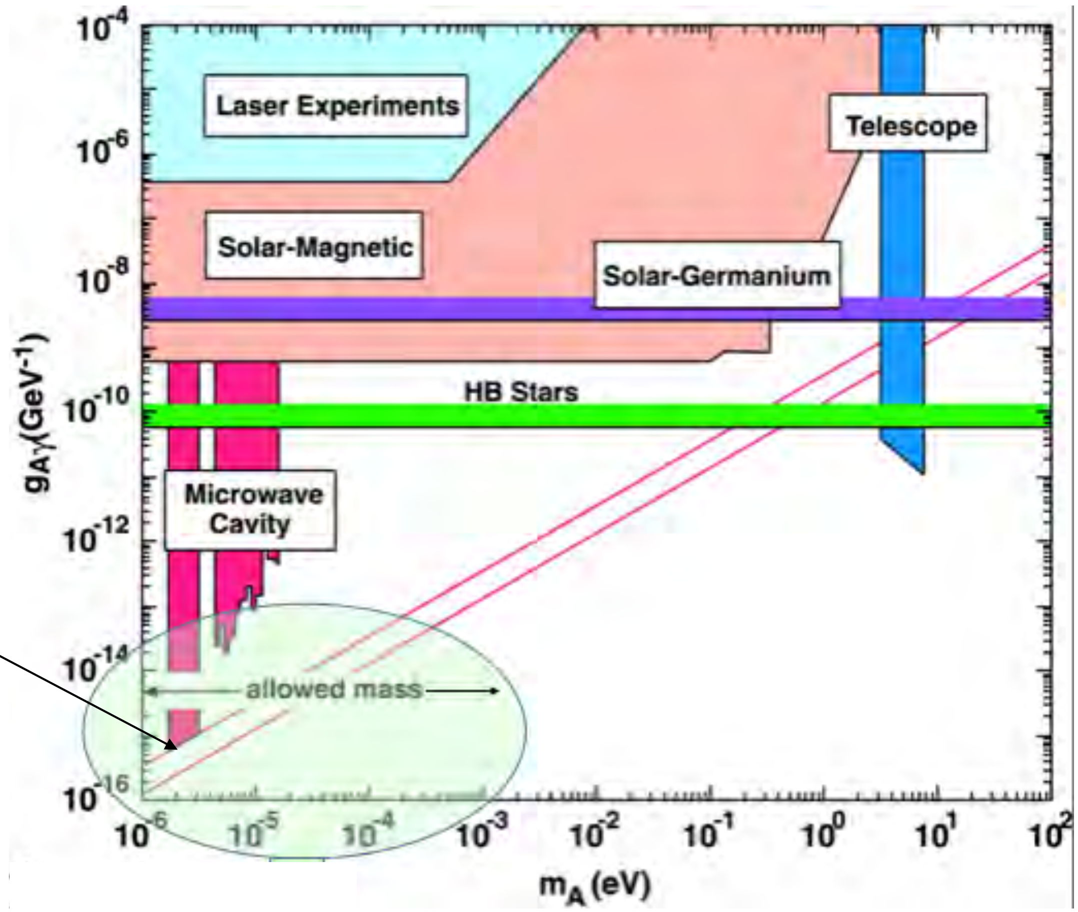
Poor understanding/simulation of gas and feedback mechanisms
or new dark matter physics

Warm Dark Matter: few keV sterile neutrino with tiny mixing angles
Some excitement about an 3.5 keV X ray line (but ≲3σ) => 7keV sterile neutrino
seen in Andromeda, Perseus Cluster, co-added clusters
Balbul et al. arcXiv: 1402.2031 Boyarski et al. arXiv:1402.4119
but not in co-added dwarfs. Should be clear with Astro-H!
Would probably have the same problem as CDMD with cusp

Self Interactive Dark Matter: which would smooth the center distribution
Would clearly be a sign for a "Dark Sector"

Particle Detection Axions

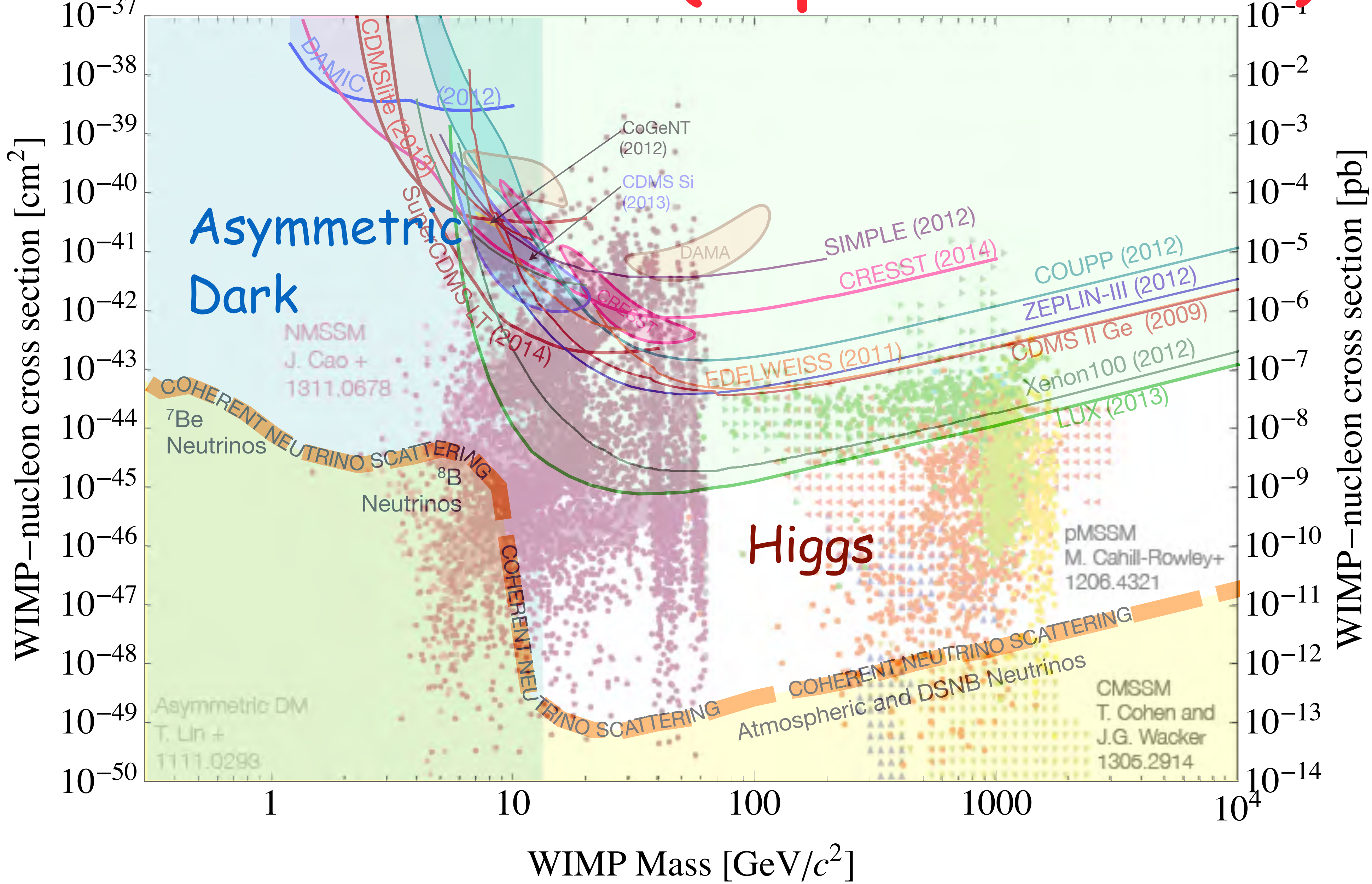




No detection so far but at the Cosmological limit

Direct Detection

Current Situation (September 2014)



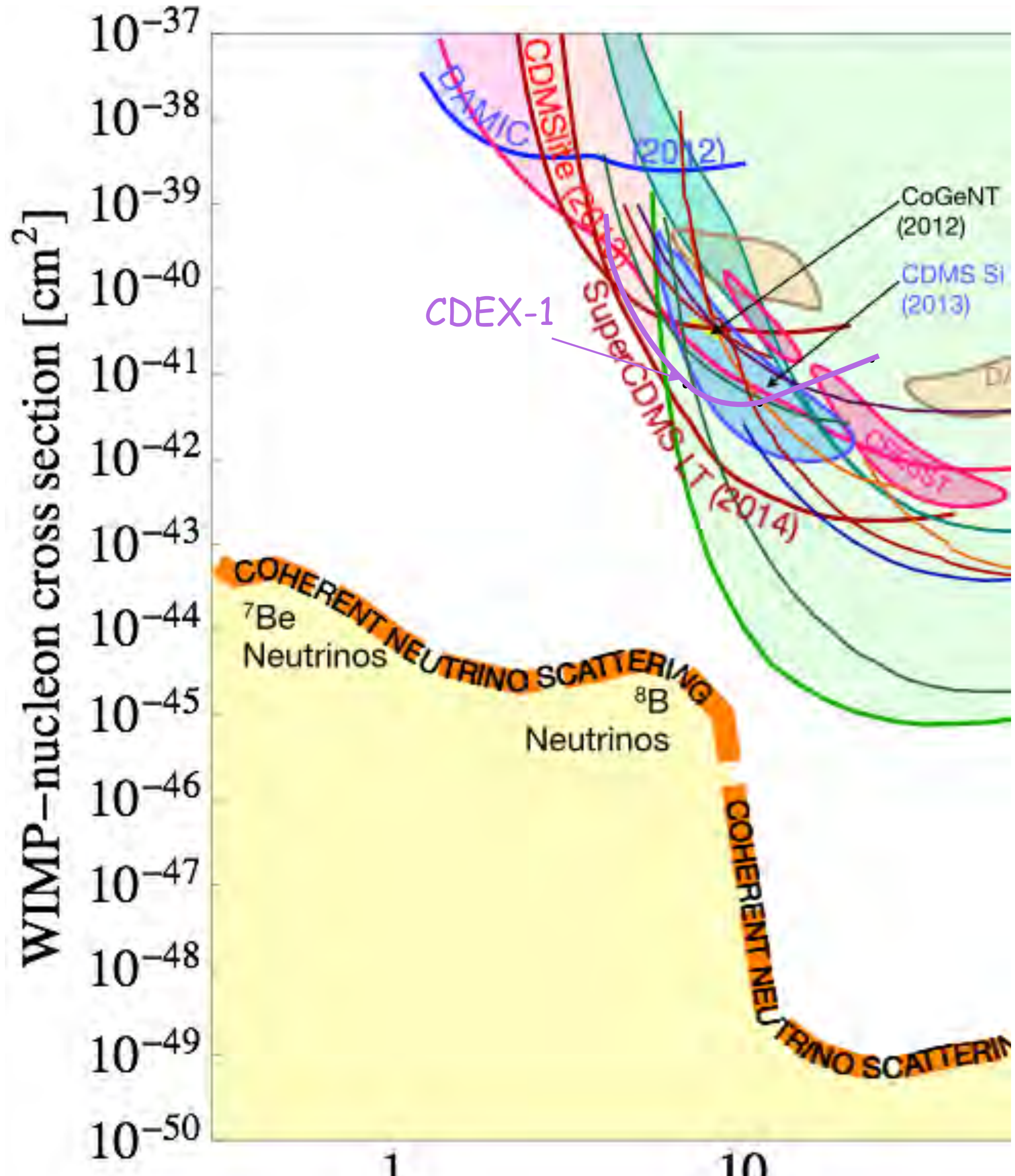
Low Mass Region

Optimistic

- Accumulation of claims in that region
- The exclusion by some experiments is based on unreliable calibration
- Just the region expected for asymmetric dark matter

Pessimistic

- Not compelling evidence
- Close to threshold: Outliers ?
- Excluded by
  - XENON100
  - LUX
  - SuperCDMS Soudan

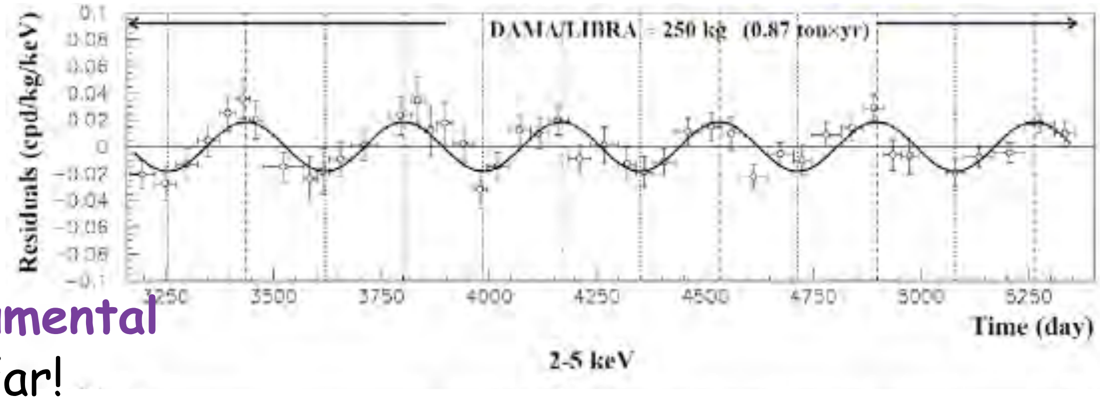


Hope for grand unification of claims was clearly premature!

Modulation

DAMA

clear summer-winter modulation



Wide suspicion that this is instrumental

but no convincing explanation so far!

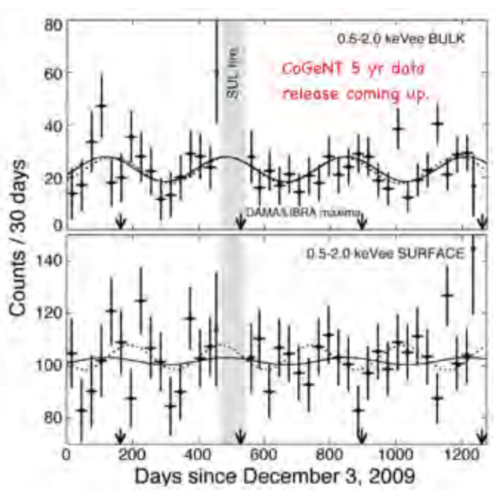
CoGeNT

weak evidence

CoGeNT 5 year data to be released soon

Not seen in CDMS II above 5 keVnr

Difficult control of systematics



Not necessarily a proof of WIMPs

But we need to check!

KIMS NaI

200kg run starts at the end of 2015

ANAIS

DM-ICE NaI

See appendix

SABRE NaI

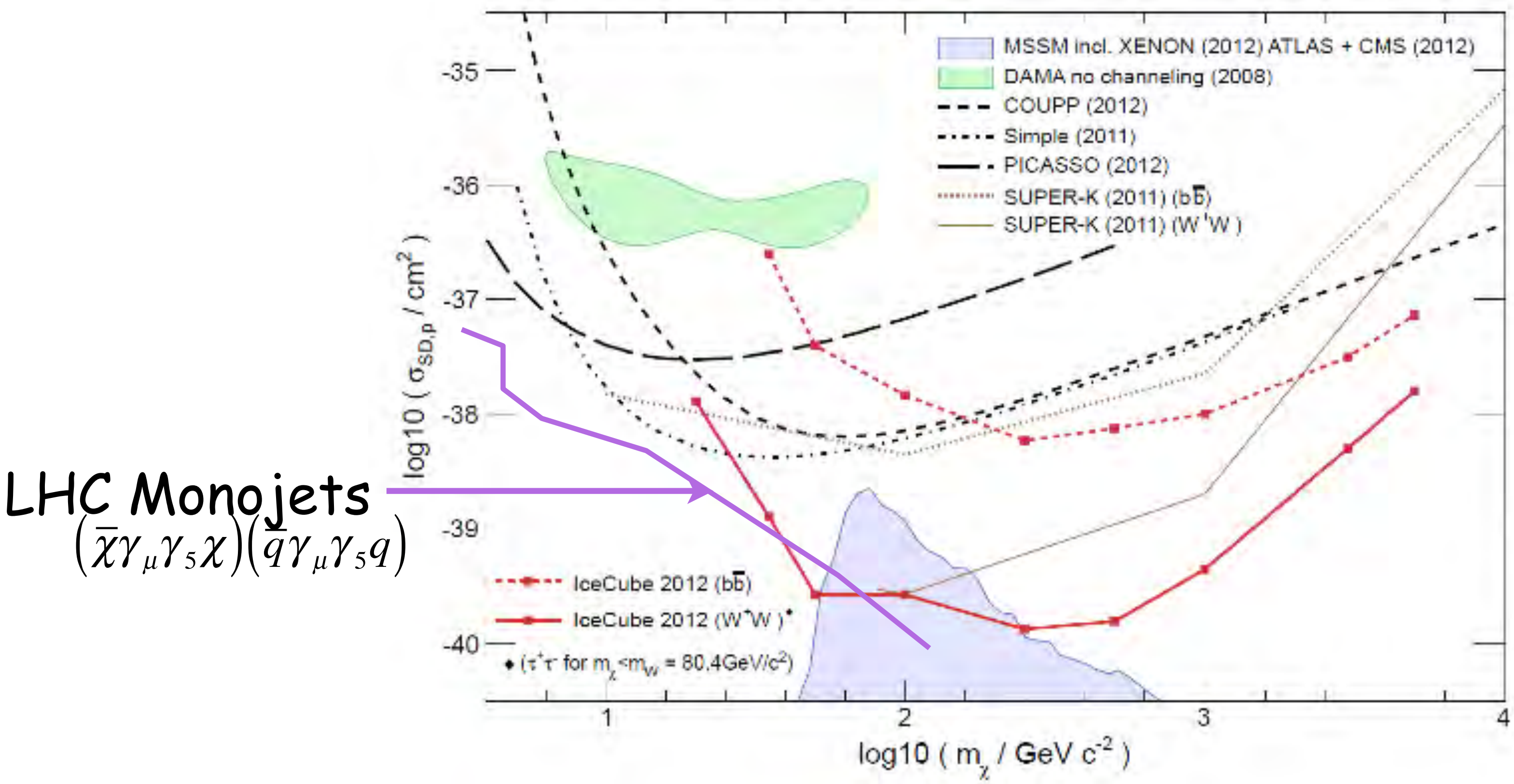
low radioactivity

neutron veto

C4 (Ge)

Spin dependent limits (e.g. p)

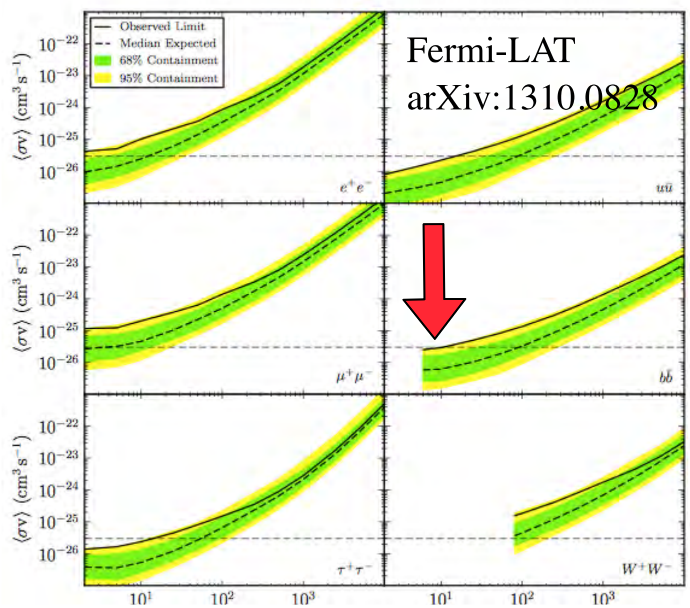
Finally entering SUSY region



Indirect Detection

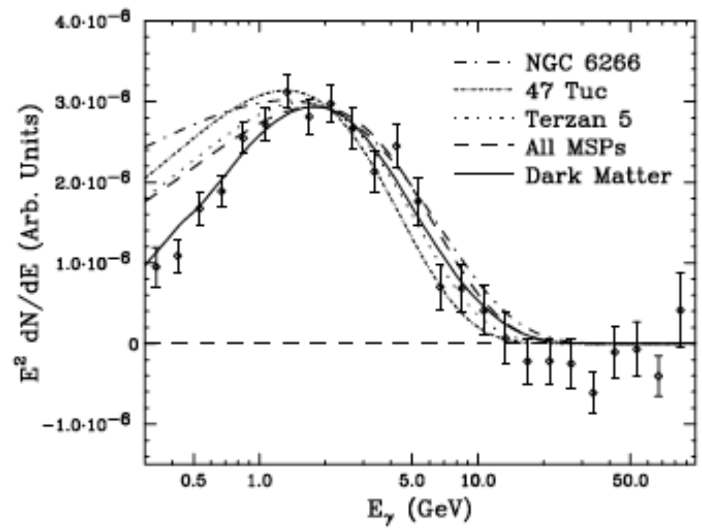
No significant evidence from dwarf galaxies

although limit at small masses higher than expected in all channels
arXiv:1310.0828



10-30 GeV/c^2 towards Galactic Center?

arXiv: 1402.6703 Standard question:
Is it dark matter or standard astrophysics: millisecond pulsar



also 135 GeV/c^2 line:

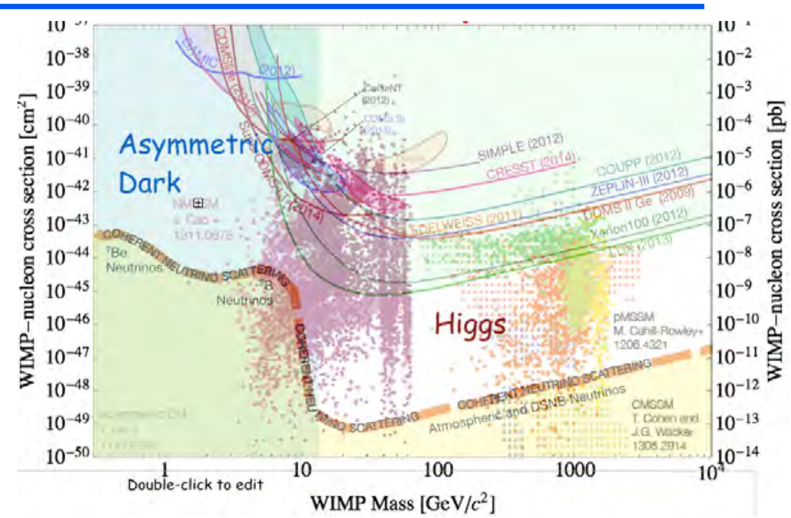
would need strange couplings: no continuum, large $\gamma\gamma$ cross section
statistical significance decreasing?

Recent Input from Particle Physics

Higgs at 126 GeV/c

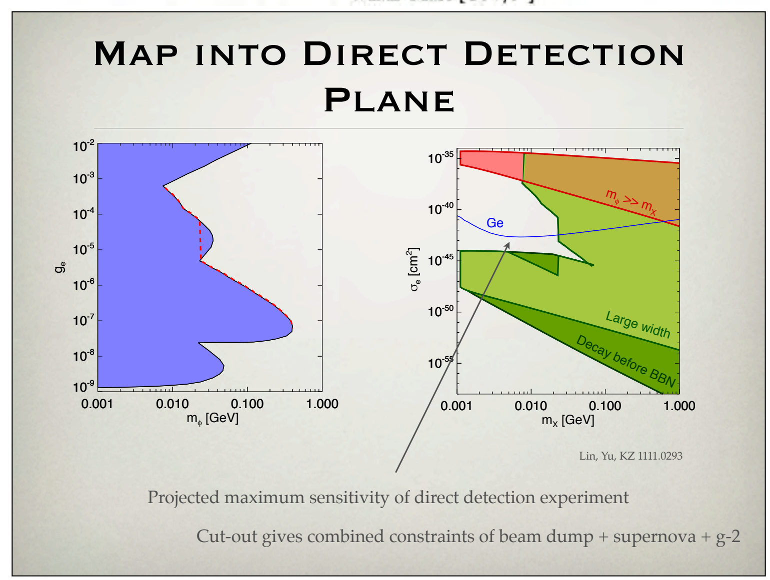
No sign for supersymmetry

CMSSM too simple ->pMSSM,NSSM
Crisis of naturalness?



No evidence from mono-jets,mono-γ's

Note: Limits only apply with high mass mediator
Dark Sector models have typically low mass mediators
Complementarity with "Dark Photon" searches



Basic complementarity

LHC probes well:
- masses below $m_H/2$ or high mass mediator
- intermediate mass in decay of gluinos (≈6x LSP), but needs to produce it!

Direct Detection do not mind light mediators and only looses linearly at high mass

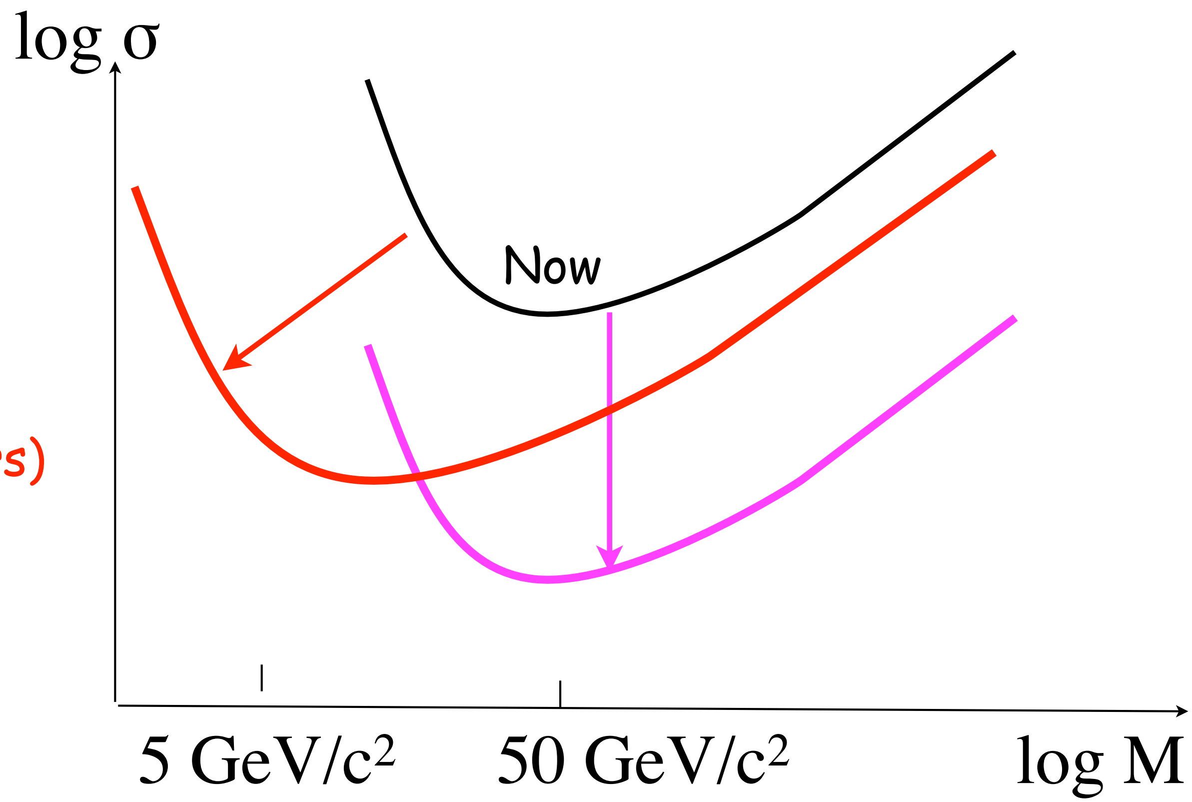
Conclusion on current state of affairs

No real smoking gun yet!

