

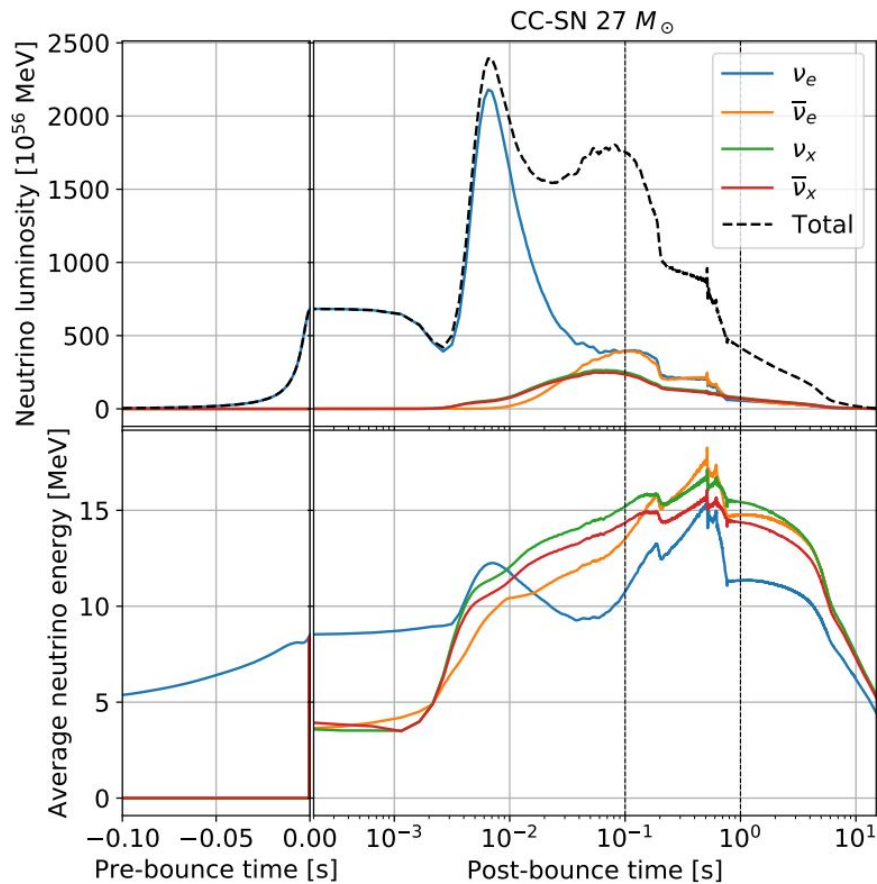
Archeological lead purification for RES-NOVA



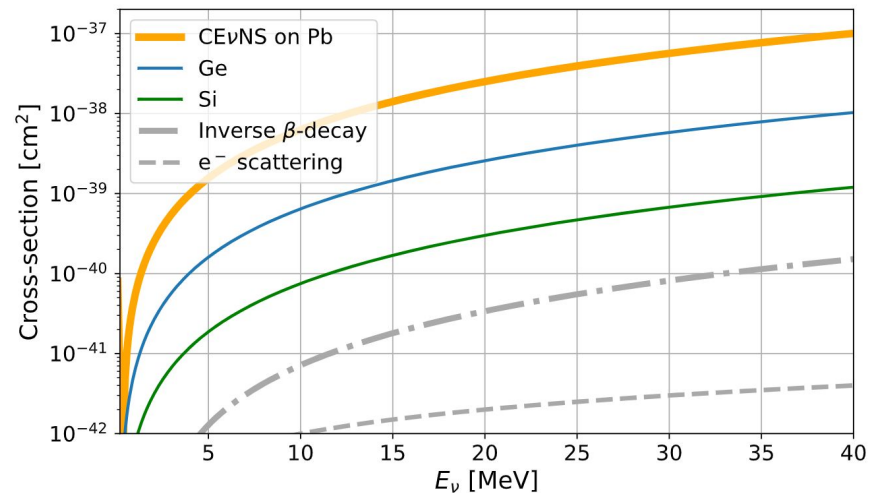
G. Benato for the RES-NOVA collaboration

