Laser driven beams for radiation-to-electronics study

R. Versaci
Extreme Light Infrastructure ERIC
ELI Beamlines facility

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Outline

Laser acceleration basic concepts

Laser facilities panorama

Laser acceleration features & limitations

“Cultural aspects”

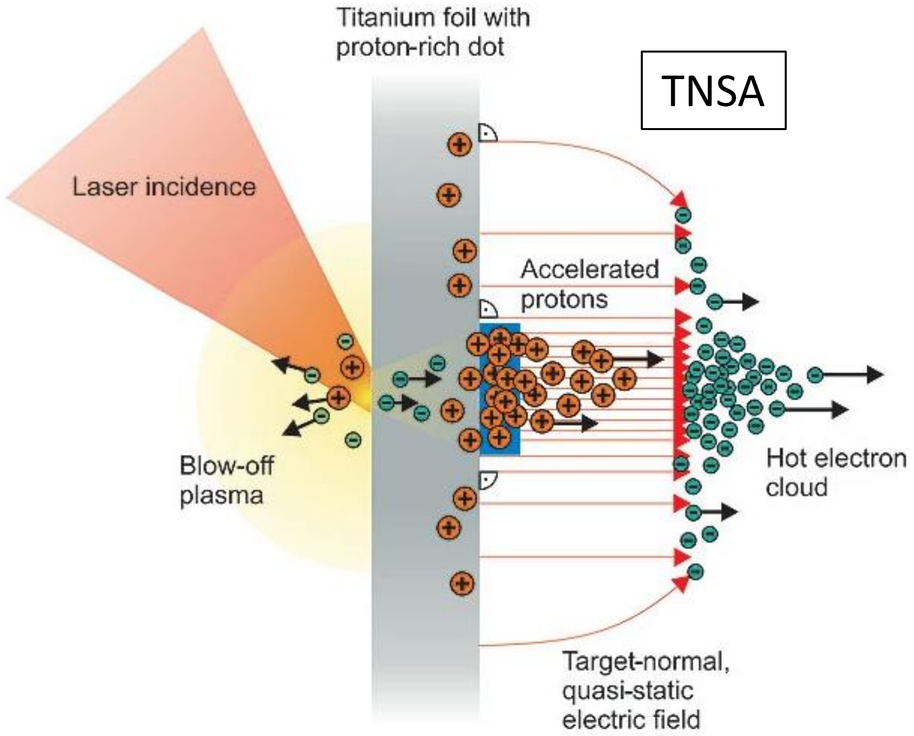
Today

Future

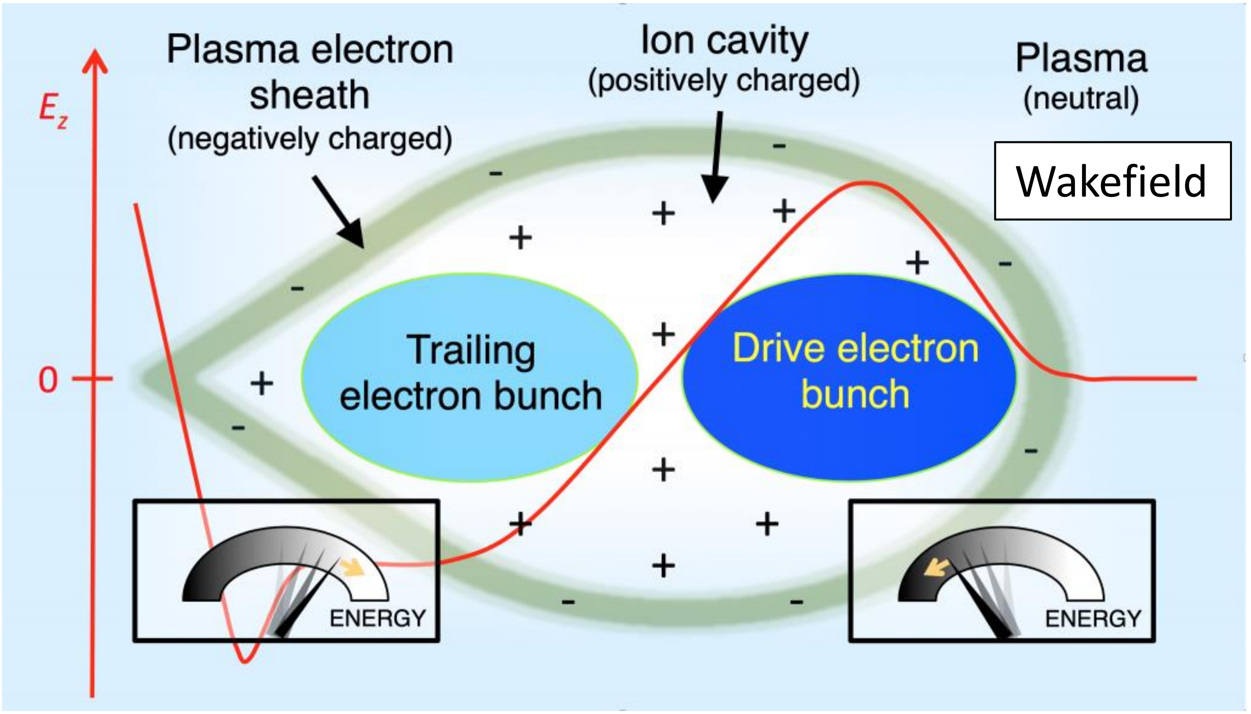
Laser acceleration

Different mechanisms at play, examples:

- Target Normal Sheath Acceleration for ions acceleration
- Wakefield for electron accelerations

