Development of Room Temperature and Superconducting CH-Structures

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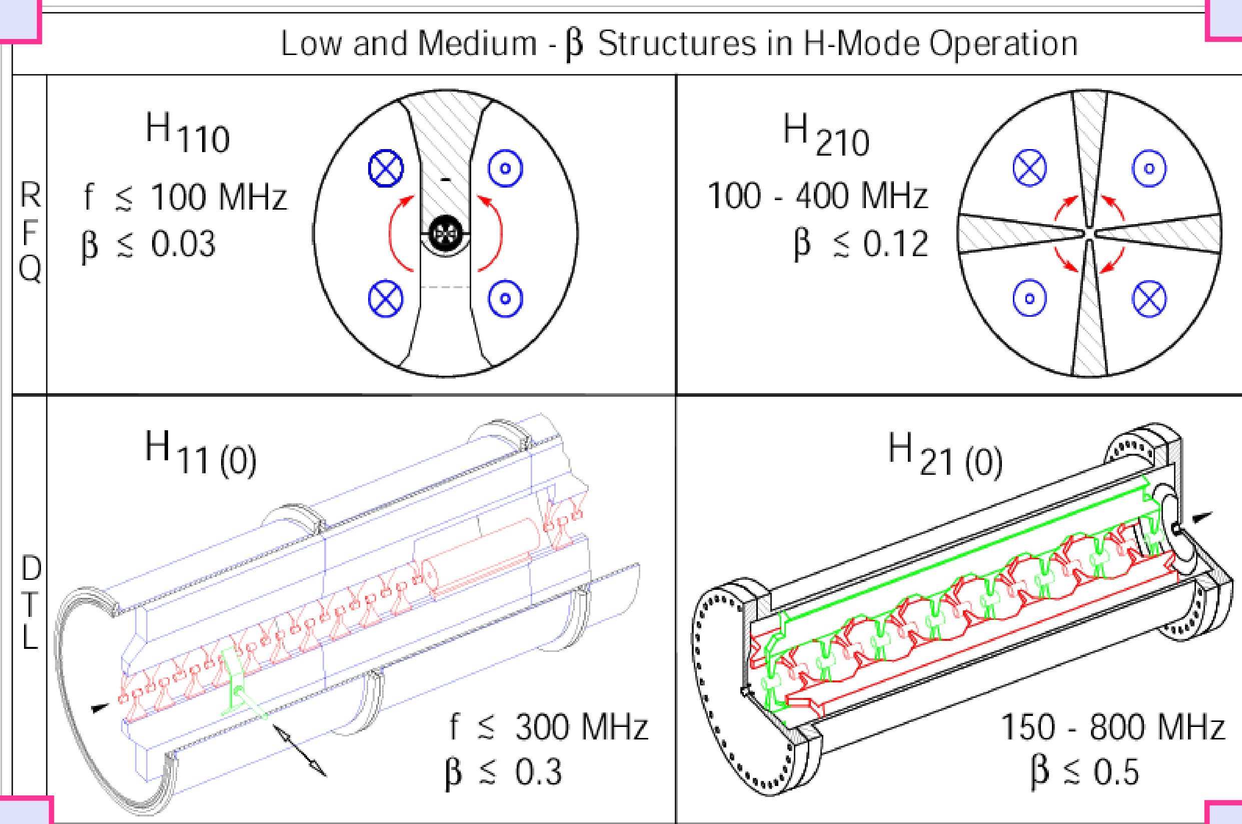
Overview

- H-mode cavities
- The CH-structure
- Room temperature CH-structures
- Superconducting CH-structures
- Applications of s.c. CH-structures
- Summary and outlook

The Family of H-mode Resonators

IH-RFQ

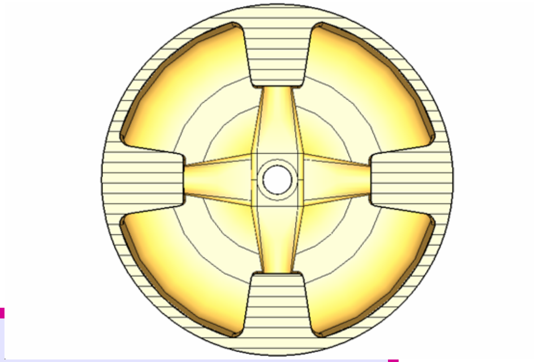
4-vane RFQ



IH-Structure

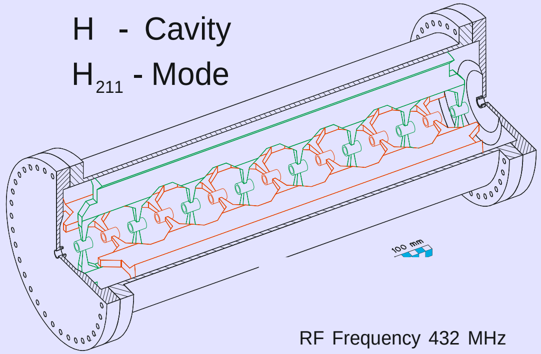
CH-Structure

The CH-Structure



Cross-Bar **H**-mode-structure

- High efficiency (Z) for low and medium energies ($0.1 \leq \beta \leq 0.5$)
- Homogeneous distribution of losses
- High real estate gradients
- Possible cw operation
- High mechanical stability
- Room temperature- and superconducting operation



Efficiency of CH-Structures

- Slim drift tubes (without focusing elements inside)
- Use of KONUS beam dynamics (Combined 0°-Structure)
- Less rf defocusing
- Longer lens free sections (s.c. cavities)
- Higher real estate gradients (long active length)

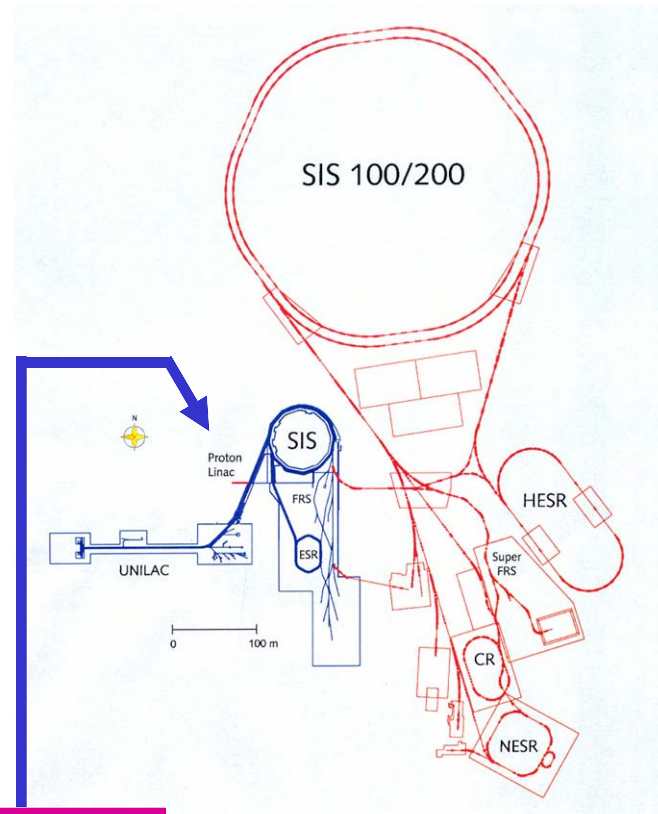
Development of r.t. CH-structures

A New Proton-Linac for FAIR/GSI

In order to fill the SIS 18 up to its proton space charge limit the UNILAC proton intensities are too low by a factor of 70 :

