MPI Project Review 2007

CRESST

Cryogenic Rare Event Search
with Superconducting Thermometers

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CRESST is a collaboration of the Max-Planck-Institut
für Physik, Technische Universität München,
University of Oxford and Universität Tübingen,
hosted by the Laboratori Nazionali del Gran Sasso

Overview

1. Principles
2. Gran Sasso Status
3. Light Detector
4. Inductive Measurements
5. Gluing Technique
6. New Materials
7. Summary & Outlook

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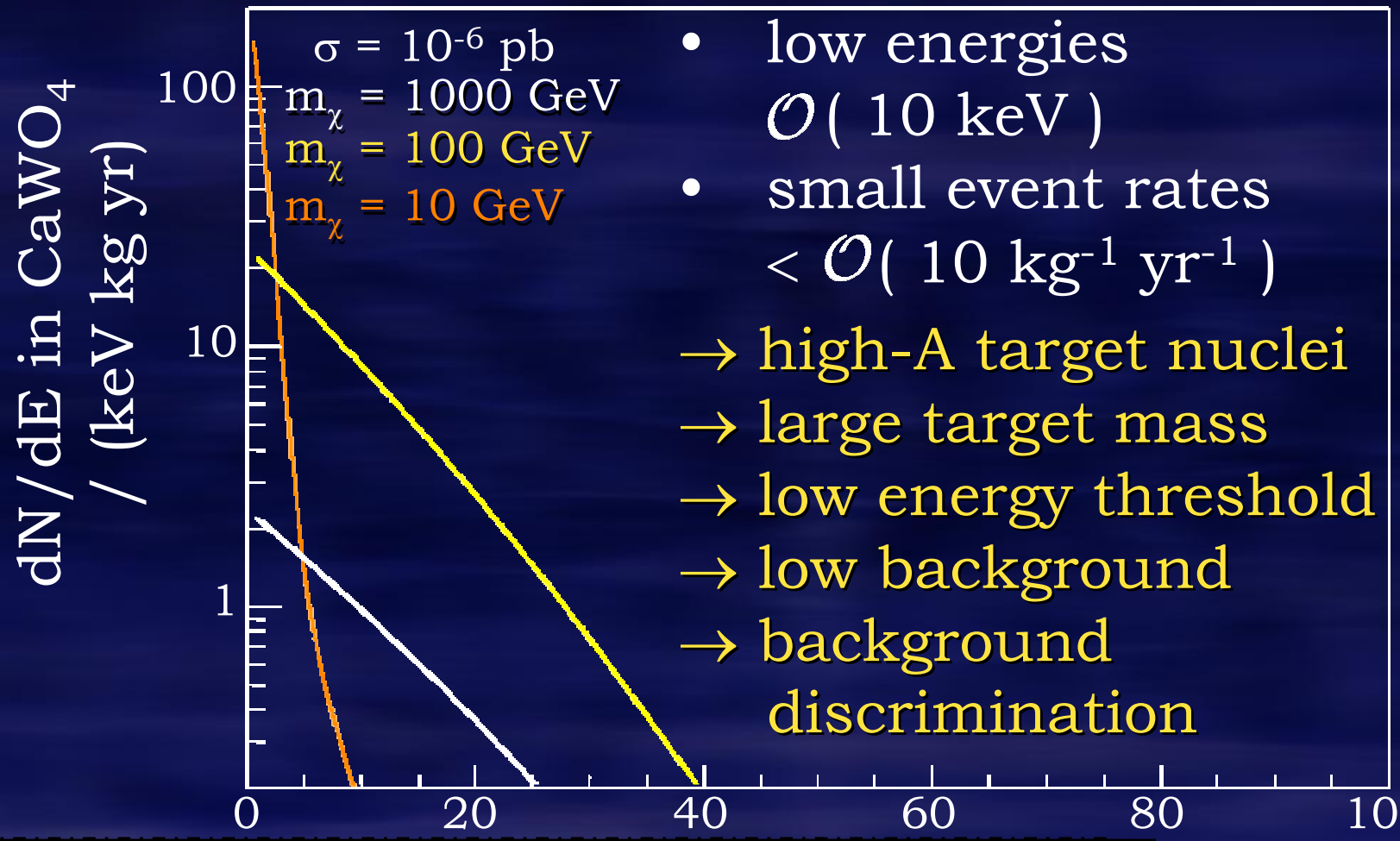
Expected WIMP Spectrum

- isothermal halo
- coherent scattering $\propto A^2$
- v_{earth} ~ 240 km/s
- Helm form factor



- low energies
  $\mathcal{O}$(10 keV)
- small event rates
  < $\mathcal{O}$(10 kg^{-1} yr^{-1})

→ high-A target nuclei
→ large target mass
→ low energy threshold
→ low background
→ background discrimination

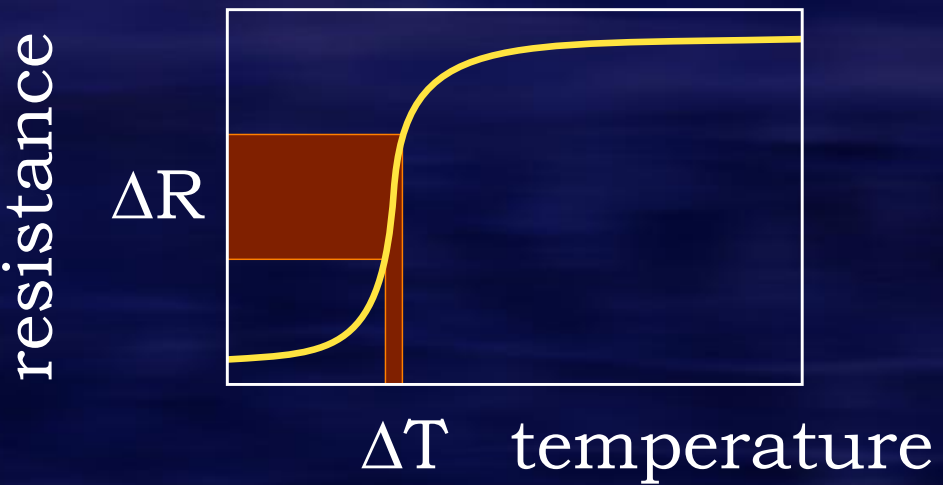
Target Mass & Material

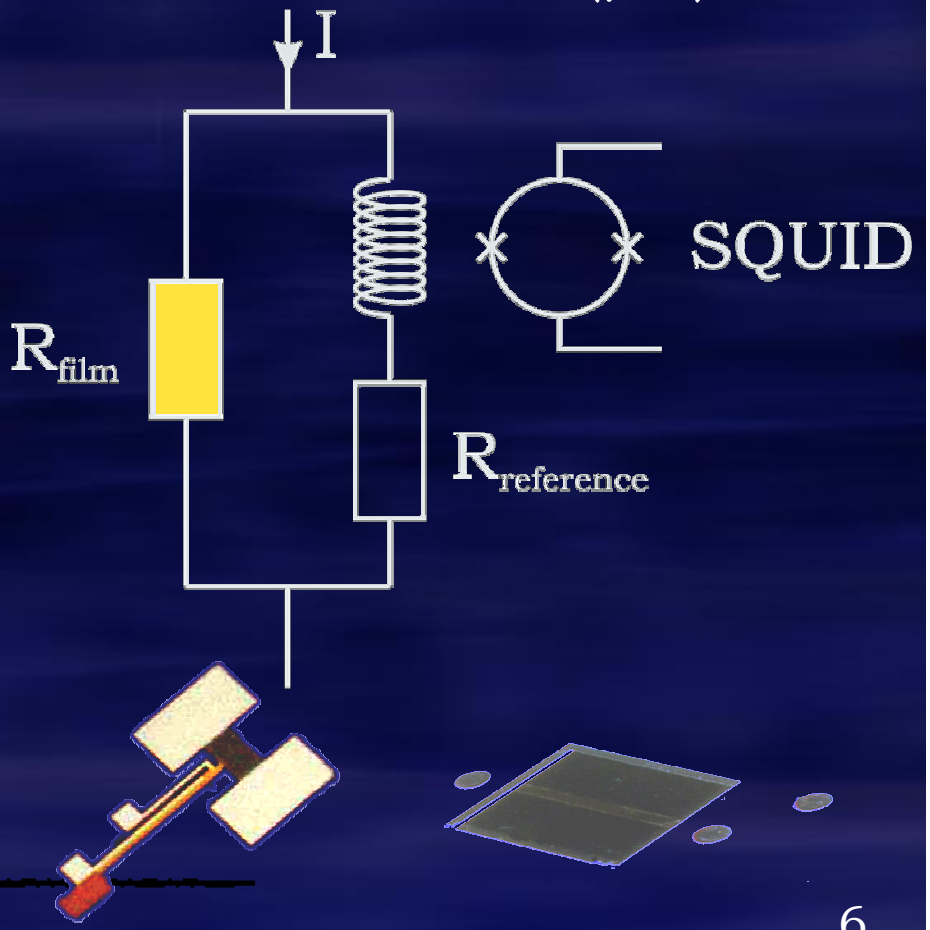
- tungsten in $CaWO_4$ (A=184)
- modular structure
- up to 33 modules
- 10 kg target mass
- multi-target possible

$CaWO_4$, h=40mm ∅=40mm m=300g

Detecting Low Energies

- measure phonons
  $^3He/^4He$ dilution cryostat for T ≈ 10 mK ($c \propto T^3$)
- phase transition thermometer, stabilization $\mathcal{O}$(μK)

