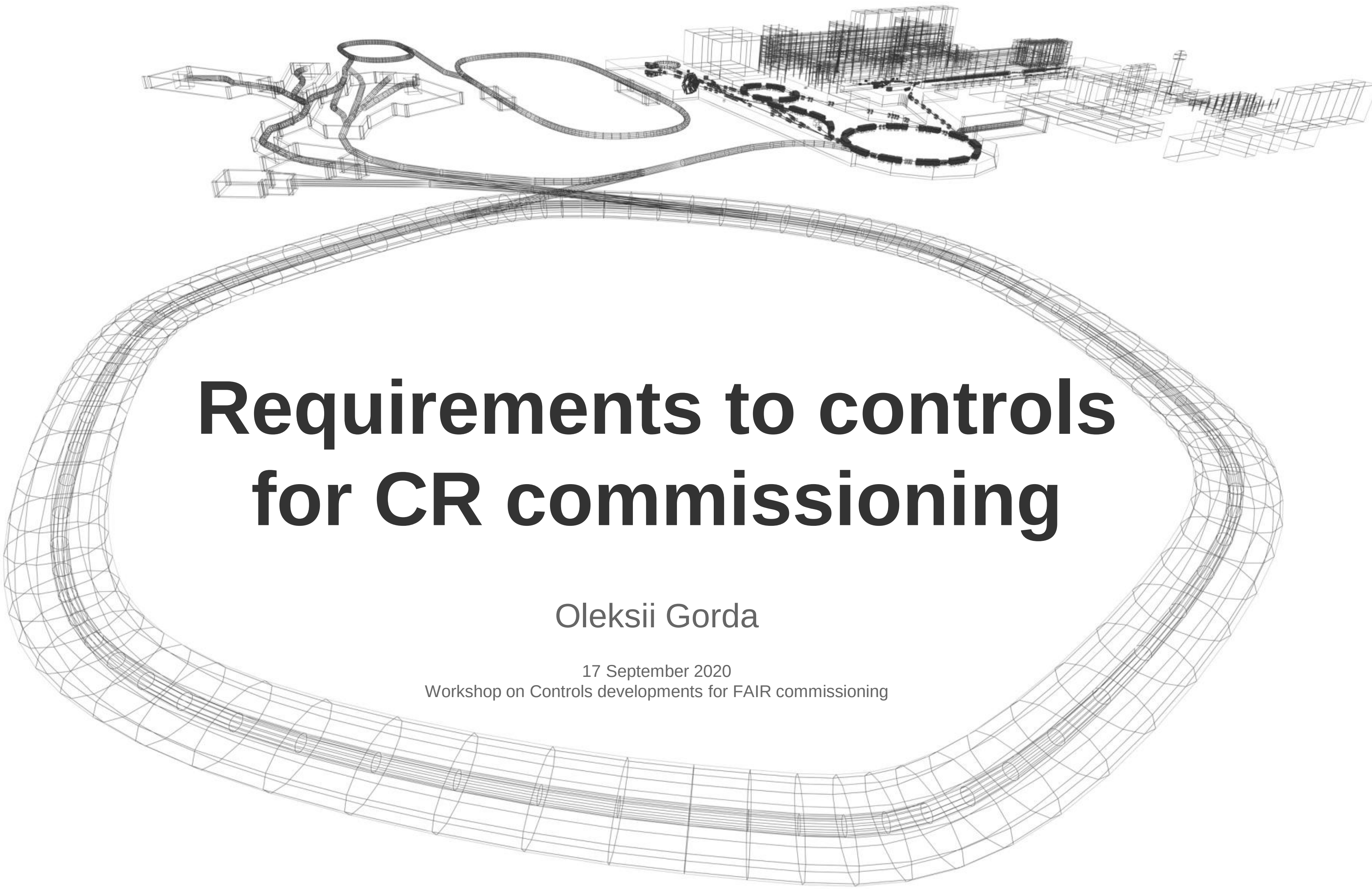
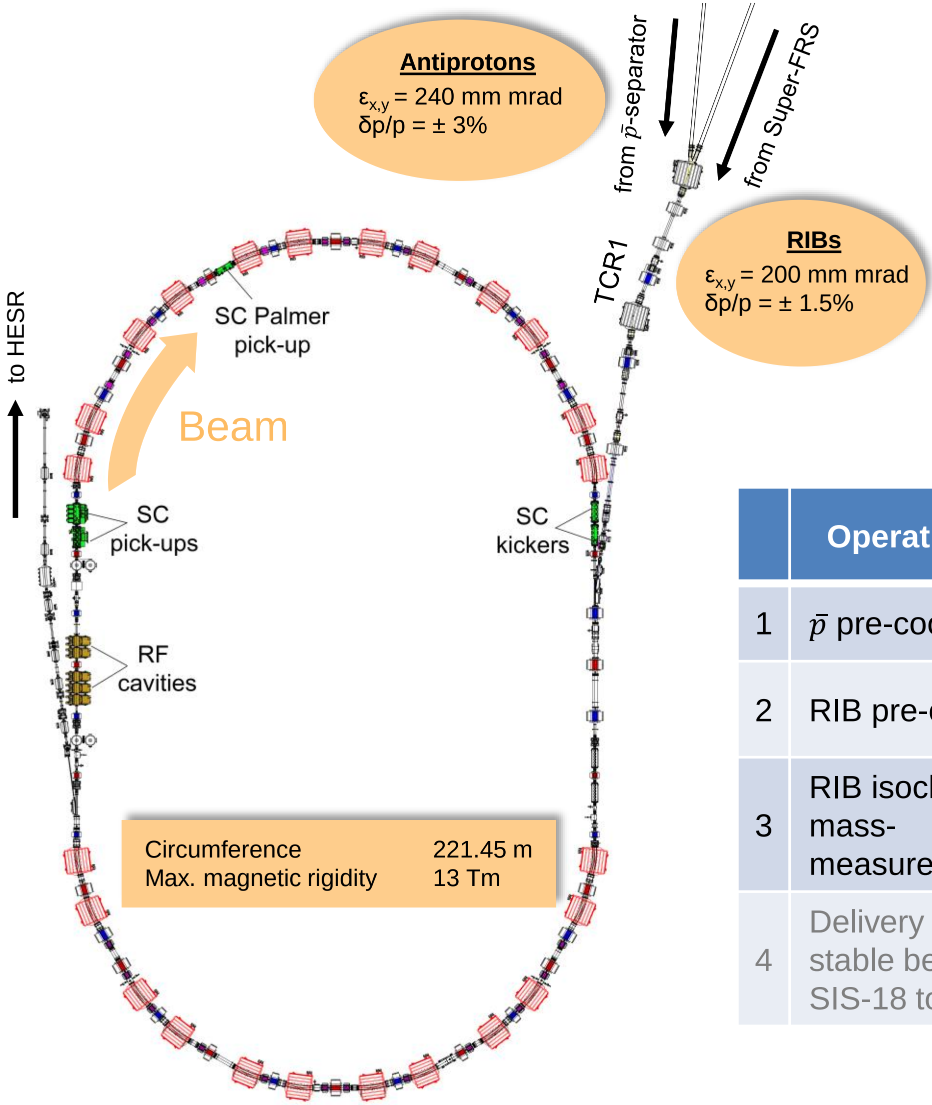


