# Cryogenic Rare Event Observatory

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for

the CRESST collaboration

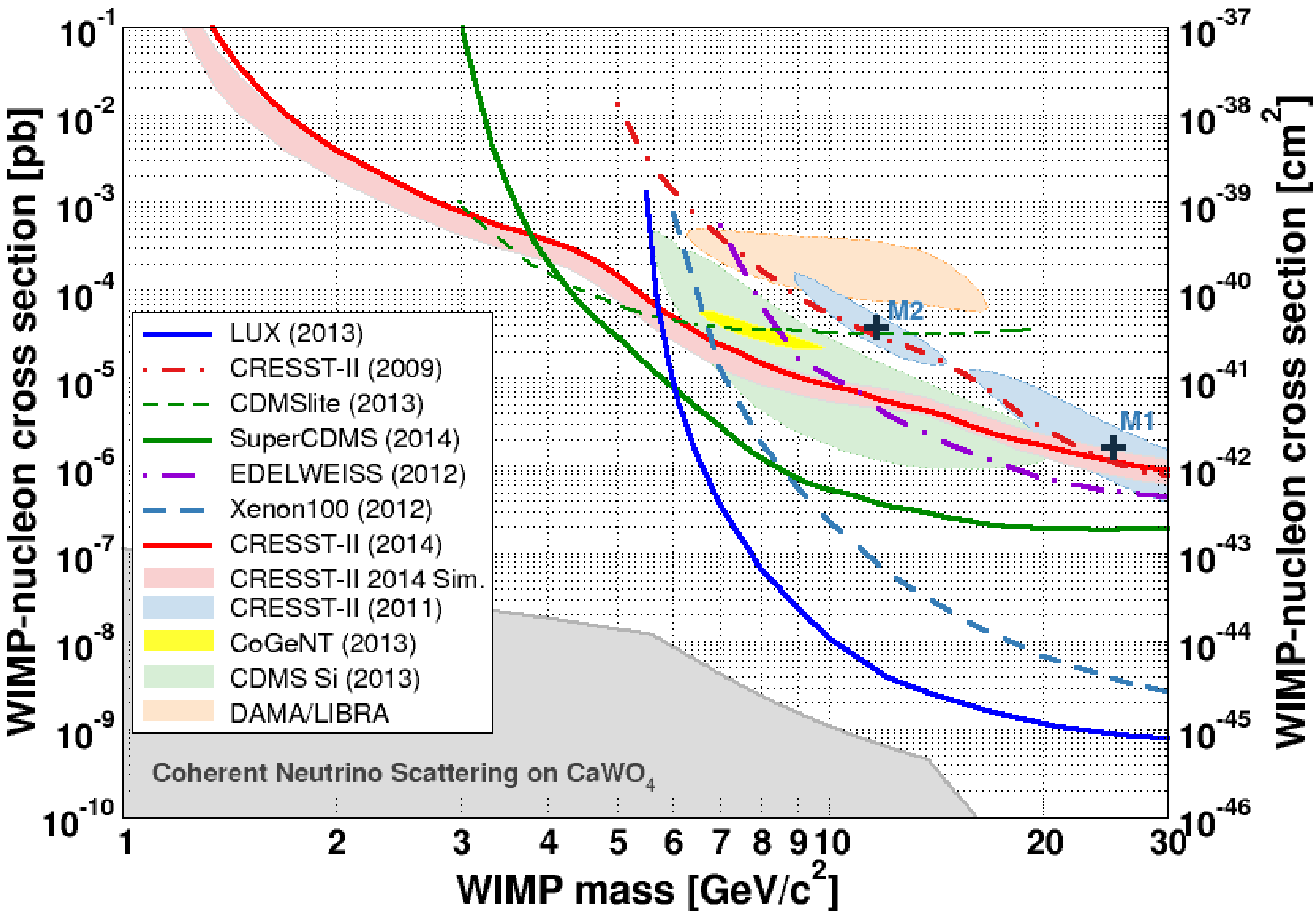
XLIII meeting of the Gran Sasso Scientific Committee

28 – 30 April 2015, LNGS

# Outline

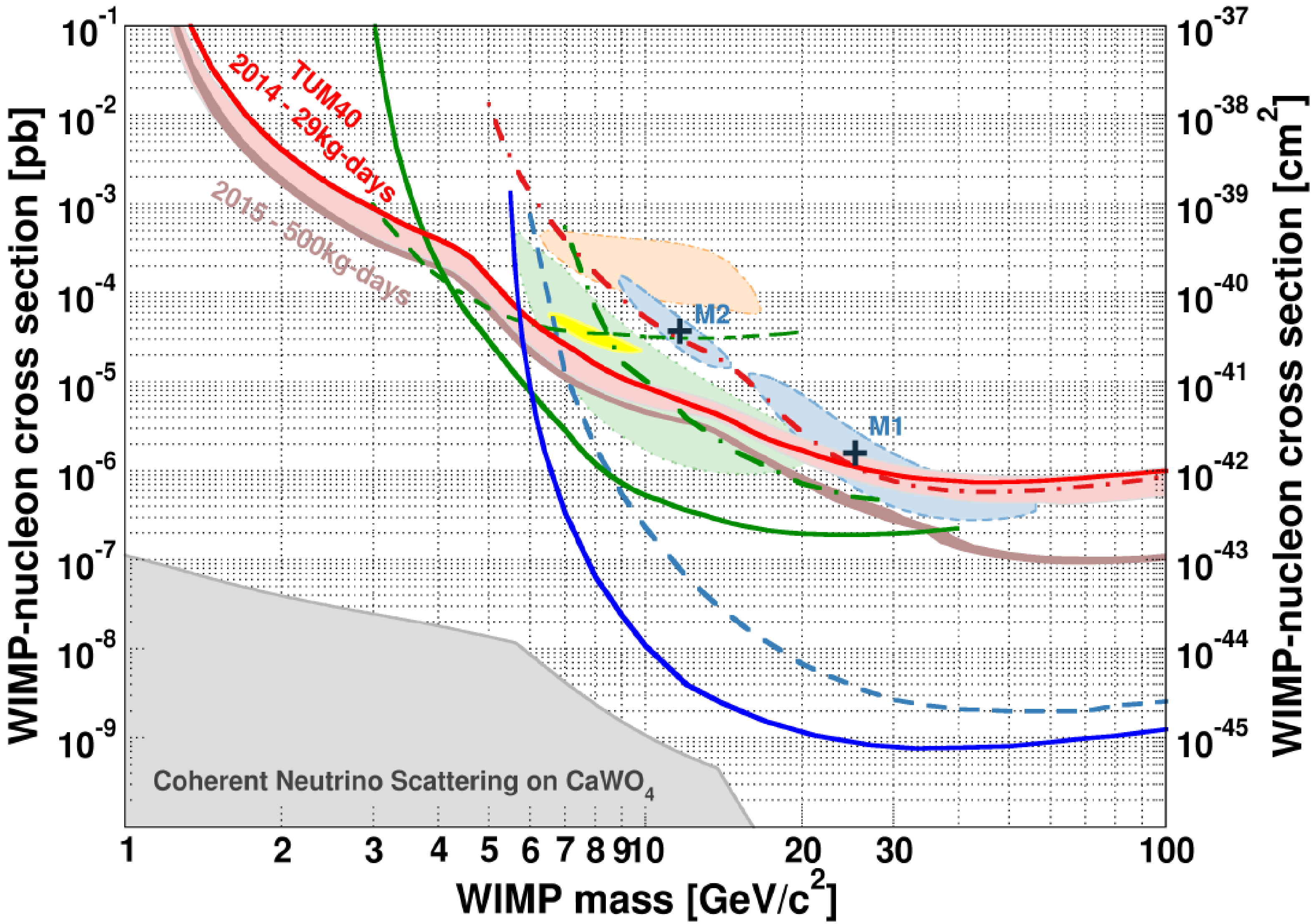
- CRESST: Status and short term strategy
- Visions beyond 2020
- The CREO project
- In reach of CNNS

