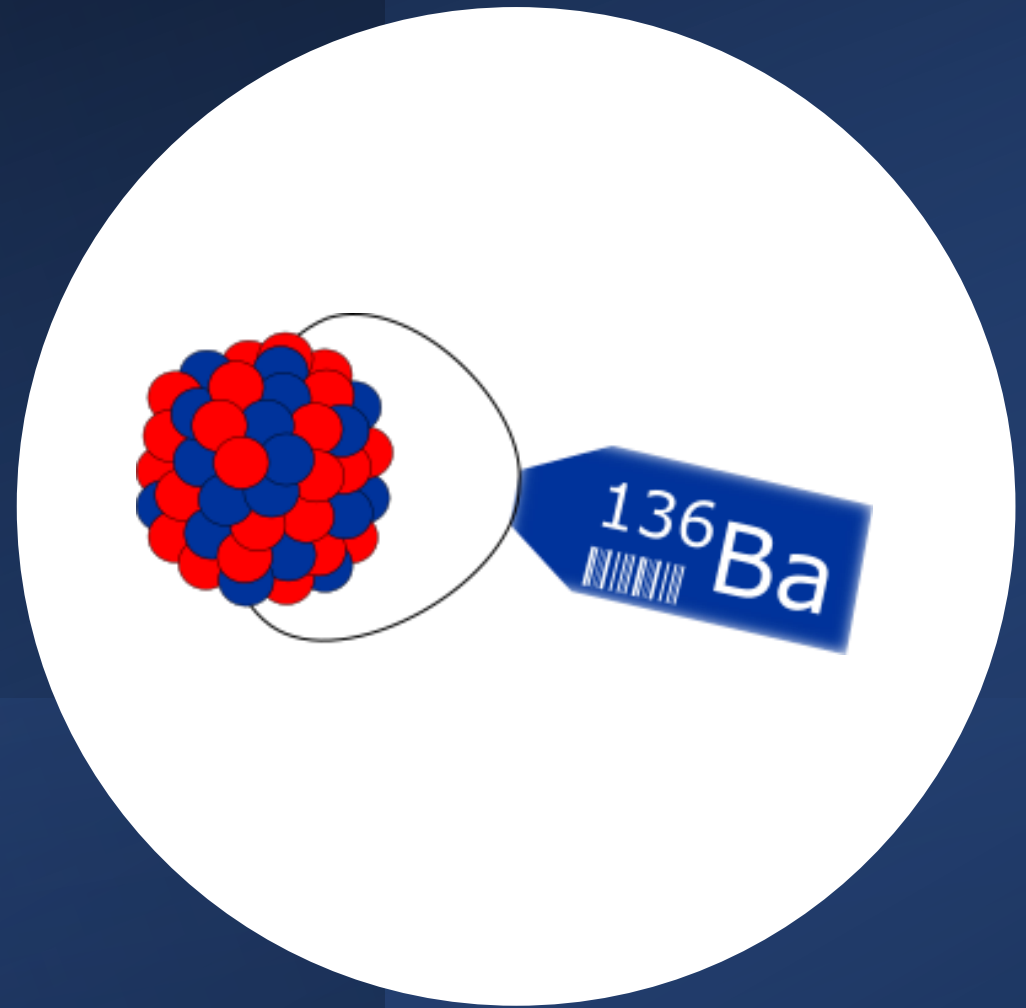


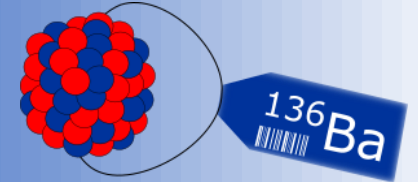
# Ion trapping for a Ba-tagging technique

Hussain Rasiwala

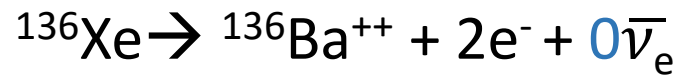
Brunner's neutrino lab,  
McGill University



# nEXO Experiment

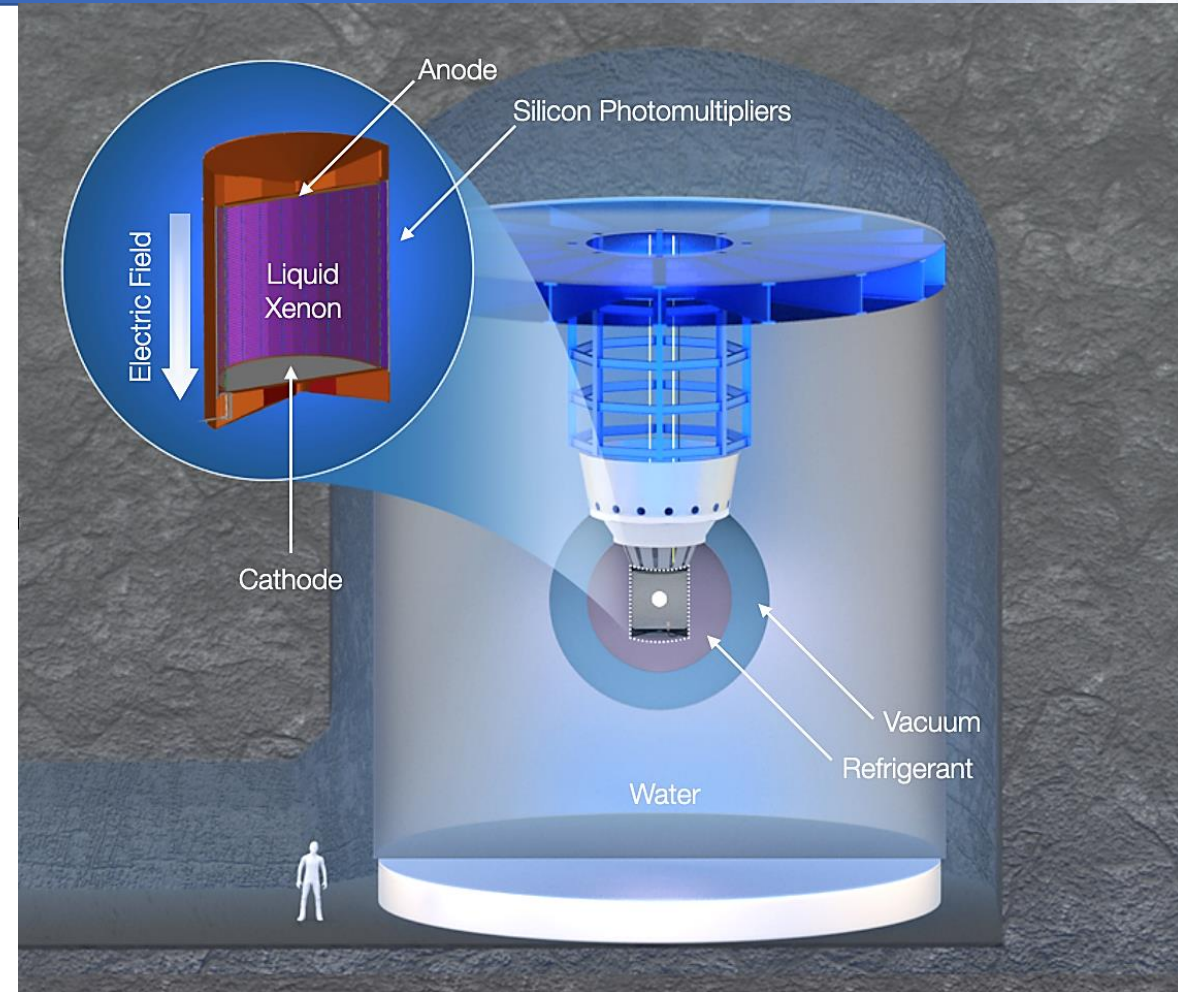


Searches for  $0\nu\beta\beta$  events in liquid xenon (LXe) enriched in Xe-136 isotope (90%).



✓ To reduce non-double-beta decay backgrounds, **Barium tagging** is proposed as a potential future upgrade to nEXO.

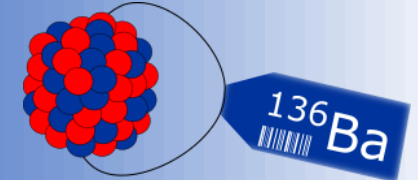
Detect Ba-136 ion at the position of potential  $0\nu\beta\beta$  decay.



