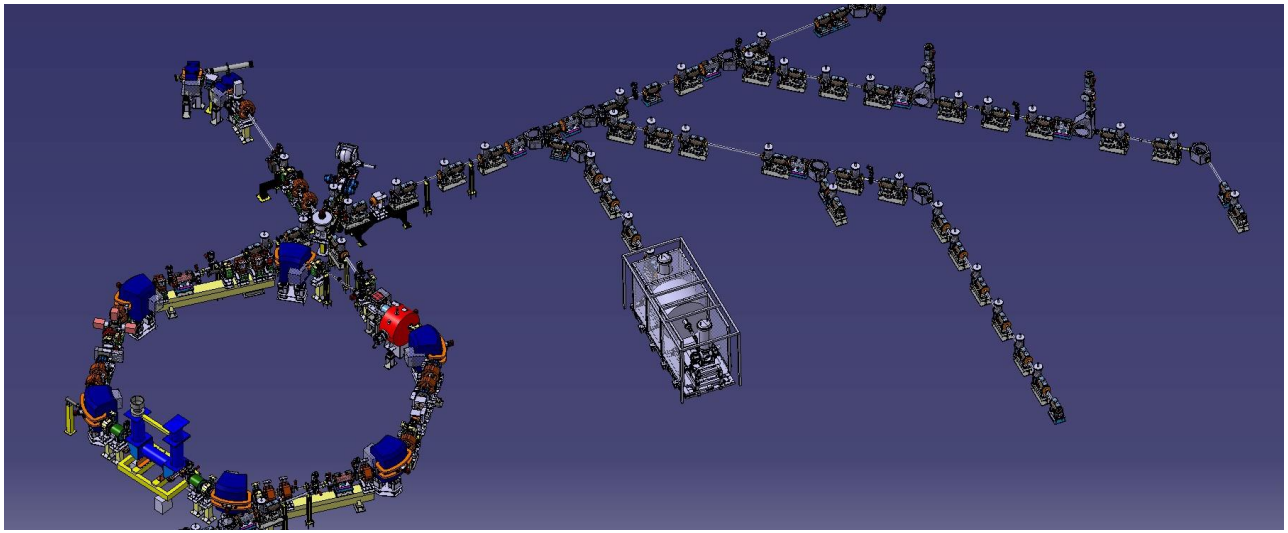
ELENA Status and Recent Progress

C. Carli on behalf of the AD/ELENA team

AD Users Committee 19th January 2021



- Ion Source
- Transfer Line Commissioning
- ELENA Ring Studies
- Profile Monitors
- Summary and Outlook

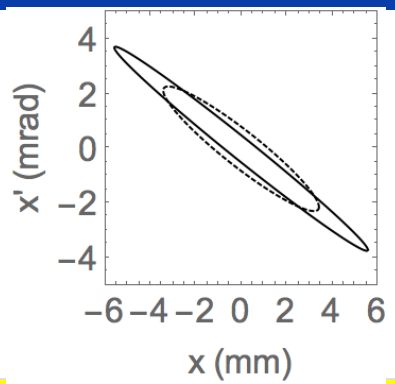
Transfer line commissioning
General

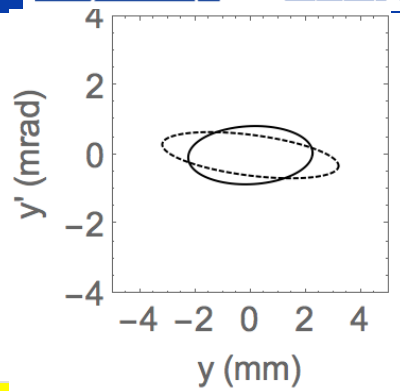
- Main target for 2020
- Some delay with preparations mainly related to Covid
- Preparations (source, ring, LLRF, profile acquisitions ...) end of August and September
- Proper start of transfer line commissioning towards end of September

Transfer Line Commissioning LNE50 (GBAR Experiment)

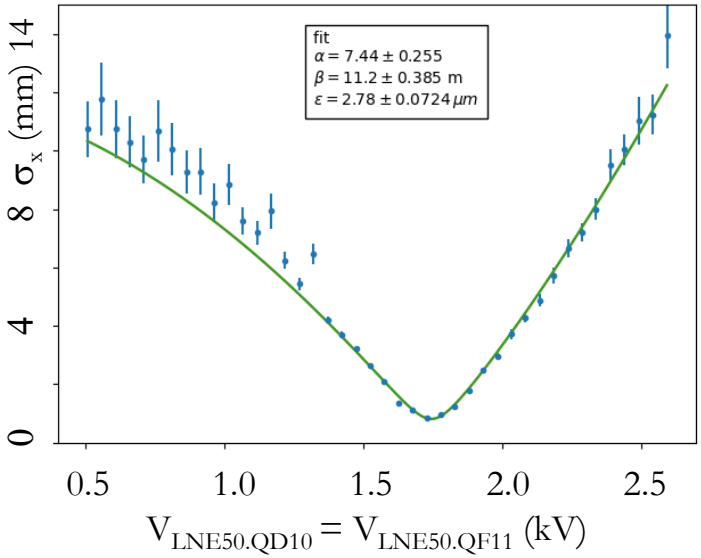
Studies done and materiel provided by SY/ABT team

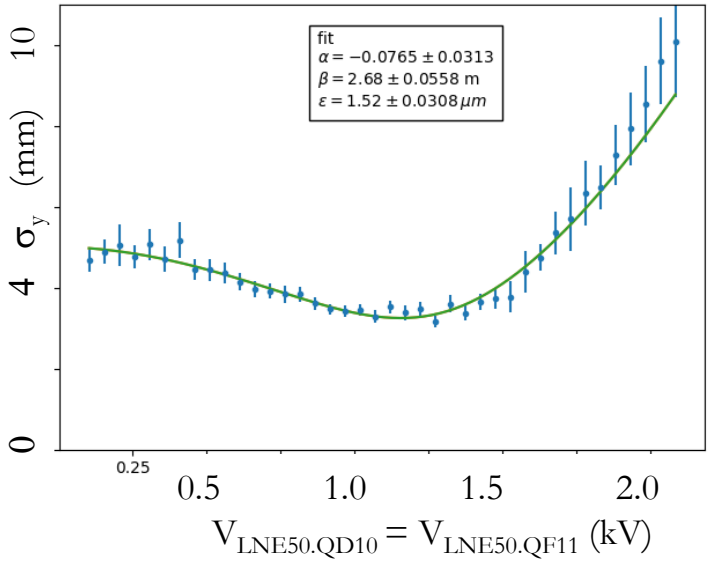
- Quad scan using LNE50.QD10 and LNE50.QF11 and observing on LNE50.BSGW60





LNE50 Start	ϵ_x	α_x	β_x	D_x	ϵ_y	α_y	β_y	D_y
Design	NA	2.63	4.22 m	0.90 m	NA	0.52	5.39 m	0
Measurement	2.78 µm	7.44	11.2 m	1.56 m	1.52 µm	-0.08	2.68 m	0.43 m

