LATEST NEWS FROM STOCHASTIC COOLING DEVELOPMENTS FOR THE COLLECTOR RING AT FAIR

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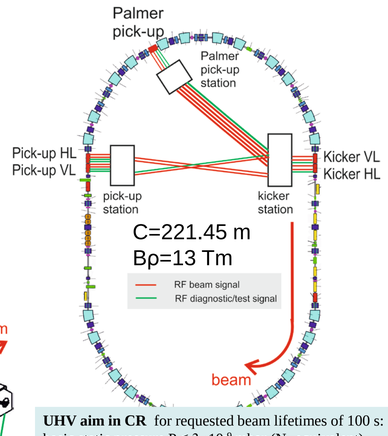
CR stochastic cooling

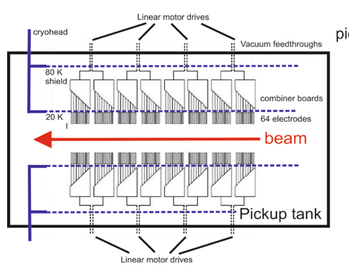
for antiprotons v=0.97 c (f_{rev}= 1.315 MHz)
for ions/RIBs v=0.83 c (f_{rev}= 1.124 MHz)

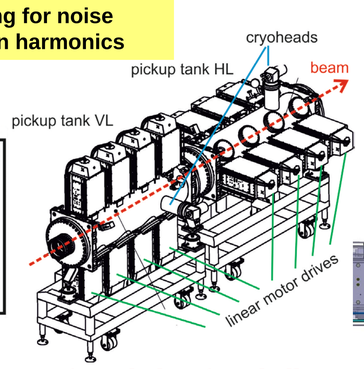
Main issue for antiprotons: increase ratio $\frac{\text{Schottky signal } (\propto Q^2)}{\text{thermal noise}}$

- **Pick-up electrodes cooled at 20-30K**
- **Plunging pick-up electrodes i.e. synchroneously moving closer to the beam during cooling**
- **Notch filter longitudinal cooling for noise suppression around revolution harmonics**

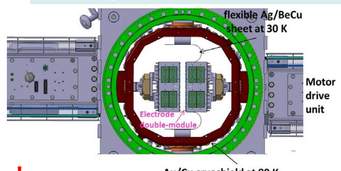
System bandwidth=1-2 GHz







UHV aim in CR for requested beam lifetimes of 100 s: basic static pressure P ≤ 3 ·10^{-9} mbar (N_2 equivalent) at room temperature, **without in situ bakeout**



UHV, cryogenic and plunging challenges!

Damping of unwanted microwave modes

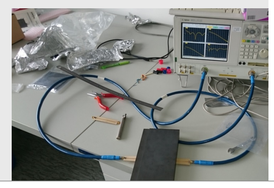
- Large-aperture PU/KI/magnet vacuum chambers in between: many propagating modes
- High gain (>130 dB) in signal paths for fast cooling; short beamline Palmer PU-KI

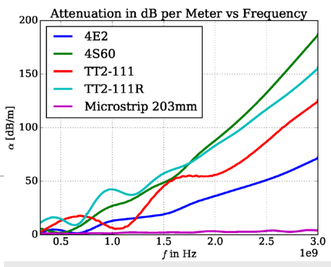
→ high microwave damping requirements in the band 1-2 GHz

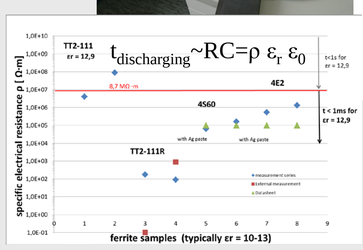
- Need UHV-compatible microwave absorbers, NO in situ bakeout in the CR!

inside magnet vacuum chambers, between PUs and KI in the arcs : ***Al_2O_3 ceramic tubes with resistive outside coating (≤ 60 m² per arc)***

Inside PU/KI tanks: ***ferrites (≤ 2 m² per tank)***



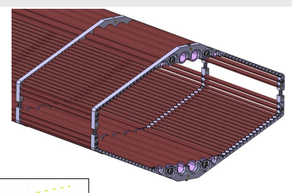


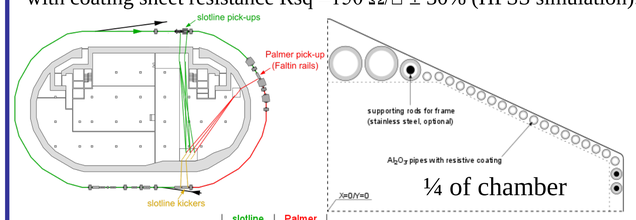


Outgassing rate of TT2-111R and 4S60 UHV-acceptable:
x2-3 of stainless steel (< 1.6 ·10^{-10} mbar·l/s ·cm² after 1 week of pumping without bakeout)

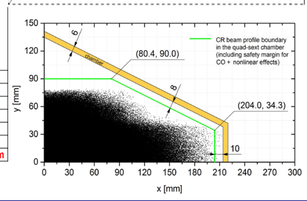
Min, max values TT2-111R at room temperature from E. Chojnacki et al., (Cornell), DC Conductivity of RF absorbing materials, Proc. SRF2009, Berlin, Germany (2009).

