Comparison of Production in Direct and Two-Step Targets

Itacil C. Gomes (1) and Jerry Nolen (2)
(1) I.C.Gomes Consulting & Investment Inc.
(2) Argonne National Laboratory

First Workshop on Actinide Target Development

Vancouver, BC

April 27-29, 2006

International Conference on Applications and Utilization of Accelerators (AccApp'07)
30 July to 4 August, 2007
Idaho State University, Pocatello, Idaho

Organizers: ANS Accelerator Applications Division and Idaho Section in cooperation with the International Atomic Energy Agency.

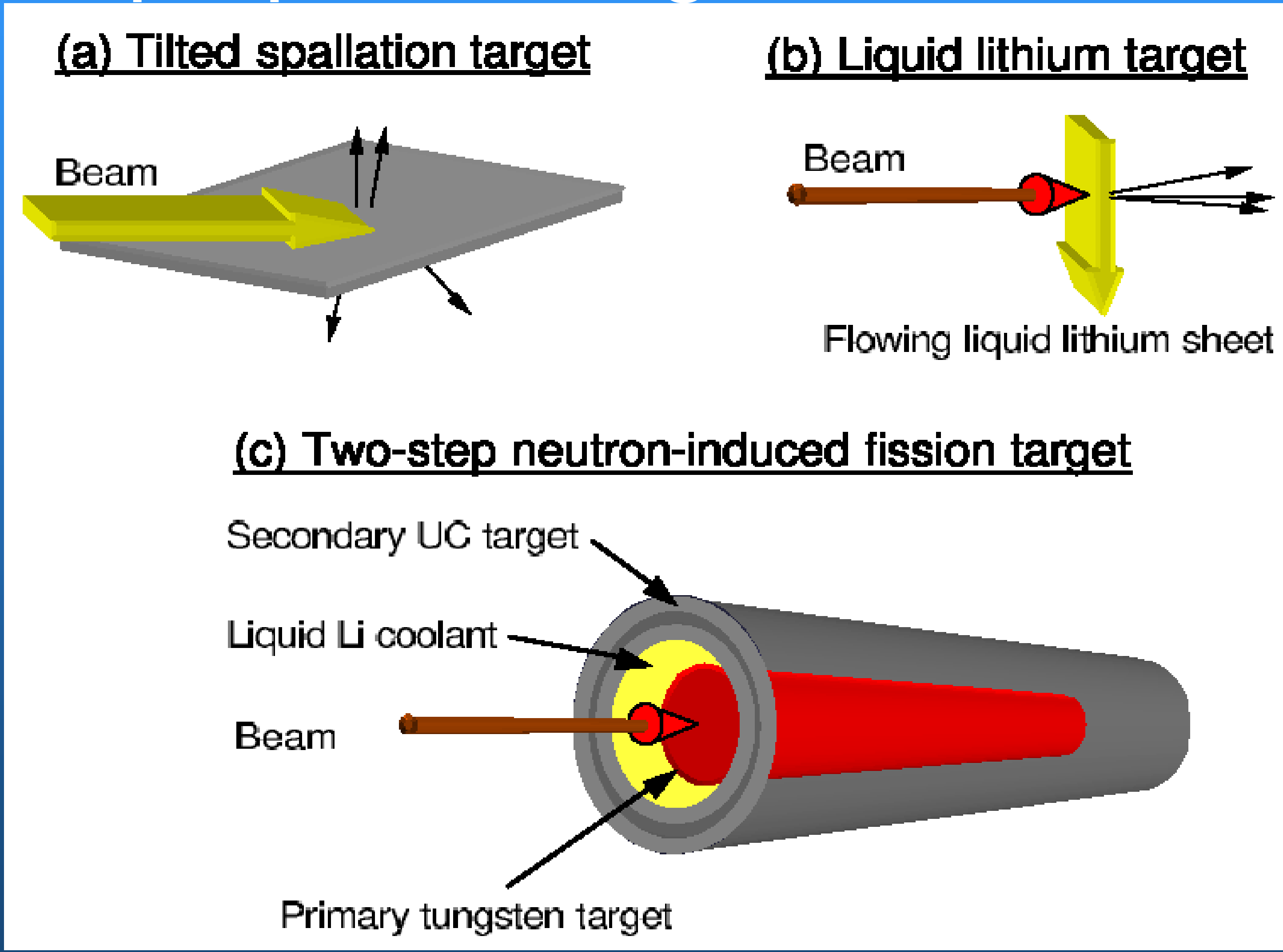
Host: Idaho Accelerator Center

Chair (Denis Beller, UNLV) and TPC Chair (Phil Cole, ISU).

