ELENA
Machine Status

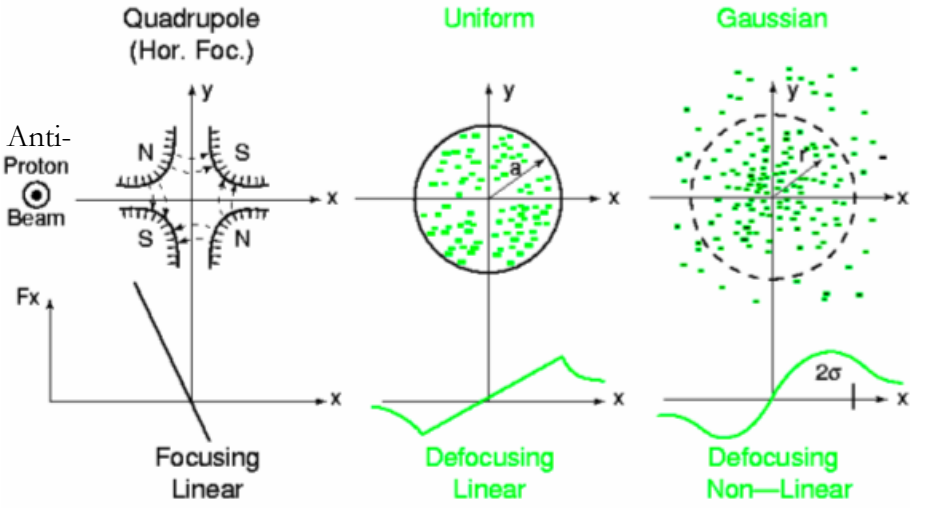
C. Carli on behalf of the ELENA team

ADUC, 20th November 2012

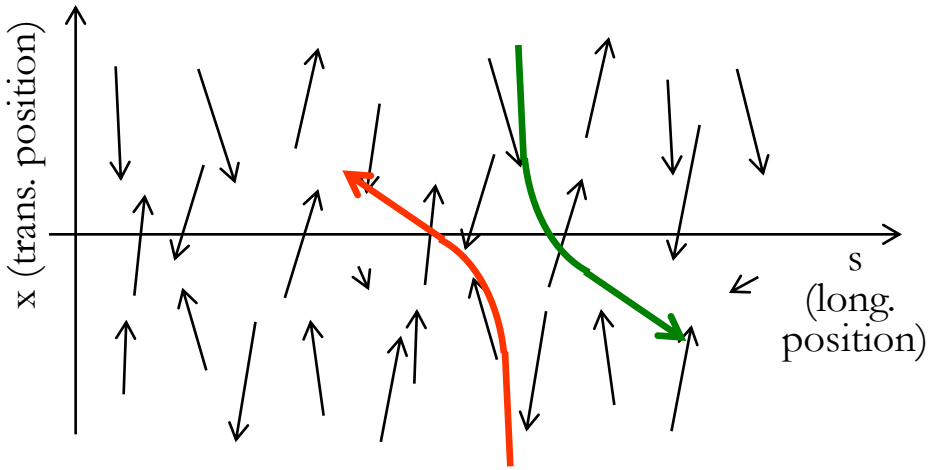
- (Brief) Recap of ELENA Challenges
- Selected Topics studied recently
  - Lattice, Layout and Integration
  - RF System
  - Instrumentation
  - Electron Cooling (with bunching)
  - Requirements from experiments
  - Magnetic Cycle
  - Magnets
  - External Source for Commissioning
- External Contributions
- Status

(Brief) Recap on ELENA challenges

- (Not that) short synchrotron decelerating p-bars to very low energy of 100 keV
- Increase of phase space density by electron cooling at (two) very low energy
- Transverse direct space charge defocusing
  - Additional, very non-linear, defocusing due to Coulomb repulsion limits intensity
- Very low energy and, in consequence, low beam rigidity and magnetic fields (stray fields?)
- Diagnostics with very low intensities
- Intra Beam Scattering IBS
  - Coulomb scattering between beam particles
  - Transfer of heat (unordered motion) between phase spaces (long. & transverse)
  - Emittance blow-up – determines together with cooling emittances of available beams
- Instabilities possibly despite low intensity with small emittances (momentum spread) and energy?



