Status report of MORA @ JYFL

ISOL FRANCE, Maison d'hôtes, GANIL - 10/03/2022 -

- Table of contents -

- Context
- Installation at JYFL
- Trapping commissioning and principle
- Online measurements and results
- Future schedule of the experiment

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- Theoritical context -

THE MORA PROJECT
MATTER'S ORIGIN FROM RADIOACTIVITY

Matter's Origin from RadioActivity of trapped and oriented ions

Goal: Looking for new CP violations

The probability rate function of beta decay:

$$\omega(\langle \mathbf{J} \rangle | E_e, \Omega_e, \Omega_\nu)\, \mathrm{d}E_e\, \mathrm{d}\Omega_e\, \mathrm{d}\Omega_\nu = \overbrace{\frac{F(\pm Z, E_e)}{(2\pi)^5}}^{\text{Fermi function}} \overbrace{p_e E_e (E_0 - E_e)^2\, \mathrm{d}E_e\, \mathrm{d}\Omega_e\, \mathrm{d}\Omega_\nu}^{\text{Phase space}}$$

$$\times \underbrace{\frac{1}{2}\xi}_{\text{nuclear transition matrix elements}} \underbrace{\left\{ 1 + a\frac{\mathbf{p}_e \cdot \mathbf{p}_\nu}{E_e E_\nu} + b\frac{m}{E_e} + \frac{\langle \mathbf{J} \rangle}{J} \cdot \left[A\frac{\mathbf{p}_e}{E_e} + B\frac{\mathbf{p}_\nu}{E_\nu} + D\frac{\mathbf{p}_e \times \mathbf{p}_\nu}{E_e E_\nu} \right] \right\}}_{\text{Correlation parameters } a, b, A, B, \text{ and } D}$$

Correlation parameters *a, b, A, B, and D*
(correlation between spin & momenta of particles)

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The probability rate function of beta decay:

Fermi function — Phase space

$$\omega(\langle \mathbf{J}\rangle | E_e, \Omega_e, \Omega_\nu)\, dE_e\, d\Omega_e\, d\Omega_\nu = \frac{F(\pm Z, E_e)}{(2\pi)^5} p_e E_e (E_0 - E_e)^2\, dE_e\, d\Omega_e\, d\Omega_\nu \times \frac{1}{2}\xi \left\{ 1 + a\frac{\mathbf{p}_e \cdot \mathbf{p}_\nu}{E_e E_\nu} + b\frac{m}{E_e} + \frac{\langle \mathbf{J}\rangle}{J} \cdot \left[A\frac{\mathbf{p}_e}{E_e} + B\frac{\mathbf{p}_\nu}{E_\nu} + D\frac{\mathbf{p}_e \times \mathbf{p}_\nu}{E_e E_\nu} \right] \right\}$$

nuclear transition matrix elements

Correlation parameters *a, b, A, B, and D*
(correlation between spin & momenta of particles)