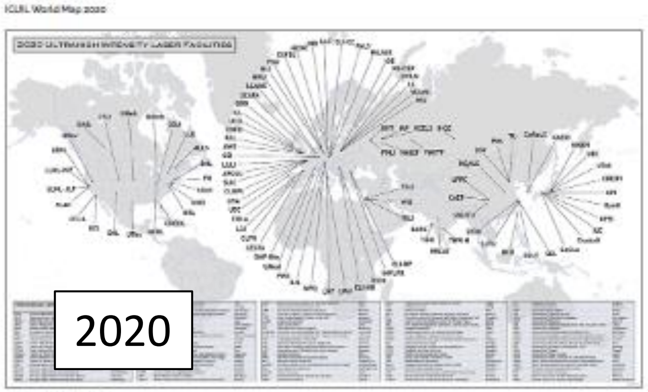


H. Schwoerer *et al.* 2006

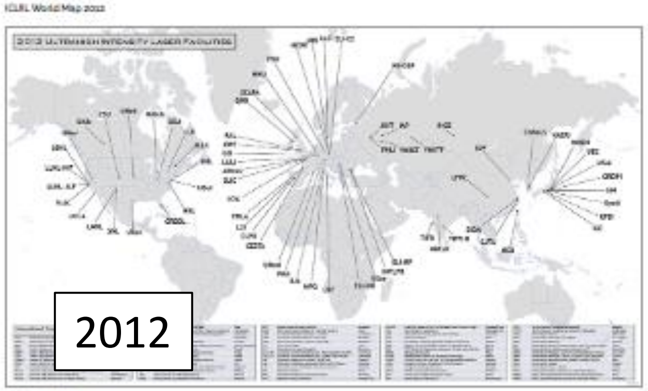


LOA website

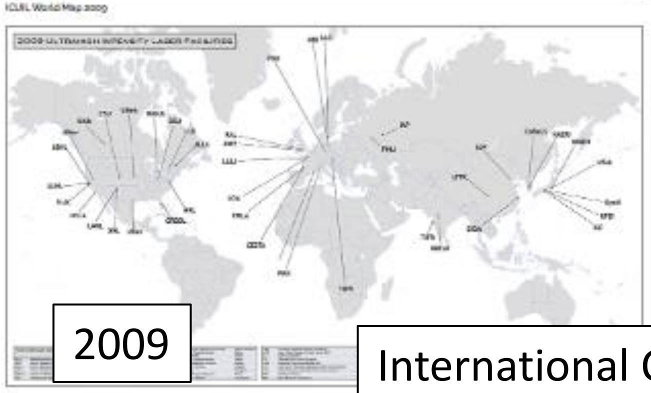
Laser facilities worldwide



2020



2012

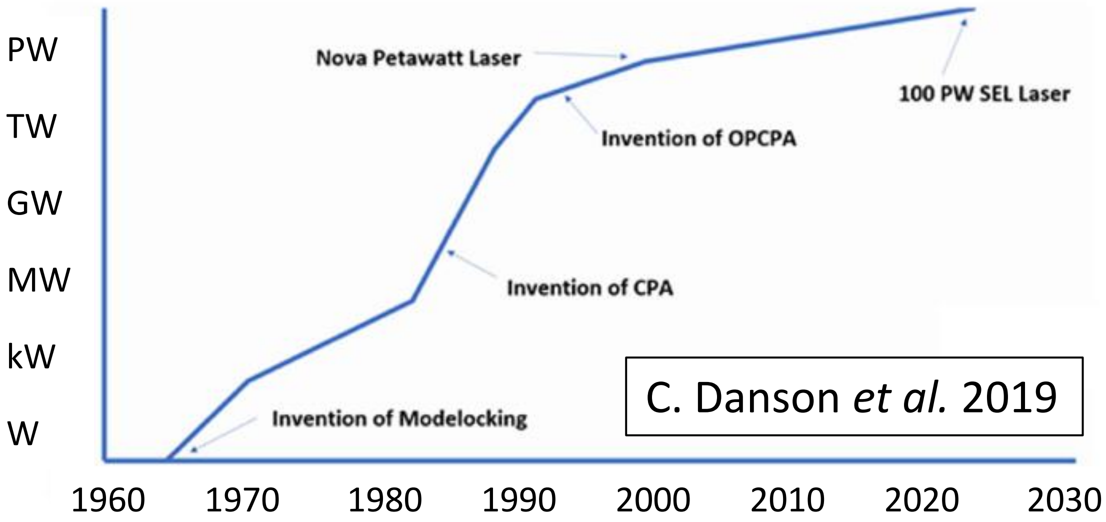


2009

Sparked by Chirped Pulse Amplification 2018 Physics Nobel prize

Fast growing number

Continuous energy increase



C. Danson *et al.* 2019

Laserlab Europe

International Committee on Ultra-High Intensity Lasers

Laser acceleration

Fast growing field, about 40 PW-scale facilities worldwide

In 20 years from zero to high technological readiness

Continuous technological development

