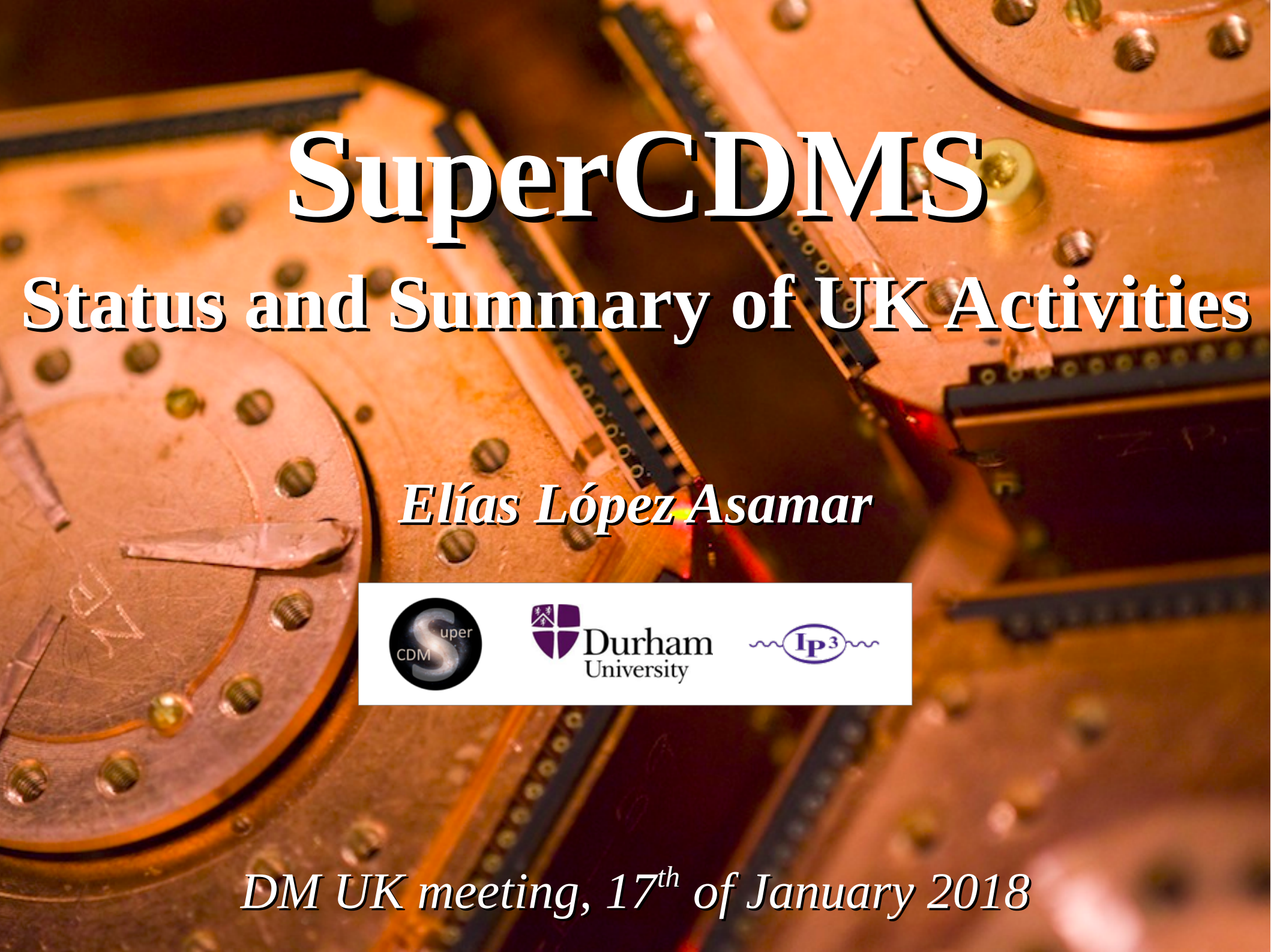


SuperCDMS

Status and Summary of UK Activities

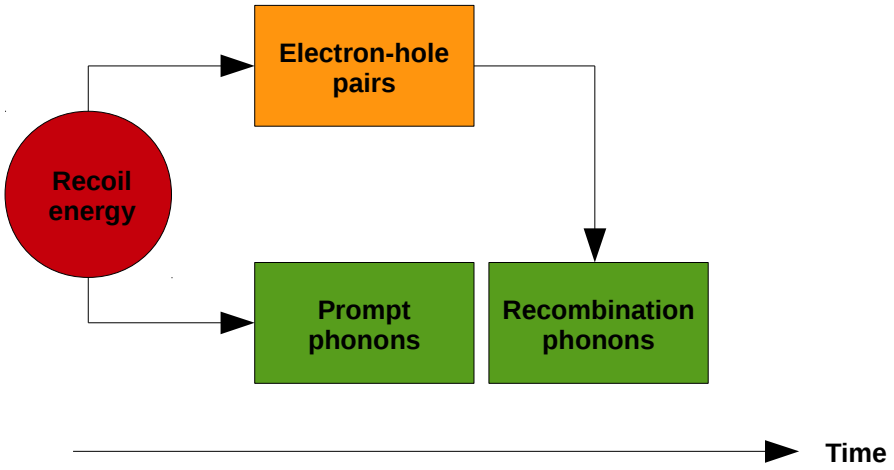
Elías López Asamar

DM UK meeting, 17th of January 2018

THE CONCEPT

Use **semiconductor technology** to detect **recoiling nuclei** caused by DM particles

Measuring charge (N_q) and phonon (E_P) signal



$$N_q = Y\frac{E_R}{\epsilon}, \qquad \epsilon(\mathrm{Ge}) = 3.0\ eV$$

$$E_P = E_{P,prompt} + E_{P,recombination} = E_R$$

	Y
Recoiling electron	1
Recoiling Ge nucleus	~0.3

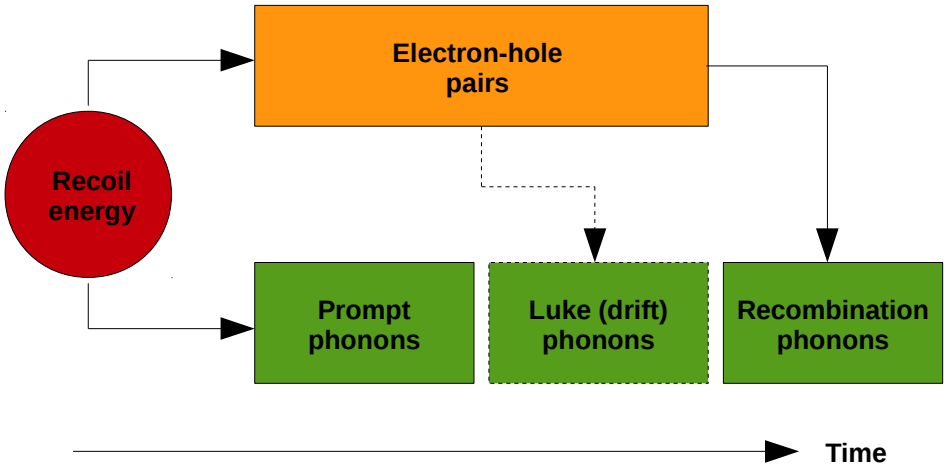
*Initially part of the energy (**Y**) is used to create e-h pairs*
*But eventually all the recoil energy is released as phonons (**heat**)*

It's possible to know recoil energy (E_R) and type of recoiling particle (Y) from E_P and N_q

THE CONCEPT

Use **semiconductor technology** to detect **recoiling nuclei** caused by DM particles

