Status of the SPES facility at INFN-Legnaro

Alberto Andrighetto
SPES Technical Coordinator

CERN-Isolde 25-1-2018
Talk Overview

- The SPES Project goals
- The RIB +1 line.
- Possible first RIB’s @ SPES
- Conclusions
Direct UC\textsubscript{x} Target for the SPES Project

Alberto Andrighetto
INFN - Laboratori Nazionali di Legnaro
CERN - 01/03/2005
The SPES at LNL: Facility Layout

New Building:

New infrastructure for:
- Application Facility
- Cyclotron
- RIB facility (2nd generation ISOL)

Project financed by INFN
Definition of RIB (Radioactive Ion Beam) -> Ions with ‘exotic’ protons-to-neutron ratio. The RIB is an important probe in order to investigate the nuclide chart, for nuclei far from the stability valley -> different behavior!

Nuclear Physics with RIB
- High angular momentum
- Deformed nuclei
- Correlation (pairing)
- Shell evolution

Nuclear Astrophysics with RIB
- Heavy elements origin (r,p,s process)
- Stellar explosion
- Neutron stars
- X-ray burst and supernovae

Nuclear Medicine with RIB
Radiopharmaceutical prodution for:
- Therapy
- Diagnostic
SPES: Is the future of LNL

SPES is: 1) A second generation ISOL facility (for neutron-rich ion beams)
2) An interdisciplinary research center (for p,n applications)

Cyclotron installation & commissioning:
- $E=70\text{ MeV}$ proton beam, $I=750\ \mu\text{A}$

Production & re-acceleration of exotic beams, from $p$-induced Fission on UC$x$

LINUS Neutron facility
- Proposal
- Lenos
- Nephir
- Accelerator based neutron source (Proton and Neutron Facility for Applied Physics)

Application Facility

SPES-RIB facility
- Financed & Under construction

SPES for medicine
- LARAMED & ISOLPHARM projects
- Radioisotopes for medical applications
Medical applications @ SPES:

important investment and great opportunity for the INFN

Radioisotope Laboratory

Radioisotope Factory

Double extraction cyclotron

ISOL 2 -> Isolpharm facility?
**ISOLPHARM Method overview**

The **ISOLPHARM** method is capable of selecting and isolating on-line a SINGLE RADIO-ISOTOPE

- extremely high specific activity
- higher efficacy in therapy and diagnosis

**Production target** → **Extraction and ionization** → **Mass separation** → **Ions collection**

**Primary Proton Beam** → **Radioactive Ion Beam** → **Isobaric Ion Beam**

**PHARM**

- Diagnosis and therapy
- Radiopharmaceuticals production
- Chemical purification
**ISOLPHARM 1**

- **First set** of isotopes studied in the framework of ISOLPHARM collaboration:
  - Radiopharmaceuticals **available** in the market

**ISOLPHARM 2**

- **Innovative** radio-isotopes produced with different types of target:
  - Radiopharmaceuticals **absent** in the market
Innovative Target concepts: overview

The ISOL method requires specific targets.

Targets have to be:

- **Solid**
- **Refractory** (more refractory than the element for which they were designed)

Three target concepts are currently under investigation:

1. **UCₓ new targets (Operation temperature: 2200°C)**
   - Target R&D and state of Nuclear reactions studied | Designed | Tested
   - Innovative isotopes production: $^{111}$Ag

2. **ZrGe target (Operation temperature: 1800°C)**
   - Target R&D and state of Nuclear reactions studied | Designed | Tested
   - Innovative isotopes production: As & Ga isotopes
   - $^{64/67}$Cu unexpected production!