Transverse direct space charge defocusing

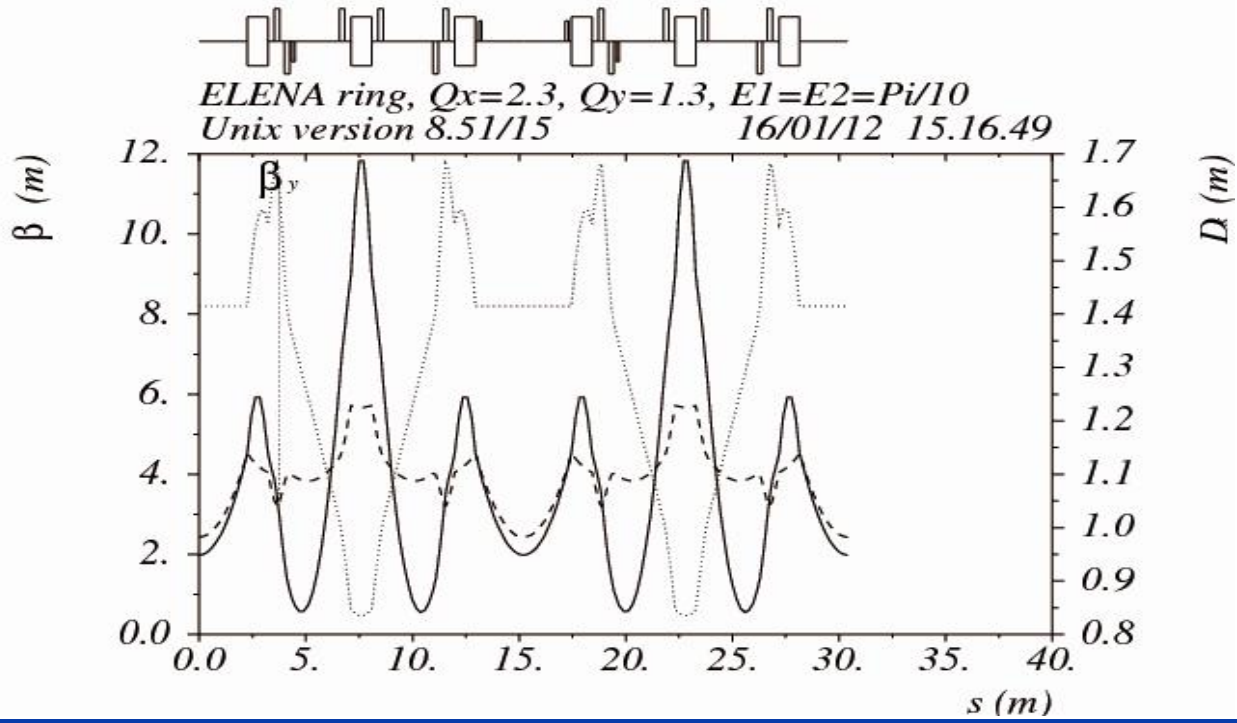


Intra Beam Scattering IBS – co-moving coord. system

Lattice, Layout and Integration

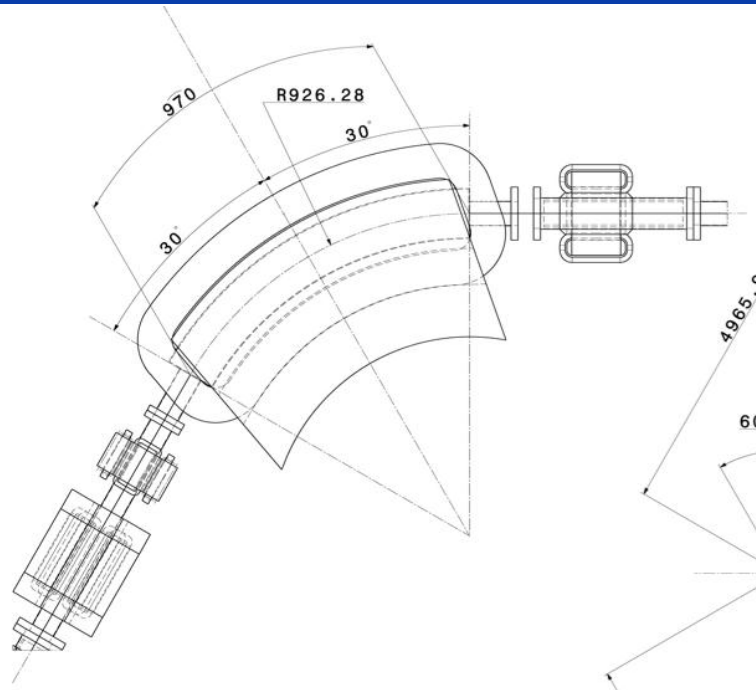
Pavel Beloshitsky

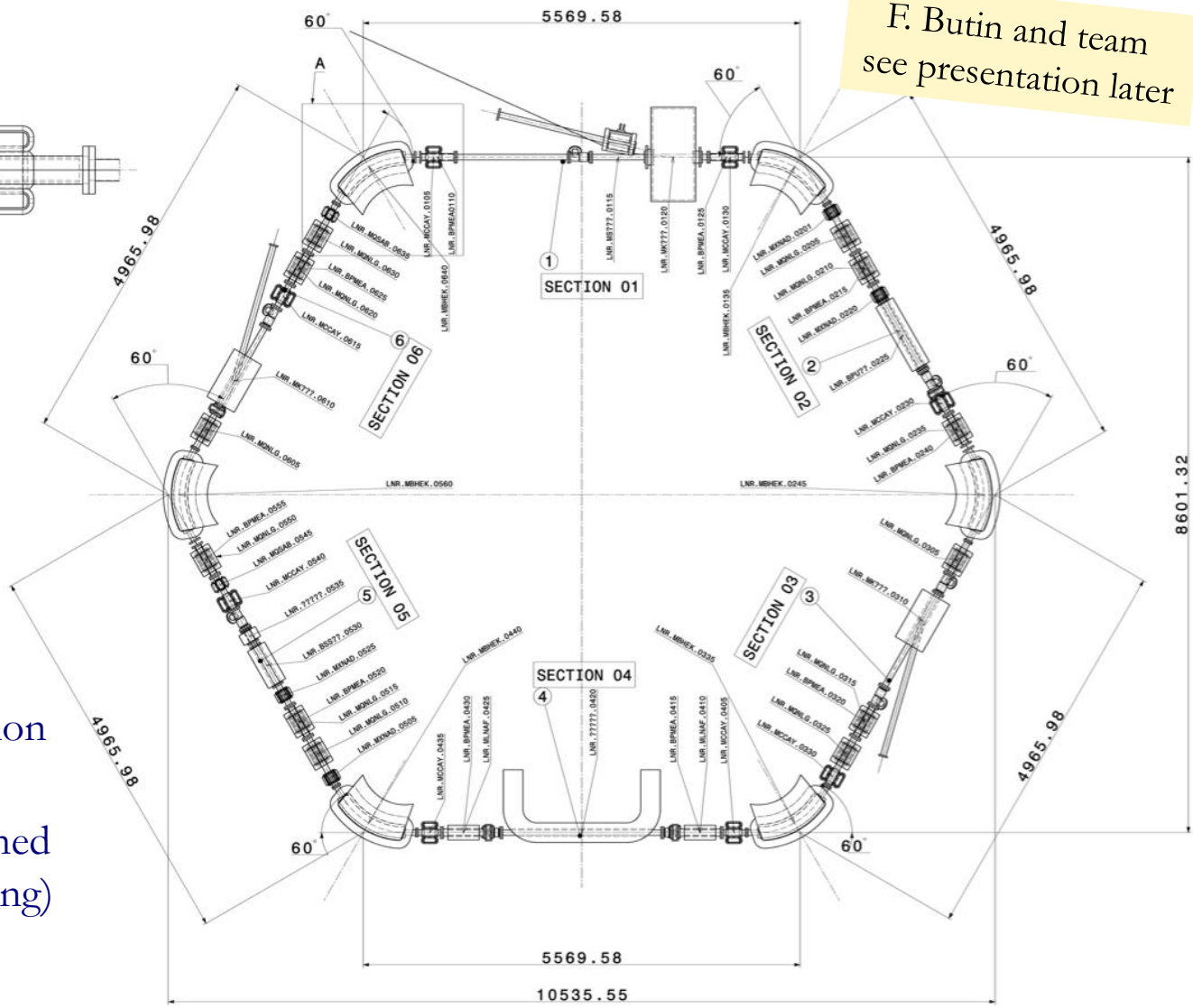
- Challenges (usual for low small rings) for lattice design and optics
  - Many constraints and few "free parameters" (quads)
    - Suitable working point and sufficient acceptances (small maximum beta function, but also large dynamic aperture with non-linearities)
    - Long straight with small dispersion for electron cooling ..
  - Modeling of magnets with not that small gaps (compared to bending radius)
- Many geometries and lattices studied since last autumn
  - Square, hexagonal, triangular shape, different quadrupole locations
- Baseline lattice ($Q_X \approx 2.3$, $Q_Y \approx 1.3$) chosen



Lattice, Layout and Integration

F. Butin and team
see presentation later

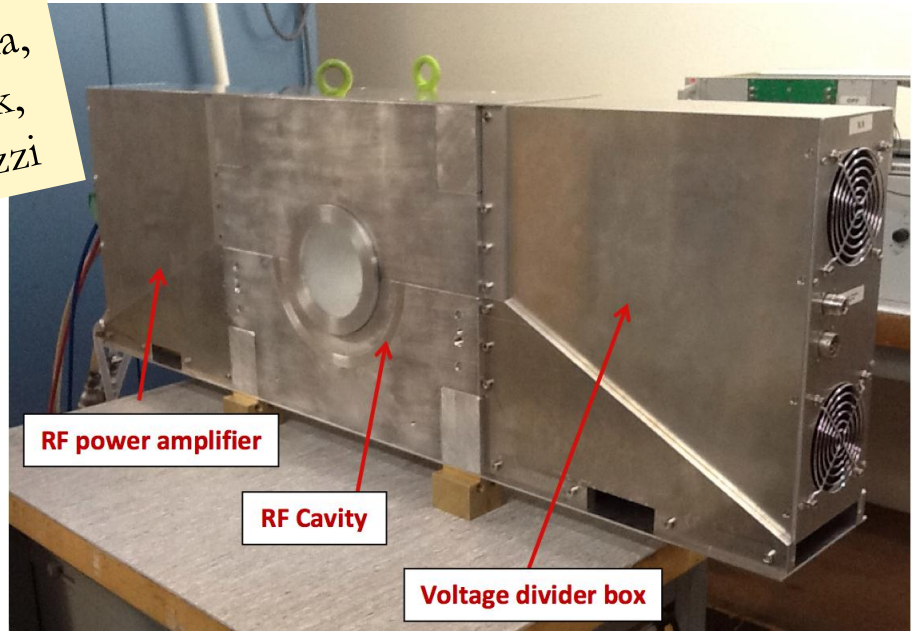


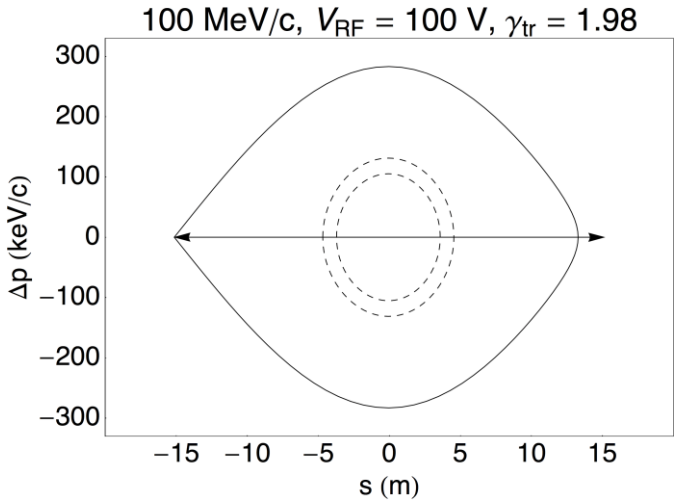


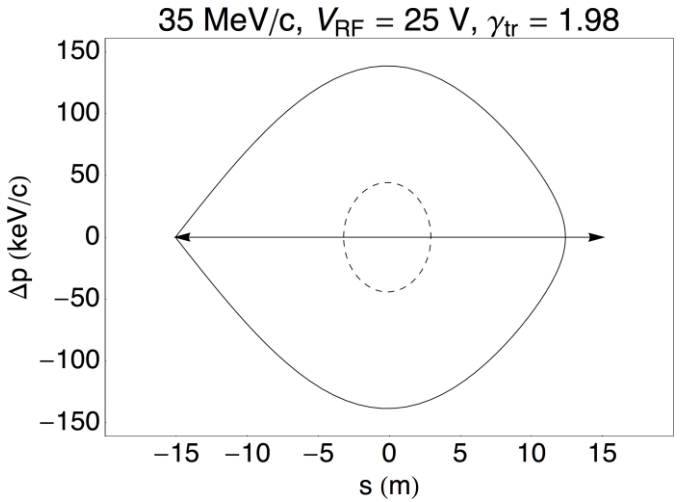
- First iteration of integration and layout drawings
- To be discussed and refined (flanges, bellows, (pumping) ports, instruments …)