Under **applied voltage** (***V***) e-h pairs acquire kinetic energy, released as **additional phonons**



$$N_q = \frac{Y E_R}{\epsilon}, \qquad \epsilon(\mathrm{Ge}) = 3.0\ eV$$

$$E_P = E_R + q_e V N_q = E_R\left(1 + Y\frac{q_e V}{\epsilon}\right)$$

	Y
Recoiling electron	1
Recoiling Ge nucleus	~0.3

Luke phonons emmitted while e-h pairs drift by action of V
Phonon energy larger than recoil energy

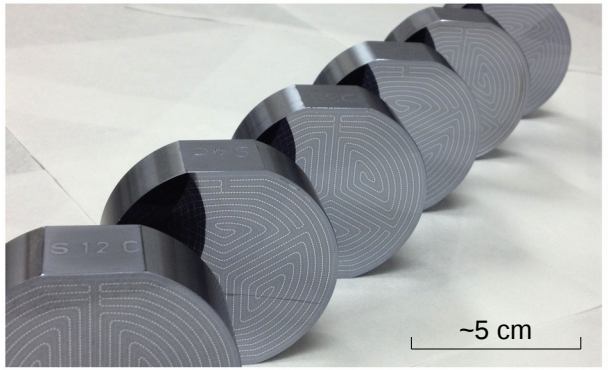
It's possible to know recoil energy (***E*** $_R$) and type of recoiling particle (***Y***) from ***E*** $_P$ and ***N*** $_q$

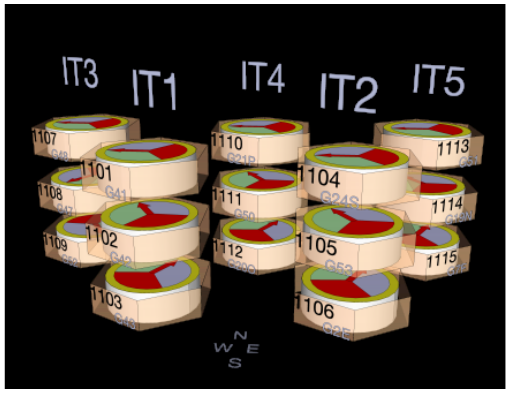
SUPERCDMS SOUDAN

Detectors: 15 cylindrical **Ge** monocrystals, **9.2 kg total**

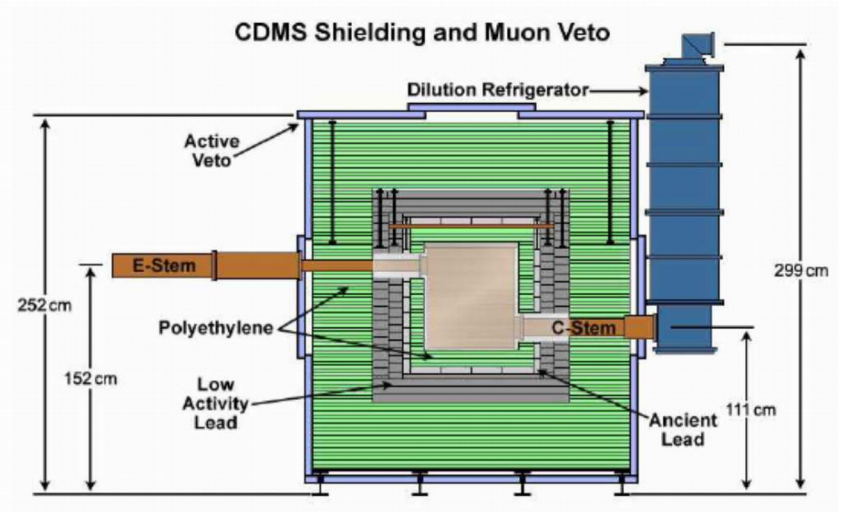
Deployed at **Soudan Underground Laboratory** (US, 714 m depth)

Operated between **March 2012** and **November 2015**





Active shielding: ***scintillating plastic****, full solid angle*
Passive shielding: ***polyethylene****,* ***lead***
Using ***radiopure Cu*** *for inner structures*



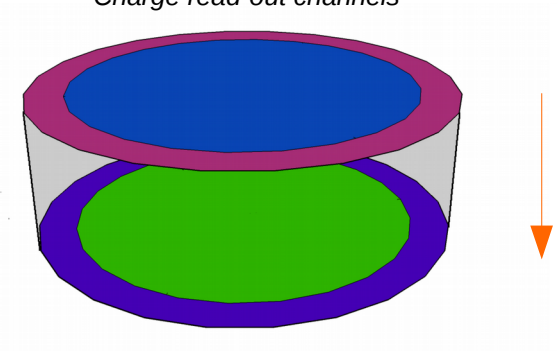
SUPERCDMS SOUDAN

Measuring both N_q and E_P ⇒ capable of determining both E_R and Y

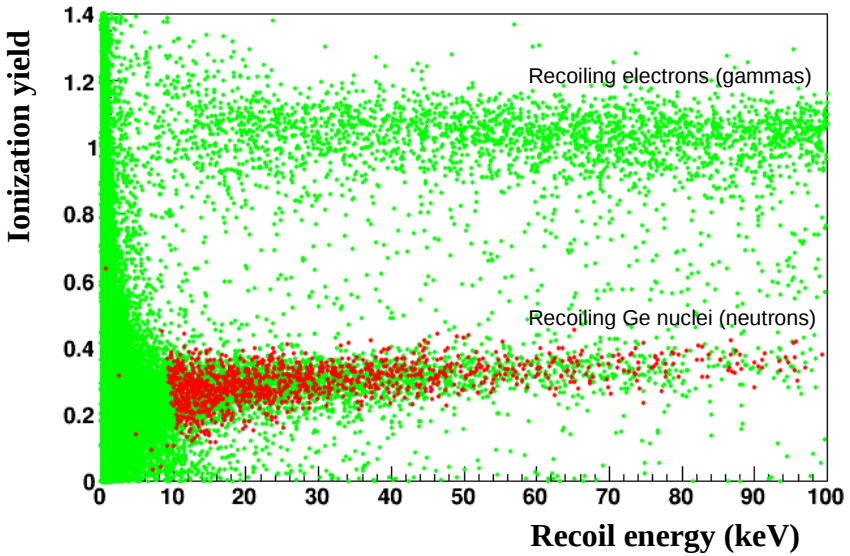
Applied electric field + segmented readout ⇒ full fiducialization

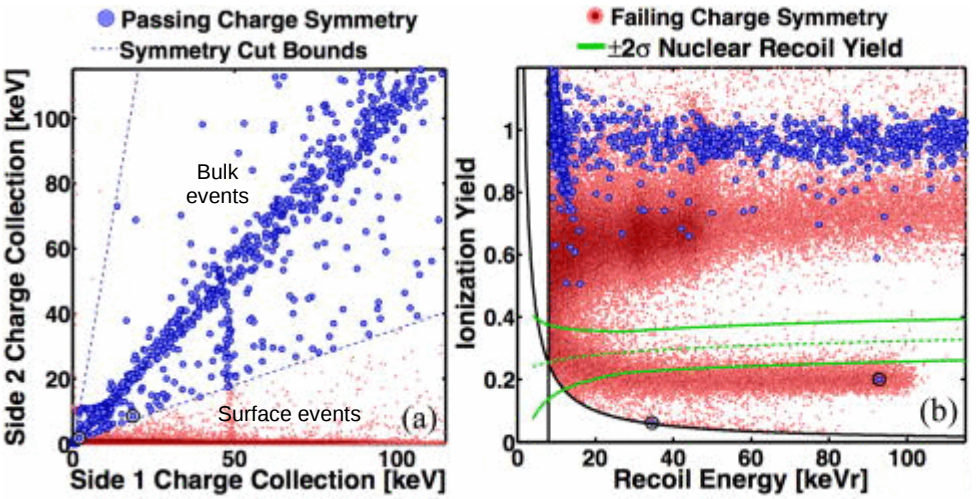
*Applied voltage is **4 V** in regular operation conditions*