Low Radioactivity Techniques 2024

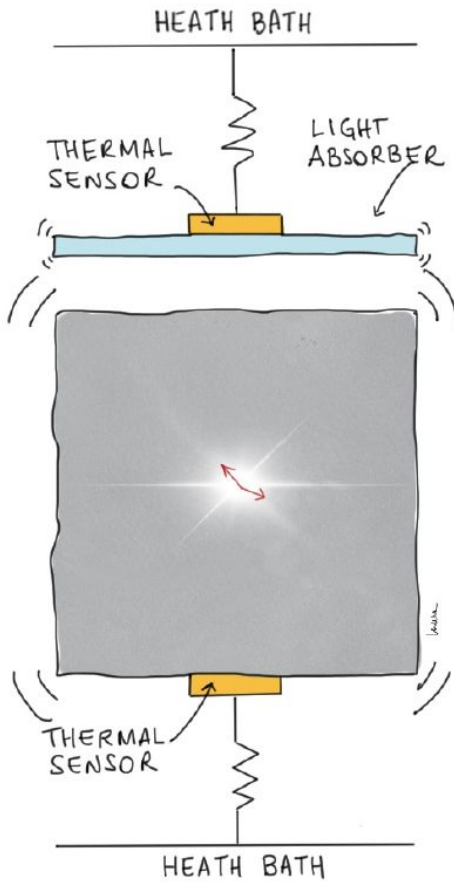
Measuring SuperNova neutrinos via CE ν NS



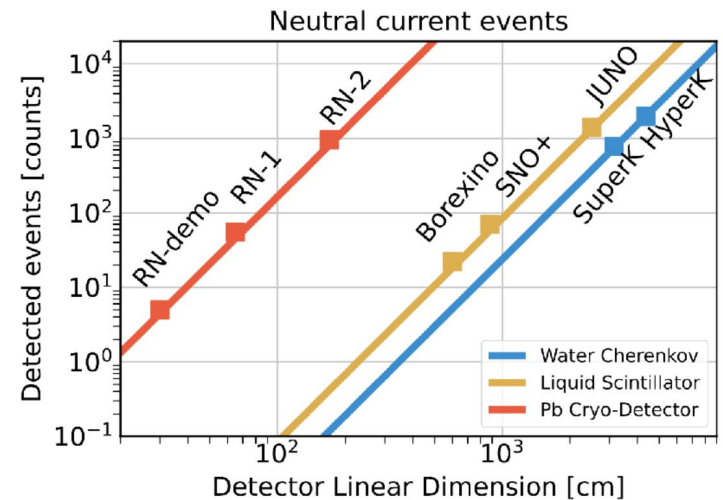
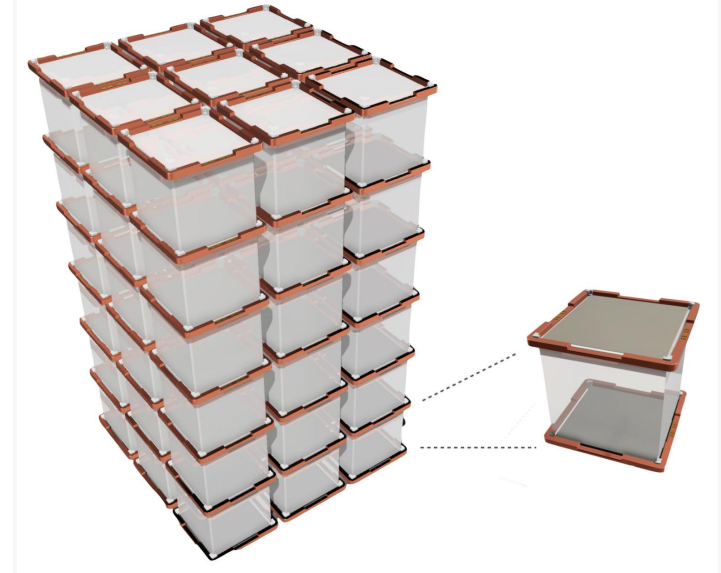
- CE ν NS cross section much greater than for inverse β decay or e^- scattering
→ Significantly suppress detector size
- Agnostic with respect to neutrino flavor
→ Sensitivity to full neutrino emission
- Time development from ms to 10 s
→ ms time resolution is enough
- Neutrino energy of O(10) MeV
→ Required energy threshold of ~ 1 keV



