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On the Potential of Laser Driven Isotope Generation at ELI-NP

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Nuclear Physics

IFIN-HH

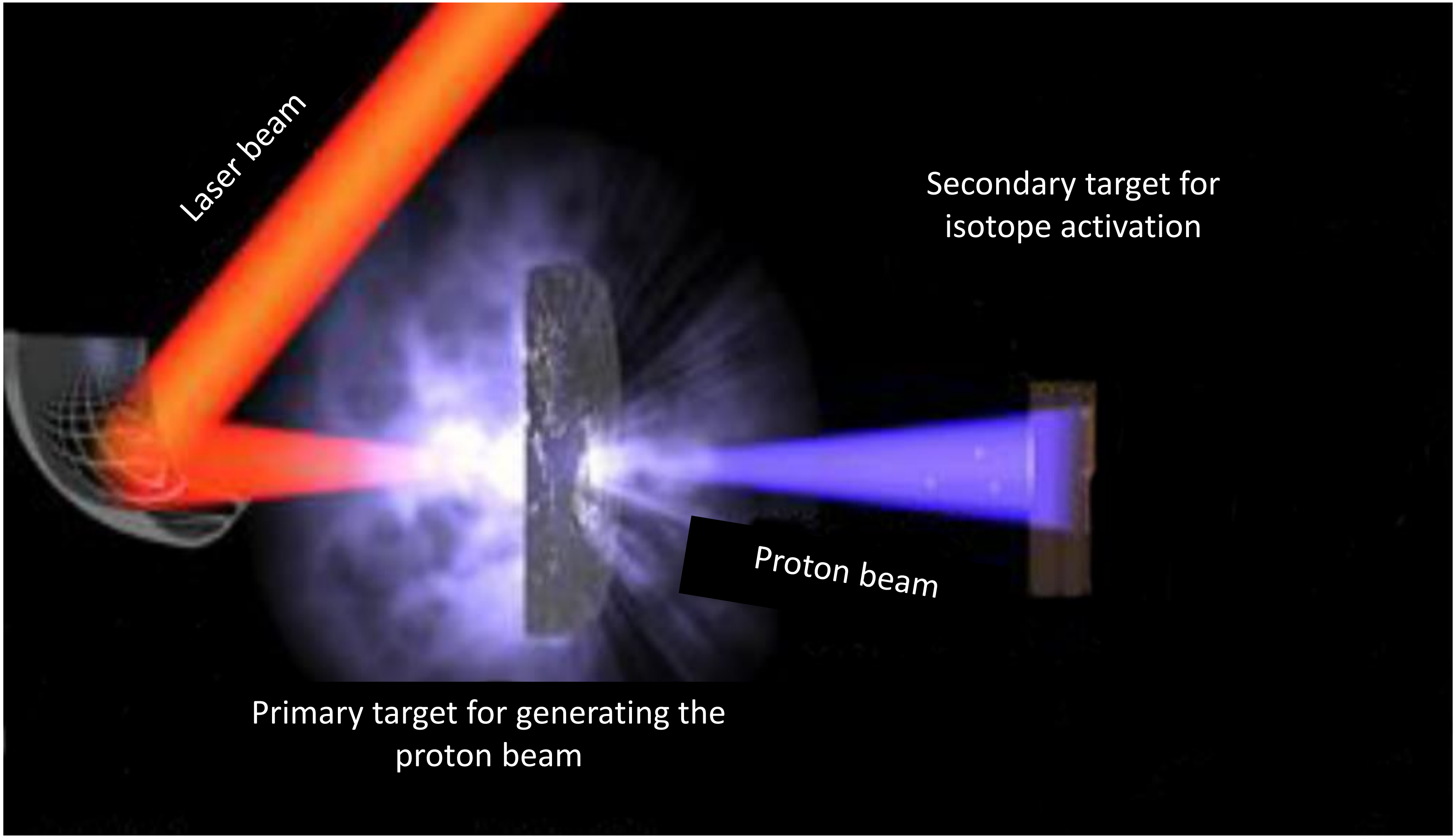
Present Issues in Medical Radioisotopes Production

Radioisotopes play a crucial role in nuclear medicine, being used for the diagnosis and the treatment of ones of the most spread diseases: **the cancer and the cardiovascular disease.**

Medical radioisotopes have a limited lifetime ➔ the production centers and the clinics should be placed relatively close one to each other.

