H^0 Diagnostics For the ELENA Electron Cooler

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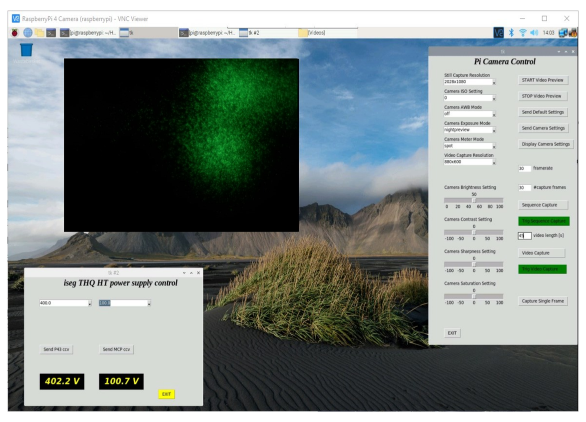
ABSTRACT

In addition to antiprotons, the ELENA ring at CERN can also inject protons and H^- ions from a dedicated ion source located close to the ring. These particles offer the possibility for extra diagnostics for detailed investigations into the cooling process at the very low energy of the ELENA ring. To this effect a monitor was installed downstream of the electron cooler to measure the recombination of protons with the cooling electrons. Although protons have never been used in ELENA, H^- ions are routinely used to setup and optimise the ring. The installed device is now used to monitor the stripping of the H^- ions on the residual gas and in the presence of electrons generated by the cooler, providing some insight on the evolution of the beam size during the deceleration cycle and the performance of the electron cooler on the two cooling plateaus.

CONTROLS

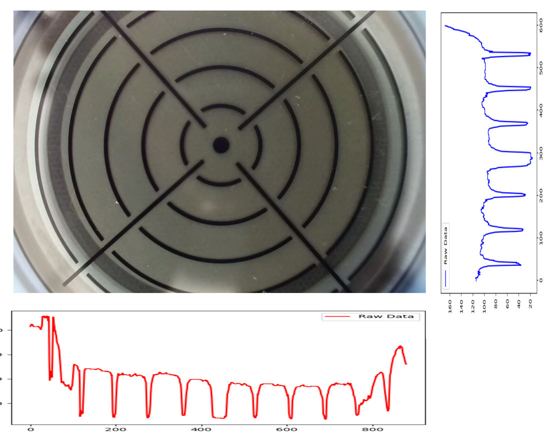
The high voltage for the MCP and P43 screen is provided by an iSeg THQ dual channel power supply. A Python script controls the voltage ramp that is applied to the MCP and screen.

Camera control is also performed via a Python script which enables the user to adjust the camera settings (resolution, exposure etc.) and to select the acquisition mode. Single-frame, multi-frame and video capture are available and can be triggered synchronously with events in the ELENA magnetic cycle



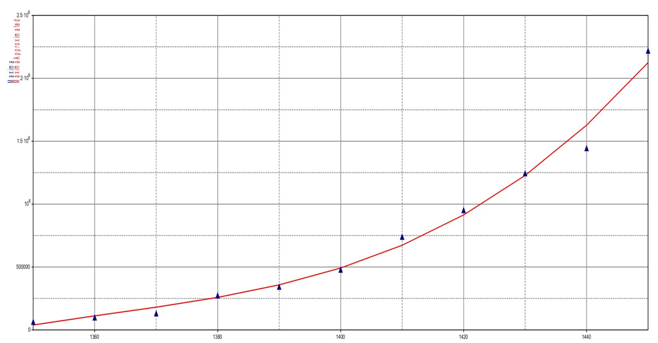
CALIBRATION

The 12.3 megapixel CCD camera allows single image capture resolutions up to 4056x3040 pixels. A transparent target was mounted on the window and the images at all the available resolutions were acquired in order to determine the spatial resolution for the different lens/resolution combinations



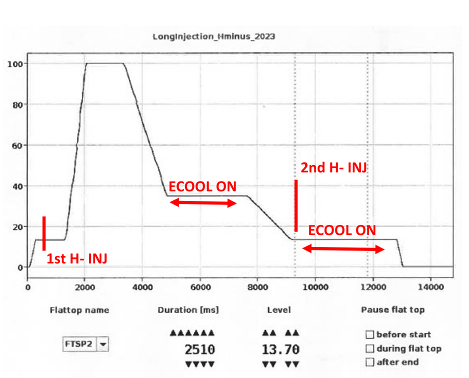
In video mode, to keep an acquisition rate of 30 Hz, a lower resolution of 880x600 was chosen.