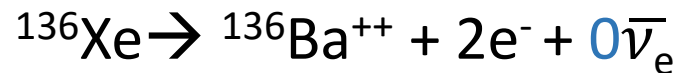
{nEXO pCDR, arXiv:1805.11142}

{Moe, M. K. *Physical Review C* 44.3 (1991) R931}

# nEXO Experiment

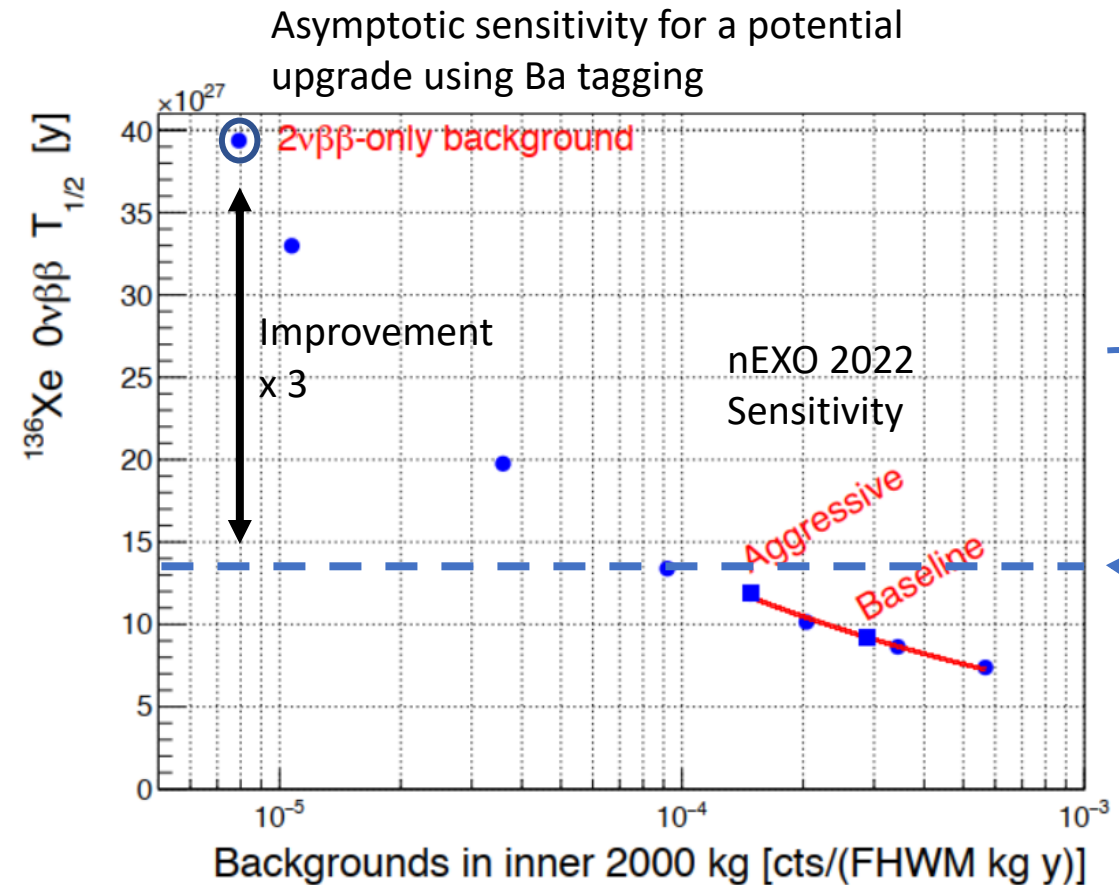


Searches for  $0\nu\beta\beta$  events in liquid xenon (LXe) enriched in Xe-136 isotope (90%).



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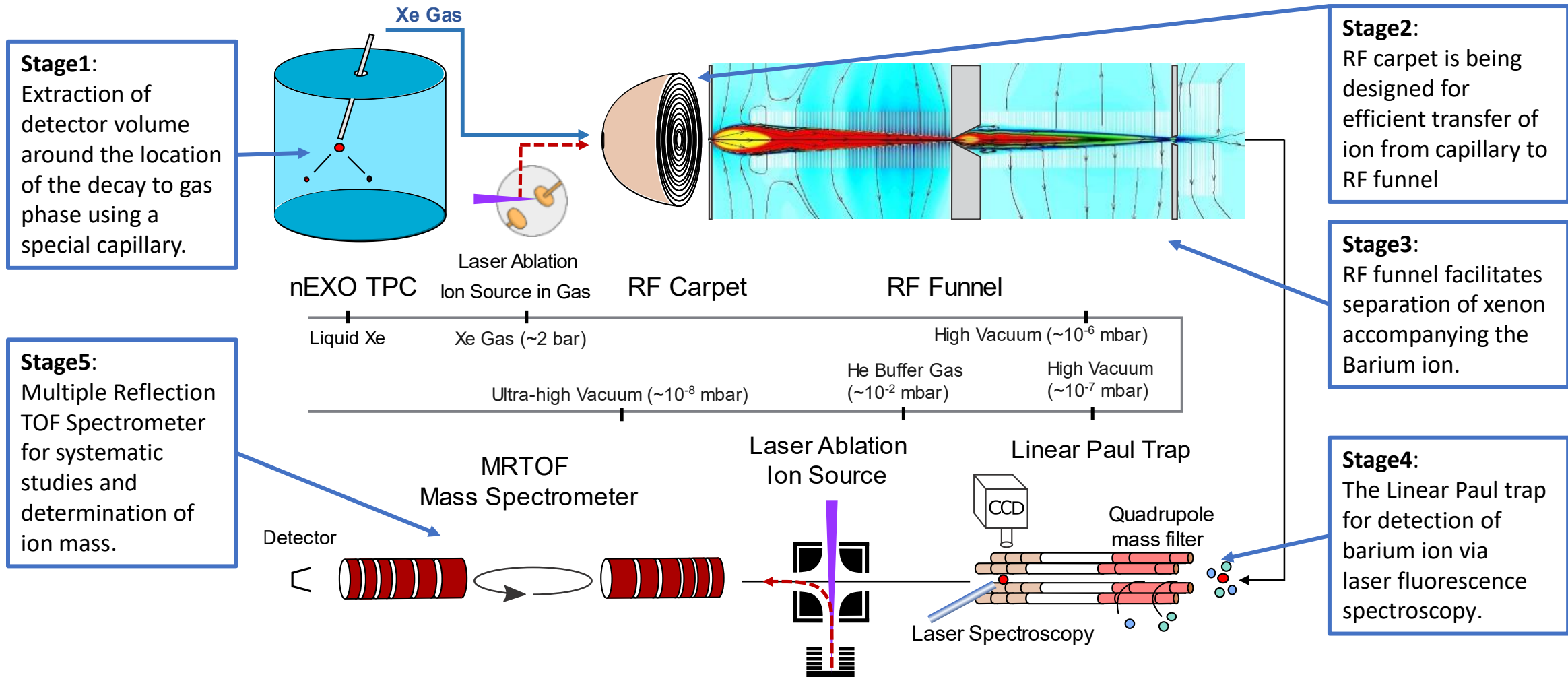
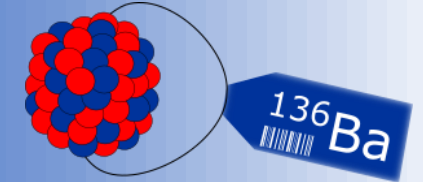
Detect Ba-136 ion at the position of potential  $0\nu\beta\beta$  decay.



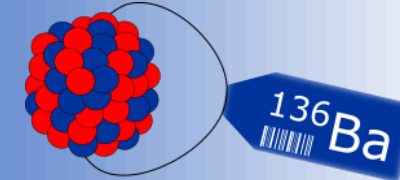
{Albert, J. B., et al. (2018). *Physical Review C*, 97(6), 65503.}

{Adhikari, G., et al. (2021) *Journal of Physics G: Nuclear and Particle Physics* 49.1: 015104.}

# Ba-tagging Technique (Canadian approach)

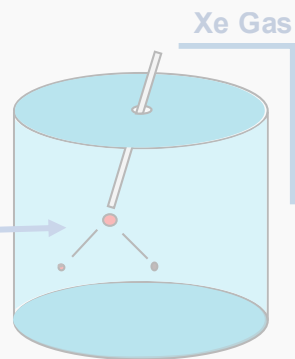


# Ba-tagging Technique (Canadian approach)



## Stage1:

Extraction of detector volume around the location of the decay to gas phase using a special capillary.



Xe Gas

nEXO TPC

Laser Ablation  
Ion Source in Gas

RF Carpet

RF Funnel

Liquid Xe

Xe Gas (~2 bar)

High Vacuum ( $\sim 10^{-6}$  mbar)

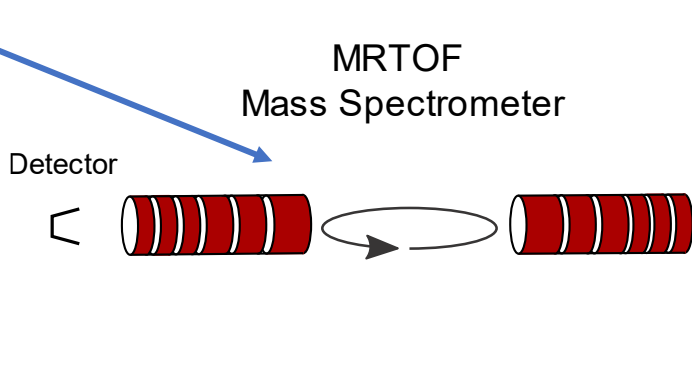
Ultra-high Vacuum ( $\sim 10^{-8}$  mbar)

He Buffer Gas  
( $\sim 10^{-2}$  mbar)

High Vacuum  
( $\sim 10^{-7}$  mbar)

## Stage5:

Multiple Reflection TOF Spectrometer for systematic studies and determination of ion mass.

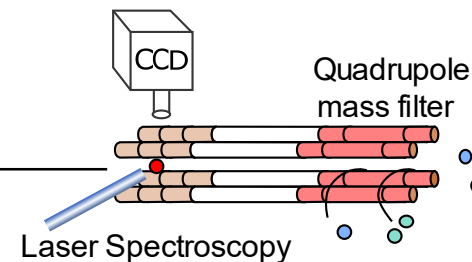


Detector

MRTOF  
Mass Spectrometer

Laser Ablation  
Ion Source

Linear Paul Trap



Laser Spectroscopy

Quadrupole  
mass filter

## Stage2:

RF carpet is being designed for efficient transfer of ion from capillary to RF funnel

