(some) 15 MeV protons at the MC40 cyclotron

Dr Tony Price
University of Birmingham

ITRF/LhARA Bi-Weekly meeting

16th July 2024

MC40 Cyclotron

- Variable RF allows proton energys from ~3-36 MeV to be extracted from the cyclotron
- Bread and butter 28 MeV for radiobiology, krypton production, ATLAS high intensity irradiator etc.
- 12 way switching magnet selects end-station with two beam lines extracted from the vault to experimental rooms.
- BL4 serves radiobiology, detector testing, and nuclear structure experiments

Geant4 Simulation

- Geant4 simulation developed over numerous years and validated versus measurements at 36 and 28 MeV
  - Bragg peaks
  - GafChromic Films
  - Silicon measurements
- Includes magnets, collimators, 80um Ta scattering foil, exit windows, ionisation chambers + whatever experiment is running
- Recent examples are WP3 scintillators, WP4 acoustic chamber, WP5 gas profiler
- Now able to run multithreaded with ROOT output (thanks to WP4 geometry…)

Bragg Peak Measurements

- Beam current monitored using ionisation chamber (IC)
- Known material (thickness and composition) placed down stream of the IC
- Marcus Chamber (MC) with calibration from NPL down stream of material to calculate dose rates
- Ratio of beam current in the IC and MC plotted as a function of depth to map out Bragg Peak

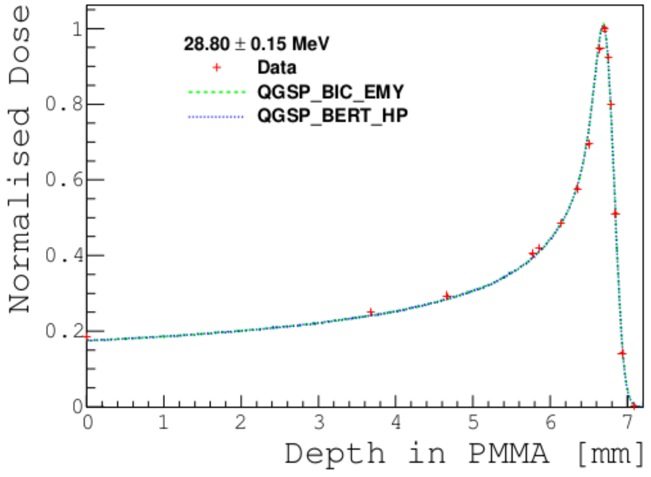


Figure 3: DDP for a nominal 29 MeV proton beam overlaid with simulation corresponding to the best initial parameters of 28.80 ± 0.15 MeV

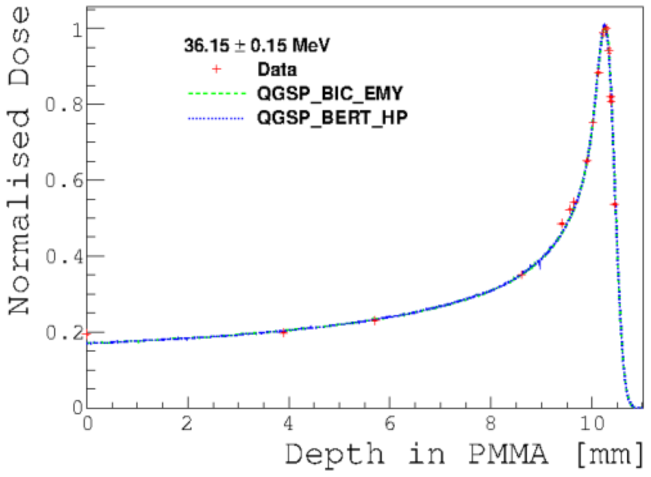
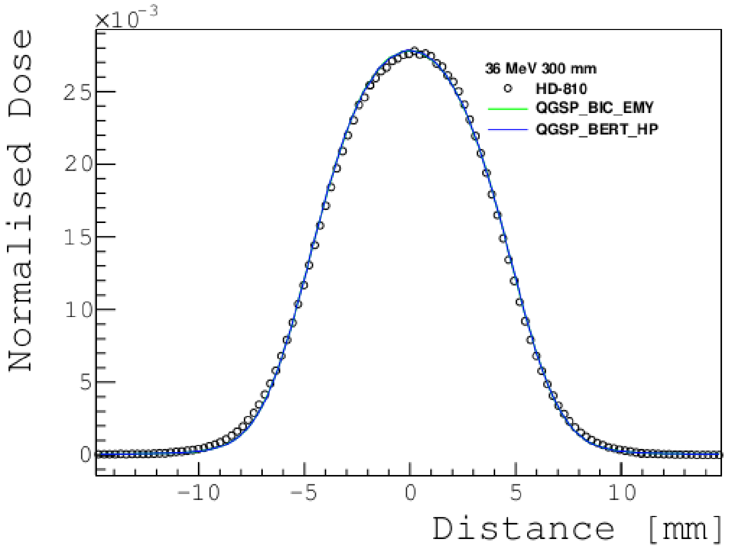
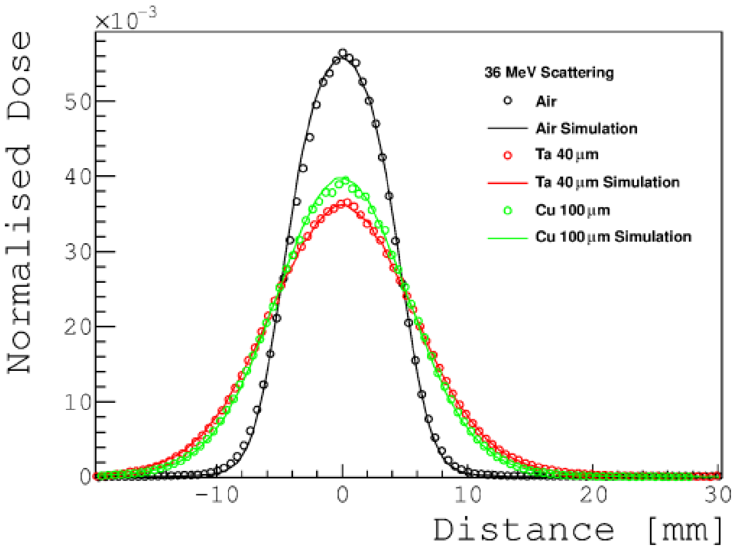


