

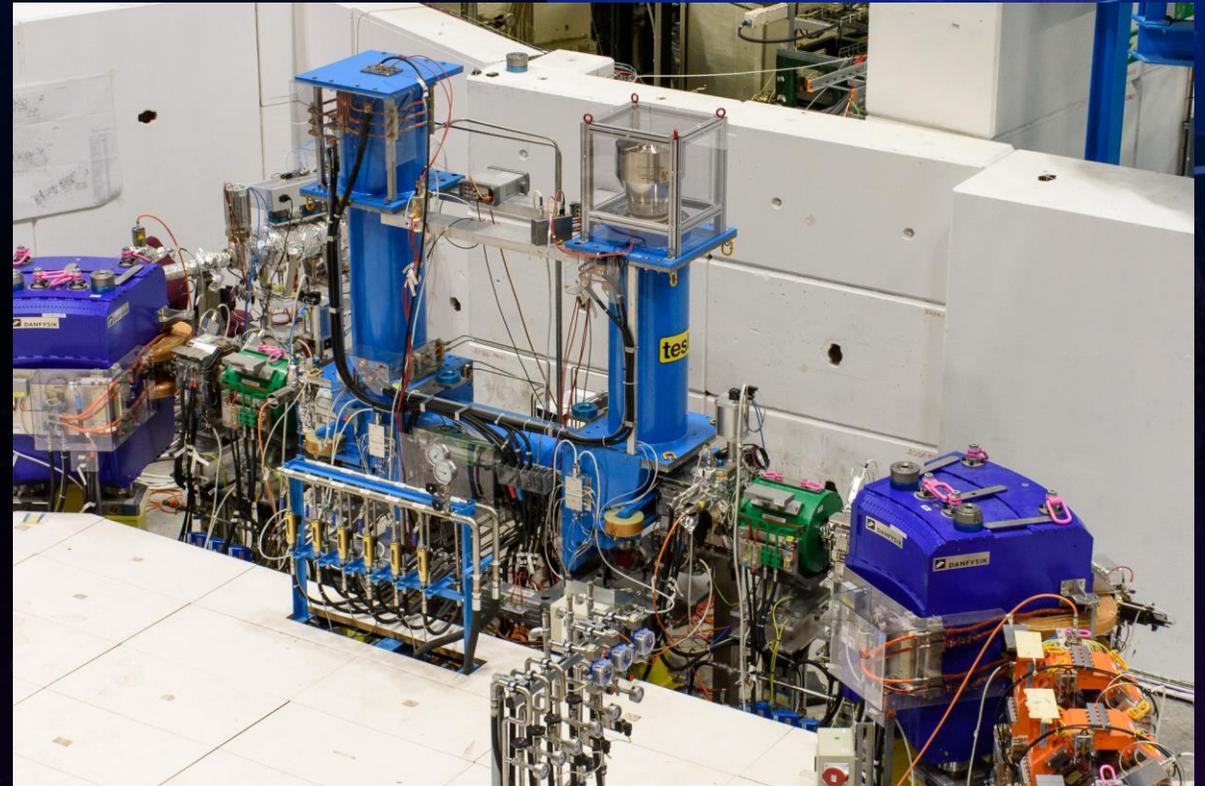
A Neutral  
Hydrogen Monitor  
for Electron  
Cooling Studies of  
H<sup>-</sup> ions in ELENA

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SY Department, CERN

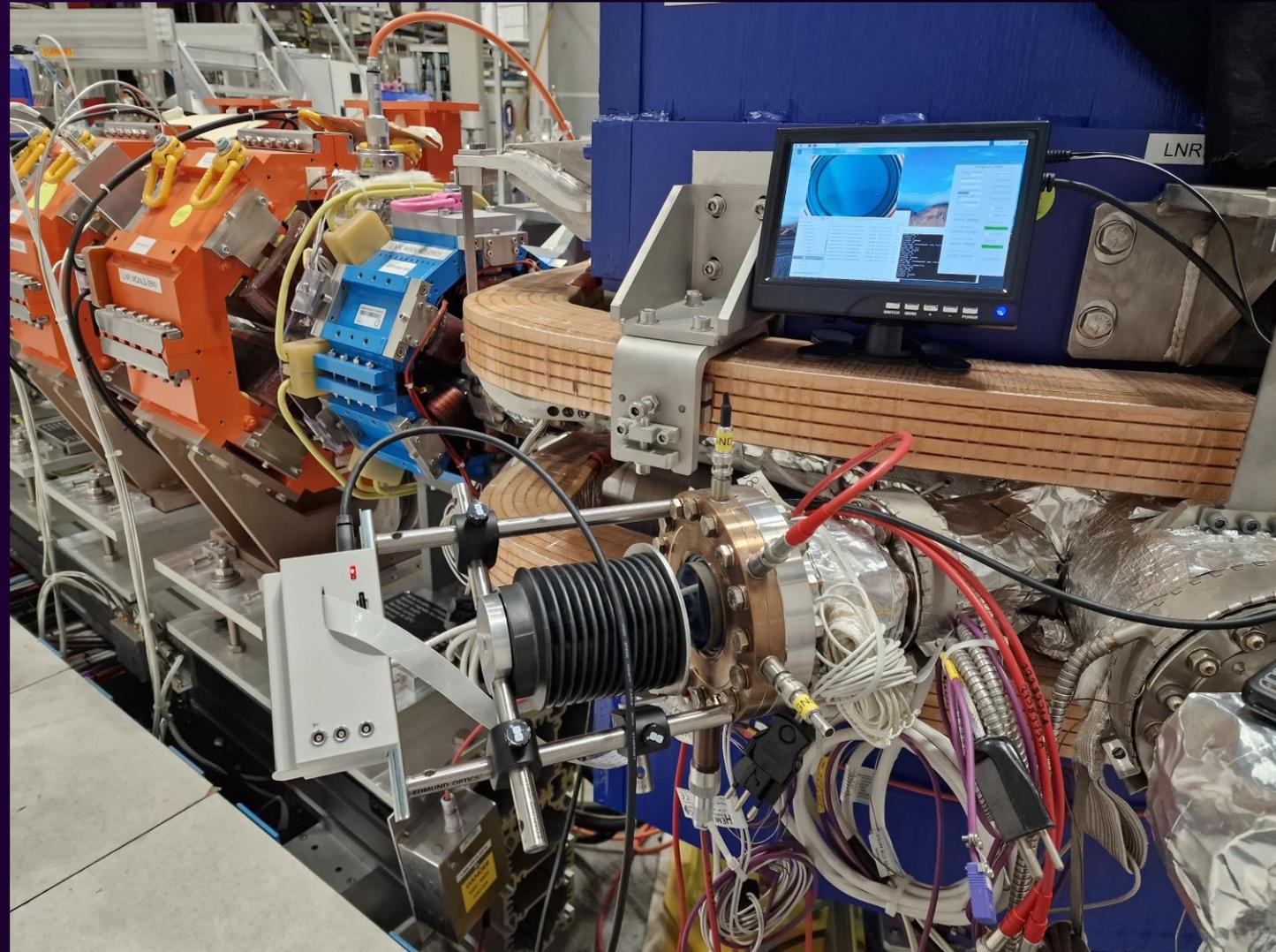
# Why?

For commissioning at 100 keV with the proton source, optimisation of the electron cooler can be performed by measuring the recombination of electrons with the circulating protons.

- The proton source has never been used on ELENA
- $H^-$  ions are injected for machine studies and commissioning experimental hardware
- Stripping of  $H^-$  ions with the residual gas and cooling electrons gives some insight into machine performance



# Hardware



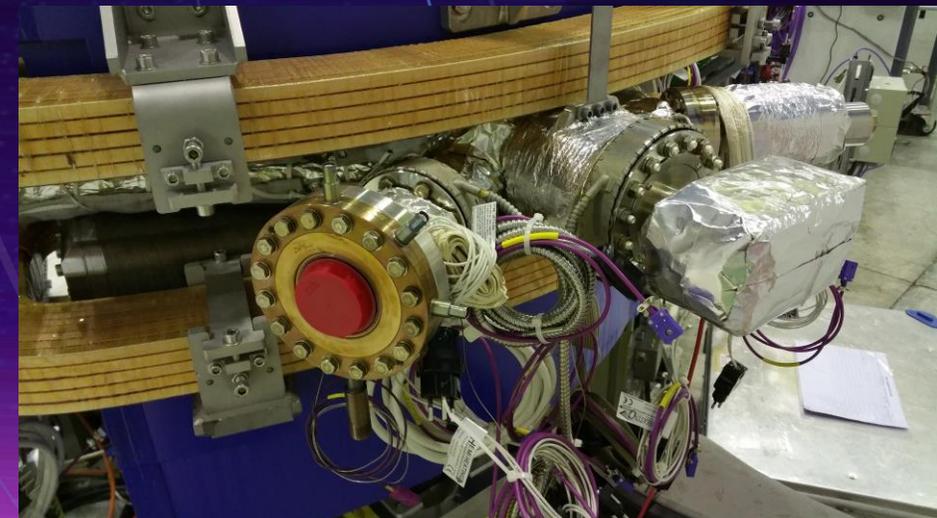
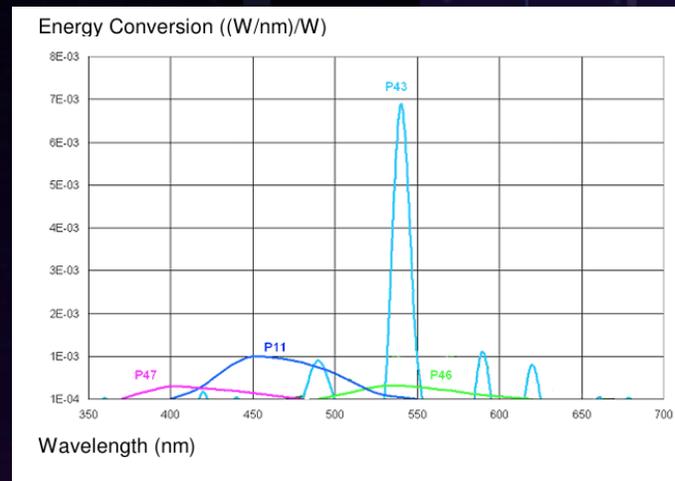
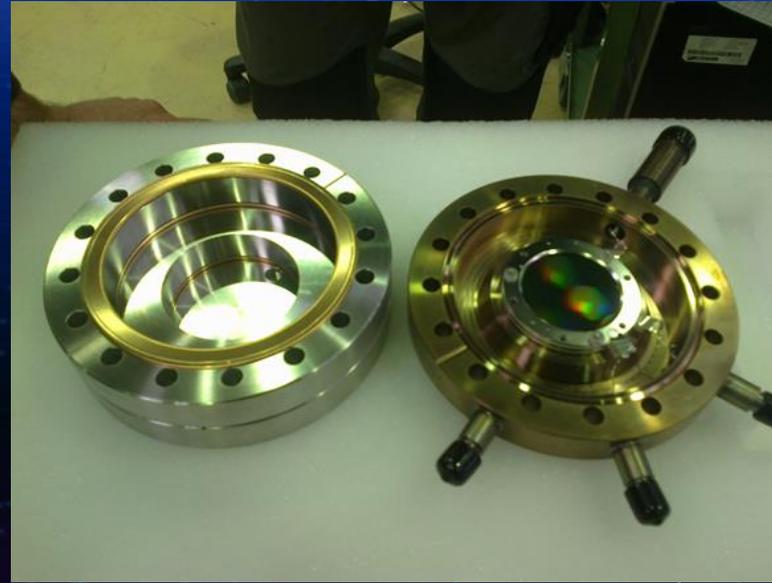
# Beam Profiler