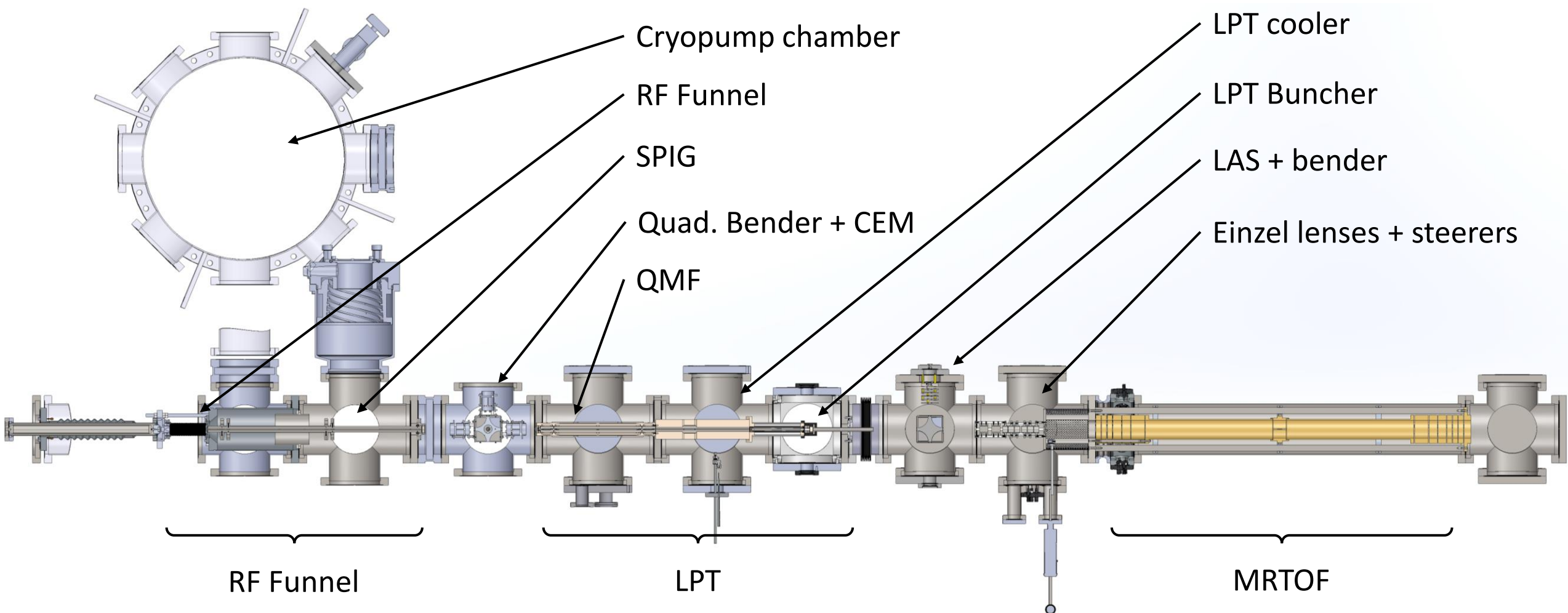
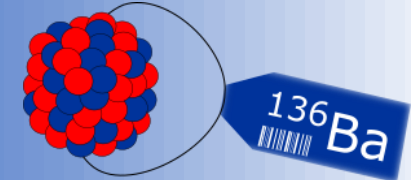
## Stage3:

RF funnel facilitates separation of xenon accompanying the Barium ion.

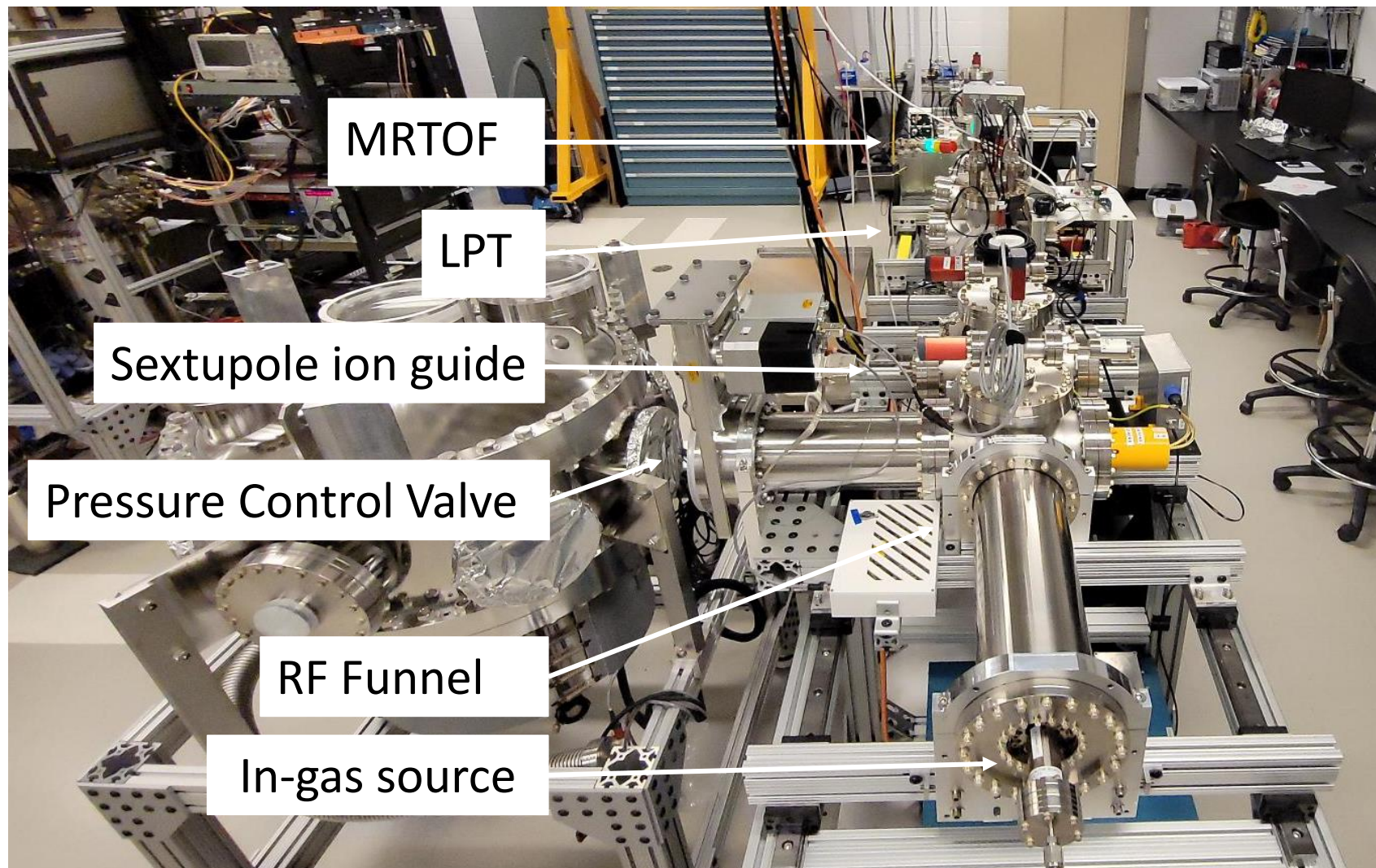
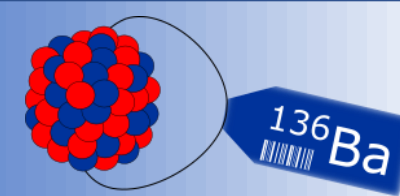
## Stage4:

The Linear Paul trap for detection of barium ion via laser fluorescence spectroscopy.

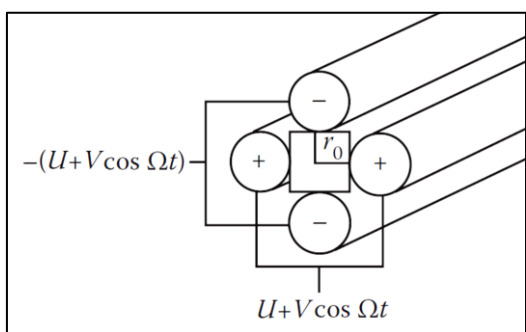
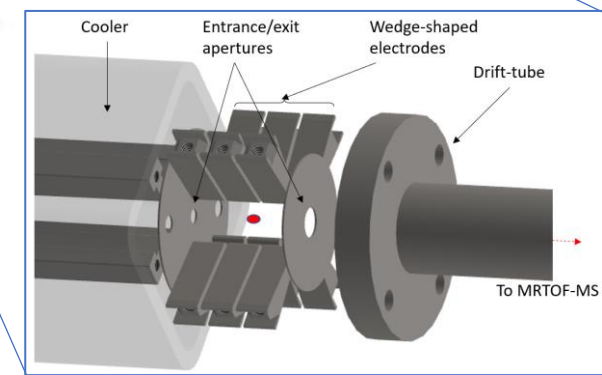
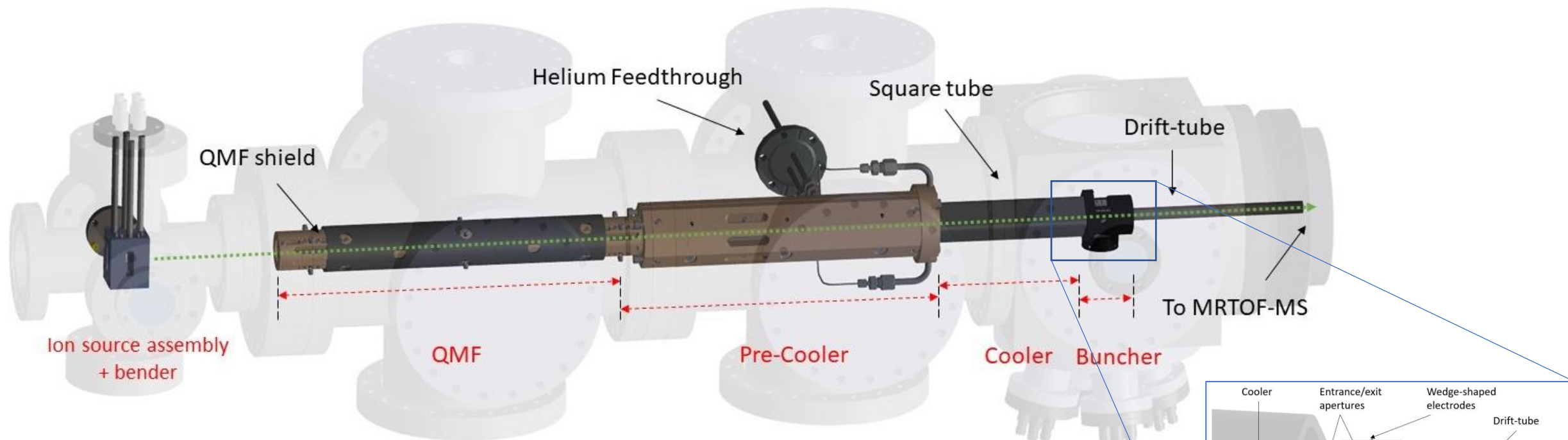
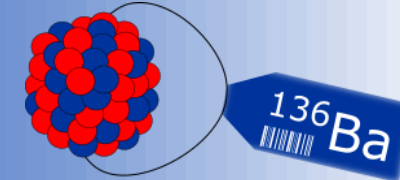
# Ba-tagging setup at McGill