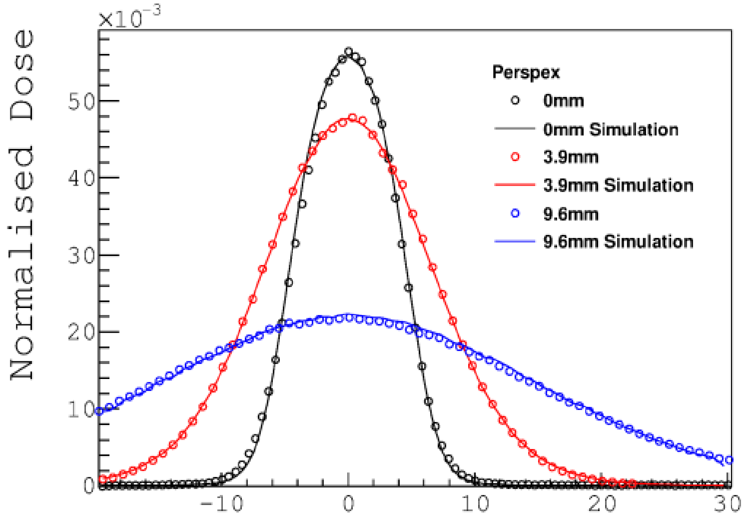
Figure 4: DDP for a nominal 36 MeV proton beam overlaid with simulation corresponding to the best initial parameters of 36.15 ± 0.15 MeV

Beam Profiles and divergence

- Model validated vs RCF measurements
- different distances from the collimator to evaluate divergence
- and with various amounts of material to validate scattering







Microbeams (Elisa Gazzera)

100um slits wire eroded in 2mm Ta
500um centre-to-centre spacing
Designed for max PVDR at entrance and uniform at BP

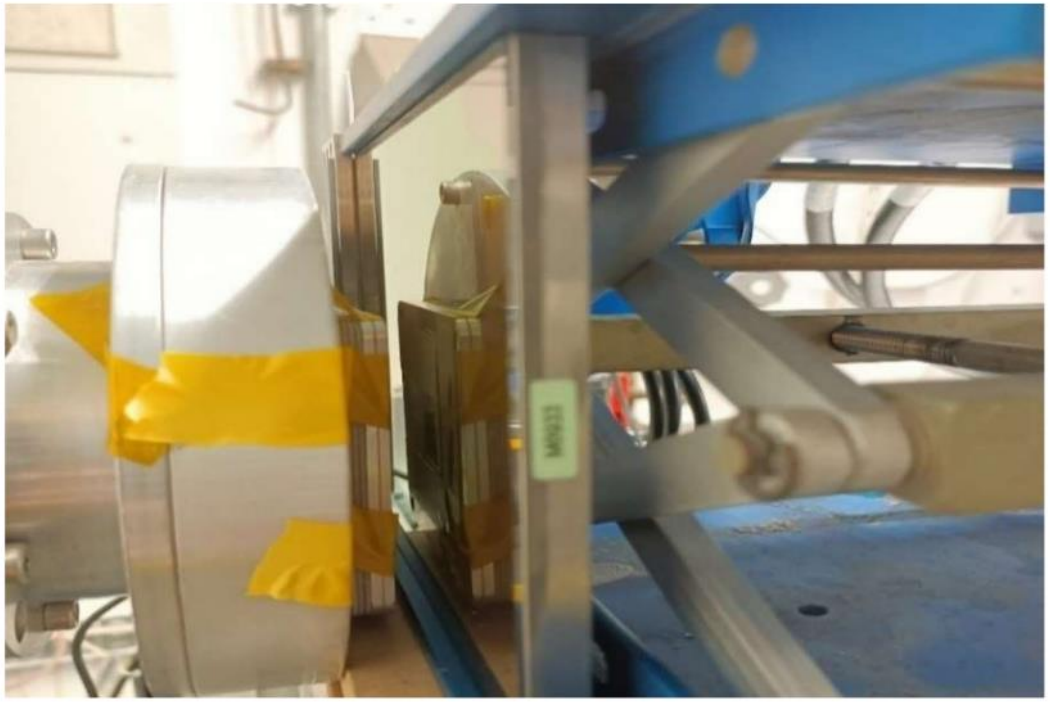


Figure 3.10 – Experimental setup of the air measurements. The reflection of the taped collimator can be noticed in the CMOS.

