OPPIS Polarized Proton Source: Status and Outlook

A. Zelenski, G. Atoian, J. Alessi, T. Lehn, D. Raparia,
J. Ritter, D. Steski, V. Zubets

July 25, 2013
RHIC retreat 2013

In Run-13 the upgraded polarized proton source was used

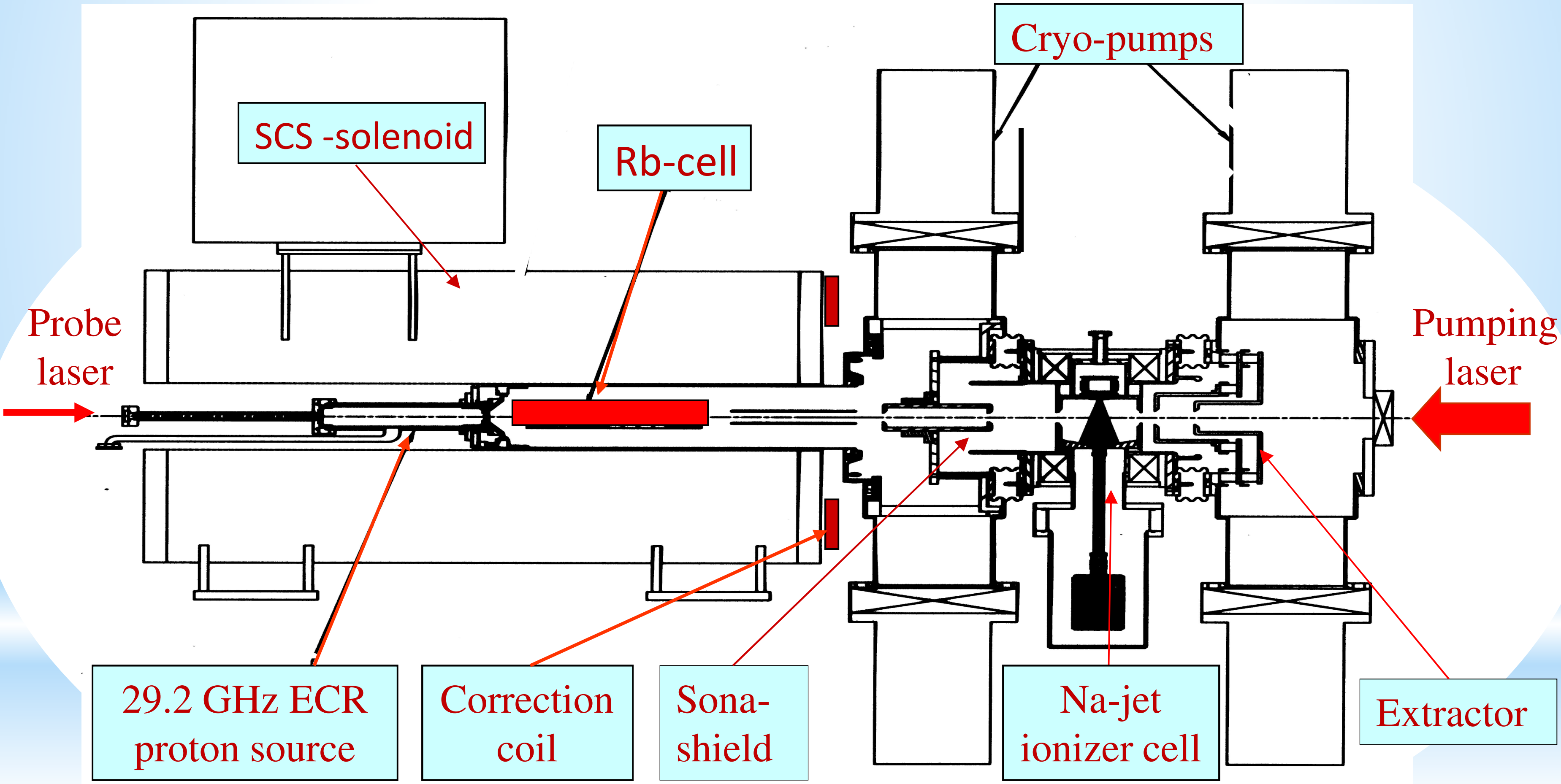
OPPIS H^- ion source had been upgraded to a higher intensity and polarization.

Up until Run-13 a ECR-type source was used for primary proton beam generation. The source was originally developed for DC operation and placed inside of the super conductive solenoid (SCS).

A tenfold intensity increase was demonstrated in pulsed operation by using a high-brightness Fast Atomic Beam Source (FABS) instead of the ECR proton source. FABS was developed at BINP, Novosibirsk to improve the source parameters such as beam current density, angular divergence, and stability.

Run-12: ECR proton source

- OPPIS produces 0.5-1.0mA polarized H^- ion DC current
- Polarization at 200MeV polarimeter ~79-80 %

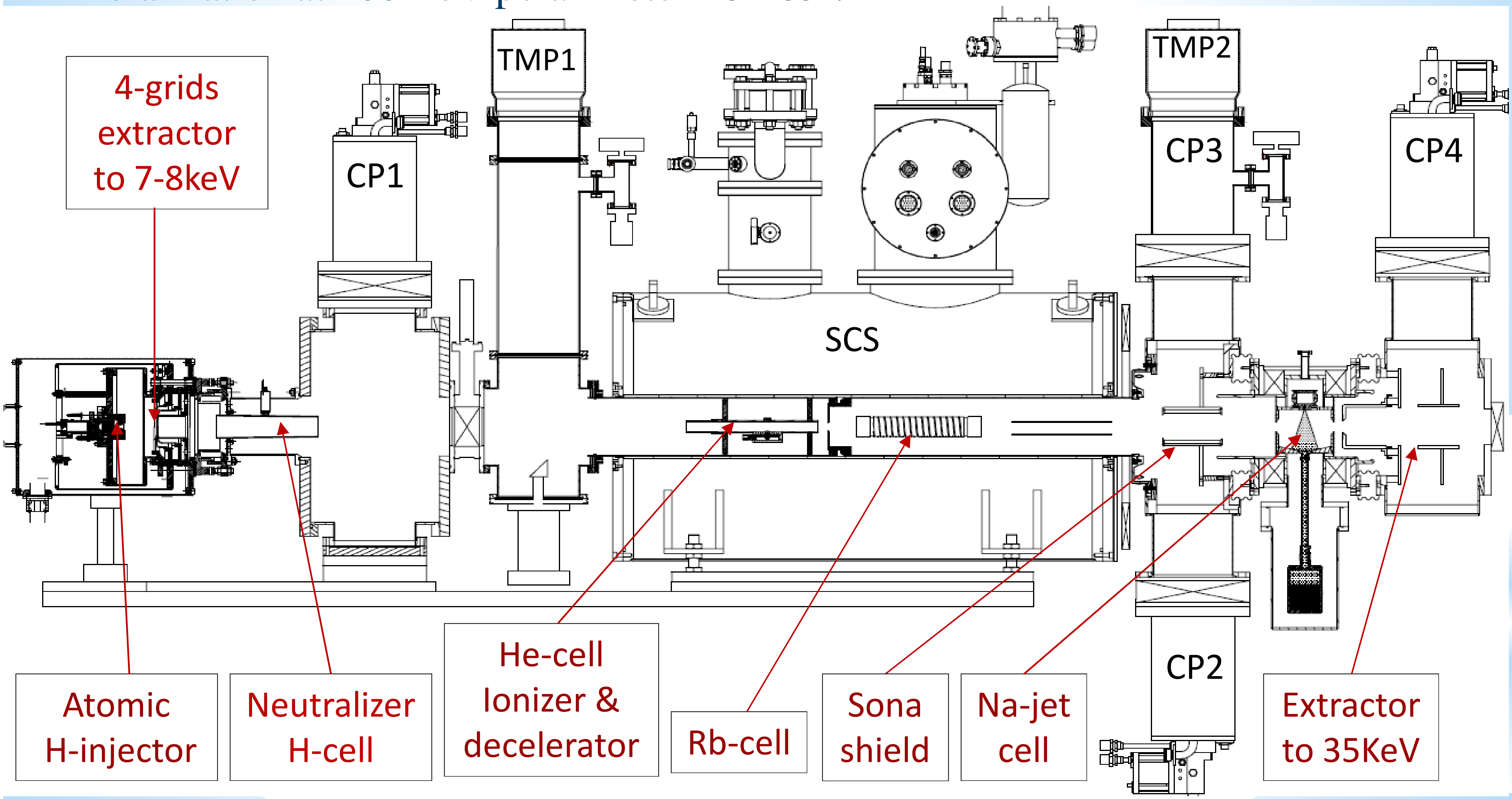


$$H^+ \xrightarrow{\text{Rb-cell}} H^0 \xrightarrow{\text{Na-jet}} H^-$$

0.5-1.0mA

Run-13: FABS proton source

- OPPIS produces 5-10mA polarized H^- ion pulse current
- Polarization at 200MeV polarimeter ~82-83 %



$H^+ \xrightarrow{\text{H-cell}} H^0 \xrightarrow{\text{He-cell}} H^+ \xrightarrow{\text{Rb-cell}} H^0 \xrightarrow{\text{Na-jet}}$ 5-10mA H^-

