ISOLDE physics & technical report: INTC 8th Feb 2017

Richard Catherall
Karl Johnston

Technical developments
Status of nano-structured targets

Physics from 2016
Preliminary overview of 2017
Safety/access
Development of ionization schemes in 2016

- **Te**: Ionization efficiency >18%
- **Fe**: First RILIS beam of Fe
- **Mo**: Ionization of refractory metal
- **Eu**: Many transitions to autoionizing states
- **Ra**: 1st RILIS scheme using optical pumping
RILIS operation in 2016

- **130** days of RILIS operation (mostly 24-hr operation)

- **22** separate RILIS runs => **75% of ISOLDE Physics**

- **14** different elements:
  
  Be, Cr, Cu, Mg, Ni, Dy, Mn, In, Bi, Sn, Ra, Cd, Al, Zn

- **1** laser failure which required a factory repair
  (it did not adversely affect operation)

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**Isomer selective ionization of Indium isotopes**

\[ ^{129}\text{In} \]

- \( I^\pi = 1/2^- \)
- \( I^\pi = 9/2^+ \)
Expected TISD @ ISOLDE

• Sc: Ti foils (CF4, RILIS)
• Te: yields with RILIS
• M(CO)x formation @ MEDICIS irradiation point
• ThO felt + Negative ion source
• LIEBE @ GPS-online
• STAGISO beam test
• Si from UCx (pending INTC endorsement)
• TiC-CNT (pending safety clearance)
The LIEBE target – design & manufacturing

Assembly on-going

M. Delonca
Nano Composites: Ti-Carbide

2016

Beams extracted:
- Li (high)
- Na (very high)
- K (similar)
- Ca (much lower)

Probable chemical reaction with carbon black

2017?

- Short lived K and Ca beams
- Si beams? Molecular?

Nanomaterials research and operation is on hold until full risk analysis and clearance.

- New glove box for class A lab required
- Request permission to continue work with non-pyrophoric materials launched
- Asking for new and dedicated labs

Status of nano-material production

- Following an incident with the handling of actinide nano-material last year, all production of nano-material targets (with the exception of CaO) is suspended.
  - Partly due to a lack of labs to provide a suitable and safe environment for their handling
    - Two labs are required
      - 1 for actinide and 1 for non-actinide
- The scientific program for the following experiments may be jeopardised following this moratorium
- Two propositions have been presented...
  - With full support from EN management
- In the meantime I will ask for a derogation for non-pyrophoric non-actinide materials and investigate a temporary solution for actinide materials.

<table>
<thead>
<tr>
<th>nano-mat</th>
<th>exp</th>
<th>isotopes</th>
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<tbody>
<tr>
<td>LaCx</td>
<td>IS545</td>
<td>114-118Cs</td>
</tr>
<tr>
<td>UCx</td>
<td>P487</td>
<td>133In</td>
</tr>
<tr>
<td></td>
<td>P469</td>
<td>11Be</td>
</tr>
<tr>
<td></td>
<td>P478</td>
<td>28Mg</td>
</tr>
<tr>
<td></td>
<td>P471</td>
<td>78-80Cu</td>
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<tr>
<td></td>
<td>P470</td>
<td>28,30Mg</td>
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<tr>
<td></td>
<td>P458</td>
<td>52,53K</td>
</tr>
<tr>
<td></td>
<td>P449</td>
<td>130, 135In</td>
</tr>
<tr>
<td>C</td>
<td>P463</td>
<td>8B</td>
</tr>
<tr>
<td>SiC</td>
<td>P459</td>
<td>22Mg</td>
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<tr>
<td></td>
<td>P366</td>
<td>20Mg</td>
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</table>
Successful runs for:
- **ISOLTRAP** (Cr, Bi, Cd, Mg isotopes)
- **CRIS** (Cu, Ra)
- **COLLAPS**: (Ni, Sn, Al, Bi)
- **Medical isotopes**: excellent runs with both 149Tb and 152Tb
- **Nuclear Astrophysics**: 16N and 64Ge
- **Solid state physics**: Mg for nitride semiconductors and Mn/In for Mossbauer spectroscopy. Cd, Hg for local structure investigations of graphene and multiferroic materials.
- **IDS**: N, Mn, In, Ba, He, Hg. Inauguration of the new ISOLDE-built neutron time of flight spectrometer.
- **Tatra spectrometer**: Hg isotopes
- **7Be collection for nToF** was finally possible. Promising results…
- Bi run involving ISOLTRAP/Windmill/COLLAPS/RILIS
- First **Miniball** run with 110Sn.
### HIE ISOLDE runs in a nutshell

<table>
<thead>
<tr>
<th>September</th>
<th>October</th>
<th>November</th>
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<tr>
<td>35</td>
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<td>44</td>
<td>45</td>
<td>46</td>
</tr>
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</table>