3. **TiC/TiB₂ target (Operation temperature: 2000°C)**
   - Target R&D and state of Nuclear reactions studied | Designed | Tested
   - Innovative isotopes production: Sc isotopes
ISOLPHARM: possible beams

- $^{89}$Sr
- $^{90}$Y
- $^{125}$I
- $^{131}$I
- $^{111}$Ag
- $^{64}$Cu (ZrGe target (?)
- $^{67}$Cu
- $^{43}$Sc (TiC target)
- $^{44}$Sc
- $^{47}$Sc

UC$_x$ target

Diagram showing isotopes and their properties.
Almost 60 isotopes (up to now!) are producible with the ISOL technique.
ISOLPHARM as future facility...
Status of the ISOL facility
SPES-RIB construction phases

- **Phase 1.** - Building + First operation with the cyclotron
- **Phase 2.** - From C.B. to RFQ + SPES target, LRMS, 1+ Beam Lines
- **Phase 3.** - From the LRMS to the CB + from RFQ to ALPI
- **Phase 4.** - HRMS + Beam Cooler
- The driver
- The RIB manipulation
- The post accelerator
- The RIB production & L.E. line
Cyclotron installation

Dual port Cyclotron
Proton beam 35-70 MeV
Total current 750μA

<table>
<thead>
<tr>
<th>Accelerated Particle</th>
<th>H-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extracted Particle</td>
<td>Protons</td>
</tr>
<tr>
<td>Energy</td>
<td>35-70 MeV (variable)</td>
</tr>
<tr>
<td>Current</td>
<td>&gt; 700 μA (variable)</td>
</tr>
<tr>
<td>Extraction System</td>
<td>By stripping (\rightarrow) simultaneous dual beam extraction</td>
</tr>
<tr>
<td>Injection System</td>
<td>Axial Injection (\rightarrow) External Multicusp Ion Source 15-20mA DC</td>
</tr>
</tbody>
</table>
| Main Magnet          | \(B_{\text{max}} = 1.6\) T  
                        | Coil current = 127 kA  
                        | Power supply = 30 kW  
                        | 4 sectors, deep valley |
| RF System            | 2 resonators  
                        | Frequency = 58 MHz  
                        | Harmonic mode = 4  
                        | Dissipated Power = 15 kW per cavity  
                        | DEE voltage = 60-80 kV |
| Operational Vacuum   | 2 e \(-7\) mbar |
- The driver
- The RIB manipulation
- The post accelerator
- The RIB production & L.E. line
The beam transport line

- Cyclotron
- Front End
- RFQ Cooler
- HRMS
- Coolers
- Charge Breeder
- n^+ Beamline to post-accelerator
- 1^+ Beamline 1st section
- 1^+ Beamline 2nd section
The 1+ beam line: the construction phases
n+ Beam line

STATUS:
Infrastructures ready for installation
Beam transport components ordered
Technical services under implementation
Charge Breeder and 1+source available
- The driver
- The RIB manipulation
- The post accelerator
- The RIB production & L.E. line
Goal: To achieve $E=10$ MeV/A for $A/q$ up to 7

a) Cavity upgrades
   1. Lower-$b_{opt}$-resonators added
   2. Field increase in medium-$b_{opt}$-cavities
   3. Two additional higher-$b_{opt}$-CMs (8 resonators)

b) Cryogenic power increase

c) New magnetic triplet of quadrupoles
Cavity Upgrades

4.8 MV/m → 6.5 MV/m

CR12 → CR18 → CR19-20

Additional 8 cavities

10-11 MeV/amu for A=130-140

Re-positioned low β cavities

4.8 MV/m

5 MV/m
- The driver
- The RIB manipulation
- The post accelerator
- The RIB production & L.E. line
The SPES ISOL - RIB source

- TIS unit
- horizontal handling device
- vertical handling device
- PROTON BEAM
- RIB
- temporary storage
- front-end
The SPES TIS UNIT

- Primary beam
- Fission fragments
- Ions

- Extraction Electrode (GND)
- Transfer Line
- Ion Source (+HV)

Driver vs. Target
Target vs. Ion Source
I.S. study: The experimental set-up

Off-line TIS Front-end: operative at LNL since 2011

- Ion Source with calibrated marker (2200 °C)
- Mass separation (Wien Filter)
- Diagnostic system BP + FC
front-end (protonic beam line)
Characterization of the SPES Surface Ion Source