Charge read-out channels



^{252}Cf calibration data





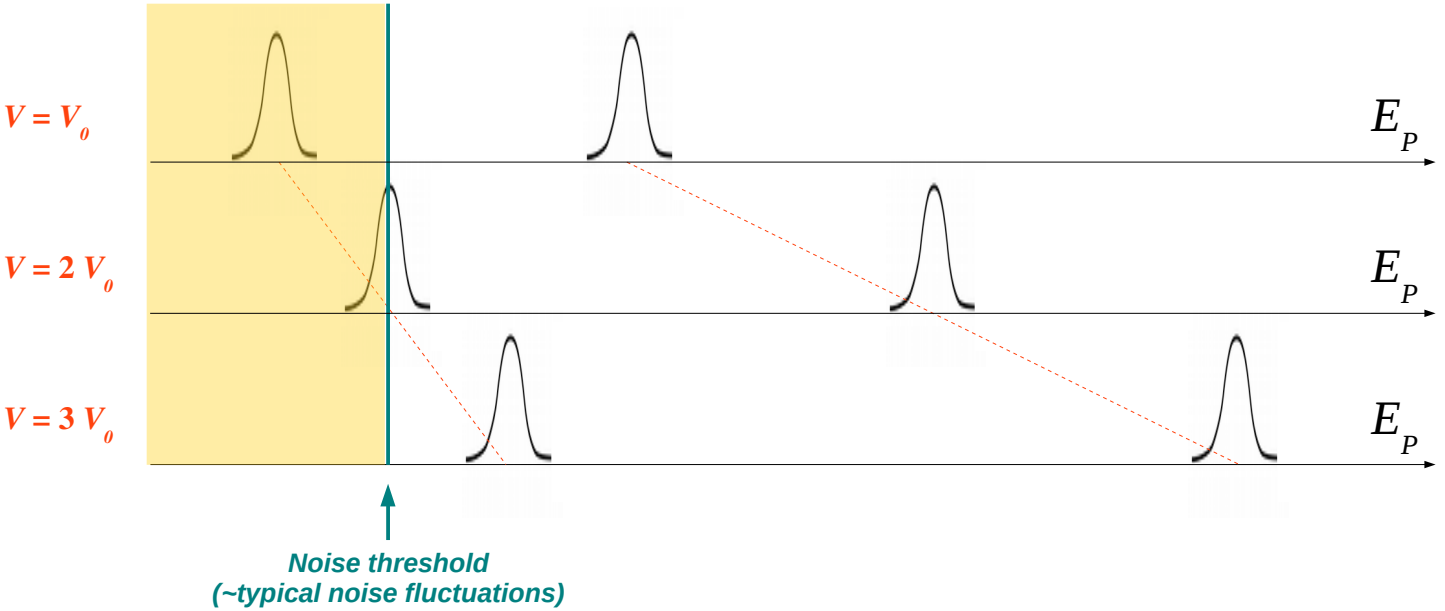
SUPERCDMS SOUDAN

Increased applied voltage (*V*) allowed to effectively decrease threshold: CDMSlite

$$E_P = E_R + q_e V N_q = E_R(1 + Y\frac{q_e V}{\epsilon}) = g(V) E_R$$

contribution from applied electric field

$g(V) > 1$



However N_q **remains below threshold ⇒ charge signal is useless**

Particle-ID & fiducialization compromised, reconstruction of E_R requires assumptions on Y

SUPERCDMS SOUDAN

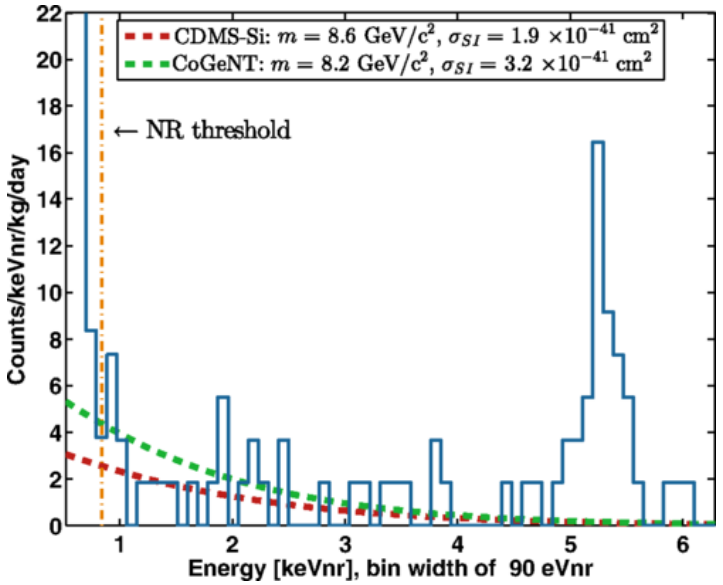
Scientific results:

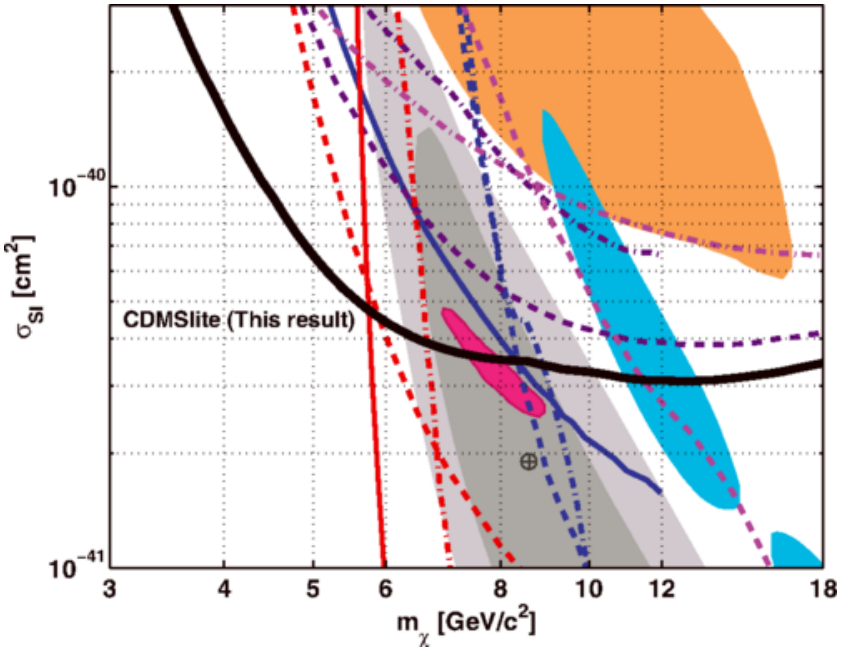
- Demonstration of **CDMSlite** technology arXiv:1309.3259
- **Low-threshold** WIMP search arXiv:1402.7137
- Second **CDMSlite** run arXiv:1509.02448, arXiv:1707.01632
- WIMP search using **full data set** arXiv:1708.08869

SUPERCDMS SOUDAN

Scientific results:

- Demonstration of **CDMSlite** technology arXiv:1309.3259
- **Low-threshold** WIMP search arXiv:1402.7137
- Second **CDMSlite** run arXiv:1509.02448, arXiv:1707.01632
- WIMP search using **full data set** arXiv:1708.08869

