Transmutation Products in Steel and Tungsten Samples at FMITS

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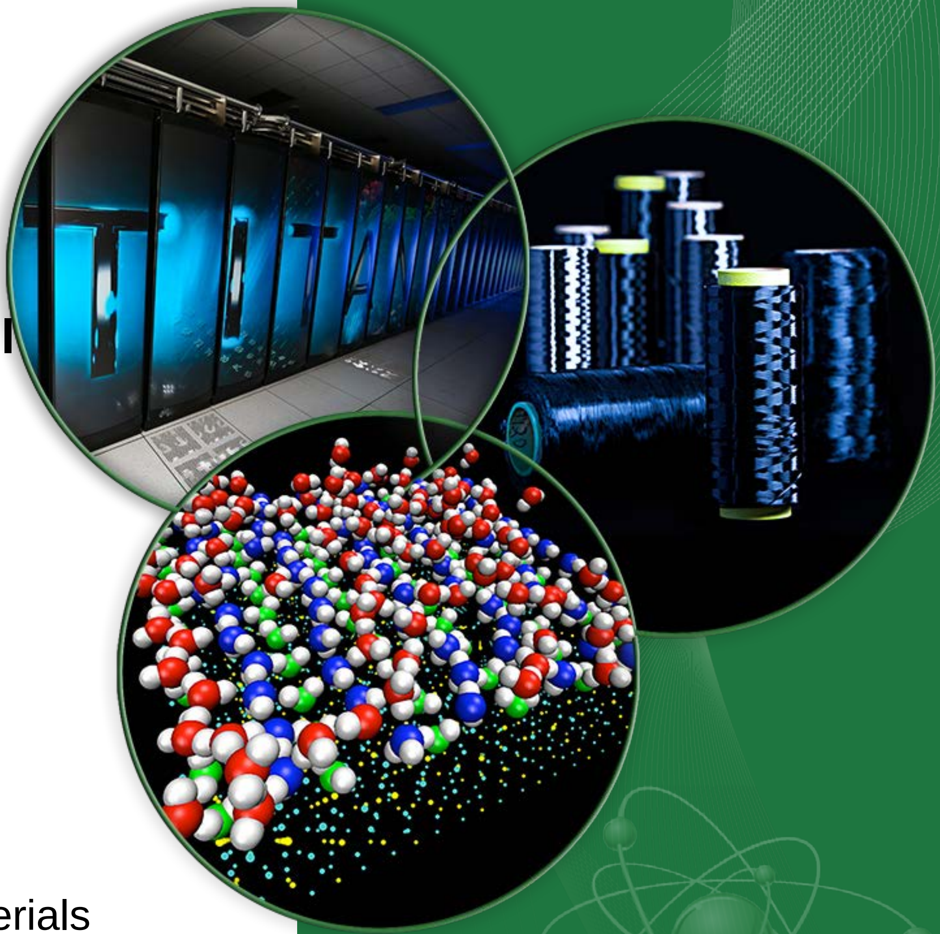
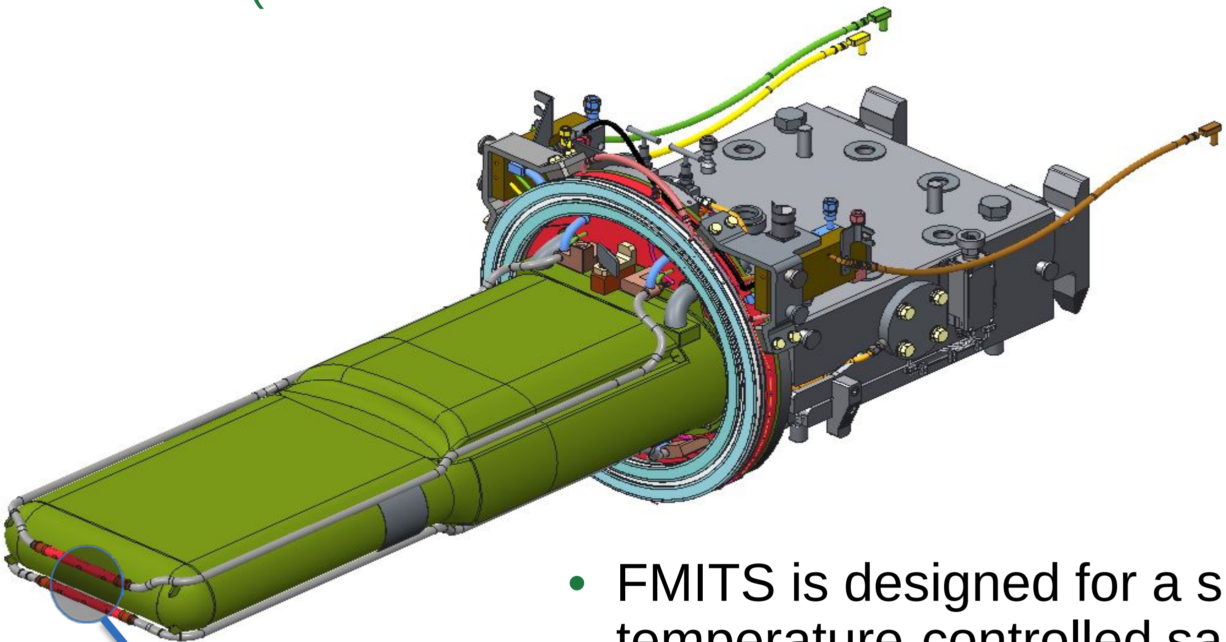
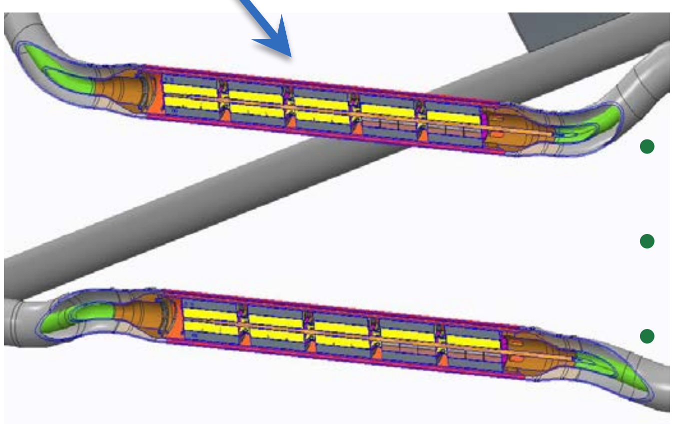


12th International Workshop on Spallation Materials Technology (IWSMT-12)

