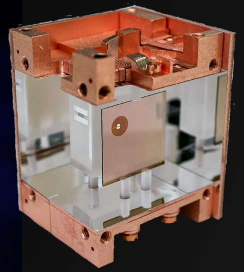


CRESST

Cryogenic Rare Event Search with Superconducting Thermometers

TU WIEN | HEPHY INSTITUTE OF HIGH ENERGY PHYSICS | INFN Laboratori Nazionali del Gran Sasso | UNIVERSITAS COMENIANA BRATISLAVENSIS MCMXIX | Max-Planck-Institut für Physik (Werner-Heisenberg-Institut) | EBERHARD KARLS UNIVERSITÄT TÜBINGEN | TUM | UNIVERSITY OF OXFORD

Detectors, Shielding and (α,n) Background in the CRESST Dark Matter Search

Alexander Fuss
for the CRESST Collaboration

(α,n) yield in low background experiments
21-22 November 2019, CIEMAT, Madrid

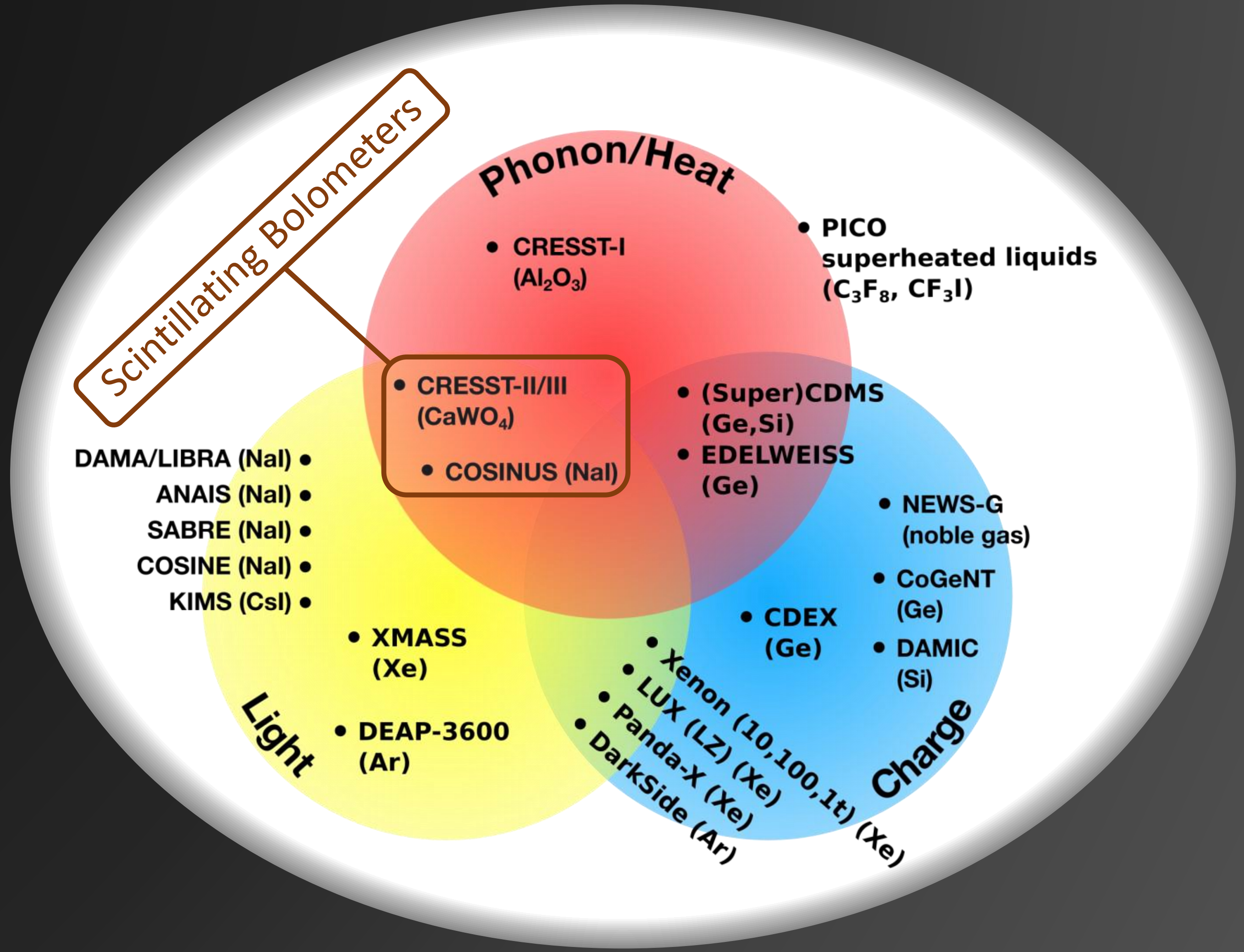
Outline

- CRESST Detectors
- Shielding used in CRESST
- Background Simulation with focus on possible (α,n) contribution