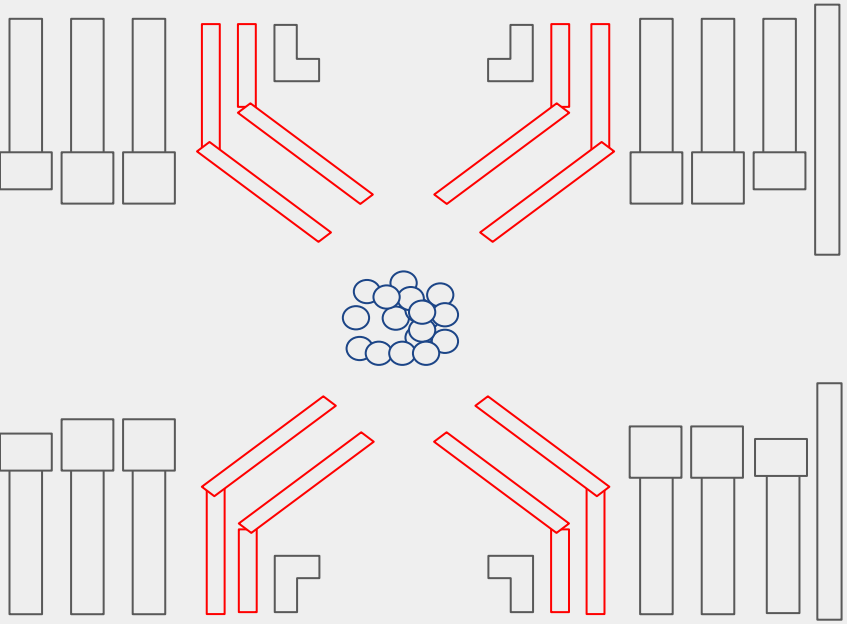
If D ≠ 0 then T violation

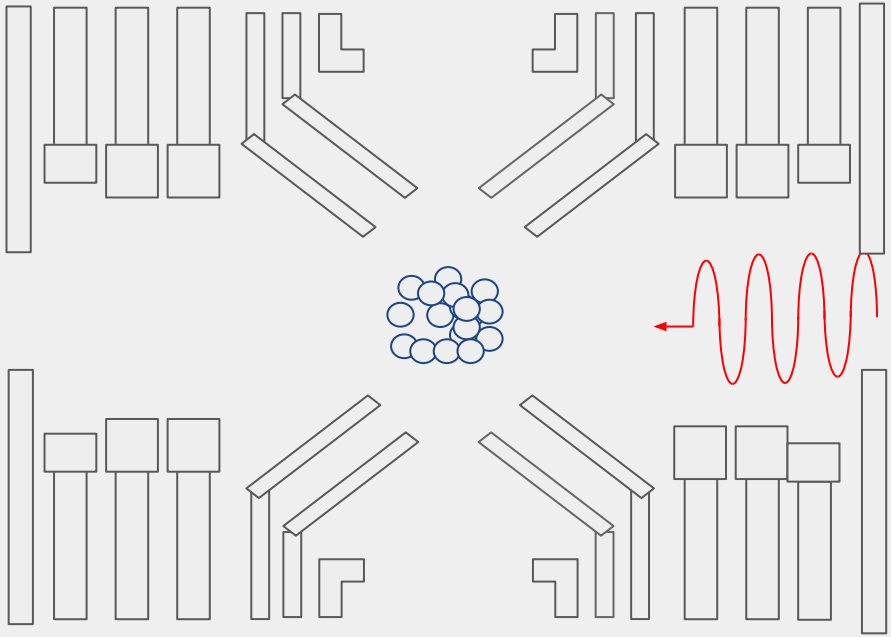
$$\frac{<\vec{J}>}{J} \cdot \frac{(\vec{p}_e \times \vec{p}_\nu)}{E_e E_\nu}$$ equivalent to $$\frac{<\vec{J}>}{J} \cdot \frac{(\vec{p}_e \times \overrightarrow{p_{recoil}})}{E_e E_{recoil}}$$ according to momentum conservation

Recoil ions at very low energy ⟹ needs of a trap to detect them

MORA is composed of:

Transparent Paul trap + Laser(Ti:Sa)

