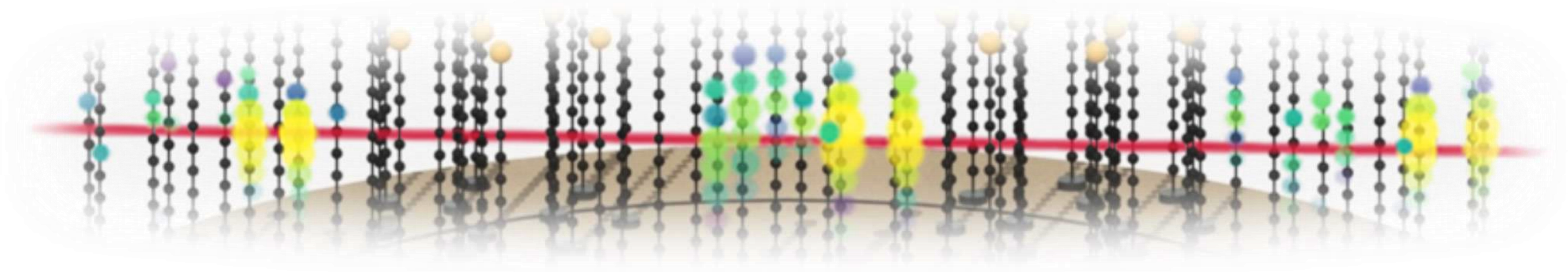


Acoustic neutrino signatures

Felix Henningsen, Juan Ammerman-Yebra

ARENA 2024, Chicago

Image Nat Astron 4, 913–915 (2020)

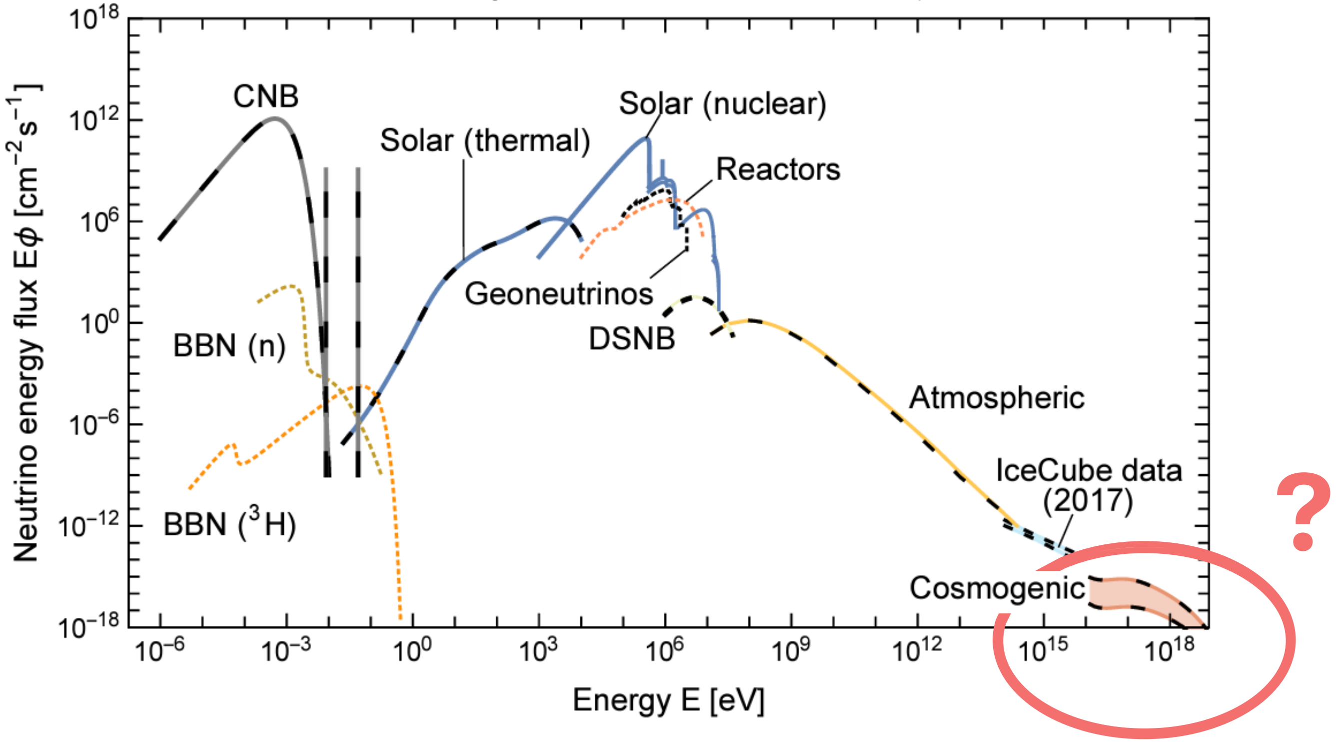
Acoustic neutrino signatures

Motivation

UHE neutrinos are a key science target

- Messengers for UHE particle accelerators
- Radio detection activities for neutrinos going strong