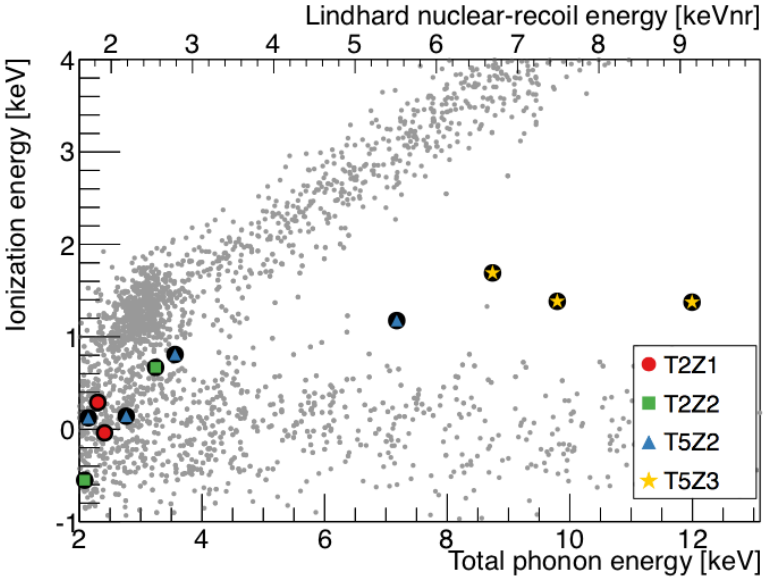


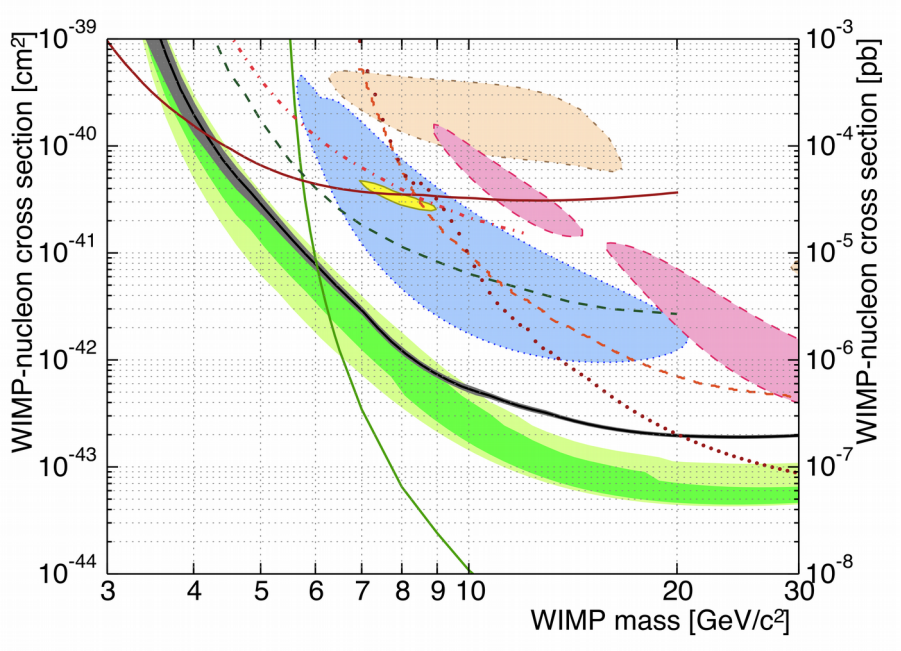


SUPERCDMS SOUDAN

Scientific results:

- Demonstration of **CDMSlite** technology arXiv:1309.3259
- **Low-threshold** WIMP search arXiv:1402.7137
- Second **CDMSlite** run arXiv:1509.02448, arXiv:1707.01632
- WIMP search using **full data set** arXiv:1708.08869

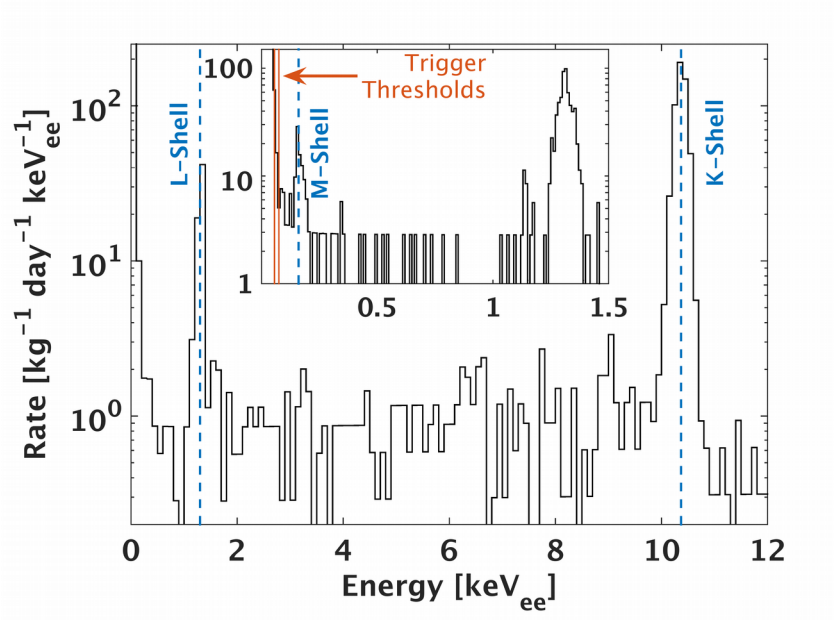


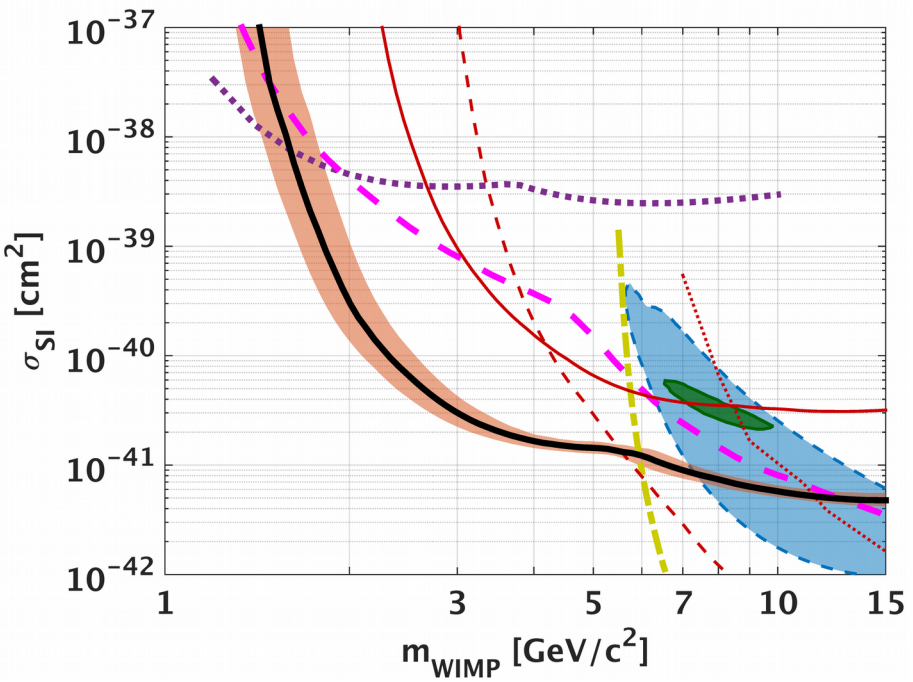


SUPERCDMS SOUDAN

Scientific results:

- Demonstration of **CDMSlite** technology arXiv:1309.3259
- **Low-threshold** WIMP search arXiv:1402.7137
- Second **CDMSlite** run arXiv:1509.02448, arXiv:1707.01632
- WIMP search using **full data set** arXiv:1708.08869

