Status of ELENA H- /p source

10/12/2019

- Ion source overview
- Insulation transformer issues: observations and present solution
- Beam instability observations and possible cure
- Plans and conclusions
Overview of ELENA Source Installation

- Faraday cage (source power supplies)
- HV power converter(s)
- HV insulation transformer
- Actual ion source
- ELENA Ring
- Control PLC, Interlock, PC

ADUC 10-13-2019: Status of ELENA H- p source
Built by a (new) **external company** and installed in spring 2019

- After a few days of tests it started have spark when run @100 keV DC (nominal settings)

**Several attempt improvements by EPC**

Still sparking + degradation: secondary to magnetic core sparks
After investigation by EPC, it turned out that last turn of secondary winding was too close to magnetic core: possibly a construction error – design maybe good.

- Company agreed to build a new transformer, with more space between ground and HV, and being more careful in the construction.
Cycling the HV @100keV (2019v1)

Still, it has been possible to cycle HV and have 100 keV beams in ELENA

However:
- Had to program about 107 kV on HV PC
  - Slow ramp up of HV in the source
  - Tested for several hours without problems
- Only possible to arrive @95 kV with positive HV, i.e. for possible proton operation
  - sparks in transformer

- 200 ms ramp from 56 kV to 106.6 kV
- Plateau of about 1 s before making beam
New\textsuperscript{n} transformer (2019v2)

- **Installed** on Thursday 5/12/19
- **Tested** up to 105 keV DC for a few hours on Friday 6/12/19
- **Used** with beam at 100 keV DC for about 6 hours on Monday 8/12/19
- **TODO:**
  - Continue testing for several hours, eventually for a few days. (partial discharges still audible in the transformer)
  - Test with positive HV (i.e. proton beam production)
Beam: from source to ring

Wish list:

- ~100 uA; ~1 us; ~square pulses
  - Only 650 ns-long pulses injectable by kicker
  - 500 ns @ 100 uA ≈ 3.1x10^8 particles

- Good Stability/Repeatability
  - Order a few % intensity and beam shape
  - Better than <0.1% energy stability

- Transverse optics matched to ring to maximize injection efficiency

Only DC Power Supplies control via PLC in Faraday Cage
Initial beam observations

Poor instrumentation available

Poor position stability after some time, sometimes

Shot-to-shot, Intra-pulse, Intensity Instability in ELENA

Differential pumping (3x Turbo + 1x NEG)

Ion Switch

Electrostatic Quadrupoles

Vertical Corrector

BTVs

Kicker

Quadrupole + BPMs

ELENA Dipole

Pearson BCT

SEM

Differential pumping (3x Turbo + 1x NEG)

Ion Switch

Electrostatic Quadrupoles

Vertical Corrector

BTVs

Kicker

Quadrupole + BPMs

ELENA Dipole

See Mark’s talk

Pick-ups in ELENA: Sum signals

20us

Calibration pulse

18 us-long beam

18 us-long beam
Looking for other possible signals

Using one plate of Ion Switch as a Faraday Cup

• Deposited charge evacuated by a resistance to ground
Looking for other possible signals

Using the orbit corrector in LNS line as BPM (with charge amplifier used in ELENA ring BPMs)

- **Difficult measurement**, as **amplifiers saturate** quickly if there are **beam losses** on the electrodes.
- **New tests** in **LNE50** foreseen for the end of this week
Back to BPM in the ring as main observable scan over arc voltage

- Basic parameters: $2650 \, V_{\text{puller}}$; 6% filament;

---

**Gas: 0.8 sccm**

---

**Gas: 1.7 sccm**

---

Warning: ~x2.5 over-estimated current
Looking at ~long pulses (390 us)

- Does the oscillation dump with time? (doesn’t seem so)
- Is there a specific (plasma?) frequency?
  - For 1 MHz oscillation one would expect $\sim 10^{10}$ m$^{-3}$ plasma density
  - Possible!? To be investigated.

