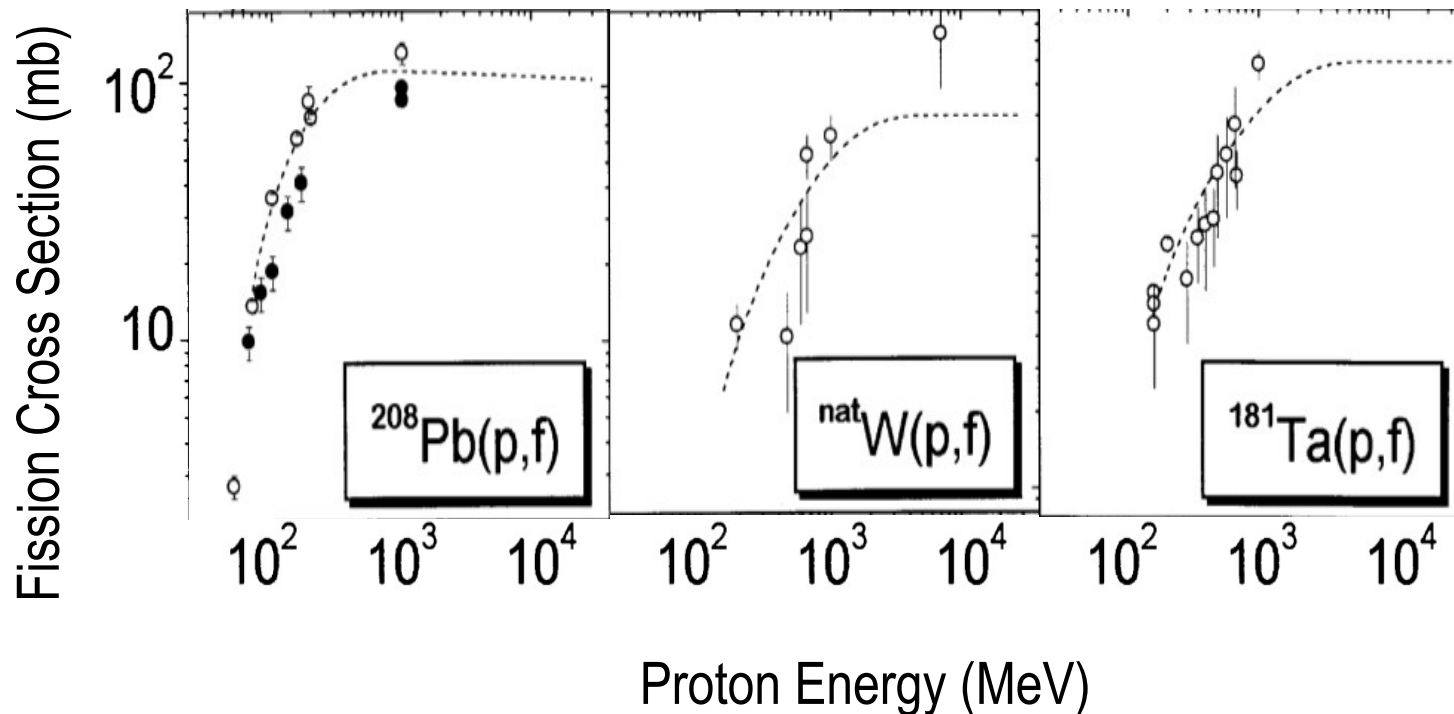


Total fission cross section in proton-induced reactions on ^{181}Ta measured in inverse kinematics

