HINDAS: A European Nuclear Data Program for Accelerator-Driven Systems

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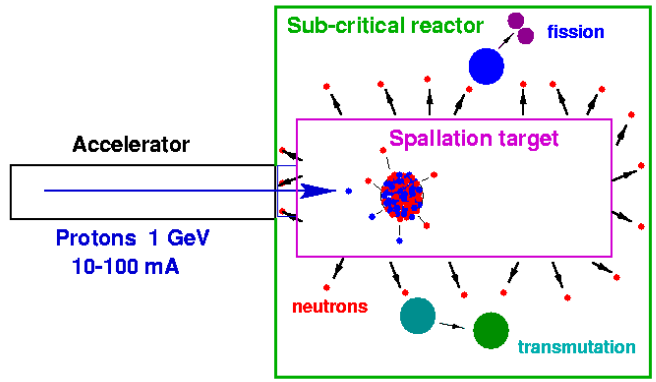
General motivations:

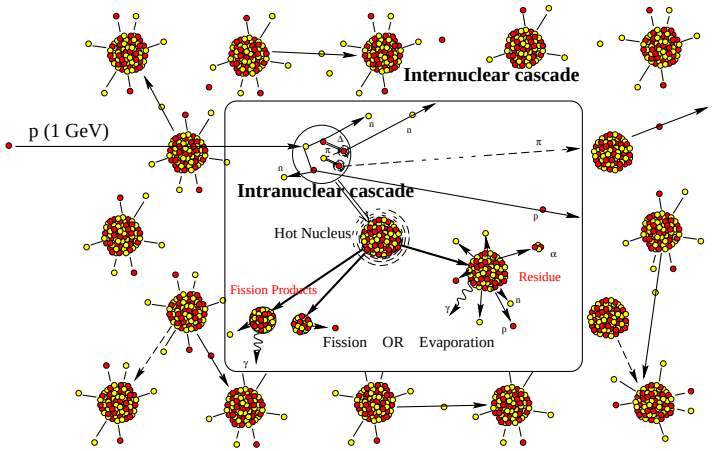
Accelerator-driven systems for the transmutation of nuclear waste

➨ Nuclear physics is needed to build reliable and validated simulation tools



- **Multiplicity and characteristics of the produced neutrons**
  - ⇨ performance of the target, damages, radioprotection
- **Charged particle production**
  - ⇨ gas (H_2, He) production, DPA
- **Residual nuclide production**
  - ⇨ radiotoxicity, corrosion, damages

Nuclear physics for ADS design



- **Monte-Carlo transport codes**
  - ➢ **propagation of all particles created in elementary interactions**

    (HETC + MCNP type)

- **Nuclear physics models**
  - ➢ **above 150-200 MeV : Intra-nuclear cascade, evaporation-fission ➨ cross-sections, properties of emitted particles used directly by the transport codes**
  - ➢ **below 150-200 MeV : optical model, pre-equilibrium, direct reactions, evaporation, fission… ➨ Evaluated data files providing all reaction channels**
- **Experimental data**
  - ➢ **Directly useful ones**
  - ➢ **To understand the physics, constrain and validate the models**

HINDAS: High and Intermediate energy Nuclear Data for Accelerator-driven Systems

GOAL: To provide ADS-relevant nuclear data and models in the 20-2000 MeV range

- Measurements for a few targets (Fe, Pb and U) of experimental data covering all the reaction channels (neutron, light charged particle, residue production) in the whole energy range
- Improvement of nuclear physics models and validation on the experimental data
- Generation of evaluated nuclear data libraries in the 20-200 MeV range
- Implementation of the high-energy models into High-Energy Transport Codes
- Assessment of implications for ADS

HINDAS: High and Intermediate energy Nuclear Data for Accelerator-driven Systems

16 laboratories in Europe

- UCL Louvain-la Neuve Belgium
- Subatech, Nantes, France
- LPC Caen, France
- RuG Groningen, Netherlands
- UU Uppsala, Sweden
- ZSR, Hannover, germany
- PTB, Braunschweig, Germany
- IPP Zürich, Switzerland
- PSI Zürich, Switzerland
- FZJ Jülich, Germany
- CEA Saclay, France
- CEA Bruyères, France
- GSI Darmstadt, Germany
- Universitad Santiago de Compostella, Spain
- ULG Liège, Belgiun
- NRG Petten, Netherlands

