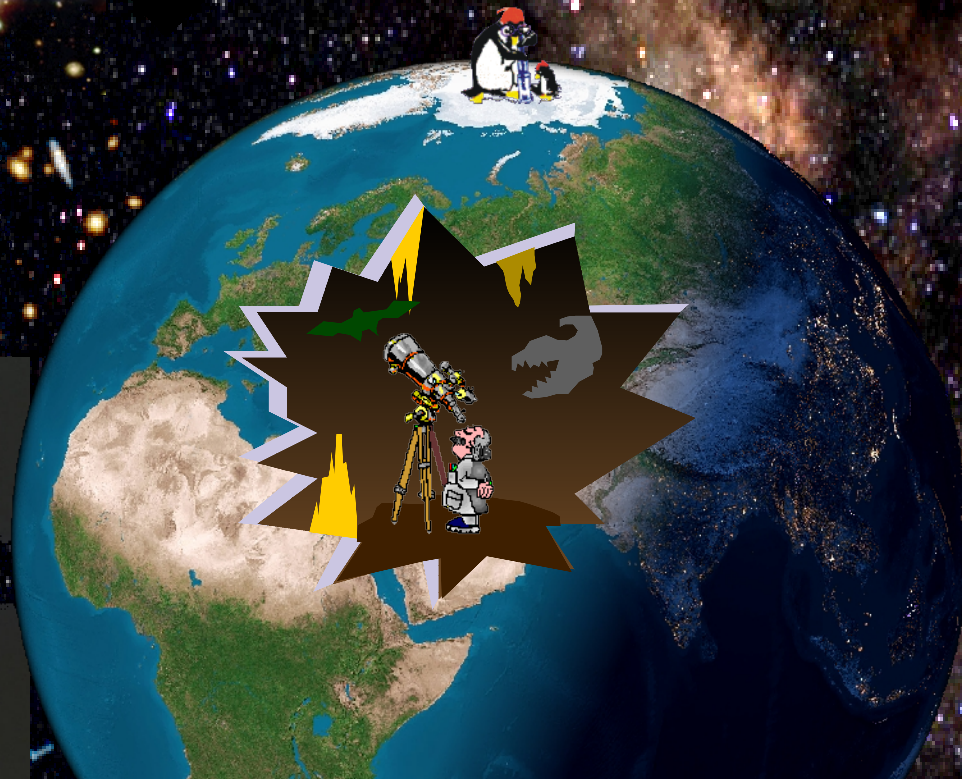
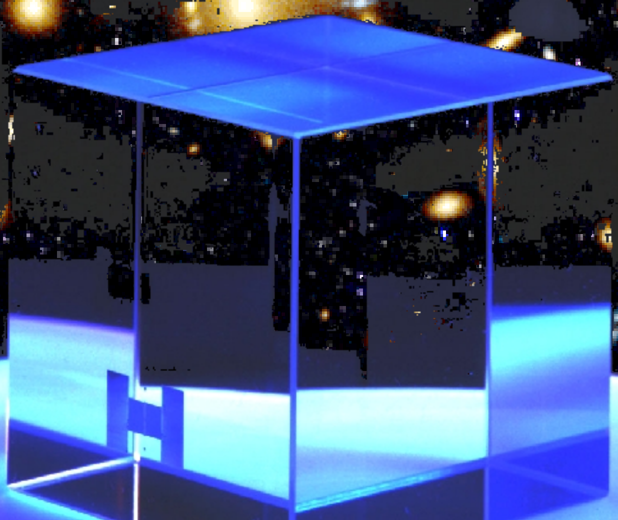
Direct Dark Matter Search
CRESST



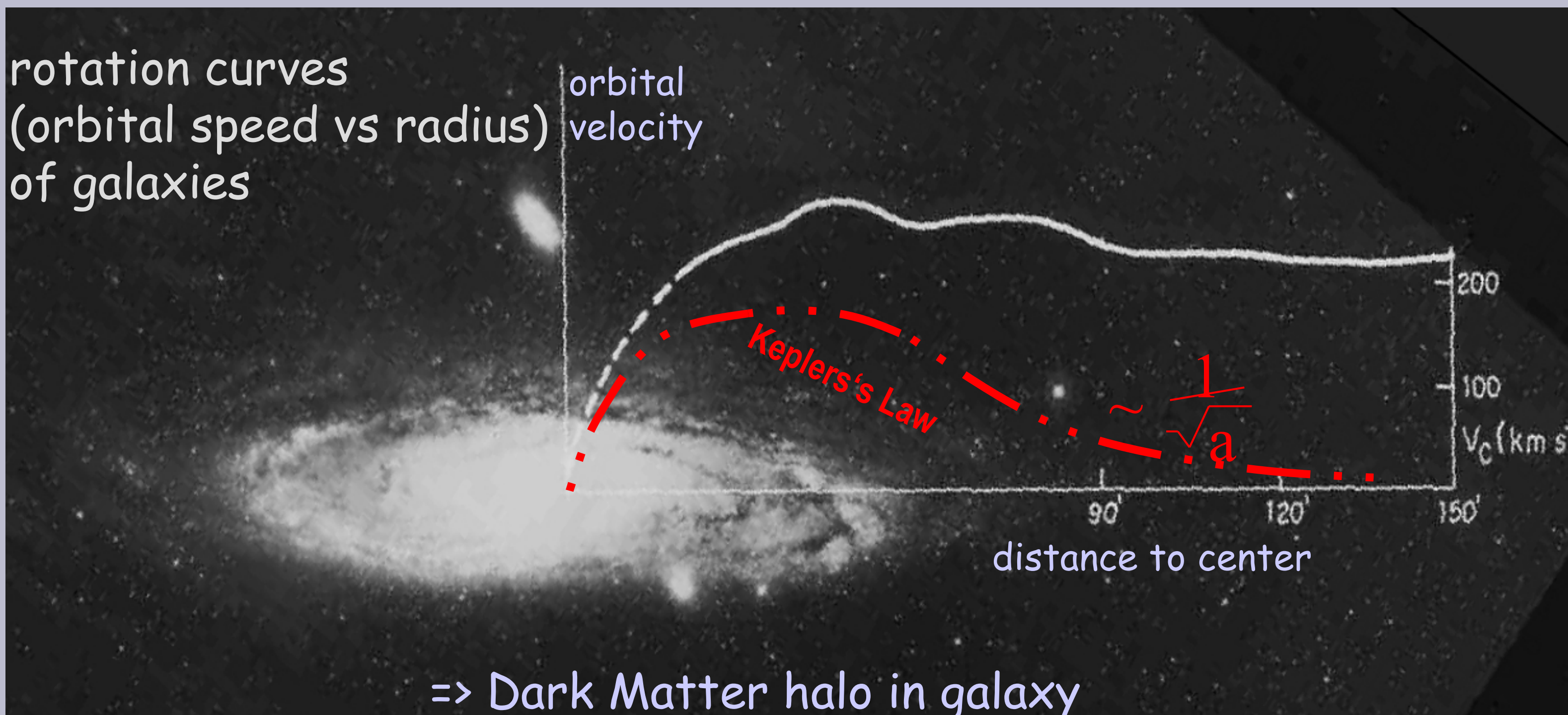


J.Jochum

Eberhard Karls
Universität
Tübingen

Kepler Center for Astro and Particle Physics

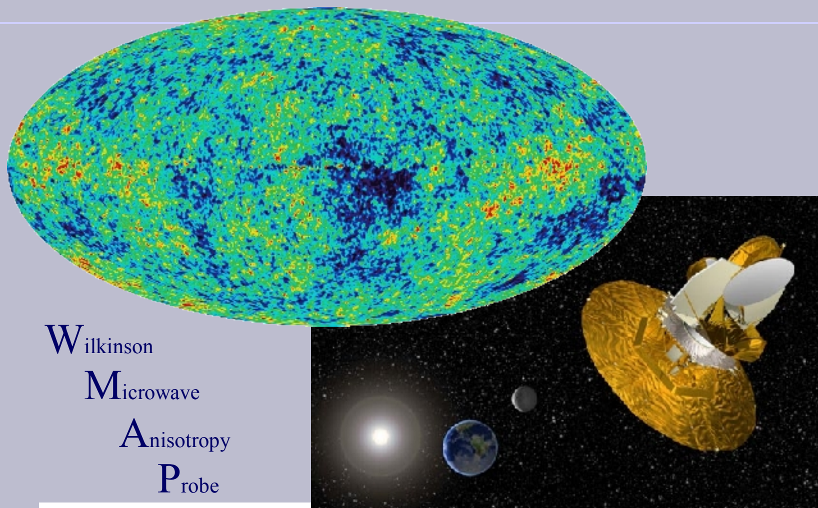
Dark Matter - Evidence



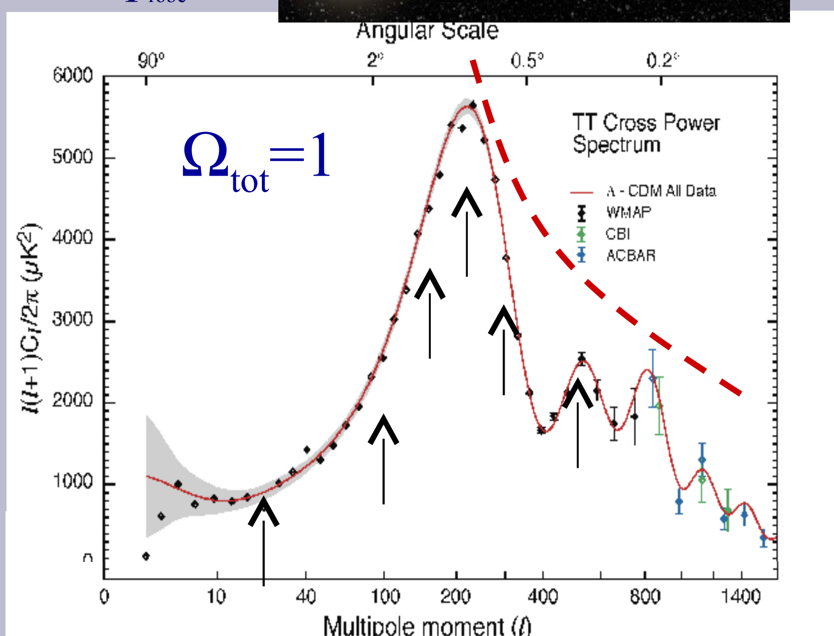
$$\Omega_{Mat} > \Omega_{Lum} \approx 0.01$$

there must be more matter in the universe than we see

Cosmic Microwave Background – Matter-Density Ω_{matter}



Wilkinson Microwave Anisotropy Probe



Anisotropy:

