H-jet status

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H-jet status and preparation for the Run-2024

- Since 2004, the H-jet is used to measure absolute proton beam polarization at RHIC
- After last using H-jet in the polarized proton run-22, we routinely running the H-jet keep it operational.
- For Run-24, we are continuing a major upgrade of the turbomolecular pump power and control system to ensure the future long-term operation of the H-jet. All upgrades are carried out without interrupting the operation of the H-jet.
- One of the important parts of the H-jet is the vacuum system. With the strong support of the Vacuum Group, we have made good progress with the H-jet vacuum system and continue to work on it.
- Another important part is the water-cooling system. Thanks to the support of Water Group, the water-cooling system works stably.
- Many other upgrades was done to improve performances and reliability.

The parameters of proton jet:

- Atomic Beam intensity - $12.6 \cdot 10^{16}$ atoms/s;
- Thickness at the collision point - $1.2 \cdot 10^{12}$ atoms /cm^2;
- Gaussian profile of jet - $\sigma \sim 2.6$ mm.

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H-jet polarimeter

The H-jet polarimeter includes three major parts:

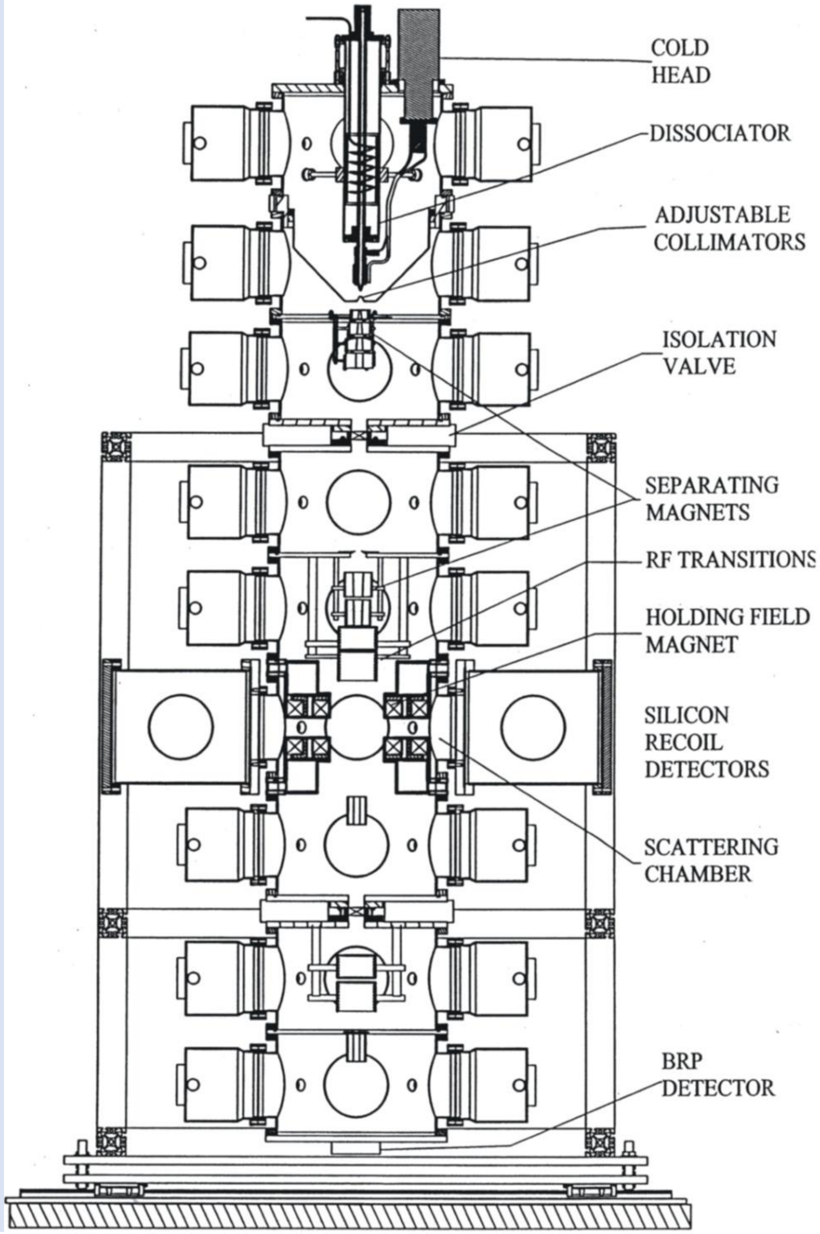
1. Atomic beam source (ABS) for formation of a vertically polarized and directed proton jet;
2. Scattering chamber with recoil proton spectrometer for measuring the polarization of the beam;
3. Breit-Rabi polarimeter (BRP) for determining the polarization of the jet protons.

H-jet operation supported by:

Vacuum system. The common vacuum system is assembled from nine identical vacuum chambers. Nineteen turbomolecular pumps with four scroll pumps provide the required vacuum. Nine TC and IG gauges provide control of vacuum.

Temperature control system. He-compressor, three water chillers and several heaters with flow-meters, temperature sensors is important part of stable operation of H-jet.

PLC system. The vacuum system, water cooling and temperature control system, interlocks and valves are controlled and monitored by the PLC system to ensure the safe operation of the H-jet.



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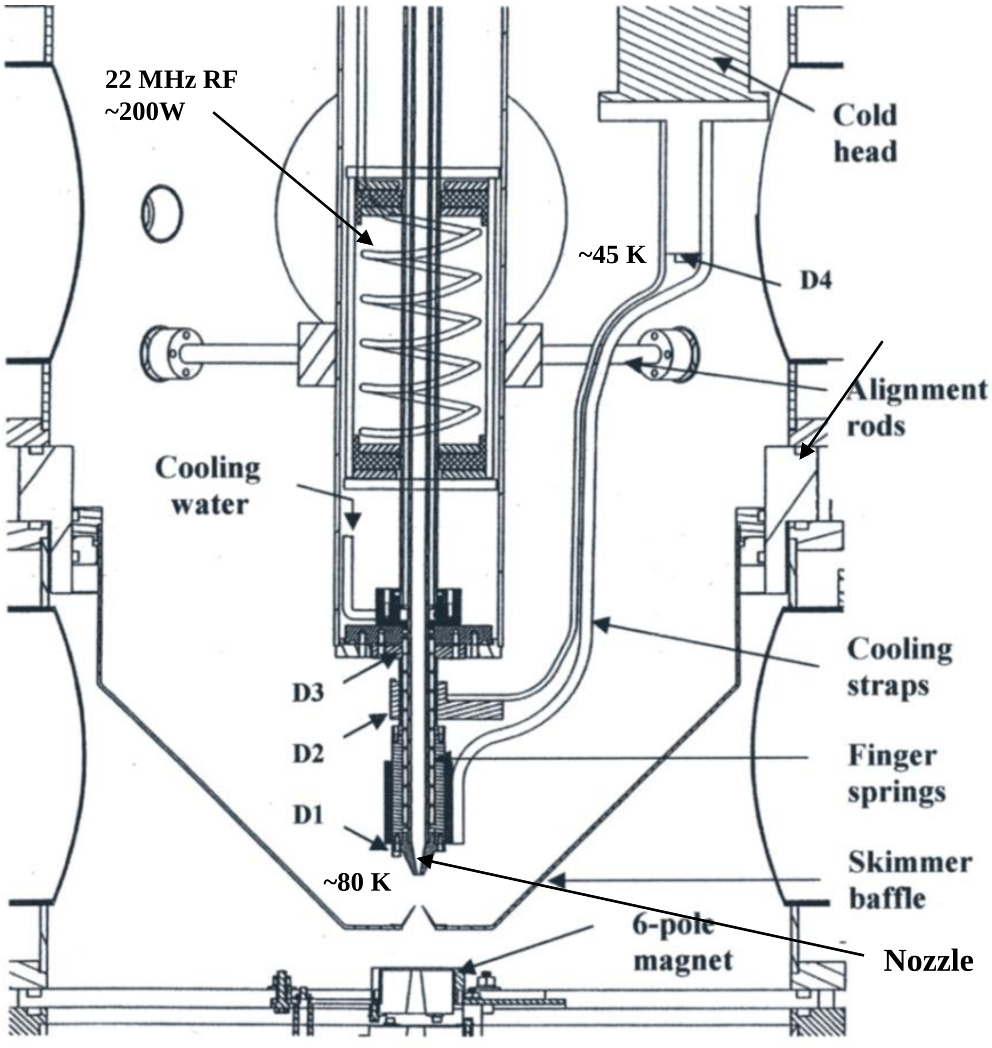
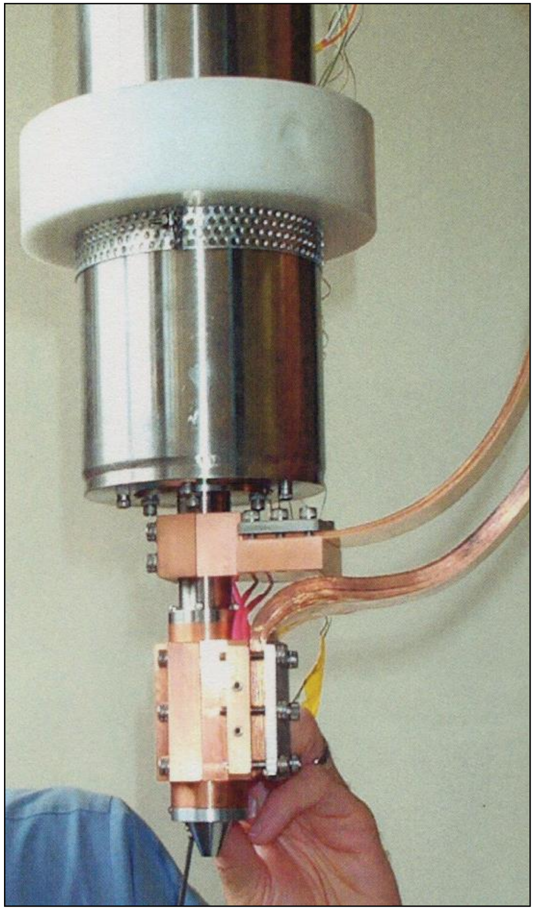
Dissociator

