HIE-Isolde: The Superconducting RIB Linac at CERN

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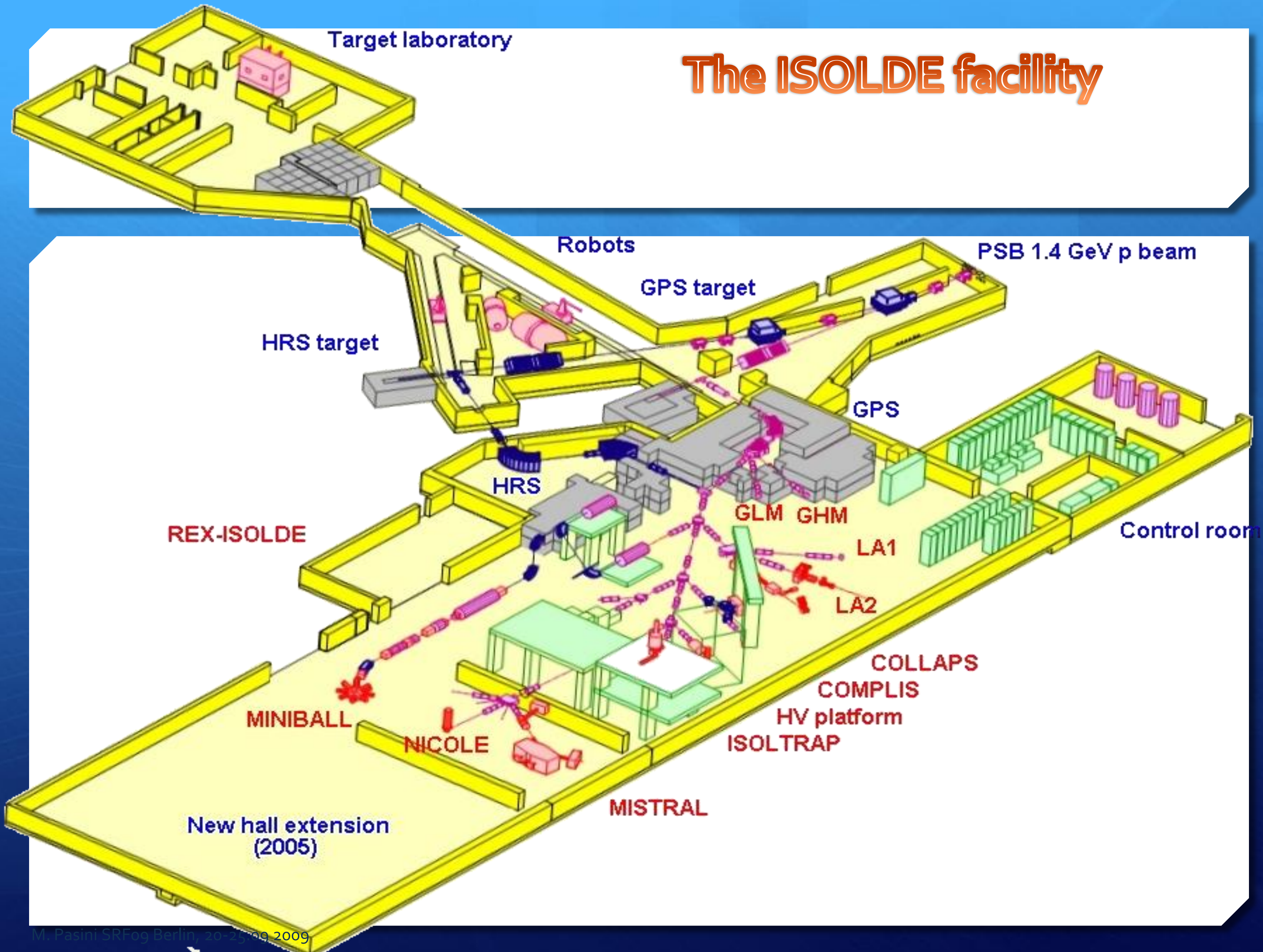
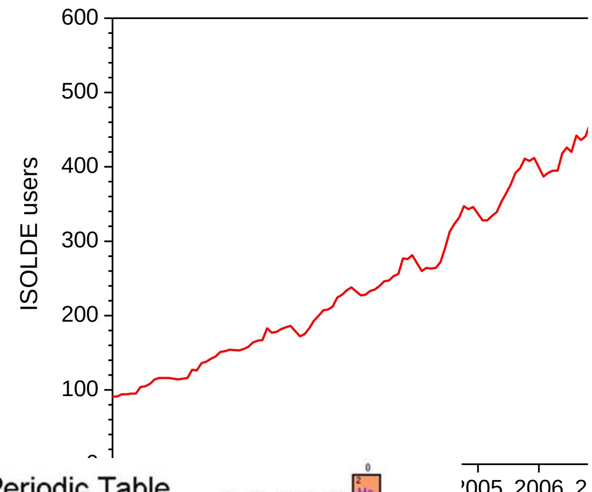
Overview

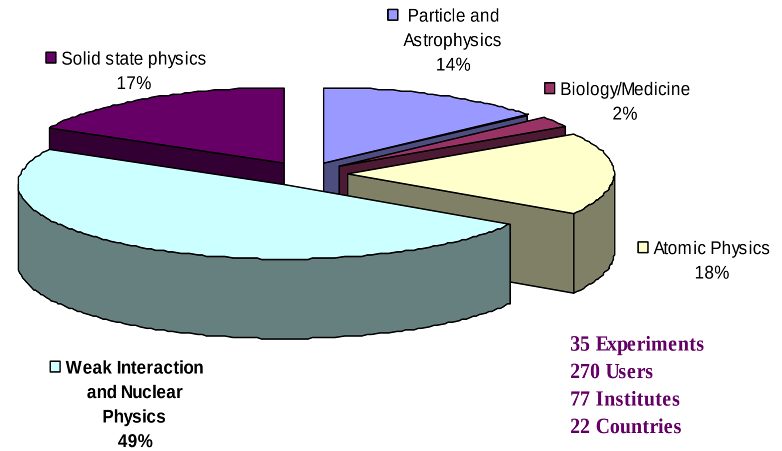
- The ISOLDE Facility- status
- The HIE-ISOLDE project: a SC linac for Radioactive Ion Beams
- R&D activity
- Status of the project
- Summary

The ISOLDE facility

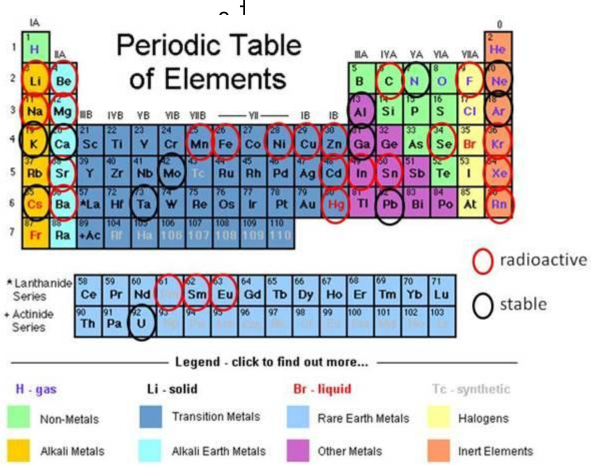


ISOLDE Community and RIBs available





35 Experiments
270 Users
77 Institutes
22 Countries



Radioactive elements run in REX so far
(click on the mass for machine summary of the run):

$^{8}Li^{3+}$(2006), $^{9,11}Li^{2+}$(2004), $^{9}Li^{2+}$(2005), $^{10,11}Be^{3+,4+}$(2006), $^{11,12}Be^{3+,4+}$(2005),

$^{10}C^{3+}$(2008), $^{17}F^{5+}$(2004), $^{17}F^{5+}$(2007), $^{24-29}Na^{7+}$, $^{29,31}Mg^{9+}$(2006), $^{30}Mg^{9+}$(2007),

$^{30}Mg^{7+}$(2008), $^{30,31}Mg^{9+}$(2007), $^{28,30,32}Mg^{8+}$, $^{61,62}Mn^{15+}$(2008), $^{61,62}Fe^{15+}$(2008),

$^{68}Ni^{19+}$(2005), $^{70}Cu^{19+}$(2008), $^{67,69,71,73}Cu^{19+,20+,20+,19+}$(2006), $^{68,69,70}Cu^{19+,20+,19+}$(2005),

