Status and Perspectives of the HELIAC-Project

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HELIAC

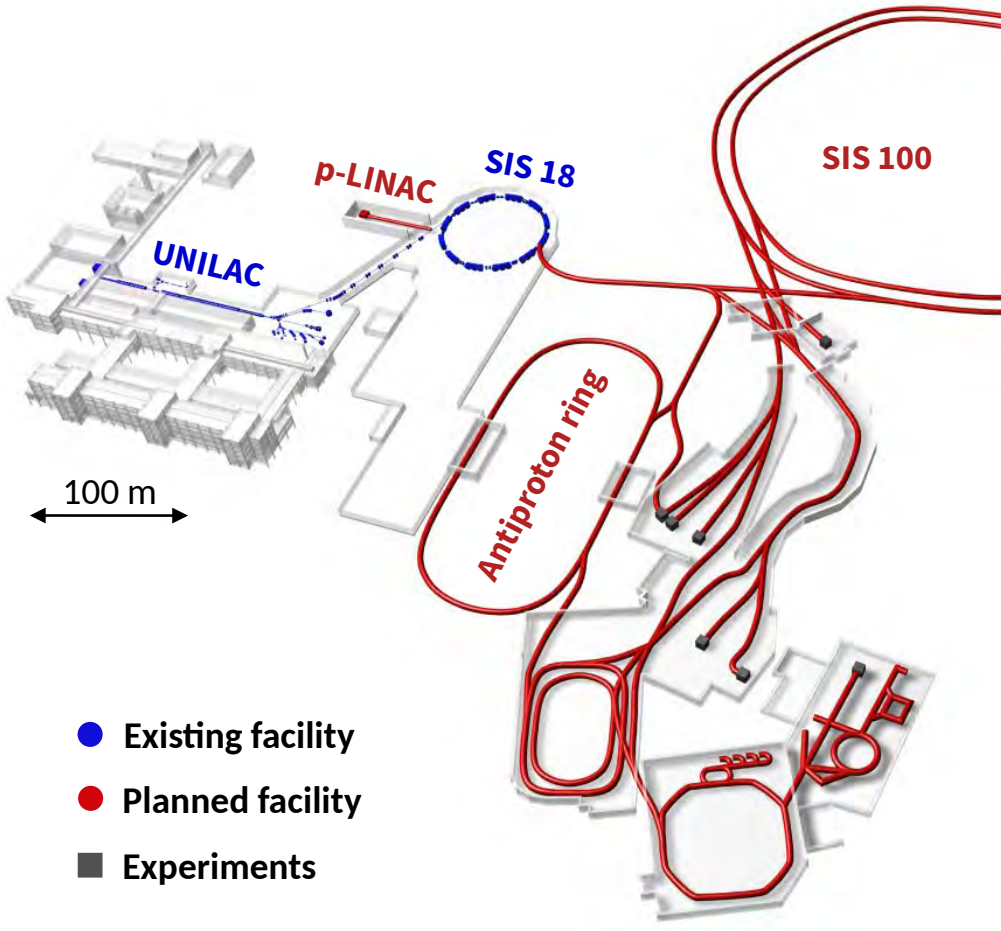
GSI DARMSTADT

Introduction

FAIR Requirements
- high *peak* beam currents
- low duty factor (~0.1 %)
- → low repetition rate (max. 3 Hz)

UNILAC-Poststripper RF Upgrade
- optimised for FAIR requirements
- oposes high duty factor / rep. rate

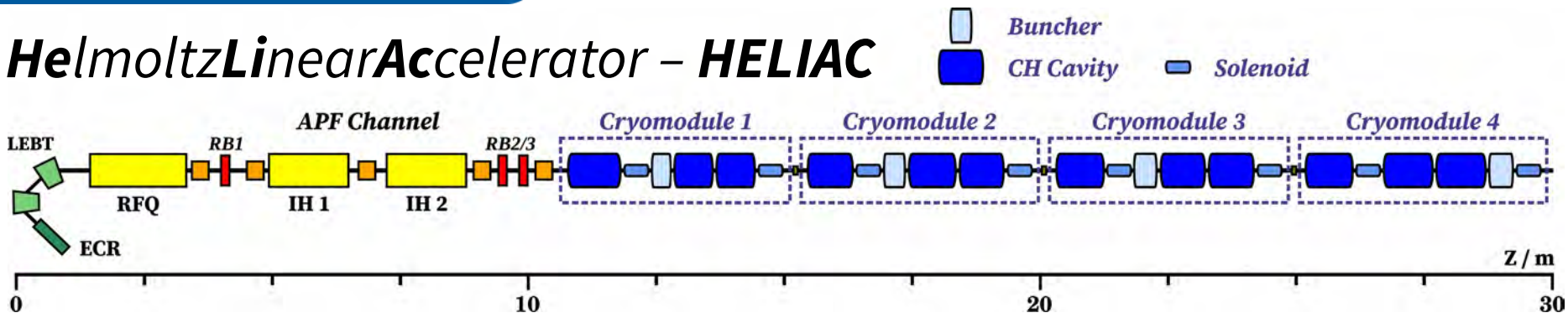
Super Heavy Element Requirements
- high *average* beam currents
- high duty factor (~100 %)
- high repetition rate or just *c.w.*



Existing GSI facility and future FAIR complex

Introduction

He**lmoltz**Li**near**Ac**celerator – **HELIAC



Source

Parameter	Unit
Type	ECR
Frequency	18 GHz

Normal-Conducting Injector

Parameter	Unit	Value
Output energy	MeV/u	1.4
RF Cavities		6
Operation mode		cw
A/Z		≤ 6

Superconducting Accelerator

Parameter	Unit	Value
Output energy	**MeV/u**	**3.5 – 7.3**
Beam current	mA	≤ 1
Operation mode		**cw**
A/Z		≤ 6
RF Cavities	#	12
RF Bunchers	#	4
Transversal Focussing	2 Solenoids per Cryom.	

Introduction

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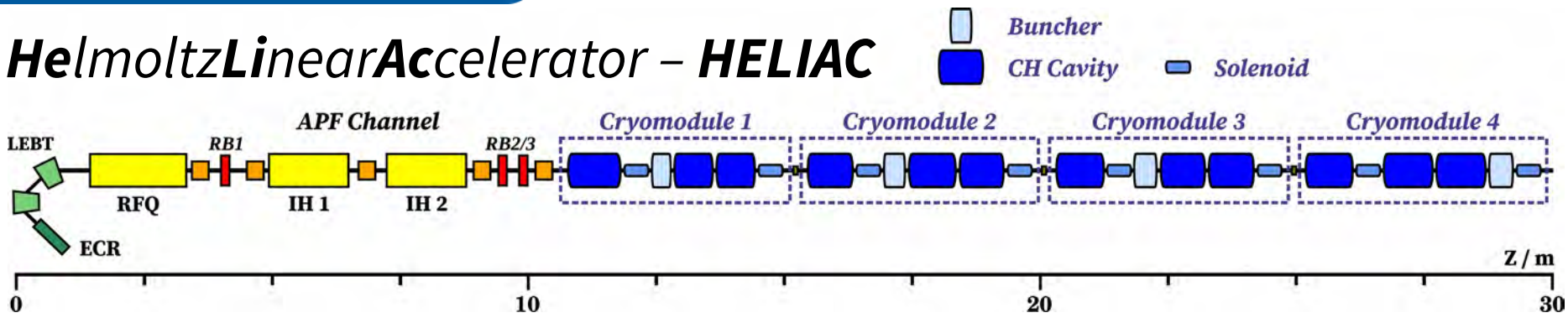

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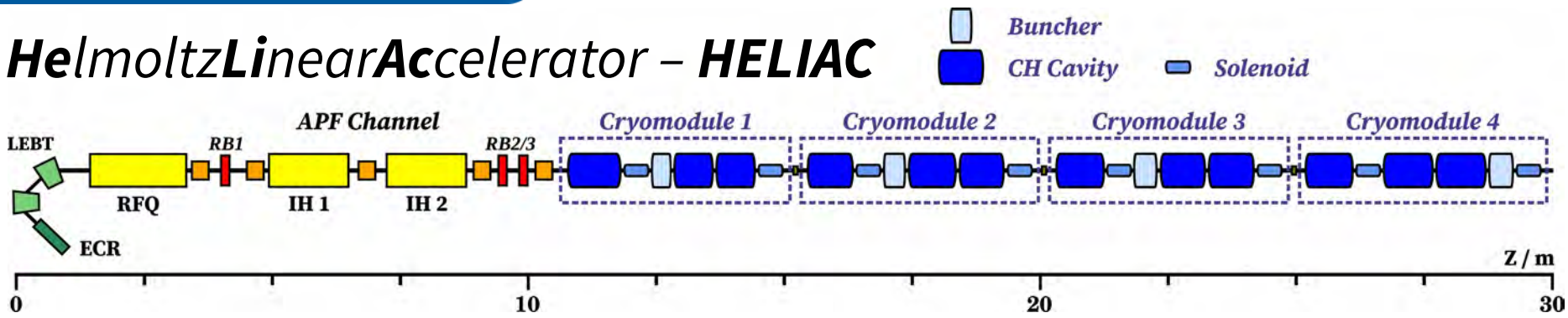

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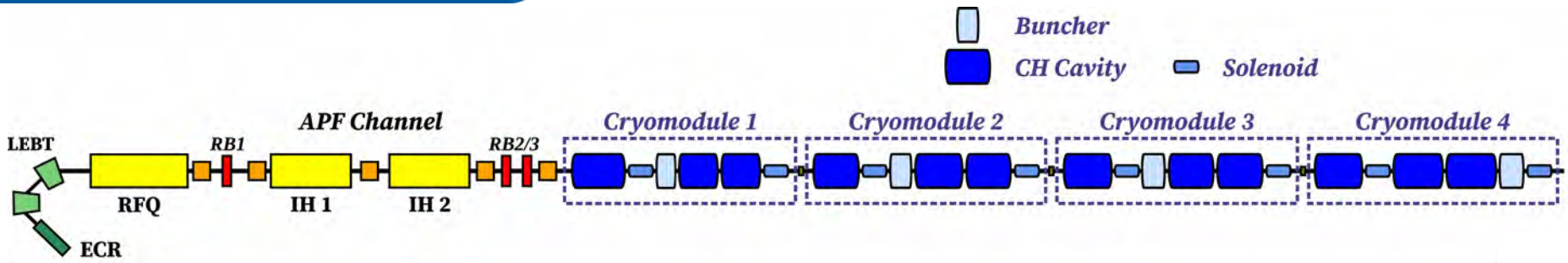
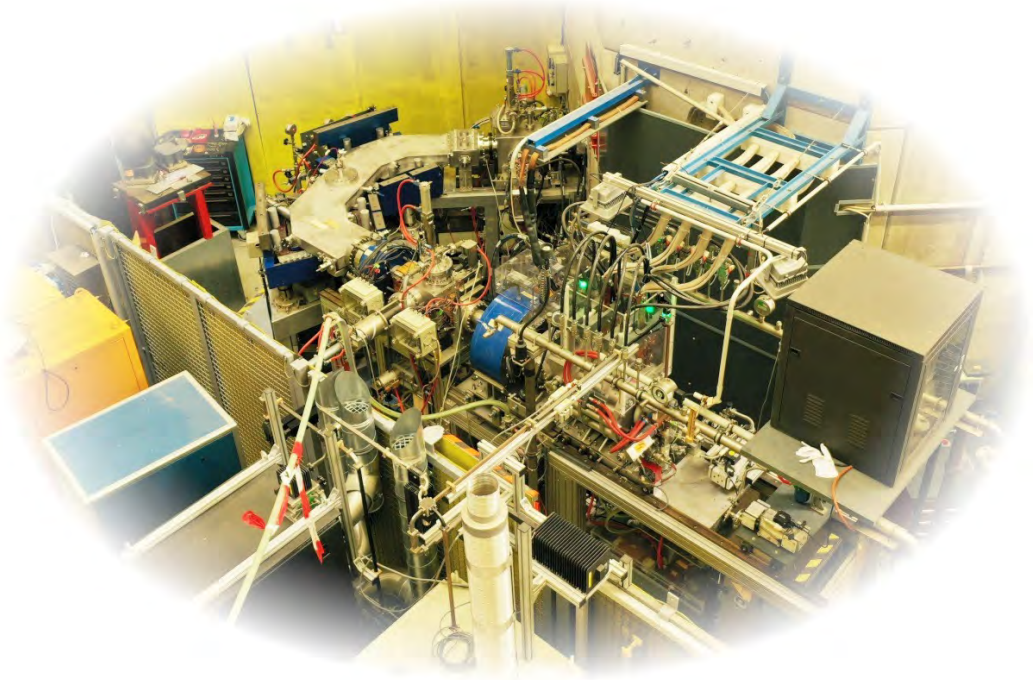


Source — 18-GHz-ECR

- 14-GHz-ECR @ GSI
- Higher charge desired:
  → Higher density plasma
  → 18-GHz-ECR
- LEBT
  - Spectrometer
  - Transport to RFQ

Funding still unclear!



