in partnership with

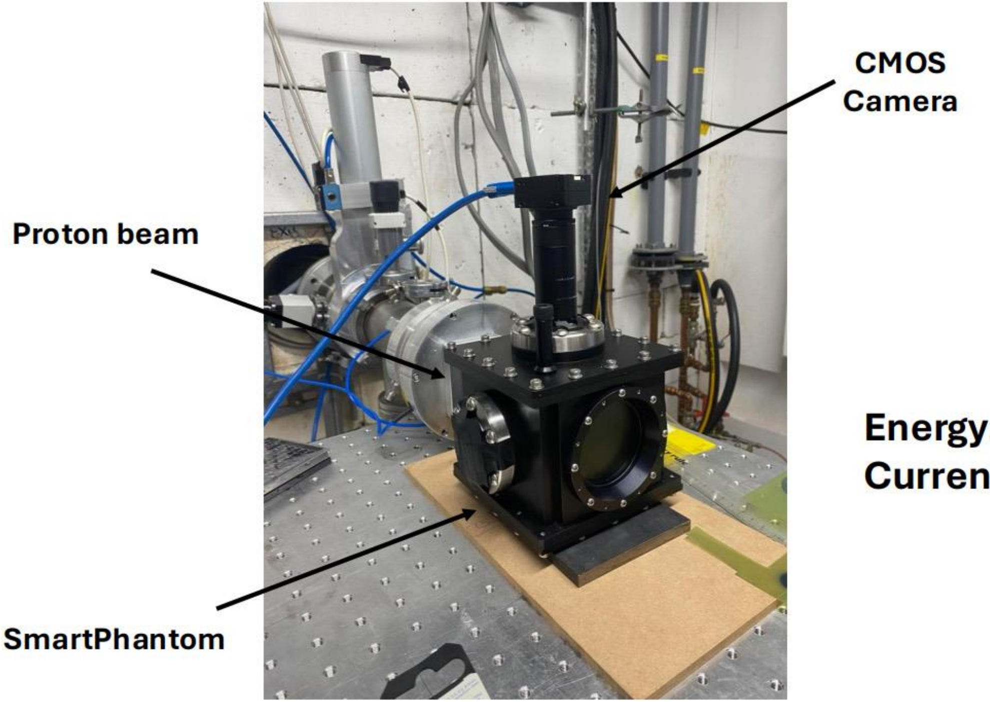
Ion-acoustic dose mapping (WP4) status

- Introduction
- Recent experiment on the MC40 accelerator at Birmingham
- Upcoming experiment on the laser-driven ion (LION) accelerator at LMU in Munich:
  - reminder/update on plans
  - further preliminary data from experiments at ICR
- Summary of status

