Superconducting Helmoltz LInear ACcelerator-project

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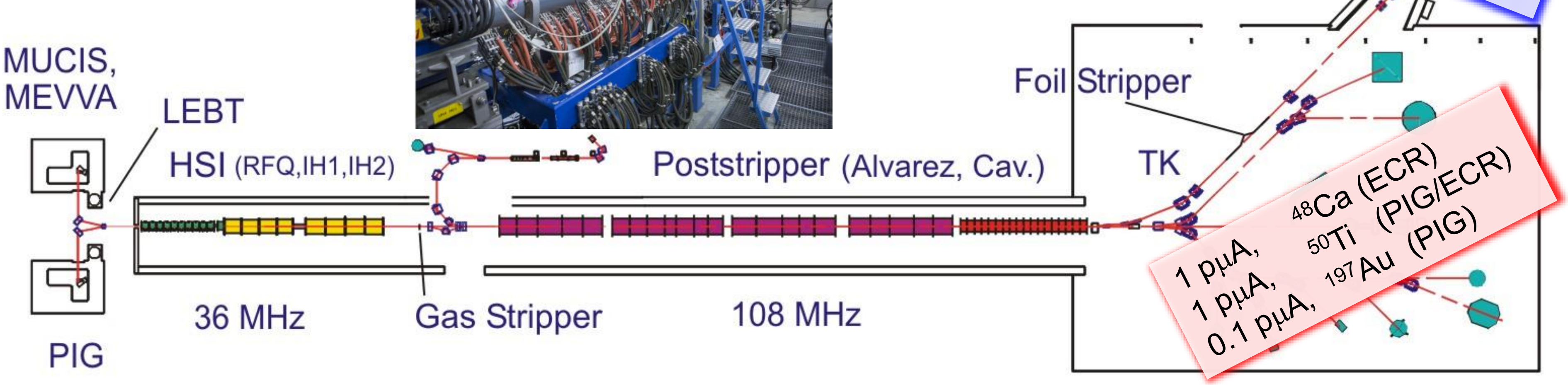
1. Introduction & general HELIAC layout
2. Impact for user community
3. R&D activities
4. HELIAC status
5. Outlook

Introduction
GSI UNIversal Linear ACcelerator

High Charge State Injector (1991)



High Current Injector (1999)

Alvarez (1975)

Single Gap Resonators (1975)

cw-Linac@GSI/Motivation

FAIR:

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

“Super Heavy Element”:

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

“Material Science”:

- Heavy Ions ($m \geq 200$)
- High Beam Energy (up to 10 MeV/u)
- high repetition rate (50 Hz)
- Continuous Beam Energy Variation (1.5 – 10 MeV/u)

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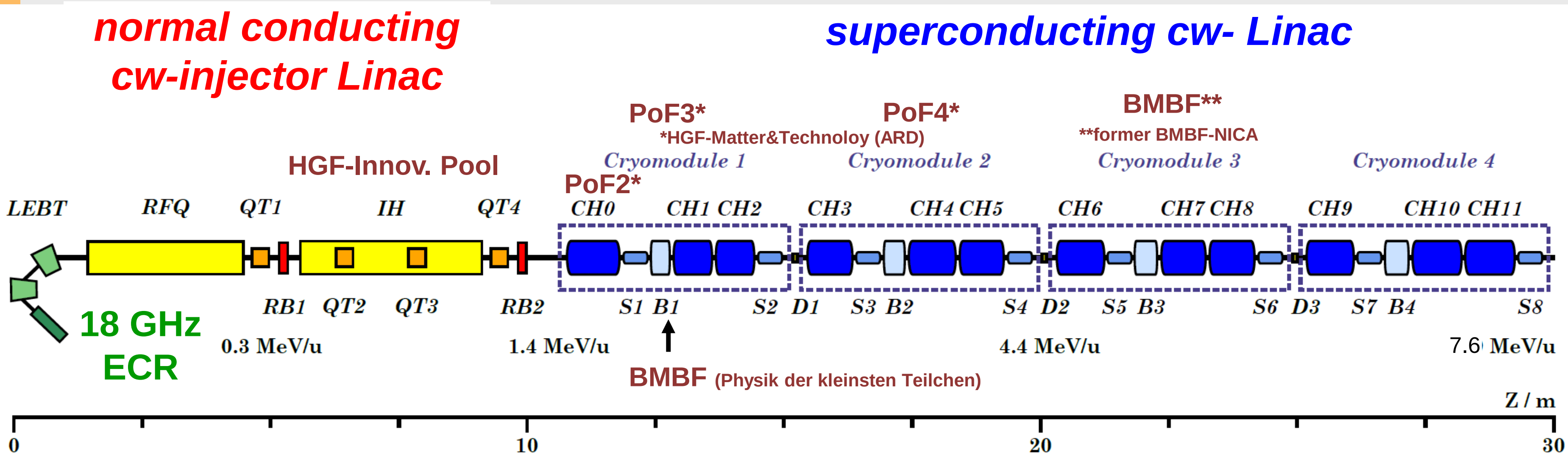
Layout of the future superconducting cw HELIAC*

