Accelerator Physics and Integrated Detectors

Kurt Aulenbacher, Winfried Barth

cw-Linac Project (ACID I)

Leader: **W. Barth**
Post-Docs/Scientists:
F. Dziuba (until 9/2017)
M. Miski-Oglu
Th. Kürzeder
S. Yaramyshev (GSI)
(Former) PhD:
M. Amberg
Working Student:
J. List
Engineers/Technicians
V. Gettmann
Collaborators:
H. Podlech (GUF), et al.

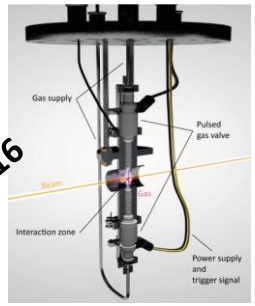
Requirements for FAIR and the SHE-Program

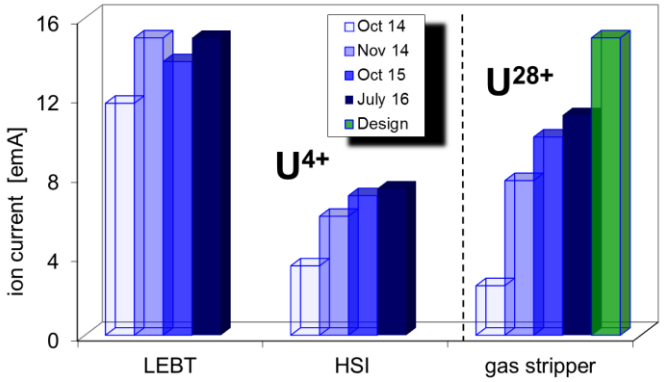
GSI-UNILAC-Status:

1 pμA, ^{48}Ca (ECR)
1 pμA, ^{50}Ti (PIG/ECR)
10 emA, ^{238}U (0.03%, MeVVa)

H_2-gas stripper (SHE/ACID)

2014-2016





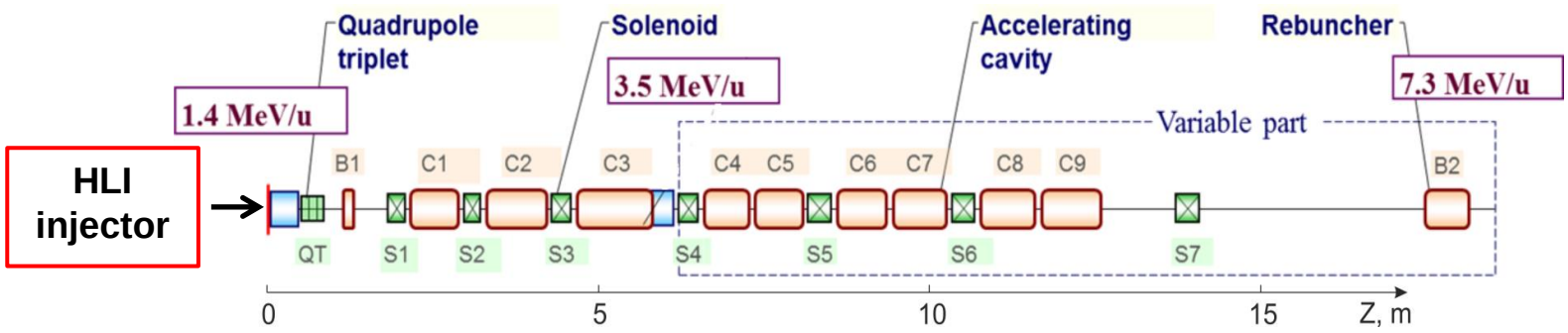
FAIR requirements:

- high beam currents
- low repetition rate (max. 3 Hz)
- low duty factor (0.1 %, pulse length for SIS18 only 100 μs)

“Super Heavy Element” requirements:

- relatively low beam currents
- high repetition rate (50 Hz)
- high duty factor (100 %, pulse length up to 20 ms)

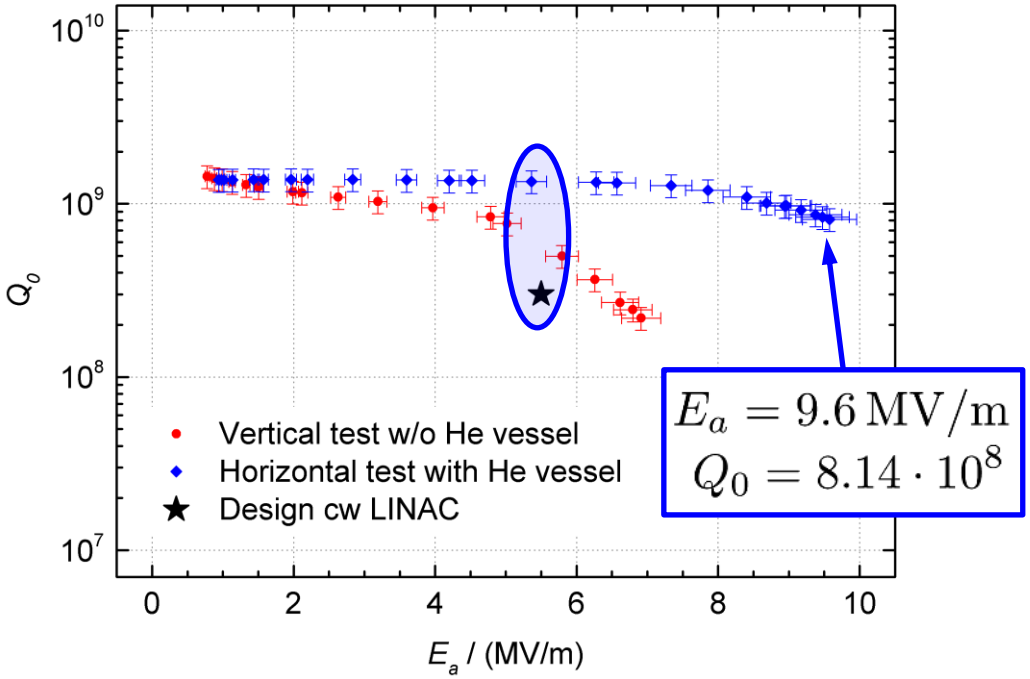
Requirements for FAIR and the SHE-Program