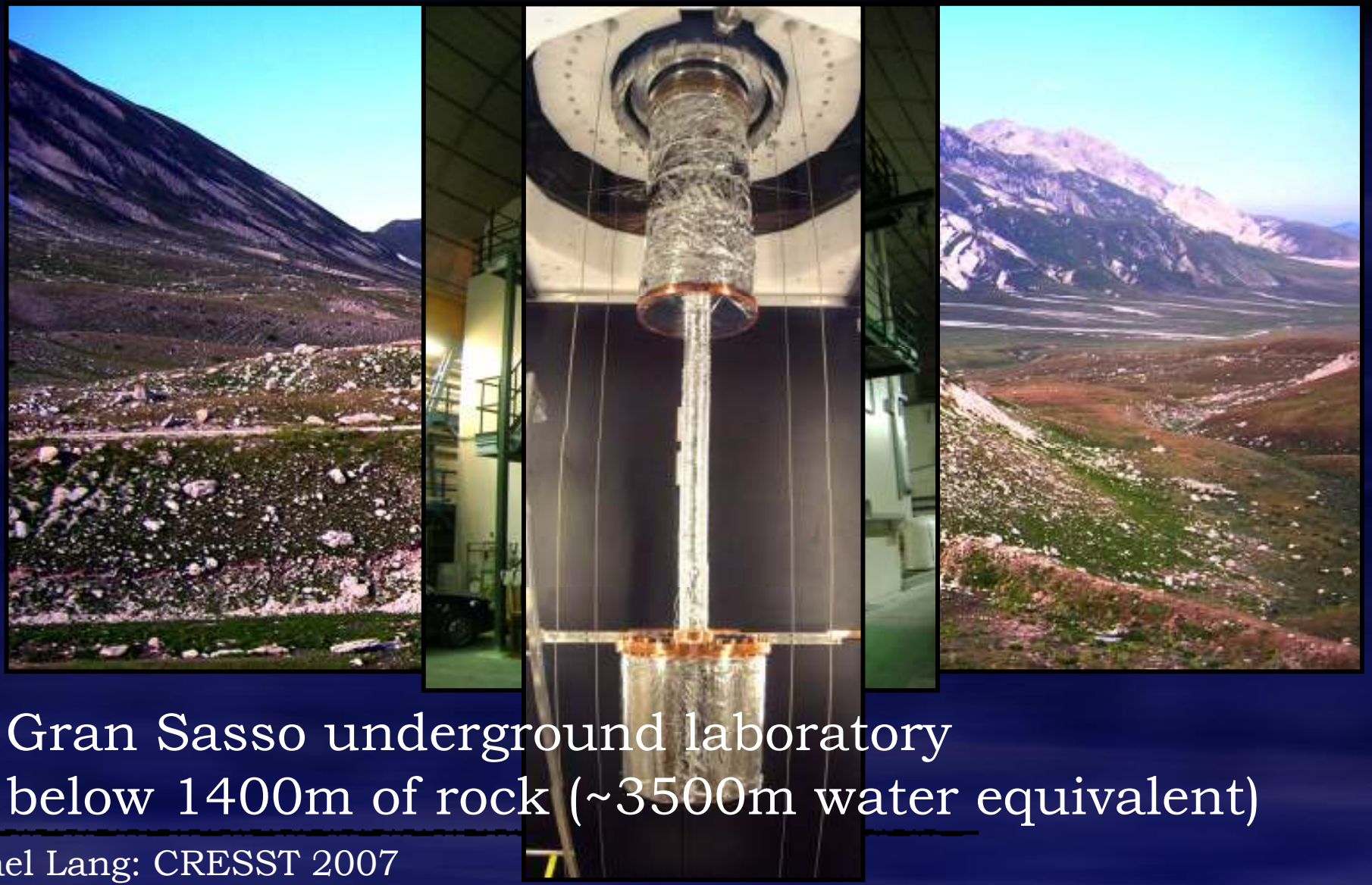




- SQUID-based amplification
- $E_{threshold}$ < 1keV
  noise FWHM 300eV

Background Shielding

- go to underground laboratory:



Gran Sasso underground laboratory
below 1400m of rock (~3500m water equivalent)

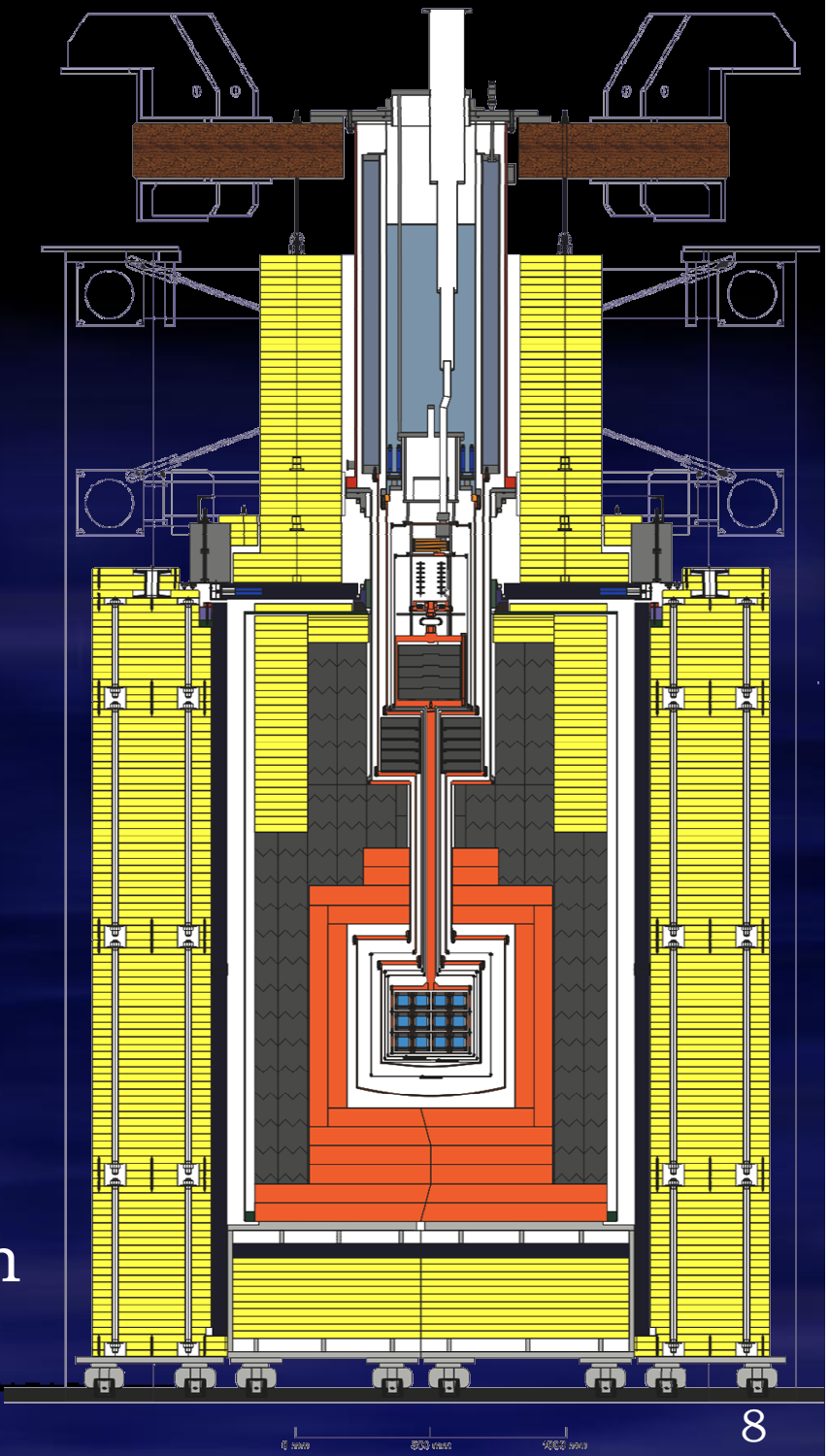
Passive Shielding

passive shielding:

- go to 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

good is not good enough!

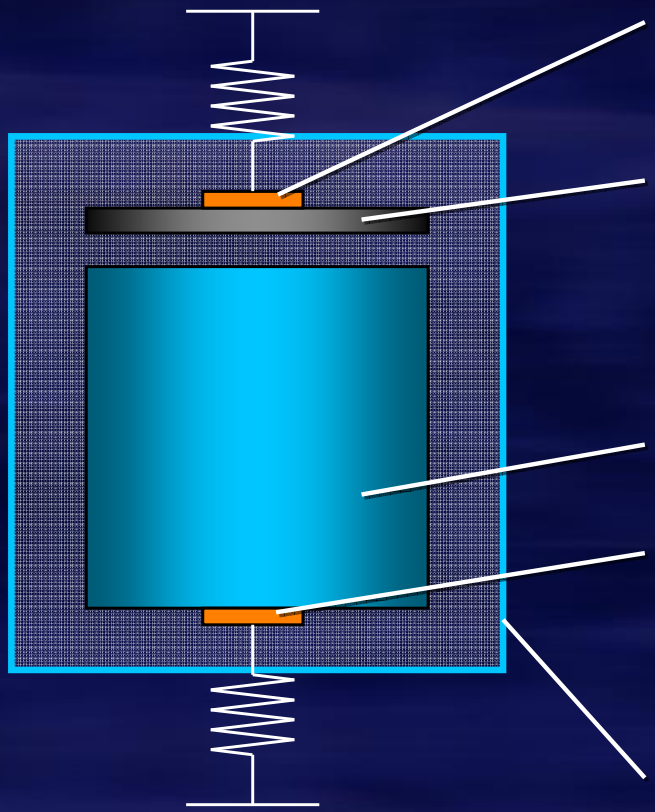
$\mathcal{O}$(1000 events/kg/day) still remain

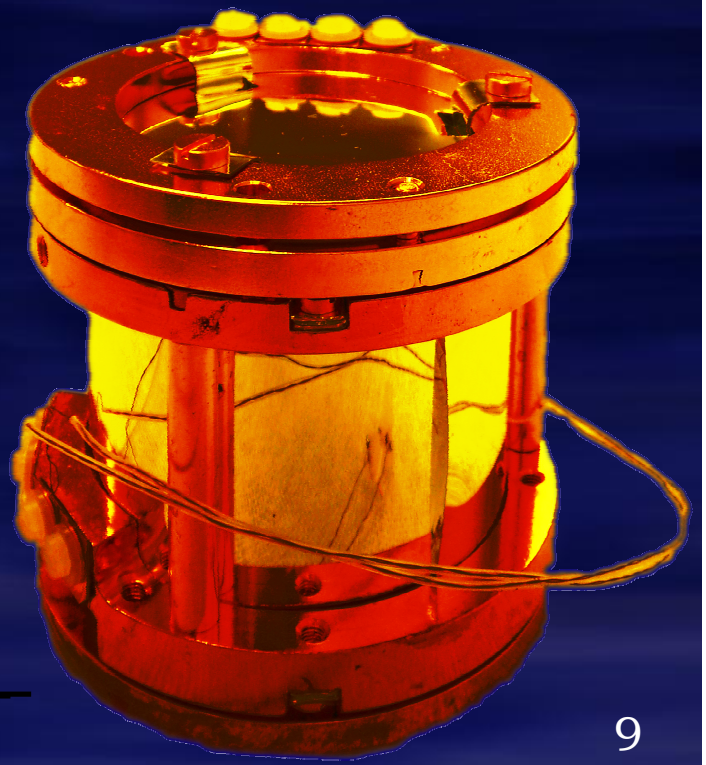


Active Background Discrimination

active discrimination between signal and background:

