A New 80 MHz Cavity in the Heavy Ion Synchrotron SIS18

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Abstract

Experiments and simulations regarding the micro spill structure of slowly extracted bunched beams have been performed at GSI for years [1]. In SIS18 the bunch spacing was limited to a minimum of 185 µs due to the operating frequency range of the installed cavities and LLRF. To overcome this limit, which is not suitable for many detectors, a new cavity system was developed. It is based on an UNILAC single-gap resonator [2] which was modified to include an evacuated beam pipe. The cavity was installed in SIS18 in July 2023 and commissioned with beam in November 2023. Challenges in the development and selected measurements with and without beam are presented.

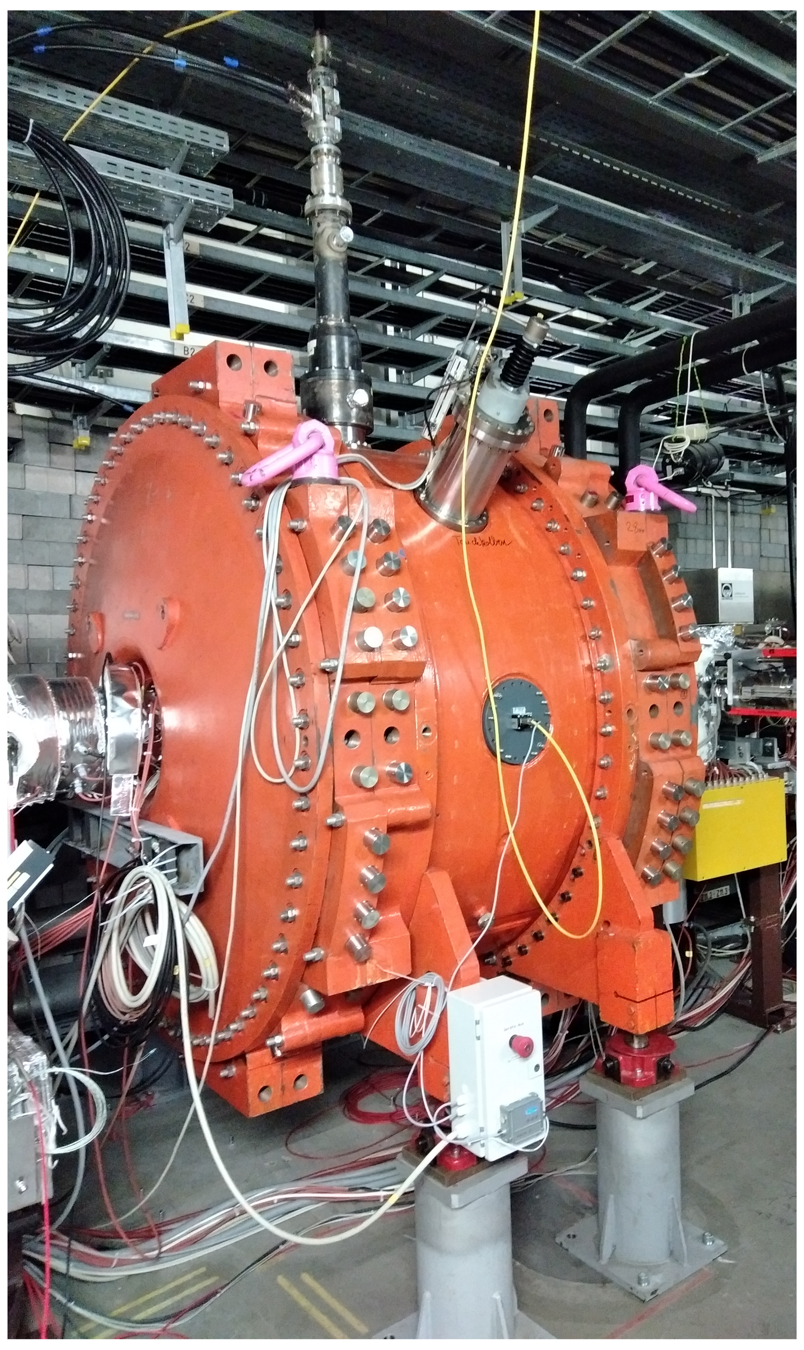
[1] S. Sorge, P. Forck, and R. Singh, Phys. Rev. Accel. Beams 26, 014402, Jan. 23.
[2] J. Glatz, and L. Groening, Proc. of EPAC 2002, Paris, France.