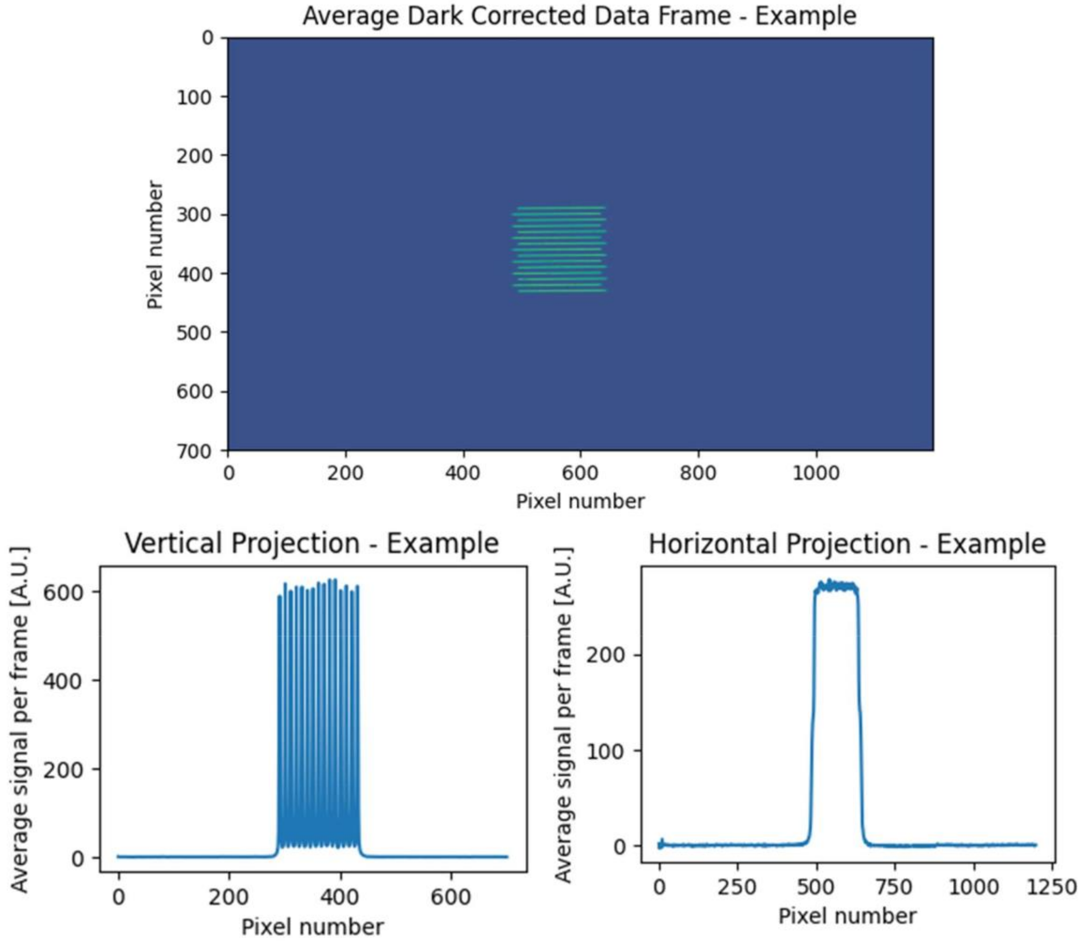


Figure 3.13 – Example of an average dark corrected data frame depicting the profile of the microbeams, together with its vertical and horizontal projections.

Microbeams (Elisa Gazzera)