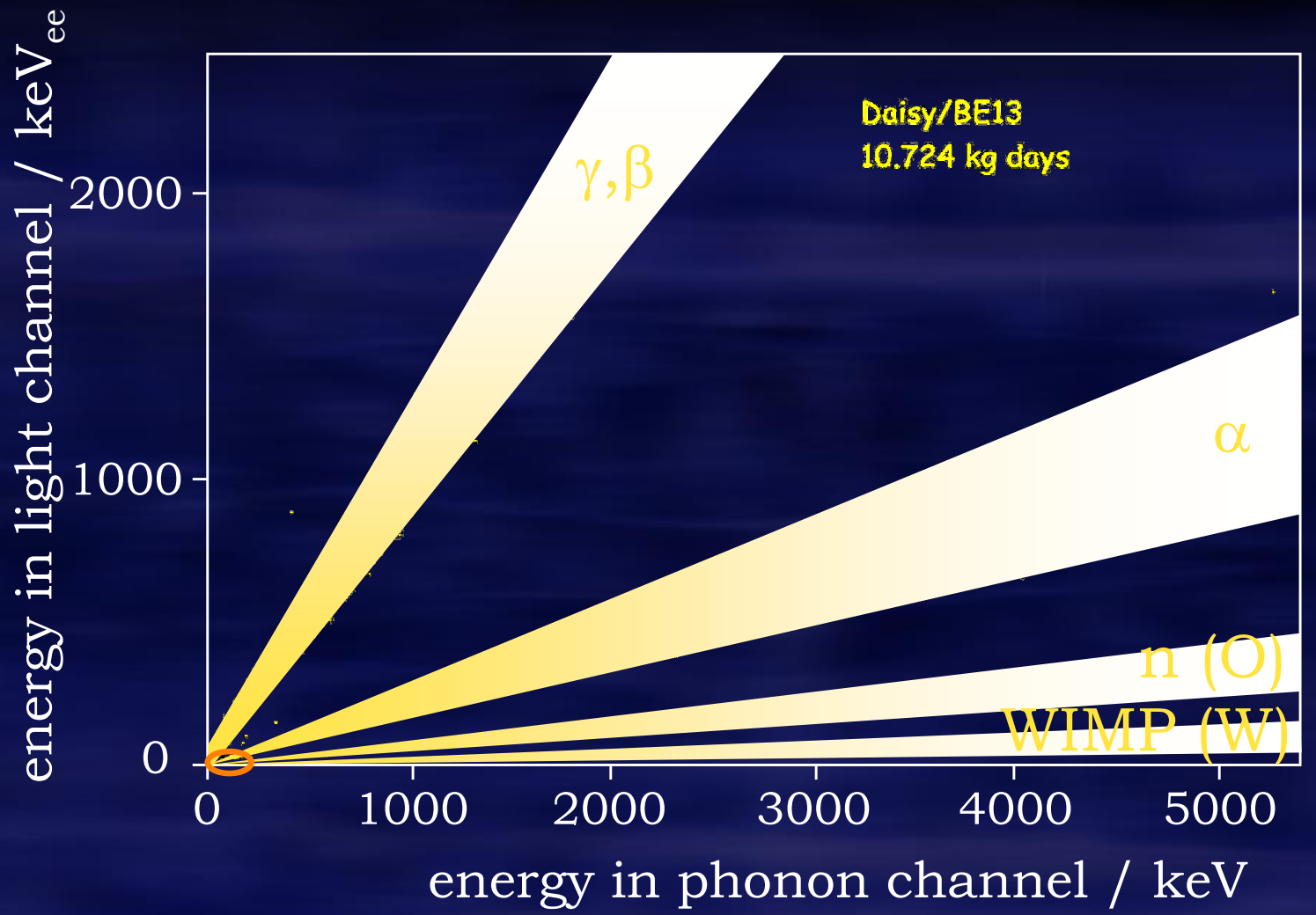
- scintillating crystals





Signal Regions

event-by-event separation !



slope

1 (def.)

1/5

1/10

1/40

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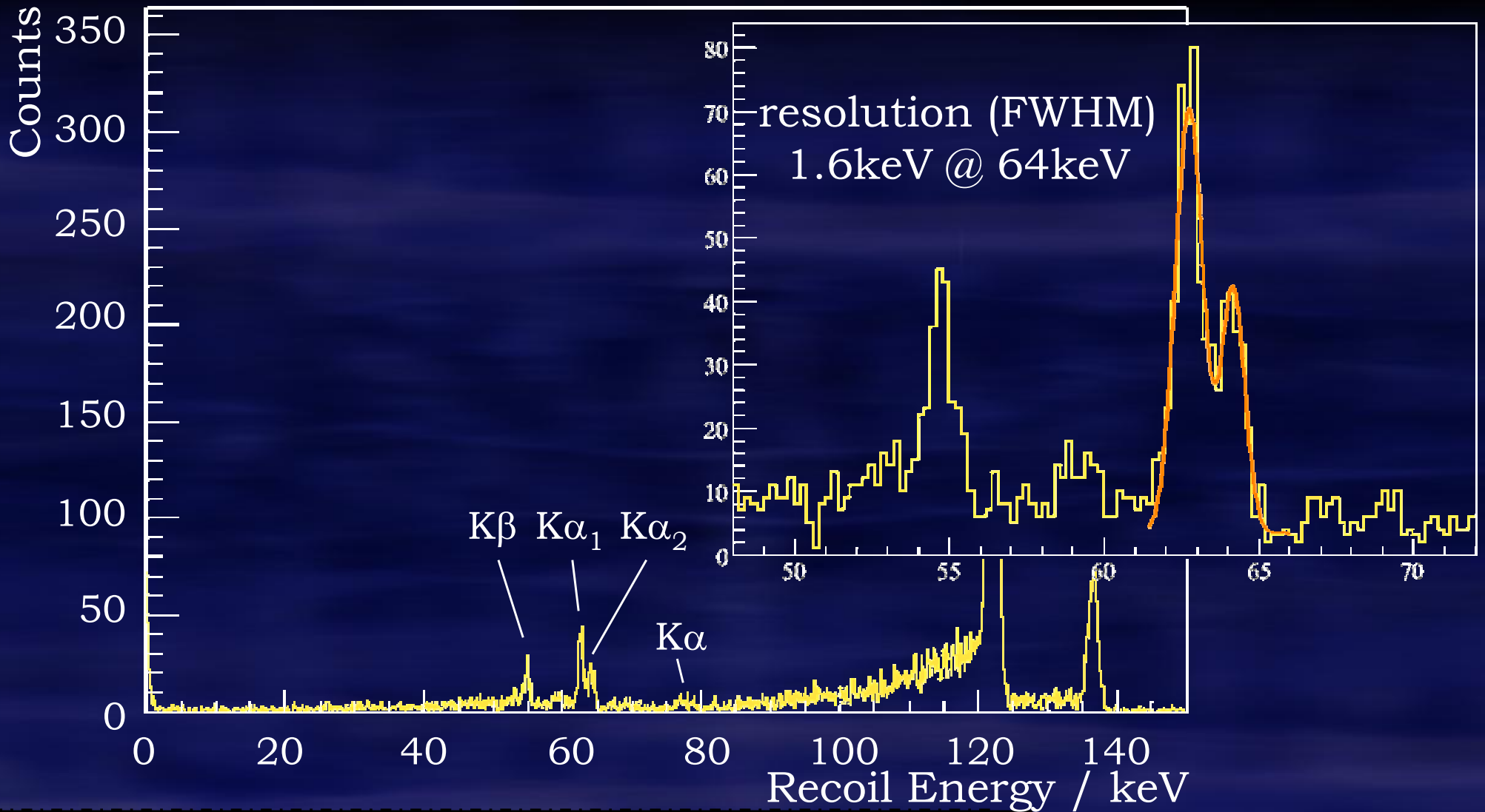
Since October '06

after major upgrade

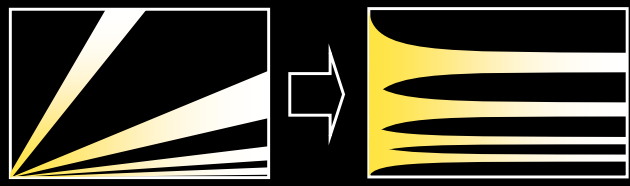
- 9 modules placed
- cryostat cooled down
- 4 months commissioning ("Run 29")
- 2-3 modules operational
- background "Run 30"
- ^{57}Co-calilbrations
- Neutron-Calibration