Requirements to controls for CR commissioning

Oleksii Gorda

17 September 2020
Workshop on Controls developments for FAIR commissioning

Recap: overview and tasks of CR



- No beam acceleration or deceleration. Operation at the fixed magnetic rigidity.
- Flexibility in switching between the different operation modes.
- Polarity change of equipment required when switching between antiproton and RIB modes.

	Operation mode	Kin. Energy	N_{max}	Cycle Time	
1	$\bar{p}$ pre-cooling	3 GeV	10^8	10 s *	→ extraction to HESR *
2	RIB pre-cooling	740 MeV/u	10^8	1.5 s	→ extraction to HESR *
3	RIB isochronous mass-measurements	400-790 MeV/u	1-10^8	few turns	→ in-ring
4	Delivery of primary stable beams from SIS-18 to HESR **	On demand, (with pre-cooling if necessary)			→ extraction to HESR **

* *within the Modularized Start Version (MSV) of the FAIR project*
** *option under consideration*

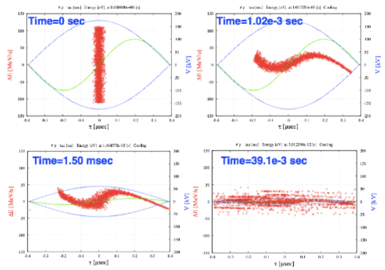
CR cooling cycle

Injection

- single-turn
- injected bunch length σ_b ~ 50 ns.

