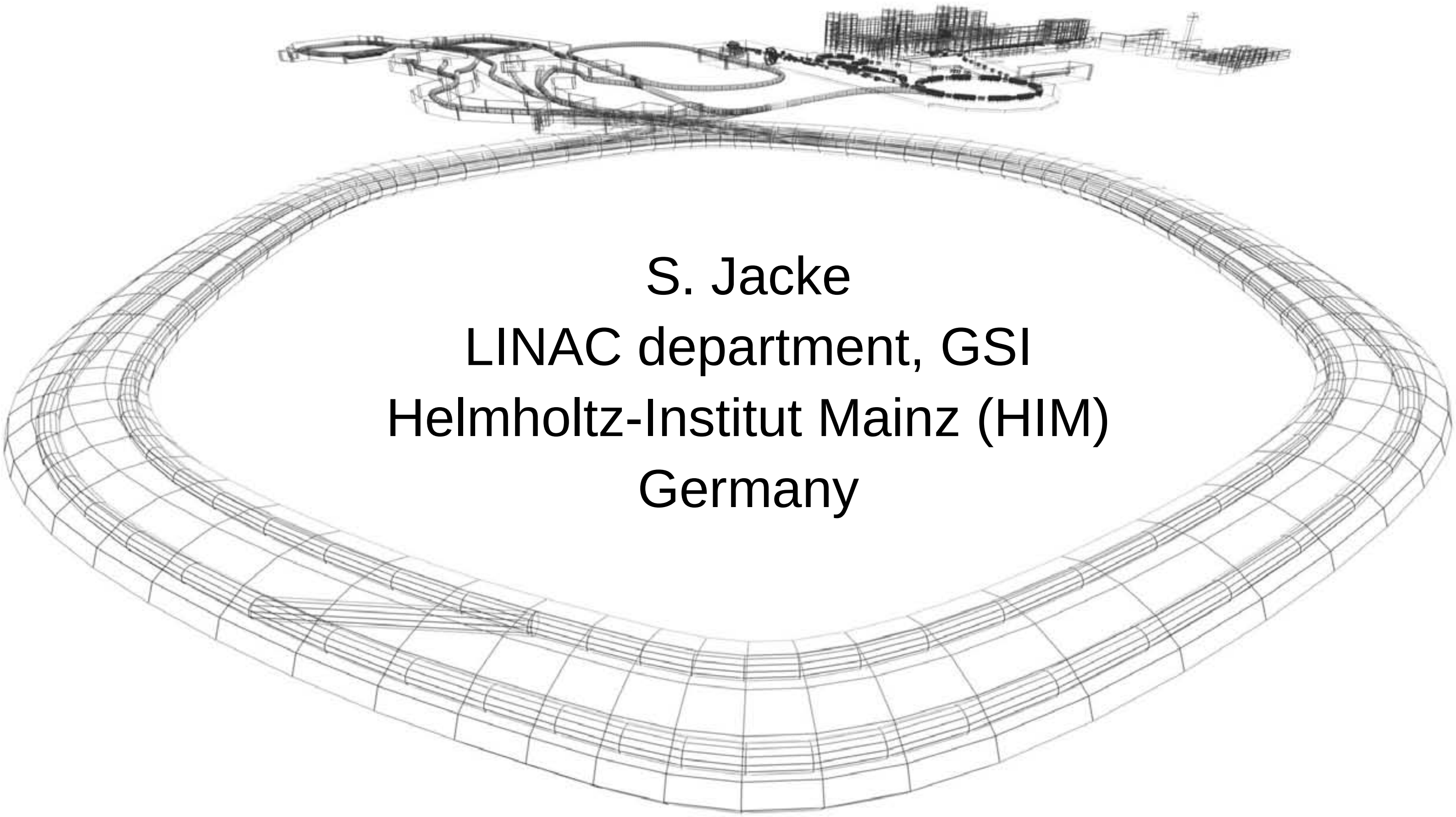
A new sc cw-LINAC – for Super Heavy Element Research



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Germany

Tasca-Workshop, 14.10.2011

Content

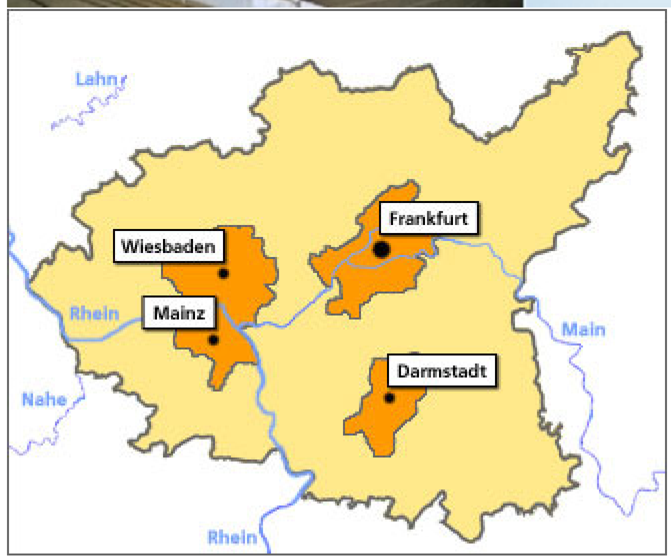
- Introduction
- General project planning
- cw-linac@GSI
- Conceptual design of the cw heavy ion linac
- cw-linac demonstrator project
  - Conceptual design
  - Technical layout
  - Time schedule
- Summary and current status

Collaboration

IAP

HELMHOLTZ ASSOCIATION

Helmholtz Institute Mainz



Structure of Matter

Physics of Hadrons and Nuclei (HIM)

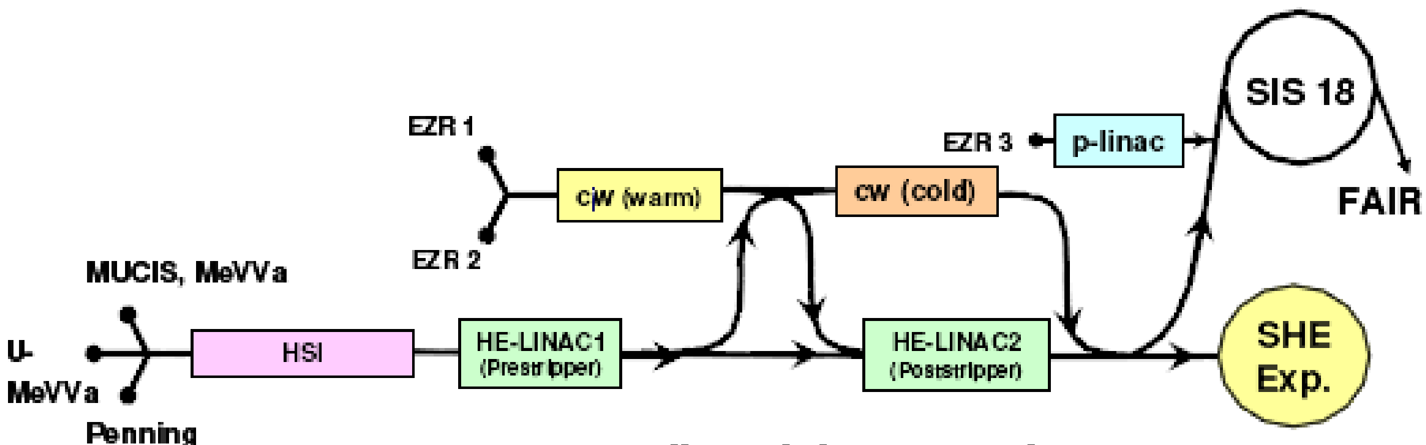
Planning

• a dedicated cw heavy ion LINAC providing energies to overcome the Coulomb barrier is desired by a broad community of users

