Summary of MultiDark activities in SuperCDMS

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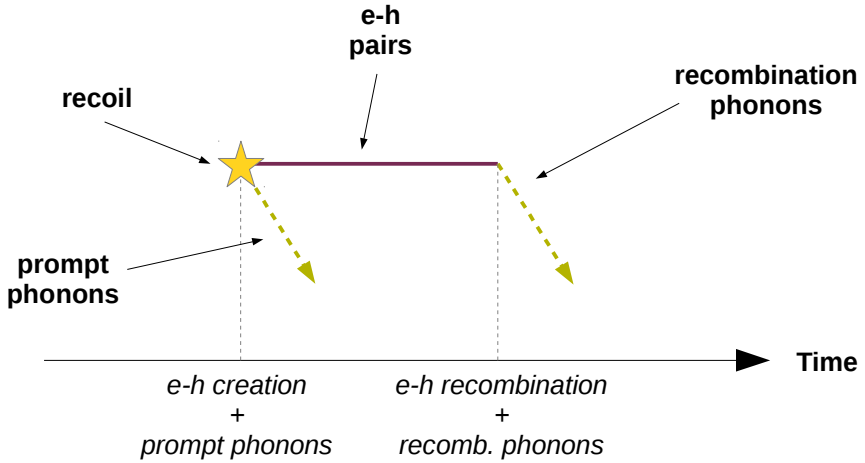
XIV MultiDark workshop, 25th of May 2017

THE CONCEPT

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

Measuring charge (N_q) and phonon (E_P) signal



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

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

	Y
Recoiling electron	1
Recoiling Ge nucleus	~0.3

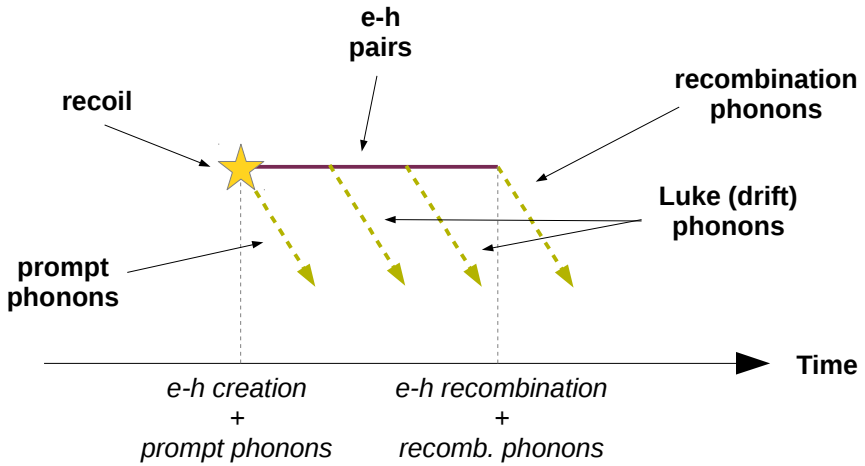
*Initially, part of the energy (**Y**) is used to create e-h pairs*
*But eventually all the recoil energy is released as phonons (**heat**)*

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

E_P is increased if voltage bias V is applied because of **work done on e-h pairs**



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

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

	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

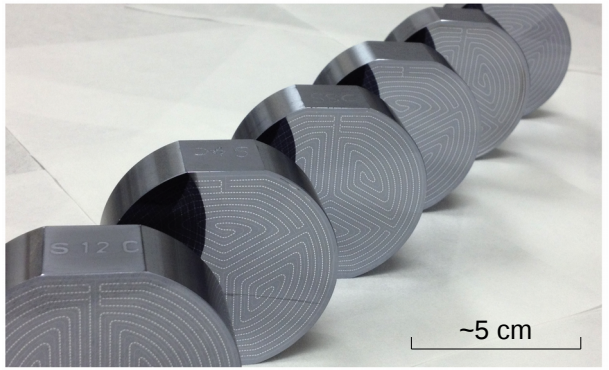
It's possible to know recoil energy (E_R) and type of recoiling particle (Y) from E_P and N_q

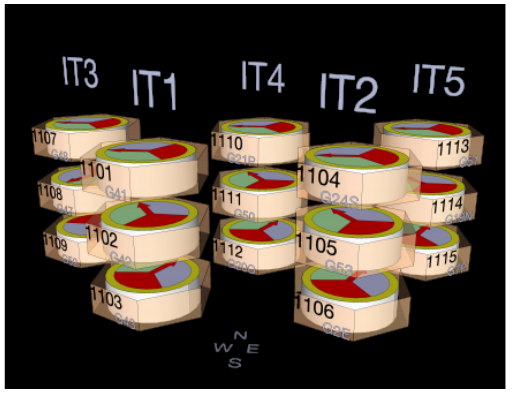
SUPERCDMS SOUDAN

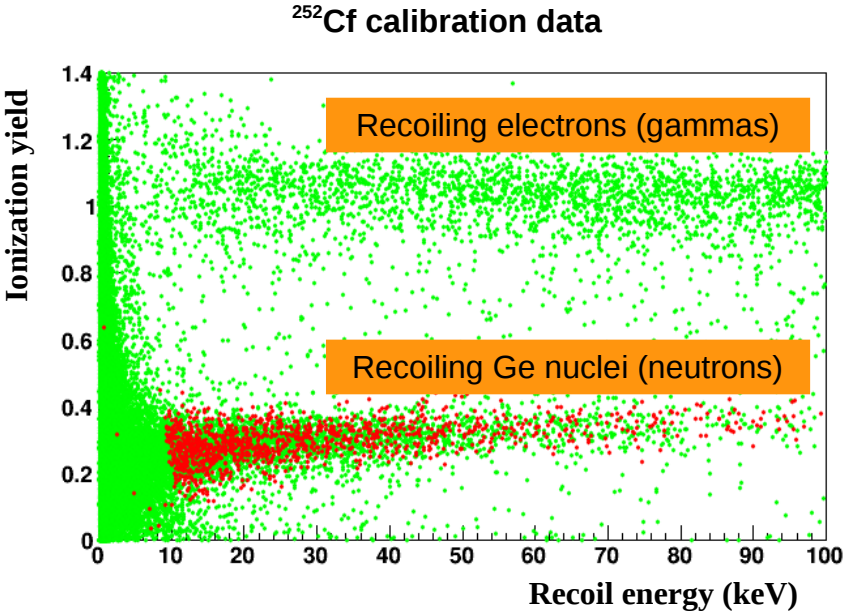
Operated between **March 2012** and **November 2015**

