ICHEP 2022 BOLOGNA

RES-NOVA

Detecting Supernova neutrinos with archaeological Pb-based cryogenic detectors

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Supernovae: cosmic fireworks

Setting the stage

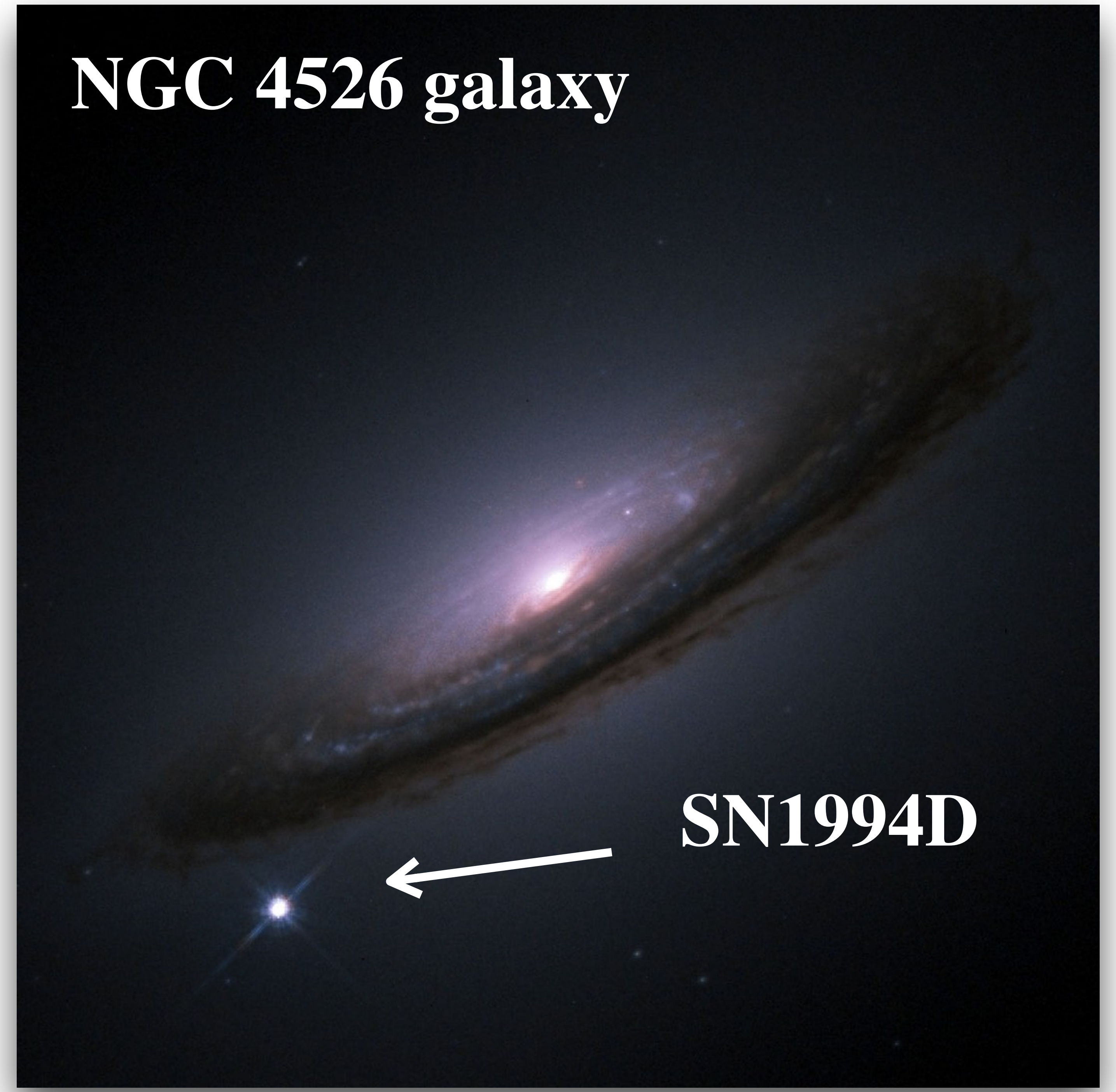
Supernovae (SN): high-energy **explosions of massive stars**

Almost total star binding energy converted into **all flavor-neutrinos**
but also **GW** and **EM** radiation

Neutrinos: direct **probes** and **messengers** of SNe hidden dynamics

Rare event (~1.6 SN/100 y): **1 observation** with underground instrumentation

1987 Birth of
Neutrino Astronomy



Credit: NASA/ESA, The Hubble Key Project Team and The High-Z Supernova Search Team

SN neutrino detection nowadays

Same technology for the last 35 years

First observation SN1987A @ 50 kpc ➜ **~25 $\overline{\nu}_e$ events**

Nobel Prize in Physics
"... for the detection of
cosmic neutrinos"

Detectors: Kamiokande, IMB, Baksan

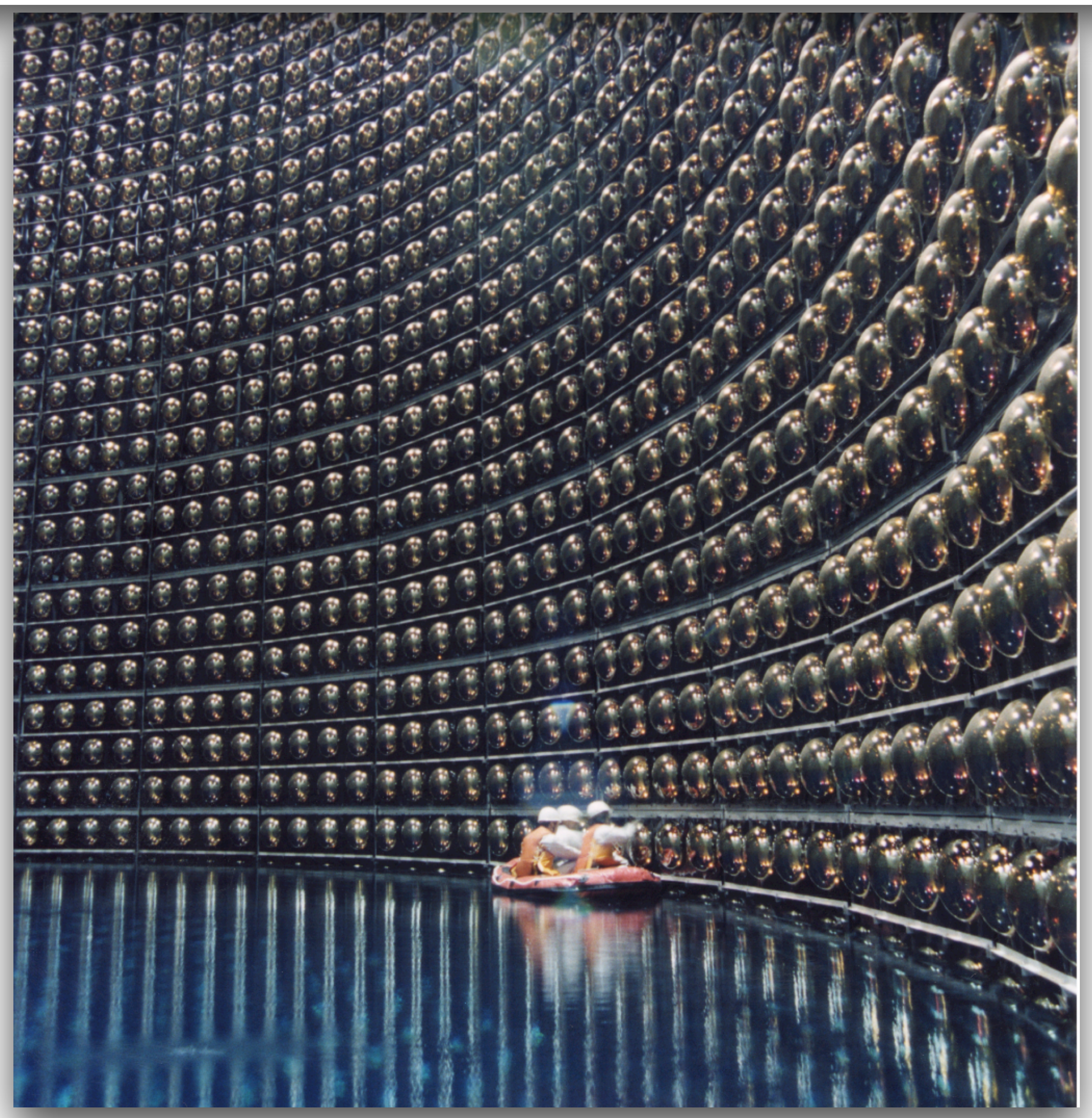
Technology: Water Cherenkov & Liquid Scintillator

Detection Channel: $\overline{\nu}_e + p \rightarrow n + e^+$ (Inverse-β decay)

Detector Volume: monolithic (10 m)^3

@ 1987

Conventional neutrino detector



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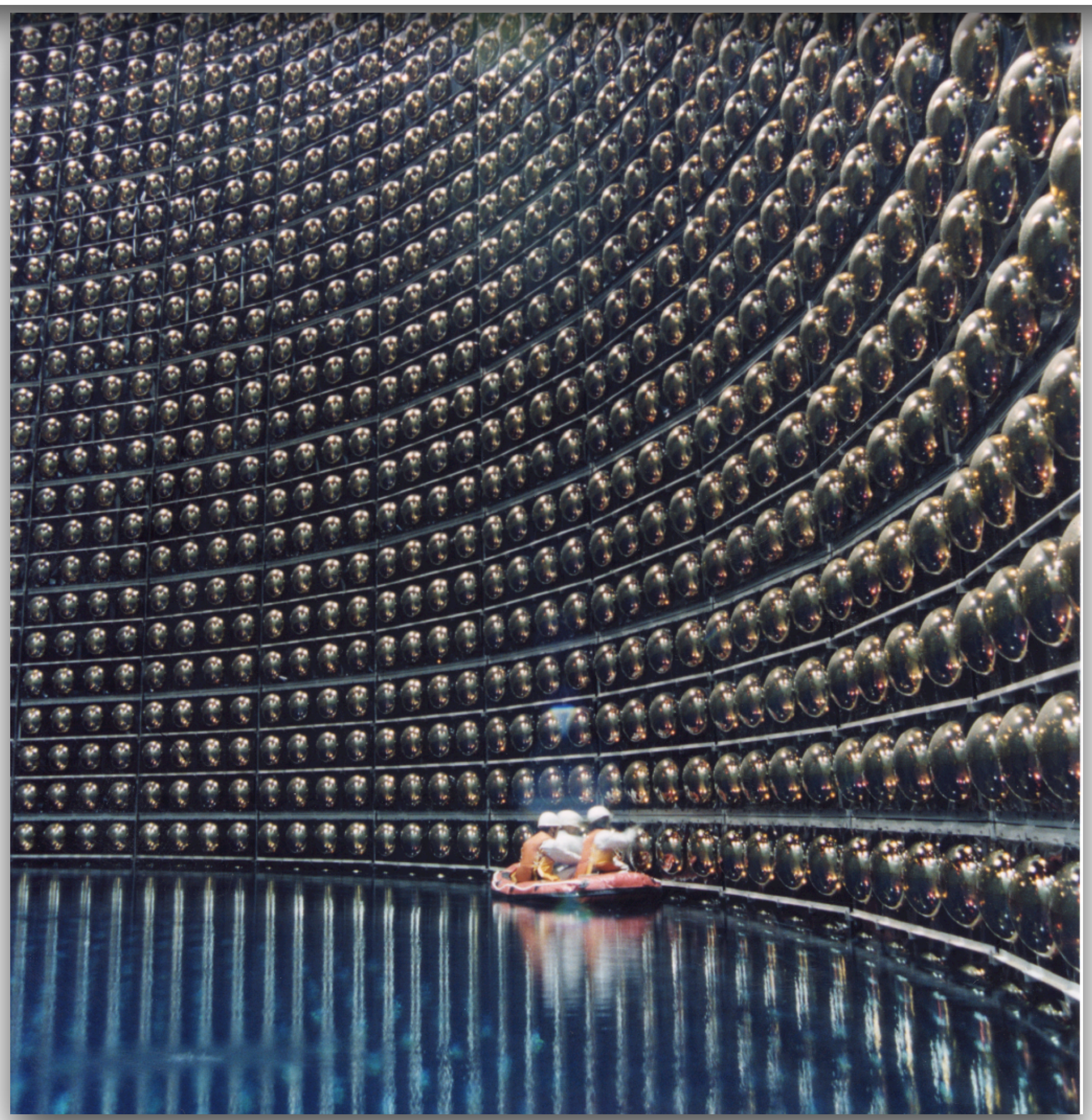