• the exisiting UNILAC will have to be replaced on the long term (HE-LINAC as a high current heavy ion synchrotron injector)

• the planned sc cw LINAC could replace the existing UNILAC temporarily during longterm upgrade measures of the UNILAC due to FAIR

• proof of principle of the CH-cavity and full performance beam tests at the HLI-injector



Future GSI linac injector environment

FAIR vs. SHE-Program

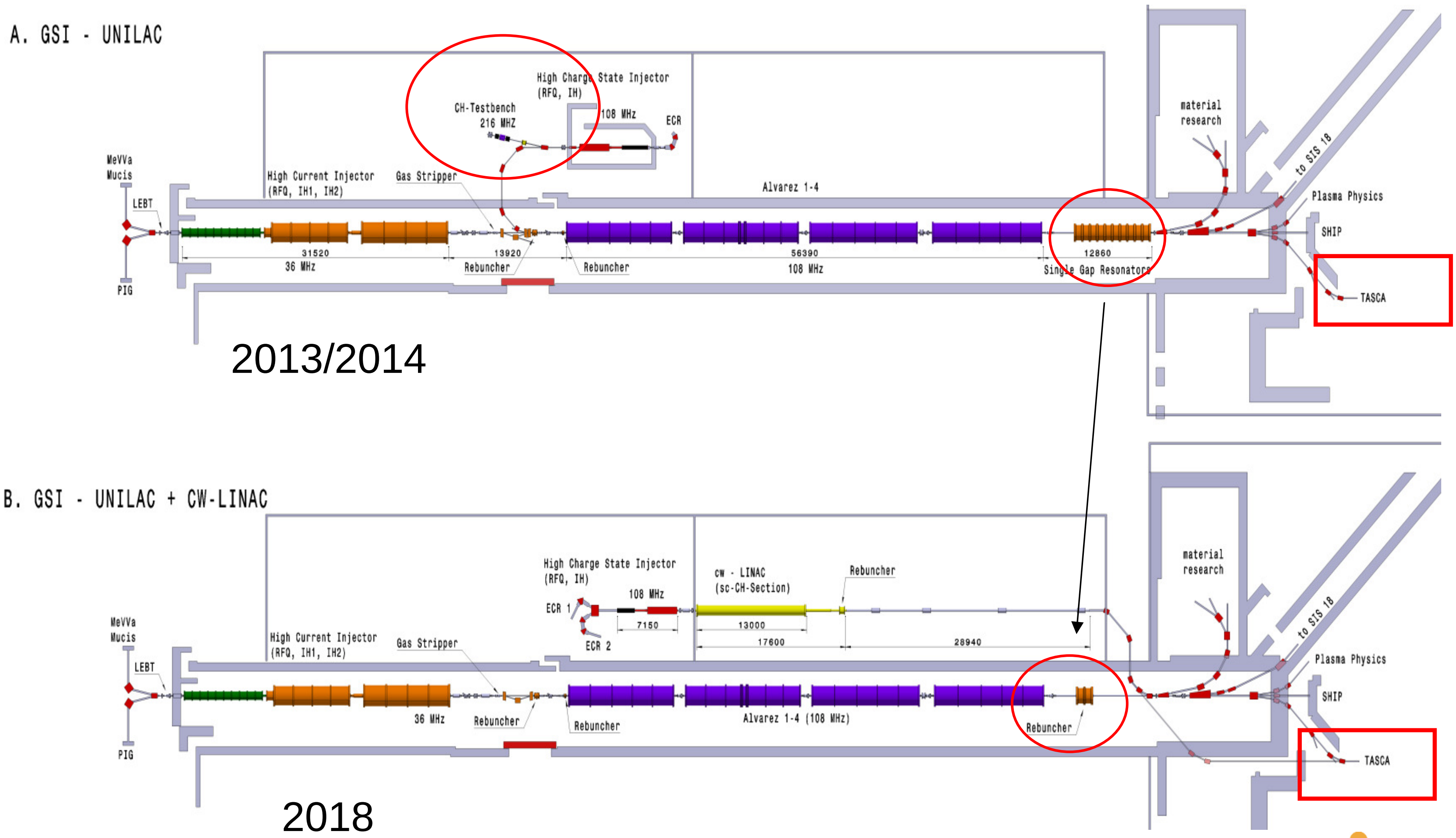
FAIR-requirements:

- Extremly high Intensities per pulse
- low repetition rate (max. 3 Hz)
- low duty cycle (0,1 %) (pulse length for SIS18: 100 µs)

SHE-requirements:

- High Intensities per pulse
- high repetition rate (50 Hz)
- High duty cycle (-> 100 %, continuous wave operation) (pulse length up to 20 ms)

