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CENTRE D'ETUDE DE L'ENERGIE NUCLEAIRE

Upgrading the proton beam of ISOLDE from 1.4 to 2.0 GeV:

The impact on beam intensities

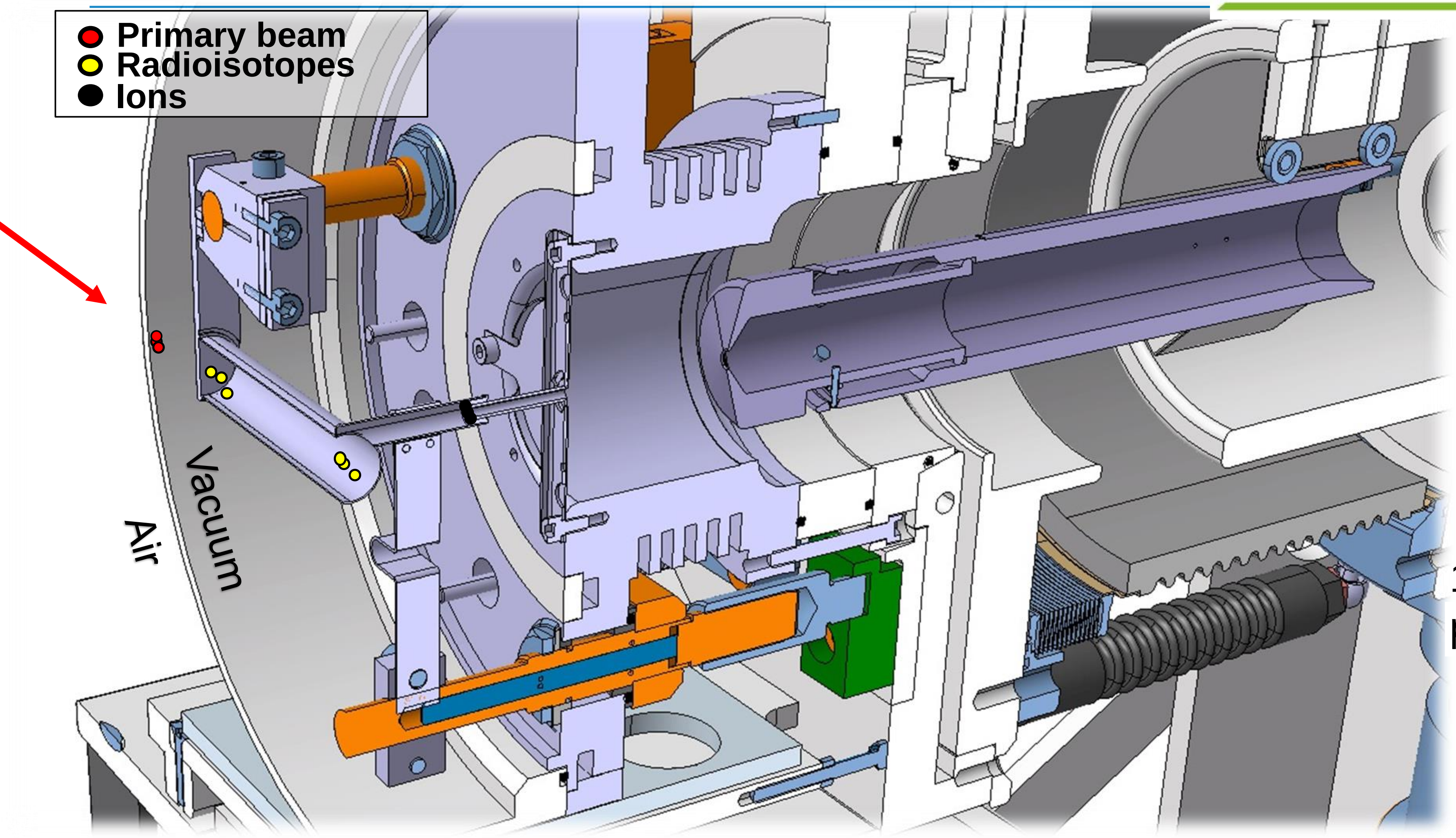
CERN

ISOLDE

ISOLDE – EPIC Workshop, 3-4 Dec 2019

João Pedro Ramos, T. Stora, S. Rothe, C. Duchemin

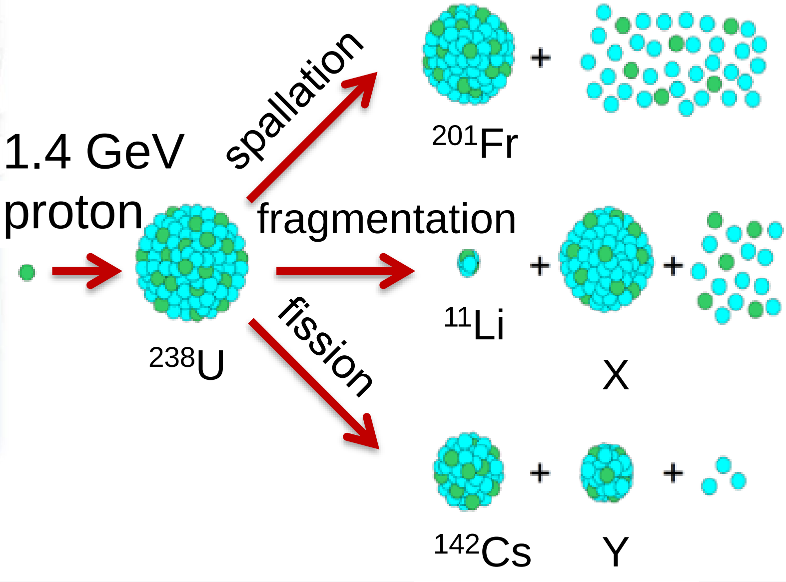
Target Unit – Heart of ISOLDE



*picture and animation courtesy of M. Delonca

Beam power
- 2.8 kW in average
- 8 GW (bunch length 230 ns)
  - ~10% deposited

ISOLDE can certainly take 2 GeV on their targets



Past and future driver energy increase at ISOLDE

ISOLDE (1967) – with the SC

ISOLDE 2 (1976)
- **SC intensity increase**

ISOLDE 3 (1983)
- **Second target station with HRS**
- **Still in SC**

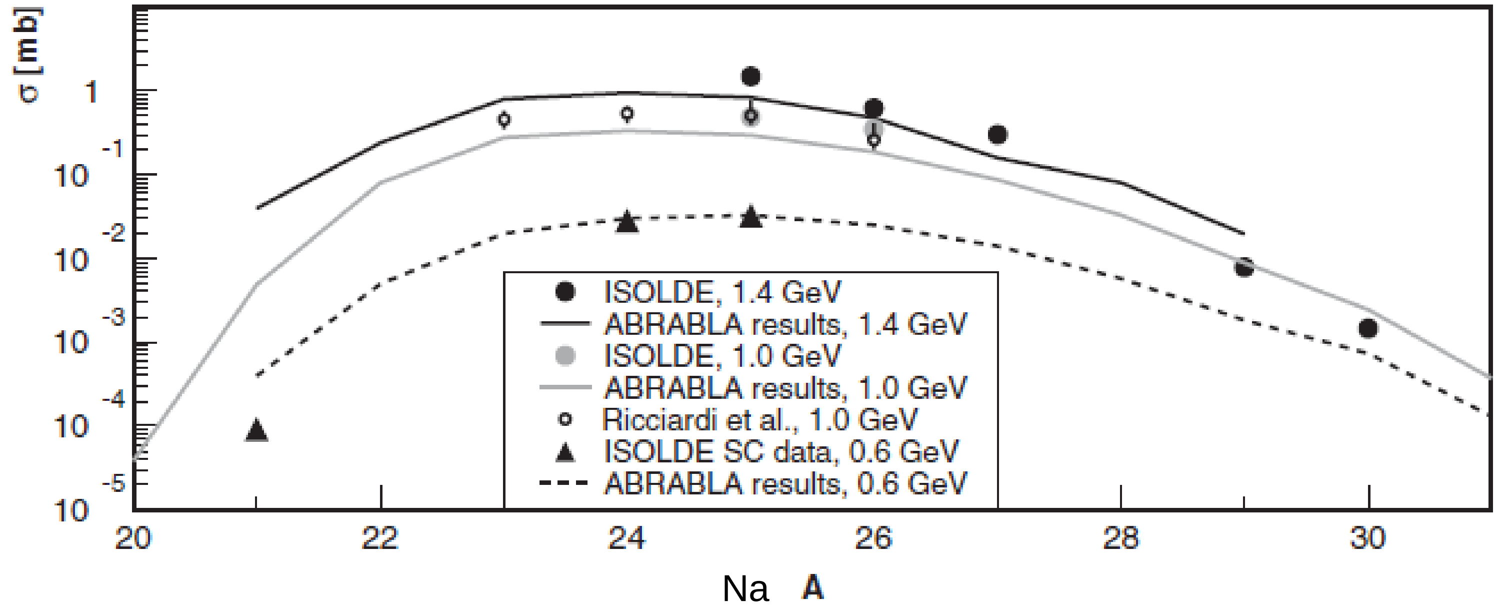
ISOLDE 4 (1992)
- **With PSB – 1 GeV**

ISOLDE 4.5 (2000)
- **With PSB – upgrade to 1.4 GeV**

ISOLDE 5 (202x)
- **With PSB – 2 GeV?**

M. Borge, M. Kowalska, T. Stora, INTC-O-016

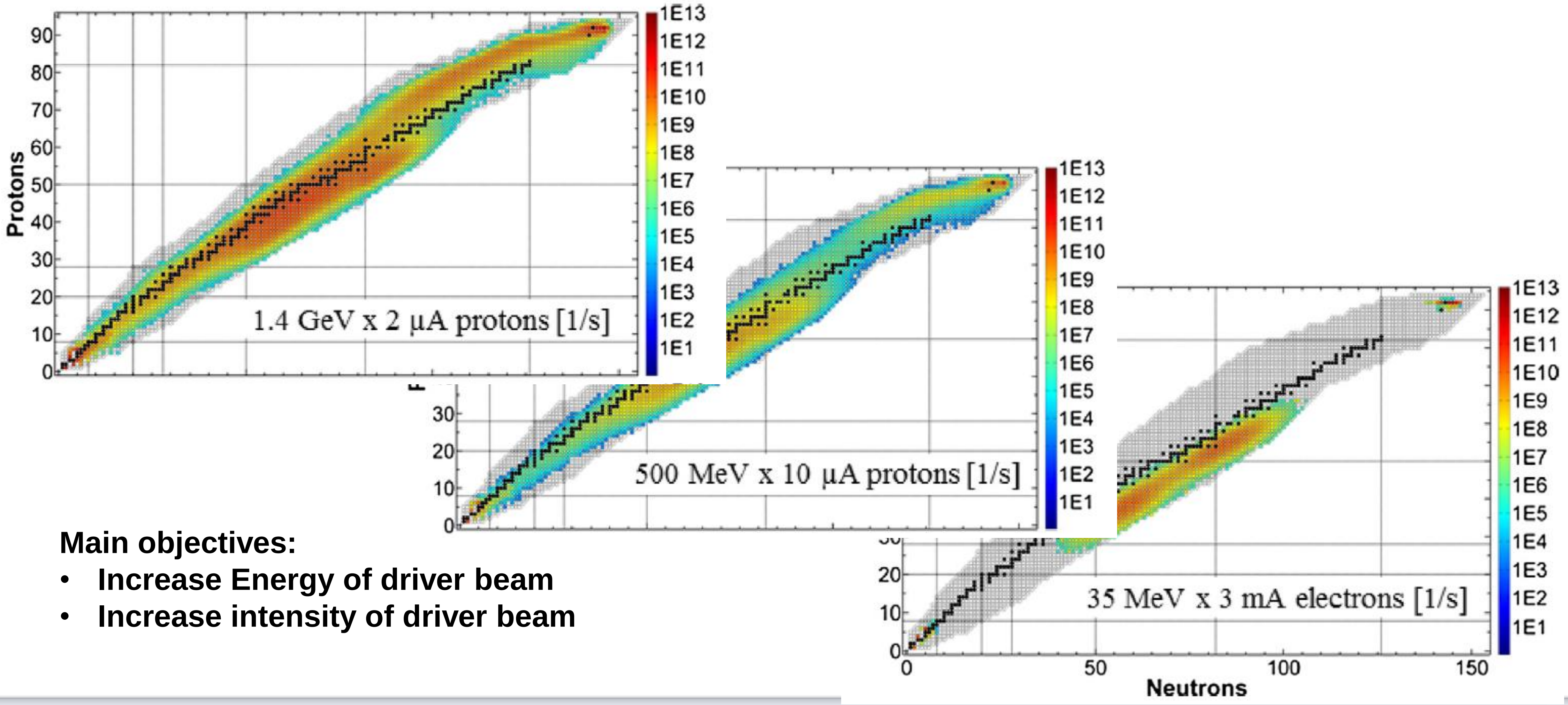
- 600 MeV -> 1.0 GeV (+67%)
- 1.0 GeV -> 1.4 GeV (+40%)
- **1.4 GeV -> 2.0 GeV (+43%)**



Can be seen that the code was underestimating the yields (fragmentation reactions)!