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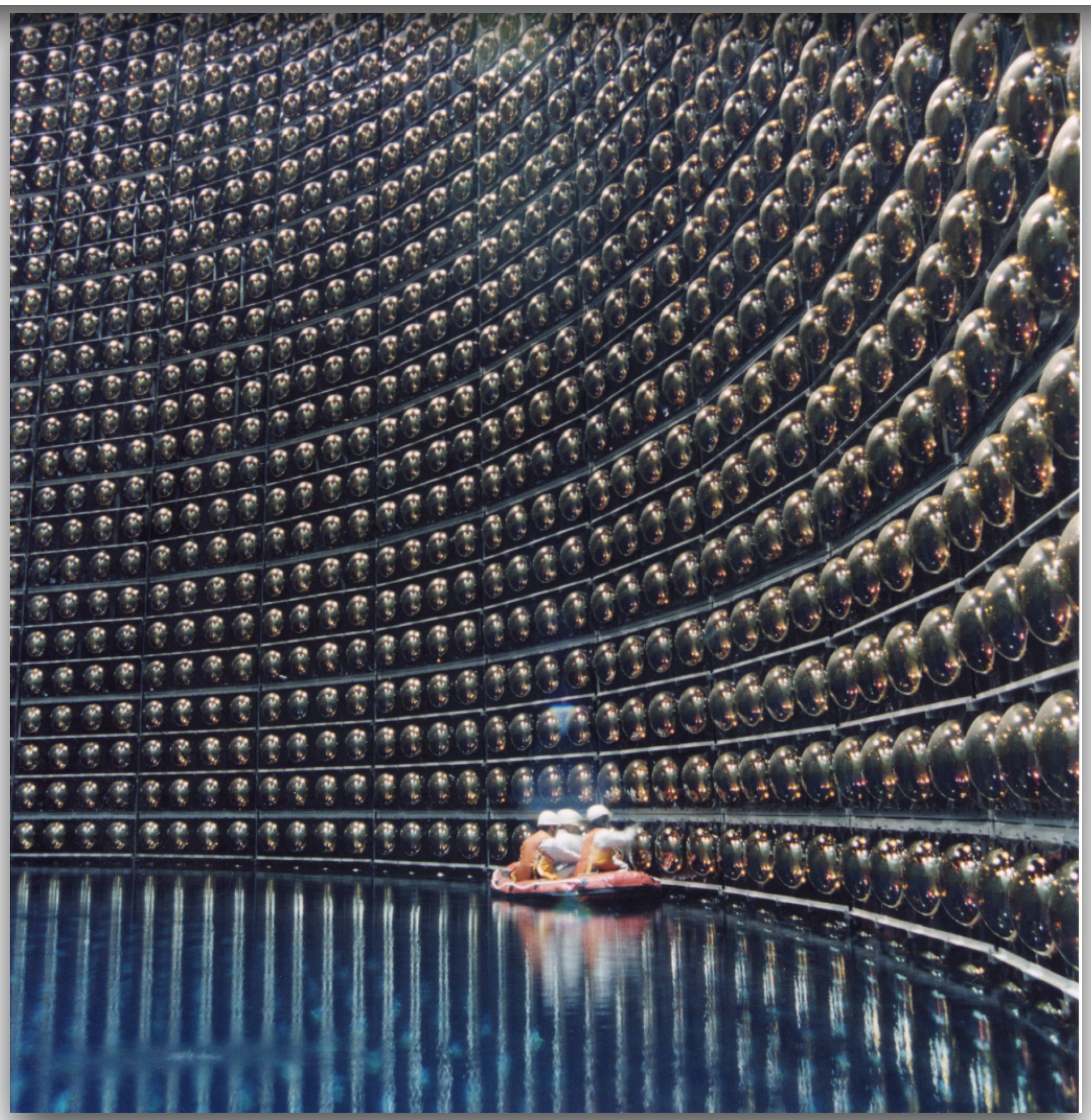
Need for a **new technology:**

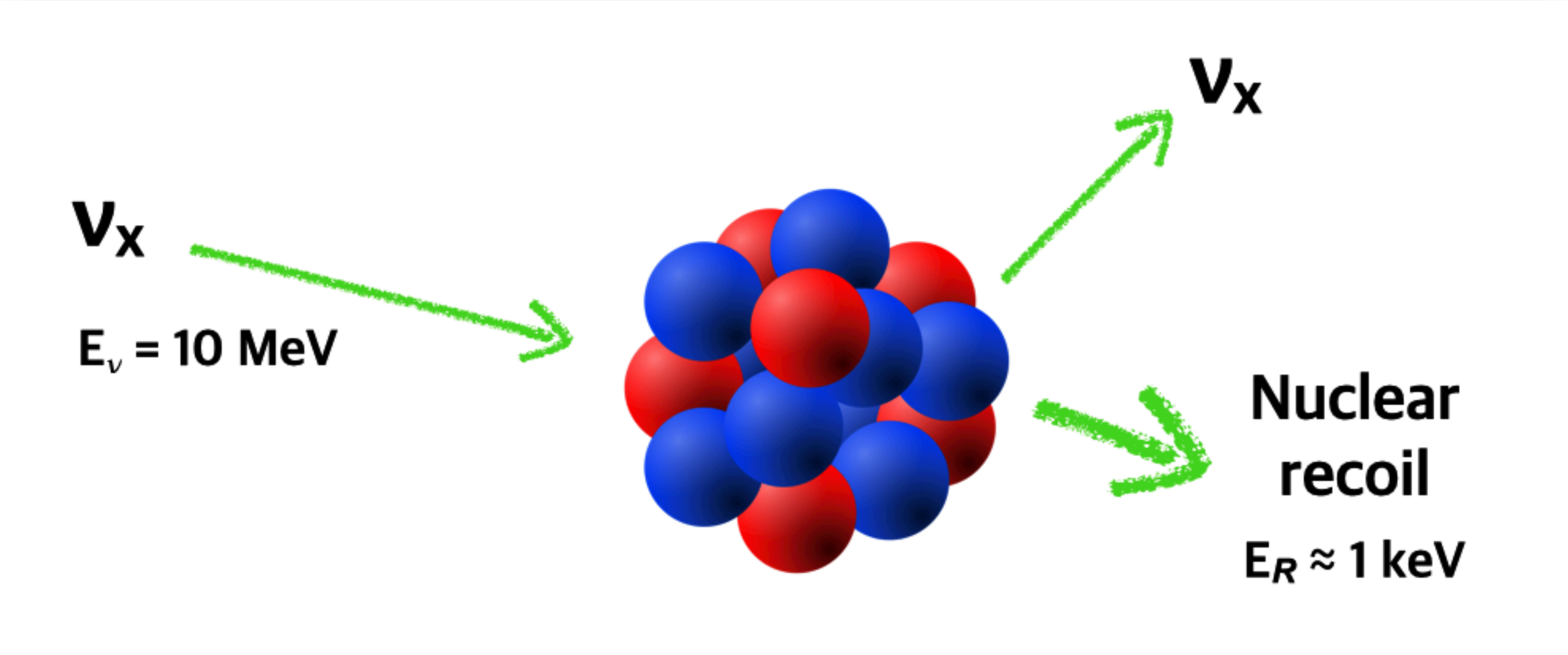
- ☐ All flavor neutrino detection
  $\nu_{\mu/\tau}$ / $\overline{\nu}_{\mu/\tau}$ most energetic and abundant component
- ☐ High neutrino cross-section
- ☐ Sensitivity to near (~3 kpc) and far (>50 kpc) SNe