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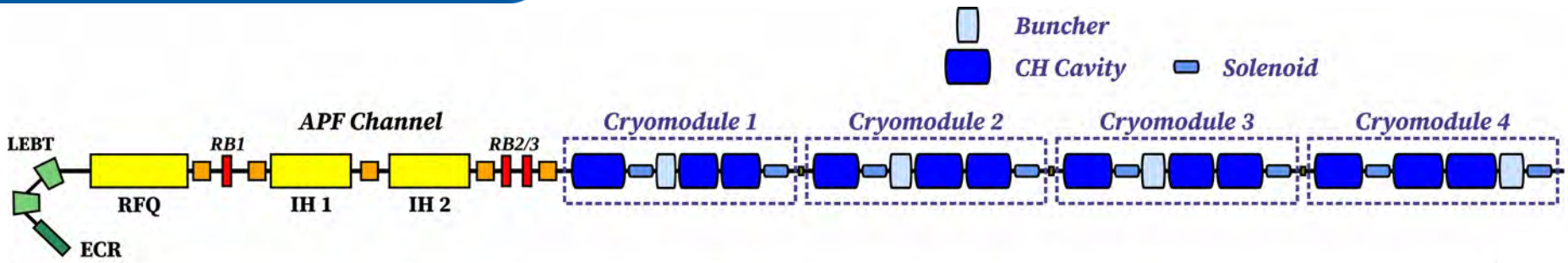
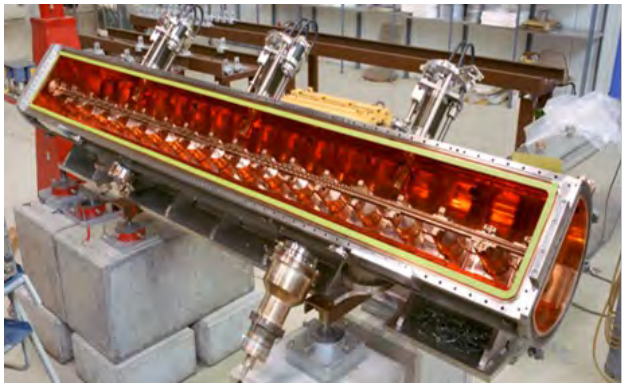
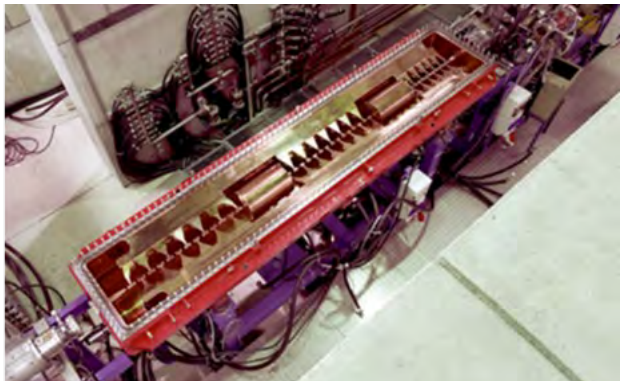


Source	18-GHz-ECR
Normal-Conducting Injector	R&D required; Tendering started

HLI RFQ



HLI IH Cavity



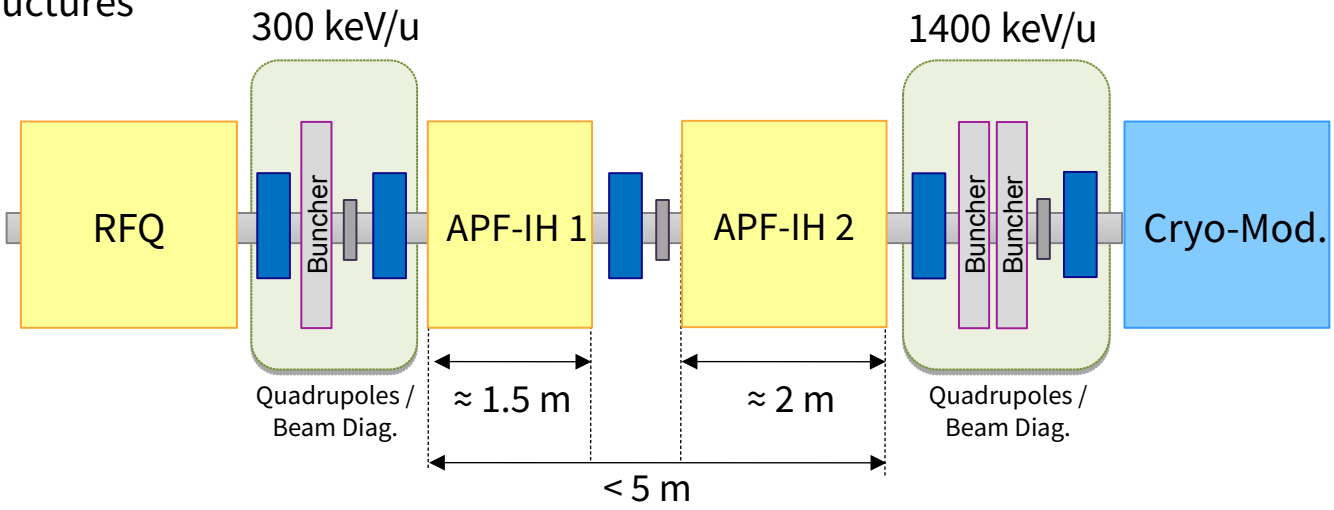
25% duty factor vs. 100 % → Heat Load

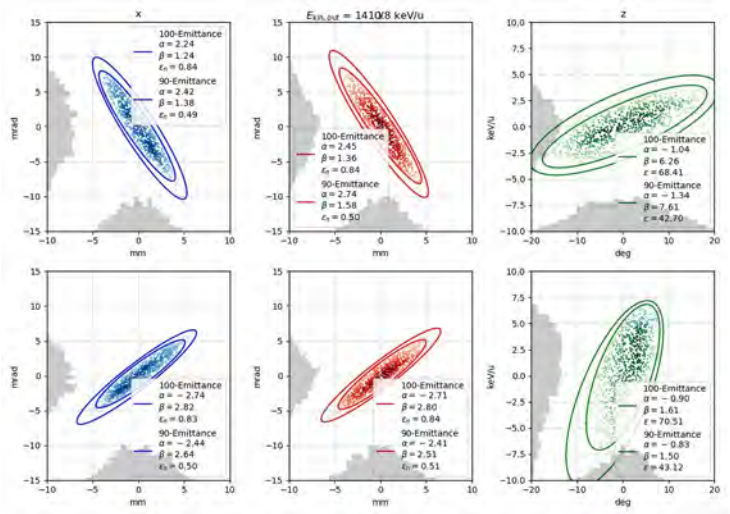
+

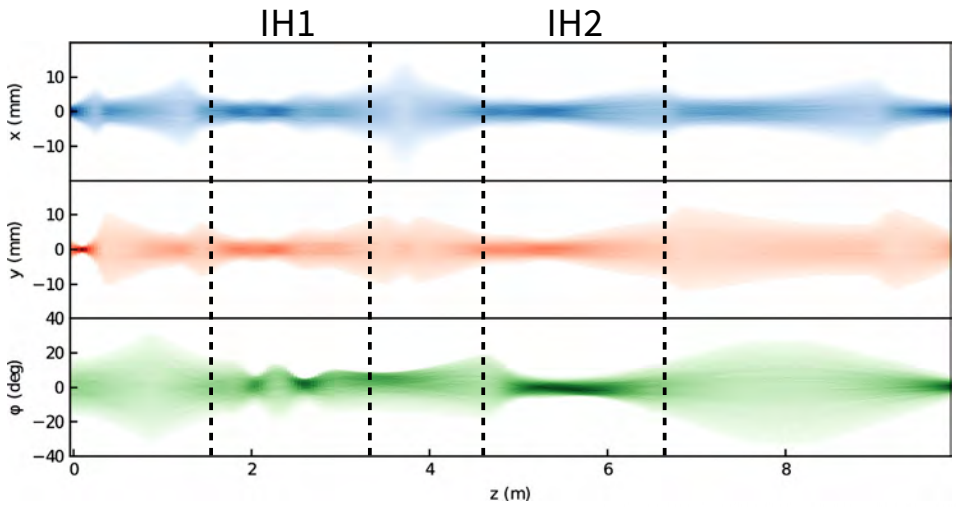
Tight space constraints

Status: Injector

- Limited space for IH structures
- Two-cavity design
- APF: **A**lternating **P**hase **F**ocusing
- Mature beam dynamics design