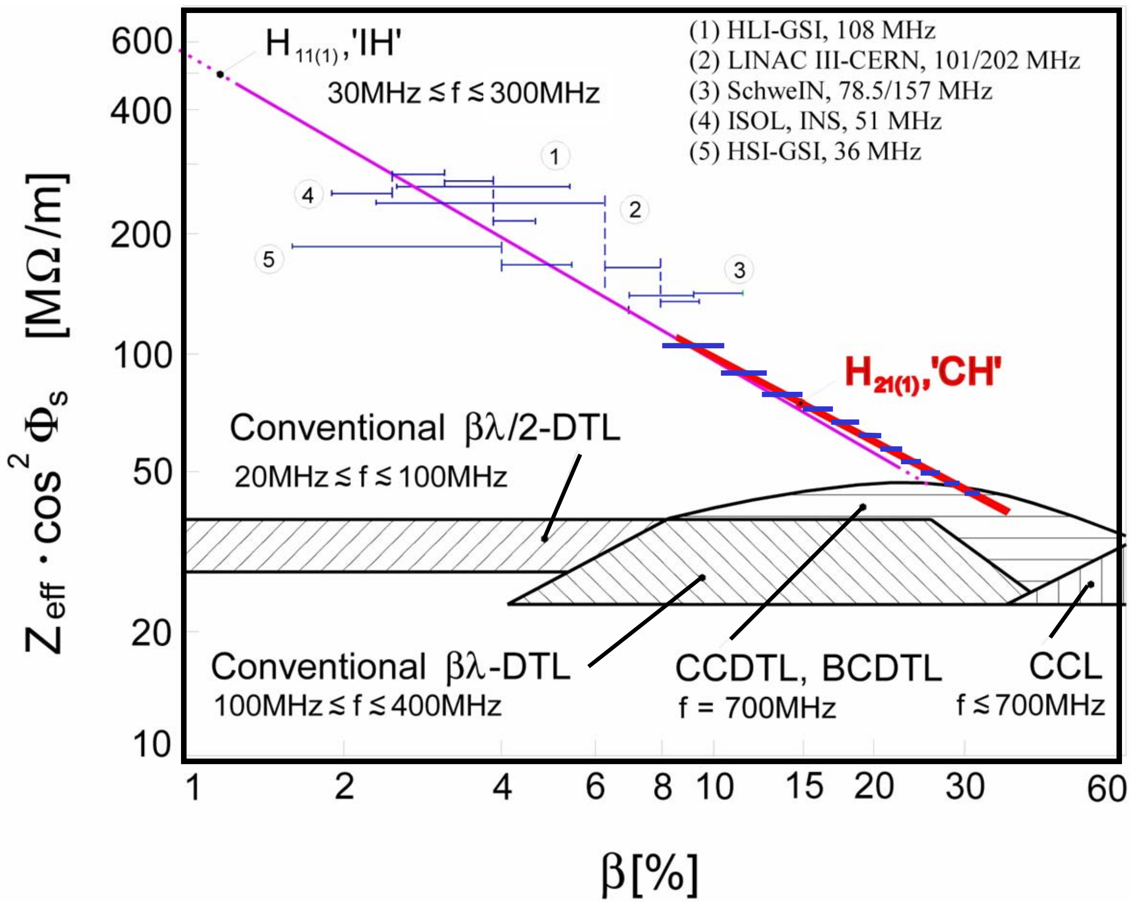
- 1×10^{11} protons / SIS 18 fill from UNILAC
  (0.25 mA × 4 μs × 25 turns)
- 7×10^{12} protons / SIS 18 fill for antiproton production
  (70 mA × 2 μs × 10 turns)

Development of a dedicated p-injector

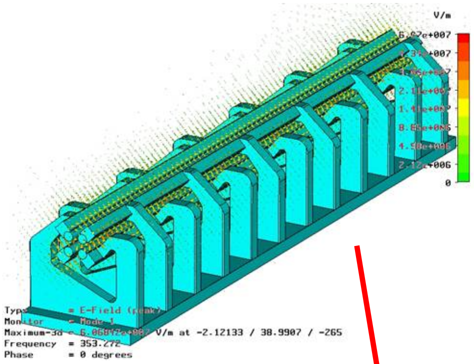


L. Groening et al., MOP06

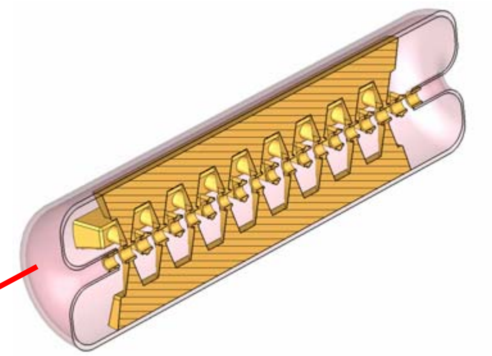
Effective Shunt Impedance of different RF Structures