Conventional neutrino detector



Coherent Neutrino-Nucleus Scattering

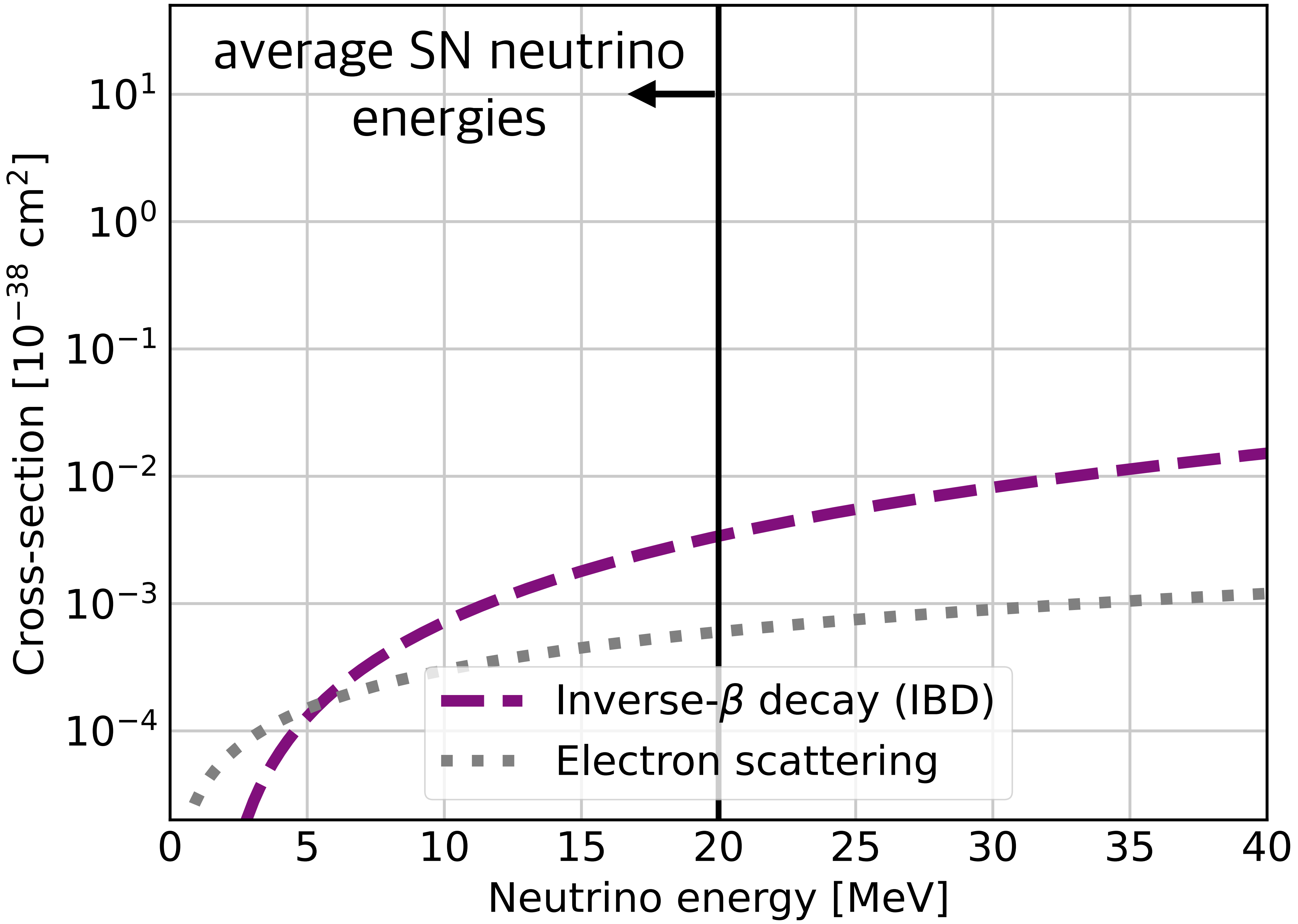
RES-NOVA detection channel



cross-section

$$\sigma \propto N^2$$

neutron number

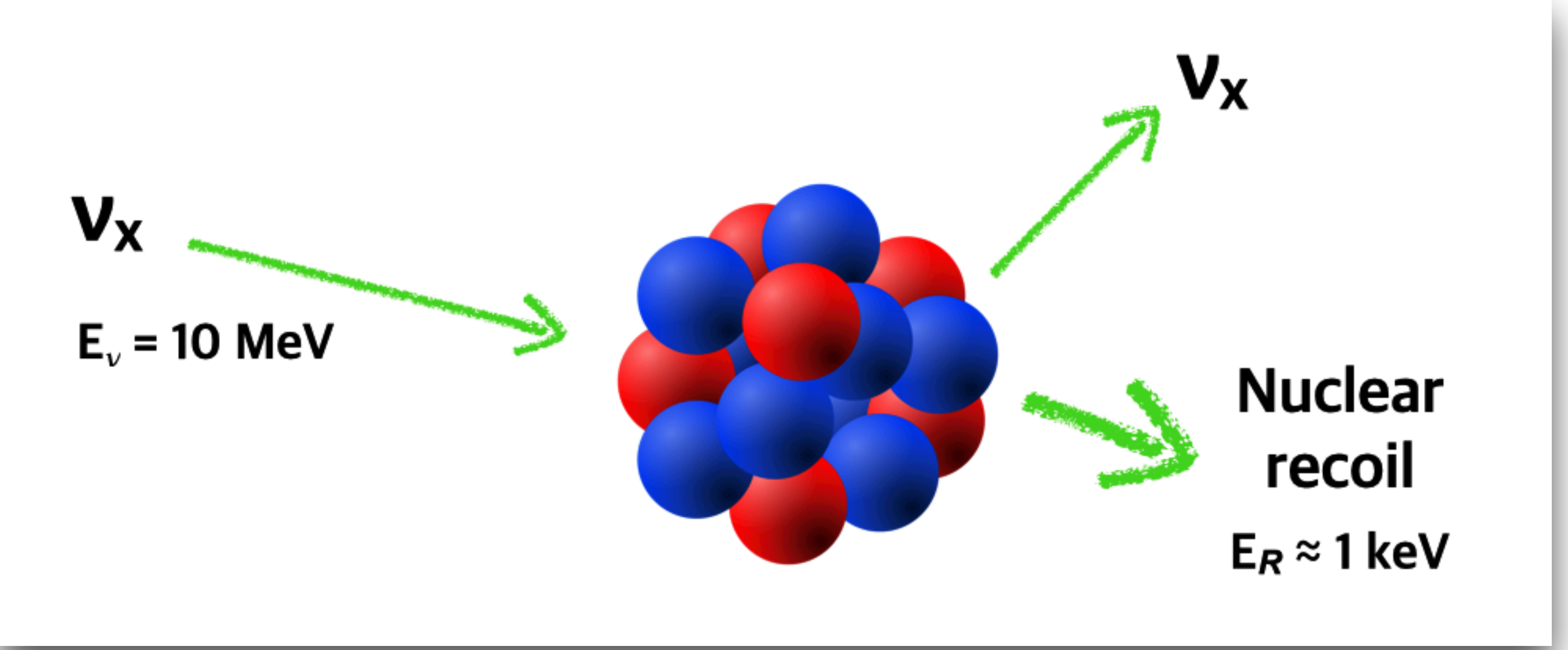


> Equally sensitive to all ν-flavors

> High interaction cross-section

Coherent Neutrino-Nucleus Scattering

RES-NOVA detection channel



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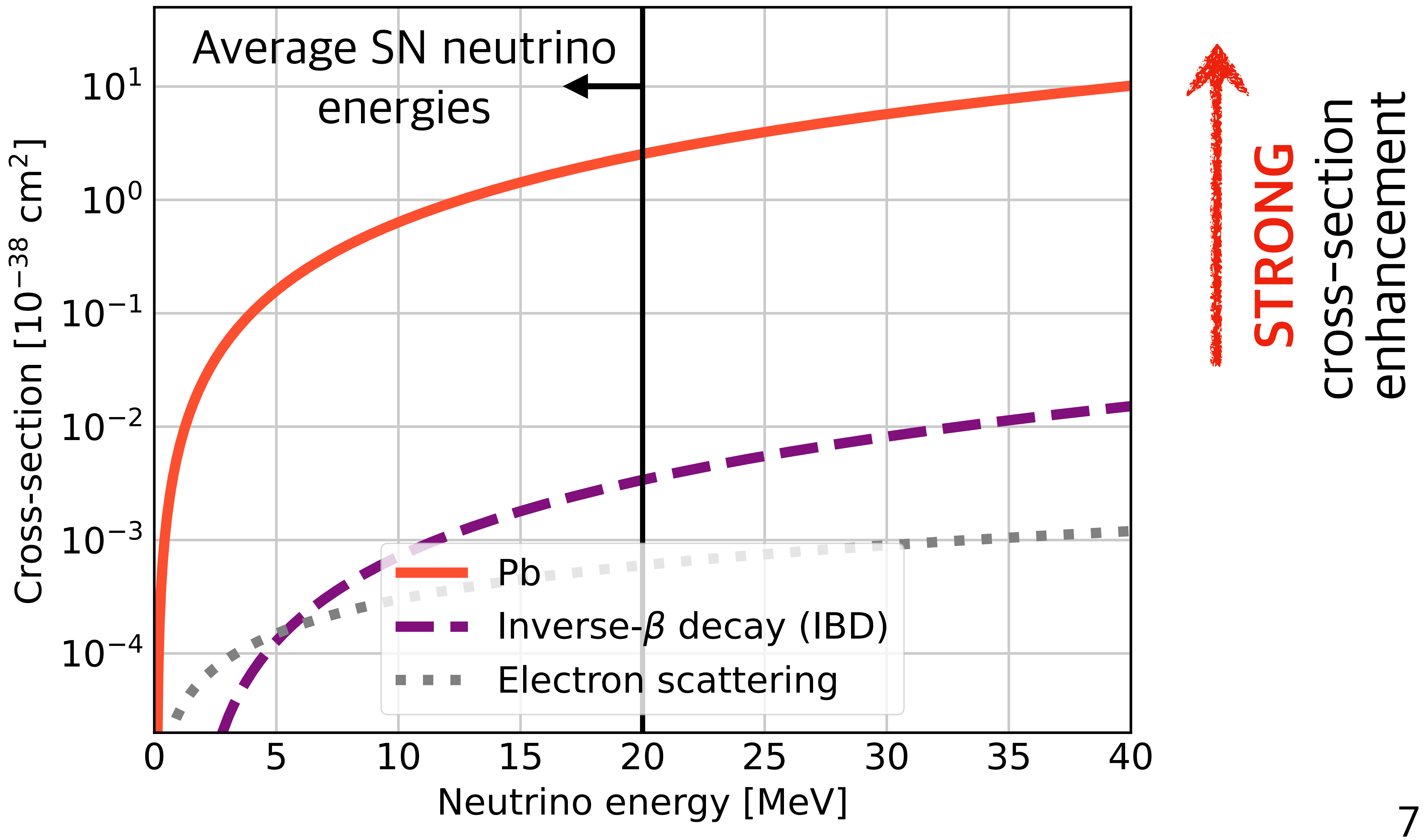


