Residual Nuclei Produced In Iron By Spallation Reactions.

Motivations

Iron is the main material taking part in the composition of the ADS's window.

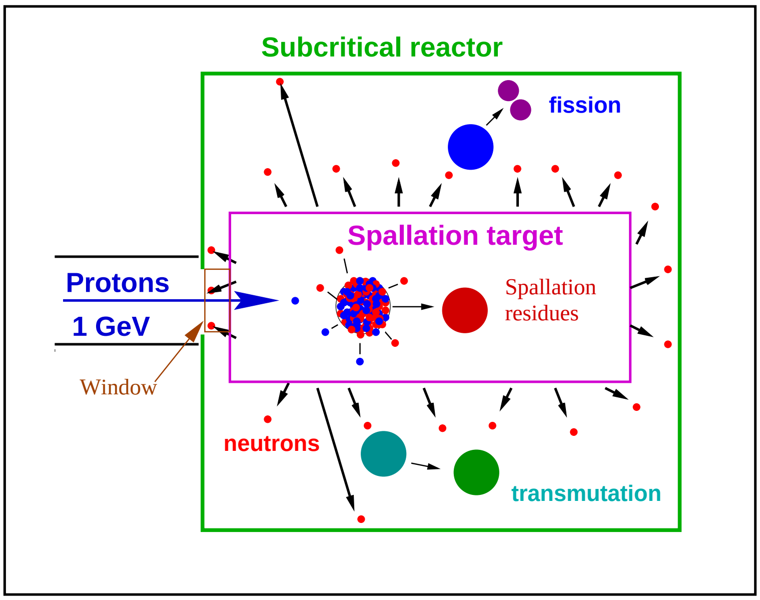

Figure 1: ADS's schematic representation

- **Spallation reactions p + Fe at an energy beam of 1 GeV take place in the window**

- **We would like to know damage in the window: changes in the metal alloy caused by the different residual nuclei nature and estimation of the displacements par atom (dpa) depending on their velocity distribution.**

- **Astrophysics: production of secondary nuclei during the propagation of cosmics rays in the Galaxy.**

Residual Nuclei Produced In Iron By Spallation Reactions.

- Beam induced radiation damage in an ADS window.
- Existing data.
- New experimental data. Spallation reactions using reverse kinematics Fe + p at different energies.
- Preliminary results for fragments of p + Fe reaction at 1 GeV.
- Concentrations evaluated after one year of irradiation.
- Conclusion.

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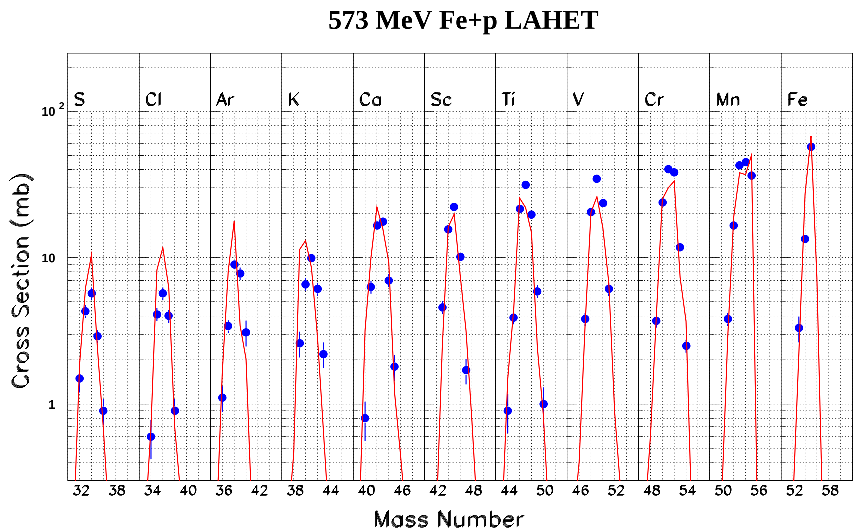
FRS users meeting
21,22 February 2002

Existing Data

isotopic cross sections Fe + p at 573 MeV/A.

