# POLARIZATION OPTIMIZATION STUDIES IN THE RHIC OPTICALLY-PUMPED POLARIZED ION SOURCE.

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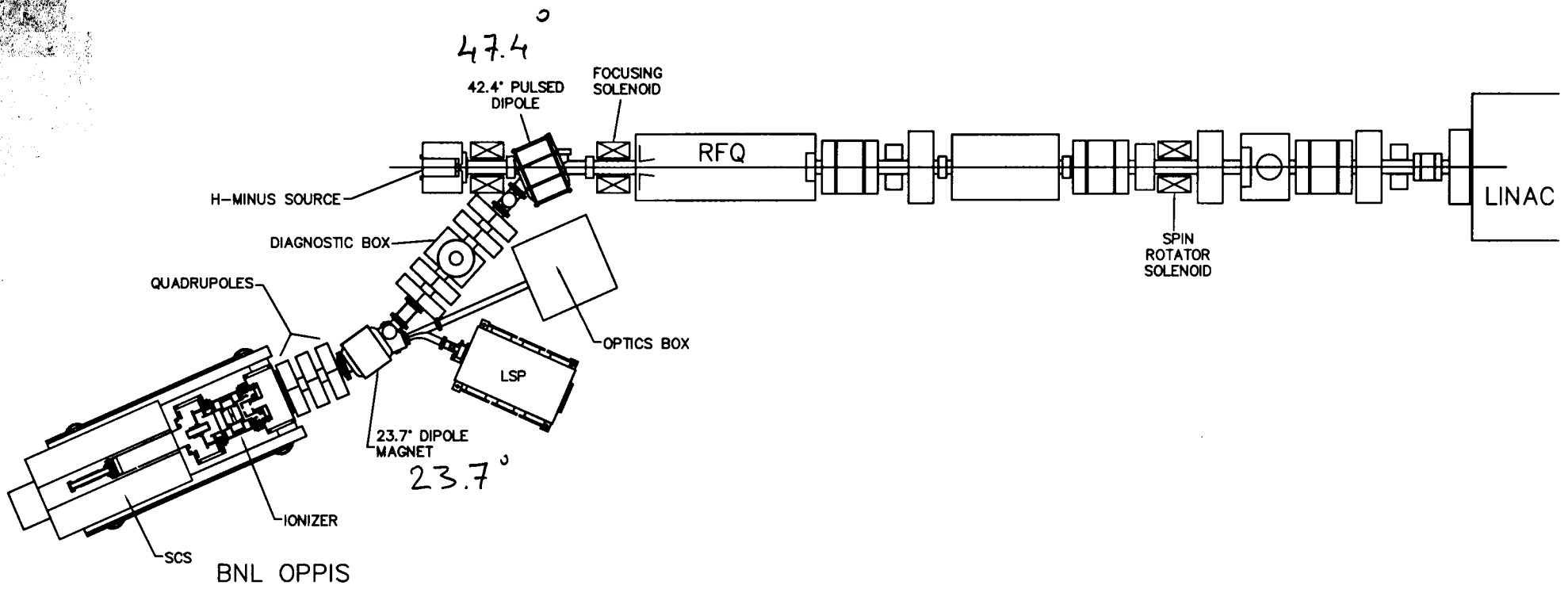
## ABSTRACT

The performance of the RHIC Optically-Pumped Polarized $H^-$ Ion Source (OPPIS) in the 2000-2002 runs for AGS and RHIC is reviewed. The OPPIS met the RHIC requirements for the beam intensity with the reliable delivery of about 500 μA polarized H- ion current in 400 μs pulse duration (current can be increased to over 1.0 mA, if necessary). The beam intensity after the linac at 200 MeV was $(5\text{-}6)\cdot10^{11}$ H/pulse, which is sufficient to obtain the required $2\cdot10^{11}$ polarized protons per bunch in RHIC. A Lamb-shift type polarimeter was used for polarization measurements and optimization at a source energy of 2.6-3.0 keV (extraction voltage turned off). A proton polarization of 80% was measured in the Lamb-shift polarimeter, after OPPIS-parameter optimization. At that time the presence of a half-energy beam component coming from dissociation of $H_2^+$ molecular-ions was observed. The molecular ions are produced in the ECR (Electron Cyclotron Resonance) primary proton source. This component can be as high as 20%, and the polarization is significantly lower than polarization of the main beam. At the 35 keV extraction energy, this component has 33.5 keV, and is matched into the RFQ and accelerated along with the full energy ions, reducing the beam polarization. The molecular-ions can be reduced to about 5% by the ECR source-operation optimization. They can be suppressed further by optimization of the extraction optics and by use of a decelerating einzel lens in 35 keV LEBT line. As a result, the proton polarization of the accelerated beam was increased to over 80%, as measured in a 200 MeV proton-deuterium polarimeter. The polarimeter upgrade will be also discussed, which includes the high-current polarization measurements and continuous polarization monitoring (by interleaving beam pulses injected to Booster with the pulses transported to the polarimeter).