* HElmholz LInear ACcelerator



Design parameters sc cw-LINAC		
A/q		≤ 6
Frequency	MHz	216.816
Beam current	mA	≤ 1
Injection energy	MeV/u	1.4
Output energy	MeV/u	3.5-7.6
Length	m	20
CH cavities	#	12
Rebuncher	#	4
Solenoids	#	8

Maximum energy per CM

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

Scientific opportunities for SHE at the cw-linac

cw linac modules	no cw-Linac*	CM1-2	CM1-3 25%	CM1-3 100%	CM1-4 100%
Synthesis (Z ≤ 118)		up to 105			
Synthesis (Z > 118)					
Nuclear structure		up to 105	too low duty cycle		
Mass spectrometry		up to 105			
Laser spectroscopy		up to 105			
Chemical studies					
Overall SHE programm	**Not possible**	**Only very small fraction of program**	**Possible, hardly long-term competitive**	**Full capability**	

*Consequences of Poststripper-Rf-upgrade

Main advantages

- ✓ Higher machine availability for low-energy program
- ✓ Terminates interference SIS-injector ⇔ SHE program
- ✓ Backup SIS-injector

Scientific opportunities for Material Science at HELIAC

cw Linac module/ Duty cycle (%)	no cw-Linac*	CM1-2 25%	CM1-3 25%	CM1-4 100%
Nanotechnology				
Bulk material				full MAT program
Surface processes	not suitable for MAT		60% fraction for MAT use	
In-situ analysis		limited MAT use		
Microprobe				
Overall MAT program	10%	20%	60%	100%

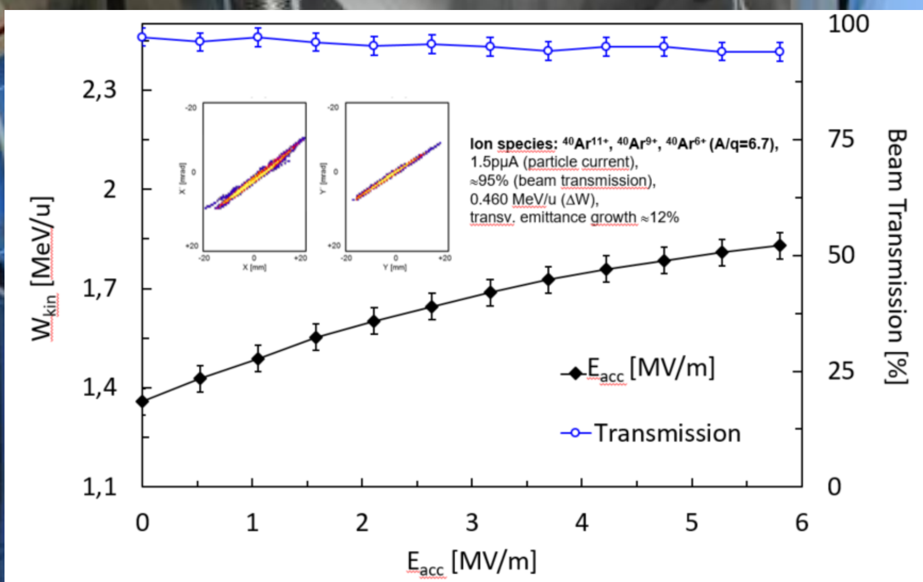
*Consequences of Poststripper-Rf-upgrade