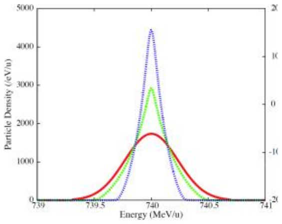
Bunch rotation & de-bunching

- Max. RF voltage of 100 kV for p-bar bunch rotation.



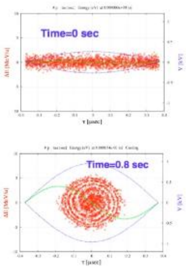
Stochastic cooling

- Simultaneous 3D cooling



Re-bunching

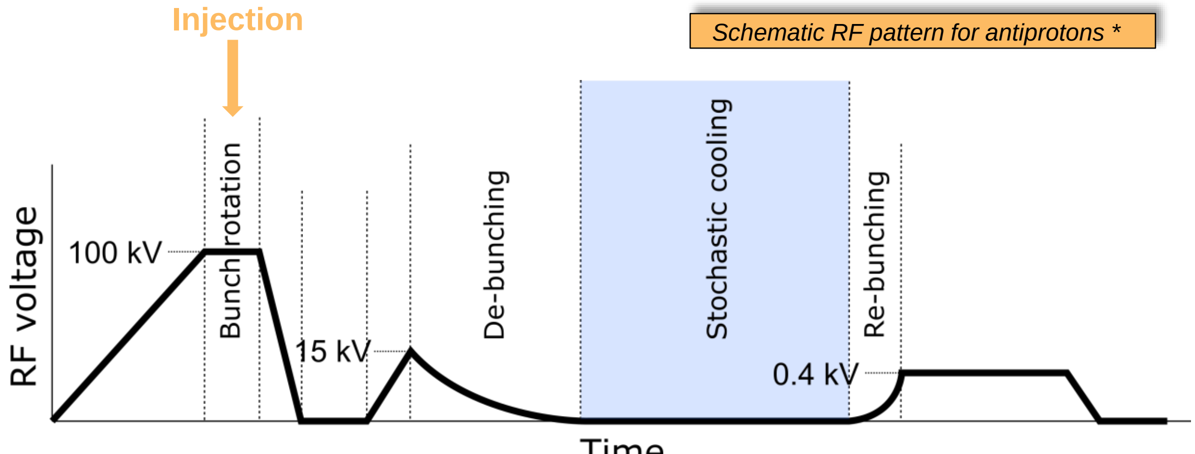