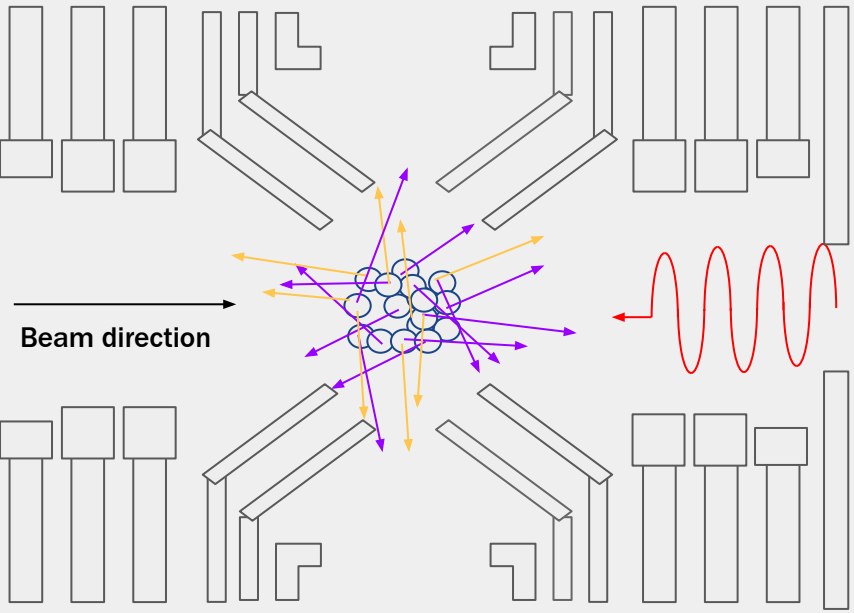


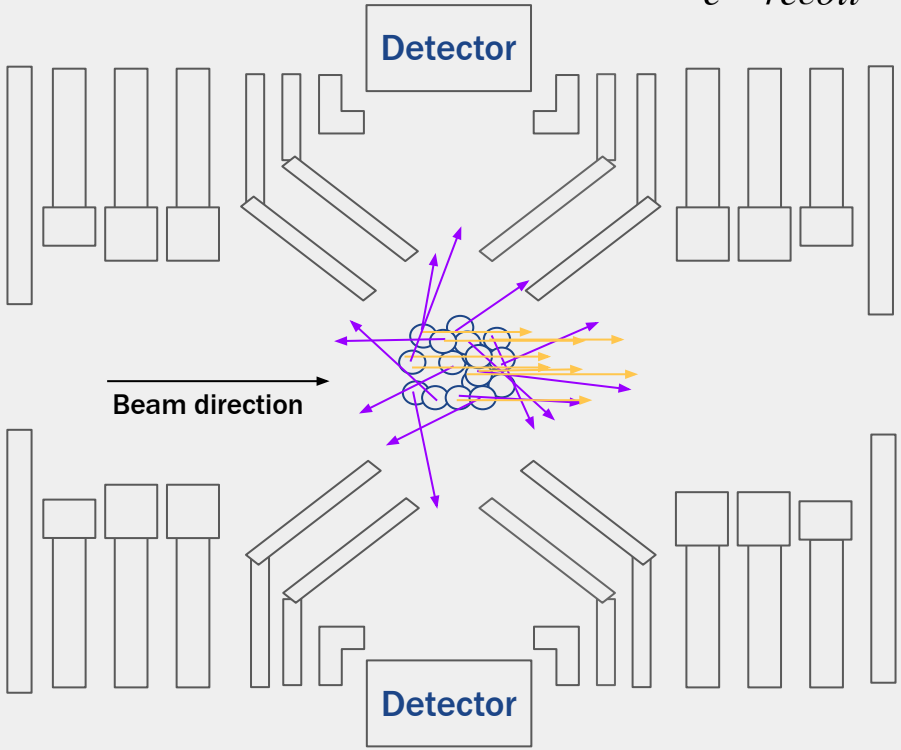


- Principle of MORA: Spin alignment -

Nuclear spin direction
Direction of decay
Beam direction

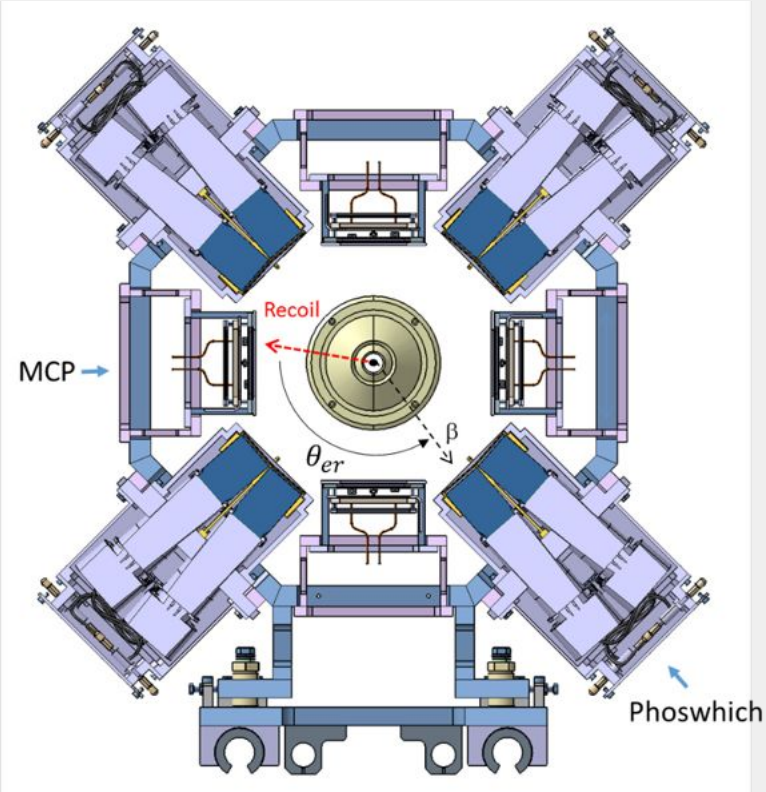
$$\frac{<\vec{J}>}{J} \cdot \frac{\left(\vec{p}_e \times \vec{p}_{recoil}\right)}{E_e E_{recoil}}$$

