Helmholtzzentrum für Schwerionenforschung GmbH

FAIR

# RF-System for Stochastic Cooling in the FAIR Collector Ring

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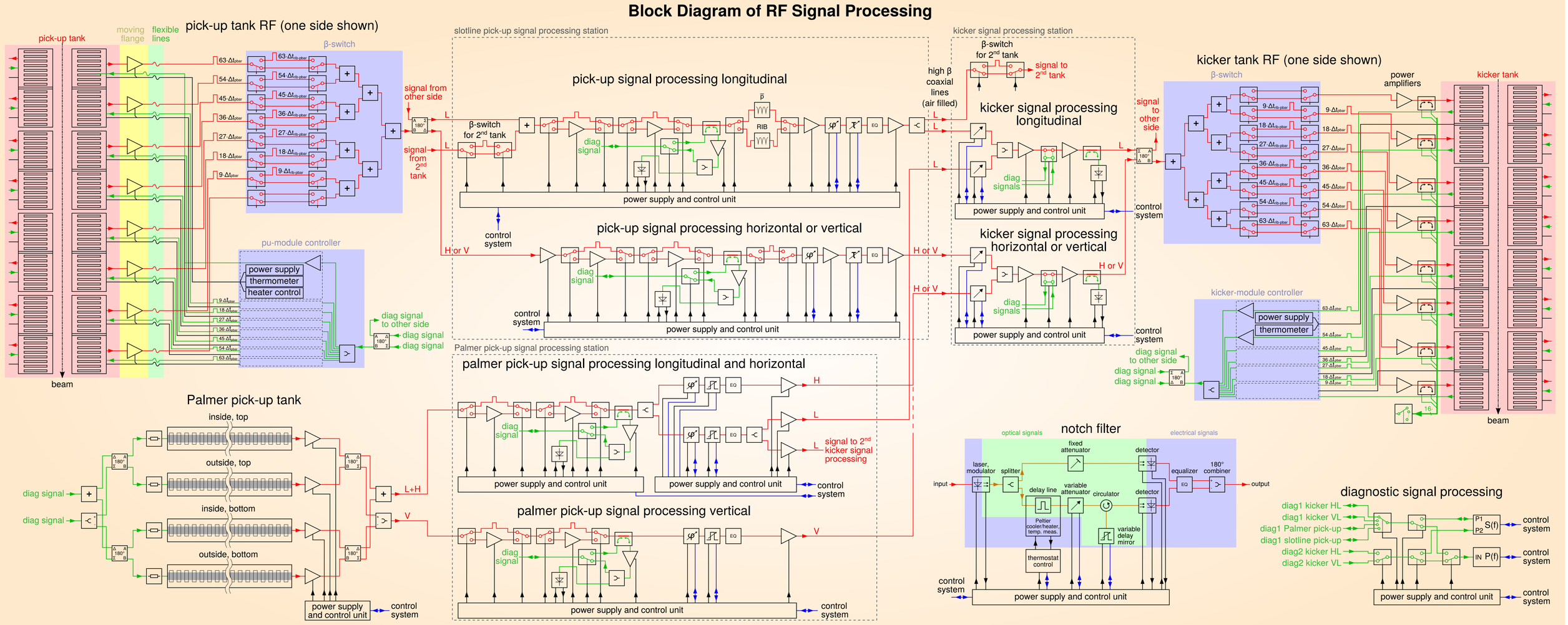
## Block Diagram of RF Signal Processing