**RHIC SPIN COLLABORATION MEETING**

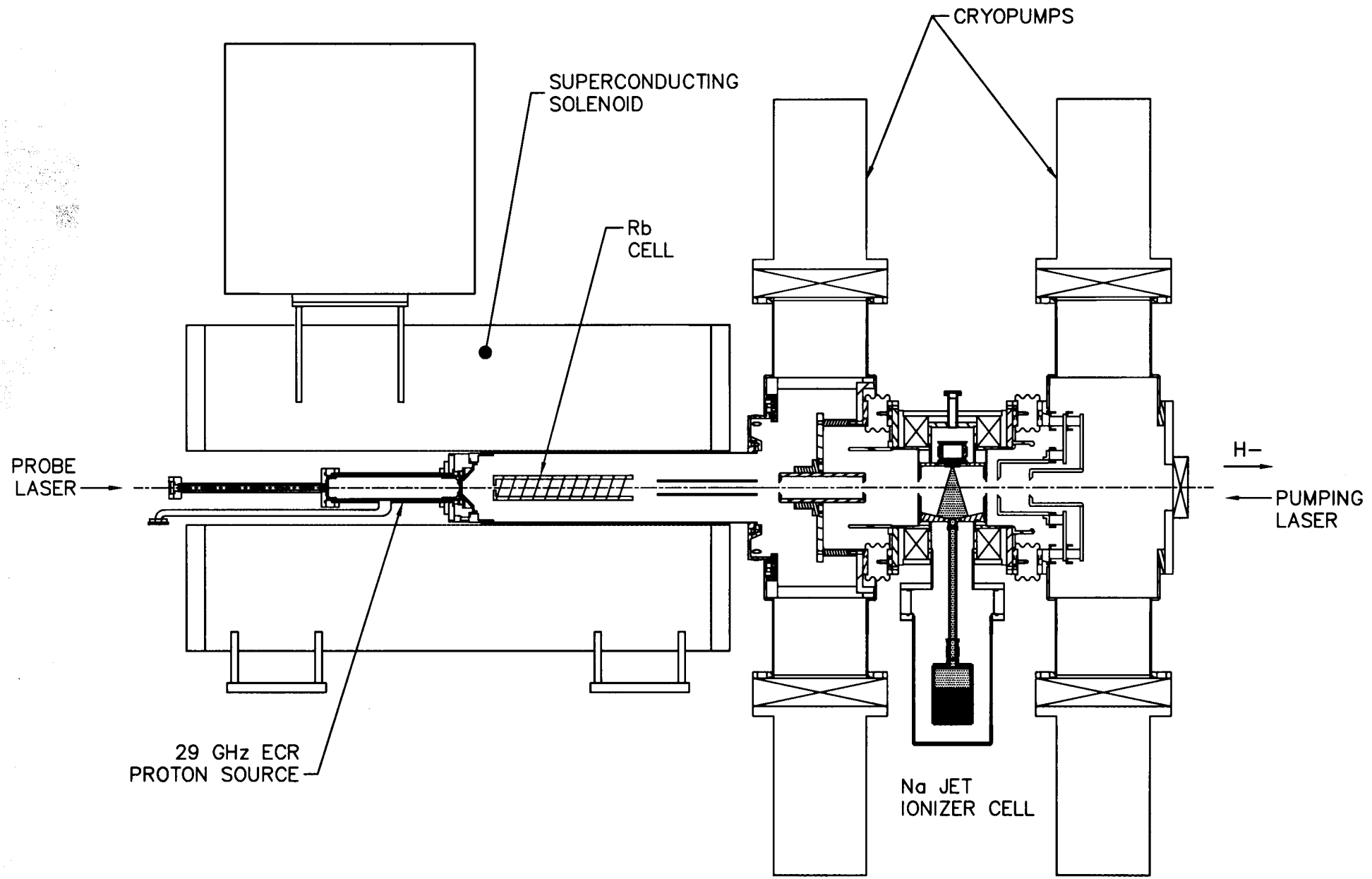
**September 16, 2002**

# POLARIZED SOURCE LAYOUT AT THE LINAC INJECTOR

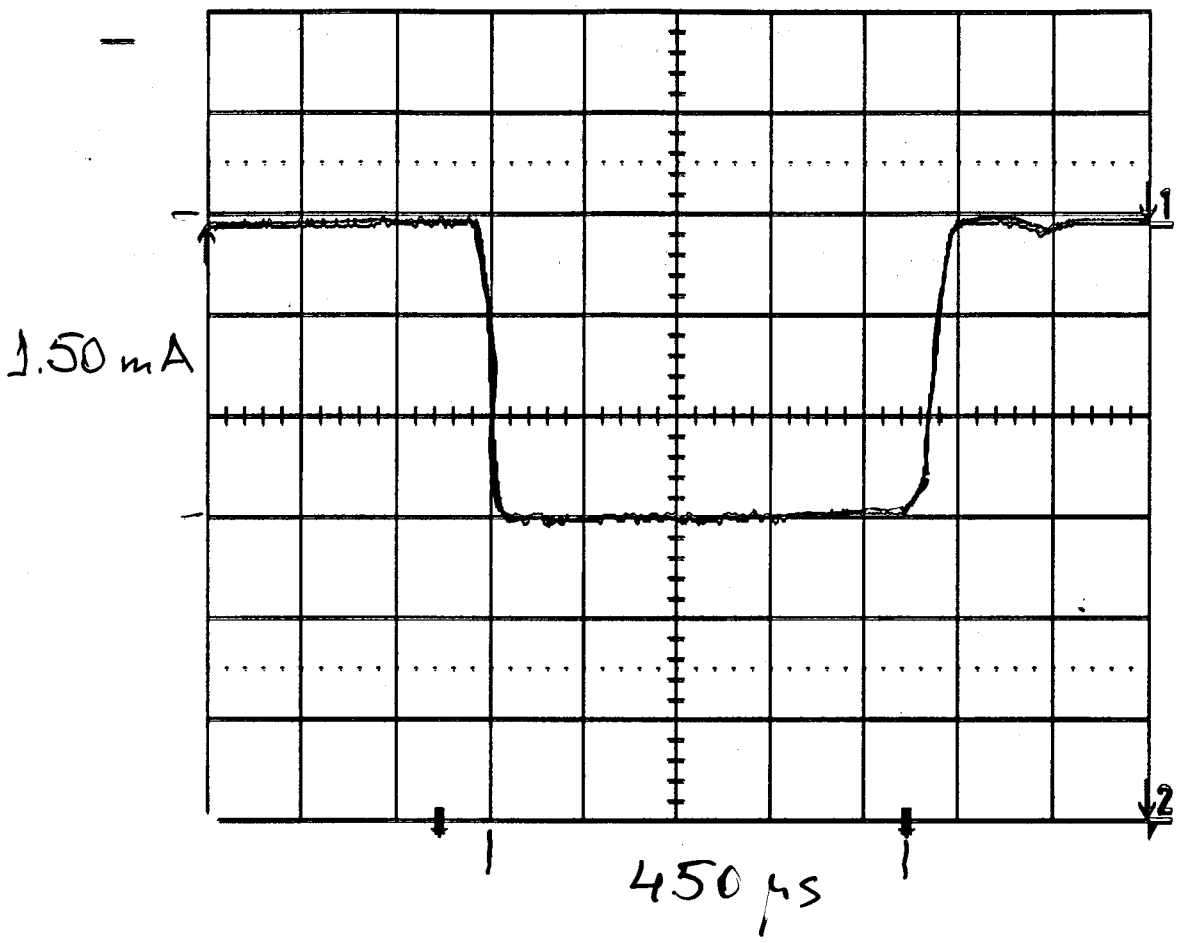



Allows interleaving of 1mA polarized H– beam and 100 mA unpolarized beam on pulse–to–pulse basis.
Longitudinal polarization out of the source converted to vertical polarization at the linac entrance.

