Laser-hybrid Accelerator for Radiobiological Applications

LhARA Laser-Driven Proton & Ion Source WP2

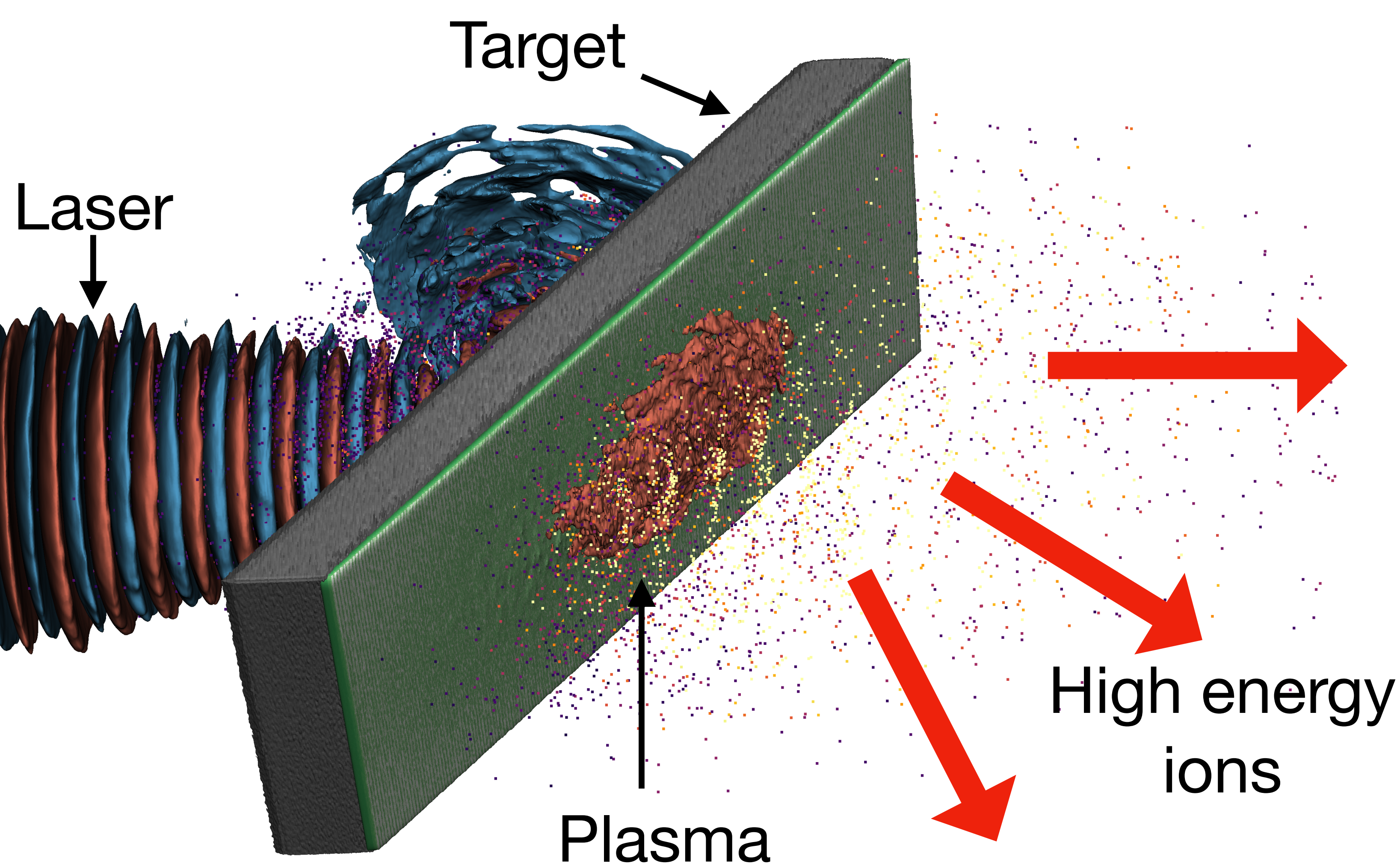
Update on recent scintillator measurements

4th June 2024

Diagnostic requirements of ion source

Laser driven ions:

- Quasi-thermal energy spectrum
- Divergent, but not isotropic (ie spectrum varies with angle)
- Multispecies, multi-charge state
- Generated alongside high energy electrons (> MeV) & x-rays

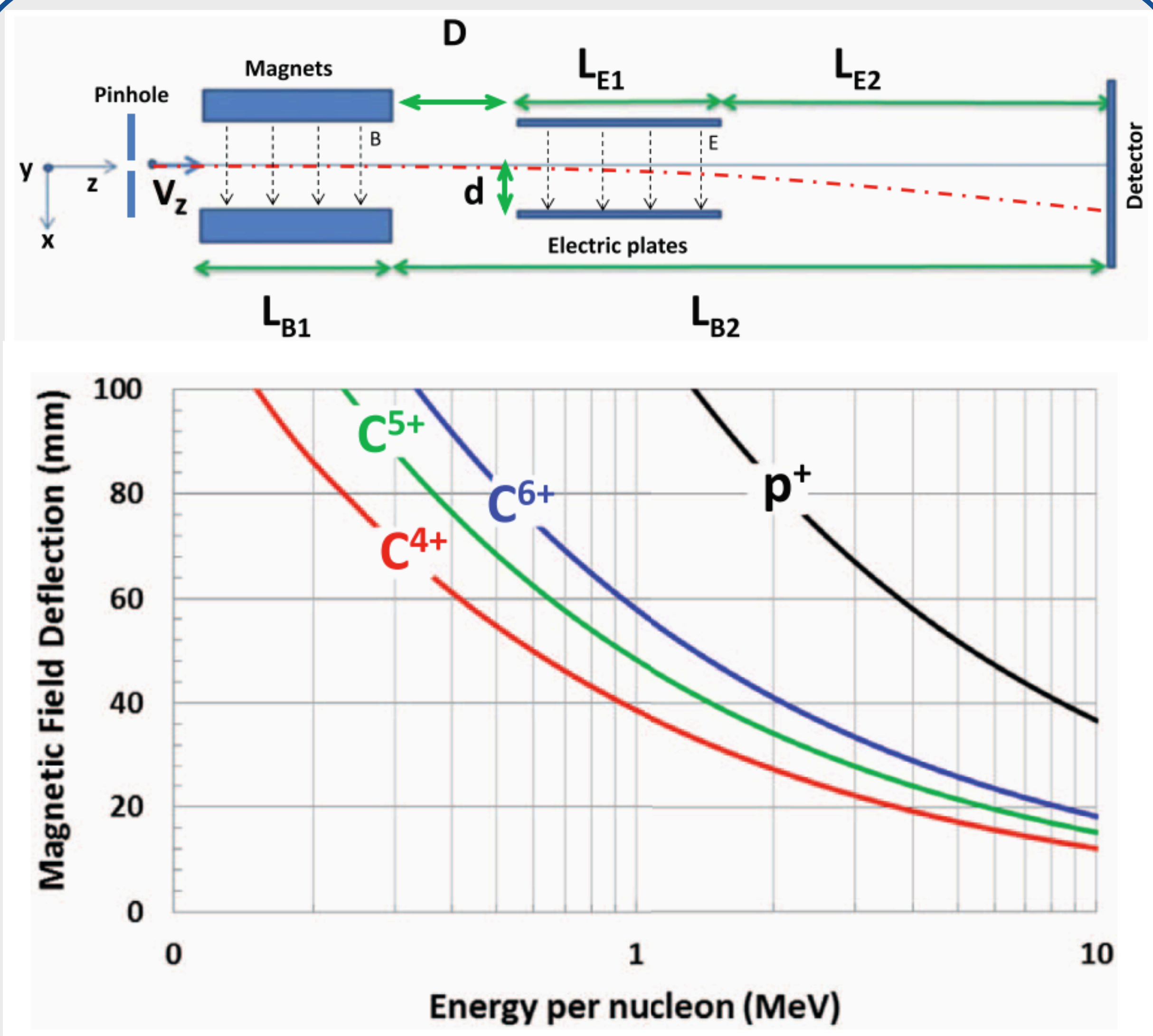


Diagnostic requirements:

- Angularly resolved
- High resolution spectrum
- Minimise background
- High repetition rate (!)