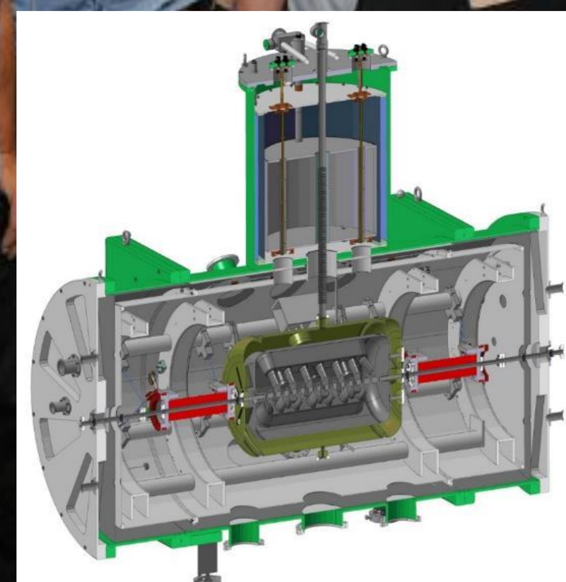
Main advantages for MAT program

- ✓ more regular beam access
- ✓ more suitable beam structure
- ✓ (no dose spikes, lower pulse current compensated by higher duty cycle)
- ✓ higher beam stability (no interference due to SIS injection)
- ✓ conditions suitable for commercial irradiations (scanning large areas, electronic devices)
- ✓ Backup SIS-injector

HELIAC R&D (PoF2)

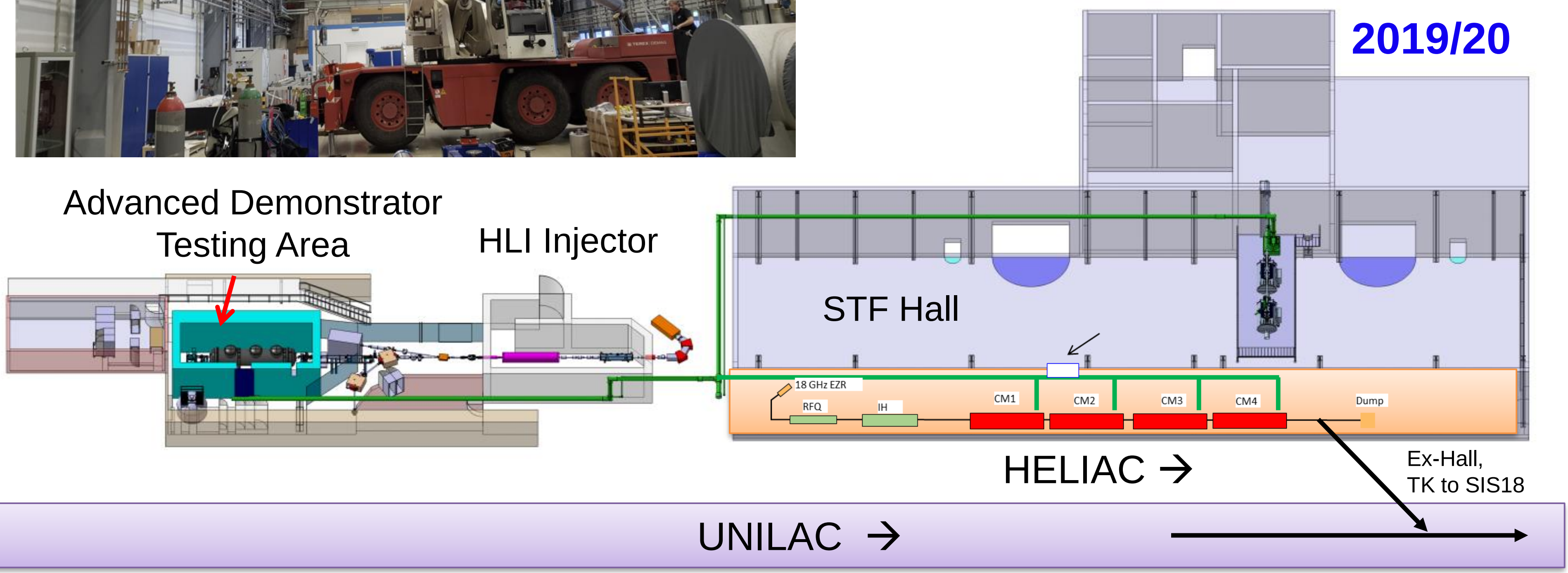
- First superconducting 217 MHz-CH-Cavity
- High E_{acc}-gradient up to 10 MV/m
- High quality factor → low RF-dissipation (<10W)
- Equidistant gaps → **continuous energy variation**
- 2017: Successful beam commissioning



