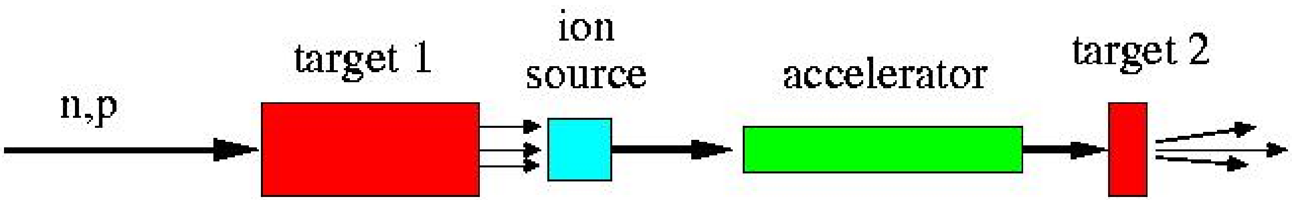
Yields expected from secondary Fragmentation at Eurisol

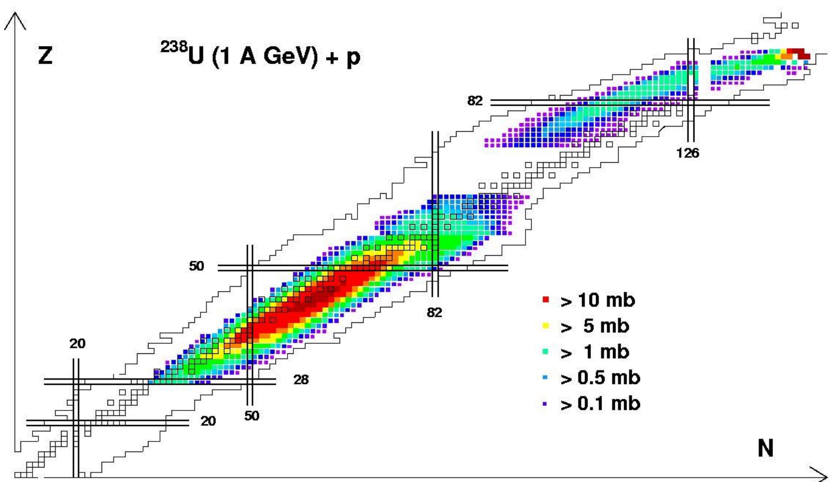
J. Benlliure

Universidad de Santiago de Compostela, Spain

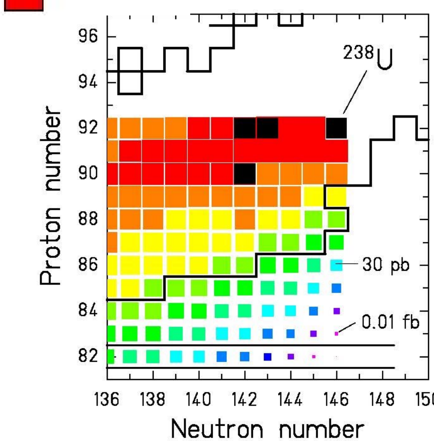
Two-step reaction scheme



n,p + $^{238}U \rightarrow {}^{132}Sn$ + Be → X



J. Taieb and M. Bernas, submitted to NPA

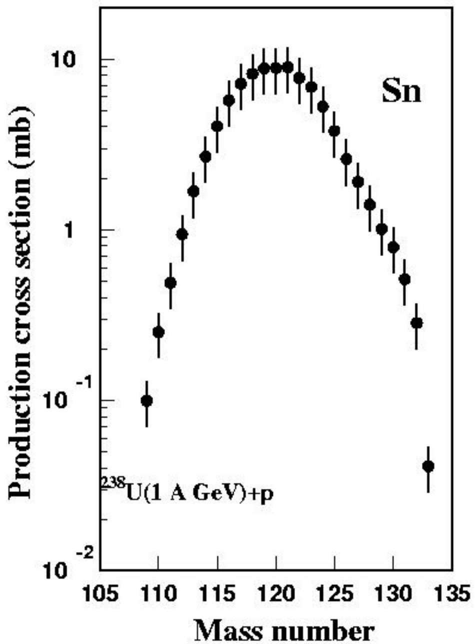


Peripheral heavy-ion reactions at relativistic energies:
- ✓ large fluctuations in N/Z and excitation energy

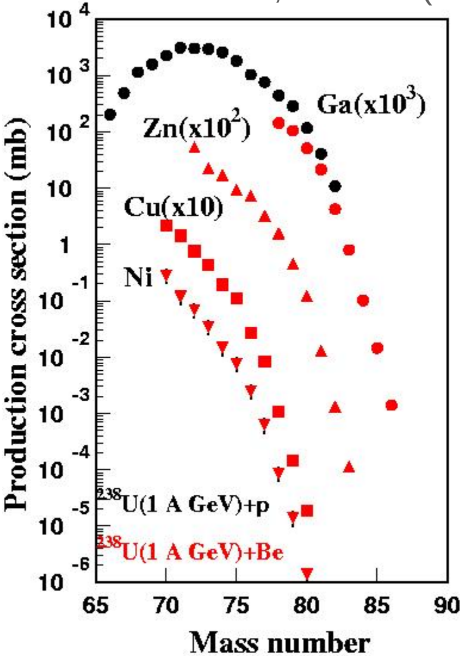
Proton-removal channel:
- ✓ only protons are abraded and the induced excitation energy remains below the particle emission threshold

Fission rates

M. Bernas et al., submitted to NPA



M. Bernas et al., PLB 415(1997)111



Fission yields are obtained assuming:

✓ a post-accelerated yield of 10^{11} ^{132}Sn/s

✓ evolution of the yields according to measure cross sections

✓ same extraction efficiency for all elements

These yields can be easily scaled to any other scenario (low energy fission), primary intensity or extraction and post-acceleration efficiencies.