Parameters

Dimensions	
Weight, Diameter, Length	> 5 t, 1.8 m, 1.4 m
Properties	
Frequency range (low voltages	81 to 81.8 MHz down to 79 MHz)
Gap voltage amplitude (in test environment	up to 6 kV up to 25 kV)
Impedance (without shortcut)	about 500 kΩ
Quality factor Q_0	≈ 5000

Locally operated during dedicated proof-of-principle experiments.

Cavity

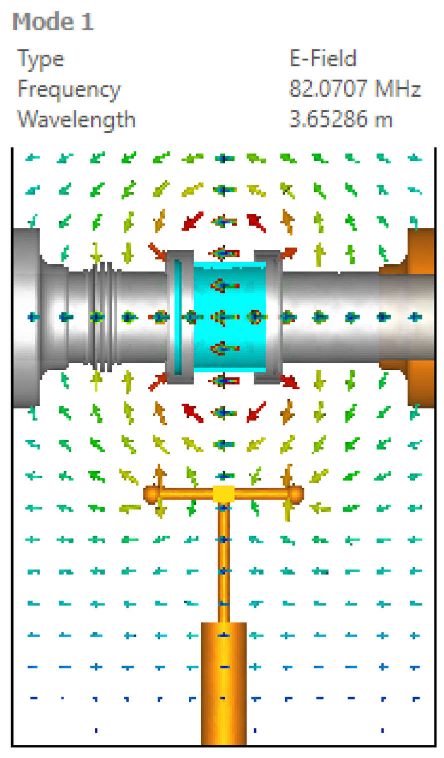


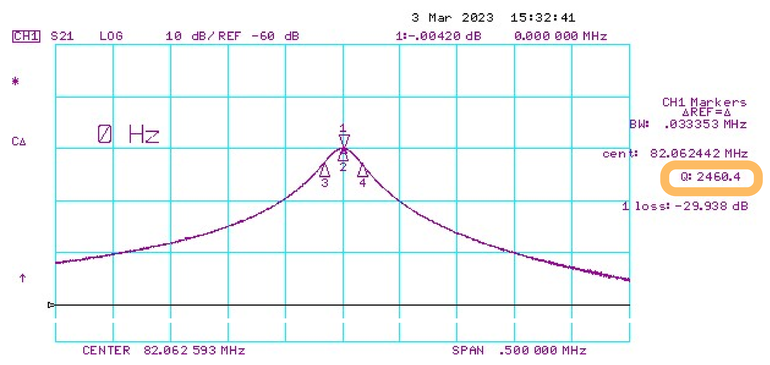
Installed in SIS18 in July 2023.

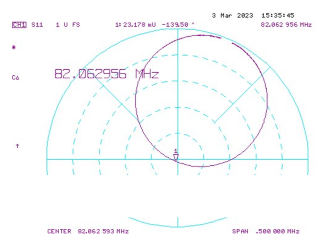
CST & Quality Factor

The losses in the resonator were analyzed using CST MICROWAVE STUDIO®.

Material/Solid	Conductivity	Mu	Loss/%	Q
Cond. Enclosure	5.8000e+07	1	5.99	7.6492e+04
Kovar	2.0000e+07	1000	4.98	9.1913e+04
Stainless Steel	1.4000e+06	1	43.2	1.0595e+04
Copper	5.8000e+07	1	1.41	3.2488e+05
Sum of Surface Losses			55.6	8.2363e+03
Volume Losses			44.4	1.0321e+04
Sum				4.5807e+03

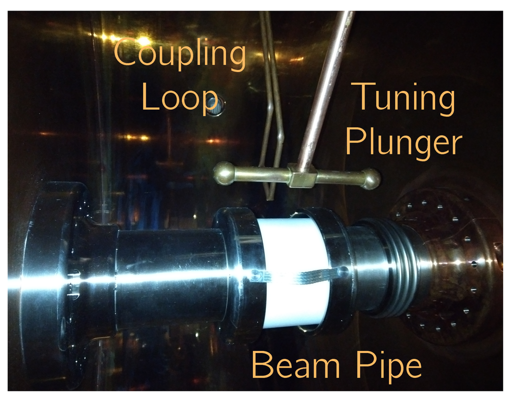






Due to the critical coupling, the unloaded Q-factor is $Q_0 = 2Q_L \approx 4920.8$ in good agreement with field simulation.