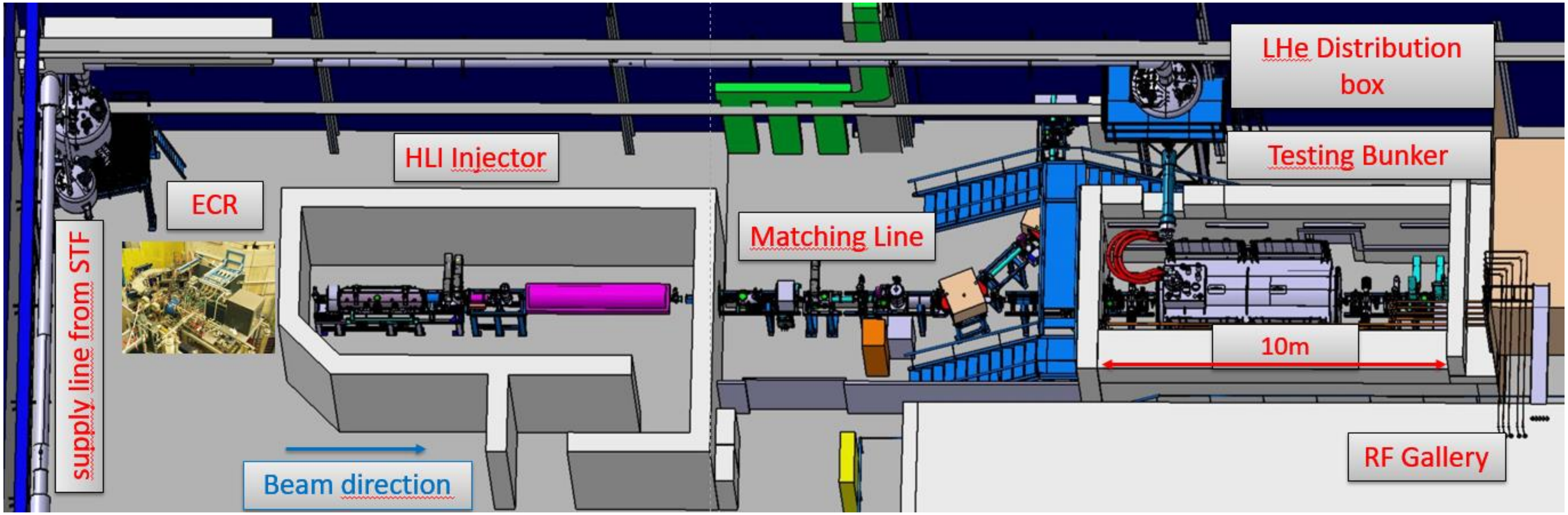


4K He-supply infrastructure@GSI

Link to STF (Series Test Facility)



