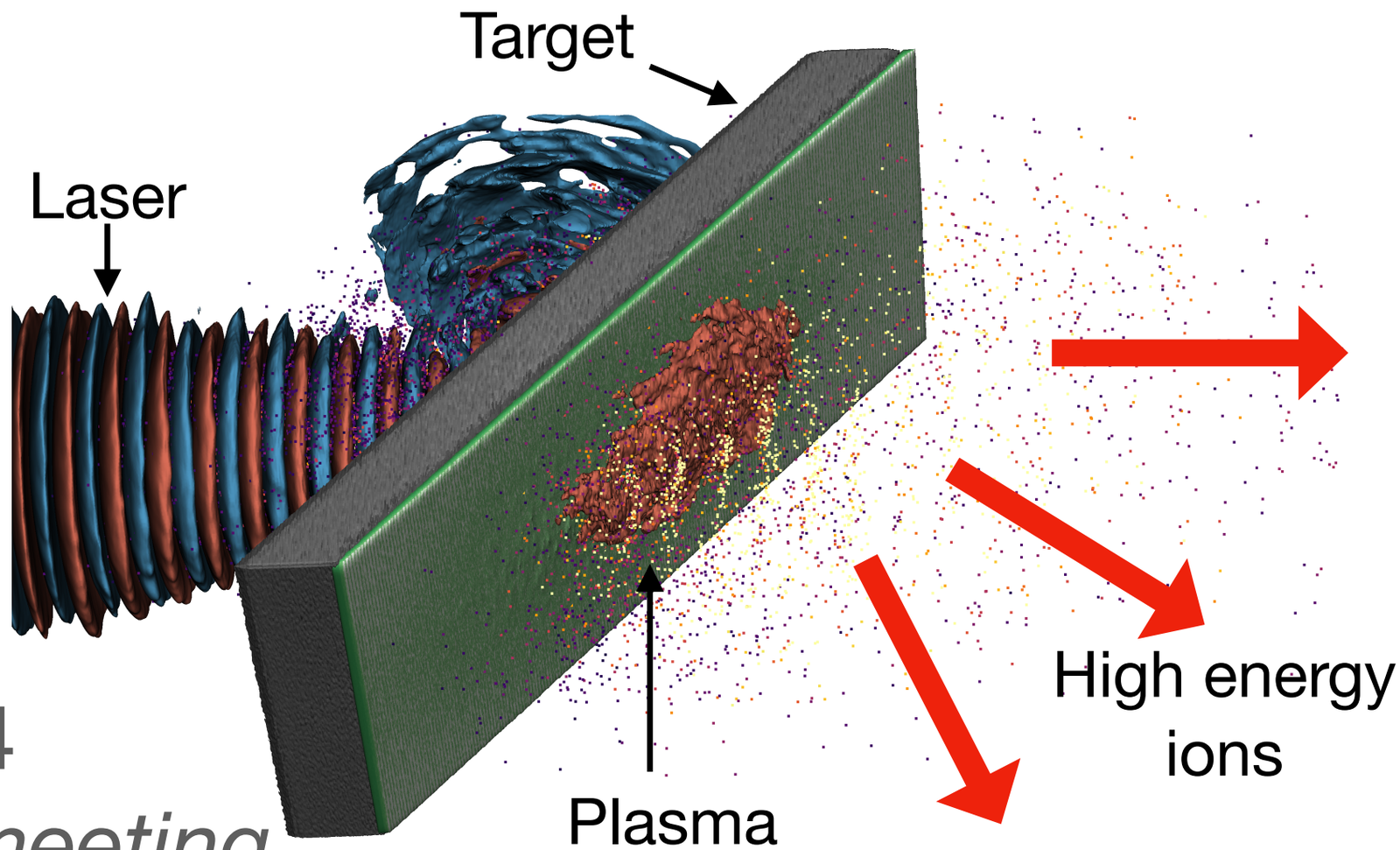
Laser-hybrid Accelerator for Radiobiological Applications

WP2 Update: ITRF laser specification



24 September 2024

LhARA fortnightly meeting

Anticipated baseline laser requirements

Old specification (Aymar et al.)

Aymar et al.

TABLE 1 | Design parameters of the components of the LhARA facility.