Vitagliano, Tamborra and Raffelt, Rev.Mod.Phys 2019, arXiv:1910.11878



Acoustic neutrino signatures

Motivation

UHE neutrinos are a key science target

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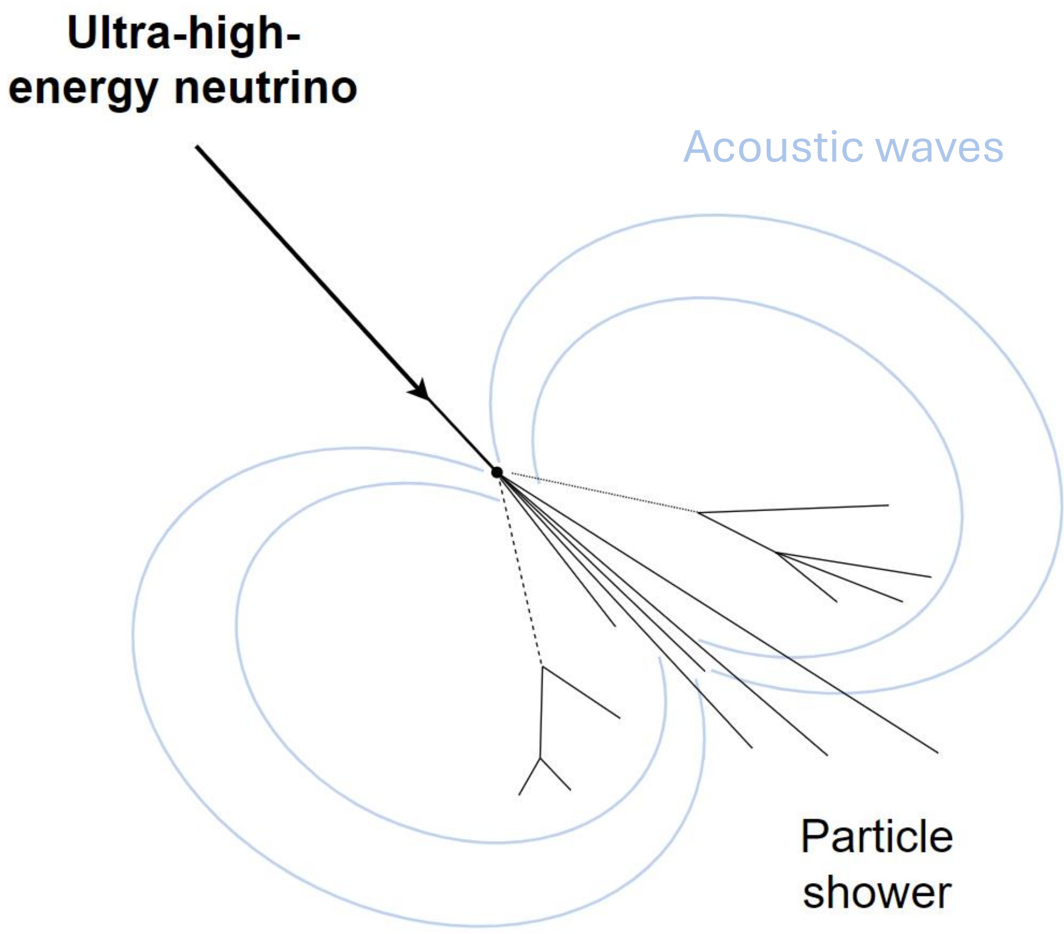
Acoustic neutrino detection an “old dream”

- Askaryan effect creates radio and acoustic emission
- First studies reach back to DUMAND times
- Technology and background were major obstacles



Acoustic neutrino signatures

Experimental landscape

Reference http://dx.doi.org/10.1051/epjconf/201921601001 (2019)

Experiment	Location	Medium	Sensor Channels	Host Experiment
SPATS [37, 38]	South Pole	Ice	80	IceCube
Lake Baikal [39]	Lake Baikal	Fresh Water	4	Baikal Neutrino Telescope
OνDE [40]	Mediterranean Sea (Sicily)	Sea Water	4	NEMO
AMADEUS [41]	Mediterranean Sea (Toulon)	Sea Water	36	ANTARES
ACoRNE [42]	North Sea (Scotland)	Sea Water	8	Rona military array
SAUND [43]	Tongue of the Ocean (Bahamas)	Sea Water	7/49$^{(\star)}$	AUTEC military array
SMO sensor array [44]	Mediterranean Sea (Sicily)	Sea Water	10	NEMO Phase-II prototype
KM3NeT sensor array [45]	Mediterranean Sea (Sicily, Toulon)	Sea Water	under constr.	KM3NeT
ANDIAMO Marinelli et al (2022)	Adriatic Sea	Sea Water	proposed	-

$^{(\star)}$ The number of hydrophones was increased from 7 in SAUND-I to 49 in SAUND-II

NEW

Acoustic neutrino signatures

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(*) The number of hydrophones was increased from 7 in SAUND-I to 49 in SAUND-II

Is it worth to re-investigate this effort?

- Better hydrophones, new technologies
- Modern computing, machine learning
- **Key:** Sensitivity in the sub-100 PeV regime

Acoustic neutrino signatures

Simulation

The study of acoustic neutrinos requires simulation

- **I:** Shower development, energy deposition
- **II:** Velocity potential, medium effects
- **III:** Acoustic pulse
- **Future:** Sensor arrays, event reconstruction, sensitivities

CORSIKA 8 simulation framework [1][2]

- Encouraging support, had running software after a few hours
- Shower development possible in both water, ice
- Started new branch for acoustic shower developments