Testing Area @GSI



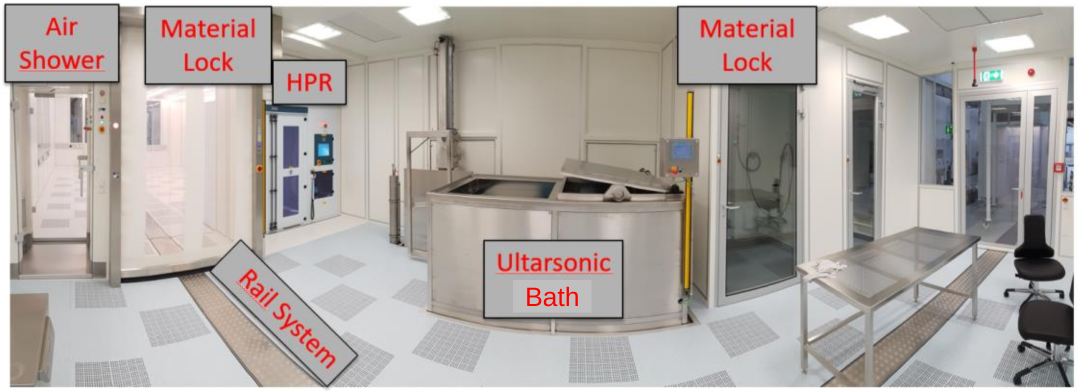
- ✓ Bunker, matching beam line and beam diagnostic bench in operation since 2020
- ✓ He-Infrastructure (linked to STF) is commissioned and in operation since 2021
- ✓ Preservation of transversal alignment of components during cool down <0.1mm
- ✓ Cold Button Beam Position Monitor (BPM) is commissioned
- ✓ sc-Solenoids are tested with beam. Design with integrated steerer is validated

New Testbunker with test bench (2020)

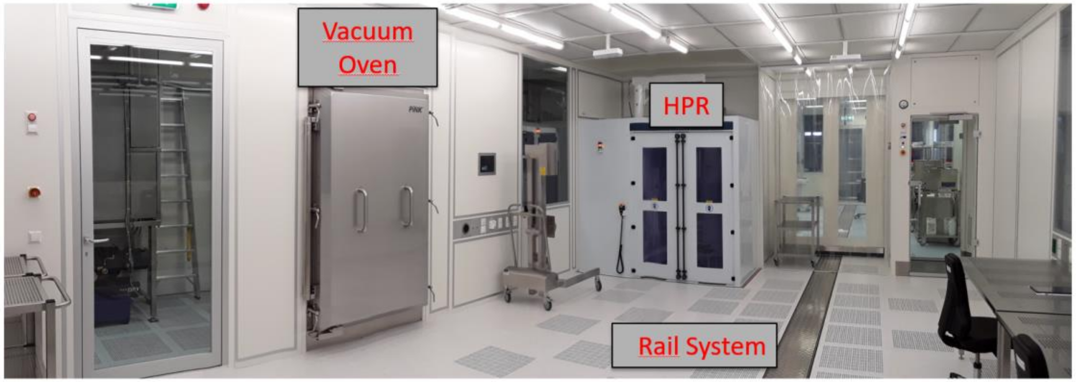
CM1 at Test Bunker (2021)

Clean Room @ HI-Mainz
unique infrastructure for SRF-R&D

ISO 6 Clean Room



ISO 4 Clean Room



- Two interconnected clean rooms 42m² (ISO6)+42m² (ISO4)
- Ultra high purity water supply
- Ultrasonic bath and conductance rinse
- High Pressure Rinse (HPR)
- RF-test bunker LHe infrastructure