<table>
<thead>
<tr>
<th>beam</th>
<th>ion. eff. (%)</th>
<th>hot-cavity temp. (°C)</th>
<th>hot-cavity material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>47,6</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>K</td>
<td>55,4</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>Ga</td>
<td>1,4</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>Rb</td>
<td>54,5</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>Sr</td>
<td>18,5</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>In</td>
<td>3,2</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>Cs</td>
<td>43,2</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>Ba</td>
<td>58,8</td>
<td>2200</td>
<td>Ta</td>
</tr>
<tr>
<td>La</td>
<td>20,1</td>
<td>2200</td>
<td>Ta</td>
</tr>
</tbody>
</table>
Characterization of the SPES Plasma Ion Source

<table>
<thead>
<tr>
<th>beam</th>
<th>ion. eff. (%)</th>
<th>injection mode</th>
<th>cathode temp. (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ar</td>
<td>6</td>
<td>gas tube</td>
<td>2200</td>
</tr>
<tr>
<td>Br</td>
<td>WIP</td>
<td>oven</td>
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</tr>
<tr>
<td>Kr</td>
<td>8,5</td>
<td>gas tube</td>
<td>2200</td>
</tr>
<tr>
<td>Y</td>
<td>very low</td>
<td>oven</td>
<td>2300</td>
</tr>
<tr>
<td>Sn</td>
<td>10</td>
<td>oven</td>
<td>2200</td>
</tr>
<tr>
<td>I</td>
<td>19</td>
<td>oven</td>
<td>2200</td>
</tr>
<tr>
<td>Xe</td>
<td>11</td>
<td>gas tube</td>
<td>2200</td>
</tr>
</tbody>
</table>
Off-line Laser Laboratory

- 1 Nd:YAG Ablation laser
- 1 TOF
- 2 Nd:YAG Pump lasers:
- 3 Tunable DYE Lasers
- 1 Monochromator
- 8 HCL

Ready for test since 2014...

Equipment's ready

SPES laser group
STATUS of resonant laser ionization

**Spectroscopy:**
- Study of different elements of interest
- Offline-lab with 10Hz dye laser system
- HCL & ToF-MS

**New SS laser:**
- Defining RIB production laser requirements
- 10 kHz TiSa laser
- New laser lab requirements

**Laser FE:**
- ToF system
- Hot cavity
- Efficiency measurements
The target chamber handling

Two systems are foreseen in order to increase the handling security level

- **TIS unit**
- **Vertical device**
- **Horizontal device**
- **Target Front End**

**Environmental conditions and consequences:**

- Very high radioactive emission due to the Exotic Beam
- Replacement of TIS unit every 28 days
- Impossibility to operate by humans
- Remote handling system
The Horizontal machine

- Simulation software Siemens in Tia Portal
- Movement test in automatic mode
- Experimental tests with 3 transponder
The new Chamber Unit Storage

The layout:

Storage cartesian system prototype
Bunker subsystems

1- front-end (radioactive beam line @ High Voltage)
2- front-end (radioactive beam line @ Ground Voltage)
3- front-end (proton beam line)
4- diagnostic box 1
5- Wien filter
6- Steerers
7- diagnostic box 2
8- quadrupole triplet

- Electric power
- Signal cables
- Buffer gas
- Cooling water
- Compress air
- vacuum
HV subsystem

locale A16

locale A6

Preliminary Technical report ready
front-end (radioactive beam line piping)

1- CABLELING_PIPING_BUNKER_A6_rev02.xlsx
First Goal -> First Beam to 1+ Experimental area

1+ beam line from **TIS to Tape System**

**First Goal**

- **Tape System**
- RIB Bunker
- To Post-Acc
1+ beam line operation: Devices
Possible SPES RIBs
(for first physics experimental campaign)
a) First goal: RIB for users

**Total Beams:** 89

<table>
<thead>
<tr>
<th>Beam with LMR:</th>
<th>47 (95 LOI)</th>
<th>53% (56%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit with 5000 HMR:</td>
<td>3 (3 LOI)</td>
<td>56% (58%)</td>
</tr>
<tr>
<td>Benefit with 10000 HMR:</td>
<td>17 (31 LOI)</td>
<td>75% (77%)</td>
</tr>
<tr>
<td>Benefit with 15000 HMR:</td>
<td>15 (25 LOI)</td>
<td>92% (92%)</td>
</tr>
<tr>
<td>Benefit with 20000 HMR:</td>
<td>7 (10 LOI)</td>
<td></td>
</tr>
</tbody>
</table>

