Progress on ELENA development 2019 and plans for 2020

C. Carli on behalf of the ELENA Team  
AD Users Committee, 10th December 2019

- Situation about a year ago
- Installation of transfer lines
- Source and Isolation Transformer
- Issues with Tune Kicker Repair
- Electron Cooler
- Profile Monitors
- Analysis of Observations
- Plans for 2020 and beyond
- Summary and Outlook
Situation about a Year ago

- Finally promising results from commissioning with beam
  - Not yet nominal beam parameters (in particular larger transverse emittances)
  - Most progress made with antiprotons and not, as expected, with $H^-$ from source
  - Performance a clear improvement for experiments and potential for further improvements

Whole ELENA cycle with beam (combining two acquisitions, 2\textsuperscript{nd} with slightly higher intensity)

- Decision to go ahead with installation of lines formally agreed at ADUC on 30\textsuperscript{th} October 2018
Situation about a Year ago

First Ideas on Activities with Beam in LS2 (Input for a Discussion and instead of Conclusions)

- Aims of possible tests in 2019 - mainly preparation of transfer line commissioning in 2020
  - Demonstration of reliable source operation at 100 keV with upgraded isolation transformer
  - Investigations on intensity fluctuation along pulse: requires line to ring for observation on 1st ring pick-up (can one increase the pick-up saturation level for this pick-up?)
  - Increase of intensity from source (sufficient intensity of extracted bunches for line commissioning possibly with scraping to adjust emittances?)
  - H⁻ injection matching (BTV after septum and possibly observation in SEMs)
  - Probably not possible (but would be of interest!): injection tests to optimize efficiency (even without RF), tests with beam on SEM in GBAR line

- Aims for 2020
  - Commissioning of transfer lines to experiments in “old” experimental zone with H⁻
    - Profile monitors mandatory!!
    - Requires sufficient intensity H⁻ within appropriate transverse emittances
    - Show control of beam along lines and arrival with expected characteristics at the last monitor
    - Magnetic stray fields and shielding: plans for investigations and, possibly?
  - Possible other tests with H⁻ and/or proton beams from source?
    - Electron cooling with protons or H⁻
    - Lattice control and understanding, (loss on ramp at low energy?) …
    - Acceleration, deceleration …

From an extended ECC meeting on 7th March (https://indico.cern.ch/event/803767/)
Installation of transfer lines

- Main activity this year
- Progressing well in spring
- Some delay in autumn,

=> installation of many profile monitors and most bake-outs moved to 2020

Beginning of 2020 with magnets still installed

Autumn 2020 – most equipment installed, several profile monitors missing

For all details, see dedicated presentation by Francois
Source and Insulation Transformer

Two more iterations with an insulation transformer in an oil bath

- Beginning of summer:
  - New isolation transformer (design by company following CERN instructions)
  - After first good results, sparks again (probably between secondary and yoke)
  - Issue with last two windings of secondary
  - Pulsing the HV shown to work to generate 100 keV H⁻ and used for profile monitor tests

- Since last week
  - Another transformer arrived and installed
  - Used already this week to generate beam in DC mode foreseen (recommendation by CERN experts), HV pulsing as back-up in case of troubles

Many studies, improvements and important findings on the ion source

- Fluctuations along pulse from source seen last year confirmed
- Studies on increase of beam current and fluctuations along pulse with different source settings
Issues with Tune Kicker Repair

- Taken out for repair to replace electrode supports (one electrode had detached from support)
  - Incident (tap broken & stuck in threaded hole)
- More series repair required (collaboration BE/BI, TE/VSC and main workshop)
  - Removal of piece and re-welding
  - Was known to be risky for NEGs, pollution by hydrocarbons identified in vacuum acceptance tests
- Repair, installation and bake-out completed since last Friday
  - Ring closed and available again, but without RF system for RP
  - Tune kicker finally available earlier than replacement chamber prepared in parallel!
Electron Cooler

- Recap: Cooling in all three planes and at both energies observed in 2018
  - Fundamental to show that ELENA is an improvement for experiments
  - Lack of time for thorough (empirical) optimizations (more effort than expected required for magnetic cycle)
  - Potential for performance improvements (compared to 2018 results)

- Electron position measurement implemented during 2019
  - Modulation of electron beam
  - Electron beam position from ratio between sum and difference signals
    => Beam position of circulating beam and electrons measured with same PU
  - More efficient alignment (position and angle) of circulating pbars w.r.t. electron beam from next restart on