Planned cw linac@GSI

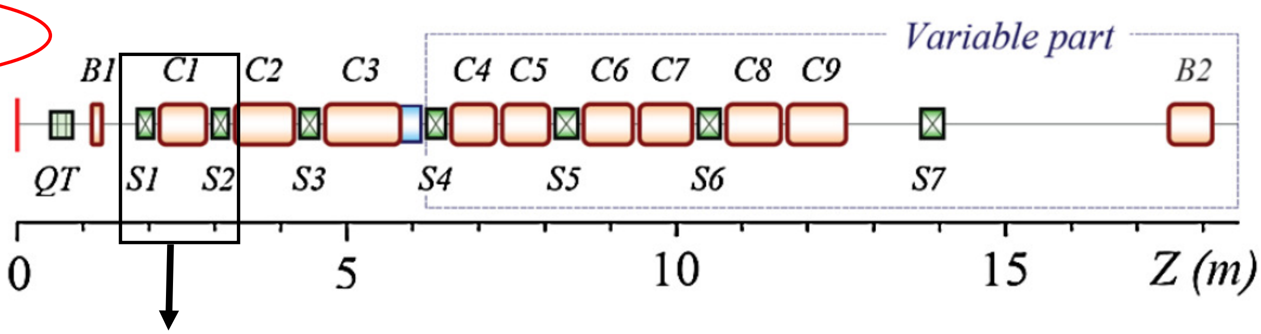


Parameters cw linac

Table 1: General Parameters of the cw-LINAC

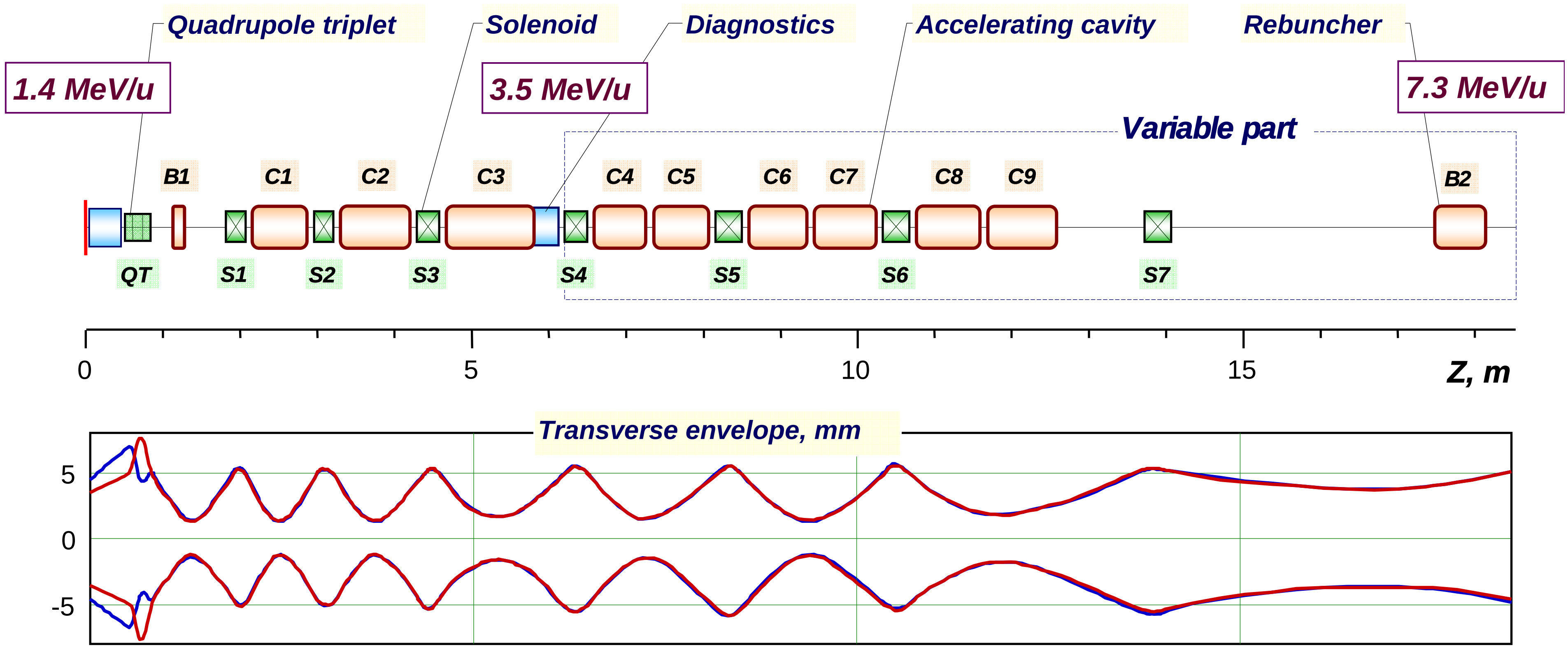
Mass/Charge		**6**
Frequency	MHz	217
max. beam current	mA	1
Injection Energy	MeV/u	1.4
Output energy	MeV/u	3.5 – 7.5
Output energy spread	keV/u	+- 3
Length of acceleration	m	12.7 !!!
Sc CH-cavities		9
Sc solenoids		7

Minaev et al (2009)



Demonstrator

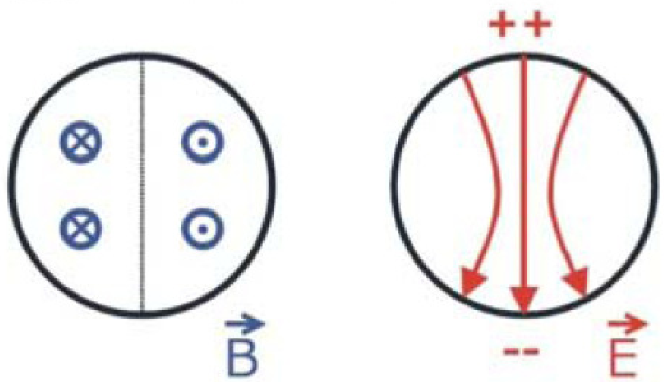
CW linac layout



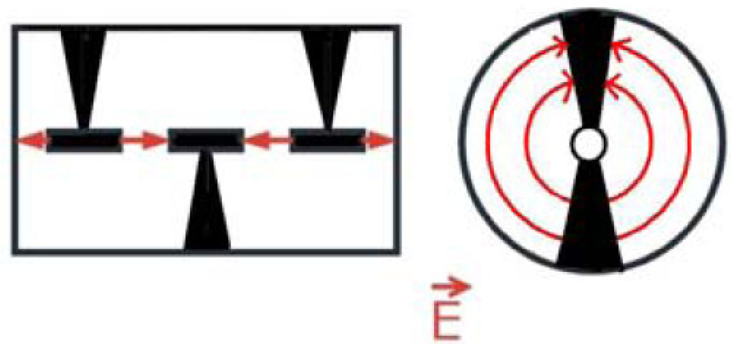
By Minaev: A. Minaev, Phys. Rev. ST Accel. Beams 12, (2009)

Cavity Field CH Stucture

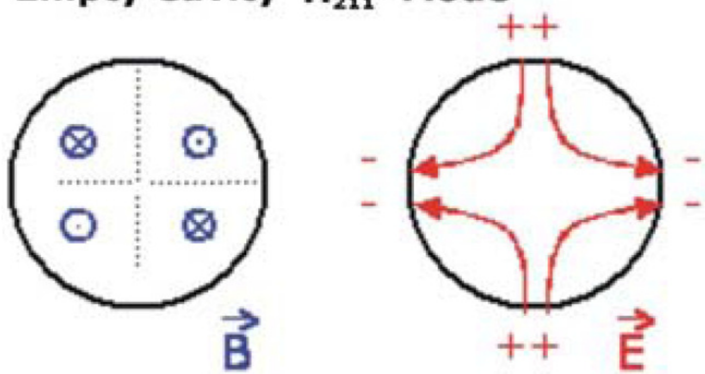
H_{111} - Empty Cavity

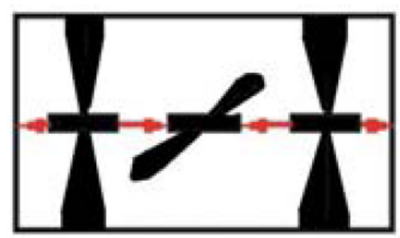


Interdigital H-Mode (IH)



