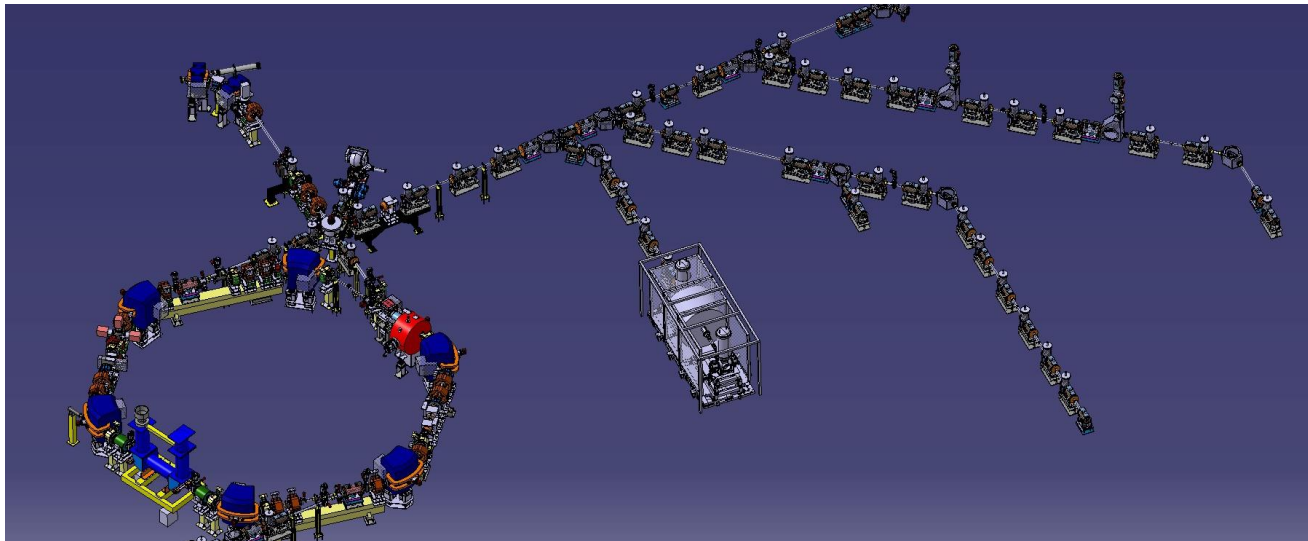


# ELENA Status



C. Carli on behalf of the AD/ELENA team(s)

AD Users Committee, 23<sup>rd</sup> January 2018



- Introduction
- Results from ELENA Commissioning
- Electron Cooler
- Plans for 2018
- Summary and Outlook

# Introduction

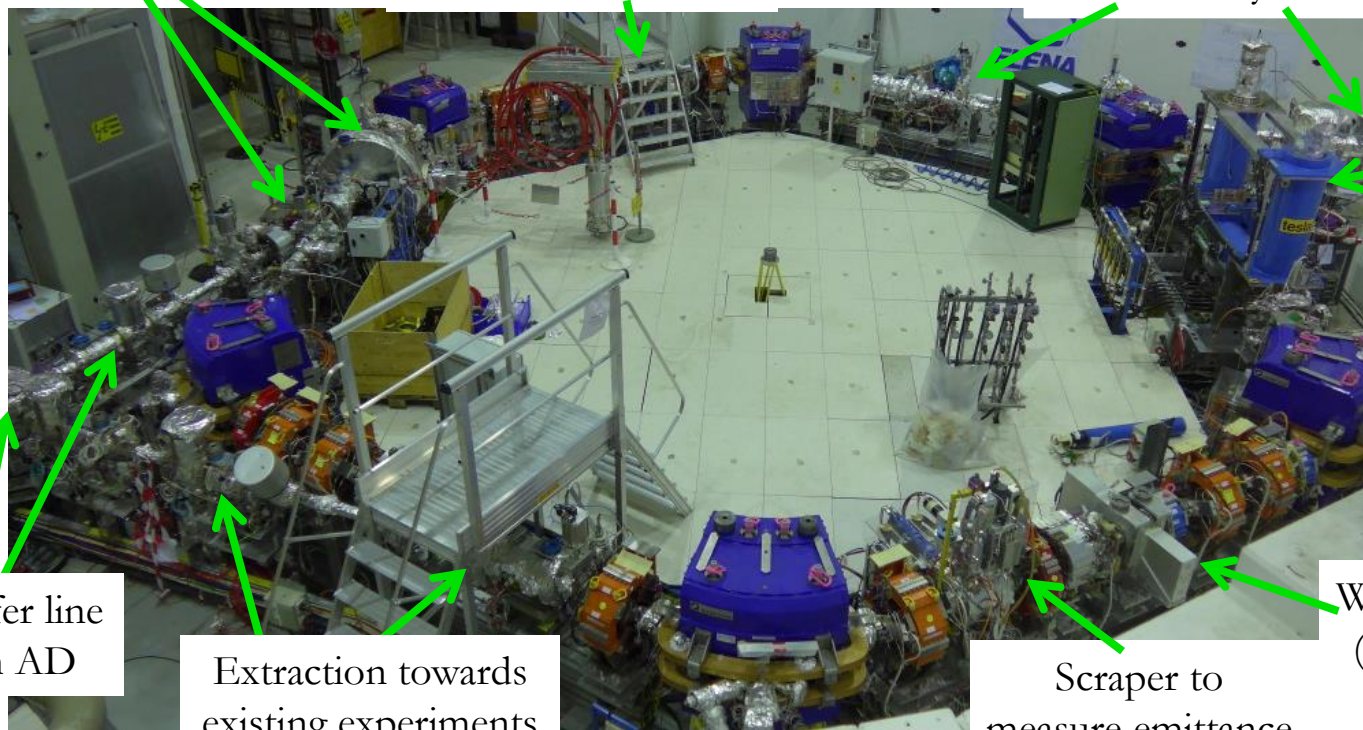


- Controlled Deceleration of 5.3 MeV Antiprotons from AD down to 100 keV
- Improved Capture Efficiency of (typical) existing Experiments and new types of Experiments (GBAR)
- Magnetic ring and injection line, electrostatic ejection lines (effective at low energies)
- Challenges related to low energy (e.g. magnetic field quality) and intensity

Injection with magnetic septum and kicker

Magnetic Pick-up  
(Schottky diagnostics for intensity, LLRF..)