- Re-excite RF voltage for re-bunching



Extraction

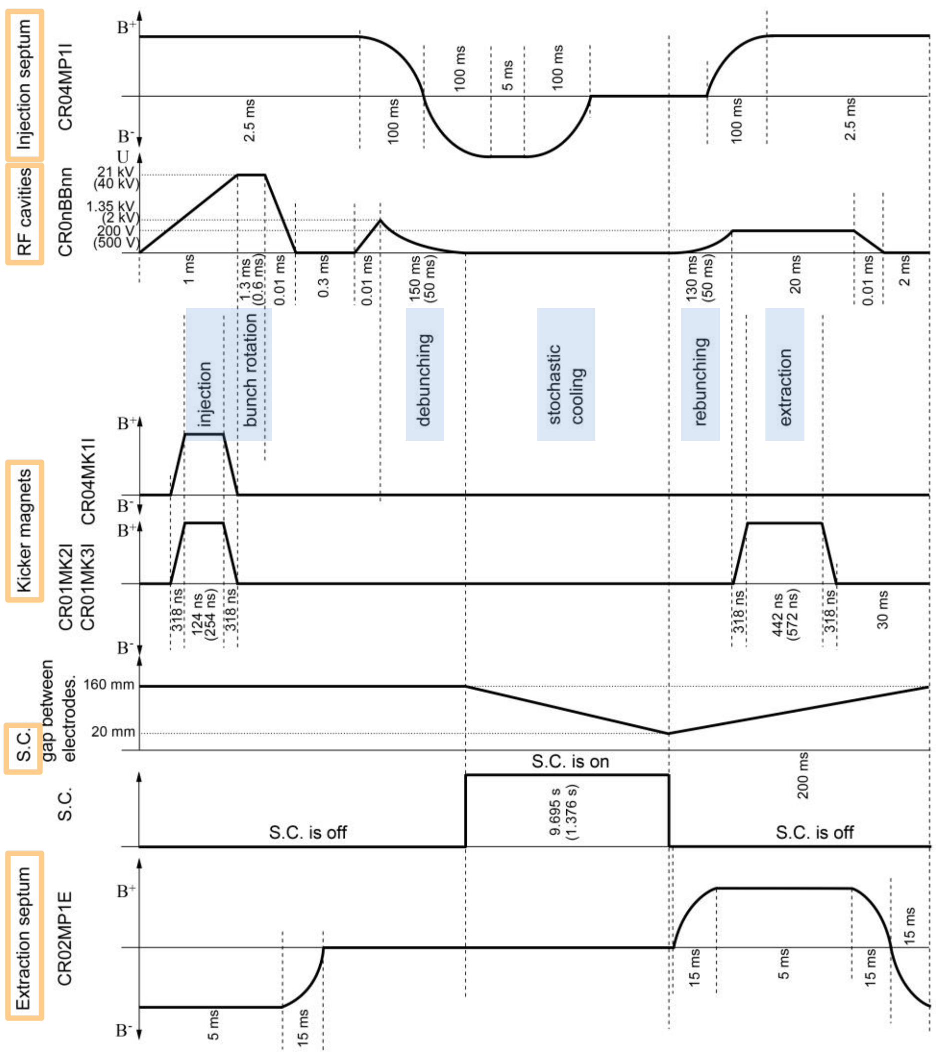
- to HESR

*Schematic RF pattern for antiprotons **



** not true to scale*

Planned operation cycle



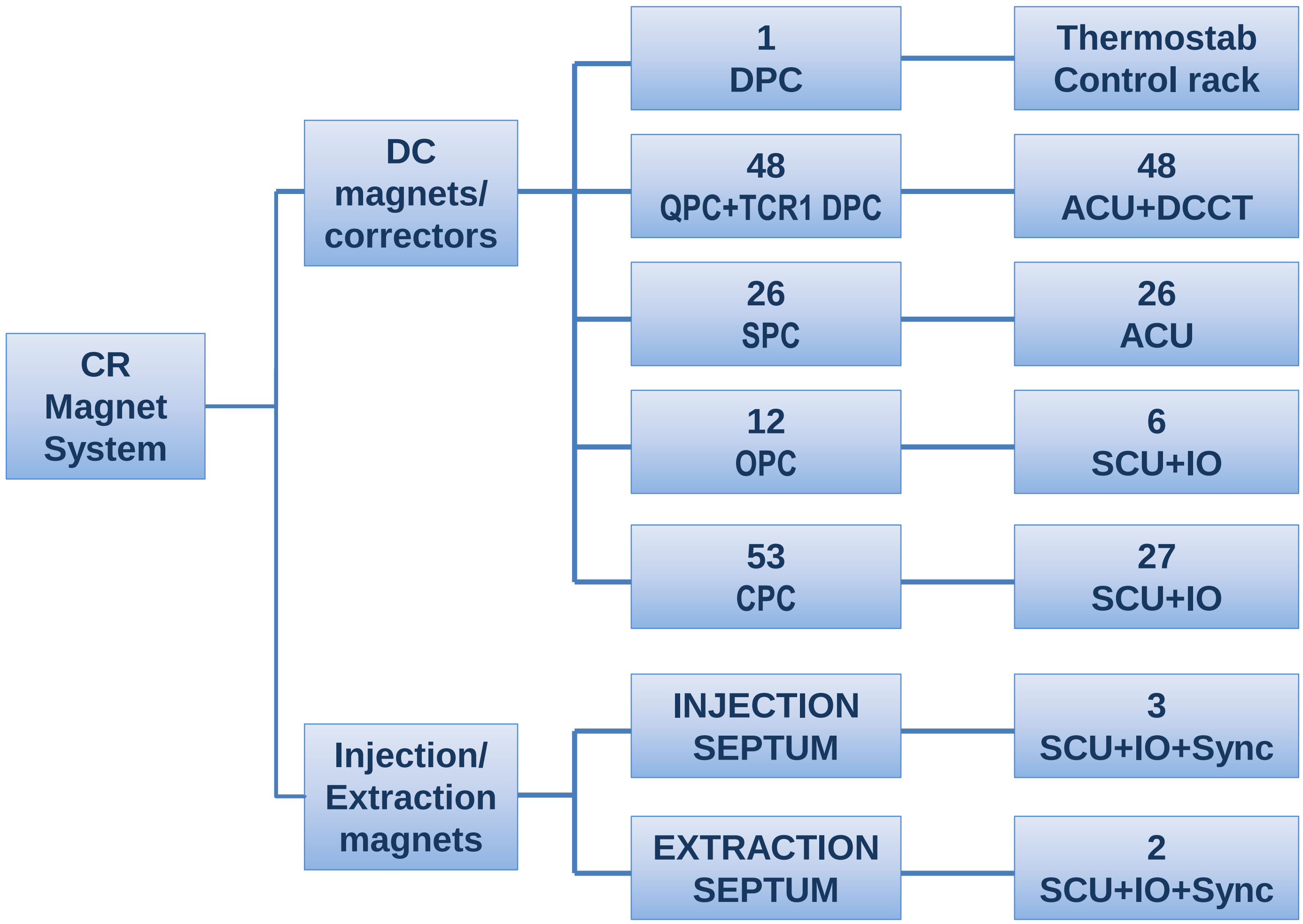
** not true to scale* *** values in () correspond to RIB mode*

