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Verifying the 3D energy deposition profile of an MeV proton bunch using a liquid scintillator in an ion-acoustic experiment

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1. Ion-Acoustic Technique

- A short-pulsed ion beam deposits localised energy, a Bragg peak
- Under stress-confinement conditions, this energy produces a transient pressure rise, launching an acoustic wave
- Ultrasound transducers record the waves and enable reconstruction of the initial energy deposition distribution

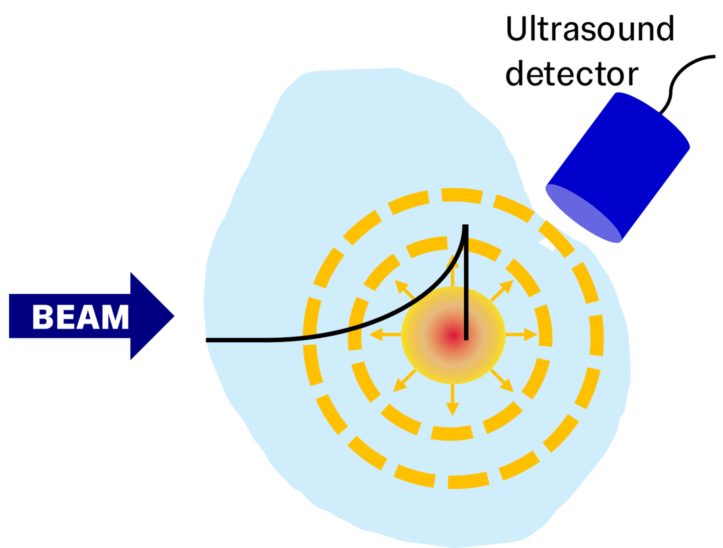


Figure 1. Illustration of Ion-Acoustic technique in general medium

2. Diagnostic Potential

- **Directly Probes Energy-Deposition:** Bypasses delayed decay limits and indirect modelling required by nuclear-based techniques.
- **Pulse-to-pulse monitoring:** Microsecond acoustic transit times enable shot-to-shot characterisation
- **High spatial resolution:** MHz frequency waves provide submillimeter spatial profiling
- **Broad scientific generality:** Non-invasive, deeply penetrating and suitable for any energy deposition that generates a detectable acoustic signal

3. SmartPhantom (Proof-of-Principle)

- The SmartPhantom is a proof-of-principle hybrid detector
- Two transducers collect the acoustic signal
- Two cameras collect the optical signal from liquid scintillator
- Enables calibration of the acoustic diagnostic to a known measurement

