

# **Superconducting multigap H-mode cavities - R&D projects and perspectives**

# What are the R&D projects and perspectives?

1. Sc cw LINAC Demonstrator Project
2. Sc cw LINAC
3. MAX – Project
4. Summary

# Demonstrator Project = Collaboration-Project





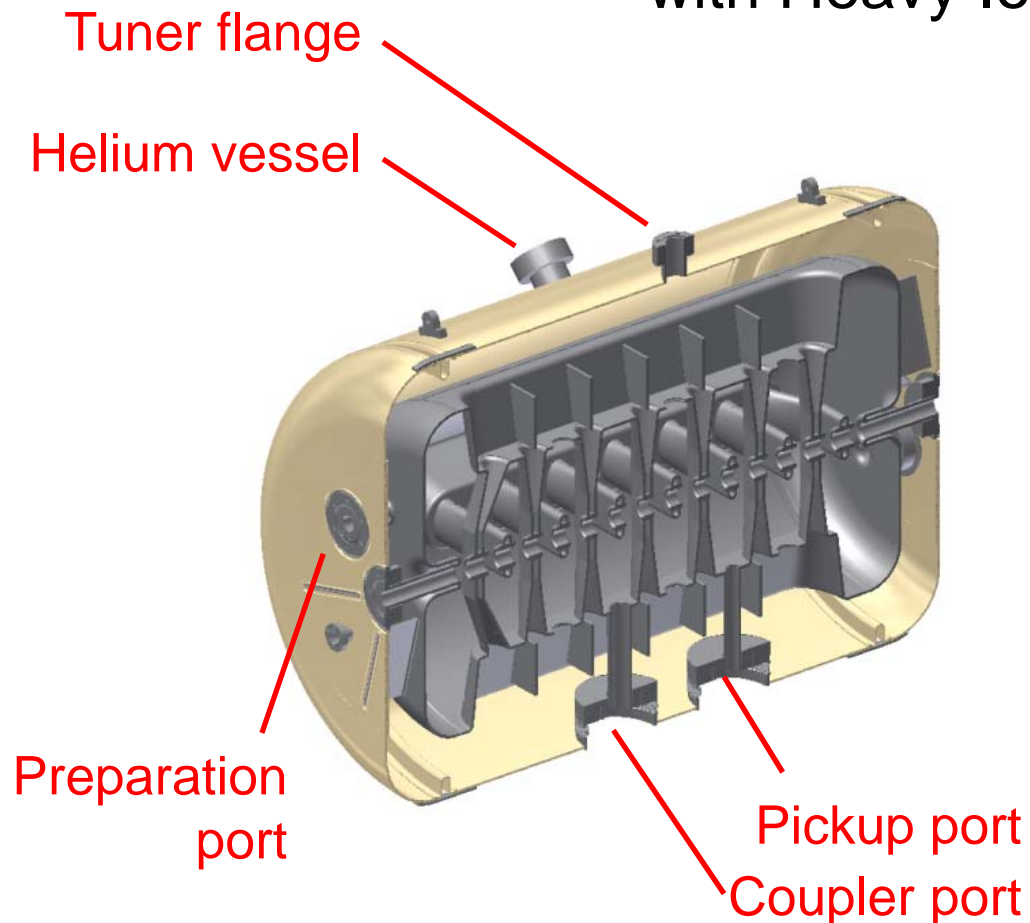
# ARD-Program of the Helmholtz-Gemeinschaft



- GSI 1x Postdoc
- IAP 1x PhD
- HIM 1x Postdoc  
1x PhD  
1x Engineer

# What is the aim?

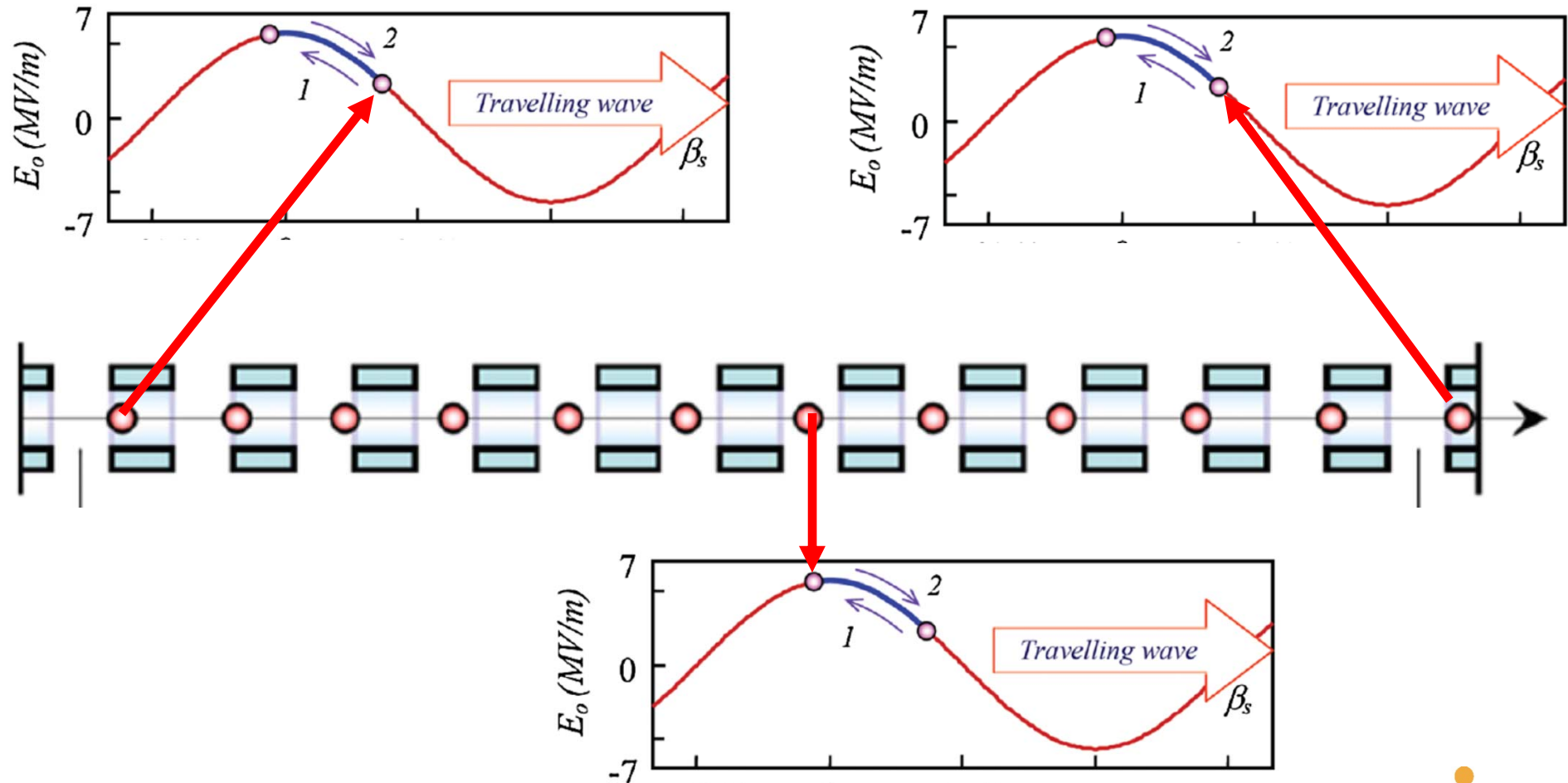
Full performance tests of a sc Crossbar H-mode (CH) Cavity with Heavy Ion Beam.