Angular scale => geometry, Ω_{tot}

Intensities => gravitational potentials, matter densities

- gravitation Ω_{matter}
- coupling to radiation Ω_{baryon}

$$\Omega_{matter} = 0.27$$

$$\Rightarrow \Omega_{matter} \gg \Omega_{lum} \approx 0.01$$

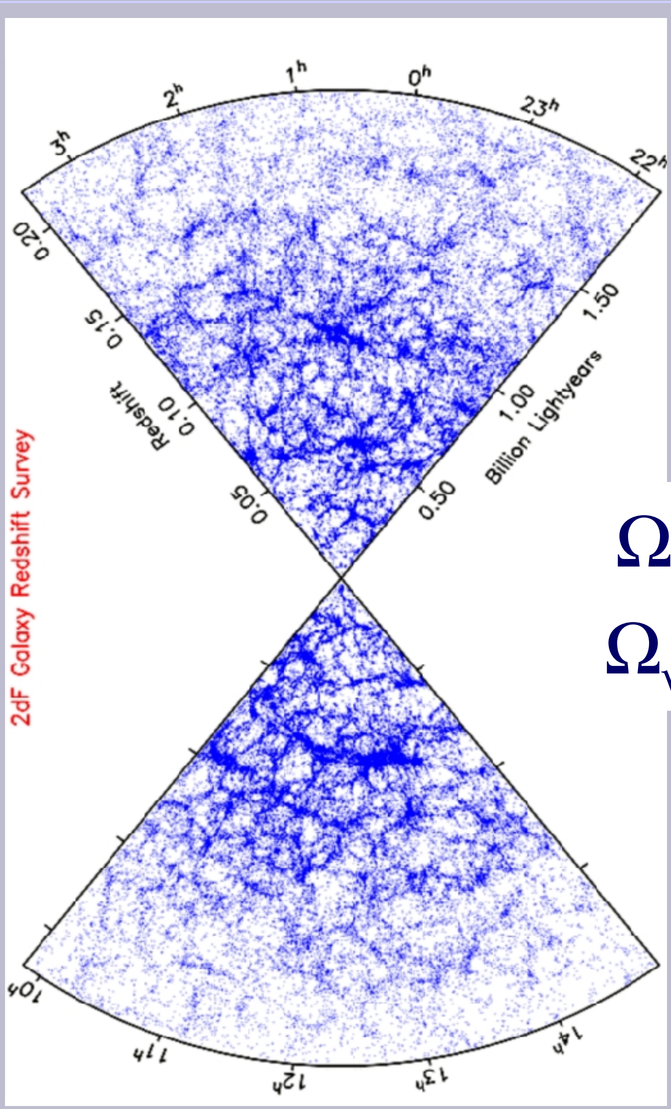
mostly Dark Matter

$$\Omega_{baryon} = 0.044$$

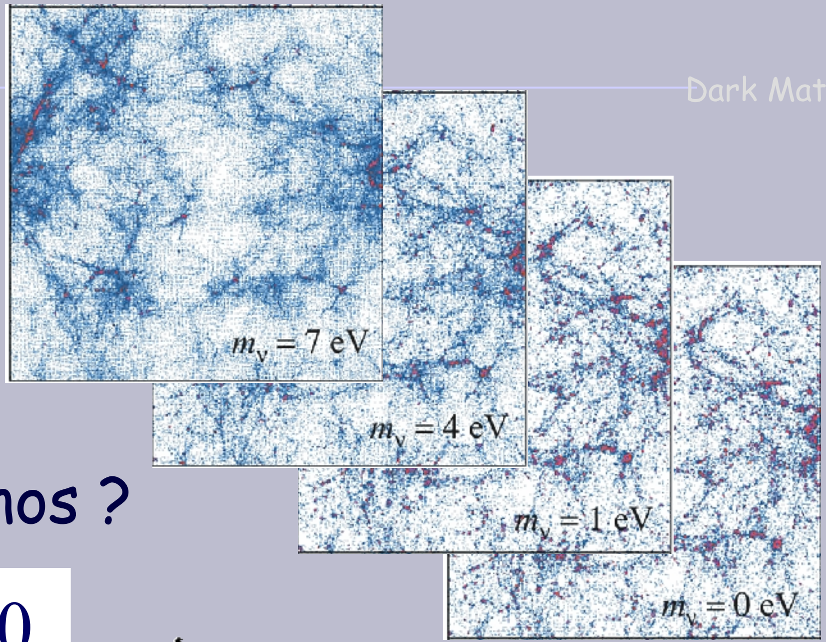
u d e

$$\Rightarrow \Omega_{matter} >> \Omega_{baryon}$$

Structure in the Universe and Neutrinos

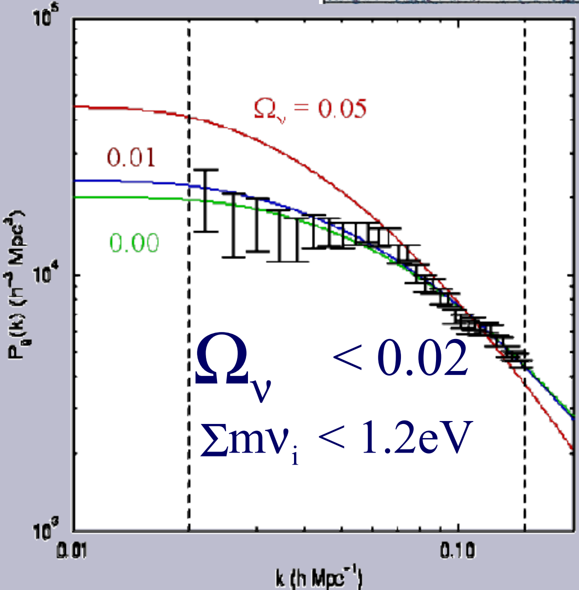


Why not Neutrinos ?



$$\Omega_{matter} \sim 0.30$$

$$\Omega_\nu \quad < 0.02$$

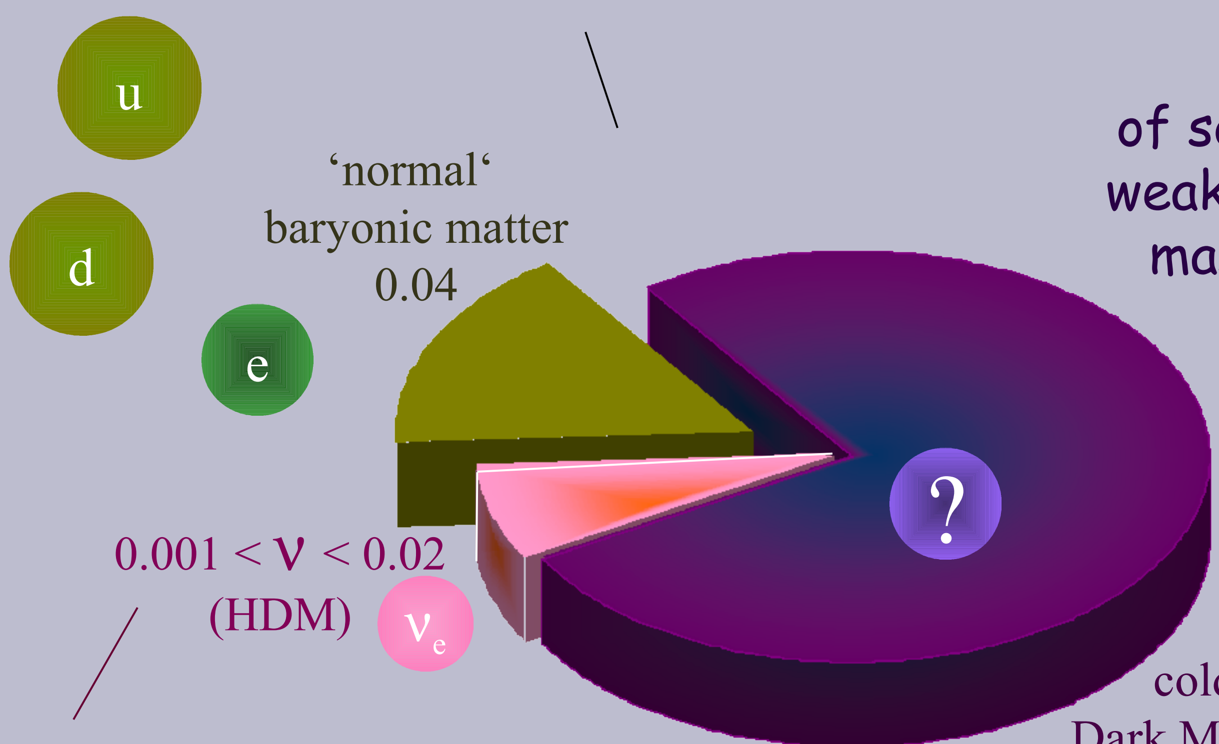


$$\Omega_\nu \quad < 0.02$$

$$\Sigma m\nu_i < 1.2\text{eV}$$

Matter in the Universe - Composition

$$\Omega_{mat} = 0.27 \pm 0.04$$



$0.001 < \nu < 0.02$
(HDM)

from ν–oscillations
=> $\Sigma m_\nu > 0.05$eV

cold
Dark Matter
(CDM)
0.23

'ν too light' =>
most of the
Dark Matter
is cold

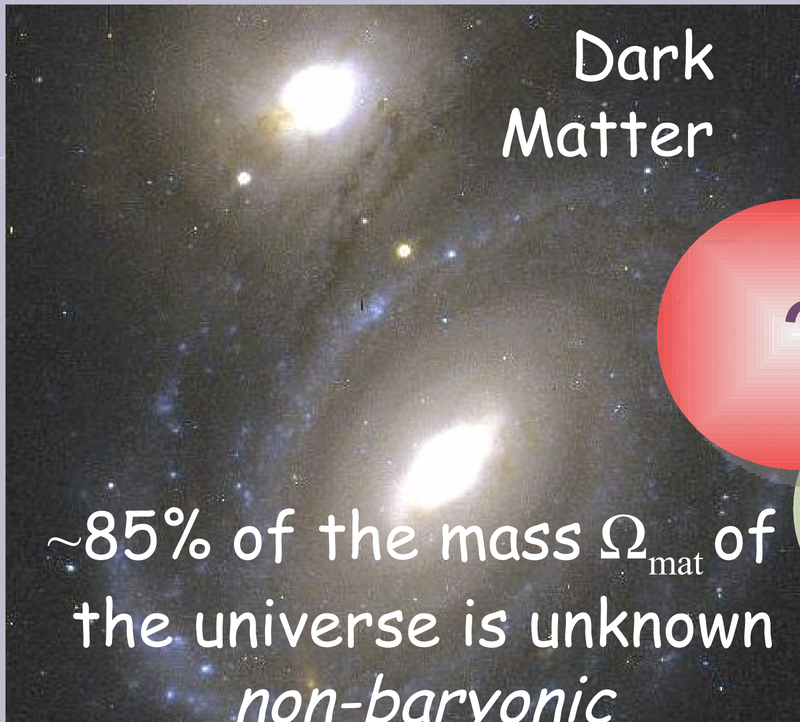
of so far unknown
weakly interacting,
massive particles
WIMPs
(50GeV~1000GeV
Neutralino?)

or

AXIONs

AXINOs

GRAVITINOs



search for
physics beyond
the Standard Model

observations in
Cosmology

Particle Physics

new elementary particles

QCD: Axions

supersymmetry: <u>Neutralino</u> $\chi = a\tilde{\gamma} + b\tilde{Z}^0 + c\tilde{H}_1^0 + d\tilde{H}_2^0$

Gravitino, Axino

➠ perfect particle Dark Matter candidates (WIMP)

WIMP – direct detection

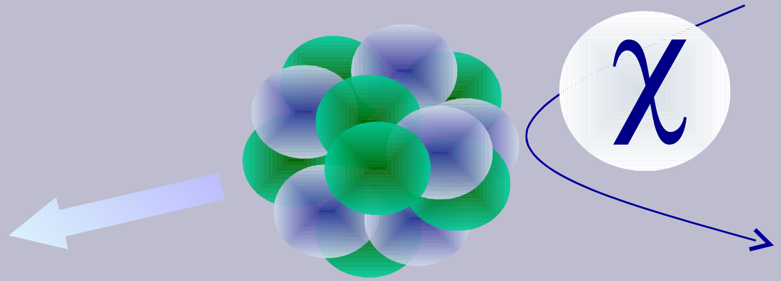
Weakly Interacting Massive Particles = WIMPs

elastic scattering on nuclei in a detector

- nuclear recoils: reduced efficiency for charge and/or light production

  - mass *50 GeV - ~ 1000 GeV*
  - speed relative to earth *270 km/s*

    (~ our speed going around the galaxy)

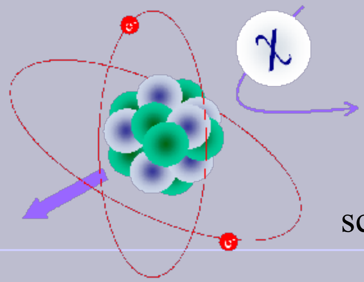


⇒ a few keV of energy only

- cross section $\sigma_\chi < 10^{-36} cm^2$
- locale WIMP-density $\rho_\chi \approx 0.3\ GeV / cm^3$
  - corresp. 3 WIMPs$^{(100GeV)}$ / Liter
  - 75000 /s /cm^2

⇒ very very very rare scattering events (< 0.1 / week / kg)

Background

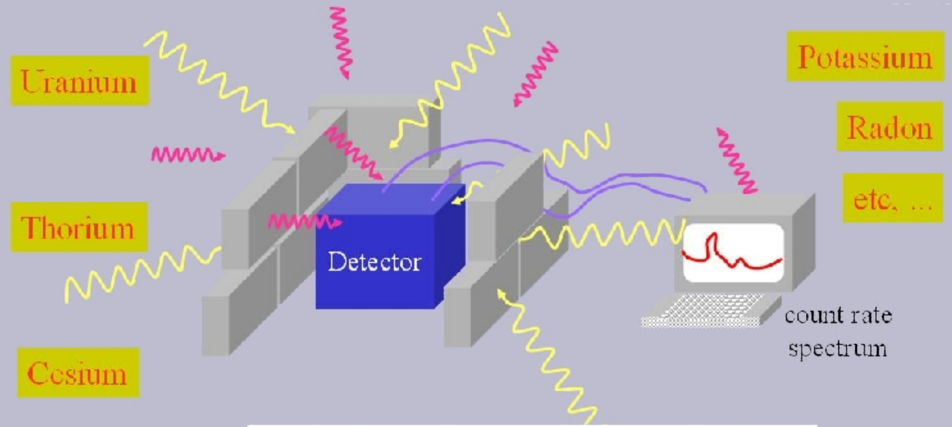


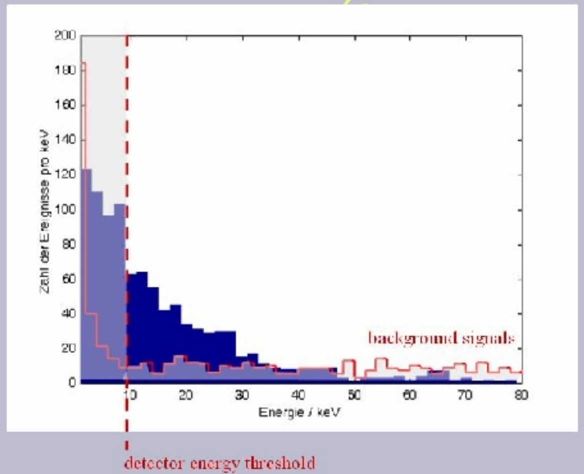
Count rates < 1 / month / kg

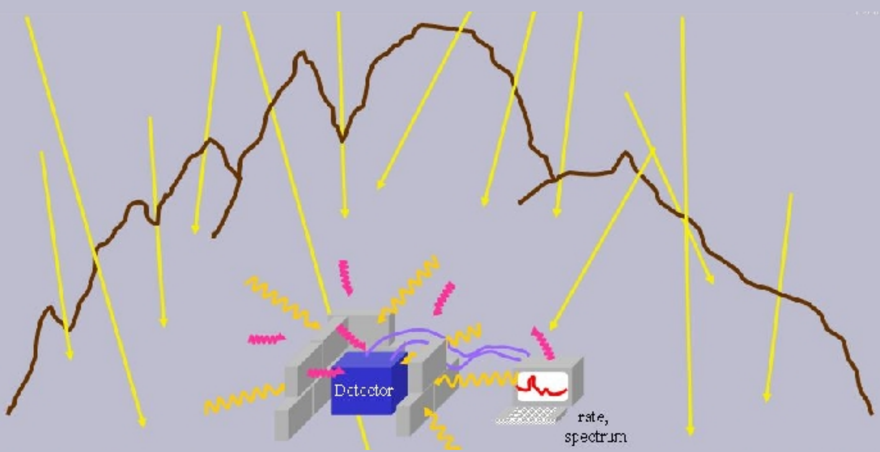
- clean shielding against
  enviromental radioactoivity