# Ba-tagging setup at McGill



# LPT Setup

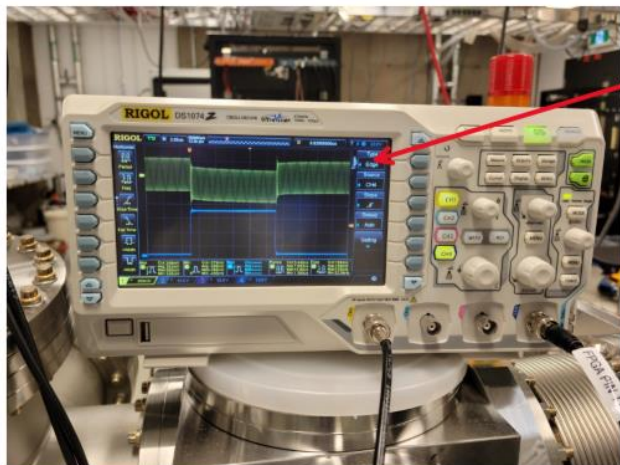
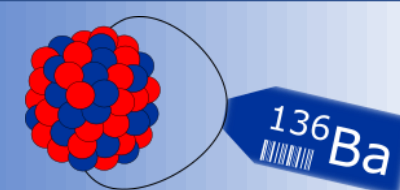


LPT setup is composed of following segments:

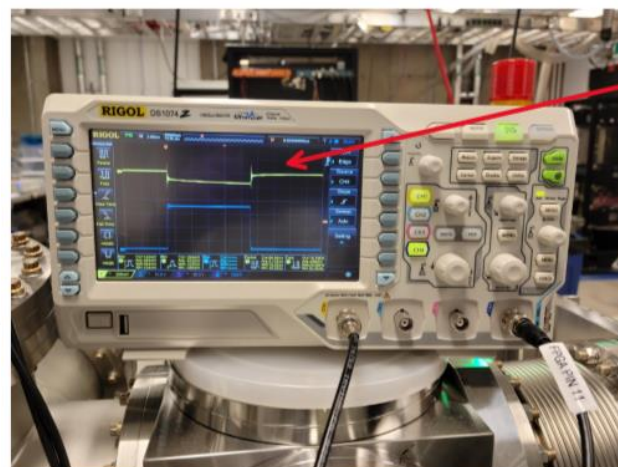
- Quadrupole mass filter (QMF)
- Precooler
- Cooler
- Buncher



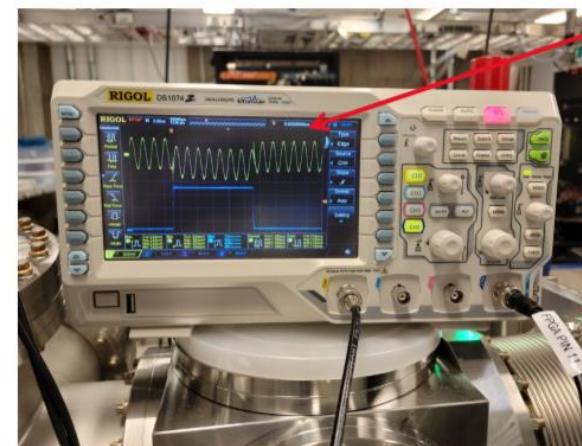
# Previous challenge with ion detection



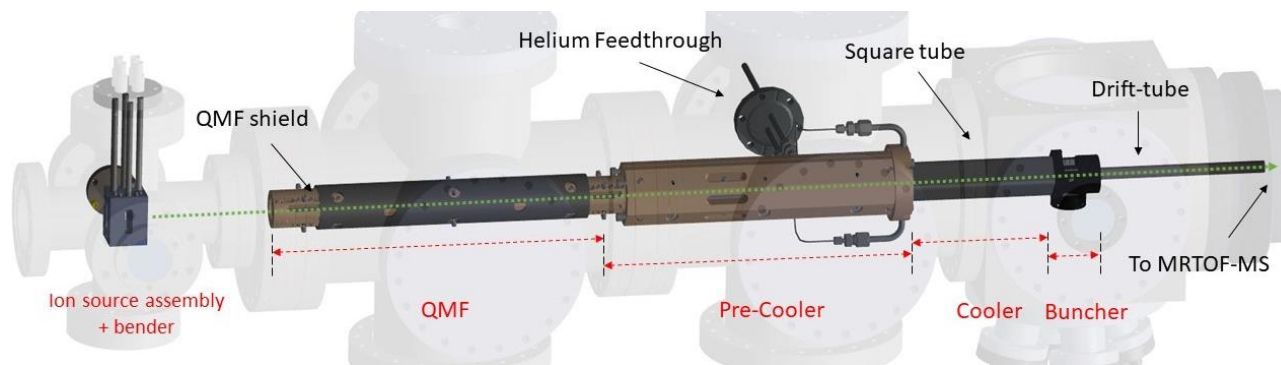
Actual signal that gets induced is mix of RF + switched signals with peak-peak potential reaching up to 0.5-1V



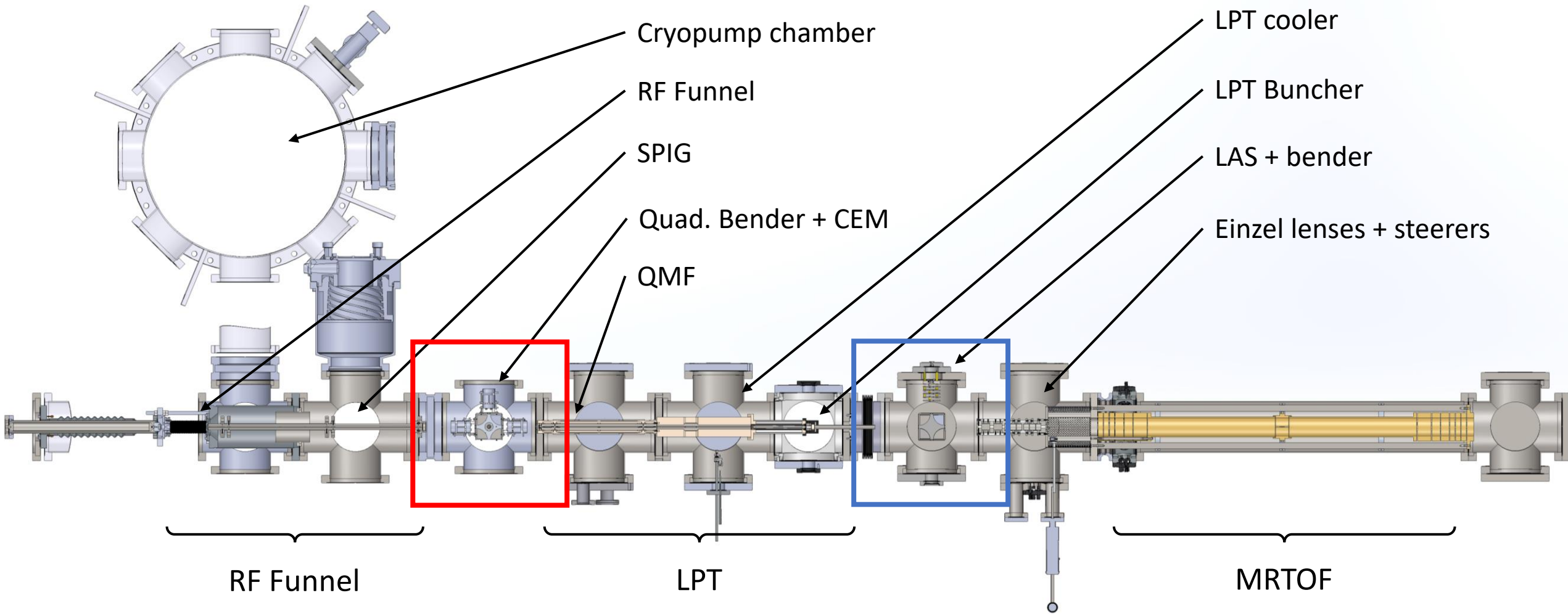
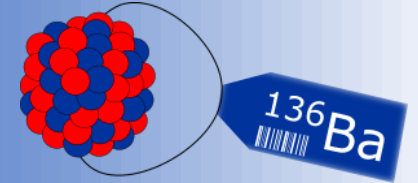
The induced signal from the switched potential triggers the pre-amp.