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

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





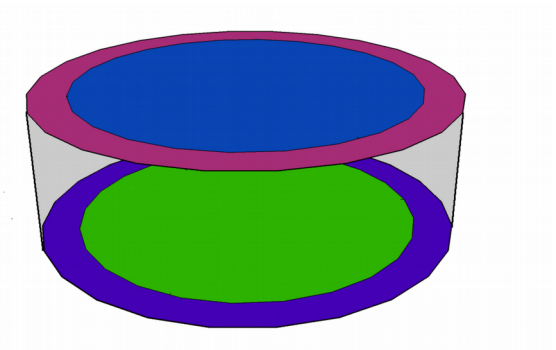


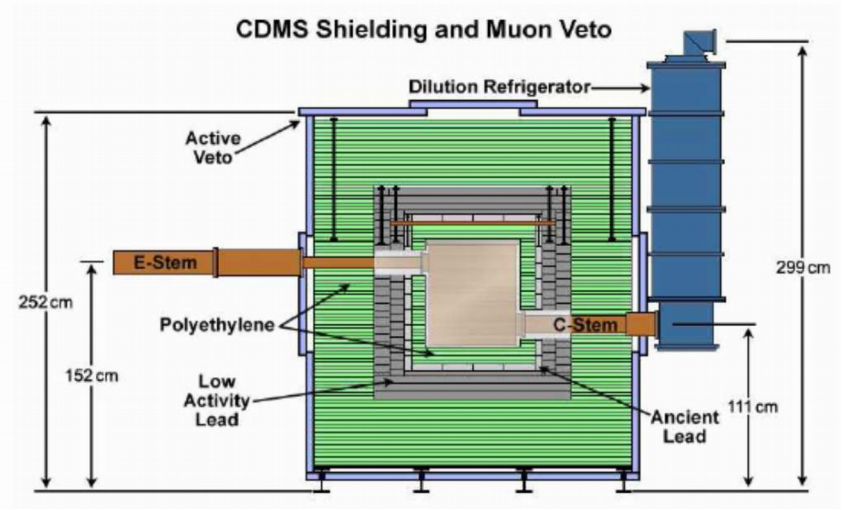
SUPERCDMS SOUDAN

Background suppression:

- Deployed at **Soudan Underground Laboratory** (714 m depth)
- Active shielding (muon showers): **scintillating plastic**, full solid angle
- Passive shielding: **polyethylene** (neutrons), **lead** (gammas)
- Structures within shielding: **radiopure Cu**
- Full fiducial volume: applied **electric field**+**segmented read-out** configuration
- Particle identification: using **measured *Y***

Charge read-out channels



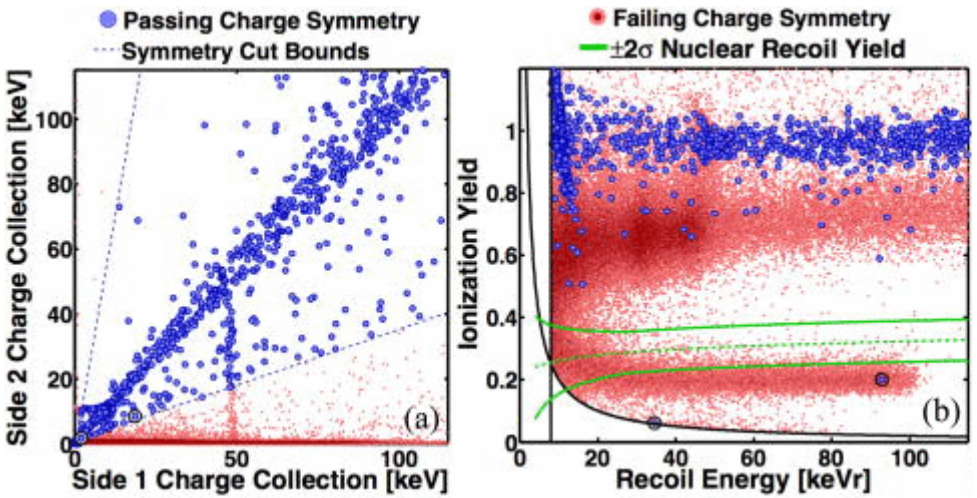


SUPERCDMS SOUDAN

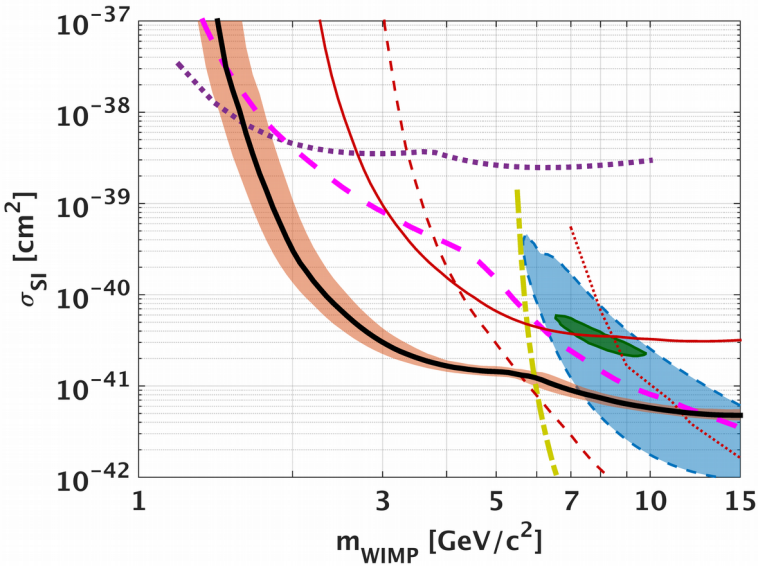
Results:

- Demonstration of **surface event rejection** arXiv:1305.2405
- Demonstration of **CDMSlite** technology arXiv:1309.3259
- **Low-threshold (*LT*) WIMP search** arXiv:1402.7137
- **Effective field theory** paper arXiv:1503.03379
- Second **CDMSlite** run arXiv:1509.02448
- **Conventional (*HT*) WIMP search** already unblinded, paper in preparation