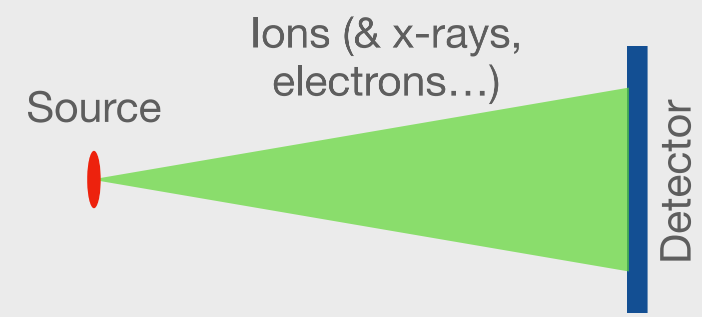
Types of diagnostics

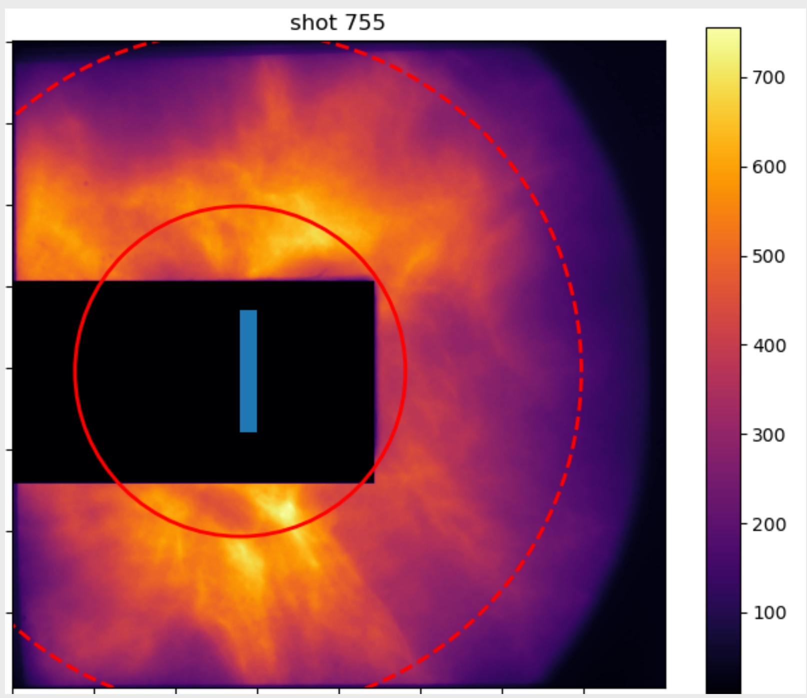
Thomson Parabola Spectrometer



- High resolution spectrum
- No spatial information

Beam profiler





- No spectral information
- High spatial resolution

Types of diagnostics

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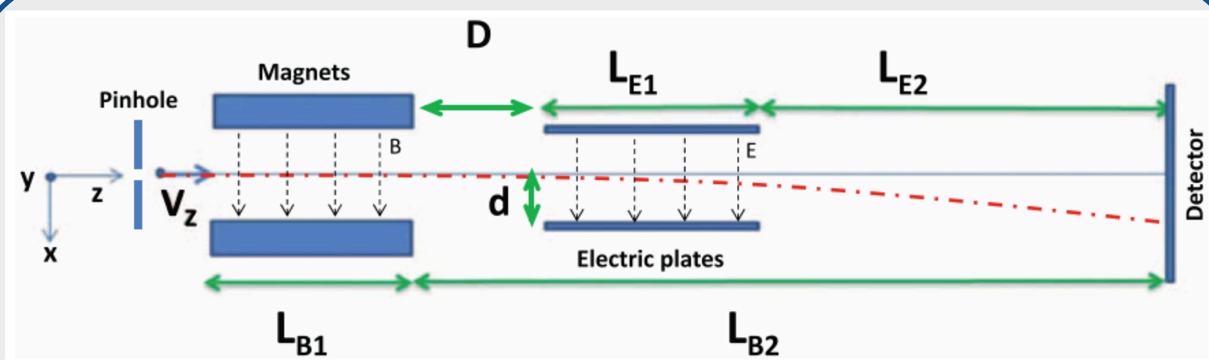
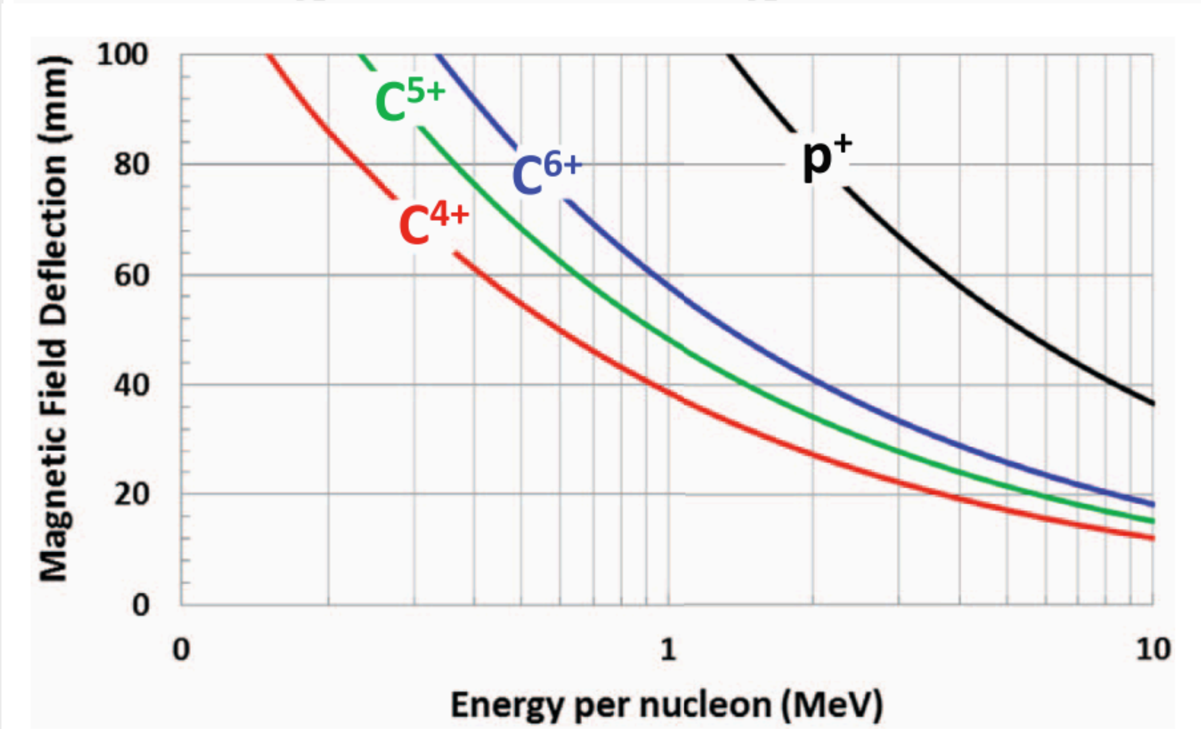
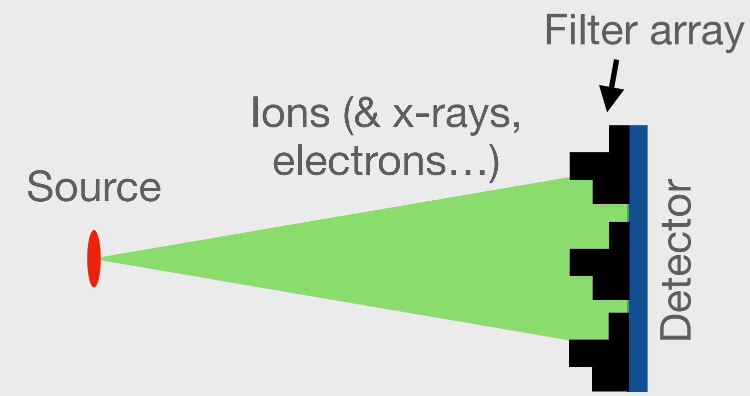
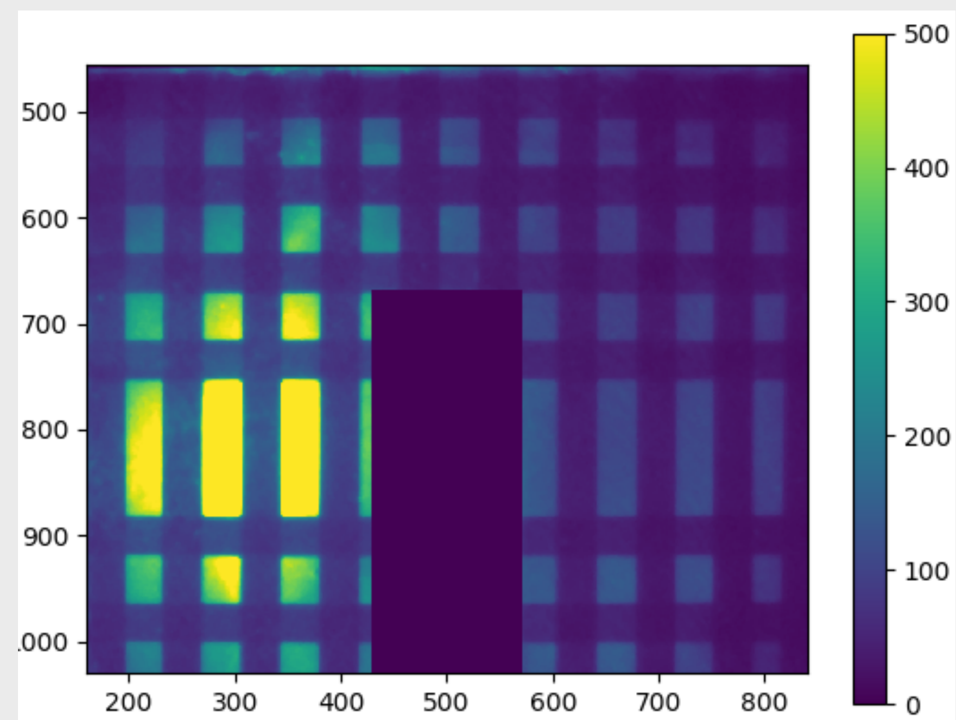




- High resolution spectrum
- No spatial information

"PROBIES"
~~Beam profiler~~





- Some spectral information
- Some spatial information

What do we need from the scintillator?