Axions
WIMPs

2 directions (WIMPs)

1. Improve sensitivity at large mass (e.g., liquid noble)
2. Improve sensitivity at small mass
(low temperature detectors)



Lessons learnt in the last few years

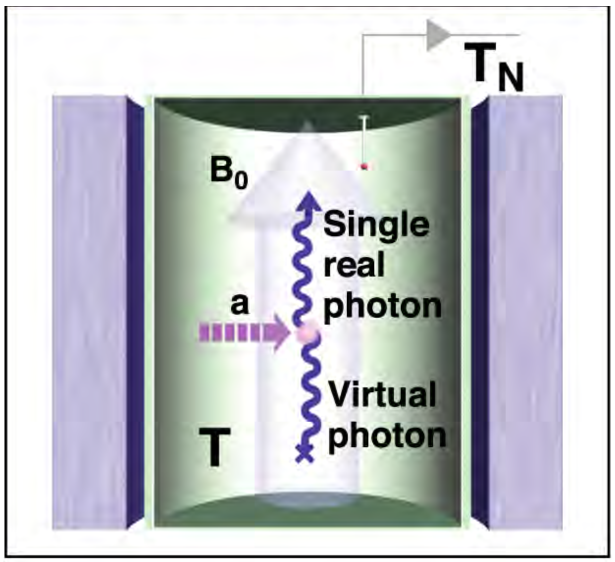
Phenomenology may be more complex than for the “vanilla” scenarios.
Difficulty to get unambiguous results

The US Generation 2 Direct Detection Dark Matter Program

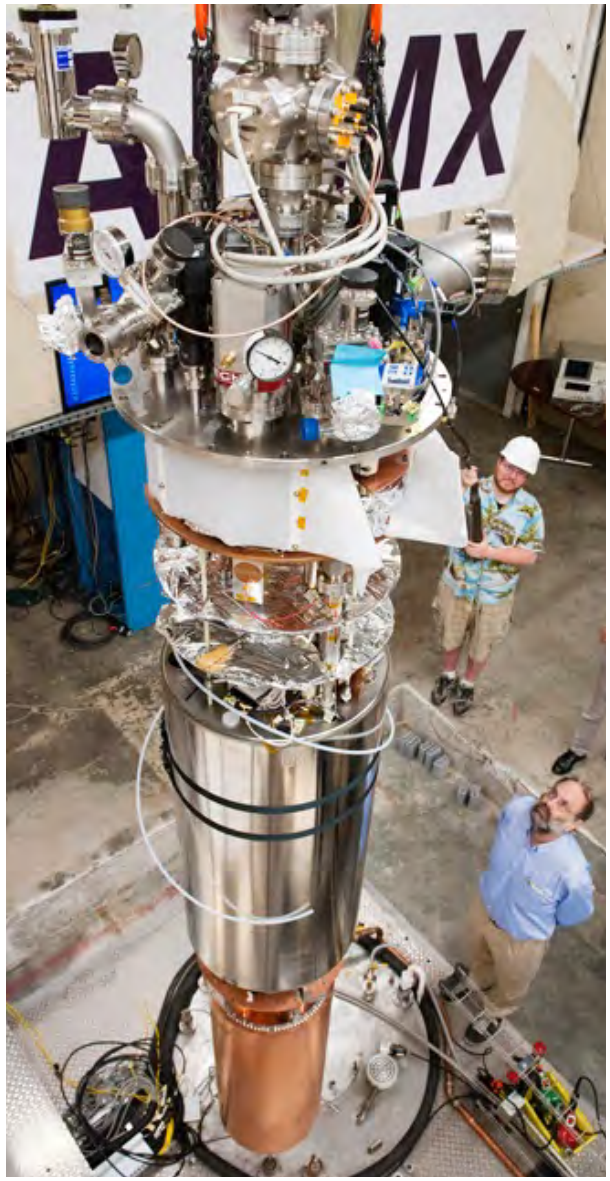
Complementarity with other US and international efforts and timeliness

Gen 2 ADMX: Principle of Operation

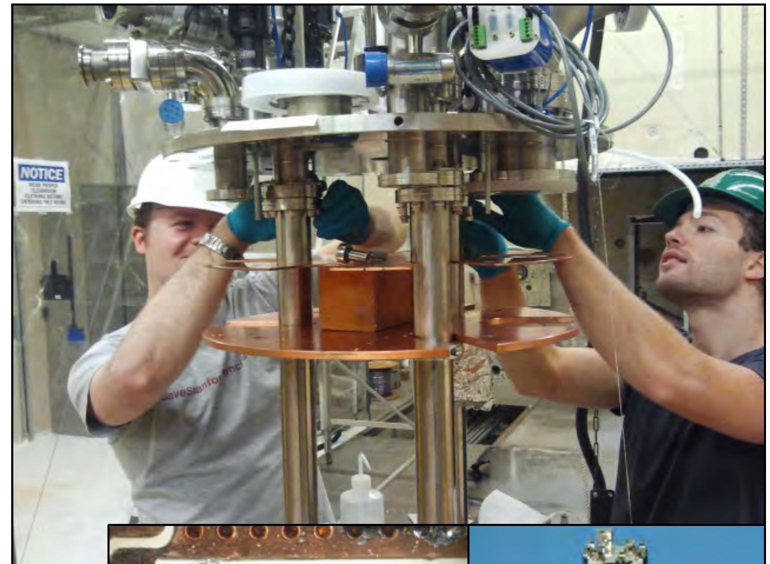
Halo axions convert into microwave photons inside a RF cavity threaded by a strong magnetic field

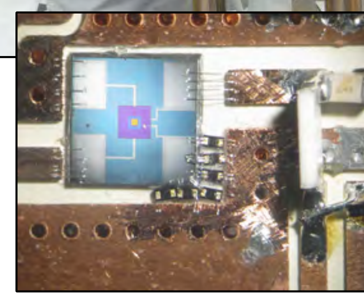


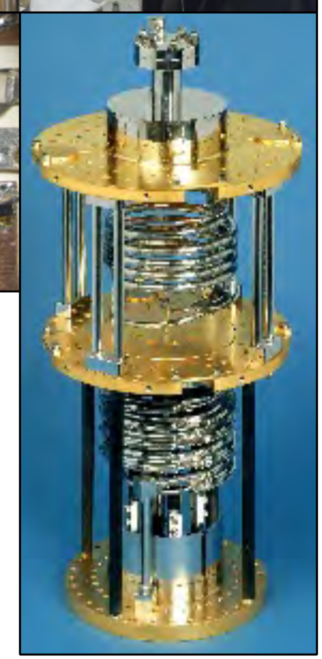
ADMX is sensitive to sub-yoctowatts of microwave power



New ADMX experiment insert fabricated and being assembled



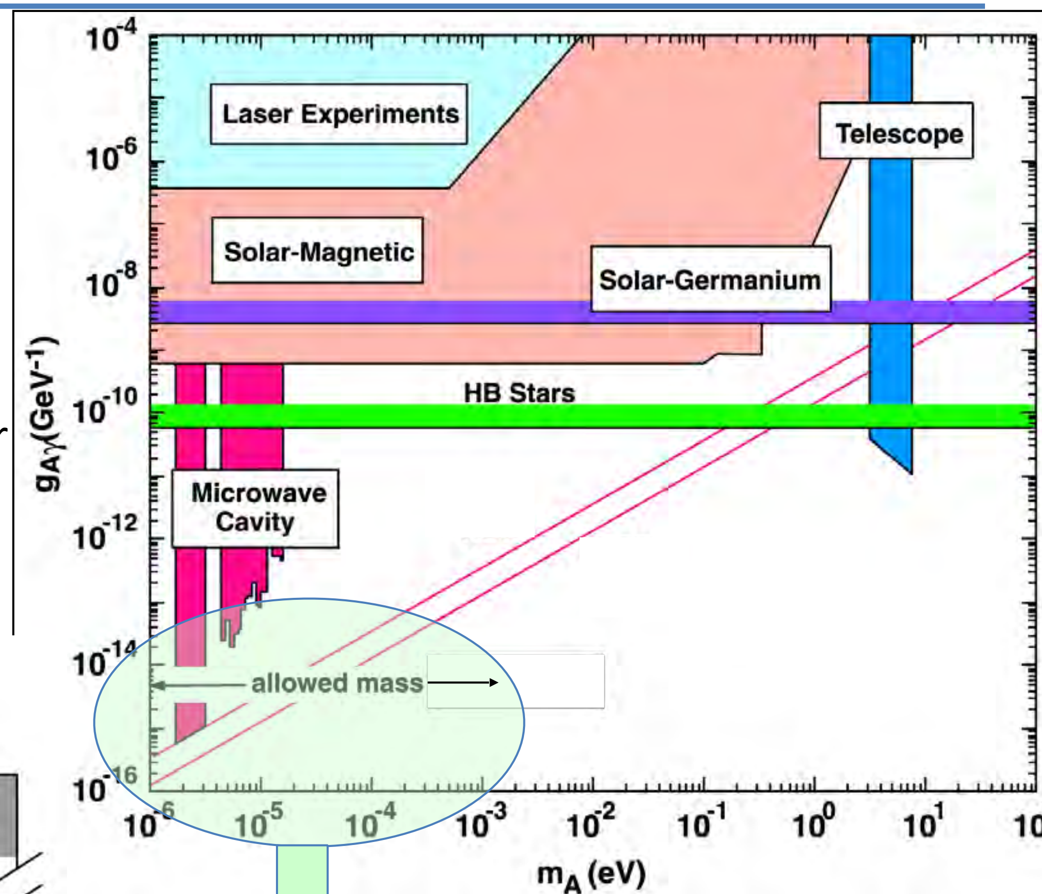




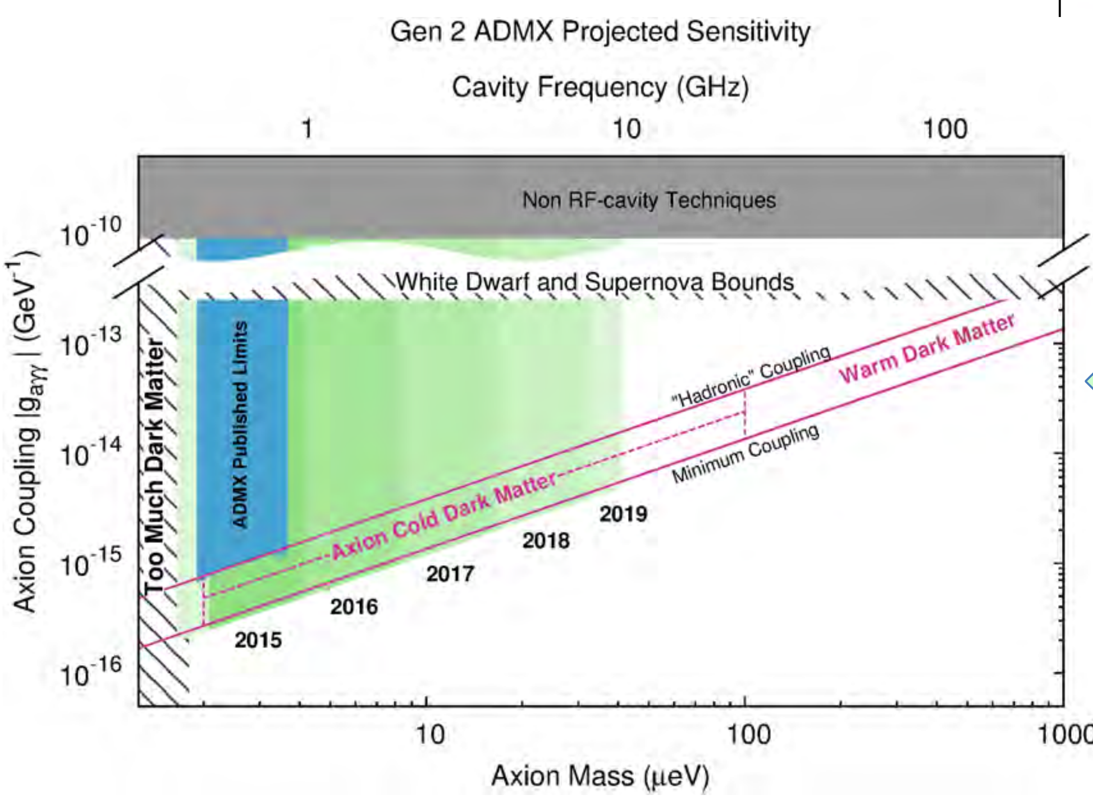
Dilution refrigerator and quantum-limited amplifiers provide sensitivity for the ADMX "Definitive Search"

Gen 2 ADMX: Search Capability

U. Washington, LLNL, U. Florida, U.C. Berkeley, National Radio Astronomy Observatory, Sheffield U., Yale U., U. of Colorado (+ new collaborators soon)



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



… 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".

Gen 2 ADMX: Schedule

While one frequency band is searched, resonators for next frequency band are constructed

Year	Construction	Operations
2014	Refrigeration	
2015	1-2 GHz cavities	500 MHz-1GHz search
2016	2-4 GHz cavities	1-2 GHz search
2017	4-10 GHz resonators	2-4 GHz search
2018		4-8 GHz search
2019		8-10 GHz and <500 MHz search

Budgetary guidance: ≈$5M DOE

Plus ongoing Gen 3 R&D:
Explore theoretically allowed higher mass region, 10-100 GHz

LZ Method: 2 Phase Xenon TPC

Z position from S1–S2 time interval (σ≈0.2 mm)

X-Y positions from S2 light pattern (σ≈5 mm)

Reject gammas by charge (S2) to light (S1) ratio.

Expect > 99.5% rejection.

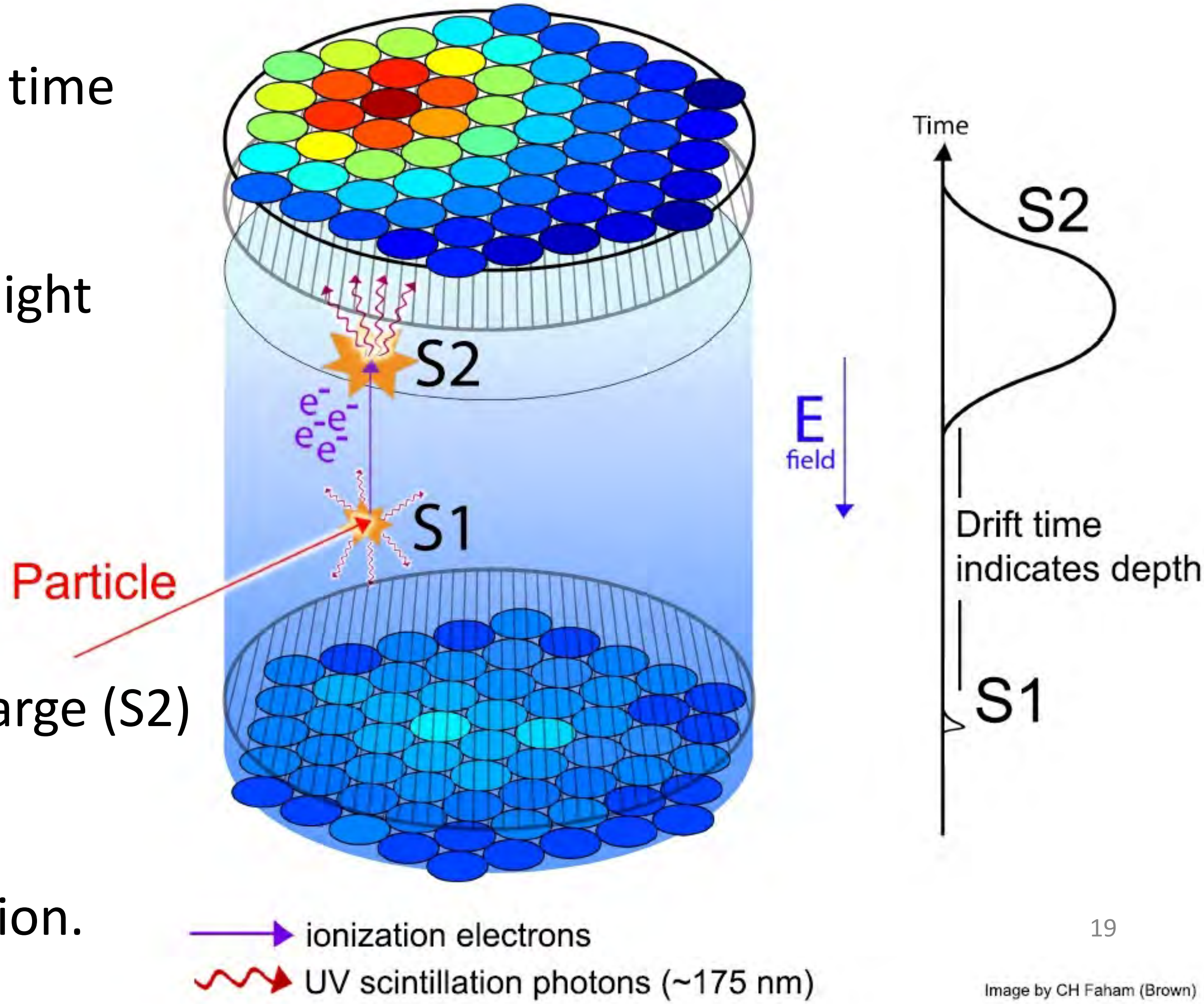
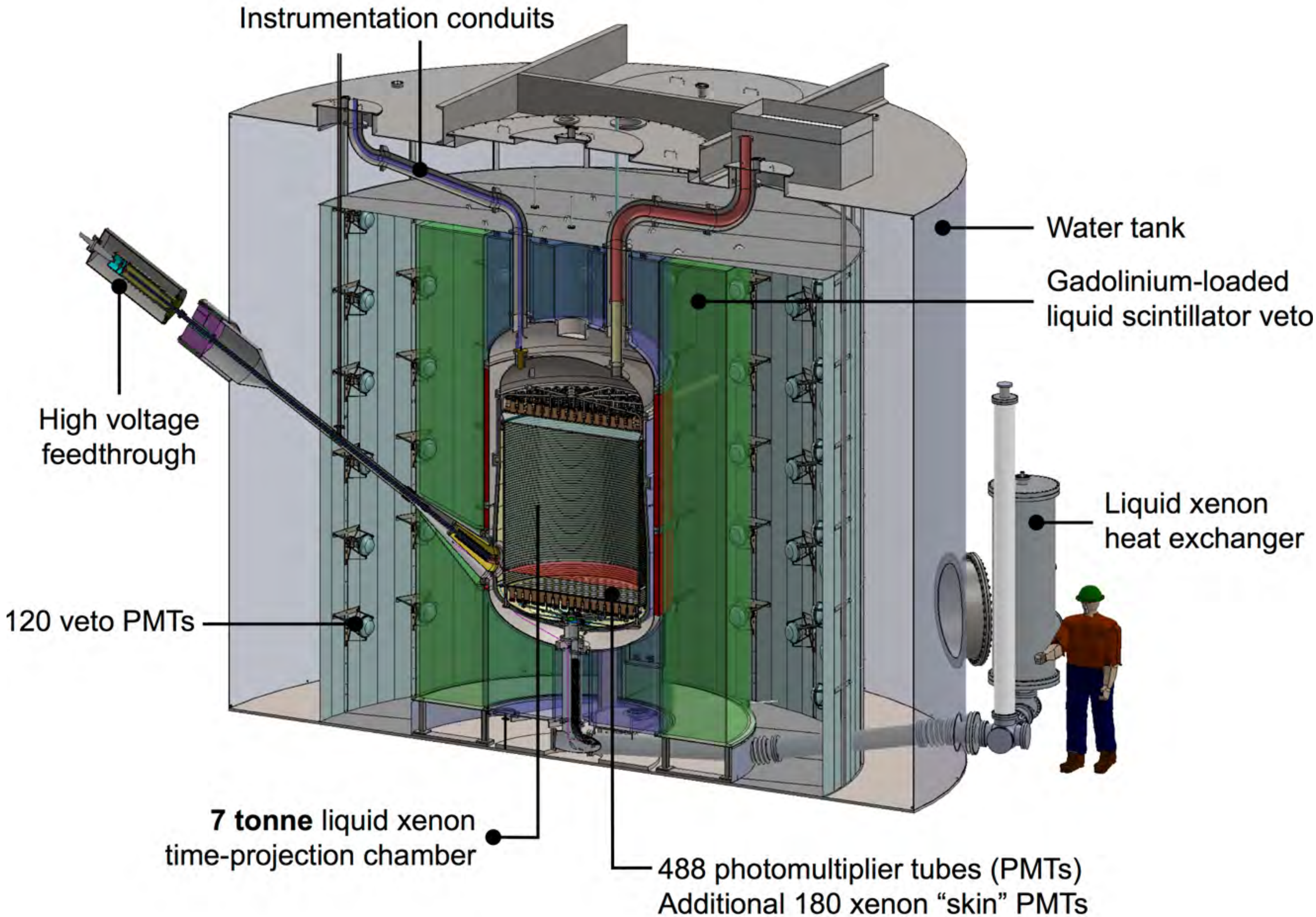


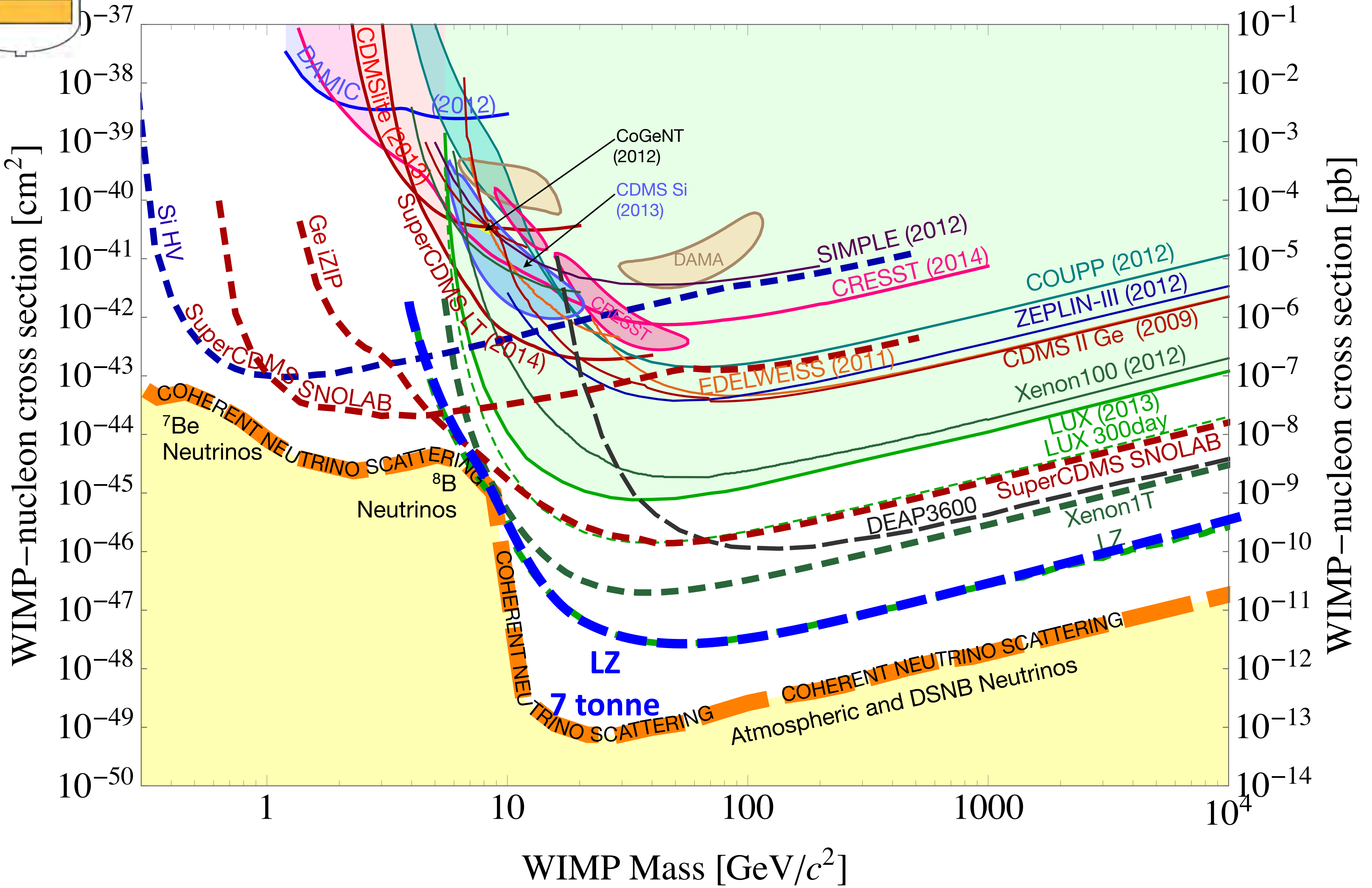
Image by CH Faham (Brown)

LZ Design Overview

Replaces LUX at the Sanford Underground Research Facility (SURF)



LZ on Snowmass über Plot

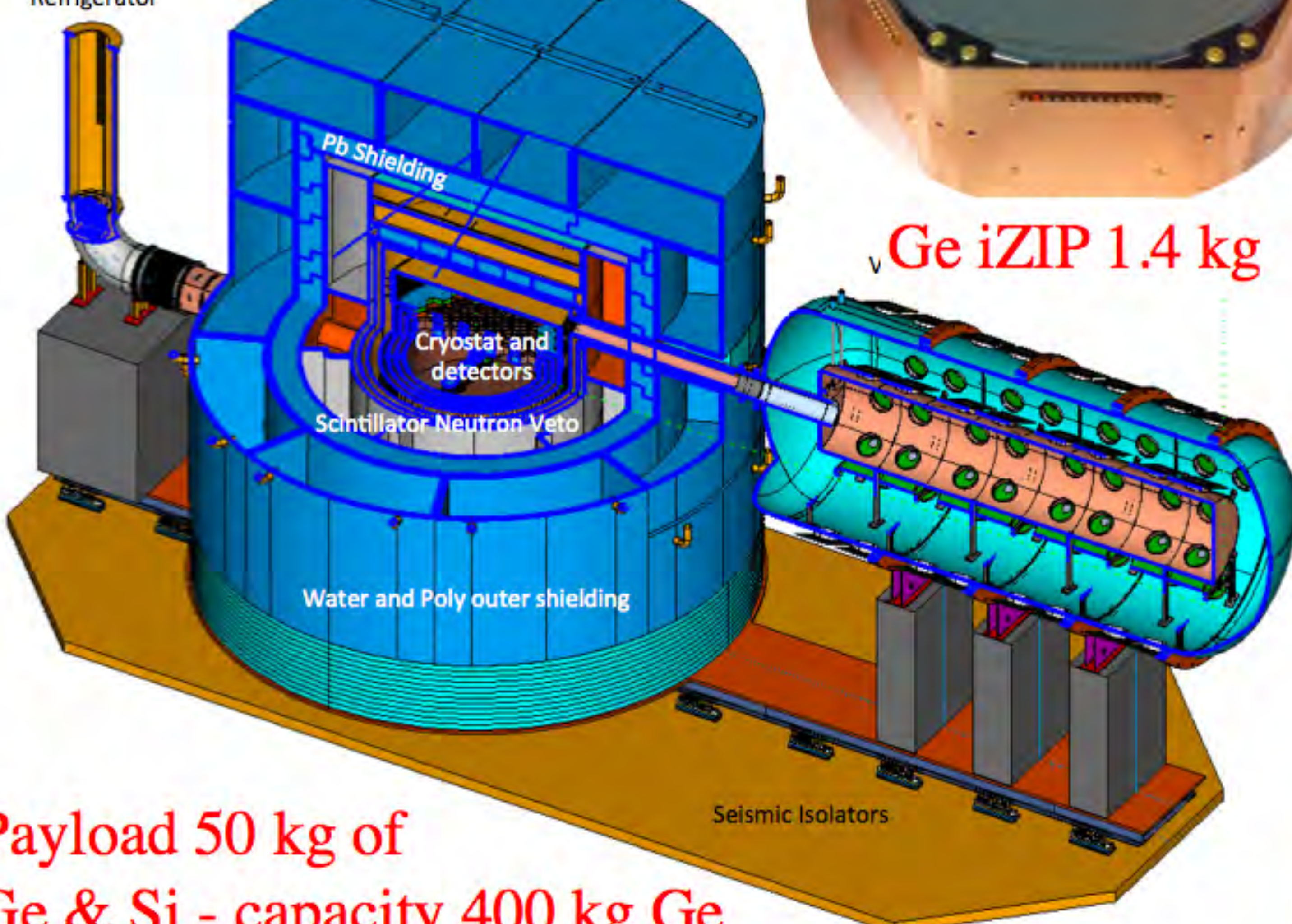


Current Cost Estimation

- LZ was proposed in Nov. 2013 as a DOE-NSF project with a total U.S. equivalent cost of $55.5M(FY14), of which about $21M was assumed from non–federal sources (UK, Portugal, Russia, SDSTA).
- LZ was approved on July 7, 2014 as a DOE–only supported Project.
- A successful "director's review" of LZ was completed Aug. 12-13, 2014 at LBNL.
- A CD-1 review has been requested in the next few months.
- LZ cost and schedule will be updated for the CD-1 review based on recent DOE funding guidance. Data taking start in 2018 desired but that depends on the profile.
- WIMP sensitivity curve based on 1000 day live time.

SuperCDMS SNOLAB Experiment

•SNOLAB 6010 mwe



Ge iZIP 1.4 kg

Payload 50 kg of
Ge & Si - capacity 400 kg Ge

Ge Tower 8.4 kg

SuperCDMS SNOLAB

Low temperature Ge/Si detector

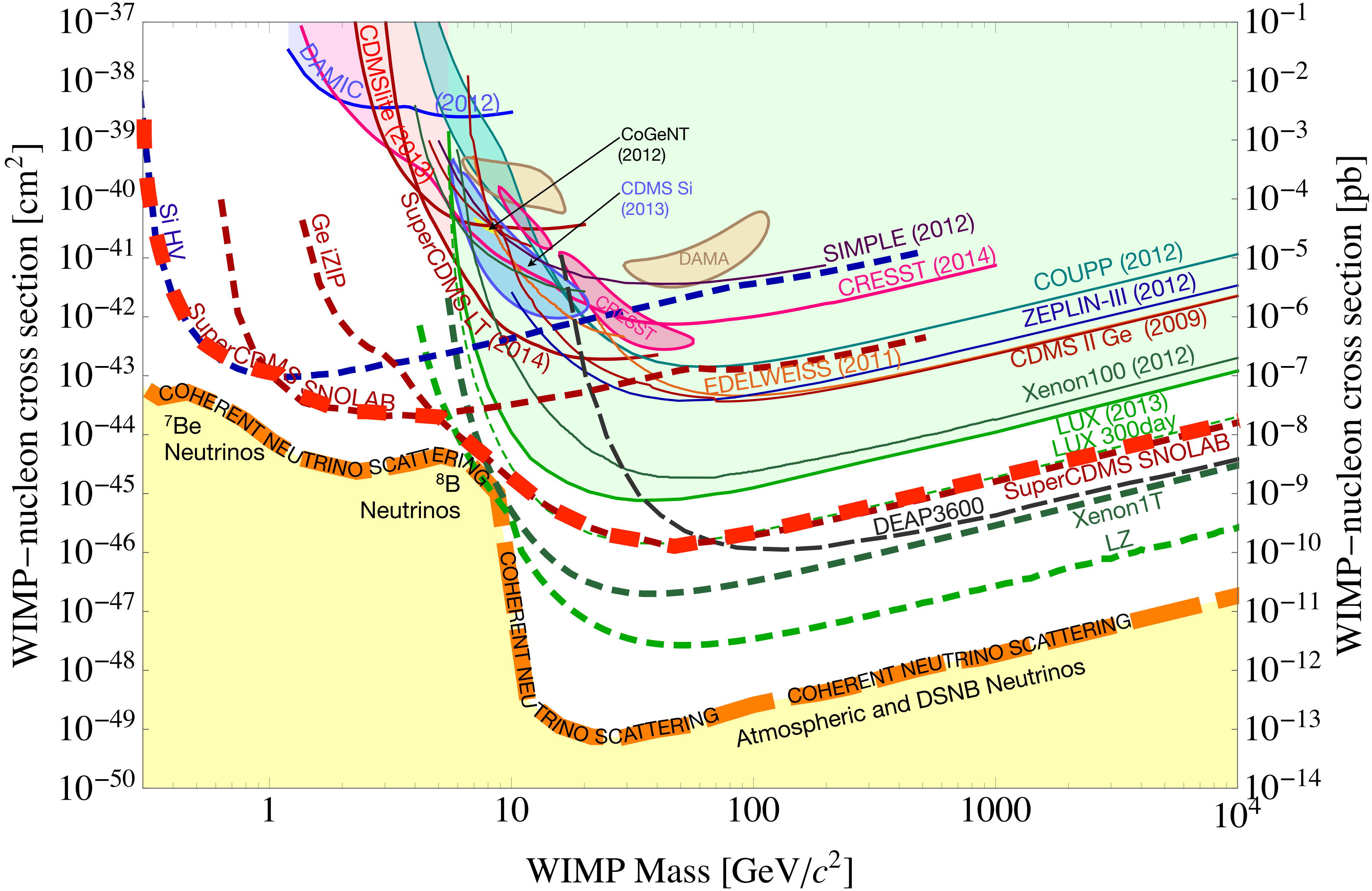
Focus

- Low mass 0.3-10GeV/c^2
  - Above 5 GeV/c^2 6 towers ≈50kg Ge full nuclear recoils recognition through ionization (σ=100eV) + athermal phonon (σ=50eV). Surface rejection demonstrated for a run of 7 years.
  - 0.3-5 GeV/c^2, 1 tower of e.g., 3 Ge, 3 Si, CDMS HV (Luke Neganov amplification of ionization). No discrimination. Background limited after 1 year
- High mass
  - Complementary role to confirm a discovery by say LUX 300 days with different technology, different background sensitivity and different target

Cryostat able to house 400kg => upgrade paths

- Current discussions with EURECA to increase target mass/diversity within the same tower geometry (evaluation of feasibility of operating at 15mK)
  - Edelweiss 30kg re-equipped with HEMT to decrease threshold, Potentially additional Ge payload -> ≈200kg
  - CRESST $CaWO_4$.
- Possibility of rapidly increasing the mass with CDMS technology if there is a serious hint for a signal at medium or high mass.
- Follow up of a possible hint at small mass: if we can improve the phonon to better than 20eV we begin to recover discrimination (Matt Pyle)

SCDMS 50kg on Snowmass über Plot



Funding and Schedule

Funding

Funding guidance from US agencies: ≈$25M (no award yet)

Approximate parity between NSF and DOE?

would be a new type of joint venture

80% of our request 100kg->50kg

+ $3.4M Canada Fund for Innovation

Hope to attract EURECA. May be $10M US equivalent.