Fission rates

Nuclide	^{238}U+Be	^{238}U+p	ISOL yield	Post-accelerated
^{132}Sn		380 μb	10^{12}/s	**10^{11}/s**
^{124}Pd	32nb		9 10^{7}/s	9 10^{6}/s
^{84}Se	1.15 mb	3.4 mb	9.6 10^{12}/s	9.6 10^{11}/s
^{83}As	503 μb	1.3 nb	3.8 10^{12}/s	3.8 10^{11}/s
^{82}Ge	207 μb	308 μb	1.1 10^{12}/s	1.1 10^{10}/s
^{81}Ga	22 μb	34 μb	9.6 10^{10}/s	9.6 10^{9}/s
^{82}Ga	4.3 μb		1.2 10^{10}/s	1.2 10^{9}/s
^{83}Ga	810 nb		2.2 10^{9}/s	2.2 10^{8}/s
^{80}Zn	1.2 μb		3.4 10^{9}/s	3.4 10^{8}/s
^{79}Cu	15 μb		4.2 10^{7}/s	4.2 10^{6}/s
^{78}Ni	200 pb		5.6 10^{5}/s	5.6 10^{4}/s

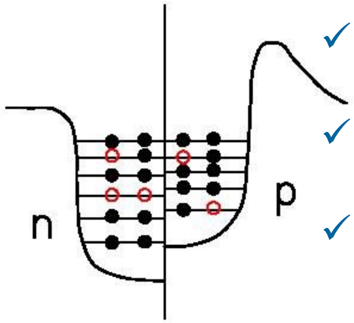
Fragmentation models

COFRA:analytical description of cold-fragmentation reactions

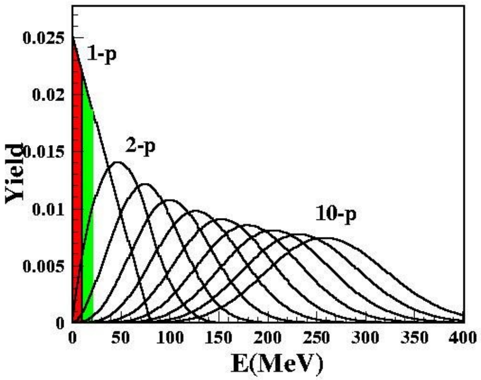
EPAX:semi-empirical parameterization of measured xs

Two-step process:

1 Prefragment formation (statistical equilibrium)

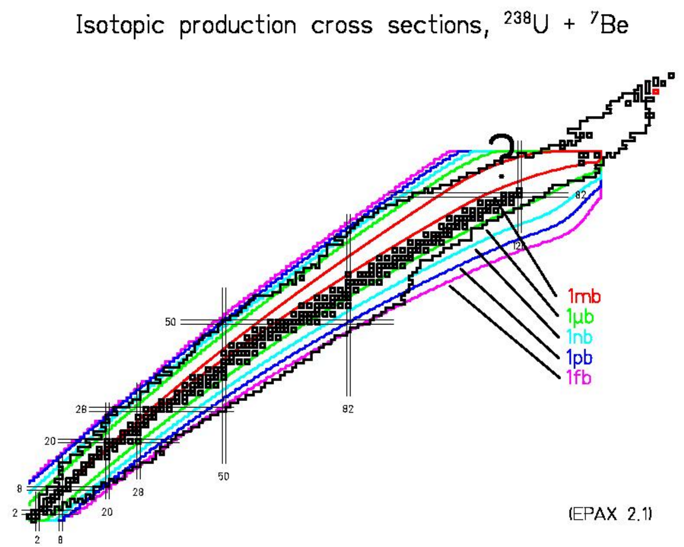


- ✓ Mass loss: impact parameter geometry
- ✓ N/Z: hypergeometrical distribution
- ✓ Excitation energy: particle hole excitation+final interactions



2 Neutron evaporation

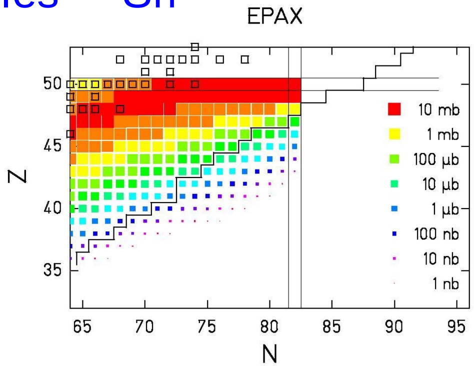
- ✓ Binding energies+temperature

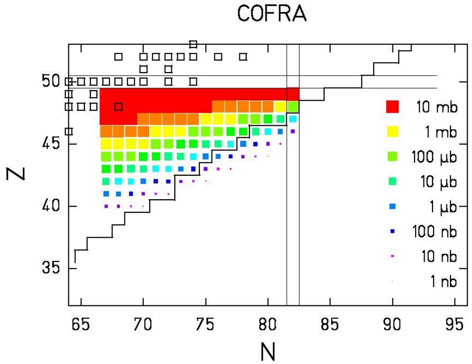


Validation of the fragmentation codes with neutron-rich projectiles and medium energies !!