RF System

M.Angoletta, S.Hancock, M.Paoluzzi

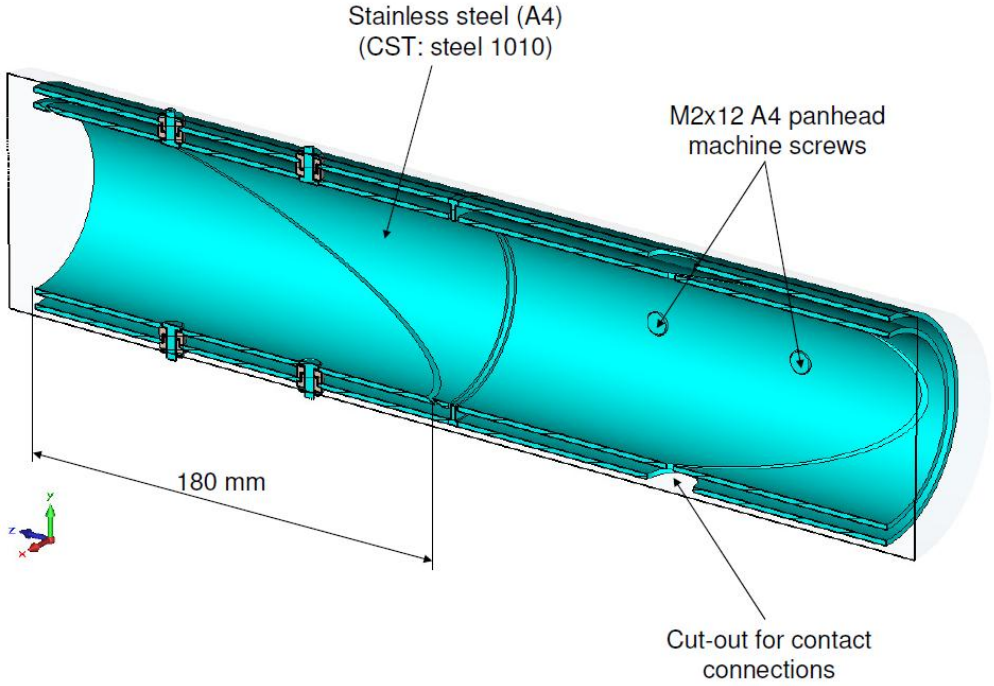




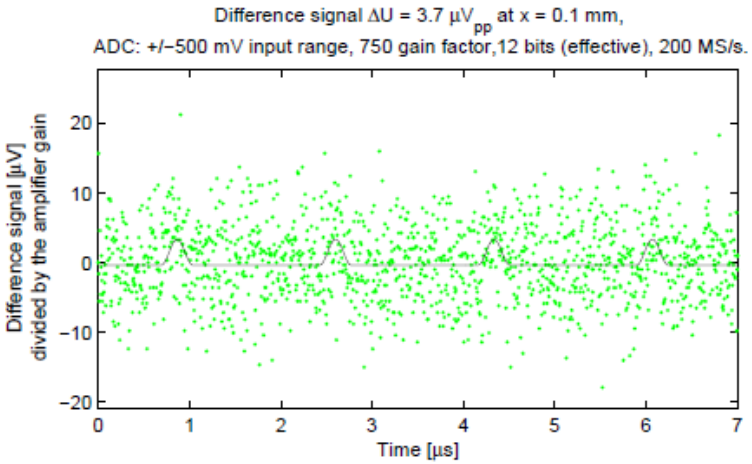


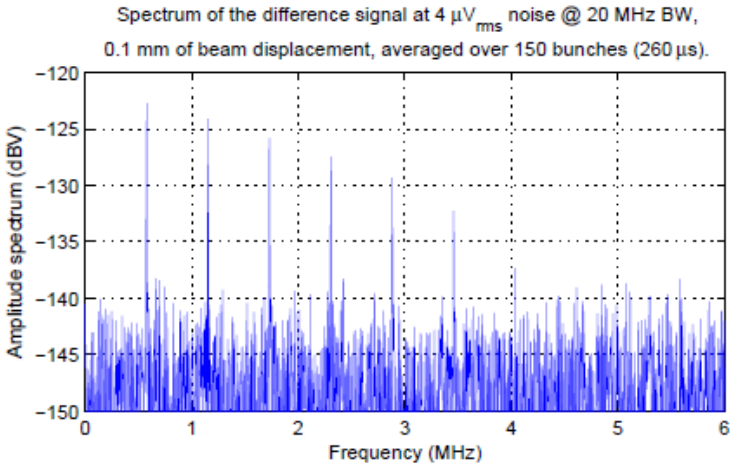
- RF Cavity
  - Finemet low Q cavity based on development for PS Booster(similar to LEIR cavity)
  - One gap sufficient for V_{RF} = 500 V (sufficient)
- Low Level RF: fully digital system based on new development for the PSB (similar to LEIR system)
- Voltages required: ~16 V for injection, 25 to 100 V for deceleration,~100 to 500 V for bunching

Instrumentation –
Position Pick-up



L.Soby, J. Harasimowicz





- Design well advanced
  - Required precision reachable
  - Awaiting finalized apertures and machine integration
- Proposal to use all position PUs for Schottky diagnostics
  - Larger distance from PU to chamber and, thus, quads, steerers and solenoid
  - Larger bandwidth head amplifier
  - Complicated (digital) signal treatment

Instrumentation –
High sensitivity longitudinal Pick-up

M. Angoletta, F. Caspers, S. Federmann F. Pedersen, L.Soby ……

- With low intensity AD and ELENA and AD beam, high Sensitivity longitudinal pick-up
  - For intensity estimate of debunched beam via Schottky diagnostics
  - For Low level RF and intensity measurement of bunched beams (less stringent for sensitivity)
- Comparison of proposals (Schottky spectra in AD at 100 MeV/c and h=8)
  - Magnetic Pick-up based on AD one:
    - Redesign for ELENA (bake-out, size, bandwidth …)
    - Proven in AD
  - Electrostatic Pick-up: competitive at low energies (relativistic βs),
    - Transverse signal as well?
    - Small transverse size (use signal from all position PUs)
    - Limited bandwidth (depends on length) or several short electrodes

Instrumentation

G. Tranquille et al.

- ELENA ring emittance measurements
  - Scrapers for destructive measurements
    - Sufficiently fast for measurements faster than typical cooling times
    - Different speeds to study
  - Discussion on feasibility of wire scanner
    - Motivation: no risk for systematic measurements as for a slow scraper (scrapers)
    - Very fast and thin wire would intercept ~20% of beam at 100 keV, sufficient signal from annihilations?
    - Risk: frequent interventions in a XUHV fully baked machine
- Tune measurements
  - Standard CERN BBQ signal analysis chain
  - Tune Kicker and Pick-up to be defined