# RHIC OPTICALLY PUMPED POLARIZED H− SOURCE

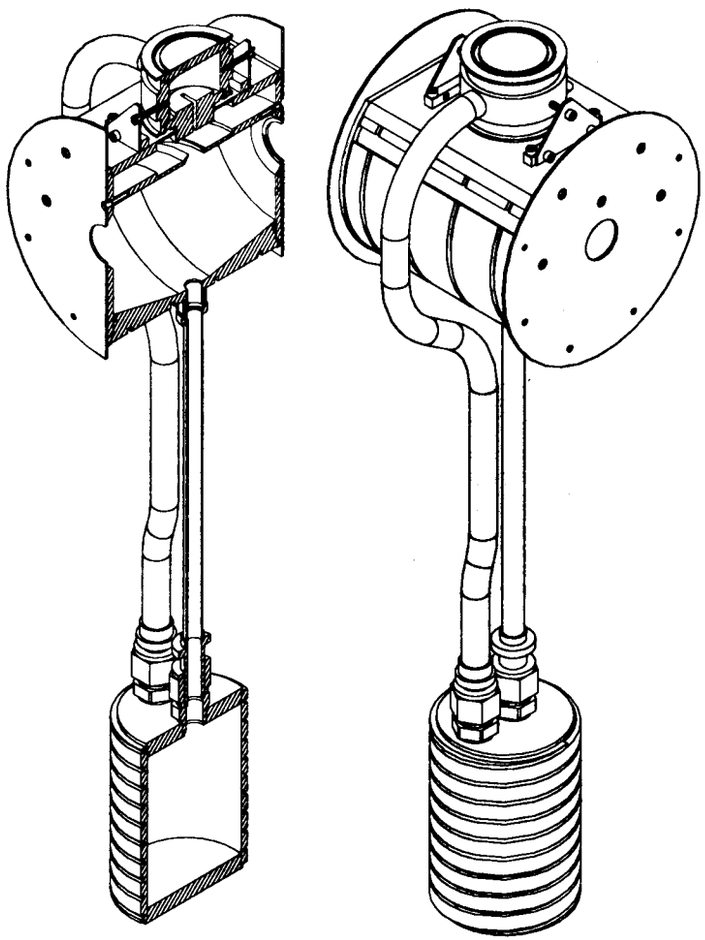


# H- current pulse in 35 keV LEBT FC

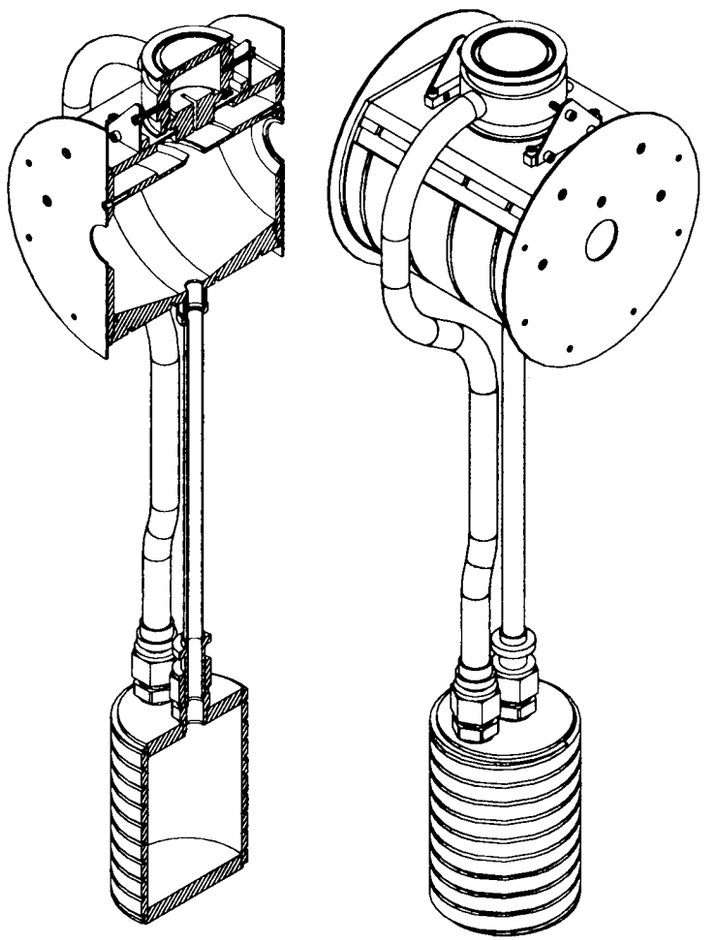



**Vertical current scale is 500 uA/div.**

**Horizontal scale is 100 us/div.**



- Na ionizer cell at high voltage - avoided the need to have the entire source sit on a high voltage platform
- Low Na loss, despite the large aperture
- Reservoir is loaded with 150 g of sodium metal
- Reservoir and jet nozzle are operated at a temperature of 530 C.
- Sodium vapor density is ~$10^{17}$ atoms/$cm^3$, resulting in a vapor jet with an effective thickness of ~5 x $10^{14}$ atoms/$cm^2$, sufficient for saturation of the $H^-$ yield.
- Although the entire 150 g circulates in ~3 hours, the cell provides continuous, stable operation for 1-2 months.
- The Na loss has proven to be much less than with the previous oven-type cell.