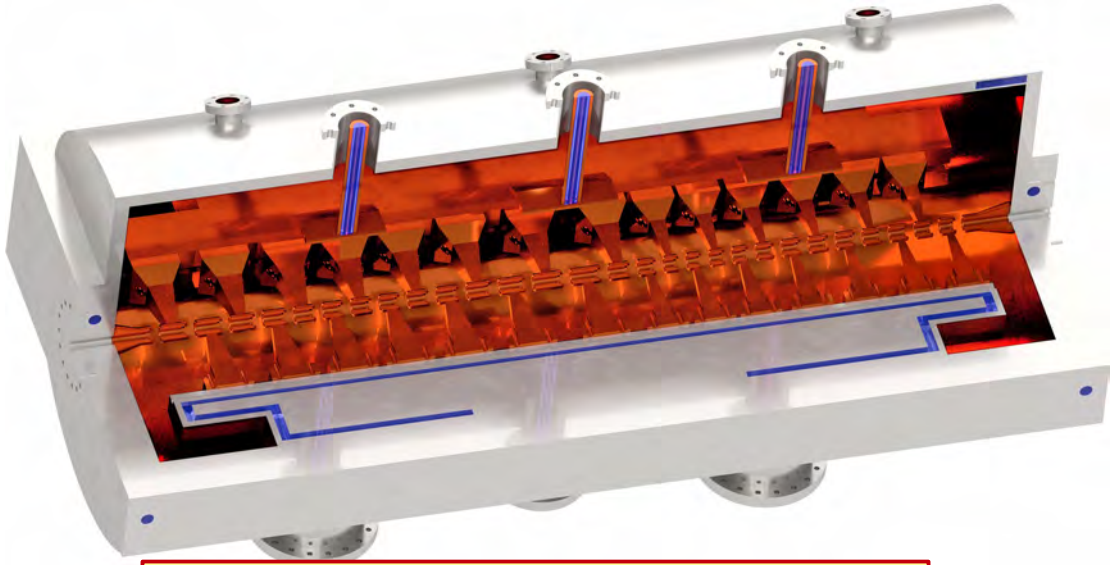




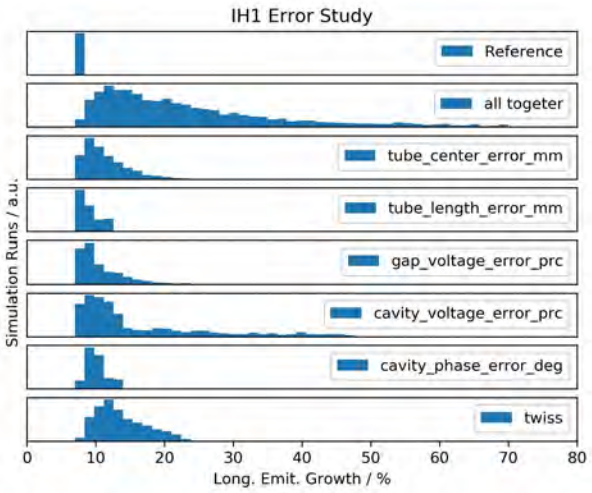


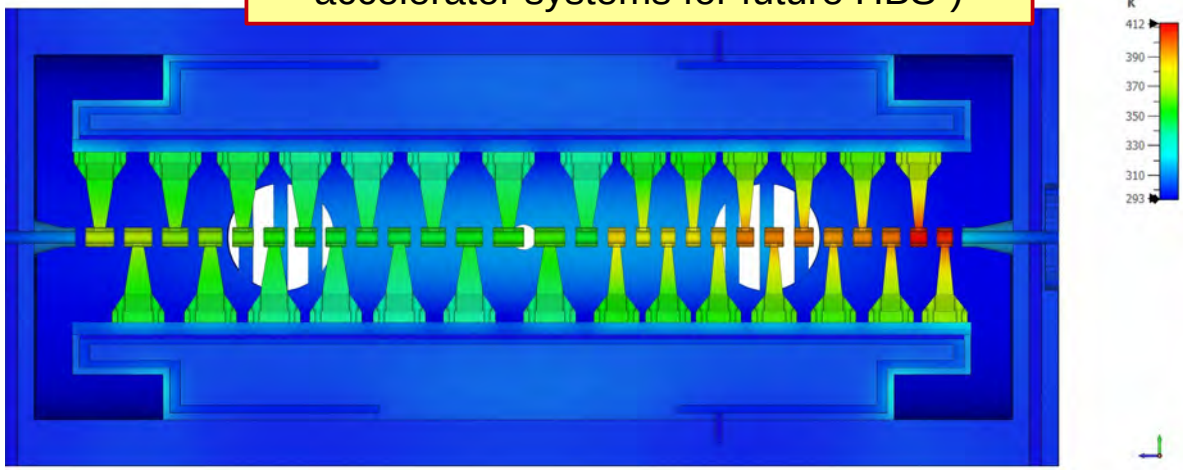
Status: Injector

- Extensive Simulations:
  - 3D e.m. field
  - Thermal
  - Multi-physics
  - Error studies
- Copper-plated steel structure
- Contract for production awarded (delivery 2023)



strong funding support by the HGF (innovations pool-project „High current accelerator systems for future HBS“)





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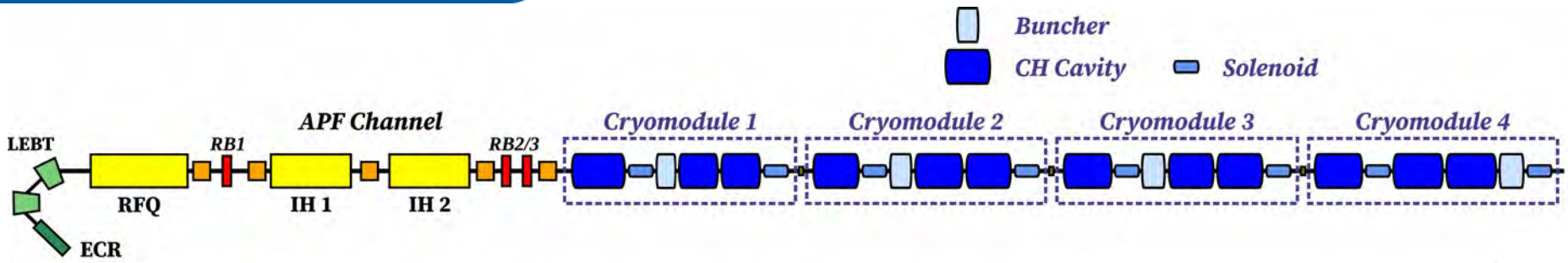


Source	Copy of Existing Design
Normal-Conducting Injector	R&D required; Tendering started
Superconducting Accelerator	

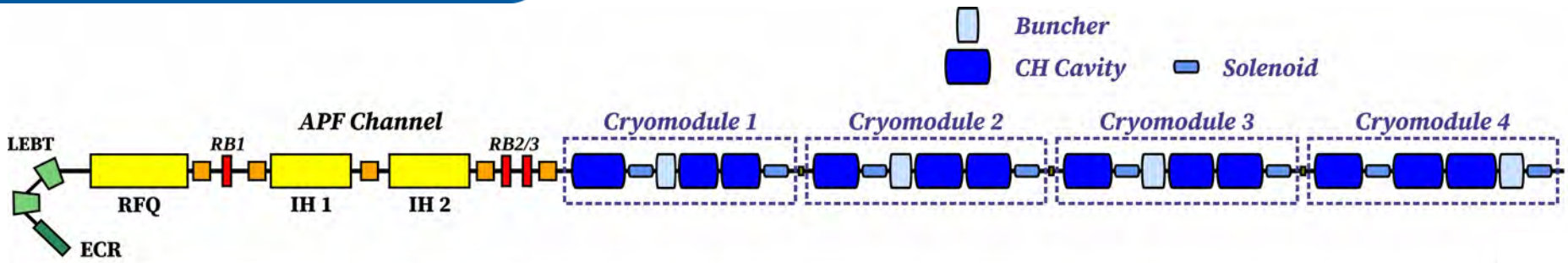
CH Cavity Qualification

Beam Dynamics Qualification

Cryomodule Qualification

HELIAC Setup

Status



Source	Copy of Existing Design
Normal-Conducting Injector	R&D required; Tendering started
Superconducting Accelerator	„Advanced CW-Linac Demonstrator“