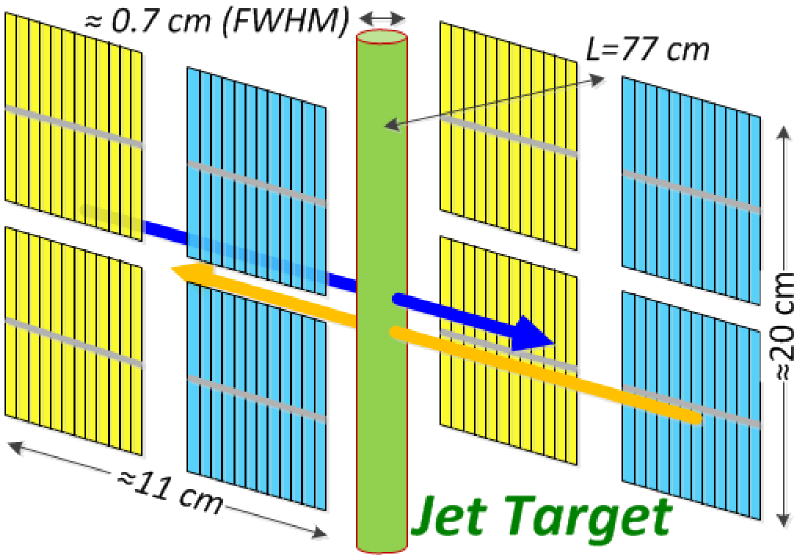
A powerful cryocooler with 30W cooling power, used to cool the last 12cm dissociator. Flexible copper cooling straps provide thermal conductivity between the cold head and dissociator. The contact between cold copper clamp and quartz tube is provided by the indium wire.

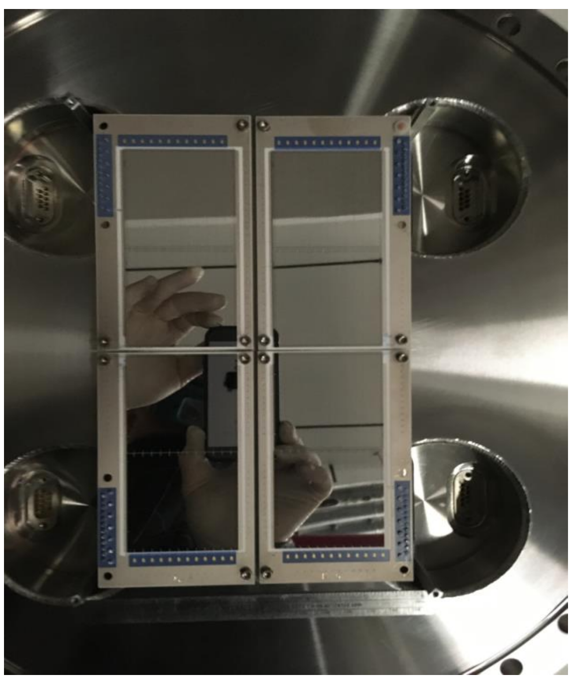
Driven worm-type gears allow the position of the skimmer to be adjusted by +/- 10 mm to optimize the intensity of ABS operation. The optimal distance from the nozzle to the skimmer is 15 mm, from the skimmer to the 6-pole magnet - 40 mm.





The HJET recoil spectrometer





- Recoil protons from the proton beam scattering off the jet are detected in the left-right symmetric silicon detectors.

8 detectors (12 strips per detector)

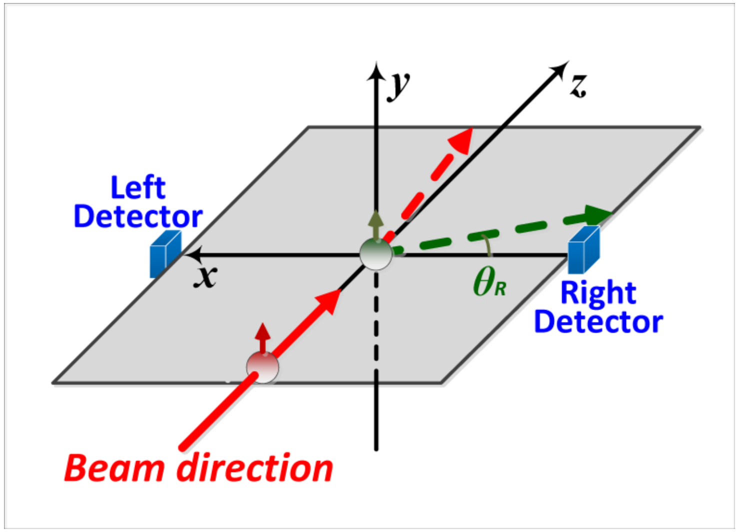
Detector size	$2\times(45\times45)mm^2$
Gap between detectors	$\approx 19\ mm$
Strip size	$2\times(3.75\times45)\ mm^2$
Gap between strips	$50\ \mu m$
Depletion region	$470\ \mu m$
Uniform Dead-layer	$\sim\ 0.37\ mg/cm^2$
Distance to the beam	$770\ mm$
Bias Voltage	$150\ V$

The measured recoil proton parameters

- T_R - kinetic energy,
- $ToF = t_R - t_0$ - time of flight,
- z_R - coordinate in detectors (discriminated by Si strip)
- and signal waveform shape analysis allows us to isolate the elastic events.

- ✓ **Energy resolution $\sim 20-25\ keV$**
- ✓ **Systematic errors in energy calibration $\delta E/E < 0.5\%$ for 1-6 MeV protons**
- ✓ **Time alignment of electronic channels is better than $\delta t \sim 120\ ps$**
- ✓ **z-coordinates of detectors with accuracy $\delta z \sim 100\ \mu m$**
- ✓ **beam angle and x-coordinate may be monitored with accuracy $0.1\ mrad$ and $100\ \mu m$, respectively.**

Proton beams polarization measurement at HJET



The beam (↑↓) and target (±) single spin asymmetries are concurrently measured in the recoil energy range:

$$0.5 < T_R < 10 \text{ MeV}$$

The same events are used to determine a_{beam} and a_{jet} . Therefore, for the elastic pp scattering, the jet and beam average analyzing powers are expected to be equal.

$$a_{\text{beam}} = \langle A_{\text{N}} \rangle P_{\text{beam}} \Rightarrow \frac{\sqrt{N_R^{\uparrow} N_L^{\downarrow}} - \sqrt{N_R^{\downarrow} N_L^{\uparrow}}}{\sqrt{N_R^{\uparrow} N_L^{\downarrow}} + \sqrt{N_R^{\downarrow} N_L^{\uparrow}}}$$

$$a_{\text{jet}} = \langle A_{\text{N}} \rangle P_{\text{jet}} \Rightarrow \frac{\sqrt{N_R^{+} N_L^{-}} - \sqrt{N_R^{-} N_L^{+}}}{\sqrt{N_R^{+} N_L^{-}} + \sqrt{N_R^{-} N_L^{+}}}$$

$$\Bigg\} \; P_{\text{beam}} = \frac{a_{\text{beam}}}{a_{\text{jet}}} P_{\text{jet}}$$

