Sensitivity, Performance, Stability and Intrinsic Background in Bolometric detectors for Dark Matter searches

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Summary

- The Dark Matter Signal
- Low Temperature (Phonon) Detectors
- Techniques
- Sensitivity
- Relevant Parameters
- Perspectives
- Conclusions

The signal

Direct Detection Concept:

Interaction of Dark Matter Candidates on Terrestrial Targets

Still unknowns/uncertainties on

- nature of the candidates
- their interactions
  - Weak intensity
  - Spin-independent/dependent
  - Coherent scattering
  - Elastic/Inelastic

“Model independent” features

- Rate Modulation
- Directionality
- Target dependence

Periodic change of the WIMP velocity in the detector frame due to the motion of the Earth around the Sun.
The variation is only of a few percent of the total WIMP signal: $v_{Earth/Sun}/v_{Sun}$ ~ 15 km s-1/230 km s-1 ~ 0.07

Another consequence the motion of the Earth around the Sun

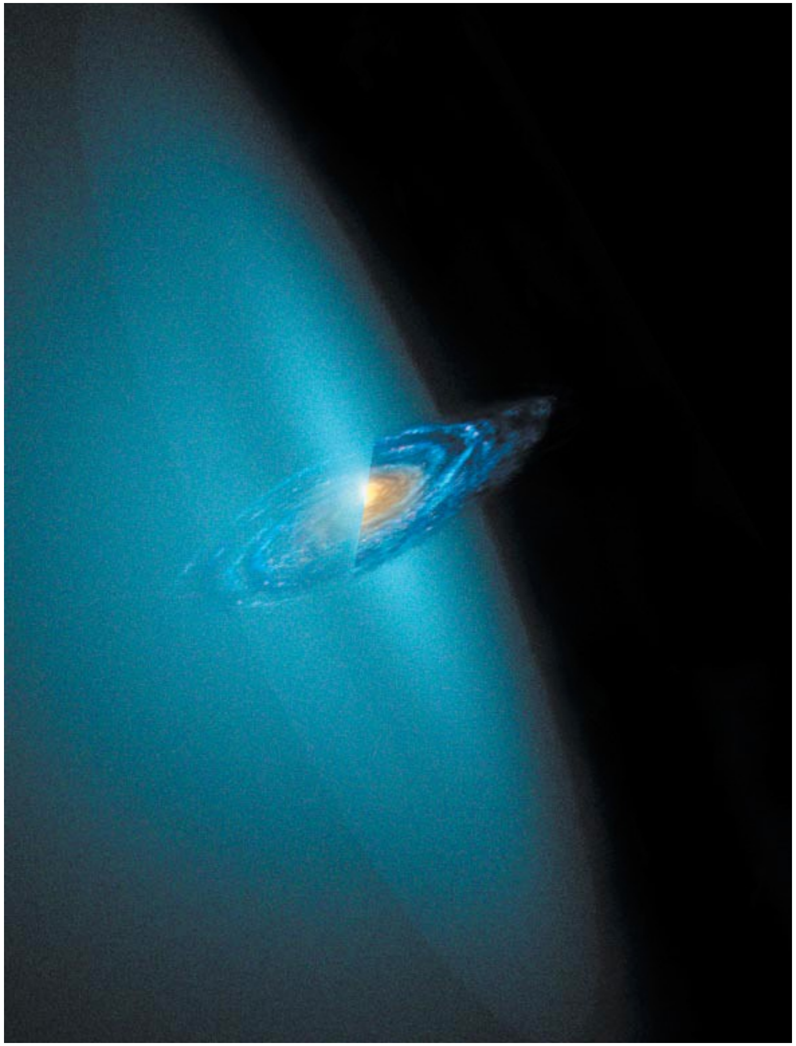
WIMPs: the naive version of dark matter

Cosmology and Particle Physics suggest a common “excellent candidate”:

Lowest Stable Particles (LSP) in the SUSY Zoo

Spherical Halo Model:

- Local density: $\rho_o = 0.3$ GeV/cm^3
- Maxwellian distribution of the velocities
  - rms velocity: $v_o = 230$ km/s,
  - Escape velocity (cutoff): $v_{esc} = 650$ km/s



WIMPs Direct Detection

Nuclear recoils produced by the WIMP elastic scattering off target nuclei in underground detectors.

Weak interaction ⇒ very low expected signal rates

Expected signal (zero threshold) for a WIMP particle χ with mass m_χ, density ρ_χ, average velocity $<v_\chi>$, and cross section $\sigma_{\chi A}$ for scattering off a nucleus containing A nucleons

$$R \cong \frac{\rho_\chi}{m_\chi} \langle v_\chi \rangle \frac{\sigma_{\chi A}}{A} \longrightarrow$$

Coherent scattering ($\sim A^2$) corrected for Nuclear effects (for factor $F(E_R)$)

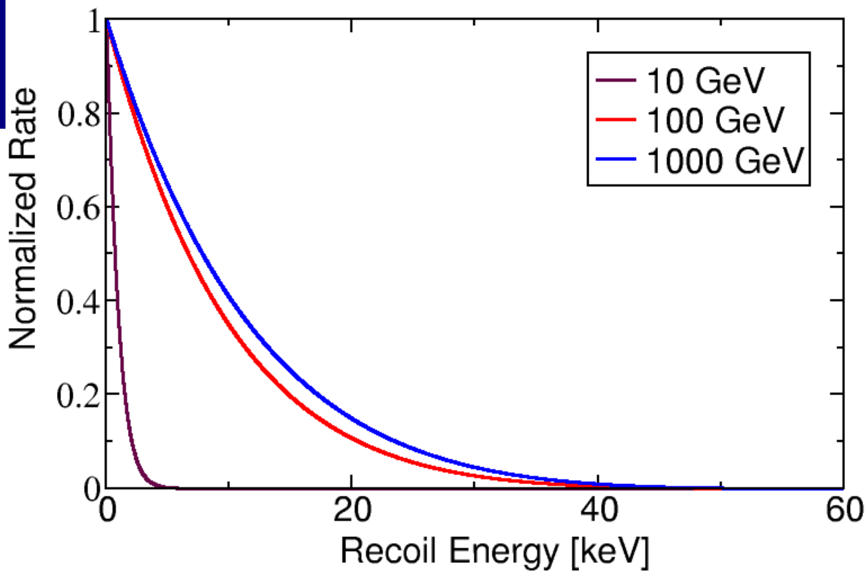
$$\cong \frac{3.6}{A} \left(\frac{GeV}{m_\chi} \right) \left(\frac{\rho_\chi}{0.3\ GeV / cm^3} \right) \left(\frac{\langle v_\chi \rangle}{230\ km / s} \right) \left(\frac{\sigma_{\chi A}}{10^{-38}\ cm^2} \right) \frac{events}{kg \cdot day}$$

For any given measured recoil energy E_R, the experimetal rate R^{exp} constrains a set of m_χ values. The envelope of these curves is the exclusion plot.

WIMPs signal

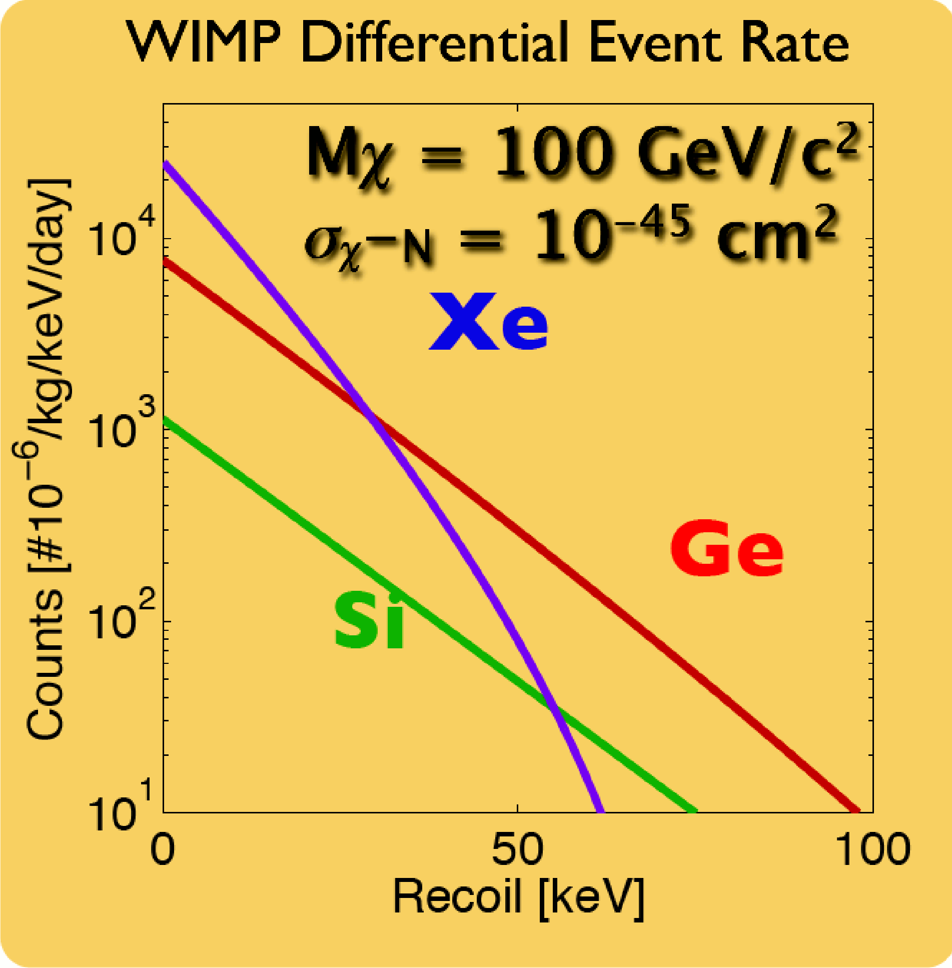
The challenge:

- feeble interactions rates
- feeble signals (a few keV)
- featureless exponential spectrum



The detectable energy is further quenched, since only a fraction of the recoil energy goes to the observed channels (**Nuclear Recoil Quenching Factor**)

- Expected rate: < 0.01/kg-d
- Radioactive background of most materials higher than this rate.
- Dependence on the target material



Experimetal Strategies

Two possible approaches

Blind or “Best effort”

- No preferred candidate or interaction
- No special cuts
- Reduce possible background
- Collect all available piece of information

Model dependent or based on Dark Matter Model guidance

- Select favorite channel
- Select the best technique to apply the best cuts

Common Requests

Low energy thresholds

  as low as allowed by the eventual onset of background dominance

Rigid background controls

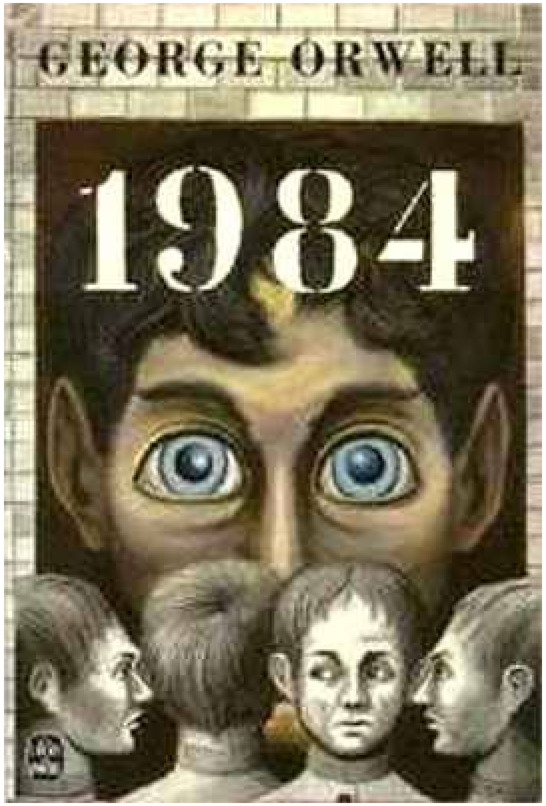
  Clean materials
  Shielding
  Background identification (Discrimination power)
  Substantial Depth
  Neutrons care

Long exposures

Large target masses

Long term stablility

Phonon detectors … a long history



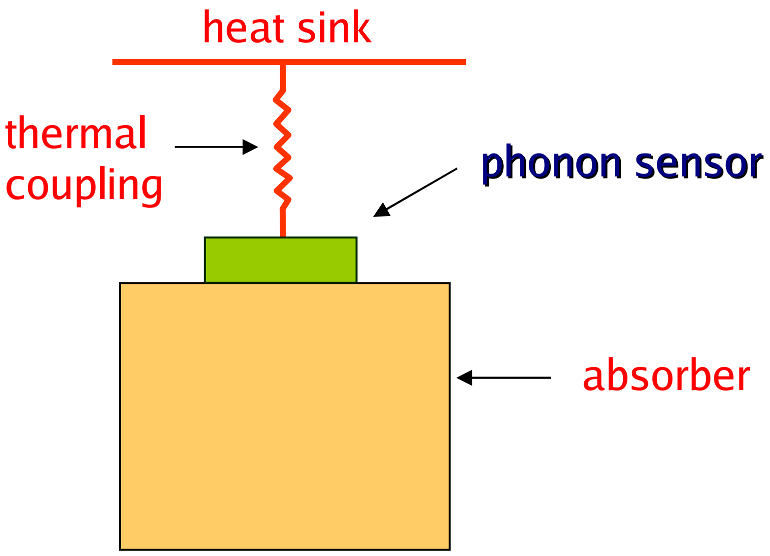
- S.H. Moseley et al.: J. Appl. Phys. 56 (1984) 1257: Thermal detectors as X-ray spectrometers

- E. Fiorini and T.O. Niinikoski: Nucl. Instr. Meth. 224 (1984) 83: **LOW-TEMPERATURE CALORIMETRY FOR RARE DECAYS**

"The recent developments in underground low-counting experiments give limits to rare decays which are hard to improve since
scaling the size and the resolution of the combined source-detector is difficult with the existing techniques. We explore here the
possibility of low-temperature calorimetry to improve the limits on processes such as neutrinoless double-beta decay and electron decay"

Dark Matter is not explicitely mentioned simply because at the t ime it was just a fledgling discipline

Phonon detectors



Particle interactions produce out of equilibrium (high energy) phonons which "slowly" degrade to thermal phonons.

Different phonon sensors (sensitive to different stages of the phonon degradation process) characterize different detectors.

Bolometers are usually identified as
the class of phonon detectors sensitive to the thermal phonons (heat).

Event details (position, precise timing) are completely washed out in the thermalization process.
They are only available to detectors sensitive to out of equilibrium phonon.

Phonon detector properties

Advantages

- Very good energy resolution
- Large target masses
- Free choice of the target isotope

To be cured

- Stability: Response and measurement
- Limited information
- Difficult to shield

Drawbacks

- Complexity (of the detector and the setup)
- Unexpected/Unknown behaviours

Require long R&D phases

A progressive knowledge

Data reliabilty directly relies on the level of knowledge of the detector working principles

Critical in many occasions

- Improvement of sensitivity
- Data quality
- Results reliability

Phonon detectors are not really more complex than conventional detectors but work in extreme conditions and need long R&D programs before reaching satisfactory performance.

Physics programs tend to start as soon as the detector performance is enough to guarantee a competitive sensitivity.

Incomplete knowledge is however payed at the next development stage

An uninterrupted R&D program aiming at a complete understanding of all the detector working mechanisms is however a key investment on future developments and must be always supported with an equilibrate approach weighting both aspects (R&D and Physics).

Background sources

Conventional

Environmental radioactivity → Heavy shields

Setup Materials radioactivity → Carefulmaterial selection

Cosmic rays secondaries from interactions → Deep underground sites

- In the overburden rock → Heavy shields
- In the detector setup/shields → Muon vetos

Neutrons are the most dangerous background source because they mimic WIMP interactions

Intrinsic

Instrumental: deviations from perfect behaviour

Radioactive contaminations of the detector materials

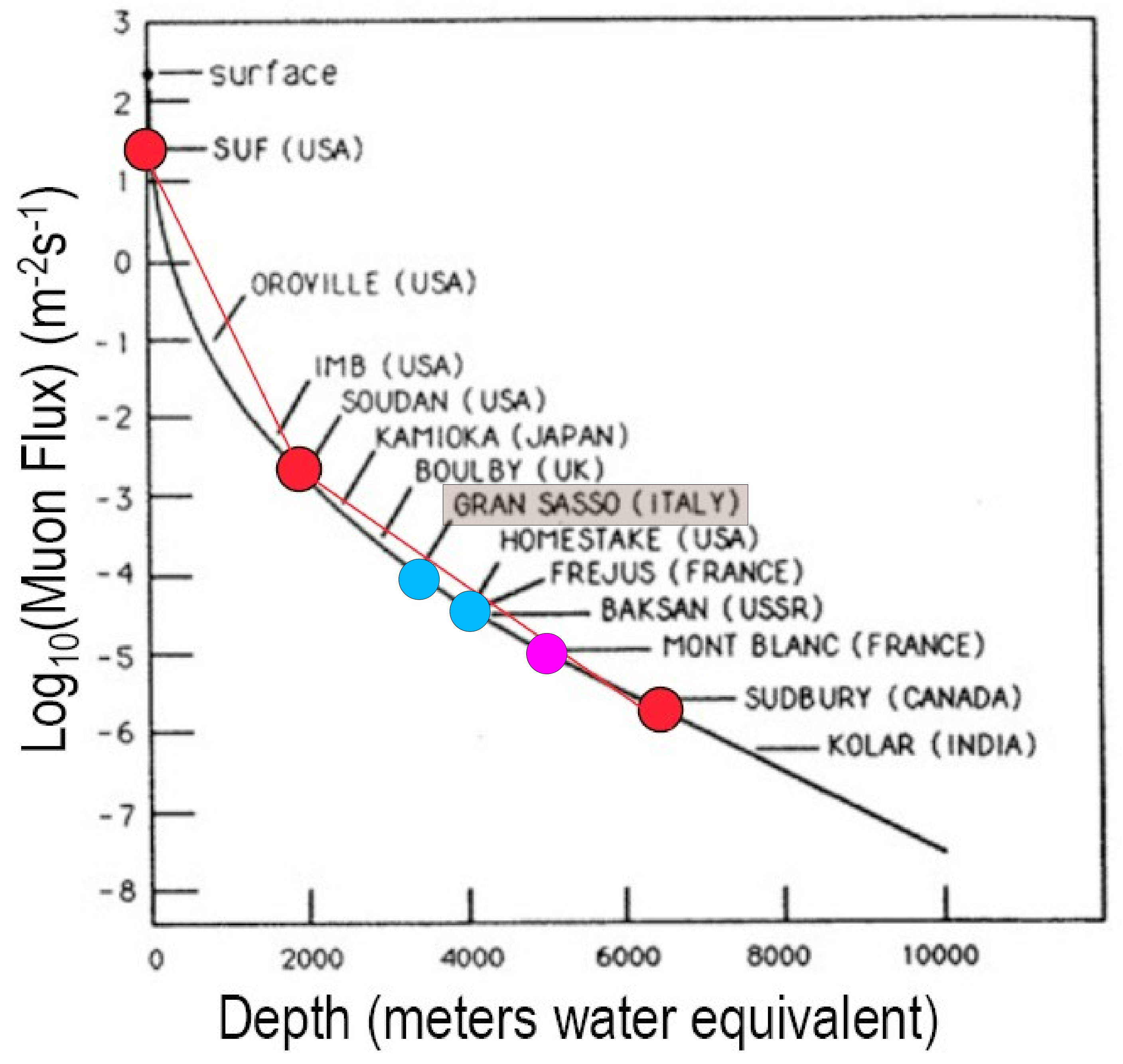
- Bulk → Material selection
- Surface → Specific surface treatments

Intrinsic sources are also dangerous because they strongly depend on the Detector concept