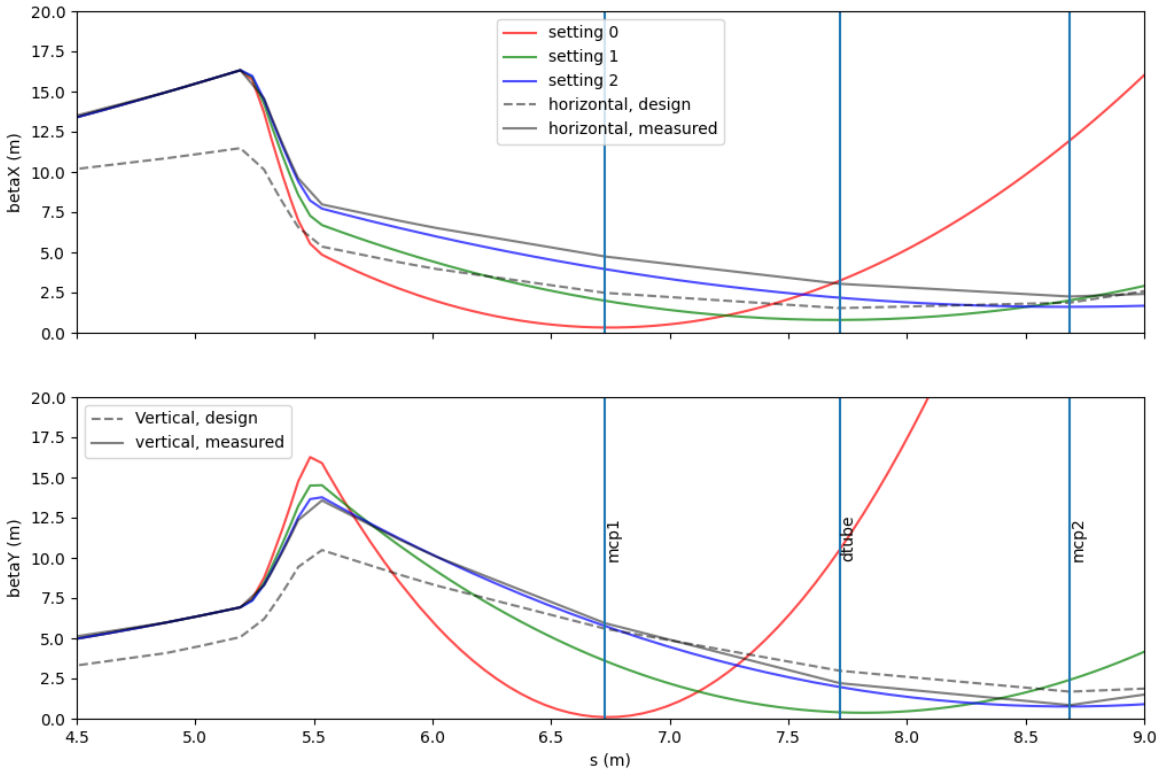




Transfer Line Commissioning LNE50 (GBAR Experiment)

- Average results of several quad scans used for rematching (three different cases)

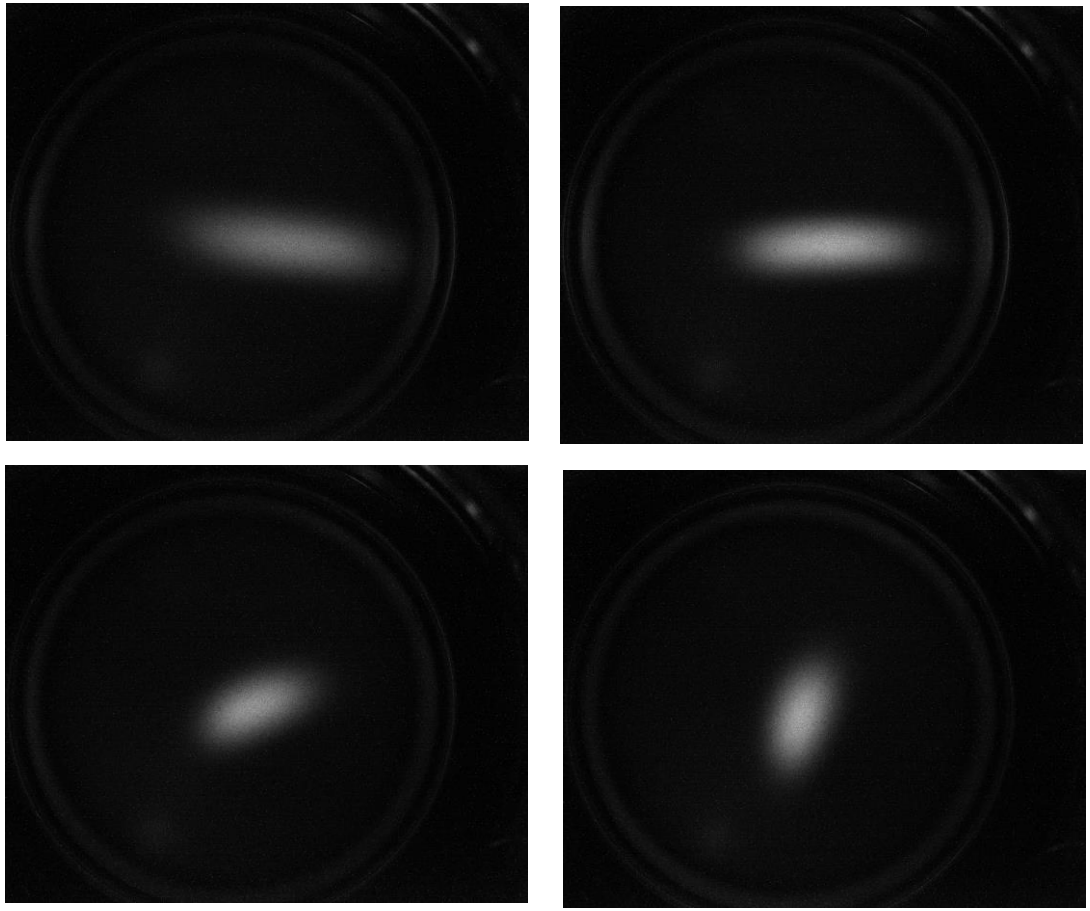
LNE50 Start	ϵ_x (μm)	α_x	β_x (m)	D_x	ϵ_y (μm)	α_y	β_y (m)	D_y
Design	NA	2.63	4.22	0.90	NA	0.52	5.39	0
Avg. Measurement	3.89±0.69	5.37±1.21	8.67±1.65	1.58	1.55±0.18	-0.09±0.24	2.55 ± 0.72	0.43 m



Studies done and materiel provided by SY/ABT team

Transfer Line Commissioning LNE50 (GBAR Experiment)

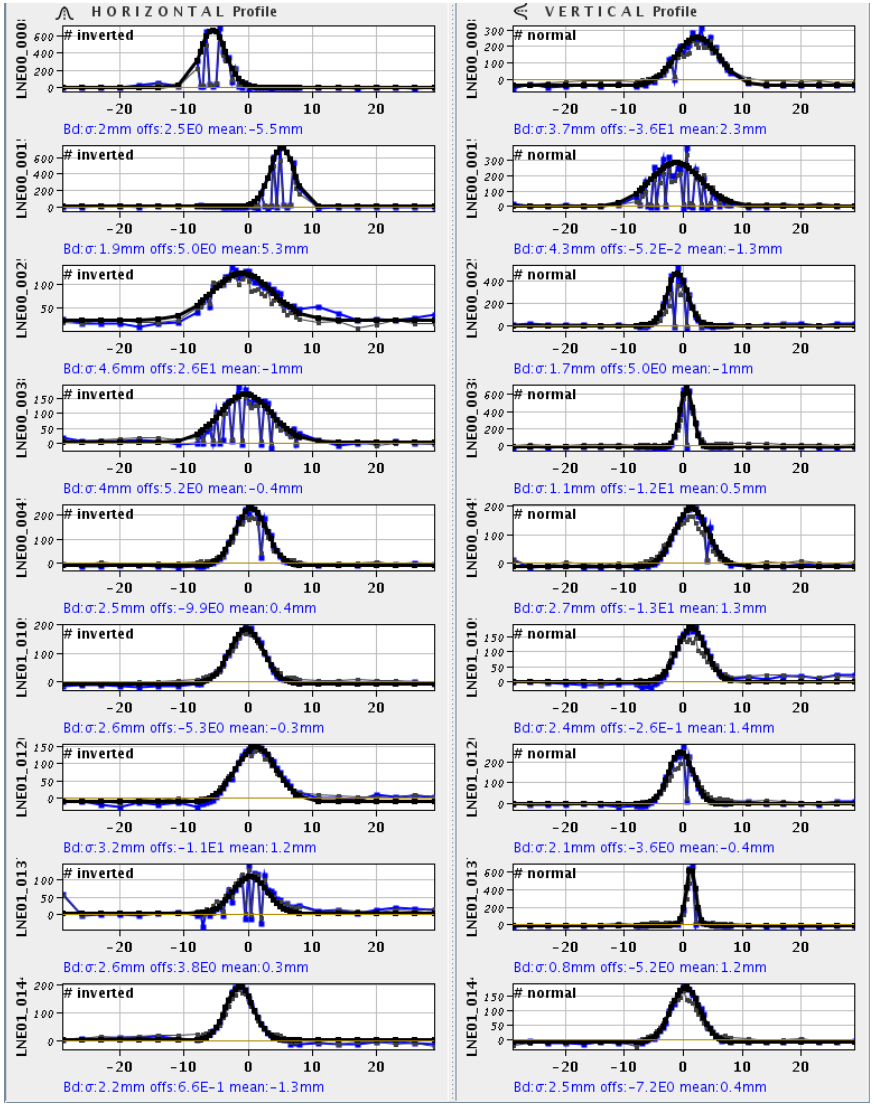
- Observation of Coupling
  - Tilt of beam seen by the experiment on MCPs images (taken with different optics settings)
  - Should not be an issue provided emittances are small enough?
  - Systematic investigations?