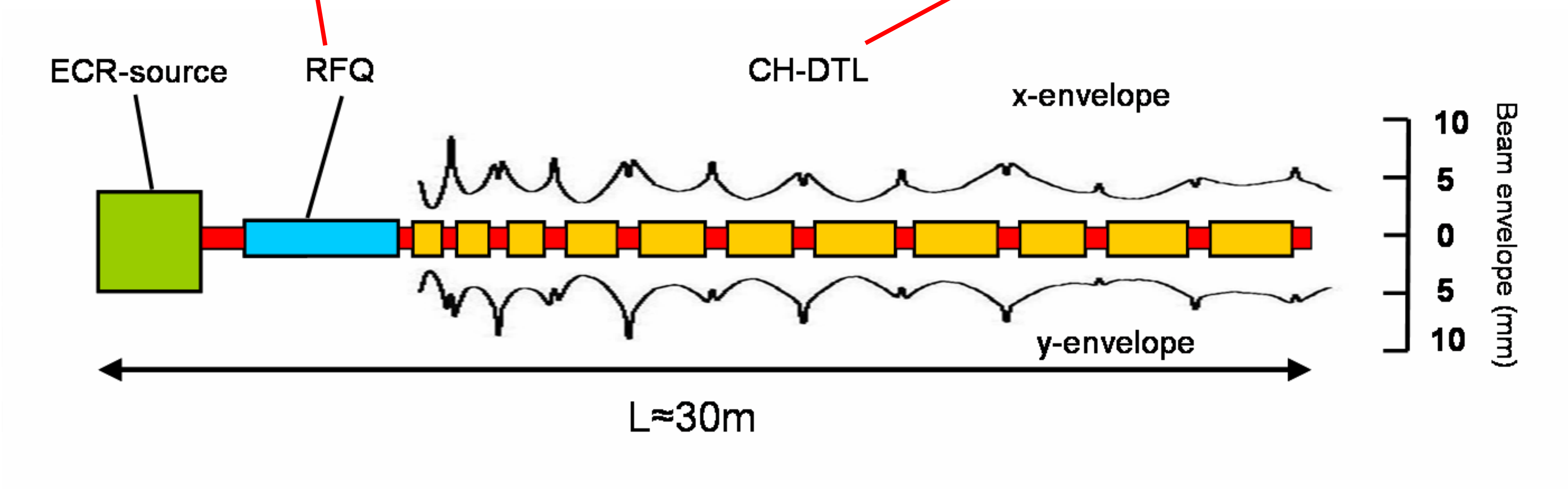


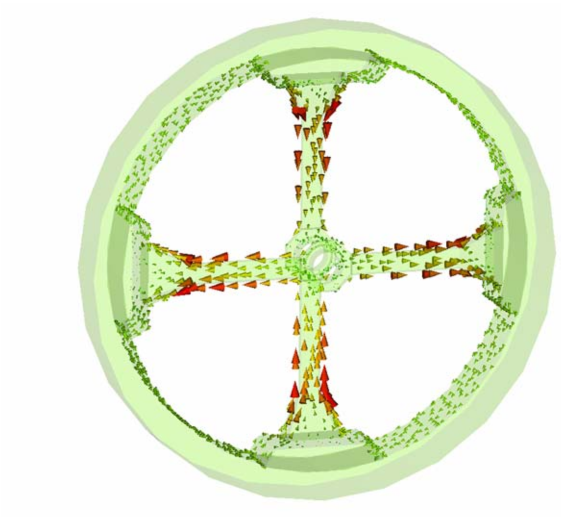
A. Schempp et al., THP11

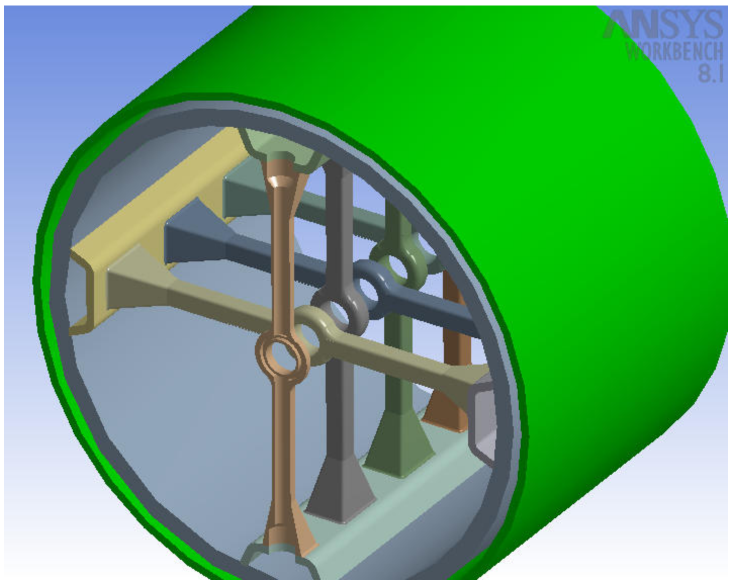


Schematic Layout of the FAIR p-Injector







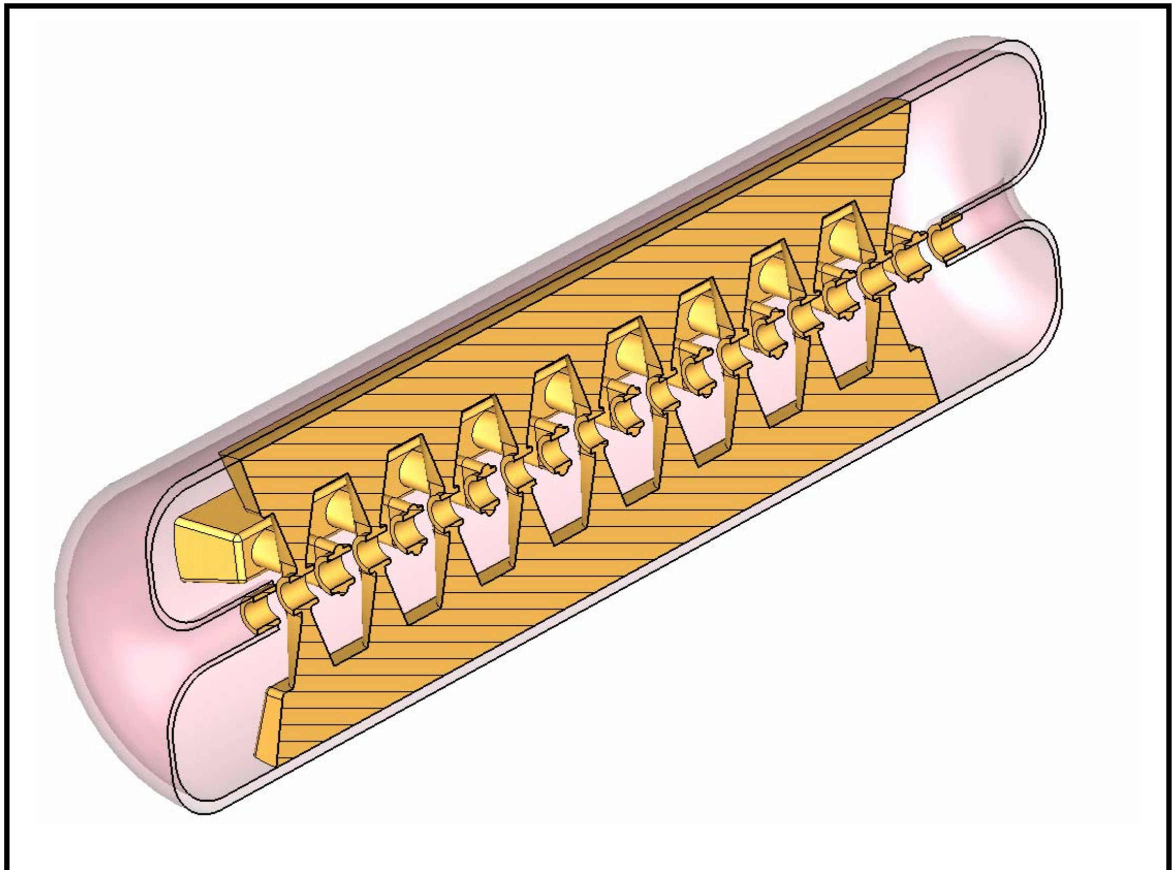


Frequency	352 MHz
rf pulse length	1 ms
Repetition rate	5 Hz
Macro pulse length	100 μs
Current (design/operation)	90/70 mA
Energy	70 MeV
Nr. of CH-cavities	11
Length CH-DTL	22 m
Single tank length	0.6-2.2 m
Accelerating gradient	6.7-2.2 MV/m
Eff. Shunt impedance	100-45 MΩ/m
rf power/cavity	600-1100 kW
ε_{tr} (99%, norm)	1.9 mm mrad
ε_{tr} (rms)	0.35 mm mrad
ε_{long} (99%)	0.45 MeV deg
ε_{long} (rms)	0.075 MeV deg

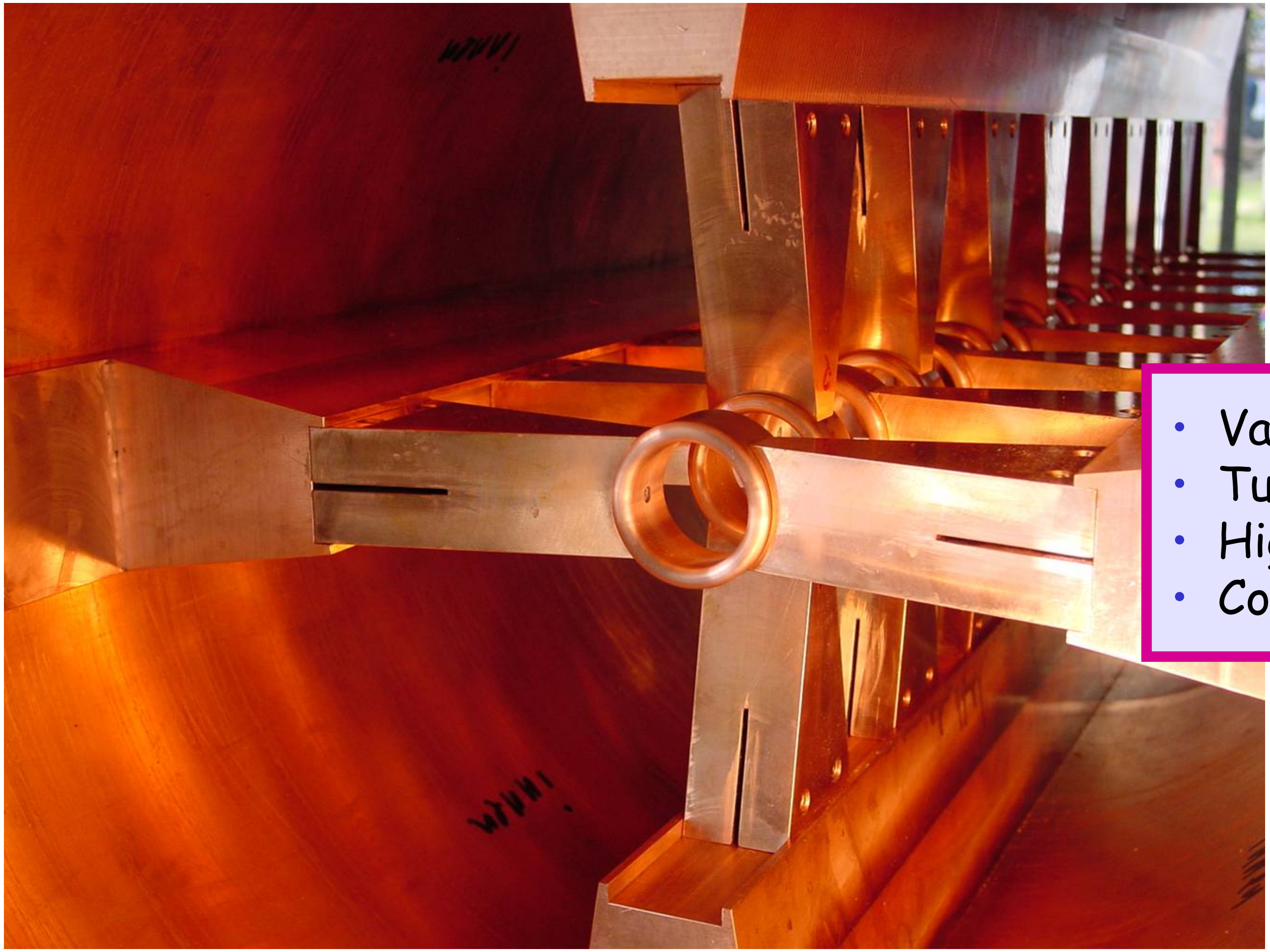
Z. Li et al., MOP20

R. Tiede et al., MOP12

Superconducting CH-Prototype



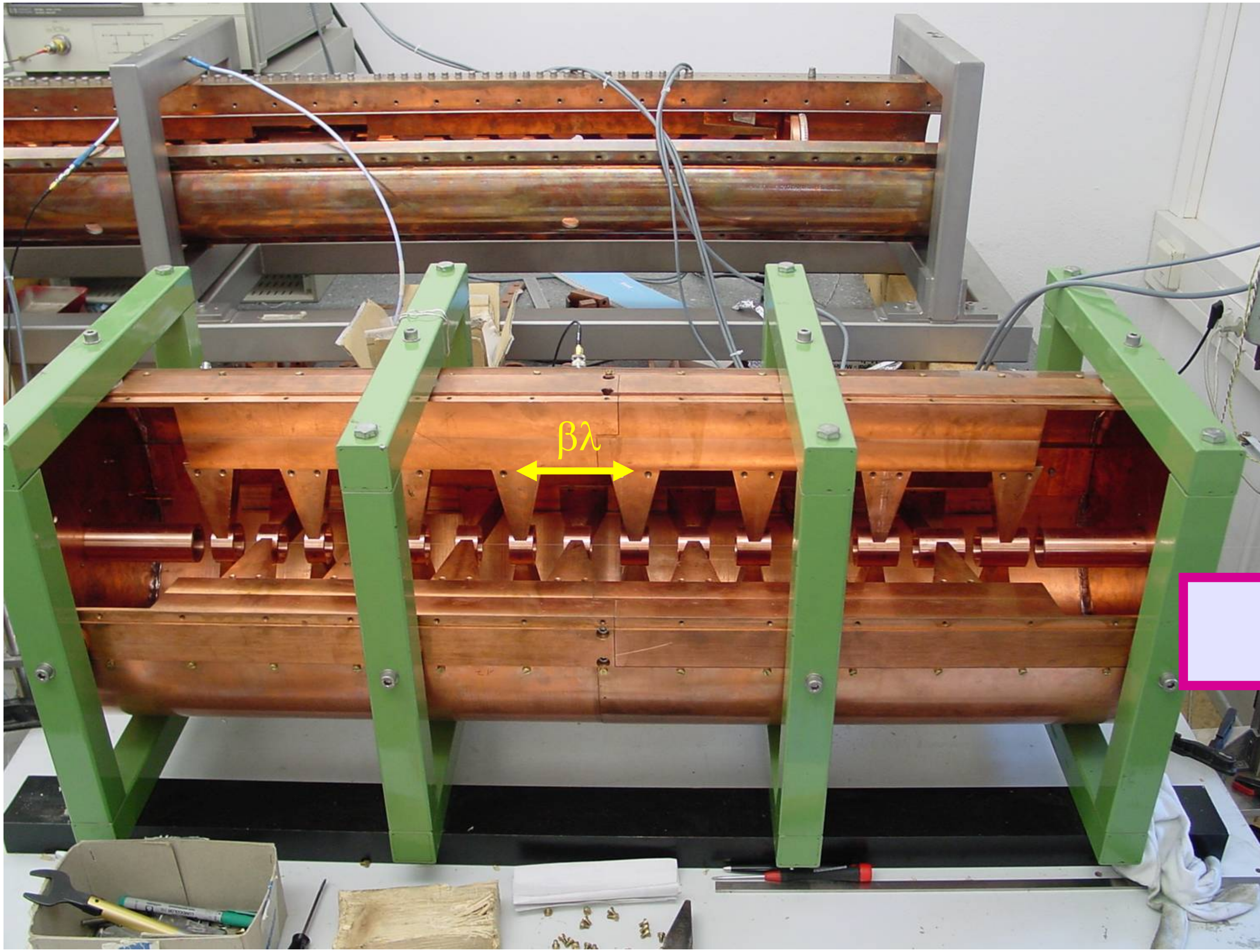
Gap number	19
Length (cm)	105
Frequency (MHz)	352
β	0.1
Material	bulk Niobium
E_0 (MV/m)	4
E_a=ET (MV/m)	3.2
E_p (MV/m) @ 3.2 MV/m	21.0
B_p (mT) @ 3.2 MV/m	23.3
G=R_sQ_0 (Ω)	56
R_a/Q (Ω) (T incl.)	3220
(R_a/Q)G (Ω^2)	180000
Q_0 (BCS, 4K, 352 MHz)	$1.5x10^9$
Q_0 (total R_s=140 nΩ)	$4x10^8$
W (mJ/(MV/m)^2)	155
W @ 3.2 MV/m (J)	1.58
P @ 3.2 MV/m und R_s=140 nΩ (W)	9