6 facilities

- Louvain-la Neuve cyclotron
- AGOR cyclotron Groningen
- Svedberg lab. Uppsala
- PSI ZürichCOSY Jülich
- SIS GSI Darmstadt

Measurements

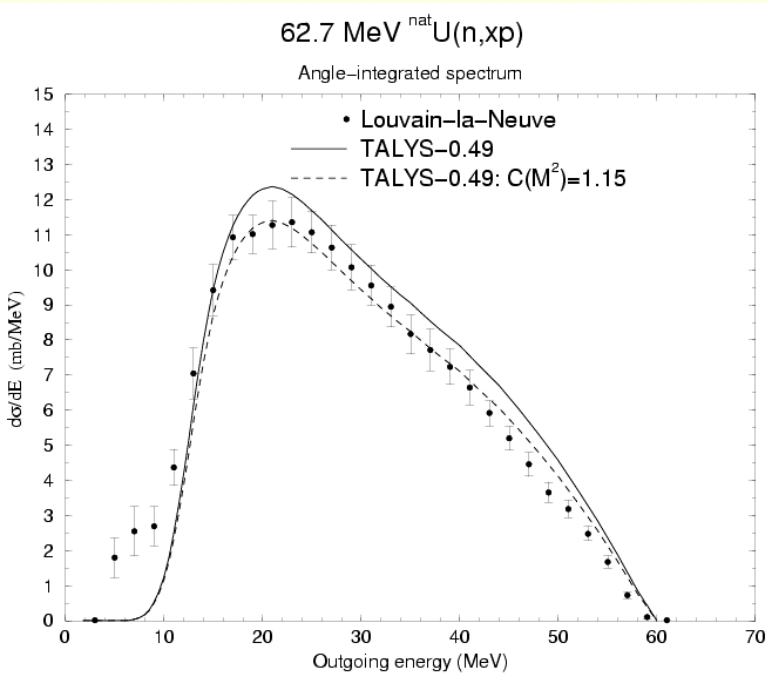
- DDXS (p,xn), (n,xn)
- DDXS (p,xp), (p,xd) … (p,xα)
  (n,xp), (n,xd) … (n,xα)
- Neutron multiplicities in thin and thick targets
- Residue production in direct and inverse kinematics