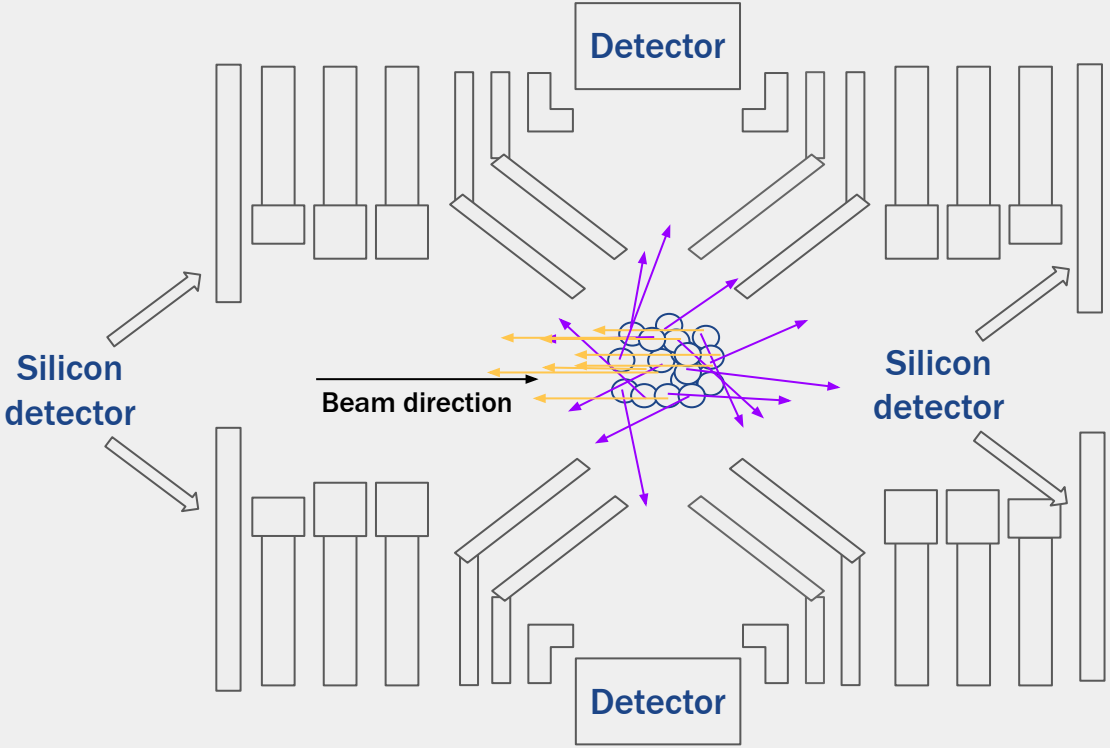




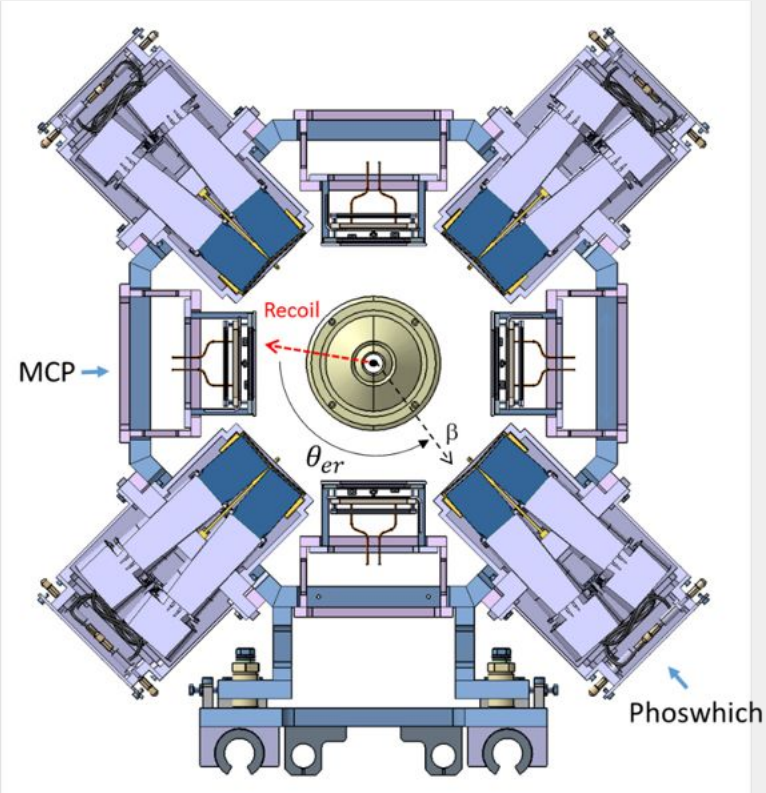
- Principle of MORA: Spin alignment -

$$\frac{N^{+45^\circ}_{coinc} + N^{+135^\circ}_{coinc} - N^{-45^\circ}_{coinc} - N^{-135^\circ}_{coinc}}{N^{+45^\circ}_{coinc} + N^{+135^\circ}_{coinc} + N^{-45^\circ}_{coinc} + N^{-135^\circ}_{coinc}} \sim D.P$$





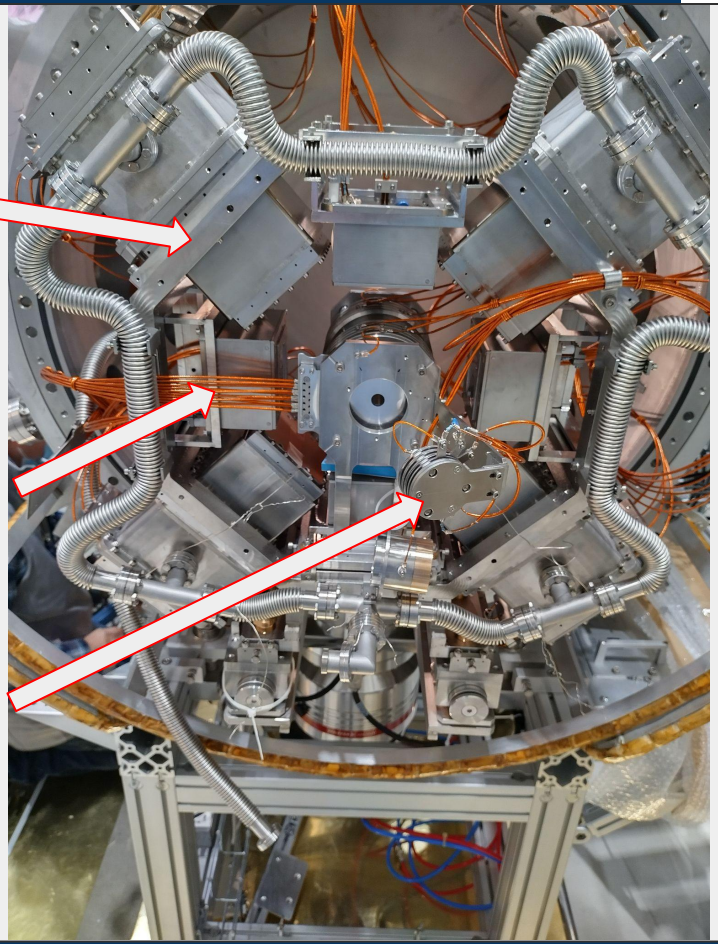
- Principle of MORA: Spin alignment -



Phoswich (β)

Recoil Ion DEtector (RIDE)

Micro Channel Plate (Extraction)



$$\frac{N^{+45°}_{coinc} + N^{+135°}_{coinc} - N^{-45°}_{coinc} - N^{-135°}_{coinc}}{N^{+45°}_{coinc} + N^{+135°}_{coinc} + N^{-45°}_{coinc} + N^{-135°}_{coinc}} \sim D.P$$