Surface event rejection in SuperCDMS Soudan



Exclusion limit from CDMSlite II



SUPERCDMS SNOLAB

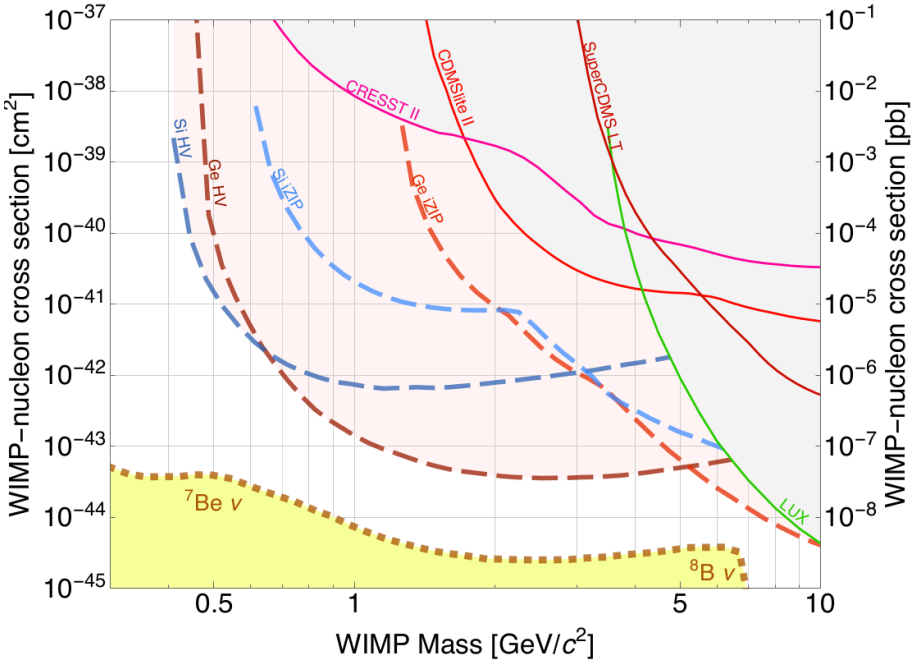
Project proposal:

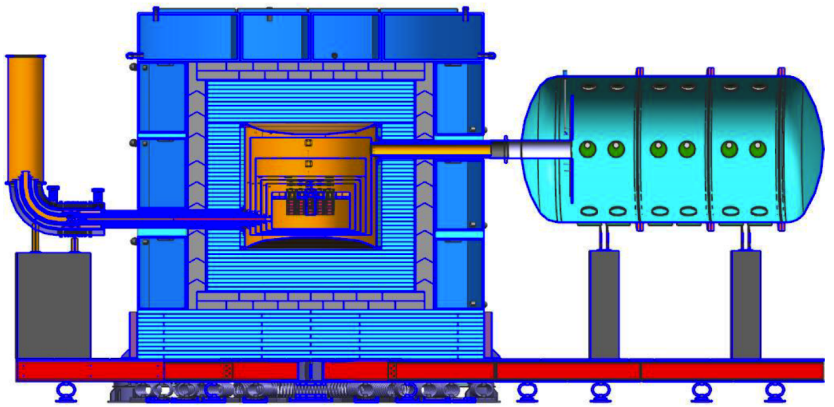
- Detectors with **full background rejection** capabilities: **14 kg Ge**, **1.2 kg Si**
- Detectors with **lowered energy thresholds** (increased V): **10 kg Ge**, **2.4 kg Si**

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





THE SUPERCDMS GROUP AT IFT-IPPP

Started in 2011, currently having a consolidated presence in the experiment

Members:

- **David G. Cerdeño** (2011-current), PI
- **Elías López Asamar** (2012-current), postdoc
- **Leyre Esteban Otano** (2011-2014), PhD student
- **Marina Peñalver Martínez** (2016), MSc student

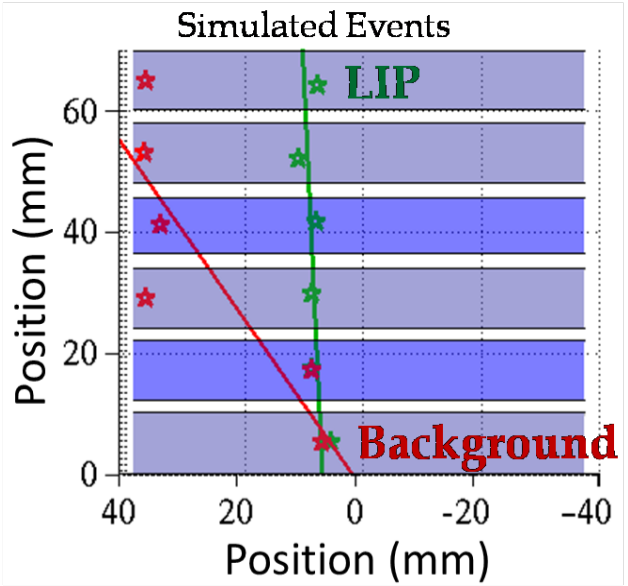
Mainly devoted to **data analysis** and **backgrounds assessment**

SEARCH OF PARTICLES WITH FRACTIONAL CHARGE WITH CDMS II DATA

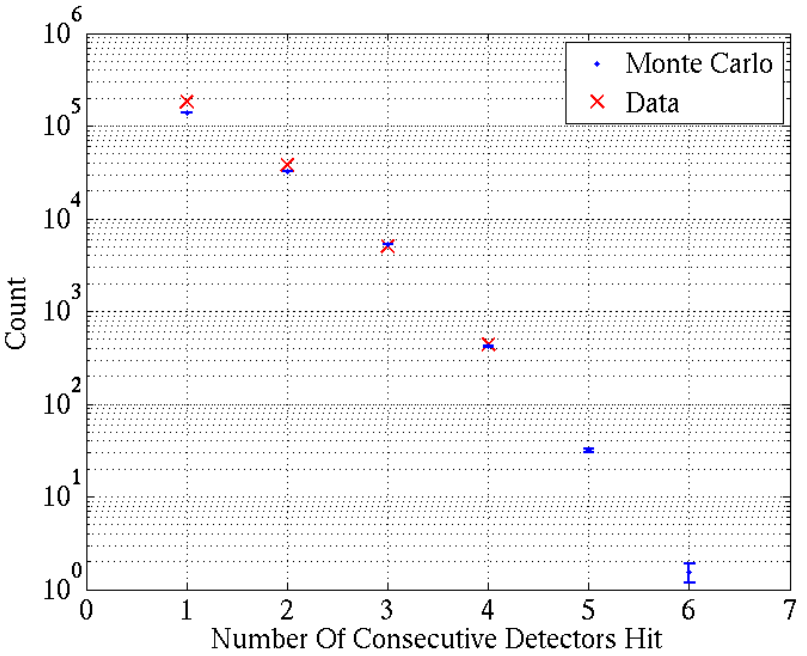
Signal: column of 6 detectors all with small ionization measurement