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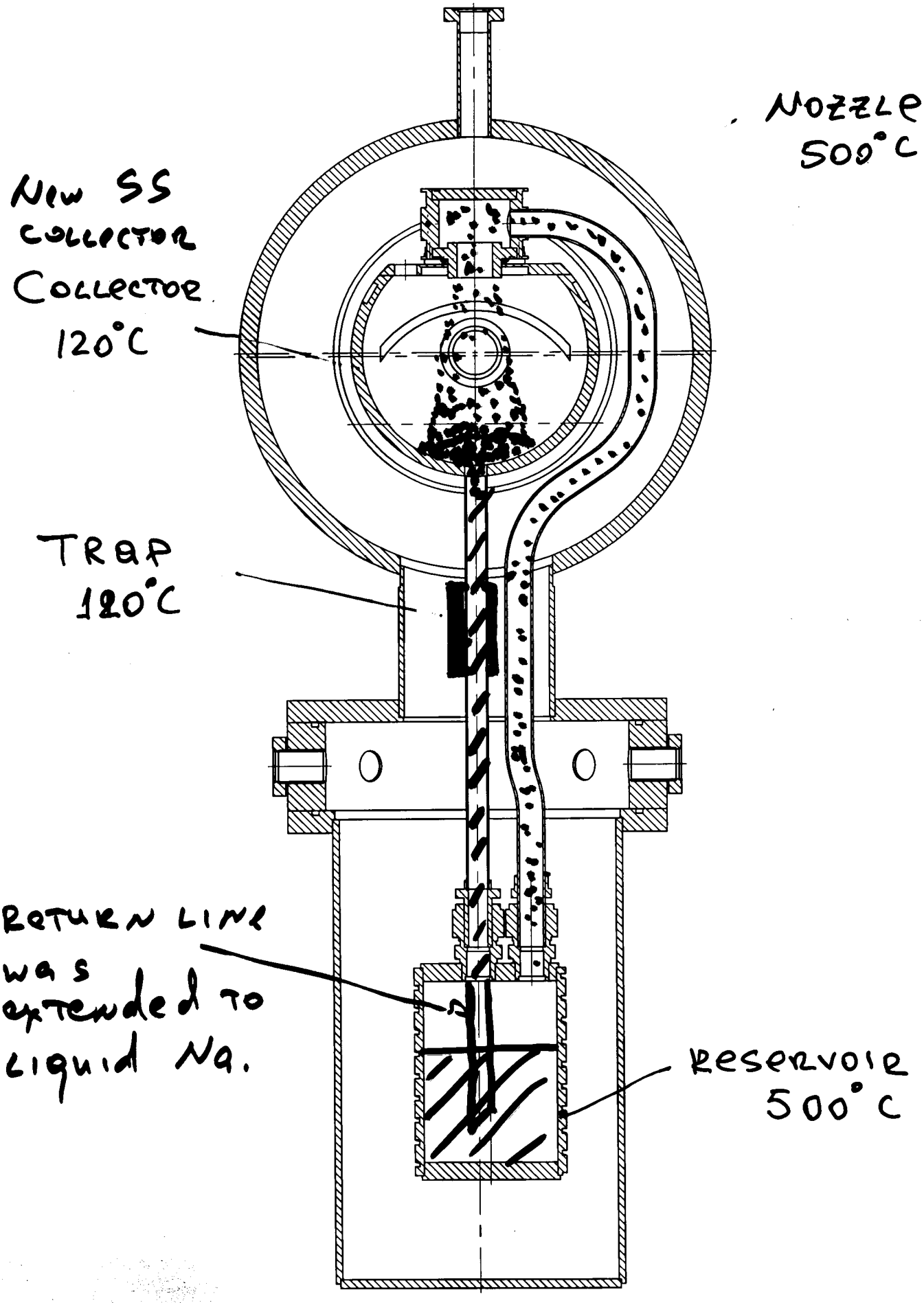
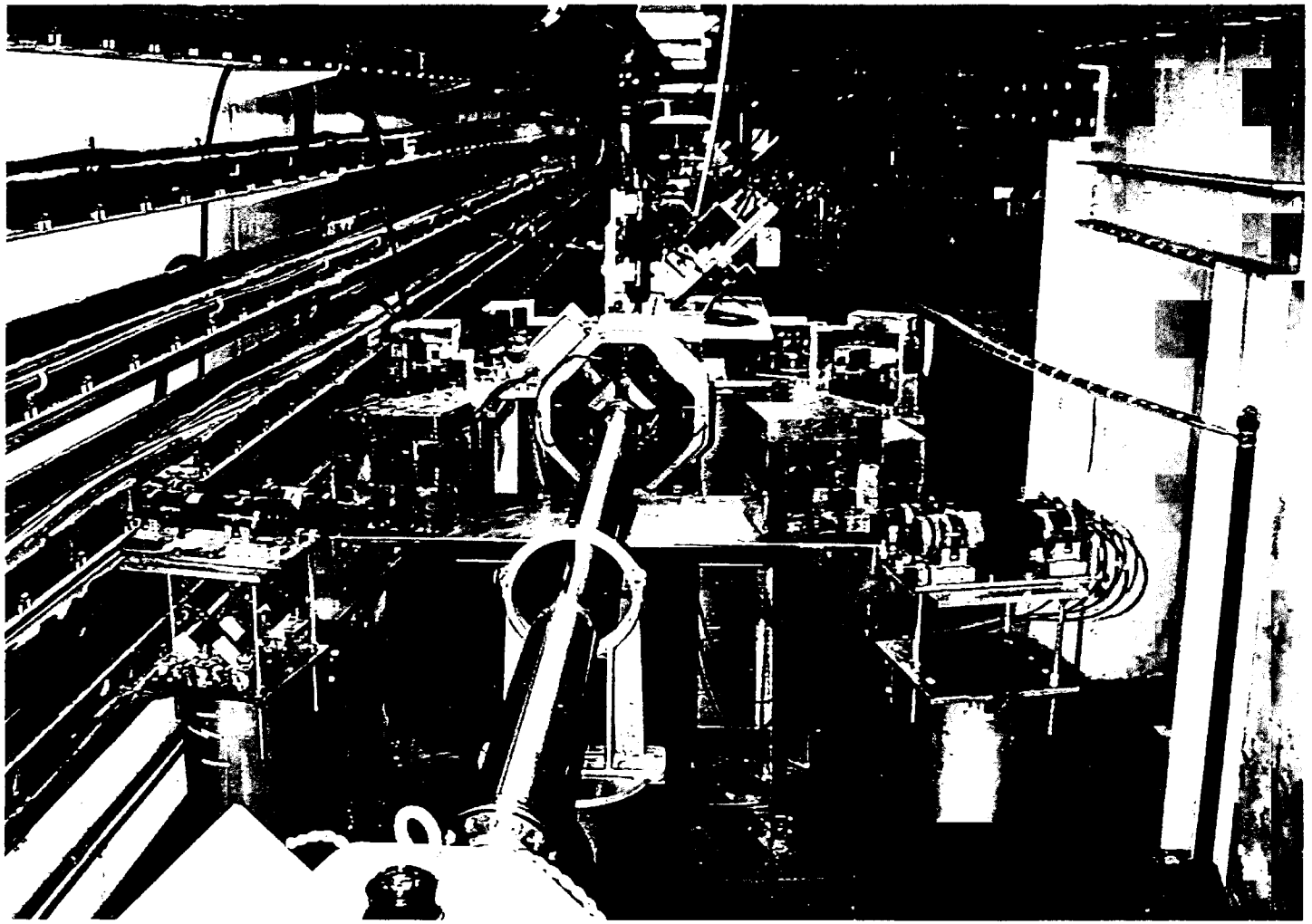
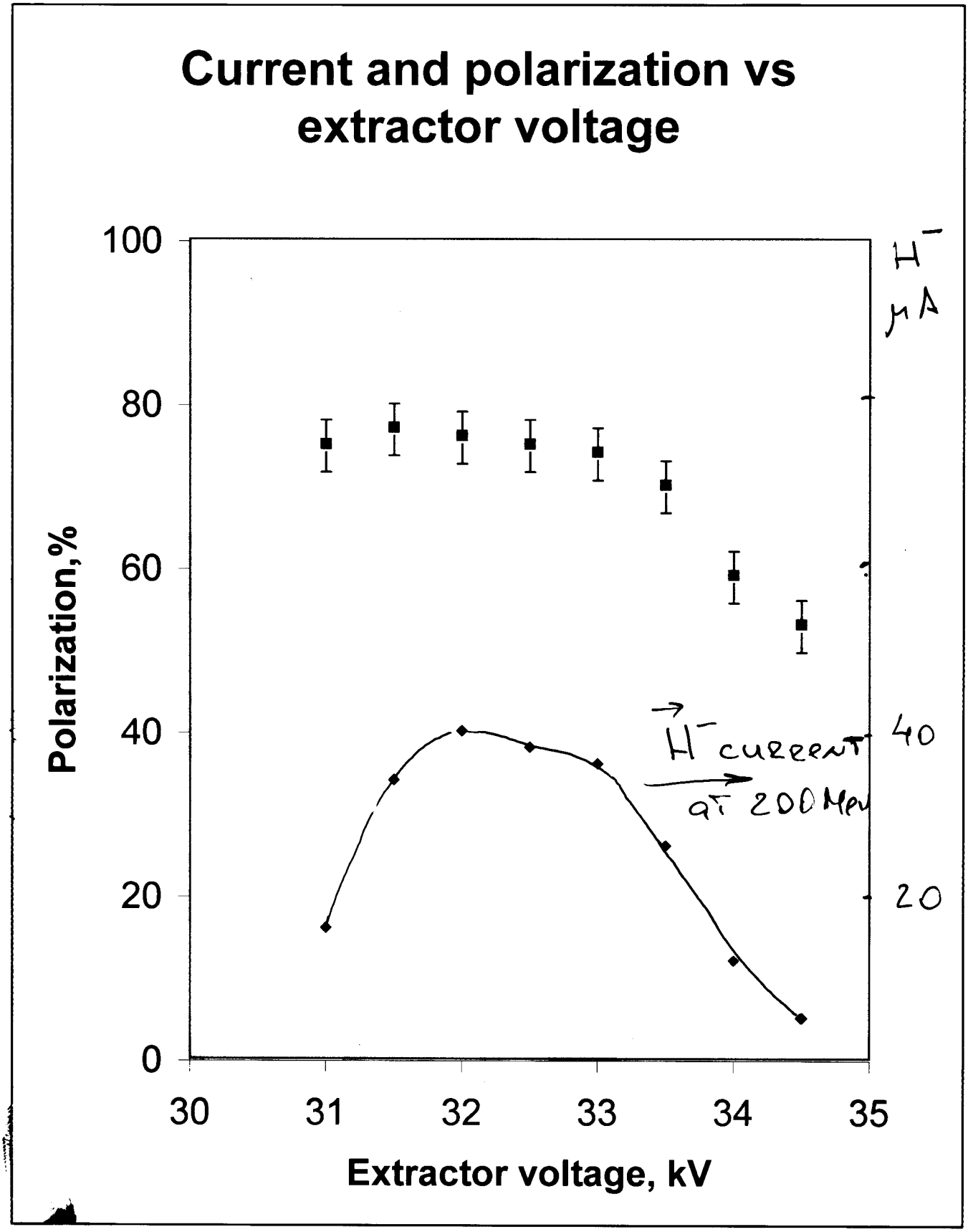
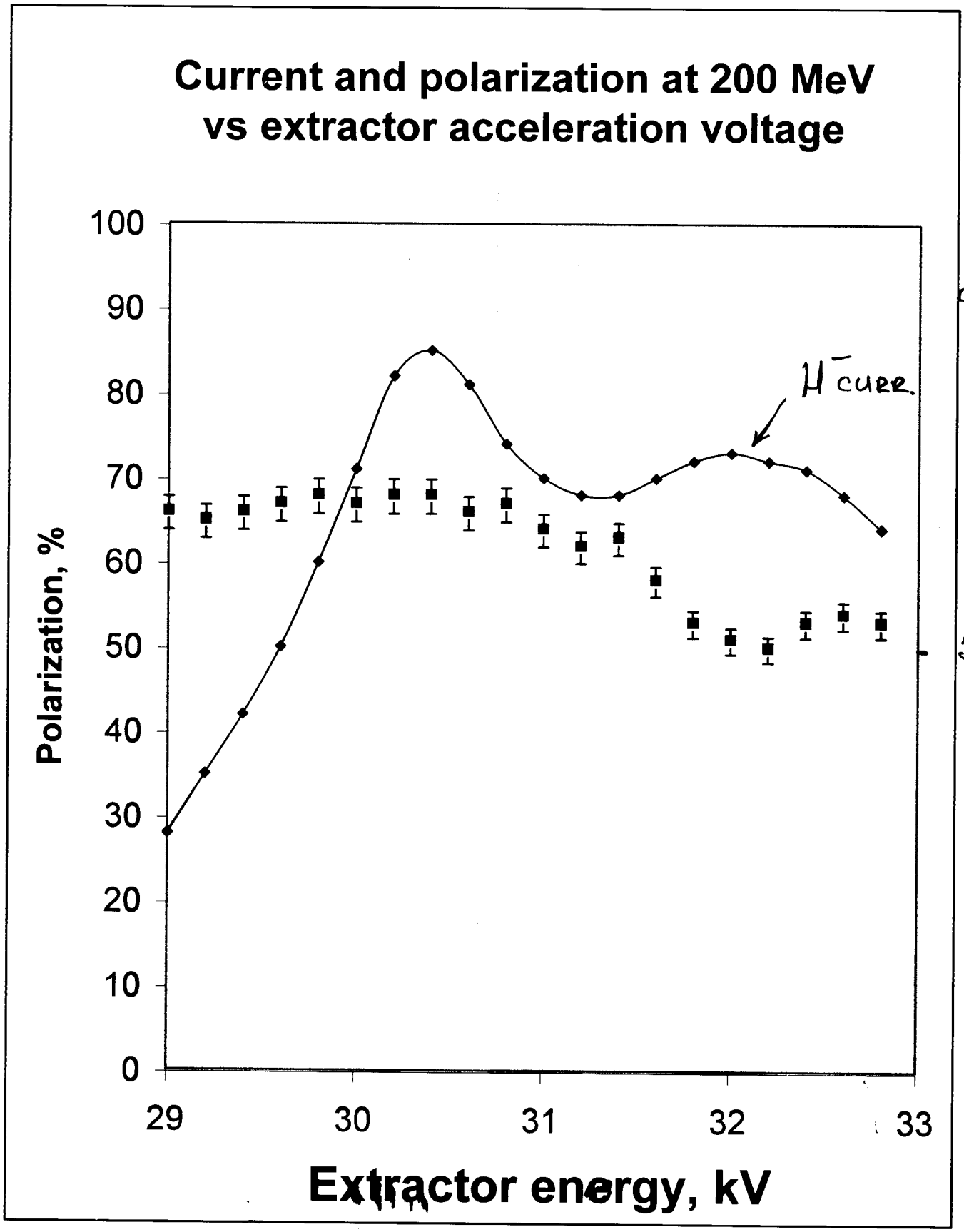

