Technische Universität Braunschweig

E.ON Kraftwerke GmbH

IGB-TUBS

Hydro sound emissions during impact driving of monopiles using Hydro Sound Dampers and Big Bubble Curtain

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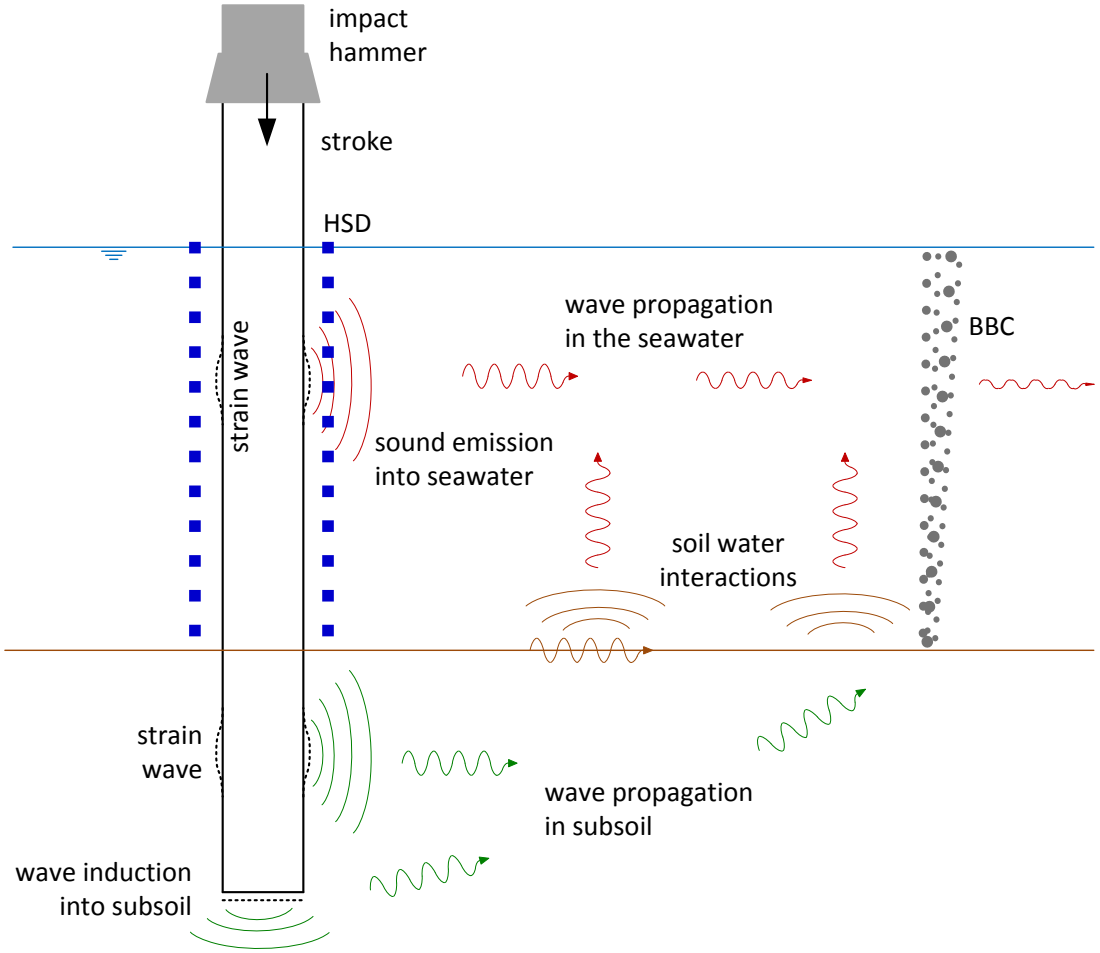
motivation



- energy input
  - into the pile
  - into the seawater
  - into the subsoil
- wave propagation
  - in the pile
  - in the seawater
  - in the subsoil
- soil water pile interactions
- damping effects of noise mitigation systems (NMS)
  - Hydro Sound Dampers (HSD)
  - big bubble curtain (BBC)

OWF Amrumbank West

E.ON Kraftwerke GmbH

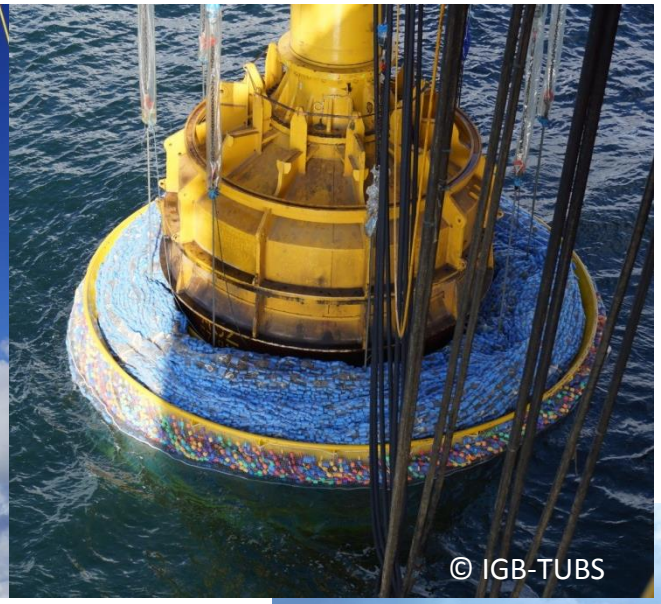
80 turbines (3.6 MW) → 288 MW
German Bight, water depth approx. 20 m
monopile foundations (D = 6 m, L ≈ 55 m)
impact driven (Menck MHU 1900S)