$^{74,76,78}Zn^{18+}$(2004), $^{80}Zn^{21+}$(2006), $^{70}Se^{19+}$(2005), $^{88,92}Kr^{21+,22+}$, $^{96}Sr^{23+}$(test),

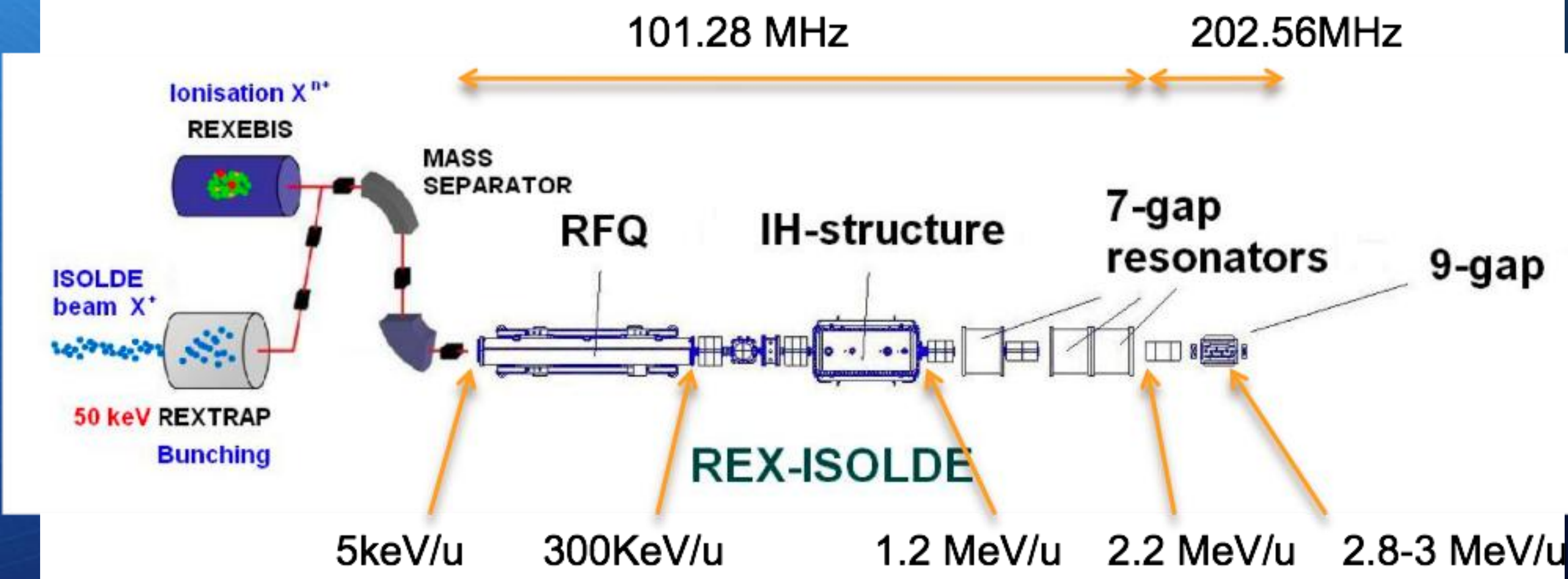
$^{96}Sr^{27+}$(2007), $^{108}In^{30+}$(2005), $^{106,108}Sn^{26+}$(2006), $^{108}Sn^{27+}$(2005), $^{110}Sn^{30+}$(2004),

$^{100,102,104}Cd^{24+,25+,25+}$(2008), $^{122,124,126}Cd^{30-31+}$(2004), $^{124,126}Cd^{30,31+}$(2006),

$^{138,138,140,142,144}Xe^{34+}$, $^{140,142,148}Ba^{33+,33+,35+}$(2007), $^{148}Pm^{30+}$, $^{153}Sm^{28+}$, $^{156}Eu^{28+}$,

$^{184,186,188}Hg^{43+,43+,44+}$(2007), $^{182,184,186,188}Hg^{44+,44+,44+,45+}$(2008), $^{202,204}Rn^{47+}$(2008)

REX-ISOLDE Post accelerator



Users next requirements:

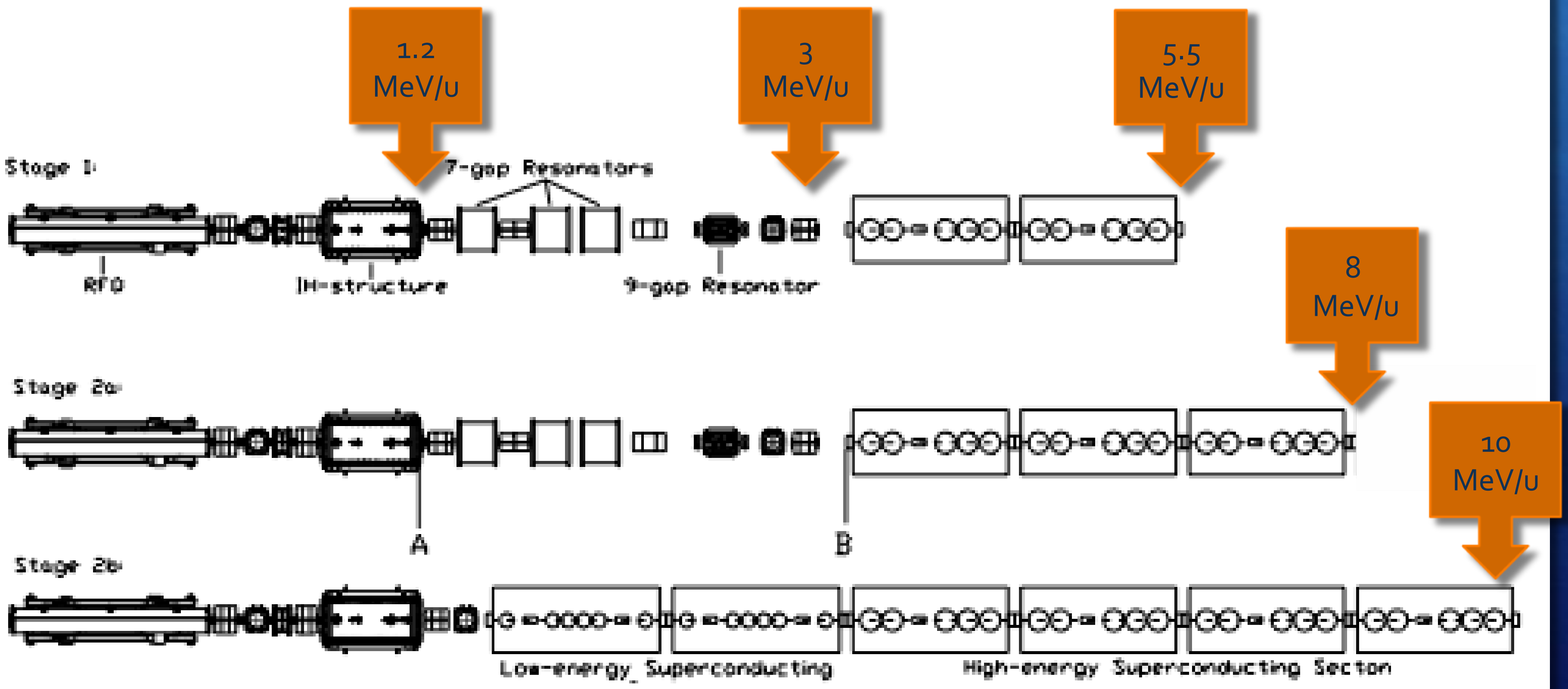
- Higher energy for the post-accelerated beam
- More beams (Intensity wise and different species)
- Better beams (High purity beams, low emittances, more flexibility in the beam parameters)

HIE-ISOLDE Project: SC-linac

- SC-linac between 1.2 and 10 MeV/u
- 32 SC QWR (20 @ β_0=10.3% and 12@ β_0=6.3%)
- Energy fully variable; energy spread and bunch length are tunable. Average synchronous phase ϕ_s= -20 deg
- 2.5<A/q<4.5 limited by the room temperature cavity
- 16.02 m length (without matching section)
- No ad-hoc longitudinal matching section (incorporated in the lattice)
- New beam transfer line to the experimental stations