Extraction towards new experimental zone (GBAR) - fast deflector followed by el.-static transfer lines



Electron Cooler installed, bake-out soon

Transfer line from AD

Extraction towards existing experiments

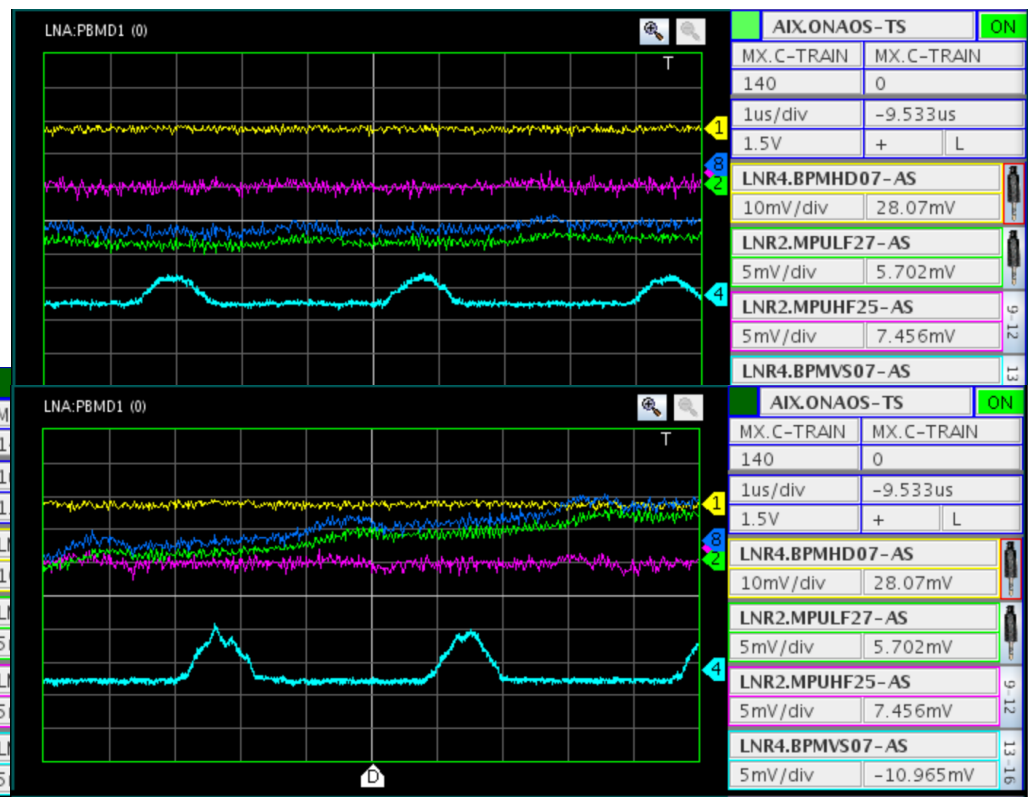
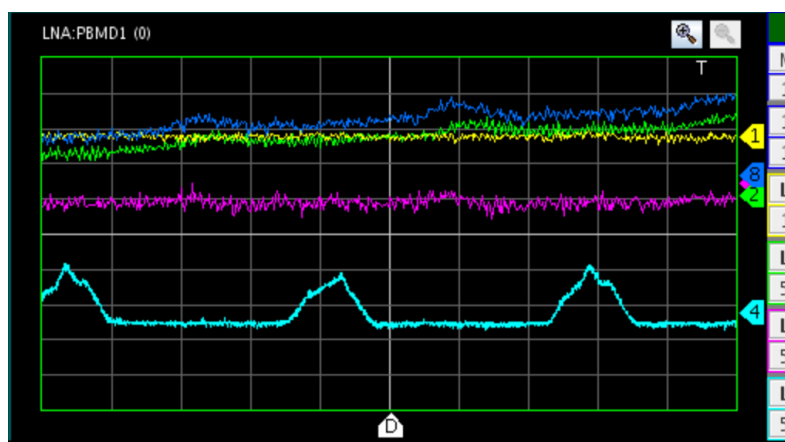
Scraper to measure emittance

Wideband RF cavities (very similar to new PSB cavities)

# Results from ELENA Commissioning – with H<sup>-</sup> Beams from Source



- Source operated now at 85 keV instead of 100 keV because of problems with the isolation transformer
- Few 100 ms life-time observed with RF (very basic functionalities) since spring
- Successful commissioning of orbit system, partly tune system and scraper
- Issues during summer: poor reproducibility (shot-to-shot fluctuation and long term drift) of H<sup>-</sup> injection, times technical problems with source, more time than expected to install GBAR line
- Improved reproducibility of injection from about end of September (Why? Just careful tuning?)
- Two bunches with about 1 to 2.10<sup>6</sup> H<sup>-</sup> ions each after 140 ms
  - Ready to continue commissioning of systems as RF, tune measurement ...?
  - Measurements from 3<sup>rd</sup> October (had again been difficult on 2<sup>nd</sup> October)