Active and close community

Large variety of sources

primaries and secondaries

p, $e^{\pm}$, neutrons, μ…

Laserlab Europe network

Laser acceleration features

Accelerated beam characteristics “driven” by laser features

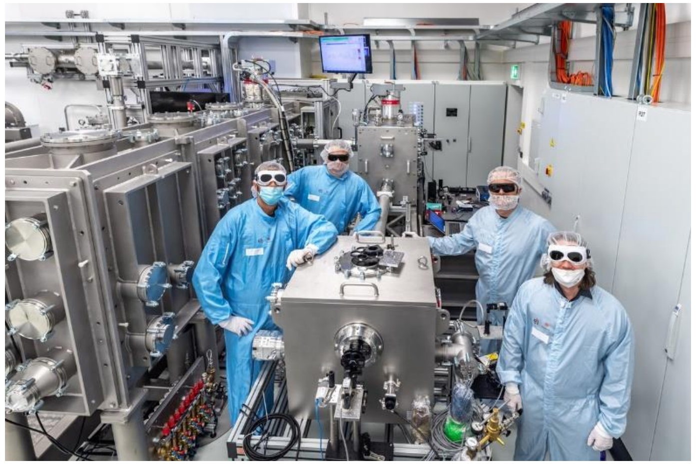
Vacuum and cleanliness requirements

High-energy lasers propagate in vacuum, ~10^{-6} mbar

Cleanroom default ISO-7, 352,000 p(≥0.5µm)/m3

at times ISO-5 is required

Vacuum compatible devices



Laser acceleration features

Accelerated beam characteristics “driven” by laser features

Pulse duration

As low as ~10 fs laser pulse: doesn’t mean 10 fs particle bunch

To take into account:

particle mass

passage from vacuum to air

transport in air

Still: dose rate per pulse can be very high

Laser acceleration features

Accelerated beam characteristics “driven” by laser features

Repetition rate

More energetic particles →

more powerful laser →

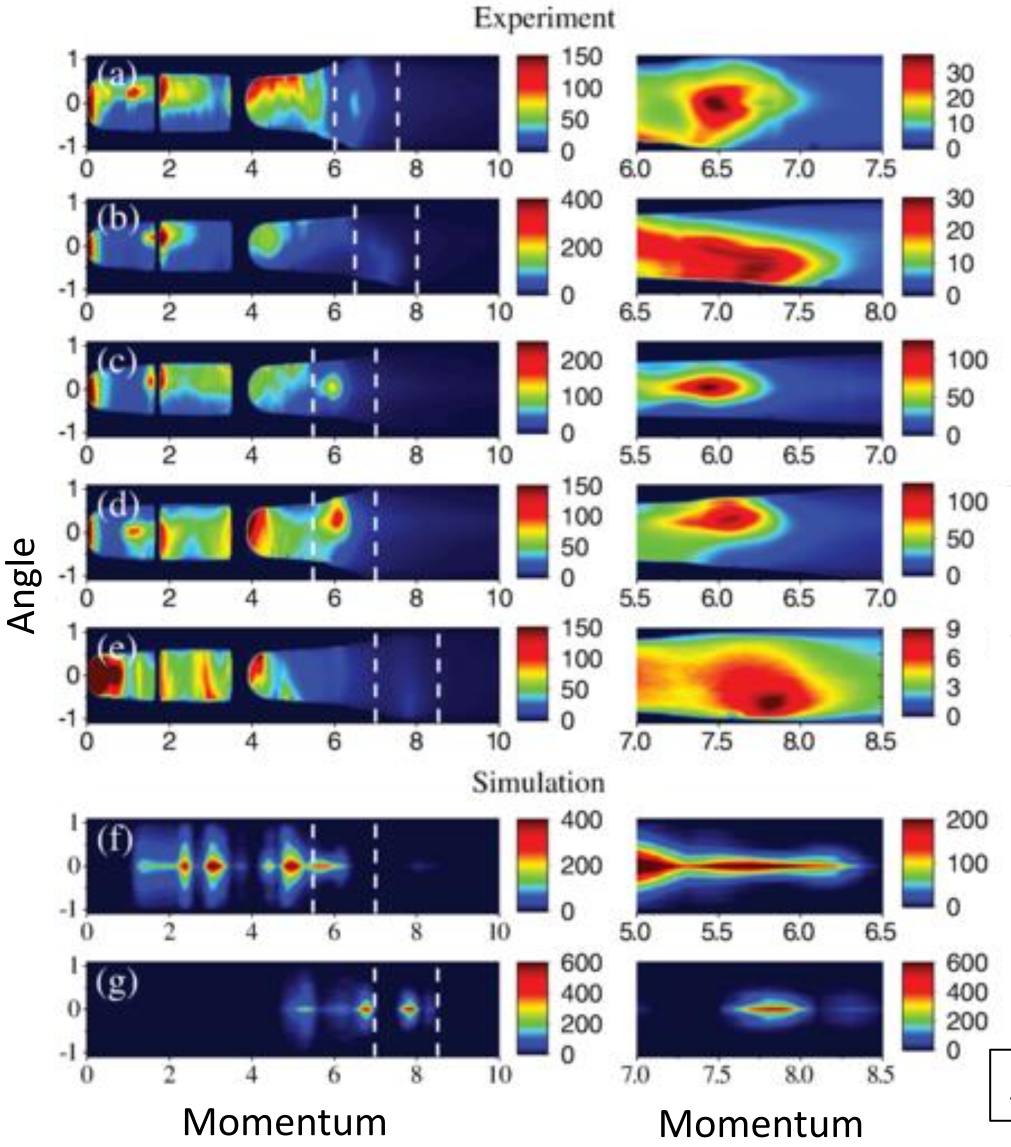