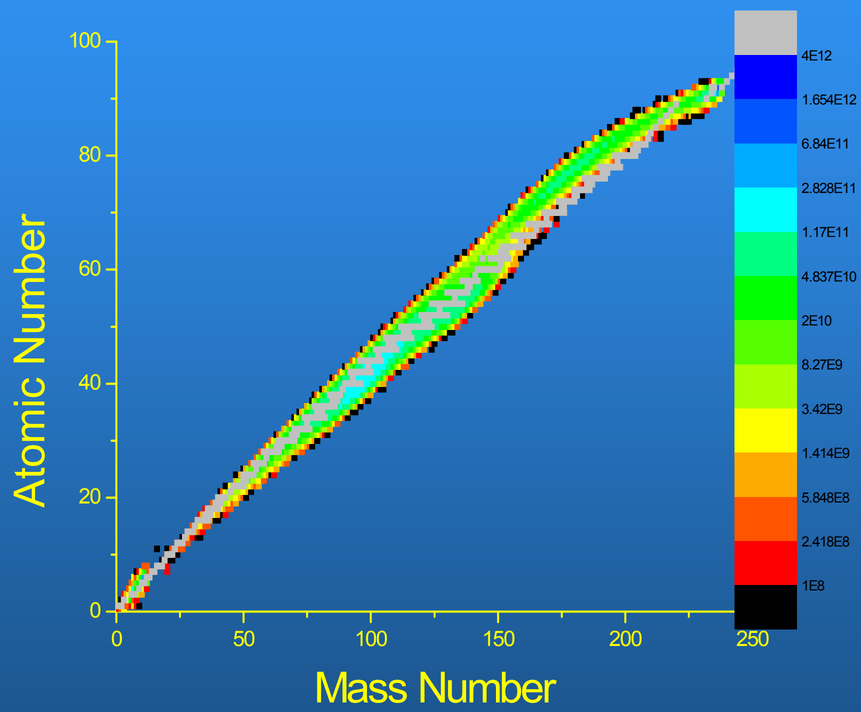
Introduction

- The two main concepts for ISOL type rare isotope production are the direct and the two-step targets.
- The two-step target was first proposed by ANL in the mid-1990's.
- This concept has several advantages concerning high-power targets.
- The neutron production from light ions with tungsten (for ex.) produce a neutron spectrum well suitable for production of neutron rich fission products in U-238.
- Several aspects of the different light ion beams regarding providing the highest rare isotope production and the associated radiological impact were studied for several years.
- This presentation shows a short compilation of the most important aspects of the two main ISOL target concepts.

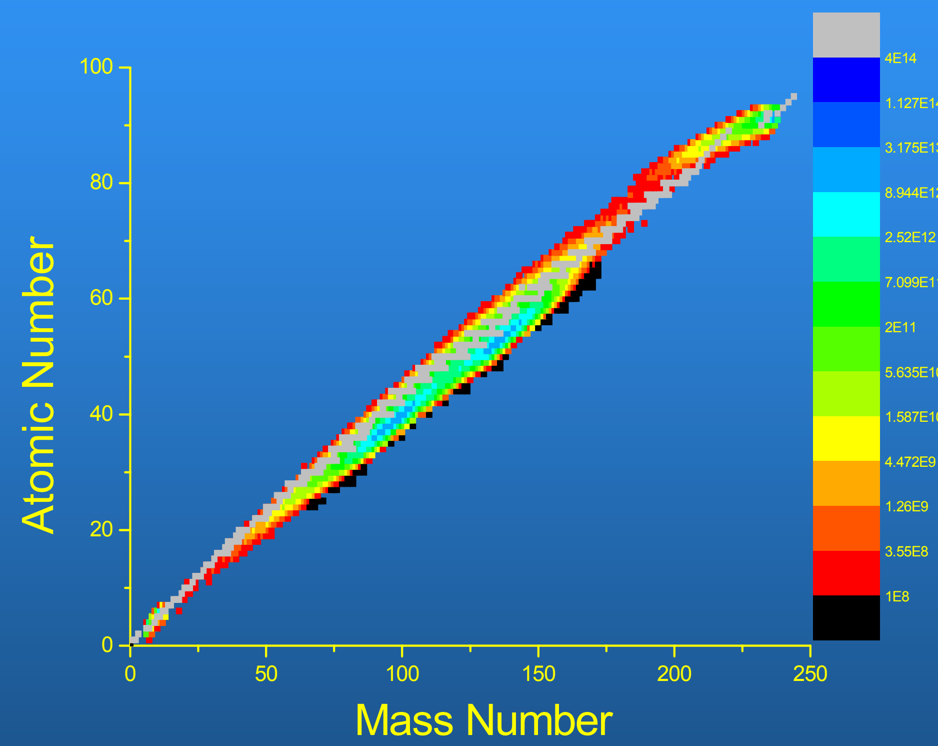
The two target concepts are proposed targets for RIA



Comparison of the Two-Step and Tilted Target Production Each Target has its advantages and disadvantages.