# Results - 2014




Current **world-best sensitivity** for WIMP masses below 3GeV/c$^2$

Total exposure of ongoing run with actively discriminating modules

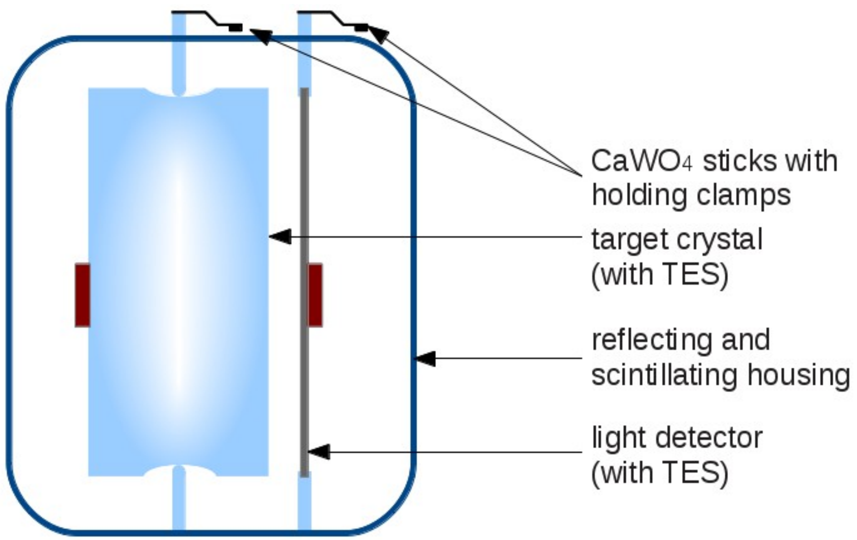



Clarify low-mass WIMP scenario

# Small modules

## Detector layout optimized for low mass WIMPs

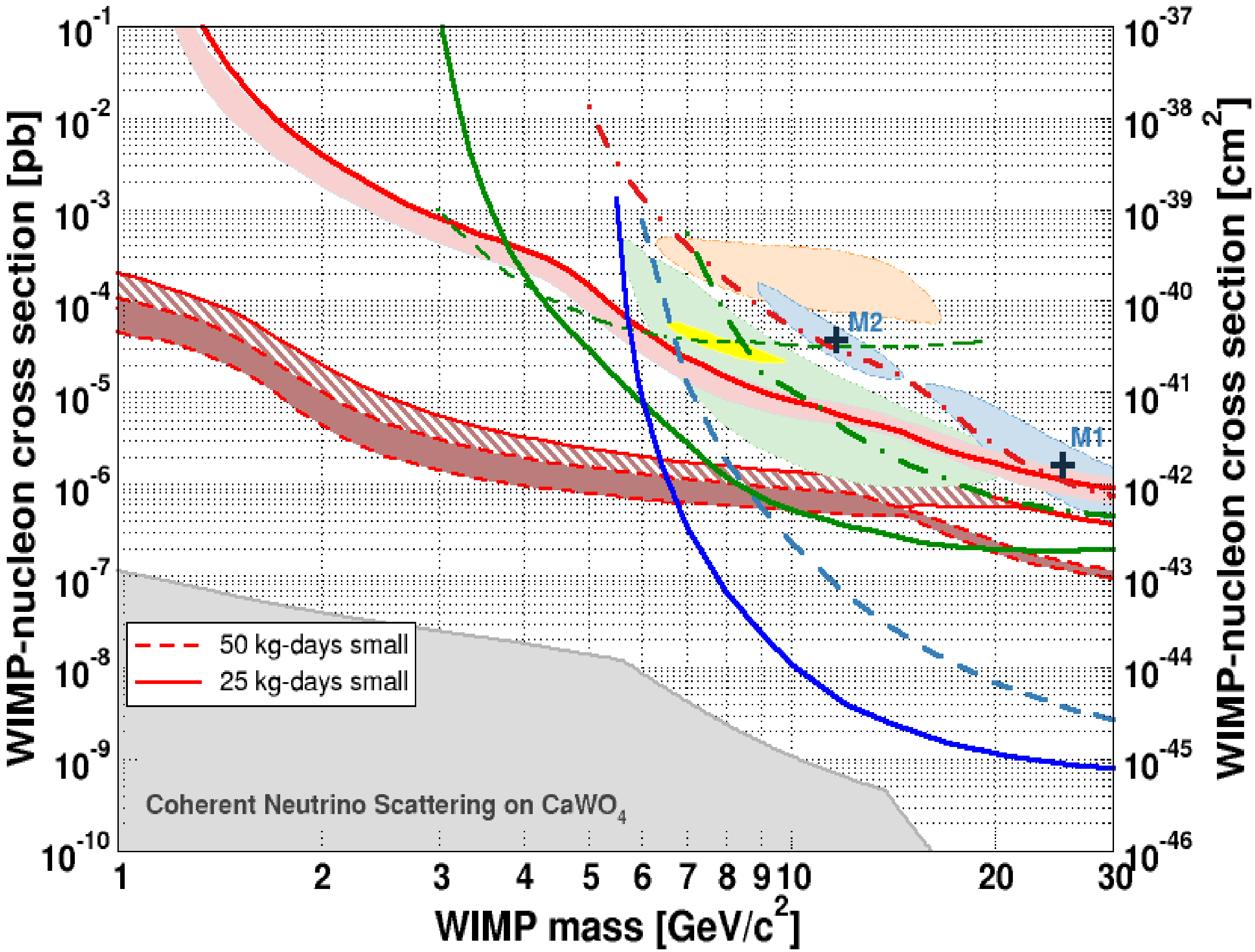
- Crystal of available quality (e.g. TUM40)
- Block shaped crystal of $(20\times20\times10)\mathrm{mm}^3$ (~ 25g)
- Light detector $(20\times20)\mathrm{mm}^2$




- 100 eV threshold
- Detected light increased by a factor of 3
- Light detector noise reduced by a factor of 2

# Future potential – 2 years

Detector layout optimized for low mass WIMPs (small modules)