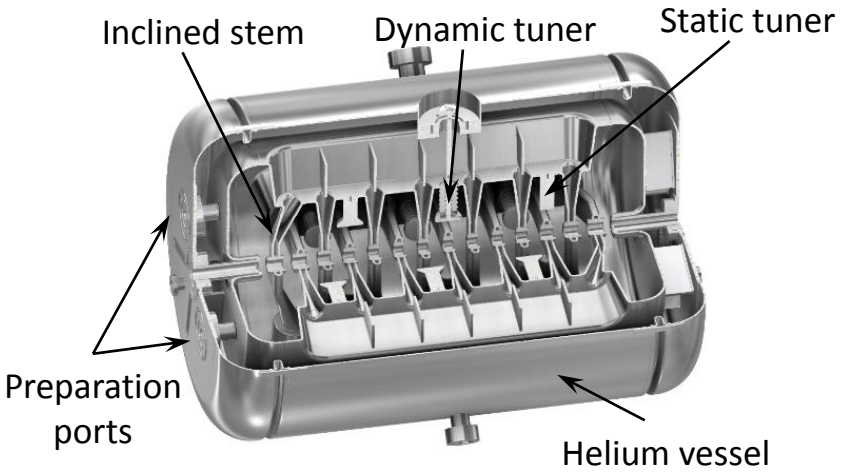


cw-Linac Design:

- Reactions at coulomb barrier → production of SHE
- Operation: cw
- Mass / Charge: 6
- Beam current: ≤1 mA
- Injection energy: 1.4 MeV/u
- Output energy: 3.5 - 7.3 MeV/u

RF Tests of the multi cell CH-cavity





→ Improved performance due to advanced HPR

→ Low field emission activity

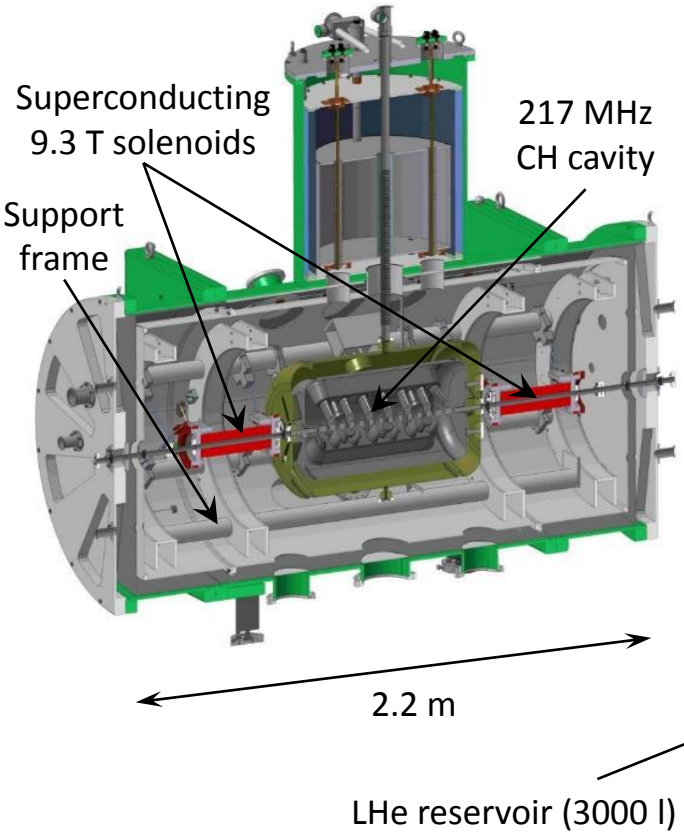
→ Very high gradient

→ Thermal quenching above 9.6 MV/m

		Vertical test w/o He vessel	Horizontal test with He vessel
Q_0^{low}		$1.44 \cdot 10^9$	$1.37 \cdot 10^9$
R_S	nΩ	36	38
R_{BCS}	nΩ	15	15
R_{mag}	nΩ	9	12
R_0	nΩ	12	11
E_a	MV/m	6.9	9.6
Q_0		$2.19 \cdot 10^8$	$8.14 \cdot 10^8$
V_a	MV	4.2	5.9
E_p	MV/m	43	60
B_p	mT	39	55

