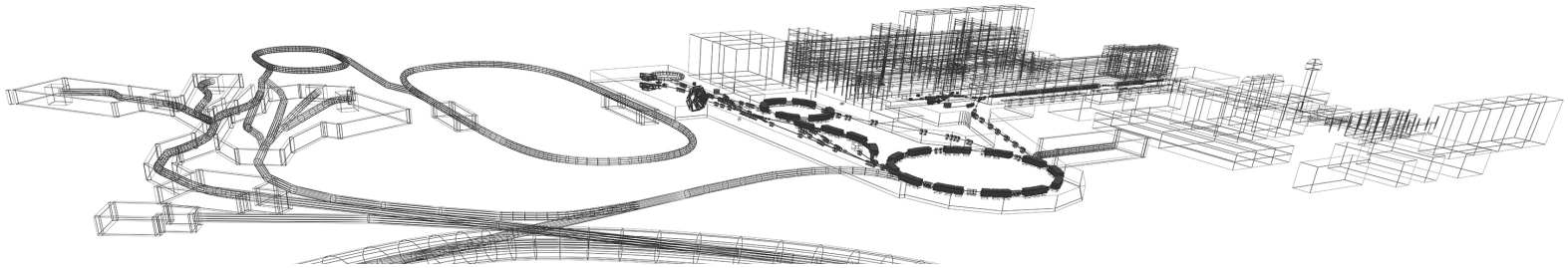


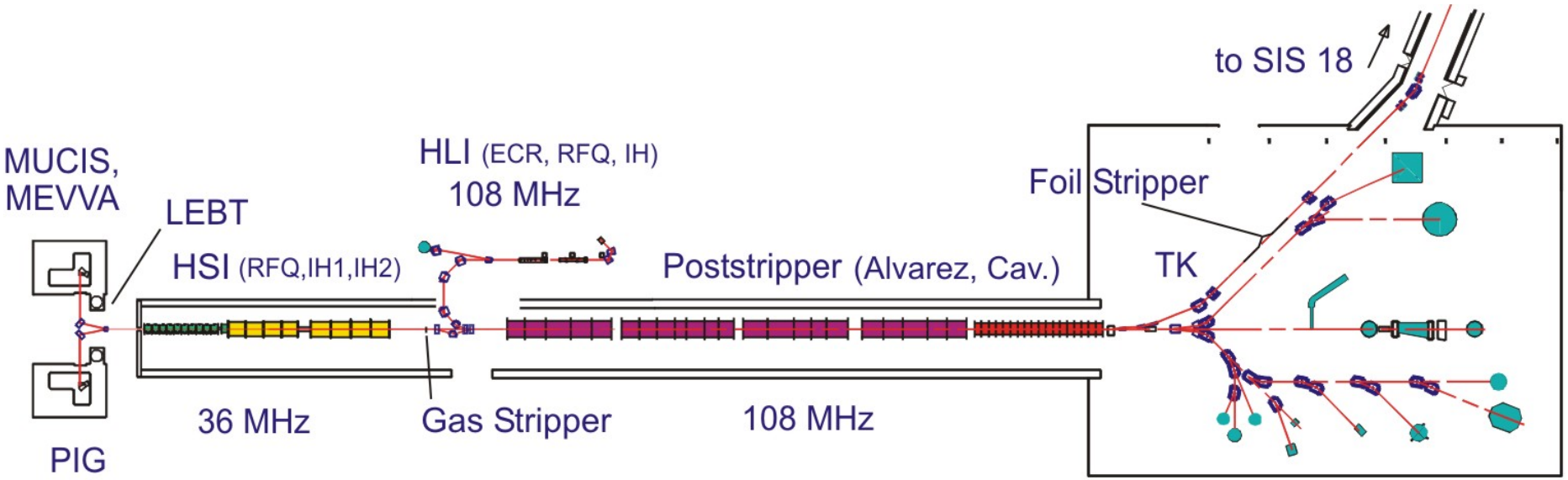
Heavy Ion Beam Test with the cw-CH-Cavity

C. Burandt[1,2]

K. Aulenbacher[1,2,4], W. Barth[1,2,5], M. Basten[3], M. Busch[3],
F. Dziuba[1,2], V. Gettmann[1,2], M. Heilmann[2], S. Lauber[1,2,4],
J. List[1,2,4], H. Podlech[3], A. Schnase[2],
M. Schwarz[3], S.Yaramyshev[2,5]

[1]HIM, Helmholtz Institute Mainz, Mainz, Germany
[2]GSI Helmholtzzentrum, Darmstadt, Germany
[3]IAP, Goethe Univ. Frankfurt, Frankfurt, Germany
[4]KPH, Johannes Gutenberg Univ., Mainz, Germany
[5]National Research Nuclear Univ., Moscow, Russia

Existing Accelerator



SHE and "Material Science" requirements:

- high *average* beam currents
- high repetition rate (50 Hz)
- high duty factor up to 100 %

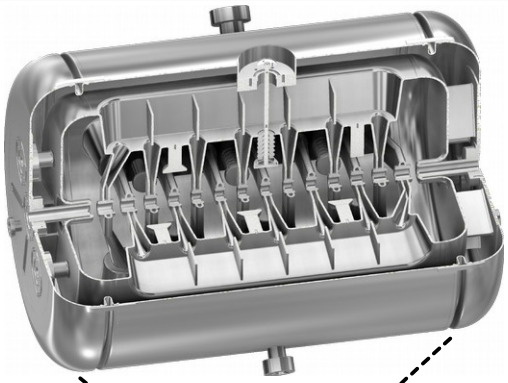
FAIR requirements (implies synchrotron injection):