NOZZLE
500°C
NEW SS
COLLECTOR
COLLECTOR
120°C
TRAP
120°C
RETURN LINE
WAS
EXTENDED TO
LIQUID Na.
RESERVOIR
500°C

SECTION B–B

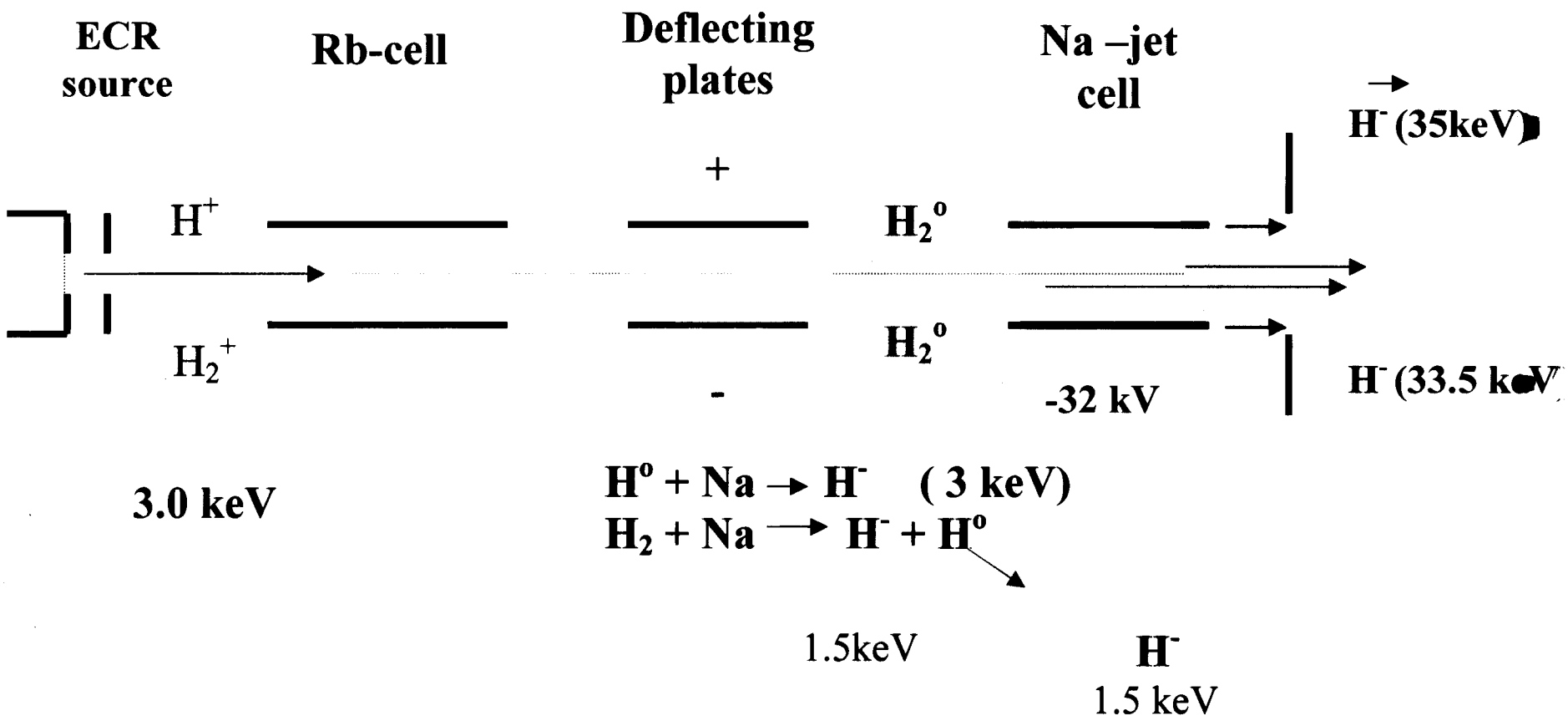
# 200 MeV $pD$, $pC$ POLARIMETER

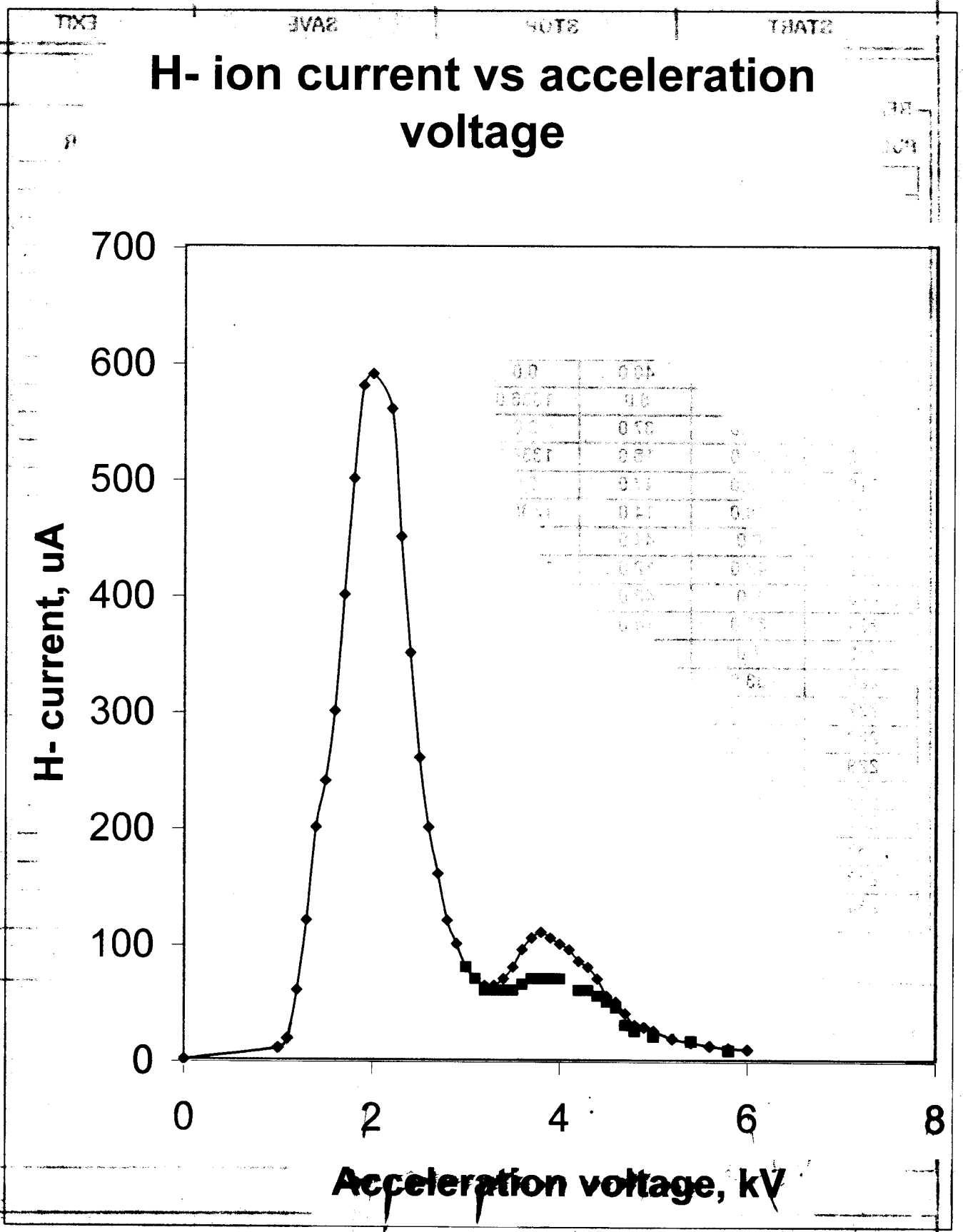


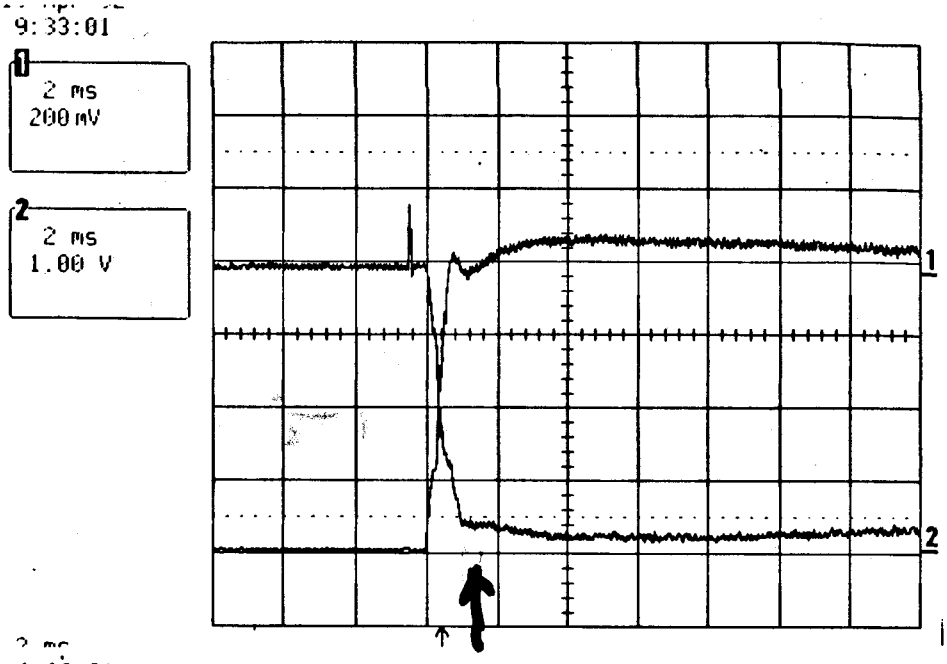


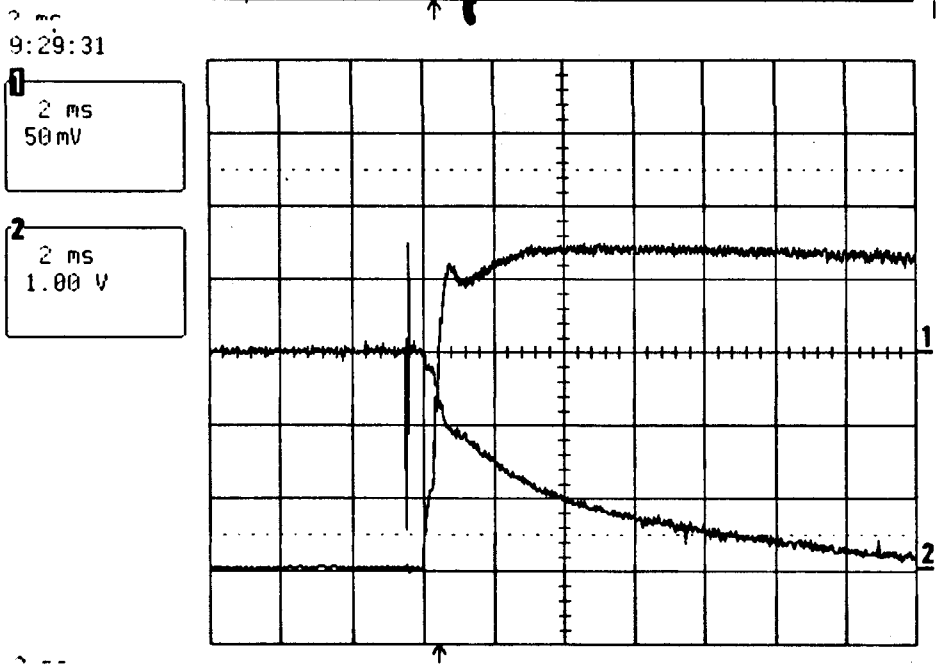


# POLARIZATION DILUTION DUE TO MOLECULAR $H_2^+$ IONS FROM THE ECR SOURCE.

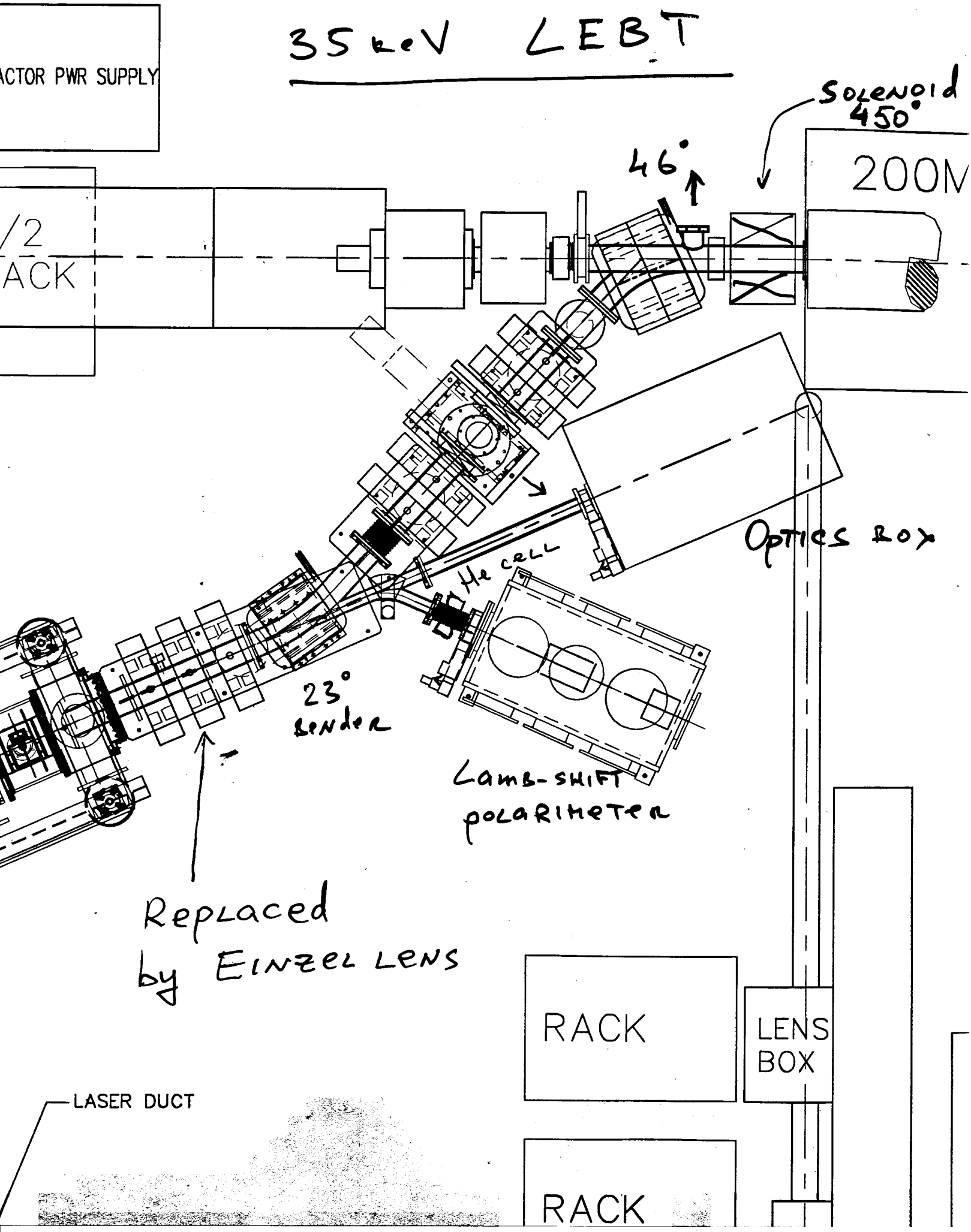


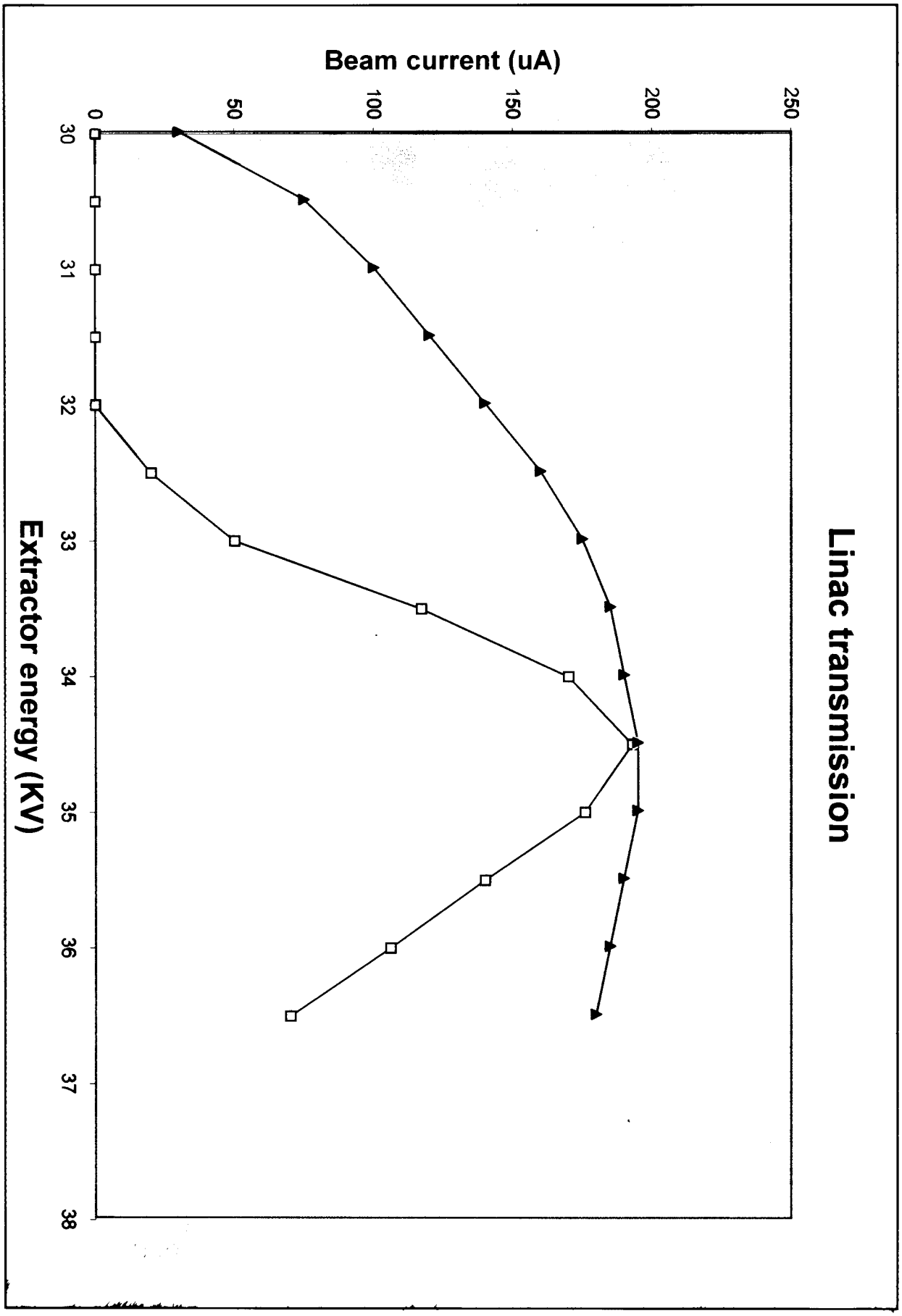


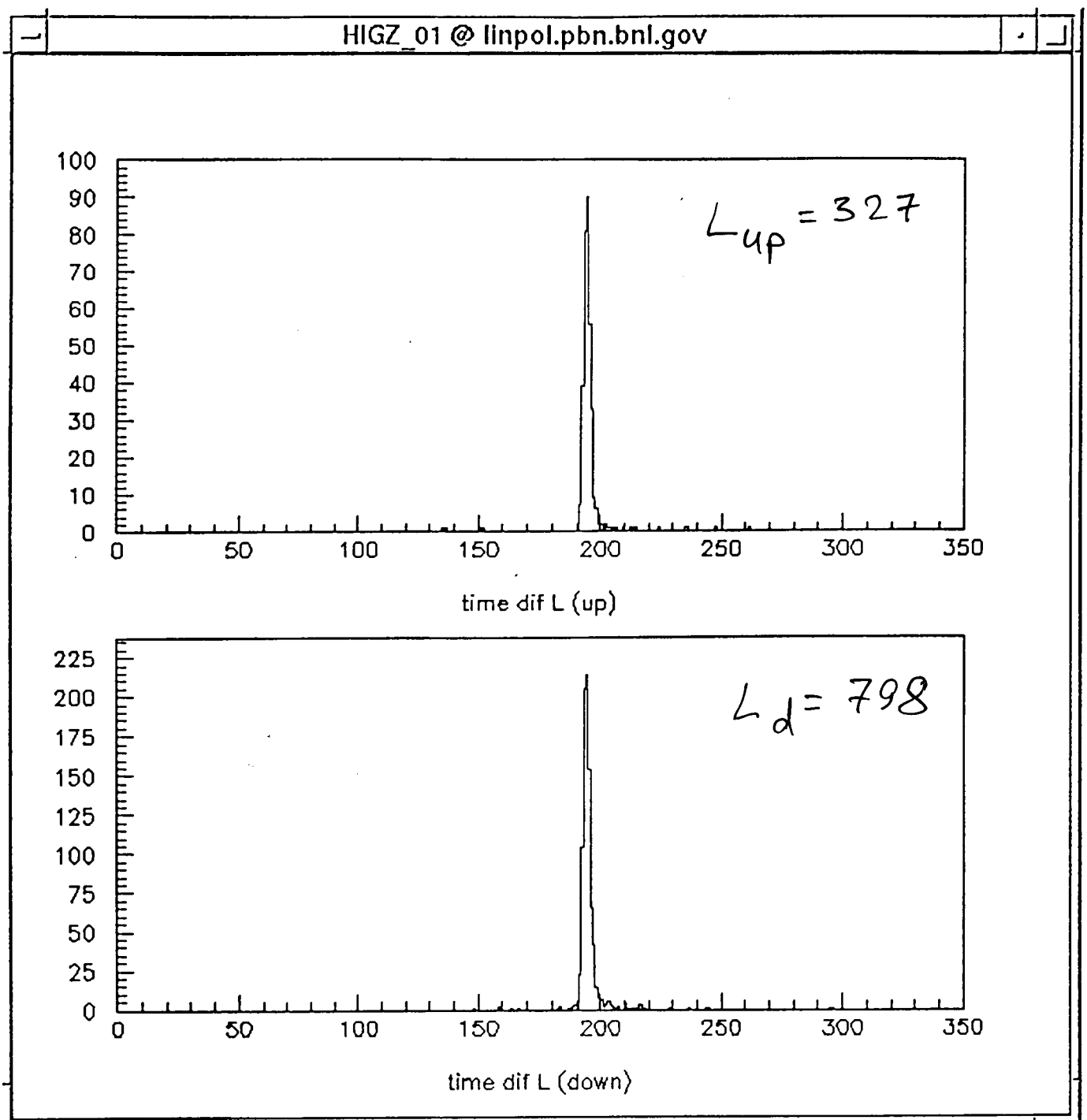



# Pulsed ECR operation

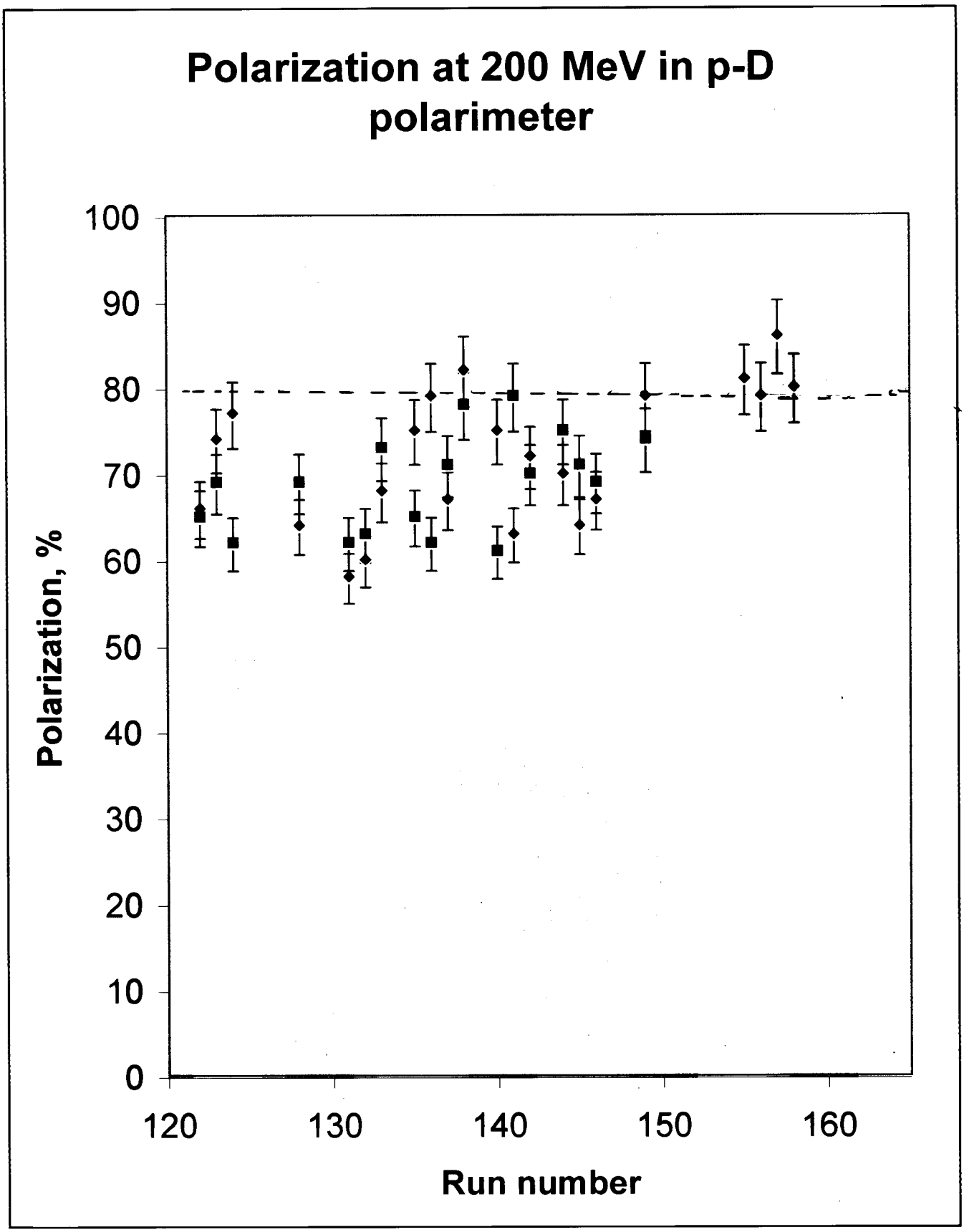

35 keV LEBT
ACTOR PWR SUPPLY
/2
ACK
Solenoid
450°
46°
200M
OPTICS BOX
He CELL
23°
BENDER
LAMB-SHIFT
POLARIMETER
Replaced
by EINZEL LENS
RACK
LENS
BOX
LASER DUCT
RACK






```
PAW-E950: '[24]'>
PAW-E950: '[24]'> vec/create out(6)
 *** VECTOR/CREATE OUT(6): existing vector OUT(6) replaced
PAW-E950: '[25]'>
PAW-E950: '[25]'> for/call asym.f(327,798,844,321)
  polarization -0.8558564      +-  0.3714243E-01
PAW-E950: '[26]'>
```

$A_{p\gamma} = 0.507 \pm 0.002$



200 MeV POLARIMETER(12 degree-accidental)

STATUS: APRIL 6, 02

PROCESSING

START | STOP | SAVE | EXIT

READING

| PULSE | LEFT | RIGHT | CLK+ | CLK- | POL. | ACC_L | ACC_R |
|---|---|---|---|---|---|---|---|
| 196 | 2.0 | 22.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 197 | 17.0 | 11.0 | 1336.0 | 0.0 | -0.9833 | 0.0 | 0.0 |