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag

noise mitigation at OWF Amrumbank West

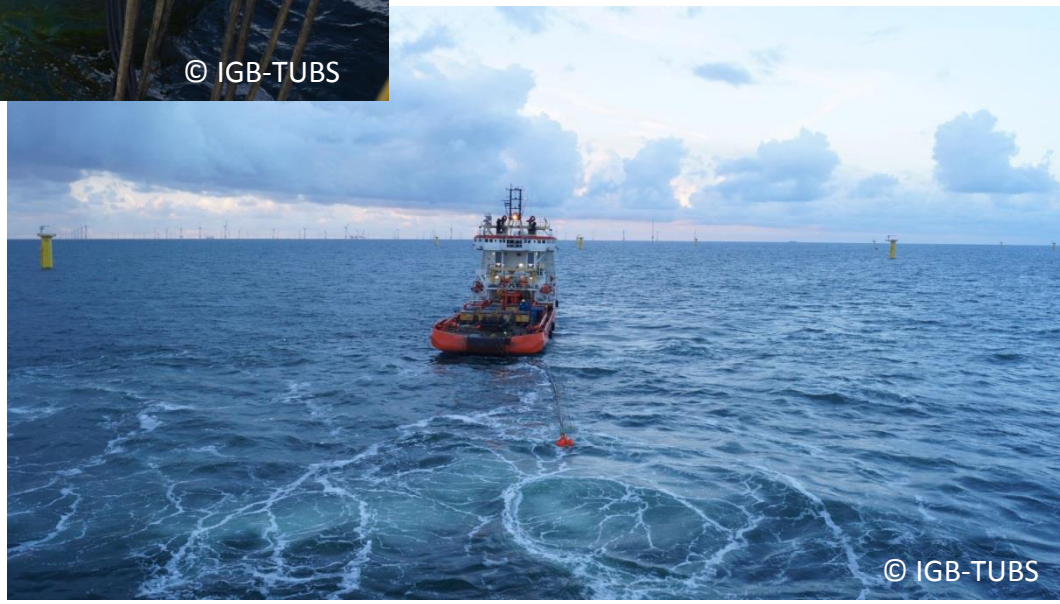


hydro sound dampers (HSD)
OffNoise-Solutions GmbH

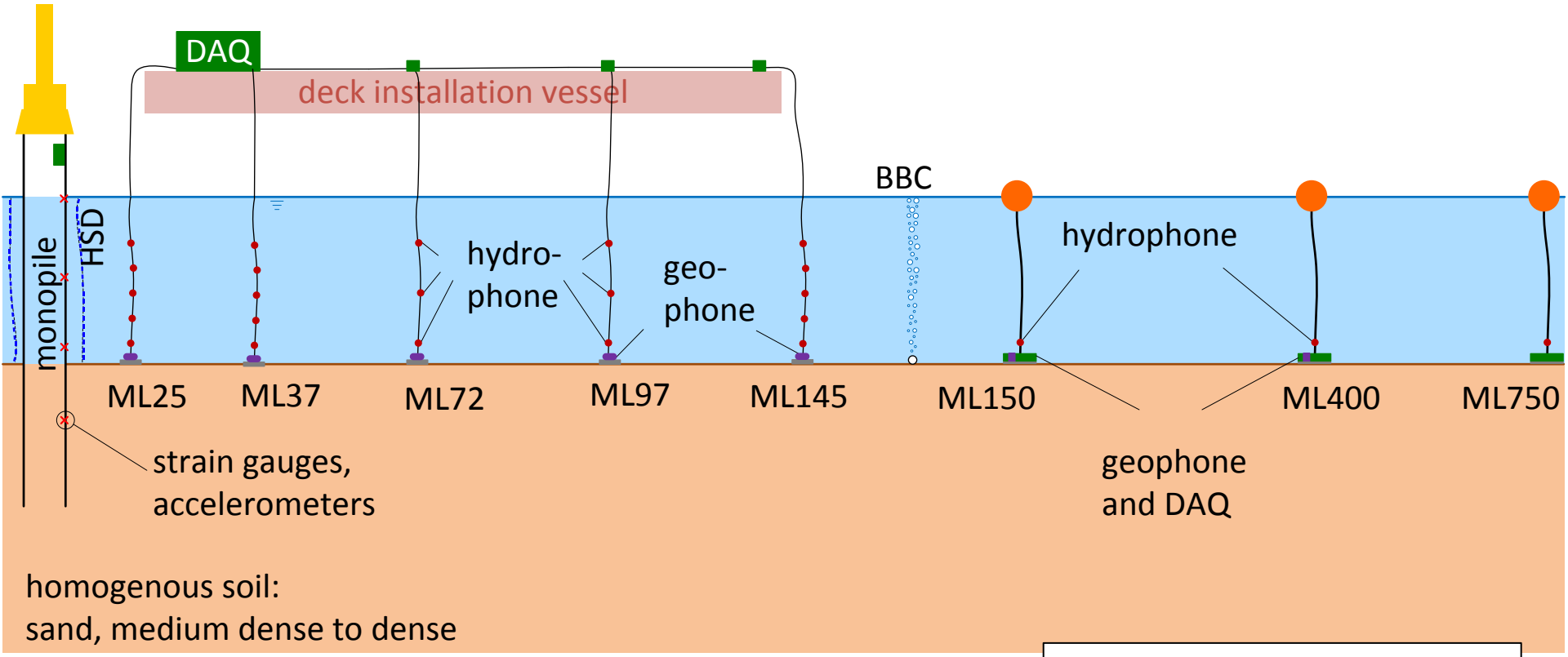
- at the pile
- 2nd phase of installation

big bubble curtain (BBC)
HydroTechnik Lübeck GmbH (HTL)