The beam polarization can be determined with no detailed knowledge of the analyzing power

Typical results for 8-hour store in RHIC Run 17 (255 GeV)

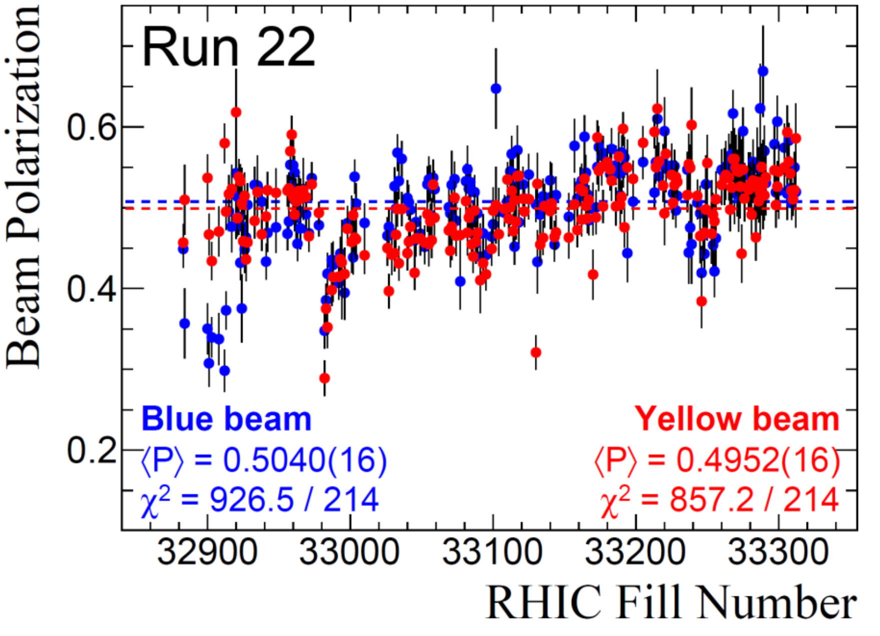
$$P_{\text{beam}} \approx (56 \pm 2.0_{\text{stat}} \pm 0.3_{\text{syst}})\%$$

$$\sigma_P^{\text{syst}} / P_{\text{beam}} \lesssim 0.5\%$$

Online measurements of the beam polarization in Run 22

From report in PSTP-22 at 2022.09.29

- For online measurement of the 255 GeV proton beam polarization, we used effective analyzing powers calibrated in Run 17.
- To verify the method, we can compare the measured analyzing powers (for Cuts I) in RHIC Runs 17 and 22.



Run 22: $\langle A_N \rangle_B = 3.757 \pm 0.007\%$

$\langle A_N \rangle_Y = 3.757 \pm 0.007\%$

Run 17: $\langle A_N \rangle_B = 3.769 \pm 0.006\%$

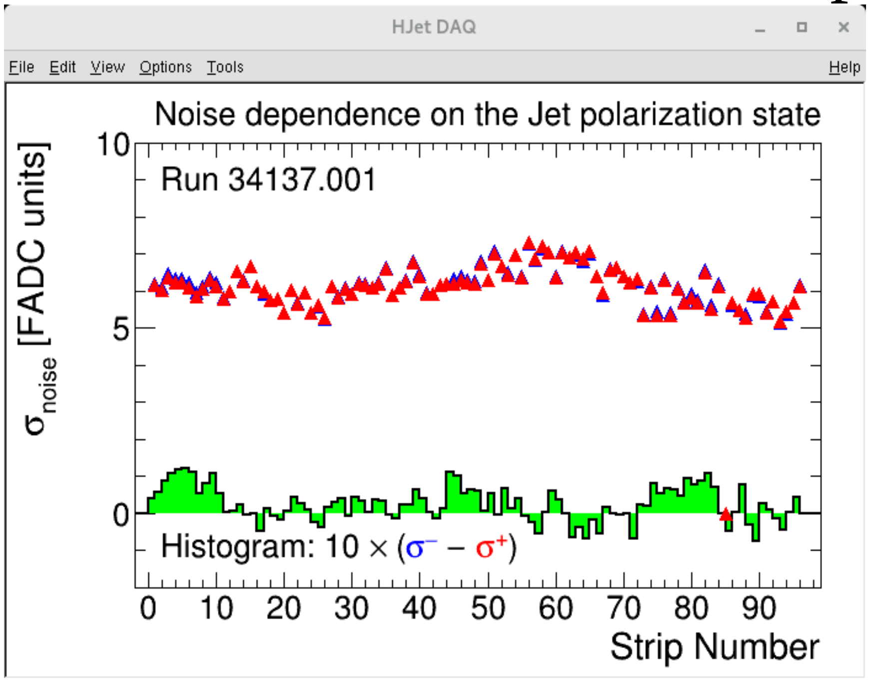
$\langle A_N \rangle_Y = 3.765 \pm 0.006\%$

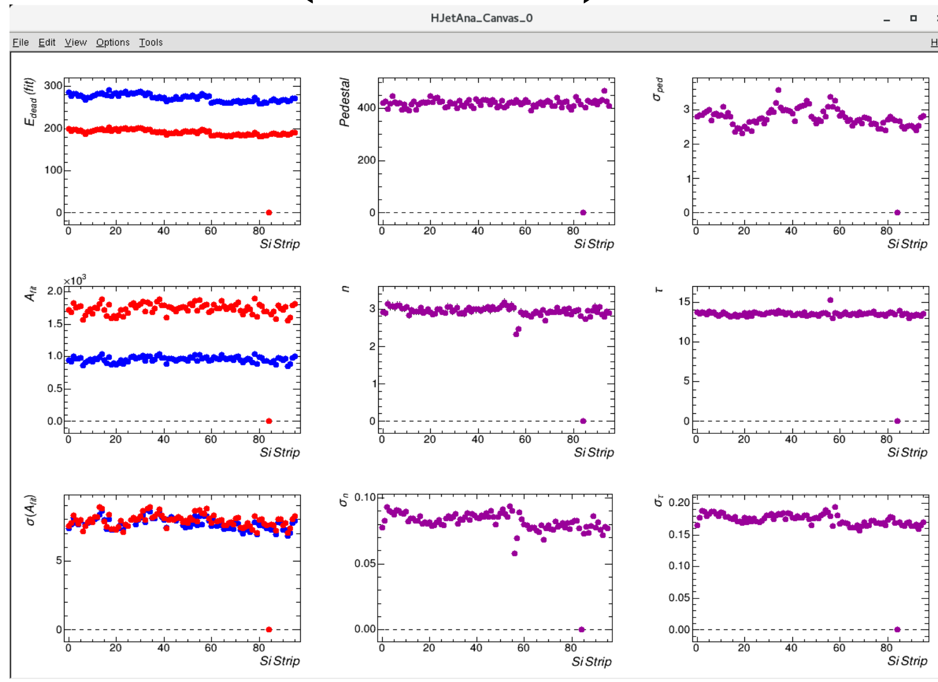
The result consistency $\chi^2/\text{ndf} = 2.3/3$

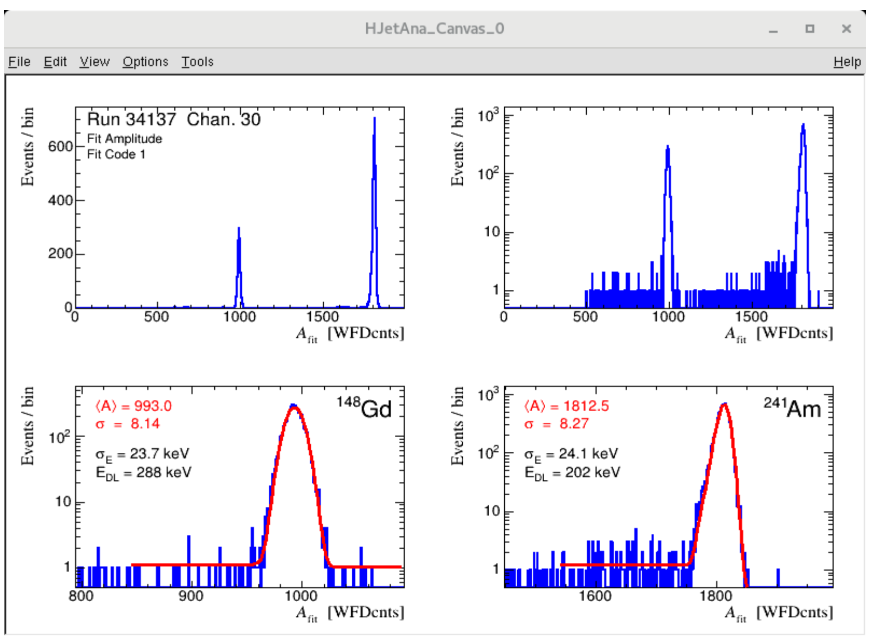
- Run 17 and 22 measurements are consistent within $< 0.3\%$ statistical accuracy.
- In Run 22, systematic uncertainties of online measurements are $\sigma_P^{\text{syst}}/P_{\text{beam}} \lesssim 0.6\%$.
- That is, the online results may be considered as final (offline) ones