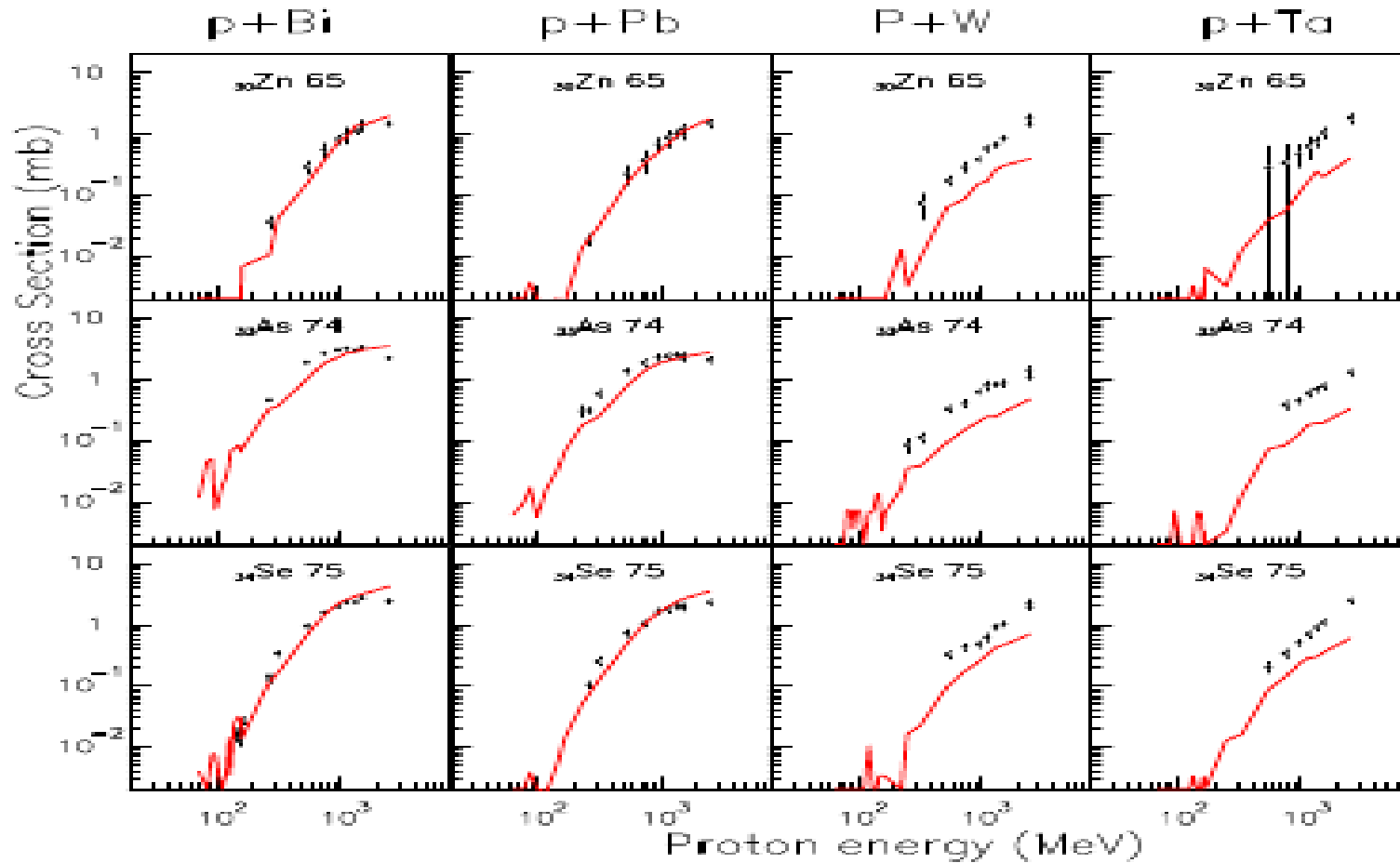
Yassid Ayyad
Universidad de Santiago de Compostela

Subactinides fission cross section

- ✓ Pb, W and Ta as a *production target* : neutron multiplicity, thermal distribution, material properties...
- ✓ Fission may have a significant effect on the performance of an spallation target: production of radioactive and chemically hazardous materials.
- ✓ (n,f) and (p,f) cross sections are used as standards for flux measurements in the energy region important for ADS.