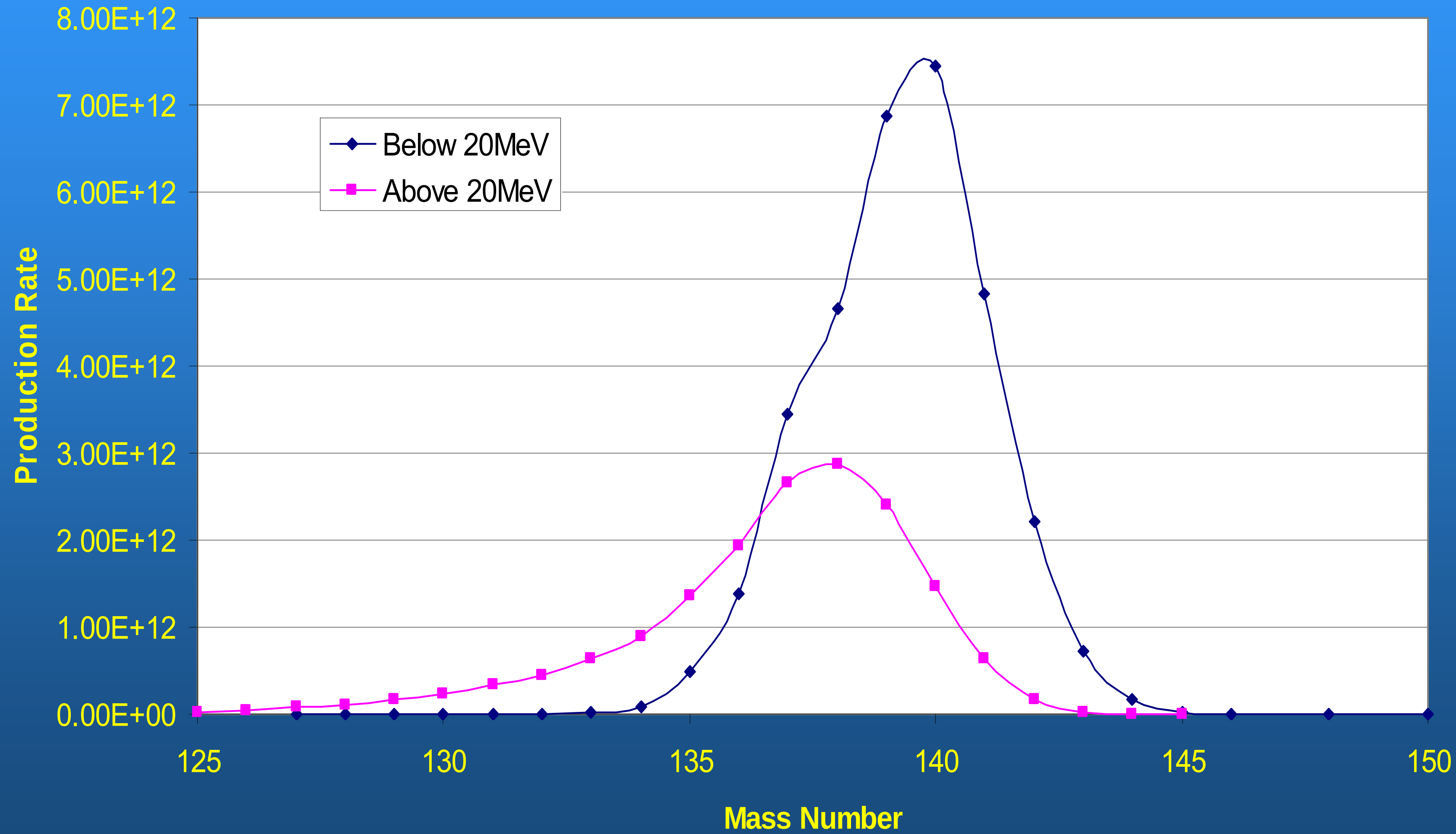


Tilted Target – much higher Production in the Spallation Region – More Proton Rich Products



Two-Step Target – higher Production in the Fission Product Region – More Neutron Rich

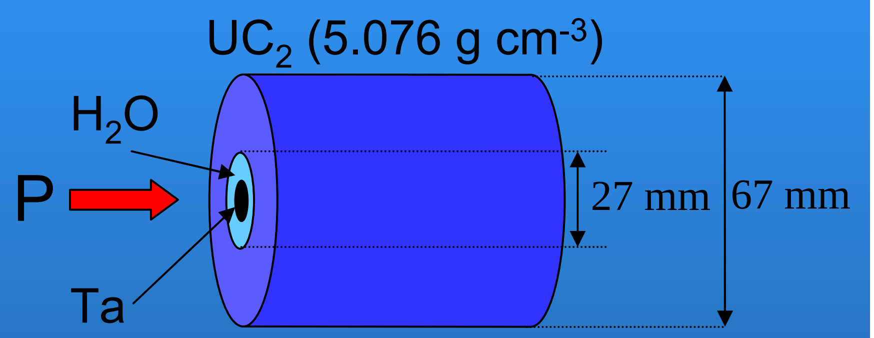
Xenon Production Above and Below 20 MeV – 1.2GeV Deut

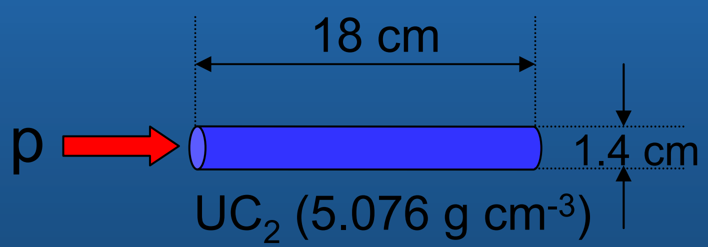


There are Several Aspects to Address about these Concepts

Using ISAC example:
ISAC has a beam power
of 50kW of Proton beam at 500MeV

This design is not the same as the design that we optimized for RIA.

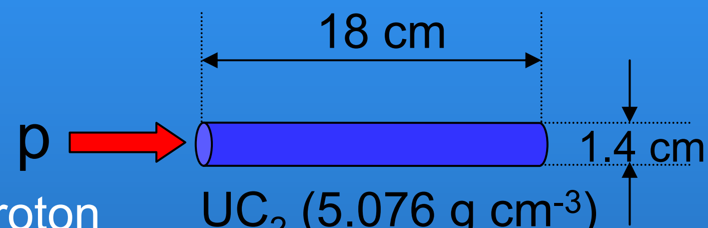




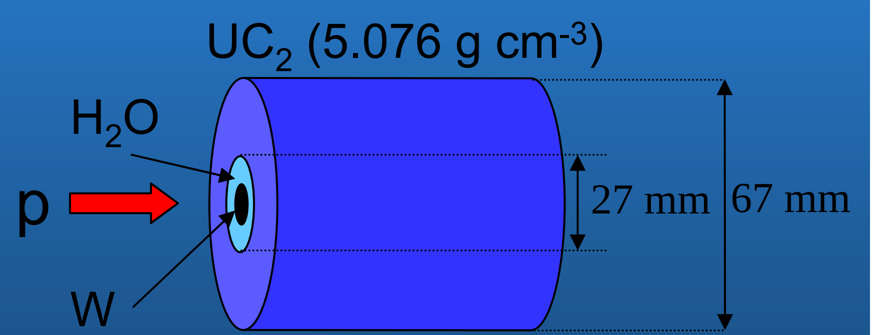
This study compares Direct and 2-Step with ISAC Beam.

Comparison - Total Number of Fission using LAQGSM model of MCNPX

- Multiplicity is function of Beam Energy
- – Using 500 MeV Proton Beam



- Direct 500-MeV Protons
- Total Fission > 20MeV = 2.19e-01 fission/proton
- Total Fission < 20MeV = 8.74e-03 fission/proton
- Total Fission = 2.27e-01 fission/proton



- Two-Step 500-MeV Protons
- Total Fission > 20-MeV = 7.77e-02 fission/proton
- Total Fission < 20-MeV = 8.65e-02 fission/proton
- Total Fission = 1.64e-01 fission/proton