ResNova: measuring SN neutrinos with PbWO_4 bolometers



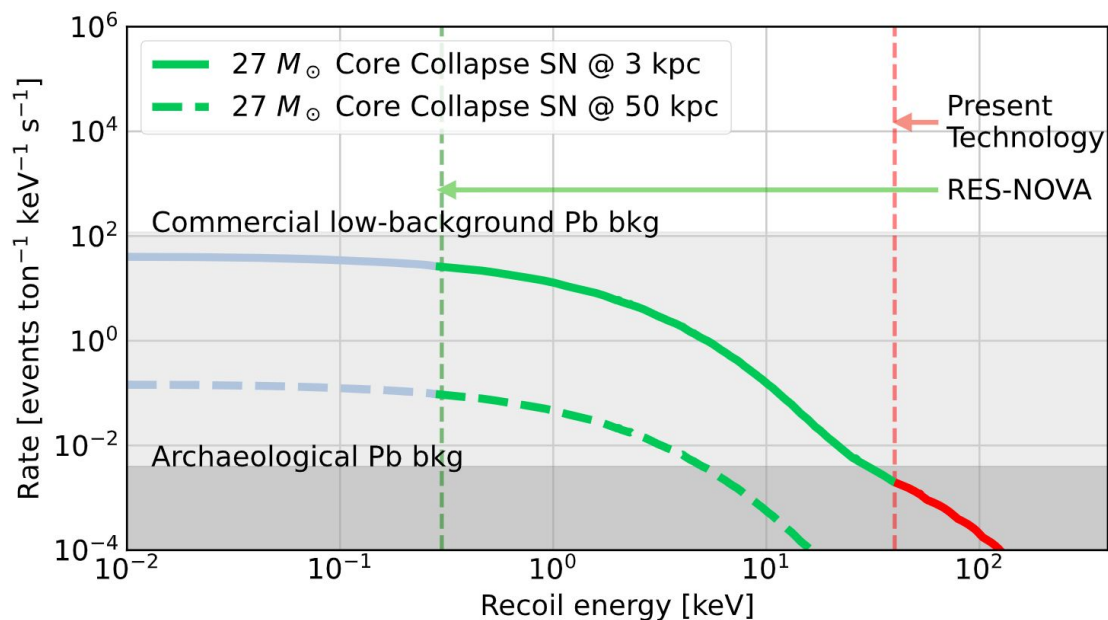
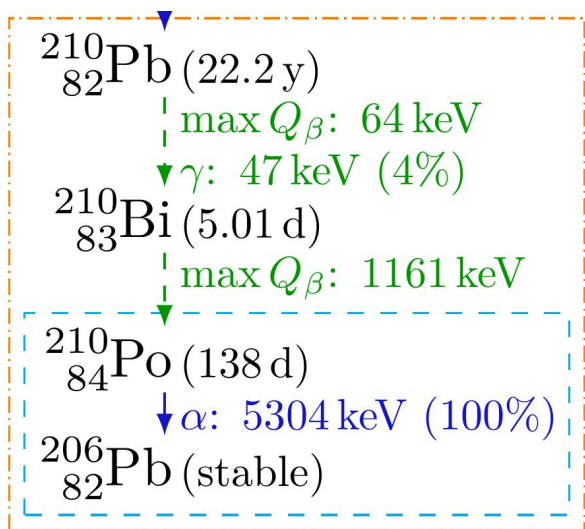
- RN-demo: $(30 \text{ cm})^3$ of PbWO_4 scintillating bolometers
→ Double readout to select nuclear recoil events
- Transition Edge Sensor as thermal sensor
- Would measure 10 events for SN@10 kpc



Why ^{arch}Pb and not just low-bkg Pb?

