The CERN heavy ion source
present status

D. Küchler, R. Scrivens
for the source team
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Outline

• Source and Linac3
• Operational beams
• Experimental beams
• Calcium
Source and Linac3
Linac3
• Operational since 1994.
• Always Pb production has been the priority.
• Source, RFQ and 3 accelerator tanks
• Final energy 4.2 MeV/u
• Stripper stage at final energy
Linac3

• One hall contains all power systems and the accelerator, access is needed during operation.
• Creates limits for radiation which are due to:
  • Source x-rays.
  • IH RF cavity x-rays (limit to RF field and repetition rate).
  • Neutron production (an issue more for lighter ions e.g. argon).
GTS-LHC ion source

- Electron Cyclotron Resonance Ion Source (ECRIS), installed in 2005.
- Pulsed operation in afterglow mode, produces ~ms long pulses at 10Hz, only ~200us pulses are accelerated, not all pulses.
- Equipped with gas injection and 2 micro ovens
- Beam energy 2.5 keV/u (adapted to the RFQ)
Material input

• Gas via gas injection
• Solids from the micro ovens (max. temperature around 1000°C)
• In some cases chemical compounds for easier injection can be considered
• If element is a mixture of isotopes isotopically enriched material should be used
Operational beams
Lead – data sheet

- Material: solid, isotopically enriched $^{208}_{82}$Pb (99.5% purity)
- Input method: micro oven
- Cost: 1.39 CHF/mg
Lead – operational facts

• Many years of experience
• Is the main operational beam for Linac3 (2015, 2016, 2018)
• Oxygen as support gas
• Lead Consumption: 2-3 mg/h
• Oven refill every second week needed, around 10 hours down time
• From the source: ~170 eµA Pb^{29+}
• From the linac: ~30 eµA Pb^{54+}
Xenon – data sheet

- Material: isotopically enriched gas of $^{129}_{54}\text{Xe}$
- Input method: gas injection
- Cost: $\sim 2500$ CHF/l
Xenon – operational facts

• Beam used for operation in 2017.
• Operation for SPS fixed target operation and 1 day LHC fills.
• Source operated with oxygen as support gas
• Linac final energy sufficient for neutron production
• From the source: \( \sim 160 \, \text{e\(\mu\)A Xe}^{22+} \)
• From the linac: \( \sim 30 \, \text{e\(\mu\)A Xe}^{39+} \)
Argon – data sheet

• Material: natural, chemical pure gas (99.6% of $^{40}_{18}\text{Ar}$)
• Input method: gas injection
Argon – operational facts

• Operation for SPS fixed target operation in 2015
• Source operated without support gas
• Reduced life time of plasma chamber due to heavy sputtering inside the source
• No stripping at the end of the linac Ar$^{11+}$ Q/A sufficient for Linac3 -> LEIR line.
• Ion getter pumps in the low energy section lose pumping speed, needs additional pumping.
• Linac final energy sufficient for neutron production
• From the source: >100 eµA Ar$^{11+}$
• From the linac: ~60 eµA Ar$^{11+}$
• Neutron Production would need better management for future runs.
Experimental beams
Indium

• Operation for SPS fixed target with the ECR4 ion source in 2003

• Material input: micro oven with solid, natural metal (95.7% of $^{115}_{49}$In)

• Problem: liquid indium is wetting insulating surfaces, reduced life time of micro oven due to short circuits, limited beam stability

• From the source: $\sim$70 eµA In$^{21+}$

• From the linac: $\sim$25 eµA In$^{37+}$

• Neutron production at Linac unknown
Oxygen

• $\text{O}^{4+}$ beam used to set-up LEIR the first time in 2005
• Material input: injection of natural, chemical pure gas (99.8% of $^{16}\text{O}$)
• Stable operation for 4 weeks
• From the source: >250 eµA $\text{O}^{4+}$
• From the linac: 70 eµA $\text{O}^{4+}$
• Neutron production at Linac unknown
Helium

• Short experiment with the ECR4 ion source
• Material input: gas injection of $^{4}_2\text{He}$
• Very low extraction voltage (10.8 kV) lead to space charge problems in the LEBT
• High losses along the linac
• From the source: >500 eµA He$^+$
• From the linac: ~160 eµA He$^+$
• Neutron production at Linac not measured.
Other Elements - Calcium
Other Elements

• When considering a new element:
  • Chemical characteristics of the raw material. Isotope availability.
  • Compounds (gas, liquids or solids).
  • Safety considerations for the material.
  • Stability, producing a few weeks of stable operation is not the same as a fast test of a few days (both stability, and fast sputtering onto insulators can be an issue).
  • Charge state available -> source acceleration voltage, acceleration etc.
    • Up to stripper: \((Q/A) > 0.1202\) RF power limit.
    • Up to stripper: \((Q/A) < 0.275\) lowest source voltage >~9kV.
    • After stripper: \((Q/A) > 0.25\) Limit of transfer line magnet field and cooling.
  • Matching the source plasma density to the extraction voltage.
  • Tuning the material injection method (gas is quick and reactive, oven heating requires even longer tests). Support gas usage.
Calcium – data sheet 1

• Six stable isotopes, $^{40}_{20}$Ca 96.9% abundance
  -> Natural, metallic calcium can be used if there are no other special requirements.

• Calcium can be run ~80K cooler for the same vapour pressure same as Pb. This will put it close to the solid/liquid phase. Tests could be made on the oven test stand (but already requires handling safety procedures).

• $^{48}$Ca used in some labs with ECR sources
  • Bogomolov et al.
  • Lang et al, Proc ECRIS 2002
Calcium – data sheet II

• Expected charge state from the source: experiment needed
  • 40Ca10+ will overlap with impurities.

• Expected charge state after stripping: Ca\textsuperscript{17+} (37% of the beam) Baron’s formula.

• Path to tests for production, intensity and stability:
  • Assuming metallic calcium, handling procedures needed (for oven filling, venting etc).
  • Spare parts needed to dedicate to testing (chambers, insulators, ovens).
  • Testing period up to 2 months needed for the source (tests without support gas, oxygen gas [reacts with Ca, may be unstable], Ne support gas).
Questions to GF

• Are you looking to fix an ion type, a few types. Light? Heavy?
• Does the charge state matter?
• Does proof of principle use Pb (or whatever is needed)?
Summary

- Linac3 and its source have strongly prioritized Pb production since 1994. A few other elements have been produced with this source (O, Ar, Xe) and a former ECR source (In, He in short tests).
- Experience will be used from other labs, but testing at CERN is absolutely necessary for new elements.
- Calcium likely to need a minimum of 2 months source testing even for short running period. Needs advanced planning to any run.
- Time and resources will be needed for more development work (material preparation and source testing).