LEIR Commissioning

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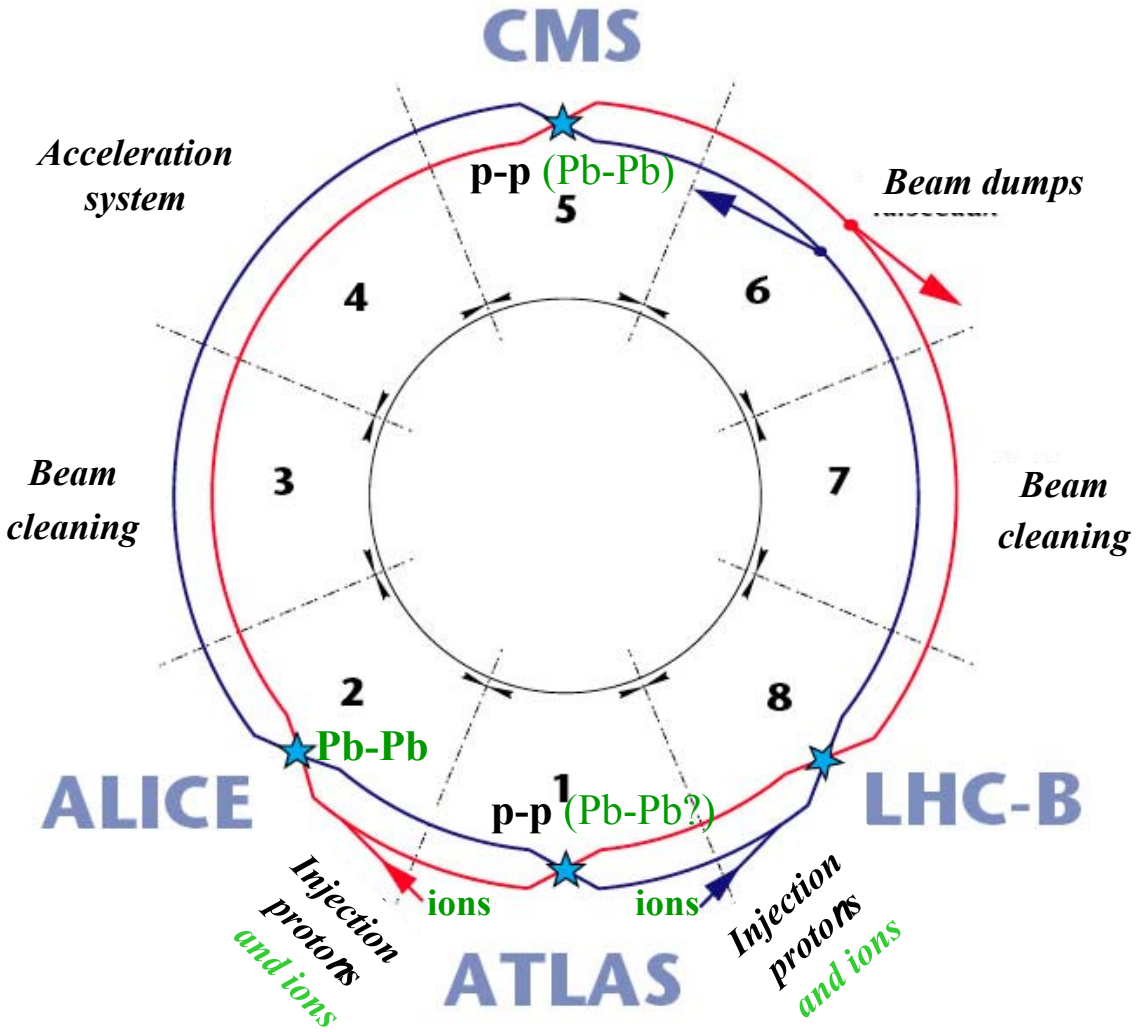
- Introduction
  - Motivation (why LEIR)
  - LEIR overview
  - General remarks
- LEIR Commissioning :
  - Brief Summary
  - Expected and unexpected difficulties
  - LEIR status
- Summary and outlook

Many people from several departments have contributed to prepare, to construct and to install LEIR and in LEIR commissioning:

