IMPERIAL

LhARA

Global trends in laser-driven radiobiology

An evaluation of field trends, beam capability and requirements for radiobiology

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Data collection & analysis

Analysis aims

1	**Collect data**	Compile database of all laser driven radiobiology experiments
2	**Find trends**	Explore how beam and sample parameters might be correlated
3	**Evaluate biology**	Compile survival and foci data to look for global trends
4	**PoPLaR**	Explore how PoPLaR fits with the current global experiments
5	**LhARA**	Explore gaps in the field, how LhARA can fill these gaps & what would requirements be

Data selection

Summary of data selection using PICO analysis and PRISMA flow

32
Candidate publications

10
Excluded after full-text review

22
Included in the analysis

21 PROTON / 1 CARBON
Nearly all included studies are proton-only

4 IN VIVO
3 zebrafish embryo studies + 1 mouse-ear study

Search criteria

What information was stored?

Information was stored about:

Laser–target

Short, intense proton/ion bunch

›

Transport

Focusing + energy spread

›

Beam shaping

Scatterers, apertures

›

Diagnostics

Energy, dose and timing

›

Biology

Survival, γH2AX.

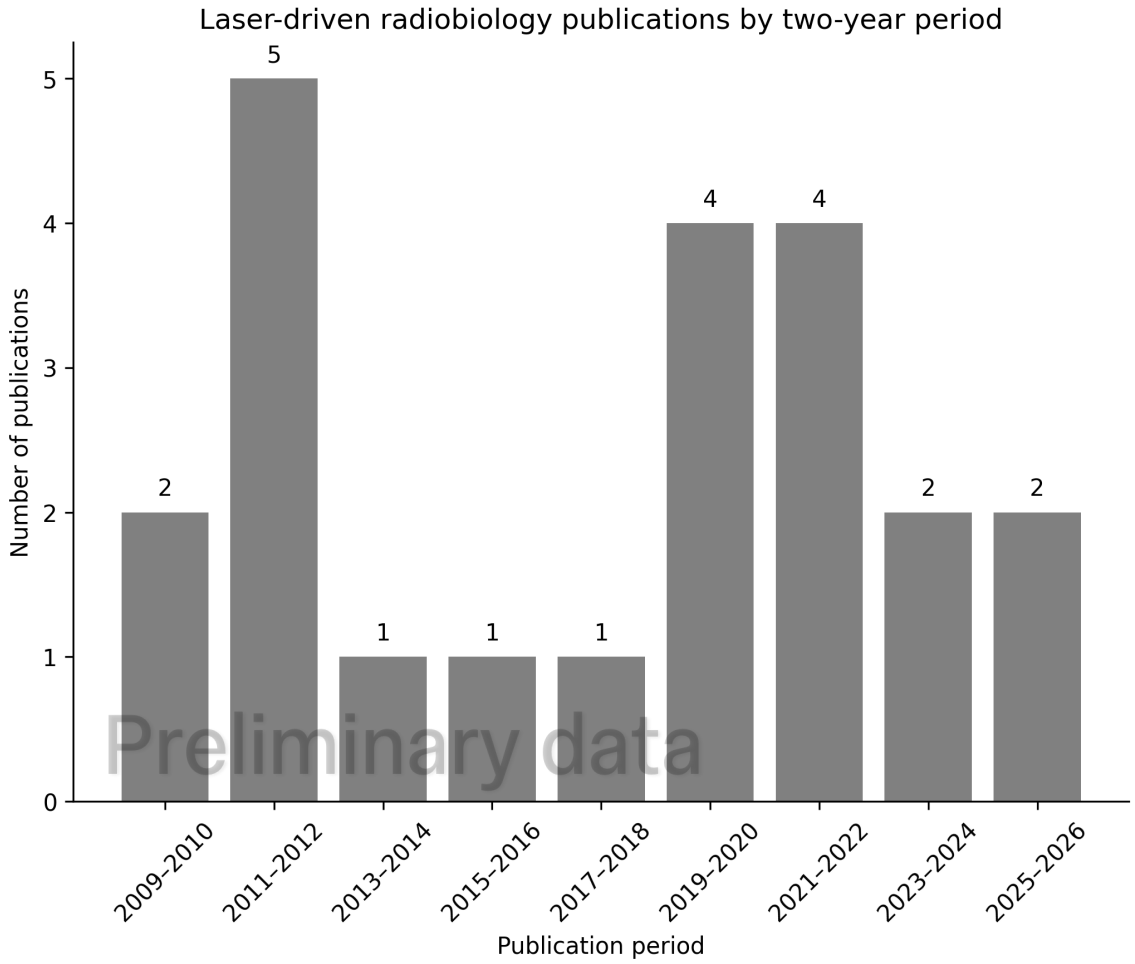
Limits:

- Not all papers stored individual energies, doses etc. Some gave ranges- max and mins were stored in this case.
- Not all parameters had results from multiple papers- these were excluded from analysis
- Repeated use of same beamlines may produce repeated parameter values across different papers