**September**
- Setup IS562 (LE)
- Setup IS557 (LE)
- Setup IS561 (LE)
- Setup IS559 (LE)
- Setup IS562 (LE)
- Setup IS557 (LE)
- Setup IS559 (LE)

**October**
- Setup IS562 (LE)
- Setup IS557 (LE)
- Setup IS561 (LE)
- Setup IS559 (LE)
- Setup IS562 (LE)
- Setup IS557 (LE)
- Setup IS559 (LE)

**November**
- Setup IS561 (LE)
- Setup IS559 (LE)
- Setup IS562 (LE)
- Setup IS557 (LE)
- Setup IS561 (LE)
- Setup IS559 (LE)
- Setup IS562 (LE)
- Setup IS557 (LE)
- Setup IS561 (LE)
- Setup IS559 (LE)

**Broken 9-gap Amplifier. Only 110Sn possible**

### RILIS laser window required replacement. Only 78Zn possible.

### Difficult setup. Transmission and alignment questions. First test of XT02

### Regular trips of SC cavities: users can reset.

### Regular trips of 7-gap...15 mins each time...

### Extremely heavy load on operators for each run...

**RILIS**
- Sn RILIS
- Dy RILIS
- Zn RILIS
- Zn RILIS
- Ni RILIS
- Ni RILIS
- Ni RILIS

**HIE-ISOLDE (GPS)**
- 142Xe @ 4.5MeV/u
- 132Sn @ 5.5MeV/u

**HIE-ISOLDE (HRS)**
- 142Xe @ 4.5MeV/u
- 132Sn @ 5.5MeV/u

**LOI168?**
- Bi RILIS
- RILIS
- Sn RILIS

**HRS**
- Delay due to repair of Amp; leaking target. 15 shifts instead of 30
- RILIS laser window required replacement. Only 78Zn possible.
- Difficult setup. Transmission and alignment questions. First test of XT02
- Regular trips of SC cavities: users can reset.
- Regular trips of 7-gap...15 mins each time...
- Extremely heavy load on operators for each run...

**HIE ISOLDE runs in a nutshell**

**Sn RILIS**
- Sn RILIS
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- Sn RILIS
- Sn RILIS

**Dy RILIS**
- Dy RILIS
- Dy RILIS
- Dy RILIS
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- Dy RILIS

**Zn RILIS**
- Zn RILIS
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**Ni RILIS**
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**HIE ISOLDE (GPS)**
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**LOI168?**
- Bi RILIS
- RILIS
- Sn RILIS
IS609: Study of beta-delayed neutron decay of \( ^{8}\text{He} \) using the newly commissioned IDS Neutron Detector

IS610: Gamma-ray and fast-timing spectroscopy of nuclei around the doubly-magic \( ^{132}\text{Sn} \) nucleus

IS474: Fast-timing studies of nuclei below \( ^{68}\text{Ni} \) populated in the \( \beta \)-decay of Mn isotopes

IS579: Study of octupole deformation in \( n \)-rich Ba isotopes

IS588: Study of core breaking and octupole low-spin states in \( ^{207}\text{Tl} \) through gamma and beta spectroscopy of \( ^{207,208}\text{Hg} \)

Thanks to Razvan Lica
Interstitial $^{27}\text{Mg}$ in different doping types of GaN

- Interstitial Mg $^{i}$ enhanced in $p$-GaN and suppressed in $n$-GaN.
- Site change of $^{27}\text{Mg}$ from interstitial to substitutional Ga sites as function of implantation temperature allows to estimate activation energy for migration of Mg $^{i}$ as $E_M \approx 1.3$–2.0 eV.

Arrhenius step models:

<table>
<thead>
<tr>
<th>$N$</th>
<th>$E_M$ [eV]</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>10$^5$</td>
<td>1.3</td>
</tr>
</tbody>
</table>

implantation current [pA]:

- 0.20
- 0.27
- 1.4–3.0

Mg $^{i}$ (mobile) + $V_{Ga} \rightarrow \text{Mg}_{Ga}$

$f_i = f_{i0} N \nu_0 \tau \exp[-E_M/k_B T]$ with attempt frequency $\nu_0 = 2 \times 10^{13} \text{ s}^{-1}$

Accepted for PRL: Wahl et al, 2017
IS624 Irradiation

- Next generation neutron source, build in Lund, Sweden
- First neutrons 2020 … (we hope!)
- New target concept
- 5 MW average power
- 2 GeV protons as 2.86 ms pulses (14 Hz)
- Rotating Helium Cooled Tungsten Target
Preliminary data from $^{142}$Xe for IS548