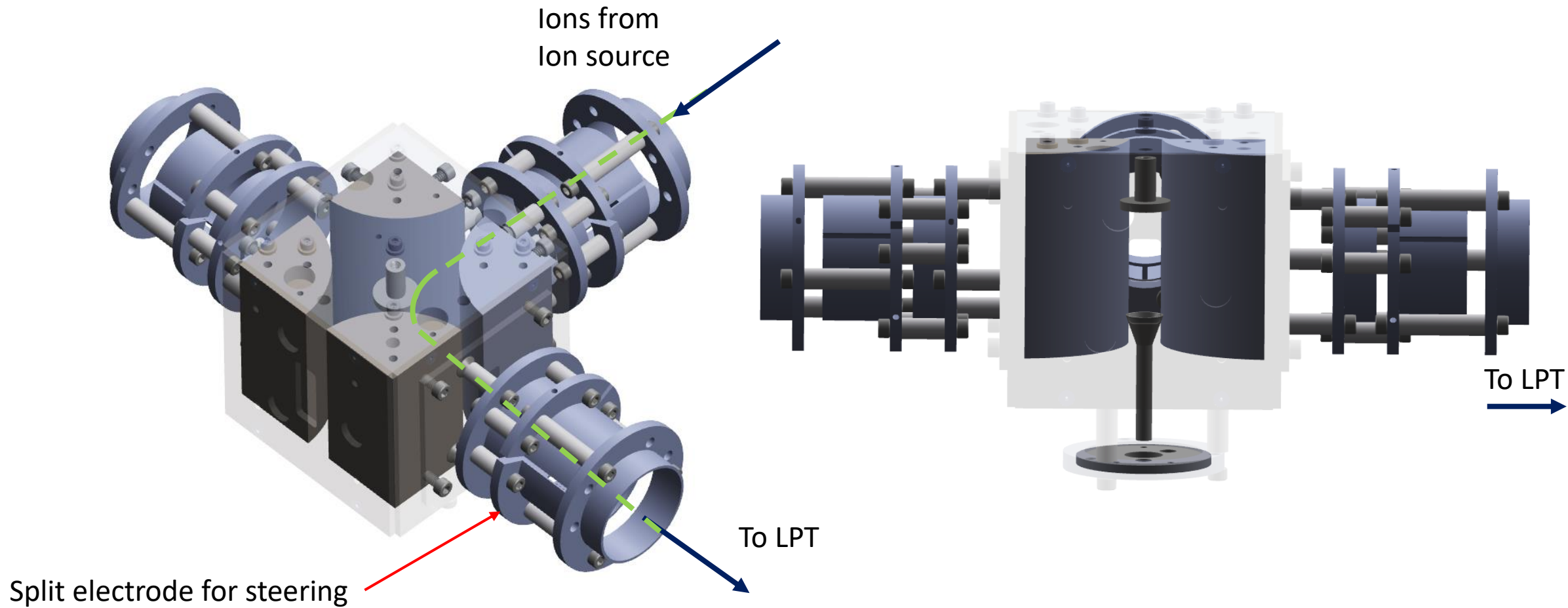
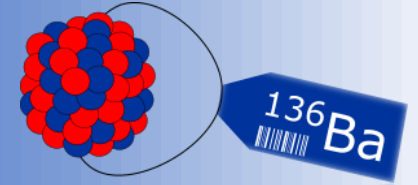
Single frame of above output



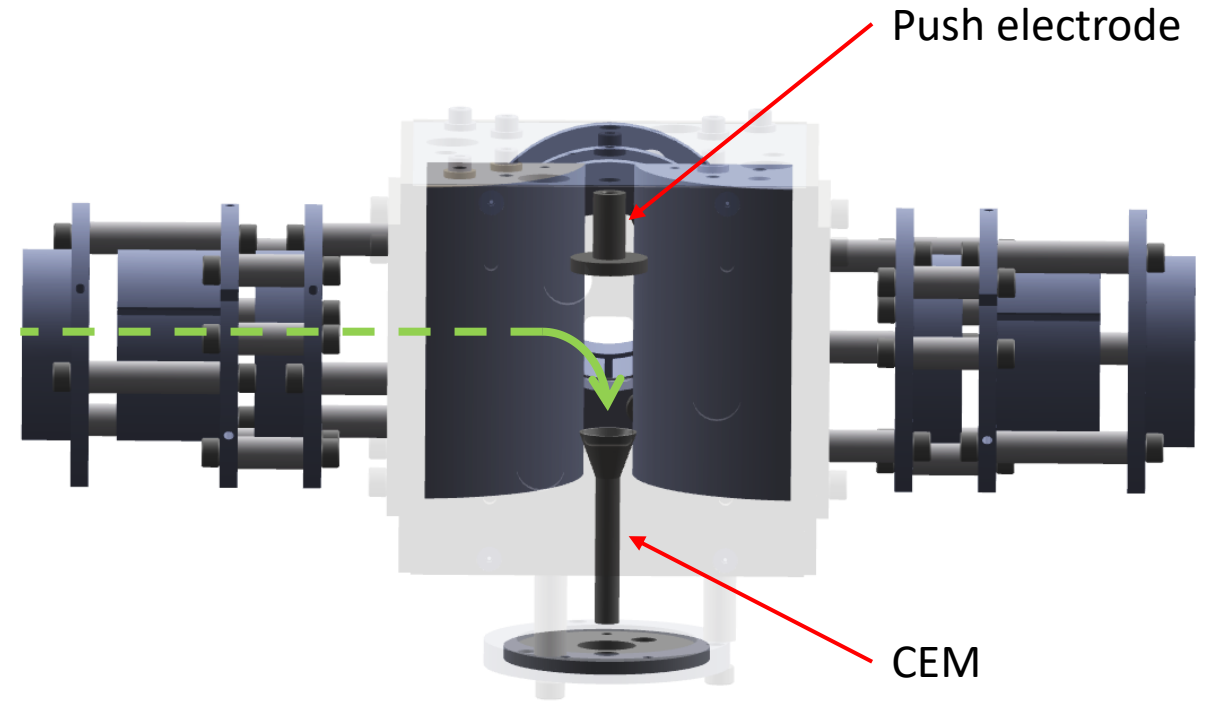
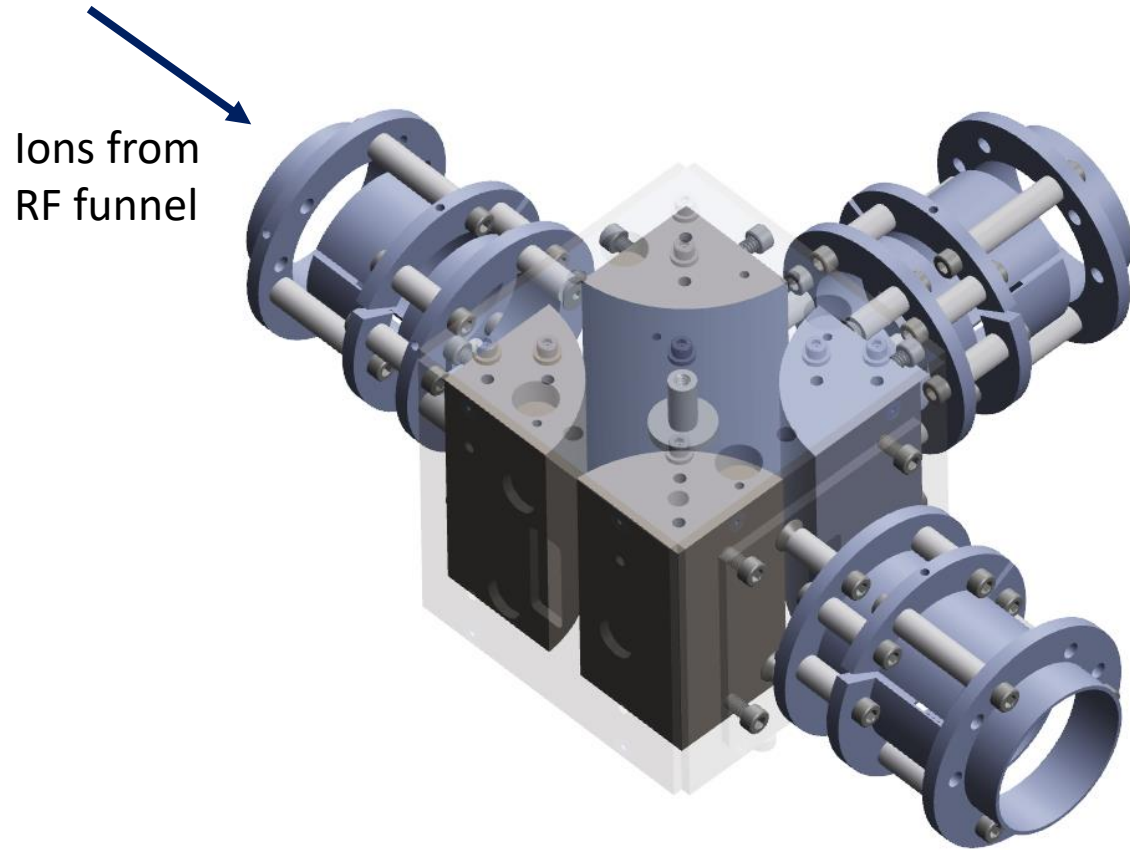
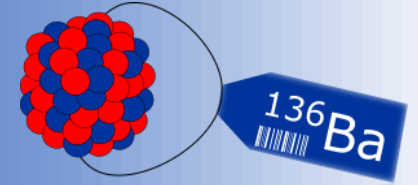
# Ion source and detector upgrades