- clean detector components

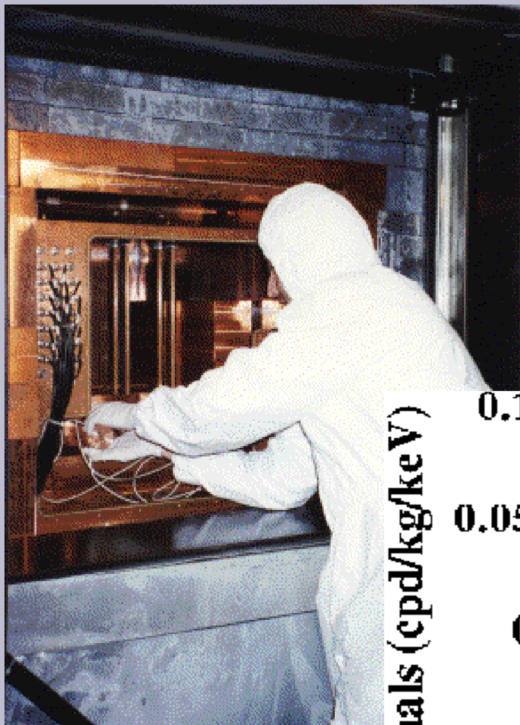
- shielding against cosmic rays (muons)
  need reduction by ~ 10^6







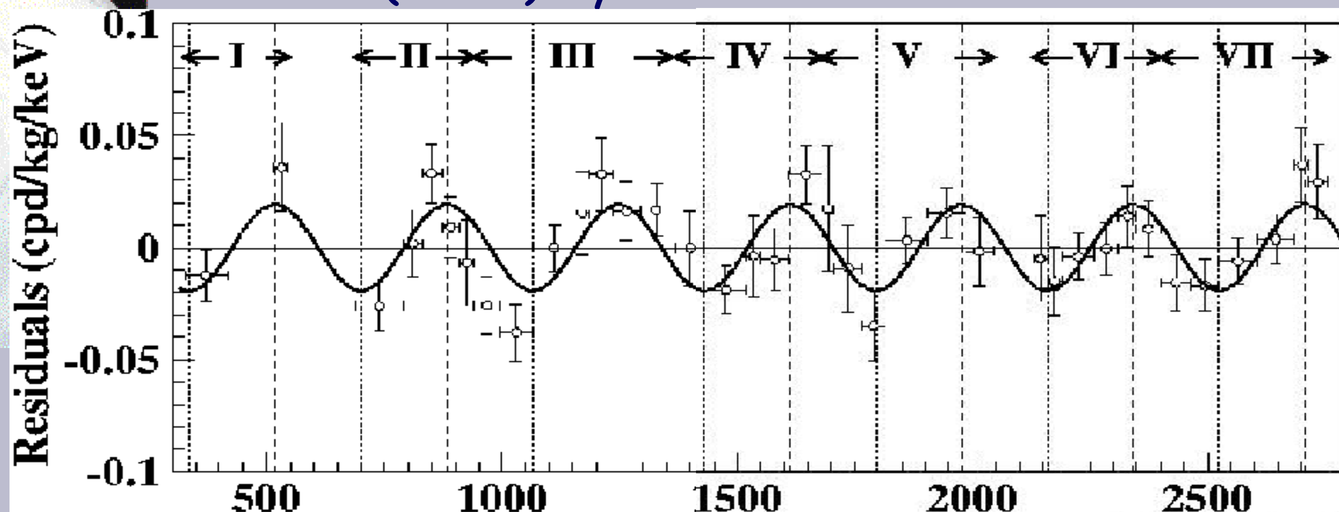
Low energy, few keV recoil
=> quenching
- Low threshold detectors

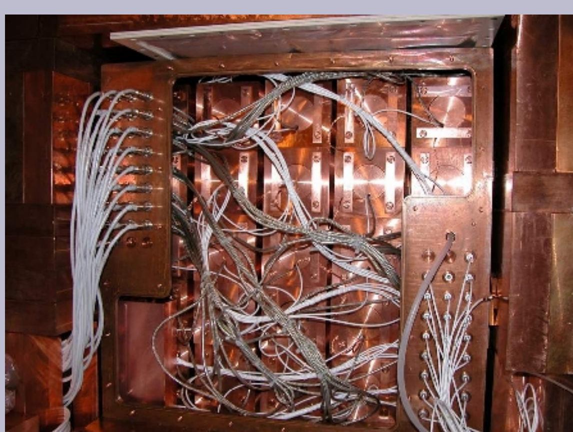


Annual Modulation

recoil energy spectrum modulates
due to earth motion relative to halo

DAMA - Experiment: first hint to WIMPs ?
(1998) by annual modulation





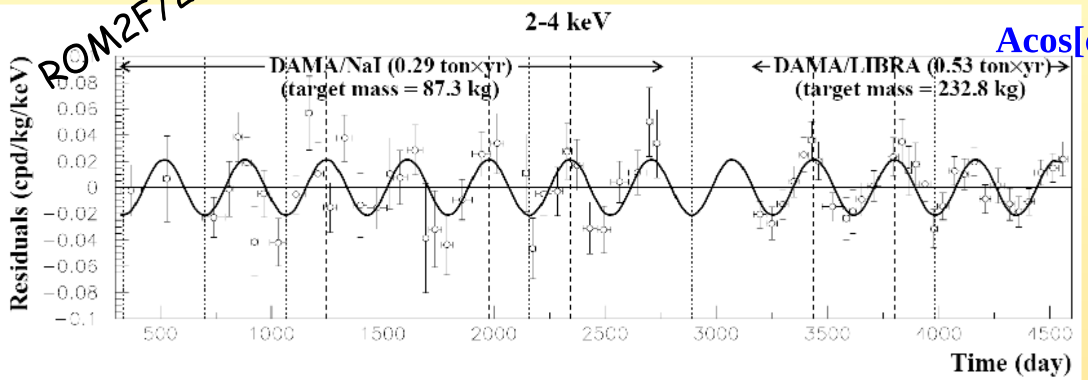
up to know 11 years of measurement
(~ 300.000 kg x days, 0.8 ton x year)

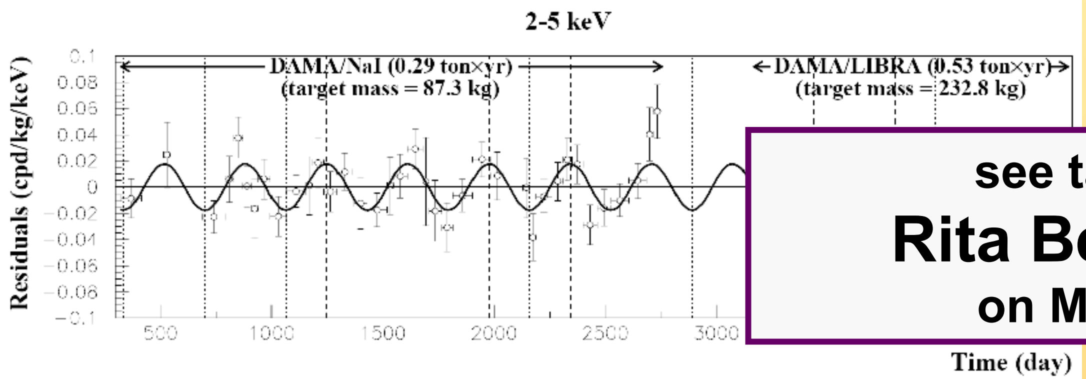
Modulation with 8σ Confidence

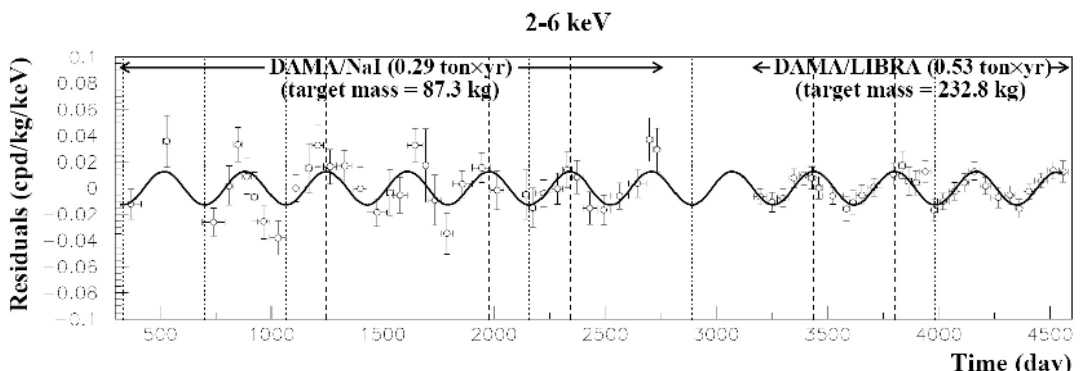
Model Independent Annual Modulation Result

DAMA/NaI (7 years) + DAMA/LIBRA (4 years)   Total exposure: 300555 kg×day = 0.82 ton×yr

experimental single-hit residuals rate vs time and energy







$A\cos[\omega(t-t_0)]$; continuous lines: t_0 = 152.5 d, T = 1.00 y

2-4 keV

A=(0.0215±0.0026) cpd/kg/keV

χ^2/dof = 51.9/66   **8.3 σ C.L.**

Absence of modulation? No

χ^2/dof=117.7/67 ⇒ P(A=0) = 1.3×10^{-4}

2-5 keV

…0020) cpd/kg/keV

…6   **8.8 σ C.L.**

…odulation? No

χ^2/dof=116.1/67 ⇒ P(A=0) = 1.9×10^{-4}

see talk by

Rita Bernabei

on Monday

2-6 keV

A=(0.0129±0.0016) cpd/kg/keV

χ^2/dof = 54.3/66 **8.2 σ C.L.**

Absence of modulation? No

χ^2/dof=116.4/67 ⇒ P(A=0) = 1.8×10^{-4}

The data favor the presence of a modulated behavior with proper features at 8.2σ C.L.

Direct DM Searches

Present best sensitivities
(for spin independent WIMP scattering)

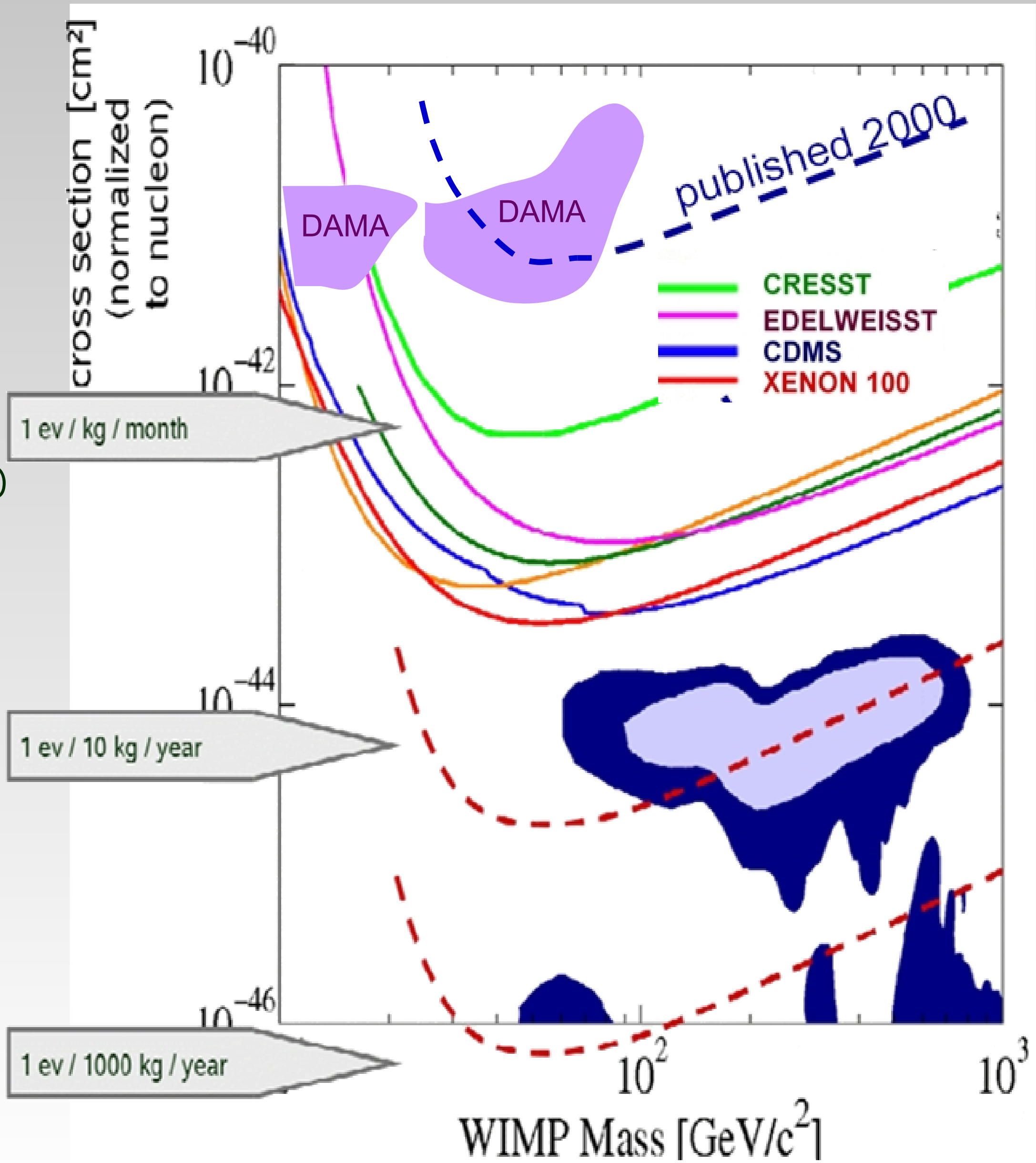
- Cryogenic
- Liquid Xenon
- NaI

+ other techniques
(doing better for spin dependent WIMP scattering)