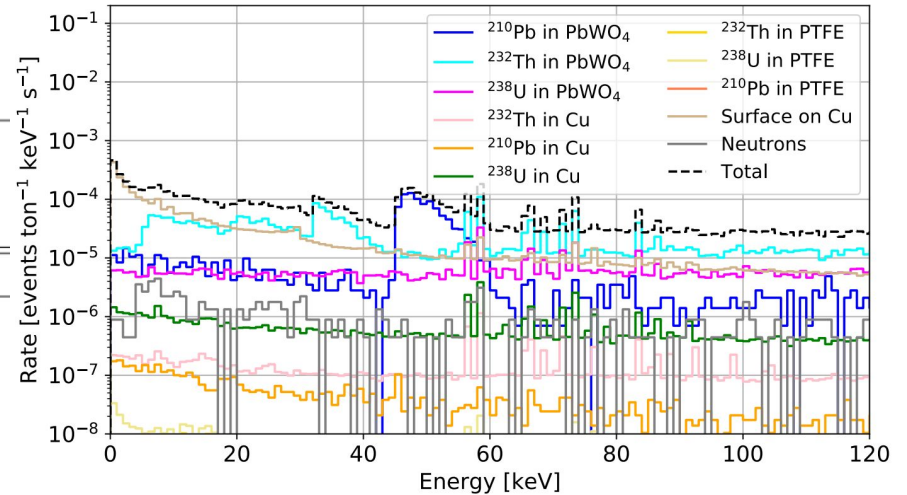
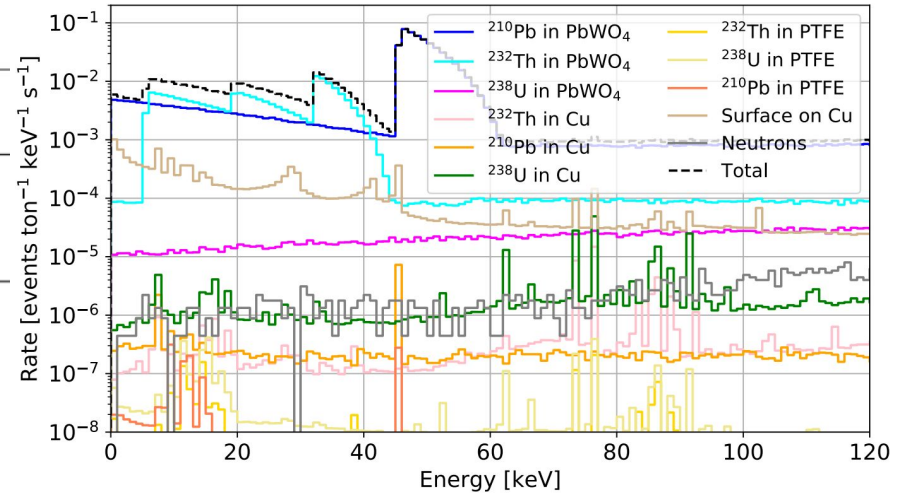
- Low-energy β 's from ²¹⁰Pb can leak into nuclear recoil band
- Suppressing ²¹⁰Pb background is crucial!

Nuclide	Low-bkg Pb (Boliden)	Roman Pb
²³² Th	<46 μ Bq/kg	<45 μ Bq/kg
²³⁸ U	<31 μ Bq/kg	<46 μ Bq/kg
²¹⁰ Pb	$(2.3 \pm 0.4) \cdot 10^7$ μ Bq/kg	<715 μ Bq/kg



Background budget

<i>Component</i>	<i>Source Isotope</i>	<i>Activity</i> [Bq/kg] ([Bq/cm ²])
PbWO ₄ crystals	²³² Th	< 2.3 × 10 ⁻⁴
	²³⁸ U	< 7.0 × 10 ⁻⁵
	²¹⁰ Pb	< 7.1 × 10 ⁻⁴
Cu structure	²³² Th	< 2.1 × 10 ⁻⁶
	²³⁸ U	< 1.2 × 10 ⁻⁵
	²¹⁰ Pb	< 2.2 × 10 ⁻⁵
Cu surface	²³² Th - 10 μm	(5.0 ± 1.7) × 10 ⁻⁹
	²³⁸ U - 10 μm	(1.4 ± 0.2) × 10 ⁻⁸
	²¹⁰ Pb - 10 μm	< 1.9 × 10 ⁻⁸
	²¹⁰ Pb - 0.1 μm	(4.3 ± 0.5) × 10 ⁻⁸
	²¹⁰ Pb - 0.01 μm	(2.9 ± 0.4) × 10 ⁻⁸
PTFE holders	²³² Th	< 6.1 × 10 ⁻⁶
	²³⁸ U	< 2.2 × 10 ⁻⁵
	²¹⁰ Pb	< 2.2 × 10 ⁻⁵
Environment	neutrons	3.7 × 10 ⁻⁶ cm ⁻² s ⁻¹



