SIS100 RF Systems

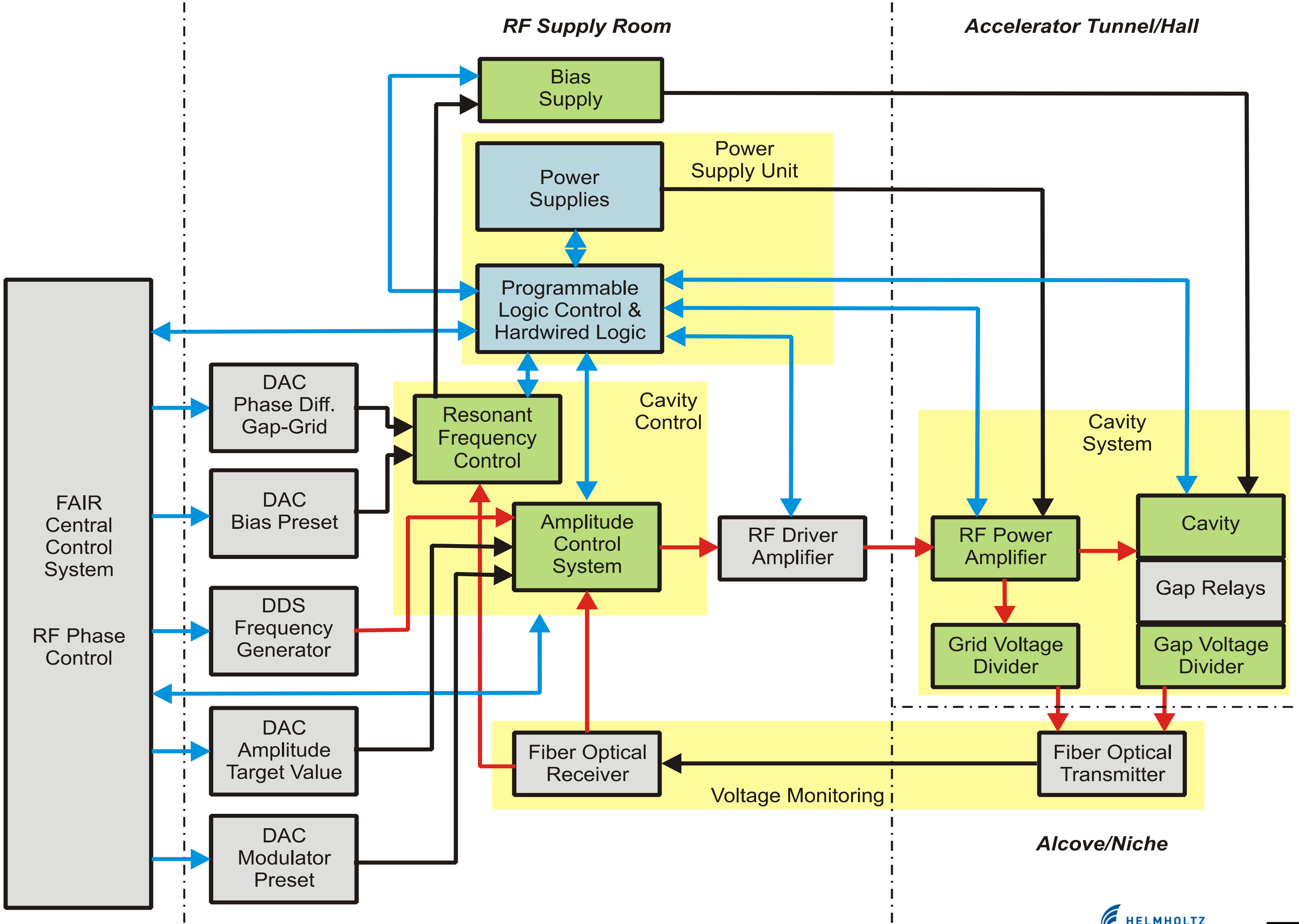
Synchrotron RF Systems

Ring	RF System	Frequency Range [MHz]	Total Voltage [kV] Stage A/B	Duty Cycle	Cavity Length	Qty Stage A/B
SIS18 Upgrade 2.2.4	Accel. h=2 Bunch Compression	0.43 ... 2.8 0.8	40 40/80	50% 0.05%	1.27 m 1 m	3 1/2
SIS100 2.8.4	Accel. h=10 (Ferrite) Bunch Compression Barrier Bucket Long. Feedback	1.1 ... 2.7 0.395 ... 0.485 1.5 (broadband) LF...5.6 (broad-band)	280/400 360/640 2 x 15 20	100% 0.05% 20% 100%	2.8 m 1 m 1 m 1 m	14/20 9/16 2 2
SIS300 2.12.4	Accel. h=10 (Ferrite)	1.1 ... 2.7	0/160	100%	2.8 m	0/8

Technical Structure of Ring RF Systems