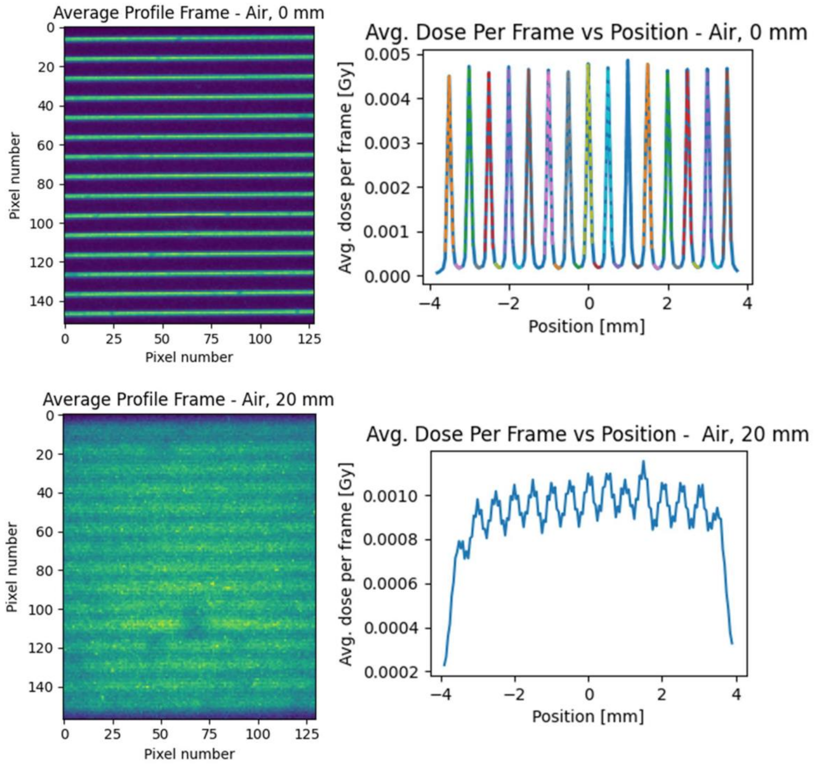
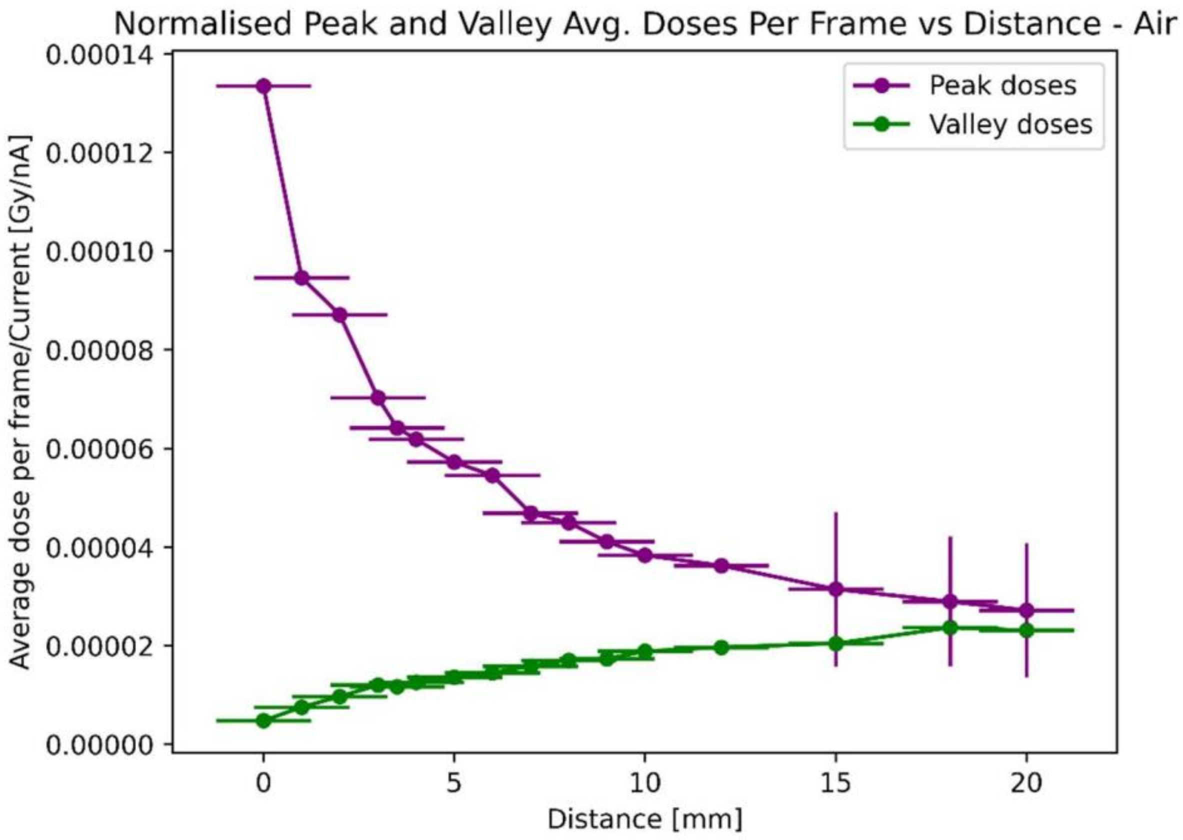


Figure 3.16 – Average profile of the microbeams in air (L) and corresponding average dose distribution per frame (R). The coloured dashed curves represent either the Gaussian or the 4th order polynomial fit functions of the peaks and the valleys. The first set of images corresponds to a 0 mm distance, while the second refers to a 20 mm one.



Microbeams (Elisa Gazzera)