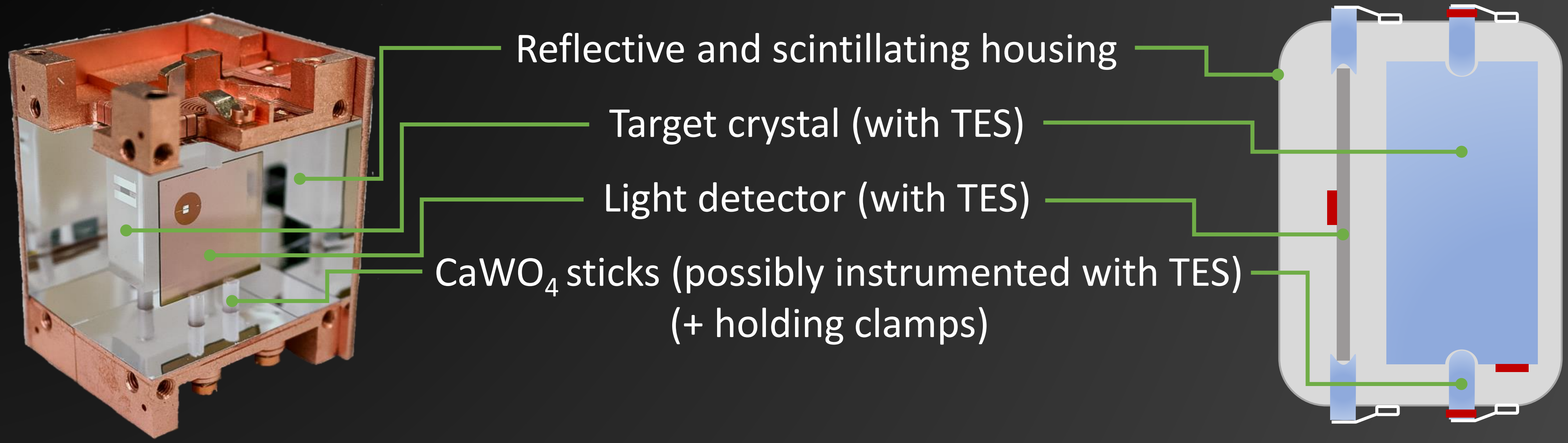
CRESST

The CRESST Collaboration

Searching for Dark Matter (DM) via direct detection



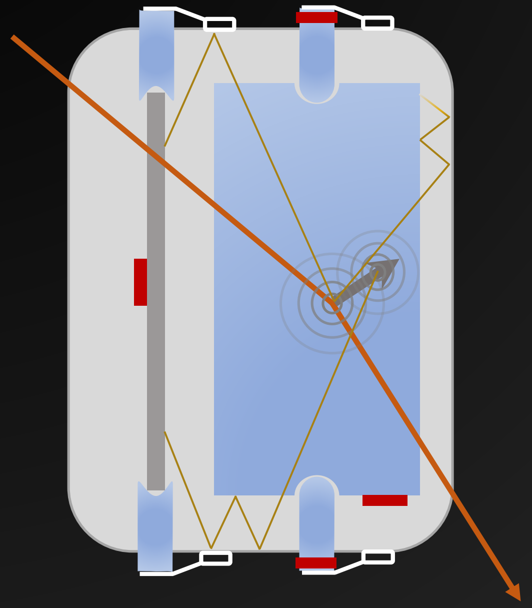
CRESST Detectors



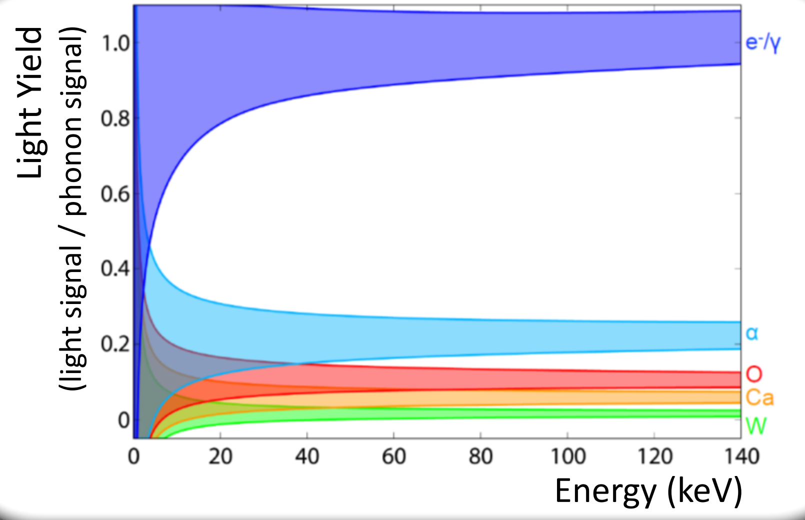
Detector design optimized for **low-mass dark matter search**:

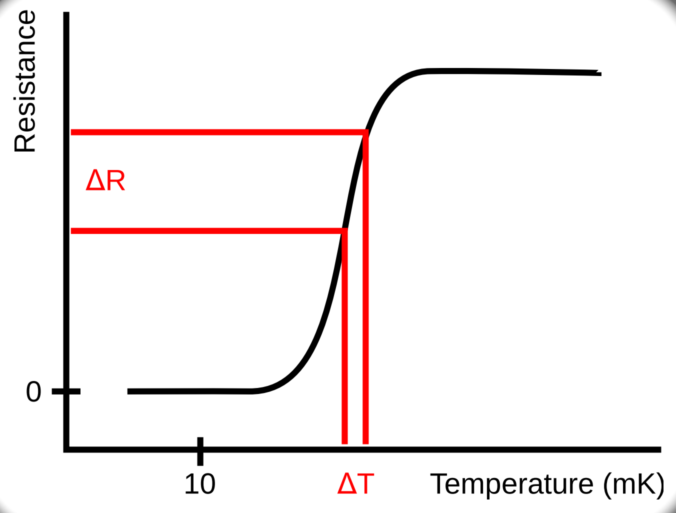
- **Small cuboid crystals** (20x20x10) mm^3 → mass: ~24 g
- Nuclear recoil energy **threshold < 100 eV**
- **Low background rate in region of interest** (ROI: threshold to ~16 keV) → ~4 – 6 dru
- **Veto against surface related background** (scintillating housing + instrumented sticks)

Detection Principle – 2-Channel Read-Out

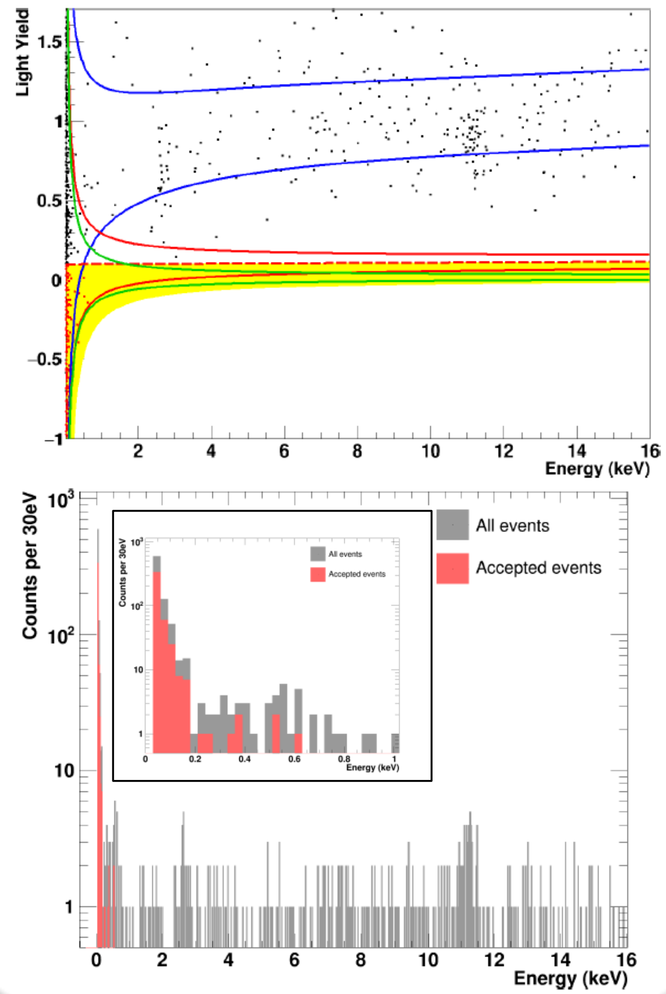


- Cryogenic operation at **~15 mK**
- **Phonon + scintillation light signal** simultaneously **read out with TESs**
- **Particle discrimination** via ratio between light and phonon signal