Bregenz, Austria Oct. 19-23, 2014

FMITS (Fusion Materials Irradiation Test Station) at SNS



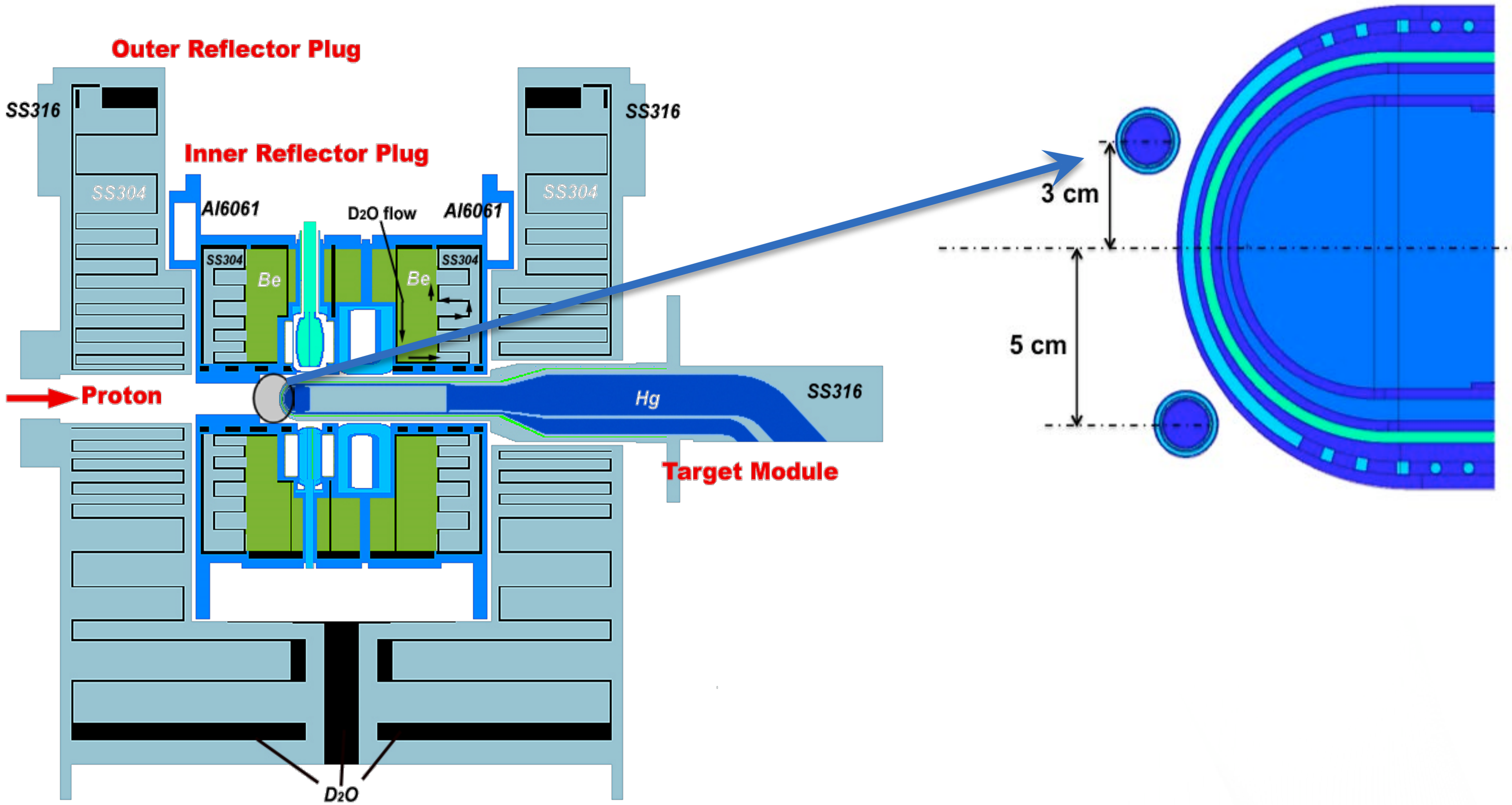


- FMITS is designed for a small-scaled and temperature-controlled sample irradiation environment with appmHe/dpa prototypic of a fusion reactor
- Preliminary study in Dec, 2011
- Feasibility study (30% design report) in Jun. 2014
- $13.4 M in 4 years
- $20 K from OFES in addressing problems identified in the feasibility review

FMITS (Fusion Materials Irradiation Test Station) at SNS

- Feasibility study
  - To advance technical design of FMITS
    - FMITS experiment harness
    - SNS target module
    - SNS vent line shield block (VLSB)
  - To analyze the risk to the SNS operation
    - No impact on the neutron operation and performance
    - Off-normal conditions:
      - 2-4 days more in case of the target failure
      - worst case : replace the target module to the the vintage one in case of FMITS experiment harness failure
  - Neutronics problems addressed
    - Instant displacement production rate effects on materials
    - Transmutation products in samples deviated from a fusion environment

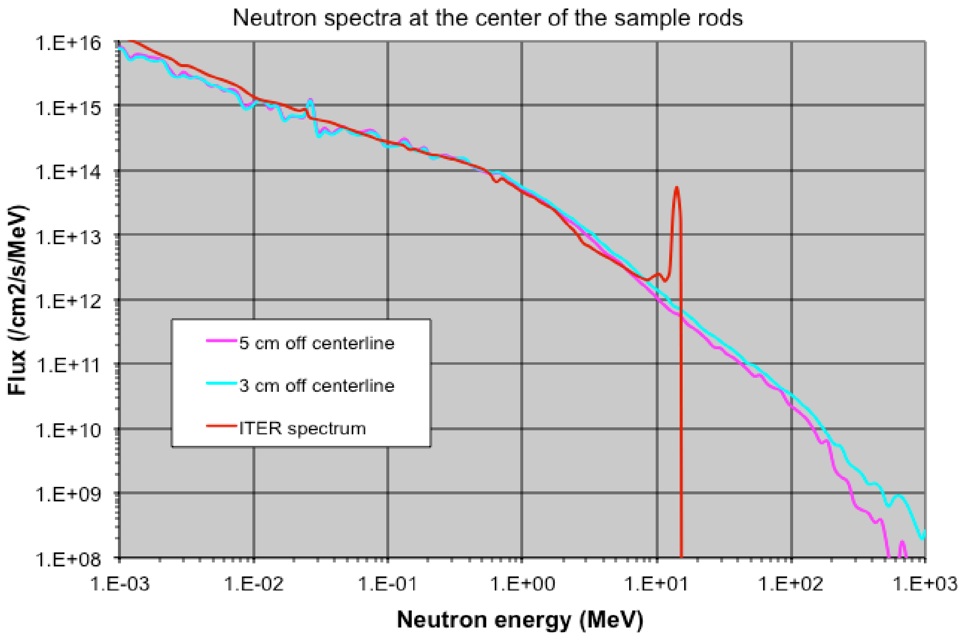
Calculation method



- An as-built SNS target system model with FMITS sample rods
- Neutron fluxes at sample position and spallation-induced production and destruction rates simulated by a revised MCNPX version
- The transmutation products calculated by CINDER by processing MCNPX output files

Calculation method

- The neutron flux at the first shielding wall of ITER is used for comparison



- One year of irradiation time (5000 hr), 1.4 MW for SNS
- The sample at the center position of the rod 3 cm off the target centerline
  - Stainless steel (%wt)