CH Cavity Qualification

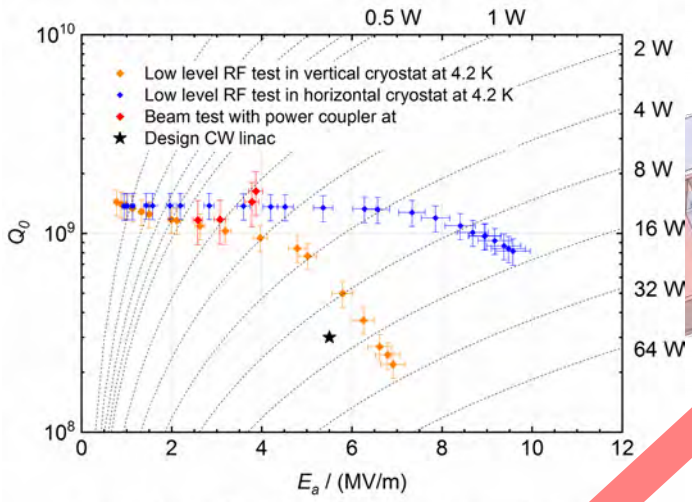
Beam Dynamics Qualification

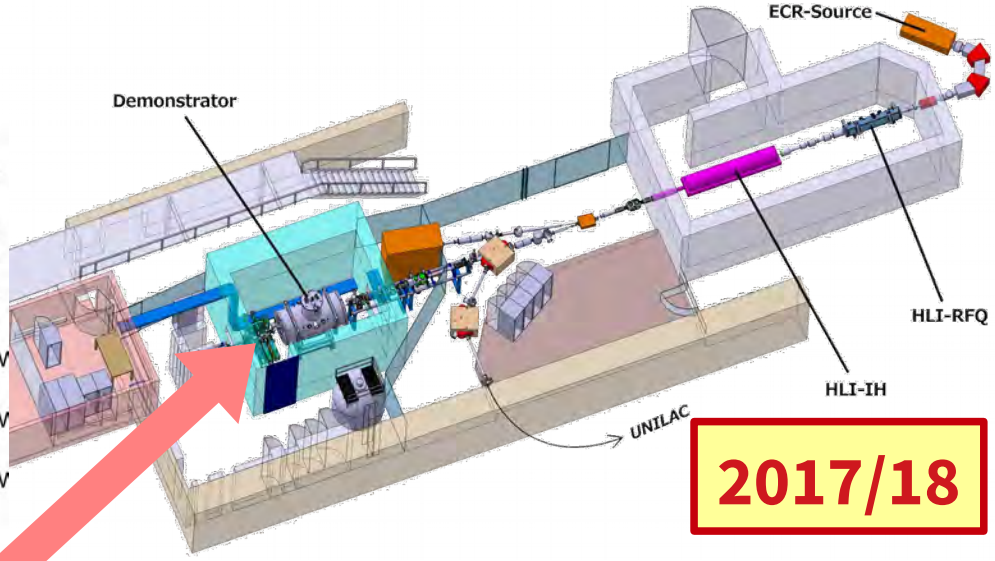
Cryomodule Qualification

HELIAC Setup

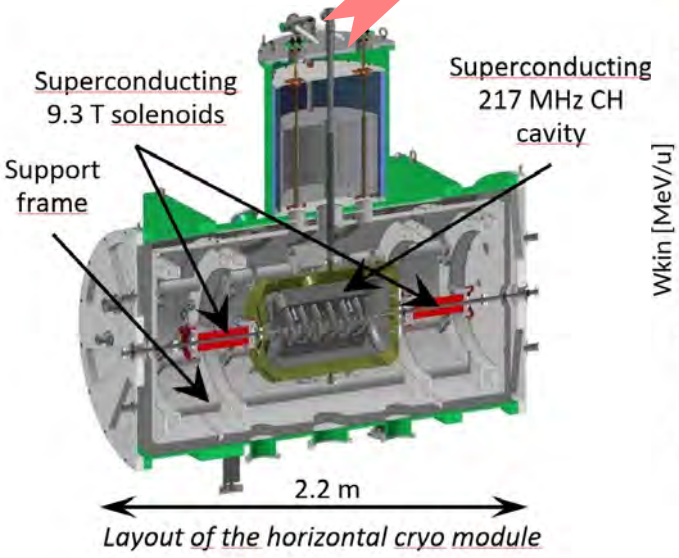
CH Qualification

2016/17

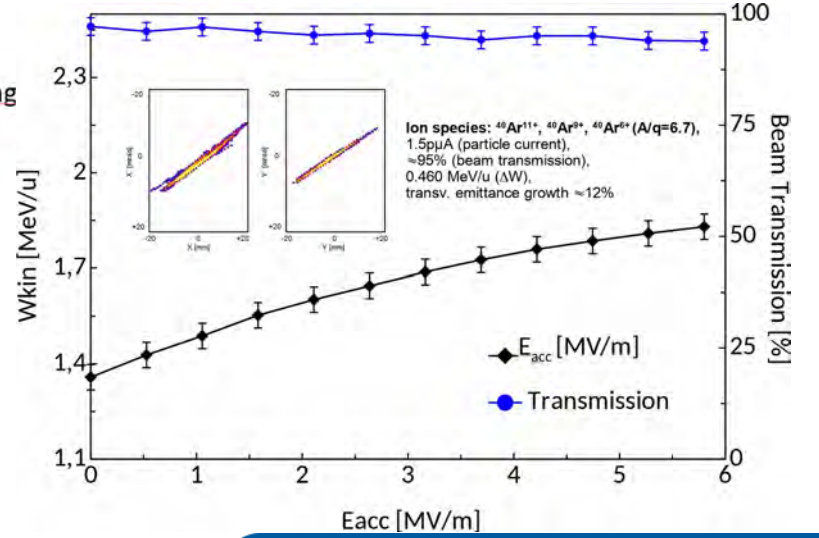




2017/18



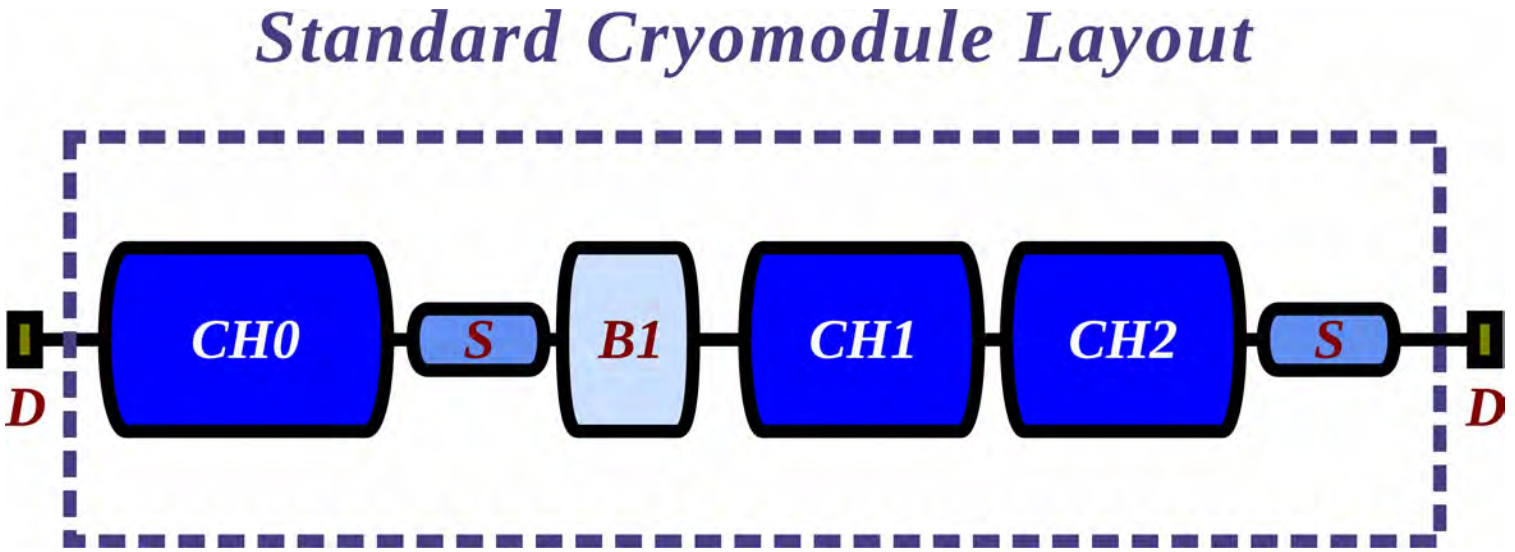
Layout of the horizontal cryo module



Cryomodule Qualification

Advanced CW Linac Demonstrator

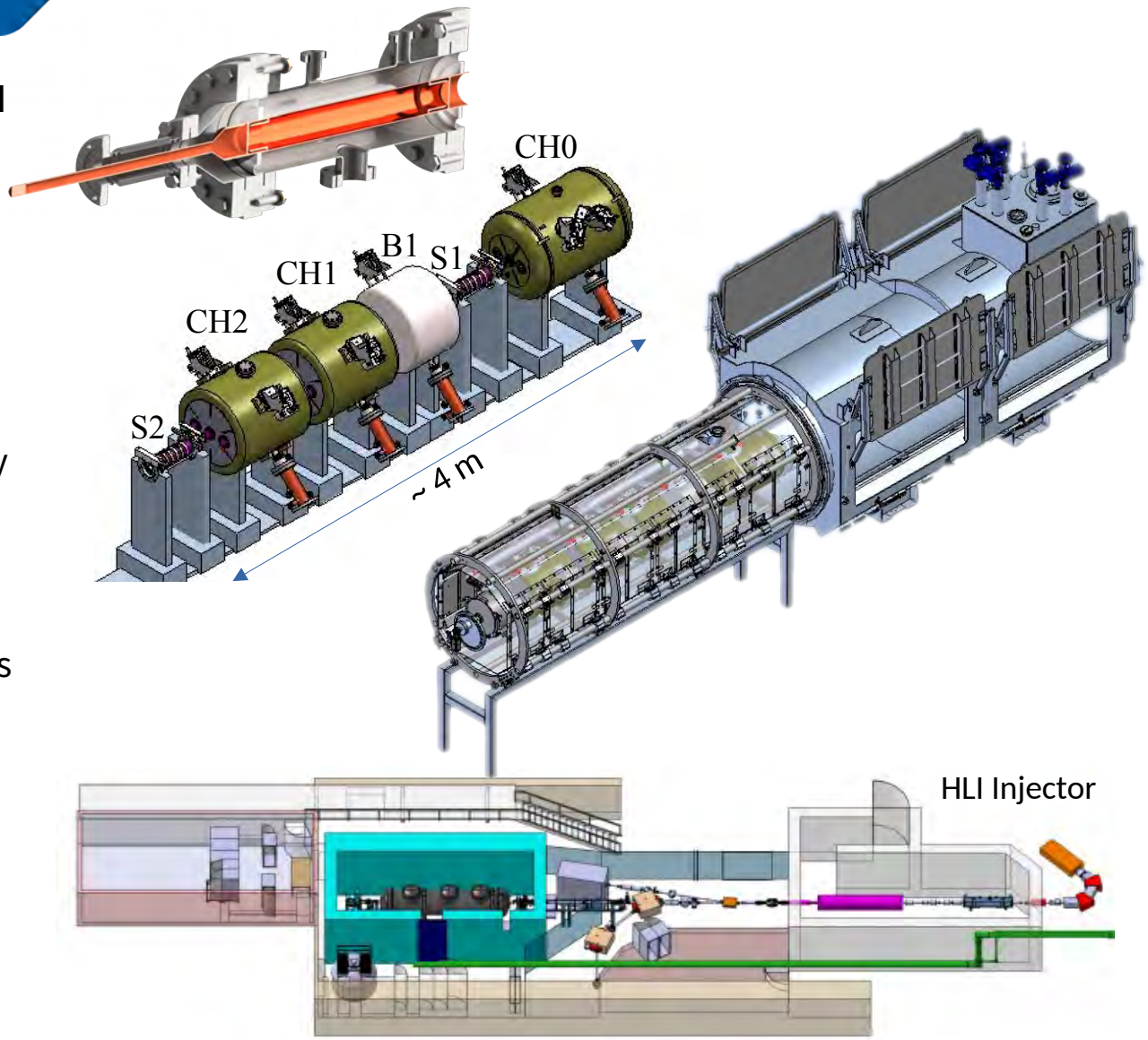
- 3 CH cavities
- 1 Rebuncher
- 2 Solenoids



Cryomodule Qualification

Test of fully equipped standard cryomodule:

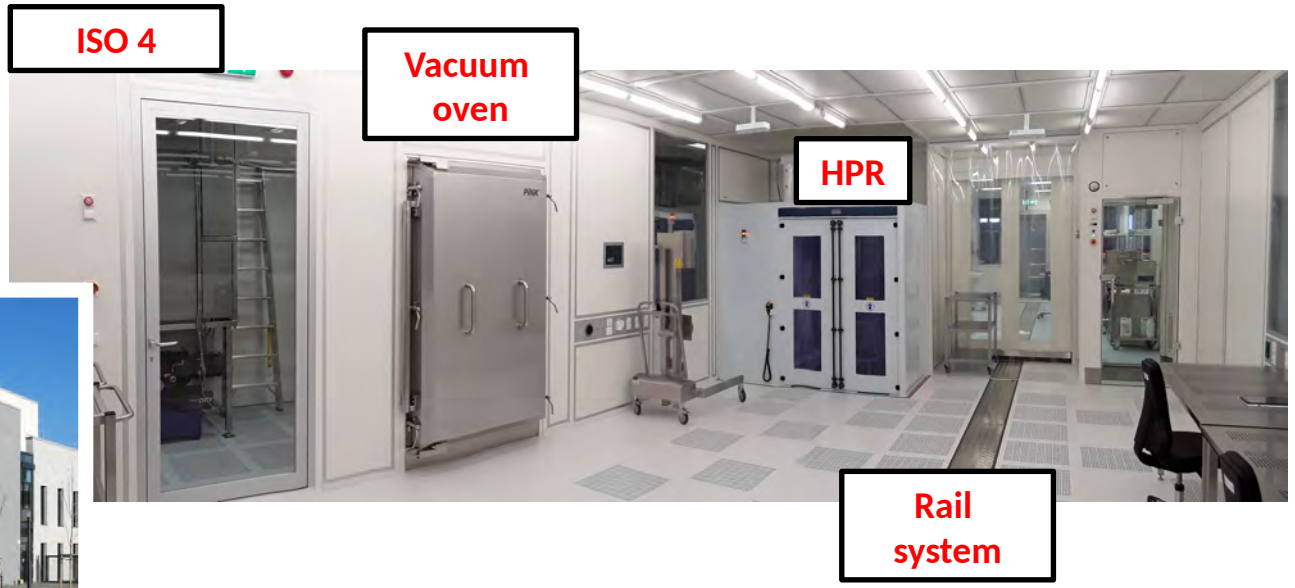
- Components delivered:
  - Cavities
  - Power couplers
  - Solenoids
  - Cryomodule
- Clean and precise assembly required
- Many „firsts“:
  - Mounting procedures
  - Auxiliary constructions
  - Transport HIM ↔ GSI
- Test site + infrastructure



Cryo String Assembly @ HIM

Major features

- Aluminum double floor (5 tons/m^2)
- Heavy duty rail system
- Air-shower
- Ultra high purity water supply (0.055 µS/cm, 2500 l/h))
- High pressure washer
- High pressure rinse (HPR)
- Ultrasonic bath and conductance rinse
- 160°C vacuum oven



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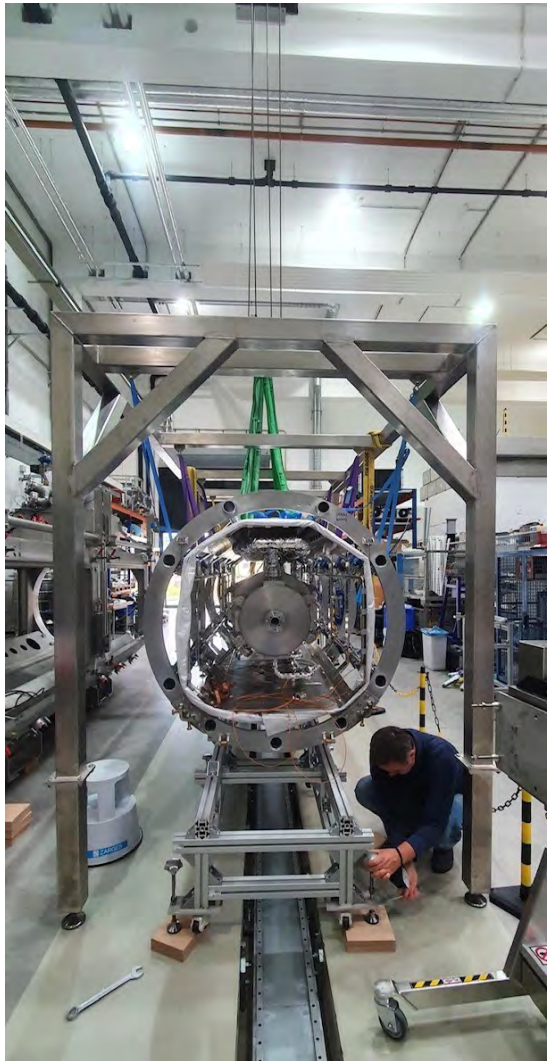