- approximately 70 m from pile
- whole installtation process

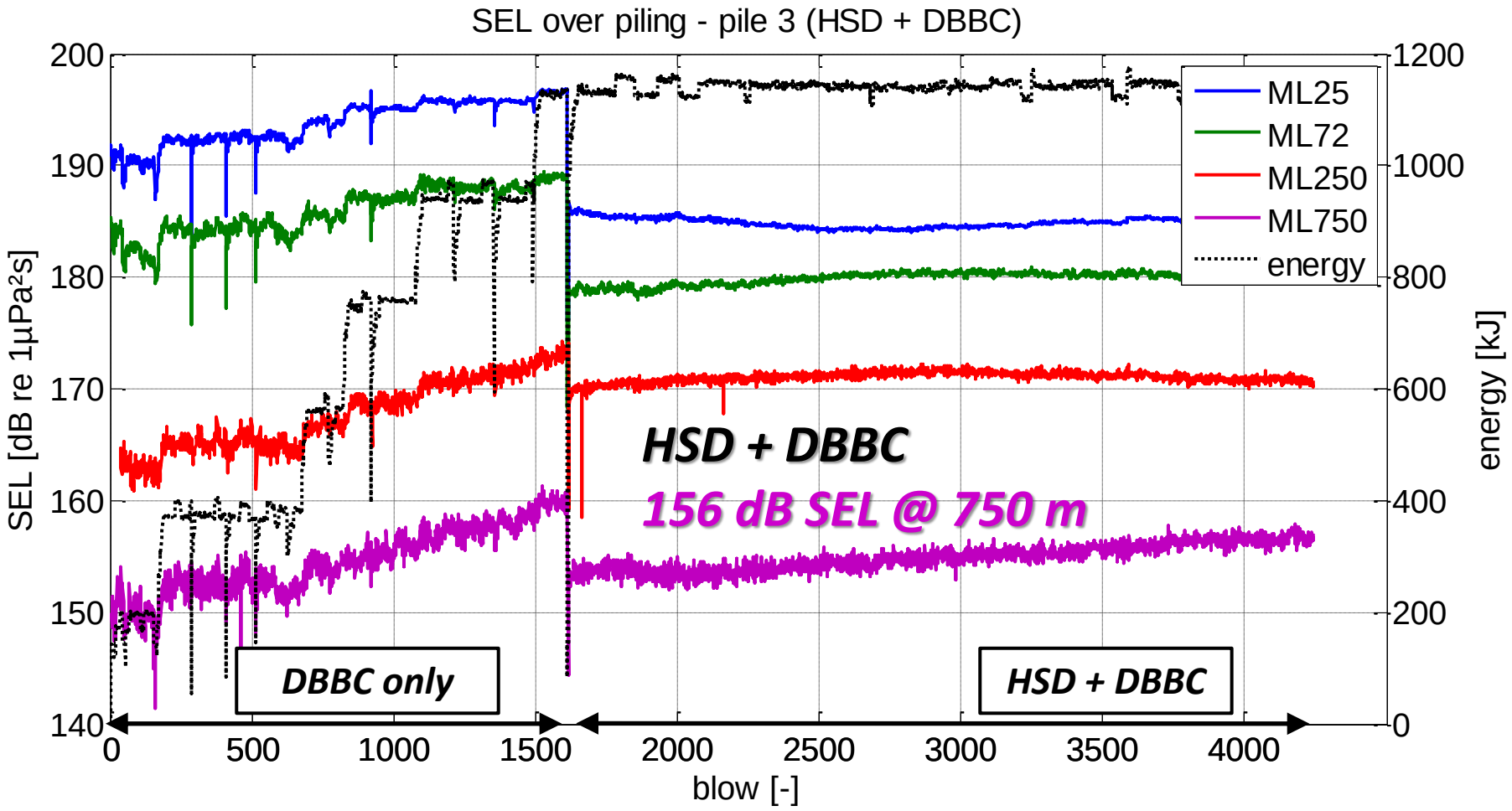


measuring concept research project triad – pile, soil, water

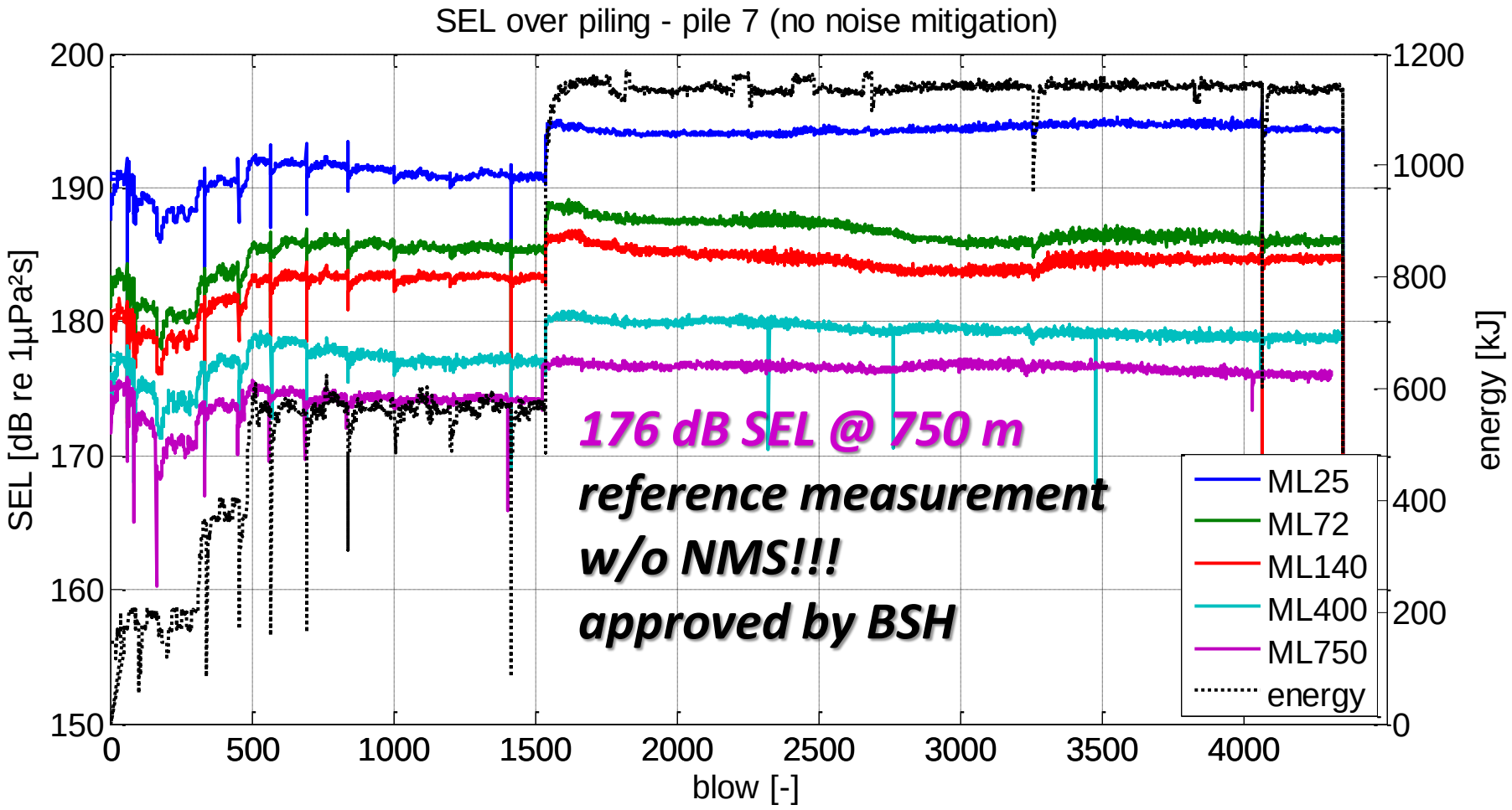


ML25: Measuring Location 25 m from pile

SEL over piling – combined use of HSD and BBC



SEL over piling – reference (no noise mitigation system)