Parameter	Value or range	Unit
Laser driven proton and ion source		
Laser power	100	TW
Laser energy	2.5	J
Laser pulse length	25	fs
Laser rep. rate	10	Hz
Required maximum proton energy	15	MeV

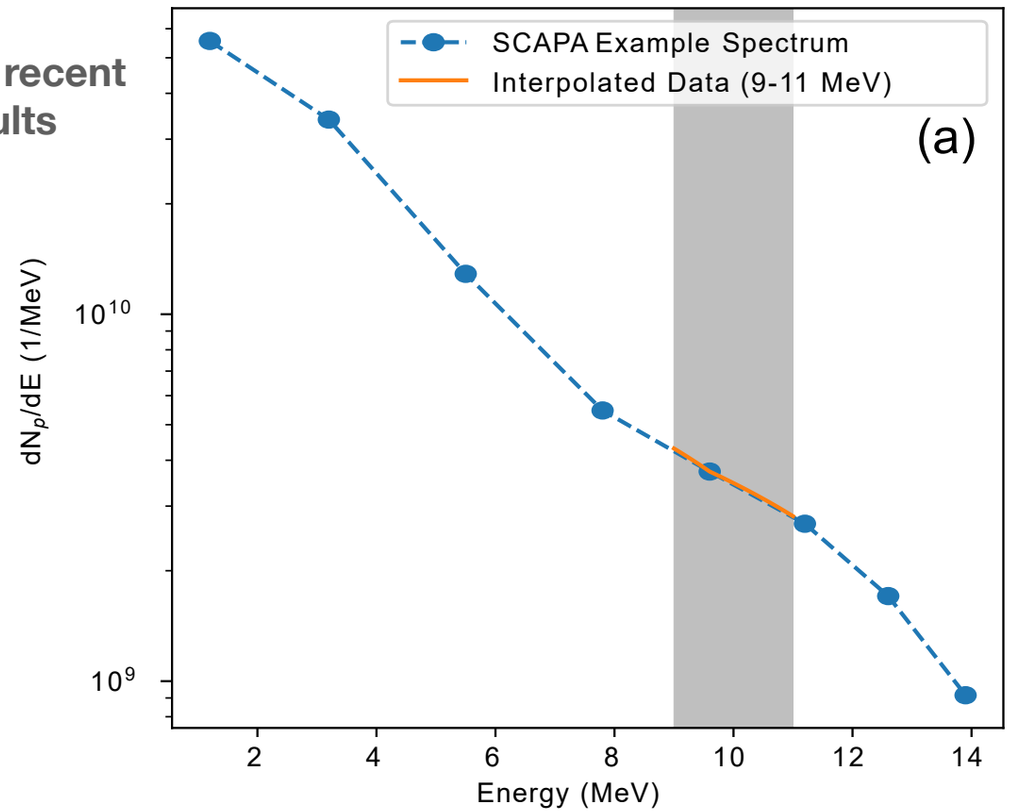
New specification (CDR)

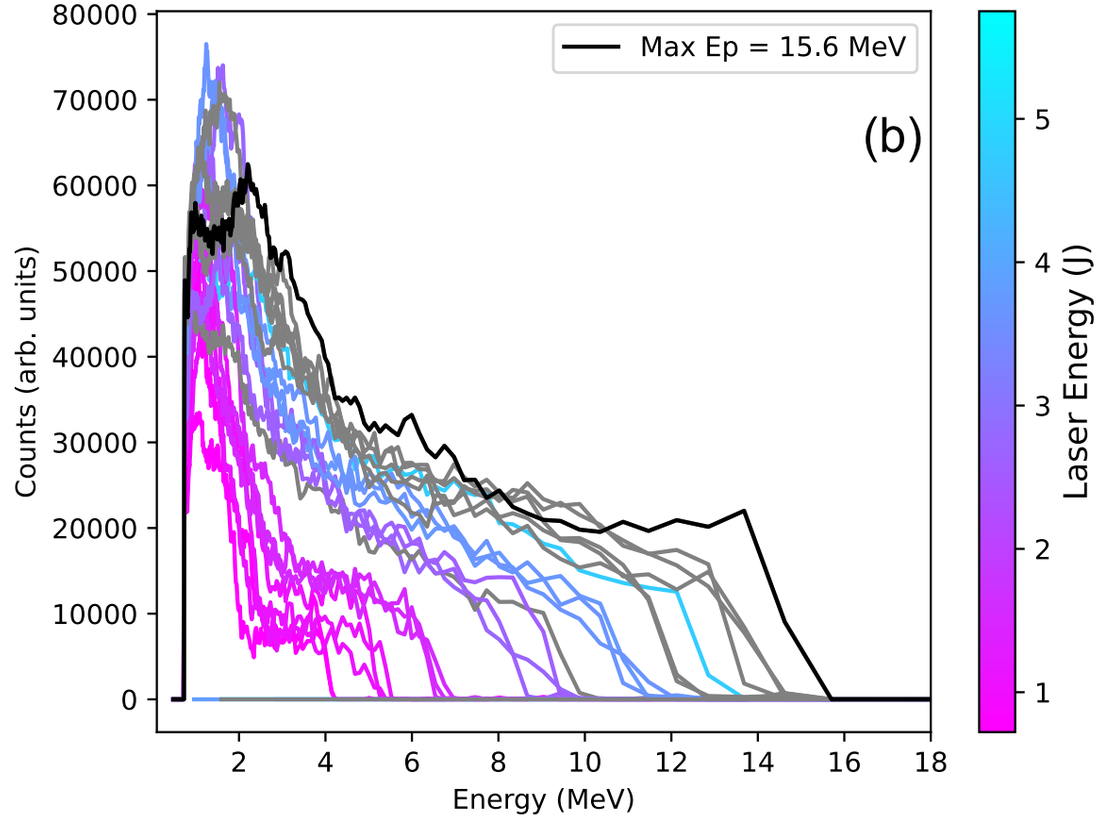
Parameter	Value	Unit
Laser Parameters		
Central wavelength	800	nm
Energy before compressor	> 18	J
Energy stability (RMS)	< 2	%
Energy stability (RMS over 12 hours)	< 5	%
Pulse Length (FWHM)	< 50	fs
Pulse length stability (RMS)	< 5	%
Rep. rate	10	Hz
Contrast at 5 ps	10^{-8}	
Contrast at 10 ps	10^{-9}	
Contrast at 100 ps	10^{-10}	
Laser delivery parameters		
Energy on target	> 10	J
Focal spot size (FWHM)	< 3	μm
Strehl ratio (Measured)	> 0.5	
Angle of incidence	30	$^\circ$
Pointing stability	< 5	μrad