Benchmark of fragmentation models

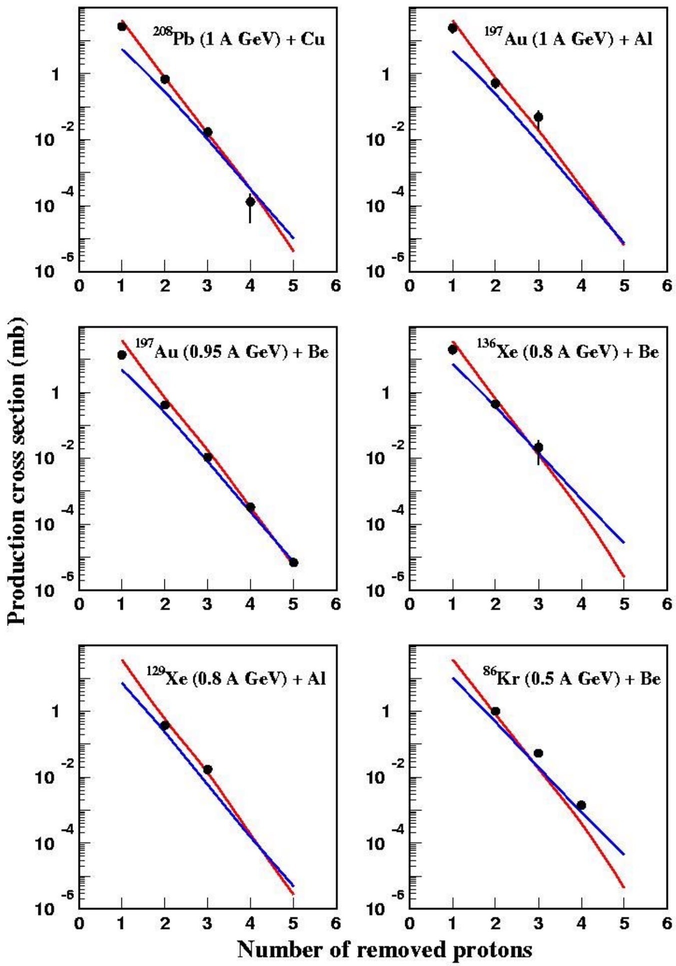
Fragmentation of neutron-rich Projectiles ^{132}Sn





