Other WIMP Direct Detection Experiments

Jodi Cooley
Southern Methodist University

Outline

- Principles common to experiments
- The Experiments
  - Part 1: The low mass region
  - Part 2: The long standing DAMA/LIBRA experiment
  - Part 3: The search continues...
- Concluding Remarks

World-Wide Experiments

Phonon/Charge/Light:
- CDMS/SuperCDMS
- EDELWEISS
- CRESST

Charge Only:
- CoGeNT/C4
- TEXANO
- CDEX
- CDMSlite

Multi-purpose:
- Majorana Demonstrator
- COURE-0/COURE

Modulation:
- DAMA/LIBRA
- DM-ICE
- KIMS
- ANAIS
- SABRE
- KamLAND-PICO

Directional:
- DRIFT
- DM-TPC

Other:
- DAMIC
- NEXT

Bubble Chambers/Superheated:
- PICASSO
- COUPP
- PICO

*Experiments in red are presenting results or status in parallel sessions.

World-Wide Experiments

Too Many Experiments, Too Little Time - My Apology for not Covering All

Phonon/Charge/Light:

CDMS/SuperCDMS

EDELWEISS

CRES

Charge

CoGe

TEXA

CDEX

CDMS

Modulation:

DAMA/LIBRA

DM-ICE

Directional:

DRIFT

DM-TPC

er:

AMIC

EXT

eated:

Multi-purpose:

Majorana Demonstrator

COURE-0/COURE

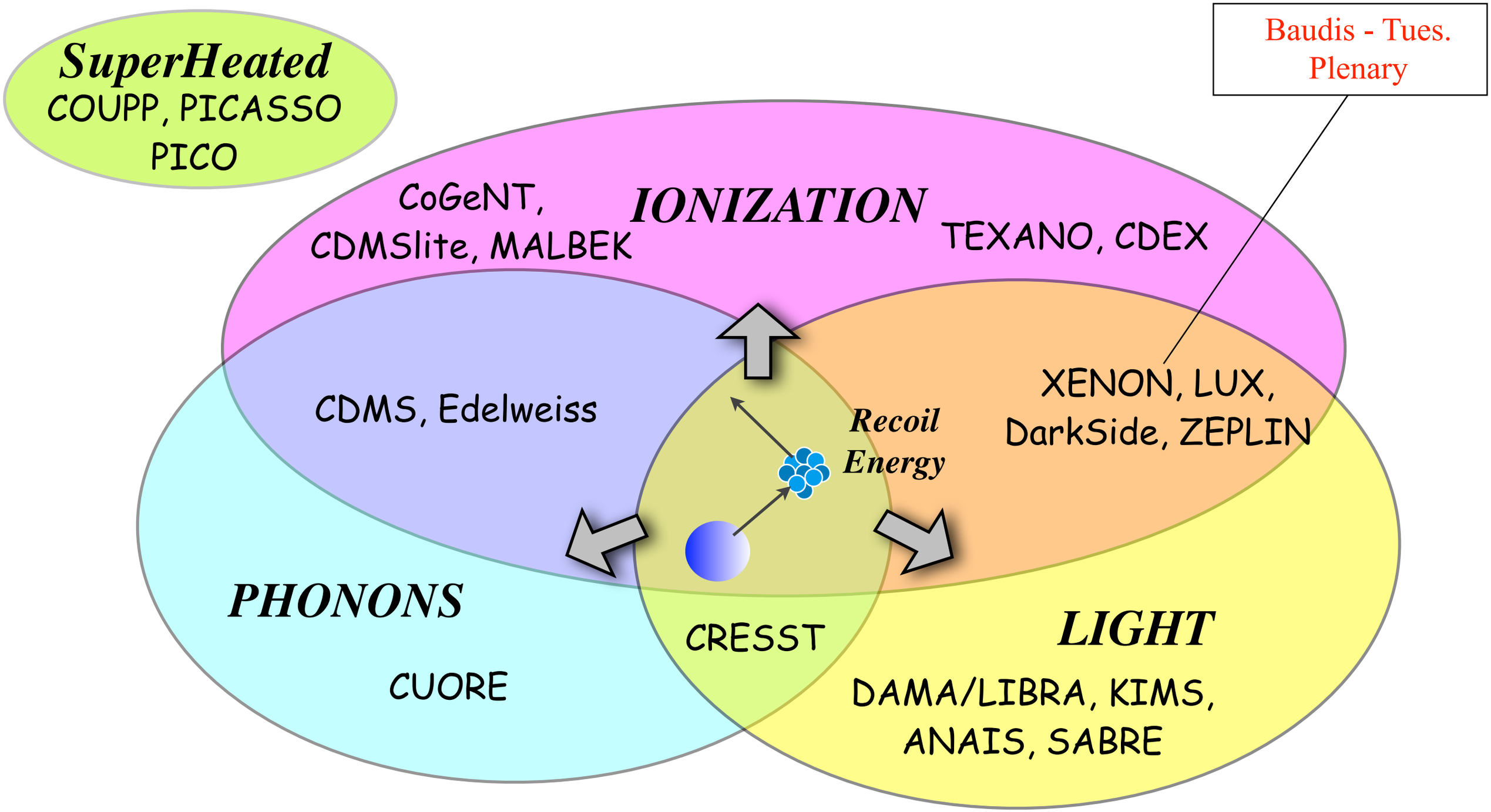
PICASSO

COUPP

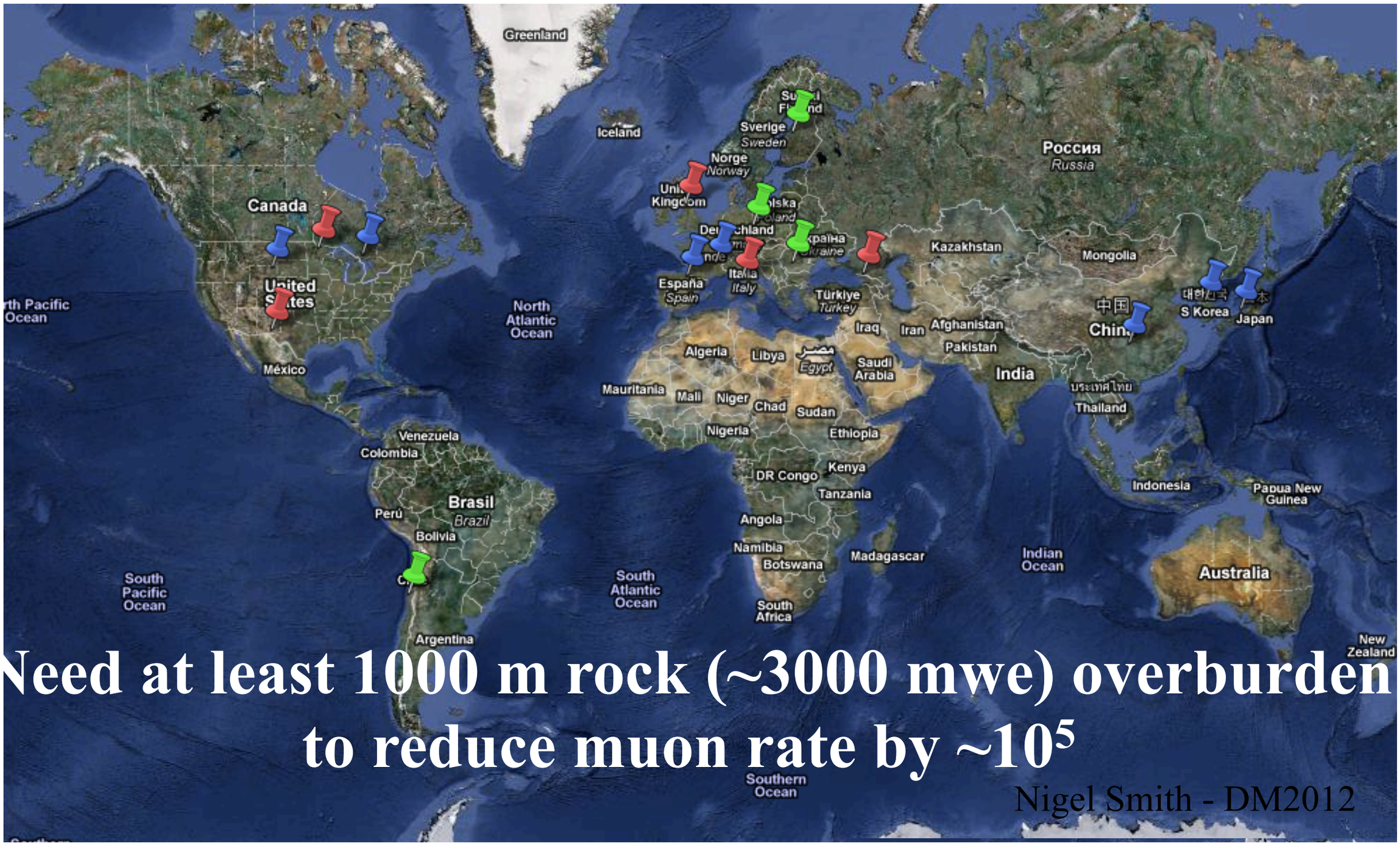
PICO-lite

*Experiments in red are presenting results or status in parallel sessions.

Direct Detection



Minimize Backgrounds



Need at least 1000 m rock (~3000 mwe) overburden to reduce muon rate by ~10^5

Nigel Smith - DM2012

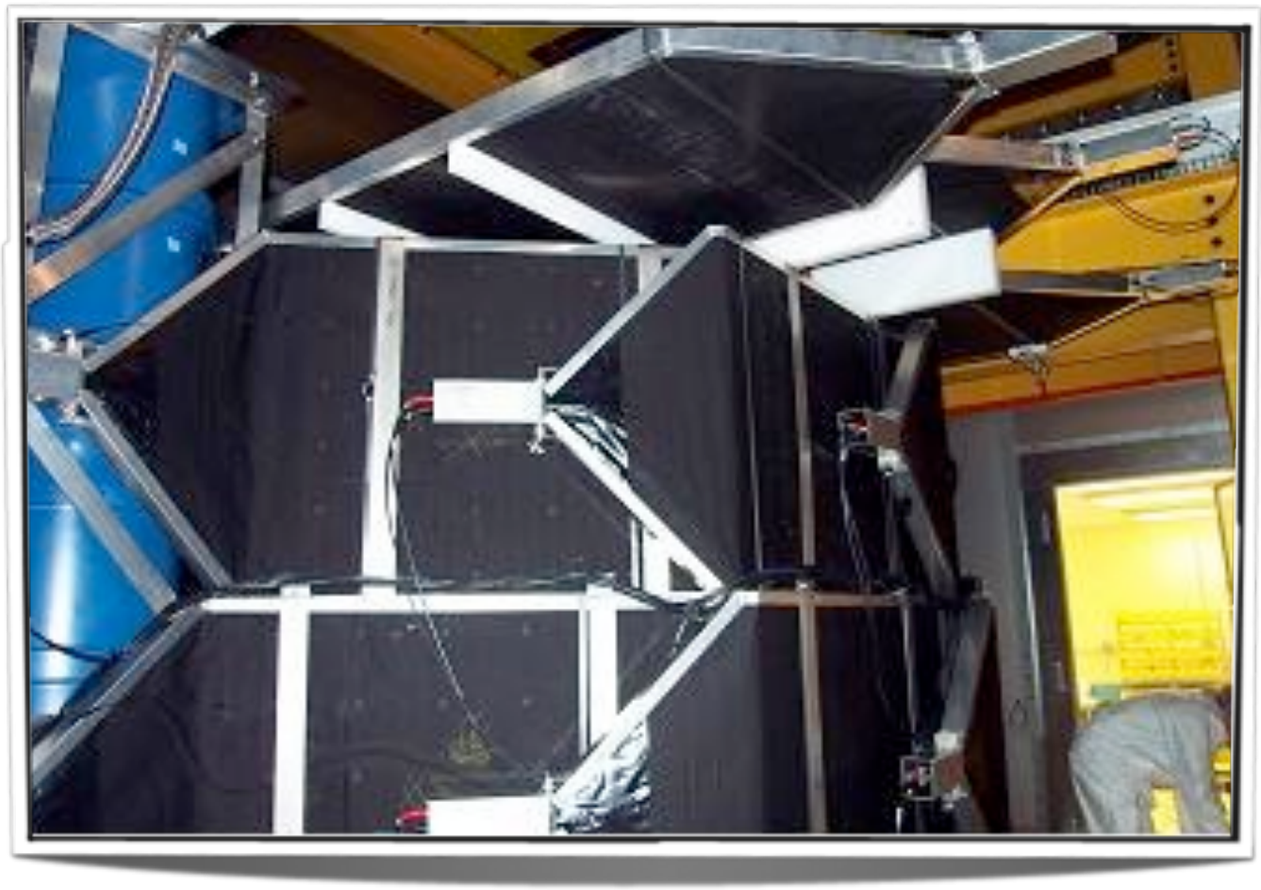
Site experiments underground.