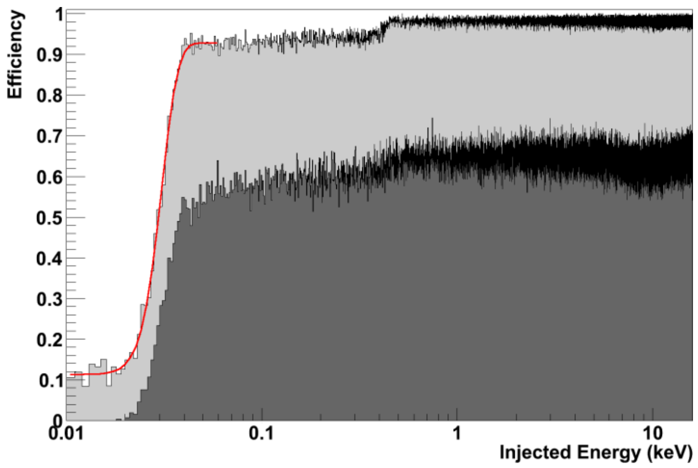


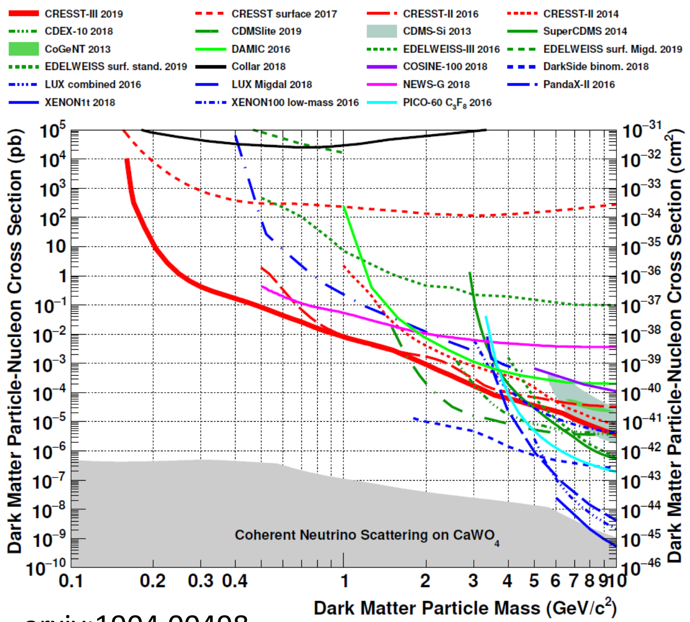
First CRESST-III Results



Detector A (data taking: 10/2016 – 01/2018):

- Target crystal mass: 23.6 g
- Nuclear recoil threshold: 30.1 eV
- Gross exposure: 5.689 kg days

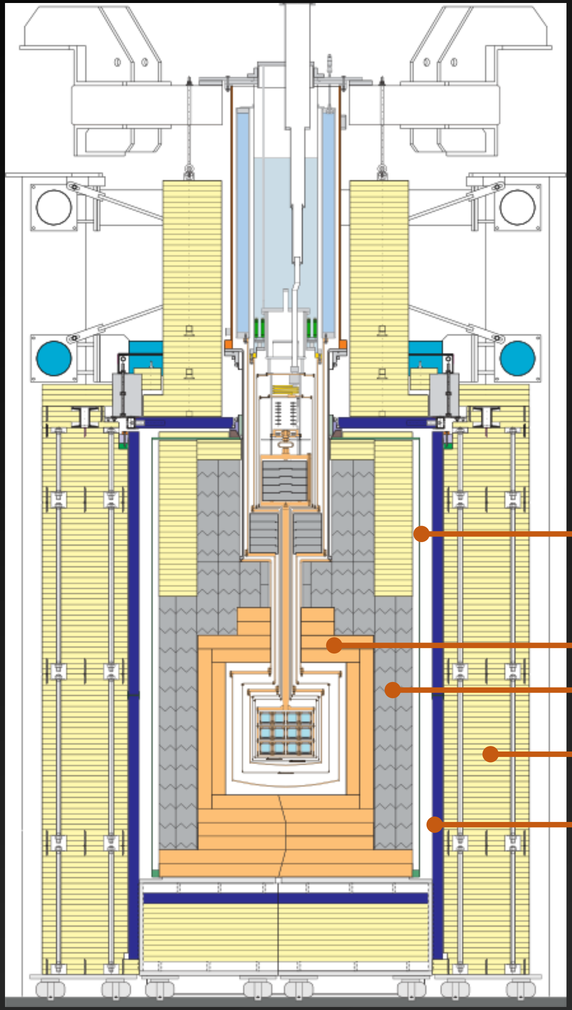




arxiv:1904.00498

CRESST Shielding Structure

Located at the LNGS Underground Laboratory
~3600 m.w.e. rock overburden



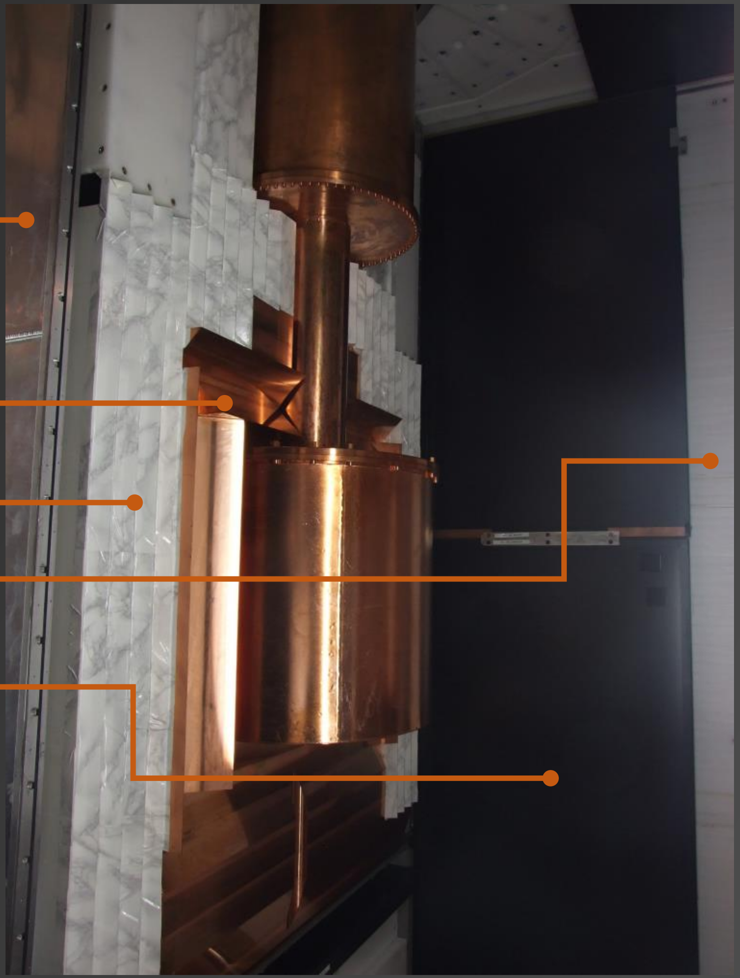
Radon Box

Min. 14 cm Cu

Min. 20 cm Pb

Min. 45 cm polyethylene (PE)