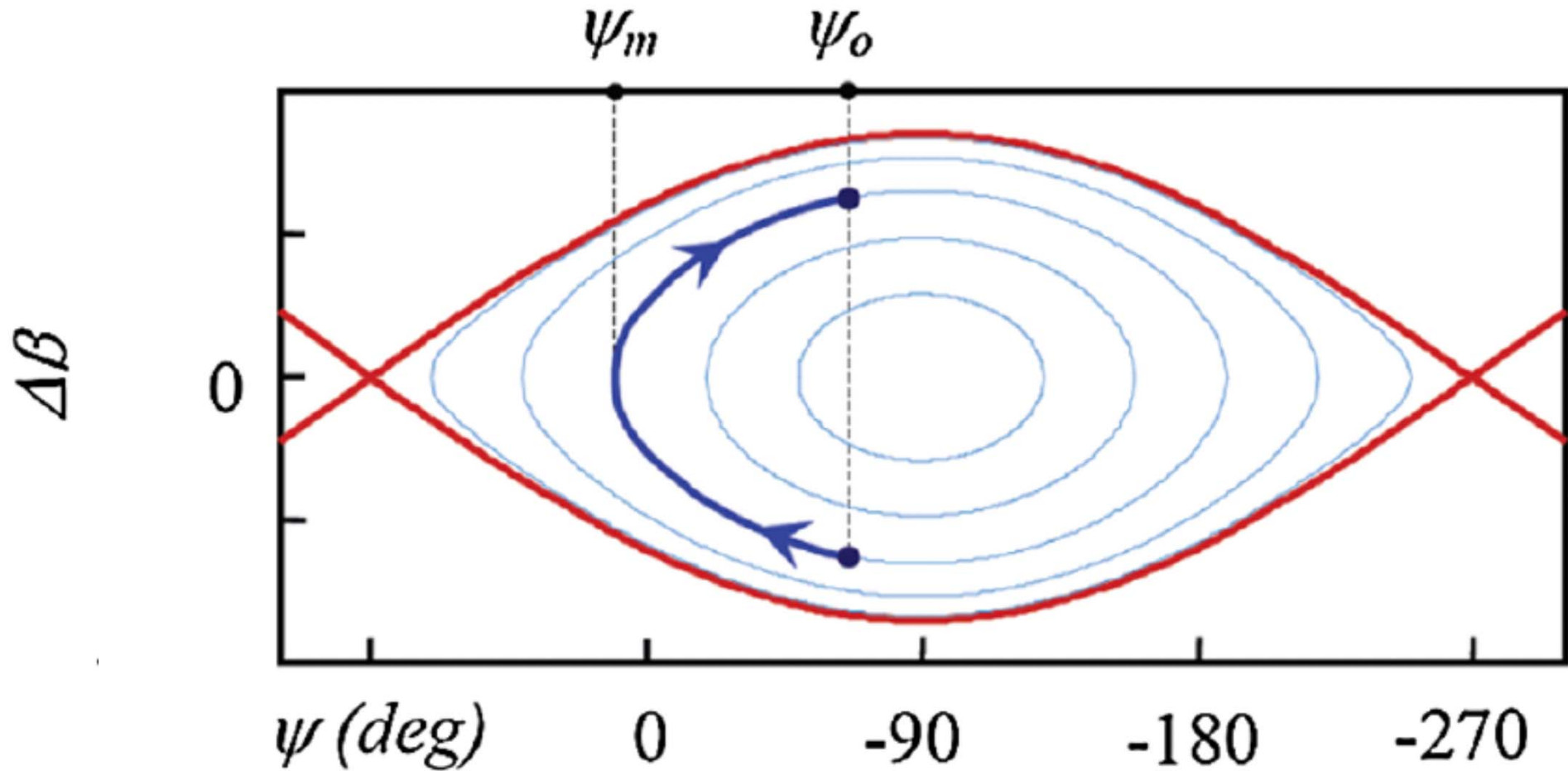
| Parameter             | Unit  |         |
|-----------------------|-------|---------|
| Beta                  |       | 0.059   |
| Frequency             | MHz   | 216.816 |
| Gap number            |       | 15      |
| Total length          | mm    | 687     |
| Cavity diameter       | mm    | 409     |
| Cell length           | mm    | 40.82   |
| Aperture              | mm    | 20      |
| Energy gain           | MeV   | 2.97    |
| Accelerating gradient | MV/ m | 5.1     |
| Static tuner          |       | 9       |
| Dynamic bellow tuner  |       | 3       |

