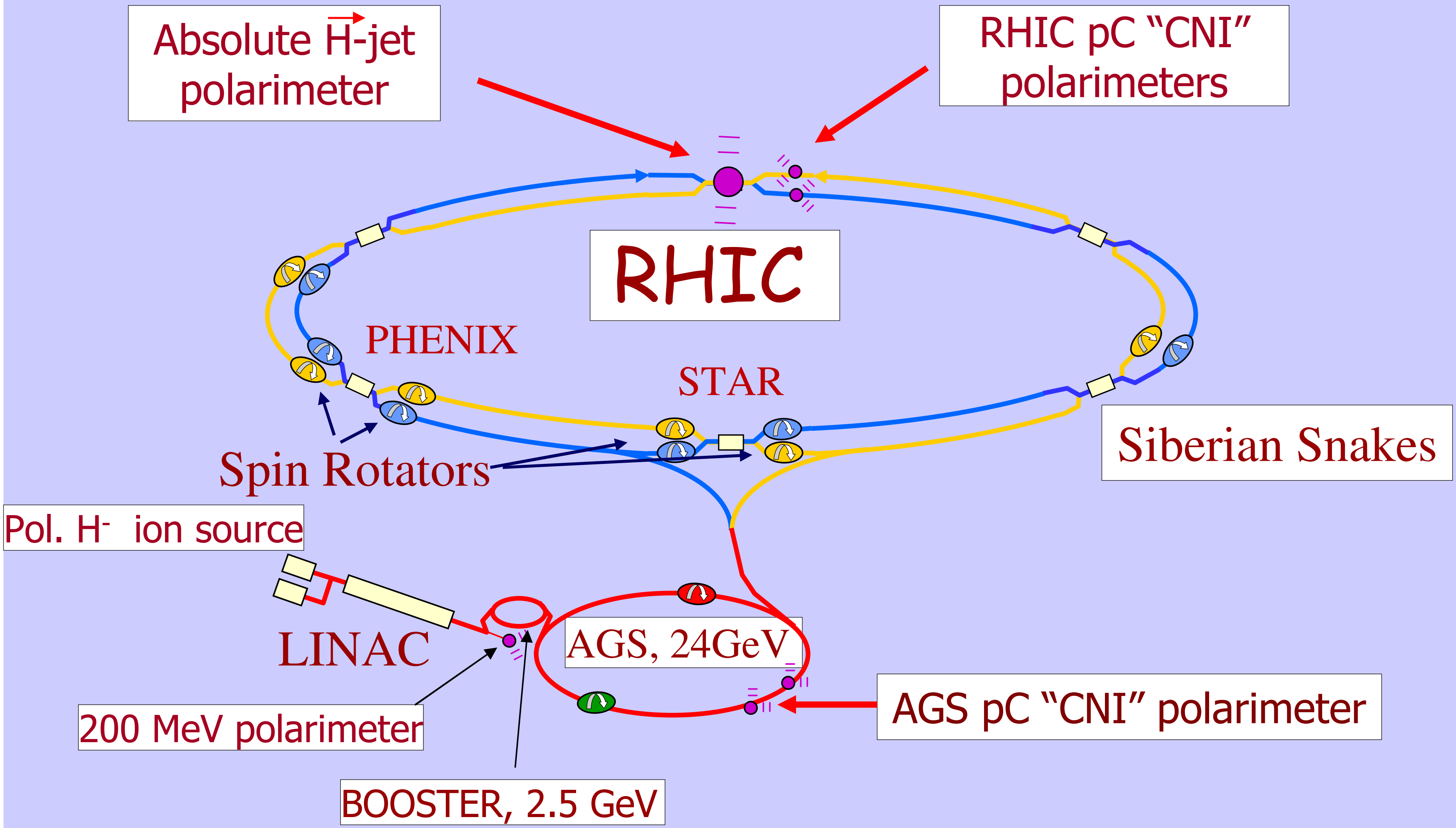
RHIC polarized source upgrade.

A.Zelenski, BNL

Pasadena,Sptember 30, 2013

Polarization facilities at RHIC

$L_{max} = 1.6 \times 10^{32}\ s^{-1}cm^{-2}$ $\quad 50 < \sqrt{s} < 510$ GeV



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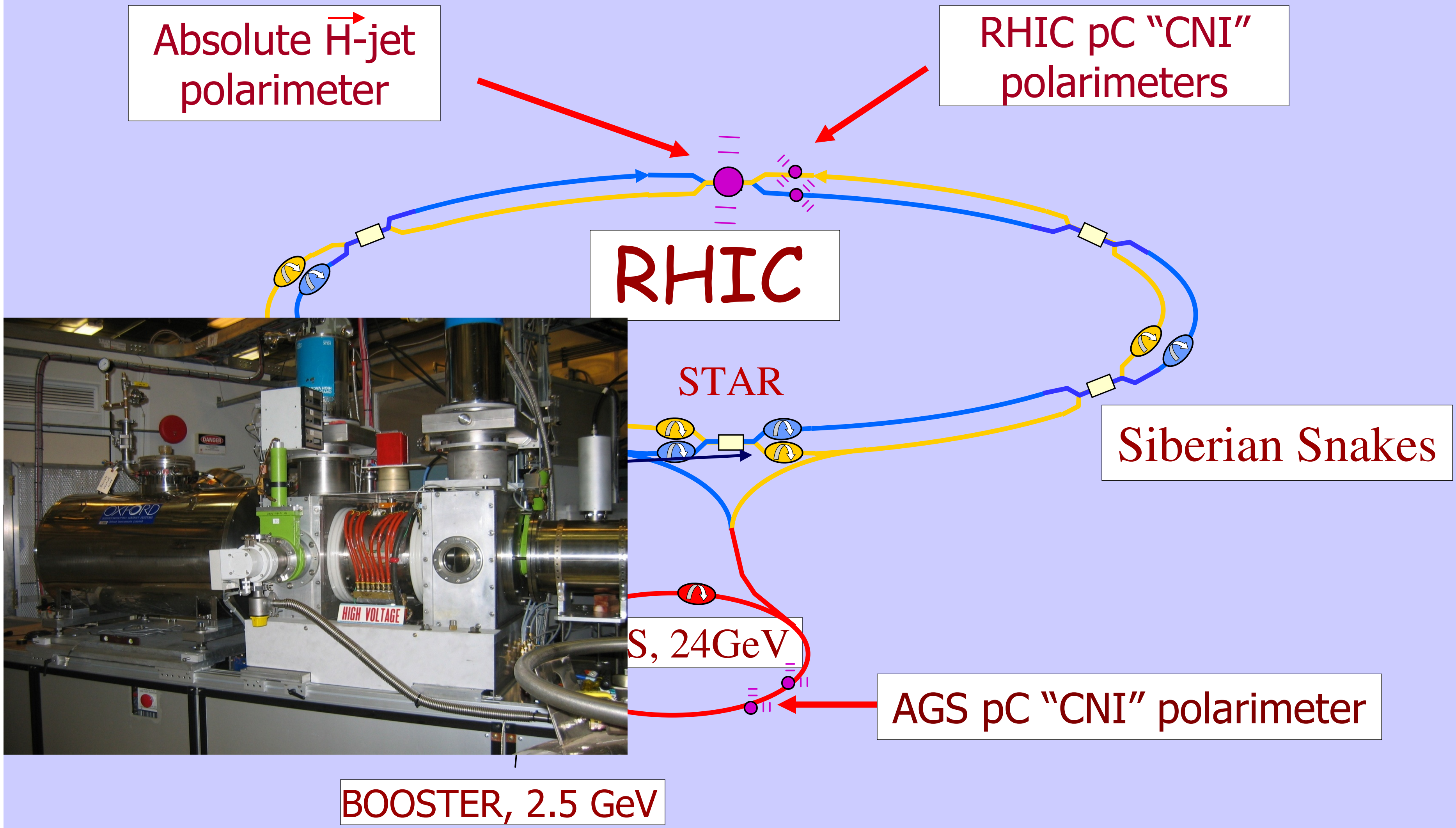
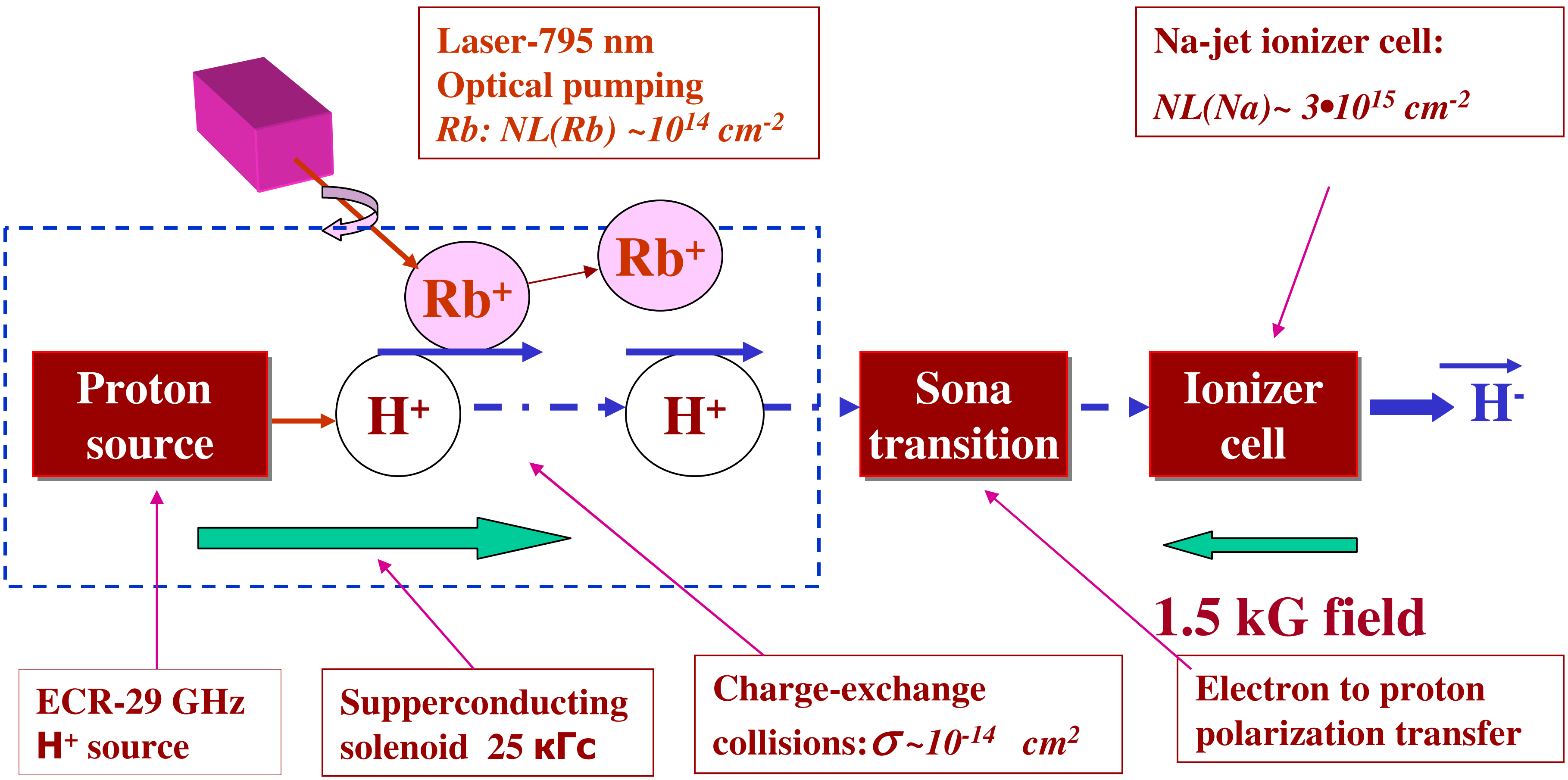