Minimize Backgrounds

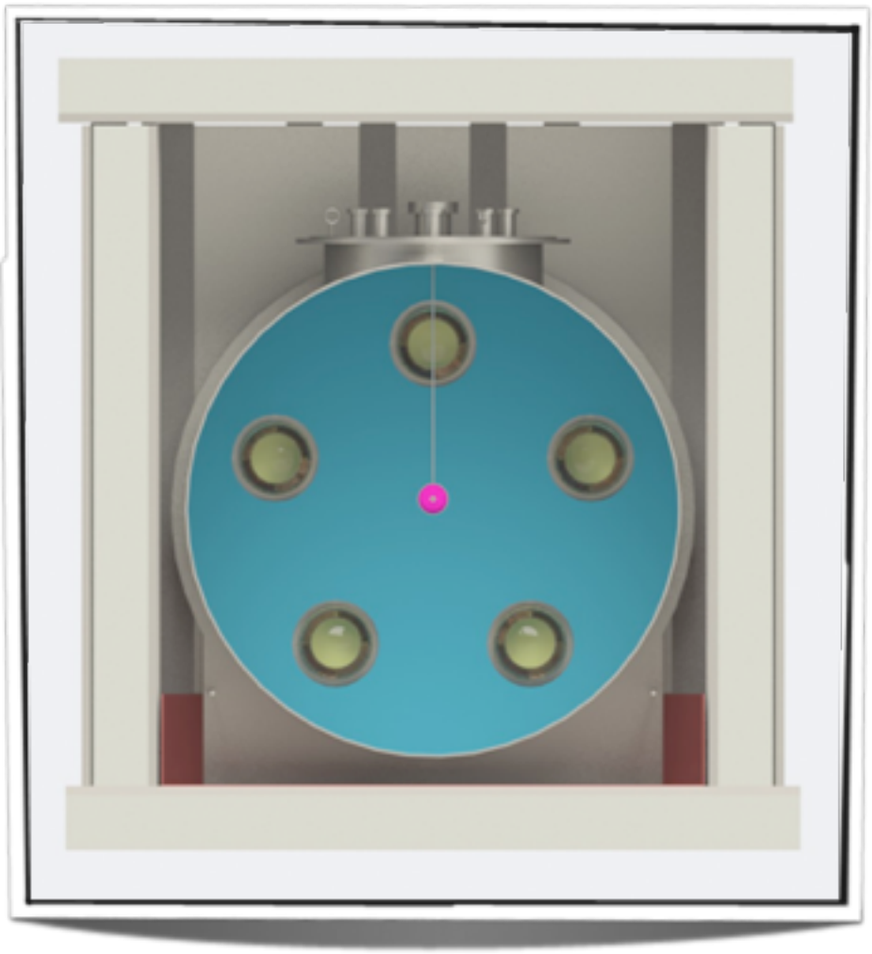
Active Muon Veto:

rejects events from cosmic rays

- Scintillating panels
- Water/Liquid Scintillator Shield



SCDMS active muon veto



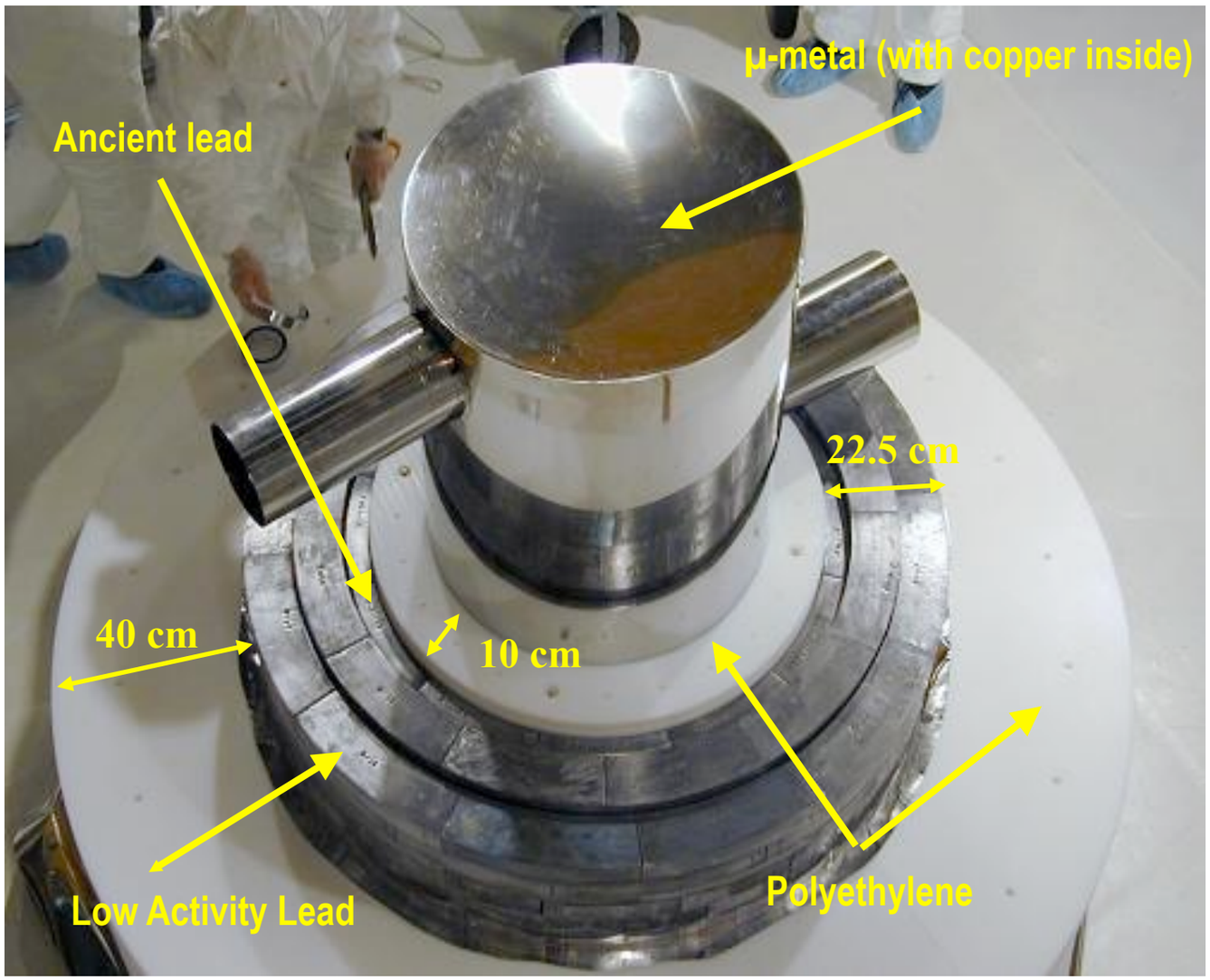
SABRE LAB shield design

Minimize Backgrounds

Use Passive Shielding

Pb: shielding from gammas resulting from radioactivity

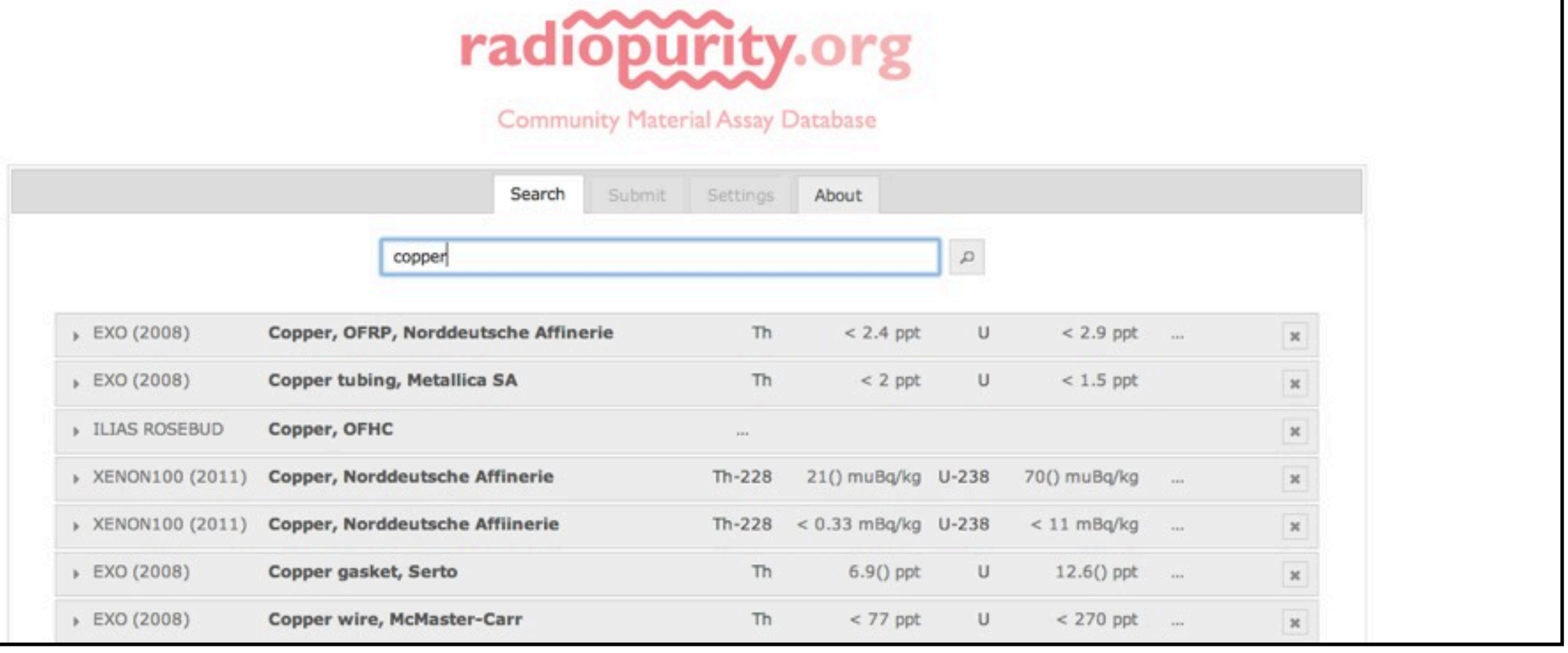
Polyethyene: moderate neutrons produced from fission decays and from (α,n) interactions resulting from U/Th decays



SCDMS - Layers of Polyethylene and Lead

Minimize Backgrounds

Use Clean Materials

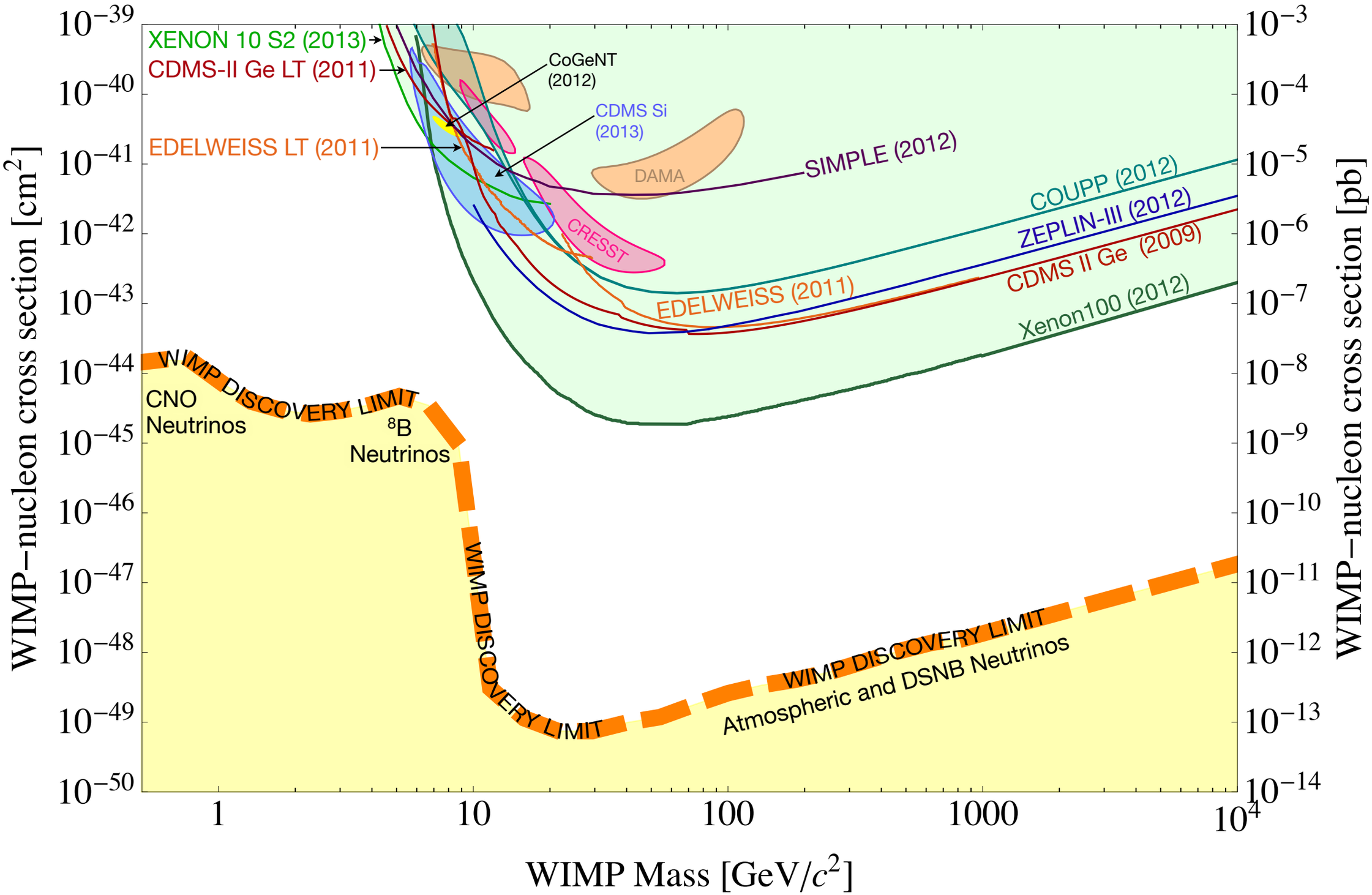


EXO (2008)	**Copper, OFRP, Norddeutsche Affinerie**	Th	< 2.4 ppt	U	< 2.9 ppt	...
EXO (2008)	**Copper tubing, Metallica SA**	Th	< 2 ppt	U	< 1.5 ppt	
ILIAS ROSEBUD	**Copper, OFHC**	...				
XENON100 (2011)	**Copper, Norddeutsche Affinerie**	Th-228	21() muBq/kg	U-238	70() muBq/kg	...
XENON100 (2011)	**Copper, Norddeutsche Affiinerie**	Th-228	< 0.33 mBq/kg	U-238	< 11 mBq/kg	...
EXO (2008)	**Copper gasket, Serto**	Th	6.9() ppt	U	12.6() ppt	...
EXO (2008)	**Copper wire, McMaster-Carr**	Th	< 77 ppt	U	< 270 ppt	...

http://radiopurity.org

Supported by AARM, LBNL, MAJORANA, SMU, SJTU & others

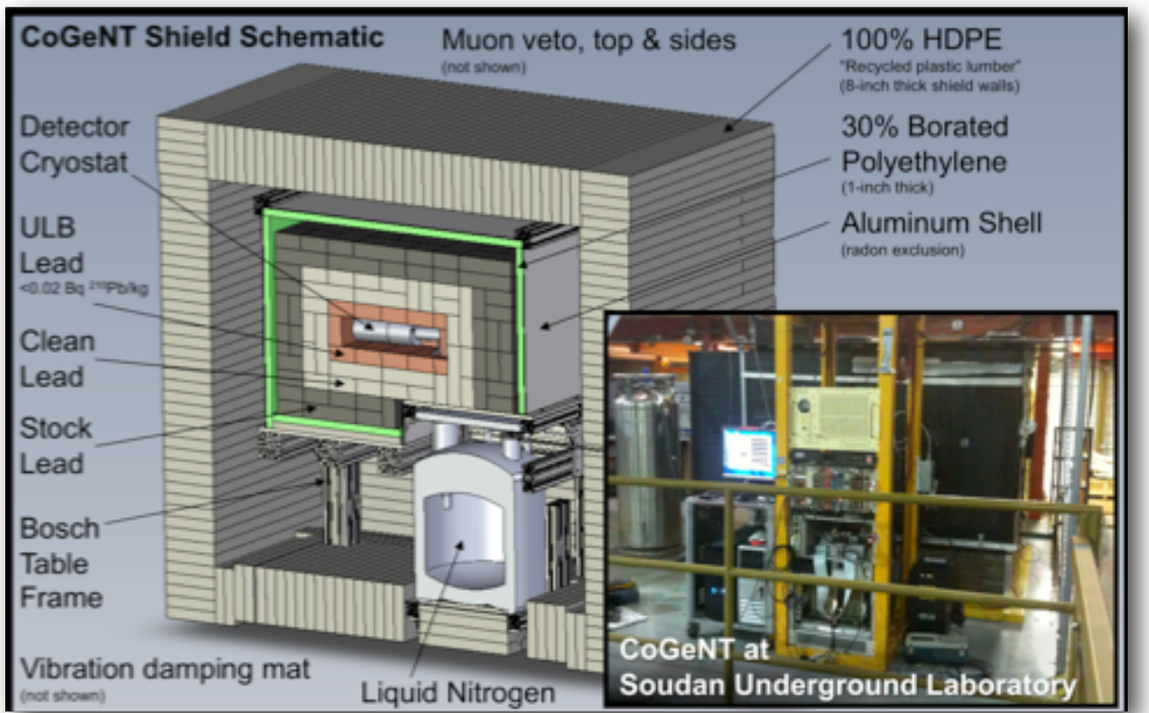
Where Are We Now?