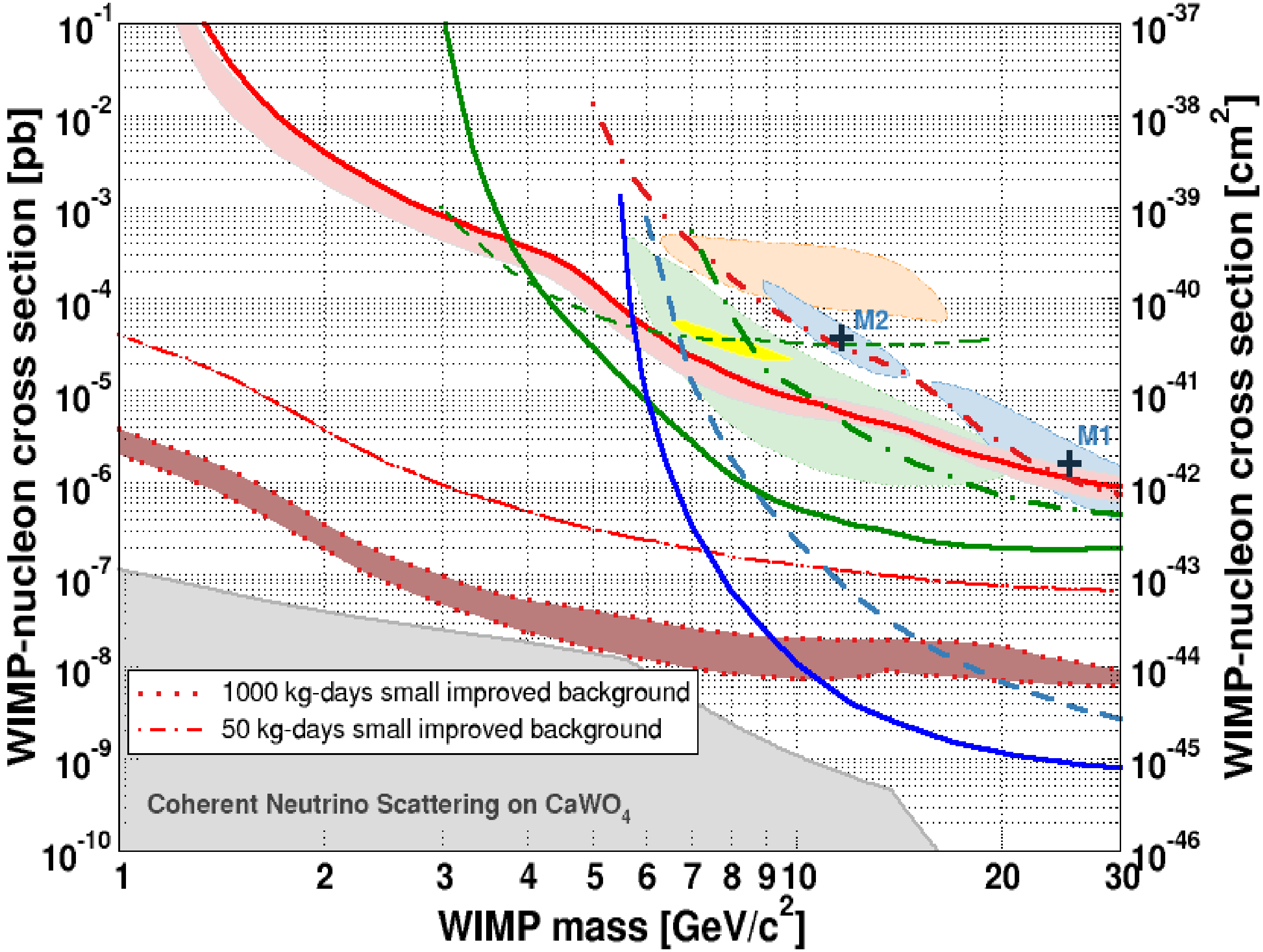

50 kg-days small
≈ 1 year of running with
~10 small modules of 25g

Substantial sensitivity gain for low WIMP masses

# Future potential – 5 years

Factor of 100 reduction in background:

- improved crystal radiopurity
- lower external radioactive contamination




1000 kg-days small
≈ 2 years of running with
~100 small modules of 25g

Moderate target mass to fix a new state of the art

# What Next?

Well defined strategy until 2020 http://arxiv.org/abs/1503.08065

- Present setup
- Enhanced number of SQUIDs / read out channels

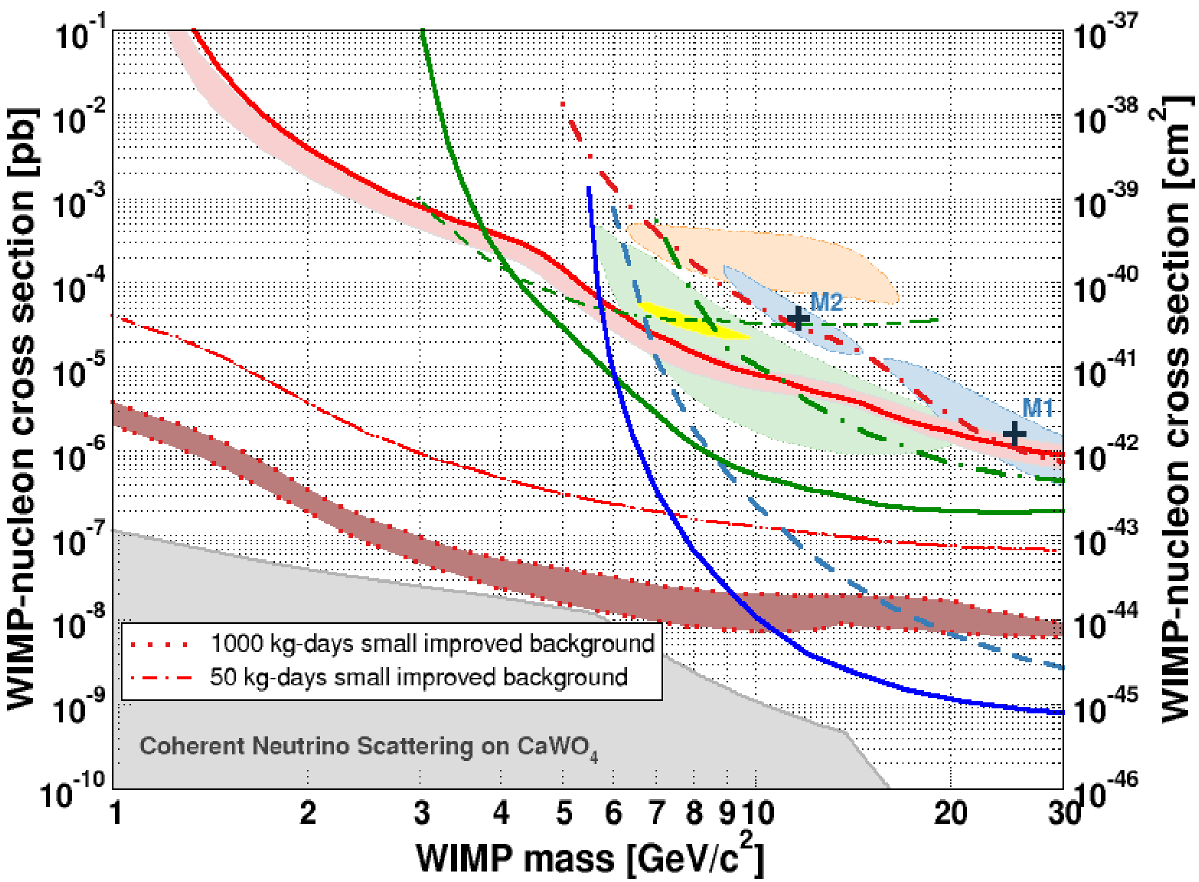
**What Next?**

# Visions beyond 2020

Limitations:

Exposure ➡ increase experimental volume/number of channels

Background ➡ large active shielding



# Visions beyond 2020

Limitations:

Exposure ➡ increase experimental volume/number of channels

- *O*(1000) read out channels
- *O*(100kg) target mass

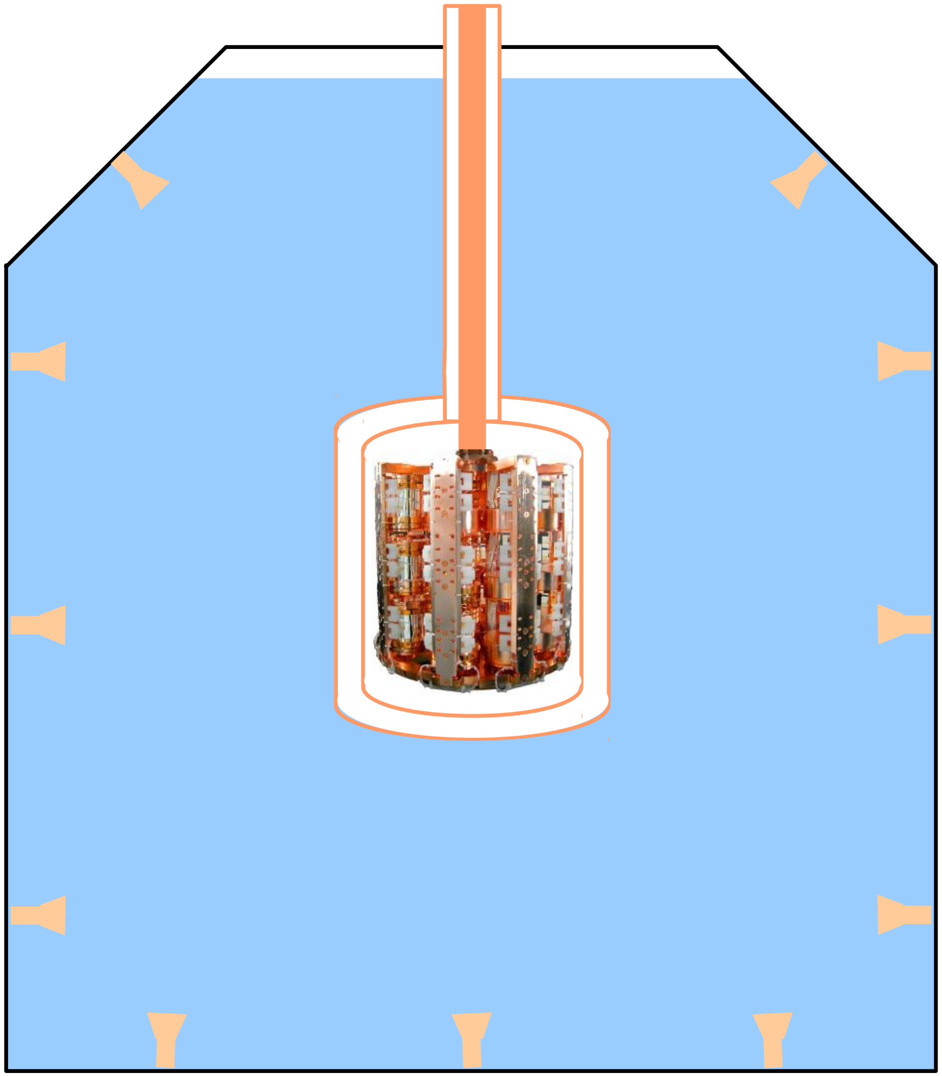
Dilution unit of CUORE type (~2mW @ 100mK)
but only *O*(100l) experimental volume

# Visions beyond 2020

Limitations:

Background ➡ large active shielding

- *O*(5m) water around
  (e.g. XENON 1T, Gerda)



# Visions beyond 2020

Limitations:

Exposure ➡ increase experimental volume/number of channels

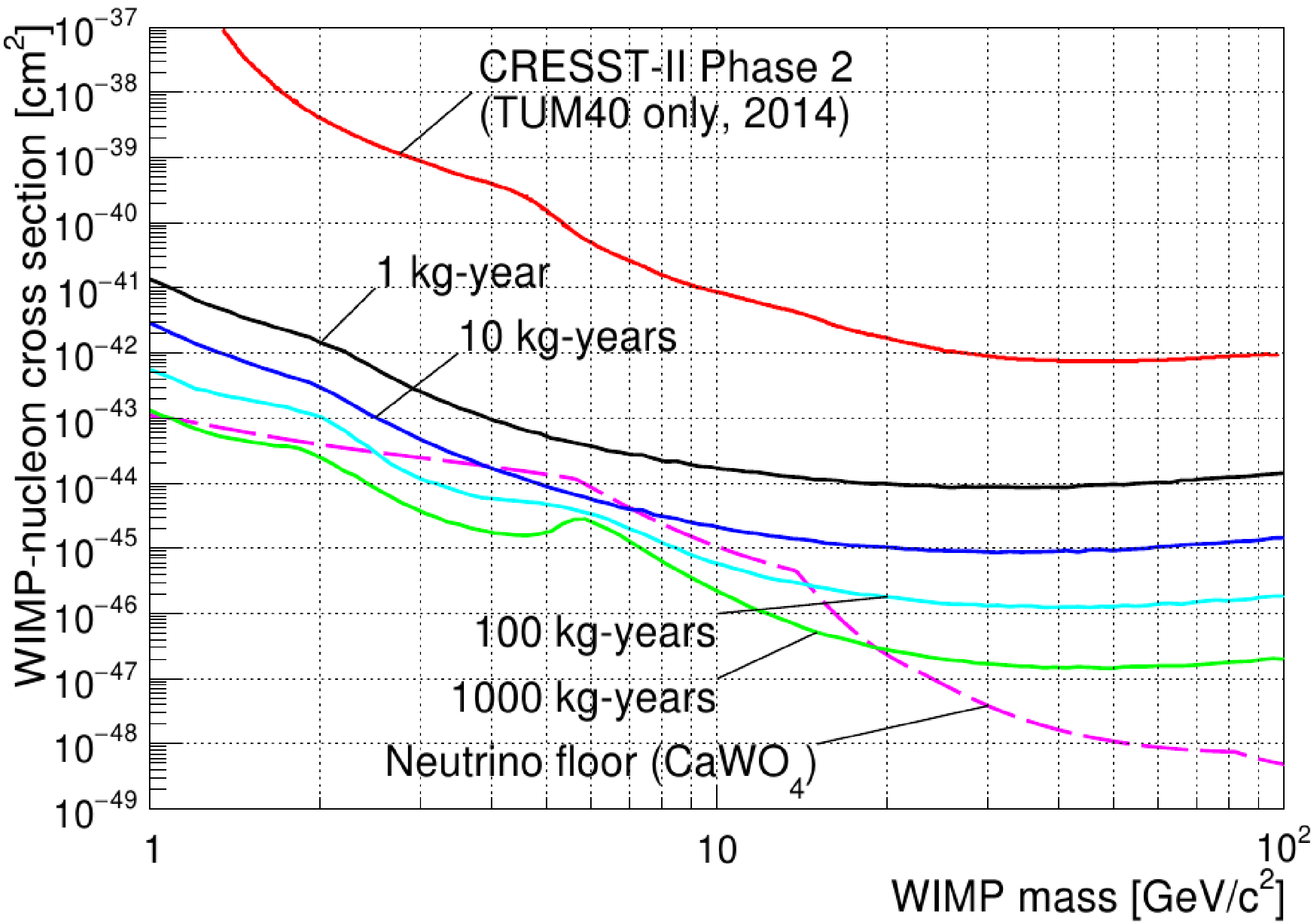
Background ➡ large active shielding

- CRESST detector technology
- *O*(1000) read out channels
- water shielding

# Visions beyond 2020

Scenario: No direct WIMP signal observed

**The ultimate dark matter experiment for low mass WIMPs**

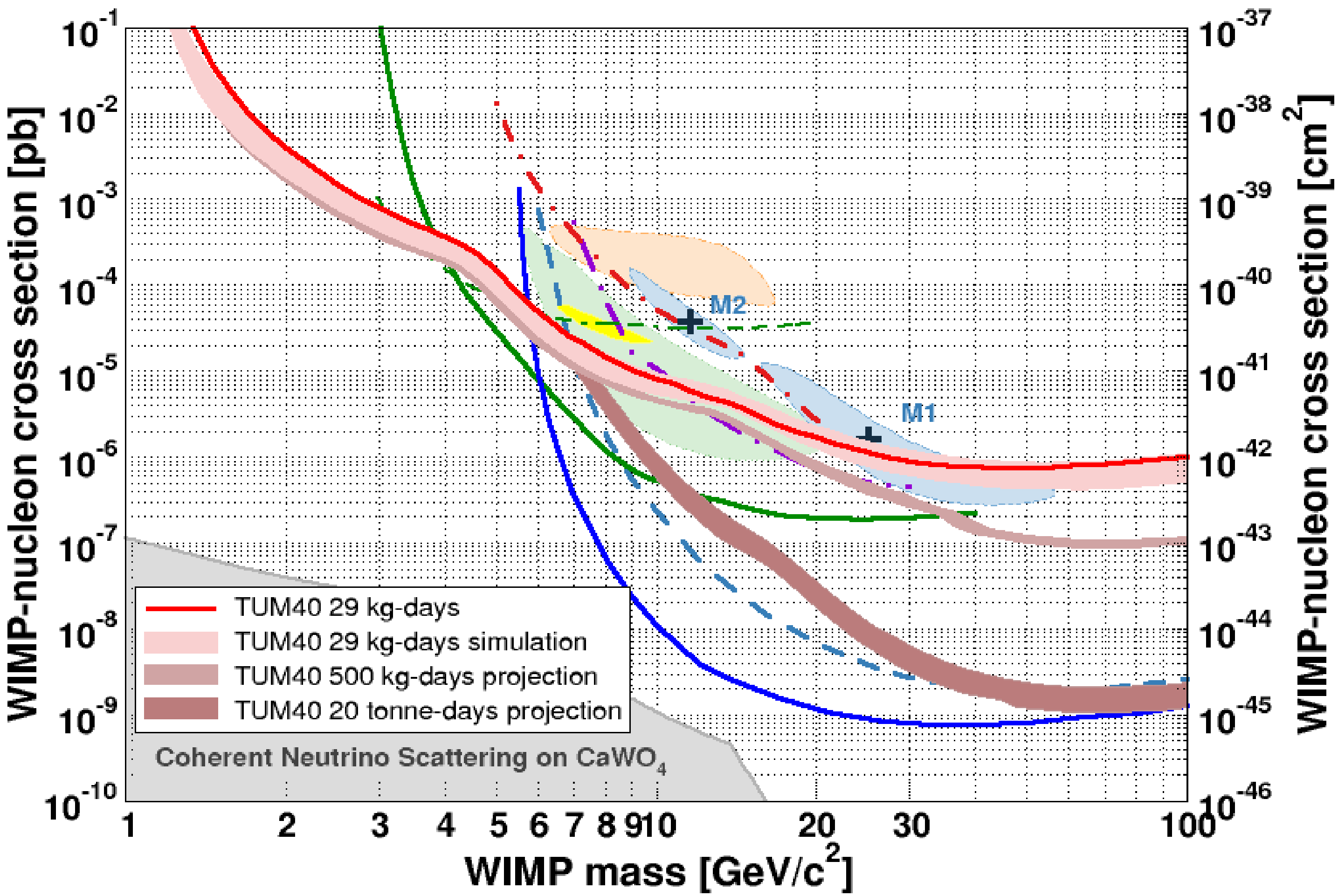



- 10kg-years high performance detector (2 years of running with ~200 small modules )

# Visions beyond 2020

Scenario: WIMP signal in the high mass region observed

**Unique multi-element target experiment to cross check a possible signal**




- 100kg detector (~300 state-of-the-art CRESST modules or 100 modules *O*(1kg))

# Visions beyond 2020

Scenario: Something else than WIMPs

**Detector for Coherent Neutrino Nucleus Scattering**

## Observation Requires a Visit by all Three Marias

- The experimental signature is a difficult to detect low-energy nuclear recoil
  - sub-keV to keV
- Low backgrounds
  - 1-1000 counts $keV^{-1}\,kg^{-1}\,d^{-1}$
- Large masses
  - 1 kg – 1 ton

This is really a question of how far you can push the detector technology…

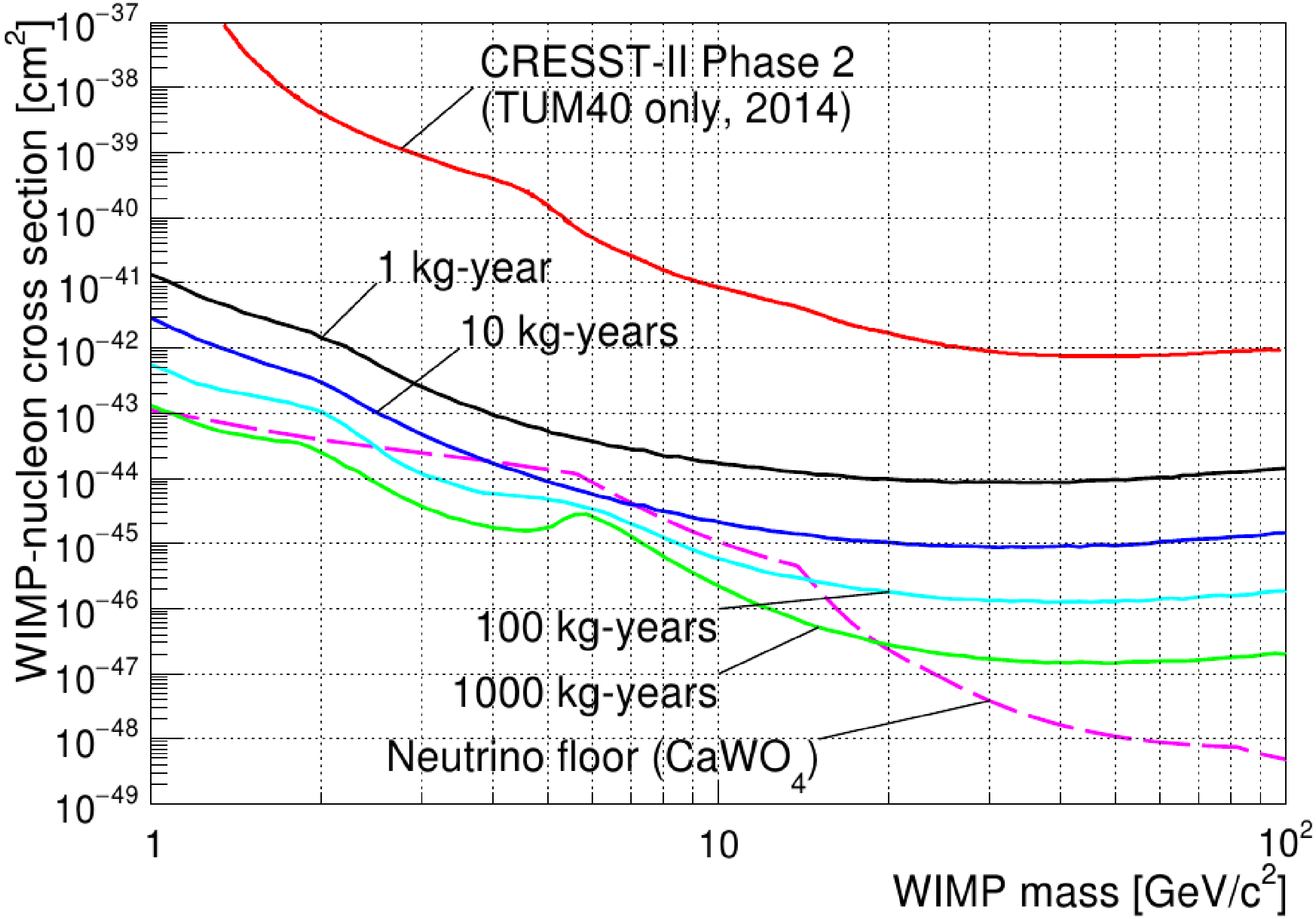
• P. S. Barbeau, Neutrino 2014 6/6/14 • 3