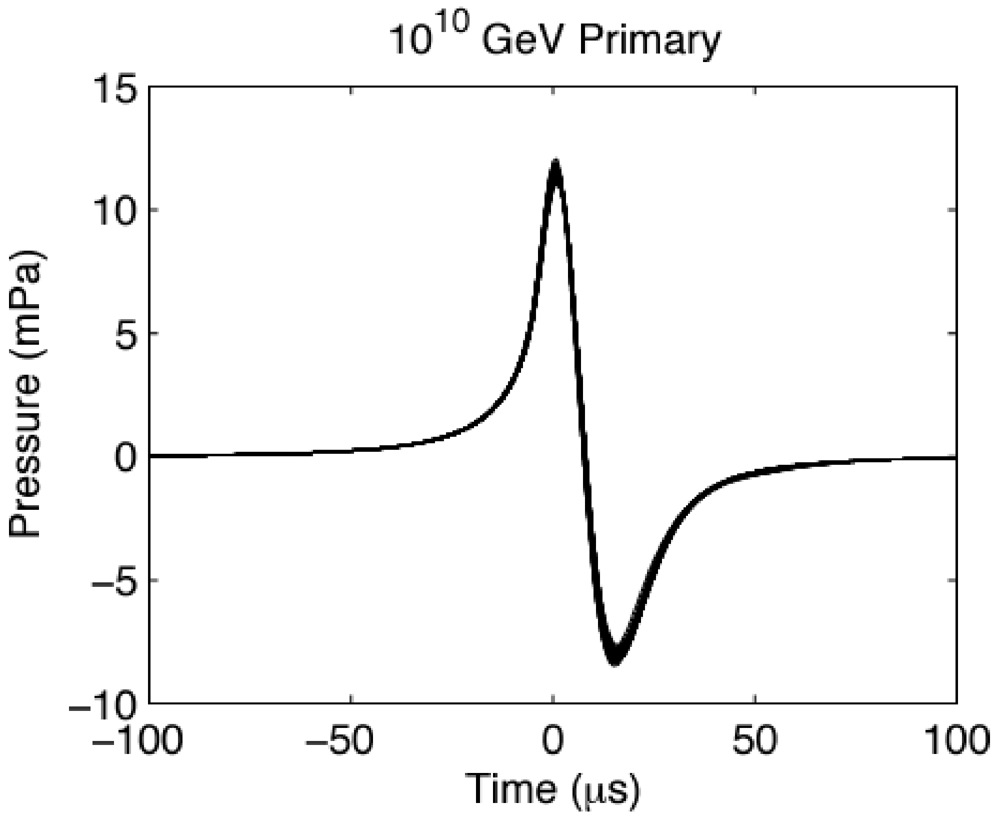


Image Bevan et al., ACORNE Coll., *NIM:A* (2009)

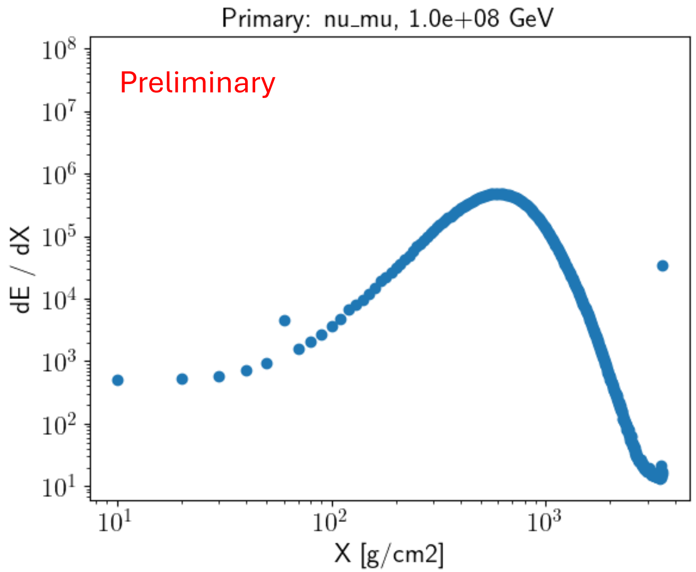
[1] Huege et al., *PoS(ICRC2023)* 310
[2] Engel et al., *Comput Softw Big Sci* 3, 2 (2019)