Birmingham experiment

MC40 Cyclotron

Scintillating Fibre Detectors

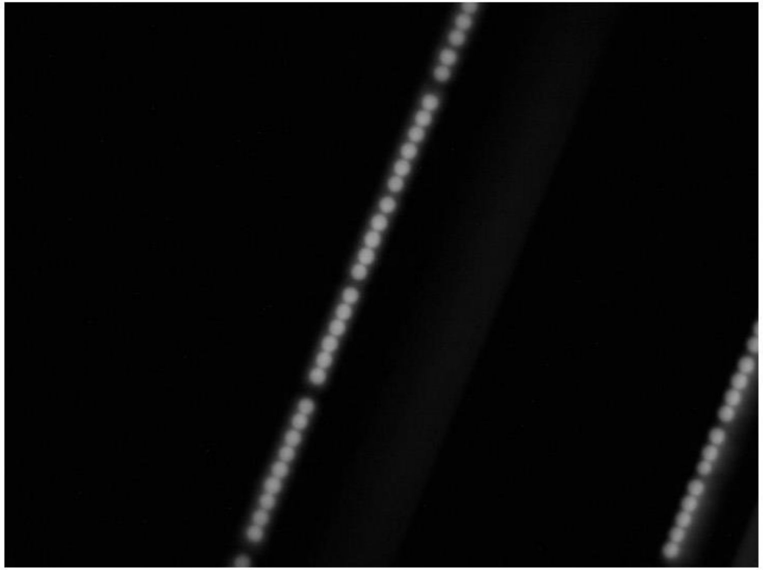


Energy: 28 & 13.5 MeV
Current: 10 – 200 nA

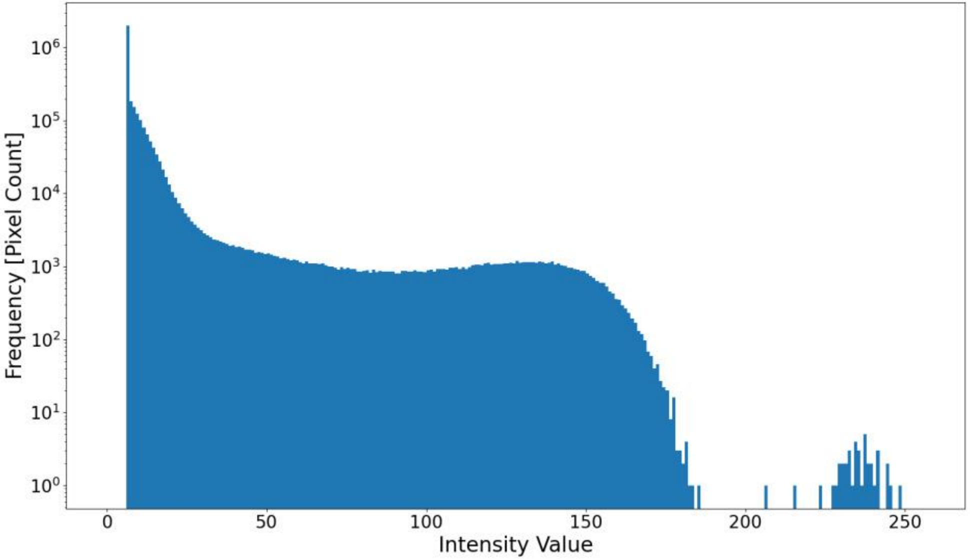
MC40 Cyclotron

Scintillating Fibre Detectors

Background Corrected Average Image



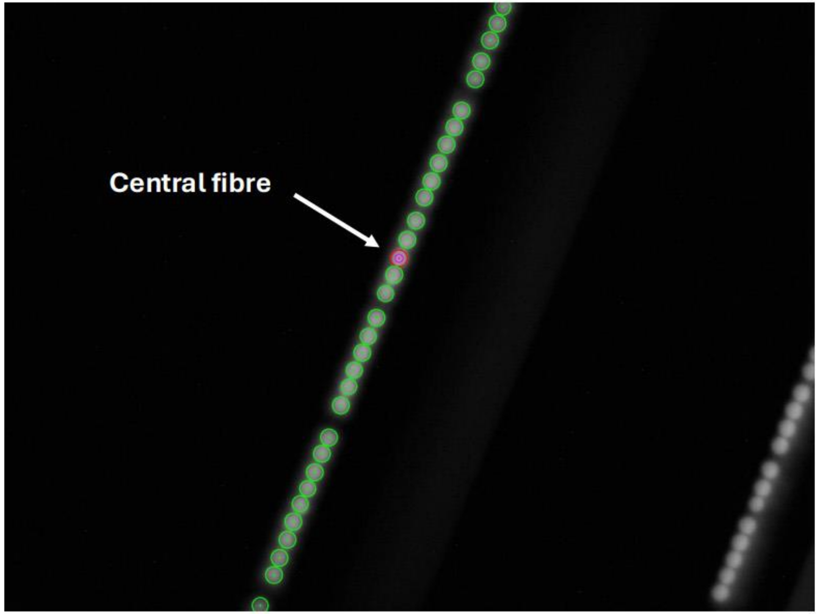
Pixel Intensity Histogram



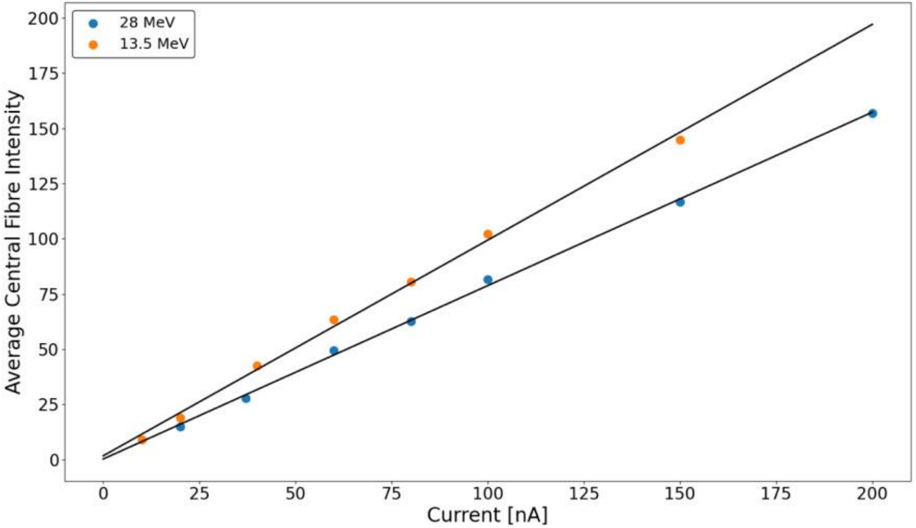
28 MeV, 200 nA

MC40 Cyclotron
Scintillating Fibre Detectors

Fibre Detection



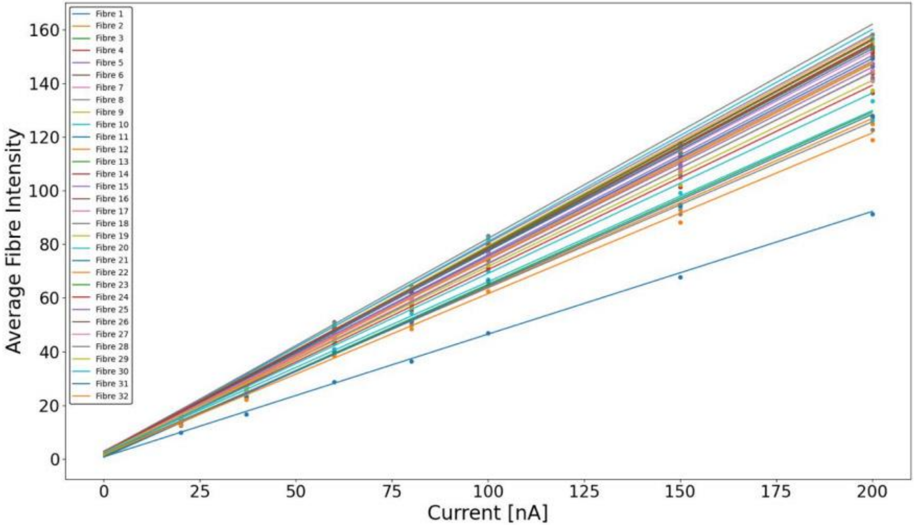
28 MeV, 200 nA

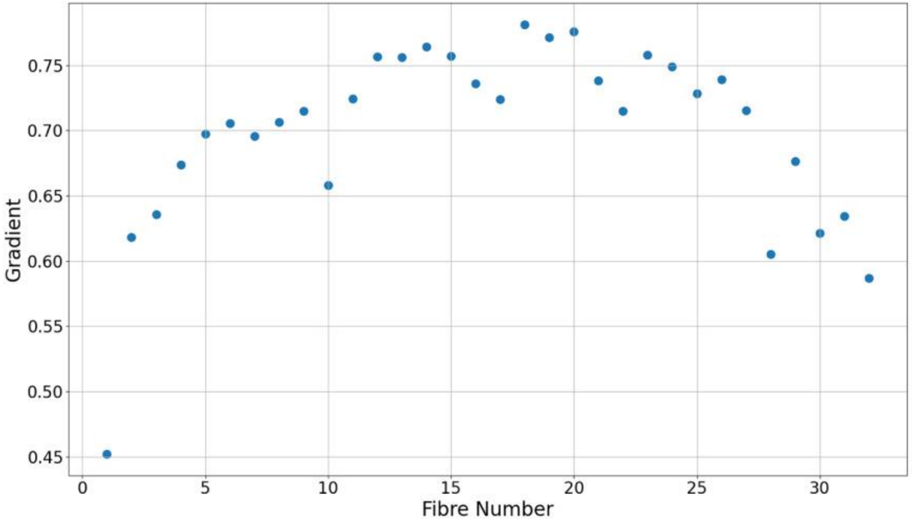


MC40 Cyclotron

Scintillating Fibre Detectors

28 MeV

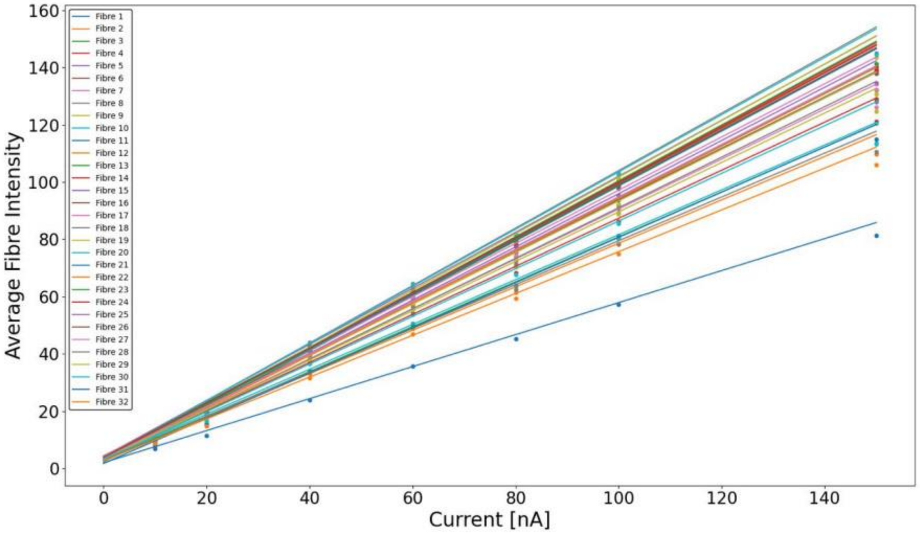