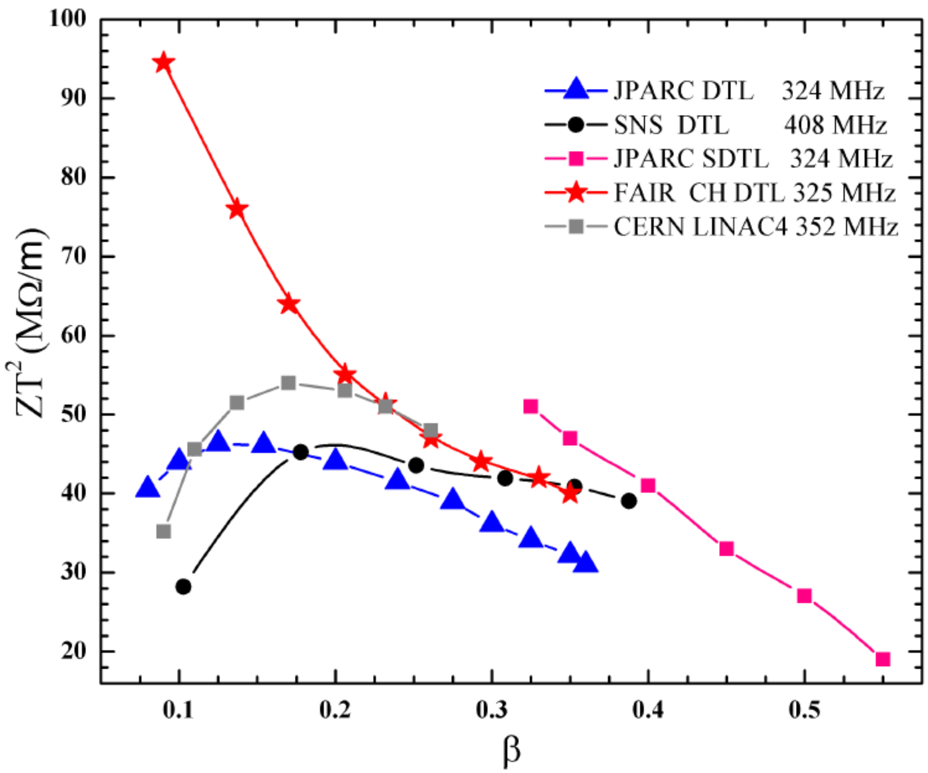
Empty Cavity H_{211} - Mode





Crossbar H-Mode Linac (CH)

CH-Cavity Structure II



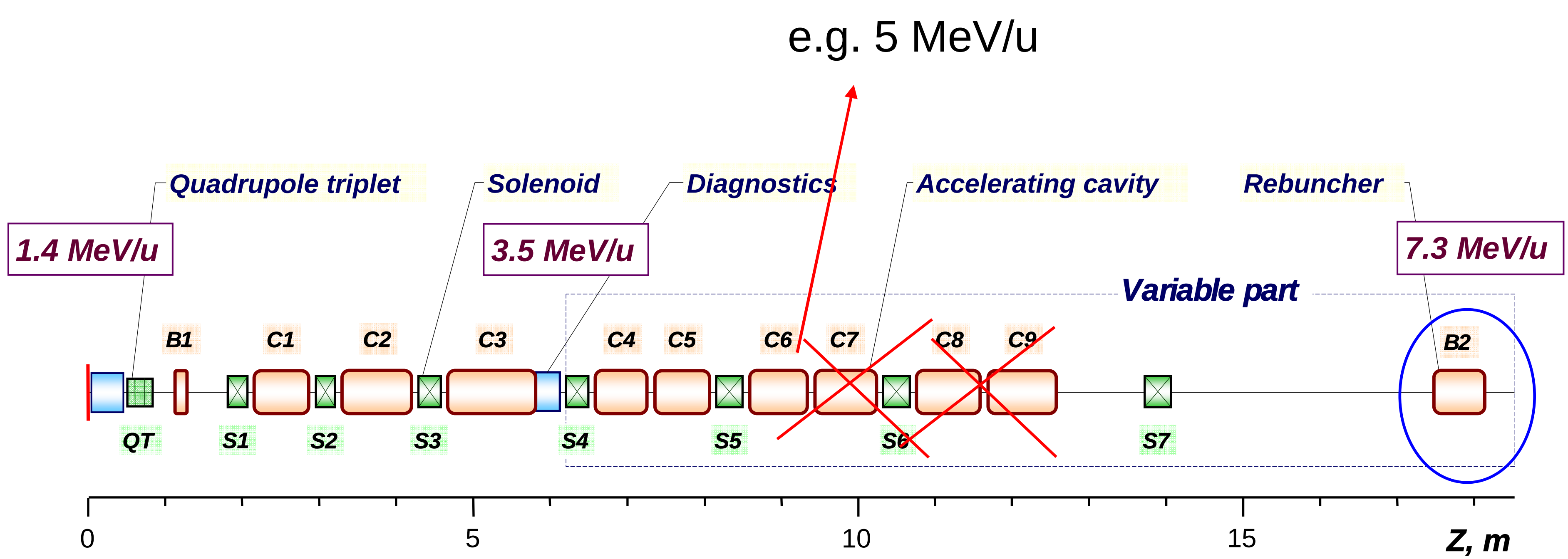
By G. Clemente, Linac

- for ß<0.5, the CH structure is the best choice (for high acc. gradients)
- H structures have generally high shunt impedances
- for a cw linac and high gradients -> superconductivity

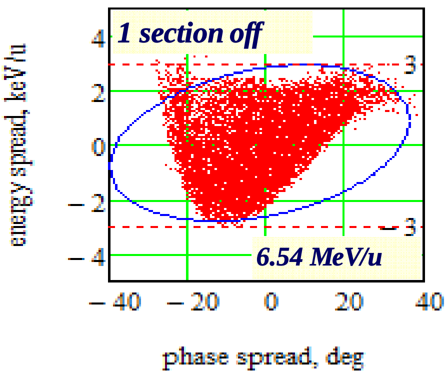
(Podlech et al.Phys. Rev. ST Accel. Beams **10,** (2007))