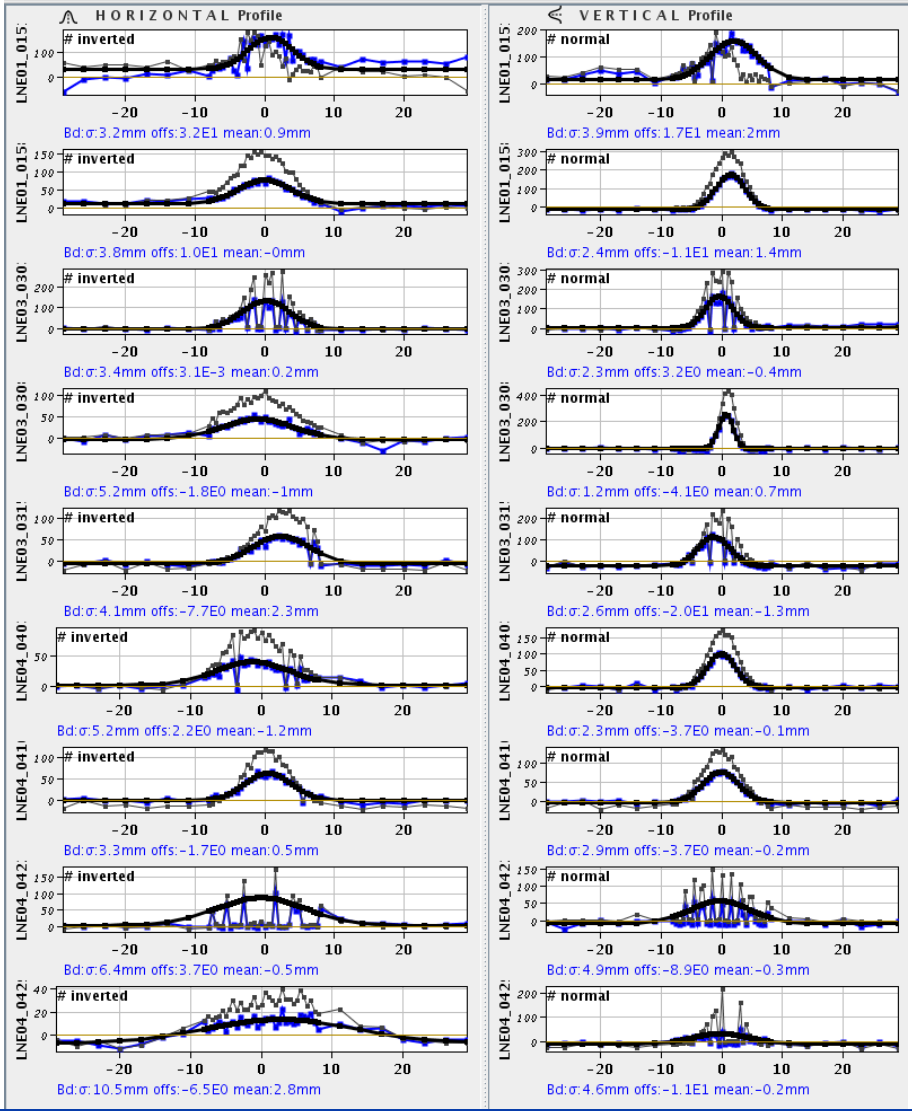


  - Vertical dispersion measured in lines (and as well in ring)

Transfer Line Commissioning
ALPHA Line

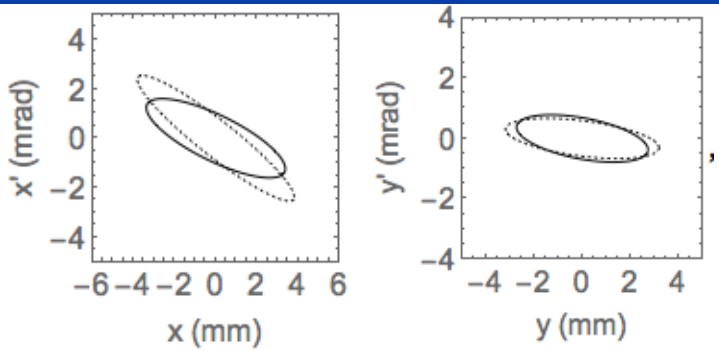
- Beam on all monitors between ELENA extraction and the ALPHA experiment





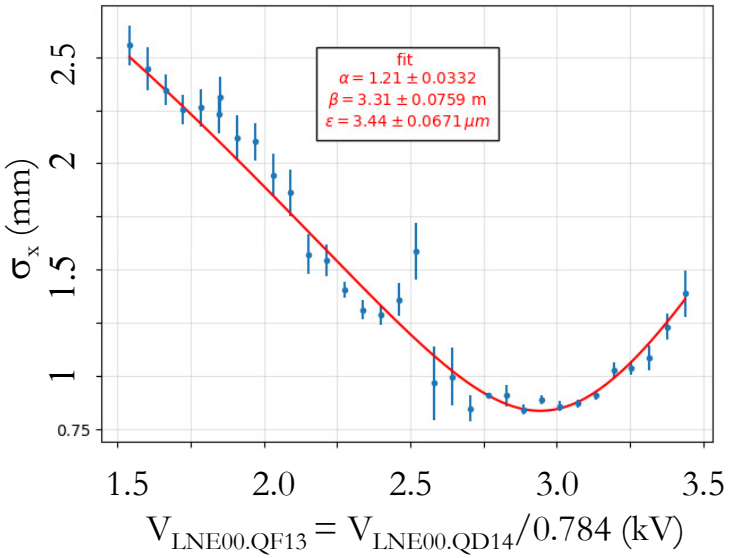
Transfer Line Commissioning
ALPHA Line

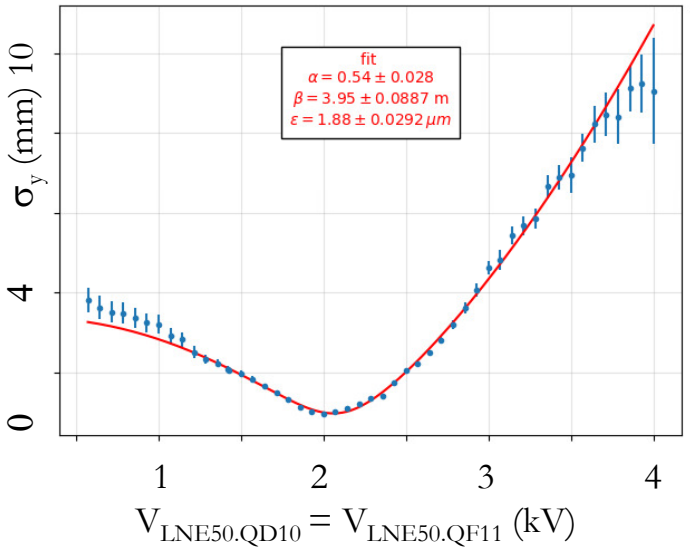
- Quad scan at beginning of line using observing on LNE00.BSGW15



Studies done and materiel provided by SY/ABT team

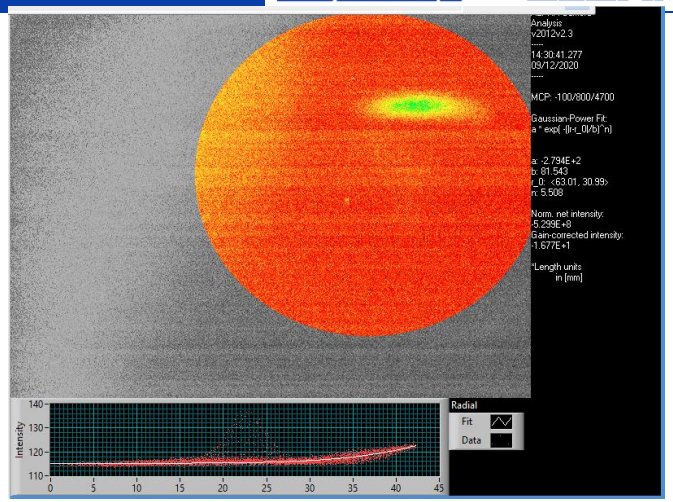
LNE00 Start	ϵ_x	α_x	β_x	D_x	ϵ_y	α_y	β_y	D_y
Design	NA	2.63	4.22 m	0.90 m	NA	0.52	5.39 m	0
A Measurement	3.44 μm	1.21	3.31 m	1.37 m	1.88 μm	0.54	3.95 m	- 0.37 m