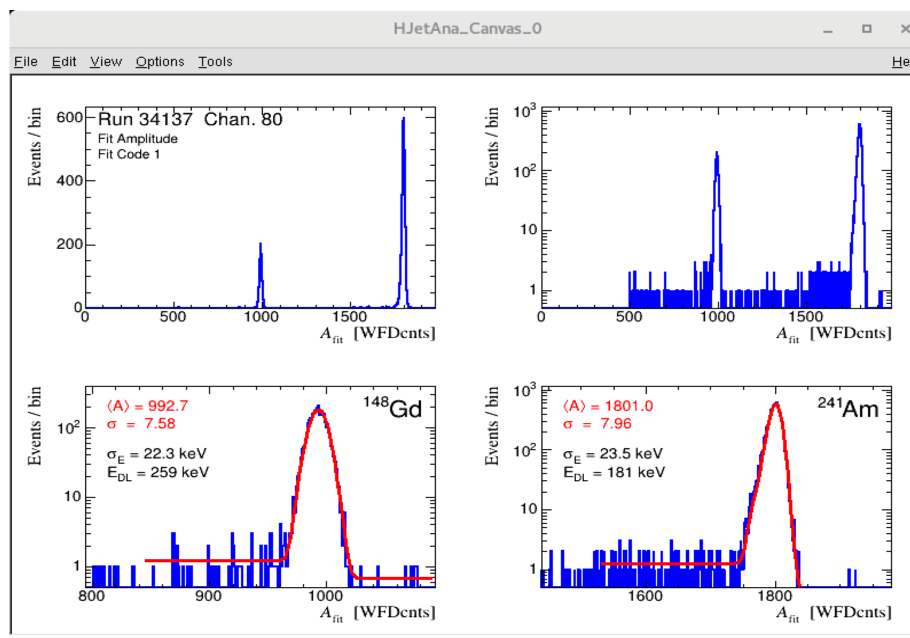
- Good long-term stability for both RHIC Runs 17 and 22
- Good consistency for Run 17 and 22 results
- In Run 22 measurements, variation of the systematic errors, if any, is small compared to the statistical uncertainties.

The HJET recoil spectrometer (10/01/23)

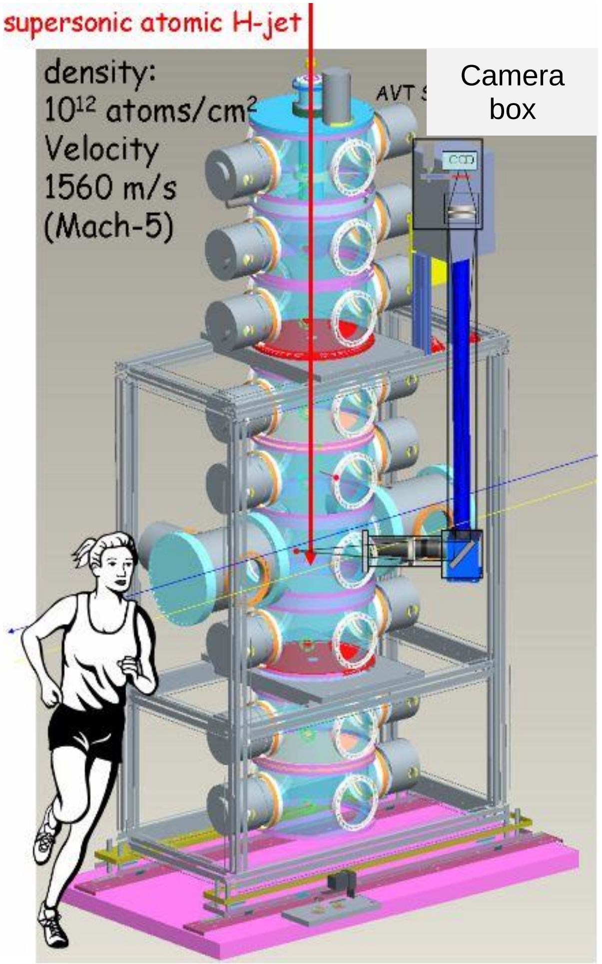




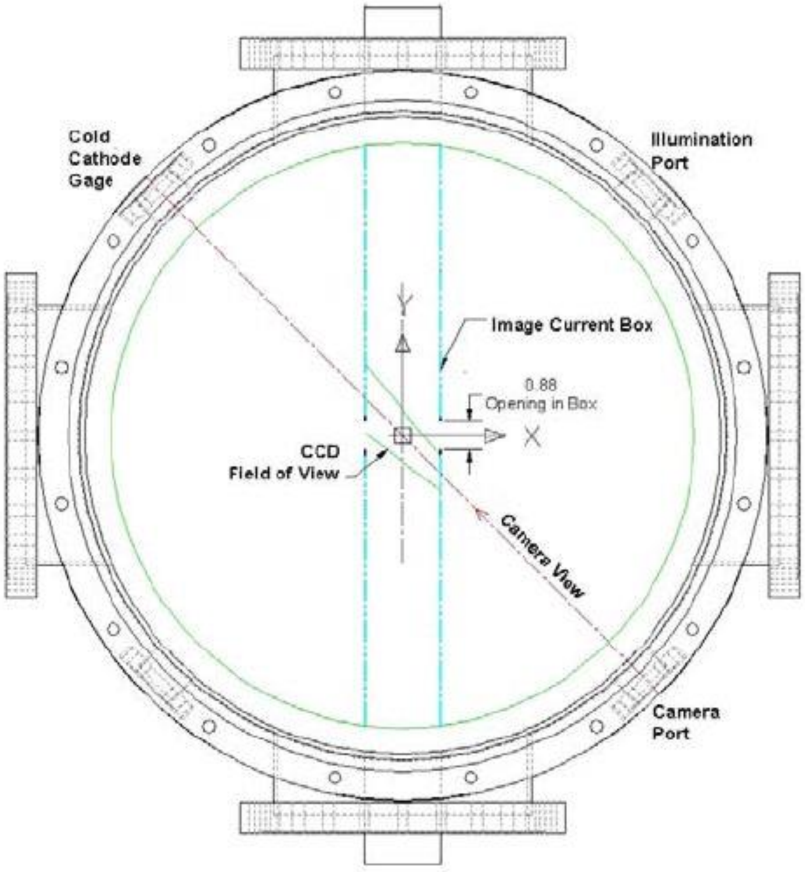




Optical Beam Profile Monitor



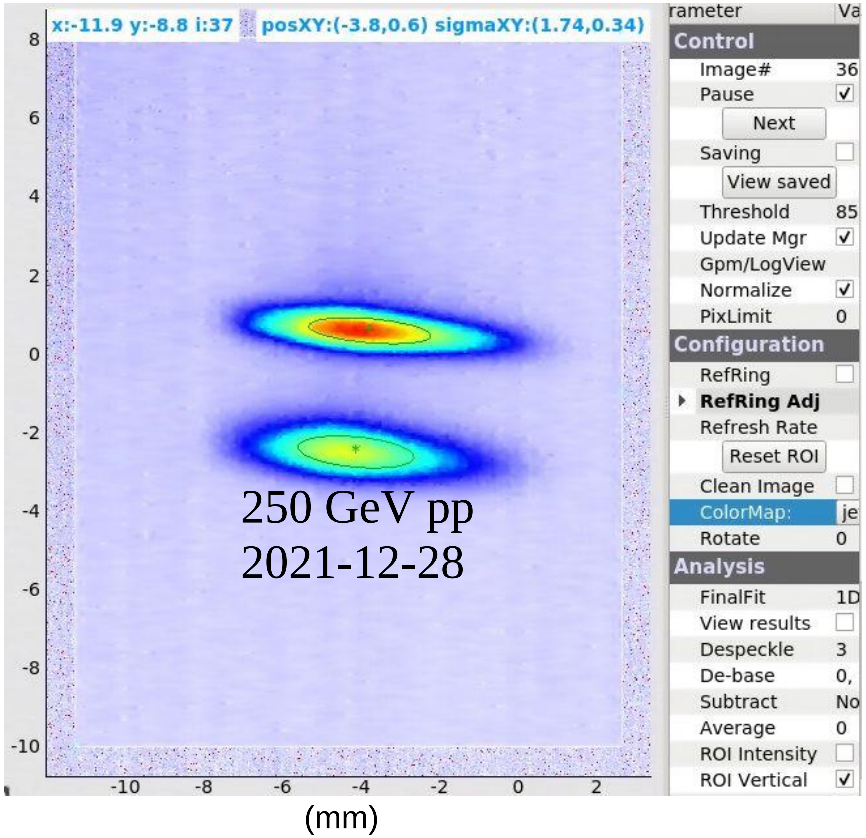
Beam crossing chamber



Reference: T. Tsang et al. Optical beam profile monitor at the RHIC polarized hydrogen jet. Proceedings of PAC09, Vancouver, BC, Canada. 2009

