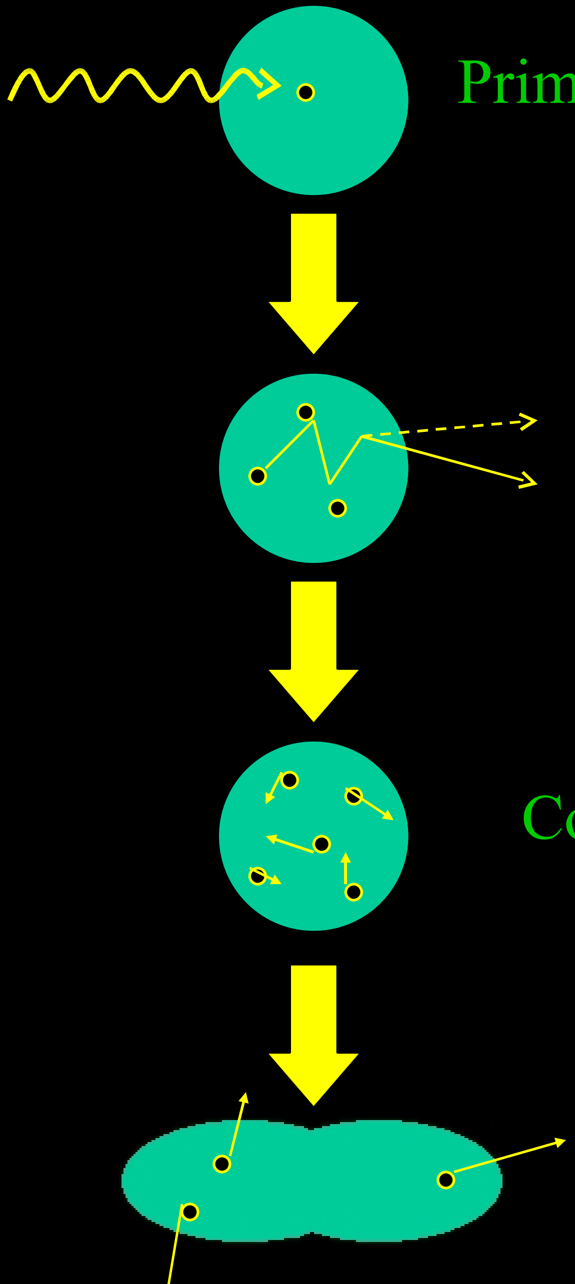
The CRISP package
(Rio-São Paulo Collaboration)

Airton Deppman

The intermediate energy photon-nucleus reaction mechanism:



The CRISP package results from the coupling of the MCMC code for intranuclear cascade process and the MCEF code for the evaporation-fission competition process.

The intranuclear cascade process have been usually described by means of Monte Carlo methods. The classical codes usually describes the process as an assyncronous sequence of single particle events.

The MCMC code performs Monte Carlo calculations of the intranuclear cascade in a time-ordered sequence of events.

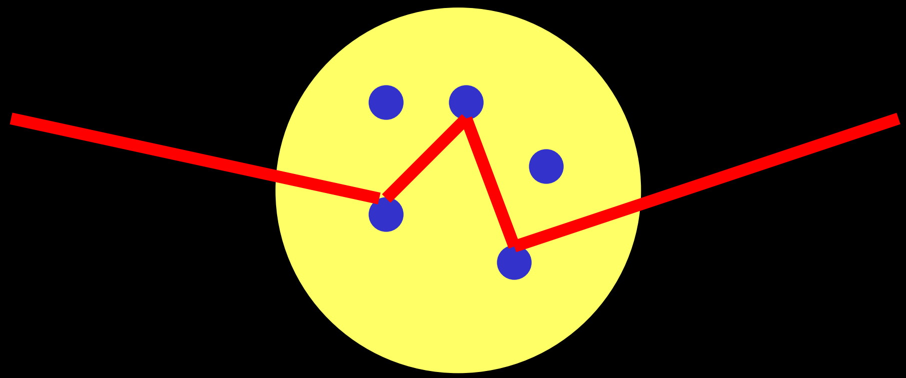
-naturally takes into account the nuclear density fluctuations in the nucleus during the cascade;

-allows a more realistic description of the cascade;

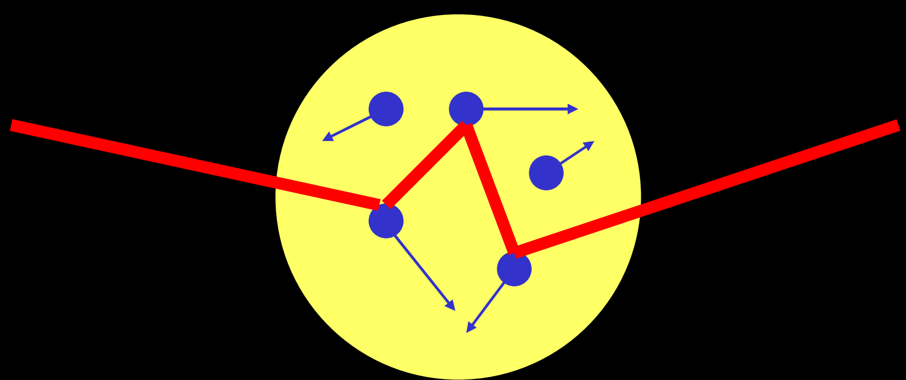
-enables to take into account the variations of the occupation numbers for discrete states;

-allows a better description of the Pauli blocking mechanism.