# Results from ELENA Commissioning – with H<sup>-</sup> Beams from Source

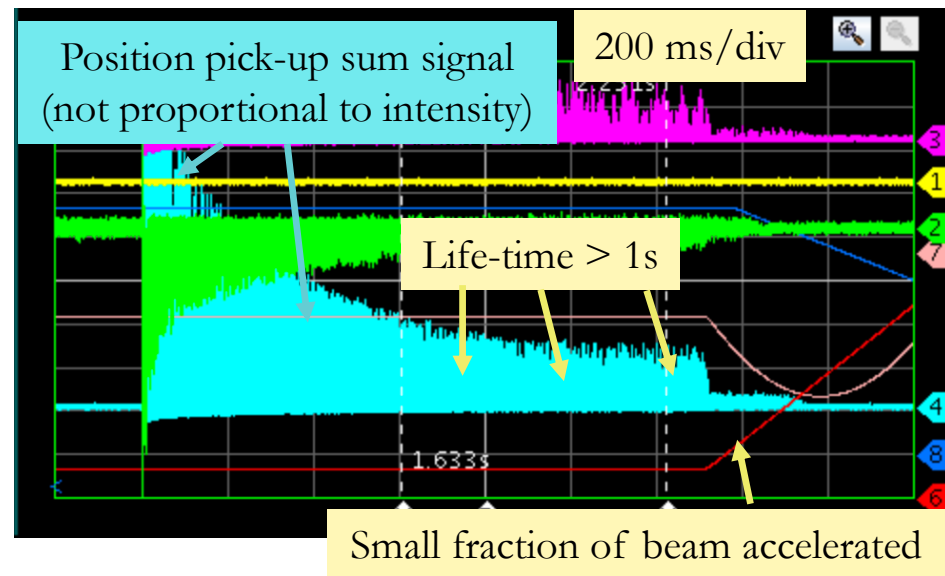
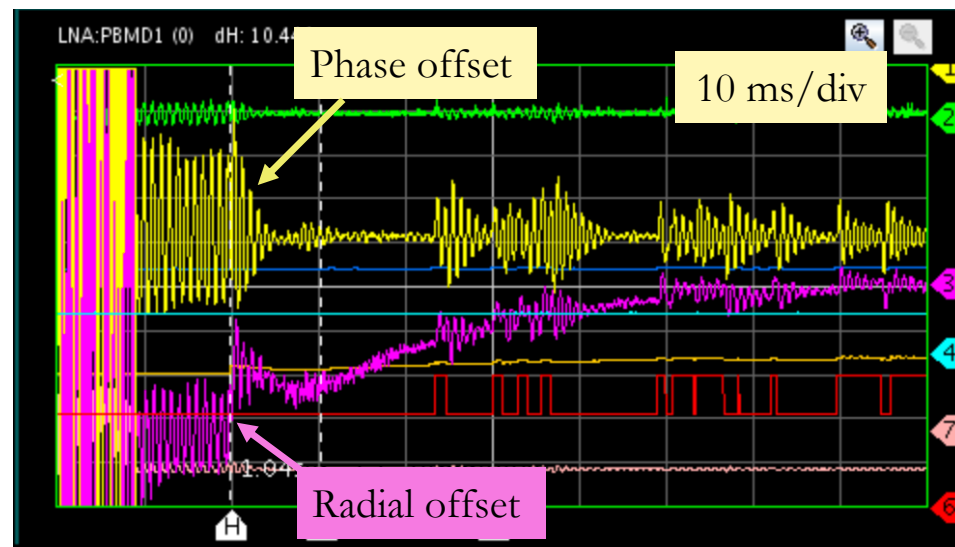


## ■ RF System

- Issues with noise on magnetic pick-up  
=> RF system uses sum signal of position pick-up to detect beam phase
- Phase and radial loop operational
- Improved life-time with phase loop
- Sometimes sudden jumps of frequency from “B-train” excites synchrotron oscillations

## ■ Recent results

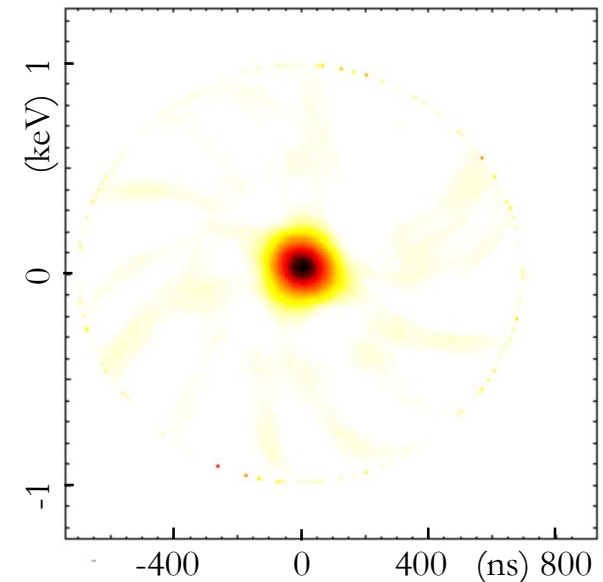
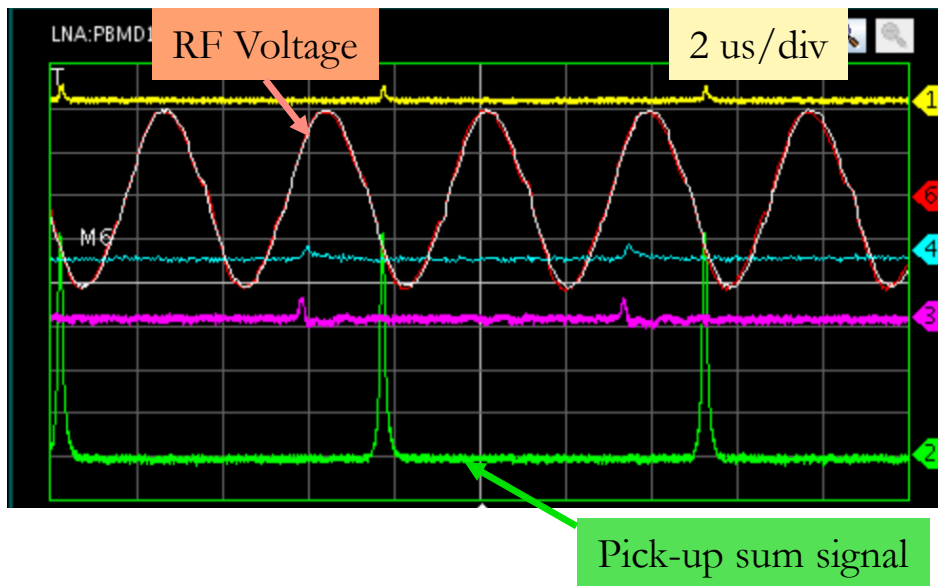
- Improved life-time with phase loop of RF system
- Allowed further increase of life-time to > 1s by adjustments of quadrupole currents
- Small amount of beam accelerated (was not aim at that time, fast transition from flat-bottom to ramp ...)