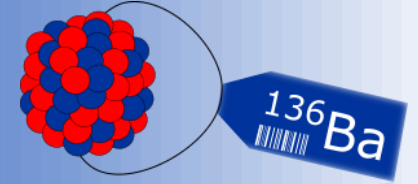
# Ion source and detector upgrades



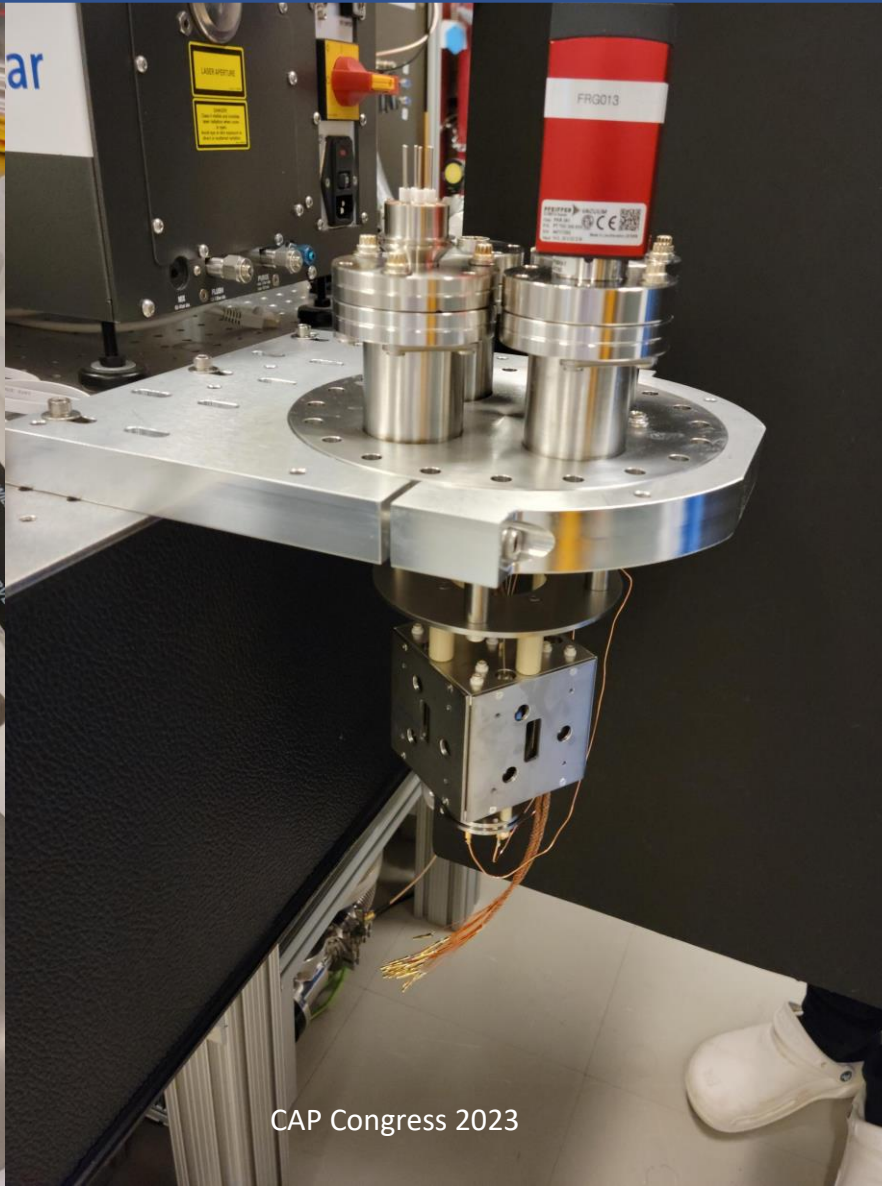
# Ion source and detector upgrades



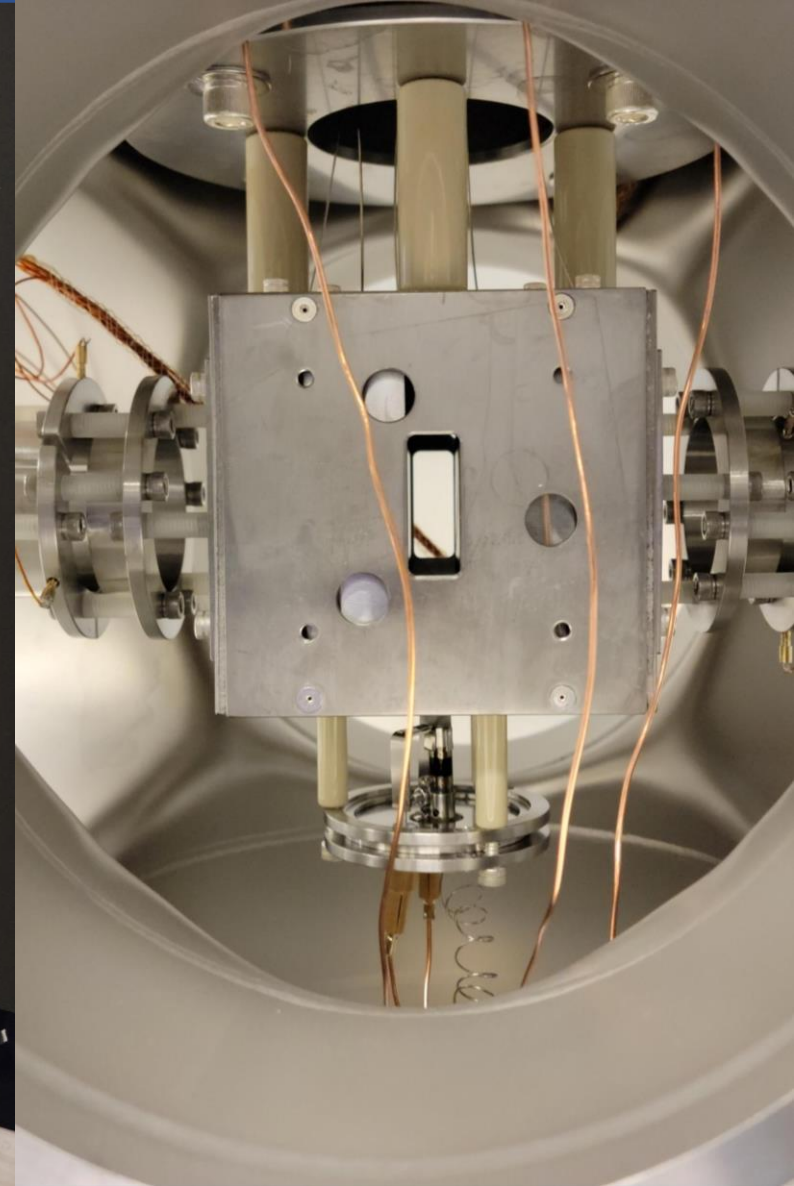
# Ion source and detector upgrades



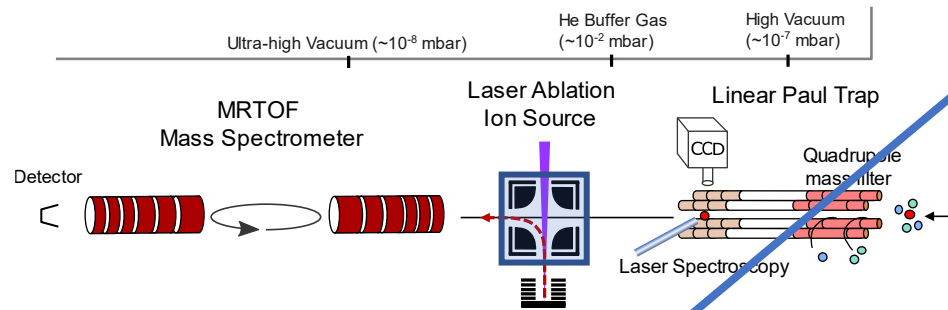
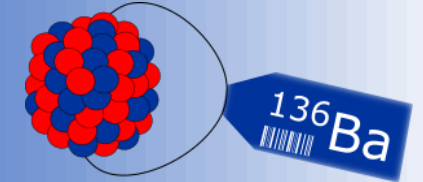
2023-06-22



CAP Congress 2023

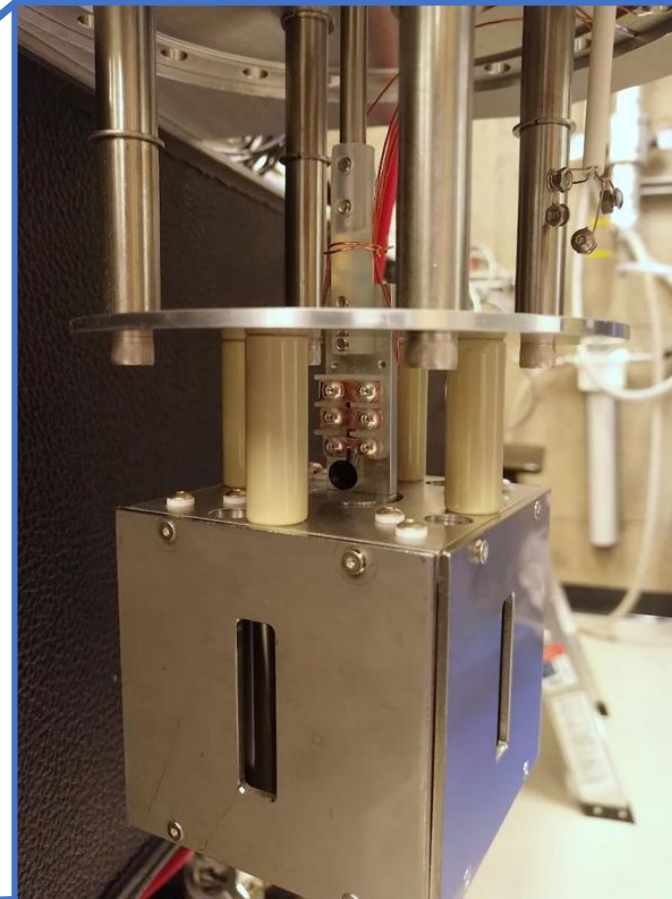
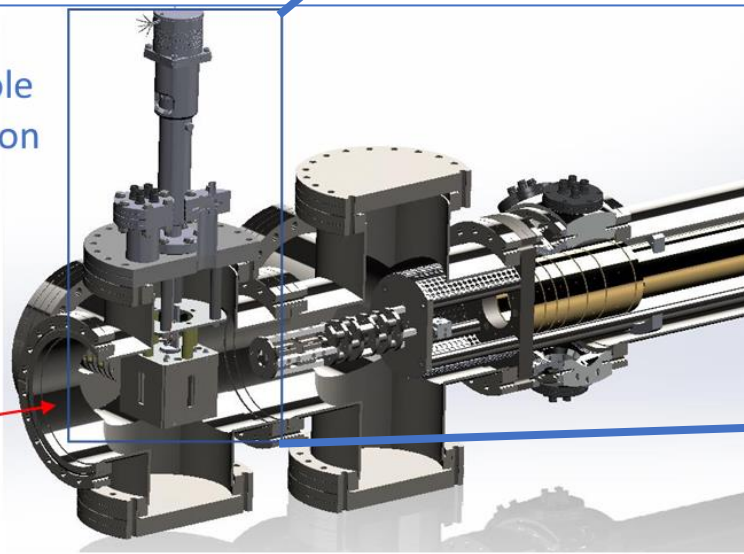