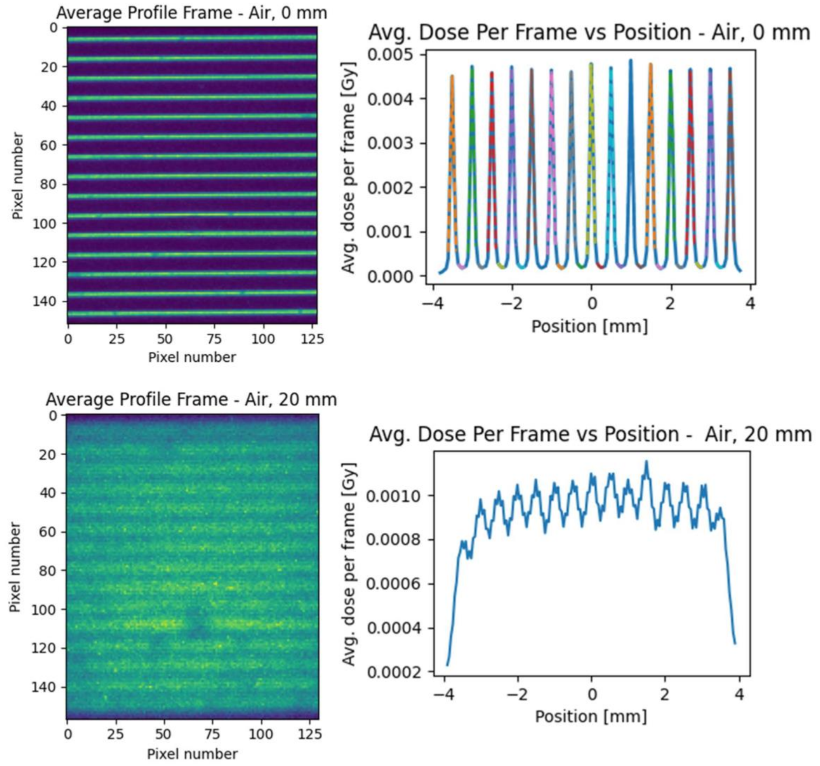
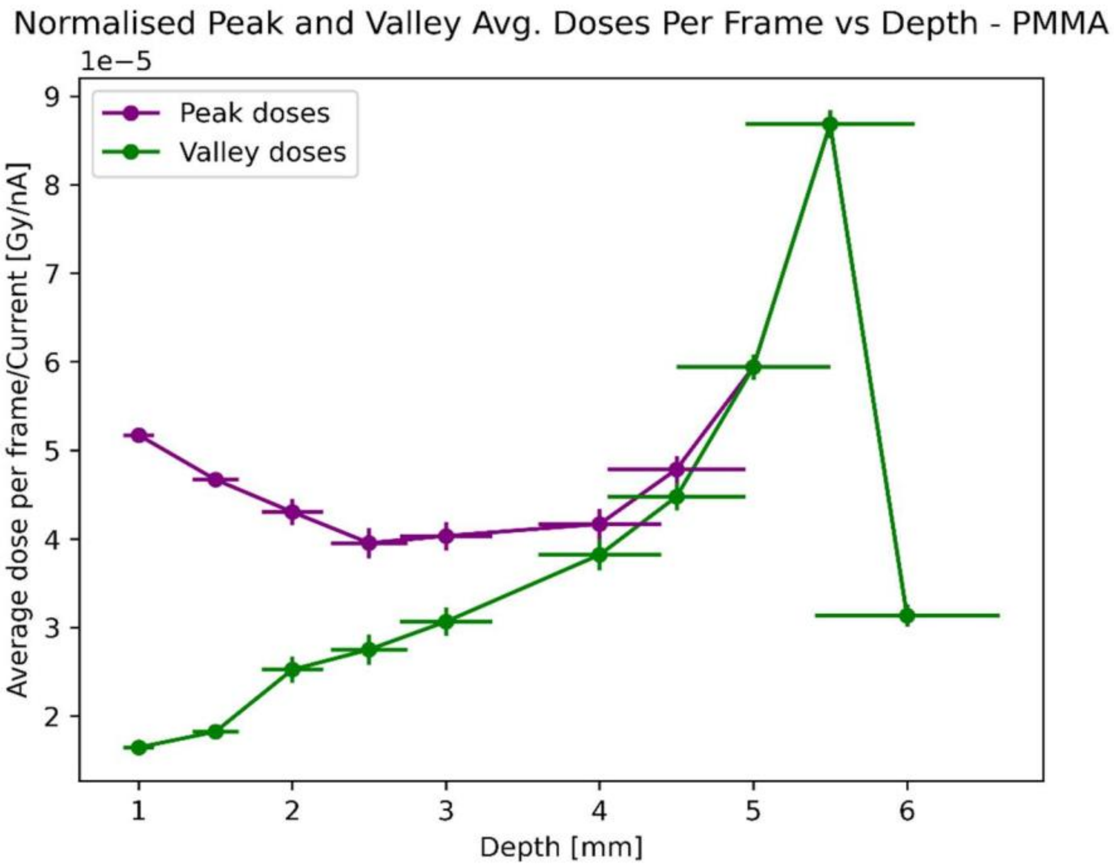
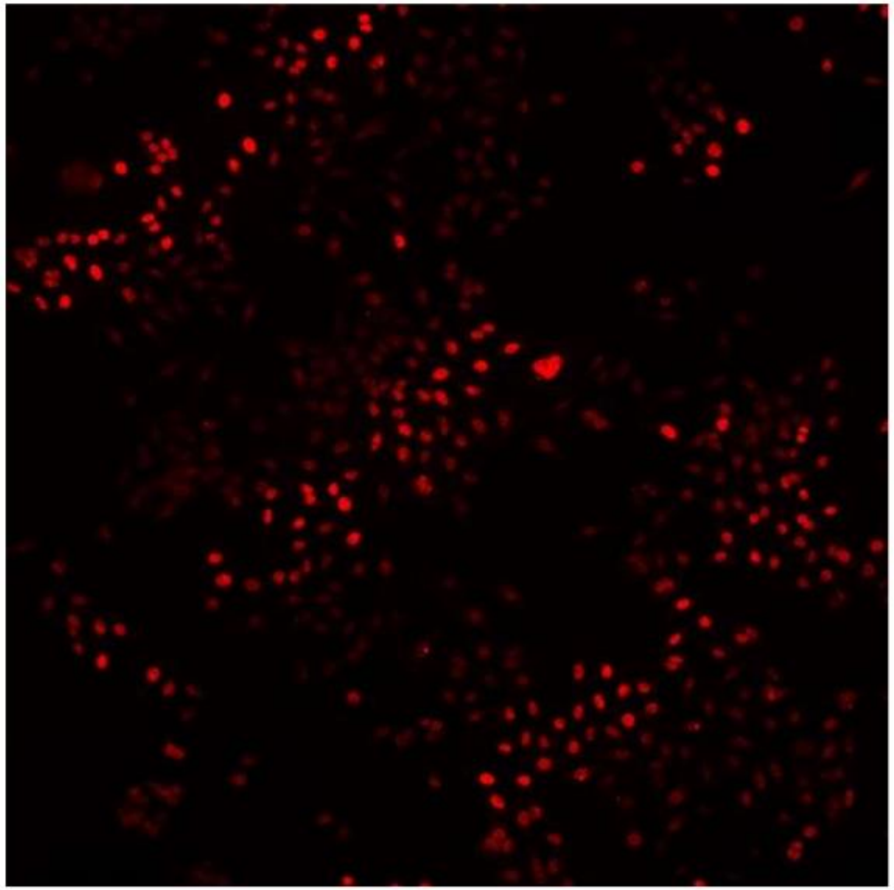