# Visions beyond 2020

Scenario: Something else than WIMPs

**Detector for Coherent Neutrino Nucleus Scattering**

Atmospheric and solar neutrinos



# Visions beyond 2020

Scenario: Something else than WIMPs

## Detector for Coherent Neutrino Nucleus Scattering

Atmospheric and solar neutrinos

| | Detection potential | | |
|---|---|---|---|
| **Exposure** | 99.9 % CL | 99.99 % CL | 99.9999 % CL |
| 10 kg-years | 12.8 % | 7.6 % | 3.3 % |
| 20 kg-years | 28.9 % | 19.7 % | 9.3 % |
| 30 kg-years | 44.6 % | 29.9 % | 16.5 % |
| 40 kg-years | 61.1 % | 45.2 % | 23.7 % |
| 50 kg-years | 73.4 % | 57.9 % | 34.0 % |
| 60 kg-years | 80.8 % | 68.0 % | 42.1 % |
| 70 kg-years | 89 % | 79.4 % | 55.1 % |
| 80 kg-years | 91.7 % | 83.2 % | 64.9 % |
| 90 kg-years | 96.1 % | 90.6 % | 70.5 % |
| 100 kg-years | 97.4 % | 92.7 % | 77.2 % |

probability to observe a data-set which allows a detection of CNNS at the desired CL

- 50kg-years high performance detector (2 years of running with ~1000 small modules )

# Visions beyond 2020

Scenario: Something else than WIMPs

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probability to observe a data-set which allows a detection of CNNS at the desired CL

**4 years of running with ~500 small modules**

- 50kg-years high performance detector (~~2 years of running with ~1000 small modules~~ )

# Ce source

Scenario: Something else than WIMPs

**Detector for Coherent Neutrino Nucleus Scattering**

Artificial neutrino source

Source "a la SOX"

- Radioactive $^{144}$Ce-$^{144}$Pr source

$$^{144}\mathrm{Ce} \rightarrow {}^{144}\mathrm{Pr} + e^{-} + \bar{\nu}_e (Q = 318.7,\mathrm{keV},\ T_{1/2} = 284.91\,\mathrm{d})$$

$$^{144}\mathrm{Pr} \rightarrow {}^{144}\mathrm{Nd} + e^{-} + \bar{\nu}_e (Q = 2997.5,\mathrm{keV},\ T_{1/2} = 17.28\,\mathrm{min})$$

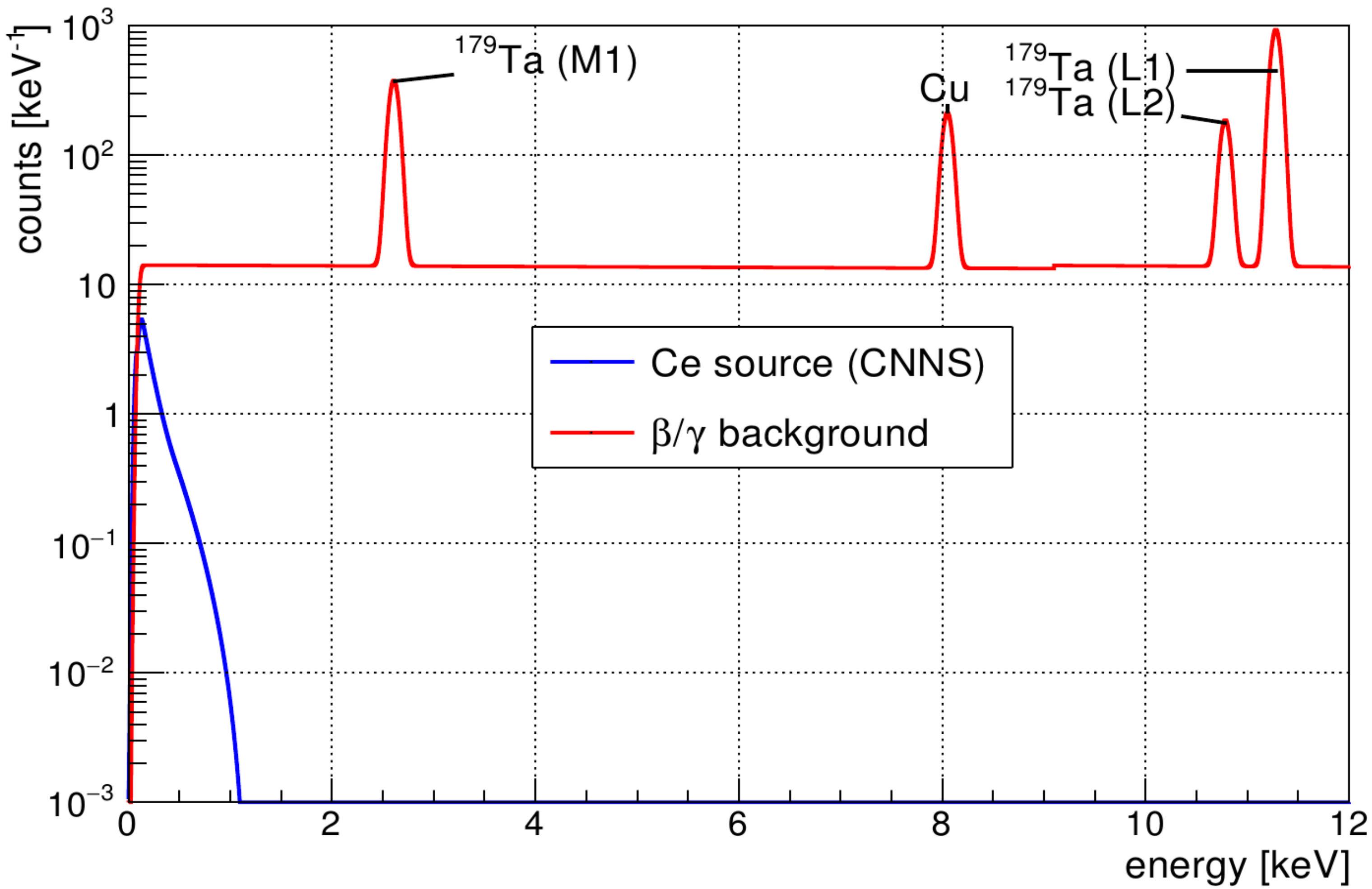
- Activity: 100kCi
- Distance: 2m
- Exposure: 1 year with 100 small modules
- Threshold: 100eV

