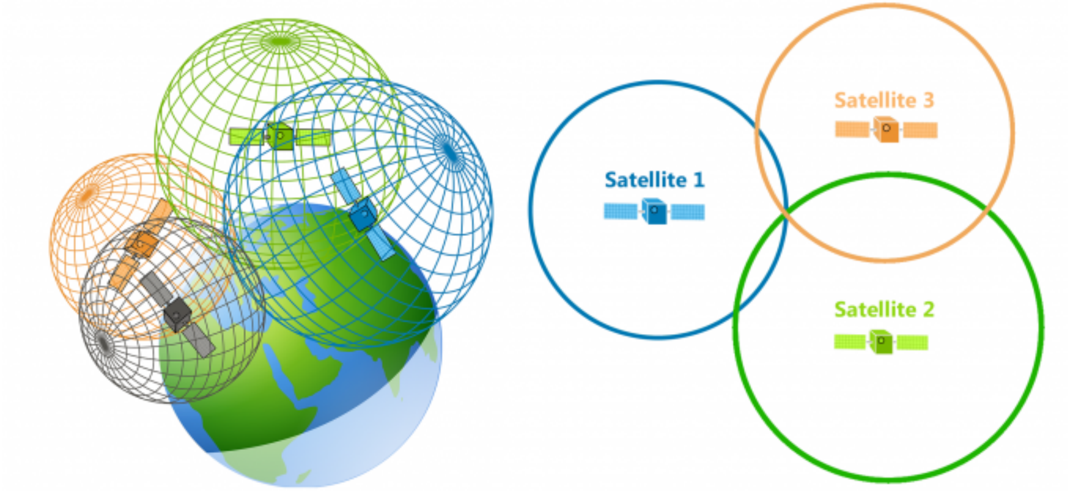
systematic studies of the second sound method for quench detection of SRF cavities

Lea Steder, Bosse Bein

SRF Dresden, 05.07.2019

basic concepts

second sound in a nutshell



https://gisgeography.com/trilateration-triangulation-gps

- run-time measurement at sensor positions
- minimisation of spherical error function (RMSE)
- quench of superconducting cavity

  ⇒ second sound wave

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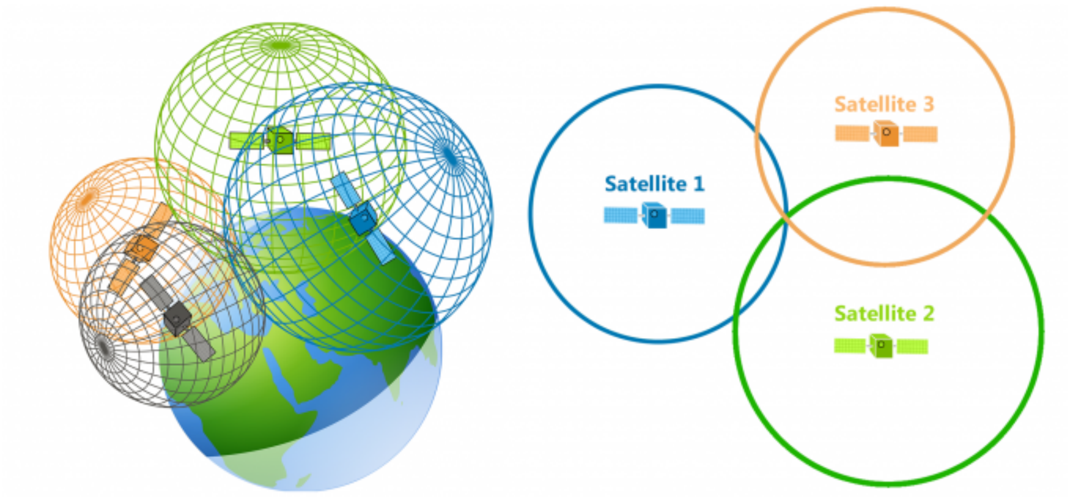

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second sound

- temperature driven entropy wave
- carrier: He I, superfluid He II produces counter flow
- propagation velocity @ 2K about 20 m/s

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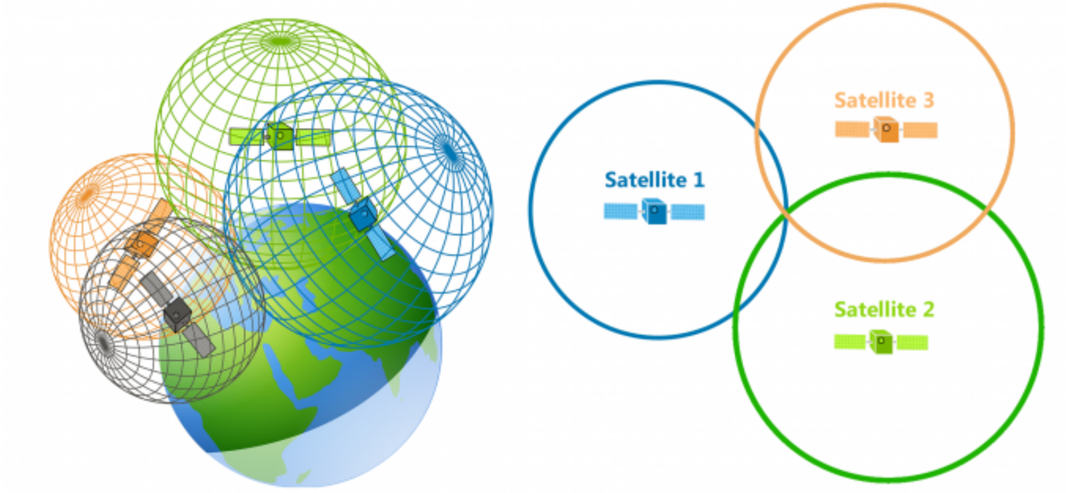

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oscillating superleak transducer (OST)

- principle of capacitor microphone
- electrodes: Brass body and porous membrane
- only superfluid Helium can enter pores due to vanishing viscosity

motivation and goals of studies

a kind of an outline

- **OST installation** improvements ⇒ a new level of precision
  - coverage and symmetry
- **automation** of analysis environment ⇒ better efficiency & comparability
  - noise filtering
  - quench-time and run-time determination
  - quench-spot reconstruction
  - graphical user interfaces (GUIs)
- **comparison** of quench-spot reconstruction algorithms ⇒ method of choice
  - impact of systematic uncertainties
  - two approaches: 3 x 2 + 2 algorithms
- external **reference** ⇒ realistic evaluation of reconstruction methods
  - the answer to (almost) everything