# Results from ELENA Commissioning – with H<sup>-</sup> Beams from Source



- H<sup>-</sup> extraction into LNE50 line towards GBAR
  - Modification of timings system: revolution train generated by the Low Level RF system (LLRF) to trigger source and fast deflector for extraction
  - Possible to inject with RF on (into “buckets”) to keep small longitudinal emittances and short bunches (had not been foreseen initially)
  - Fast deflector for extraction synchronized with RF (even for RF not yet synchronized with external reference)

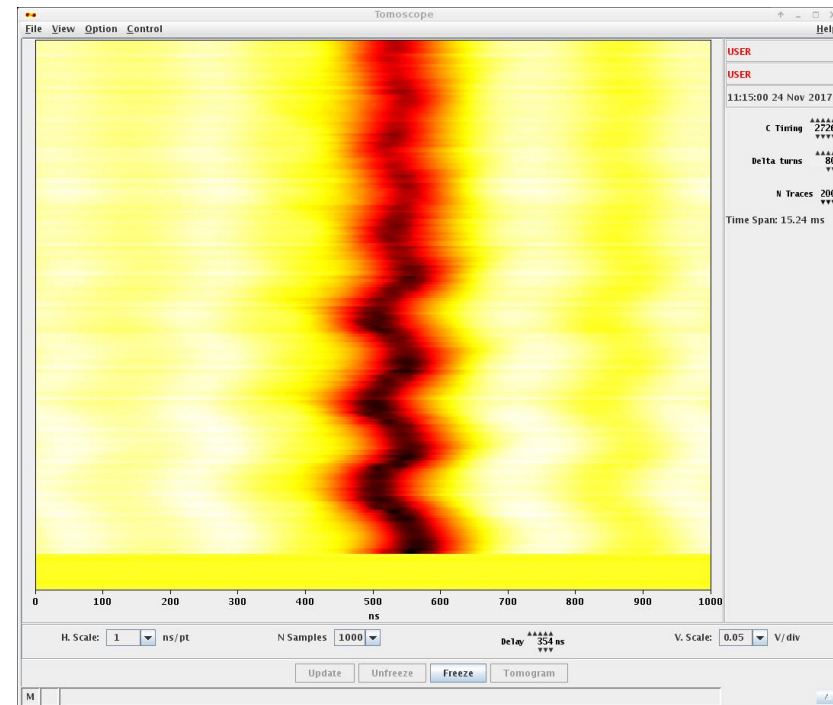
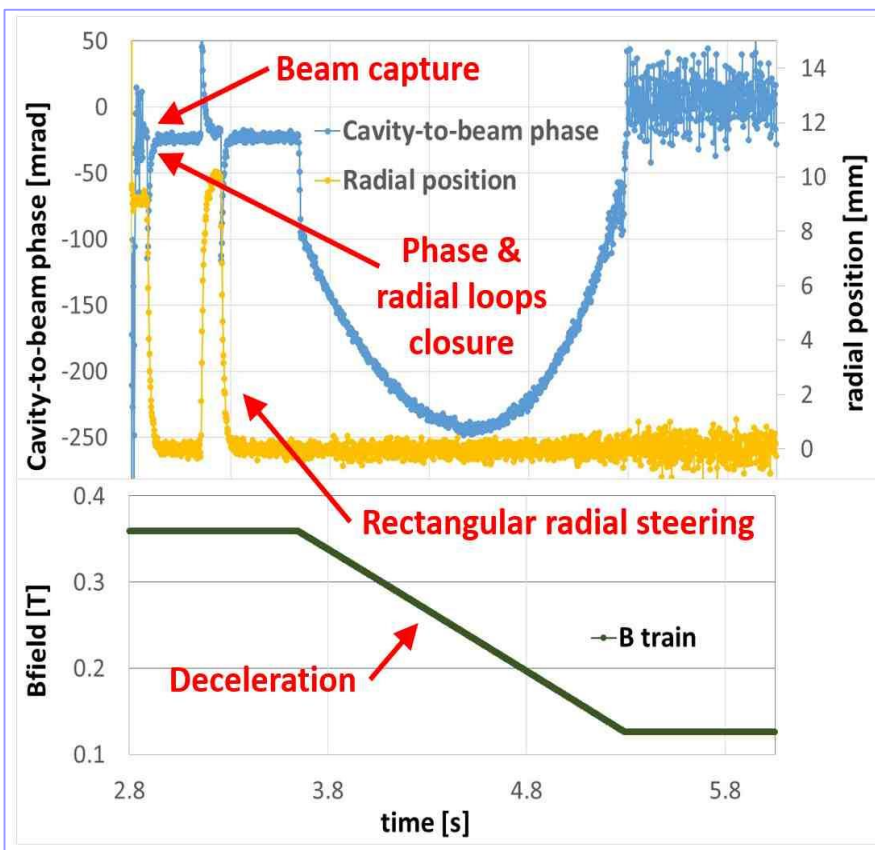




# Results from ELENA Commissioning – with Antiprotons from the AD



- Successfully deployed in ELENA bunch to bucket transfer from AD ( $\sim 3.2E7$  pbars) of radial loop