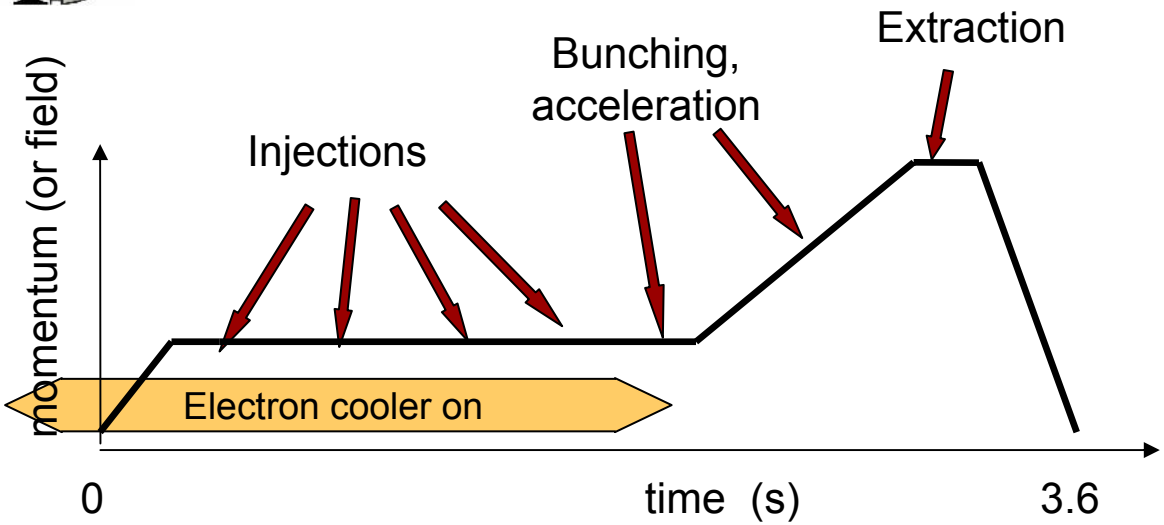
- I-LHC project leader(s) : S. Maury (and before K. Schindl)
- LEIR project leader : M. Chanel
- LEIR commissioning team : P. Belochitskii, L. Bojtar, C. Carli, M. Chanel, K. Cornelis, B. Dupuy, J. Duran, T. Eriksson, S. Gilardoni, D. Manglunki, E. Matli, C. Oliveira, S. Pasinelli, J. Pasternak, F. Roncarolo, G. Tranquille
- Many people from several CERN departments and many groups (almost all AB groups, AT/MEL, AT/VAC, AT/MTM, TS/CV, TS/EL, TS/SU, …) have constructed and installed equipment:
  - Almost all equipment was available on time,
  - Impossible to compile a complete list (note that more than 100 contributors are on the I-LHC mailing list).
- Contributions from other institutes (e.g. electron cooler constructed from a BINP team)

Introduction
Why LEIR

- LHC (Large Hadron Collider) main diet : protons.
- In addition, ion operation (at the beginning Pb):
  - ALICE experiment optimized for ion-collisions, others interested.
- ➢ Pre-LHC ion chain not suitable (dense bunches needed)
- ➢ Fundamental upgrade of the ion chain:
  - New ECR ion source,
  - ➢ Accumulation of Pb^{54+} at low energy in the Low Energy Ion Ring (LEIR).
  - New RF gymnastics in the PS, low beta stripping insertion … .