Reference: THE RHIC HYDROGEN JET LUMINESCENCE MONITOR, T. Russo, S. Bellavia, D. Gassner, P. Thieberger, D. Trbojevic, T. Tsang, Proceedings of PAC07, Albuquerque, New Mexico, USA

Imaging of 250 GeV pp beams.

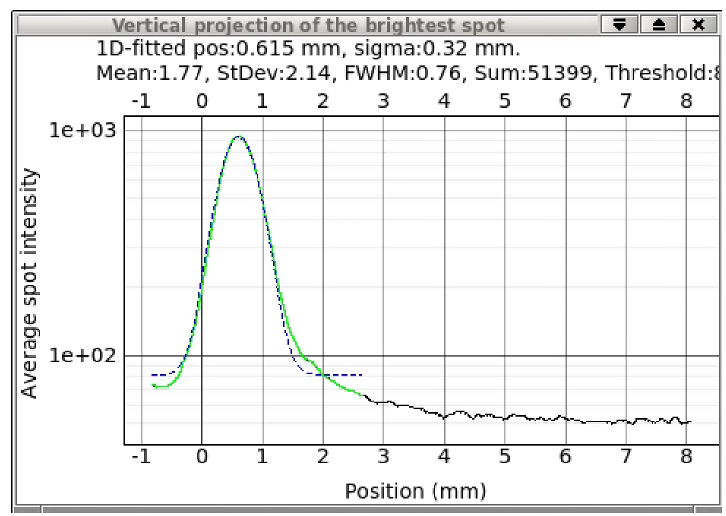


In 2019 The camera was replaced with Prosilica GT1930.

- Temporal dark noise 3.3e vs 11.5e.
- Sensor size 1/1.2” vs 2/3”

Reliable Au beam size measurements:

- 6+ bunches with exposure 1s.
- 1 bunch with exposure 10s.



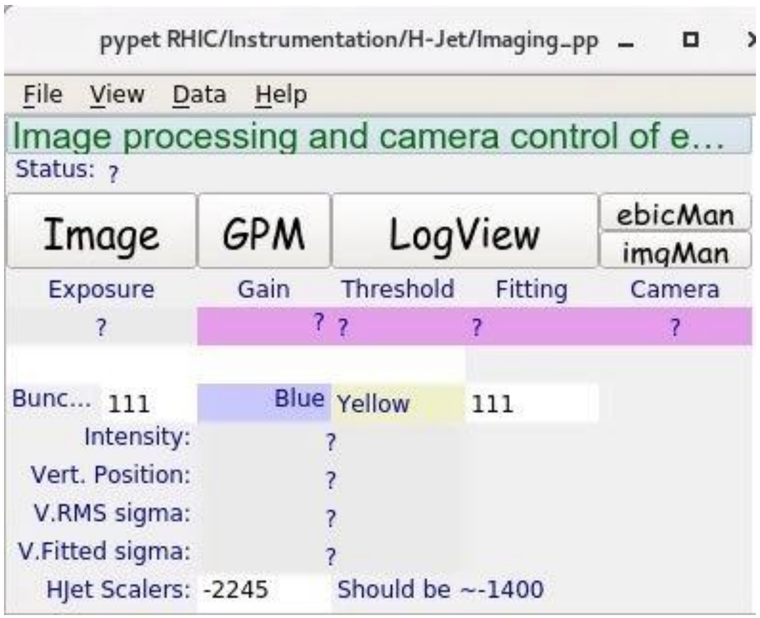
H-jet beam measurement issues.

H-jet can be used only for qualitative analysis of the beam size.

- The beam size reported by H-jet is overestimated, discrepancy is larger at higher energy.
- Beam image intensity depends on beam energy.
- Beam size depends on bunched bunch intensity, rather than total beam intensity.

Extra luminescence probably comes from electron cloud accelerated by the bunch wake field.

Pet page: RHIC/H-Jet/Imaging.