Chevron mounted MCP detector

MgO coating

Fibreoptic phosphor screen with P43

Direct image of cooled beam on CMOS camera



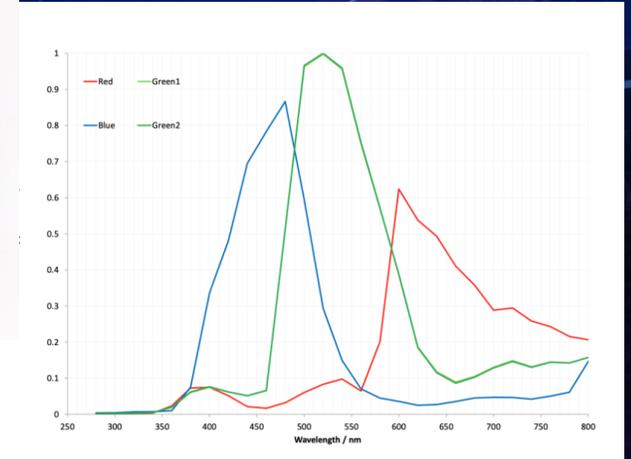
# Camera System

Raspberry Pi HQ camera module

Sony IMX477 12 megapixels CCD

CS mount lenses: Fujion 25 mm

Rpi 6 mm wide angle



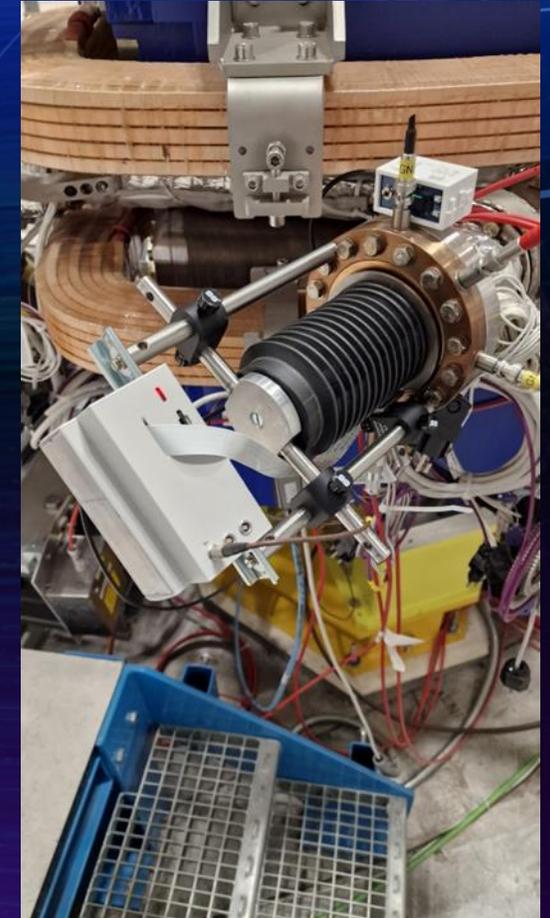
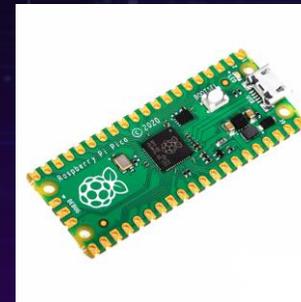
# Controls & Data Acquisition

Raspberry Pi4 8GB micro computer

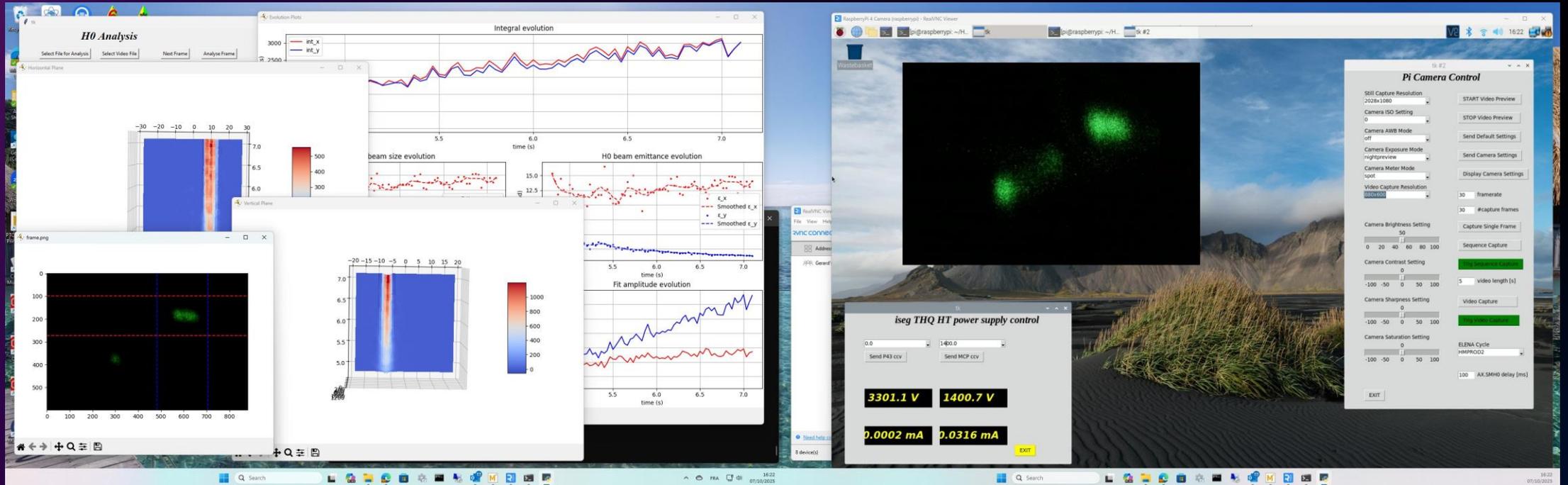
Direct control of HQ camera

Pi Pico & 10-DOF IMU Sensor Module  
(B field monitoring)

Control of high voltage power supplies  
via USB/ethernet



# Software



# Camera & PS Control S/W

Python script for the camera settings and still/video capture

Script for the control of the iSEG high voltage power supply (mcp and P43 settings)

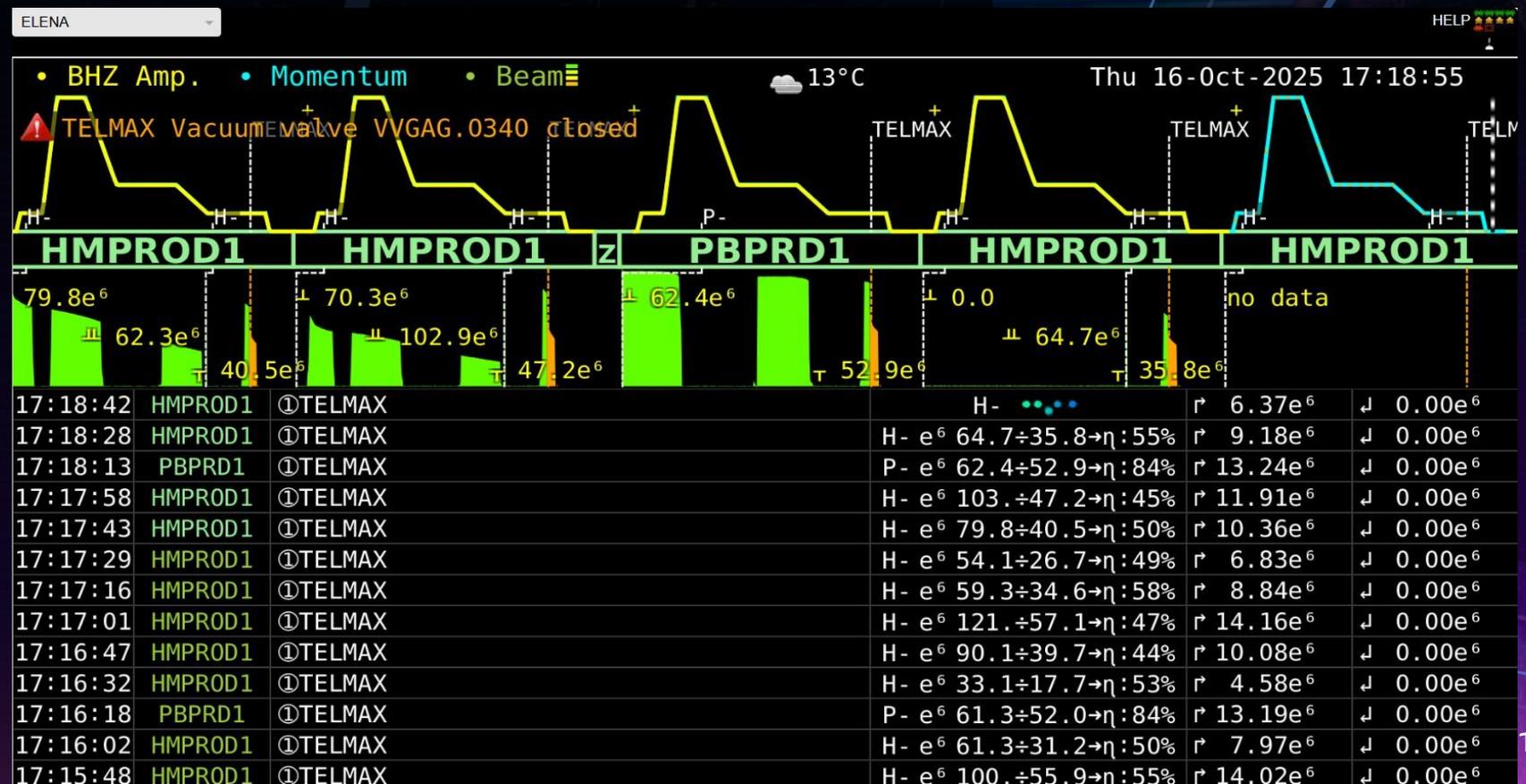
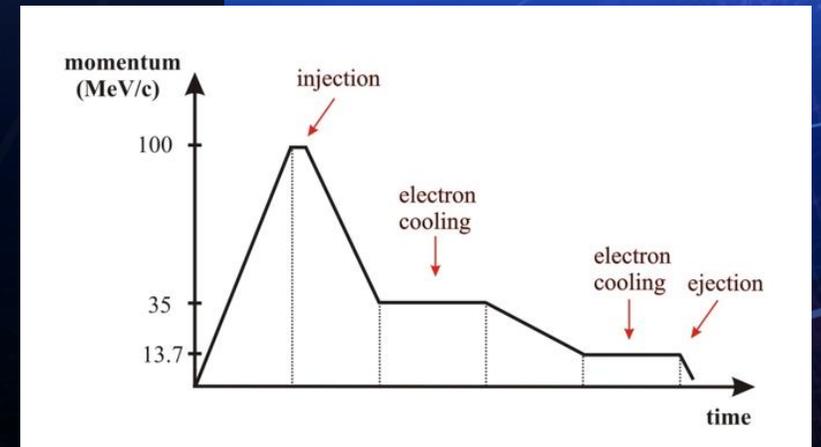
The screenshot displays a Raspberry Pi desktop environment with the following windows:

- File Manager:** Shows the file system structure, including folders like 'Videos' and 'Python - Tkinter Scal', and files like 'camera.py' and 'Camera\_C'.
- Terminal:** Displays sensor data and a plot. The data includes Gyro, Accel, and Mag values. The plot shows a signal over time.
- Pi Camera Control GUI:** A window titled 'Pi Camera Control' with various settings and controls:
  - Still Capture Resolution: 2028x1080
  - Camera ISO Setting: 0
  - Camera AWB Mode: off
  - Camera Exposure Mode: nightpreview
  - Camera Meter Mode: spot
  - Video Capture Resolution: 880x600
  - framerate: 30
  - #capture frames: 30
  - Camera Brightness Setting: 50
  - Camera Contrast Setting: 0
  - Camera Sharpness Setting: 0
  - Camera Saturation Setting: 0
  - video length [s]: 5
  - ELENA Cycle: HMPROD2
  - AX.SMH0 delay [ms]: 100
  - Buttons: START Video Preview, STOP Video Preview, Send Default Settings, Send Camera Settings, Display Camera Settings, Capture Single Frame, Sequence Capture, Trig Sequence Capture, Video Capture, Trig Video Capture, EXIT.
- iseg THQ HT power supply control GUI:** A window titled 'iseg THQ HT power supply control' with two input fields (both set to 1000.0) and two buttons: 'Send P43 ccv' and 'Send MCP ccv'. It displays four large digital readouts:
  - 999.0 V
  - 1000.7 V
  - 0.0001 mA
  - 0.0221 mAand an 'EXIT' button.