Thomson Parabola Spectrometer

- High dynamic range & linearity
- High spatial resolution
- 10 Hz operation
- Very high brightness
  - High scintillation efficiency
  - Minimal dE/dx quenching

“PROBIES” Beam profiler

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    Scintillator thickness not exceeding stopping distance of highest energy ions

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Plastic scintillators

Decent light output
Fast response
Cheap & flexible
Strong quenching?

Powder phosphors

High light output
Slower response
Quite cheap & flexible
Low quenching?

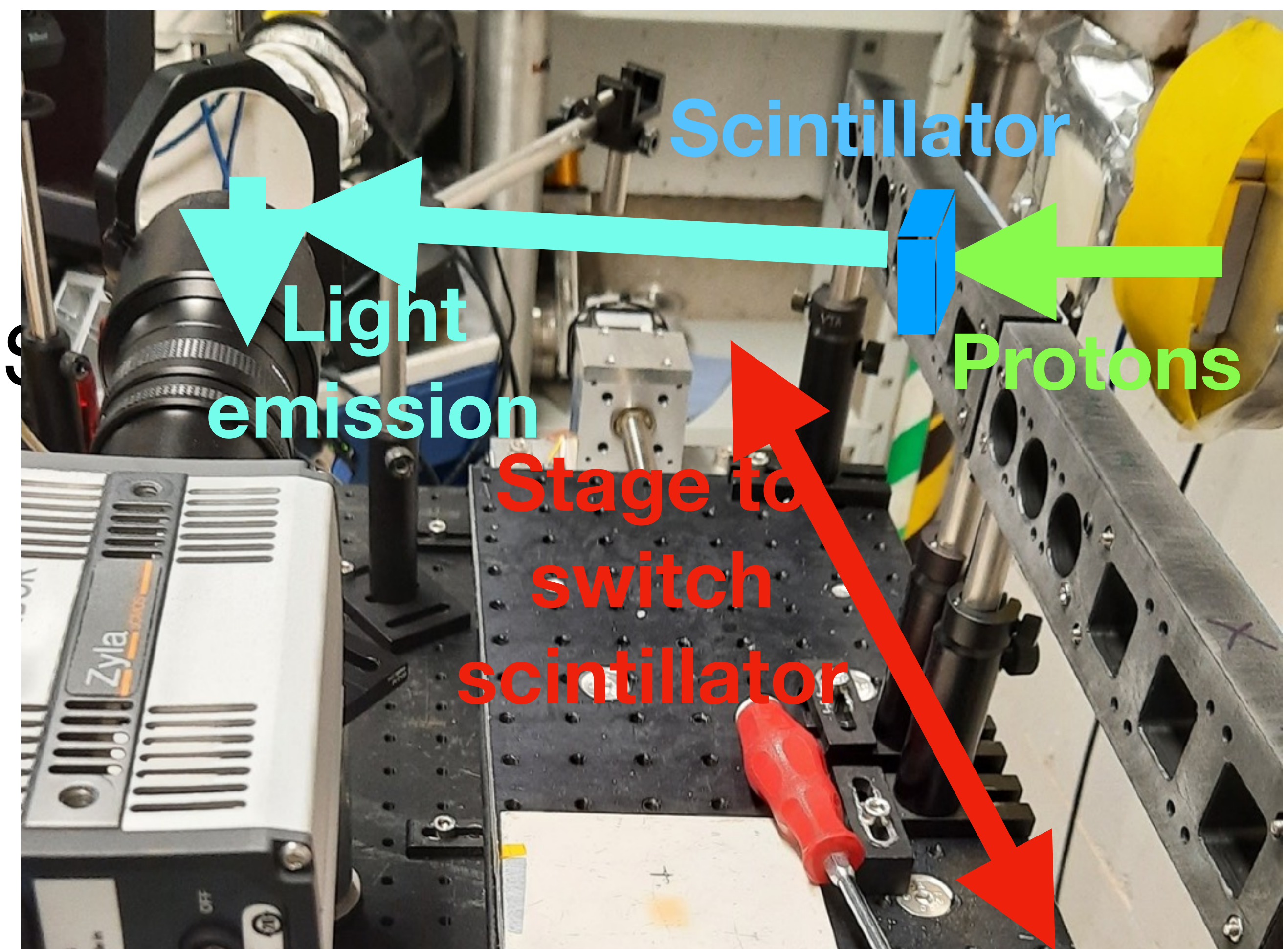
Crystals

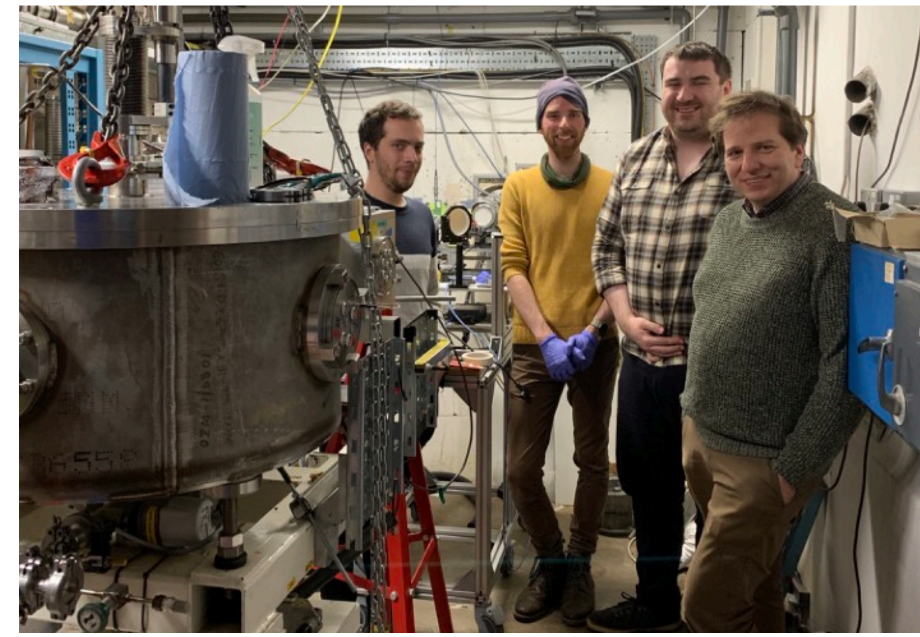
Decent light output
Slower response
Relatively expensive
Low quenching?

Scintillator testing at MC40

Scintillator calibration experiment at MC40 Beamline at Birmingham

- Total 4 days beamtime, Dec 2023 and May 2024
- Data taken for protons at 28 and 20 MeV





University of Strathclyde Glasgow: M. Alderton, T. Frazer, R. Wilson, R.J. Gray, P. McKenna

Central Laser Facility: M. Cook, H. Ahmed, J.S. Green

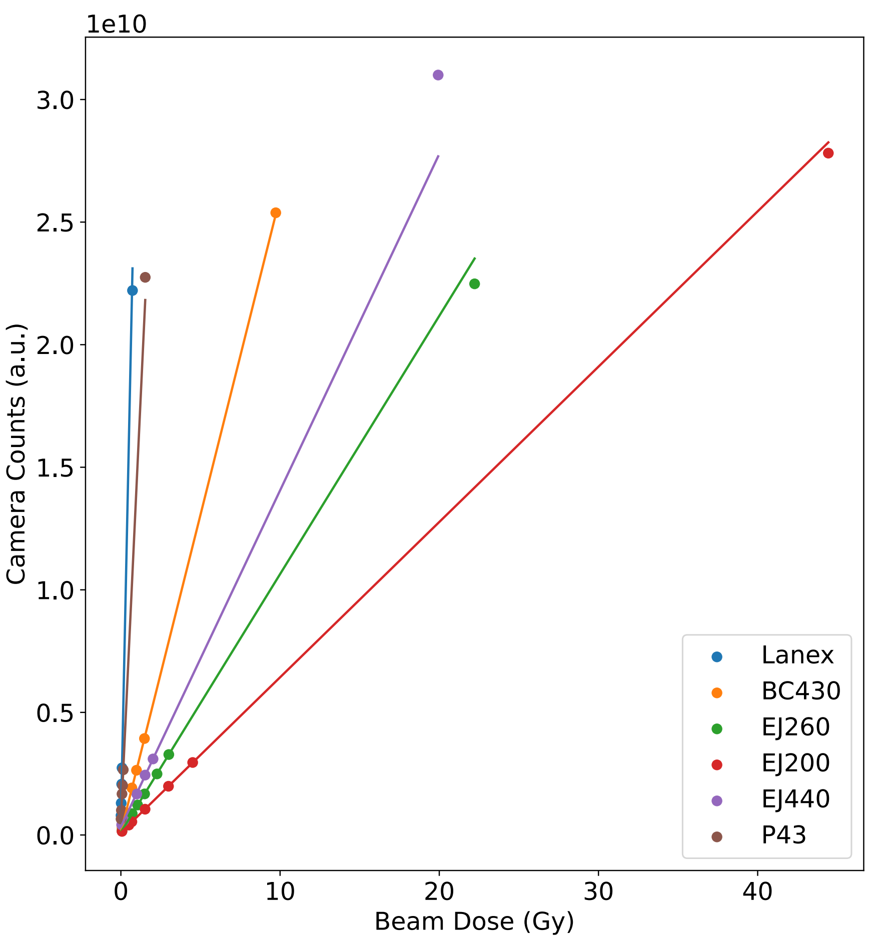
Queen's University Belfast: P. Parsons, C.A.J. Palmer