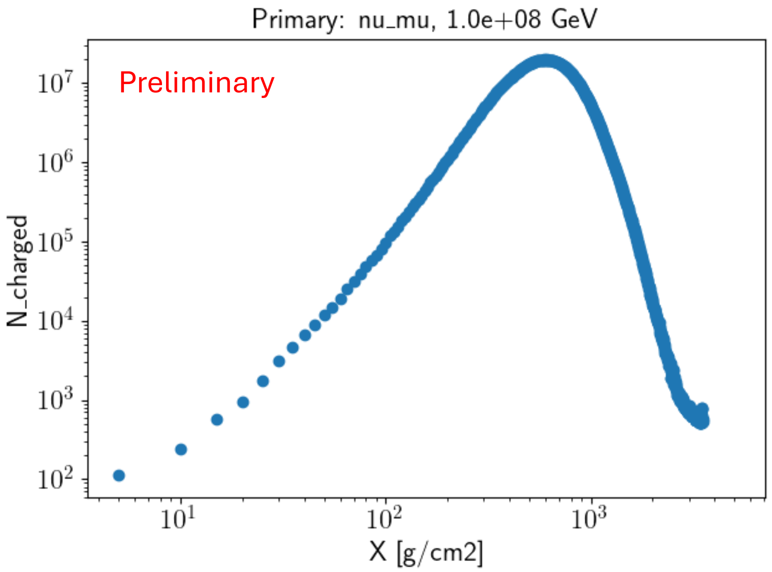
Acoustic neutrino signatures

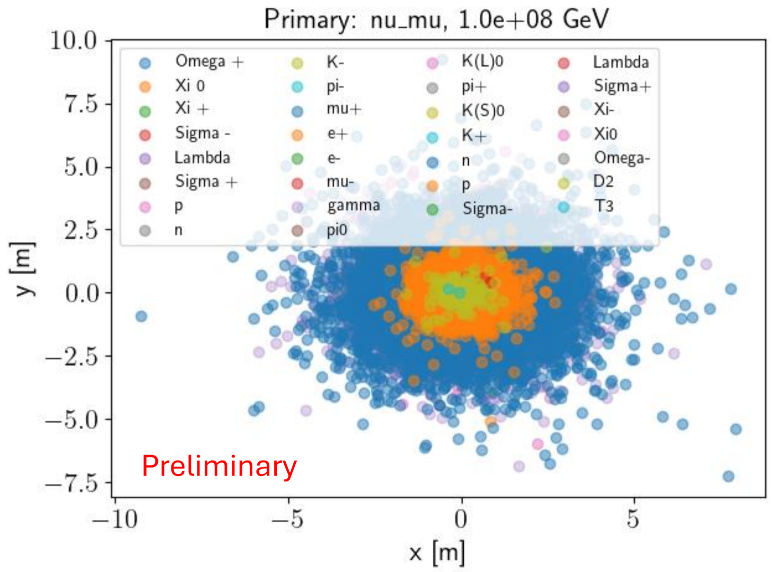
Simulation

Standard CORSIKA8 shower outputs

(ν_μ with 10^8 GeV, NC)







Acoustic neutrino signatures

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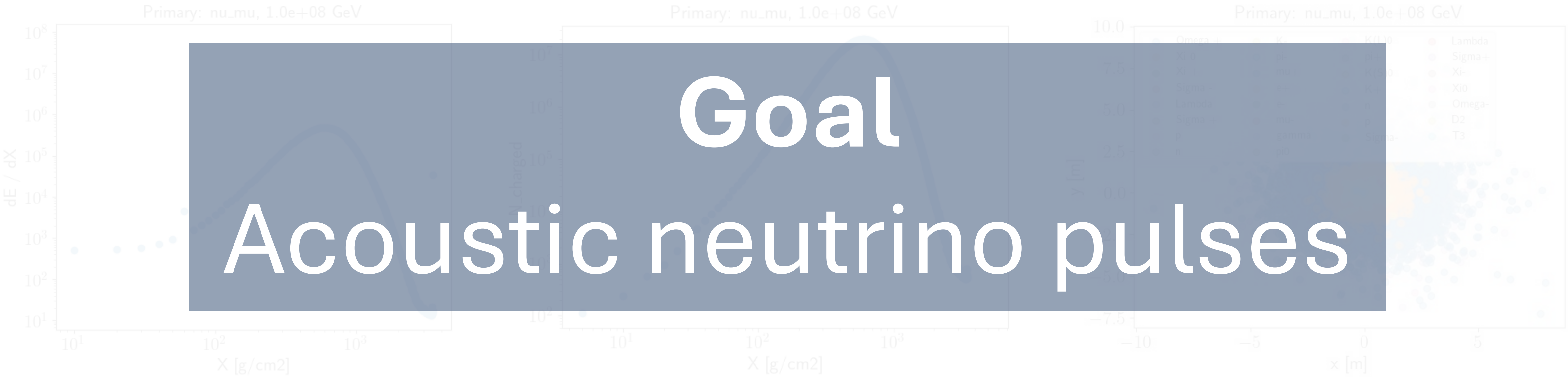


Goal

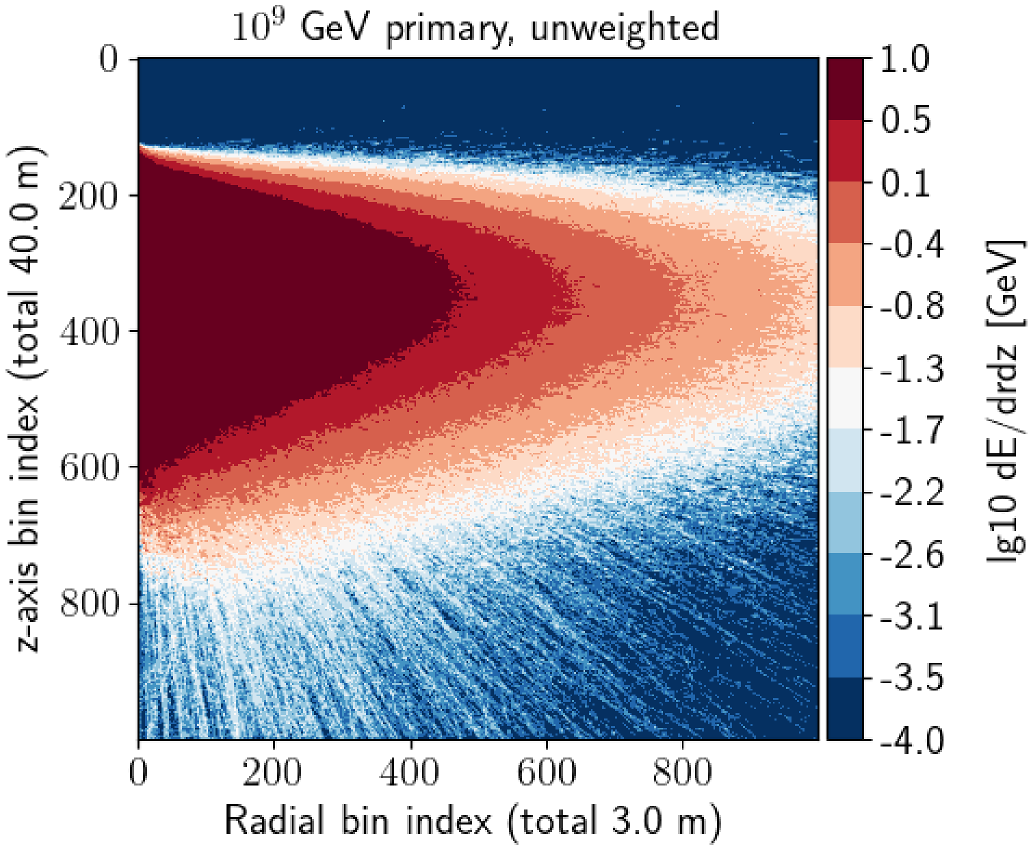
Acoustic neutrino pulses

Acoustic neutrino signatures

Simulation

Step 1: Radial shower profiles

- Writing radial energy deposits (with cut particles excluded)
- **Goal:** Radial, longitudinal energy density distribution