The intranuclear cascade process:

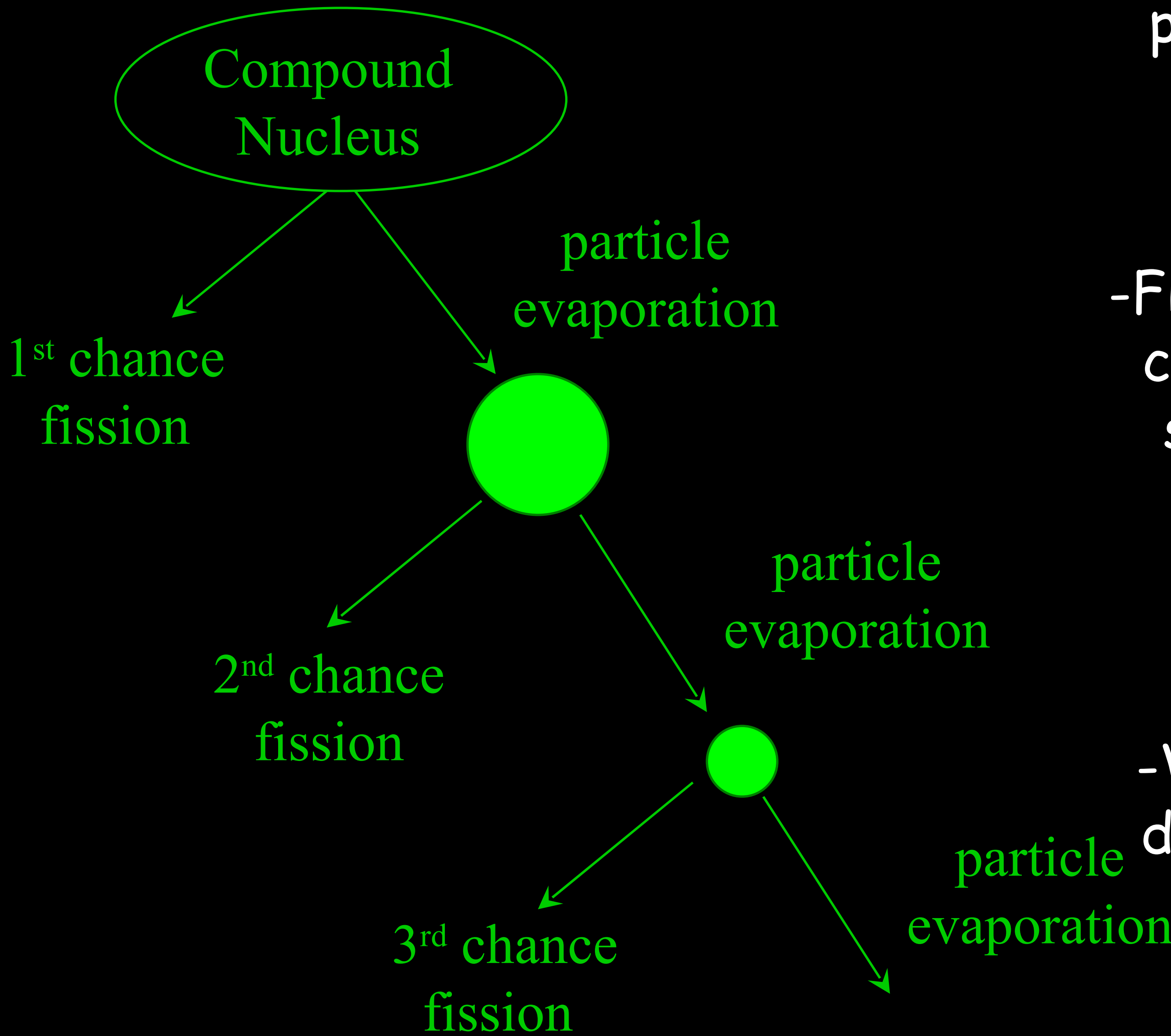


Classical calculations: uncorrelated sequence of semi-classical trajectories



CRISP: a time-ordered sequence of events including all nucleons inside the nucleus

The evaporation-fission competing processes:



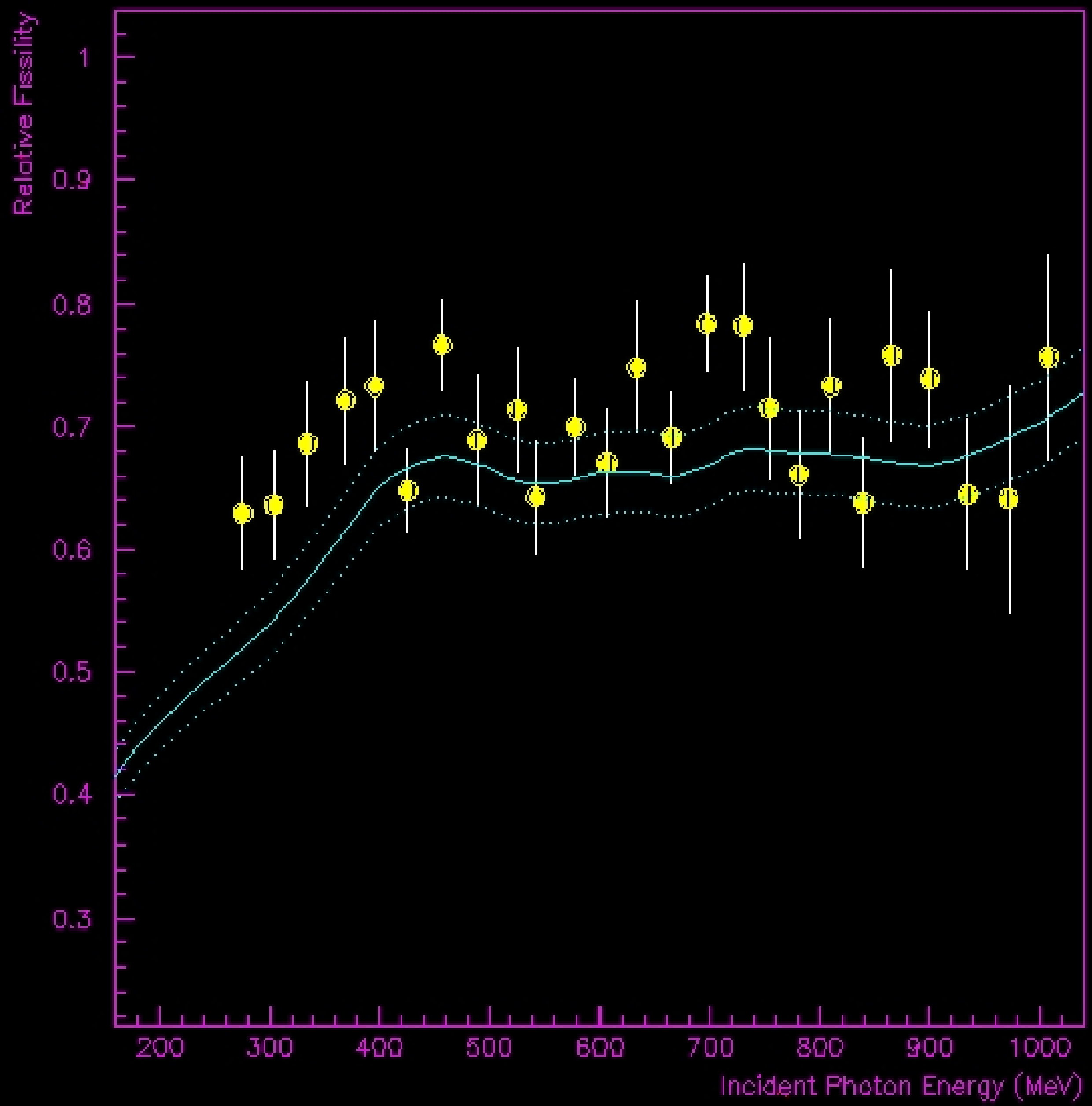
The MCEF takes into account:

-the possibility of protons and alpha-particles evaporation;

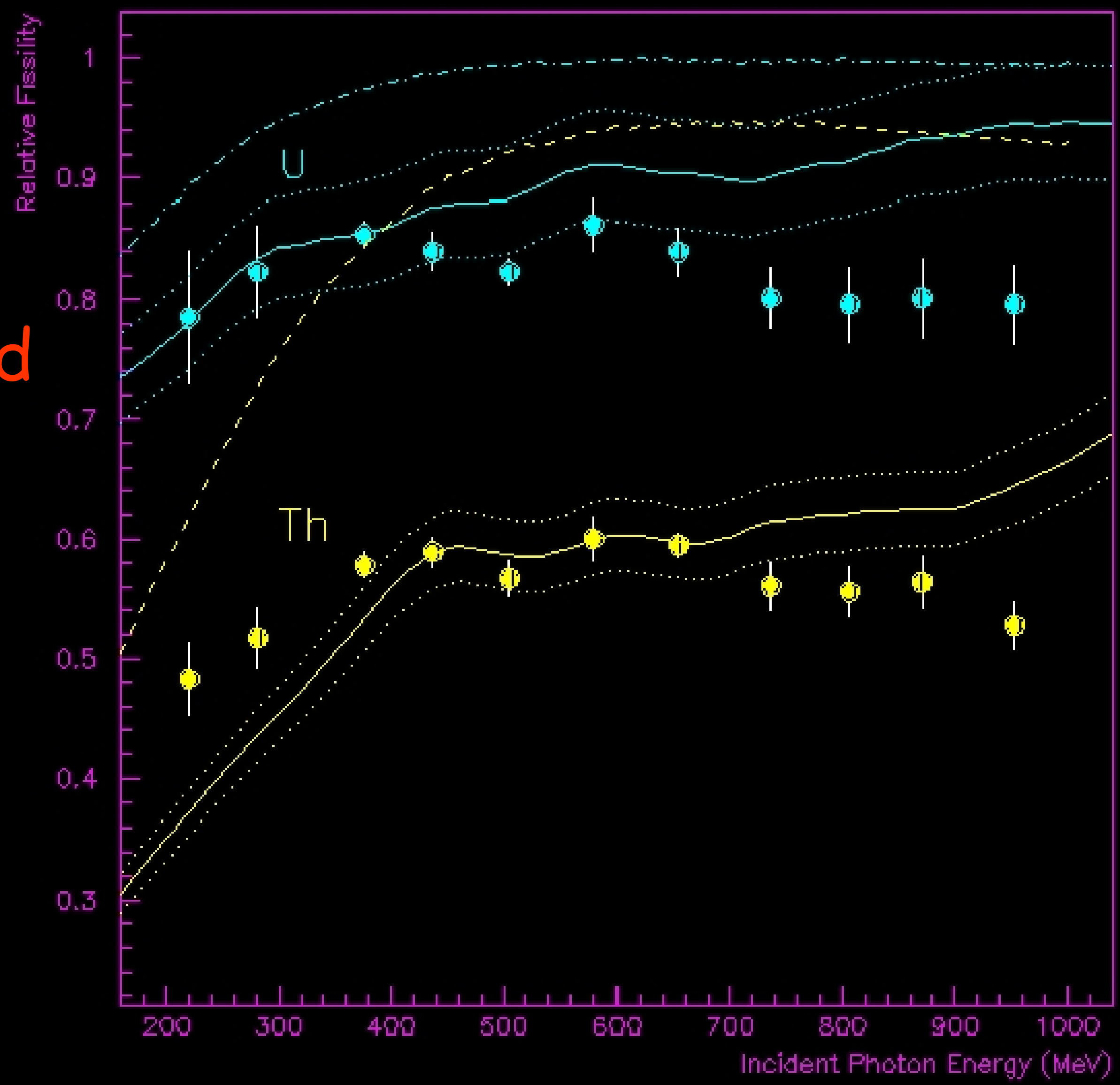
-Fission-barrier and charged particle`s separation energy corrections with nuclear temperature;

-Weisskopf energy distribution of the evaporating particles.