Figure 3.16 – Average profile of the microbeams in air (L) and corresponding average dose distribution per frame (R). The coloured dashed curves represent either the Gaussian or the 4th order polynomial fit functions of the peaks and the valleys. The first set of images corresponds to a 0 mm distance, while the second refers to a 20 mm one.

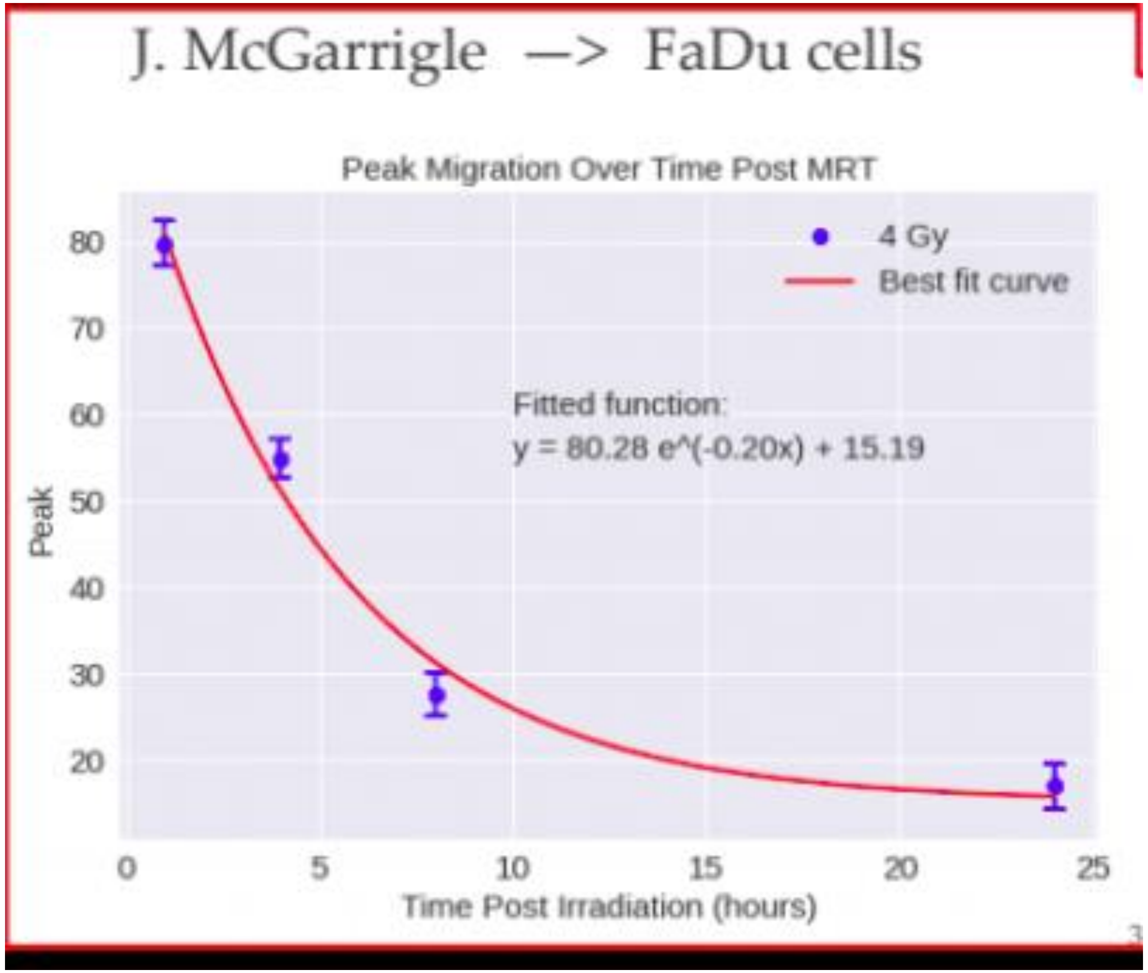


Microbeams onto cells

Elisa showed possible to see damage in streaks

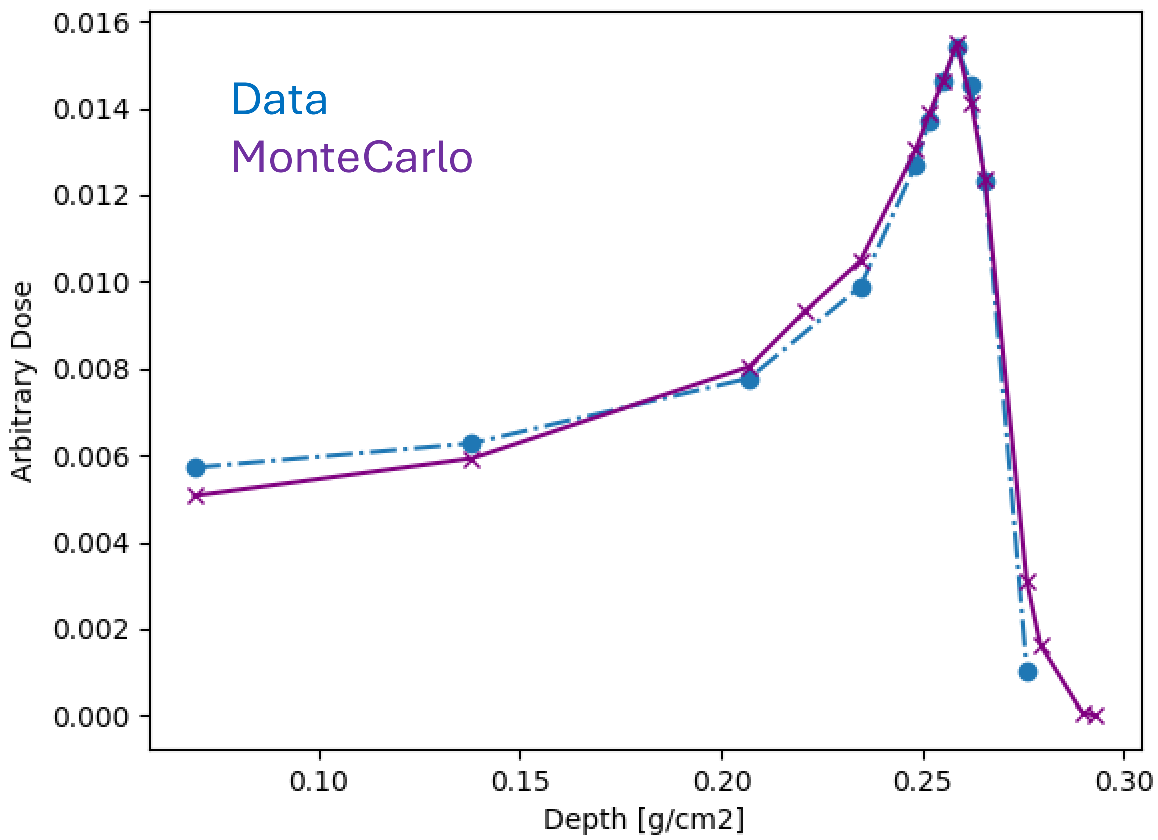


Josie showed potential migration. Work to be repeated September 2024



15 MeV Validation

- During the work with WP3 recently
- Wanted 15 MeV onto sample. Optimal energy was 18 MeV but cyclotron issues and time constraints meant we ran 20 MeV + 0.5mm PMMA shim