Pb ideal target

Highest neutron number

Highest nuclear stability

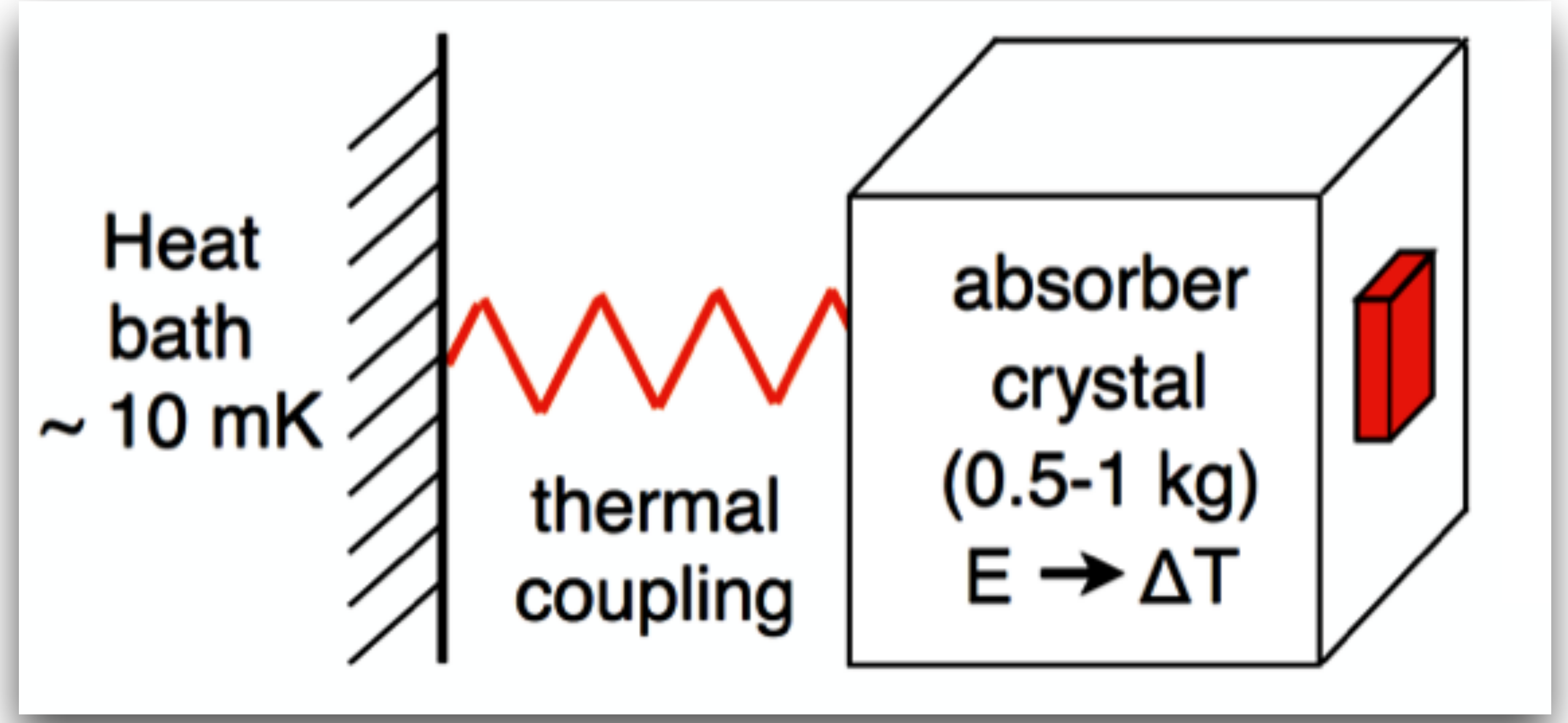
RES-NOVA detector technology

Advanced Cryogenic Detectors

Cryogenic calorimeters made from Pb

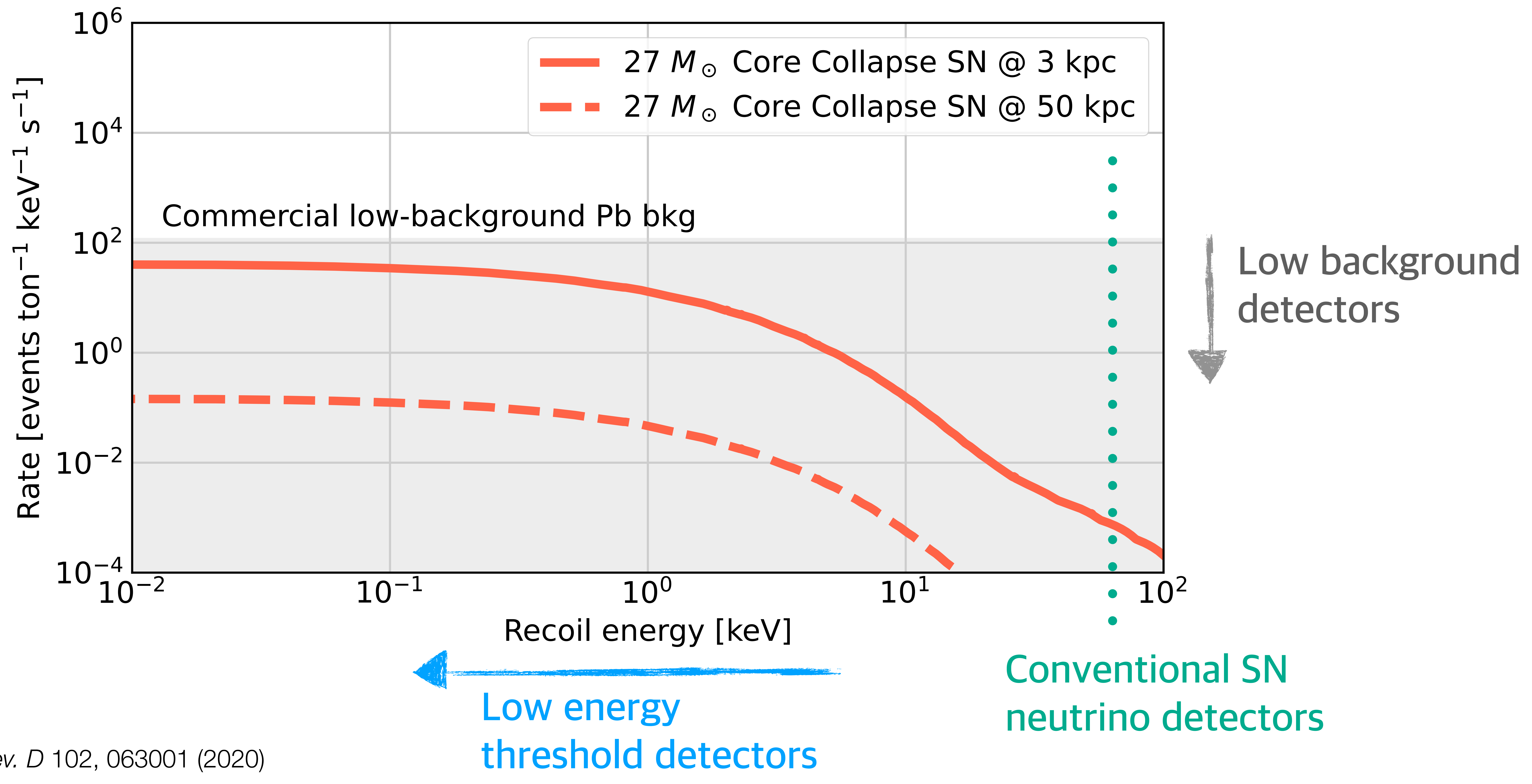
Thermometer at mK
Transition Edge Sensor
low-threshold DM technology

High-radiopurity crystal
$PbWO_4$
low-background DBD technology



RES-NOVA: the challenges

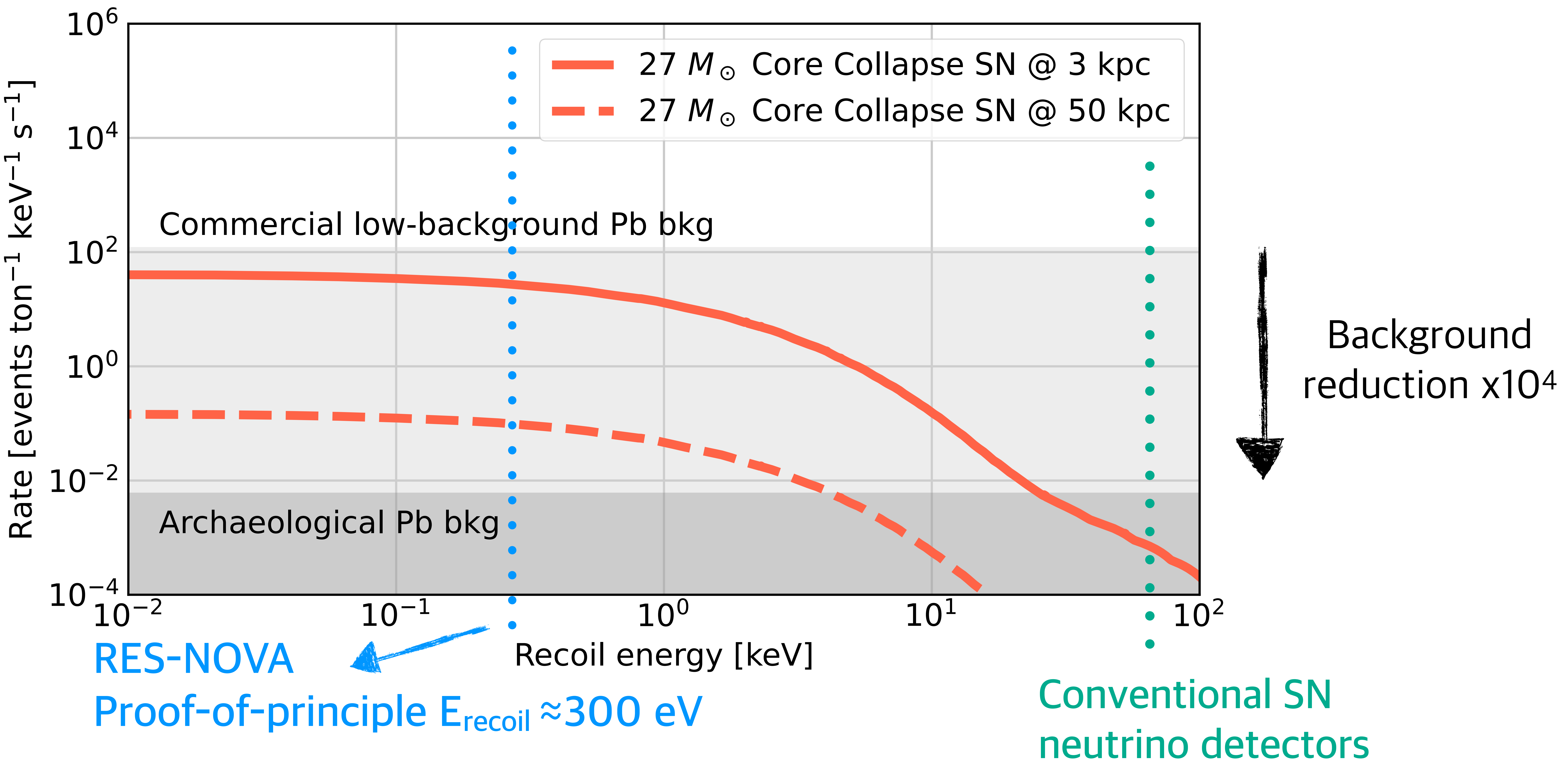
Neutrino signal rate in RES-NOVA



L. Pattavina et al., *Phys. Rev. D* 102, 063001 (2020)
L. Pattavina et al., JCAP 10, 064 (2021)

RES-NOVA: the potential

Neutrino signal rate in RES-NOVA



L. Pattavina et al., *Phys. Rev. D* 102, 063001 (2020)

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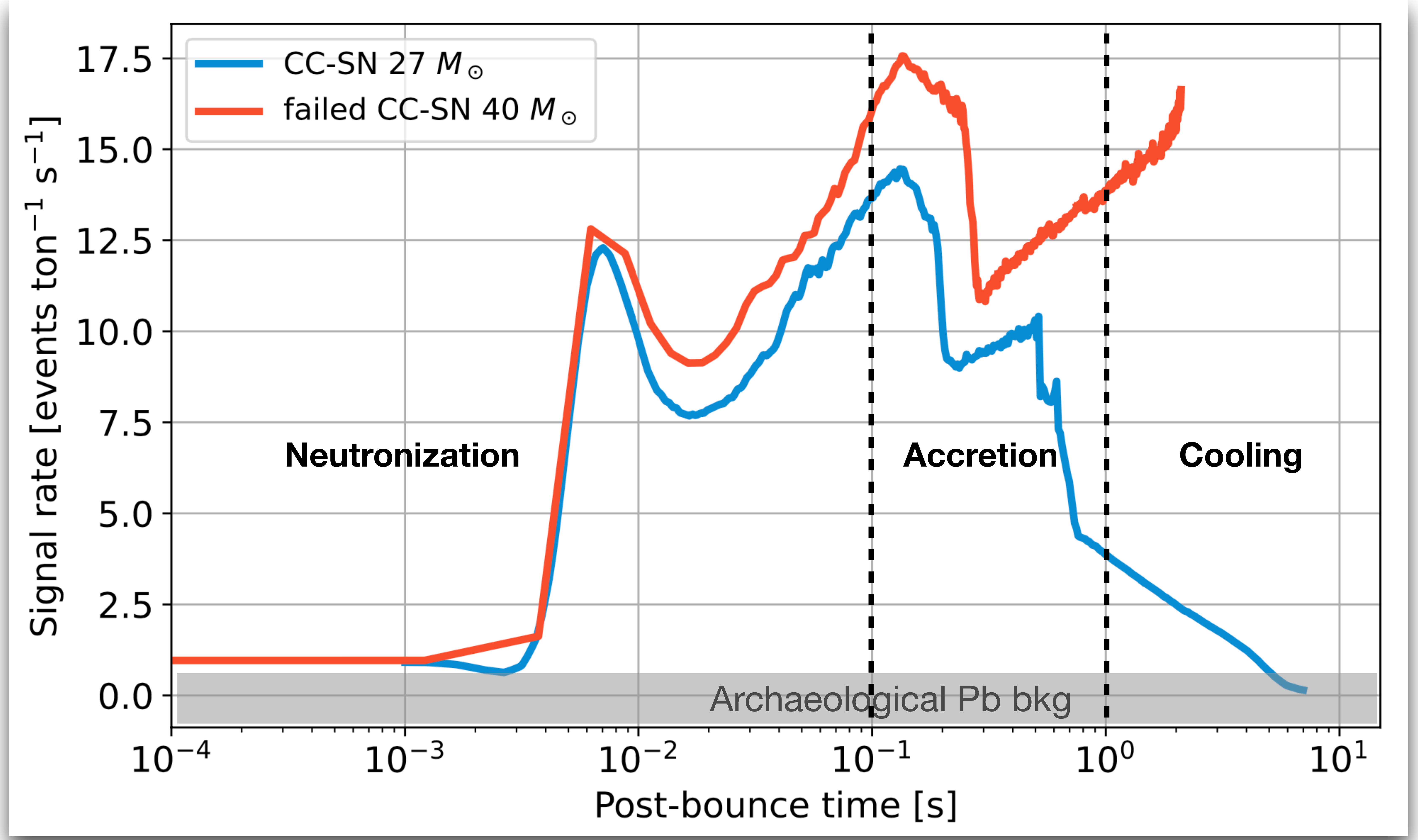
RES-NOVA: THE POTENTIAL