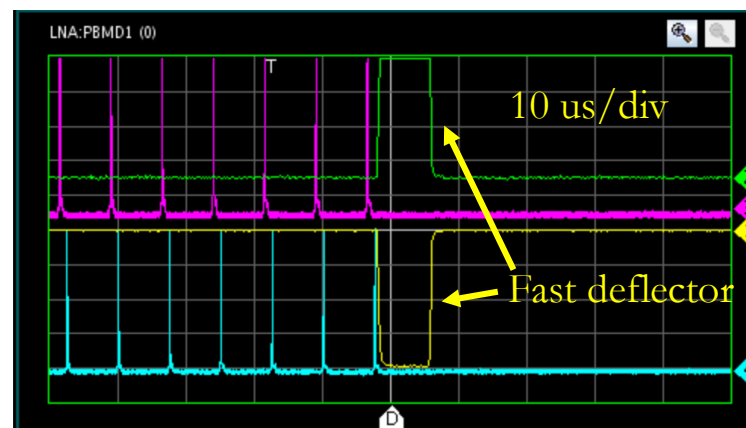
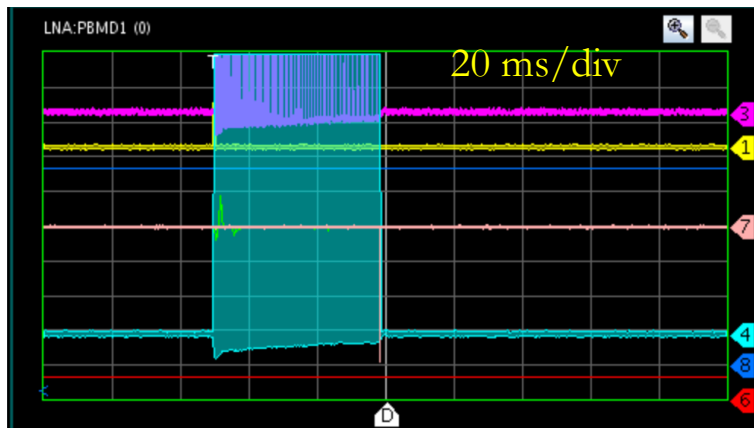


Bunch transferred into ELENA waiting bucket - Phase loop damps synchrotron oscillations

# Results from ELENA Commissioning – with H<sup>-</sup> Beams from Source

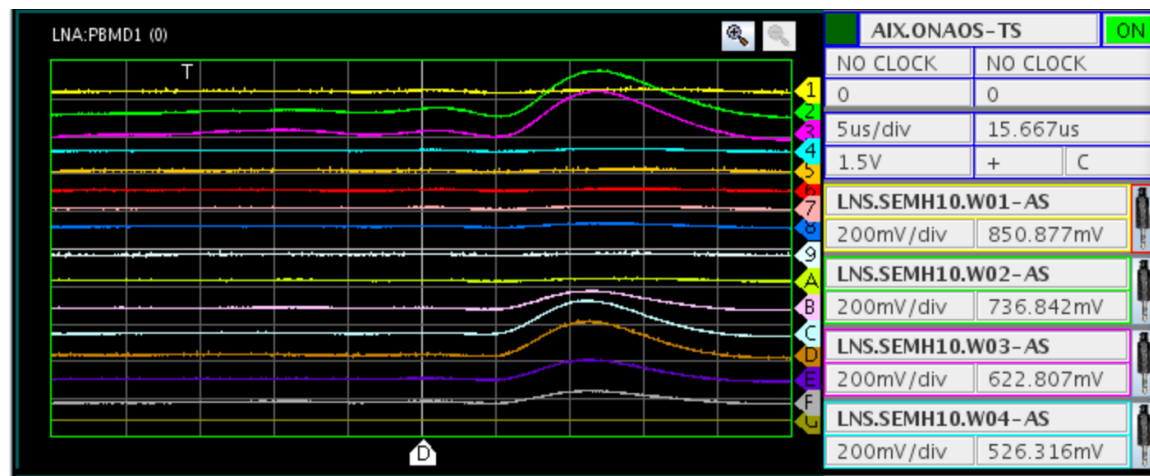


- H<sup>-</sup> extraction into LNE50 line towards GBAR (cont'd)



Acquisitions of signals from position pick-ups in ring

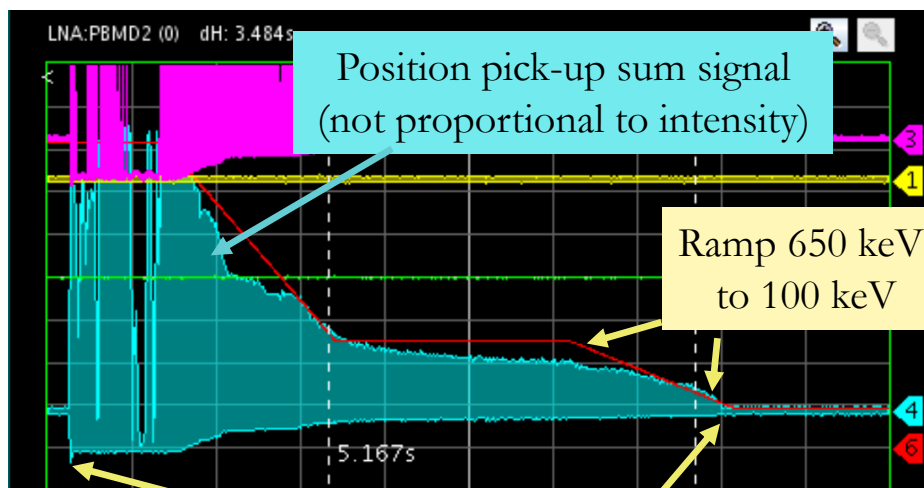
- Acquisition with profile monitor in LNE50 line
  - Signals clearly due to beam .. .. difficult to interpret
  - Hypothesis: vertical profile (horizontal wires) observed and connections not correct



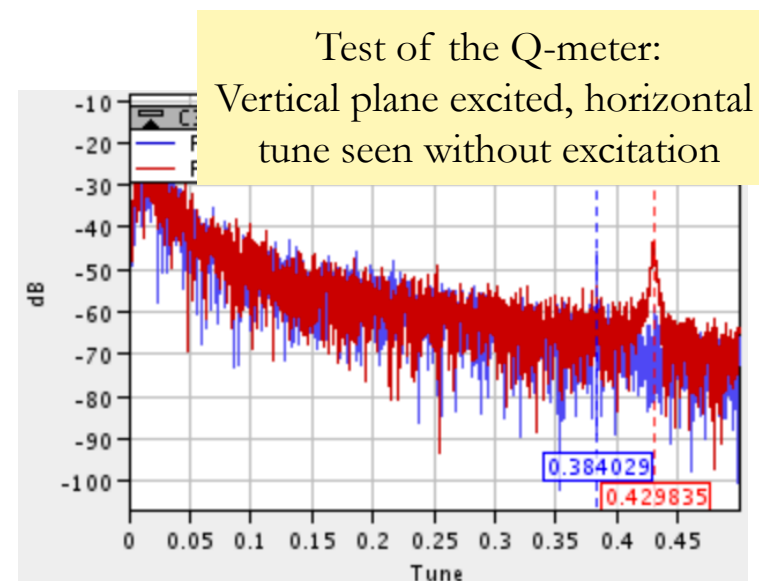
# Results from ELENA Commissioning – with Antiprotons from the AD