- Scattered beam with 80um Ta
- Energy onto sample 15.5 MeV (close enough!)
- Bragg Peak found using 100um mylar shims and 12.5um Al.
- Geometry matched to WP3 experiments.
- Beam profile 50mm diameter and uniform measured on RCF.



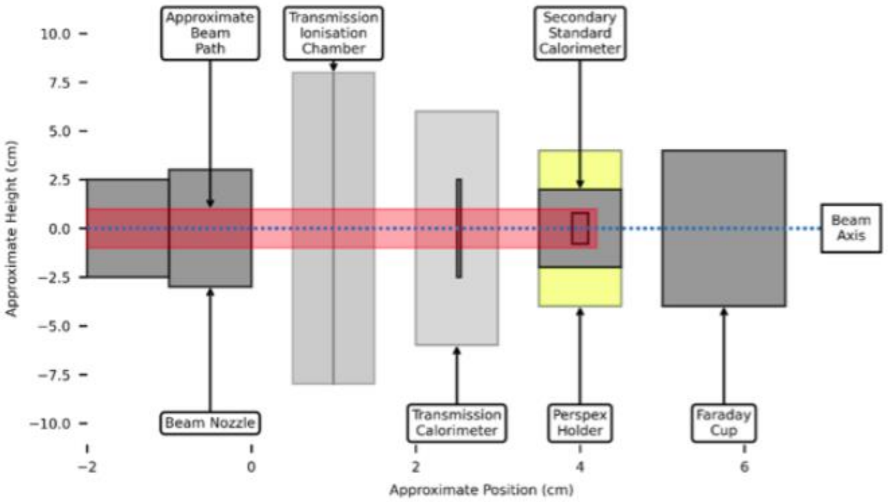
End-station simulations

- Shown at previous collaboration meetings
- End-station components being tested
  - environmental boxes,
  - cell dishes,
  - gas profiler,
  - RCF
- Can extract
  - Beam profiles
  - Energies
  - LETs
  - Particle species and energy deposits
- New: ability to change from gaussian profile (MC40) to wider distributions (LhARA)
- Results to be evaluated for changes for 24 month report.