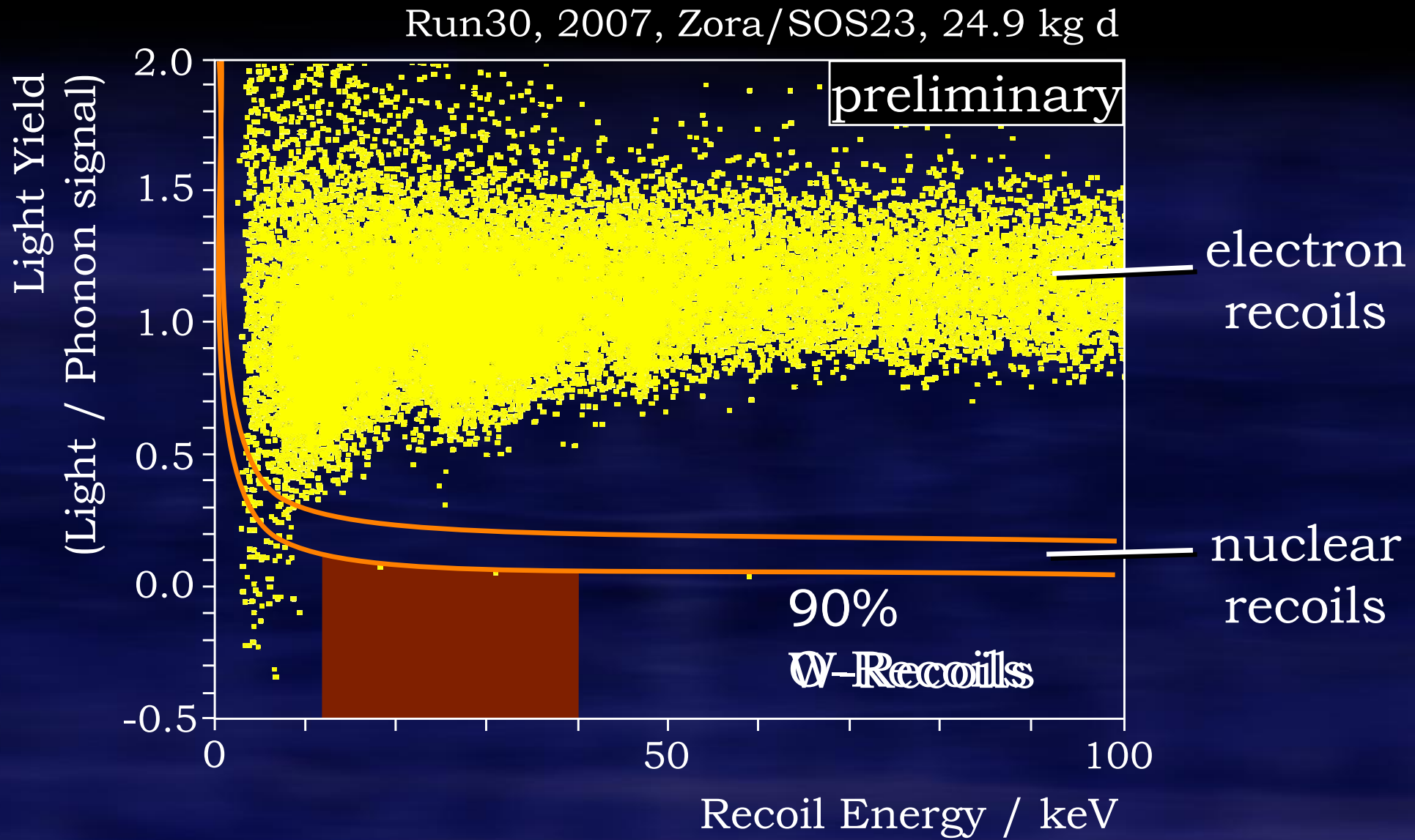
A Spectrum…

^{57}Co-Calibration of Phonon-Detector Verena

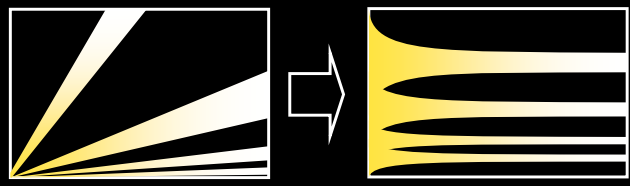


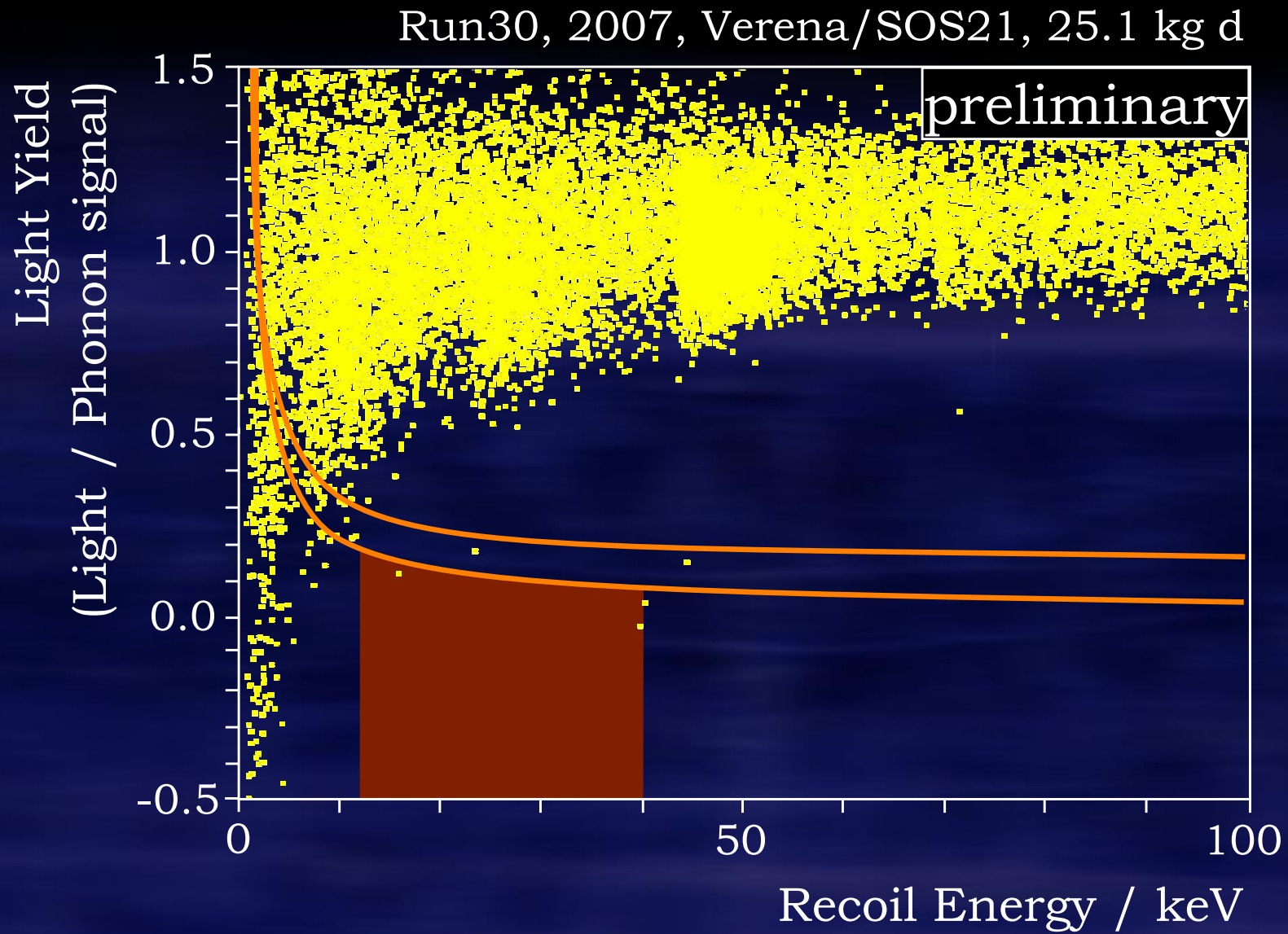
Acceptance Region



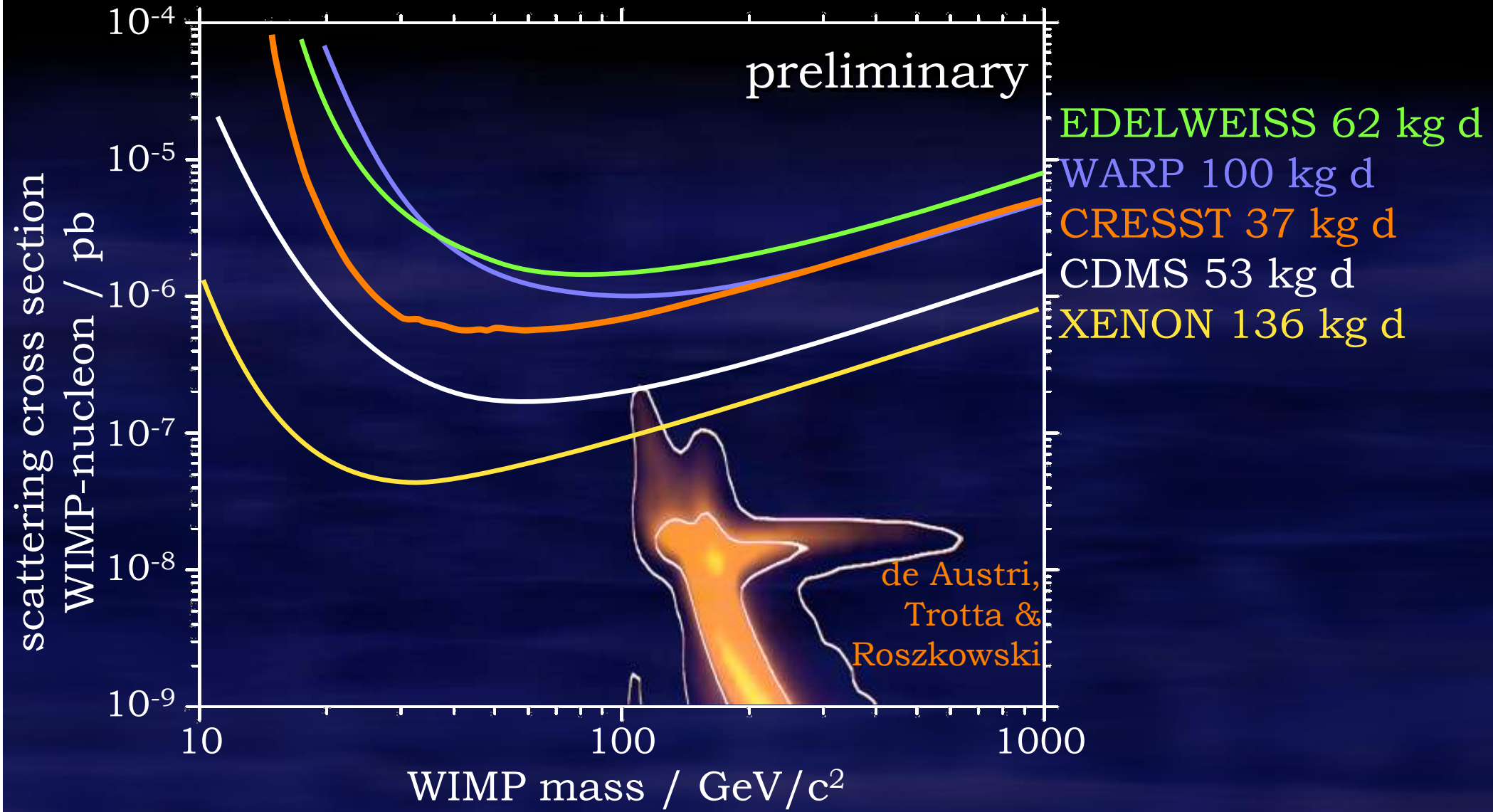


Acceptance Region



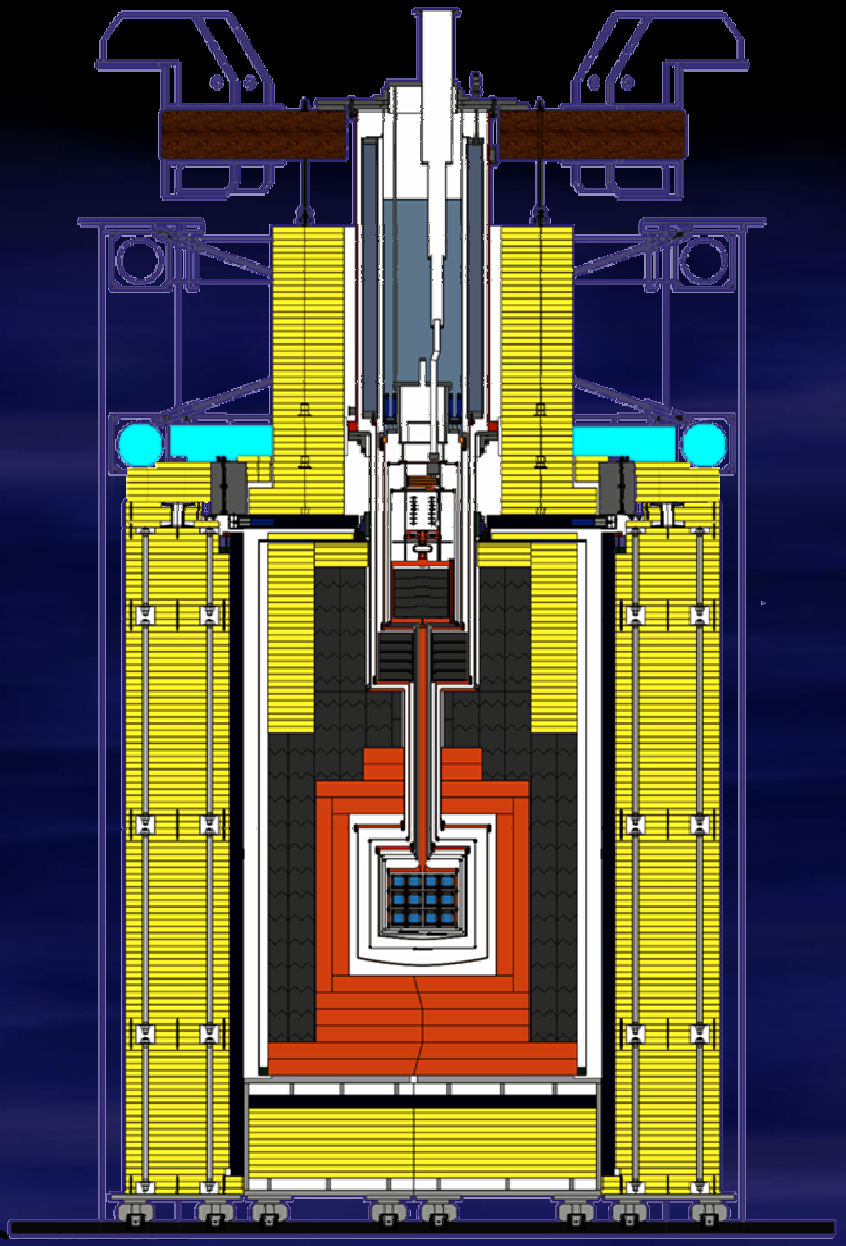


Limits…


preliminary
EDELWEISS 62 kg d
WARP 100 kg d
CRESST 37 kg d
CDMS 53 kg d
XENON 136 kg d
de Austri, Trotta & Roszkowski
scattering cross section WIMP-nucleon / pb
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10
100
1000