Webber et al. The Astrophysical Journal,508:940-958, 1998



Charge-changing cross sections Fe + p at 1 GeV/A.

Webber et al. The Astrophysical Journal,508:940-958, 1998, C.Zeitlin et al. Phys. Rev C (56) 1997 388, G.D.Westfall et al. Phys. Rev C (19) 1979 1309

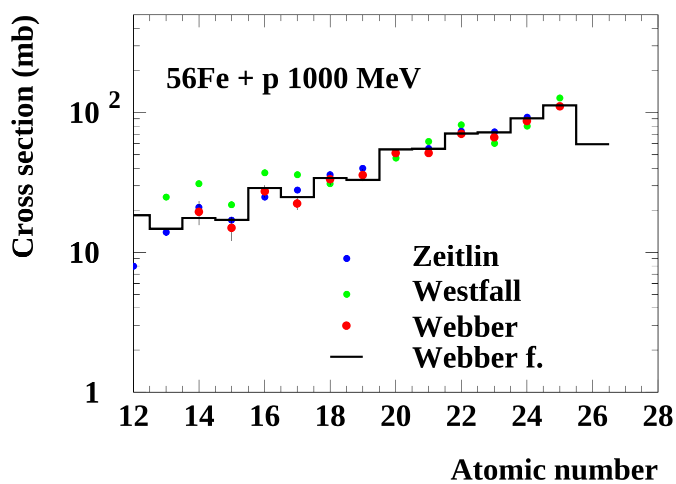


Figure 2: Existing data of charge-canging cross section for iron in hydrogen target at beam energy around 1 GeV/nucleon.

New experimental data.

Experiment Fe + p at 300, 500, 750, 1000 and 1500 Mev/A

Done by the collaboration CEA/SPhN; IPN Orsay; GSI; Universidade de Santiago de Compostela et University of Chicago; CEN-Bordeaux; Argonne National Laboratory; CalTech; CENPA.

- Experiment was done in October 2000 with spectrometer FRS facility at G.S.I, Darmstadt.
- Using the FRS spectrometer in reaction Fe + p we can obtain isotopic cross sections of every spallation residue and their velocity spectrum.
- Data obtained at different energies allow to improve models and to give them a predictive character in the energy dependence.
- Preliminary results of reaction Fe + p at 1 GeV/A

Experimental methods and data analysis. Corrections.

$$\sigma(Z,A) = \frac{N(Z,A)}{N_p \cdot n_t} f_\tau \cdot f_\epsilon \cdot f_{tr} \cdot f_{sec} \cdot f_{tar}$$

- Empty target substraction.
- f_τ correction factor for the dead-time of the data adquisition.
- f_ϵ correction factor for the detection efficiency.
- f_{tr} correction factor for the FRS transmission
- f_{sec} correction factor for the secondary reactions in the different layers of matter in the beam line.
- f_{tar} correction factor of multiple reactions inside the hydrogen target.

Identification of the spallation residual nuclei.

