Polarized Proton Source OPPIS for Run-24 at RHIC

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Retreat 2023

08/30/2023

Upgrades polarized proton source

OPPIS (*Optically Pumped Polarized Ion Source)* H^- ion source has been upgraded several times and continuously improves polarization, intensity and emittance.

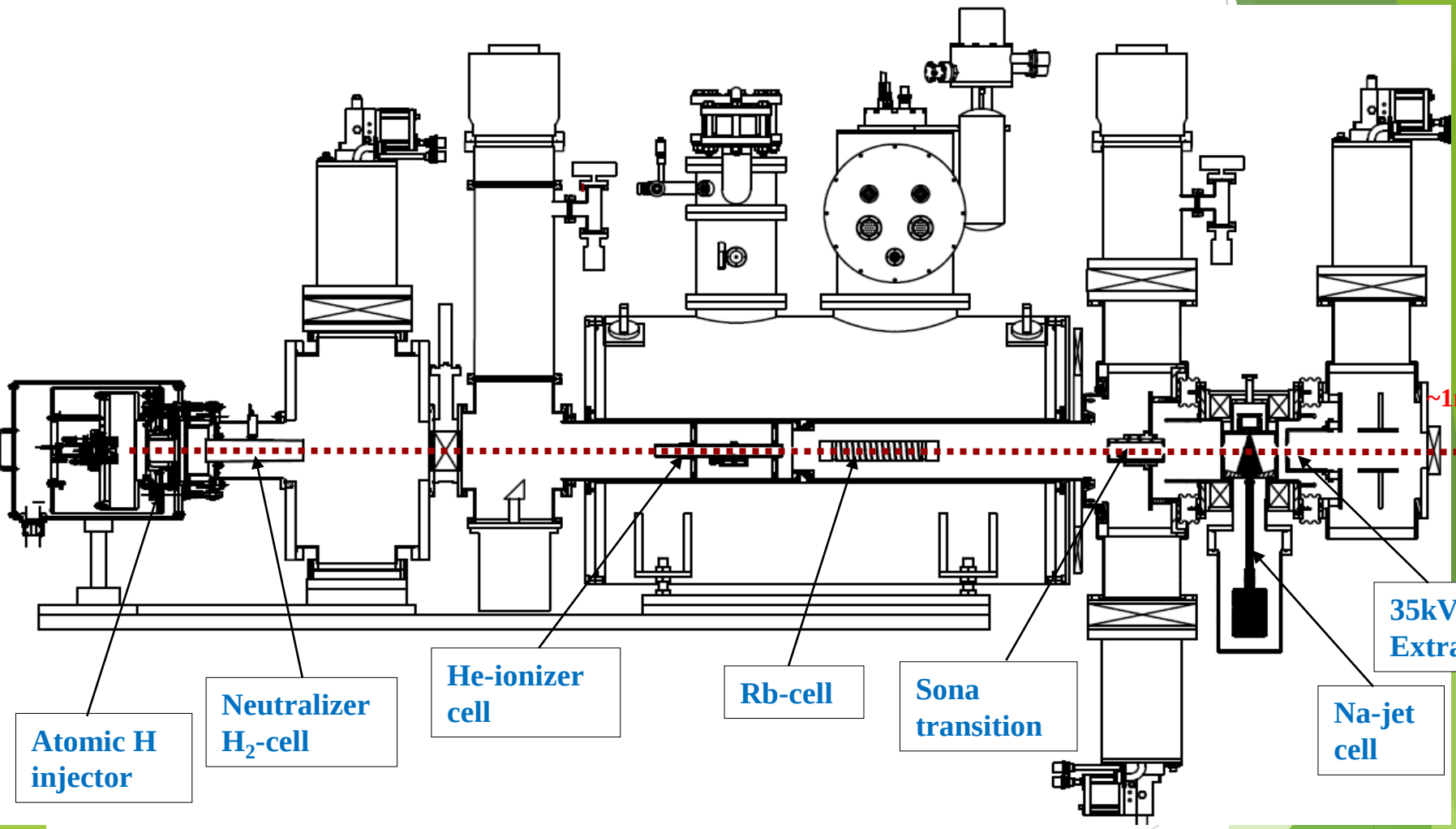
* Prior to Run-13, the ECR-type source was used to generate the primary proton beam. The ECR-source was originally developed to operate on DC current and placed inside a super conductive solenoid (SCS).

* In 2013, the ECR-source was replaced by a high-brightness source “Fast Atomic Beam Source” (FABS) operating in a pulsed mode. The FABS-source improved such source parameters as beam current density, angular divergence and stability.

* The last upgrade of OPPIS-source was made in 2020-22:

1. Reduced the LEBT portion of the beam line more then 4 feet;
2. Modify polarization part of OPPIS (He-cell, Rb-cell and Na-cell);
3. Change the 35kV extractor powering transformer system;
4. Made new laser box.

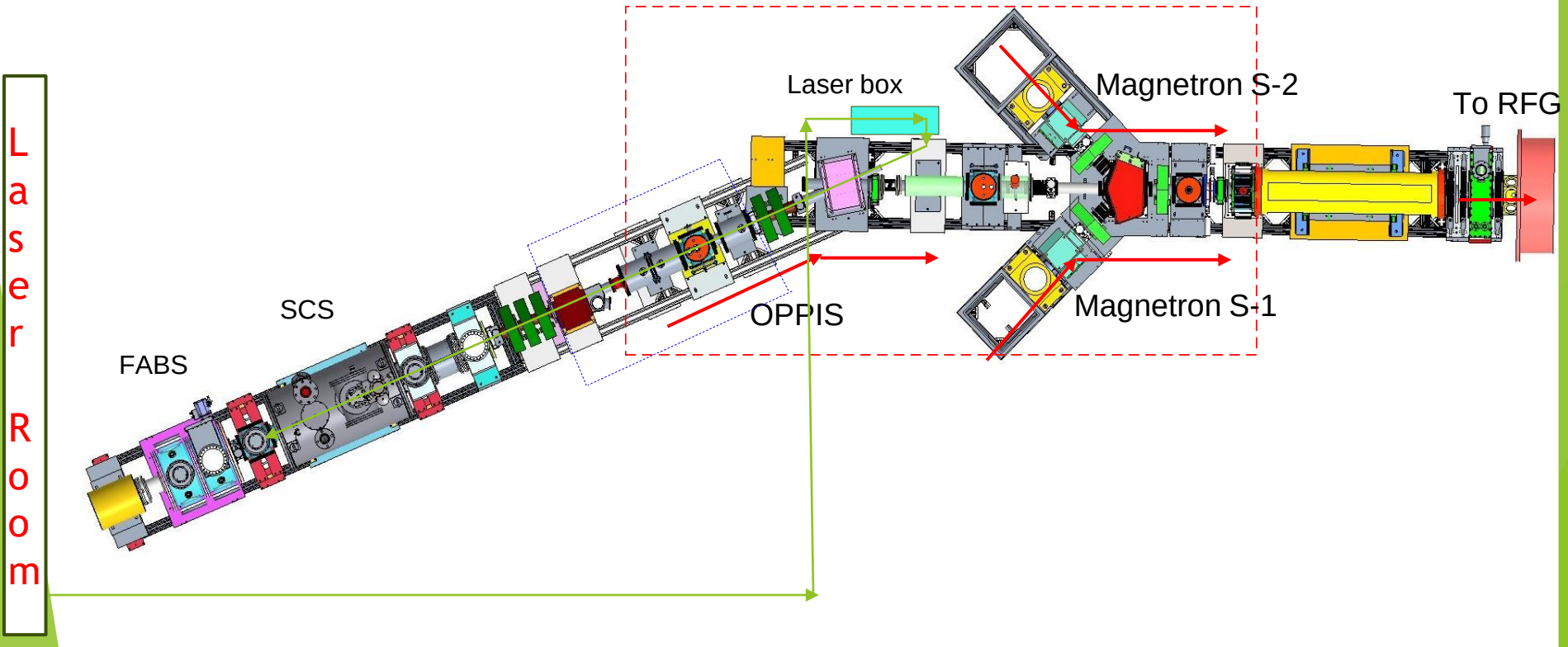
2013 OPPIS upgrade with FABS source



$H^+ \rightarrow H_2 \xrightarrow{H^0} He \xrightarrow{H^+} Rb \xrightarrow{H^0} Na \xrightarrow{H^-}$

OPPIS upgrade 2020-22

The Low Energy Beam Transport (LEBT) lines combine three beams. The first line is the polarized OPPIS beam-line and the second and third are the high-intensity un-polarized beam-line.



Polarization transfer technique (OPPIS)

Polarized light ⇒ **Polarized electron** ⇒ **Polarized proton**

Production of circular polarized tunable wavelength (~795nm) laser beam

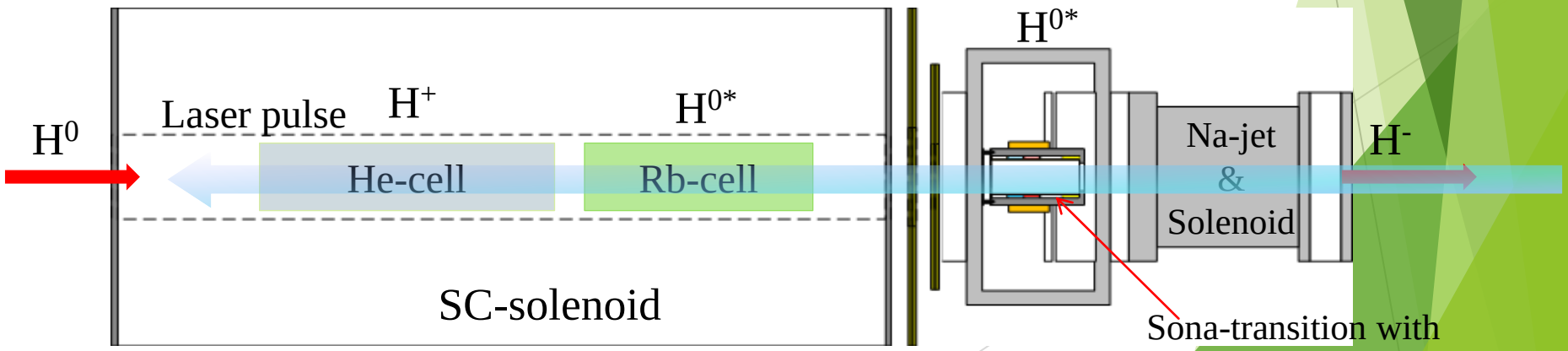
Polarization of the Rb-atom (Rb-cell)

Ionization of hydrogen atom by He (He-cell).

Production of electron spin polarized hydrogen atoms by capture electron from Rb

Polarization transfer from electron to proton by "Sona-transition" technique

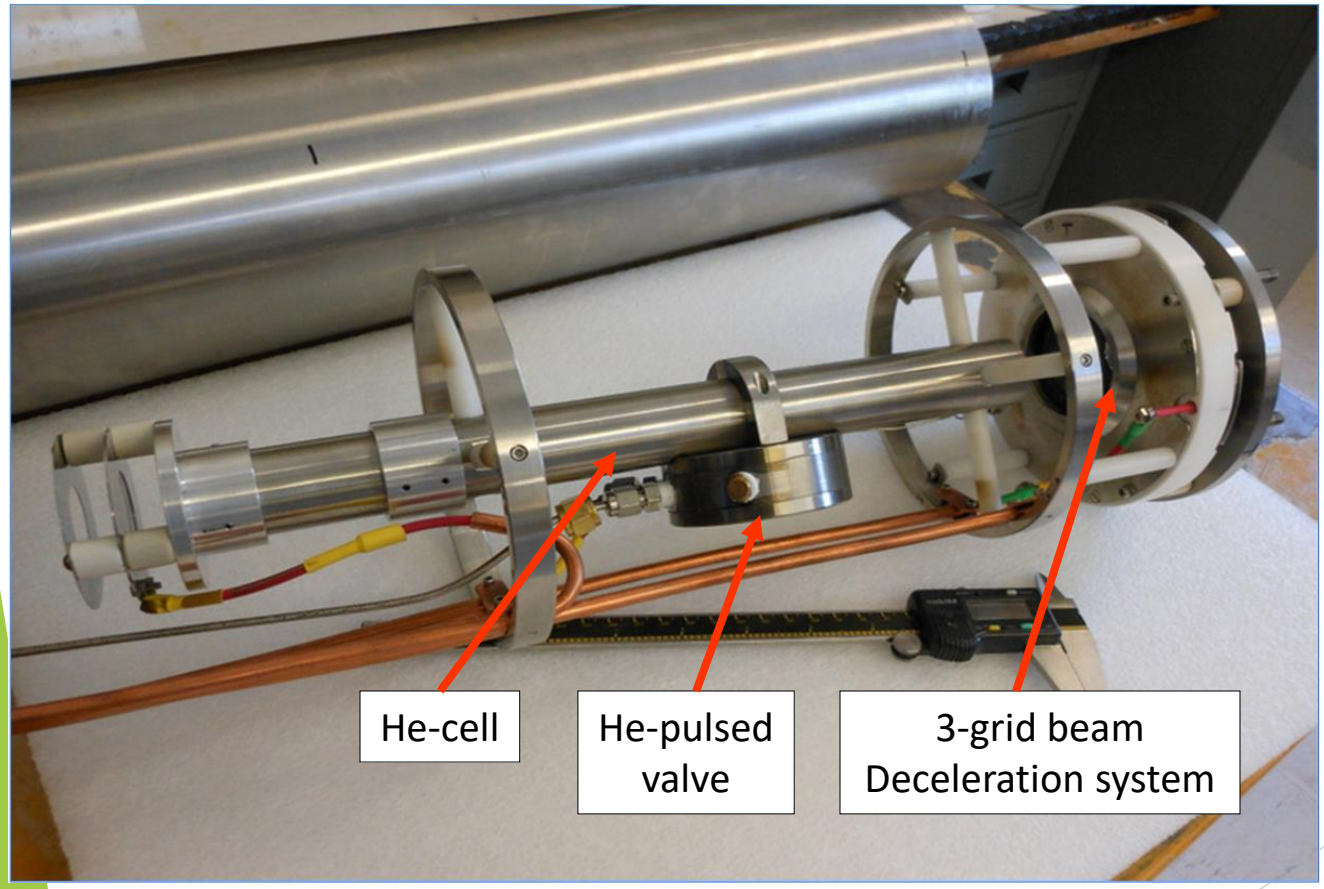
Ionization of hydrogen atoms by capture of second electron in Na-jet for acceleration (Na-cell)