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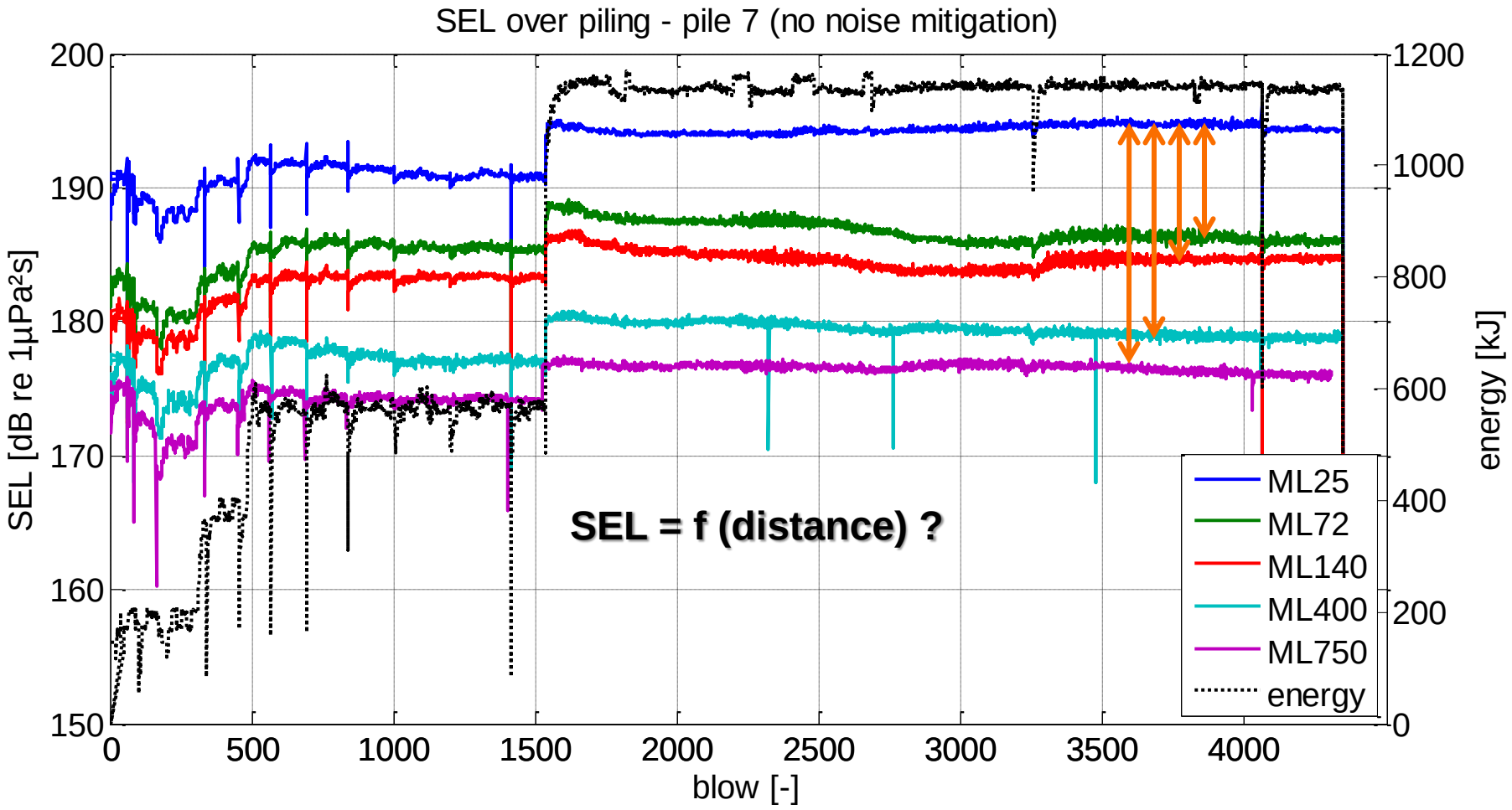
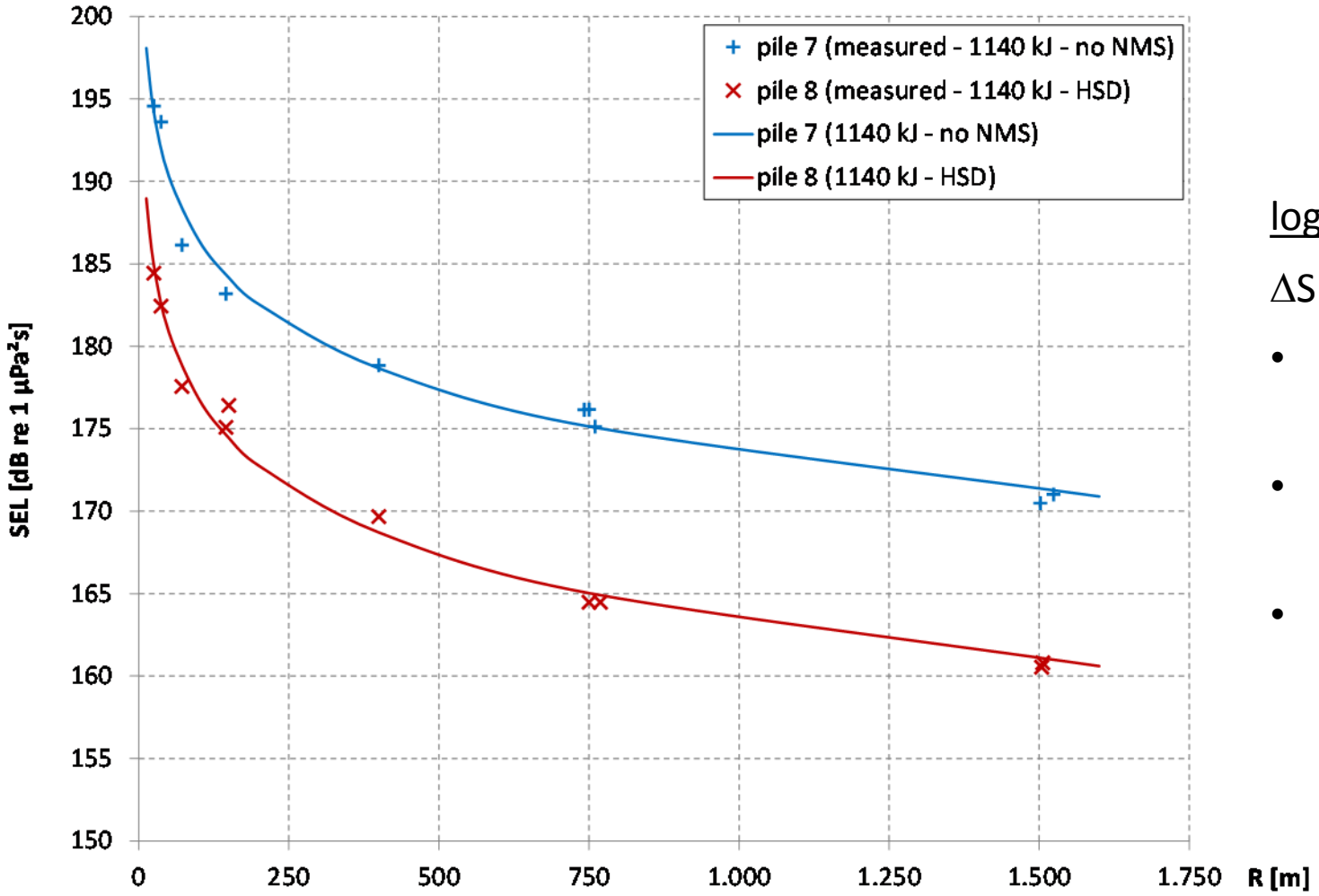