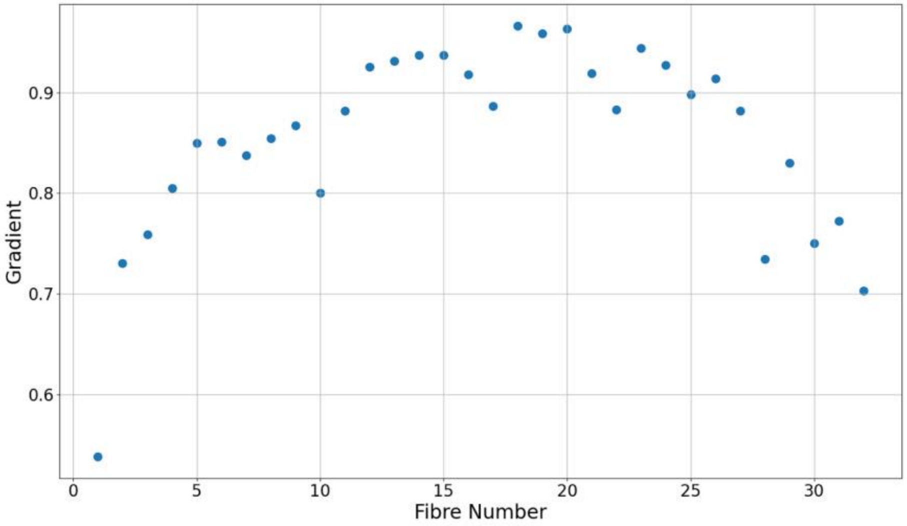


MC40 Cyclotron

Scintillating Fibre Detectors

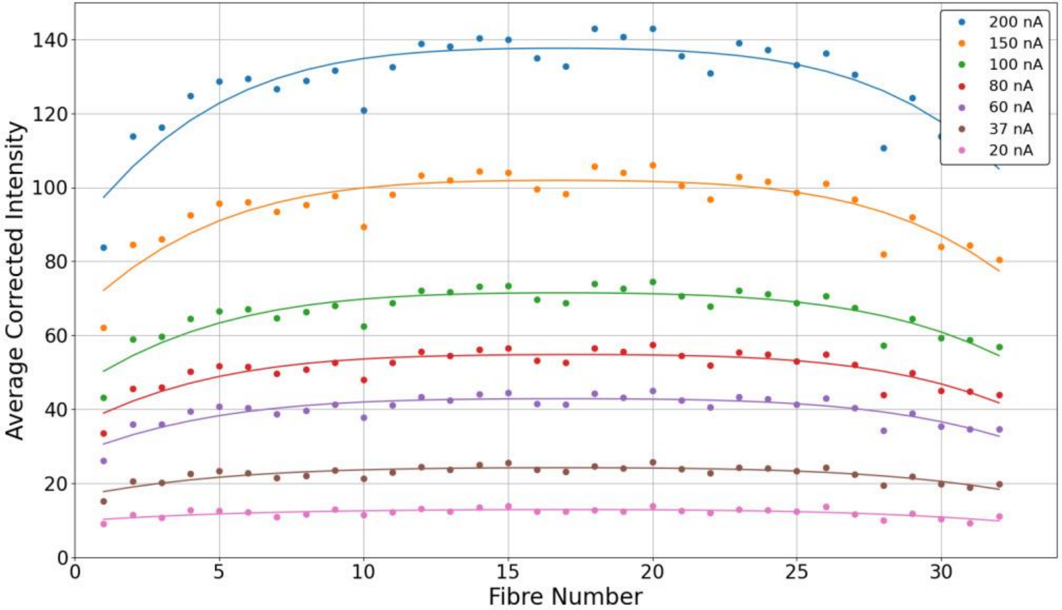
13.5 MeV





MC40 Cyclotron
Scintillating Fibre Detectors

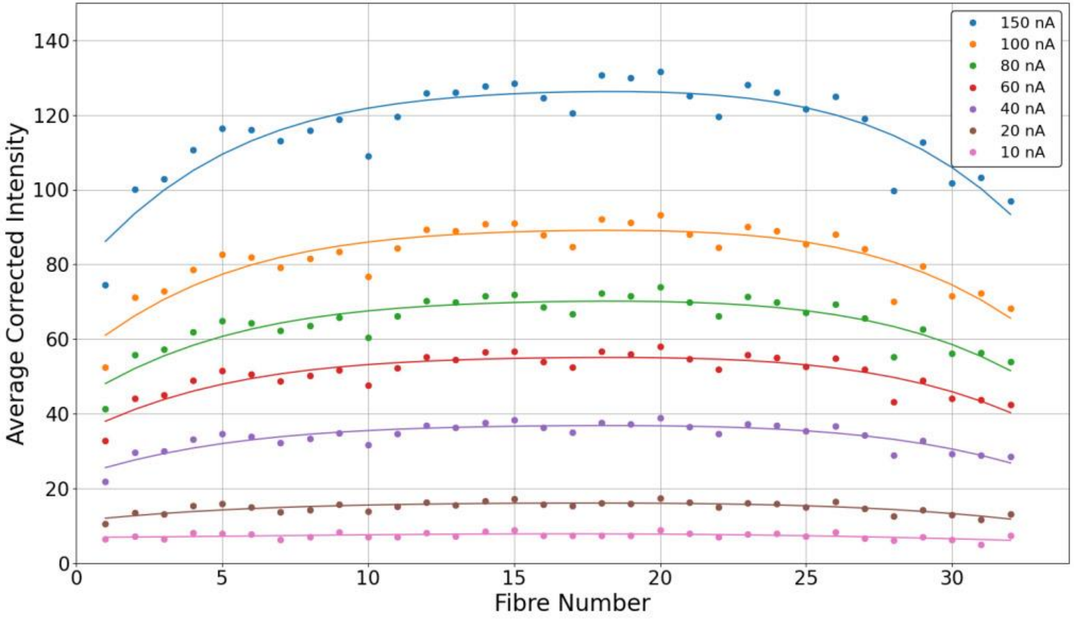
28 MeV



MC40 Cyclotron

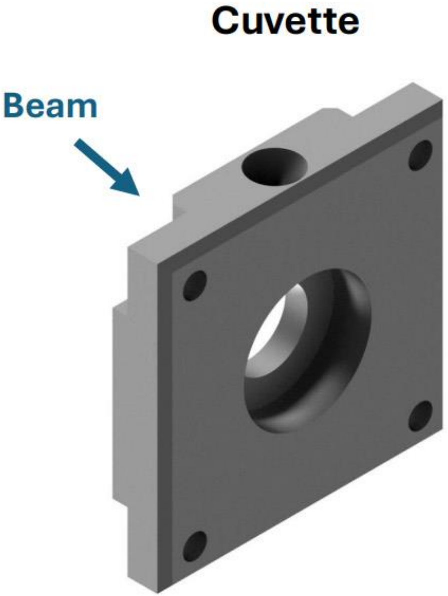
Scintillating Fibre Detectors

13.5 MeV

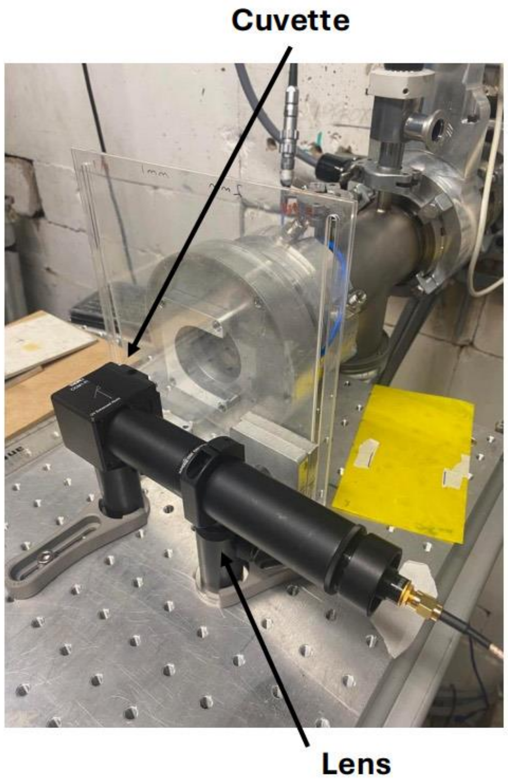


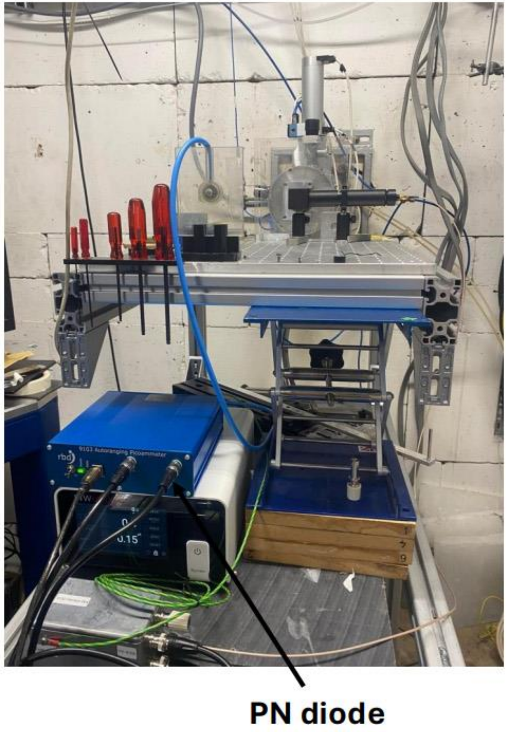
MC40 Cyclotron

Liquid Scintillator



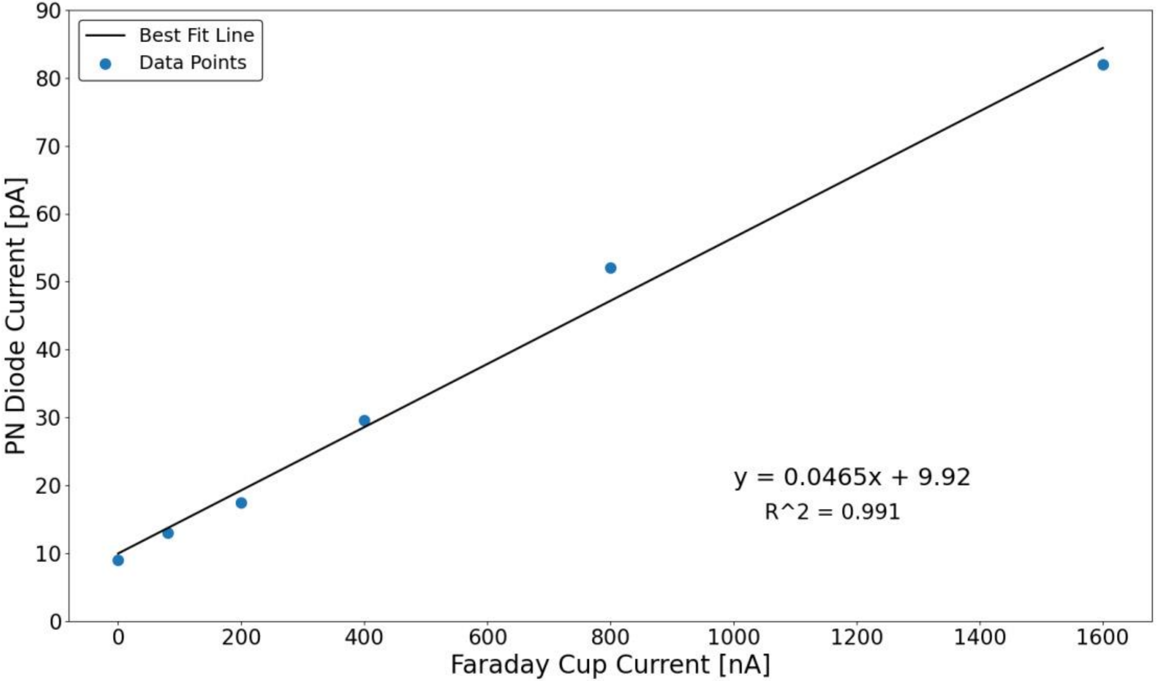
2 mm thick quartz window
on optics side





MC40 Cyclotron

Liquid Scintillator

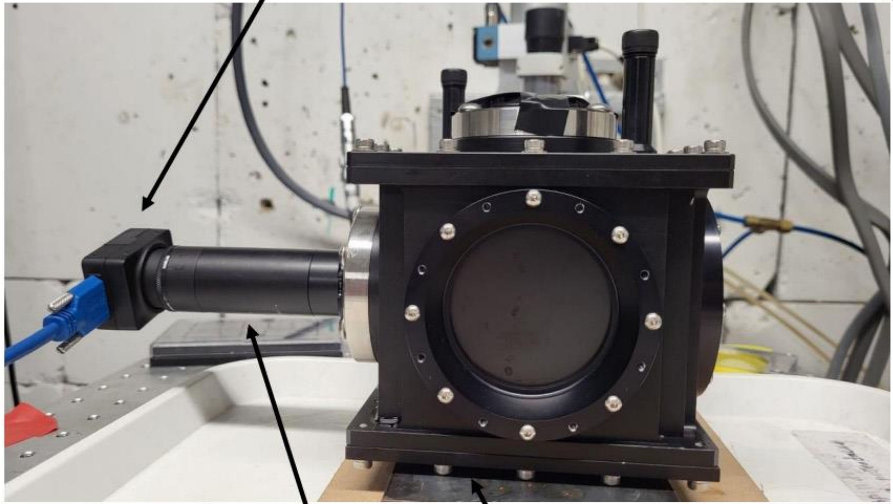


MC40 Cyclotron