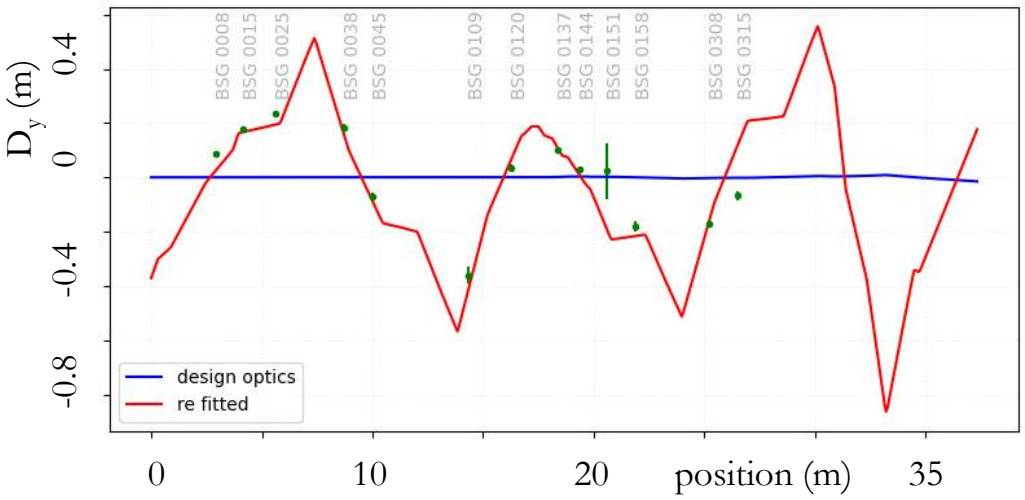
Transfer Line Commissioning
ALPHA Line

- Beam observed by ALPHA on MCP on 9th December
  - Rematching to make beam round

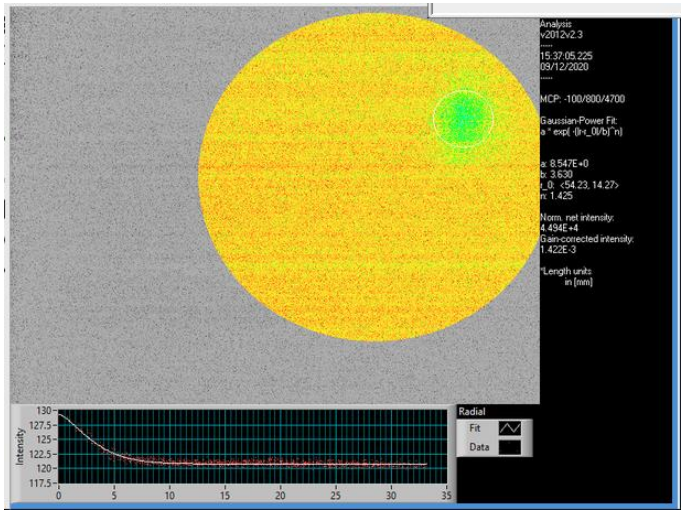


First H- Beam seen by ALPHA on MCP

- Vertical dispersion (small) measurement



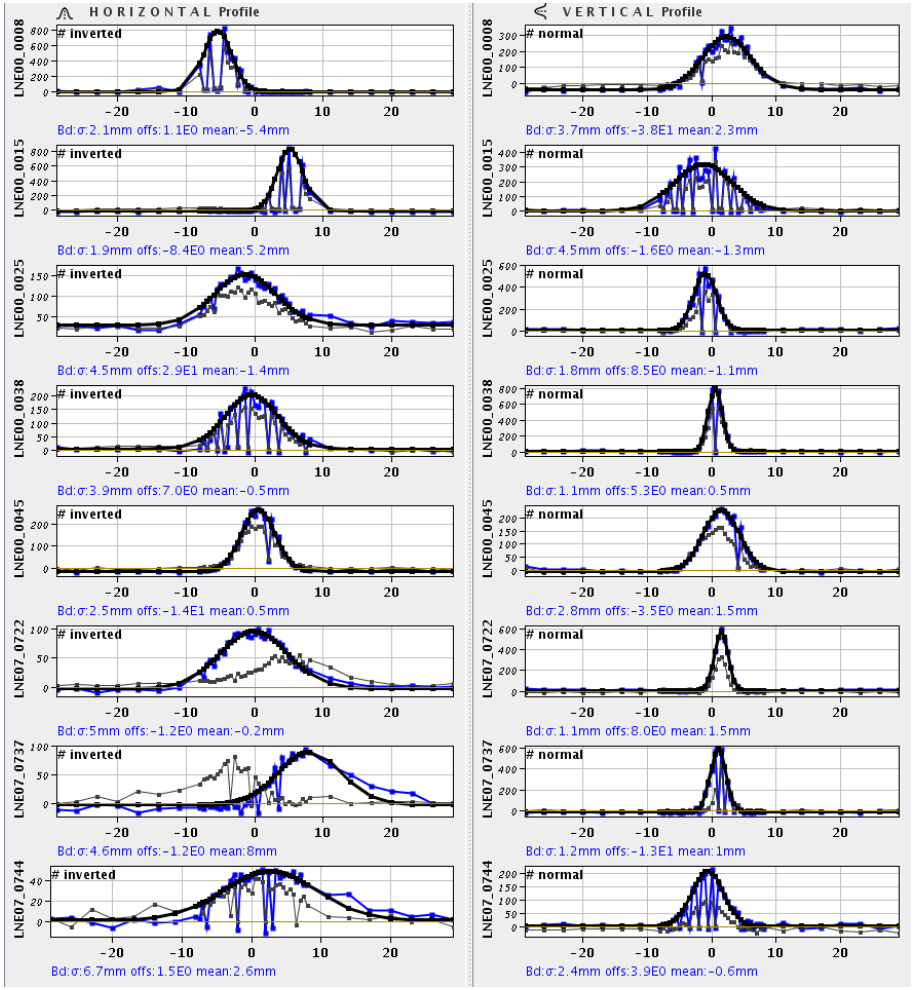
- Horizontal dispersion measured along line close to expectations



After rematching with last three quads (to obtain round beam)

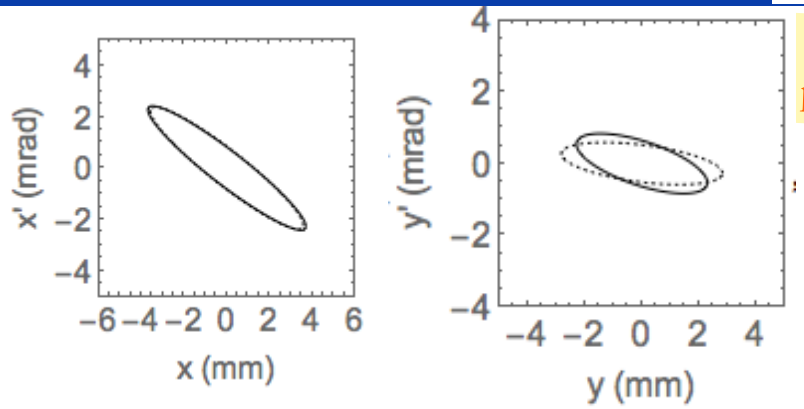
Transfer Line Commissioning
BASE Line

- Last of the available lines tested
- "Long" section with two bendings and without monitors
- End of line again reached quickly
- Beam not well centered in region between bendings
  - Quadrupole setting variations and observation on downstream monitor used to improve