IFT group assessed dominant background: multiple gamma scattering

Predicted 0.16 $^{+0.12}_{-0.07}$ (stat) $^{+0.01}_{-0.1}$ (sys) events after cuts, none found



Background predicted before cuts, against data



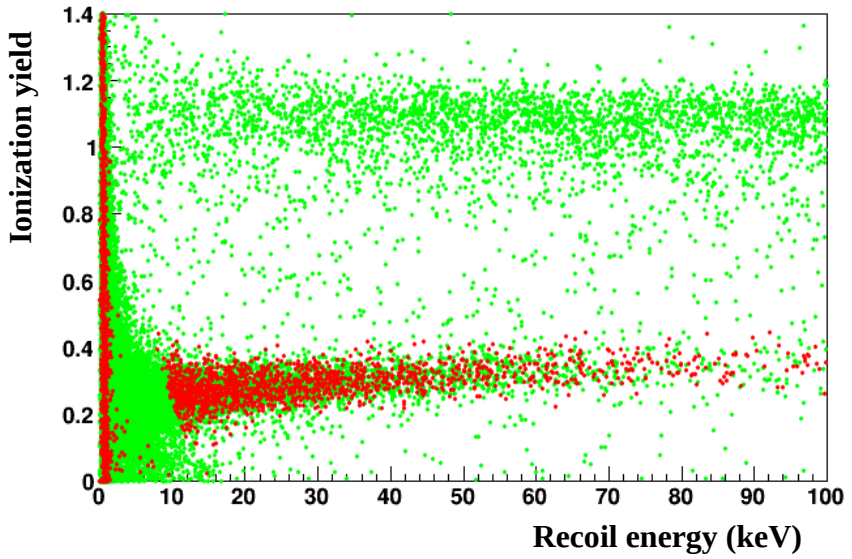
DATA BLINDING

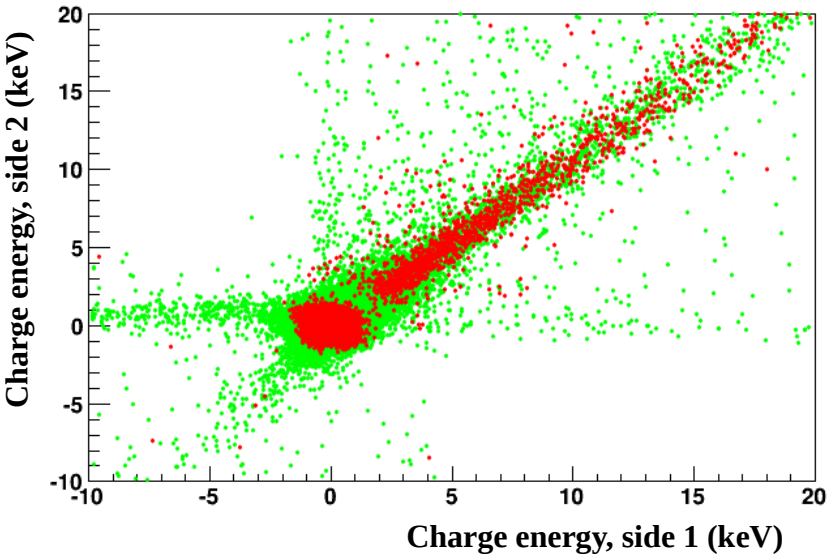
IFT group carried out data blinding for LT and HT WIMP searches

High-responsibility task

Required good understanding of experiment performance ⇒ **provided valuable information for data analyses**