# Ion source and detector upgrades

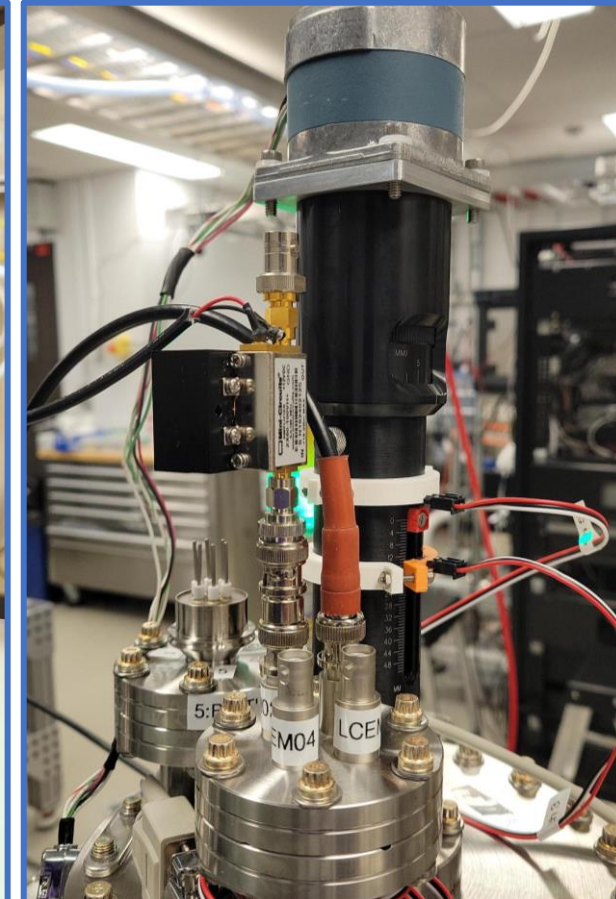


New quadrupole with channeltron sub-assembly.

Ions from LPT

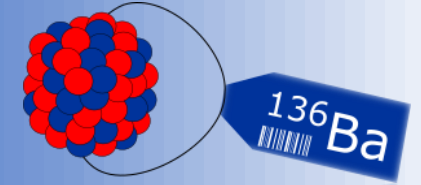


CEM and Quadrupole bender



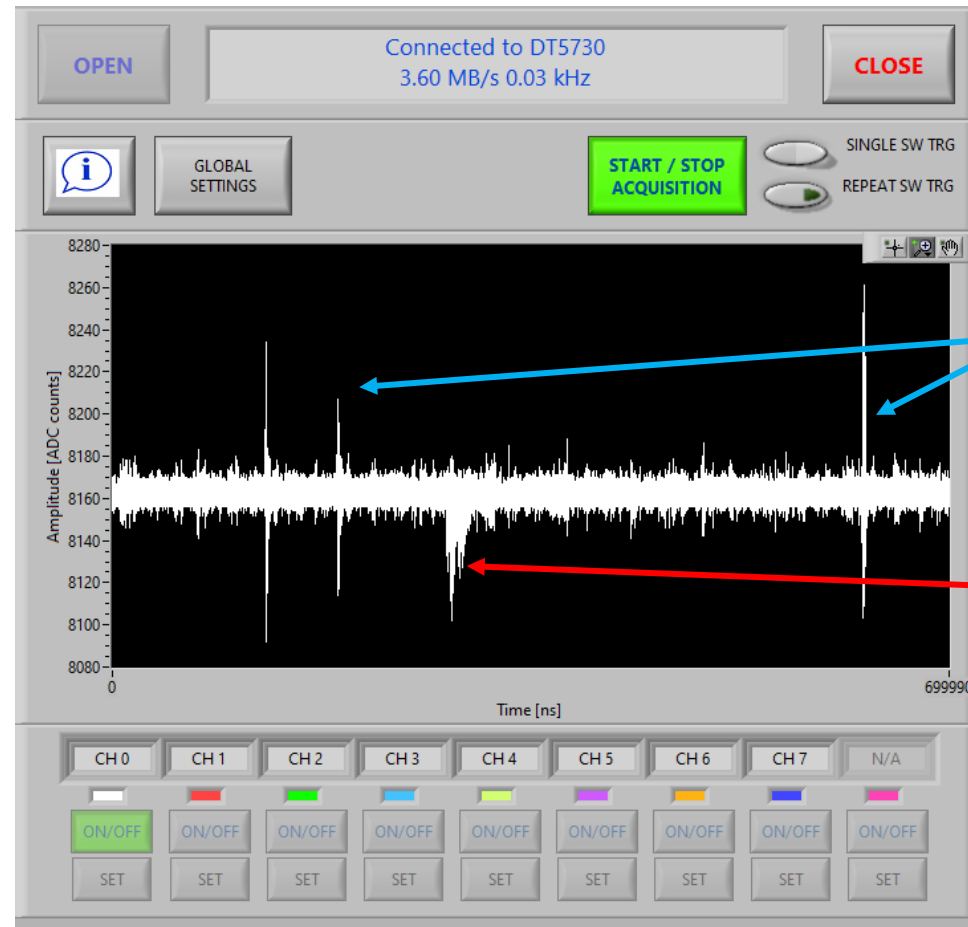
Actuator to control position of CEM

# Ion bunching with LPT



Ion bunching is currently being tested and optimized to achieve low ToF spread of the bunched ions  $\sim O(1 \text{ ns})$ .

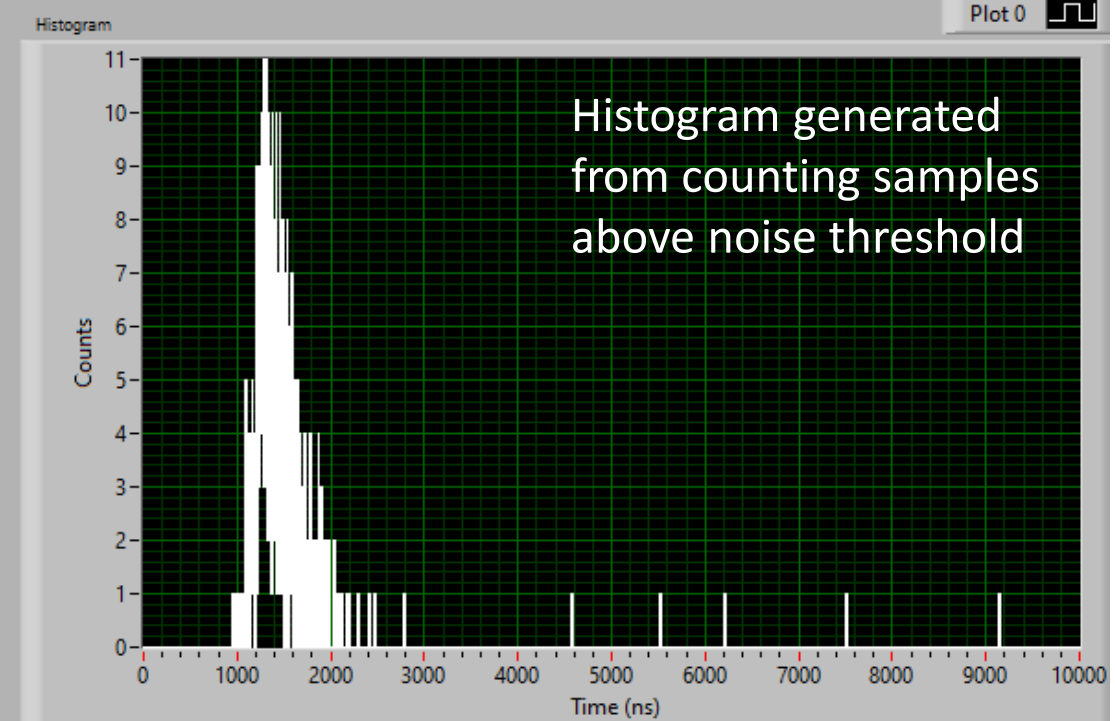
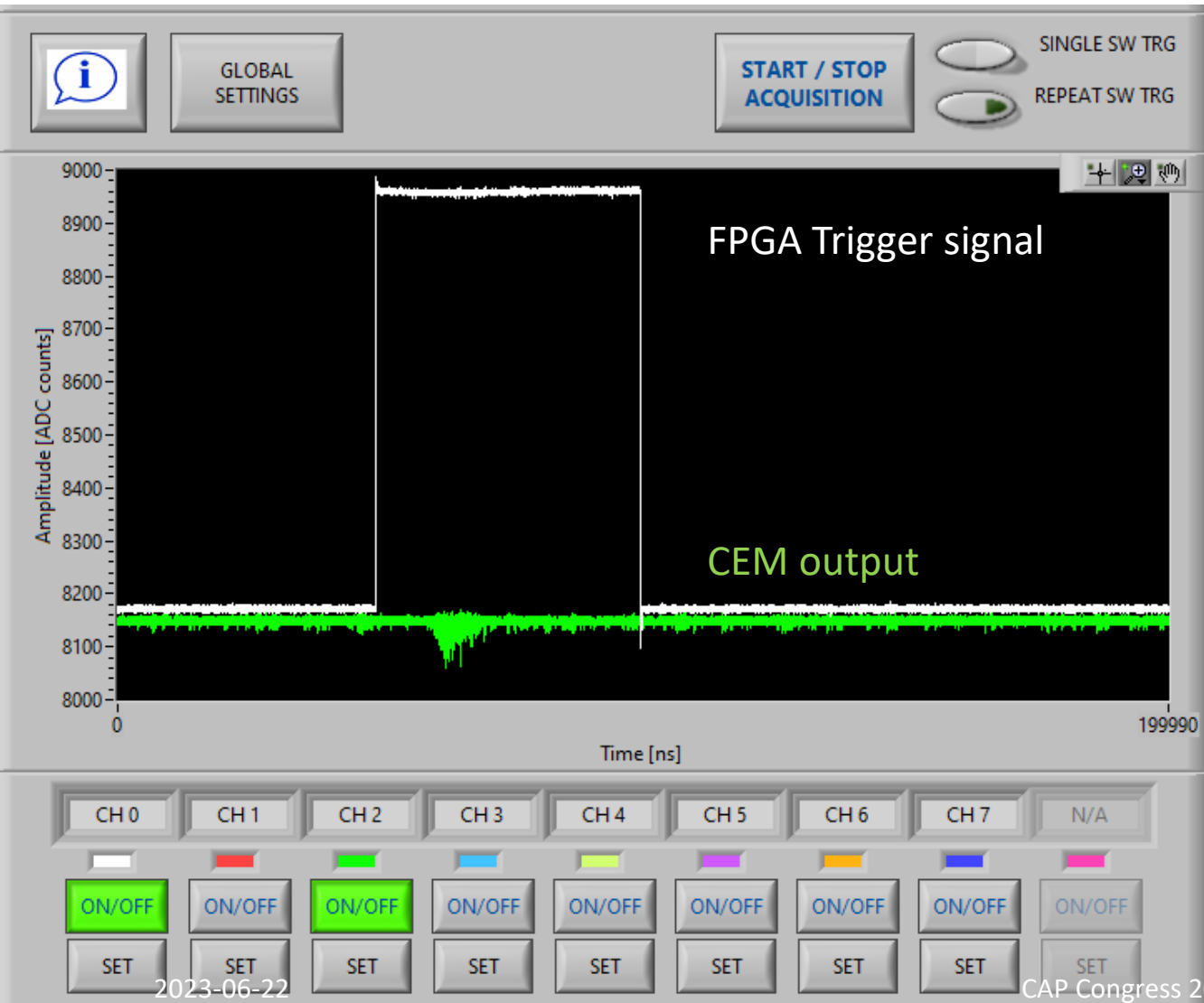
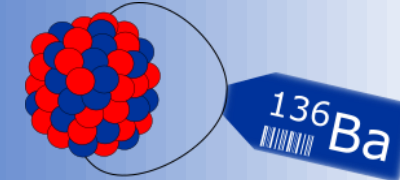
- Image on the right shows a waveform of ion bunch signal from the CEM.
- Work is underway to optimize the operational parameters such as buffer gas pressure and buncher potentials.