**19 Elements**

**Beam Required by users**

**BEAMS vs. Ion Source**

- LIS
- SIS
- PIS
Best LOI Beams

Best SPES Beams (high selectivity & yield values)

Selectivity without HRMS (%)

Yield (1/s)

selectivity without HRMS (%)
LIS Beams

LIS LOI Beams

Yields (1/s)

- 126Sn
- 127Sn
- 129Sn
- 133Te
- 123Sn
- 130Sb
- 131Sb
- 113Ag
- 132Sn
- 78Ge
- 83Ge
- 78Ga
- 84Se
- 110Ag
- 80Ga
- 138Te
- 82Ge
- 86Se
- 74Cu
- 108Ag
- 75Cu
- 84Ge
- 77Cu

LIS LOI Beams

Resolution (M/ΔM) required to reach the maximum selectivity

Online (SS laser): RIB prod.
- 3 TiS laser @ 10 kHz rep. rate

Offline: Spectroscopy
- 3 Dye Laser @ 10 Hz rep. rate

LASER Beams

57 63
10 5
12 13
14 14
6 5
0 10 20 30 40 50 60 70
300 5000 10000 15000 20000

% beams
% LOIs

3 beams/LOIs %
### SIS Beams

#### SIS LOI Beams

![SIS LOI Beams Graph](image-url)

#### Sourface Ion Source Beams

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<tr>
<td>La</td>
<td>20.1</td>
<td>2200</td>
<td>Ta</td>
</tr>
</tbody>
</table>

#### Resolution (M/ΔM) required to reach the maximum selectivity

![Resolution Graph](image-url)
## PIS Beams

### Plasma Ion Source Beams

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<th>cathode temp. (°C)</th>
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<tbody>
<tr>
<td>Ar</td>
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<td>2200</td>
</tr>
<tr>
<td>Xe</td>
<td>11</td>
<td>gas tube</td>
<td>2200</td>
</tr>
</tbody>
</table>

*Plasma Ion Source Beams*
Selectivity: Summary

Beam Selectivity at SPES

- Good Beam without HRMS
- Benefit with HRMS=5000
- Benefit with HRMS=10000
- Benefit with HRMS=15000
- Benefit with HRMS=20000

- No HRMS (53%)
- 10000 HRMS (75%)
- 15000 HRMS (92%)
First Experiment in the LE area

<table>
<thead>
<tr>
<th>Devices</th>
<th>Number</th>
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</thead>
<tbody>
<tr>
<td>ETQ (triplets)</td>
<td>6</td>
</tr>
<tr>
<td>ED (el. Dipole)</td>
<td>3</td>
</tr>
<tr>
<td>Steerer</td>
<td>6</td>
</tr>
<tr>
<td>MD (mag. Dipole)</td>
<td>1</td>
</tr>
<tr>
<td>Diagnostic Box</td>
<td>4 + 5</td>
</tr>
</tbody>
</table>
**Possible Low Energy RIBs (1)**

**Option 1: UCx Target + Surface Ion Source (→ Easy Configuration)**

<table>
<thead>
<tr>
<th>beam</th>
<th>yield (pps) @ 20 µA</th>
<th>selectivity (%)</th>
<th>ion source type</th>
<th>main contaminants (if sel. &lt; 60%)</th>
<th>notes</th>
<th>LOI reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>96 Rb</td>
<td>9.89E+07</td>
<td>31</td>
<td>SIS</td>
<td>Sr</td>
<td>easy beam</td>
<td>37</td>
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<tr>
<td>147 Cs</td>
<td>4.91E+04</td>
<td>1.7</td>
<td>SIS</td>
<td>Ba</td>
<td>easy beam</td>
<td>10</td>
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<tr>
<td>100 Rb</td>
<td>4.49E+04</td>
<td>1.2</td>
<td>SIS</td>
<td>Sr</td>
<td>easy beam</td>
<td>10</td>
</tr>
</tbody>
</table>

**LOI n.10)**
K.P. Rykaczewski (ORNL Oak Ridge, USA)
Nuclear structure of neutron-rich nuclei determined through beta decay spectroscopy of fission fragments