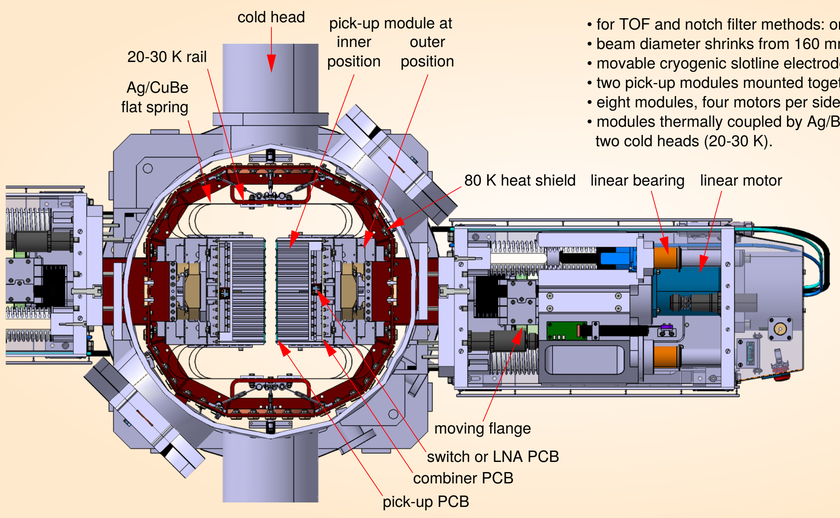



- flexible signal processing: RIBs with β=0.83 and $\bar{p}$ with β=0.97, beam currents from 21 nA ($10^5$ $\bar{p}$) to 17 mA $10^9$ $U^{92+}$
- phase space reduction of $9 \cdot 10^3$ in 9 s for $1 \cdot 10^8$ $\bar{p}$, $1 \cdot 10^6$ in 1 s for $1 \cdot 10^8$ $U^{92+}$
- signals from eight slotline pick-up modules per side combined to one signal by combiner with β-switch
- 180° hybrid combines both sides to sum signal (longitudinal) and difference signal (transversal)
- variable (switchable) gain amplifier (VGA) (longitudinal: -103 dBm for $10^5$ $\bar{p}$ with -76 dBm noise, -20 dBm for $10^9$ $U^{92+}$
- notch filters for longitudinal path: optical fibers for short and long path, one laser transmitter, two receivers, 180° combiner
- longitudinal TOF cooling: long path of notch filter switched off
- rampable variable phase shifters (0…360°), delay lines (0…1.28 ns) and attenuators (-6…-36 dB)
- kicker tank: same type of 180° hybrid and β switch splitter, eight signals per side
- two slotline kicker tanks with two sides times eight water cooled power amplifiers (250 W @ $P_{-1dB}$) per side: 8 kW total RF power
- setup and test: transfer switch for beam transfer function measurement, directional couplers with power meters and switchable pathes to network/spectrum analyzer
- no mechanical switches or delay trombones, all components are solid state devices
- connection to control room: primarily by Ethernet, for commissioning: some single mode optical fibers and low frequency cables
- most components connected by same type of power supply and control units with with current monitoring, digital and analog I/O and async. serial connention

lines: RF beam signal, RF diag signal, optical signal, digital control, LF signal

parts: Wilkinson combiner, resistive splitter, solid state relais, delay line, flexible line, ground, coupling slot, antenna, resistor, coaxial feedthrough, 180° hybrid, 180° combiner, equalizer, directional coupler, variable delay, var. phase shifter, variable attenuator, attenuator, amplifier, power meter, network analyzer, spectrum analyzer

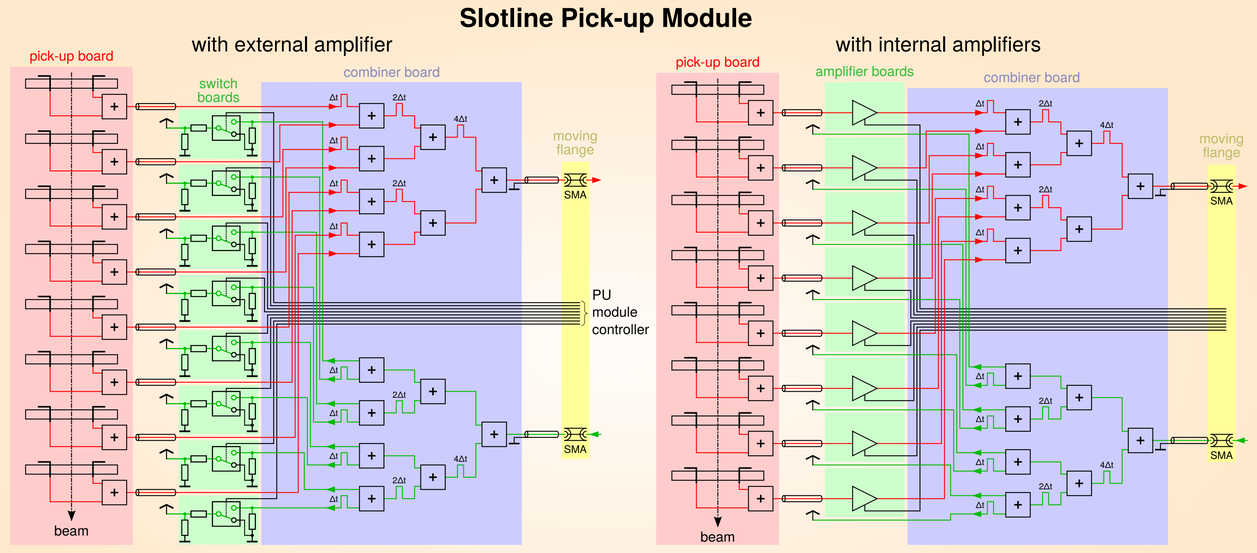
## Sectional View of the Prototype Cryogenic Slotline Pick-up Tank




- for TOF and notch filter methods: one horizontal and one vertical pick-up tank
- beam diameter shrinks from 160 mm at injection to ≲20 mm
- movable cryogenic slotline electrodes for ions with two different β
- two pick-up modules mounted together on linear motor-driven support
- eight modules, four motors per side; 128 coupling slots per tank
- modules thermally coupled by Ag/BeCu flat springs to second stage of two cold heads (20-30 K).