Comparison between our calculations and experimental data



The role played by the proton and alphas particle emissions:



In the CRISP package, we also included the following improvements:

-Discrete levels for bound particles according to the Uncertainty Principle;

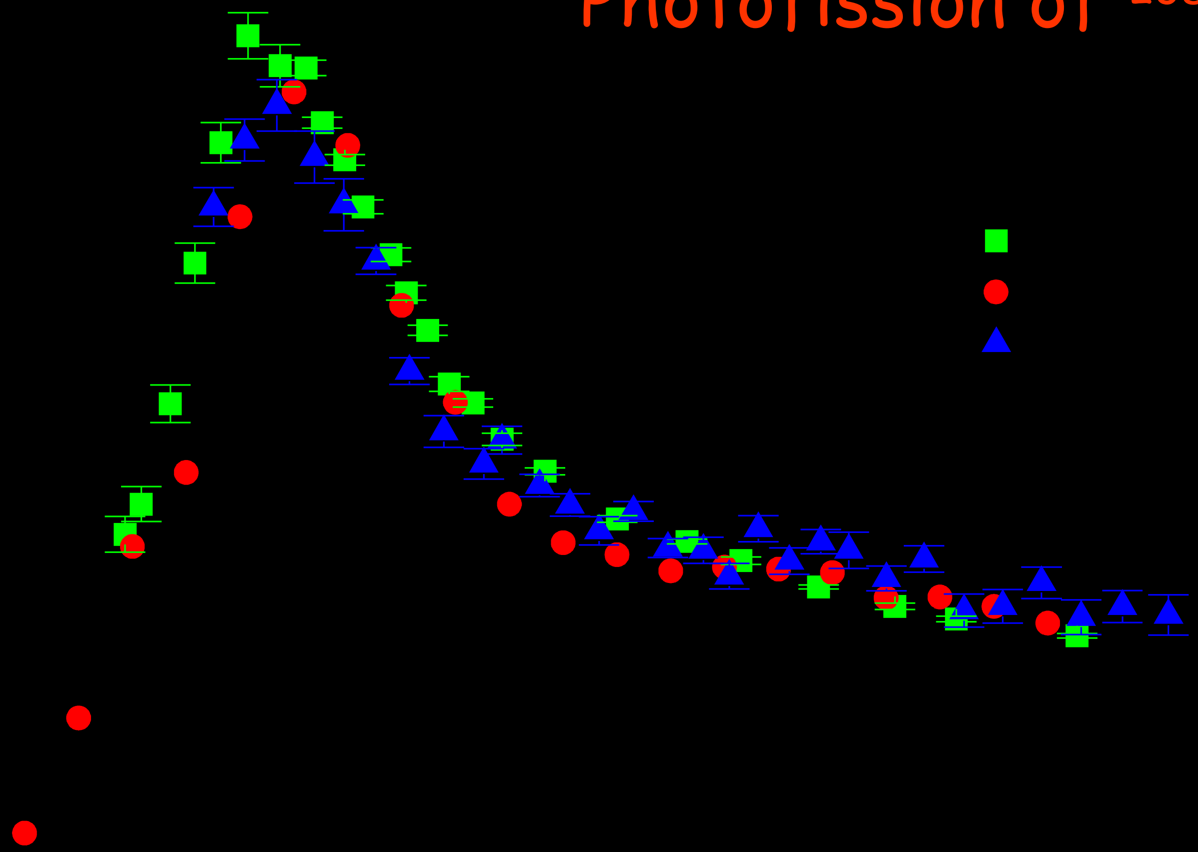
- Deterministic formation of the initial nuclear ground state, in accordance with the Pauli Principle;

- Dynamical Pauli blocking mechanism, where all the variations of the occupation numbers are taken into account;

- More photon-nucleon elementary interactions, as nucleonic resonances excitation,propagation and decay, quasi-deuteron mechanism and the shadowing effect which is a consequence of the photon hadronization.