HIE-ISOLDE LINAC - layout

3 stages installation



QWR cavities (Nb sputtered)

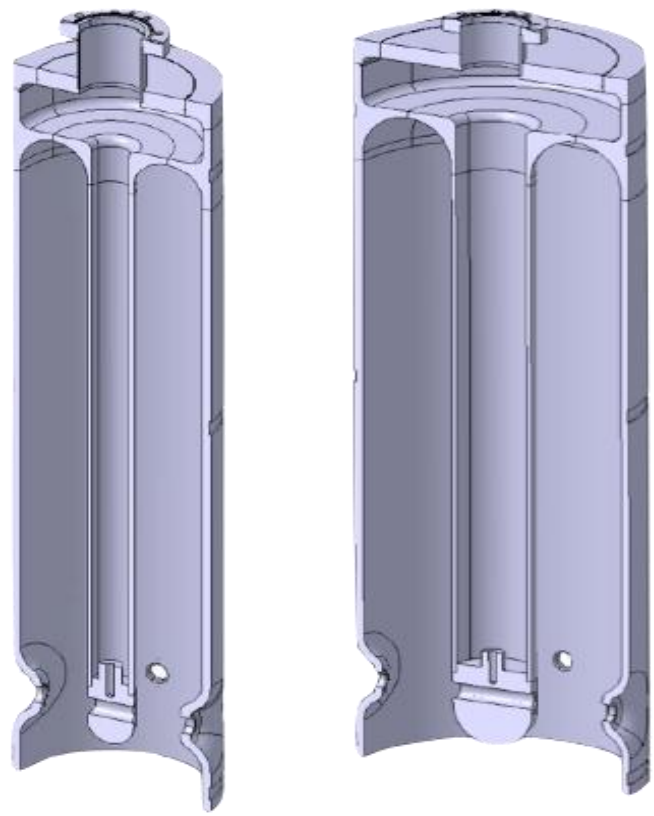


Table 1: Cavity design parameters

Cavity	**Low β**	**highβ**
No. of Cells	2	2
f (MHz)	101.28	101.28
β_0 (%)	6.3	10.3
Design gradient E_{acc}(MV/m)	6	6
Active length (mm)	195	300
Inner conductor diameter (mm)	50	90
Mechanical length (mm)	215	320
Gap length (mm)	50	85
Beam aperture diameter (mm)	20	20
$U/E_{acc}{}^2$ (mJ/(MV/m)^2	73	207
E_{pk}/E_{acc}	5.4	5.6
H_{pk}/E_{acc} (Oe/MV/m)	80	100.7
R_{sh}/Q (Ω)	564	548
$\Gamma = R_S \cdot Q_0$ (Ω)	23	30.6
Q_0 for 6MV/m at 7W	$3.2 \cdot 10^8$	$5 \cdot 10^8$
TTF max	0.85	0.9
No. of cavities	12	20

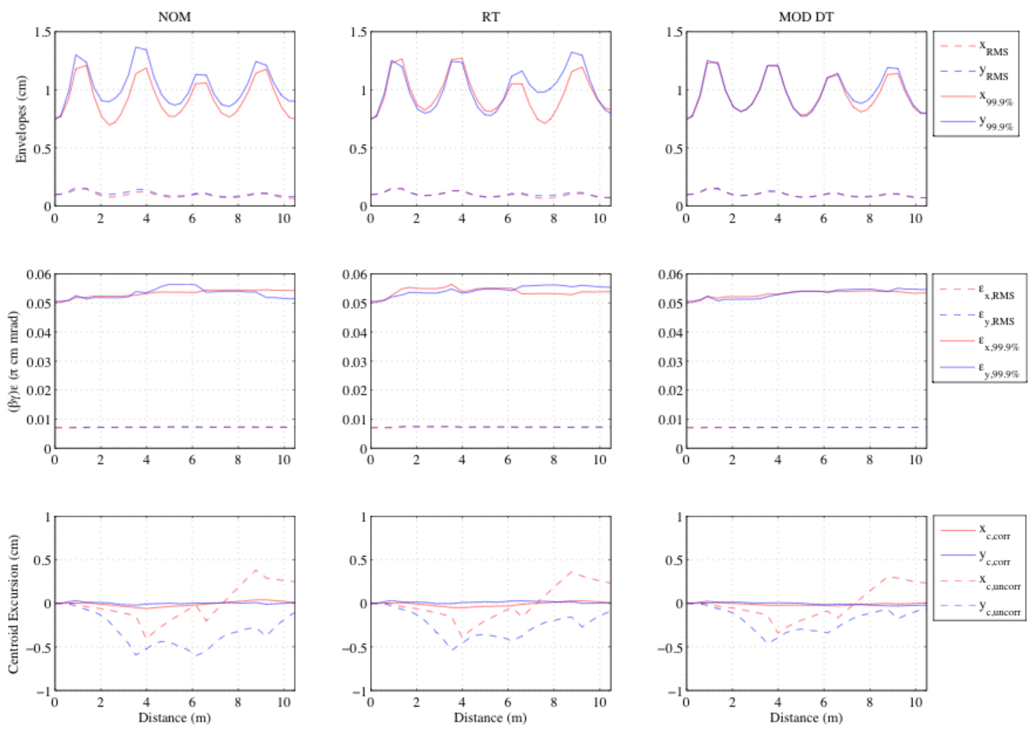
R&D activity

- RF – Beam dynamics studies
- High β cavity prototype
  - Copper substrate manufacturing
  - Chemical etching
  - Nb sputtering
- RF sub-system prototypes
  - Tuner
  - Power coupler
- SC solenoid prototype
- Cryomodule design

➢ In parallel preparation of a test stand for QWR at CERN

RF – Beam Dynamics studies

- Beam Port shape studies



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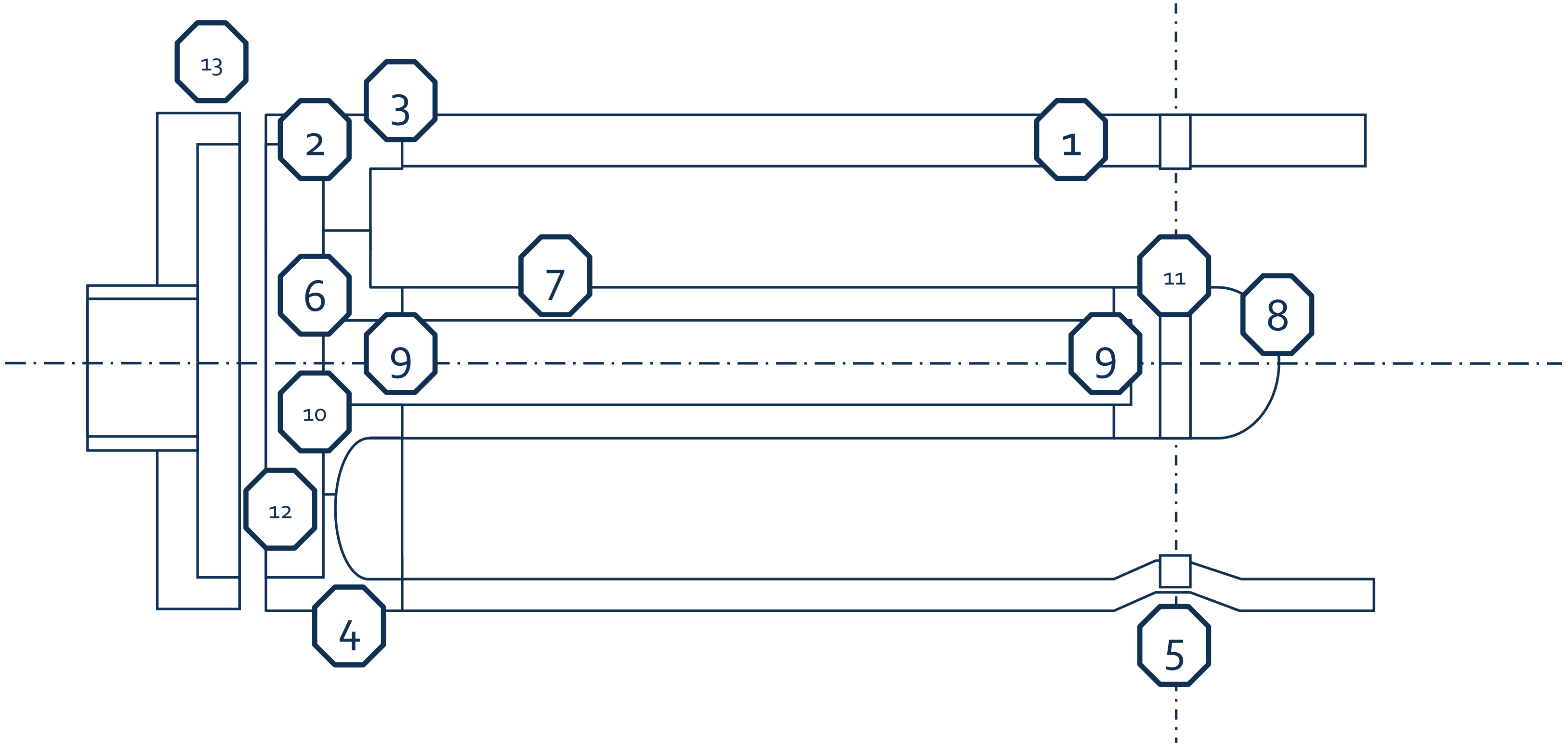
Copper Cu substrate Manufacturing