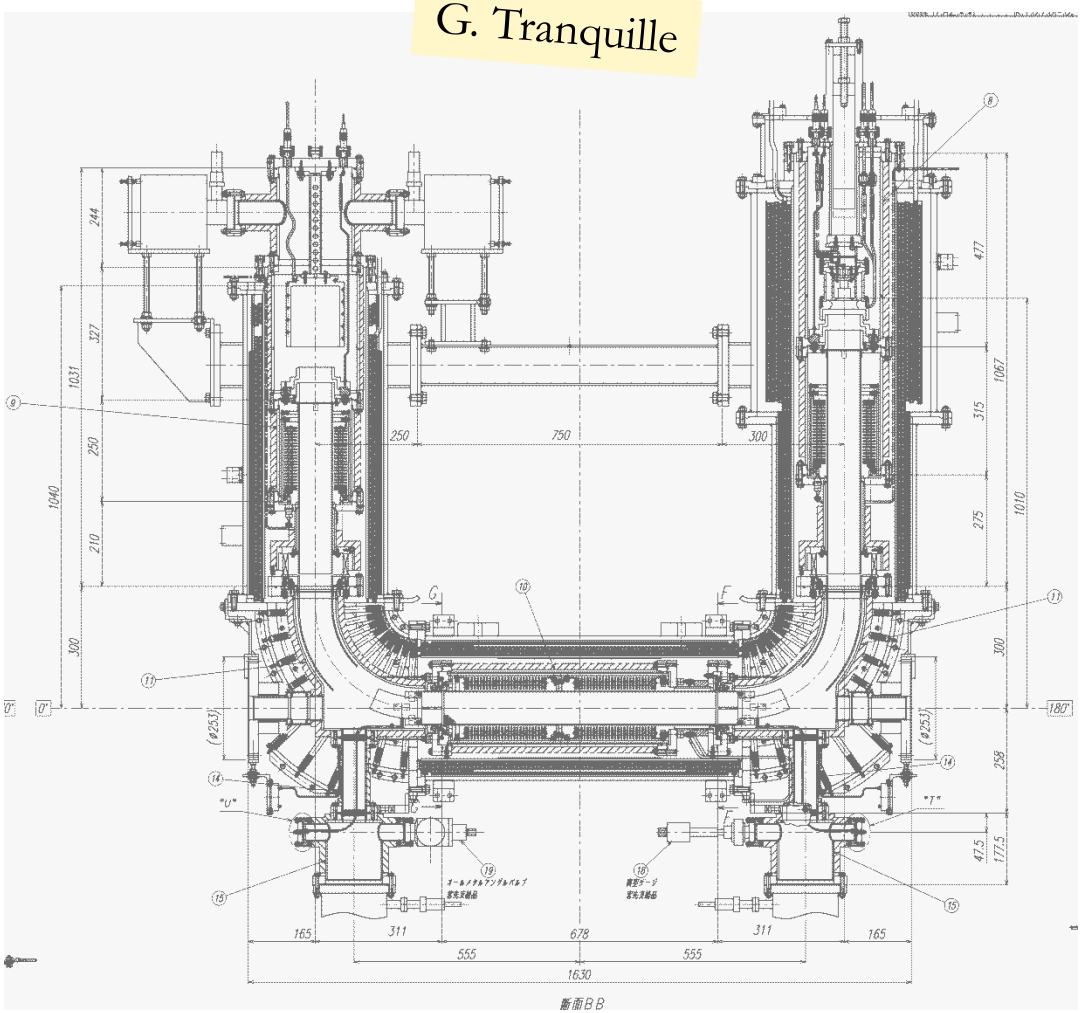
- No Beam Current Transformers (BCTs)
  - Too low intensities for standard BCTs, Intensity measurement with high sensitivity longitudinal PU
  - May-be in the future SQUID (superconducting) BCTs for AD and ELENA

Electron Cooling

Hardware

- Based on S-LSR (Kyoto) design
  - To be constructed by Toshiba as the S-LSR cooler
  - Interaction (drift) increase to 1.07 m
  - New gun & collector design
  - Lower electron energy
  - Larger expansion and lower magnetic field in interaction regions
- Status
  - Electron cooler as contribution by University of Tokyo
  - Discussions on technical details and organization ongoing with University Tokyo and Toshiba

G. Tranquille

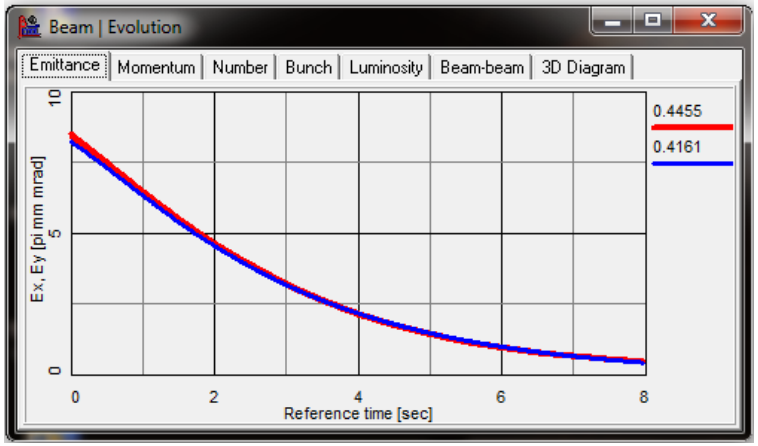


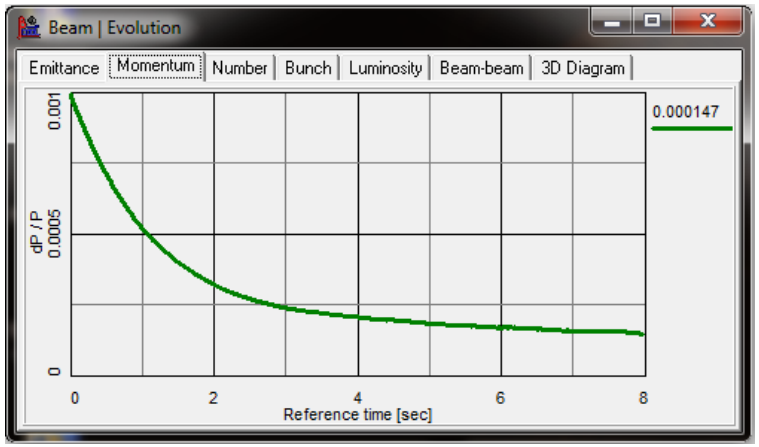
Sketch of the S-LSR Electron Cooler

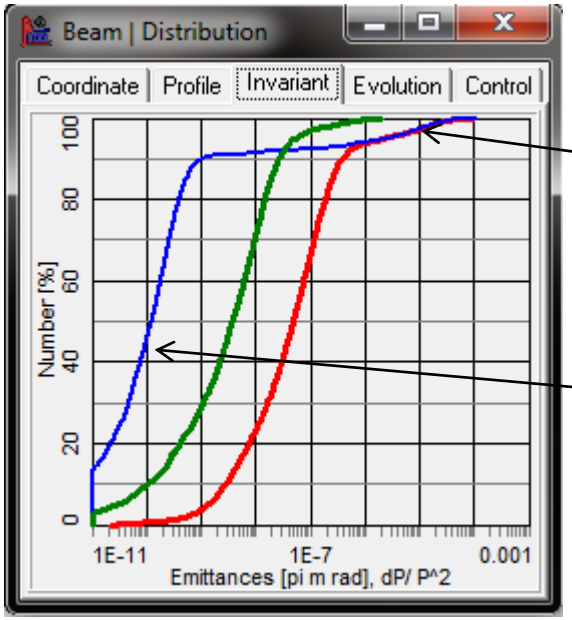
Electron Cooling

BetaCool simulations at intermediate 35 MeV/c plateau

G. Tranquille

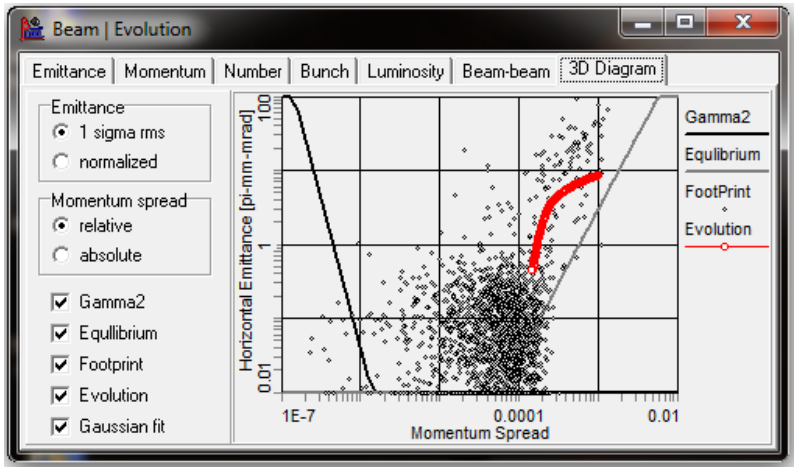






Transverse emittances (similar in both planes) dominated by tails

Very dense core (vert. phase space) realistic and compatible with electron temperature?