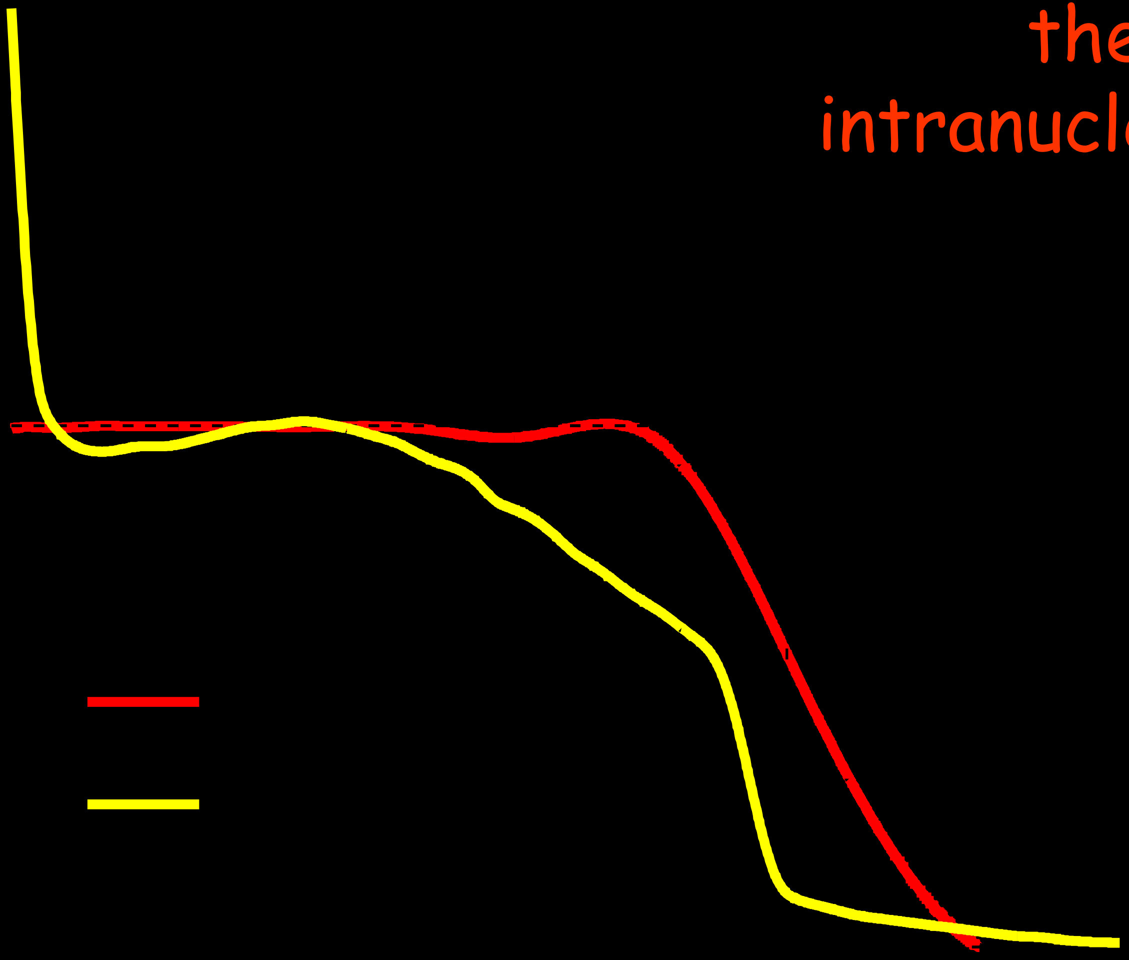
Preliminary results:

Photofission of ^{238}U



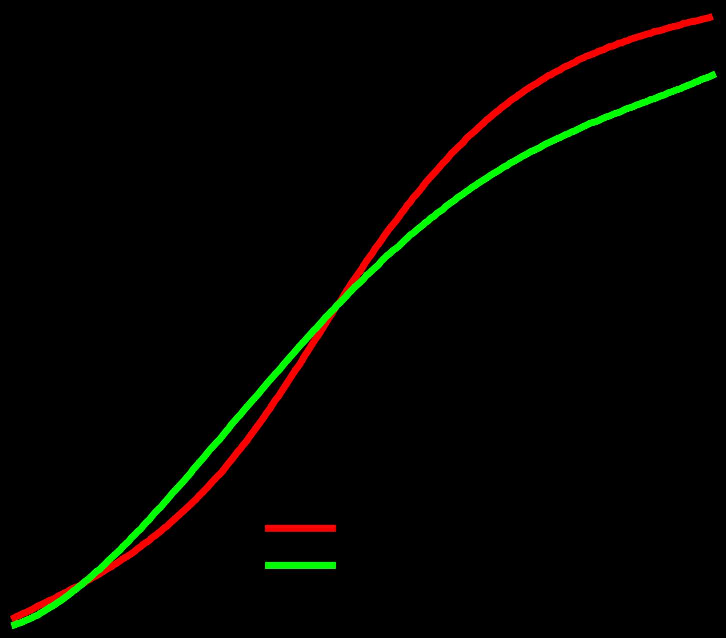
■ C. Cetina et al, Phys. Rev. Lett. 84 (2000) 5740.
■ N. Bianchi et al., ; Phys. Lett. B299 (1993) 219.

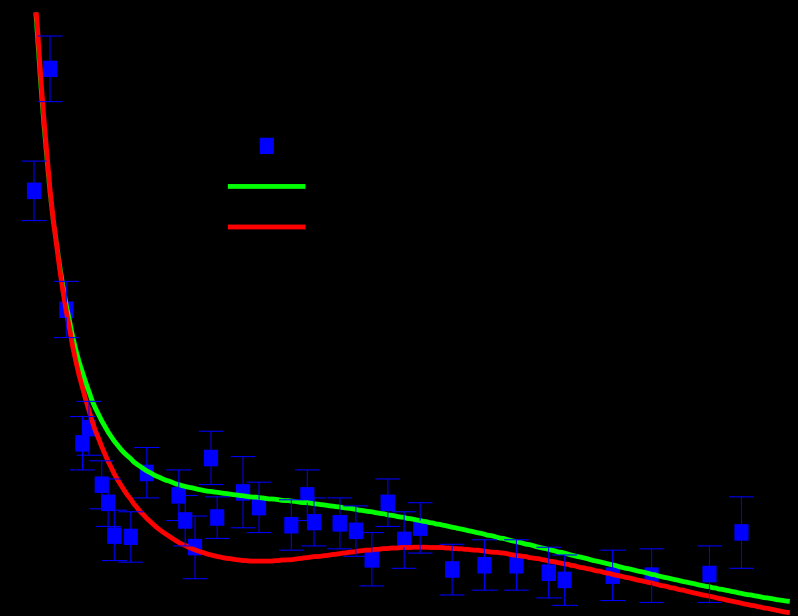
Occupation numbers for residual nucleus at the end of the intranuclear cascade process



- J. Cugnon, C. Volant, and S. Vuillier, Nucl. Phys. A620, 475 (1997).