- Appropriate timing signals/sequences for the septum magnets, kicker magnets, RF cavities and stochastic cooling system.
- Real-time timing triggers for the machine modes, RF clock, stochastic cooling and other events:
  → manual adjustment/optimization of the timing sequence depending on the operation mode.
- Individual equipment timing triggers during the commissioning with/without beam.
- Synchronization of hardware operation including Super-FRS, pbar-separator, RF turn on, equipment state changes, data acquisition for power supplies and beam diagnostics.
- Polarity change of the main magnets, kickers and septa for commissioning and operation with different beams.

Commissioning without beam

- Testing/dry running of individual TCR1 and CR equipment – testing of components and data acquisition systems according to specifications (magnets/power converters, RF system, injection/extraction, beam diagnostics, stochastic cooling components, experimental devices).
- Manual and/or automated testing with using of programmable sequencer tasks (connection/communication, powering, interlocks, etc.).
- Tools for data analysis and visualization – manual or automated (for standard testing procedures)?
- Possibility of parallel equipment testing: lock test circuits during testing to prevent simultaneous access.
- Dry running of the complete CR system within programmed sequencer tasks taking into account the required timing dependencies.

Example: power converters



Example: quadrupole PC control

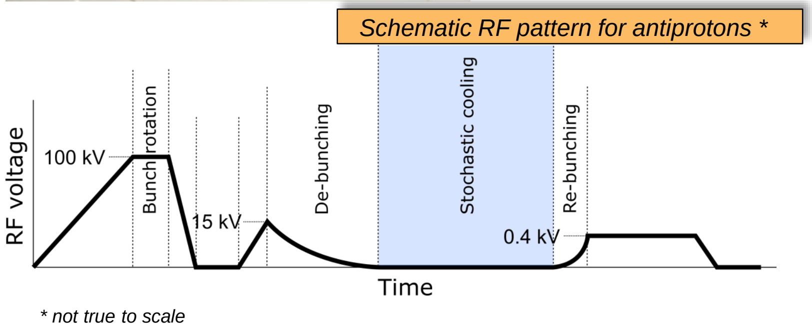
Interlock source	Interlock	ICM target connector
ICM board		
Main contactor	DIN1 - Main contactor	X4
Fast shutdown + Door switch	DIN2 – Fast OFF	X5
Control Part Mains Monitor	DIN3 – Control Part Mains Voltage	X6
Power Part Mains Monitor	DIN4 – Power Part Mains Voltage	X7
Control part power CBs status	DIN5 – Protective Power Switch	X8
Heatsink TSW	DIN6 – Heatsink overheat	X9
PAS Interlock / reserve	DIN7 – PAS interlock	X10
WCable connection TSW	DIN8 – Load cable TSW	X11
Termoswitch @130 Transformer	DIN9 – Step-down transformer warning	X12
TermoSwitch @120 Transformer	DIN10 – Step-down transformer Overheat	X13
Output overvoltage	AIN1 – Load voltage	X2
Primary overcurrent	AIN2 – Primary current	X31
DC Link voltage level	AIN3 – DCLink voltage	X3
Earth current monitor	AIN4 – Earth current	X32
Out Oscillations	AIN5	X15
Waterflow monitor 1	WF1 – PC waterflow monitor	X30
Waterflow monitor 2	WF2 – WCable waterflow monitor	X30
40 DIN Extention board		
Thermo SW Magnet 1 – EXT1	DIN11 – Load protection TSW	EBoard
CWater SW Magnet 1 – EXT1	DIN12 – Load protection Water	EBoard
Thermo SW Magnet 2 – EXT2	DIN13 – Load protection TSW	EBoard
CWater SW Magnet 2 – EXT2	DIN14 – Load protection Water	EBoard
Thermo SW Magnet 3 – EXT3	DIN15 – Load protection TSW	EBoard
CWater SW Magnet 3 – EXT3	DIN16 – Load protection Water	EBoard
Thermo SW Magnet 4 – EXT4	DIN17 – Load protection TSW	EBoard
CWater SW Magnet 4 – EXT4	DIN18 – Load protection Water	EBoard

