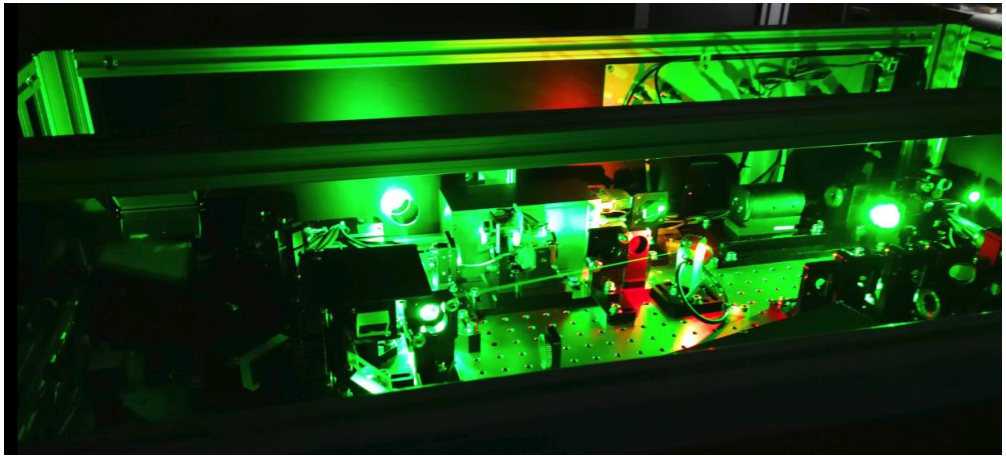
Commissioning and exploitation of the Laser Laboratory for Acceleration and Applications



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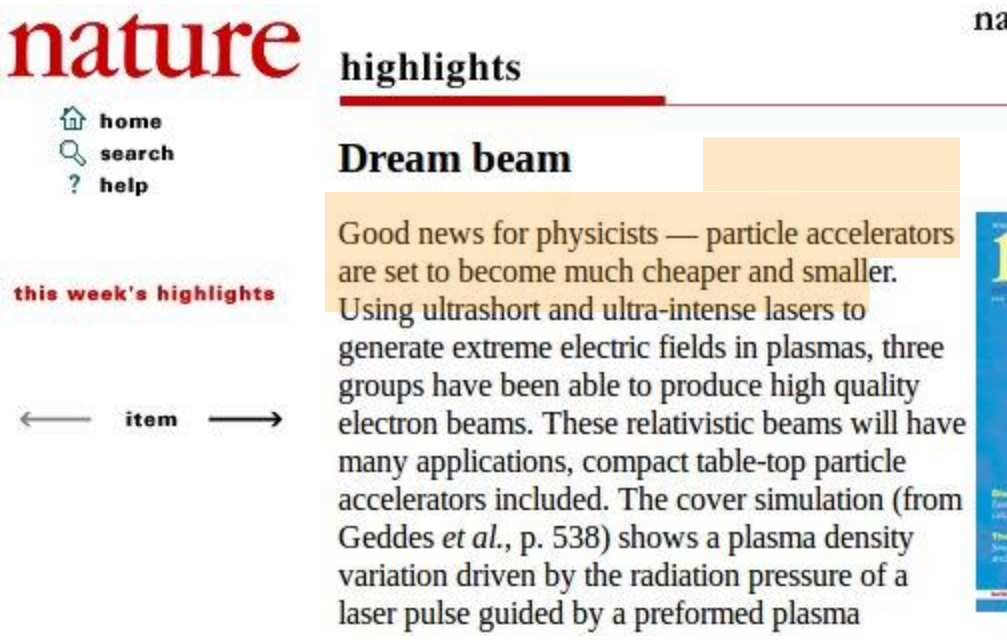
A new technology for particle acceleration

2004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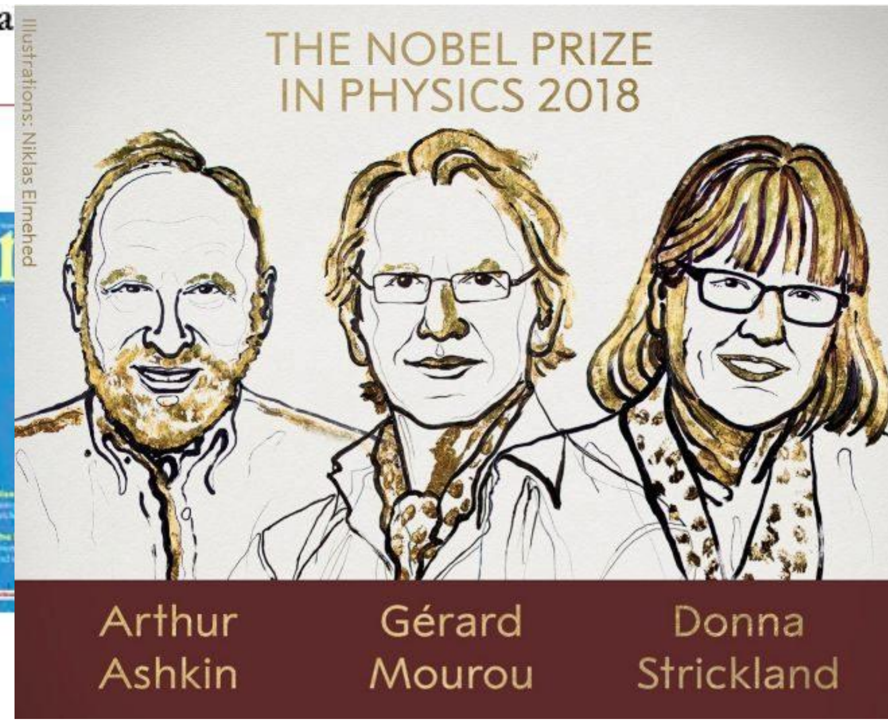
Dream beam