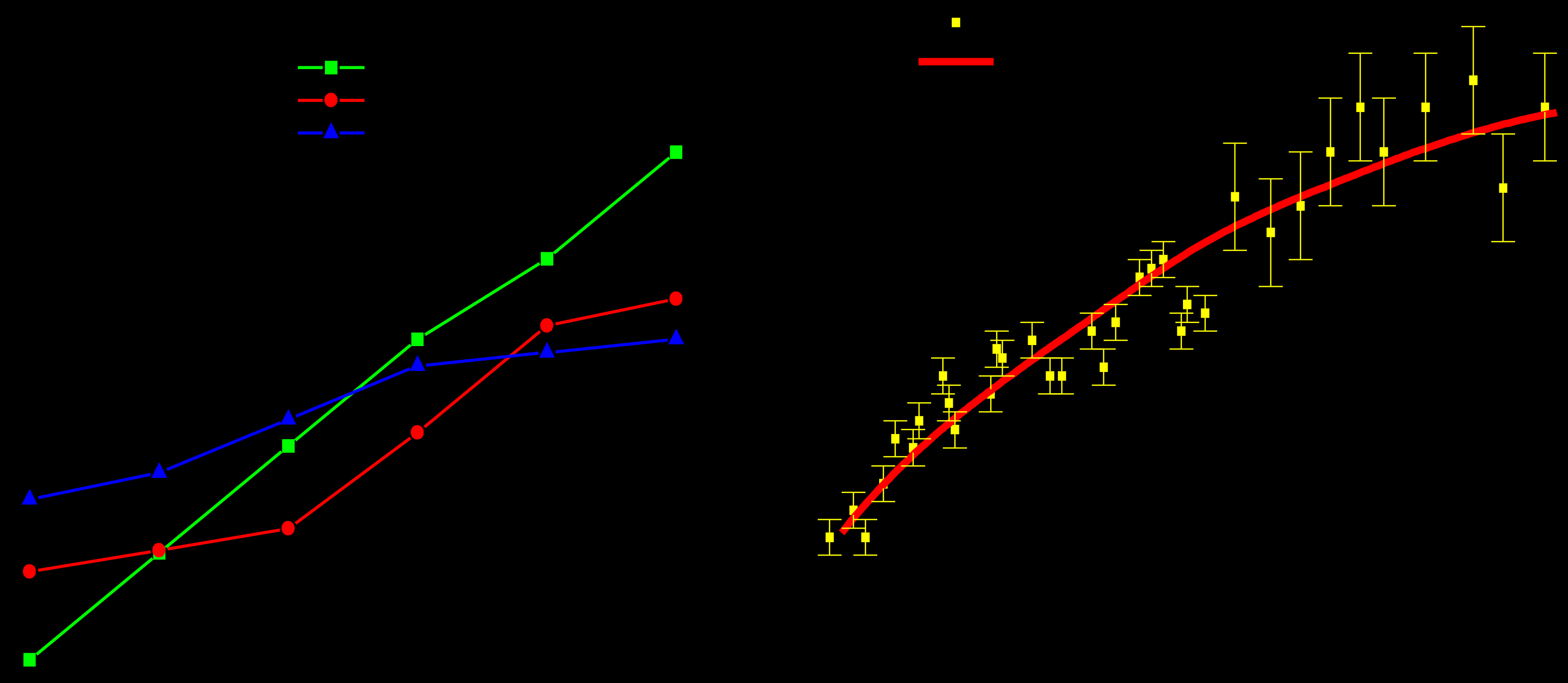
Pauli blocking effectiveness and quasi deuteron cross section





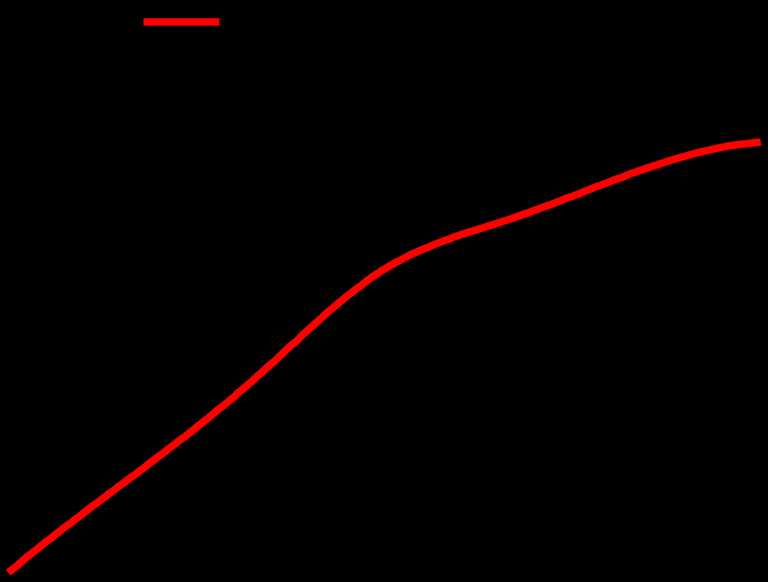
M. B. Chadwick *et al.*, Phys. Rev. C 44, 814 (1991).
A. Leprête *et al.*, Nucl. Phys. A367, 237 (1981).