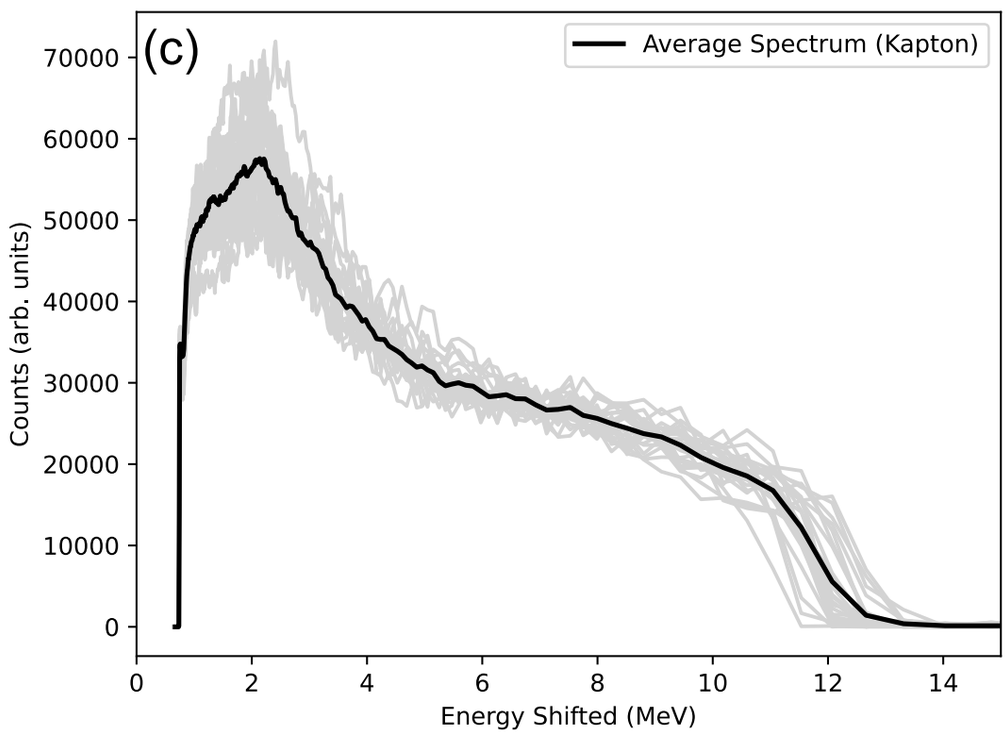
Table 1.1: Envisioned laser specification for ITRF.