- superheated droplets
- anorganic scintillators
- …

we have different techniques
with promising sensitivity

simultaneously
LHC is starting
and will march upward in mass

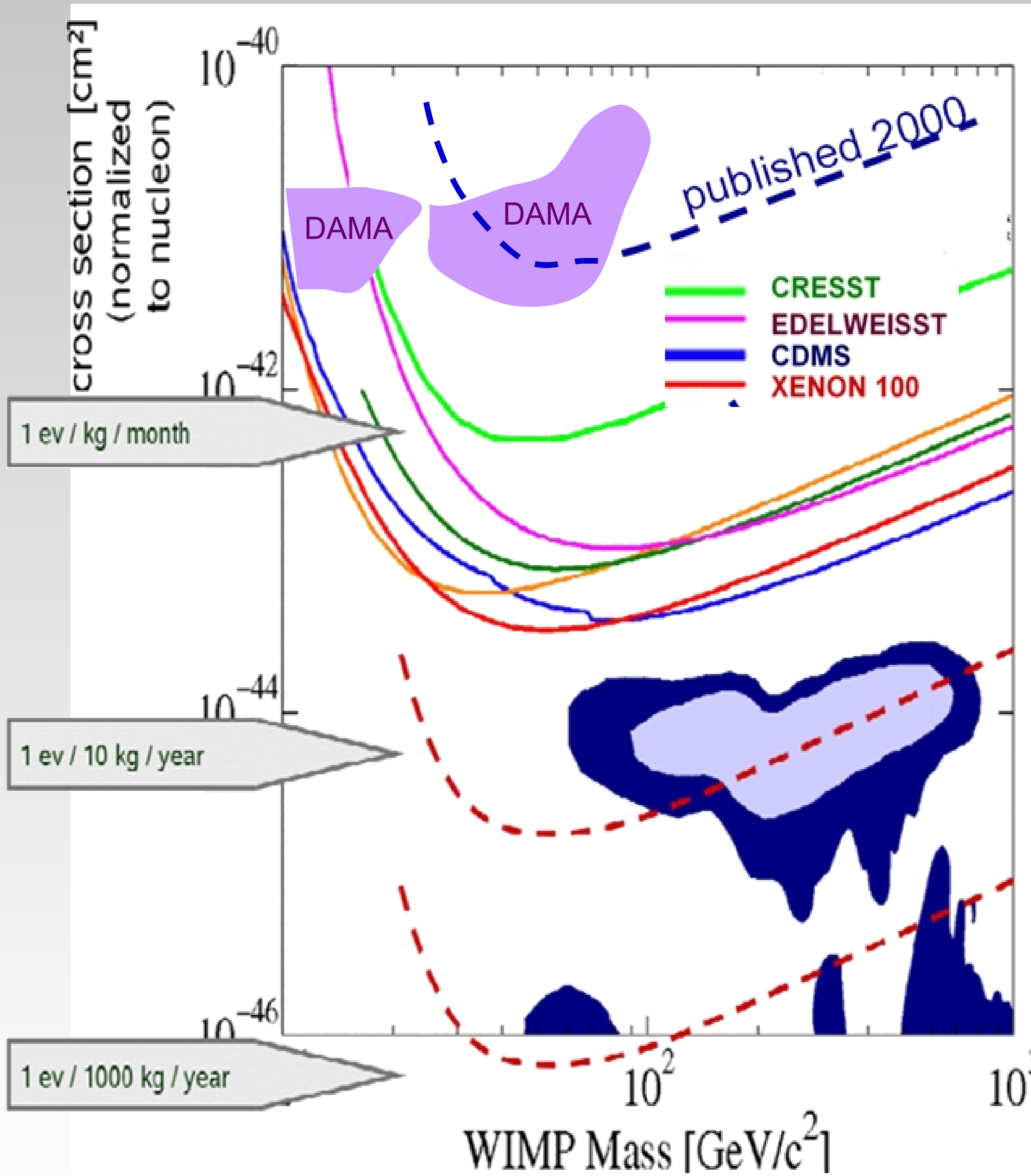


Direct DM Searches

Remarkable progress

x 100 improvement in sensitivity
in 10 yrs

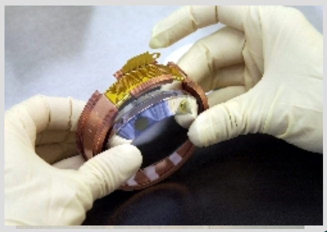
a number of experiments are demonstrating sensitivities
interesting from SUSY perspective



Particle Identification by Combination of Channels

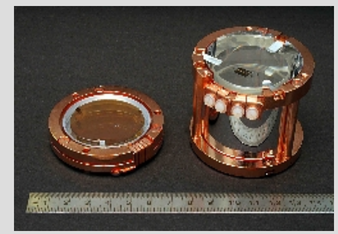
cryogenic charge / phonon

EDELWEISS
CDMS,
EURECA



Phonons

cryogenic light / phonon



CRESST
EURECA

radioactive background can be rejected => highly improved sensitivity

Charge

Light

see talk by
Christian Weinheimer
on Monday

XENON
WARP, ArDM,
LUX, ZEPLIN

liquid noble gas light / charge

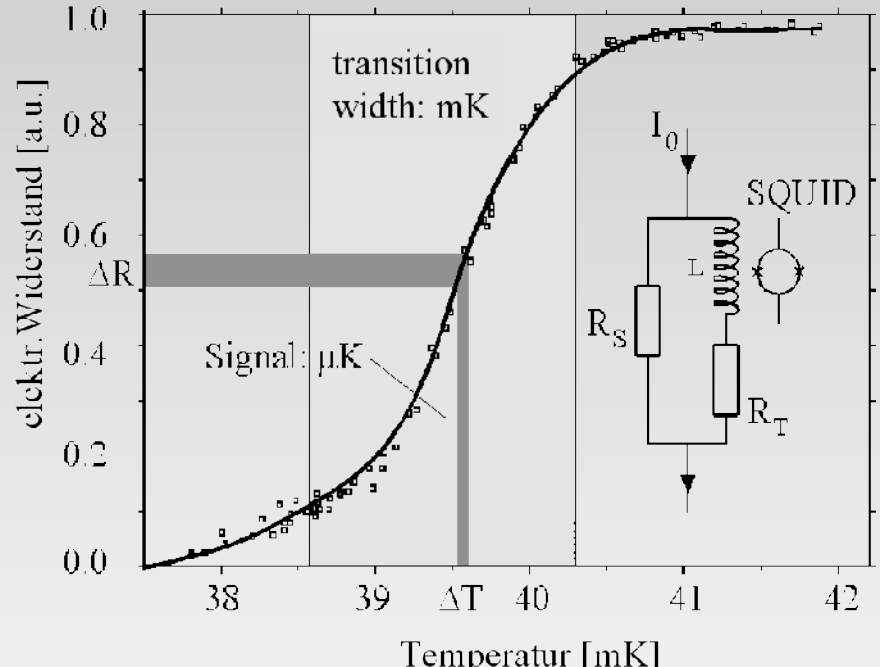
Calorimeters for Dark Matter Search

superconducting phase-transition-thermometer
tungsten $T_c \approx 15mK$

heat capacitance sapphire 250gr
3.4 MeV / K @ 25mK
220 GeV / K @ 1K

Sapphire- or $CaWO_4$-absorber

250gr, 4cm x 4cm x 4cm



CRESST-collaboration

(Cryogenic Rare Event Search with Superconducting Thermometers)

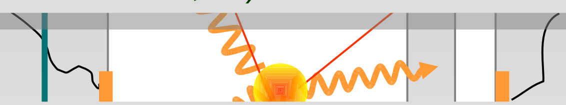
Max-Planck-Institut München, TU München
Universität Tübingen, Oxford University, Gran Sasso Labor

Phonon + Light or Phonon + Charge

CDMS
Cryogenic Dark M
US Collaboratio

charge + phon
(semiconductors Ge, Si)

see talk by
Enectali Figueroa-Feliciano
on Monday



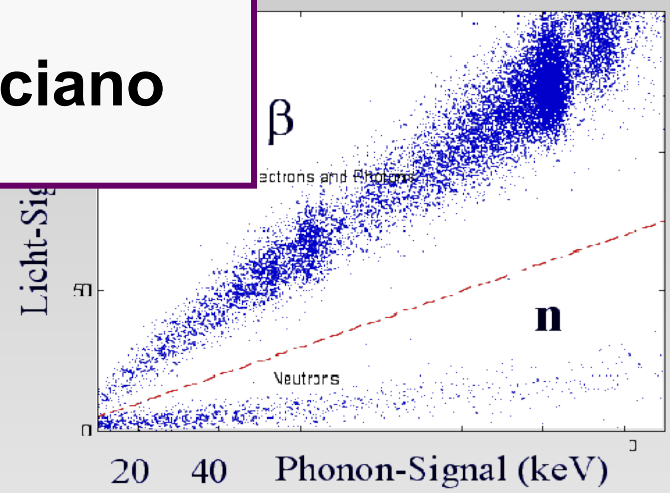
EDELWEISS
Experience pour DEtecter Les Wimps En SIte Souterrain
France and Karlsruhe

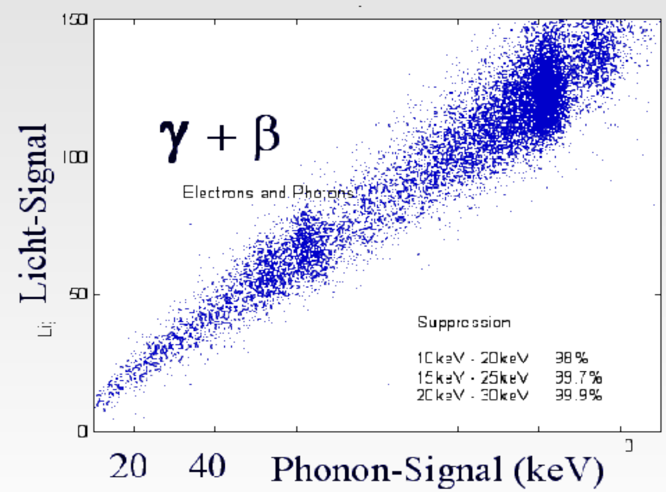
charge + phonon
(semiconductors Ge, Si)

Phonon-Detector
reflecting foil

CRESST
Cryogenic Rare Event Search with
Superconducting Thermometers

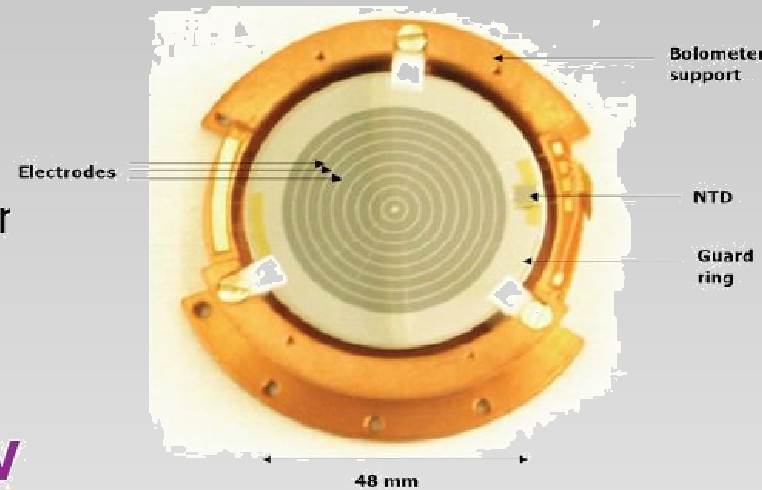
Max-Planck-Institut München, TU München
Universität Tübingen, Oxford University, Gran Sasso