r.t. CH-Model

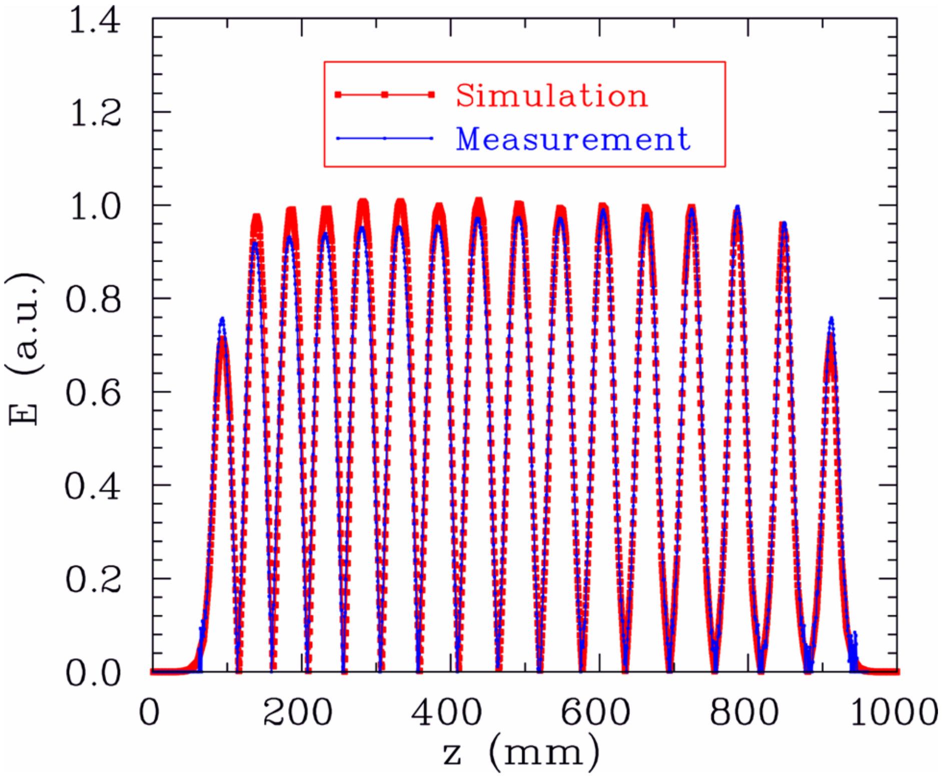
- Validation of the Simulations
- Tuning (frequency- und field)
- Higher Order Modes (HOM)
- Coupling