C	Si	P	S	Cr	Mn	Fe	Co	Ni	Mo
0.08	1.0	0.045	0.03	17.0	2.0	65.245	0.1	12.0	2.5

  - Pure tungsten (plasma facing material due to its high erosion resistance, high neutron irradiation resistance and high heat conductivity under intense neutron irradiation)

CINDER

- To calculate inventory of nuclide in irradiated materials, originated at BAPL in 1960
- Significant improvement was made in 1990 at LANL by W. B. Wilson for accelerator application (CINDER'90)
- The development continued at LANL by S. T. Holloway et al to produce CINDER'08
- Compared to CINDER'90, CINDER'08
  - modern programming language and methods
  - new algorithms to more accurately solve the underlying differential equations
  - new extended data libraries developed using fission, fusion and constant weighting functions
    - ENDF-VII.0, JEF-3.1.1, JENDL-4.0 and EAF-2010
  - Comes with new data library development tool
  - Post processing capability and etc
- An ORNL lead collaboration (F. X. Gallmeier et al) in validating CINDER'08 and simplifying its input is undergoing.
- CINDER'08 to be released to RSICC in near future

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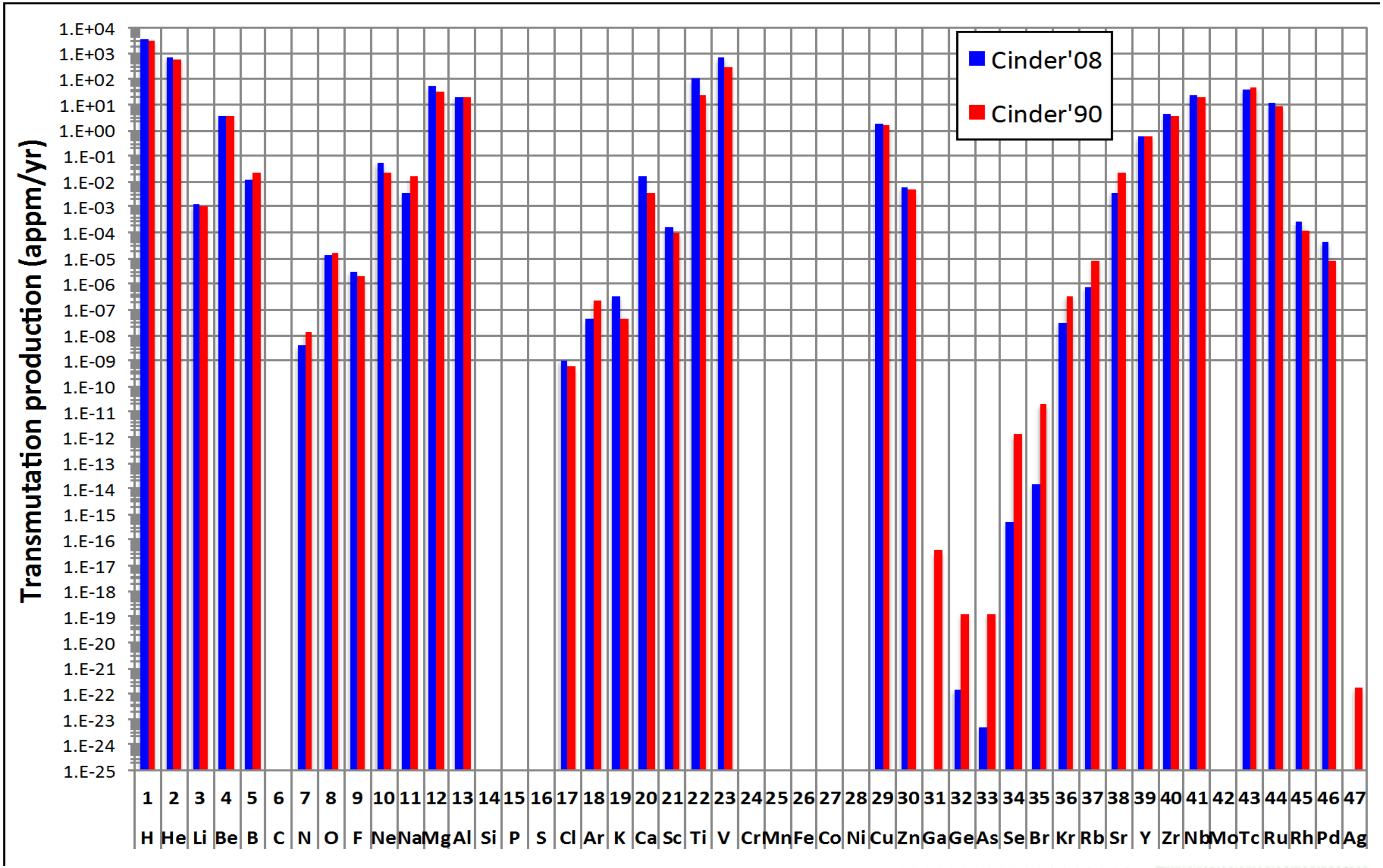
Transmutation products at ITER
- stainless steel



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Transmutation products at ITER
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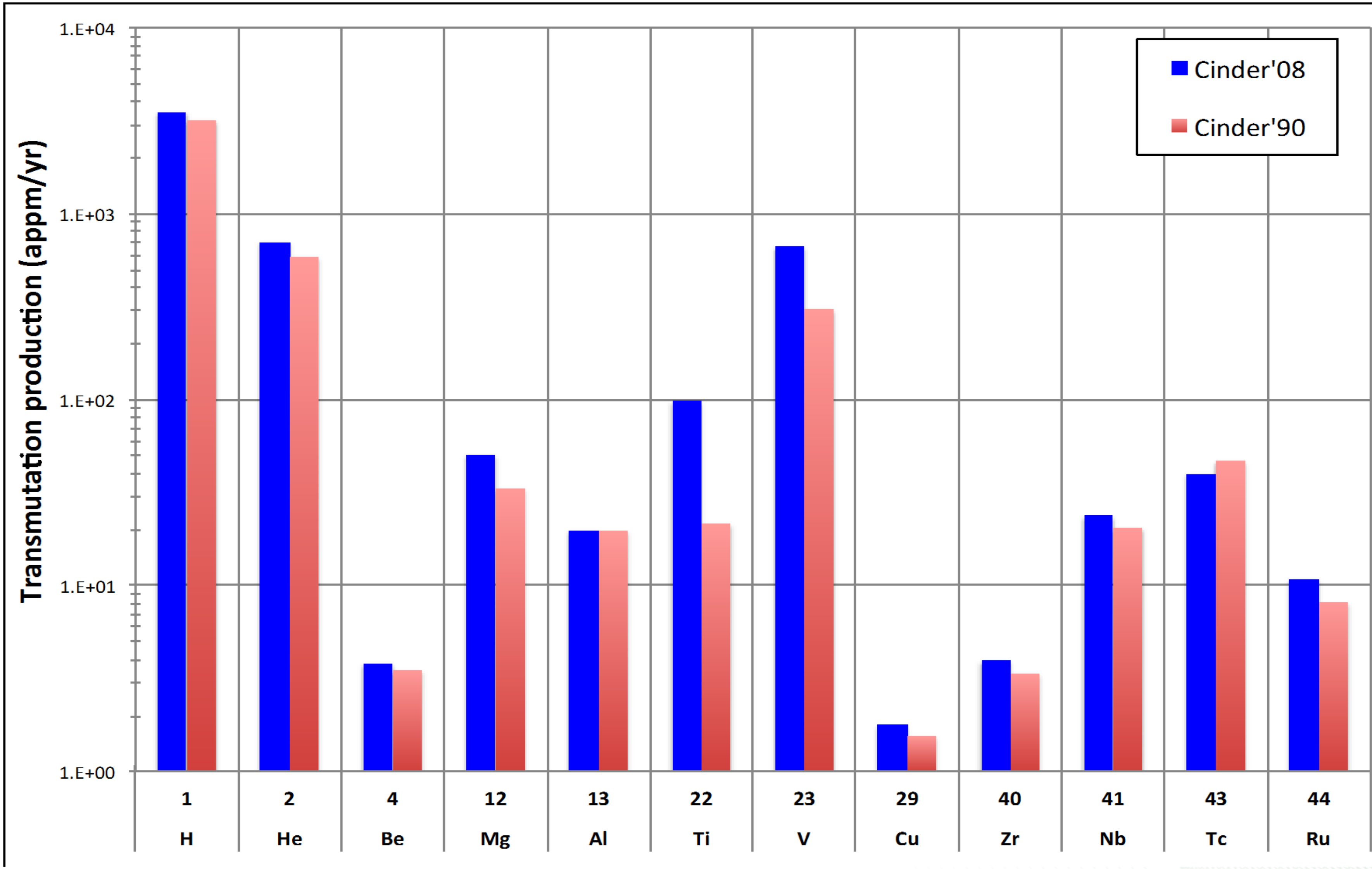