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Mechanical design criteria

- Avoid any brazing or annealing:
  - Negative experience from LNL for coating performance
  - Loss of mechanical properties
- Cu-OFE C10100 cold worked (rolled sheets, forged billets).
- Choice of manufacturing 100% at CERN workshop, thus using only available techniques:
  - Long distance EB welding possible
  - Inner EB welding not possible
  - Deep drawing preferred over 3D machining for beam ports.

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Inner and Outer conductors

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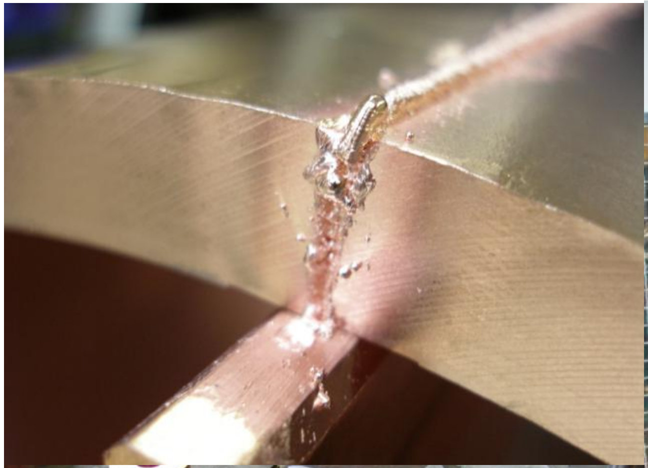
Critical construction phases



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Final welding and cleaning

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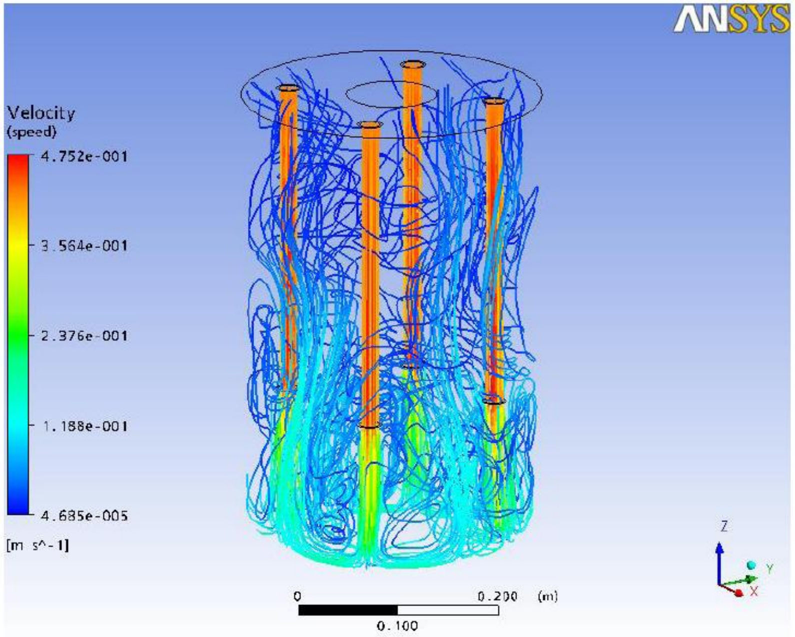
Surface treatment - Chemical etching

CFD studies of chemical polishing bath



The velocity of the fluid close the bottom wall of the cavity is quite uniformly distributed.
The values obtained are comprised between 0.04 m/s and 0.06 m/s.

SUBU: Sulfamic acid (H_3NO_3S) 5 g/L, H_2O_2 5% vol, n-butanol $C_4H_{10}O$ 5% vol, di-ammonium citrate ($C_6H_{14}N_2O_2$) 1 g/L.
Chemical polishing is carried out at 72 °C and is preceded and followed by washing with H_3NO_3S.

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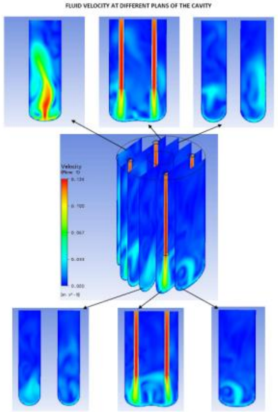
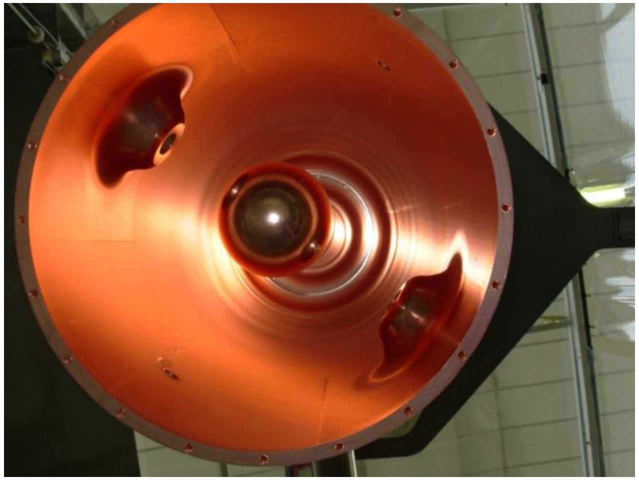
Surface treatment
(dummy and real cavity)





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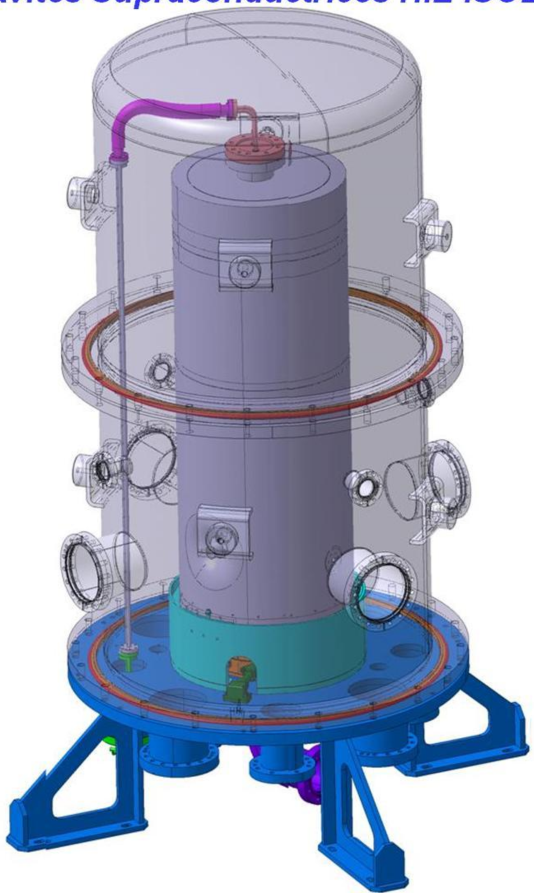
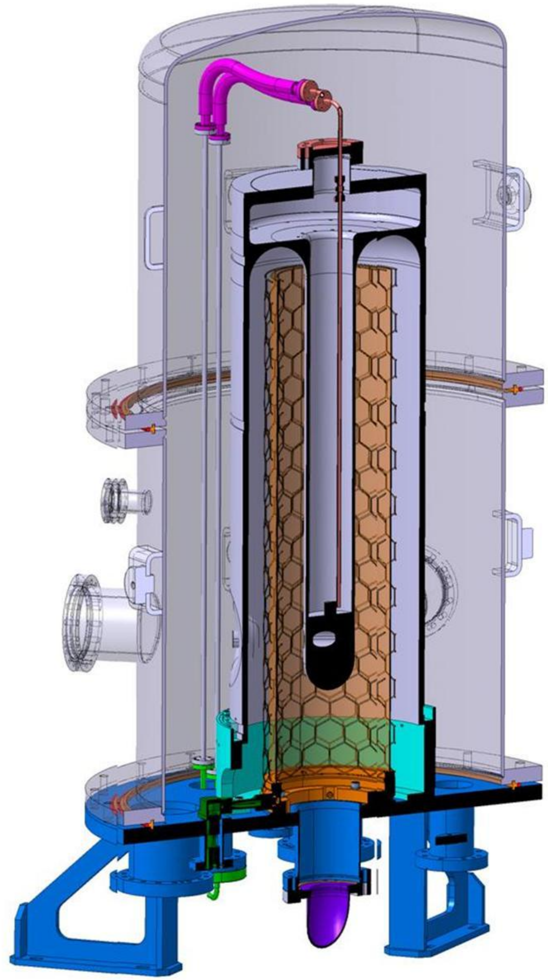
Nb Sputtering