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

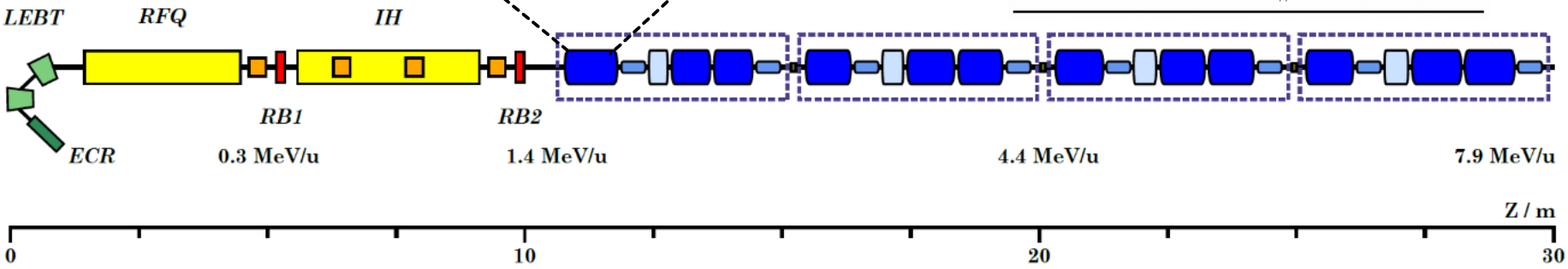
Proposed cw-Linac

Helmholtz **Li**near **Ac**celerator **HELIAC:**

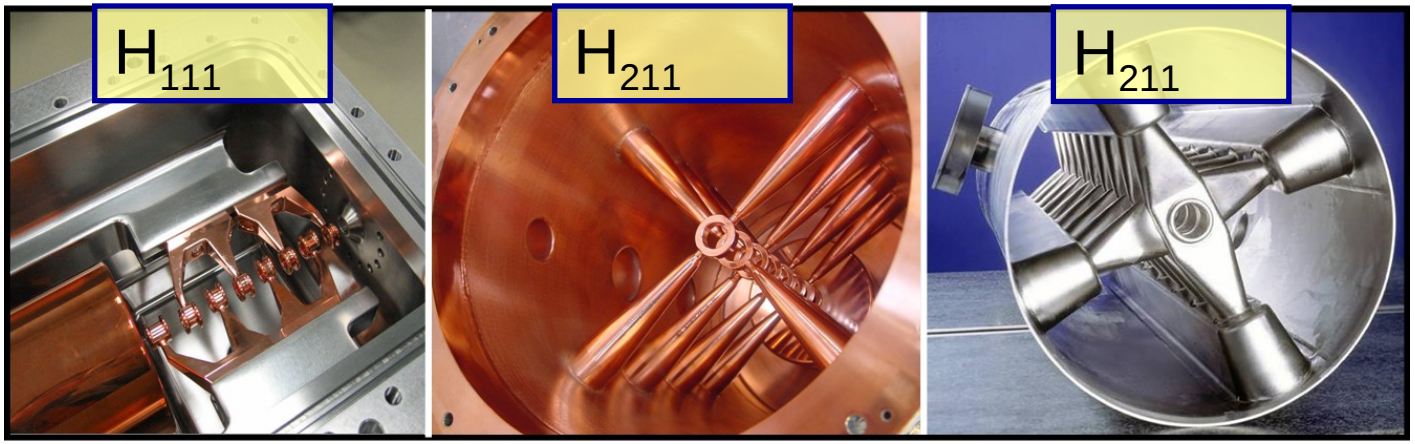
- Independend source + injector
- Continuous beam energy variation
- **cw operation @ high gradients → superconducting rf acceleration**



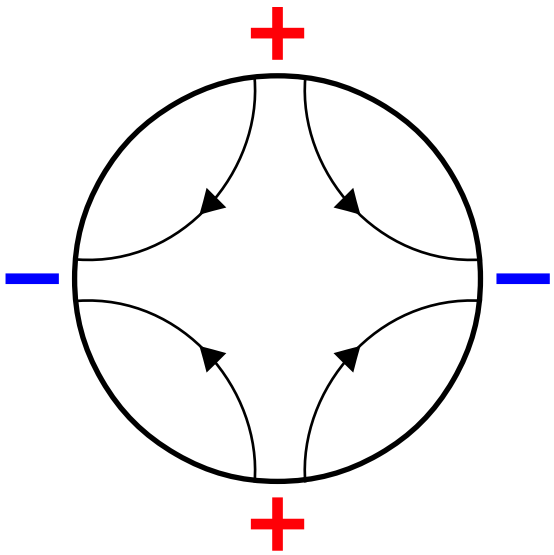
Design parameters sc cw-LINAC		
A/q		≤ 6
Frequency	MHz	216.816
Beam current	mA	≤ 1
Injection energy	MeV/u	1.4
Output energy	MeV/u	3.5–7.9
Length	m	20
CH cavities	#	12
Rebuncher	#	4
Solenoids	#	8



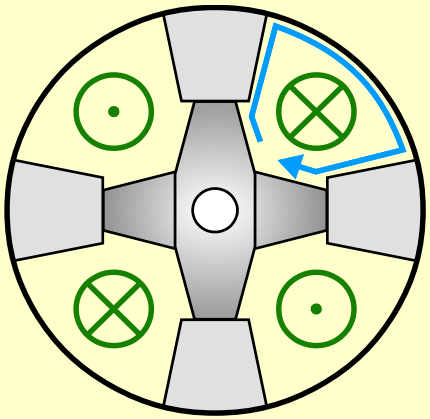
CH-Mode Cavities



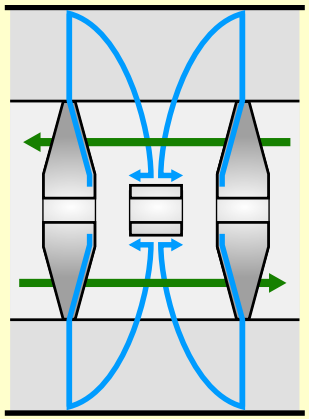
H_{211} mode of ”pillbox“ cavity



Cross-bar-**H**-mode cavity



Current
H Field



cw-Linac Demonstrator Cavity

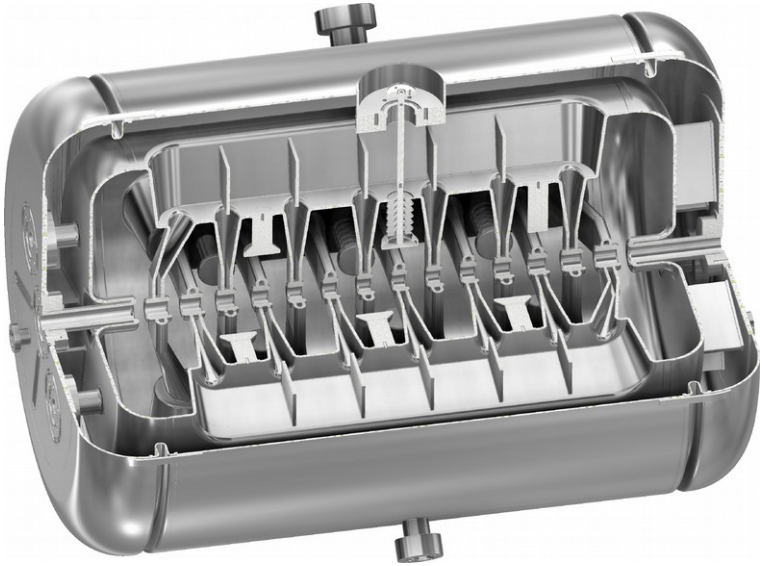
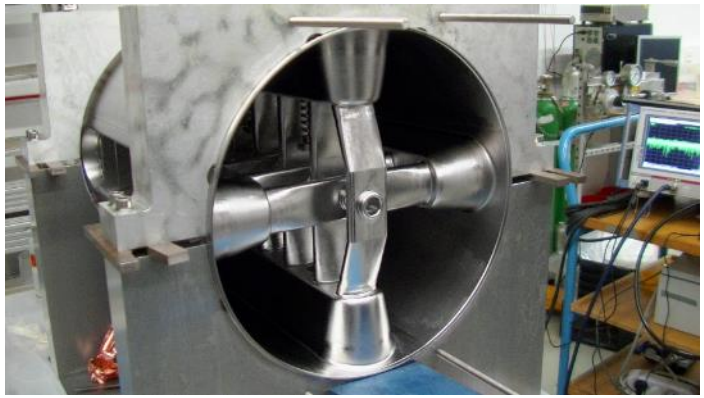
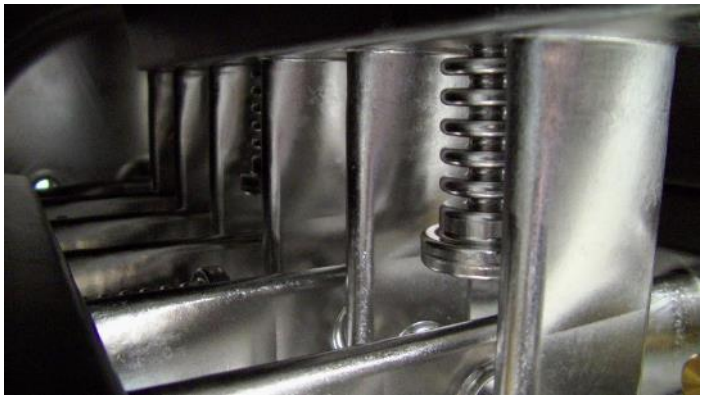