K.-H. Schmidt, et al. Phys Rev Spec Topics 10 (2007) 014701

Energy vs Intensity



Main objectives:

- **Increase Energy of driver beam**
- **Increase intensity of driver beam**

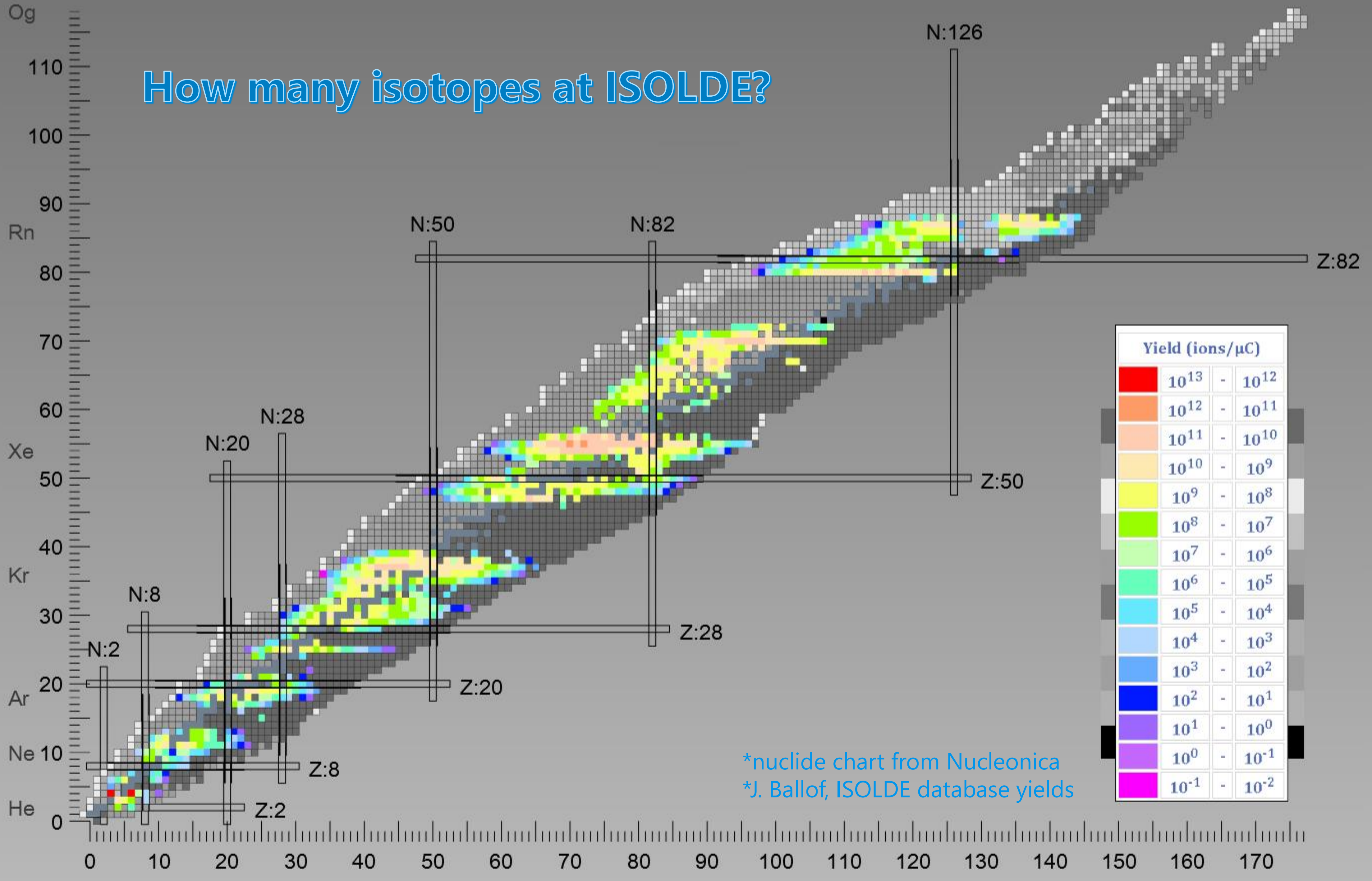
How many isotopes at ISOLDE?