Cold String Assembly at HI-Mainz-Clean Room

cleaning of S2 in material lock

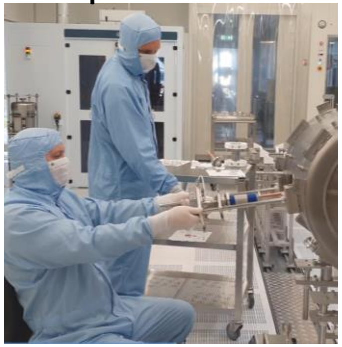
cleaning of S2 in ultrasonic bath

transfer to HPR with lifter

gear to trolley stand

CH2 on trolley stand

integration of rf–power coupler with CH2



connection of S2 and CH2 with bellow

10/2022 Assembly of the cold string

11/2022 Integration into cryostat

12/2022 Integration into beamline @ GSI

02/2023 Cryo commissioning

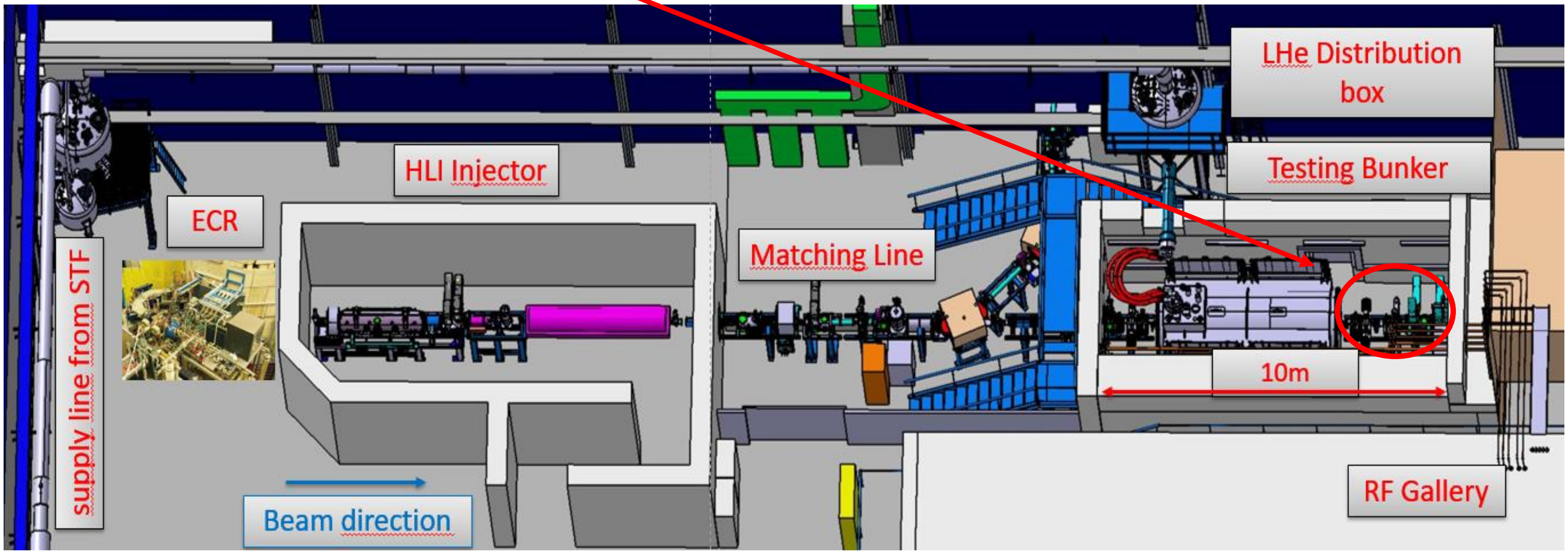
03/2023 RF conditioning and commissioning of LLRF

08/2023 Commissioning with beam

Outlook I

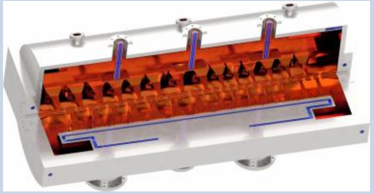
- CM1-beam test in 2023
- First user experiments with CM1 in SH1/4 (installed instead of beam diagnostic test bench)