Active muon veto



CRESST Shielding Structure

Additional inner PE shield directly outside and inside the OVC of the cryostat since 2012

Background Simulations – Geant4

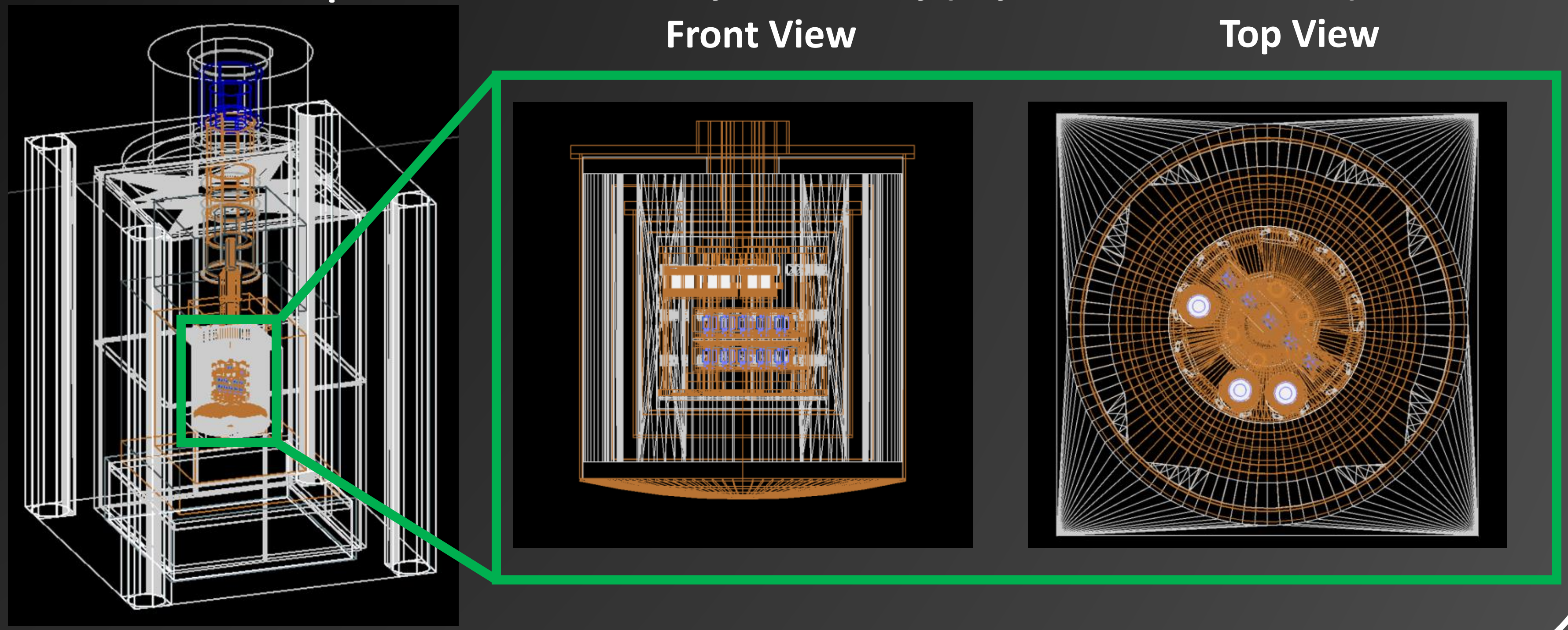
- A dedicated simulation code based on Geant4 has been developed
- The shielding geometry has been implemented (up to necessary levels of detail)

Simulated Geometry

Whole Setup

Cryostat Cavity (Cryoshields + Carousel)

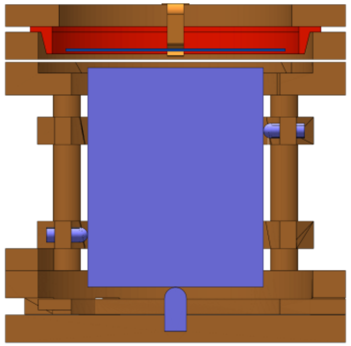
Front View **Top View**

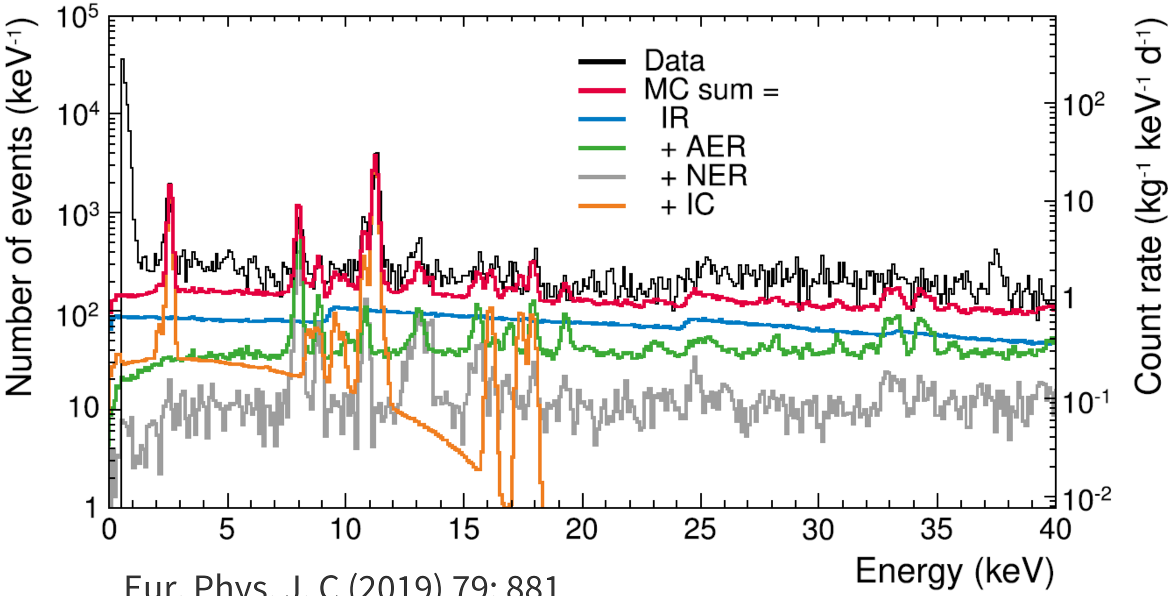


Electromagnetic Background Model

- An electromagnetic background model has been developed for the lowest-background module (TUM40) of CRESST-II