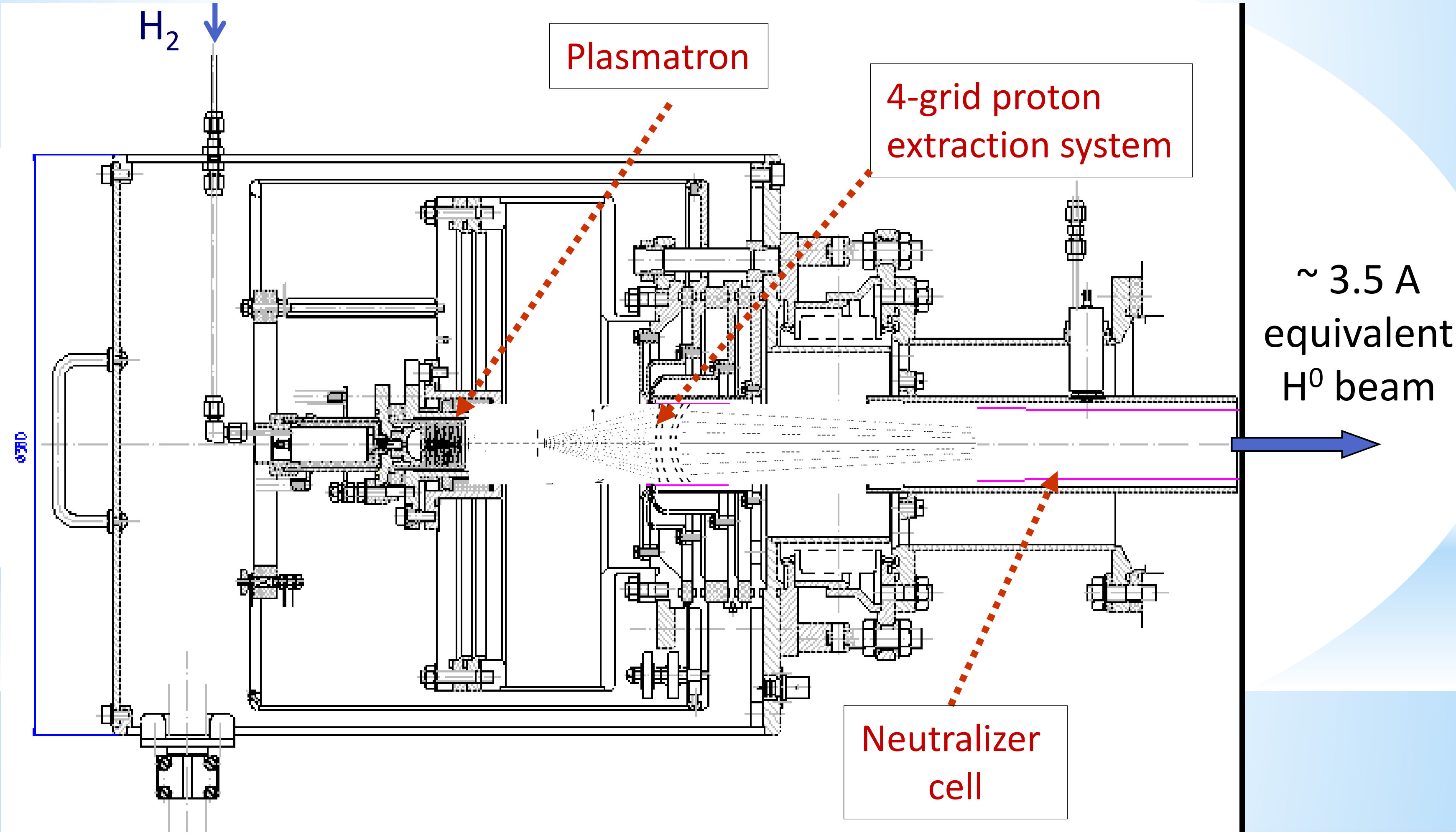
A result of 2012-13 “upgrade” is practically a new source

1. A new atomic hydrogen injector with pulsed PS system
2. A new superconducting solenoid
3. A new He-ionizer cell with energy separation system
4. Major modifications of the Low Energy Beam Transport (LEBT) system
5. Major upgrades of laser system
6. Upgrades vacuum system
7. A new PLC interlock and control system
8. A new test-bench for atomic injector studies

1. “Fast Atomic Beam Source”, BINP 2011

In FABS the pulsed proton beam from the arc plasma generator (plasmatron) is extracted by a four-grid multi-aperture ion optical system and neutralized in the H-cell. The multi-hole grids are spherically shaped to produce “geometrical” beam focusing. New source placed outside of the SCS.

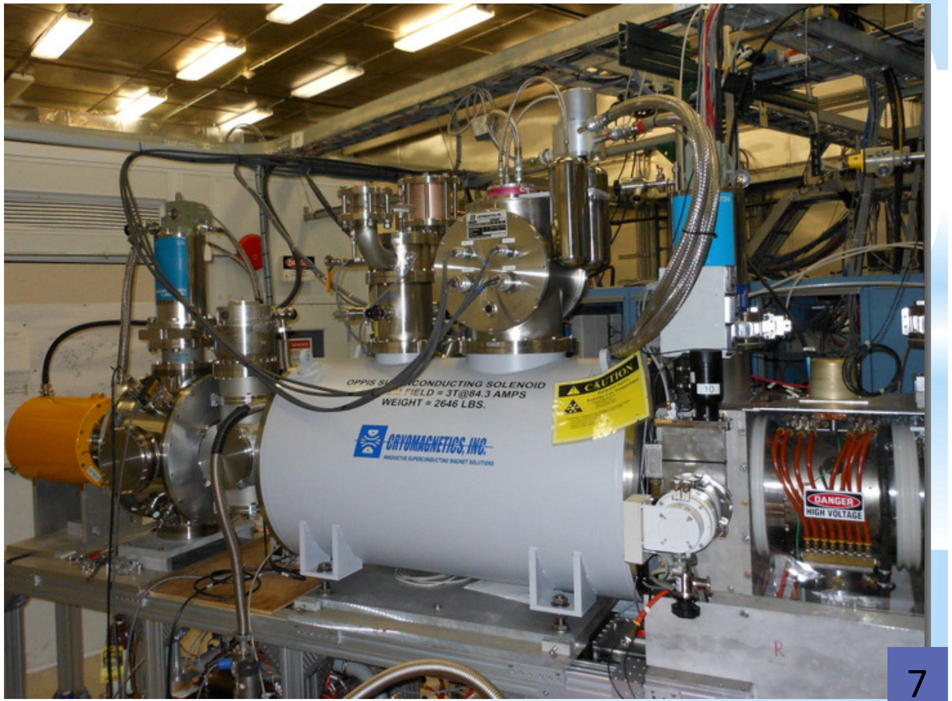
Out of the FABS we have a pulse current of 3.5A with an energy of 7keV.



2. Superconducting Solenoid

- Magnet designed and built by "Cryomagnetics" to BNL specification
- $390k Contract Awarded 7/26/2010 - Delivered 2/16/2012
- Acceptance tests completed in March and installed on the source line in May 2012.
- Solenoid can operate with double hump field shape for ECR mode of operation or with a 3T flat field for use with external injector.
- Solenoid is fully re-condensing with no measurable helium losses.

Delivered in February, tested in March and installed on the beam line in May 2012



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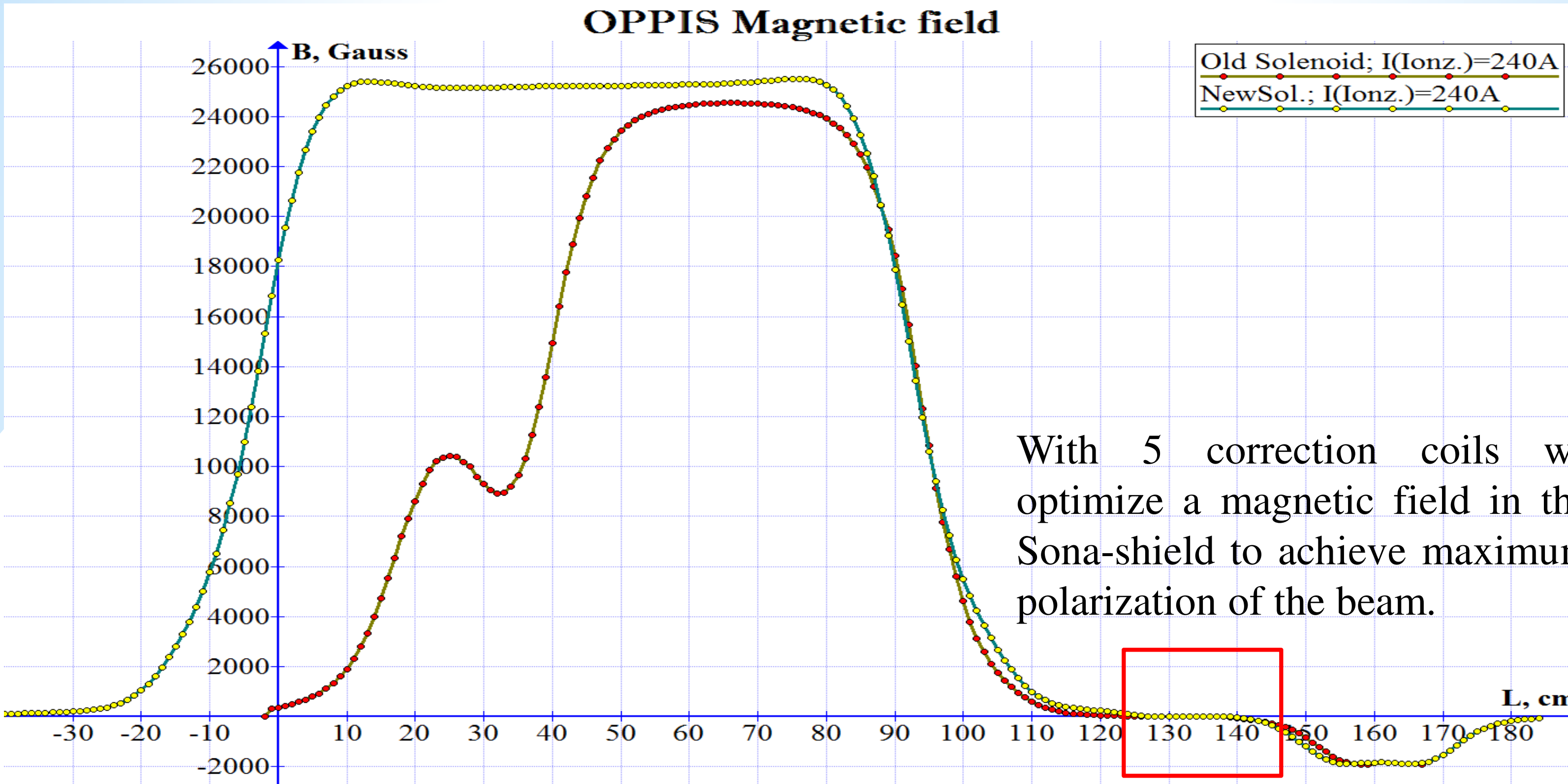
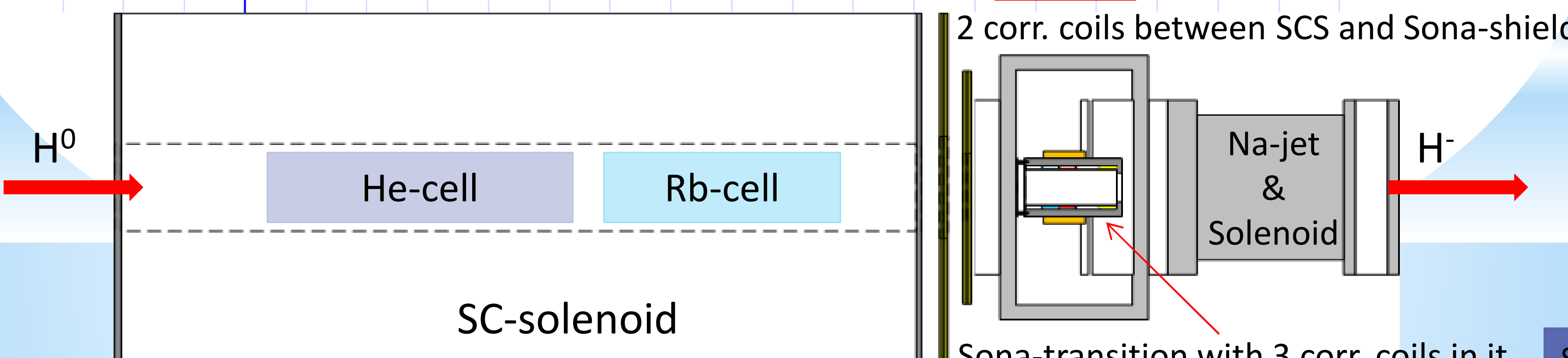
2. OPPIS Magnetic field

New SCS gives a longer flat magnetic field (green line) for the fitting of the He- and Rb-cell.