Liquid Scintillator

CMOS Camera

Proton beam



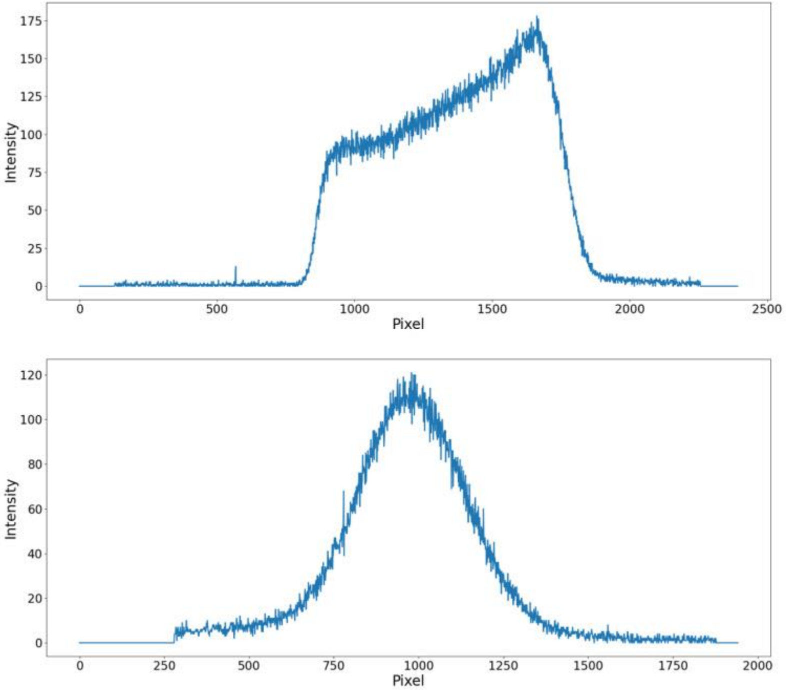
Optical system

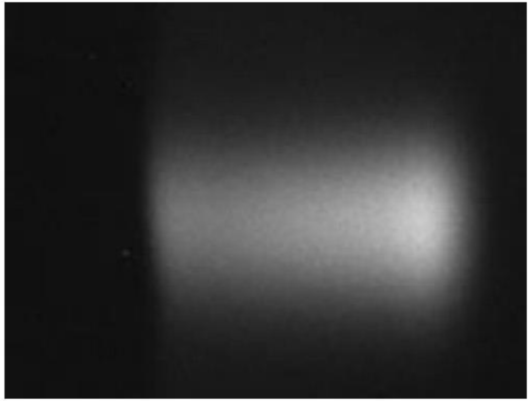
SmartPhantom

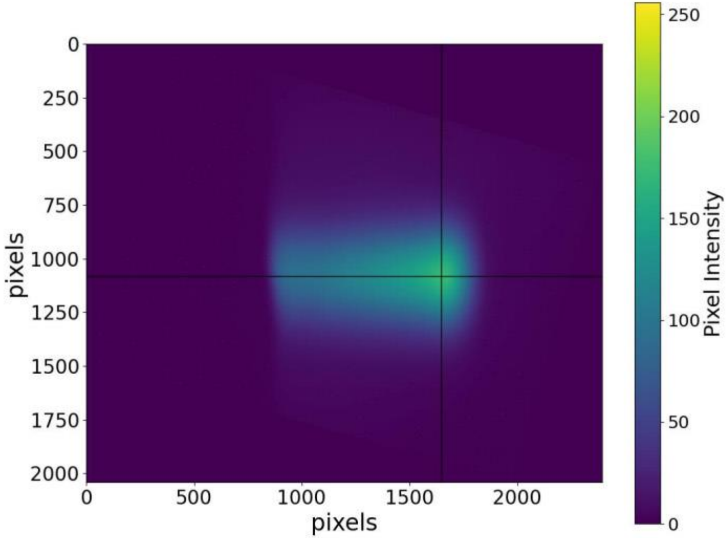
MC40 Cyclotron

Liquid Scintillator

Profile Plots

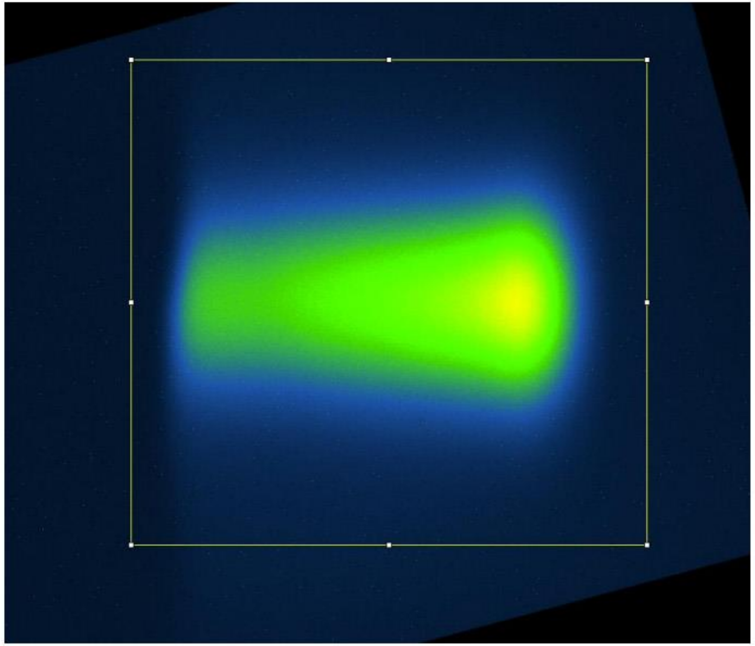




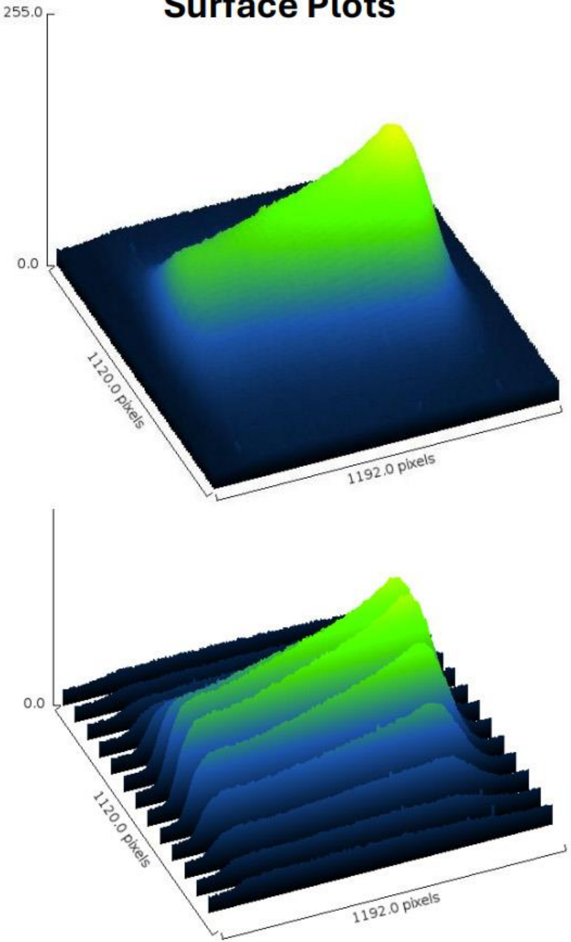


MC40 Cyclotron

Liquid Scintillator

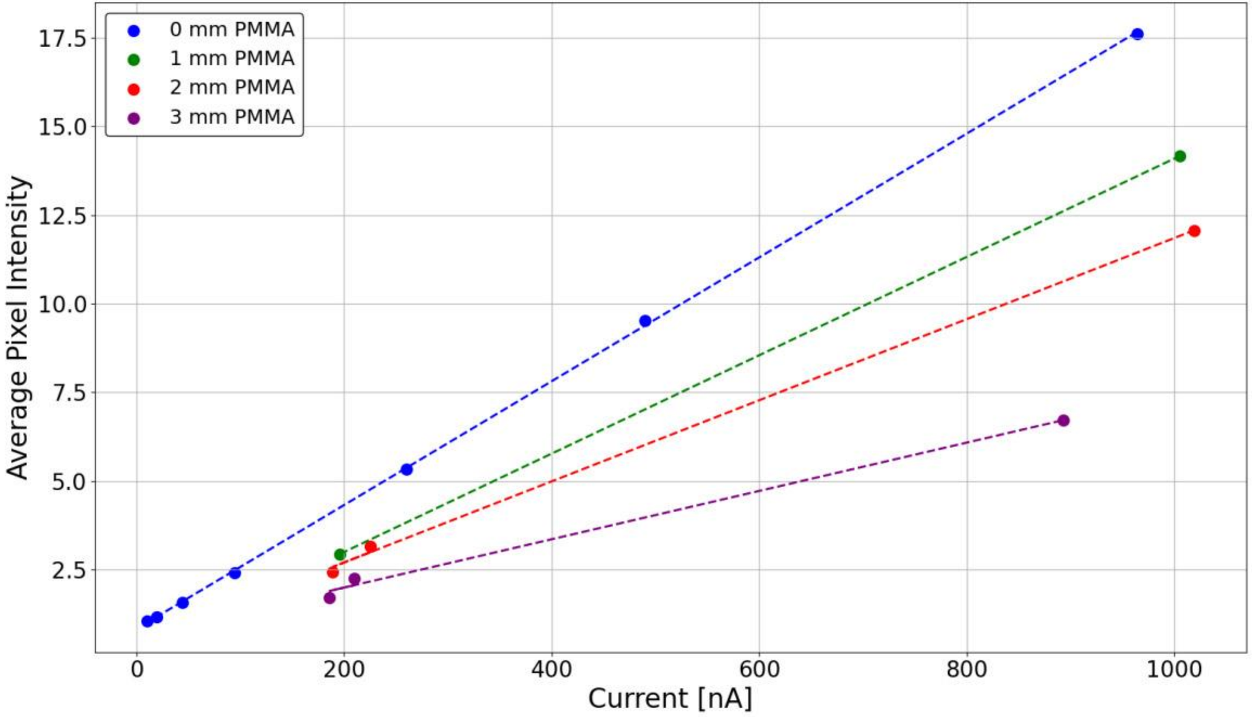


Surface Plots



MC40 Cyclotron

Liquid Scintillator



LMU, Munich, experiment

Design of an Ion-Acoustic Proof-of-Principle Experiment for LhARA

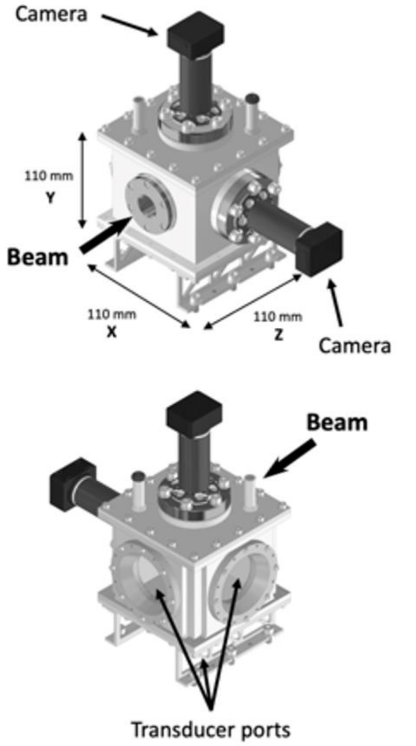