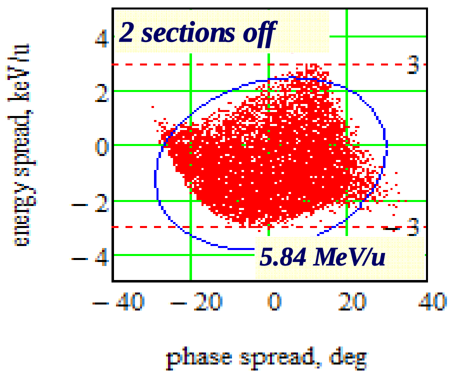
End Energy Variation

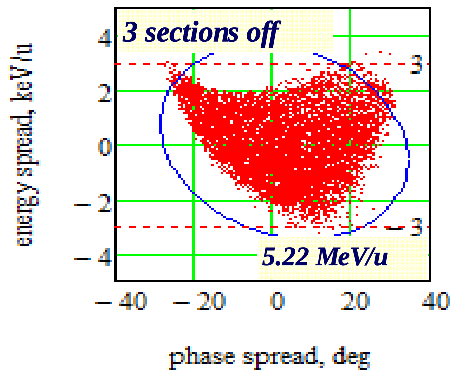
Different output energies were calculated-
in principal the tanks just have to be switched off from the back for major E variation;
for small variations, the phases/voltages of the last used cavity are altered



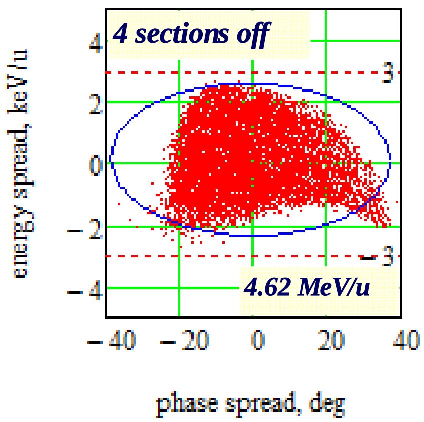
Longitudinal emittance plots

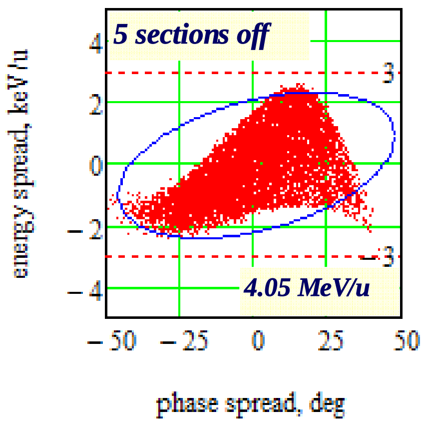


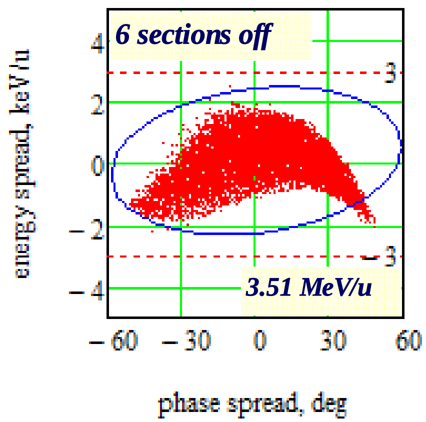




For coarse energy variation sections are switched off
LORASR Code







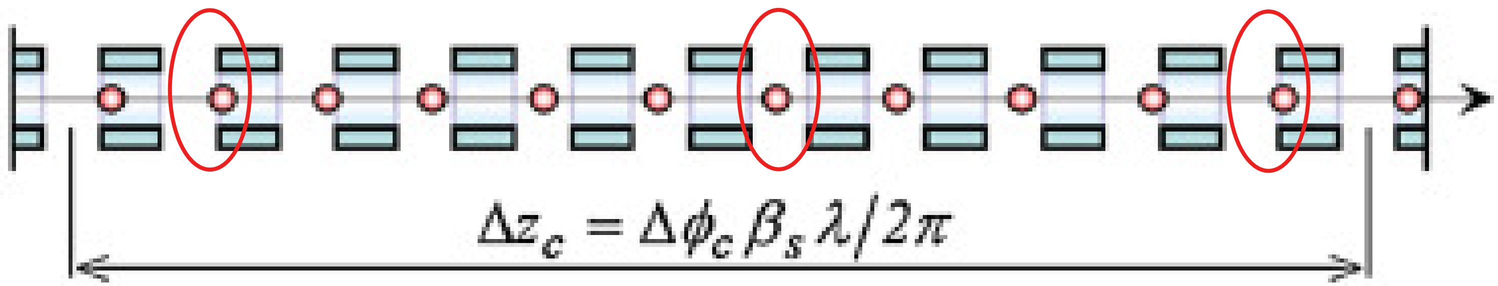
EQUUS-Concept

EQUUS (EQUidistant mUltigap Structure):

-longitudinal motion in periodical structure: equal distance, equal cells-> easier manifacturing

-Final energy depends on accelerating field and phase of particle and is flexible
(not determined by the geometry of structure)

-External focusing lenses and negative synchronous phase for longitudinal and transverse stability (like KONUS)



Bunch position in the equidistant section compared to a defined „synchronous" particle

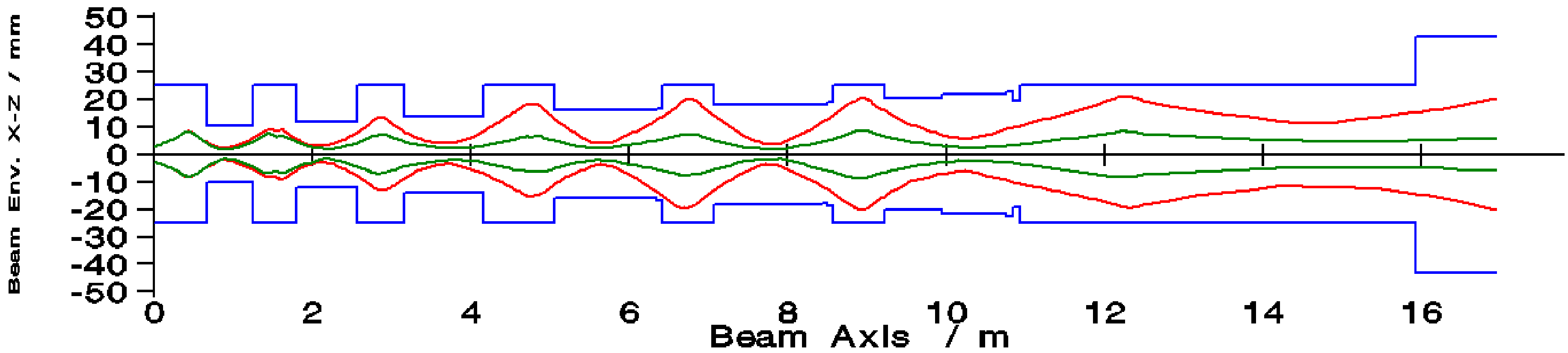
Beam Simulation

Error Calculations for Tolerance investigations are performed using LORASR (developed by U. Ratzinger, supported by R.Tiede, Uni Frankfurt)