Neutron multiplicity for proton-lead interaction around 1GeV

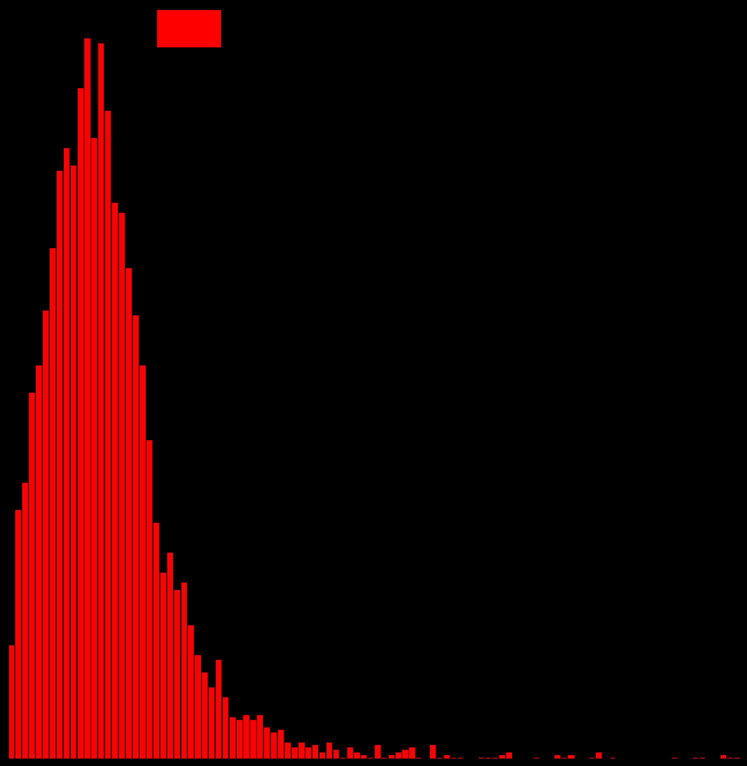


A. Letourneau et al., Nucl. Instr. Meth. B 170 (2000) 299.
R. E. Prael and H. Linchtenstein; LA-UR-89-3014, Los Alamos National Laboratory, 1989.
A. Leprête *et al.*, Nucl. Phys. A390, 221 (1982).

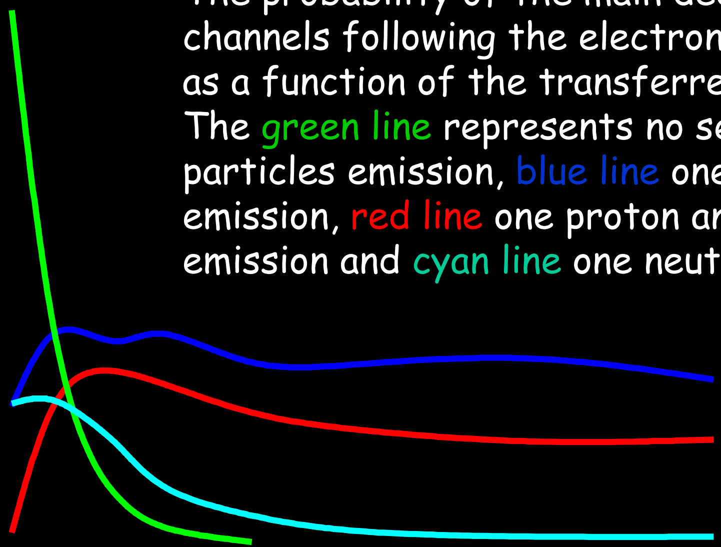
Residual nucleus excitation energy as a function of the incident photon energy



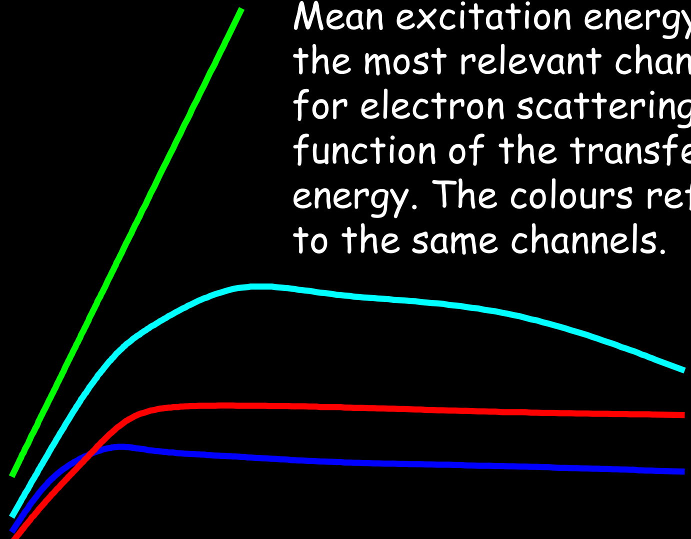
Elapsed time till the end of intranuclear casacade



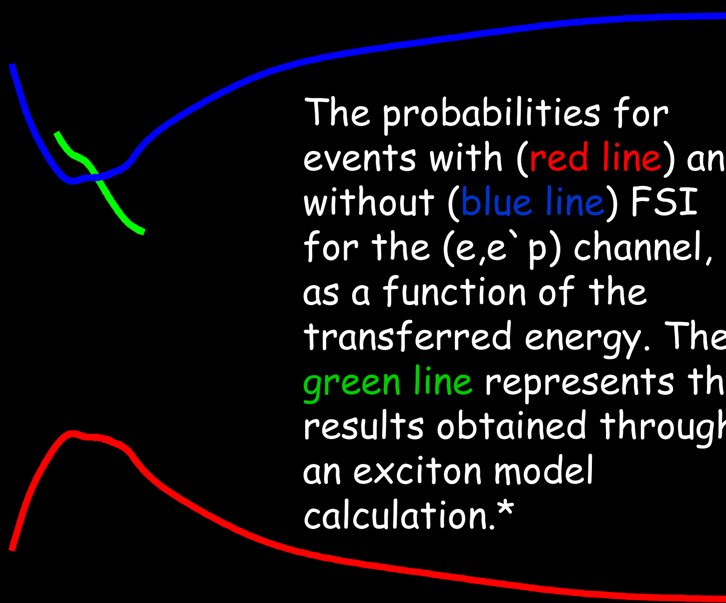
Quasi-free (e,e`pf)



The probability of the main decaying channels following the electron scattering, as a function of the transferred energy. The green line represents no secundary particles emission, blue line one proton emission, red line one proton and neutron emission and cyan line one neutron emission.