Imperial: N.P. Dover

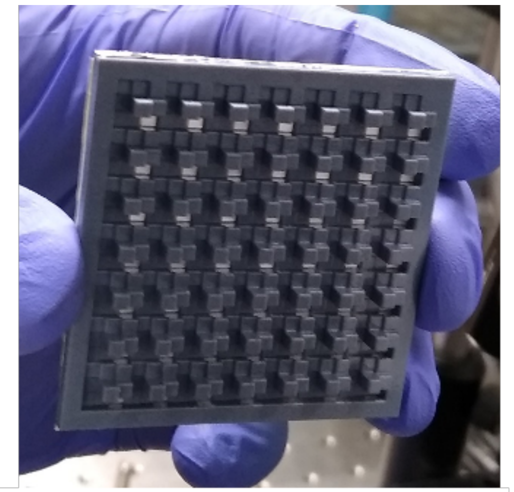
University of Birmingham: T. Price

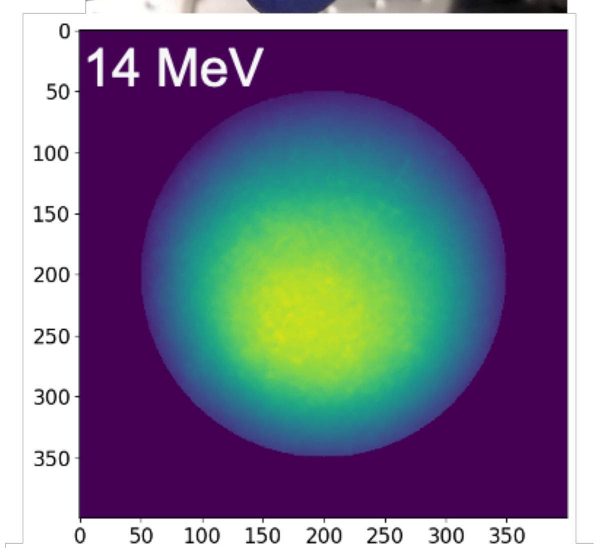
Summary of 2023 December beamtime

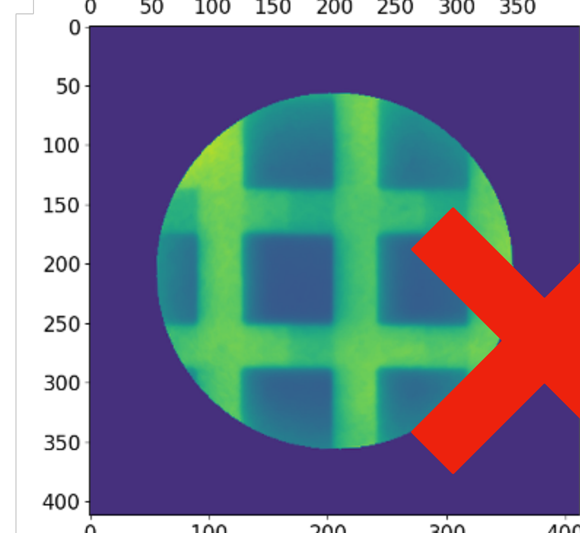
Dose linearity & absolute calibration at low dE/dx



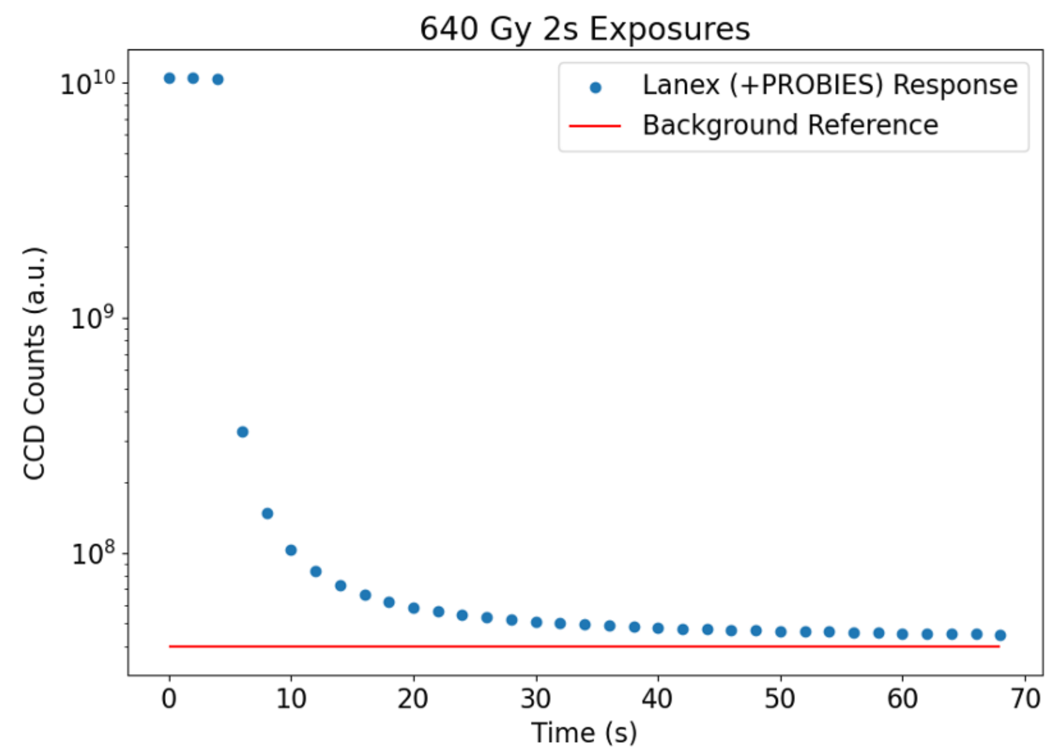
dE/dx dependence







Afterglow measurement



Results of May 2024 beamtime

Plastic scintillators	Powder phosphors	Crystals
EJ 260 (.1 and 1 mm)	Lanex medium (Tb doped Gadox) P43 (Gadox) P46 EJ 440 (ZnS:Ag)	YAG:Ce

1) Used characterised 15ish MeV beam, with Bragg peak measurements using Markus Chamber - thanks to Tony

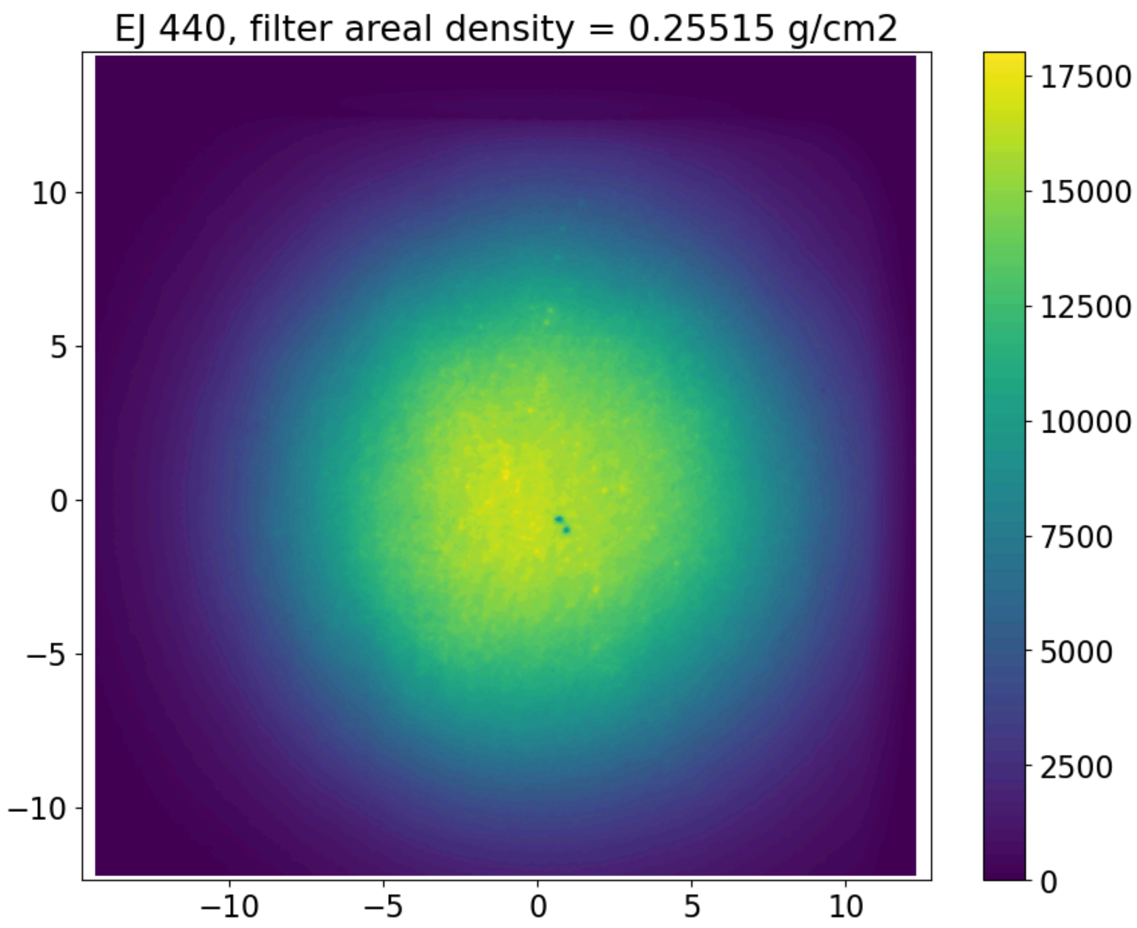
2) Performed dE/dx scan, using full aperture filters to avoid scattering issues from last time