- **The main medical radioisotopes are produced in nuclear reactors** (ex. ^{99m}Tc). ➔ **the production could be affected by long maintenance periods, safety issues, etc.** (see the Tc crisis from 2009).
- **Another important part of medical radioisotopes are produced in cyclotrons** (ex. ^{11}C, ^{13}N, ^{15}O, ^{18}F). Cyclotrons have big dimensions (and price) ➔ **they could deserve a relatively small amount of hospitals concentrated in big cities.**

Could High Power Lasers play a role in this field ?



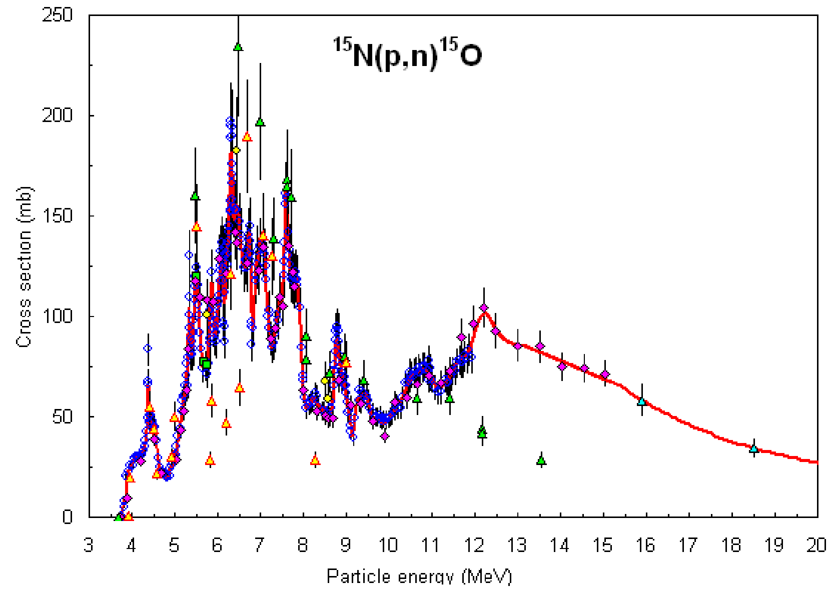
Could High Power Lasers play a role in this field ?

- **Lasers** (like accelerators, unlike reactors) are a **green technology.**
- **Lasers-based particle beams have big density** → many activations/shot produced.
- **Acceleration field more intense than at accelerators and less shielding against radiation is needed** → potential for size reducing.
- **The actual challenges** are related to the quality of the proton beam, the repetition rate and the size minimization.
- **Many synergies** with cyclotron related isotope production and with laser-related physics experiments.