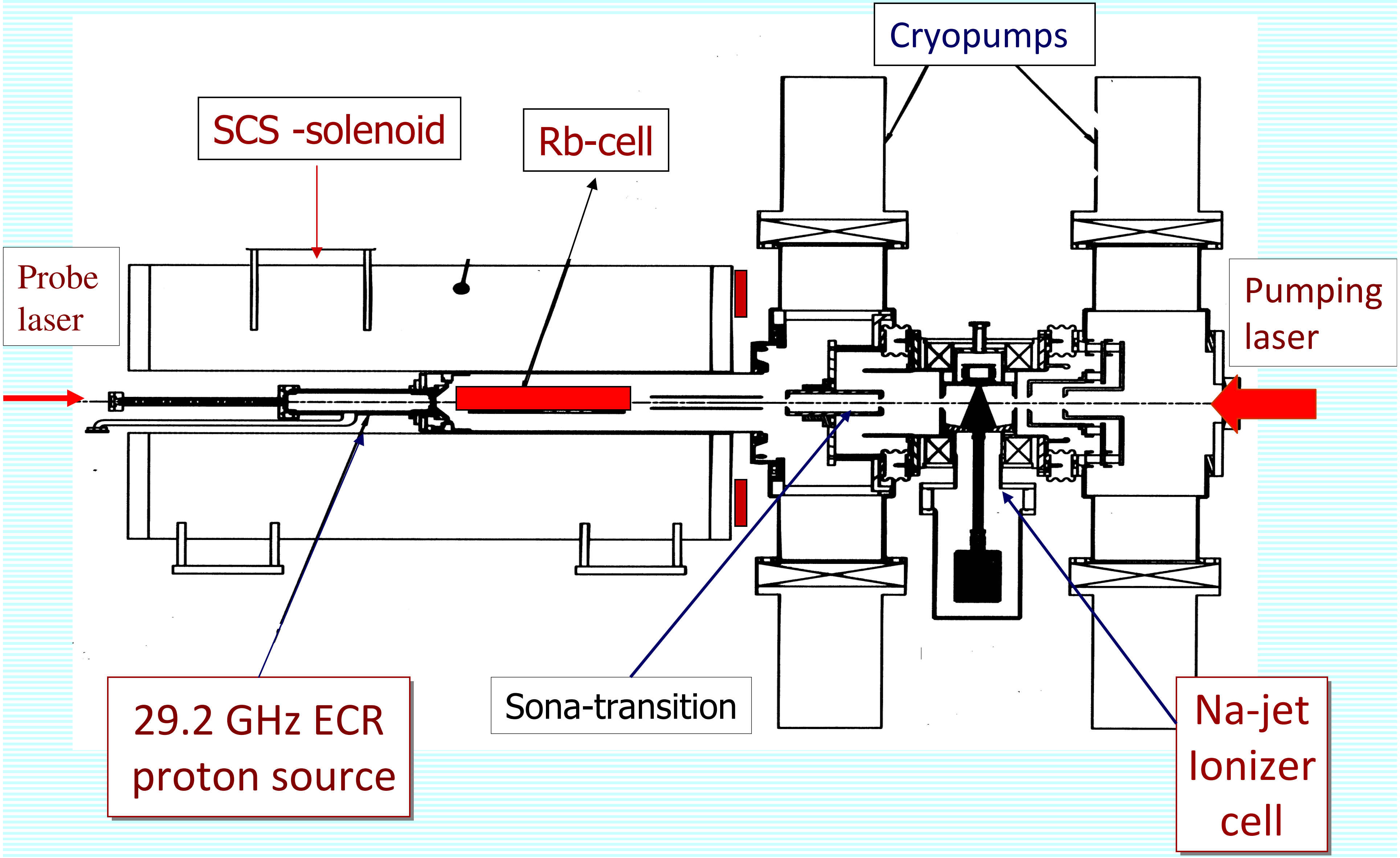
SPIN -TRANSFER POLARIZATION IN PROTON-Rb COLLISIONS



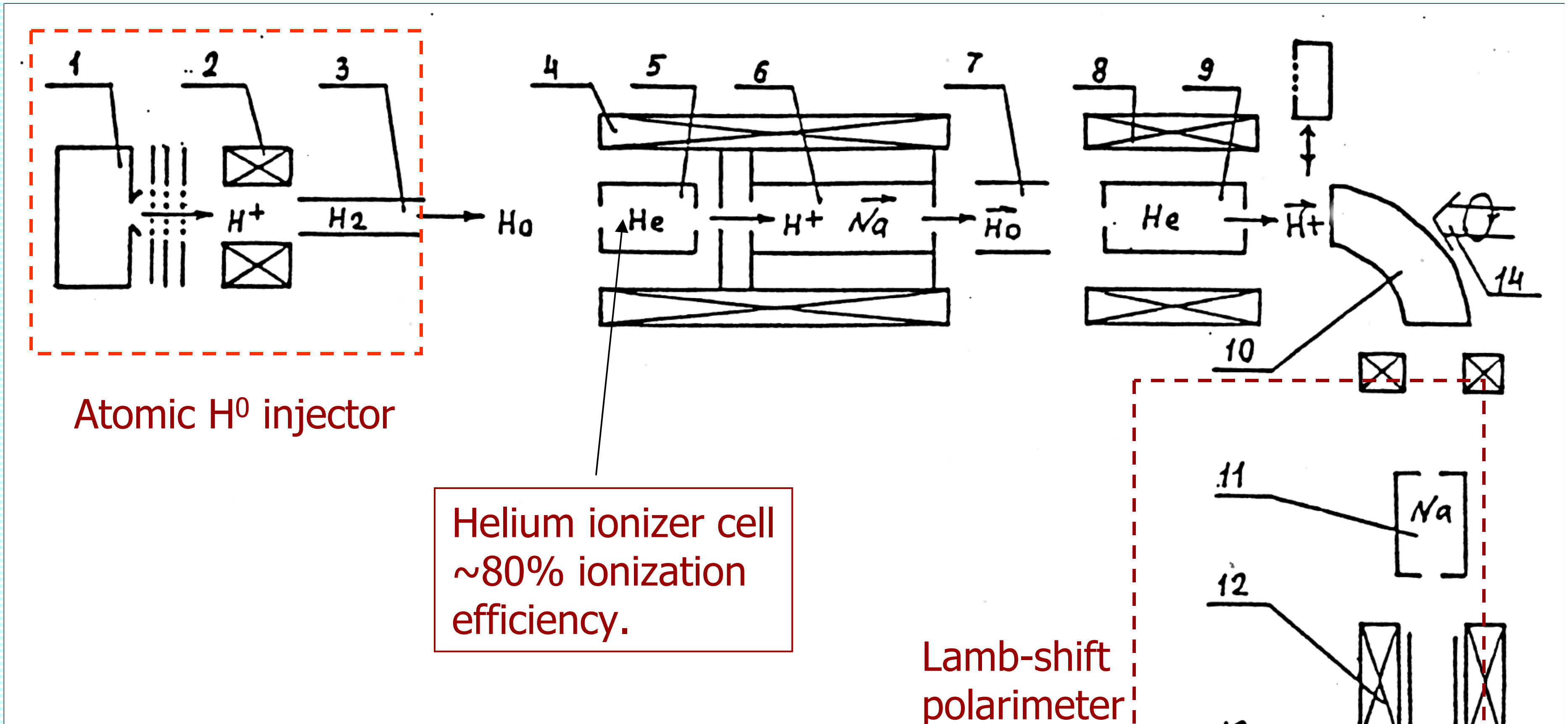
Laser beam is a primary source of angular momentum:

10 W (795 nm) ⇨ 4•10^{19} hν/sec ⇨ 2 A, H^0 equivalent intensity.

Schematic layout of the RHIC OPPIS.



