

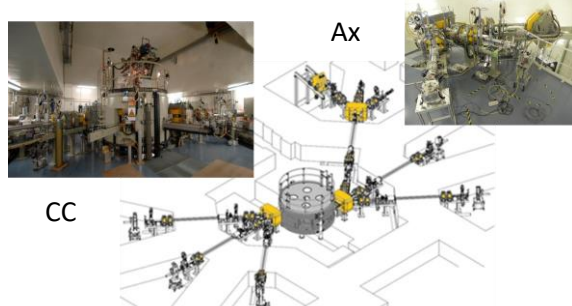
# THE ARRONAX PLATFORM FOR PROTON FLASH IRRADIATION: FROM BEAM PRODUCTION TO THE TARGET

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## Arronax facility

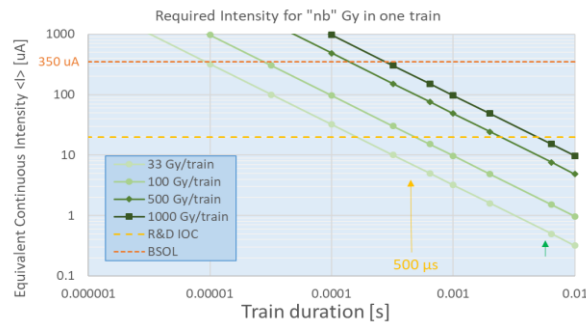
ARRONAX facility [1] hosts an accelerator that can produce several beams: protons, deuterons and alpha up to 70 MeV. The beam ranges from low (<1 pA) to high (up to 350 μA) intensities. The main field is the radionuclides production for nuclear medicine. In parallel, several developments have been conducted to allow preclinical research with Very High Dose Rate (VHDR) proton beam.



3D view and pictures of the cyclotron (CC) and the experimental hall (Ax)

## Beam production and pulsing system

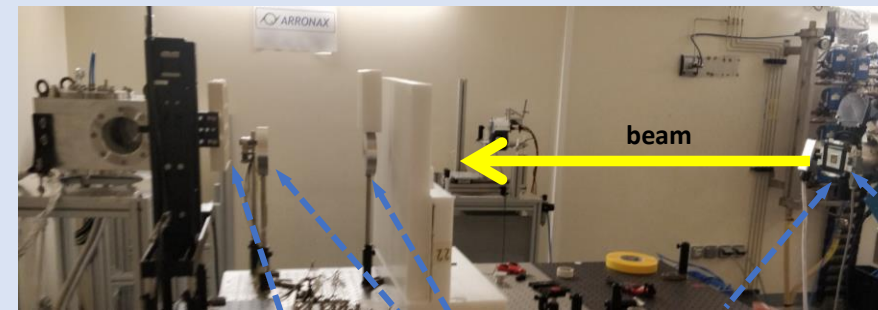
Using a homemade chopper device [2], irradiation durations and frequency rates can be redefined. With this system, the cyclotron can deliver a large range of mean dose rates from low (<1 mGy/s) to high (>1 MGy/s) values. Modification of the beam time structure with the injection chopper allowing flash irradiation with short trains



The capacities in terms of dosimetry within one train is shown above. As an example in used at the present time, R&D internal operation constrain is 20uA, allowing at the exit of the beampipe to reach 100 Gy in one 500μs train. This is possible with an additional air-cooling system of the kapton exit window.

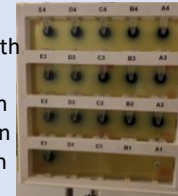
**Conclusion:** The Arronax Cyclotron offers a wide range of dose rates for proton flash studies with a dosimetry environment. Several biological models (cells, zebrafish) have been irradiated up to 70 kGy/sec. The next steps are the preparation of an alpha 68 beam for Flash studies and the beginning of small animal irradiation (April 2022). The preclinical platform is open to collaboration.

## Experimental setup for FLASH irradiation with 68 MeV proton beam



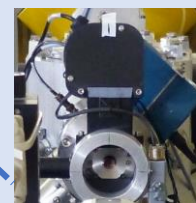
Target holder (X,Y) Collimators Tungsten scattering foil

Eppendorff tubes filled with zebrafish eggs irradiated with 68 MeV proton beam for Flash studies

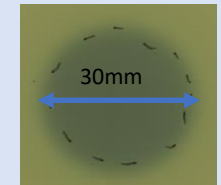


- The beam passes first a scattering foil and then through two collimators to keep the central part.
- The beam Homogeneity is > 90% on a 8 and 25 mm diameter area located respectively at 70 cm and 200 cm from the exit window.

Kapton exit window+ Air-cooling system

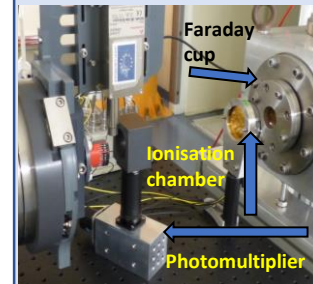


The exit window can handle a maximum beam current of 200 μA

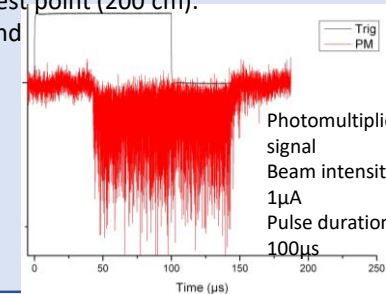


Beam spot on a radiochromic film

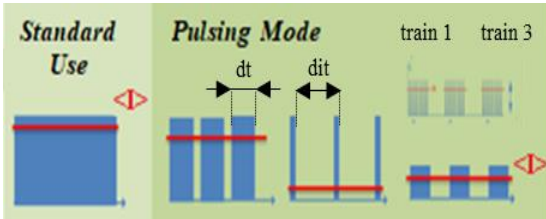
## Beam monitoring



- Currently, the maximum dose rate at the "plateau" of the 68 MeV proton beam is about 70 kGy/sec at the closest point to the exit window (70 cm) and 7 kGy/sec at the farthest point (200 cm).
- The control of the beam at high intensity and for a pulse duration between μs and 10 ms is provided by a photomultiplier to detect UV photons generated by the interaction of the beam with the air molecules [3]
- The doses measurements are ensured by radiochromic films



Continuous standard mode and the pulsed modes (train of bunches) of the beam. The bunches are separated by 32.84 ns.



[1] F. Haddad, N. Michel, A. Guertin, J. Barbet J, J.F. Chatal, J. Martino, "ARRONAX, a high intensity cyclotron in Nantes", ICNDST, 2008, 2, 1383-1385.

[2] F.Poirier et al., "The Injection and Chopper-Based System at Arronax C70XP Cyclotron", CYC19, September 2019, TUP006.

[3] C.Koumeir, "Proton Beam Flash Online Monitoring at Arronax Cyclotron", O083, FRPT21, This conference.