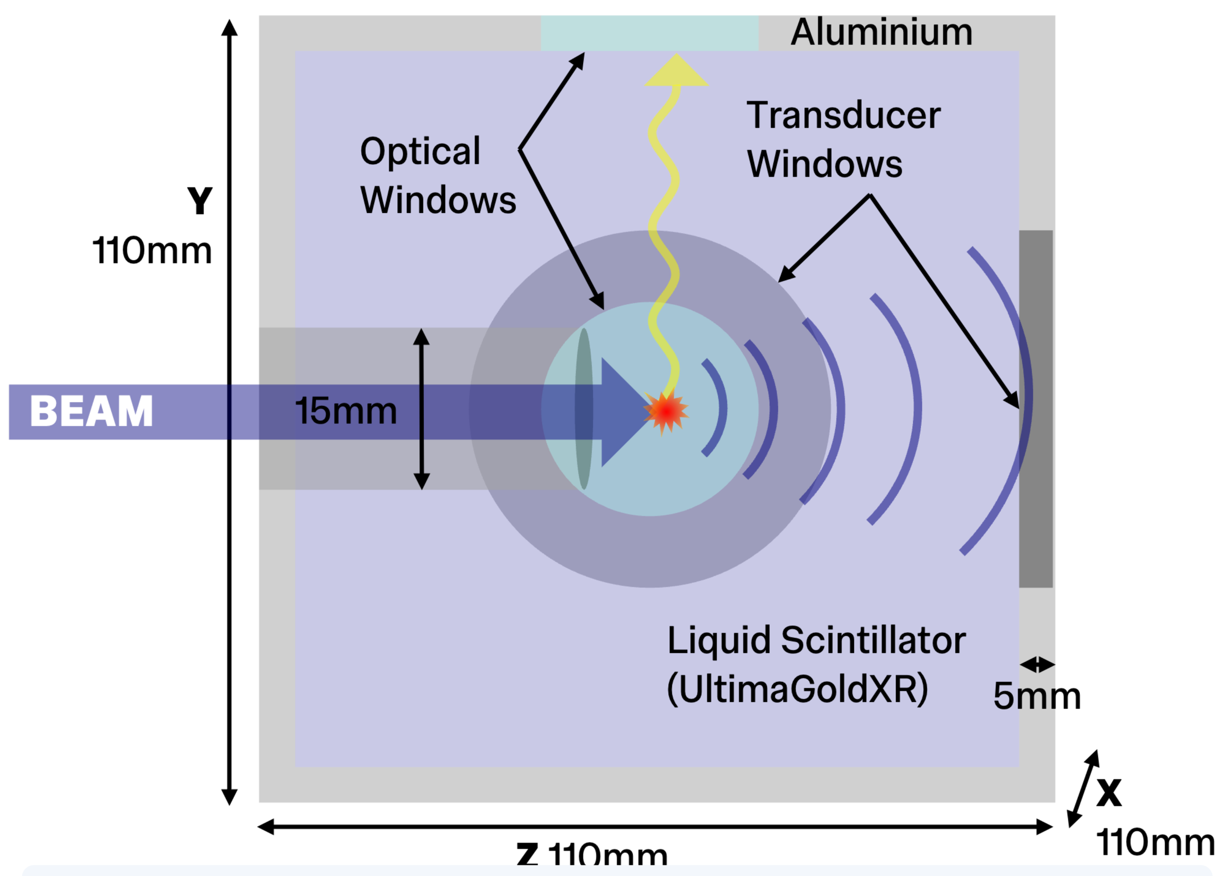


Figure 2. Schematic of SmartPhantom from the side

4. Optical Response Verification

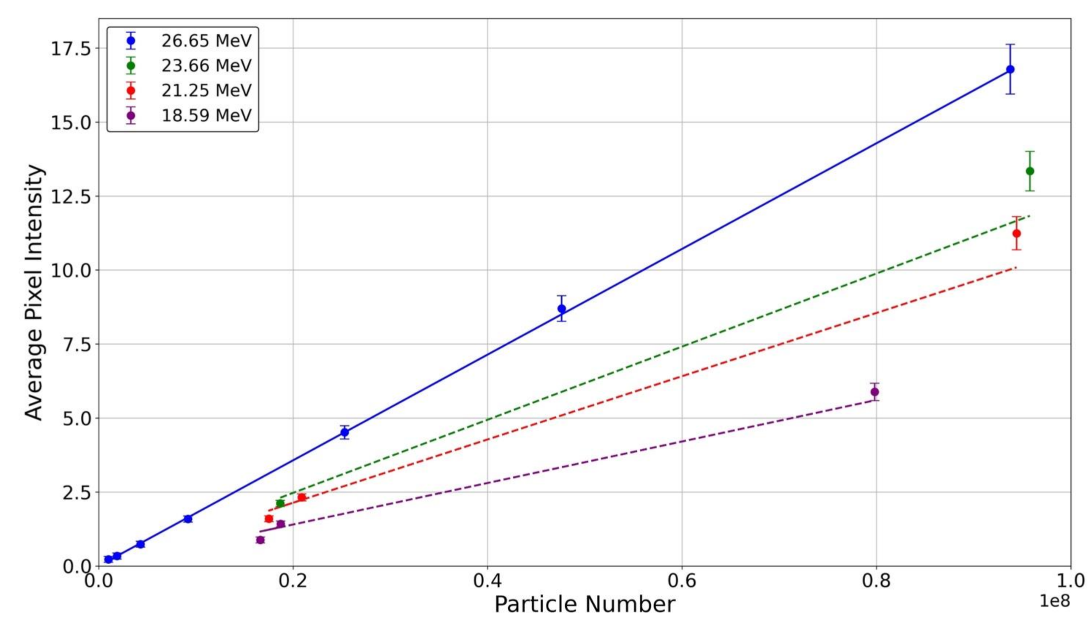


Figure 3. Tests at Birmingham's MC40 Cyclotron show liquid scintillator's linear response to dose and lack of quenching