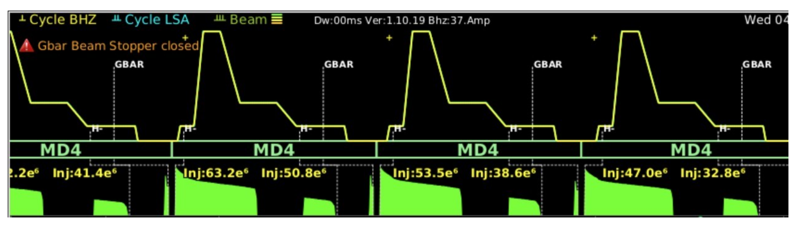
Video resolution	FUJINON 25 mm	RPI 6mm
640 x 480	39 µm/pixel	110 µm/pixel
880 x 600	22 µm/pixel	64 µm/pixel
1280 x 720	18 µm/pixel	
1600 x 900	15 µm/pixel	
1920 x 1080	12 µm/pixel	



The gain calibration was made by scanning the voltage applied on the MCP and recording the integrated beam profile signal on the phosphor screen. An operational voltage of 1400 V was chosen to avoid saturation issues.

DATA ACQUISITION



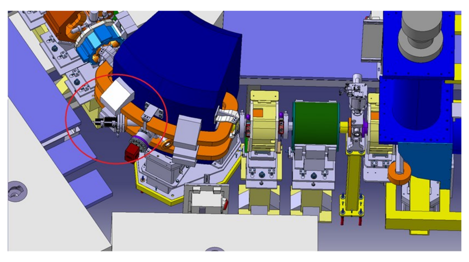


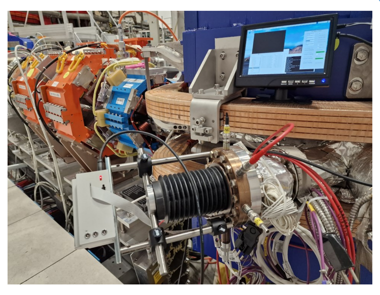
The MD4 cycle is a dedicated H^- cycle used for setting up the ELENA ring and the experiments. H^- ions are injected on the first 100 keV plateau, bunched, accelerated to 5.3 MeV and then decelerated to the first cooling plateau at 648 keV. After cooling, a further deceleration to 100 keV takes place where a new batch is injected before the cooling is switched on. The cooled beam is then ejected towards the experiments

A dedicated timing event (SMH0) is used to trigger the acquisition of the camera. The trigger is linked to the general start of the ELENA cycle and can be delayed to start the acquisition at a specific event during the deceleration (e.g. START ECOOL on FT2 at 4800 ms). The acquired video file is stored for offline data analysis. Single or sequential image capture is also available but rarely used due the lag in acquisition time.