- With Antiprotons from the AD (typically one or two 8hr-shifts per week)
  - Successful transfer from the AD, injection with bunch-to-bucket transfer, correction of injection oscillations tested, tests of instrumentation ....
  - Some antiprotons (fraction of injected beam) decelerated until end of ramp without electron cooling (lost at 100 keV arriving at the low energy plateau)



Beam in machine during ~6.5 s until end of 2<sup>nd</sup> ramp  
(not yet nominal cycle, longer plateaus)



- Electron cooler installed now and prepared for bake-out: looking forward to completion of ELENA commissioning next year aiming at demonstrating nominal cycle



# Results from ELENA Commissioning – with Antiprotons from the AD



## ■ Correction of injection oscillations

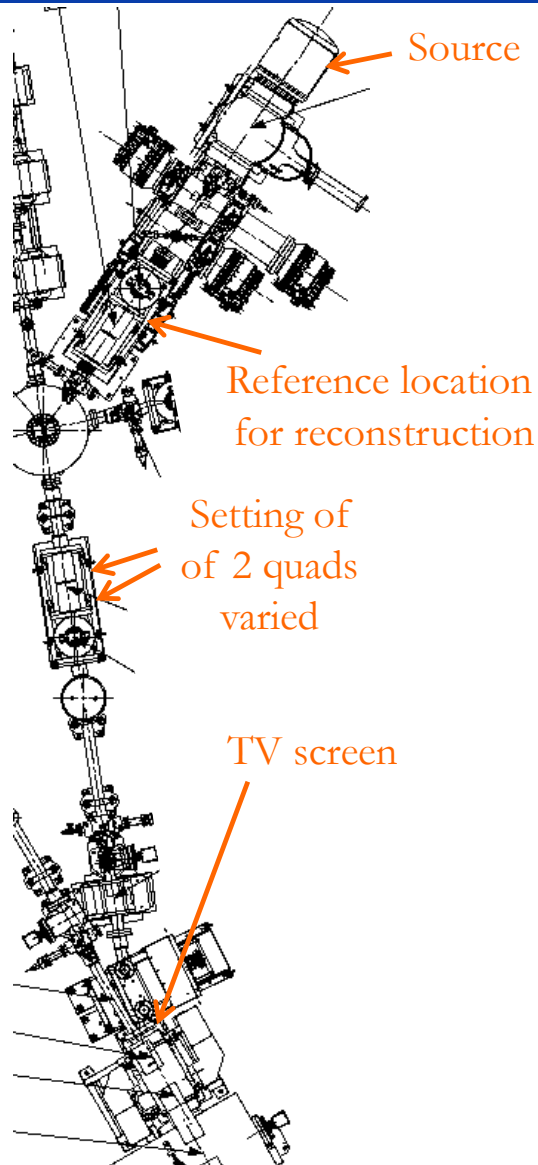
- Use sum signal to detect turn-by-turn positions
- Quantify injection mis-steerings
- Compute correction

## ■ Procedure set up and tested

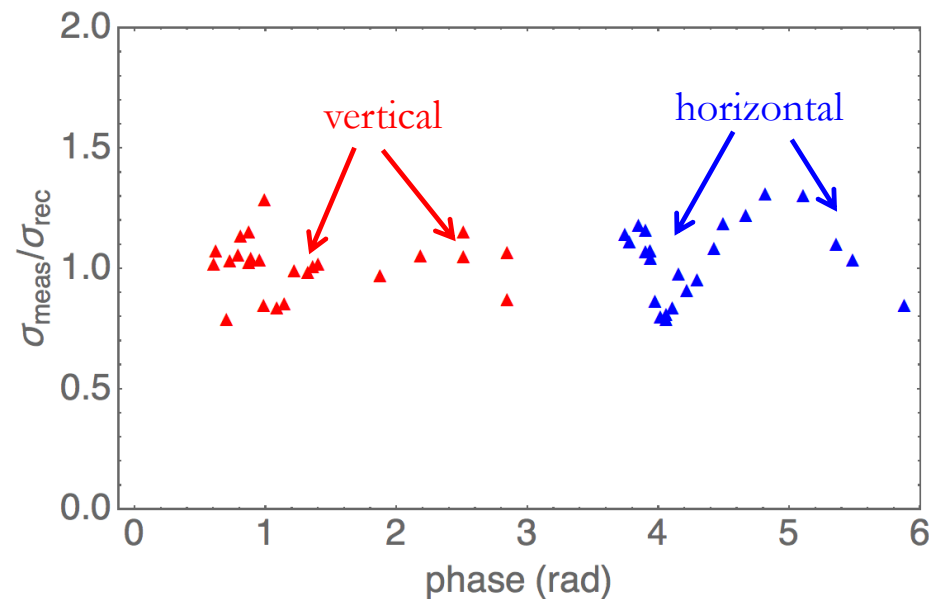
## ■ Good basis to work on deceleration together with bunch to bucket transfer



# Results from ELENA Commissioning – Line from Source to Ring



- Quadrupole scan to measure beam characteristics
  - Variation of the setting of (two) quadrupoles
  - Observation of beam sizes with a monitor (TV screen between septum and kicker)
  - Reconstructed characteristics at the reference
    - Hor.:  $\epsilon_{x,rms} = 4.71 \mu\text{m}$ ,  $\beta_x = 1.4151 \text{ m}$  and  $\alpha_x = -3.0061$
    - Vert.:  $\epsilon_{y,rms} = 5.08 \mu\text{m}$ ,  $\beta_y = 0.8381 \text{ m}$  and  $\alpha_y = -2.6142$
- Improved setting of line not (yet) tested