EPAX predicts larger production of neutron-rich isotopes

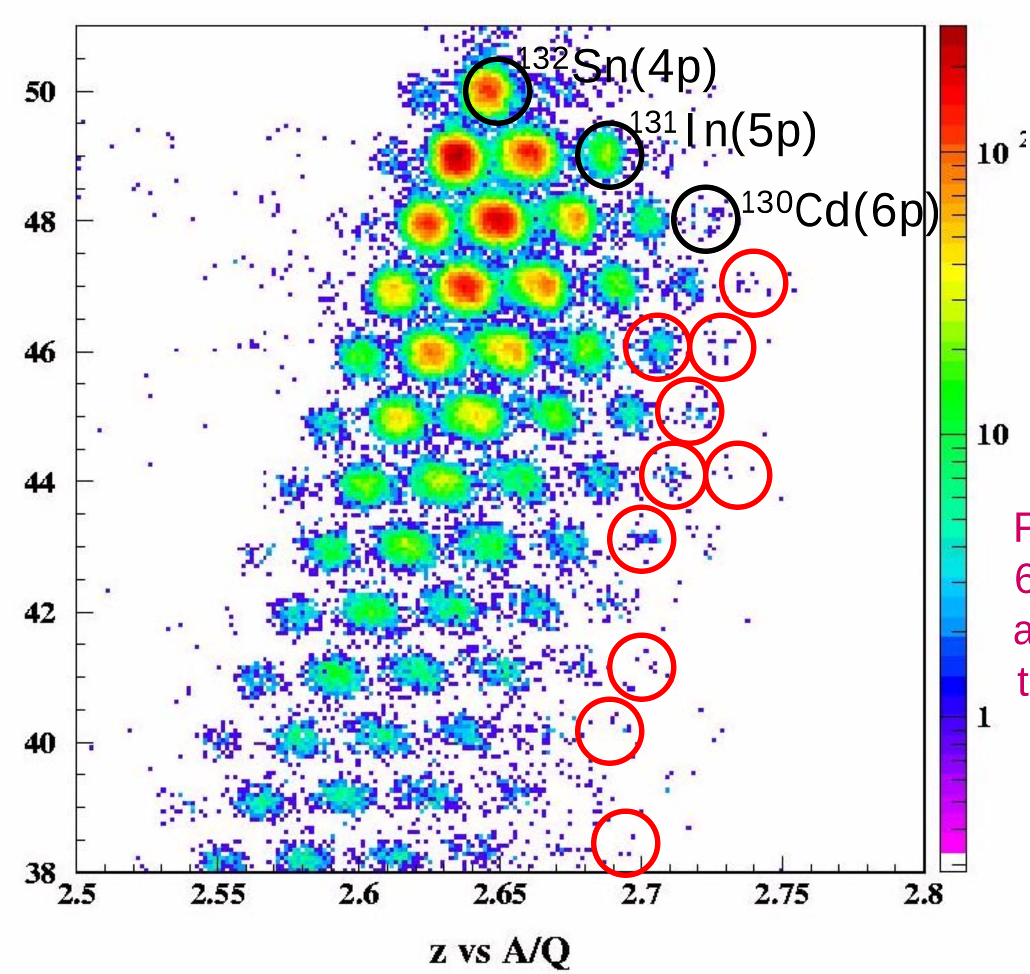
Proton-removal channels: EPAX, COFRA



Eurisol´03

Fragmentation of ^{136}Xe at 1 A GeV

$^{136}Xe + Be \rightarrow X$ (preliminary data: M. Fernández et al.)

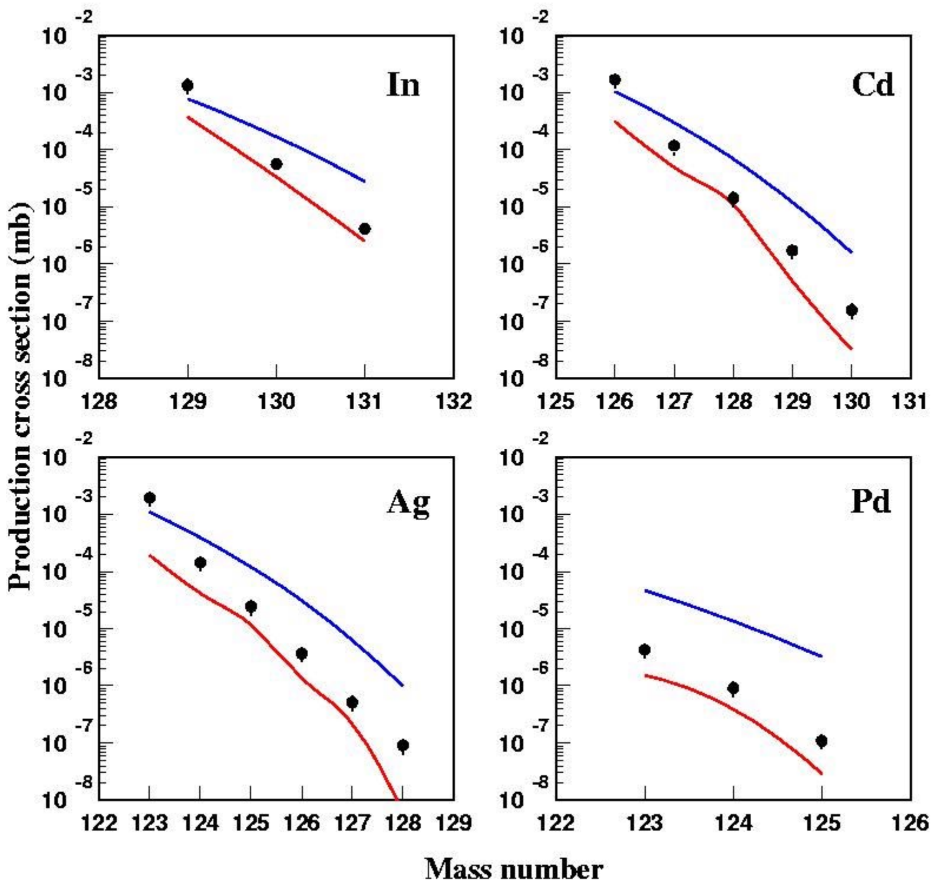


- ✓ beam: 10^{10} ^{136}Xe /s
- ✓ target: 2 g/cm^2 Be

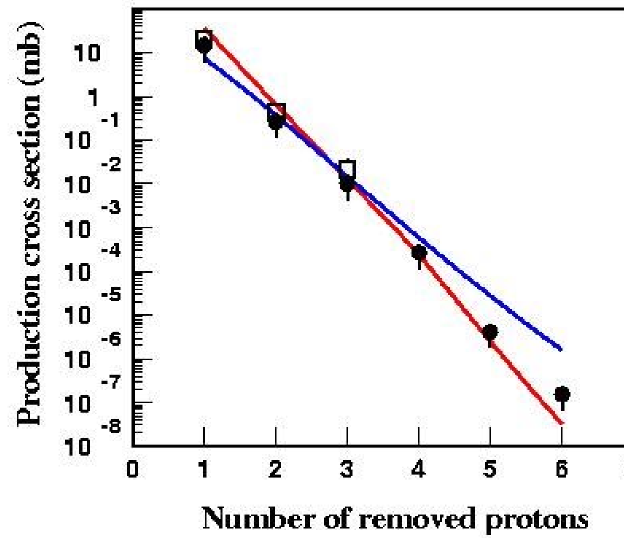
First observation of the 6 proton-removal channel and some new isotopes close to N=82