Such as - Offset in injector plane (BOFF)

- Transverse Lens offset (QOFF)
- Lens rotation error (QROT)

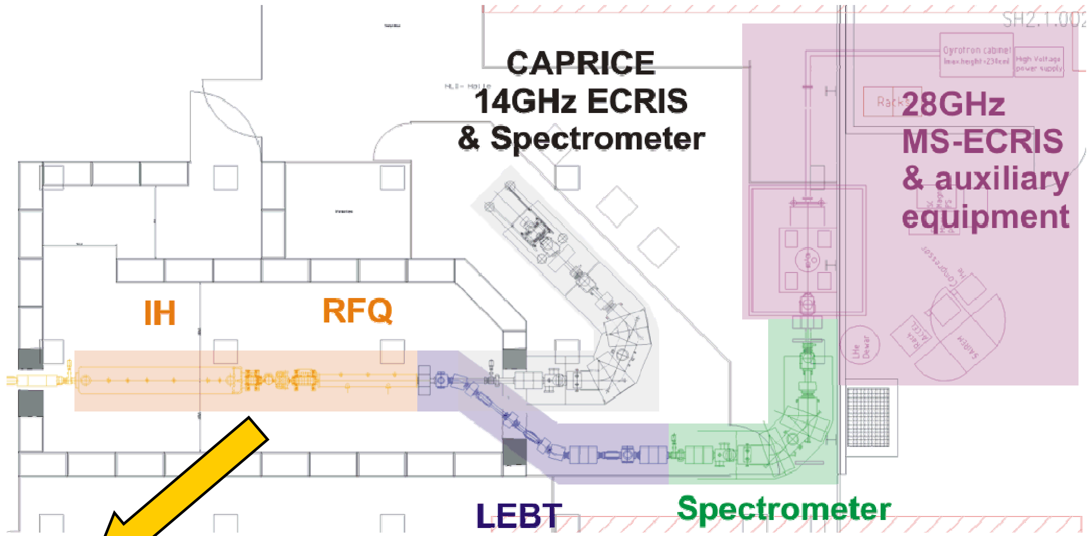
The CH DTL Errors can be randomly generated by the LORASR code (and are Gaussian distributed)

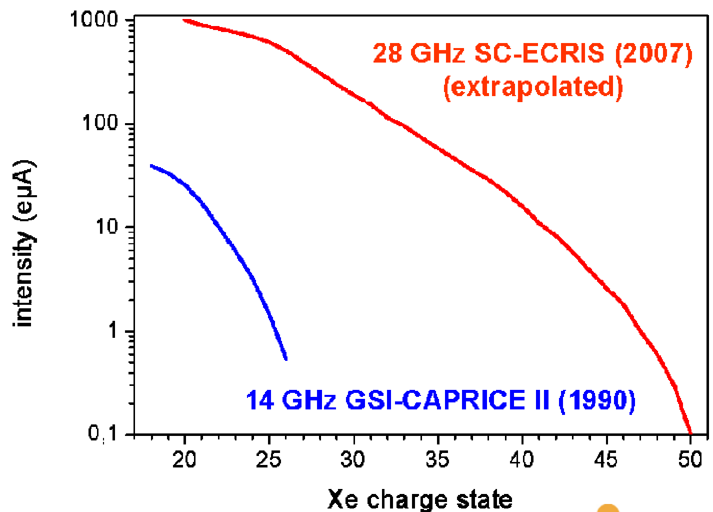


Example of combined rotational and offset errors,
Red: overall maximal envelope -all 300 runs, green: no error