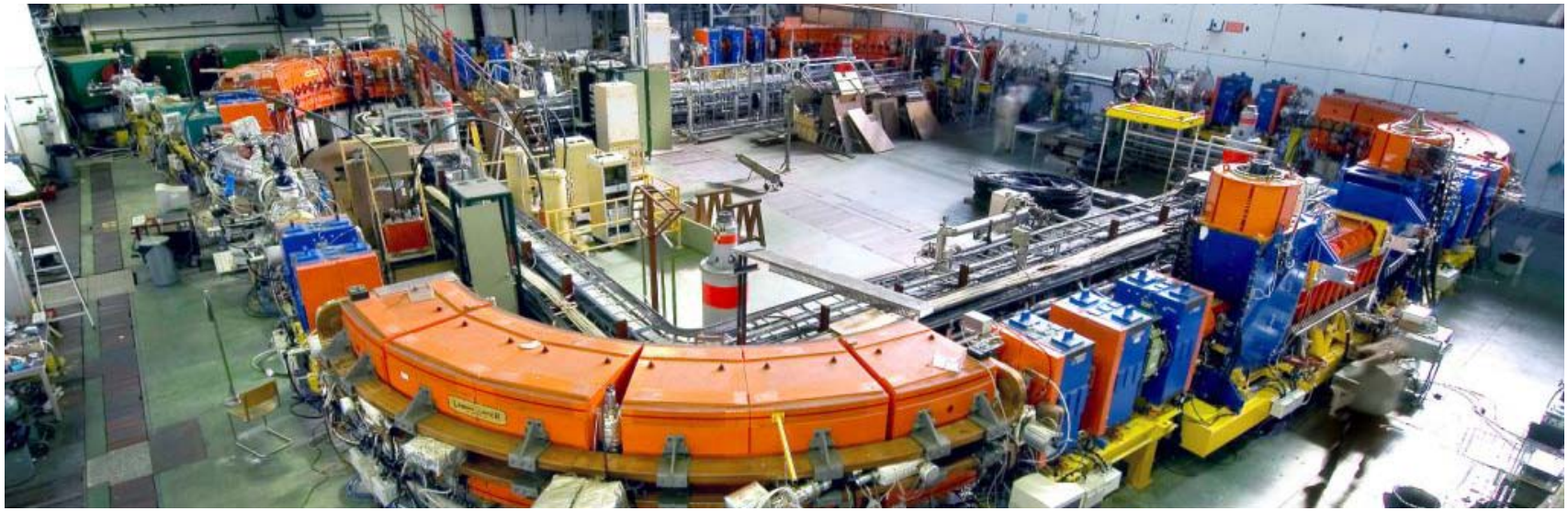
Introduction: LEIR overview



Sketch of a nominal LEIR cycle

Accumulation alternates :

- Elaborate multiturn injection :
  - Stacking in all three phase planes,
  - Momentum ramping and dispersion at the injection point,
  - 70 turns with >50% efficiency every 200 ms to 400 ms.
- Fast electron cooling :
  - New state-of-the-art cooler constructed by a BINP team.



Introduction
General remarks

- Aim of LEIR commissioning : "Early LHC Pb beam" for first ion run(s)
  - Less demanding for injectors and LHC) :
  - LEIR provides within a shorter 2.4s cycle (one injection ?) one bunch with :
    - 2.25 10^8 ions,
    - transverse (normalized RMS) emittances <0.7 µm,
    - Longitudinal emittance <0.025 eVs/u.
  - "Nominal" LEIR beam will come later.
- Commissioning in phases :
  - Lines in May and June 2005,
  - LEIR ring in autumn 2005 and beginning of 2006.
- First phase of LEIR ring commissioning with O^{4+} :
  - Beam rigidity very close to Pb^{54+},
  - Longer life-time expected (is that true ?) and cooling times,
  - ➢ Simplifications for diagnostics expected.

Highlights of LEIR commissioning
Brief summary

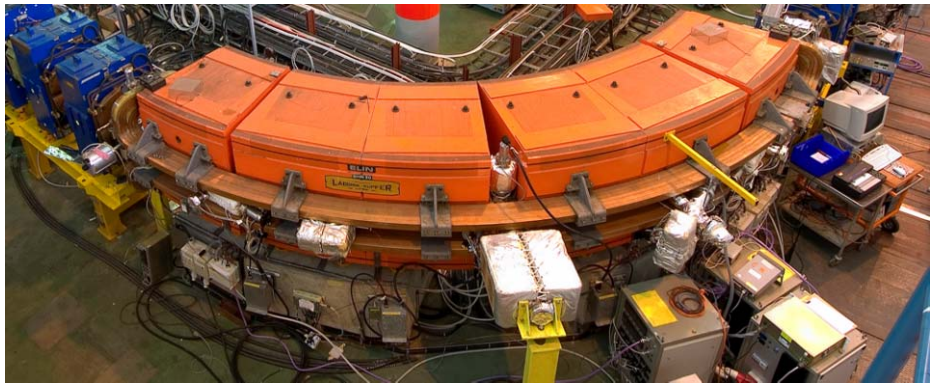
- Start of injection line commissioning (Hardware Tests …) in May 2005 (in parallel with installations).
- Arrival of the beam at the injection region: 6 July 2005.
- Completion (as planned) of LEIR ring installation over the summer 2006.
- LEIR ring commissioning start (with O^{4+}) : October 2005.
- First circulating beam: 11 October 2005.
- Situation at the end of 2005:
  - Injection, lattice (poster MOPCH096), acceleration (with reduced “Bdot”) o.k.,
  - No clear sign of electron cooling (almost no increase of local density due to short life-time),
  - High pressure in sector 5 (old bellows, beam hit an ionization profile monitor).
- January 2006: “Shutdown” used for improvements in vacuum sector 5.
- LEIR restart with Pb^{54+} : ~ mid of February 2006.
- Clear observation of fast electron cooling: 3 March 2006.
- LEIR ring commissioning completed: 12 May 2006.

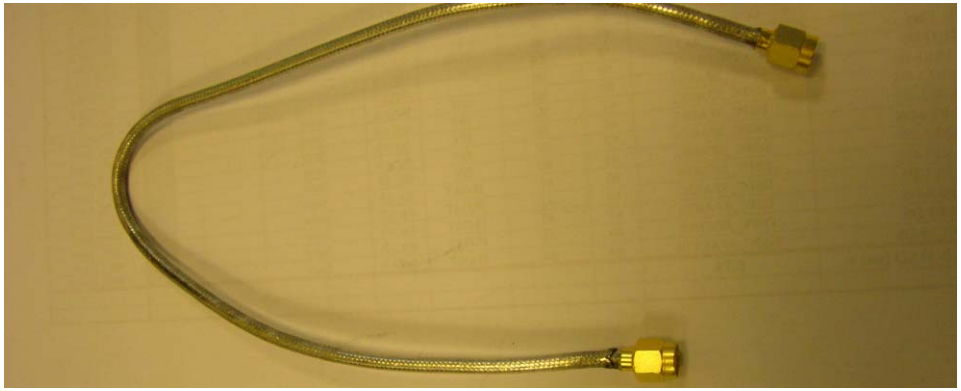
Highlights of LEIR commissioning
Expected and unexpected difficulties

