Collector Ring (CR) - FAIR EoI 13b: 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)

Collector Ring (CR) - FAIR EoI 13b: RF Systems

13b⑤: CR Debuncher System (2.5.4.1)

Included Items

- 5 Debuncher Cavities incl. Tetrode Amplifier and Amplitude Control (2230.5 k€) — 2.5.4.1.1
- 5 Supply Units (1425.5 k€) — 2.5.4.1.3

Excluded Items

- Driver Amplifiers (however included in 13b③) – 369k€ — 2.5.4.1.2
- Dig. Phase Control, Control System Interfaces (however included in 13b③) – 211.5k€ — 2.5.4.1.4
- Dig. Cavity Synchronization (however included in 13b③) – 120.6k€ — 2.5.4.1.5
- Optical Transmission of Gap and Grid Voltages, Vacuum Gap Relays, Fast Switches (however included in 13b③) – 137.0k€ — 2.5.4.1.6
- Media Supply Infrastructure
- Room-to-Room Cables

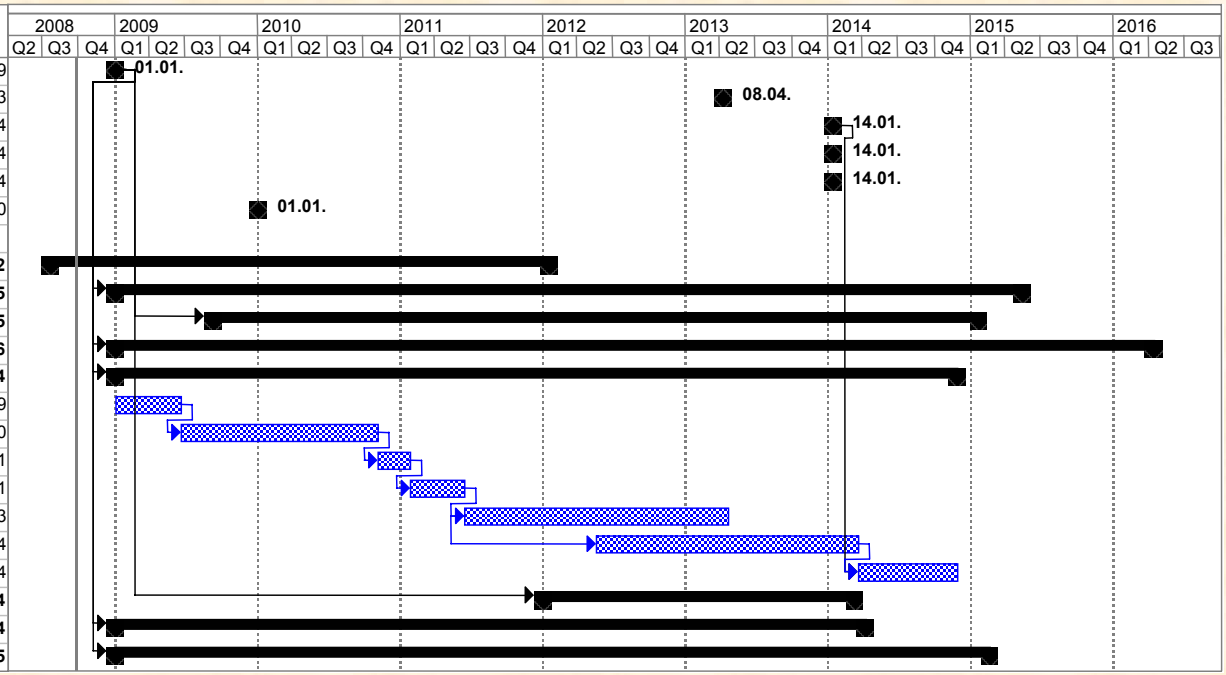
Collector Ring (CR) - FAIR EoI 13b: RF Systems

13b⑤: CR Debuncher System (2.5.4.1)

Time Schedule

- Design completed: Draft 06/2009, Final 11/2009
- 11/2010 First system produced
- 06/2011 First system tested and optimized
- 04/2013 Series production completed
- 03/2014 Lab & acceptance tests completed