Underground sites: depth

Laboratory depth fixes the level of the cosmic ray background

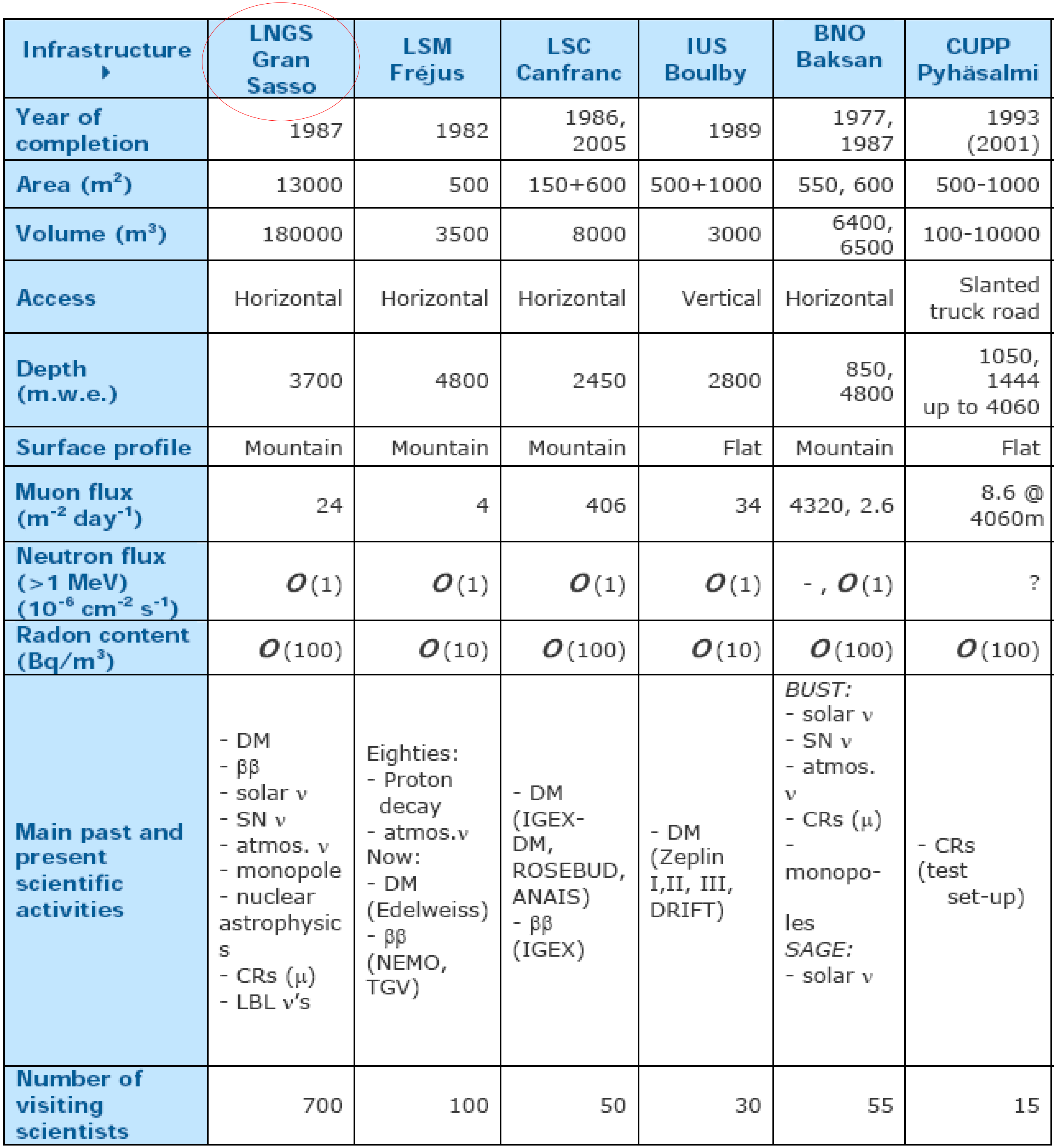
… but is not the only relevant parameter …



Underground sites in Europe

Depth is not the only relevant parameter

Underground labs must be :
Accessible
Proper area
Proper Volume



Infrastructure ▸	LNGS Gran Sasso	LSM Fréjus	LSC Canfranc	IUS Boulby	BNO Baksan	CUPP Pyhäsalmi
Year of completion	1987	1982	1986, 2005	1989	1977, 1987	1993 (2001)
Area (m^2)	13000	500	150+600	500+1000	550, 600	500-1000
Volume (m^3)	180000	3500	8000	3000	6400, 6500	100-10000
Access	Horizontal	Horizontal	Horizontal	Vertical	Horizontal	Slanted truck road
Depth (m.w.e.)	3700	4800	2450	2800	850, 4800	1050, 1444 up to 4060
Surface profile	Mountain	Mountain	Mountain	Flat	Mountain	Flat
Muon flux (m^{-2} day^{-1})	24	4	406	34	4320, 2.6	8.6 @ 4060m
Neutron flux (>1 MeV) (10^{-6} cm^{-2} s^{-1})	$O(1)$	$O(1)$	$O(1)$	$O(1)$	- , $O(1)$	?
Radon content (Bq/m^3)	$O(100)$	$O(10)$	$O(100)$	$O(10)$	$O(100)$	$O(100)$
Main past and present scientific activities	- DM - ββ - solar ν - SN ν - atmos. ν - monopole - nuclear astrophysics - CRs (μ) - LBL ν's	Eighties: - Proton decay - atmos.ν Now: - DM (Edelweiss) - ββ (NEMO, TGV)	- DM (IGEX-DM, ROSEBUD, ANAIS) - ββ (IGEX)	- DM (Zeplin I,II, III, DRIFT)	*BUST:* - solar ν - SN ν - atmos. ν - CRs (μ) - monopoles *SAGE:* - solar ν	- CRs (test set-up)
Number of visiting scientists	700	100	50	30	55	15

Rates: the statistics problem

A clear separation line distinguishes first generation experiments from those of the next generation (this is unfortunately a common problem to rare event searches):

$$N_{TOT} \sim O(1)$$

where N_{tot} is the total number of candidate events observed during the whole meauring time.

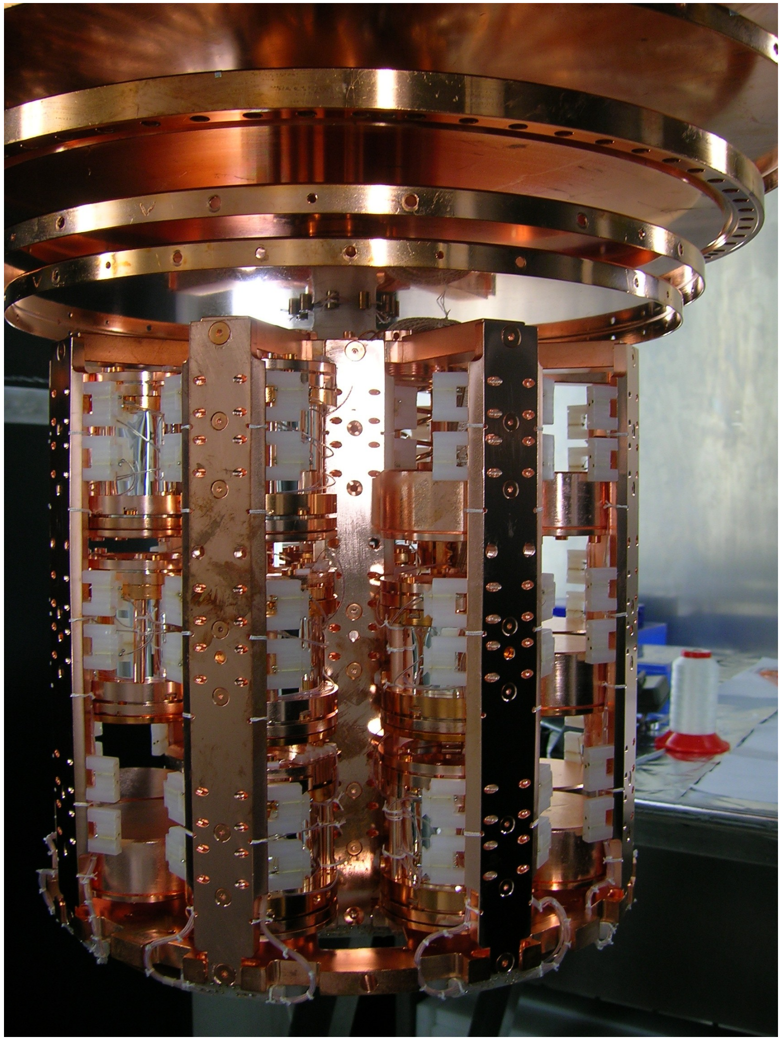
Since usually

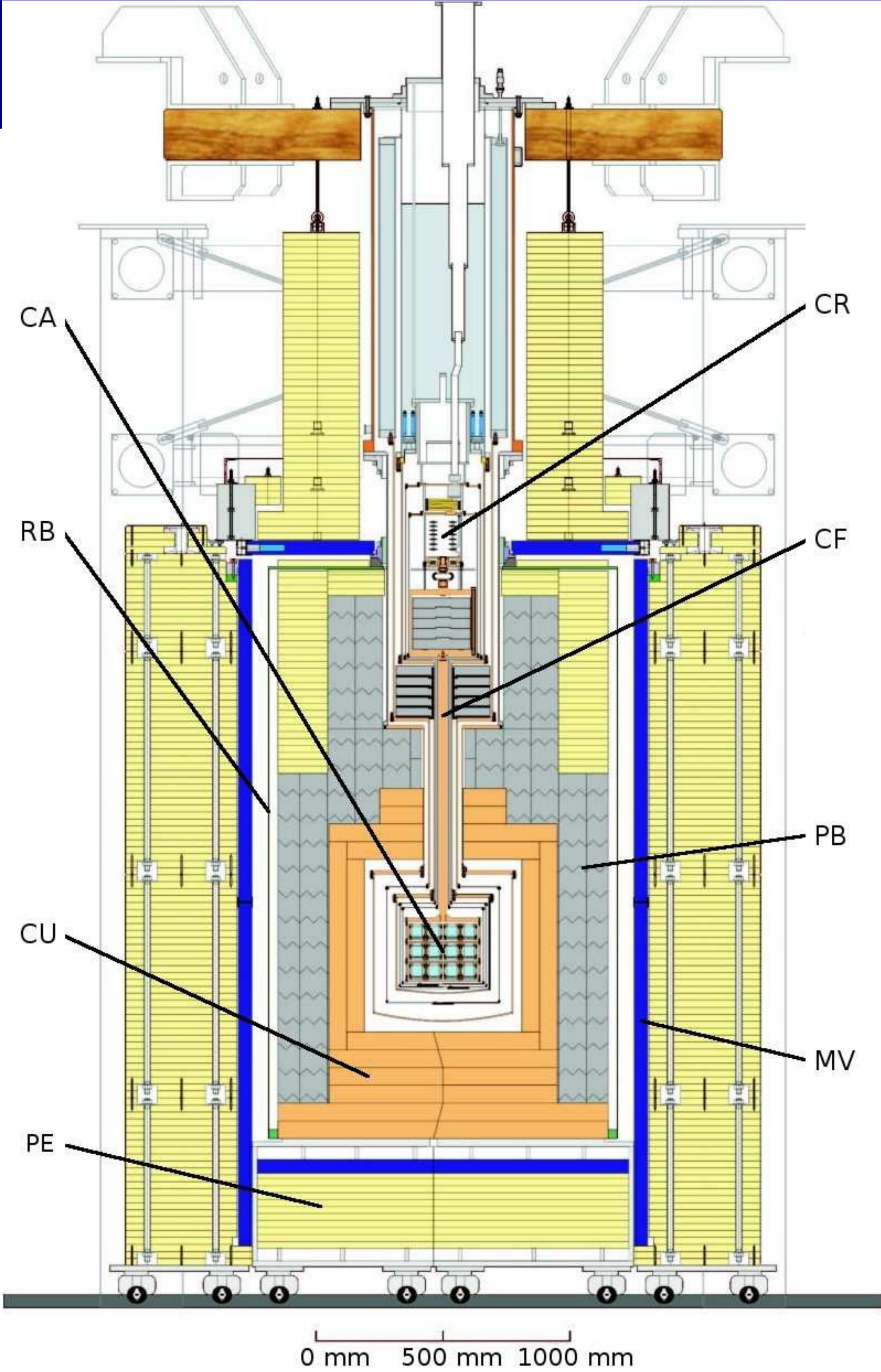
$$N_{TOT} \sim M \times T \times B$$

It is useless to reduce the background rate without a corresponding increase in the target mass.

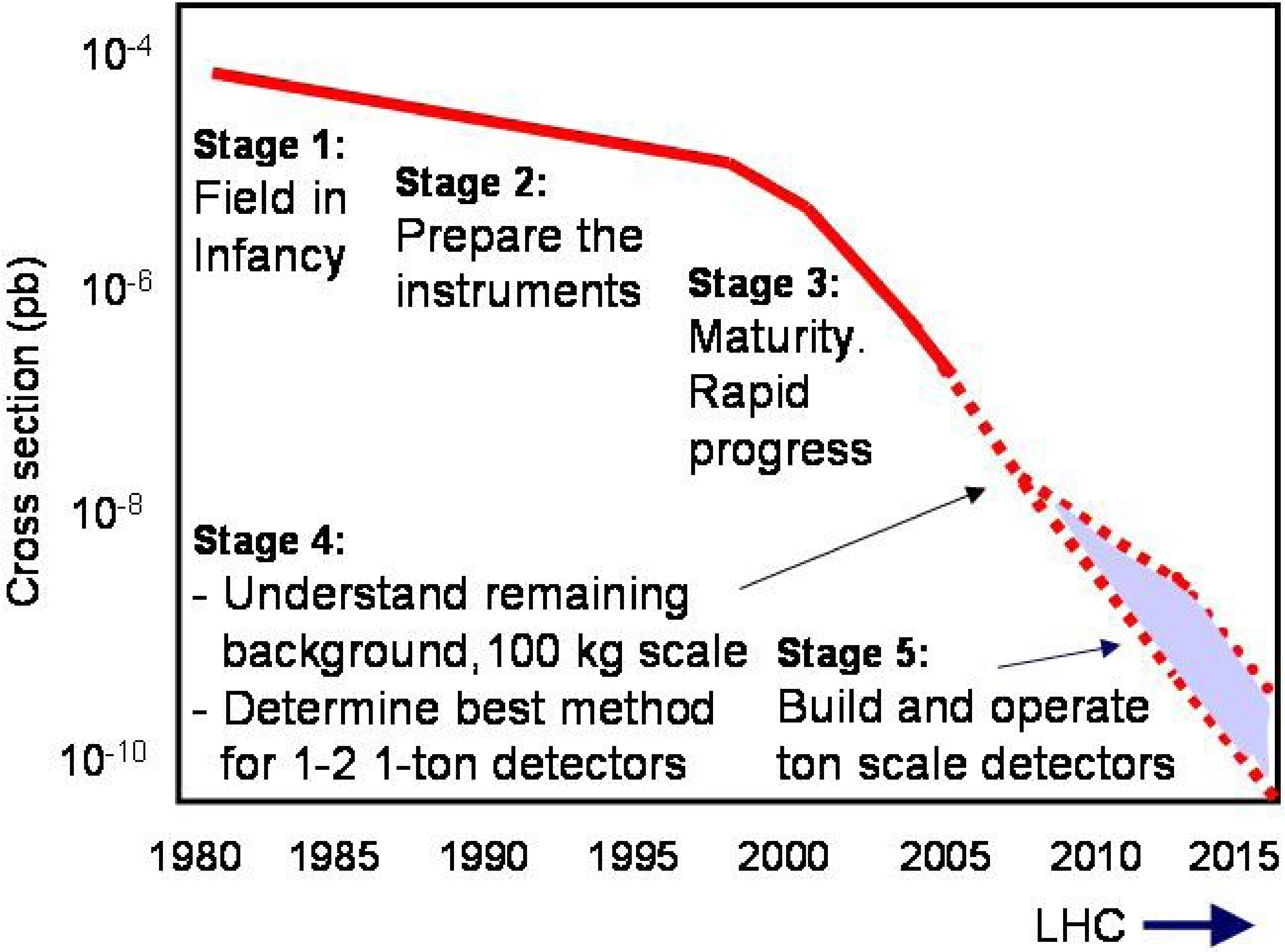
Installations complexity

Just an example: CRESST II





A phased program: roadmaps



Stage 1:
Field in Infancy

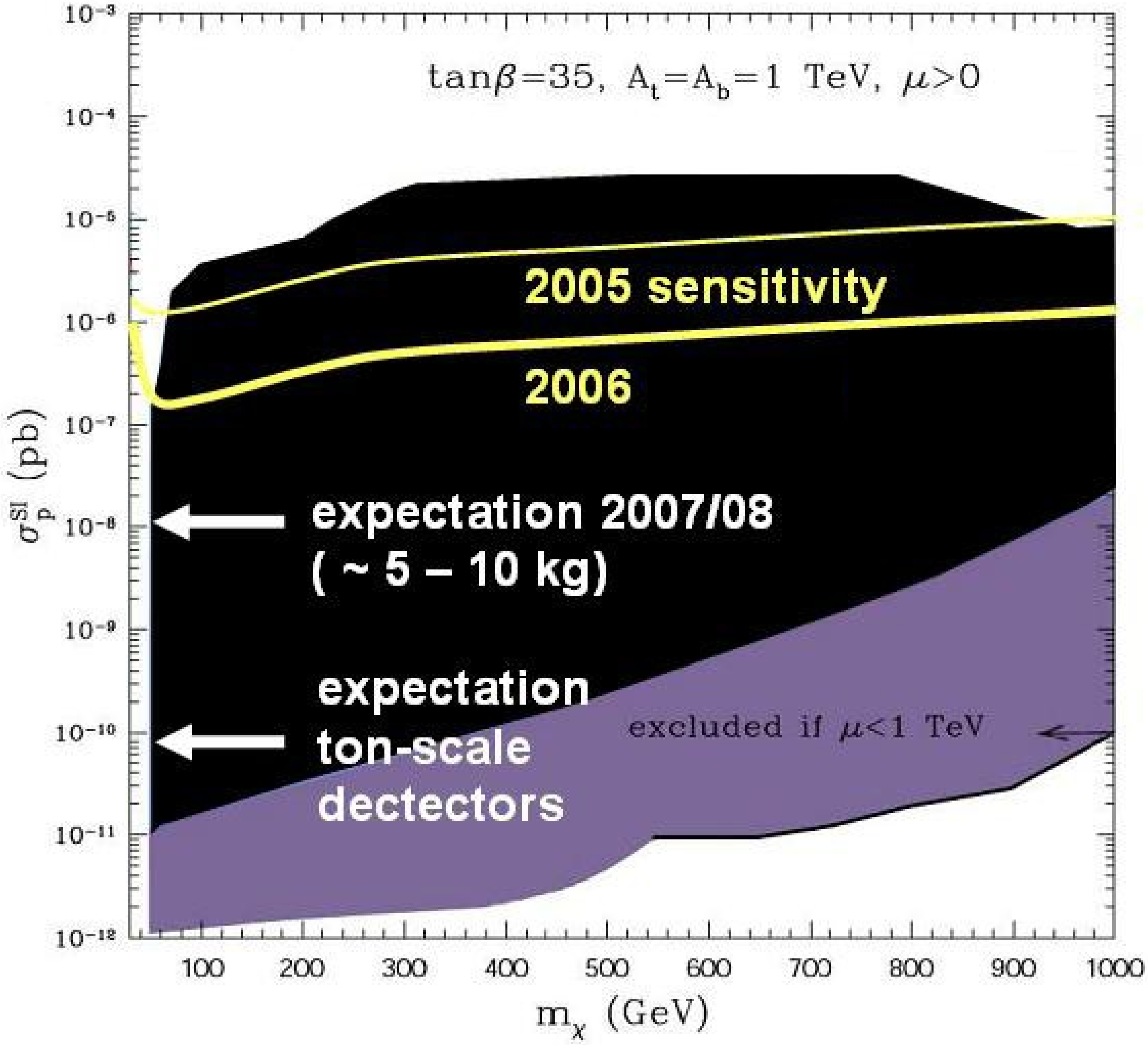
Stage 2:
Prepare the instruments

Stage 3:
Maturity. Rapid progress

Stage 4:
- Understand remaining background, 100 kg scale
- Determine best method for 1-2 1-ton detectors

Stage 5:
Build and operate ton scale detectors

Sensitivity: a different perspective



Cross section sensitivities directly translate to (very small) rate constraints

An ambitious program

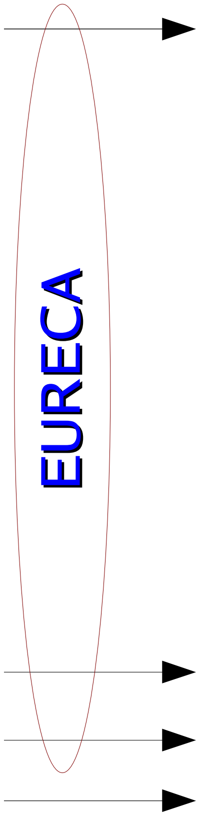
The 10^{-10} pb sensitivity goal and the related coverage of a large part of the MSSM parameter space is in reach within the next 7-8 years.

However, to realise this scenario several conditions have to be met:

- **realization of the expected progress in background rejection and signal identification**
- **demonstration of continuous running over a long period**
- **sufficient funding for developing and building worldwide three detectors on the one-ton scale based on different methods and nuclei.**

The eventual confirmation of a positive observation will require transparency of the experimental process, disclosure of details on used materials and free access to the data.