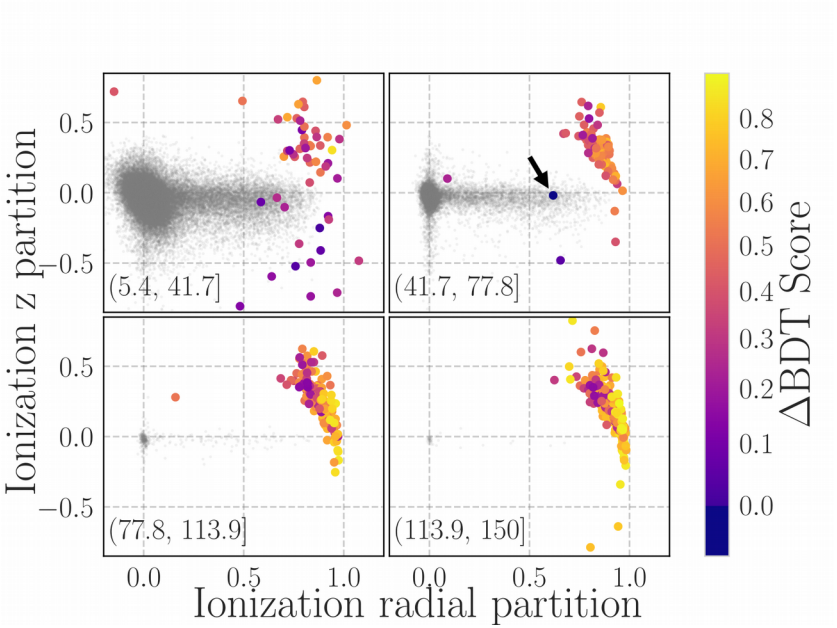


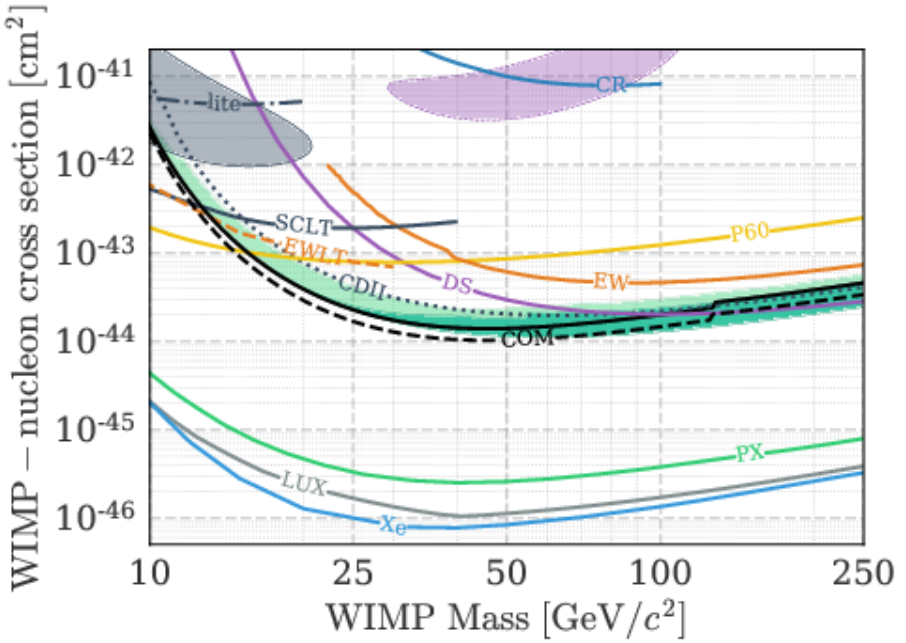


SUPERCDMS SOUDAN

Scientific results:

- Demonstration of **CDMSlite** technology arXiv:1309.3259
- **Low-threshold** WIMP search arXiv:1402.7137
- Second **CDMSlite** run arXiv:1509.02448, arXiv:1707.01632
- WIMP search using **full data set** arXiv:1708.08869





SUPERCDMS SNOLAB

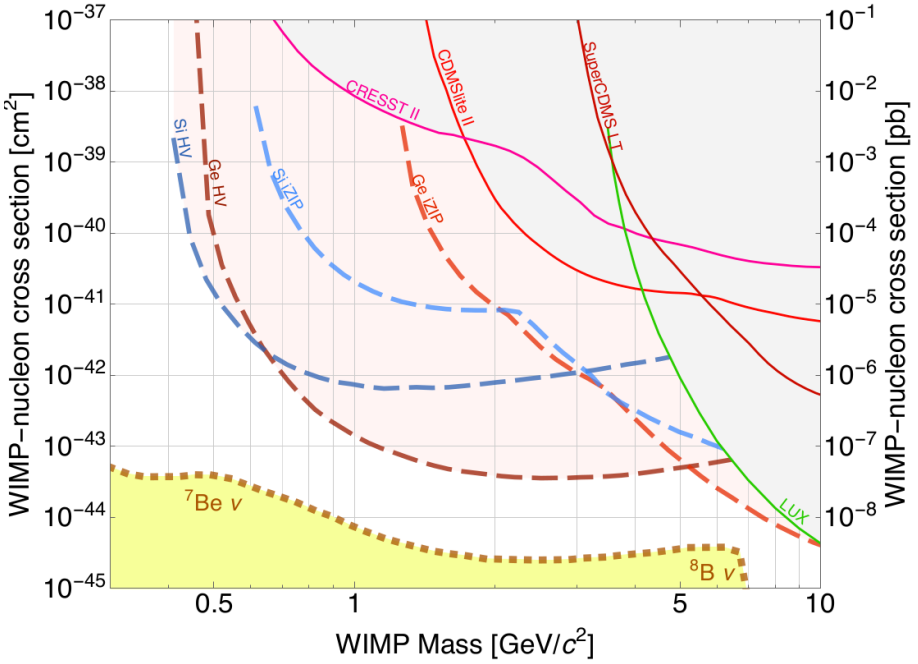
Project proposal:

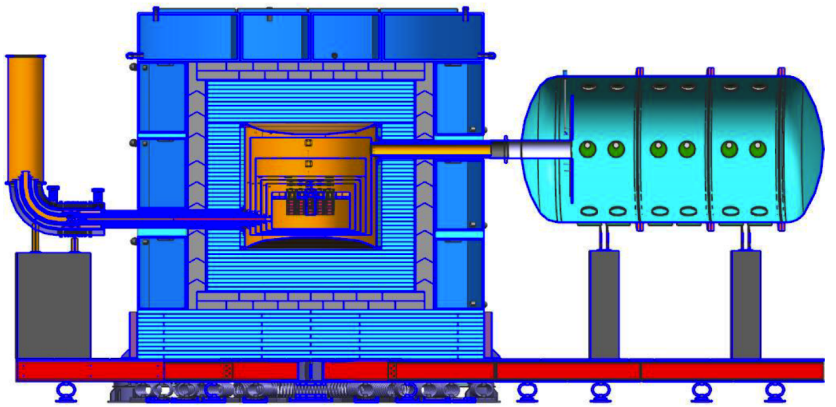
- Detectors with **full background rejection** capabilities (**iZIP**): **14 kg Ge**, **1.2 kg Si**
- Detectors with **lowered energy thresholds** (increased ***V***, **HV**): **10 kg Ge**, **2.4 kg Si**

Project approved by US DoE as a low-mass WIMP search experiment

Planned to **start operations in 2020**, expecting ~5 years of data taking

Projected sensitivity: arXiv:1610.00006





SUPERCDMS GROUP AT DURHAM UNIVERSITY

Currently having a consolidated presence in the experiment

Members:

- **David G. Cerdeño**
- **Elías López Asamar**
- **Marina Peñalver Martínez** (MSc student, 2016)

Mainly devoted to data analyses, backgrounds assessment and event reconstruction

MODEL OF GAMMA-RAY SPECTRUM

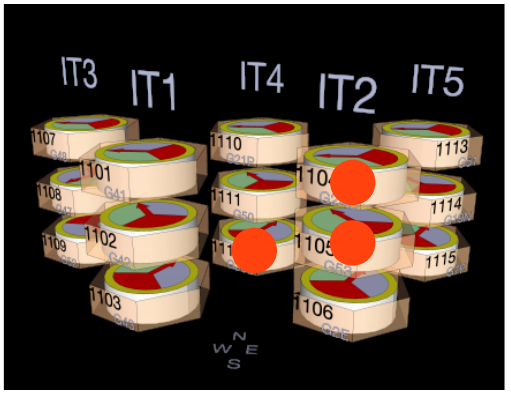
Durham group built the model of gamma-ray spectrum at Soudan