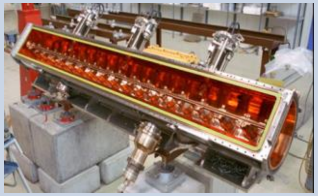
Cryomodule	Cavity	Output energy (MeV/u)		
		$A/z = 6$	$A/z = 3$	$A/z = 1$
	HLI	1.4	1.4	1.4
	CH0	2.1	2.2	3.0
CM1	CH1	2.6	3.0	4.2
	CH2	2.9	3.6	4.6



Outlook II: HELIAC „basic approach“

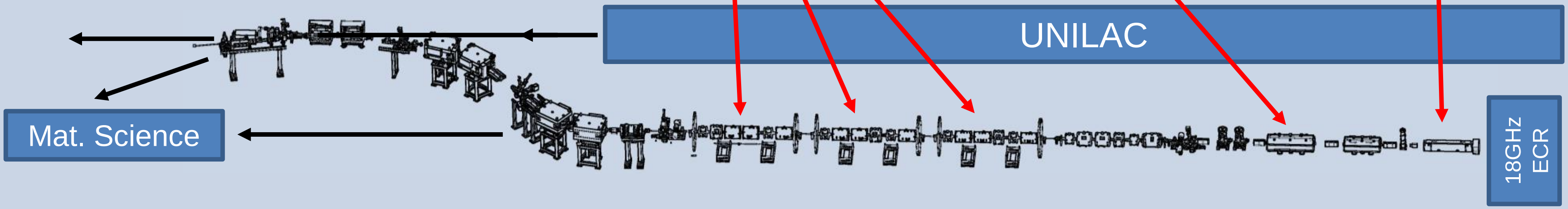
CM I - III | IH I - II | RFQ





***FAIR Phase*-0 and beyoned**

- SHIP(TRAP)
- TASCA
- UBIO
- Plasmaphysics (Z6)
- SIS18 => FAIR



- HELIAC is designed to fit into existing hall
- Feasibility study for civil construction/tunnel
- STF cryogenic plant for supply of HELIAC
- ECR 18GHz+LEBT → purchasing?
- RFQ → old HLI RFQ (25% duty)
- High power RF-amplifiers
- IH1/IH2 in manufacturing
- CM1 in assembly/testing
- CM2 in manufacturing
- CH-Cavities for CM3 in manufacturing
- Bending magnets from GSI-Stock, power supplies to be ordered
- Most of beam line magnets on GSI-Stock, most of power supplies to be ordered
- For „basic approach“ (25% duty) reuse of existing high power rf-amplifiers
- water- and electrical-supply, vacuum system

Save Energy – buit HELIAC !

Power consumption UNILAC vs. HELIAC

HELIAC (sc)
A/Z= 6, 7.5 MeV/u
cw-operation

subsystem	section	P [kW]
Ion source	ECR	230
RF-amplifiers	nc-Injector	270
RF-amplifiers	CM1-4	80
cryo supply	CM1-4	130
Power Supplies	HELIAC tot.	150
Beam diagnostics	UNILAC	50
Cooling water	HELIAC tot.	200
	tot.	*1110*

UNILAC (nc)
A/Z 26 (HSI), A/Z = 6 (poststripper), 7.5 MeV/u (A3 intermediate energy/7.1 MeV/u +3xERs)
30% RF-duty factor

subsystem	section	P [kW]
RF-amplifiers	HSI	600
RF-amplifiers	Al-AIII	1900
RF-amplifiers	SGR	190
Power Supplies	HSI	70
Power Supplies	Poststripper	145
Beam diagnostics	UNILAC	100
Cooling water	UNILAC	1200
Basic load	UNILAC	650
Ion source	Penning	40
	tot.	**4895**