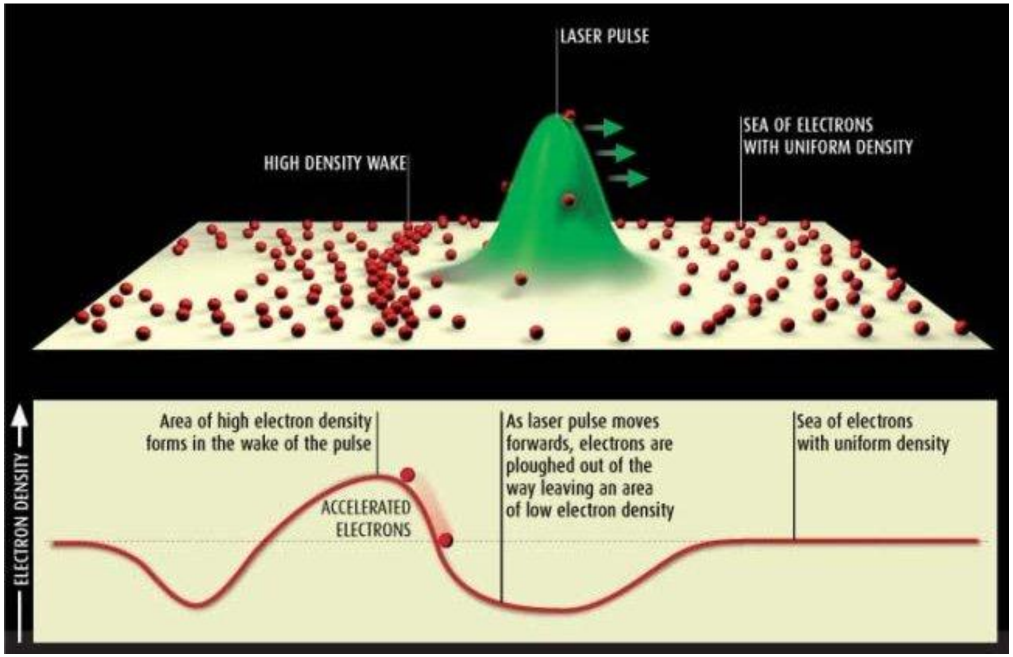
Good news for physicists — particle accelerators are set to become much cheaper and smaller. Using ultrashort and ultra-intense lasers to generate extreme electric fields in plasmas, three groups have been able to produce high quality electron beams. These relativistic beams will have many applications, compact table-top particle accelerators included. The cover simulation (from Geddes *et al.*, p. 538) shows a plasma density variation driven by the radiation pressure of a laser pulse guided by a preformed plasma

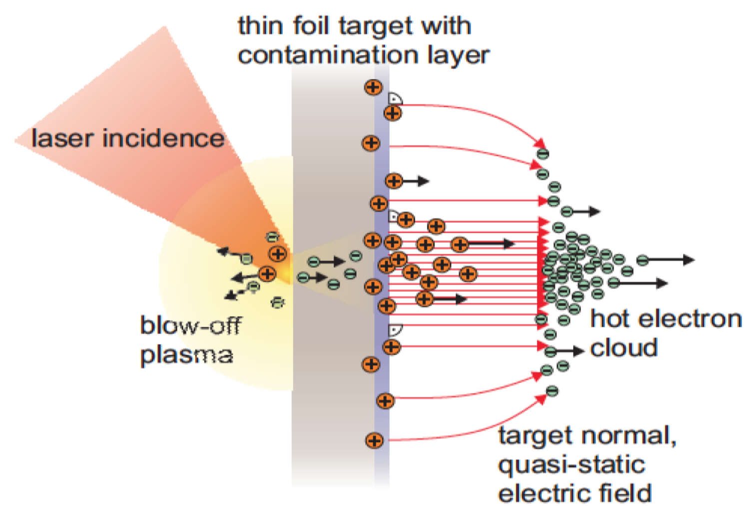
2018



Laser-plasma accelerators rely on the Chirped Pulse Amplification invented by Mourou and Strickland.

Laser-plasma acceleration in a nutshell





Ultra-intense and ultra-short laser pulses with power densities above **10^{18} W/cm^2** , traversing an electron plasma create a charge separation, which can build up to a charge-density wave (wakefield) of the order of **TV/m**, electrons entering this wakefield can be accelerated to relativistic energies.

The cloud of accelerated electrons may leave the target material forming a charge-separation field at the surface of the order of **TV/m**. Such fields can ionize atoms and rapidly accelerate ions normal to the initially unperturbed surface.

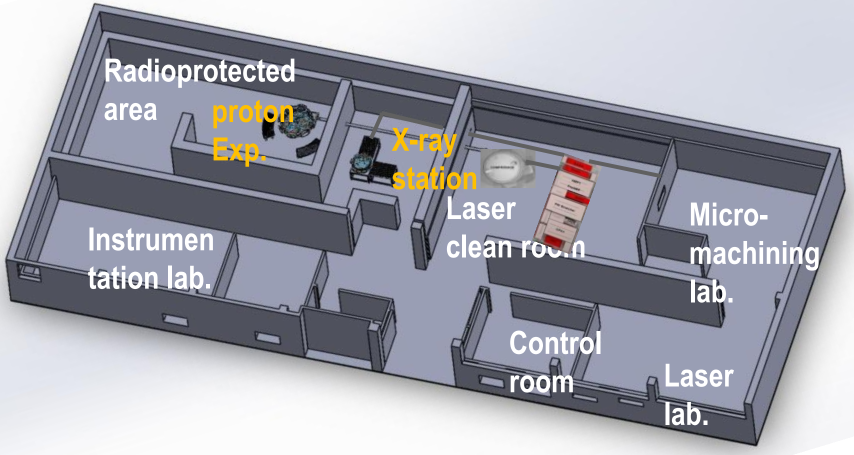
The Laser Laboratory for Acceleration and Applications