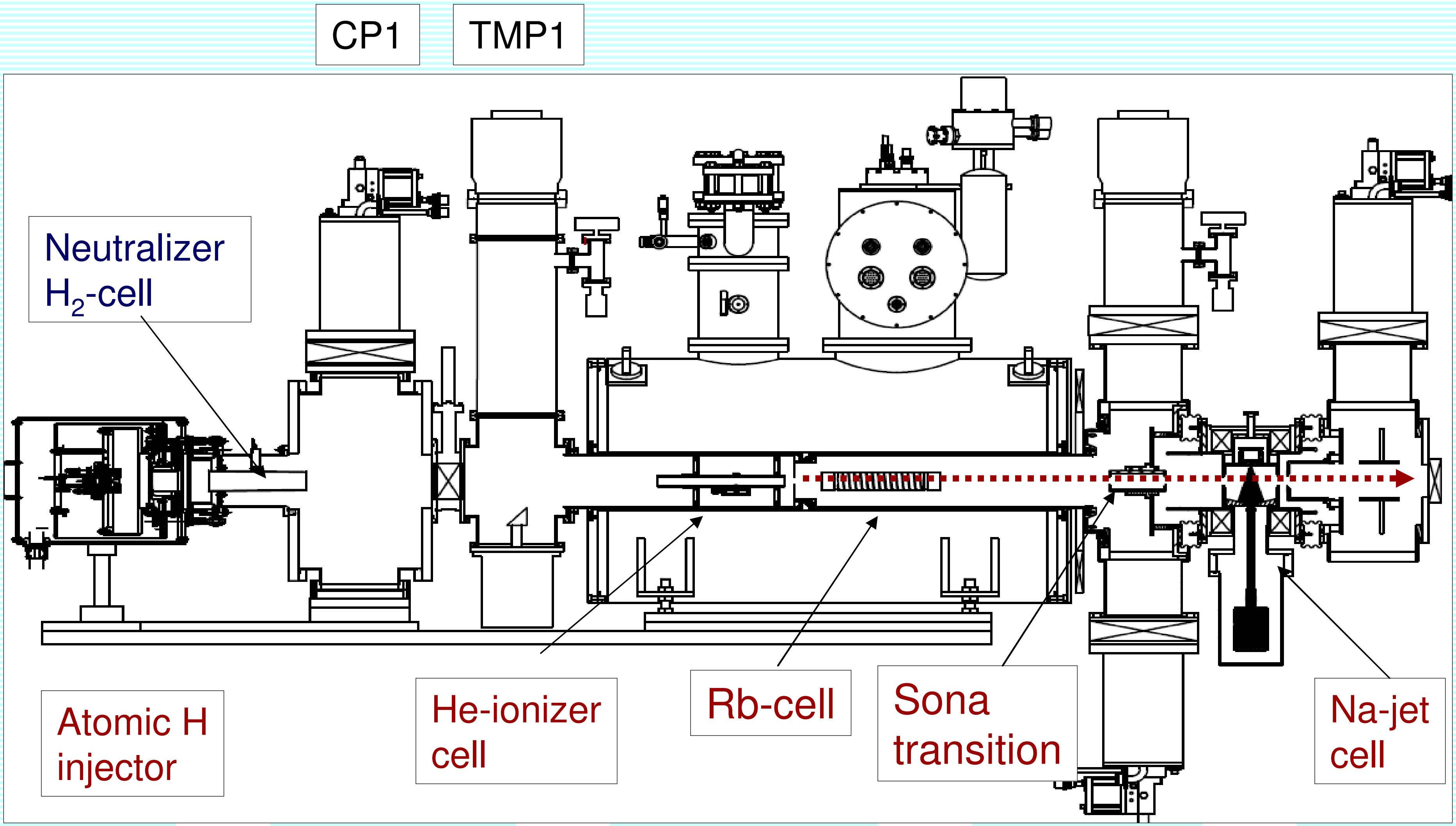
Pulsed OPPIS with the atomic hydrogen injector at INR, Moscow, 1982-1990. First generation



H^- current- 0.4mA

H^+ current- 4.0 mA, P=65%, 1986

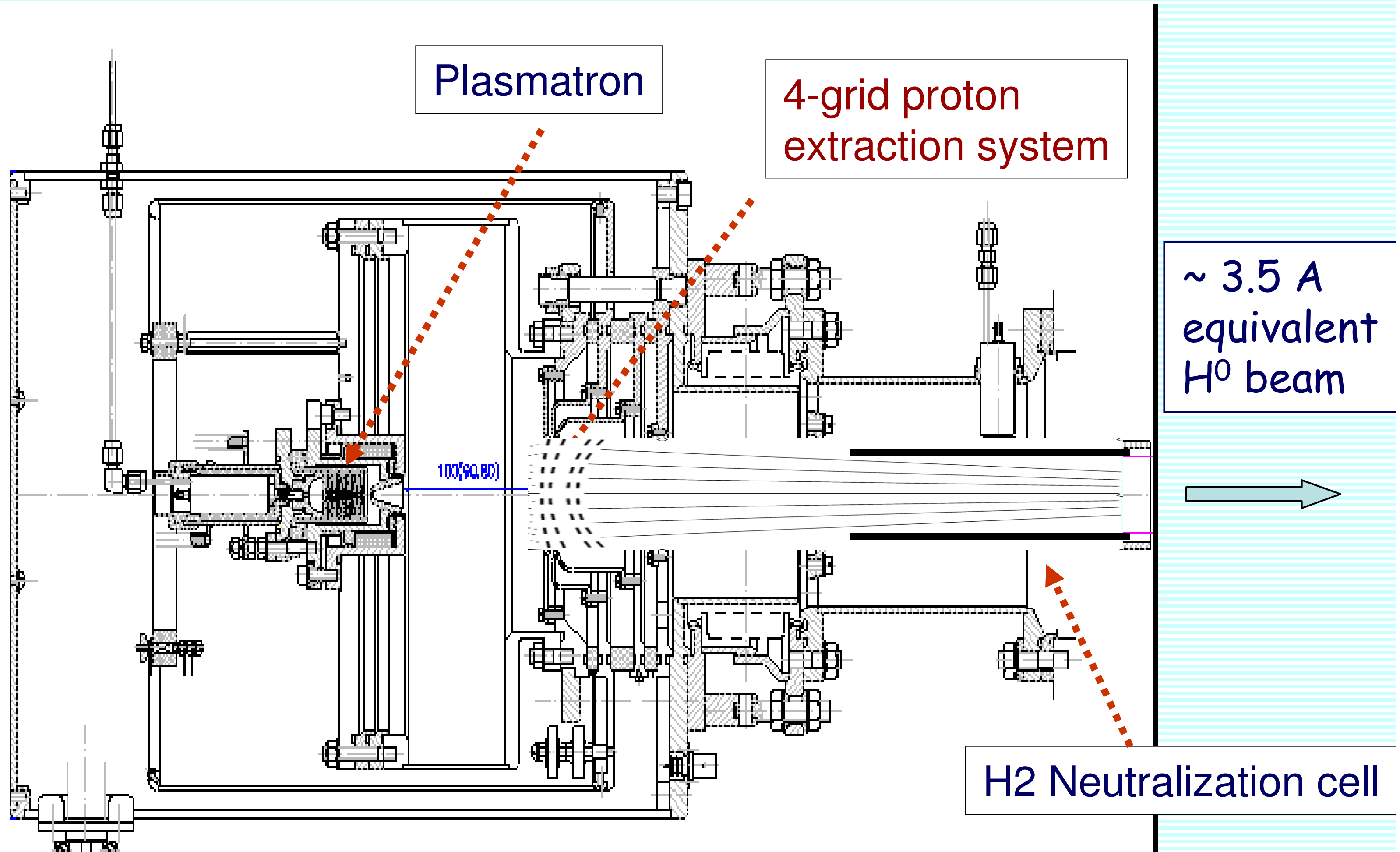
OPPIS with atomic H^0 injector layout



$H^+ \xrightarrow{H2} H^0 \xrightarrow{He} H^+ \xrightarrow{Rb} H^0 \xrightarrow{Na} H^-$

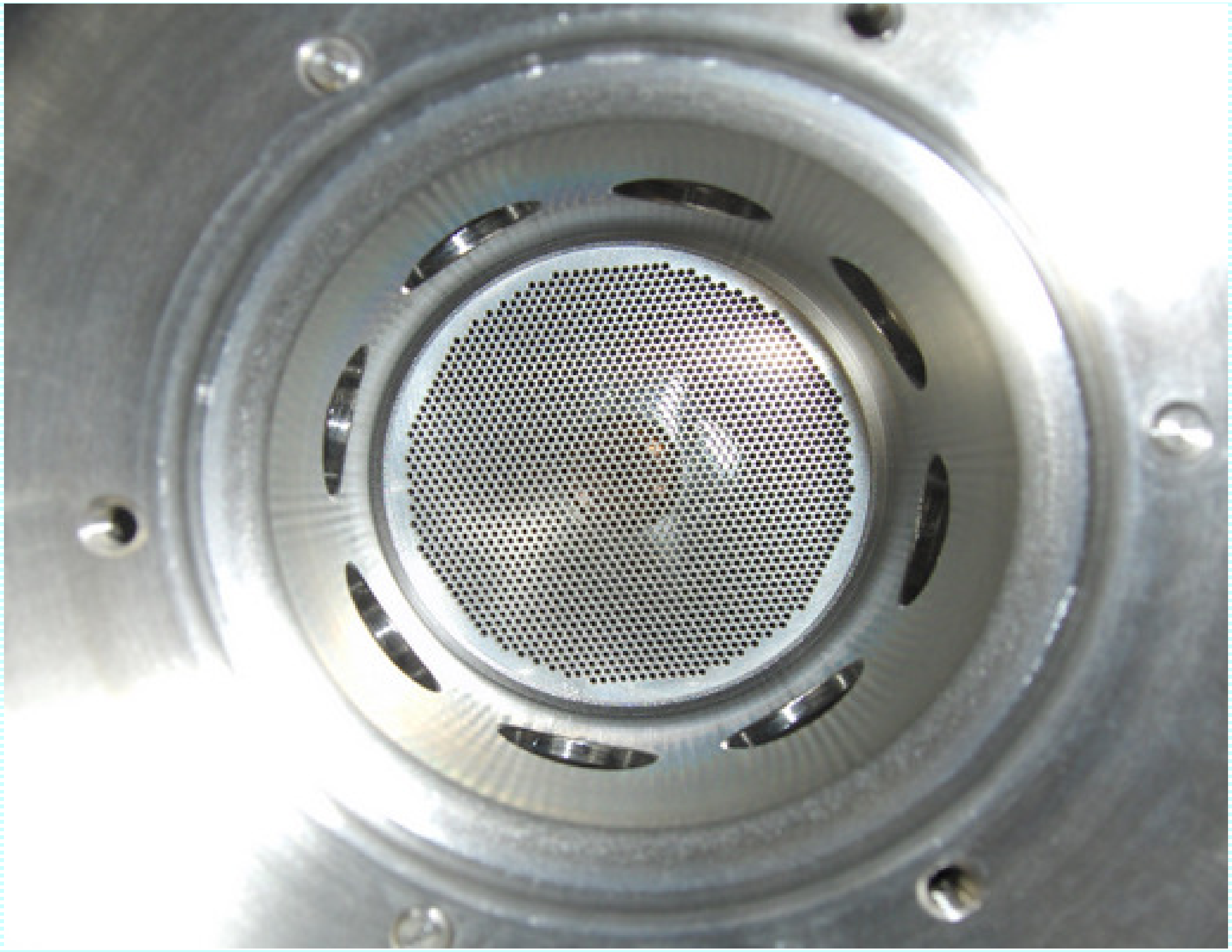
OPPIS with atomic H injector layout. RHIC 2012. The third generation.