ISOLDE
~1000

Elements
74
$t_{1/2}$
>tens of ms

Currently the leading facility of its type

But other ISOL are getting close…

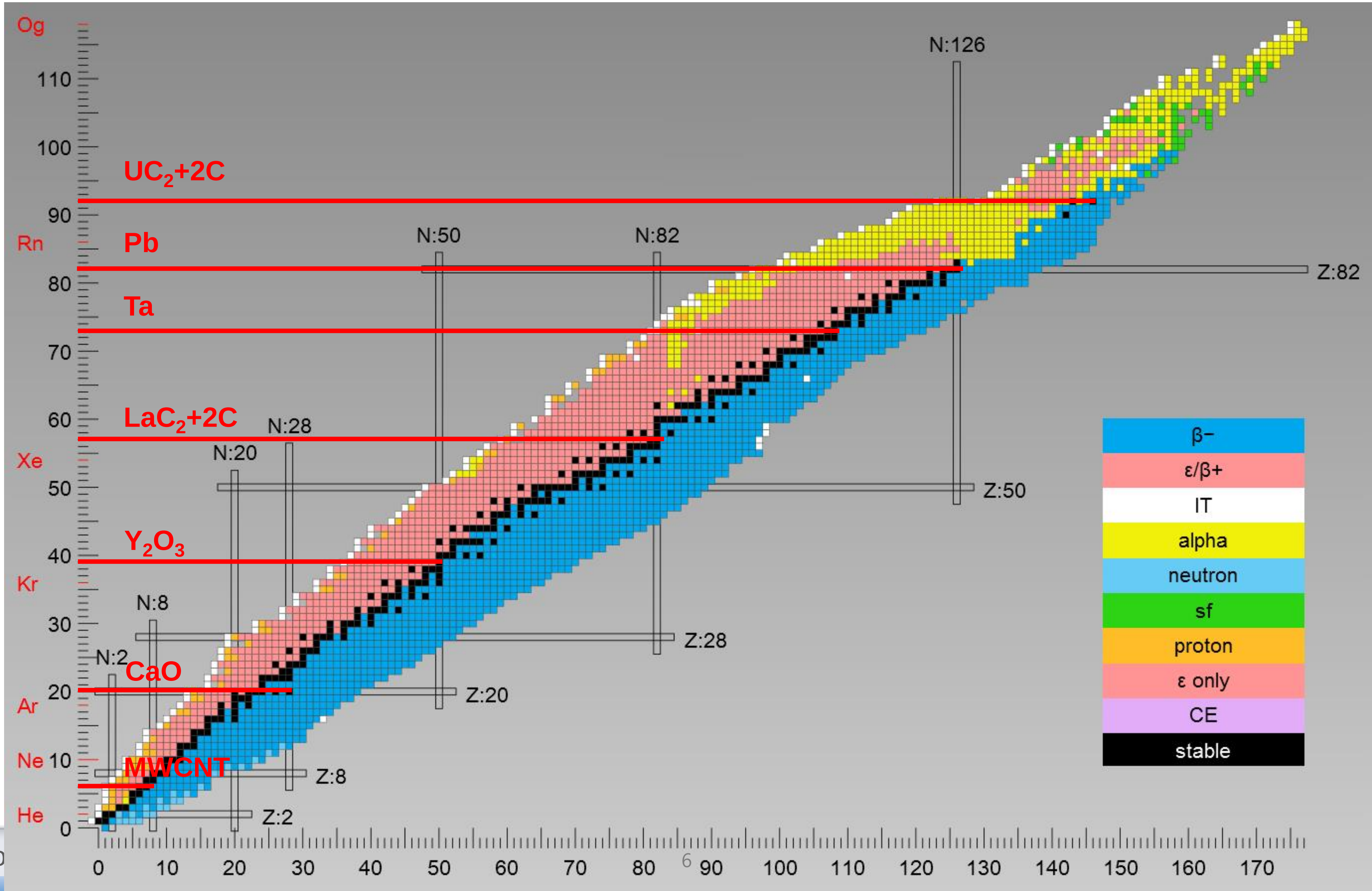


*nuclide chart from Nucleonica
*J. Ballof, ISOLDE database yields

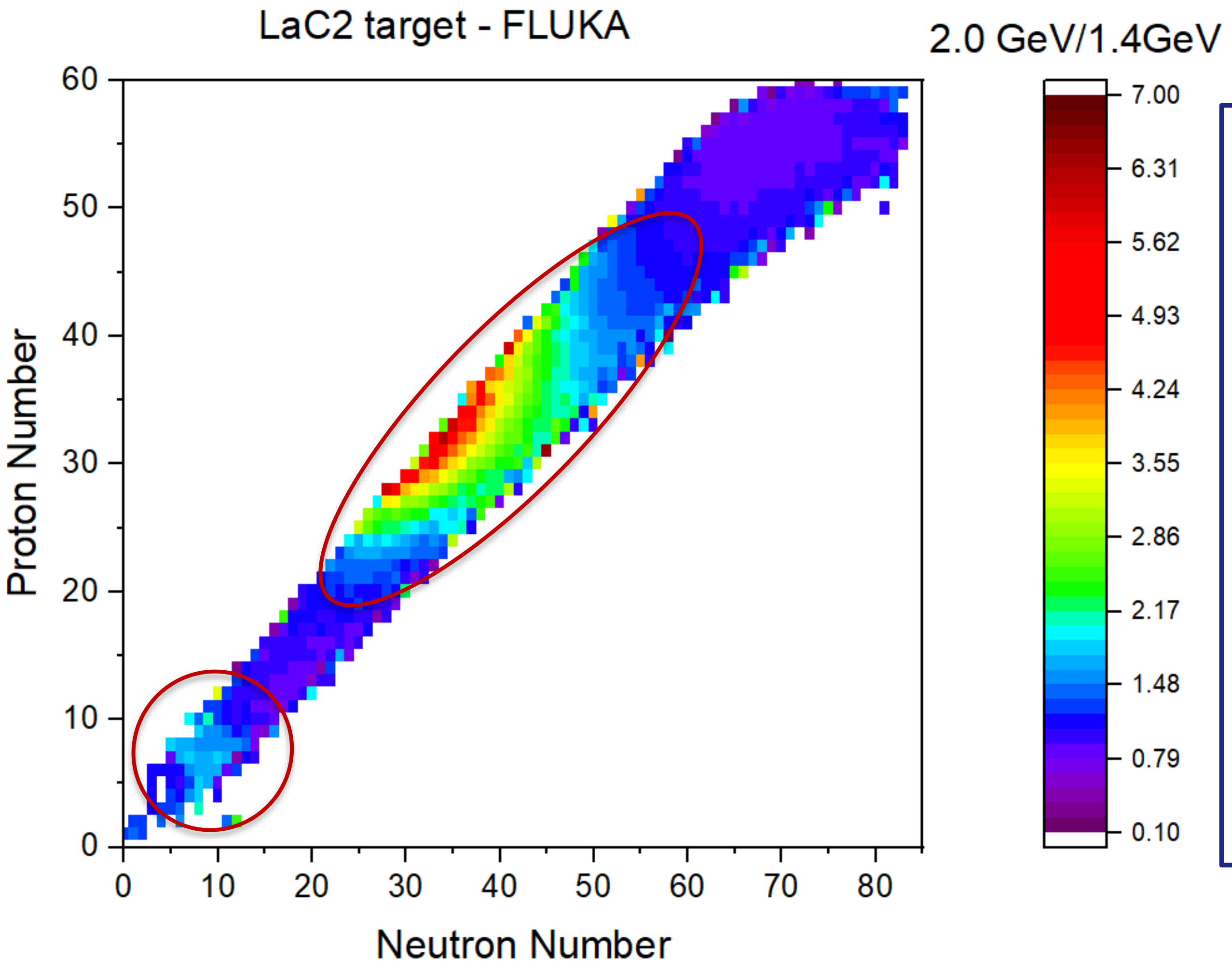
Chosen case studies

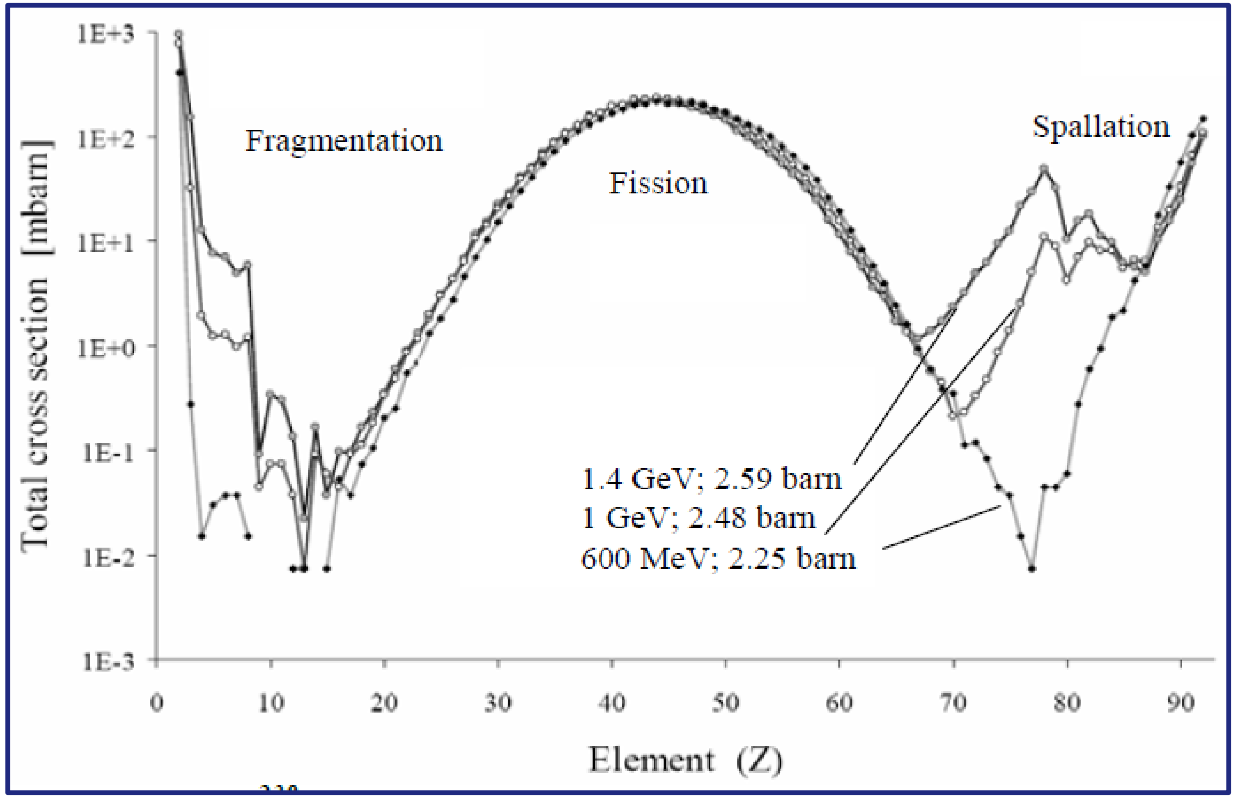
By far not all ISOLDE targets!

But a good representation to give an idea of the 2 GeV upgrade effect across a wide target Z.



1.0/1.4 GeV vs 1.4/2.0 GeV

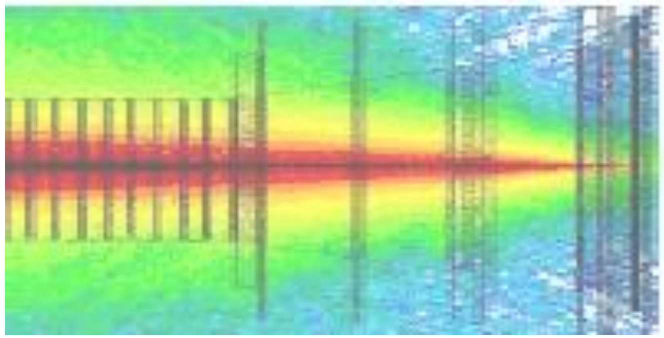




Cross section increase increase stabilizes around 3-4 GeV

The Simulation codes: FLUKA and ABRABLA

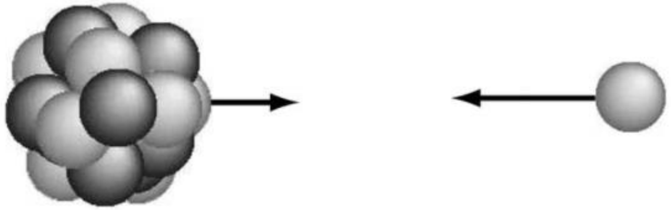
FLUKA



300 Mevents
40 cores (cluster)
max 4 days per simulation

Very complete
Very good for high Z materials

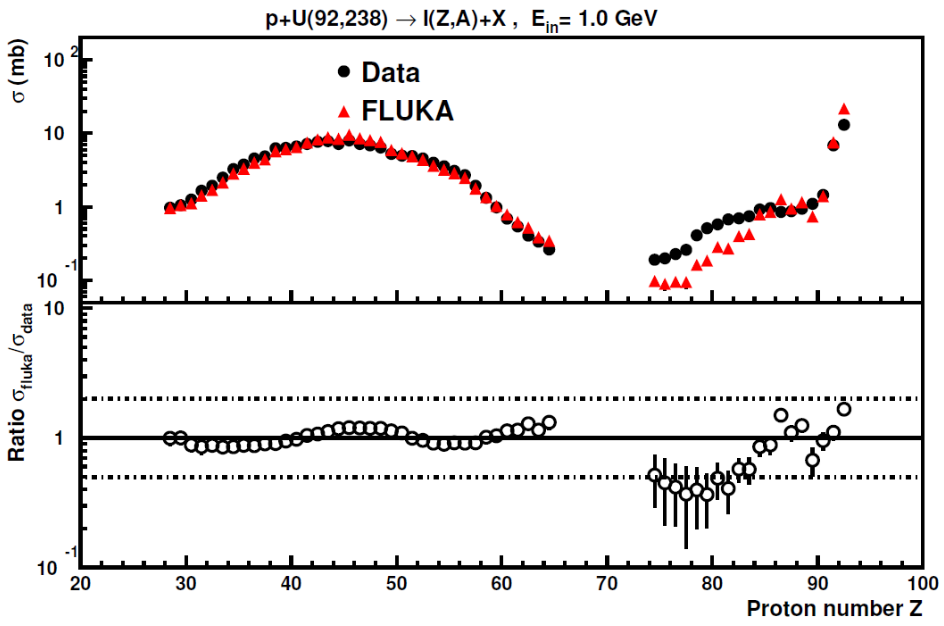
ABRABLA



1 Gevents
8 cores (CERN Personal PCs)
max 1 week per simulation

Well benchmarked for spallation at ISOLDE
Does not account for:
Secondary particles
Beam energy degradation (high Z targets)