M. Maxouti[1,2,3], P.R. Hobson[4], O. Jeremy[1], B. Cox[5], N. Dover[1], S. Gerlach[6],
J. Lascaud[6], R.A. Amos[5], C. Whyte[7], J. Schreiber[6], K. Parodi[6], J.C. Bamber[8], K. Long[1,2,3]

Introduction

LhARA, the Laser-hybrid Accelerator for Radiobiological Applications[1], is a proposed facility for the study of radiation biology. The accelerator will deliver ions at ultra-high dose rates and hence requires real-time measurement of the dose distribution. A proposed experiment is presented that exploits the acoustic waves and luminescence generated by the beam's energy deposition to obtain a calibrated 3D dose map[2]. The experiment will be performed at the Laser-Driven Ion Accelerator at the Center of Advanced Laser Applications in Munich[3].

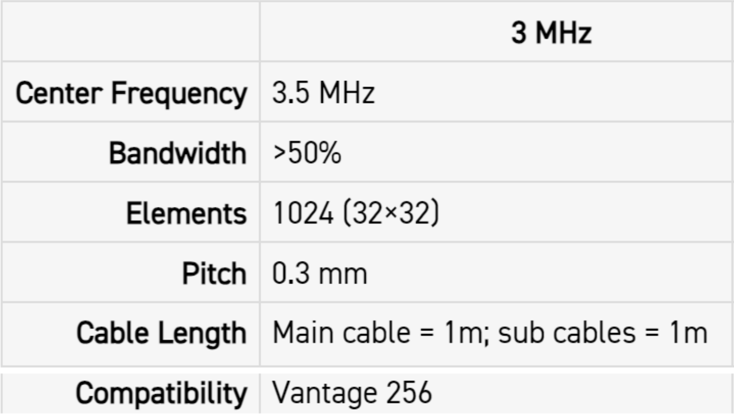
Methods

A water-based phantom, the SmartPhantom, features a beam entry window sealed with Kapton. Three ports located on orthogonal sides mount ultrasonic transducer arrays for detecting the acoustic waves. To calibrate their response, a liquid scintillator is added to the water and the luminescence arising from the energy deposited by the beam is imaged by two cameras, positioned perpendicularly to it. The performance of the experiment has been evaluated in a series of simulations using BDSIM[4], Geant4[5], k-Wave[6] and OpticStudio[7].

