Test of weak and strong factorization

Davide Mancusi[1]

Lembit Sihver[1,2]

Chiara La Tessa[1]

[1] Chalmers University of Technology, Gothenburg, Sweden
[2] Roanoke College, Salem, VA, USA

Summary

- Radioprotection in space
- The need for modeling
- The abrasion-ablation model
- Factorization properties
- Testing the factorization
- Results
- Open questions

Radioprotection in space

- Risk assessment for crews in long-term space missions
- Single-event upsets of electronic devices
- Space radiation environment
- Influence of shielding from the space vessel

Experiments

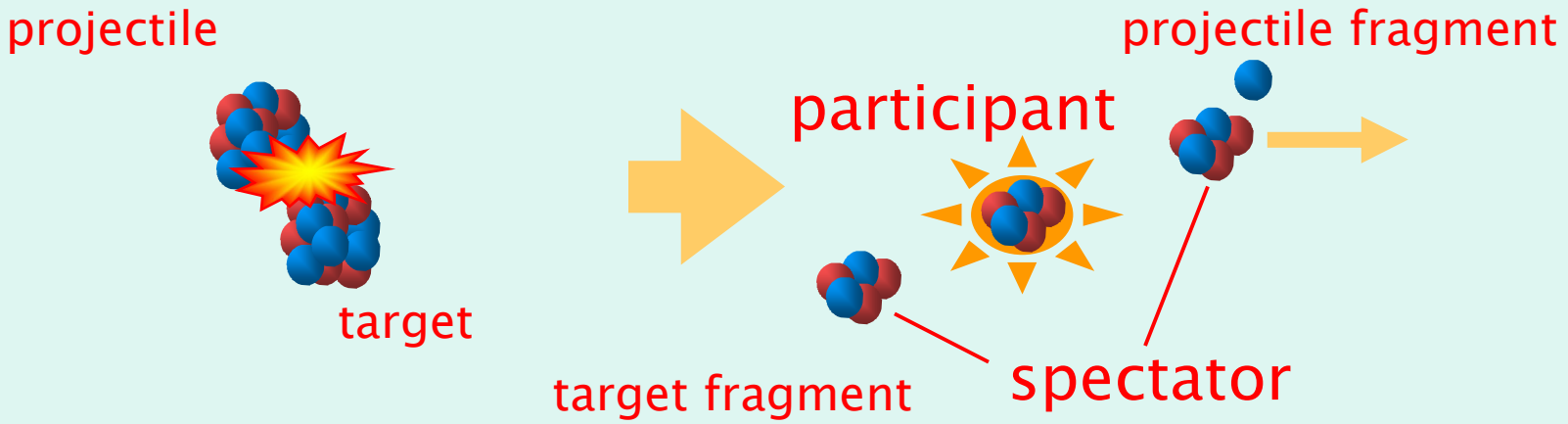
- Ground-based accelerator experiments
  - Fragmentation cross sections for different projectile-target pairs
  - Nuclear databases
- Space-based detector experiments
  - Altea-Alteino
  - Matroshka

Infeasibility of the experiments

- Too many projectile-fragment-target-energy combinations
- Time/money-consuming

Development of semi-empirical systematics, mathematical models and/or numerical codes to predict the cross sections

Abrasion-ablation model



Straight-ahead approximation (1D model)

A few transport codes are based on this model

Factorization properties in the abrasion-ablation model

Predictions:

$$\sigma_{PTF} = \sigma_{PF}\gamma_{PT}$$ *Valid*

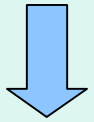
Weak factorization

$$\sigma_{PTF} = \sigma_{PF}\gamma_{T}$$ *Violated*

Strong factorization

Weak factorization in semiempirical cross-section models

If γ_{PT} and $\sigma_{P\bar{T}F}$ can be parametrized semi-empirically



Scaling

$$\sigma_{PTF} = \frac{\gamma_{PT}}{\gamma_{P\bar{T}}}\sigma_{P\bar{T}F}$$

- NUCNUC (Sihver *et al.*)
- model in HIBRAC (Sihver *et al.*)

Many correction terms must be included to account for deviations from the available experimental data (EMD, multifragmentation,evaporation...)

Investigating the model

- The real reaction mechanism is more complicated than the simplified abrasion-ablation picture
- Rescaling procedures are scientifically unsatisfactory

Test the foundations of the abrasion-ablation model through the factorization properties

Methods to test the factorization properties

- Graphical approach
  - gives a general idea of the data behaviour
- Analytical approach
  - provides quantitative evidence
  - factorization parameters