Table 1: Main Parameters of the Cavity

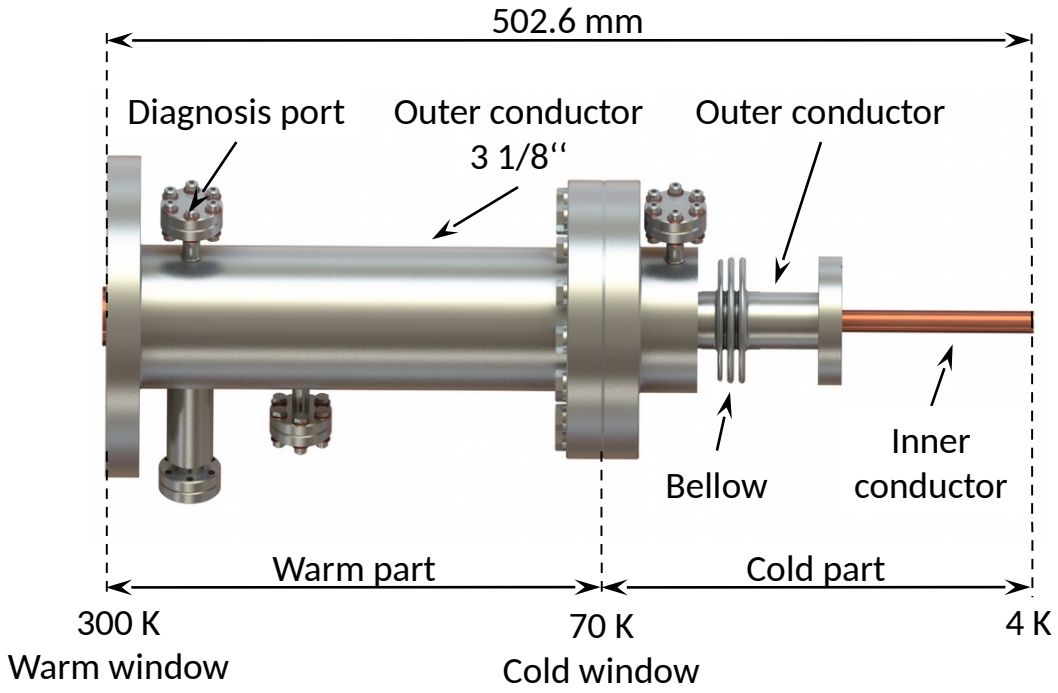
$\beta\,(v/c)$		0.059
Frequency	MHz	216.816
Accelerating cells		15
Effective length ($\beta\lambda$)	mm	612
Diameter	mm	409
Tube aperture	mm	18 / 20
G	Ω	52
R_a/Q_0		3240
$R_a R_S$	kΩ^2	168
E_a (design)	MV/m	5.5
E_p/E_a		6.3
B_p/E_a	mT/(MV/m)	5.7





Power Coupler

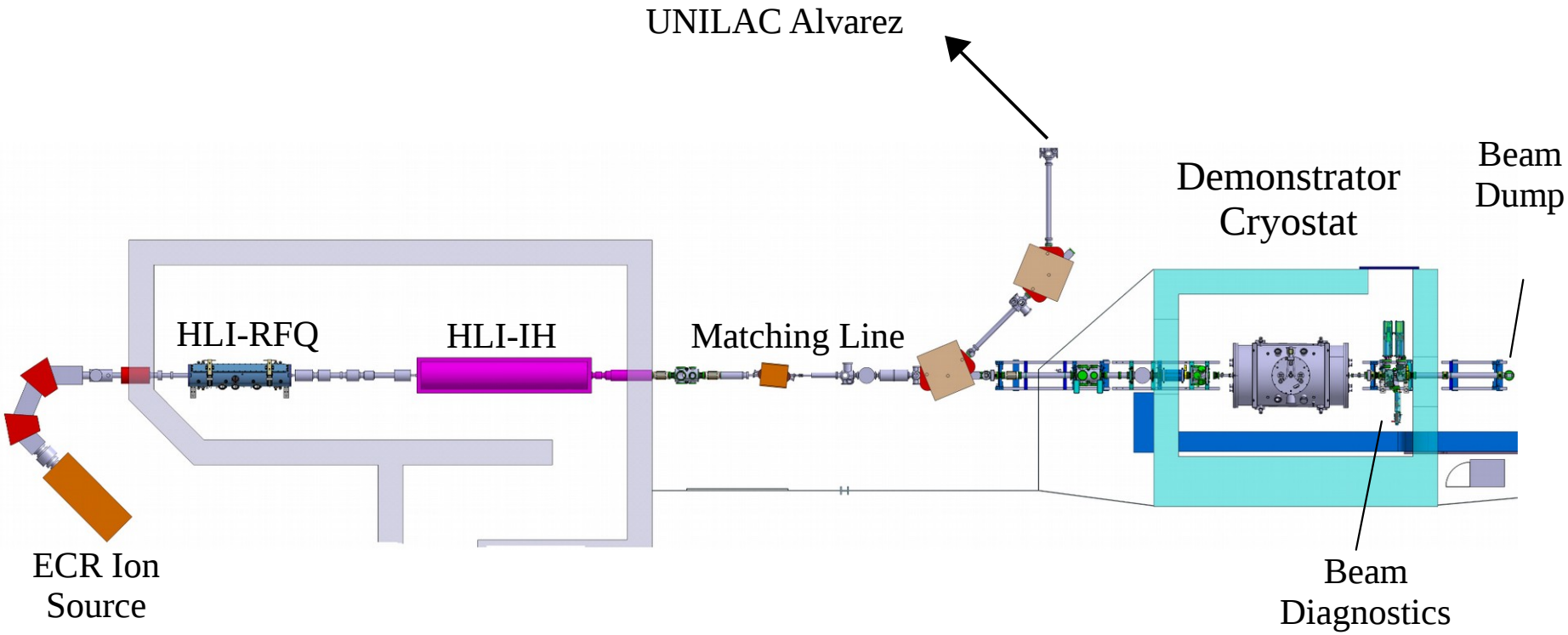
- Capacitive coupling of RF power
- Coaxial antenna setup (inner conductor made from copper)
- Devided into cold & warm part by 2 ceramic windows (Al_2O_3), TiN coated
- 5 kW cw operation, cold window connected to LN_2 supply
- 216.816 MHz operation frequency with 33 MHz bandwidth