Equipement Dépôt Niobium

Cavités Supraconductrices HIE ISOLDE





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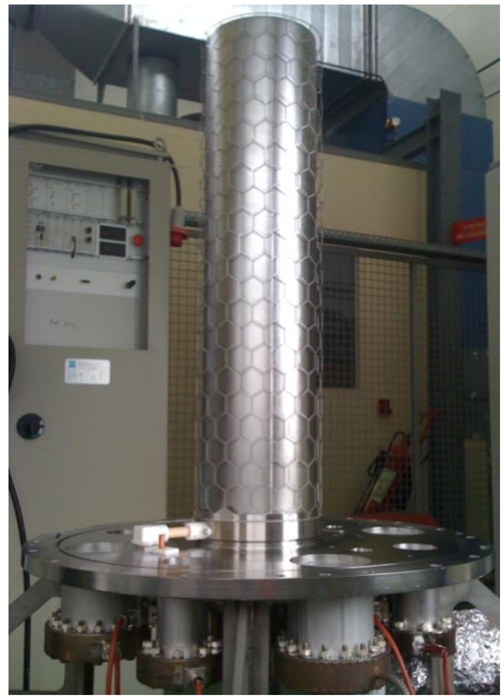
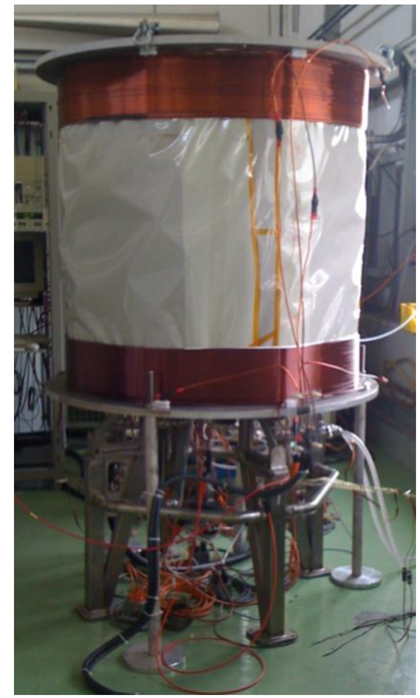
From Bias to Magnetron sputtering





<u>Bias Diode Sputtering</u>:

Outcomes:

- Unstable plasma: after 20-40 min the plasma disappeared from the outer part of the cathode. Non homogeneous distribution of the plasma.

<u>Magnetron Sputtering</u>:

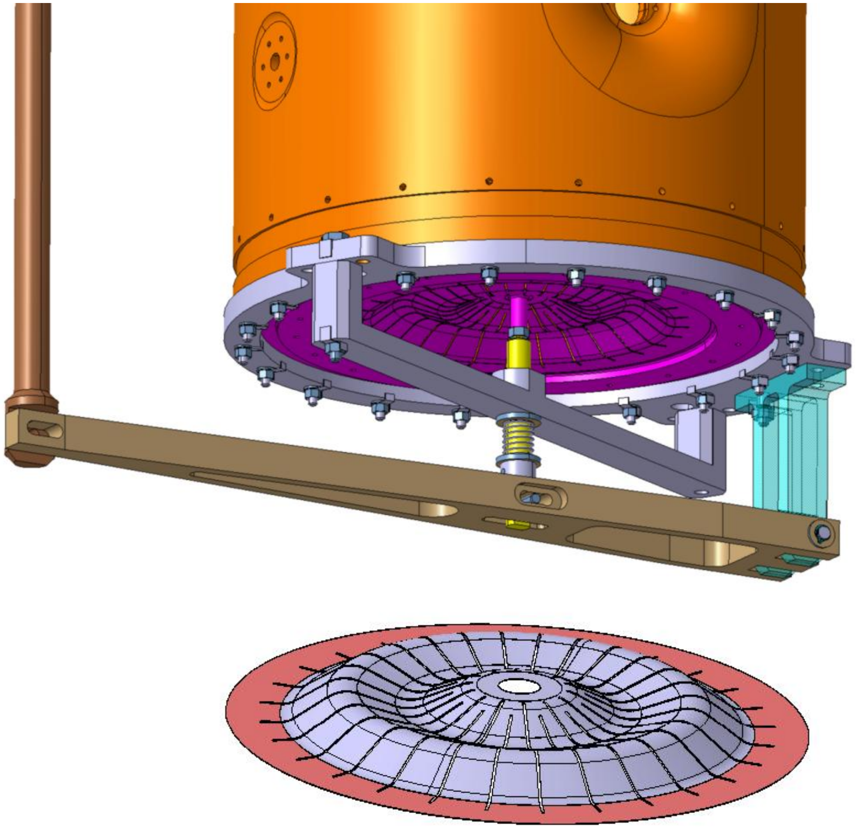
Outcomes:

- Stable plasma
- Improvements on the thickness
- More homogeneous distribution of the plasma between outside and inside