Goal: from archeo-Pb to PbWO_4 crystals

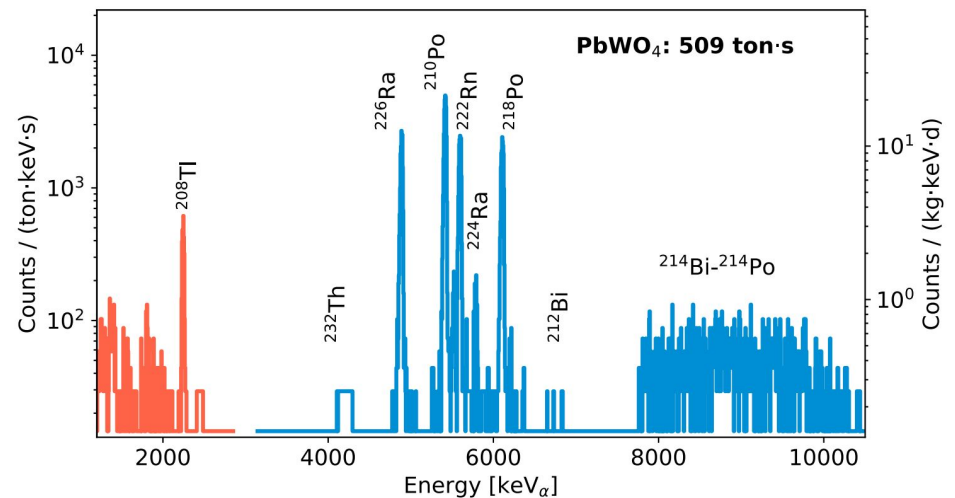
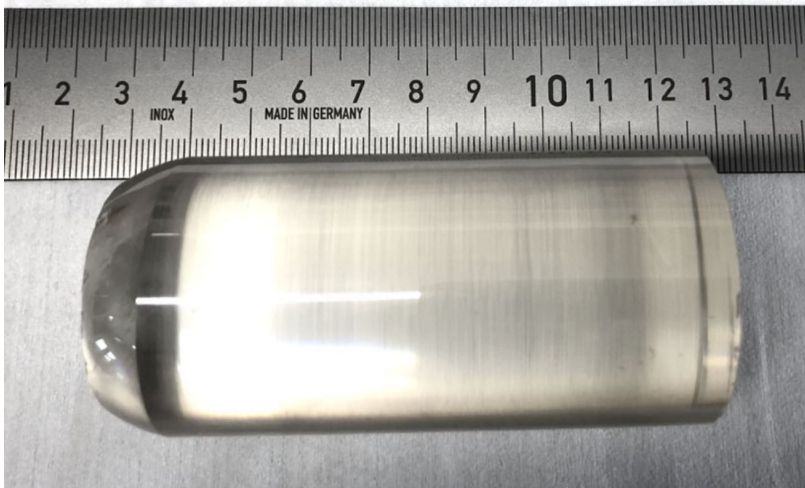


First test of $^{\text{arch}}\text{PbWO}_4$ as a bolometer

- Pb obtained from Greek ship sunk in Black Sea in 1st century BC
- Pb purification procedure:
 - a. Melting + filtration
 - b. Distillation with vapor condensation into liquid phase
 - c. High-temperature heating to remove volatile impurities
- 0.84 kg crystal grown from PbO and WO₃

Chain	Nuclide	Activity [mBq/kg]
^{232}Th	^{232}Th	<0.04
	^{228}Th	0.80 ± 0.09
	^{238}U	<0.03
^{238}U	^{238}U	<0.03
	^{234}U	<0.03
	^{230}Th	<0.04
	^{226}Ra	11.34 ± 0.35
	$^{210}\text{Pb}/^{210}\text{Po}$	22.50 ± 0.49