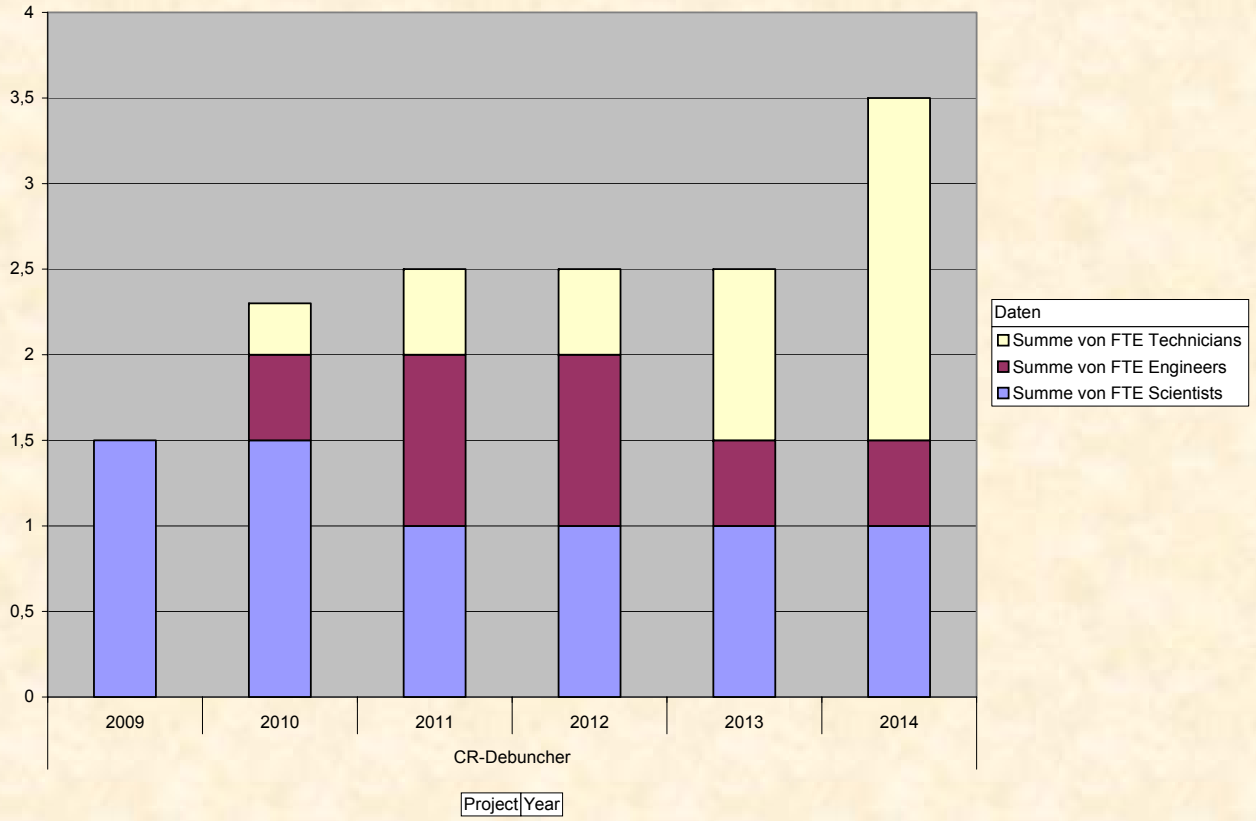
Nr.	Vorgangsname	Dauer	Anfang	Ende
1	Availability FAIR Project Financing	0 Tage	01.01.09	01.01.09
2	Building SIS100 available for installation	0 Tage	08.04.13	08.04.13
3	Building CR available for installation	0 Tage	14.01.14	14.01.14
4	Building NESR available for installation	0 Tage	14.01.14	14.01.14
5	Building RESR available for installation	0 Tage	14.01.14	14.01.14
6	Testing hall available	0 Tage	01.01.10	01.01.10
7				
8	**SIS12/18 h=2 System**	**910 Tage**	**22.07.08**	**16.01.12**
17	**SIS100 Acceleration**	**1660 Tage**	**01.01.09**	**13.05.15**
25	**SIS100 Barrier Bucket**	**1400 Tage**	**10.09.09**	**21.01.15**
33	**SIS100 Bunch Compression**	**1900 Tage**	**01.01.09**	**13.04.16**
41	**CR Debuncher**	**1540 Tage**	**01.01.09**	**26.11.14**
42	Completion of design	6 Monate	01.01.09	17.06.09
43	Production of first system	18 Monate	18.06.09	03.11.10
44	Lab tests & acceptance tests first system	3 Monate	04.11.10	26.01.11
45	Optimization first system	5 Monate	27.01.11	15.06.11
46	Series production	24 Monate	16.06.11	17.04.13
47	Lab & acceptance tests	24 Monate	17.05.12	19.03.14
48	Installation	9 Monate	20.03.14	26.11.14
49	**RESR Acceleration**	**571 Tage**	**02.01.12**	**10.03.14**
53	**NESR Deceleration**	**1373 Tage**	**01.01.09**	**07.04.14**
59	**NESR Barrier Bucket**	**1600 Tage**	**01.01.09**	**18.02.15**