Transmutation products at ITER
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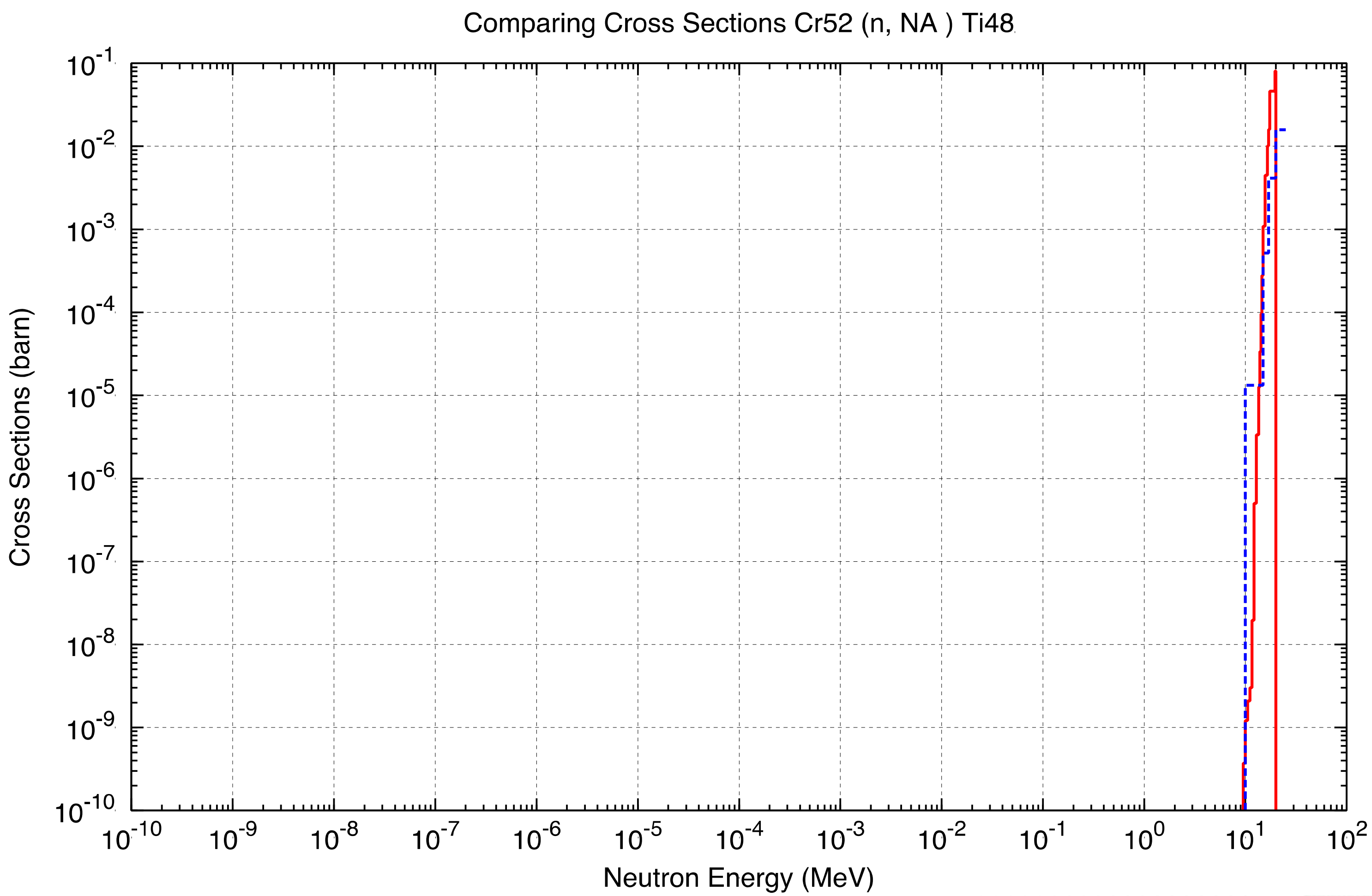
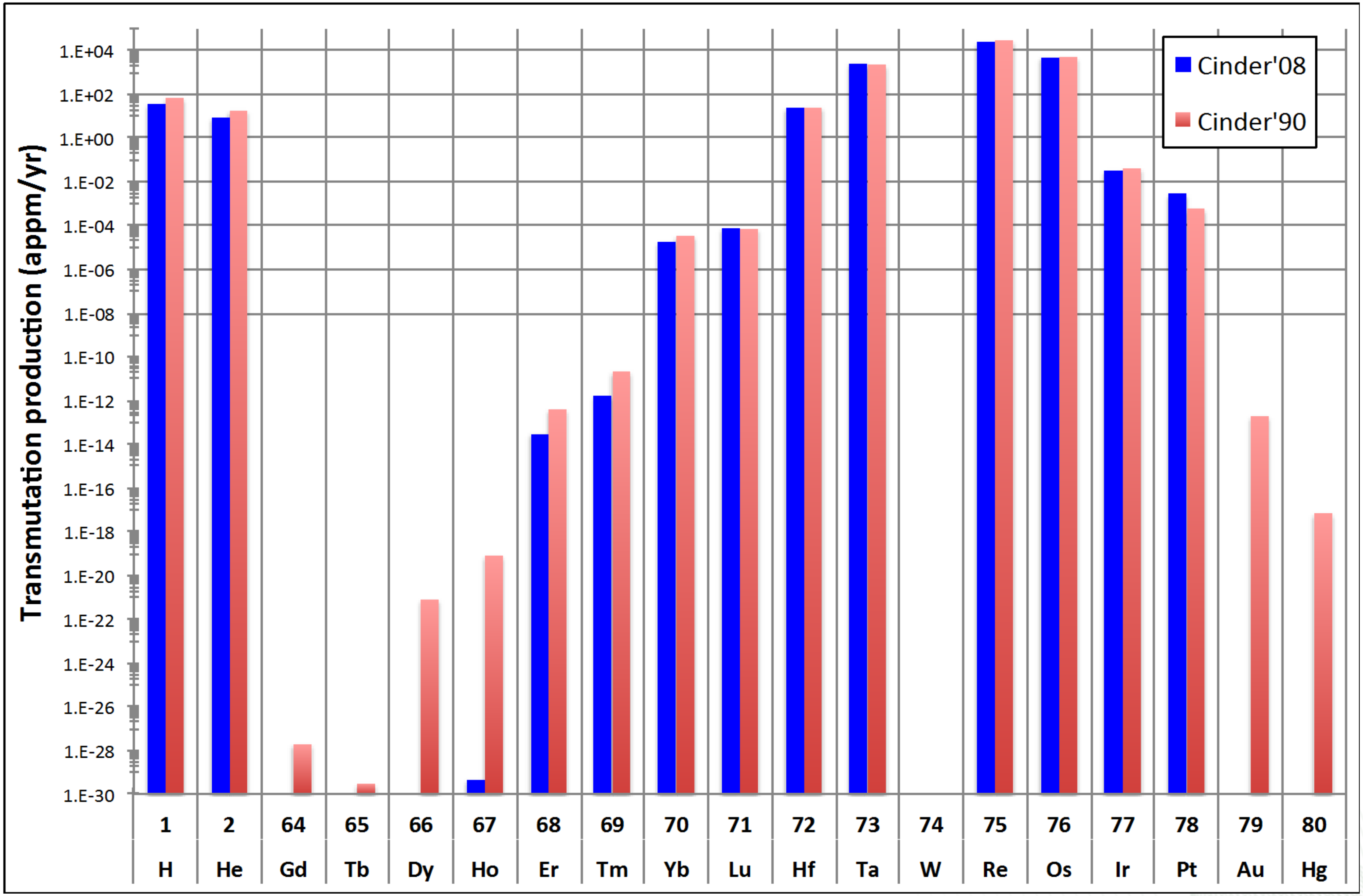