assembly frame

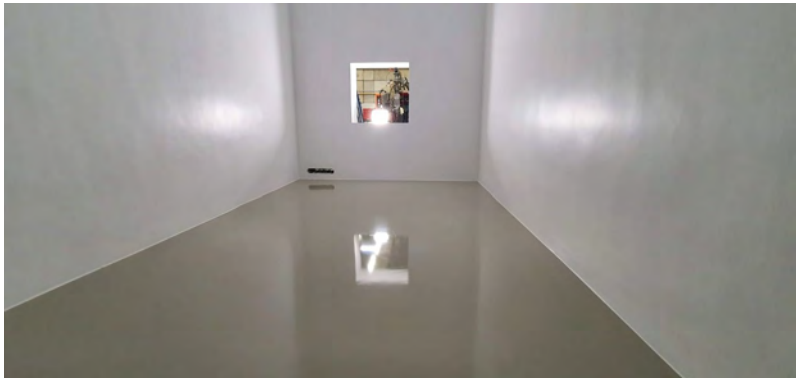
rail system → clean room

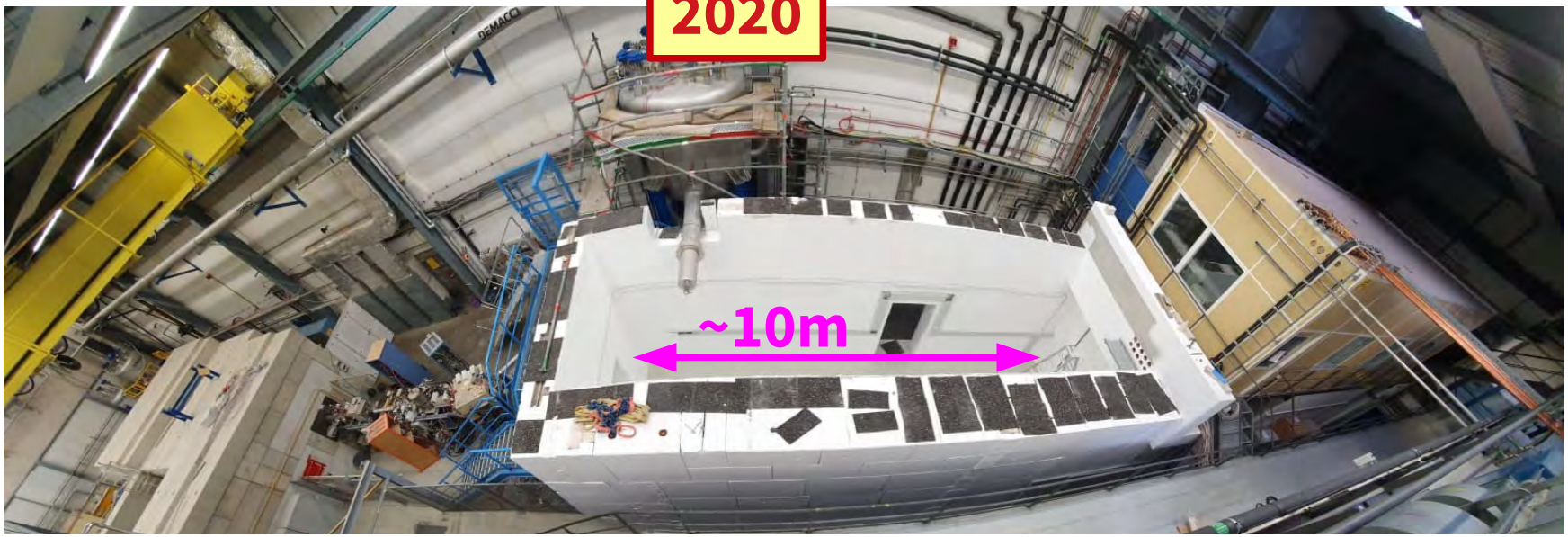
Pre-cleaning at airlock

2022 - ongoing

Test Site @ GSI

- Radiation protected area
- Cleanable surfaces
- Link to GSI‘s HLI as injector
- Link to cryo plant





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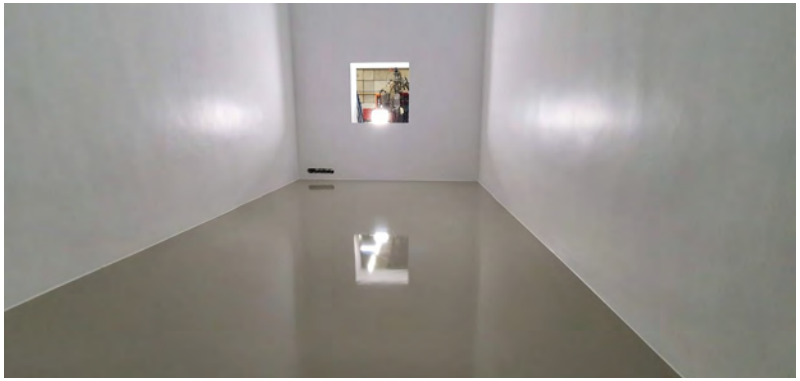
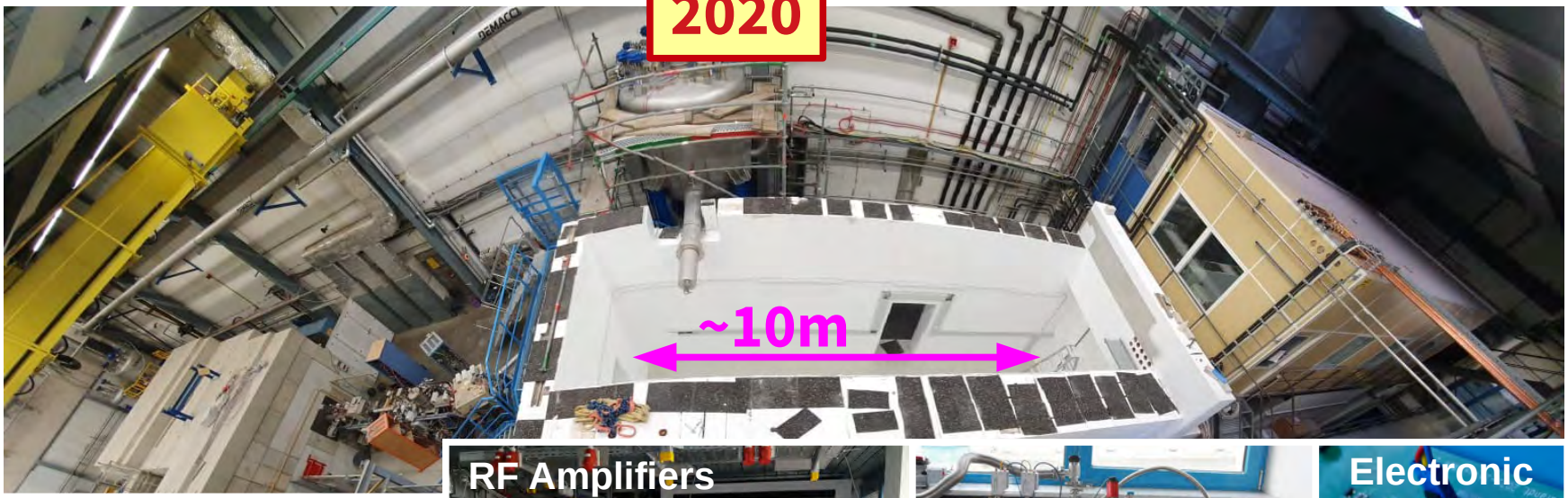
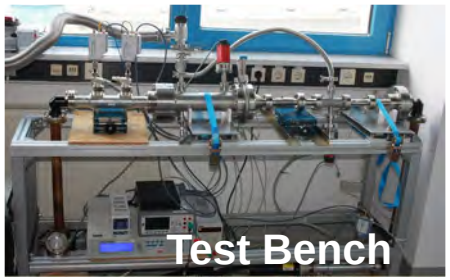


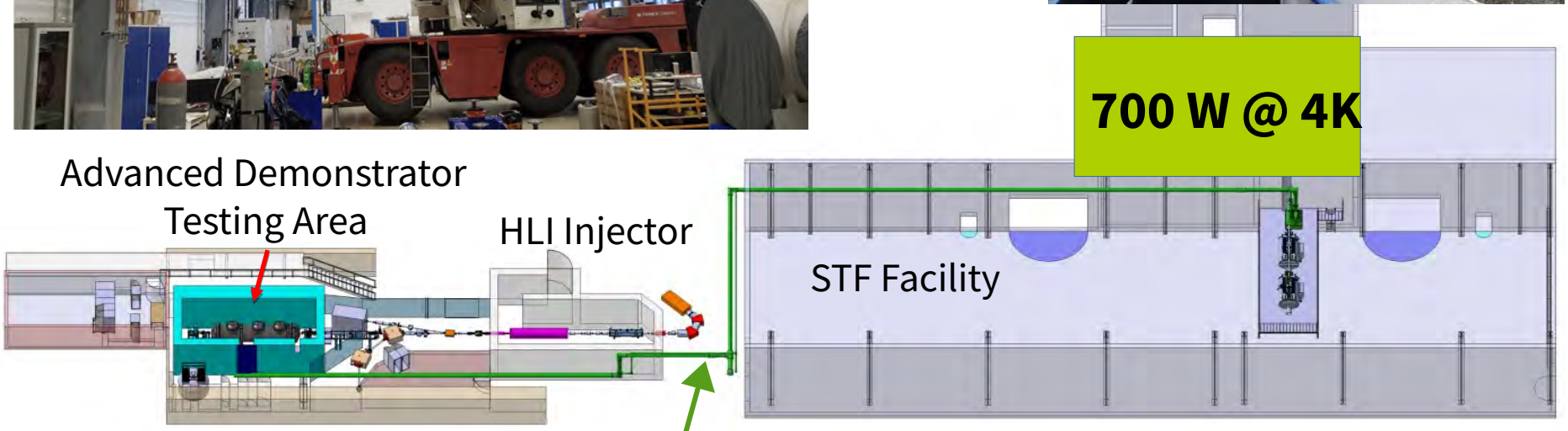




Test Site @ GSI

2020

700 W @ 4K



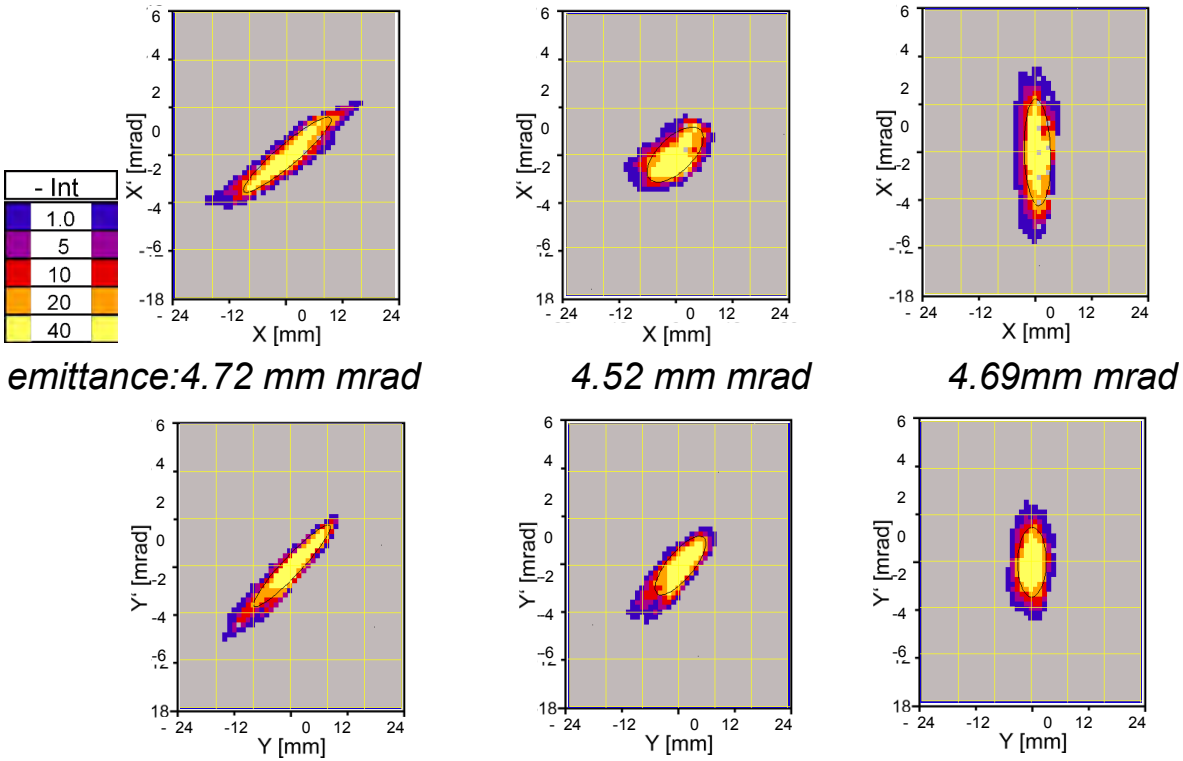
Test Site @ GSI

CM1 with dummy cavities

2021

Beamline Commissioning (Ar^{8+} beam)

w/o solenoid	>Focus I_{Sol1} = 15A	Focus I_{Sol2} = 25A
emittance:5.4 mm mrad	*5.73 mm mrad*	*6.44 mm mrad*
emittance:4.72 mm mrad	*4.52 mm mrad*	*4.69mm mrad*
62 eμA	**61 eμA**	**60 eμA**