13b⑤: CR Debuncher System (2.5.4.1)

Prerequisites

Construction and manufacturing by industrial partner



13b③: Interfaces & Low-Level RF

Included Items (for all CR RF systems)

- Driver Amplifiers
- Dig. Phase Control, Control System Interfaces (incl. all DDS units)
- Dig. Cavity Synchronization
- Optical Transmission of Gap and Grid Voltages, Vacuum Gap Relays, Fast Switches
- Tunable capacitors

Excluded Items

- Gap and grid voltage dividers (part of the cavity)
- Amplitude control (part of the cavity system)
- DAC units (included in EoI 13d)

13b③: Interfaces & Low-Level RF

Time Schedule & Required Resources

- Driver Amplifiers (0.25 FTE): ext. company
  Availability of prototype: 06/2009
- Dig. Phase Control and Dig. Cavity Synchronization (2.5 FTE): in-house
  Continuous development
- Maintenance & Diagnostics (0.5 FTE): Continuous development ext. companies
- Optical Transmission of Gap and Grid Voltages (0.5 FTE): ext. company
  Availability of prototype: 09/2009
- Vacuum Gap Relays: Call for tenders starts after funding series product
- Fast Switches: Availability of prototype: 12/2009 ext. company

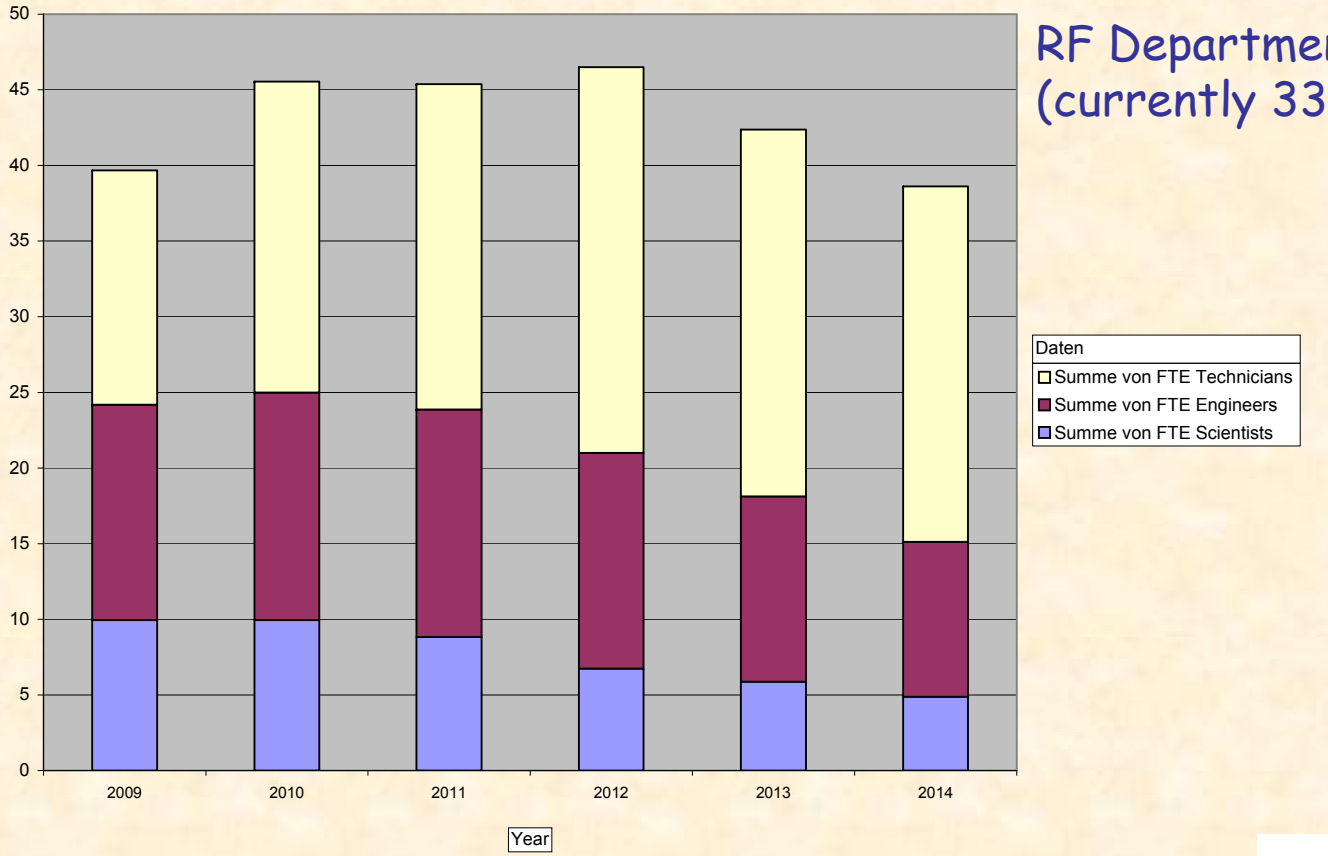
These components are not on the critical path, i.e. they can be ordered in time for the corresponding cavity systems.

3.75 FTE are required continuously

Decision for this in-kind contribution must be valid for all synchrotrons & storage rings.

Prerequisites for All Tasks

- Official assignment of in-kind contribution 12/2008
- Assignment of manpower (about 5 additional specialists in 2009, about 5 additional specialists in 2010)
- Funding