Recent Updates-RFQ, ECR SOURCE

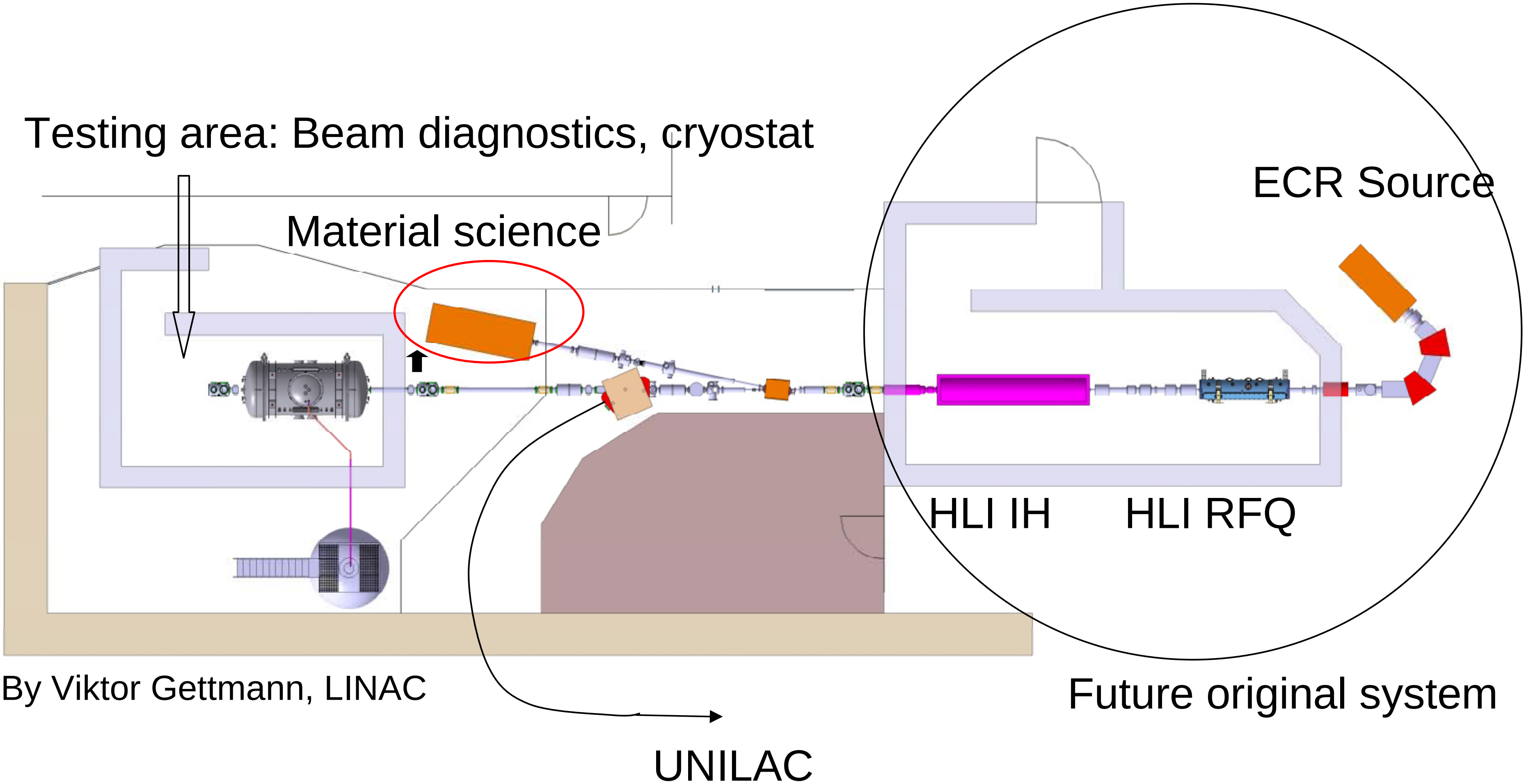
To Demonstrator / cw linac





Planned CW Linac-Demonstrator

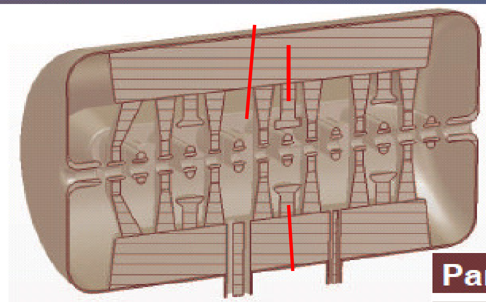
Helium temperature tests with frequency adjustment and (heavy) ion beam

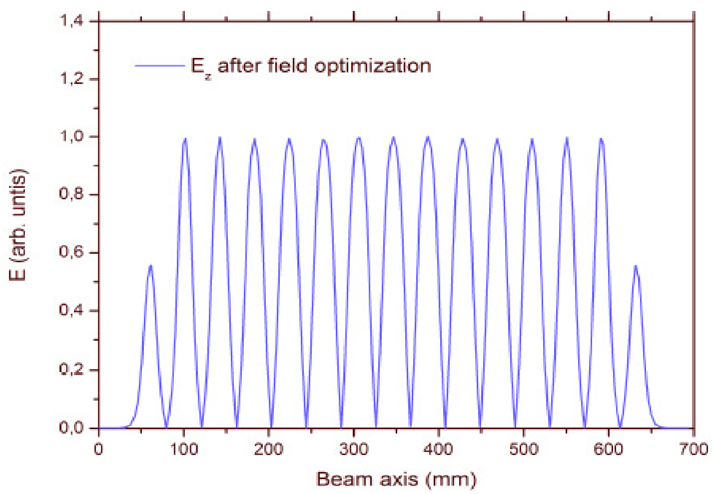


By Viktor Gettmann, LINAC

Cavity-Demonstrator

Institut für Angewandte Physik
LINAC AG
Florian Dziuba
GOETHE UNIVERSITÄT FRANKFURT AM MAIN





3D-view of the new cavity (top) and E_z along the beam axis after field optimization (bottom)

Main parameters of the 217 MHz CH-structure

Parameter	Unit	CH-1
Beta		0.059
Frequency	MHz	217
Gap number		15
Total length	mm	690
Cavity diameter	mm	420
Cell length	mm	40.82
Aperture	mm	20
Effective gap voltage	kV	225
Voltage gain	MV	3.13
Accelerating gradient	MV/ m	5.1
E_p/ E_a		6.5
B_p/ E_a	mT/ (MV/m)	5.9
R/ Q	Ω	3540
Static tuner		9
Dynamic bellow tuner		3

Status-Demonstrator and cw linac

-the first step for SHE research was the upgrade of the ECR-28Ghz source
-the second step the cw capable RFQ
-missing is the cw linac dedicated for SHE research

Current Status of the demonstrator parts (financed mostly by HIM):
-the cavity has been ordered
-the tank and solenoids are in the tender procedure
-some further parts like He gas bag and He tank are delivered
-HIM is planning a building for the cw linac assembly

-> the tests will start ~ 2013

2013-14	full performance tests @GSI-HLI
>2018	sc cw-LINAC

Summary

- the demonstrator setup is on its way which will be the first part of the cw-linac setup
- the conceptual layout is finished, parts of the demonstrator have been ordered
- the project is driven by a joint collaboration between HIM, IAP and GSI
- the commissioning of the sc-cw linac is planned for 2018, the first proposal to the HGF was rated „excellent“, an updated proposal (due to a time shift) was handed in
- Beam dynamics layout mostly finished

Thank you very much for your attention!

Acknowledgements

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by name:

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BEL:
Udo Krause
Ralph Bär

References

- Phys. Rev. ST Accel. Beams 13 (2010): C. Zhang et al., ***CH cavities for EUROTRANS*** (now: MYRRHA).

- Phys. Rev. ST Accel. Beams 12 (2009): S. Minaev,U. Ratzinger,H. Podlech, M. Busch and W. Barth, ***Superconducting, energy variable heavy ion linac with constant , multicell cavities of CH-type***

- Phys. Rev. ST Accel. Beams 13 (2010): F. Dziuba, M. Busch, M. Amberg, H. Podlech, C. Zhang, H. Klein, W. Barth and U. Ratzinger, ***Development of superconducting crossbar-H-mode cavities for proton and ion accelerators***

- Phys. Rev. ST Accel. Beams 10 (2007): H. Podlech, U. Ratzinger, H. Klein, C. Commenda, H. Liebermann and A. Sauer, ***Superconducting CH structure***

- Habilitation: H. Podlech, ***Development of normal- and superconducting CH-structures for efficient acceleration of protons and ions (in german)***