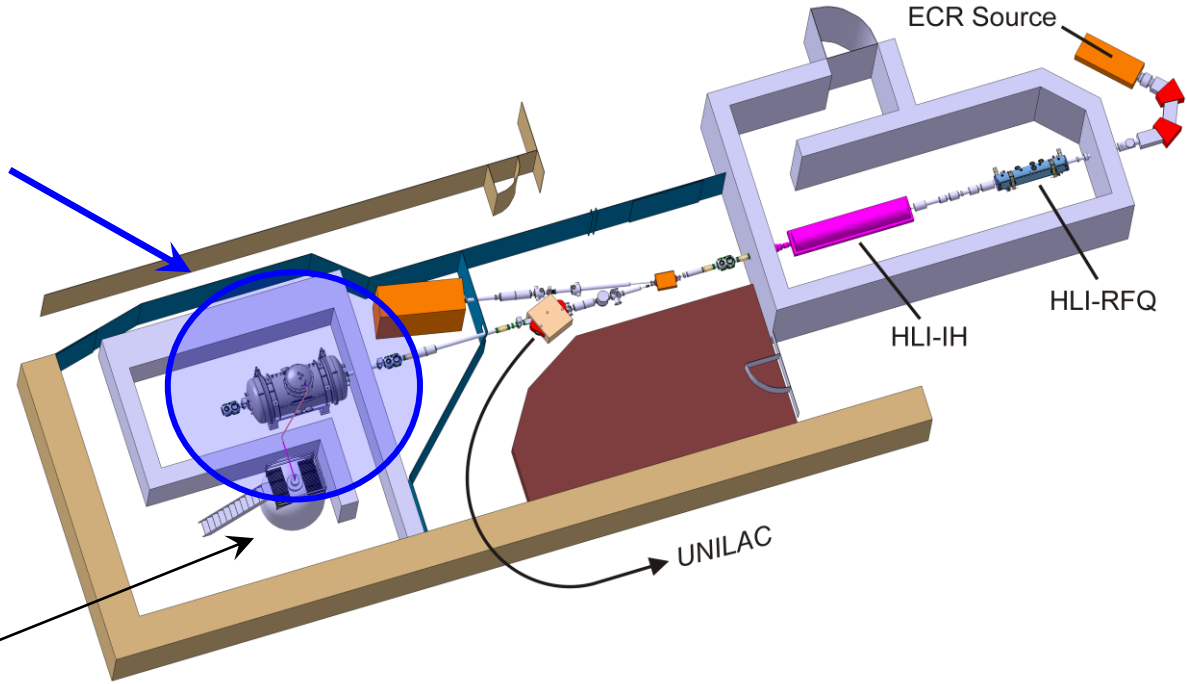
Beam Commissioning Environment

Layout of the Demonstrator Cryo Module



Integration into cryostat

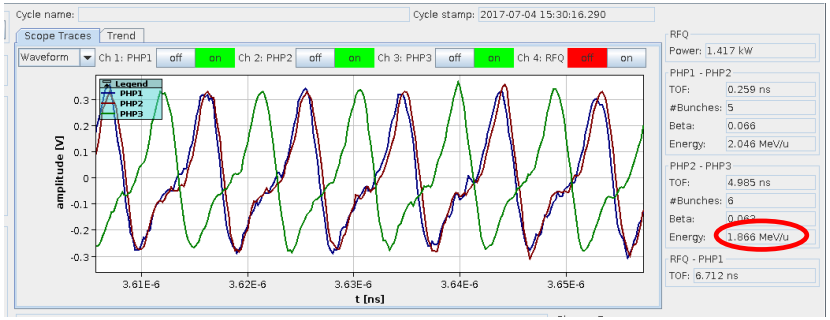
Upgrade of GSI clean room (ISO2)



Experimental setup of the demonstrator at GSI

Beam Measurements

First Beam Acceleration (June, 28th., 2017)



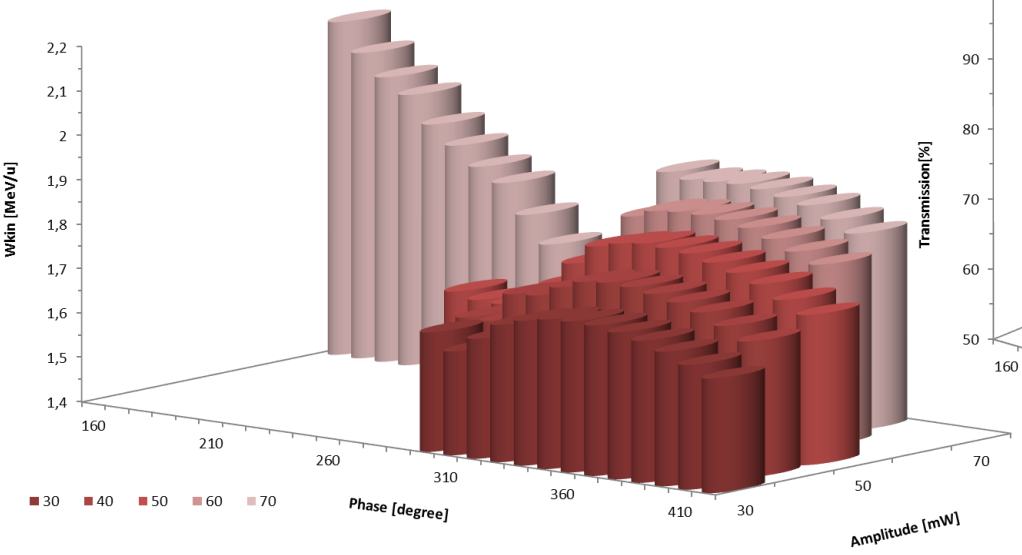
Acceleration! Energy gain of 0.5 MeV/u

=> Systematic scan of rf-phase and amplitude

- Variation of phase and amplitude of RF-Power
- Beam transmission is high for most of RF phases
- max. beam energy of 2.2 MeV/u reached
- Energy variation 1.2-2.2MeV/u
  → Feature of sophisticated beam dynamics layout