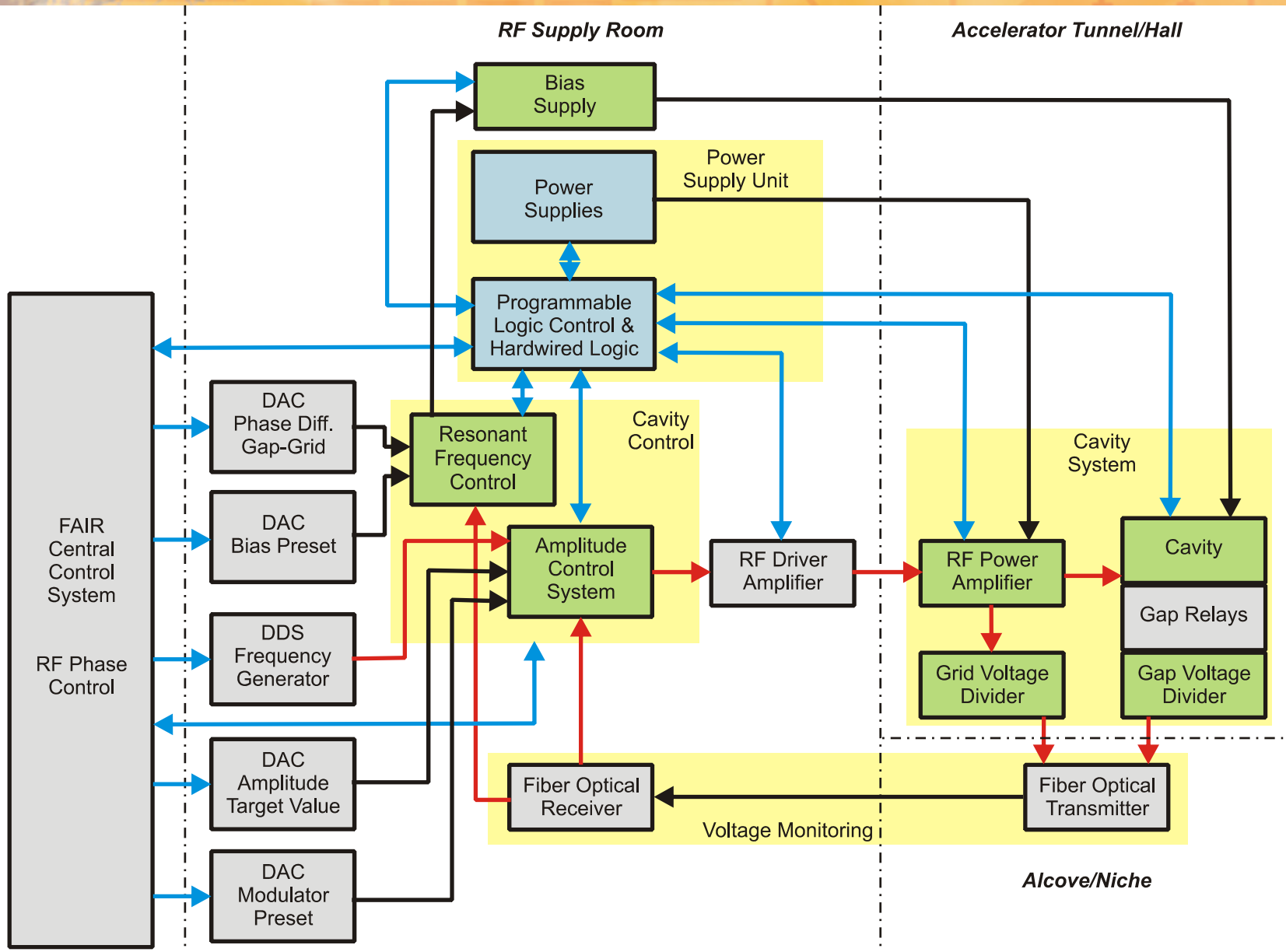
RF Department (currently 33 FTE)

Appendix

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

Collector Ring (CR) - FAIR EoI 13b: 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)

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"