TUM40
schematic design





Eur. Phys. J. C (2019) 79: 881

$(\mathrm{MC} / \mathrm{Data})_{1\text{-}40\,\mathrm{keV}} \leq (68 \pm 16)\,\%$

Neutron Background Model

- Neutron background studies were done for past shielding configurations
- Neutron studies for current shielding and detector design are ongoing

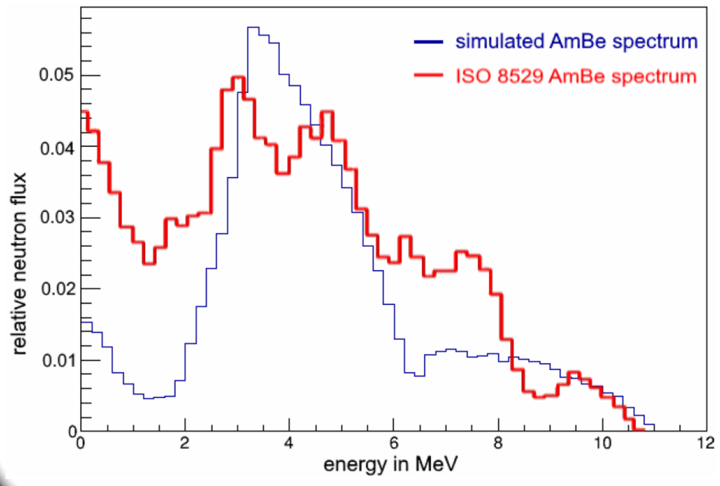
- All sources are taken into account (ambient, radiogenic, μ-induced)

- For radiogenic neutrons, we use the SOURCES4C code
  - Radiogenic neutrons include those produced in (α,n) reactions as well as those produced through spontaneous fission reactions

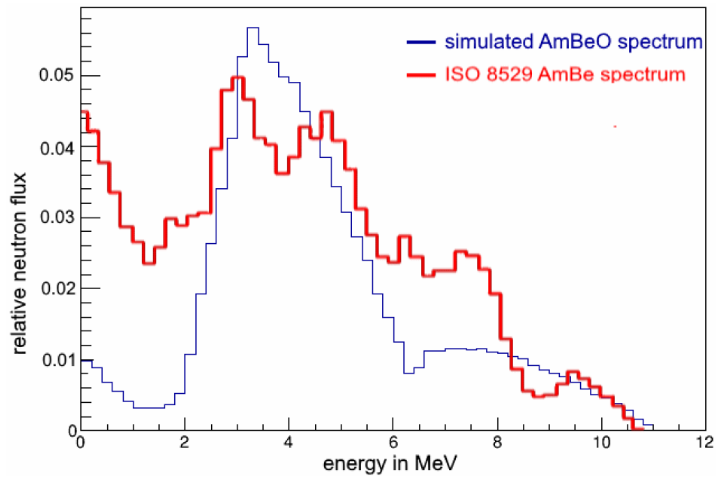
(α,n) Study

- In 2016, we did a **comparison** of a **real** and a **simulated (Geant4.10.2.1) AmBe** neutron spectrum
- The **simulated spectra did not match** the measured spectrum for any simulated configuration:

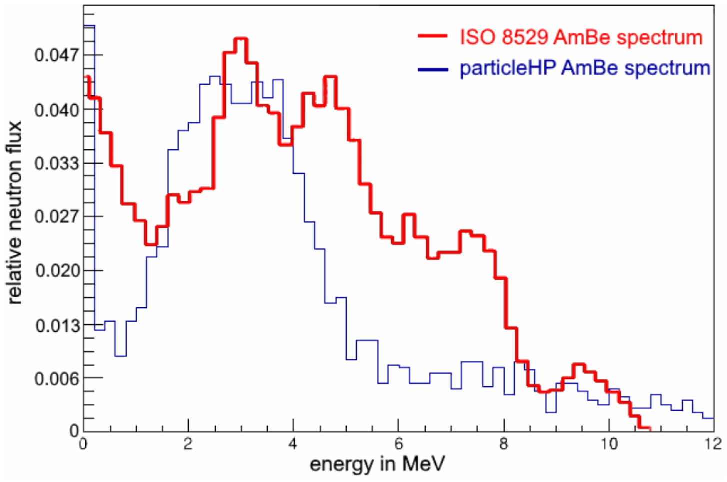
Using pure ^{9}Be base material



Using BeO base material



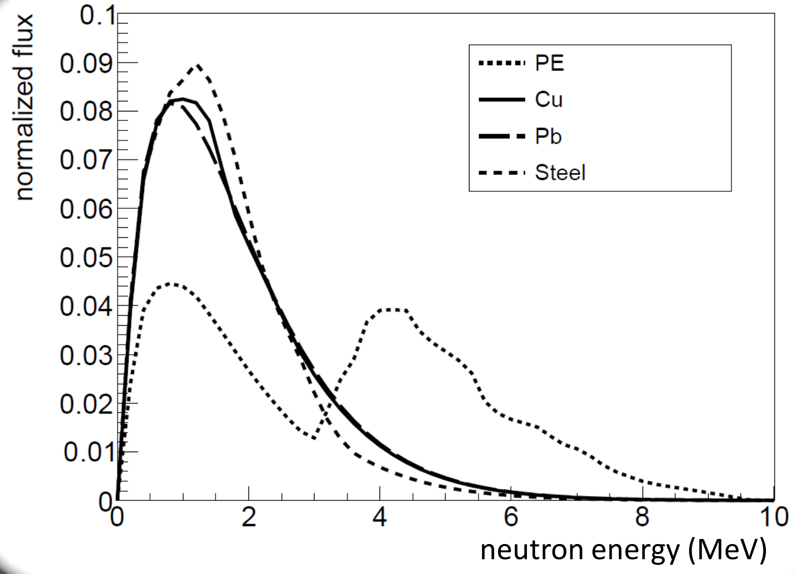
Using pure ^{9}Be base material + ParticleHP model



- Conclusion: **Geant4.10.2.1 does not simulate (α,n) reactions reliably**
- We hence use **SOURCES4C to attain (α,n) neutrons** (as well as s.f. neutrons)

