Nuclear Reactions at Intermediate and High Energies

by the collaboration of groups from Rio and São Paulo (CBPF and IFUSP)

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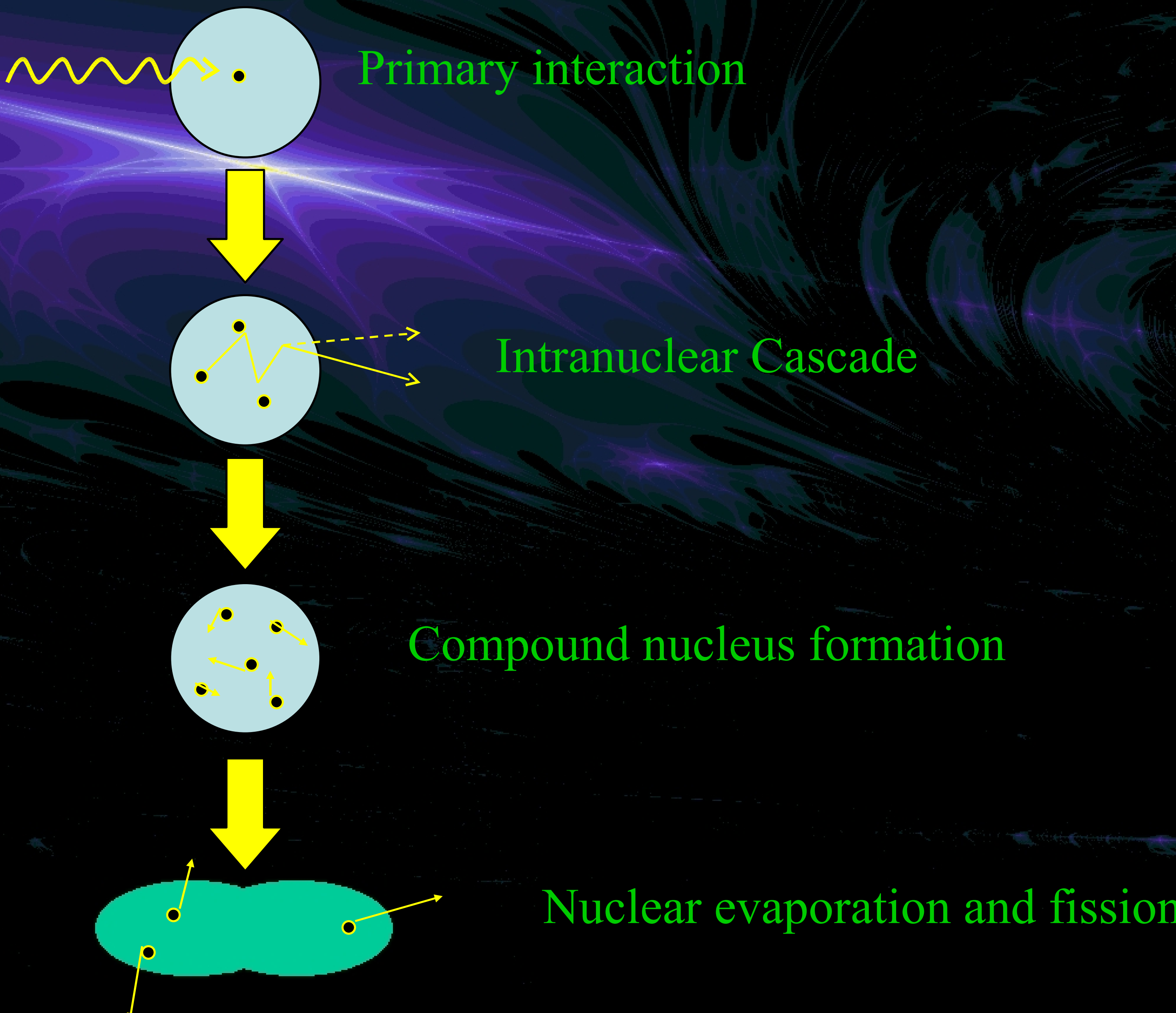
SUMMARY

- Brief description of the reaction process;
- Intranuclear cascade;
- Evaporation-fission;
- Main features of the CRISP model;
- Main reasults;
- Conclusions.

The main steps of the nuclear reaction



Main features of the CRISP code

it inherits many of its features from the MCMC and MCEF codes

- Realistic time-ordered sequence of events during the intranuclear cascade;
- Each interaction is taken into account according their known cross section and angular distributions;
- Barion resonance formation, propagation and decay;
- Resonant and direct pion production;
- Kaon production.

M. Gonçalves et al. PLB 406 (1997) 1.
S.B. Duarte et al. PRL49 (1982) 536
Deppman et al. PRL87 (2001) 182701; CPC 145 (2002) 385

CRISP: main features

- Quasi-Deuteron photoabsorption mechanism;
- Realistic Pauli blocking mechanism calculation based on the Fermi gas model;
- Photon hadronization;
- Shadowing effect;
- Vector meson production;
- One or two pions direct production in nucleon-nucleon interactions during the cascade.

Deppman et al. PRC66 (2002) 067601; NIMB 211 (2003) 15;

Intranuclear Cascade
main primary reaction

$\gamma\, p \rightarrow N^{*} \rightarrow (p\, \pi^{0})\ (n\, \pi^{+})\ (N^{*}\, \pi)$

$\gamma\, n \rightarrow N^{*} \rightarrow (n\, \pi^{0})\ (p\, \pi^{-})\ (N^{*}\, \pi)$