Acoustic neutrino signatures

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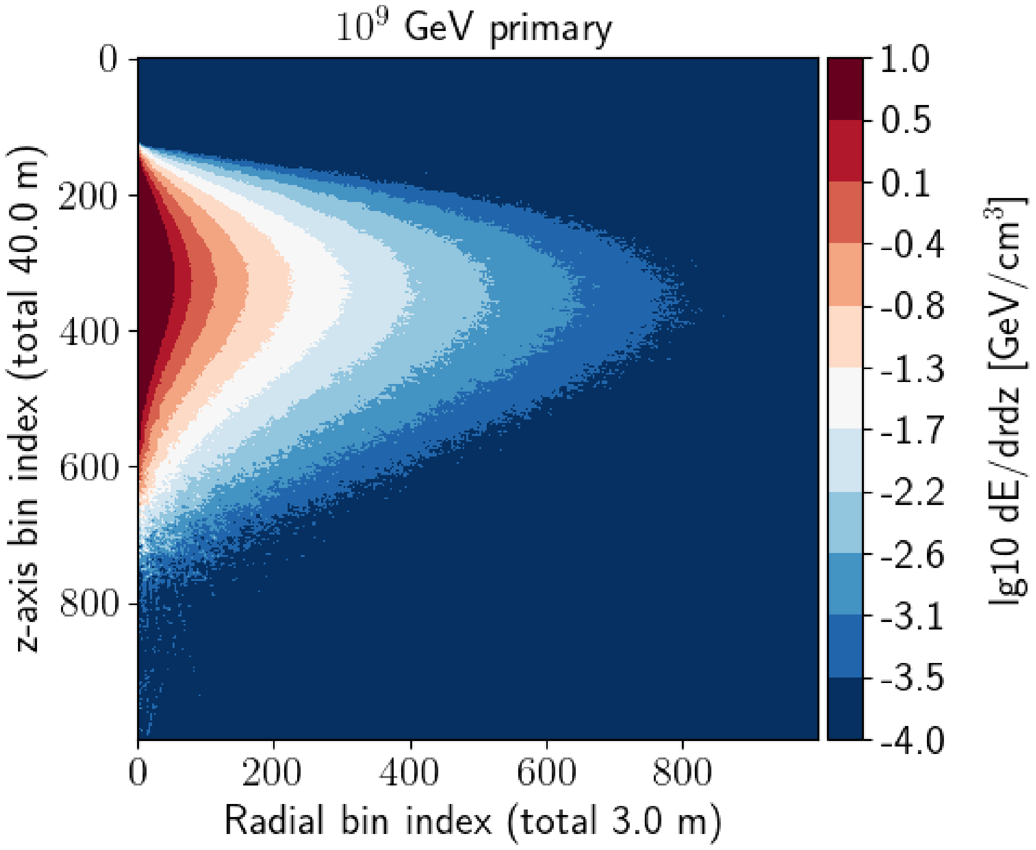

Acoustic neutrino signatures

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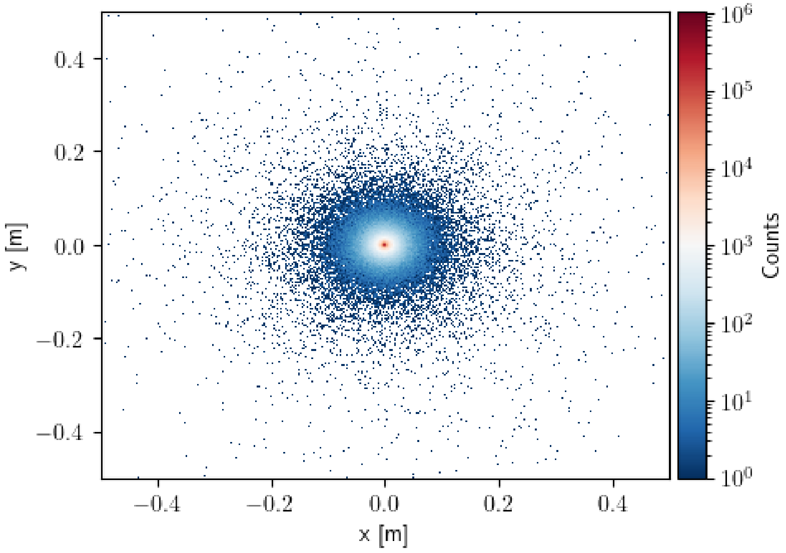
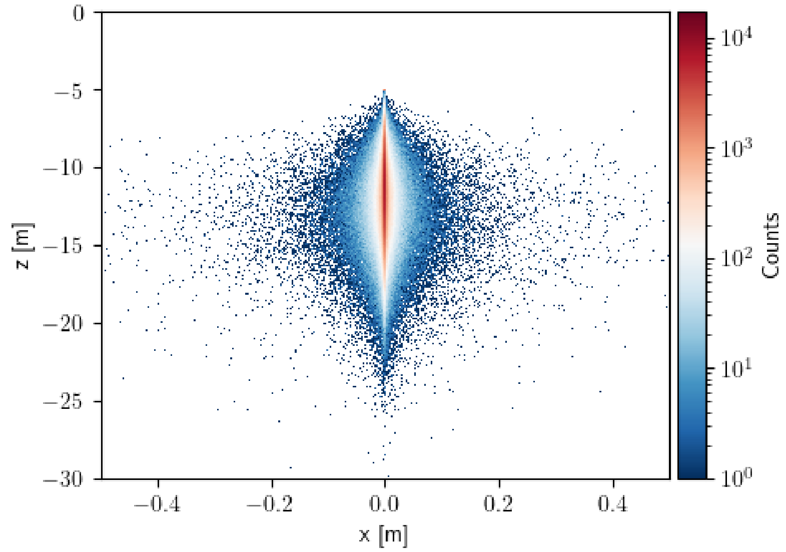
Step 2: MC shower energy density