A research infrastructure at USC promoted by IGFAE:

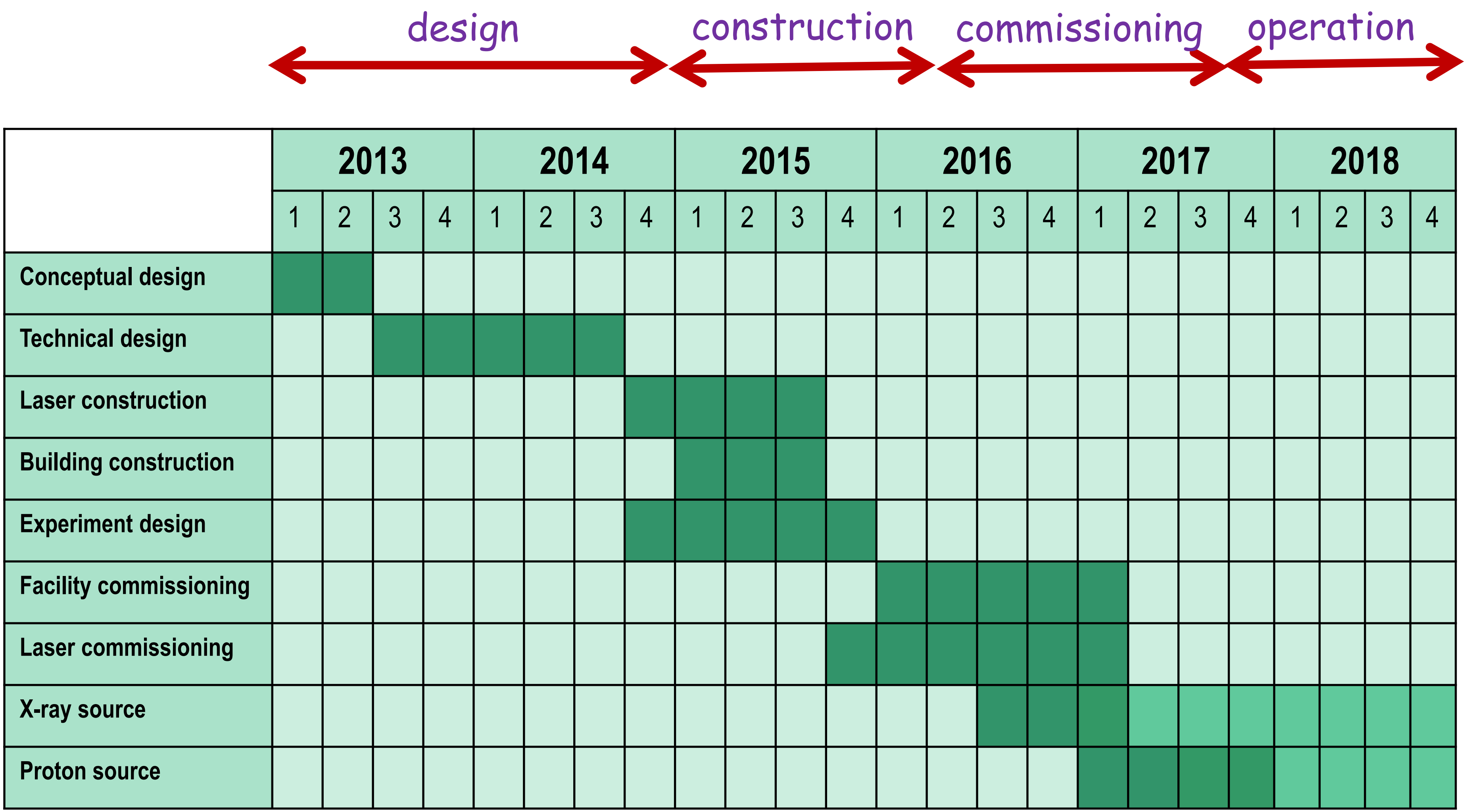
- High-power laser with two beam outputs:
  → 1 J, 25 fs, 10 Hz, ~ 50 TW
  → 1 mJ, 25 fs, 1 kHz, ~50 GW
- Radio-protected area.
- Laser clean room.
- Instrumentation laboratory.

Two main experiments:

- Coherent X-ray source (Lasex):
  → 1 mJ, 25 fs, laser pulses.
  → New imaging technologies.
- Proton source (LaserPET):
  → 1 J, 25 fs, laser pulses
  → New technologies for medical radioisotope production and radiotherapy.



Construction and commissioning time schedule



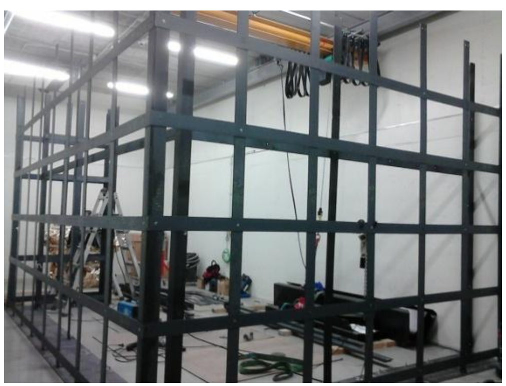
2016: L2A2 commissioning

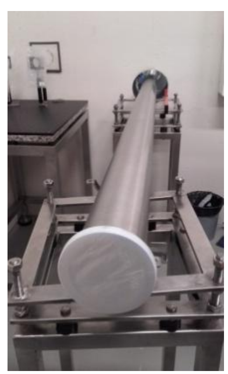
L2A2 experimental area as in January 1st 2016

2016: L2A2 commissioning

Installation of cranes and vacuum chambers:

Radiation shielding and vacuum systems:



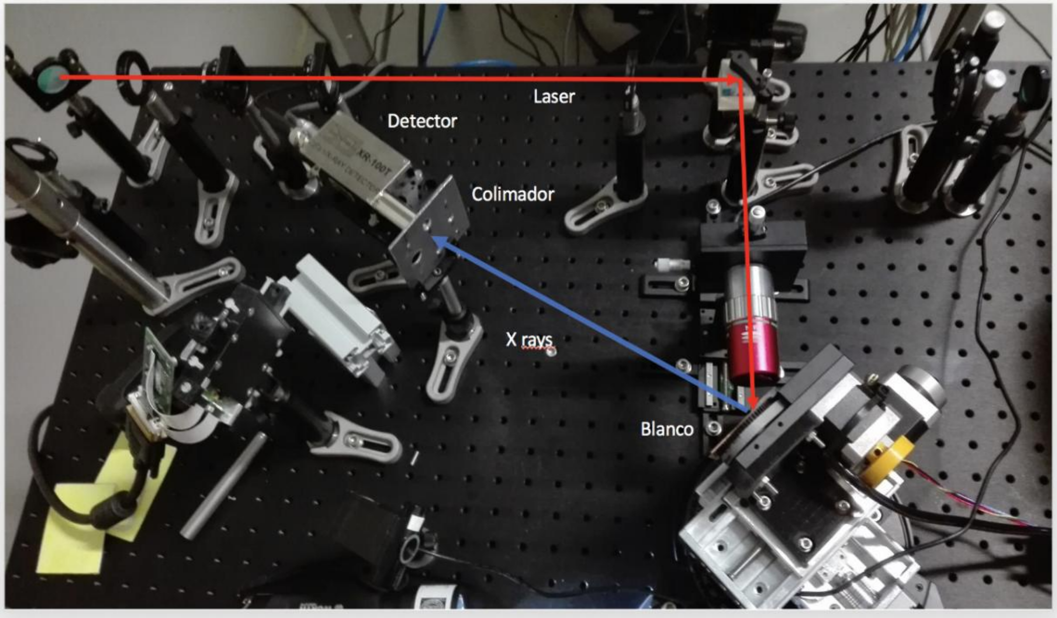


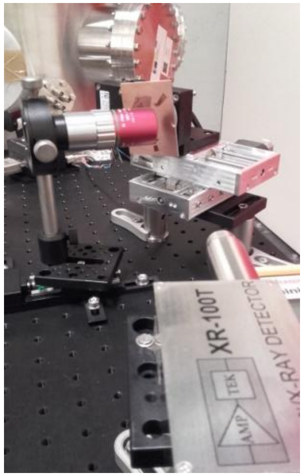
2017: Setting-up and first results with the X-ray source

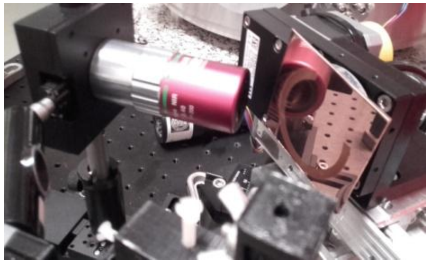
A Khz X-ray source for imaging and laser-plasma acceleration targets development

- ✓ Laser parameters: ~ 1 mJ, 35 fs, 1Khz.
- ✓ X-ray source: continuous operation ~15 min., T~15-30 KeV , source size ~10 μm, small divergence.

Setup for X-ray absorption and phase contrast imaging).