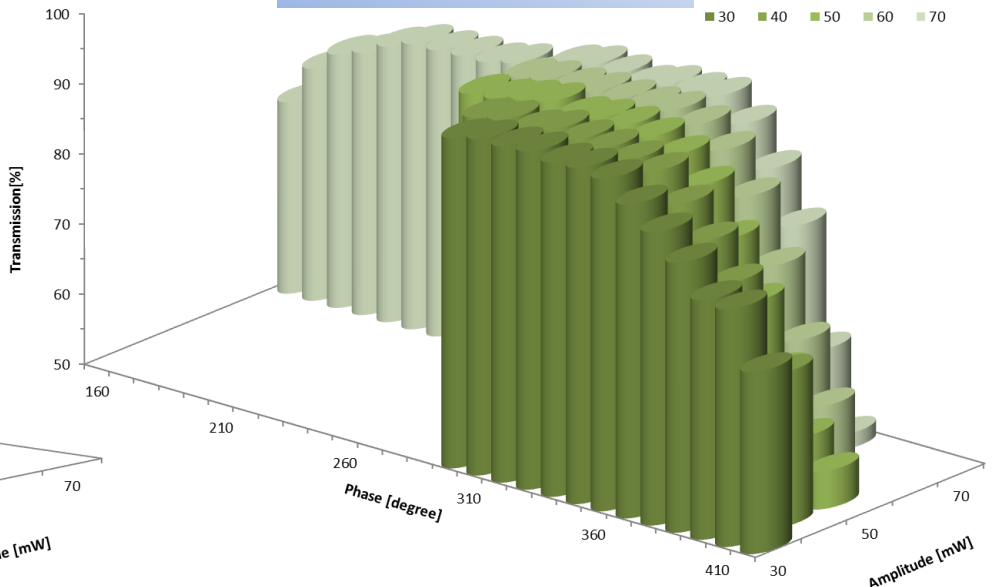
Ar^{9+}

Beam Energy



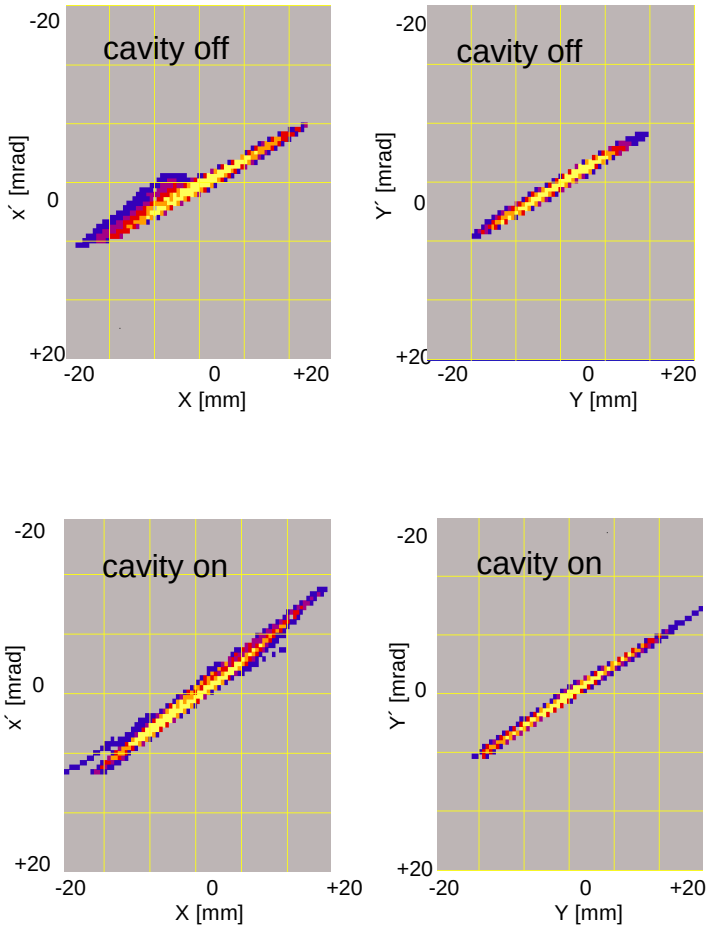
Ar^{9+}

Beam Transmission

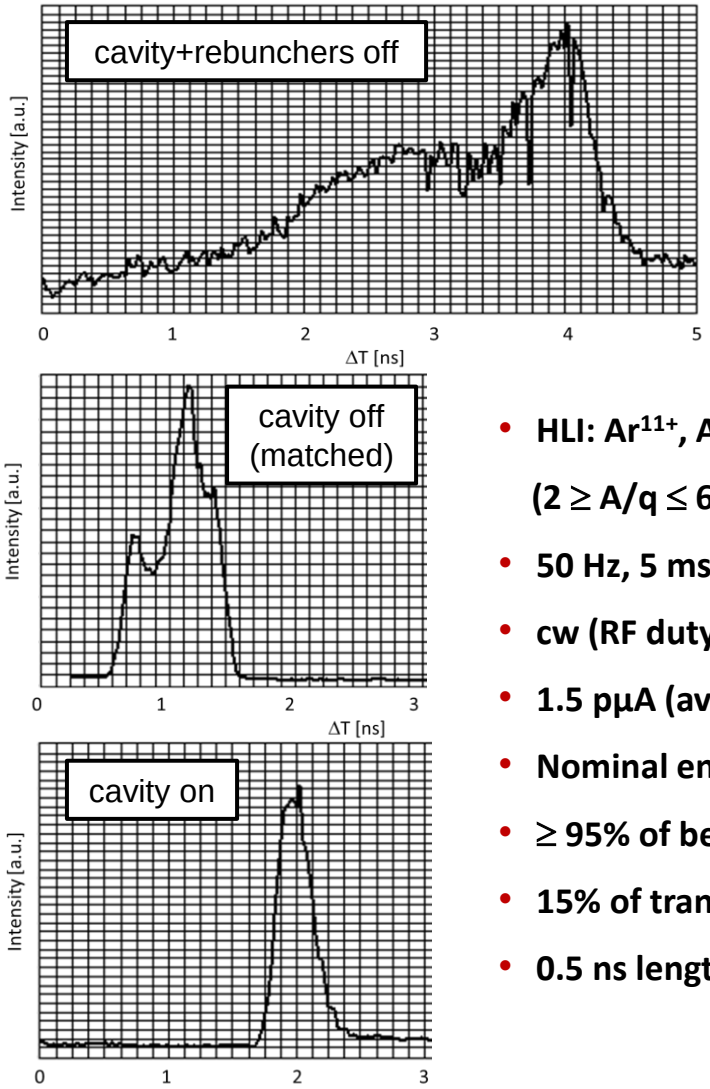


6D-Emittance Measurement

Transversal



Longitudinal



- **HLI: Ar^{11+}, Ar^{9+}, Ar^{6+}, He^{2+} beam ($2 \geq A/q \leq 6.7$)**
- **50 Hz, 5 ms (25% beam duty)**
- **cw (RF duty)**
- **1.5 pμA (average particle current)**
- **Nominal energy: 1.85 MeV/u**
- **≥ 95% of beam transmission**
- **15% of transversal emittance growth**
- **0.5 ns length of the bunch**