The Experiments Part 1: The Low Mass Region

Excesses Reported by DAMA/LIBRA, CoGeNT, CRESST and CDMS

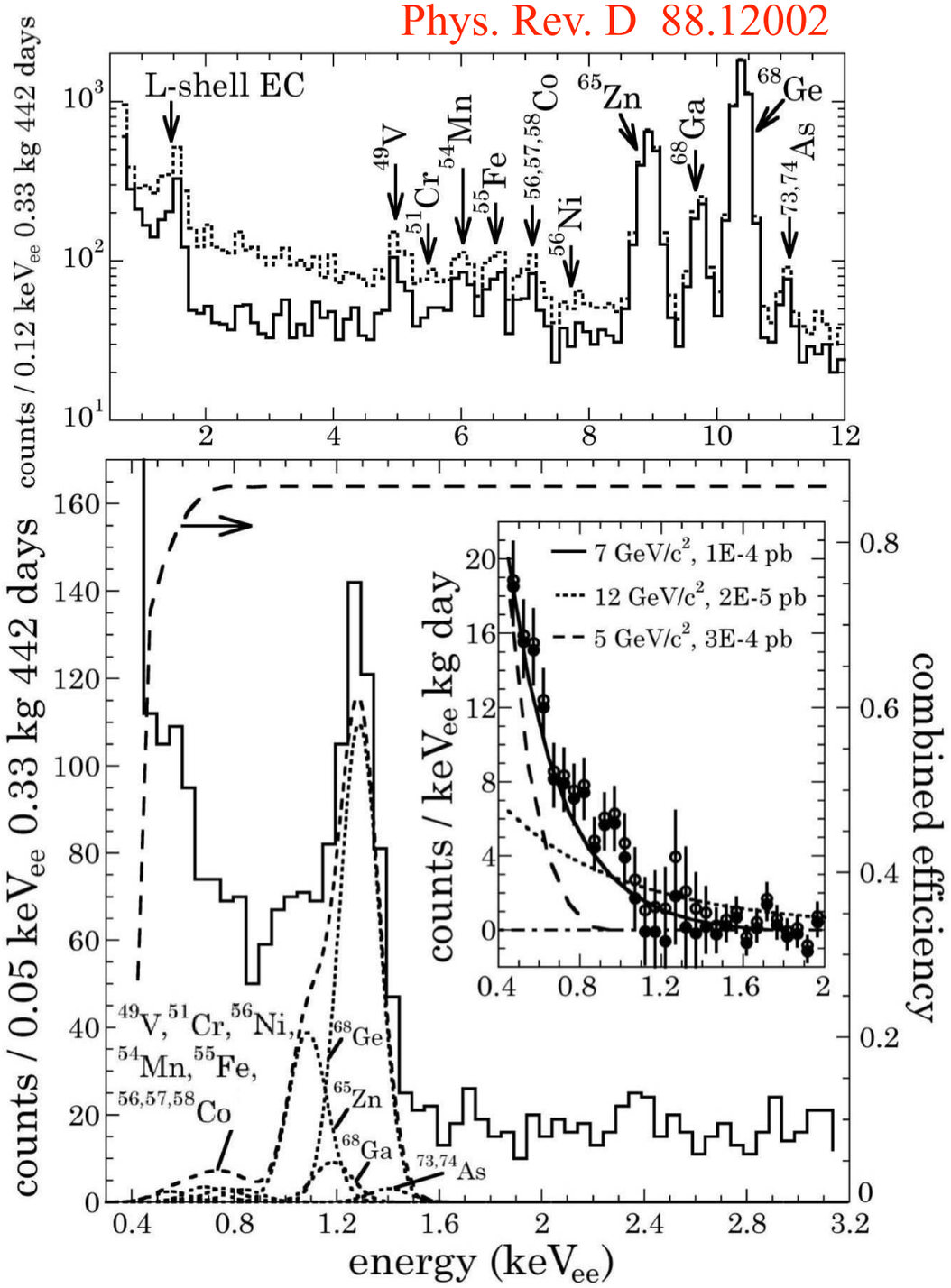
CoGeNT



- Location: Soudan Underground Laboratory, Minnesota, USA
- 440 g HPGe ionization spectrometer
- Data collection from Dec. 4, 2009 - Mar. 6, 2011 (442 live days)
- Data collection interrupted due to fire.
- Data collection resumed July 2011.

CoGeNT

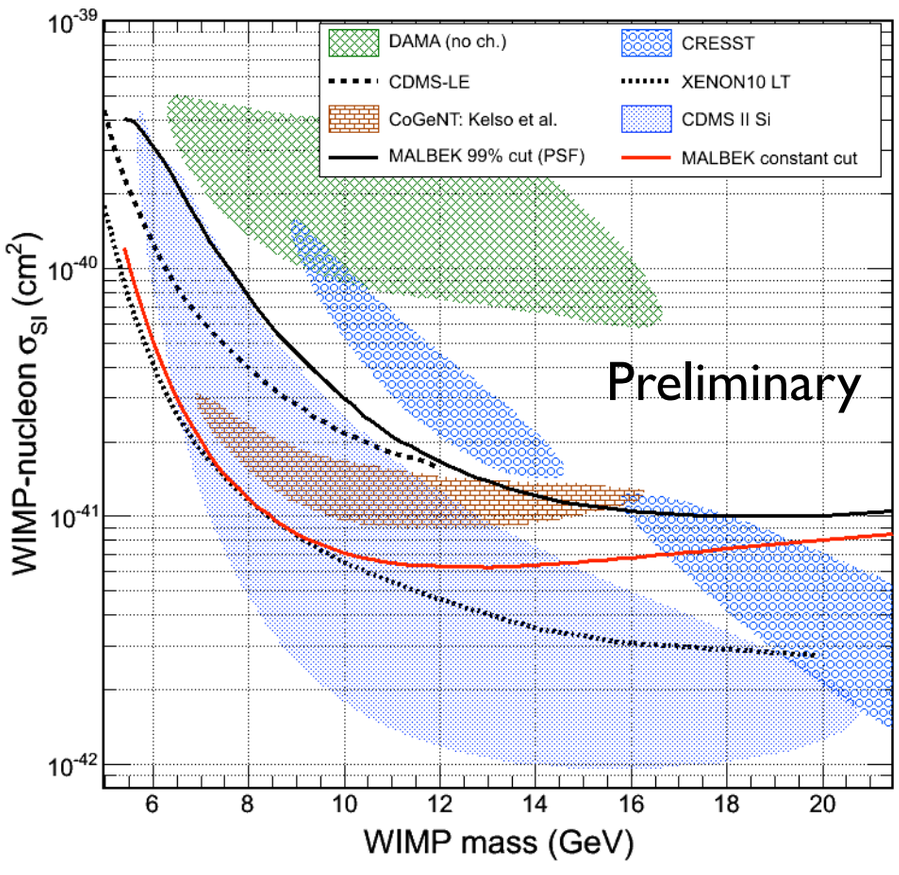
Phys. Rev. D 88.12002

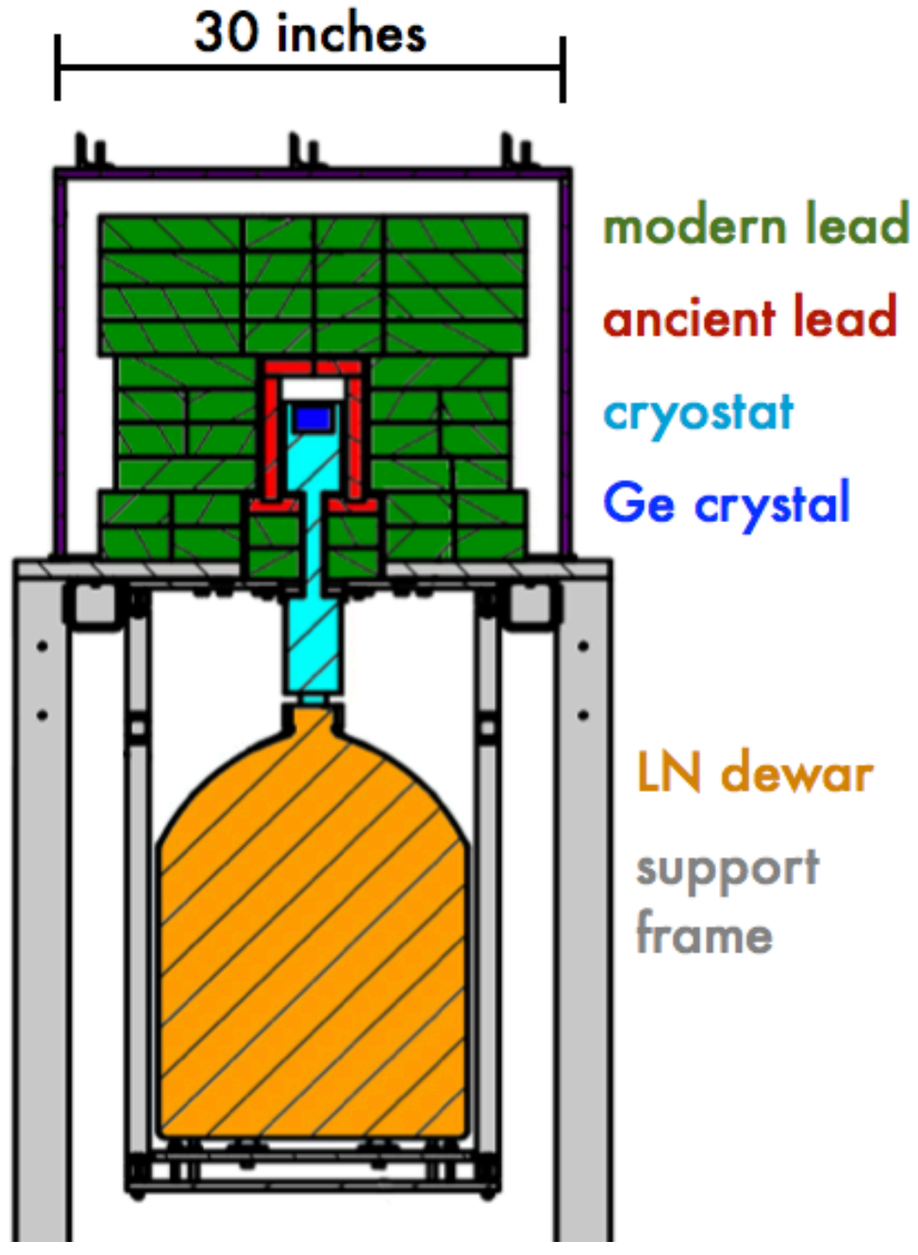


- First claim of excess in 2010.
- Reject surface events using risetime cut (2011).
- Peaks due to cosmogenic activation of Ge
- After subtraction of known background, an exponential excess of events remains
- Fits to a variety of light-WIMP masses and couplings shown in inset of lower figure.
- Publication of new data coming soon.

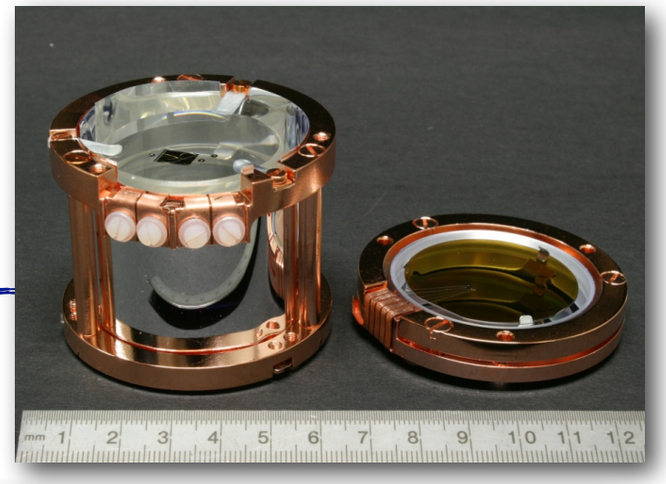
MALBEK

- MAJORANA Low-background BEGe detector at KURF.
- 450g Canberra Broad Energy Ge (BEGe) detector with ultra-low background components provided by J.I. Collar.
- Location: Kimballton Underground Research Facility (KURF), VA at 1450 mwe.
- 90% exclusion limits from 221 day data run.