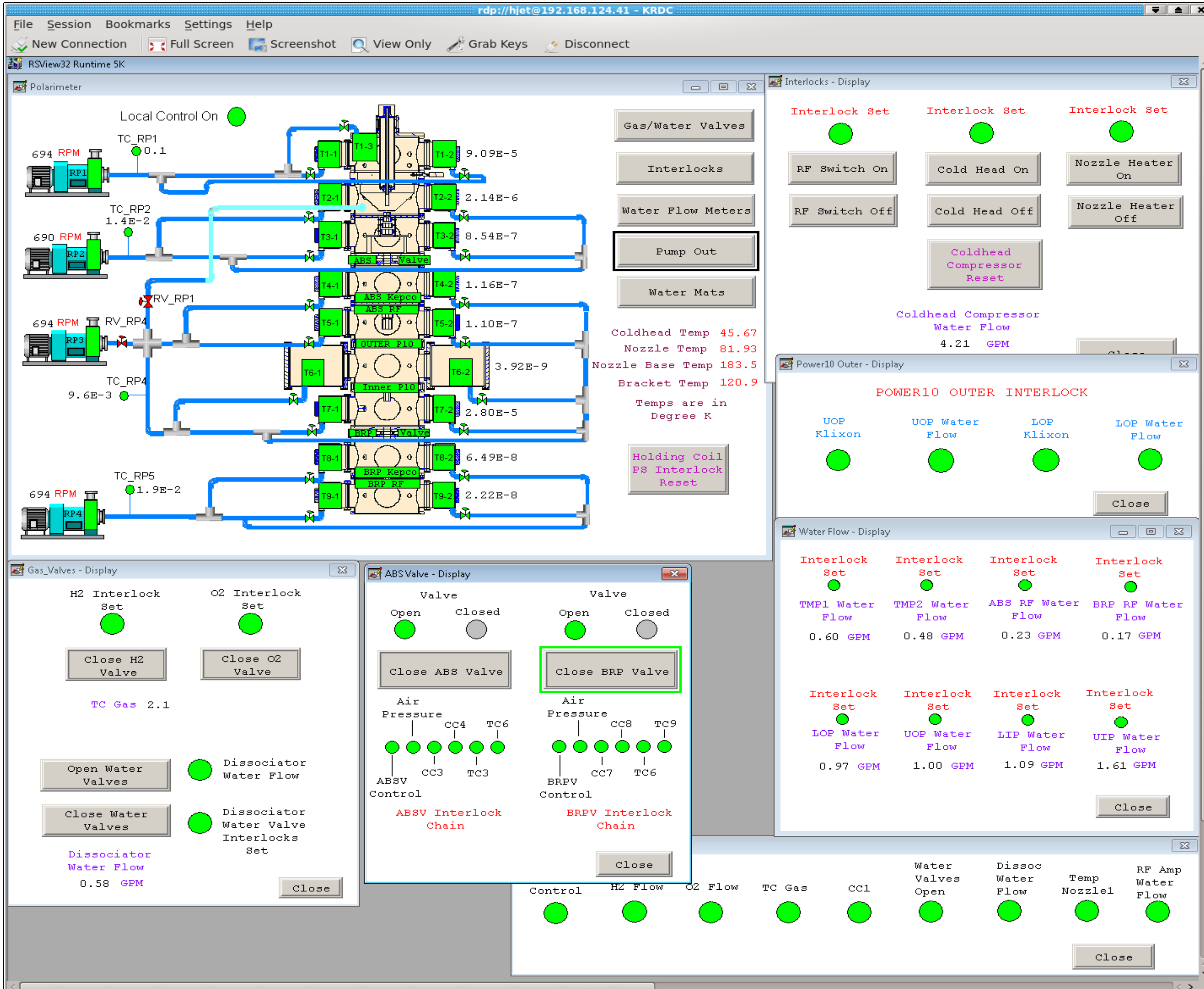


H-jet Image Monitoring

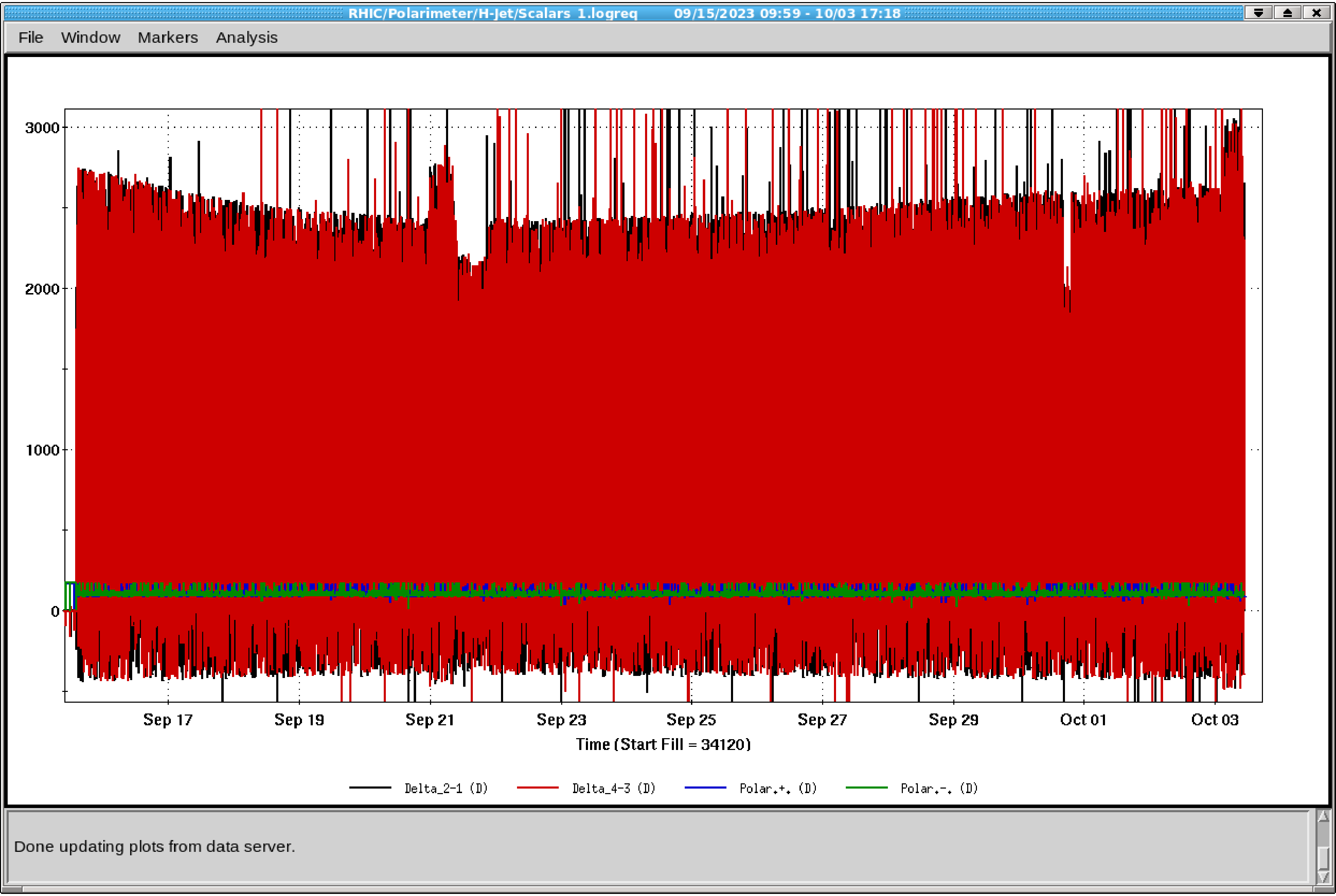
Prior to Run24 operations the camera focus need to be adjusted. Two options:
1) Tune by beam for the minimal vertical beam size.
2) Focus on front and back guard wires and take and set the focus to the mean value.