Graphical approach

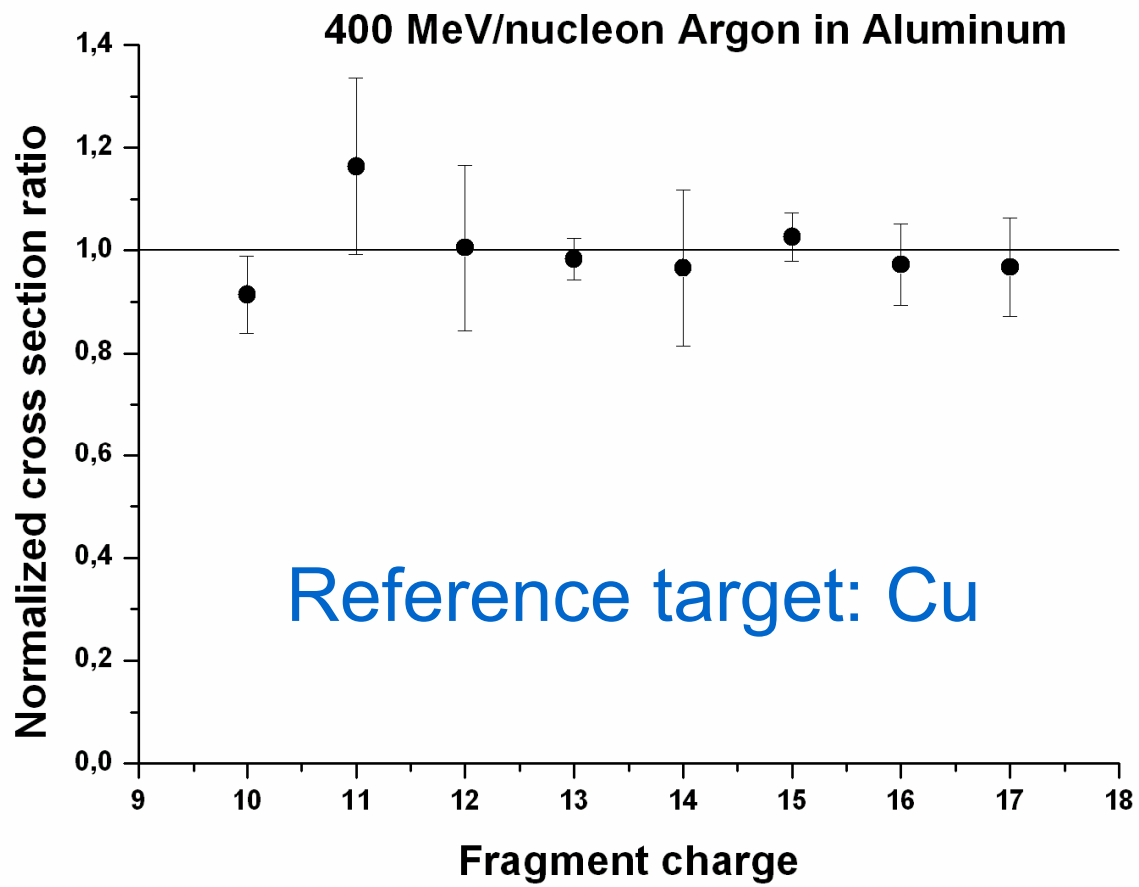
Plot

$$\frac{\sigma^{\exp}_{PTF}}{\sigma^{\exp}_{PT_{\mathrm{ref}}F}}$$

Weak factorization — Independent on the fragment

Strong factorization — Independent on the fragment and the projectile

Graphical approach



Experiment performed by the LBNL group

Analytical approach

Fit the factorization parameters σ_{PF} and γ_{PT} (γ_T) to the data by minimizing the χ^2 function:

$$\chi^2_{\text{weak}} = \sum_{T,F} \left(\frac{\sigma^{\text{exp}}_{PTF} - \sigma_{PF}\gamma_{PT}}{\delta\sigma_{PTF}} \right)^2$$

$$\chi^2_{\text{strong}} = \sum_{P,T,F} \left(\frac{\sigma^{\text{exp}}_{PTF} - \sigma_{PF}\gamma_{T}}{\delta\sigma^{\text{exp}}_{PTF}} \right)^2$$

One parameter must be fixed to determine all the others uniquely

Goodness-of-fit assessment

How well does the fit represent the data?

1. χ^2 test
2. Average discrepancy:

$$d = \left\langle \frac{\left| \sigma^{\mathrm{exp}} - \sigma^{\mathrm{calc}} \right|}{\sigma^{\mathrm{exp}}} \right\rangle$$

Test properties

χ^2

- Tests if factorization holds within the errors
- Sensitive to outliers
- Dependent on the uncertainties estimation

d

- Tests if factorization is a useful concept for modeling
- More robust against outliers
- Less dependent on the uncertainties

Results

Literature

- Olson et al. (1983)
  - Isotopic cross sections
  - Weak factorization valid (χ^2-test)
  - Strong factorization violated?
- Other articles
  - Confirm the validity of the weak factorization

Our group

- Charge-changing cross sections
  - Si detectors (LBNL)
  - CR39+emulsions (HIMAC, Dubna, etc.)
- χ^2-test might not confirm weak factorization
- Can we trust χ^2?

Future work and open questions

- Final results will be published elsewhere
- If χ^2 is not a suitable test for the utility of factorization for modeling, we have to devise other tests (average discrepancy)
- Test strong factorization
- Is abrasion-ablation really suitable to be used in transport codes?
- Is a 1D deterministic code suitable for radioprotection of crews and equipment in long-term, high-orbit space missions?