Radiogenic Neutrons – SOURCES4C

Radiogenic neutron spectrum due to SOURCES4C (spontaneous fission + (α,n))



- PE: $9.368 \cdot 10^{-12}$ n / (cm³ s)
- Cu: $6.607 \cdot 10^{-13}$ n / (cm³ s)
- Pb: $1.249 \cdot 10^{-13}$ n / (cm³ s)
- Steel: $2.995 \cdot 10^{-12}$ n / (cm³ s)

- As a first approach, **contamination levels measured by other rare event search experiments** were considered

Reference values from CUORE and XENON:

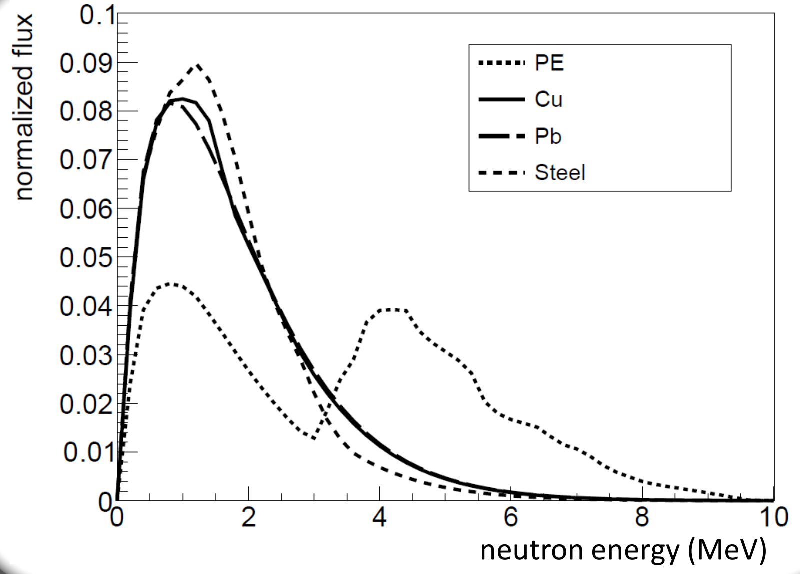
C. Alduino et al., JINST 11 07 (2016), P07009
E. Aprile et al., Astroparticle Physics 35 2 (2011), p. 43
D. R. Artusa et al., Eur. Phys. J. C74 (2014), p. 3096

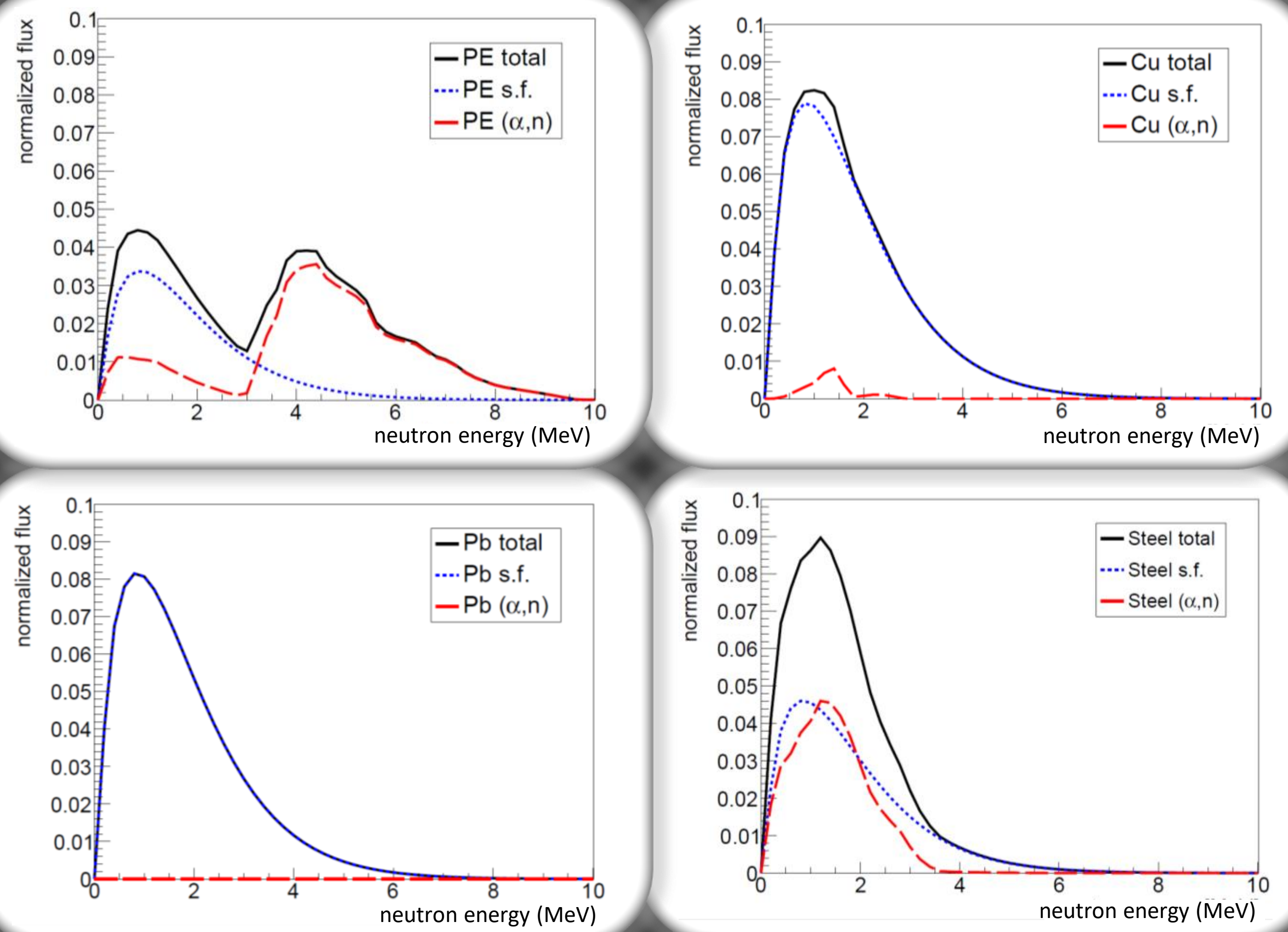
Material	^{238}U [mBq/kg]	^{235}U [mBq/kg]	^{232}Th [mBq/kg]
Cu	< 0.065	–	< 0.002
PE	< 3.8	< 0.37	< 0.14
Pb	< 0.01	–	< 0.07
Steel	< 0.2	–	< 0.1

- Currently, **screening** of our materials is **ongoing** to **characterize new batches** and **improve sensitivity** of old measurements
- Next step: simulations using our screening results

