WG2: Ion Acceleration (L. Lancia, D. Margarone)

- Facilities: status, upgrades and applications
- New targetry and target manipulation
- Interaction and acceleration diagnostics
- Acceleration mechanisms and insights
S. Steinke, BELLA, LBNL (USA)

LBNL BELLA (BERkeley Lab Laser Accelerator) Center houses four main laser systems:
- **1Hz-1PW class laser for High-Energy Physics applications**
- **5Hz-100TW class laser for LPA-Thomson Gamma rays source**
- **1kHz-1TW class laser for medical and UED research**
- **5Hz-100-TW class laser for LPA-FEL research**

Pulsed implantation of SiC with ion pulses from BELLA – towards formation of vacancy centers:
- 50 μm spot, ~40 J/30 fs
- Ti foil, 1 to 9 μm
- Si, SiC, GaAs transistors

SIMS: Secondary Ion Mass Spectrometry
- 5x10^{13} Ti/cm²/shot near surface
- 400 keV
Focusing of laser-accelerated proton beams with active plasma lens

- 1st demonstration of focusing of laser driven proton beam with APL, ~mm spot size, up to ~260× flux increase
- 1st radiobiological study @ BELLA
Dose controlled irradiation experiments with LAP @ Draco PW

- Installed tunable pulsed high-field beamline for **3D dose delivery** for radiobiological experiments at Draco PW
- Using two solenoids to focus protons of two different energies in one laser shot
- **Spectral homogenisation** via two solenoids; lateral by overfocussing, scatter foil, apertures (both below ±8,5%)
- Dose rate of **0.7 Gy/shot** with homogenisation achieved
- First irradiation studies with **3D tumor spheroids** (in-vitro) and **zebrafish embryos** (in-vivo) conducted

![Diagram of irradiation setup](image)

3D tumor spheroids

F. Brack, HZDR, Dresden
D. Margarone, ELI-BL (Prague)
F. Catalano, INFN-LNS (Italy)

A Monte Carlo user application of the ELIMED section has been developed using the Geant4 code.
I. Pomerantz, Tel Aviv Un. (Israel)

gatling gun target delivery system
Gas-foil target for Ion acceleration


2. Self-focusing and temporal compression/steepeening expected to increase intensity up to 10 times.

Already at $1.5 \times 10^{19} \text{ cm}^{-3}$
Plasma Gratings

- In the presence of an under-dense plasma, the ponderomotive force leads to grating formation.
A. Lehrach, Julich (Germany)

3D VLPL simulation ($\lambda = 800$ nm, normalized laser amplitude $a_0 = 12$, 25 fs duration, 5 $\mu$m focal spot size)

Laser acceleration via TNSA mechanism

Proton polarization is conserved during acceleration

Possible experimental realization:
Polarized $^3$He target

Start of measurements
Unpolarized $^3$He already accelerated up to 4.65 MeV

New approach with two atomic pre-polarized target
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pre-plasma-probing setup
Measurement of aluminium pre-plasma for a wide parameter range (angle of incidence, intensity, polarization...)
Off-harmonic probing of hydrogen jets

Cylindrical Ø 5μm cryogenic hydrogen jet: ~30n_c @ 800nm
Synchronized stand-alone probe laser system @ 515nm

L. Obst PPCF (2018)

Conclusion:
- PW-laser induced target evolution effect at full energy can be studied
- Target pre-expansion beneficial for proton acceleration up to 80 MeV

Probe beam
- 100μJ, 160fs, 515nm
- ~10^{12}W/cm² > 0.1J/cm²
- DRACO beam
  - 16J, 30fs, 800nm
  - PM cleaned contrast
  - Hydrogen jet target
  - 2.3 x 10^{21}W/cm²

Shadowgraphy

0.7 ps
0.6 ps
0.2 ps

DRACO pulse arrival
S. Keppler, Un. Jena (Germany)

6.5 μm - Al

Current status of POLARIS:
- high-power, high-contrast laser system, well suited for experimental program
- variable contrast settings possible

Experimental results from campaign on laser-driven proton acceleration:
- characterization of the scaling (from $I_L^{0.5} \cdots I_L^{1}$) of TNSA-protons with different plasma scale length
- observed a change in scaling at high intensities

Extensive Numerical Simulations with the ANTARES code:
- scaling depends on $E_{\text{max}}(t)$ and $x(t)$ of protons
- protons don’t experience highest field at higher intensities anymore
- laser contrast affects peak/length ratio of $E_x$
- $p^+$ are accelerated longer for higher scale-length
10-100 nm

Enhanced TNSA
Proton acceleration experiments at the Draco-PW laser

- **third order dispersion** dependence for different **contrast** conditions at target
- twofold increase in proton energy (up to 60 MeV) for optimized dispersion settings
- differences in pulse shape on linear (asymmetry) and logarithmic scale (contrast) need to be considered
E.J. Ditter, Imperial College (UK)

Ultrathin target: 2-100 nm
PIC simulations

- Average electron density in focal spot
- Linear Polarisation
- Circular Polarisation
- 2 - 10nm go transparent
- Targets $\geq$ 25nm remain overdense
A. McIlvenny, Queen’s Un. Belfast (UK)

Ultrathin target: 5-25 nm
Hybrid RPA-TNSA

Multi-species acceleration

- Protons are mostly accelerated by the plasma expansion (few MeV) / sheath effects
- Carbon is initially accelerated by RPA
- Target (optimum thickness) goes transparent just after the peak of the pulse as the density drops
- RPA shuts off, enhanced acceleration takes place with transparency effects
- Followed by sheath effects