geometrical damping

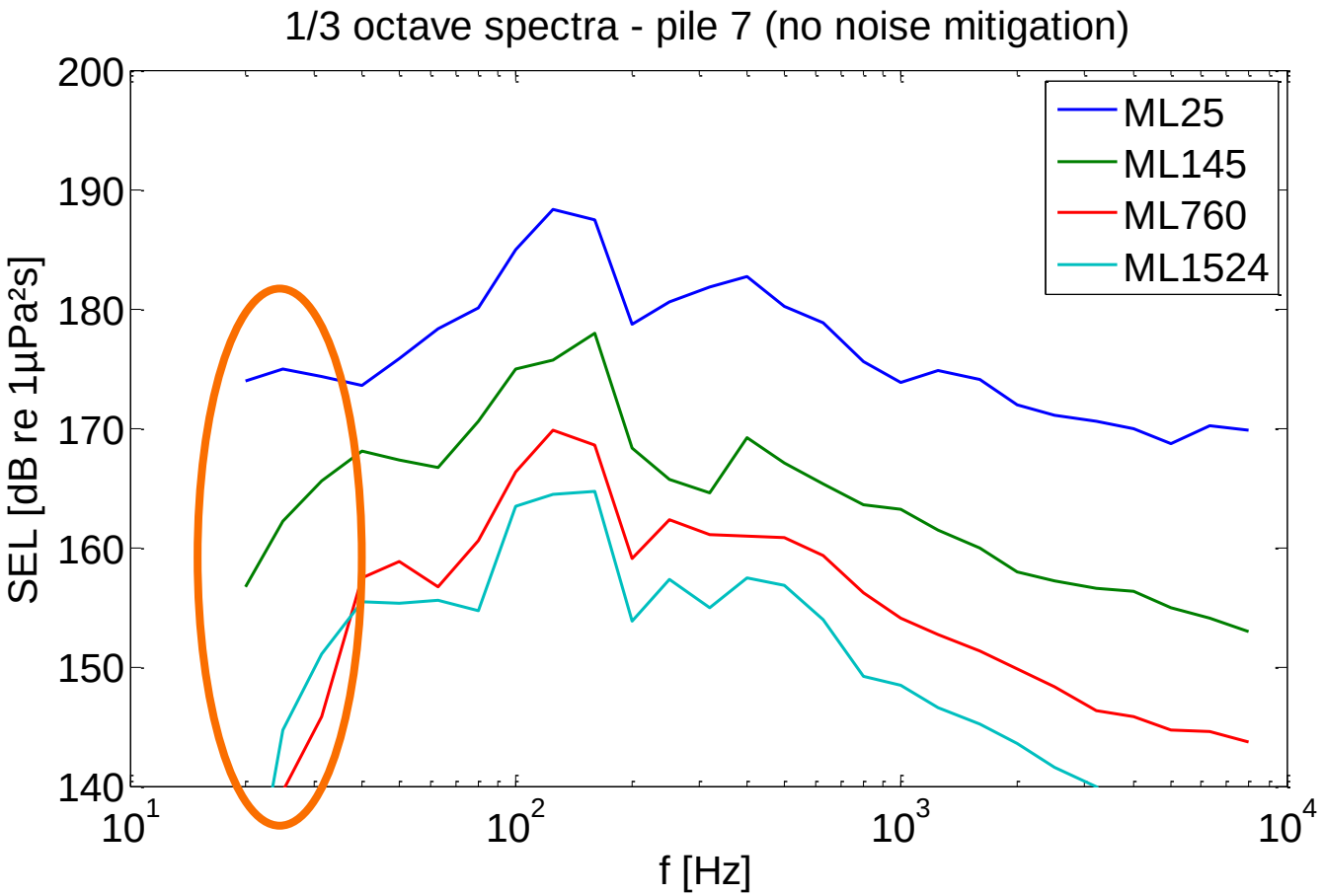


<u>logarithmic decrease</u>

$\Delta SEL = k \log (R)$

- spherical wave:
  k = 20
- plane wave:
  k = 10
- fit:
  k ≈ 12..13

geometrical damping



lower cut-off frequency

depending on water depth and soil conditions

<u>logarithmic decrease</u>

$\Delta SEL = k \log (R)$

- spherical wave:
  k = 20
- plane wave:
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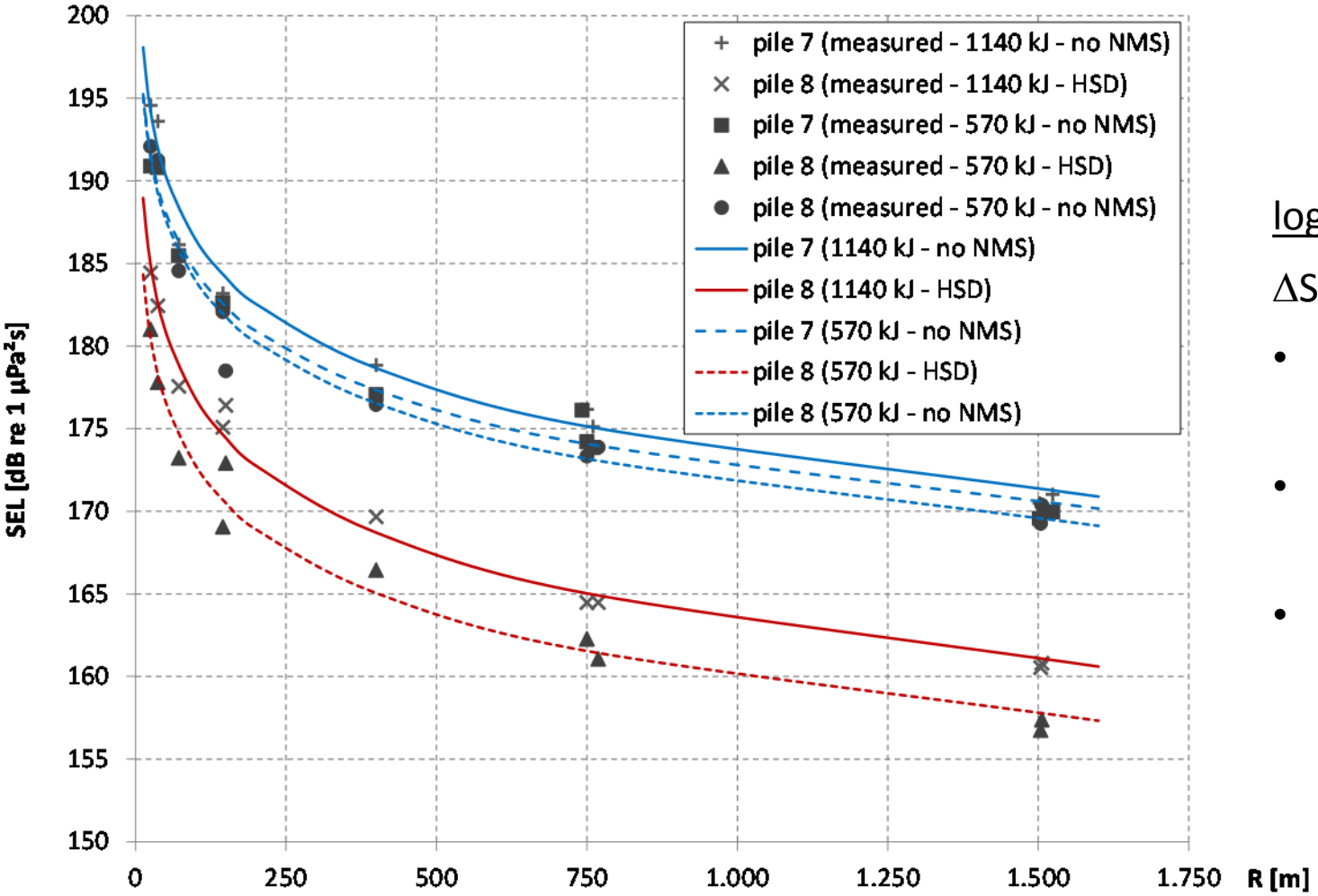
- fit:
  k ≈ 12..13