The ASPERA list



Name	Type	Status	Location	European Members	Others
DAMA/ LIBRA	NaI	running	LNGS	IT	China
ANAIS	NaI	construction	LSC	ES	-
KIMS	CsI	R&D	Korea	-	Korea
HDMS	Ge	running	LNGS	DE	RU
ROSEBUD	bolometer	R&D	LSC	ES, FR	-
DAMA-LXe	LXe scint	running	LNGS	IT	China
ZEPLIN-II	LXe	running	IUS	PT, UK	RU, US
ZEPLIN-III	LXe	installation	IUS	PT, UK	RU, US
XENON10	LXe	commissng	LNGS	DE, IT, PT	US
LUX	LXe	R&D	DUSEL	UK	US
XMASS	LXe	?	Kamioka	-	Japan
WARP	LAr	running	LNGS	IT	US
ArDM	LAr	construction	LSC	CH, ES, PO	-
DEAP	LAr	R&D	SNOLAB	-	Can, US
CLEAN	LNe	R&D	t.b.d.	-	US, Can
DRIFT	CS_2 gas TPC	R&D	IUS	UK	US
MIMAC	^{3}He gas TPC	R&D	t.b.d.	FR	-
EDELWEISS	bolometer	running	LSM	FR, DE	RU
CRESST	bolometer	running	LNGS	DE, UK, IT,	-
CDMS	bolometer	running	Soudan	-	US
SIMPLE	Superheated droplet SHD	running + R&D	LSSB	PT, FR	US
PICASSO	SHD	running + R&D	SNOLAB	CZ	CA, RU, US
COUPP	SH liquid	R&D	t.b.d.	-	US

Techniques

CRESST I
ROSEBUD
[CUORE]

(Al_2O_3)

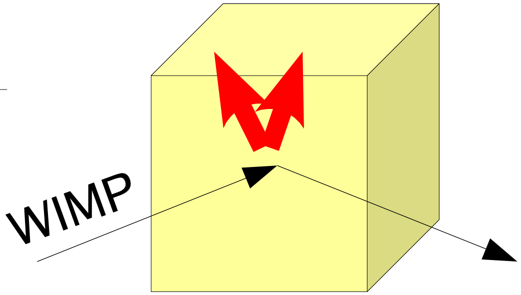
CRESST II
ROSEBUD
EURECA
[LUCIFER]

($CaWO_4$, $ZnWO_4$, BGO, Al_2O_3)

CDMS
EDELWEISS
SuperCDMS

(Ge, Si)

Phonons



Scintillation

Ionization

NAIAD
ZEPLIN I
DAMA/LIBRA
XMASS
DEAP
Mini-CLEAN

(NaI, Xe, Ar, Ne)

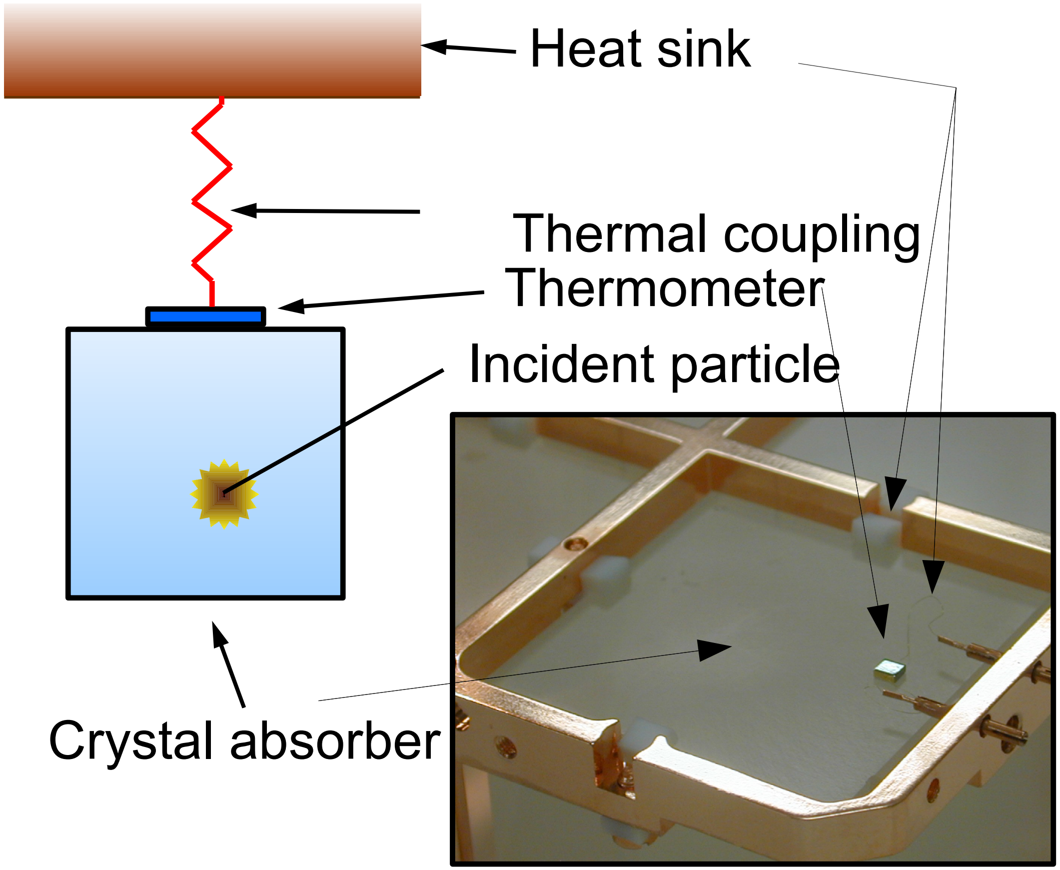
DRIFT
IGEX
COUPP

(Ge, CS2, C3F8)

ZEPLIN II, III
XENON, WARP
ArDM, SIGN,
LUX

(Xe, Ar, Ne)

Low Temperature Calorimeters



Detection Principle

$\Delta T = E/C$

C: thermal capacity

- low C
  - low T (i.e. $T \ll 1$K)
  - dielectrics, superconductors
- ultimate limit to E resolution: statistical fluctuation of internal energy U

$$\langle \Delta U^2 \rangle = k_B T^2 C$$

Thermal Detectors Properties

- **good** energy resolution
- wide choice of absorber materials
- true calorimeters
- slow $\tau = C/G \sim 1 \div 10^3$ ms

Phonon Sensors

- Thermistors (NTD)
- Transition Edge Sensors (TES)

Pure calorimeters

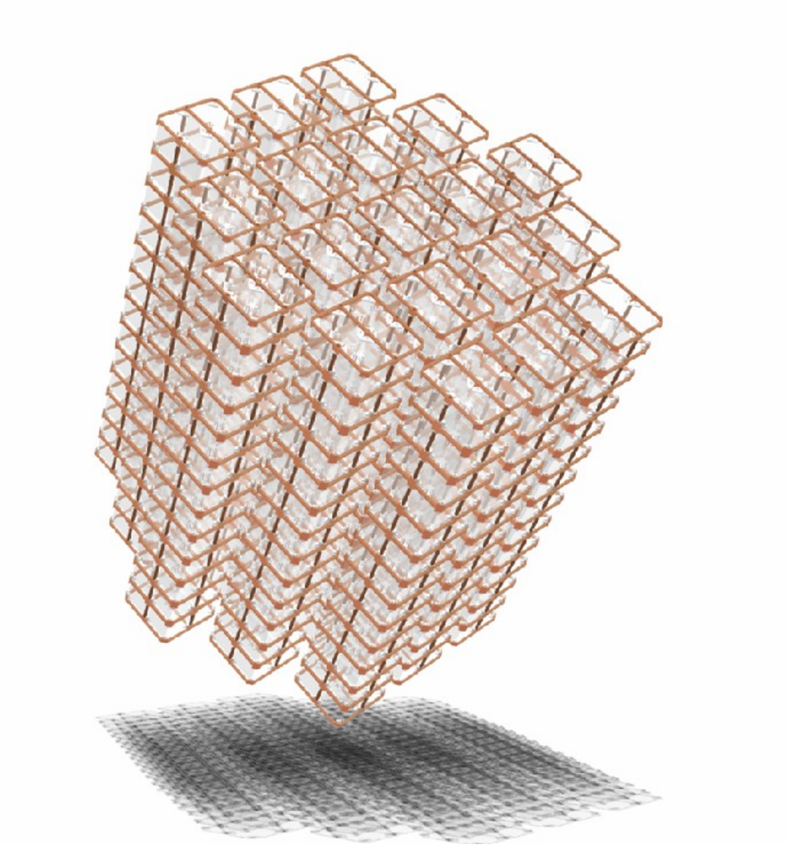
Historical importance: pioneering approach

CRESST I
ROSEBUD

Can still play a role in the future for the implementation of the model independent approach at the ton scale: CUORE

Requests:

- Stability
- Low energy threshold



Possible!
… however NOT a dedicated experiment:
estimated R_B ~ 0.1-1 c/kev/d @ few keV

Phonons + Charge

Historically **the first hybrid approach**.
Actually other complementary information is collected

- **Position**
- **Timing**

Successful multi-messenger approach: Excellent results on WIMPs

CDMS
- Phonons
- Charge
- Position
- Timing (PSA)

EDELWEISS
- Heat
- Charge
- Radial “Position”

Ultimate enemy at present is STATISTICS
“Future” developments (larger mass):

SuperCDMS

EURECA

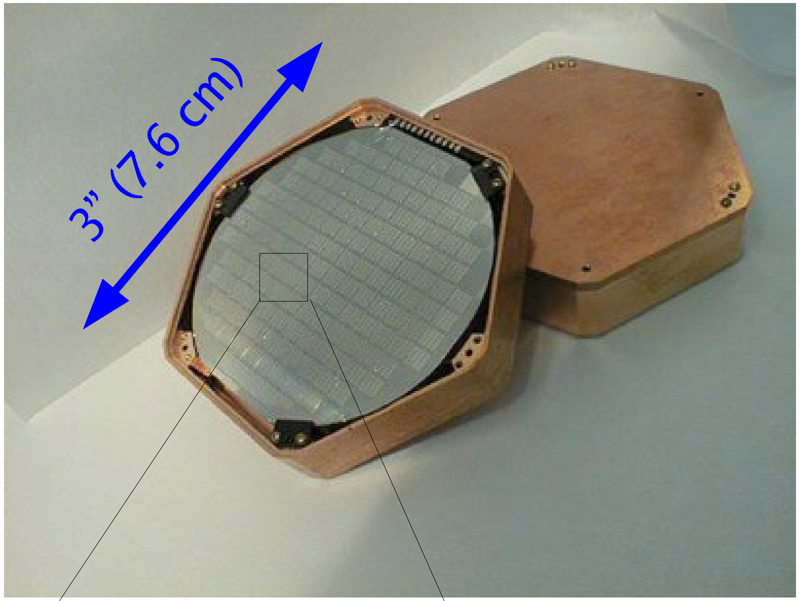
CDMS: Ge & Si

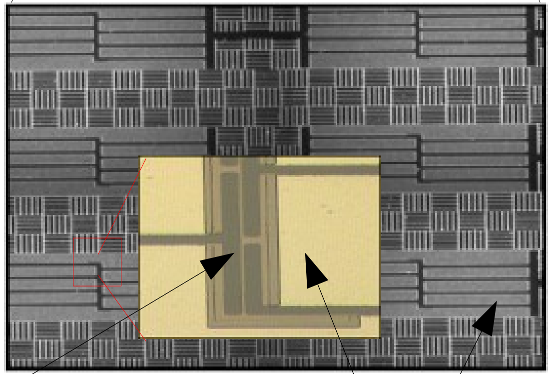
Z-sensitive Ionization and Phonon mediated 230 g Ge or 100 g Si crystals(1 cm thick, 7.5 cm diameter)

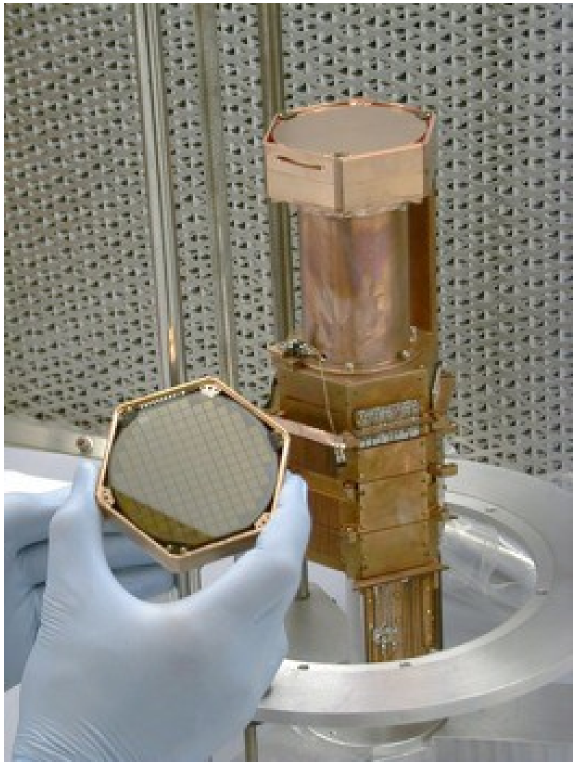
Photolithographically patterned to collect **athermal phonons and ionization signals**

- xy-position imaging
- surface (z) event rejection from pulse shapes and timing

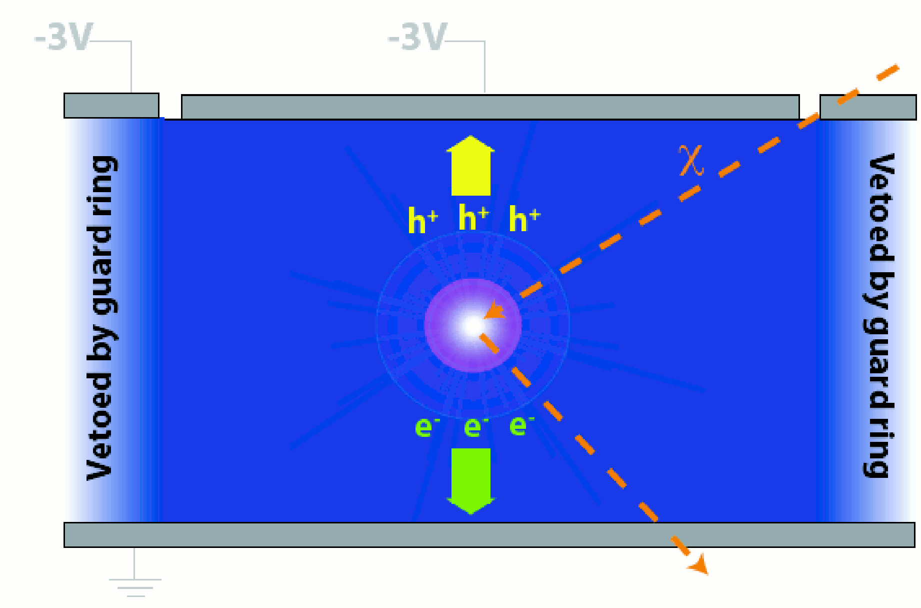
30 detectors stacked into 5 towers of 6 detectors (6.9 kg)



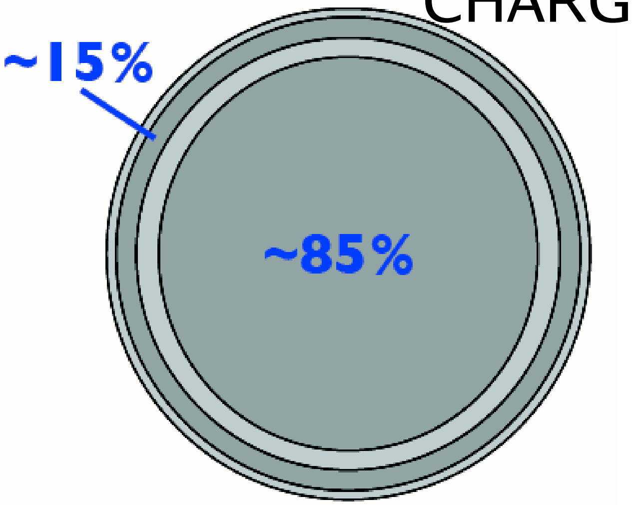




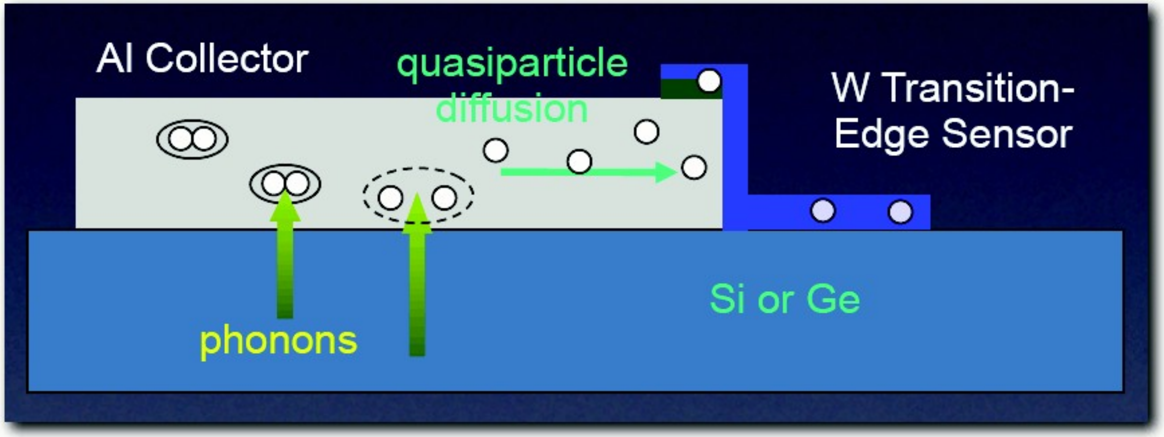
CDMS: ZIP detectors

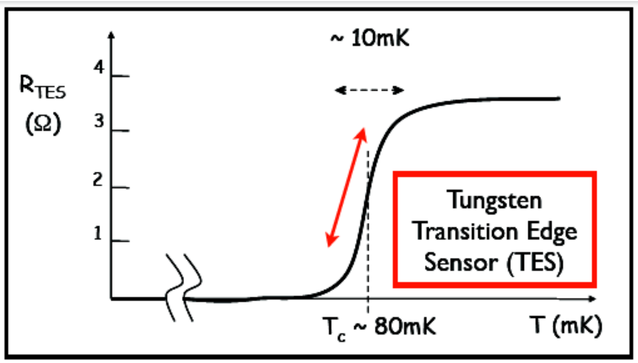


CHARGE



PHONONS





4 SQUID readout channels, each reads out 1036 TESs in parallel

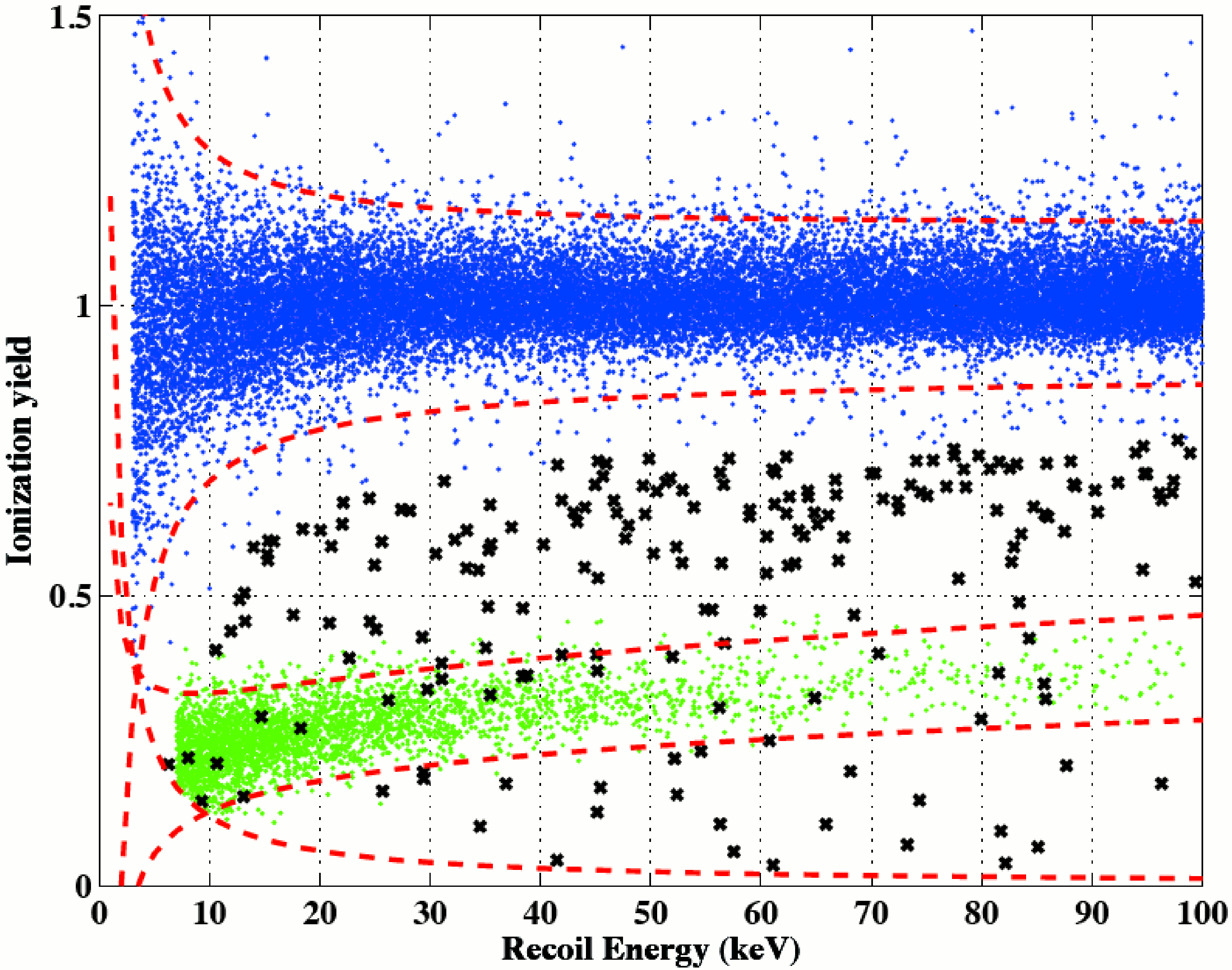
Background rejection

Most backgrounds (e, γ) produce electron recoils

WIMPS and neutrons produce nuclear recoils

Ionization yield (ionization energy per unit phonon energy) strongly depends on particle type.