H-jet today

PLC Graphical User Interface

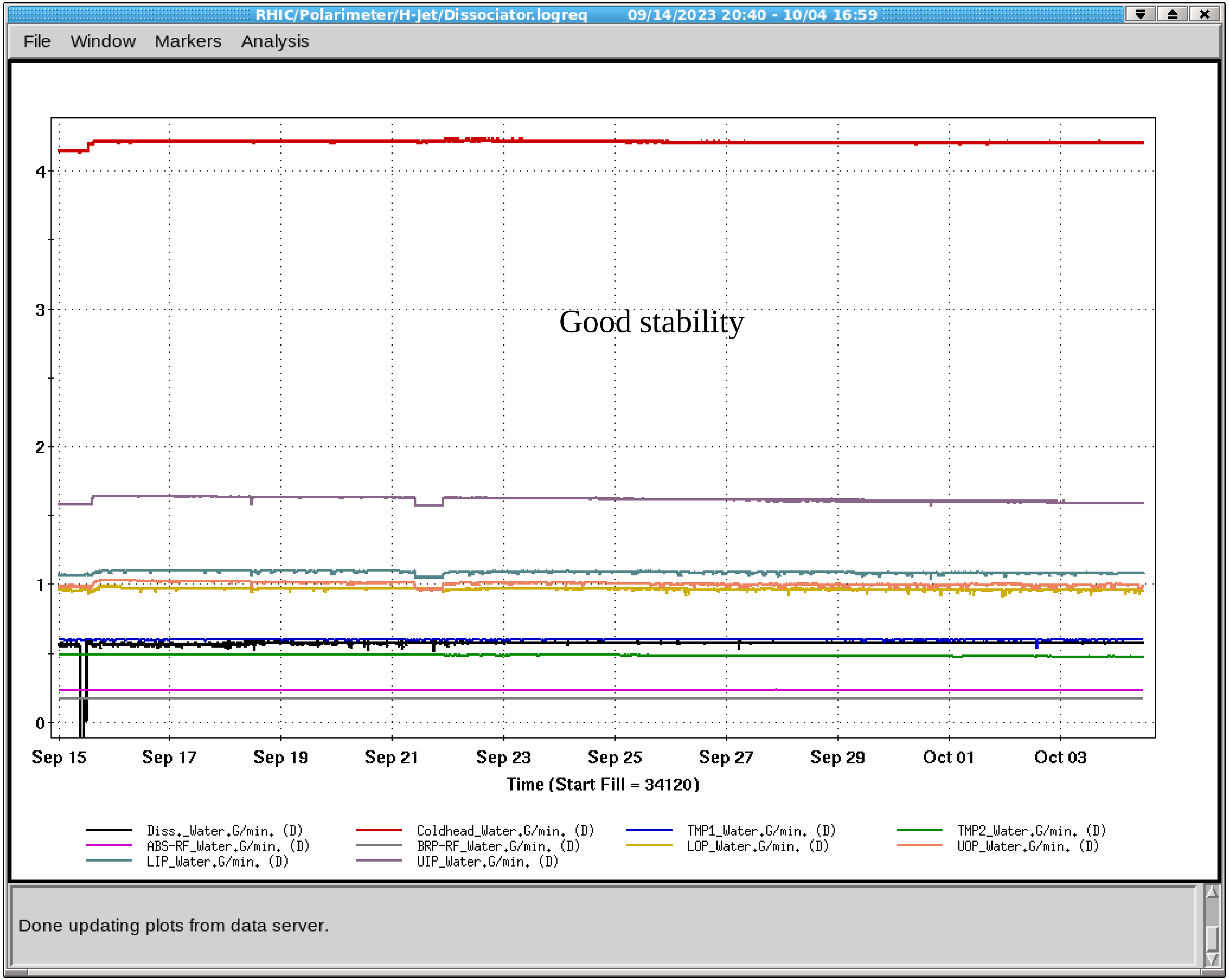


Jet intensity over the last 19 days



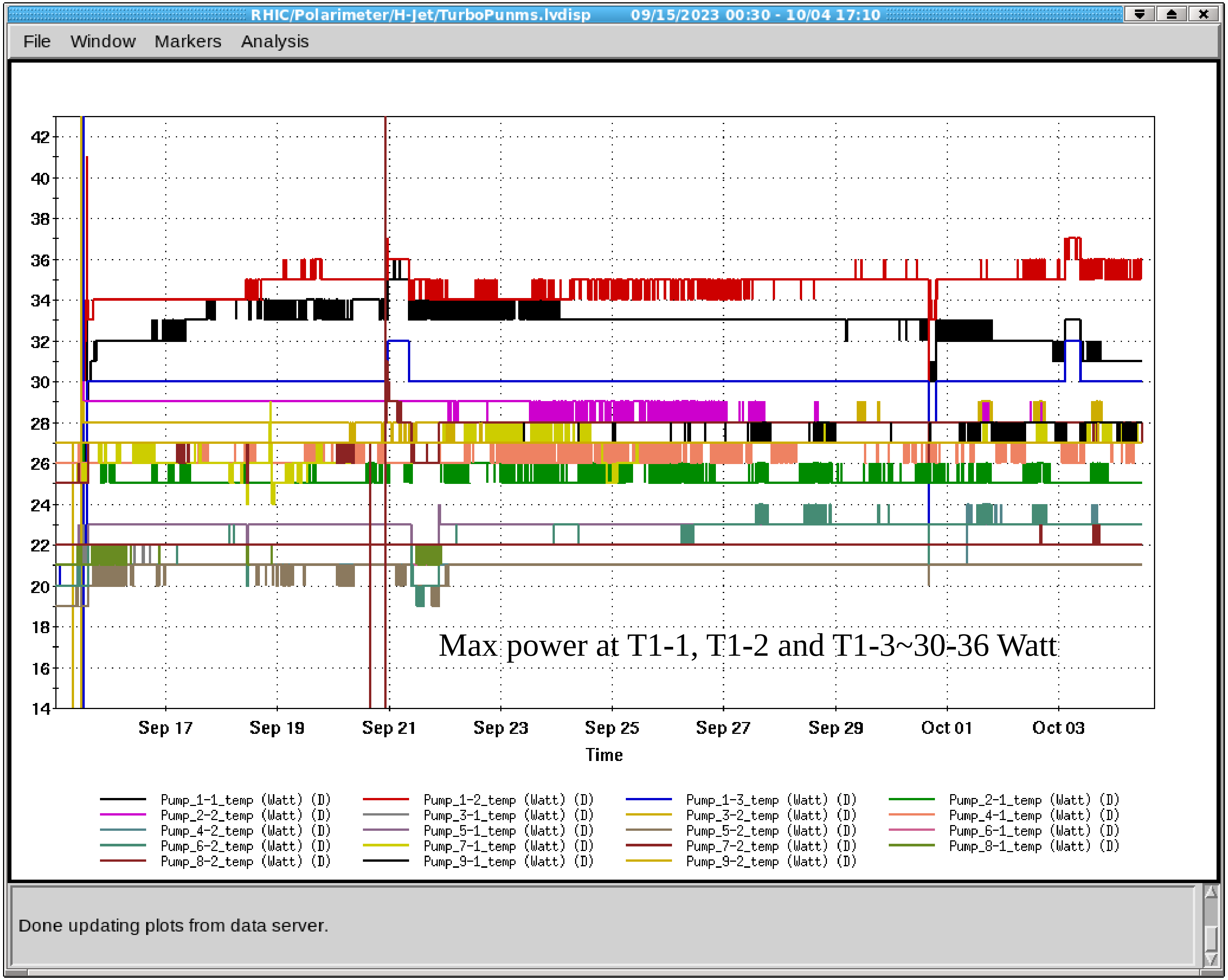
Cold head and nozzle temperature over the last 19 days

Cooling water flow monitor over the last 19 days

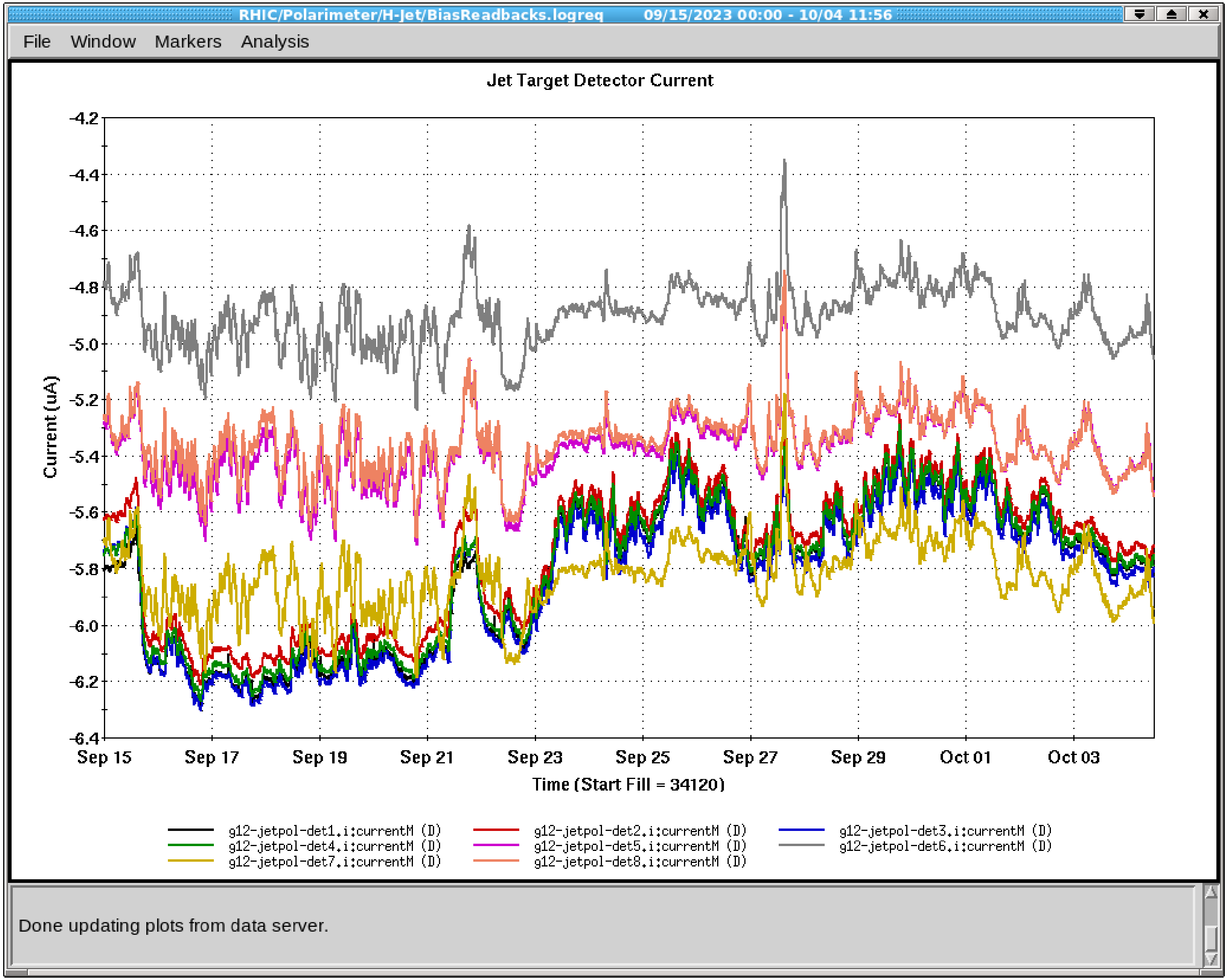


Ion Gauges over the last 19 days

Turbomolecular pumps performance over the last 19 days



Dark current of detectors



C-AD Vacuum Group responsibility for the H-jet vacuum

The C-AD Vacuum Group will assume responsibility for the vacuum performance of the RHIC Hydrogen Gas Jet as follows:

1. Maintaining inventory of spare vacuum components such as turbo pumps and turbo controllers, scroll pumps, related vacuum pumping manifold components, gauges and gauge controllers.
2. Regular vacuum system monitoring and preventive maintenance to maintain required vacuum for H-Jet and RHIC beam vacuum
3. Support H-Jet operators requests to investigate and resolve vacuum system performance issues as they arise.
4. Upgrade Vacuum system I&C in coordination with H-Jet operators and Controls Group to improve monitoring, control, and robust operation.