Field-wide trends

Publication activity

Publication frequency from 2019-present in 2 year increments

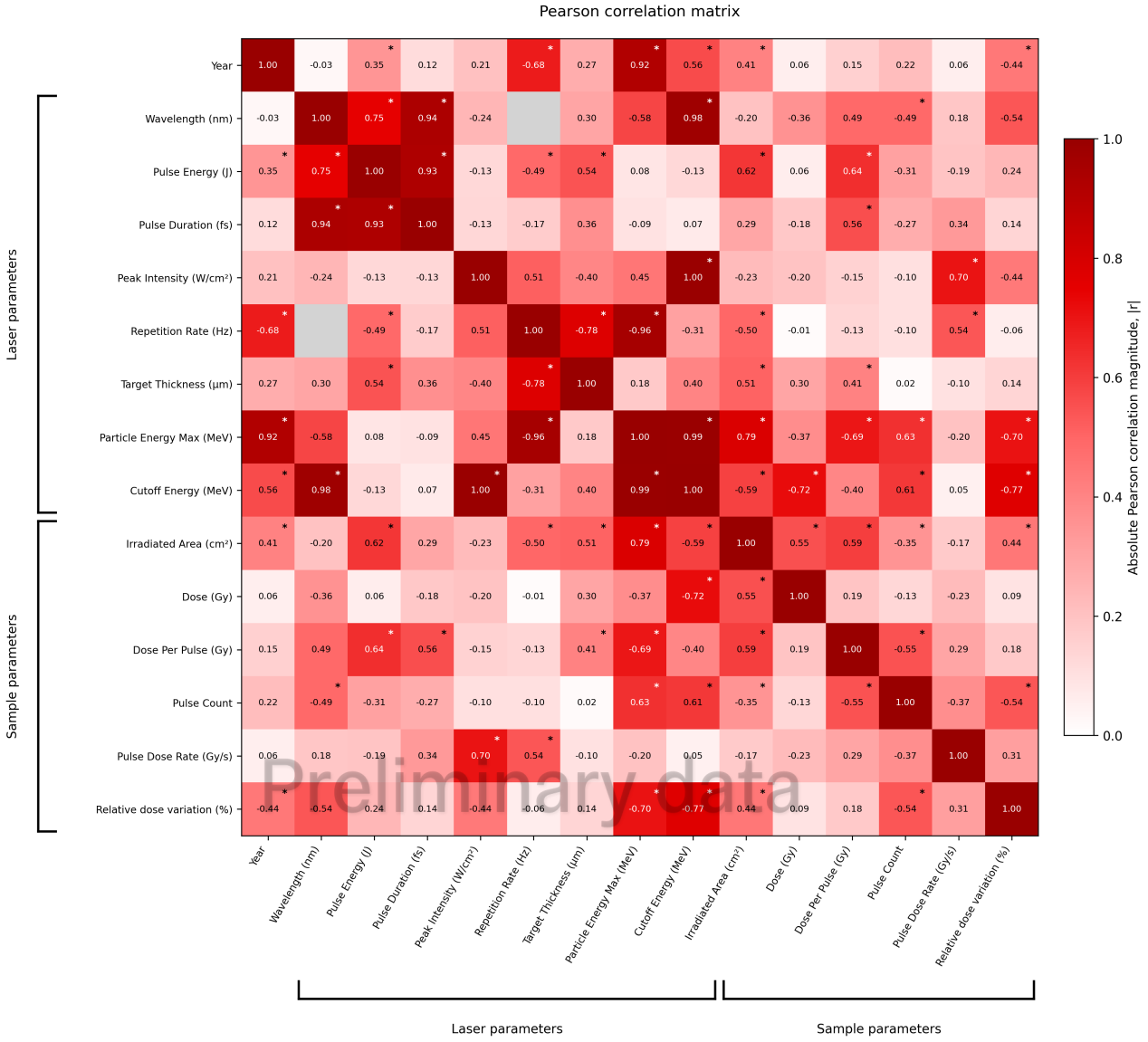


Reading the trend

- Peak of 5 papers in 2011–12
- 8 across 2019–22
- 4 across 2023–25
- 0 papers in 2026 (at time of collection)

Parameter correlation analysis

Pearson correlation scores



Top relations:

Beam parameters with beam parameters

R = +0.99

Peak laser intensity vs cutoff energy (n=13)

Beam parameters with sample parameters

R = −0.77

Cutoff energy vs relative dose variation (n=19)