Fragmentation of ^{136}Xe at 1 A GeV

^{136}Xe + Be → X



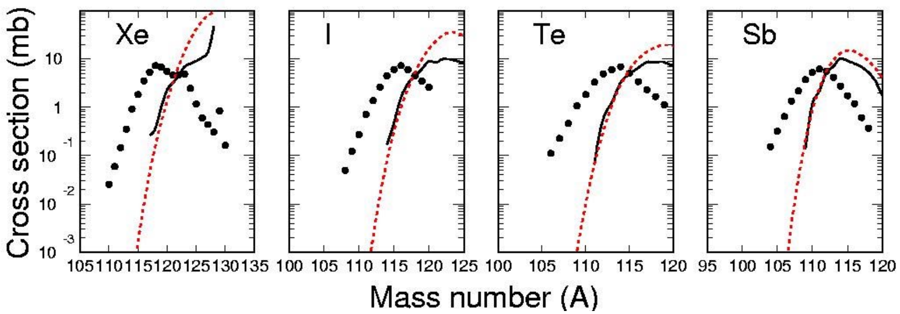
EPAX, COFRA



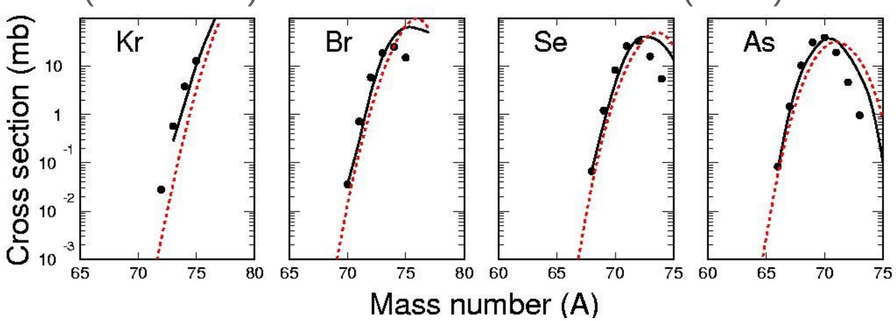
M. Fernández, PhD in preparation

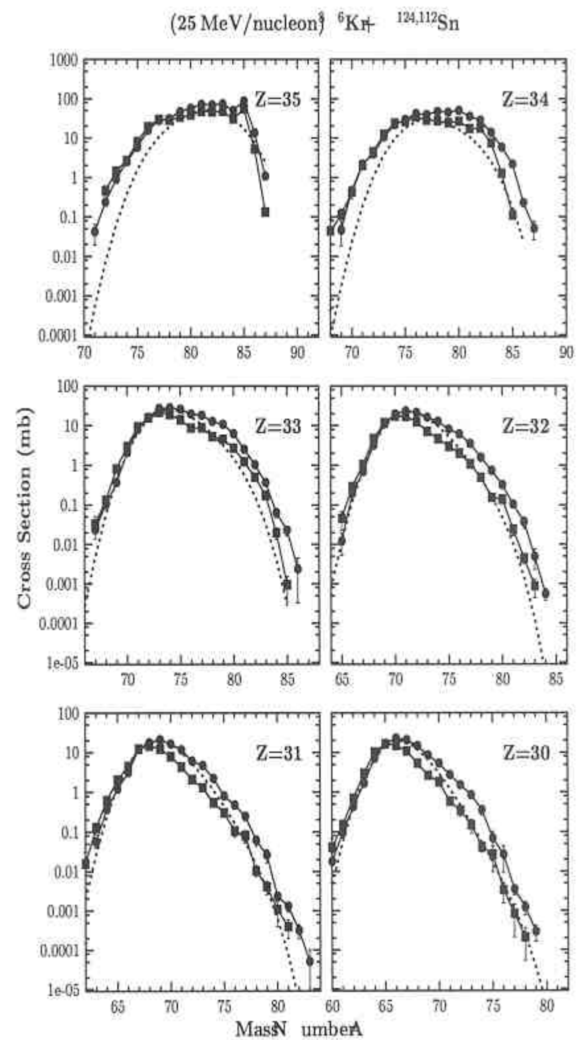
Fragmentation at medium energies

^{129}Xe(50 a MeV)+Al: K.H. Hanold et al. PRC 52 (1995) 1348



^{186}Kr(70 a MeV)+Al: R. Pfaff et al. PRC 51 (1995) 51





G.A. Souliotis et al. PLB 543 (2002) 163

Measured production cross sections of fragmentatic residues at medium energies provide contradictory conclusions