Radiogenic Neutrons – SOURCES4C

Radiogenic neutron spectrum due to SOURCES4C (spontaneous fission + (α,n))





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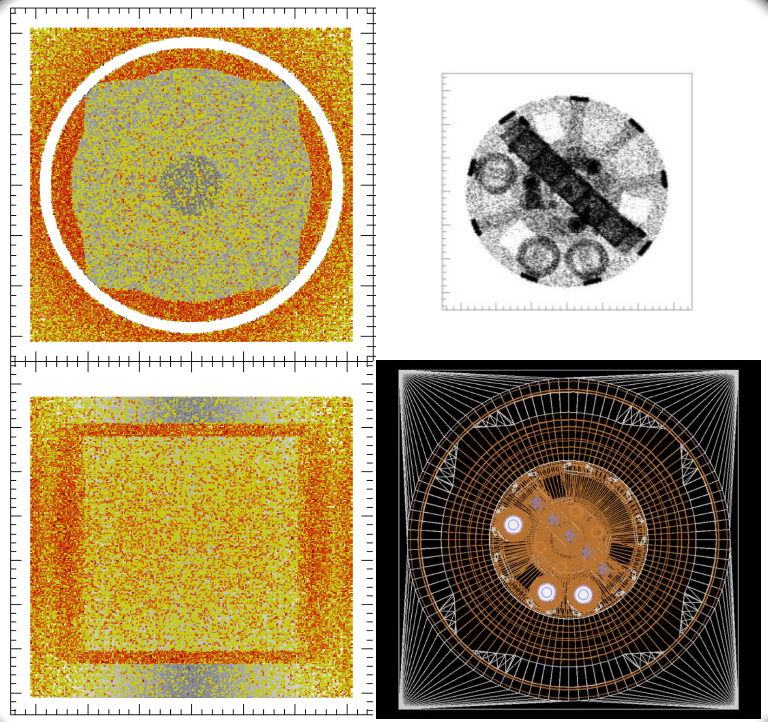
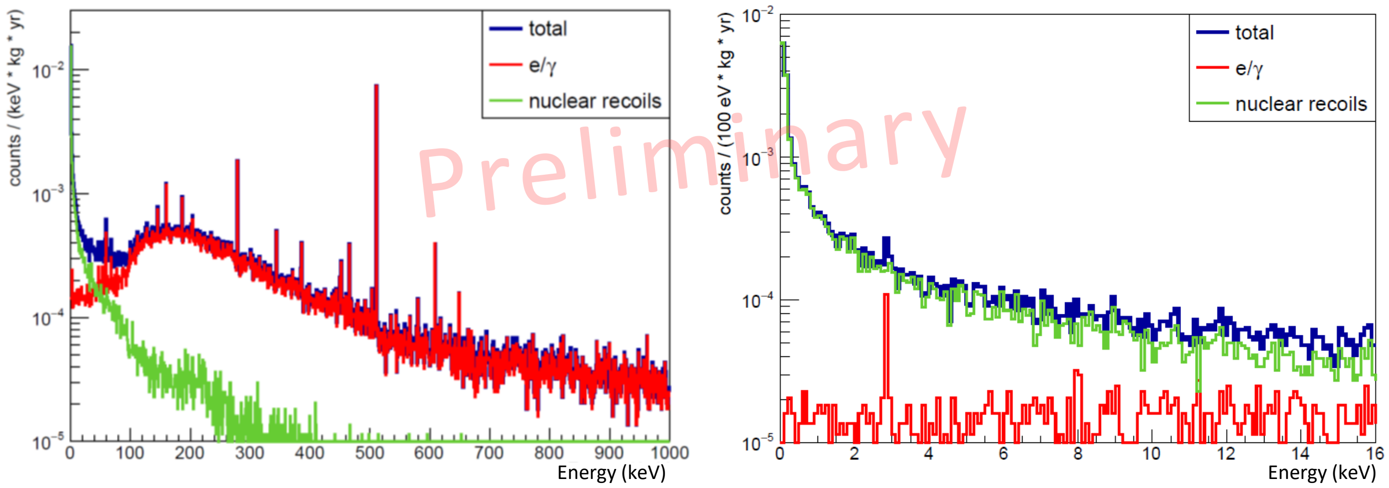
Radiogenic Neutron Simulation

Simulation of homogeneous contamination in inner PE

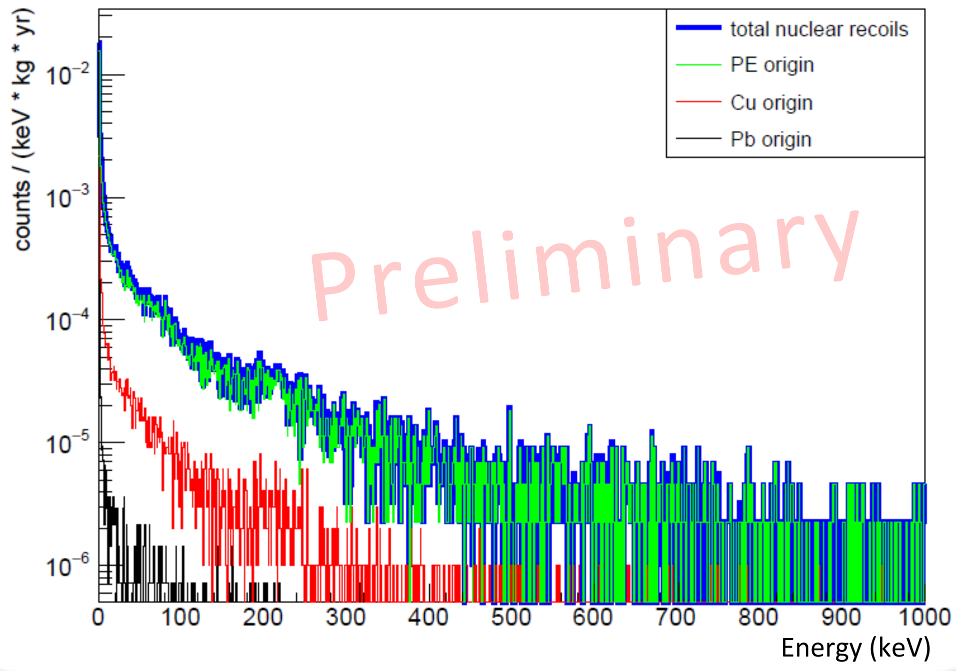


Detected events originating from radiogenic neutrons produced in the inner PE shields