The production next door

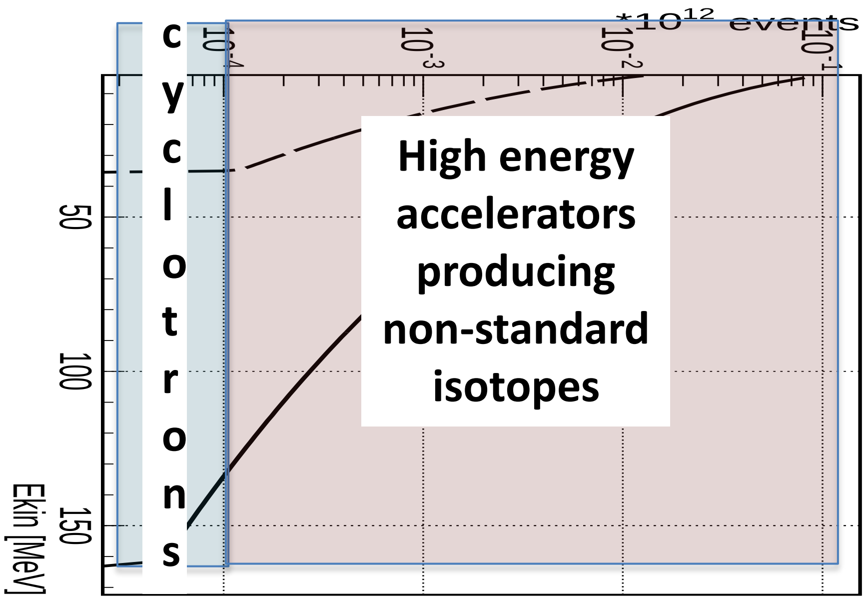
See Tajima, Nakajima & Mourou "Laser Acceleration" Rev.Nuov.Cim. V.40 2 2017

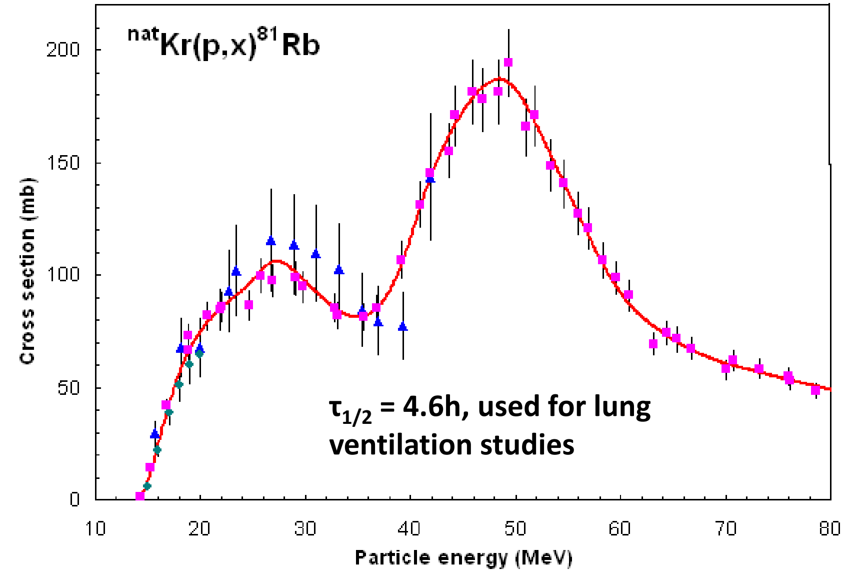
In laser based systems the shielding against radiation is needed only after laser-target interaction, in a much smaller volume/space than in the case of cyclotrons. ➔ possibility of producing short-live isotopes with small laser-based accelerators and deserving hospitals far away from the big cities.