3) Measured scintillator resolution using pinhole array

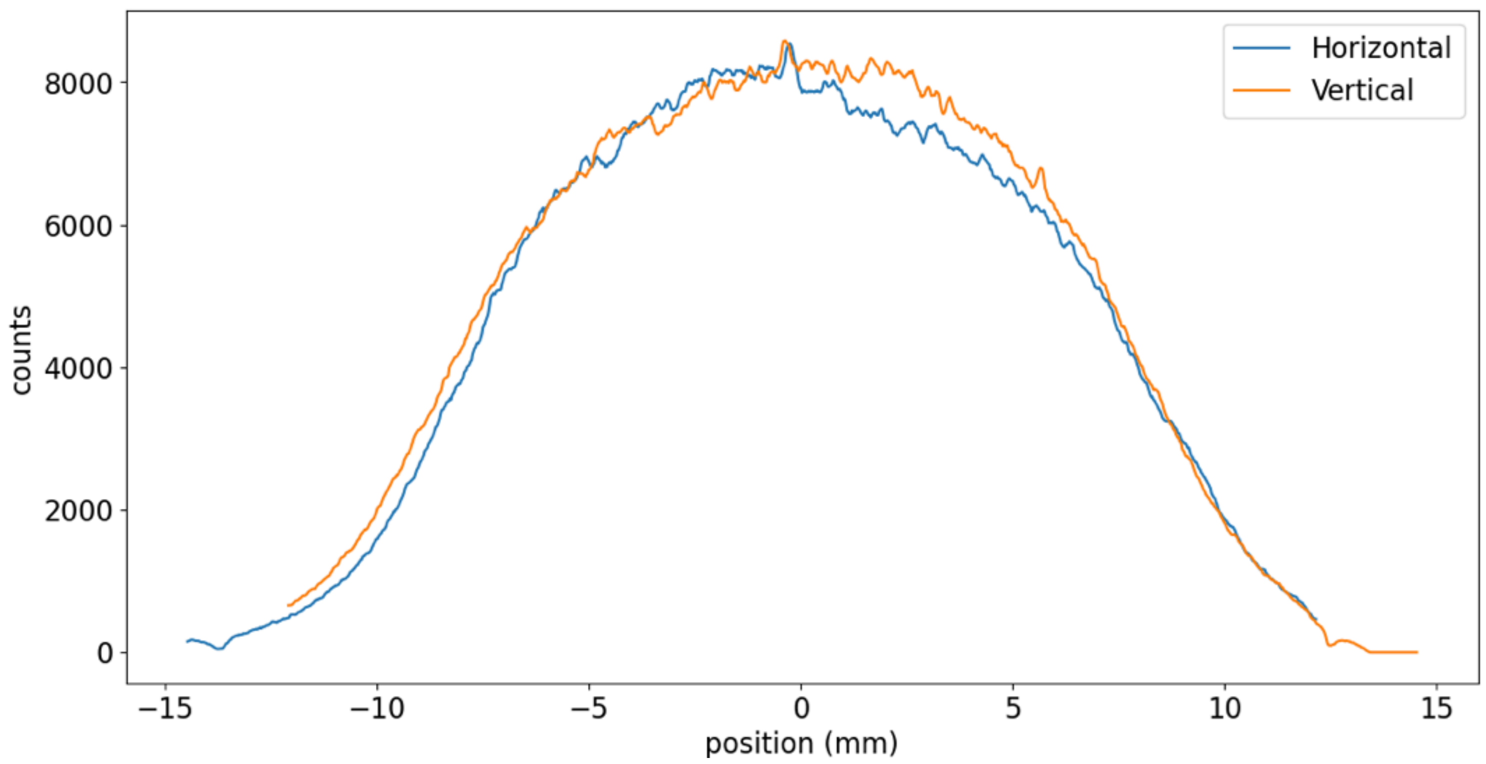
4) Performed better quantified afterglow scan for different scintillator types

15 mm beam @ 20 MeV from beamline

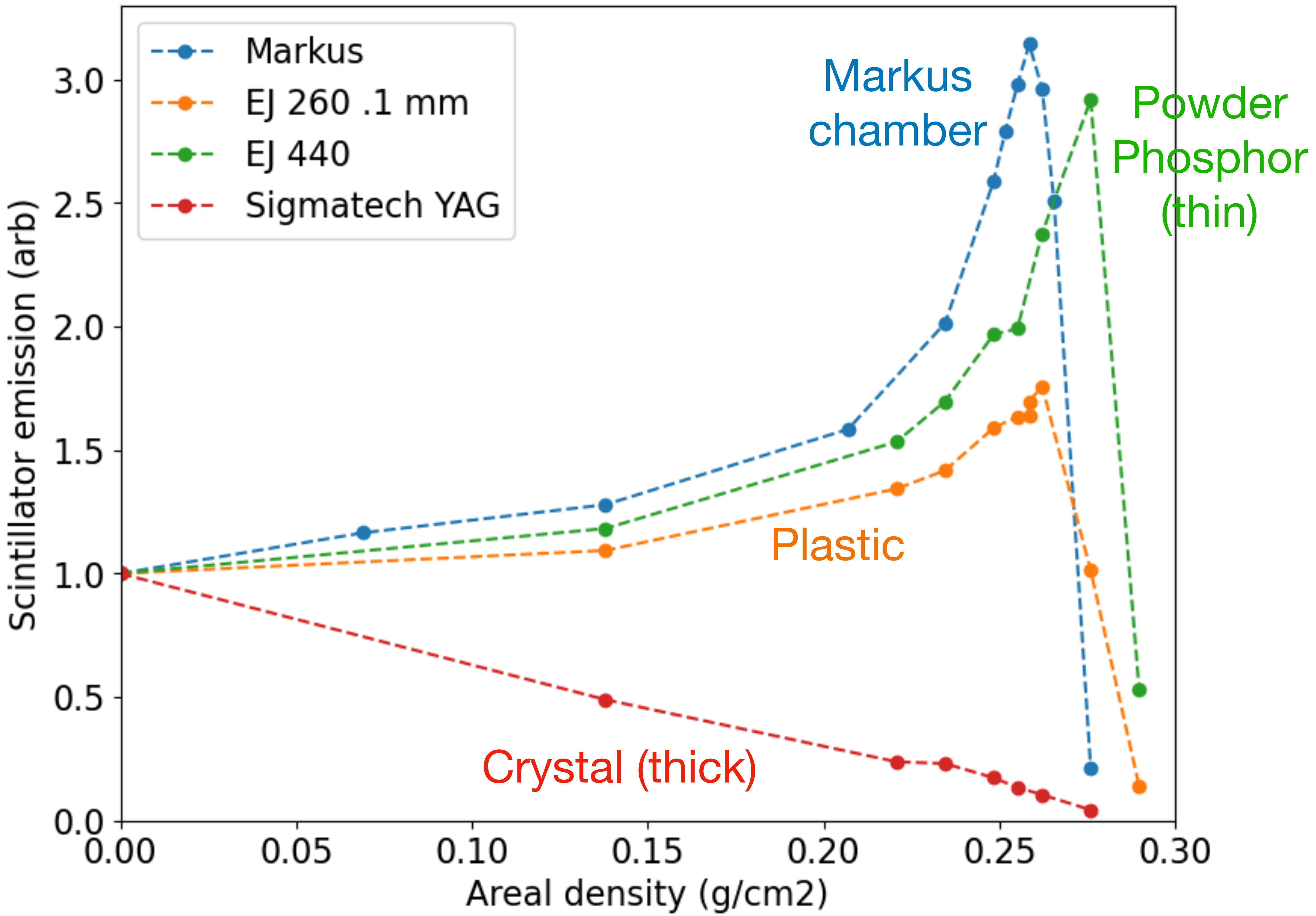
Typical scintillator image:



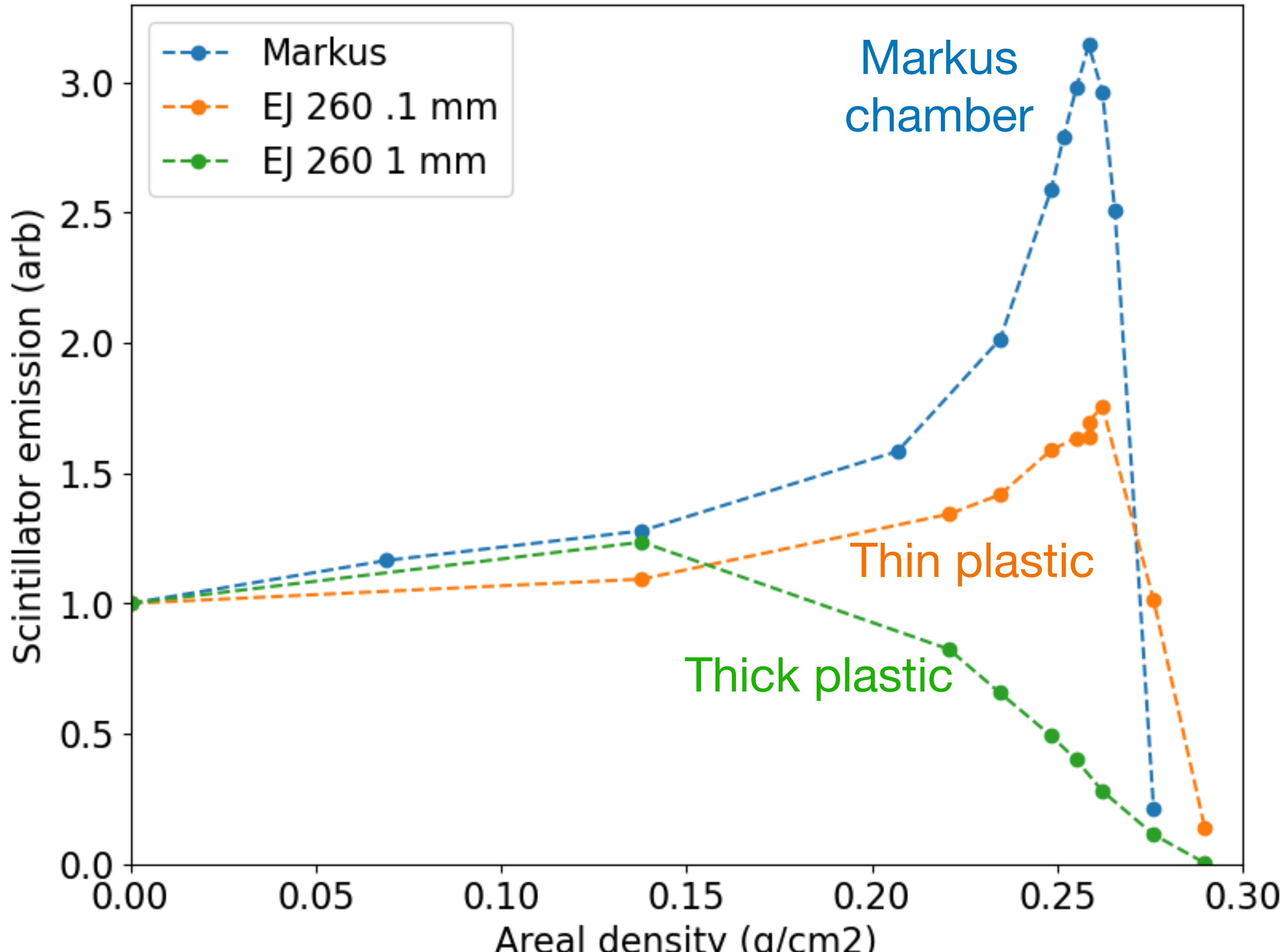
Beam lineouts:



Varied areal density before scintillators:

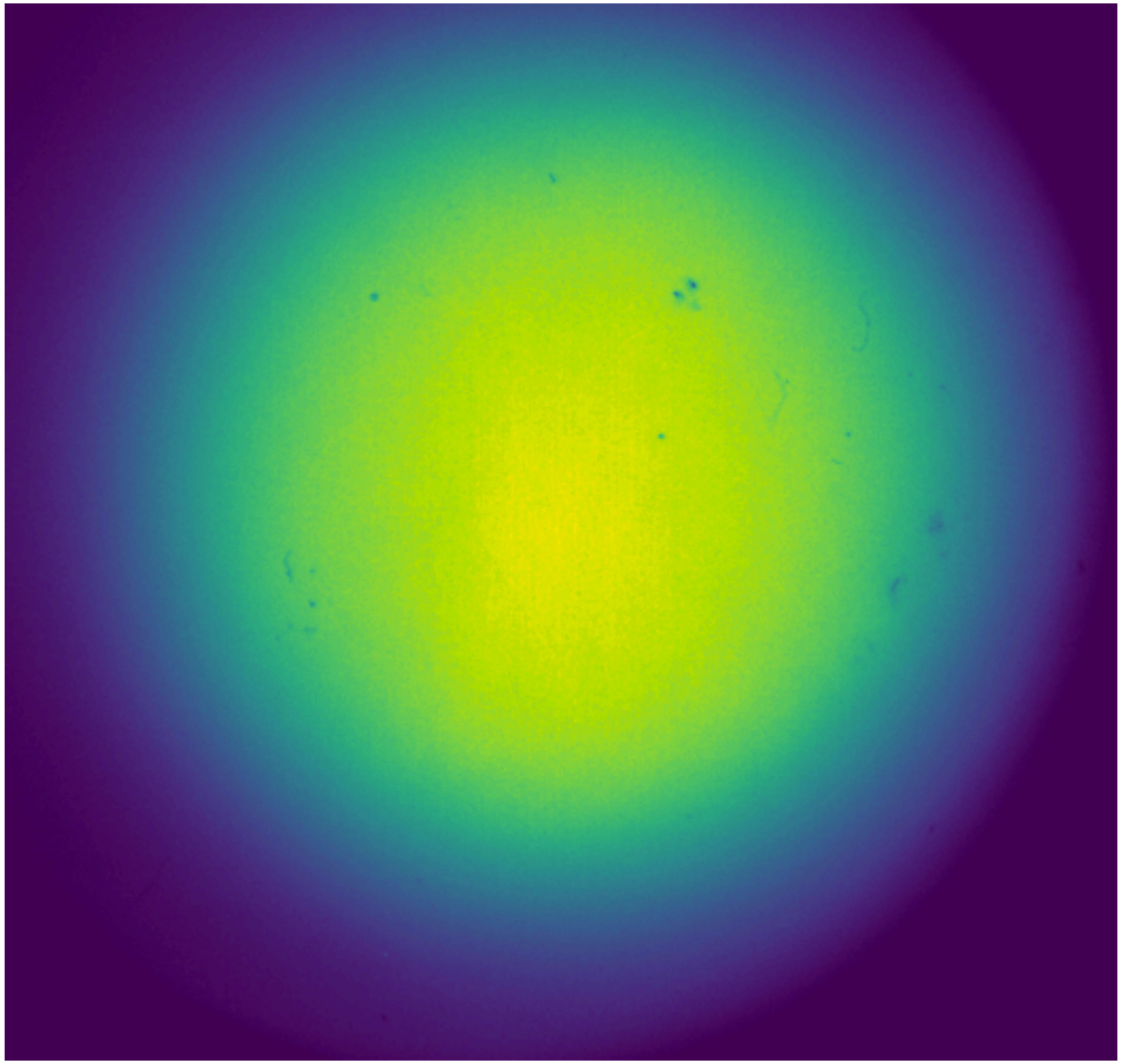


Effect of scintillator thickness

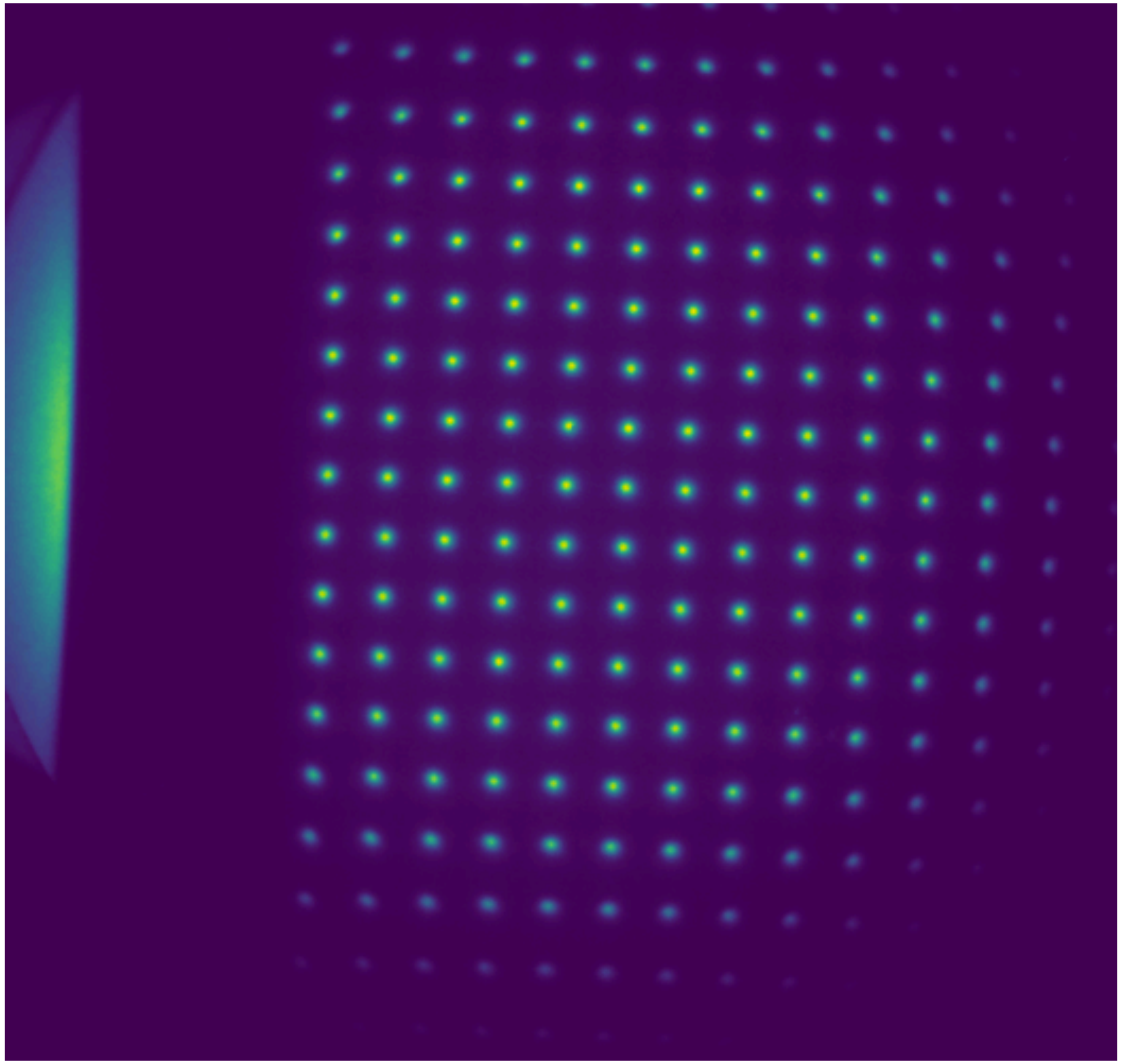


Resolution grid

Input beam, no grid

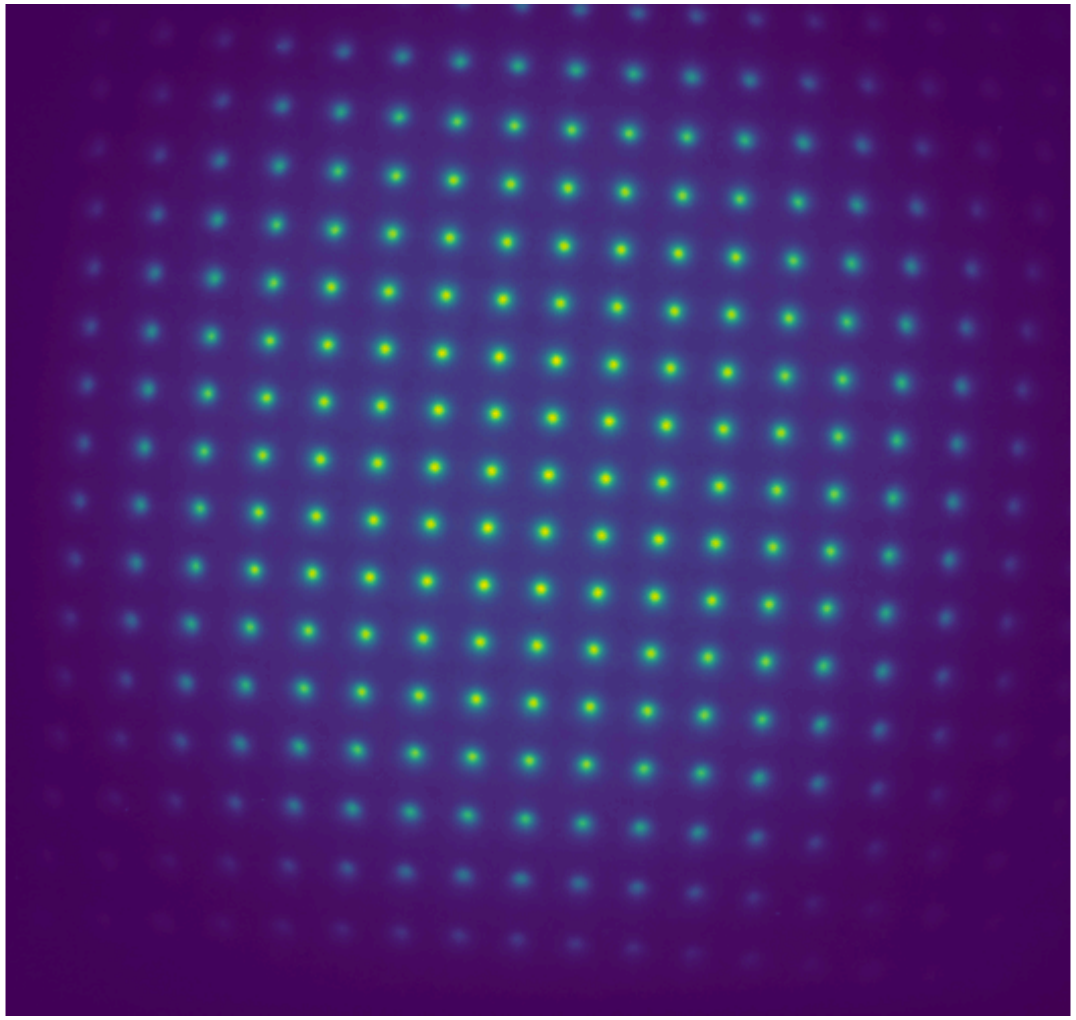


100 μm pinhole array in tungsten, in contact with scintillator

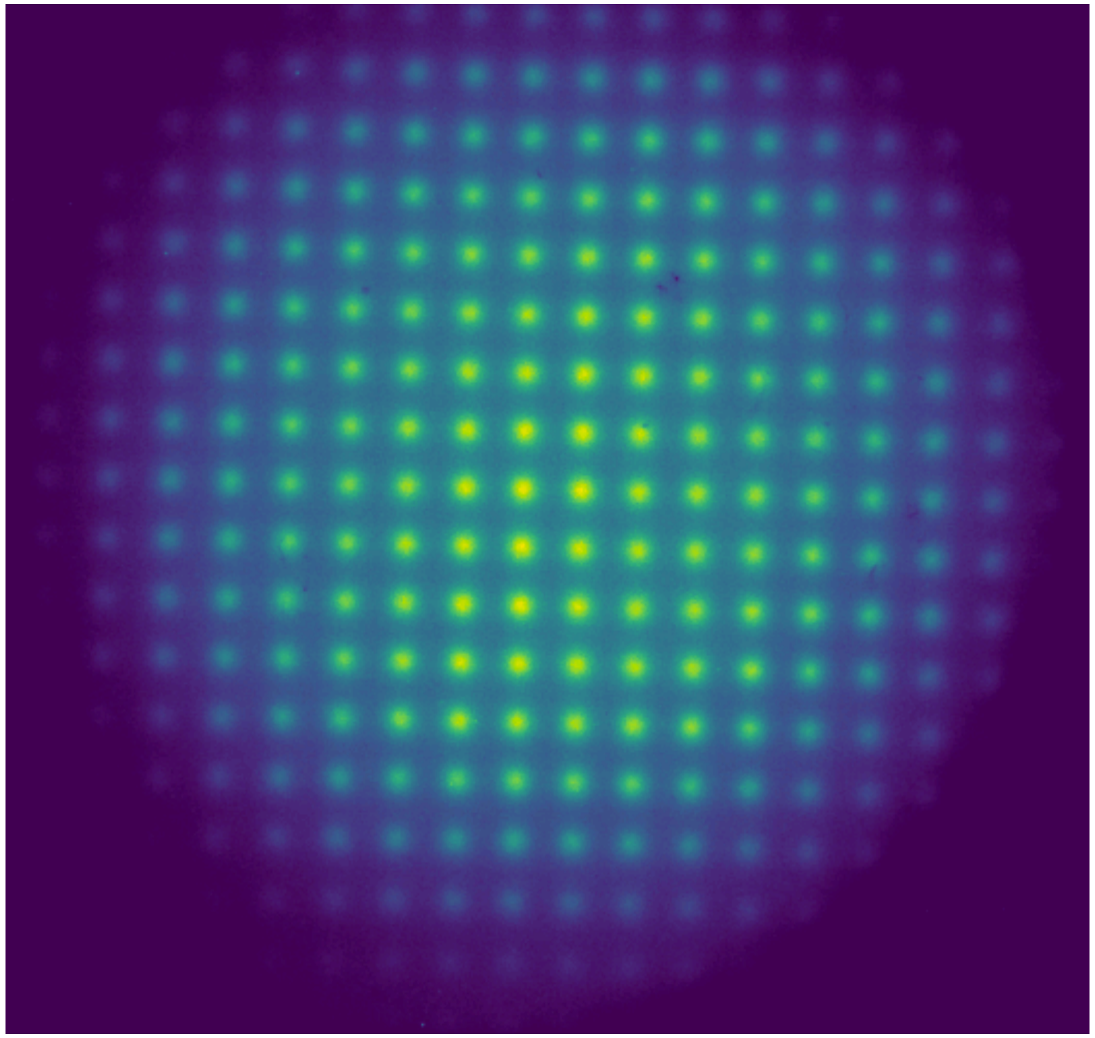


Impact on resolution of lanex scintillator

Lanex, phosphor away from beam



Lanex, phosphor closest to beam



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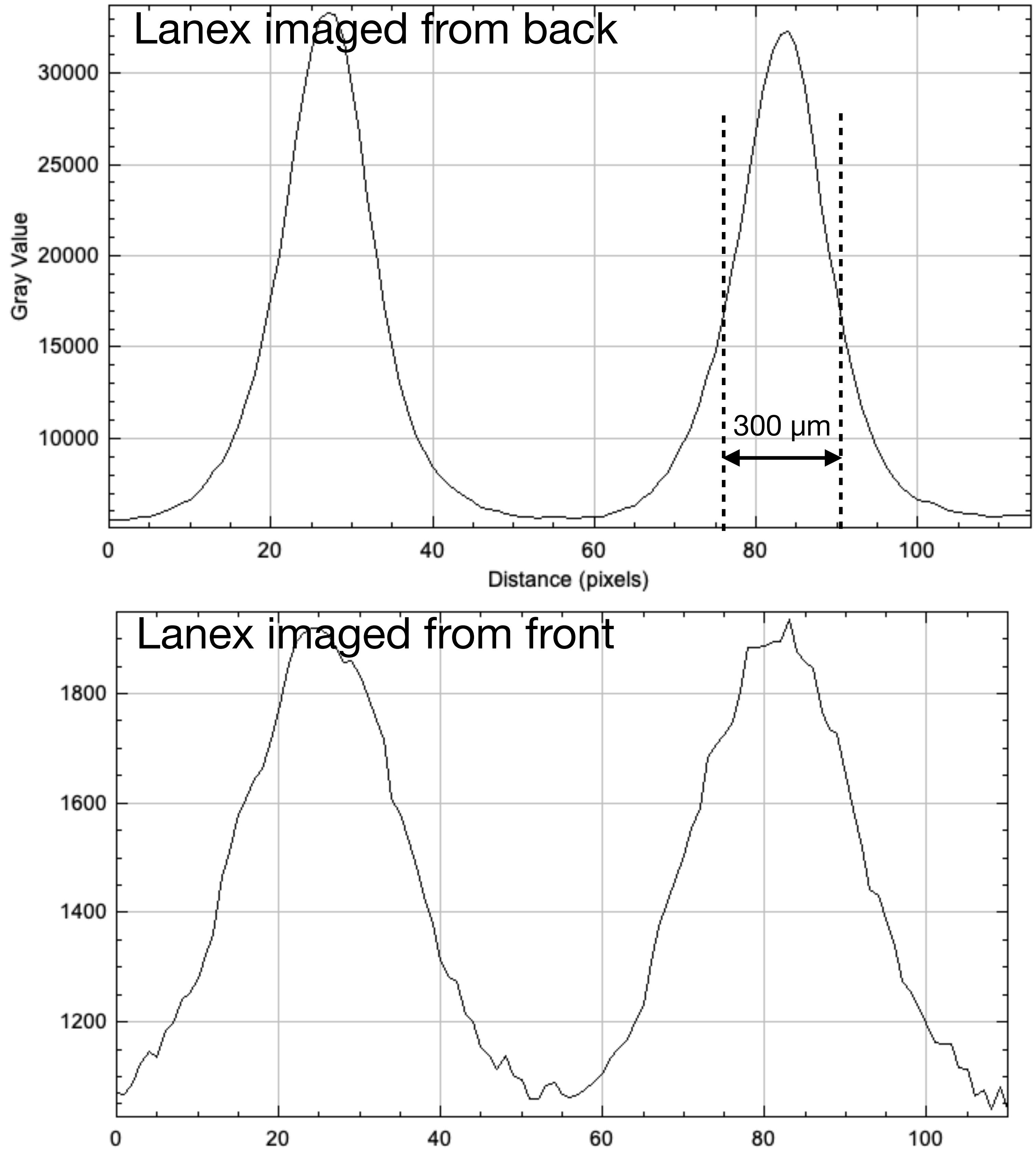