Blinded calibration data (red) in detector T4Z3





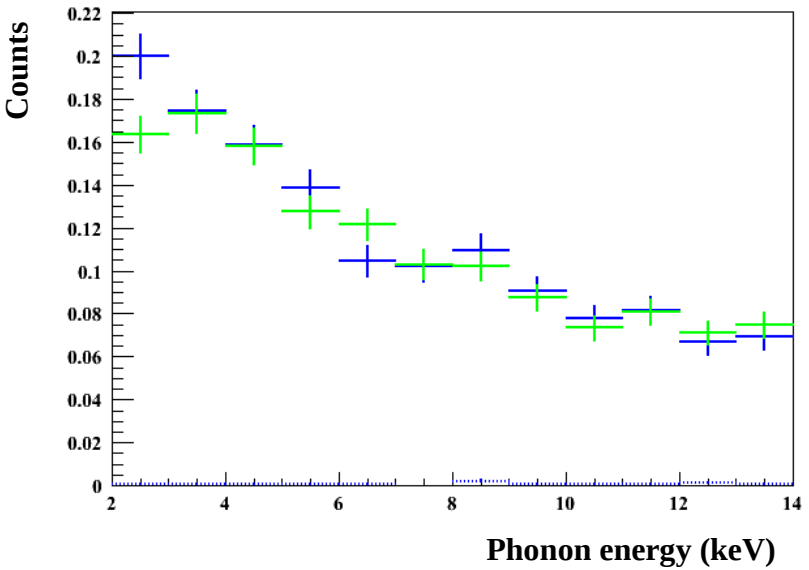
DETERMINATION OF FIDUCIAL VOLUME FOR LT WIMP SEARCH

IFT group contributed to LT WIMP search by determining the fiducial volume

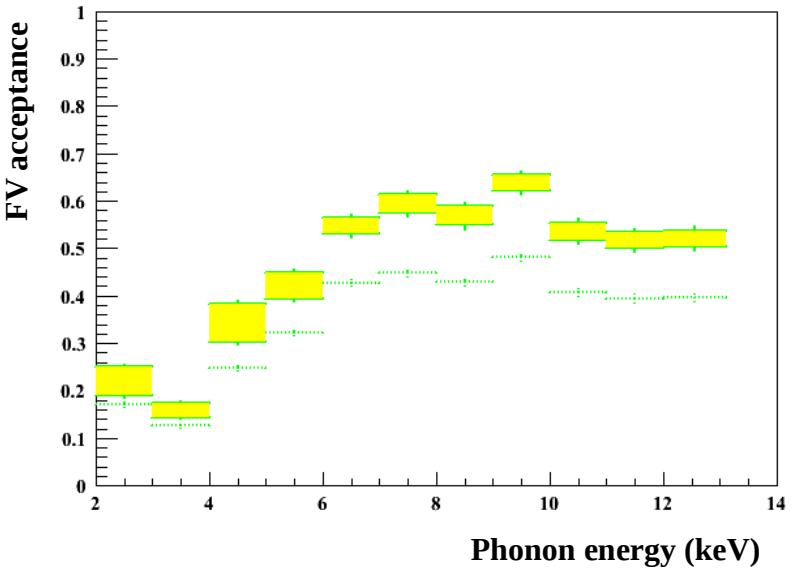
Knowledge of fiducial mass necessary to calculate WIMP exclusion limits

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

MC spectrum of ^{252}Cf neutrons (blue) against data (green) for detector T4Z3



Corrected FV acceptance (yellow band) for detector T4Z3



STUDY OF VETOED EVENTS

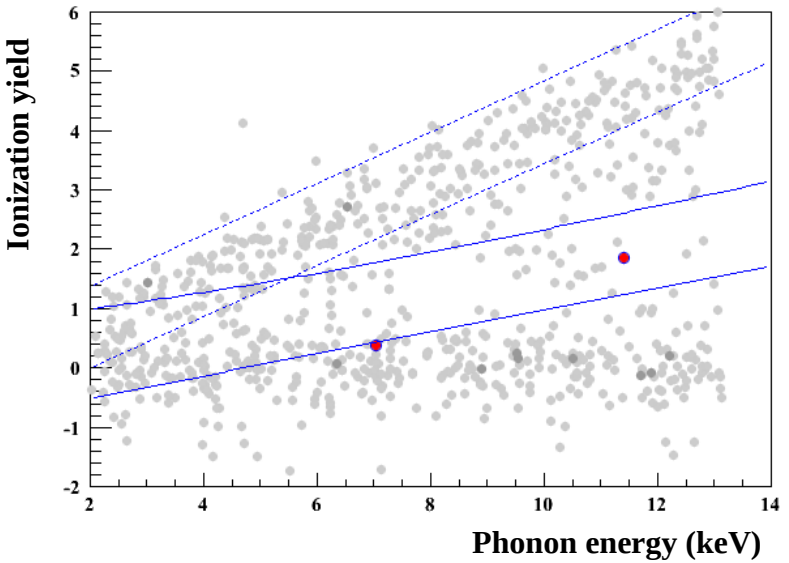
IFT group in charge of understanding vetoed events for LT and HT WIMP searches

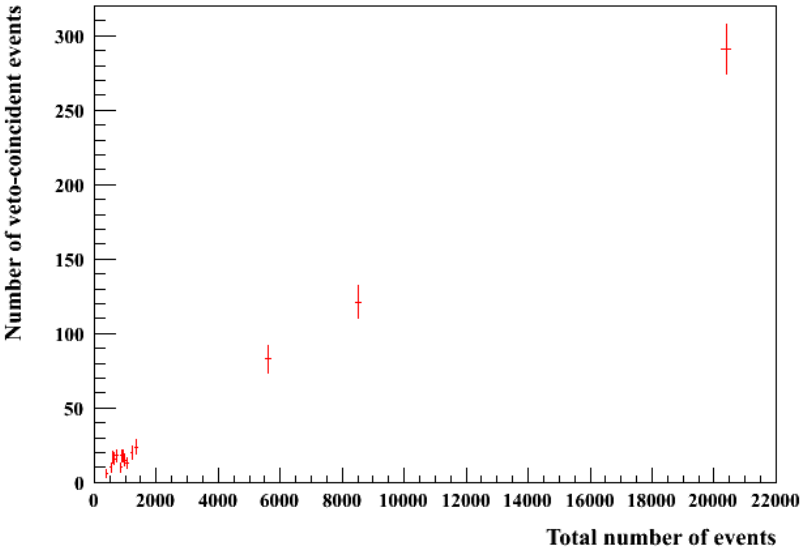
Vetoed data allows to check MC predictions of cosmogenic neutron background

Excess found: **3 single-scattering NR predicted, 6 observed**

Identified **contribution from accidental coincidences** (veto signal independent of detector signal) using novel method developed by us

Vetoed events in LT WIMP search (red) for detector T4Z3





EFFECTIVE FIELD THEORY PAPER

IFT group lead study considering all LO and NLO operators in effective lagrangian describing WIMP-nucleon interaction

$$\boxed{\mathcal{O}_1 = 1_\chi 1_N}$$ Standard SI

$$\mathcal{O}_3 = i\vec{S}_N \cdot \left[\frac{\vec{q}}{m_N} \times \vec{v}^\perp\right]$$

$$\boxed{\mathcal{O}_4 = \vec{S}_\chi \cdot \vec{S}_N}$$ Standard SD

$$\mathcal{O}_5 = i\vec{S}_\chi \cdot \left[\frac{\vec{q}}{m_N} \times \vec{v}^\perp\right]$$

$$\mathcal{O}_6 = \left[\vec{S}_\chi \cdot \frac{\vec{q}}{m_N}\right]\left[\vec{S}_N \cdot \frac{\vec{q}}{m_N}\right]$$

$$\mathcal{O}_7 = \vec{S}_N \cdot \vec{v}^\perp$$

$$\mathcal{O}_8 = \vec{S}_\chi \cdot \vec{v}^\perp$$

$$\mathcal{O}_9 = i\vec{S}_\chi \cdot \left[\vec{S}_N \times \frac{\vec{q}}{m_N}\right]$$

$$\mathcal{O}_{10} = i\vec{S}_N \cdot \frac{\vec{q}}{m_N}$$

$$\mathcal{O}_{11} = i\vec{S}_\chi \cdot \frac{\vec{q}}{m_N}$$

$$\mathcal{O}_{12} = \vec{S}_\chi \cdot \left[\vec{S}_N \times \vec{v}^\perp\right]$$

$$\mathcal{O}_{13} = i\left[\vec{S}_\chi \cdot \vec{v}^\perp\right]\left[\vec{S}_N \cdot \frac{\vec{q}}{m_N}\right]$$

$$\mathcal{O}_{14} = i\left[\vec{S}_\chi \cdot \frac{\vec{q}}{m_N}\right]\left[\vec{S}_N \cdot \vec{v}^\perp\right]$$

$$\mathcal{O}_{15} = -\left[\vec{S}_\chi \cdot \frac{\vec{q}}{m_N}\right]\left[\left(\vec{S}_N \times \vec{v}^\perp\right) \cdot \frac{\vec{q}}{m_N}\right]$$