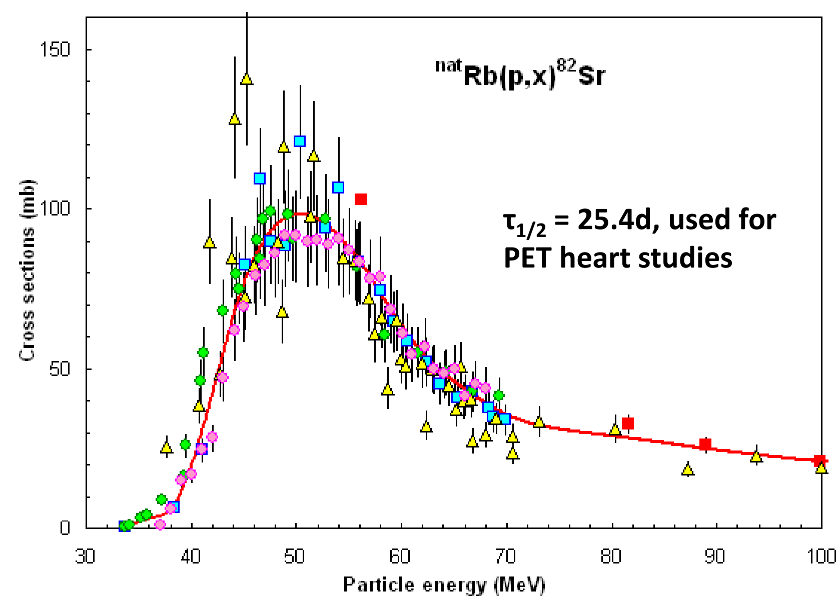


Short lived isotopes such as ^{15}O (122s !!) from $^{15}N(p,n)^{15}O$ are inaccessible to conventional cyclotrons. They can be produced in the future with "table-top" lasers at dedicated <u>production</u> centers <u>inside clinics.</u>

Beyond Cyclotrons







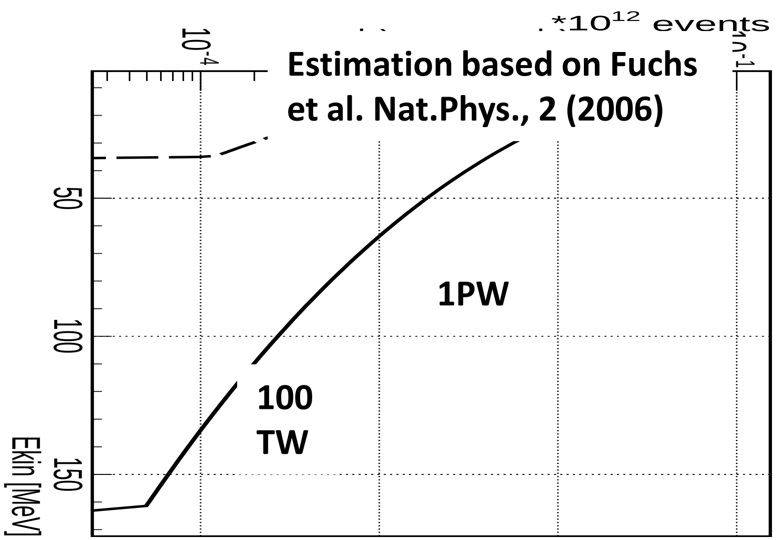
The increasing the average proton intensity at high energy will allow the production of rare isotopes and will open new reaction channels for the traditional ones.

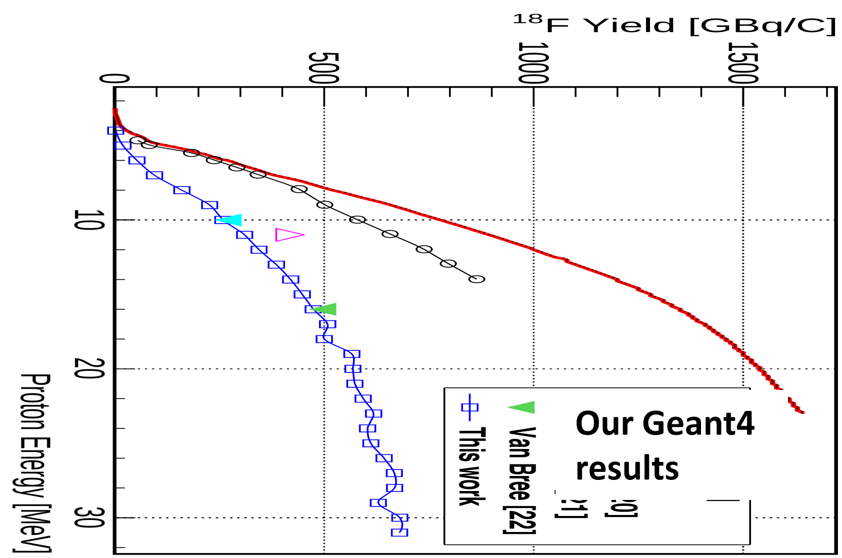
A Case Study: ^{18}F production via $^{18}O(p,n)^{18}F$ @ELI-NP

^{18}F is integrated in the composition of fluorodeoxyglucose ([18F]FDG), the most widely used radiopharmaceutical nowadays. It has a relatively long half-live of 110 min.