"Fast Atomic Beam Source", BINP 2011



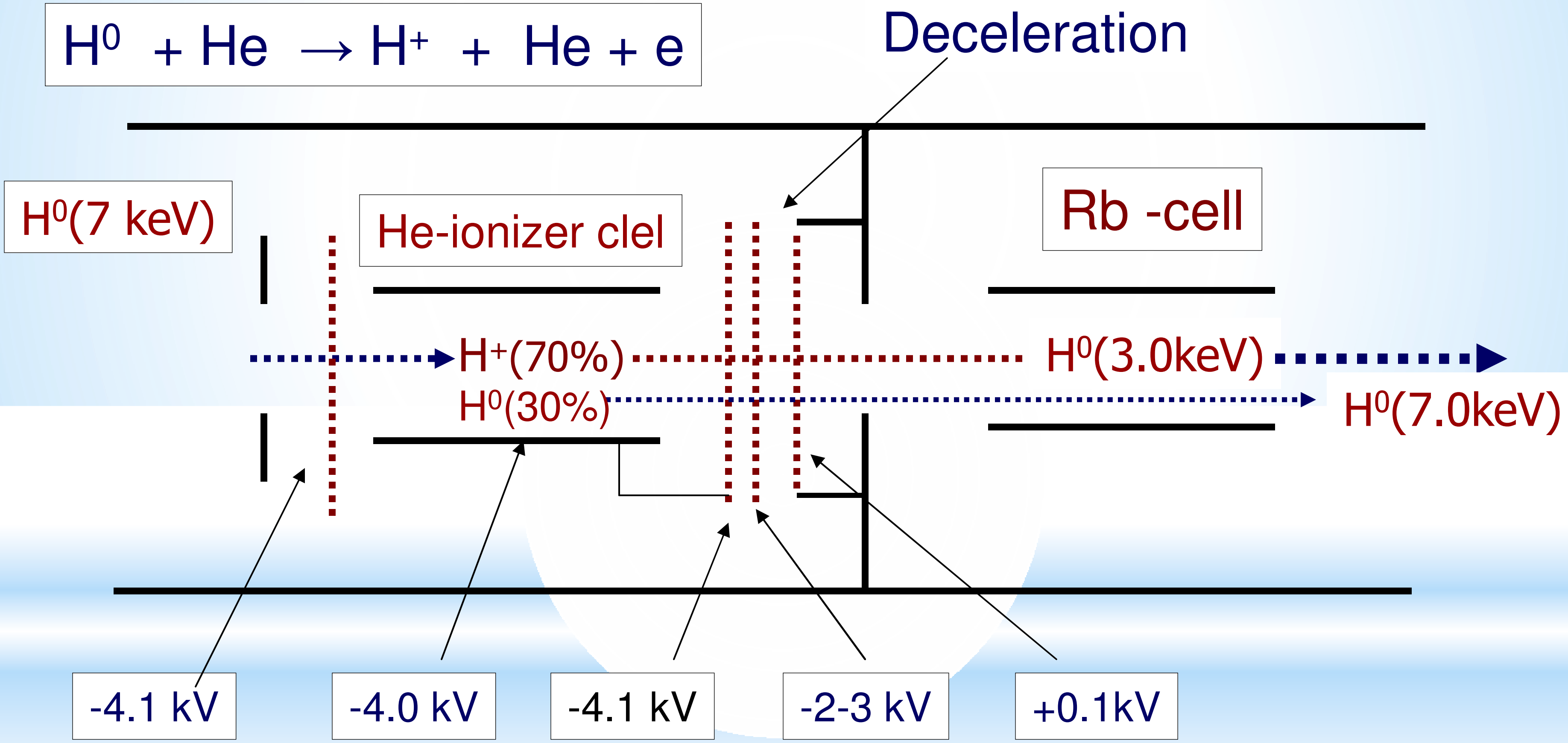
FABS produces 200-300 mA equivalent H0 beam intensity
Within the Na-jet ionizer acceptance.

FABS 4-grid spherical Ion Optical System (IOS)



* Residual un-polarized H^0 beam component suppression by the energy separation

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

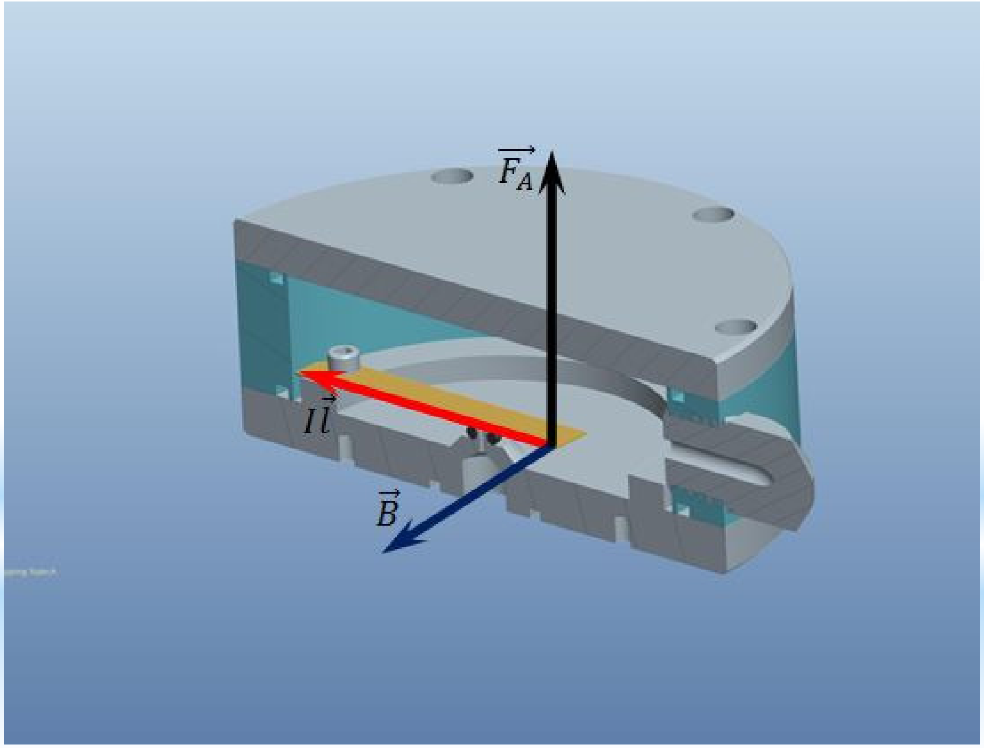


"Electro-dynamic" valve operation principle.

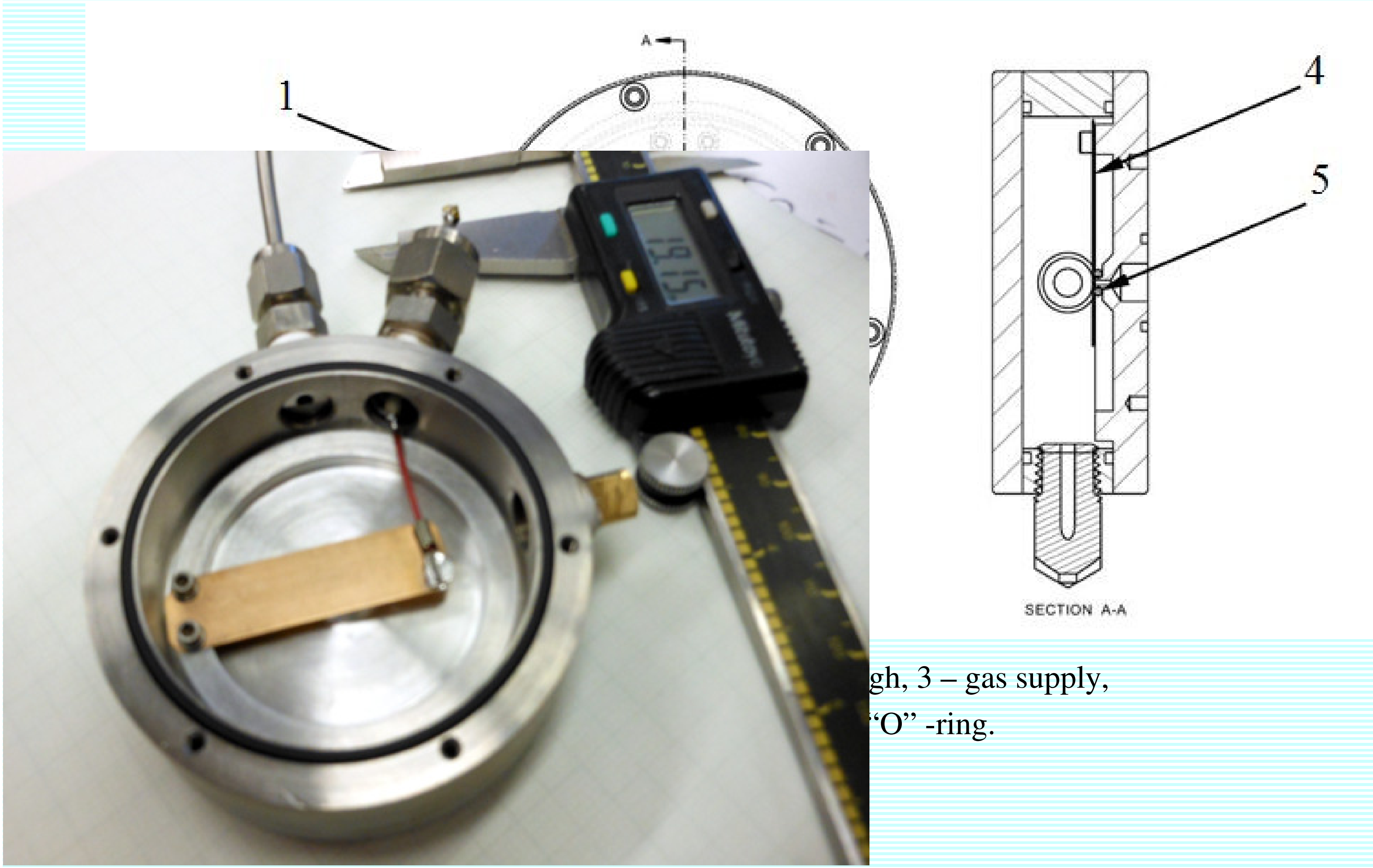
Force to the conducting plate in the (high ~ 3 T) magnetic field.

$$d\overrightarrow{F_A} = I[d\vec{l}\ \vec{B}]$$

For I=100 A, L=5 cm, F=15 N).