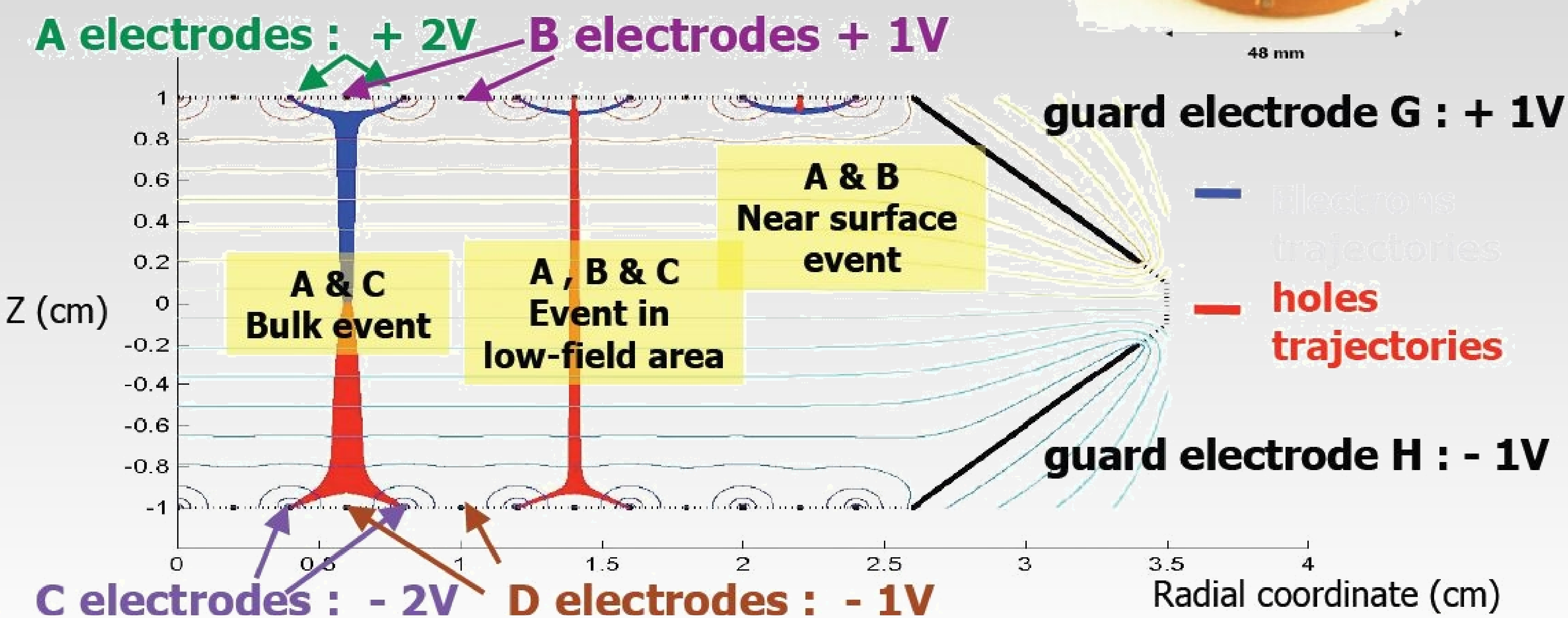




EDELWEISS: InterDigit Detectors – Surface Events

- GeNTD heat sensor
- E-field modified near surface with interleaved electrodes
- B + D signals = vetos against surface ever
- 1x200g and 3x400g tested in 2008
- 10x400 g in operation in 2009

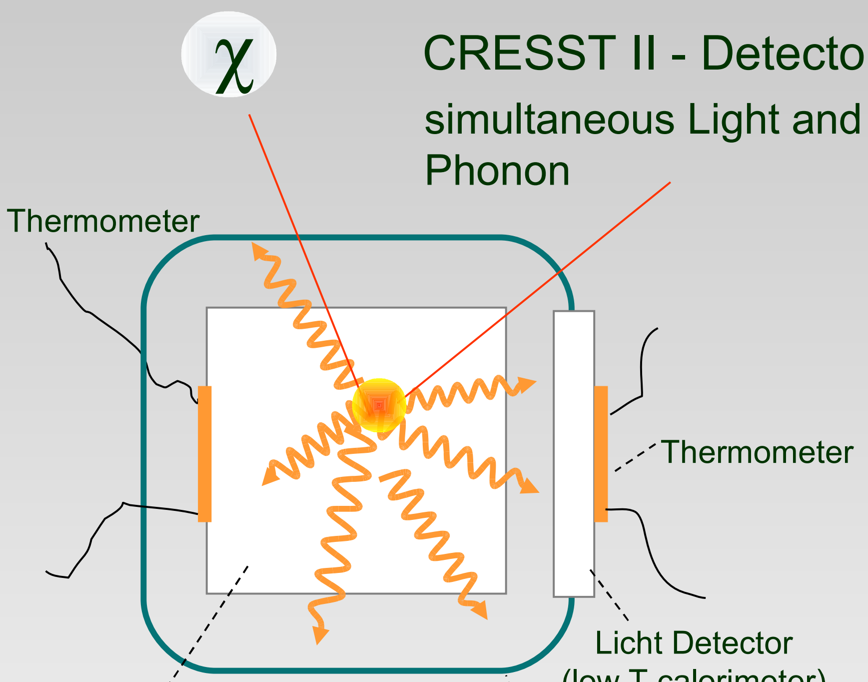


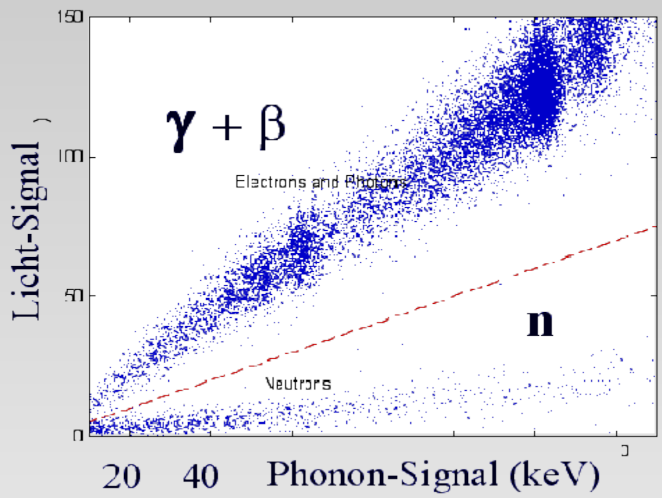


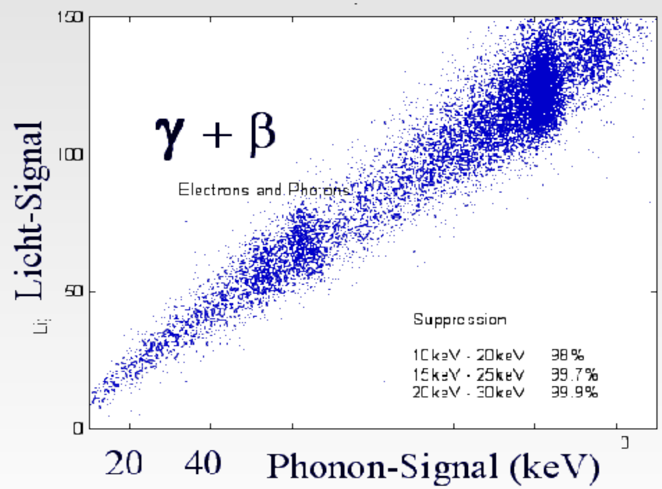
CRESST: Phonon + Light

CRESST II - Detectors

simultaneous Light and Phonon







CRESST
Cryogenic Rare Event Search with Superconducting Thermometers

Max-Planck-Institut München, TU München
Universität Tübingen, Oxford University, Gran Sasso

CRESST

Cryogenic Rare Event Search with Superconducting Thermometers

Max-Planck-Institut für Physik

University of Oxford

Technische Universität München

Laboratori Nazionali del Gran Sasso

Universität Tübingen

Cryogenic Dark Matter search

Located in Hall A of LNGS

Scintillating $CaWO_4$ target crystals

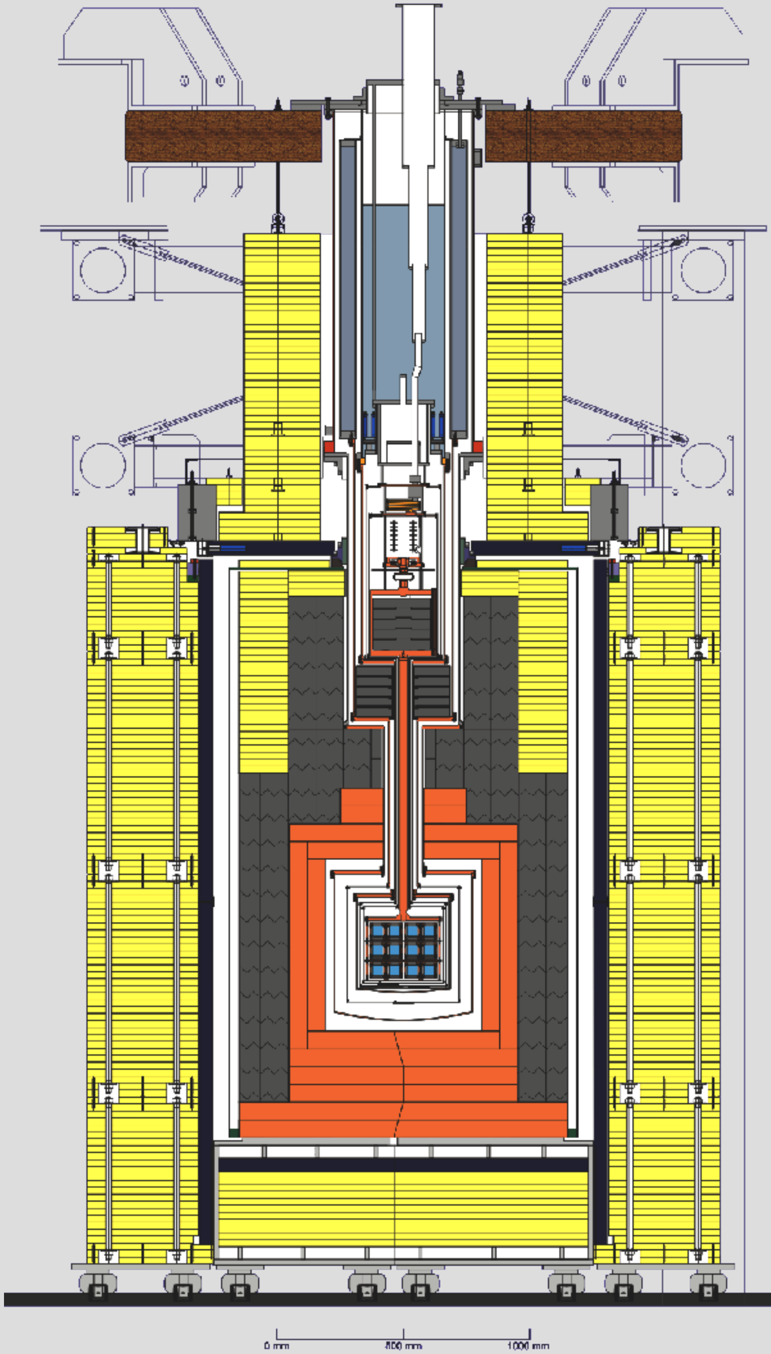
Up to 33 crystals in modular structure (10 kg target mass)