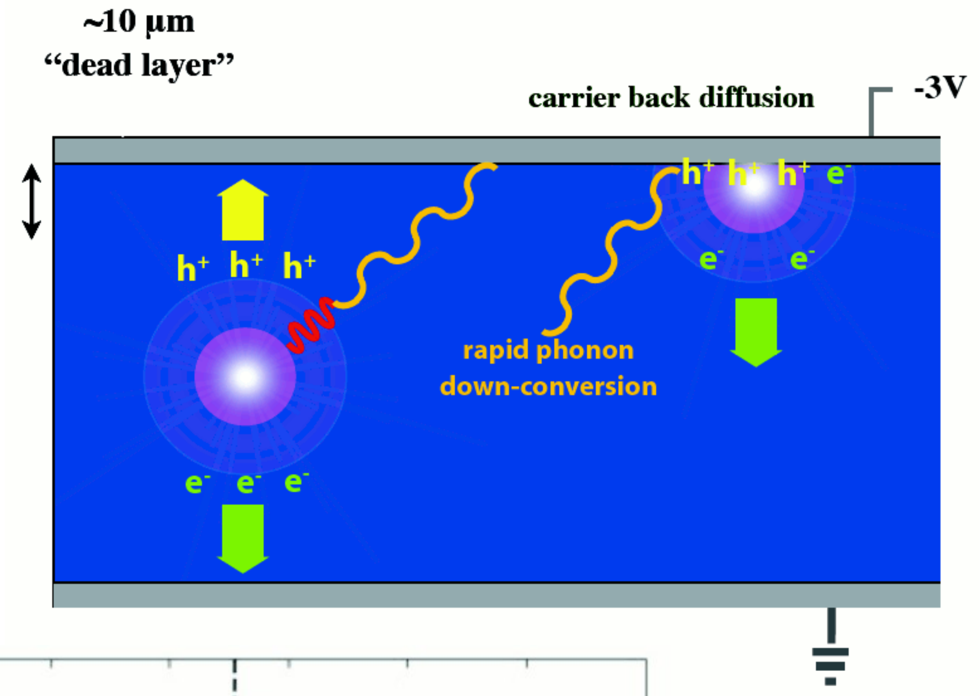
Particles that interact in the “surface dead layer” result in reduced ionization yield



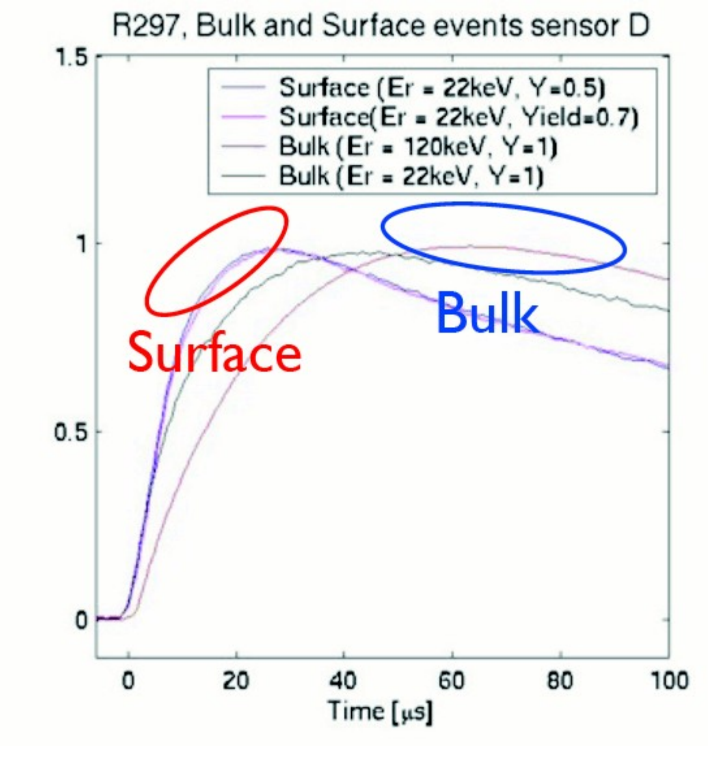
Surface contributions

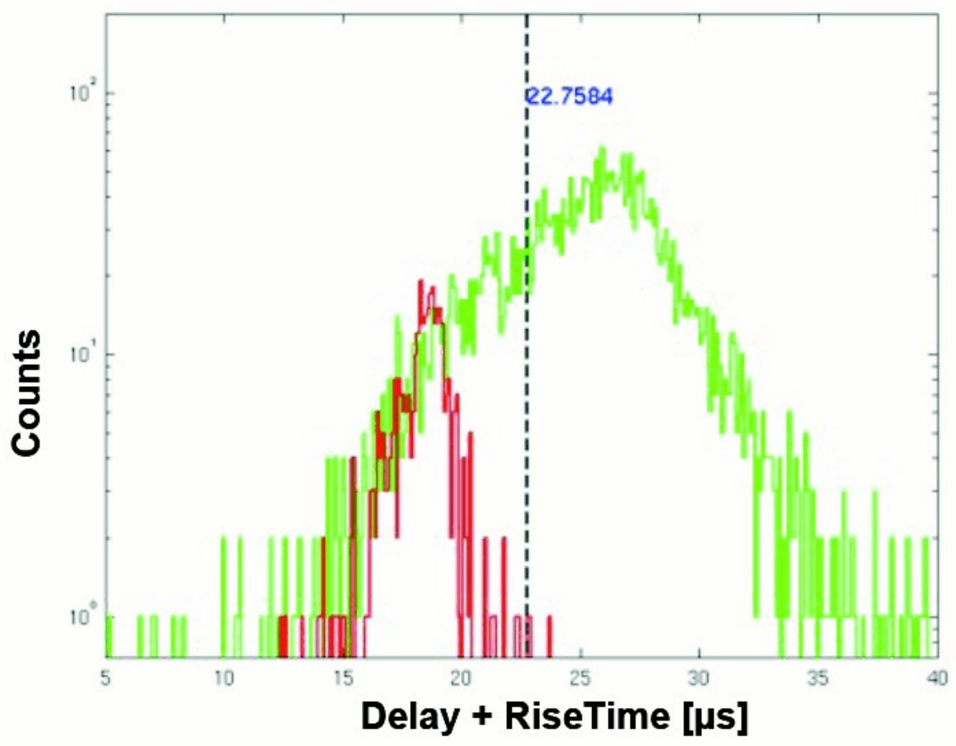
Reduced charge yield is due to carrier back diffusion in surface events.

“Dead layer” is within ~10µm of the surface.

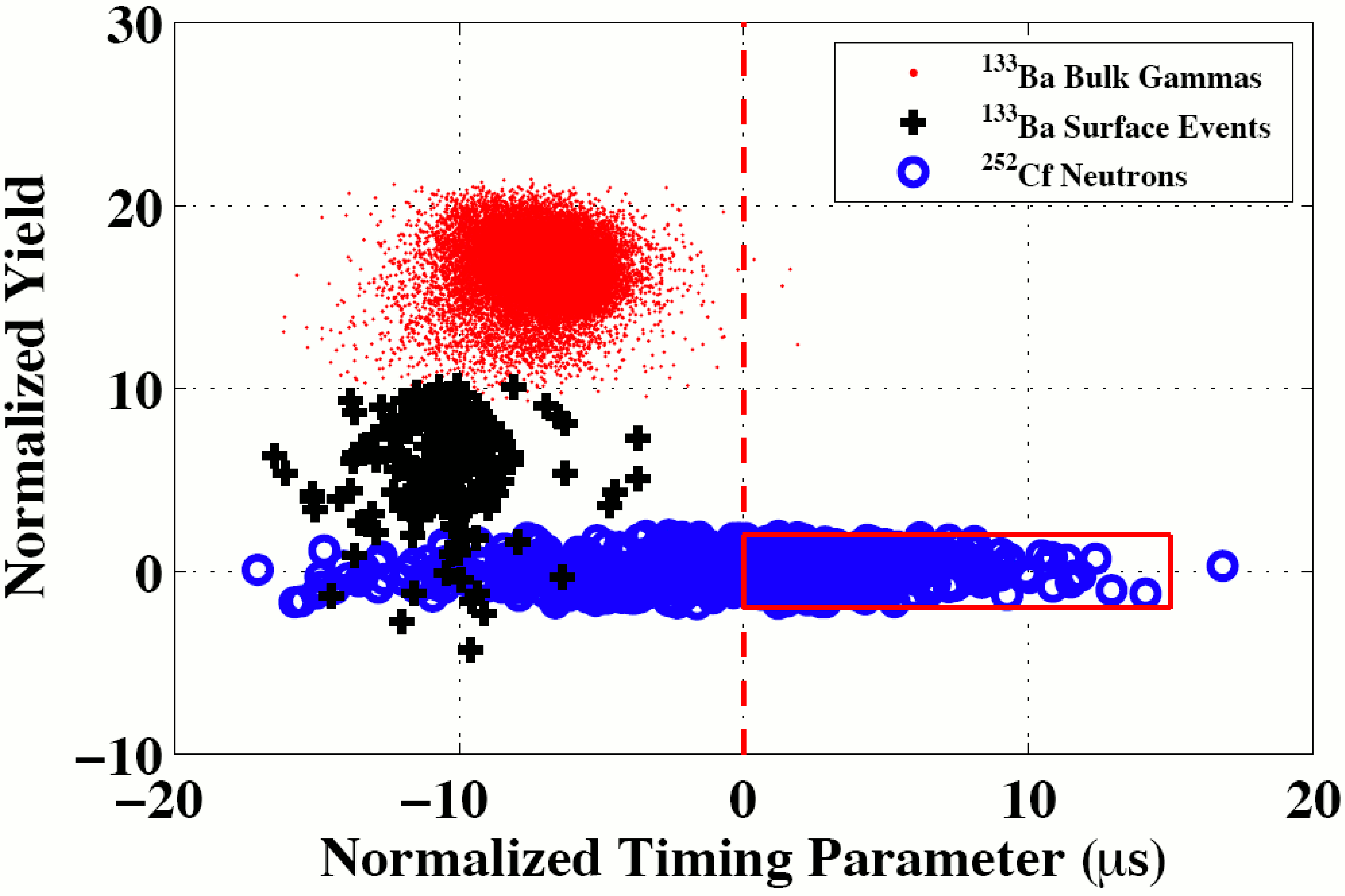


Surface Event Rejection: timing





Timing



133Ba Bulk Gammas
133Ba Surface Events
252Cf Neutrons
Normalized Yield
Normalized Timing Parameter (μs)
30
20
10
0
−10
−20
−10
0
10
20

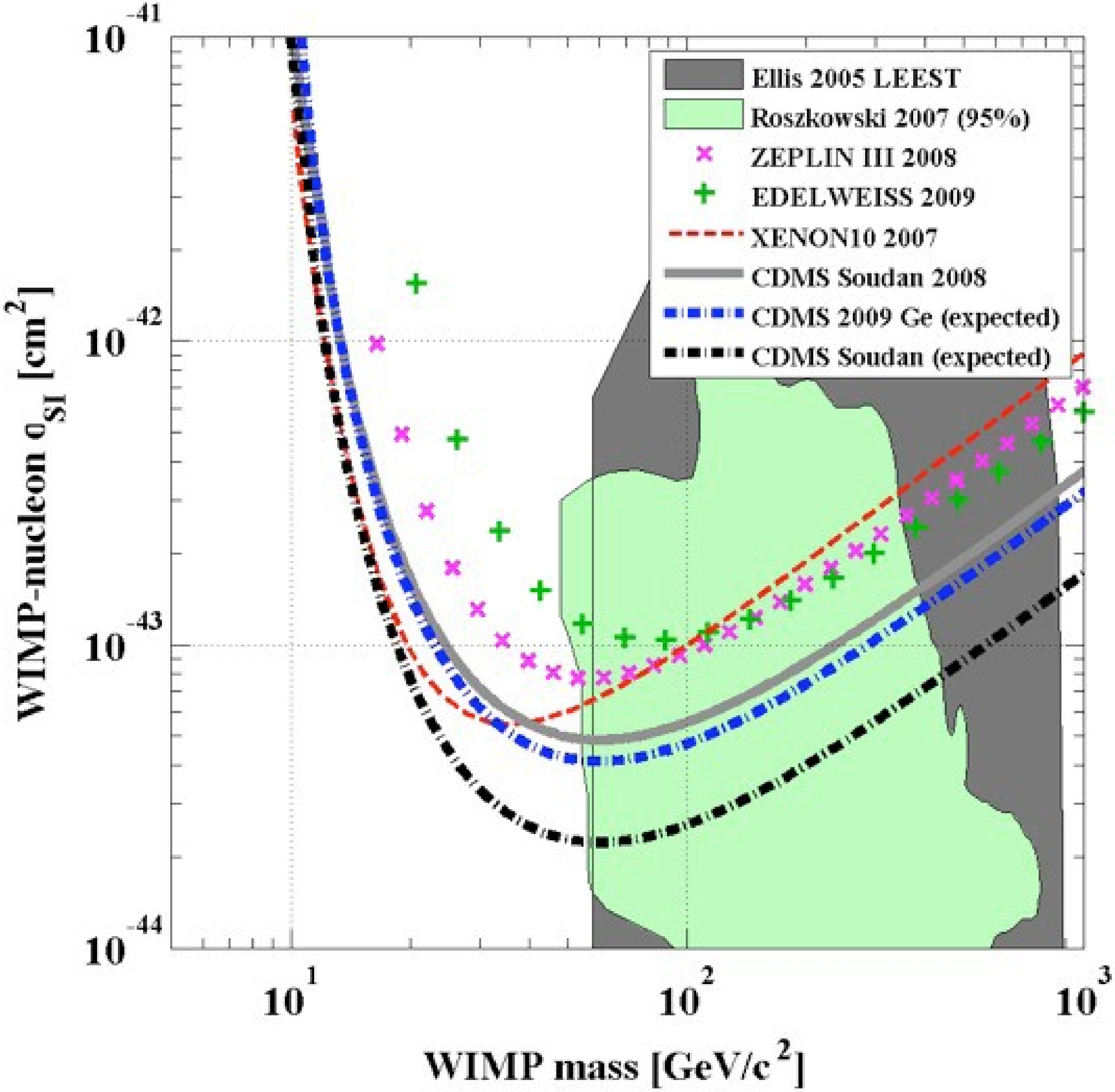
Estimated sensitivity

612 kg-d raw
194.1 kg-d WIMP (!)

10 -100 keV analysis energy range

Surface Background
0.6 ± 0.1(stat.)

Neutron Background
Cosmogenic
$0.04^{+0.04}_{-0.03}$ (stat.)
Radiogenic
0.03 - 0.06



CDMS results

Blind analysis

Event Selection:

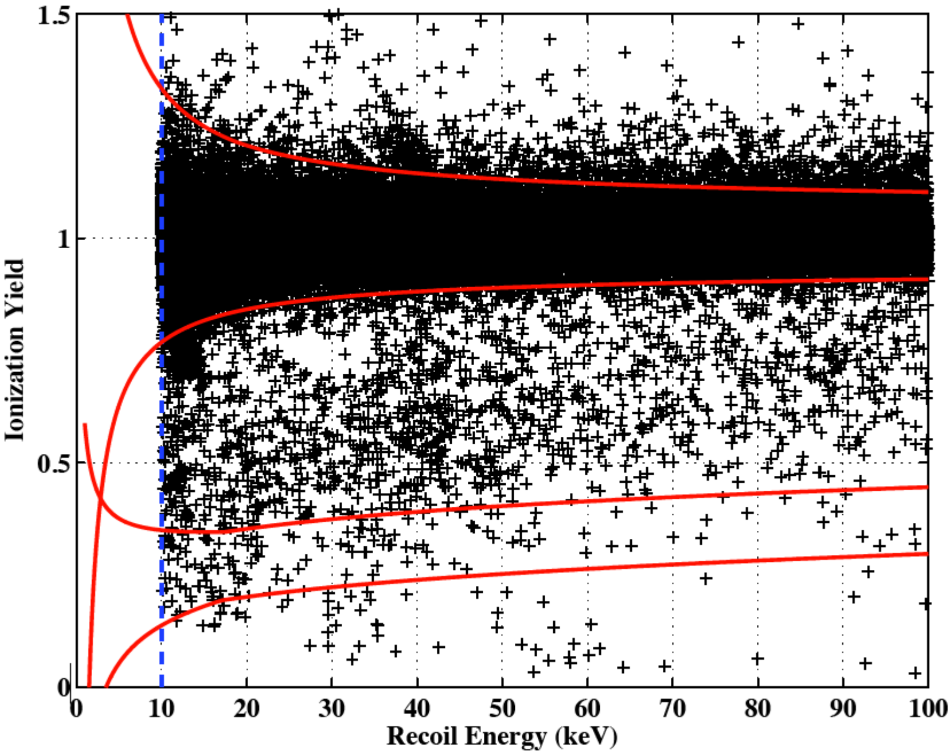
- **Veto-anticoincidence cut**
- **Single-scatter cut**
- **Qinner (fiducial volume) cut**
- **Ionization yield cut**

3σ region masked

Hide unvetoed singles

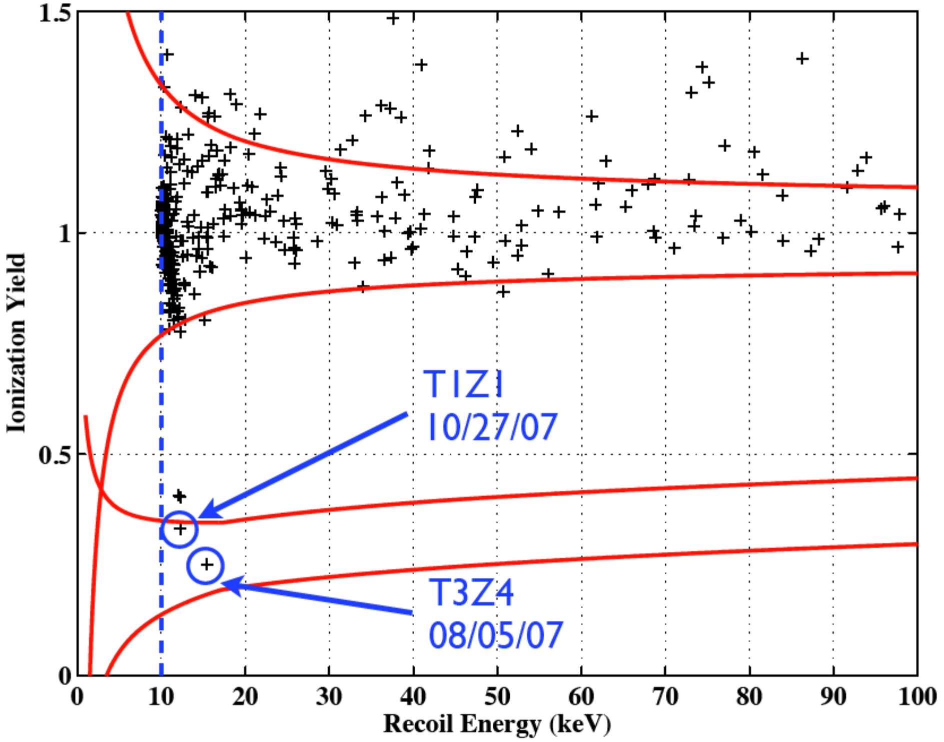
Lift mask, see 150 singles failing timing cut.

Apply the timing cut …**2 events selected**

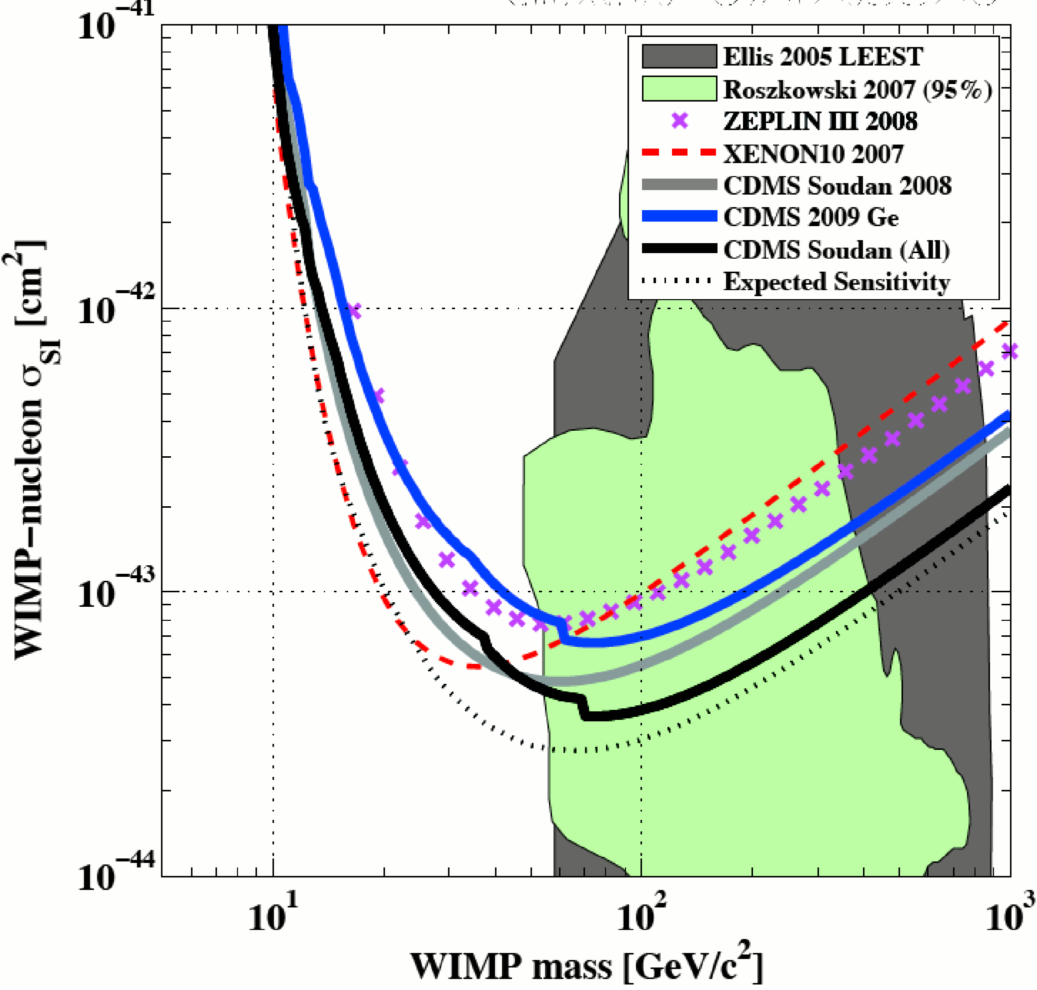


Unblind analysis

- Reducing the surface event estimate by ~1/2 would remove both candidates while reducing our exposure by 28%
- Additional events would not enter the signal region until we increased the surface event estimate by a factor of ~2.