Demonstrator Test Setup at GSI

- 2017: Successfull commissioning (presented 2018 at M&T-meeting)

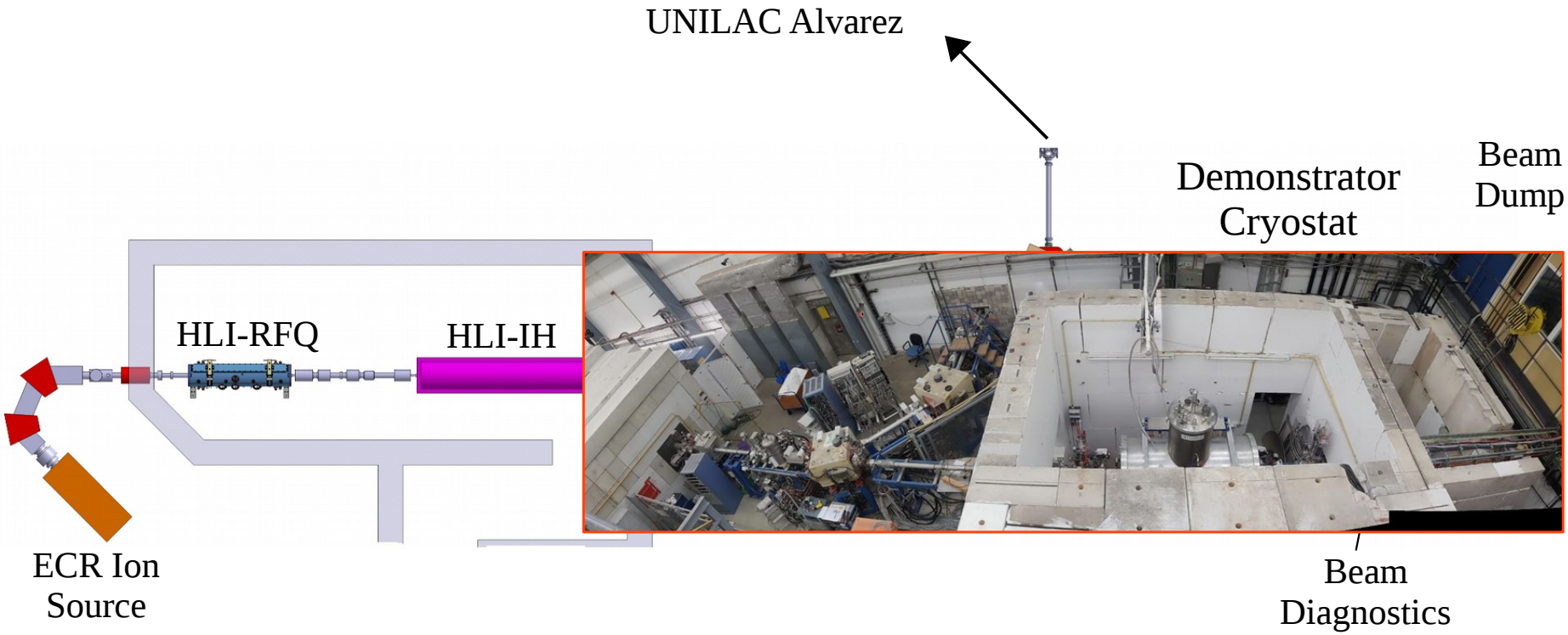
- Additional beam times in 2018
  - Confirmation of 2017 results
  - Additional investigations



Demonstrator Test Setup at GSI

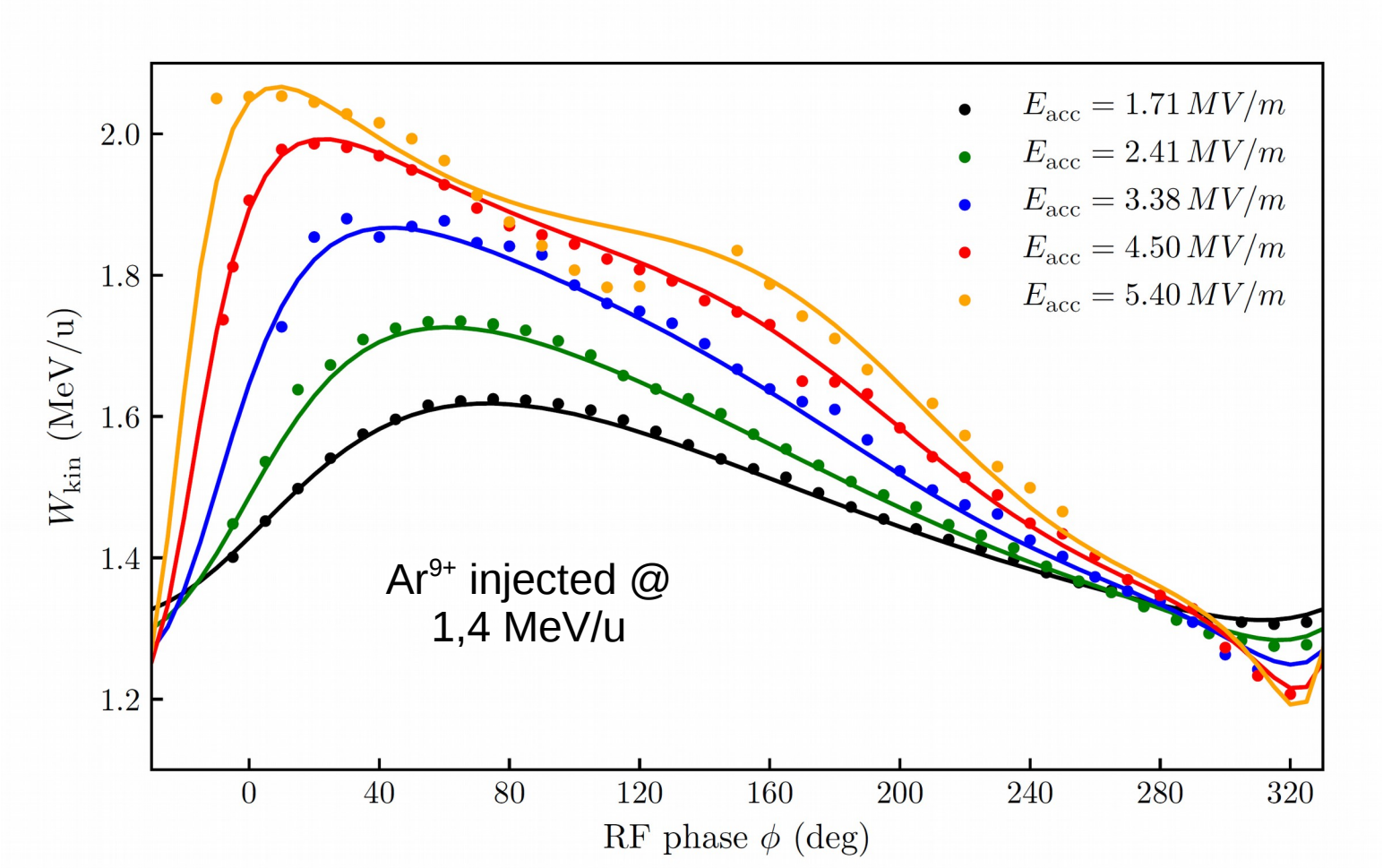
- 2017: Successfull commissioning (presented 2018 at M&T-meeting)