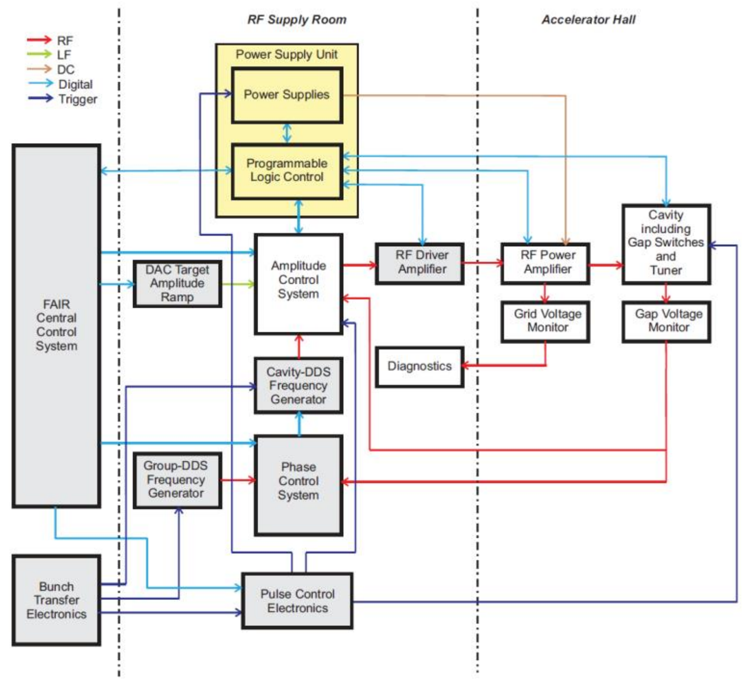
List of QPC type PC control and status channels:

- Control: PC soft start
- Control: PC on/off
- Control: Output current setpoint
- Status: Load current
- Status: Load voltage
- Status: Primary current
- Status: Dclink voltage
- Status: Earth current
- Status: up to 20 DIN

- Specific features:
  - testing of the polarity change within the specified time of 60 sec.
  - quadrupole ramping test within the planned antiproton cooling cycle according to the requirements (0.024 T/s ramping rate).

RF de-bunchers

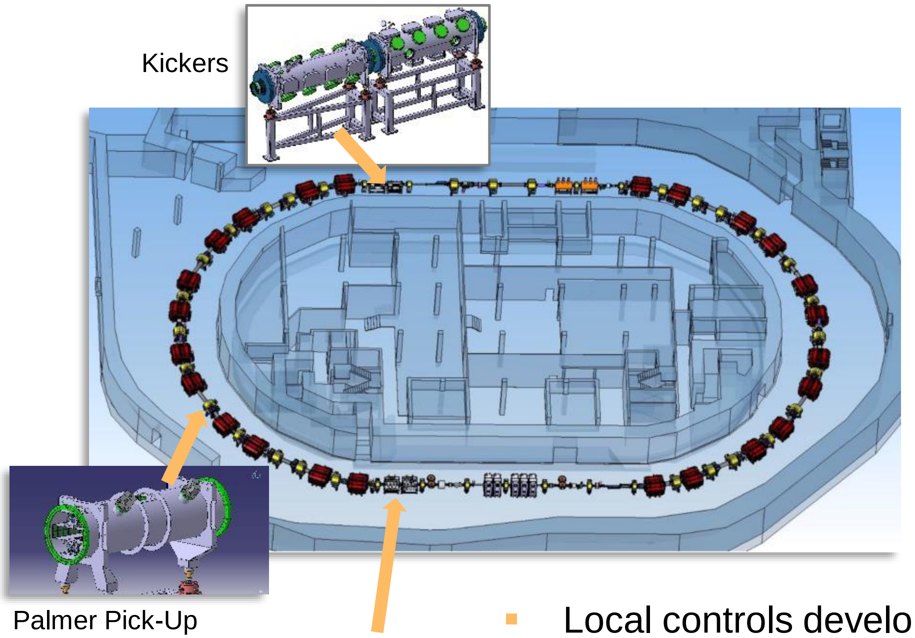




- Testing of interfaces for pulse, amplitude and phase control in operational environment.
- Flexibility in manual setting and testing of the RF pattern implementation and timing sequences for the RF processes during commissioning and operation with beam.
- Different operation modes (antiprotons, RIBs, stable ions) require specific settings and timing:
  → system optimization and dry running of pre-defined RF cycles according to the planned operation modes (create sequencer tasks?).
- Saving settings and archiving measured parameters.