- Sample radial energy density to arrive at 3D energy density
- Produce MC shower sampled from that density





Acoustic neutrino signatures

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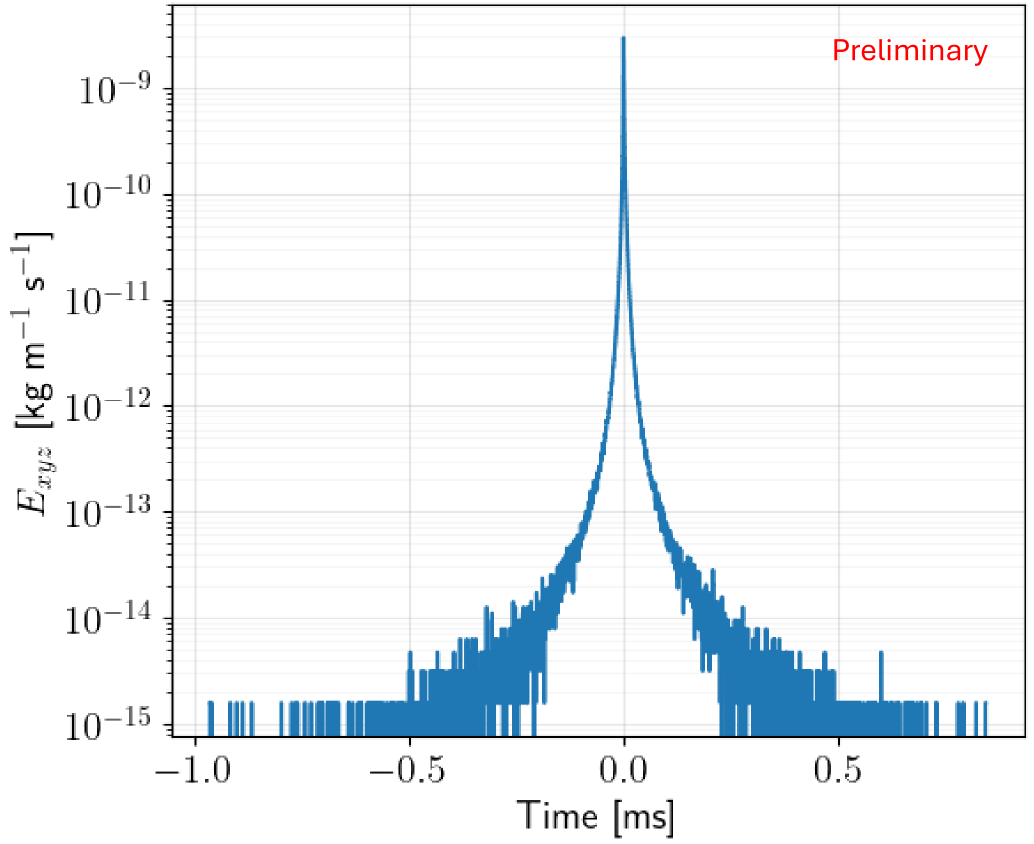
Step 3: Velocity potential, acoustic pulse [3]

- Sample propagation times from MC shower cells to sensor position in medium
- **Velocity potential:** Scale with total energy, medium properties