- Controls :
  - Decision to apply LHC developments for LEIR:
    - "Teething problems" to be expected,
    - Challenge to get LEIR controls operational.
  - Many many (often recurrent) problems encountered,
  - Good collaboration of the commissioning team and controls experts,
  - Working (not yet perfect) control system available,
  - (Validation of controls developed for LHC era).
- Understanding of injection line matching (see poster WEPCH046):
  - Difficulties underestimated (from experience with old LEIR line),
  - Trajectory measurements -> Updated model of the line (for O^{4+} and Pb^{54+}).
  - Essential for good injection efficiencies.
- First injections (almost no diagnostics) :
  - Finally not a problem at all - circulating (low intensity) beam after ~1 day!!

Highlights of LEIR commissioning
Expected and unexpected difficulties

- PU cable problem:

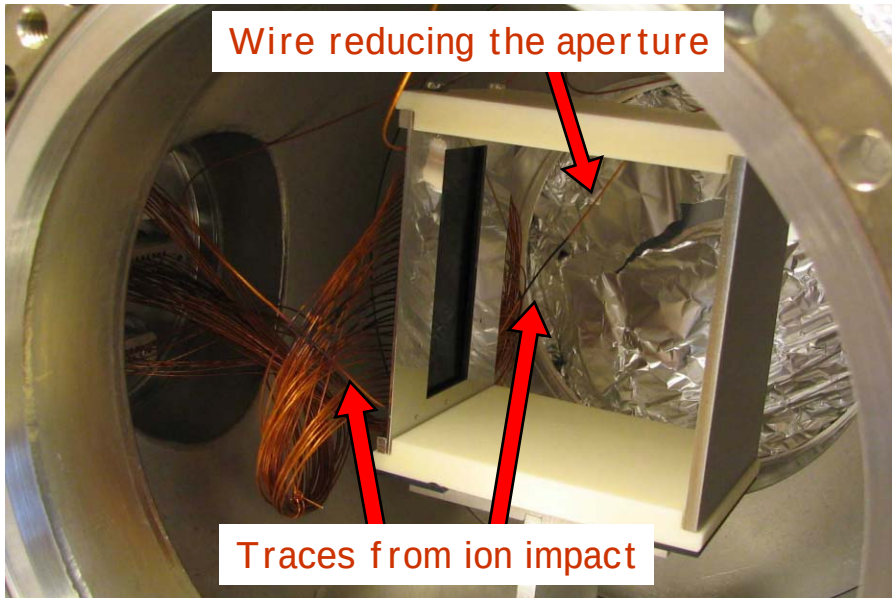




  - Ramp induces electrical fields,
  - ➢ Net current along the chamber (-> gradient “seen” by the beam, see later),
  - ➢ Currents driven damage PU cables,
  - Cure(s) (of cabe damage):
    - Ramp reduced temporarily in autumn 2005,
    - Amplifier box insulated w.r.t ground.