# What is EQUUS concept?

## EQUidistant mUltigap Structure

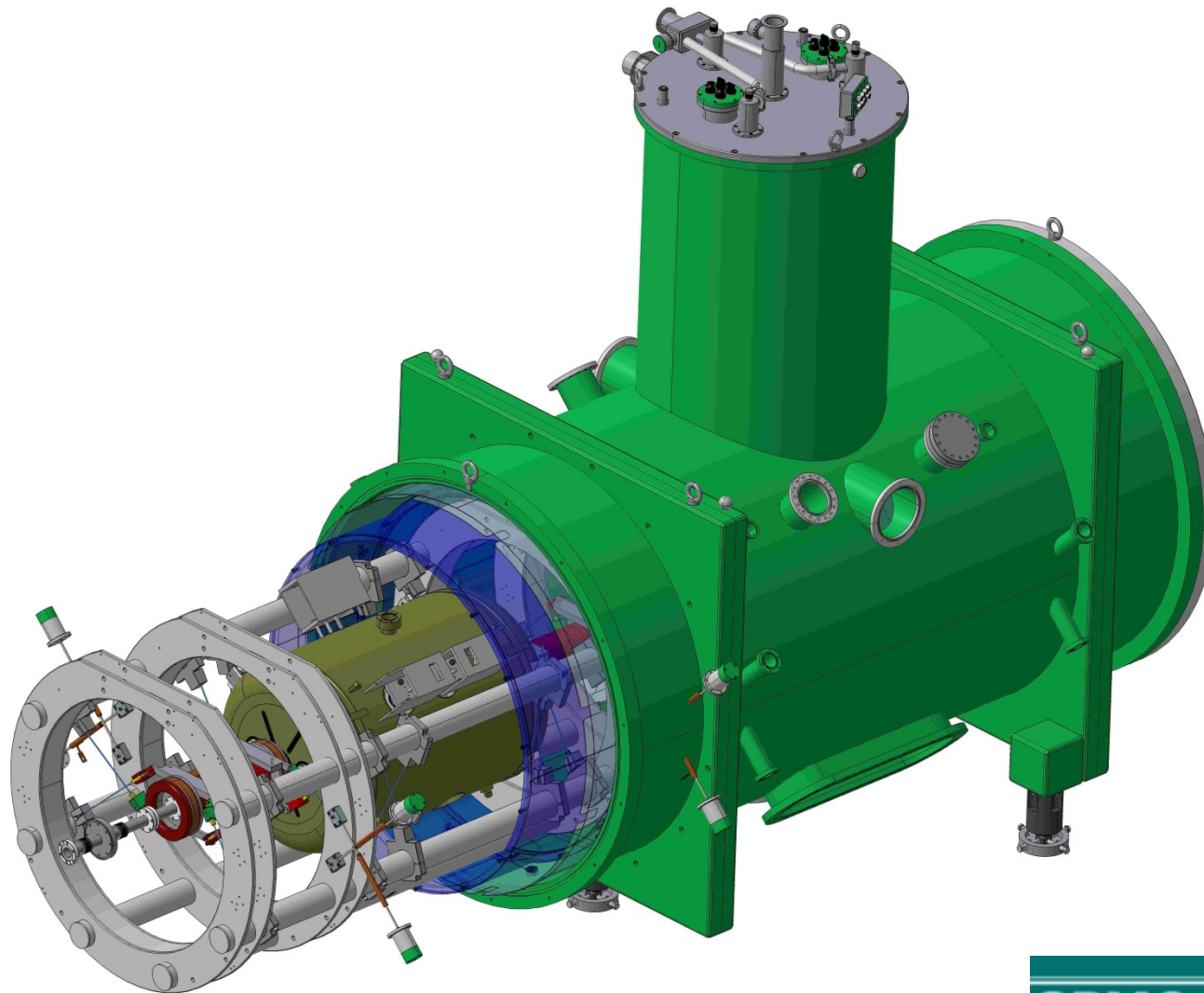


# Longitudinal Motion





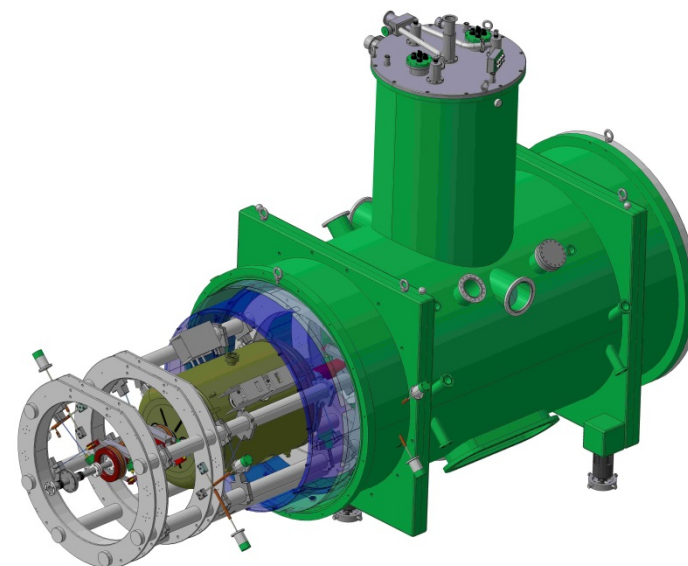
# What is the sc cw-LINAC Demonstrator?





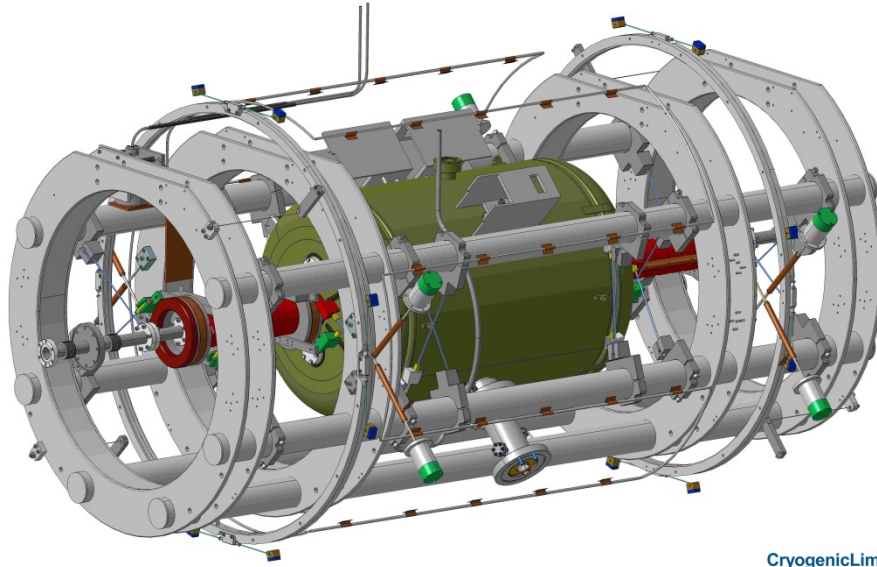
# What are the parameters of the cryostat?

|   |   |
|---|---|
| <b>Inner length (mm)</b>                                  | <b>2200</b>                             |
| <b>Inner diameter (mm)</b>                                | <b>1120</b>                             |
| <b>Material tank</b>                                      | <b>Al</b>                               |
| <b>Isolation vacuum (mbar)</b>                            | <b><math>&lt;1 \cdot 10^{-5}</math></b> |
| <b>Total leak rate (mbar*l/s)</b>                         | <b><math>10^{-9}</math></b>             |
| <b>Max. operation pressure (bar)</b>                      | <b><math>&lt;0,5</math></b>             |
| <b>Operation temperature (K)</b>                          | <b>4,4</b>                              |
| <b>Temperature hydrogen shield (K)</b>                    | <b>77</b>                               |
| <b>Material magnetic shielding</b>                        | <b><math>\mu</math>-Metall (2 mm)</b>   |
| <b>Max. static losses in stand-by operation (W)</b>       | <b><math>&lt;10</math></b>              |
| <b>Cold-warm-transition (beam-pipe) - gradient (K/cm)</b> | <b>10</b>                               |



Cryogenic Limited, UK

# How is the position monitored?



CryogenicLimited, UK

## Tolerances for position-stability

|               |        |
|---------------|--------|
| transverse:   | 0.2 mm |
| longitudinal: | 2.0 mm |

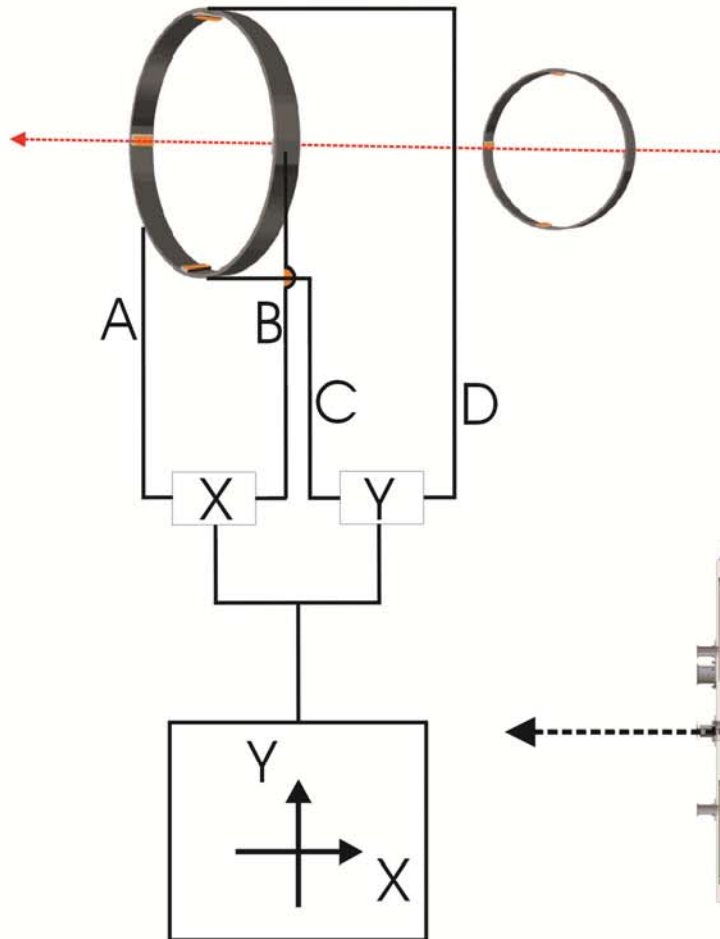
**Interferometric concepts – (e.g. LHC-dipole)**