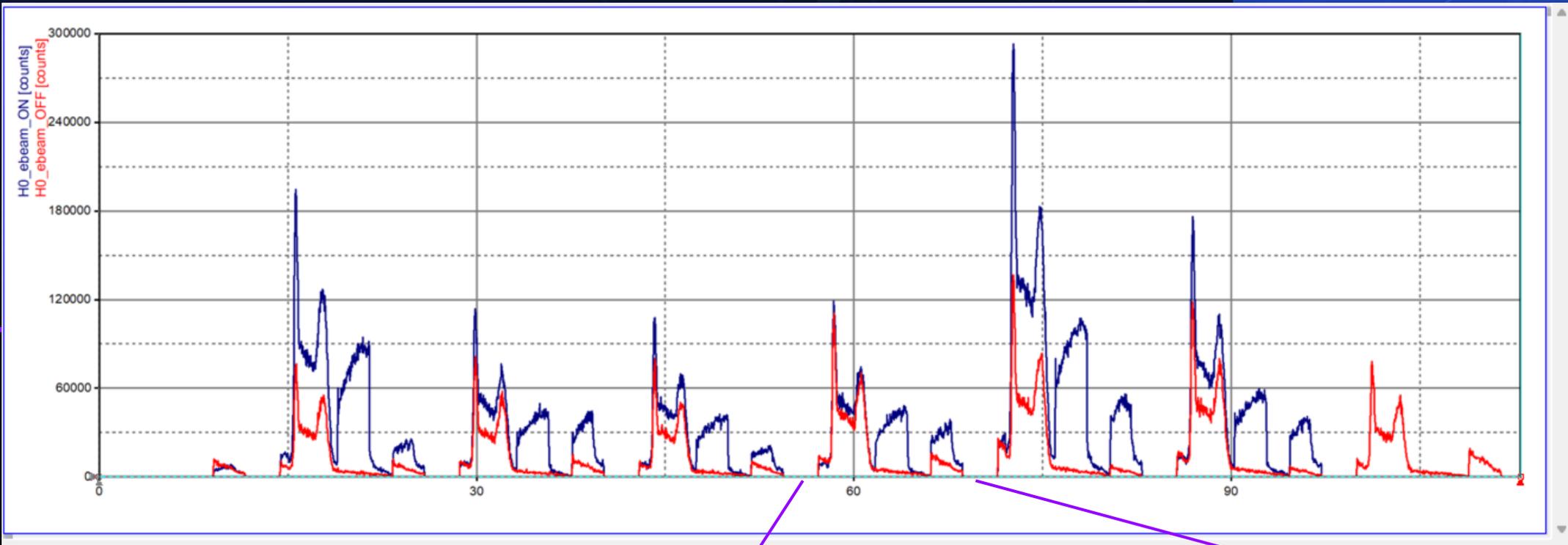


# ELENA Magnetic Cycle

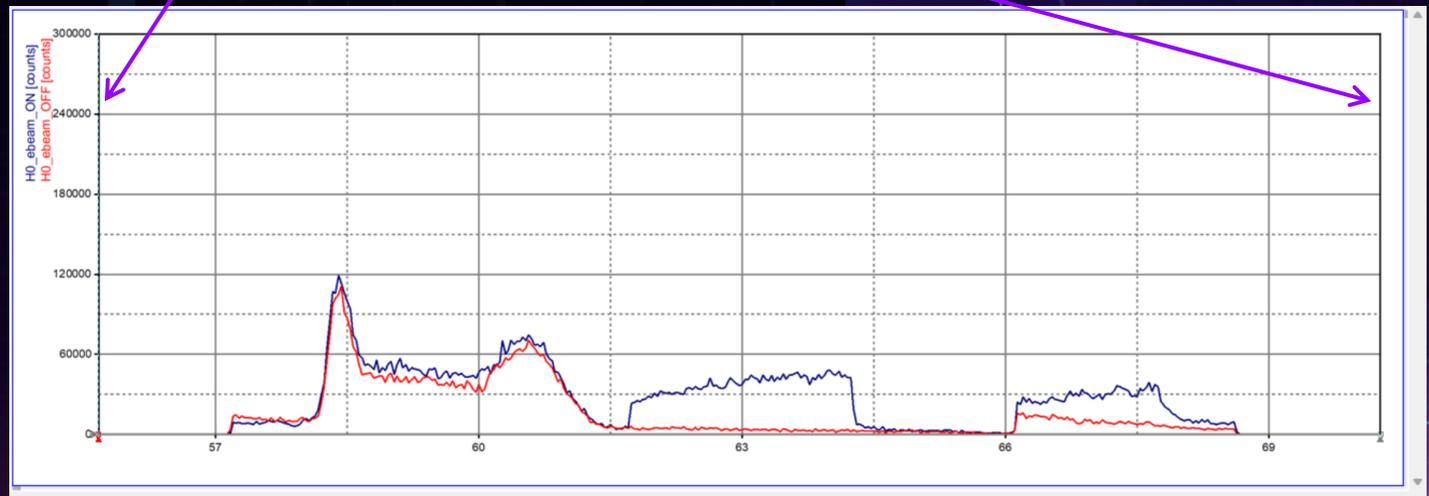


AD cycle length 110 s

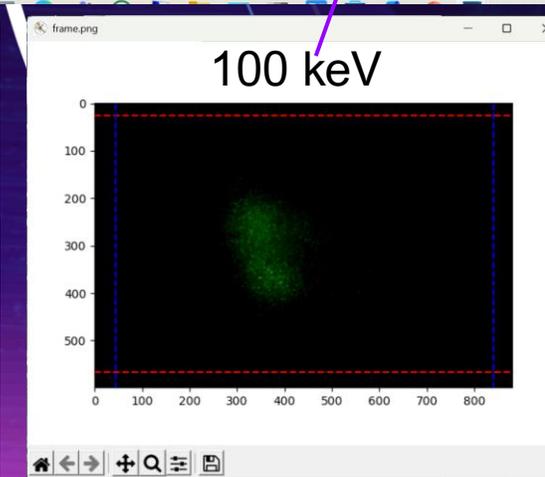
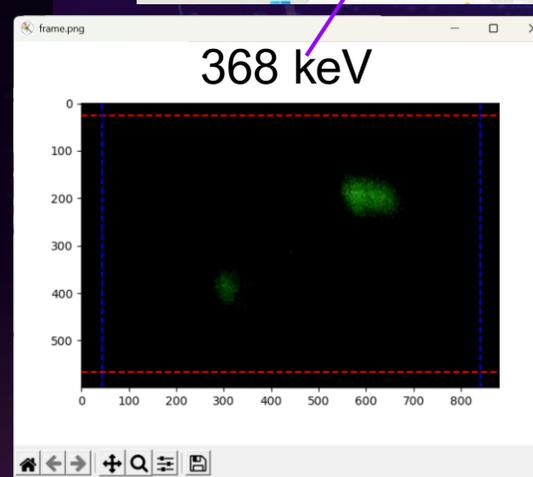
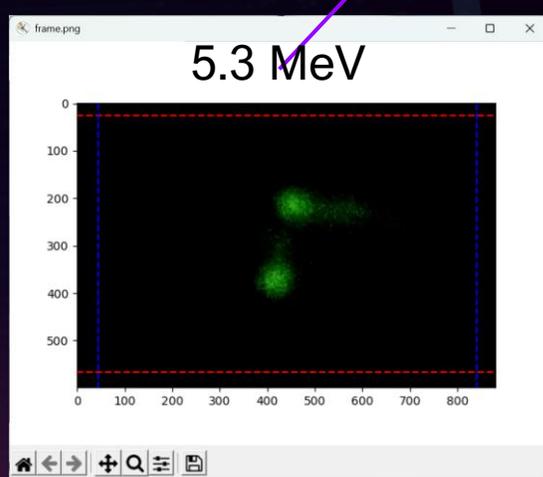
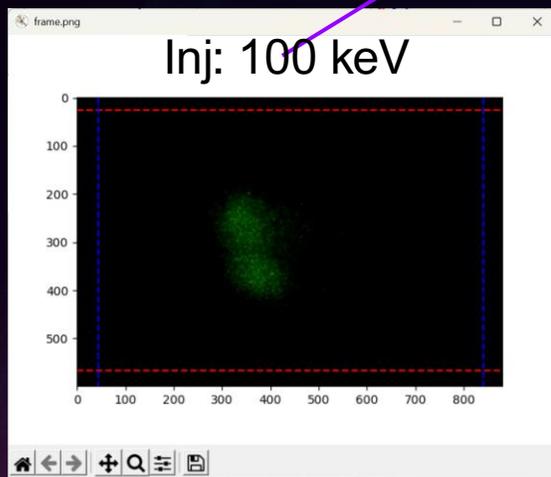
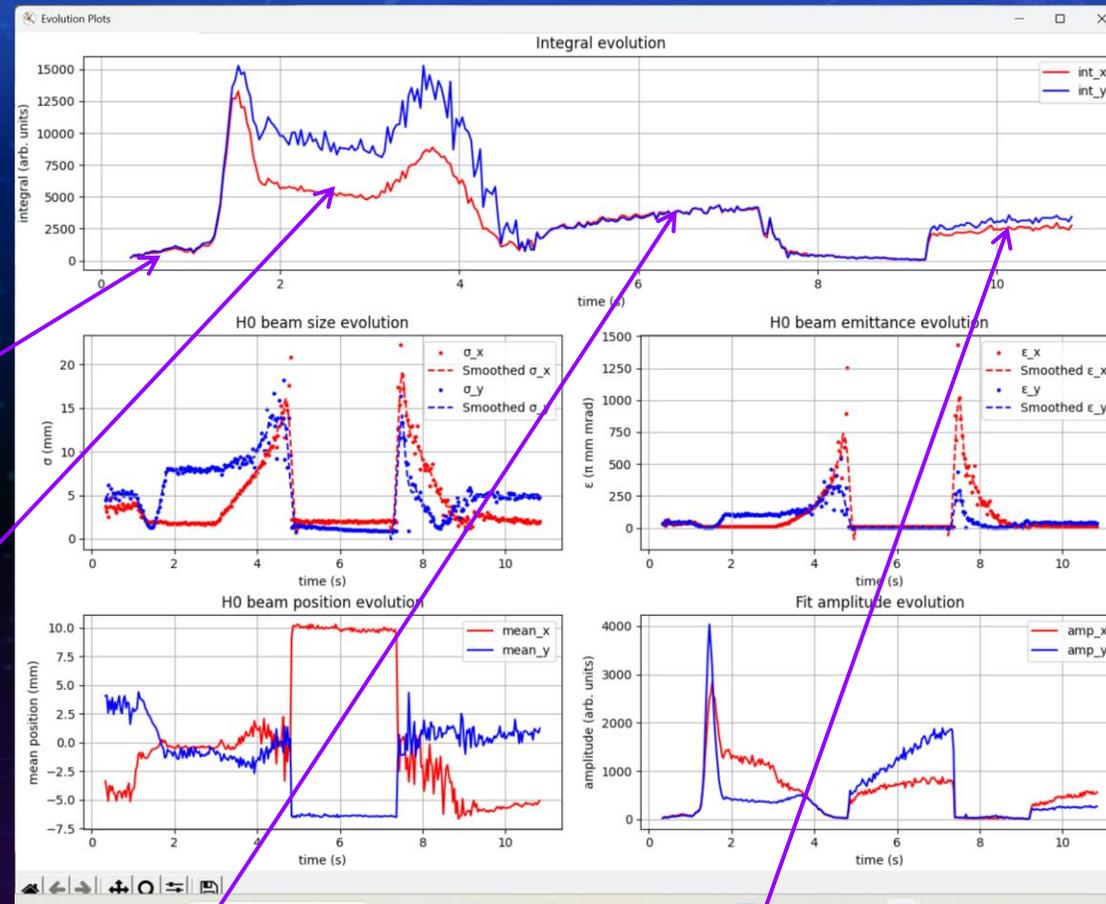
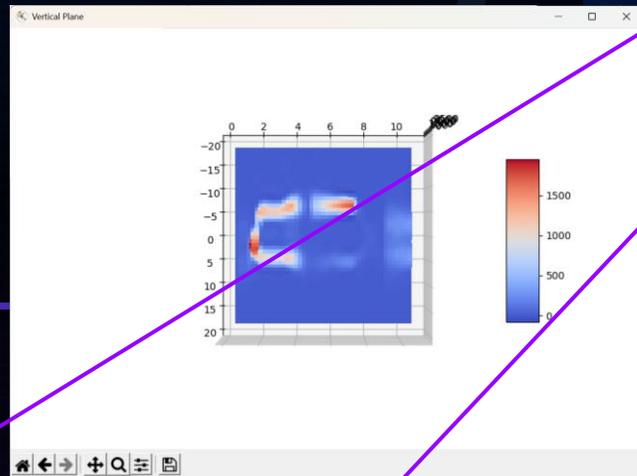
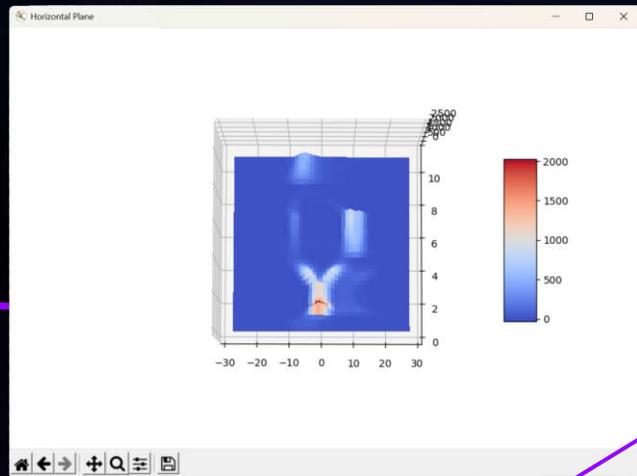
ELENA cycle length 15 s