WIMP mass / GeV/c^2

Reducing Background

- patch neutron shielding



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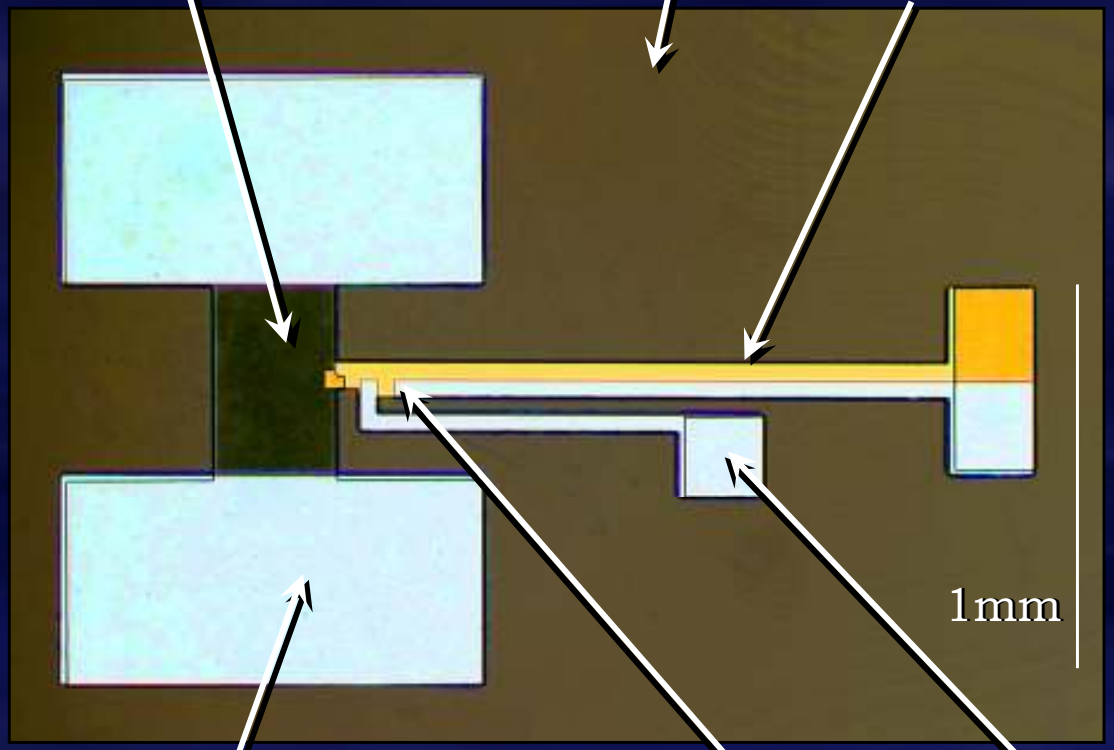
Light Detector Design

W SPT
0.45 x 0.3 mm^2
d=200nm

Silicon-On-Sapphire waver
0.46mm Al_2O_3, 1µm Si

Au thermal link



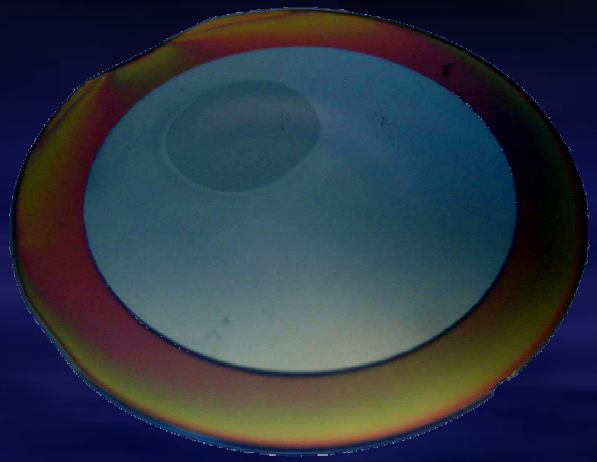
Al phonon collectors
1 x 0.5 mm^2

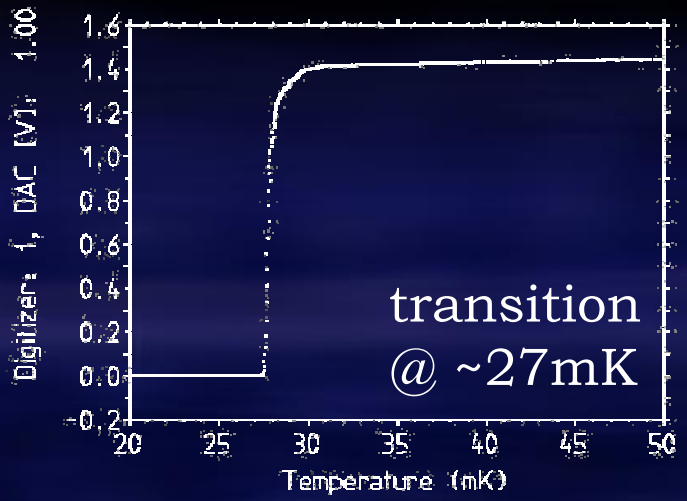
Au heater

Al contacts

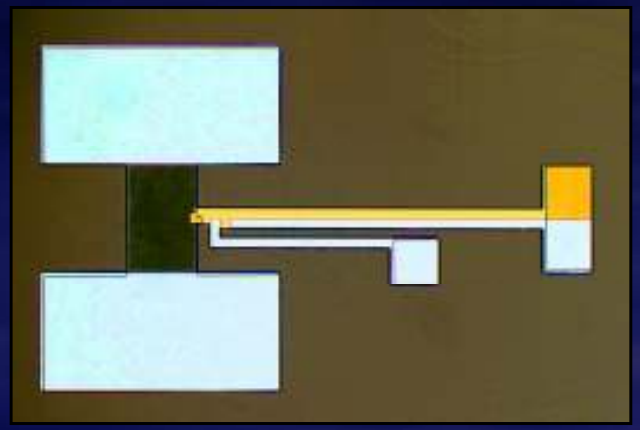
The Problem…

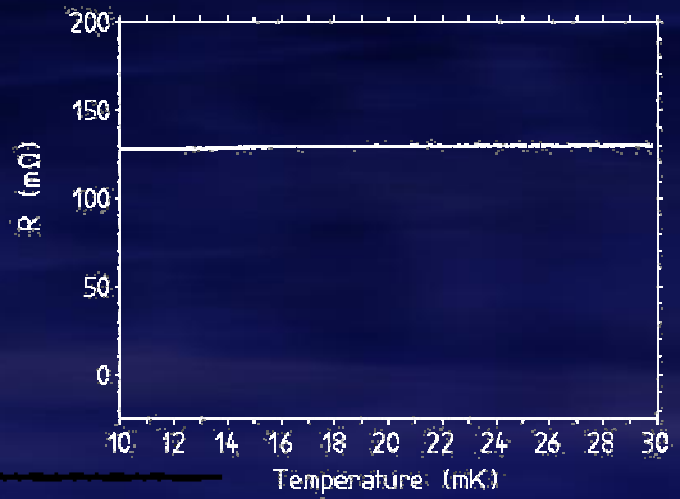
full, unstructured films show transitions