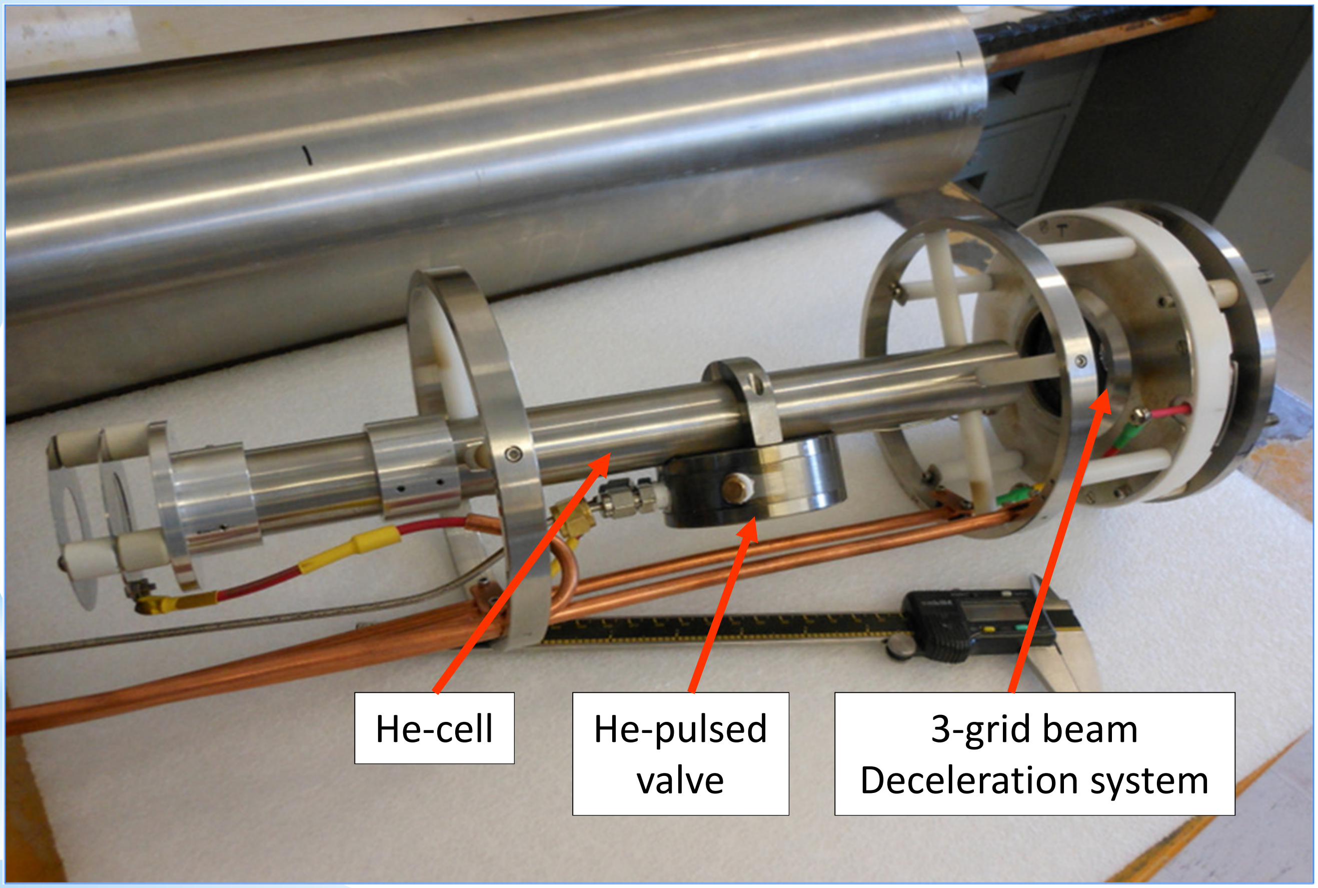
With 5 correction coils we optimize a magnetic field in the Sona-shield to achieve maximum polarization of the beam.



3. He-ionizer cell with three-grid energy separation system

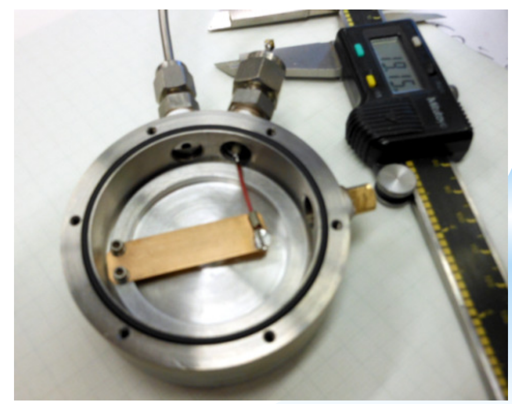
Two functions of the new He-cell with pulsed valve:

- Ionization of the injected neutral beam
- Deceleration of the ionized part of the beam to separate from the no-ionized part



He-valve

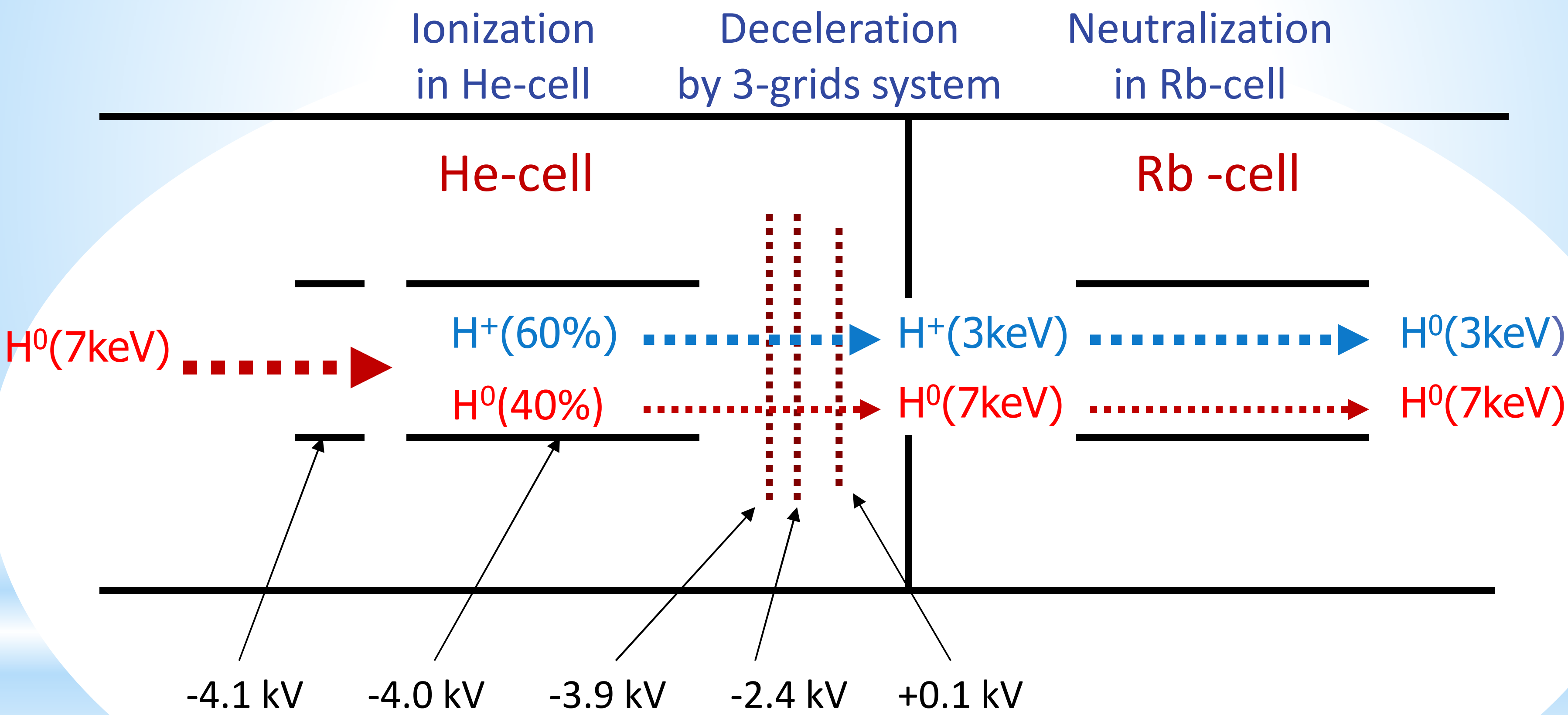
❖ Operating in high magnetic field ~1-3T



3. Energy separation a residual un-polarized H^0 component

Only a portion of the beam is ionized in the He-cell (~60%) can be further polarized.