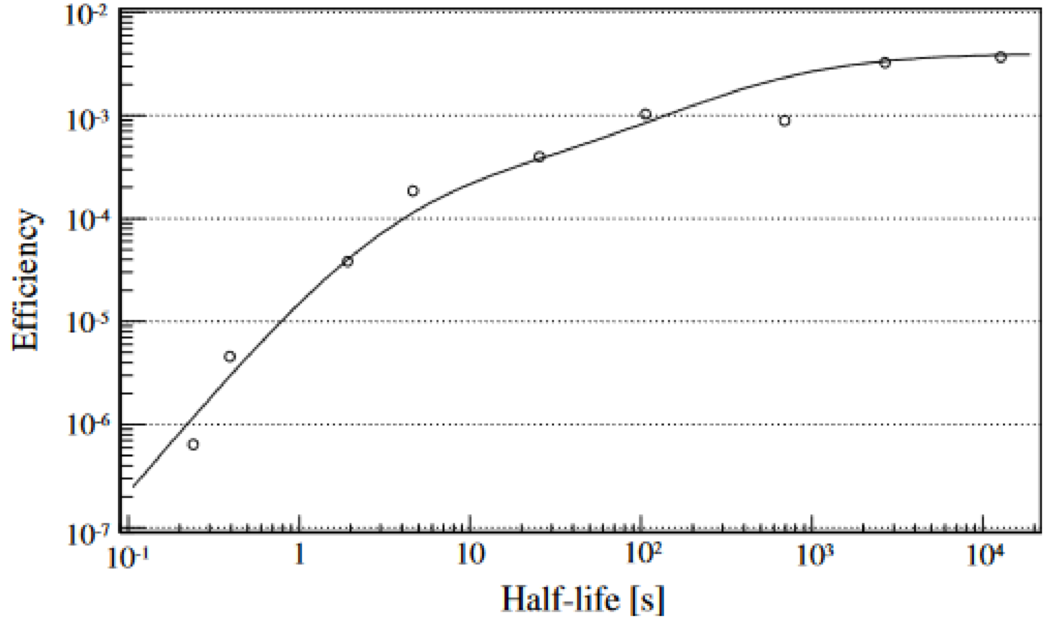
Simulation codes experience at ISOLDE



Code benchmarked in most cases to be less than a factor of 2

M. Felcini, A. Ferrari, CERN-AB-Note-2006-006, 2006

Po isotopes from UCx target



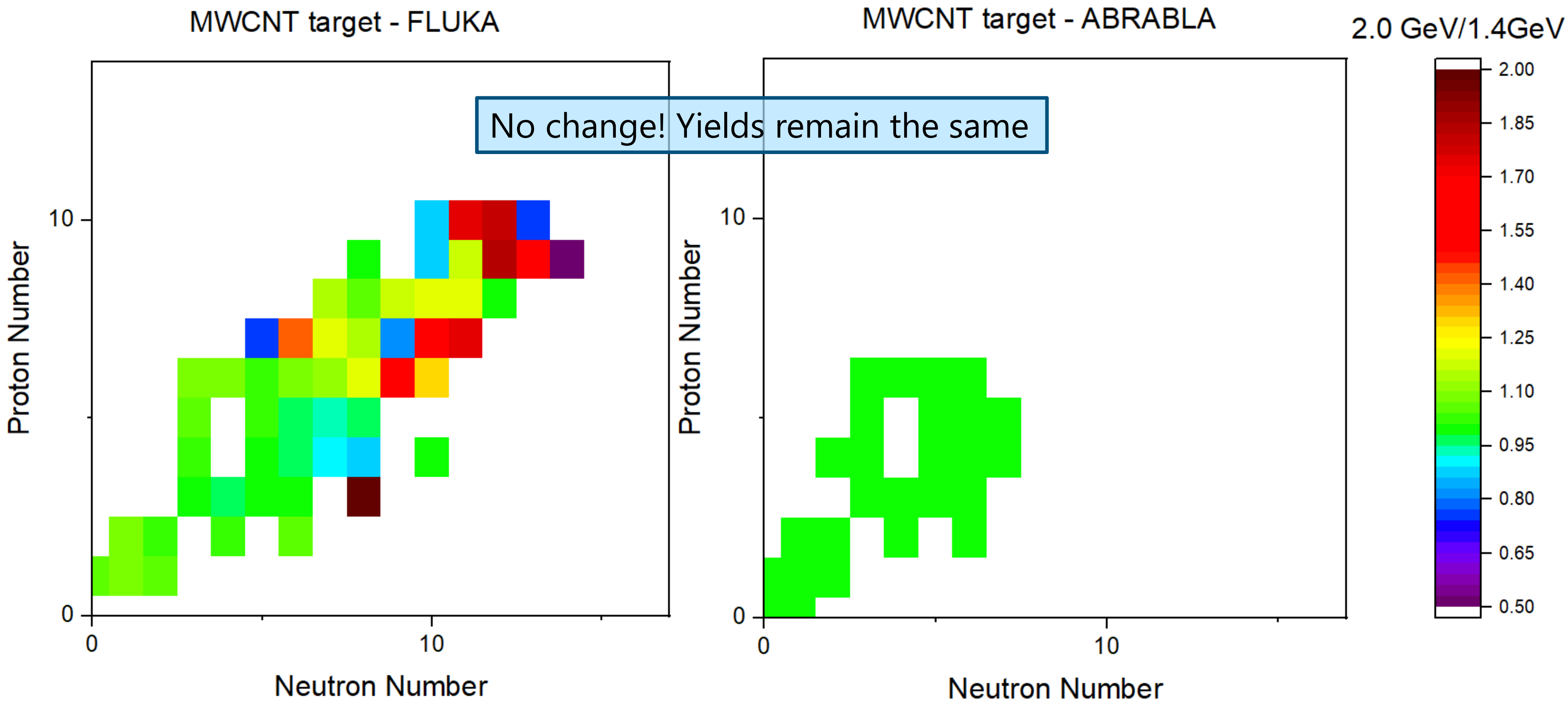
Deconvolution of release from in-target production

From experience ABRABLA is usually strong for spallation in-target production yields.

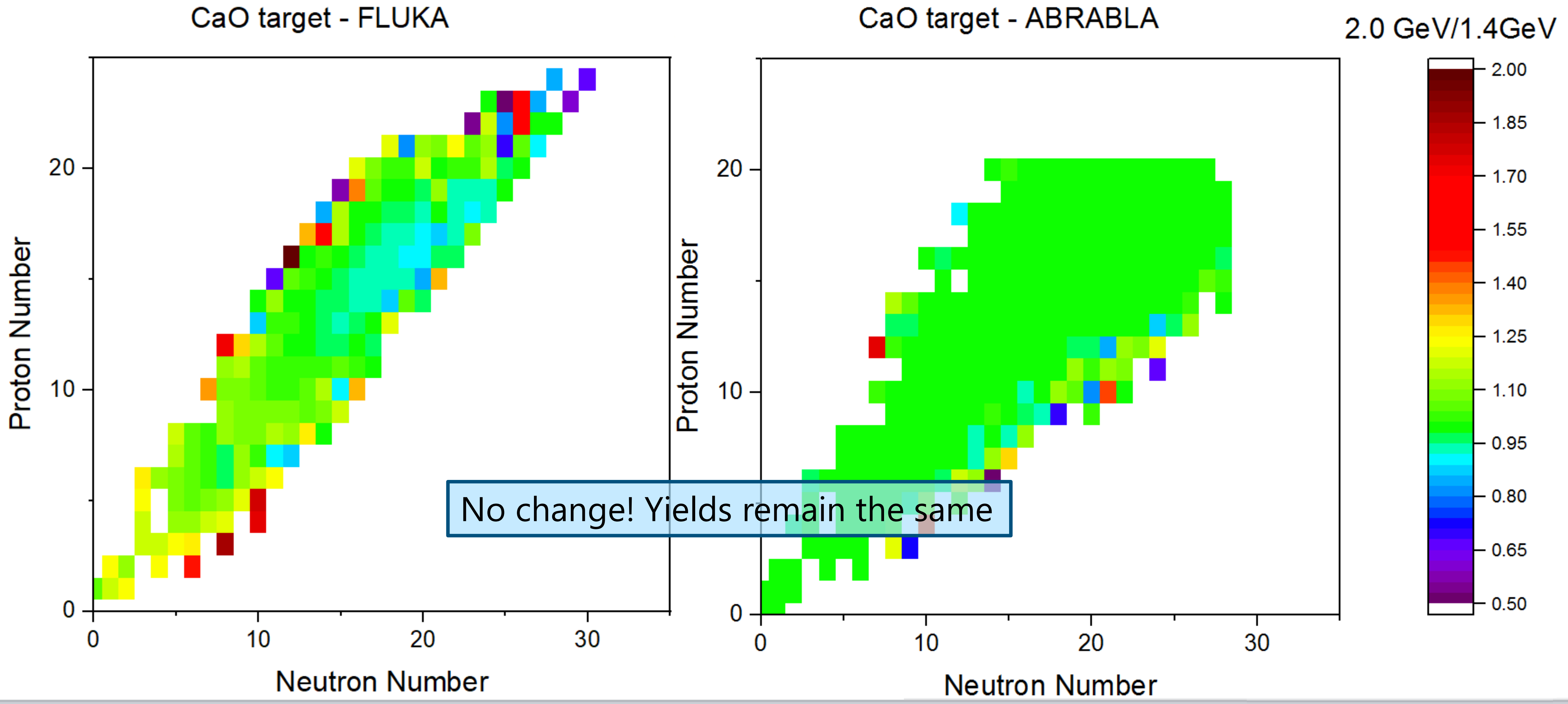
T.E. Cocolios, et al., NIMB 266 (2008), 4403-4406