Mean excitation energy for the most relevant channels for electron scattering, as a function of the transferred energy. The colours refers to the same channels.

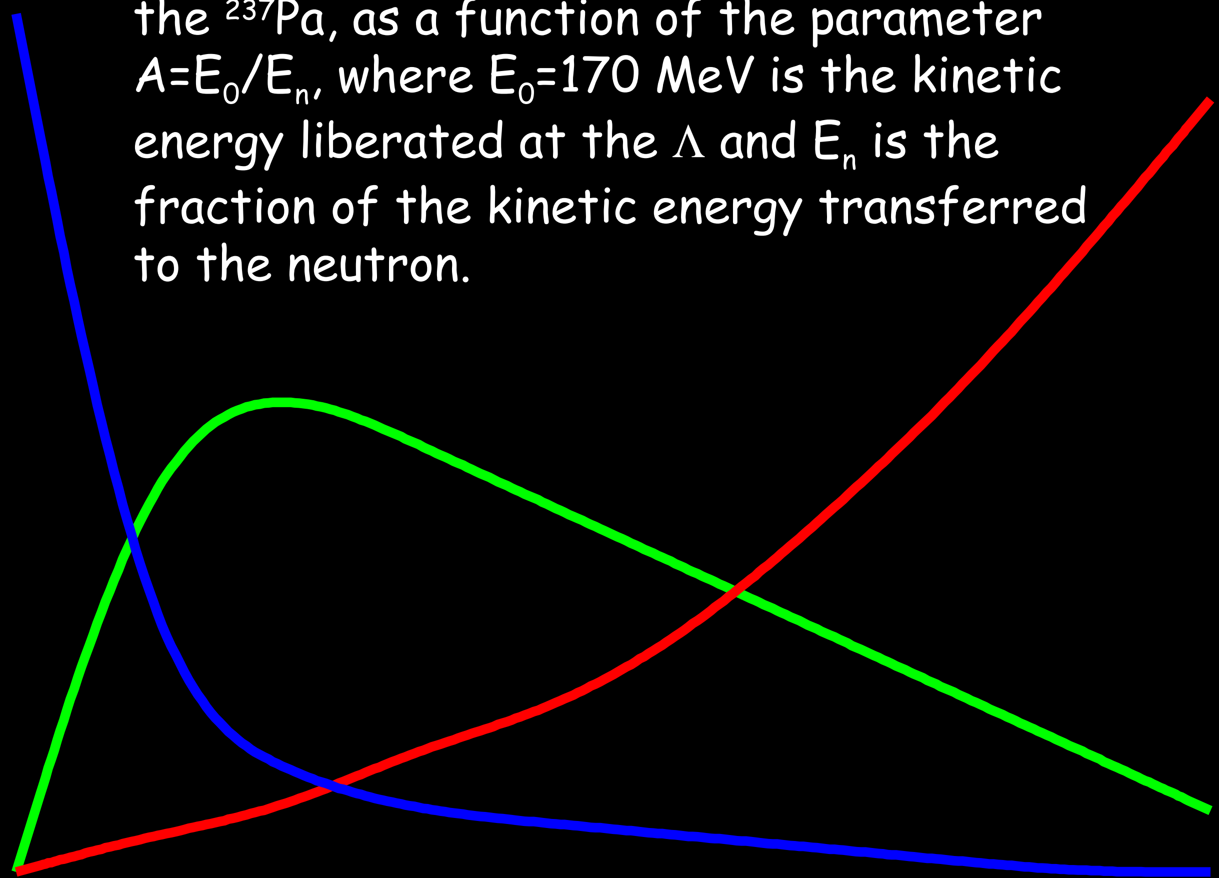


The probabilities for events with (red line) and without (blue line) FSI for the (e,e`p) channel, as a function of the transferred energy. The green line represents the results obtained through an exciton model calculation.*

*A. Letourneau et al., Nucl. Instr. Meth. B 170 (2000) 299.

Fission induced by Λ production and decay inside heavy nuclei

The probability of formation of residual nuclei (N-1,Z) (blue line), (N-1,Z-1) (green line), and (N,Z-1) (red line) after Λ decay in the [237]Pa, as a function of the parameter $A=E_0/E_n$, where E_0=170 MeV is the kinetic energy liberated at the Λ and E_n is the fraction of the kinetic energy transferred to the neutron.



applications

Possible applications of the CRISP code

- Study of hadron formation propagation and decay inside the nucleus;

- Study of nuclear reactions, as e.g. spallation, induced by different probes;

- Study of the properties of exotic nuclei, as fission barrier, level density, separation energies;

- Development of Accelerator Driven Systems (ADS);

- Evaluation of delivered doses during radiotherapic treatments, as proton-therapy.

Conclusions

• The CRISP package couples the MCMC and MCEF codes and provides us with an useful tool for nuclear reaction calculations, representing an improvement respect to the classical Monte Carlo calculations;

• We have successfully applied this code for the description of a few nuclear reactions at intermediate energies;

• The CRISP can be used for reactions with different probes, as photons (from a few MeV up to a few GeV), protons and neutrons;

• This software can be used for many applications in nuclear and hadron physics, nuclear reactor physics and biomedical applications;

Collaboration

This work was developed in collaboration with:

O.A.P. Tavares, S.B. Duarte, E.C. Oliveira, J.D.T. Arruda-Neto, G. Silva, T.E. Rodrigues, V.P. Likhachev, O. Rodriguez, J. Mesa and M. Gonçalves.

- Instituto de Física da USP – IFUSP, São Paulo;

-Centro Brasileiro de Pesquisas Físicas – CBPF, Rio de Janeiro.

Grazie!!