$H^0 + He \rightarrow H^+ + He + e^-$

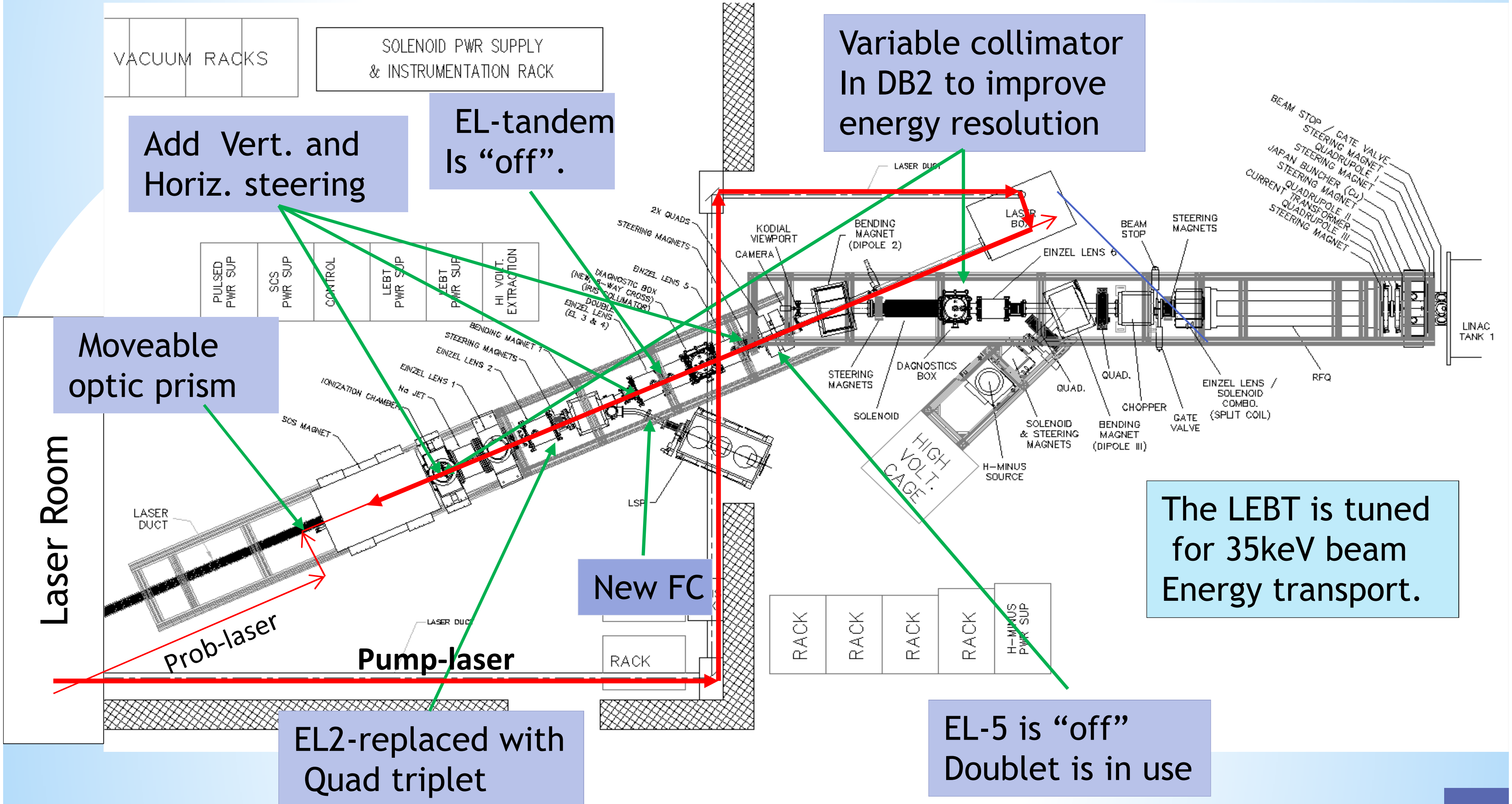


Polarized part of the beam separates from un-polarized by the bending magnet and collimators. Energy separation is better than 25-30 times.

4. Modifications of Low Energy Beam Transport line

The entire beam line has been modified for:

- an additional space for the new source (more then 1.5m);
- to transport more intense beam;
- energy separation of polarized component of the beam.



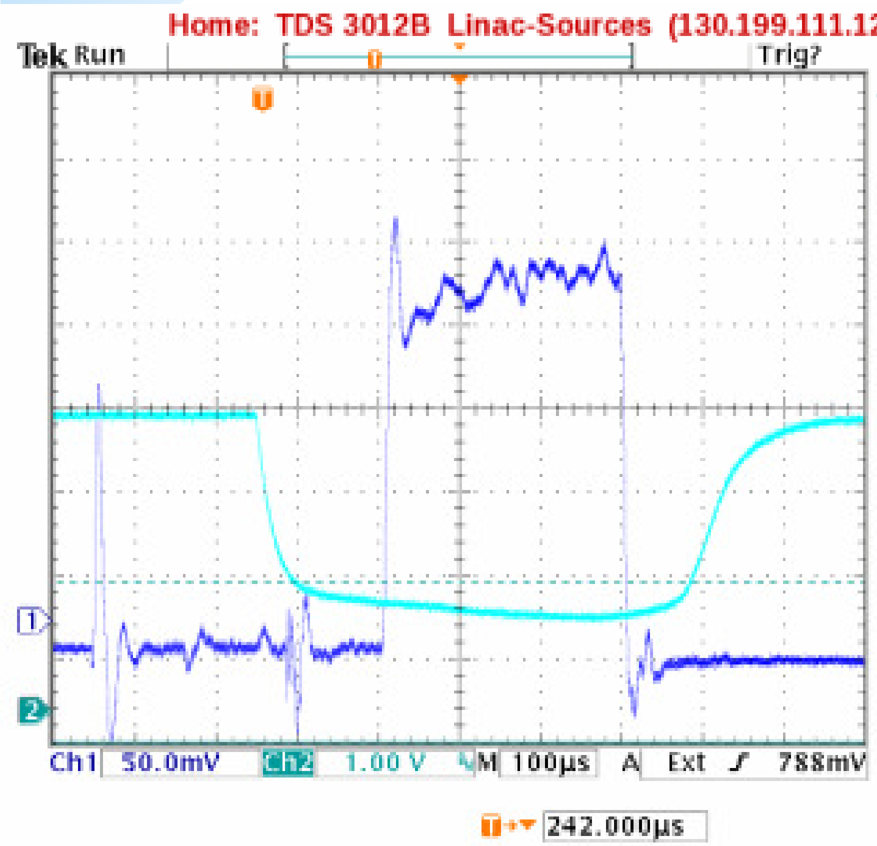
5. Laser system upgrades

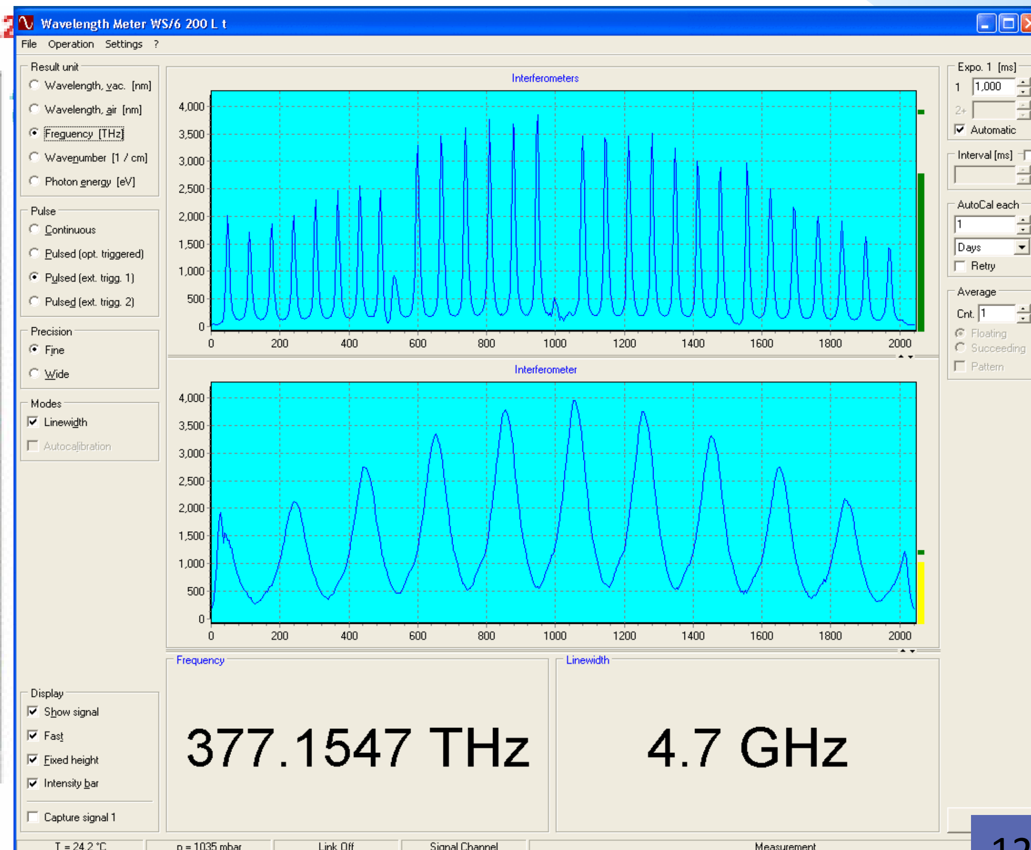
Polarization strongly depends on the power, frequency, and the line width of the pumping laser.
By a new wave-meter we can:

- adjust of power, frequency, and line width of pumping laser;
- monitor and control frequency, and line width.

Control the laser parameters

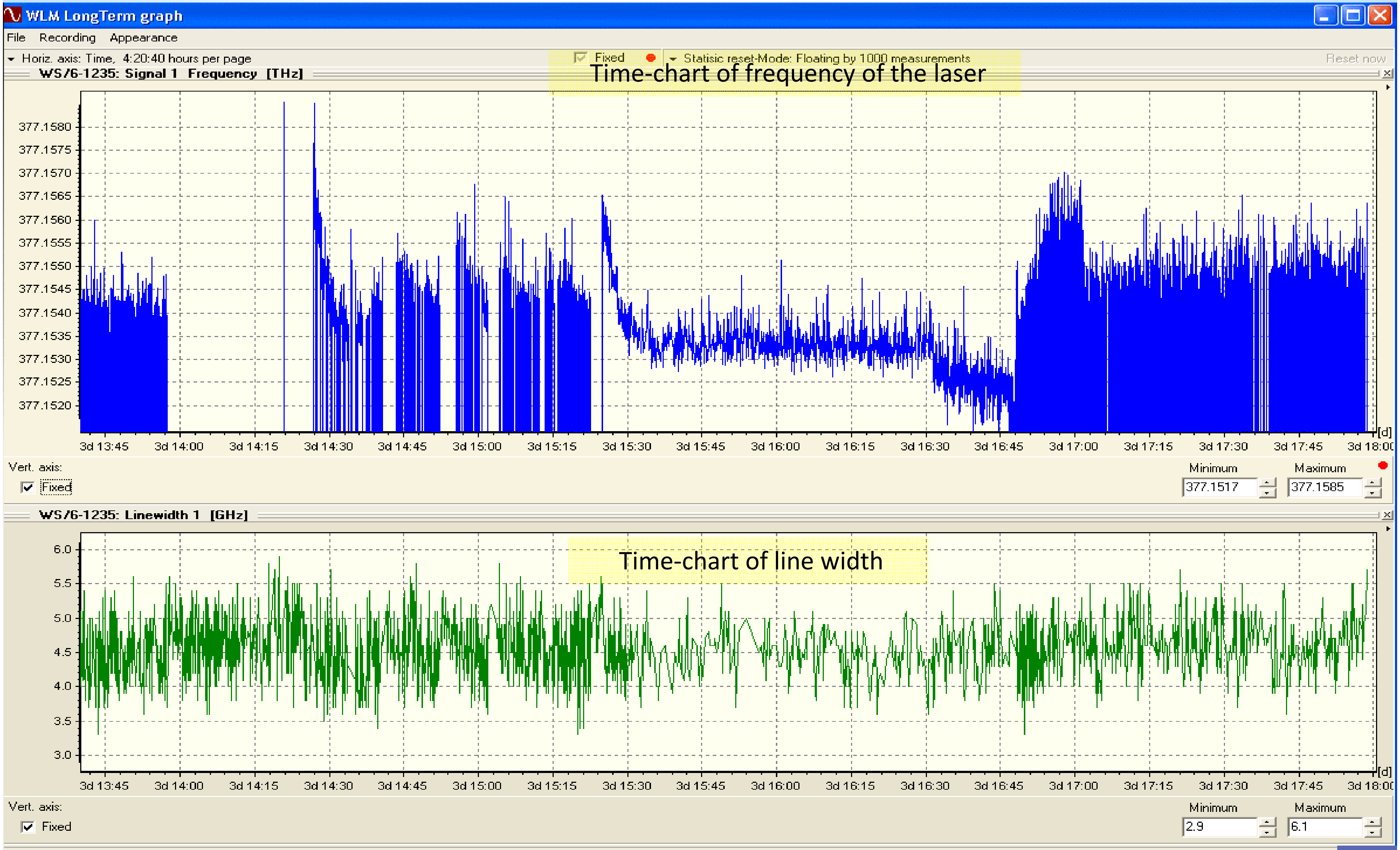
Before	Now
By quality of the probe-laser pulse	By measured frequency and line width of pump-laser