Concept: Generate **MC spectra** for all sources, then find **weighted sum** that best fits to data

Leads to a measurement of radioactivity levels of the experiment

Intensity of low-energy lines sensitive to **distance** to source

Sensitive to **anisotropies** in gamma-ray flux by combining spectra from different detectors



*Detectors used are shown with an orange circle (**T2Z1**, **T2Z2**, **T4Z3**)*

Results from material screenings used as constraints
Otherwise consistent upper limits obtained

^{40}K, cryogenic vessels	< 4 mBq/kg
^{232}Th, cryogenic vessels	< 16 mBq/kg
^{238}U, cryogenic vessels	< 16 mBq/kg
^{232}Th, dust on bottom OVC lid	2.8 ± 1.5 mBq/cm^2
^{238}U, dust on bottom OVC lid	1.5 ± 1.4 mBq/cm^2
^{222}Rn, outer side of OVC	< 0.36 mBq/cm^2

MODEL OF GAMMA-RAY SPECTRUM

Durham group built the model of gamma-ray spectrum at Soudan

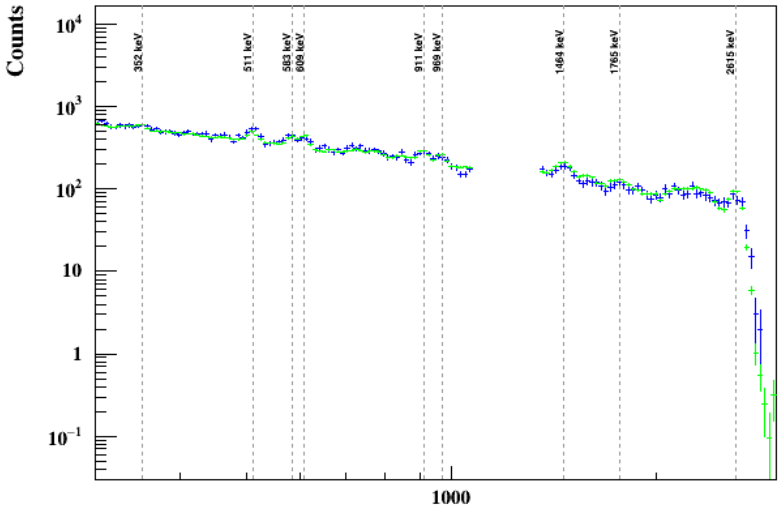
Concept: Generate **MC spectra** for all sources, then find **weighted sum** that best fits to data

Leads to a measurement of radioactivity levels of the experiment

Intensity of low-energy lines sensitive to **distance** to source

Sensitive to **anisotropies** in gamma-ray flux by combining spectra from different detectors

MC gamma spectrum (green) against data (blue) for detector T2Z1



Results from material screenings used as constraints
Otherwise consistent upper limits obtained

^{40}K, cryogenic vessels	< 4 mBq/kg
^{232}Th, cryogenic vessels	< 16 mBq/kg
^{238}U, cryogenic vessels	< 16 mBq/kg
^{232}Th, dust on bottom OVC lid	2.8 ± 1.5 mBq/cm^2
^{238}U, dust on bottom OVC lid	1.5 ± 1.4 mBq/cm^2
^{222}Rn, outer side of OVC	< 0.36 mBq/cm^2

MODEL OF GAMMA-RAY SPECTRUM

Durham group built the model of gamma-ray spectrum at Soudan

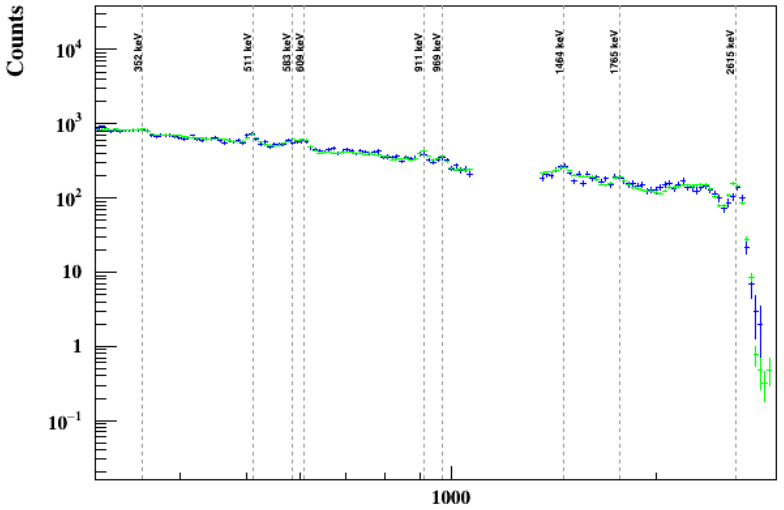
Concept: Generate **MC spectra** for all sources, then find **weighted sum** that best fits to data

Leads to a measurement of radioactivity levels of the experiment

Intensity of low-energy lines sensitive to **distance** to source

Sensitive to **anisotropies** in gamma-ray flux by combining spectra from different detectors

MC gamma spectrum (green) against data (blue) for detector T2Z2



Results from material screenings used as constraints
Otherwise consistent upper limits obtained

^{40}K, cryogenic vessels	< 4 mBq/kg
^{232}Th, cryogenic vessels	< 16 mBq/kg
^{238}U, cryogenic vessels	< 16 mBq/kg
^{232}Th, dust on bottom OVC lid	2.8 ± 1.5 mBq/cm^2
^{238}U, dust on bottom OVC lid	1.5 ± 1.4 mBq/cm^2
^{222}Rn, outer side of OVC	< 0.36 mBq/cm^2

MODEL OF GAMMA-RAY SPECTRUM

Durham group built the model of gamma-ray spectrum at Soudan

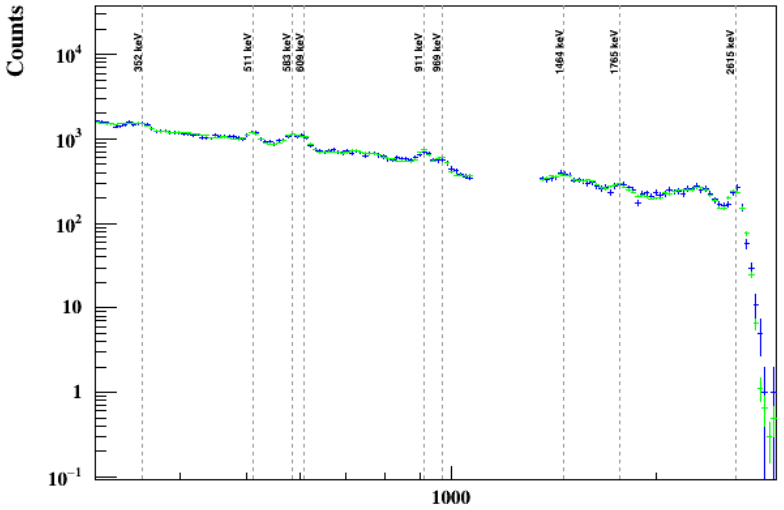
Concept: Generate **MC spectra** for all sources, then find **weighted sum** that best fits to data

Leads to a measurement of radioactivity levels of the experiment

Intensity of low-energy lines sensitive to **distance** to source

Sensitive to **anisotropies** in gamma-ray flux by combining spectra from different detectors

MC gamma spectrum (green) against data (blue) for detector T4Z3



Results from material screenings used as constraints
Otherwise consistent upper limits obtained