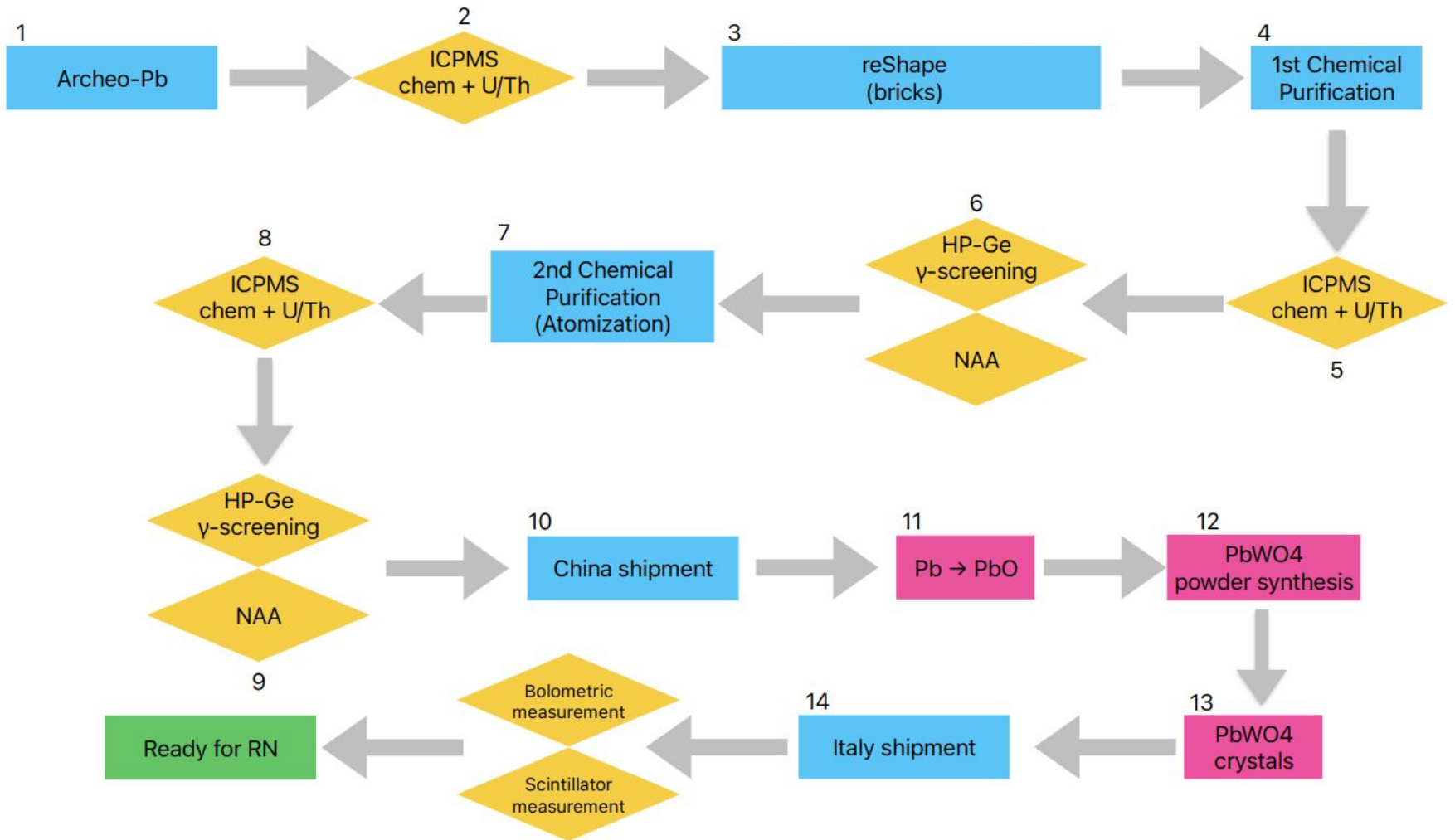
[EPJC 82 \(2022\) 692](#)



From ancient Greek to ancient Rome

- 200 kg of ^{arch}Pb retrieved from Roman shipwreck made available by LNGS-INFN to the ResNova collaboration
 - Th and U contamination values used for background budget
 - ResNova demonstrator will operate ~200 kg of PbWO₄, ~60% of which is Pb
- Required improvements:
 - Simpler purification procedure
 - Scalable method to produce Pb powder for crystallization

Workflow for lead processing



Cutting and first purification



Chemical etching



Boil and skim



Casting



Atomization

Purified Pb



Ultrasonic atomizer



Pb powder
(50 μm)



Send to SICCAS for
crystal growth



More info:
3D-LAB.pl



Contamination values

ICP-MS

- ICP-MS measurement performed @LNGS on purified and atomized Pb
- Atomization seems to act as a further purification!

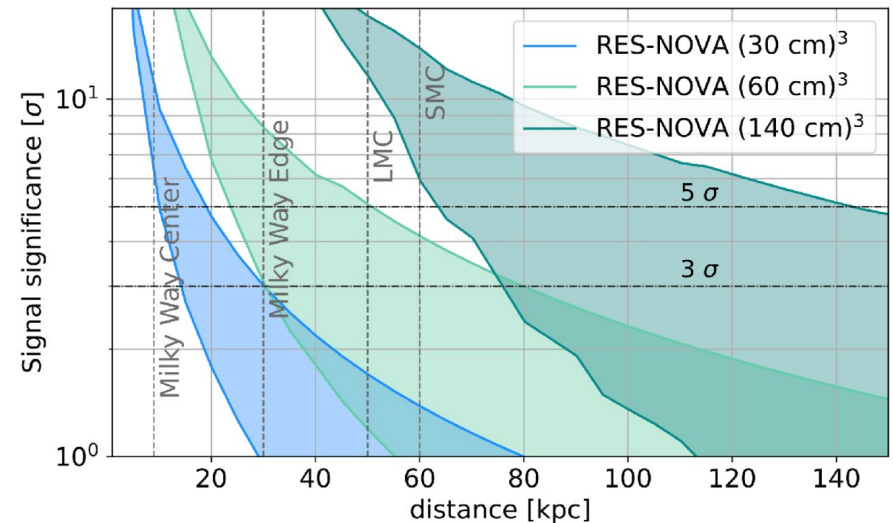
Ge γ screening

- 100 kg of purified Pb being measured in GeMPI-2 @LNGS since July
- Expected limits on U and Th at the level of few $\mu\text{Bq/kg}$
→ Contamination values should fulfill ResNova requirements