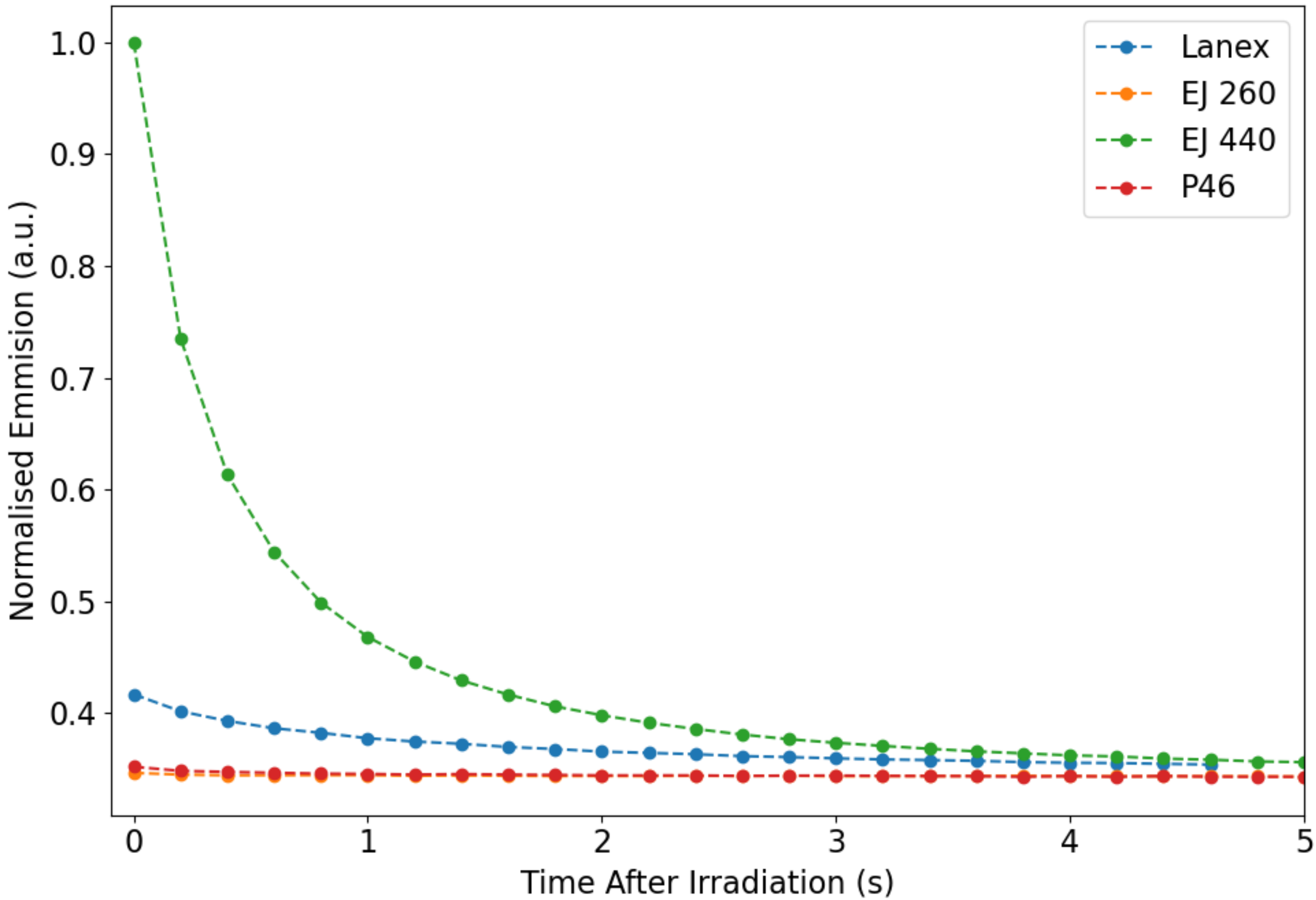


Afterglow measurements



Summary

- ➡ Understanding and calibrating scintillator response is key for diagnostic design for the LhARA source
- ➡ Performed series of experiments at MC40 to characterise scintillator response
- ➡ Promising data, next stage is combining with Monte Carlo modelling to measure dE/dx quenching factor and absolute scintillation yield
- ➡ Results will be used to select scintillator detectors for deployment at SCAPA and other laser driven ion sources