Actual work: 2 ELI-NP related configurations tested:

30J in 30fs @1Hz (1PW) and 3J in 30fs @10Hz (100TW)





Need for optimization of the matching between the proton spectrum and the isotope production yield by increasing the number of highly energetic protons.

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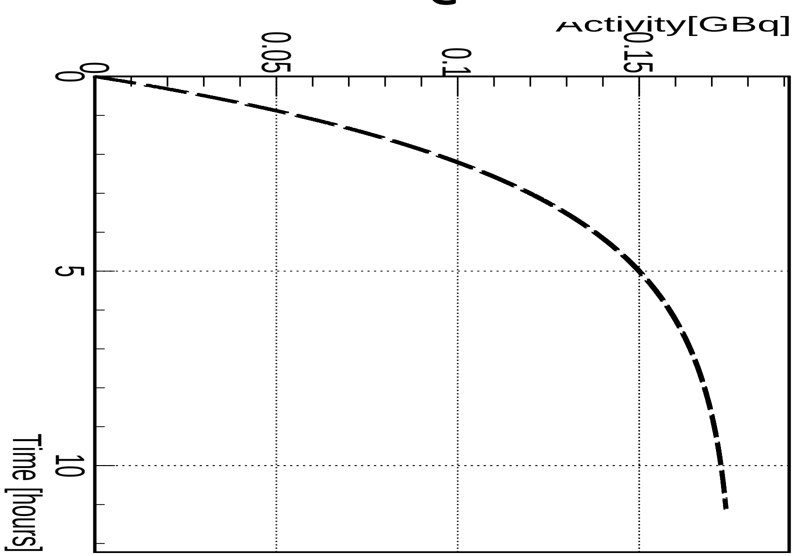
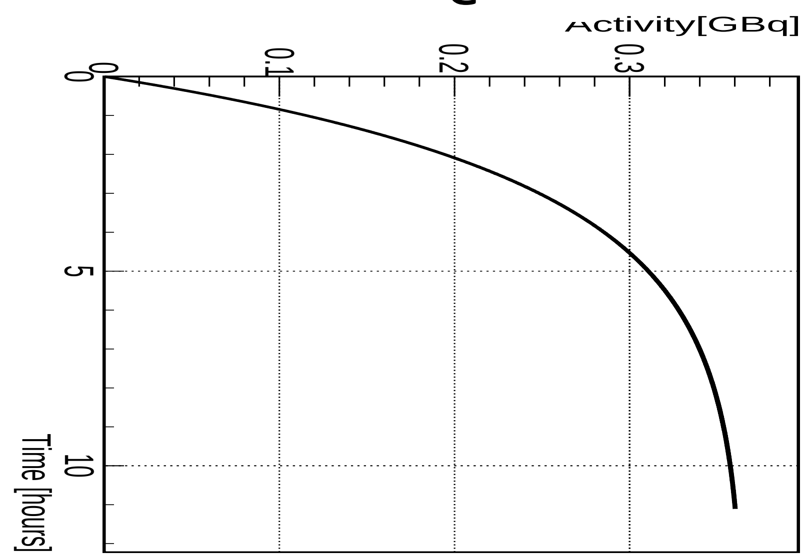
100 TW @10Hz