$\gamma\, N \rightarrow \pi\, N$

$\gamma\, N \rightarrow \Lambda\, K$

$\gamma\, N \rightarrow \rho\, N$

CRISP: main features

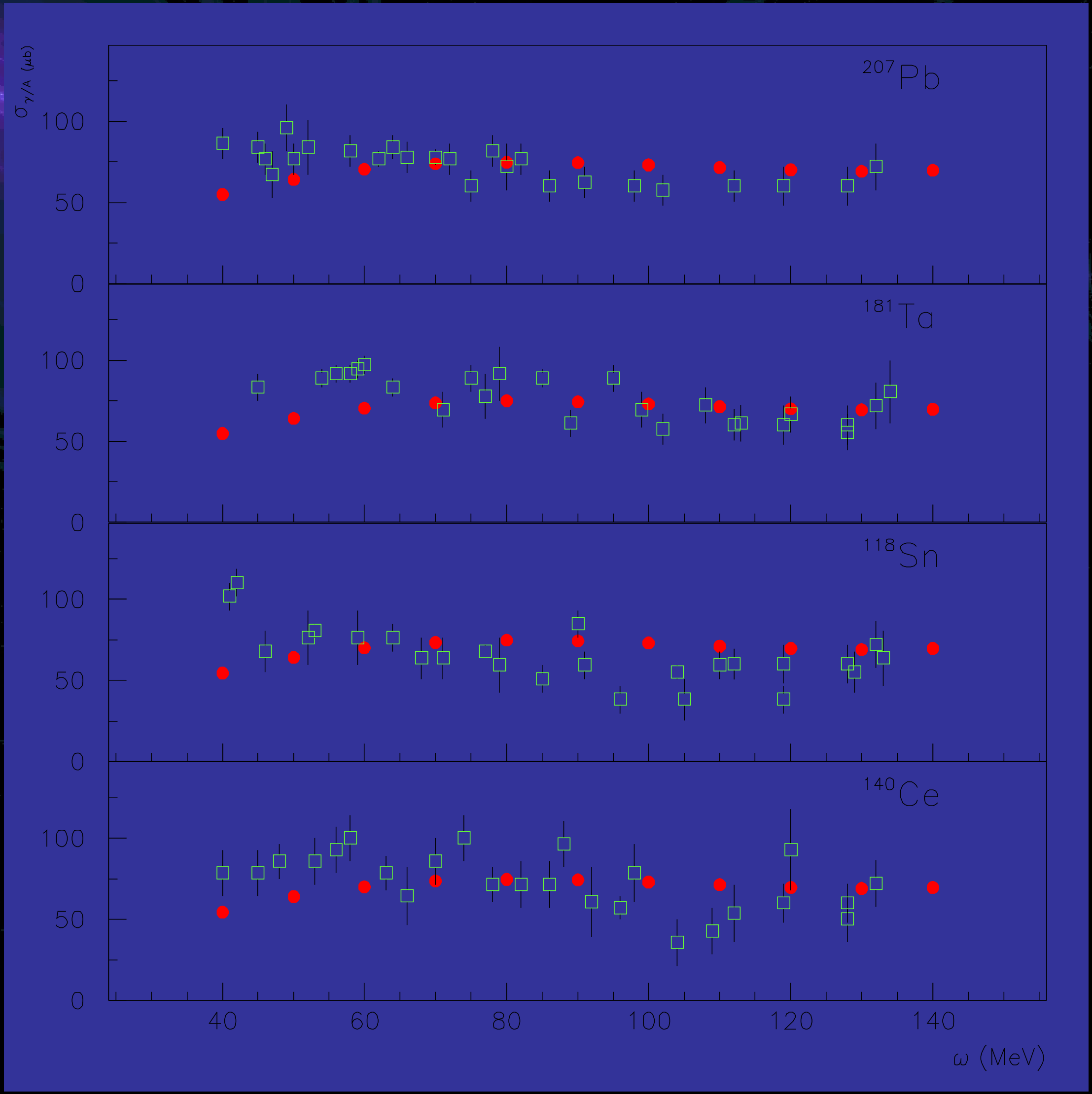
- Particles evaporation by Weisskopf’s statistical model;
- Evaporation of neutrons, protons and alpha-particles are included;
- Fission according the Bohr-Wheeler model;
- Nuclear mass calculation according droplet model;
- Separation energies are calculated from the mass formulas;

CRISP: main features

- Level density parameter after neutron evaporation is calculated by Dostrovsky parametrization;
- Level density parameters for proton and alpha evaporation following fenomenological formulas;
- Tunneling effect included in the Coulomb potential according LeCouteur;

Main results with CRISP

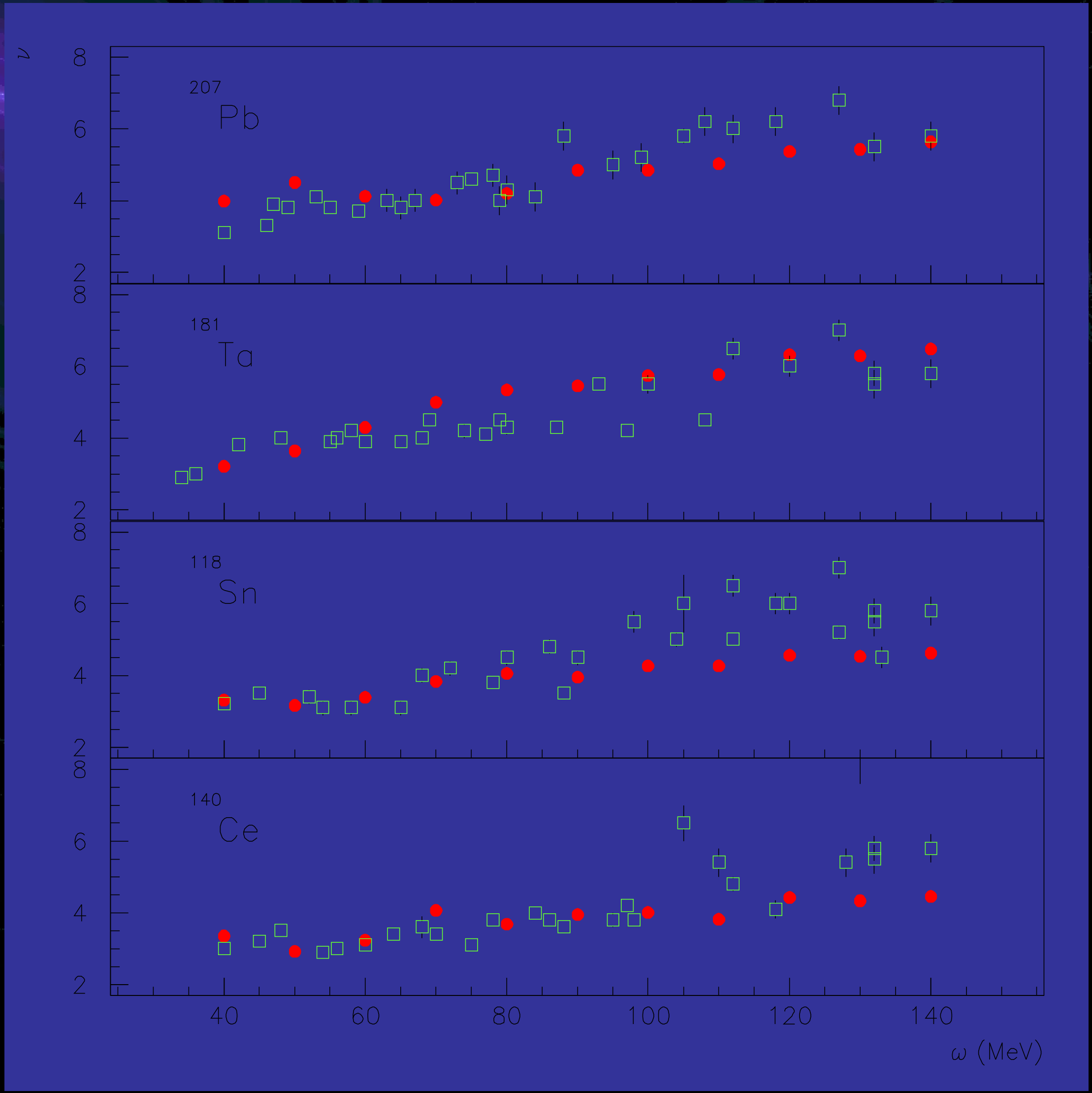
Photoabsorption cross sections at the quase-deuteron region.