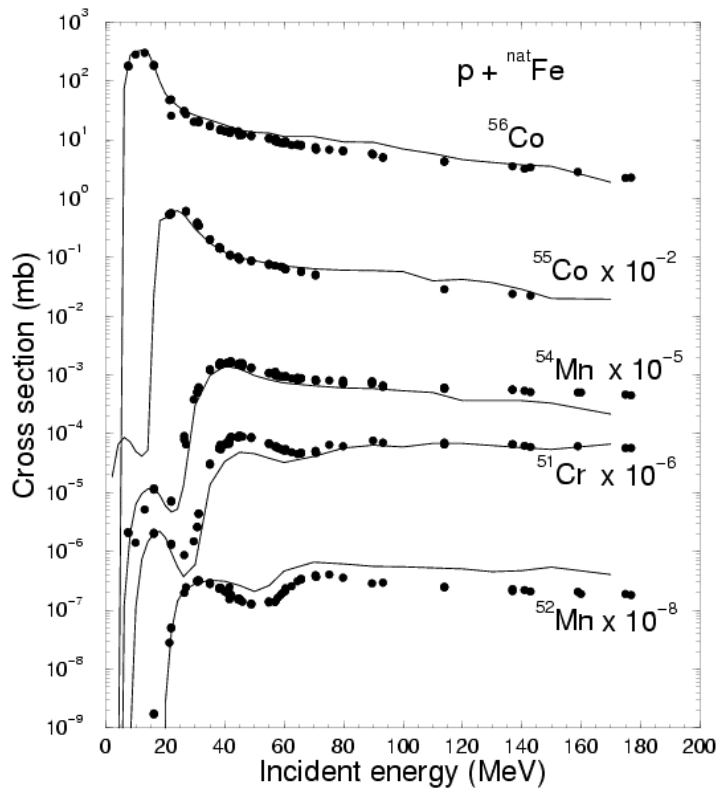
Theory and evaluation

Intermediate energy theory, code development and evaluation

- **Experimental data**
- **The TALYS code (NRG Petten / CEA Bruyères)**

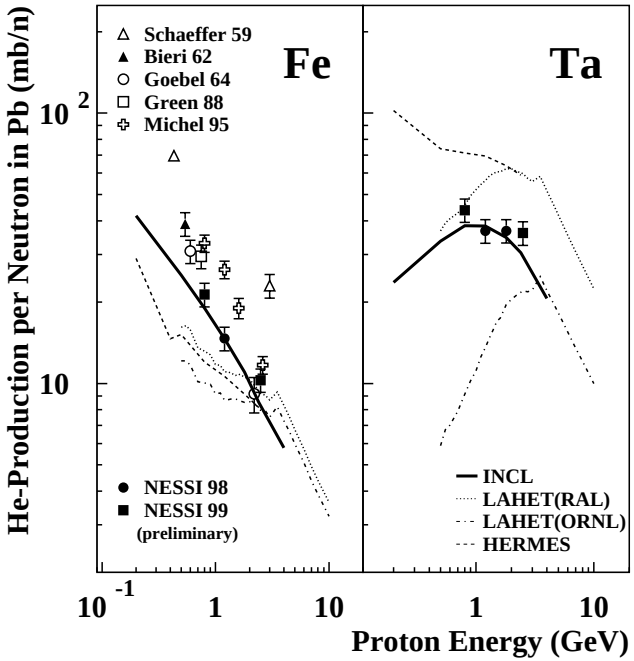
⇒ **Fe, Pb, U evaluated libraries**





From A. Koning, F.Joliot – O.Hahn Intern. School, Cadarache, August 2002

Damage due to spallation reactions in the ADS window



Production of helium in the window per neutron produced in the target as a function of beam energy

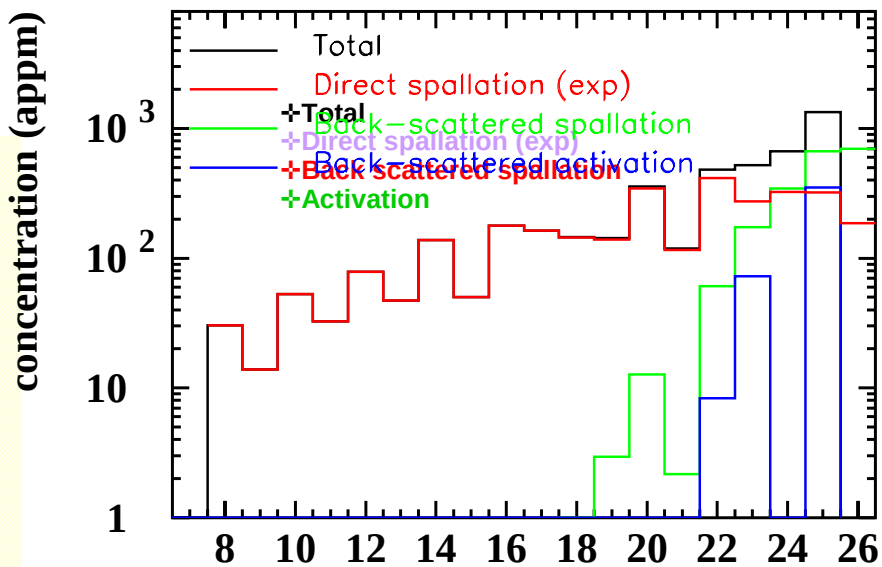
From Hilscher et al., J. of Nucl. Mat., 296 (2001) 83

- LAHET and HERMES strongly disagree with the data
- For iron, high energy preferable