**high accuracy: up to 0.001mm -> expensive**

**Wire Position Monitoring – (e.g. ISAC II cryomodule)**

**complex mechanical setup**

# Laser-Beam Position Monitoring



horizontal

$$\frac{A}{B} = 1 \rightarrow X=0$$

$$\frac{A}{B} > 1 \rightarrow X < 0$$

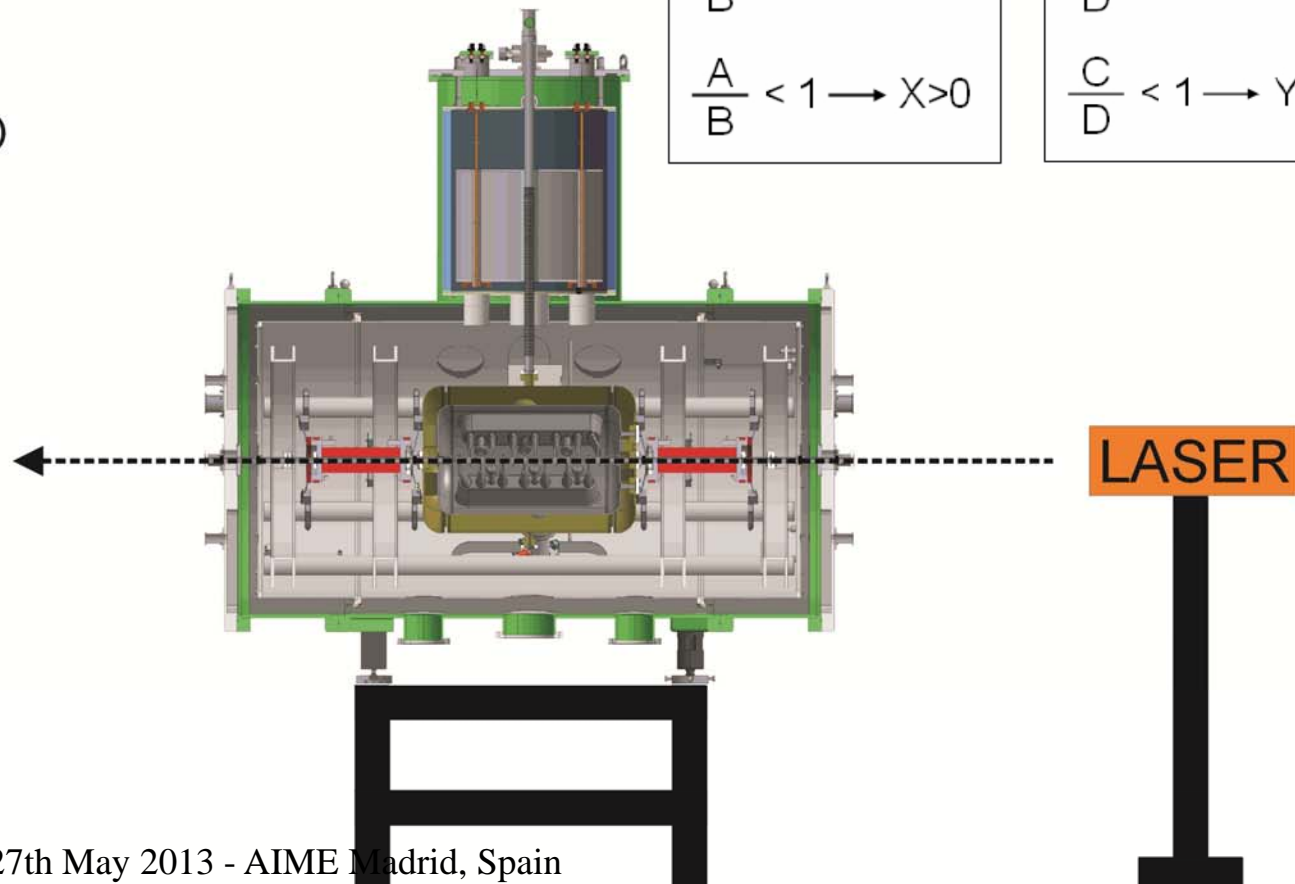
$$\frac{A}{B} < 1 \rightarrow X > 0$$

vertikal

$$\frac{C}{D} = 1 \rightarrow Y=0$$

$$\frac{C}{D} > 1 \rightarrow Y > 0$$

$$\frac{C}{D} < 1 \rightarrow Y < 0$$





# Where is the Demonstrator located @GSI?

pulse operation

3 ions (from p to U)