CDMS results 2



Upper limit at the 90% C.L. on the WIMP-nucleon cross section is **3.8 x 10^{-44} cm^{2}** for a WIMP of mass 70 GeV/c^{2}

Very careful analysis of the 2 events

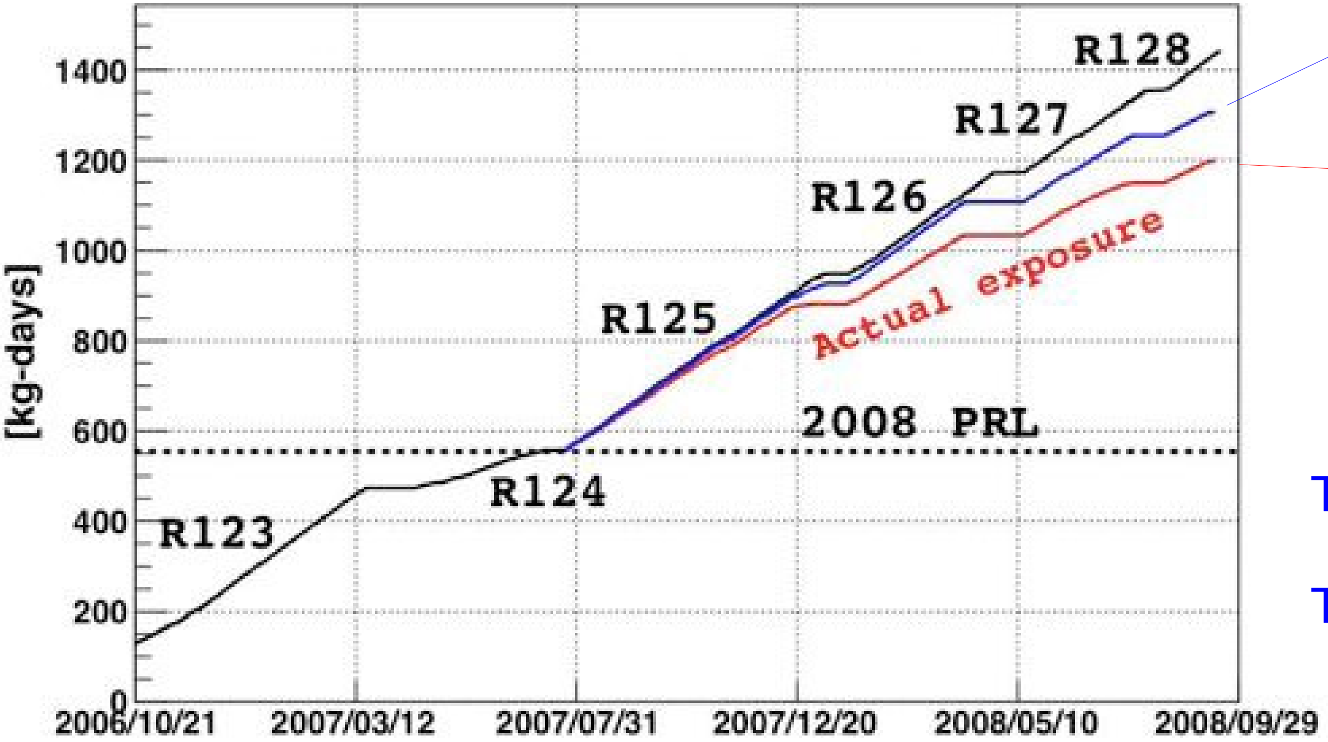
- The two events occur during a time of nearly ideal detector performance.
- They are separated in time by several months and occur on detectors in different towers (T1Z5 and T3Z4).
- They occur on inner detectors where we have a stronger handle on our background estimate.
-

A refined calculation of the surface background taking into account larger errors in the timing estimate a low energy produced a post-unblinding leakage estimate of **0.8 ± 0.1 ± 0.2**

Probability ofobserving 2 or more events is 23%

CDMS: some final consideration

1) Statistics: required cuts reduce significantly the available statistics



some detectors not analyzed for WIMP scatters

periods of poor data quality removed

30 ZIPs (5 Towers)
~4.4 kg Ge, ~1.1 kg Si

Total raw exposure is 612 kg-days

Total exposure after all cuts: 194.1 kg-days

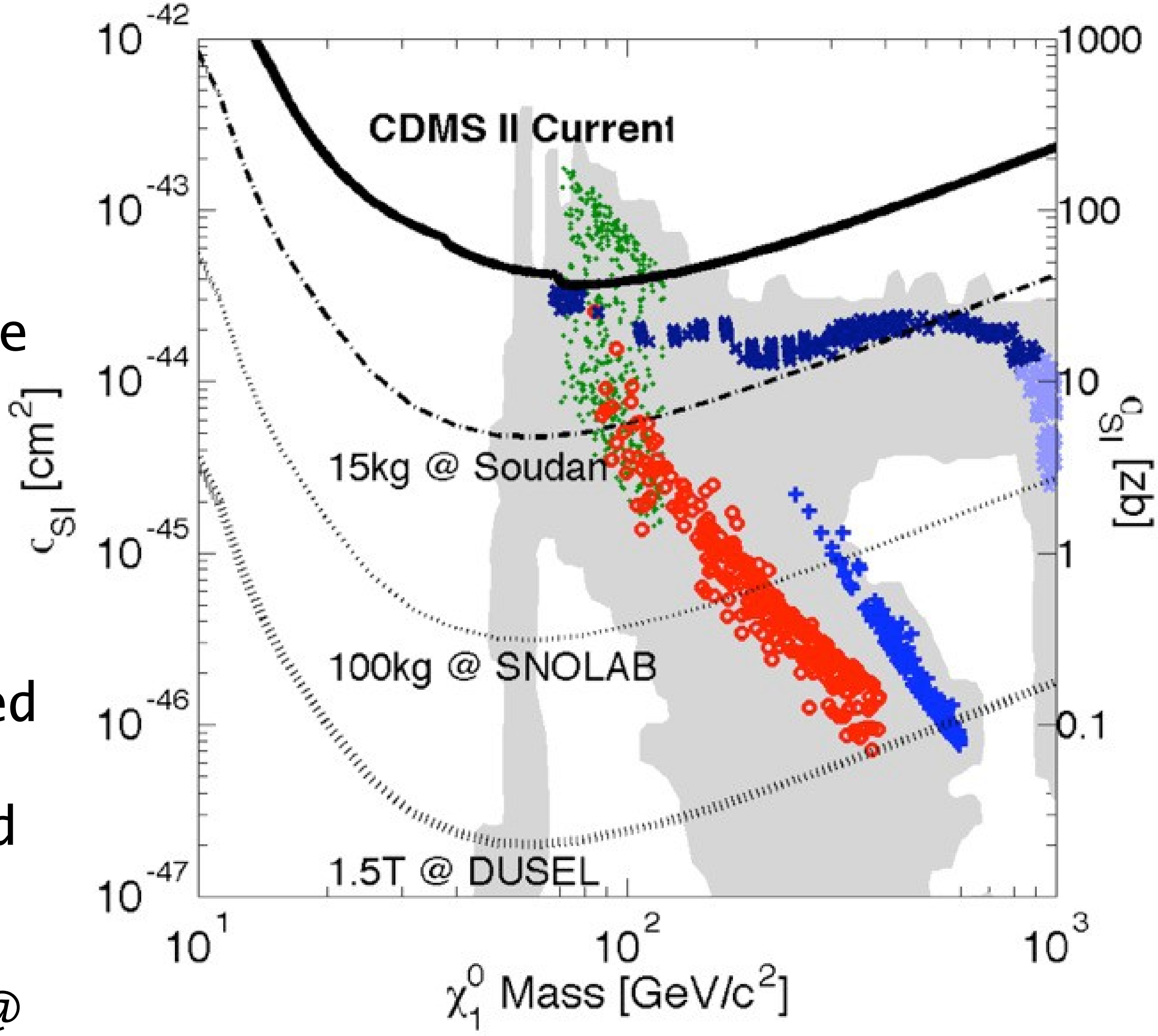
2) Incomplete charge collection at surface creates a dangerous leakage in the acceptance region. Get rid of this through timing. How much is this understood? Further cuts and statistics shortage

3) “Dark” counts

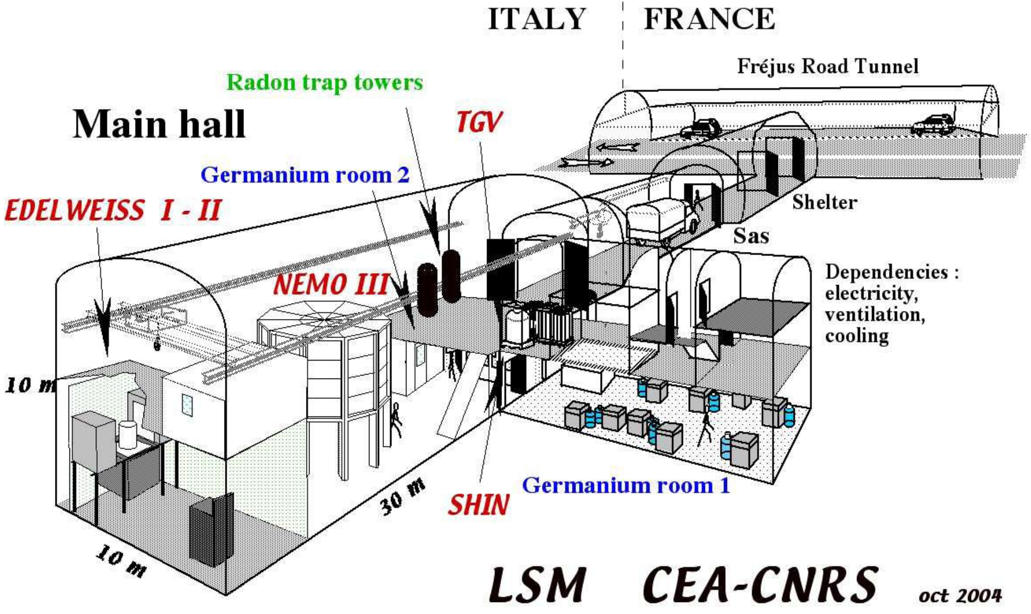
SuperCDMS

15 kg of Ge at Soudan, arranged as 5 SuperTowers

- March 2009: Start installation and commissioning of the first SuperCDMS detectors. Commissioning runs of the first SuperCDMS tower is underway.
- Fabrication of remaining detectors for the SuperCDMS Soudan project (15 kg Ge deployed in existing Soudan setup) underway. Installation and commissioning summer 2010.
- Final goal: SuperCDMS @ SNOLAB (100 kg Ge)



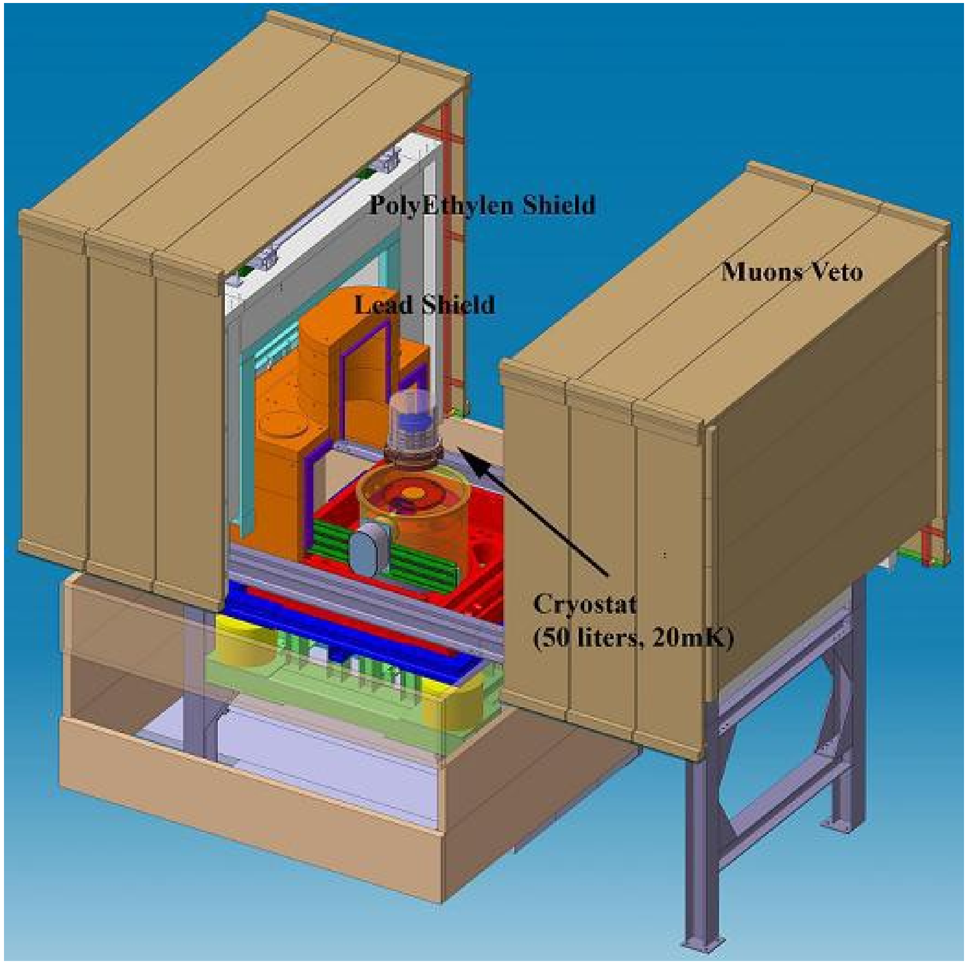
EDELWEISS



Goal: 10^{-8}pb, **<0.002 evts/kg/d**

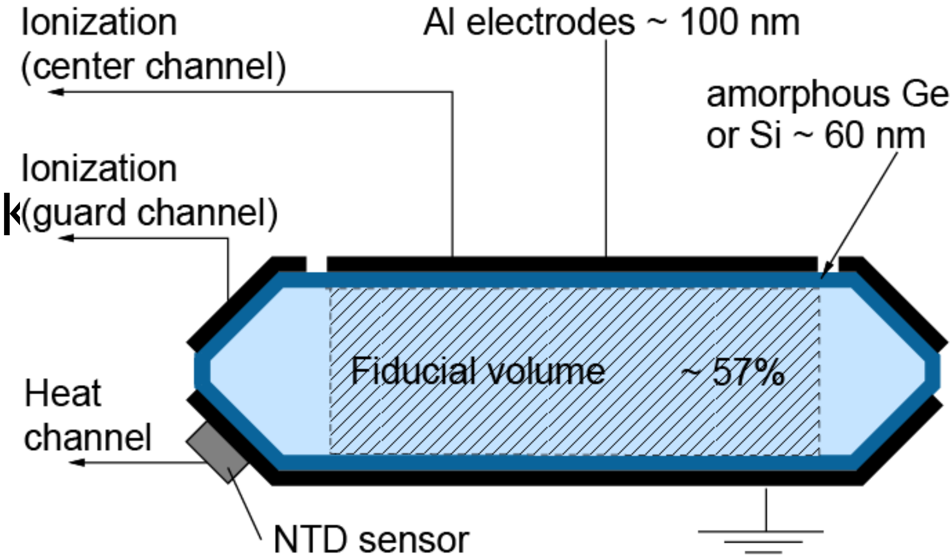
- **5 kg Ge, can host up to 40 kg**
- **Installed at LSM in Frejus Tunnel**
  (4 muon/day/m^2)
- **Neutron shield designed for <10^{-8}pb**
  - 50cm polyethylene
  - muon veto
- **Strict control of material selection / Cleaning procedure / Environment**
  X4 reduction of γ background

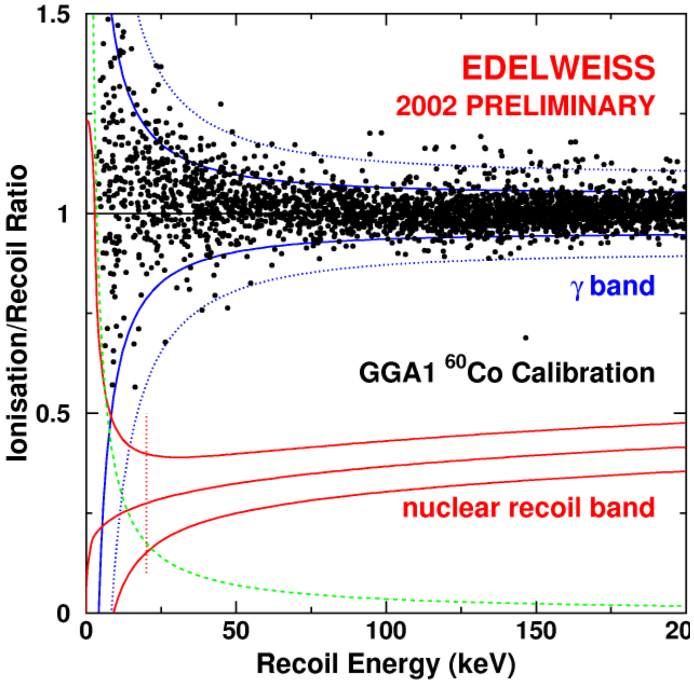
Alternative surface events rejection based on charge signal

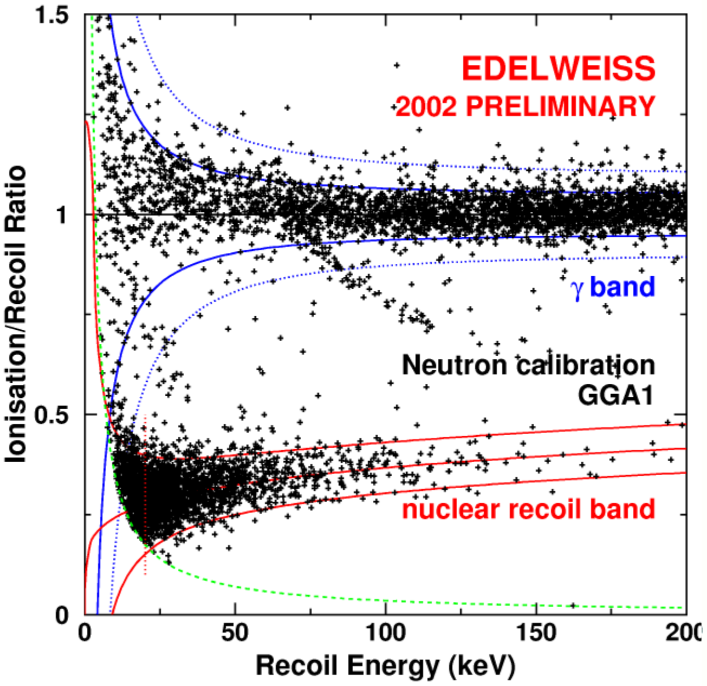


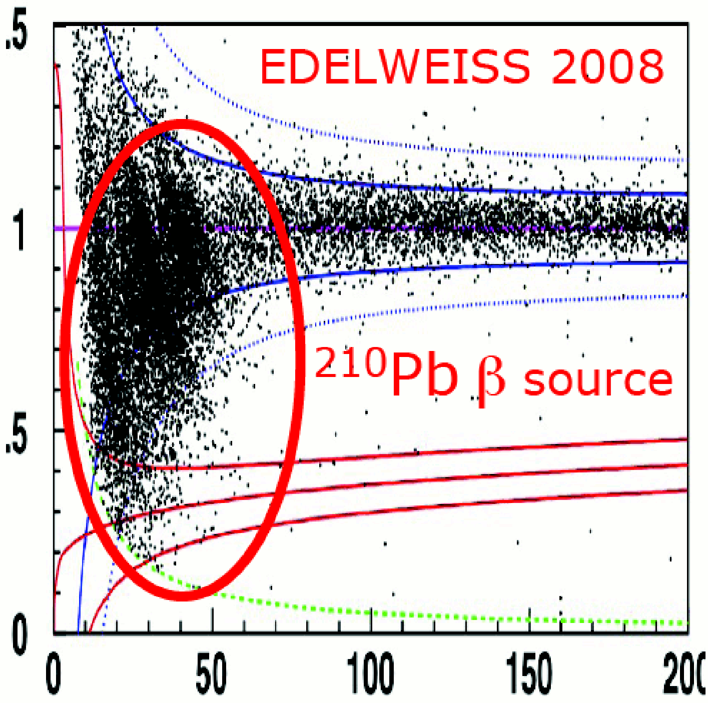
EDELWEISS Detector

400g Germanium bolometers:
-Ionization measurement @ few V/cm
-Heat measurement (NTD sensor) @ 20 mK
Discrimination between electronic
and nuclear recoils :
« Q » ~ ionization/heat