Schedule

Technically limited: CD2/CD3a end of 2015 + 2 year construction: Operation beginning 2018

We have not received yet a budgetary profile. May be slower than scientifically desirable and technically feasible.

Technical Challenges (My opinion)

Radiopurity

LZ: very large extrapolation: 2.5 orders of magnitude.

Although "it is just chemistry", fairly challenging.

Potential leaching of radioactive products in the liquid. Adapt methods of SuperK, Borexino, Kamland etc.

CDMS has demonstrated surface rejection for this stage for the region where it has nuclear recoil discrimination (mass above 5GeV/c^2). But:

- Needs to improve radio purity of surrounding material by ≈200, not to have neutrons from fission!
- For CDMS-HV: control of ^{32}Si, cosmogenic ^{3}H in Ge/Si, Cu activation lines

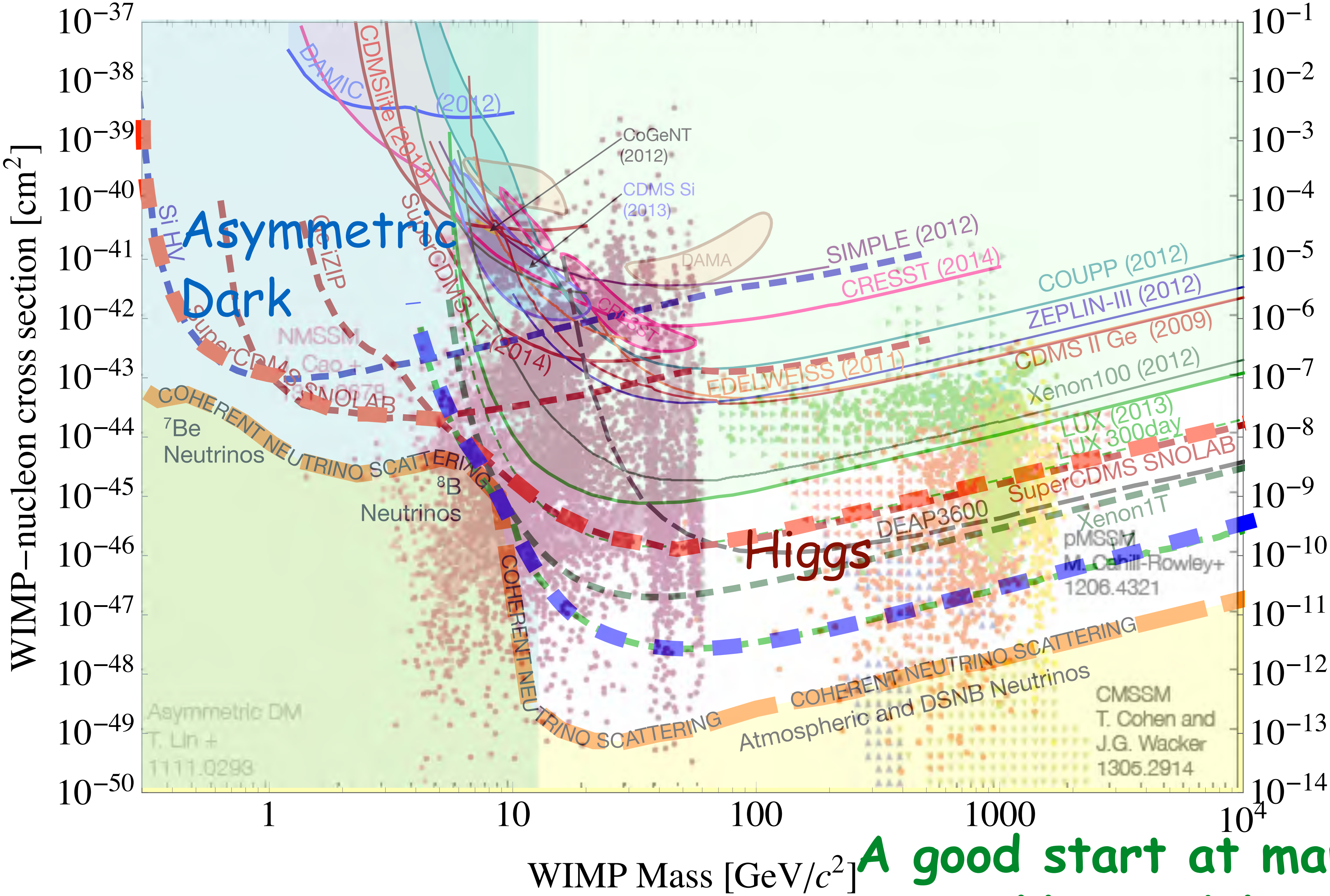
Thresholds -> Low Mass +^{8}B solar neutrinos

LZ: control few electrons emission from surface/grid

CDMS:

- Intermediate mass: importance of ionization (σ=100eV) . Athermal phonon (σ=50eV) for fiducial region control
- CDMS HV Athermal phonon (σ=50eV) + structure able to withhold voltage without carrier injection

G2 WIMPs: Very Complementary



A good start at mapping SUSY like models

Complementarity between LZ and SCDMS

High Mass-Low Mass

Different technologies with different susceptibility to backgrounds.

Need of course for the two experiments to have both sensitivity to the signal claimed

WIMPs

At high mass, CDMS-LZ overlap if relatively high cross sections ≈ LUX 300 days

But Edelweiss III

DEAP 3600 should be able to do that sooner

XENON 1T

Around 10 GeV very similar

^{8}Boron solar neutrinos

Cross check between two experiments

Complementarity with solar neutrino-electron scattering which should be unambiguously observable deep inside LZ.

Complementarity with on going experiments 1.

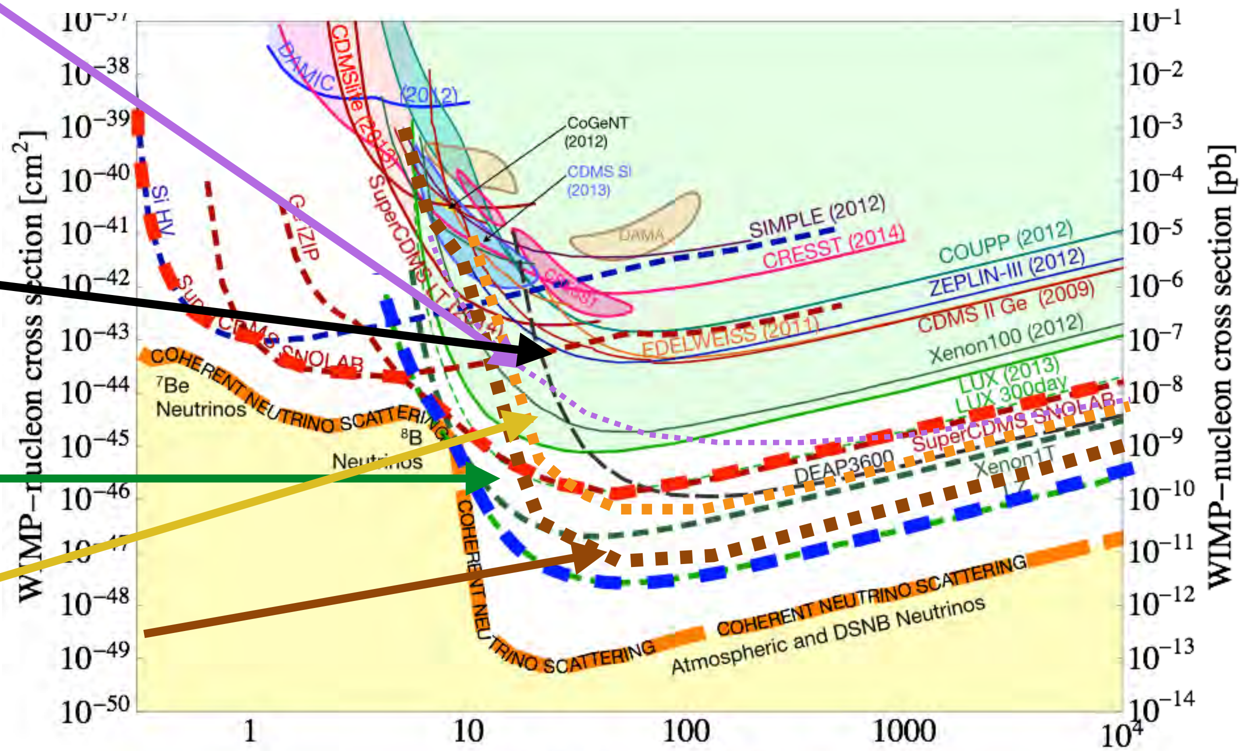
LUX and SuperCDMS Soudan,
Edelweiss III (data taking 7/14)
Doubling energy of LHC
More stats Fermi + IceCube
CTA in a few years

Intense competition!

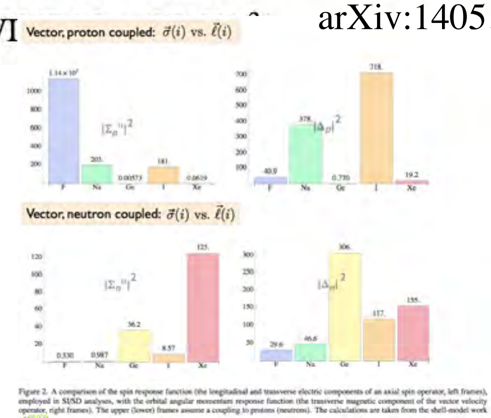
DEAP 3600
Physics starting early 2015
≈ XENON 1T at high mass

XENON1T
Commissioning late 2015

XMASS
XMASS 1.5 Operation in 2017
≈ XENON1T at high mass
+ XMASS 2 Operation ≈2019?
close to LZ at high mass



WI arXiv:1405.6690



Reasonable complementarity of Nuclei

But we are missing nuclei (F, I) with unpaired protons, which is most sensitive to axial couplings and velocity dependent effects
cf Haxton, Zurek

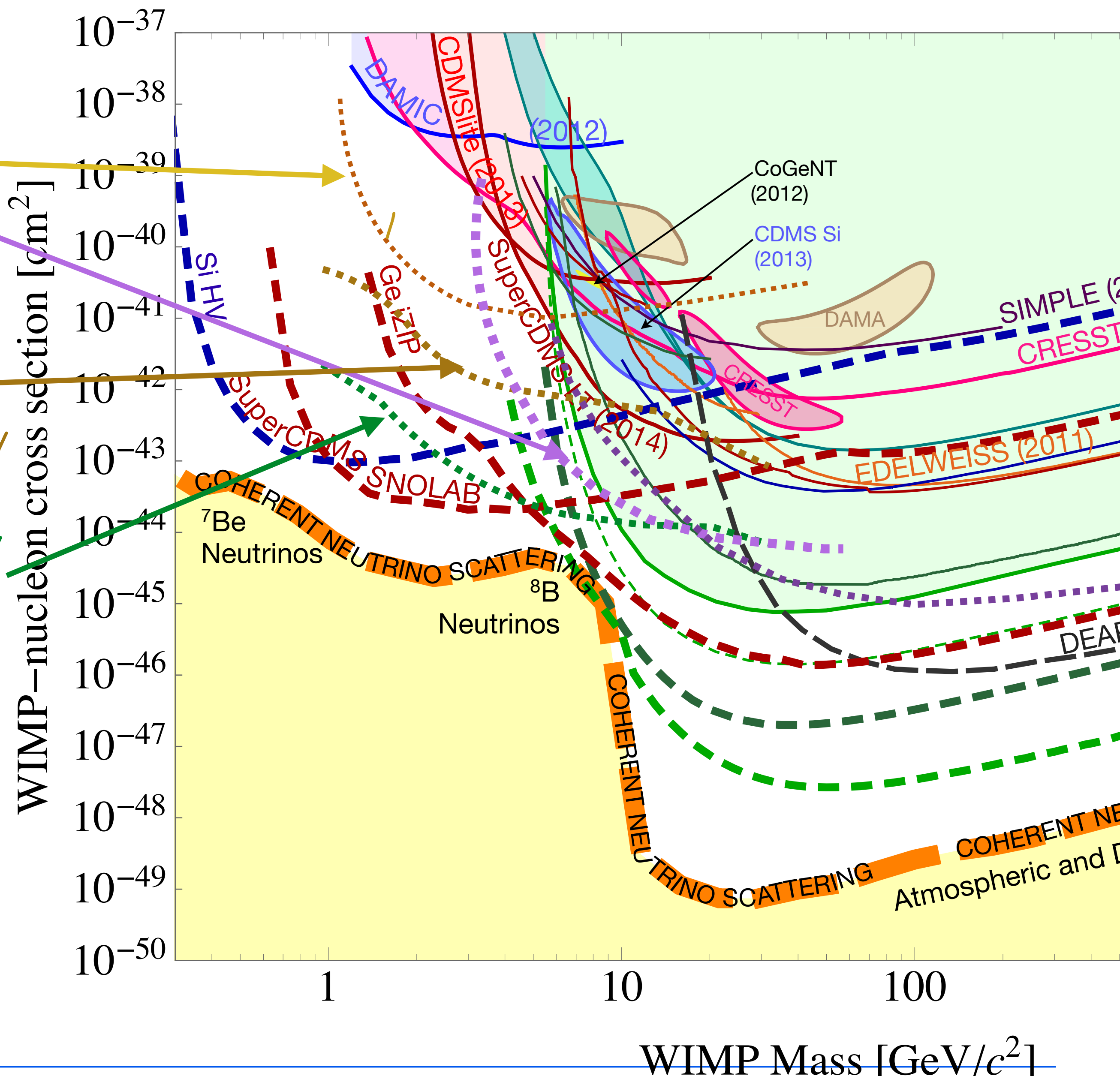
Complementarity with on going experiments 2.

Low mass

CDEX, C-4
SuperCDMS Soudan
DAMIC
Edelweiss III Low Mass

CRESST
50kg days Gran Sasso
20g detectors
with current radioactivity

1000kg days, 100x purity
EURECA/CDMS?



B.Sadoulet

A lot of Collaborative Opportunities

Clear focus of the theoretical discussion around G2 program, XENON1T, DEAP3600, XMASS etc. and low mass searches.

Continue a vigorous debate on experimental results

Comparison of results, backgrounds, systematics
Difficulty of outliers close to threshold

Common analysis when this adds information

Model independent comparison , à la Weiner

Low radioactive backgrounds

New consortium starting (see AARM slide in appendix)

Share codes in background modeling
Common data base of material properties
Optimization of screening facility use => save effort and money

Complementarity between AARM (NSF) and PNNL (DOE)

Timeliness

G2: Very interesting scientifically

In spite of the difficult choices which had to be made

Great potential for unambiguous results

provided it is executed rapidly

Competitive environment

For various reasons, we started late (e.g. first SNOLAB proposal CDMS 25kg in 2006)

Strong competition of already approved projects

XENON1T (Approved Summer 2012), DEAP3600, XMASS

Now it is important to apply "overwhelming force" to get there

Great help of P5 in stressing both priority and need for more funds.

Unfortunately, it appears that the budgetary profile will be fairly slow

budgetary situation

legacy of other decisions made when G2 scale and importance was not fully recognized

=> Delay to science

Increase of cost because of marching army

Potential descoping to stay within envelop

We will try to borrow from our universities to rectify the profile, but there are limits to what can be done. Strong worry of LZ and SuperCDMS teams

The Preparation of Generation 3

How do we get ready for a breakthrough

Generation 3

Goals

- In case of discovery:
  - High statistics (with negligible background) both for Cosmology (velocity distribution) and Particle Physics (cross sections, mass, coupling to nucleus)
  - Directionality
  - Eventually Dark Matter Observatory
- In case of conflicting results: clean up with better detectors, higher purity and rejection
- In case of no discovery in direct detection (even if convincing evidence at LHC or in Indirect Detection): Cover the full observational space
  - Down to the neutrino floor
  - Lower masses

How to maximize chances of success and timeliness?

Maintain diversity of approaches

Support R&D of promising directions

Pathfinders/demonstration project

Learn from difficulties encountered in G2: e.g. backgrounds / outliers

G3 R&D recommended by P5 (≥ 1 US G3)

Implementation and time scales. Be ready for breakthrough!

Combination of upgrades ≈ 2018?

new set ups (US, elsewhere) ≈ early 2020's?

Probably need new cavity at Homestake or SNOLAB.

cf. HEPAP facility report.

Axion Dark Matter eXperiment – High Frequency (ADMX-HF)

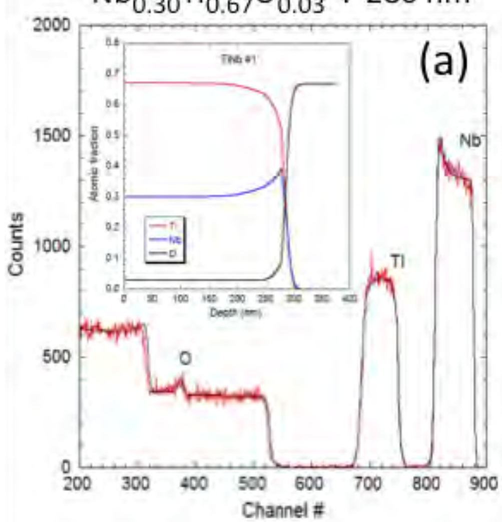
Yale – Berkeley – Colorado – LLNL

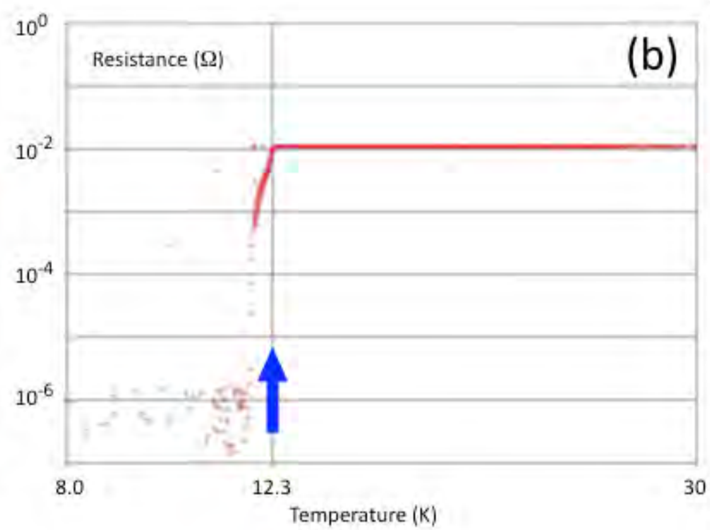
- ADMX-HF serves both as a
  - *Pathfinder Search* – First look at higher frequencies (5-25 GHz)
  - *Innovation Testbed* – R&D new cavity & amplifier technologies
- Funded by NSF & DOE ECRP; operates under MOU w. ADMX
- Technologies: NbTi magnet (9.4T), Josephson Parametric Amplifiers (≈ 1.5 × Standard Quantum Limit), Dilution refrigerator

- Immediate R&D thrusts:
  - Thin-film superconducting cavities to boost Q, signal power
  - Sub-quantum limited squeezed-vacuum state receiver
  - Photonic band-gap resonators to access higher decade of mass

Example: $Nb_xTi_{1-x}N$ s'con thin films showing promise

$Nb_{0.30}Ti_{0.67}O_{0.03}$: 280 nm





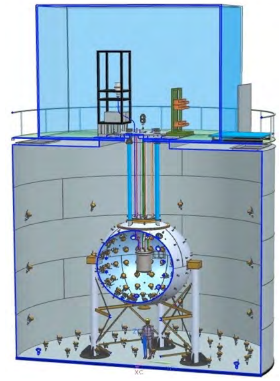
Three-year goal – baseline exp't:
Cover 15 - 33 μeV @ ≈ 1.5 × KSVZ

Masses to 100 μeV, and coupling down to ≈ DFSZ with successful R&D program

PathFinders: Liquid Argon

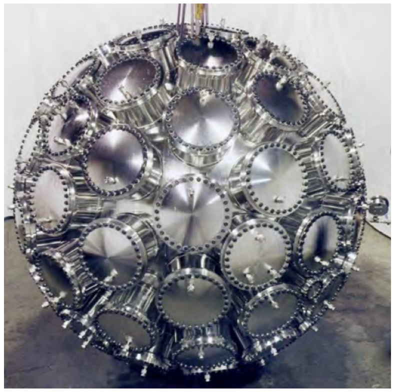
Dark Side 50l

Currently running in Gran Sasso
in CTF (Borexino)
High efficiency neutron veto
Will test underground Argon (depleted in ^{39}Ar)



Mini Clean

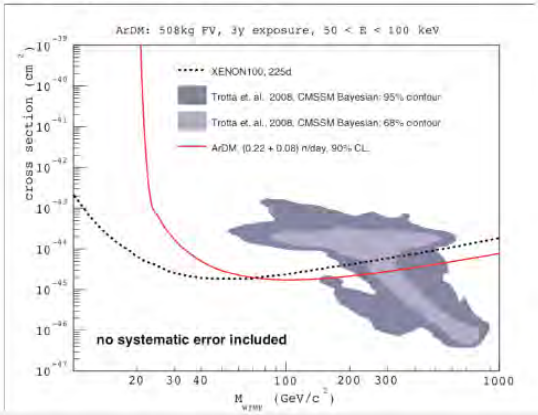
- Single phase Liquid Argon
  - 2014: Detector construction complete
  - 2015: Natural Ar & ^{39}Ar Spike Run
- 4π coverage to maximize light-yield at threshold …
  - 3D Position Reconstruction
  - Particle-ID via Pulse-shape discrimination (PSD)
- Radon-reduced assembly



ArDM

Start in data-taking mode
in scintillation only
mode
Ready to rapidly install
the TPC after first run

Projected sensitivity of ArDM for a background expectation of (0.22 + 0.08) n/d at 90% CL

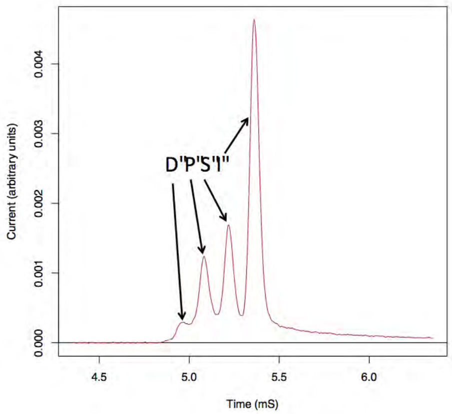


PathFinders: Directional Detectors

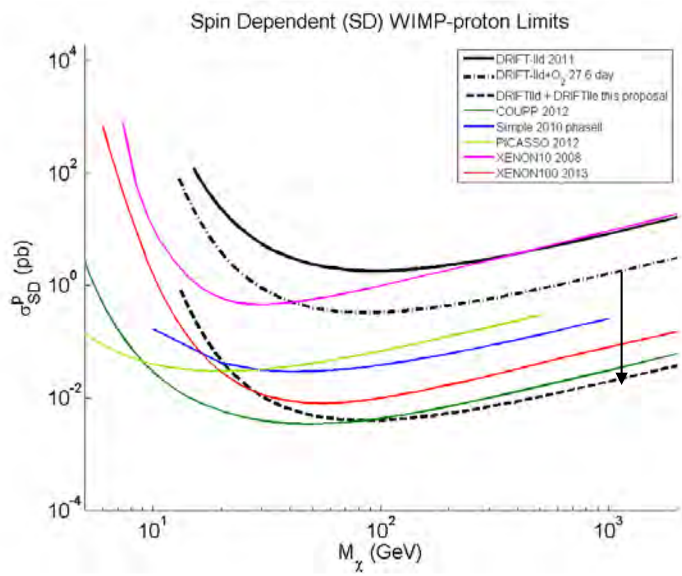
Low Pressure Gas TPC Challenge:

At 100 torr: 100g/m^3 Instrument >>1,000m^3 with mm^3 pixels. Start with m^3 z measurement (in particular to get rid of cathode radioactivity)

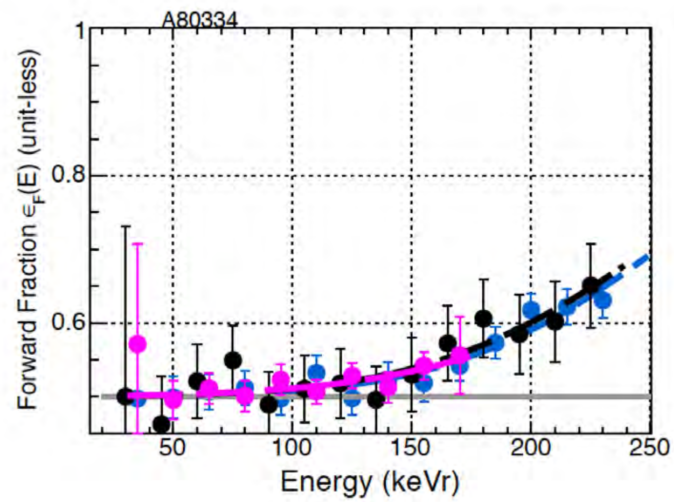
In the US: DRIFT



The addition of O_2 to a CS-CF_4 mixture produces minority peaks with separation proportional to distance. + texturing of electrode: background free on 75% F fiducial volume



DMTPC



Measurement of directional sensitivity with 25 cm drift using neutrons.

Currently constructing 1,000L detector for use underground

Other approaches:

Columnar recombination (Nygren)

Generation 3 Aspirations

Crystals

CDEX 1 ton in new cavities in the Chinese Jin Ping laboratory (7000m.w.e.)

GEODM 1.5 ton

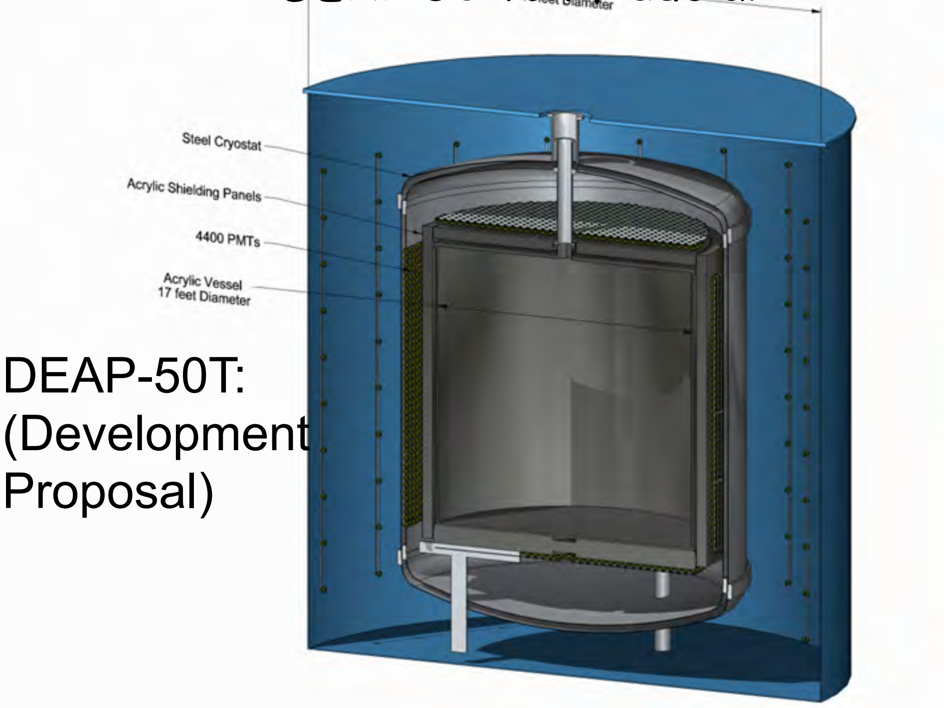
EURECA 1 ton | combined? Focusing on G2 for the time being

SNOLAB or Modane

Noble Liquids

Ar: CLEAN 150 tons

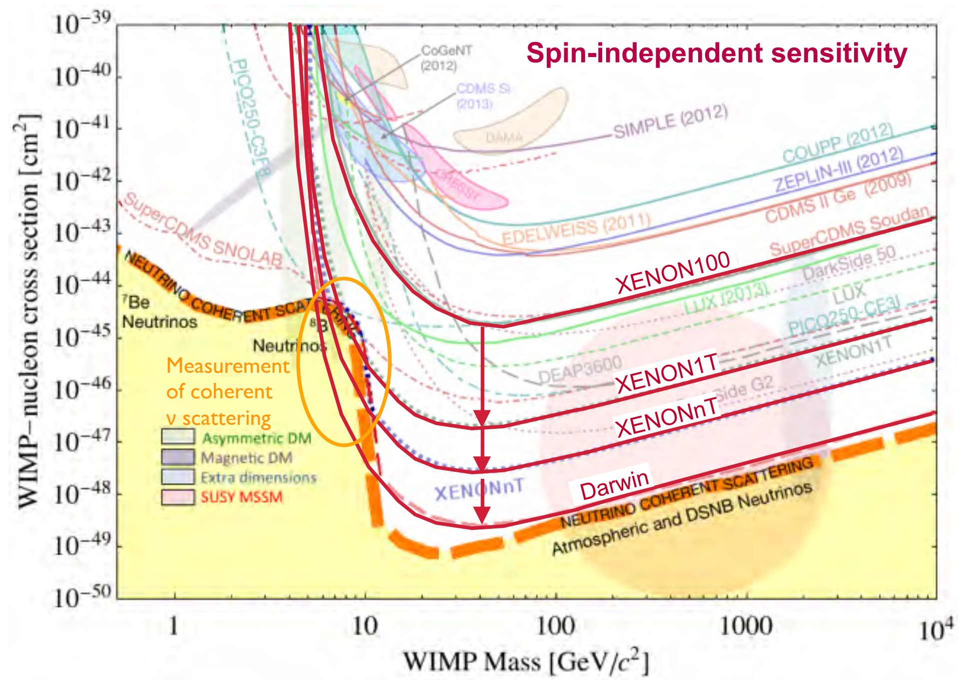
DEAP 50 ton fiducial



DEAP-50T:
(Development
Proposal)

XENON: e.g. upgrade of XENON 1T

then Darwin Xe+Ar



Bubble chambers similar to PICO

Conclusions

The Dark Matter problem: still a fundamental question

Central to Astrophysics,Cosmology, Nuclear and Particle Physics

A vibrant field

See appendix

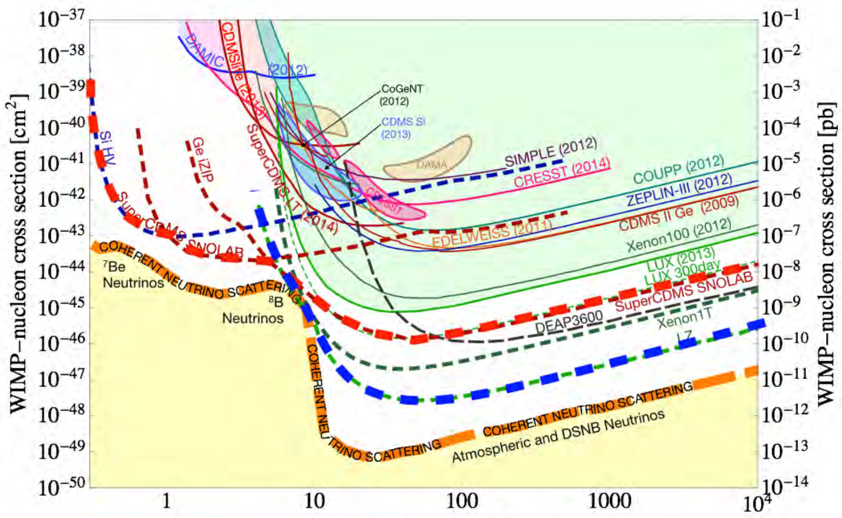
The Generation 2 Direct Detection program

A wise choice, given the budgetary situation; aligned with P5

Axions- WIMPs high mass, WIMPs low mass

Can we implement G2 fast enough? Problematic budgetary profile?