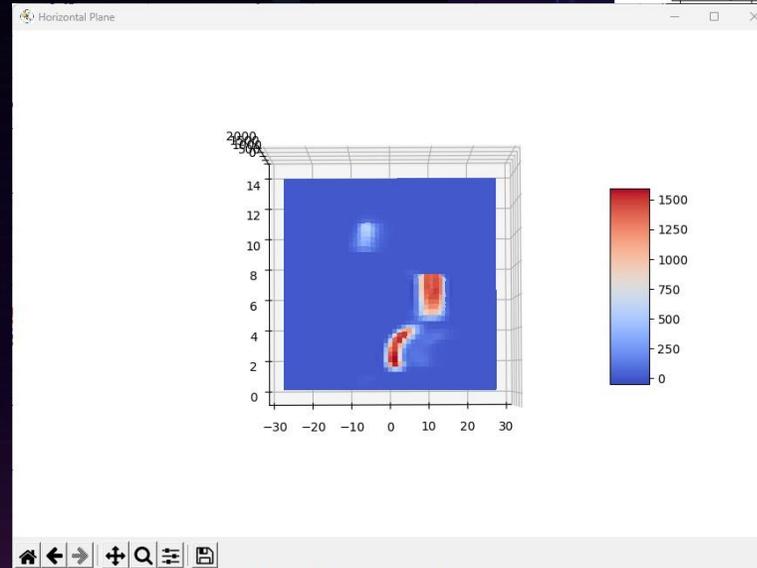
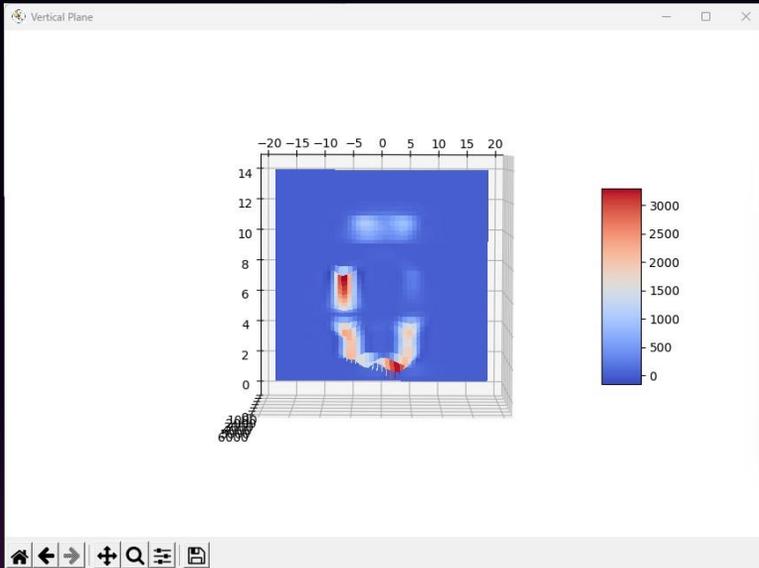
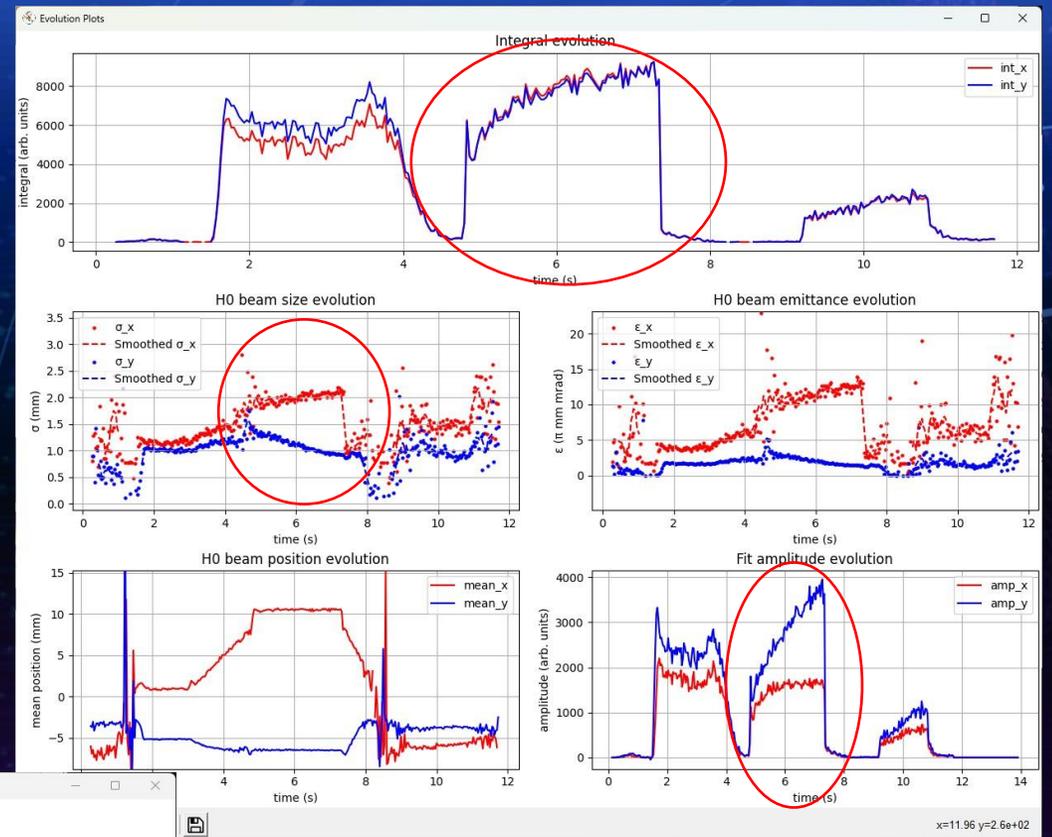
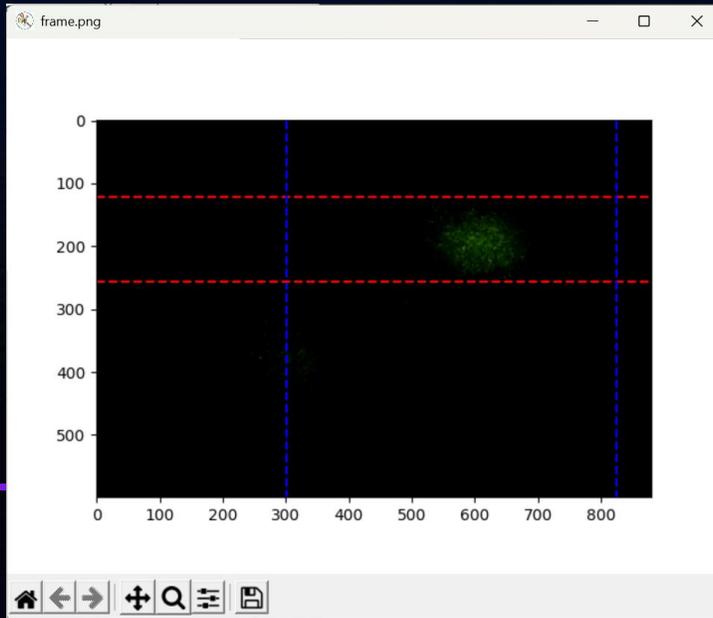
- Can insert up to 7 ELENA H<sup>-</sup> cycles per AD cycle
- Stripping due to cooling electrons clearly seen



# A Typical ELENA Cycle



Selective analysis is needed to obtain the beam evolution on individual plateaus

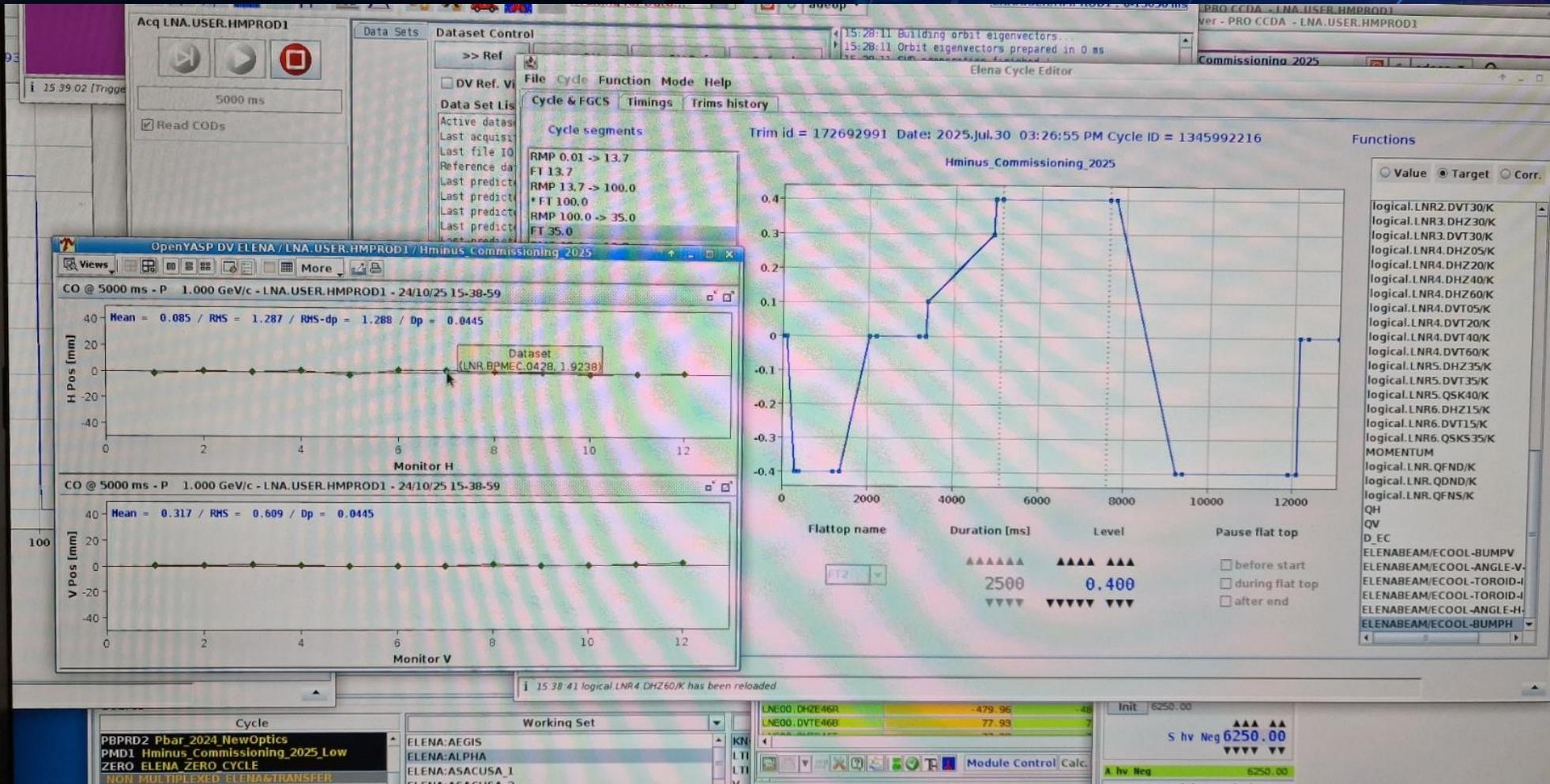


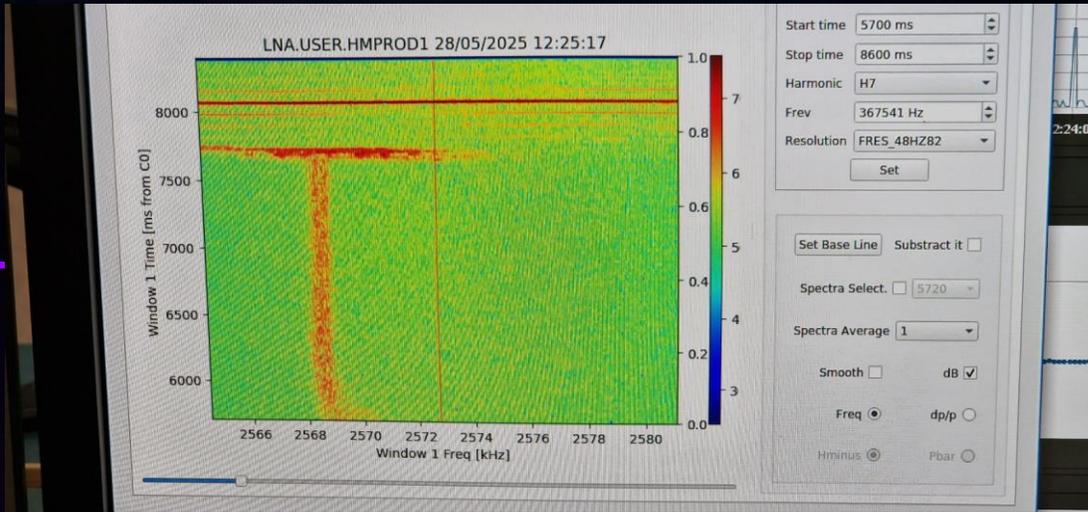
# Initial Machine Parameters

H- momentum (MeV/c)	Vcath (V)	Vgrid (V)	Ie (mA)	BUMPH	ANGLEH	BUMPV	ANGLEV
35	-368.86	-300	4.45	3.4	1.4	4.0	0.5
13.75	-57.62	-50	0.35	-0.4	-3.8	4.2	-3.8