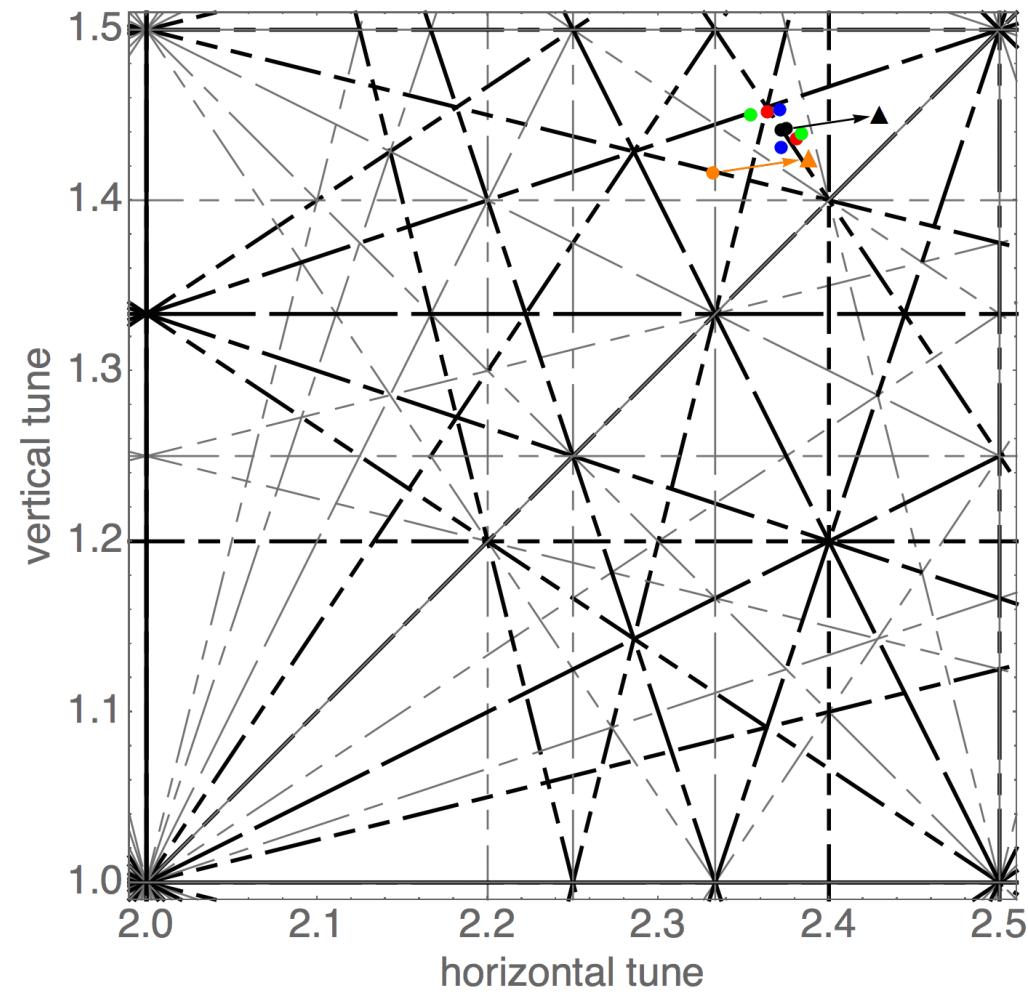
Ratio between measured beam size and beam sizes from reconstruction

# Results from ELENA Commissioning



## Working points (at 85 keV with H<sup>-</sup>)

- Tune: number (average) of transverse oscillations per revolution (two tunes for the horizontal and vertical plane)
- Working point is the combination of the two tunes – must avoid “resonances”
  
- Black: measured working point with initial quadrupole currents
- Red, blue and green: current of one of the three quadrupole circuits changed by  $\pm 0.05$  A
- (Orange: working point from model with programmed quad currents)
  