simultaneously

**SIS18:**  
0,9c (1-2 GeV/u)

**Facility for  
Antiproton and  
Ion Research  
(FAIR)**

**UNILAC:**  
0.2c ( $\approx 12.5$  MeV/u)

Webcam

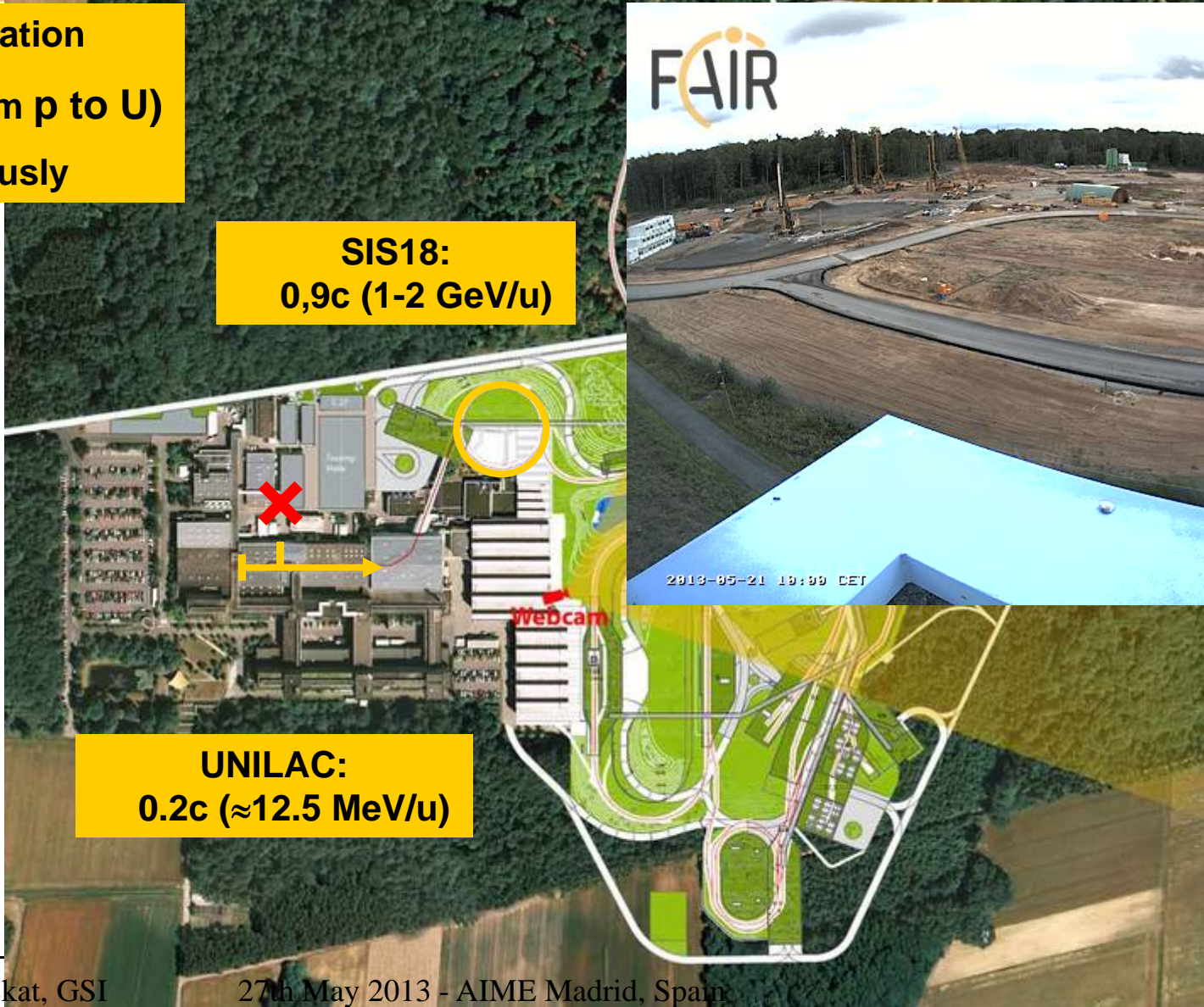


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pulse operation  
3 ions (from p to U)  
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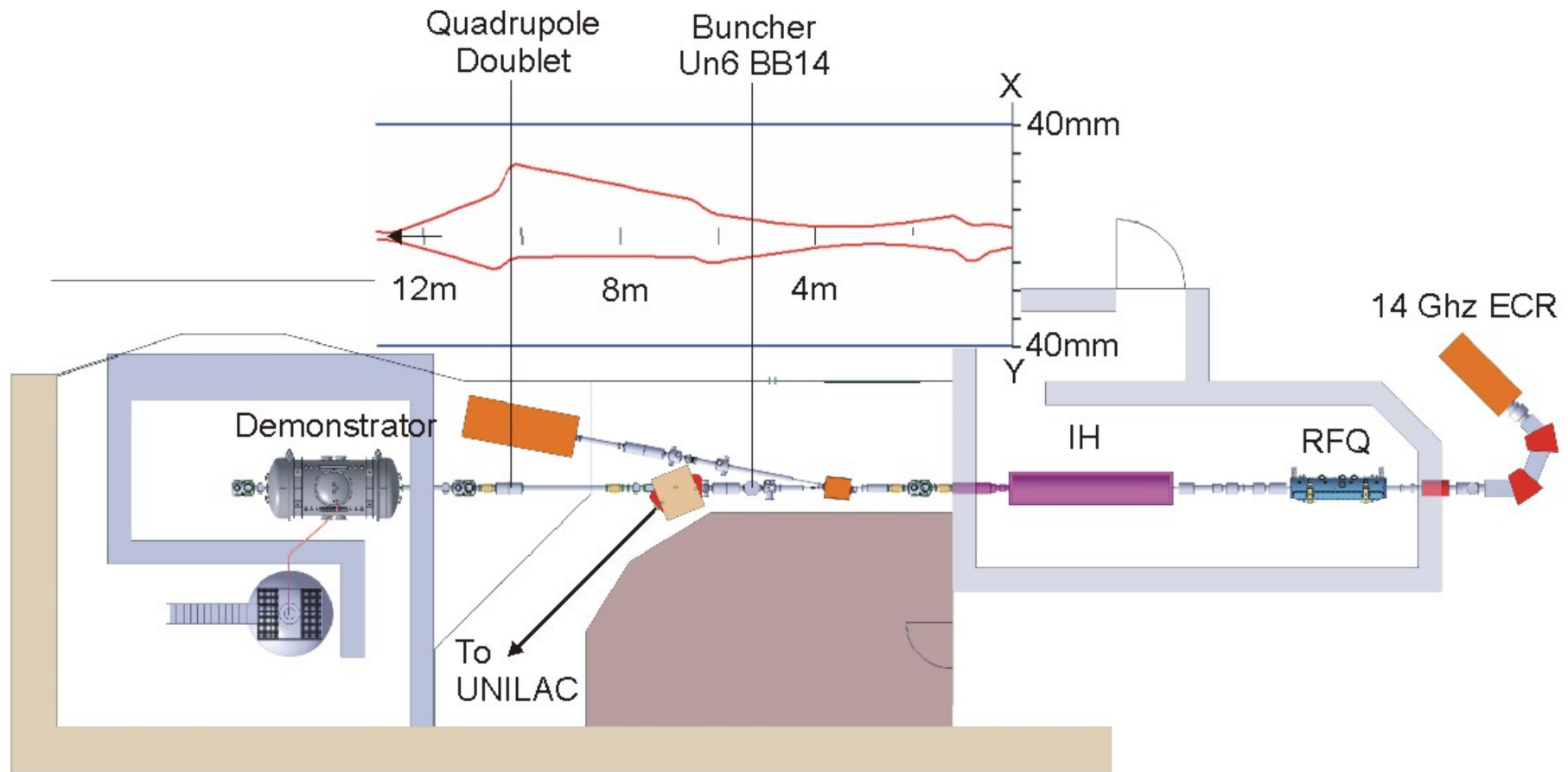
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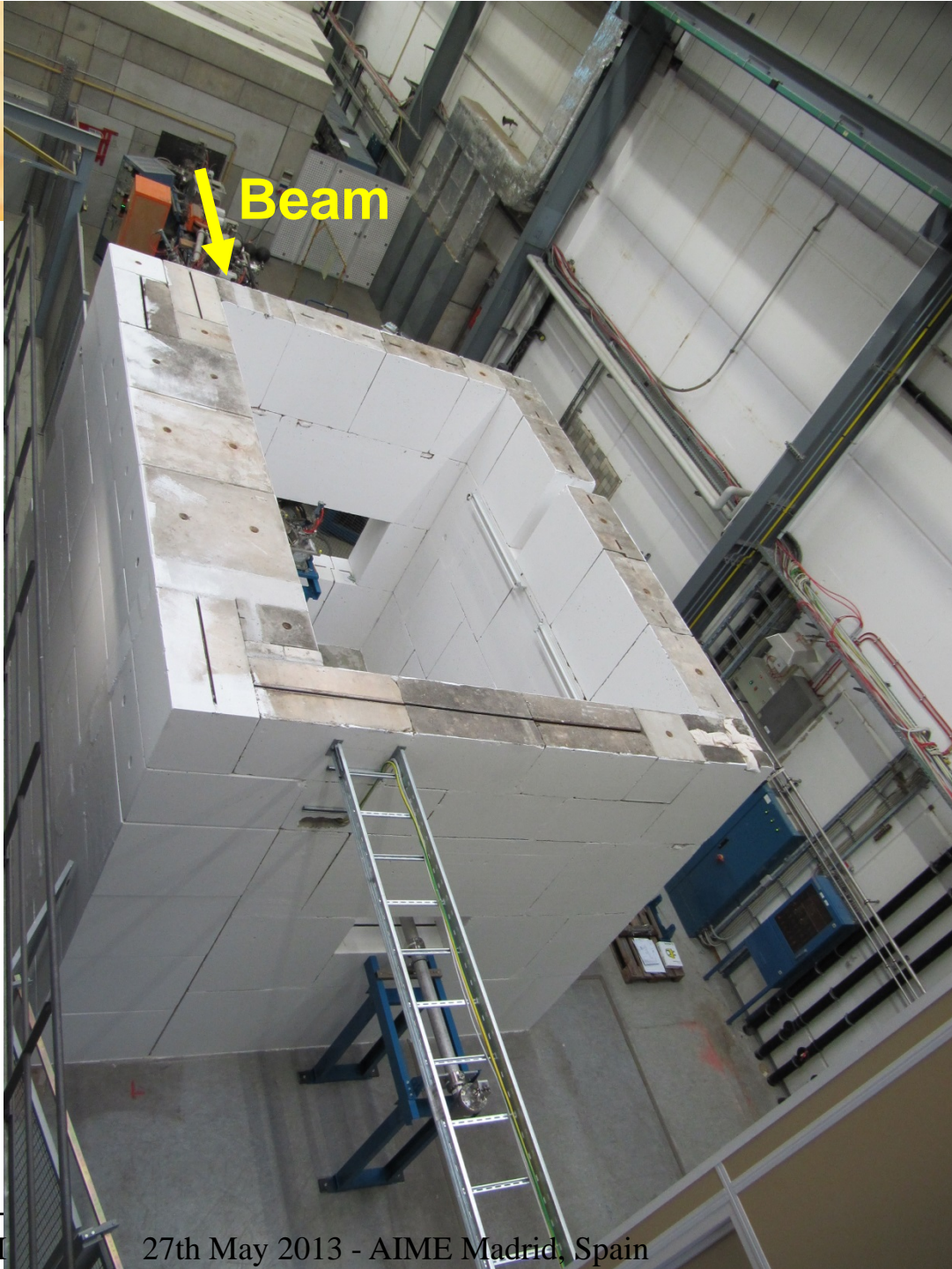