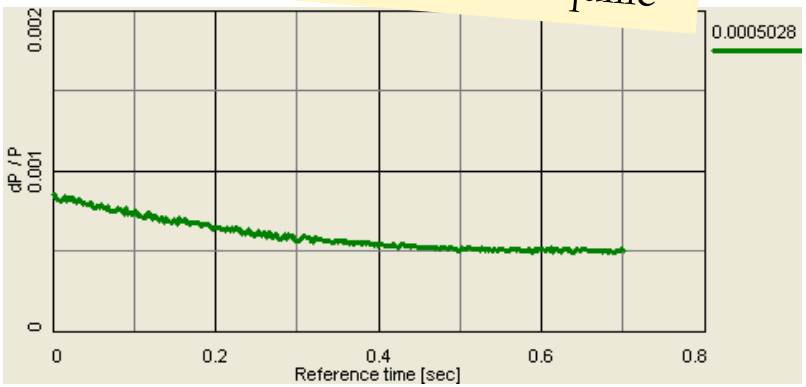
- BetaCool Simulation at 35 MeV/c yield
  - Transverse rms emittances 0.43 μm
  - Rms rel. momentum spread $\sigma_p/p = 0.15\ 10^{-3}$
  - Further studies: understanding of very dense core and long tails in distributions

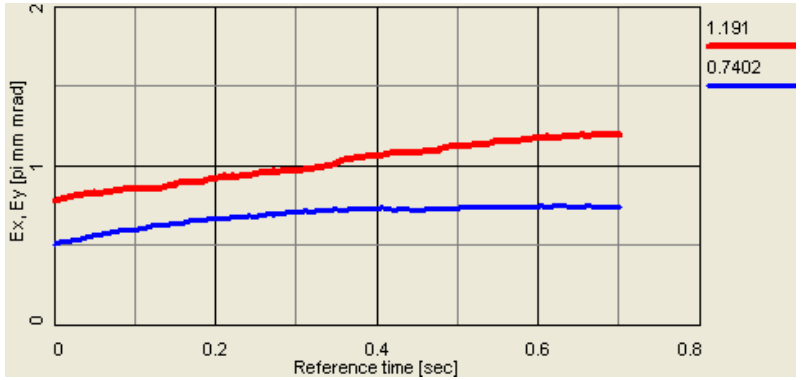
Electron Cooling

Bunched beam cooling at 100 keV simulated with BetaCool

P. Belochitski with contributions by A. Burov and G. Tranquille

- Motivation
  - Recent simulations gave larger than expected equilibrium momentum spread
  - Larger momentum spread – issue for acceptance of line and possibly experiments
- Keep cooler on during bunching process
  - Reduces longitudinal emittances
  - First simulation with increase of RF voltage in three steps
  - Expected beam parameters for baseline ELENA operational scheme (4 bunches per cycle)
    - 0.6 10^7 pbars per bunch
    - Within 300 ns (full length) and $\sigma_p/p = 0.5\ 10^{-3}$
    - Transverse (physical rms) emittances of 1.2 μm and 0.74 μm
  - Larger intensities (larger intensities available at low energy or less bunches per cycle)
    - Expect larger momentum spread and emittances



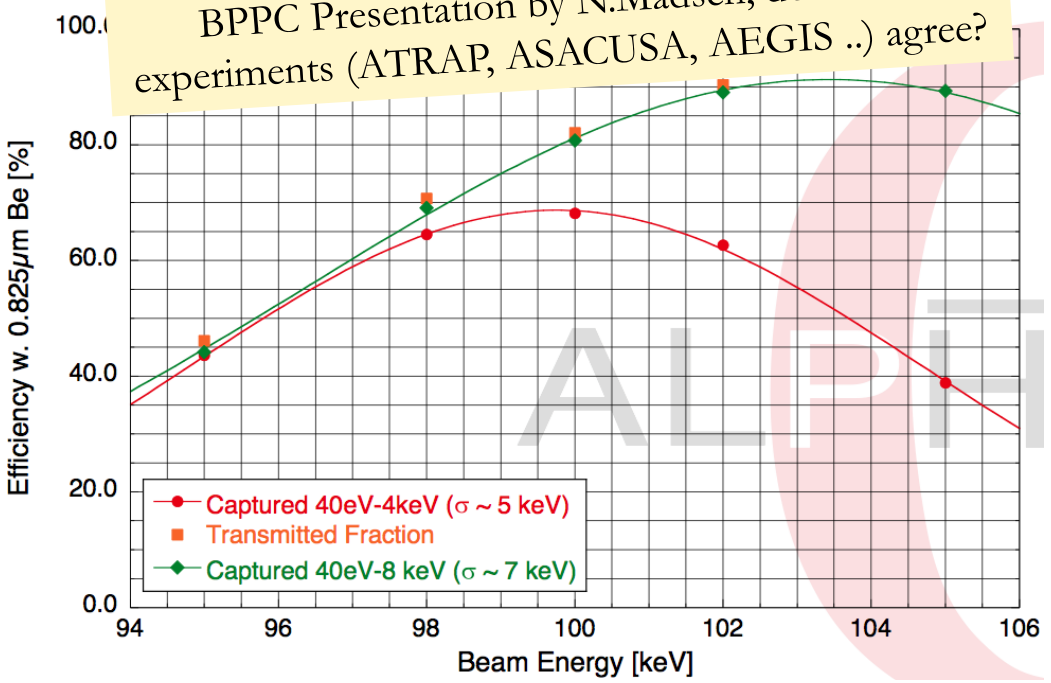


Last cooling step with:
- 0.6 10^7 pbars per bunch
- harmonic h = 4 (number of bunches)
- RF Voltage: 36.4 V

Requirements from experiments (ALPHA as example)

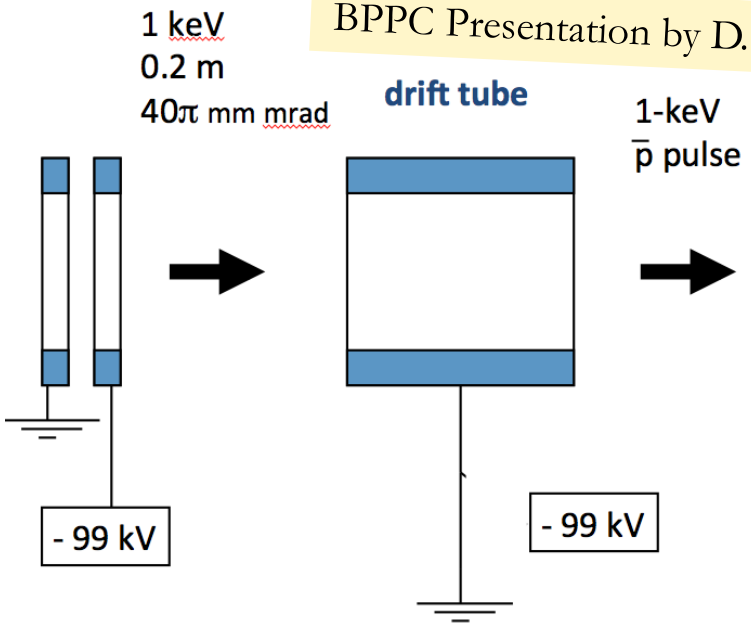
- Longitudinal, energy spread seen by experiments from
  - Machine (cooling, IBS, bunching)
  - Straggling in foil (reduced with ELENA – reason for gain)
    - Experiment can acceptable an energy spread of a few %
    - Limitation on machine side (acceptance of ring & lines)
- Transverse
  - Beam size on foil small enough (rms size <1 mm) to have pbars within electron beam after capture
  - Angles smaller 100 mrad .. corresponding with an rms beam size of 1 mm to emittances well above the ELENA acceptance
    - Transfer line optics yielding small beam size and with sufficient acceptance
- Full bunch length less than 300 ns

BPPC Presentation by N.Madsen, do other experiments (ATRAP, ASACUSA, AEGIS ..) agree?