5a. LION Beamline

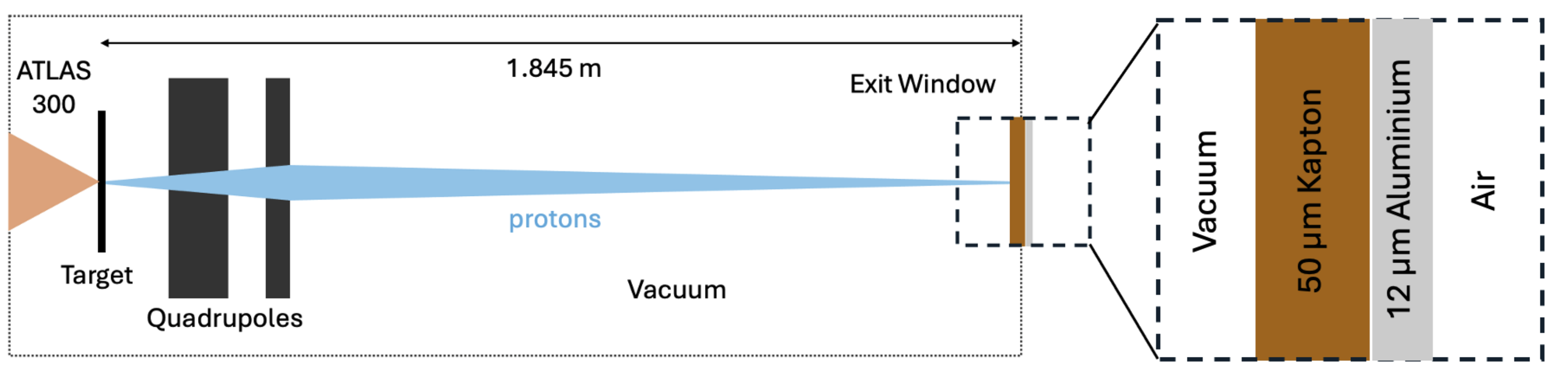


Figure 4. The LION beamline uses a 50 fs laser pulse to produce a laser-driven proton beam. Two quadrupoles focus the beam into the SmartPhantom.