Radiogenic Neutrons – Background

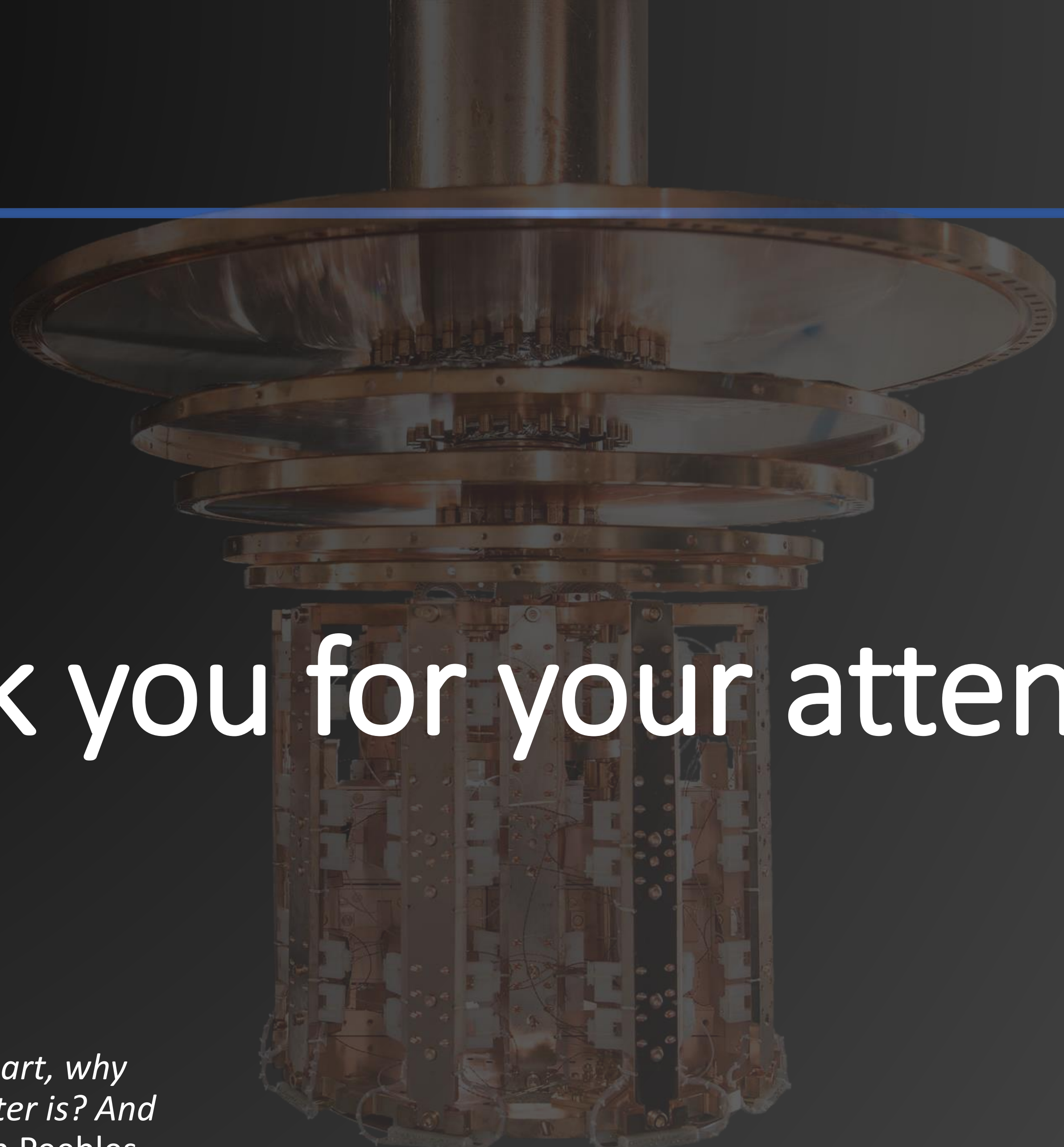
Total nuclear recoil background due to radiogenic neutrons



- With assumed contamination levels, the inner PE shields actually contribute most to the radiogenic neutron background
- But: expected **radiogenic neutron background is very low → O(10^{-2} $kg^{-1}yr^{-1}$)**

Summary

- CRESST has a well-shielded setup and highly sensitive detectors for low-mass Dark Matter search
- Screening measurements and simulations for developing and improving background models are ongoing
- (α,n) reactions are not supposed to give a high contribution to our background, but a precise knowledge of the processes is necessary for a precise neutron background model



Thank you for your attention!

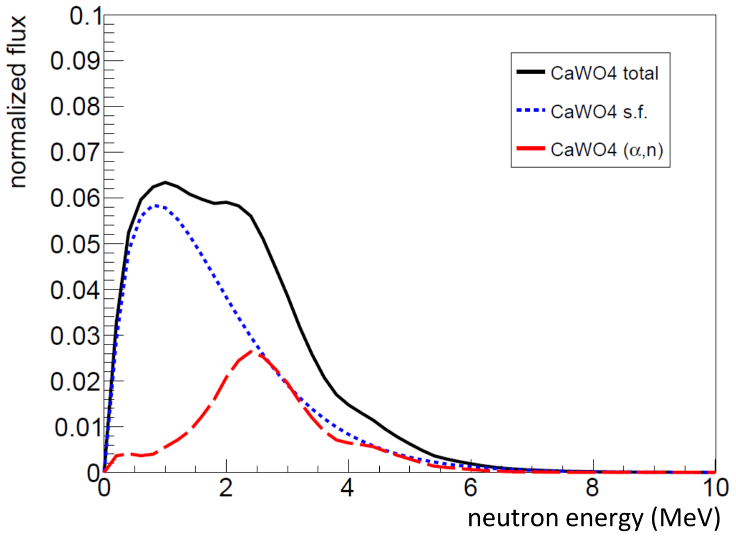
“You're entitled to say, if you're so smart, why don't you tell me what that dark matter is? And I'll have to confess I don't know” – Jim Peebles

Additional Material

Radiogenic Neutrons – SOURCES4C

Radiogenic **neutrons due to intrinsic contamination in CaWO4**, taking contamination levels of TUM40 as reference:

Material	^{238}U [mBq/kg]	^{235}U [mBq/kg]	^{232}Th [mBq/kg]
$CaWO_4$	1.073	0.045	0.011



$1.003 \cdot 10^{-11}$ n / (cm^3 s)

CRESST Screening Measurements

CRESST Shielding Material Contamination Levels

Material	^{238}U [mBq/kg]	^{235}U [mBq/kg]	^{232}Th [mBq/kg]
Cu (Cryostat + Detector Holders)	< 0.02	< 0.05	< 0.021
Outer PE	52.66	–	43.55
Inner PE	1.0 ± 0.1	< 0.28	0.3 ± 0.1
Pb	< 2.85	–	< 0.91

Preliminary

This is not meant to be a complete list of our screening measurements (e.g. not listed are crystals and scintillating foils)

ICP-MS and NAA of new batch of Cu currently ongoing