geometrical damping



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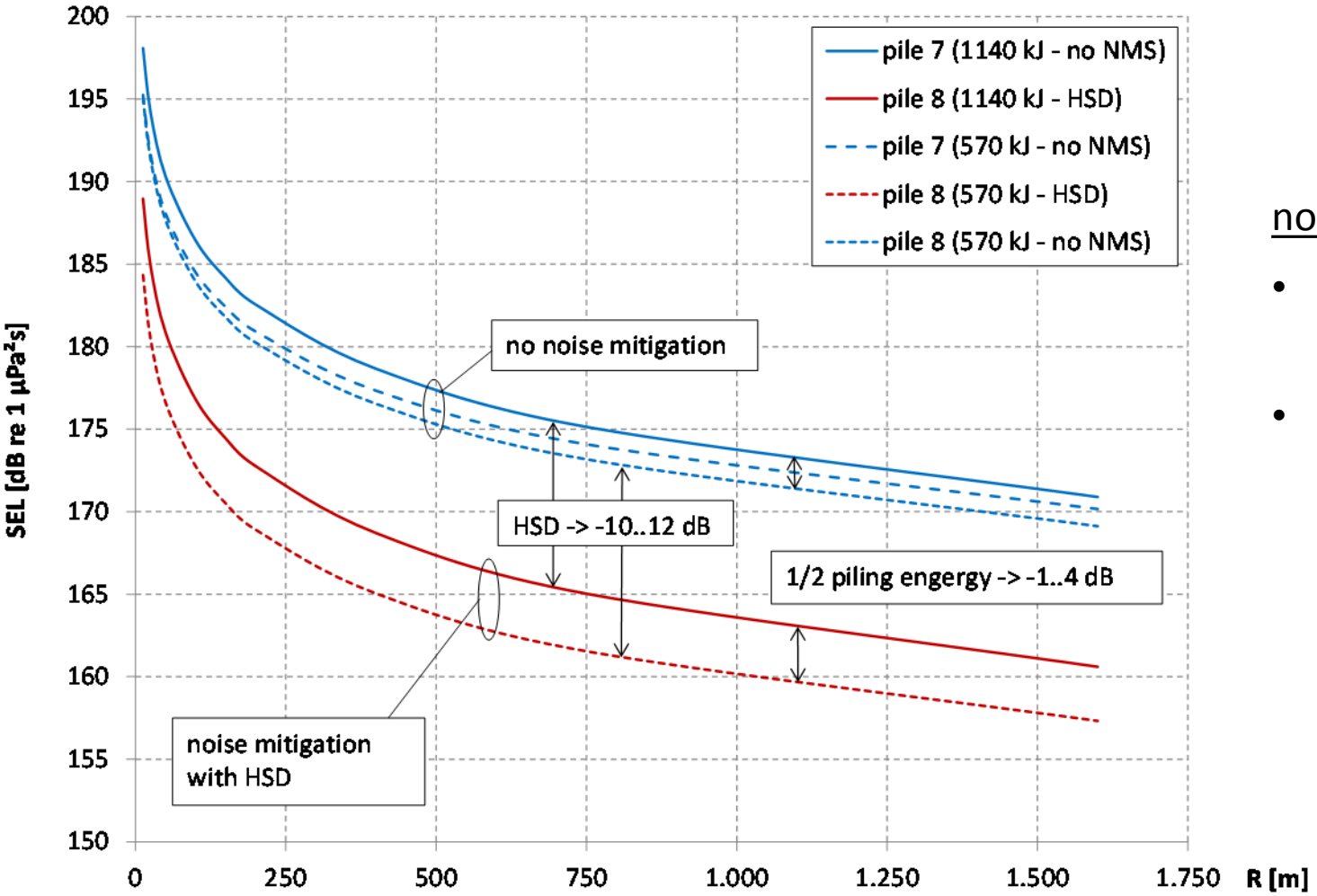


noise mitigation

- HSD:
  - 10..12 dB
- ½ piling energy:
  - 1..4 dB

influence of noise mitigation systems

different piles with different noise mitigation systems

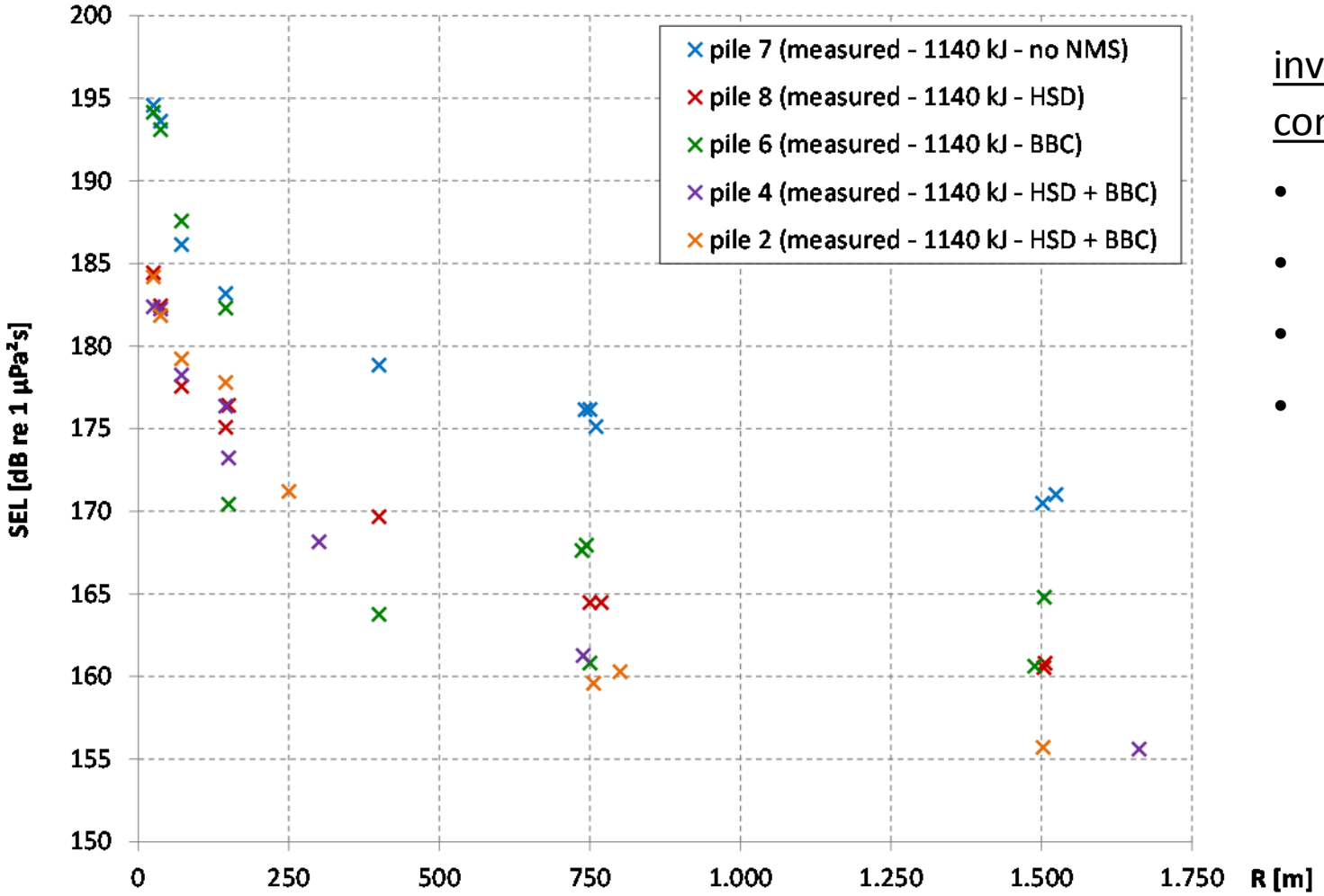
- Hydro Sound Dampers (HSD)
  - phase 1 without HSD
  - phase 2 with HSD