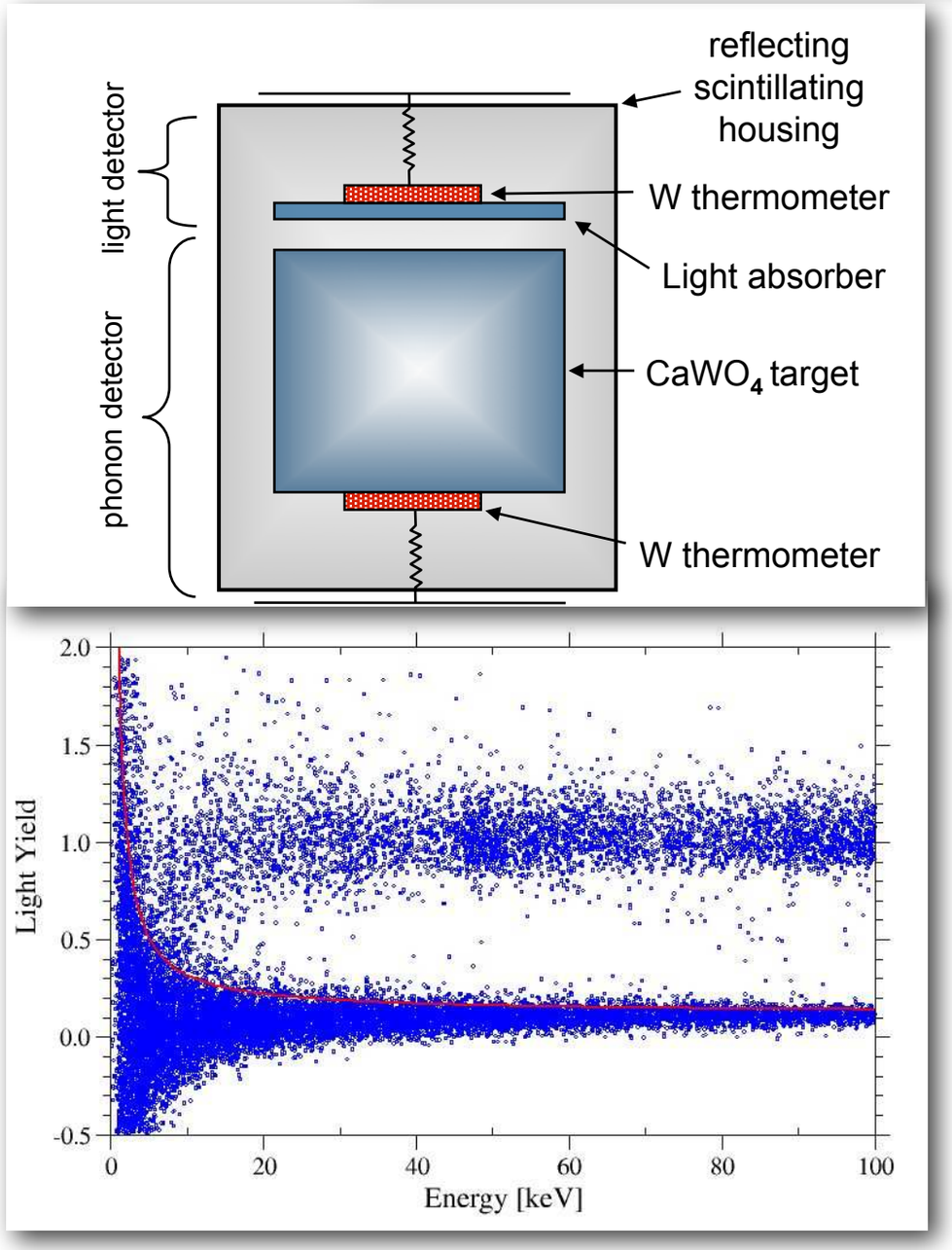




CRESST

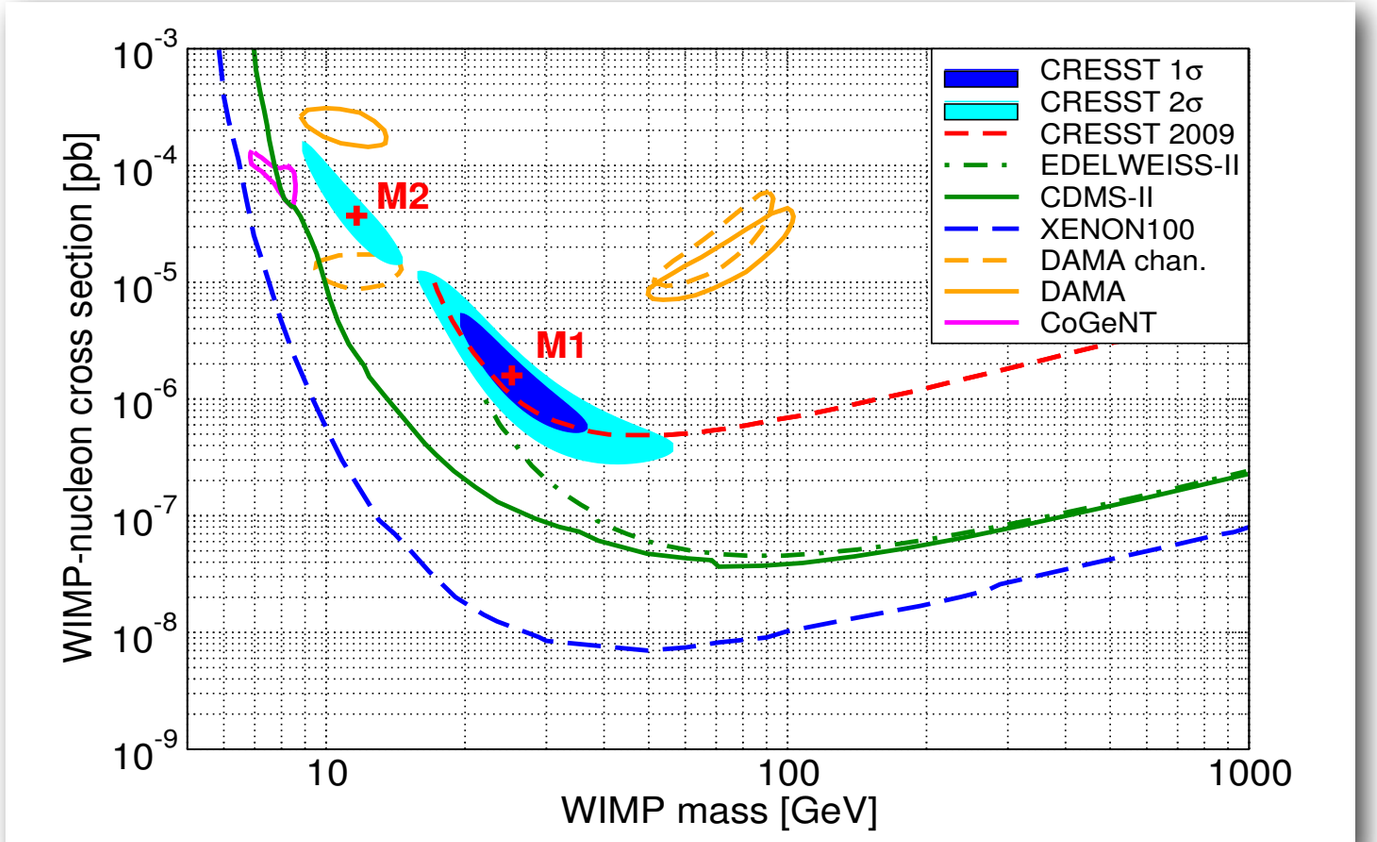


- Cryogenic $CaWO_4$ crystals (~300 g each) are instrumented to readout phonon energy and scintillation.
- Location: Laboratori Nazionali del Gran Sasso, Italy
- Discrimination between ER and NR events via light yield (light/phonon energy)
- Net exposure: 730 kg-day (July 2009 - March 2011) from 8 detector modules.
- Observed 67 events in acceptance region (orange). **arXiv:1109.0702**
  - Analysis used a maximum likelihood in which 2 regions favored a WIMP signal in addition to predict background.
  - Excess events can not be explained by known backgrounds
  - Large background contribution



CRESST Plans

- Current data run aims to reduce background, increase detector mass.
  - Alphas - new clamping design and material
  - Detector assembly in a radon free environment
  - New detector design to discriminate ^{206}Po recoils
  - Add additional shielding to reduce neutron background

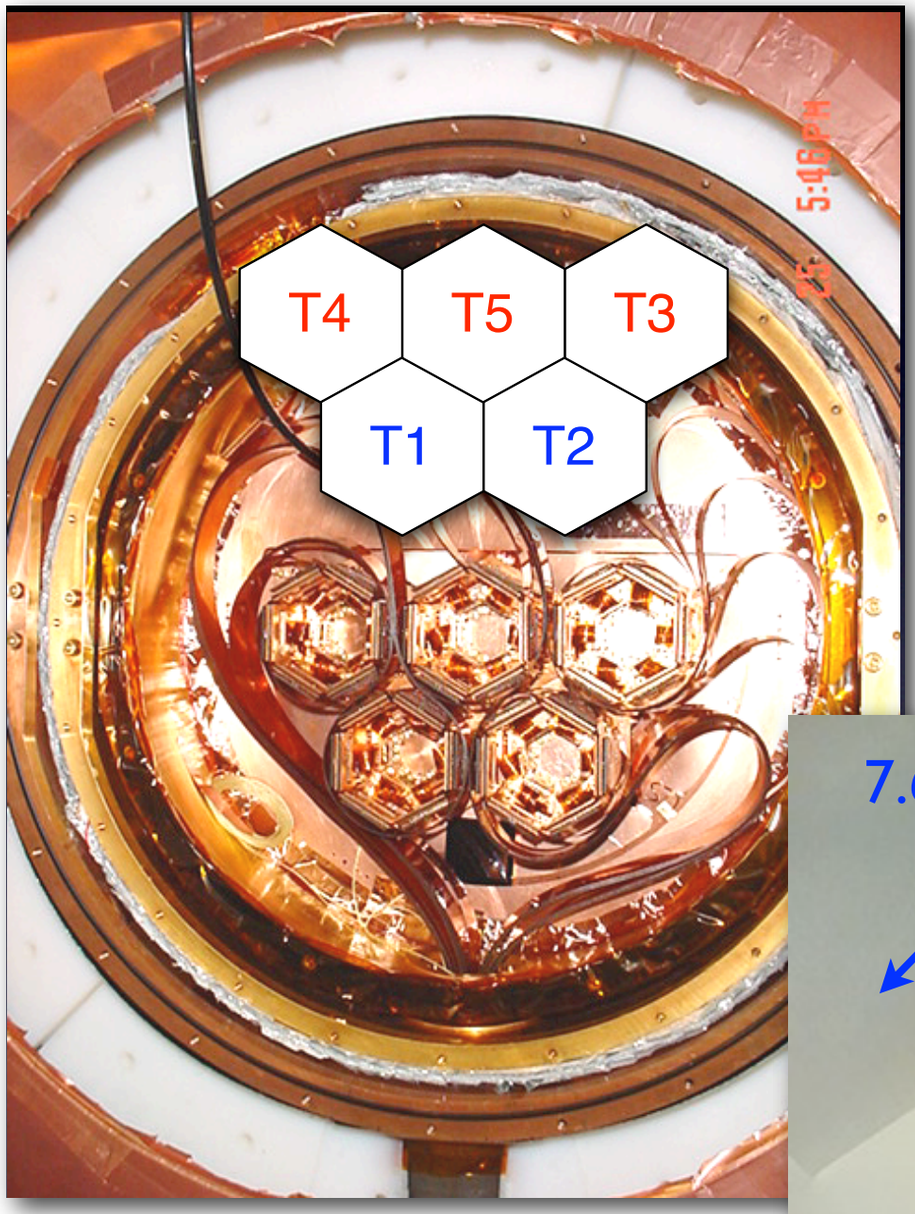


arXiv:1109.0702

- June & July calibration runs with ^{57}Co source were successful.
- **July 30th, 2013 Science Runs Begin!**

CDMS II

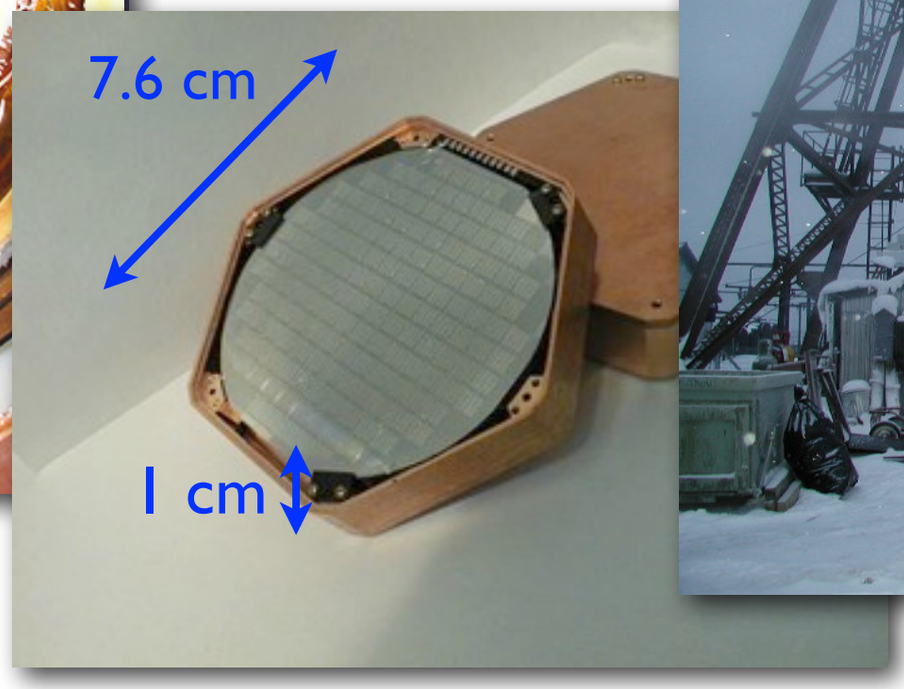
Billard - Mon. DM I
Nelson - Mon. DM II
Speller - Poster



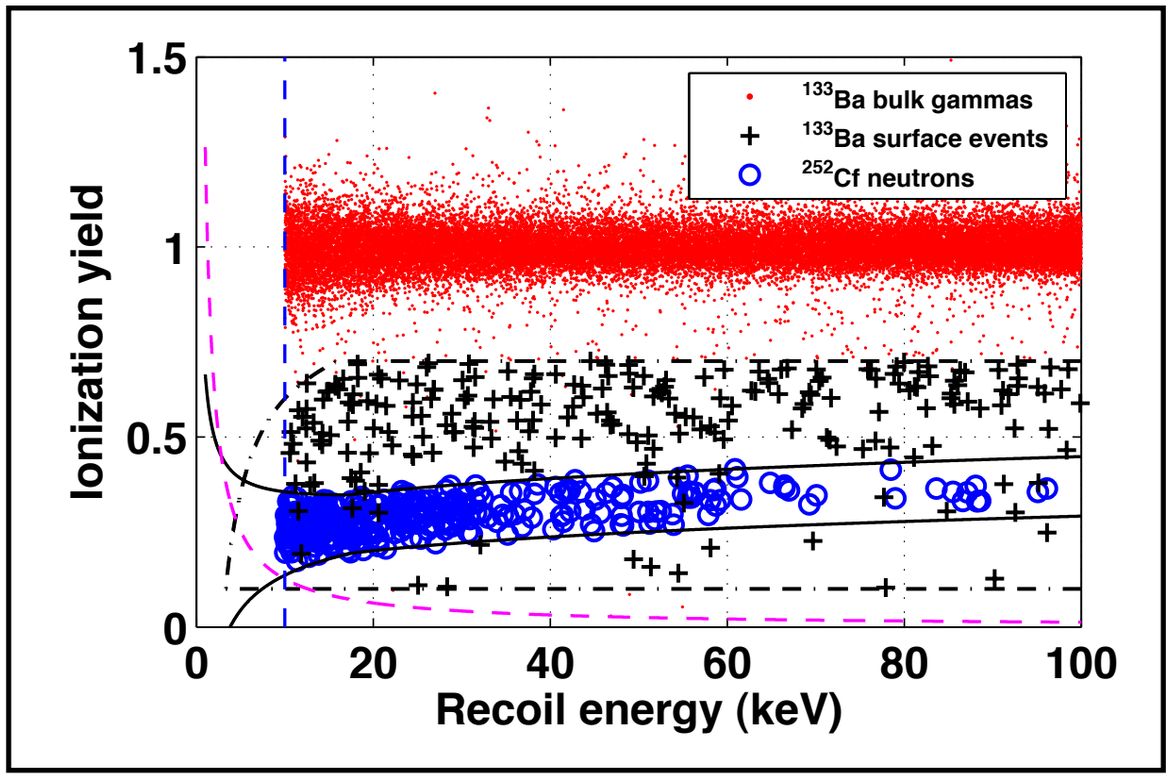
- CDMS II: 30 detectors (19 Ge, 11 Si) installed and operated in the Soudan Underground Laboratory, MN, USA from Jun. 06 - Mar. 09.