He-cell and 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 not ionized part

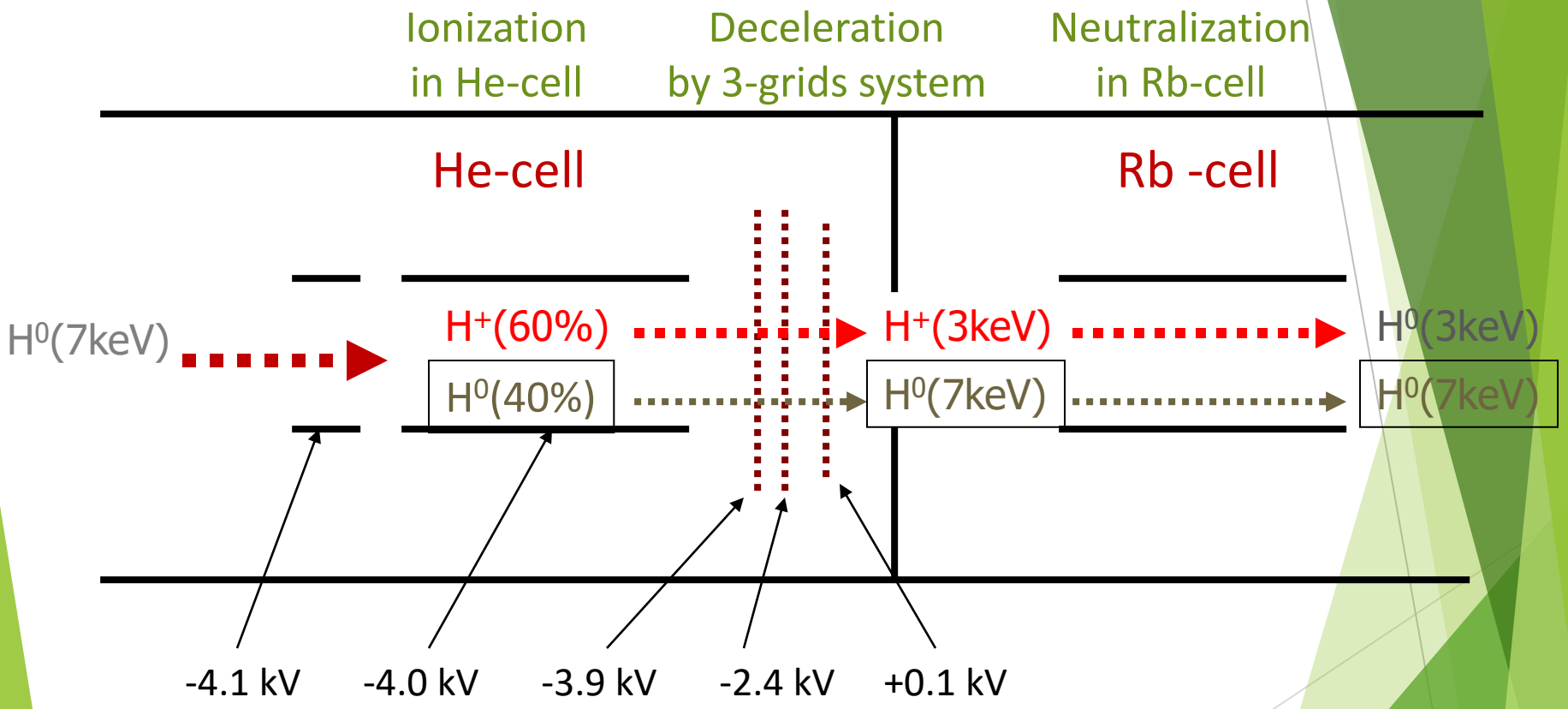


He-valve operating in high magnetic field ~1-3T.

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.

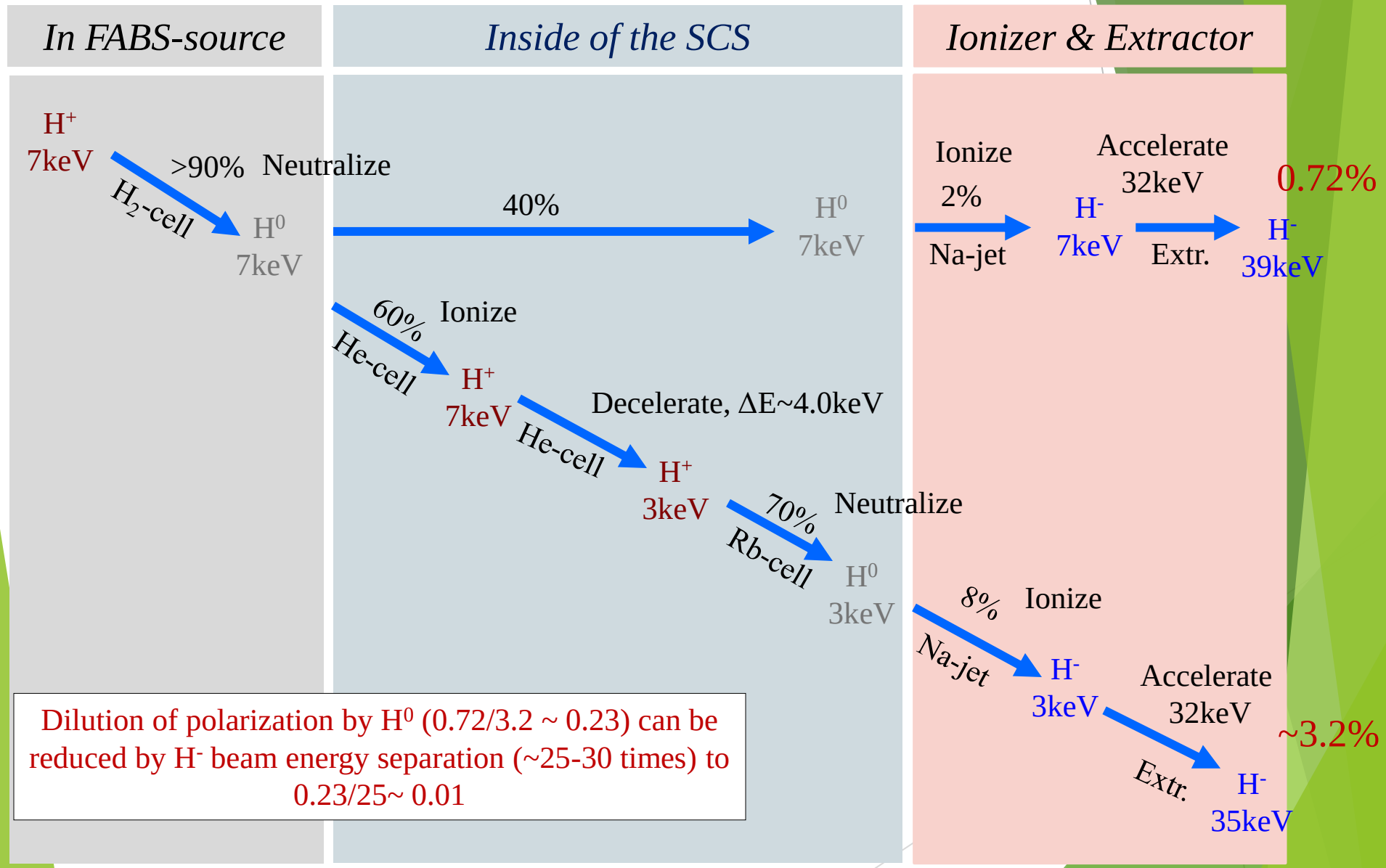
Depolarization factors

Depol. factor		Process	Estimate
1	E_H^0	Dilution due H^0 part of the beam (LEBT)	0.99 - 0.99
2	P_{Rb}	Rb-optical pumping (Laser system)	0.99 - 0.99
3	S	Rb polarization spatial distribution (Collimators)	0.97 - 0.98
4	B_{RG}	Proton neutralization in residual gas (Vacuum)	0.98 - 0.99
5	E_{LS}	Depolarization due to spin-orbital interaction	0.98 - 0.98
6	E_{ES}	Dilution due to incomplete energy separation not polarized component of the beam (LEBT)	0.98 - 0.99
7	E_{Sona}	Sona-transition efficiency (Adjustment of correction coils)	0.96 - 0.98
8	E_{ion}	Incomplete hyperfine interaction breaking in the ionizer magnetic field	0.98 - 0.99

Total: 0.85 - 0.90

$$P = E_{H2} \cdot P_{Rb} \cdot S \cdot B_{RG} \cdot E_{LS} \cdot E_{ES} \cdot E_{Sona} \cdot E_{ion} \sim 85\text{-}90\%$$

1	E_H^0	Dilution due H^0 part of the beam (LEBT)	0.99 - 0.99

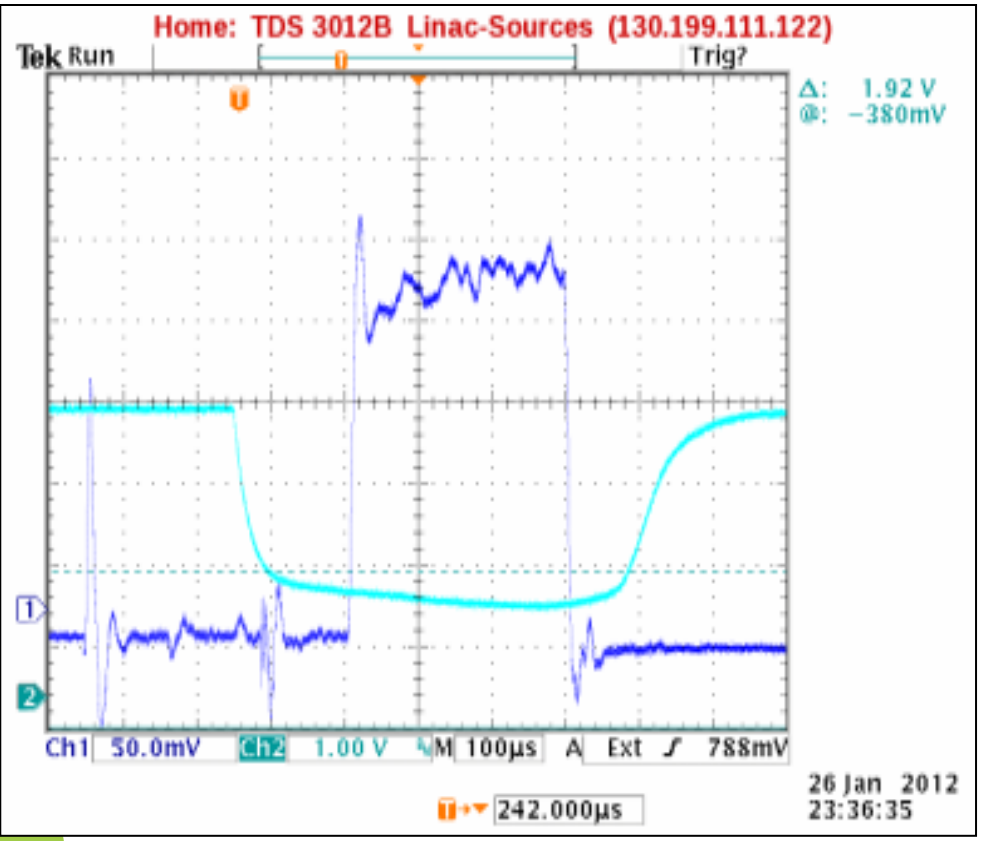


2	P_{Rb}	Rb-optical pumping (Laser system)	0.99 - 0.99

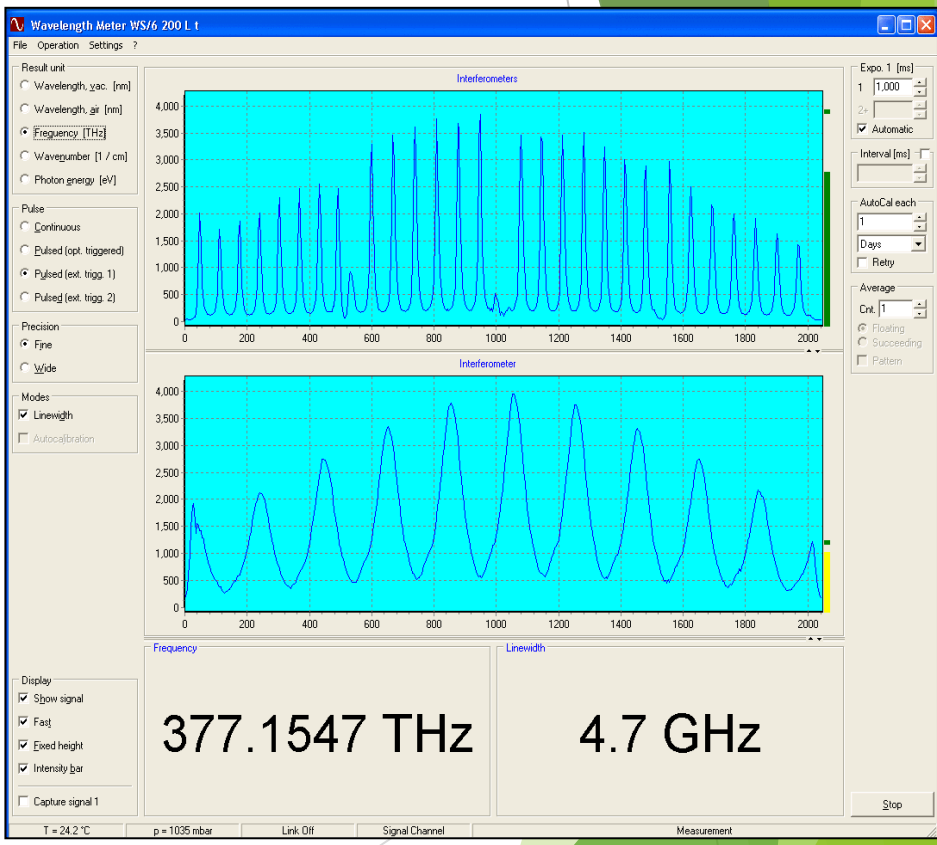
Polarization strongly depends on the power, frequency, and the linewidth of the pumping laser.