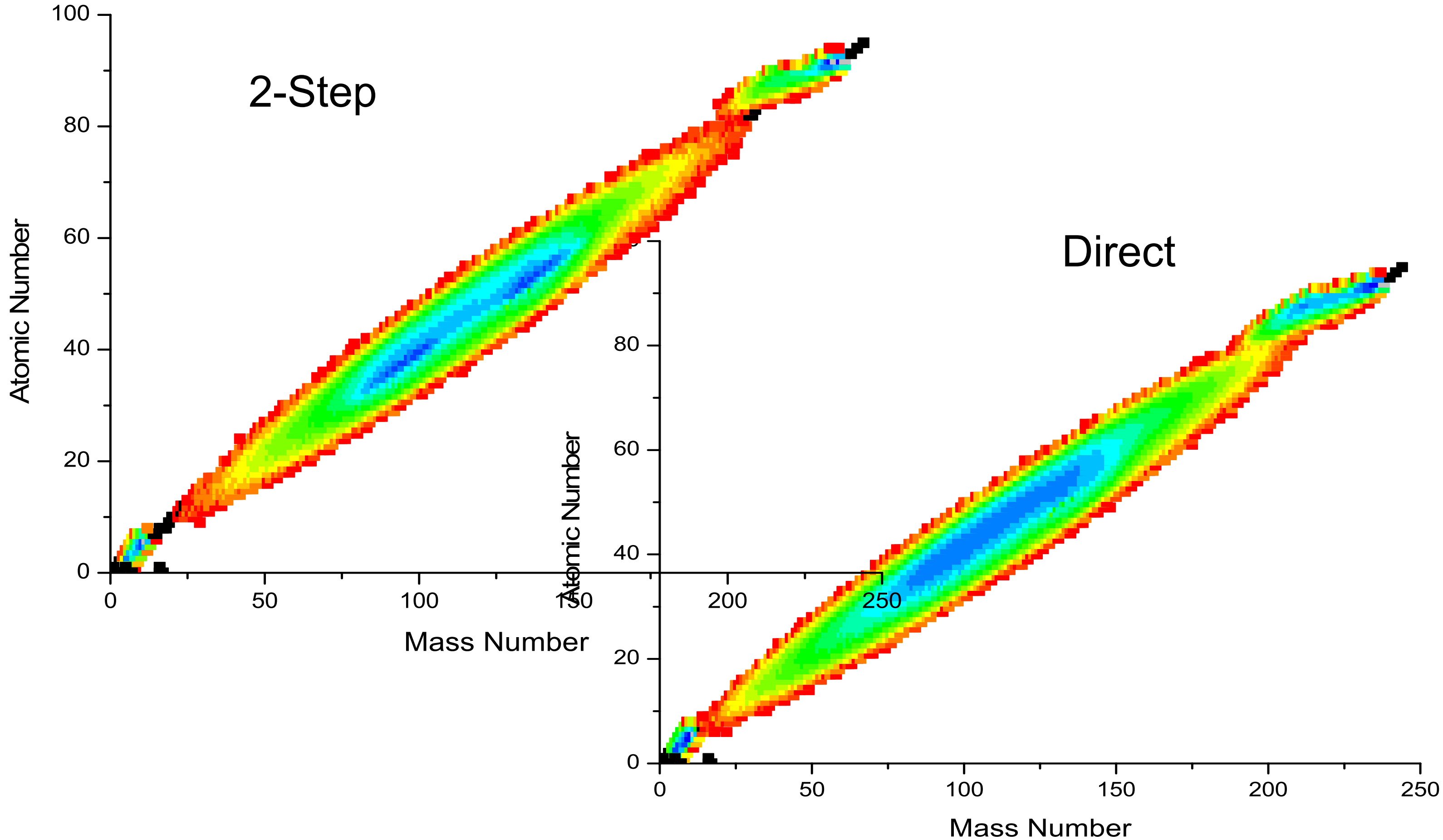
Comparison 50kW Proton Beam

	Direct	2-Step
0.1KeV to 5MeV	3.78e+12	3.16e+13
5 to 20MeV	3.65e+12	2.24e+13
> 20MeV	1.39e+14	4.85e+13
Total	1.47e+14	1.02e+14

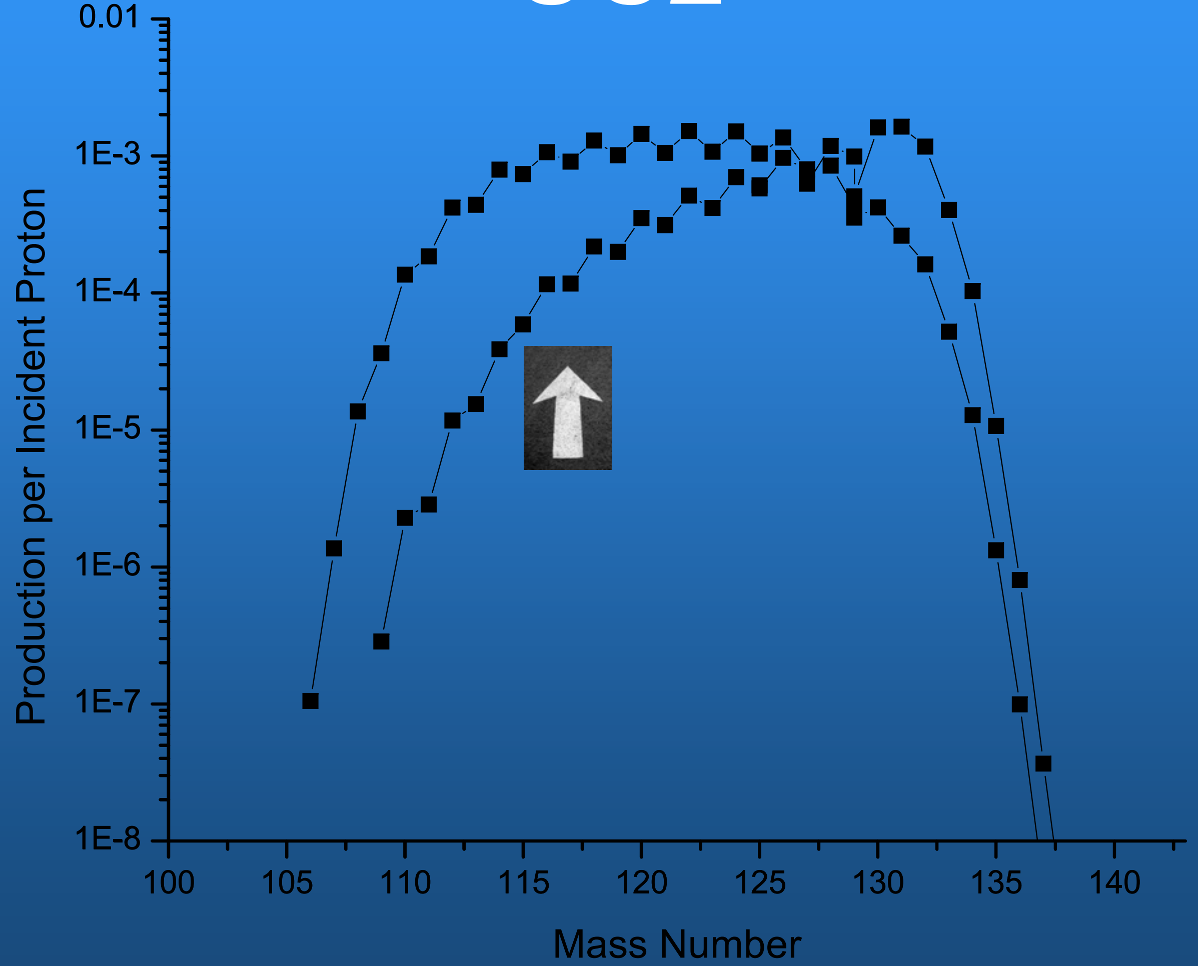
Number of Fissions in Several Energy Regions for Few Configurations – 400kW