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Beam test in Q2/3 2022
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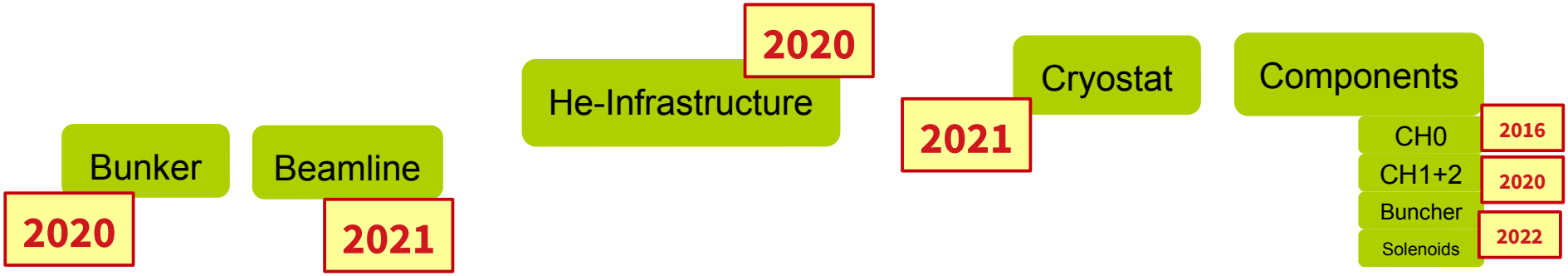

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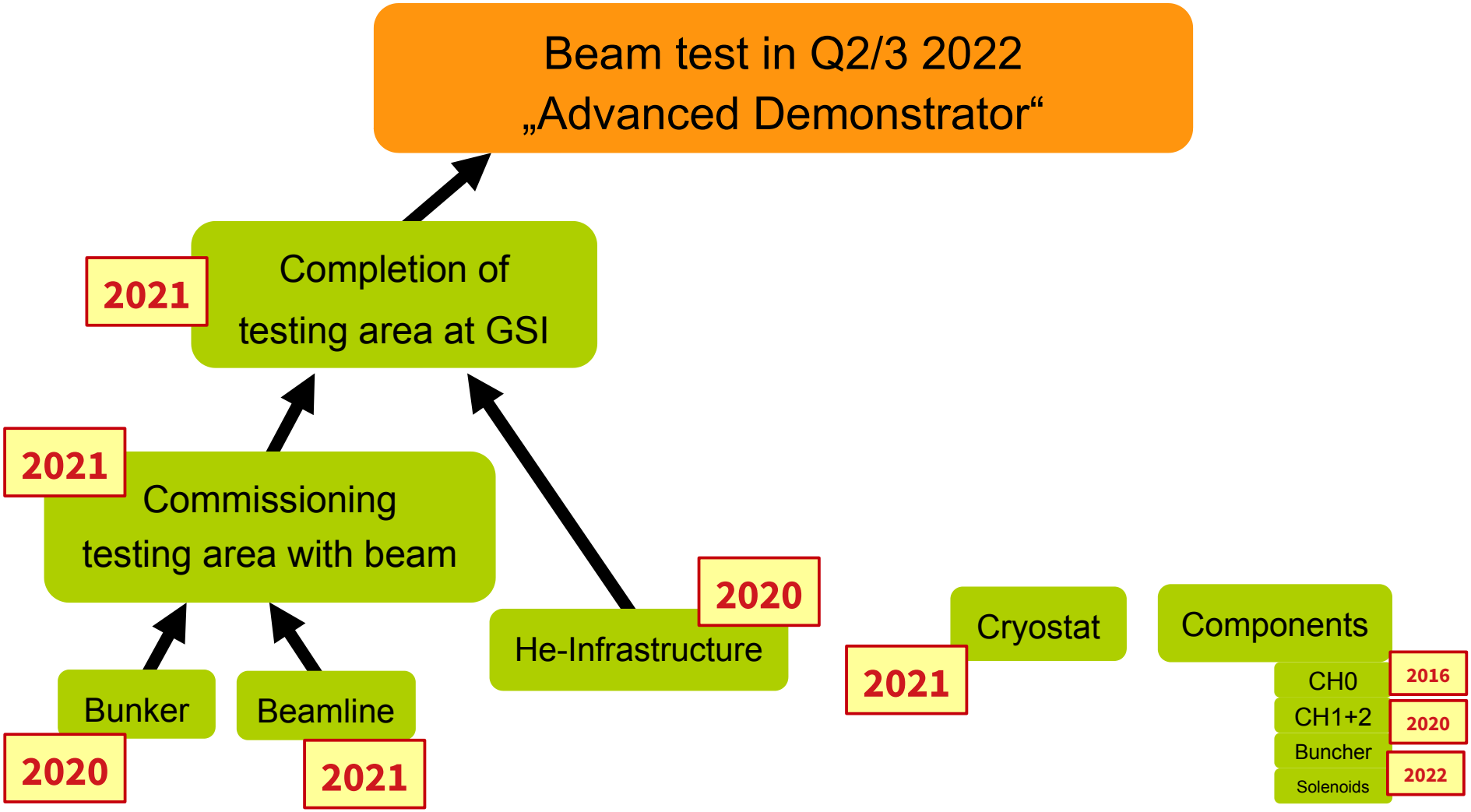

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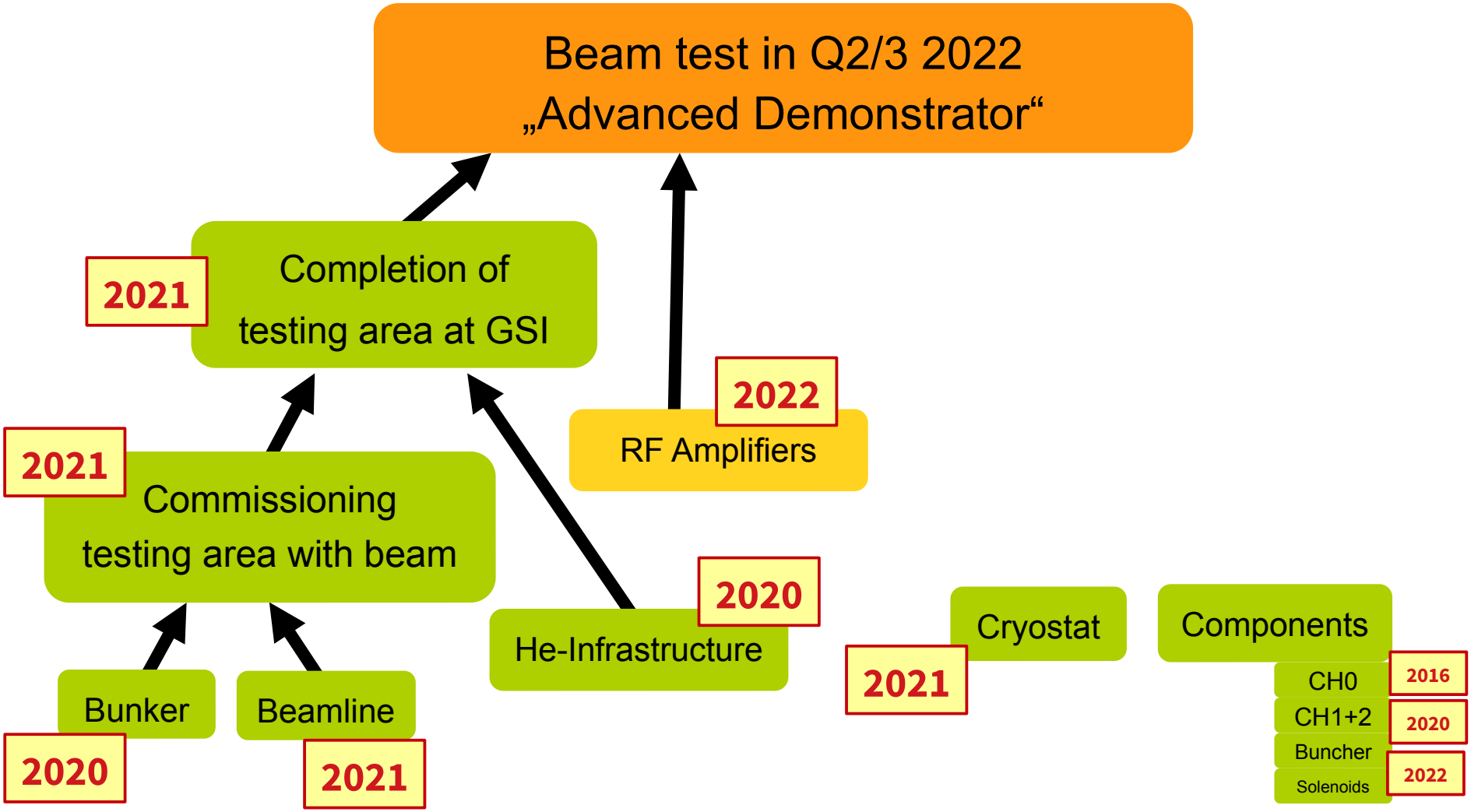