PU sum signals with electron beam modulation - all four (two planes at two locations) signals similar

PU difference signals

Long Schottky spectrum during cooling @ 100 keV
Profile Monitors for Lines

- Recap:
  - Technically very interesting and impressive in-kind contribution
  - More and more taken over by BE/BI
    - Starting with the mounting of the monitors,
    - Recently contributions to electronics, revision of FPGA code, tests with beam, ...
- Tests with beam using the second but last front-end electronics prototype

Example of profiles measured (on a monitor in the line from the source to the ring)
- Signal generated by beam (effect of steering, beam on/off, quads settings seen )
- Many missing channels for monitor in GBAR and two monitors in source to ring lines
- Two monitors in GBAR have few missing channels (similar to last year)

Still a lot of work to be done: completion and installation of monitors, test of last prototype front-end electronics, electronics mass productions, missing channel issue, testing of installed monitors
Analysis of observations and improvements of tools

- Offset between measured and expected (from model) tunes increase along 2\textsuperscript{nd} ramp
  - Possibly due to hysteresis (even though expected hysteresis not sufficient)?
  - Larger effect at 100 keV than seen in 2016 with H\textsuperscript{-} coherent injection oscillations
  - Dispersion from model increases as well from about 1m to about 1.7 m …
- Many discussions on magnetic cycle editing with a new program available
  - Programming directly tunes
  - Very flexible!

Comparison of tunes from measurements (on last beam day by Laurette) with expectations from currents

From programmed currents and model without hysteresis (added to plot from Q-meter)

From currents plus about 5 times the expected Hysteresis

- $Q_M = 2.439, Q_V = 1.401$
- $Q_M = 2.435, Q_V = 1.393$
- $Q_M = 2.444, Q_V = 1.397$
- $Q_M = 2.457, Q_V = 1.413$
- $Q_M = 2.459, Q_V = 1.412$
- $Q_M = 2.439, Q_V = 1.401$
Plans for 2020

- January to March: cabling campaign - other activities (bake-outs, tests with beam) unlikely
- April to June: bake outs (TE/VSC manpower needed) and cable connections
  - Compatible with tests with beam of source, injection … (probably no RF at most/all of the time)
- July until end of year: transfer line commissioning with H⁻
  - Details to be worked out (extended ELENA Commissioning Committee meeting again?)
  - Profile monitors mandatory (review of situation by March)!!
  - Show control of beam along lines and arrival with expected characteristics at the last monitor
  - Sufficient H⁻ intensity within appropriate emittances (studies on increase of current from source)
  - Magnetic stray fields and shielding: investigations and, if needed, implementation of shielding
  - Optional depending on progress: other tests to better understand machine optics and cooling

Beyond 2020 (dates from 1st version of LHC injector schedule 2021)

- Restart of ELENA with H⁻ ions on 1st February
  - Depending on progress made in 2020, completion of commissioning of lines, acceleration/deceleration,
- AD production beam on target on 22nd March
  - Commissioning of new target and AD re-commissioning after a long shutdown
- Antiproton beam to ELENA on 19th April
- Start of physics with 100 keV antiprotons from ELENA on 10th May
Summary and Outlook

- **Aims for 2019**: preparation of transfer line commissioning in 2020
  - Most installation work for transfer lines done, some delays due to, amongst others, profile monitors
    - Most bake-outs delayed to next year
  - Two more iterations of isolation transformer in oil bath – solid solution implemented (?)
  - Less tests with beam due to various issues (mainly isolation transformer and tune kicker)
    - Nevertheless interesting observations on source (fluctuations, intensity, …) and profile monitors
    - Still some hope for studies this week (injection matching, few turns in ring … profile monitor …)
- **Aims for 2020**
  - Completion of preparations for transfer line commissioning (cabling, bake-outs ..)
  - Commissioning of transfer lines to experiments in “old” experimental zone with H⁻
    - Profile monitors mandatory!!
    - Show control of beam along lines and arrival with expected characteristics at the last monitor
    - Magnetic stray fields and shielding: plans for investigations and, possibly ?
  - Possible other tests with H⁻ and/or proton beams from source?
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    - Lattice control and understanding, (loss on ramp at low energy?) …
    - Acceleration, deceleration …
- **First 100 keV antiprotons from ELENA for experiments expected in May 2021**