More specifically:

a. Revise PLC vacuum control logic as requested by cognizant scientist with approval from Vacuum engineering

b. Update graphical user interface (GUI) to correct errors per cognizant scientist request

c. Work with Controls Front End Software group to move PLC data communication from VME to LINUX managers, ensuring device name compatibility with vacuum schematic and GUI

d. Work with Controls Front End Software group to move vacuum gauge controller communication from VME to Digi Terminal Server manager and verify data logging

e. Replace convection gauge cable back-shells with improved design for easier disconnection (rack end)

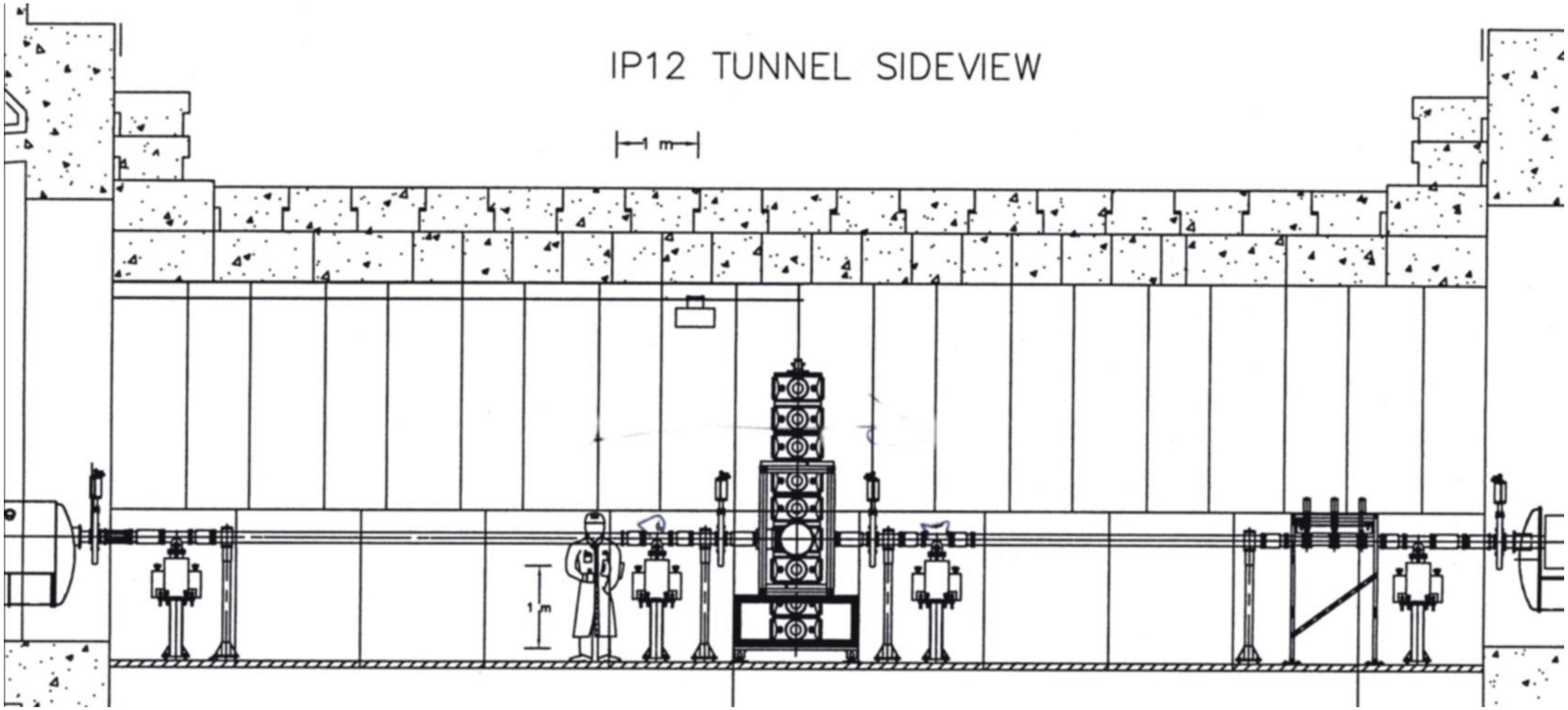
Summary

- After last using H-jet in the Run-22, we routinely run the H-jet keep it operational.
- We are continuing a major upgrade of the turbomolecular pump power and control system to ensure the future long-term operation of the H-jet.
- One of the important parts of the H-jet is the vacuum system. With the strong support of the Vacuum Group, we have made good progress with the H-jet vacuum system and continue to work on it.
- Another important part is the water-cooling system. Thanks to the support of Water Group, the water-cooling system works stably.
- Many other supports from Instrumentation, Control, … Groups improve the performances and reliability of the H-jet.
- All upgrades are carried out without interrupting the operation of the H-jet.

- We have a scheduled maintenance day next week. In addition, the vacuum group will replace the faulty ion sensors and we will continue to operate the H-jet regularly.

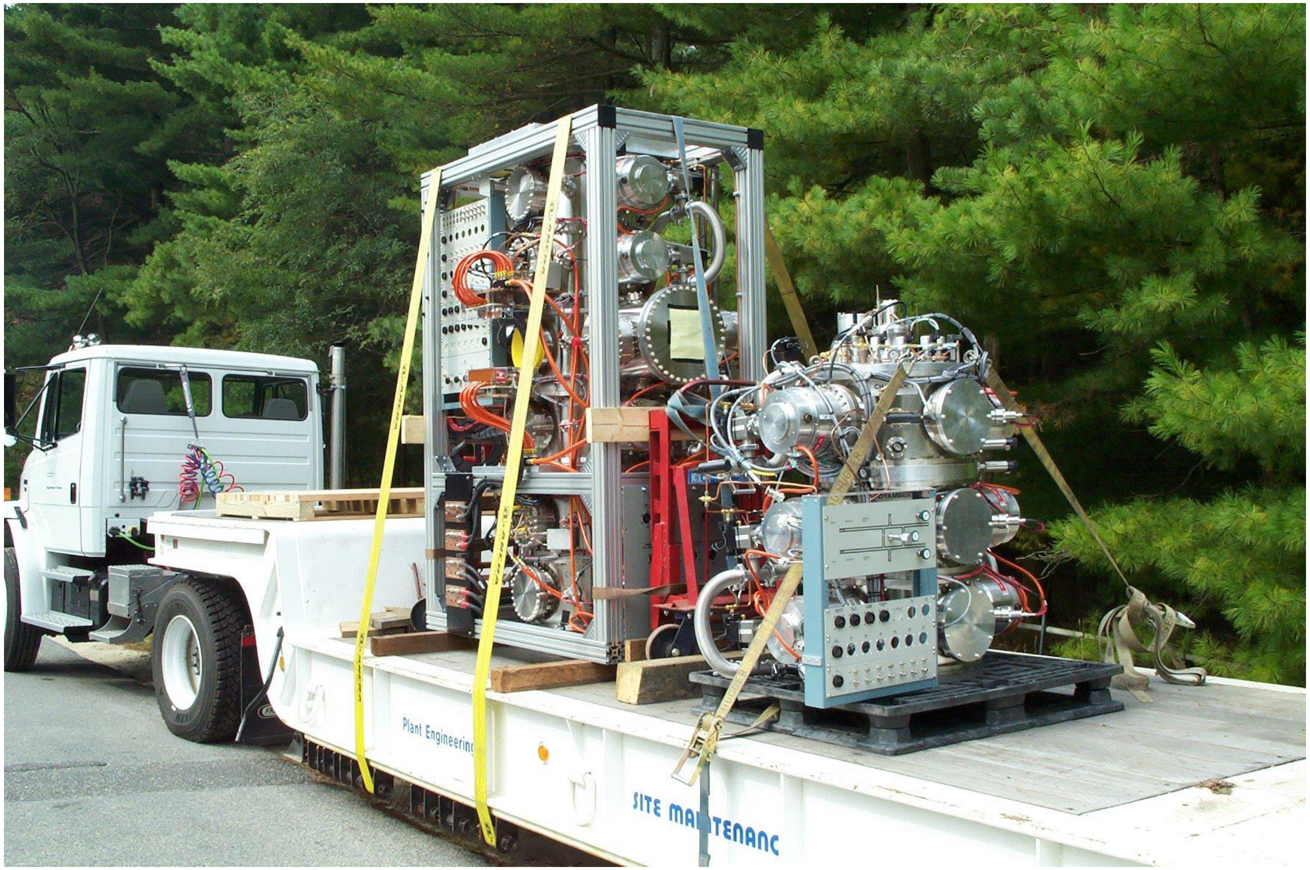
The H-jet is in a good shape for the Run-2024.

H-jet layout at the IP-12.



H-jet polarimeter can be moved and installed into the RHIC ring in one day.

A. Zelenski for H-jet collaboration, **VARIAN, October 7, 2004**



The power supply and control system is assembled in seven joint racks on the wheels.