- Power Supply Unit (including Programmable Logic Control, PLC) – especially relevant for RF tube power amplifiers, PLC required for slow-control, interlock handling, etc. – Siemens S7 is standard
- Cavity and Power Amplifier
- Driver Amplifier
- Low-Level RF System
  - Cavity control
    - Amplitude control
    - Resonant frequency control (if required)
    - Feedback around the amplifier (if required)
  - Phase control and other higher-level control systems

SIS100 RF Systems



Grey Boxes:

Content of

EoI 13b

"Interface and Low-Level RF"

Green Boxes:

Usually included in content of delivery of cavity supplier

Standardization Requirements

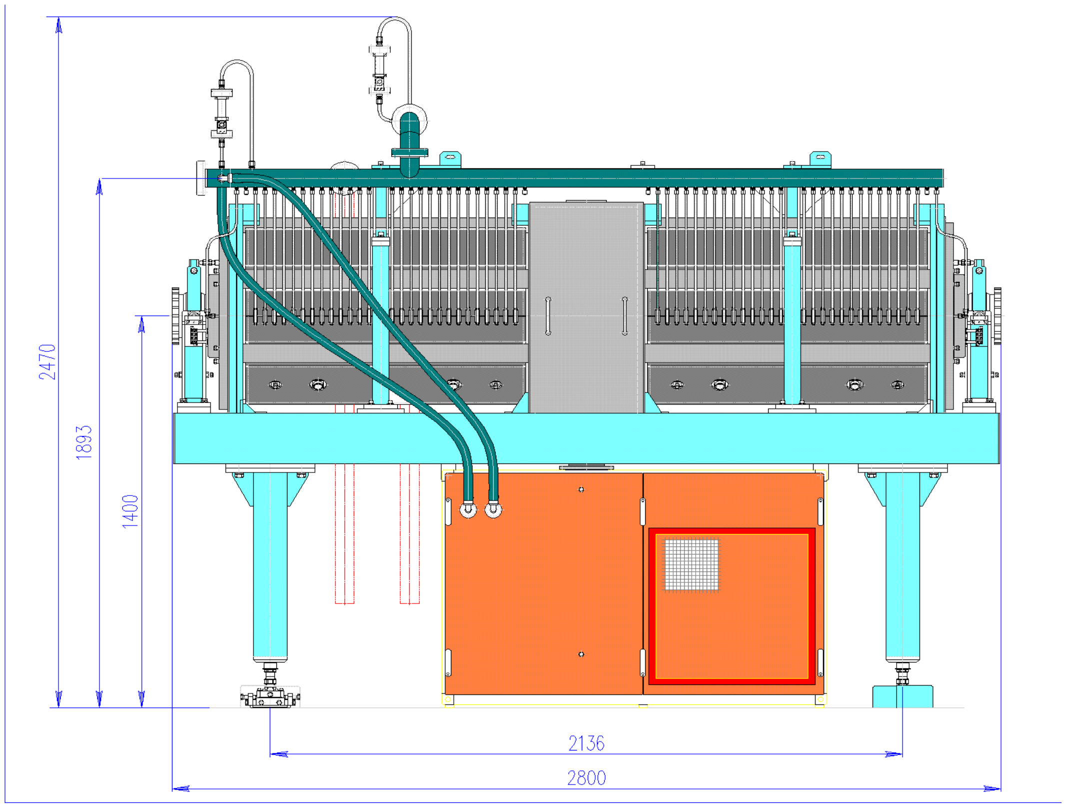
Background: Keep maintenance effort & costs for spare parts low