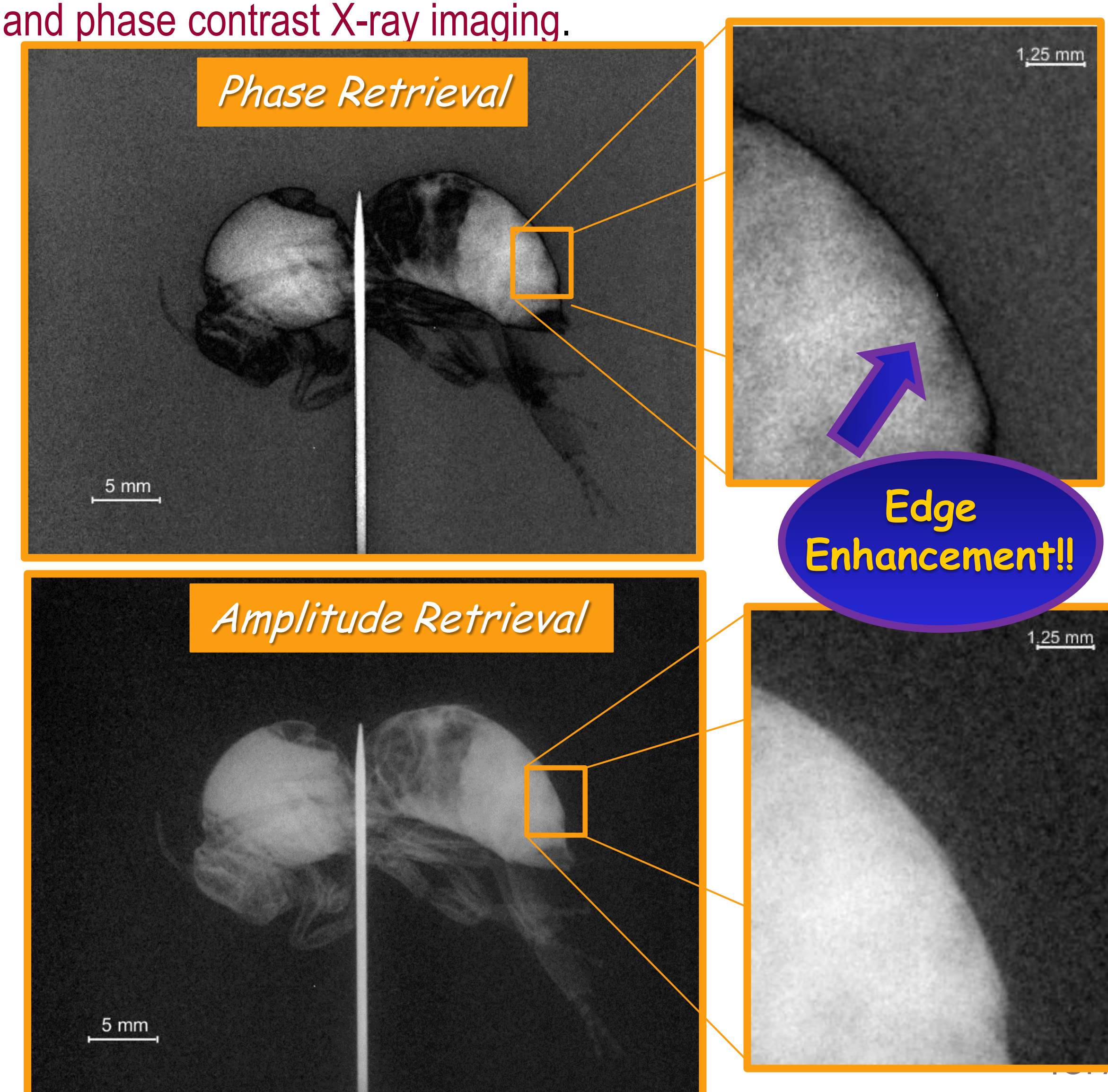






2017: Setting-up and first results with the X-ray source

Absorption and phase contrast X-ray imaging.



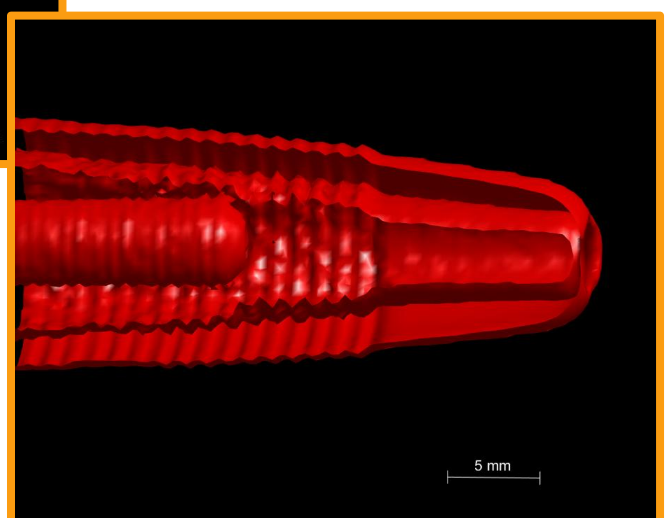
2017: Setting-up and first results with the X-ray source

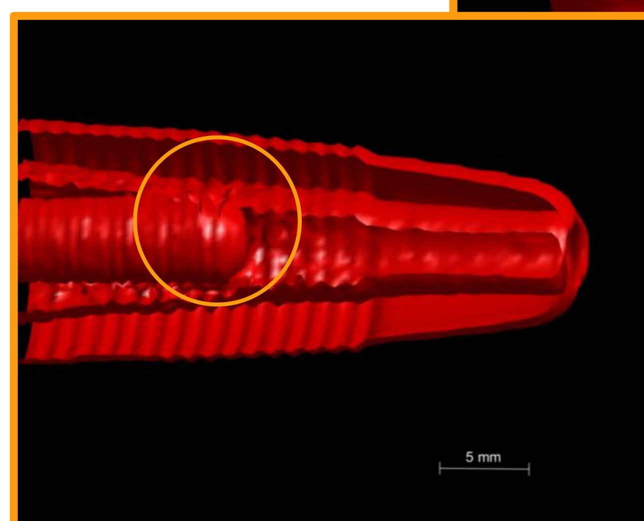
Tomographic imaging.

Phase Contrast Tomography

Absorption Tomography

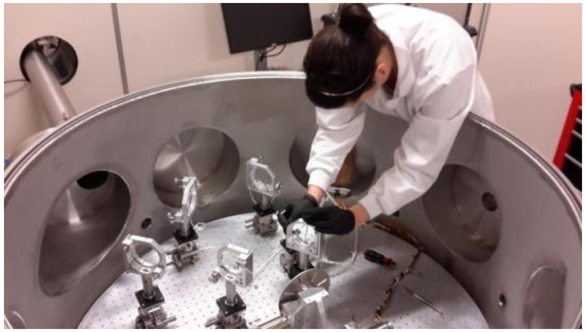
- Phase retrieval algorithm applied to each projection image.
- 100 projections in 180° using the Radon Transform
- Outer parts are well reconstructed with both techniques.
- Inner parts are very well reconstructed with phase contrast.
- Conventional tomography fails reconstructing inner parts