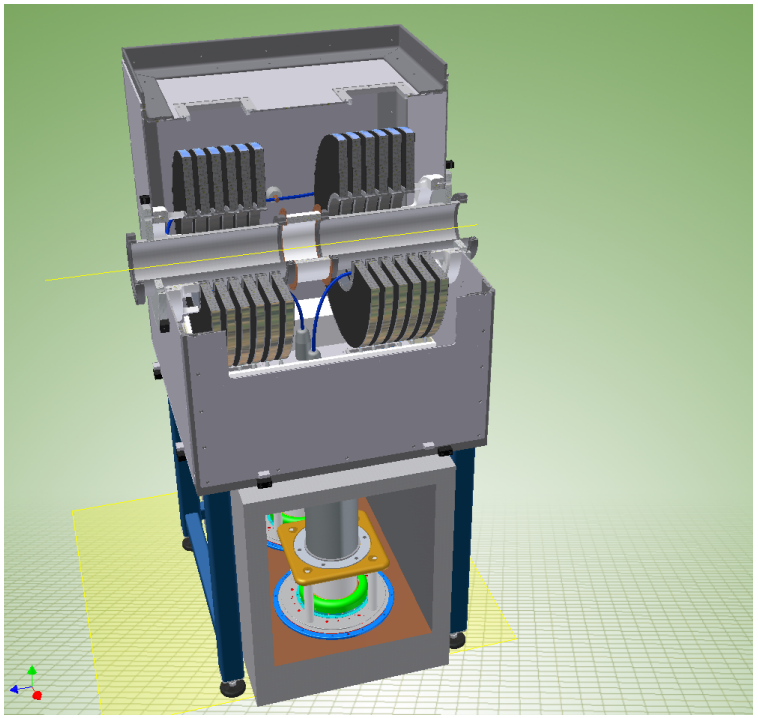
FAIR RF Work Packages (2/2)

- 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"

Collector Ring (CR) - FAIR EoI 13b: RF Systems

CR Debuncher



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.