Transmutation products at ITER
- tungsten



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Transmutation products at ITER
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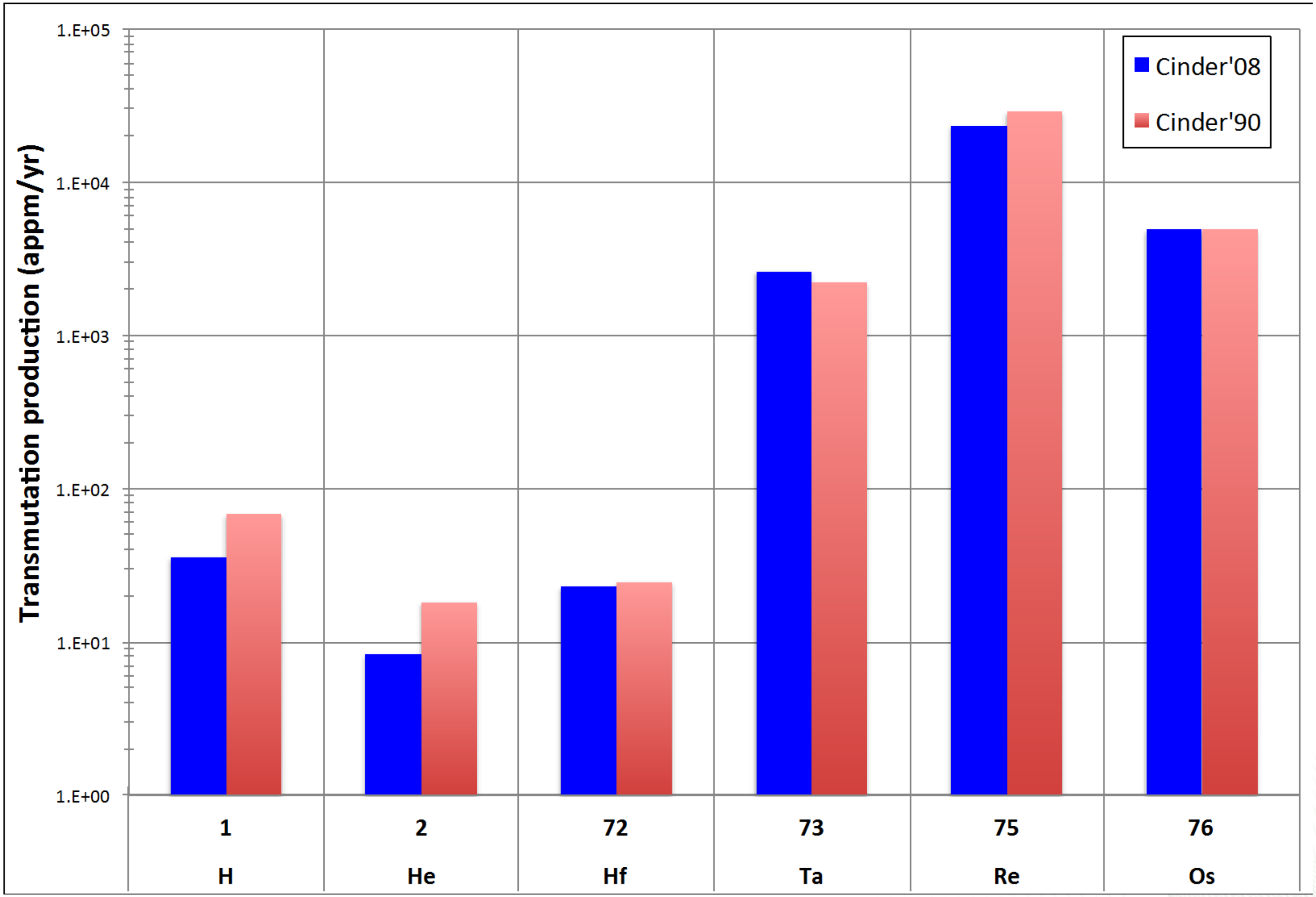
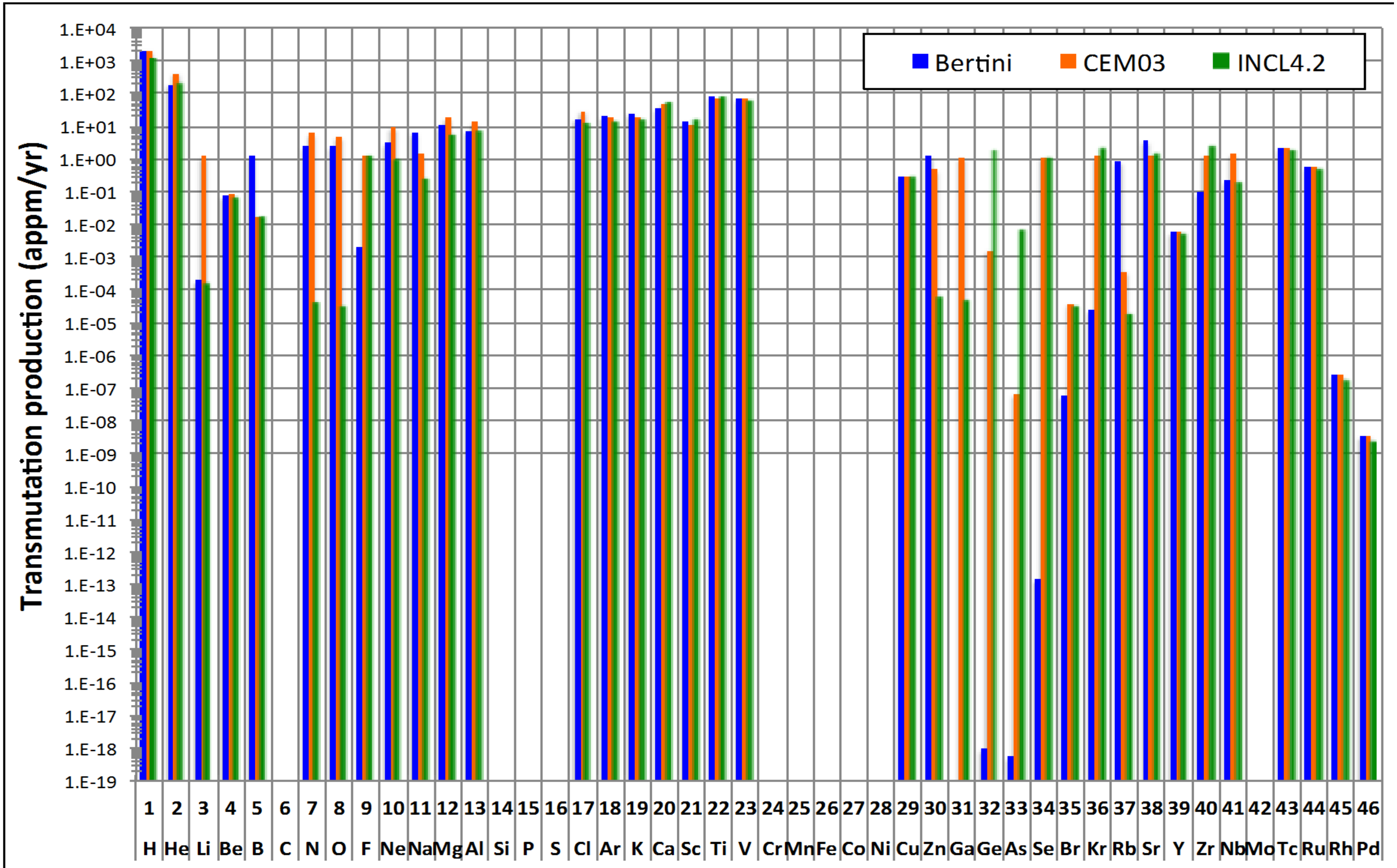