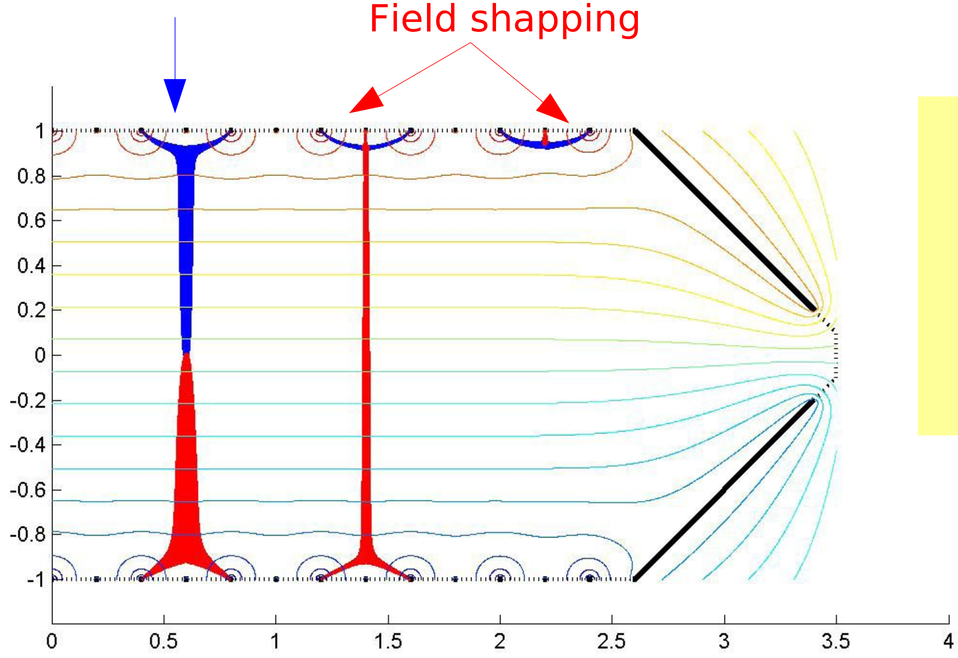






Surface Leakage: InterDigit Detectors

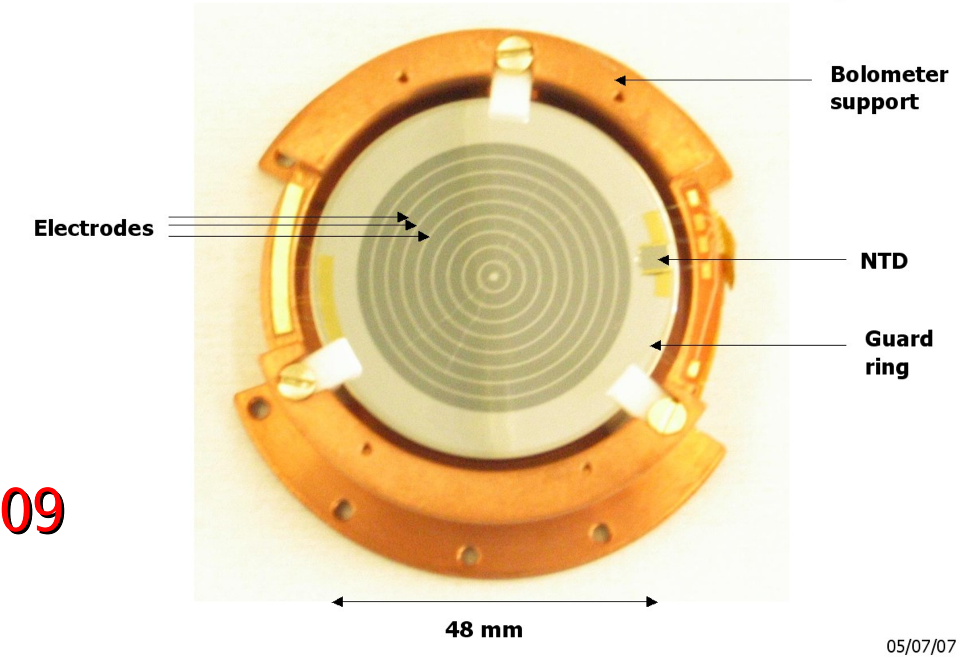
a’ electrodes (+4V)
Fiducial collection ‘b’ electrodes (-1.5V)
Field shapping



- Keep the EDW-I NTD thermal detector
- Modify the E-field near the surfaces with interleaved electrodes
- Use ‘b’ and ‘d’ signals as vetos against surface events

- First 200g detector built 2007
- 1x200g + 3x400g tested in 2008

- 10x400g running since beginning 2009



EDELWEISS II data analysis

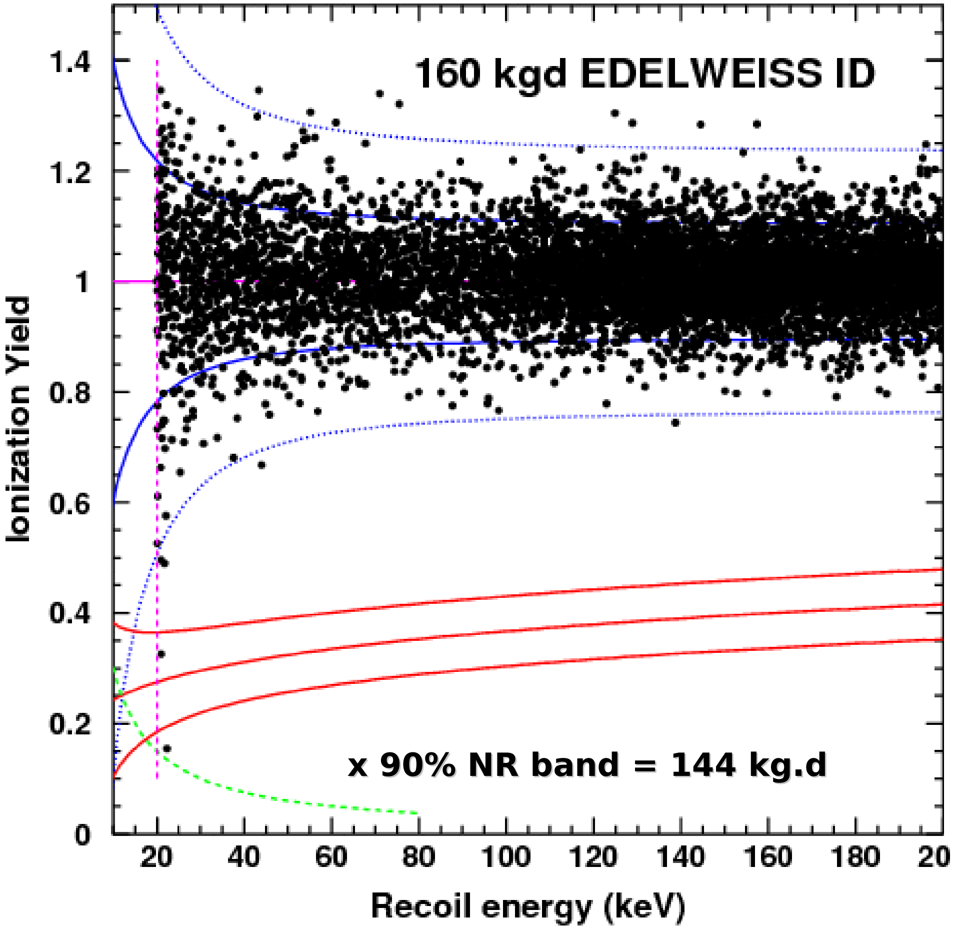
arXiv:0912.0805

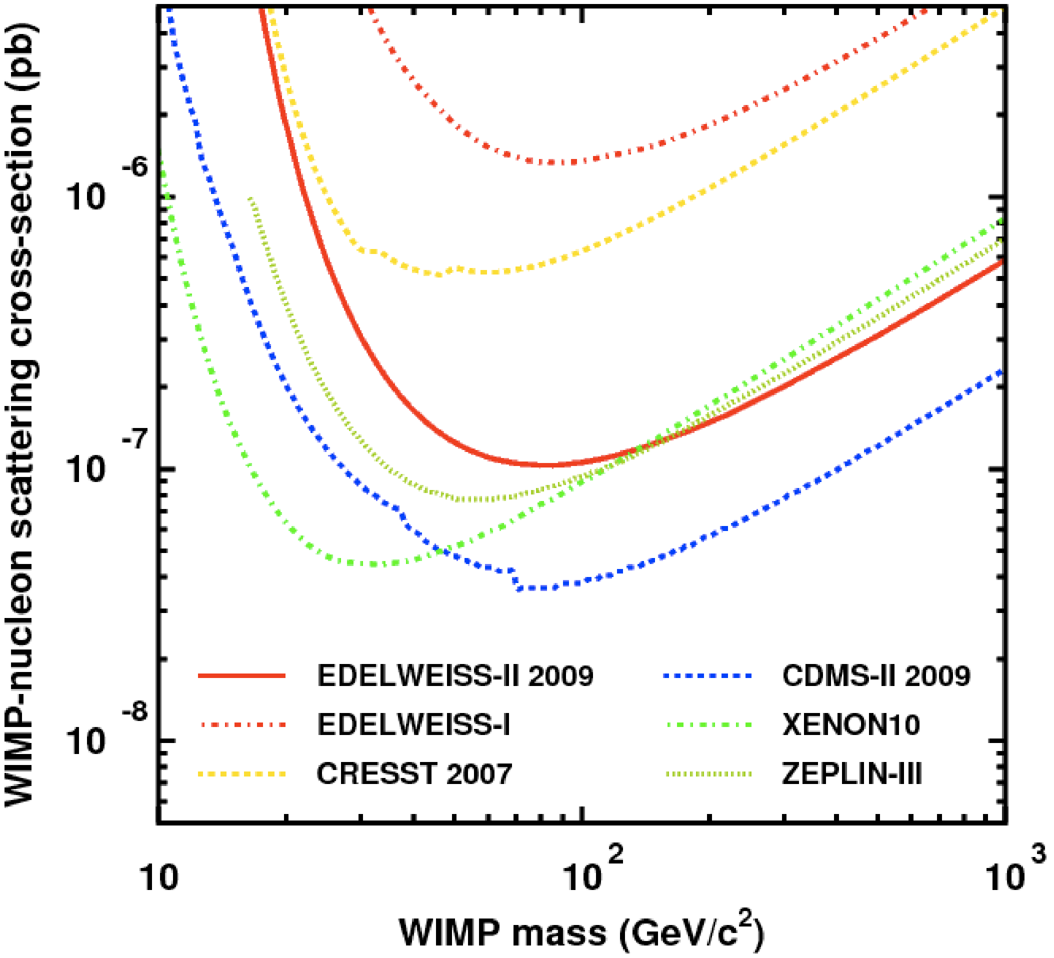
10 ID (400 g units, 160g fiducial) tested/built/installed/run in 2008-2009

- First assessment of technology in real physics run: **144 kgd / ~6 months**
  - Reliability: 9/10 detector used for physics
  - >50% physics running efficiency (wrt to 186 days x 1.6 kg_fiducial)
  - Average resolutions: σ ~ 400 eV ionization, 500 eV heat
- 2 independent processing pipelines
- Pulse fits with optimal filtering using instantaneous noise spectra
- Period selection based on baseline noises: 80% efficiency
- Pulse reconstruction quality (χ2): ε = 97%
- Fiducial cuts based on ionization signals (160g): ε = 90%
- Nuclear recoil/gamma rejection 99.99%
- Bolo-bolo & bolo-veto coincidence rejection (ε>99%)
- WIMP search threshold fixed a priori E_{recoil} > 20 keV

  20 keV recoil far from efficiency thresholds (full efficiency achieved with ~3 keV ionization and ~7 keV heat thresholds): robust results independent of analysis details
- Agreement between the results the two analyses

EDELWEISS II results



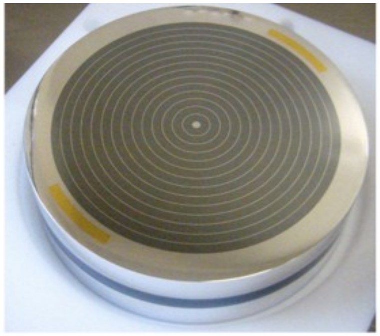


1 WIMP Candidate

Background estimation from previous calibrations/ simulations:

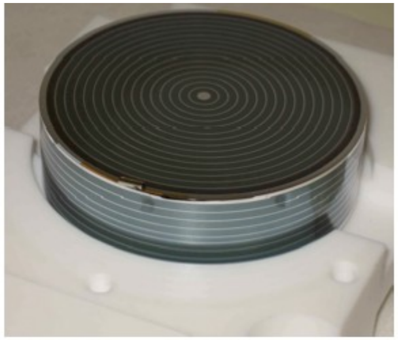
- gamma < 0.01 evt (99.99% rejection)
- beta ~ 0.06 evt (from ID201 calibration+obs. surf. evts)
- neutrons from 238U in lead < 0.1 evt
- neutrons from 238U+(α,n) in rock ~ 0.03 evt
- neutrons from muons < 0.04 evt

EDELWEISS: new ID detectors



ID401 to 405:
Φ 70mm, H 20mm, 410g

ID2 to ID5:
Φ 70mm, H 20mm, 410g



FID401 and FID402:
Φ 70mm, H 20mm, 410g

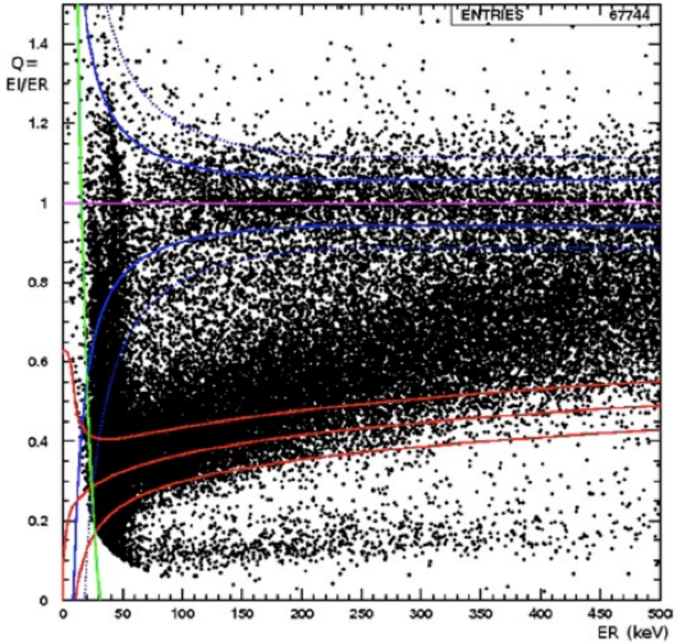
Currently searching for WIMPs with its new generation ID detectors:

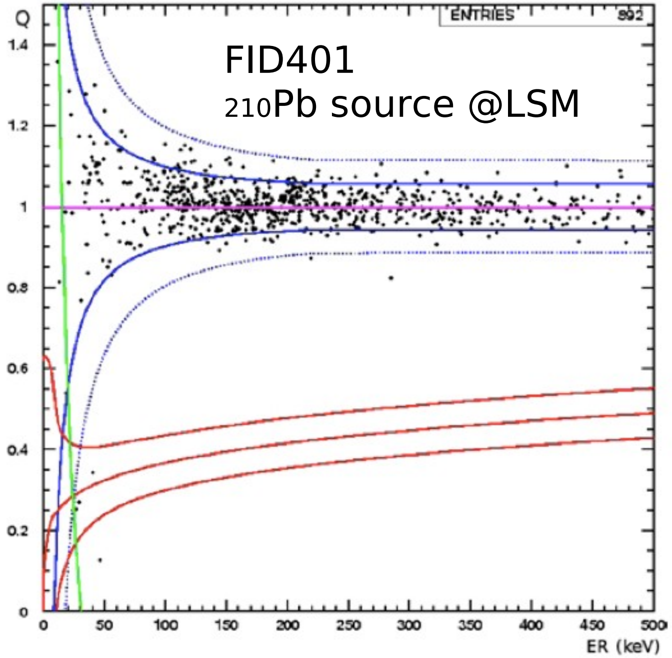
- Robust detectors with redundancy and very high beta rejection
- First 160kg.d => WIMP limit @ 10^{-7}pb, 1 evt observed
- X2 exposure in Spring (+lower thresholds & improved bkg estimations)

Goals: continue FIDs program until (400+800g) doubling accumulated exposure every year

- 2011 = 1000 kg.d
- 2012 = 3000 kg.d

Longer term: Eureca@Ulisse, new LSM cavity





FID401
^{210}Pb source @LSM

After fiducial volume cut

Phonons + Light

Bolometric readout of the Scintillation signal

CRESST II

Phonons
Scintillation
Isotope dependence

- Large choice of target materials: **multi-targets**
- Precise measurement of the total energy (through heat)
- Stability: **constant calibration with heat pulses**
- **No leakage effect**: ‘third class’ of events between ‘nuclear recoils’and e/γevents
- Surface (physical) events

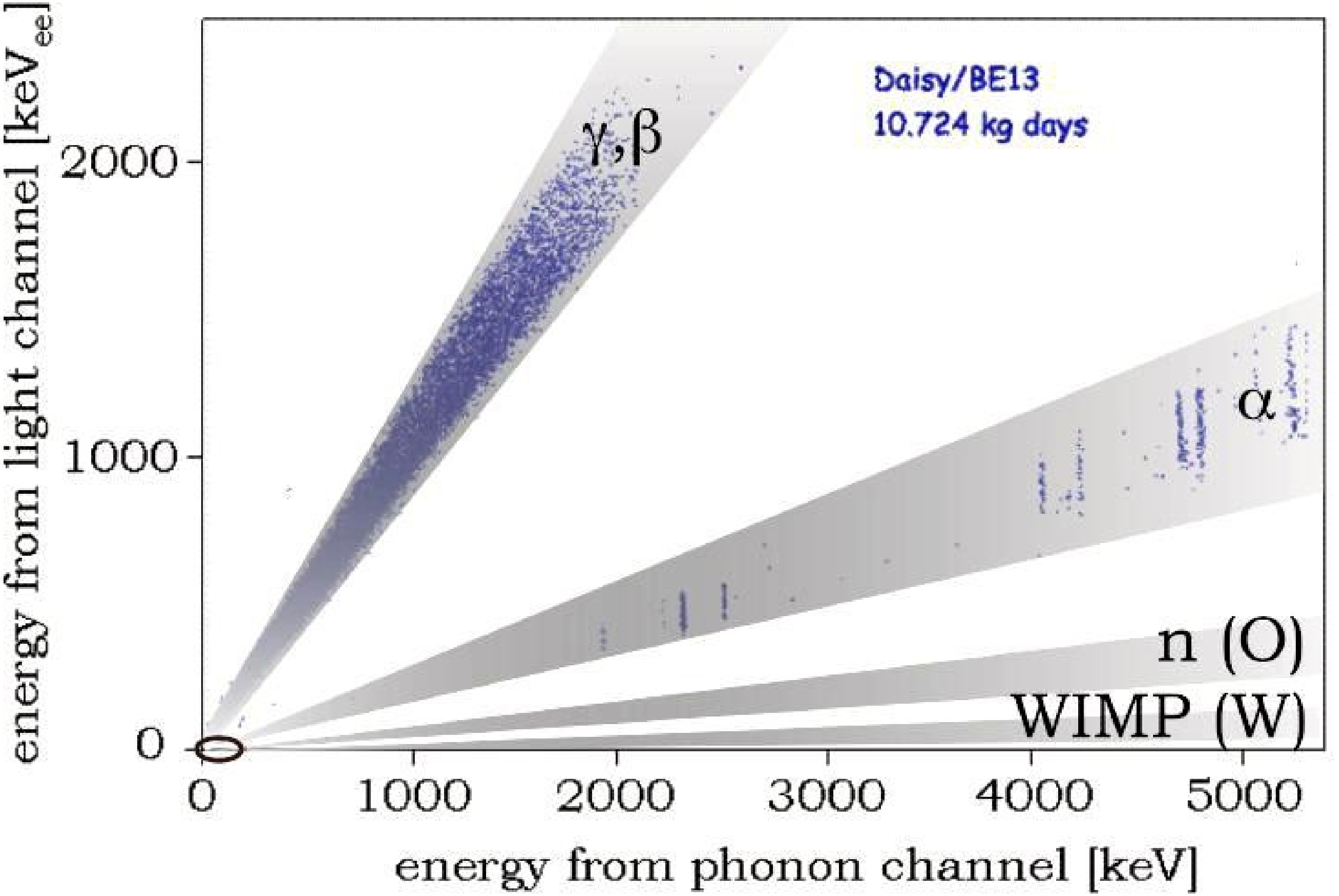
Promising technical developments under study