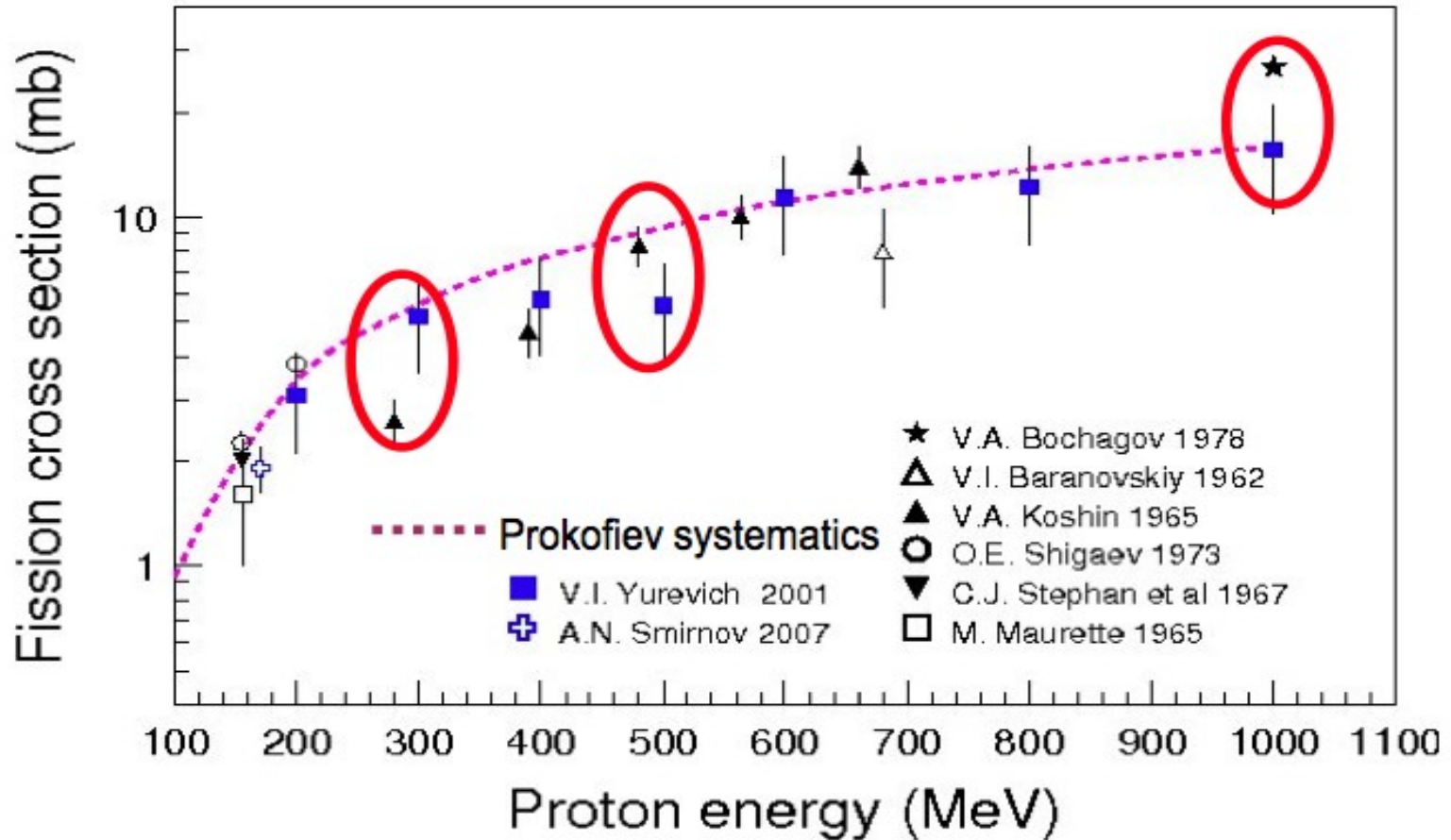


Models and experimental data



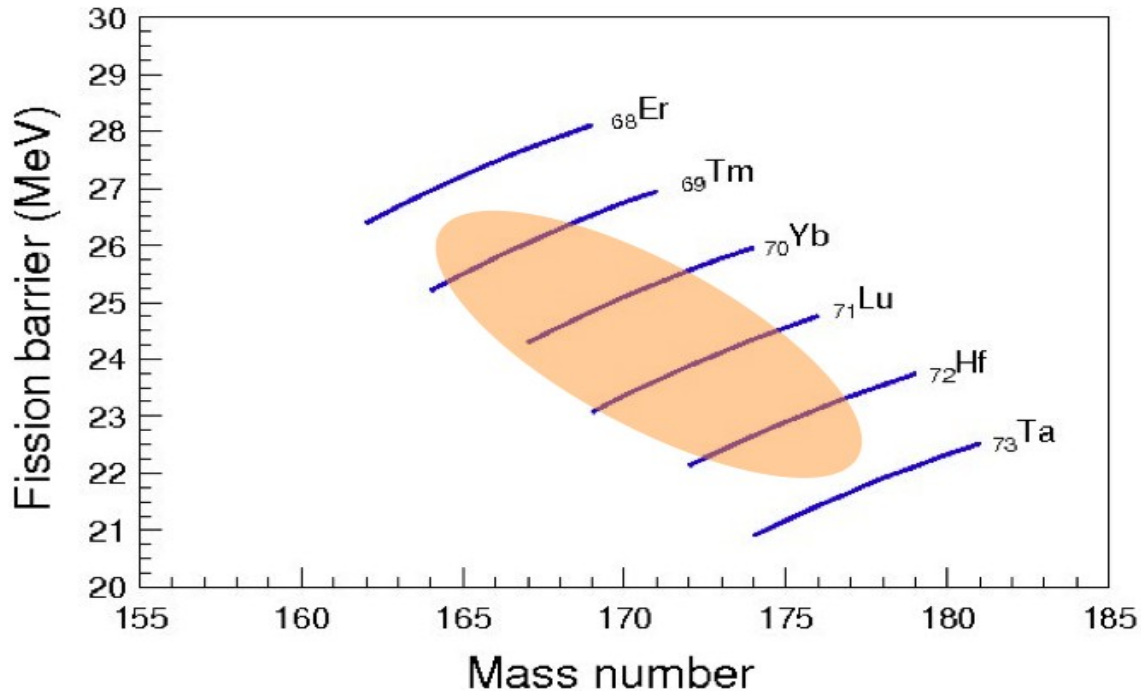
- Discrepancies in fission cross sections for light targets.
- Discrepancies between existing data and parameterizations.

Previous experimental data



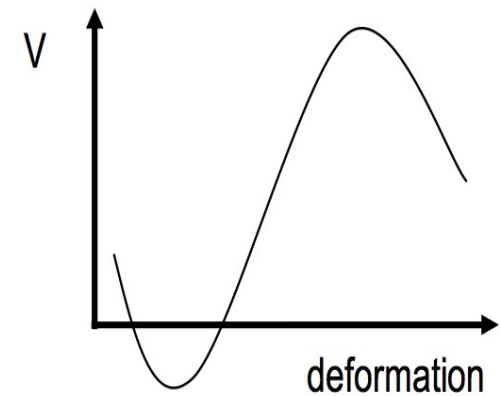
- Discrepancies between widely-used Prokofiev systematics and the experimental measurements. Disagreement between recent data (2000) and previous one .