Different materials possible

CRESST set-up at LNGS

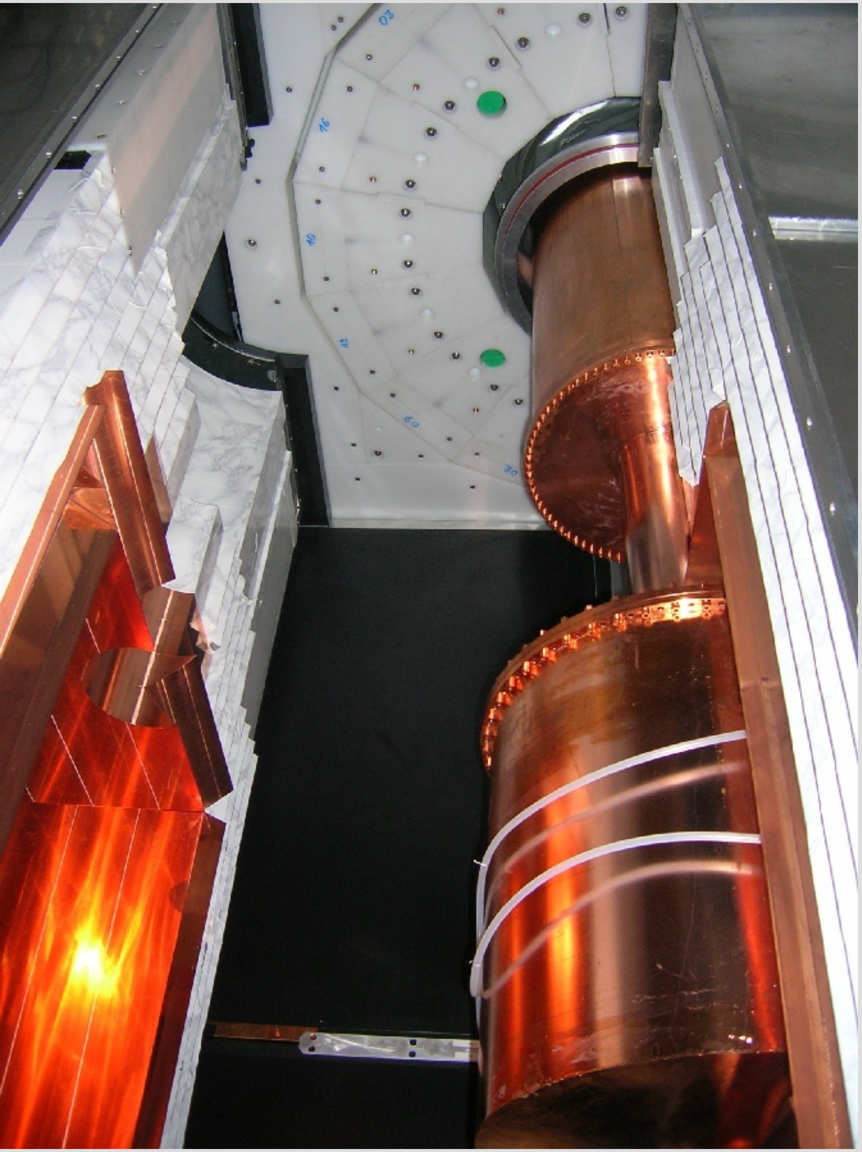
shielding:

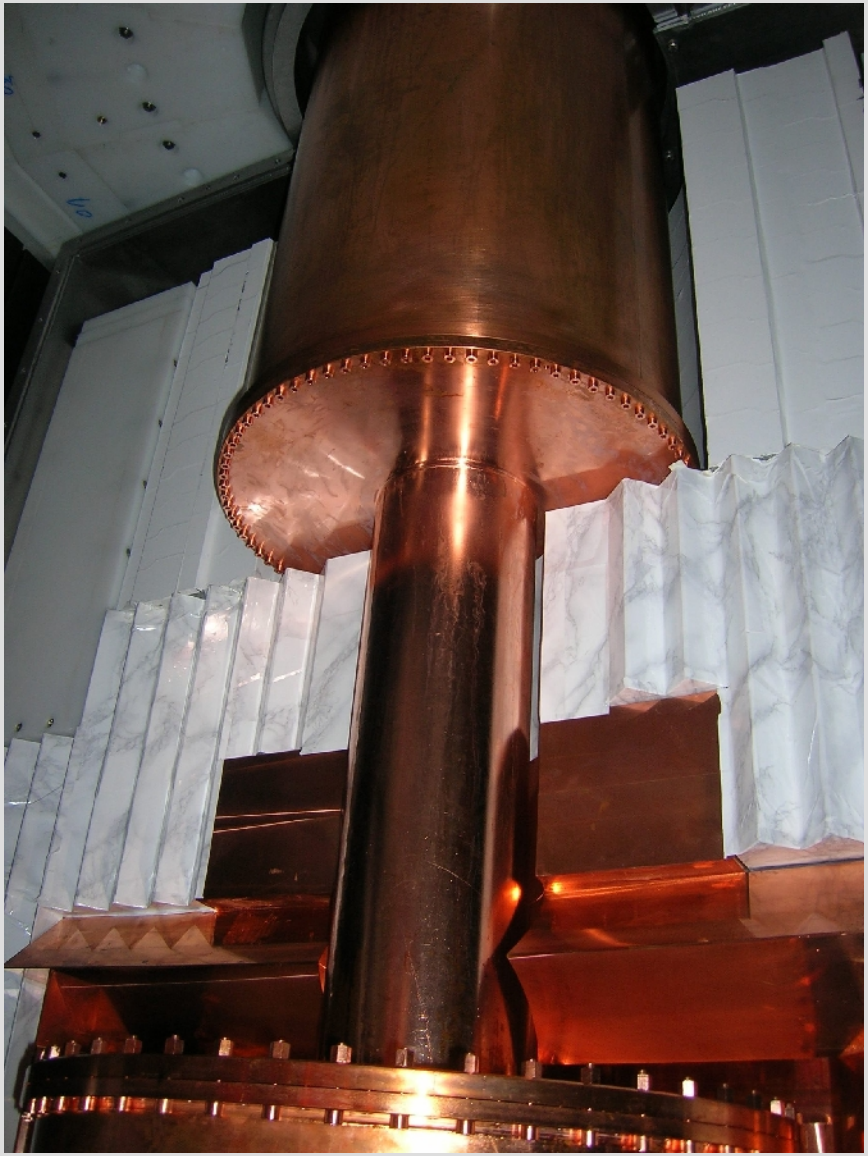
- underground laboratory
- 45 cm PE (12 tons)
- muon-veto
- radon box
- 20 cm lead (24 tons)
- 14 cm copper (10 tons)
- use only radio-pure materials



Coldbox closed

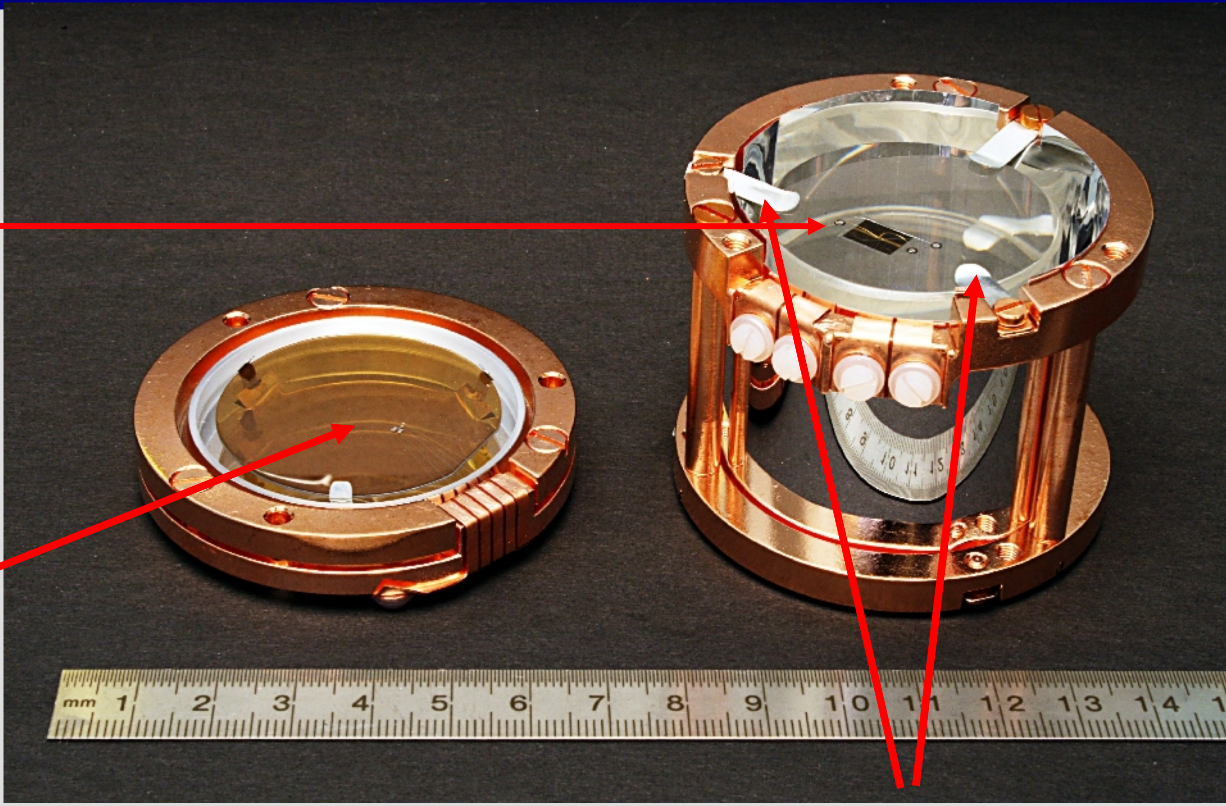
Half Cu/Pb schield closed

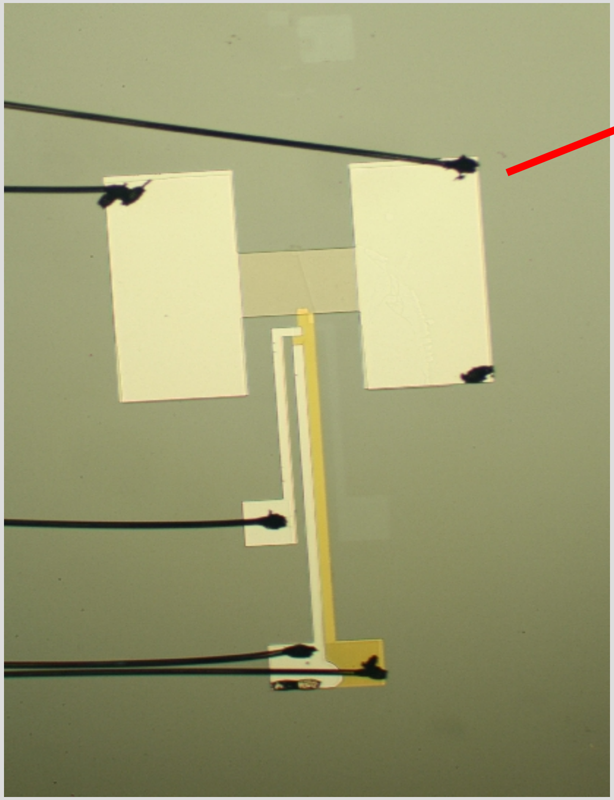




300 g CRESST-II Detector Module

The phonon detector:
300 g cylindrical $CaWO_4$ crystal. Evaporated tungsten thermometer with attached heater.





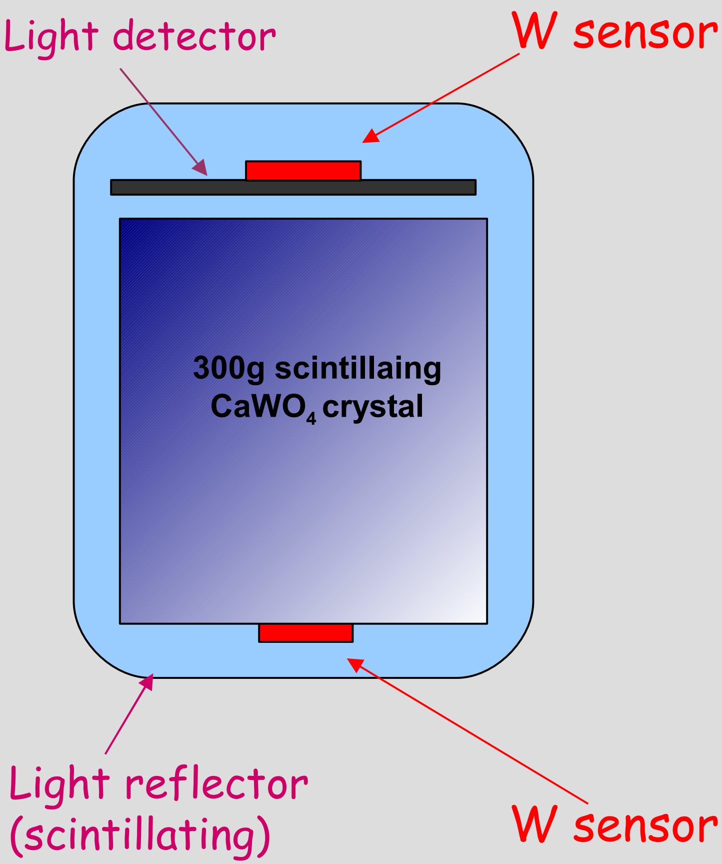
Clamps not scintillating

The light detector:
Ø=40 mm silicon on sapphire wafer.
Tungsten thermometer with attached aluminum phonon collectors and thermal link.
Part of thermal link used as heater