Deppman et al., Journal Phys. G: NPP30 (2004) 1991

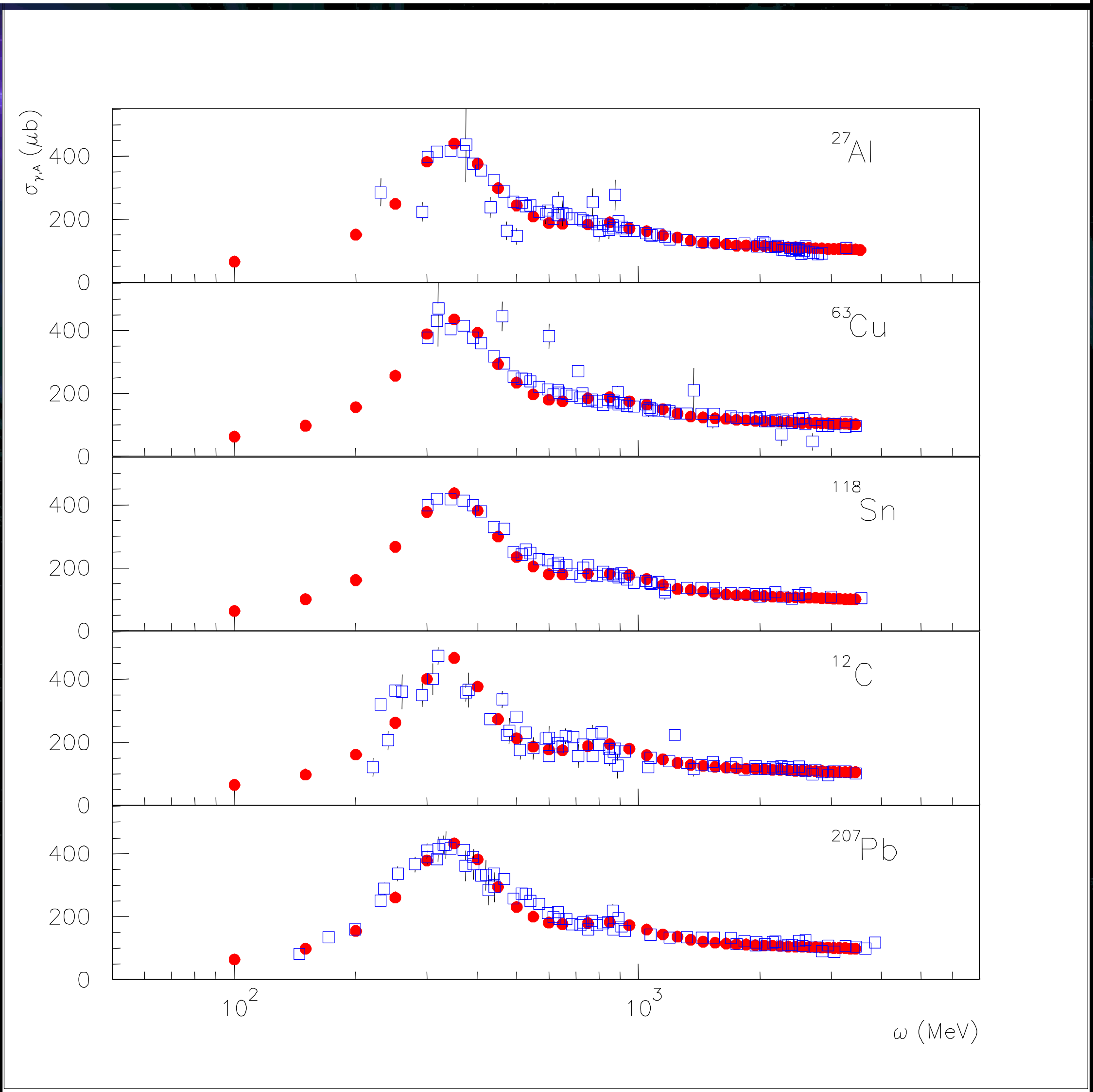
Main results with CRISP

Neutron multiplicity after photoabsorption at the quase-deuteron region.