Fragmentation rates

Role of the energy in the target thickness

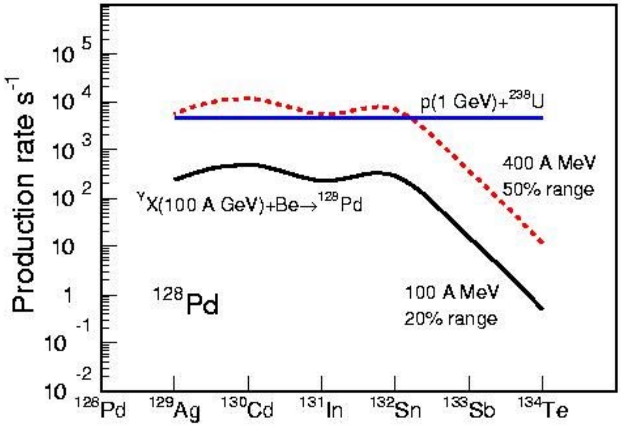
E_i(A MeV)	20% of range of ^{132}Sn in Be(mg/cm^2)	50% of range of ^{132}Sn in Be(mg/cm^2)
100	114	286
200	365	912
400	1083	2709

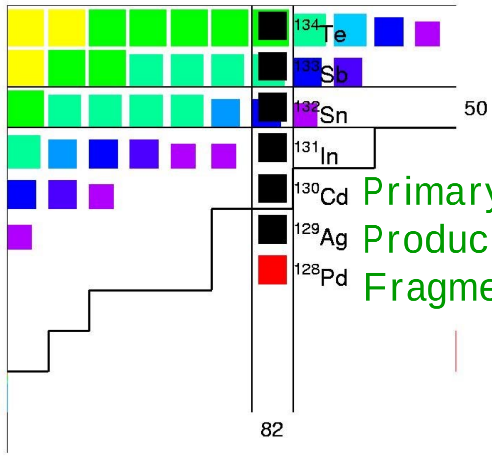
Production of ^{124}Pd in the fragmentation of ^{132}Sn at different energies

	20% of range of ^{132}Sn in Be(mg/cm^2)			50% of range of ^{132}Sn in Be(mg/cm^2)		
E_i(A MeV)	Rate s^{-1}	E(A MeV)	$\Delta E/E$(%)	Rate s^{-1}	E(A MeV)	$\Delta E/E$(%)
100	$1.8\ 10^4$	86.8	0.63	$4.4\ 10^4$	66.9	2.3
200	$5.5\ 10^4$	173.8	0.72	$1.3\ 10^5$	131.8	2.7
400	$1.4\ 10^5$	346.1	0.80	$2.8\ 10^5$	260.0	3.0

Yields in secondary fragmentation

Two-step schemes: fission + cold fragmentation

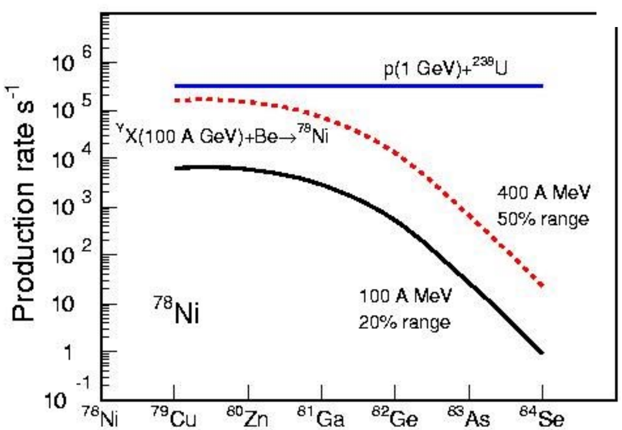


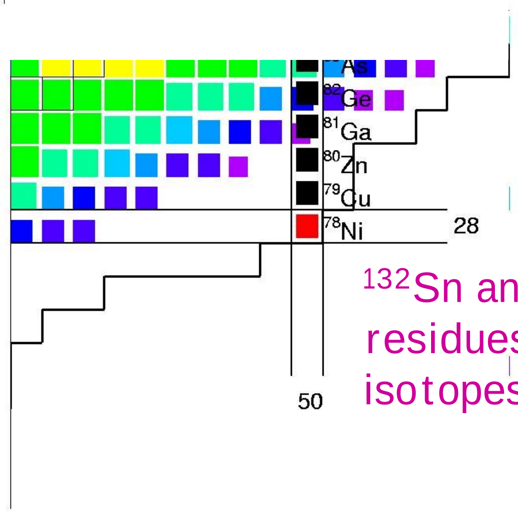


Primary beam: 1 mA

Production target: 100 g/cm^2 UCx

Fragmentation target: Be 20% of range

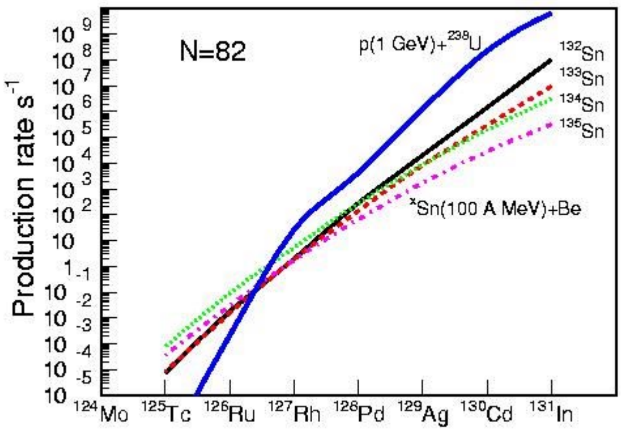


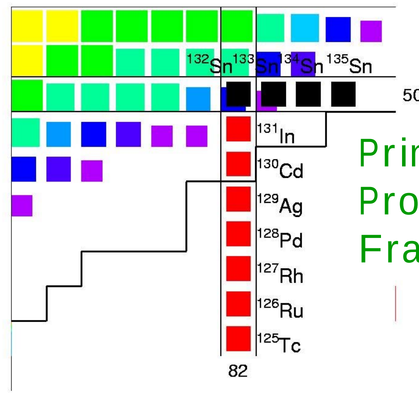


^{132}Sn and ^{81}Ga are optimum fission residues to produce neutron-rich isotopes by secondary fragmentation