We should take advantage of collaborative opportunities, e.g., low radioactivity



Generation 3 preparation

Another P5 recommendation

Exploration of new concepts

Pathfinder/demonstration

Learning from G2 projects

How do we maintain the balance between these three essential components?

Also be ready for totally new ideas (theory and experiments)

Appendix

Slides Submitted by Individual Collaborations

by alphabetical order

For convenience repeats th few slides included in the talk

AARM

G2 WIMP Search Regime ➔ The Low Background Frontier

Common Problems require Collaborative Solutions

Challenges

- Naturally occurring radioactivity in experimental targets and construction materials
  Backgrounds will eventually limit scientific reach
  Incomplete assay risks additional loss in cross-section sensitivity
- Insufficient material screening resources for next generation large-scale experiments
  Not enough production throughput (sparse sampling will be insufficient)
  Insufficient assay sensitivity for crucial components
  Access to existing resources is limited by inefficient scheduling and proprietary use
- Incomplete understanding of background source production, cross sections, processes, etc

Snowmass 2013 highlighted assay infrastructure requirements

Enhance multiple assay techniques: HPGe, NAA, α-counting, ICP-MS, Rn mitigation
Link worldwide assay resources, Community Database (radiopurity.org)
Develop and retain expertise: workshops, shared research, cross-instrument comparisons

Recommendation to form Materials & Assay Consortium

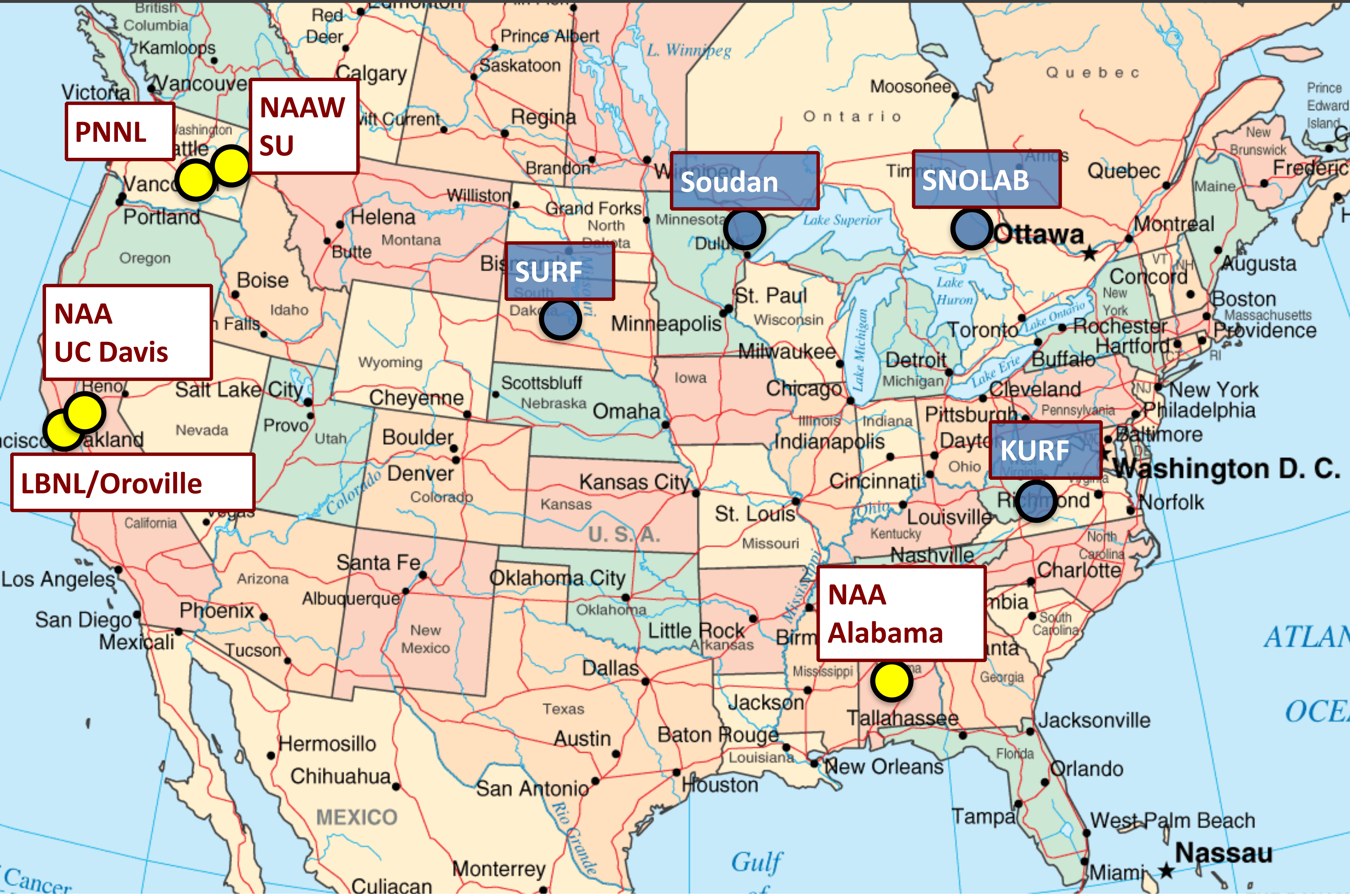
Network of existing institutions (see map), close collaboration with International Partners
Initial Organizational Steps:

*Extension of **Assay & Acquisition of Radiopure Materials (AARM)** – (NSF)*
*Leverage existing **Pacific Northwest National Lab (PNNL)** resources – (DOE)*

Synergistic with $0\nu\beta\beta$, multi-purpose ν detectors, and applied instrument development

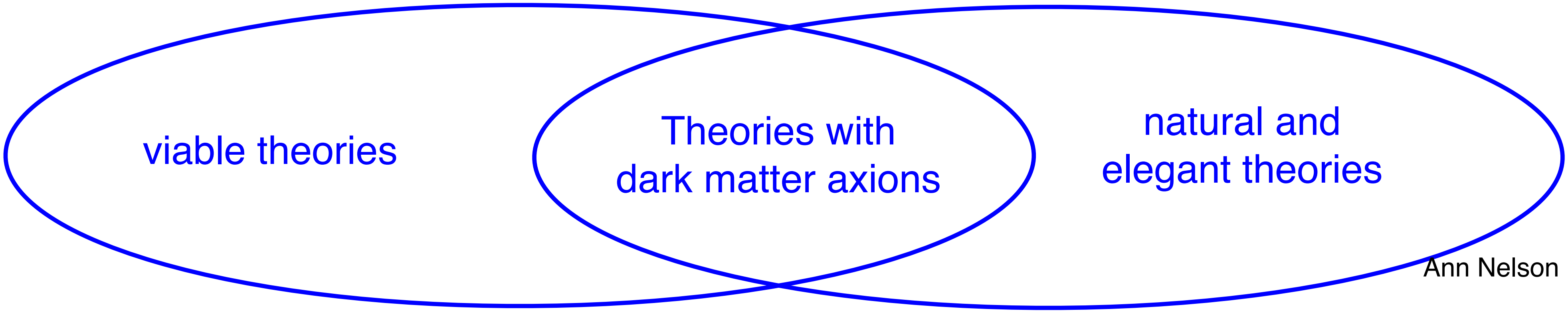
Assay and Materials Consortium

Initial suite of institutions with existing expertise and expressed interest

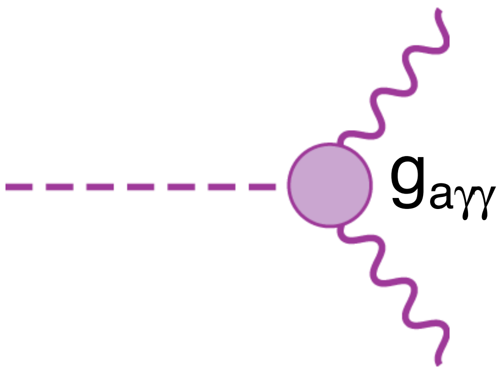


ADMX

Gen 2 ADMX: Search for Dark-Matter QCD Axions



The axion couples extraordinarily weakly to normal particles, including a very feeble 2γ coupling.



$g_{a\gamma\gamma} \propto m_a$

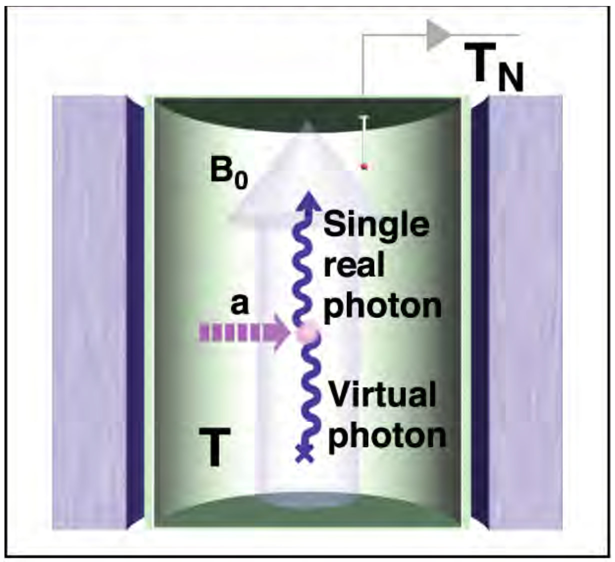
The lighter the axion, the weaker its couplings.

Axion Mass 'Window'
$10^{-(5\text{ to }6)}$ eV < m_a < $10^{-(2\text{ to }3)}$ eV
(Overclosure) (SN1987a)
With lower end of window preferred if $\Omega_{CDM} \sim 1$

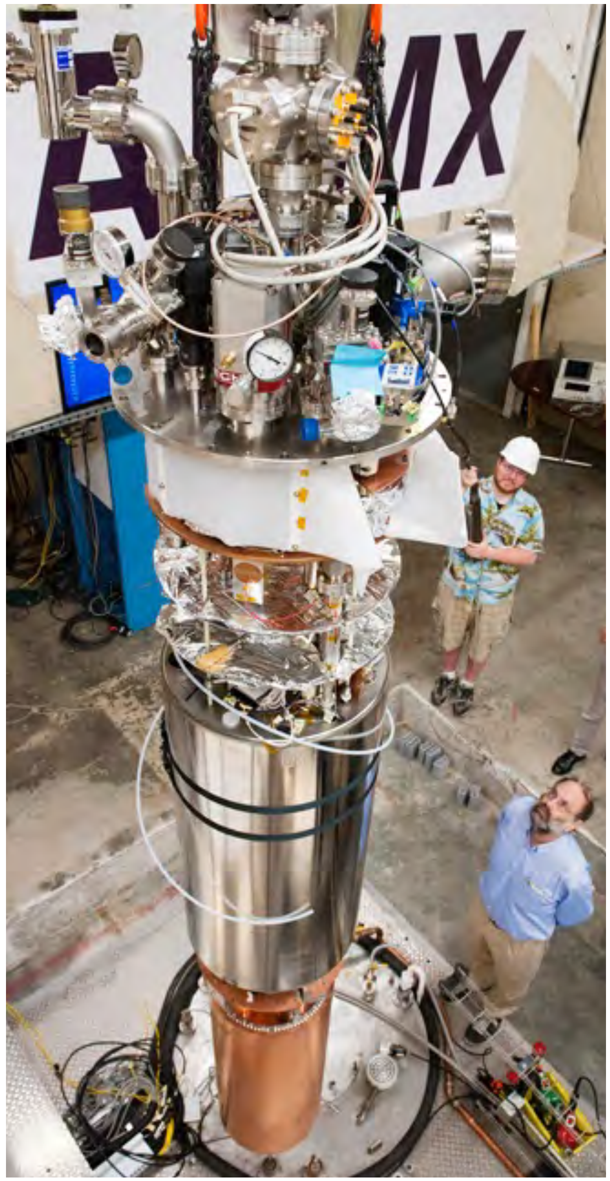
Axions constituting our local galactic halo would have huge number density ~10^{14} cm^{-3}

Gen 2 ADMX: Principle of Operation

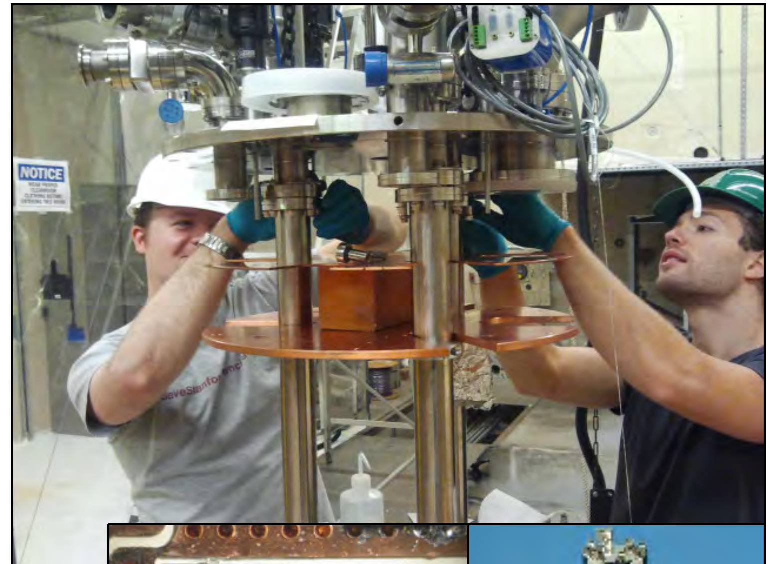
Halo axions convert into microwave photons inside a RF cavity threaded by a strong magnetic field

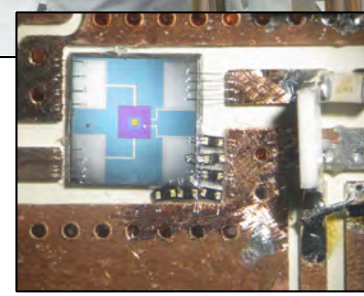


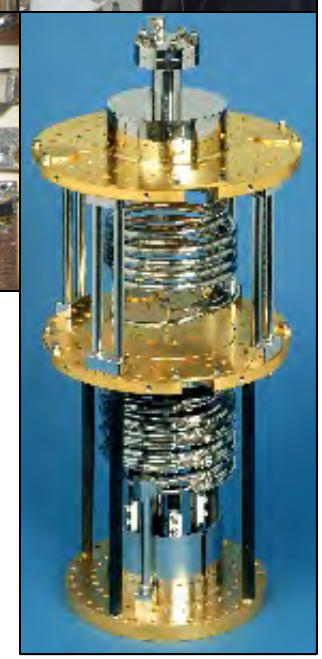
ADMX is sensitive to sub-yoctowatts of microwave power



New ADMX experiment insert fabricated and being assembled





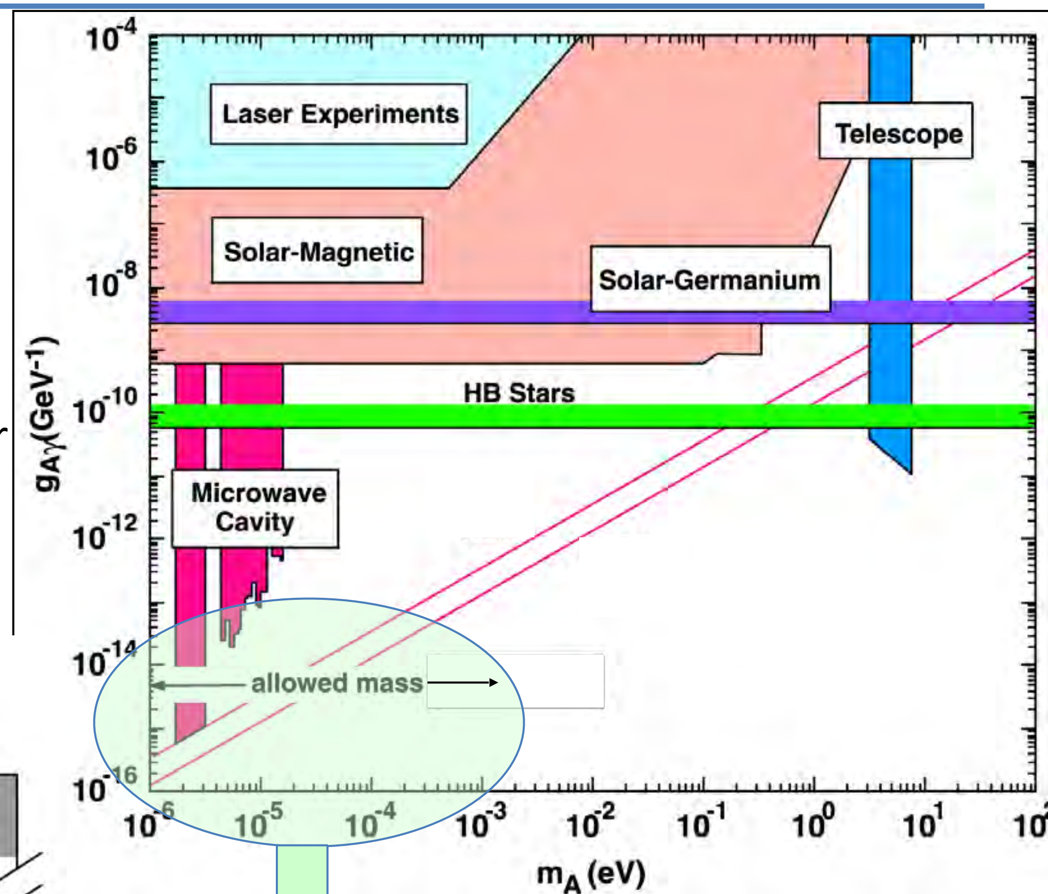


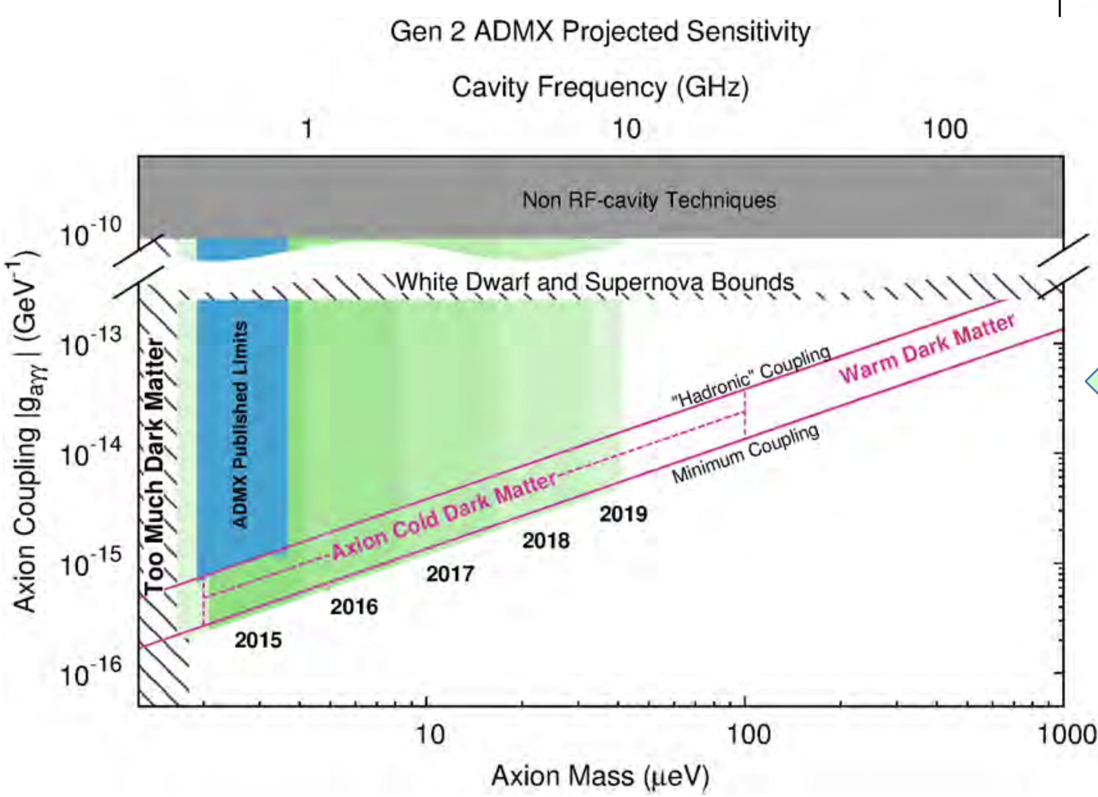
Dilution refrigerator and quantum-limited amplifiers provide sensitivity for the ADMX "Definitive Search"

Gen 2 ADMX: Search Capability

U. Washington, LLNL, U. Florida, U.C. Berkeley, National Radio Astronomy Observatory, Sheffield U., Yale U., U. of Colorado
(+ new collaborators soon)

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





… 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".

Gen 2 ADMX: Schedule

While one frequency band is searched, resonators for next frequency band are constructed

Year	Construction	Operations
2014	Refrigeration	
2015	1-2 GHz cavities	500 MHz-1GHz search
2016	2-4 GHz cavities	1-2 GHz search
2017	4-10 GHz resonators	2-4 GHz search
2018		4-8 GHz search
2019		8-10 GHz and <500 MHz search

Budgetary guidance: ≈$5M DOE

Plus ongoing Gen 3 R&D:
Explore theoretically allowed higher mass region, 10-100 GHz

ADM HF

Axion Dark Matter eXperiment – High Frequency (ADMX-HF)

Yale (PI: S. Lamoreaux) – Berkeley (PI: K. van Bibber) – Colorado (PI: K. Lehnert) – LLNL (PI: G. Carosi)

- Microwave cavity dark matter axion search

- ADMX-HF serves both as a
  - *Pathfinder Search* – First look at higher frequencies (5-25 GHz)
  - *Innovation Testbed* – R&D new cavity & amplifier technologies

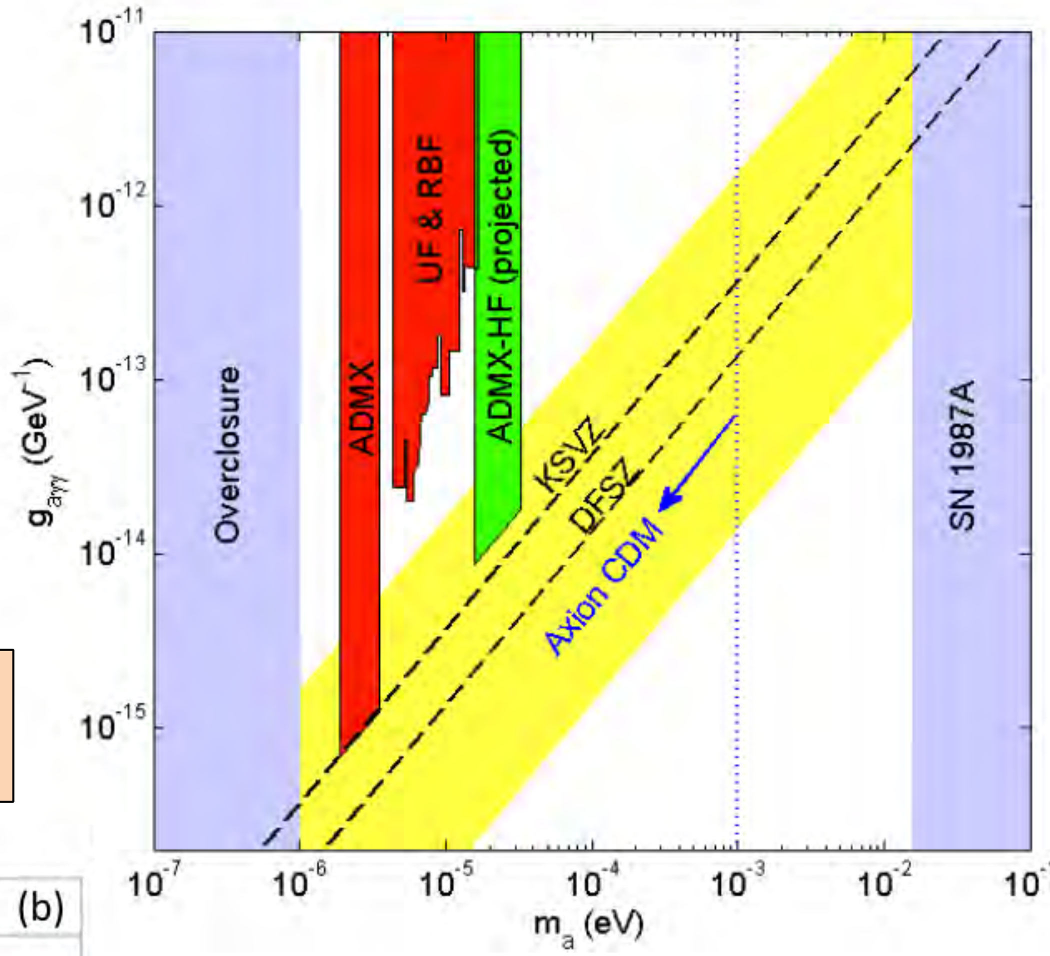
- Funded by NSF *(& G. Carosi, DOE ECRP)*
  - Project start: August 2011
  - Commissioned: July 2014 (on schedule)
  - First data run: October 2014 (cooling)

- Operates under MOU with ADMX to do R&D, technology

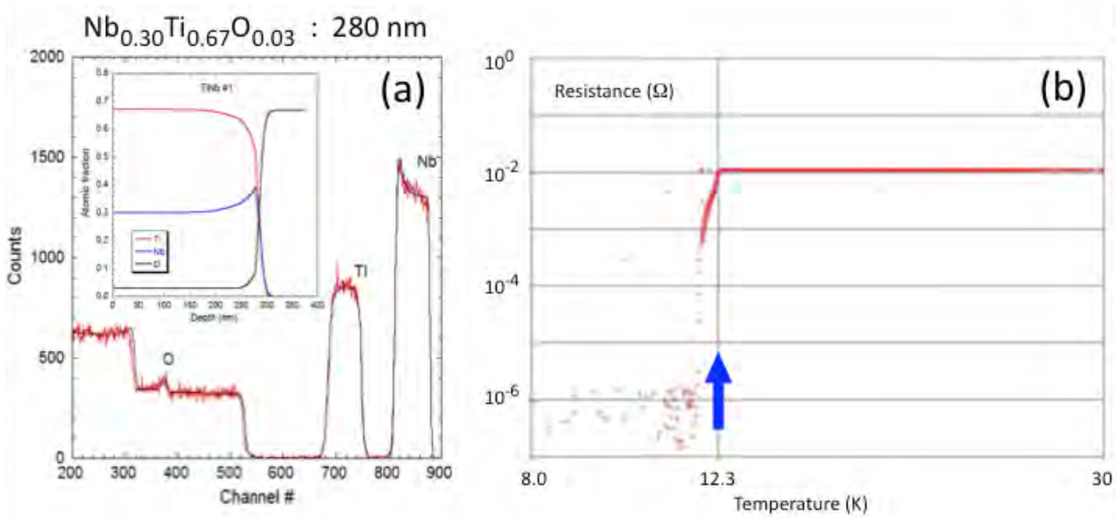
- Parameters *(demonstrated in commissioning)*
  - Magnet: 9.4 T, 17.5 cm diam. × 40 cm
  - Cavity: TM_{010} , 3.6 – 5.9 GHz ; 2000 cm^3
  - Amplifier: Josephson Parametric Amplifier (JPA)
  - T_{PHY} : 27 mK whole experiment (VeriCold dil-fridge)
  - T_{SYS} : (1.5-2) × T_{SQL} (Standard Quantum Limit)

Projections for ADMX-HF operation and R&D

- Immediate R&D thrusts:
  - Thin-film superconducting cavities to boost signal power & scan rate
  - Squeezed-vacuum state receiver, for sub-quantum limited detection
  - Photonic band-gap resonators to access highe decade of mass range



Example: Type-II s'con films ($Nb_xTi_{1-x}N$) fabricated and showing great promise



Three-year goal – baseline experiment:
Cover 15 – 33 μeV @ ≈ 1.5 × KSVZ

Masses up to 100 μeV, and coupling down to ≈ DFSZ with successful R&D program

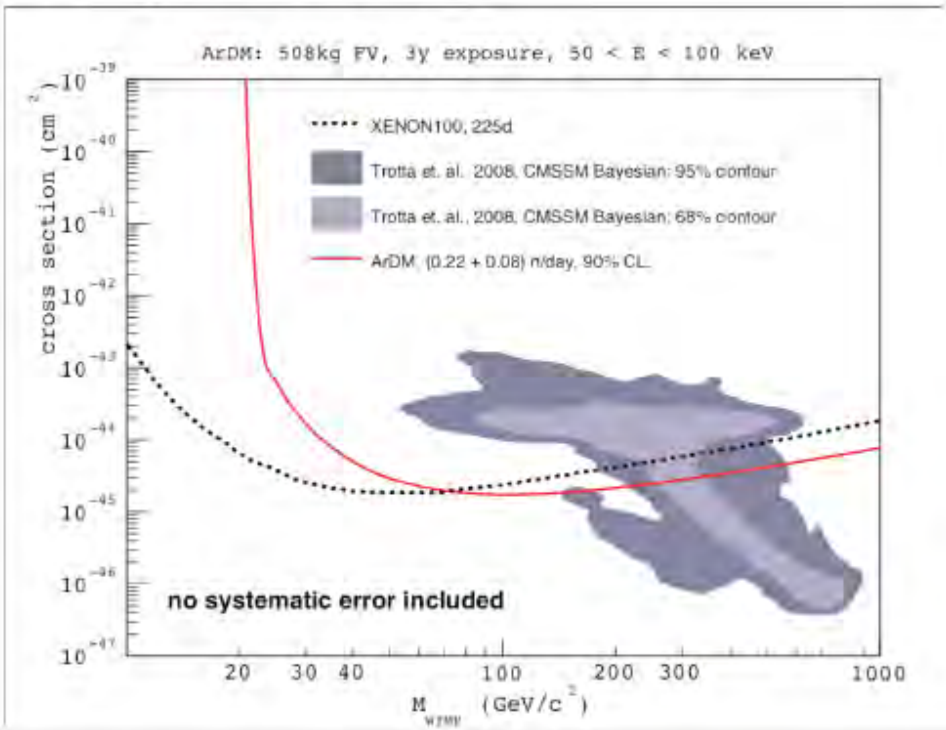
ArDM

Canfranc Natural Ar 500kg Fiducial Volume.

Projected sensitivity

(assuming no resolution effect for the moment).