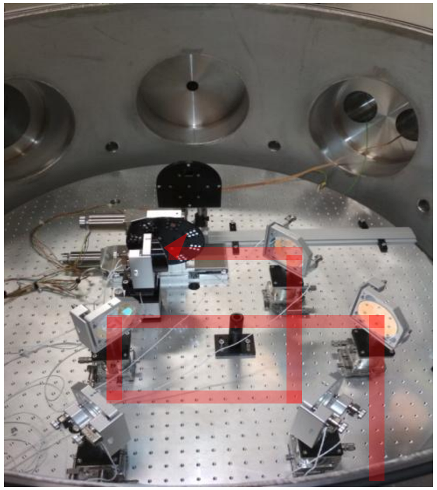




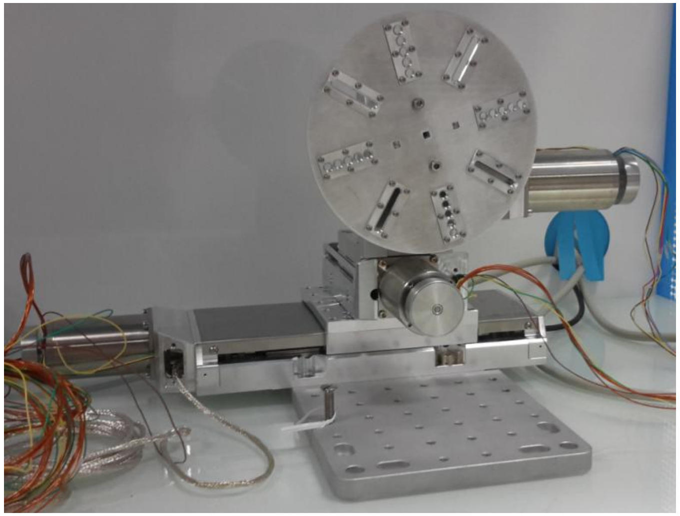
2018: Setting-up the proton source

Laser pulses transport and focusing systems.





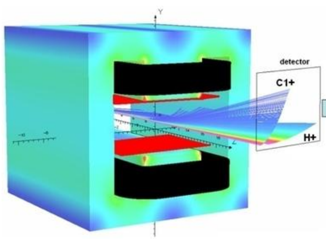
Acceleration target assembly and positioning systems.

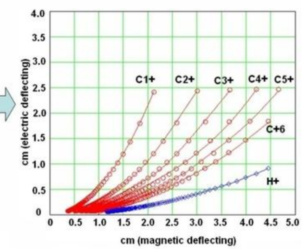


2018: Setting-up the proton source

New detection devices for ultra-short proton pulses.

Thomson parabola for ion identification and energy measurement.

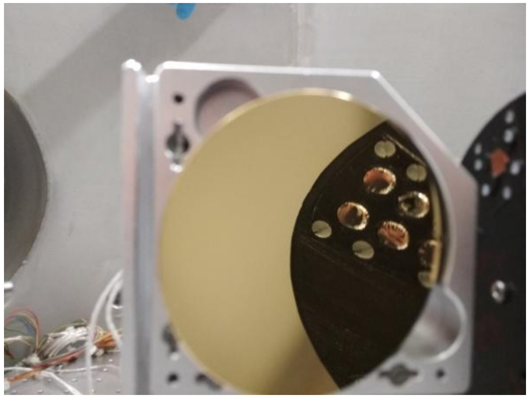


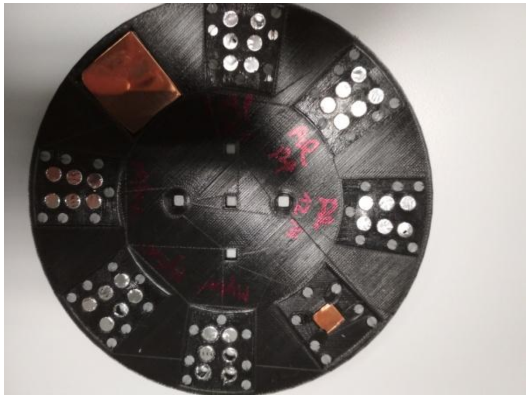


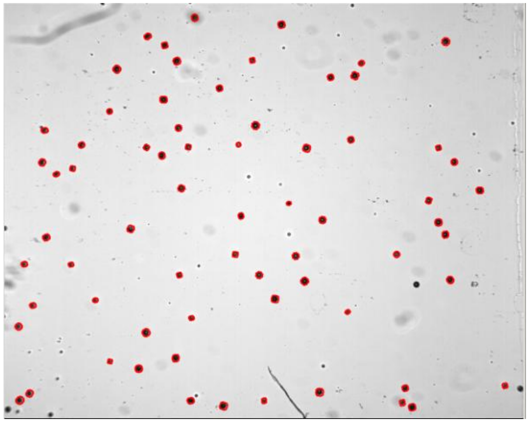
Time of flight detector for energy spectra measurement.

2018: First shots for proton acceleration

April 2018.