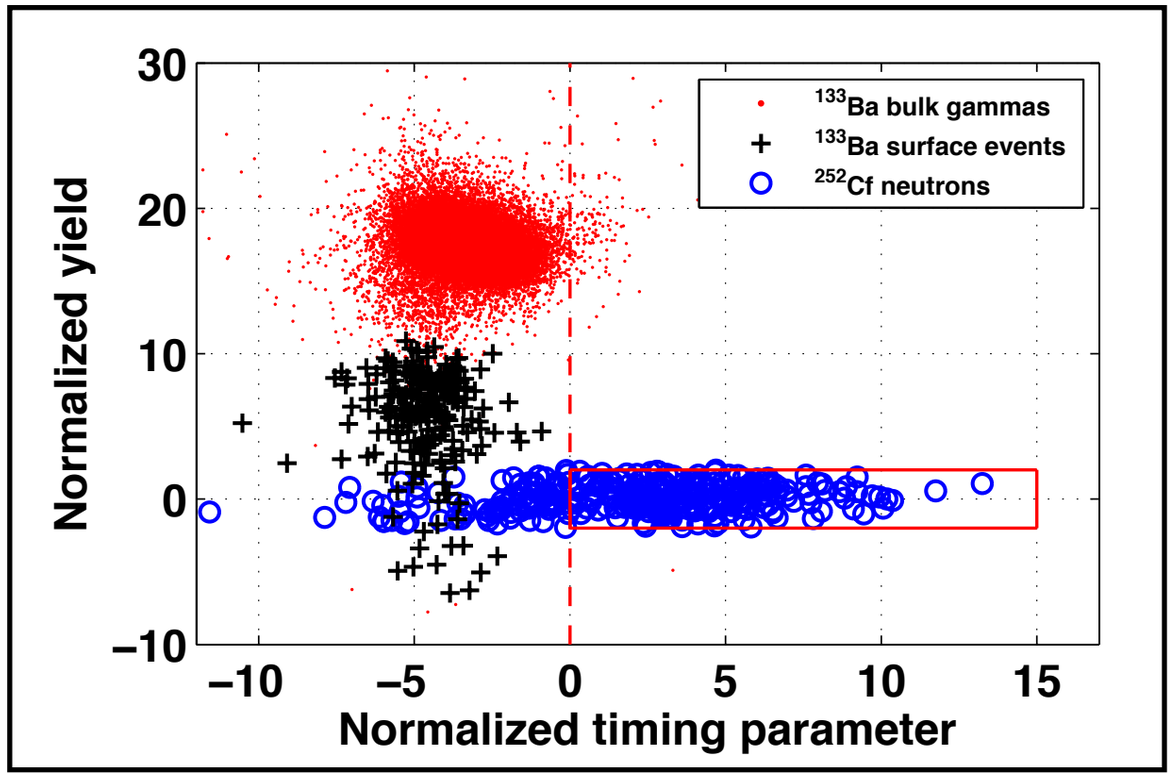
- Measures ionization and phonons (read out by TES)

- Science Results: CDMS-Ge, CDMS-Si, Ge-Low Threshold, Annual Modulation



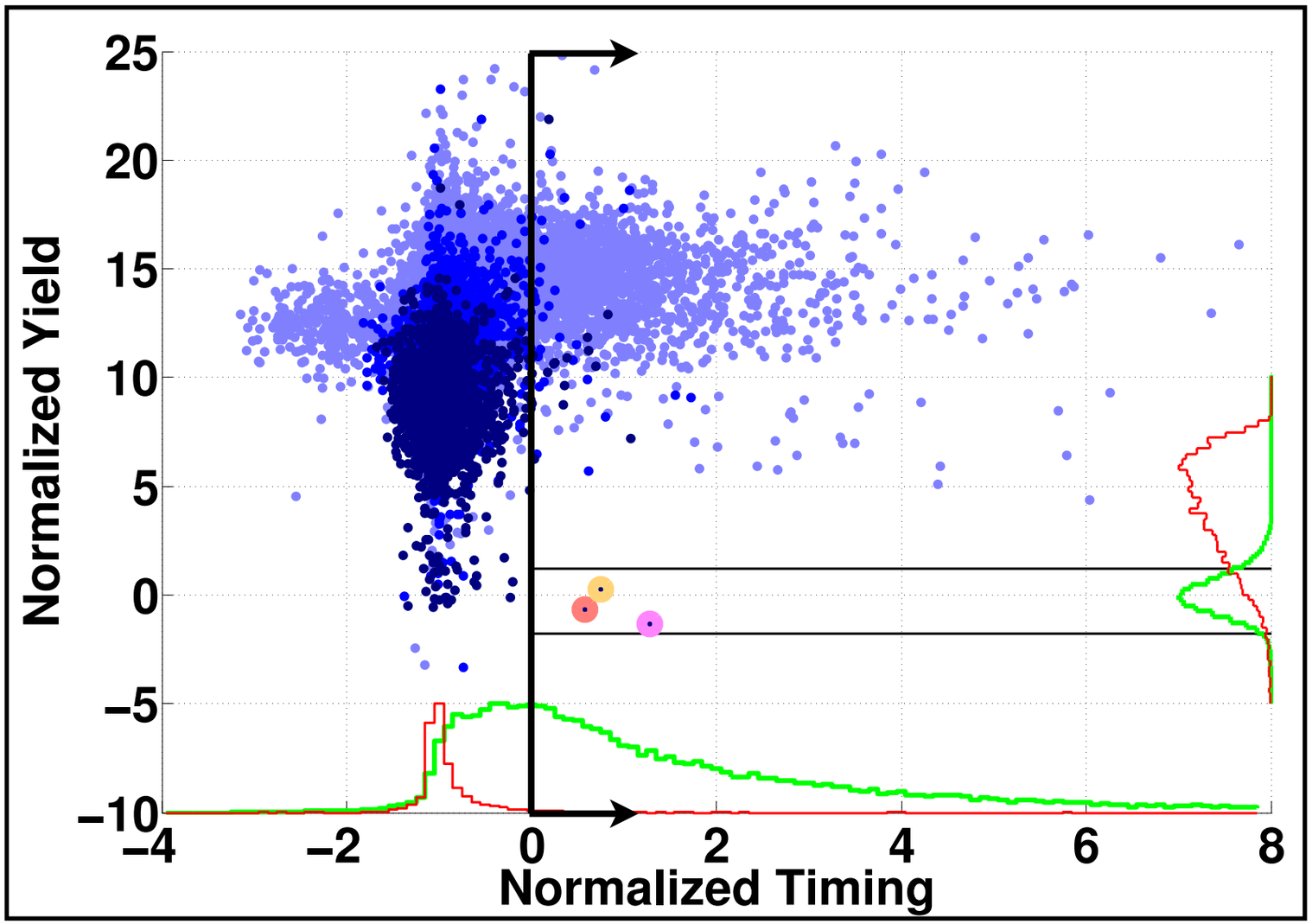
Background Rejection





- Most backgrounds produce electron recoils and have yield (ionization/phonon energy) ~1.
- WIMPs and neutrons produce nuclear recoils and have yield ~0.3.
- Surface events can be identified using timing properties of the phonon and charge pulses.

Recent Results: CDMS II-Si Detectors



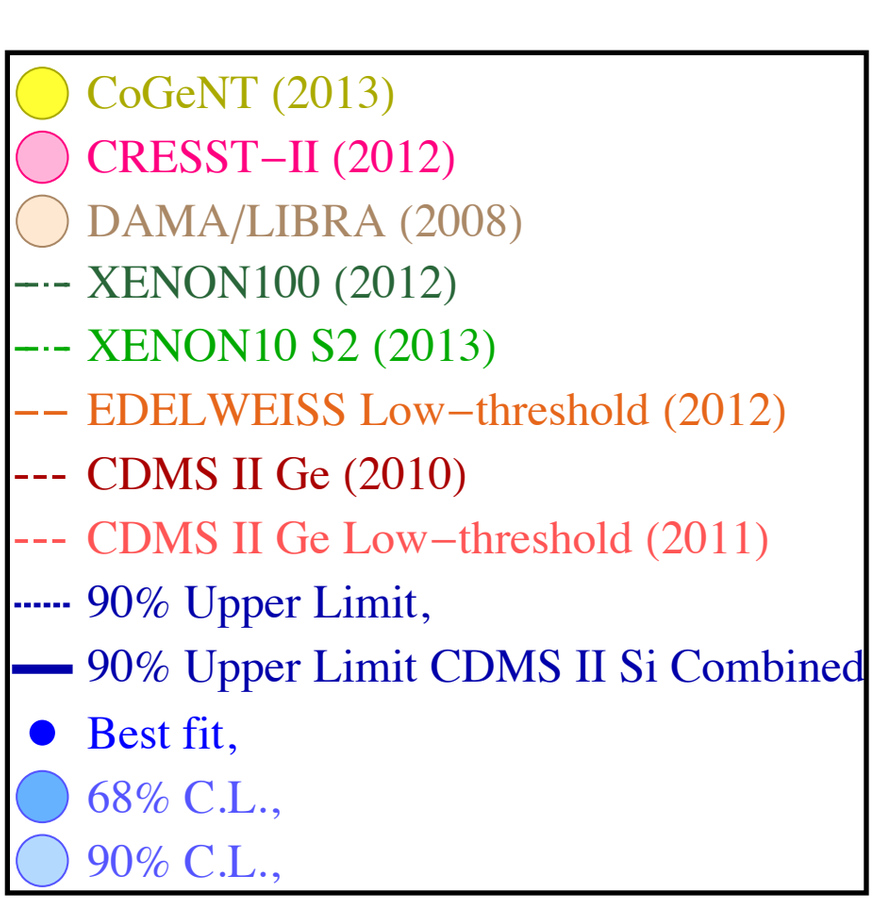
Observed 3 events.

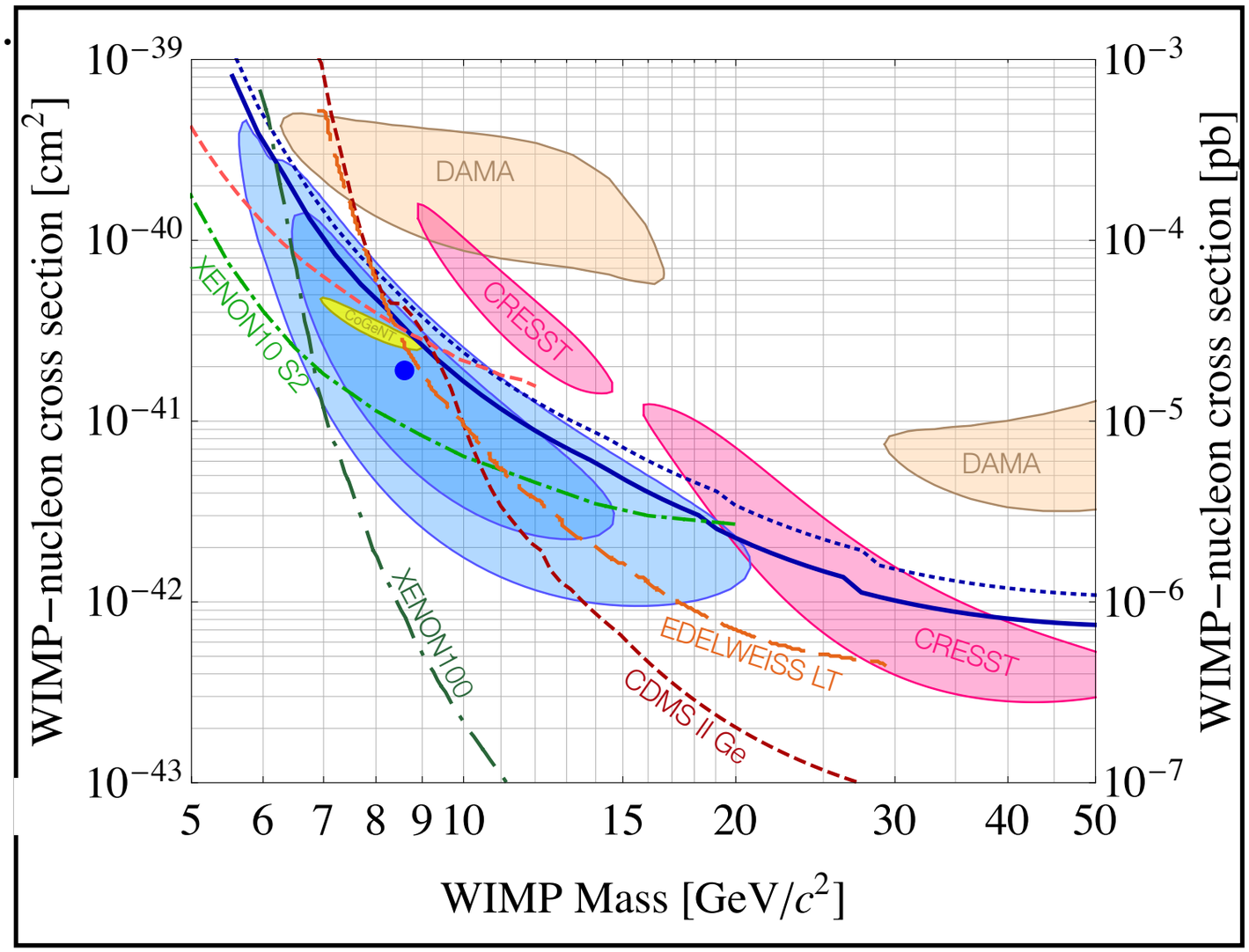
- Shades of blue indicate three separate timing cut energy ranges.
  - 7- 20 keV
  - 20 - 30 keV
  - 30 - 100 keV
- Background Estimate
  - Surface Events

    $0.41^{+0.20}_{-0.08}(stat.)^{+0.28}_{-0.24}(syst.)$
  - < 0.13 neutrons from Cosmogenics & Radiogenics
  - < 0.08 ^{206}Pb recoils from ^{210}Pb decays