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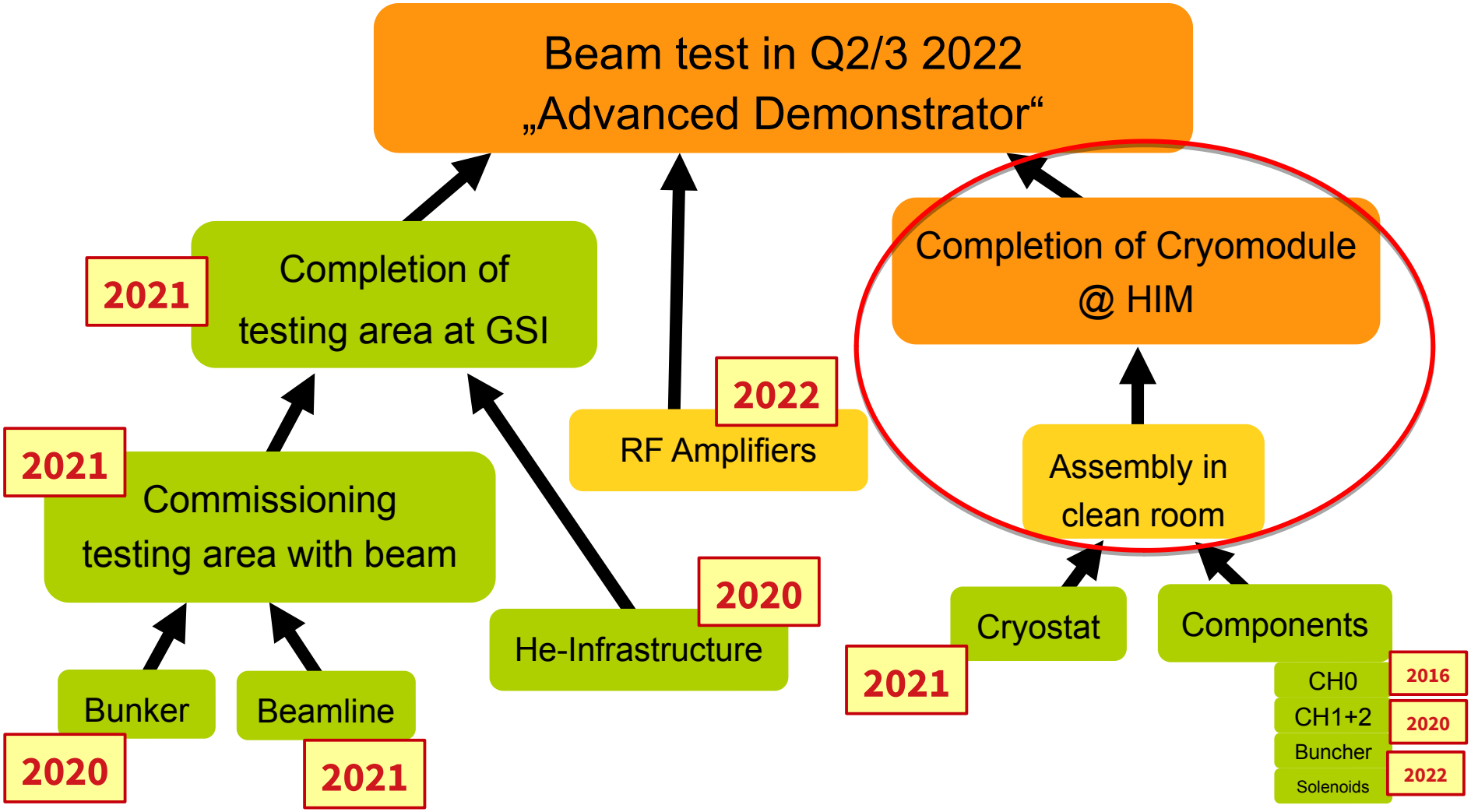


Perspectives

HELIAC „Basic Approach“

2024: - Linac-tunnel completed
- 18 GHz ECR and LEBT @ Tunnel
- CM2 offline test

2025: - provisional RFQ + IH commissioning @ Tunnel
- CM1 + 2 commissioning @ Tunnel
- CM3 offline test

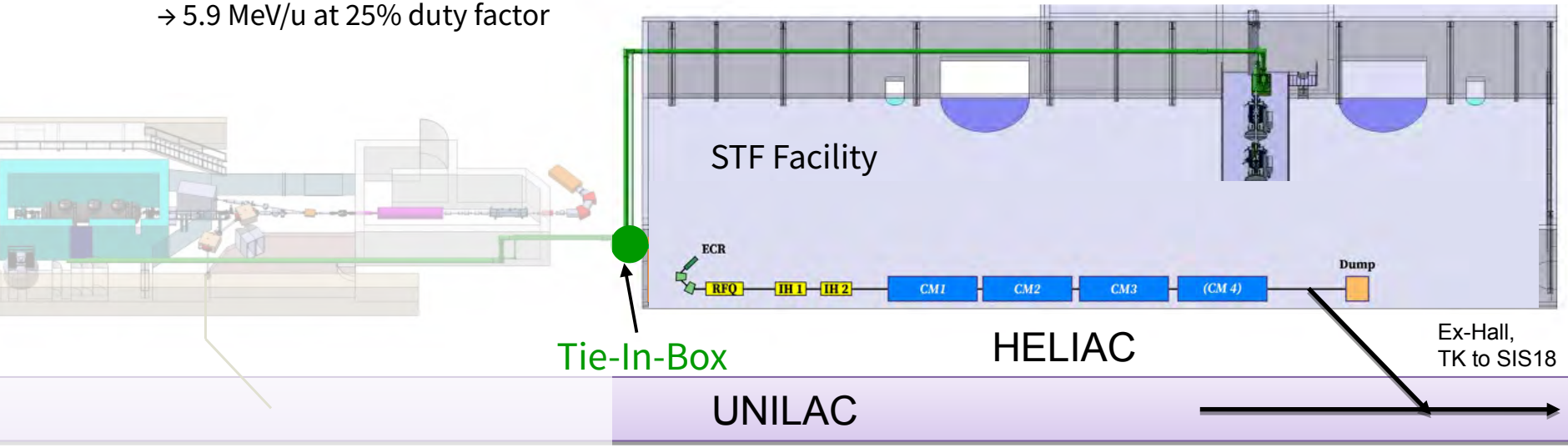
2026: - CM3 commissioning @ LinacTunnel
- HEBT to Ex-Hall/SIS18

→ 5.9 MeV/u at 25% duty factor

Possible Upgrades

1) C.W. upgrade
   - C.W. RFQ cavity
   - C.W. RF amplifiers for RFQ + IH cavities

2) Energy boost
   - CM4 with 3 CH cavities
   - Additional amplifiers



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- HEBT to Ex-Hall/SIS18

→ 5.9 MeV/u at 25% duty factor

Only if 18-GHz-source was funded!

Timeline presented is quite optimistic …

Existing contracts for:
- additional RF amplifiers
- second cryostats
- second S.C. buncher

Call for tender:
- CM2 CH cavities
- (CM3 CH cavities)

Possible Upgrades

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   - C.W. RFQ cavity
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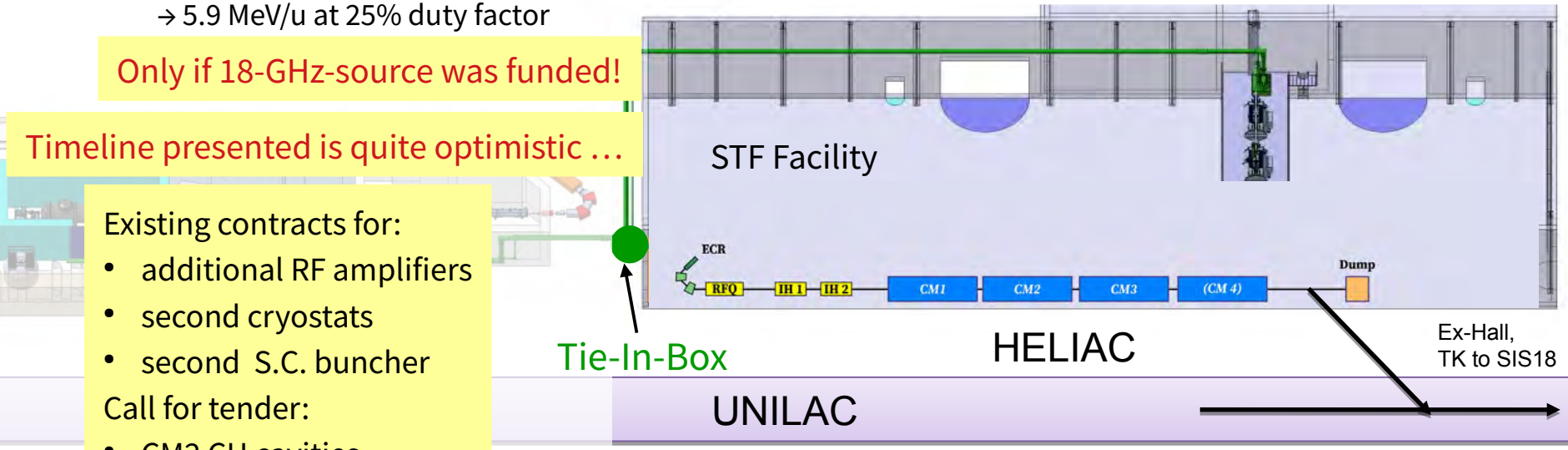
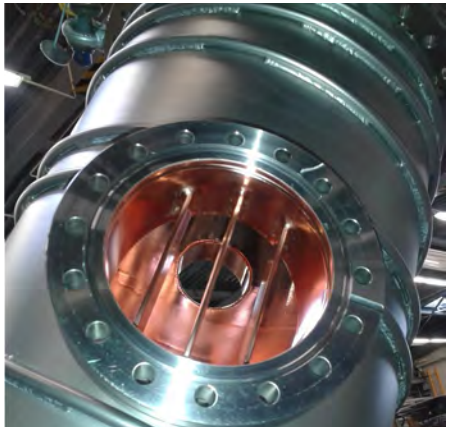
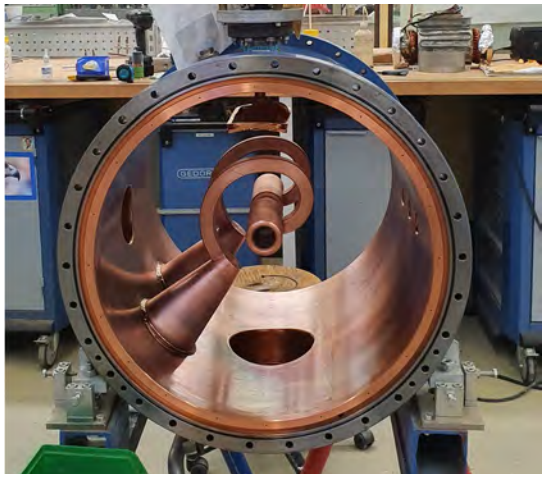


Perspectives

β = 0.054 Buncher

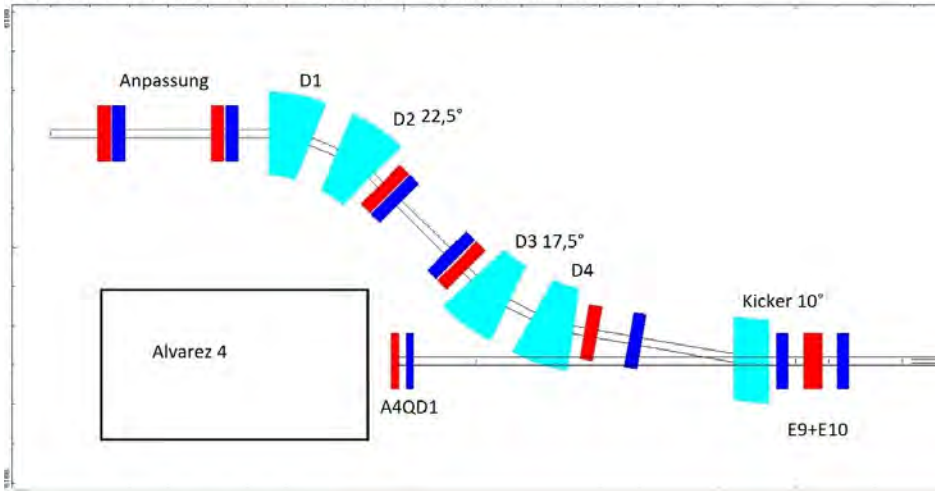


β = 0.1 De-Buncher



Source and cavities are not enough …

- Matching sections
  - Source → RFQ
  - RFQ → IH-DTL
  - IH-DTL → S.C. Linac
  - S.C. Linac → Experiment
- Transport lines
  - LEBT
  - MEBT
  - HEBT



… and require many additional components …

- C.W. Re-/De- buncher cavities
- QP doublets / triplets
- Deflecting magnets (HEBT)
- Magnet power supplies
- Beam diagnostics, vacuum, controls, …

… which we started to obtain.