^{40}K, cryogenic vessels	< 4 mBq/kg
^{232}Th, cryogenic vessels	< 16 mBq/kg
^{238}U, cryogenic vessels	< 16 mBq/kg
^{232}Th, dust on bottom OVC lid	2.8 ± 1.5 mBq/cm^2
^{238}U, dust on bottom OVC lid	1.5 ± 1.4 mBq/cm^2
^{222}Rn, outer side of OVC	< 0.36 mBq/cm^2

MODEL OF GAMMA-RAY SPECTRUM

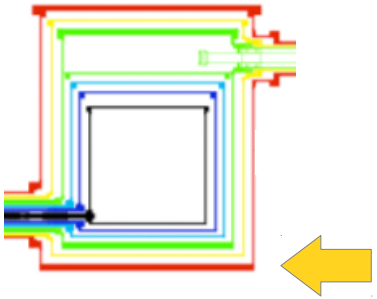
Durham group built the model of gamma-ray spectrum at Soudan

Concept: Generate **MC spectra** for all sources, then find **weighted sum** that best fits to data

Leads to a measurement of radioactivity levels of the experiment

Intensity of low-energy lines sensitive to **distance** to source

Sensitive to **anisotropies** in gamma-ray flux by combining spectra from different detectors



Cryogenic vessels, showing bottom OVC lid

Results from material screenings used as constraints
Otherwise consistent upper limits obtained

^{40}K, cryogenic vessels	< 4 mBq/kg
^{232}Th, cryogenic vessels	< 16 mBq/kg
^{238}U, cryogenic vessels	< 16 mBq/kg
^{232}Th, dust on bottom OVC lid	2.8 ± 1.5 mBq/cm^2
^{238}U, dust on bottom OVC lid	1.5 ± 1.4 mBq/cm^2
^{222}Rn, outer side of OVC	< 0.36 mBq/cm^2

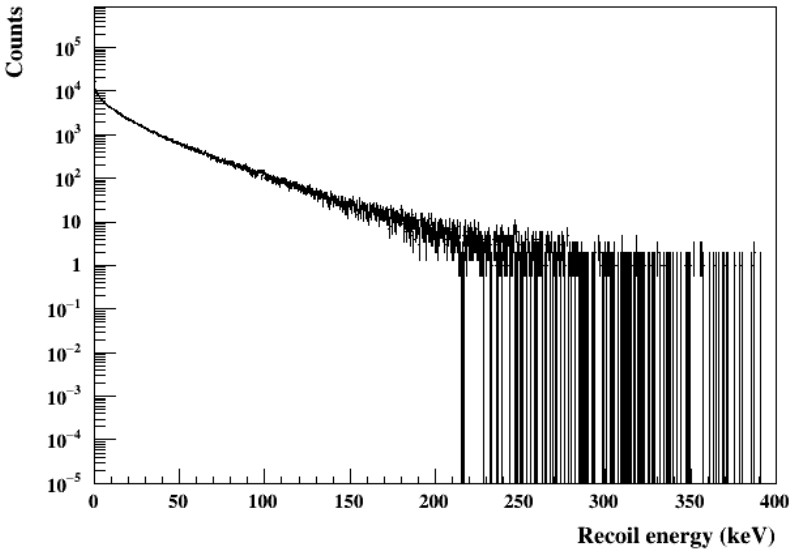
ASSESSMENT OF RADIOGENIC NEUTRON BACKGROUND FOR HT WIMP SEARCH

Subject of MSc thesis of Marina Peñalver Martínez at Durham University

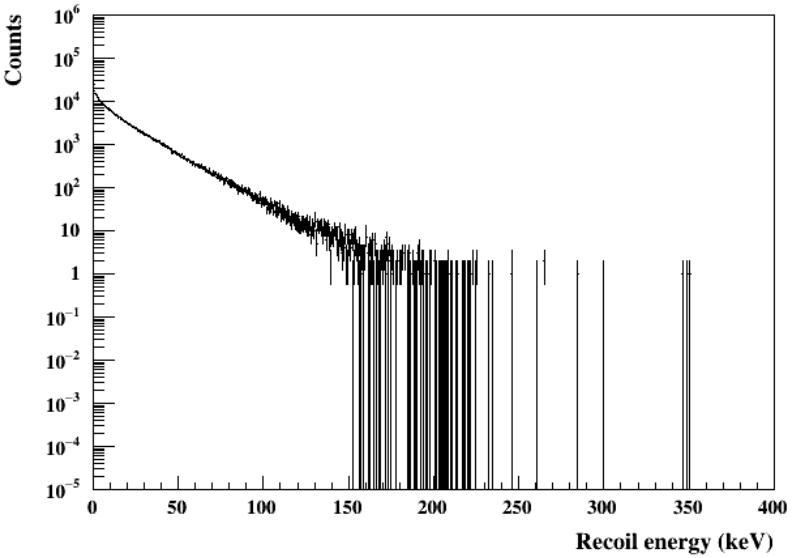
Used MC+radioactivity levels from the model of gamma spectrum

Predicted radiogenic neutron background for HT WIMP search: **$0.095^{+0.06}_{-0.05}$ events**

^{238}U in cryogenic vessels



^{232}Th in cryogenic vessels

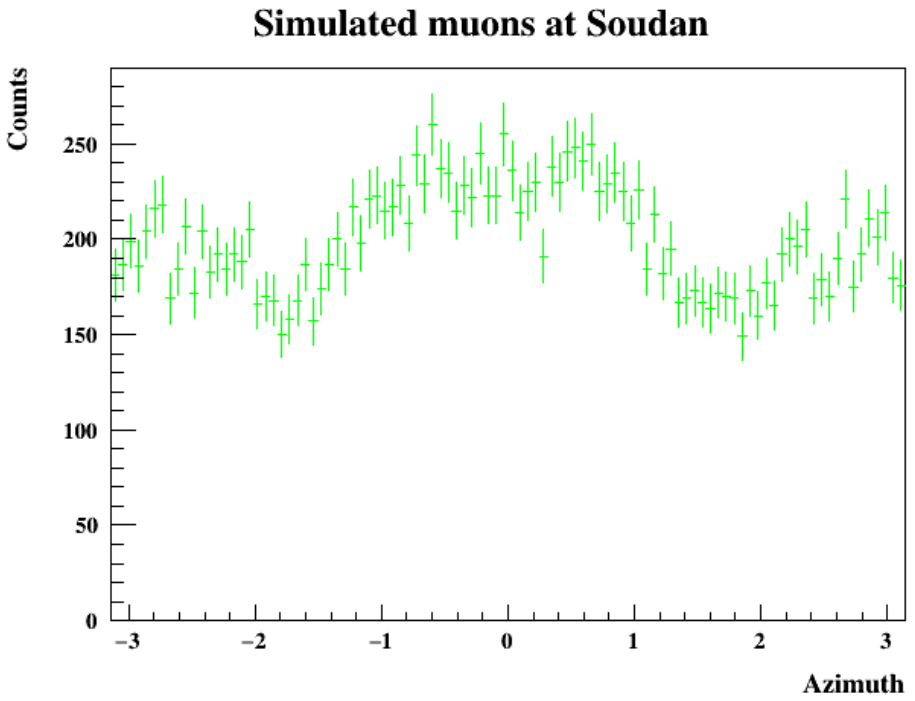


ASSESSMENT OF COSMOGENIC NEUTRON BACKGROUND FOR HT WIMP SEARCH

Durham group calculated the full neutron background for HT WIMP search

Used MC including effects of orography (MUSUN)

Predicted cosmogenic neutron background for HT WIMP search: **0.024 ± 0.024 events**