Dynamics of fission at high energy

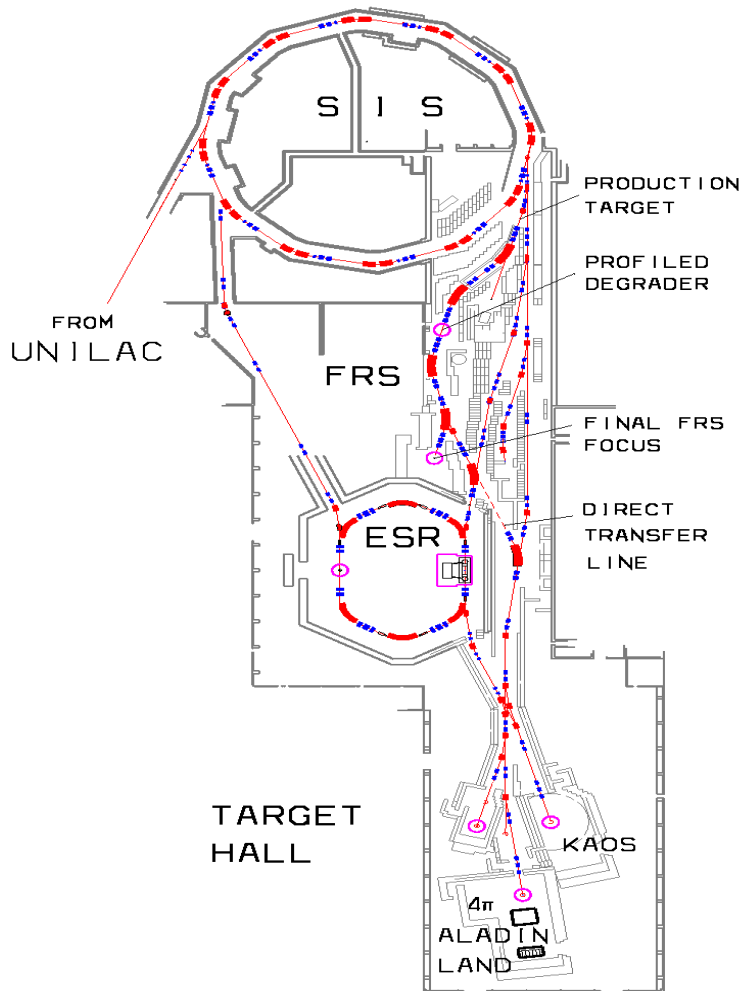


In reactions induced on tantalum, the spallation process produces highly excited remnants with high fission barriers

The total fission cross sections resulting from the competition between fission and neutron evaporation represents a good observable of the fission dynamics: the longer the system needs to reach the saddle point, the lower the fission probability because the nucleus will be cooled down by neutron evaporation.

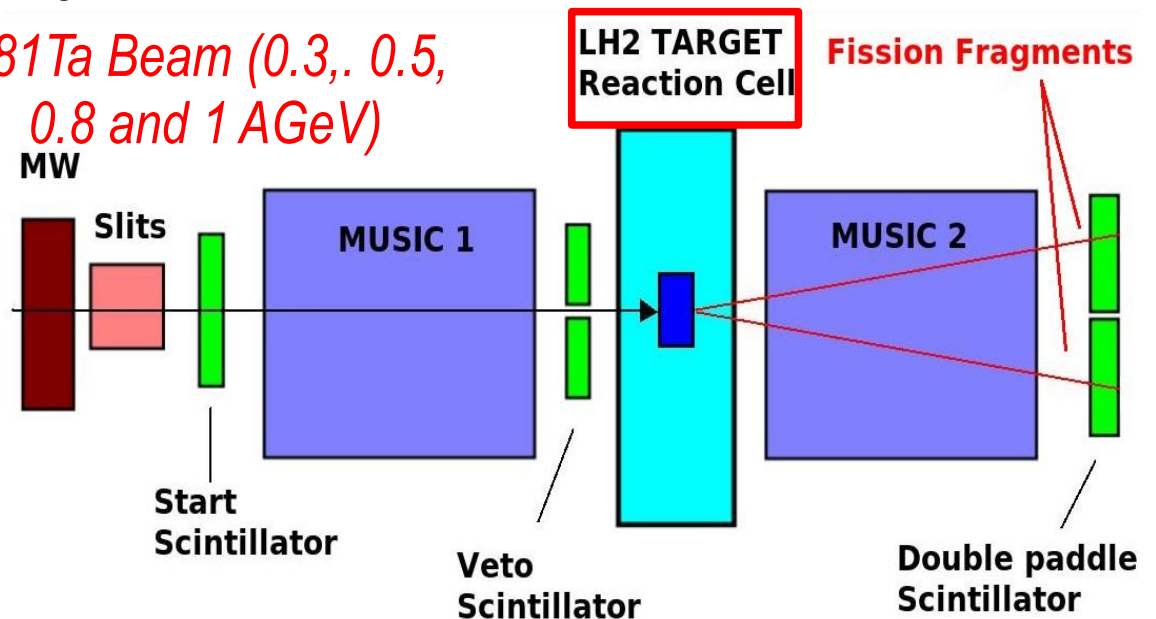


GSI Helmholtzzentrum für Schwerionenforschung.