CINDER'08 vs CINDER'90

- CINDER'08 shows consistent results compared to CINDER'90
- The difference in the comparison is mainly due to:
  - CINDER'08 uses more recent and accurate cross section data
  - CINDER'08 uses new algorithm in cutting off partial productions
- CINDER'08 results are used for this work

Transmutation products at FMITS
- stainless steel



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Transmutation products at FMITS
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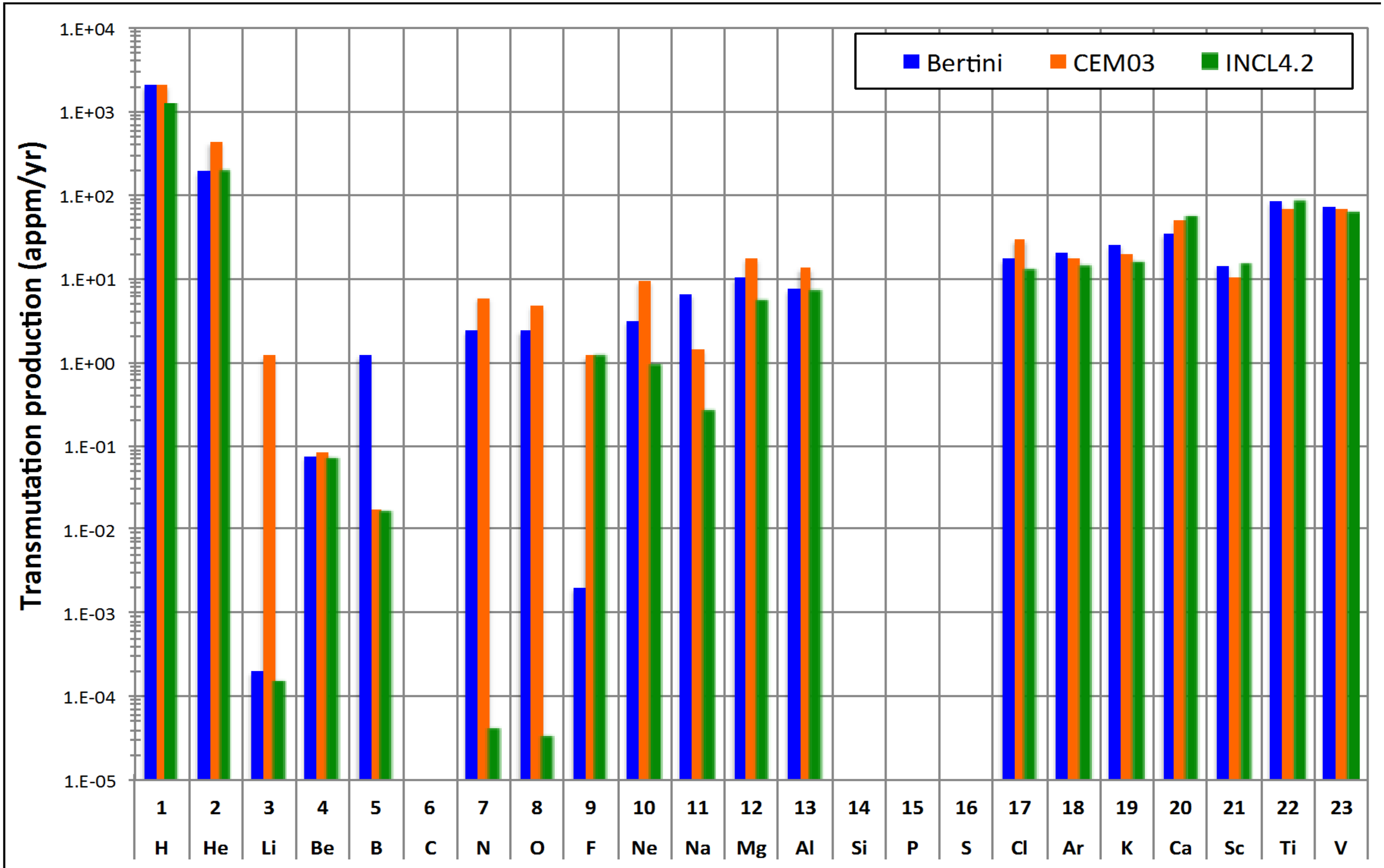