Sub-systems to be standardized (EoI 13b):

- Limited number of different types of **driver amplifier** (modular system)
- **Gap switches**
  - Fast semiconductor switches for cycle-to-cycle switching
  - Slow ones for de-activating cavities (vacuum relays)
- Gap and grid **voltage monitors** (optical transmission)
- Limited number of different types of **supply units** (only one type of PLC)
- **Interfaces** to central control system (e.g. DDS, DAC)

Reference: H.Klingbeil et al.: "Standardization Requirements for FAIR RF Systems" (Common Remarks for FAIR RF Systems)

SIS100 Acceleration



Drawing by BINP

Tasks:
- Main RF system of the SIS100
- Acceleration (*h=10*)
- AP Batch compression (t.b.d.)

Main Parameters (one of 14/20 RF units):

Frequency (MHz)	$1.1 < f \leq 2.7$
Gap voltage (kV)	0.03 to 20
Duty cycle	c.w.
Aperture of the beam pipe, circular diameter (mm)	150 (CF160)
Installation length, flange to flange (m)	2.8
Installation width (m)	±0.70
Installation height around beam axis (m)	+ 0.50 / -1.40
Height of beam axis (m)	1.4
Pressure of beam pipe (mbar)	$\leq 1 \cdot 10^{-12}$
Heating of the cavity beam pipe (°C)	300

SIS100 Acceleration

Important Design Considerations

- Ferrite cavity (a MA solution could be more compact, but the power/cooling requirements would be much higher). Ferrite solutions are a well-proven concept.
- Ferrite cores are segmented and glued together (simplifies production of ring cores, good experience at BINP) – this also reduces Q loss effects
- Only one tetrode (GSI SIS18 concept) instead of push-pull amplifier (original BINP concept) due to reliability considerations (reduced number of "hot spots")
- Solid-copper cooling disks (length reduction, simplified mechanical solution)