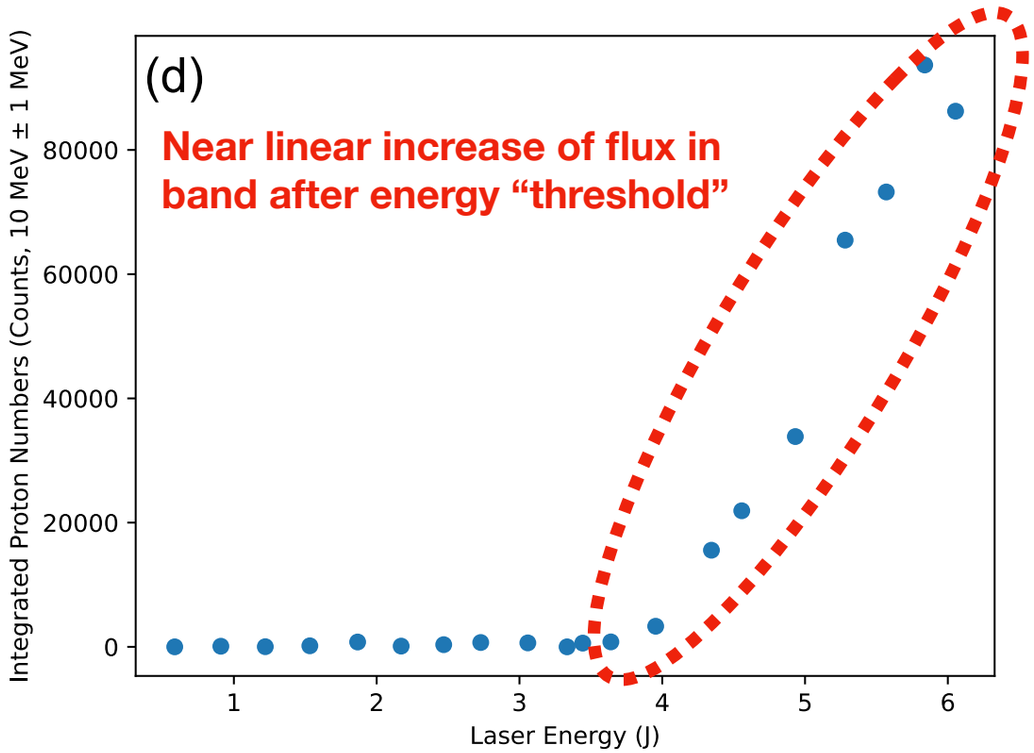
Reasons for the increase in laser energy - experiment

From R. Gray - recent SCAPA results









Reasons for the increase in laser energy - simulation

From Milestone Report 2:1 - from simulations performed by T. Dascalu

- 1 J on target, but *perfect* spot - corresponds to '100 TW laser' from Aymar et al
- Particle number that is far too low!
- Current specification is E=15 +- 2%
- Current angular acceptance is 15 mrad
- Ie. Particles going into capture <10^8 !
- Need to boost numbers -> increase laser energy significantly
- Would also help if bandwidth & angular acceptance could be increased

Table 3: Summary of the baseline parameters for the LhARA proton source as predicted by high-fidelity hydrodynamic and 3-D kinetic simulations (at normal laser incidence).

	Parameter	Value	Unit
Realistic conditions	Cutoff energy	21.5	MeV
	Particle number per pulse (15.0 ± 0.5 MeV)	3.1×10^8	
	RMS beam divergence (>1 MeV)	52	mrad
	RMS beam divergence (15.0 ± 0.5 MeV)	32	mrad
	Max. emission half opening angle (15.0 ± 0.5 MeV)	141	mrad
	Emittance‡	0.133	mm-mrad
Optimal conditions†	Cutoff energy	45.4	MeV
	Particle number per pulse (15.0 ± 0.5 MeV)	4.0×10^8	
	RMS beam divergence (>1 MeV)	33	mrad
	RMS beam divergence (15.0 ± 0.5 MeV)	19	mrad
	Max. emission half opening angle (15.0 ± 0.5 MeV)	99	mrad
	Emittance‡	0.052	mm-mrad

†Here, optimal conditions refer to the preplasma density profile we found to result in the maximum proton cutoff energy for the nominal laser and target parameters listed in Table 2.

‡RMS emittance, $\epsilon_{\mathrm{RMS}} = \sqrt{\langle x^2 \rangle \langle x'^2 \rangle - \langle x \cdot x' \rangle}^2$

Is the laser specification reasonable?

Parameter	Value	Unit
Laser Parameters		
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Pulse Length (FWHM)	< 50	fs
Pulse length stability (RMS)	< 5	%
Rep. rate	10	Hz
Contrast at 5 ps	10^{-8}	
Contrast at 10 ps	10^{-9}	
Contrast at 100 ps	10^{-10}	
Laser delivery parameters		
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Table 1.1: Envisioned laser specification for ITRF.

- Laser specification discussed with Amplitude last week
- Contrast specification may be difficult to reach - but probably would still be “good enough”
- Water cooled amplifier possible at 5 Hz, definitely cryogenic amplifier at 10 Hz -> increase 30% in cost
  - Thermal issues in e.g. compressor gratings also become increasingly difficult
- No clear route to >10 Hz in standard product range, unless laser energy is reduced significantly
- Increasing laser energy further would also be possible - cost will be correlated with laser energy