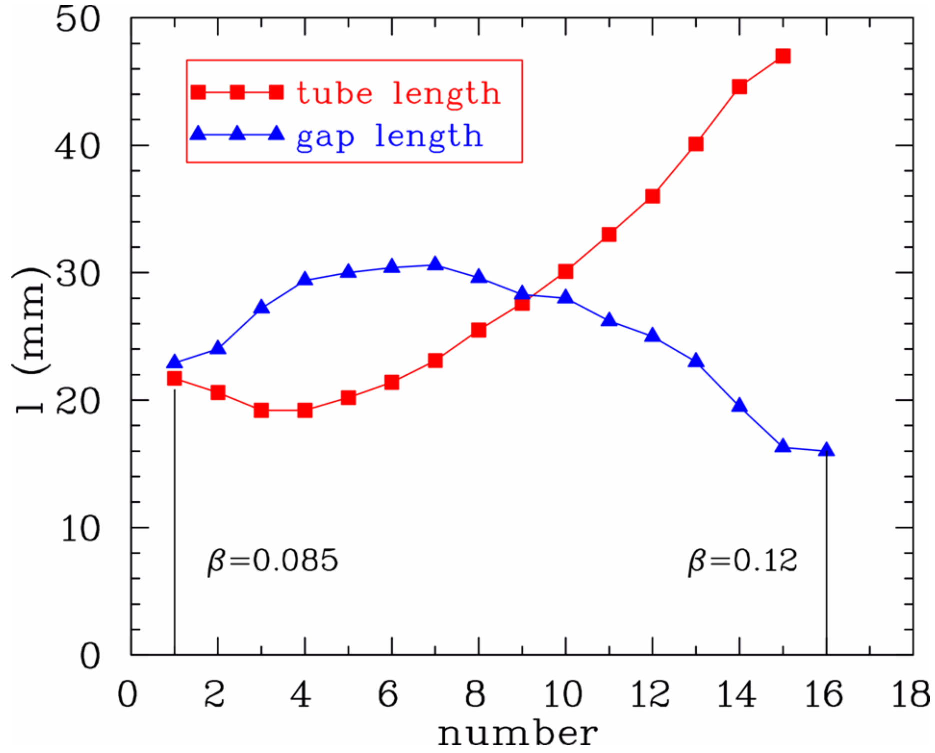
CH-Model with β-profile



$0.085 \leq \beta \leq 0.12$

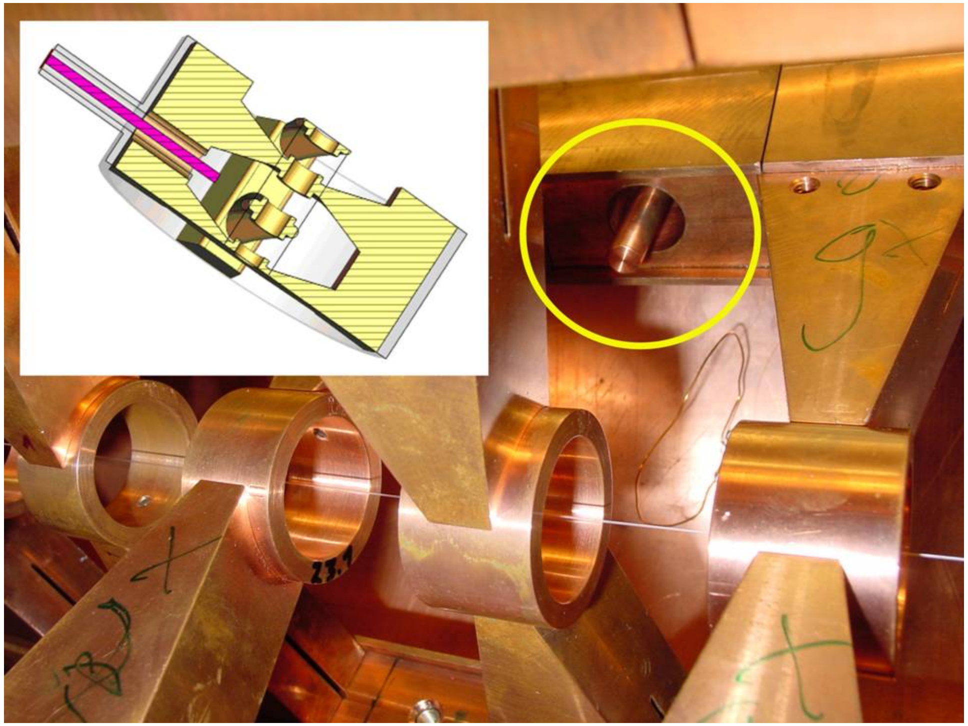
CH-Model Measurements

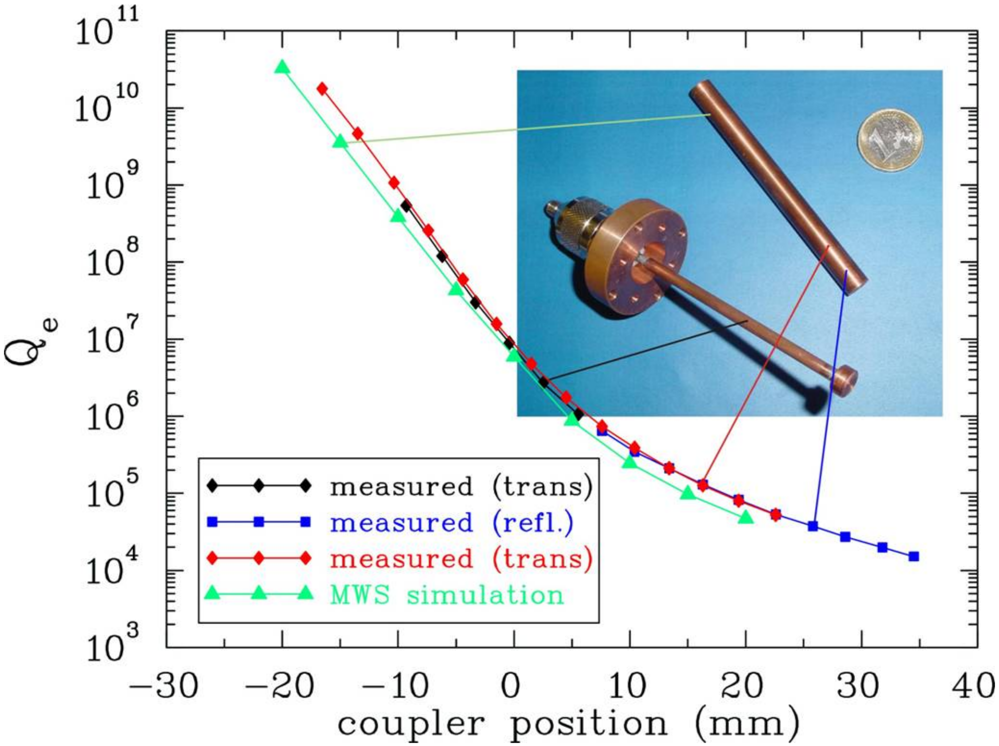




Coupling rf to CH-Structures

Capacitive coupling

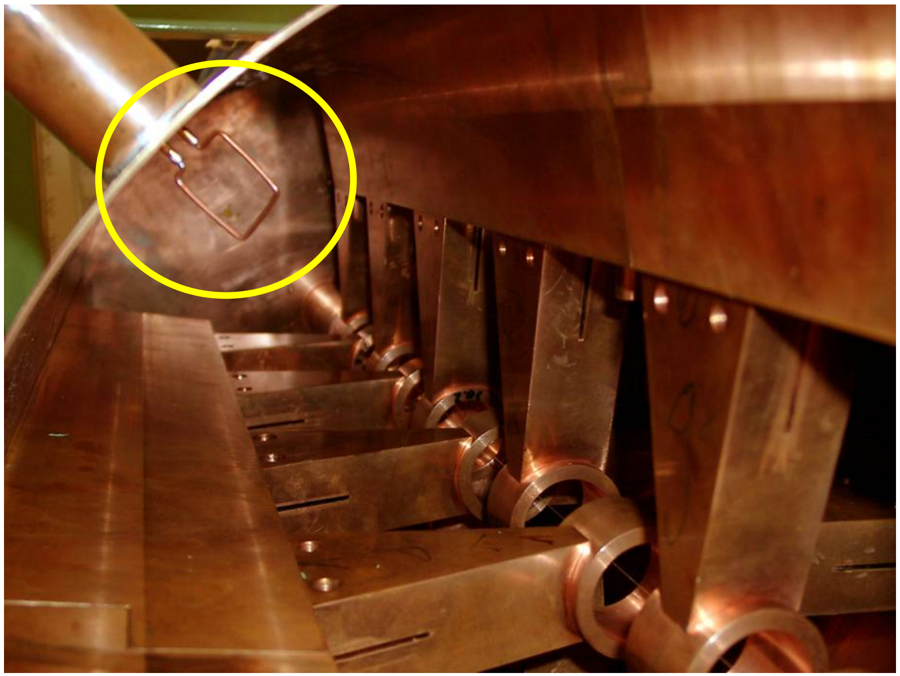


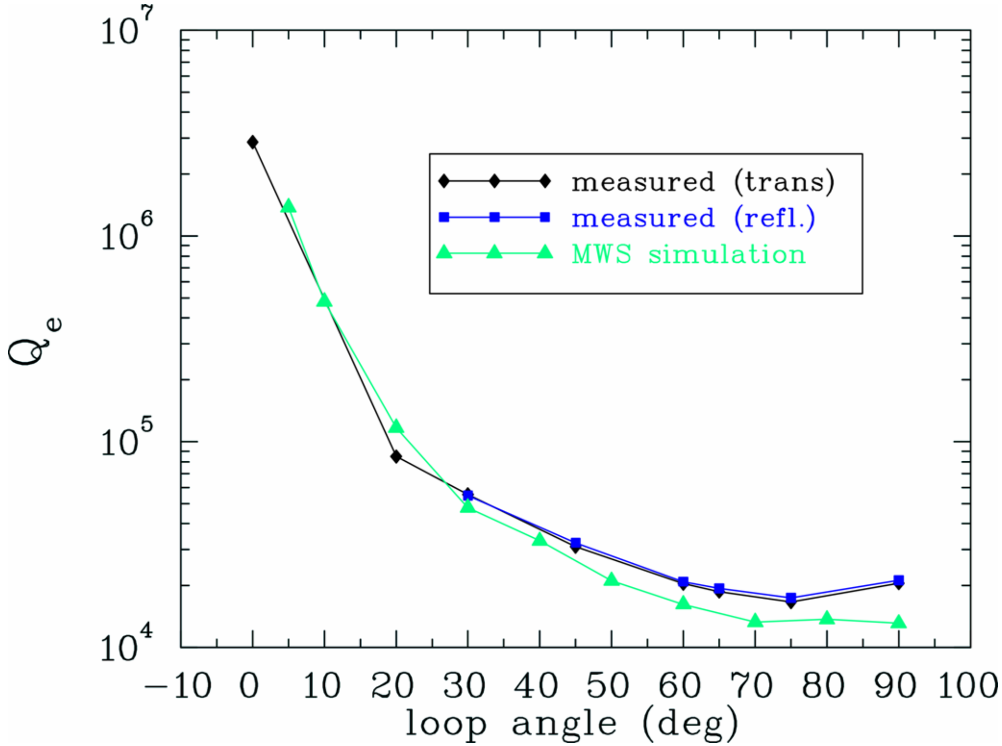


H. Liebermann et al., TUP86

Coupling rf to CH-structures

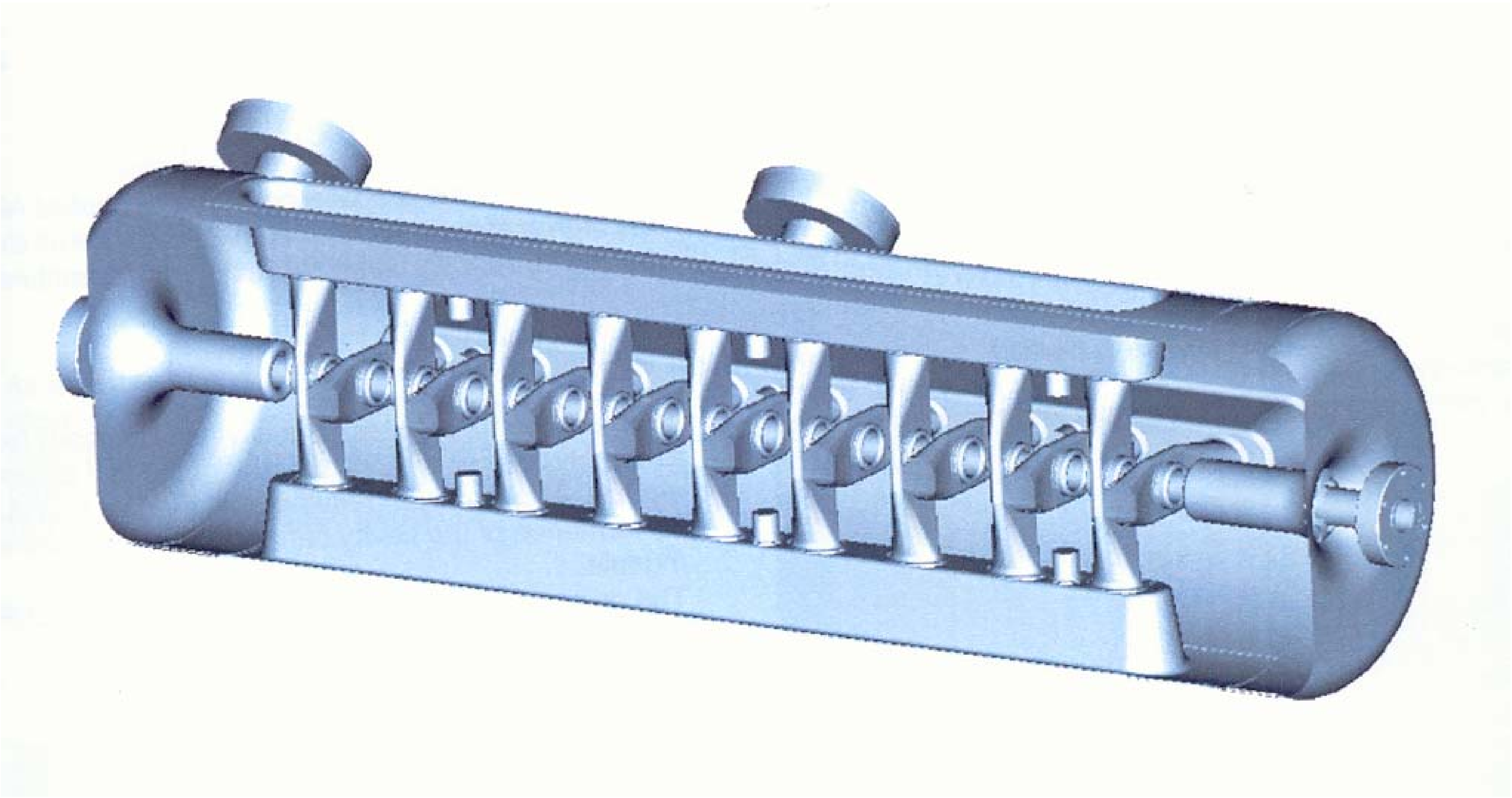
Inductive coupling