SIS100 Acceleration

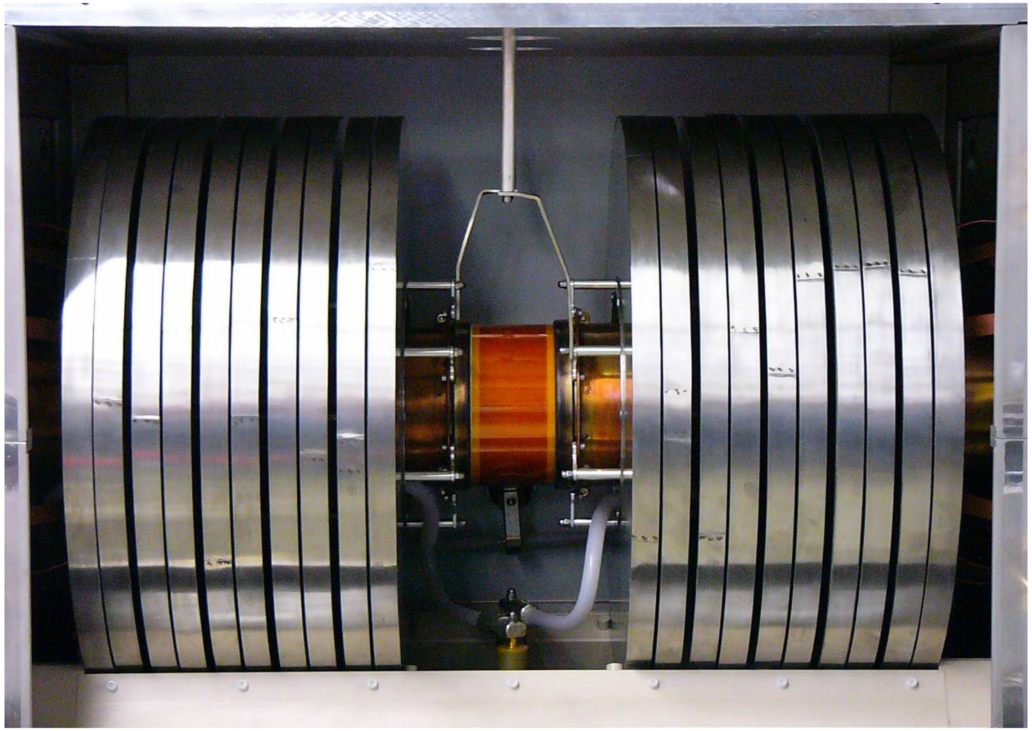
Status

- Project leader: Dr. H. G. König/Dr. U. Laier
- Production documents available, only minor modifications required
- BINP is willing to manufacture the system, but only on a contract basis, not as an inkind contribution

Outlook on Realization

- BINP estimation:
  - Two years for realization of the first series system (after signing contract)
  - Two months per system for series production (about 2.5 years in total)
  - → about 5...6 years total project time including lab acceptance tests

SIS100 Bunch Compression



Tasks: • Bunch compression by rotation of bunches in phase space *(h=2)*

Main Parameters (one of 9/16 RF units):

Frequency (MHz)	$0.39 \leq f \leq 0.49$
Gap voltage (kV)	1 to 40
Duty cycle	$3 \cdot 10^{-4}$ ($5 \cdot 10^{-4}$)
Maximum pulse duration (µs)	300 (500)
Maximum repetition rate (Hz)	1
Aperture of the beam pipe, circular diameter (mm)	150 (CF160)
Installation length, flange to flange (m)	1
Height of beam axis (m)	1.4
Pressure of beam pipe (mbar)	$\leq 1 \cdot 10^{-12}$
Heating of the cavity beam pipe (°C)	300

Design Sketch:
Two inductively loaded (MA) quarter wave coaxial resonators operating on a common gap. Air cooling of MA cores. Push-Pull Amplifier consisting of two tetrodes. Design based on existing SIS18 BC (see above).

SIS100 Bunch Compression

Important Design Considerations

- Only MA material allows sufficiently high flux density, compact cavity design, and required broadband behavior
- Project can be based on experience with existing SIS18 bunch compressor system
- Technical risks:
  - Operating frequency must be reduced significantly
  - Activation level of Co-based MA material still under discussion (alternative: Fe-based MA material, but availability of appropriate ring-cores not yet guaranteed)