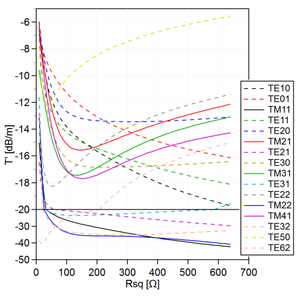
The concept: MW damping tube modules inside all hexagonal quadrupole/sextupole chambers in the CR arcs.
4x24 Al_2O_3 tubes (4 diameters from ⌀6 mm to ⌀24 mm), with coating sheet resistance Rsq =150 Ω/□ ± 30% (HFSS simulation).





values for **new hexagonal** quadrupole and sextupole chambers	slotline pick-ups to slotline kicker	Palmer pick-up to slotline kicker
maximum electronic gain	150 dB	133 dB
minimum required damping	135 dB	130 dB
number of chambers type Ia	4	2
number of chambers type Ib	6	4
number of chambers type III	1	1
Σ length of all chambers	19.6 m	12.7 m
minimum damping per length	6.9 dB/m	**10.2** dB/m





Simulations of antiproton cooling performance

Reference (most critical) case:
10^8 antiprotons at 3 GeV
cooling for 10 s in all 3 phase-space planes
1-2 GHz band

conservative = no PU electrode plunging
= assuming el. gain transverse=const.

Already with these assumptions cooling performance close to the design limits for the HESR downstream of the CR.

Longitudinal notch filter cooling (CERN code Fokker Planck)

best for constant el. gain=150 dB (3.2·10^7) no safety margin, high power requirement

Transverse cooling with 'rms' model

$$-\frac{1}{\varepsilon}\frac{d\varepsilon}{dt}=\frac{1}{\tau_\perp}=\frac{2W}{N}\left[2gB-g^2(M+U)\right]$$

$$M(t)\approx\frac{1}{m_c|\eta|\frac{\Delta p}{p}(t)}$$

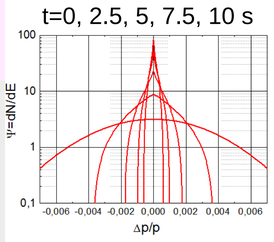
Mixing KI-PU
Interplay between transv. & long. cooling

Simultaneous notch filter long. cooling ON. Ansatz from Fokker-Planck results at 150 dB $\frac{\dot{\delta p}}{p}(t)=\left(\frac{\dot{\delta p}}{p}\right)_{ini}e^{-\frac{t}{\tau_{long}}}$

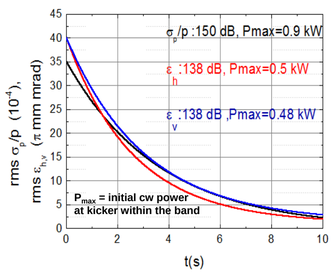
best for *assumed const.* el. gain=138 dB some margin @ decreasing gain and plunging

- pbar lattice: η=+0.014 (γ_{tr}=4.84), η_{pk}≈0 (suppresses undesired mixing).
- Response of designed slotline PU/KI included
- Feedback by the beam in long. and transverse model
- T_{eff} at preamplifier 100 K (amp. noise)

t=0, 2.5, 5, 7.5, 10 s

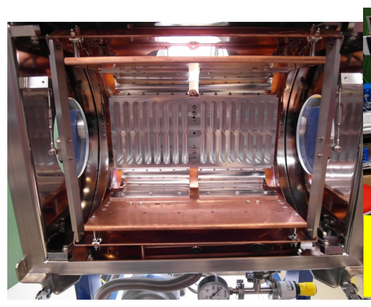


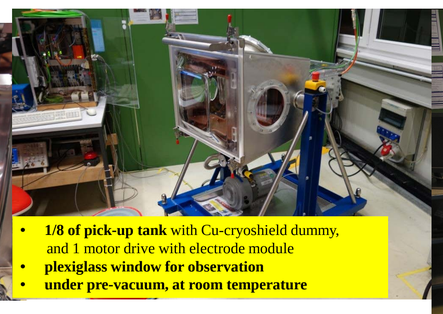
Reached δp/p (rms) =2.2·10^{-4};
ε_h / ε_v (rms) = 1.9/2.8 mm mrad in 10 s