Monitor and control the laser parameters

Amplitude and timing

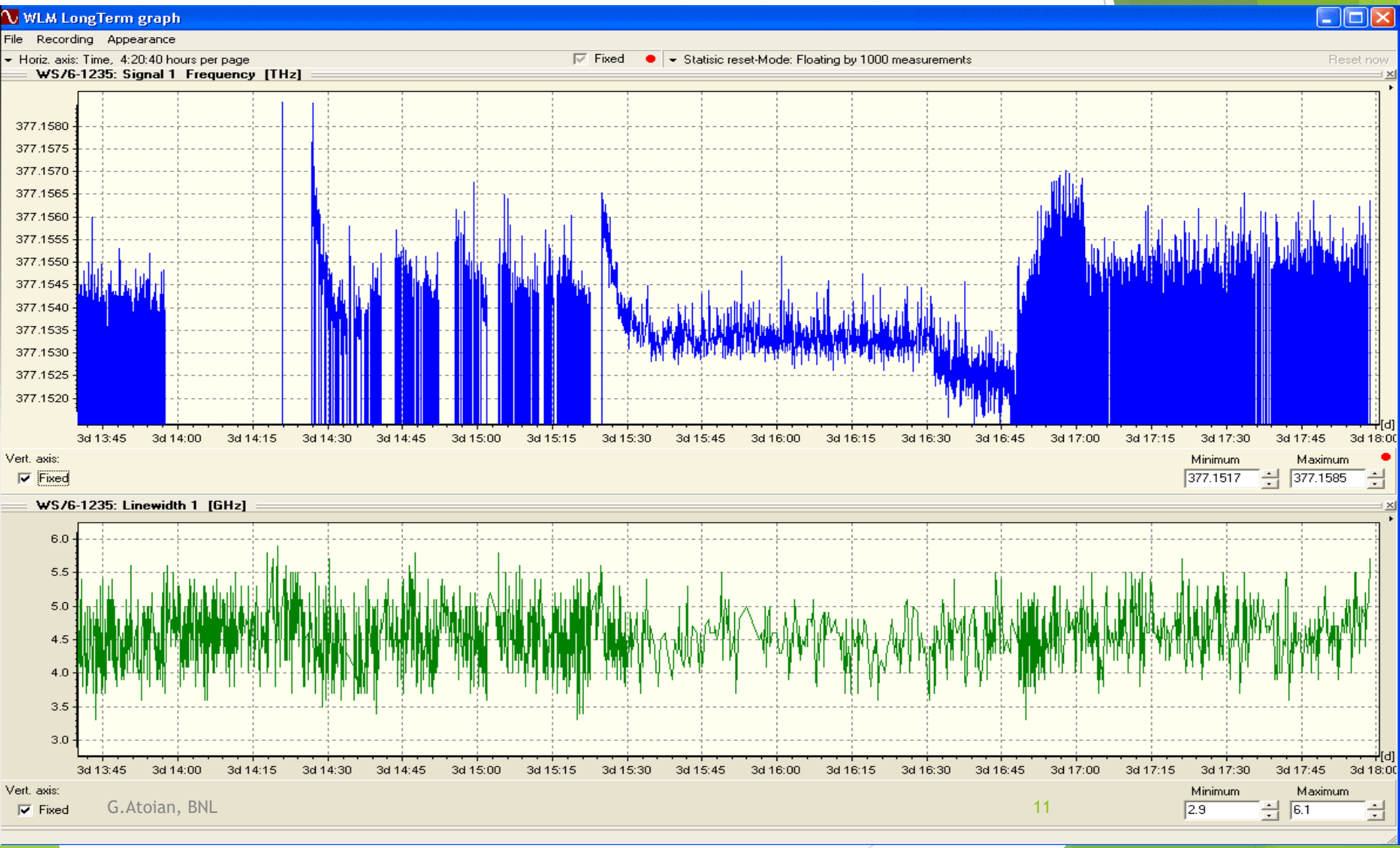


Frequency and linewidth

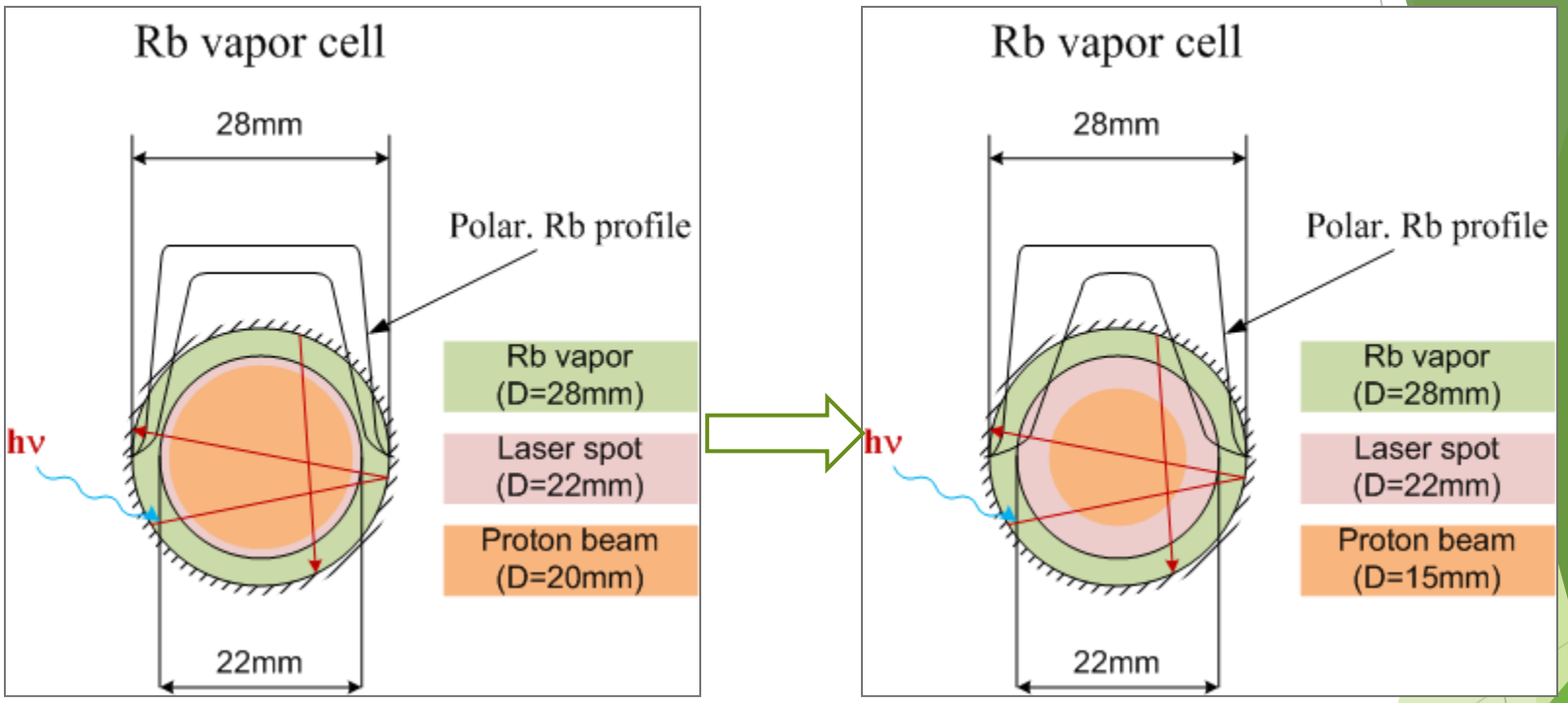


2	P_{Rb}	Rb-optical pumping (Laser system)	0.99 - 0.99

Time-chart of frequency and line width and store data for analyzing.

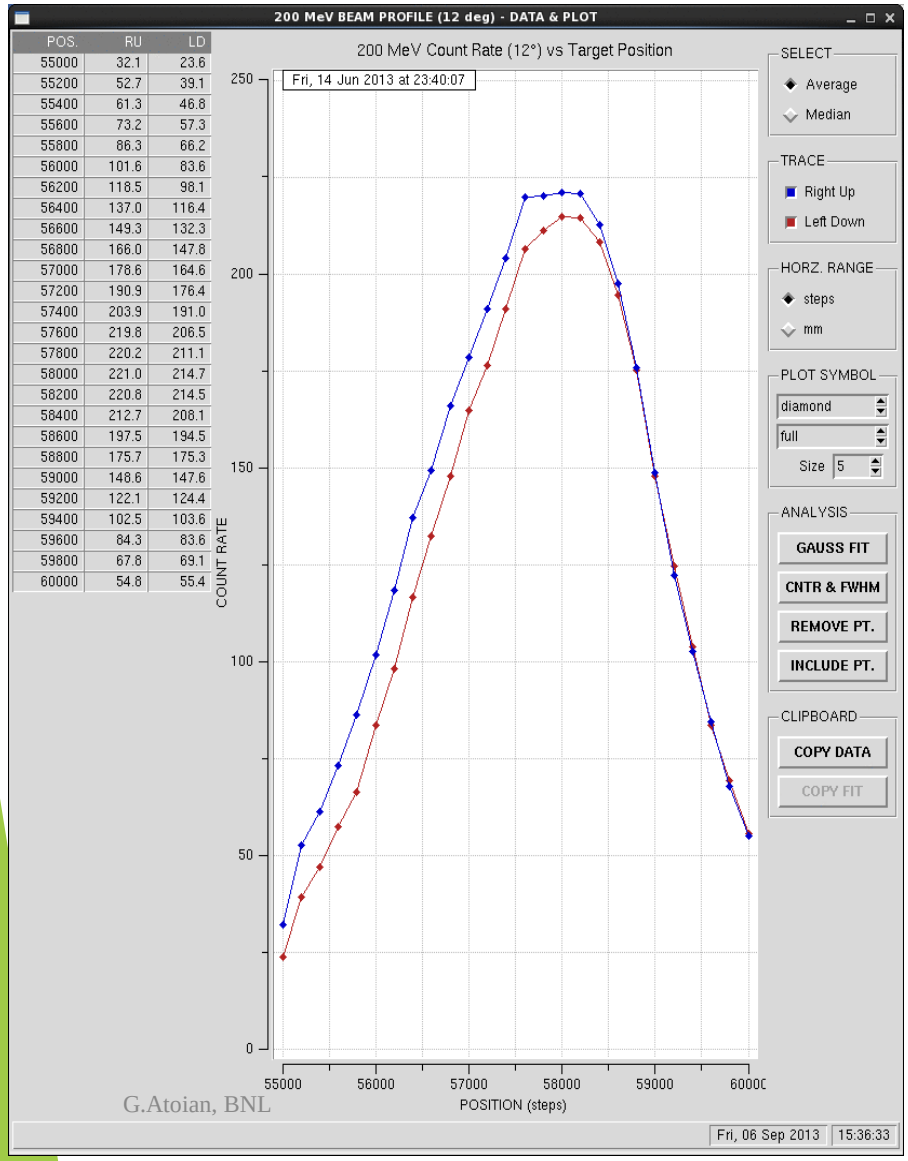


3	S	Rb polarization spatial distribution (Collimators)	0.97 - 0.98



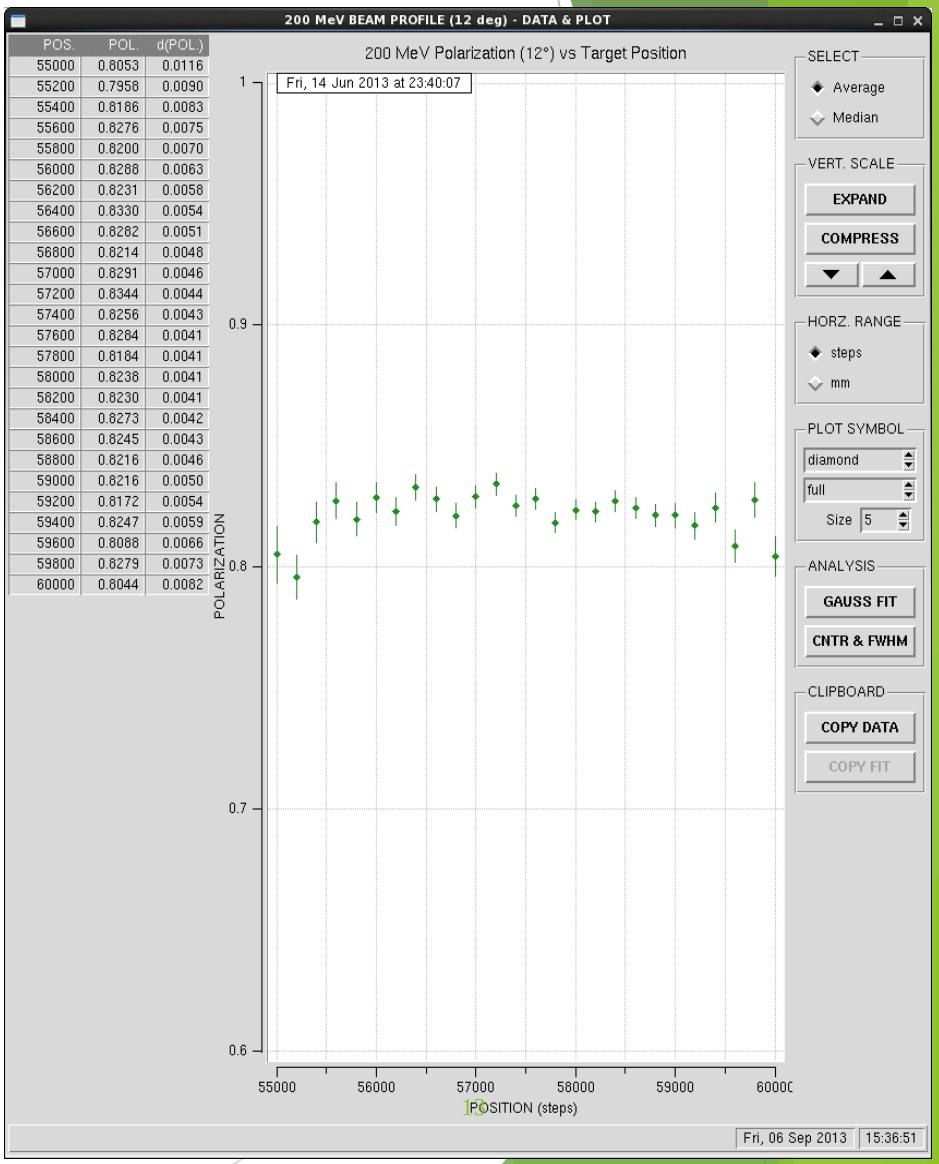
3	S	Rb polarization spatial distribution (Collimators)	0.97 - 0.98