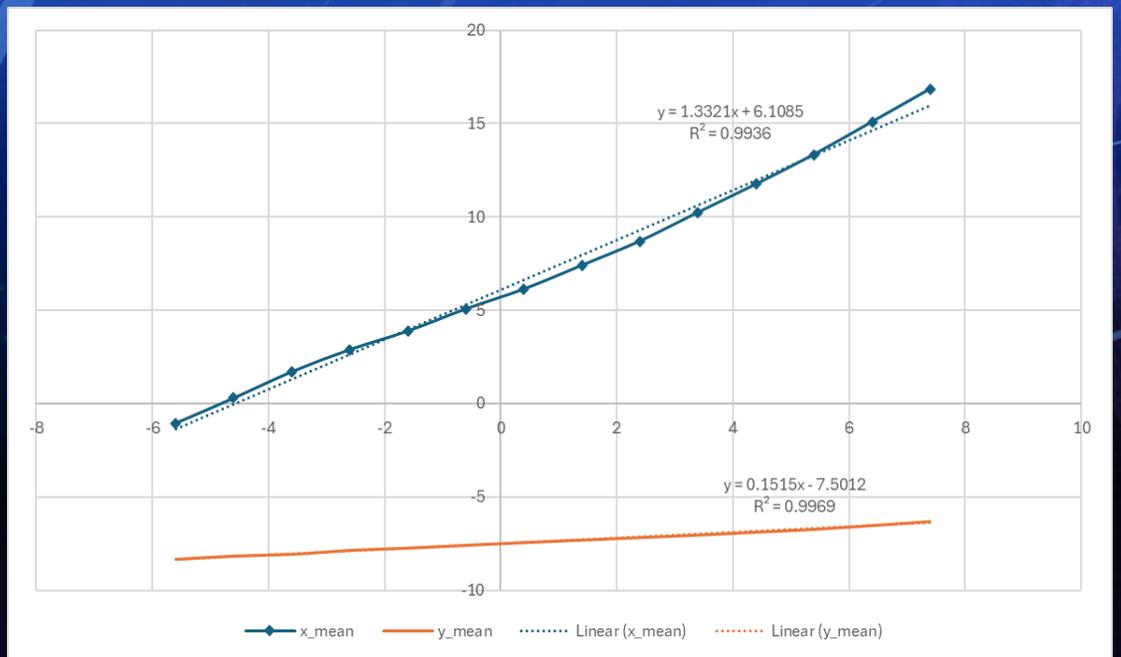
# Horizontal Position Scan at 35 MeV/c

Horizontal position of the H<sup>-</sup> beam bumped in (programmed) 1 mm steps (-5.6 mm to +7.4 mm)

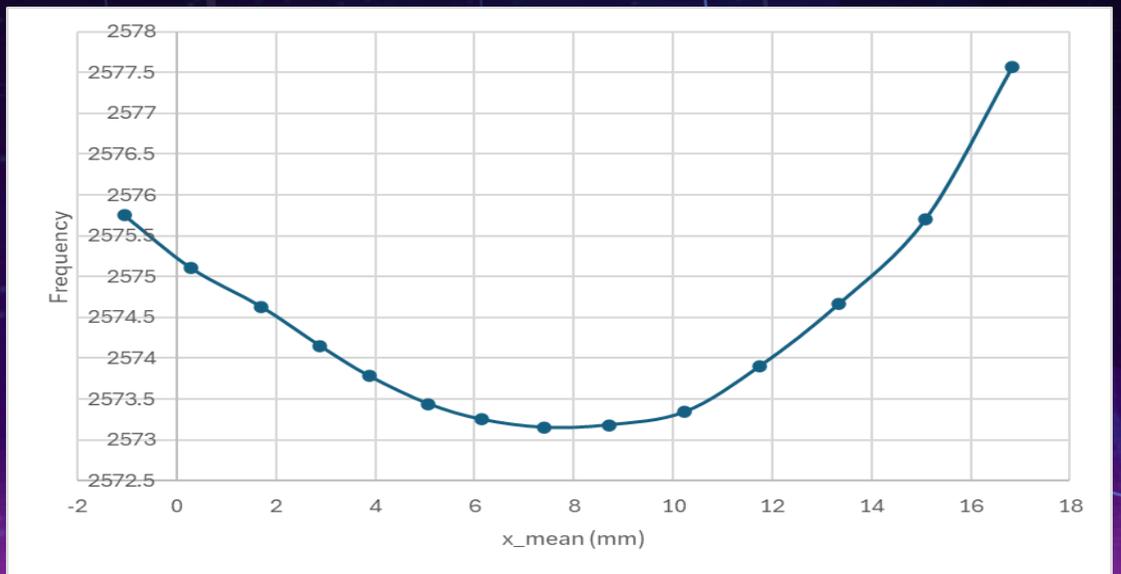




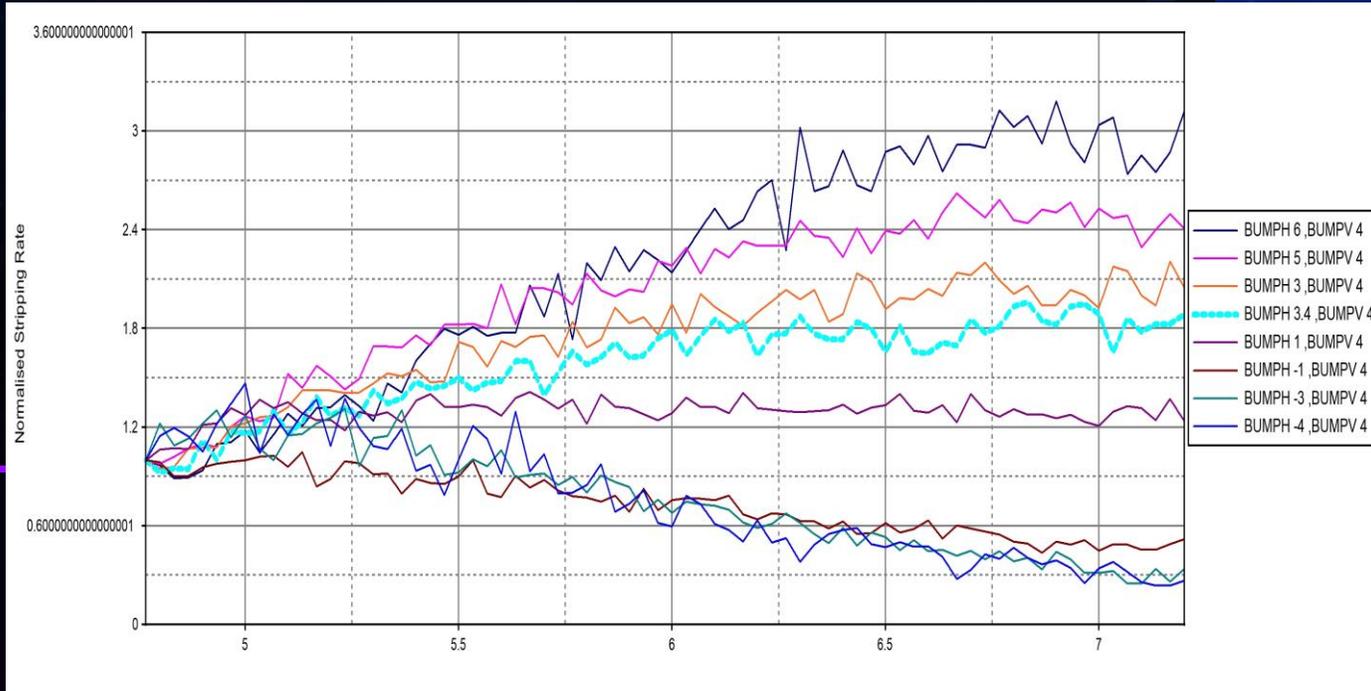
Revolution frequency vs beam position measured with the longitudinal Schottky monitor



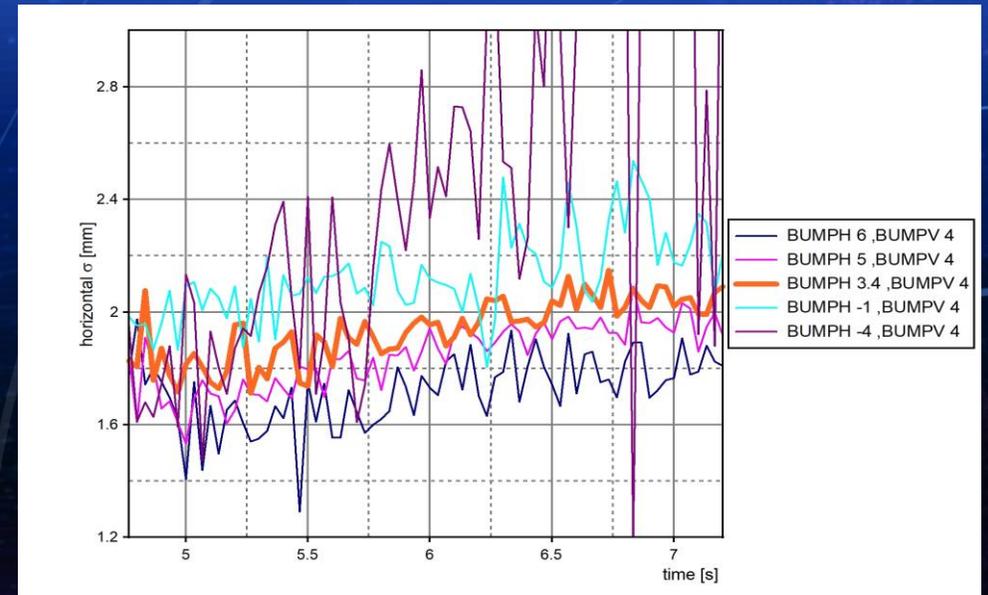
Measured position change vs programmed position bump



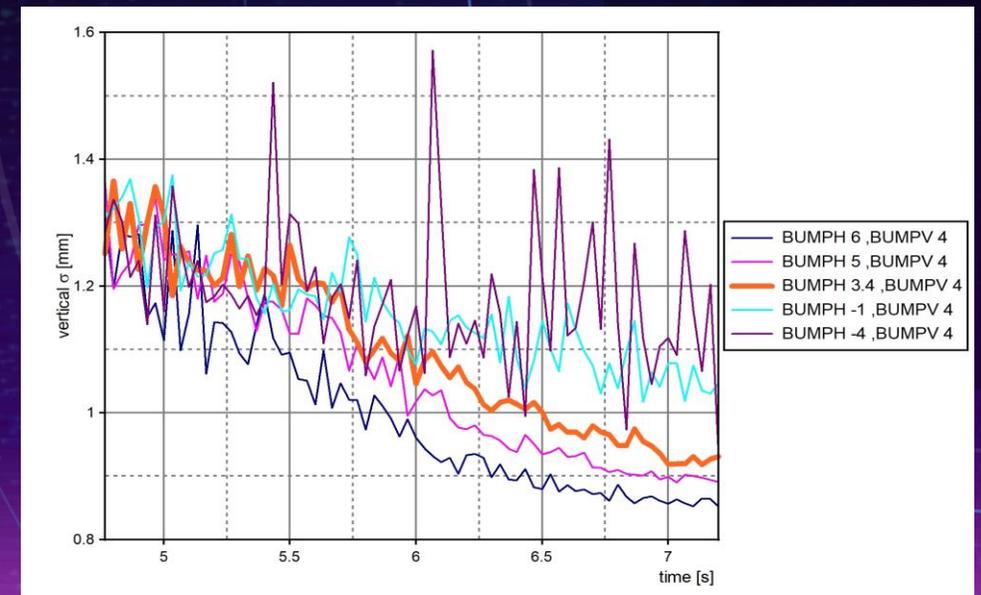
Revolution frequency vs measured H0 horizontal position



Stripping rate as a function of horizontal offset (BUMPH)