FFT over several shots and mean over all FFTs

(2650 V$_{\text{puller}}$; 6% filament (7V$_{\text{fil}}$, 45.8 A$_{\text{fil}}$); 30 V$_{\text{arc}}$ (1.5 A$_{\text{arc}}$); 0.8 sccm)
Doubling injected gas

- If plasma oscillation, the “dominant” frequency should move of $\sqrt{2}$
- Maybe compatible with preliminary observation, but more needed…

ADUC 10-12-2019: Status of ELENA H-/p source
Still, a possible solution identified

- Installed a more **sensitive BCT** in the source
  - Allows for “standalone” investigations
- Running with “**low**” arc voltage
  - Great stability, but **lower beam current production**

![Graph](Image)
Future investigations:
intra-pulse instability: some wrong configuration?

Permanent decapole magnets for plasma confinement

“Bad” filament shape?

Not so pure H$_2$ source?

Permanent magnets for “magnetic filter” and H$^-$ production
Future investigations:
position instability: something charging in front of source?

- "Bad" cables?
- Soldered?!
- Evaporation?

Pearson transformer
Puller electrode
Quadrupole shielding
Maybe some surface degradation
Conductive Shielding
Conclusions

- **HV insulation transformer**
  - **2019v1** version can run @100 keV in pulsed mode
    - Only possible to run with H⁻, no protons @100 keV (but lower maybe possible)
  - **2019v2** version looks promising
    - So far tested only for negative voltage (H⁻): to be tested for protons

- **Beam intra-pulse stability**
  - Still investigating the mechanism that generates the instability
  - **Backup solution:** run at low arc voltage
    - ~about 40 uA stable beam can be produced and transported to the ring

- **Beam position stability**
  - Probably due to charging up of some components
    - plans to improve shielding and components quality/grounding
  - “Sporadic” effect – not a major threaten for transfer line commissioning

- **Beam instrumentation improved** for standalone investigations

Thank you!
Backup
Source control

- Control via PLC of main DC voltages
- Filament automatically regulated to keep Arc current stable (?)

---

**Flow controller**

- 0.80 sccm
- 0.82 sccm

**Filament**

- 6 V, 44.7 A

**Arc**

- 70 V, 1.5 A
- 70 V, 0.0 mA

**Puller positive**

- 2560 V, 0.0 mA

**Puller negative**

- 250 V, 0.0 mA

---

**Potential**

- 0.000 kV
- 55 kV, 232 μA

---

**Quadrupole 1**

- On, Off

**Quadrupole 2**

- On, Off

---

**400Hz Converter**

- State: On/Off

---

**Puller [V]**

- t

---

**Decapole magnets**

- Filament

**Electron suppressor magnets**

- Puller electrode

**Magnetic filter**

- Plasma chamber
Source cabling

from Ana Megía-Macías - [link](#)

ADUC 10-12-2019: Status of ELENA H-/p source
In which regime are we?

Does our control allows to explore this region?

We need ~30 V to "start" the plasma, then down to ~20 V to stop it.

Fig. 3: The current voltage characteristics of a typical electrical discharge

From *Ion sources for high-power hadron accelerators* by D. C. Faircloth - [link](#)
Measure instabilities of arc current

1 µs / div
5 mA / div

A & B – switching of puller voltage

Pearson 110 current transformer placed around arc return cable 10 cm from the exit of the plasma chamber. The source was operated with 38 A filament current and 1 A arc current.

The first peaks in the damped oscillation corresponds to 170 mV/0.1 A/V = 17 mA, which is still significantly lower than the average 1 A arc current. The noise is related to the switching of the puller electrode in time.

! No erratic noise corresponding to the signal seen on the extracted current!
**Source perveance**

4 mA extractable H- current

* analytic formula for a planar diode
* plasma electrode diameter 4.2 mm, distance plasma electrode to puller 5 mm, extraction voltage 3000 V, ignoring electrons)

significantly higher than 100 uA being extracted

Ralf Gebel from Julich writes ‘9 mm and 6 mm plasma electrode versions should be available too, if you need more beam current. 6 mm is fine for 300 uA. 9 mm if you need a milliamp
ELENA source
I_{arc}=1-2\ A
U_{arc}=70\ V
Q=0.006-0.018\ Torr*1/s