Beam profile out of Linac



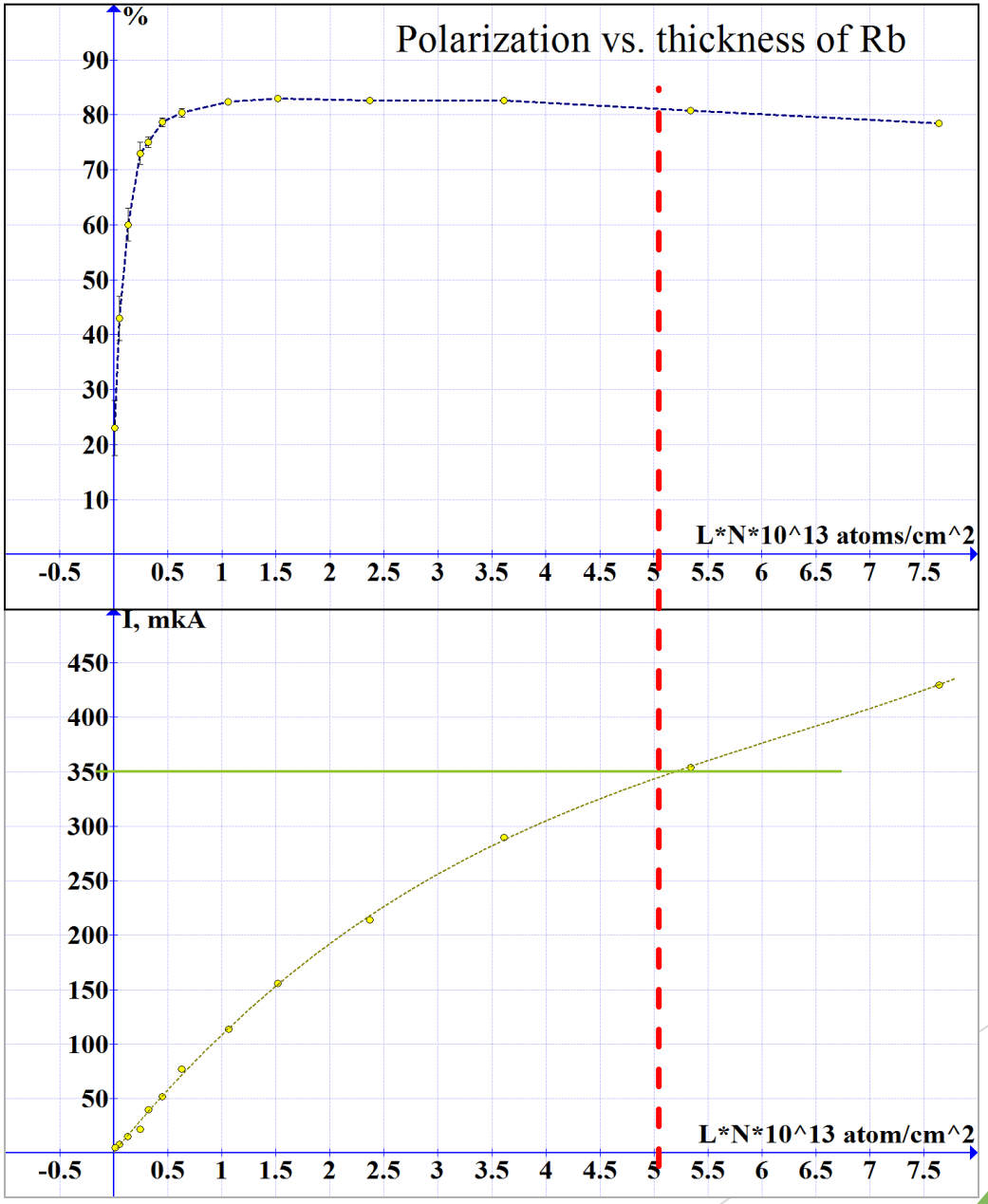
POS.	RU	LD
55000	32.1	23.6
55200	52.7	39.1
55400	61.3	46.8
55600	73.2	57.3
55800	86.3	66.2
56000	101.6	83.6
56200	118.5	98.1
56400	137.0	116.4
56600	149.3	132.3
56800	166.0	147.8
57000	178.6	164.6
57200	190.9	176.4
57400	203.9	191.0
57600	219.8	206.5
57800	220.2	211.1
58000	221.0	214.7
58200	220.8	214.5
58400	212.7	208.1
58600	197.5	194.5
58800	175.7	175.3
59000	148.6	147.6
59200	122.1	124.4
59400	102.5	103.6
59600	84.3	83.6
59800	67.8	69.1
60000	54.8	55.4

Polarization profile out of Linac



POS.	POL.	d(POL.)
55000	0.8053	0.0116
55200	0.7958	0.0090
55400	0.8186	0.0083
55600	0.8276	0.0075
55800	0.8200	0.0070
56000	0.8288	0.0063
56200	0.8231	0.0058
56400	0.8330	0.0054
56600	0.8282	0.0051
56800	0.8214	0.0048
57000	0.8291	0.0046
57200	0.8344	0.0044
57400	0.8256	0.0043
57600	0.8284	0.0041
57800	0.8184	0.0041
58000	0.8238	0.0041
58200	0.8230	0.0041
58400	0.8273	0.0042
58600	0.8245	0.0043
58800	0.8216	0.0046
59000	0.8216	0.0050
59200	0.8172	0.0054
59400	0.8247	0.0059
59600	0.8088	0.0066
59800	0.8279	0.0073
60000	0.8044	0.0082

4	B_{RG}	Proton neutralization in residual gas (Vacuum)	0.98 - 0.99



4	B_{RG}	Proton neutralization in residual gas (Vacuum)	0.98 - 0.99

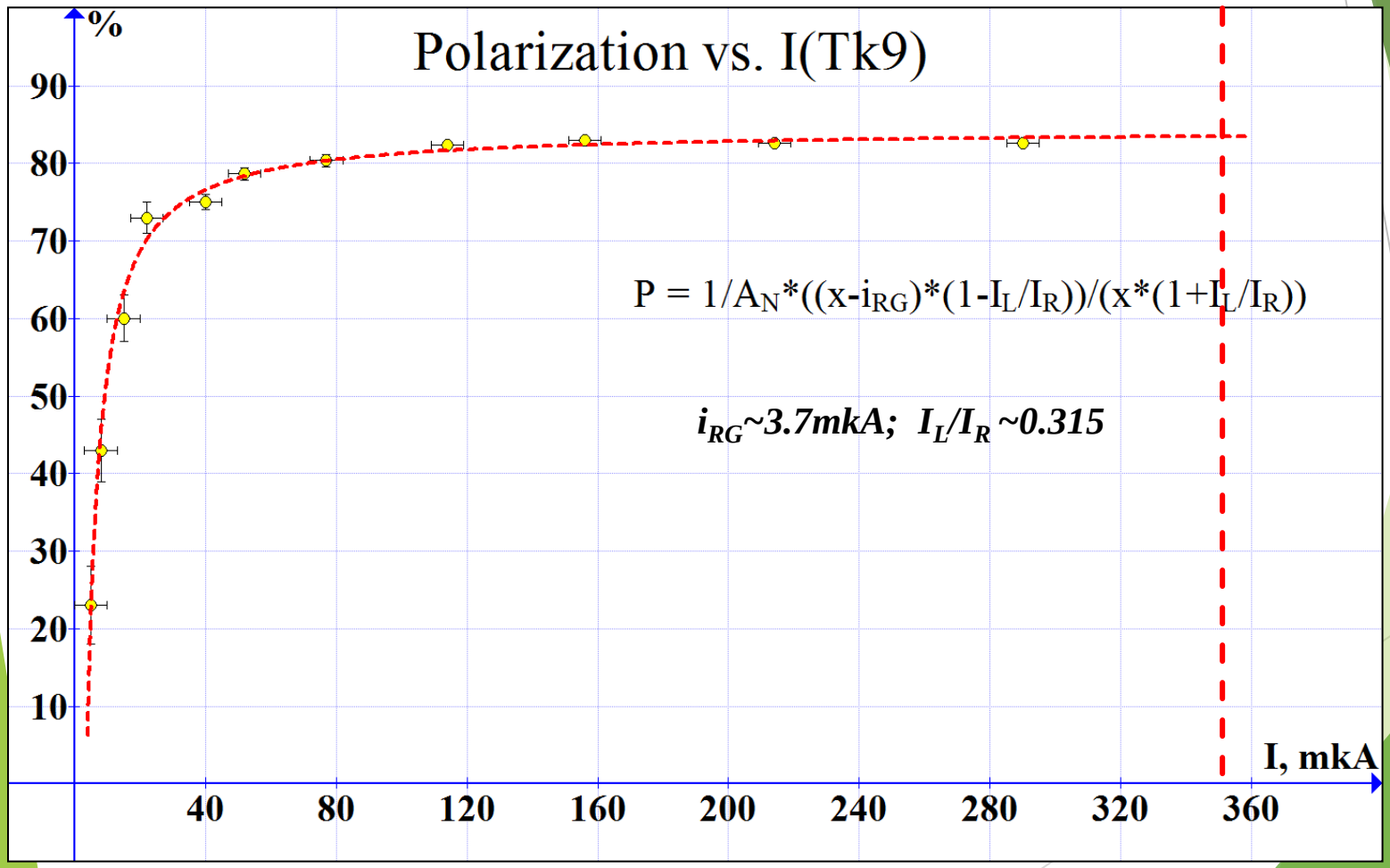
$P \sim 1/A_N[(I_L-0.5i_{RG})-(I_R-0.5i_{RG})] / [(I_L-0.5i_{RG})+(I_R-0.5i_{RG})]$