NEUTRINO SIGNAL RATE IN RES-NOVA



L. Pattavina et al., JCAP 10, 064 (2021)

RES-NOVA first prototype

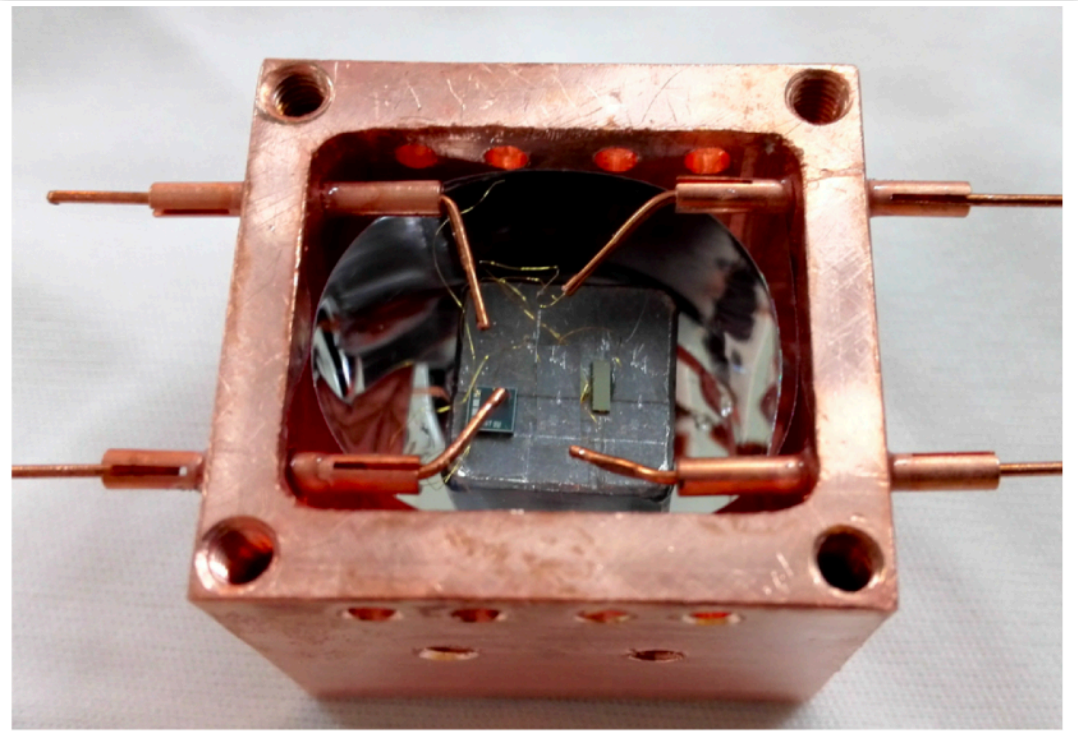
Archaeological Pb cryogenic detector

N. Nosengo, Nature (2010)

Archaeological Roman Pb:

- ★ from underwater shipwreck
- ★ 2000 years old

Archaeo-Pb
cryogenic detector



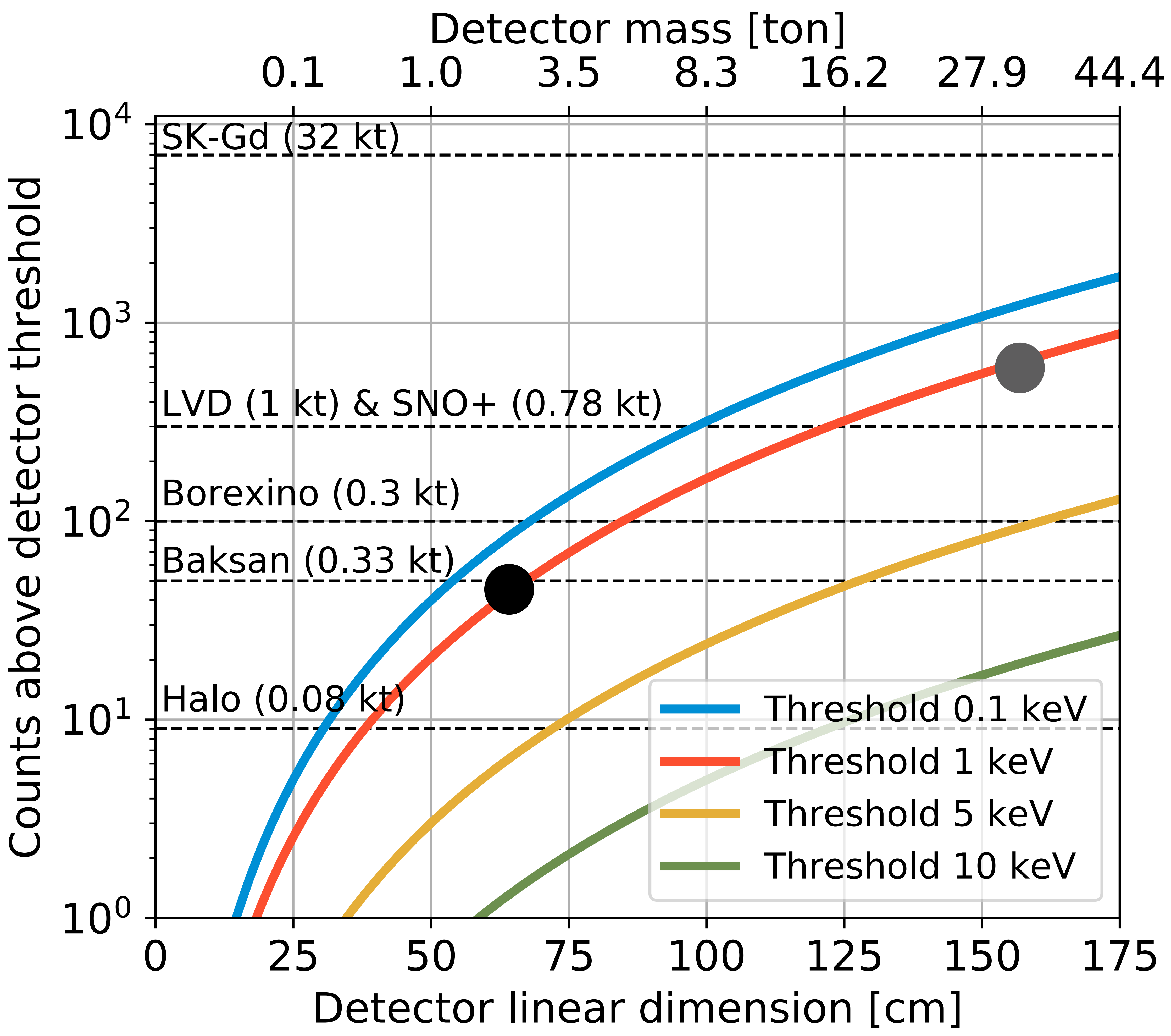
High radiopurity: < 1 mBq/kg

x10^4 better than commercial low-background Pb

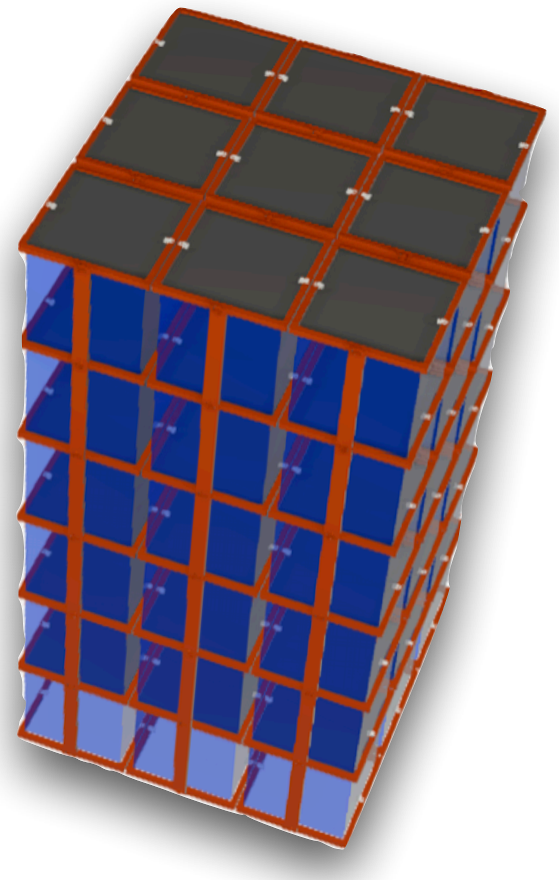
L. Pattavina et al.,
Eur. Phys. J. A 55, 127 (2019)