SIS100 Bunch Compression

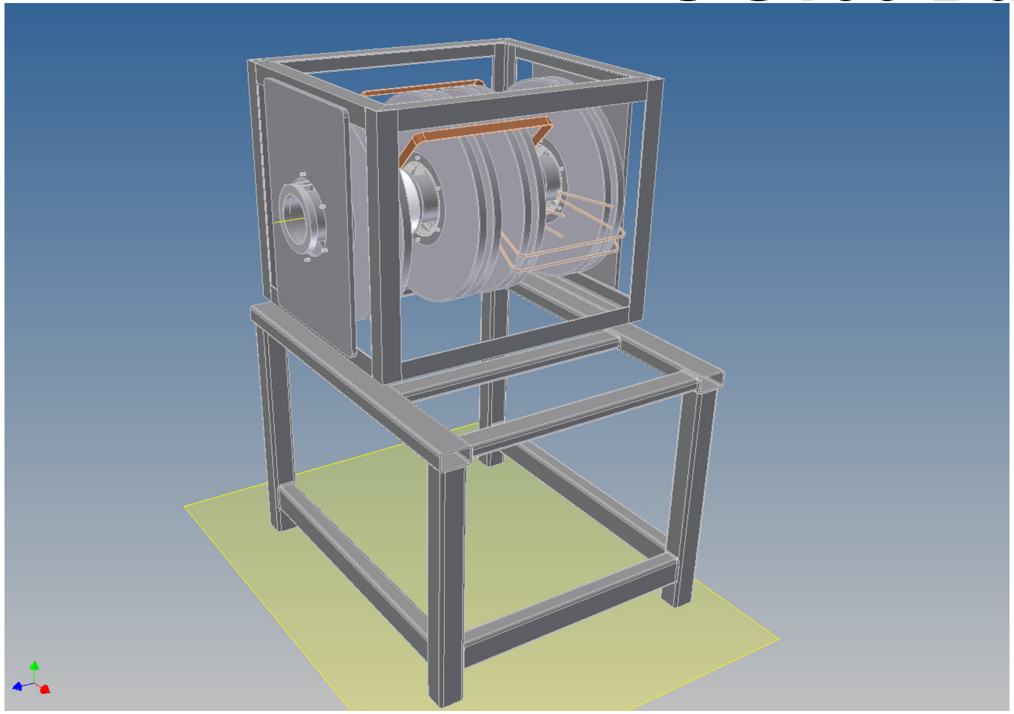
Status

- Project leader: M. Mehler/Dr. P. Hülsmann
- Only technical concept available
- SIS100 BC is part of the German EoI

Outlook on Realization

- Manufacturer not yet clear; only two identified, technical discussions with only one of them
  (ACCEL performed a design study for the CR debuncher; Hitachi manufactures Fe-based MA material)
- Estimation: about 5...6 years total project time including lab acceptance tests

SIS100 Barrier Bucket



Design Sketch:
Inductively loaded (MA) quarter wave resonator.
Two gaps connected in parallel.
Inductively coupled (two figure of 8 coupling loops) push-pull amplifier consisting of two tetrodes. Rectangular offset pulses to generate single sine waves.

Tasks:
- Precompression by moving single sine wave barriers.

Main Parameters (one of two RF units):

Frequency (MHz)	1.5
Max. barrier voltage (kV)	15
Duty cycle	20% (3.2%)
Aperture of the beam pipe, circular diameter (mm)	150 (CF160)
Installation length, flange to flange (m)	1
Height of beam axis (m)	1.4
Pressure of beam pipe (mbar)	$\leq 1 \cdot 10^{-12}$
Heating of the cavity beam pipe (°C)	300

SIS100 Barrier Bucket

Important Design Considerations

- Only Fe-based MA material allows the required broad-band behavior (Hitachi FT3M)
- Resonant design due to efficiency considerations (offset pulse)
- For MA type cavities, the desired resonant frequency (1.5 MHz) is rather high leading to a small number of ring-cores per cell
- Air cooling due to low duty-cycle
- Technical risks:
  - Ringing of cavity must be kept low
  - Compensation of DC current