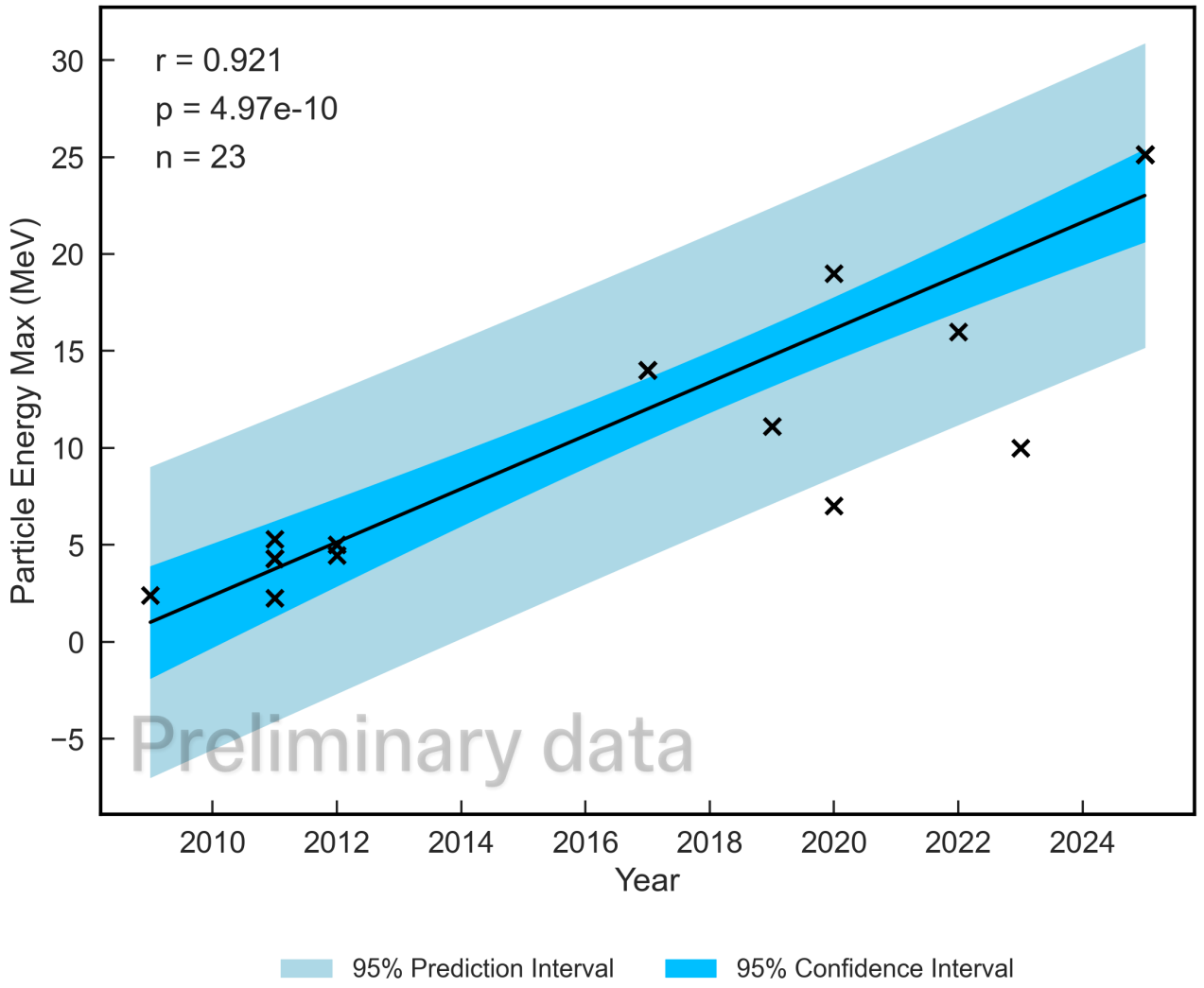
Correlations with year

R = +0.92

Year vs maximum particle energy (n=23)