Dose Rate measurements

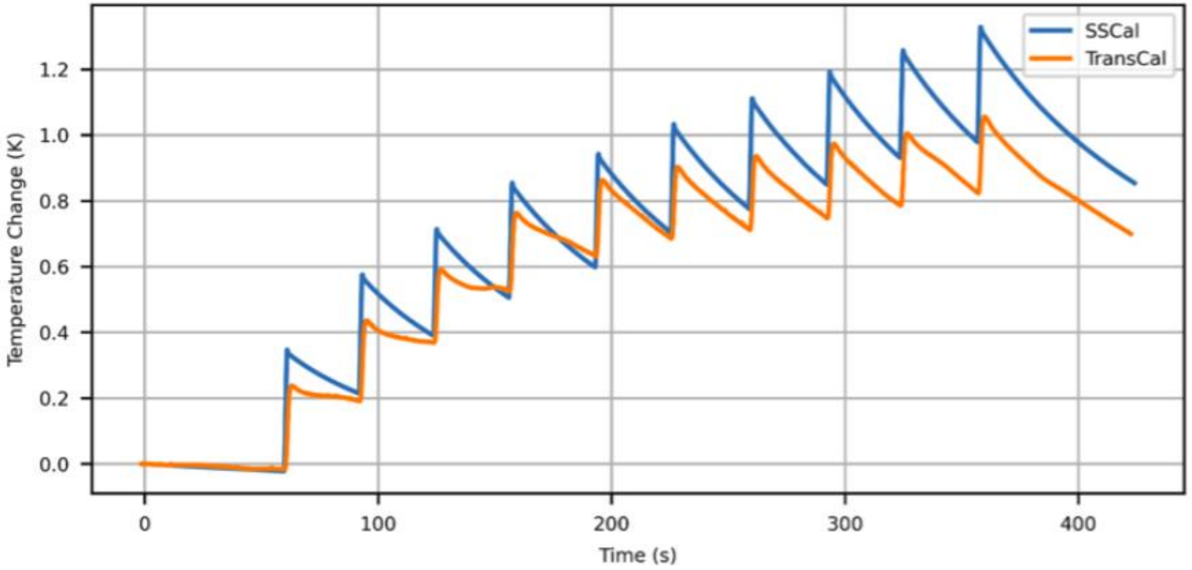
- Experimental campaign with NPL
- Utilised the Secondary Standard Calorimeter.
    - Designed to be size of Roos chamber
    - Could be used in clinical QA
    - aim of it being traceable to NPL
- Also experimental TransCal designed by S. Flynn to measure FLASH doses
    - Thin which minimally perturbs the beam
    - None of the temperature shielding of the calorimeters so best suited for high dose rates
- Beam current monitored using Ionisation chamber and/or Faraday cup depending on dose rates.
- Publication under review

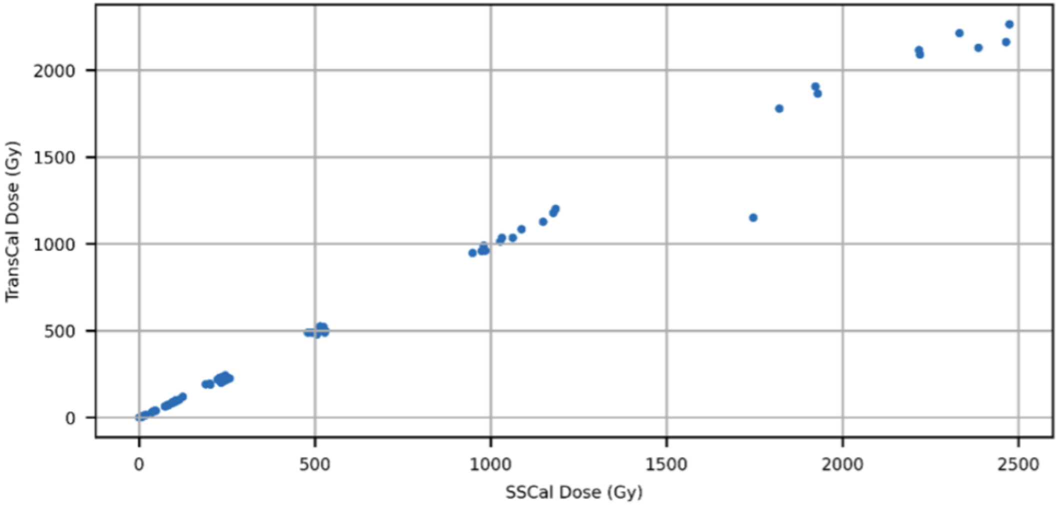
Experimental Setup 1



Dose Rate measurements

- Experimental campaign with NPL
- Utilised the Secondary Standard Calorimeter.
  - Designed to be size of Roos chamber
  - Could be used in clinical QA
  - aim of it being traceable to NPL
- Also experimental TransCal designed by S. Flynn to measure FLASH doses
  - Thin which minimally perturbs the beam
  - None of the temperature shielding of the calorimeters so best suited for high dose rates
- Beam current monitored using Ionisation chamber and/or Faraday cup depending on dose rates.
- Publication under review
- Dose rates up to 2.5 kGy/s measured in SSCal.
- Higher dose rates suffered from cyclotron vacuum leak so more fluctuations





Conclusions

- Experimental work conducted at MC40 as part of ITRF
  - WP3 scintillator studies
  - WP4 liquid scintillator and SmartPhantom testing
  - WP5 Gas Profiler measurements (planned for August 2024)
  - Dose rate measurements with NPL
  - Validated Geant4 model assisting with these studies
- G4EndStation will be tidied up and made available to ITRF members at the end of PA1
- MC40 model paper needs to be submitted
- Microbeam paper being written, poster at FRPT, Josie & Jason using for cell measurements
- Dose rates up to 2.5 kGy/s achieved