# Where is the Demonstrator mounted @ GSI?

High Charge Injector (HLI), 1.4 AMeV, 108 MHz







Dec 2012

Sascha Mickat, GSI

27th May 2013 - AIME Madrid, Spain



# What is the timetable?

**2010-12**

## **Tendering & Ordering**

order of CH-cavity is placed to RI, Germany

order of cryostat & solenoids is placed to Cryogenic, UK

**2011**

## **Delivery**

5kW-Amplifier (DB Elettronica, Italy),

3000 ltr LHe-Tank (Cryoanlagenbau, Germany)

25m<sup>3</sup> He-Recovery Balloon (Bieri-Zeltaplan, Germany)

**2013**

## **Test environment at GSI HLI is assembled**

### **Delivery of the cavity**

### **1st tests (warm & cold) @IAP**

**2014**

## **Delivery of the cryostat and the solenoid**

## **Starting full performance tests @GSI-HLI**

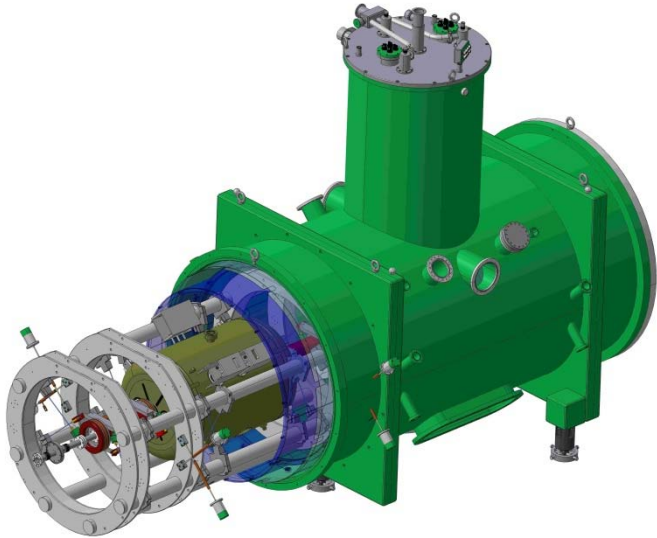


# What are the applications?

| No | Frequency [MHz] | Beta          | Status  | Application  |
|----|-----------------|---------------|---|--|
| 1  | 360             | 0.1           | 1st prototype<br>Successful rf-tests<br>(warm + cold) @IAP<br>in 2007 | Accelerator Driven System<br>(ADS)<br>„EUROTRANS“                  |
| 2  | 325             | 0.16          | 1st SAT was<br>successful in 2012                                     | Energy Booster LINAC<br>2nd stage upgrade option for<br>GSI-UNILAC |
| 3  | 217             | 0.06          | In fabrication<br>Delivery in 2013                                    | Sc cw LINAC @GSI   |
| 4  | 176             | 0.12-<br>0.18 | Under development   | MYRRHA , Mol/Belgium   |

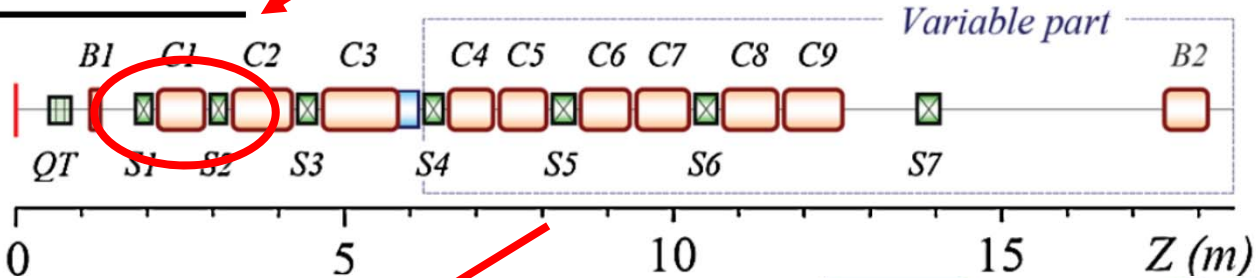


|                        |       |           |
|------------------------|-------|-----------|
| Mass/Charge            |       | 6         |
| Frequency              | MHz   | 217       |
| max. beam current      | mA    | 1         |
| Injection Energy       | MeV/u | 1.4       |
| Output energy          | MeV/u | 3.5 – 7.3 |
| Output energy spread   | keV/u | + - 3     |
| Length of acceleration | m     | 12.7      |
| Sc CH-cavities         |       | 9         |
| Sc solenoids           |       | 7         |

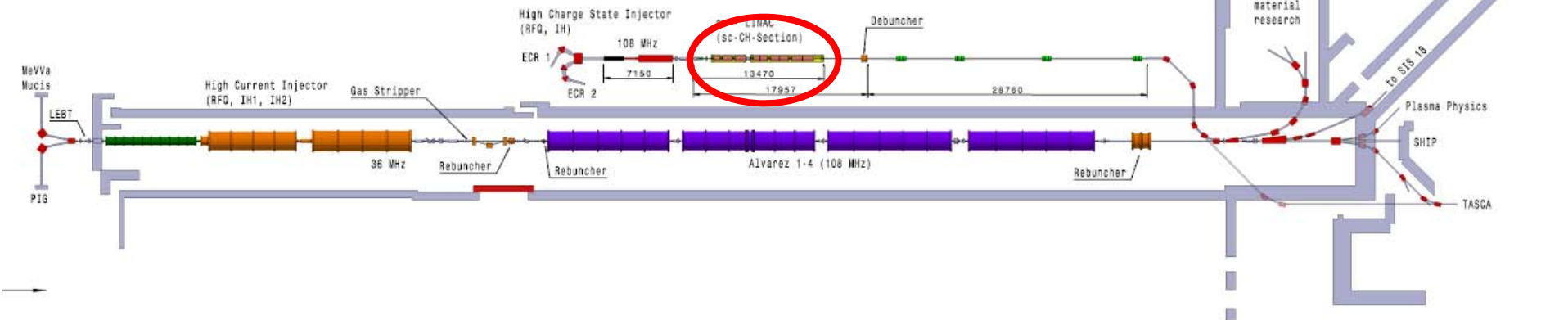


Cryogenic Limited, UK

Minaev et al (IAP, 2009)