$P = 1/A_N(I_L-I_R)/(I_L+I_R+i_{RG})$

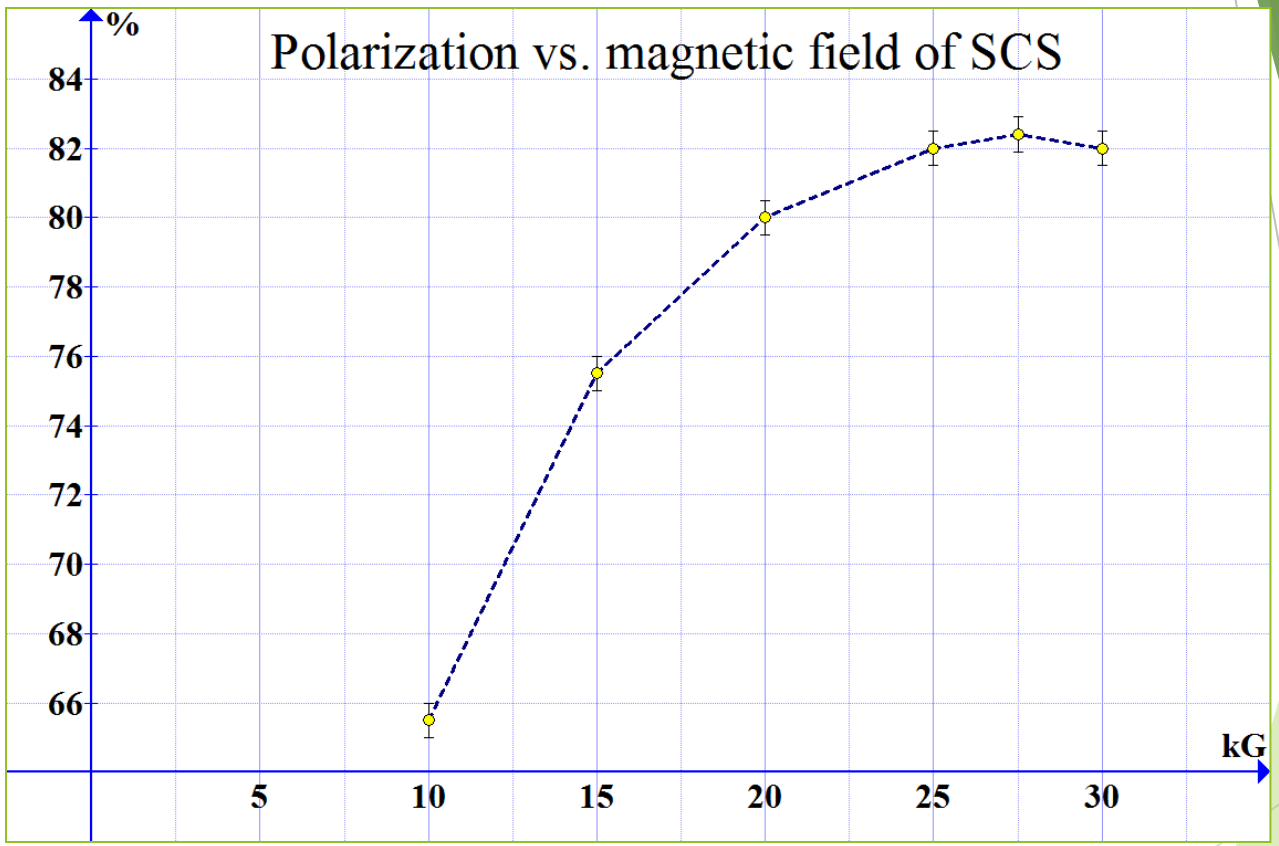
$I_M=I_L+I_R+i_{RG}$, if $I_R = aI_L$

$P = 1/A_N\,(I_M-i_{RG})(1-a) / I_M(1+a) \rightarrow i_{RG} \sim 3.7mkA$

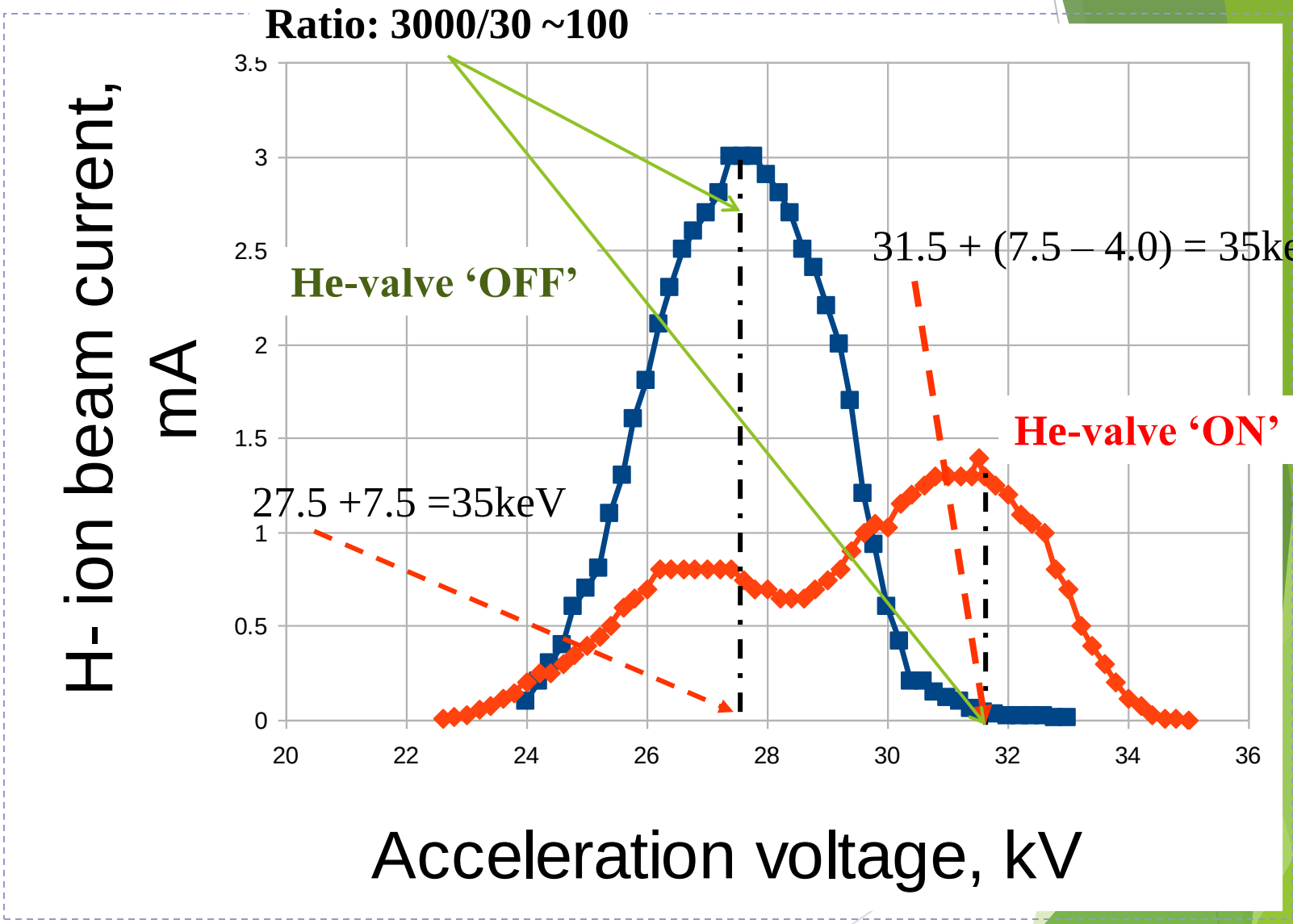
Dilution of polarization due residual gas at Rb-thickness ~$5*10^{13}$ atoms/cm^2 (~350mkA) is 3.7/350 < 1.1%



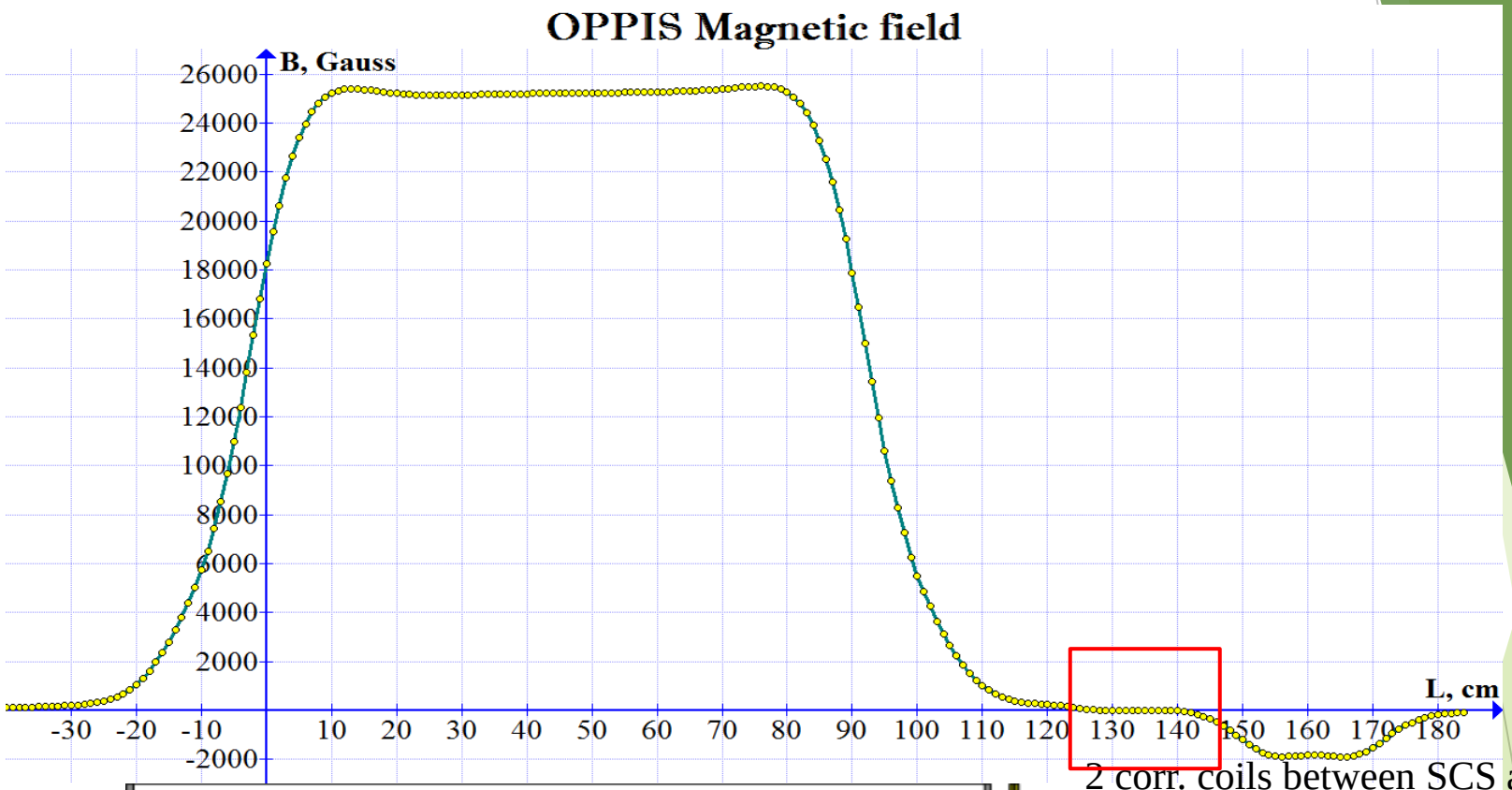
5	E_{LS}	Depolarization due to spin-orbital interaction	0.98 - 0.98



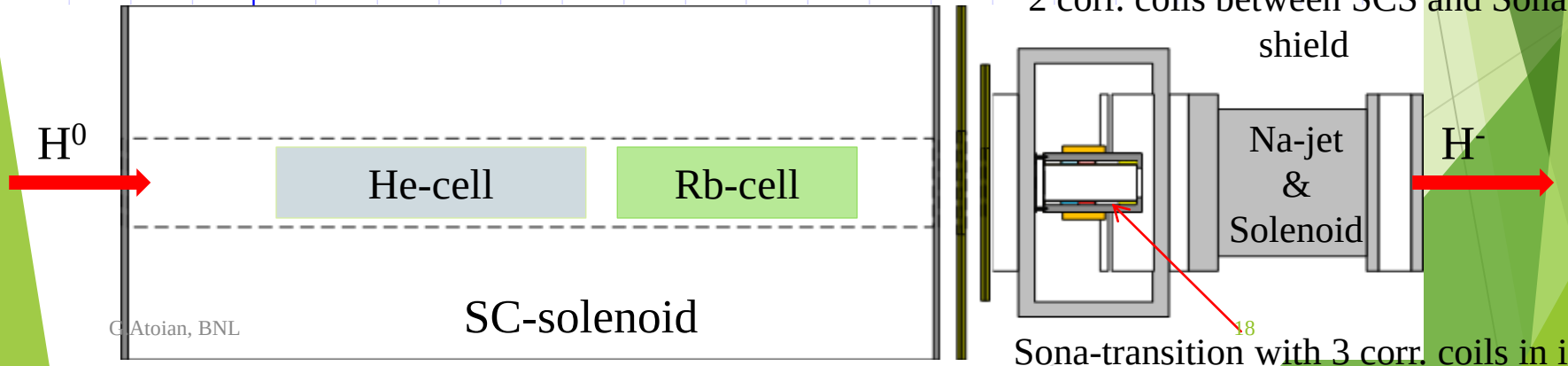
6	E_{ES}	Dilution due to incomplete energy separation not polarized component of the beam (LEBT)	0.98 - 0.99



7	E_{Sona}	Sona-transition efficiency (Adjustment)	0.96 - 0.98



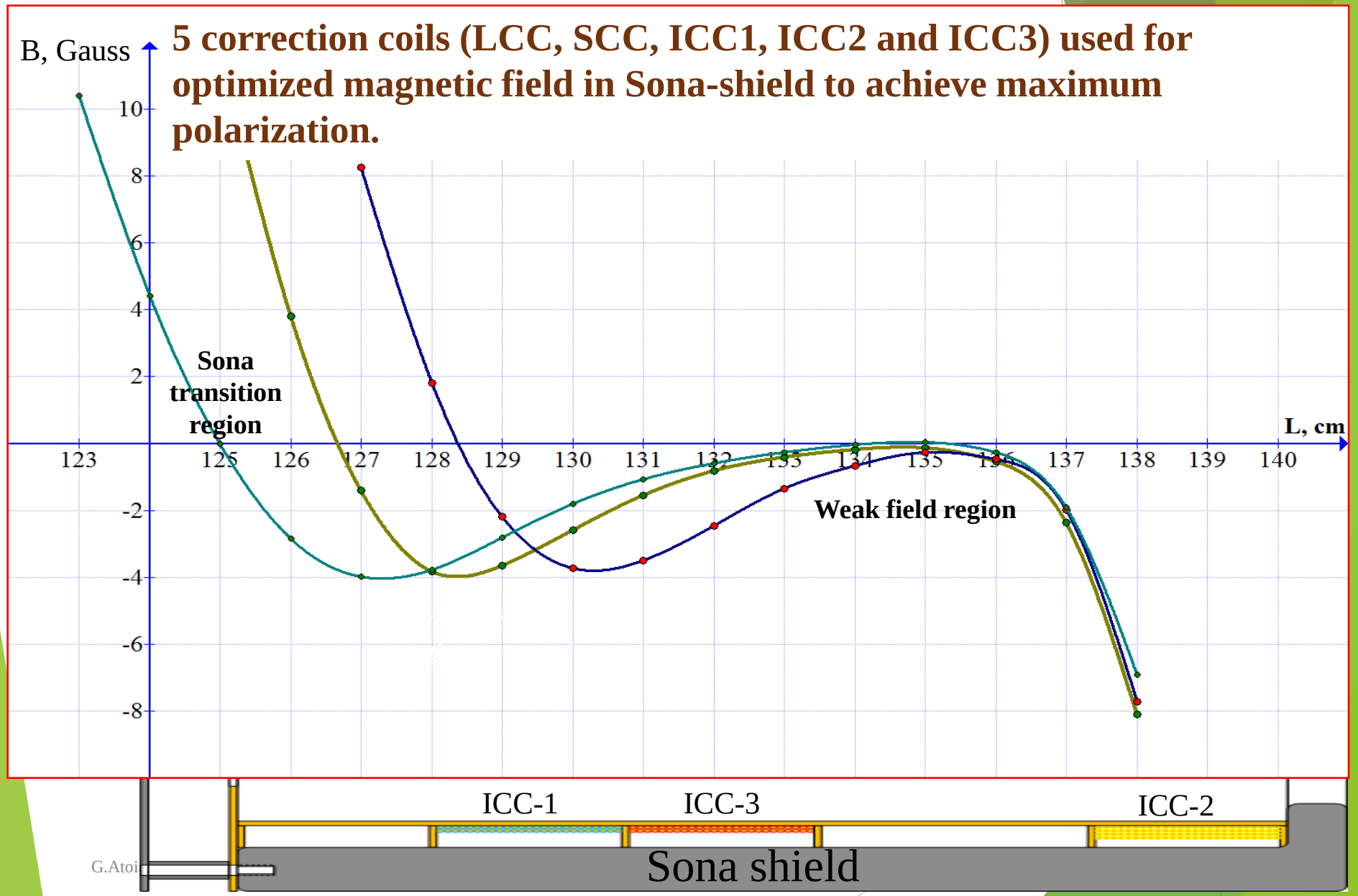
2 corr. coils between SCS and Sona-shield