OST installation and coverage

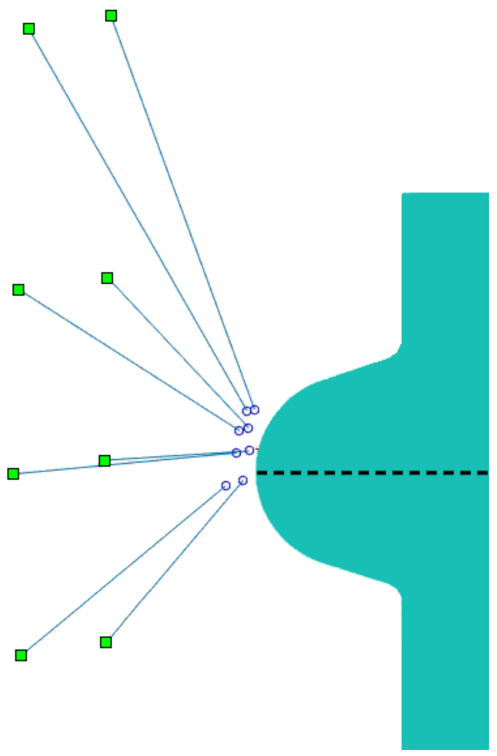
precision but not at all costs

- reproducible fixed 3D positions
  - notches in rods at equator heights
  - measurement accuracy: 10 microns
  - placement accuracy: 1 mm
- for even better precision
  - exchange of cavities possible w/o removal of OSTs
  - coverage insufficient
- blind spots to be avoided!
  ⇒ additional holders in preparation

symmetric positioning

for the sake of unbiased reconstruction

> signal run-time distance not exactly fitting OST distance
> ⇒ reconstructed spot biased towards centre-of-mass of all used OSTs



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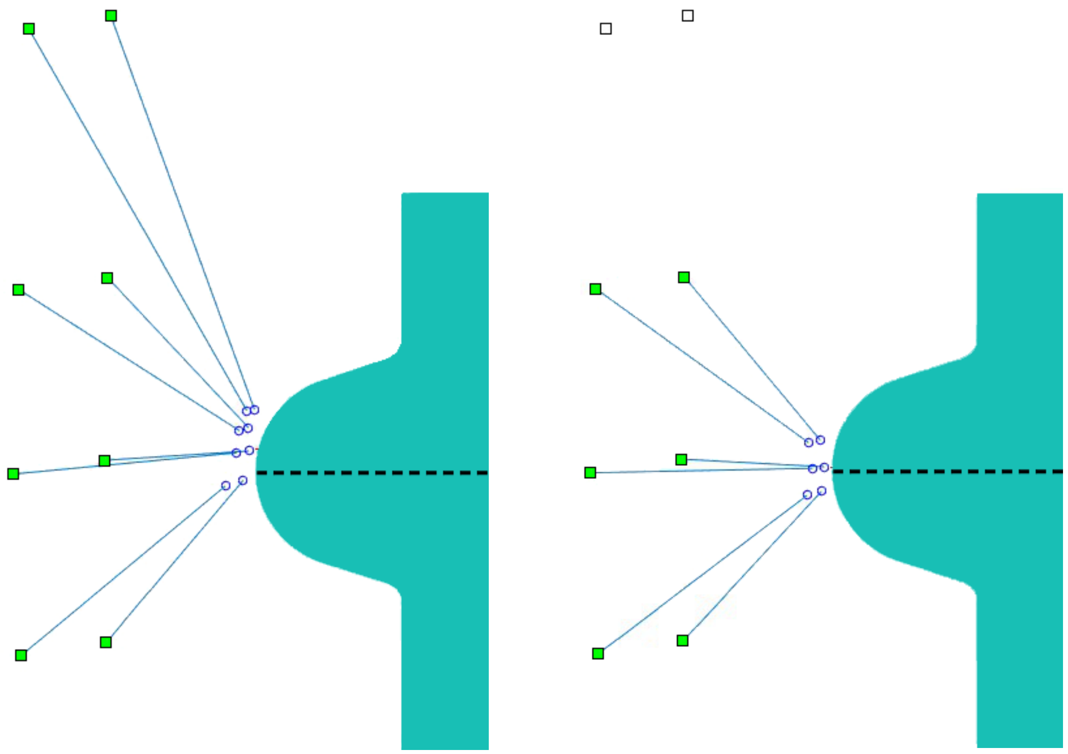


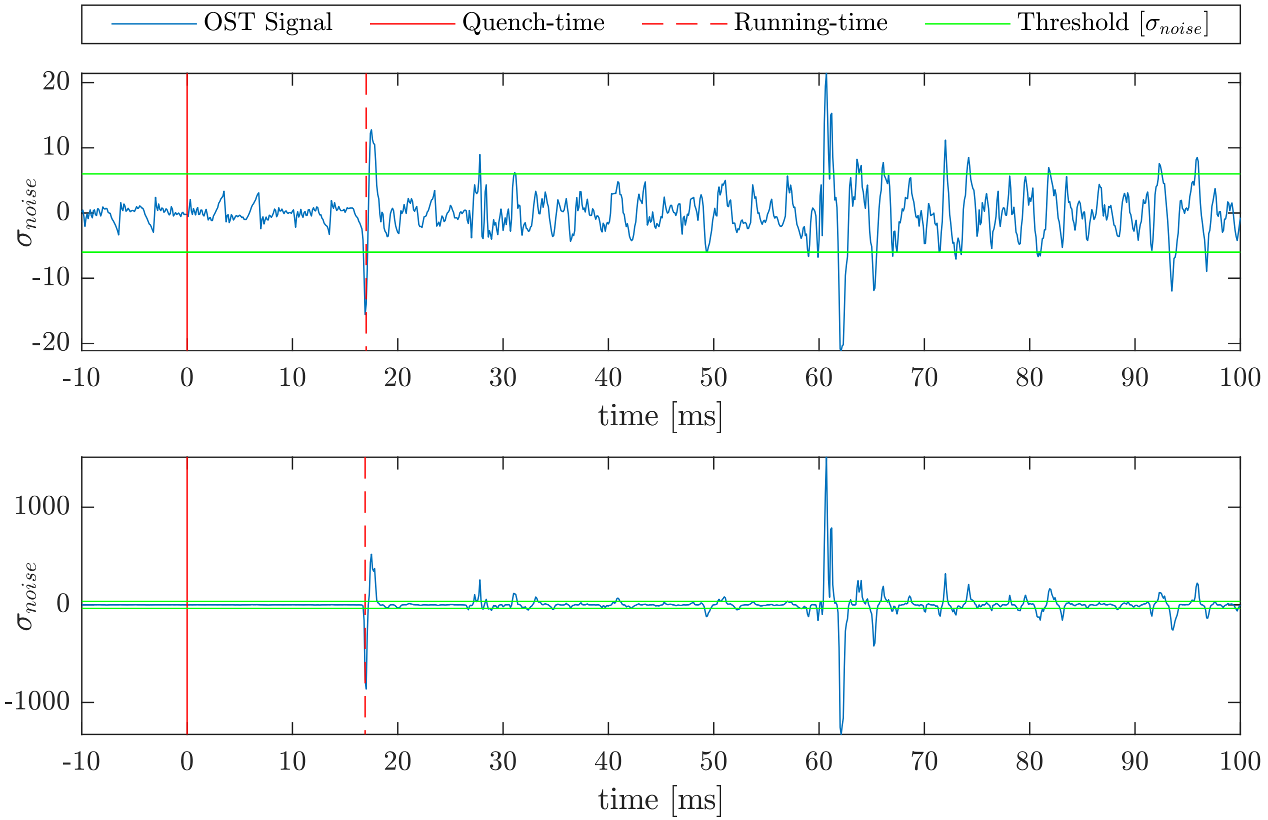
- effect easy to avoid by OST symmetry around equator plane

quench-time and signal run-time deduction

crucial input for reconstruction

- noise filtering of OST signal
  - Fourier, Notch filter: multiples of 50 Hz
  - significant reduction