SIS100 Barrier Bucket

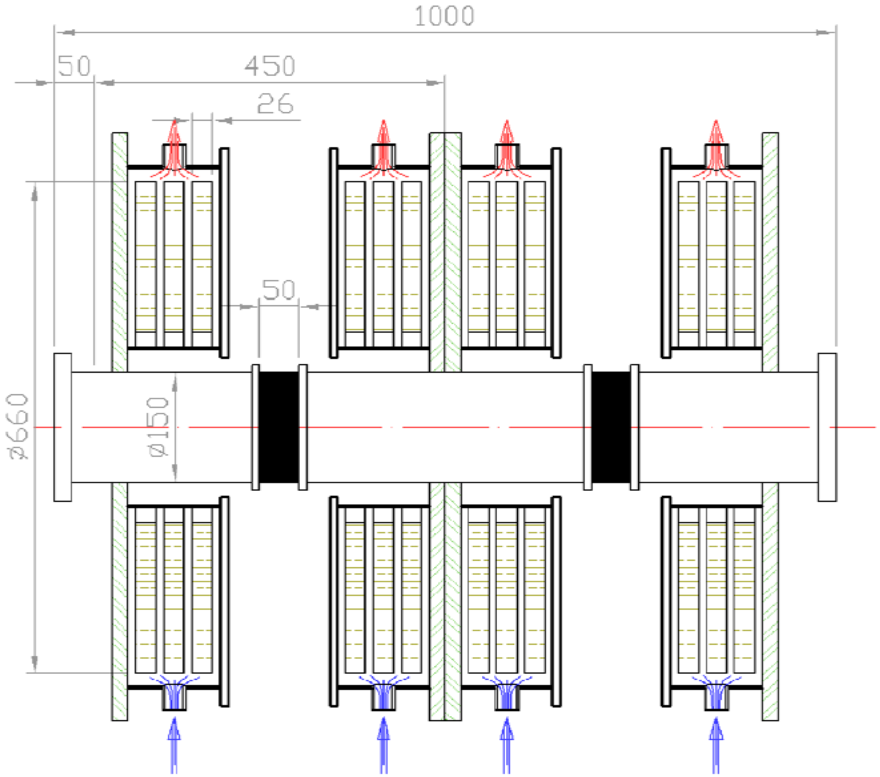
Status

- Project leader: Dr. G. Schreiber/Dr. P. Hülsmann
- Only technical concept available
- A broadband test cavity is currently built to analyze MA ring cores
- SIS100 BB is part of the German EoI

Outlook on Realization

- Manufacturer not yet clear
- Current staffing not sufficient

SIS100 Longitudinal Feedback System



Tasks: • Damping of longitudinal beam instabilities.

Main Parameters (one of two RF units):

3dB bandwidth (MHz)	5..6
Max. voltage (kV)	10
Duty cycle	CW
Aperture of the beam pipe, circular diameter (mm)	150 (CF160)
Installation length, flange to flange (m)	1
Height of beam axis (m)	1.4
Pressure of beam pipe (mbar)	$\leq 1 \cdot 10^{-12}$
Heating of the cavity beam pipe (°C)	300

Design Sketch:
MA loaded (MA) quarter wave resonator. Oil-cooling of ring cores.
Push-pull amplifier consisting of two tetrodes.

SIS100 Longitudinal Feedback System

Important Design Considerations

- Only MA material allows the required broad-band behavior
- Risks:
  - CW operation is a challenge with respect to cooling
  - Bandwidth is challenging

SIS100 Longitudinal Feedback System

Status

- Project leader: M. Mehler/Dr. H. Klingbeil
- Detailed specification available
- Signal processing design verified during EU FP6 design project (task SIS100_2), final report available
- Not part of any EoI

Outlook on Realization

- Manufacturer not yet clear
- System has a lower priority

General Comments

- Staffing is critical
- External manufacturers required, only few potential suppliers
- No external (non-GSI) EoIs for SIS100 RF in-kind contributions
- Technical risks moderate
- Time schedule depends on resources
  (i.e. project organization, money flow, personnel)

Appendix

Storage Ring RF Systems

Ring	RF System	Frequency Range [MHz]	Maximum Voltage [kV] Stage A/B	Duty Cycle	Cavity Length	Qty Stage A/B
CR **2.5.4**	Debuncher (RIB, anti-protons, includes Bucket Generation)	1.18...1.38	200 10	0.05% 100%	1 m	5
NESR **2.6.4**	Deceleration Barrier Bucket Stacking High Harmonics	0.998...2.28 5 (broadband) 44.8	15 2 0/50	100% 20% 100%	2.8 m 0.8 m 1 m	1 4 0/1
RESR **2.10.4**	Deceleration	0.52...1.21	15	100%	3.2 m	1
HESR **2.11.4**	Responsibility Jülich					