Maximum particle energy has increased over time

Maximum energy of particles at the sample vs year of publication



R = 0.921

Maximum energy vs publication year

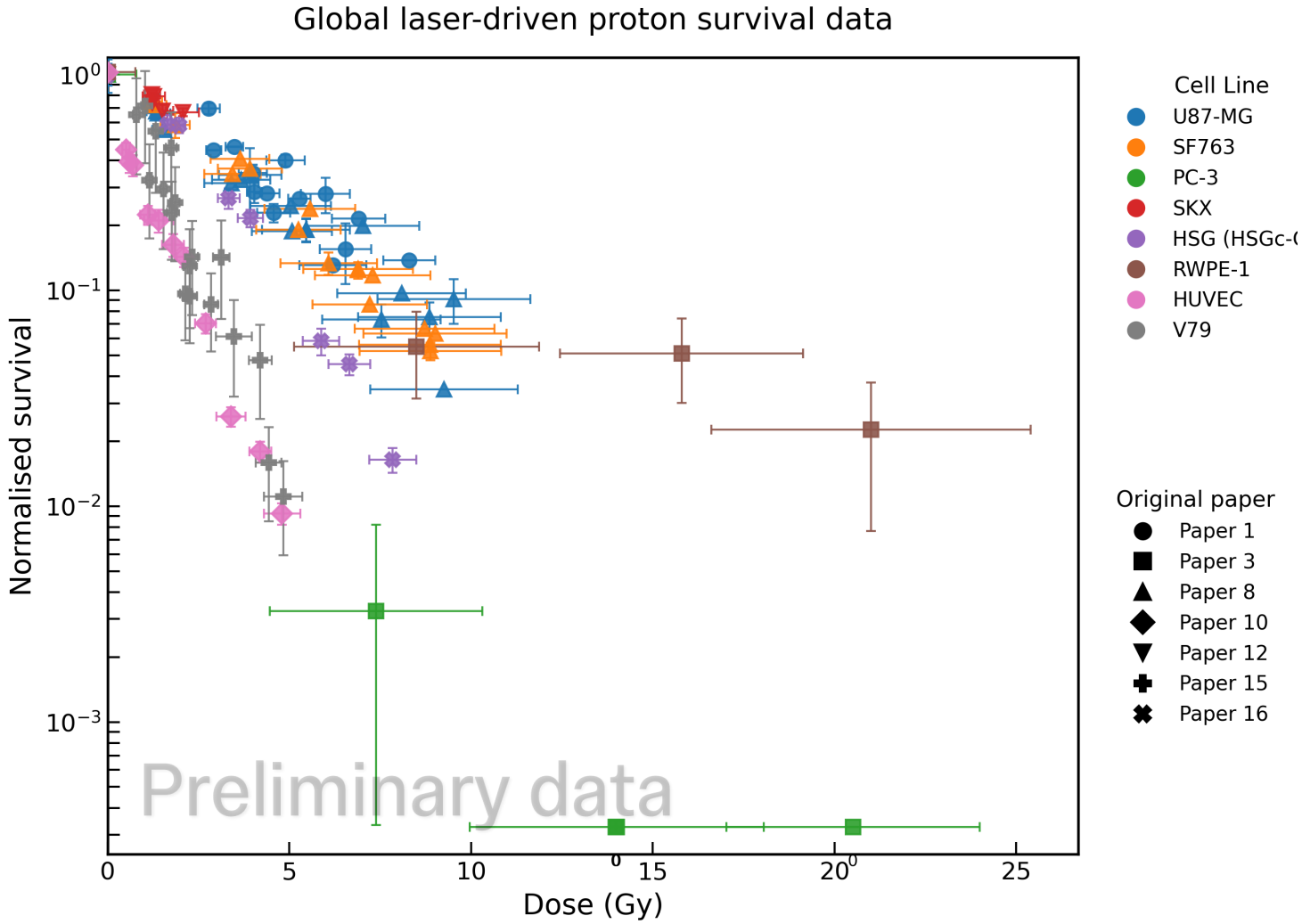
N = 23

Conditions used in reported correlation

Biological data

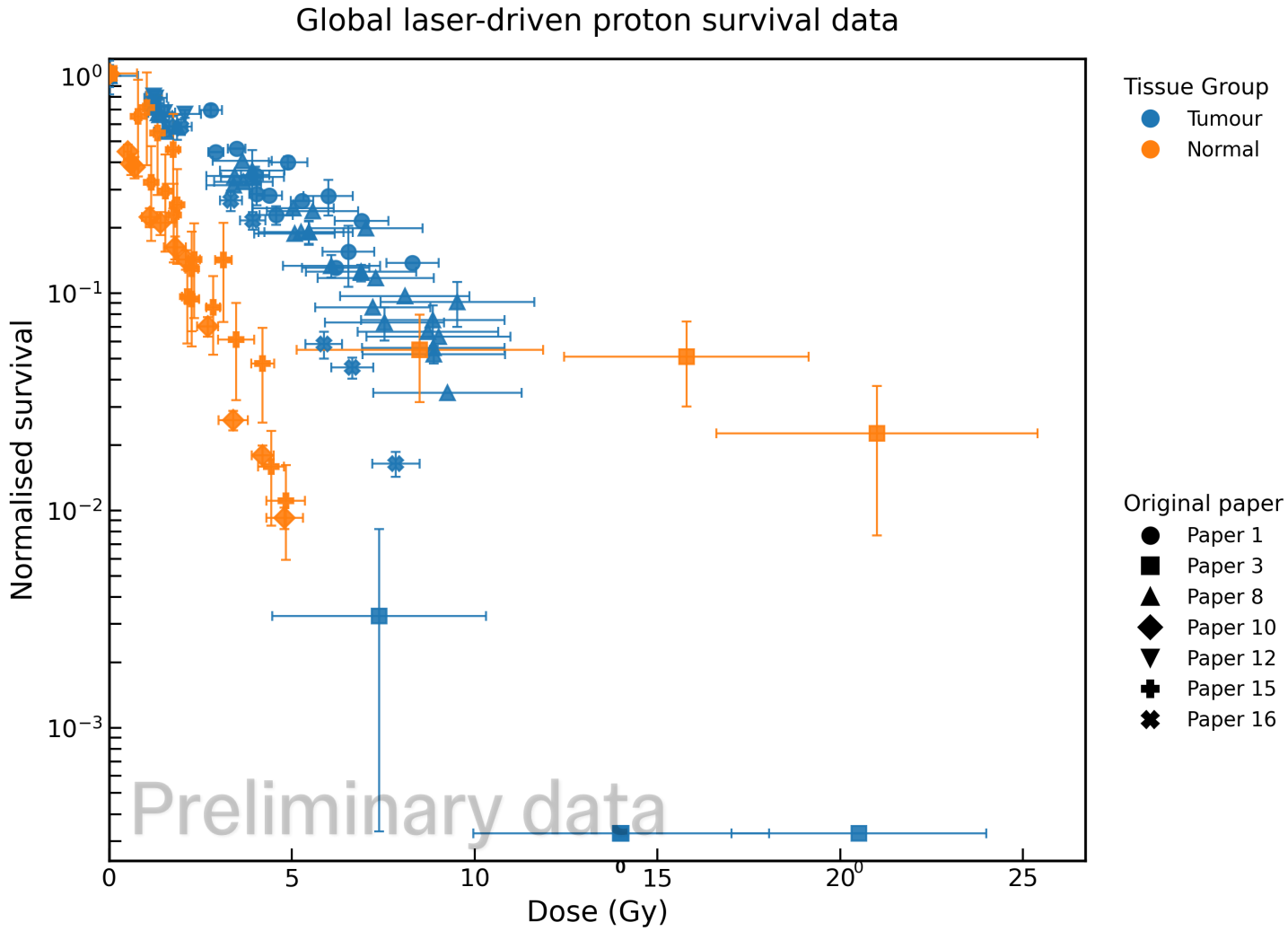
Clonogenic survival: separated by cell line & paper

Survival curves colour coded by cell line, marker shape defines paper.