Contaminant	Contamination [ppm]		
	Purified Pb	Atomized Pb	Residual Pb
Ni	3	2.9	3.4
Zn	<0.3	<0.3	0.85
Ag	64	61	60
Cu	725	580	1330
W	<0.04	0.03	1.2
U	<0.002	$4 \cdot 10^{-6}$	
Th	<0.002	$7 \cdot 10^{-6}$	

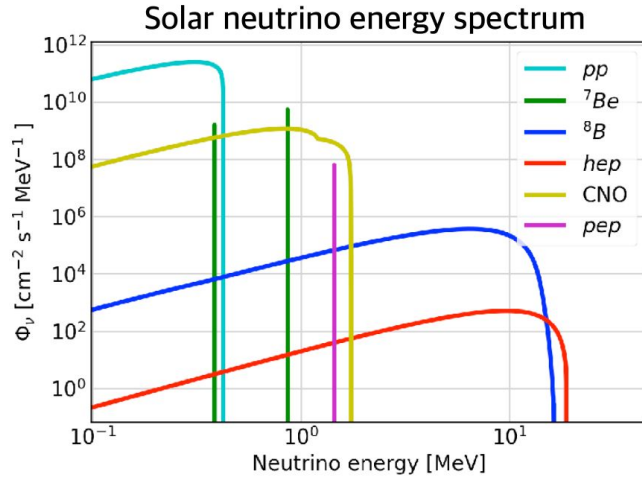
Next steps

- Purification of second 100 kg of Pb
- Atomization of 200 kg of purified Pb
→ Will be performed by 3D printing workshop @LNGS
- More and more screening measurements
- Crystal growth
- Detector testing

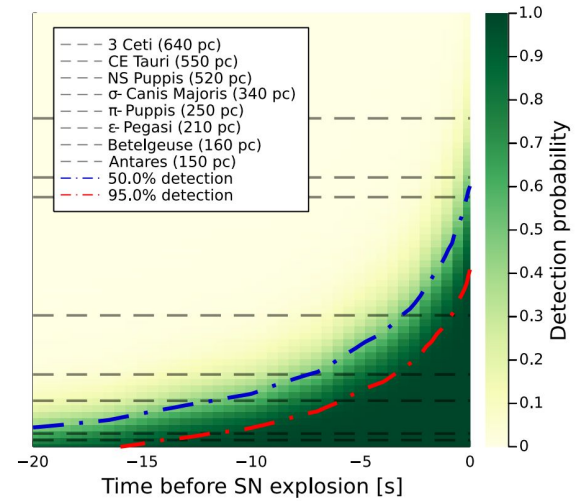


What else?