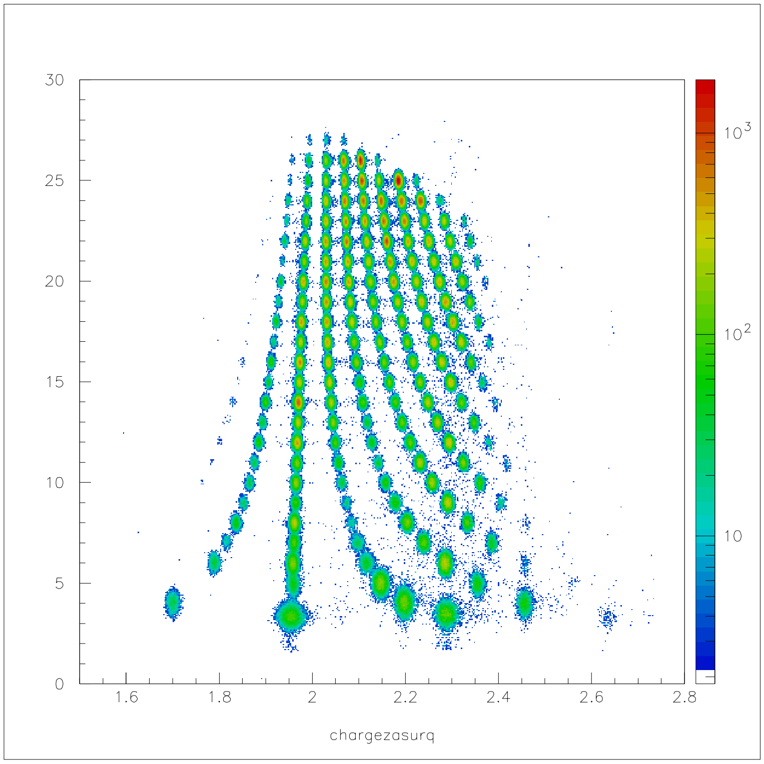


Figure 3: Produced nuclei

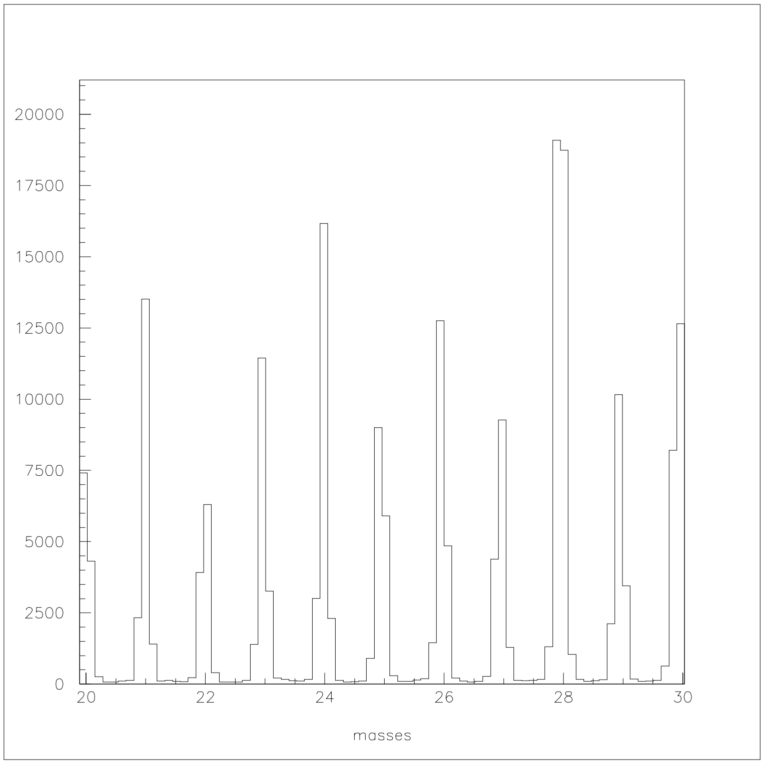


Figure 4: Mass Resolution achieved

Preliminary Results. Fragments Cross sections

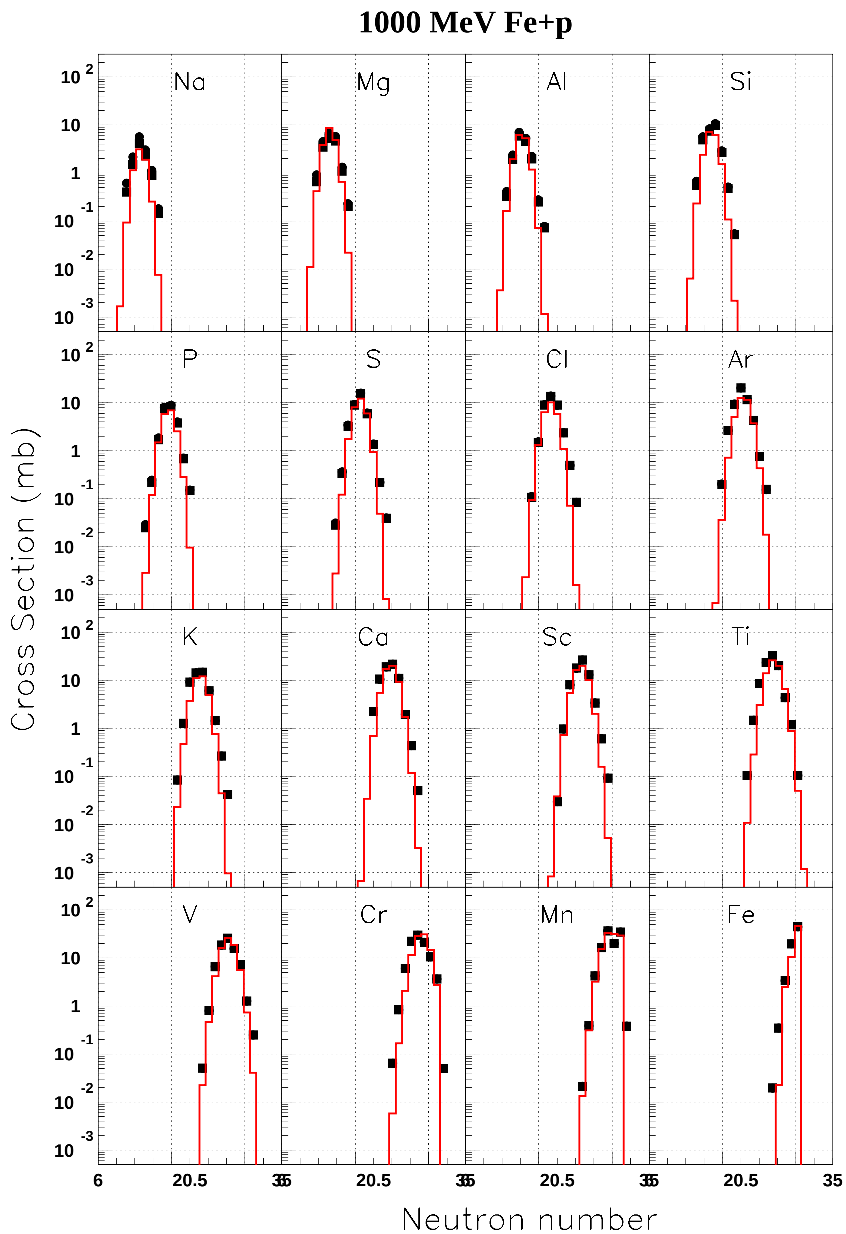


Figure 5: Preliminary results of some fragments in the p + Fe reaction at 1 GeV compare to Webber's parametric function.

Position of the maximum depends on the exitation energy of the pre-fragment.

Velocity of the fragments.