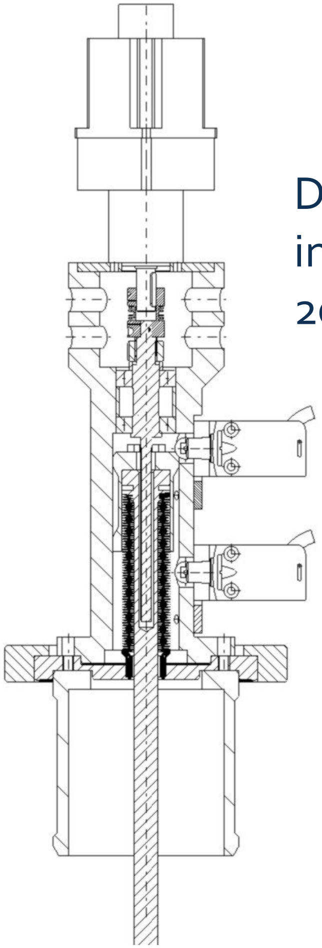
THPPO075

RF ancillaries: Tuner

Zero backlash system design



CoBe 0.3 mm diaphragm



Drive precision in the order of 200nm

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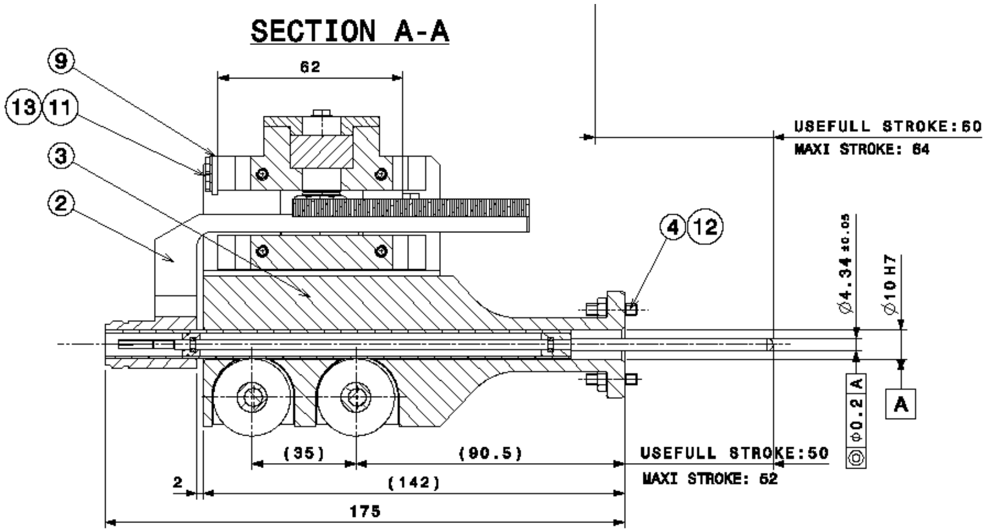
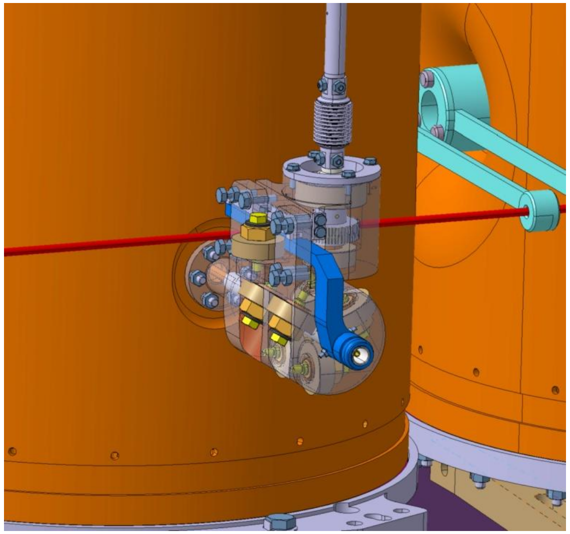
RF ancillaries: power coupler





Designed for coupling factor up to 150, no need to active cooling the coupler
Pf max= 500W

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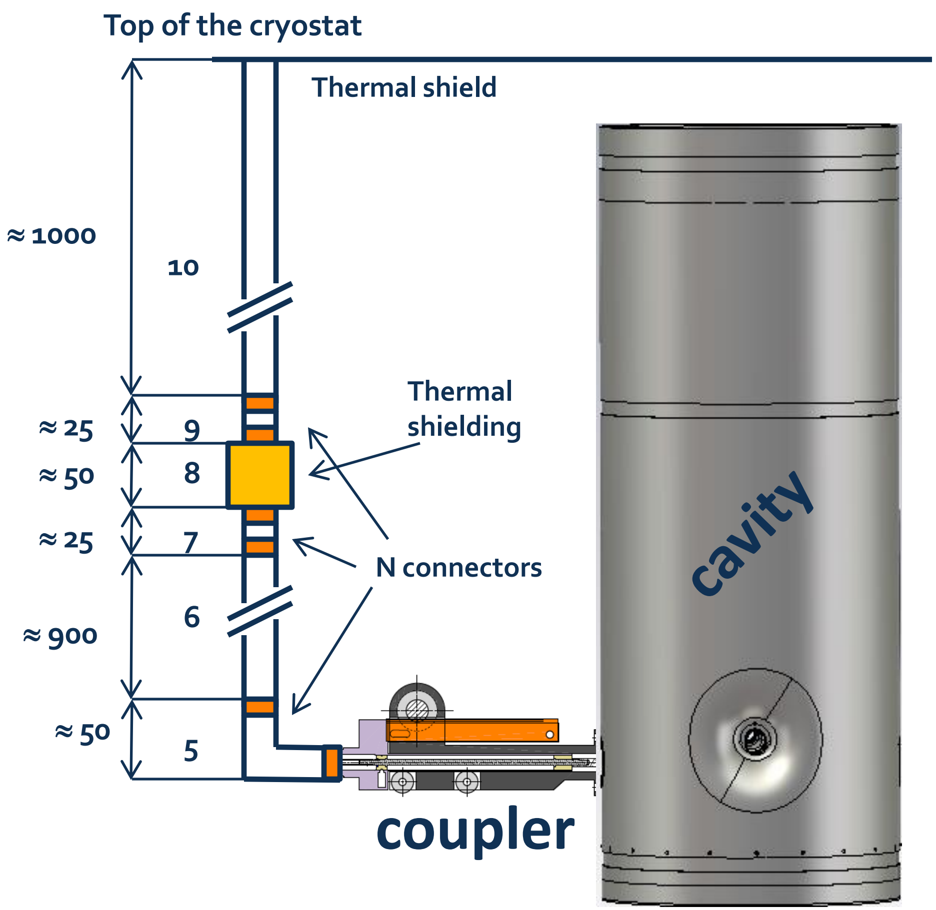
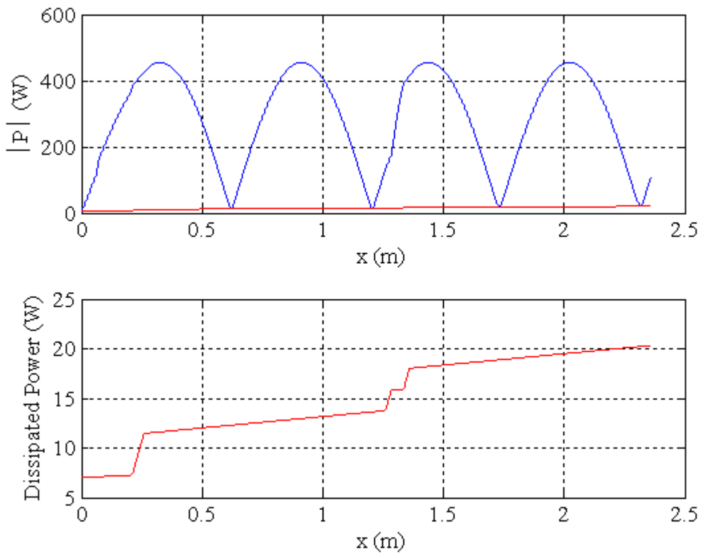
Study of the RF Power Coupler Line





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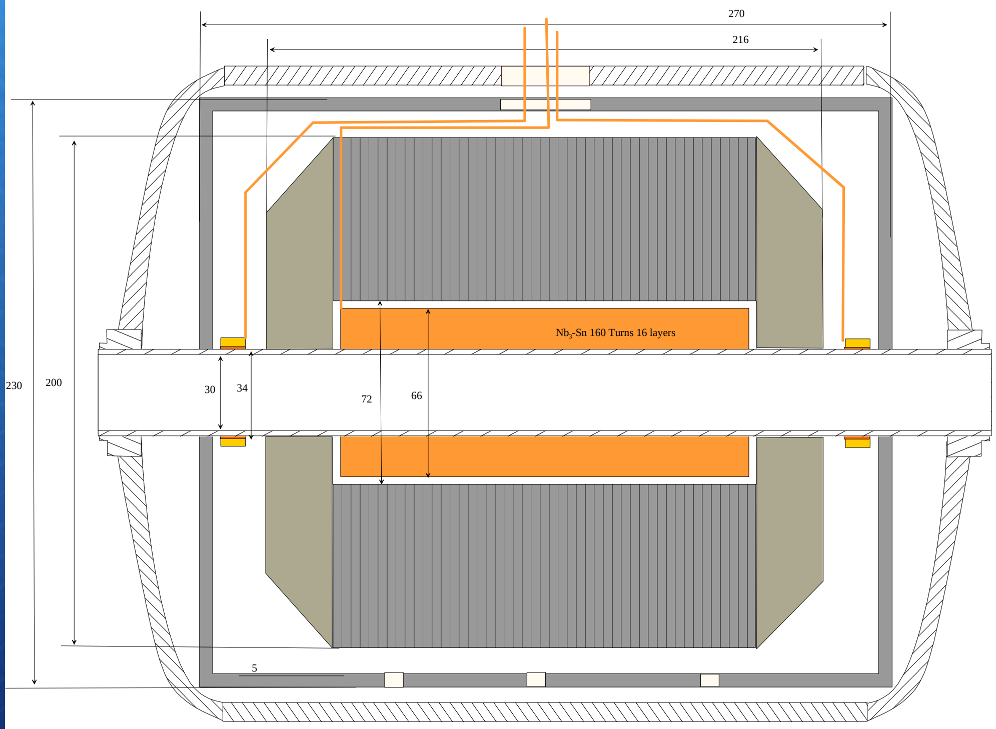
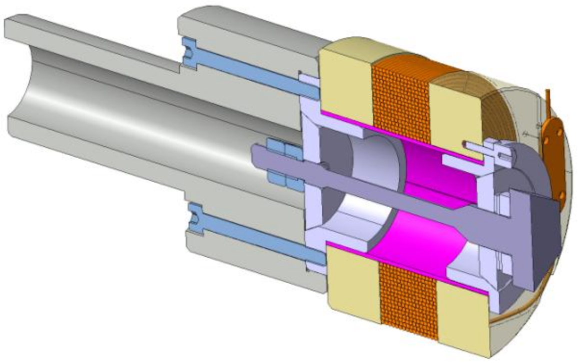
SC solenoid prototype (Nb3-Sn technology)