Multiwall carbon nanotubes targets - **Z=6**

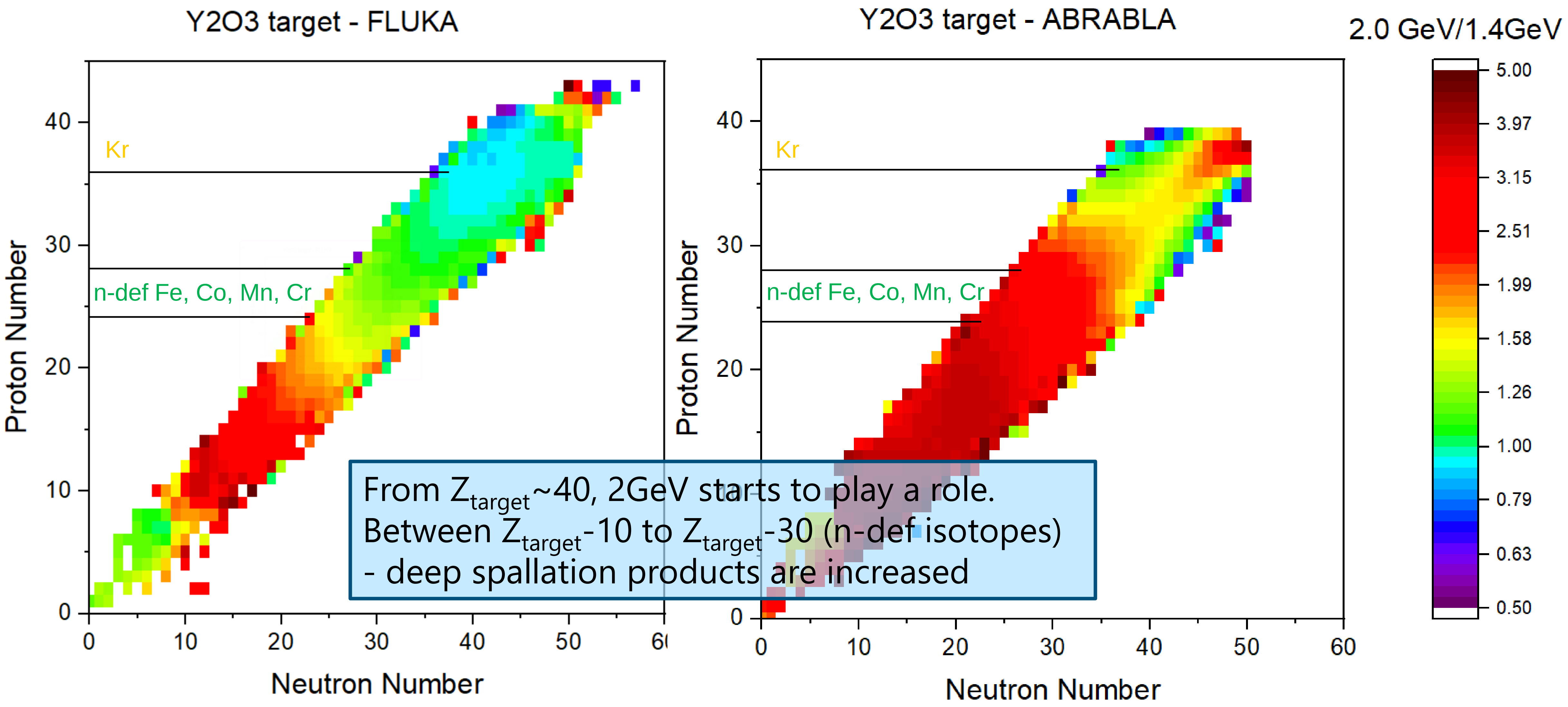
No change! Yields remain the same



Calcium Oxide targets - **Z=20**

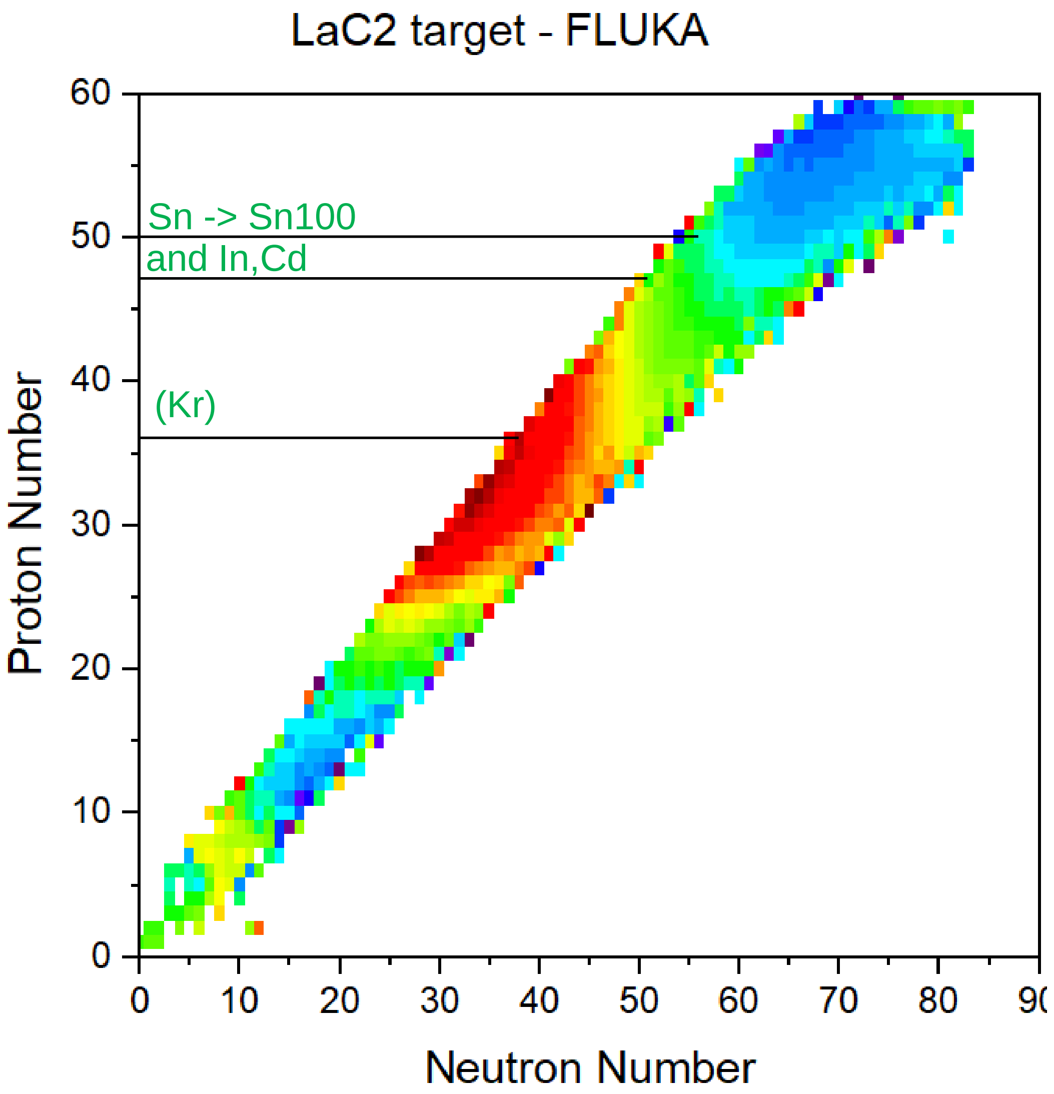


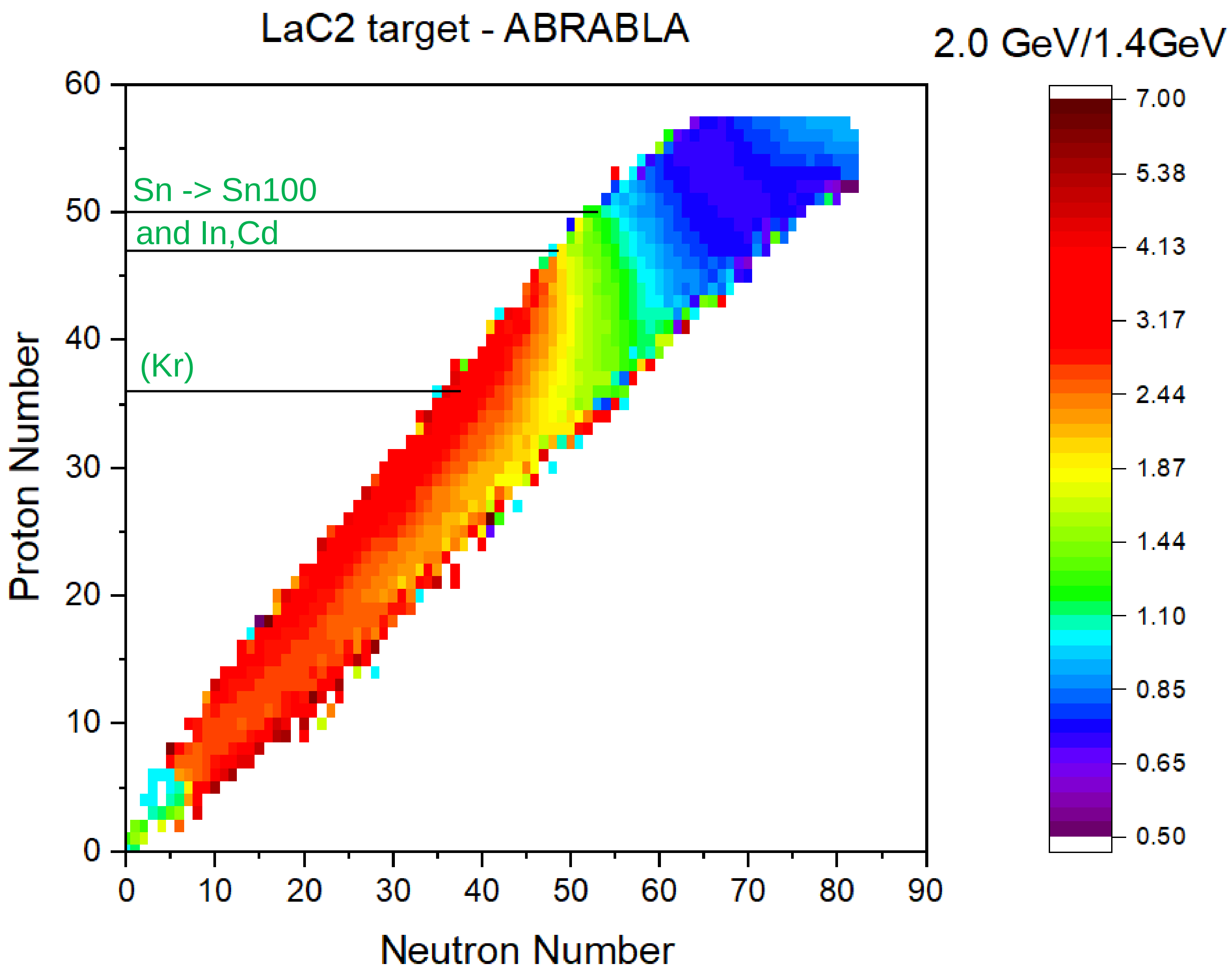
Yttrium Oxide targets - **Z=39**



From Z_{target}~40, 2GeV starts to play a role.
Between Z_{target}-10 to Z_{target}-30 (n-def isotopes)
- deep spallation products are increased