# Ce source

Scenario: Something else than WIMPs

### Detector for Coherent Neutrino Nucleus Scattering

Artificial neutrino source



# Conclusions

## Leading role in the field of dark matter search

No direct WIMP signal observed until 2020

- reach the solar neutrino floor
- potential to measure the solar neutrino coherent scattering

WIMP signal observed until 2020

- precision measurement with already existing detectors

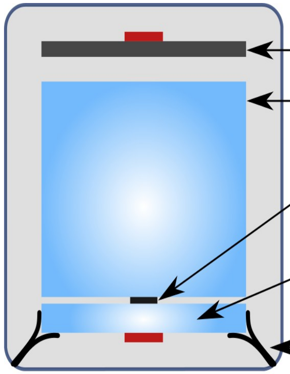
# Additional material

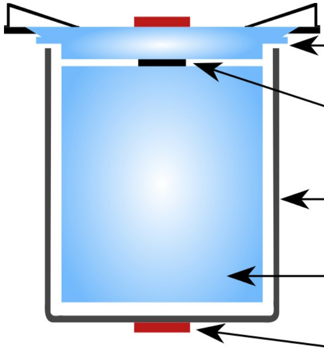
# Active modules

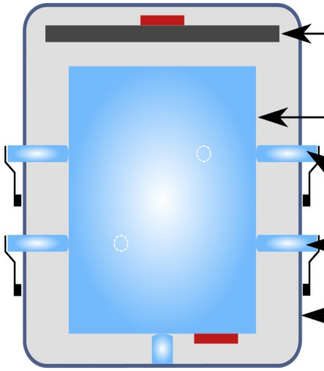
Active modules (6 modules):

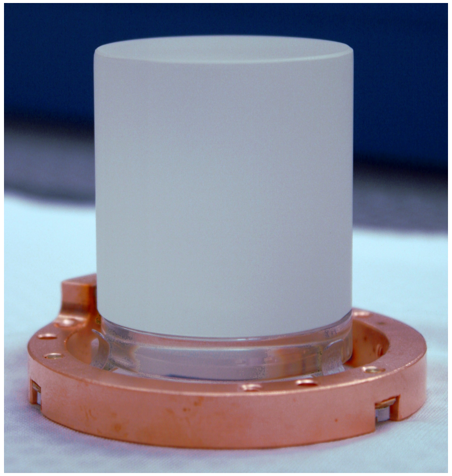
- Crystal Clamped on Carrier
- Silicon Beaker Light Detector
- Crystal Held by Sticks

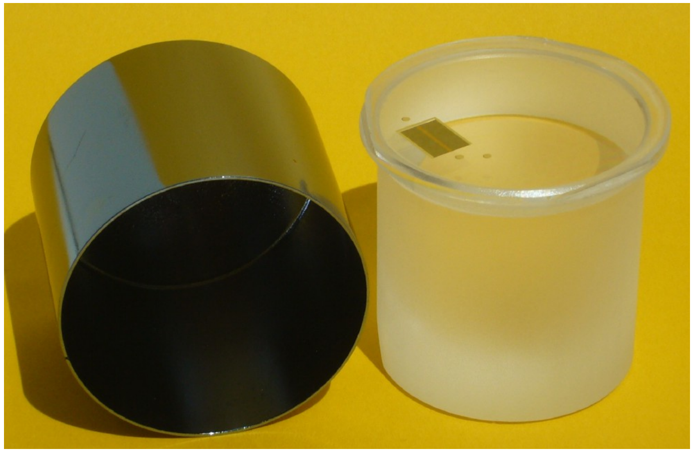
Tag alpha decays originating from all inner surfaces fo the detector module

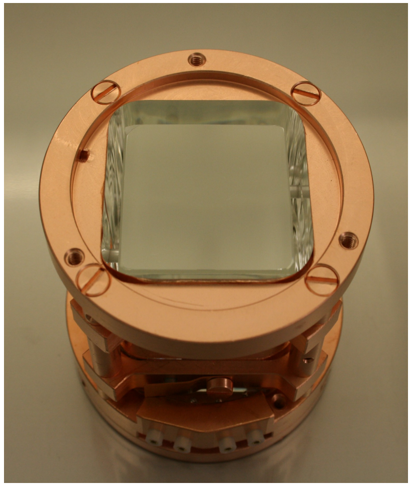


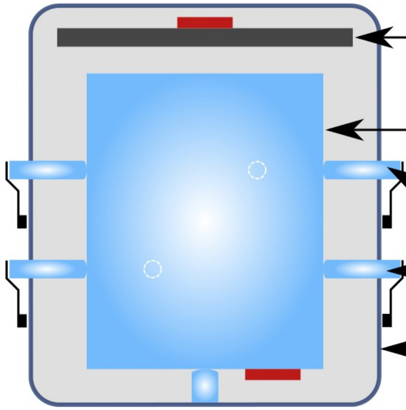



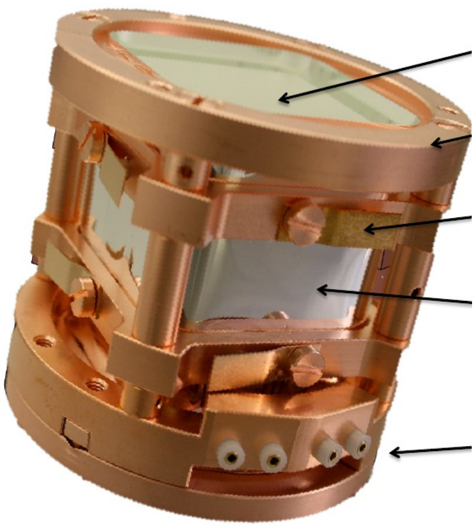







# First results: detector module




Non-blind dataset of ≈ 29 kg days:

- no surface background
- best radiopurity (≈ 3.5 /[kg keV day])
- low trigger threshold (≈ 600 eV)
- excellent resolution (σ ≈100 eV at 2.6 keV)

➡ Low threshold analysis

arXiv:1410.1753 [physics.ins-det]

arXiv:1410.4188 [physics.ins-det]

# Self grown crystal - TUM40

$^{181}W + e^- \rightarrow {}^{181}Ta + \nu_e + \gamma$ (121d)

L-shell
11.7 keV + 6.2keV

K-shell
67.4 keV +6.2keV

$^{179}Ta + e^- \rightarrow {}^{179}Hf + \nu_e$ (1.8y)