EFFECTIVE FIELD THEORY PAPER

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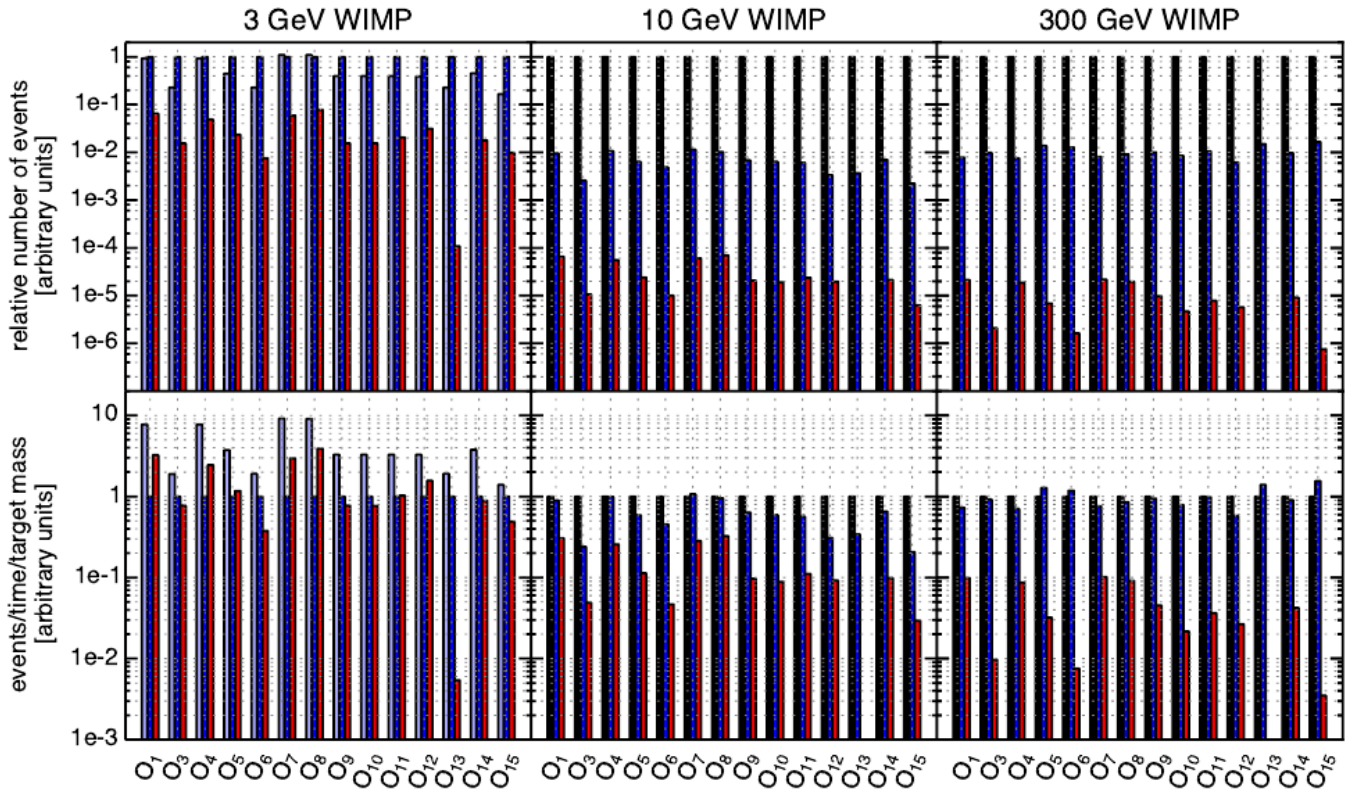
WIMP rates in G2 experiments as a function of operator



LZ
SCDMS-SNOLAB, Ge
SCDMS-SNOLAB, Si

GLOBAL MODEL OF GAMMA BACKGROUND

IFT-IPPP group built the global model of gamma background at Soudan

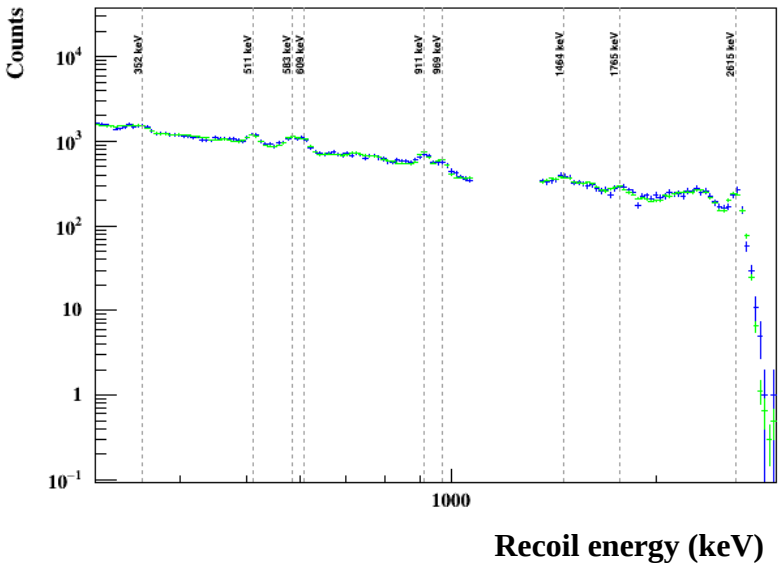
Concept: **MC model of gamma spectrum with radioactivity levels as free parameters**