Transmutation products at FMITS
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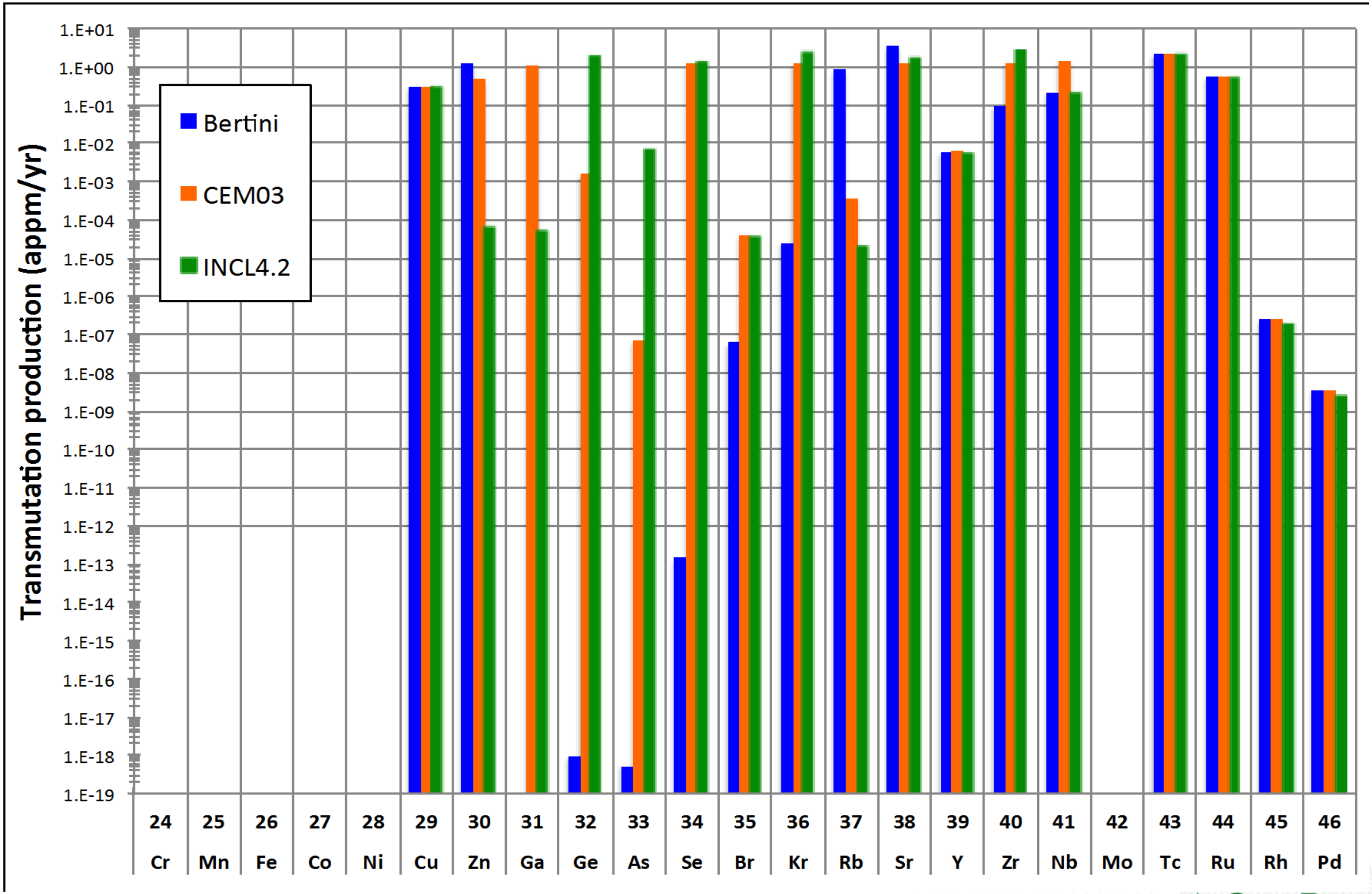

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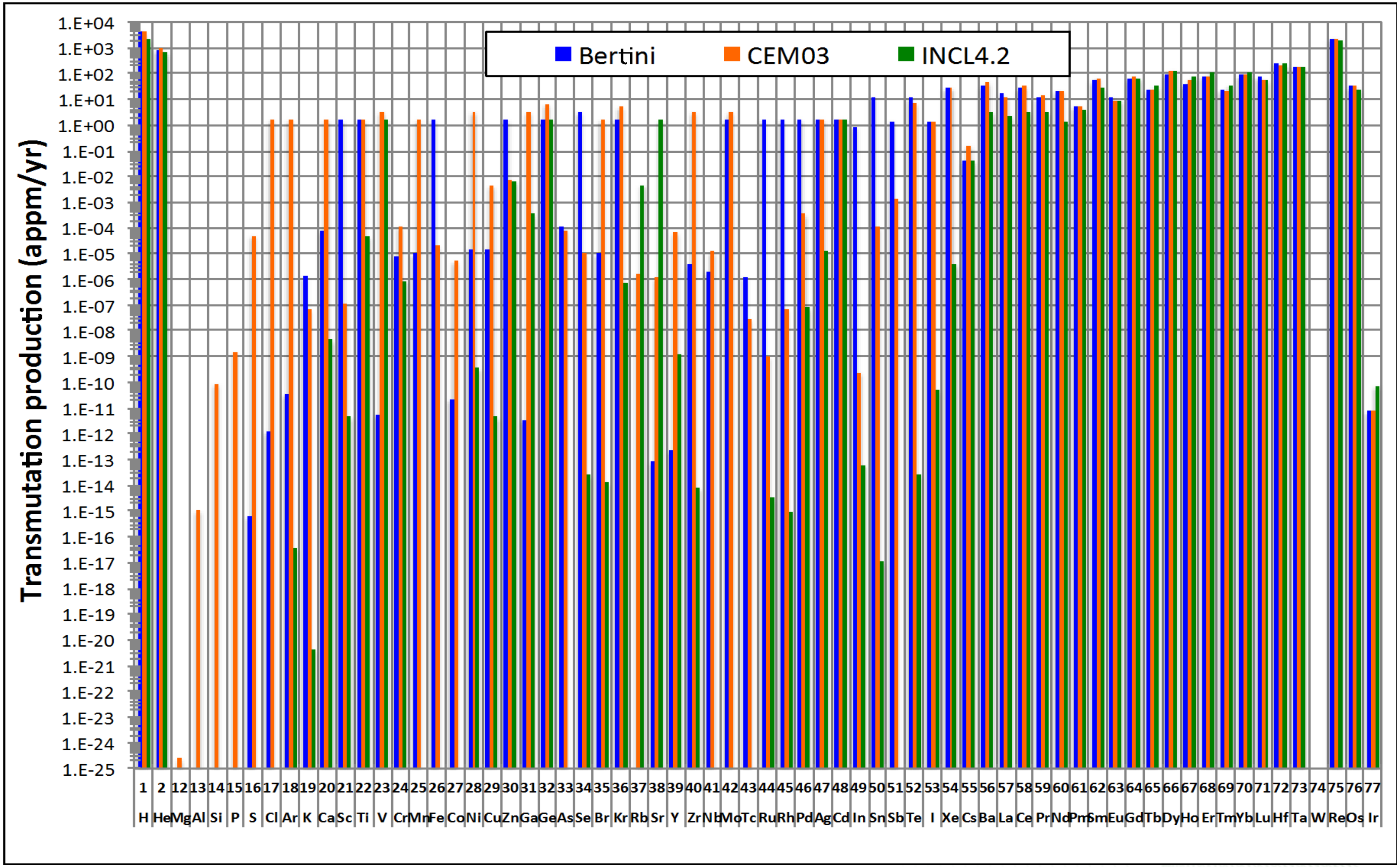
Transmutation products at FMITS - tungsten