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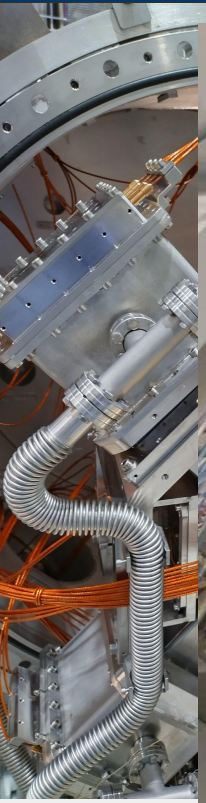
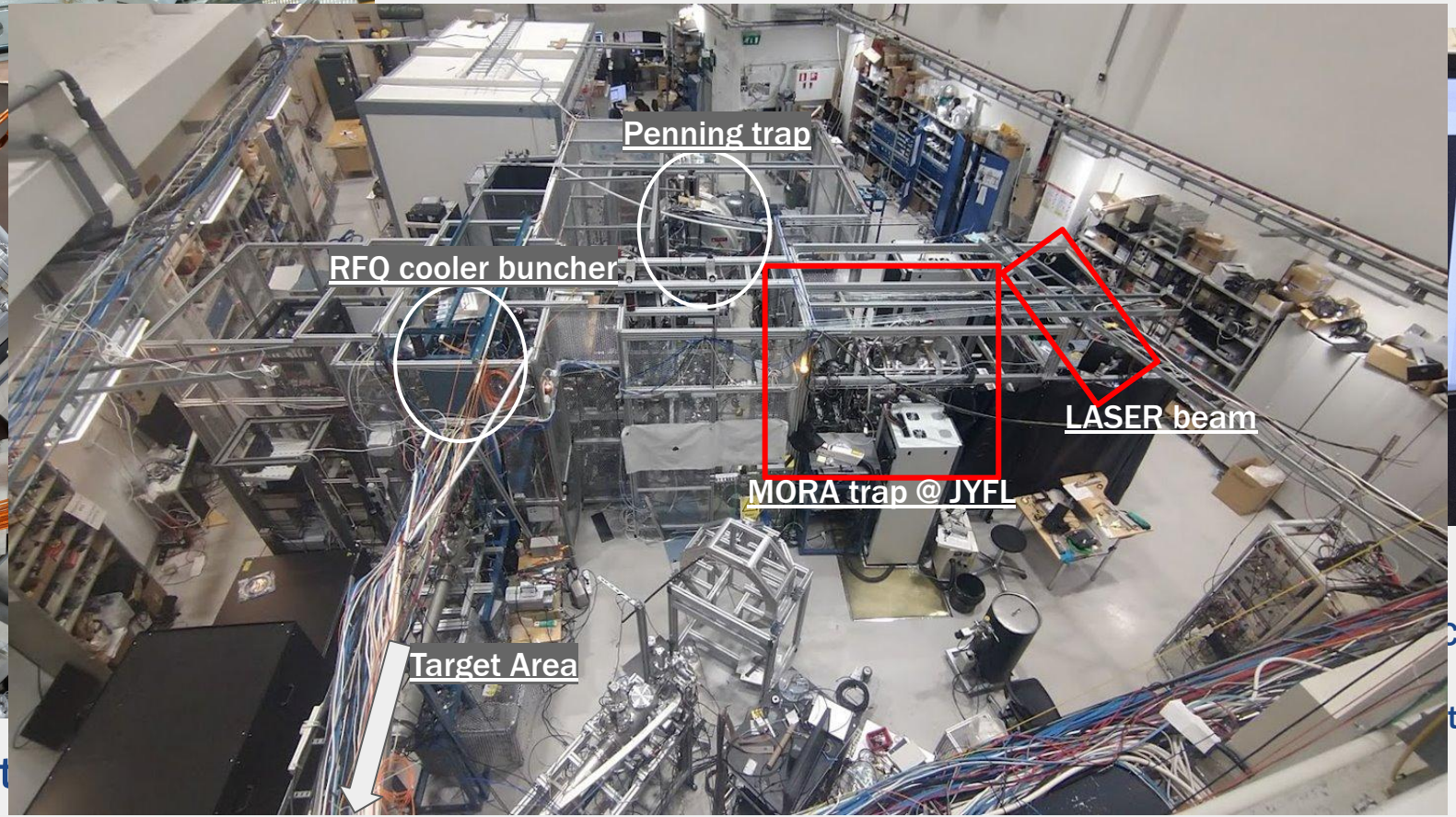
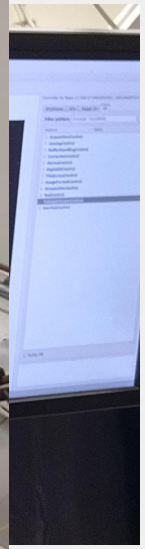
- Installation @ JYFL -







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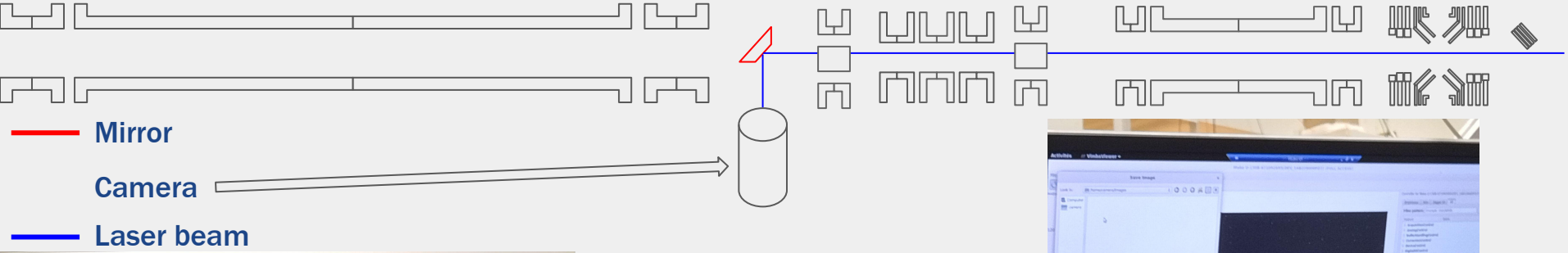
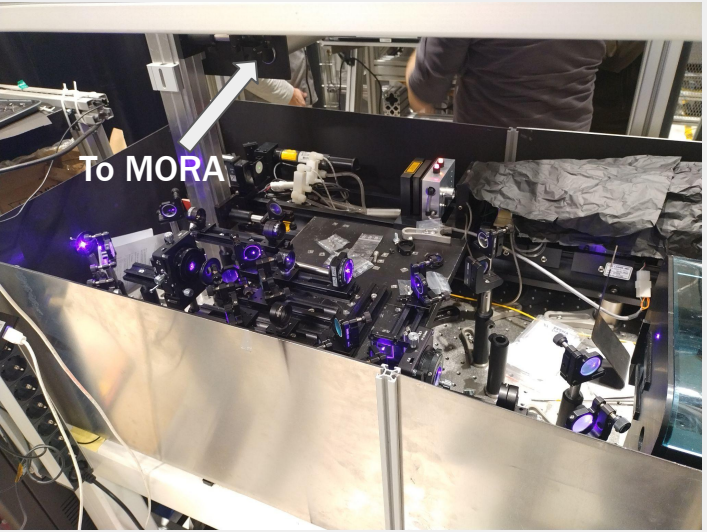
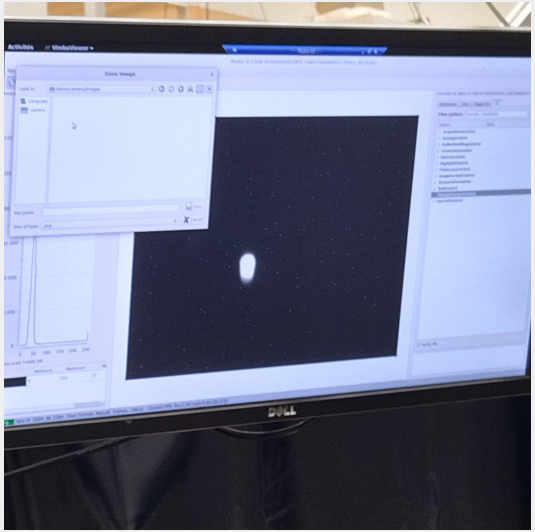
- Installation @ JYFL -