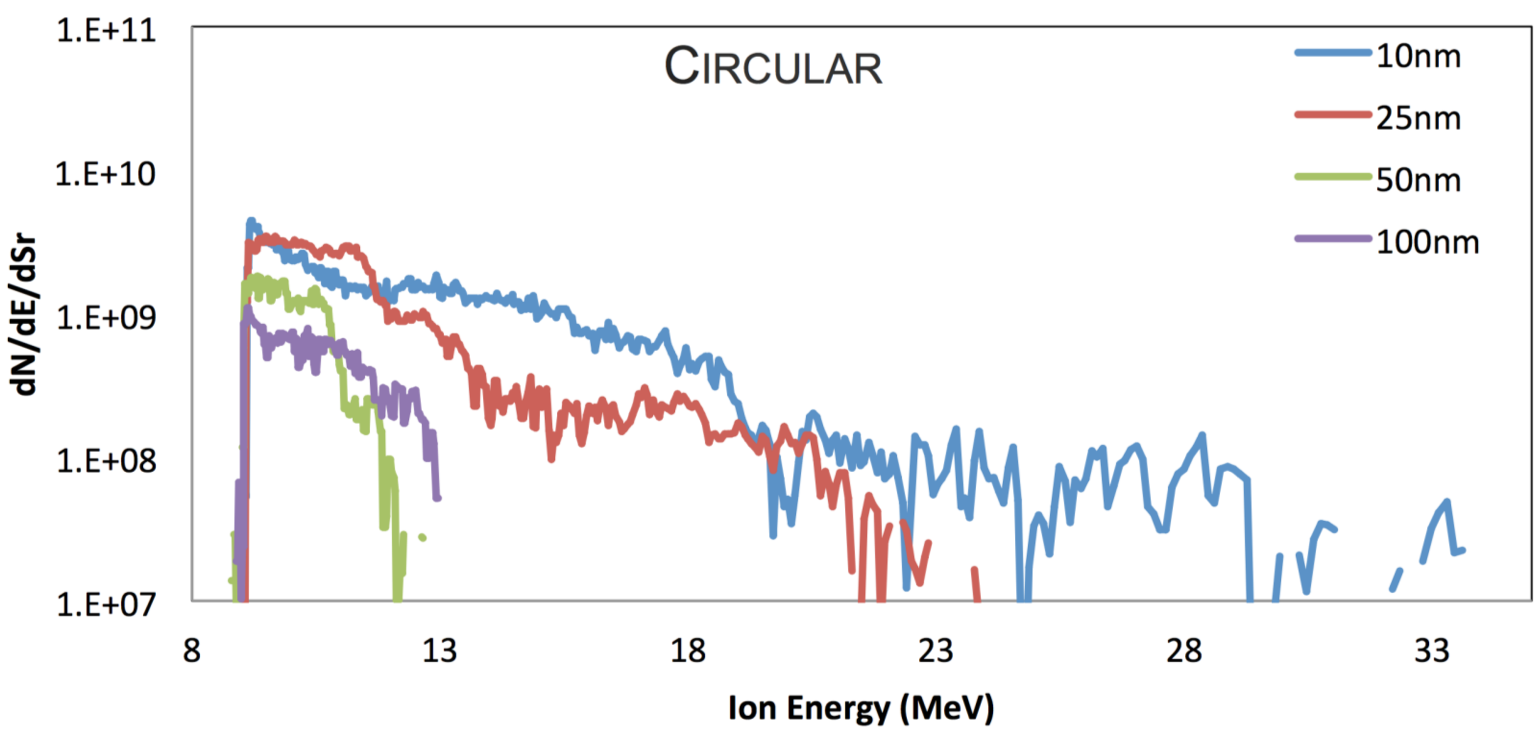
1PW @1Hz



The isotope decay during irradiation saturates the activation time profiles

Ways for improvements

Proton beam generated in by acceleration processes (e.g. RPA, BOA) in very thin foils could increase the <u>average proton current intensity</u>.



Conclusions

Excellent societal application of high power laser systems.

Laser based proton accelerators are under rapid development. A lot of features but also some challenges ahead.

Many synergies with the physics studies and the "conventional" production.

Opportunity for non-standard isotopes (fast decaying, high energy) production and non-standard reaction channels.