  ⇒ identify/eliminate sources



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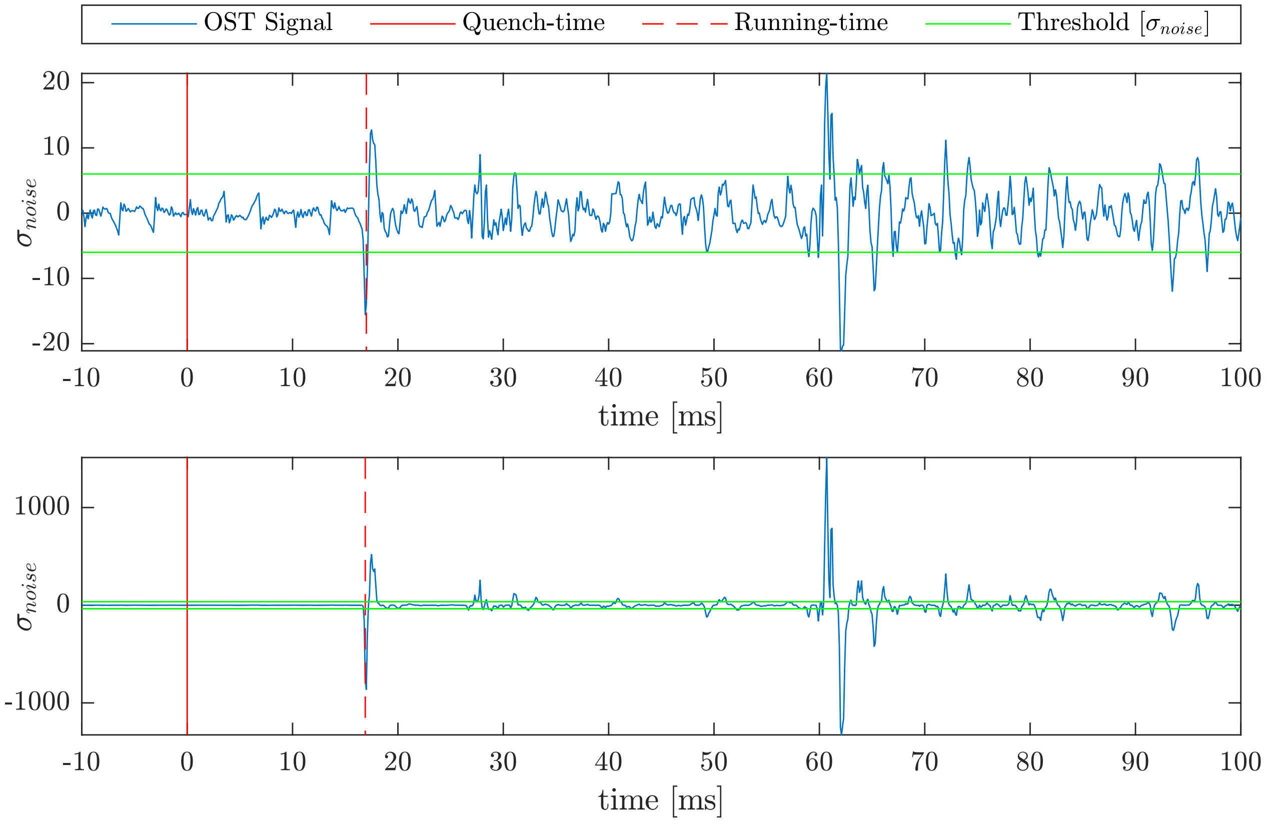

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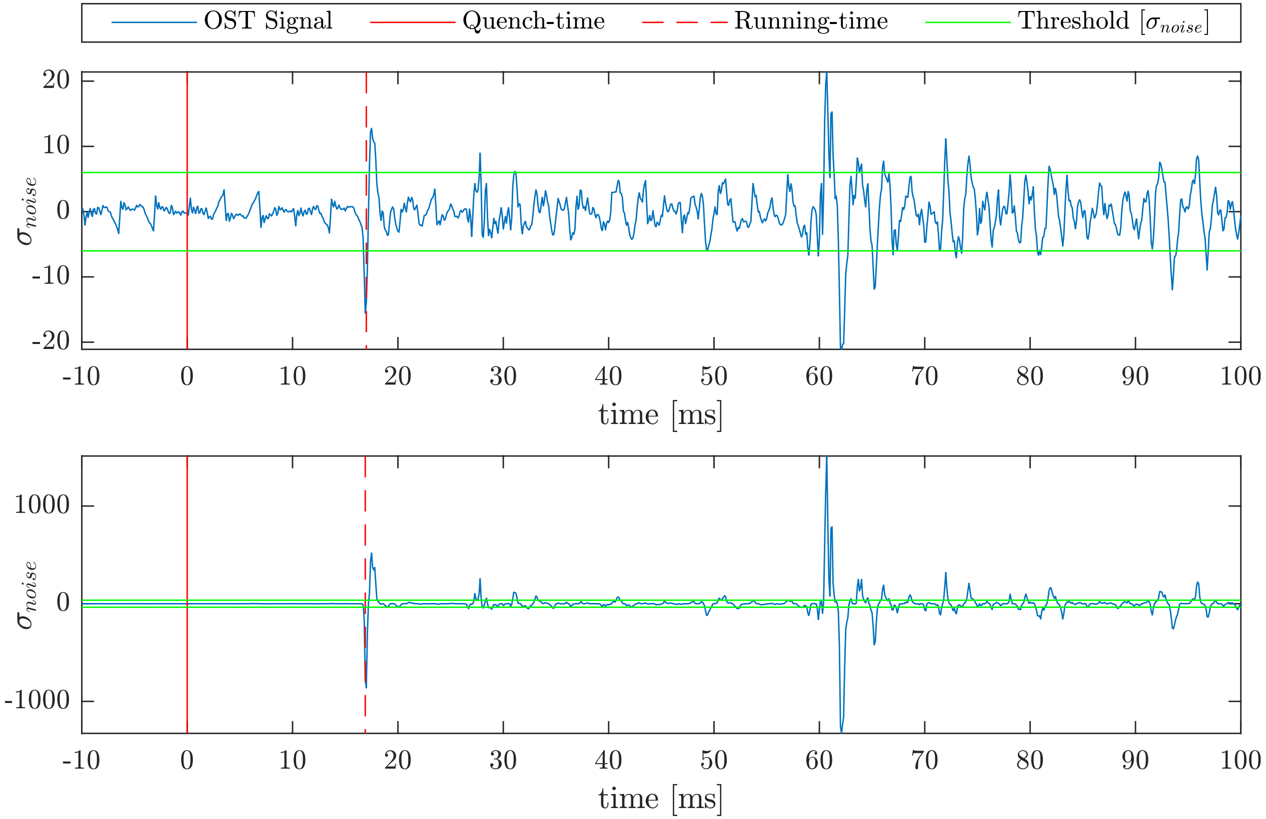
crucial input for reconstruction