	Protons (500MeV) Direct	Protons (568MeV) 2-Step	Deuterons (640MeV) 2-Step	Helium-3 (1281MeV) 2-Step
0.1KeV to 5MeV	2.66e+13	2.04e+14	2.58e+14	1.40e+14
5 to 20MeV	2.57e+13	1.55e+14	1.74e+14	1.28e+14
> 20MeV	9.80e+14	3.53e+14	3.89e+14	2.65e+14
Total	1.03e+15	7.12e+14	8.21e+14	5.34e+14

Using ISAC Beam Energy – Comparison of Yields



Comparison of 50-Tin Isotopes Production – 500-MeV Protons on UC2



Numerical values of Tin Production per incident Proton – Partial List

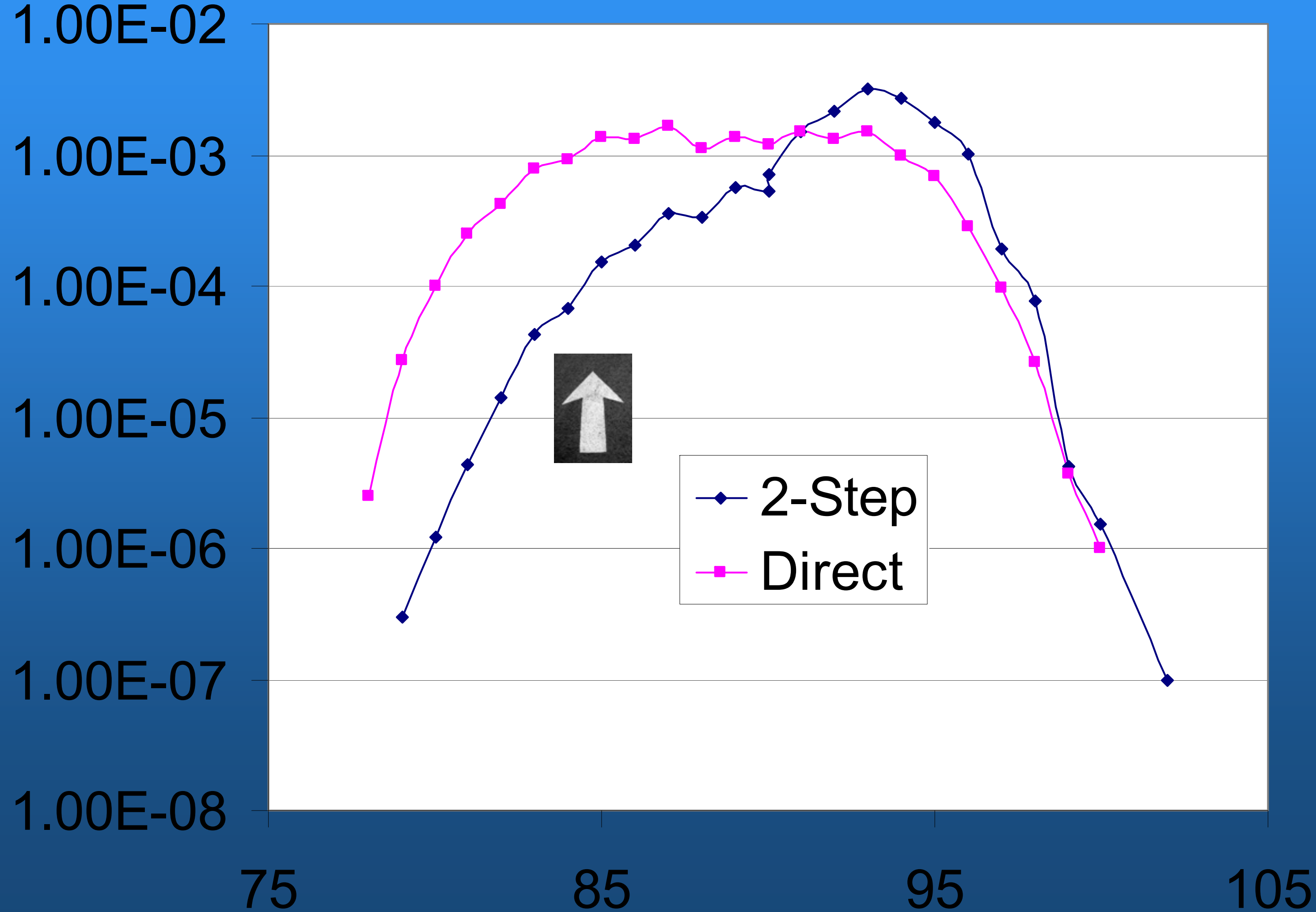
500-MeV Protons – TWO-STEP

	E<20MeV	E>20MeV	Total
125	3.93E-05	5.71E-04	6.10E-04
125	9.09E-06	5.71E-04	5.80E-04
126	1.26E-04	8.42E-04	9.68E-04
127	2.21E-04	5.77E-04	7.99E-04
127	5.10E-05	5.77E-04	6.28E-04
128	5.09E-04	6.76E-04	1.19E-03
129	6.72E-04	3.20E-04	9.92E-04
129	1.89E-04	3.20E-04	5.09E-04
130	1.38E-03	2.36E-04	1.62E-03
131	1.58E-03	5.66E-05	1.64E-03