Ceramic Gap



Coupling loop, tuning plunger and beam pipe with gap and shortcut.

From the specific heat capacity, the temperature gradient $\Delta\theta$ can be calculated for a certain heat input W_c. The fraction of the dielectric (volume) losses found from the field simulation shown on the right is about 40%. As an example for 36 W input power the initial heat gradient is

$$\Delta\theta = \frac{W_c}{m \cdot 900 \frac{\mathrm{J}}{\mathrm{kg\,K}}} = \frac{0.4 \cdot 36\,\mathrm{W}}{3.22\,\mathrm{kg} \cdot 900 \frac{\mathrm{J}}{\mathrm{kg\,K}}} \approx 0.3 \frac{\mathrm{K}}{\mathrm{min}}.$$

Frialit 99.7 hf		
Specific heat	900	J/(kg*K)
Relative permittivity	9.8	at 70 MHz
Dielectric loss tangent	$3.8 \cdot 10^{-4}$	at 70 MHz

Acknowledgements

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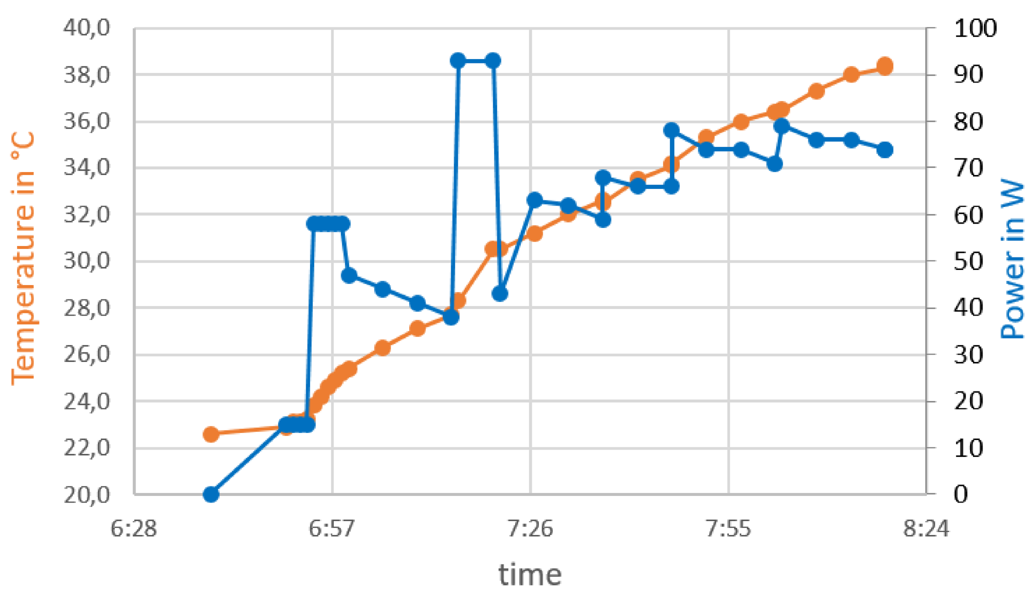
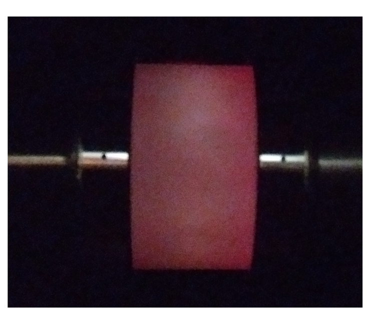
Measurements & Outlook

The first proof-of-principle experiment took place in two shifts on November 29th, 2023. The $^{14}N^{7+}$ beam was adiabatically bunched at 300 MeV/u before being slowly extracted. In the first shift the cavity was conditioned and beam current measurements with different gap voltages and rf frequencies were performed. From the revolution frequency of 904.851 kHz the operating frequency of 81.43659 MHz (12.3 µs) was derived. The second shift was used for spill measurements which are shown on the poster "Nano-second time scale measurements of the particle arrival times" by Jiangyan Yang. Further machine experiments are in planning to get a feedback from physics experiments using the cavity.