CDMS II - Si Results

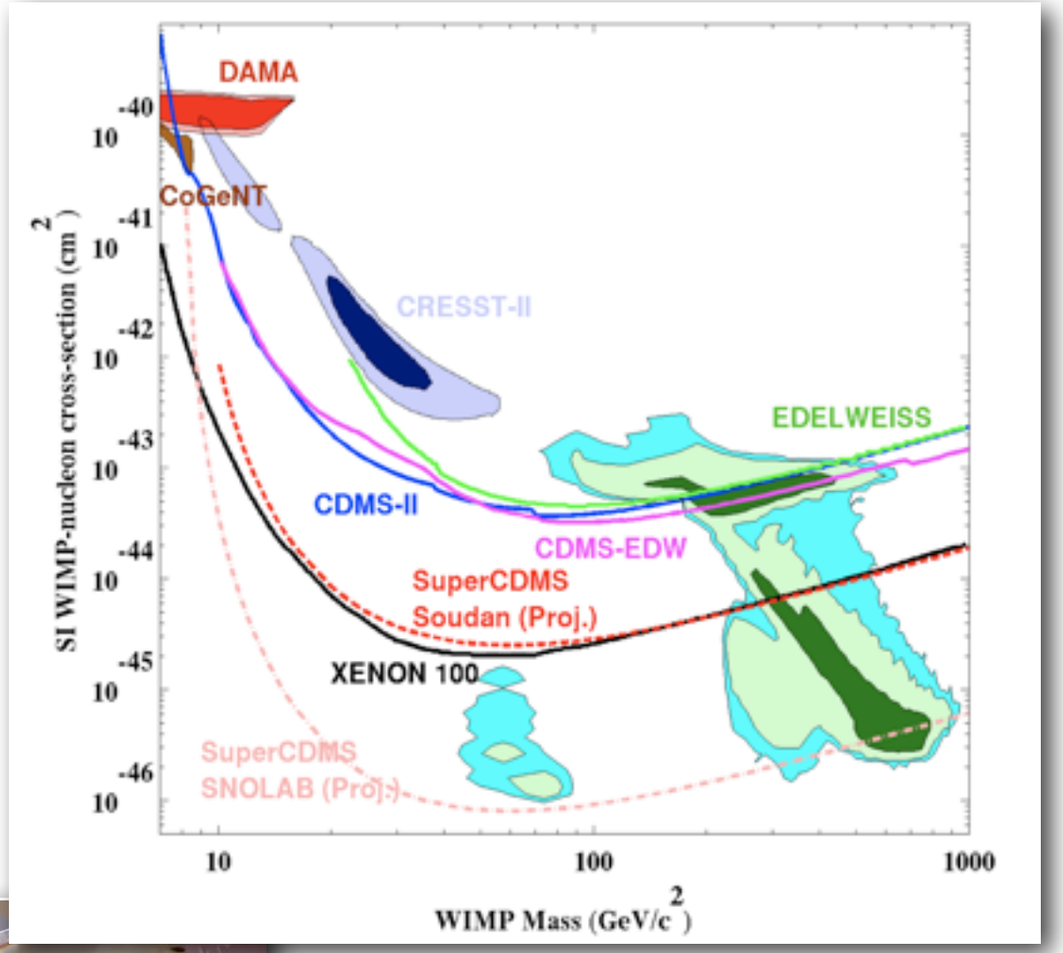
- Three events observed in the signal region.
- A profile likelihood analysis favors a WIMP+background hypothesis over the known background estimate as the source of our signal at the 99.81% C.L. (~3σ, p-value: 0.19%)
- The maximum likelihood occurs at a WIMP mass of 8.6 GeV/c^2 and WIMP-nucleon cross section of 1.9 x 10^{-41}.
- Does not rise to level of discovery, but does call for further investigation.

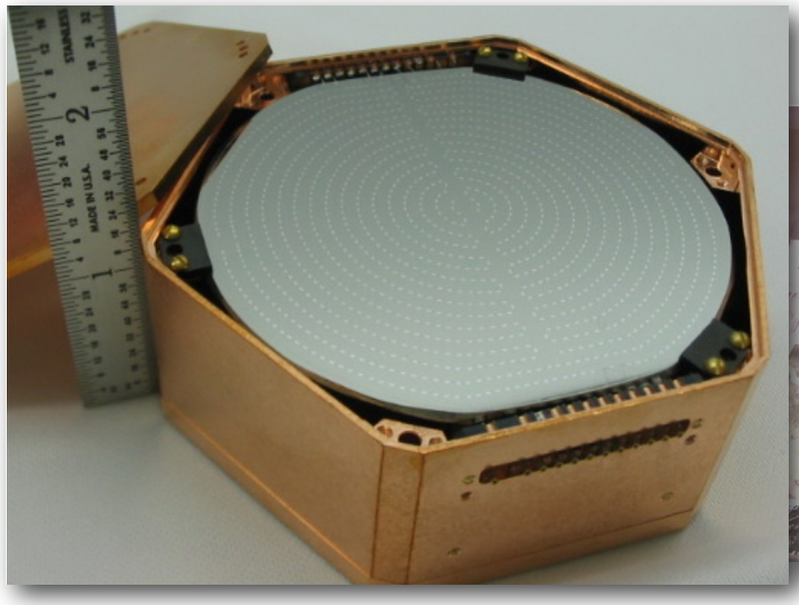


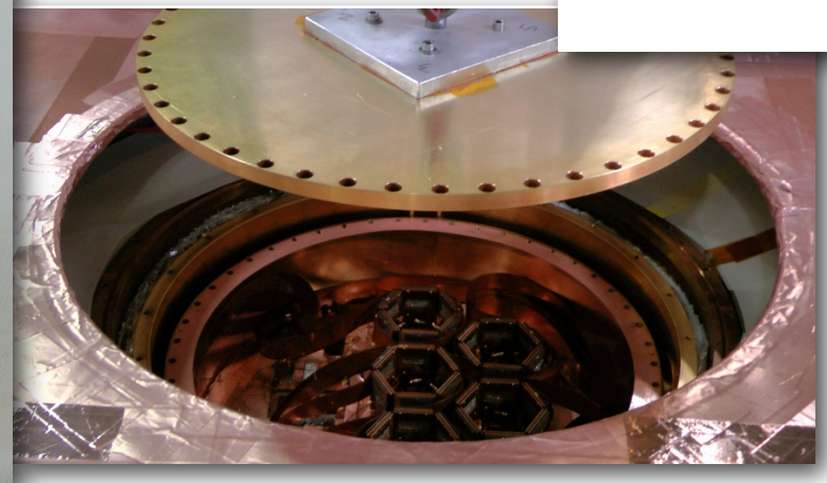


SuperCDMS @ Soudan

- Currently operating 5 towers of advanced iZIP detectors (~9 kg Ge) in the existing cryostat at the Soudan Underground Laboratory.
- After 3 years of operation, expected to improve sensitivity to spin-independent WIMP-nucleon interactions by a factor of ~10 over existing CDMS II results.





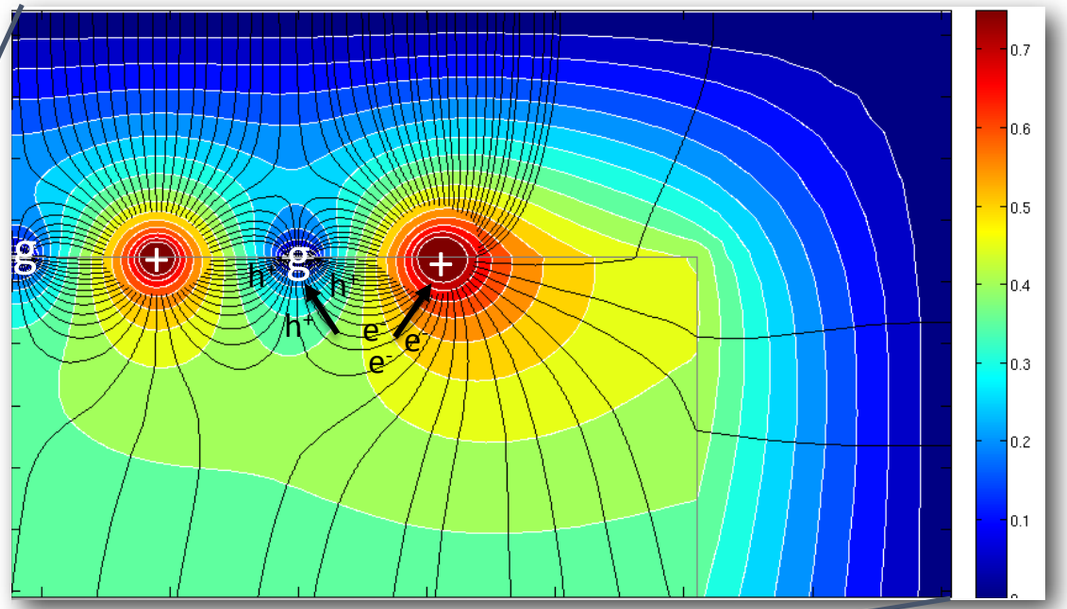


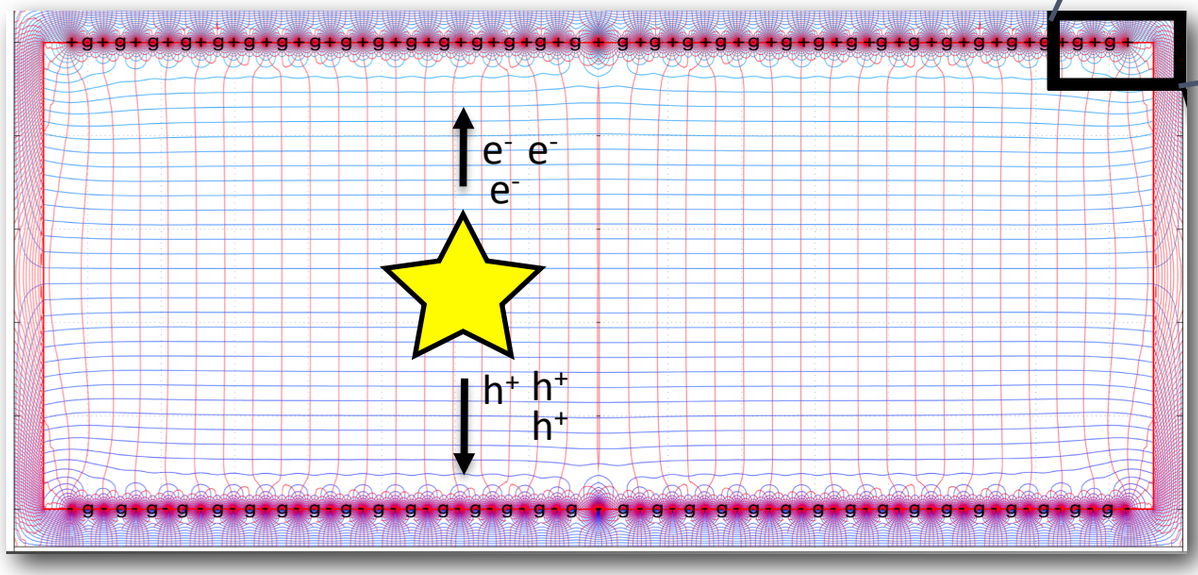
Installation complete Nov. 8, 2011. Operating with final detector settings since Mar. 2012.

SCDMS iZIPs: Charge Signal

Bulk Events:
Equal but opposite ionization signal appears on both faces of detector (symmetric)

Surface Events:
Ionization signal appears on one detector face (asymmetric)



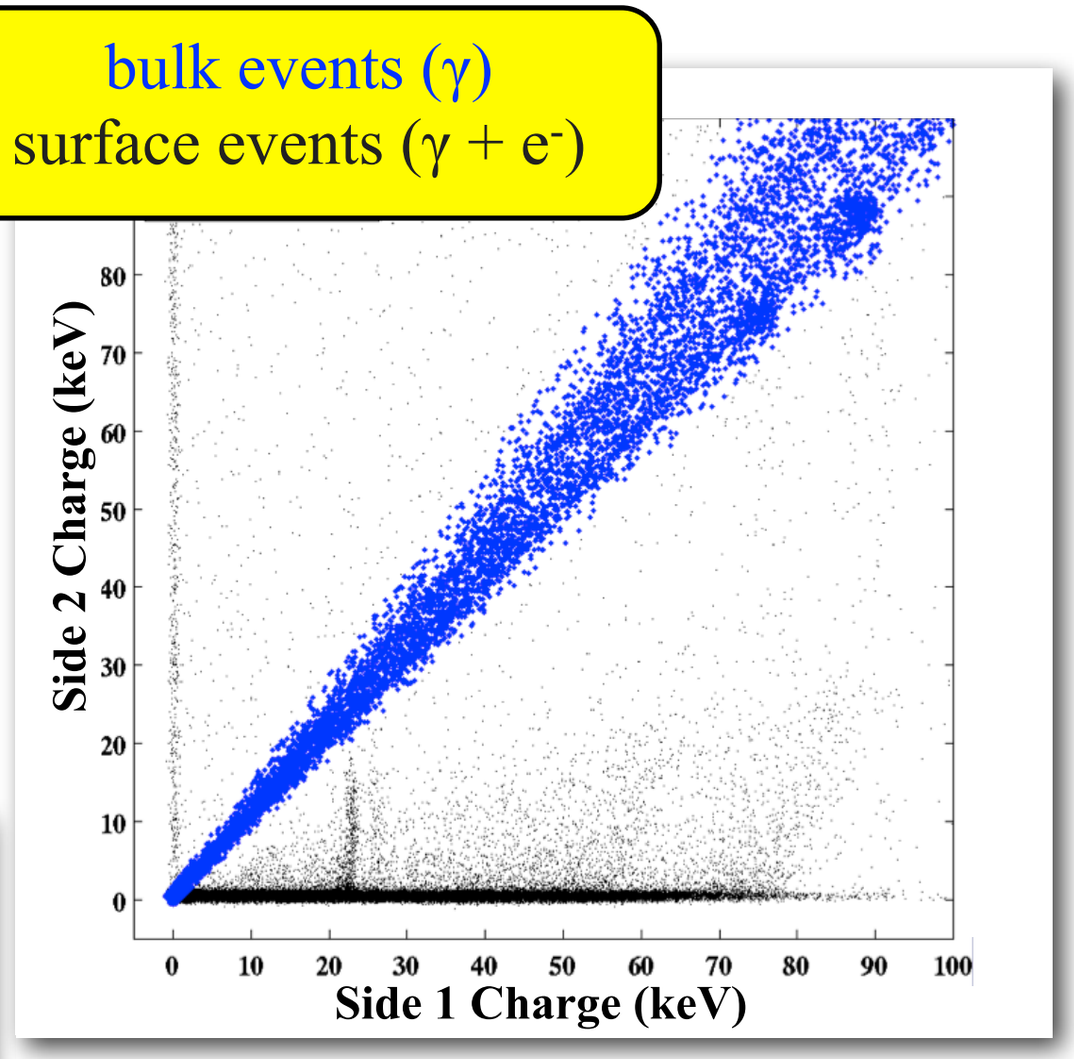


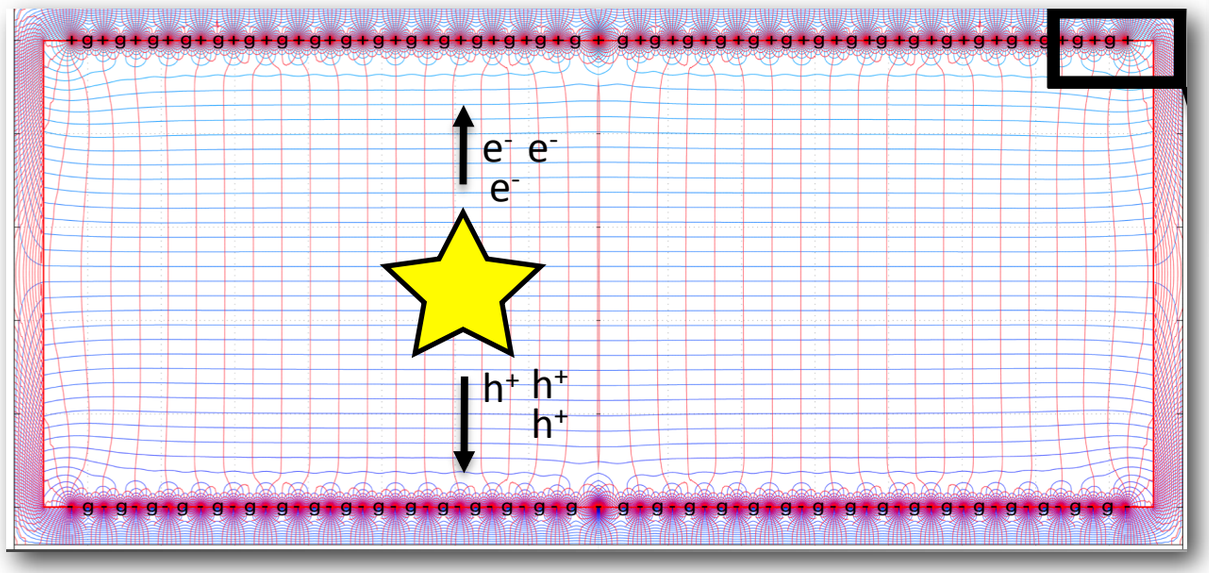
arXiv:1305.2405

SCDMS iZIPs: Charge Signal

Bulk Events:
Equal but opposite ionization signal appears on both faces of detector (symmetric)