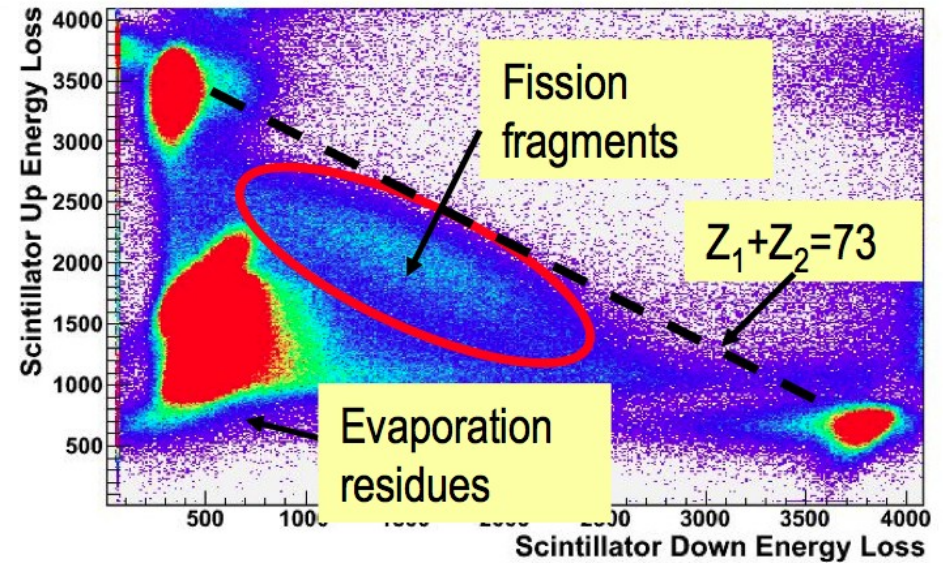
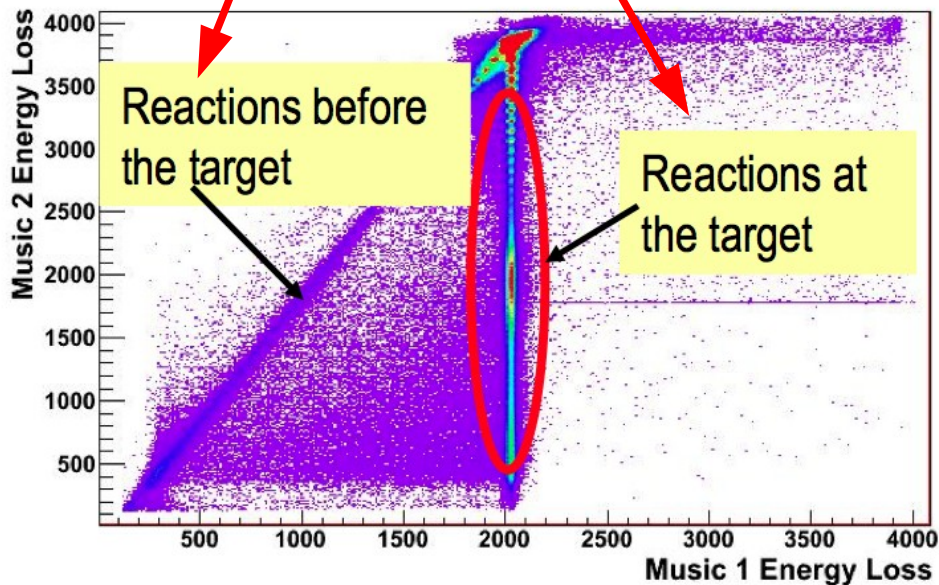
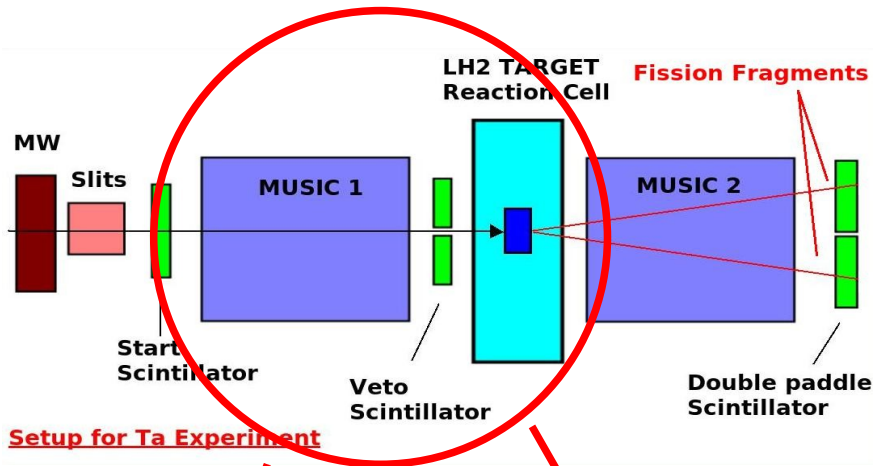
- Inverse kinematics provides high accuracy. Time-of-Flight wall and double ionization chamber would allow to identify the charge and the mass of the fragments.
- Both fragments detected in coincidence
- Beam dose measured together with the fragments
- Large detection efficiencies