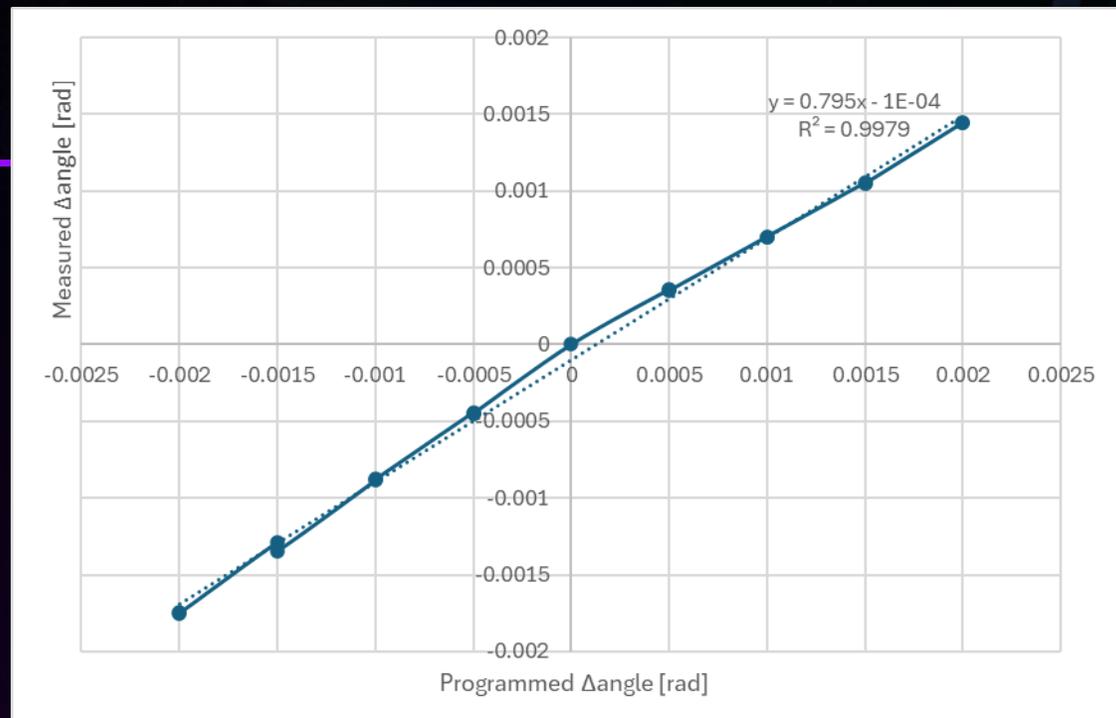


Beam size evolution  $f$  horizontal offset (BUMPH)

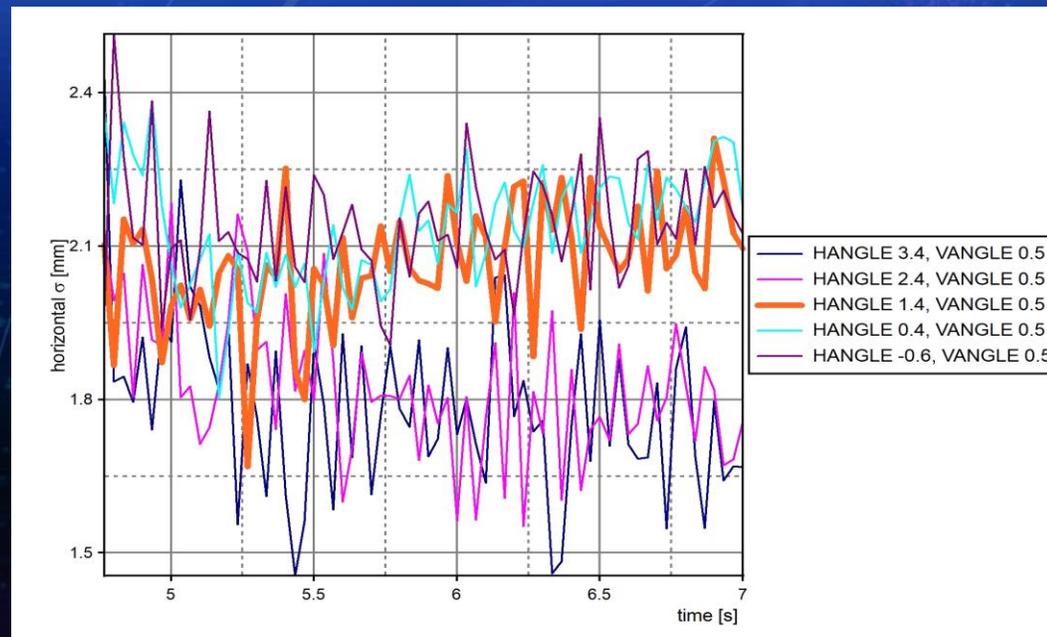


# Horizontal Angle Scan at 35 MeV/c

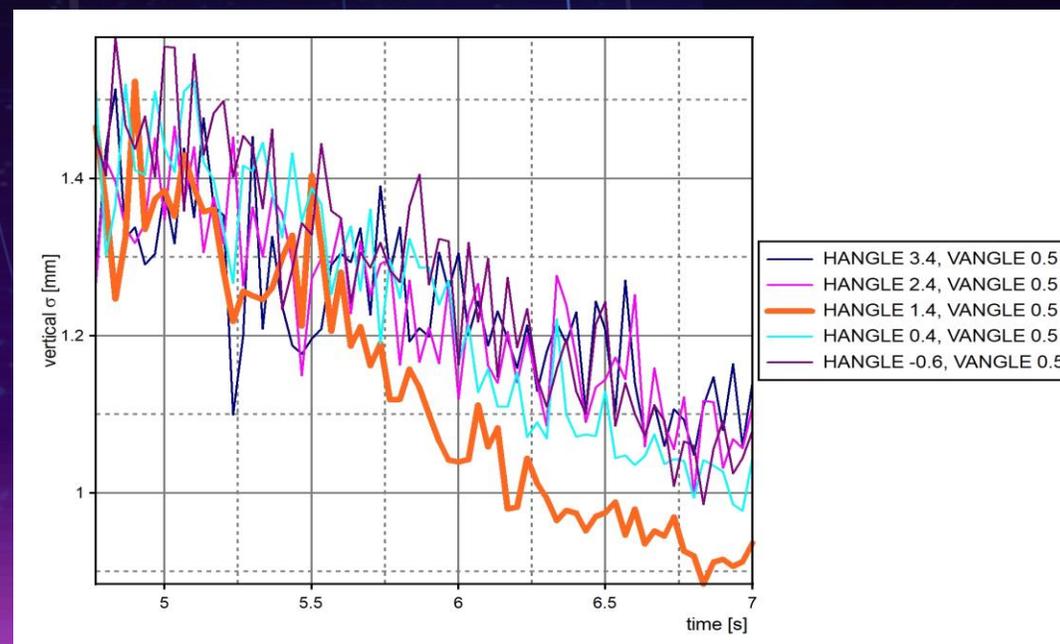
Horizontal angle of the H<sup>-</sup> beam bumped in (programmed) 0.5 mrad steps (3.4 mrad to -0.6 mrad, initial angle = 1.4)



Measured angle change vs programmed angle bump

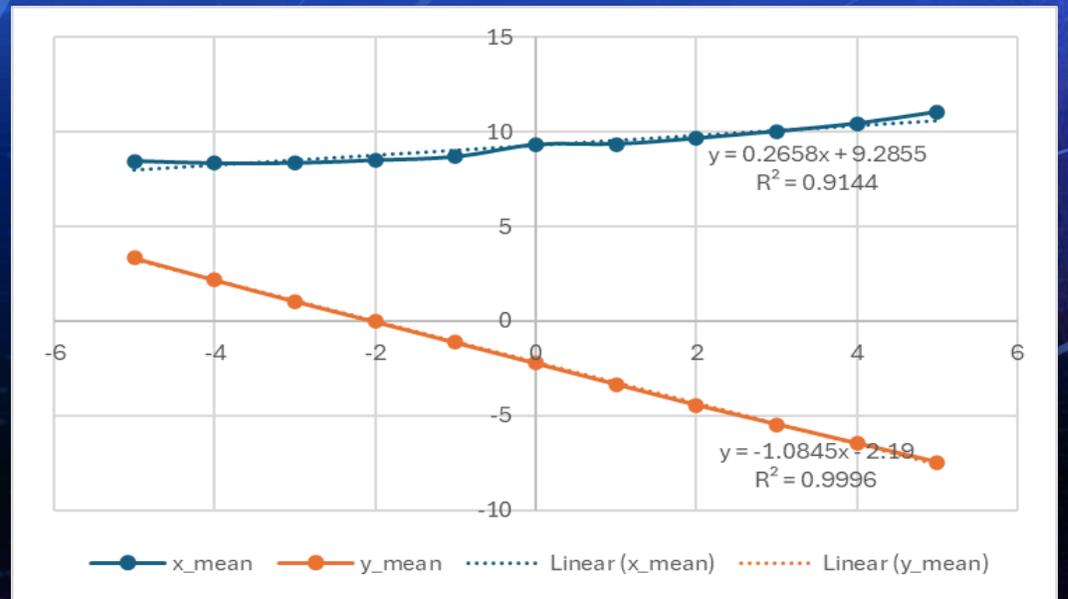


Beam size evolution  $f$  horizontal angle (HANGLE)

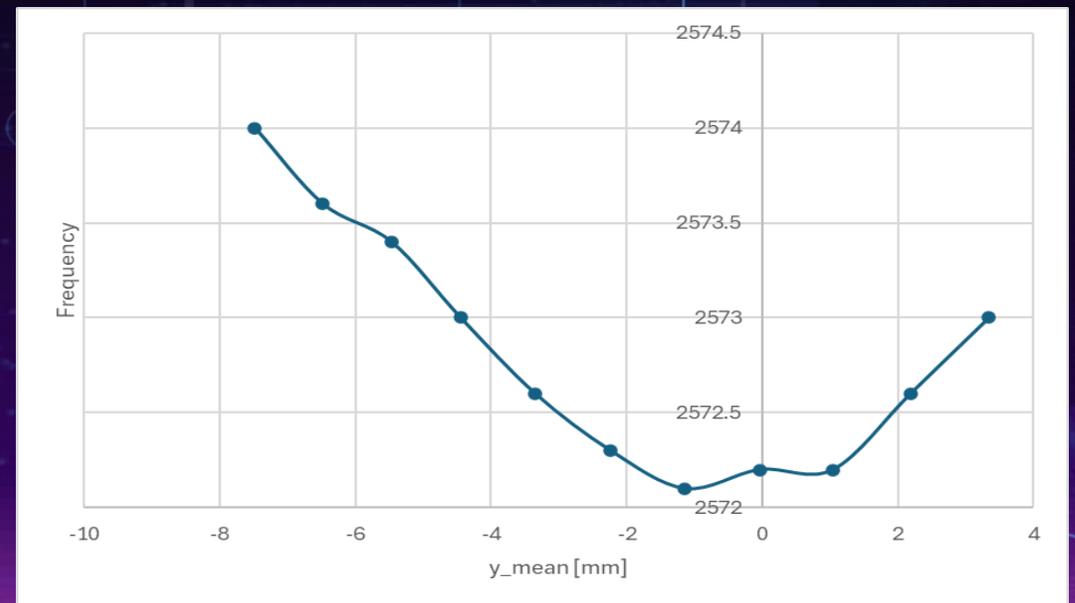


# Vertical Position Scan at 35 MeV/c

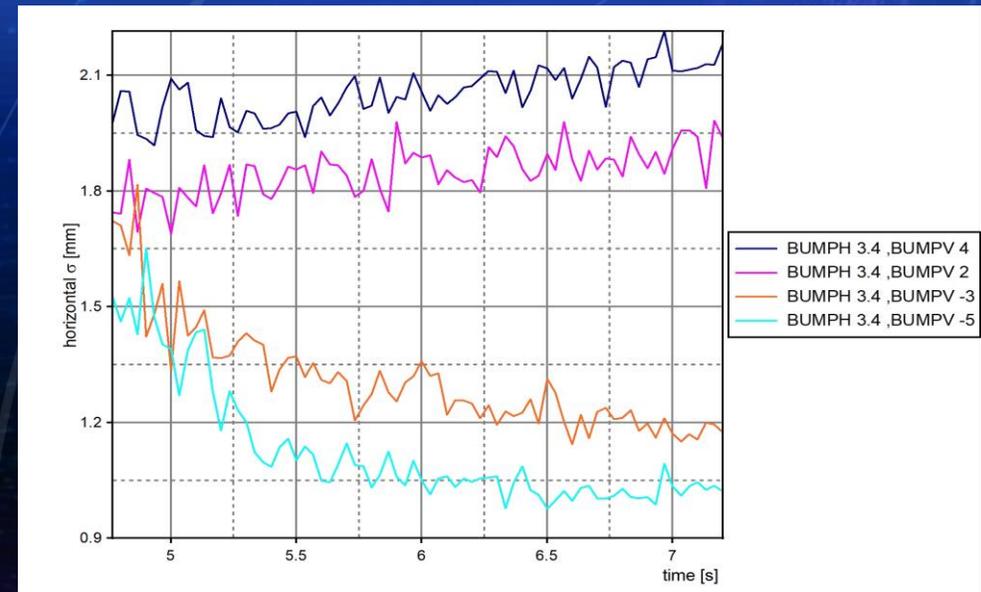
Vertical position of the H- beam bumped in (programmed) 1 mm steps (-5 mm to +5 mm)