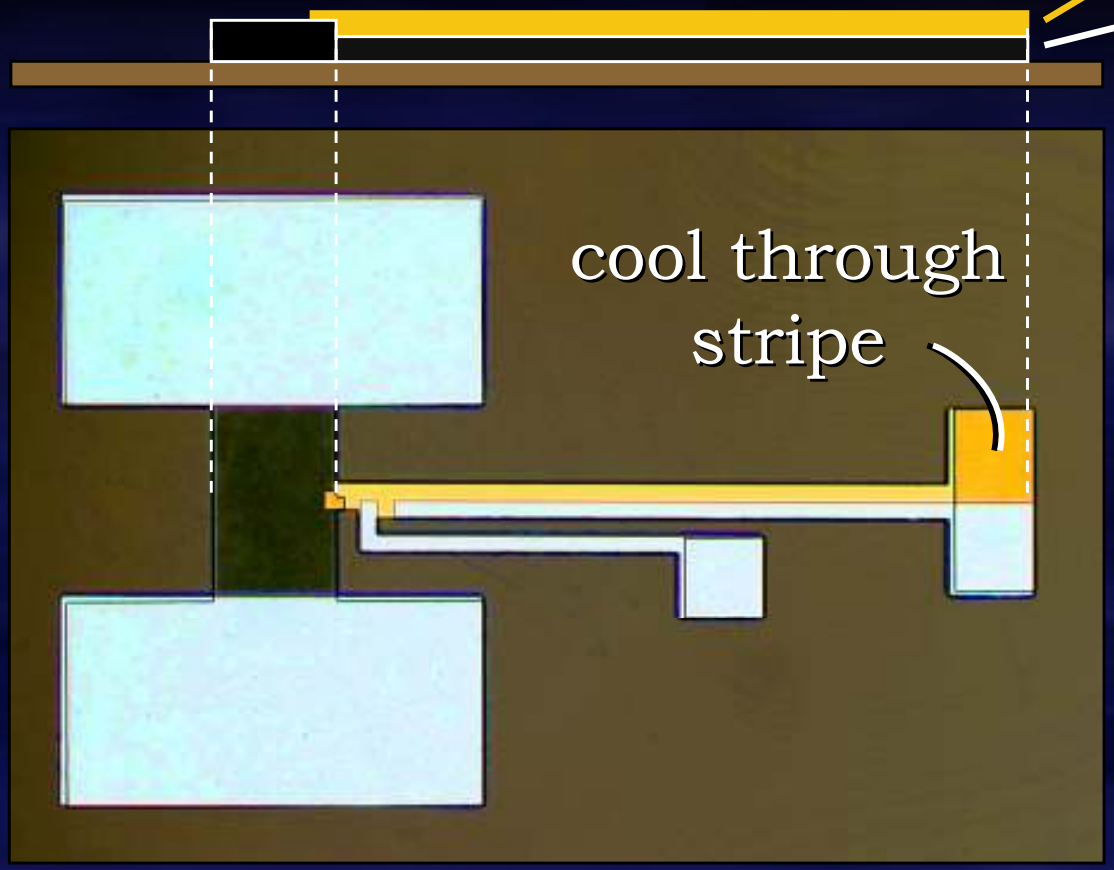


but many structured light detectors do not

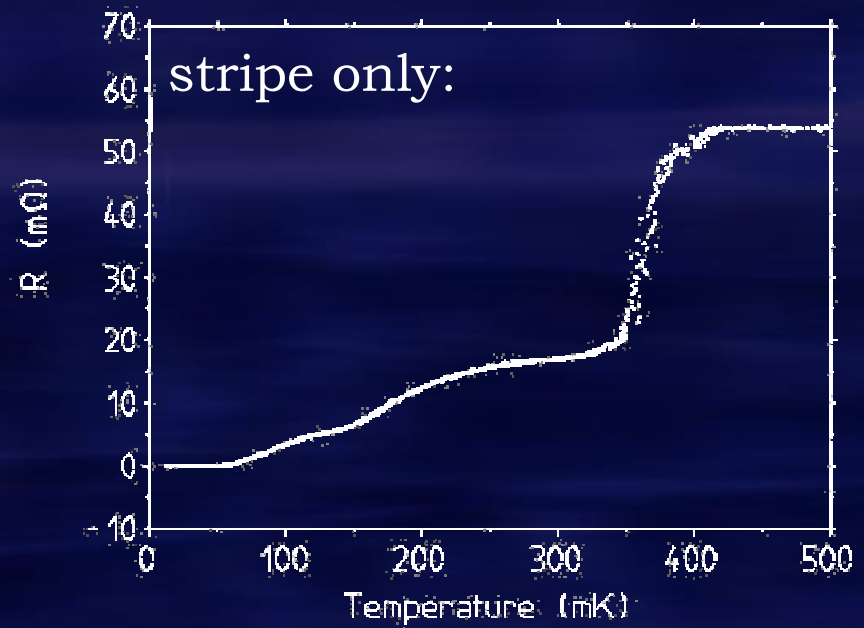




…The Solution



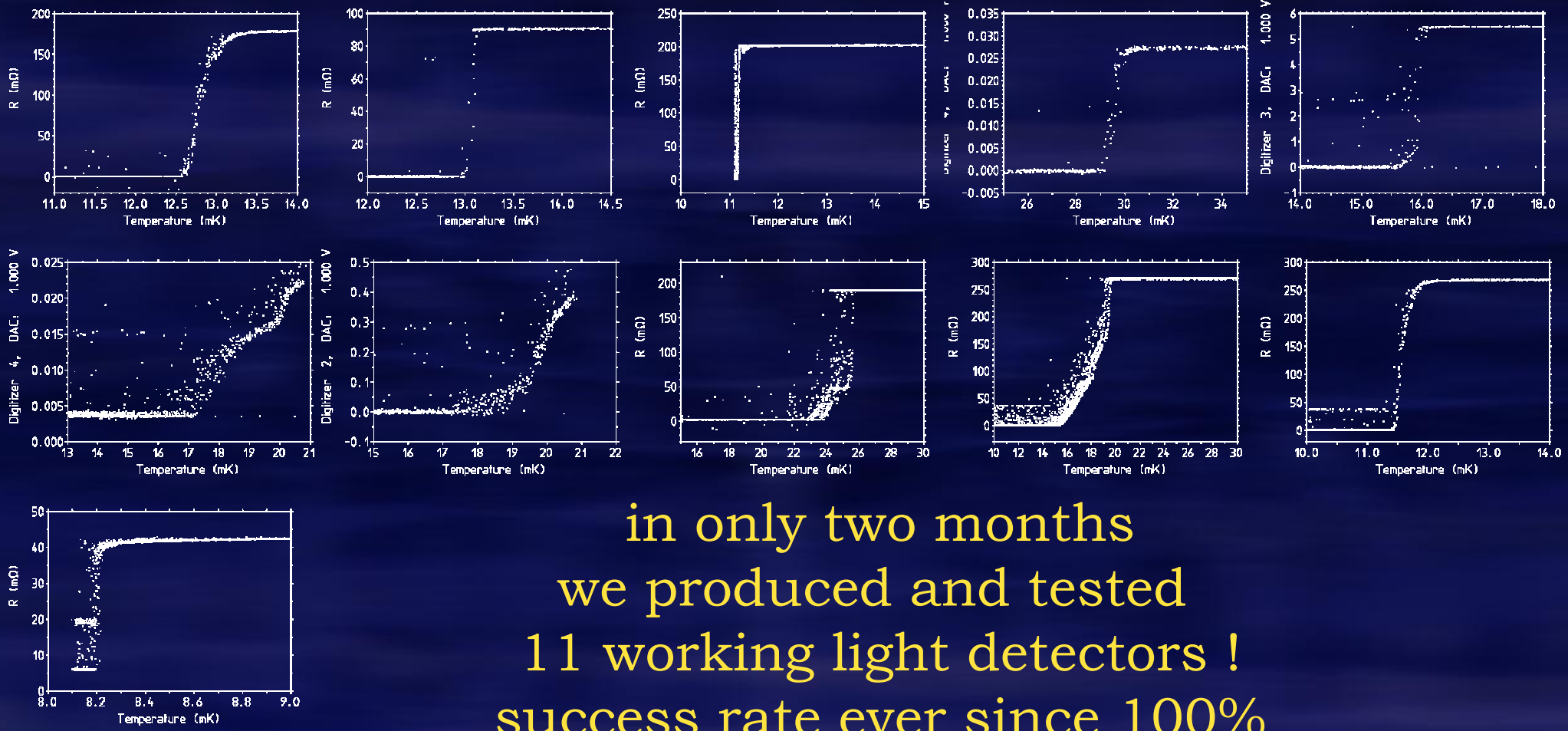
Au (30nm)
sputtered W (30nm)
substrate



Proximity-Effect of β-W prevented cooling through Au stripe

Problem Finally Solved

sputter Au directly onto Al_2O_3
(only leave W under bond pad)



in only two months
we produced and tested
11 working light detectors !
success rate ever since 100%

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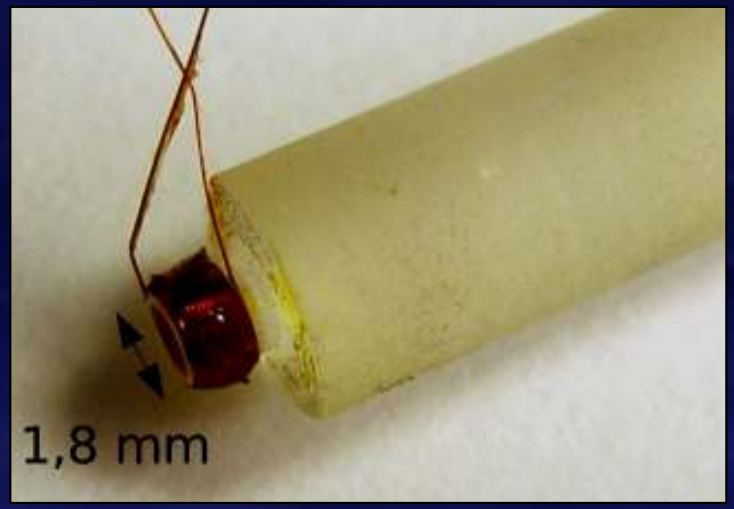
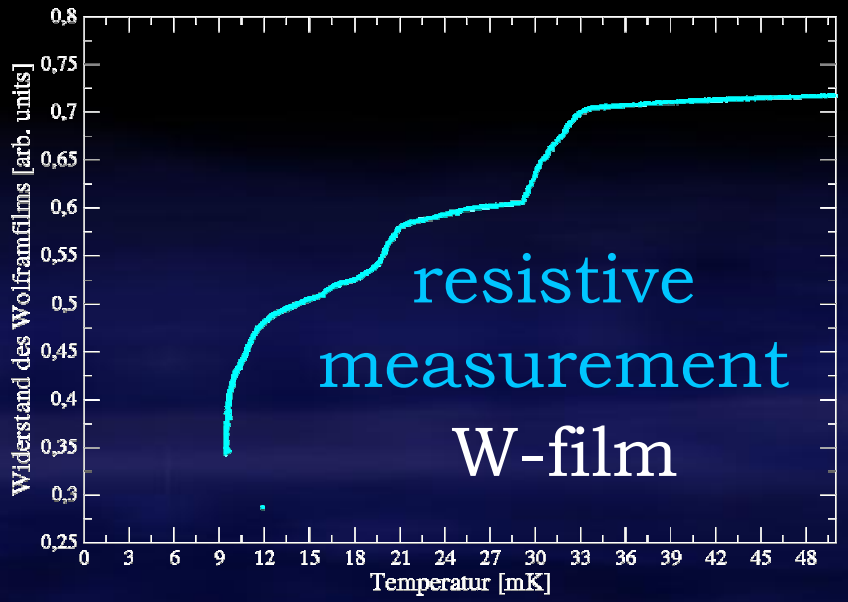
Measure Transitions Inductively