181Ta Beam (0.3, 0.5, 0.8 and 1 AGeV)



Setup for Ta Experiment

Data evaluation



- Reactions in other layers of matter and reaction mechanisms other than fission are fully identified
- Detectors surrounding the target define an active target
- Additional effort for background suppression for high accuracy measurements

$$\sigma = \frac{N_{fis}}{N_{pro} \cdot t} \cdot f_{d.t.} \cdot f_{m.r.}$$

Empty target contribution (dummy target) has to be subtracted to the fission contribution of the full target

→ N_{fis} : Fission events

→ N_{pro} : Number of Ta projectiles

→ t : liquid hydrogen target thickness

→ f_{dt} : Dead time correction factor

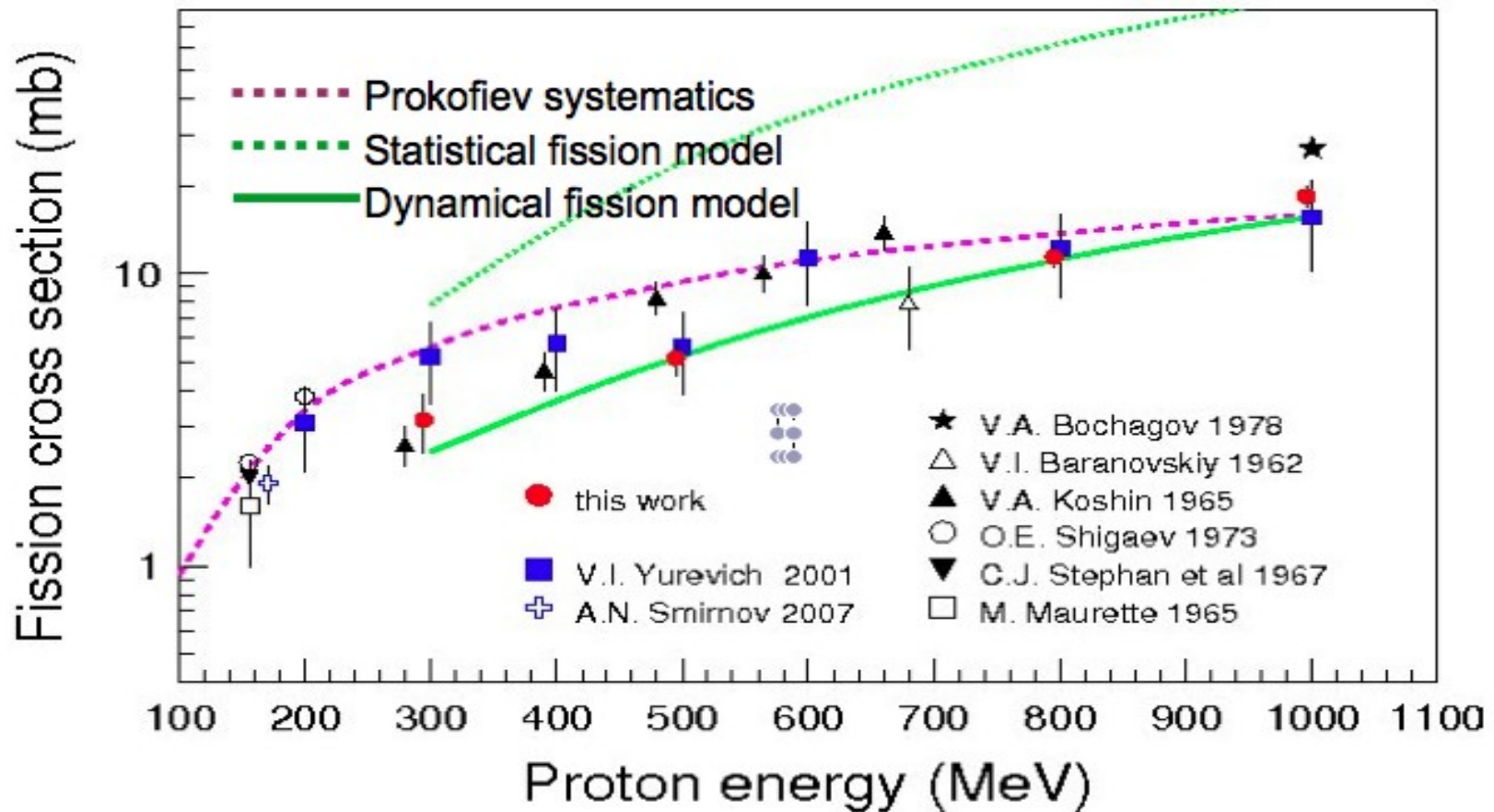
→ f_{mr} : Multiple reaction correction factor