Possible improvement of light collection ⇒ sensitivity improvement

Ultimate enemy: STATISTICS

Larger mass: EURECA

CRESST II concept



slope

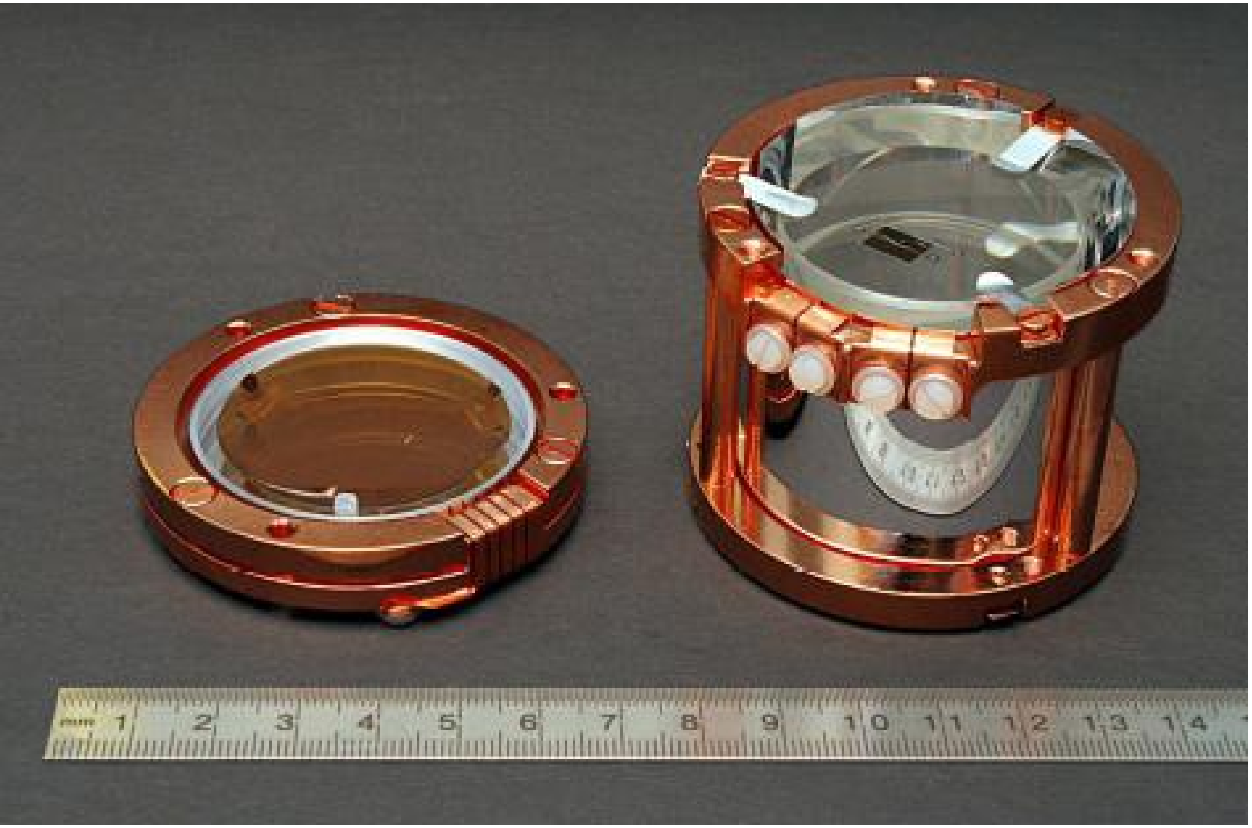
1 (def.)

1/5

1/10

1/40

CRESST II detectors



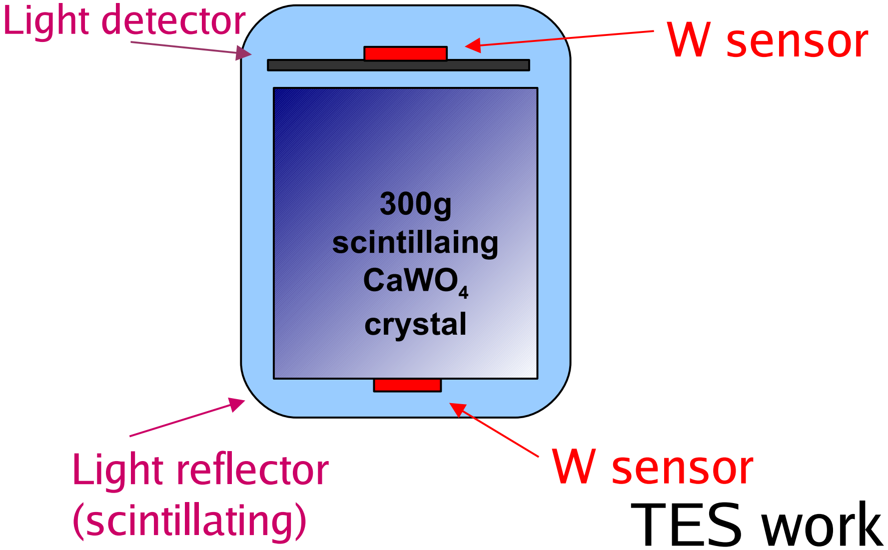
Tungsten (W) thin films (200nm respectively 120nm) as Transition Edge Sensors (TESs)

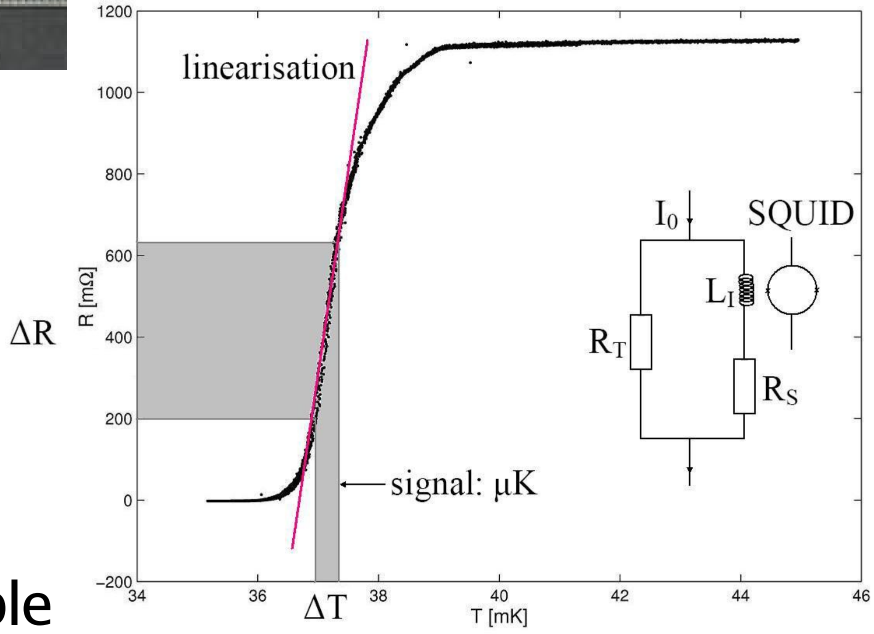
Phonon channel

Scintillating $CaWO_4$-crystal (300g, height=40mm) as target with W-TES on top

Light channel

SOS (Silicon on Sapphire) crystal (=40mm) with W-TES on top



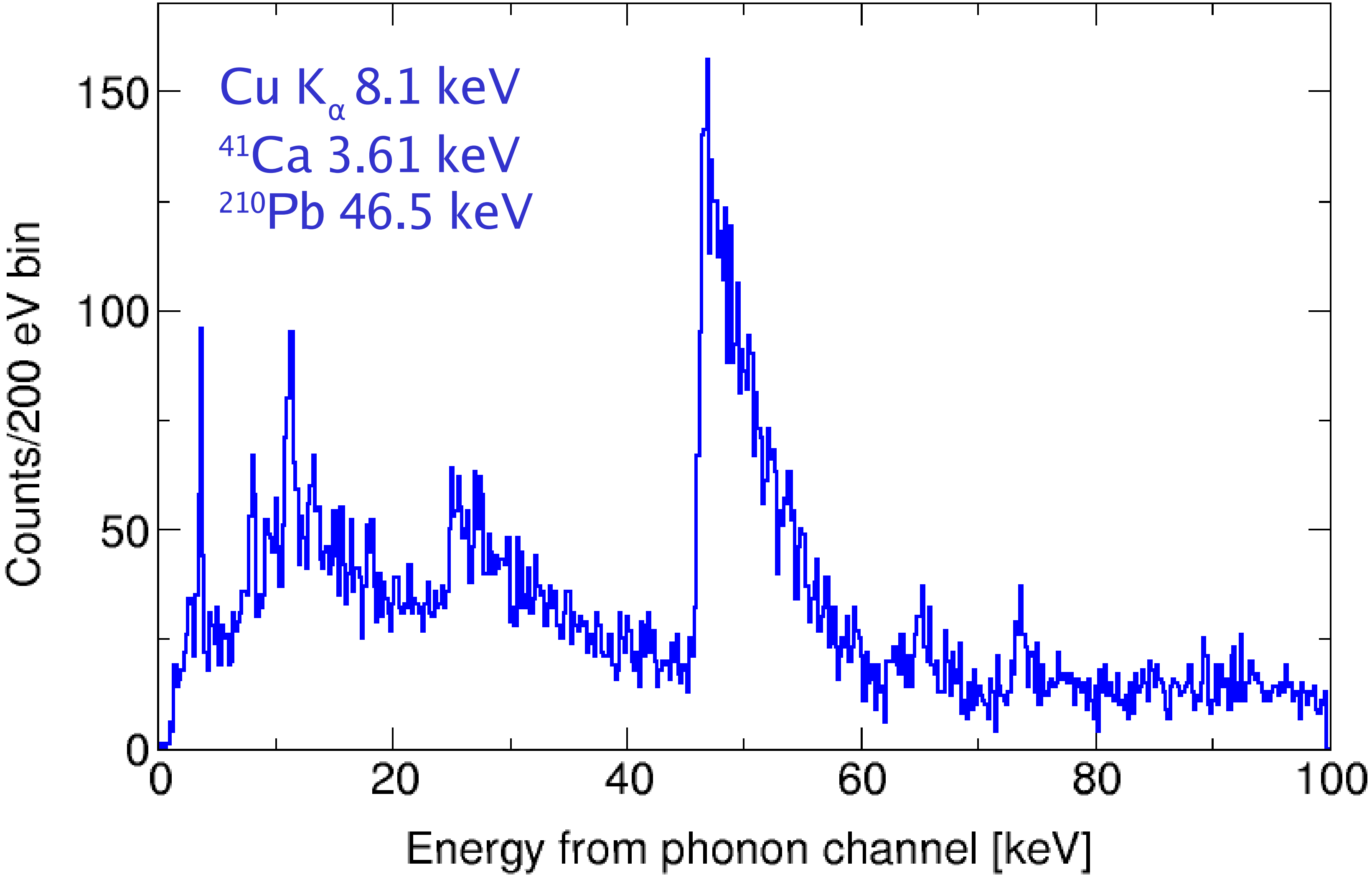


TES working principle

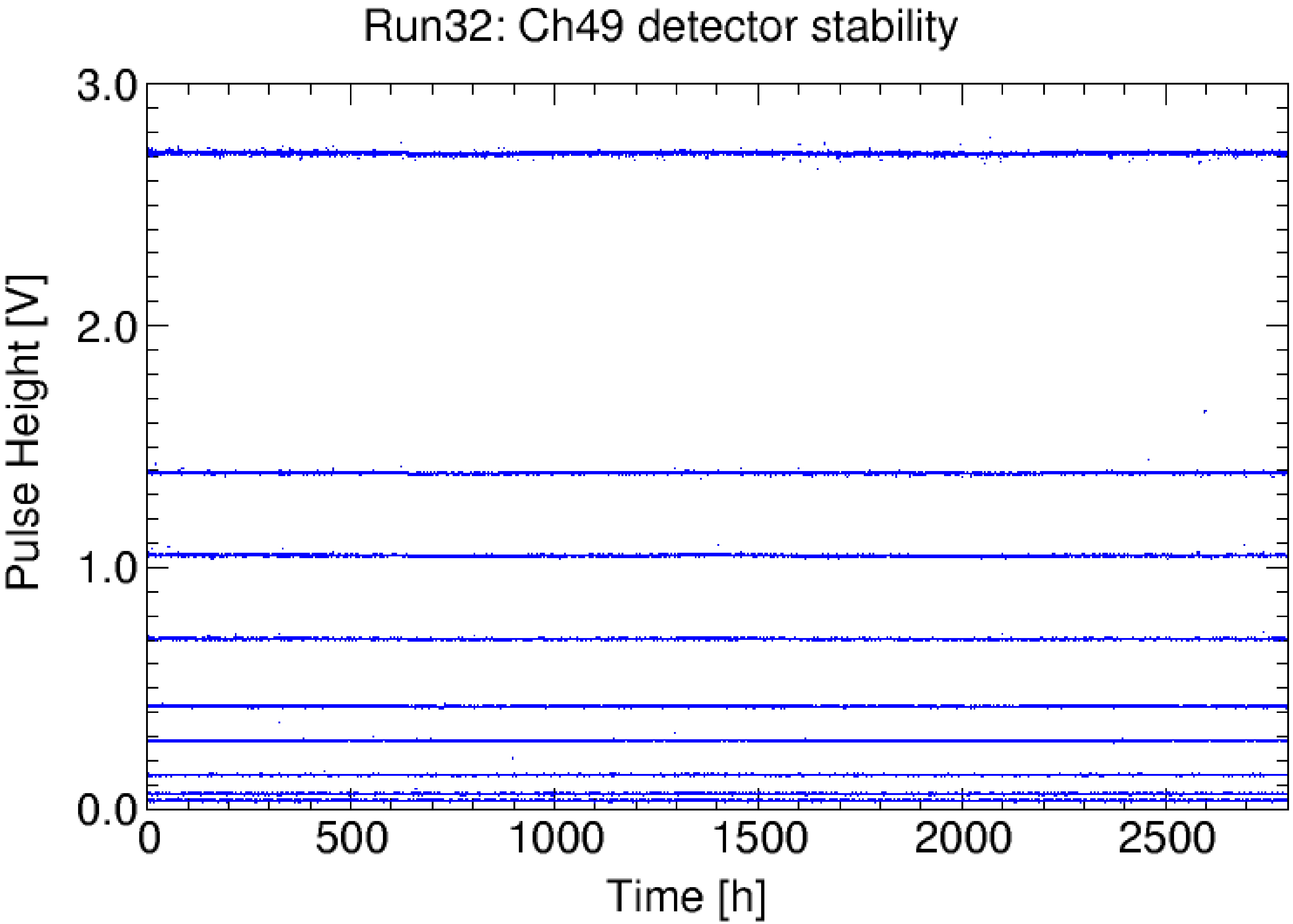
CRESST II: low energy precise spectroscopy

Very precise energy calibration

Lines down to 3.6 keV identified with excellent energy resolution (300 eV=

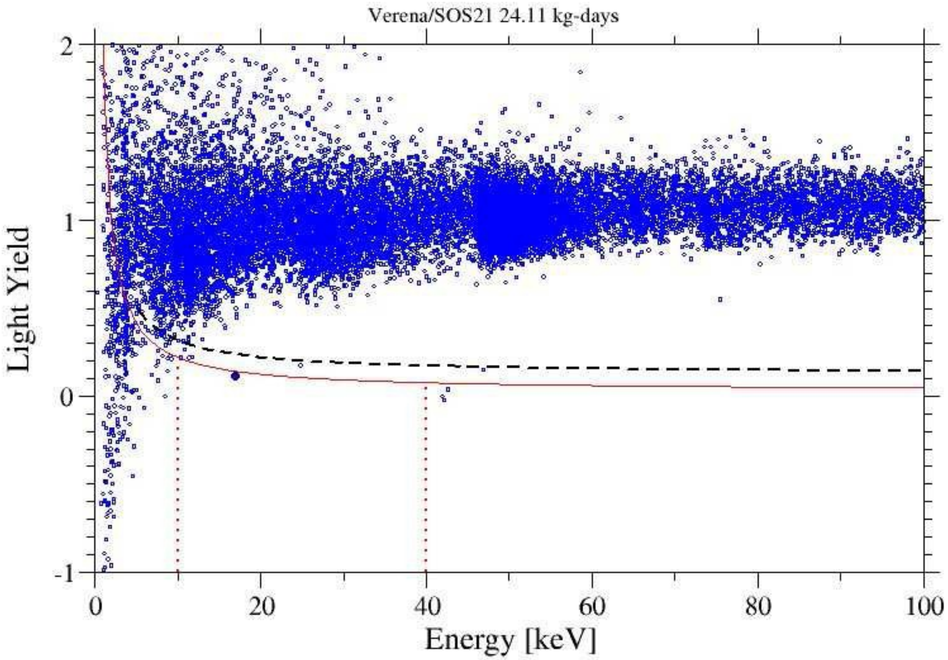


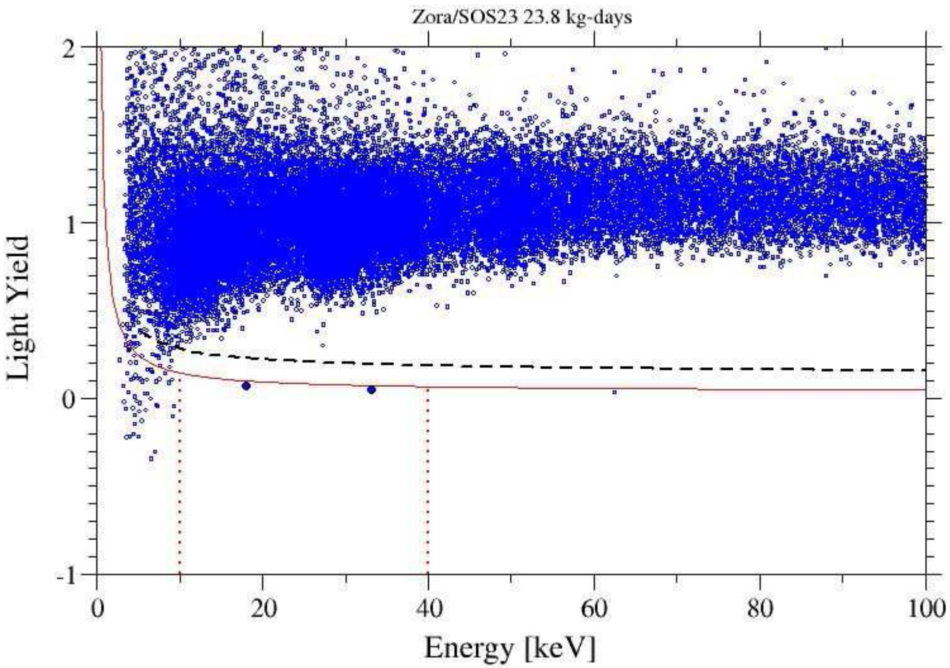
CRESST II: stability



CRESST II

Commissioning Run: nov.2006 - oct.2007 - Two Modules $CaWO_4$, 48 kg-days. Three 'unexplained events'. $\sigma = 4{:}8\ 10^{-7}$pb for $M_{WIMP} \sim 50$ GeV





Present, Ongoing, Run: Eight Modules $CaWO_4$, One module $ZnWO_4$,

So far 300 – 400 good kg-days

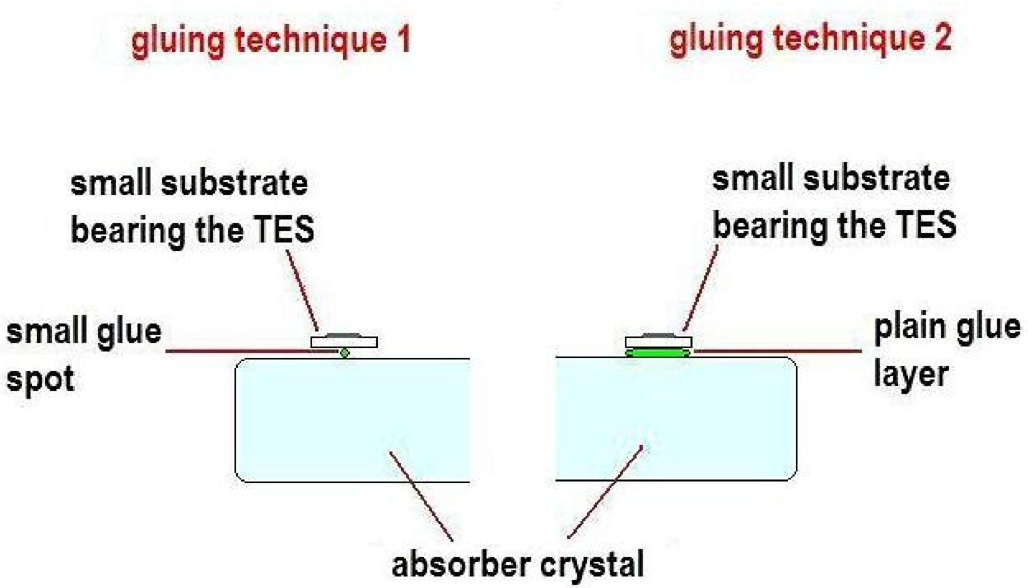
Analysis in progress

- Patch of a leakage in the neutron shield
- Introduction of redesigned holding clamps of the absorber crystals
- 3 detector modules built according to the so-called **composite detector design**