- first stages (80K) connected to heat shield and support rods
- major parts of a first prototype slotline pick-up tank with motor drives and cryogenics is designed and constructed
- test: later this year.

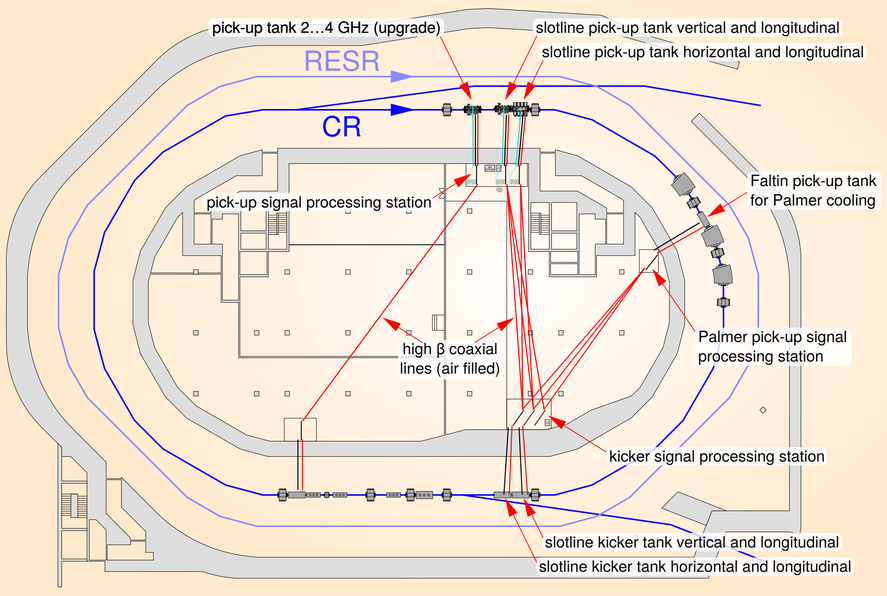
## Slotline Pick-up Module




- eight coupling slots in a row with 25 mm spacing integrated together with the first Wilkinson combiner on common $Al_2O_3$ PCB
- eight signals from this PCB combined to single vacuum feedthrough by seven Wilkinson combiners and delay lines integrated on second PCB
- delay lines dimensioned for antiprotons; slight performance degradation for RIBs
- test signal input on each module; individual slots switchable
- start version: one low noise amplifier per module directly behind vacuum feedthrough

- performance ugrade: cryogenic LNA inside the module
- LNA at this point would not see losses of internal combiners and RF lines
- slotline coupler with first Wilkinson combiner has high reflection factor; LNA would see own electrically cold input as terminator
- significant increase of the signal to noise ratio
- radiation hardness and reliability is critical and has to be checked

## CR/RESR Building with Stochastic Cooling Installations




- two cryogenic slotline pick-up tanks with movable slotline electrodes located at zero dispersion for $\bar{p}$ and pre-cooled RIBs (1…2 GHz)
- for hot RIBs: pick-up with Faltin type electrodes at high dispersion
- additional pick-up and kicker tanks foreseen (2…4 GHz upgrade)
- two slotline kicker tanks for all cooling methods and both particle species
- major part of signal processing installed in radiation shielded inner part of building
- components of intermediate power RF signal processing: mounted on vertical aluminum boards, thermally stabilized by water cooling

## Summary and Outlook

- presented RF signal processing can be used for Palmer, TOF, and notch filter cooling in three planes for particles with two different β and a wide range of beam currents
- calculations of power levels and delay time in the whole circuit currently in progress
- some of the standard components are already chosen and characterized
- for the β-switches with integrated combiner, a prototype exists
- for variable attenuators, delays, and phase shifters the development has begun
- most of the other components are pending but commercially available
- power amplifiers are specified; call for tender in progress
- first prototype of pick-up module built up and measured earlier without tank and beam
- second prototype with some minor modifications is underway
- design of the Faltin pick-ups is in progress

## Slotline Kicker Module

- each power amplifier drives one kicker module
- module consists of splitter board and slotline electrode board
- eight slots with 25 mm spacing
- major part of power reflected from slotlines through last Wilkinson splitter
- different lengths of delay lines on splitter board: power would be dissipated in splitters
- 180° hybrids: reflected power comes out of difference ports
- water cooled power terminators inside tank
- design of kicker tank not yet started