5. Laser system upgrades

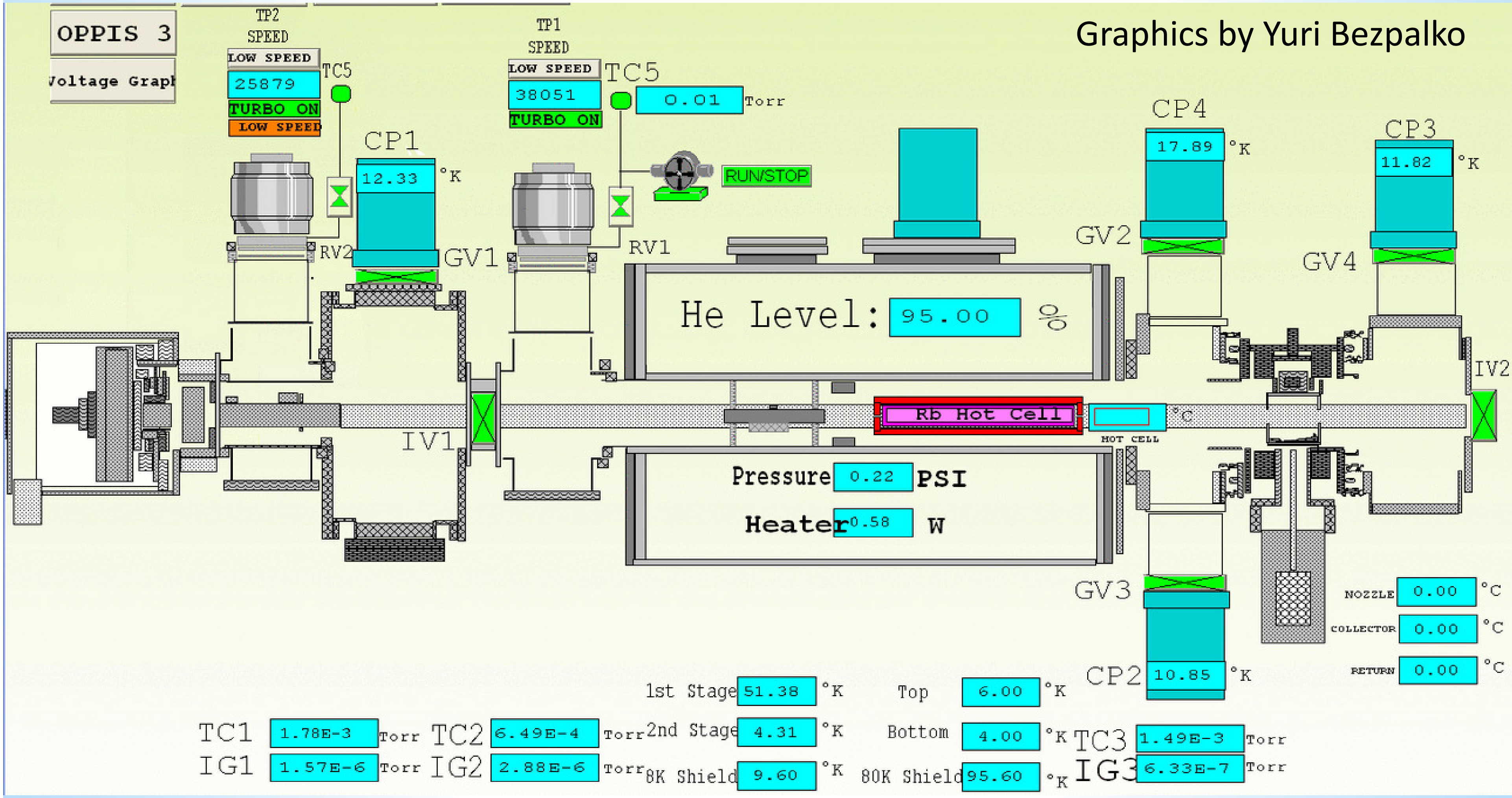
We can create a time-chart of power, frequency and line width and store data for analyzing.



6. & 7. New vacuum, PLC interlock and monitoring systems

F&E support –CAS group has created a new PLC system, which ensures the logical interlock and visualizes the monitoring and control of vacuum, temperature and water pressure of the OPPIS beam line.

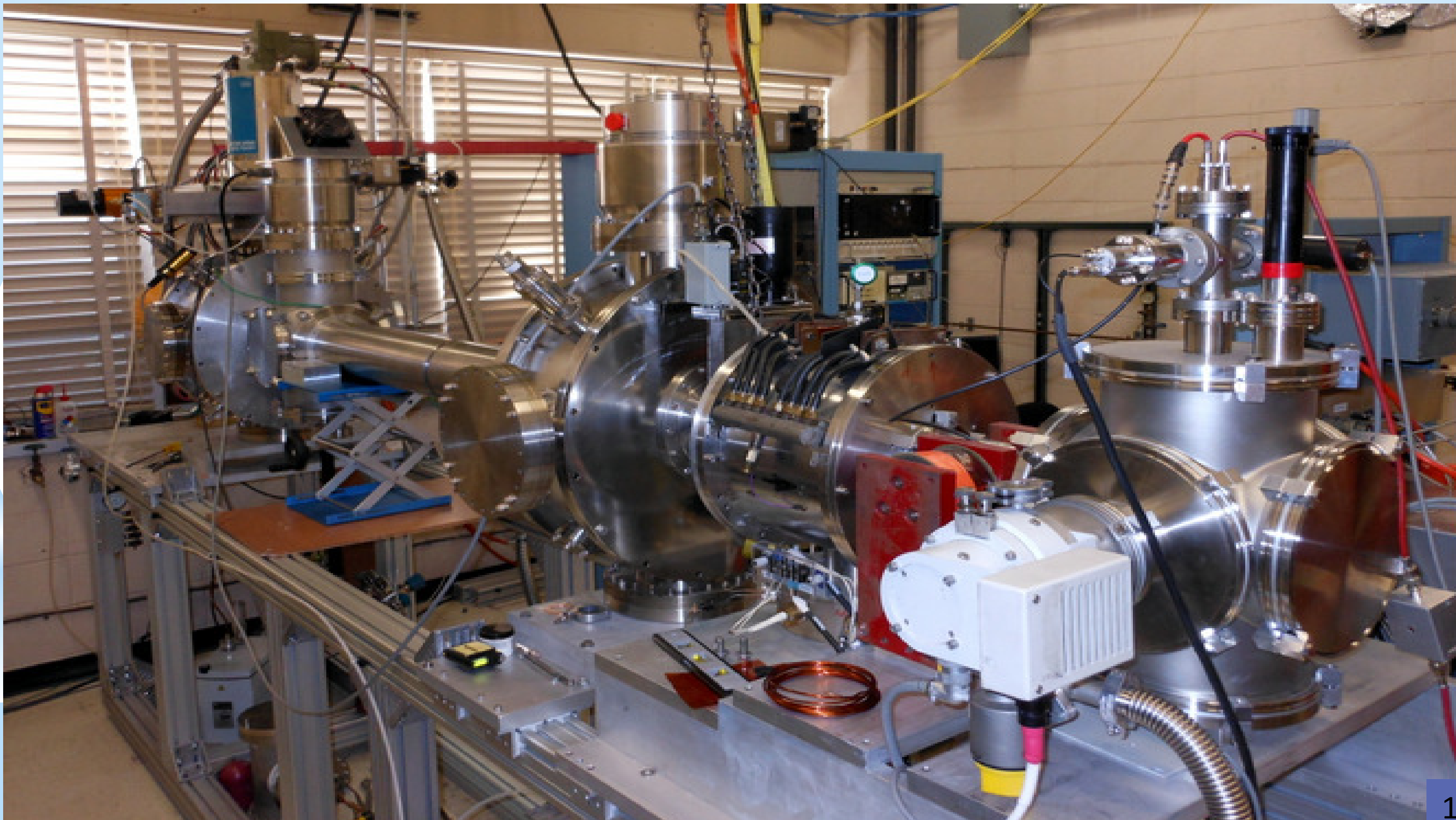
Graphics by Yuri Bezpalko



8. A new FABS test bench

New source has double or triple spare elements: plasmatron, four-grid proton extraction system, H-cell, complete He-cell…

On the picture submitted a full test bench of FABS-source including pulsing PS, vacuum, gas and control systems that provides a study of characteristics of a source.