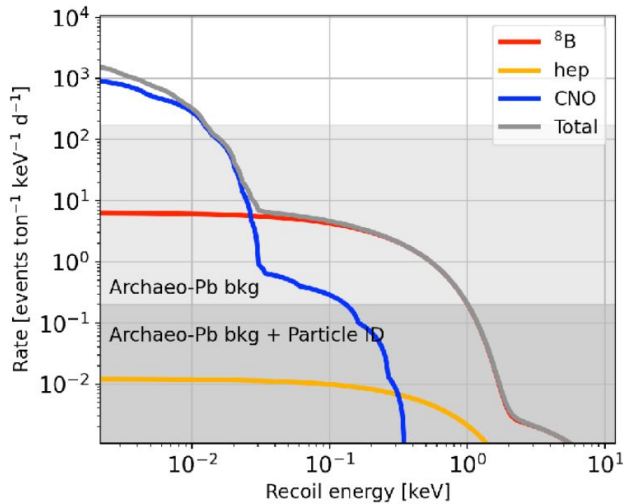
Precision measurement of solar ν 's



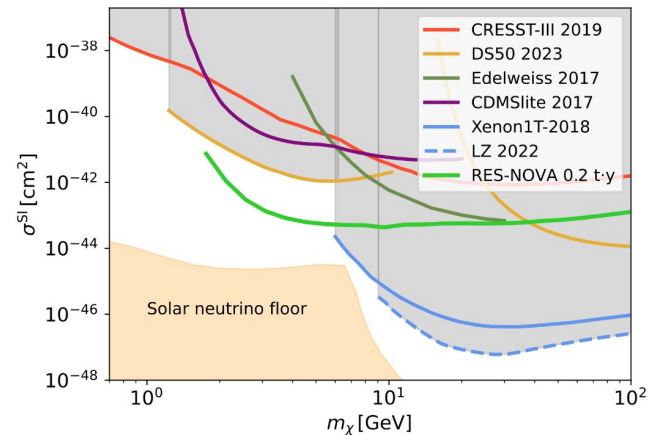
Trigger for pre-SN ν 's



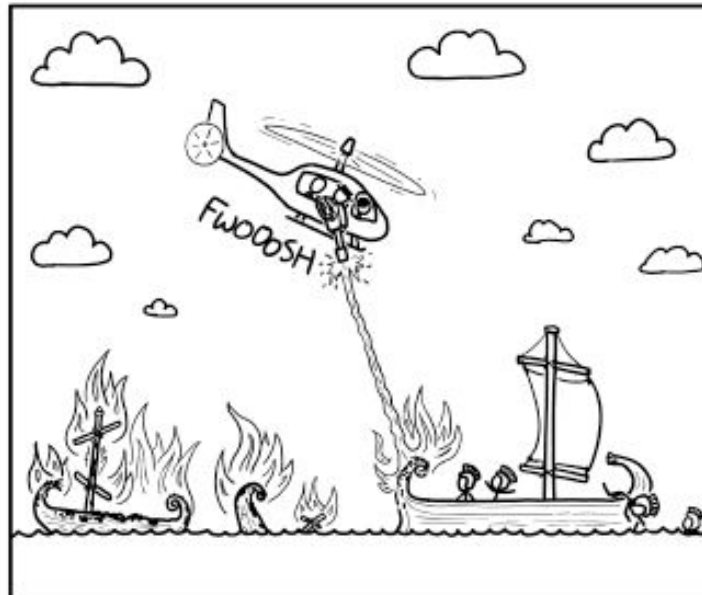
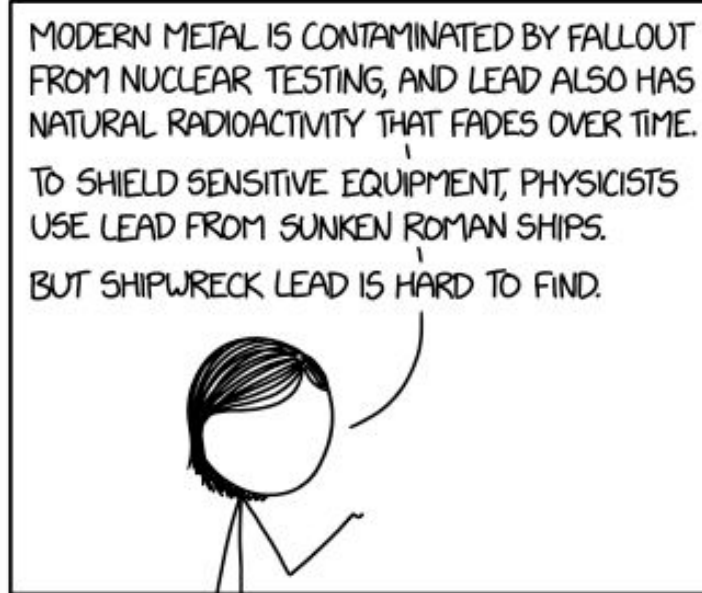
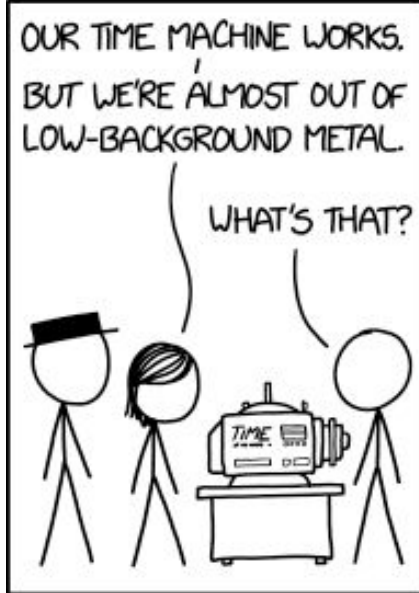
Recoil energy spectrum in RES-NOVA



WIMPs



Acknowledgements



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