- Re-Use of many devices possible
- Multiple bunchers, QPs, Dipoles obtained

Institutions Involved

C. Burandt[1,2], K. Aulenbacher[1,2,3], W. Barth[1,2,3], M. Basten[1,2], M. Busch[4], F. Dziuba[1,2,3], V. Gettmann[1,2], T. Kürzeder[1,2], S. Lauber[1,2,3], J. List[1,2,3], M. Miski-Oglu[1,2], H. Podlech[4] , M. Schwarz[4] , S. Yaramyshev[2]

[1]*Helmholtz Institute Mainz, Mainz, Germany*
[2]*GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany*
[3]*KPH Johannes Gutenberg-University Mainz, Mainz, Germany*
[4]*IAP Goethe Universität Frankfurt, Frankfurt am Main, Germany*

IAP Institut für Angewandte Physik Frankfurt am Main

- Accelerator beam dynamics (PhD)
- S.C. CH cavity R&D (PhDs)
- In-production cavity performance monitoring

GSI

- Installation site, cryo plant
- Ion source
- Operational expertise
- Integration with existing facility

HELIAC

JG|U

- Injector beam dynamics (PhD)
- RF power coupler R&D (PhD)
- S.C. buncher cavity R&D

HIM HELMHOLTZ Helmholtz-Institut Mainz

- S.C. cavity acceptance tests
- Cleanroom
- Injector cavity R&D

Summary

- HELIAC as counterpart to upgraded UNILAC
- 1st CH-Cavity qualified
- 1st full cryomodule test about to begin
- Mature injector design
  → tendering started
- Many procurements initiated
- Commissioning of „Basic approach“ possible in 2026

EQUUS

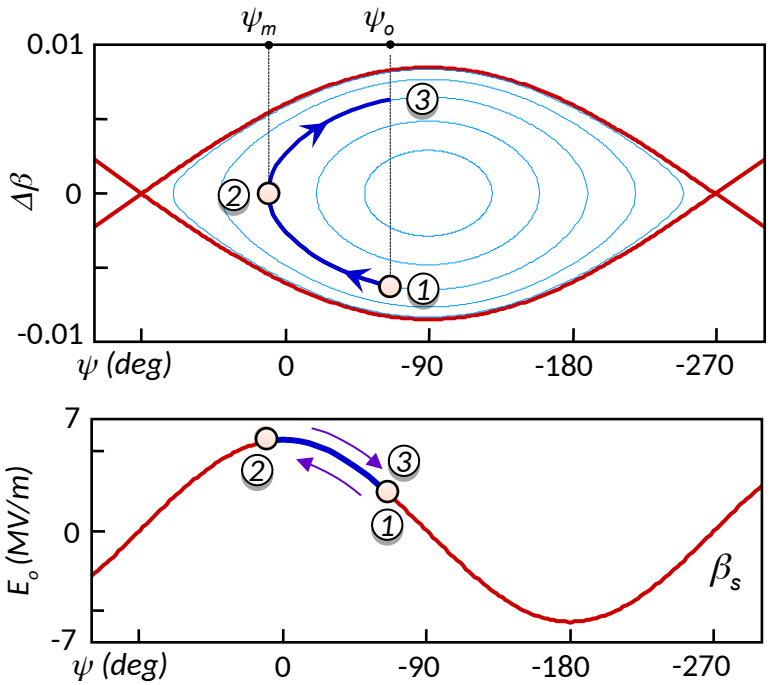
EQUUS - EQUidistant mUltigap Structure

① Particles too early ➡ obtain less acceleration
➡ longitudinal focussing

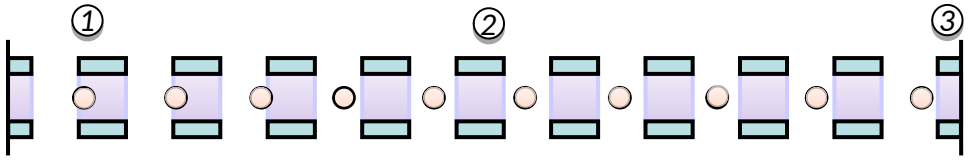
② Particles synchr. ➡ reach max. acceleration
➡ longitudinal defocussing

③ Particles too early ➡ obtain less acceleration
➡ longitudinal focussing

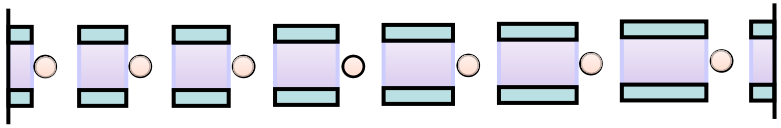
Longitudinal motion of an accelerated bunch in the constant-β-section



EQUUS



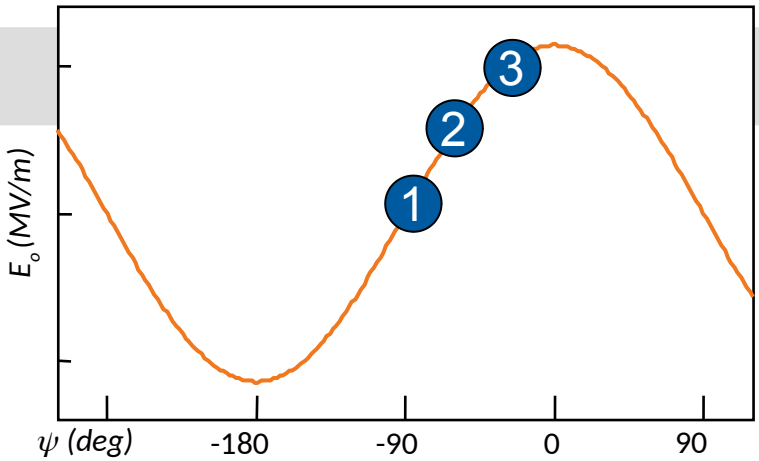
Resonant Acceleration at φ=-30



APF

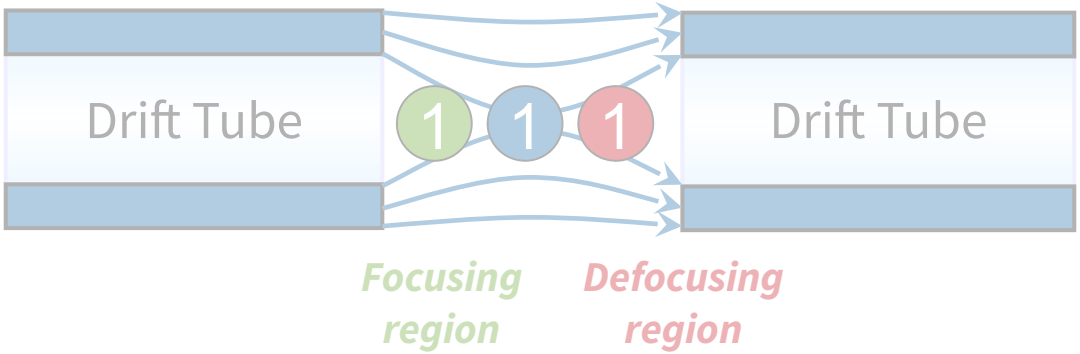
APF: **A**lternating **P**hase **F**ocusing

Longitudinal:



→ focusing

Transversal: *Field increases during particle traversal* → net **de**focusing

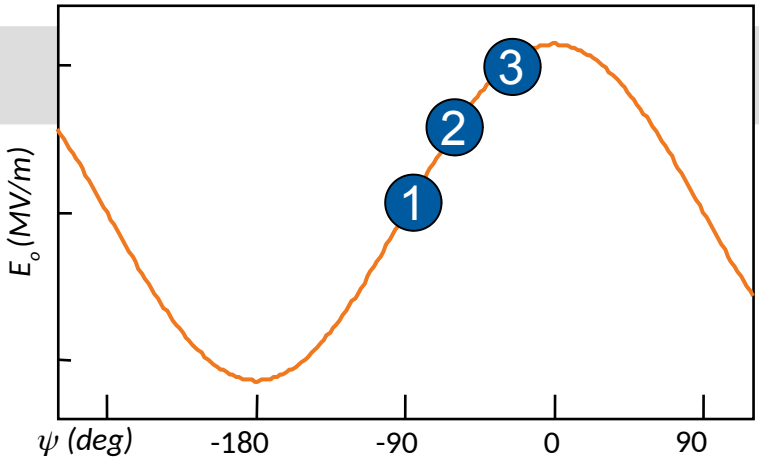


→ F0D0-Lattice gives both (net effect)

APF

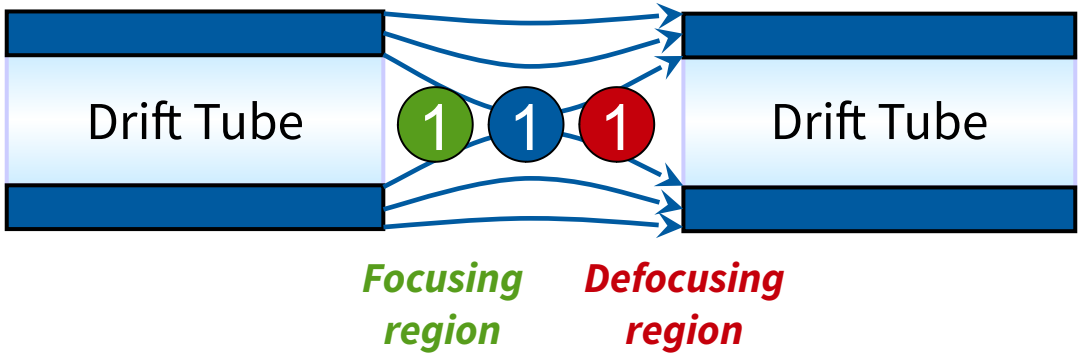
APF: **A**lternating **P**hase **F**ocusing

Longitudinal:



→ focusing

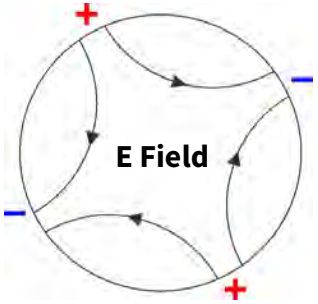
Transversal: *Field increases during particle traversal* → net **de**focusing



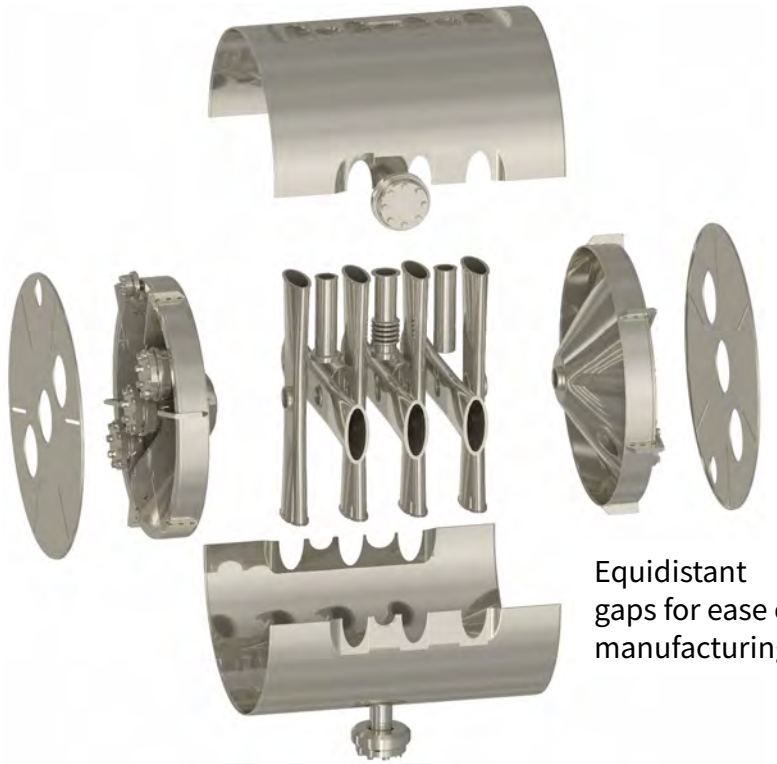
→ F0D0-Lattice gives both (net effect)

Cross-Bar-H-Mode Cavities

H_{211} mode of pillbox cavity



Parameter	Unit	Value
β		0.059 – 0.12
Gradient	MV / m	5.5 – 7.1
Q_0		~ 10^9
Operation mode		cw
Gaps	#	5 – 15
Diameter	m	0.4
Effective Length	m	< 1
Material		Niobium



Equidistant gaps for ease of manufacturing

E Field Along Beam Axis