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
Time for full sweep of the operating frequency (s)	<60	
Aperture of the beam pipe, circular diameter (mm)	150 (CF160)	
Available installation length, flange to flange (m)	1	
Available installation width (m)	±0.75	
Available installation height (m)	+0.8/-1.3	
Height of beam axis (m)	1.3	
Pressure of beam pipe (mbar)	$\leq 1 \cdot 10^{-9}$	

Collector Ring (CR) - FAIR EoI 13b: RF Systems

Technical Basis

- SIS18 Bunch Compressor
- Design study performed by ACCEL: "FAIR R Cavity Study – Final Report", 1606-BP-7046-0, 18.12.2006

Challenges

- Dual-mode operation (c.w. vs. bunch rotation)
- Switching between these modes of operation (tube working point, e.g. TH555)

Synchrotron RF Systems

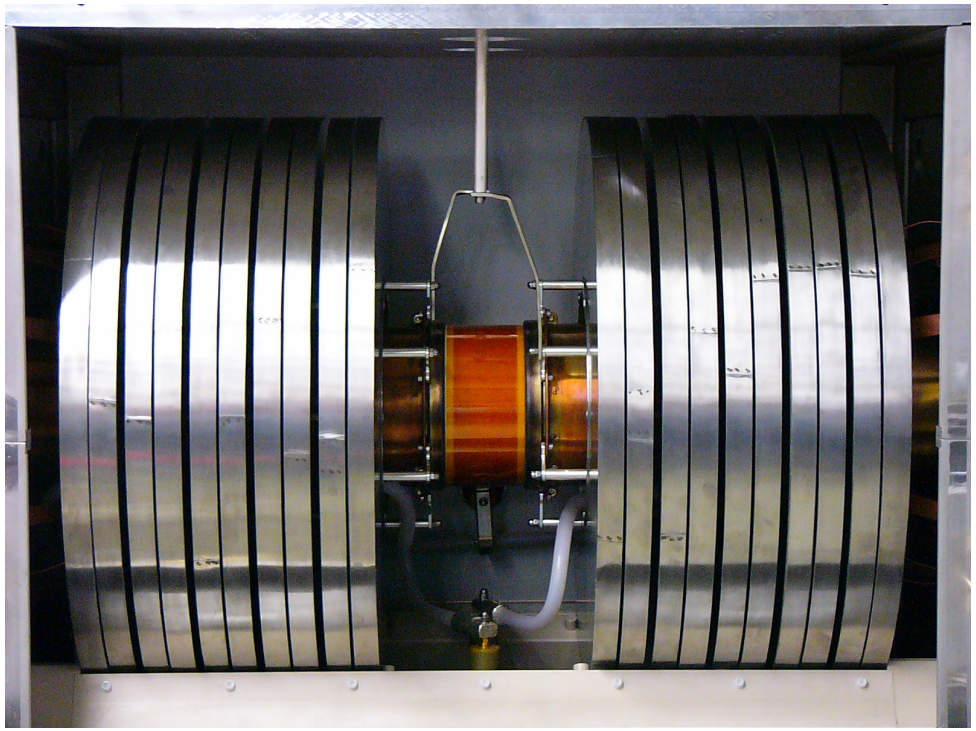
Ring	RF System	Frequency Range [MHz]	Total Voltage [kV] Stage A/B	Duty Cycle	Cavity Length	Qty Stage A/B
SIS18 Upgrade **2.2.4**	Accel. h=2 Bunch Compression	0.43 ... 2.8 0.8	40 40/80	50% 0.05%	1.27 m 1 m	3 1/2
SIS100 **2.8.4**	Accel. h=10 (Ferrite) Bunch Compression Barrier Bucket Long. Feedback	1.1 ... 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

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					

Collector Ring (CR) - FAIR EoI 13b: RF Systems

SIS100 Bunch Compression (for Comparison)



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).

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

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

Frequency (MHz)	$0.395 \le f \le 0.485$
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)	$\le 1 \cdot 10^{-12}$
In situ heating of the cavity beam pipe (°C)	300