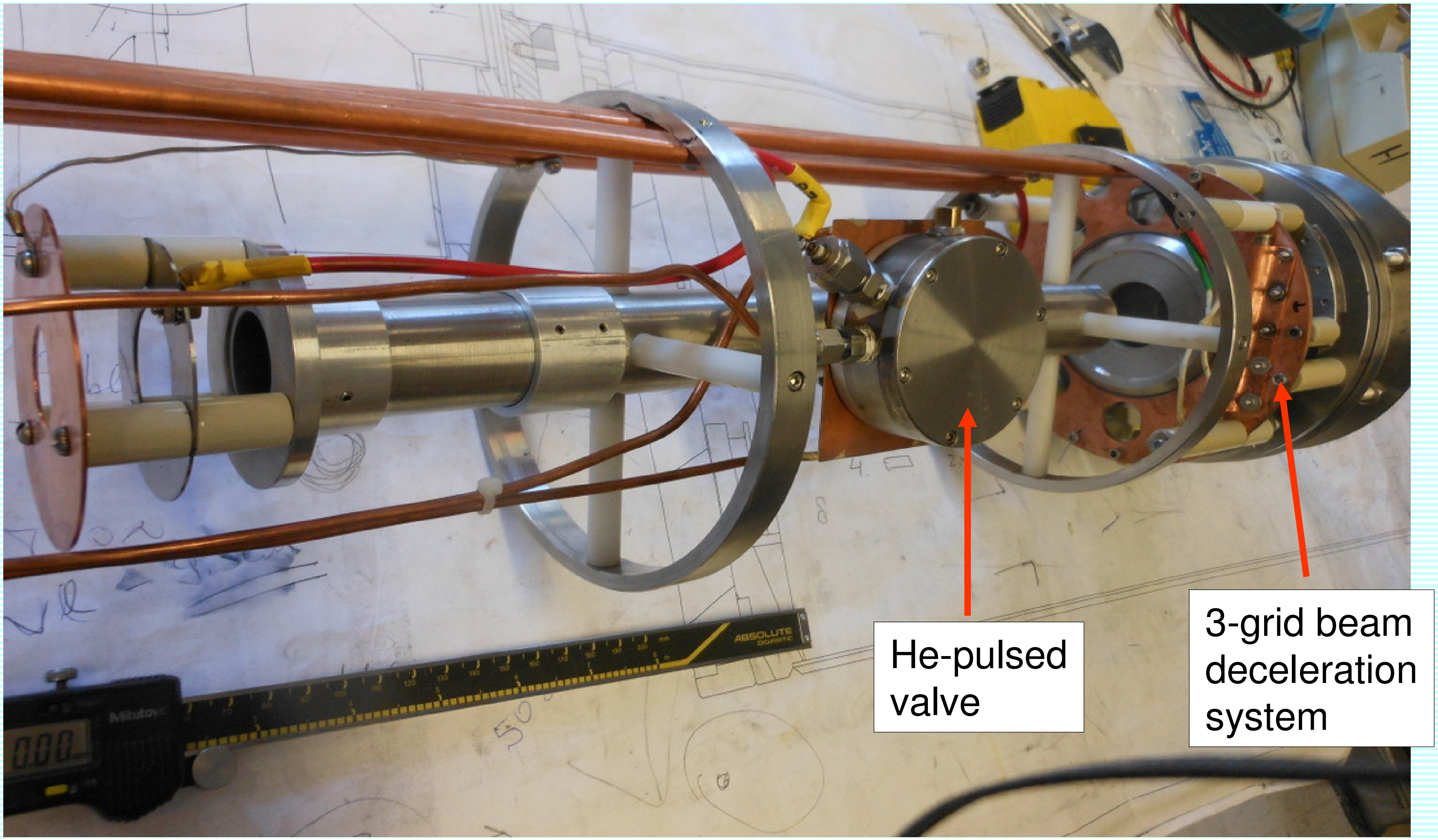
“Electro-dynamic” He-gas valve.



gh, 3 – gas supply,

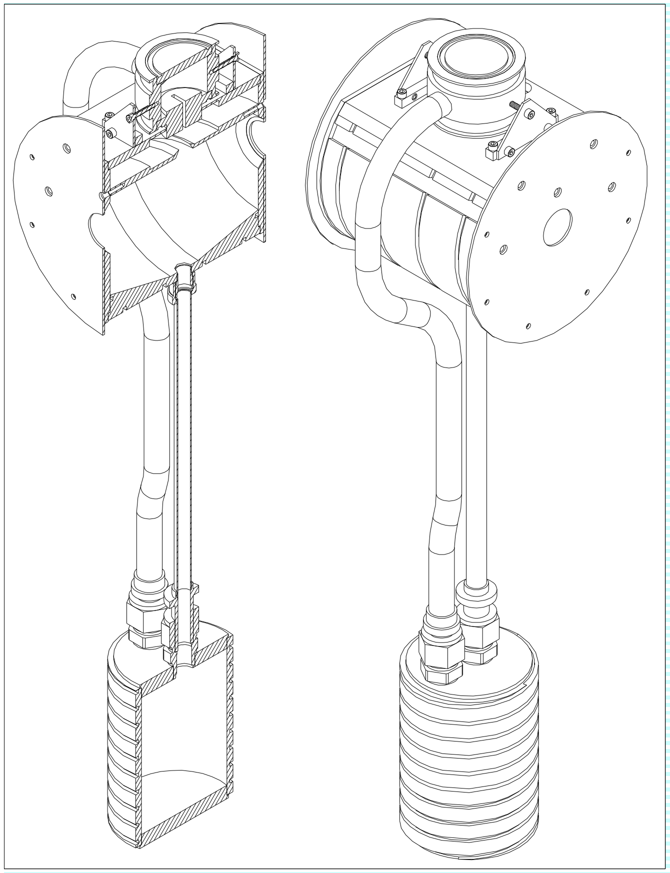
“O” -ring.

He-ionizer cell and three-grid energy separation system.

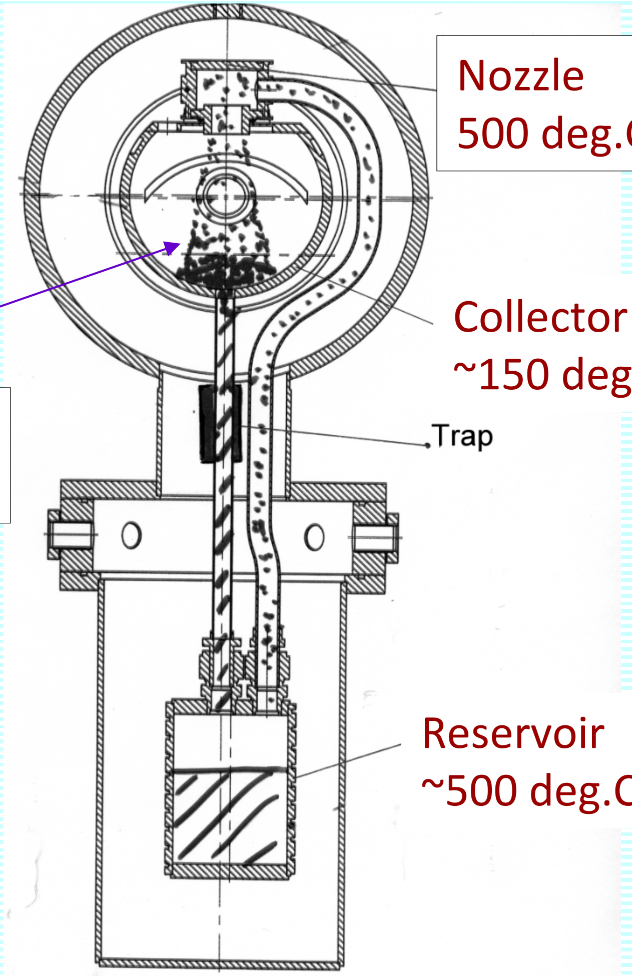


Sodium-jet ionizer cell

Transversal vapor flow in the N-jet cell.
Reduces sodium vapor losses for 3-4 orders of magnitude, which allow the cell aperture increase up to 3.0 cm .