132	1.15E-03	2.26E-05	1.17E-03
133	4.03E-04	5.71E-07	4.04E-04
134	1.03E-04	5.71E-07	1.03E-04
135	1.07E-05	0.00E+00	1.07E-05
136	8.03E-07	0.00E+00	8.03E-07
137	3.67E-08	0.00E+00	3.67E-08
138	1.81E-09	0.00E+00	1.81E-09

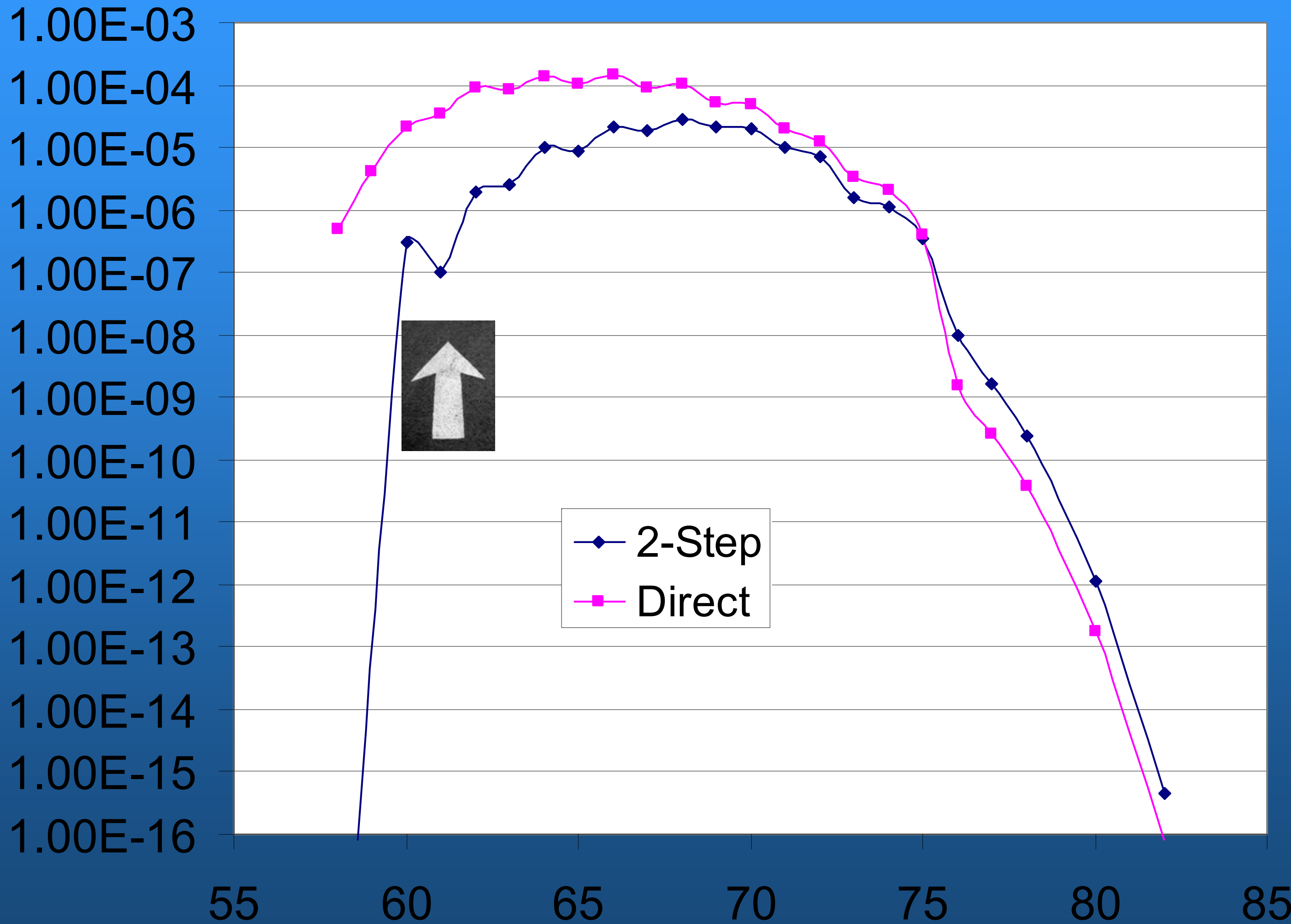
500-MeV Proton - DIRECT

		E<20-MeV	E>20-MeV	Total
50	125	6.25E-06	1.04E-03	1.04E-03
50	125	1.43E-06	1.04E-03	1.04E-03
50	126	2.01E-05	1.34E-03	1.36E-03
50	127	3.49E-05	7.62E-04	7.97E-04
50	127	7.92E-06	7.62E-04	7.70E-04
50	128	7.84E-05	7.73E-04	8.51E-04
50	129	9.56E-05	3.29E-04	4.25E-04
50	129	2.60E-05	3.29E-04	3.55E-04
50	130	1.89E-04	2.33E-04	4.22E-04
50	131	2.07E-04	5.43E-05	2.62E-04
50	132	1.45E-04	1.66E-05	1.62E-04
50	133	5.09E-05	1.37E-06	5.23E-05
50	134	1.27E-05	1.05E-07	1.29E-05
50	135	1.33E-06	0.00E+00	1.33E-06
50	136	9.96E-08	0.00E+00	9.96E-08
50	137	4.59E-09	0.00E+00	4.59E-09
50	138	2.46E-10	0.00E+00	2.46E-10

