A temporary storage for UCx target @ SPES

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SATIF-12, 28th April 2014
• The SPES project at Laboratori Nazionali di Legnaro, INFN
• The target – irradiation cycle and inventory
• Storage design
• Simulation set up
• The worst scenario

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SPES Selective Production of Exotic Species: INFN project towards EURISOL
The SPES project: re-acceleration of RIBS

3° Hall

ALPI
PIAVE
TANDEM

Cyclotron

RIB: Sn-132$^{+n}$, I-135$^{+n}$, 9 MeV/amu
RIB: Sn-132$^{+n}$, I-135$^{+n}$, … up to 40 kV
RIB: Sn-132$^{+1}$, I-135$^{+1}$, … up to 40 kV according to mass
Protons, 40 MeV, 200 µA

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The SPES target is made of 7 UCx disks, 4 cm diameter, 1 mm thickness (about 30 g uranium-238 content)

The irradiation cycle lasts 14 days, a total of $10^{21}$ protons on target and a total of $10^{19}$ fissions are induced on the target
The target: irradiation cycle and inventory

- 14 days
- $10^{21}$ protons on target
- $10^{19}$ fissions/cycle
- About 1 kCi totally produced in 1 cycle

$T_{1/2} < 1$ hour
1 hour $< T_{1/2} < 1$ day
1 day $< T_{1/2} < 1$ month
1 month $< T_{1/2} < 1$ year
1 year $< T_{1/2} < 10$ years
$T_{1/2} > 10$ years
The temporary storage design

Small area to store the irradiated targets before their final destination as waste

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**Simulation set up**

**Exploitation of the possibility to change material for radioactive decay product transport**

**Blackhole** during the irradiation of the target, changed into vacuum at the end of beam.

The FLUKA code version 2011 has been used for the simulations.

**Lead box 2.5 cm**

**Target in a small vacuum sphere**

**Evaluation of the gamma dose rate outside of the box**

Beam on

Beam off

200 uA

0 uA

2 weeks

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• gammas emitted by the source are in the range 300 keV - 3 MeV

• A concrete slab of at least 70 cm thickness is needed in order to shield the corridor, and to reduce the dose rate by a factor $10^3$.

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More results

Gamma dose rate at the end of the first irradiation cycle

Irradiated target

300 uSv/h

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The worst scenario

- It was required to calculate the residual dose rate in case all the available positions were filled with irradiated targets.

Will it be the worst possible scenario?
- 44 dedicated locations in order to house irradiated targets inside their shielding boxes (2.5 cm Lead).
- The target is remotely handled and placed in the farthest available position from corridor.
- The “hottest” target is always put in the farthest place so be shielded by the previous boxes.

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The temporary storage design

View from side

Passage for personnel

1st
2nd
3rd
4th
5th
6th
7th

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Artistic view of the beam line as included in the FLUKA geometry.
Lead and steel box, as designed and realized by the target group at LNL.
• Separate simulations have been run to reproduce the irradiation of each target
• Each position is occupied by a target of a well-known irradiation cycle
• Assuming a cycle lasts 2 weeks (irradiation) and after 2 weeks (cooling in bunker) the target is moved to the storage, then the timescale to fill the position \( x \) after irradiation is

\[
\text{Time}_{\text{pos } x} = 2\text{weeks} + 4\text{weeks} \times (n_{\text{cycle } x} - 1)
\]

<table>
<thead>
<tr>
<th>weeks</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>10</th>
<th>12</th>
<th>14</th>
<th>16</th>
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<tbody>
<tr>
<td>Pos 1</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td>Pos 3</td>
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</tbody>
</table>
Simulation set up

Time_{\text{pos } x} = 2\text{weeks} + 4\text{weeks} \times (n_{\text{cycle } x} - 1)

<table>
<thead>
<tr>
<th>Corridor</th>
<th>First cycle</th>
<th>Second cycle</th>
<th>Third cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pos. 1</td>
<td>The first target is put in the first position after 2w cooling in bunker</td>
<td>The first target (decayed) is moved in the second position (2w cooled +4w it was in pos 1) and the second target in the first position</td>
<td>The first target (even more decayed) is moved in the third position (2w cooled +4w it was in pos 1+4w in pos 2), the second target in the second position (2w cooled +4w it was in pos 1) and the third target in the first position</td>
</tr>
</tbody>
</table>

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Results

Gamma dose rate from exhausted targets

- Once filled the rack, targets will shield each other: dose rate below 50 uSv/h
- A concrete wall 50 cm thick will reduce the dose rate by a factor 100

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Results

Gamma dose rates at different levels

First level

Second level

Third level

Fourth level

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The worst scenario

- It was required to calculate the residual dose rate in case all the available positions were filled with irradiated targets

Will it be the worst possible scenario?

No, it won’t
What if we shield the first target with some empty boxes?

Dose level comparable to the full case

The first target put in the storage will be surrounded by a few spare boxes
Gamma dose rate at the end of the first irradiation cycle

Empty boxes

Irradiated target

More results

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Results and outcome

- The energy of gamma rays emitted by the targets ranges from 300 keV to 3 MeV.
- The storage must be shielded with 50 cm concrete or 8 cm lead, to fulfill radioprotection constraints (dose in controlled areas < 0.5 µSv/h).
- Most likely both material will be used, concrete for overall shielding and lead for a sliding door.
The SPES target is made of uranium carbide and it will be irradiated with 8 kW protons for two weeks.

At the end of each irradiation cycle and after a short cooling time in the irradiation cave, some 30 Ci of activity must be stored in a temporary area (few years).

The rack designed to house 44 targets in lead boxes will be remotely filled.

Simulations showed that the residual dose rate after the complete filling of the rack, in the controlled areas close by is not a concern, provided a 50 cm thick concrete wall (targets will self-shield each other).

Nevertheless at the very first operational stage one single target can cause a problem.

Some empty containers will be used to surround the first target, so that a light shielding will still be effective.
Many thanks to the target group, in particular R. Silingardi, who designed the rack and shared with us the details of the storing mechanisms.

Thank you for the attention