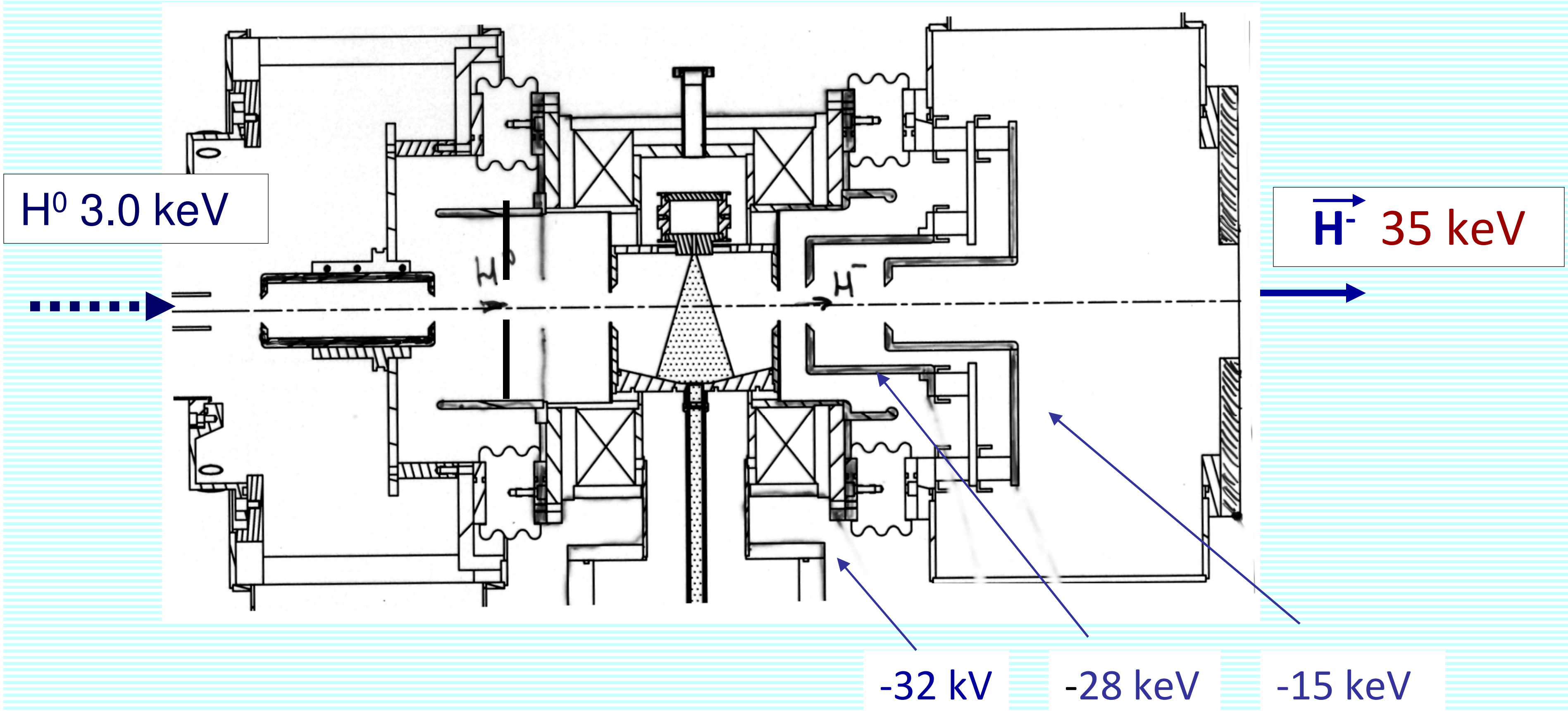


NL ~$2 \cdot 10^{15}$ atoms/cm^2
L ~ 2-3 cm



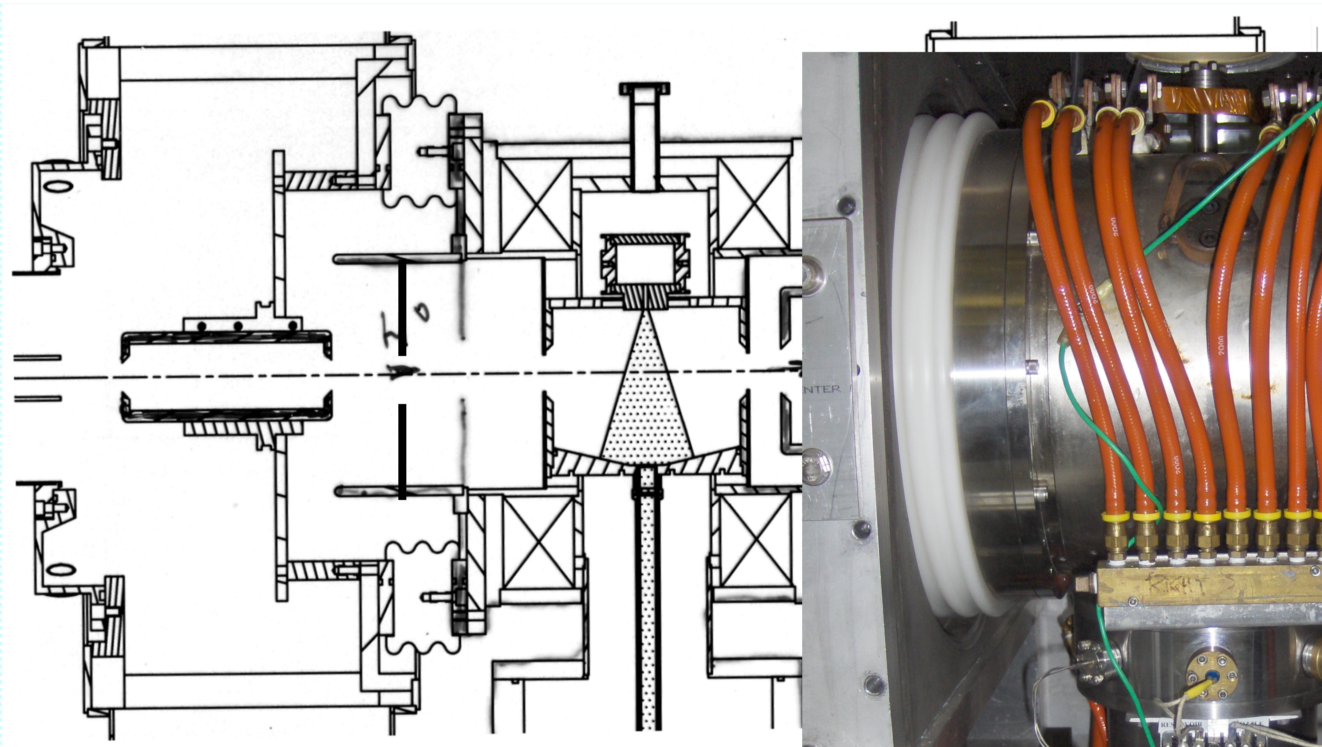
Reservoir– operational temperature. Tres. ~500 ^{o}C.
Nozzle – Tn ~500 ^{o}C.
Collector- Na-vapor condensation: Tcoll.~120^{o}C
Trap- return line. T ~ 120 – 180 ^{o}C.

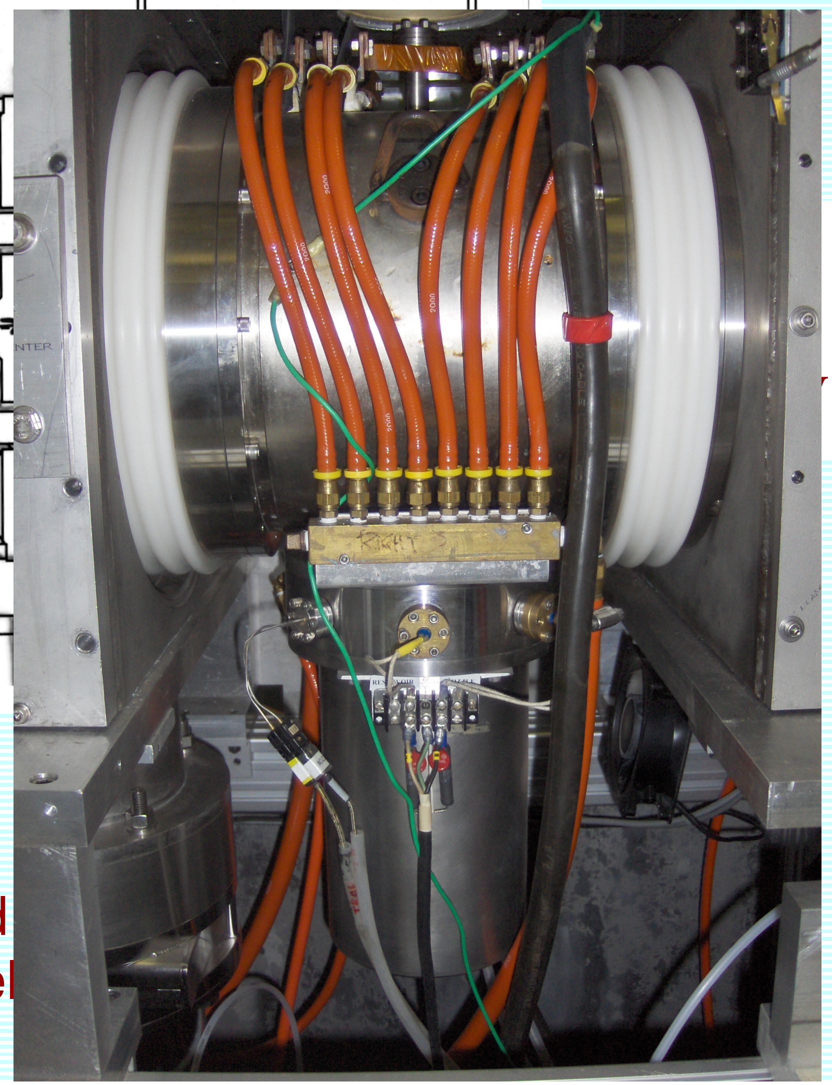
H^- beam acceleration to 35 keV at the exit of Na-jet ionizer cell



Na-jet cell is isolated and biased to – 32 keV. The H^- beam is accelerated in a two-stage acceleration system.