Milestones of the Demonstrator Project

09/2012 — **Project start**
Ordering of the cavity, solenoids and 5 kW cw RF amplifier

M. Heilmann, GSI (20%)
S. Yaramyshev, GSI
J. List, GSI (master student)

03/2014 — **Intermediate RF measurements on the cavity during fabrication**

~~F. Dziuba, HIM~~
T. Kürzeder, HIM
M. Miski-Oglu, HIM
V. Gettmann, HIM
F. Maas, HIM
K. Aulenbacher, HIM
~~M. Amberg, former HIM~~

12/2015 — **Commissioning of cryomodule and soleniods**

01/2016 — **First RF test of the cavity at IAP (vertical orientation)**

09/2016 — **Assembly of He vessel to the cavity and HPR**

10/2016 — **Second RF test of the cavity at GSI (horizontal orientation)**

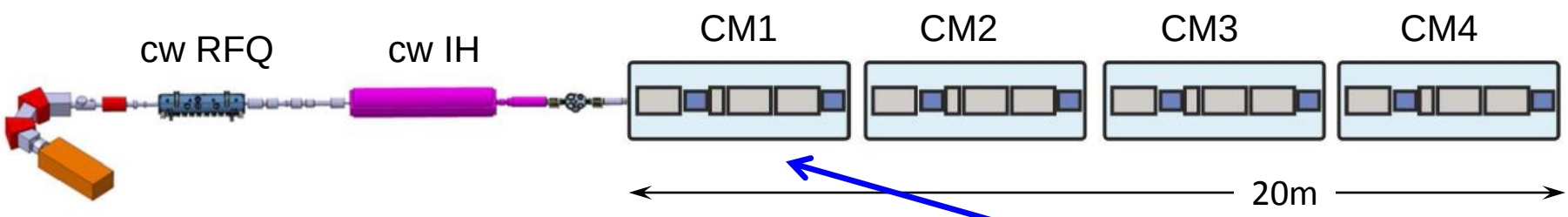
12/2016 — **Commissioning of clean room at GSI**

H. Podlech, GUF-IAP
M. Busch, GUF-IAP
M. Basten, GUF-IAP
D. Mäder, GUF-IAP
U. Ratzinger, GUF-IAP
M. Schwarz, GUF-IAP

04/2017 — **RF conditioning of power couplers**

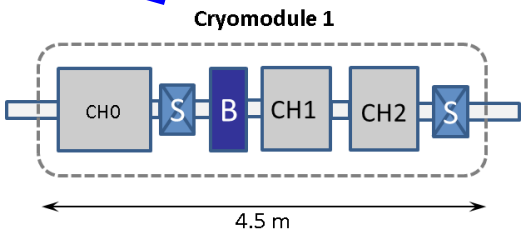
05/2017 — **Succesfull beam test of the demonstrator**

Future Design (fixed)

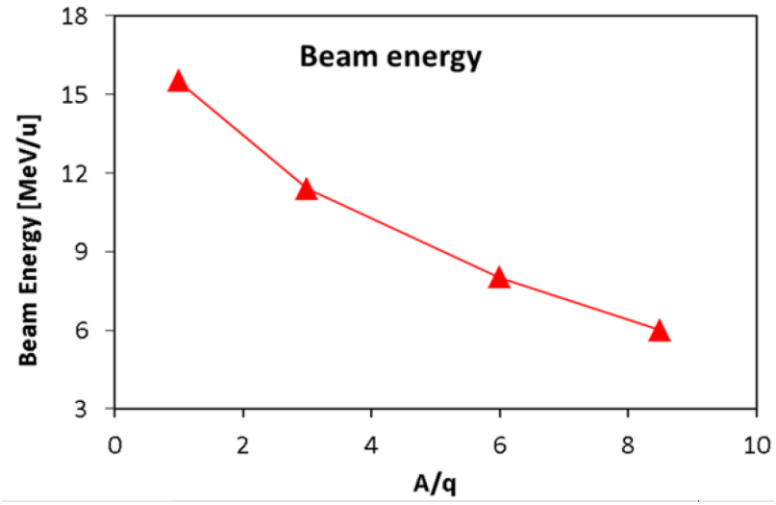


EZR 18GHz

- Total of 12 CH cavities
- Each cryomodule comprises 3 CH cavity + rebuncher +2 solenoids
- Variable beam energy 3.6-7.5 MeV/u
- delivery of CH1 + CH2 of CM1 in Q4/2017



Cryo Module	Output energy (MeV/u			
	A/Z=8.5	A/Z=6	A/Z=3	A/Z=1
CM1	2.6	2.9	3.6	4.6
CM2	3.5	4.2	5.5	7.7
CM3	4.5	5.8	7.8	10.9
CM4	5.55	7.6	10.5	14.6