Surface Events:
Ionization signal appears on one detector face (asymmetric)





arXiv:1305.2405

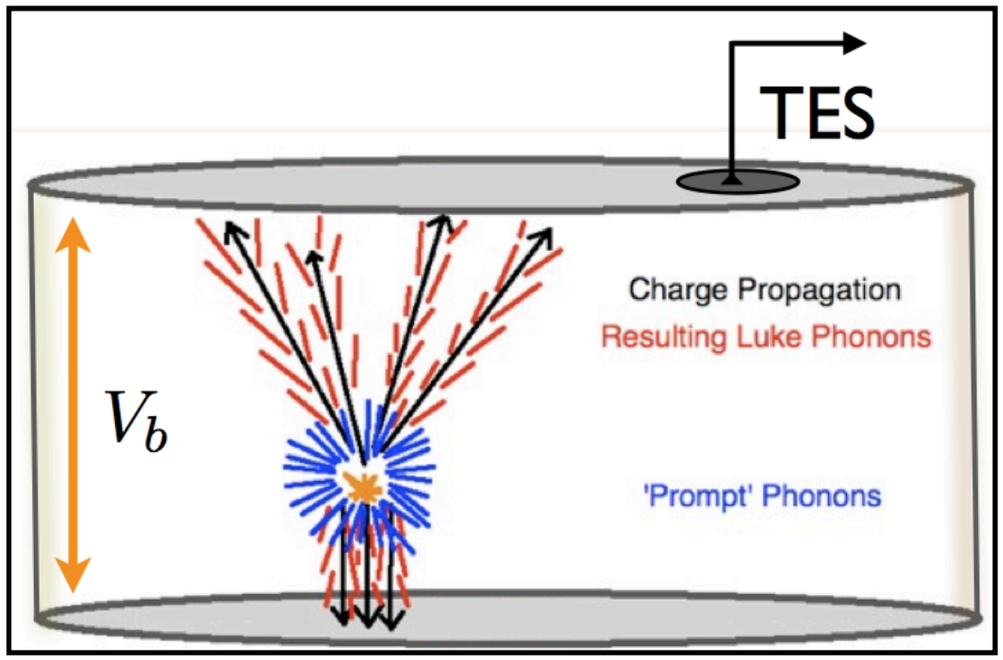
- ~50% fiducial volume (8-115 keVr)
- < 0.6 events in 0.3 ton-years
- **Good enough for a 200 kg experiment run for 4 years at SNOLAB!**

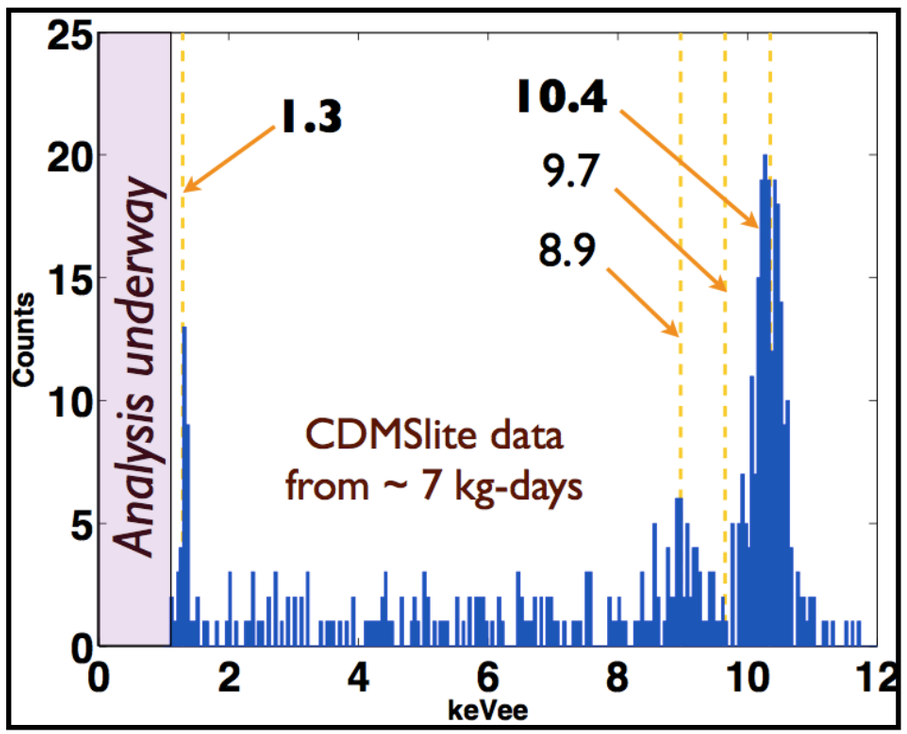
CDMSlite

- Alternate running mode to explore low mass WIMPs utilizing Luke phonons

$$E_{luke} = N_{e/h} \times eV_b$$

- Luke energy scales as bias voltage and noise remains constant until breakdown



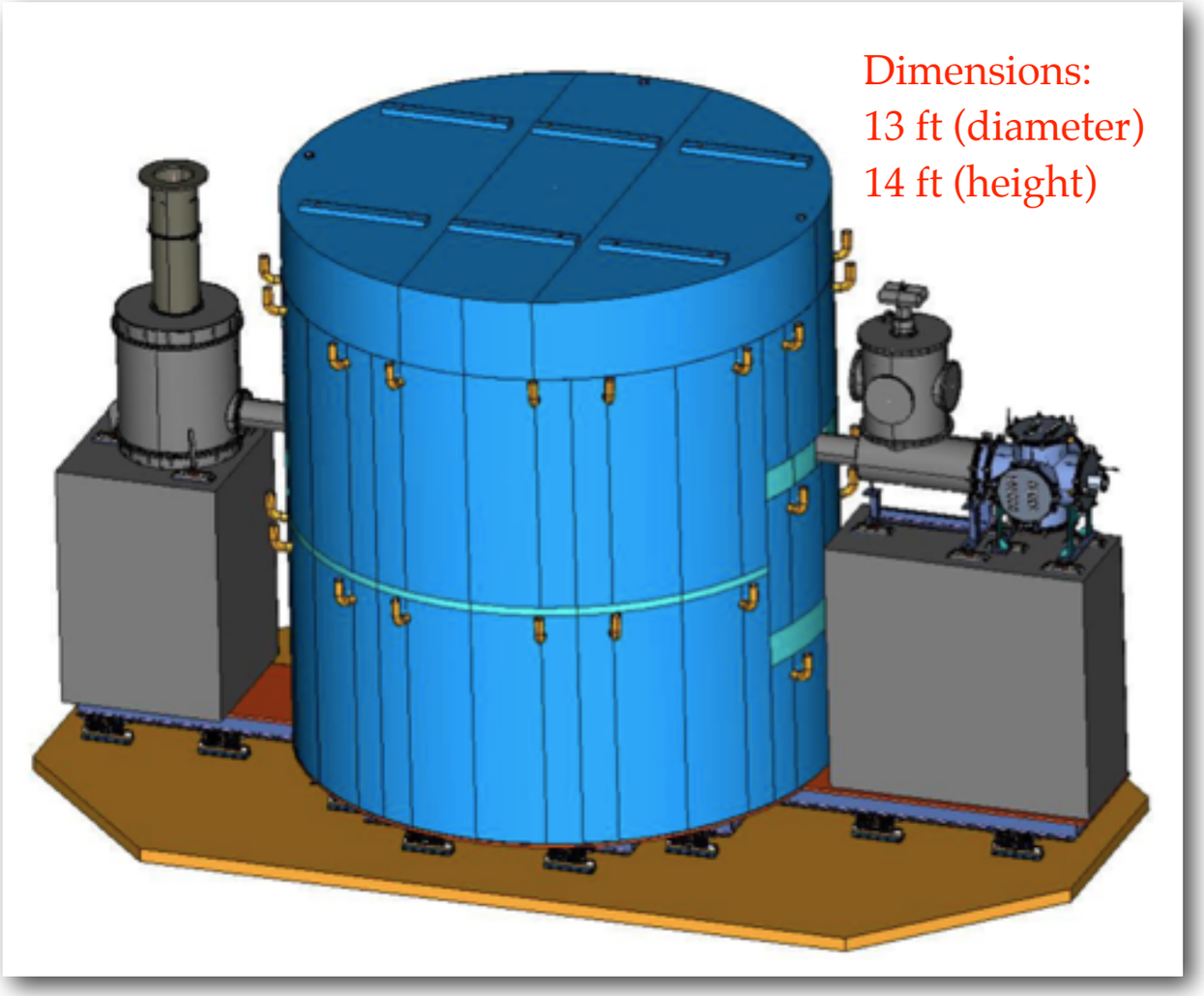


- Resulting Luke amplification has excellent energy resolution potentially down to 1.3 eeV_{ee}.

- Resolution of various Ge activation lines.

New Results to be Announced Wednesday!

Future: SuperCDMS @ SNOLAB

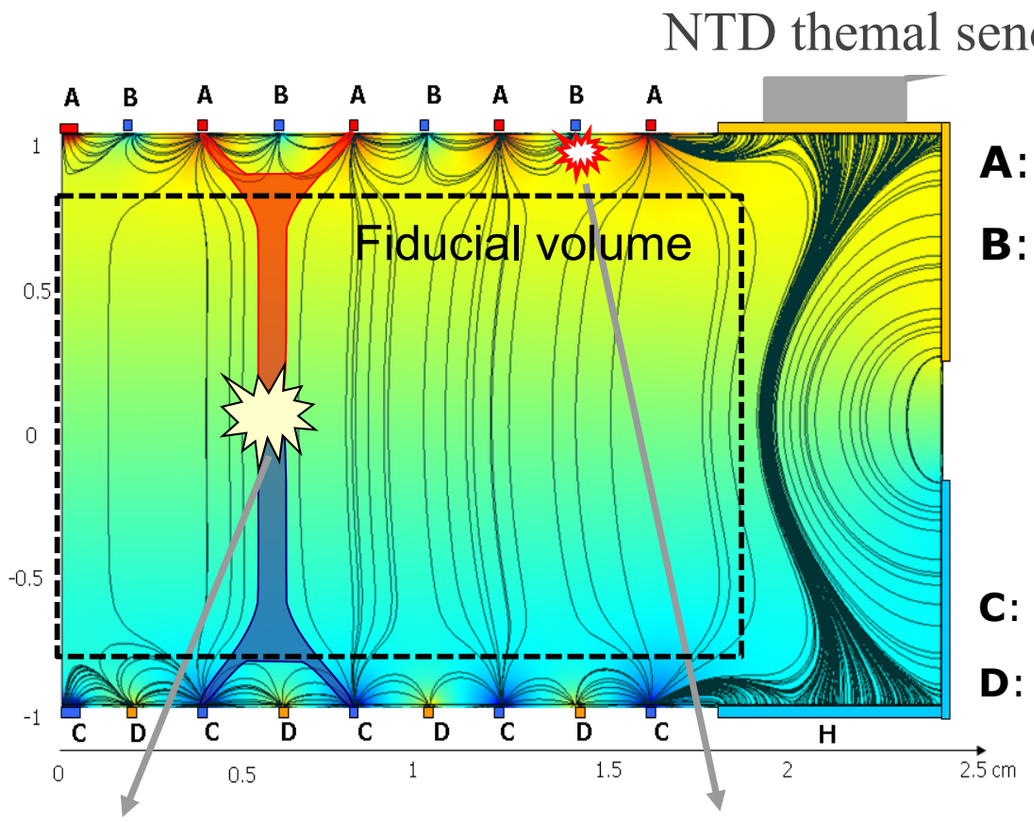


Planned Setup

- cryostat volume of up to 400 kg target
- 200 kg experiment with sensitivity of 8×10^{-47} cm^2 at 60 GeV/c^2
- Pb/Cu shielding for external radiation
- increased PE shielding (neutrons)
- possible neutron veto

- Calibration runs at Soudan indicate that the new iZIPs have good enough surface rejection capabilities for a 200 kg experiment at SNOLAB to run 4 years! **(arXiv:1305.2405)**

EDELWEISS III



Bulk/Fiducial event
Charge collected on electrodes A&C

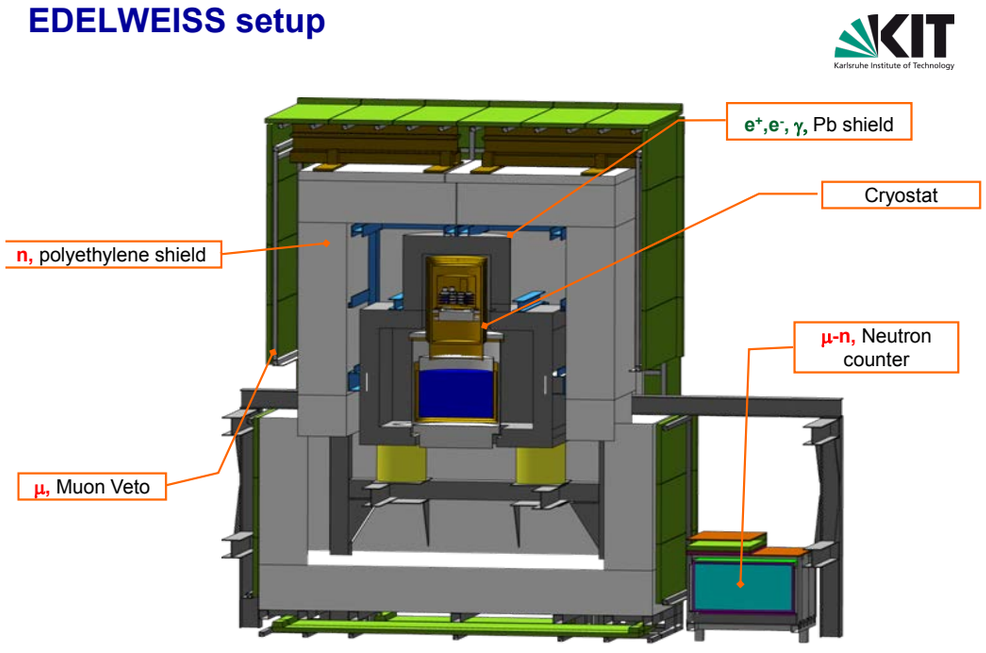
Surface event
Charge collected on electrodes A&B

- Discrimination from ionization yield and charge collection symmetry.