Measurements using the inverse kinematics technics at GSI of Fe+p (C.Villagrasa thesis)

➡ **Impurities produced in the iron window of an ADS after irradiation during 1 year by 1 GeV protons**

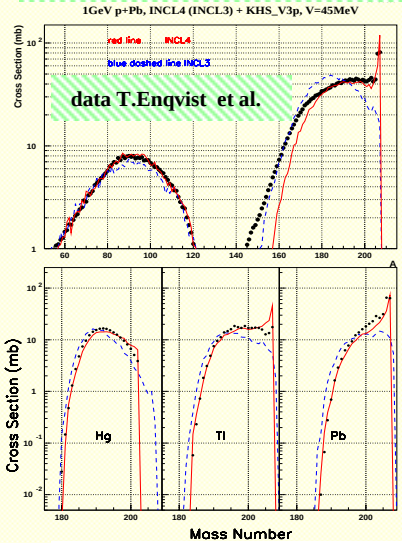
Fe-Cr 9% window irradiated by p, 1GeV, 1 year, 10 mA

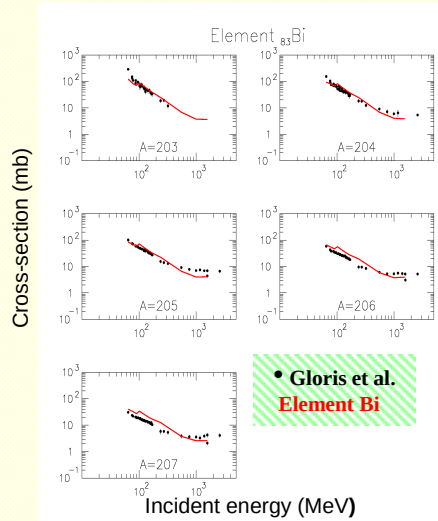


Spallation residue production in a liquid Pb-Bi target

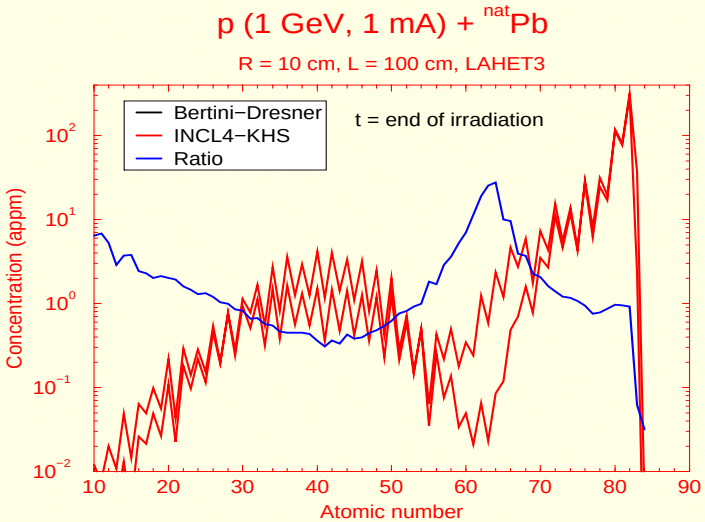
- **Experiments**
  - ^{208}Pb (1 GeV/A)+H2 (GSI)
  - Excitation functions (R.Michel et al.)
- **Models**
  - ➡ Improvement of the physics
  - ➡ Validation on the bulk of data
  - ➡ Implementation into high-energy transport codes (LAHET3)

Calculations INCL4 (A.Boudard et al.) and ABLA (K.H.Schmidt et al.)