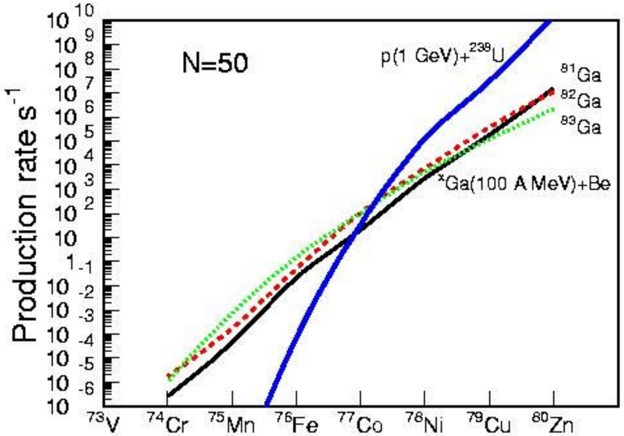
Yields in secondary fragmentation

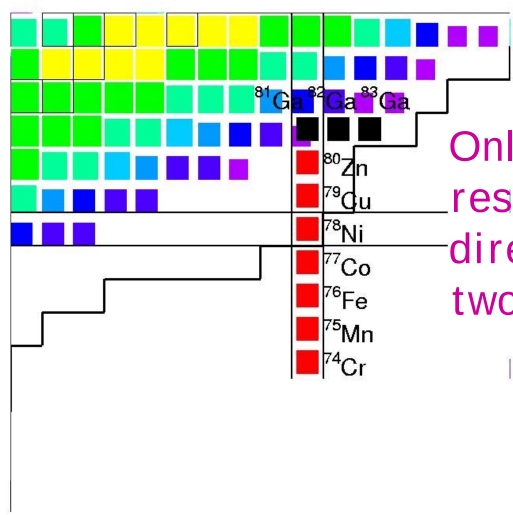
Two-step schemes: fission + cold fragmentation





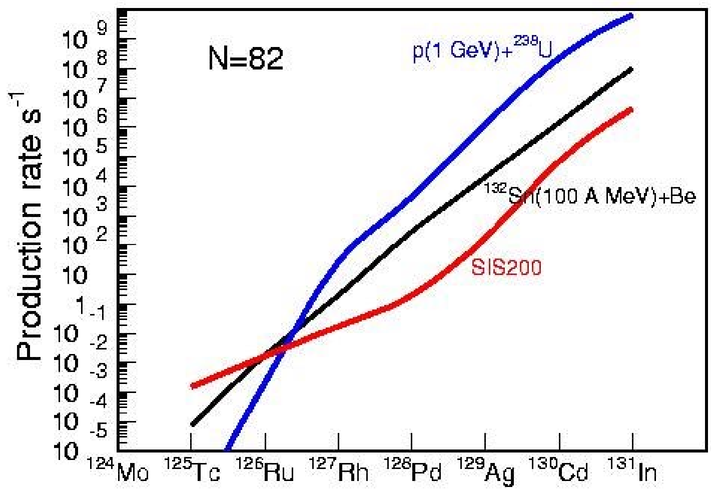
Primary beam: 1 mA
Production target: 100 g/cm^2 UCx
Fragmentation target: Be 20% of range

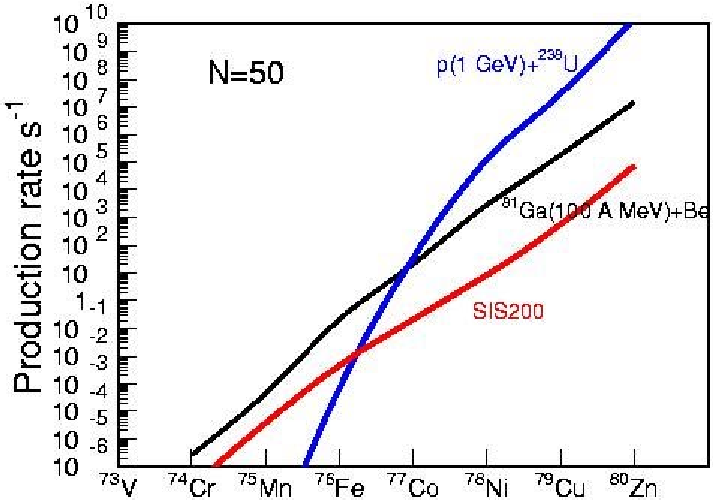




Only for extremely neutron-rich residues the production rates by direct fission is below the two-step scenario