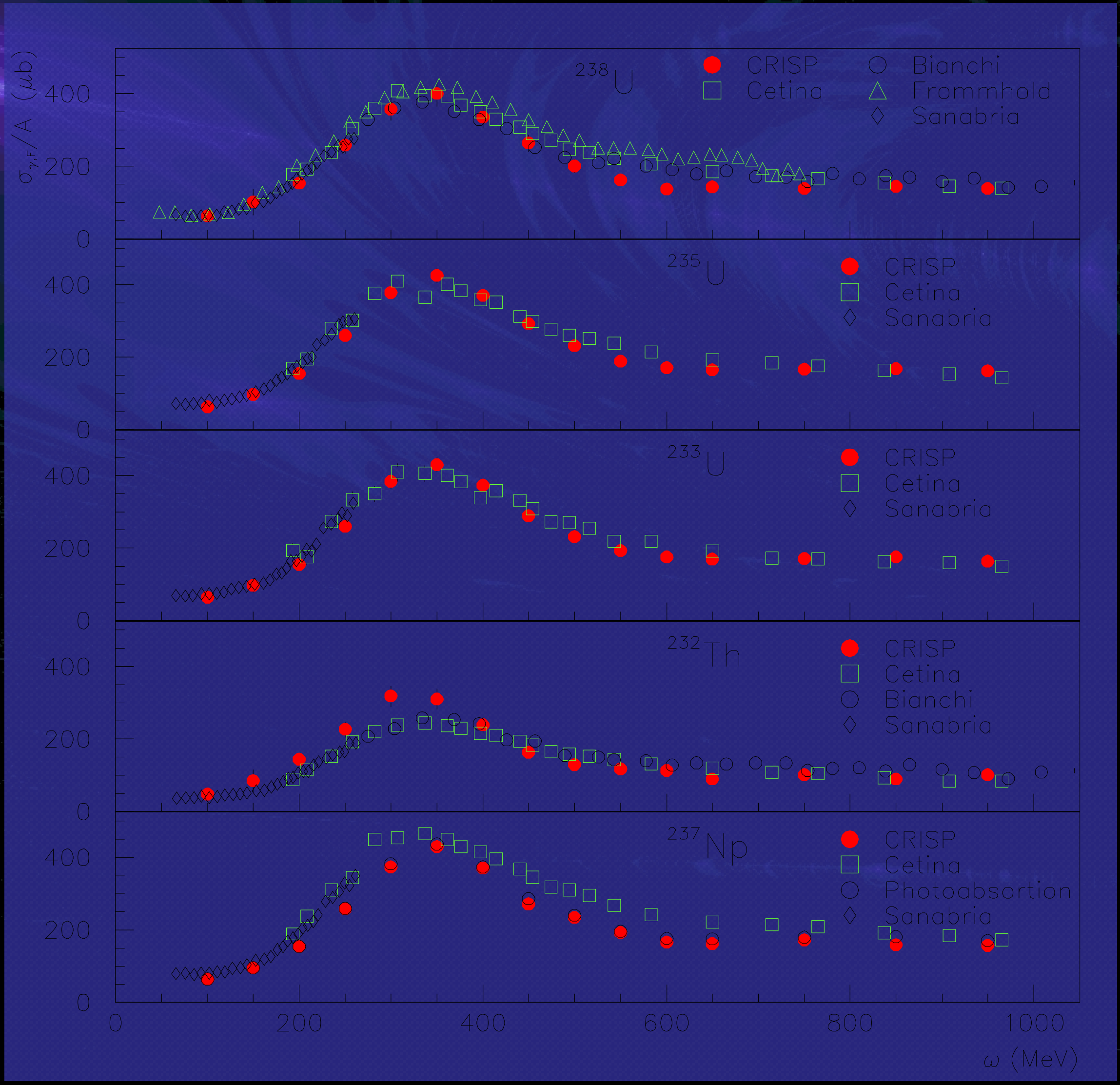
Results

Photoabsorption cross section between 100 MeV and 3.5 GeV.