DETERMINATION OF FIDUCIAL VOLUME FOR HT WIMP SEARCH

Durham group contributed to HT WIMP search by determining the fiducial volume

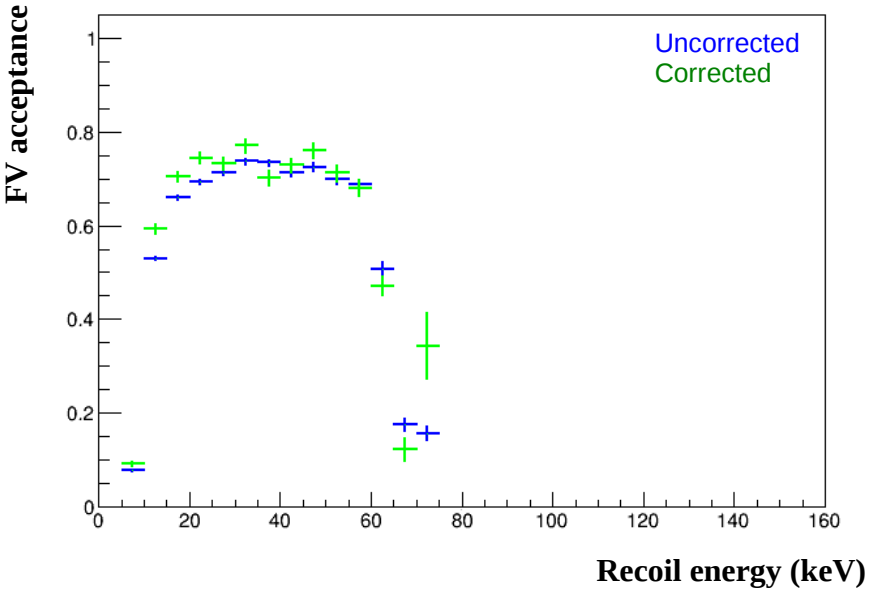
Knowledge of fiducial mass necessary to calculate WIMP exclusion limits

Estimated as fraction of accepted neutrons from ^{252}Cf, correcting for multiple neutron scattering effects inside the detector

$$\alpha_\chi = \frac{\tilde{\alpha}_\chi}{\tilde{\alpha}_n}\alpha_n \equiv k\,\alpha_n$$

*From **calibration data***
(uses NRs from ^{252}Cf neutrons)

*Correction factor, from **MC***

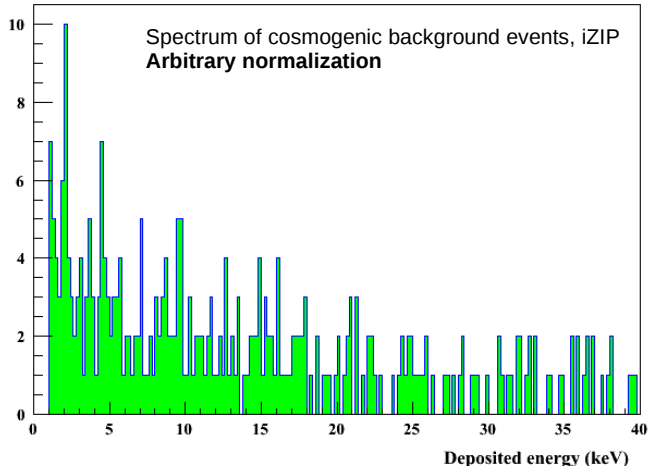


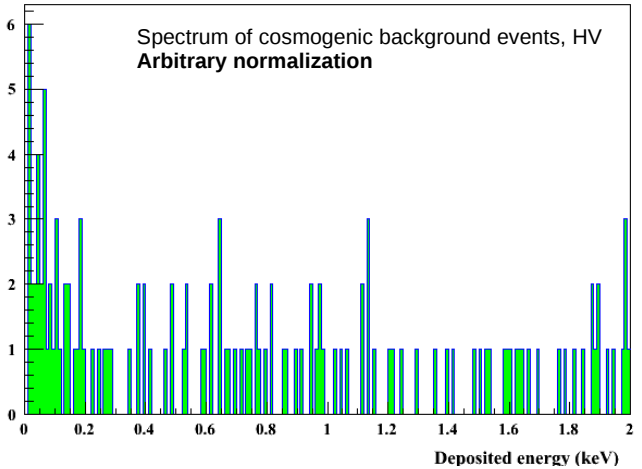
ASSESSMENT OF COSMOGENIC BACKGROUND FOR SUPERCDMS SNOLAB PROJECT

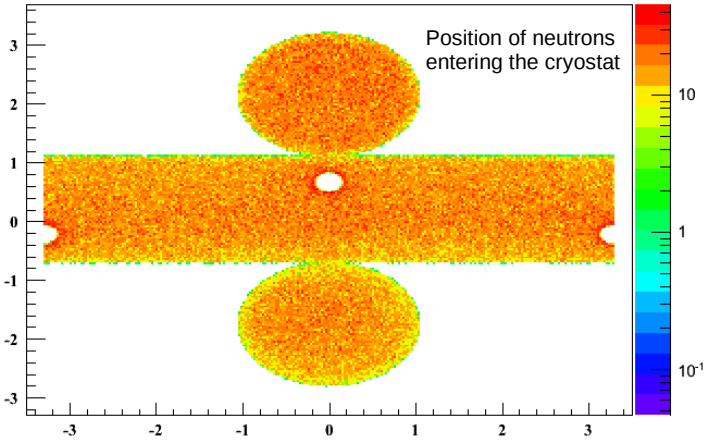
Durham group calculated the predicted cosmogenic background at SNOLAB

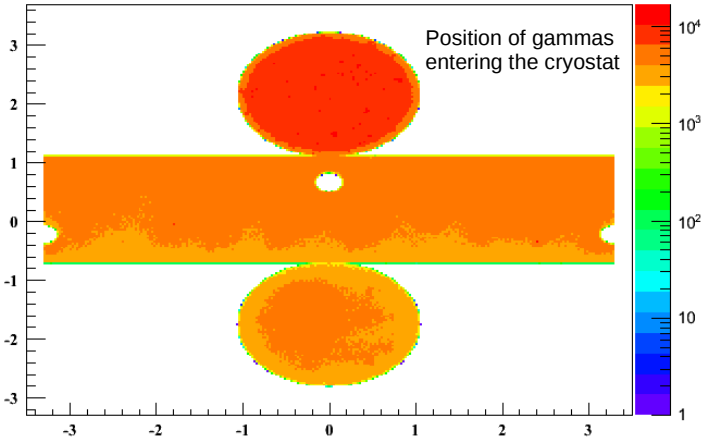
Predicted cosmogenic background in Ge (ev/kg yr): **0.0042** (iZIP), **0.0021** (HV)

Predicted cosmogenic background in Si (ev/kg yr): **0.0048** (iZIP), **0.0028** (HV)









DEVELOPMENT OF EVENT RECONSTRUCTION FOR SUPERCDMS SNOLAB PROJECT

Durham group coordinates the development of the event reconstruction for SNOLAB

Introduced the use of MC to guide the development of reconstruction algorithms

Use of MC is an opportunity to improve the reconstruction with respect to Soudan

For example enabling **position reconstruction** from phonons, important in HV detectors

DEVELOPMENT OF EVENT RECONSTRUCTION FOR SUPERCDMS SNOLAB PROJECT

Durham group coordinates the development of the event reconstruction for SNOLAB

Introduced the use of MC to guide the development of reconstruction algorithms

Use of MC is an opportunity to improve the reconstruction with respect to Soudan

For example enabling **position reconstruction** from phonons, important in HV detectors

Considering **global methods** (all channels processed simultaneously)

Channel-by-channel methods not optimal to extract the maximum information from data

SUMMARY

- SuperCDMS based on **semiconductor technology**, measuring phonon and charge signal
- SuperCDMS Soudan operated between **March 2012** and **November 2015**
- **SuperCDMS SNOLAB project approved**, expected to start operations on 2020
- **The presence of the Durham University group in the collaboration is well consolidated**
- Several relevant contributions to **data analyses**, **backgrounds assessment** and **event reconstruction**

THANK YOU…