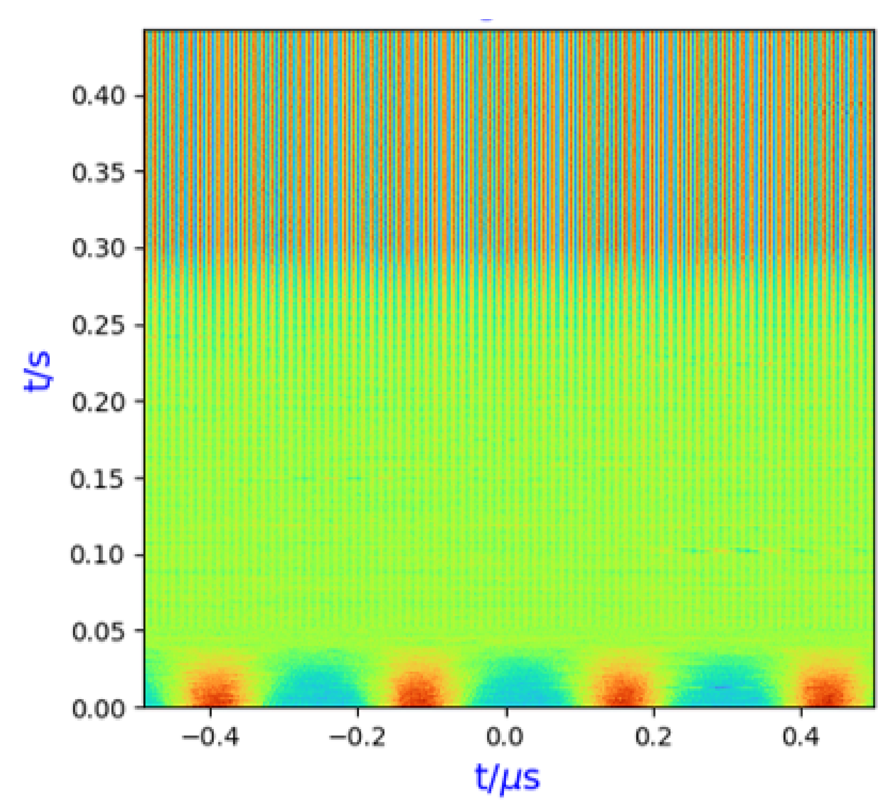
Conditioning





Manually controlled input power and increase in temperature of the ceramic during 100 minutes of conditioning.
Photo of ceramic at conditioning.

Beam Current Measurement

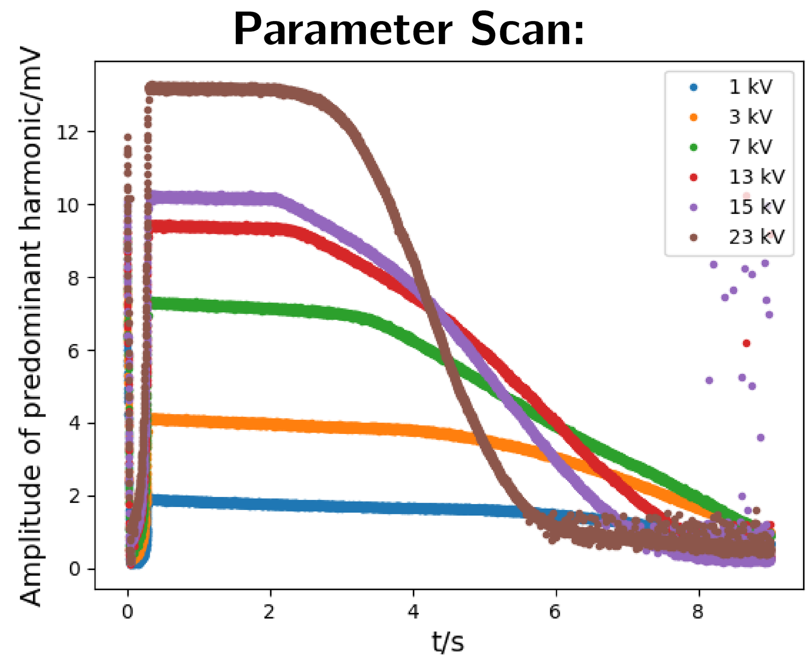


Waterfall plot of beam current (FCT) with debunching at harmonic number h=4 and rebunching at h=90.

Further Analysis

Synchrotron Frequency: No synchrotron oscillations are detectable in the spectrum of the beam current.

Parameter Scan:



Amplitude of fundamental harmonic of beam current (FCT), scaled by the number of particles in the cycle.

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