[3] Bevan et al., Astropart.Phys.28:366-379,2007

Acoustic neutrino signatures

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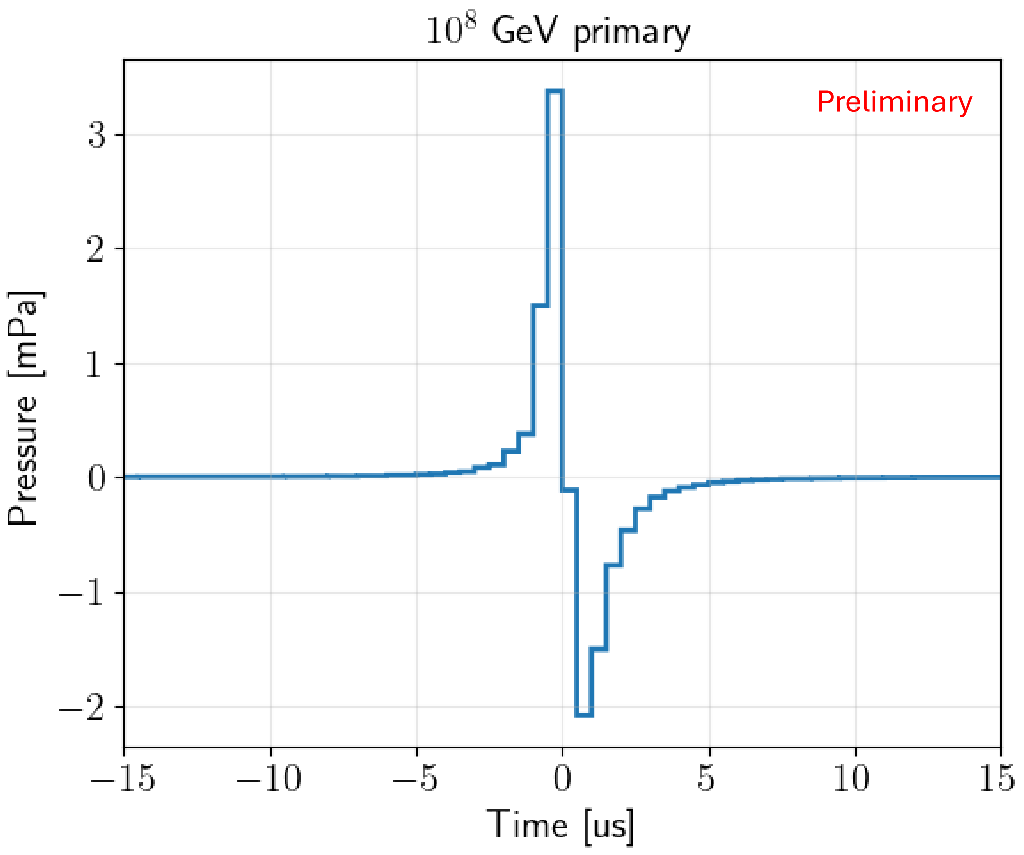
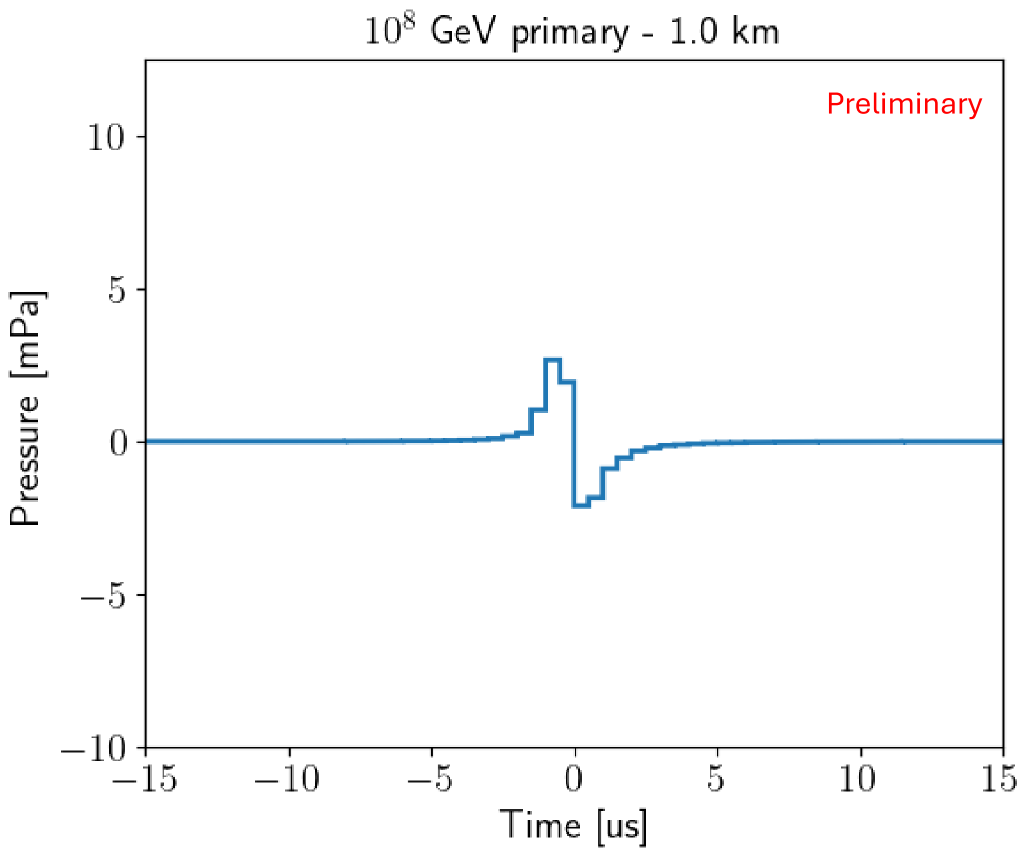
- Sample propagation times from MC shower cells to sensor position in medium
- **Velocity potential:** Scale with total energy, medium properties
- **Acoustic pulse:** Differentiate