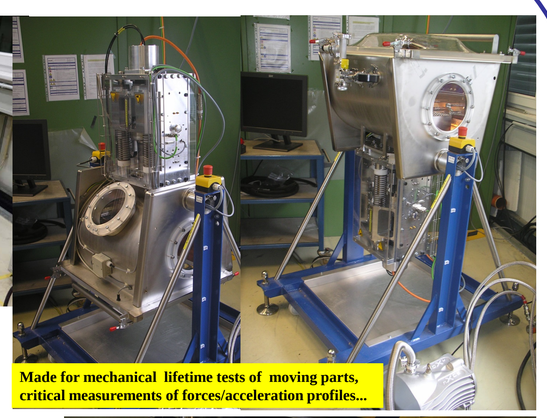
Four times (i.e. accounting for statistical beam signal fluctuations) the total max. cw power is just ≤ installed microwave power of 8 kW.

Linear motor drives for plunging the pick-ups





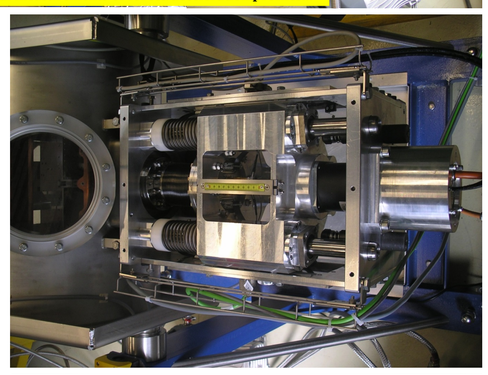
- **1/8 of pick-up tank** with Cu-cryoshield dummy, and 1 motor drive with electrode module
- **plexiglass window for observation**
- **under pre-vacuum, at room temperature**



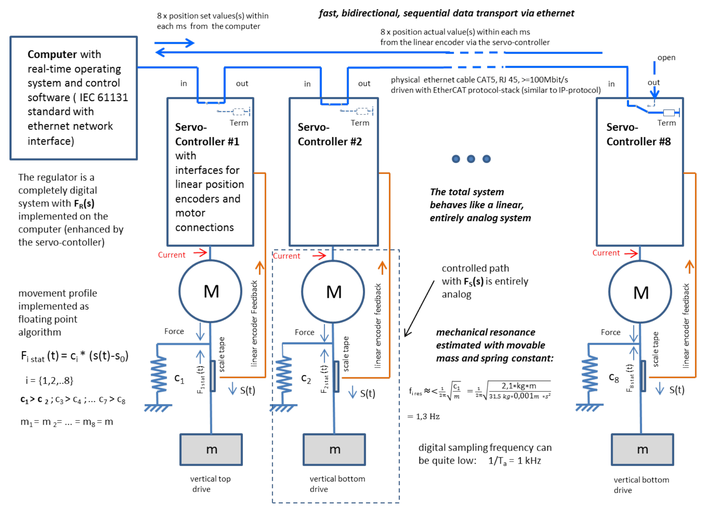
Made for mechanical lifetime tests of moving parts, critical measurements of forces/acceleration profiles...

Features / Requirements

- The load is a resonant system of springs-masses of about 30 kg.
- Stability possibile via real-time electronic support/control.
- Motor drives must plunge outwards jerk-free along a path S=70 mm in T=0,2 s.
- In synchroneous operation, the middle-point (Schwerpunktabweichung) of 2 motor drives deviates < 100 µm for horizontal plunging; see more detailed consideration for vertical plunging (with a scale tapes (Maßband) precision of 5 µm)
- Water-cooled motors for CR beam cycles



Linear drive control scheme (CR pick-up tanks)

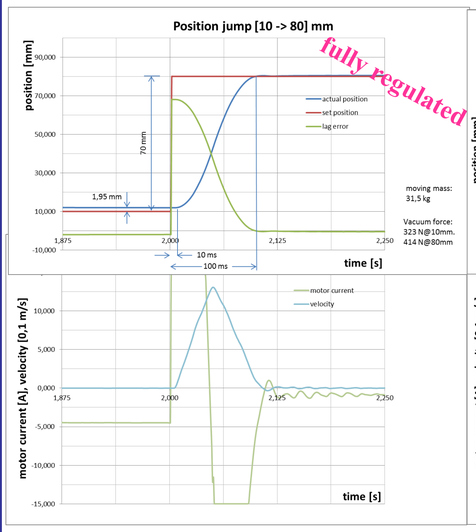


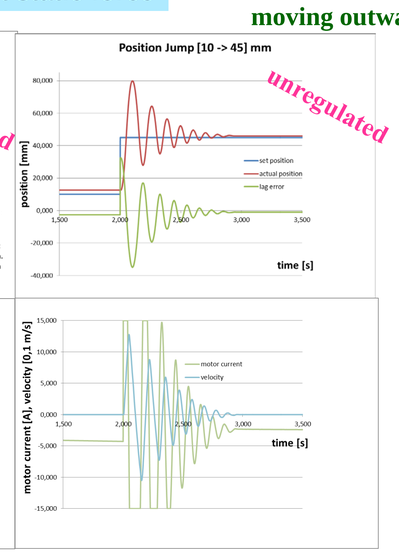
Dynamically most critical case:
Vertical, top plunging
Max. positioning velocity at highest static force