| 198 | 5.0 | 28.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 199 | 27.0 | 12.0 | 1336.0 | 0.0 | -0.904 | 0.0 | 0.0 |
| 200 | 12.0 | 24.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 201 | 24.0 | 8.0 | 1336.0 | 0.0 | -0.6777 | 0.0 | 0.0 |
| 202 | 10.0 | 19.0 | 0.0 | 1335.0 | | 0.0 | 0.0 |
| 203 | 24.0 | 10.0 | 1336.0 | 0.0 | -0.5839 | 0.0 | 0.0 |
| 204 | 4.0 | 29.0 | 0.0 | 1335.0 | | 0.0 | 0.0 |
| 205 | 33.0 | 7.0 | 1336.0 | 0.0 | -1.142 | 0.0 | 0.0 |
| 206 | 5.0 | 25.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 207 | 21.0 | 7.0 | 1336.0 | 0.0 | -0.9509 | 0.0 | 0.0 |
| 208 | 3.0 | 24.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 209 | 21.0 | 9.0 | 1336.0 | 0.0 | -1.007 | 0.0 | 0.0 |
| 210 | 7.0 | 24.0 | 0.0 | 1335.0 | | 0.0 | 0.0 |
| 211 | 27.0 | 9.0 | 1336.0 | 0.0 | -0.8463 | 0.0 | 0.0 |
| 212 | 12.0 | 20.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 213 | 32.0 | 7.0 | 1336.0 | 0.0 | -0.7551 | 0.0 | 0.0 |
| 214 | 8.0 | 25.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 215 | 28.0 | 7.0 | 1336.0 | 0.0 | -0.9017 | 0.0 | 0.0 |
| 216 | 9.0 | 29.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 217 | 18.0 | 6.0 | 1336.0 | 0.0 | -0.828 | 0.0 | 0.0 |
| 218 | 3.0 | 27.0 | 0.0 | 1335.0 | | 0.0 | 0.0 |
| 219 | 29.0 | 9.0 | 1336.0 | 0.0 | -1.108 | 0.0 | 0.0 |