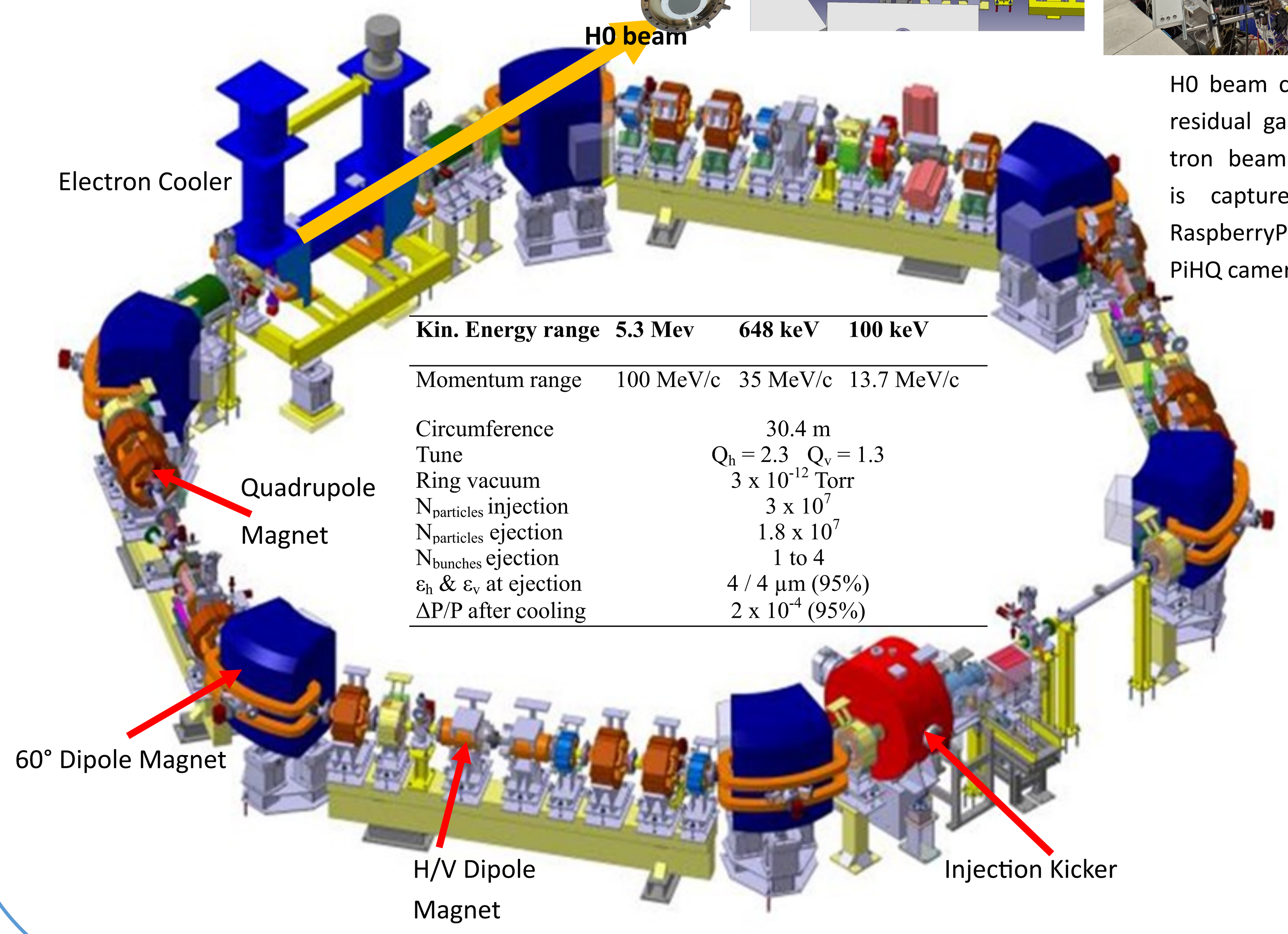
MEASUREMENT SETUP

Beam profiler consisting of a chevron mounted MgO coated MCP coupled to a P43 phosphor screen installed downstream from the electron cooler





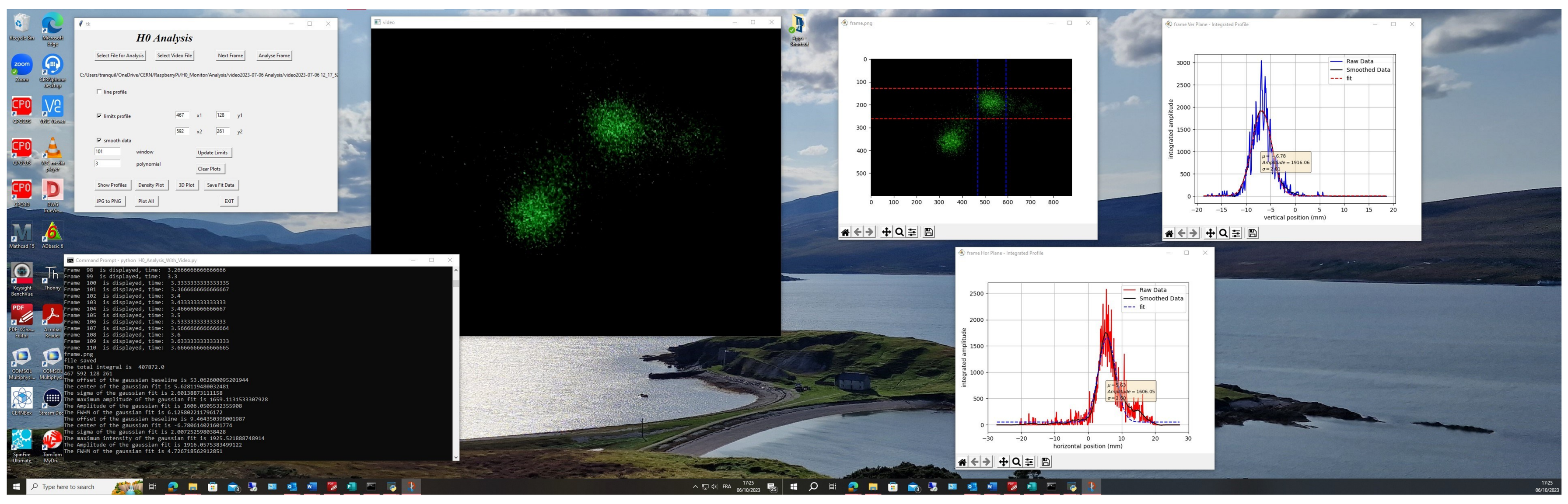
H0 beam created by residual gas or electron beam stripping is captured on a RaspberryPi with PiHQ camera mount