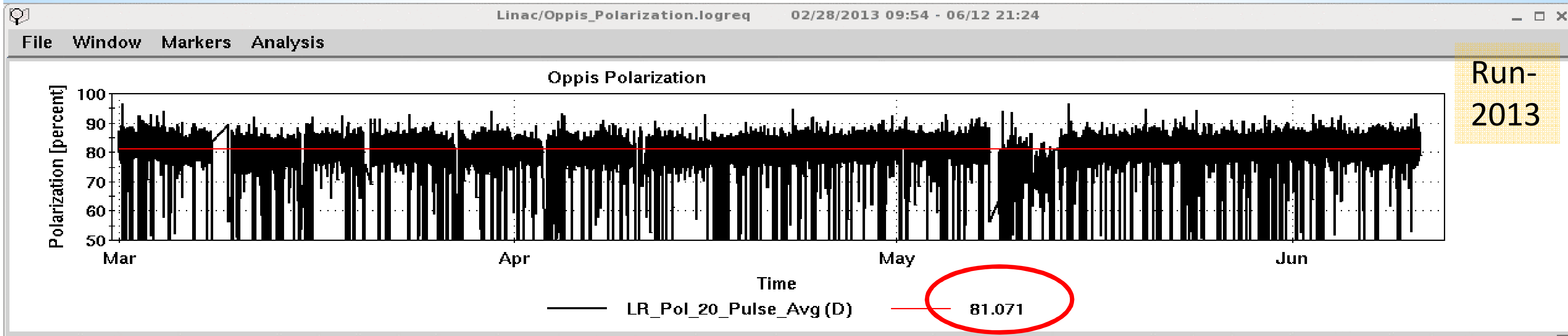


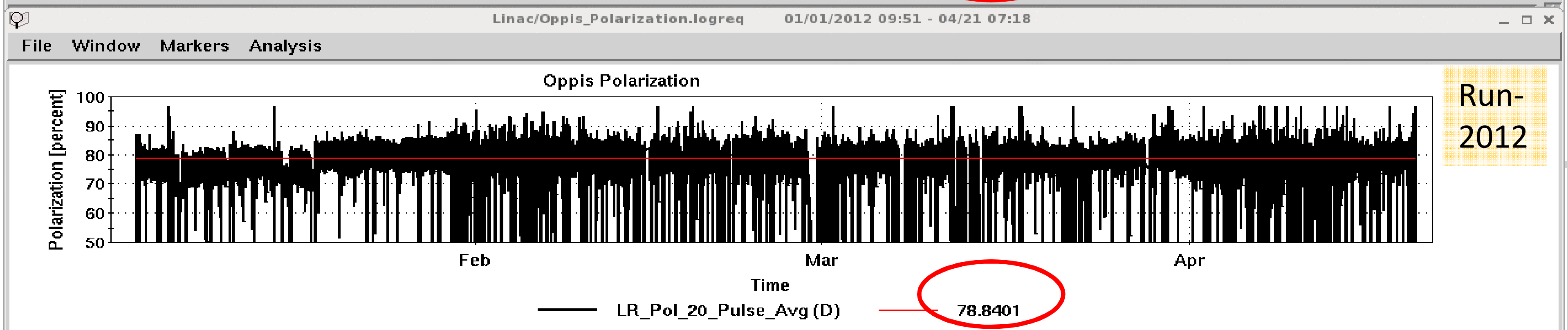
Average beam performance during Run11-12-13

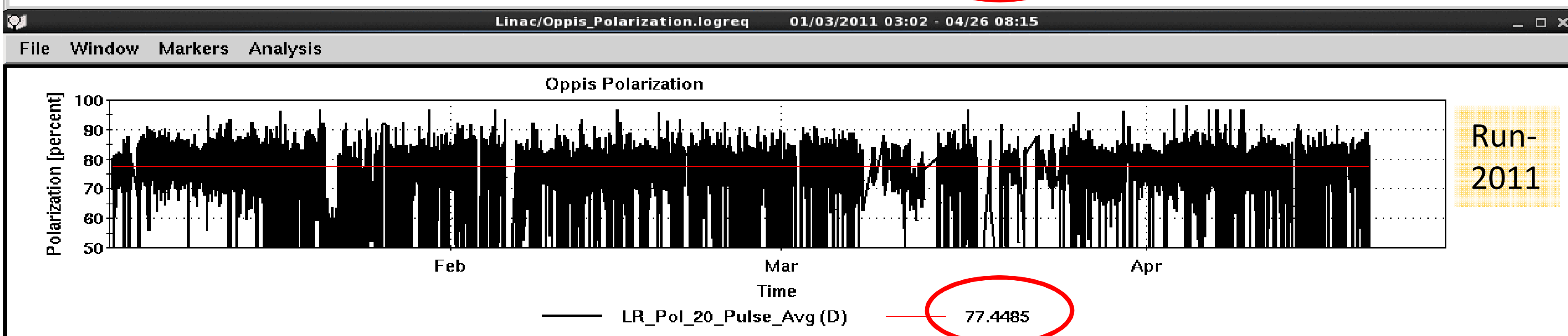
Improvement of polarization, current, emittance and reliability

		Run-11	Run-12	Run-13
Polarization	Pol. %, at 200 MeV	~77.5	~79	~81
Current	Booster Input $\times 10^{11}$,	3.5	4.5	5.0
Emittance	Beam emittance out of Tk9, pi	H- 5.3 V- 6.3	H- 4.5 V- 5.0	H- 4.0 V- 1.55
Reliability	Temp. of Rb-cell, C^0	~92	~93	~86