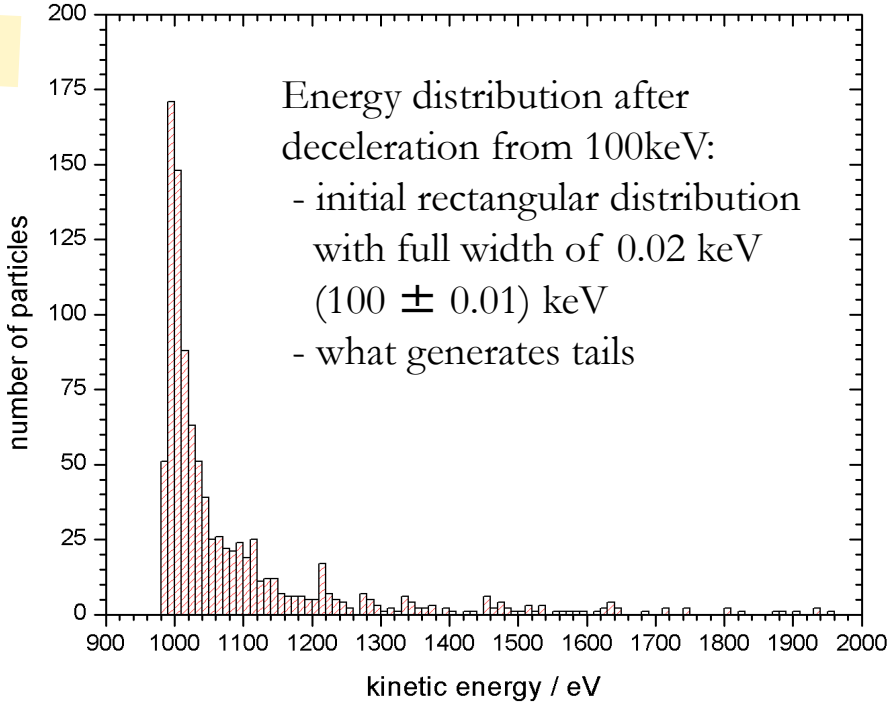


- Does this correspond to needs of other experiments (except Gbar)?

Requirements from experiments
(GBAR - deceleration with pulsed drift tube)



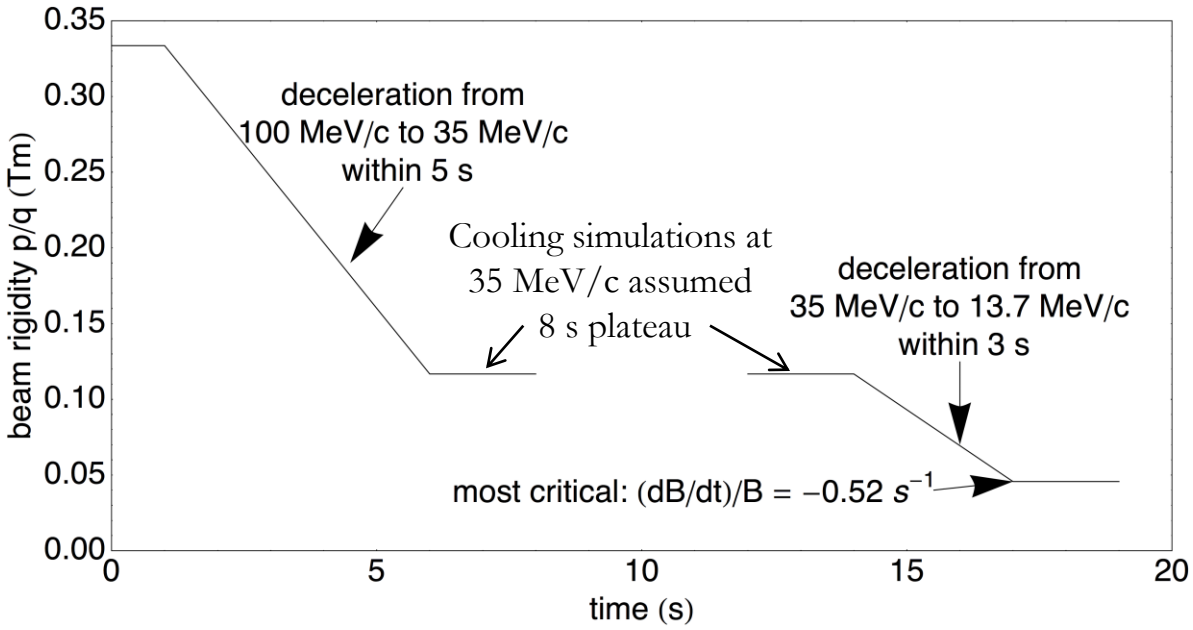
BPPC Presentation by D. Lunney



- Longitudinal beam properties
  - Conclusion from this study: energy spread of 1×10^{-4} (halfwidth) would be o.k., but larger spreads (recent estimates of ELENA parameters) compromise experiment
    - Discussion during meeting: Sources for energy spread
    - Situation may not be so bad, if final spread is sum on initial spread plus a contribution due to deceleration
- Transverse - Expected ELENA emittances about o.k.
  - Details on matching to be discussed with team working on line

Magnetic Cycle –
Assumptions on the magnetic cycle

- Magnetic Cycle (working hypothesis – see discussions between Pavel and Daniel Schoerling)

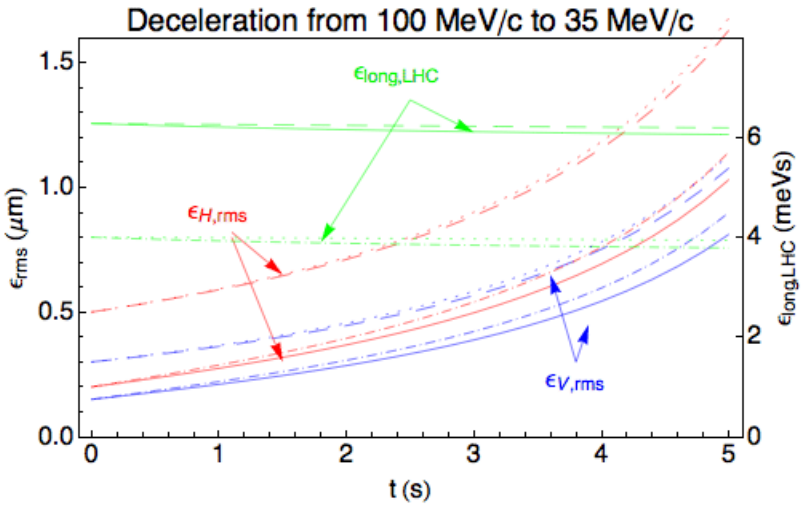


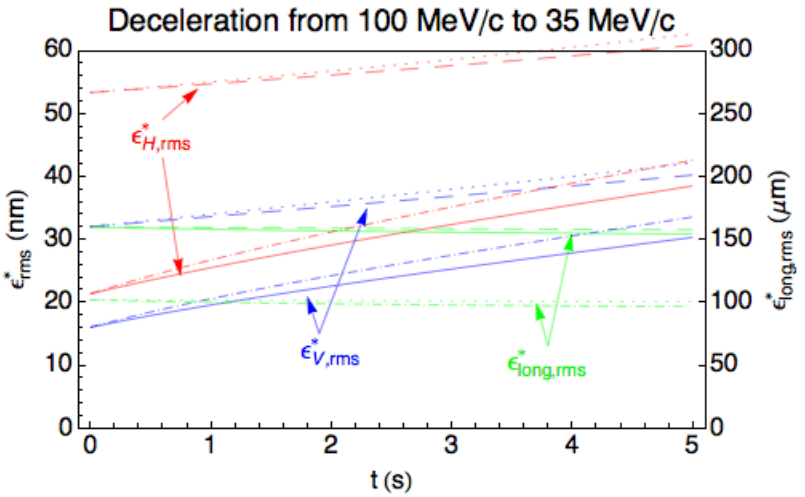
- Acceptable (compromise between two effects)
  - For blow-up due to Intro Beam Scattering along ramp (requires not too long ramps)
  - Eddy currents in bending magnet chamber induced by ramp and affecting optics (requires not too short ramps)