Sona-transition with 3 corr. coils in it

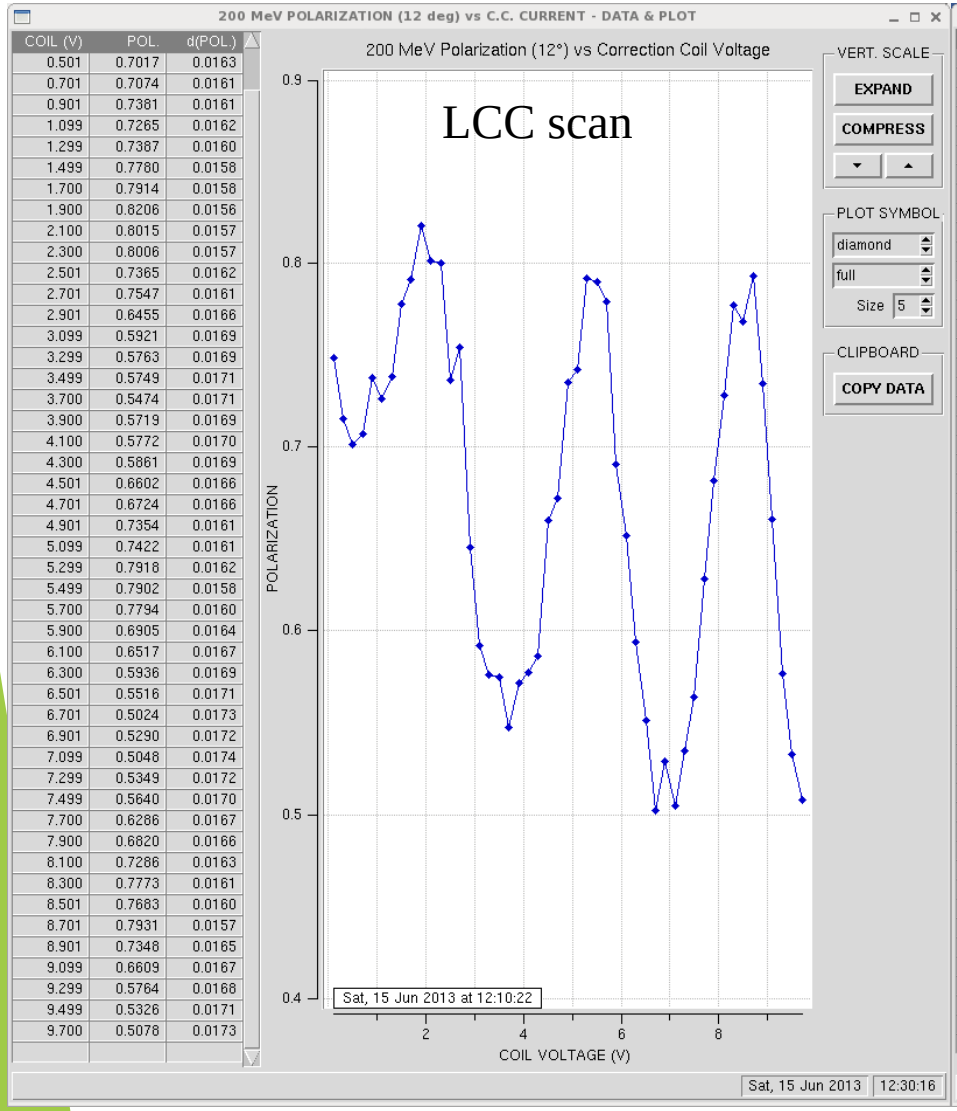
7	E_{Sona}	Sona-transition efficiency (Adjustment)	0.96 - 0.98

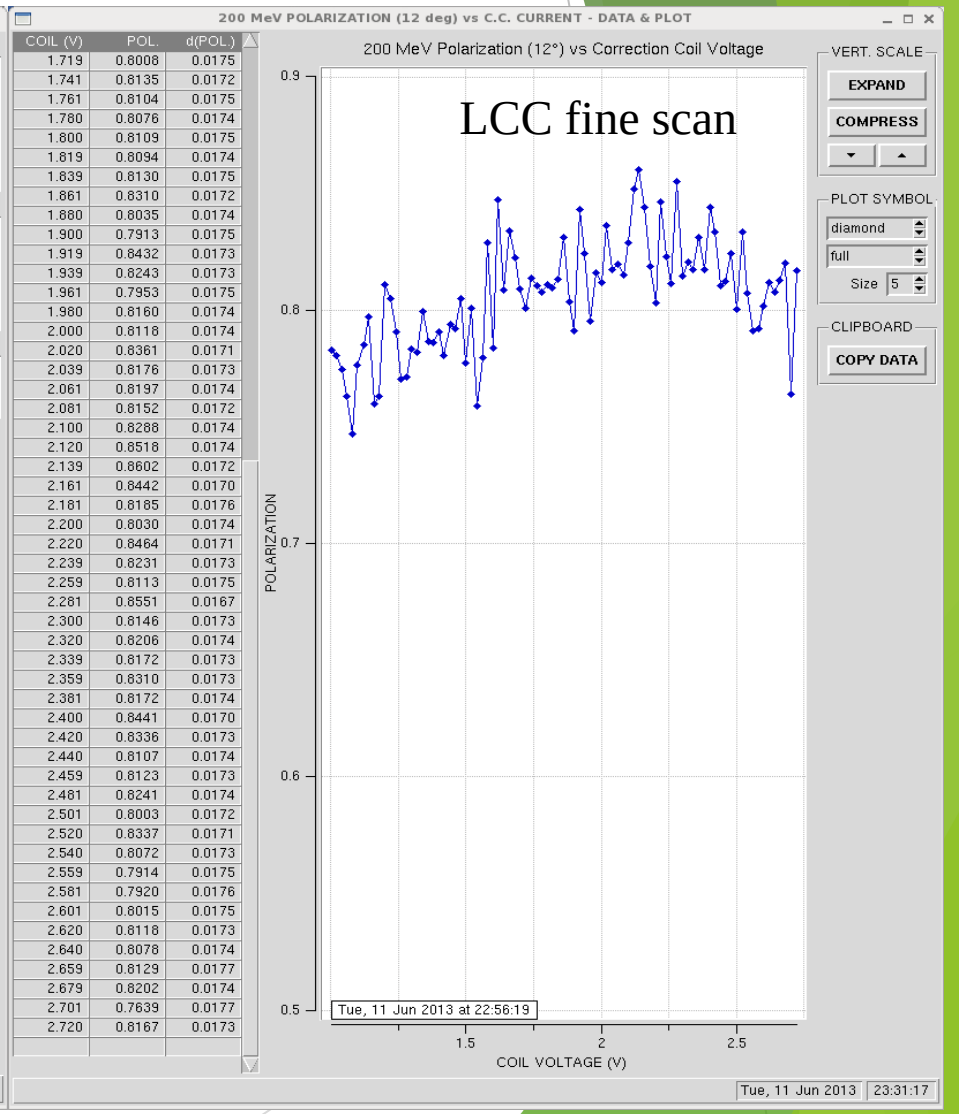
5 correction coils (LCC, SCC, ICC1, ICC2 and ICC3) used for optimized magnetic field in Sona-shield to achieve maximum polarization.



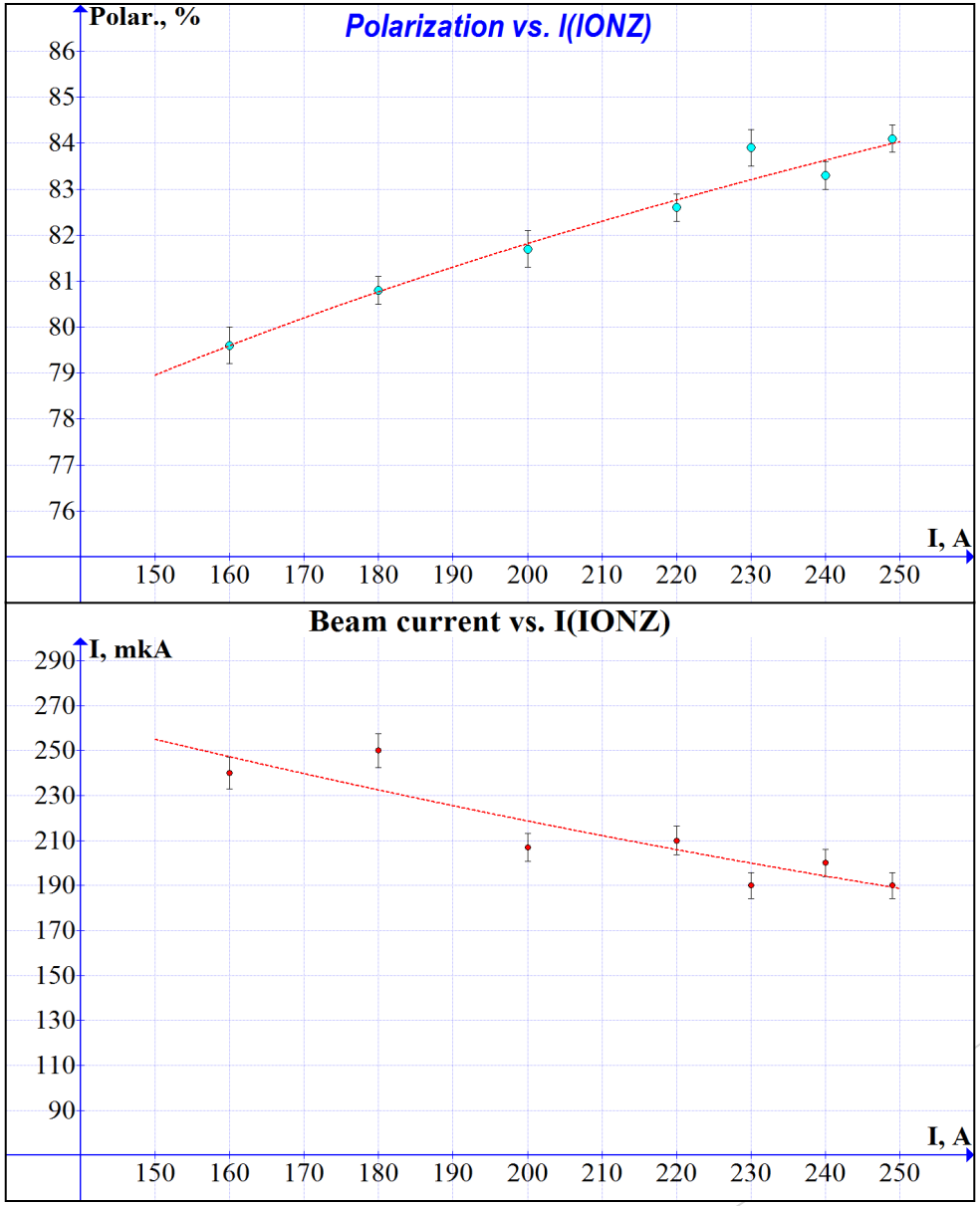
7	E_{Sona}	Sona-transition efficiency (Adjustment)	0.96 - 0.98

For maximum polarization must be accurate selection of settings all correction coils. Any change in the magnetic field of coils, SCS or ionizer as well as their position requires a new setting.