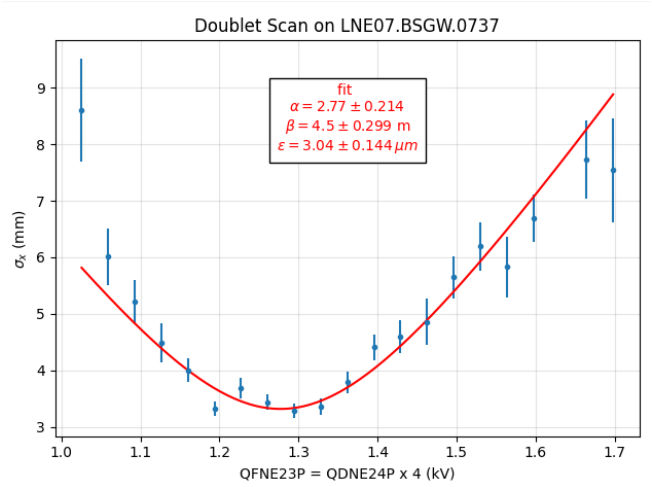
Transfer Line Commissioning
BASE Line

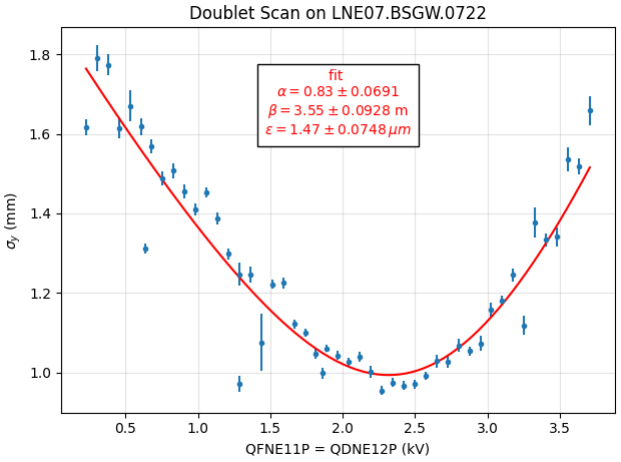
- Quad scan "close" to end of line
- Static bend between quads used and monitor for vertical measurement



Studies done and materiel provided by SY/ABT team

LNE00 Start	ϵ_x	α_x	β_x	D_x	ϵ_y	α_y	β_y	D_y
Design	NA	2.63	4.22 m	0.90 m	NA	0.52	5.39 m	0
A Measurement	3.04 µm	2.77	4.50 m	1.40 m	1.47 µm	0.83	3.55 m	- 0.23 m





Ion Source
Status

Slides by Davide Gamba on behalf of team working on source

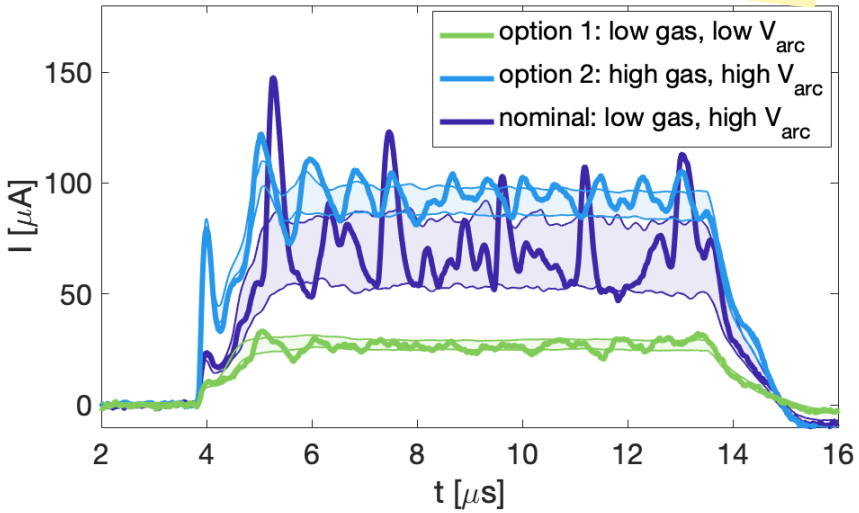
- **New (August 2020) insulation transformer**
  - Proven to be fine in **DC at 100 kV** for H^- operation
    - no partial discharge audible
    - no tests done for p operation
  - Decided to **run anyway** in **pulsed mode**
    - from ~60kV to 100kV in about 1 second before each beam
- **Consolidation of control and diagnostics**
  - Integration of **timing** with CERN control system
  - Single shot **beam intensity measurement** at the source now permanently available on Oasis
  - Added a viewport to allow for the installation of **beam screen** just in front of the source for diagnostic purposes
- **Still open issues:**
  1. **H^- pulse intensity stability**
  2. **Beam position drift over time**
- ***Note:*** *many details documented in NIBS2020 proceedings*

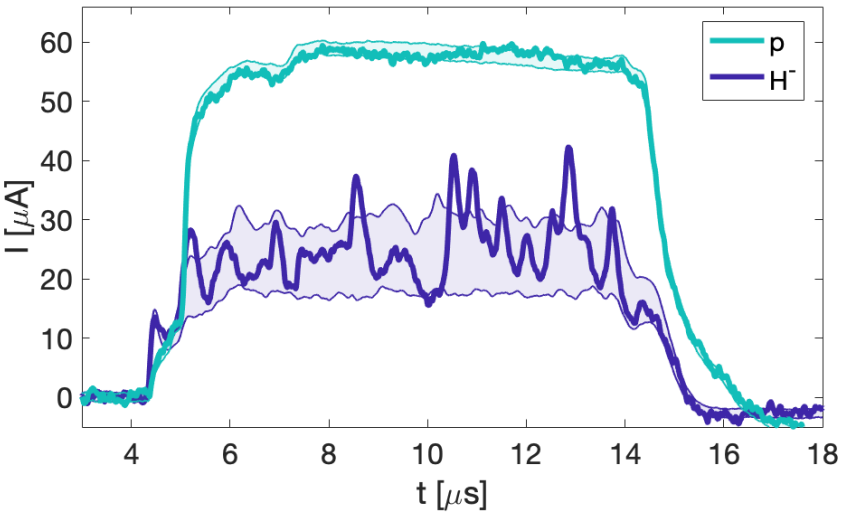
Ion Source

H^- pulse intensity stability

Slides by Davide Gamba

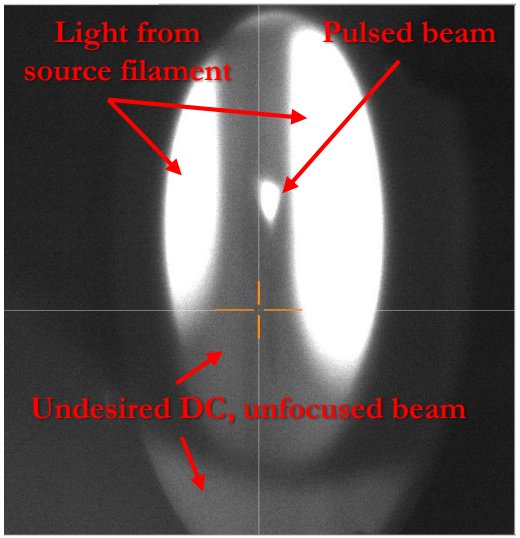
- Already identified in the past as **intra-pulse intensity fluctuation** of extracted H^-
- Two possible **workaround** found:
  - **Injecting more gas** (x5 more than usual)
  - **Working at low "arc" voltage:**
    - limited beam intensity
    - From experience, this mode seems to keep orbit stability for longer periods
    - Setting used for line commissioning => lower intensity fine with excellent profile monitor performance
- Issue **not observed on p** production:
  - This seems to exclude problems on the plasma generation and/or on the extraction system
  - Something is perturbing the delicate H^- production mechanisms
    - **Poor quality of used H2 source?** Hypothesis under investigation