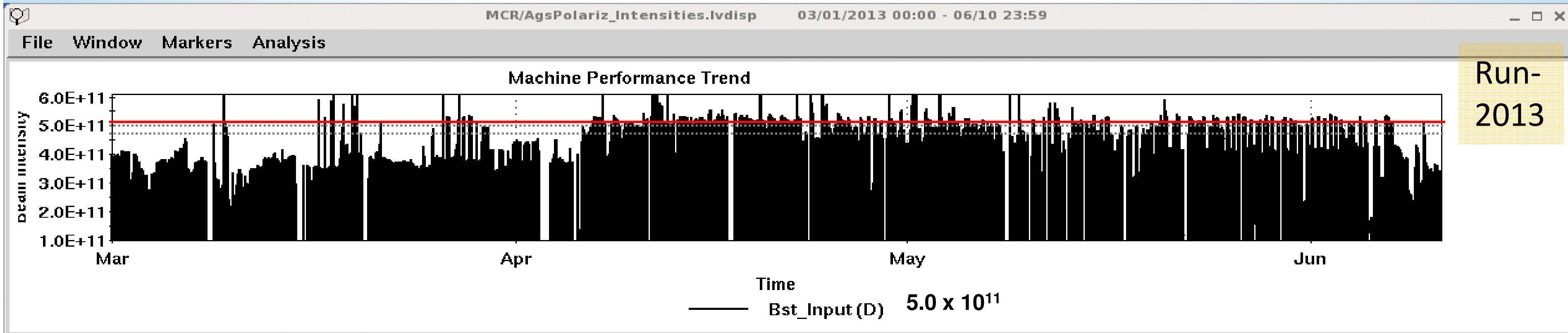
Average Polarization during Runs

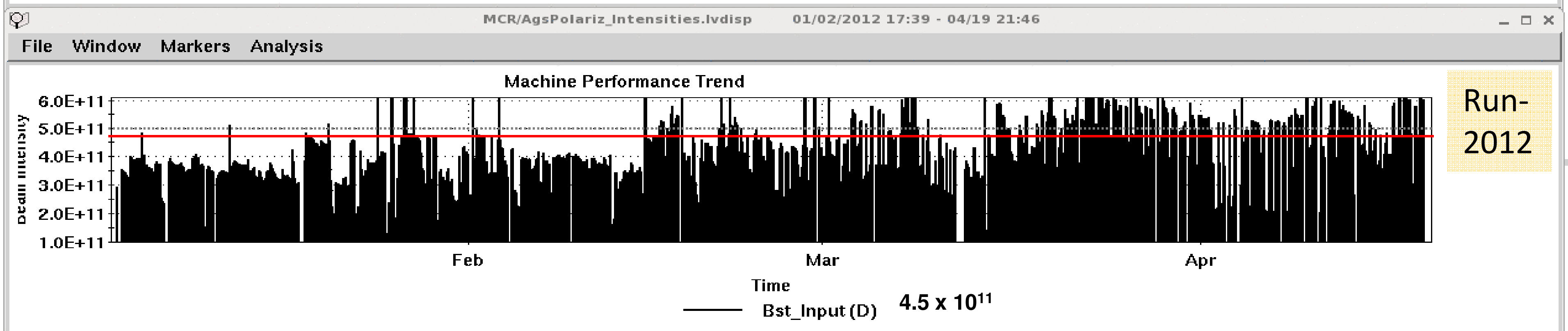


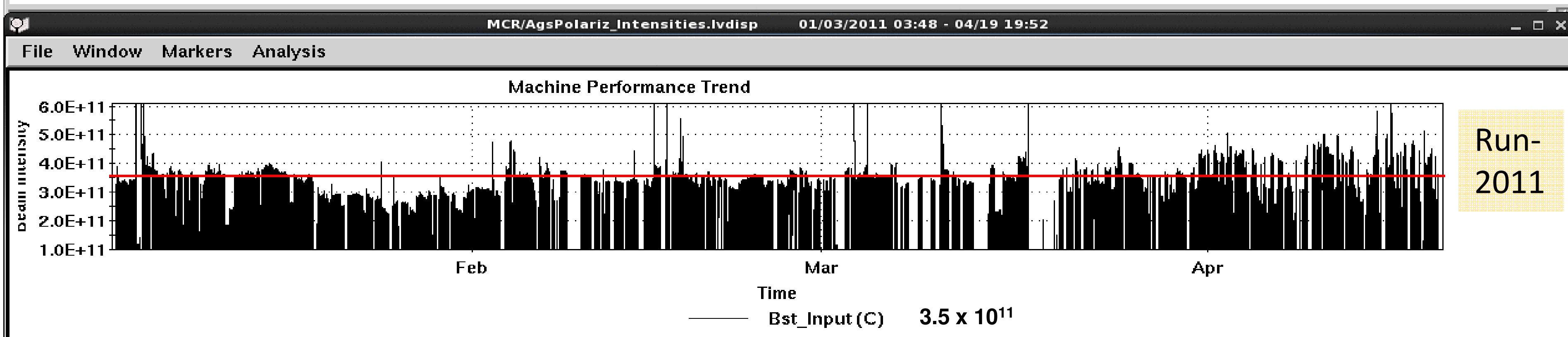




Booster Input current during Runs

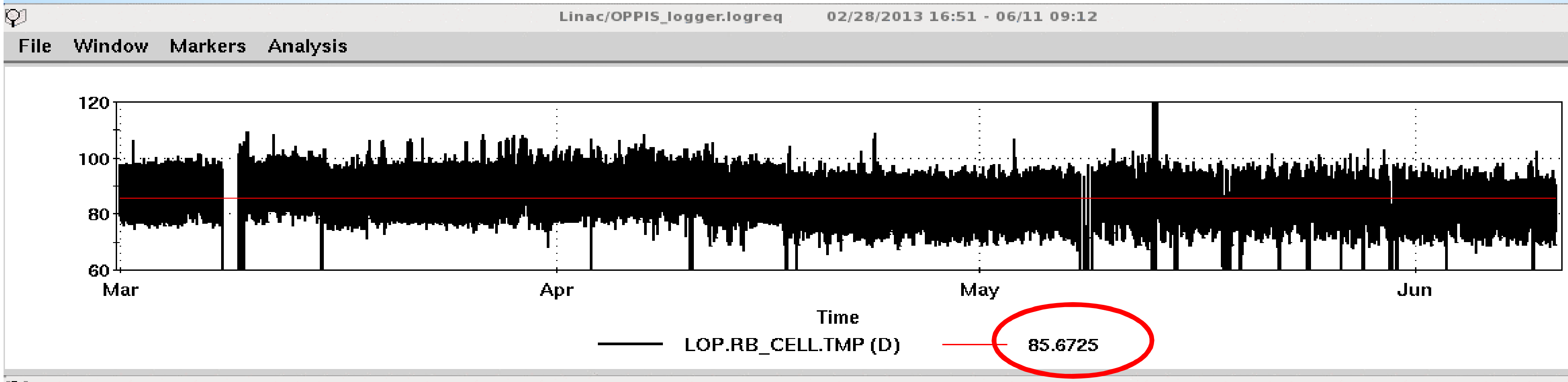




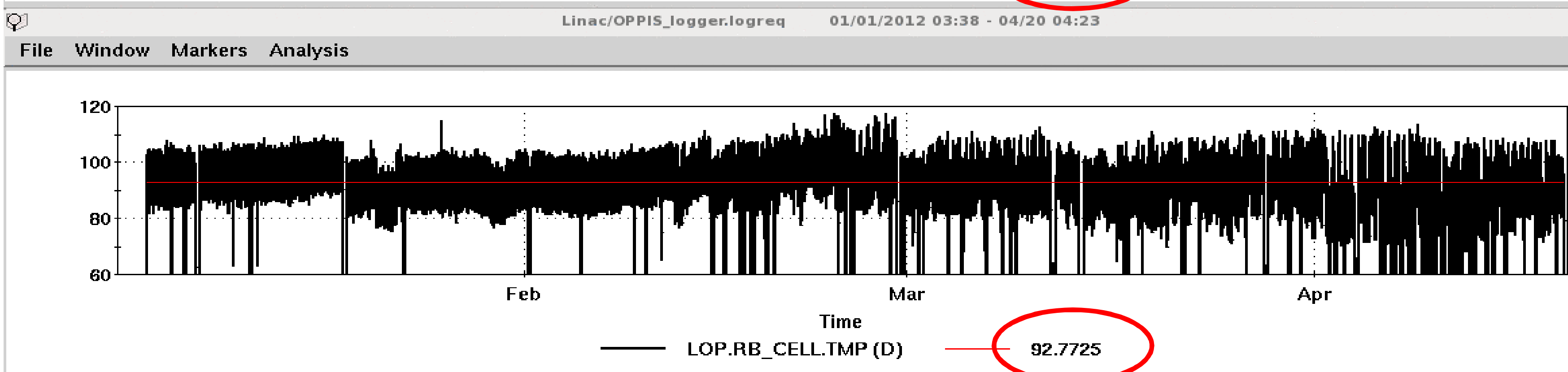


Average Rb temperature during Runs

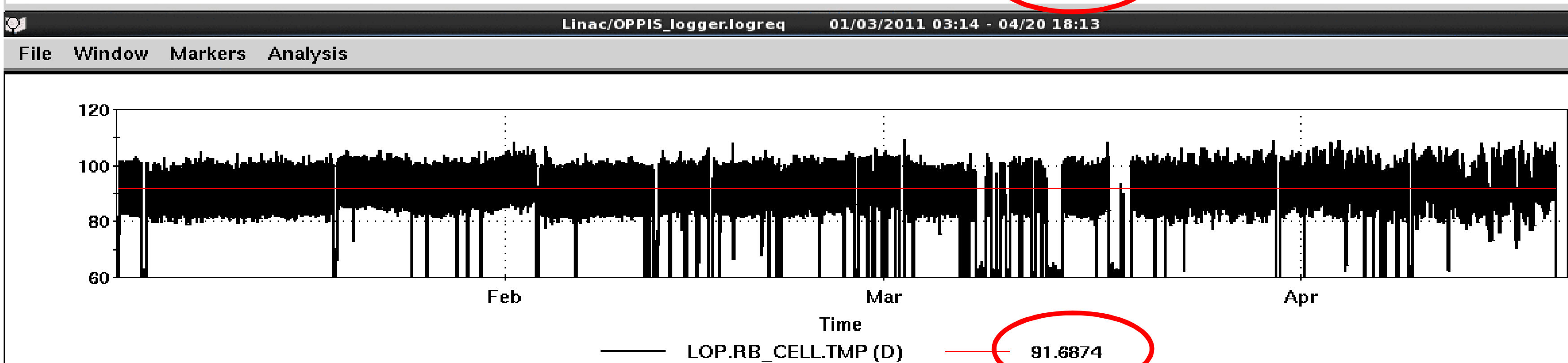
Run-2013



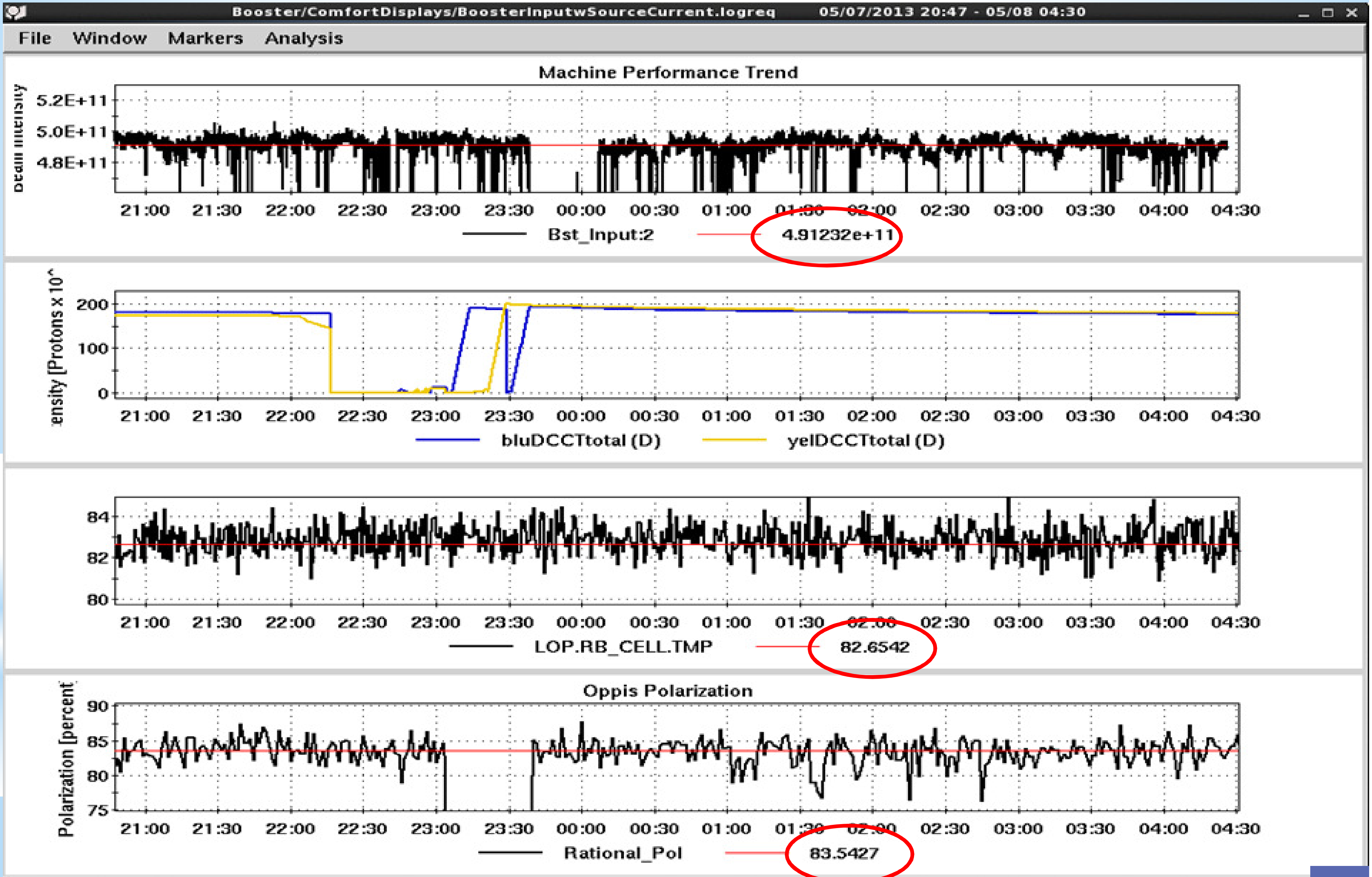
Run-2012



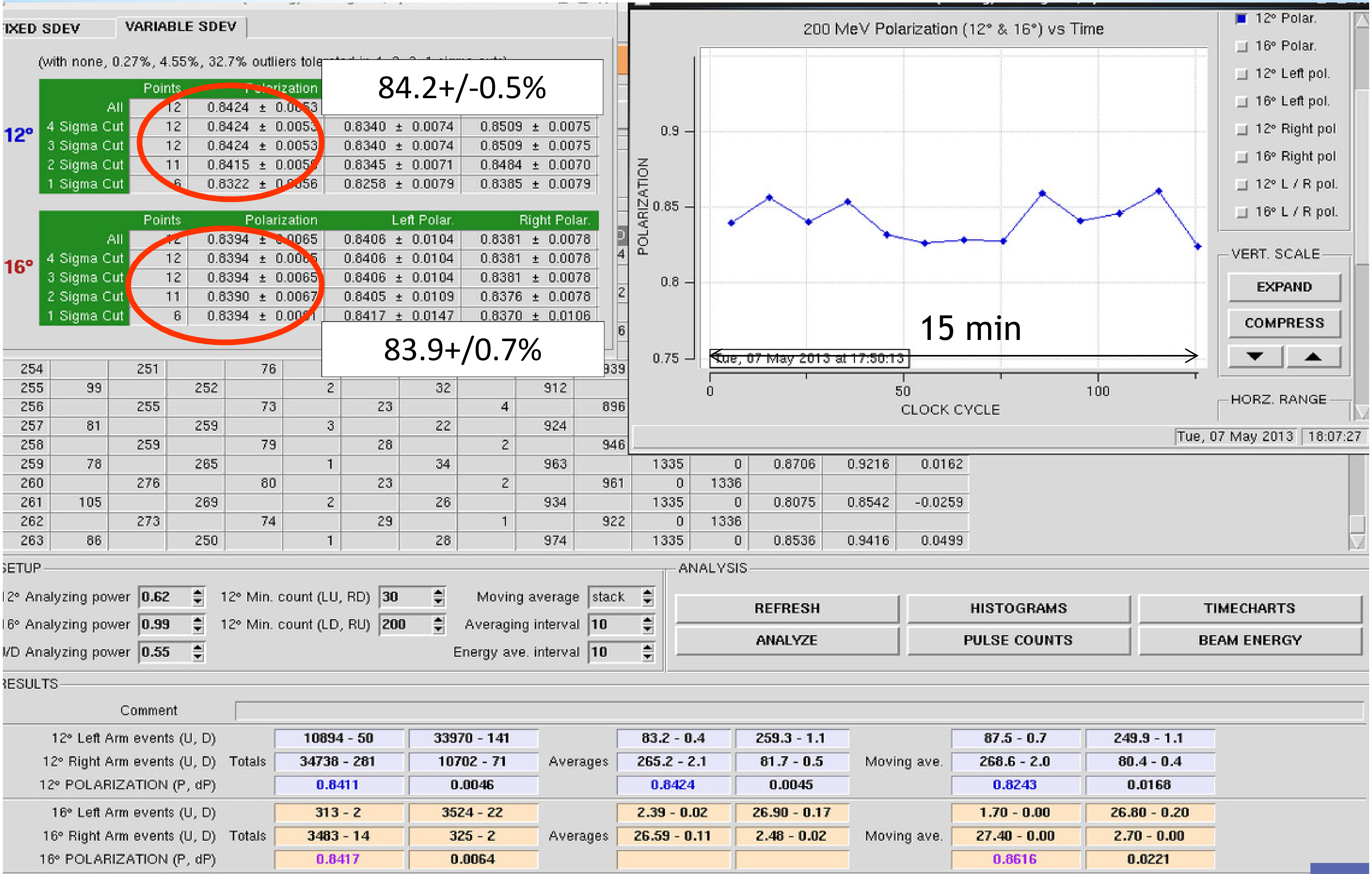
Run-2011



Beam performance during RHIC fill #17472 (May 7, 2013)



T(Rb)=81°C, I(T9)=295mkA (4.9*10^11)



Source intensity and polarization

- Long-term reliability operation of the source
- High suppression of un-polarized beam component
- Small beam emittance (after collimation for energy separation) and high transmission to 200MeV

By increasing Rb temperature increased H^- current and decreased polarization.

Why? Space charge effect, measuring problems (rate effect), transportation…

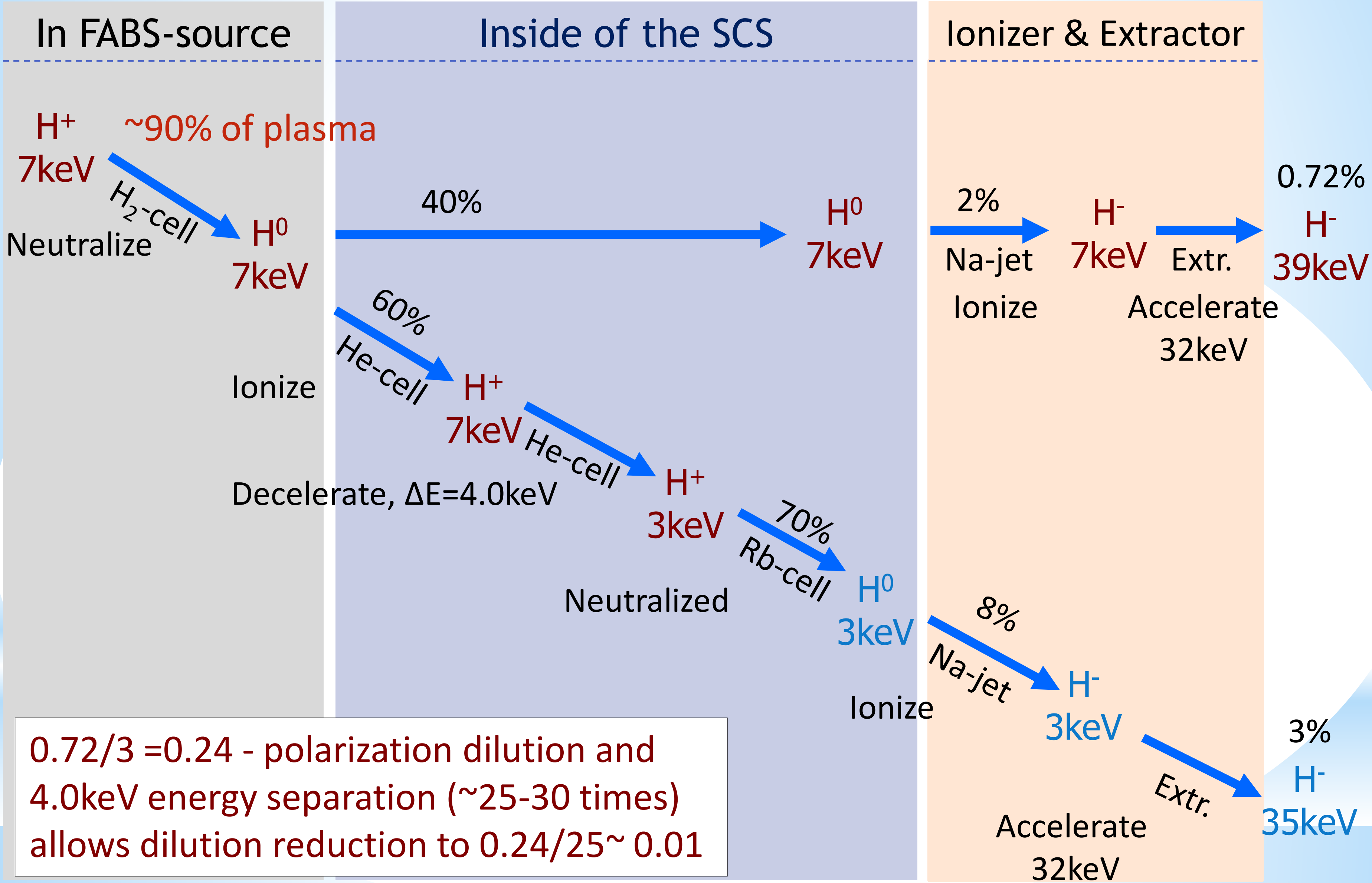
Rb-cell, Temp., deg. C	81	86	91	96