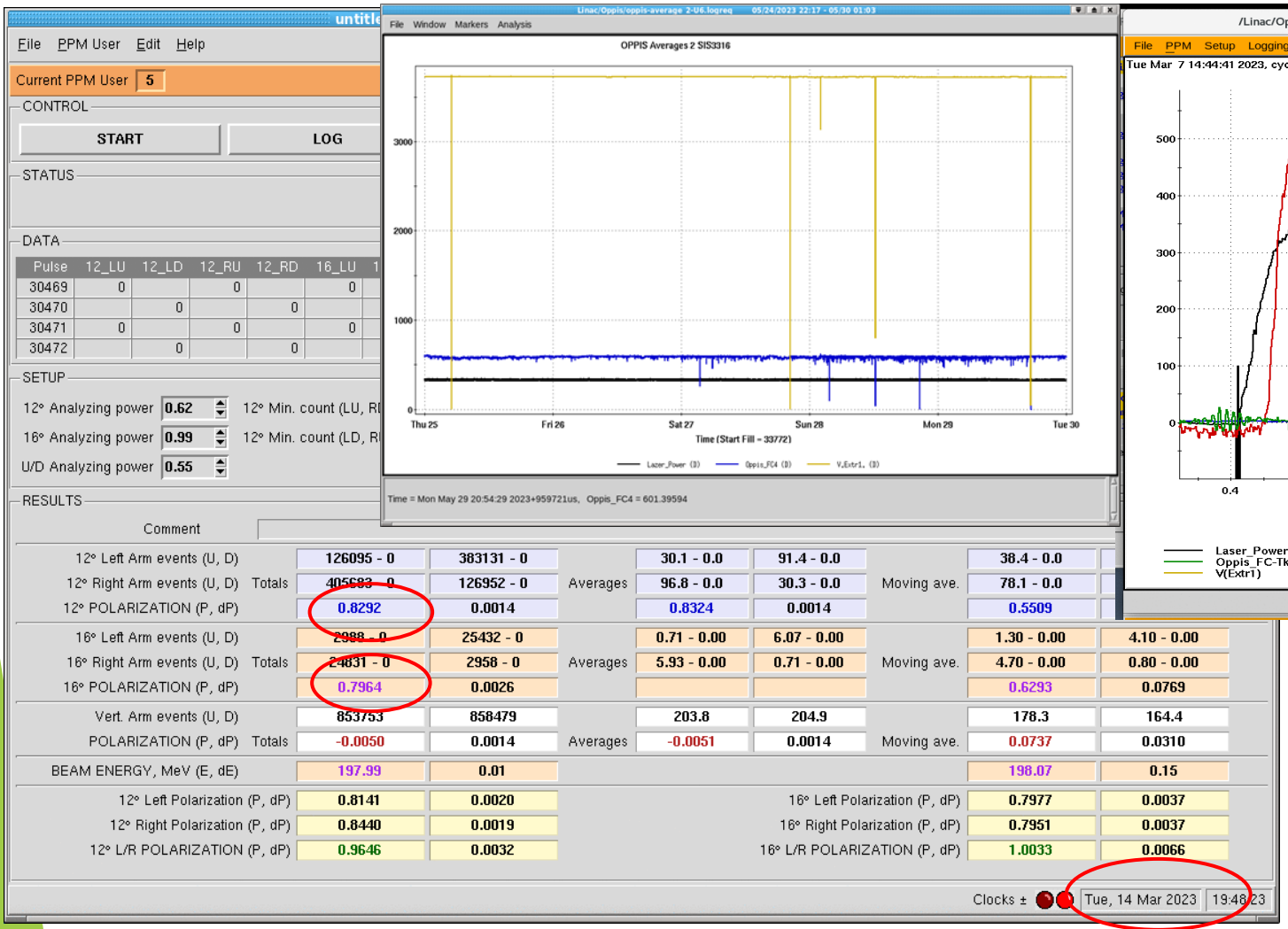




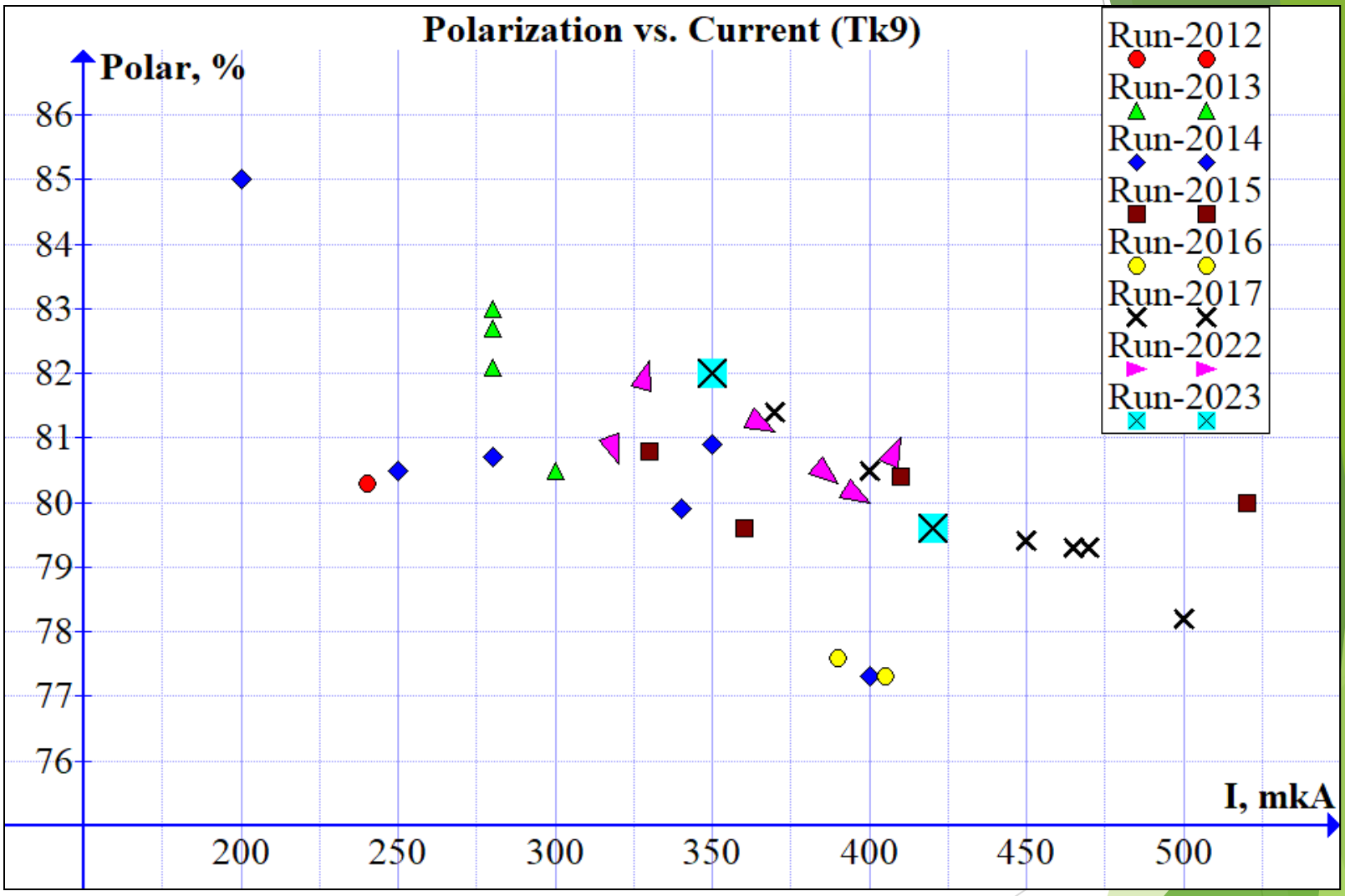
8	E_{ion}	Incomplete hyperfine interaction breaking in the ionizer magnetic field	0.98 - 0.99



Beam performance in 2023: I(T9)=420mkA (~7*10^11)



Beam performance

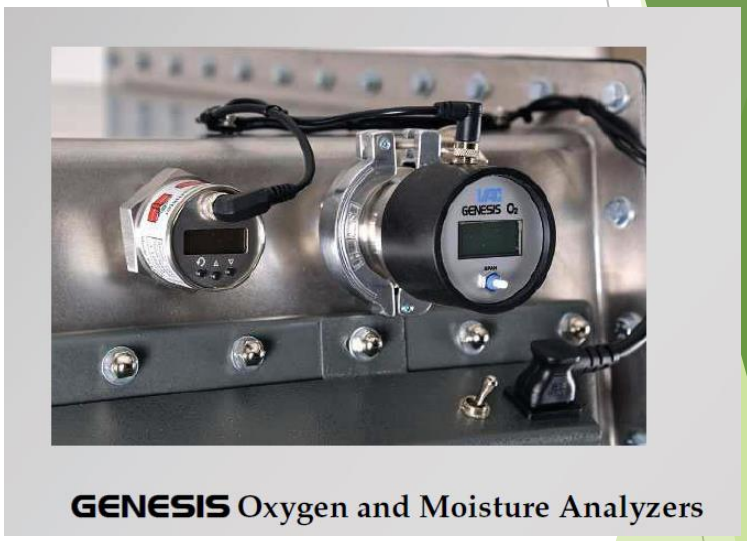


New Glovebox for reloading Na-cell and Rb-cell

As a result of the incident on June 28, the glovebox for reloading sodium cell was damaged.

Purchase of new glovebox:

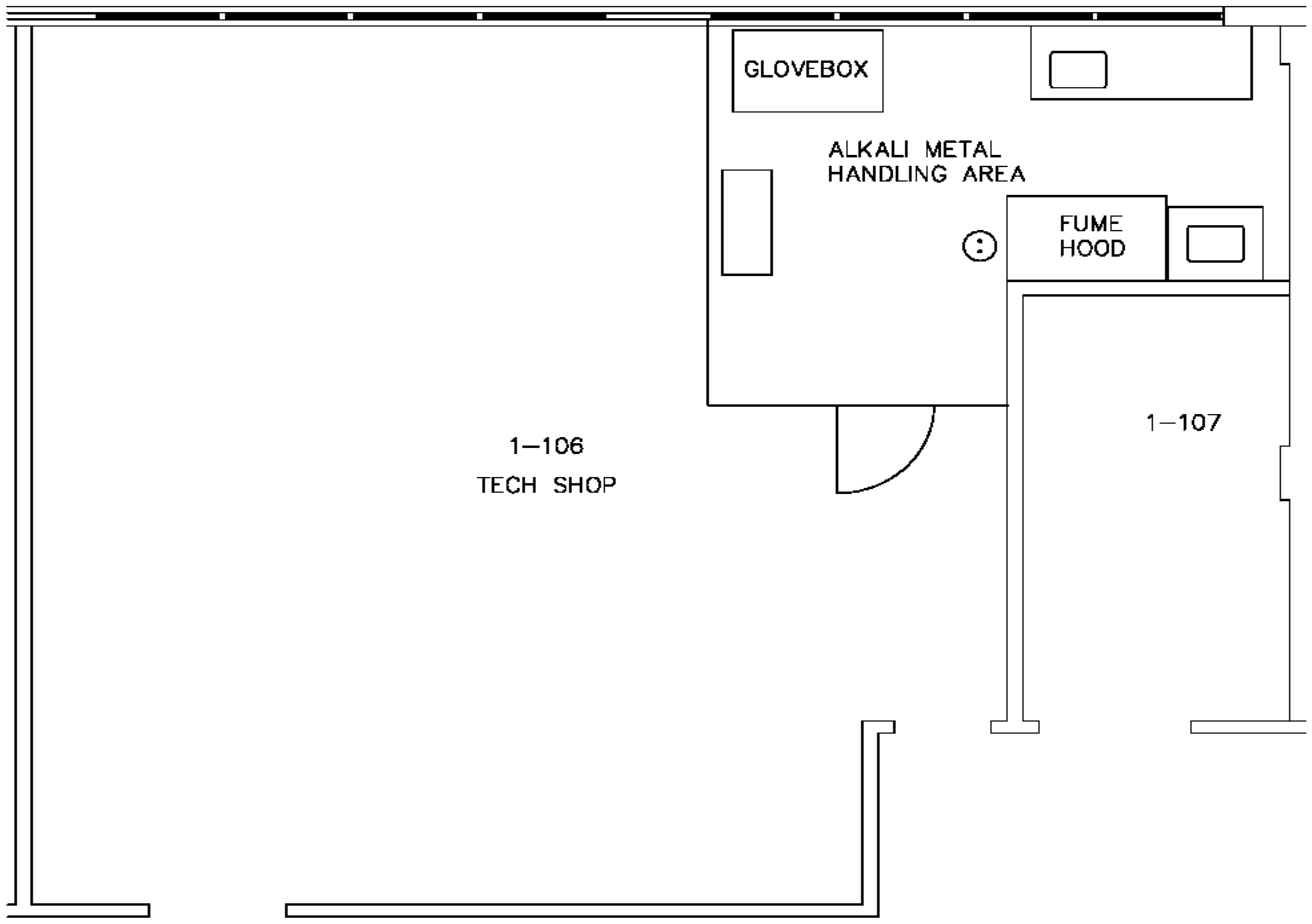
- Safety approval for purchase 8/28
- Delivery estimate is end of September
- Glovebox will use inter gas supplied by cylinders, **not** building nitrogen



Alkali Metal Handling Area

- Safety planning meeting held 8/23
- Additional barrier required to separate area from rest of shop
- Barrier material is available at BNL
- Design layout to be finalized 9/8
- 2-day installation by carpenters

Bldg.930



Summary

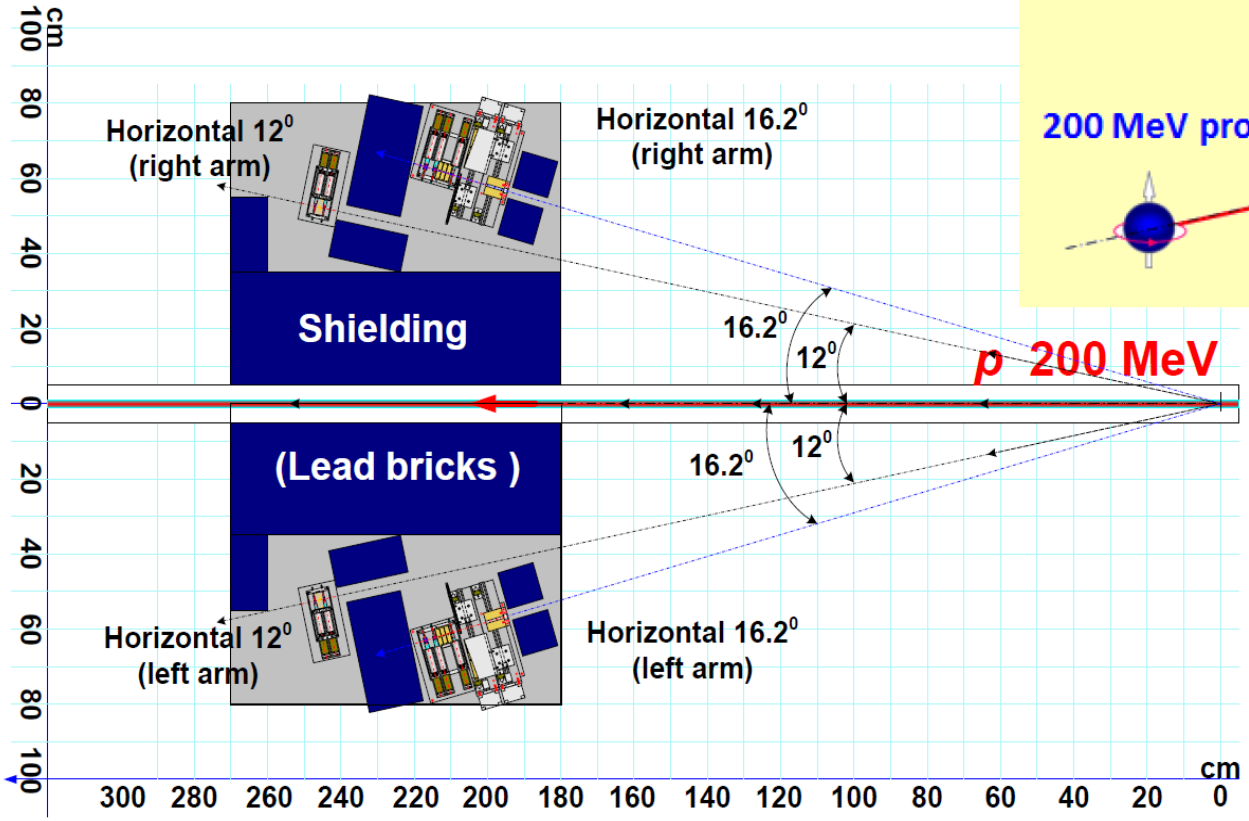
For Run-24:

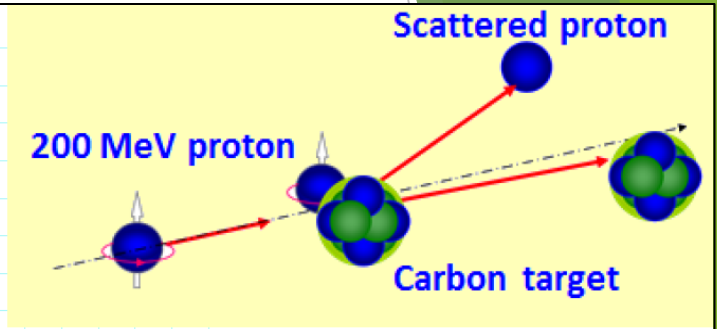
1. Modernized the He-cell with the three-grid energy separation system. Preparing a spare set;
2. Upgraded the Na-cell and prepared a spare set;
3. Modernized the powering transformer system of the 35kV extractor;
4. Modernized the Rb-cell. Preparing a spare cell;
5. Reduced length LEBT tested with all upgraded elements and new configuration. The results (current and polarization) are satisfactory.
6. Estimated delivery of a new glovebox for Na-cell and Rb-cell is the end of September.