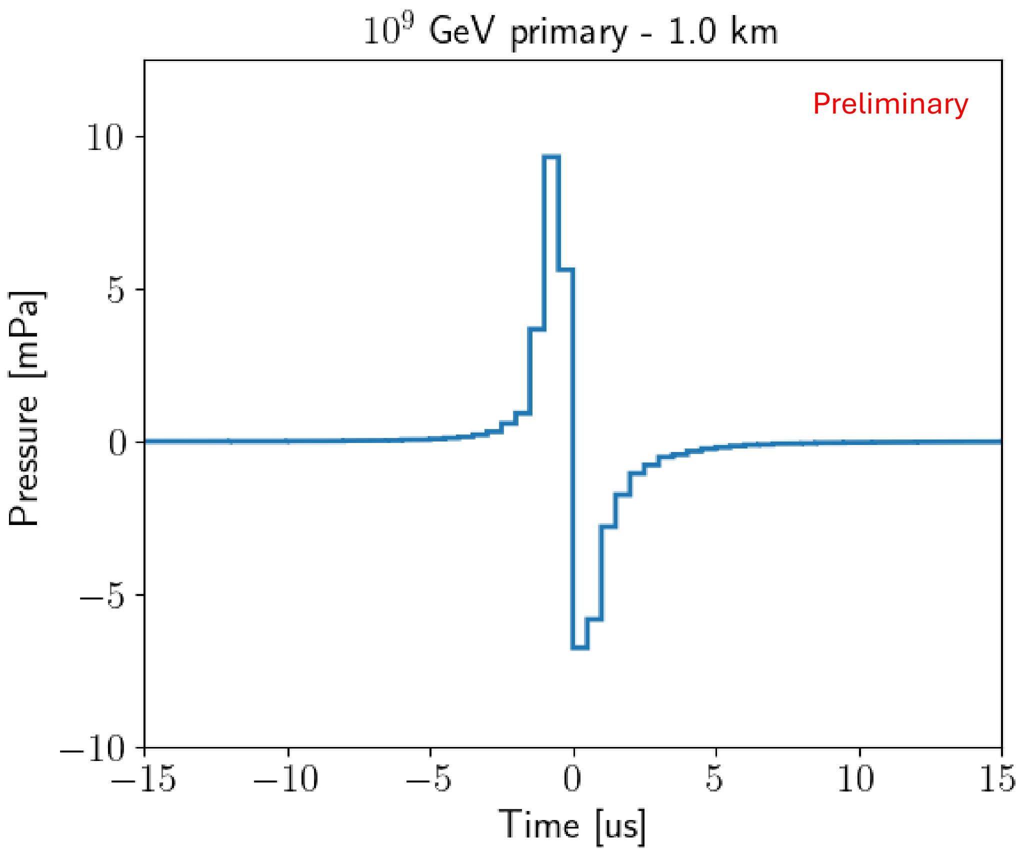


[3] Bevan et al., Astropart.Phys.28:366-379,2007

Acoustic neutrino signatures

Simulation

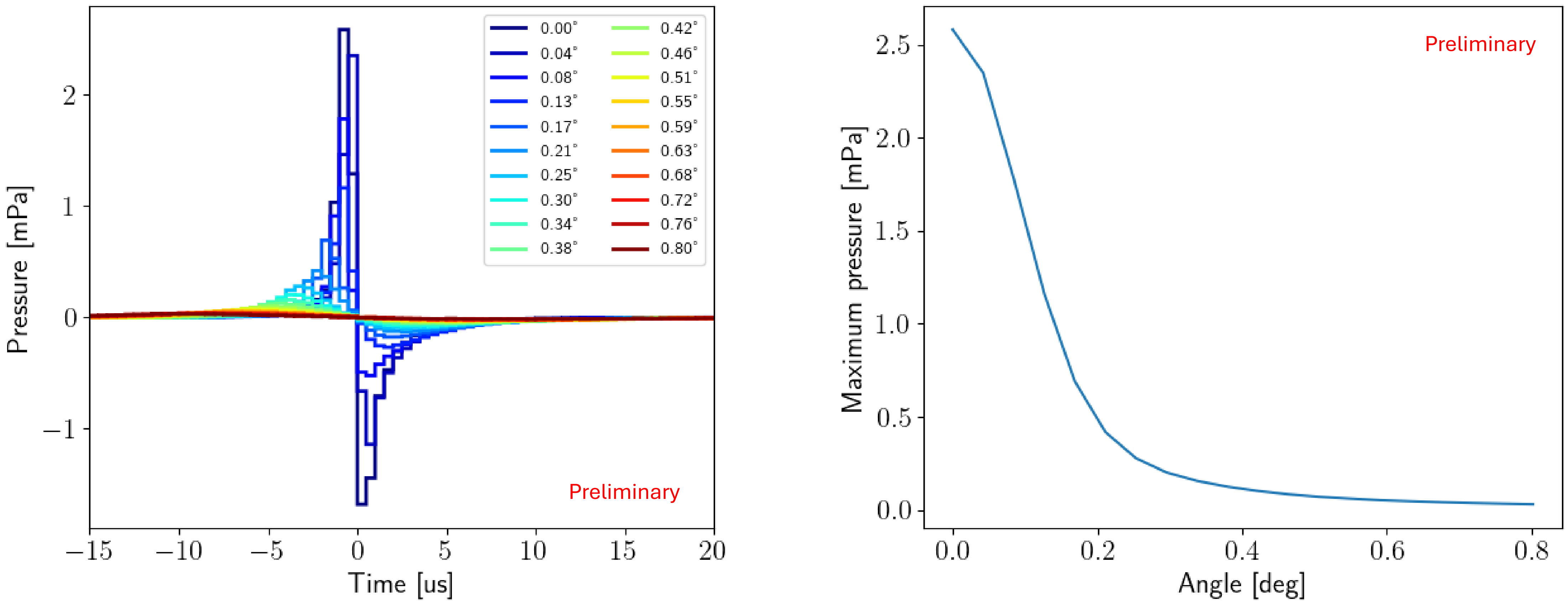




No seawater correction applied.

Acoustic neutrino signatures

Simulation



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Acoustic neutrino signatures

Summary

Successful generation of acoustic neutrino signatures in water based on CORSIKA 8 shower simulations

- More effort needed to verify results against existing work
- Systematic study of acoustic signatures (~ energy, observation angle) needed
- Intention to eventually develop an acoustic module for CORSIKA 8

Acoustic neutrino signatures

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Future work will target next steps for acoustic neutrino arrays

- Verification of acoustic pulses with literature
- Development of an acoustic neutrino simulation toolkit
- Scalable acoustic sensor technology R&D
- Event reconstruction, sensitivity studies
- Joint detection capabilities with optical, radio