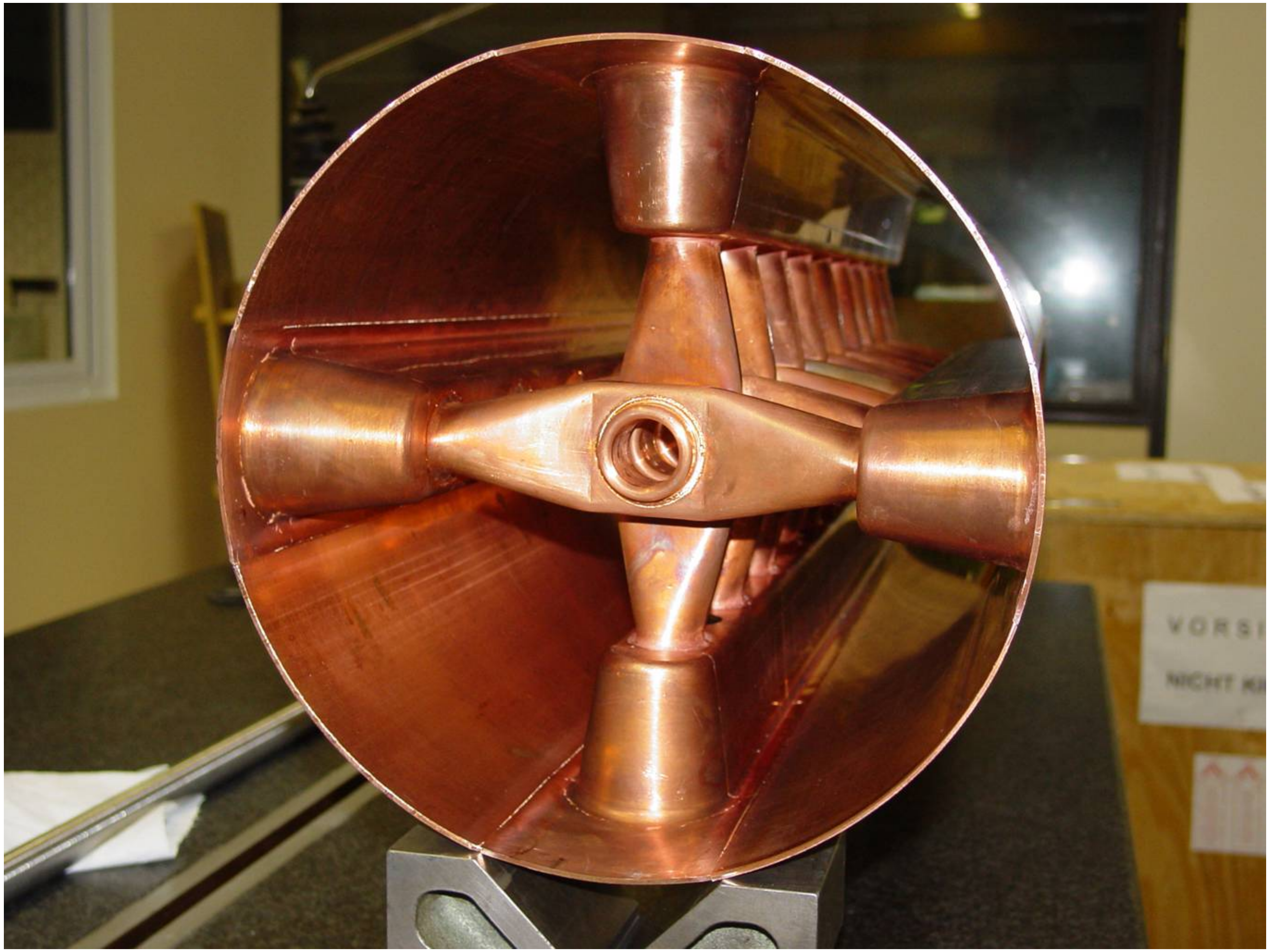


H. Liebermann et al., TUP86

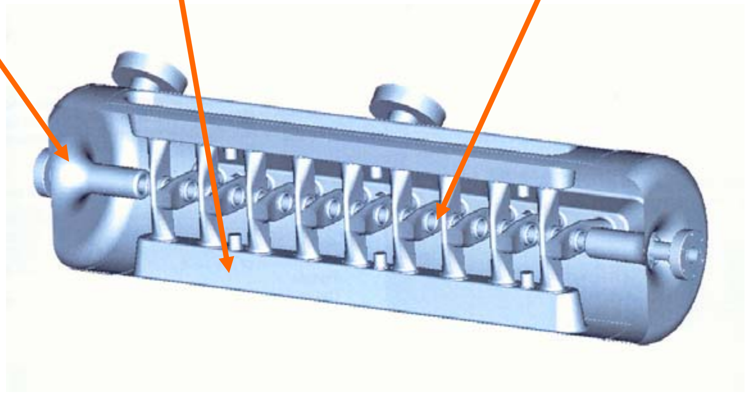
Superconducting CH-Prototype



Copper Model of the CH-Prototype



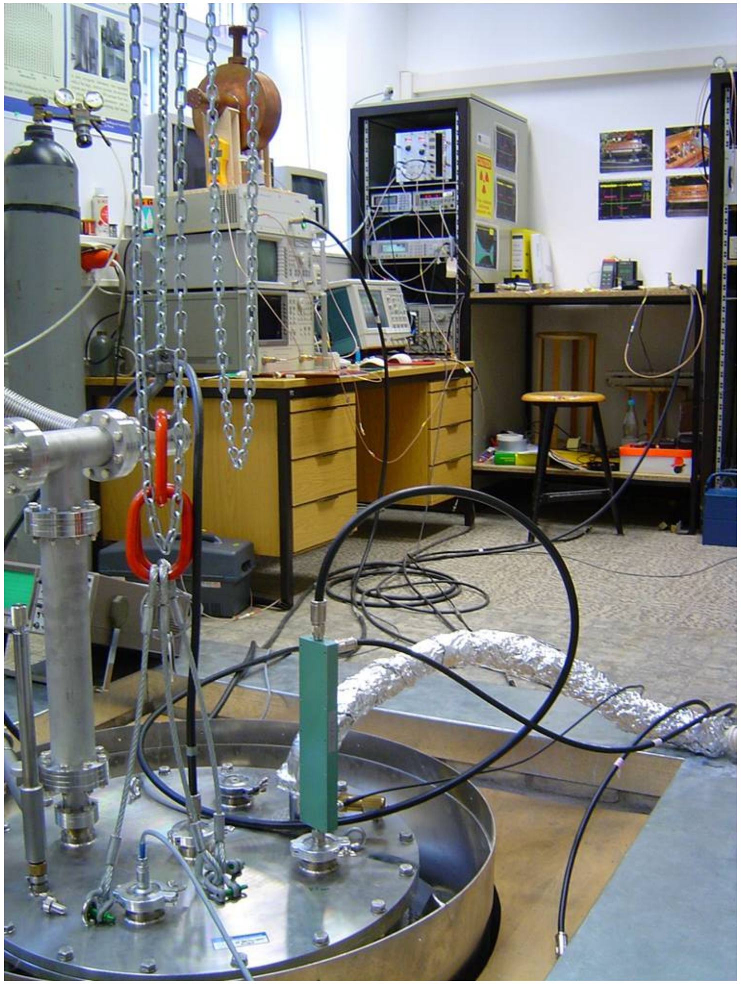
Built by ACCEL



Niobium parts of the s.c. CH-Prototype

Niobium parts of the s.c. CH-Prototype

The New Cryogenic Laboratory in Frankfurt



- 3 m vertical cryostat
- transport dewars
- Helium recovery system
- magnetic shielding
- control system (developed at IAP)