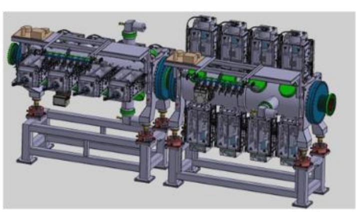
Stochastic cooling system

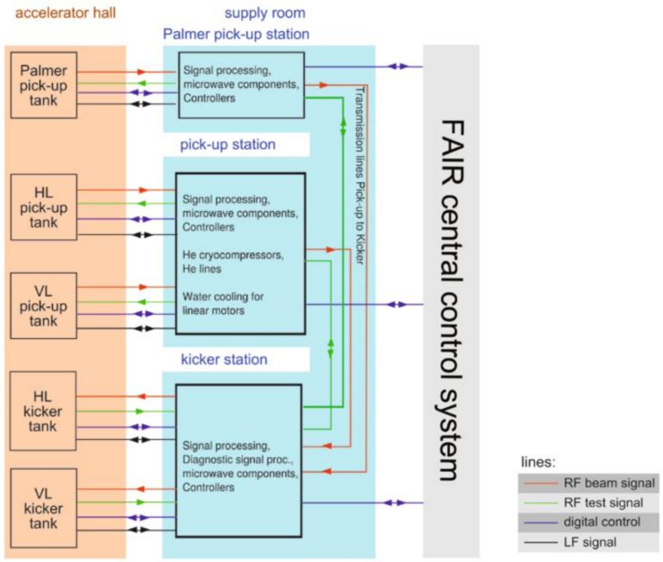
Kickers



Palmer Pick-Up

Slot-line double Pick-Up



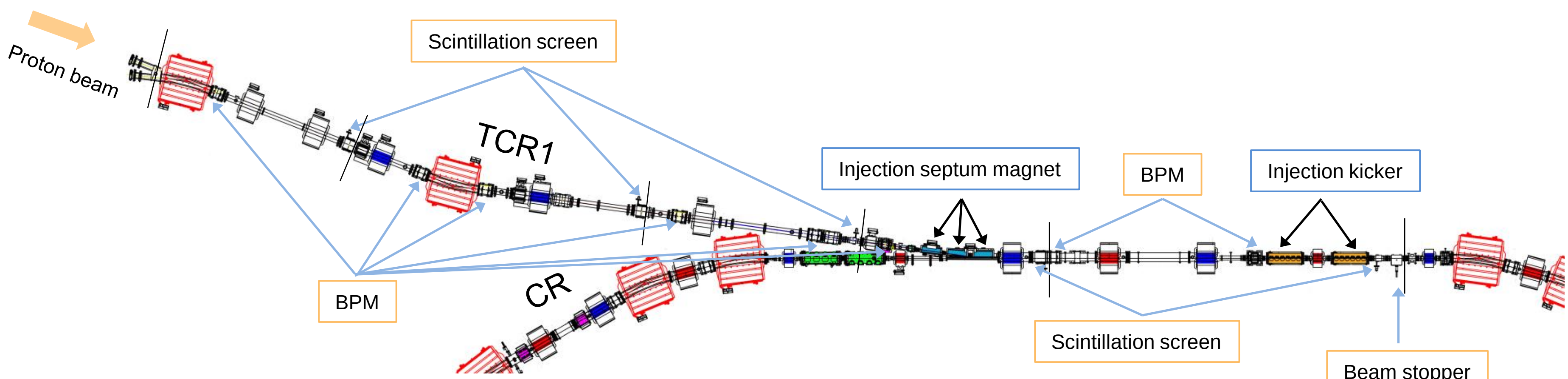


- Local controls developed by technical expert group. Development of operational planned in collaboration with FZJ colleagues
  ⟶ to be integrated into FAIR control system.
- Implementation of different cooling methods depending on operation modes (antiprotons, RIBs, stable ions) require different sequences/cooling time/hardware
  ⟶ need flexibility in setting up of the operation cycles/timing signals.
- Interfaces for testing and tuning of movable linear motors of the cryo pick-ups within planned working cycles ⟶ following shrinking beam during cooling.
- Testing of controls for the cryocompressors, interlocks etc.