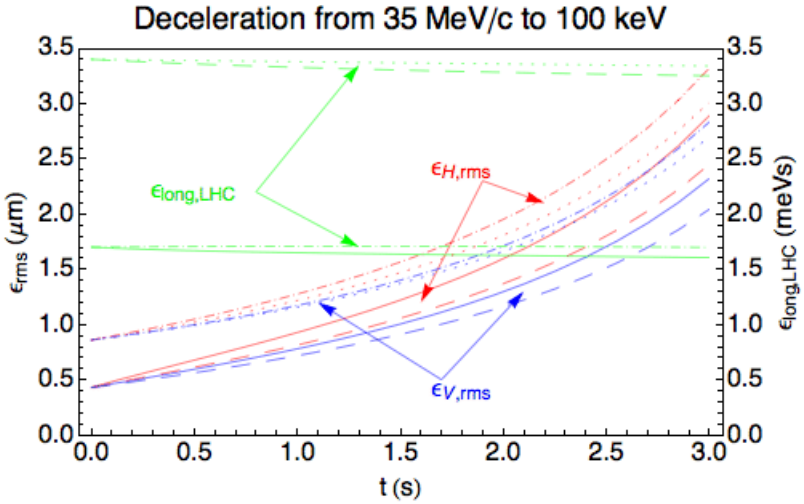
- Magnetic cycle might become a bit longer than previous estimates – not at all an issue (still short compared to the AD cycle)

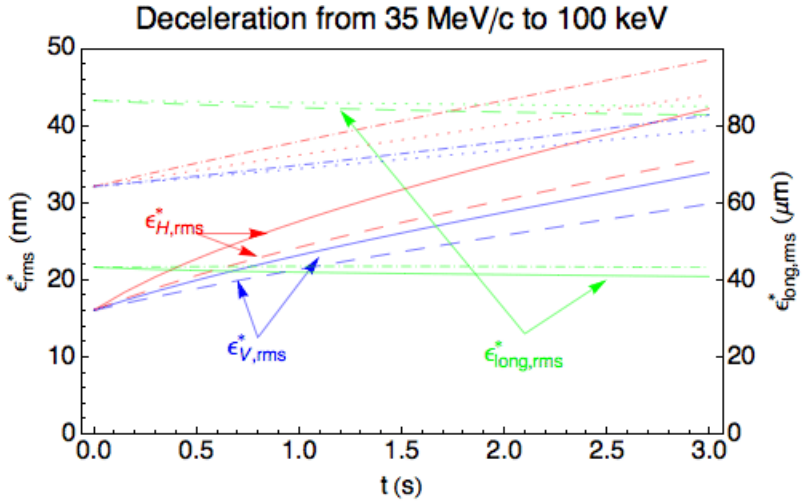
Magnetic Cycle –

Blow-up due to Intra Beam Scattering (IBS)





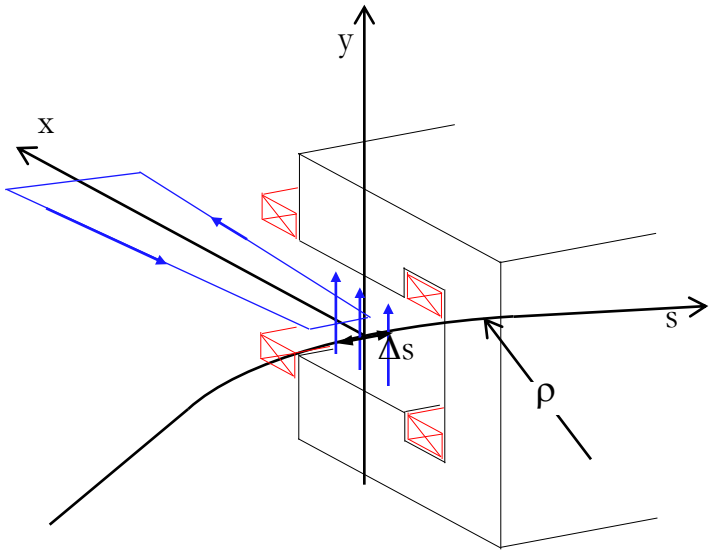




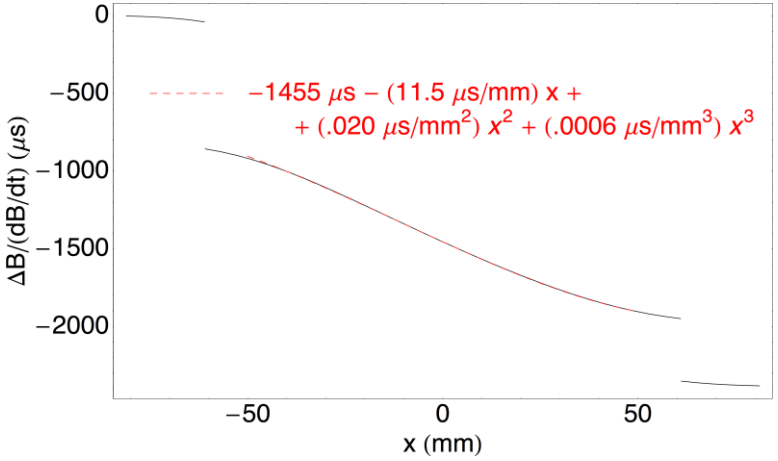
- Assuming Gaussian beams (neglecting tails – is this a problem?)
- Acceptable, but still significant blow-up (see right plots with normalized emittances, which would be constant without IBS)

Fields induced by Ramp

- Ramp of magnetic field induces electric fields and currents
  - C-shaped magnet and non-isolated chamber give net current (not opposite currents on two sides)
  - Generates quadrupolar field in addition to dipolar field (delay) and sextupole components



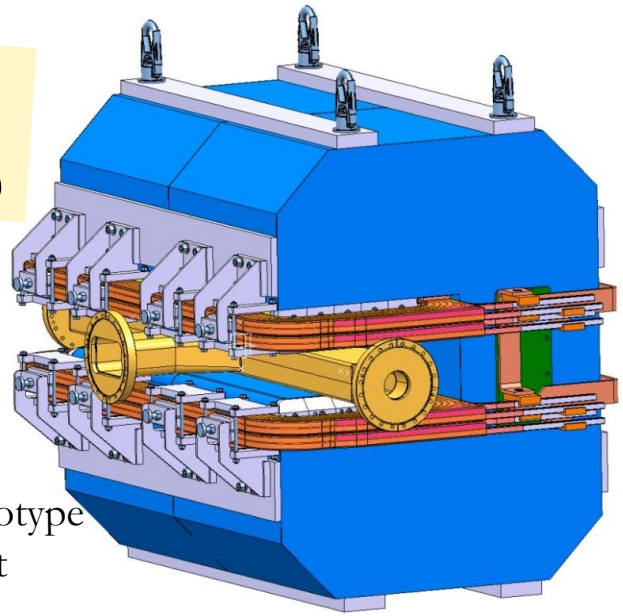
- Results (pessimistic – assuming perfect grounding of chamber on both magnet ends)
  - Delay of about 1.5 ms
  - For most critical moment in cycle (arrival at 100 keV)
    - Additional gradient: $\Delta k = 0.0064\ m^{-2}$
    - Sextupole coefficient: $-0.011\ m^{-3}$
  - Acceptable perturbation for lattice … should be corrected by (re-)tuning of quads and sextupoles



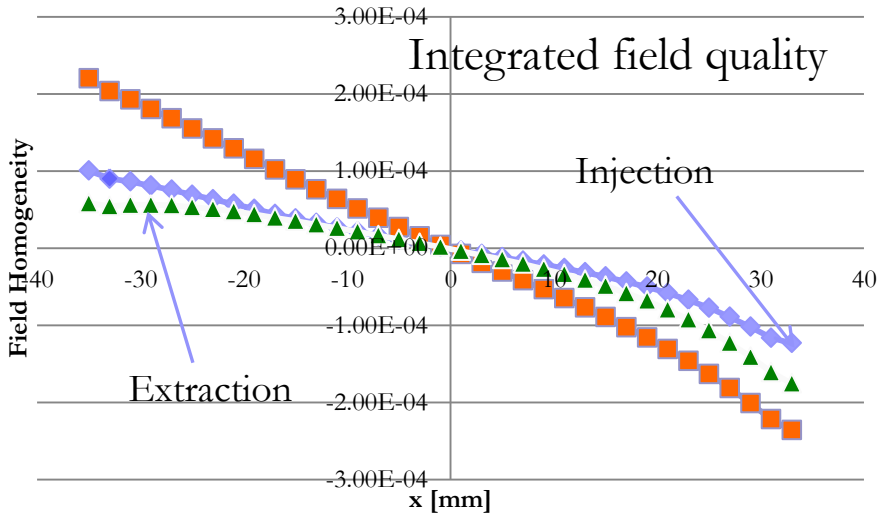
Magnets –
Example: Bending magnets with very low fields

- Magnets with very low fields (0.35 T to 0.05 T) required
  - Non-linearities due to low fields a possible issue
  - Was this the limitation for low energies in other machines?
  - "Dilution", i.e. mixing of magnetic steel and non-magnetic (stainless steel laminations)
    - Higher field in magnetic laminations
    - Mitigation of non-linearities due to low fields
- Many simulations carried out
  - 2D and 3D, static and dynamic effects, hysteresis …
  - C-shape and H magnets …
- Bending magnet prototype to verify:
  - Production process of a magnetic yoke diluted with stainless steel plates.
  - Field quality with chosen steel and hysteresis
  - Mechanical deformations
  - Wish: test heating during bake-out (NEG activation)
  - Edge angle and end shim design.