Projected sensitivity of ArDM for a background expectation of (0.22 + 0.08) n/d at 90% CL



After rather long period of waiting for the safety approval of the lab, start in data-taking mode in scintillation only mode

Ready to rapidly install the TPC after first run

C-4: improved search for annual modulation using next-generation PPCs

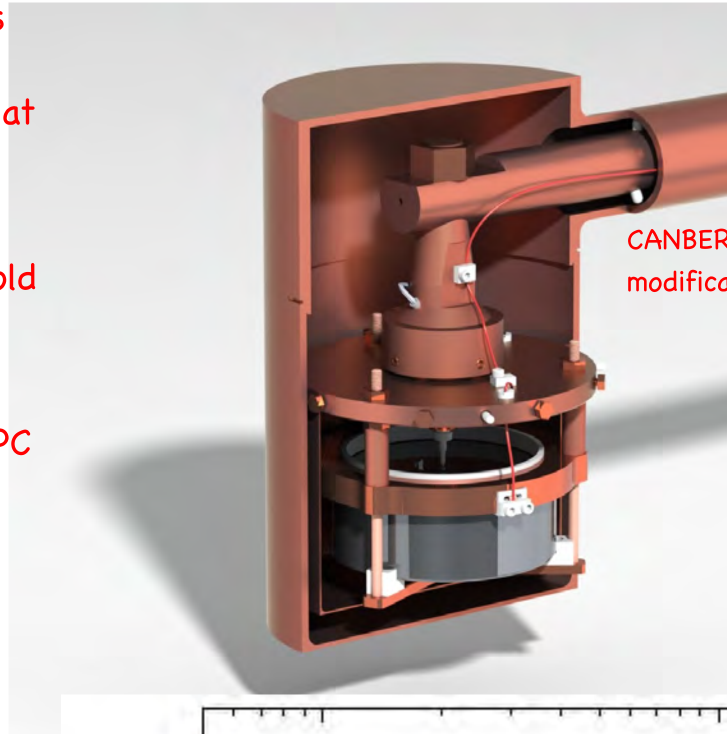
* First C-4 detector displays ~1/3 of the noise of the operating CoGeNT detector, at ~x3 its mass (1.3 kg)

* <200 eV hardware threshold within reach.

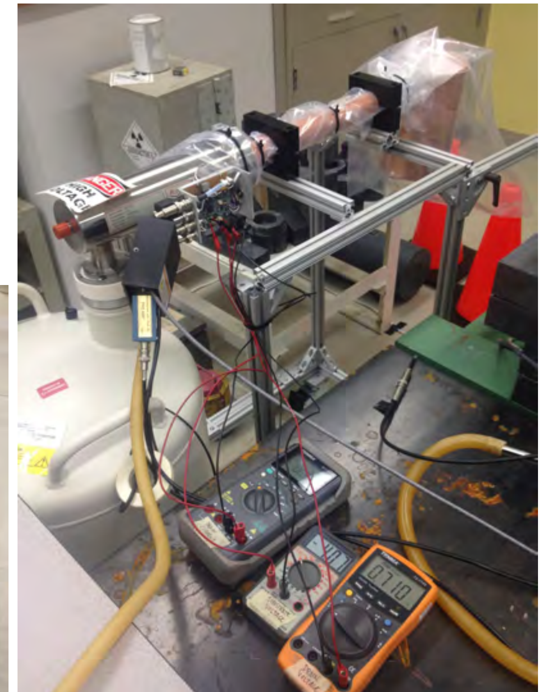
* Not a one-off detector: PPC noise performance is now reproducible in up to 2.7 kg crystals (CANBERRA R&D supported by NSF award PHY-1003940).

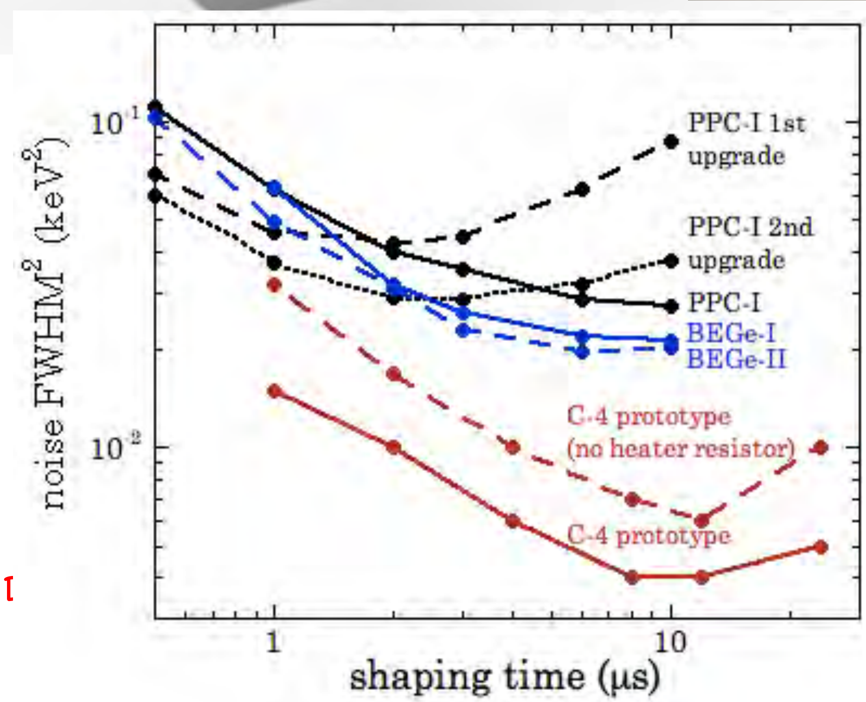
* C-4 aims at an eventual x10 total mass increase over CoGeNT, >20 background reduction, and substantial threshold improvement.

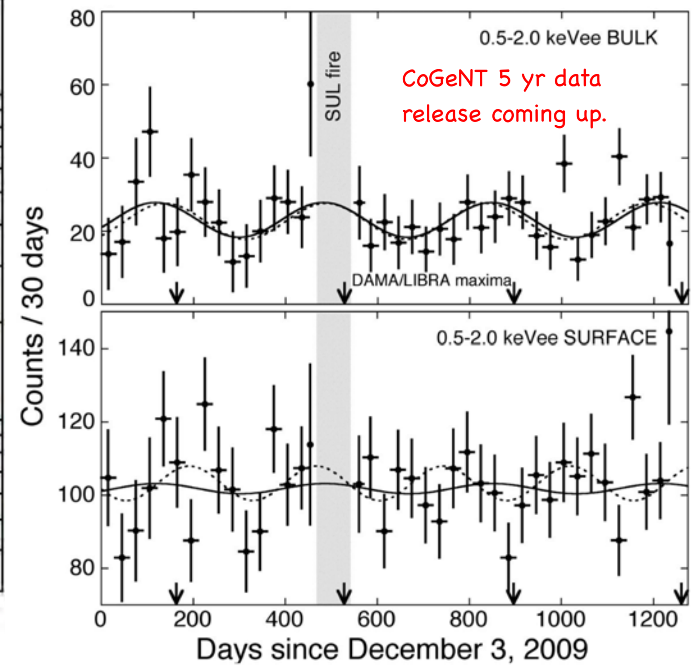
* Installation in Soudan during 2014.



CANBERRA's proprietary modifications to point contact



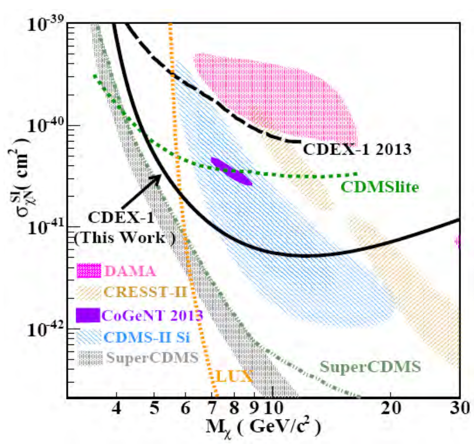




CDEX-1 Ton

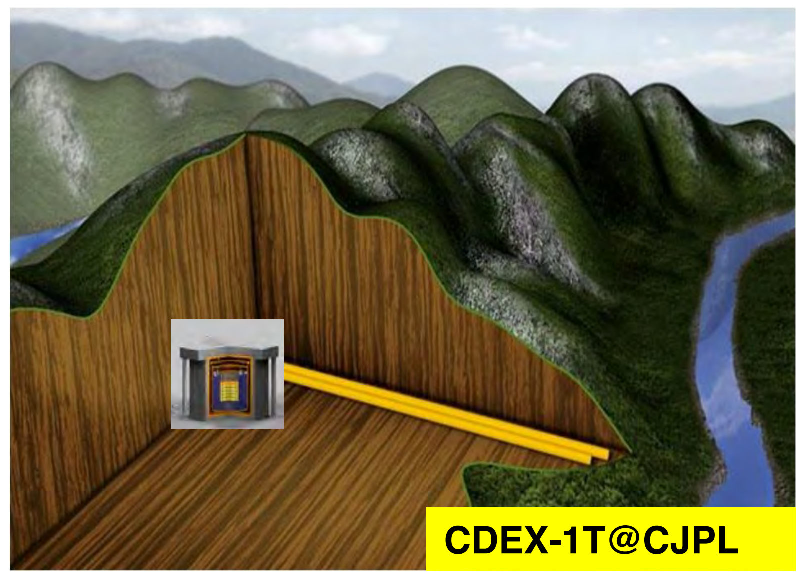
CDEX-1T Plan
---Towards a multi-purpose experiment for both DM and DBD

- Ge detector: a good choice for DM and DBD;
- CDEX Phase-I DM exp started from 2010 and physical results achieved;
- CDEX-10 (LAr Shielding+10kg PCGe Array) testing and run for DM in CJPL in 2015;
- HPGe detector fabrication and crystal growth started by CDEX for tonne-scale exp;
- CJPL with 2400m rock overburden and four W12m*H12m*L130m new space constructed and will be ready in 2016 for CDEX-1t and other experiments;
- Tonne-scale Ge experiment is important and expensive. It is necessary to develop suitable Ge detector techniques and international collaboration in next 5 years.



Q.Yue et al., arXiv:1404.4946. (2014)

Ge det. Fabrication and crystal growth

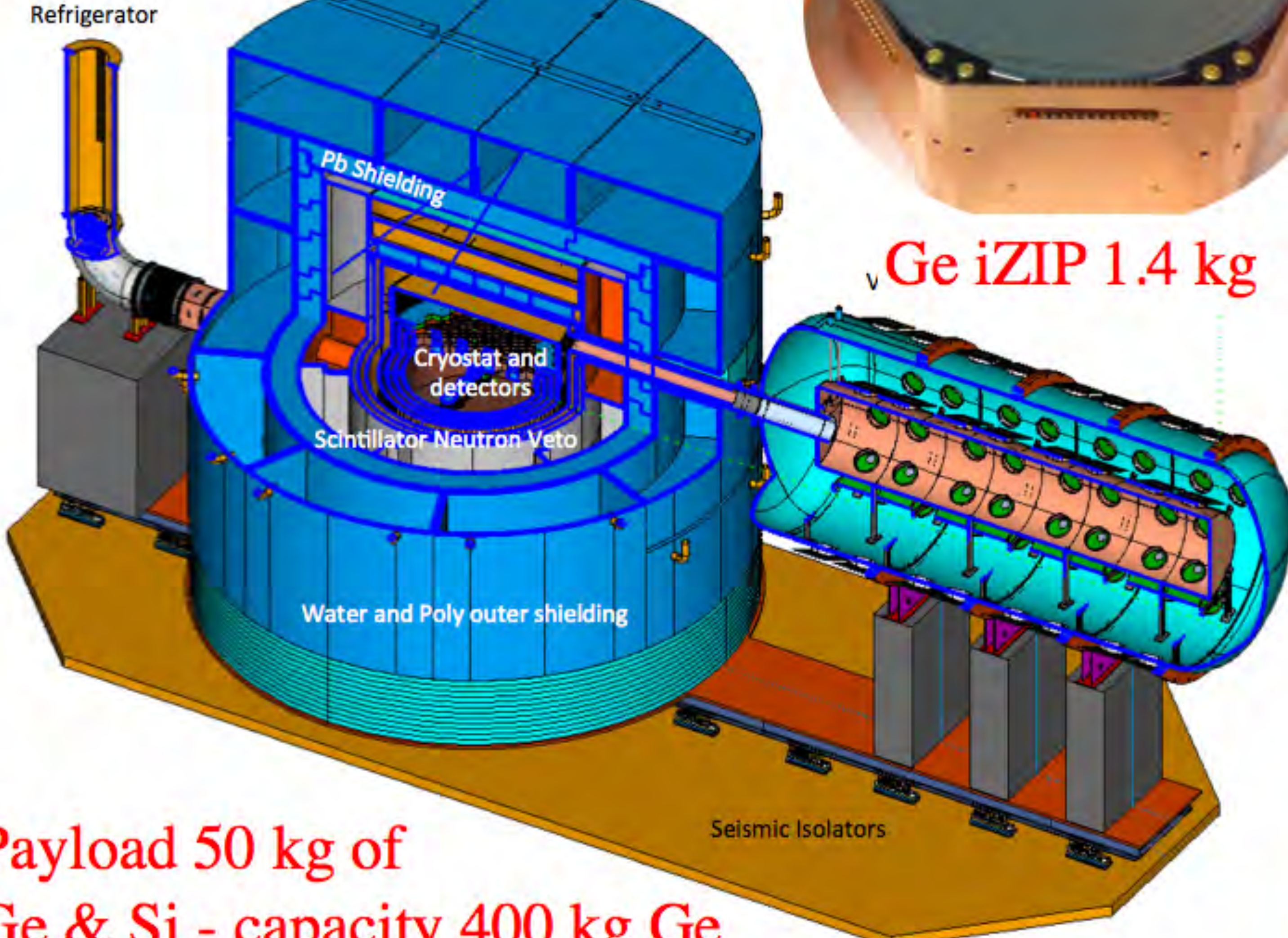


CDEX-1T@CJPL

CDMS

SuperCDMS SNOLAB Experiment

- SNOLAB 6010 mwe



Payload 50 kg of
Ge & Si - capacity 400 kg Ge

Ge iZIP 1.4 kg

Ge Tower 8.4 kg

SuperCDMS SNOLAB

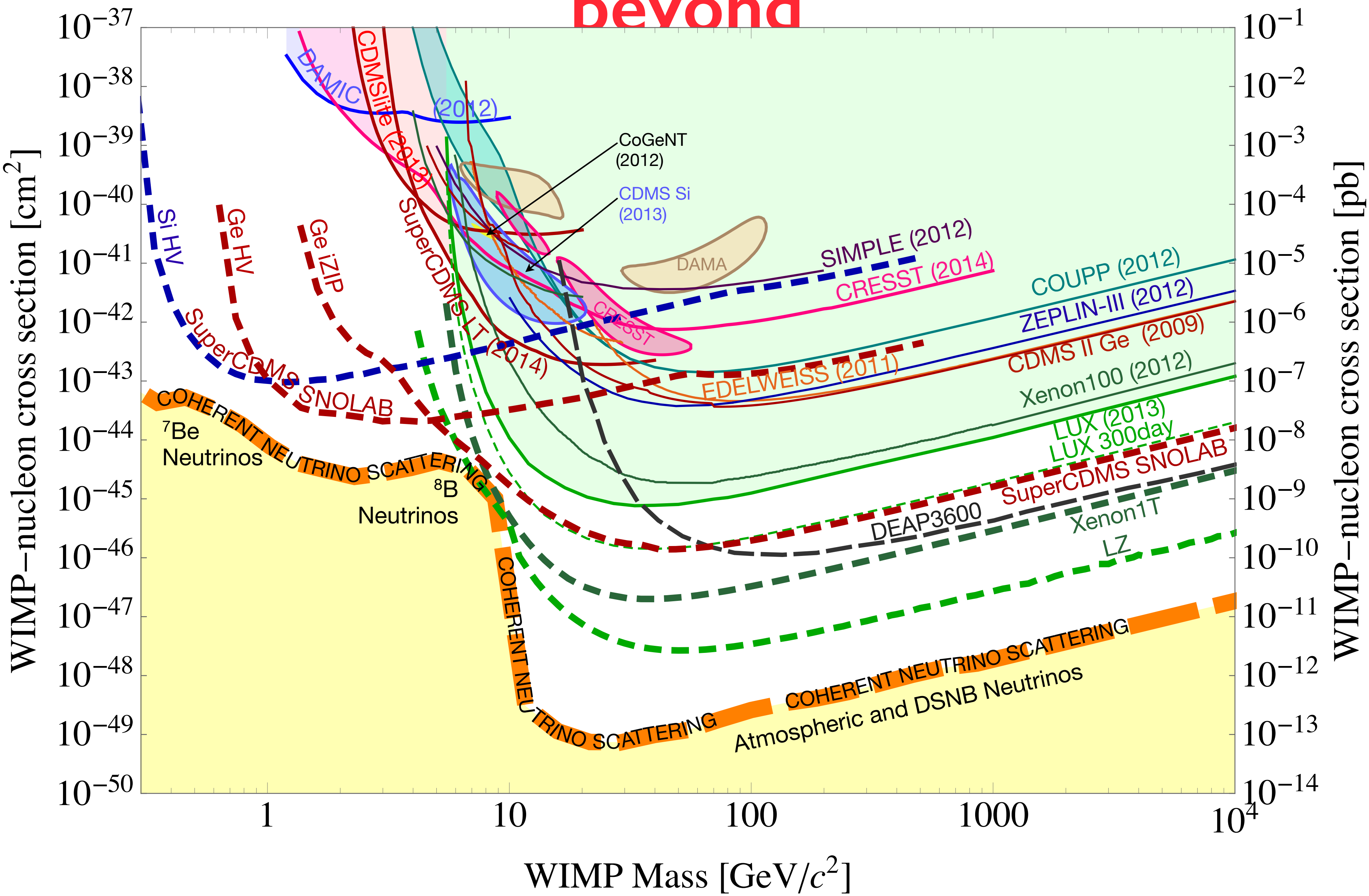
Low temperature Ge/Si detector
Focus

- Low mass 0.3-10GeV/c^2
  - Above 5 GeV/c^2 6 towers ≈50kg Ge full nuclear recoils recognition through ionization (σ=100eV) + athermal phonon (σ=50eV). Discrimination demonstrated for a run of 7 years.
  - 0.3-5 GeV/c^2, 1 tower of e.g., 3 Ge, 3 Si, CDMS HV (Luke Neganov amplification of ionization). No discrimination. Background limited after 1 year
- High mass
  - Complementary role to confirm a discovery by say LUX 300 days with different technology, different background sensitivity and different target

Cryostat able to house 400kg => upgrade paths

- Current discussions with EURECA to increase target mass/diversity within the same tower geometry (evaluation of feasibility of operating at 15mK)
  - Edelweiss 30kg re-equipped with HEMT to decrease threshold, Potentially additional Ge payload -> ≈200kg
  - CRESST $CaWO_4$.
- Possibility of rapidly increasing the mass with CDMS technology if there is a serious hint for a signal at medium or high mass.
- Follow up of a possible hint at small mass: if we can improve the phonon to better than 20eV we begin to recover discrimination (Matt Pyle)

Next Steps: SuperCDMS SNOLAB and beyond



Funding and Schedule

Funding

Funding guidance from US agencies: ≈$25M (no award yet)

Approximate parity between NSF and DOE?

would be a new type of joint venture

80% of our request 100kg->50kg

+ $3.4M Canada Fund for Innovation

Hope to attract EURECA. May be $10M US equivalent.

Schedule

Technically limited: CD2/CD3a end of 2015 + 2 year construction: Operation beginning 2018

We have not received yet a budgetary profile. May be slower than scientifically desirable and technically feasible.

SuperCDMS Collaboration

California Inst. of Tech. | CNRS-LPN | FNAL | Mass. Inst. of Tech. | NIST Inst. of Tech.

PNNL | Queen's University | SLAC | Southern Methodist U. | Santa Clara University

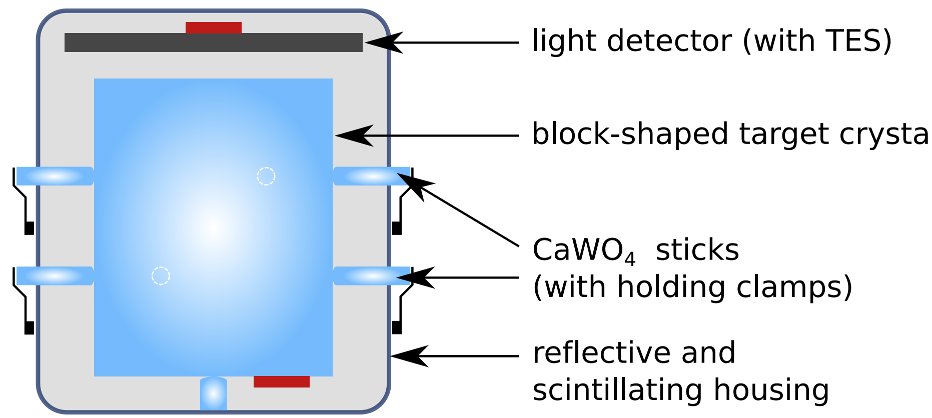
South Dakota SM&T | Stanford University | Texas A&M University | U. Autónoma de Madrid | U. British Columbia

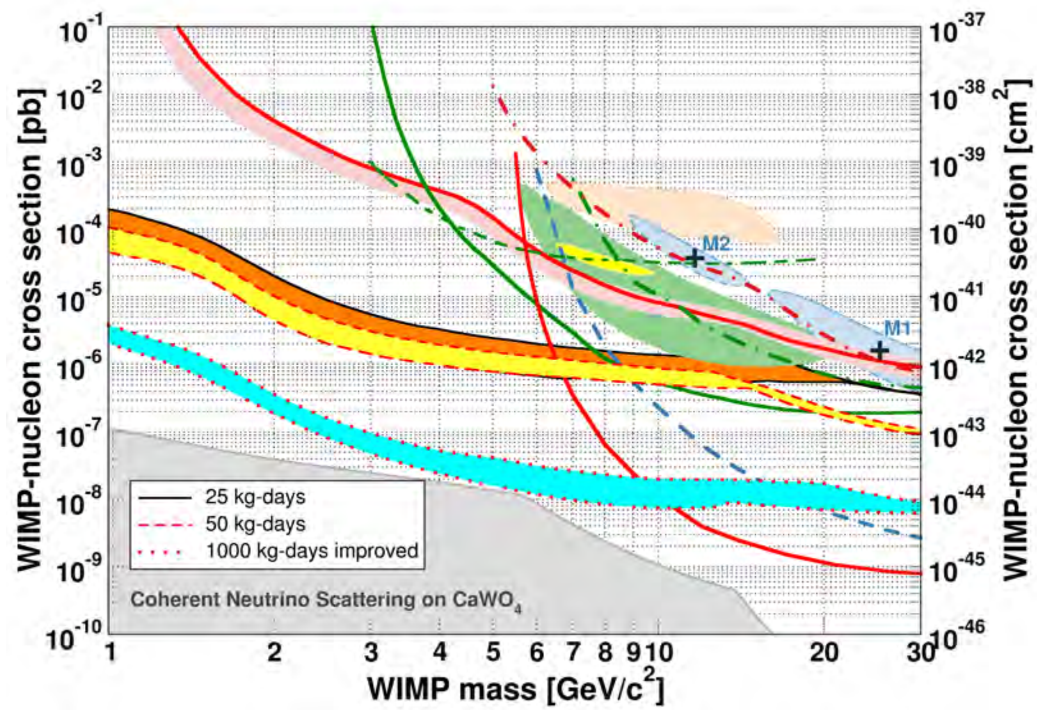
U. California, Berkeley | U. Colorado Denver | U. Evansville | U. Florida | U. Minnesota | U. South Dako

CRESST Plans

Schematic view of a new type of detector module.

Data from such a module were used in our recent paper (http://arxiv.org/abs/1407.3146). With a low threshold analysis of 29.35 kg days of data we obtained the result shown in present_results.png (see caption in paper). In this paper we demonstrated that with this new detector design we succeeded to efficiently reject any backgrounds from surface alpha decays and that thresholds as low as 0.6 keV are possible. In the mean time we were able to further lower the threshold to 0.4 keV with a 250g and some 300g detector modules.
Encouraged by the improvements in the low mass region we achieved with the low thresholds we developed a plan for the coming years to go for small mass detector modules with lower thresholds and fully exploit the low mass potential.In the next run we plan to use 20x20x10 mm^3 CaWO4 crystals (24 g instead of 250 g now) with two 20x20 mm^3 light detectors (instead of one with 40 mm diameter now). The projections in plans.png show what we expect to achieve with 10 such modules within halve a year (25 kg-days, orange 1sigma contour) or a year (50kg-days, yellow contour) of measurement time. This projection assumes the intrinsic backgrounds of the crystals as we have it now, a threshold of 0.1 keV and some moderate improvement in light detection.
The magenta contour shows what we finally hope to achieve with 100 of such small modules within 2 years of measurement time. This assumes that we are able to lower the e/gamma background by a factor of 100 with further progress in our lately established in house crystal production.





DarkSide-50

Two-phase LAr TPC 50 kg active mass surrounded by liquid scintillator veto (4m diameter sphere) inside 1000 tonne (10 m (H) x 11m (D)) water tank.

Limit of $10^{-45} cm^2$ in background free 3 yr run.

Running with atmospheric Argon till early 2015

Technical features:

Underground (low radioactivity) argon – early 2015

Active Muon and Neutron Veto (deployed)

High QE PMTs with in-liquid pre-amps

Discrimination by S1 pulse shape, S1/S2, & position

Collaboration

Arkansas, Augustana(SD), BHSU(SD), Chicago, FNAL, Hawaii, Houston, UMass, PNNL, Princeton, SLAC, Temple, UC Davis, UCLA, Virginia Tech **(U.S.)**

Jagiellonian **(Poland)**

IN2P3 Paris & Strasbourg **(France)**

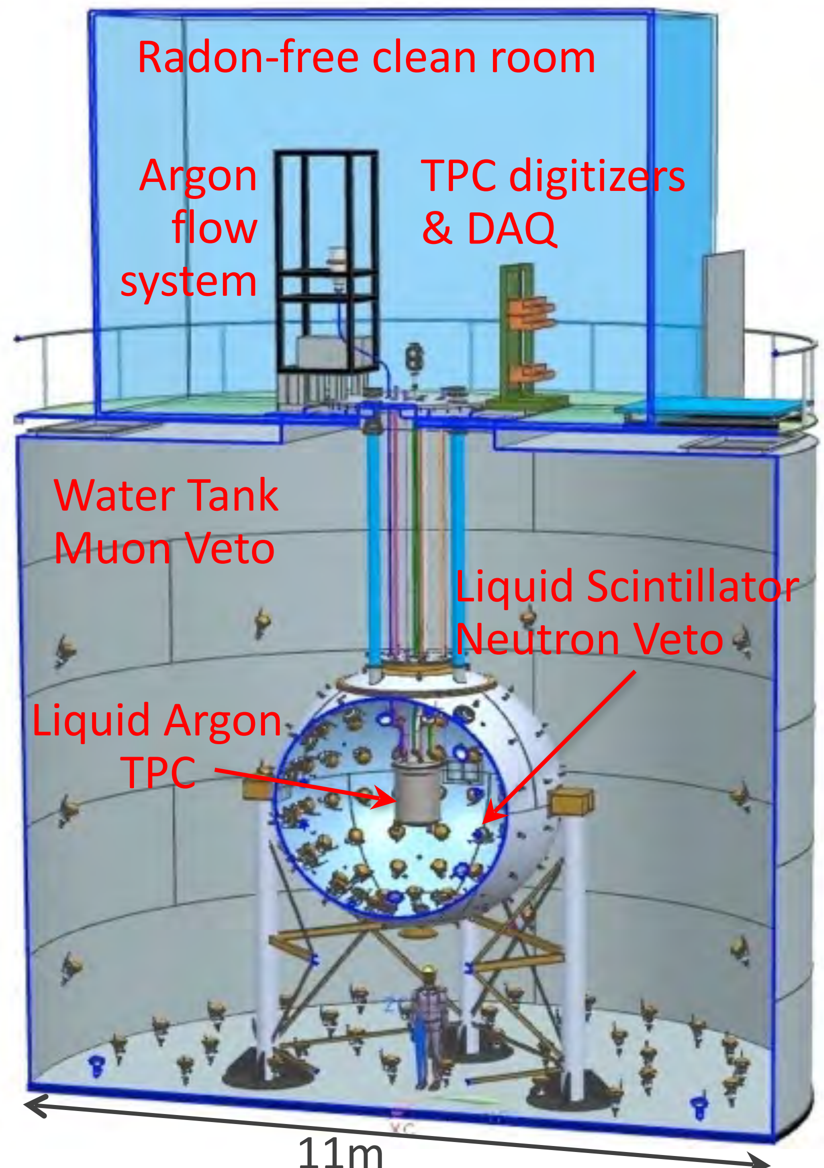
IHEP Beijing **(China)**, Kiev **(Ukraine)**

MSU, Kurchatov, Gatchina, Dubna **(Russia)**

Cagliari, Genoa, LNGS, Milan, Naples, Perugia, Rome-3 **(Italy)**

(supported by INFN, NSF, DOE)

In Hall C at LNGS, Italy



DarkSide-50 & Future

Status:

- DarkSide program starts with DS-10 deployed at Princeton, and then LNGS in 2011
- First (test) deployment of DarkSide-50: started April 2013 at LNGS;
- Second and current deployment: started September 2013;

Successes:

- Detector stability; electron drift lifetime (> 5 ms); light yield (~8 PE/keV); signal to noise in photosensor system (in-liquid preamps); DAQ speed and reliability

~ 200 kg-days sample background free presented at DM2014

~ **2000 kg-days atmospheric argon full detector** publication in preparation – first large data sample (≈ 20 yrs for electron recoil background with UAr in DS-50)

Reaction to G2 Decision

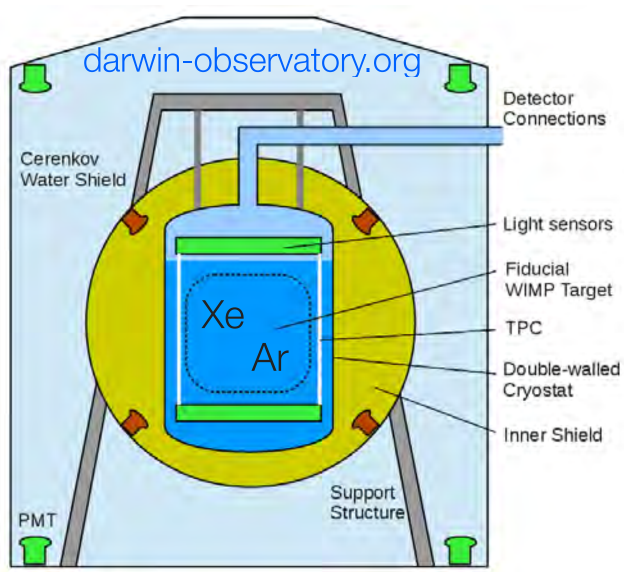
- We built DarkSide-50 to make as good a measurement with argon as we could and we aim to exploit what seems a very, very, nice apparatus.
- We believe that argon is a powerful medium as target for WIMPs and aim to exploit DarkSide-50 to establish argon's superior rejection capability.
- We are requesting funds to support operations for the next two years at least.
- We await `a program of R&D to test and develop technologies for future experiments, consistent with the recent P5 recommendations.'
- R&D for next phase: invest effort specifically on photosensors, cryostat and TPC materials, and massive production of underground argon.