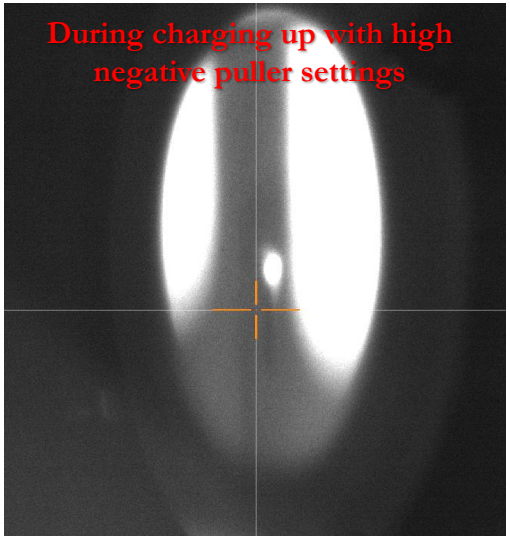


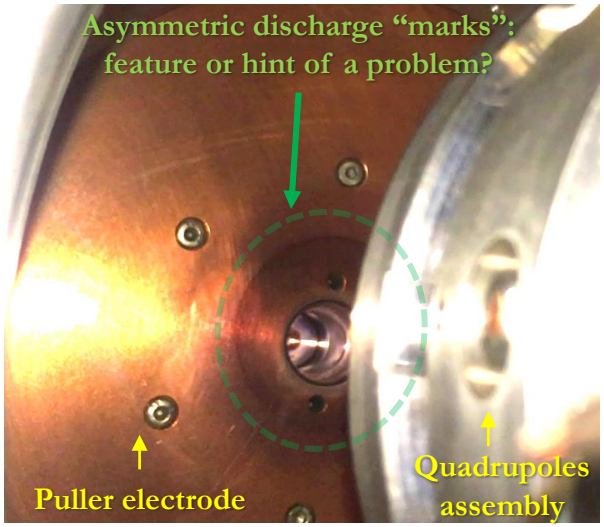


Ion Source
Beam position drift over time

- **Source** of the orbit drift **tracked back into the ion source assembly**
  - **Profile monitor** installed in LNS showed the orbit drift starting already right after the ion source
  - Movement could be observed on a **dedicated screen** installed in front of the ion source
- Movement (charging up) can be **triggered by higher negative puller voltage** settings
- Several observations points in the direction of **charging up happening in the puller region**
  - Proper investigation/fix may require to **disassemble the source**: **lengthy and risky manipulation!**
- Present **workarounds**:
  - B. Lefort working on **automatic steering** looking at turn-by-turn data in ring BPMs
  - New **beam screen with 10mm diameter hole** will be installed in February **to ease operation**

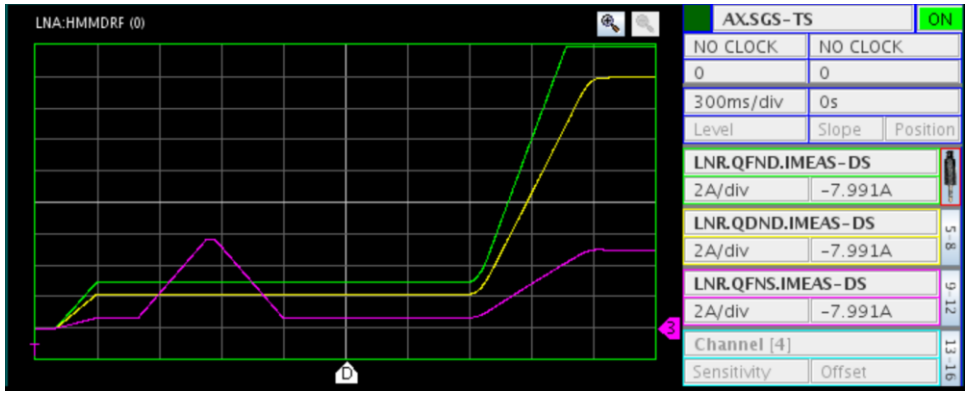




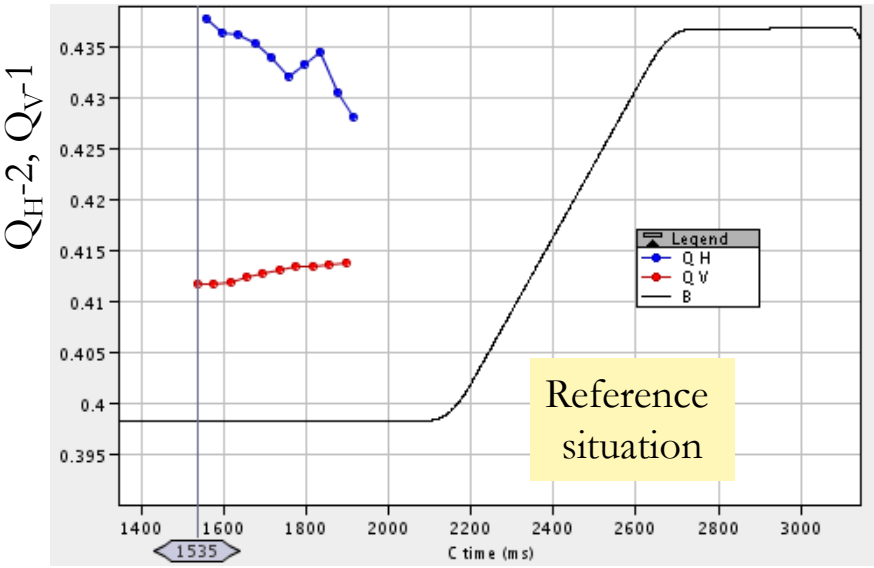


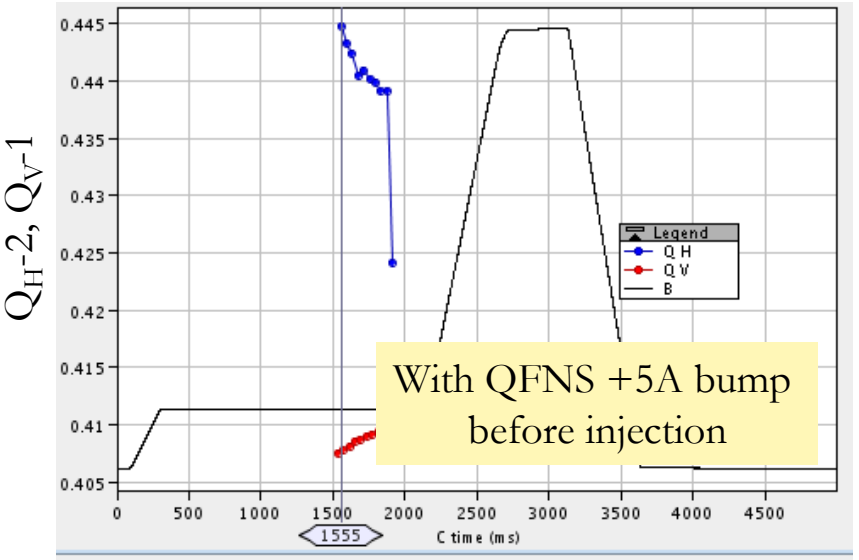
ELENA Ring Studies
Hysteresis Effects - Quadrupoles

- Measurements
  - Initial settings: $Q_H \approx 2.435$ and $Q_V \approx 1.412$
  - With +5 A bump on QFNS circuit before injection



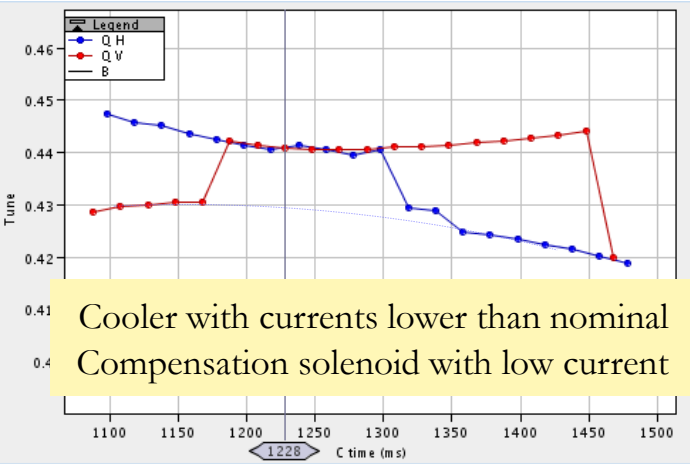
  $Q_H \approx 2.442$ and $Q_V \approx 1.408$
  - $\Delta Q_H \approx 0.007$ and $\Delta Q_V \approx -0.004$
- Expectations
  - Change of integrated gradient due to hysteresis (based on magnetic measurements)
    $\Delta kl \approx 4G/457\ Gm \approx \pm 0.008\ m^{-1}$
  - With $\beta_H \approx 7.8$ m and $\beta_V \approx 3.4$ m at QFNS location
    $\Delta Q_H \approx 4\ \Delta kl\ \beta_H/(4\pi) = 0.020$ and
    $\Delta Q_V \approx 4\ \Delta kl\ \beta_H/(4\pi) = -0.009$
- Observed effect smaller than expected