Leads to a measurement of the radioactivity levels of the experiment

Used radioactivity levels from screening measurements as constraints

Used novel approach to **exploit information from gamma data**

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



^{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

GLOBAL MODEL OF GAMMA BACKGROUND

IFT-IPPP group built the global model of gamma background at Soudan

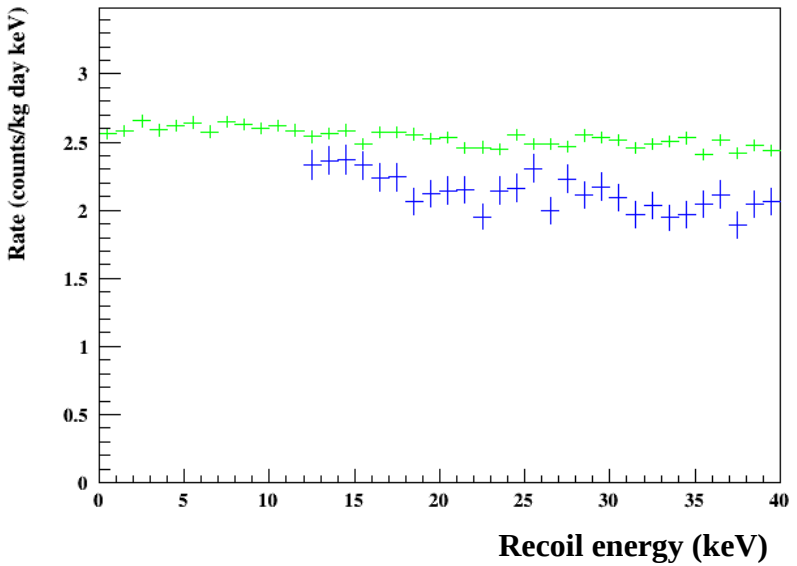
Concept: **MC model of gamma spectrum with radioactivity levels as free parameters**

Leads to a measurement of the radioactivity levels of the experiment

Used radioactivity levels from screening measurements as constraints

Checked by **extrapolating spectrum to low energies**

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



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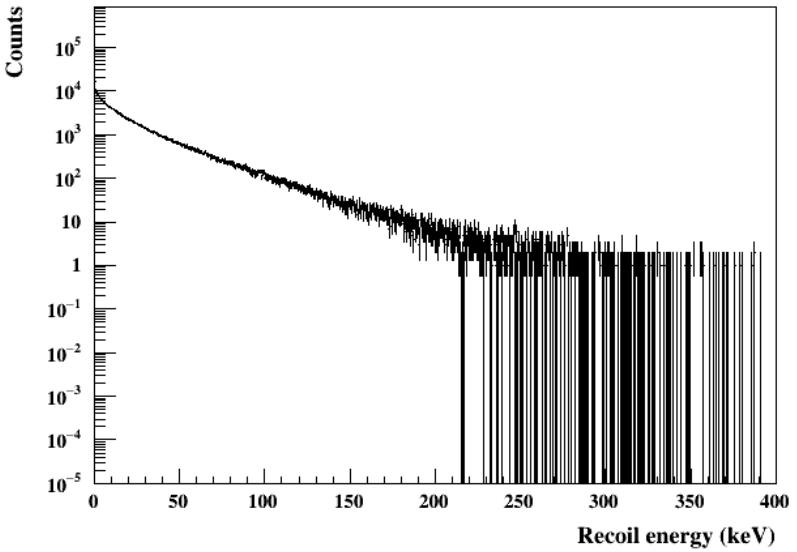
ASSESSMENT OF RADIOGENIC NEUTRON BACKGROUND FOR HT WIMP SEARCH

Subject of MSc thesis of Marina Peñalver Martínez at IPPP group

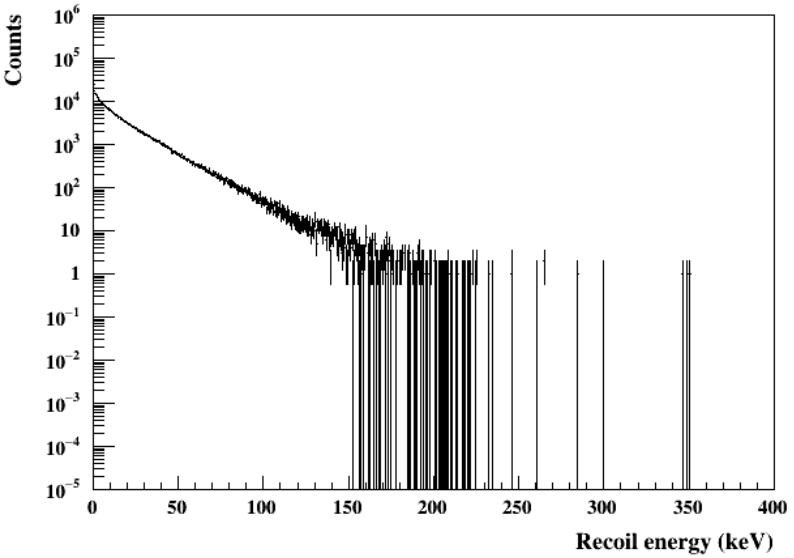
Used MC simulation+radioactivity levels from the global model of gamma spectrum