XADS Project

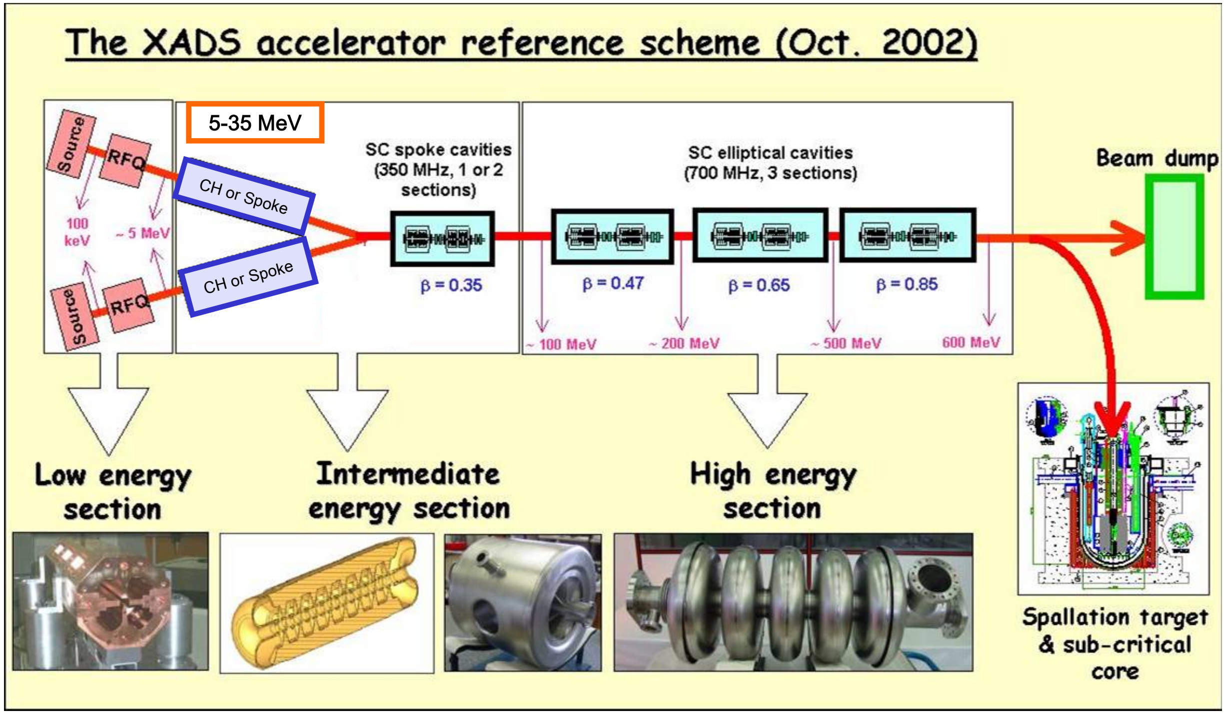
EXperimental Accelerator Driven System

- Nuclear waste transmutation project
- 10 mA proton beam (cw)
- 600 MeV energy
- Subcritical core with a liquid spallation target

Comparison of a 350 MHz 5-18 MeV section of the XADS linac

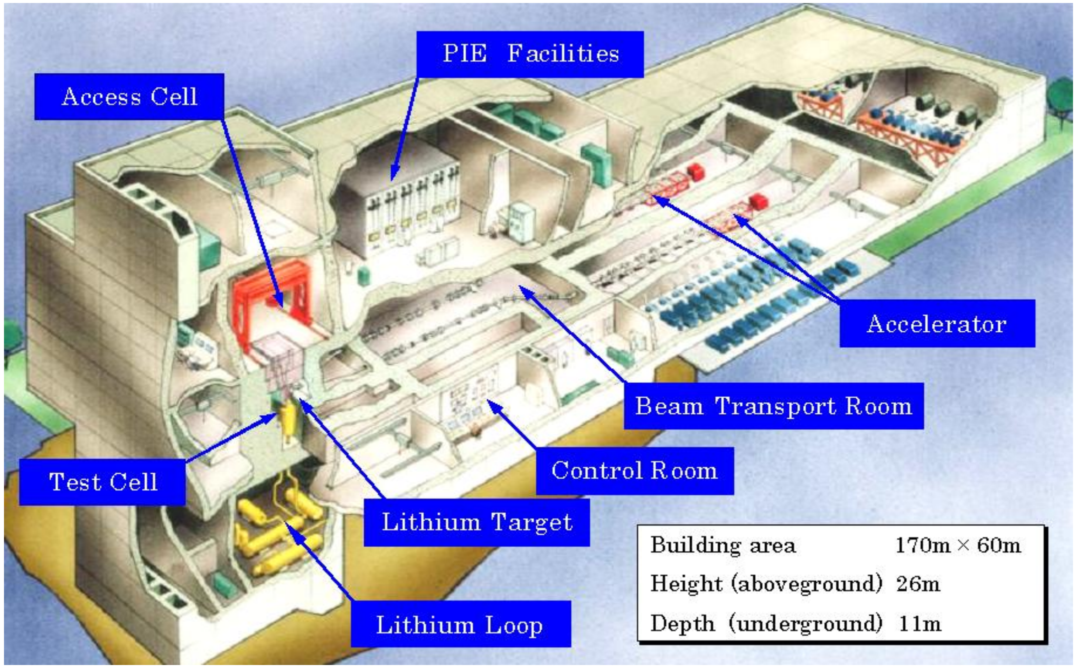
A CH-Injector for XADS

Parameter	CH	SPOKE
Nr. of cavities	4	40
Length (m)	8	40
E_a real estate (MV/m)	1.63	0.33
ΔE/cavity (MV)	3-3.5	0.12-0.42
E_p (MV/m)	19.5	25
B_p (mT)	22	50



IFMIF

International Fusion Material Irradiation Facility



- Beam: 40 MeV Deuterons
- Beam current 2x125 mA
- Beam power: 10 MW
- Duty Cycle 100%
- IH/CH Combination with 175 MHz

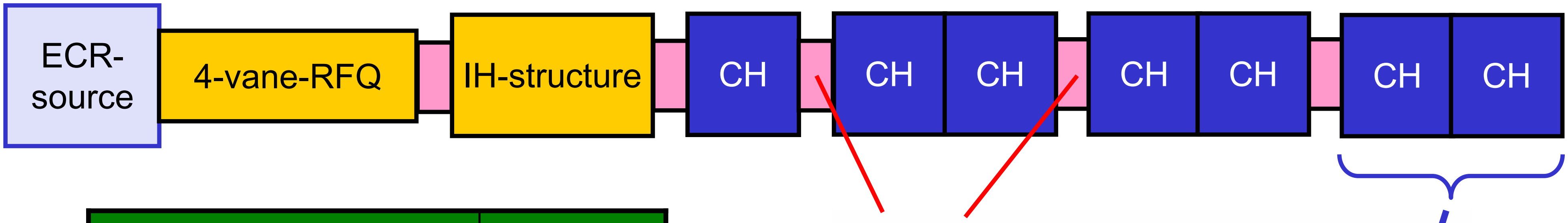
Reference design: Alvarez-DTL

- High flux source of fast neutrons
- Development of new material for fusion reactors
- Up to 100 dpa/fpy
- Liquid Li target

A 175 MHz IH-CH-Linac for IFMIF

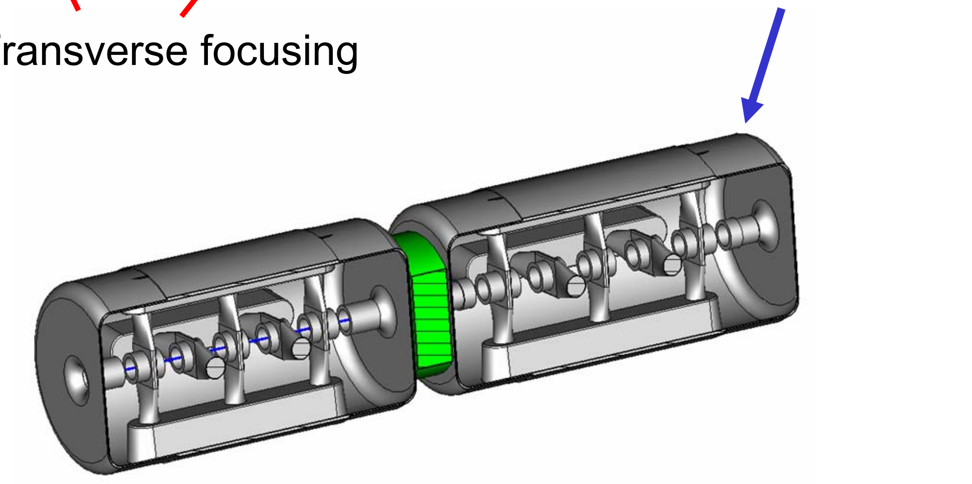
Plug power savings compared with Alvarez: 28 Million kWh/y