**LOI n.37)**
A.Nannini (INFN_Fi, Italy)
Electron conversion measurements at SPES 1+ beam line: measurement of E0 transitions in 96Sr

With this configuration other RIBs can be produced, characterized by higher selectivity values

<table>
<thead>
<tr>
<th>beam</th>
<th>yield (pps) @ 20 µA</th>
<th>selectivity (%)</th>
<th>ion source type</th>
</tr>
</thead>
<tbody>
<tr>
<td>138Cs</td>
<td>1.10E+10</td>
<td>76</td>
<td>SIS</td>
</tr>
<tr>
<td>137Cs</td>
<td>1.00E+10</td>
<td>100</td>
<td>SIS</td>
</tr>
<tr>
<td>91Rb</td>
<td>9.60E+09</td>
<td>100</td>
<td>SIS</td>
</tr>
<tr>
<td>92Rb</td>
<td>5.10E+09</td>
<td>100</td>
<td>SIS</td>
</tr>
<tr>
<td>136Cs</td>
<td>5.00E+09</td>
<td>89</td>
<td>SIS</td>
</tr>
<tr>
<td>93Rb</td>
<td>3.40E+09</td>
<td>91</td>
<td>SIS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>beam</th>
<th>yield (pps) @ 20 µA</th>
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<th>ion source type</th>
</tr>
</thead>
<tbody>
<tr>
<td>135Cs</td>
<td>1.60E+09</td>
<td>100</td>
<td>SIS</td>
</tr>
<tr>
<td>94Rb</td>
<td>1.40E+09</td>
<td>75</td>
<td>SIS</td>
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<tr>
<td>141Cs</td>
<td>1.30E+09</td>
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<td>SIS</td>
</tr>
<tr>
<td>134Cs</td>
<td>4.00E+08</td>
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<tr>
<td>95Rb</td>
<td>2.60E+08</td>
<td>65</td>
<td>SIS</td>
</tr>
</tbody>
</table>
Option 2: UCx Target + Surface Ion Source + Laser (-> Laser Lab in operation)

With this configuration other RIBs can be produced, characterized by higher selectivity values

<table>
<thead>
<tr>
<th>beam</th>
<th>yield (pps) @ 20 μA</th>
<th>selectivity (%)</th>
<th>ion source type</th>
<th>main contaminants (if sel. &lt; 60%)</th>
<th>notes</th>
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<td></td>
<td></td>
<td>LOI n.10</td>
</tr>
<tr>
<td>132 Te</td>
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<td>100</td>
<td>LIS</td>
<td></td>
<td></td>
<td>LOI n.27</td>
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<tr>
<td>132 Sb</td>
<td>1.90E+07</td>
<td>100</td>
<td>LIS</td>
<td></td>
<td></td>
<td>LOI n.38</td>
</tr>
</tbody>
</table>

K.P. Rykaczewski (ORNL, Oak Ridge, USA)
Nuclear structure of neutron-rich nuclei determined through beta decay spectroscopy

A. Gottardo (IPNO, France)
Shells and collectives excitations and res. at and beyond N=50 with decay spectroscopy

S. Cristallo (INAF, Italy)
Letter of Intent for measure. at SPES on beta-decay prop. of nuclei belonging to the s-process path

LOIs & UCx target: RIBs Low Energy (2)
### Global list of the first SPES RIBs available for low-energy experiments