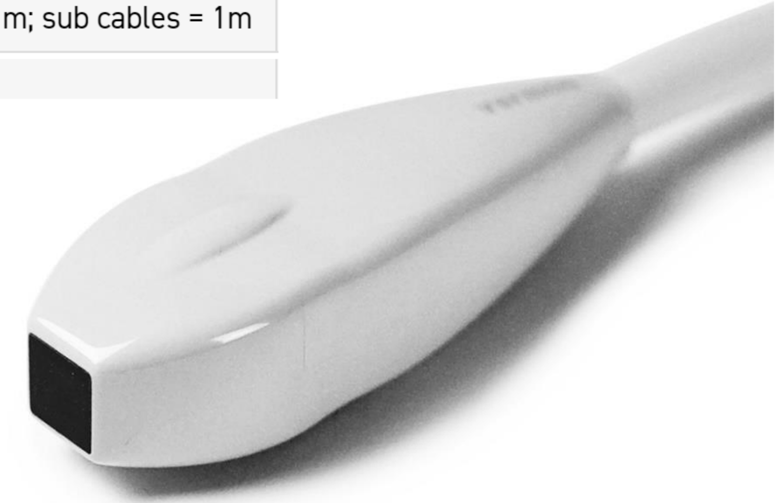


External view of the Computer-Aided Design (CAD) of the SmartPhantom

Matrix array and multiplexer



	3 MHz
Center Frequency	3.5 MHz
Bandwidth	>50%
Elements	1024 (32×32)
Pitch	0.3 mm
Cable Length	Main cable = 1m; sub cables = 1m
Compatibility	Vantage 256



Linear array

Designed for clinical ultrasound imaging – 3 to 9 MHz

Use for detecting the radially emitted wave

Reconstruction of the axial profile of the dose distribution – expect blurring of the axially steep dose gradients

“Reconstruction” of the radial profile of the dose distribution by receive beamforming and integration of the resulting received time-amplitude waveform.

Reference single element transdcuer

Olympus, single element, immersion transducer

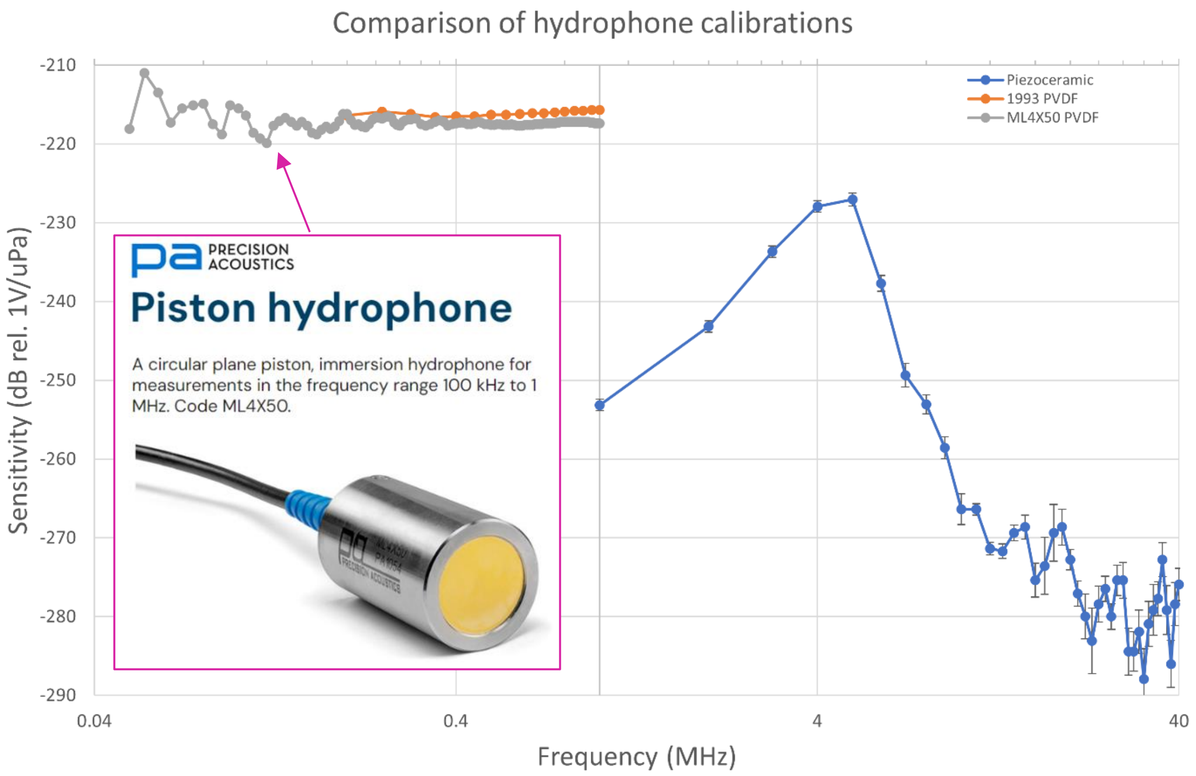
1 MHz, matched to water, narrow band

Used previously by LMU with success

Point up the beam

“Reconstruct” axial profile of deposited dose by integrating the magnitude of the amplitude-time signal

Broadband receiver



Piston hydrophone

A circular plane piston, immersion hydrophone for measurements in the frequency range 100 kHz to 1 MHz. Code ML4X50.

Single element – not an array

Extremely wide bandwidth – wider than that shown

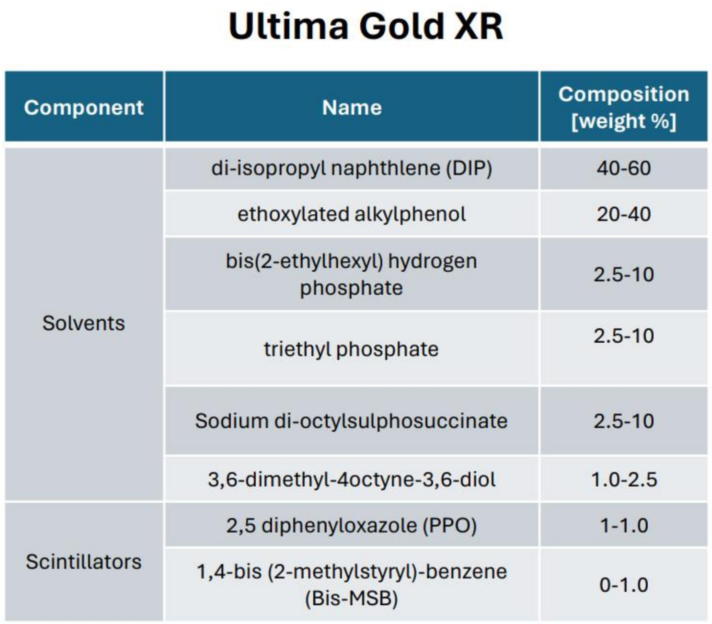
More sensitive than a piezoceramic transducer even at its peak resonant frequency

Point up the beam, on-axis, in place of the matrix array.