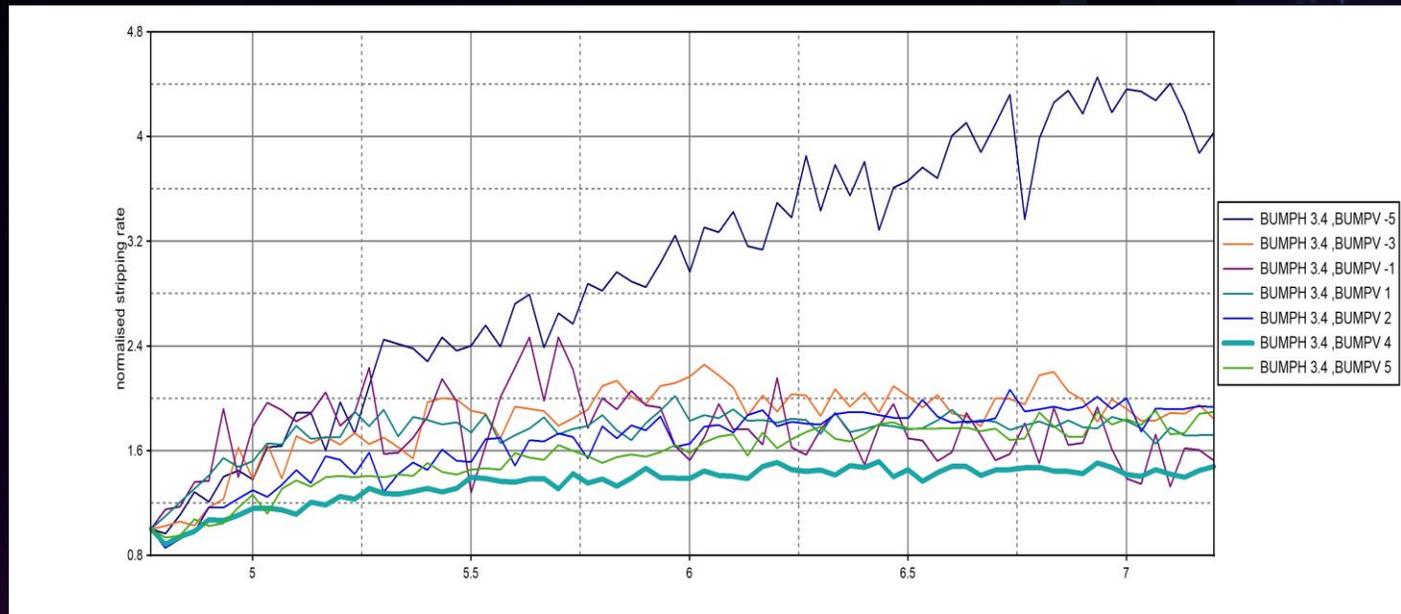
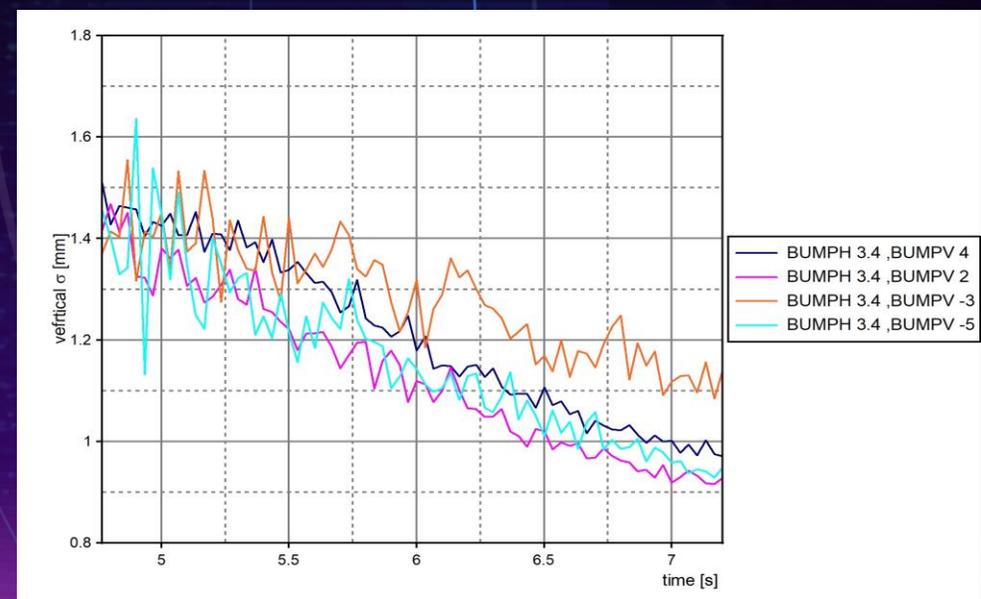
Measured position change vs programmed position bump



Revolution frequency vs measured H0 vertical position



Beam size evolution *f* vertical offset (BUMPV)

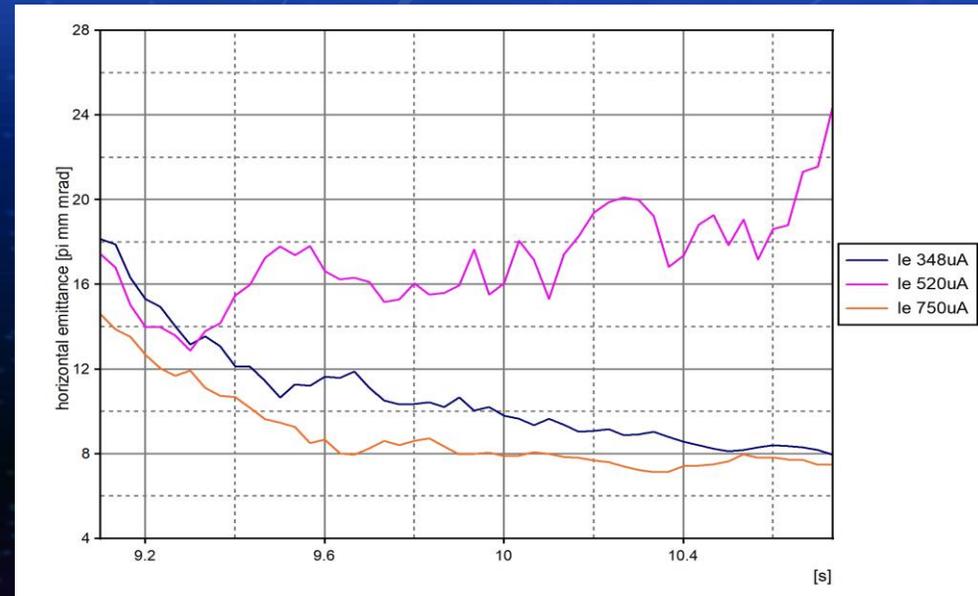


Stripping rates as a function of vertical offset

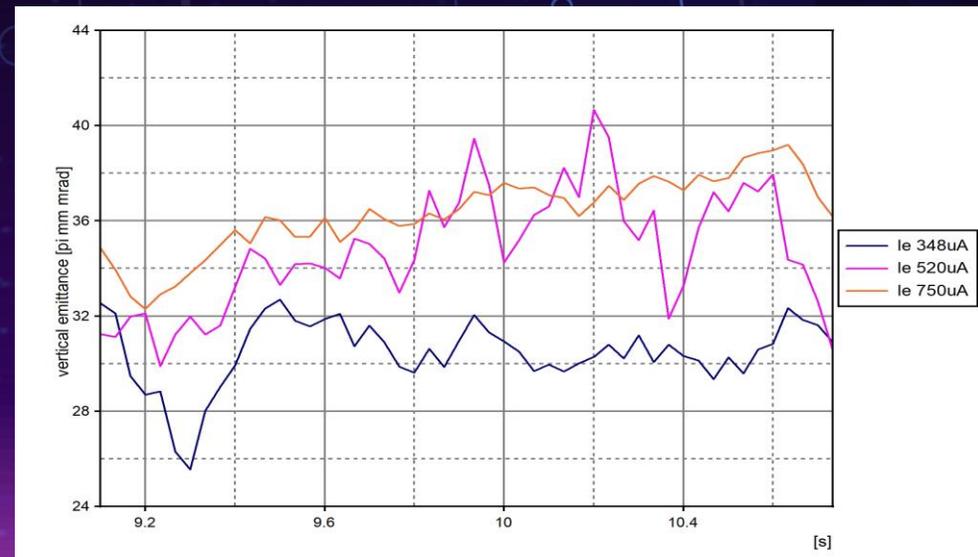
# le Scan at 13.75 MeV/c

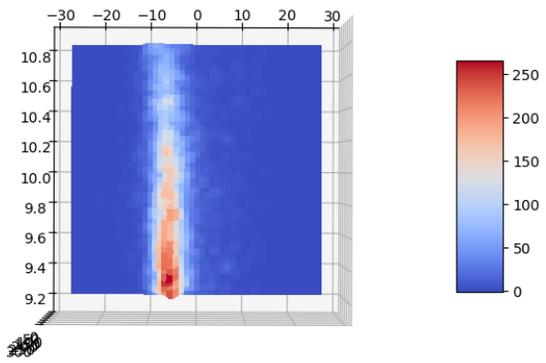
Vcath (V)	Vgrid (V)	le (uA)
-57.62	-50	348
	-48	407
	-46	460
	-44	520
	-42	590
	-40	650
-60.32	-40	750