RES-NOVA: The Detector

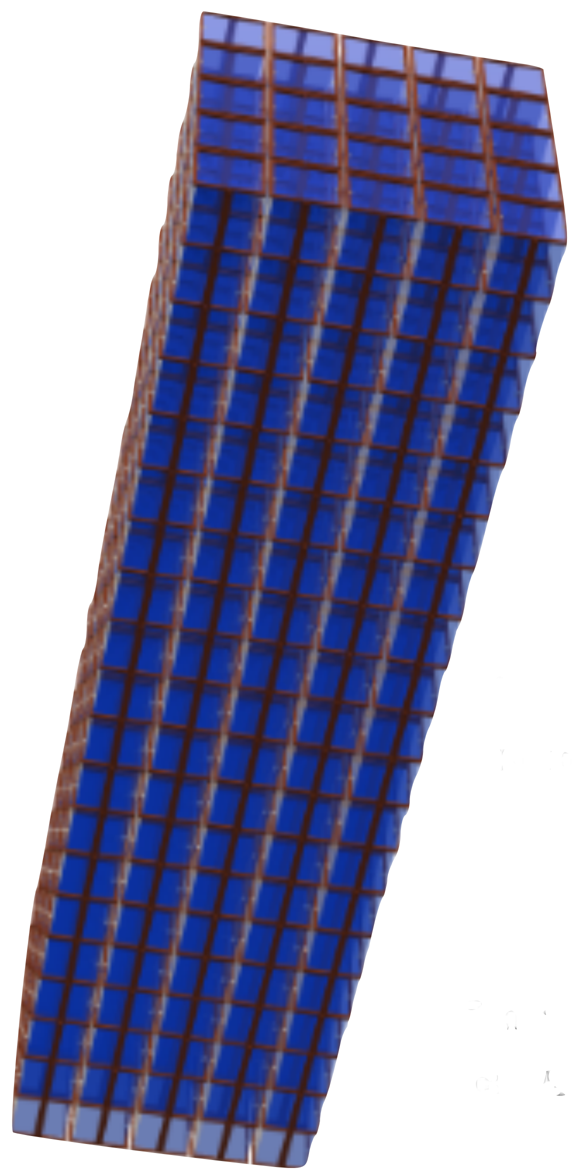
an array of $PbWO_4$ crystals



	RN-1 @ LNGS
Size:	$(60\ \text{cm})^3$
Threshold:	1 keV
SN @ 10 kpc:	~50 counts



	RN-2 @ LNGS
Size:	$(140\ \text{cm})^3$
Threshold:	1 keV
SN @ 10 kpc:	~600 counts

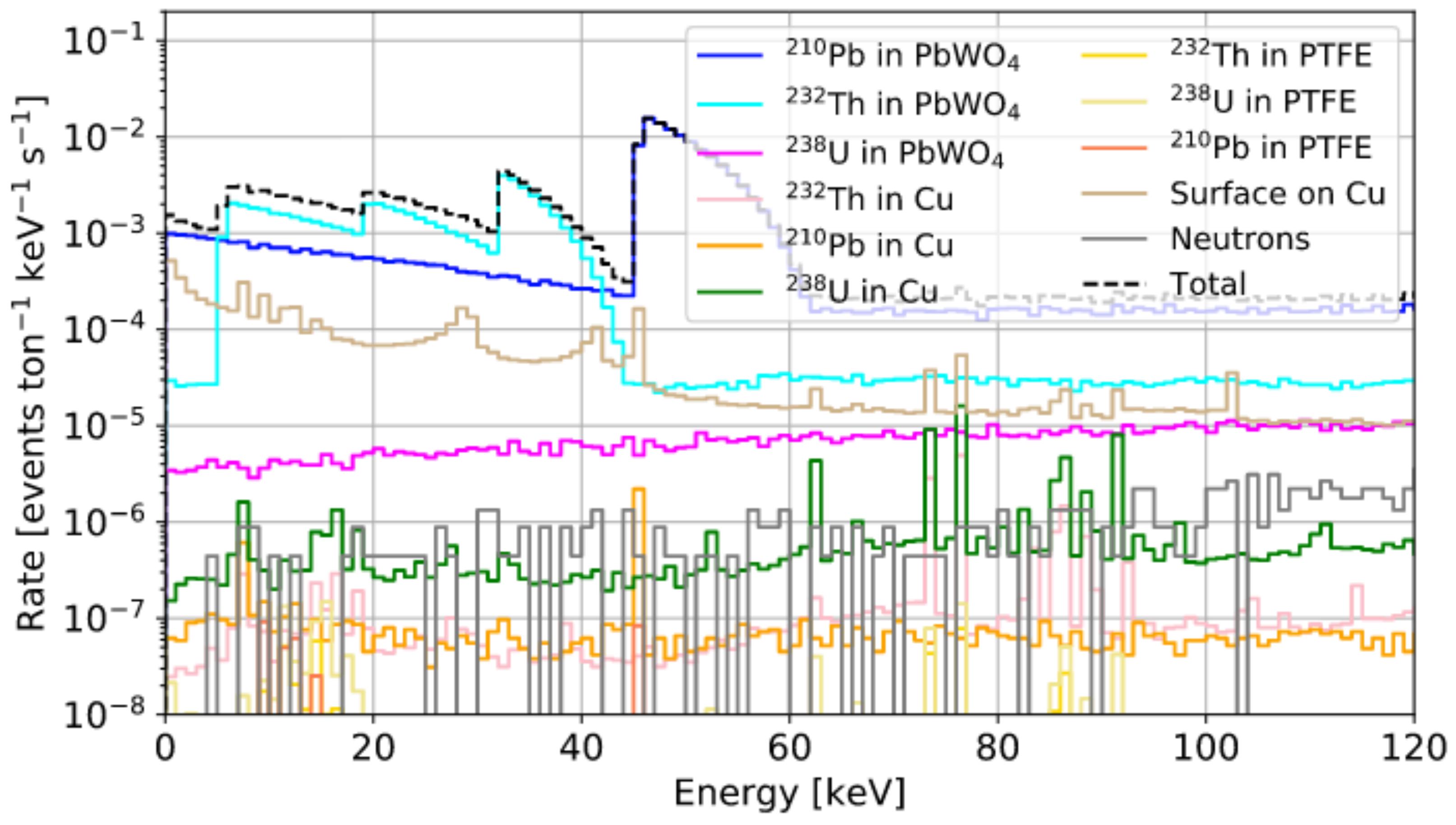


L. Pattavina et al., *Phys. Rev. D* 102, 063001 (2020)

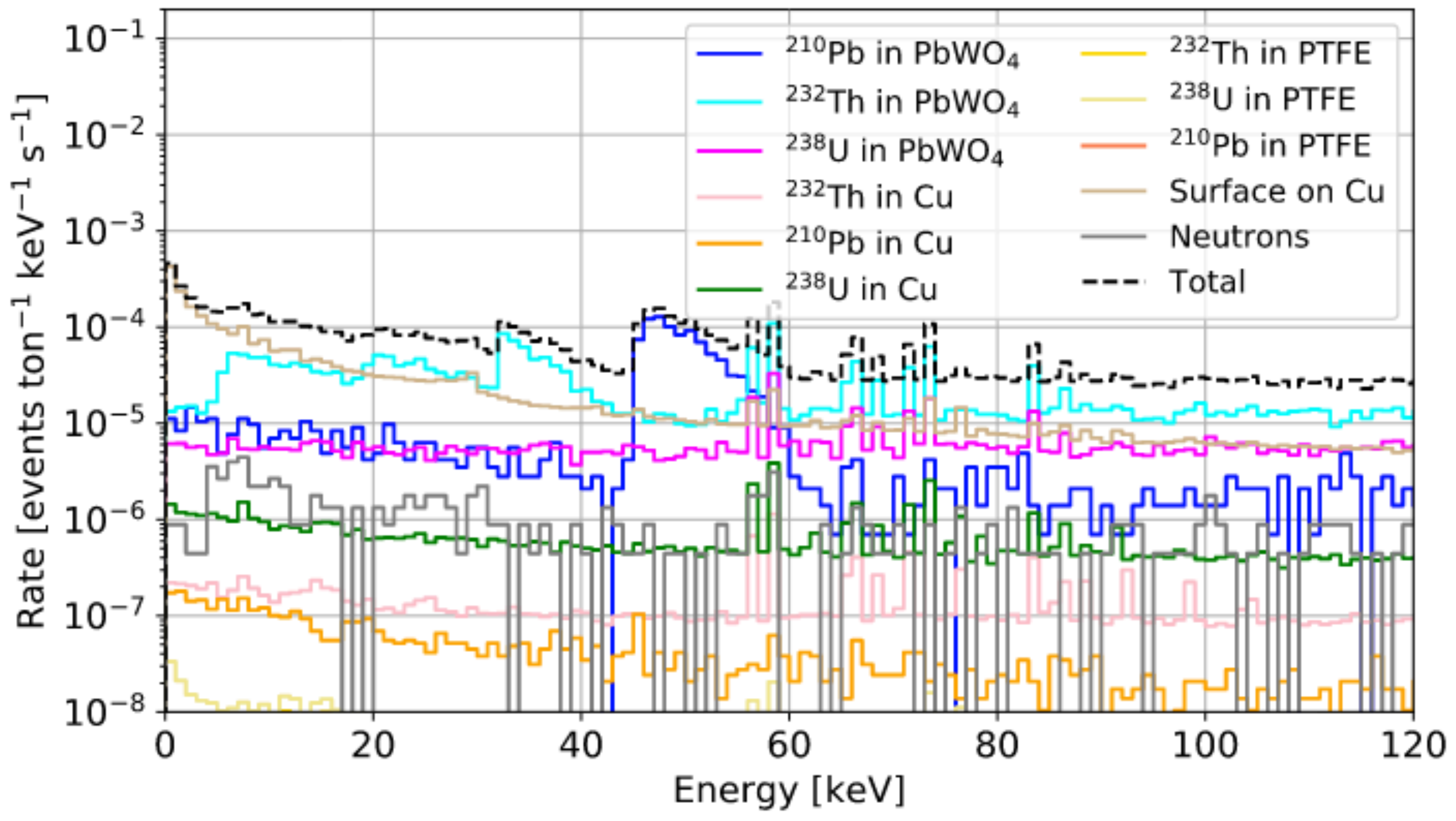
RES-NOVA background budget

Simulation of main background components

Multiplicity 1 total energy spectrum

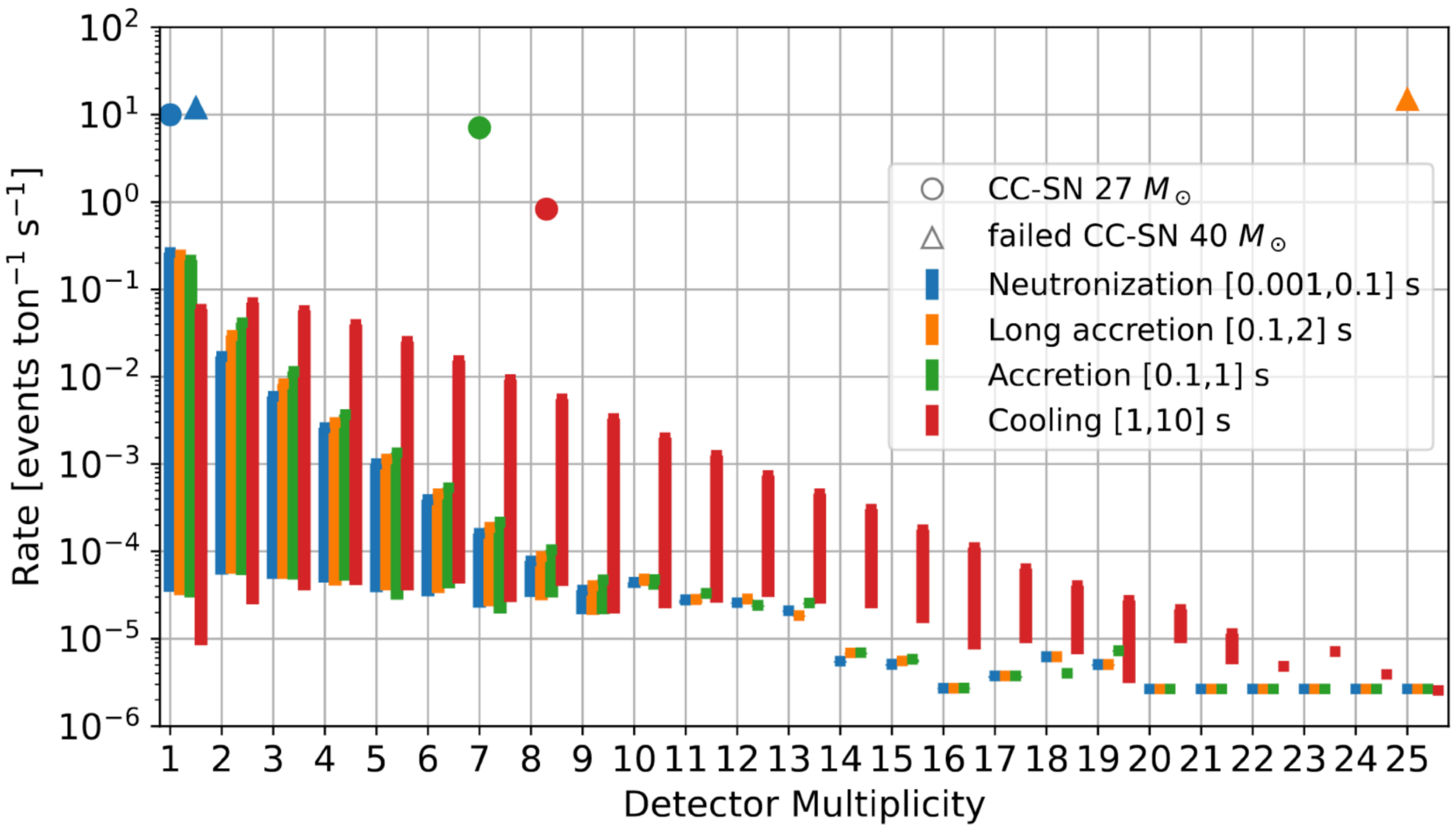


Multiplicity 4 total energy spectrum



Main background [1,30] keV : crystal radioactive impurities

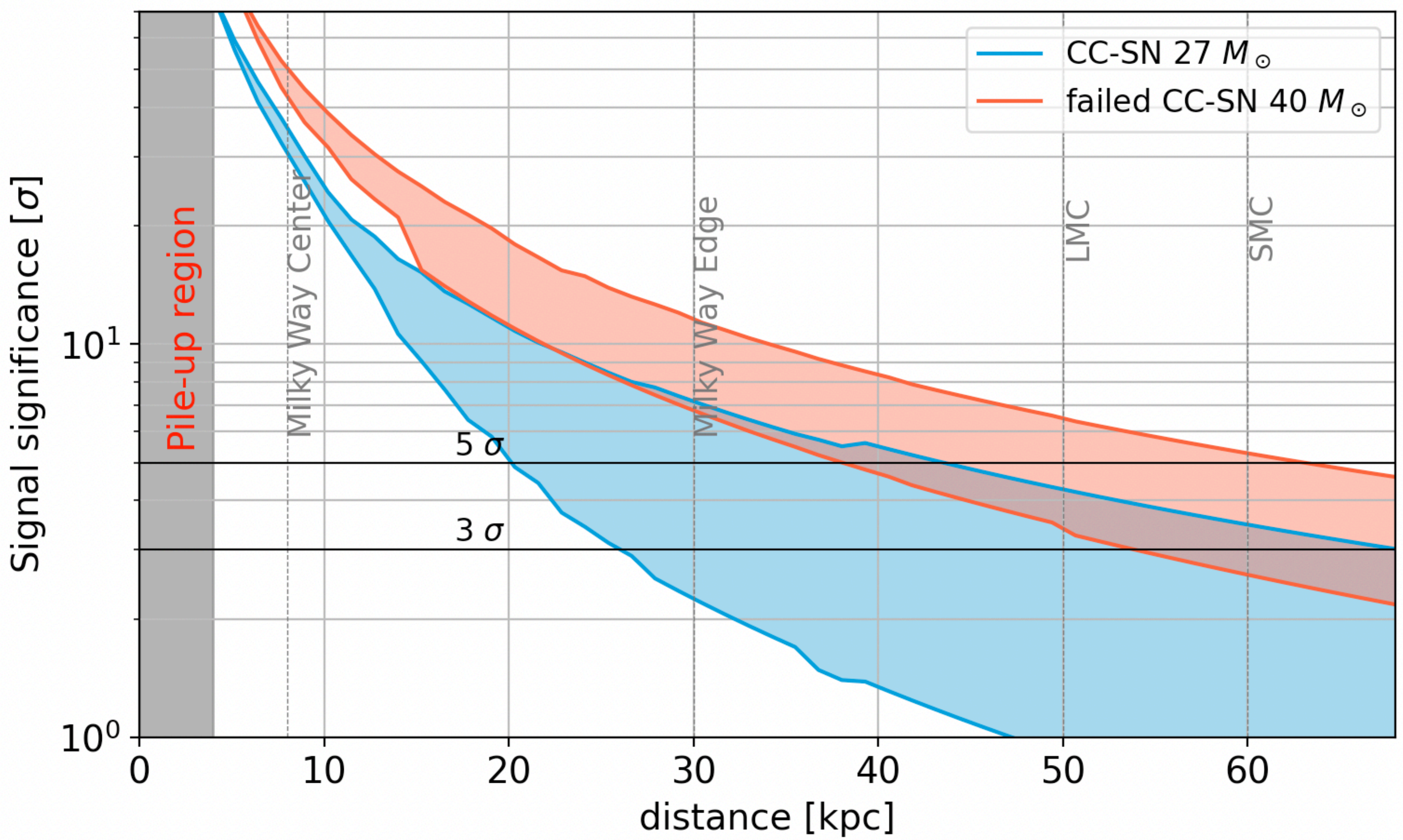
Coincidence selection ➜ Strong background suppression