Kin. Energy range	5.3 Mev	648 keV	100 keV
Momentum range	100 MeV/c	35 MeV/c	13.7 MeV/c
Circumference	30.4 m		
Tune	$Q_h = 2.3$ $Q_v = 1.3$		
Ring vacuum	3×10^{-12} Torr		
$N_{particles}$ injection	3×10^7		
$N_{particles}$ ejection	1.8×10^7		
$N_{bunches}$ ejection	1 to 4		
ε_h & ε_v at ejection	4 / 4 µm (95%)		
$\Delta P/P$ after cooling	2×10^{-4} (95%)		

THE ELENA RING

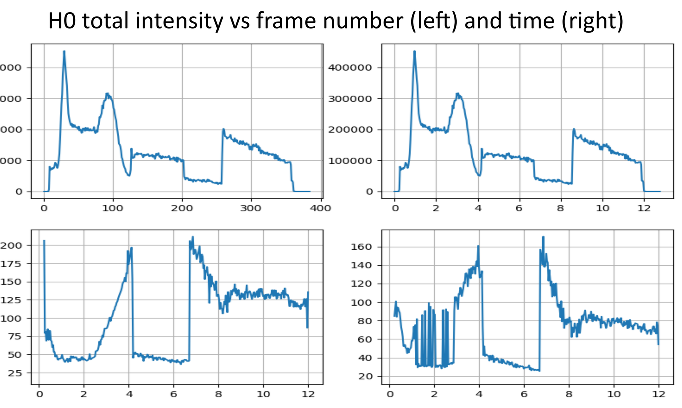
ANALYSIS SOFTWARE



Python scripts have been developed for the offline analysis of the captured data. The video file can be viewed in a frame-by-frame mode allowing for the possibility to analyse individual frames to extract information on the beam position, size and relative intensity.

For a quick analysis the whole video file can be analysed to show the evolution of the beam size and intensity throughout a full machine cycle. However, this method looks at the complete image and is not able to focus on areas of interest. This will be implemented in a future release.

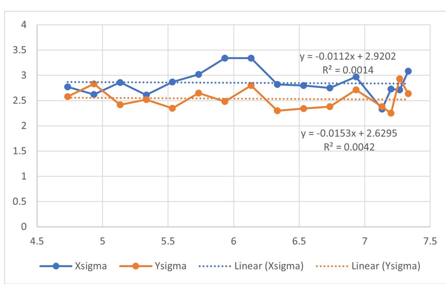
H0 total intensity vs frame number (left) and time (right)



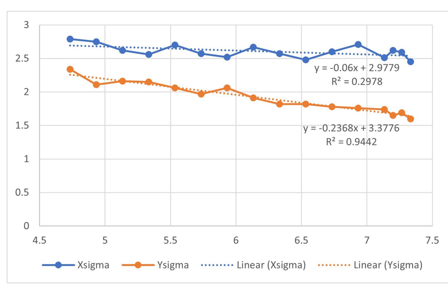
H0 horizontal beam size (1σ) vs time

H0 verticalal beam size (1σ) vs time

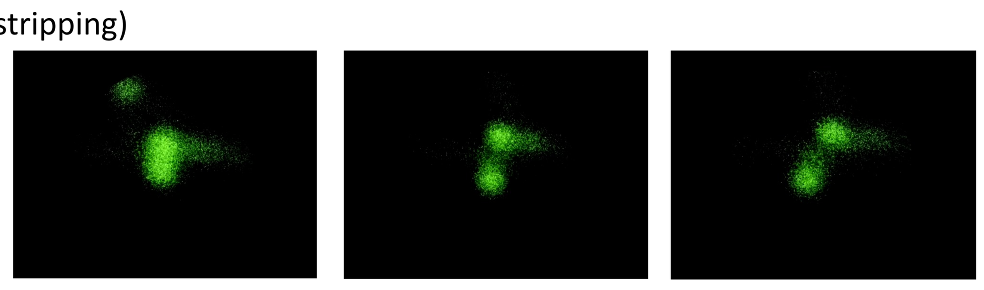
PRELIMINARY RESULTS AT 648 keV



H0 beam width evolution without électrons (residual gas stripping)



H0 beam width evolution with électrons



Evolution of the H0 video signal on the 648 keV cooling plateau

The influence of the cooling electrons has been investigated at the first cooling plateau of 648 keV. The measurements clearly show a small reduction in the H0 beam width but at the same time the intensity of the acquired signal is reduced significantly indicating beam loss. This cannot be confirmed as there is no beam current monitor available in the ring to measure the H^- beam lifetime. The measurement is made even more difficult by the fact that the H^- beam has a double-peak structure with only one part seemingly “cooled”.