CRESST-II: up to 33 detector modules

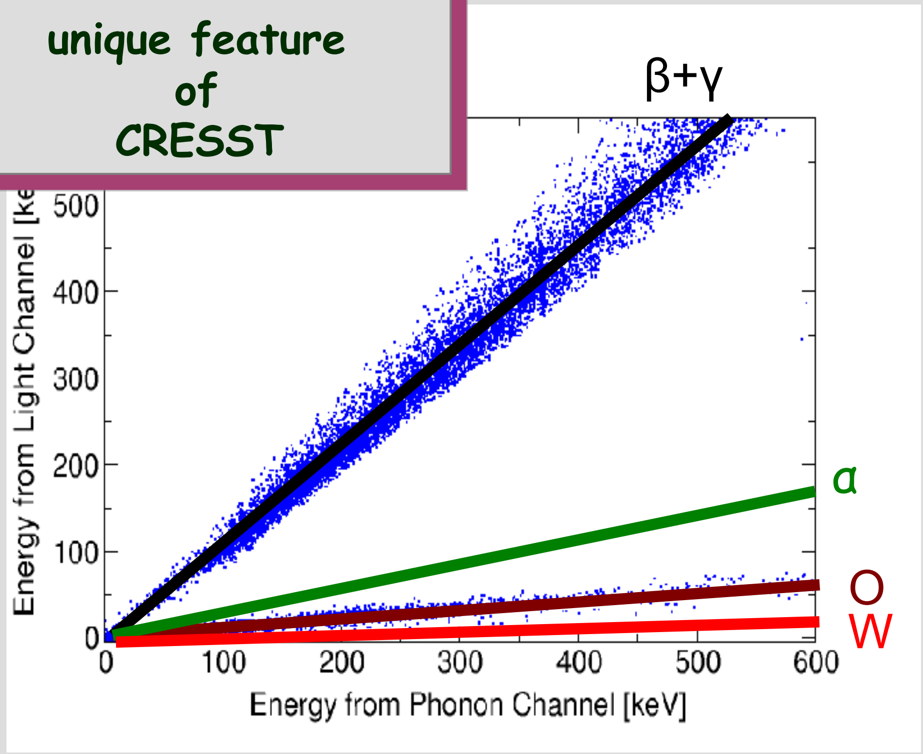
CRESST-II Detectors

Discrimination of nuclear recoils from radioactive backgrounds by simultaneous measurement of phonons and scintillation light



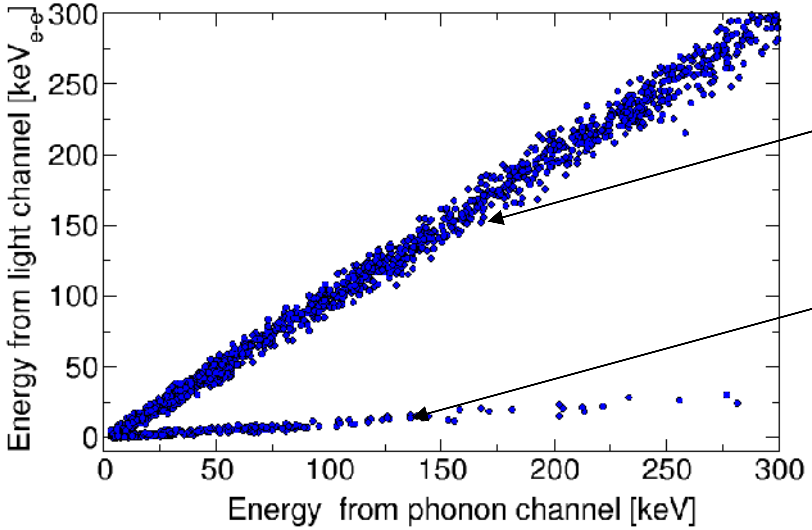
multi target

unique feature of CRESST



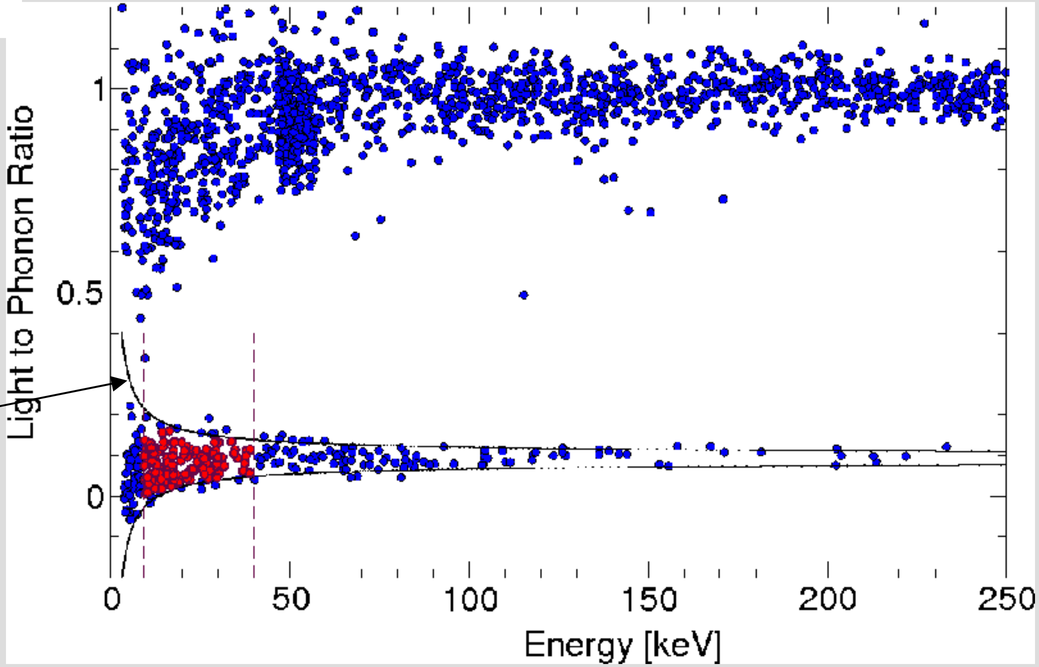
Identification of recoiling nucleus possible

neutron calibration



γ + β band

O-recoil-band



Lines calculated from e-resolution of light detector and known quenching factor

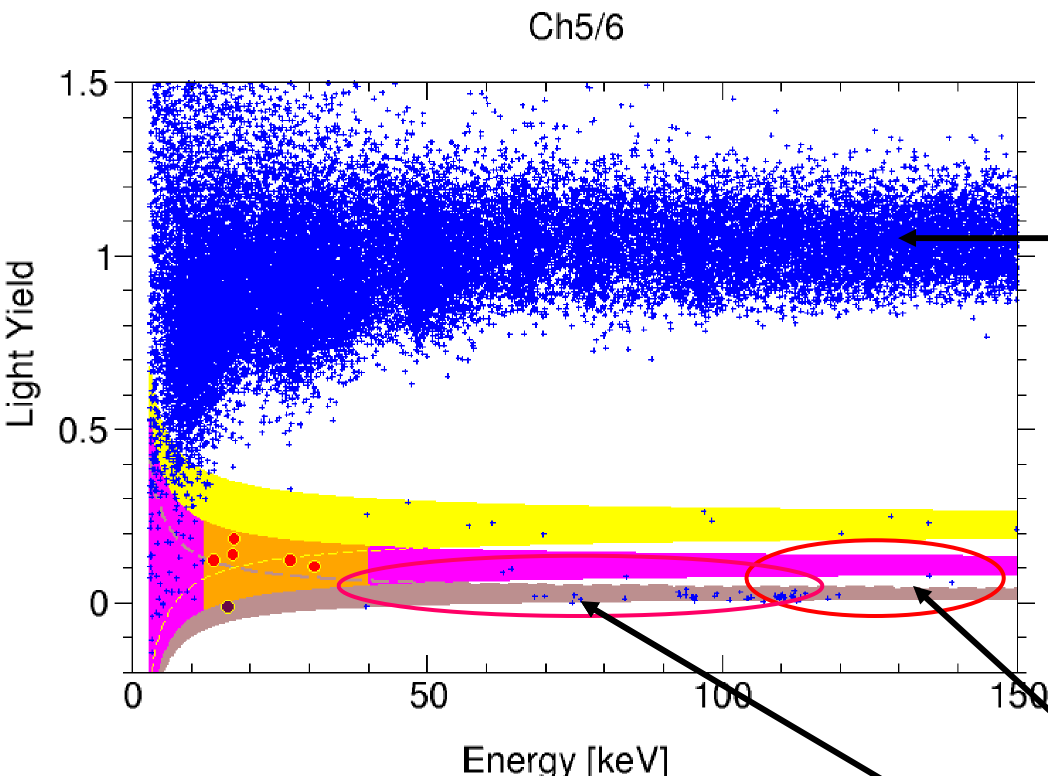
Excellent nuclear recoil discrimination

Present run

All results preliminary

- running since summer 2009
- 10 detectors running (1 $ZnWO_4$)
- Clamps not covered with scintillator
- data analysis is still in progress
- Data discussed are from 9 $CaWO_4$ detectors (about 400 kgd)

Data

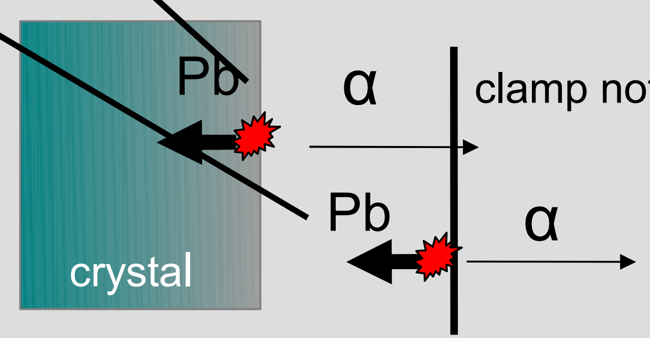


γ + β band

α band

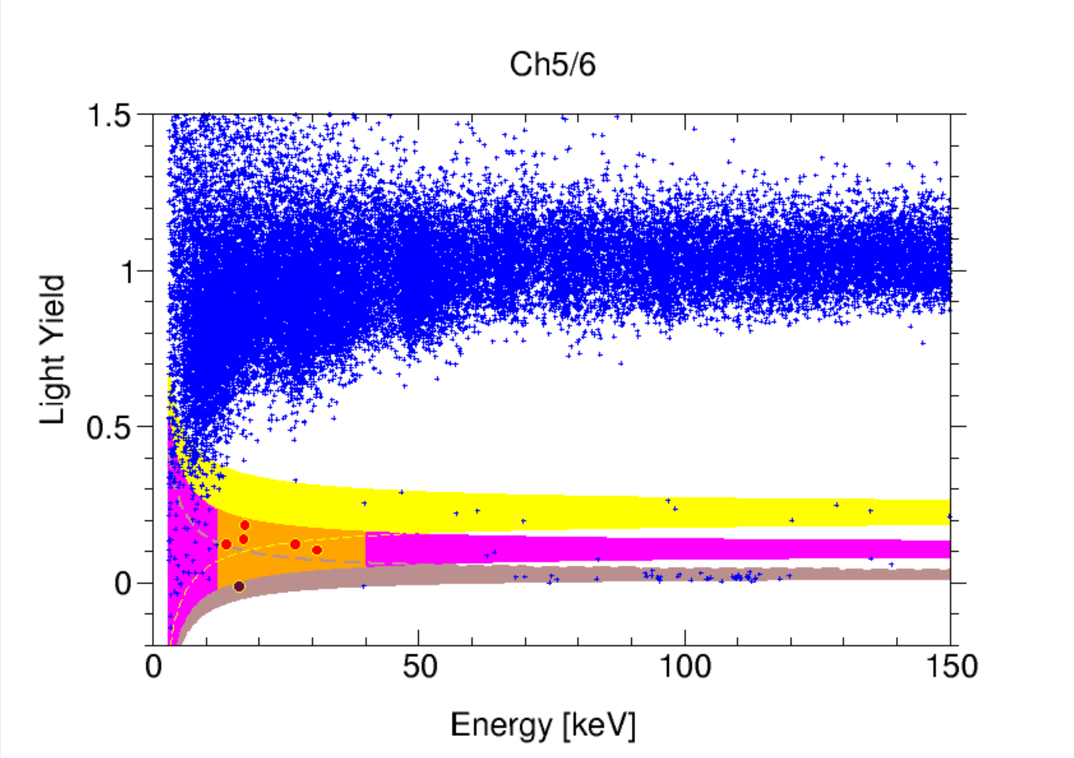
O-recoil-band < 10 GeV

W-recoil-band > 10 GeV



$^{210}Po \longrightarrow {}^{206}Pb$ (104 keV) + α (5.4 Me)

What are these events in O-band ?



Detector	E0.1[keV]	events
5	12.35	5
20	11.85	2
29	11.65	4
33	15.55	2
43	15.55	4
45	19.15	2
47	17.35	4
51	9.65	6
55	22.25	3
total		32

Try to estimate background

Check for coincidences

Neutrons ?

a leakage ?

Low mass WIMPs ?

Neutrons ?