    → hammer strokes with comparable driving energy
- big bubble curtain (BBC)
  - ML25 .. ML145 inside BBC
  - ML150 .. ML1500 outside BBC

    → geometrical extrapolation
- combined use of HSD + BBC
- reference measurements without noise mitigation

*measurements and noise mitigation configurations within research project **triad** approved by Federal Maritime and Hydrographic Agency (BSH)*

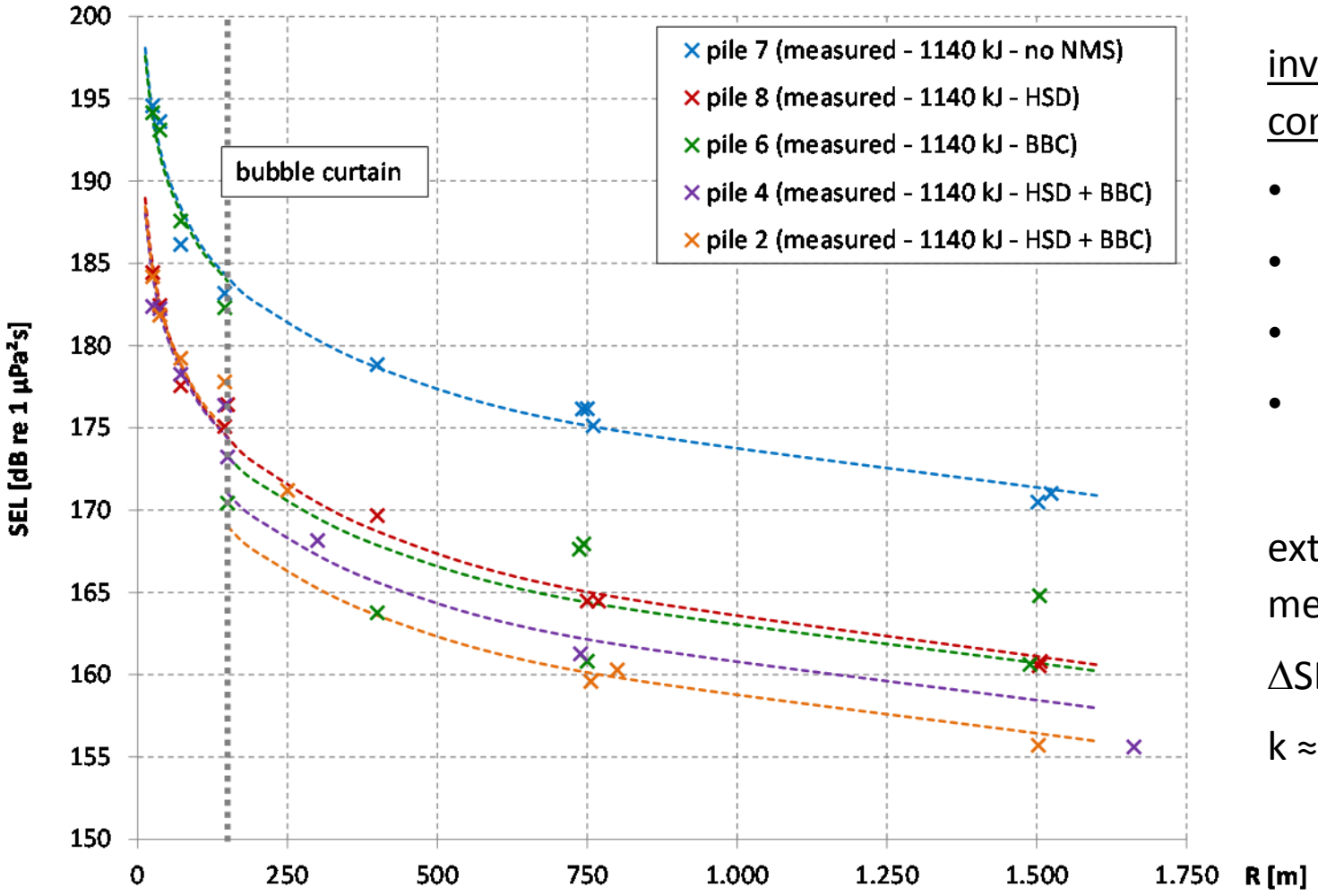
influence of noise mitigation systems



<u>investigated NMS configurations:</u>

- no NMS
- HSD only
- BBC (HTL) only
- HSD + BBC (HTL)

influence of noise mitigation systems



<u>investigated NMS configurations:</u>

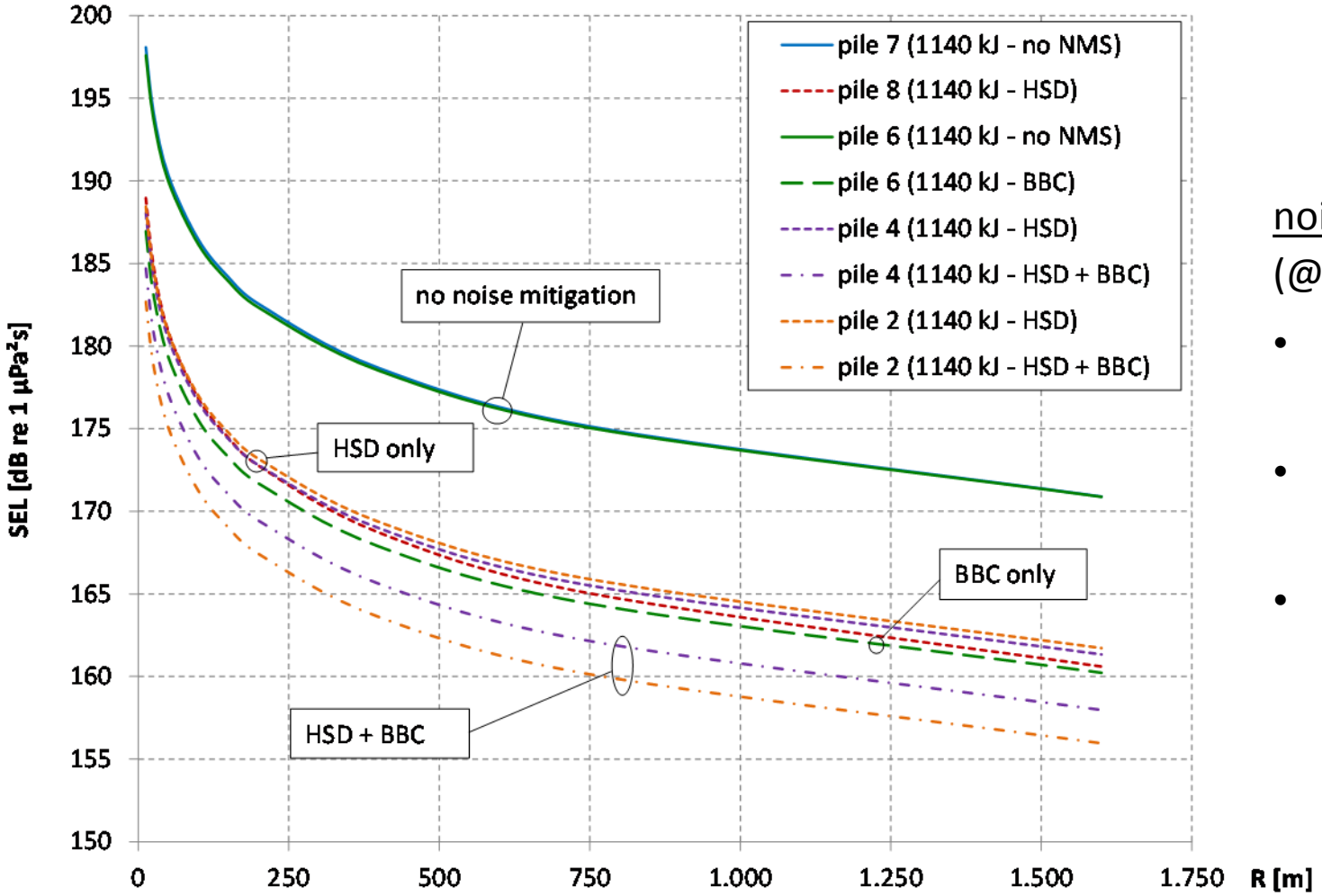
- no NMS
- HSD only
- BBC (HTL) only
- HSD + BBC (HTL)