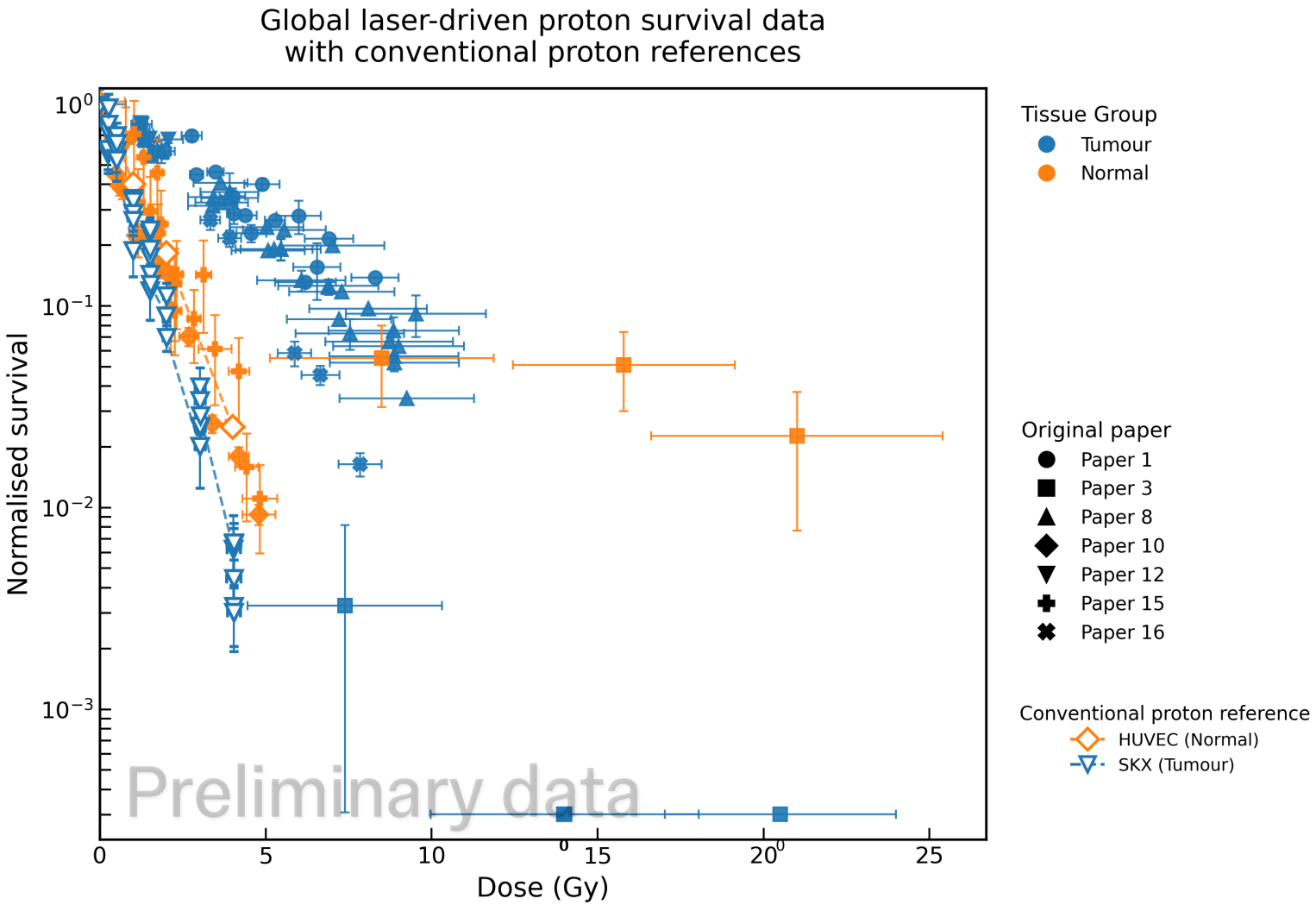
Clonogenic survival: separated by tissue type & paper

Survival curves colour coded by tissue type, marker shape defines paper.



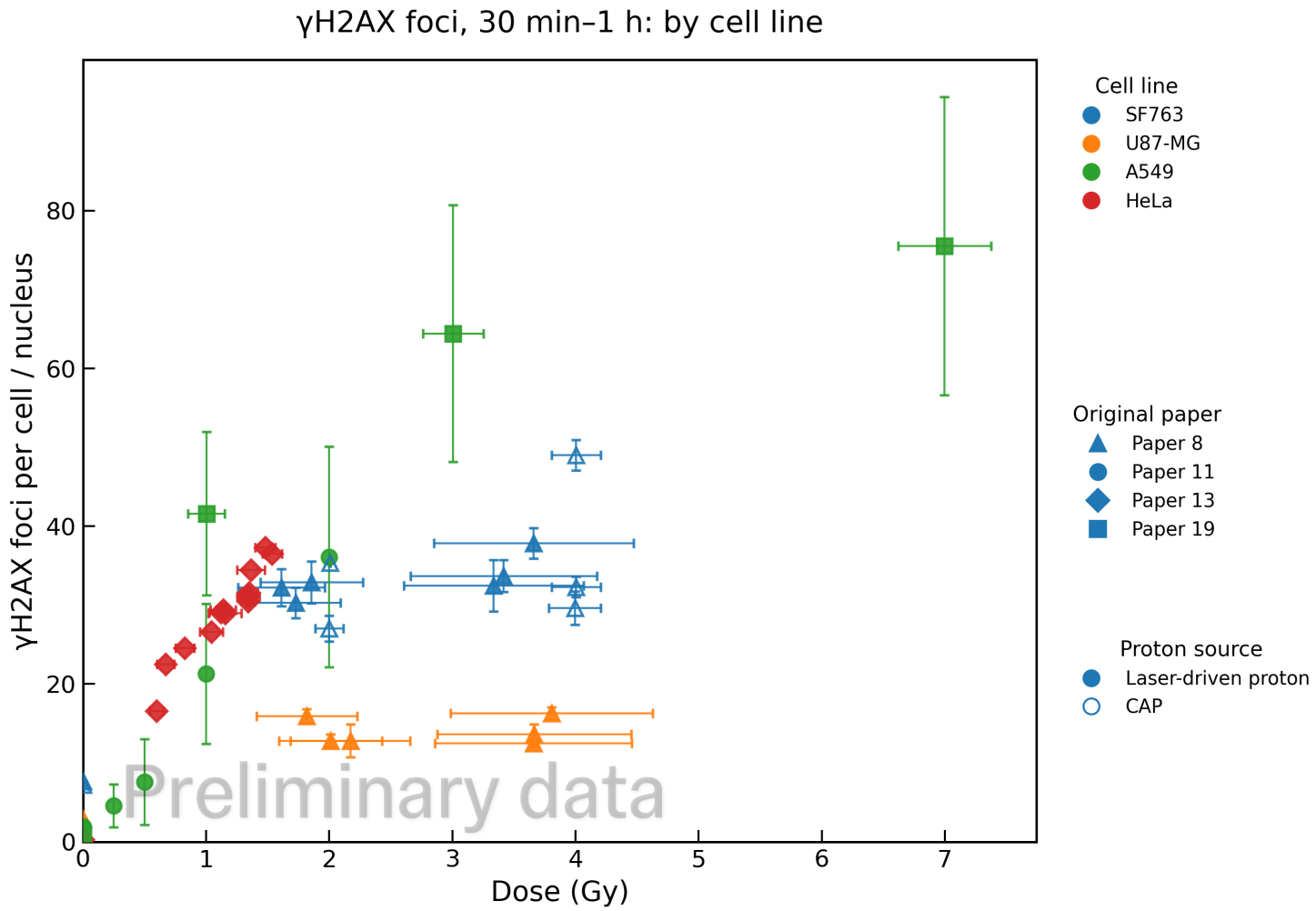
Clonogenic survival: comparing to reference radiation

Survival curves colour coded by tissue type, marker shape defines paper, hollow markers represent CAP.