lower repetition rate

Nominal: 10 Hz for 1 PW laser, 1 Hz for >1 PW laser

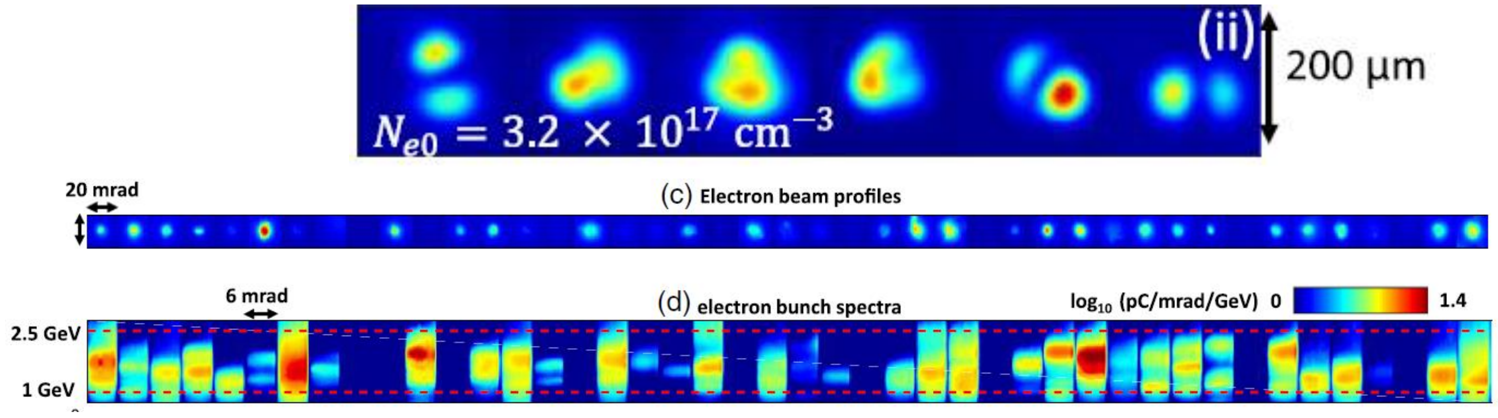
kHz laser have achieved >100 MeV electrons

Laser accelerated electron beams

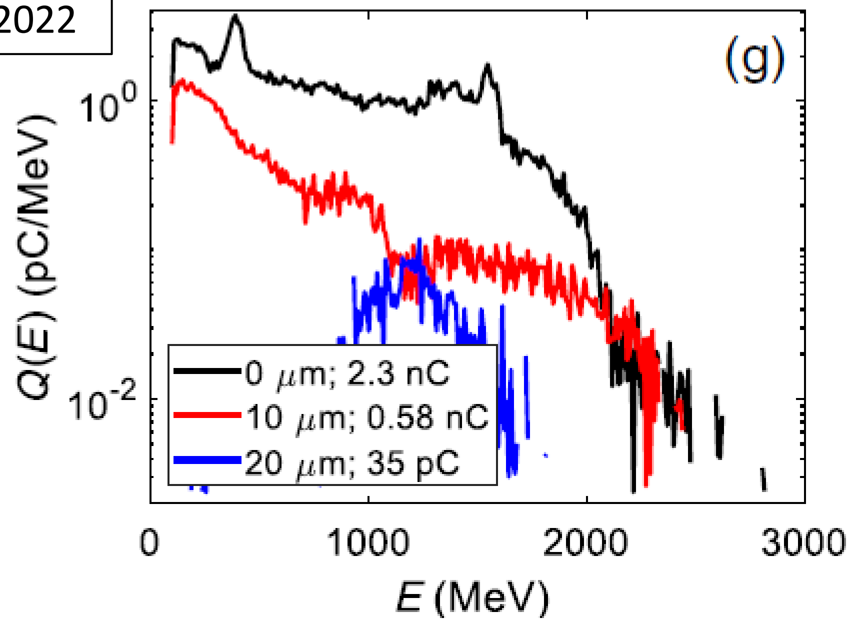
Beam characteristics different from conventional accelerators