5b. LION Output

Acoustic Output

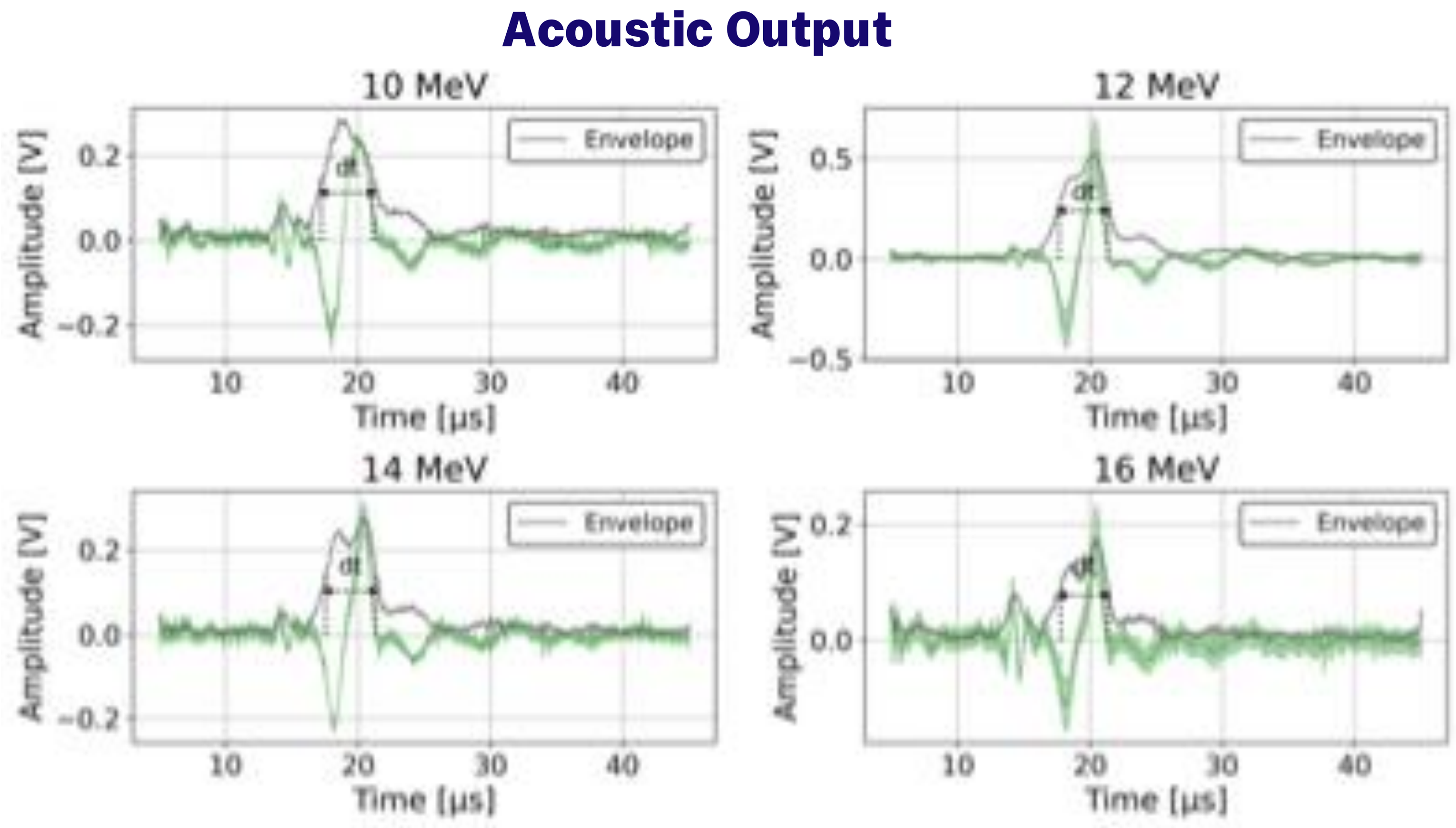


Figure 5. Acoustic signals from the Olympus transducer with a 4mm collimator. Compression and rarefaction peaks are indicated by dashed lines and the time difference, used to calculate beam width, is labelled

Optical Output

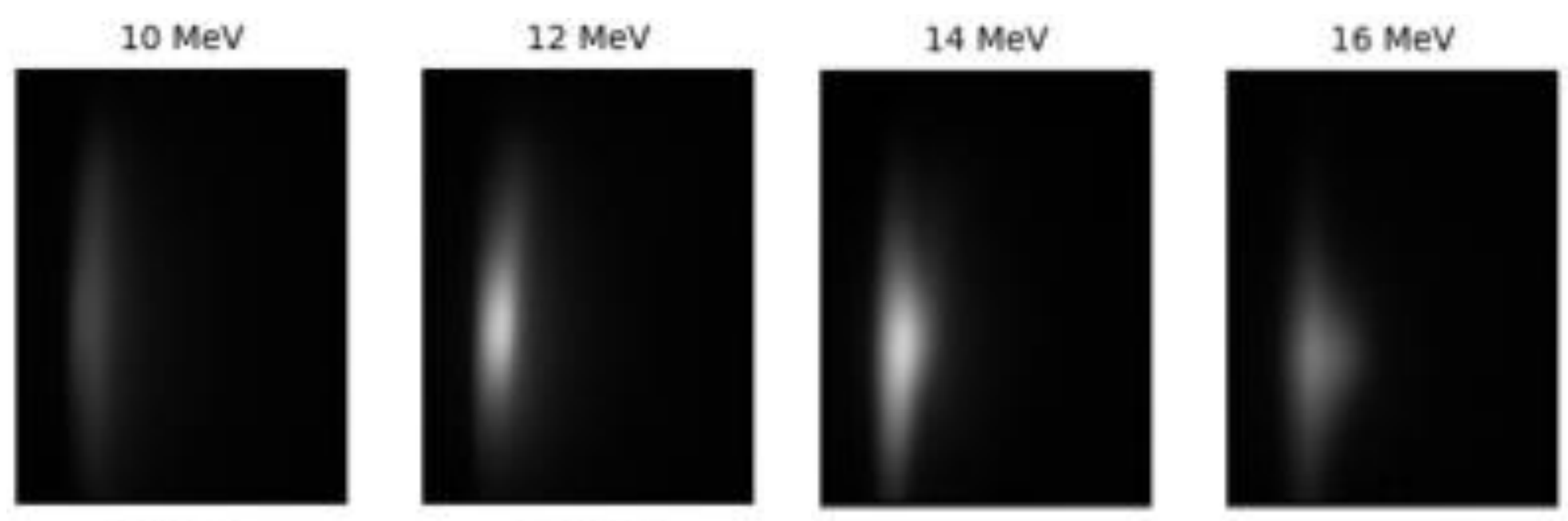
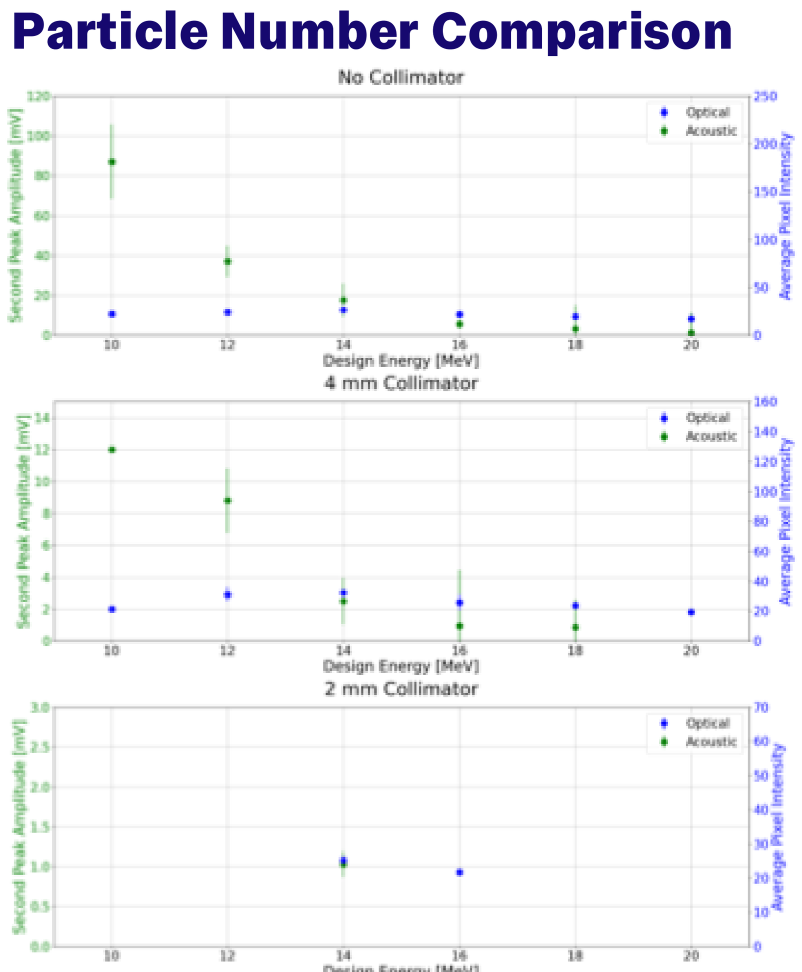