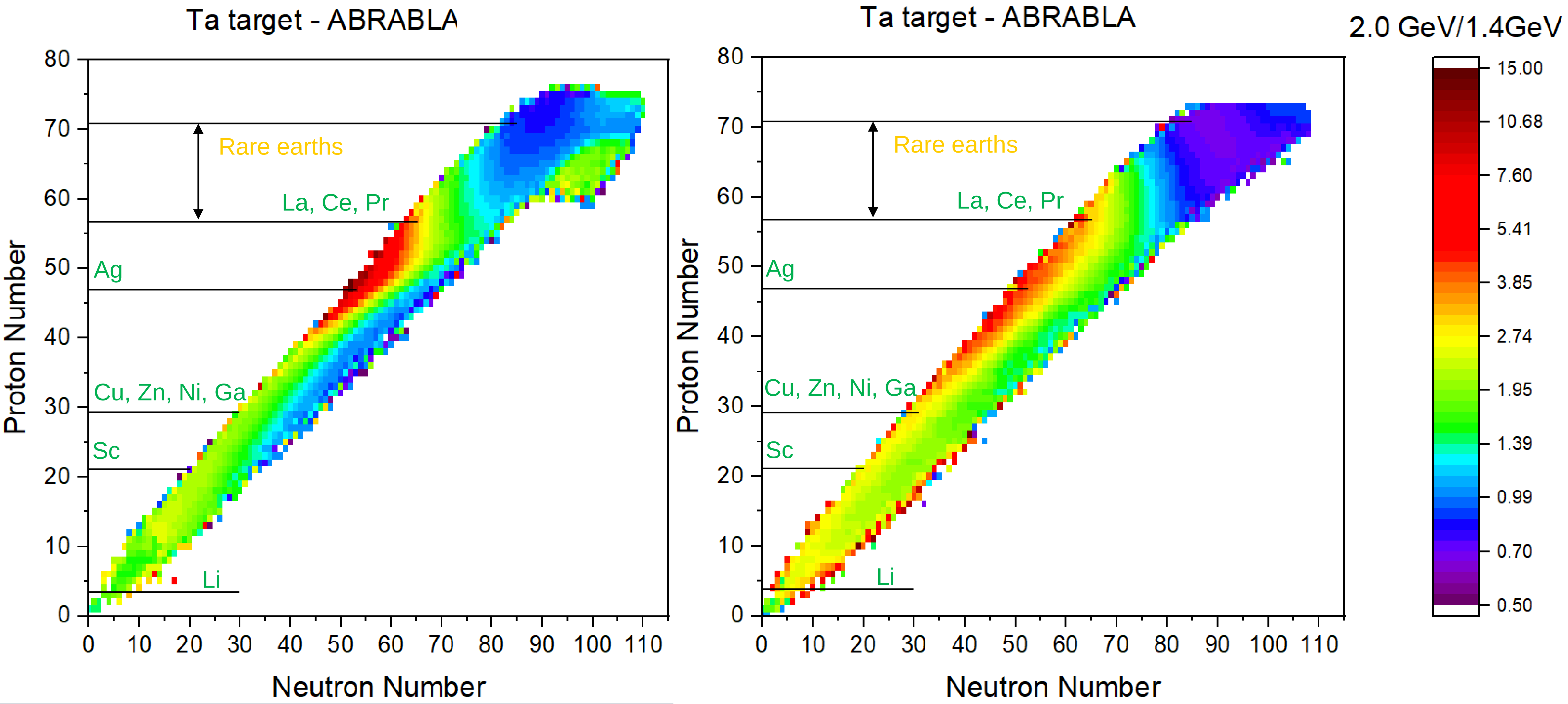
Lanthanum carbide targets - **Z=57**



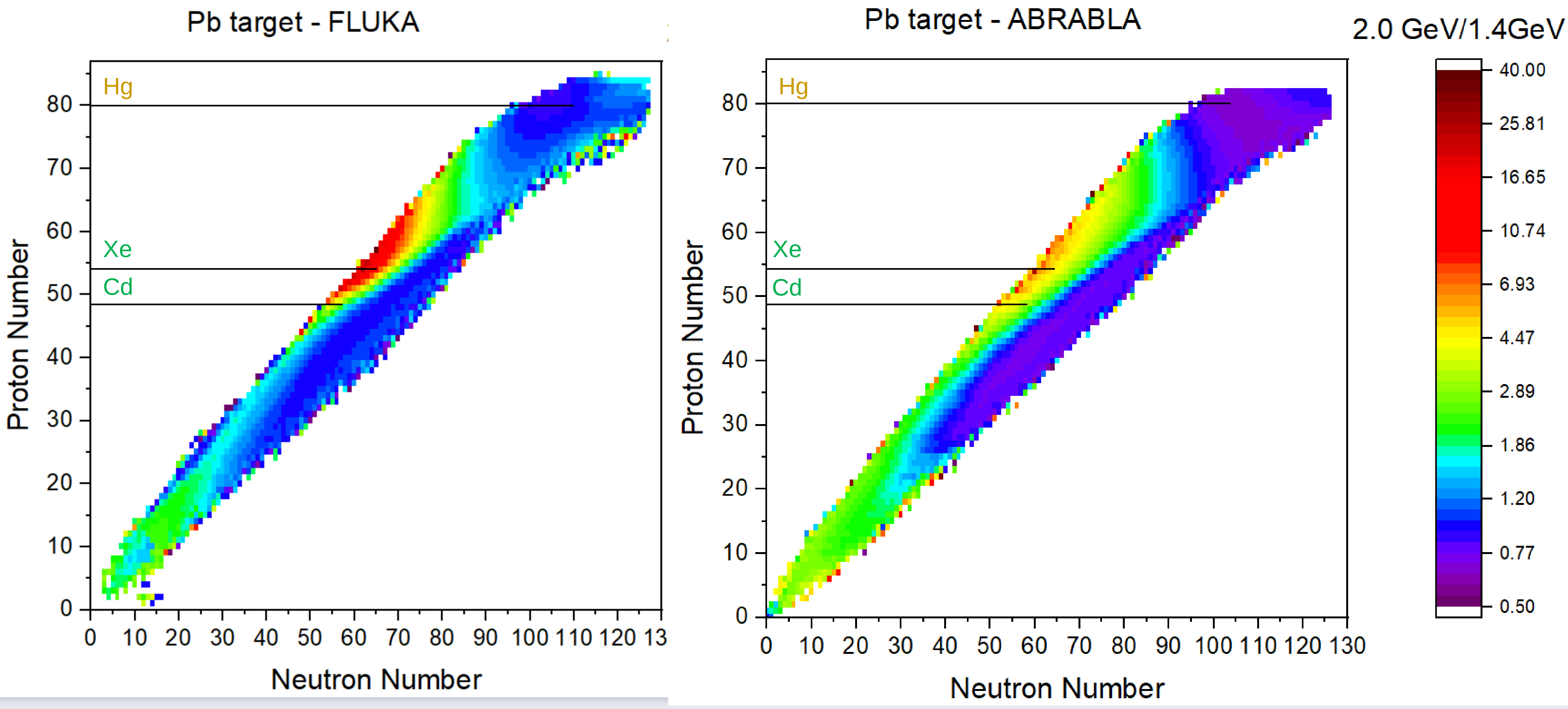


F. Pamies, et al., NIMB, EMIS 2018 Proceedings, in press

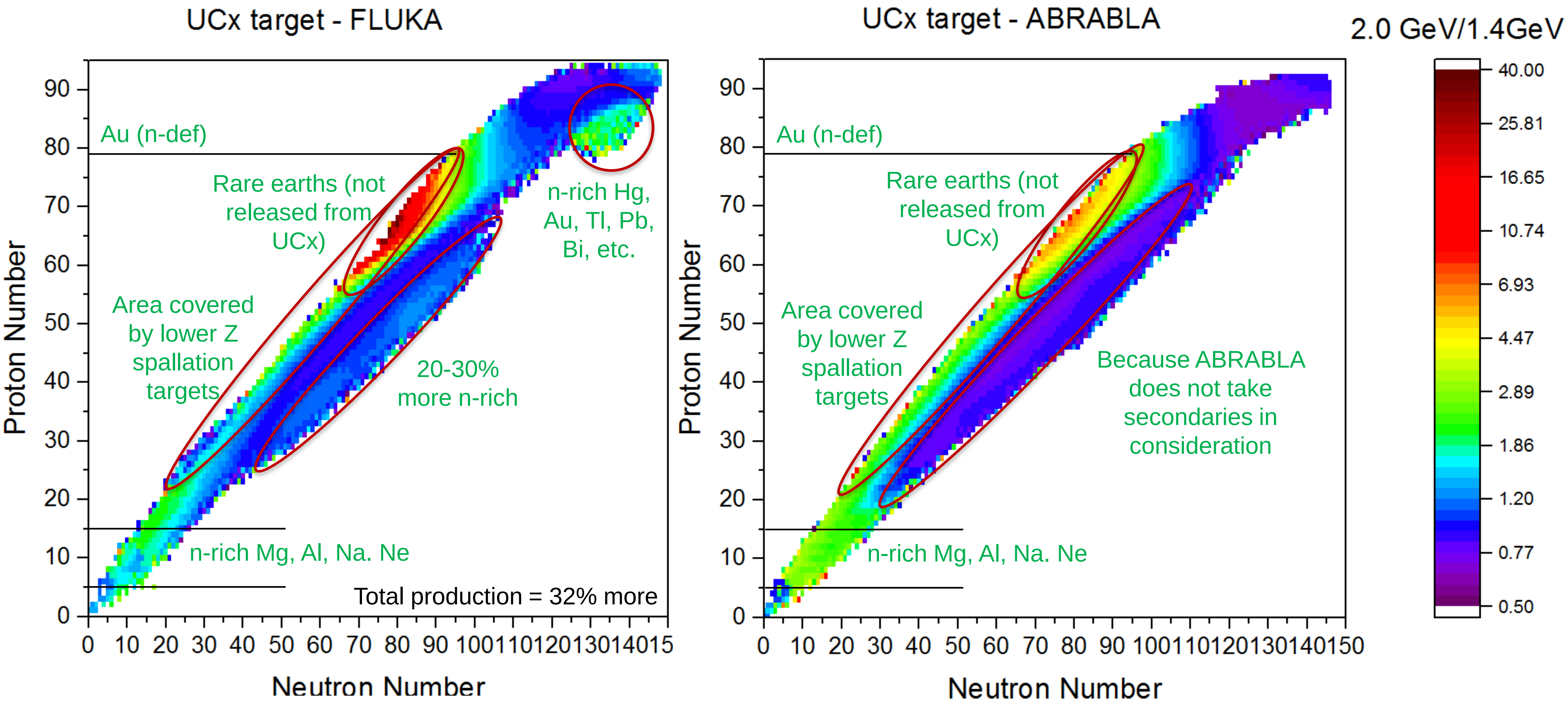
Tantalum targets - **Z=73**



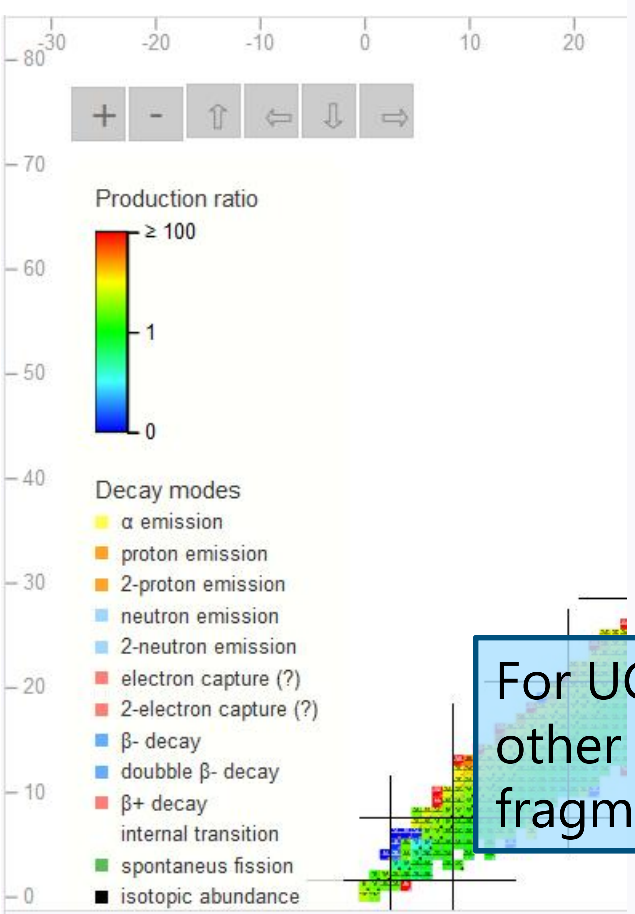
Molten lead targets - **Z=82**



Uranium carbide targets - **Z=92**



UCx at 2.0 GeV vs Ta at 1.4 GeV



For UCx targets gains are limited to Au (and other n-def isotopes) and also to fragmentation products (Mg, Na, etc.)

Using development Yield database: J. Ballof, et al., NIMB, EMIS Proceedings, in press.

What does the data say?

Products close to stability

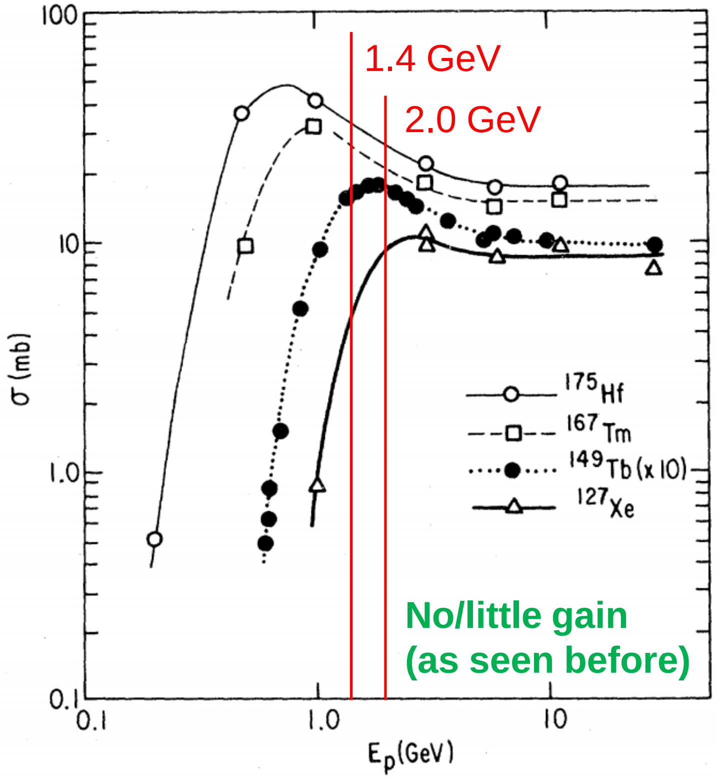


FIG. 2. Excitation functions for representative deep spallation products. The data for ^{149}Tb are from Ref. 9 and are for the α-decay branch; it is scaled up by a factor of 10 for convenience of comparison.