Systematic uncertainties defined by:

- *Target thickness (4%)*
- *Beam intensity (2%)*
- *Systematic identification of fission events (see table)*

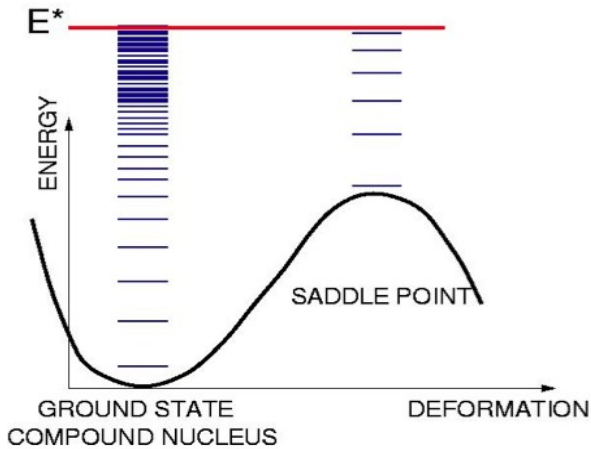
Energy (MeV)	Full target			Dummy target			Results	
	Fission events	Statistical uncertainty	Selection uncertainty	Fission events	Statistical uncertainty	Selection uncertainty	Cross section	Total uncertainty
1000	74520	0.36 %	5.71 %	3077	1.80 %	3.02 %	18.49 mb	1.46 mb
800	77643	0.36 %	5.95 %	20948	0.69 %	1.99 %	11.38 mb	0.83 mb
500	42848	0.48 %	7.19 %	13179	0.87 %	2.52 %	5.14 mb	0.61 mb
300	100834	0.31 %	8.70 %	35362	0.53 %	5.87 %	3.16 mb	0.73 mb

Results



- Simulations performed with INCL 4.1 ⁽¹⁾ + ABLAv3p ⁽²⁾, based on the statistical fission model and the dynamical fission model

Describing fission (4,5)



Interaction between proton and heavy Ta nuclei leading to excited prefragment



De-excitation of the prefragment : Competitive process between fission and neutron evaporation



Statistical description:

- Bohr-Wheeler model.
- Fission rate defined by the available phase-space at the saddle point.
- Transition-state method, reduced number of variables.

$$\Gamma_f^{\text{BW}} \approx \frac{T}{2\pi} \frac{\rho(E^* - B_f)}{\rho(E^*)},$$

Dynamical description :

- Time evolution of the probability flow across the saddle point
- Fission as a diffusion process governed by the reduced dissipation coefficient β
- Dissipation : Internal degrees of freedom (individual nucleons) coupled to collective degrees of freedom of the nuclei
- Nuclear dissipation leads to a delay of the fission channel

$$\Gamma_f^K = \Gamma_f^{\text{BW}} \left\{ \left[1 + \left(\frac{\beta}{2\omega_0} \right)^2 \right]^{1/2} - \frac{\beta}{2\omega_0} \right\},$$

- Fission cross sections in the reaction $p + \text{Ta}$ at different energies has been measured with **high accuracy**
- The existing fission cross sections **systematics overpredict** the new data in particular at the lowest energies (up to 50%)
- The new data also allowed to benchmark different **theoretical models** describing fission
- The fission **statistical model largely overpredict** the measured cross section
- A fission model including a **dynamical description** of the process provides **accurate results**

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S293 Collaboration

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