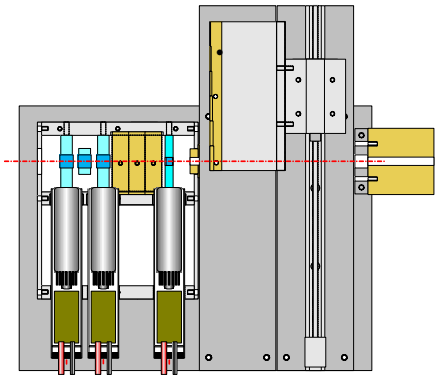
OPPIS-source are ready for Run-24

Backup

200 MeV polarimeter







12 degree polarimeter

- $\langle A_N \rangle \sim 0.62$
- High rate
- ***Used for the polarization monitoring***

16.2 degree polarimeter

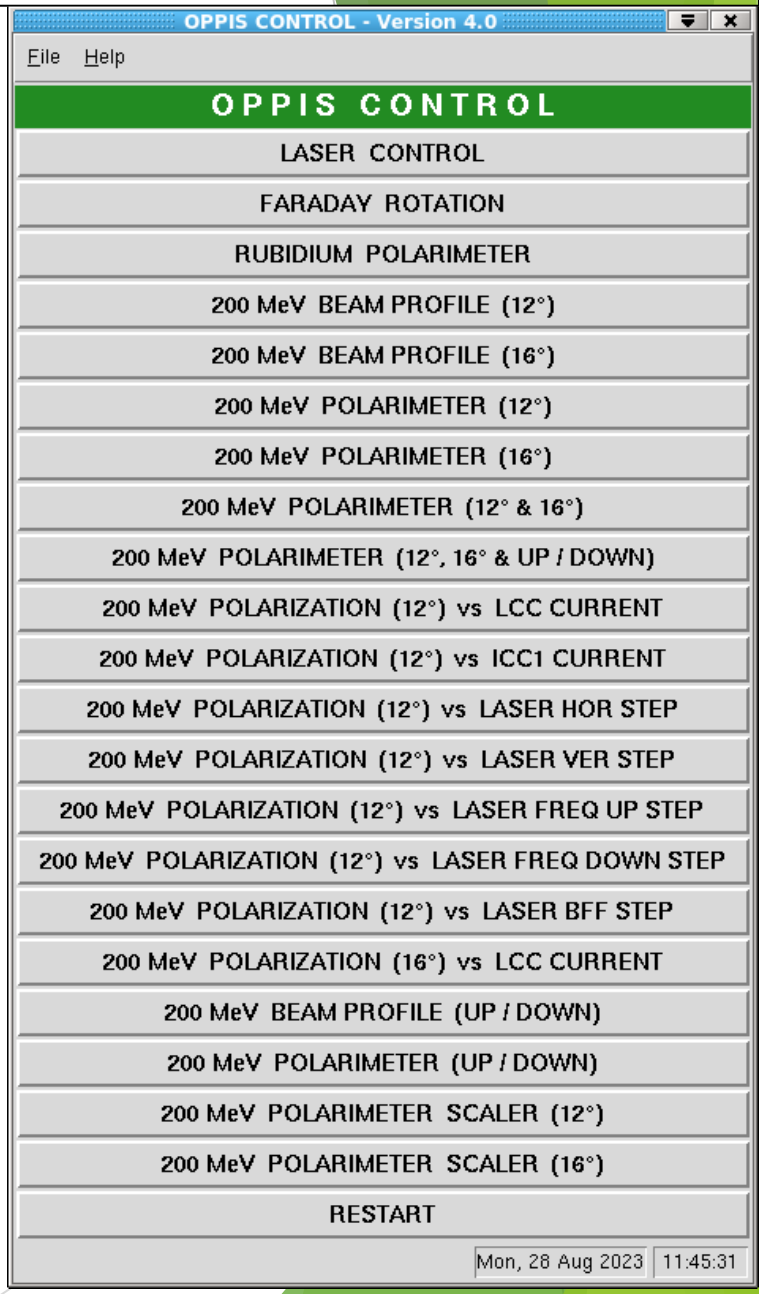
- $A_N = 0.993 \pm 0.001$ (elastic)
- Inelastic events are suppressed by absorber.
- Low rate
- ***Used for the absolute polarization measurement.***

200 MeV polarimeter

To determine the polarization, the number of events is counted by counters using a threshold amplitude analysis (“counter-analysis”). Based on the counter data, a large list of applications has been prepared with the possibility of monitoring and measuring many beam parameters. All these applications are based on the **.tcl** system, which currently works but is not supported.
In parallel with the "counter-analysis", we implemented an WFD-based data acquisition system for the 200 MeV polarimeter ("WFD-analysis").

The 200 MeV polarimeter is ready to Run 24 using both "counter-analysis" and "WFD-analysis“ of data.

August 21, 2023. Nemesure, Seth:
“The suite of programs launched by the OPPIS Control tcl application has had issues lately due to the recent RedHat upgrade (eg. input fields not responding to keyboard). We had provided a workaround to get us through the last run. Jennefer Maldonado is going to be reviewing the program and begin working on a conversion into our controls system to allow us to better maintain the program going forward.”

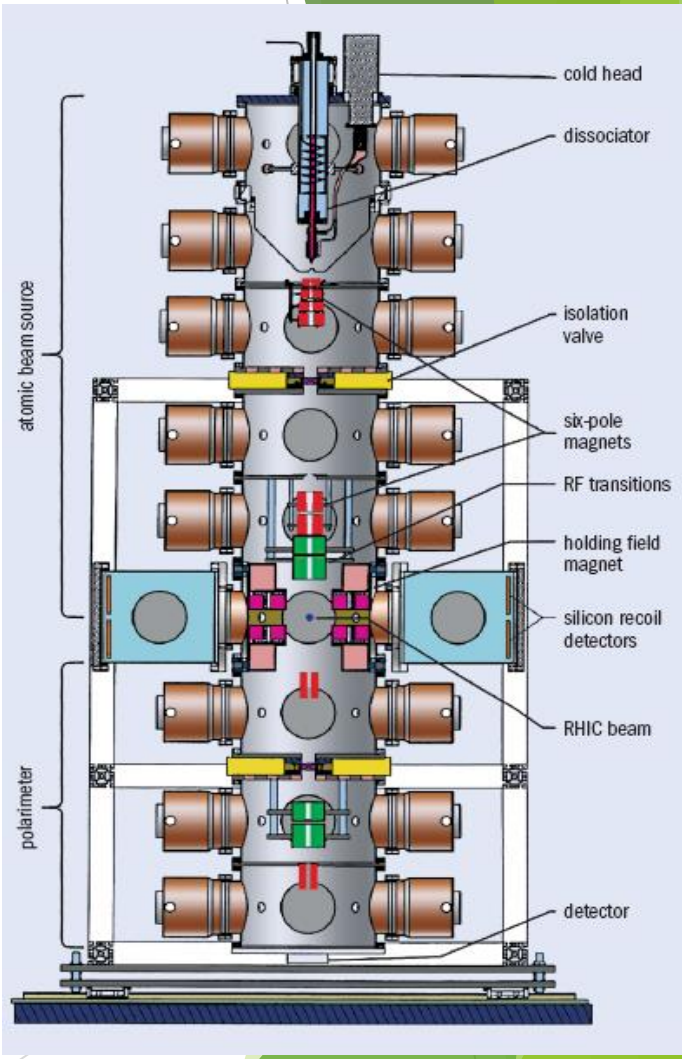


H-jet polarimeter

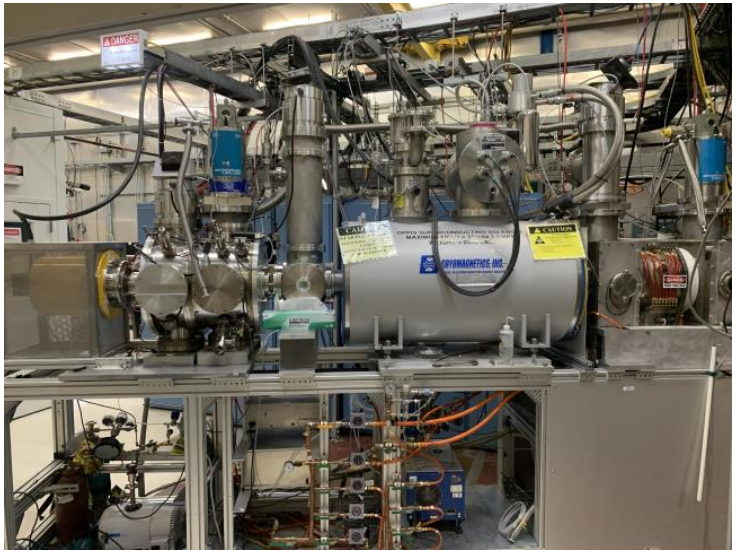
H-jet was last launched at May of 23'. H-j and polarimeter worked well.

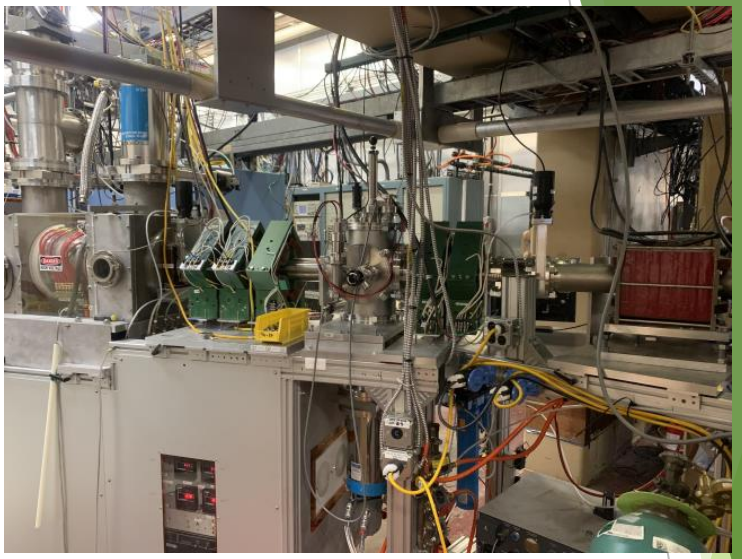
Necessary work to prepare the H-jet for Run-24:

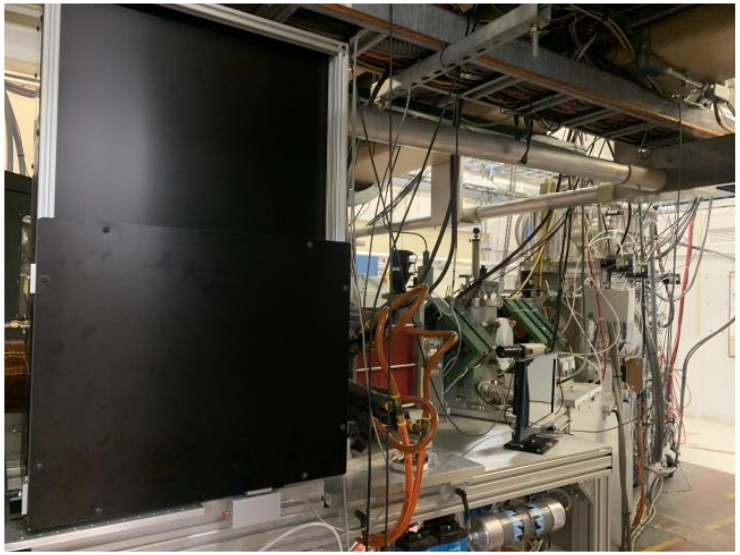
1. replace two turbopumps (5-1 and 5-2);
2. replace the old D-sub connectors of the cables connected to the TC and IG controllers;
3. replace the noisy preamplifiers of the polarimeter;
4. reconfigure interlock and ALARM signals;
5. verify that all H-jet systems and the polarimeter are operational.

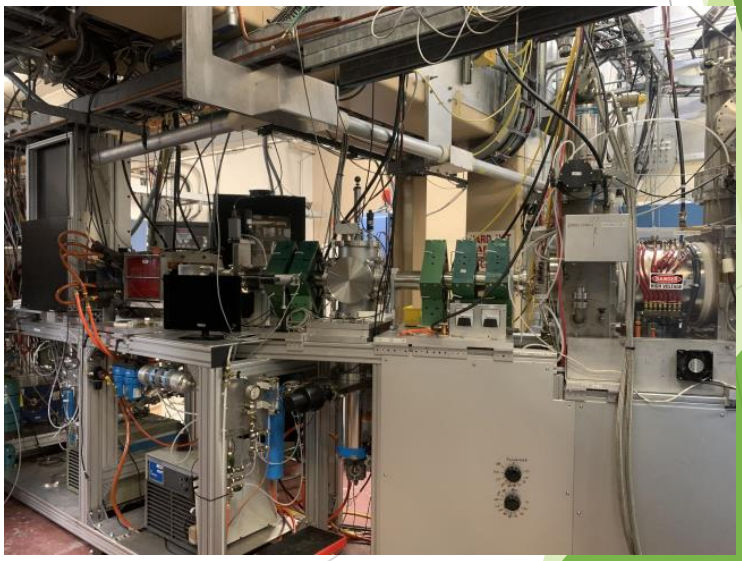


OPPIS source









He-valve operating in high magnetic field ~1-5T.