UNILAC + CW-LINAC

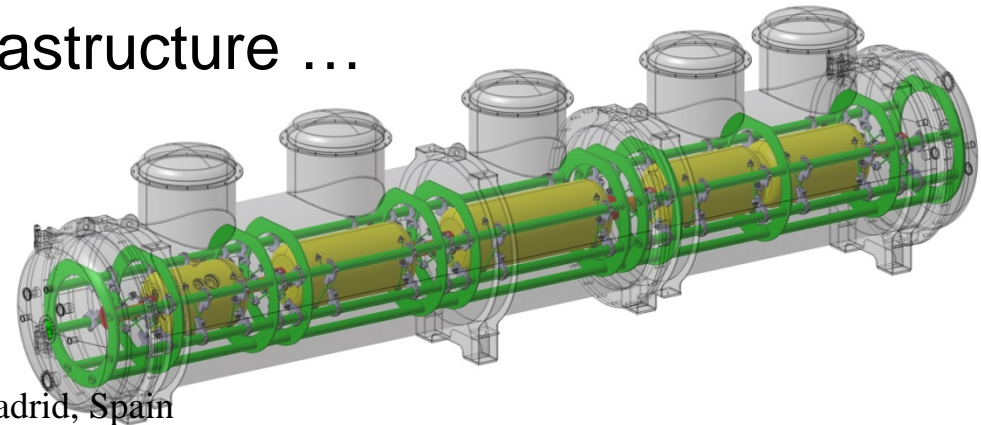


# What could be the next step?



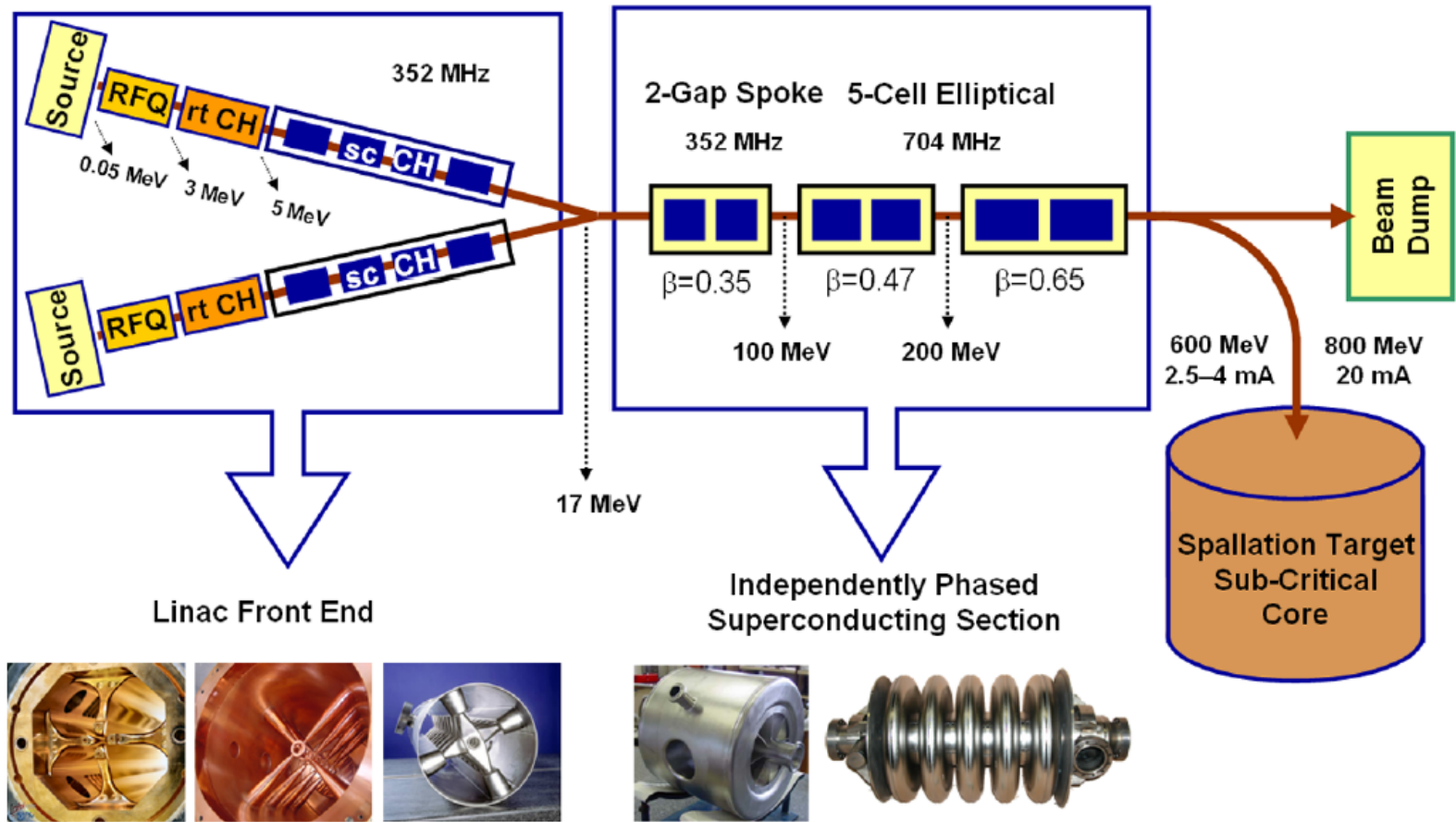
New HIM building provides Infrastructure ...

- ... for sc cavity preparation
- ... for rf testing (warm&cold)
- ... for mounting acc string





# Multi-purpose hybrid research reactor for high-tech applications (MYRRHA)







# MAX

MYRRHA ACCELERATOR eXPERIMENT  
RESEARCH & DEVELOPMENT PROGRAMME

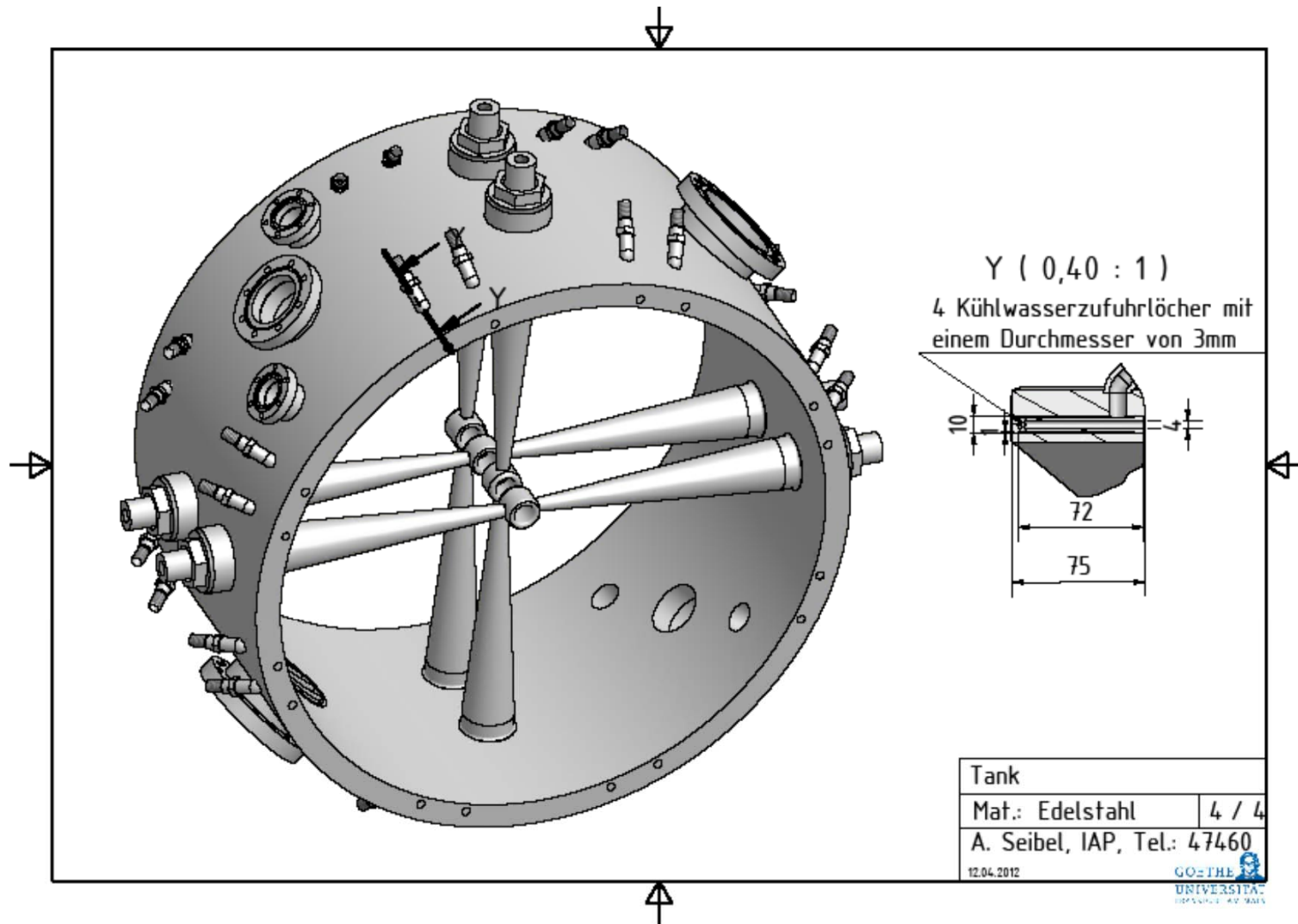


From: <http://ipnweb.in2p3.fr/MAX/>

The MAX project ensues from the recommendations of the European Union's Strategic Energy Technology Plan for the development and deployment of sustainable nuclear fission technologies in Europe.