Booster Input $\times 10^{11}$	4.9	6.2	7.3	9.0
Pol. %, at 200 MeV	~83(84)	82	80.5	78

Summary

- The new source is operational.
- Reliable long-term operation at steady current and polarization.
- The maintenance time is significantly reduced.
- Polarization is on average about 2-3% higher than ECR-based source. It is expected that polarization can be further improved to 85%.
- The source intensity is about 5-10mA. Due to strong space-charge effects only a fraction of this current is transported and accelerated in RFQ and Linac. These losses can be reduced.

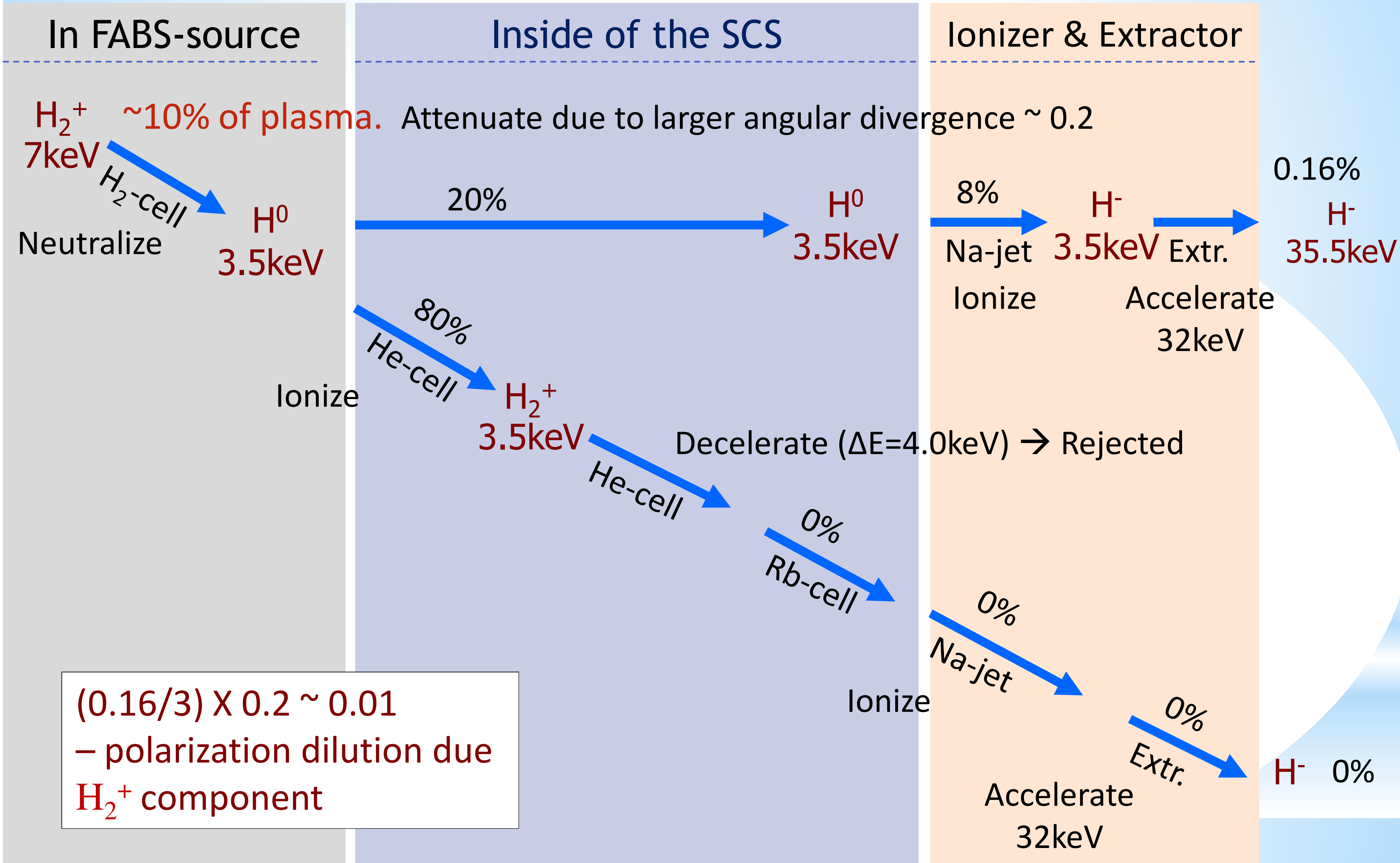
Backup slides

Polarization dilution due H+ in the new source



0.72/3 =0.24 - polarization dilution and 4.0keV energy separation (~25-30 times) allows dilution reduction to 0.24/25~ 0.01

Polarization dilution due H_2^+ in the new source



Magnetic field inside Sona - transition

5 correction coils (LCC, SCC, ICC1, ICC2 and ICC3) used for optimized magnetic field in Sona-shield to achieve maximum polarization.