- noise filtering of OST signal
  - Fourier, Notch filter: multiples of 50 Hz
  - significant reduction
  - ⇒ identify/eliminate sources
- quench-time t_0 determination (RF signals)
- signal run-time t_{OST} deduction
  - unfiltered / filtered signals as input
  - noise envelope, signal quality for peaks, threshold for channel
  - iterative peak finding algorithm, start @ t_0



GUI development

user-friendly software environment

> OST coordinate definition

- predefined position lists
- cavity angle offset
- liquid Helium temperature

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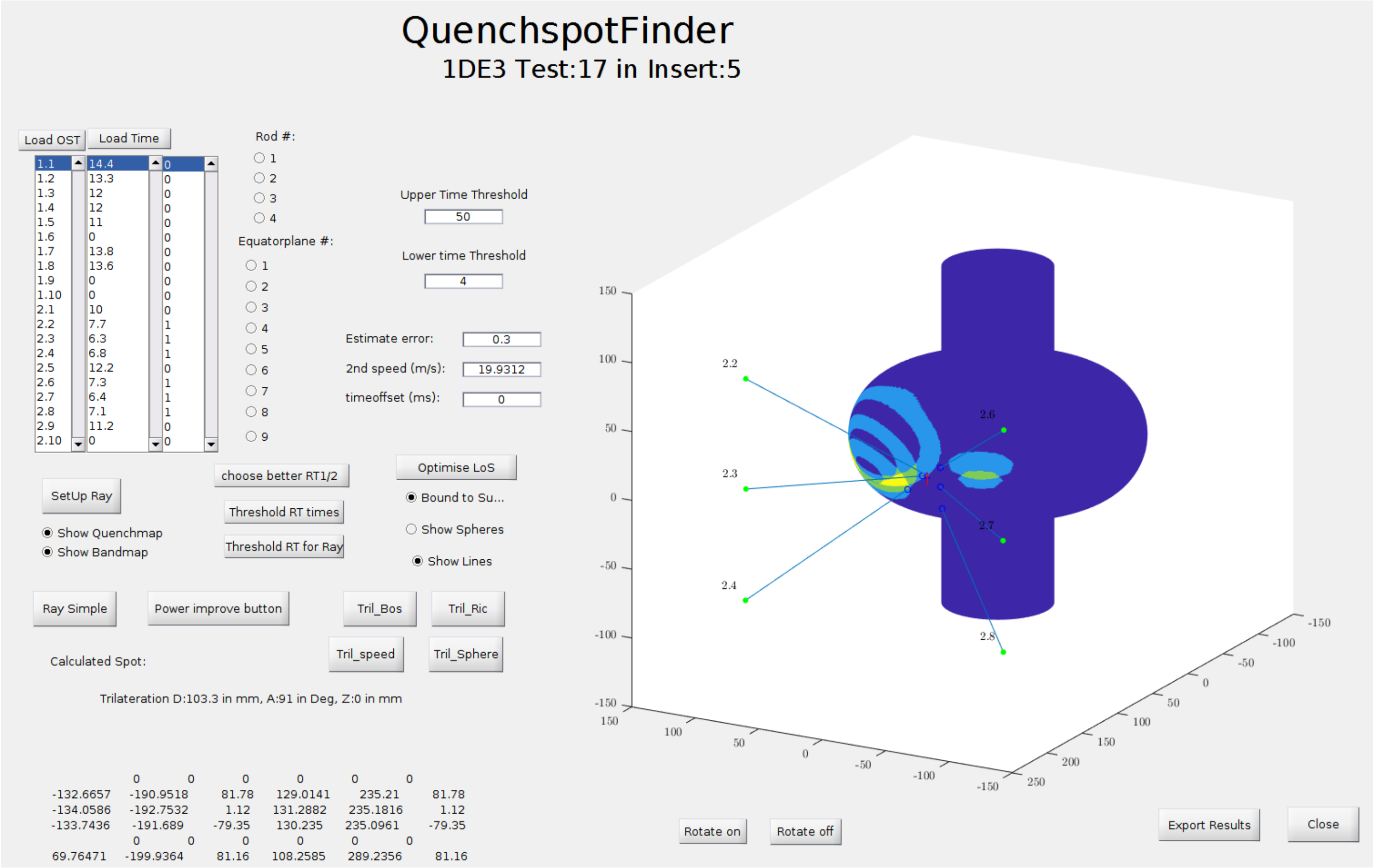
> quench-spot finding

- used OSTs
- reconstruction method
- display of quench-spot coordinates



multilateration algorithms

a wide range of methods implemented

basic assumptions

1. constant second sound velocity at given liquid Helium temperature
2. spherical wave propagation with point-like origin of waves
3. OST and quench-spot in direct line-of-sight

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  - incorporates temperature and u_2 change, induced by second sound wave itself

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> average 2nd sound velocity u_2 free parameter - w/o assumption 1
  - incorporates temperature and u_2 change, induced by second sound wave itself

> spherical quench-spot radius r as free parameter - w/o assumption 2
  - considers propagation through Niobium
  - interpretation: none point-like origin or quench-time offset

raytracing algorithm

completely different approach

basic assumptions

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4. none line-of-sight signals contribute via shortest path around cavity
5. second sound wave intrinsically assumed to be emitted at cavity surface

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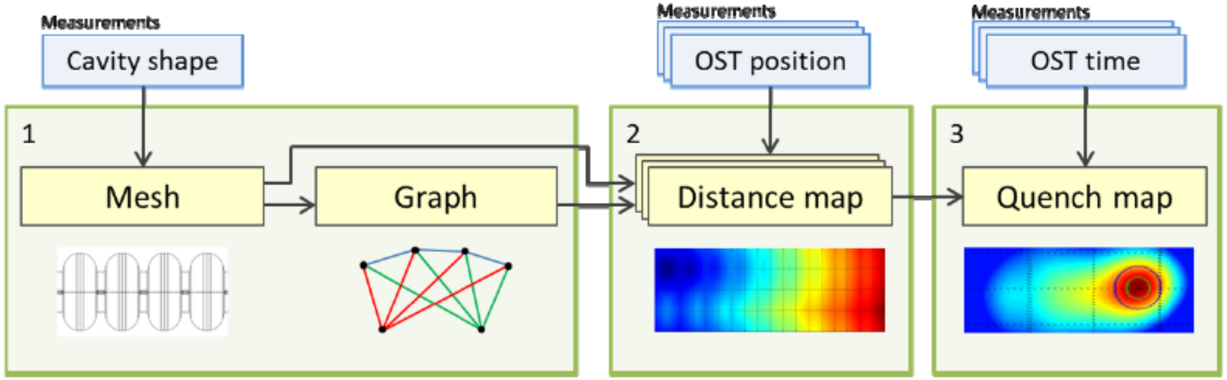