FAIR RF Work Packages (1/2)

- CAVITY SYSTEMS
  - SIS18 h=2 Cavities (SIS18_h=2_CAV)
  - CR Debuncher Cavities (CR_DB_CAV)
  - SIS100/300/NESR Accelerating Cavities (SIS100_300_NESR_CAV)
  - SIS100 Barrier Bucket Cavities (SIS100_BB_CAV)
  - SIS100 Bunch Compressor Cavities (SIS100_BC_CAV)
  - NESR Barrier Bucket Cavity (NESR_BB_CAV)
  - NESR High Harmonics (NESR_HH)
  - RESR Cavity (RESR_CAV)
  - HESR RF Systems (HESR_RF_Jülich)
  - ER Cavity (ER_CAV)
  - pLINAC Cavities (pLINAC_CAV)
  - SIS100 Longitudinal Feedback System (SIS100_Long_Feedb_CAV)

Reference: H.Klingbeil et al.: "FAIR RF Work Packages"

FAIR RF Work Packages (2/2)

- COMMON RF SYSTEMS
  - Digital Low-Level RF Control for Synchrotrons & Storage Rings (Digital_LLRF_Sync)
  - pLINAC Low-Level RF Control (LLRF_pLINAC)
  - pLINAC Power Amplifiers (pLINAC_AMP)
  - Modular Driver Amplifiers (Driver_Amplifiers)
  - Gap Periphery (Gap_Periphery)
- SUPPLY UNITS
  - Supply Units for SIS100, SIS300 and NESR Accelerating Systems (SU_SIS100_300_NESR)
  - Supply Units for SIS100 Barrier Bucket Systems and Longitudinal Feedback System (SU_BB_Long_Feedb)
  - Supply Units for CR Debuncher and SIS100 Bunch Compression (SU_CR_SIS100BC)
  - Supply Units for SIS18 h=2 System (SU_SIS18)
  - Supply Units for pLINAC RF Systems (SU_pLINAC)

Reference: H.Klingbeil et al.: "FAIR RF Work Packages"

SIS100 RF Systems

Overview on EoI 13b

① SIS100 Bunch Compression System

② SIS100 Barrier Bucket System

③ Interfaces and Low-Level RF for:

- all SIS100 RF Systems (Accel., BC, BB, Long. Feedback)
- all CR RF Systems (Debuncher)
- all NESR RF Systems (Decel., BB, HH)
- all RESR RF Systems (Decel.)
- all SIS300 RF Systems (Accel.)
- all ER RF Systems (Accel.)
- all HESR RF Systems (High-Power, Low-Power)

④ pLINAC (Interfaces & Low-Level RF – rest included in EoI 13a)

⑤ CR Debuncher System (not yet part of EoI 13b signature)

13b①: SIS100 Bunch Compression System (2.8.4.3)

Included Items

- 9 Bunch Compressor Cavities incl. Tetrode Amplifier and Amplitude Control (3026.4 k€) 2.8.4.3.1
- 9 Supply Units (2202.2 k€) 2.8.4.3.3

Excluded Items

- Driver Amplifiers (however included in 13b③) – 567k€ 2.8.4.3.2
- Dig. Phase Control, Control System Interfaces (however included in 13b③) – 437.4k€ 2.8.4.3.4
- Dig. Cavity Synchronization (however included in 13b③) – 168.9k€ 2.8.4.3.5
- Optical Transmission of Gap and Grid Voltages, Vacuum Gap Relays, Fast Switches (however included in 13b③) – 247.1k€ 2.8.4.3.6
- Media Supply Infrastructure
- Room-to-Room Cables

13b②: SIS100 Barrier Bucket System (2.8.4.4)