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

^{238}U in cryogenic vessels



^{232}Th in cryogenic vessels

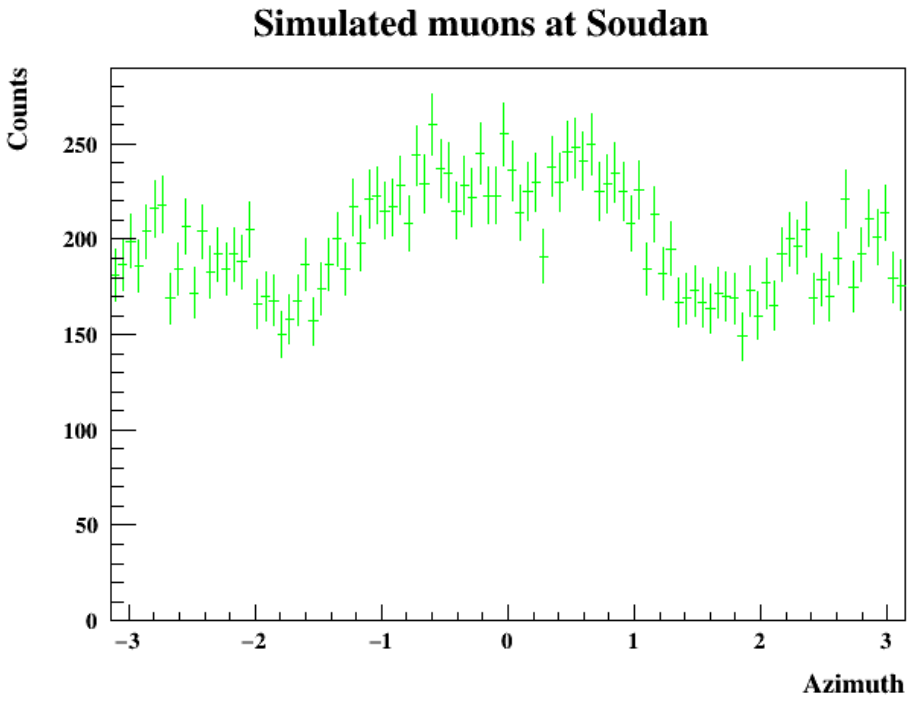


ASSESSMENT OF COSMOGENIC NEUTRON BACKGROUND FOR HT WIMP SEARCH

IPPP group calculated the full neutron background for HT WIMP search

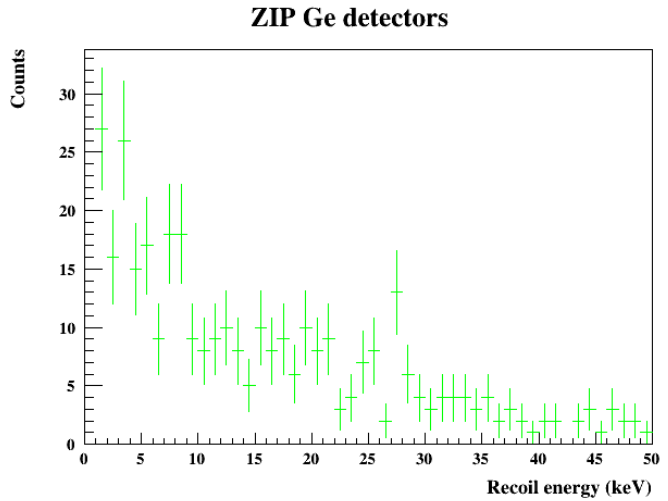
Used MC including effects of orography (MUSUN)

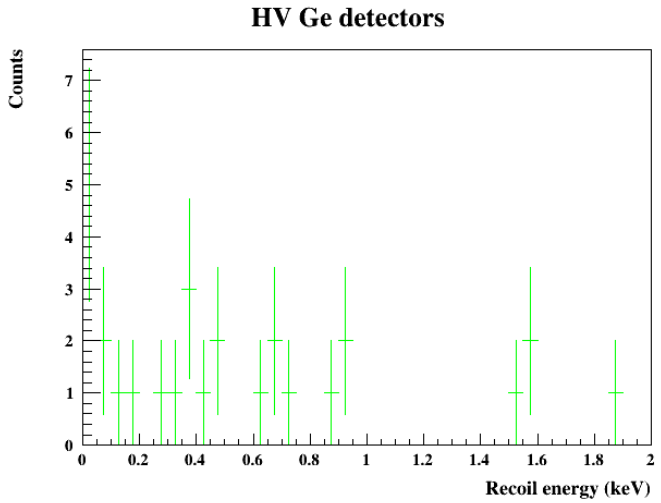
Predicted cosmogenic neutron background for HT WIMP search: **0.024 ± 0.024 events**

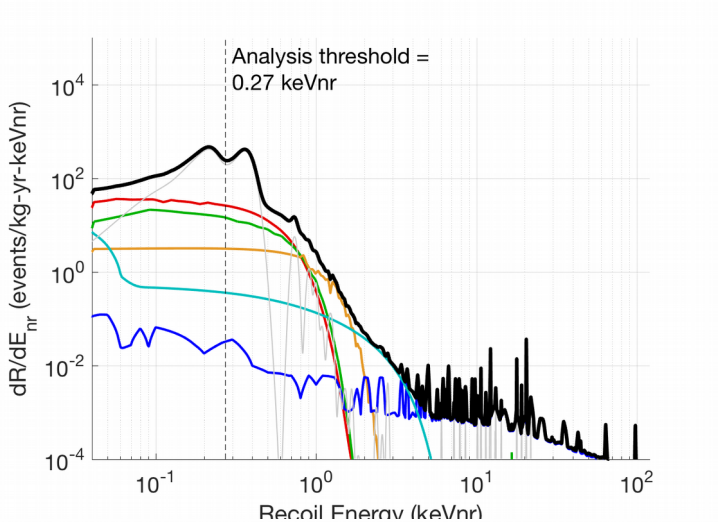


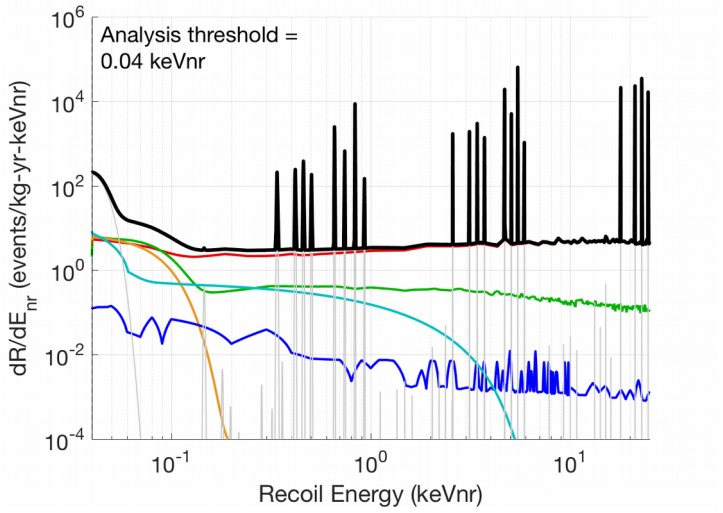
ASSESSMENT OF COSMOGENIC NEUTRON BACKGROUND FOR SNOLAB PROJECT

IPPP group contributed to SuperCDMS SNOLAB project by calculating the predicted cosmogenic neutron background









Ge activation lines
Compton + ^{3}H
Surface ß decay
Recoiling ^{206}Pb
CNS
Neutron

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 IFT-IPPP group in the collaboration is well consolidated**
- Several relevant contributions to **data analyses** and **backgrounds assessment**

THANK YOU…