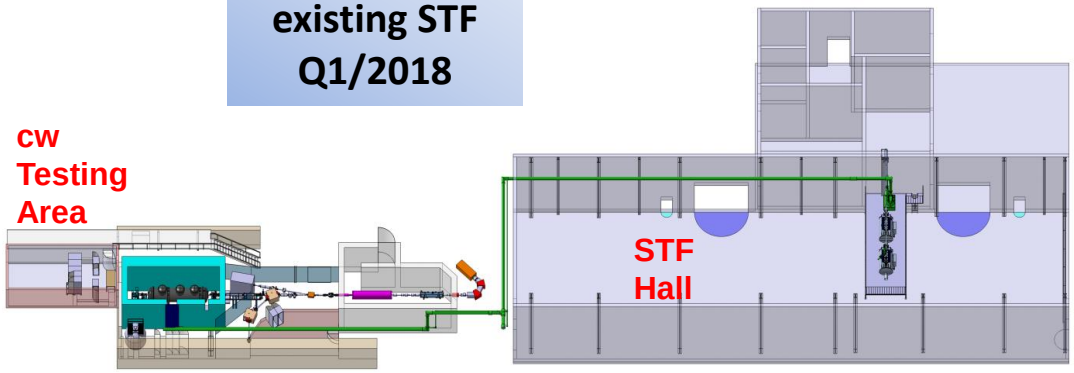
HELMHOLTZ ASSOCIATION

Helmholtz Institute Mainz

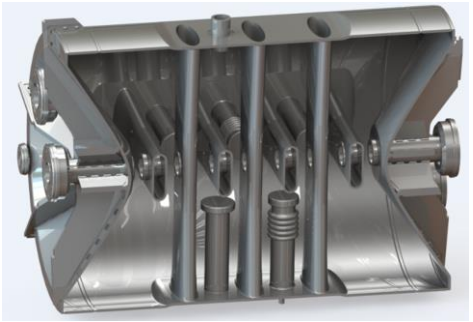
Time Schedule

HY1/2017	HY2/2017	HY1/2018	HY2/2018	HY1/2019	HY2/2019	HY1/2020	HY2/2020	HY1/2021	HY2/2021	HY1/2022	HY2/2022	HY1/2023	HY2/2023	HY1/2024	HY2/2024
POF 3															
cw-Demonstrator															
		Prep./Cryo Infrastructur													
Production + Testing/CH cavities															
	Purchase + Production Kryostat(s)														
	Purchase + Production rf-Amplifiers														
		Prep./Test area													
				Set up CM1											
					Beam Test 1										
						First User experiments									
										ECR + Injector					
											Transport Line				
						Purchasing + Production + Testing/ further CH cavities									
						Purchase + Production Kryostat(s)									
						Purchase + Production rf-Amplifiers									
										Prep./SH2&3					
											Set up + Test CM2		Beam Test 2		
												Set up + Test CM3		Beam Test 3	
													Set up + Test CM4		Beam Test 4
FAIR Magnet Testing										SH2/3 available					

Link to existing STF Q1/2018



RF-Test of 2 short CH-cavities (CH1 and CH2)



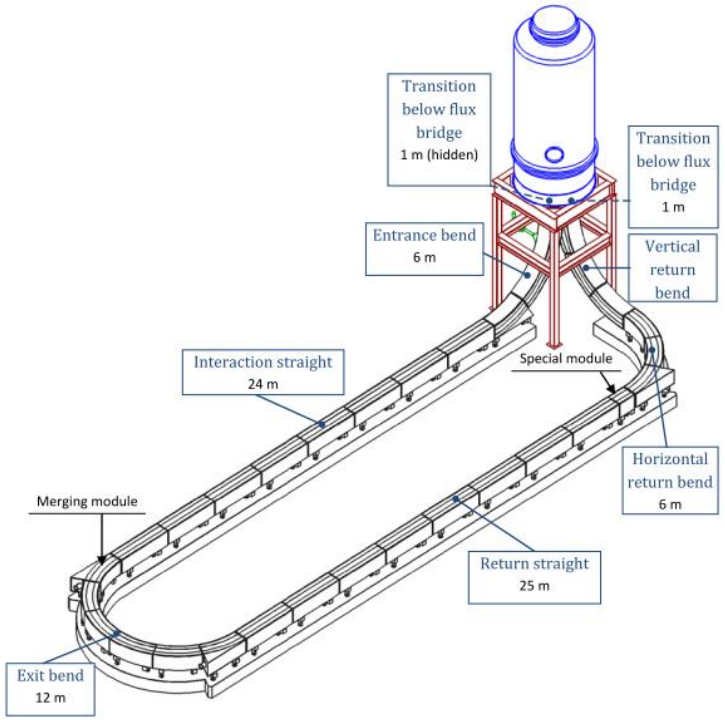
Accelerator Physics and Integrated Detectors-2

HESR-COOLER PROJECT

COOLER/MAGNET-LAB
Leader: **K. Aulenbacher**
Post-Docs/Scientists:
E Riehn (Parental leave until 2/2018)
I. Alexander
M. Bruker
PhD:
T. Weilbach
T. Beiser
Engineers/Technicians
M. Schwartz (Parental leave until 3/2018)
Collaborators:
V. Kamerzhev, FZJ
V. Parkomchuk, BINP

Critical issues for HESR cooler

Design work from Uppsala University (2009) based on research by Budker Institute for Nuclear Physics, Novosibirsk (BINP)



System Design of HESR-e⁻-Cooler

Critical (and unresolved) issues for 4.5-8 MV and 1-3 A at HESR:

- **Power generation on terminal/solenoids in HV region**
- **Beam diagnostics and control**
- **Recuperation efficiency**

HIM ACID2 adresses these topics by:

- **Cooler test stand**
- **R&D concerning power generation**

Cooler test-stand @ KPH-laboratory:

- **Very high collector efficiency**
- **Reliable&stable operation: magnetized beam@0.5 A**
- **PhD&Publ.: M. Bruker et al. : NIM A 872 (2017) 169**

→ New PhD thesis (T. Beiser)

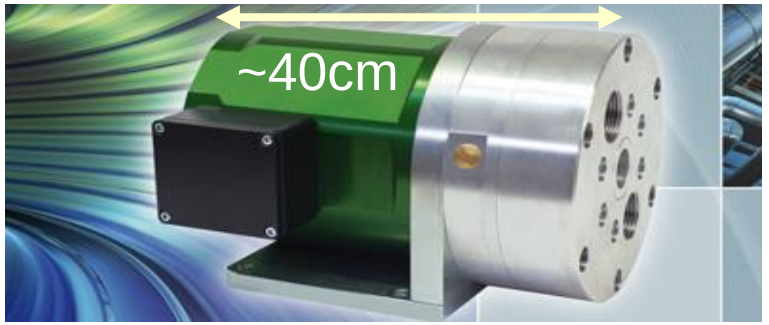
- **Ion trapping and fluorescence**
- **Beam dynamics/ space charge compensation**
- **Increased currents and potentials**

Cooler R&D Topics-II: Turbine powering

How to power solenoid channel & terminal ?