Included Items

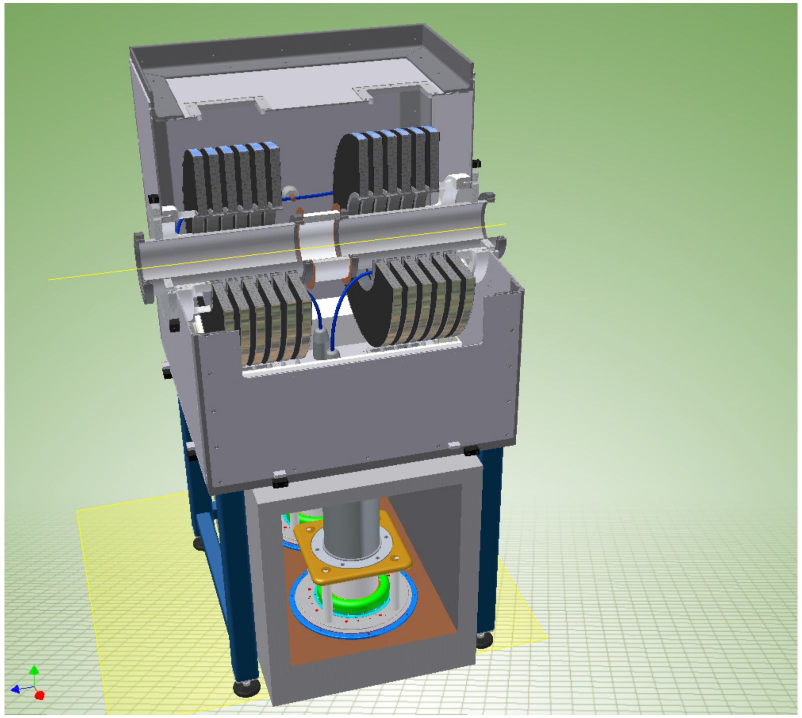
- 2 Barrier Bucket Cavities incl. Tetrode Amplifier and Driver Amplifiers (580.5 k€) 2.8.4.4.1
- 2 Supply Units (540.0 k€) 2.8.4.4.2

Excluded Items

- Dig. Phase Control, Control System Interfaces (however included in 13b③) – 84.6k€ 2.8.4.4.3
- Dig. Cavity Synchronization (however included in 13b③) – 48.2k€ 2.8.4.4.4
- Optical Transmission of Gap and Grid Voltages, Vacuum Gap Relays, Fast Switches (however included in 13b③) – 54.9k€ 2.8.4.4.5
- Media Supply Infrastructure
- Room-to-Room Cables

HELMHOLTZ GEMEINSCHAFT GSI FAIR

CR Debuncher



Tasks:
- Rotation of injected bunches in phase space → pulsed operation
- Adiabatic de- and rebunching → c.w. operation

Main Parameters (one of five RF units):

	AP	RIB
Frequency (MHz)	$1.18 < f \leq 1.38$	$f = 1.18$
Gap voltage in c.w. operation (kV)	0.05 to 1.35	0.05 to 2
Gap voltage in pulsed operation (kV)	1 to 21	1 to 40
Maximum duty cycle in pulsed operation	$1.5 \cdot 10^{-4}$ $(2 \cdot 10^{-4})$	$2 \cdot 10^{-4}$ $(5 \cdot 10^{-4})$
Maximum pulse duration (µs)	750 (1000)	200 (500)
Maximum repetition rate (Hz)	0.2	1
Time for transition pulsed ↔ c.w. operation (µs)	<400	<400
Aperture of the beam pipe, circular diameter (mm)	150 (CF160)	
Available installation length, flange to flange (m)	1	
Available installation width (m)	±0.75	
Pressure of beam pipe (mbar)	$\leq 1 \cdot 10^{-9}$	

Design Sketch:
Two inductively loaded (MA) quarter wave coaxial resonators operating on a common gap. Air cooling of MA cores. Push-pull amplifier consisting of two tetrodes in class A operation.