Highlights of LEIR commissioning
Expected and unexpected difficulties

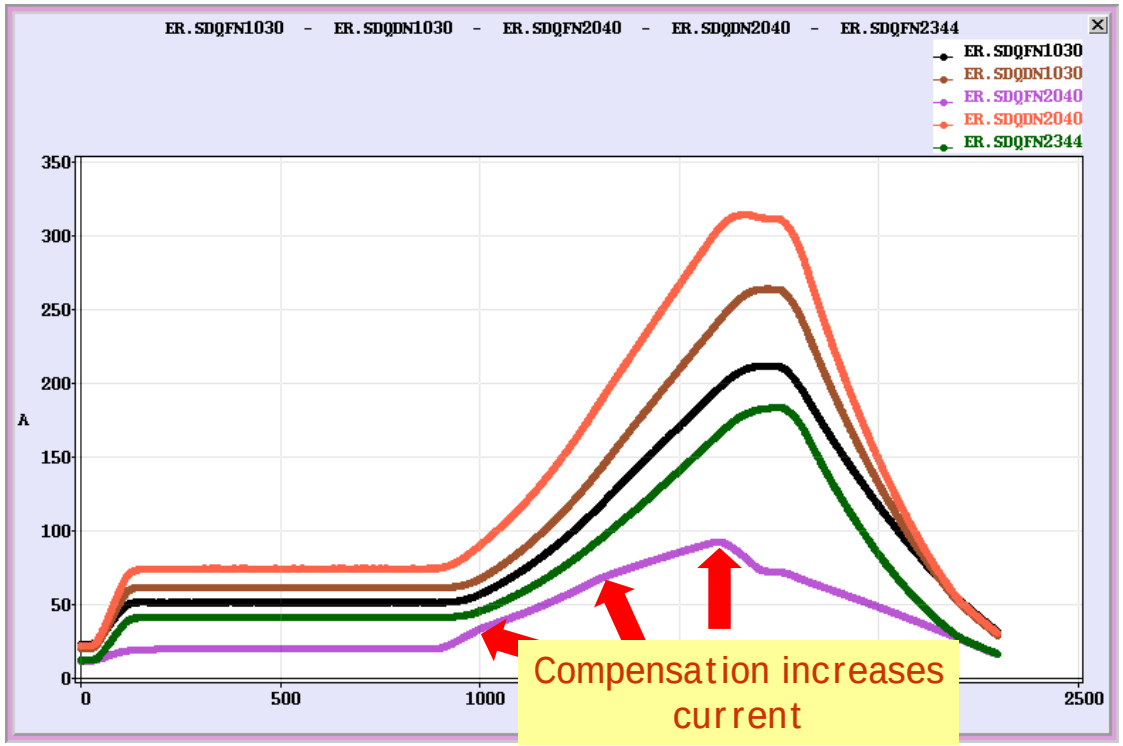
- Short life-time and weak signs of electron cooling:
  - In autumn 2005:
    - Short beam life-time,
    - Barely no increase of (longitudinal) density,
    - Reason not clear,
    - High pressures in ejection section (problems with reused bellows…),
  - January 2006 “shutdown” upgrades:
    - Traces of beam impact on Ionization profile monitor (modified afterwards).
  - Spring 2006: Cooling and accumulation without particular problems.



- Dynamic Vacuum:
  - Beam loss induced pressure rise (limitation in 1997 tests) an issue,
  - Upgrades based on measurements at Linac 3 (by vacuum and Linac 3 team):
    - Au coated collimators (fixed and movable), NEG coatings,
    - “Early LHC ion beam” without moving in movable collimators !

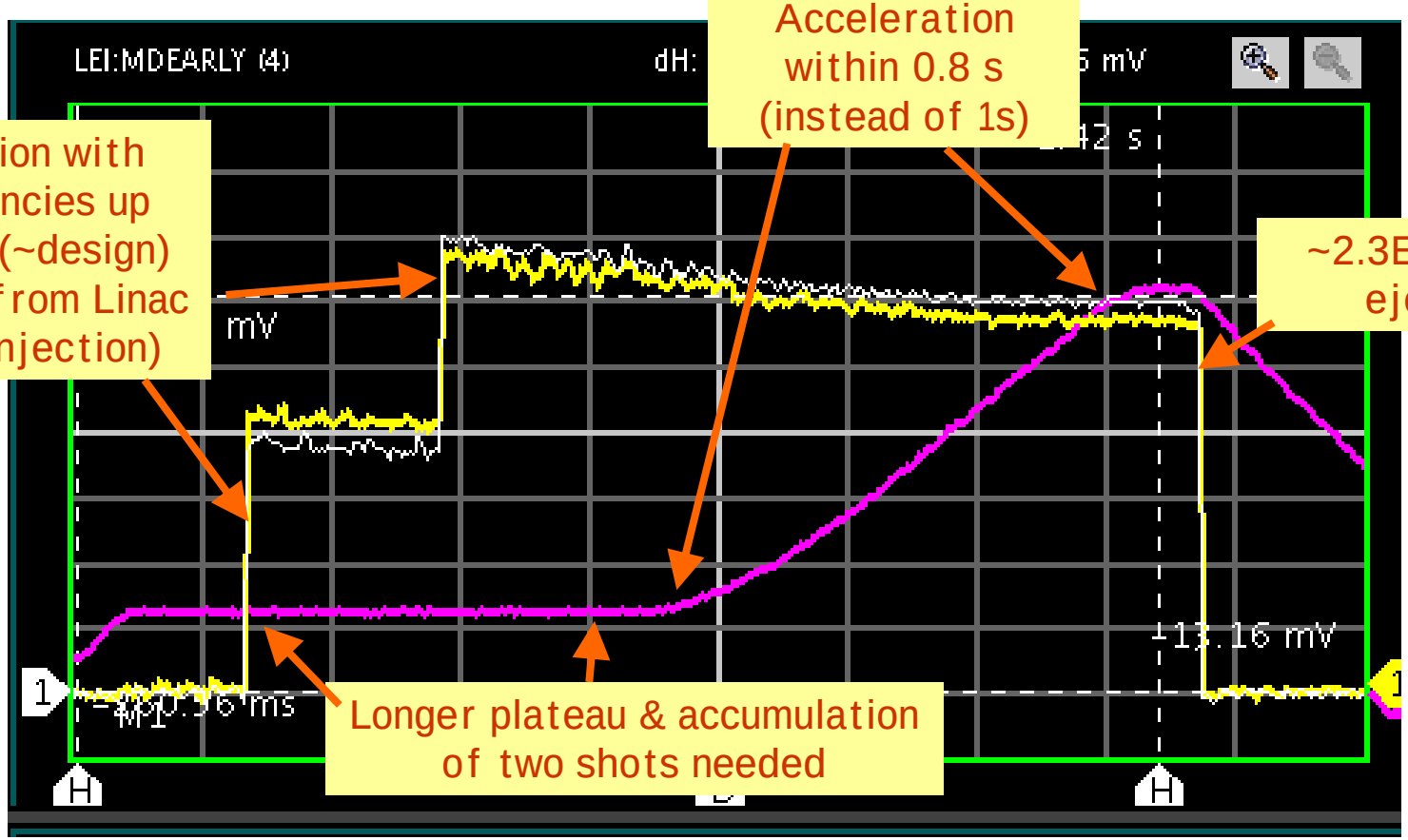
Highlights of LEIR commissioning
Expected and unexpected difficulties