Yields in secondary fragmentation





EURISOL two-step
Primary beam: 1 mA
Production target: 100 g/cm^2 UCx
Fragmentation target: Be 20% of range

SIS200 in-flight fragmentation/fission
Primary beam: 10^{12} ions/s
Production target: 2 g/cm^2 Be

A two-step reaction scheme in EURISOL will lead to larger productions of isotopes along N=82 and N=50 than the future SIS200 project at GSI

Conclusions

A two-step scenario (fission+fragmentation) is a promising tool to produce very exotic nuclei with small extraction efficiencies (refractory elements or short lived isotopes). The comprehensive investigation of this scenario leads to the following conclusions:

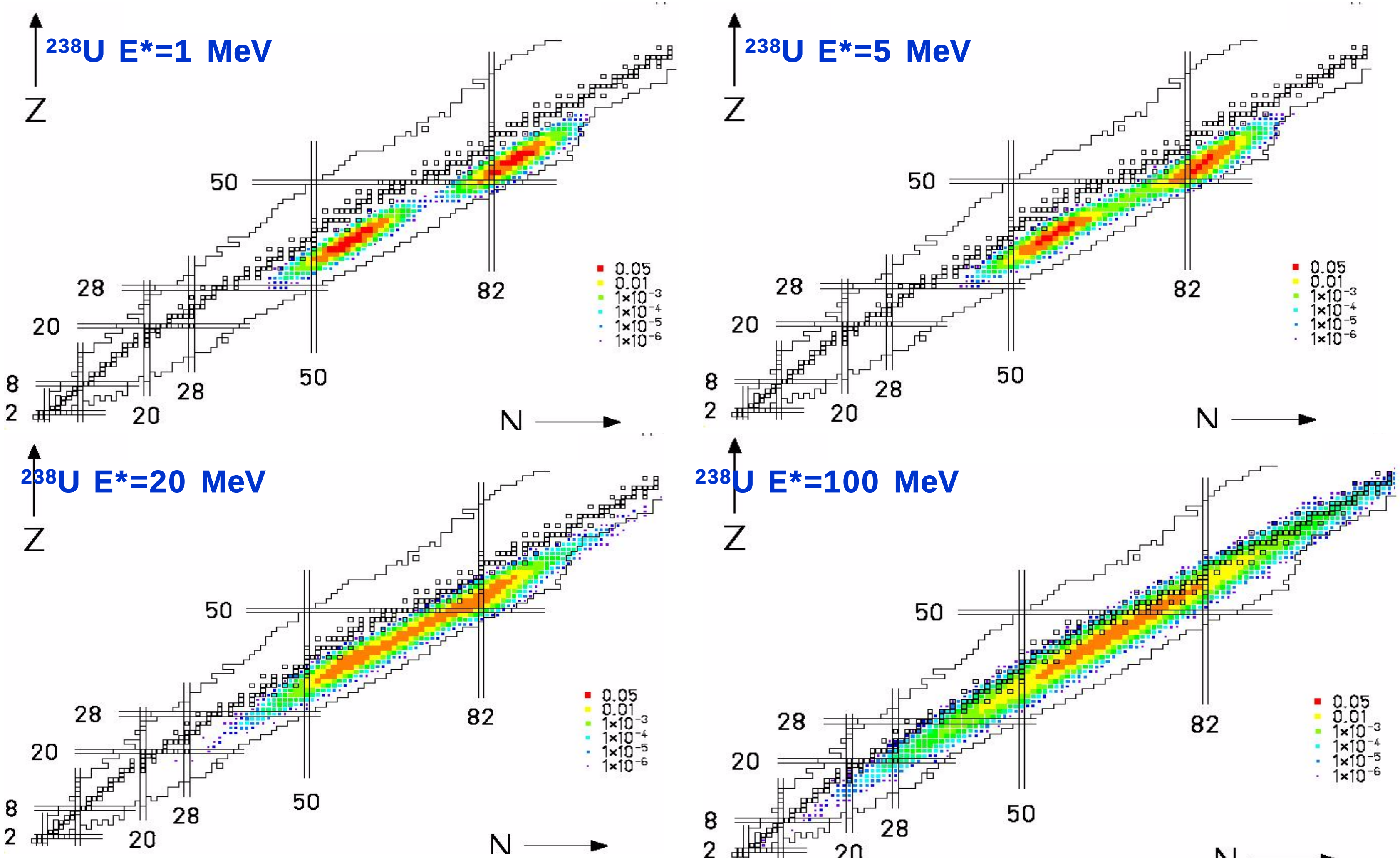
- Dedicated experiments to investigate the fragmentation of neutron-rich projectiles are needed to benchmark model calculations. However, the fragmentation of ^{136}Xe indicates that EPAX overestimates the production of neutron-rich residues

- Measured production cross sections of fragmentation residues at medium energies (20-70 A MeV) provide contradictory conclusions. New data are urgently needed.

- Model calculations indicate that ^{132}Sn and ^{81}Ga are optimum fission residues to be used as projectiles to produce very exotic nuclei along N=82 and N=50

- These model calculations also indicate that a two-step scenario with EURISOL will lead to larger production yields of isotopes along N=82 and N=50 that the ones expected with the future in-flight fragmentation facility at GSI

Fission yields



Eusisol´03