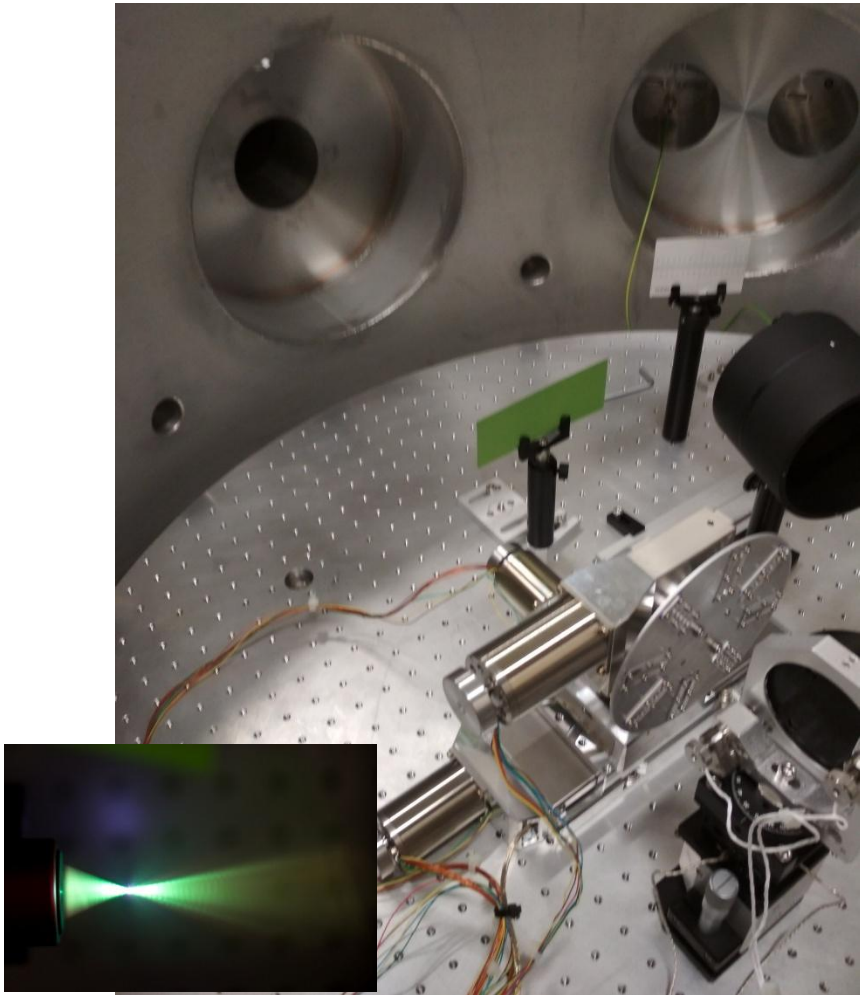


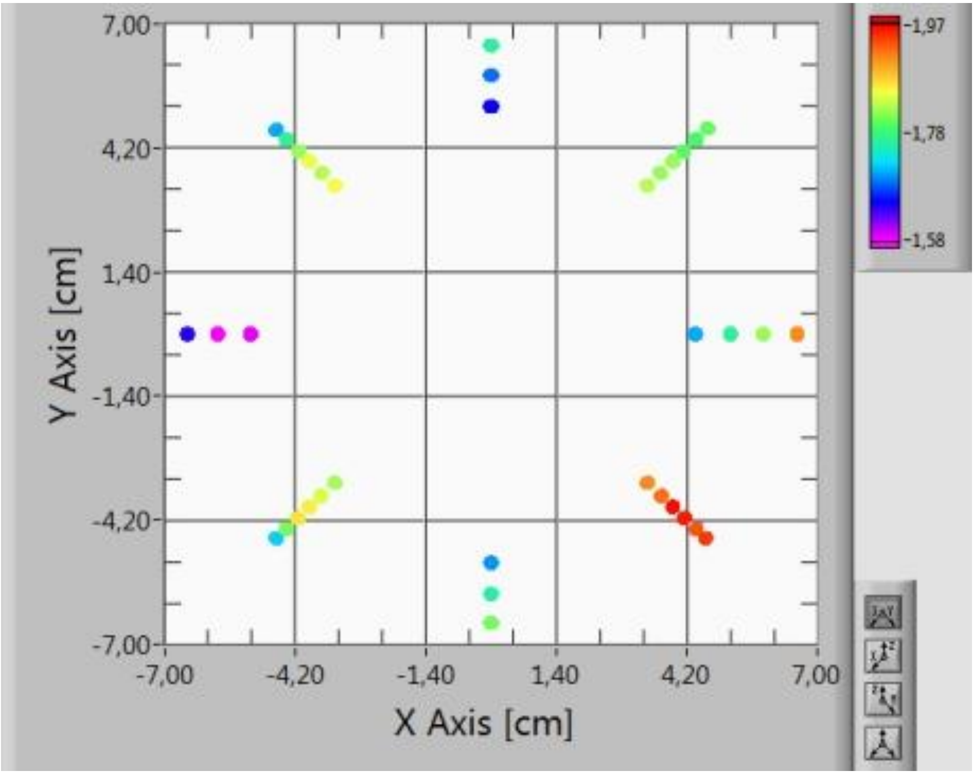




2018: New target positioning system

April-November 2018.