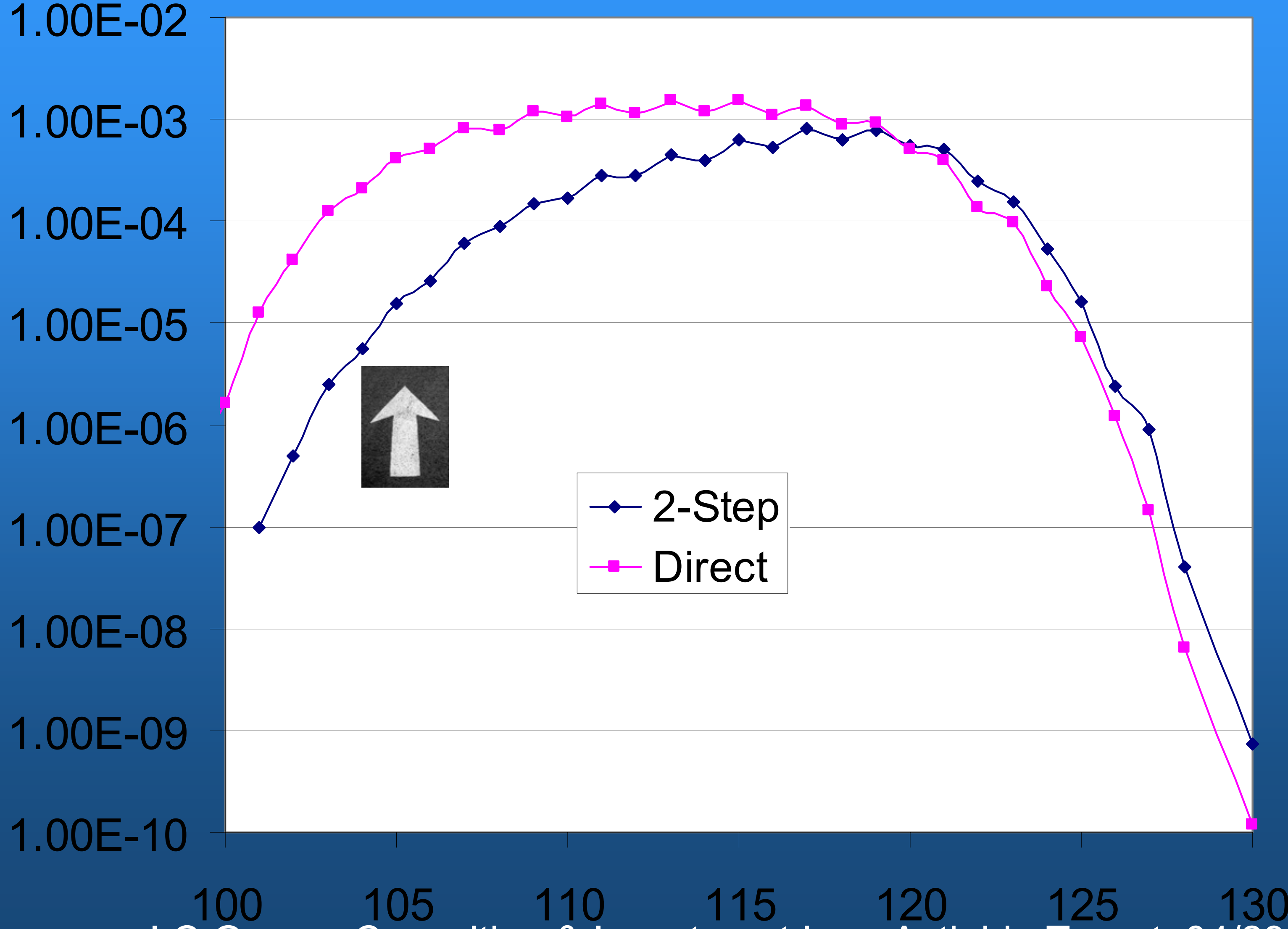
Comparison of 37-Rb Isotopes Production – 500-MeV Protons on UC2



