MINISTERIO
DE CIENCIA
E INNOVACIÓN

CSIC
Consejo Superior de Investigaciones Científicas
INSTITUTO DE ESTRUCTURA
DE LA MATERIA (IEM)
Curso 2020 - 2021

Practica de Laboratorio nº5:

Breve introducción a la utilización de LISE++

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El objetivo de esta práctica es introducir al alumno en el uso de reacciones en cinemática inversa o de fragmentación para la producción de haces radioactivos, así como en cálculos de transmisión y pureza de los núcleos deseados usando el código LISE++. LISE++, desarrollado por O. Tarasov y D. Bazin en MSU, es un código que permite configurar los parámetros del separador de fragmentos y optimizarlo para producir, seleccionar y transmitir un núcleo exótico o un "cocktail" de estos hasta un plano focal final, donde típicamente se realiza el experimento correspondiente (medida de su desintegración beta, excitación-desexcitación gamma, medida de emisión de partículas, etc). Se considera en particular el caso de reacciones de fragmentación en combinación con el separador de fragmentos FRS de la instalación GSI (Alemania).

Bibliografía

1. O.B.Tarasov, D.Bazin "LISE++: Radioactive beam production within in-flight separators"

Nucl. Instrum. Methods B 266 (2008) 4657-4664.

2. O.B.Tarasov, D.Bazin "LISE++: design your own spectrometer" Nucl. Phys. A 746 (2004) 411-414.

3. H.Geissel et al., "The GSI projectile fragment separator FRS: a versatile magnetic system for relativistic heavy ions", Nucl. Instrum. Methods B 70 (1992) 286-297.

3. Additional documentation can be found online at:

http://groups.nscl.msu.edu/lise/lise.html

https://www-win.gsi.de/frs/index.htm

https://www-win.gsi.de/frs-setup/

Materiales

El alumno dispone del siguiente material:

1. Ordenador con entorno de trabajo Windows o Linux (WINE) con LISEcute++ (Win 15.18.1_beta) http://lise.nscl.msu.edu/download/Windows/
2. Directorio de trabajo
3. Hoja anexa, donde se especifican los detalles de la reacción que se intenta simular, las restricciones experimentales, etc.

Realización

Beginning

1. Familiarize yourself with the working environment, start up the program LISE++, load the FRS configuration and options. Create your own directory inside the ~/LISE/files directory to save your files. Add the file "LISE_beginning_Init.lpp" to the directory and open it in LISE.
2. Set the spectrometer and calculate the transmission and rates of all nuclei. A smaller region can be chosen to reduce the calculation time.
3. Cross check the production rate and transmission of ^{96}Cd via ^{124}Xe beam @ 750 MeV/u and 10^9 pps on a natural Pb target of 4 g/cm^2: must be 3.38e-4 pps and 69.858% respectively.

(Remember to save your work periodically, using meaningful filenames which will permit to go back to the work at a later stage.)

Search best fragment-target combination for the production of ^{101}Sn

1. Check rates and transmission for ^{124}Xe (@750MeV/u) [beam intensity: 10^9 pps] on a 4g/cm^2 natural Pb target.
2. Find optimum target thickness using the "Optimum target" tool in the Calculation menu. (Check "target optimization option": (d) + Savitzky-Golay filter ON)
3. Find new rates and transmission and note them down.
4. Q. How does the transmission changes if you change the beam energy, keeping the same target thickness? Take a few points for ^{101}Sn to later plot a curve. Reason about the trend.
5. Now, keeping the initial beam energy (750MeV/u) and beam intensity (10^9 pps), find better combinations of beam and target to increase the production rates of ^{101}Sn (hint: low Z targets (Be, C) give largest yields, available targets: Pb, Be, C). Use the list of available beams provided (for this practice, we keep the beam intensity to 10^9 pps for all beams, even though in reality not all isotopes are available to the same intensity. Examples can be seen in the appendix "List of main primary beams available at GSI"). Reflect on this systematic study.

Obtain a pure ^{101}Sn beam at S4 (the other contaminants are at least 2 orders of magnitude smaller)

6. Once the best combination of beam and target has been found, inspect rates after each dipole magnet and write them down.
7. To measure rates, introduce Faraday cups using the "Setup" button. The fraction of the spectrometer after the Faraday Cup should turn gray. Do calculation for 'All nuclei' and read value of Total sum at the very bottom of the window ("Sum=...").