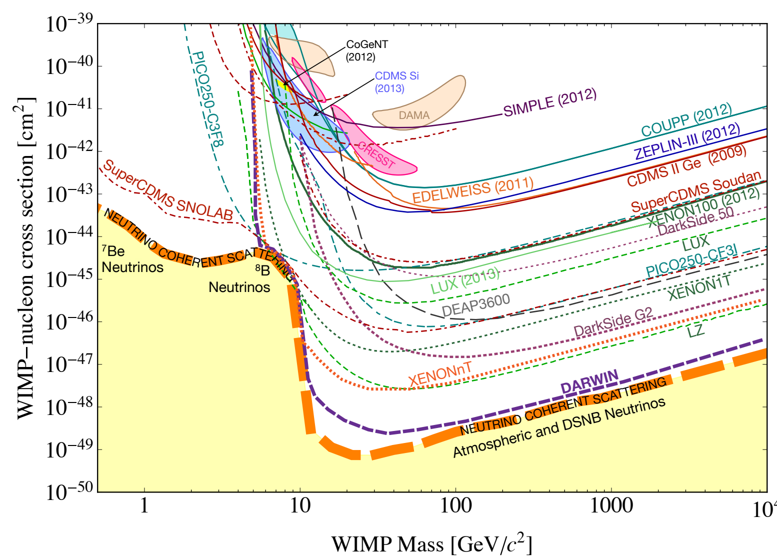
Darwin

dark matter wimp search in noble liquids

DARWIN - R&D towards a G3 LXe/LAr detector

- Design study for a LXe (20 t) and/or LAr (50 t) dark matter observatory for M_{WIMP} > 6-10 GeV/c^2
- On the European and Swiss astroparticle physics roadmaps; initial funding by ASPERA
- Goal: build ultimate Xe/Ar detector, probe the SI WIMP-nucleon cross section down to ~10^{-49} cm^2
- DARWIN consortium: 28 groups from 10 countries (in Europe, USA, Israel)





Construction: 2020; science data: 2022 - 2026

DEAP 3600

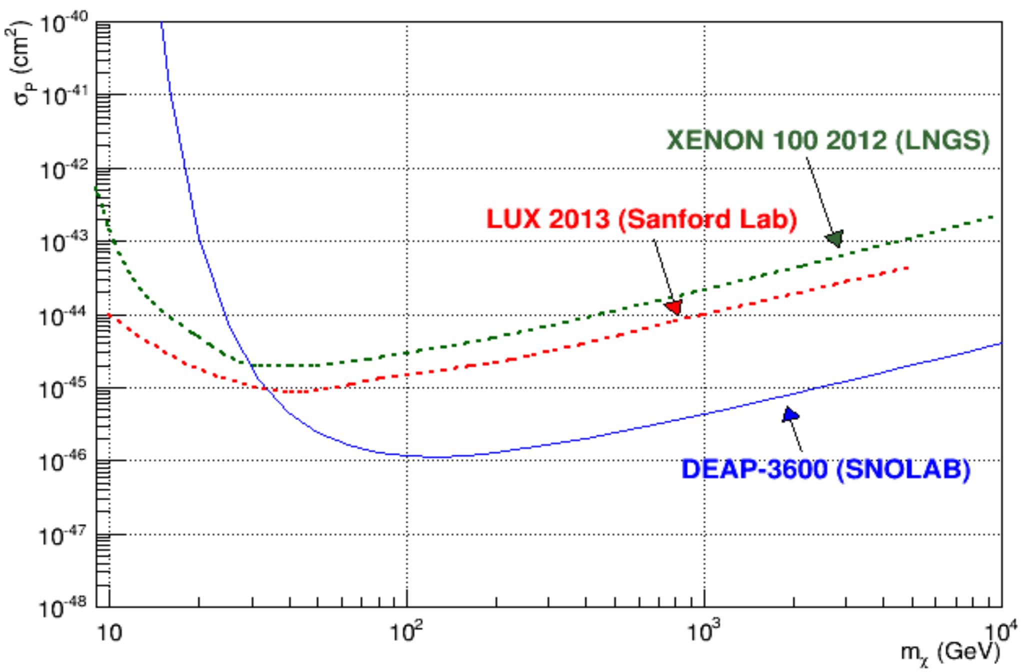
DEAP-3600 Dark Matter Search at SNOLAB

Project Overview

3.6 tonnes liquid argon in ultraclean acrylic vessel, 255 8-inch HQE PMTs

1 tonne fiducial mass designed for < 0.2 background events/year

10^{-46} cm^2 sensitivity for ~100-GeV WIMP with 3-year exposure



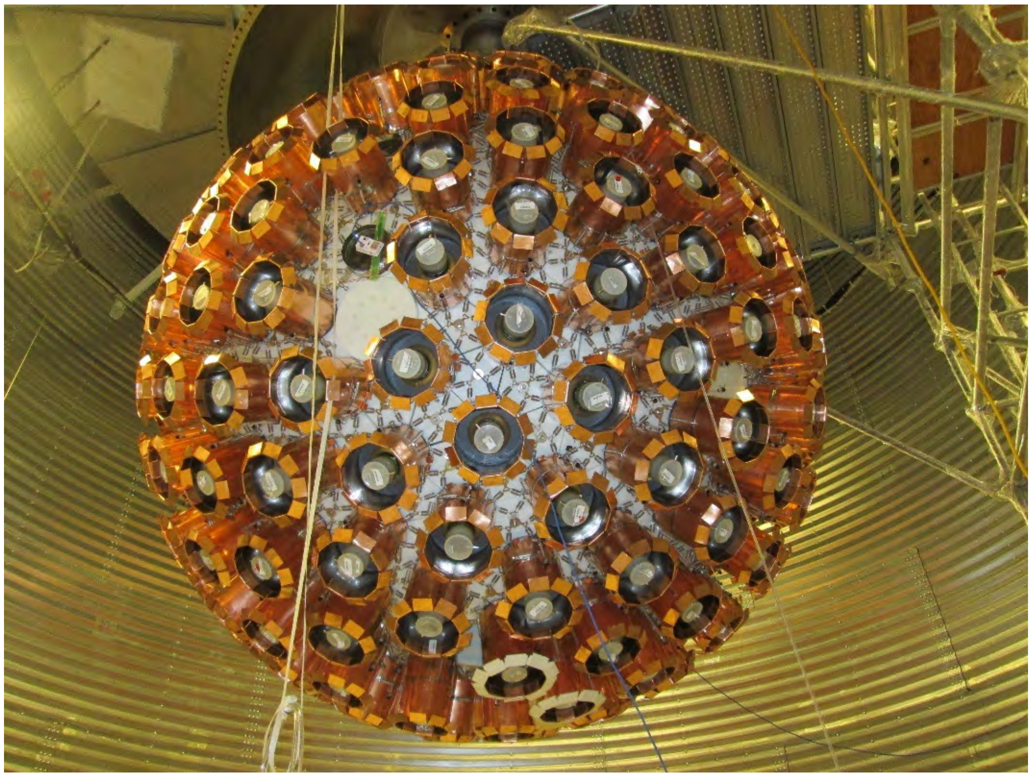
Project Timeline

Turn-on PMT systems	Oct 2014
Argon gas runs and in-situ background measurements, commissioning	Fall 2014
Physics Data start	Early 2015

Future Project

Planning for development of future 50-tonne argon experiment (photo-detector development, low-background argon and engineering proposal)

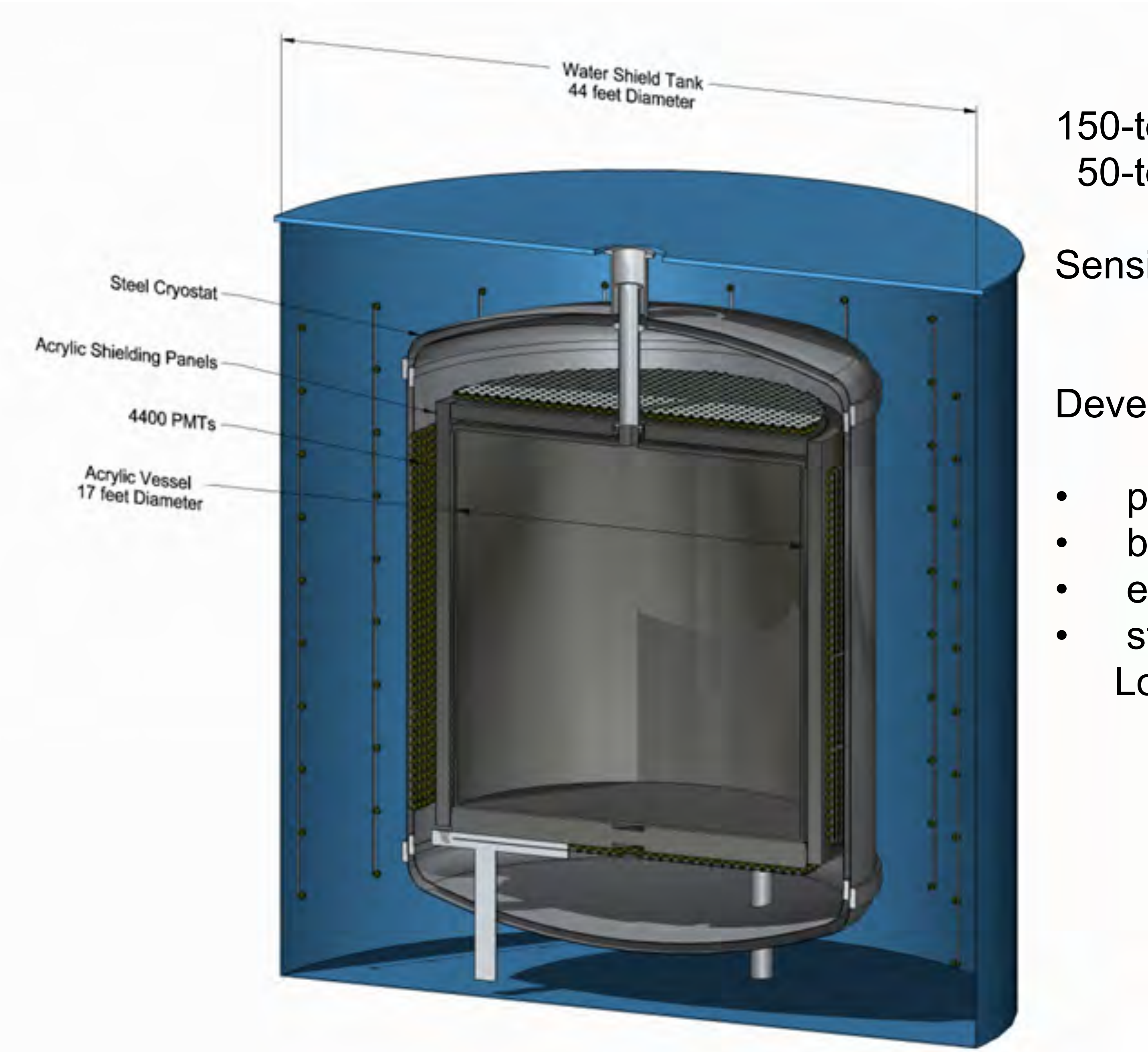
DEAP-3600 Detector at SNOLAB



Completed inner detector
255 8” R5912HQE PMTs
installed in water shield tank

Steel Containment Sphere
in 8m diameter water shield tank

DEAP-50T: Follow-up with 50-tonnes of liquid argon (Development Proposal)



150-tonnes DAr in AV
50-tonne fiducial

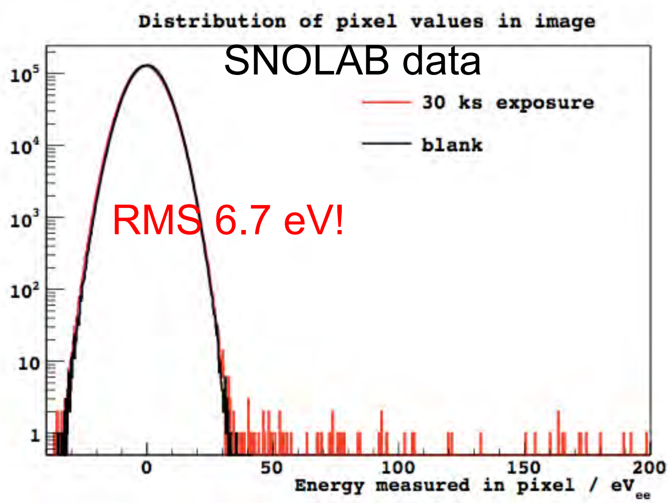
Sensitivity 10^{-48} cm^2

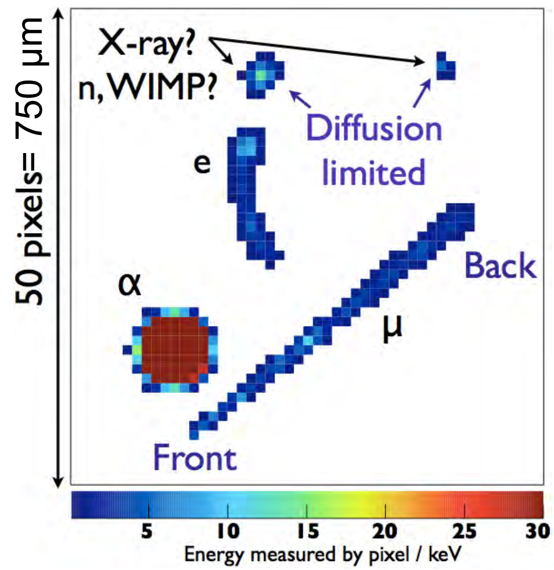
Development

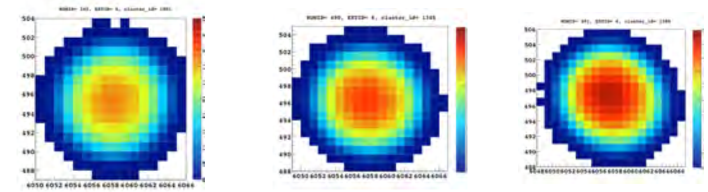
- photodetector development
- background reduction
- engineering and safety
- storage and screening of Low-Radioactivity Argon

Dark Matter in CCDs

- High resistivity, fully depleted, ≈ 40 cm^2, 675 μm thick CCDs developed at LBL
- Very low energy threshold, optimal for low mass WIMP
- Unique spatial resolution: particle id, surface bkg. rejection, bkg. measurements

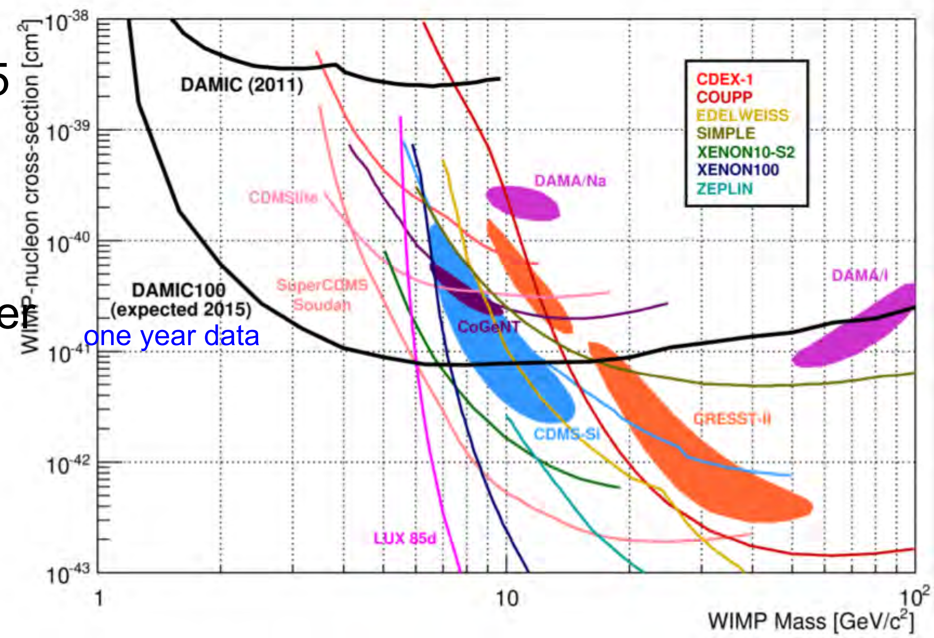






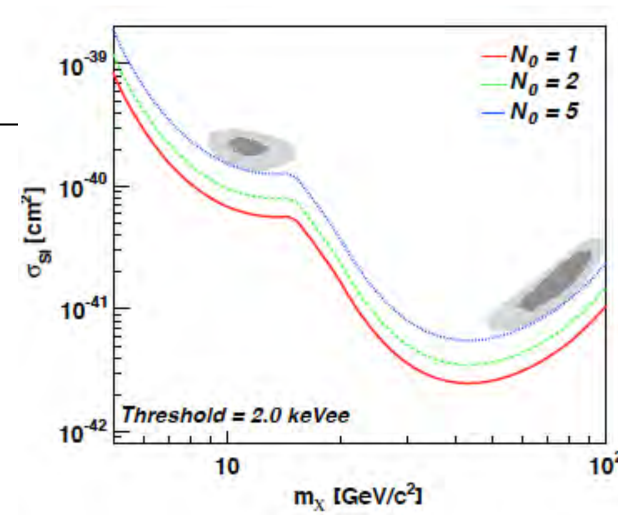
Three alphas occurring in the same location, separated in time by several days: example of a Th decay chain

- DAMIC-100: 100 g detector (18 CCDs 5.5 g each) being installed at SNOLAB
- R&D: sub-eV noise and larger mass CCDs



Fermilab, UChicago, UMichigan, UZurich, CAB, FIUNA, UNAM, UFRJ

DM-Ice



Objectives

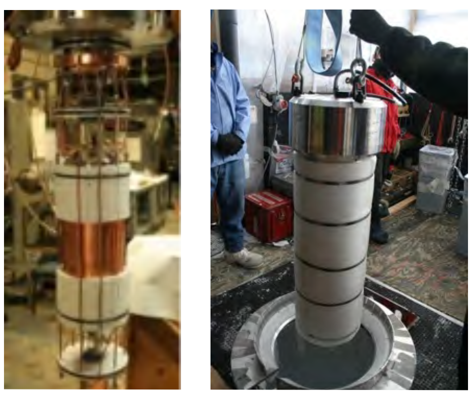
- **Directly test DAMA's observation, definitive probe of longest standing DM claim**
- **Test assertion that the observed signal is due to dark matter & understand its origin**

Key Features

- NaI(Tl) target
- only experiment with access to both Northern & Southern Hemispheres

500 kg·years
(2 - 4 keV) with 1, 2, and 5 dru background (DAMA has ~1 dru)

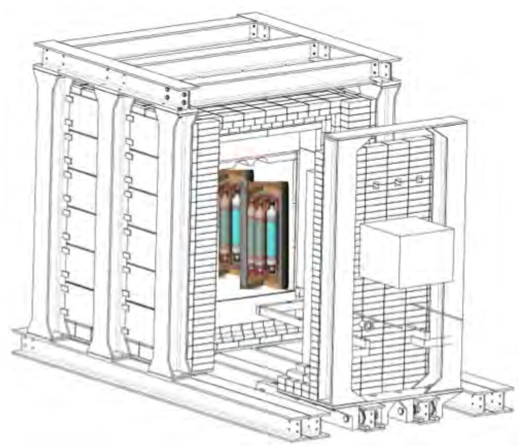
DM-Ice17



Operating continuously since 2011
17 kg of NaI(Tl) at 2450m depth at South Pole, analysis ongoing

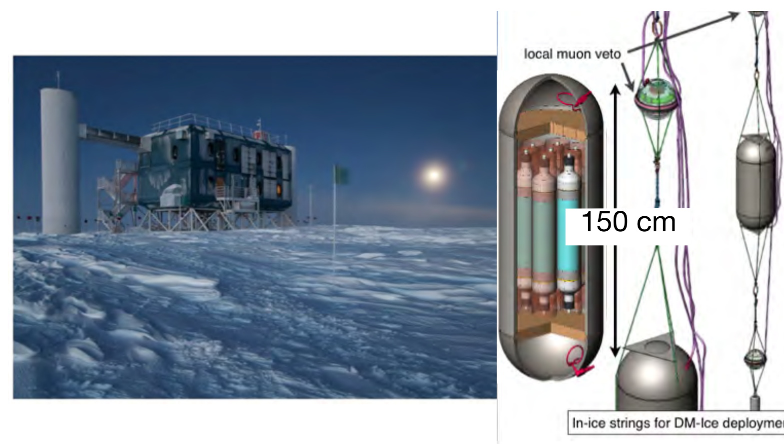
arXiv:1401.4804

DM-Ice 250 North



Northern Hemisphere Run
Portable 250 kg NaI(Tl) detector
Tests the null hypothesis & study possible sources of modulation

DM-Ice 250 South

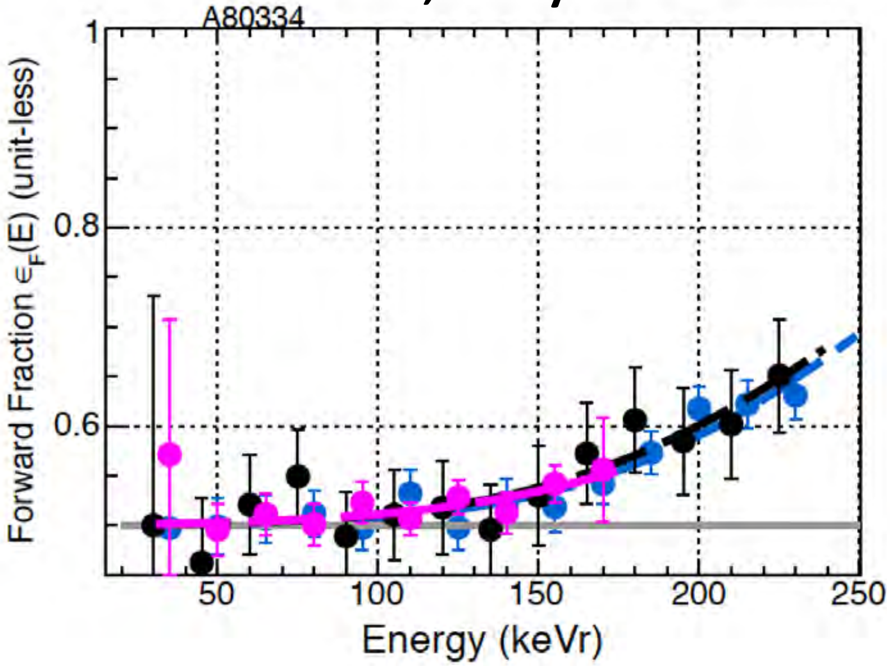


Deployment at South Pole
Definitive testing if signal observed independently from DAMA.

Astropart.Phys. 35 (2012) 749-754

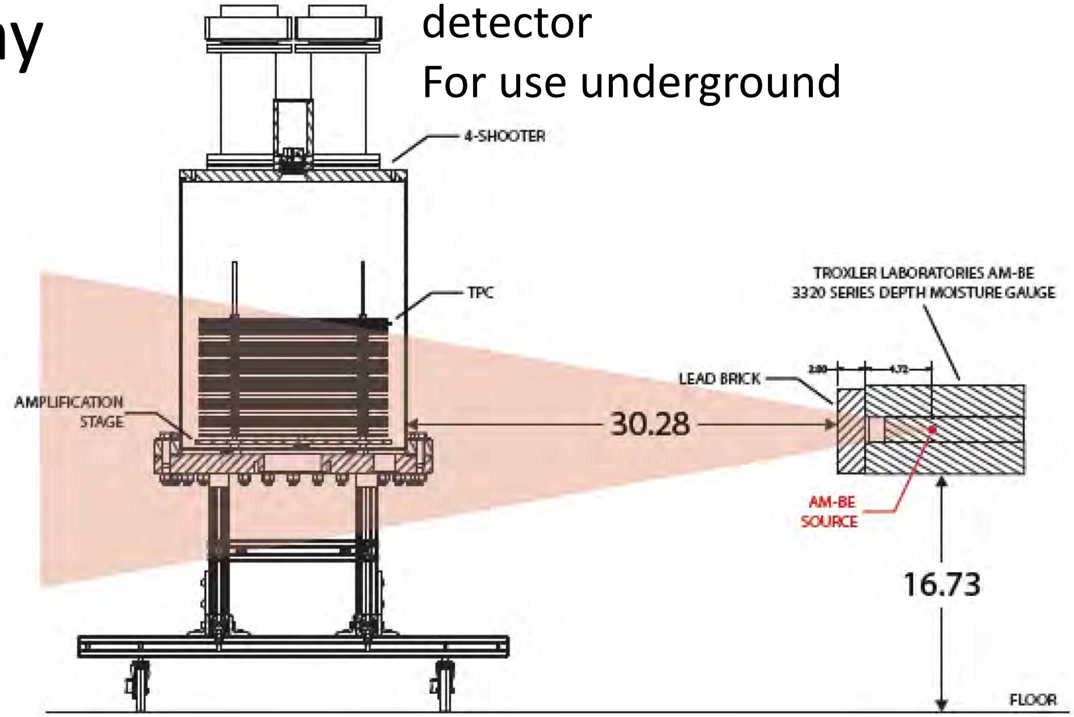
Reina Maruyama

DMTPC: MIT, Royal Holloway

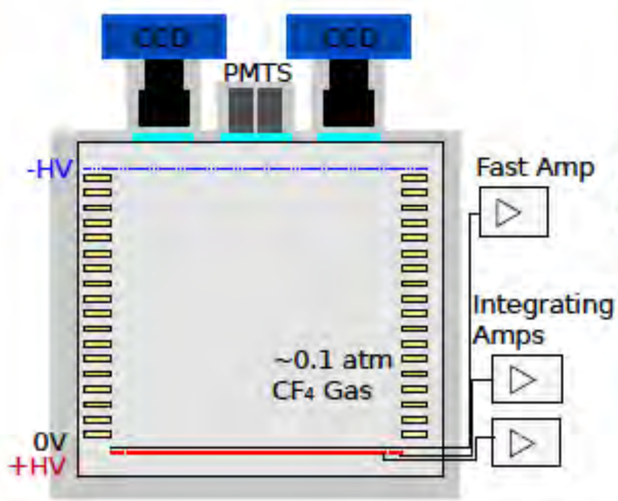


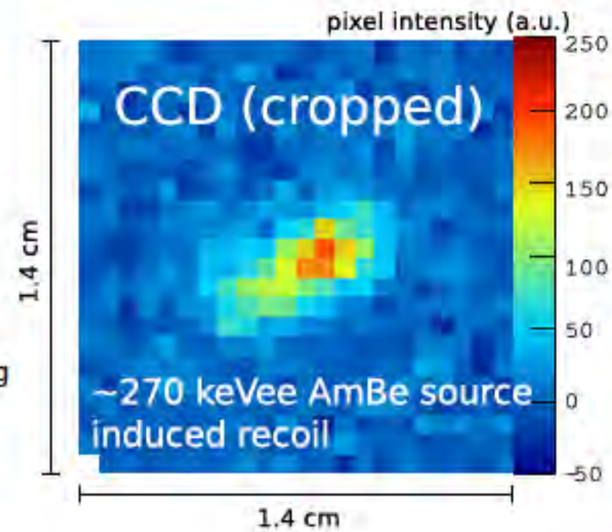
Measurement of directional sensitivity with 25 cm drift using neutrons.