- Additional beam times in 2018
  - Confirmation of 2017 results
  - Additional investigations

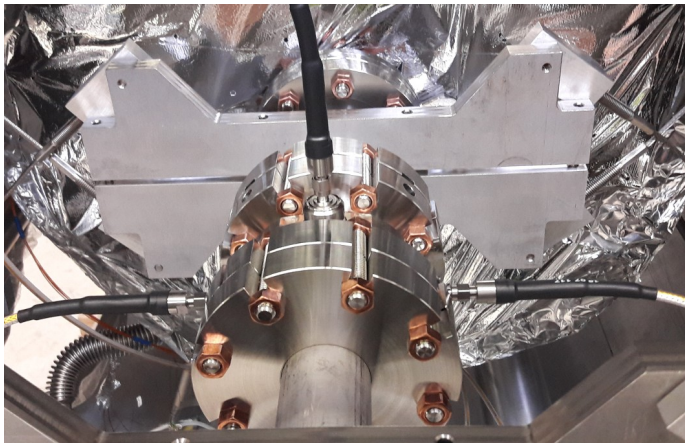


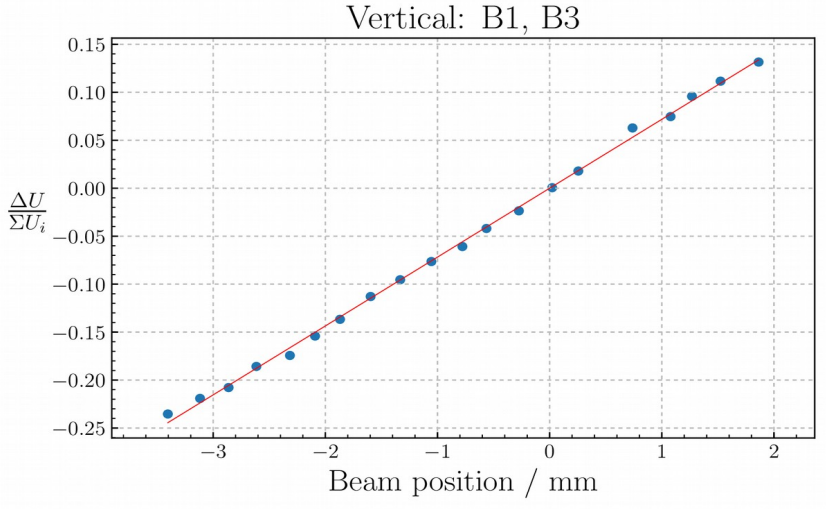
2018: Phase Scans

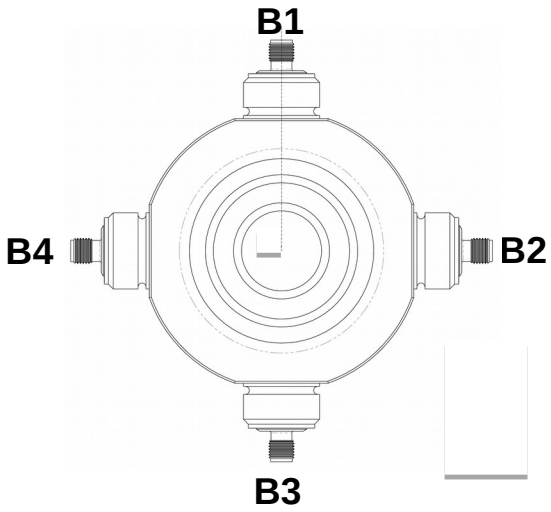
Validating Calculations of Energy Gain

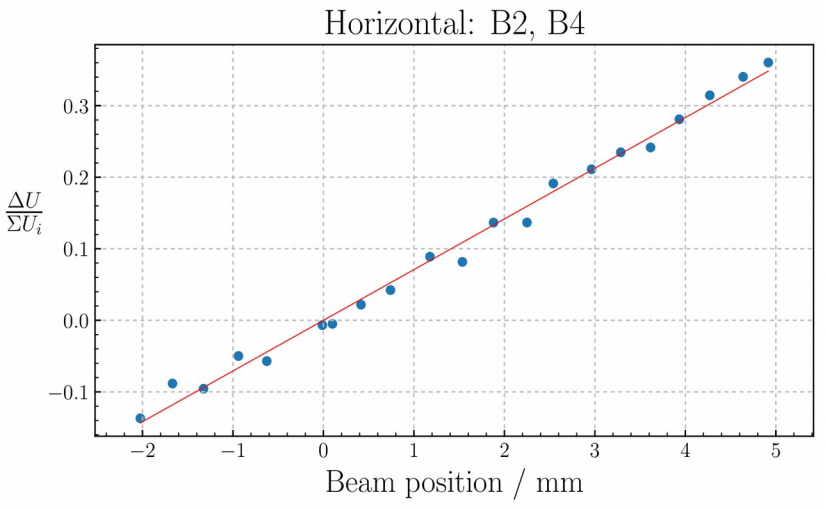


2018: Beam Diagnostics R&D



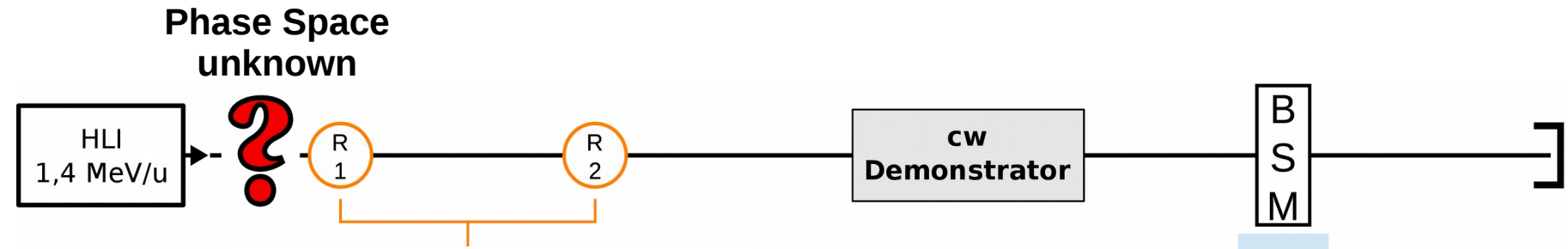






2018: Longitudinal Phase Space Reconstruction

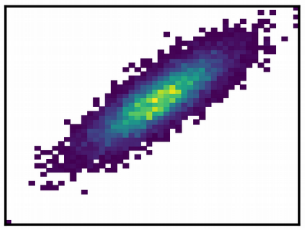
How to understand and optimize the longitudinal matching?



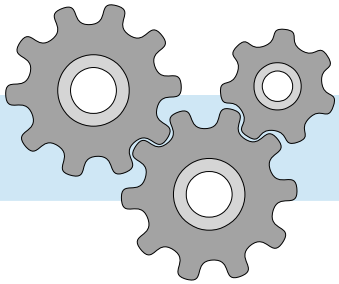
Poster presentation by Simon Lauber

W.I.P.