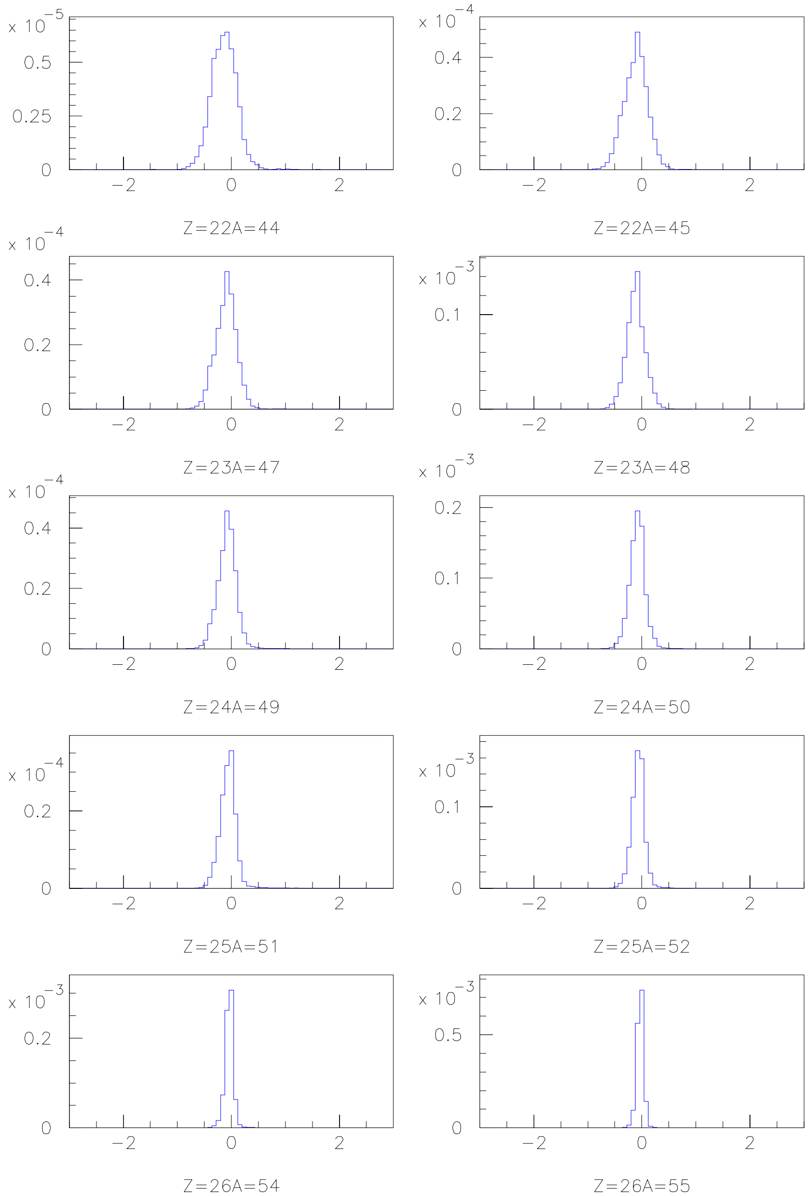


Figure 6: Velocity distributions of some fragments in the rest frame of the projectile.

Velocity distributions follows a gaussian law as it was predicted by Goldhaber (A.S. Goldhaber, Phys. Lett. B 53 (1974) 306-8) wich width depends on the mass difference between the fragment and the projectile.)

Masse and Charge distributions.