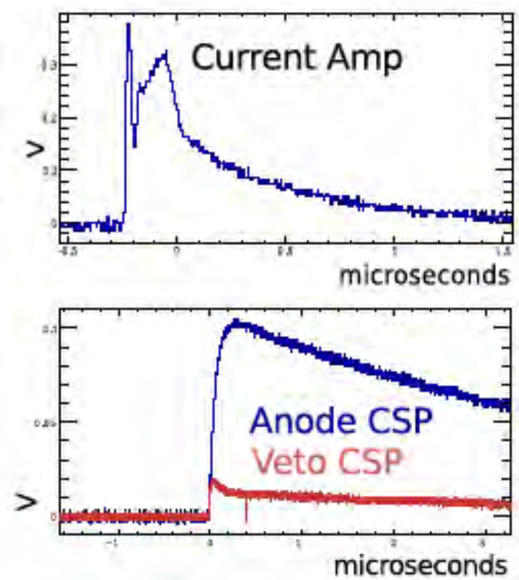
Currently constructing 1,000L detector
For use underground



2nd generation DMTPC detector, the 4shooter







DRIFT

Directional Recoil Identification From Tracks (DRIFT) Collaboration

Sheffield University
Neil Spooner – PI
Matt Robinson
Dan Walker
Stephen Sadler
Sam Tefler
Andrew Scarff
Anthony Ezeribe
Leonid Yuriev
Trevor Gamble

Occidental College
Dan Snowden-Ifft - PI
Jean-Luc Gauvreau
Chuck Oravec
Alex Lumnah
Chongmo Tang

Colorado State University
John Harton – PI
Dave Warner
Alexei Dorofeev
Fred Shuckman II

University of New Mexico
Dinesh Loomba - PI
Michael Gold – PI
John Matthews - PI
Eric Lee
Eric Miller
Nguyen Phan
Randy Lafler

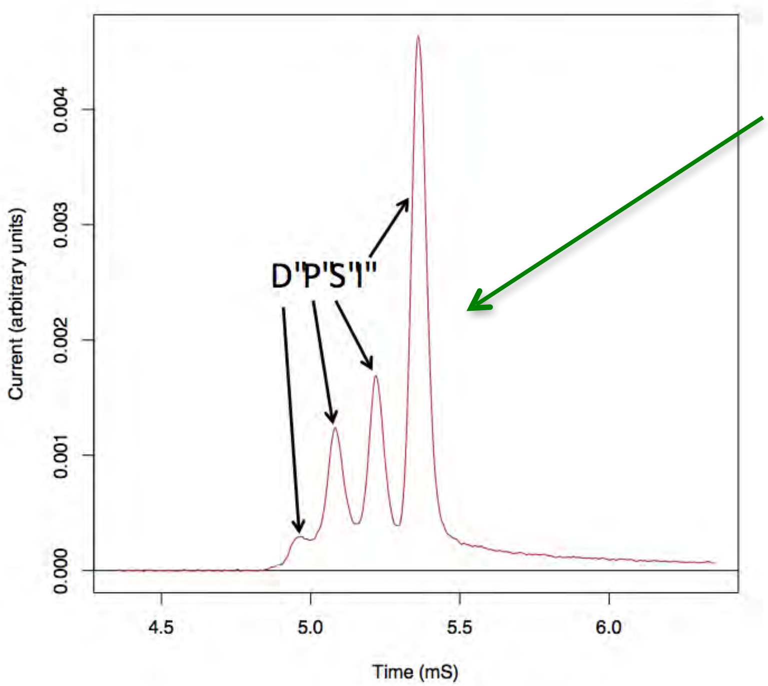
The University of Edinburgh
Alex Murphy – PI

Wellesley College
James Battat – PI

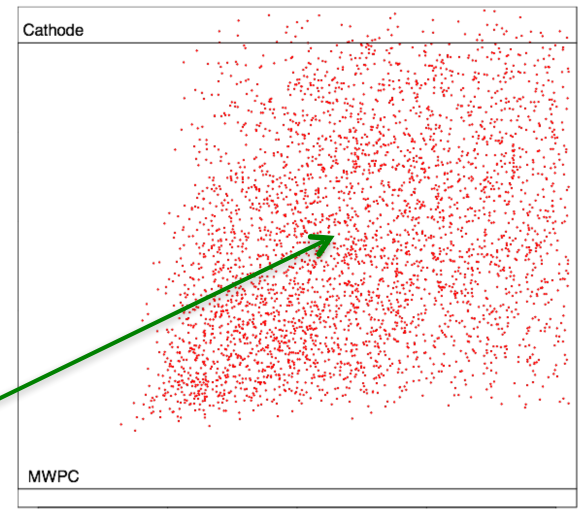
University of Hawaii
Sven Vahsen – PI
Brett Polopolus-Meredith

Boulby Mine
Sean Paling – PI
Emma Meehan
Louise Yeoman

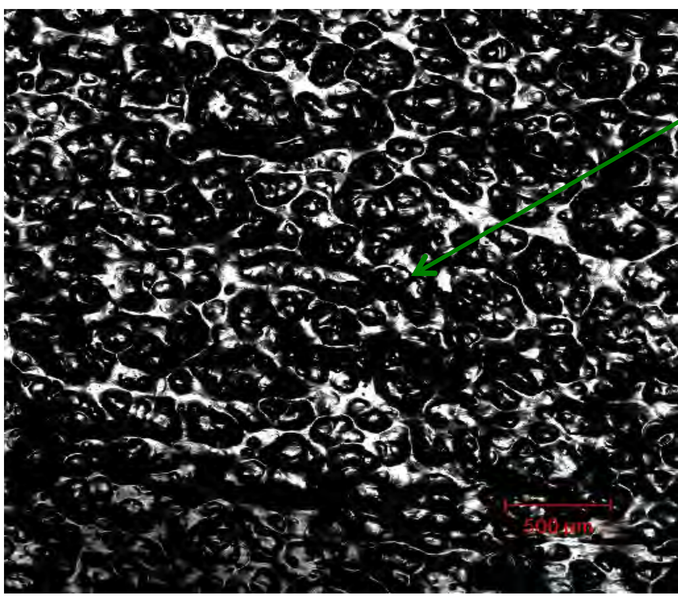
Background-Free DRIFT-IId



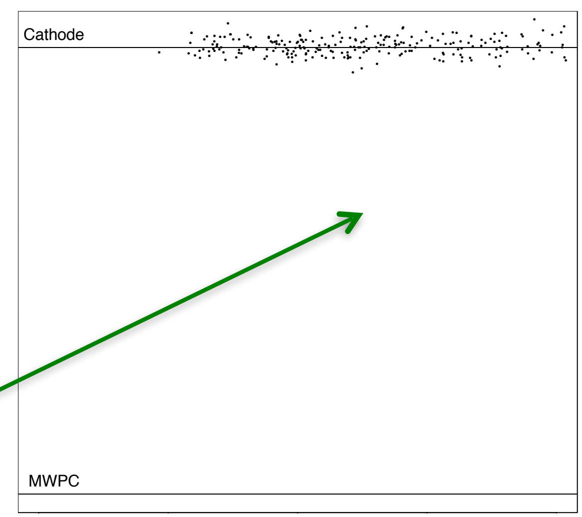
The addition of O_2 to a $CS\text{-}CF_4$ mixture produces minority peaks with separation proportional to distance.



This allows for the measurement of *z* of events

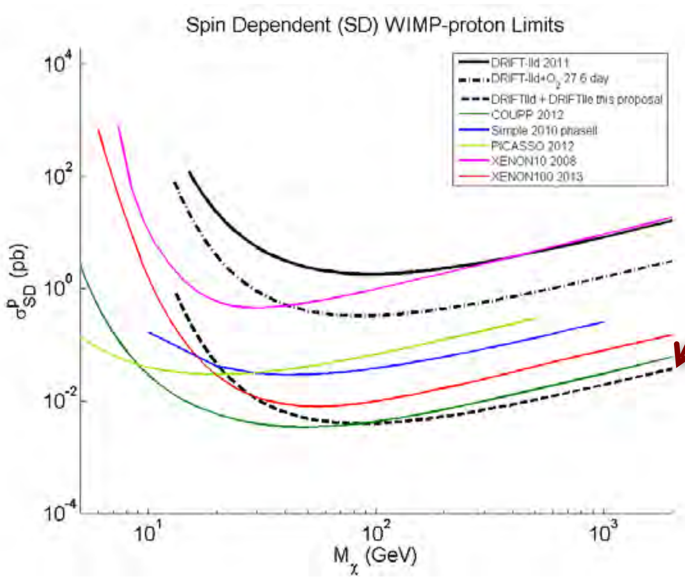


That coupled with a new texturized cathode…



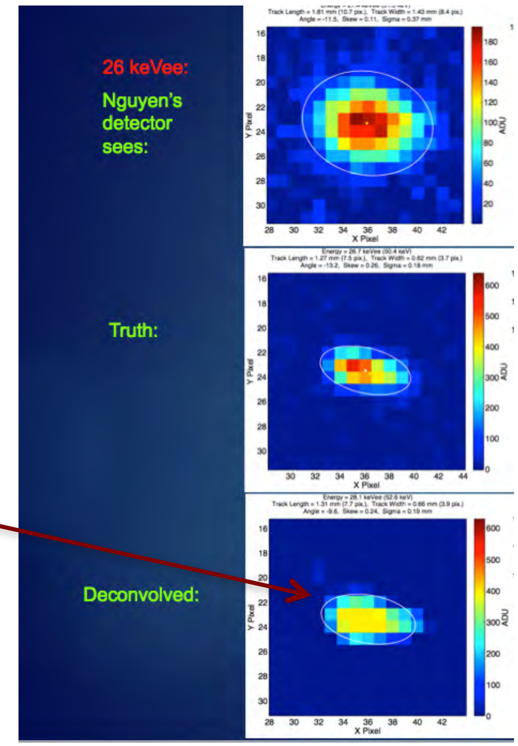
…allows us to run background free over ~75% of our available volume.

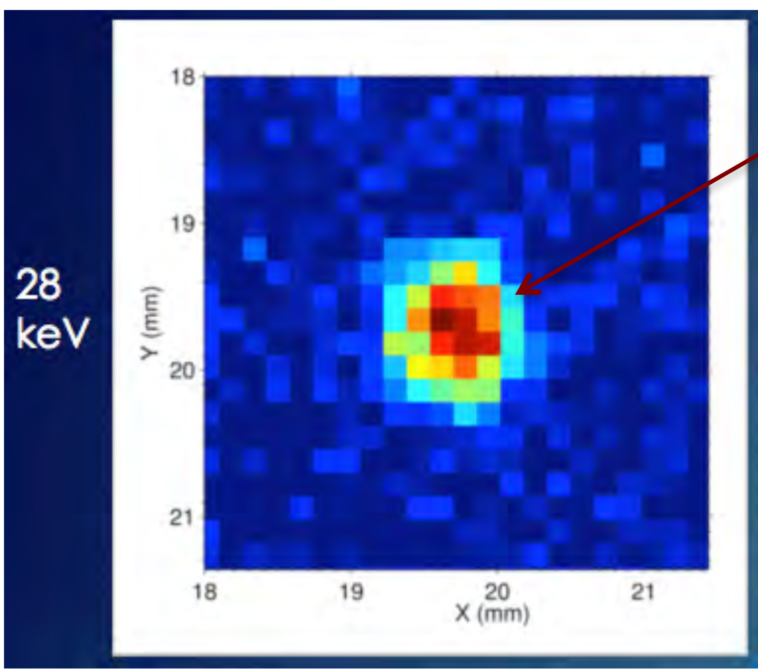
Future Plans for DRIFT



Continue running for 300x sensitivity improvement from DRIFT-IId and e

Improved directionality due to de-convolution, now that *z* is known. (Simulation)





Finer-grained 2D readout planes for improved directionality and better resolution. (Data)

- Low Pressure TPCs are the only proven directional technique.
- DRIFT's limits are already x2,000 better than any other directional detector.
- Focus now will be on improving limits further and strengthening directionality.

EDELWEISS-III status

Goals:

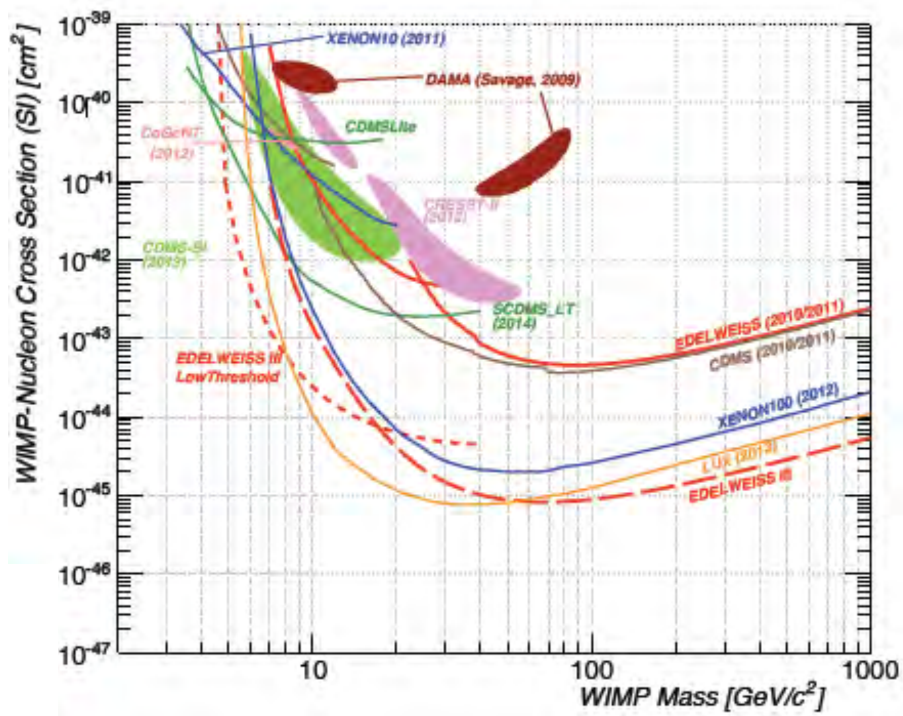
- Explore sensitivities down to ~10^{-9} pb for 0.1-10 TeV WIMPs
- Explore low-mass WIMPs (<10 GeV) with
  1. Best FID800s
  2. Best FID800s equipped with HEMT-based cold electronics
  3. Few Luke-enhanced R&D detectors

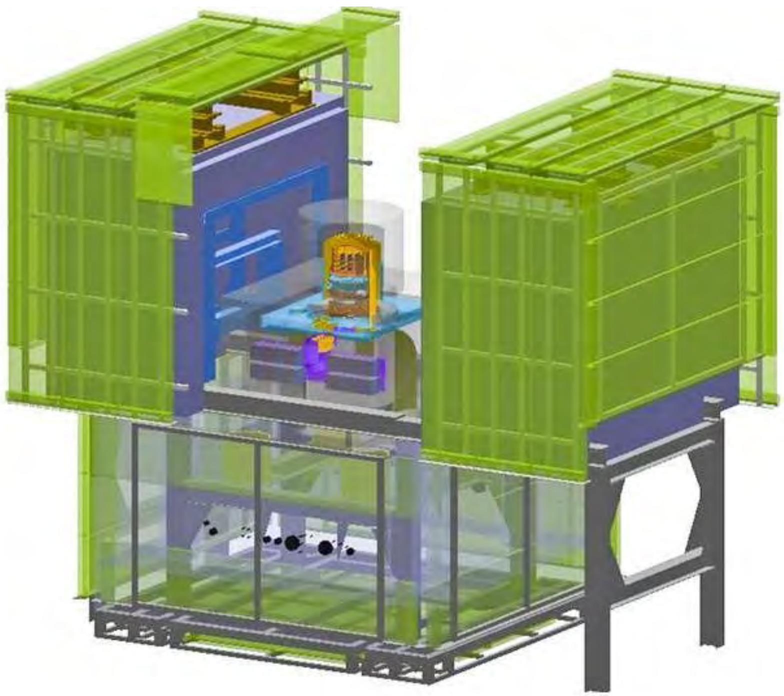
2014

- Installation of 36 FID800 detectors in the updated EDELWEISS-II setup
- 500 eV FWHM resolution on ionization; 300-1000 eV FWHM on heats
- WIMP runs started in July 2014
- 200 kg.d on disks (≈60% EDW-II)
- > 500kg.d by end of the year

2015-2016

- First 3000 kgd by summer 2015
- Run 12000 kg.d if background as expected
- Installation of Low Mass Detectors (improved FID800 with< 300eV FWHM on both heat and ioni)





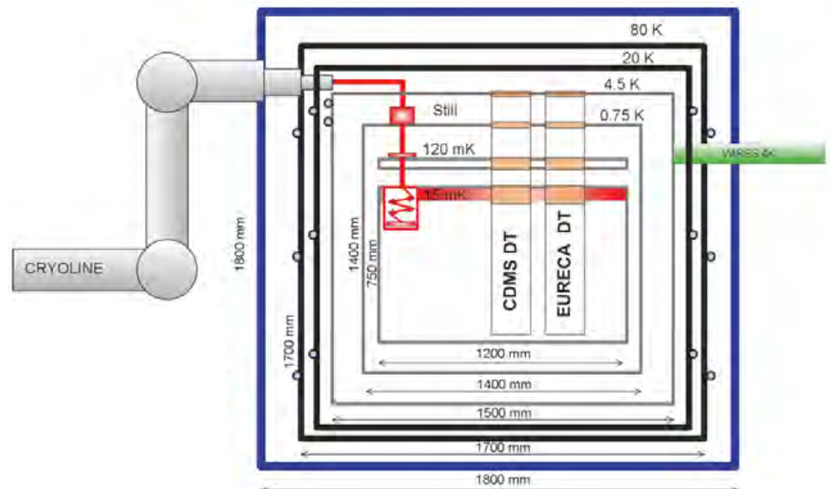
EDWIII Geant4 model

Installation of the 36 FID800 detectors at LSM

EURECA:

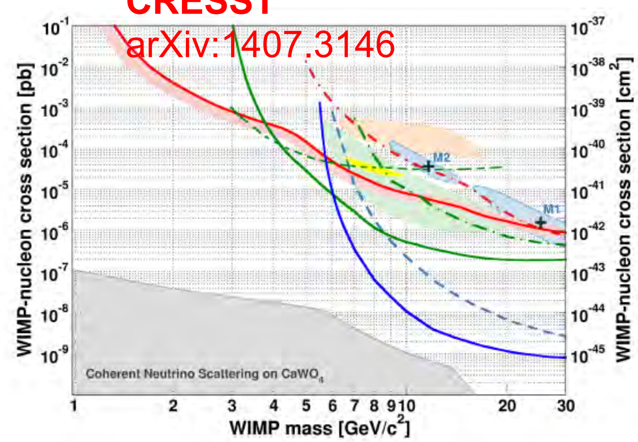
merger of European cryogenic bolometer experiments
CRESST($CaWO_4$) & EDELWEISS (Ge):
15 institutions, 7 countries, ~130 scientists
CDR: G. Angloher et al., Physics of the Dark Universe 3 (2014) 41

planned cooperation with SuperCDMS:



- cryogenic design
  - with T≤15mK (cooling power 5µW)
- shielding concept
  - borated liquid scintillator, full optical G4 model
- detector towers
  - design & build tower prototype compatible with S-CDMS concept (German BMBF funding 2014-2017)
- potential for low mass WIMPs
  - sub-keV(NR) efficiency for $CaWO_4$ crystals
  - low mass sensitivity with different targets (Oxygen)
  - 2keV(NR) thresh for EDW-Ge with new HEMT technology

CRESST
arXiv:1407.3146



KIMS @ CUP (Center for Underground Physics; a new center)

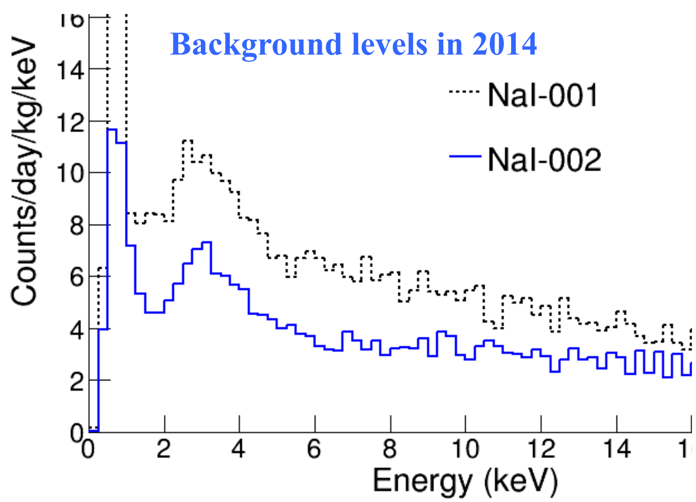
KIMS-NaI

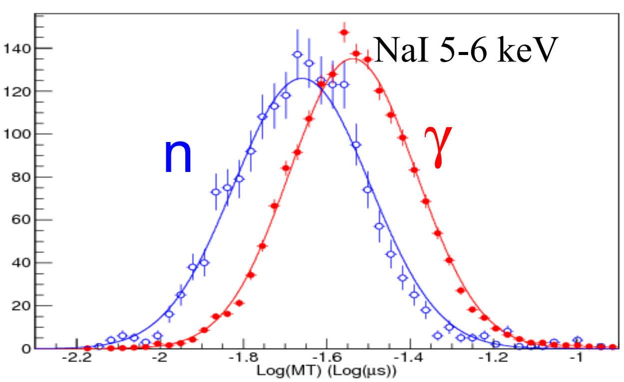
- Check DAMA using new NaI(Tl) crystals.
- Goal
  - ✓ Lower background than DAMA.
  - ✓ Lower threshold than DAMA
- Utilize PSD (Good PSD first time)
- **200kg run starts in the end of 2015.**

KIMS-LT

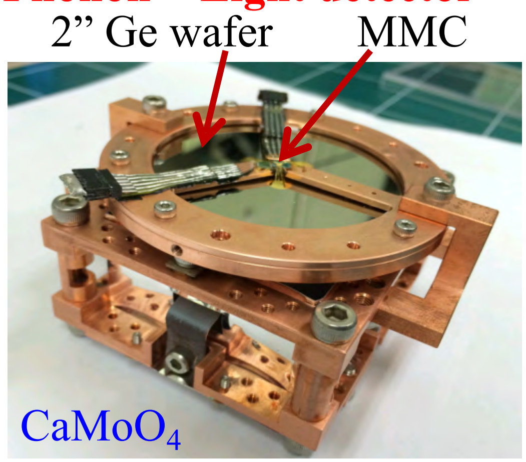
* MMC : Metallic Magnetic Calorimeter

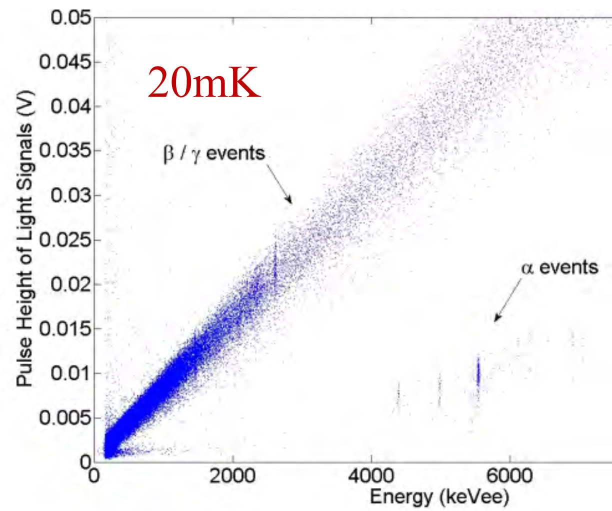
- Scintillating Crystal + MMC at Low. T.
- Similar Project to CRESST.
- R&D for optimal crystal ($CaMoO_4$, $CaWO_4$, $CdWO_4$…) & Light detector.
- Goal 200kg run starts in 5 years.





Phonon + Light detector





Background /keV/kg/day	E (keV)	For M cm2
10	5	3X10
10	1	3X10

Sensitivity is comparable to SuperCDMS

LZ

LZ Method: 2 Phase Xenon TPC

Z position from S1–S2 time interval (σ≈0.2 mm)

X-Y positions from S2 light pattern (σ≈5 mm)

Reject gammas by charge (S2) to light (S1) ratio.

Expect > 99.5% rejection.

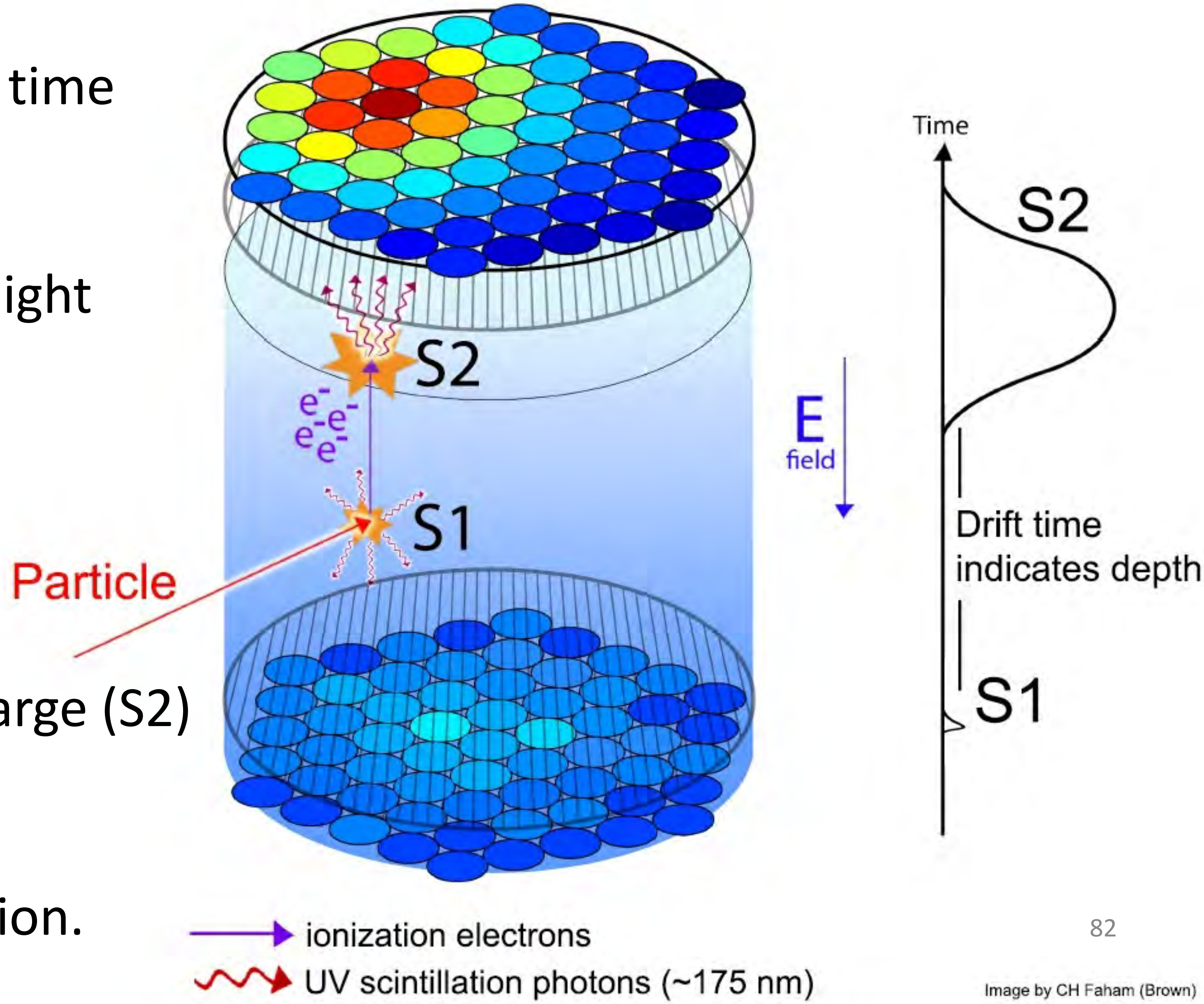
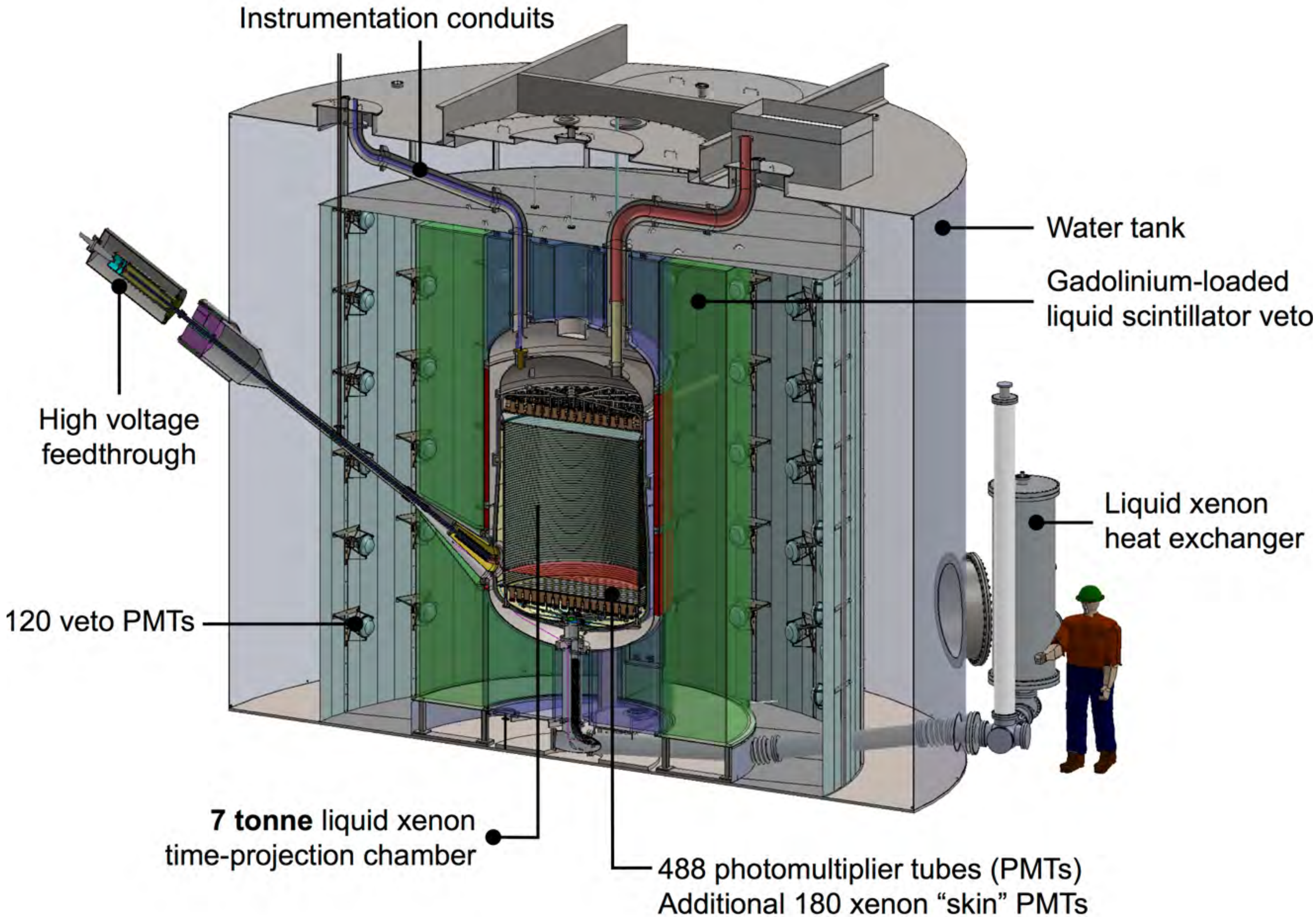


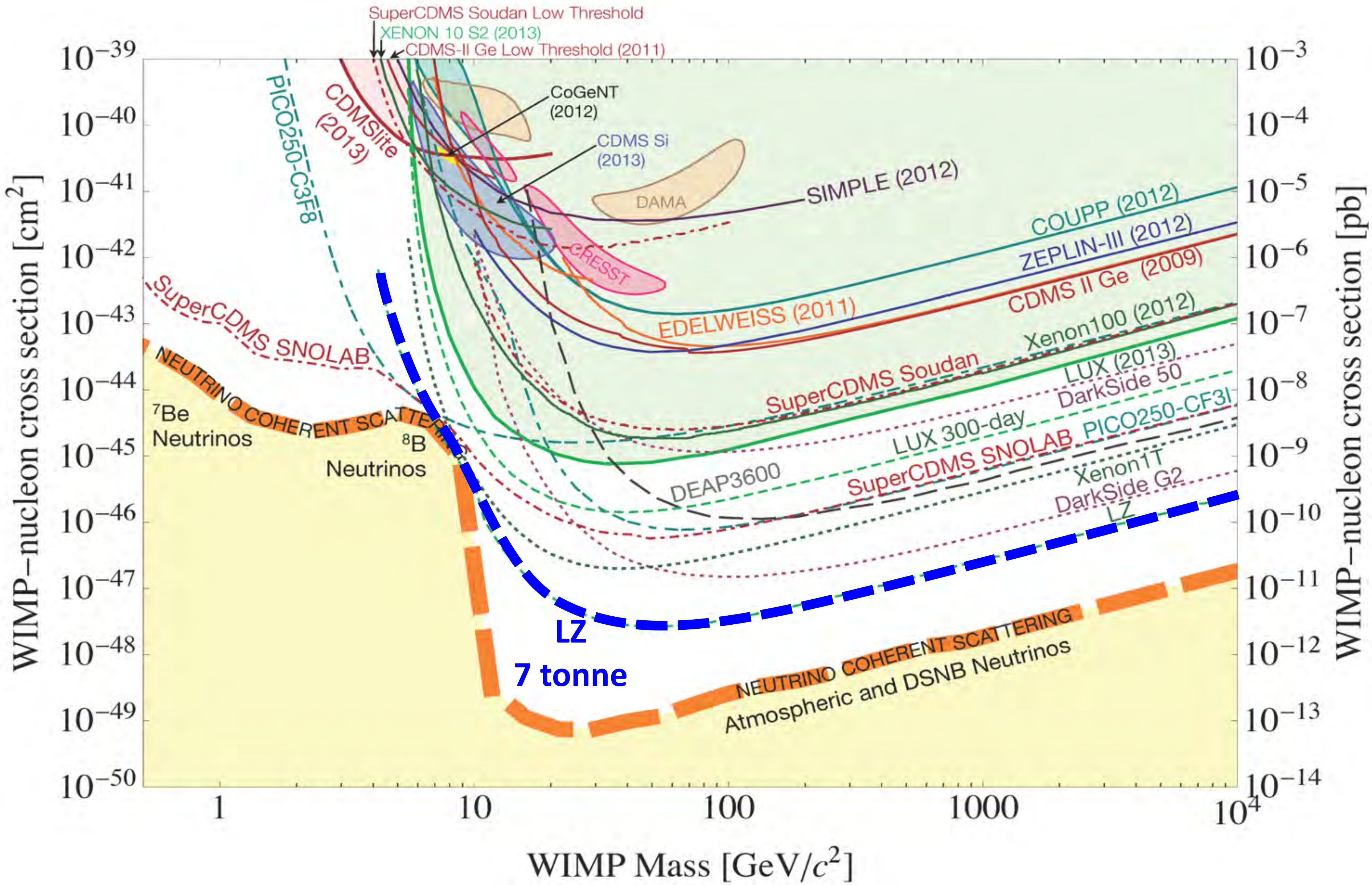
Image by CH Faham (Brown)

LZ Design Overview

Replaces LUX at the Sanford Underground Research Facility (SURF)



LZ on the Snowmass Plot



Current Cost Estimation

- LZ was proposed in Nov. 2013 as a DOE-NSF project with a total U.S. equivalent cost of $55.5M(FY14), of which about $21M was assumed from non–federal sources (UK, Portugal, Russia, SDSTA).
- LZ was approved on July 7, 2014 as a DOE–only supported Project.
- A successful “director’s review” of LZ was completed Aug. 12-13, 2014 at LBNL.
- A CD-1 review has been requested in the next few months.
- LZ cost and schedule will be updated for the CD-1 review based on recent DOE funding guidance. Data taking start in 2018 desired but that depends on the profile.
- WIMP sensitivity curve based on 1000 day live time.