Cooler voltage settings

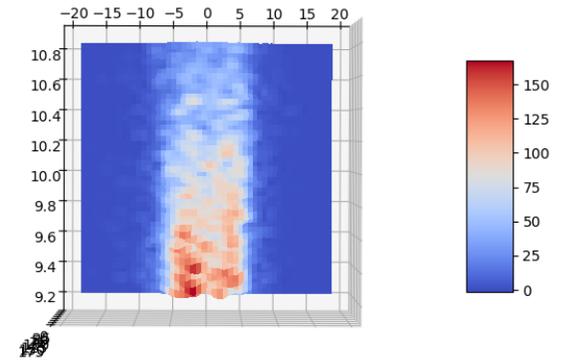


Beam size evolution for varying electron currents

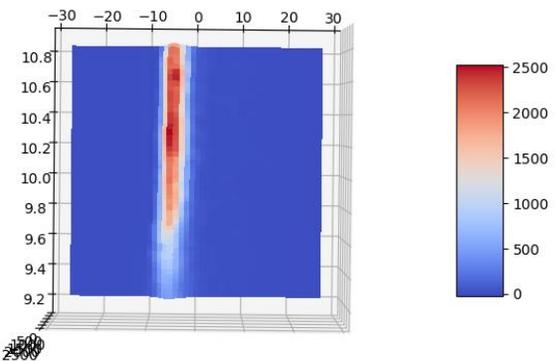




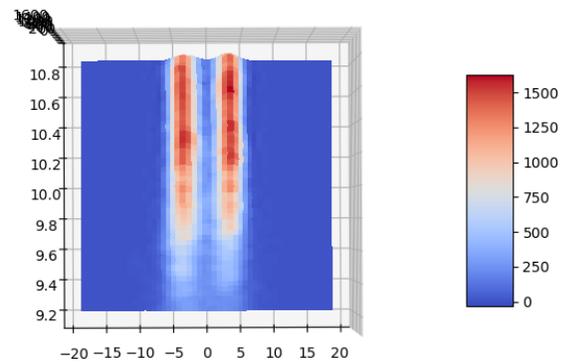
Horizontal plane  $le = 520\mu\text{A}$



Vertical plane  $le = 520\mu\text{A}$



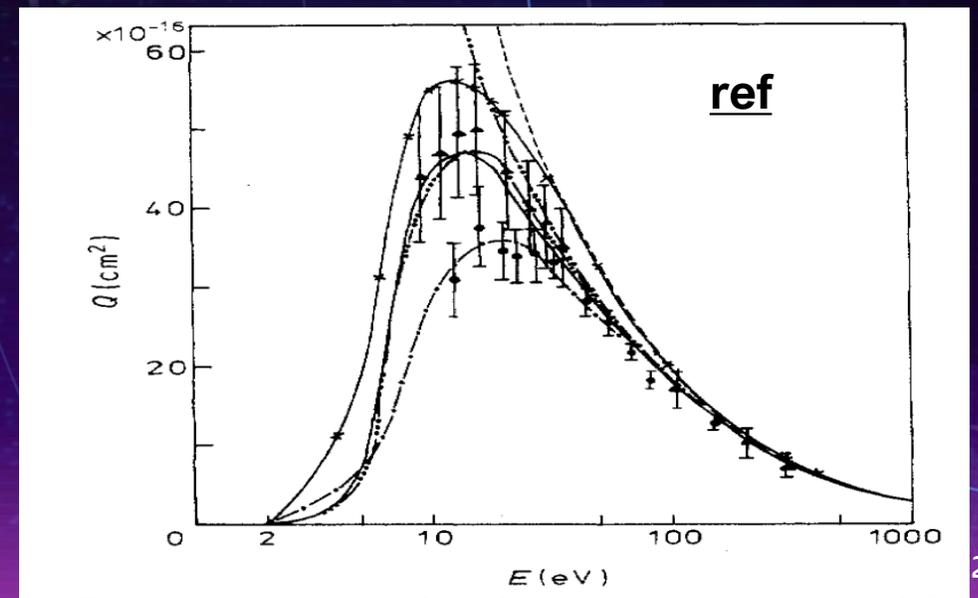
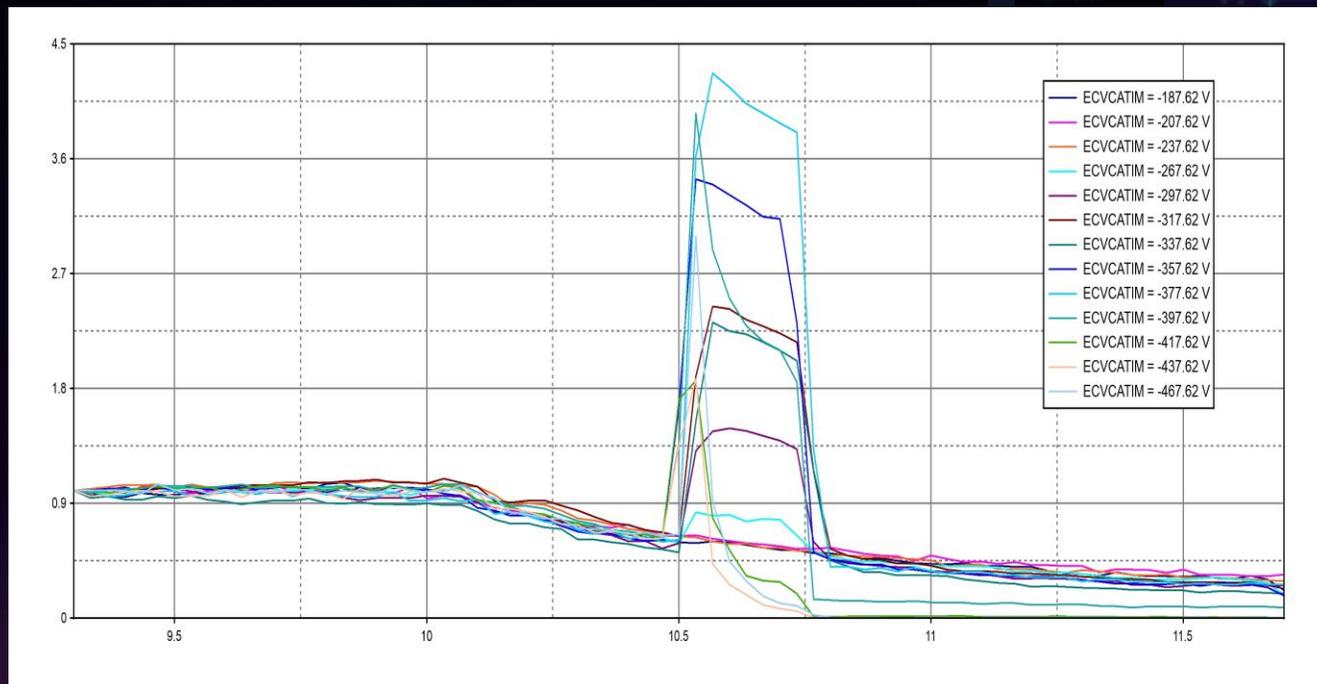
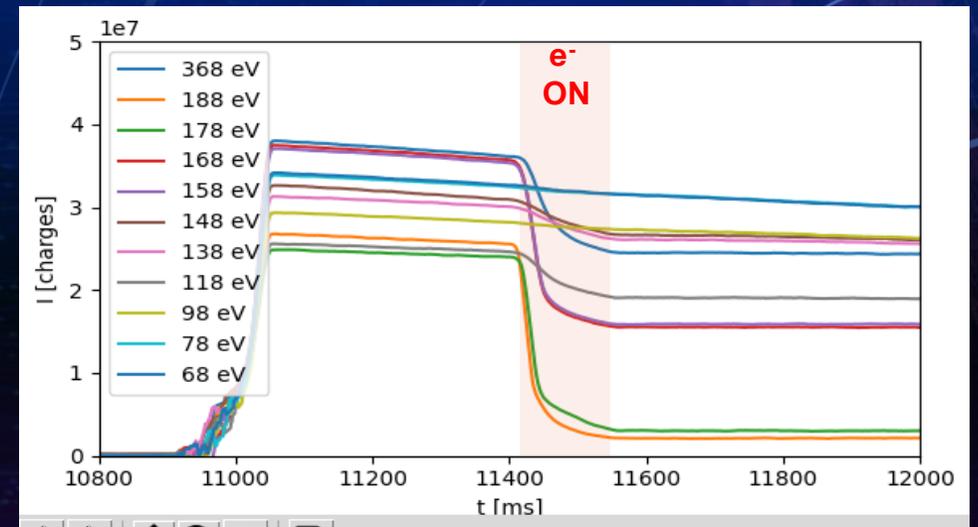
Horizontal plane  $le = 348\mu\text{A}$

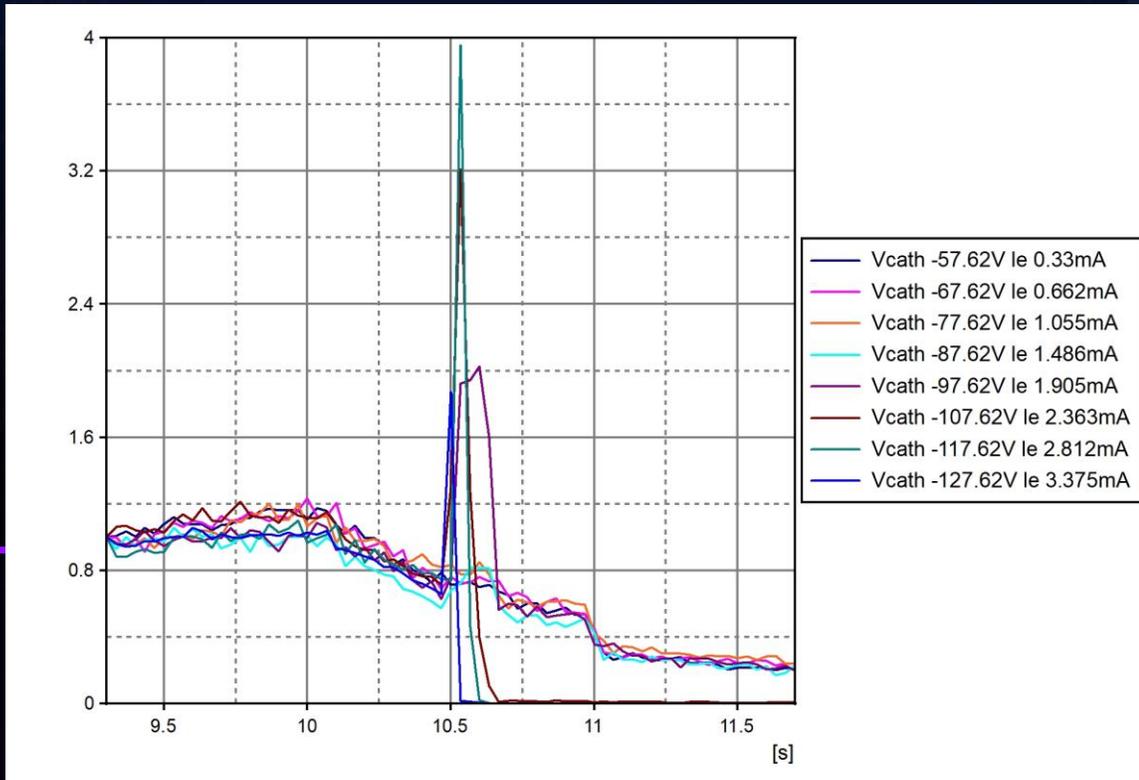


Vertical plane  $le = 348\mu\text{A}$

# Electron Detachment Cross Section of $H^-$ Studies

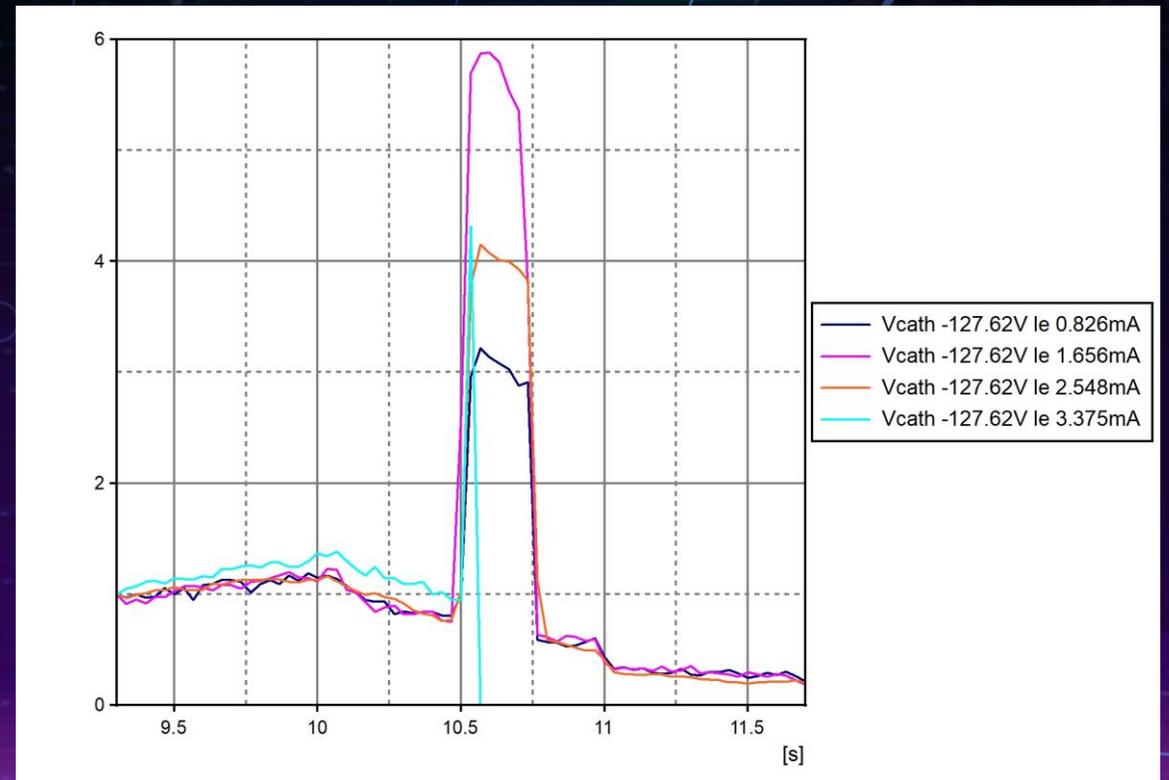
After the end of cooling at 13.7 MeV/c, the beam is bunched (to have an intensity measurement) and then the cooling is switched on again.





Scan of  $V_{\text{cath}}$  with  $V_{\text{grid}}$  fixed at  $-50\text{V}$

Scan of  $V_{\text{grid}} (I_e)$  with  $V_{\text{vath}}$  fixed at  $-127.62\text{V}$



# Conclusions and Outlook

- H0 monitor has been shown to be a useful tool to optimise the ELENA electron cooler
- It is the only non-destructive instrument for beam size measurements on ELENA
- However, measurements can only be made during dedicated machine experiment sessions due to the non-ppm power supplies used for the cooler
- The preliminary measurements on the beam alignment indicate that there is definitely room for improvement
- This needs to be confirmed with antiprotons (scraper measurements)
- Influence on electron current and beam expansion needs to be further addressed
- Electron detachment cross-section measurements will be investigated in more detail
- The camera will be replaced with a standard SY/BI system and ported to the main control system during the next shutdown