Fragmentation products Uranium

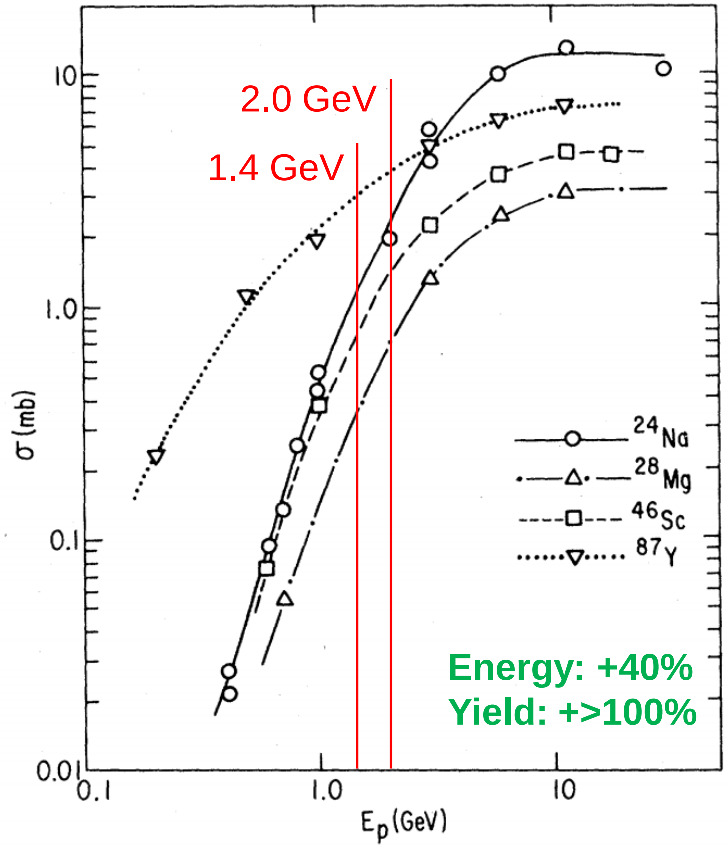
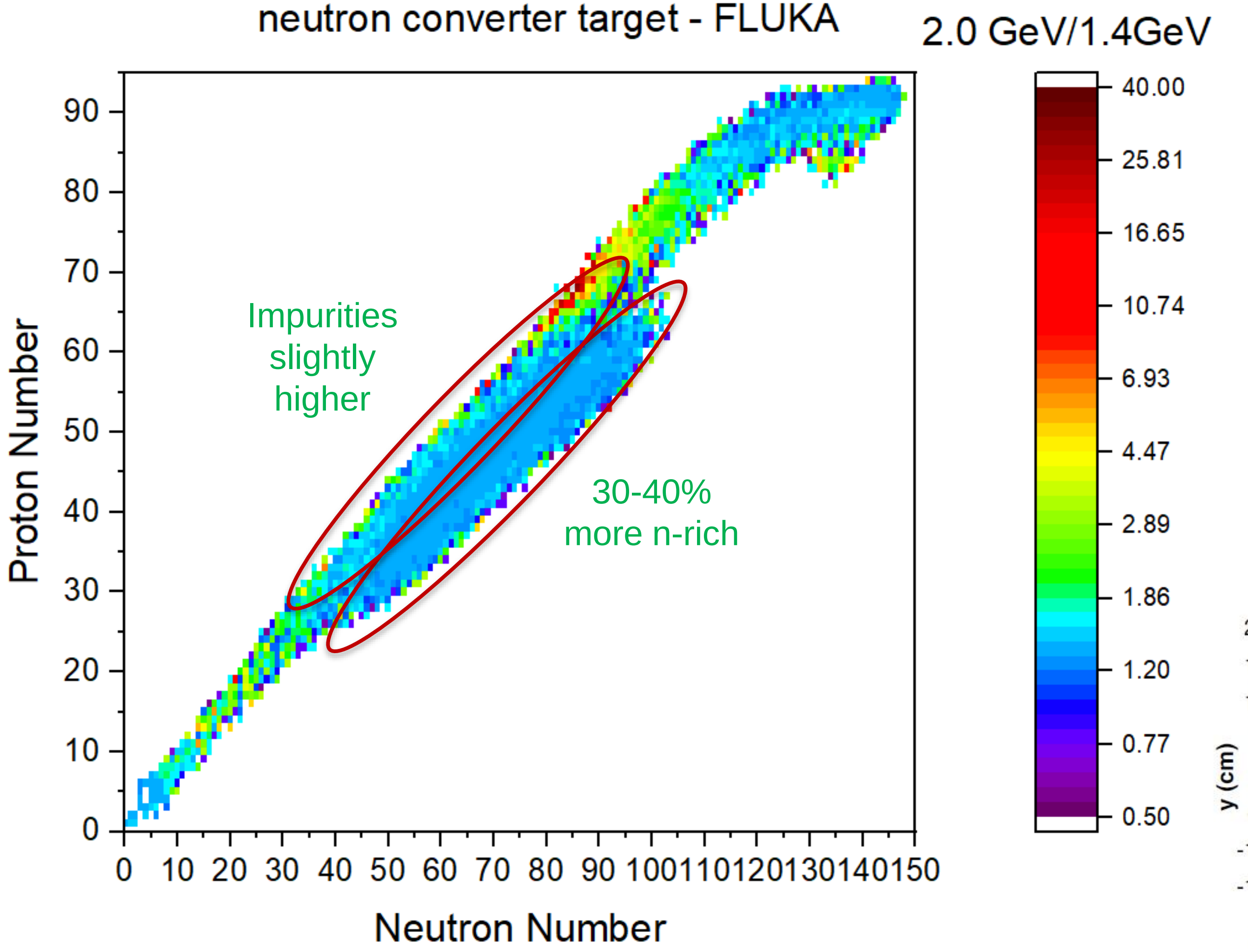


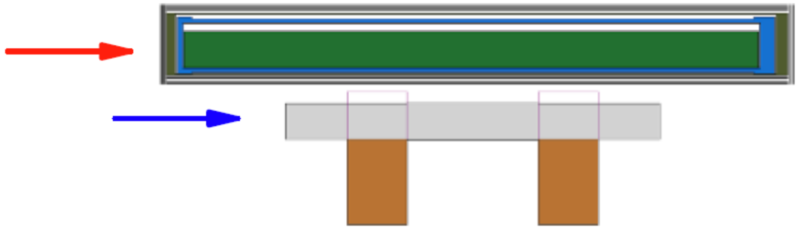
FIG. 3. Excitation functions for typical light fragmentation products.

S. B. Kaufmann and E. P. Steinberg, Phys. Rev. C **22**, 167 (1980)

Neutron converter (p2n) targets

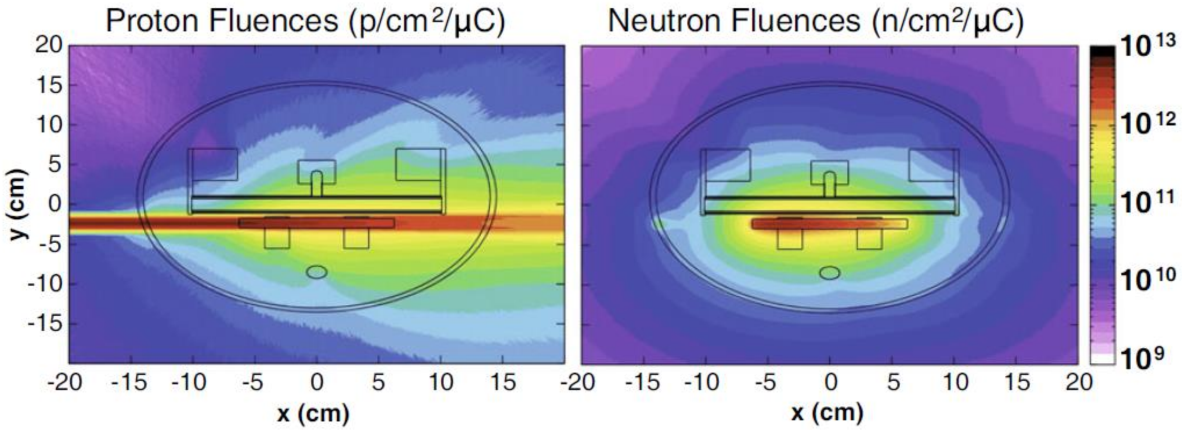


Using the default proton to neutron converter configuration

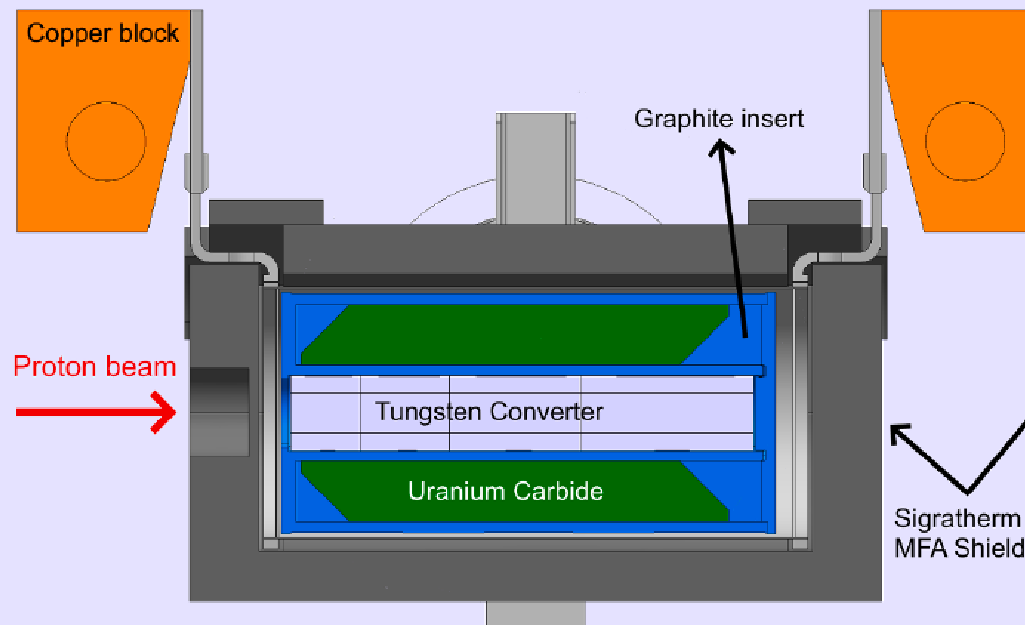


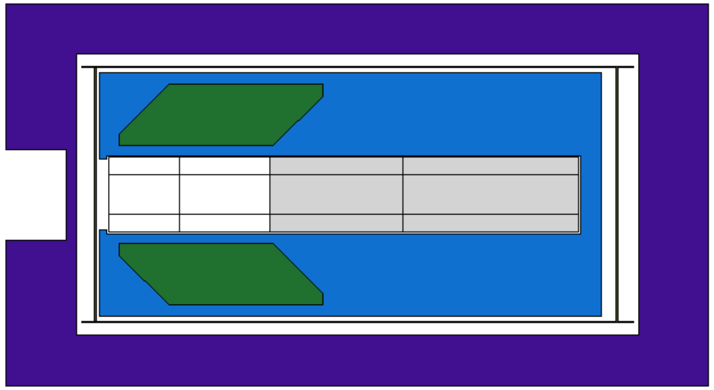
Higher energy brings higher neutron multiplicity:
Translates into yields up to 40% higher

Scattered 2 GeV protons produce more neutron deficient contaminations, **but they scatter less**