Commissioning with beam

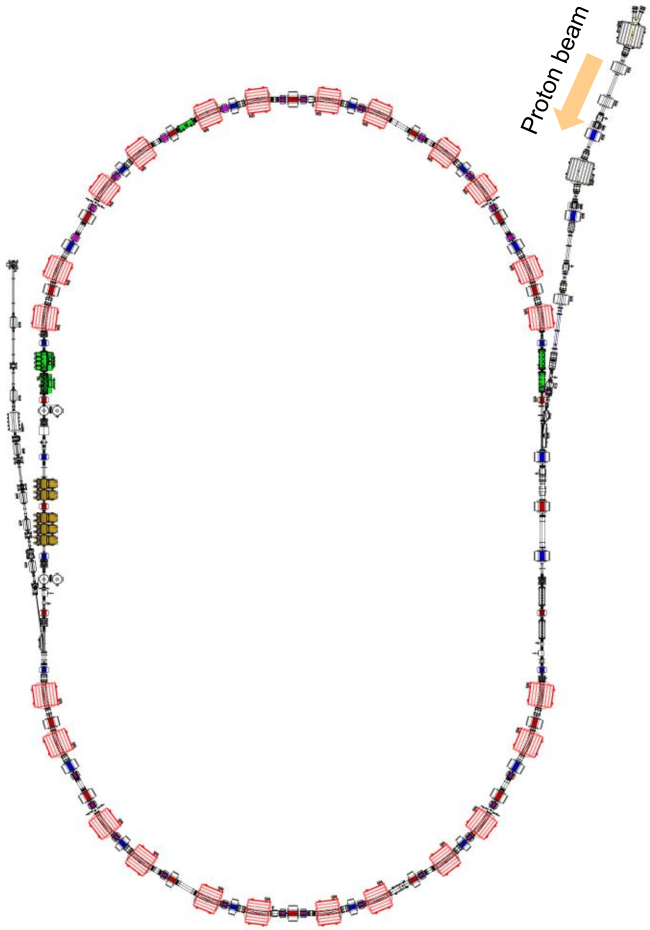
- First stage - commissioning and tuning of the machine with proton beam (later with stable ions) from SIS18:
  → commissioning with antiprotons and RIBs – later stage.
- Multiple settings have to be prepared, pre-programmed and saved according to the commissioning stages/available beams.
- Provide possibility for manual and/or automated control of individual equipment.
- Dedicated timing sequences/dependencies and hardware synchronization between SIS18, pbar-separator, Super-FRS and beamlines according to the commissioning stages/operation modes.

Commissioning with beam – injection



- Control and optimization of key equipment section-by-section.
- Collect and save equipment settings and measured data from the beam diagnostics devices.
- Diagnostics in TCR1 channel: 6 BPMs and 3 scintillation screens to measure the transverse beam position and shape.
- Diagnostics in CR injection region: 2 BPMs and 2 scintillation screens.
- Beam stopper will be used for relative measurement of the beam current and for protection of the ring equipment.
- Beam loss monitors might be used for beam loss detection at specific locations.

First turn → stored beam



- First turn – data from scintillation screens, BPMs and scrapers to monitor the beam position/profile.
- Beam stoppers for terminating the beam and measurements of relative beam current.
- Application of beam loss monitors for control of beam losses and estimation of beam position in combination with scrapers.
- For commissioning with antiprotons additional collimation in the pbar-separator might be necessary, e.g.
  → need to adjust and control the device settings and timing sequence.
- Beam current measurements and evaluation of injection efficiency.
- Stored beam – standard measurements of the main parameters:
  - orbit measurements, tuning and corrections,
  - tune and chromaticity measurements and corrections etc.
- Longitudinal bunch profile measurements during the RF processes.
- Measurements of transverse beam profile and momentum distribution during the stochastic cooling.
- Data collection and saving for further analysis and visualization.

Outlook

- Establish a more intense and regular communication with Controls department regarding interfaces to the control system and specific requirements for CR involving technical experts.
- Preparation of detailed test procedures for equipment testing by technical expert groups.
- Major part of the CR components including magnets, power converters, injection/extraction, beam diagnostics and vacuum will be produced and delivered by BINP (Novosibirsk). BINP colleagues would like to be involved into development of the control system interfaces for CR in order to prepare for testing and commissioning of equipment (writing FESA classes etc.) taking into account requirements of the FAIR control system.

Thank you!