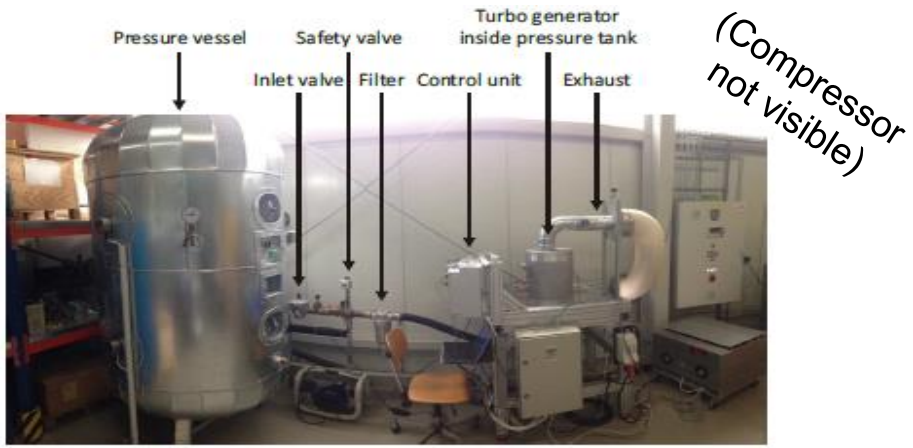
- **@HESR/PANDA: More cooling power needed (beam/ target interaction) → Magnetization of beam required!**
- **Powering of continuous solenoid channel in d.c. acceleration stage?**
- **Powering of terminal – electronics, source/collector?**
- **Power requirement: 50kW or more for supply floating at U>2MV !!!**

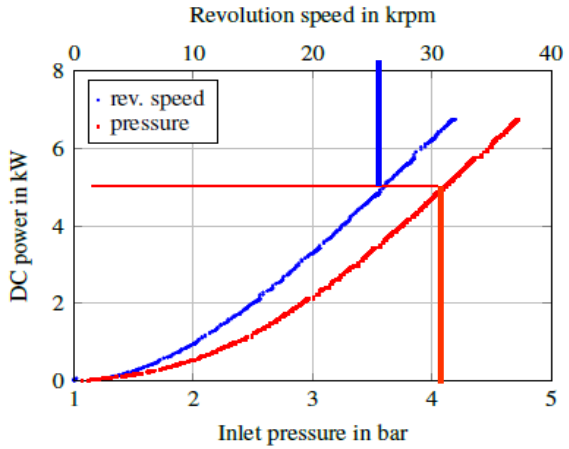
→ Powering by gas turbines (idea from BINP), investigated by ACID-II



5kW Turbogenerators purchased and thorough testing in 2015/16:

- **1000 hours operation without failure**
- **10 bar external pressure compatibility for operation in HV tank**



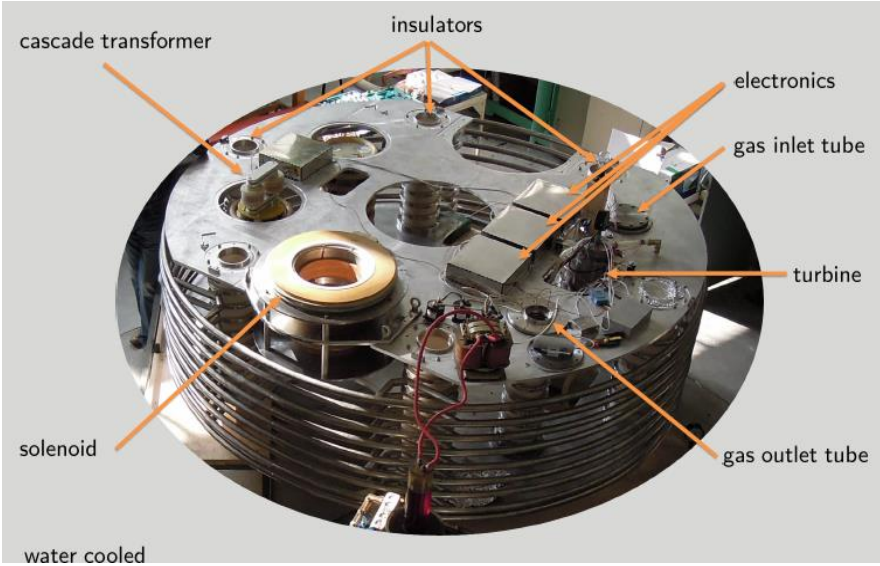


HIM- BINP-cooperation

BINP/HIM contract for fabrication of „prototype“ module

- **5kW turbogenerator integrated into prototype**
- **Turbine powers solenoid on terminal and 600kV d.c. Power supply**
- **Delivery planned spring 2018**
- **Tests foreseen @ HIM experimental hall - Module in pressure vessel (dry air or nitrogen as turbine driver and insulation gas)**

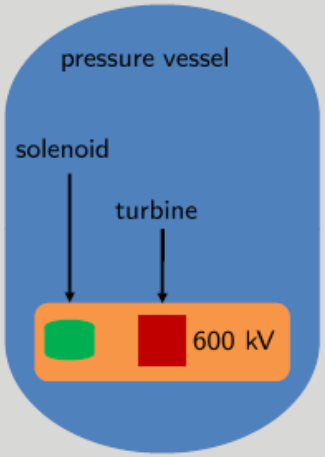
Photo of Prototype assembly @ BINP in August 2017