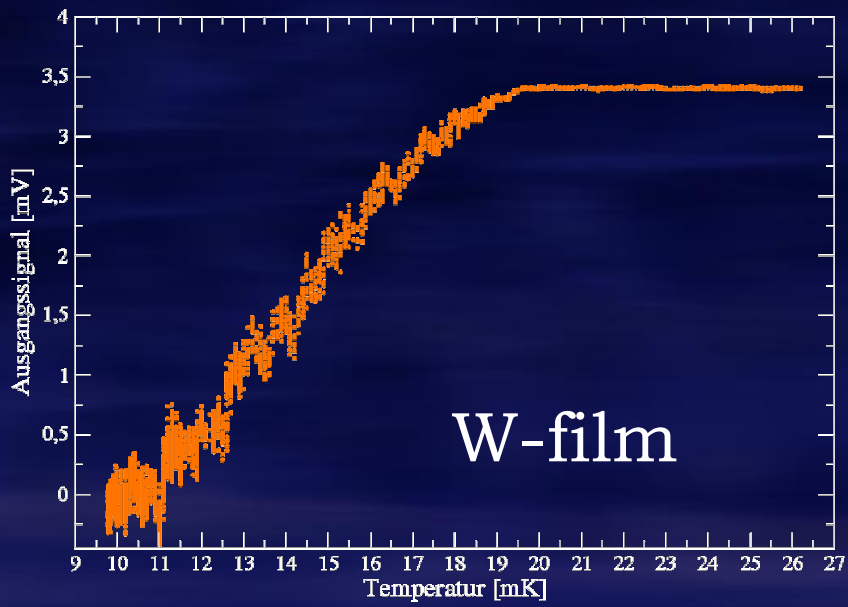
no spatial information
from resistive transition
measurement

→ inductive measurement



miniature coil
hand-rolled on Stycast 1266





Measure Transitions Inductively

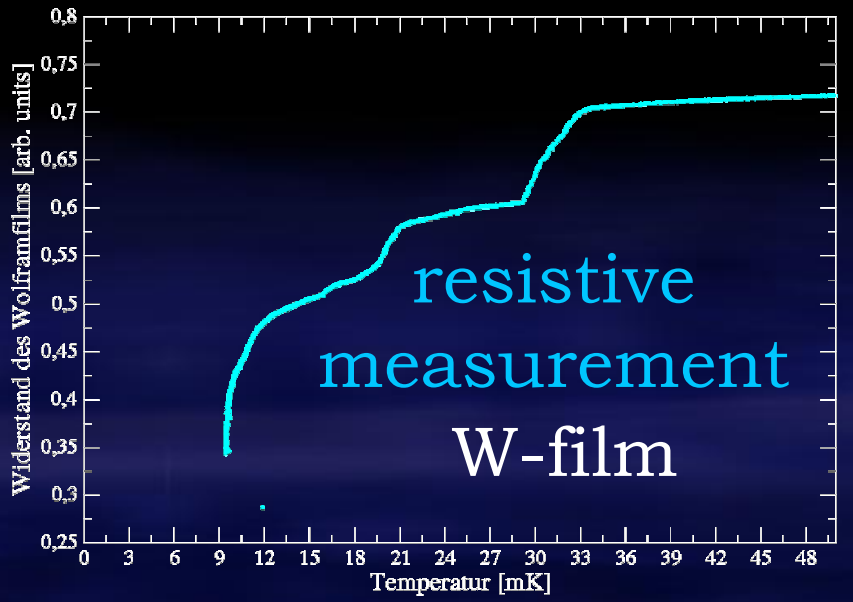
no spatial information
from resistive transition
measurement

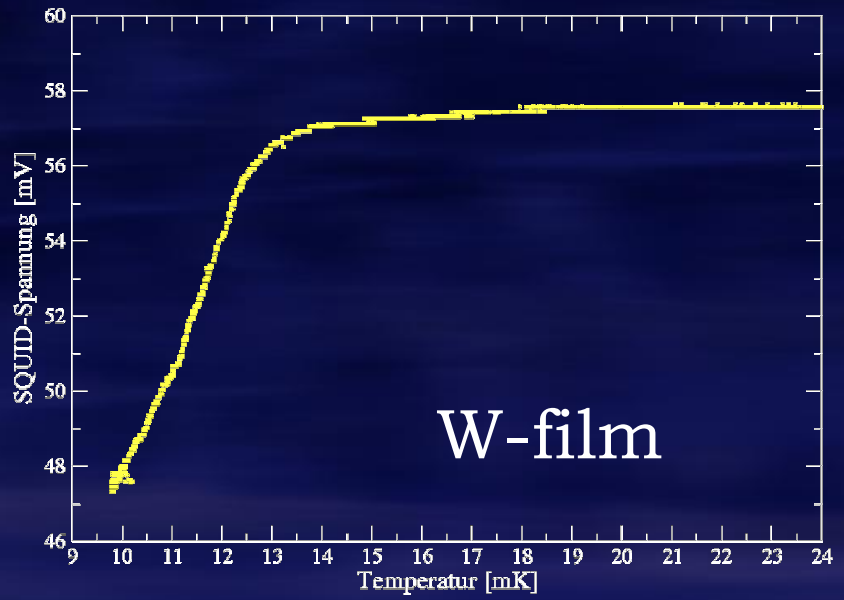
→ inductive measurement

1mm

measurements with
lithographic coil

piezos will allow
spatially resolved
transition curves





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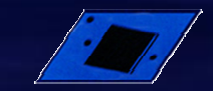
Increasing Light Output

evaporating thermometer on crystal
decreases light output by factor ~2
bad for analysis threshold

idea:
1. evaporate thermometer on carrier crystal
2. glue this onto big target crystal

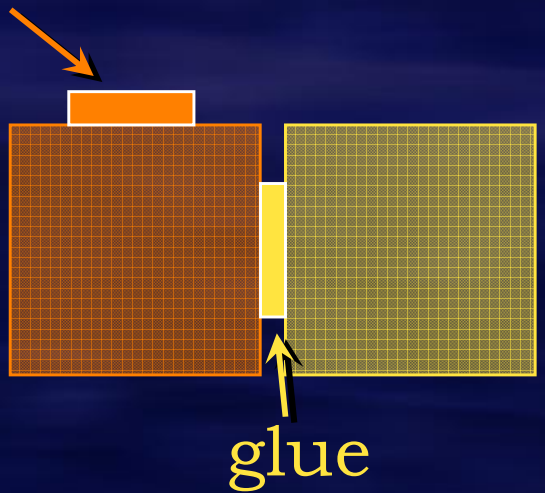


study
- feasibility
- glue behaviour
- impact on phonon channel

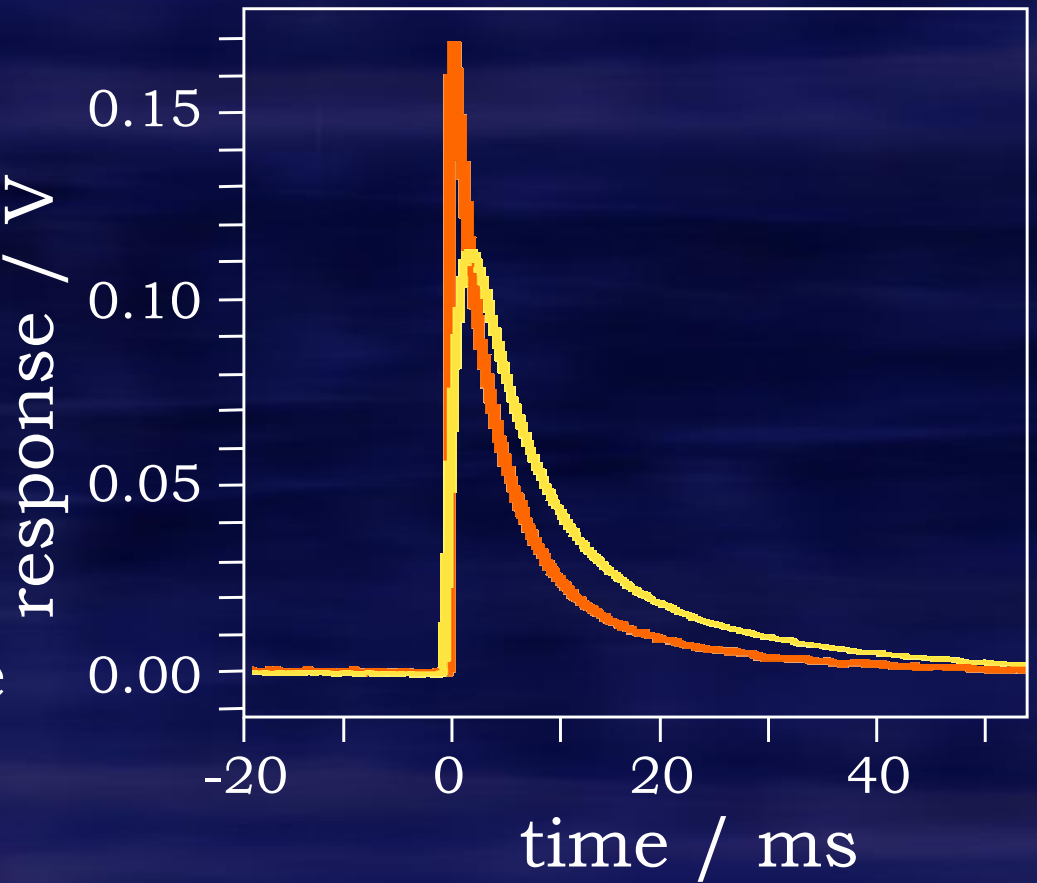
Test Setup For Gluing

20 x 10 x 5 mm^3 $CaWO_4$ with thermometer
sawed & glued again with Araldite 2011

W thermometer



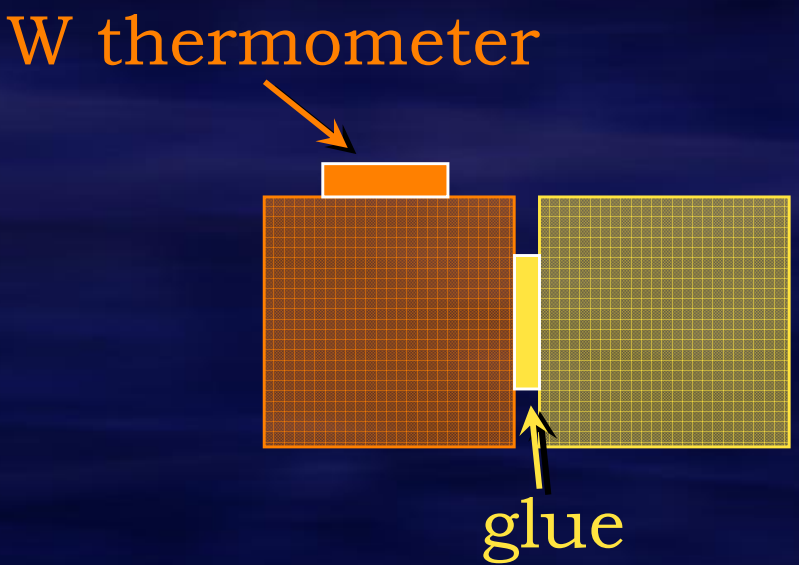
60keV pulses:

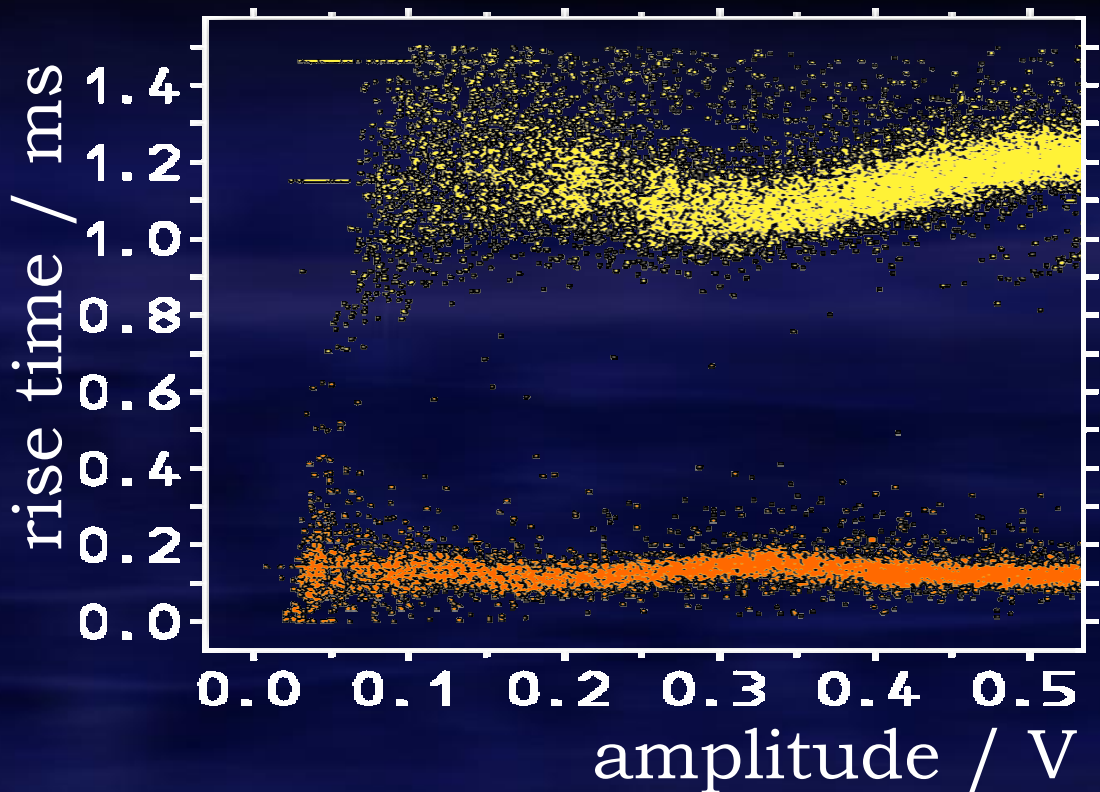


- ✓ works
- ✓ phonon signal acceptable

Pulse Shapes

distinct pulse shapes allow for a discrimination



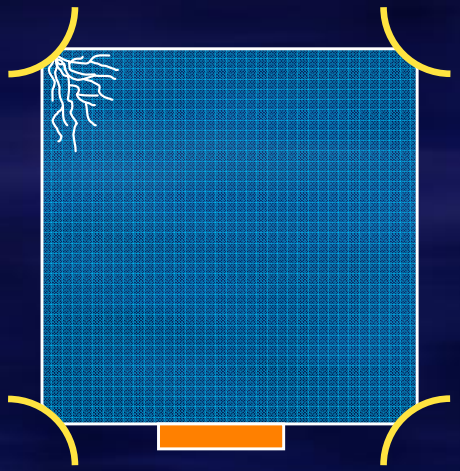


- ✓ works
- ✓ phonon signal acceptable
- ✓ pulse shape discrimination

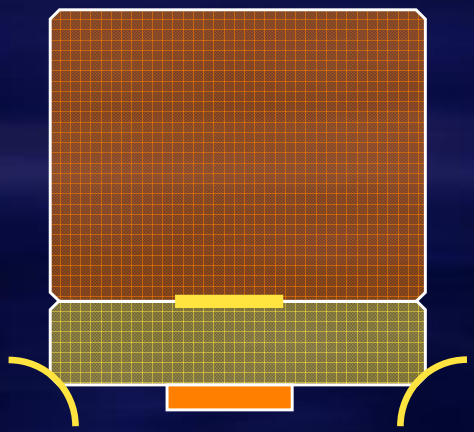
looks promising, detectors for Gran Sasso in preparation

Still Cracks?

- pin down influence of clamps:
  do they introduce dark events (cracks)?



standard module



glued module

use pulse shape discrimination to learn about cracks

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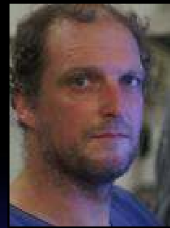
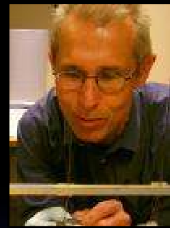
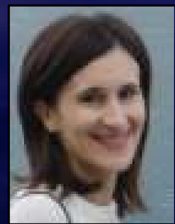
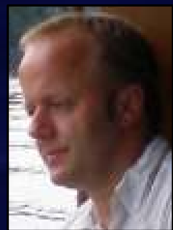
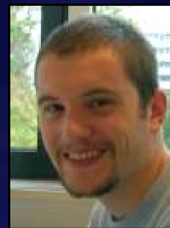
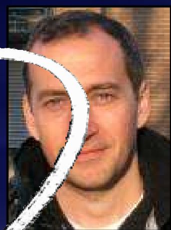







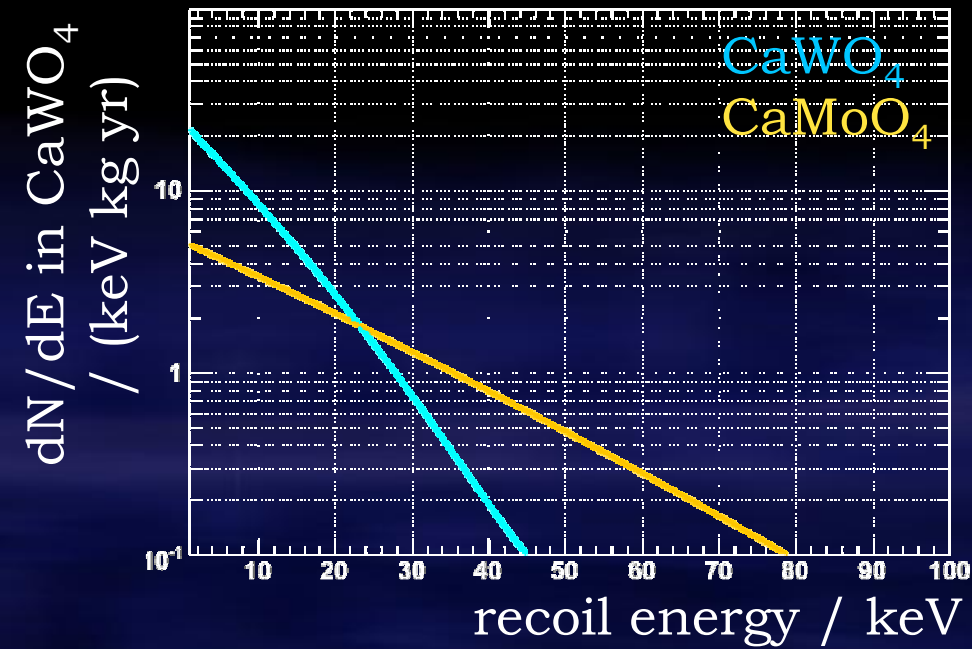



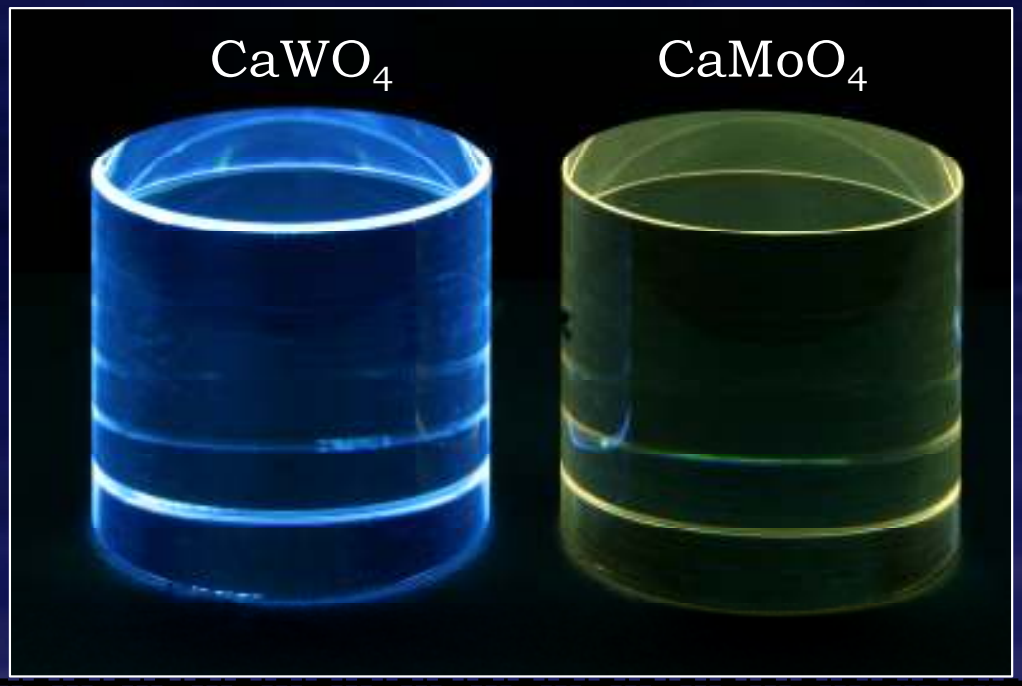



$CaMoO_4$

lighter target A(Mo) ~ 96
→ different recoil spectrum:
up to higher energies
allows systematic studies





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Conclusion and Outlook

In 2007 we went some major steps forward:

- new method for thin film characterization
- new cryostat @ MPP
- reliable production of new detectors

- constant running of cryostat in Gran Sasso
- new limits: came in third in global ranking

Preparations for the next run in Gran Sasso:

- build in >15 modules in early 2008
  some with design modifications
- learn about background
- learn about WIMPs