3 possible orientations

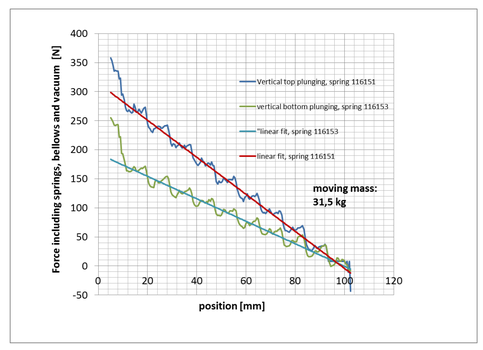
- **horizontal**
- **vertical , motor drive above beam axis, top plunging**
- **vertical, motor drive below beam axis, bottom plunging**

moving outwards from beam axis in max. 120 ms ☺



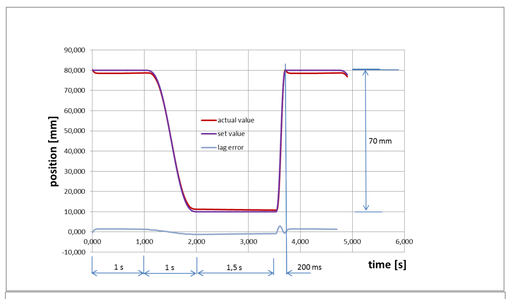


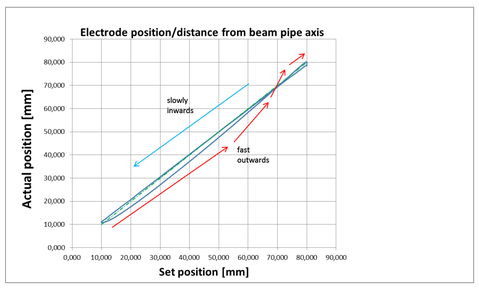
Static force measurement

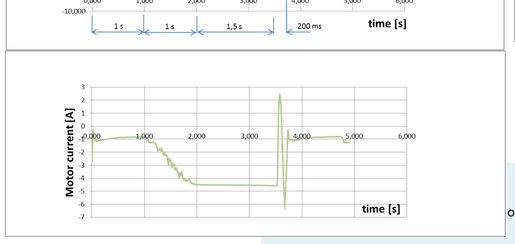


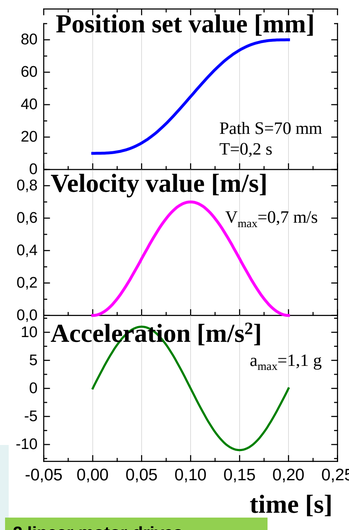
Closed-loop control characteristics

Standard set profile: 1 s inwards / 0,2 s with sin²-shaped velocity outwards

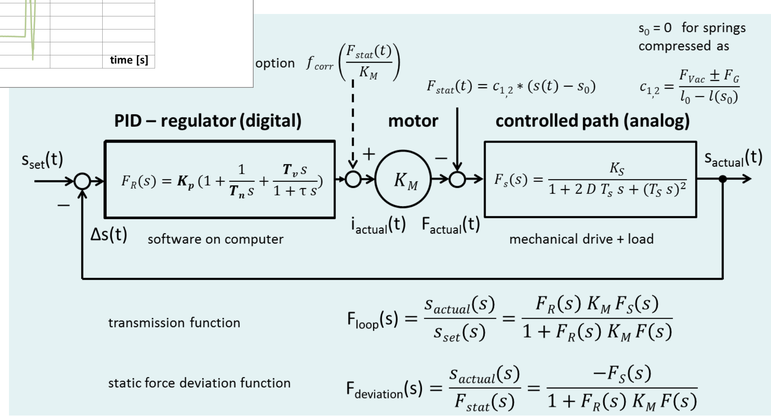








Control loop block diagram (1 of 8)



2 linear motor drives tested synchronously inside prototype pick-up tank specification for CR fulfilled!