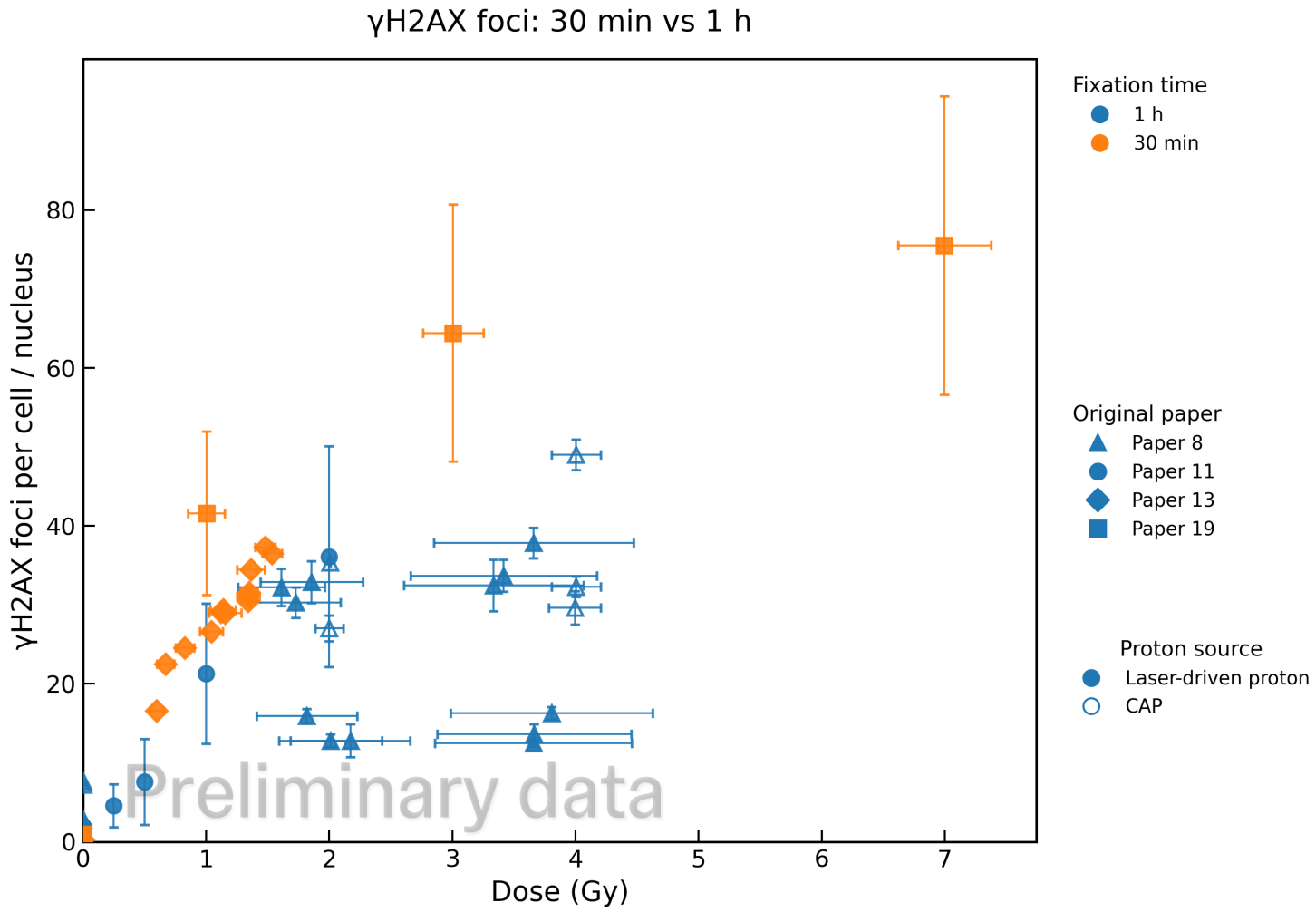
Early γH2AX signals

γH2AX foci per cell over dose, colour coded by cell line, marker shape defines paper, hollow markers represent CAP.