<table>
<thead>
<tr>
<th>nucl. sy.</th>
<th>yield (pps) @ 20 µA</th>
<th>selectivity (%)</th>
<th>ion source type</th>
<th>main contaminants (if sel. &lt; 60%)</th>
<th>notes</th>
<th>LOI reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>123 Sn</td>
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<td>12</td>
<td>LIS</td>
<td>In</td>
<td>low selectivity beam</td>
<td>38</td>
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<tr>
<td>121 Sn</td>
<td>2.02E+08</td>
<td>6.6</td>
<td>LIS</td>
<td>In</td>
<td>low selectivity beam</td>
<td>38</td>
</tr>
<tr>
<td>83 Ge</td>
<td>2.47E+07</td>
<td>100</td>
<td>LIS</td>
<td>-</td>
<td>selective beam</td>
<td>27</td>
</tr>
<tr>
<td>82 As</td>
<td>1.07E+07</td>
<td>71</td>
<td>LIS</td>
<td>-</td>
<td>selective beam</td>
<td>27</td>
</tr>
<tr>
<td>110 Ag</td>
<td>9.60E+06</td>
<td>100</td>
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<td>-</td>
<td>selective beam</td>
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<td>80 Ga</td>
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<td>-</td>
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<td>134 Sn</td>
<td>2.49E+06</td>
<td>10</td>
<td>LIS</td>
<td>In, Cs, Ba</td>
<td>low selectivity beam</td>
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</tr>
<tr>
<td>84 As</td>
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<td>-</td>
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<td>Rb, Sr, In</td>
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<tr>
<td>84 Ge</td>
<td>6.61E+04</td>
<td>100</td>
<td>LIS</td>
<td>-</td>
<td>selective beam</td>
<td>10; 27</td>
</tr>
<tr>
<td>83 Ga</td>
<td>6.06E+04</td>
<td>100</td>
<td>LIS</td>
<td>-</td>
<td>selective beam</td>
<td>10; 27</td>
</tr>
<tr>
<td>96 Rb</td>
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<td>SIS</td>
<td>Sr</td>
<td>easy beam</td>
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</tr>
<tr>
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<td>1.7</td>
<td>SIS</td>
<td>Ba</td>
<td>easy beam</td>
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<tr>
<td>100 Rb</td>
<td>4.49E+04</td>
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<tr>
<td>86 Br</td>
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<td>As, Se, Kr</td>
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<tr>
<td>139 I</td>
<td>5.94E+06</td>
<td>1.5</td>
<td>PIS</td>
<td>Xe, Cs, Ba</td>
<td>low selectivity beam</td>
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<td>PIS</td>
<td>Xe, Cs, Ba</td>
<td>low selectivity beam</td>
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</tbody>
</table>

**LOIs & UCx target: RIBs Low Energy (overview)**

**Shape coexistence and N=50 gap: transfer reactions on ground and isomeric states**

**Letter of Intent for measurements at SPES on beta-decay properties of nuclei belonging to the s-process path.**

**83,84 Ge; 80,83 Ga; 110 Ag -> LOI selective beams!**
Conclusions
Goals: beam delivery & RIB Source Commissioning

User requirements vs Project Construction Phases

- Beam delivery
- RIB Source Commissioning

**Nominal parameters**
- Target material: UCx (SiC as an alternative)
- Proton beam energy: 40 MeV
- Proton beam intensity: 200 µA
- Proton beam sigma: 7 mm
- Wobbling radius: 11 mm

**First SPES RIB (26Al)**

**Within the end of 2019**
- 40 MeV, 20 µA

**40 MeV, 200 µA, 10^{13} f/s**

**SiC target**

**UCx target**

*the scaled SPES target for low intensity RIBs*

*the full-scale SPES target for high intensity RIBs*

*first n-rich fission isotopes*
The ‘demonstrative’ (first) beam:

1st SPES RIB (26Al) at the end of 2019

A scaled SiC target (40 MeV protons up to 20 µA) will be used for the first SPES RIBs

SiC target beams requested by LOIs

High yields

High selectivity (even without HRMS)

Low energy

Different IS

1st SPES RIB preparatory beam for the post-acc. phase (requested by LOIs)

High energy LOI beams with dedicated targets (no UCx)
The collaboration network for SPES

ITHEMBA  RISP-KOREA  ORNL- HRIBF

CERN- ISOLDE

GANIL-SPIRAL 2

ORSAY-ALTO

SPES
Exotic Beam

UNISI  UNIPV  UNIPD

UNISP  DSF  DIM  DSC  DEI  DTG  DIM

CONTROLS

LASER  ION SOURCES  MATERIALS  HANDLING  FRONTEND

> 45 Tesi Magistrali
> 25 Tesi Triennali
4 Tesi di PhD
15 Ospiti Stranieri (FAI)
Conclusion

Thanks for your attention!

Few results without them ...