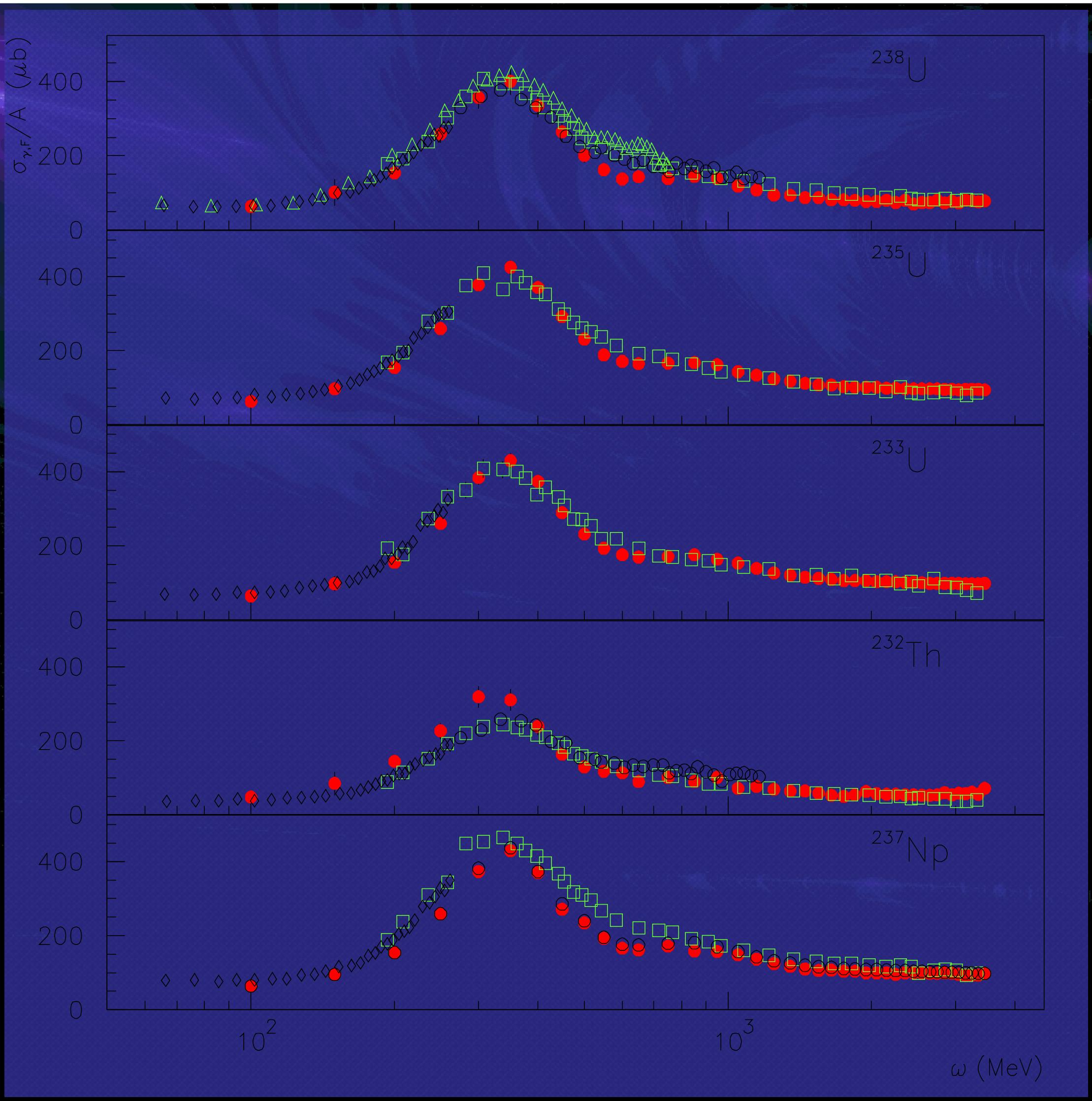
Results

Photofission cross section for actinide between 60 MeV and 1.0 GeV.