A. J. Gonsalves *et al.* 2019



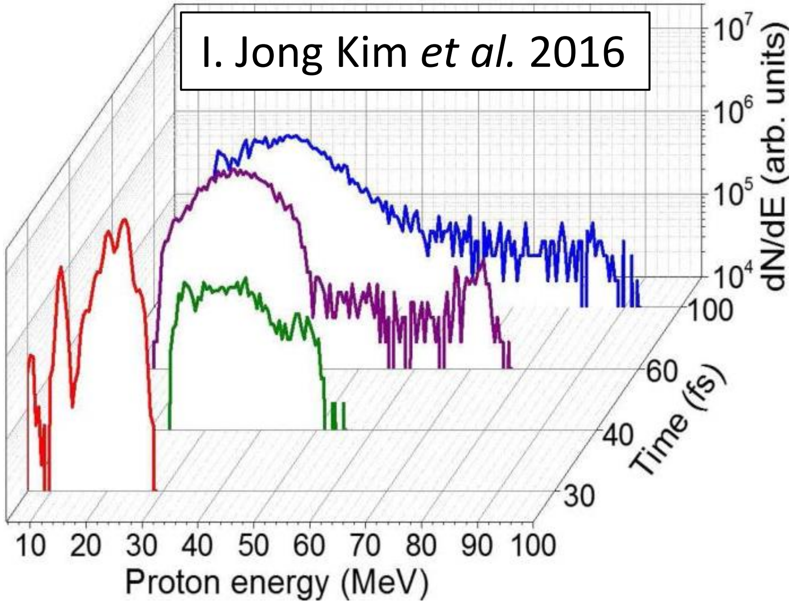
B. Miao *et al.* 2022



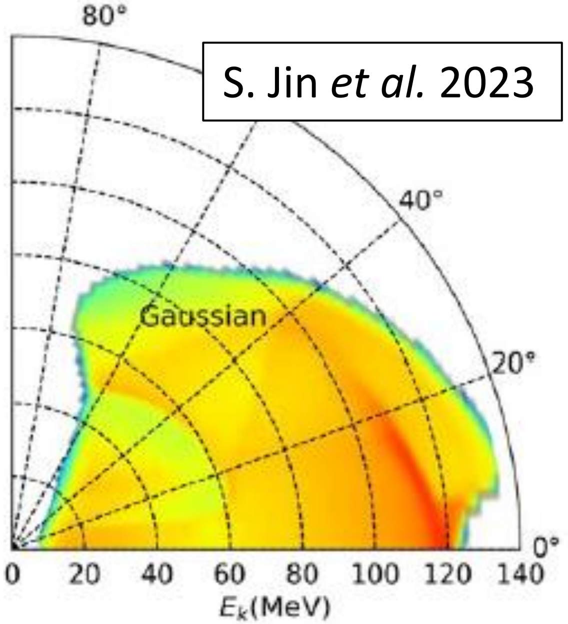
Laser accelerated proton beams

Beam characteristics different from conventional accelerators

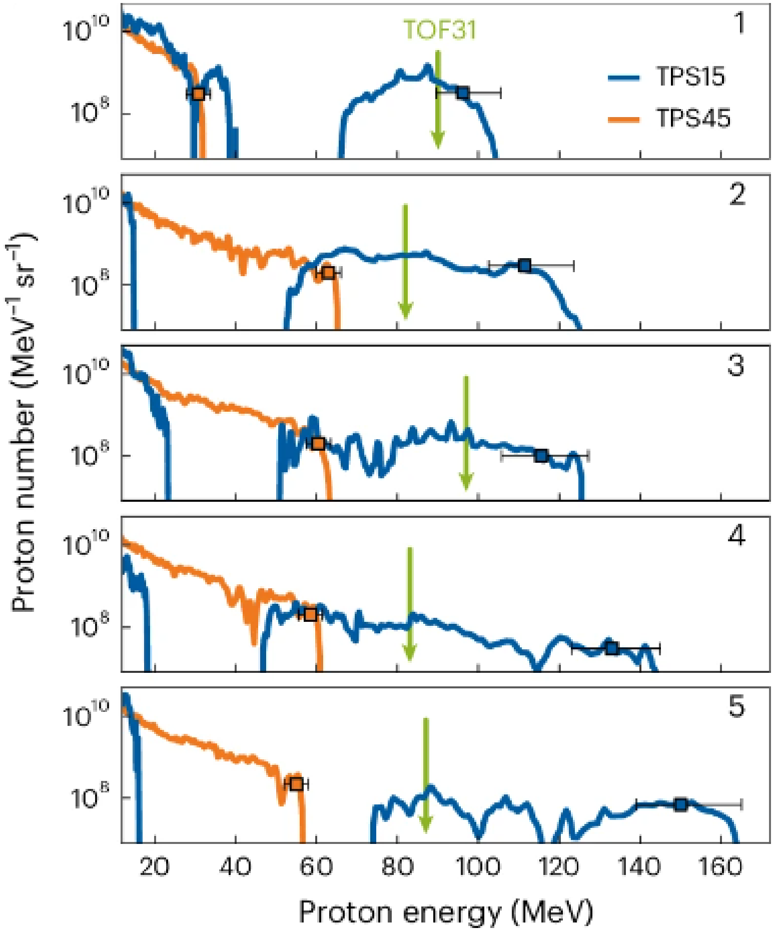
I. Jong Kim *et al.* 2016



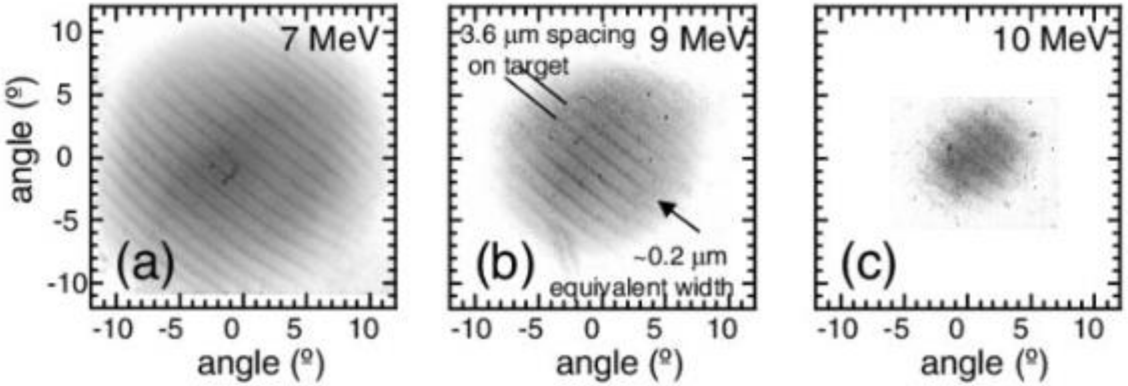
S. Jin *et al.* 2023



T. Ziegler *et al.* 2024



T. Cowan *et al.* 2004



Laser acceleration features & limitations

Strong shot-to-shot variability (intensity and pointing)

Beams are not monochromatic (unless there is post-acceleration selection)

Transverse spatial distribution not shaped by the acceleration mechanism
as much as conventional accelerators

Large beam divergence (~tens of mrad)

Laser acceleration features & limitations

The laser acceleration mechanism is itself subject of research

→ a large amount of experiments is designed to study it

The characterization of the radiation fields is “complicated”

The average energy and dose are low than in conventional accelerators

→ ionizing radiation damage is not a priority

focus is on damage by ElectroMagnetic Pulses (EMPs)

Cultural distance

Laser community low awareness of ionizing radiation damage
(with some reasons)

RADNEXT survey on R2E at laser facilities
About 35 worldwide facilities contacted in spring 2023
Despite reminders, only three replies received

R2E community is also unaware of what laser driven beams can offer

Today, not all is dark

Ionizing radiation damage awareness can be found:

ELI Beamlines, CLPU, HZDR

RADNEXT community performed the first experiments

Parasitic irradiation are feasible and “easy”

User calls are already available

The future is up for grabs

The laser world is growing:

new facilities are being built and planned

new user stations are being built and planned

beam parameters are improving

The laser community is receptive to new stimuli

and it’s eager to show its prowess in new fields

This is the right time to steer laser beams onto electronics