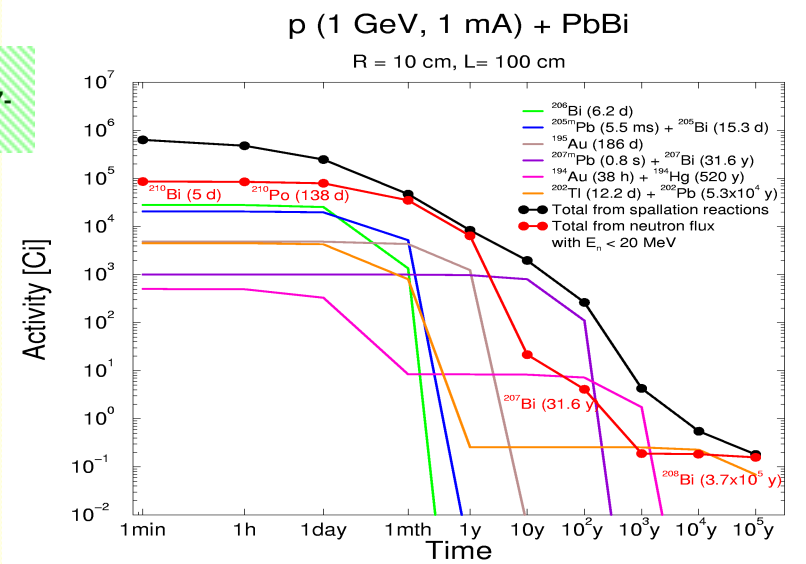




• Gloris et al.
Element Bi

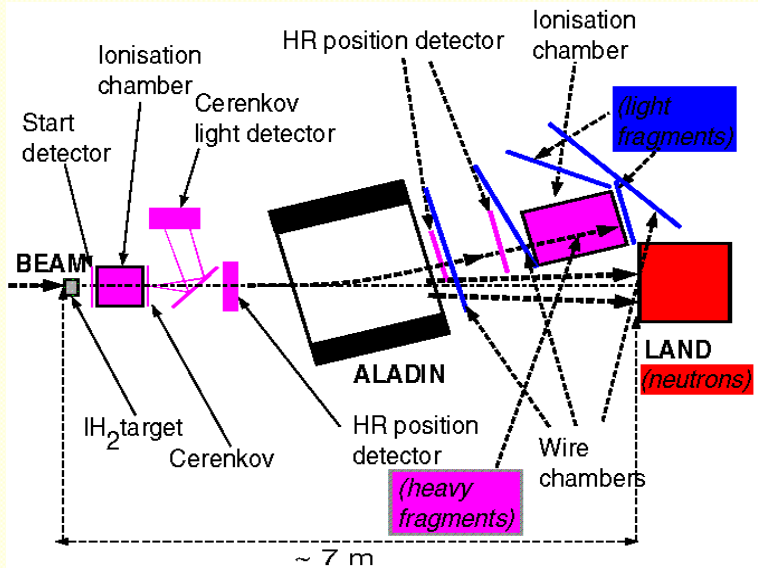


L.Donadille et al., NDST, Tsukuba, oct. 7-12, 2001



Perspectives

- **Still missing data or crucial data for physics understanding**
  - **Light and intermediate mass nuclei**
  - **Fission cross-sections**
  - **Energy dependence**
  - **Coincidence experiments**
- **Still unsatisfying behaviour of the models**
  - **Evaporation**
  - **Fission**
  - **Fermi-breakup for light nuclei**
  - **Emission of composites in INC**
  - **IMF production**



- **Validating the codes on real spallation device experiments**
  - **Ex: SINQ target samples of Pb, Pb-Bi**

⇒ **General goal: Producing reference codes relevant for spallation targets**

- **life time assessment**
- **waste management**
- **shielding evaluation**

Perspectives

TREND/SANDAT FP6 proposal on transmutation relevant nuclear data

- **Providing of nuclear data up to 1000 MeV, suitable for a range of transmutation options (including ADS) by means of a combination of well-selected experiments and nuclear models.**
  - ➔ **Use of the best suited European facilities to provide complete sets of experimental data for key elements, including minor actinides, target, coolant and structural materials.**
  - ➔ **Improvement and validation of nuclear model codes in order to generate enhanced ENDF-formatted data libraries for transmutation.**
  - ➔ **Improvement of high-energy nuclear reaction models in order to provide validated and reliable high-energy transport codes for the modelling of ADS.**
  - ➔ **Sensitivity analysis to determine the most important data and impact on important parameters of transmutation devices.**
  - ➔ **Integral experiments**