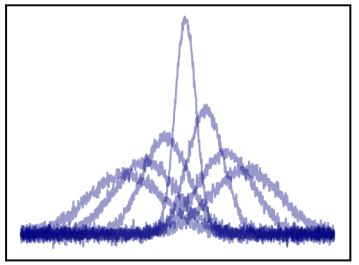
phase space
(symbolic plot)



reconstruction



many bunch shapes
(symbolic plot)



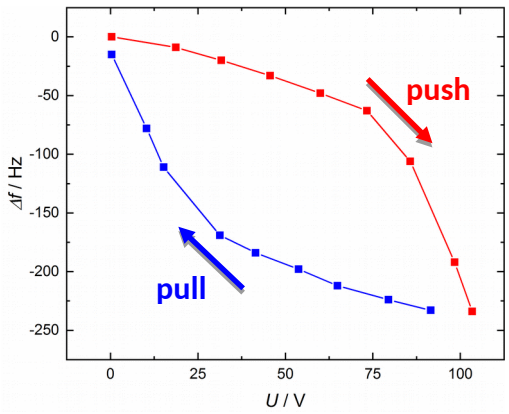
2018: Tuning System Performance

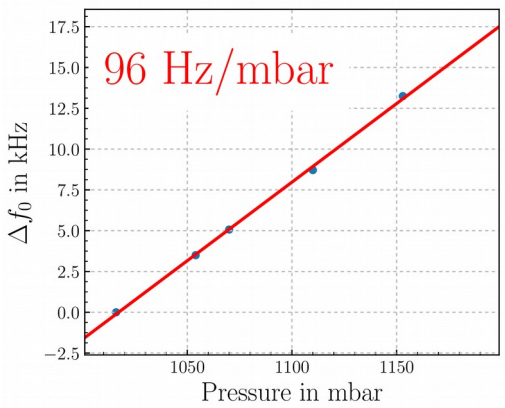
Properties of the tuning system:

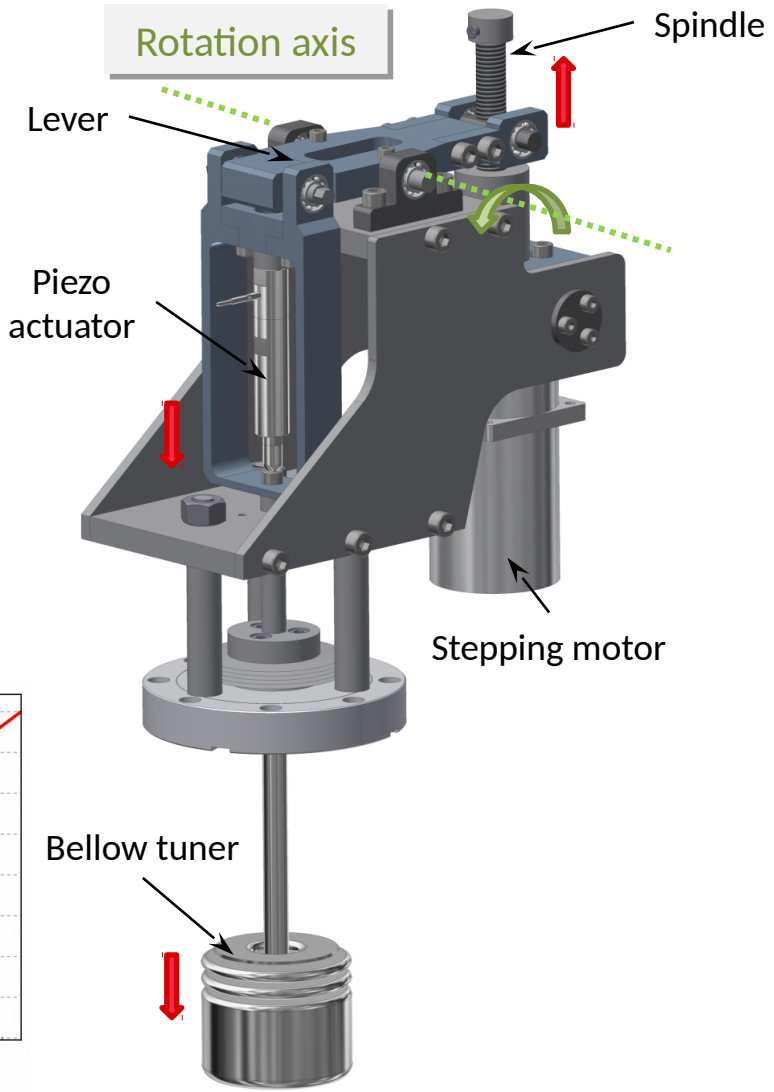
- Capacitive bellow tuner
- Electrical drives:
  - Slow stepper motor: ±1 mm (≈ ±60 kHz)
  - Fast piezo actuator: ±4 µm (≈ ±240 Hz)

Practical experience:

- Microphonics caused by stepper motor
- Pronounced hysteresis for piezo drive
- Bellow tuner actuated by He pressure changes?



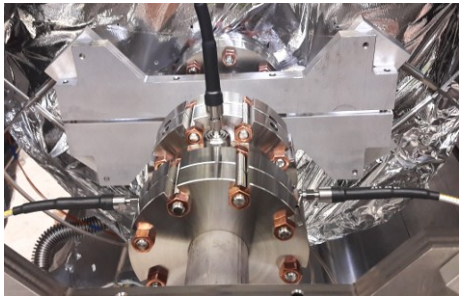


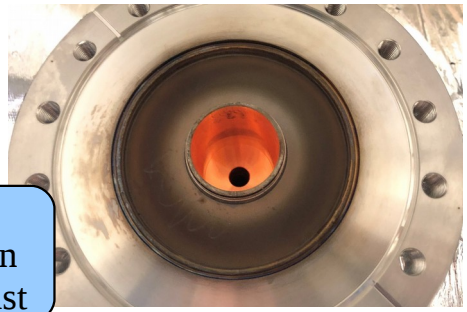


cw-Linac Demonstrator Test Results

- Verified beam dynamics simulations
- Beam acceleration above design gradient
- Evaluated BPM as part of cold string
- UNILAC-LLRF proven to be adequate for SRF operation
- Beam-based alignment
- He-Pressure sensitivity higher than expected
- Piezoresistive tuners show distinctive hysteresis
- Power coupler
  - ceramics suffered significantly
  - high dynamic heat load
  - high static heat load