CRESST II: Composite detector design

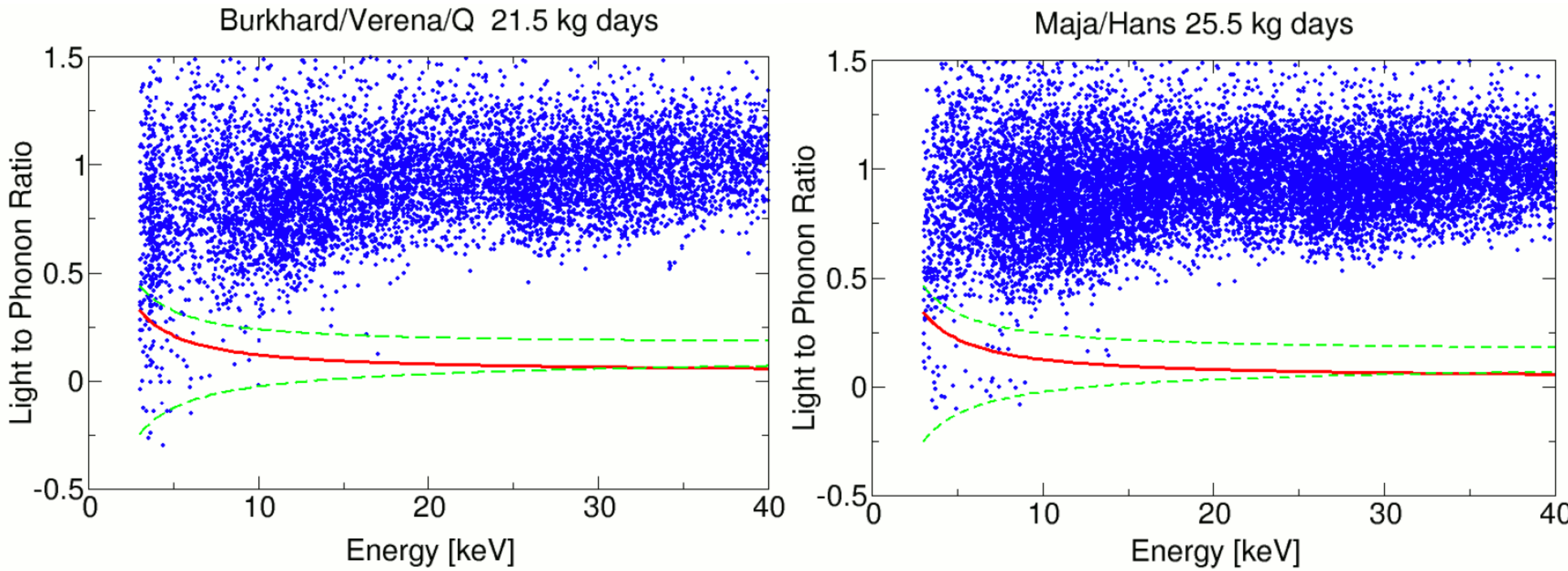
Important technical development:

- Production of the TES on a separate crystal substrate
- Gluing the TES onto the large absorber crystal



- simplied TES production process
- TESs can be pre-tested concerning their superconducting transition
- usage of small substrates for the deposition: produce several TESs in one step
- NO heating cycles of the absorber crystals that could lead to a degradation of the light output are avoided
- other crystal materials can be used more easily: e.g. one ZnWO4
- detector in the present CRESST run
- mass production is feasible

CRESST II status



‘Stability’ Cut: Construction in LNGS,Earthquakes, Apparatus…
As determined by deviant behavior of test pulses. **Removes 10-15% of running time**.

Coincidences: With muon veto panels / other cryodetector modules.
Indications that events in signal region often have multiple coincidences.
Suggests muon-induced showers?

The family of background signals

Observed features in the Light-Phonon scatter plot are identified thanks to the excellent performance of the detectors.
Result: very good control of the background:

Neutrons

- Increase light output to improve rejection
- Glued thermometers
- Avoid degradation of light output

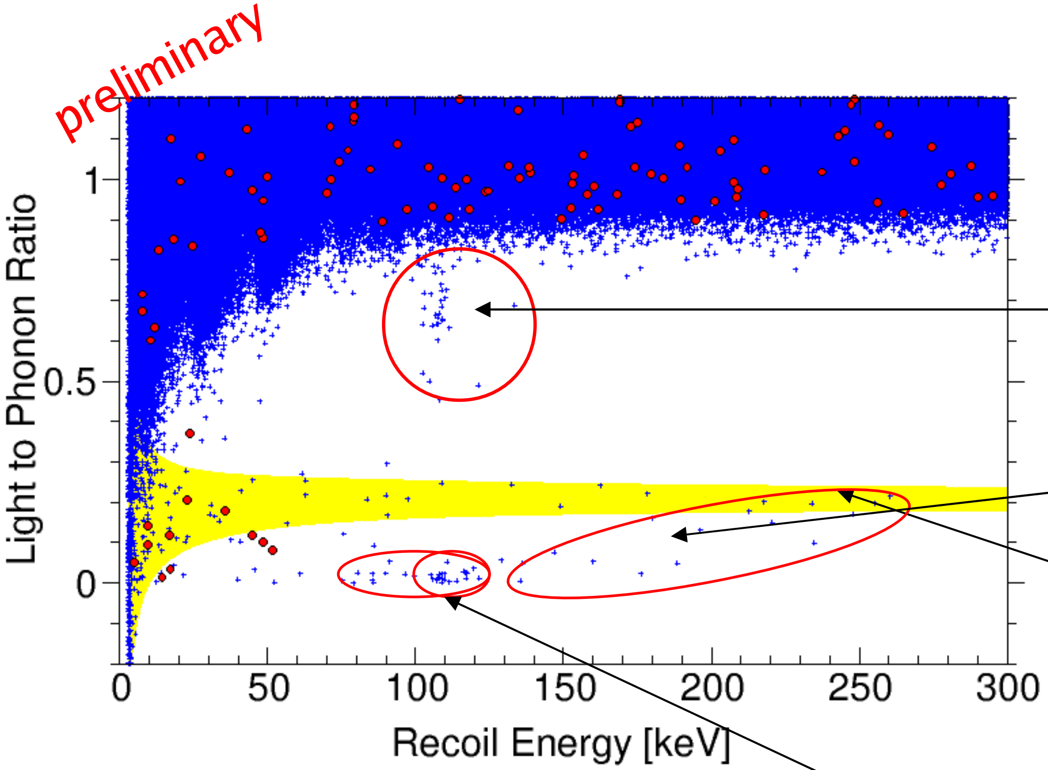
Recoils of heavy nuclei from surface alpha decays

- Veto by scintillating surrounding of crystals
- Weak point: Partially uncovered clamps holding the crystals
- Complete coating of clamps with scintillating epoxy

Dark events

- Instrumental effect: stress relaxation due to tight clamping in the crystals and/or in the plastic coating. Small crystal surface damages found after dismounting.
- New holding clamps: thinner material but no plastic coverage and no scintillation.

Alpha decays

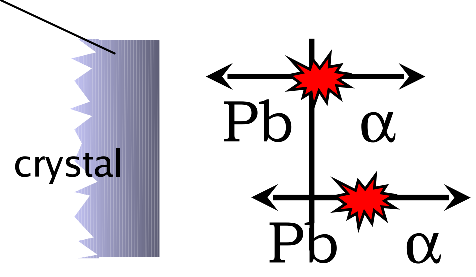


Recoiling nucleus hits crystal
α hits scintillating holder

α-emitter at crystal surface
deposits nuclear recoil +
fraction of α-energy

α-band

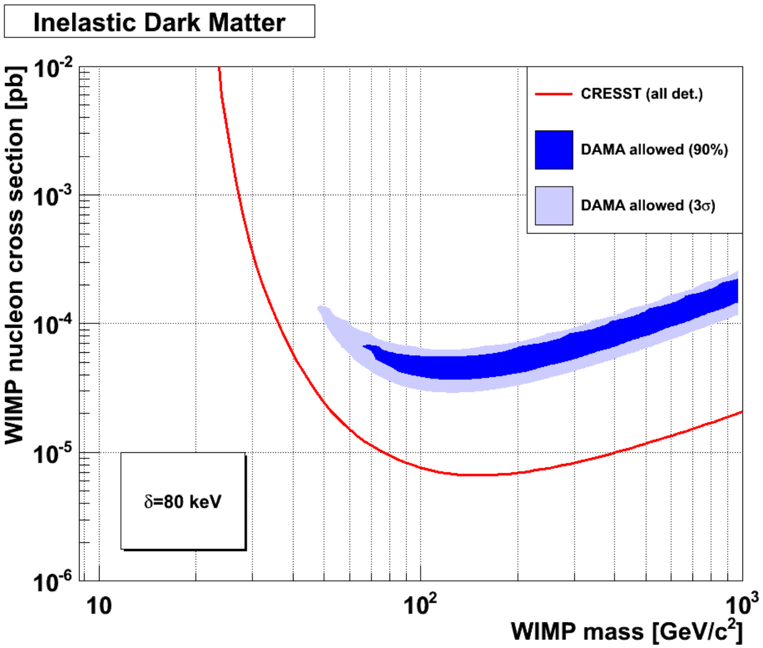
Full α-analysis
in progress

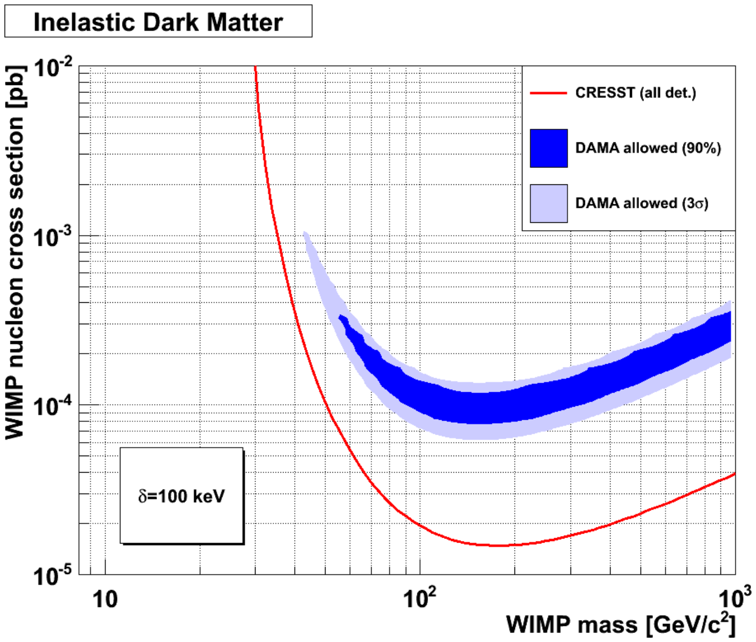


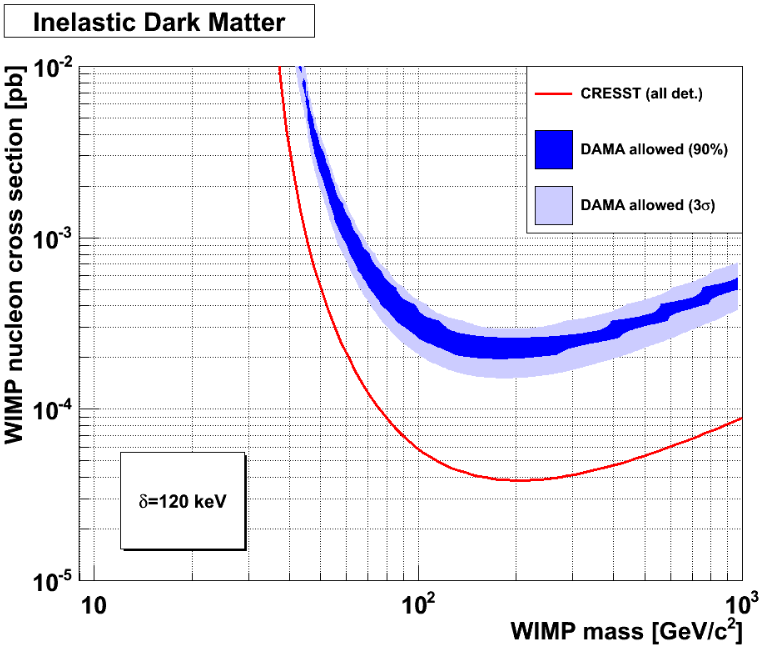
$^{210}\text{Po} \rightarrow {}^{206}\text{Pb}$ (104keV) + α (5.4MeV)

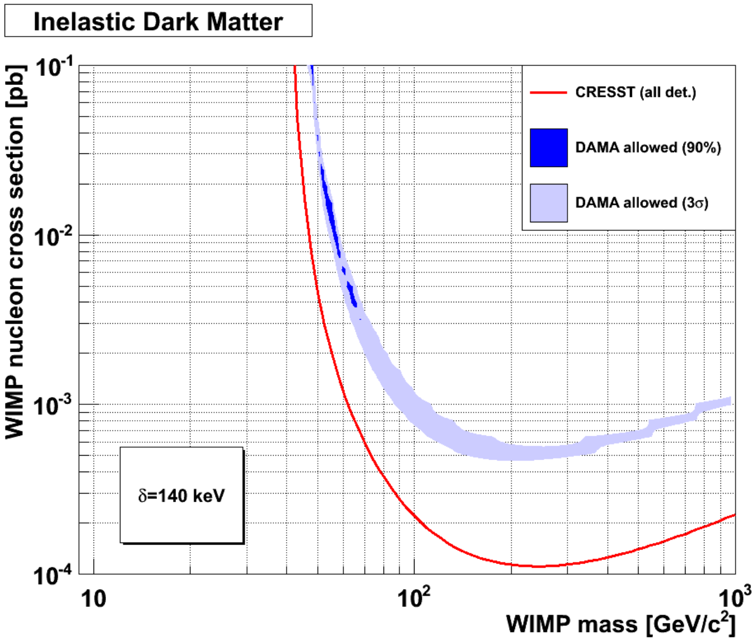
Drawn bands only schematic

CRESST II: Inelastic DM





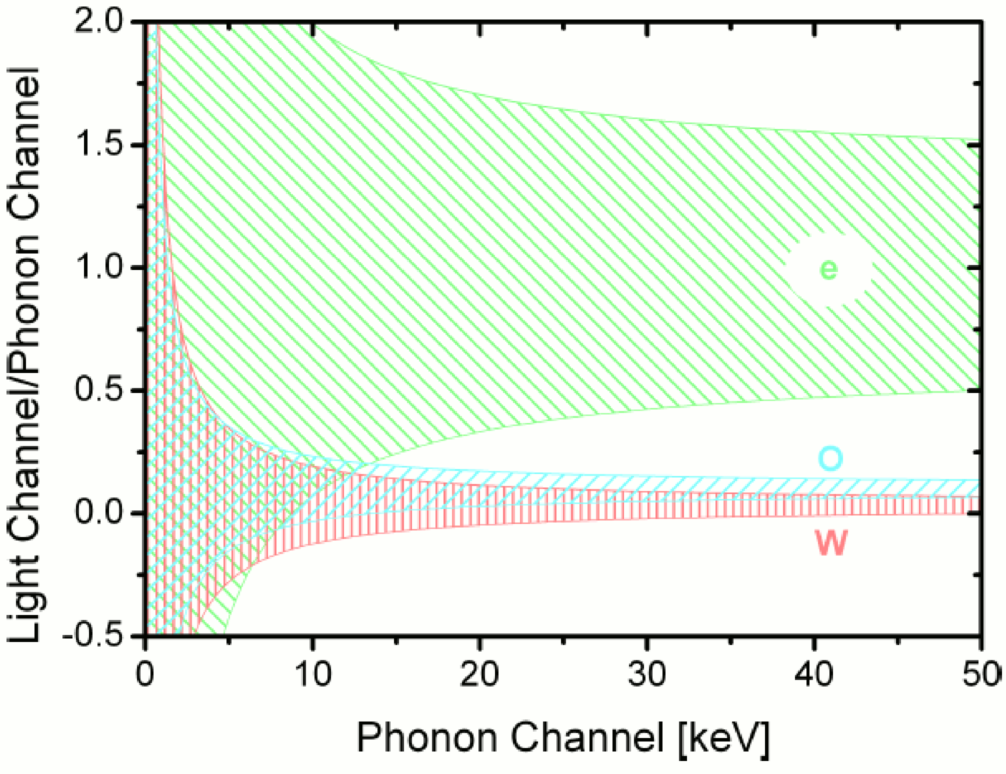


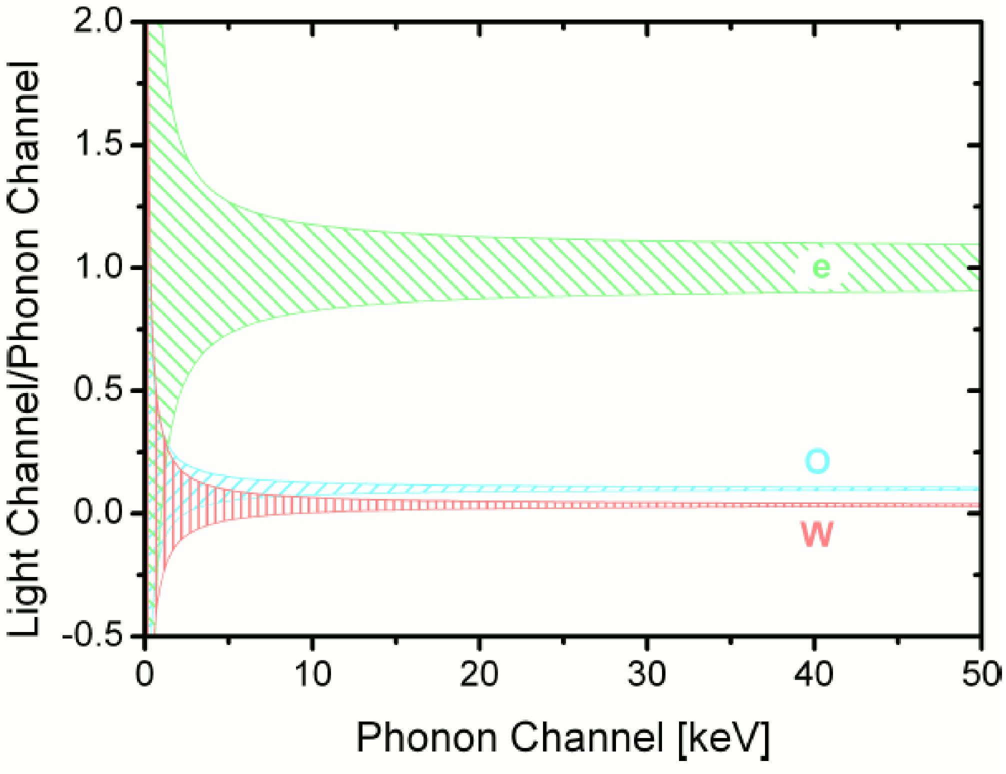


Light collection

Resolution of the light detector is the key item:

- **Improve background discrimination**
- **Lower threshold**





Composite detector design

EURECA research topics

Seeked improvements:

- Exposure: increase significantly kg-days. **Upgrade to more mass**
- Resolution of light detector
- Multi target setups

Steps:

- Composite detector design: i.e. realization, optimization and possible mass production of composite detectors
- Thermal detector model for cryogenic composite detectors
- Neganov-Luke amplified composite light detectors
- Self-grown CaWO4-crystals that are optimized concerning radiopurity and light output
- Determination of the exact quenching factor, i.e. the light output, for neutron-induced Ca, O and W recoils

Discovery potential

- Background levels have been tremendously reduced thanks to a collection of complementary simultaneous informations.

- **Statistics is the ultimate enemy**: balance between target mass and background level.

- Present background levels ask for ton scale detectors: a true technological challenge for next generation experiments.

- Even in the case of a statistically significant signal **complementary signatures are required** (modulation, directionality, observation in other targets)

Next future phonon detectors challenge:

- Ton detectors: large-scale production of detector modules
- Reproducibility: detectors with very similar properties
- Complementary information: multi-material targets
- Detailed understanding of the detector response

Status

Charge vs Scintillation

	Charge	Scintillation
Statistics	Low duty cycle	Stability and high duty cycle
	Surface leakage: timing cut	**Dark signals**: detector modifications
Multi-target	Ge & Si	CaWO4, ZnWO4, … And many others
Available Information	**Phonons, Charge, Position, Timing**	**Phonons, Scintillation**
Scalability	Complex and expensive	In progress

Phonons vs the others

Next challenge: tons detectors with good background control

+ Next available steps: 100-1000 kg
+ Quality of the data: can help in controlling the background
+ Stability and Duty cycle: under control
++ Multi Target: unique opportunity

Low temperature detectors are still a competitive approach complementary to other experimental techniques

Conclusions

- Bolometric still represent a complementary approach to DM searches characterized by redundant and quality data

- Different approaches have different “backgrounds”
- Complemetary information helps solving background and instrumental problems
- Detailed understanding of the detector response is important

- Next mass scale 1ton
  - Medium size underground lab
  - Medium depth lab (+veto)

- Duty cycle can still be a problem (bad cryogenics performance?) but control is possible.

- **Multi target approach offers a unique model independent opportunity**
- Ton scale detectors and cryogenic infrastructure are under construction

- **Low temperature detectors offer a competitive approach**
- **LNGS is an ideal lab for ton scale experiment**