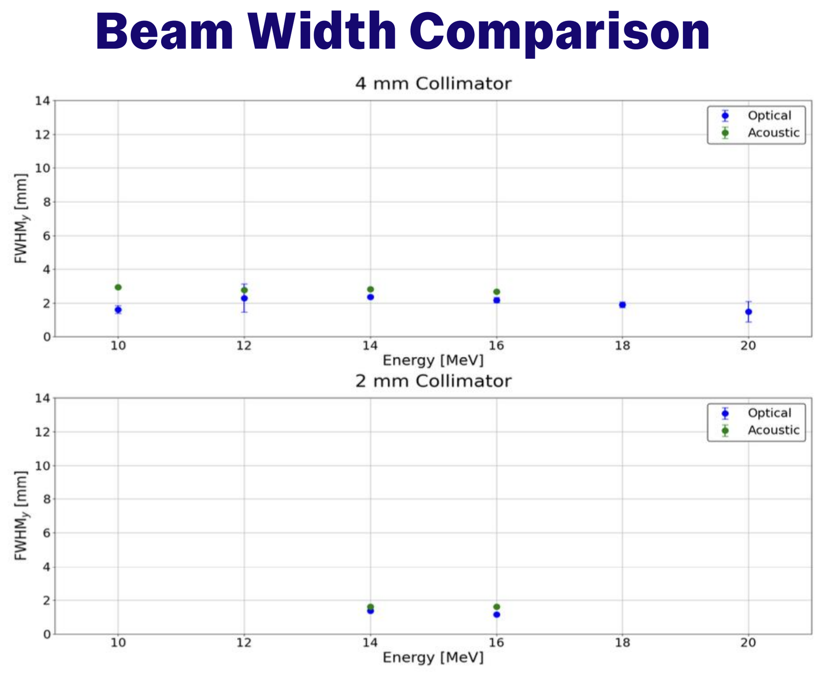
Figure 6. Averaged, background-corrected grayscale images obtained using vertical camera with a 4mm collimator

5c. LION Acoustic-Optical

Particle Number Comparison



Beam Width Comparison



- Figure 7 (above): Indicates agreement between outputs
- Figure 8 (left): Shows outliers at 10 and 12MeV