L. Pattavina et al., JCAP 10, 064 (2021)

RES-NOVA SENSITIVITY

SIMULATION OF MAIN BACKGROUND COMPONENTS



Detector volume: **(60 cm)^3**

Target: **archaeo-$PbWO_4$**

Energy threshold: **1 keV**

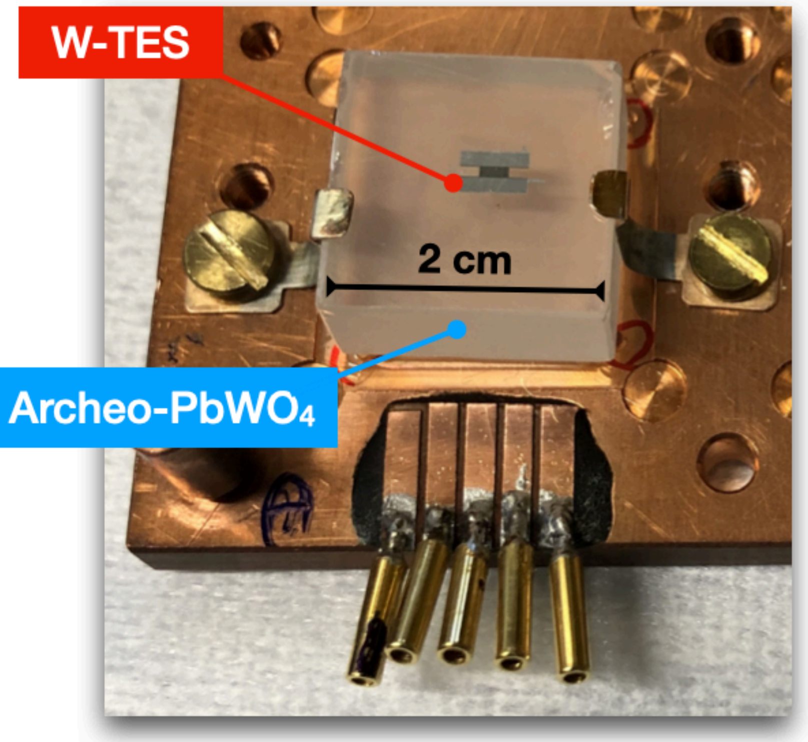
Bkg @ ROI: **10^{-3} c/keV/ton/s/**

Full investigation of the MW galaxy

L. Pattavina et al., JCAP 10, 064 (2021)

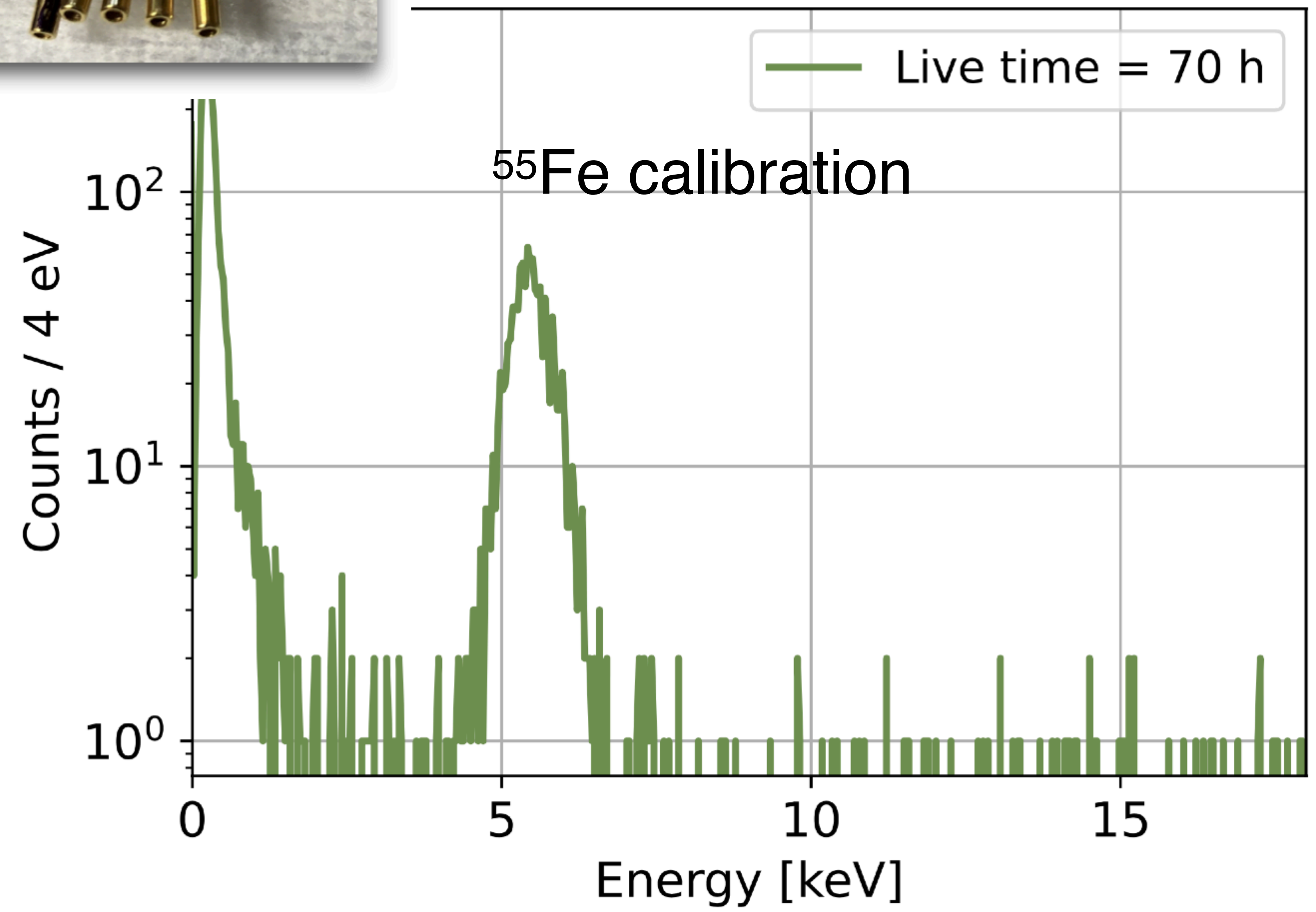
RES-NOVA PROOFS OF PRINCIPLE

ACHIEVEMENT OF LOW THRESHOLD AND LOW BACKGROUND



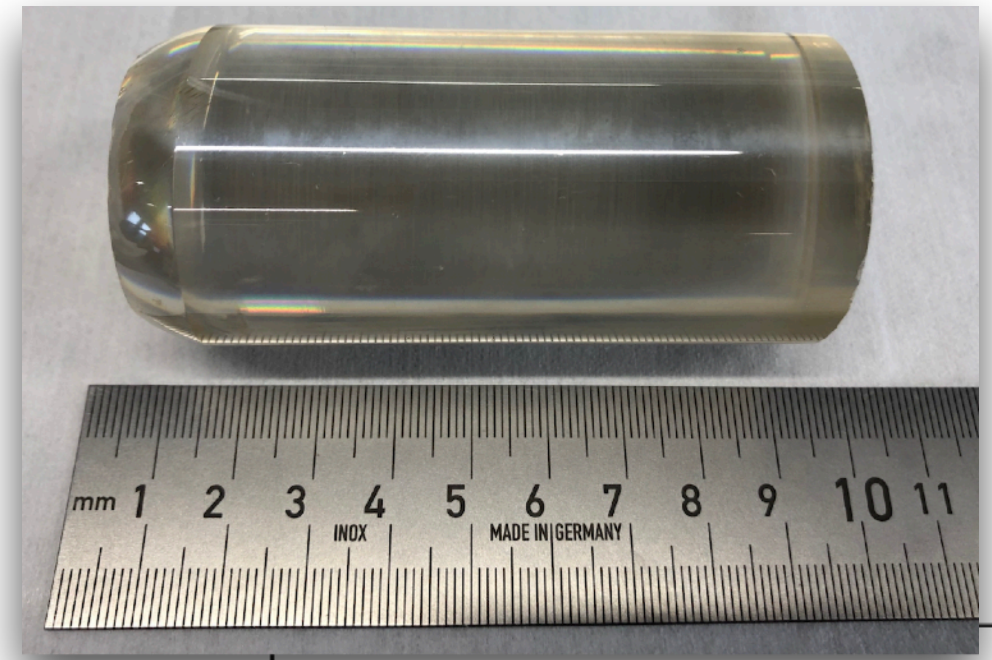
N. Ferreiro Iachellini et al.,
[ArXiv:2111.07638]
in publication on JLTP

TOTAL ENERGY SPECTRUM



Above ground @ Max Planck Munich (DE)

Nuclear recoil threshold - 300 eV (PbWO4 - 16 g)



RES-NOVA group of interest
[ArXiv:2203.07441]
in publication on EPJ-C

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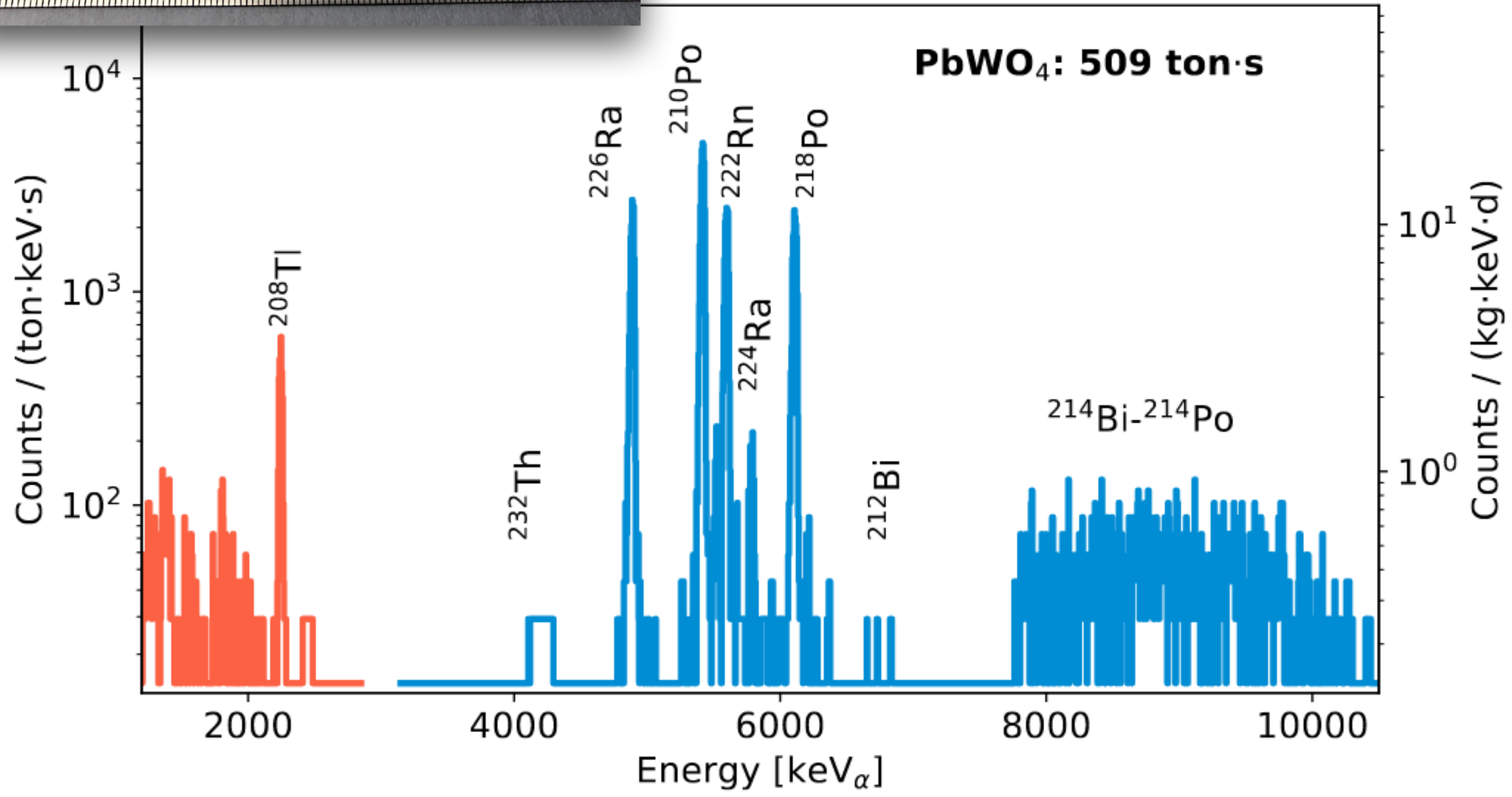