Pickup from buncher electrodes.

Ion signal

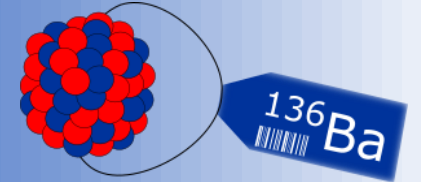
# Ion bunching with LPT



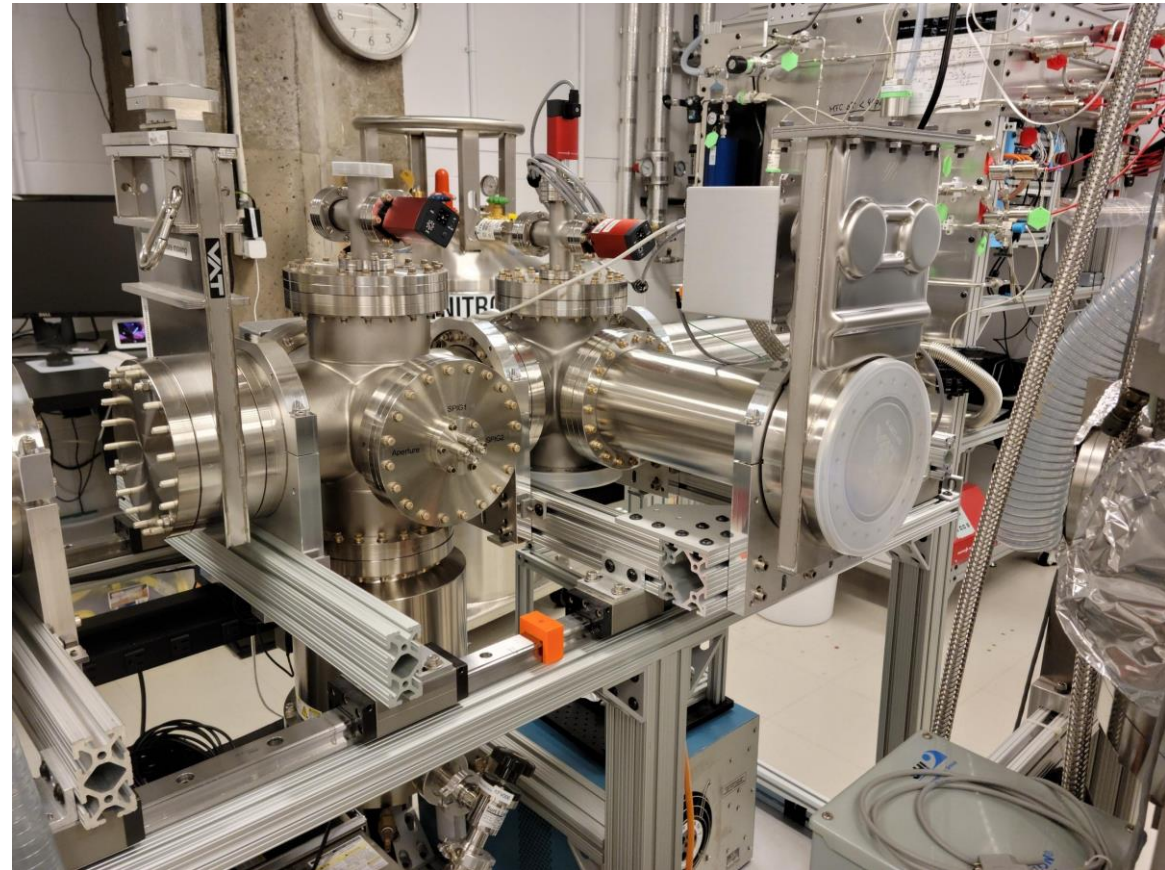
Signal trigger	No. of Sample	Total number of hits
8125	10000	2504
	No. of waveforms	
	10000	



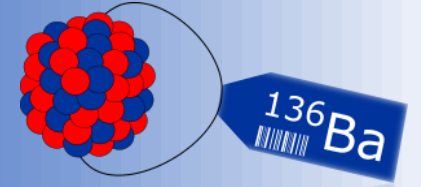
# Status of the RF Funnel



- Vacuum system and all electrical connections are in place.
- Pending installation of several vacuum gauges (ordered last year).
- Upon completion the system will be tested with Argon gas.

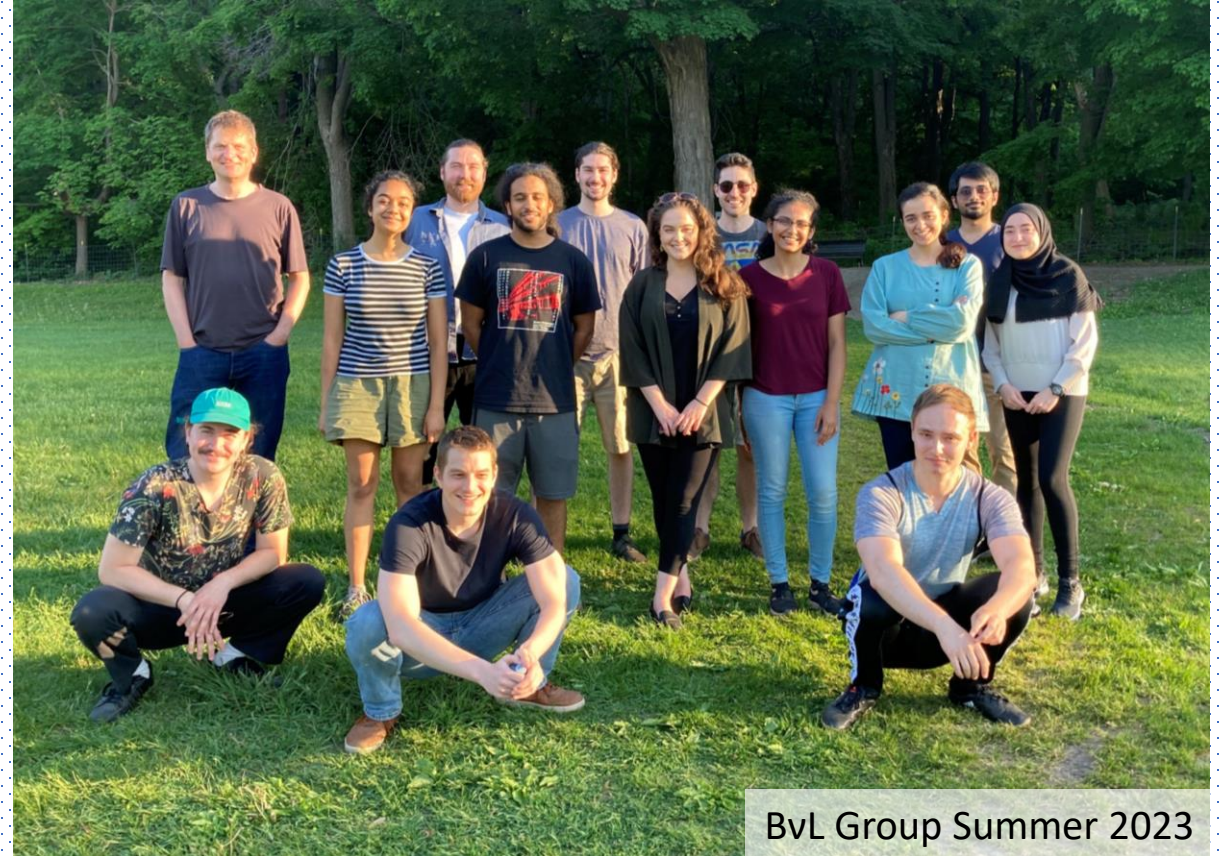


# Thank you.



## Outlook –

- The RF Funnel will be closed, aligned and coupled to the LPT and MRTOF by the end of Summer 2023.
- New time-of-flight measurements using MRTOF and cooled ion bunches from the LPT.
- Ion extraction studies from Ar gas using the RF Funnel, LPT and MRTOF.



BvL Group Summer 2023