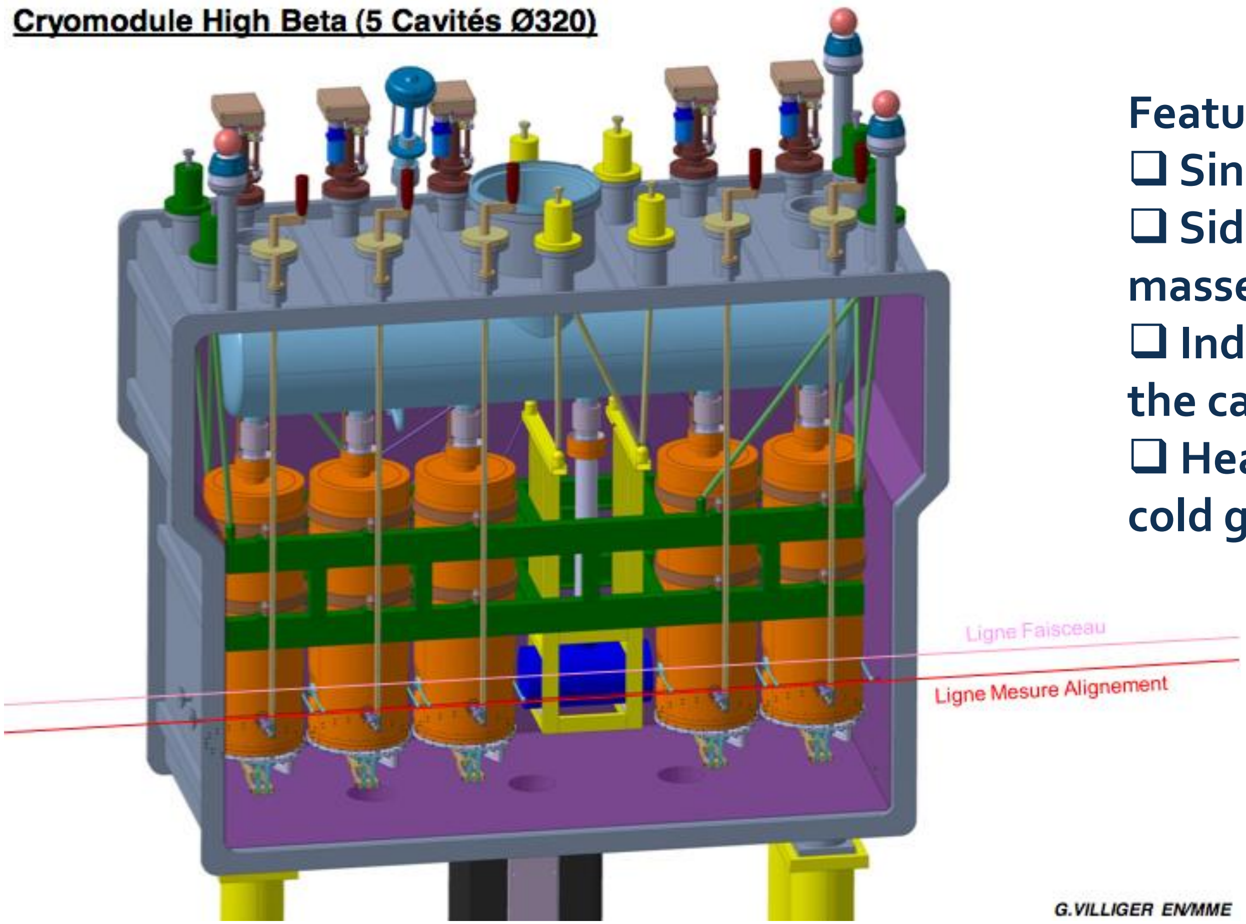


Magnetic length	0.16	m
$\int B^2\,dz$	>16.2	T^2m
B residual at 0.25m from mid	<0.2	Gauss
Max mechanical length	<0.4	m
Operating temperature	4.3	K
Inner Radius	>30	mm

Mechanical drawings for the model are completed



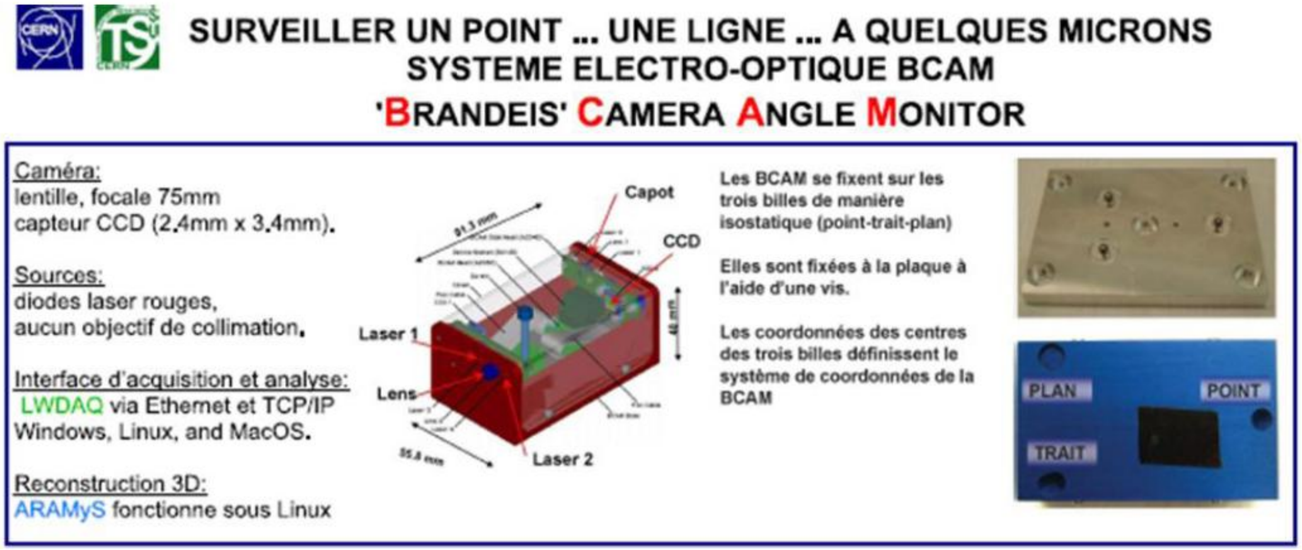
Cryomodule design



Features:
- ❑ Single vacuum cryostat
- ❑ Side loading of the cold masses
- ❑ Independent alignment of the cavities w.r.t. solenoid
- ❑ Heat shield cooled by He cold gas