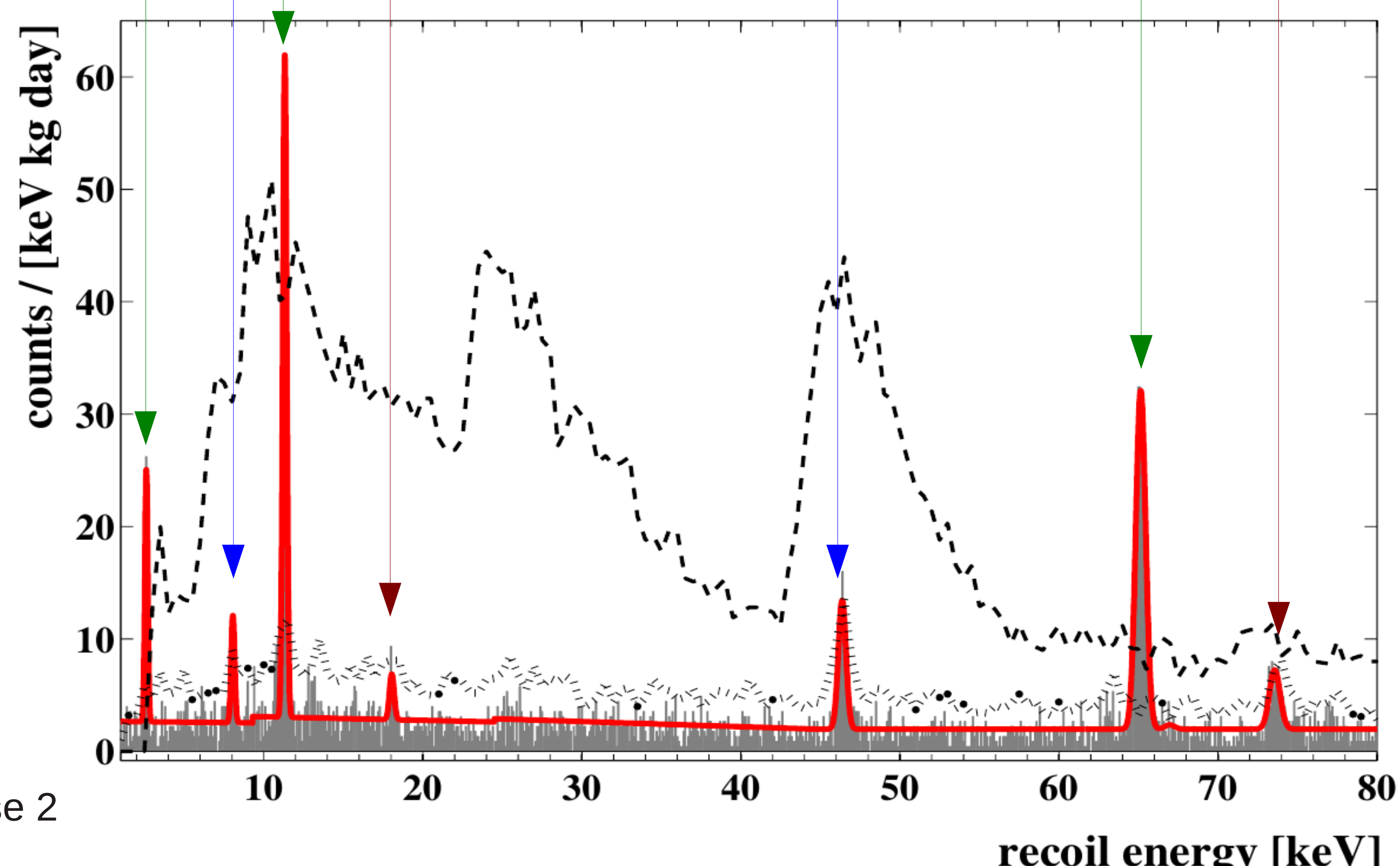
M-shell
2.6 keV

L-shell
11.3 keV

K-shell
65.4 keV

Cu X-ray
8.0 keV

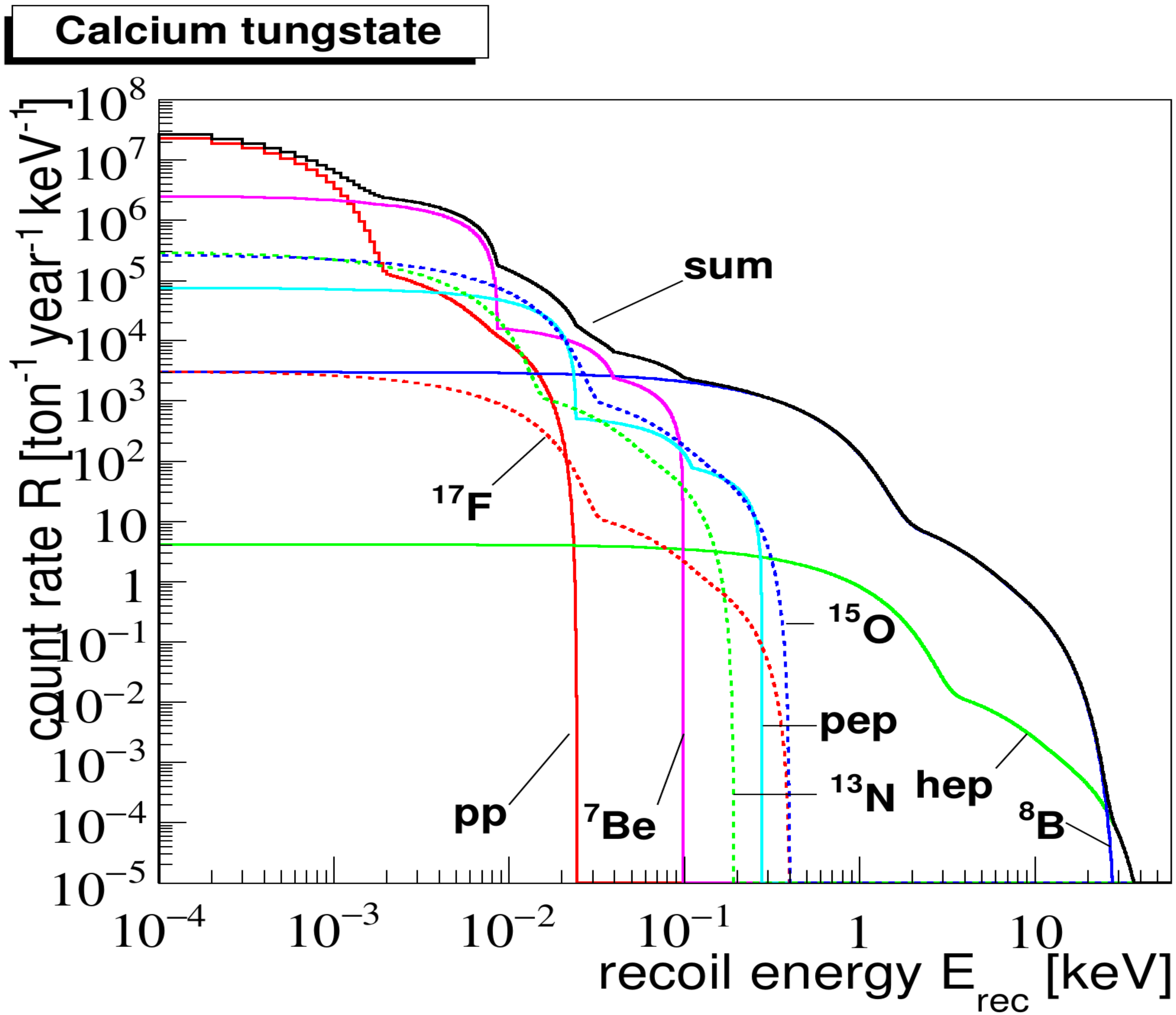
$^{210}$Pb
46.5 keV




Electron/gamma and alpha backgrounds in CRESST-II Phase 2

arXiv:1410.4188 [physics.ins-det]

# Solar neutrino recoil spectra



# Count rate above threshold