- Reassuring that behavior about as expected

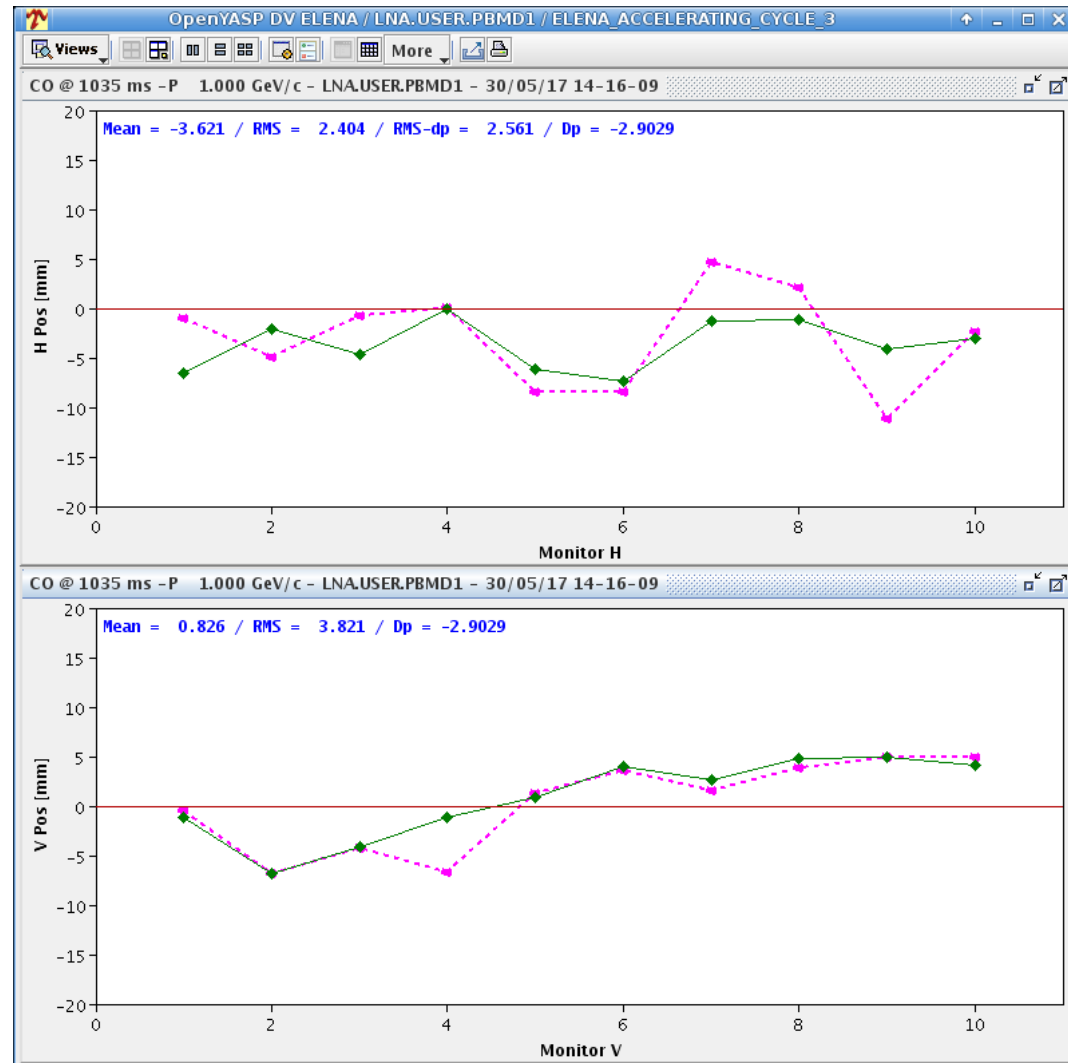


Resonance diagram with working point(s) close to 5<sup>th</sup> order resonance

# Results from ELENA Commissioning – first orbit corrections for H<sup>-</sup> at 85 keV



- Orbit is the transverse position of the beam as a function of the longitudinal position
  - Measured at some locations with “pick-ups”
  - Beam not at center of chamber due to perturbations (stray fields magnet misalignment ..)
  - Corrector dipoles to improve
  
- ⊕ Confidence in basic machine optics



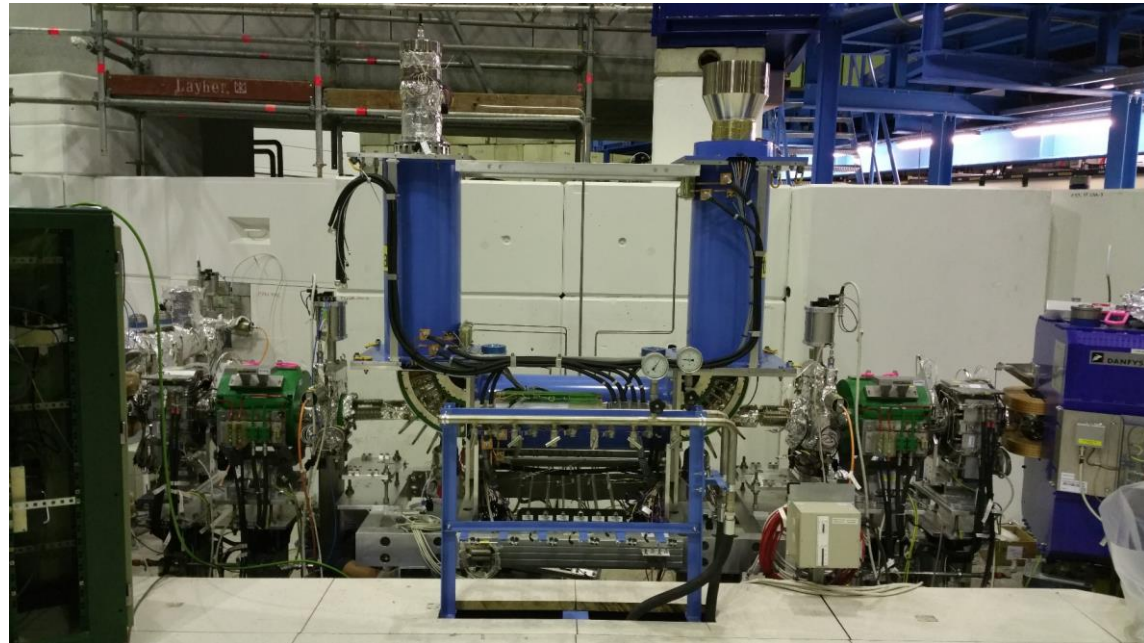


# Status of Electron Cooler



- Cooler installed beginning of December
  - Delay due to issue with alignment (position of upstream vacuum valve)
  - Vacuum leak after first bake-out last week 2018

*For details see presentation  
by Lars Joergensen*





# Plans for 2018



- Consolidation of injection line and injection into ring
  - Increase of  $H^-$  injection efficiency and consolidation of improved reproducibility
    - Injection matching and empirical improvements
  - Setting up of proton injection and cycle
    - Expect similar issues than for  $H^-$
- Acceleration of  $H^-$  and possibly proton beams
  - For machine studies without taking precious antiprotons
- Commissioning of electron cooling
  - Behavior of 100 keV beam with magnetic system of cooler on?
  - Observe cooling preferably with beams from the source
    - Probably cooling studies to be done with protons (short  $H^-$  life-time due to stripping)
- Further consolidation of instrumentation and corrections (orbit tune)
- New isolation transformer for source and 100 keV  $H^-$  and proton beams in
- Setting up of complete antiproton cycle to complete ELENA commissioning  
... highest priority to gain confidence before the installation of the new lines!
- First beams to GBAR
  - Coordination with cooling studies using protons and inversed polarity?
  - When does GBAR expect  $H^-$  and antiproton beams?

# Summary and Outlook



- ELENA commissioning up to the end of 2017
  - Progress H<sup>-</sup> beams from source and antiprotons from the AD, setting-up and testing of most systems – no showstopper
  - Less progress than expected at the beginning of the year due to various problems (e.g. poor reproducibility of the injection)
  - Electron cooler installed at the end of the year not yet available for commissioning
- Aim for 2018
  - Completion of ELENA ring commissioning
  - Get confidence that machine works properly by having an operational antiproton cycle with deceleration, cooling and extraction
  - First beams for GBAR
- Plans for after 2018
  - Installation and commissioning of lines to old experimental area during LS2
  - 100 keV antiprotons for all experiments after LS2 from 2021 on

# Contributors to the ELENA Project