LZ = LUX + ZEPLIN

Collaboration Counts: 30 Institutions

154 Headcount

LIP Coimbra (Portugal)

STFC Daresbury Laboratory (UK)

Edinburgh University (UK)

University of Liverpool (UK)

Imperial College London (UK)

University College London (UK)

MEPhI (Russia)

University of Oxford (UK)

Rutherford Appleton Laboratory (UK)

University of Sheffield (UK)

University of Alabama

University at Albany SUNY

Berkeley Lab (LBNL), UC Berkeley

Brookhaven National Laboratory

Brown University

Case Western Reserve University

University of California, Davis

Lawrence Livermore National Laboratory

University of Maryland

University of Rochester

University of California, Berkeley

University of California, Santa Barbara

University of South Dakota

South Dakota School of Mines & Technology

South Dakota Science and Technology Authority

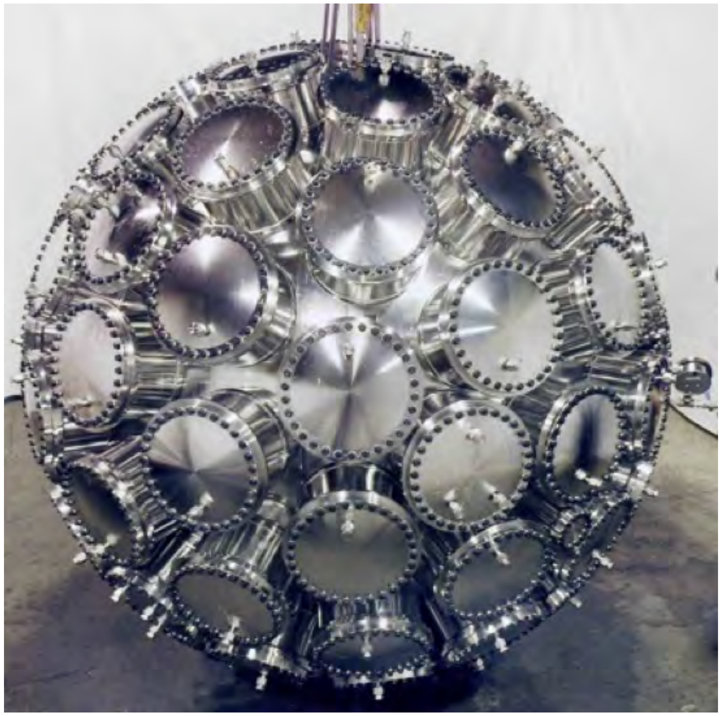
SLAC National Accelerator Laboratory

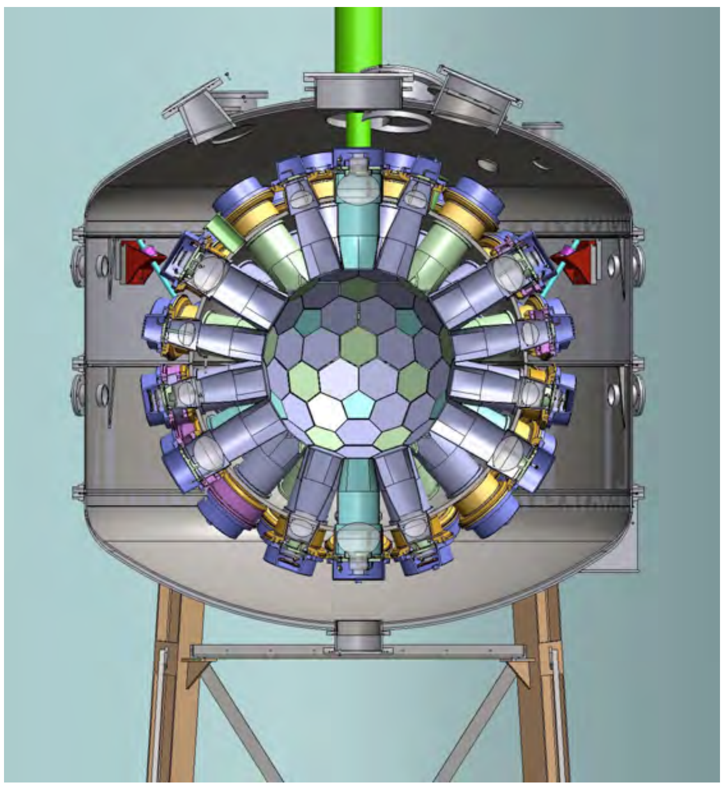
Texas A&M

Washington University

University of Wisconsin

Yale University





MiniCLEAN at SNOLAB:
A prototype for CLEAN

- Single phase Liquid Argon
  - 2014: Detector construction complete
  - 2015: Natural Ar & ^{39}Ar Spike Run
- 4π coverage to maximize light-yield at threshold …
  - 3D Position Reconstruction
  - Particle-ID via Pulse-shape discrimination (PSD)
- Radon-reduced assembly …
- No electric fields (better PSD)
  - PMTs only active component …
- "Cold" design allows both LAr & LNe
- Simple design scalable to 50–150 tonnes

OHEP funded measurement program

PandaX

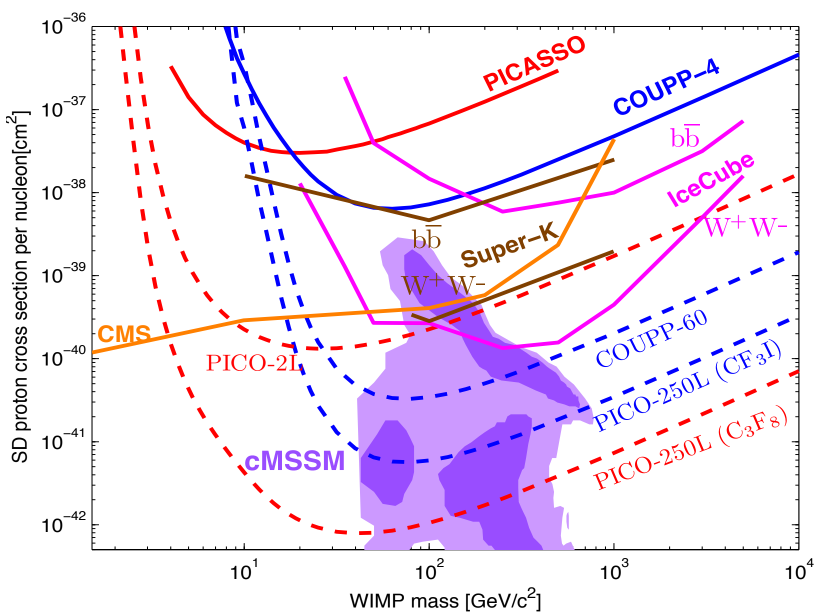
Email from Xiandong Ji (spokesperson) 9/28/14

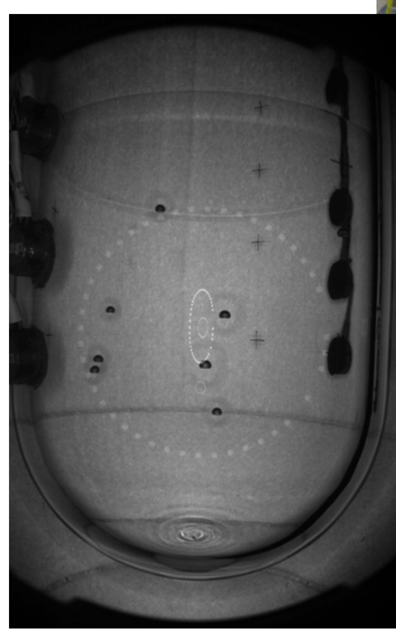
1. PandaX-II is a ½ ton LXe experiment which is under active development at this moment. We plan to take data sometime next year.
2. We will start a 20 ton LXe detector R&D soon and hope to get funding in China in the next few years to build it at Jinping underground lab.

PICO

PICO Bubble Chambers at SNOLAB

- **Exploit physics of bubble nucleation for background rejection. Multiple target liquids allow discrimination between WIMP models.**
- **PICO collaboration formed in 2013 by merger of PICASSO (primarily Canadian) and COUPP (USA). Twelve university groups + PNNL + FNAL.**
- **Currently operating: COUPP-60 and PICO-2L detectors. Most sensitive for spin-dependent WIMP- proton interactions.**
- **Ton-scale proposal: PICO-250L**





Neutron calibration

COUPP-60 Inner Vessel Installation

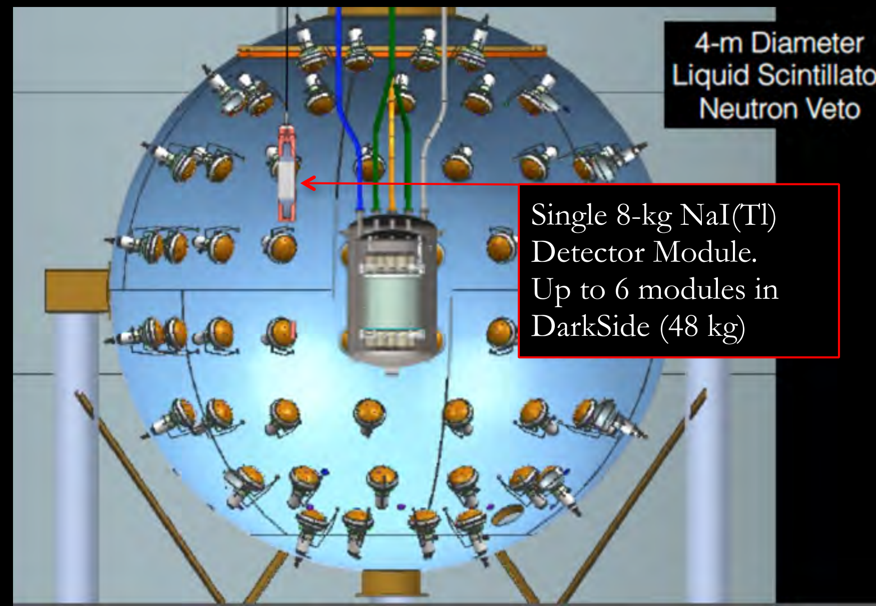
SABRE: Sodium iodide with Active Background REjection

Goal: definitive test of DAMA in 3 yr operation (>3σ).

- Ultra-high purity NaI powder and NaI(Tl) crystals.
- Low radioactivity, high Q.E. PMTs, directly coupled to crystals. (19 p.e./keV observed w/ 1" crystal).
- Active liquid scintillator veto to reject ^{40}K, etc.

Collaboration: Princeton University, University of Houston, PNNL, LNGS, INFN-Milano.

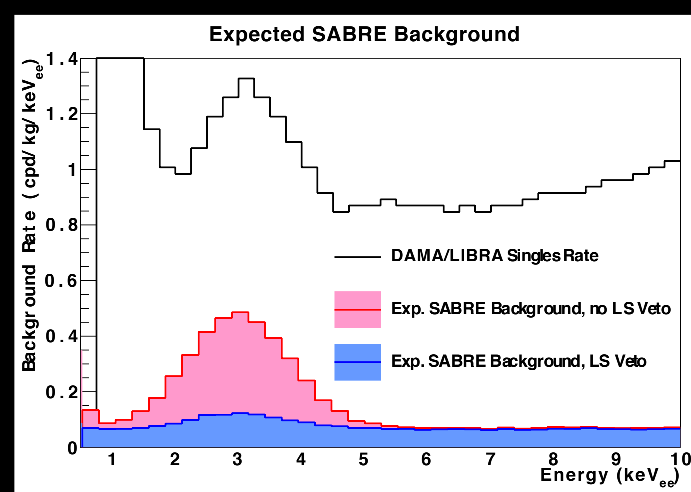
Status: Material screening and crystal growth study.



Test of single NaI(Tl) detector in Darkside, in preparation.

	SABRE NaI Powder	SABRE Test Crystals	DAMA Powder	DAMA Crystal
[K]	*3.5-18 ppb*	*T.B.D.**	*100 ppb*	*~13 ppb*
[Rb]	*0.2 ppb*	*<0.05 ppb*	*-*	*<0.35 ppb*
[U]	*<1 ppt*	*<1 ppt*	*~20 ppt*	*0.5-7.5 ppt*
[Th]	*<1ppt*	*<1 ppt*	*~20 ppt*	*0.7-10 ppt*

*Preliminary tests of crystal growing show <10 ppb increase in K.



Assuming 13 ppb K; U, Th, and Rb levels as in the current crystal tests.

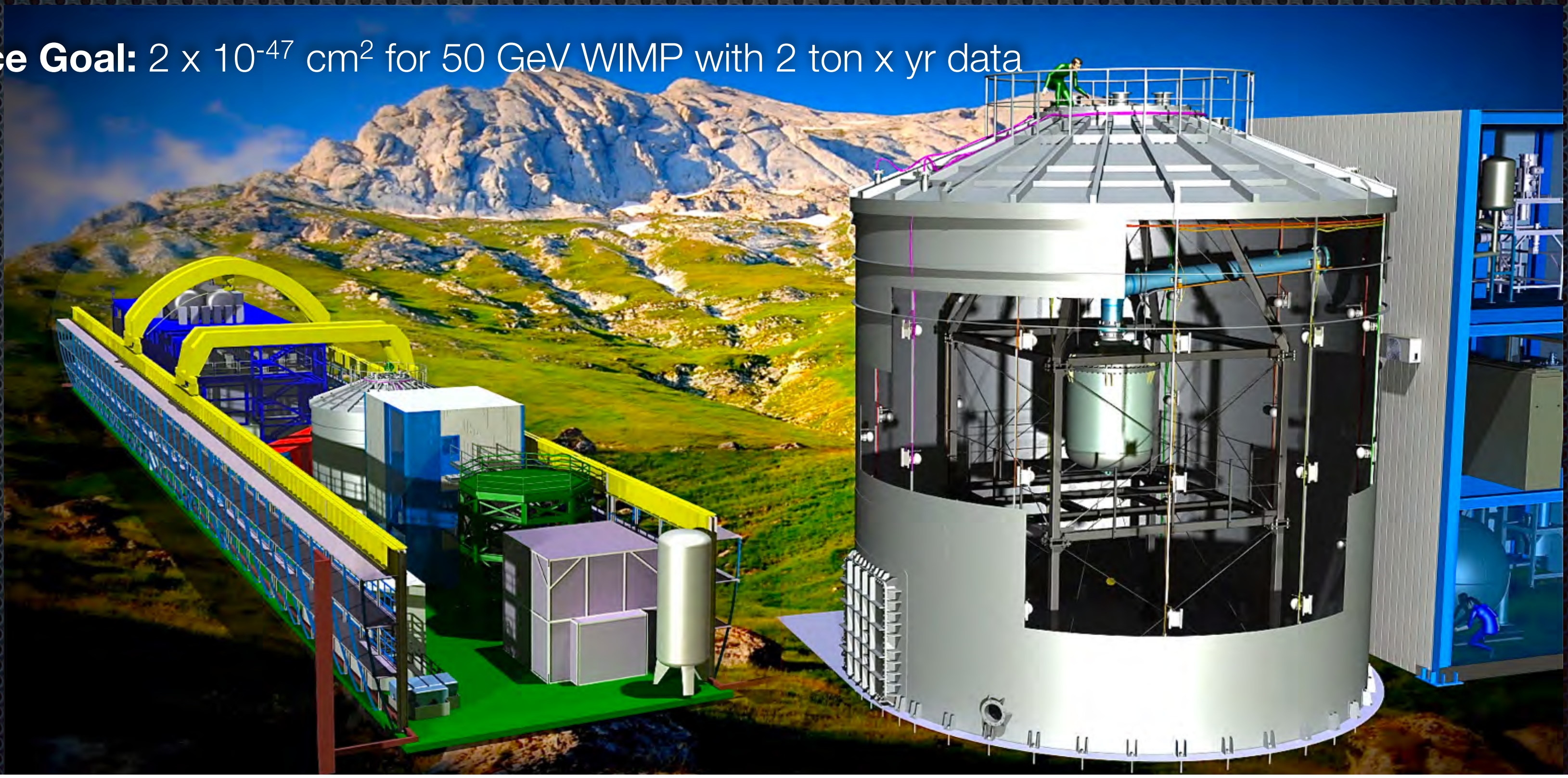
Next Steps:

- Medium size (Φ2.5"), high purity crystal (Late 2014)
- Large size(Φ4"), standard purity growth test (Late 2014)
- DS veto test (Φ3"x4" NaI(Tl) detector) (Late 2014)
- Portable LS detector available for alternate location (2015)

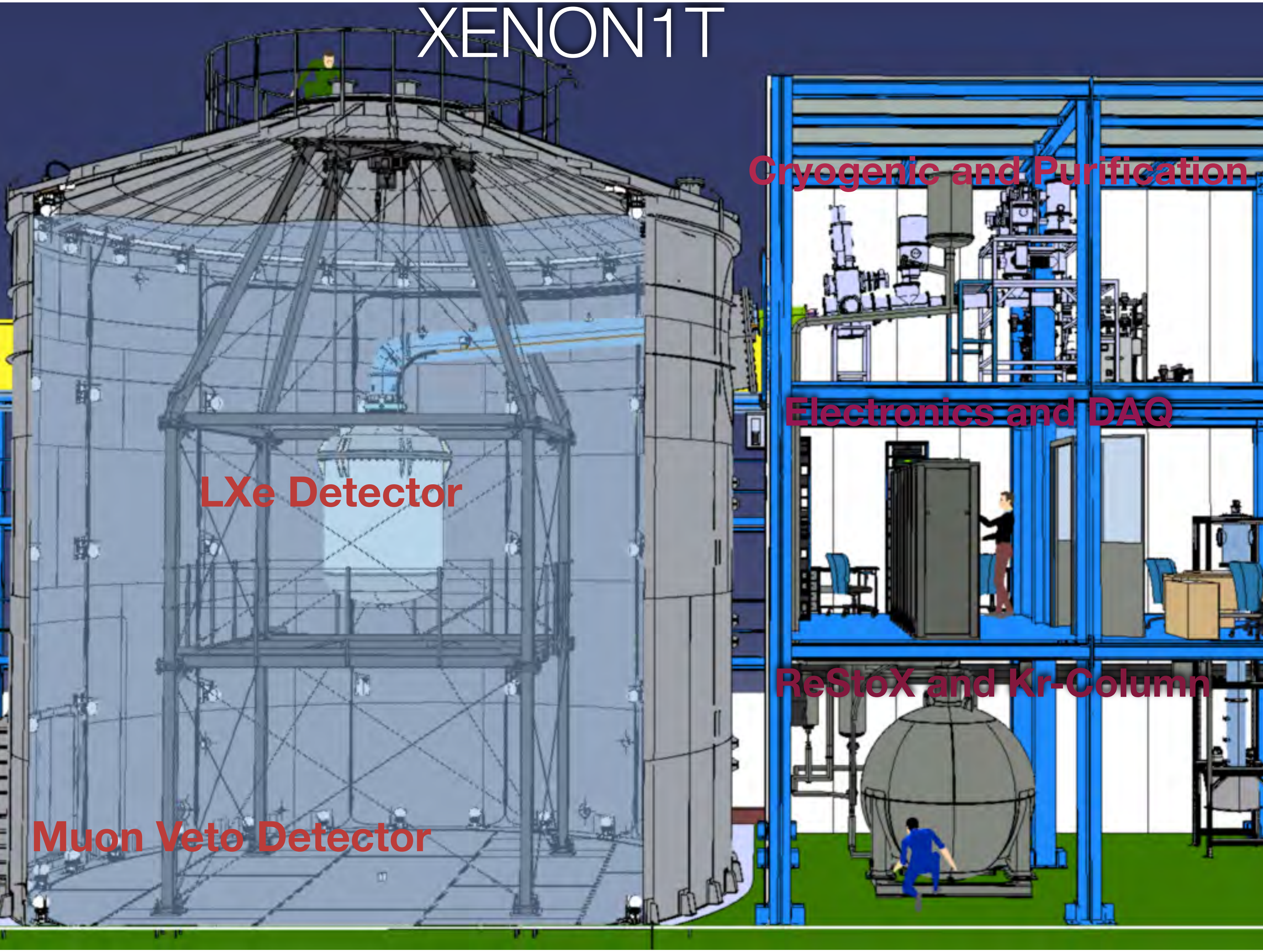
XENON 1T

The XENON1T Experiment

- **Location:** LNGS - Hall B. TDR submitted to LNGS in Fall 2010. US groups proposal submitted to the NSF in Fall 2011. Proposal reviewed by panel in March 2012. Approved by NSF in FY12.
- **Cost:** Total capital cost ~20M$ (including investments made for XENON100). 50% from non-US groups.
- **Detector:** 1m- drift dual-phase TPC with 3.3 t LXe viewed by 250 3-inch PMTs
- **Shield**: water Cherenkov muon veto. **Back goal:***100 x lower than XENON100, ~5 x 10^{-2} events/(t-d-keV)*
- **Status:** In advanced face of construction. Water Tank and Service Building completed. Cryogenic plants and Cryostat installed and commissioning ongoing. Detector installation by Spring 15. Integration with Muon Veto by Summer 15. Complete commissioning/ start science run by late 2015.
- **Science Goal:** 2 x 10^{-47} cm^2 for 50 GeV WIMP with 2 ton x yr data



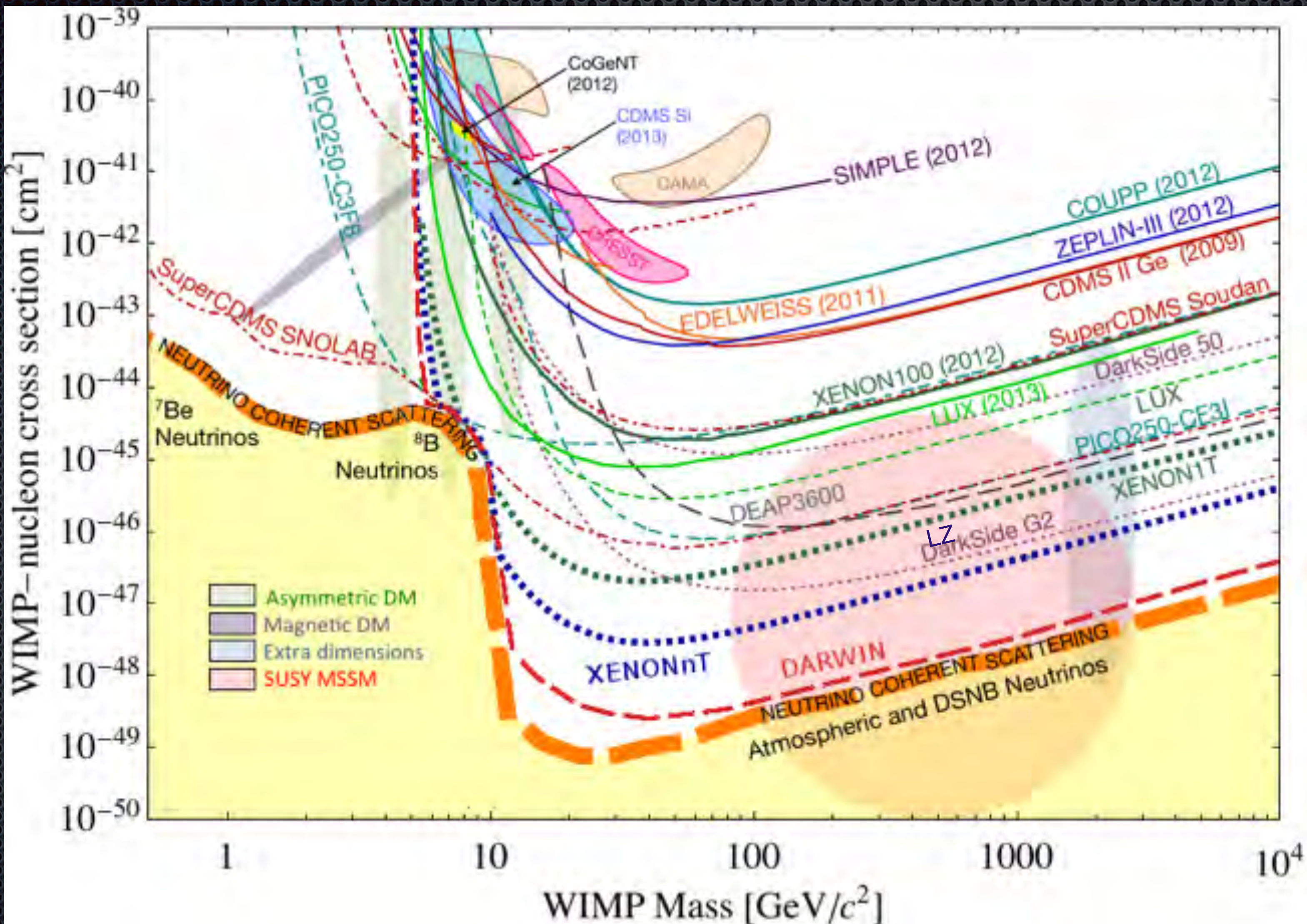
XENON1T



Cryogenic and Purification
Electronics and DAQ
LXe Detector
ReStoX and Kr-Column
Muon Veto Detector

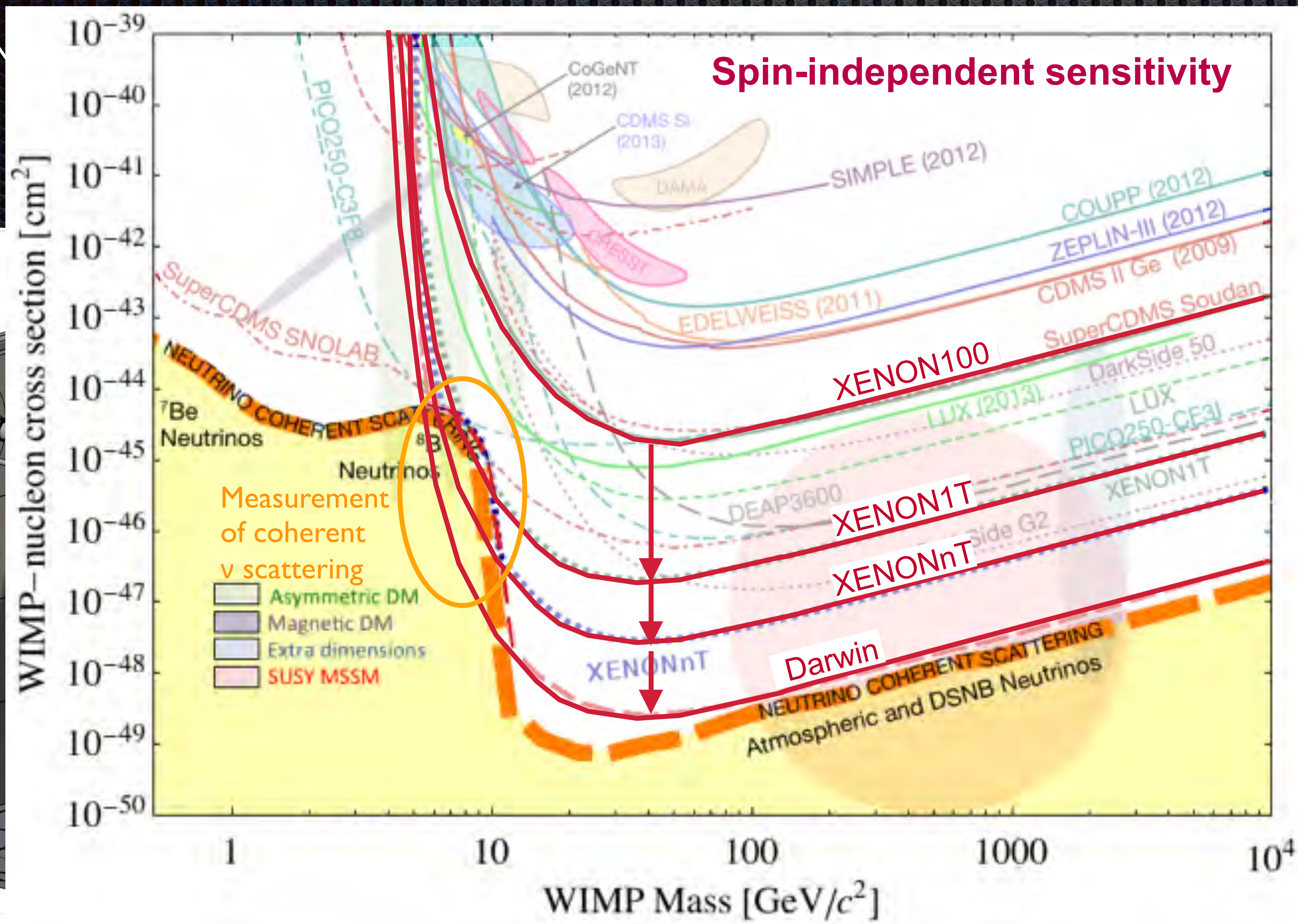

XENON

XENON1T Projected Sensitivity



XENONnT: 2018 - 2022

- Double the amount of LXe (~7 tons), double the number of PMTs
- XEN … e upgrade:



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support

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XMASS

XMASS for the next 5 years

Operation 2017

≈ 2019

XMASS1.5: Single Phase Liquid Xenon Detector (5 ton total, 1 ton fiducial mass)
Energy threshold: 2keVee for fiducial volume analysis and 0.3 keV for whole volume analysis

XMASSII: Single Phase Liquid Xenon Detector (24 ton total, 10 ton fiducial mass)
Energy threshold: 2keVee for fiducial volume analysis and 0.3 keV for whole volume analysis