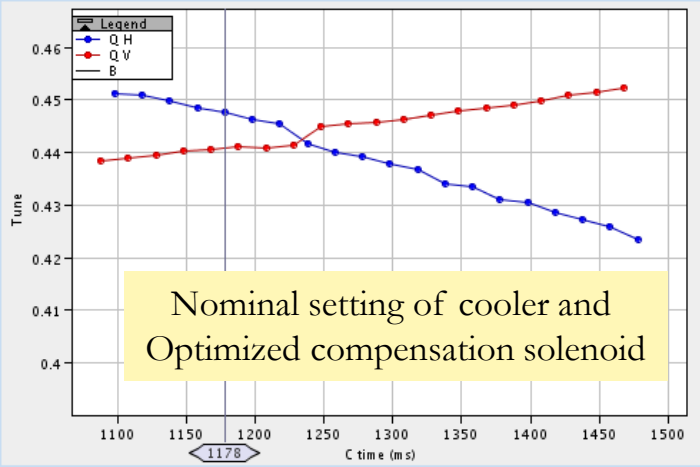


ELENA Ring Studies
Electron Cooler Studies

- Compensation of perturbations caused by the magnetic system of cooler
  - Orbit correction (and optimization of trajectory in cooler with circulating beam)
  - Compensation of coupling (between horizontal and vertical motion) introduced by longitudinal field
    - Tunes (fractional parts) programmed to cross
    - Signature of coupling is that measured tunes do not cross (left image)



Cooler with currents lower than nominal
Compensation solenoid with low current

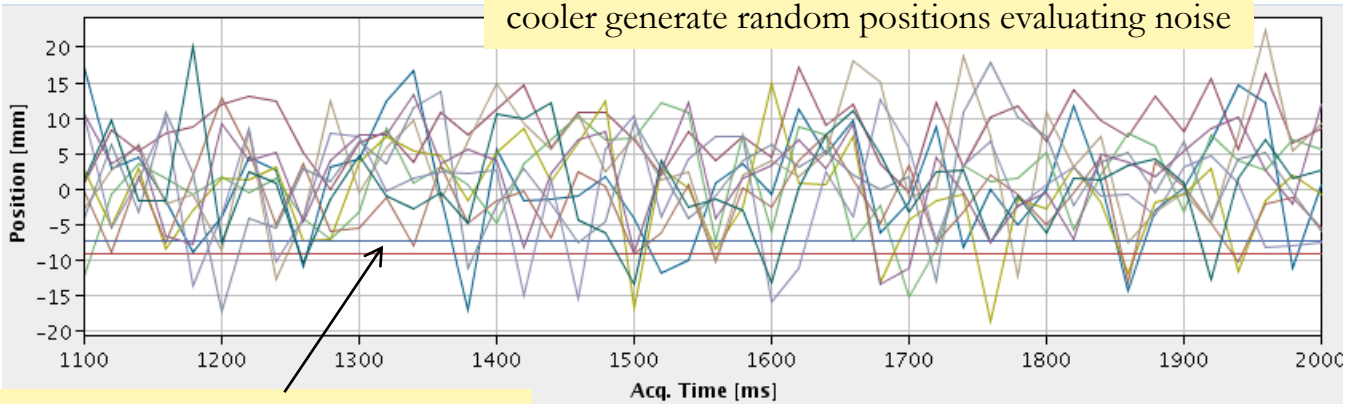


Nominal setting of cooler and
Optimized compensation solenoid

  - Adjustment of working point
    - Focusing in both planes introduced by cooler and compensation solenoid

ELENA Ring Studies
Electron Cooler Studies

- Measurement of electron beam position inside cooler
  - With pick-ups used as well for circulating beam
    - Electron beam current modulation to generate pick-up signal (at revolution frequency for acquisition with electronics for circulating beam)



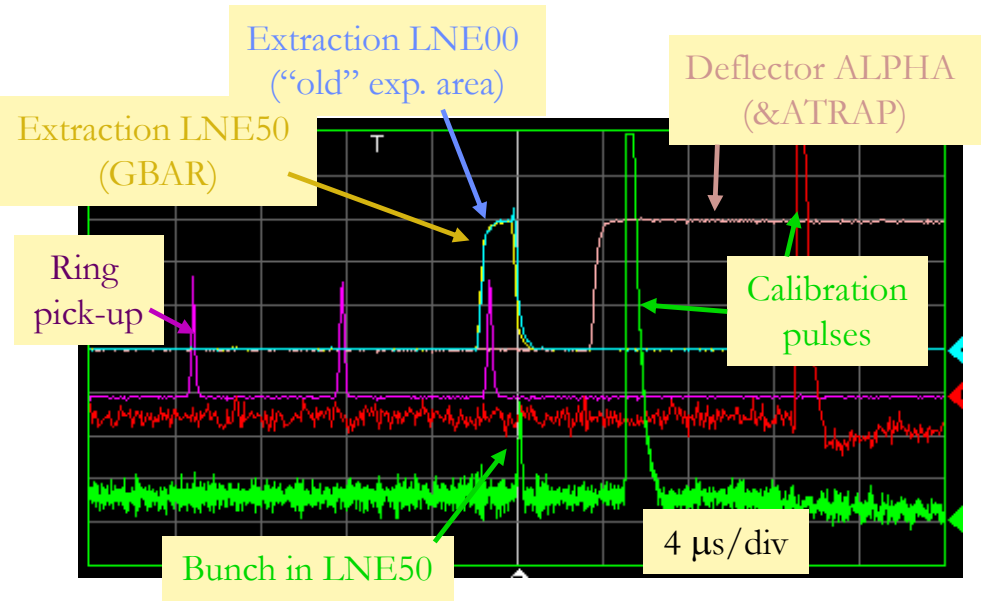
    - Will help to adjust overlap between circulating and electron beam and speed up electron setting-up with antiprotons (and, in principle any other ion with appropriate life-time)!

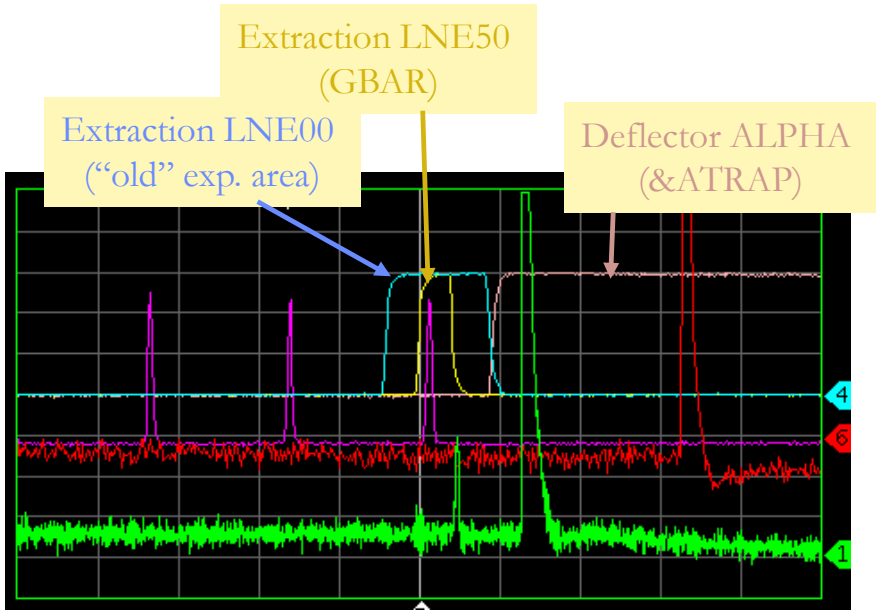
- Aim for next weeks: keep (magnetic system of) cooler on during H^- operation to gain experience with more complicated machine
  - Test effect of electron beam on circulating H^-: low life-time? Any chance to see cooling effect? ..