PhD thesis Y. Tamashevich

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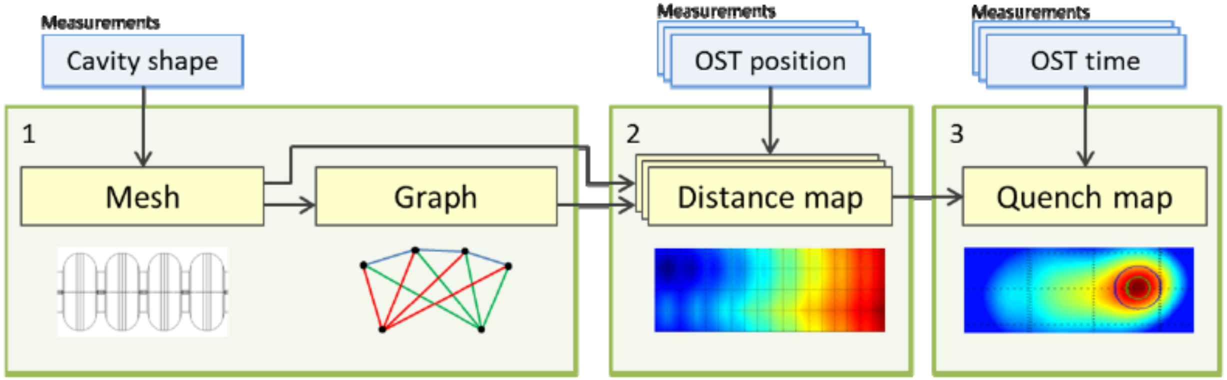

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2 algorithms

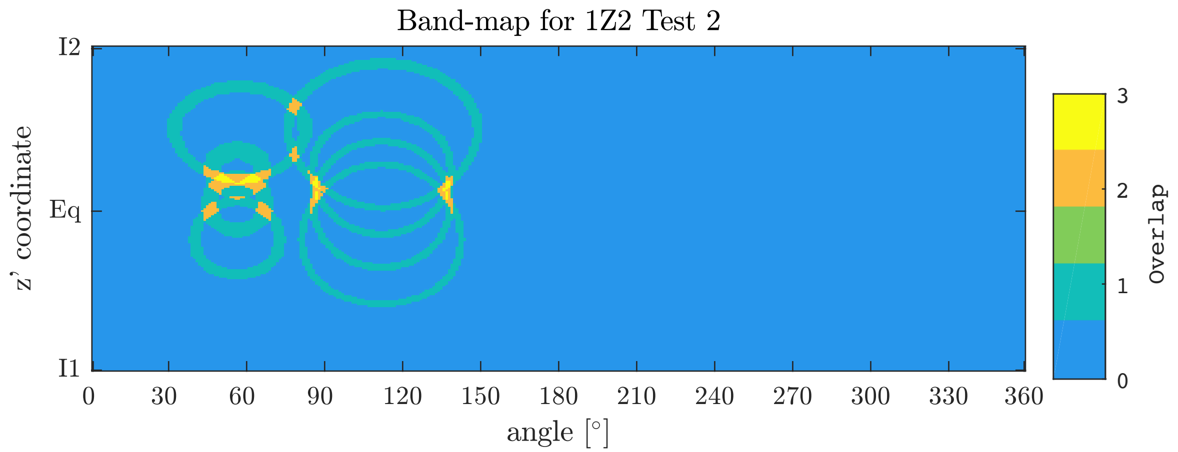
> original algorithm

> algorithm with line-of-sight requirement

raytracing observations

bands draw more precise picture

- band maps recently implemented
  - each band depicts surface reached by one OST & signal-run time t_{OST}
- band maps visualise all possible quench locations via overlaps



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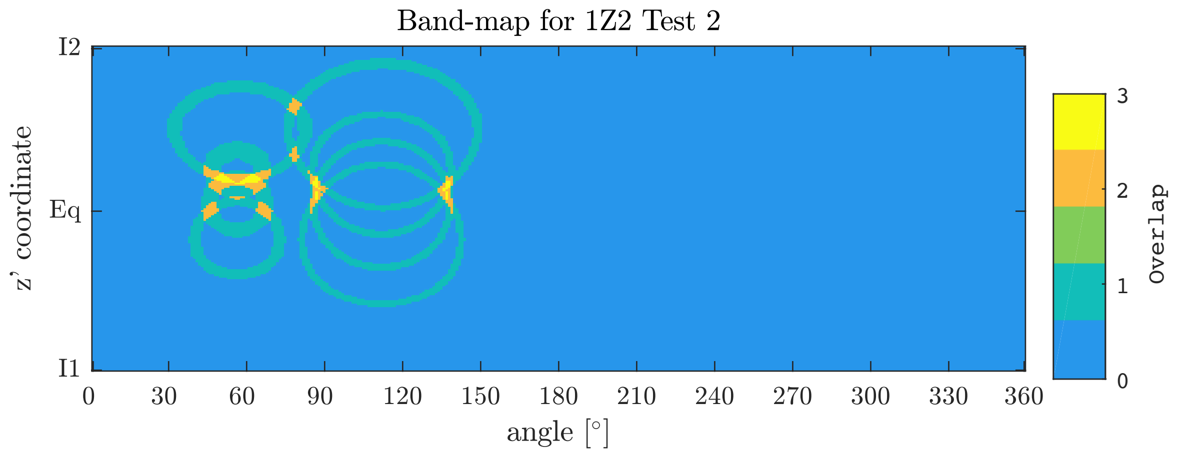

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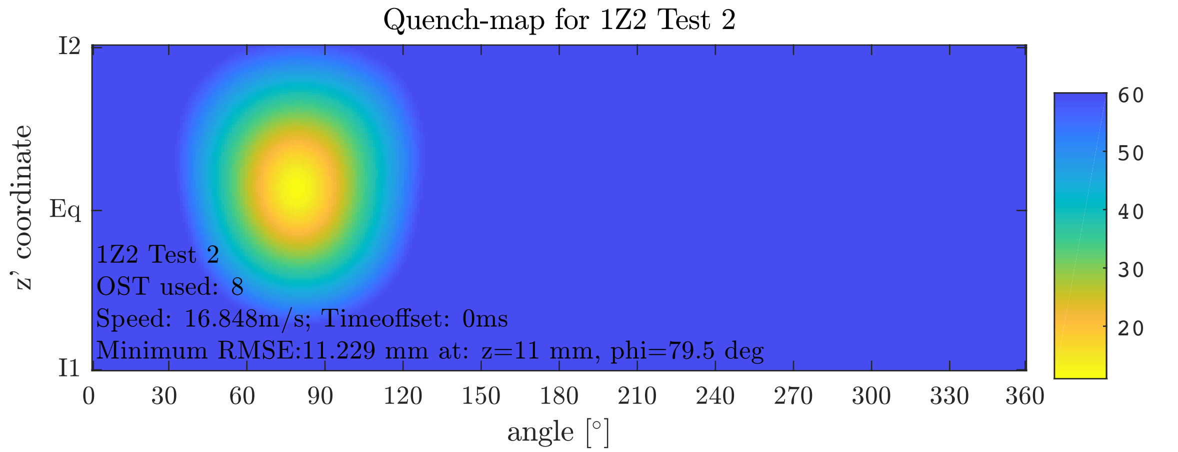

