Multiphysics simulations and validations of a Target Ion Source system for the production of Radioactive Ion Beams

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The SPES project (Selective Production of Exotic Species) aims to develop a facility at Legnaro National Laboratories (LNL) to produce Radioactive Ion Beams (RIB). The facility operates according to the isotope separation on-line technique (ISOL): the driver, a cyclotron, supplies a 200-500 MeV proton beam to the SPES Front-End producing RIBs, thanks to the Target-Ion source system. To obtain higher ion beam energies, a series of subsystems (Beam Cooler, HRMS, Charge Breeder, RFQ) are being designed to allow the use of the post-acceleration PIAVE-ALPI.

The SPES facility

- ALPI building
- Experimental Hall 3
- SPES Front-End

The core of the facility: the Target Ion Source (TIS) complex

- Target Chiller
- Dipoles
- Quadrupoles
- Diagnostics Subsystem 1
- Wien Filter

The off-line Front-End installed at Legnaro National Laboratories

- Proton beam: not available: cyclotron is arriving in 2014

Main components of the Front-End

- Dipoles: maintain the beam centered
- Quadrupoles: focus the beam
- Wien filter: speed separator
- Diagnostic subsystem 1 & 2: reveal beam position and current intensity before and after the Wien filter
- Emittance meter: measure of beam emittance

Experimental apparatus used to test the SPES target heater

1. SPES vacuum chamber
2. Electrical feedthrough
3. Turbomolecular pump
4. Cooling system
5. Pyrometer n°1
6. Pyrometer n°2
7. Kodial window n°1
8. Kodial window n°2

FEM model of the SPES target heater

- Ambient temperature
- Emissivity
- Electrical boundary conditions

Solution of FEM model

Comparison: Experimental data vs FEM model

A typical problem of beam transport: the Wien Filter

The Wien velocity filter: operating principle

Average speed of the particles after extraction electrode:

\[ v_{\text{ion}} = \sqrt{\frac{2q_{\text{ion}} V_{\text{extr}}}{m_{\text{ion}}}} \]

Lorentz force:

\[ F = q(E + v \times B) \]

In the Wien Filter:

\[ v_{\text{ion}} = E \times B \]

\[ v_{\text{ion}} = \frac{E}{B} \]

\[ E \parallel B \]

Ferromagnetic Core

In the Wien Filter:

\[ v_{\text{ion}} = E \times B \]

\[ v_{\text{ion}} = \frac{E}{B} \]

\[ E \parallel B \]

Speed of the particles with unchanged trajectory by the Wien filter:

\[ v_{\text{ion}} = \frac{E}{B} \]

Mass of the particles selected by the Wien filter:

\[ m_{\text{ion selected}} = \frac{2q_{\text{ion}} V_{\text{extr}}}{B^2} \]

Results with SIMION 8.0 (ion optics simulation program to calculate ion trajectories)

Ion trajectories calculated by SIMION 8.0

Beam from TIS

Wien Filter section in SIMION

Out of the bunker

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