HIE-Isolde: The Superconducting RIB Linac at CERN

M. Pasini on behalf of the HIE-ISOLDE study team
CERN BE-RF and Instituutvoor Kern- en Stralingsfysica, K. U. Leuven
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

Target laboratory

HRS target

Robots

GPS target

PSB 1.4 GeV p beam

HRS

GPS

GLM GHM

LA1

LA2

COLLAPS COMPLIS

HV platform

ISOLTRAP

MISTRAL

MINIBALL

NICOLE

REX-ISOLDE

New hall extension (2005)

Control room
ISOLDE Community and RIBs available

ISOLDE Physics Program 2001
Weak Interaction and Nuclear Physics 49%
Solid state physics 17%
Particle and Astrophysics 14%
Biology/Medicine 2%
Atomic Physics 18%

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):

3^4He (2006), 3^6Li (2004), 3^8Li (2005), 10^6Be (2006), 11^2Be (2005),
68^139Ba (2005), 70^135Zn (2008), 167^63Cu (2006), 139^71La (2006), 68^69Zn (2005),
74^139Zn (2004), 80^210Po (2006), 70^32Ge (2005), 89^92Mo (2005),
REX-ISOLDE Post accelerator

Ionisation X^\text{n+}
REXBIS

Mas separator

RFQ
IH-structure

7-gap resonators
9-gap

50 keV REXTRAP
Bunching

REX-ISOLDE

5 keV/u
300 KeV/u
1.2 MeV/u
2.2 MeV/u
2.8-3 MeV/u

101.28 MHz
202.56 MHz
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 @ $\beta_0=10.3\%$ and 12 @ $\beta_0=6.3\%$)
- Energy fully variable; energy spread and bunch length are tunable. Average synchronous phase $\phi_s = -20$ 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

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HIE-ISOLDE LINAC - layout

3 stages installation

1.2 MeV/u

3 MeV/u

5.5 MeV/u

8 MeV/u

10 MeV/u

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QWR cavities (Nb sputtered)

Table 1: Cavity design parameters

<table>
<thead>
<tr>
<th>Cavity</th>
<th>Low $\beta$</th>
<th>high $\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Cells</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>$f$ (MHz)</td>
<td>101.28</td>
<td>101.28</td>
</tr>
<tr>
<td>$\beta_0$ (%)</td>
<td>6.3</td>
<td>10.3</td>
</tr>
<tr>
<td>Design gradient $E_{acc}$ (MV/m)</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Active length (mm)</td>
<td>195</td>
<td>300</td>
</tr>
<tr>
<td>Inner conductor diameter (mm)</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>Mechanical length (mm)</td>
<td>215</td>
<td>320</td>
</tr>
<tr>
<td>Gap length (mm)</td>
<td>50</td>
<td>85</td>
</tr>
<tr>
<td>Beam aperture diameter (mm)</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>$U/E_{acc}^2$ (mJ/(MV/m)^2)</td>
<td>73</td>
<td>207</td>
</tr>
<tr>
<td>$E_{pk}/E_{acc}$</td>
<td>5.4</td>
<td>5.6</td>
</tr>
<tr>
<td>$H_{pk}/E_{acc}$ (Oe/MV/m)</td>
<td>80</td>
<td>100.7</td>
</tr>
<tr>
<td>$R_{sh}/Q$ ($\Omega$)</td>
<td>564</td>
<td>548</td>
</tr>
<tr>
<td>$\Gamma = R_s \cdot Q_0$ ($\Omega$)</td>
<td>23</td>
<td>30.6</td>
</tr>
<tr>
<td>$Q_0$ for 6MV/m at 7W</td>
<td>$3.2 \cdot 10^8$</td>
<td>$5 \cdot 10^8$</td>
</tr>
<tr>
<td>TTF max</td>
<td>0.85</td>
<td>0.9</td>
</tr>
<tr>
<td>No. of cavities</td>
<td>12</td>
<td>20</td>
</tr>
</tbody>
</table>
R&D activity

- RF – Beam dynamics studies
- High $\beta$ 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

THPPO026
Copper Cu substrate Manufacturing

THPPO010

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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.
Inner and Outer conductors
Critical construction phases

[Images of construction equipment and materials]
Final welding and cleaning
Surface treatment - Chemical etching

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 (H₃NO₃S) 5 g/L, H₂O₂ 5% vol, n-butanol C₄H₁₀O 5% vol, di-ammonium citrate (C₆H₁₄N₂O₂) 1 g/L. Chemical polishing is carried out at 72 °C and is preceded and followed by washing with H₃NO₃S.
Surface treatment (dummy and real cavity)
Nb Sputtering

Equipement Dépôt Niobium
Cavités Supraconductrices HIE ISOLDE
From Bias to Magnetron sputtering

**Bias Diode Sputtering:**
Outcomes:

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

**Magnetron Sputtering:**
Outcomes:

- Stable plasma
- Improvements on the thickness
- More homogeneous distribution of the plasma between outside and inside
RF ancillaries: Tuner

Zero backlash system design

CoBe 0.3 mm diaphragm

Drive precision in the order of 200 nm

M. Pasini SRF0g Berlin, 20-25.09 2009
RF ancillaries: power coupler

Designed for coupling factor up to 150, no need to active cooling the coupler
Pf max= 500W
Study of the RF Power Coupler Line

Top of the cryostat

- 10 connectors
- 500 thermal shielding
- 250 thermal shielding
- 250 N connectors
- 100 cavity

\[ P(x) \]

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THPPPOo28
SC solenoid prototype (Nb3-Sn technology)

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetic length</td>
<td>0.16</td>
<td>m</td>
</tr>
<tr>
<td>$\int B^2 dz$</td>
<td>&gt;16.2</td>
<td>T²m</td>
</tr>
<tr>
<td>B residual at 0.25m from mid</td>
<td>&lt;0.2</td>
<td>Gauss</td>
</tr>
<tr>
<td>Max mechanical length</td>
<td>&lt;0.4</td>
<td>m</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>4.3</td>
<td>K</td>
</tr>
<tr>
<td>Inner Radius</td>
<td>&gt;30</td>
<td>mm</td>
</tr>
</tbody>
</table>

Mechanical drawings for the model are completed

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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

Ligne Cryomodules
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

- HIE-ISOLDE design group
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- K.U. Leuven

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Thank you