

New horizon in
therapy & treatment

FRPT

FLASH
RADIOTHERAPY
& PARTICLE
THERAPY

2021

VIENNA & ONLINE

1-3 DECEMBER 2021

PROTON BEAM FLASH ONLINE MONITORING AT
ARRONAX CYCLOTRON



FRPT-Conference.org

Faculty Disclosure

- Nothing to disclose



Outline

- Arronax beams characteristics
- Pulsed beam production
- Pulsed beam monitoring with air fluorescence
 - Temporal structure measurement
 - Beam charge measurement
- Conclusions



Beam characteristics



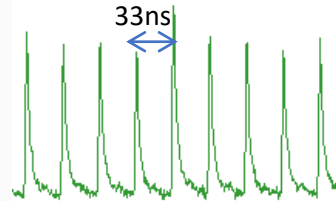
Main characteristics:

Multi-particles

High energy

Large intensity range

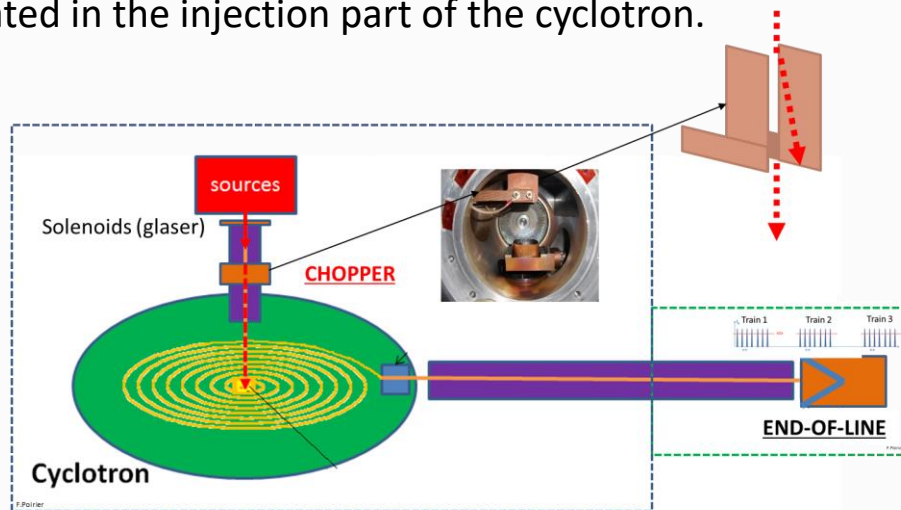
RF frequency 30.45MHz



Beam	Energy range (MeV)	Range in Water (cm)	Intensity (μA)
Proton	30-70	0,8-3,8	1^{-6} --> 375
	17	0,3	<50
Deuteron	15-35	0,1-0,6	<50
Alpha	68	0,3	1^{-6} --> 70

Pulsed beam production

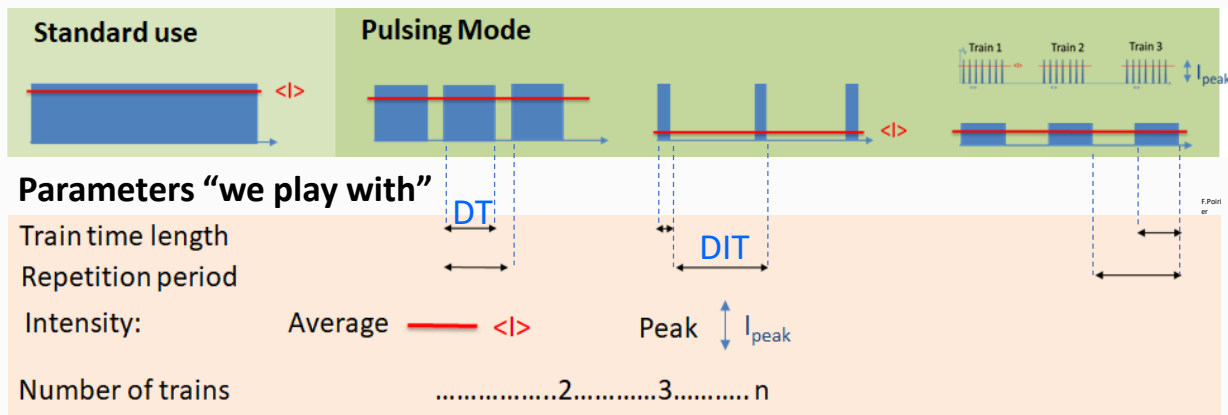
- ▶ Based on a pulsing system
(two parallel copper plates + high voltage switch)
located in the injection part of the cyclotron.



- ▶ Designed to provide a variable number of trains of bunches from an initial continuous bunch structure (30,45 MHz)

F. poirier et al., “the injection and chopper-based system at arronax c70xp cyclotron”,
cyc19, sept. 2019, doi:10.18429/jacow-cyclotrons2019-tup006

Pulsed beam production



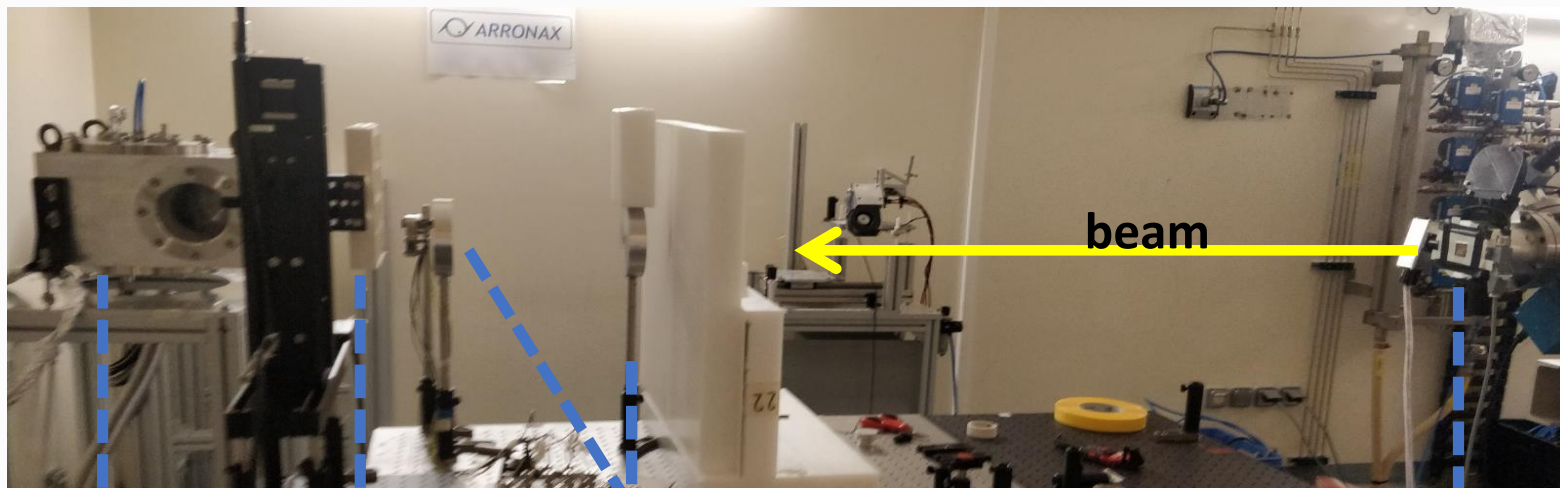
► to modify the Duration of the Train (DT) ($1\mu\text{s}$ to continuous), the répétition frequency (10Hz - 50KHz) and the Duration Inter-Train (DIT >DT).

F. poirier et al., “the injection and chopper-based system at arronax c70xp cyclotron”, cyc19, sept. 2019, doi:10.18429/jacow-cyclotrons2019-tup006

Irradiation line for radiobiology studies



Eppendorff tubes filled with zebrafish eggs irradiated with 68 MeV proton beam for Flash studies (up to 60 kGy/sec)



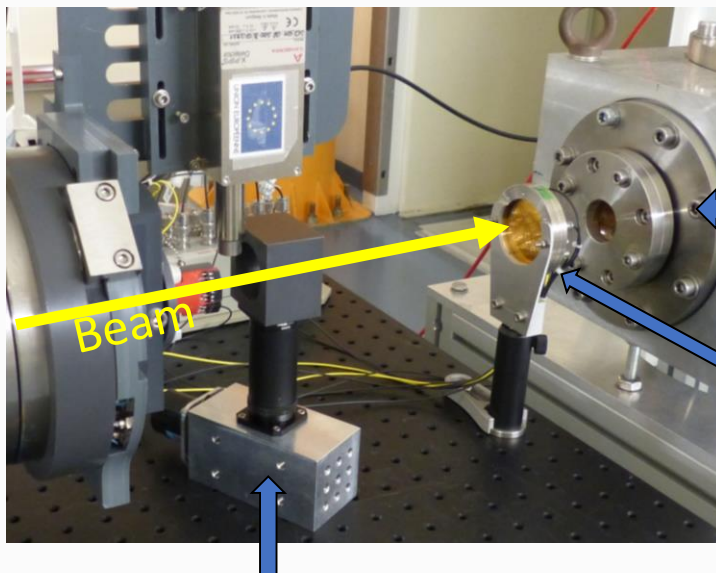
Faraday Cup

Target holder (X,Y)

Collimators: 10 mm (left)
15 mm (right)

Kapton exit window
+air-cooling system
+Photomultiplier

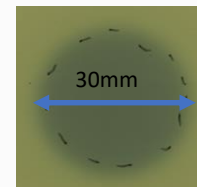
Beam monitoring @Arronax



Faraday cup:
**reference
measurement for
beam intensity**

Transmission parallel-plate
ionization chamber (IC):
for conventional beam
monitoring (low dose rate)

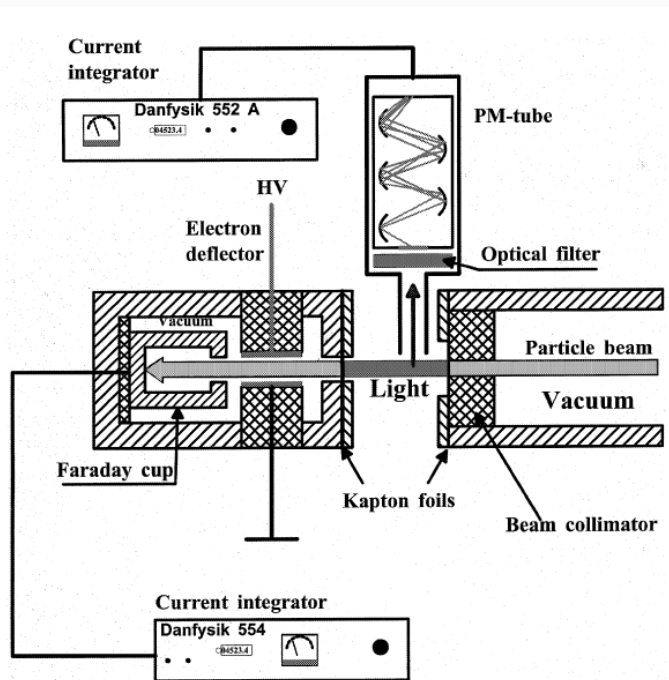
Photomultiplier tube: **for UHDR beam monitoring**



Beam spot on a
radiochromic film

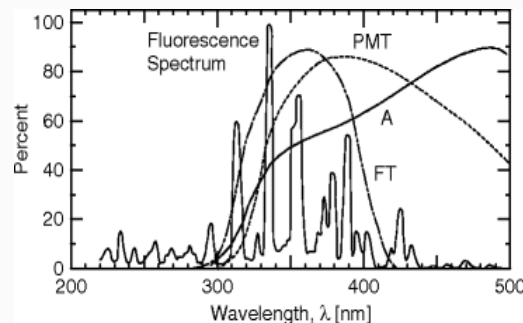
➤ Currents in these devices are measured by a Multidos electrometer (PTW)

Beam monitoring with air fluorescence



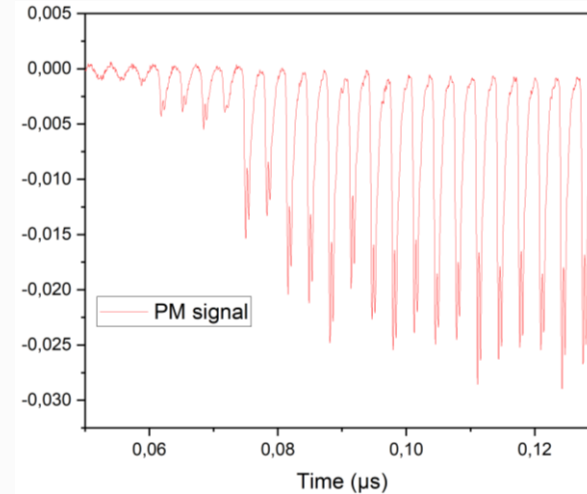
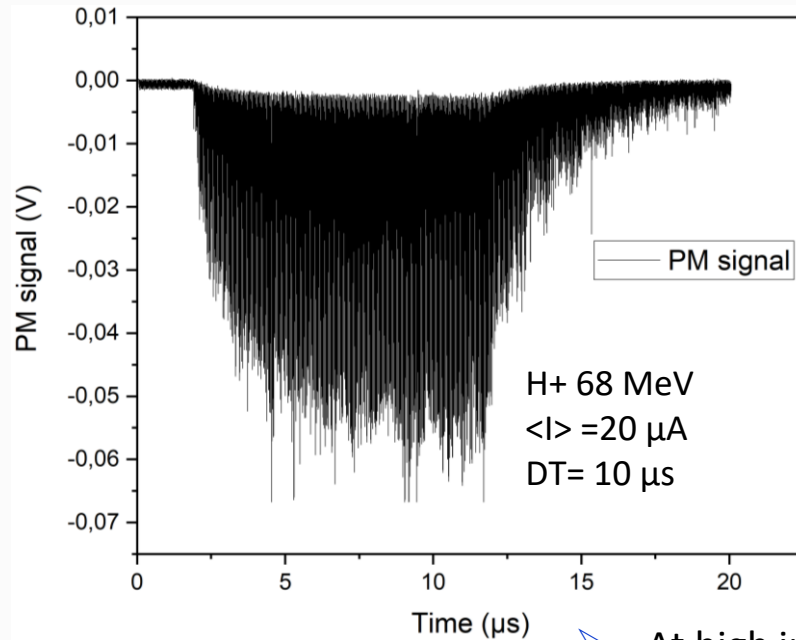
J. -O. Lill, NIMB 150 (1999) 114-117

- Method already developed for Ion Beam Analysis (IBA)
- The beam interacts with the nitrogen molecules and the UV photons of the excited molecules are emitted
- The emitted photons are detected with a photomultiplier (PM)



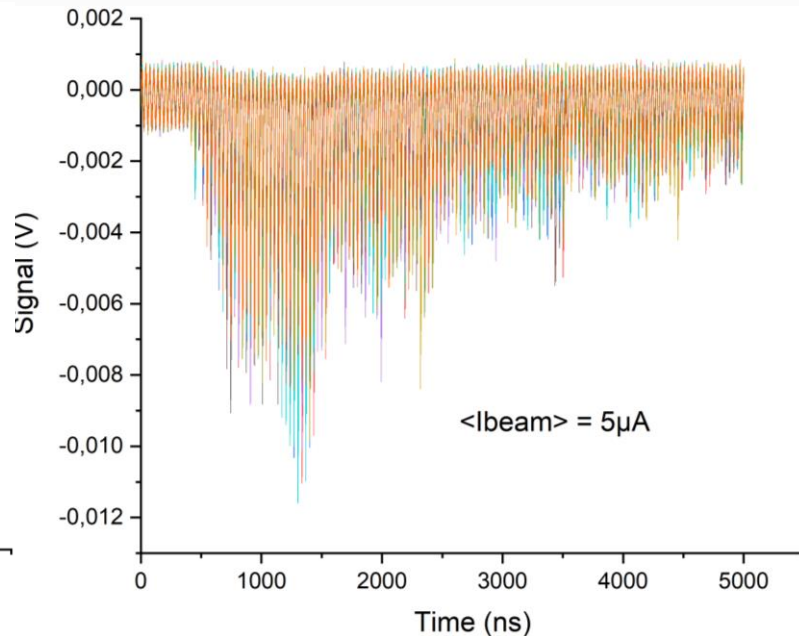
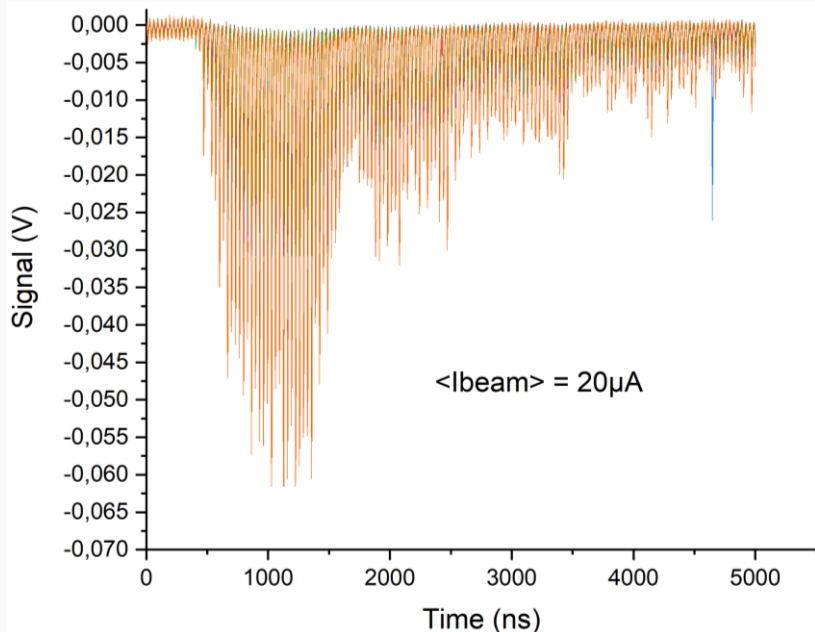
Pulsed beam monitoring

temporal structure measurement



- At high intensity the PM can see each bunch
- The beginning of the train can be detected with a ns precision

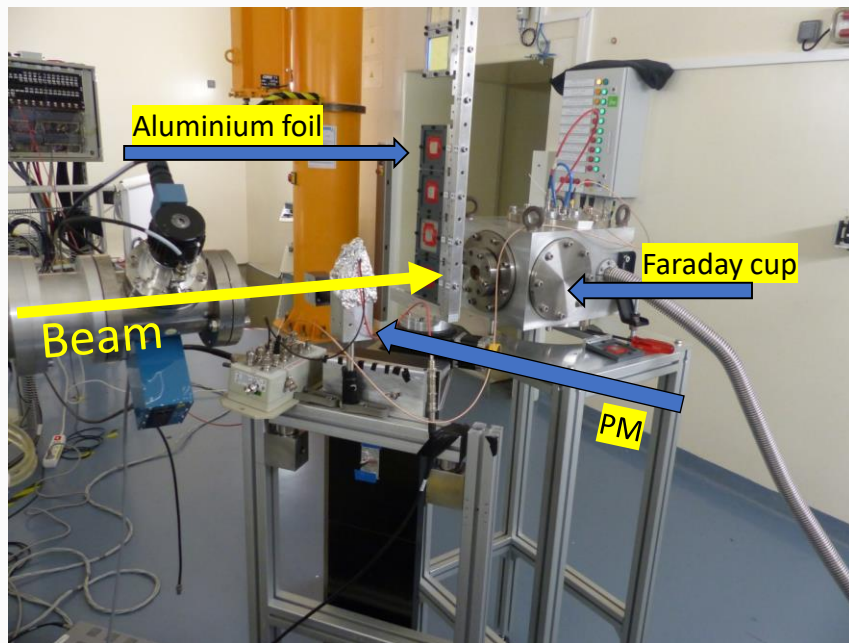
Pulsed beam monitoring (temporal structure measurement)



➤ The probability to detect the first bunch at 1 μA is around 50%. Several PM used to enhance detection

Pulsed beam monitoring

- validation of the beam charge measurement



- Several aluminum foils were irradiated with pulsed and continuous beams
- Na24 produced by activation used to measure integrated beam charge using HPGc detector

Validation Faraday Cup (FC) vs. Na24 activity (A0)

<I>(nA)	DT (μs)	DIT (ms)	FC(μC)	A0/FC	error%	pulsed/Cont.
10			4	0,00305	2,18	1
215	250	5	4	0,00306	2,17	1,009
900	250	21	4	0,00308	2,19	1,015
2500	250	58	4	0,00307	2,18	1,012
2500	50 (1Gy/50μs)	12	4	0,00307	2,18	1,011
2500	50	12	4	0,00303	2,18	1,000
2500	250	58	4	0,00305	2,17	1,005
900	250	21	4	0,00304	2,05	1,002
215	250	5	4	0,00304	2,03	1,001
47			4	0,00303	2,10	1

- Good agreement between the activities produced in the pulsed and continuous beams → validates the use of the FC and the multidos electrometer to measure the beam charge in pulsed proton beam.



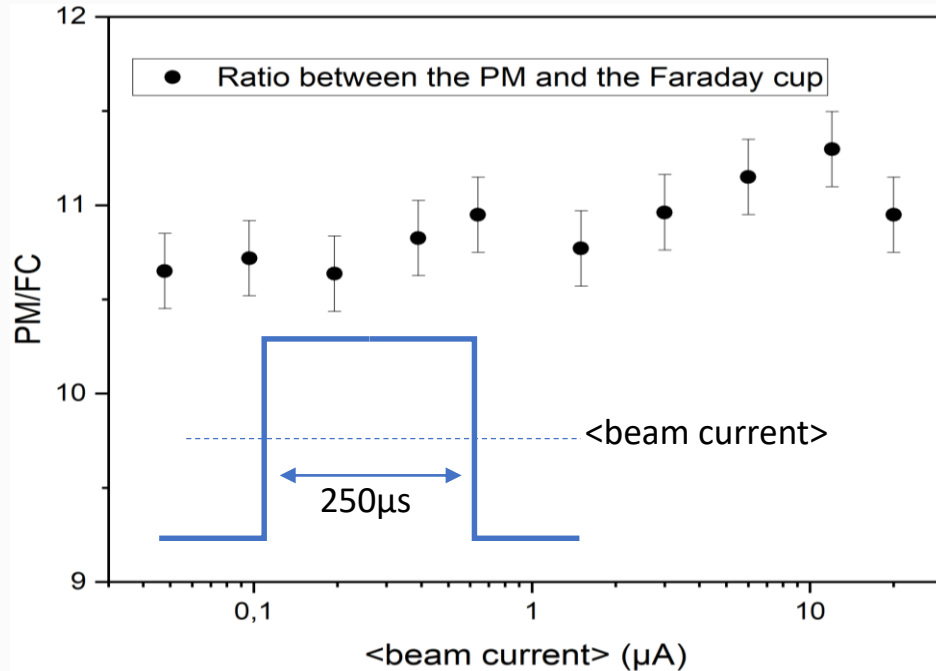
Validation PM tube vs Faraday Cup (many pulses)

$\langle I \rangle$ (nA)	DT (μ s)	DIT (ms)	FC (μ C)	PM(μ C)	PM/FC
10			4	26,02	6,52
215	250	5	4	26,04	6,57
900	250	21	4	26,08	6,55
2500	250	58	4	26,33	6,60
2500	50 (1Gy/50 μ s)	12	4	26,09	6,57
2500	50	12	4	26,19	6,63
2500	250	58	4	26,29	6,62
900	250	21	4	26,19	6,58
215	250	5	4	26,2	6,57
47			4	25,89	6,45

- ▶ The PM charge measurement is constant over a wide range of the pulsed beam structure
- validates the use of the PM to control a pulsed proton beam up to several μ A



Validation PM tube vs Faraday cup (single pulse)



one pulse ($250\mu\text{s}$), beam current: $50\text{nA} \rightarrow 20\mu\text{A}$
Pulse dose rate: $0.4\text{kGy/sec} \rightarrow 200\text{kGy/sec}$

- The PM charge measurement is constant within 5% over a wide range of the pulse dose rate (the maximum difference is about 5%)
- Utilizing multiple PMs around the beam spot could reduce this variation



Conclusions

- Arronax platform have a large panel of beams up to 70 MeV with two modes of delivrance: continous and pulsed beams
- A monitor beam based on the détection of the air fluorescence with a PM has been developed
- This method can monitor beam with ultra high pulse dose rate (200kGy/sec)
- Next step
- Build a beam profiler to measure the beam characteristics: geometric and temporal structure within the pulse



Aknowledgements

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