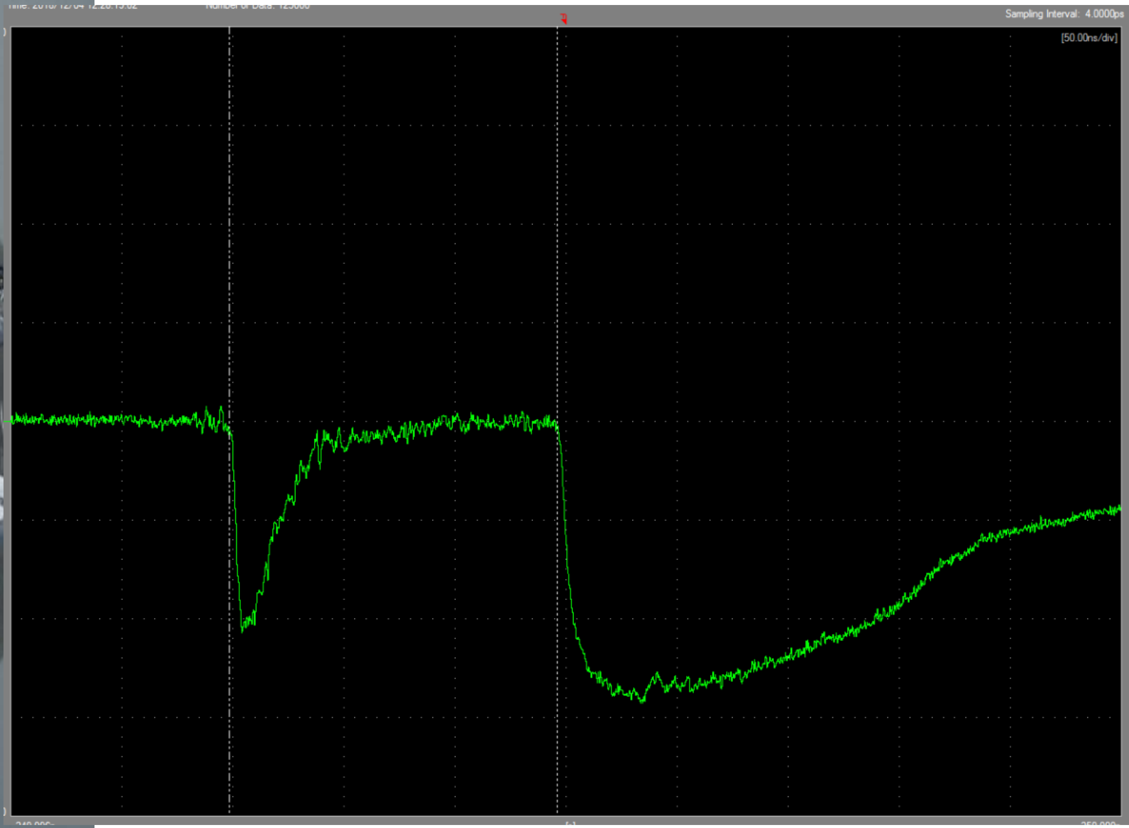




- Target position map with ~ 1 μm accuracy.
- Shot-by-shot target position correction.

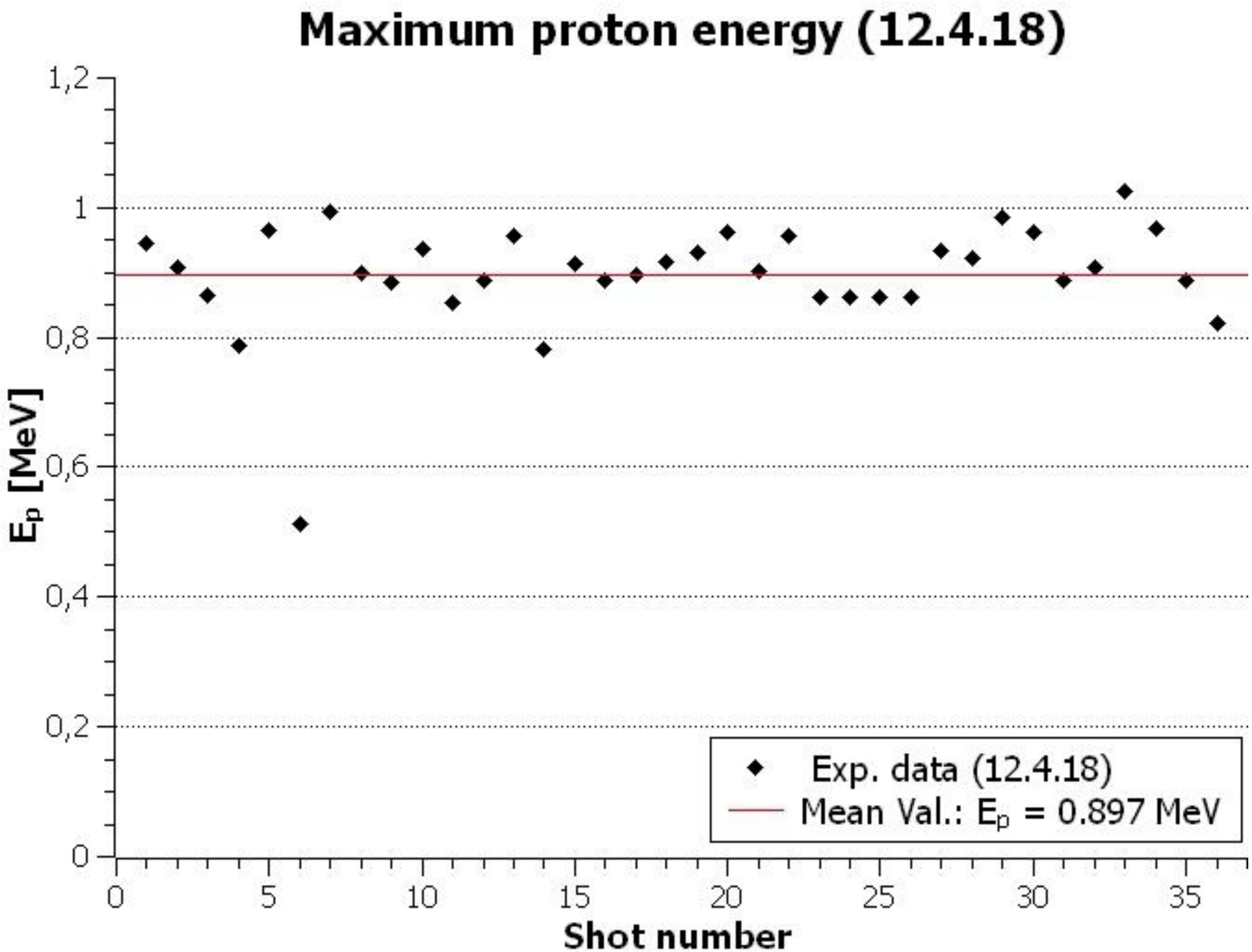
2018: First laser-accelerated protons

November 2018.



2018: First laser-accelerated protons

November 2018.



Summary

✓ The Laser Laboratory for Acceleration and Applications is a new research infrastructure at USC promoted by IGFAE.

✓ The facility is based on a Ti:Sa compact laser with two beam lines:

- 1 mJ, 1 kHz, 35-100 fs and 10^{-6} ASE contrast ratio
- 1 J, 10 Hz, 25-100 fs and 10^{-10} ASE contrast ratio

✓ Two radiation sources:

- proton acceleration: radionuclide production for medical imaging
- coherent X-ray production for tomography and laser-plasma acceleration targets development

✓ X-ray source installed and commissioned in 2017:

- The source is fully operative.
- First results on new imaging technologies obtained and close to publication and to be transferred

✓ Proton source installed and commissioned in 2018:

- First protons accelerated last November with a highly reproducible pattern.
- Improvements in the laser system on-going to reach the required 10 MeV.

Collaborators

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