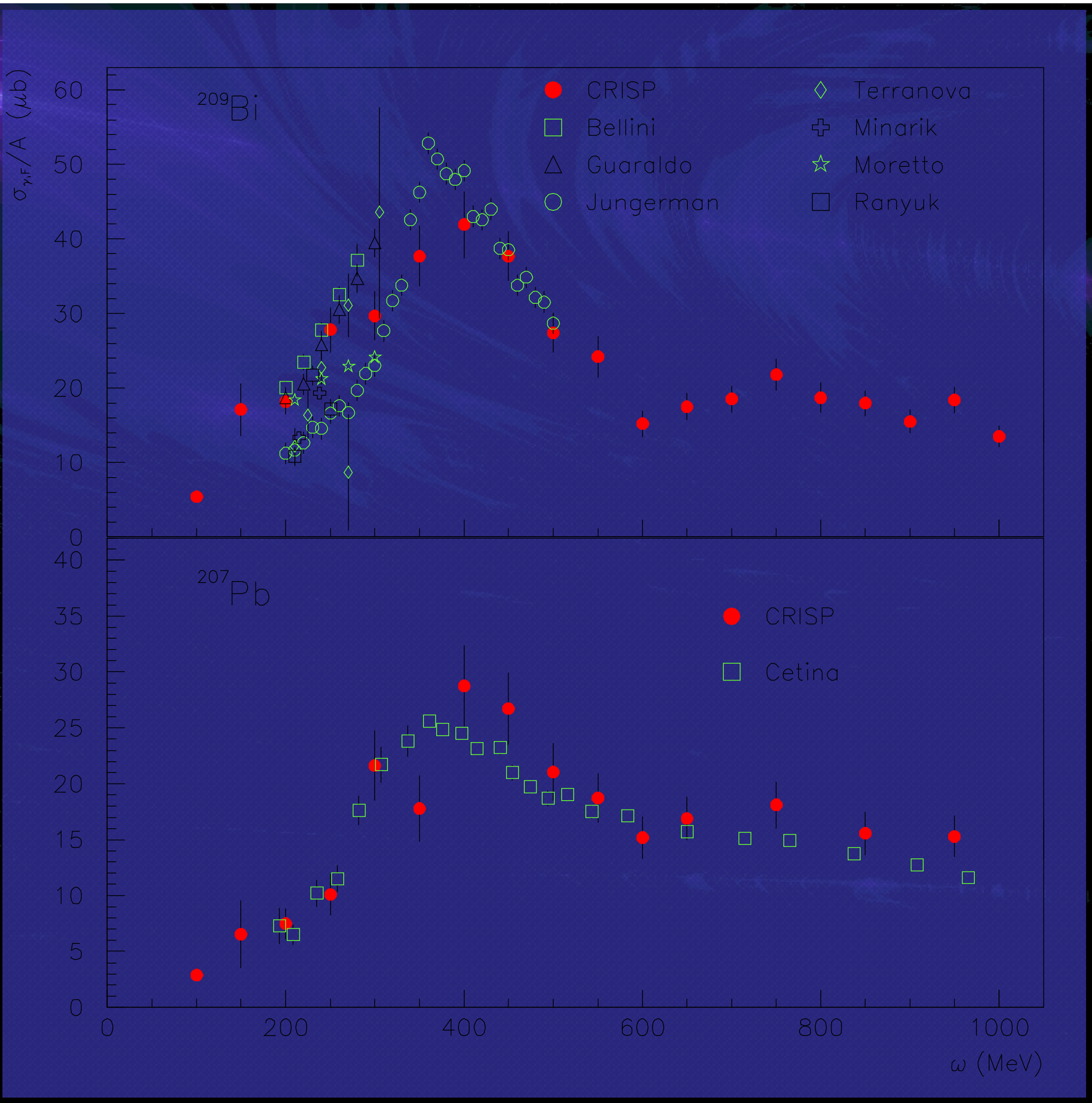
Results

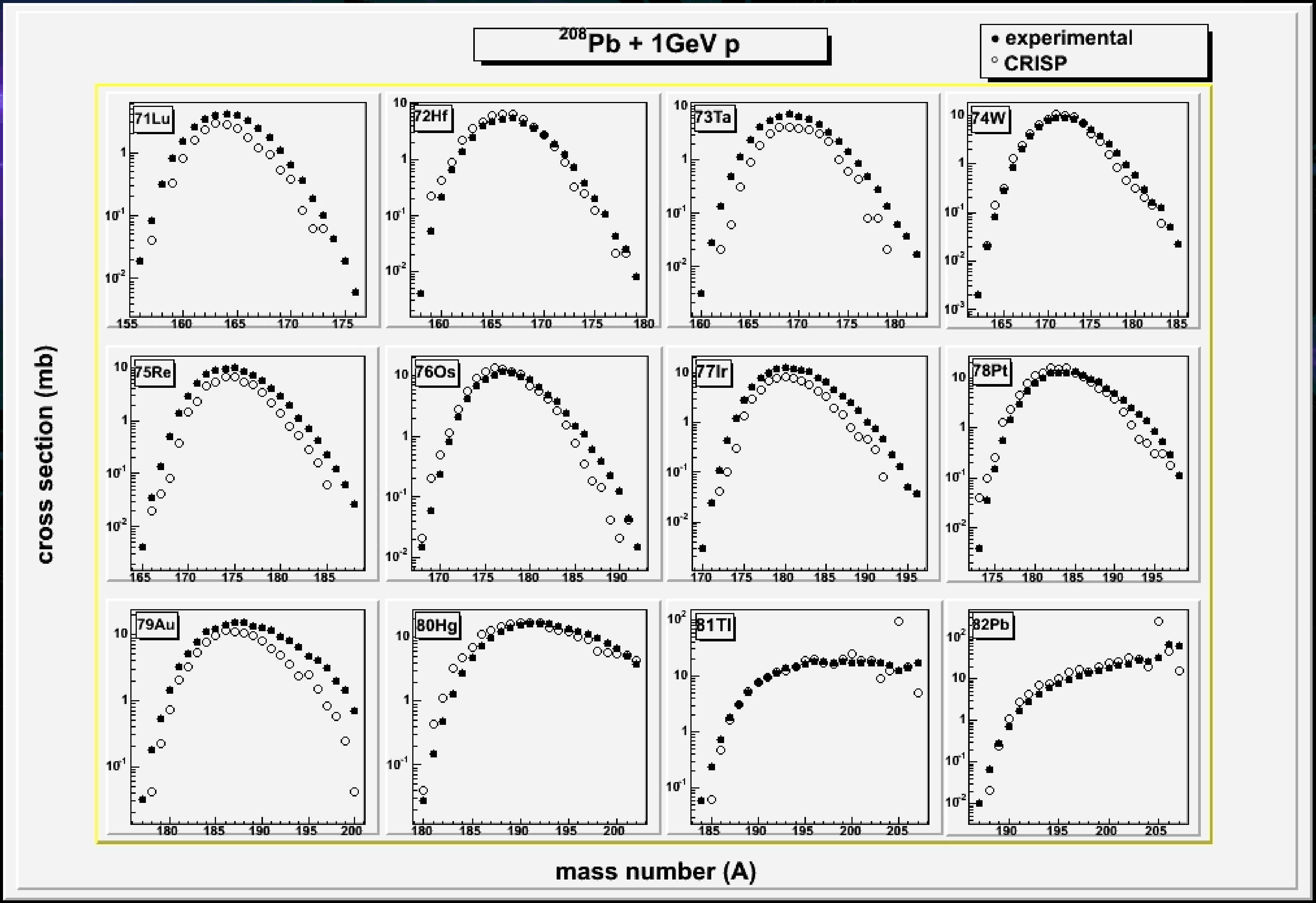
Phtofofission cross section between 60 MeV and 3.5 GeV.



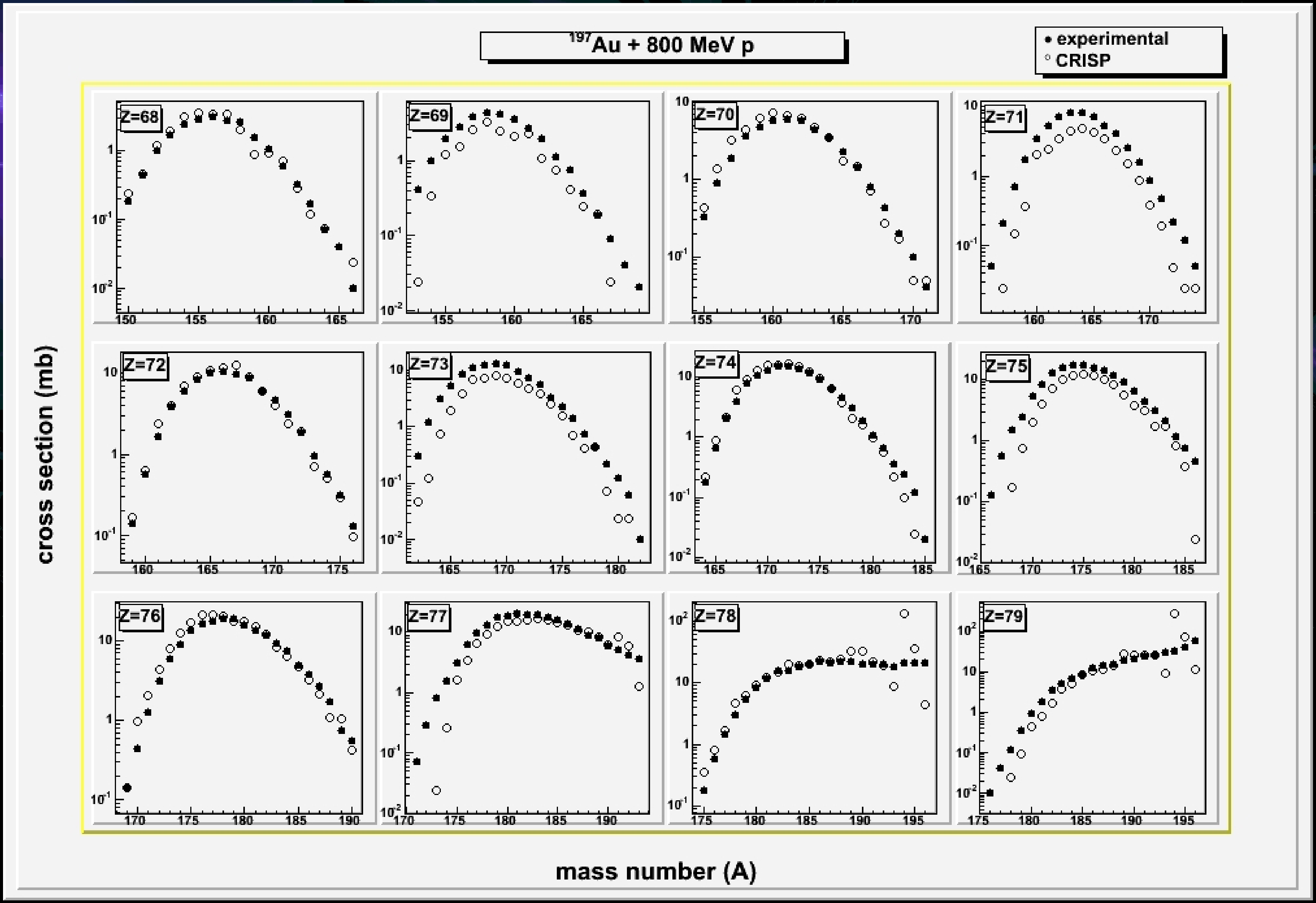
Results

Pre actinide photofission cross section between 150 MeV and 1 GeV.