- Optics on ramp (transverse optics perturbations):
  - C-shaped magnet & vacuum chamber not isolated w.r.t. ground,
  - Net current along the chamber,
  - Gradient “seen” by beam.
- Correction:
  - Readjustment of quad currents (5 families),
  - Implemented in software to generate power converter reference functions,
  - ➢ One parameter to obtain ~100% acceleration efficiency



Quadrupole currents along the machine cycle
(compensation of gradients in bends during ramp)

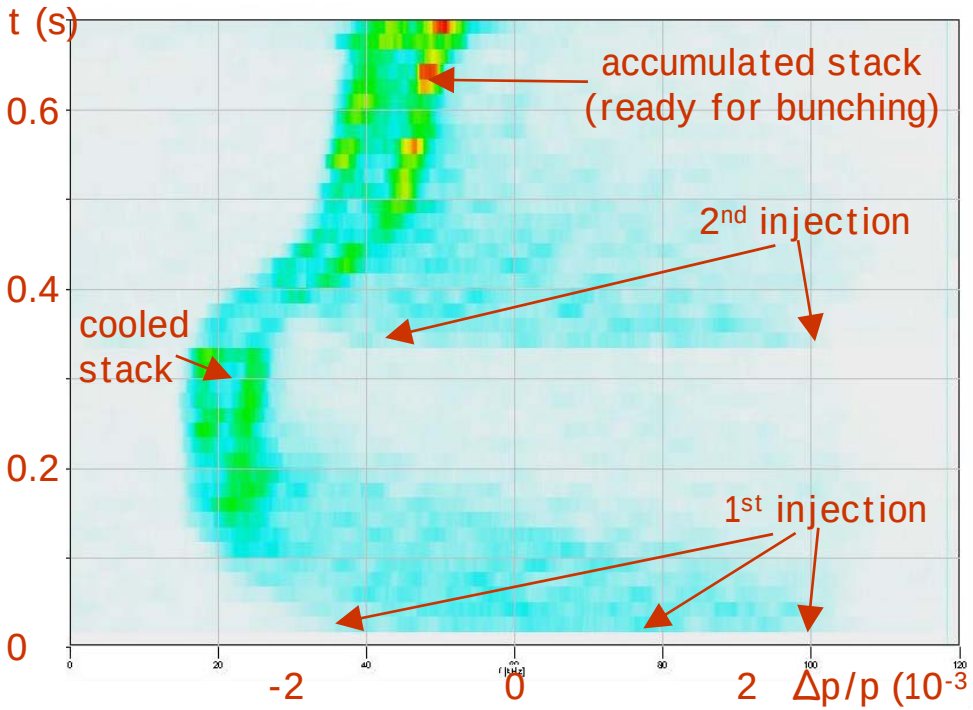
Highlights of LEIR commissioning
LEIR status (overall cycle)



Circulating beam intensity (yellow) and magnetic field (purple) vs time.
"Early LHC ion beam" produced on a 2.4 s machine cycle