ELENA Ring Studies
Extraction Timing Tests for h=4

Only one out of four "buckets" filled with H^- (nominal: all buckets filled with identical antiproton bunches)

- Fast deflectors to extract beam out of ring pulse correctly (e.g. GBAR extraction quarter of turn later for case on right side with three experiments in "old" zone expecting beam)
- Fast deflectors in line (see below deflection towards ALPHA/ATRAP) did not pulse correctly (corrected in between)





Programmed destinations: ALPHA and GBAR

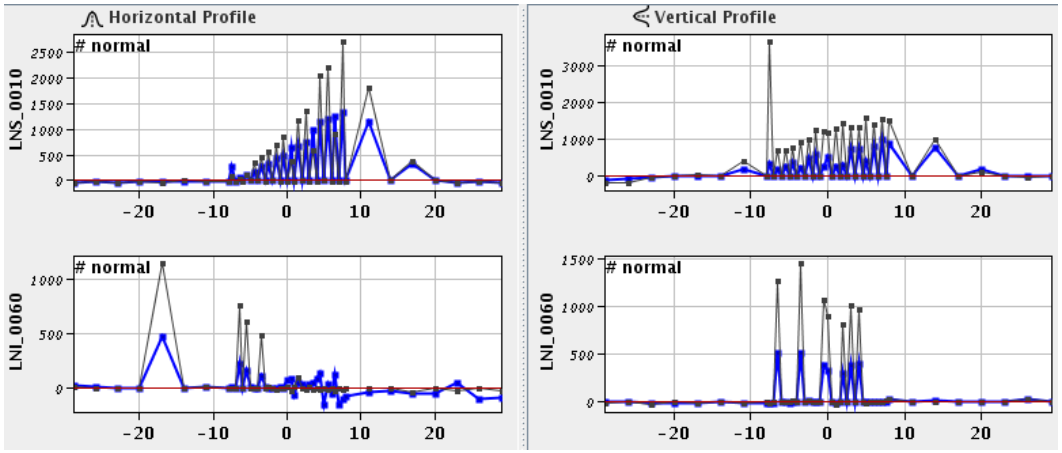
- Both deflectors pulse simultaneously
- Bunch #3 seen in LNE50 (GBAR) line

Programmed destinations: AEgIS, ALPHA, ASACUSA and GBAR

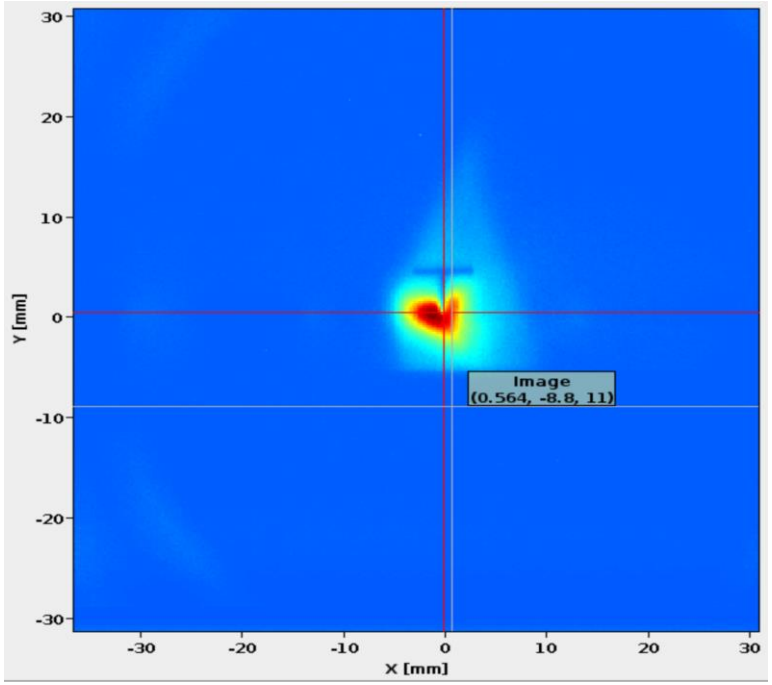
- LNE00 extraction later than LNE00 extraction
- Bunch #4 seen in LNE50 (GBAR) line

Broken BTV Screen

- BTV118 luminescent screen between injection septum and kicker and observed with camera
  - Heavily used to observe H^- beam from source tending to "move around"
  - Movement system damaged probably related to heavy use (regular in/out movements)
  - Screen now blocked in out position since 15th October



Reliable operation possible with last profile monitor LNI.0060 in front of injection septum (despite many missing channels)!!

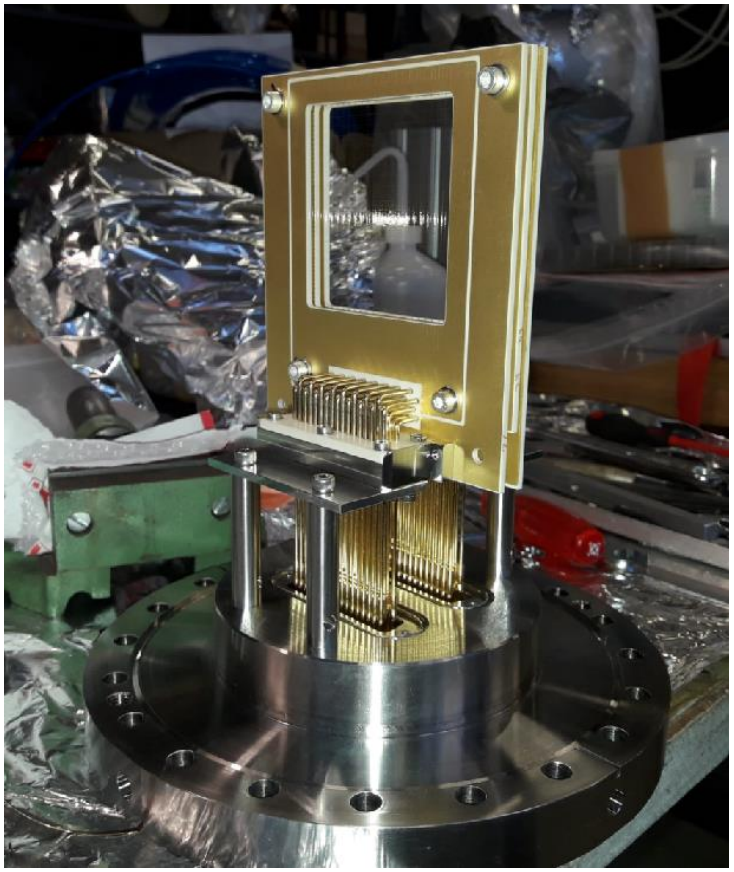


One of the last BTV118 acquisition (now blocked in "OUT"position)

- Strategy for antiproton run(s)
  - Spares and/or upgraded mechanics not available on time for 2021 run
  - Replacement of profile monitor just before injection septum instead in spring/early summer

Profile Monitors

- Tremendous progress since about a year with acquisition electronics etc.
  - Lines towards GBAR, ALPHA and BASE and one of ASACUSA lines fully equipped with monitors
  - All installed monitors equipped with front-end electronics
  - Good results so far despite missing channel problem
    - Clear information on beam position and most profiles good enough for optics studies
    - Working well with low H^- intensities



- Completion of installation and long-term
  - Availability of pieces to complete lines about fine
  - Concerns on long-term reliability
    - Leaks of DN50 feed-throughs on "bellow units"
    - Missing channel problem probably related to bake-outs
    - Attempt to exchange of feedthrough by CERN workshop
  - Electronics handed over to CERN engineer
  - Investigations by SY/BI on CERN made solutions for electrodes and bellow units

Status and Outlook

- Preparations for transfer line commissioning (details see talk by Francois)
  - Impact of COVID19 "limited"
    - Installations (in particular transfer line cabling) resumed soon after restart of on-site activities
  - Ready to start work with beam (other than source tests) in ring be second half of August

- Commissioning activities
  - Transfer line commissioning in full swing
    - Beam reached end of all available lines with moderate effort, including the longest ALPHA line
    - Matching looks reasonable everywhere
      => congratulations to the team doing the solid design!
    - Systematic investigations (quad-scans …), possibly followed by some rematching on-going
  - In parallel, many studies to better understand ELENA ring and speed up antiproton restart
  - Improved understanding of source vital – now excellent reproducibility of ring and lines
  - Availability and good performance of profile monitors!
  - Concern: test of perturbations of AEgIS solenoid on transfer line possible only soon before restart
    - Steerers strong enough to correct, may require some coordination between experiments

- On track for first 100 keV antiproton physics run for all experiments from August 2021! (for details see next talk by Laurette)