No double coincidences

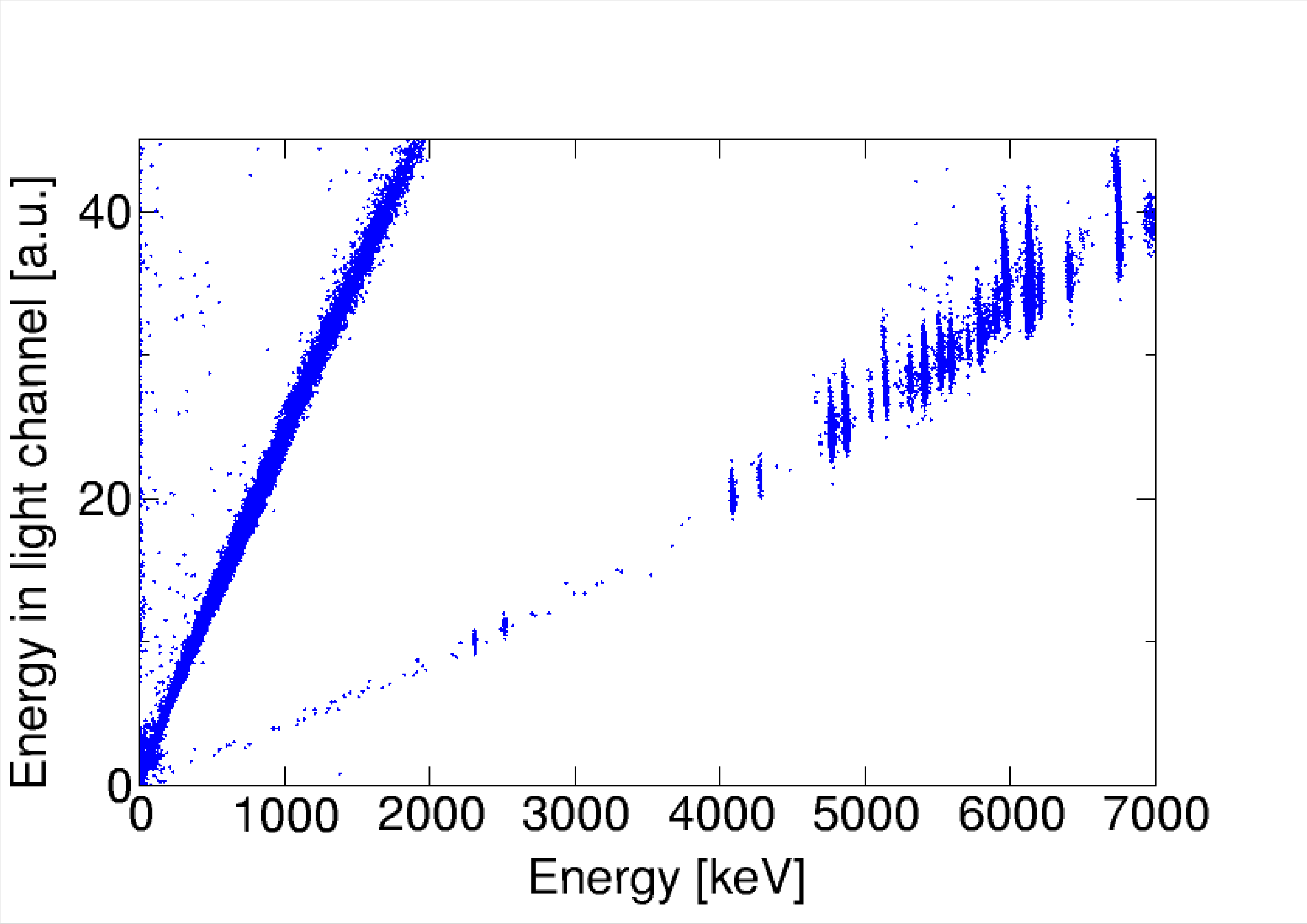
if neutrons (MeV neutrons from a source)
one would expect ~ (25-30)% double coincidences
between different detector modules

2 triple coincidences — Orecoil + Orecoil + 1.8MeV gamma
Orecoil + 30 KeV gamma + 1.18MeV gamma

~ 70% of muon induced neutrons are such coincidences with gammas
=> only ~ 3 out of the 32 events can be explained as muon induced

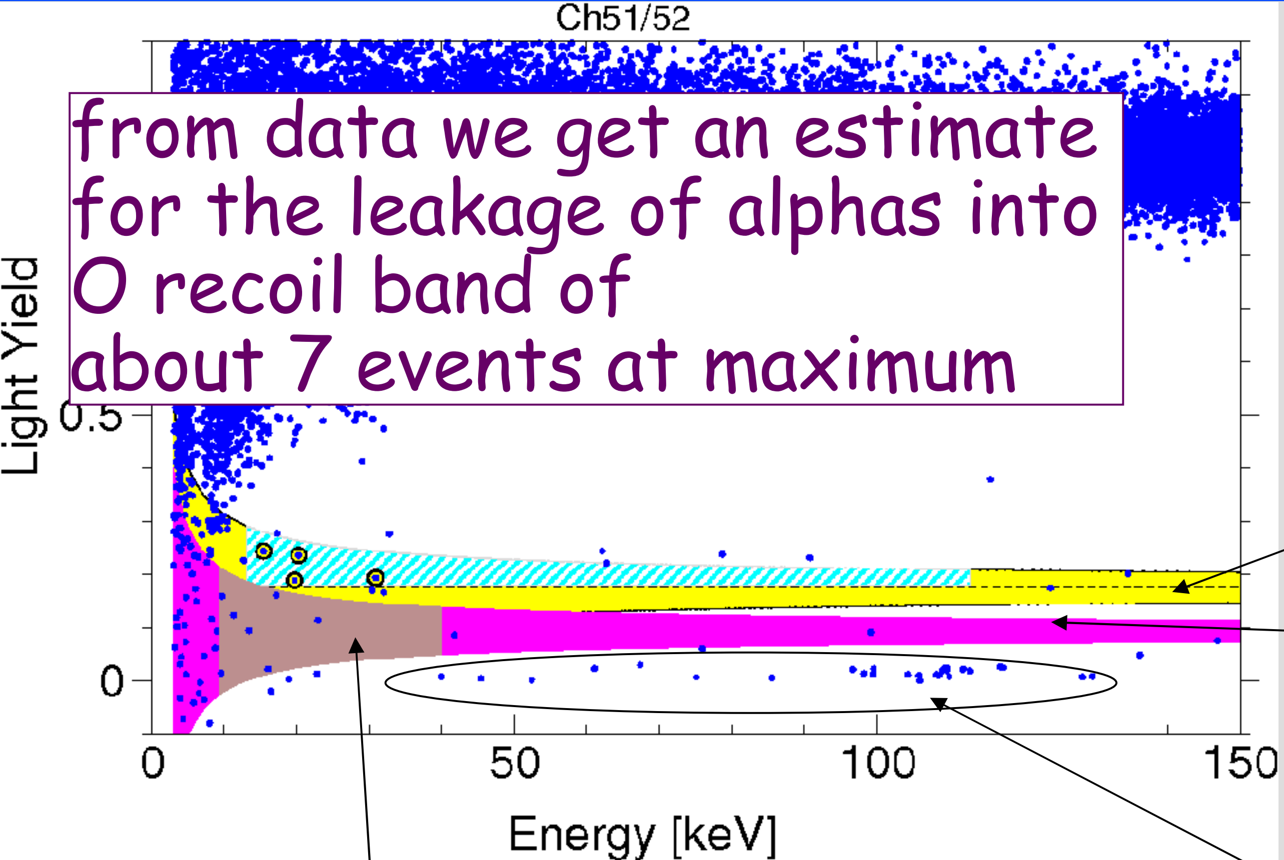
=> the events are NOT neutrons !

Degraded alphas from external contamination in clamps



- Discrete alpha lines from contamination in crystal are no problem
- Degraded alphas with continuous energy distribution down to lowest energies from external contamination in clamps

Estimation of a background in oxygen band



from data we get an estimate for the leakage of alphas into O recoil band of about 7 events at maximum

- Detector with highest external alpha background
- Also highest ^{206}Pb recoil background, with long tail extending from 100 keV down to 40 keV

- Background of degraded external a's from contaminated clamps.
- Oxygen and a band partially overlap and some a's may leak into signal band.
- Estimate dN/dE in overlap free region of alpha band and then compute expectation in oxygen band assuming constant dN/dE.

Conclusions

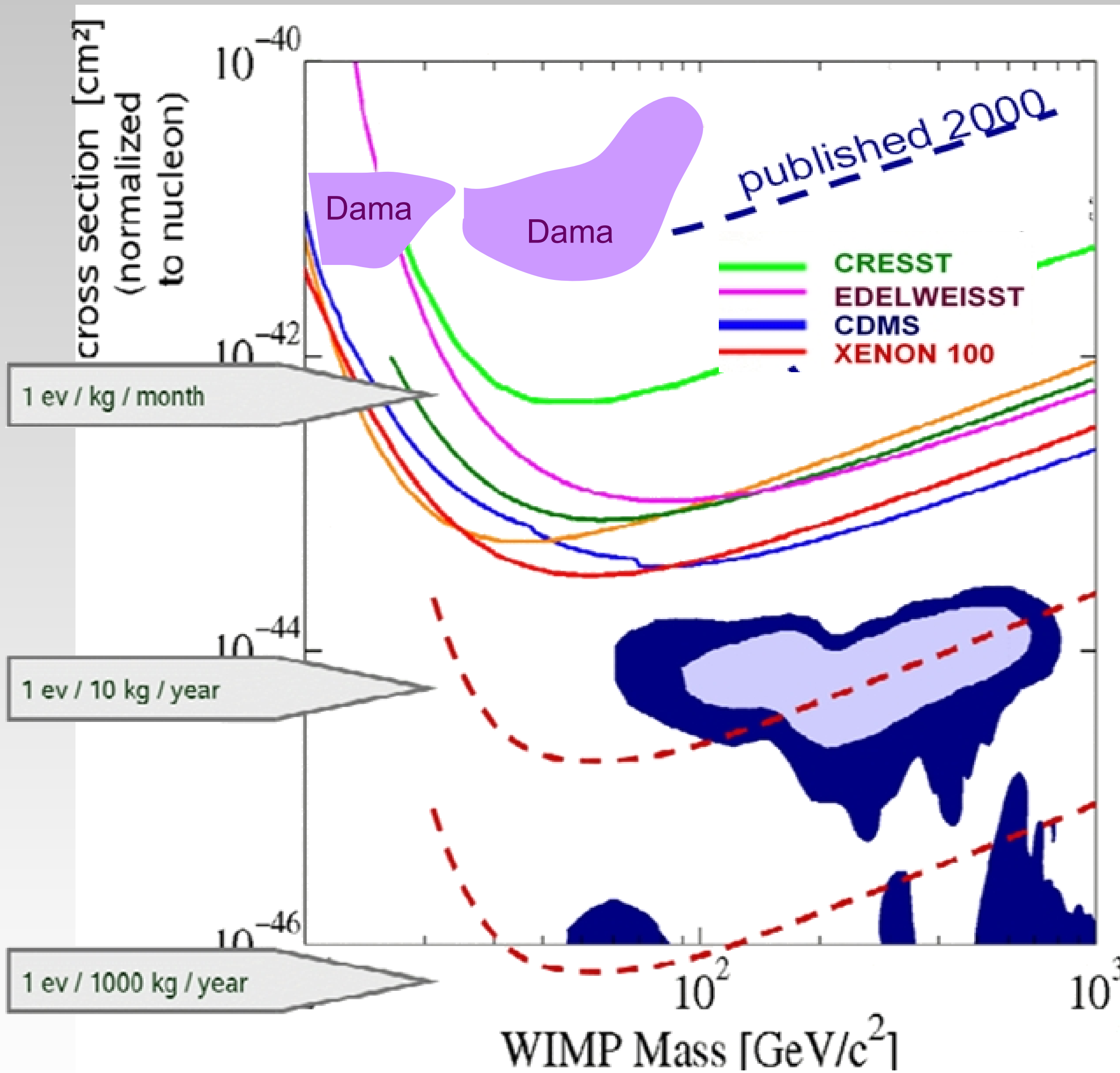
- CRESST detectors are very powerful and able to perform precision measurements
- Inelastic Dark Matter scenario becomes very unlikely to explain the DAMA result
- Neutron background is negligible and can not explain our signals in oxygen band
- Background from degraded alphas is less then observed signals in oxygen band, a precise estimate is difficult.
- presently no explanation for ~ 30 events on Oxygen recoil region could be light WIMPs or some 'strange' feature of alpha background
- a new run with strongly reduced alpha background is the next step. It should help to pin down the nature of the observed signals with high confidence.

Direct DM Searches - Future

presently:
results from
a few kg targets

coming year(s):
projects prepare / run
a few 10kg targets

where to go:
need in future
ton scale targets



Cryogenic Dark Matter Searches in Europe

CRESST

***TU Munich, MPI Munich,
Tübingen,
Oxford, Gran Sasso***

- phonon-light
- W, Zn, Ca, O
- LNGS - Gran Sa

- 3kg fiducial runn
- goal: 15 kg nxt 2

  *with diff.targets
  in same setup*

EDELWEISS

***Saclay, Orsay, Lyon,
Grenoble, Dubna, Oxford
KIT Karlsruhe***

on-charge

\- Modane

ducial running
6 kg fid. in 2010
0 kg fid. end 2011

EURECA

*TU Munich, MPI Munich,
KIT Karlsruhe,
Uni Tübingen,
Oxford, Sheffield,
Saclay, Orsay, Grenoble,
Lyon, Dubna, Kiev,
Zaragoza*

- phonon-charge/light
- Ge, W, Zn, Ca, O
- LSM

goal: 1000kg 2015-2018

EURECA

Germany, France, UK,
Spain, Russia, Ukraine

combines all European cryogenic DM efforts:

R&D cooperation with CDMS/GeoDM

2009/10: design study => TDR

2011/12: LSM excavation
+ construction EURECA components
~ 100 kg fiducal target at present sites,
~ 10^{-45} cm^2

2013/14: construction at LSM

2015: begin data taking at LSM

2015 – 2018:

- continuous upgrade to 1t target
- ~ 10^{-46}cm^2