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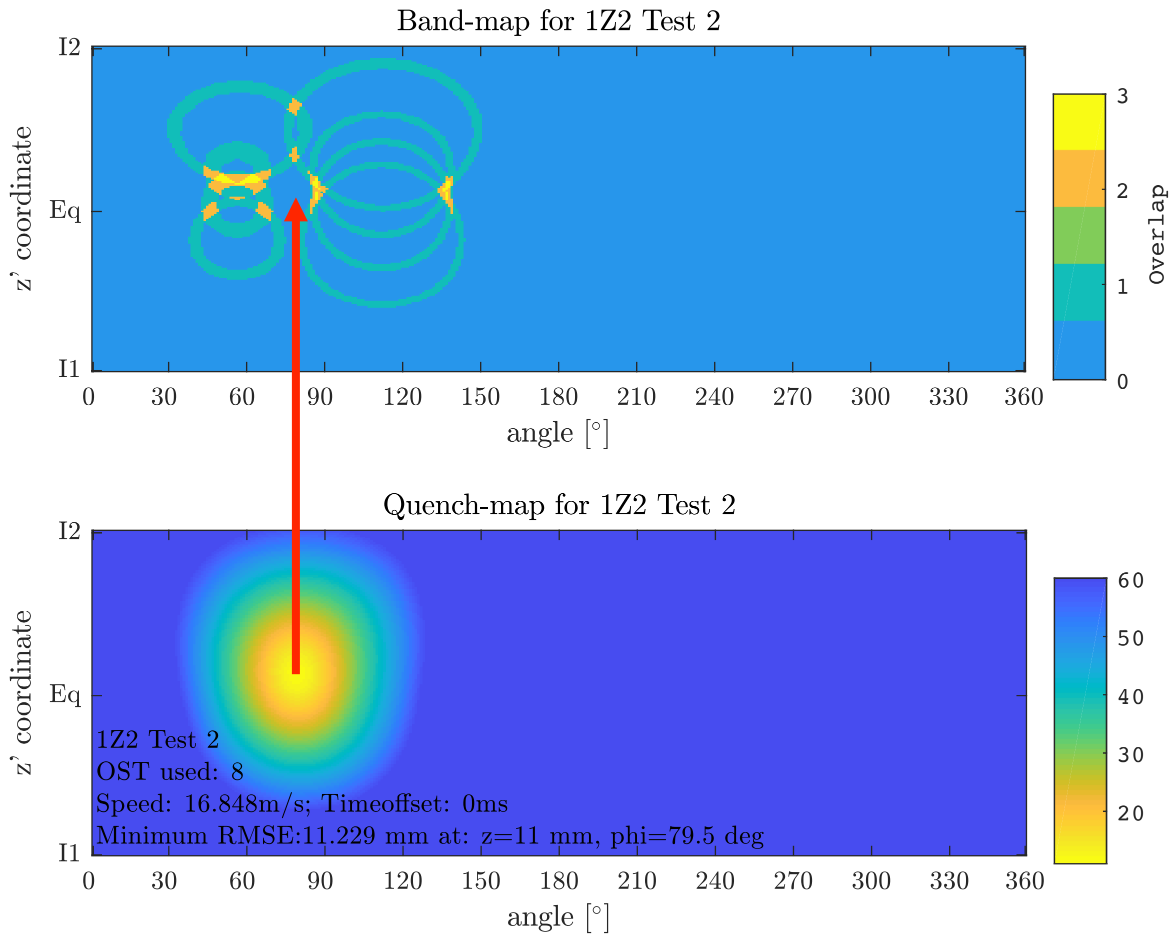