8. What are the main contaminants at the slits of S4? Plot horizontal (X) space distributions in 1D-plot menu and save them.
9. Try to cut the contaminants down to a minimum playing with slits. What are the main contaminants now at S4?
10. Plot dE-TOF. Can you clearly distinguish the different isotopes?
11. You may need to add the S2 wedge degrader to improve separation. As a first guess for the thickness, it is good to use 60% of the range (for the desired fragment) just before the wedge. To measure the range, use Calculations → Goodies, after sci21, and check the range in Al, which is the material of the wedge.
12. Introduce homogeneous wedge with thickness ~ 60% of the range, with no angle, and check again contaminants at S4.
13. Change wedge angle, using Calculate Angle program in the window which opens by clicking on Wedge in the menu. Choose achromatic value. The block in the dispersion plane is S4_Slits (where you want maximum separation of the beam components). Increase the Dimensions of wedge angle distributions to obtain a more precise determination of the minimum. Click on "Fix" next to Achromatic on the left-hand side of the window. Re-tune spectrometer and check again contaminants at S4 slits. To improve it further, try changing the wedge thickness. NOTE: If the search of the angle does not work, after changing the thickness click on "Set the spectrometer after this block using changes"; you can also reduce the slits at S4 and increase the number of points for the wedge calculation to 512 or 1024 (it takes longer, so better check with 64 and 128 first).
14. Plot dE-TOF. Can you clearly distinguish the remaining isotopes? What are the main other contaminants now? With what rate are they produced?
15. You can also try to put a homogeneous 1g/cm^2 wedge at S1. Does that improve the situation? (remember that you need to recalculate the thickness and the angle of the wedge at S2 after adding the wedge at S1).
16. If typical experimental constraints applied, the TOTAL rates on sci21 would need to be inferior to 10^6 pps, and rates at S4 inferior to 10^4 pps. Are your rates within these boundaries? If not, how could you reduce them?

Obtain mono-energetic ^{101}Sn at S4

17. Once you and the tutor are satisfied with the achieved beam purity, you shall try to obtain mono-energetic ^{101}Sn using the separator in the monochromatic mode. In the Calculate Angle program choose the monochromatic value. Plot horizontal (X) space distributions at S4 and also 1D Energy distribution. Do you see what you expect?
18. Add plexiglass stopper after sci41. What is the range of the ions in the stopper? ("1D plots → Range" distributions)
19. Before leaving, remember to copy your files and your saved graphs on a usb stick or send them to yourself by email.

Informe de Prácticas

Para la evaluación de la realización-comprensión de la práctica el alumno deberá presentar un informe de la misma antes del día 04 de junio de 2021, que enviará por correo electrónico a las direcciones:

master.nuclear@iem.cfmac.csic.es

En la misma se debe explicar la metodología seguida durante la práctica y responder a las preguntas e imperativos escritos en la realización de la práctica. Se presentarán también los siguientes puntos.

1) Una descripción general y sus propósitos de los elementos que constituyen FRS.
    I. **Ejemplos** simulados de la variaciones de la transmisión en función de la energía del haz primario, explicando cualitativamente el origen de la variación.
2) Una explicación de la diferencia entre modo acromático y mono-energético.
    I. Después de haber explicado la diferencia entre modo acromático y mono-energético (o monocromático), **espectros** 1D de distribución en X (S1, S2, S3, S4) y en Energía (S2, S4) relativos a los sectores del separador con los parámetros finales elegidos en los dos casos.
    II. Intensidad total de haz en pps en S2 y S4 en los dos casos, del fragmento y sus principales contaminantes.
    III. **Espectros** 2D de identificación de isotopos (Z vs A/Q o dE vs TOF, X vs X2 etc) en los dos casos.
3) ¿Qué tipo de experimento podría requerir un haz mono-energético, como en el caso simulado? ¿Qué tipo de experimento en vez podría necesitar de un haz puro?
4) ¿Qué espesor de plexiglass se necesita para parar los iones de ^{101}Sn en el plano focal S4?

Para la nota se tendrá en cuenta el interés y esfuerzo durante la práctica demostrado durante la práctica. Además, la claridad del informe repercutirá en la nota final.

Anexo

LIST OF MAIN PRIMARY BEAMS AVAILABLE AT THE FRS

^{238}U : 2 10^{9} pps

^{144}Sm : 2 10^{9} pps (no standard beam, used once)

^{136}Xe : 10^{10} pps

^{124}Xe : 10^{10} pps (x abundance of enriched material)

^{112}Sn : ~10^{8} pps (x abundance of enriched material)

^{107}Ag : 4 10^{9} pps

^{106}Cd : not available at GSI (poisonous)

^{86}Kr : 10^{10} pps

^{78}Kr : 10^{10} pps (x abundance of enriched material)

^{76}Ge : 3 10^{8} pps (no standard beam, needs to be developed)

^{64}Ni : 5 10^{9} pps (x abundance of enriched material)

^{58}Ni : 5 10^{9} pps

^{48}Ca : 3 10^{7} pps (low intensity from the source that is used for pulsed beams for SIS experiments; using an ECR source would improve the situation on the expense of much more material needed.)