A proposal for a novel alignment monitoring system

http://alignment.hep.brandeis.edu/



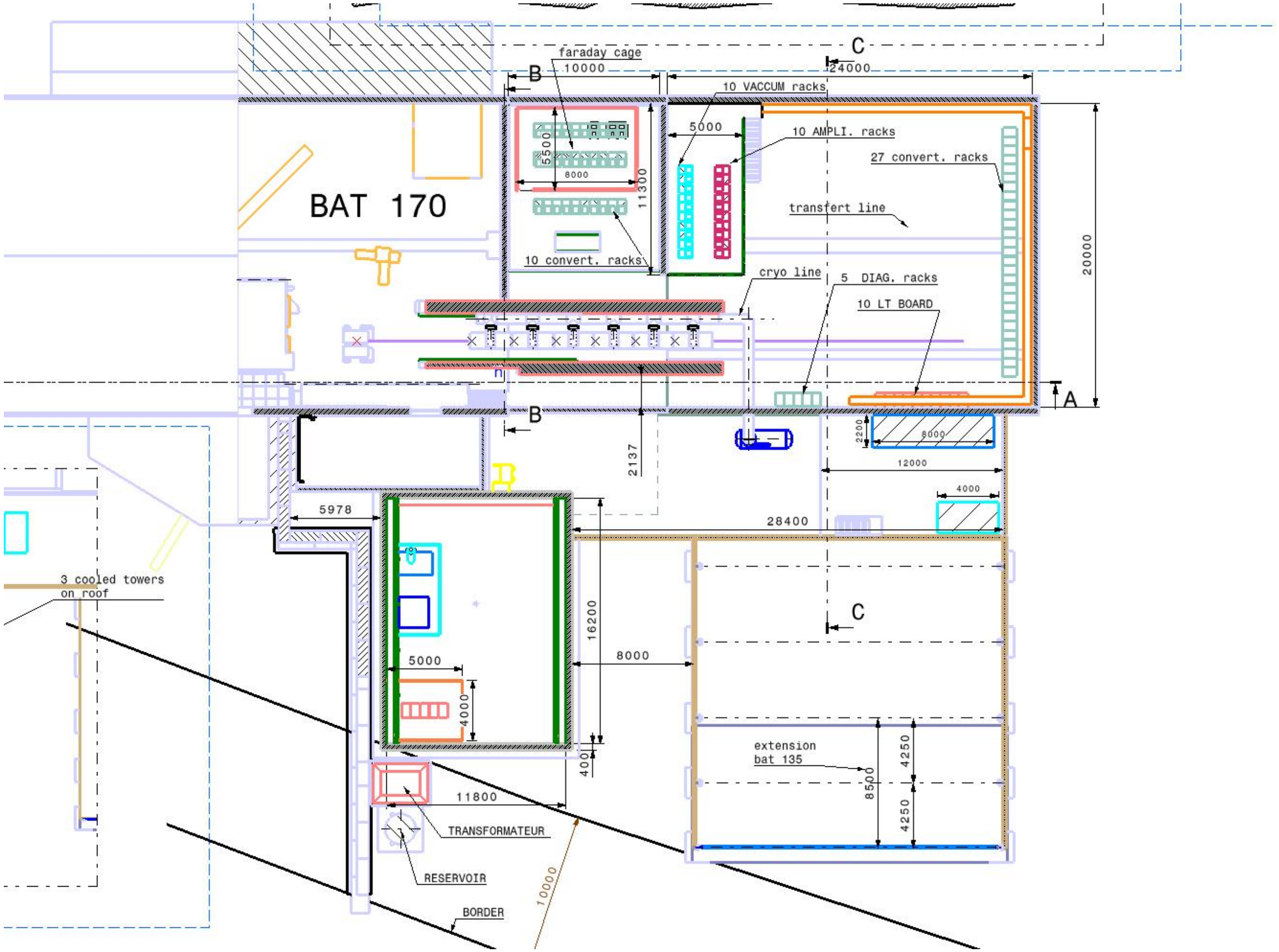
Features:

- ❑ Allows almost continuous monitoring of the position of cavities and solenoids
- ❑ Allow reconstruction of positions of cold elements in the whole linac (not limited to a single cryomodule)
- ❑ Radiation resistant and … It's affordable

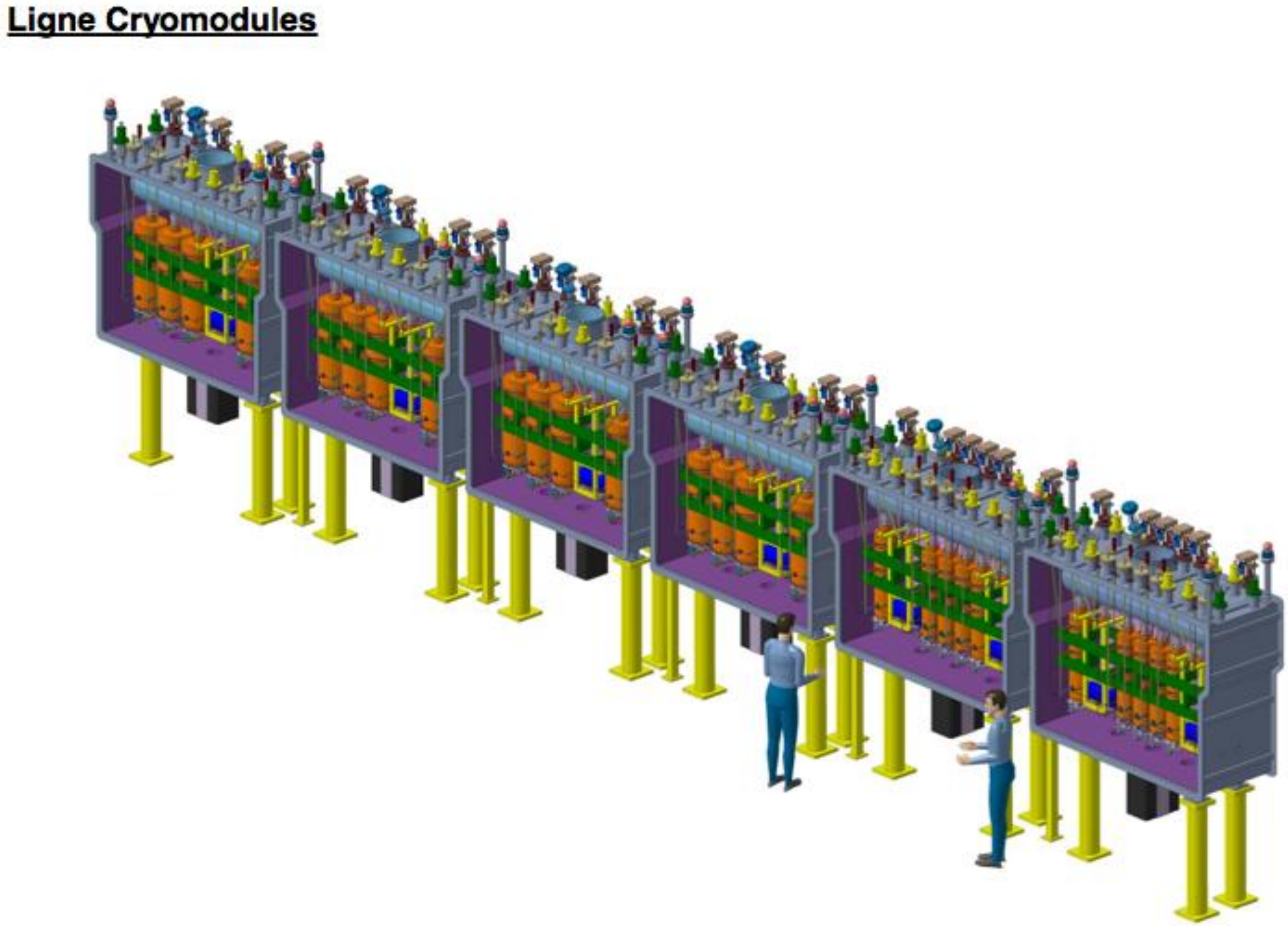
Project status

- Civil engineering and infrastructure study nearly completed
- Manpower and material cost review performed
- CERN Research board has recognized the scientific value of the project
- A project planning is being developed (tbc with resources and cash flow)
  - Start Jan 2010
  - New building delivered beginning 2012
  - Cryogenics plant installed end 2012
  - First cryomodule assembled end 2011
  - Last cryomodule installed mid 2014
  - Linac commissioned end 2014

The HIE-ISOLDE facility



The HIE-ISOLDE SC linac



Summary

- Cavity prototype nearly completed. Tests to be done @ TRIUMF before the end of the year
- Cryomodule concept design completed, will start detailed design soon after the conference
- Preparation of test bench at Cern of QWR resonators (new test cryostat is planned to be ready by end of the year)
- Complete Cavity configuration test is planned by the end of 2010.

Acknowledgments

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- ISOLDE physics and operation group
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- I would like to express my sincere gratitude to all those at CERN that have contributed and supported this activity

Thank you