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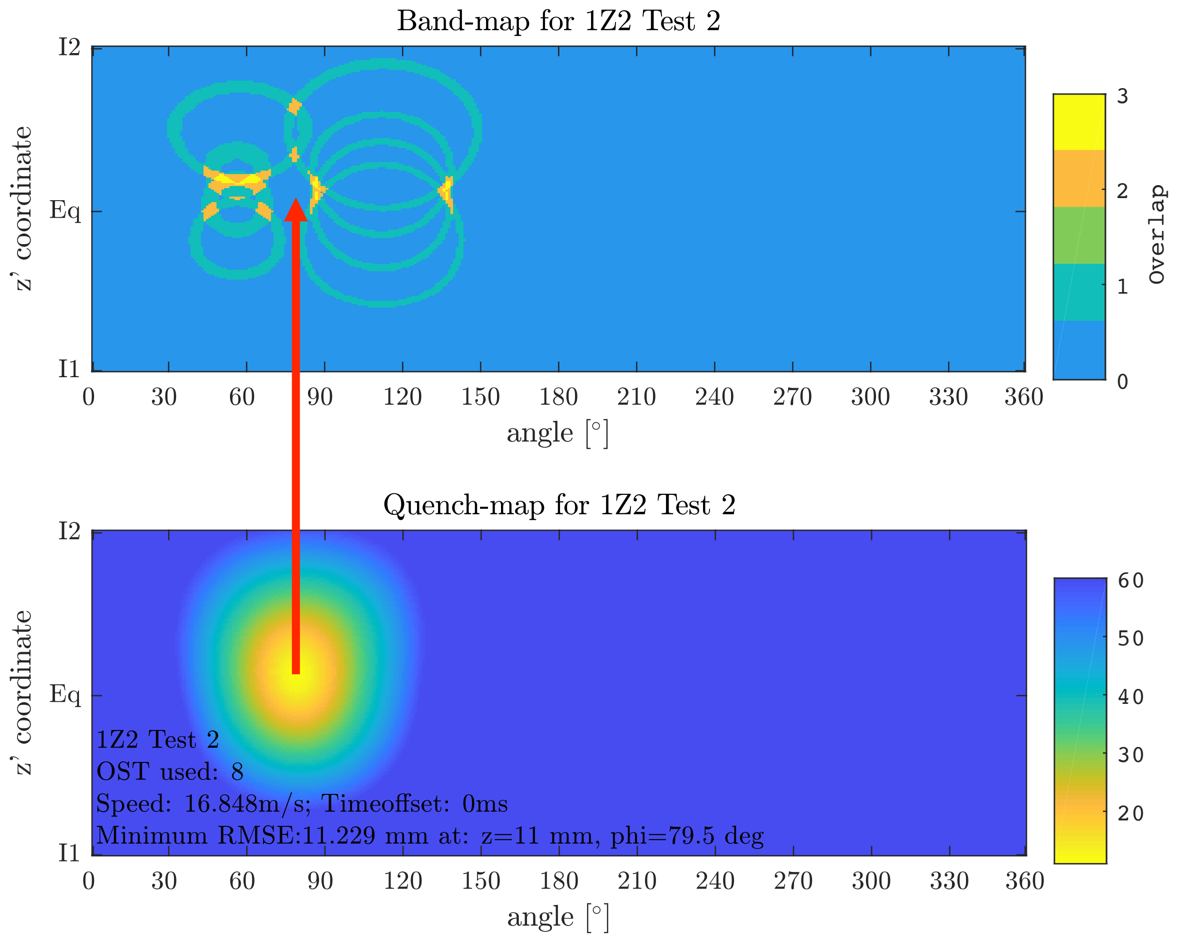
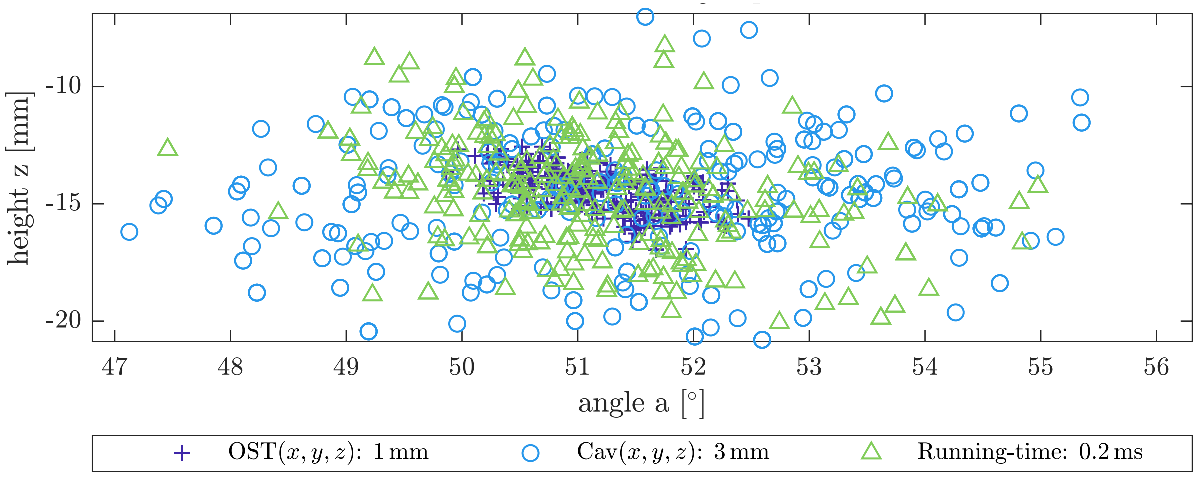
- in this case: information is lost
- incorporation of none line-of-sight OST signals seems to distort reconstruction



uncertainty estimation by simulation

know and control weak points

> OST/cavity position, quench/run-time deductions, second sound velocity



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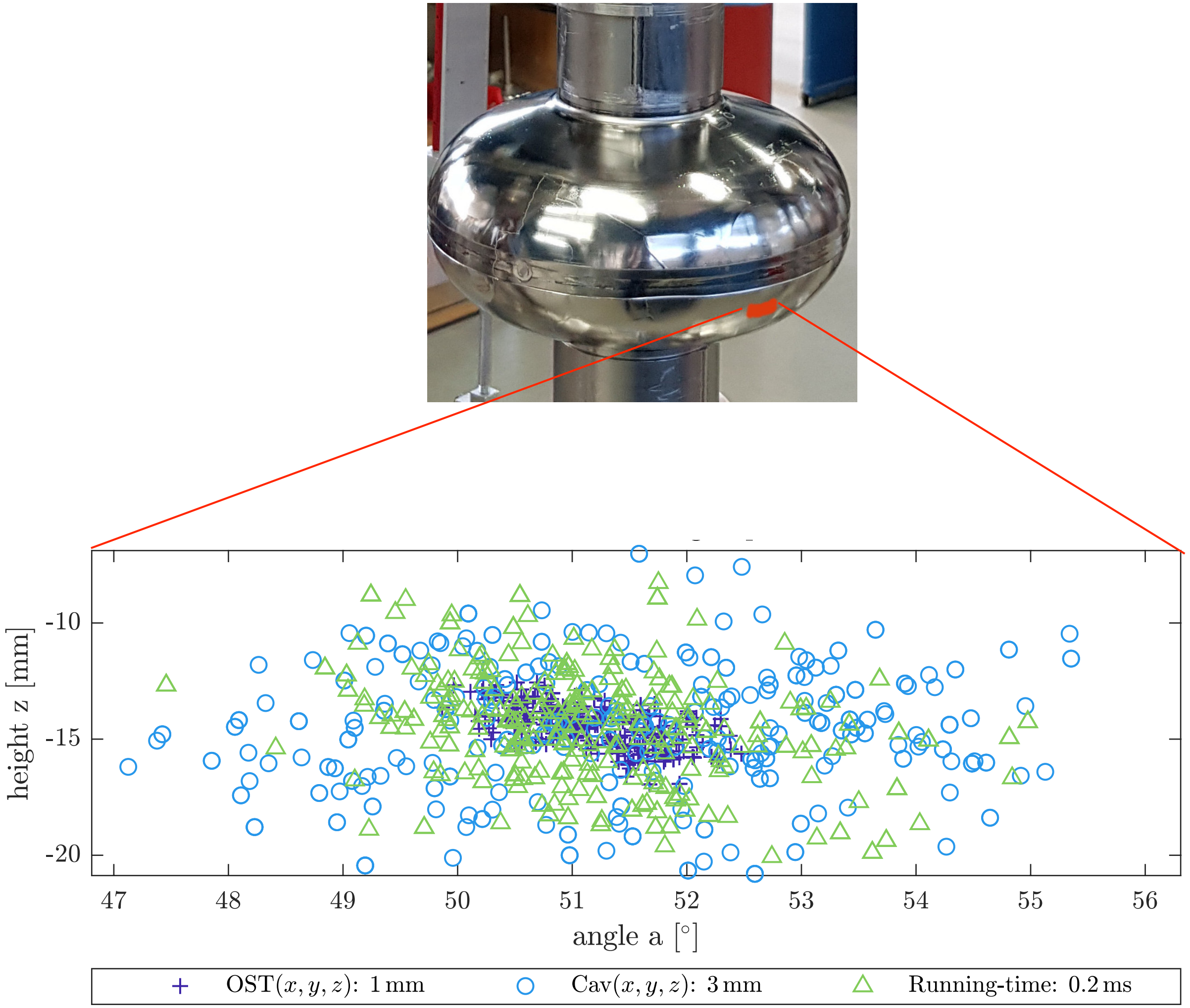
  ⇒ **impact of signal run-time t_{OST} large**
  ⇒ velocity uncertainty uncritical