- Vacuum chamber correctly aligned with the JYFL line by the LPCC team
- Laser (Ti:Sa) set up @ 90mW and 280nm for the polarisation of the cloud
- Direct readout of the laser beam with the exterior camera

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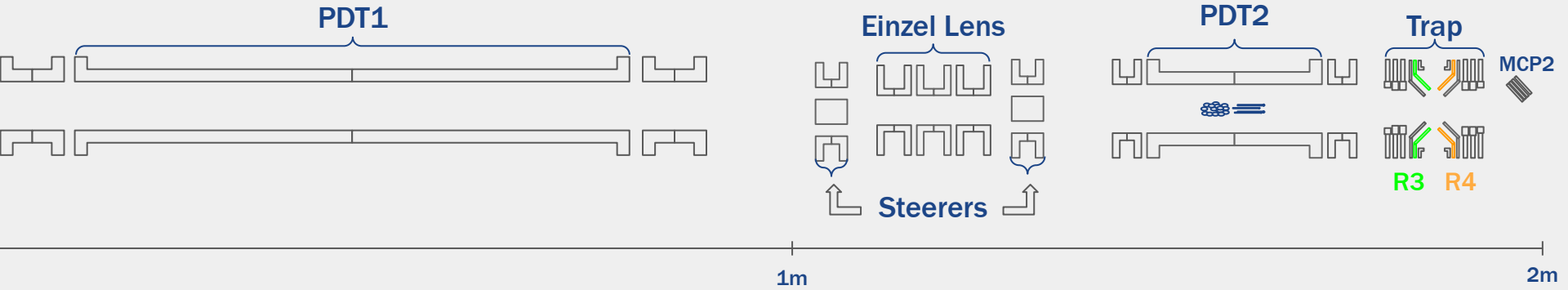
- Trapping principle -



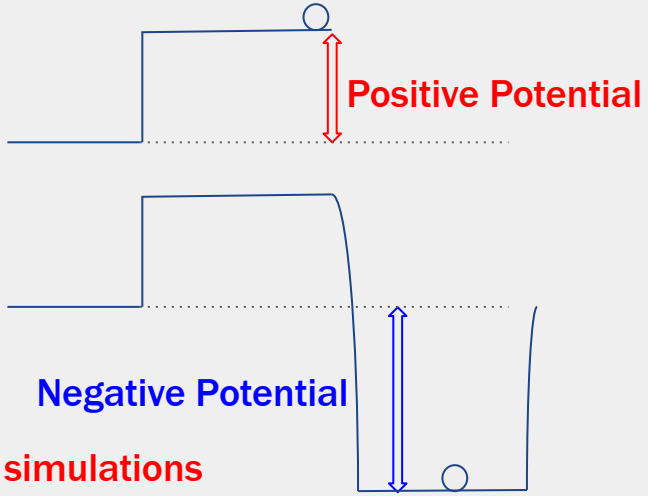
Travelling through the line:

- Pulse Drift Tube 1, first slowdown
- Steerer 1 to correct the beam direction
- Lens 1 to refocalise the beam
- Steerer 2 to adjust the beam
- Pulse Drift Tube 2, second slowdown

- R4 ⟶ Stop ions for trapping
- R3 ⟶ Eject ions, counted in MCP2

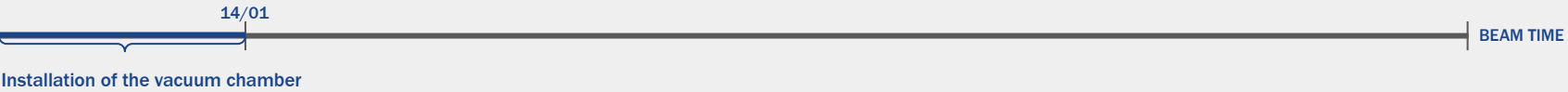
Two phases:

- Climb
- Down



Timings found by SIMION simulations

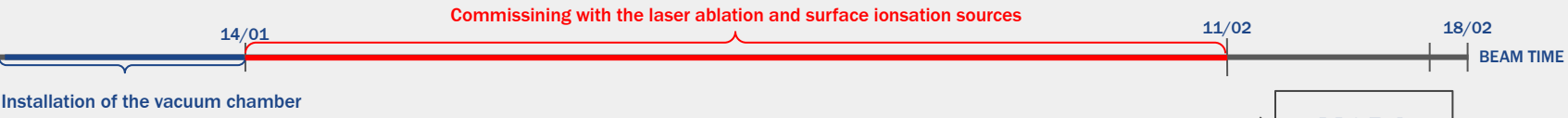
- Commissioning @ JYFL -

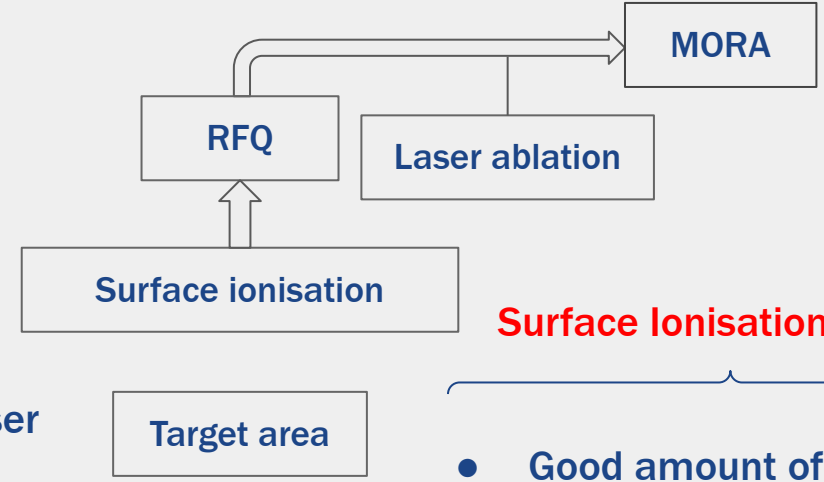


Use of three different sources:

- Laser ablation
- Surface ionization
- Spark

- Commissioning @ JYFL -





Laser ablation source

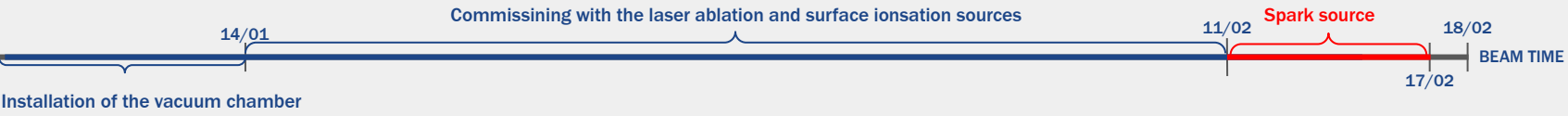
- Sodium atoms ionized by a YAG laser
- Salt pellet but difficulties to ionize and fluctuations
- Metallic pellet -> easier to use but uncertainties on the mass

⇨ Did not work

Surface Ionisation source

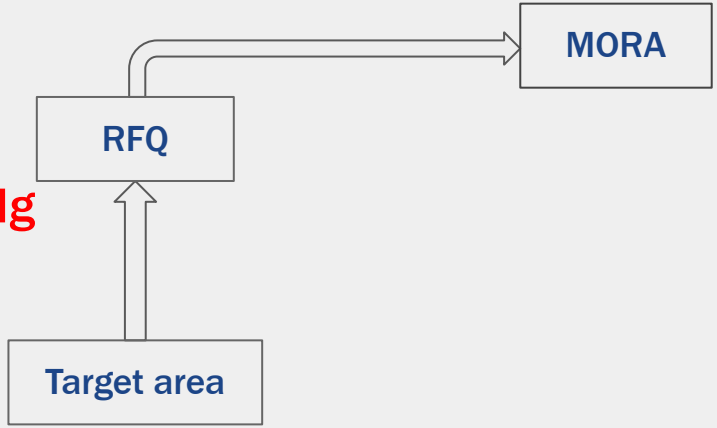
- Good amount of ions (3.8 nA)
- Use of RFQ
- But mostly Potassium according to ToF calculations

- Commissioning @ JYFL -



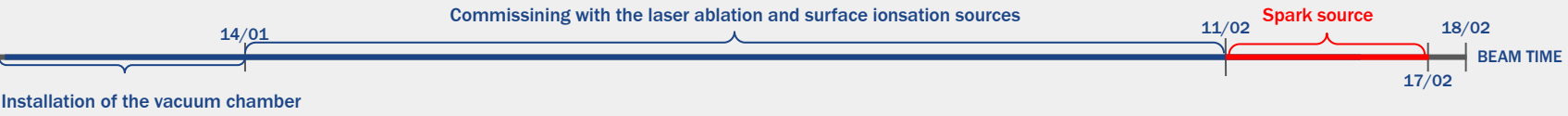
Spark source:

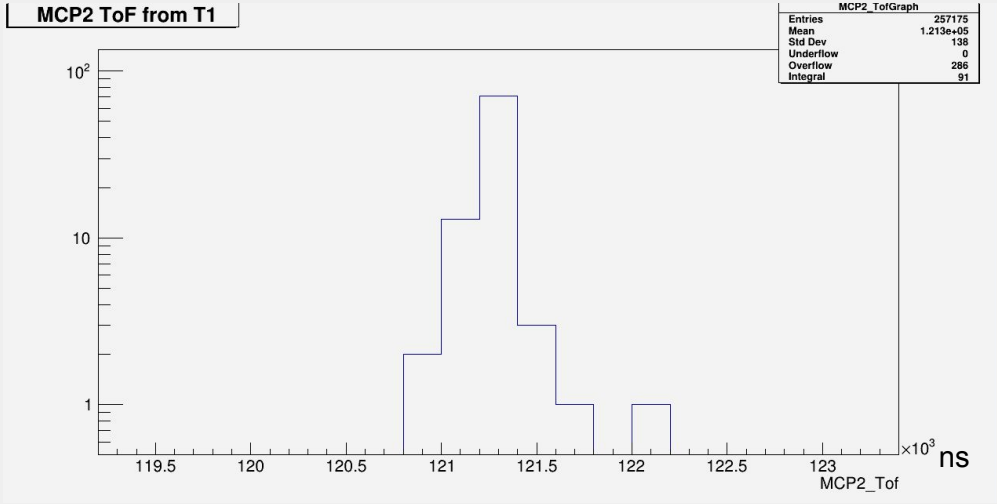
- Target area location: same path than ^{23}Mg
- Bunched by the RFQ cooler
- Trapping parameters from the LPC Caen commissioning[1] adapted and reproducible



1. Results already presented at the colloque GANIL 2021 and JRJC

- Commissioning @ JYFL -





Spark source:

- **Target area location: same path than ^{23}Mg**
- **Bunched by the RFQ cooler**

First ions(23Na) trapped by MORA at JYFL

- **Trapping parameters from the LPC Caen commissioning[1] adapted and reproducible**

1. Results already presented at the colloque GANIL 2021 and JRJC

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- Online measurement: Results -

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24Mg (p,d) 23Mg reaction with a high production rate ~10^5 pps/µA of p

Trapping efficiency:

- 5 % for a 500 ms trapping time
- reached 50% in specific conditions (continuous RF during R3/R4 phase)

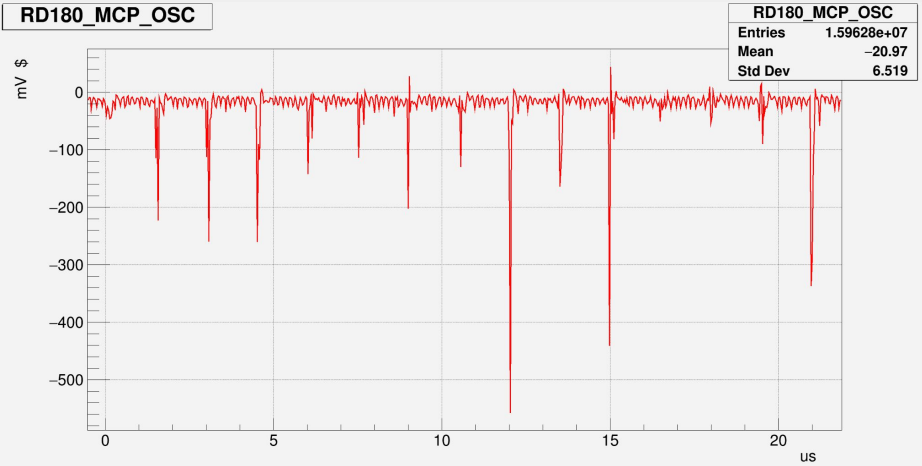
Conclusion: The trap is working correctly with radioactive conditions

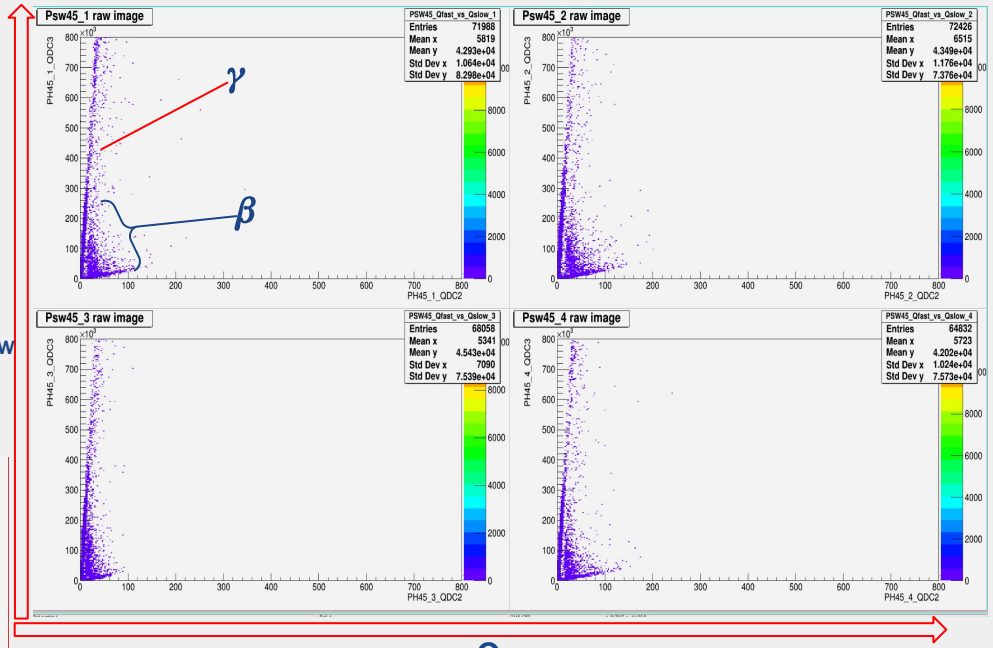
However:

- Large ^{23}Na contamination : 1/2000 of ^{23}Mg (in the best conditions)
- Pulsing down large bunch (20-100µs) from the saturated RFQ is inefficient due to MORA acceptance (~3µs)
- RF noises seen on recoil ion detectors

- Detectors -

RF noise seen on RIDE detectors





23Mg spectra on Detector 45° (4 Phoswich)

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Things to be improved for the next beam time:

- Better ratio $^{23}Mg/^{23}Na$ (1/100 max)
  - Full cleaning of the target area
- The width of bunch via the RFQ (IGISOL side)
  - Adapt the RF of the mini buncher
- Fix the RF issue on the recoil ion detector
  - Test another RF generator/amplifier
  - Strongly reduce the distance between the RIDE output signals and their PA boxes
- Install a source for offline tests (w/o RFQ)

Next dates:

- 02nd to 05th of May 2022 @ JYFL: MORA workshop
- 27th to 31st of May 2022: Beam time for online measurement

Thank you for your attention!

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