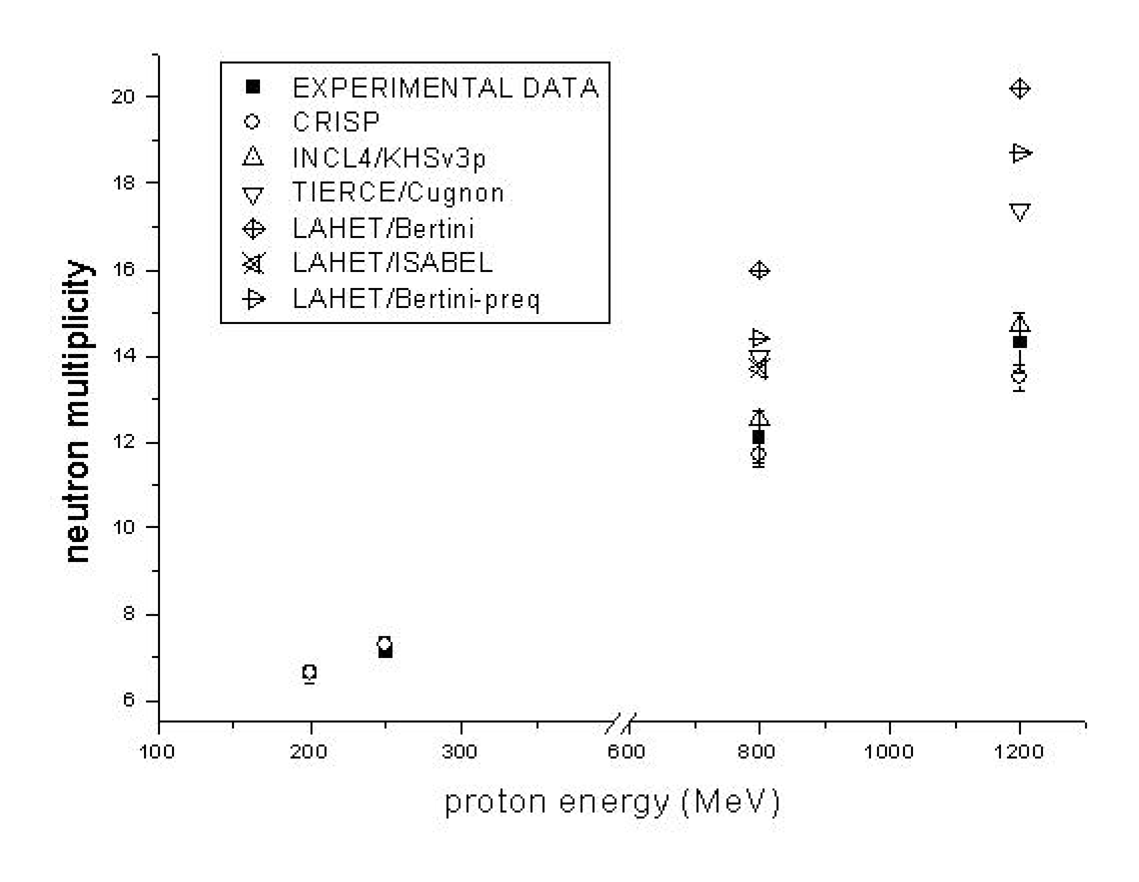


^{208}Pb + 1GeV p
• experimental
◦ CRISP
71Lu
72Hf
73Ta
74W
75Re
76Os
77Ir
78Pt
79Au
80Hg
81Tl
82Pb
cross section (mb)
mass number (A)



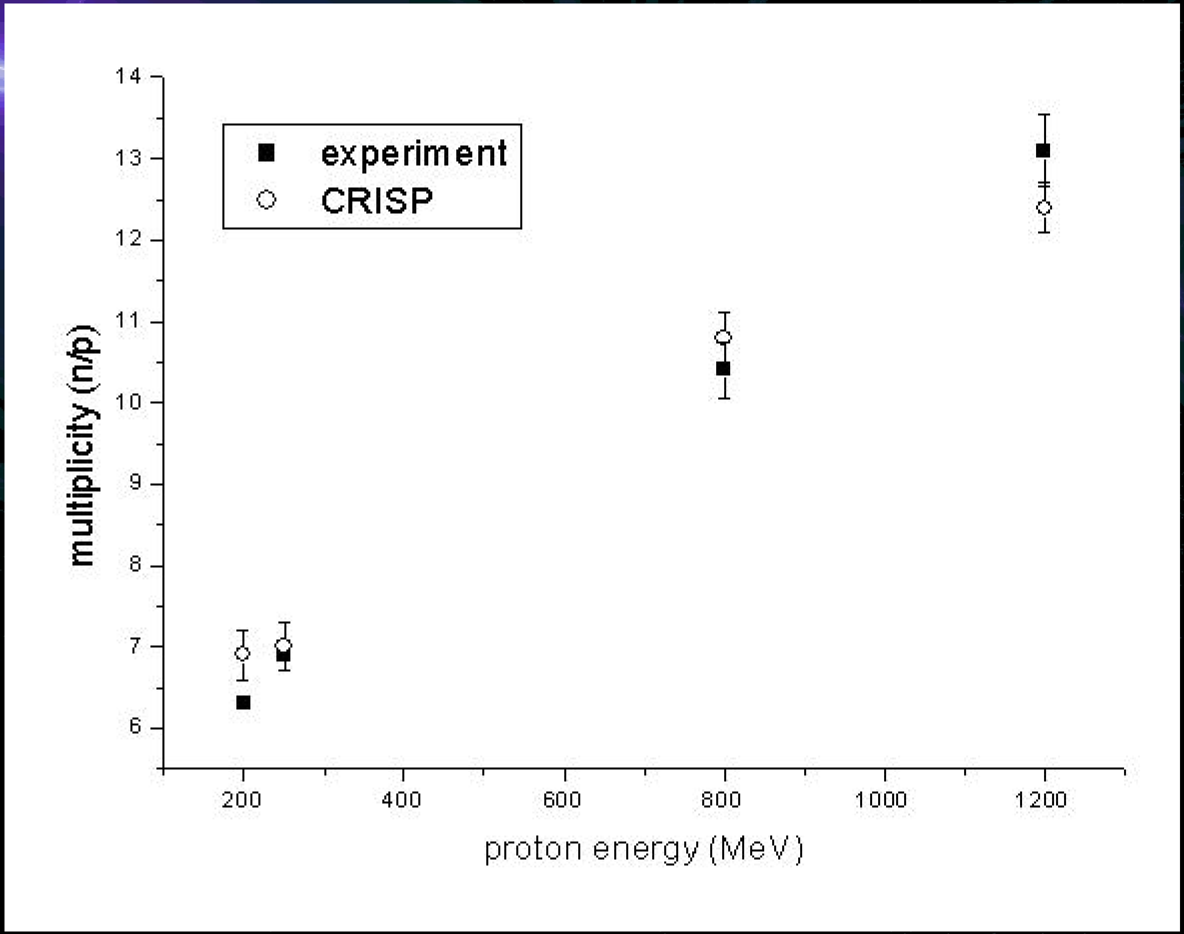
^{197}Au + 800 MeV p
• experimental
◦ CRISP
Z=68
Z=69
Z=70
Z=71
Z=72
Z=73
Z=74
Z=75
Z=76
Z=77
Z=78
Z=79
cross section (mb)
mass number (A)