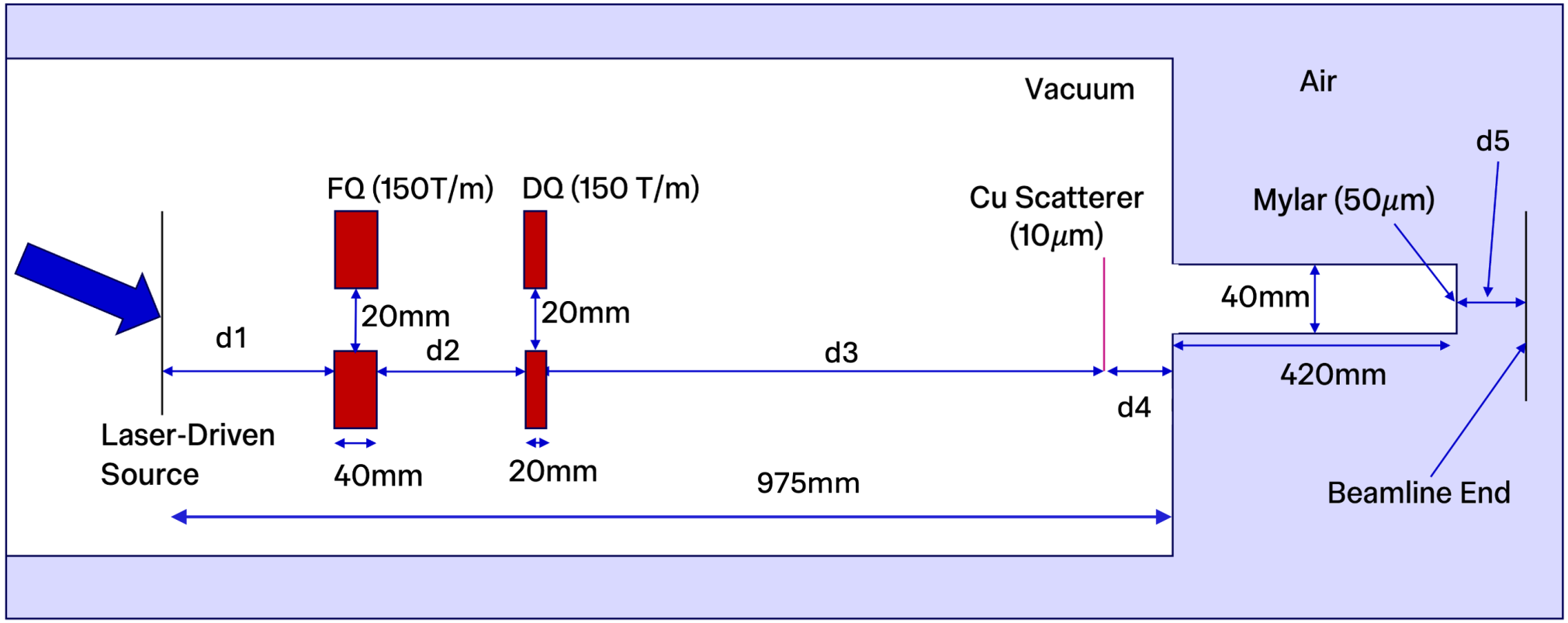
Early γH2AX signals

γH2AX foci per cell over dose, colour coded by time point, marker shape defines paper , hollow markers represent CAP.