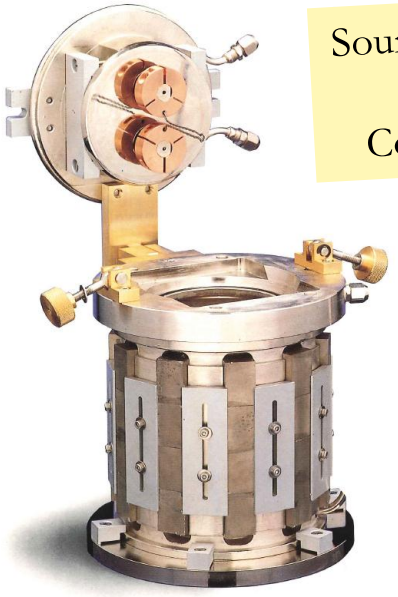
See presentation later today by D. Schoerling (other magnet type, details ..)



Dipole prototype magnet

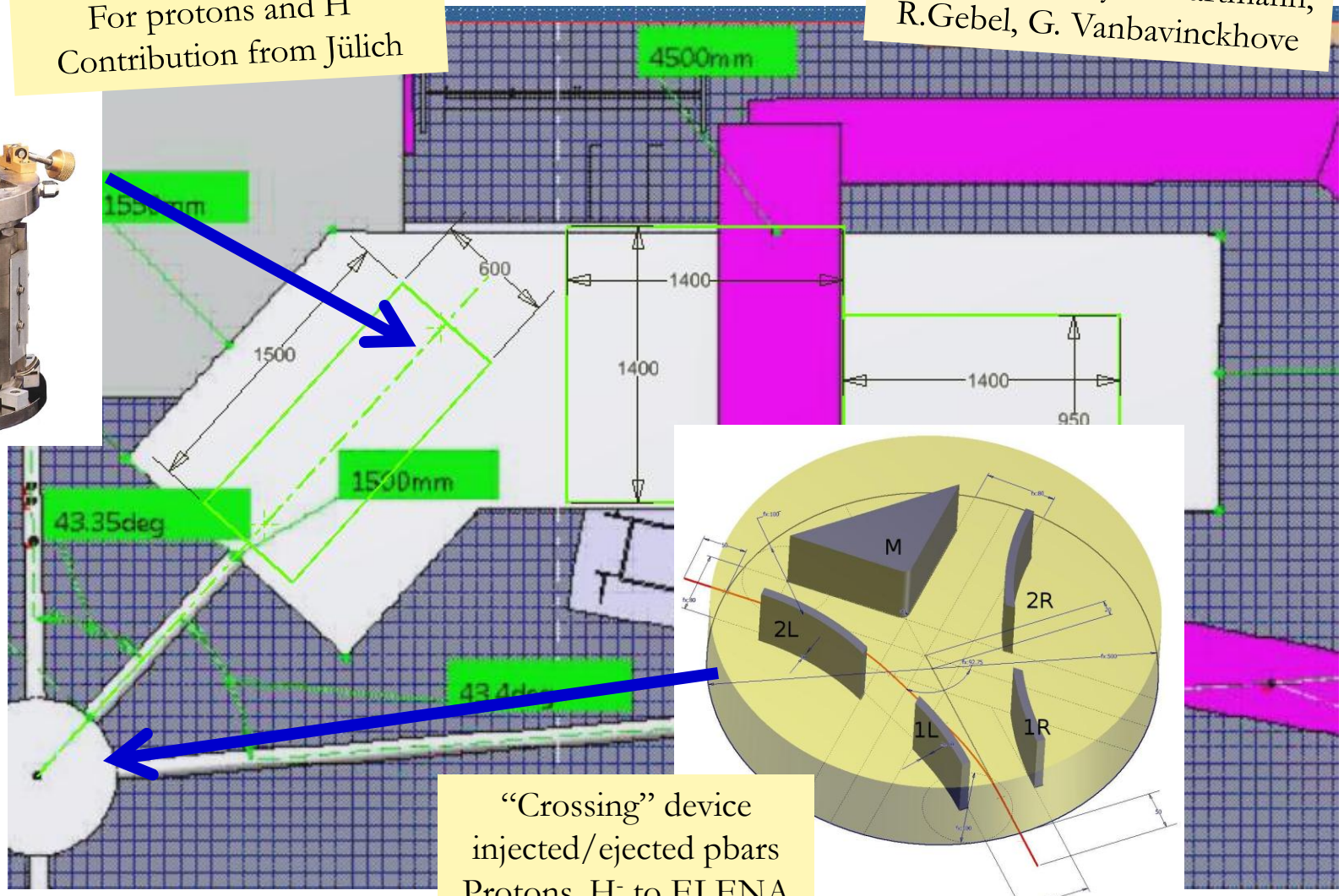


External Source for Commissioning



Source upgraded to 100 keV
For protons and H^-
Contribution from Jülich

Presentations by W. Bartmann, R.Gebel, G. Vanbavinckhove



"Crossing" device
injected/ejected pbars
Protons, H^- to ELENA

Status of external Contributions

- **Univ. Tokyo and MPQ-MPI**:
  - 2 MCHF (electron cooler, discussions for specifications ongoing)
  - 7 FTE (identified, electrostatic transfer lines and devices)

See presentation later today by W. Oelert

- **Cockcroft Institute & Univ's and Swansea University:**
  - Costing of the order of 500 kGBP has been applied by U Liverpool,
  - A proposal has been submitted for work : this would cover 2 Postdocs, some PhD students and equipment; the overall funding requested is about 1 M€; a decision is expected until June.
- **Denmark:**
  - Applied for the money for bends and quadrupoles (Danfysik), possibly funding for a postdoc
- **IKP-FZ Julich:**
  - Several aspects of the source have been discussed in meeting on 27th of March in Juelich
  - Work has started and will be again discussed tomorrow afternoon: substantial development work is required to make such a source operational for ELENA commissioning. Many interfaces to be clarified (vacuum with differential pumping, design of lines, integration, infrastructure …) .. Dedicated meeting yesterday.
- **Univ. Brescia:** 50 kEuros (to be transferred in two slices this year and next year)
- **RIKEN (since last ADUC,)**
  - Compensation solenoids for electron cooler
  - Manpower (student)
- **TRIUMF:** Help for design of electrostatic transfer lines
- **Hemholtz Institute Mainz:** Construction of supports
- **Manne-Siegmann:** Help with ELENA commissioning
- **(Berkeley:** DOE does not (yet) support – MoU not signed, but discussion not yet abandoned!)
- **(CEA-IRFU Saclay-SIGMAPHI:** only prototypes are interesting for them – did not sign MoU, but still discussions)

Summary/Status

- Studies on several technical issues
  - Better understanding of limitations
    - Intra Beam Scattering (IBS) seems the dominant limitation for ELENA
  - Better understanding of beam parameters to be expected
  - Further studies to refine understanding of limitations (e.g. on instabilities)
  - Design of some equipment started (or even well advanced) or starting
- Status
  - Machine lattice and apertures defined
  - Exact positioning of ELENA ring and lines in AD hall fixed
  - Many (converging) discussions on exact positioning, integration (flanges, bellows …)
  - Aim: Technical Design Report (TDR) to be ready soon
  - For other milestones and more details on some topics (parameter, new building, experimental zones …) see presentations by Pavel, François, Gilbert, Wolfgang
- On track for first antiproton physics with ELENA in 2017
- Thanks
  - To everybody who helped with the preparation of this presentation
  - For your attention

ELENA beam decelerated by Gbar: Momentum spread before (top) and after (deceleration)

Sent by mail by D.Lunnay on 20th November