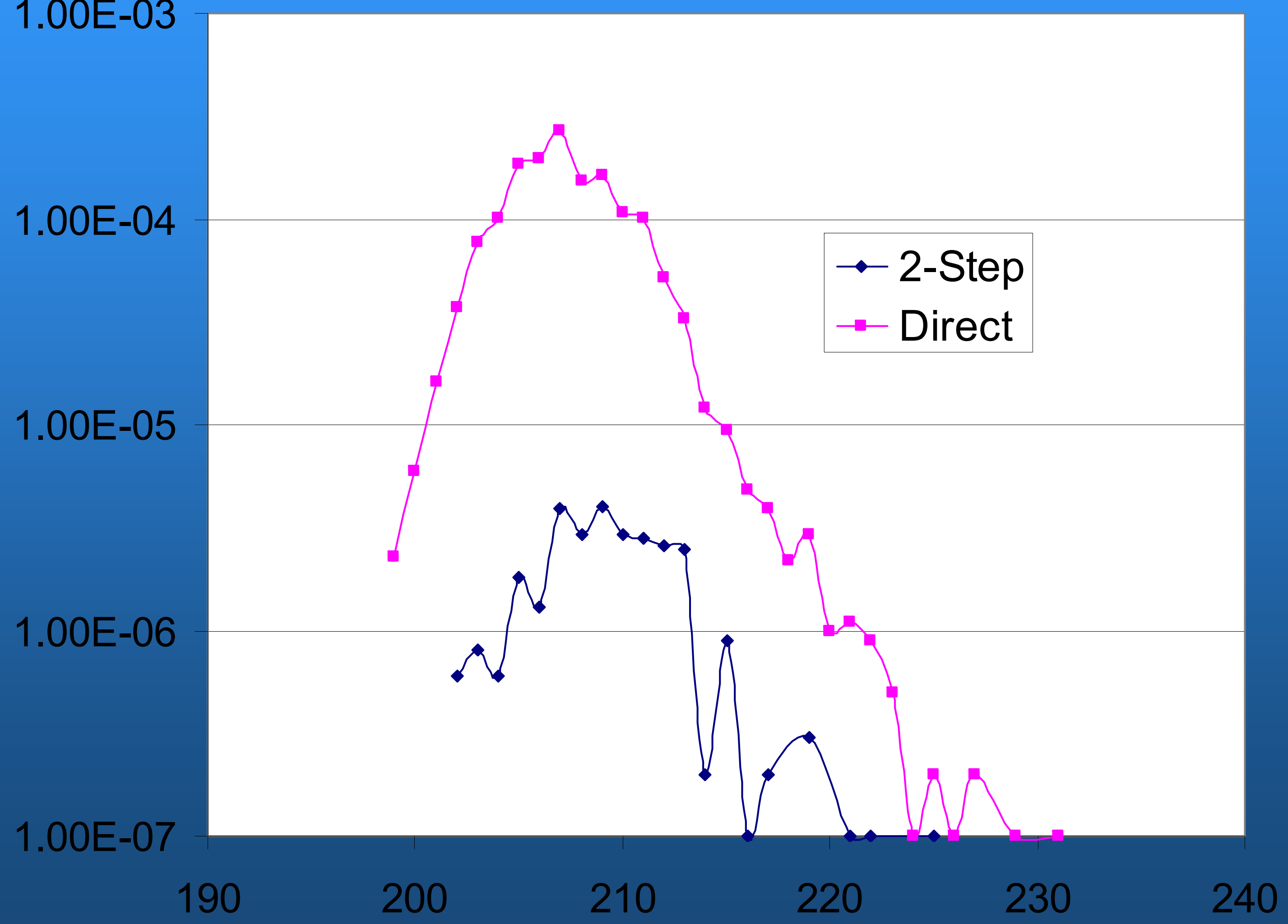
Comparison of 28-Ni Isotopes Production – 500-MeV Protons on



Comparison of 47-Ag Isotopes Production – 500-MeV P on UC2

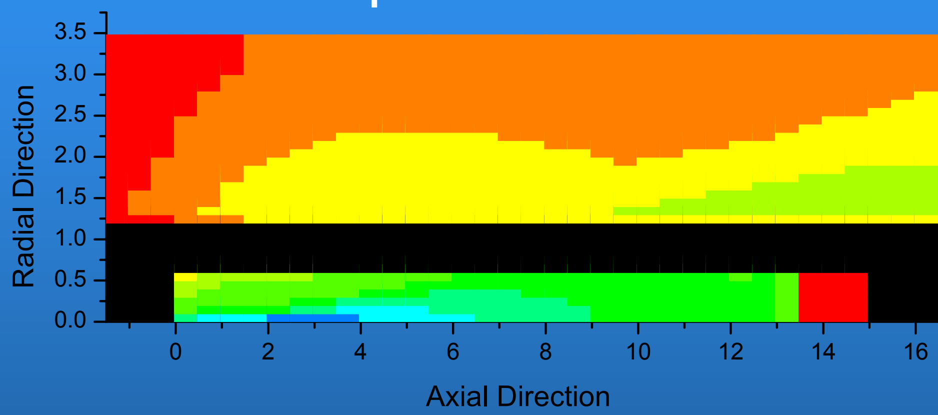


Comparison of 87-Francium Production by 500-MeV P on UC2



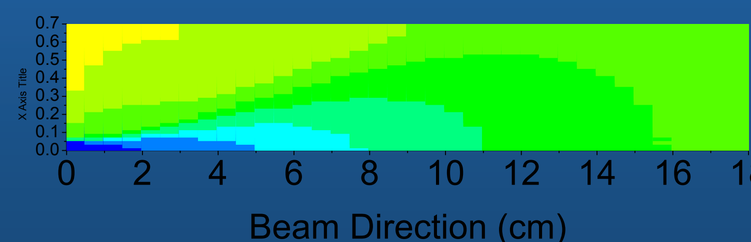
Heat Deposition on Targets – 500MeV Proton Beam

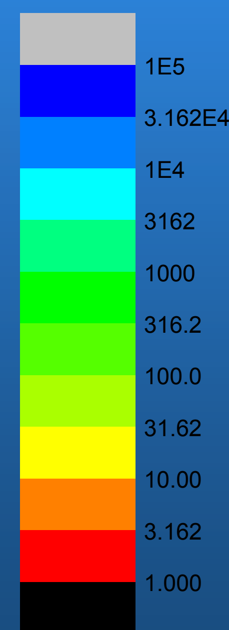
500-MeV Proton on W - 2-Step Heat Deposition in W/cc



The beam deposits up-to 85 kW/cc in the 2-Step (W – 16.65g/cc) and 35 kW/cc in the direct (UC2 – 5.072g/cc.)

500-MeV Proton on UC2 Heat Deposition in W/cc





The 2-Step target allows to separate the heat deposition from isotope production.

Alpha Emitters

- A Note: The component below 20 MeV may add significant production due to (n,2n), (n,p), (n,α),(n,γ) etc.
- The analysis of yields of these low-energy produced alpha emitters is not complete.

Conclusions

- The direct target has a higher Production for 500-MeV Proton Beam
- The 2-Step target produces more neutron rich fission products per beam particle.
- The 2-Step target has considerably less isobar contamination than direct target.
- The direct target works much better in the spallation region.
- The 2-Step target allows to separate heat deposition from the beam from isotope production.

Conclusions

- The selection of the target-beam combination is a function of the isotope of interest to be produced.
- The heat deposition on the target has be taken into account because of potential interference between isotope extraction and cooling.
- Target optimization is an important step in building high power facilities.
- Production has to be studied simultaneously with diffusion/effusion and cooling.
- The two-step target is the best choice for a variety of neutron-rich fission products.