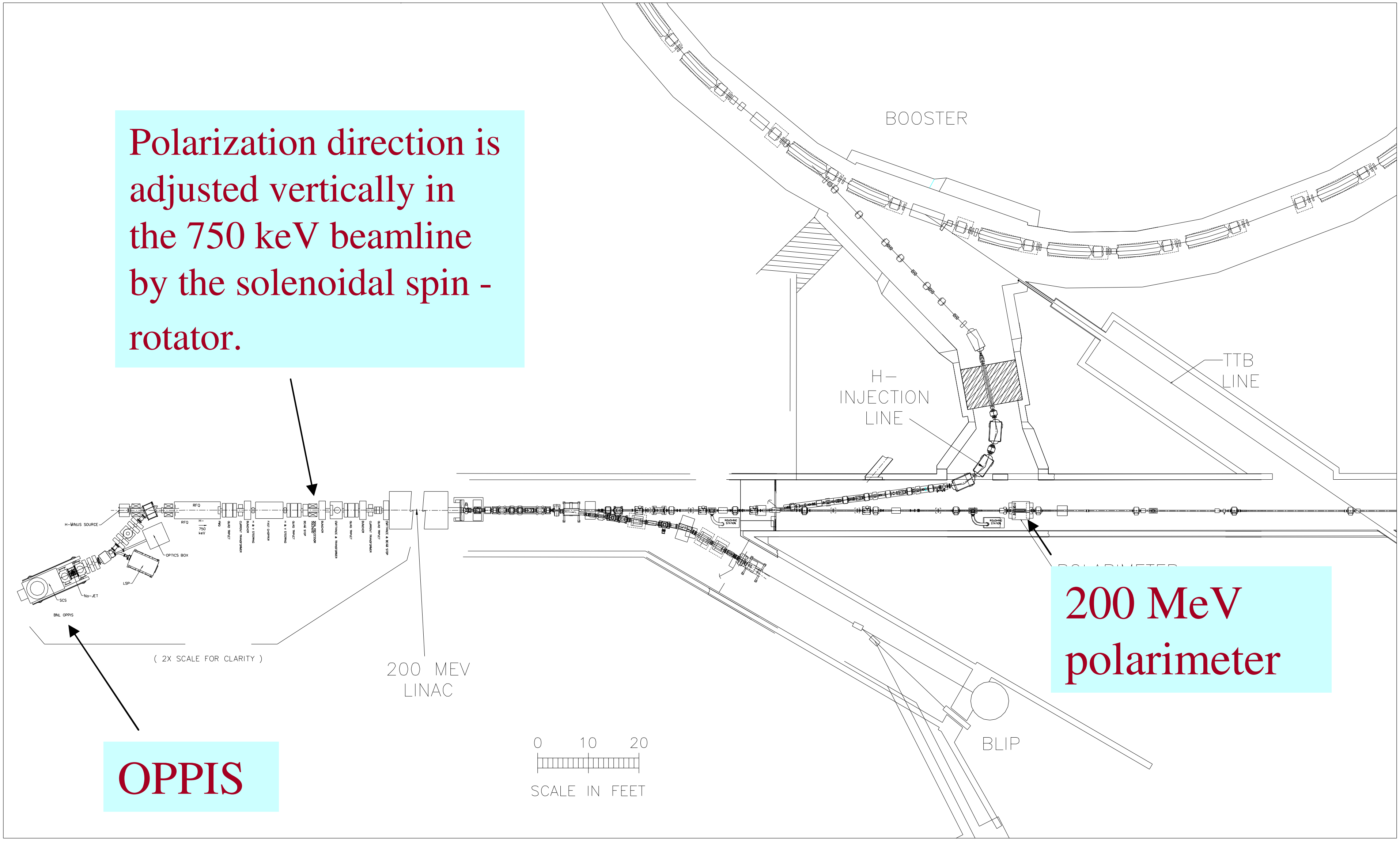
H⁻ beam acceleration to 35 keV at the exit of Na-jet ionizer cell





Na-jet cell is isolated and biased
accelerated in a two-stage accel

Polarized injector, 200 MeV linac and injection lines.



Polarization direction is adjusted vertically in the 750 keV beamline by the solenoidal spin - rotator.

OPPIS

200 MeV polarimeter

Depolarization factors

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

Depol. factor		Process	Estimate
1	E_{H2}	Dilution due H_2^+ in the new source (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 - 0.99
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
8	E_{ion}	Incomplete hyperfine interaction breaking in the ionizer magnetic field	0.98 - 0.99

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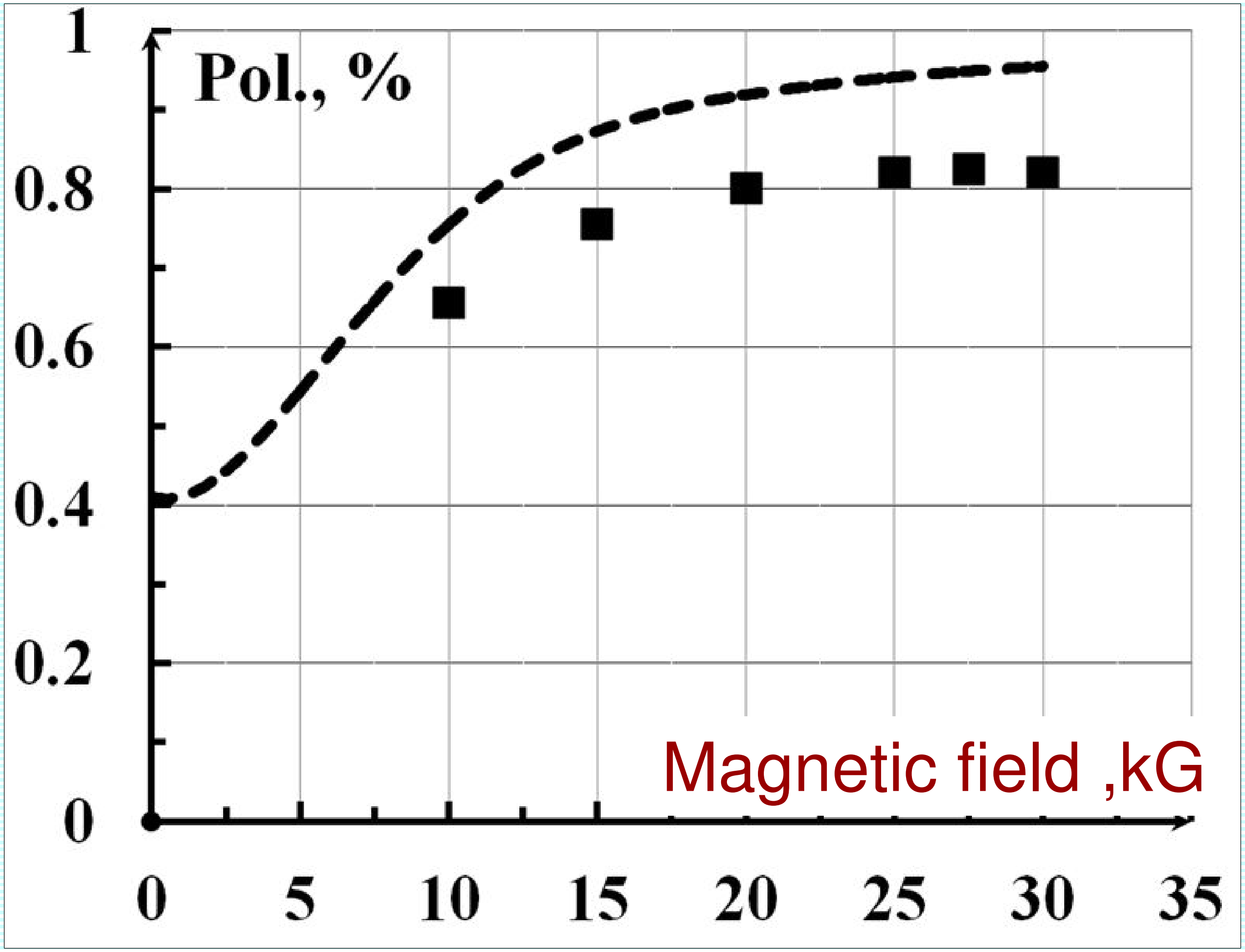
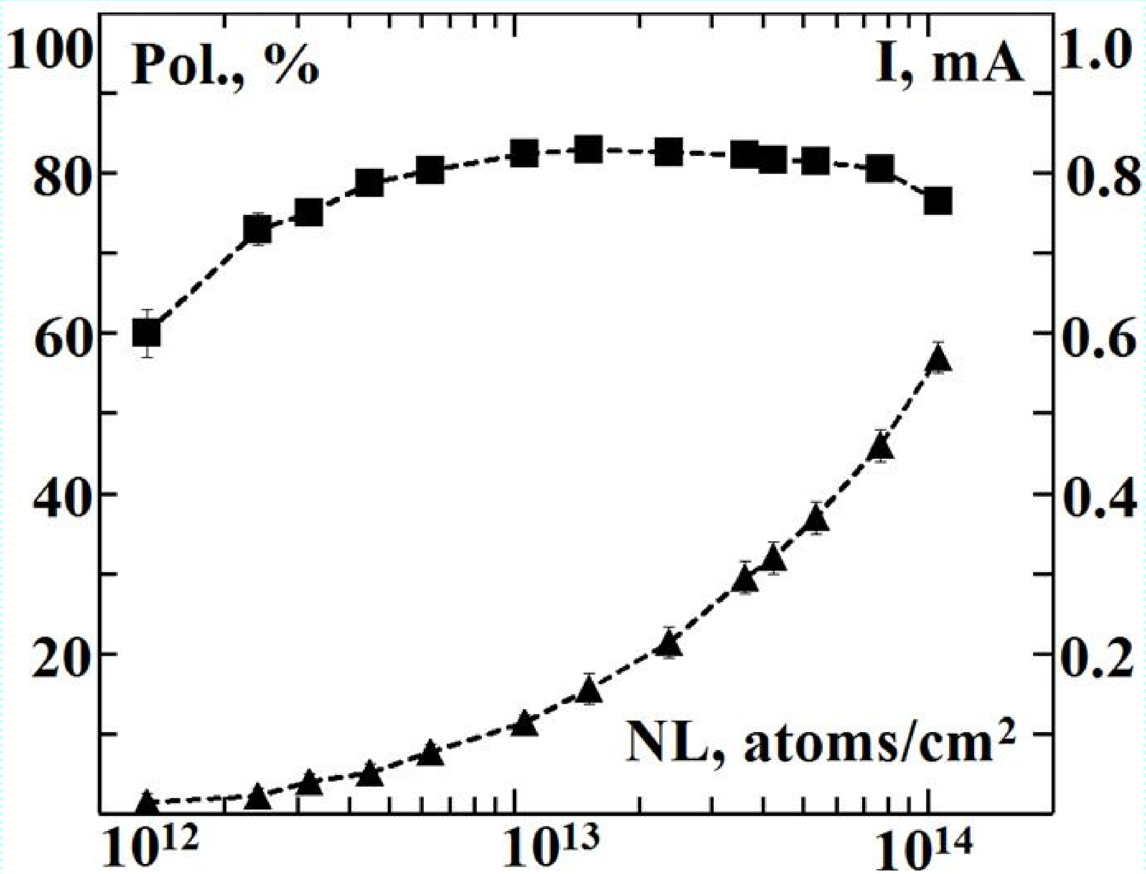
Total: 0.85 - 0.90

Polarization (at 200 MeV) vs. SCS magnetic field in He and Rb-cells



H^- beam current and polarization at 200 MeV vs. Rb vapor thickness

Polarization in 200 MeV polarimeter



H^- ion beam current (mA)

Rb-vapor thickness –nL

Source intensity and polarization.

- Reliable long-term ·operation of the source was demonstrated.
- Very high suppression of un-polarized beam component was demonstrated.
- Small beam emittance (after collimation for energy separation) and high transmission to 200 MeV.