Not to scale



Parameter CH-tank 1	Values
E_{acc} (MV/m)	3.5
Length (m)	1.2
Gaps	12
E_{peak} (MV/m)	18.2
B_{peak} (mT)	33
G (Ω)	55
E_{peak}/E_{acc}	5.2
B_{peak}/E_{acc} (mT/(MV/m))	9.3

Transverse focusing



CH-tank 6 & 7

Summary and outlook

- The CH-structure is a multi cell H-mode cavity
- Suitable for the low and medium beta range
- Very promising properties
- r.t. and s.c. operation
- GSI proton linac, r.t. cavity development
- s.c. CH cavity development
- XADS, IFMIF

- s.c. protoype cavity will be tested this year
- development of mechanical tuner has started
- Mechanical structure analysis (ANSYS) has started
- First r.t. prototype will be built and tested with power

Acknowledgement

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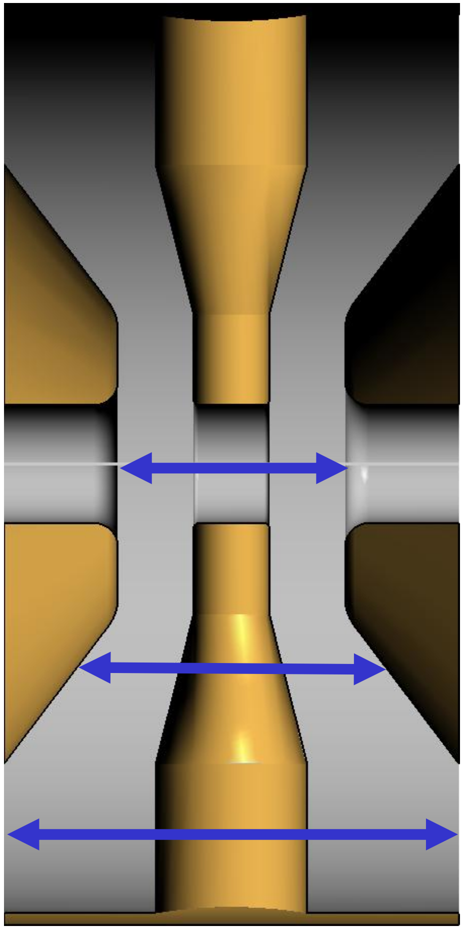
- A. Sauer
- R. Tiede

The technical staff of the IAP

Thank you for your attention

Definition of the Gradient – Peak Fields

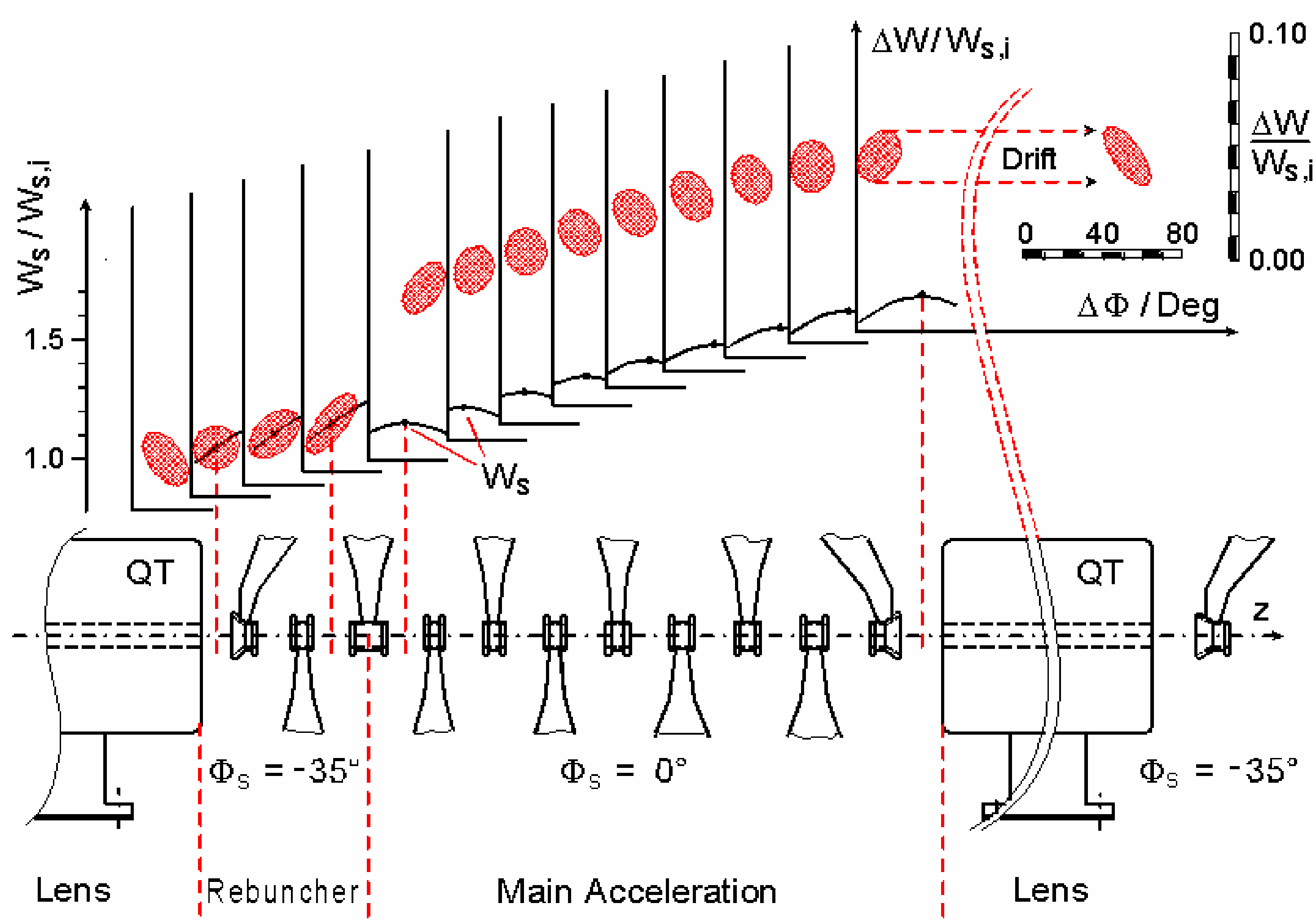


	Spoke	CH-cavity
E_p (MV/m)	25	21
B_p (mT)	50	23
E_a (MV/m) L1	6.3	---
E_a (MV/m) L2	4.2	---
E_a (MV/m) L3	2.5	3.2

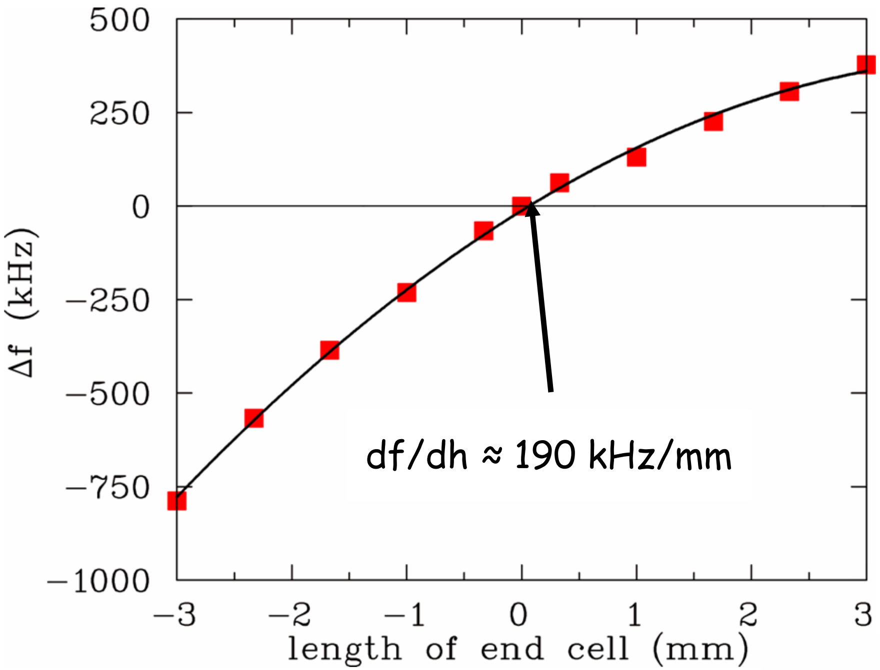
5-18 MeV section of a 352 MHz p-linac

parameter	Spoke	CH-structure
Frequency	352 MHz	352 MHz
β	0.15	0.1-0.2
E_p/E_a (L1)	3.97	---
E_p/E_a (L2)	5.92	---
E_p/E_a (L3)	10	6.59
B_p/E_a (L1) mT(MV/m))	7.95	---
B_p/E_a (L2) mT(MV/m))	11.86	---
B_p/E_a (L3) mT(MV/m))	20	7.29
Energy gain/cavity (MV/m)	0.12-0.42	3-3.5
Nr. of cavities	40	4
Total length (m)	40	8

GSI-HSI ; IH 1 tank, 2nd section



Tuning of the CH-cavitiy



Changing the length of the end cells

Development of a tuner has started