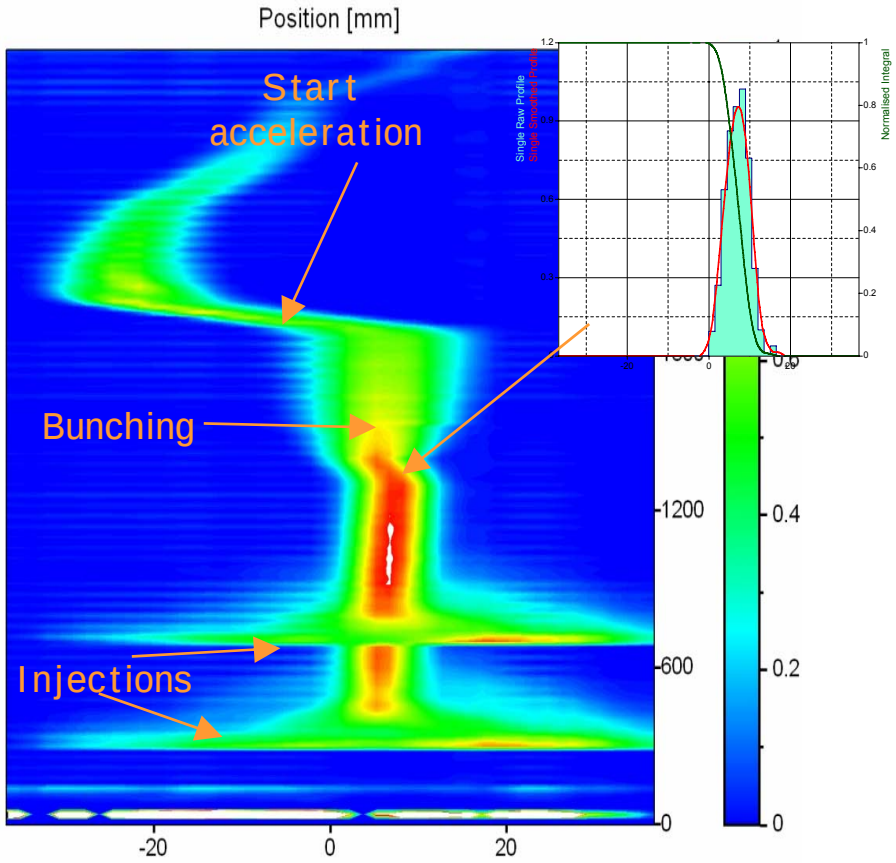
Highlights of LEIR commissioning

LEIR status (Cooling, see poster TUPLS068)



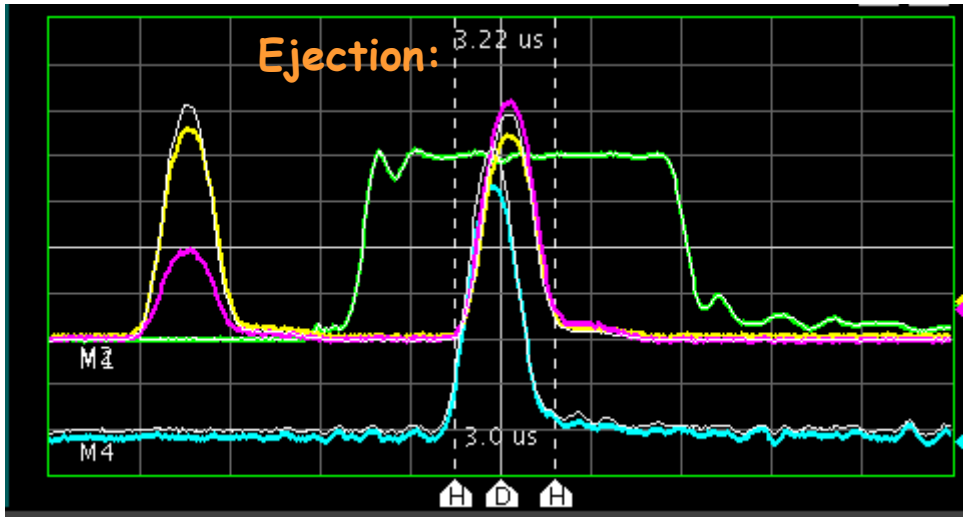
Time evolution of longitudinal Schottky spectra
(see poster TUPCH087)
-> time evolution of long. distribution
-> observation of long. cooling and accumulation

white ..... zero density
red ..... highest densities

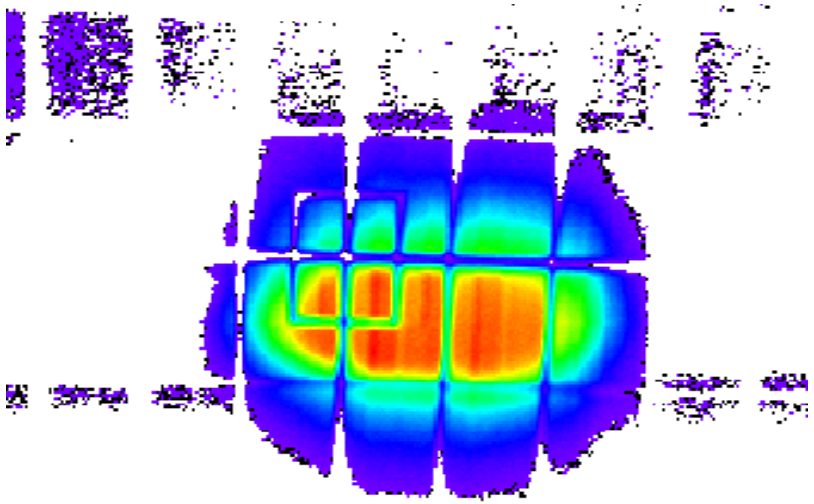


Time evolution of the horizontal beam size
measured with an ionization profile monitor
(cycle with long plateau and
400ms between injections)