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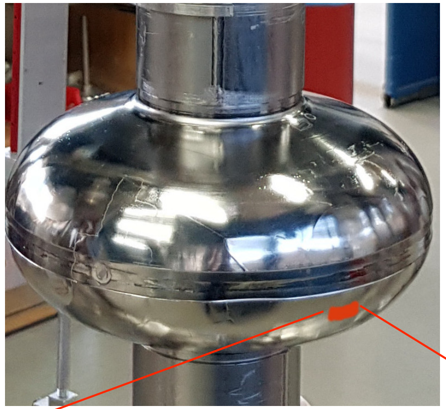
- variation all parameters describes different reconstruction methods

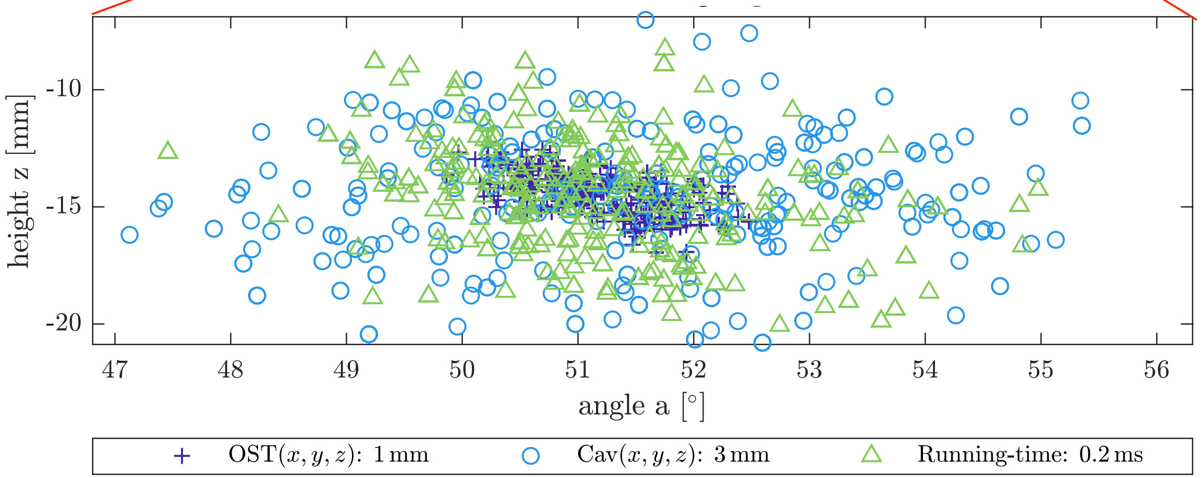
  ⇒ **surface constrained basic multilateration**:

  6.6 mm ± 5.5 mm

  ⇒ **free velocity fitting multilateration**:

  8.5 mm ± 2.8 mm





external calibration via heat deposition

a must-have we don't have... yet

1. realistic resolution determination for reconstruction algorithms!
2. ability of raytracing algorithm to enhance resolution with none line-of-sight signals?

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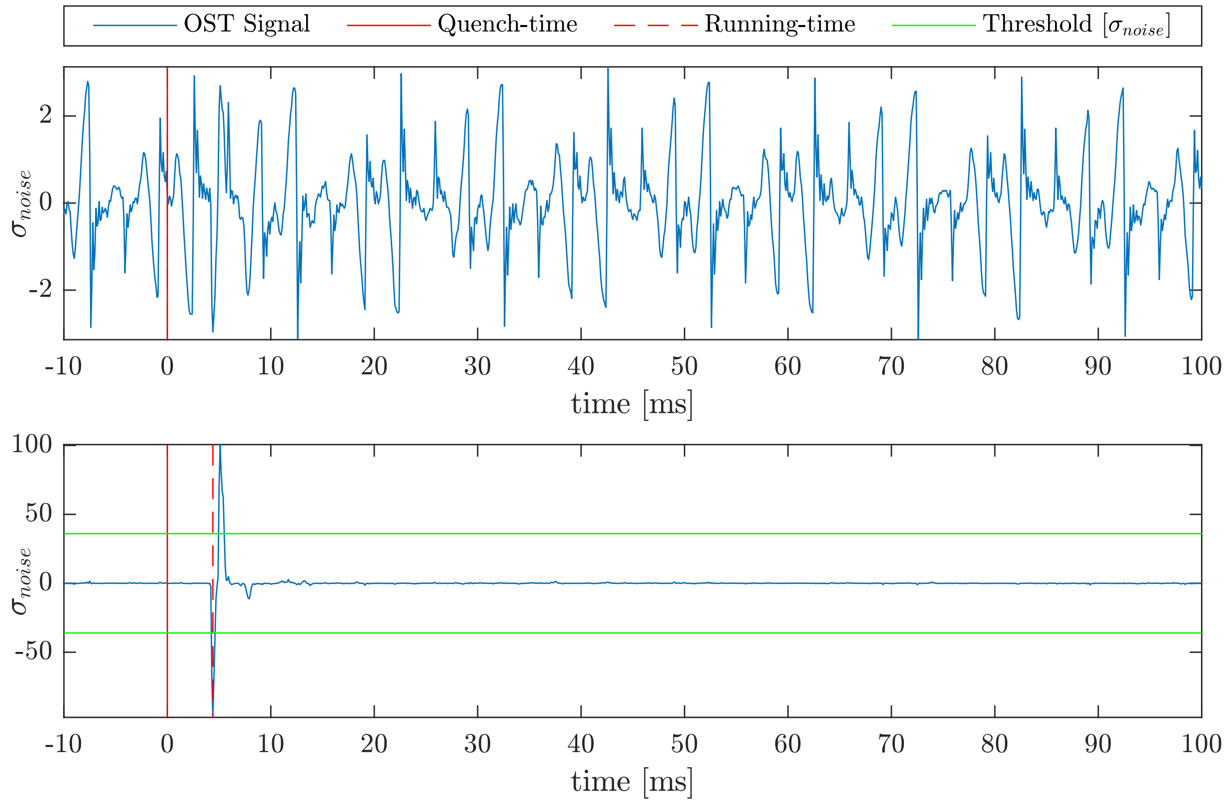

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- work in progress
- (almost) no usable signals recorded

- collaboration with INFN LASA Milano established
- next generation tool under construction at DESY

INFN LASA
Istituto Nazionale di Fisica Nucleare
Laboratorio Acceleratori e Superconduttività Applicata

conclusions second sound quench location

elegant method with lots of potential

> careful **OST positioning** is important
- coverage
- symmetry

⇒ new holders under construction

> **signal run-time deduction** is crucial

⇒ further improvements possible via noise suppression, enhanced sampling frequency

> best **resolutions** of below 10 mm achieved
- multilateration with surface constraint
- velocity fitting multilateration algorithm

> **calibration method** via known second sound wave origin essential

⇒ under development

Thank you for hanging on…

…and have a safe trip back home!

> **Based on**

B. Bein
Systematic Studies of a Cavity Quench Localization System, M.S. Thesis, University of Hamburg, 2019, DESY-THESIS-2019-010

> **Contact**

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