p + Pb



Nucl. Sci. Eng. – accepted for publication.

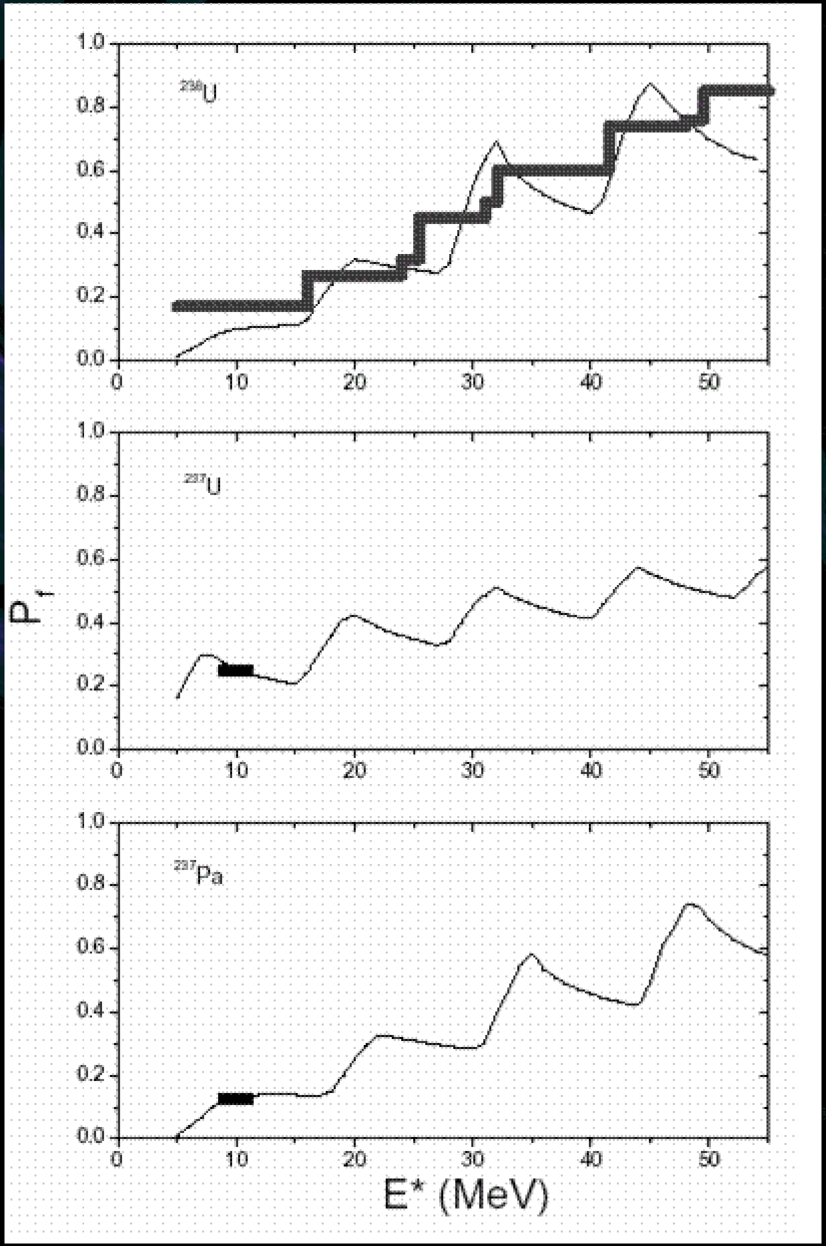
p + Au



experiment
CRISP
multiplicity (n/p)
proton energy (MeV)
14
13
12
11
10
9
8
7
6
200
400
600
800
1000
1200

Espalhamento (e,e'f)

V. Likhachev et al. PRC68 (2003) 014615



Λ production, propagation and decay in nuclear matter.

Conclusions

- A Monte Carlo calculation for nuclear reactions has been developed;
- Time-ordered sequence in the intranuclear cascade;
- Works well for photon, electron and proton probes with energies from 40 MeV up to 3.5 GeV and nuclei from Al to Np;
- It has been applied for nuclear reactions studies and for the development of hybrid reactors;

Conclusions

- It is not an event generator, but tries to simulate in a realistic way the process that take place during the nuclear reaction;
- Today we have people from São Paulo (IFUSP and IPEN), Rio de Janeiro (CBPF and IRD), Ilhéus (UESC), Havana (InsTec), Frascati (INFN-LNF) developing or applying the CRISP for simulation of nuclear reactions.