Highlights of LEIR commissioning
LEIR status (ejection, transfer)



- Ejection kicker (green),
- Sum (yellow) and difference (purple) of ring PU,
- Ejection line beam current transformer (blue)



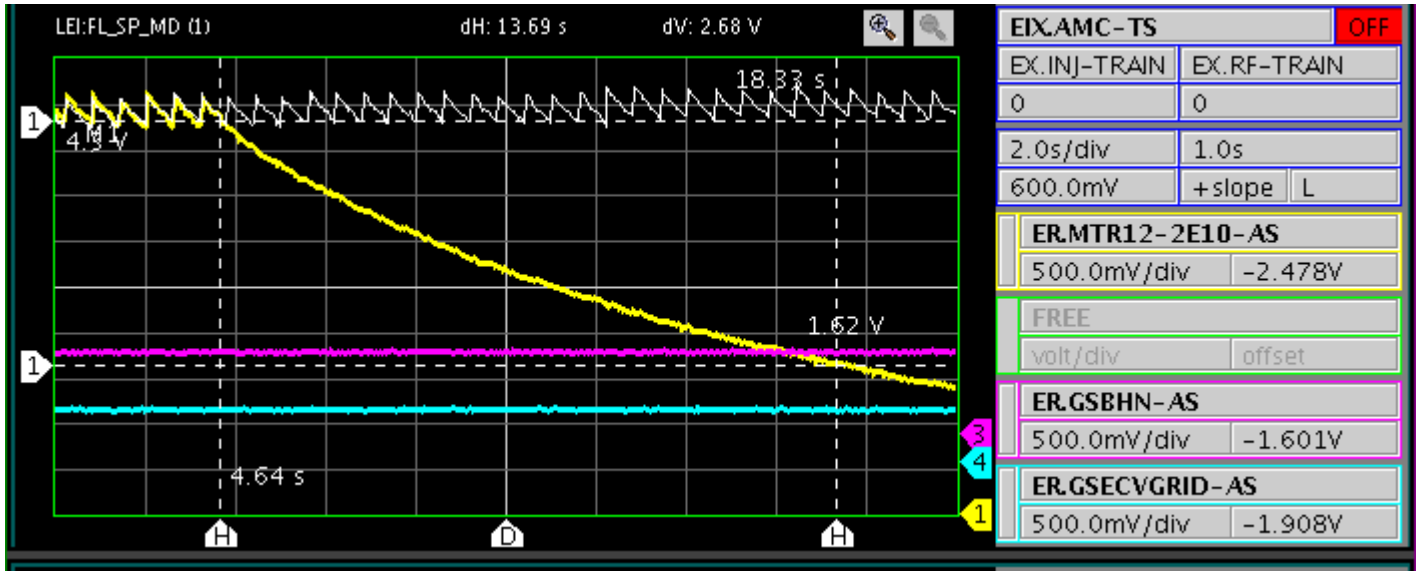
Last TV of the ejection line
(~5m before PS injection region)

SE (wires) profile monitors in the ejection line:
- transverse emittances (rms normalized) : ~0.26μm
- matching:
  (almost) no horizontal mismatch,
  vertical mismatch should be corrected.

Highlights of LEIR Commissioning
LEIR status

Towards nominal LEIR beam :

- No systematic investigations:
  - not aim of commissioning and no time available.
- Accumulation tests with very long plateaus (yellow trace shows intensity):
  - Intensities well above the nominal ones,
  - Dynamic beam life-time after accumulation (and losses) ~14s,
  - Good sign for “nominal LEIR beam”



Summary, Conclusions and Outlook

- The required “early LHC ion beam” has been produced:
  - Two injections needed (-> acceleration in 0.8s instead of 1s),
  - Parameter of ejected beam well within specifications.

➢ LEIR Commissioning is completed.

  - Success of the whole LEIR team !

- Outlook:
  - Prepare LEIR re-start from the “CERN Control Centre” CCC in autumn (still some work to simplify operations),
  - “Early LHC ion beam” in the PS in autumn 2006,
  - “Early LHC ion beam” in the SPS in 2007,
  - Nominal LHC Ion Beam in LEIR and further downstream in the accelerator chain.