For typical beam time:
>90% less power consumption, *energy savings for 6 months of operation (HELIAC vs. UNILAC) ≈ 16.4 GWh*

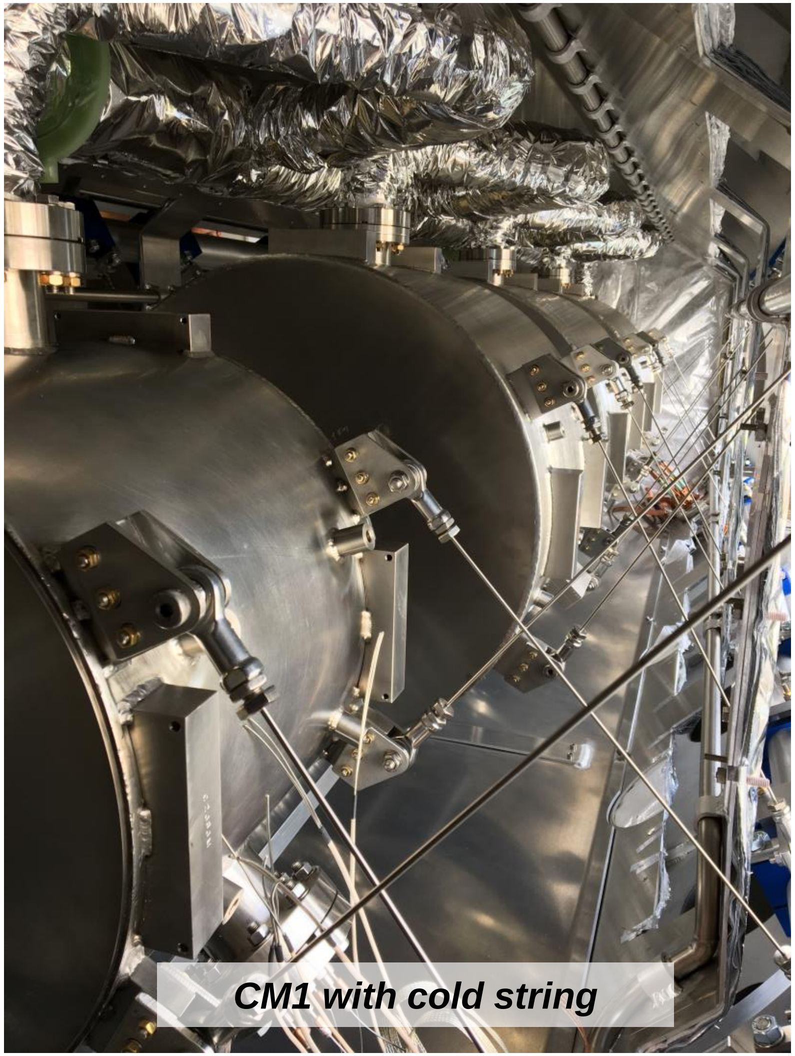
Energy savings for 6 months UNILAC-experiment vs. 1.5 months/HELIAC ≈ 20 GWh

HELIAC “basic approach”-timeline

Q4/2023	CM1 (Advanced Demonstrator) beam test at Test Area
Q2/2025	**Linac-Tunnel (@SH2/3) ready for installation of components**
Q3&4/2025	ECR and LEBT commissioning @ Linac-tunnel
Q4/2025	CM2 beam test at Test Area
Q1/2026	RFQ commissioning @ Linac tunnel
Q2/2026	cw-IH-DTL commissioning @ Linac tunnel
Q3/2026	Matching Line & CM1 commissioning
Q4/2026	CM2 commissioning (and CM3 beam at Test Area)
Q1/2027	**CM3 & HEBT to UNILAC commissioning (basic approach)**

@Additional schedule for test activities at HI-Mainz

→ **ERUM-PRO: continous wave (cw)-RFQ & (solid state) cw-high power RF-amplifier**


CM1 with cold string

Thank You for Your attention!