extrapolation of measured sound levels

$\Delta SEL = k \log (R)$

$k \approx 12..13$

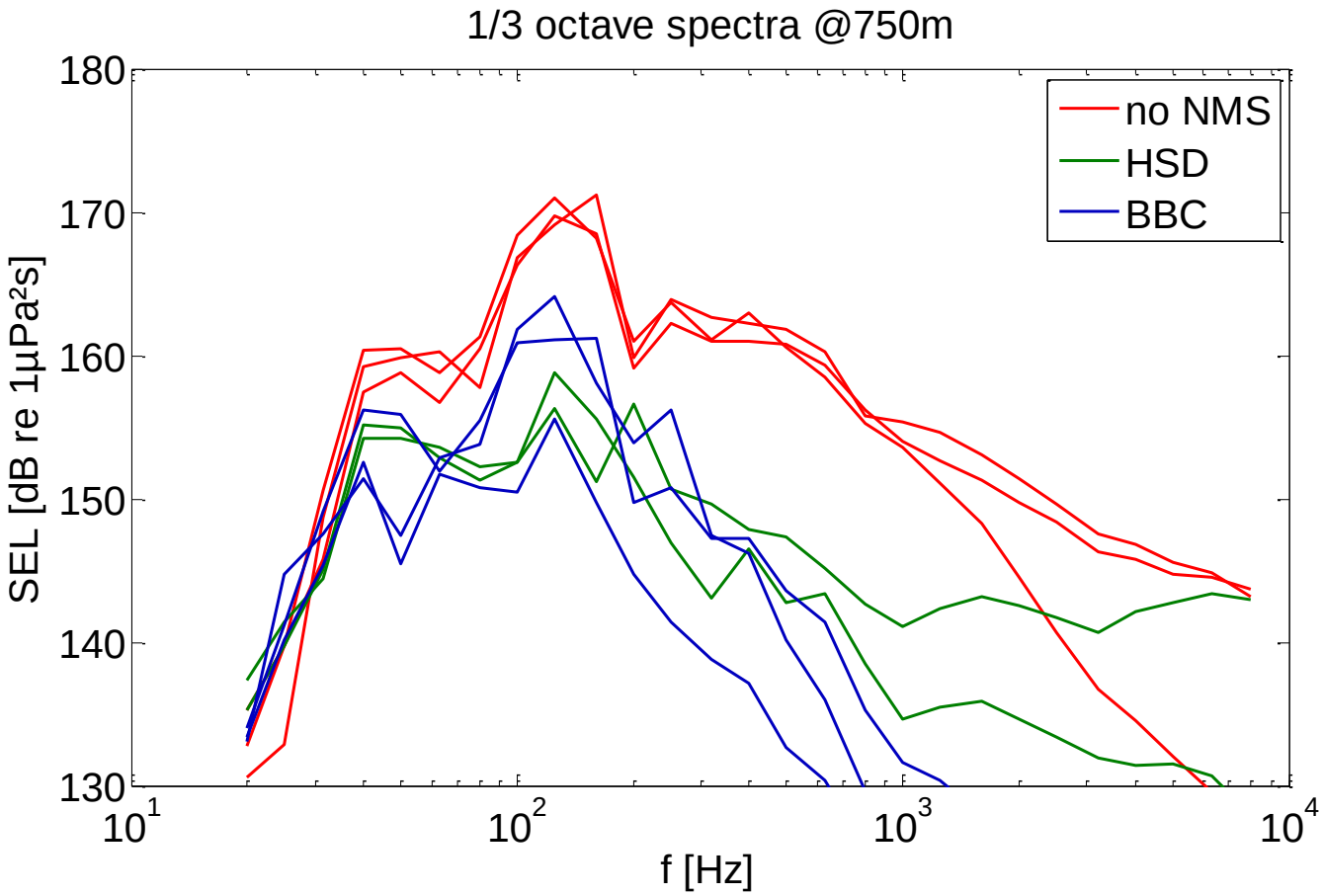
influence of noise mitigation systems



noise mitigation
(@ 1140 kJ)

- HSD:
  ΔSEL = - 10 dB
- BBC (HTL):
  ΔSEL = - 10 dB
- HSD + BBC (HTL):
  ΔSEL = - 13..15 dB

influence of noise mitigation systems



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- HSD:
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Summary

- high density of sensors inside BBC

  → good description of wave propagation around pile driving
- measurements of pile deflections (and soil vibrations)

  → investigation of phenomena in offshore pile driving noise emissions

❖ noise mitigation concept (HSD + BBC) suitable to keep limiting values (ΔSEL up to 19 dB) at monopile foundations (Ø 6m) <u>under given conditions</u> at Amrumbank West OWF

- HSD → ΔSEL ≈ 10 dB
- BBC (HTL) → ΔSEL ≈ 10 dB
- HSD + BBC (HTL) → ΔSEL ≈ 15 dB
- HSD + DBBC (HTL + Weyres) → ΔSEL ≈ 19 dB

- keeping of limiting values of hydrosound pressures remains a challenge
  - greater diameter piles
  - realisation of noise mitigation under offshore conditions
  - combined noise mitigation systems → complex logistics, high costs

Something else about acoustics: