Generation of contaminant-like beams for magnetic spectrometers characterization

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Introduction:

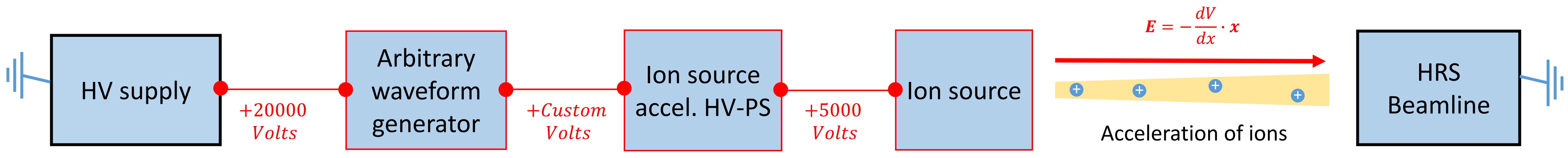
Characterizing a (high resolution) magnetic mass separator can be often tricky as it is difficult to find a stable ion source providing species with close enough masses to separate.

As these instruments perform a momentum separation ($B \cdot \rho = p/q$), their mass and energy resolution are strictly the same at first order. One can use this property to characterize the mass resolution of a spectrometer through its energy resolution.

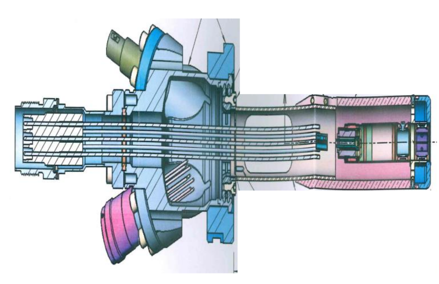
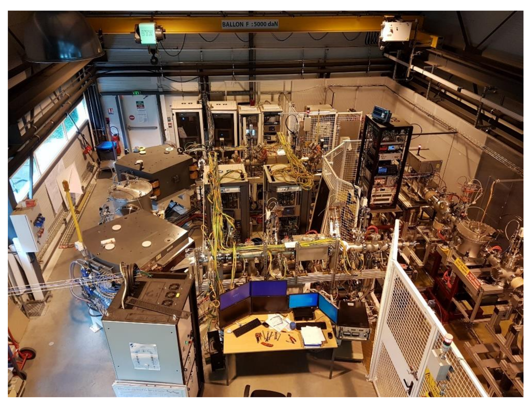
Hence, a monoisotopic beam with multiple close energies can be used to test and characterize a magnetic spectrometer in almost real separation conditions.

Create a custom energy distribution of a single monoisotopic beam : *a matter of relative potentials*

- Acceleration of ions depends on the potential between the source and the beamline
- High voltage supplies can't handle fast and small voltages variations (<V on many kV)
- A pulse generator can supply such variations





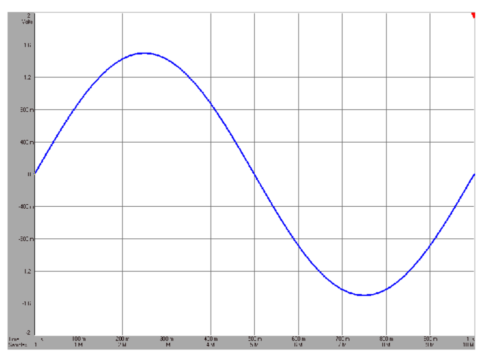
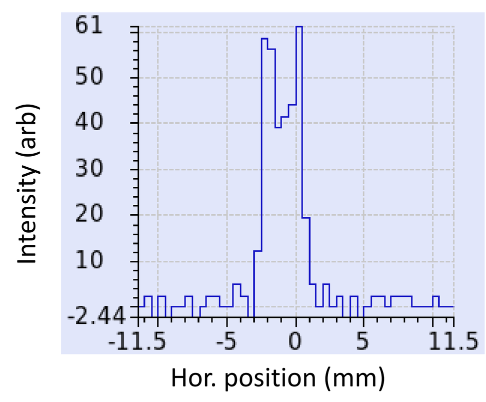




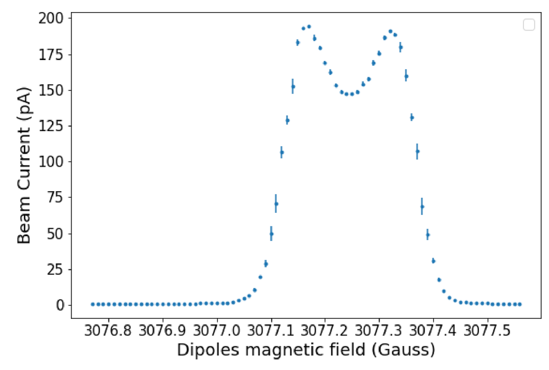
$$Energy_{total} = 25000eV + custom\ distribution\ (\pm 5eV)$$

Different types of distributions

Beam on BPMs — Magnetic spectrum

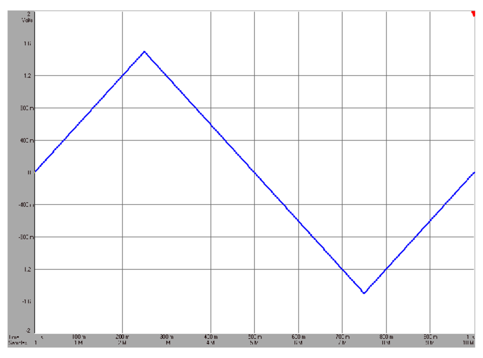
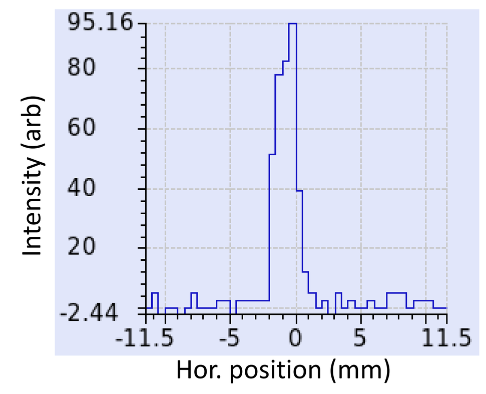
Sinusoïdal signal
3V peak-to-peak
f = 1kHz

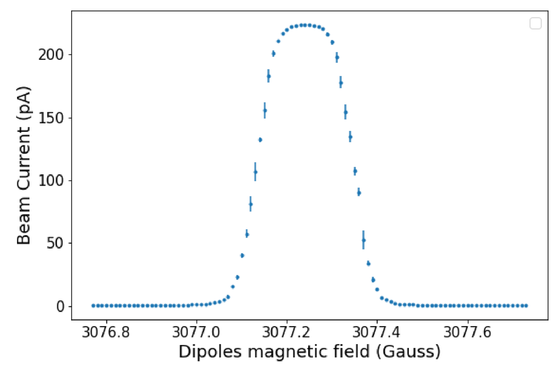





A sinusoidal signal creates a double pic on the energy distribution. This phenomenon was first observed naturally due to a voltage "jitter" on the acceleration HV plateform.

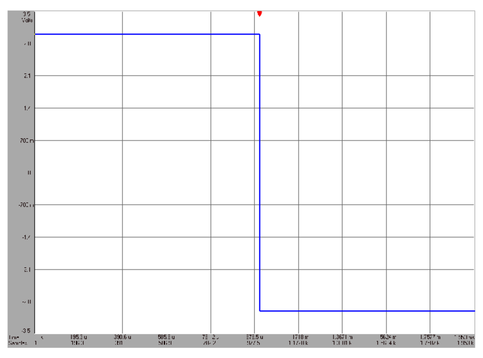
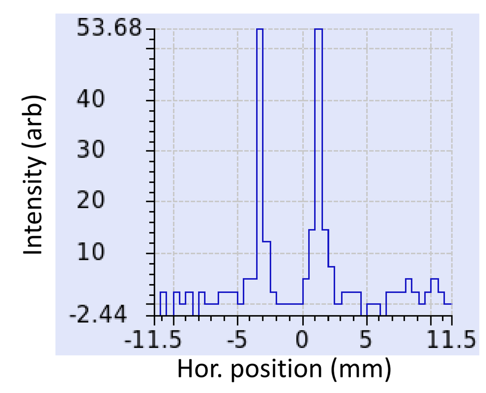
Triangle signal
3V peak-to-peak
f = 1kHz

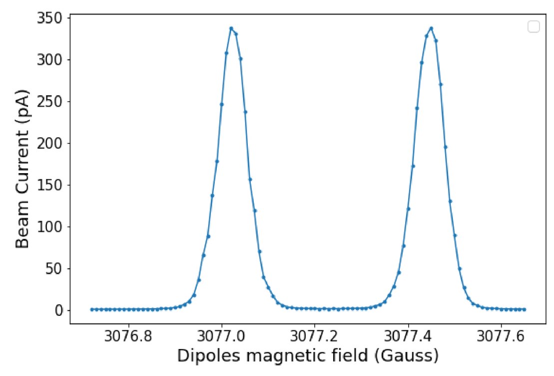





Triangle signal populates equally all energies within its range, leading to a uniform energy distribution. The resulting beam is the convolution product of a "plateau" and a Gaussian.

Square signal
6V peak-to-peak
f = 1kHz

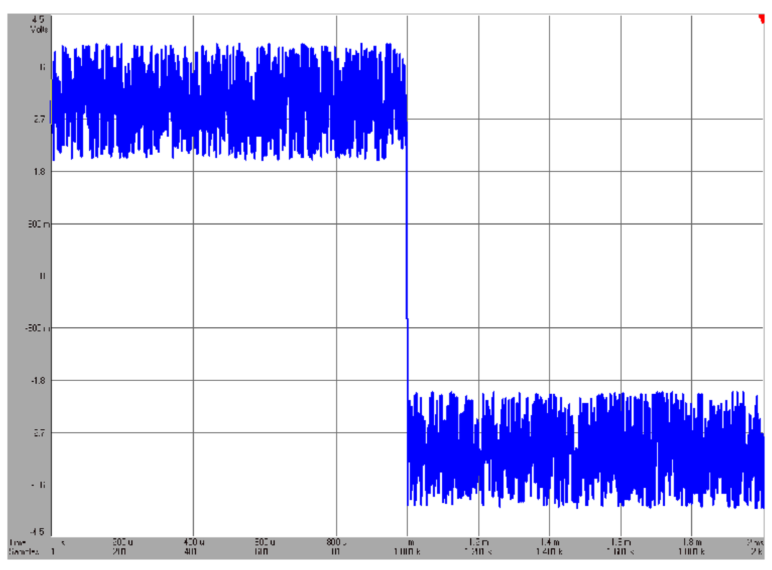





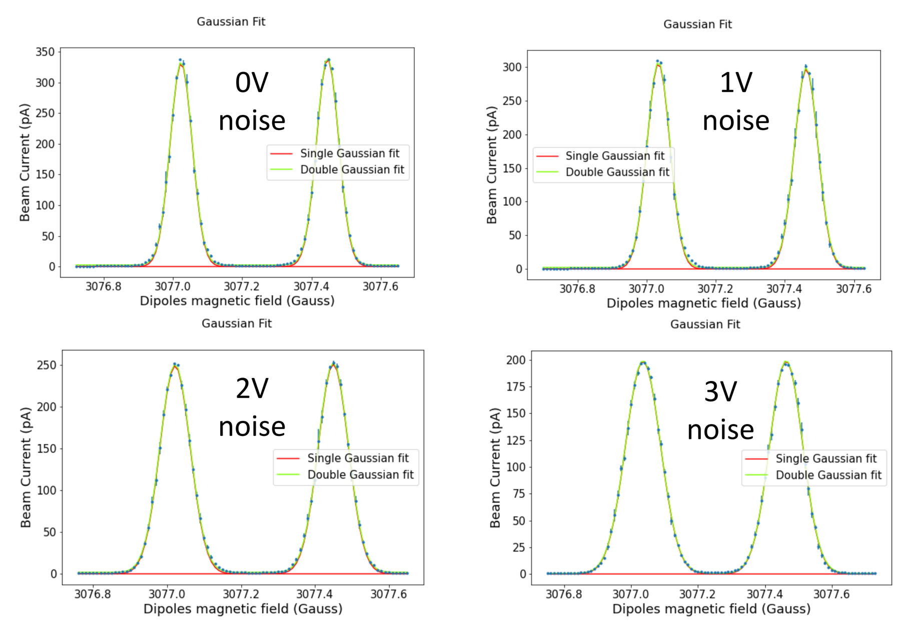
A square signal allows to populate two (or more) energies, leading to a clean separation of the energies. The amplitude of the signal determines the beams separation while its duty factor changes the beams respective intensities.

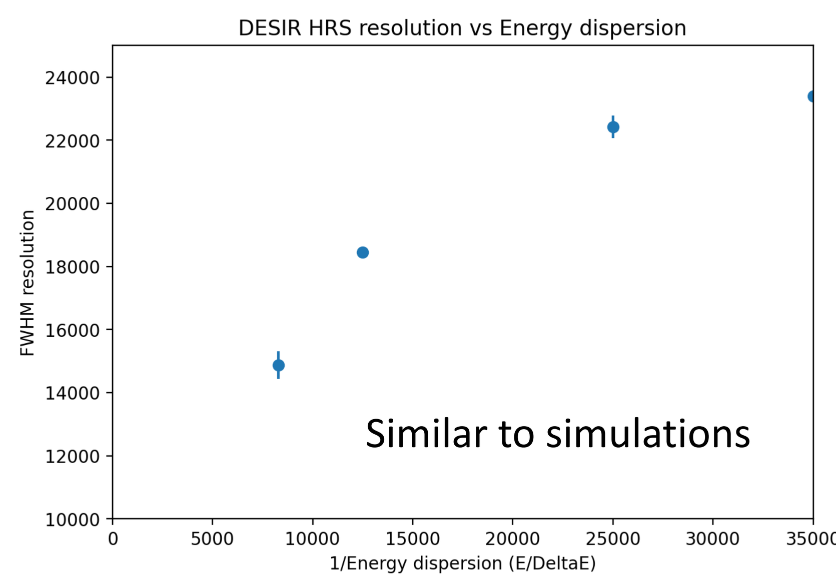
Characterisation of the spectrometer

Square signal
6V peak-to-peak
f = 1kHz
Noise level : 2V

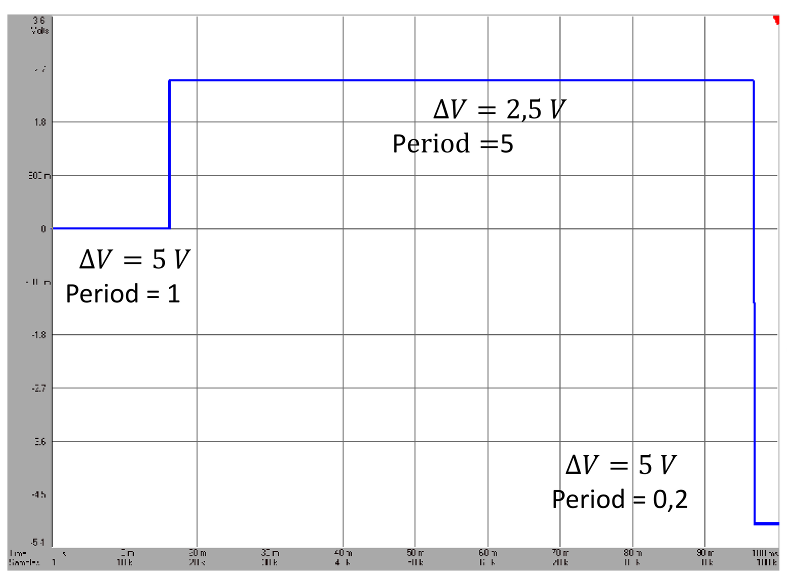


Increase the energy dispersion

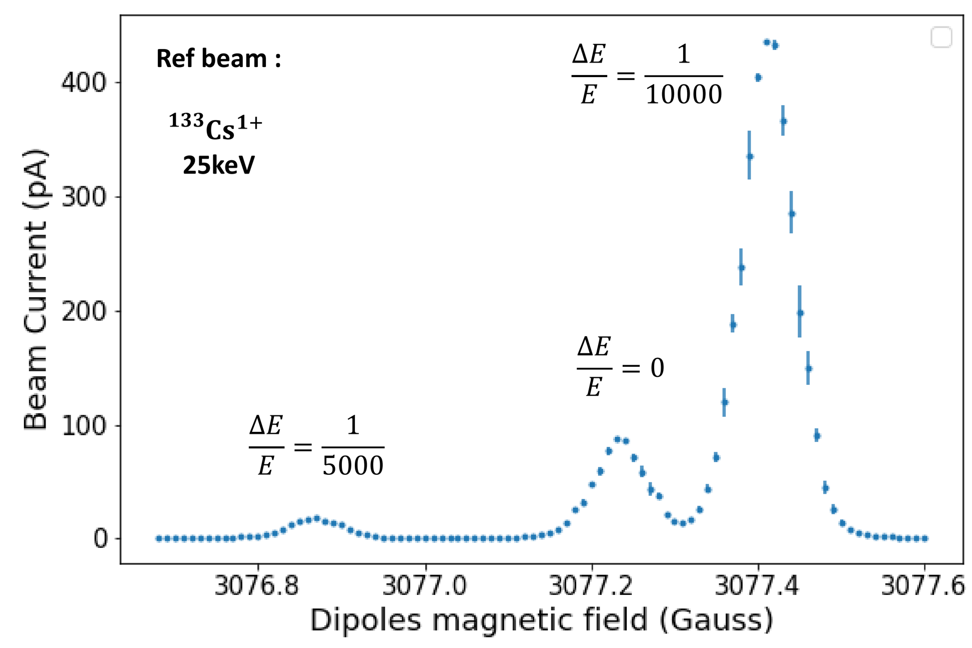




Square signals
Multiple steps
f = 1kHz
3 species generated



Create custom beam contaminants



Conclusion:

By adding up potentials from different sources, we are able to generate small and fast potential variations on high voltages acceleration systems.

An arbitrary signal generator allows us to create a custom energy distribution of the beam before sending it to the HRS.
This custom energy distribution can then be used to characterize such a spectrometer in quasi-real mass separation conditions.

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References :

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[3] Michaud, J. et al. "Status on the DESIR High Resolution Separator Commissioning." (2022). https://arxiv.org/abs/2203.11214
[2] T. Kurtukian Nieto, R. Baartman, B. Blank, T. Chiron, C. Davids, et al.. SPIRAL2/DESIR high resolution mass separator. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, Elsevier,2013, 317, pp.284-289.