Courtesy of corinna Henrich
**2016**

- Protons to ISOLDE since 11 April
- Low energy until September when HIE-ISOLDE started. Running period of 211 days.
- Dedicated low energy running from April 11th – 9th Sept.
- Thereafter HIE ISOLDE had priority: 66 days

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<tbody>
<tr>
<td>Protons</td>
<td>7.8e19</td>
<td>9.4e19</td>
<td>5.5e19</td>
<td>11.5e19</td>
<td>8.05e19</td>
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<tr>
<td>Shifts for IS exp</td>
<td>343</td>
<td>263</td>
<td>208.5</td>
<td>416</td>
<td>313.5</td>
</tr>
<tr>
<td>Shifts for LOIs</td>
<td>10</td>
<td>4</td>
<td>6.5</td>
<td>15.5</td>
<td>16</td>
</tr>
<tr>
<td>REX shifts (IS +LOI)</td>
<td>95</td>
<td>Special</td>
<td>-</td>
<td>221.5</td>
<td>190.5</td>
</tr>
<tr>
<td>Average IS shifts/day</td>
<td>1.65</td>
<td>1.4</td>
<td>1.55</td>
<td>1.61</td>
<td>1.55</td>
</tr>
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**Schedule 2017**

- **24th April:** start of physics 2017
- **Protons finishing on 20th November**
- **Running period of 210 days.** (perhaps one more week is possible, but too soon to say)
- **Low energy until ~ week 26.**
- **Interleave HIE & LE physics from end of June onwards.**
- **3 CMS → some “flexibility” in energy**
- **Fewer limitations on masses/energy for 2017**
- **For A/q = 4.33 7.5MeV/u**

- **3rd beamline needs to be installed in good time:**
  - Expect quite a few demands for the scattering chamber
- **Nanostructured Targets for 2017?**
- **Length of runs....**
- **Availability of RILIS (**
- **Autumn:**
  - Negative ion run
  - MEDITIS start-up
  - LIEBE tests: block GPS for ~ 3 weeks?
Beam Properties for 2017: Beam Energy and Energy Spread

Expected for 2017:

- A third cryomodule is currently being installed and should be ready for the 2017 Physics campaign
- The third HEBT line (XT03) should also be ready
- Highest reachable energy of a beam with A/q = 4.0:
  - If average SRF gradient is 6.0 MV/m: 8.2 MeV/u
  - If average SRF gradient is 5.5 MV/m: 7.8 MeV/u
  - If average SRF gradient is 5.0 MV/m: 7.3 MeV/u

Phase 2A of the HIE-ISOLDE project

<table>
<thead>
<tr>
<th>Cryomodules</th>
<th>3</th>
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<tbody>
<tr>
<td>HEBT lines</td>
<td>3</td>
</tr>
<tr>
<td>E [MeV/u] (A/q = 2.5)</td>
<td>11.4</td>
</tr>
<tr>
<td>E [MeV/u] (A/q = 4.3)</td>
<td>7.8</td>
</tr>
</tbody>
</table>

Highest beam energy (assuming all cavities at 6MV/m) for different A/q

- A/q | CM1 | CM2 | CM3 | CM4
- 2.5 | 5.5 | 8.6 | 11.4 | 14.2
- 3.0 | 5.0 | 7.6 | 10.0 | 12.4
- 3.5 | 4.7 | 6.9 | 9.0 | 11.1
- 4.0 | 4.4 | 6.3 | 8.2 | 10.1
- 4.3 | 4.3 | 6.1 | 7.8 | 9.5

Courtesy of Lefteris Fadakis
ISS installation preparations

- XT02 experimental setup dismounted and removed.
- ISS feet holes and XT02 triplet extension holes drilled and inserts done.
- All necessary XT03 supports and concrete dipole block removed. Cables rolled back. Main preparations done. CV and EL work to be finished.

The ISS magnet weight is close to 20T. The overhead crane at ISOLDE is 10T. ISS will need to be rolled in. Latest date set for 3 March.
- XT03 installation can only start after ISS is in position.
- All XT03 elements at CERN

Courtesy of Erwin Siesling and Liam Gaffney
Required training for **ISOHALL**

**Online:**
- Safety at CERN
- RP supervised (changed since last year)
- Basic electrical awareness

**Hands-on:**
- Electrical awareness
- RP hands-on

Every Tuesday @ 1300 – 1700), training centre Prevessin.

External trainer: try to have confirmation of participation 3 weeks in advance.

Registration in EDH...

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Access now via ADAMS rather than EDH.

Helmets and safety shoes in the hall....

Control on entering and leaving
ISOLDE block booking will run from April 15th till ~ Nov 20.

15 rooms available up to one month before arrival

If rooms can’t be obtained using the usual booking online then these can be availed of.

TNA support available for scheduled experiments. Details sent to spokespeople after schedule is released.