CH-cavity

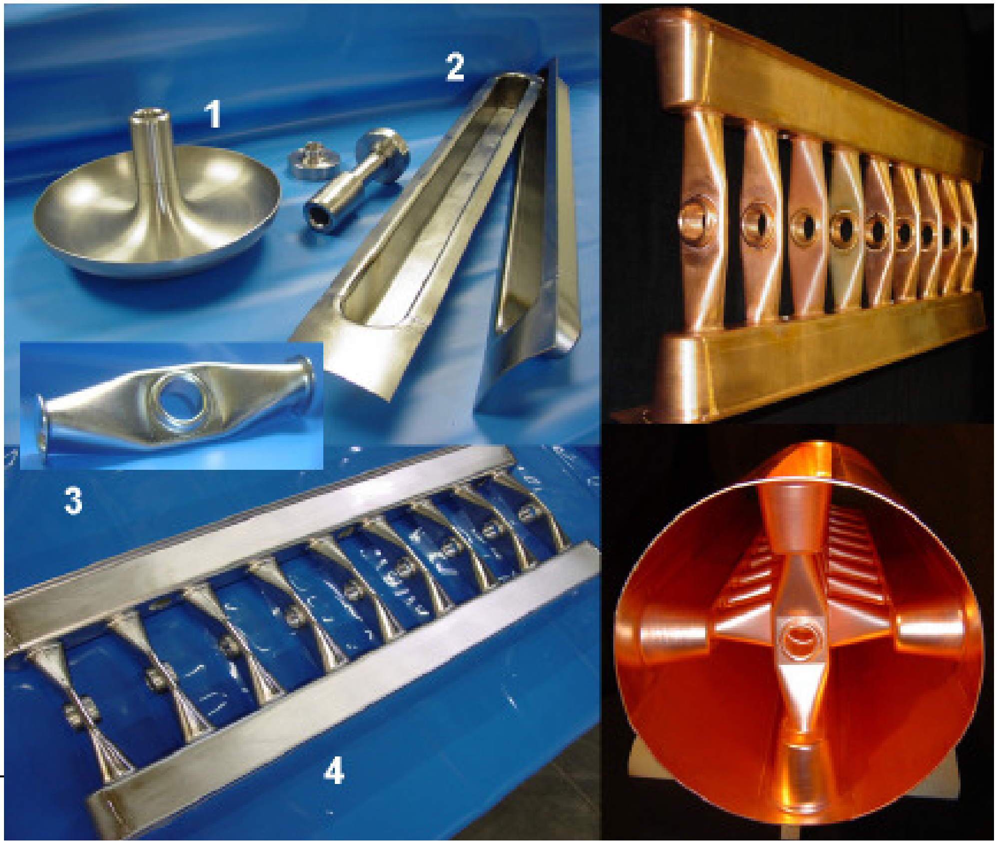
1) frequency

for f >250 MHz the dimension of the IH-DTL becomes too small transversally, due to the applied mode the transversal dimension of a CH-structure is a factor of two bigger than of IH-structures assuming a constant frequency for both

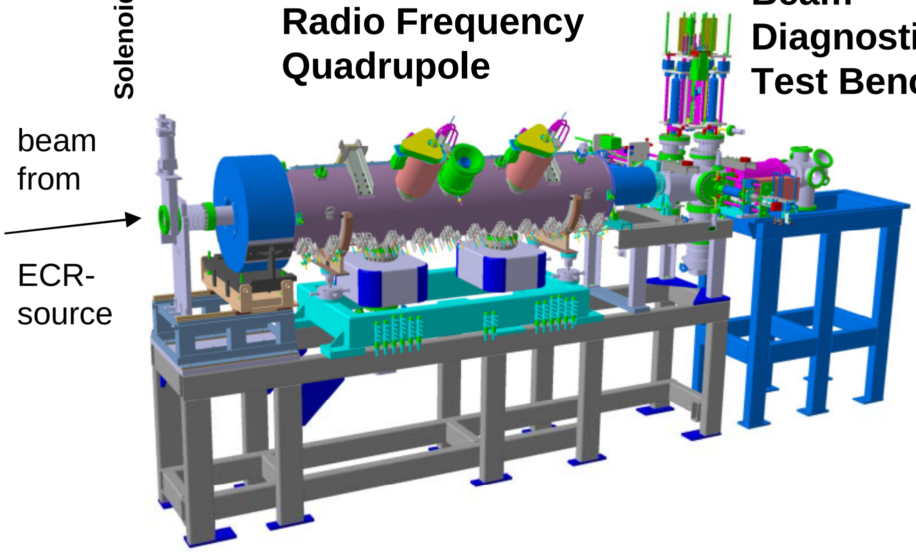
2) geometry

efficient cooling scheme together with high mechanical stability, the CH-structure is capable for cw-operation and/or superconducting –operation

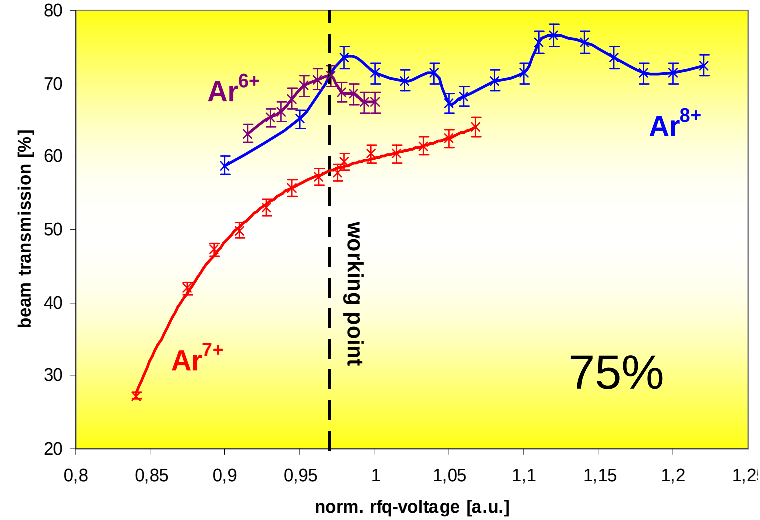
-Easy tuning and easier manufacturing is especially important for superconducting devices

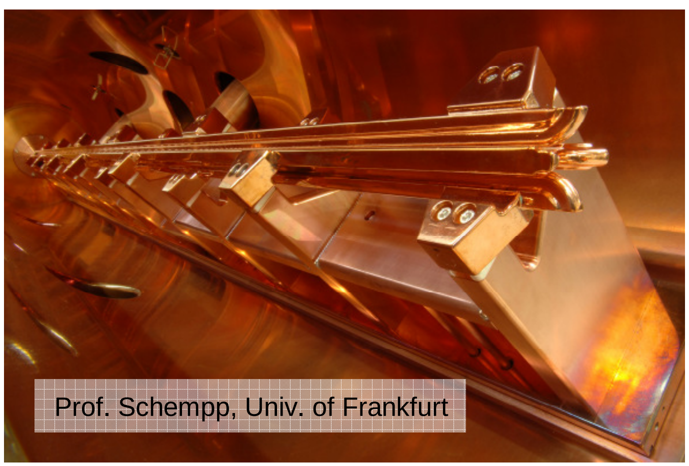


Commissioning of the GSI-HLI-RFQ (October 2009 - April 2010)

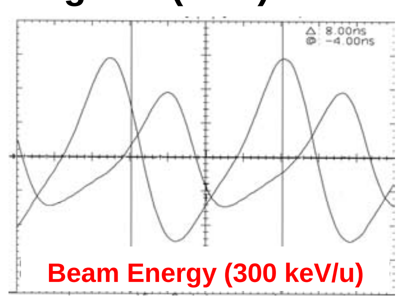


Beam Transmission





Phase Probe Signals (TOF)



Emittance Measurement (RFQ_{out})