HIM hall with compressor station installed

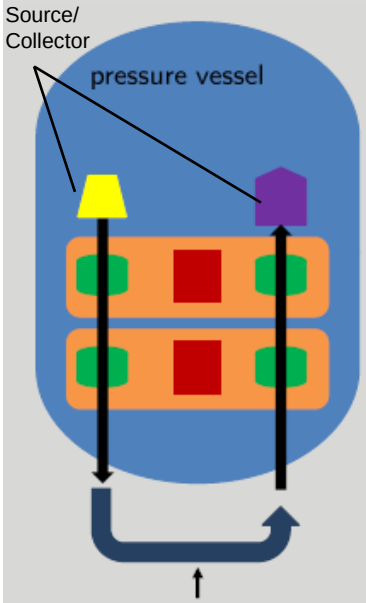
Near future extension plans

status end of 2018



- commissioning of HV module
- powering the solenoid at HV

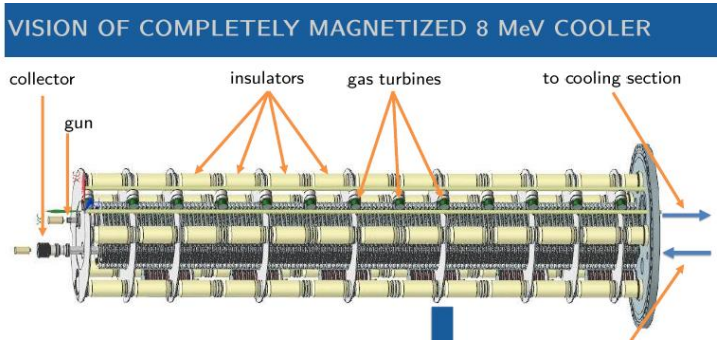
Possible Status End 2021



- install necessary solenoids
- install beam recirculation
- produce high electron current
- check if all parts work together

I. Alexander

Our means could allow to build a ~ 1:6 scaled prototype of the HESR cooler !



At the beginning of the 2020‘s the design of the whole device could be finalized!

- ACID-II HESR Cooler projects up and running
- First round of PhD thesis finished, beam diagnostic projects will go on with new PhD student.
- BINP cooperation will lead to 600kV turbine driven module
- Completion of module with electron beam recirculation planned → ~1:6 HESR cooler prototype

Infrastructure@HIM

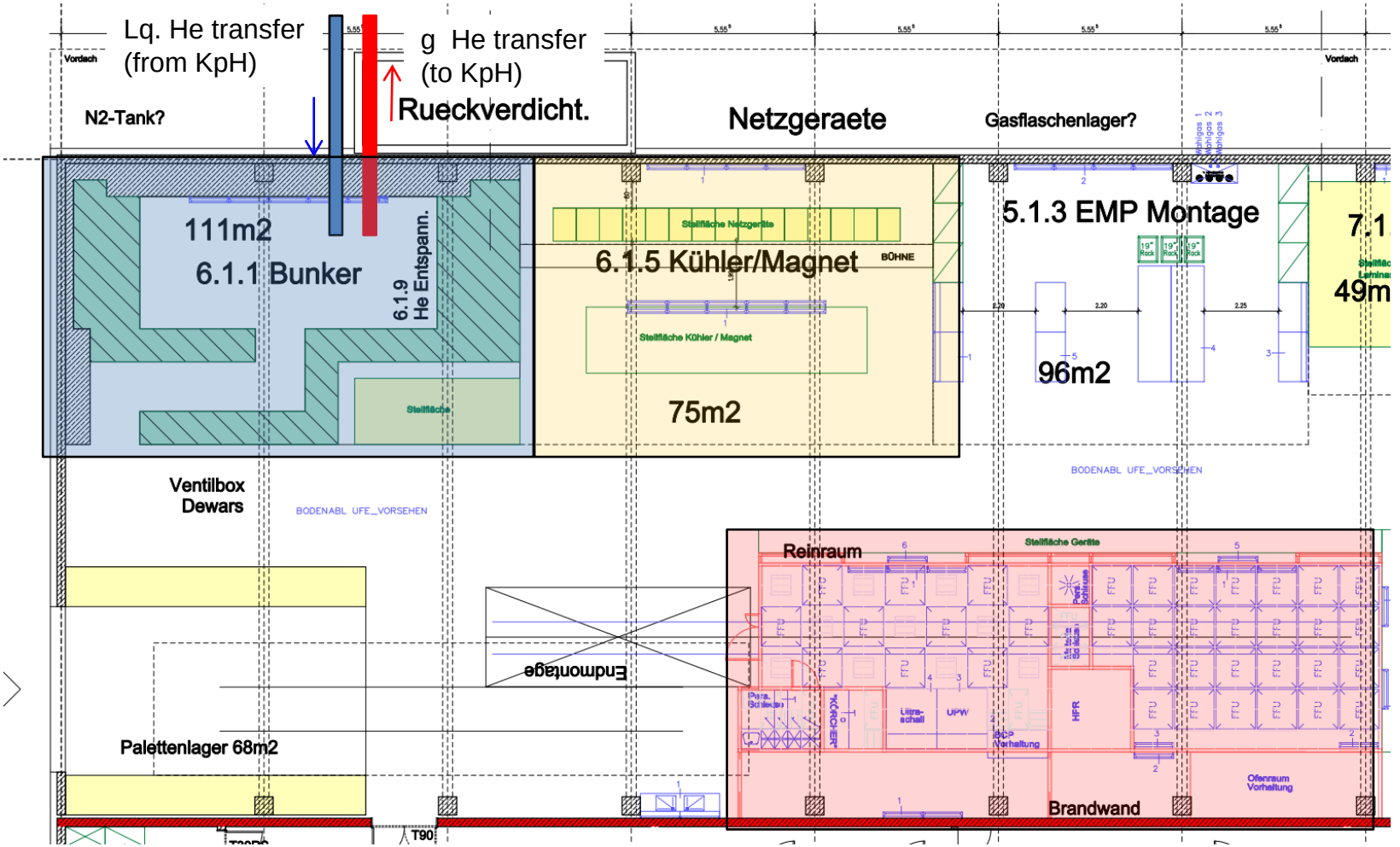
- High Pressure Rinsing (HPR)
- Bake out (oven)
- RF testing (warm & cold cavities)
- Cleanroom environment
- Optional: setup for BCP

Infrastructure: SHE-LINAC, HESR-research & more

BUNKER-LAB
SHE-LINAC (SRF)

Cooler-MAGNET-LAB
(HESR-cooler &more

Common-infrastructure:
Cleanroom



Thank you for Your attention!