| 220 | 6.0 | 23.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 221 | 23.0 | 7.0 | 1336.0 | 0.0 | -0.9038 | 0.0 | 0.0 |
| 222 | 7.0 | 30.0 | 0.0 | 1336.0 | | 0.0 | 0.0 |
| 223 | 26.0 | 12.0 | 1336.0 | 0.0 | -0.8159 | 0.0 | 0.0 |

| | | | |
|---|---|---|---|
| Left arm events (+,-): | 2651.0 | 790.0 | |
| Right arm events(+,-): | 974.0 | 2875.0 | $-83.5 \pm 1.6$ |
| POLARIZATION (P,dP): | -0.8352 | 0.01622 | |

RESET

Sat Apr 06 22:30:23 EST 2002

# POLARIZATION

| | ΔP | April 6-7 run |
|---|---|---|
| **Pulsed ECR operation** | **3 – 5 %** | + |
| **Lower ECR beam energy** | **2 – 3 %** | |
| **LEBT optics optimization for E/2 beam component suppression** | **3 – 5 %** | + |
| **Polarization direction alignment** | **1 - 2 %** | |
| **OPPIS optimization (superconducting solenoid, lasers, Sona transition)** | **3 – 5 %** | + |
| **Polarimeters. Systematic errors.** | **3 – 5 %** | + 10 % |

**GOAL : Stable operation, P > 80 % for 2002-03 run.**

# CONCLUSIONS

## The RHIC OPPIS status:

The ECR proton source has been optimized for high (up to 1.6 mA) current production. Molecular ion $H_2^+$ admixture was reduced to about 5%.

The Na-jet ionizer cell operation is very stable. The cell worked continuously trouble-free for two months in the last run. A spare cell is near completion.

The 35 LEBT optics was optimized to suppress molecular ion polarization dilution.

A 200 MeV p-Carbon plarimeter was upgraded for high current operation and continuous polarization monitoring. A new p-D polarimeter has been built for p-Carbon polarimeter calibration.

Proton polarization in excess of 80% was measured at 200 MeV after reduction of molecular ion admixture.

Source repetition rate was increased to 6 2/3 Hz.

## Problems:

Stable long-term source operation at 75-80% has to be demonstrated. Some polarization losses are expected at high repetition rate.

Higher > 85 % polarization is feasible in the optically-pumped sources and still has to be achieved in the RHIC OPPIS.

The high repetition rate of a 6 2/3 Hz might be required only during AGS polarization optimization and switch between 1 Hz and 6 2/3 Hz has to be developed.

# CONCLUSIONS

The new BNL polarized source now produces about 3 times our design goal for intensity meeting RHIC requirements. It easily produces > 1 mA of $H^-$ with polarization in excess of 75%. 50% of the source output is transported to 200 MeV. The source produces very flat beam pulses, and is very stable. It has been able to operate for 2 weeks between scheduled maintenance periods, and maintenance can sometimes be "transparent" to the RHIC spin program when done during an 8 hour period of stored beam.