Rb-cell, Temp., deg. C	81	86	91	96
Linac Current, μA	295	370	430	570
Booster Input $\times 10^{11}$	4.9	6.2	7.3	9.0
Pol. %, at 200 MeV	84	83	80.5	78

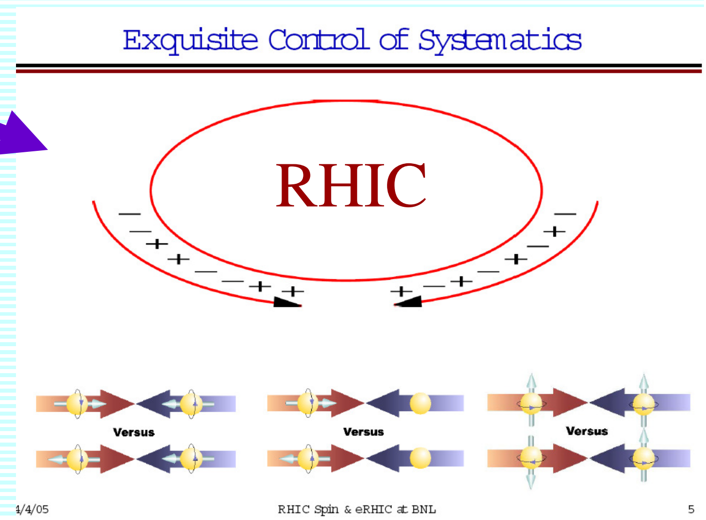
RHIC Polarized beam in Run 2012

OPPIS → 0.6mA x 300us→11·10^{11} polarized H^- /pulse.

LINAC → (6.0-6.5) ·10^{11} polarized H^- /pulse at 200 MeV

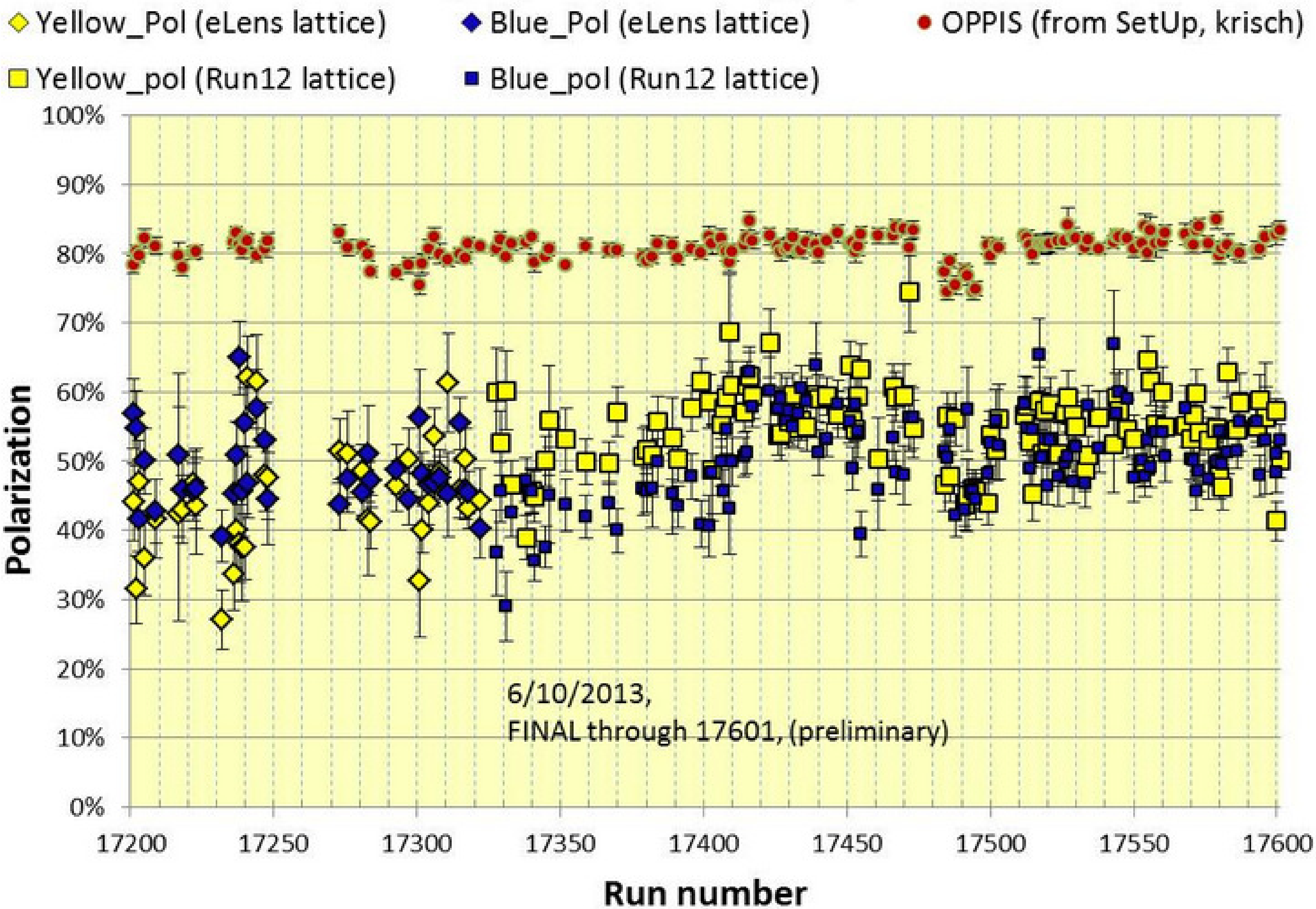
Booster → (2.2-2.4) ·10^{11} protons /pulse at 2.3 GeV

AGS → (2.0-2.2) ·10^{11} p/bunch



~1.8·10^{11} p/bunch, P~60-65% at 100 GeV
P ~ 56% at 250 GeV

Run-13, H-jet polarimeter, physics stores



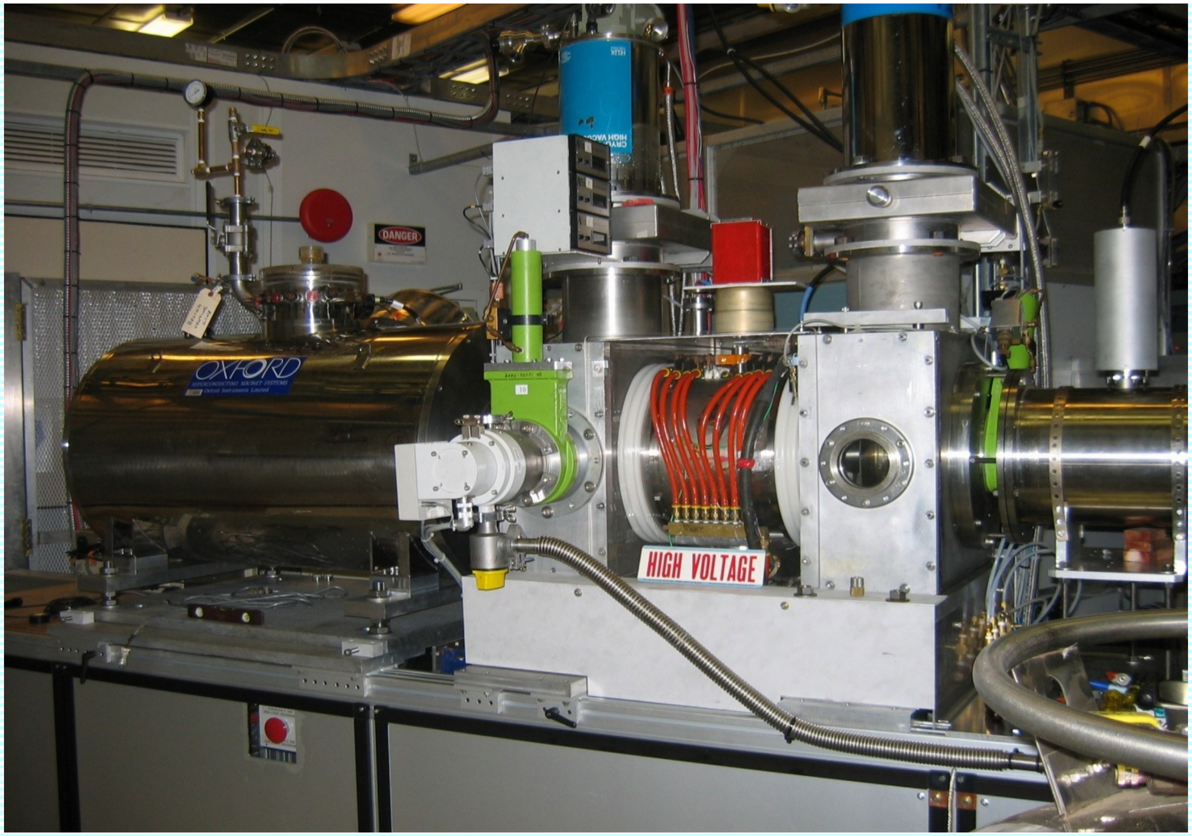
A result of this "upgrade" is practically a new source.

- A new superconducting solenoid.
- A new atomic hydrogen injector.
- A new vacuum system.
- A new H-ionizer cell, energy separation system and pulsed PS system.
- A new control and interlock system.
- Major upgrades of laser system.
- Major modifications of the Low Energy Beam Transport system.
- Major upgrades in 200 MeV polarimeter.
- A new test-bench for atomic injector studies.
- Many other upgrades…

Summary

- The new source is working.
- Reliable long-term operation at steady current and polarization. The maintenance time is significantly reduced.
- Polarization is 80-84%, which is 3-5% higher then ECR-based source. It is expected that polarization can be further improved to over 85%.
- The source intensity is about 3-5 mA. Due to strong space-charge effects only fraction of this current is transported and accelerated in RFQ and Linac. These losses can be reduced.

Old operational Polarized H^- Source at RHIC.



RHIC OPPIS produces reliably 0.5-1.0mA polarized H^- ion current.

Polarization at 200 MeV: P = 80%.

Beam intensity (ion/pulse) routine operation:

Source	- 10^{12} H^-/pulse
Linac	- $5\cdot10^{11}$
AGS	- $1.5\text{-}2.0 \cdot 10^{11}$
RHIC	- $1.5\cdot10^{11}$ (protons/bunch).

A 29.2 GHz ECR-type source is used for primary proton beam generation.
The source was originally developed for dc operation.
A ten-fold intensity increase was demonstrated in a pulsed operation by using a very high-brightness Fast Atomic Beam Source instead of the ECR proton source .