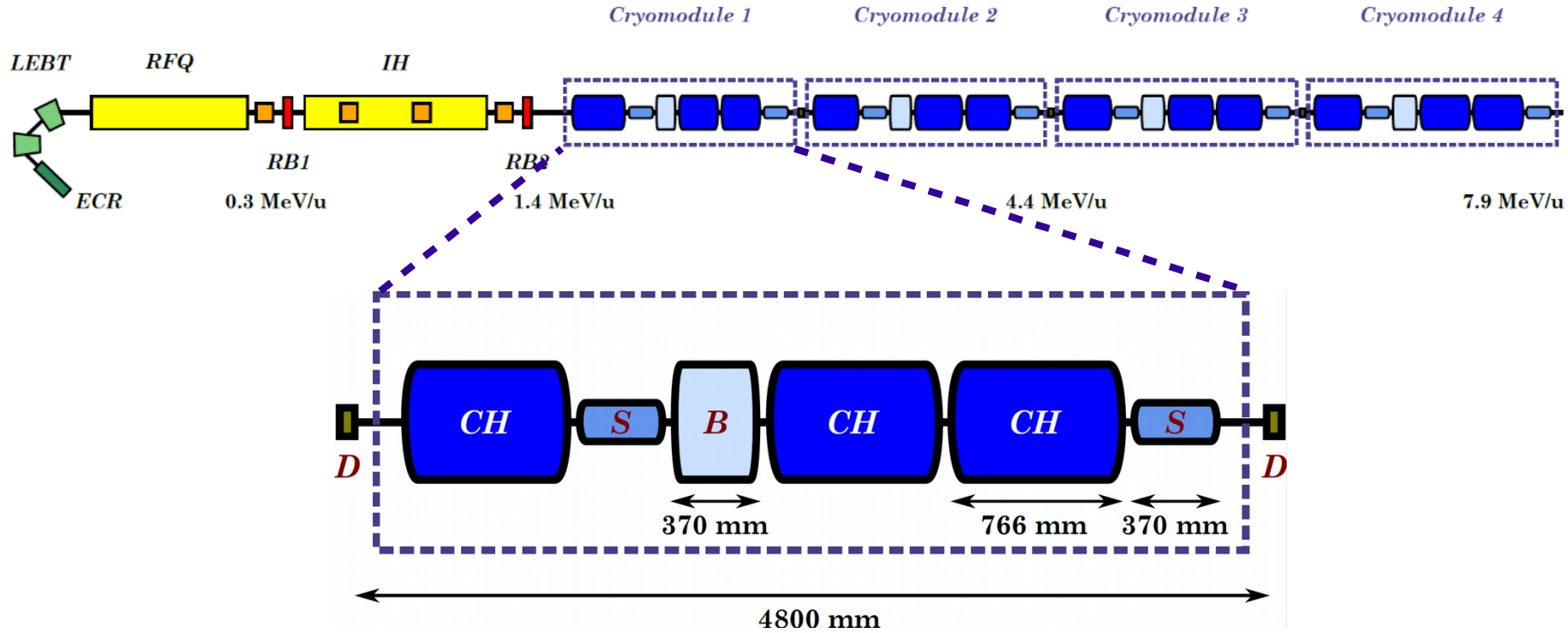
  ⇒ major rework in progress



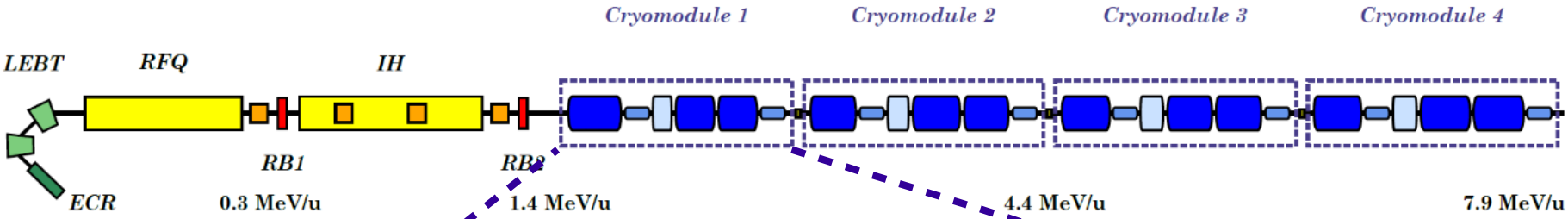


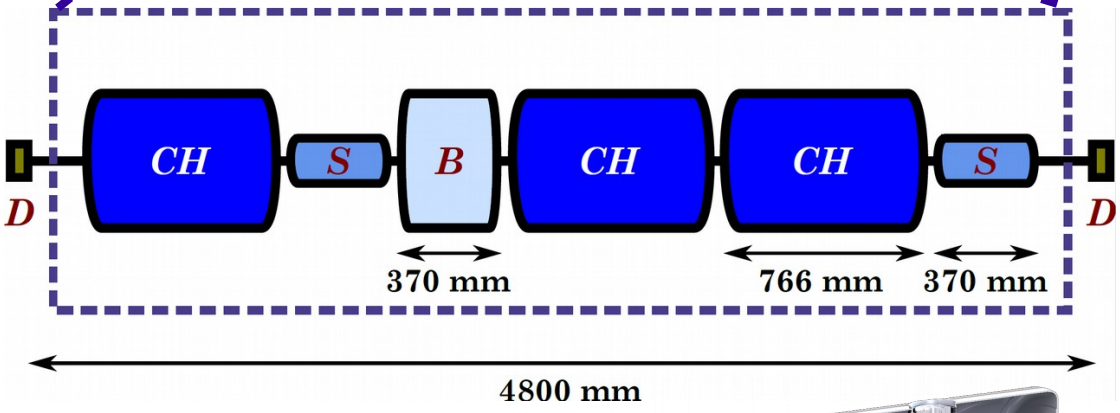
Poster presentation by Julian List

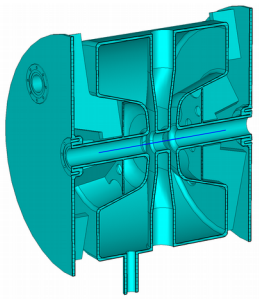
Advanced Demonstrator

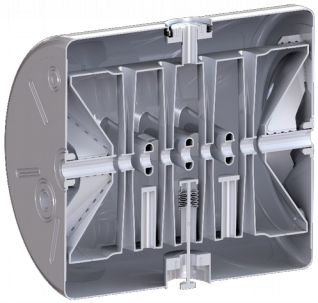


Advanced Demonstrator





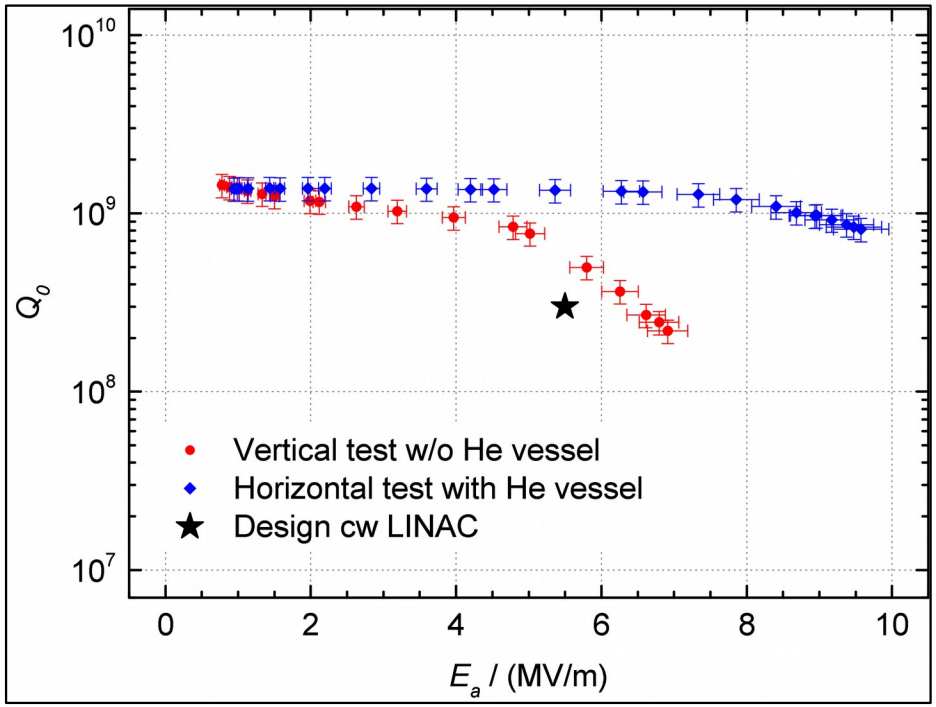




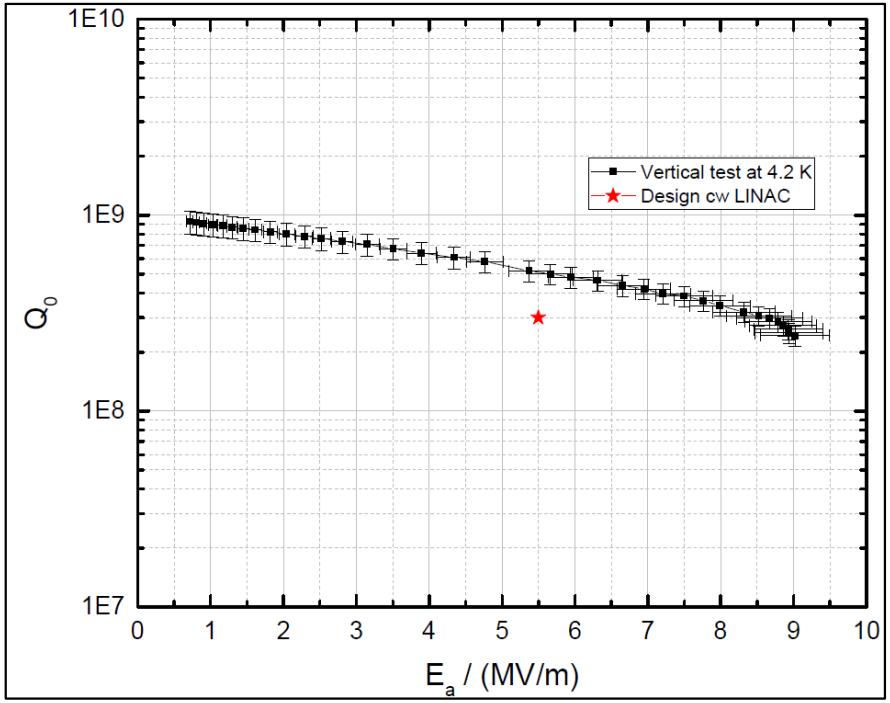
PhD thesis of M. Basten, IAP, Frankfurt University

Advanced Demonstrator

15-gap demonstrator cavity



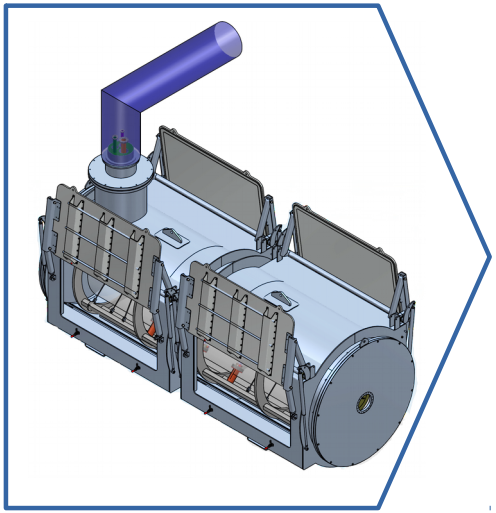
„short“ cavity



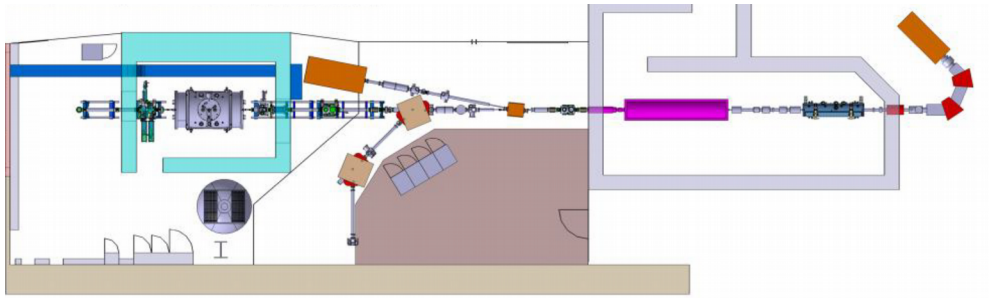
Advanced Demonstrator

Transformation of Test Site

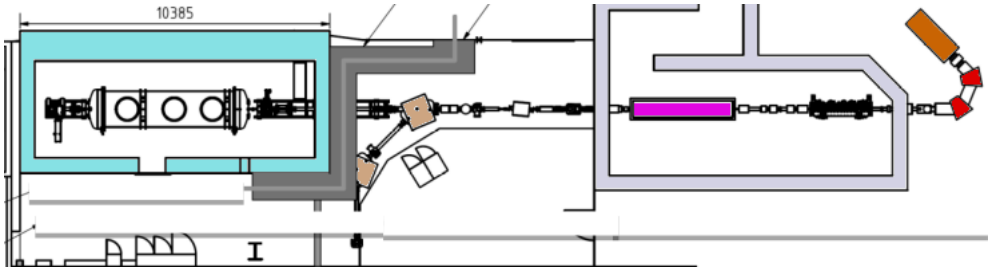
- Transfer line to cryoplant
- Modification of cave
- Change matching line
- New site for RF amplifiers
- New control room



2017/2018 Setup



2020 Setup



Helmholtz-Institut Mainz

- 155 m² Clean room
  - ISO6/ISO4
  - HPR
- RF infrastructure:
  - Radiation shielded test site
  - 5kW RF amplifier + LLRF
- He infrastructure:
  - 3 m³ LHe reservoire
  - Transfer lines
  - He-recovery compressor

Timeline for Advanced Demonstrator

02/2015	Funding of the *Advanced Demonstrator* within POF3
09/2016	Ordering of two short CH-cavities
11/2018	Tendering of cryostat
05/2019	Modification of radiation protection shelter @GSI
06/2019	Delivery of short cavities
12/2019	Link of testing area to STF cryoplant
04/2020	Delivery of cryostat
09/2020	Commissioning of beamline (w/o cryostat) @ GSI
04/2021	Assembly of cryomodule @ HIM
06/2021	Beamtest @ GSI

Acknowledgements

Thank you for your attention!

Collaboration partners

GSI / HIM
KPH - Johannes Gutenberg University Mainz
IAP - Goethe University Frankfurt