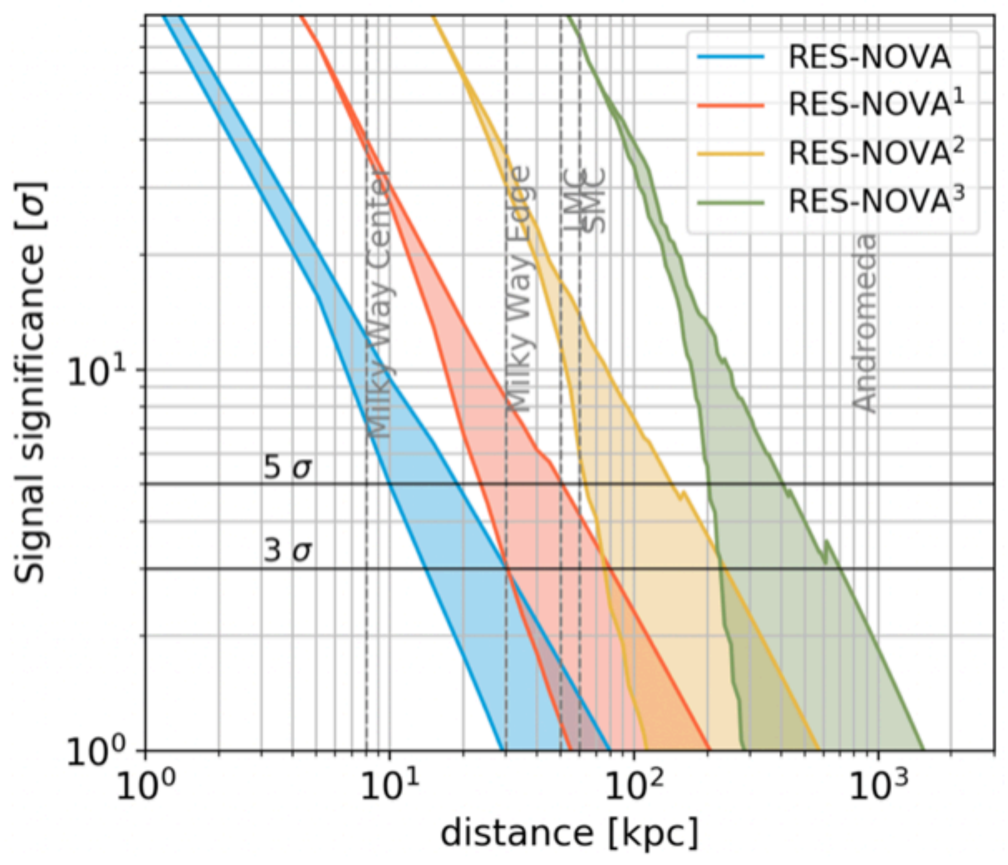
Under ground @ LNGS (IT)

Radiopurity @ µBq/kg scale (PbWO4 - 850 g)

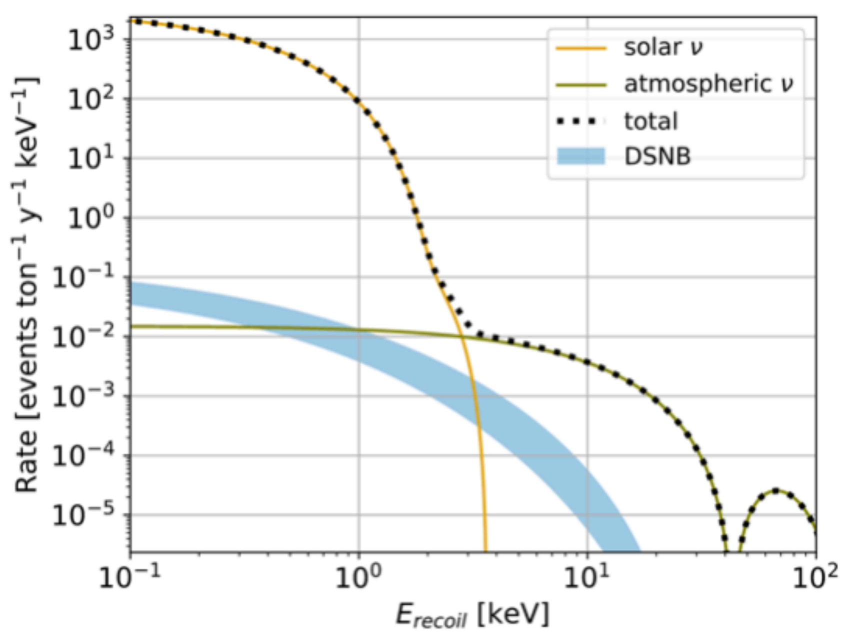
Conclusions

- RES-NOVA is a newly proposed SN neutrino exp. :
  - cm-scale neutrino telescope
- RES-NOVA technology is already established
  - Archaeological Pb can be embedded in PbWO4
  - Preliminary results exceed expectations (E_{th}= 300 eV)
- RES-NOVA provides a complementary approach to the current SN neutrino observatories

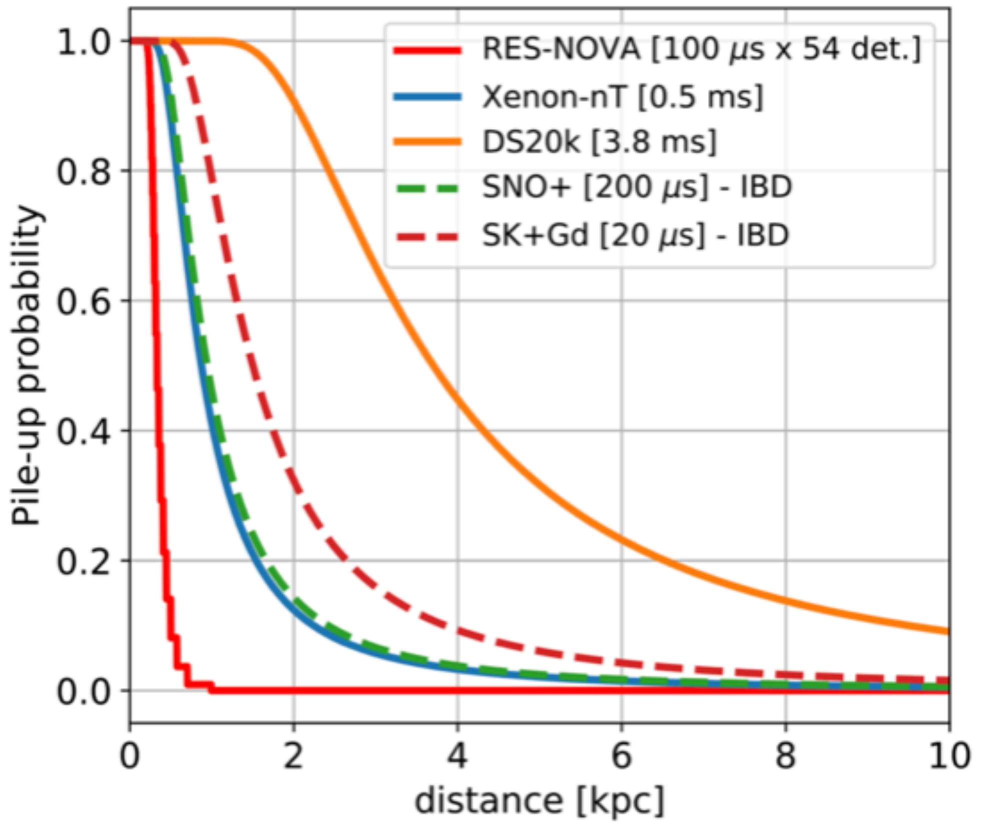
Deep space exploration



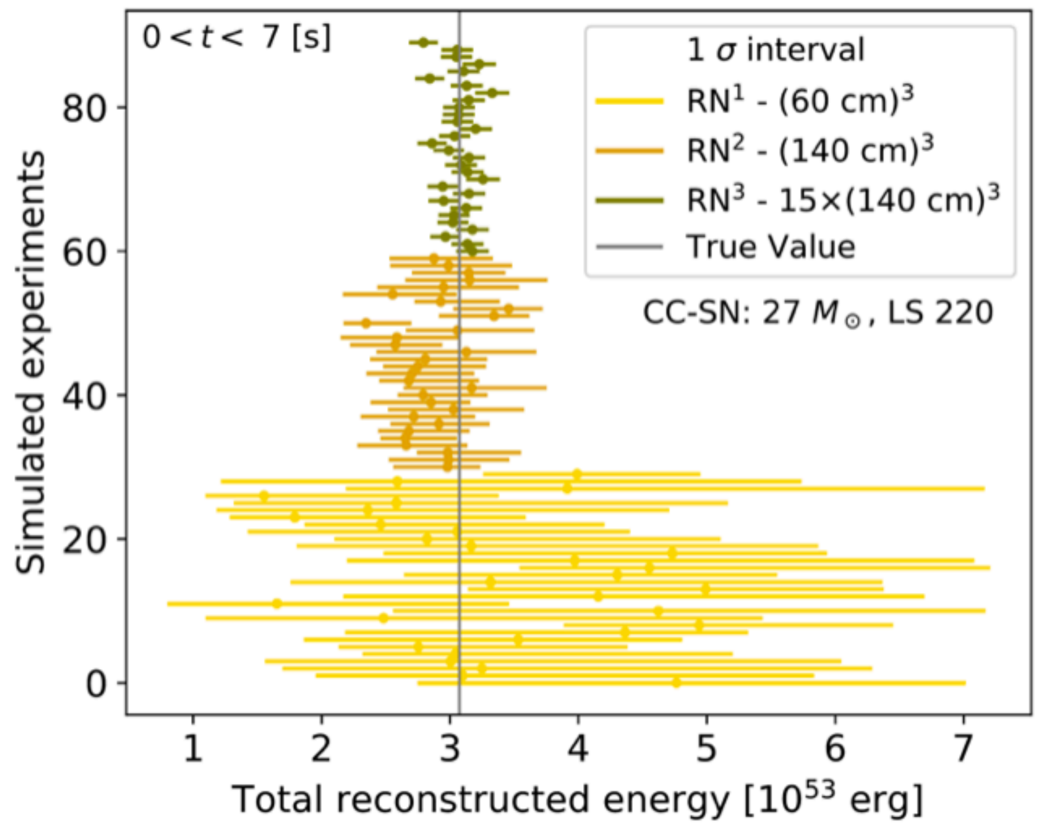
Diffuse SN neutrino Background



Nearby galaxy survey



Precise ε_{tot} reconstruction



Pre-SN neutrino detection