The main goal of the MAX project is to deliver an updated consolidated reference layout of the MYRRHA LINAC with sufficient detail and adequate level of confidence in order to initiate in 2015 its engineering design and subsequent construction phase.

# MAX CH-Cavity Prototype (rt)



# MAX CH-Cavity Prototype (rt)



February 2013

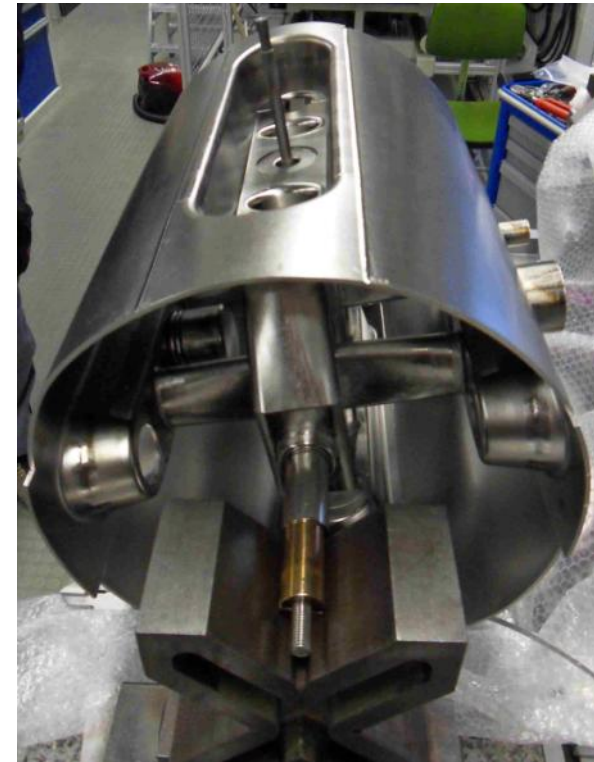
March 2013





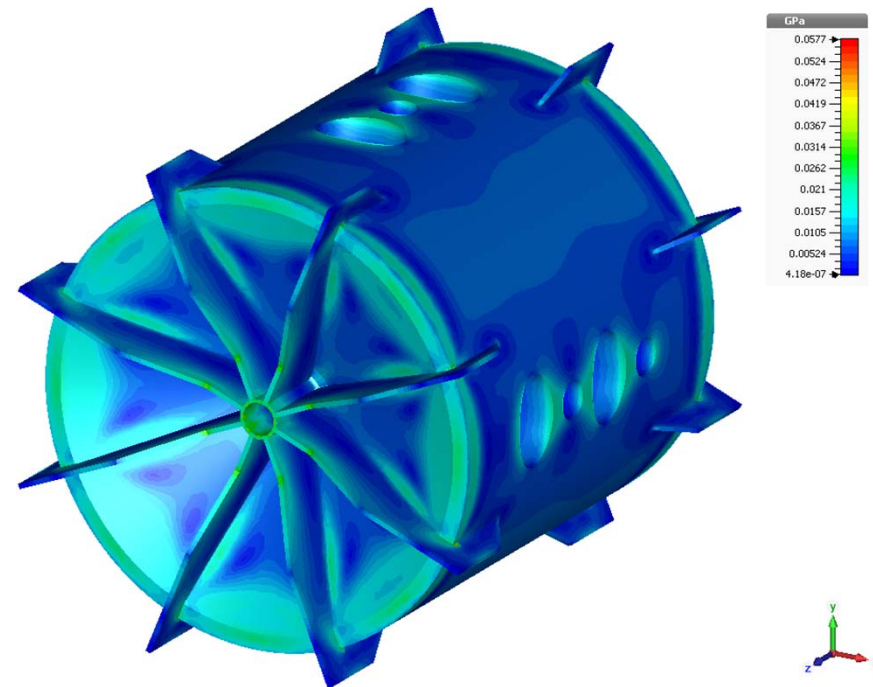
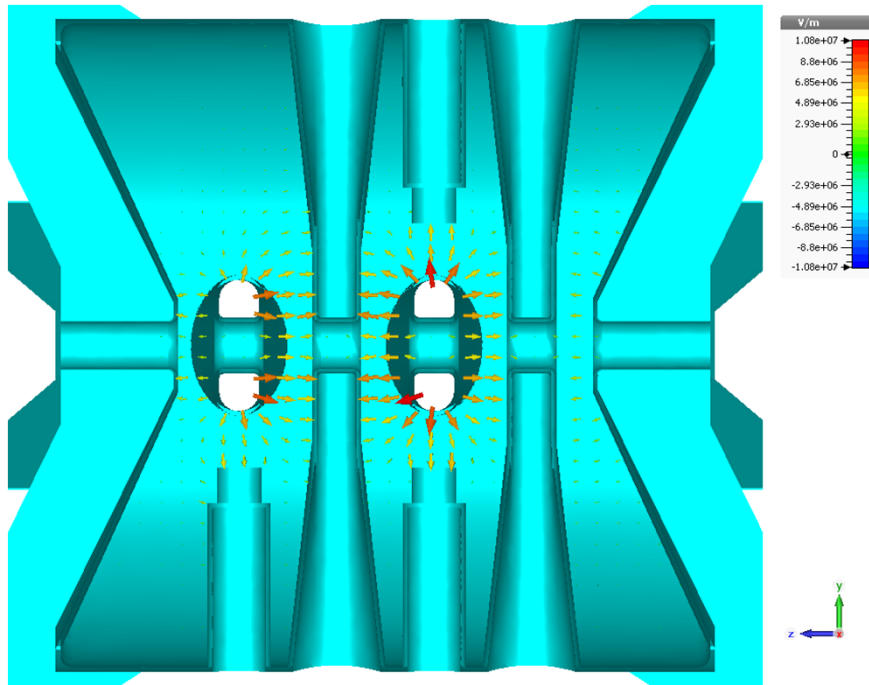
# 325 MHz CH-Cavity (sc)

During fabrication @





# MAX sc CH-Cavity Design



# What are the R&D projects and perspectives?

- The Demonstrator project is a proof-of-principle on the cavity
- The Demonstrator project itself offers a plenty of R&D, e.g. Position Monitoring System, tuning concepts, rf-coupler concepts
- Successful tests open a broad field of applications:
  - (- energy booster LINAC @GSI)
  - sc cw-LINAC
  - ADS for transmutation of nuclear waste
- Simplifying the geomtry of the cavity: fabrication, costs

# Acknowledgement

## FAIR@GSI



by name:

**Holger Podlech (MAX-Slides)**

Florian Dziuba  
Dominik Mäder  
Uli Ratzinger

Michael Amberg  
Kurt Aulenbacher  
Frank Maas

LINAC:

Thomas Dudei  
Peter Gerhard  
Victor Gettmann (HIM)  
Susanne Jacke (HIM)  
Lars Groening  
Michael Maier  
Anna Orzhekhovskaya  
Bernhard Schlitt  
Hartmut Vormann  
Chen Xiao  
Stepan Yaramishev

Winfried Barth  
Oliver Kester  
Michael Kaiser