PoPLaR

PoPLaR



C. Dyson Phase 2 Technical Note

SOURCE

SCAPA laser-driven protons

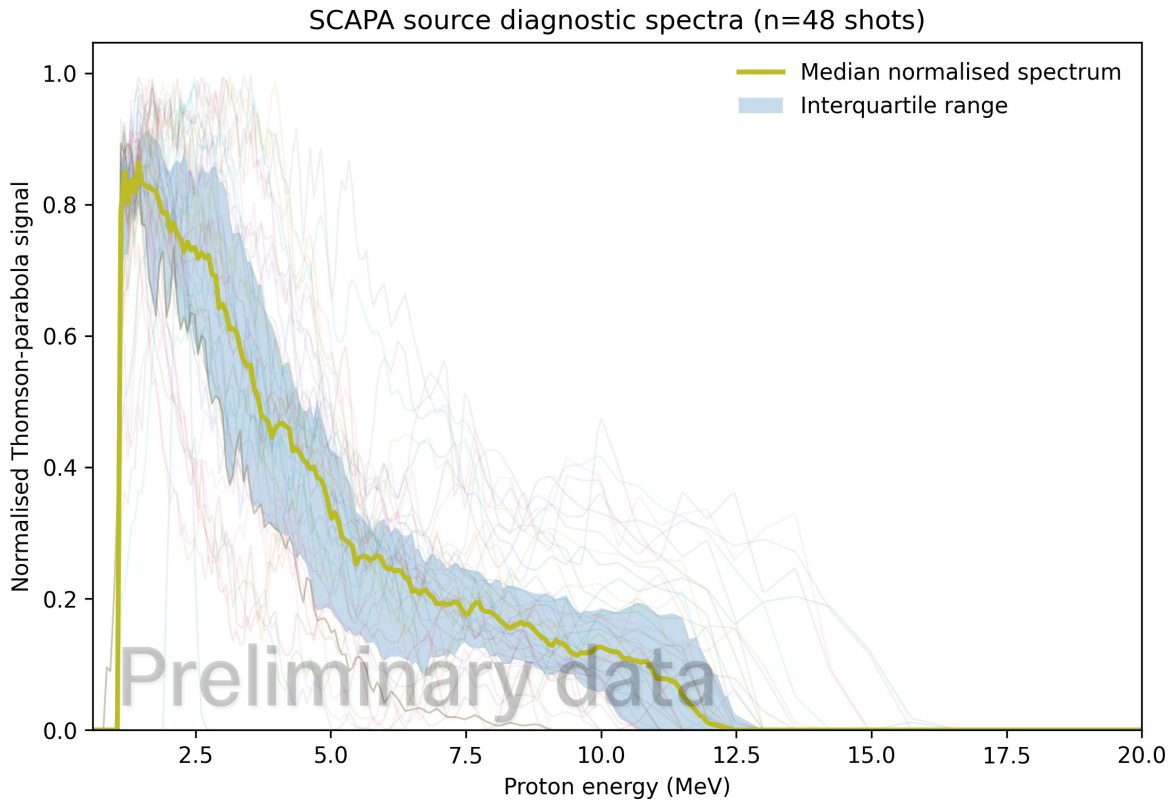
TRANSPORT

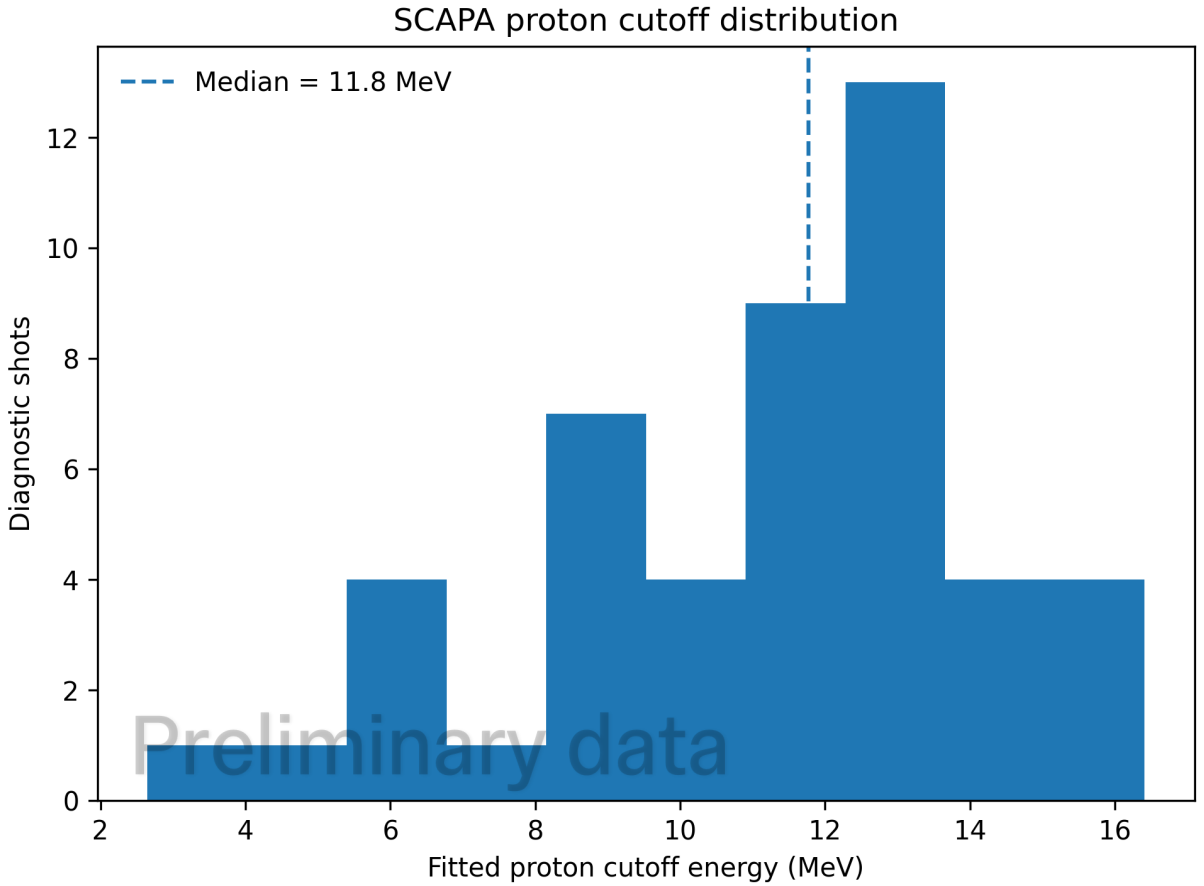
150 T/m PMQ doublet, Cu scatterer

SAMPLE

Cell carousel

PoPLaR energy spectrum





AT SOURCE

Cutoff ~12–16 MeV, centered near 14 MeV

AT CELLS

Proton median 11.8 MeV

Comparing PoPLaR to the global data

Sample type	Dose (Gy)	Dose per shot (Gy)	Max spatial variation (%)	Shot-to-shot dose variation (%)
Cell	0.433–37.1 (n=33)	0.0022–3.35 (n=31)	9 (n=10)	9.37–40 (n=28)
Zebrafish embryo	10.37 (n=1)	10.37 (n=1)	10 (n=1)	13.69 (n=1)
Mouse ear	4 (n=1)	0.66 (n=1)	5 (n=1)	10 (n=1)
PoPLaR	~2–8	~0.5	8.38--13.93%	~50%

Preliminary data

PoPLaR currently meets the general dose requirements in-vitro remit and in-vivo mouse ear;
Limitations-- beam reproducibility, dose variability and live sample dosimetry.

New modalities

New modalities

Time and spatial beam modulations

FLASH- Ultra high dose rate irradiation

CONVENTIONAL FLASH CRITERION

Mean dose rate generally >40 Gy/s

MBRT- Minibeam Radiation Therapy

MINIBEAM SCALE

Narrow beam segments ~1 mm or smaller

FLASH literature

Reported successful proton FLASH conditions

Environment	Biological model	Particle energy (MeV)	Total dose (Gy)	Mean dose rate (Gy/s)
In vitro	Cells	4.5–20	0.5–20	10–1000
In vivo	Zebrafish	68–228	9–43	100–9000
In vivo	Mouse	20–250	10–60	57–930
In vivo	Rat	226–250	5–25	60–257

Preliminary data

PoPLaR overlaps the cell energy and dose; advanced in-vivo FLASH requires higher energy for in-vivo and controlled delivery.

MBRT literature

Reported successful proton minibeam conditions

Environment	Biological model	Particle energy (MeV)	Total dose (Gy)
In vitro	Cells	100	2–20
In vivo	Mouse	100	20–30
In vivo	Rat	100	10–30

Preliminary data

PoPLaR dose range adequate for in-vitro and some of the mouse studies, lower energy.

Conclusions

1	**Field progression**	Reported maximum energy has grown, but the literature remains small, limited particle type and in-vivo experiments.
2	**Biology**	Survival and DNA damage have been successfully explored at 6 and 4 different beamlines, respectively.
3	**PoPLaR fit**	Current SCAPA-to-cell energy and total dose lie within established in-vitro ranges. Improved dose and variability would allow PoPLaR to experiment with complex biological endpoints.
4	**Development priority**	Shot-resolved dosimetry, reproducibility and spatial control.

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Thank you