Will tell us about the features of the dose distribution that could be reconstructed if we had an array of such sensors

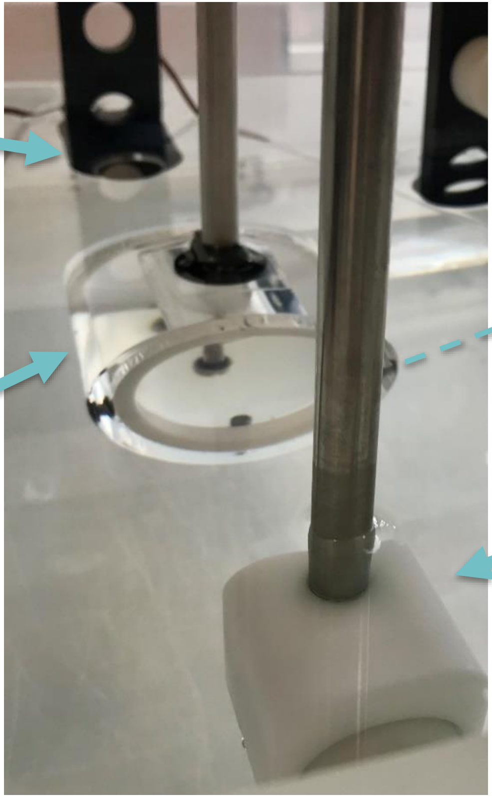
Within the 100 kHz to 1 MHz frequency range, comes with a calibration, allowing us to say what the acoustic pressures are for these frequency components

Measurement of acoustic characteristics of the liquid scintillator



Ultima Gold XR

Component	Name	Composition [weight %]
Solvents	di-isopropyl naphthlene (DIP)	40-60
	ethoxylated alkylphenol	20-40
	bis(2-ethylhexyl) hydrogen phosphate	2.5-10
	triethyl phosphate	2.5-10
	Sodium di-octylsulphosuccinate	2.5-10
	3,6-dimethyl-4octyne-3,6-diol	1.0-2.5
Scintillators	2,5 diphenyloxazole (PPO)	1-1.0
	1,4-bis (2-methylstyryl)-benzene (Bis-MSB)	0-1.0



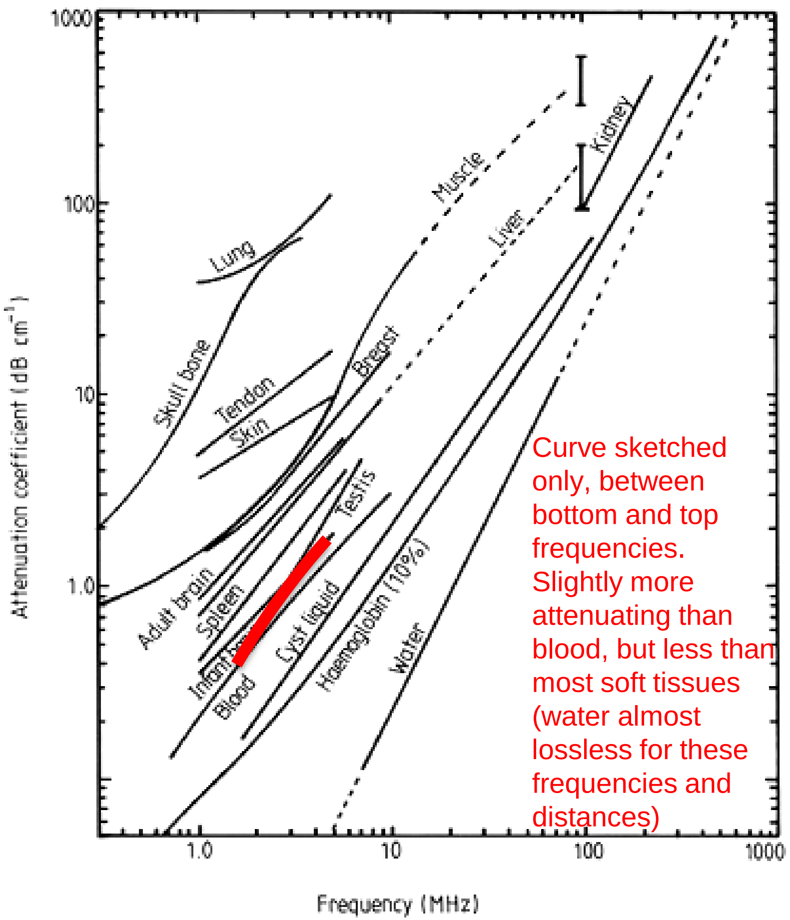
Receiving (and transmitting) transducer

UltimaGold™ Sample in position

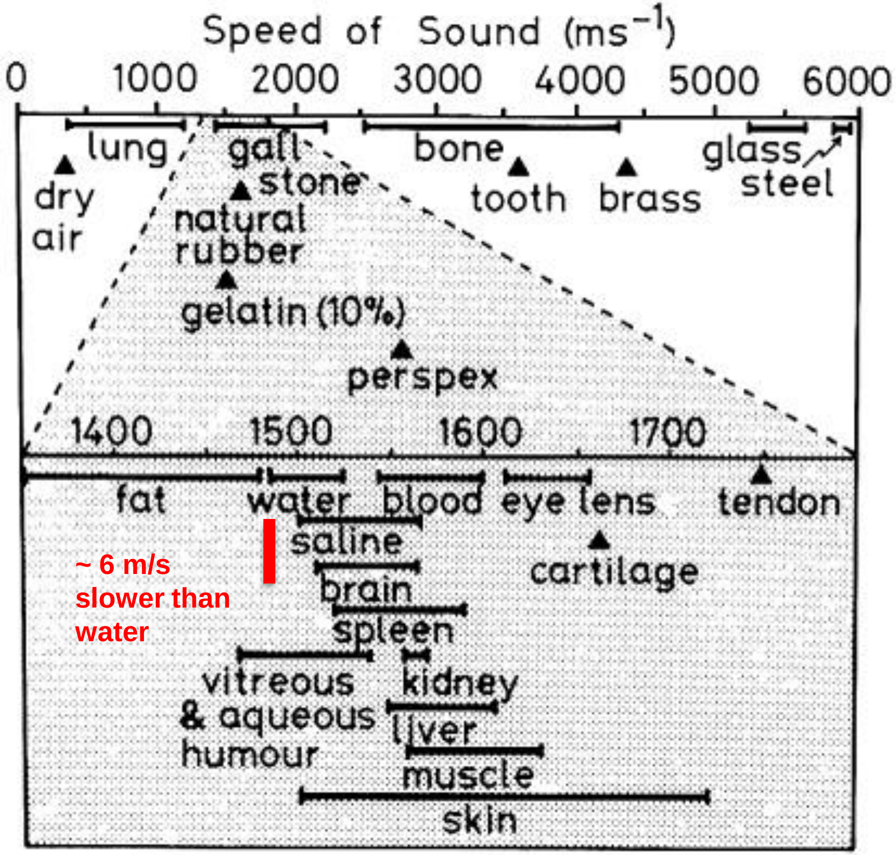
Sample slides out of the sound beam for the water reference measurement

Transmitting transducer

Rough first estimates in relation to published values for various media



Curve sketched only, between bottom and top frequencies. Slightly more attenuating than blood, but less than most soft tissues (water almost lossless for these frequencies and distances)



~ 6 m/s slower than water

Status

2-year Objectives,Tasks, Milestones

Objectives:

- The development of a Geant4 MC simulation of the forward model ✓
- The development of a k-wave acoustic forward model ✓

Tasks:

- Design of a proof of principle experiment to be executed during the Preconstruction Phase, identifying potential suppliers for components →
- Reports on progress towards above objectives. ✓

Milestones:

- 18-month:
  - forward simulation of energy deposited in a water phantom (SmartPhantom) and deposited energy in 4D ✓
- 24-month:
  - Results of forward simulation and its use to optimise SmartPhantom performance to provide the power density spectrum as input to the acoustic model ✓
  - Acoustic sensor array design complete →

Chose to prioritise LMU experiment for practical experience of sensors for eventual more informed designs.

Also added the liquid scintillator to SmartPhantom