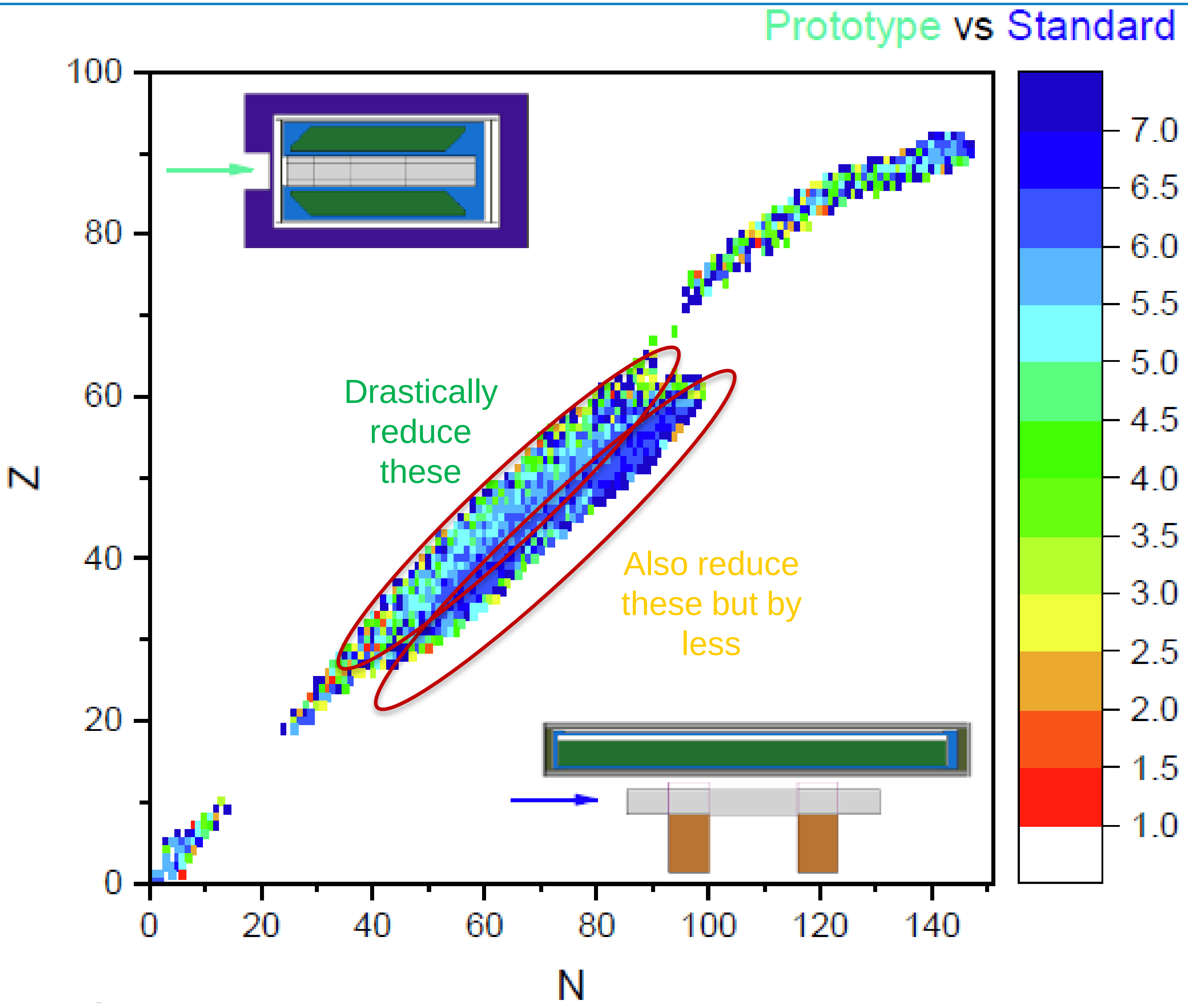


The dream p2n converter?





J.P. Ramos, et al., NIMB, EMIS 2018 Proceedings, In press

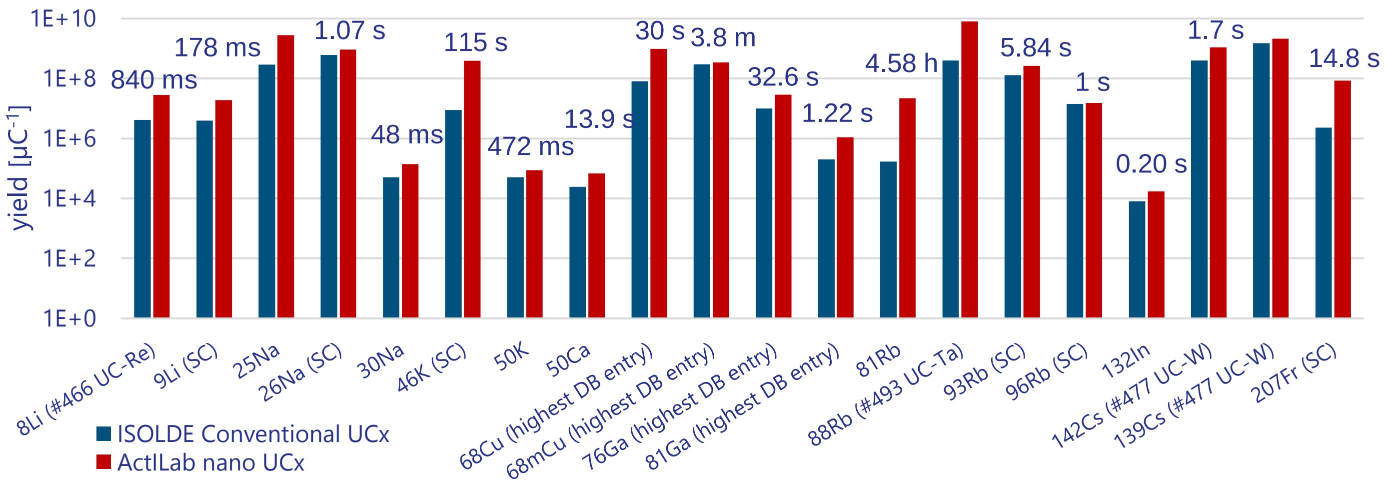


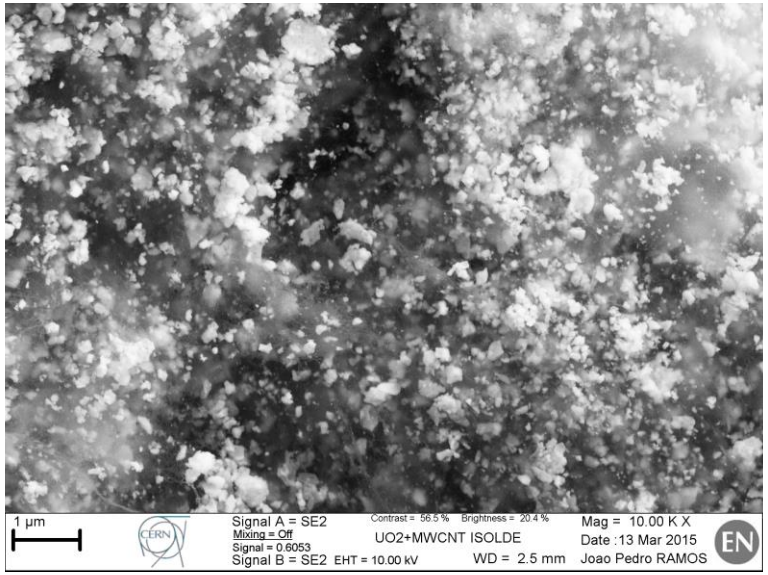
 Eur. Phys. J. A (2012) 48: 90

nanoUCx – answer for intensity upgrade

- nanoUCx has a high release efficiency with lower density (less Uranium)
  - Reduced doses in the target area
  - Reduce high level waste

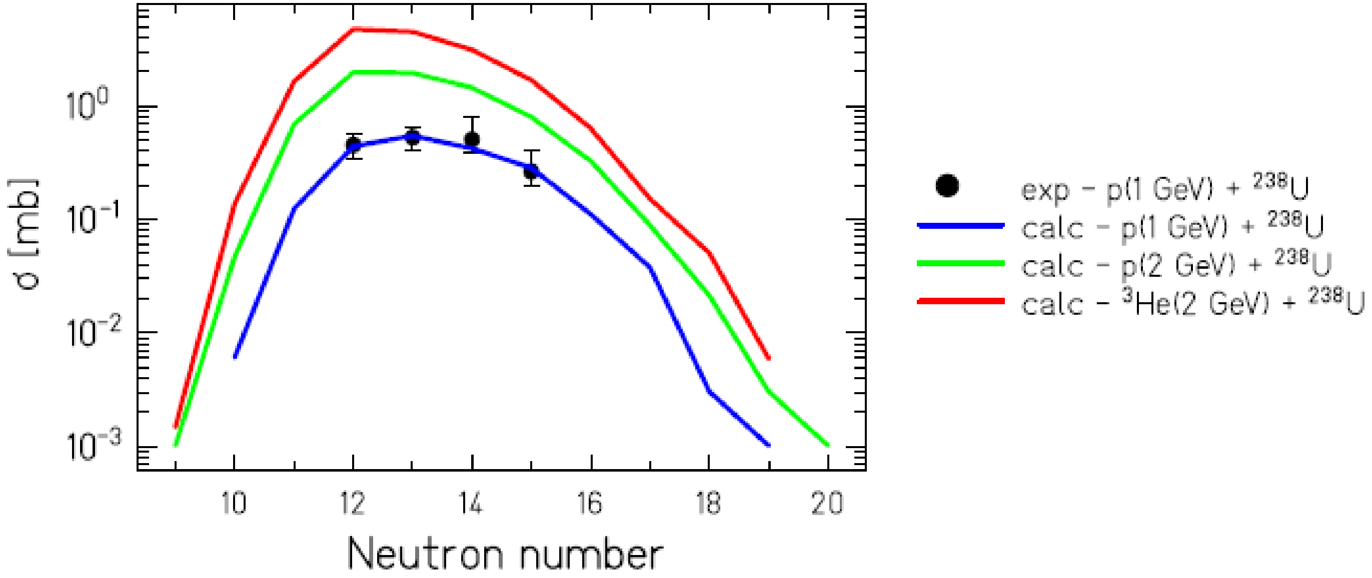
- Reduce target size (as in other facilities – for short lived cases)
  - nanoUCx to standard UCx is a factor of 2.5 – total factor of 5 reduction in waste and dose
  - Can get it very soon (new lab)





A. Gottberg, et al, to be published

EURISOL – The ISOL dream facility



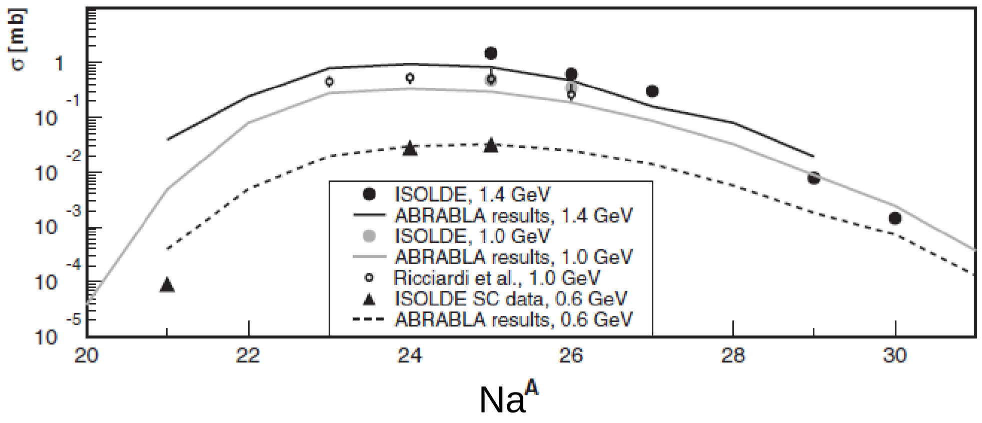


FIG. 29. (Color) Production cross sections of Na in a ^{238}U target interacting with different beams; 1-GeV protons (blue line), 2-GeV protons (green line), and 2-GeV ^{3}He (red line). Calculations were made with INCL4 + ABLA. For comparison, also sodium production cross sections (points) measured at GSI in the reaction ^{1}H(1 GeV) + ^{238}U [23] are shown.

EURISOL primary beam of choice would be 3He at 2 GeV
EURISOL = the dream ISOL facility

Second choice would be protons at 2 GeV!

K.-H. Schmidt, et al. Phys Rev Spec Topics 10 (2007) 014701

Conclusions

- Light targets do not benefit from upgrade (but also no drawbacks)
  - Only for targets with Z>40
- Regions of increase, as general rule:
  - Exotic n-deficient isotopes (largest increase):
    - **$Z_{isotope} = Z_{target} – (10 \text{ to } 30)$**
    - Factors of 2 to 40 have been seen
  - Low Z isotopes (fragmentation):
    - Increase in factors of 2 to 4
- Factor from 1.4 to 2 GeV represent a safe increase
  - Unlike target to target variations at ISOLDE
  - For e.g. factor 2 in yield – represents 2x less shifts for an experiment at ISOLDE
- No downside of increasing the beam to 2 GeV – only yield increases are achieved
- All results are only energy upgrade – if intensity is upgraded more can be gained!

Thank you!