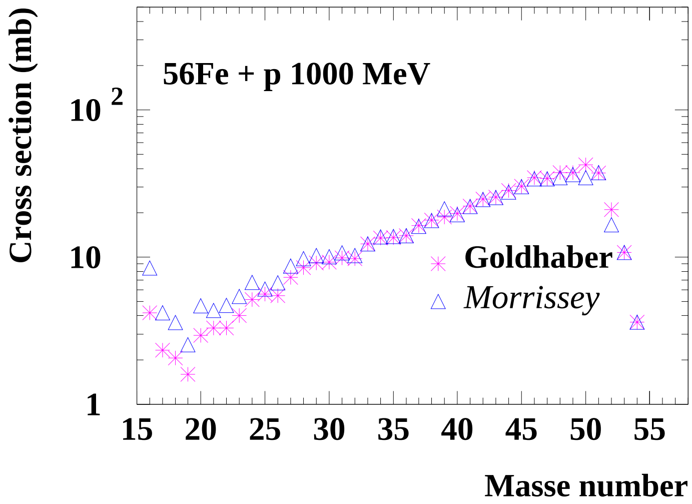


Figure 7: Masse distribution of spallation fragments from Fe + p at 1 GeV/A

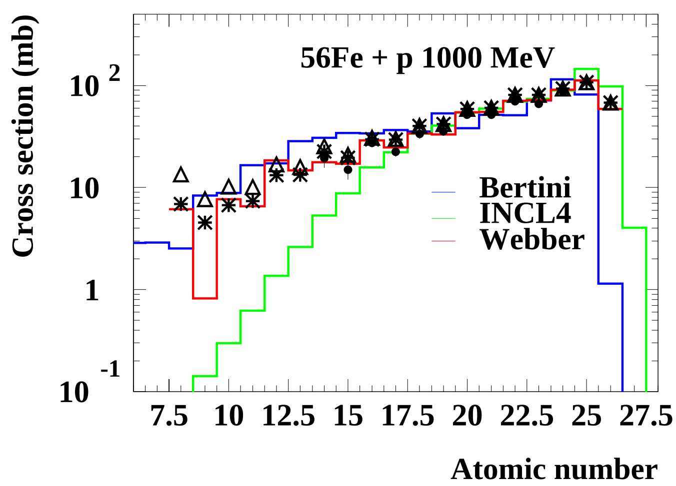


Figure 8: Charge distribution of the fragments compared to Webber's data at 1086 MeV/A and to two different models: Bertini + Dresner and INCL4 + KHS .

Concentrations

After one year of irradiation by a characteristic proton beam of an ADS prototype

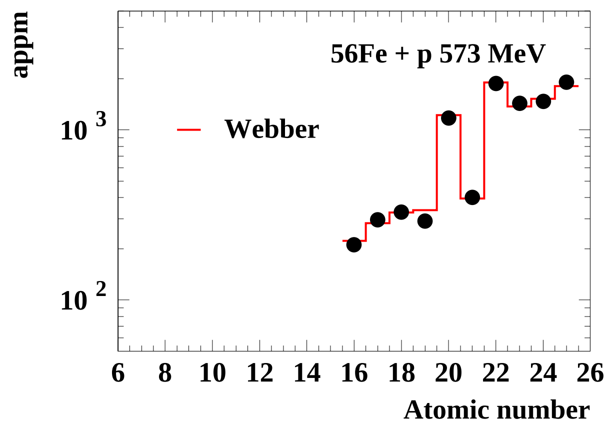


Figure 9: Concentration at 573 MeV/A calculated with the DARWIN code.

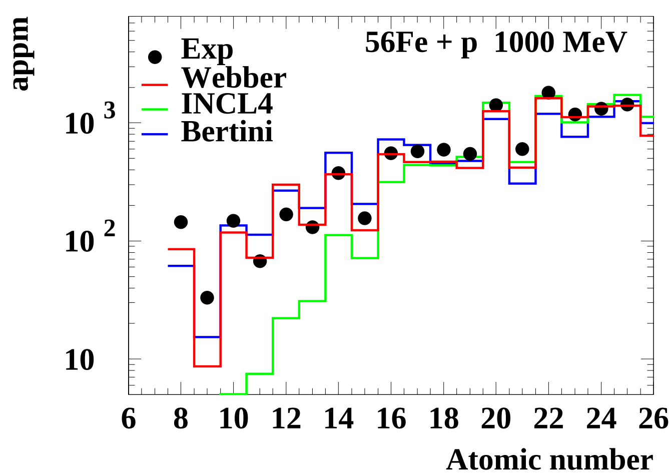


Figure 10: Concentration for a 1 Gev energy proton beam. Black poins represents concentrations calculated with the ORIHET code after one year of irradiation using ours experimental cross sections. They are compared to calculations using the Webber's parametric function or codes for the spallation cross sections

Conclusion.

- In order to estimate the beam induced radiation damages in the window an experiment using reverse kinematics for the reaction Fe + p took place at GSI using the FRS facility for different energies of the beam: 300-1500 MeV/A.
- Preliminary results at 1 GeV/A have been presented. Isotopic cross sections and velocity distributions of the spallation fragments were obtained down to N (Z=7). Experimental data for other energies will be available soon. These data will allow to test the energy dependence of the models.
- From our experimental cross sections we have evaluated concentrations of every element in the window after one year of irradiation. Some of these elements can create embrittlement problems in the material as S with high concentrations (around 525 appm) or corrosion problems as Ca (Z=20) (around 1200 appm).