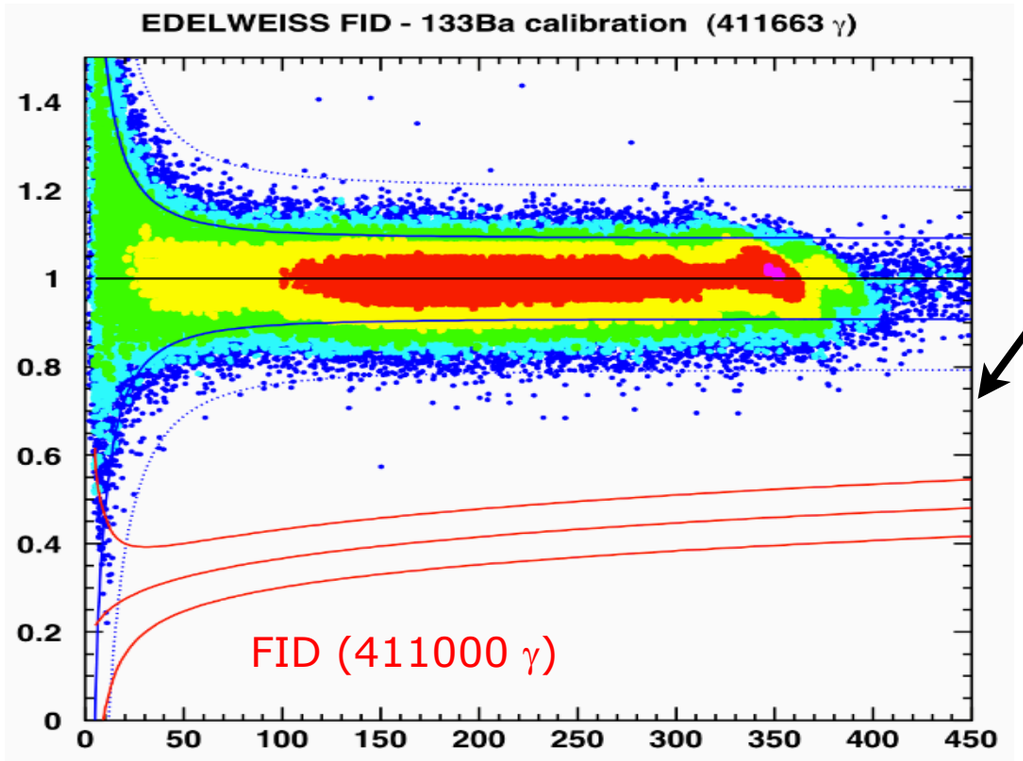
- Located in the Laboratoire Souterrain de Modane (LSM) between Italy and France.

- Detectors instrumented with electrodes to measure charge and NTD thermal sensors to measure phonon signal.

or



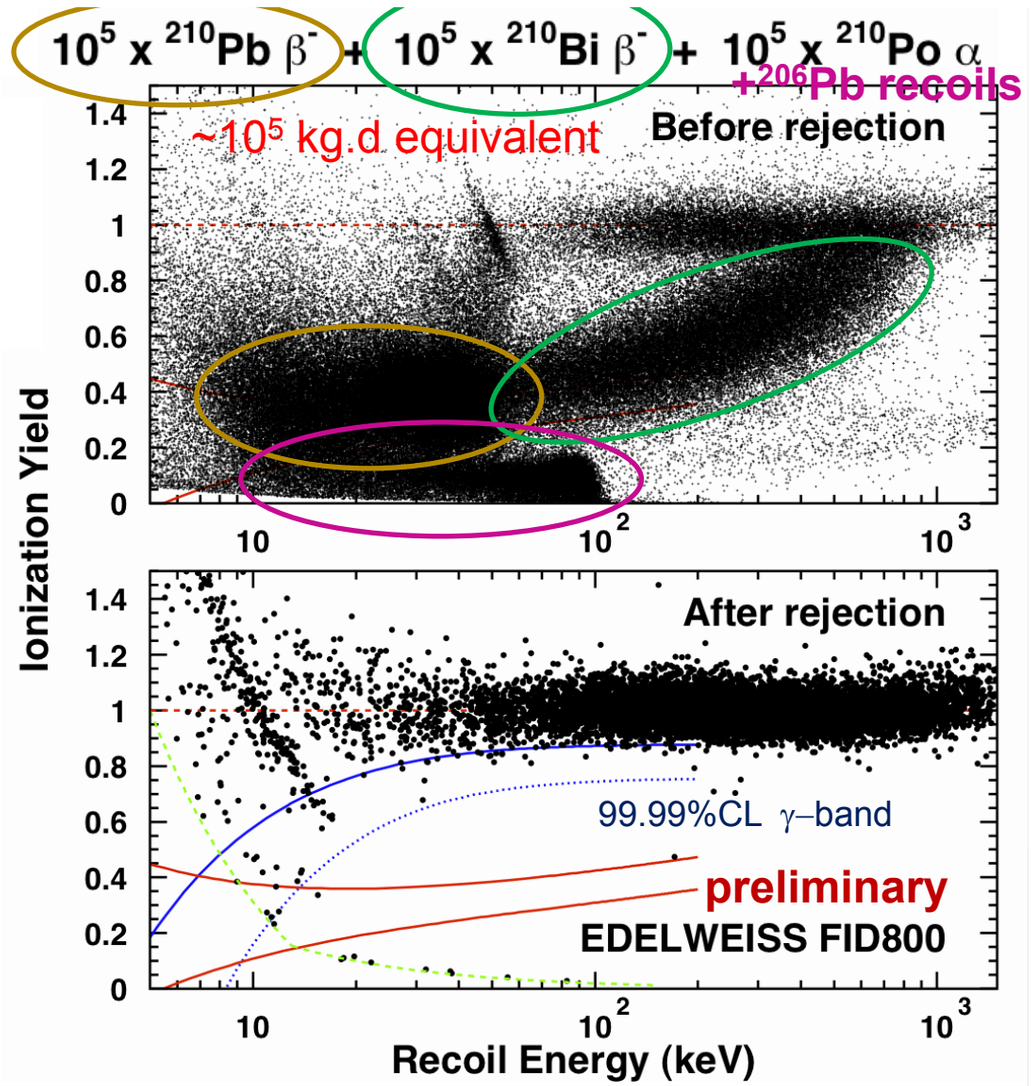
EDELWEISS III



- Improvements to γ-discrimination

- Improvements to surface event discrimination

  - < 4 x 10^{-5} misID events per kg-d (E_r > 15 keV)



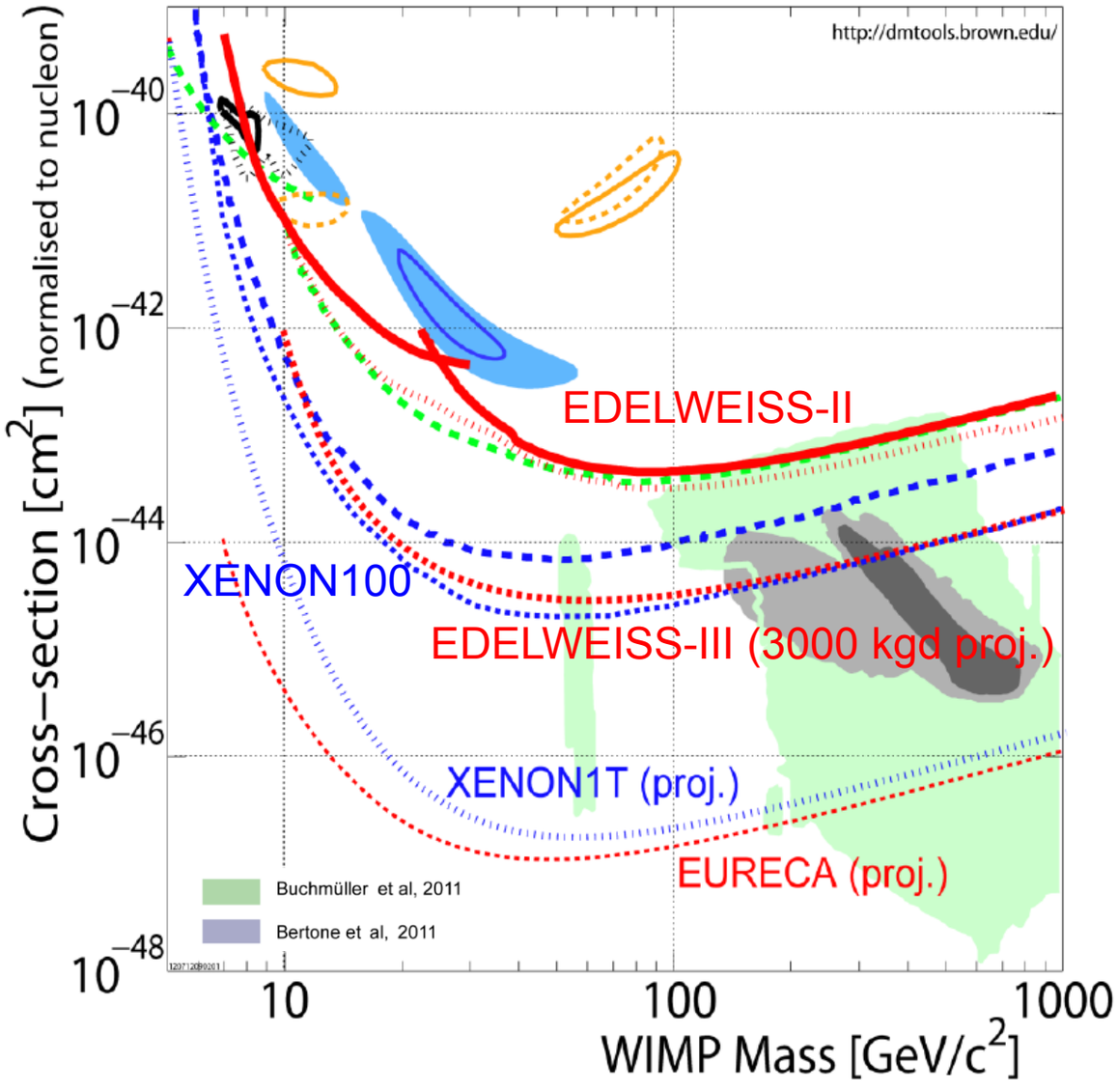
EDELWEISS III - Projections

Sept. 2013

- EDELWEISS III Commissioning runs underway
- 15 FID detectors of mass 800g each
  - upgraded cryostat, readout electronics and kapton cables
  - New PE shield and copper screens

End of 2013

- Fully equiped cryostat with 40 FID detectors of 800g mass each.

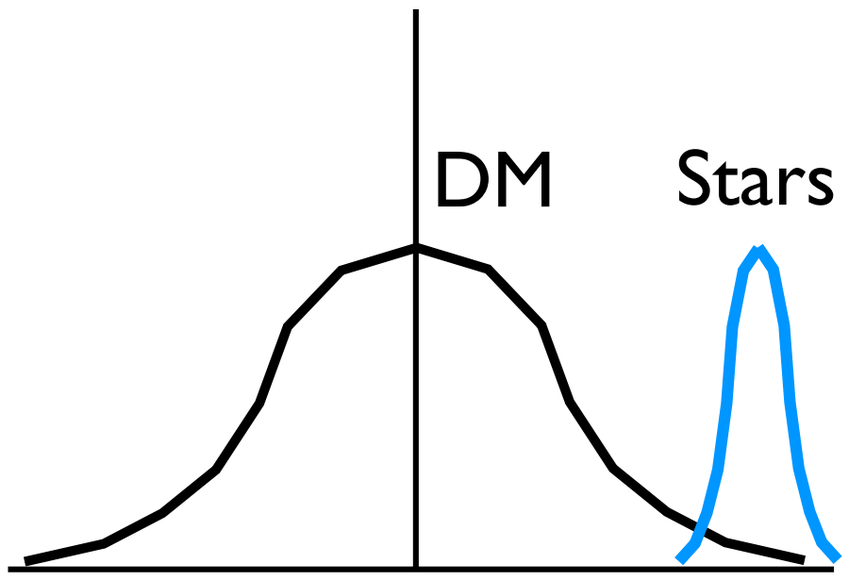


The Experiments Part 2: Addressing a Long Standing Issue

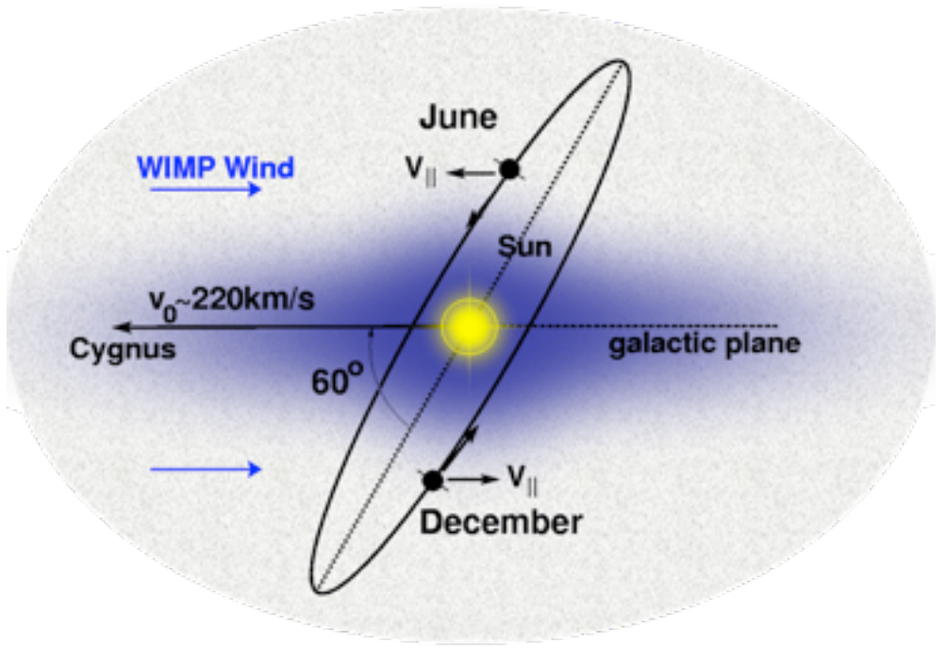
DAMA/LIBRA Modulation Signal

Signal Modulation

- Baryons travel together in roughly circular orbits with small velocity dispersion
- Dark matter particles travel individually with no circular dependence and large velocity dispersion



V_θ (at out galactic radius)



- As a result, the flux of WIMPs passing through Earth modulate over the course of a year as Earth rotates around the sun.