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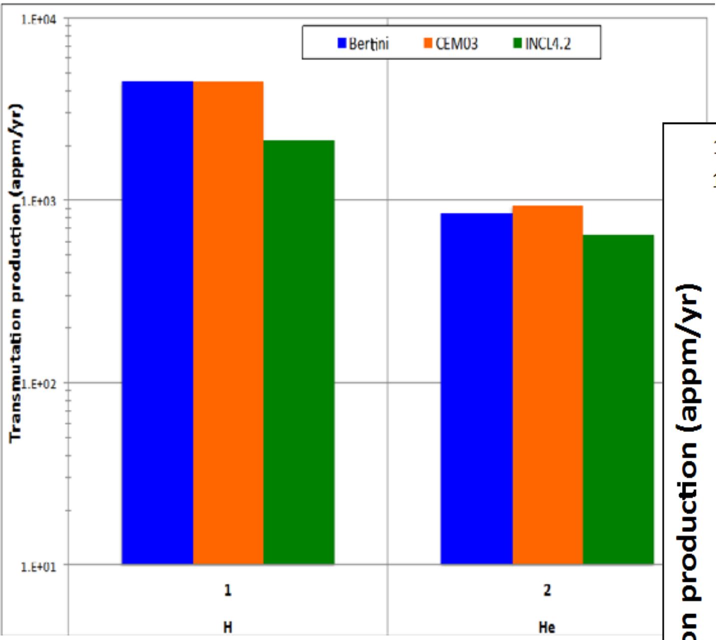
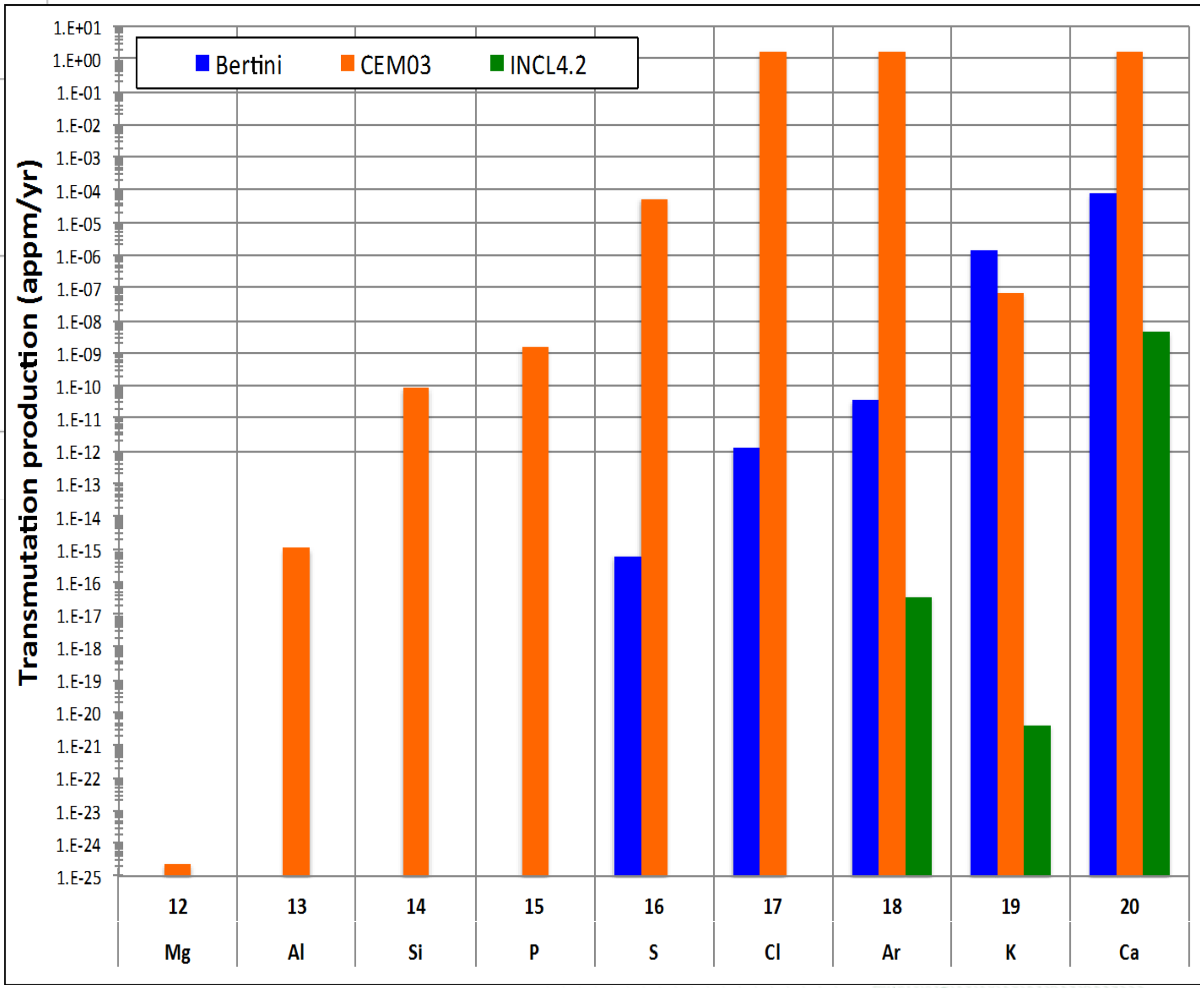
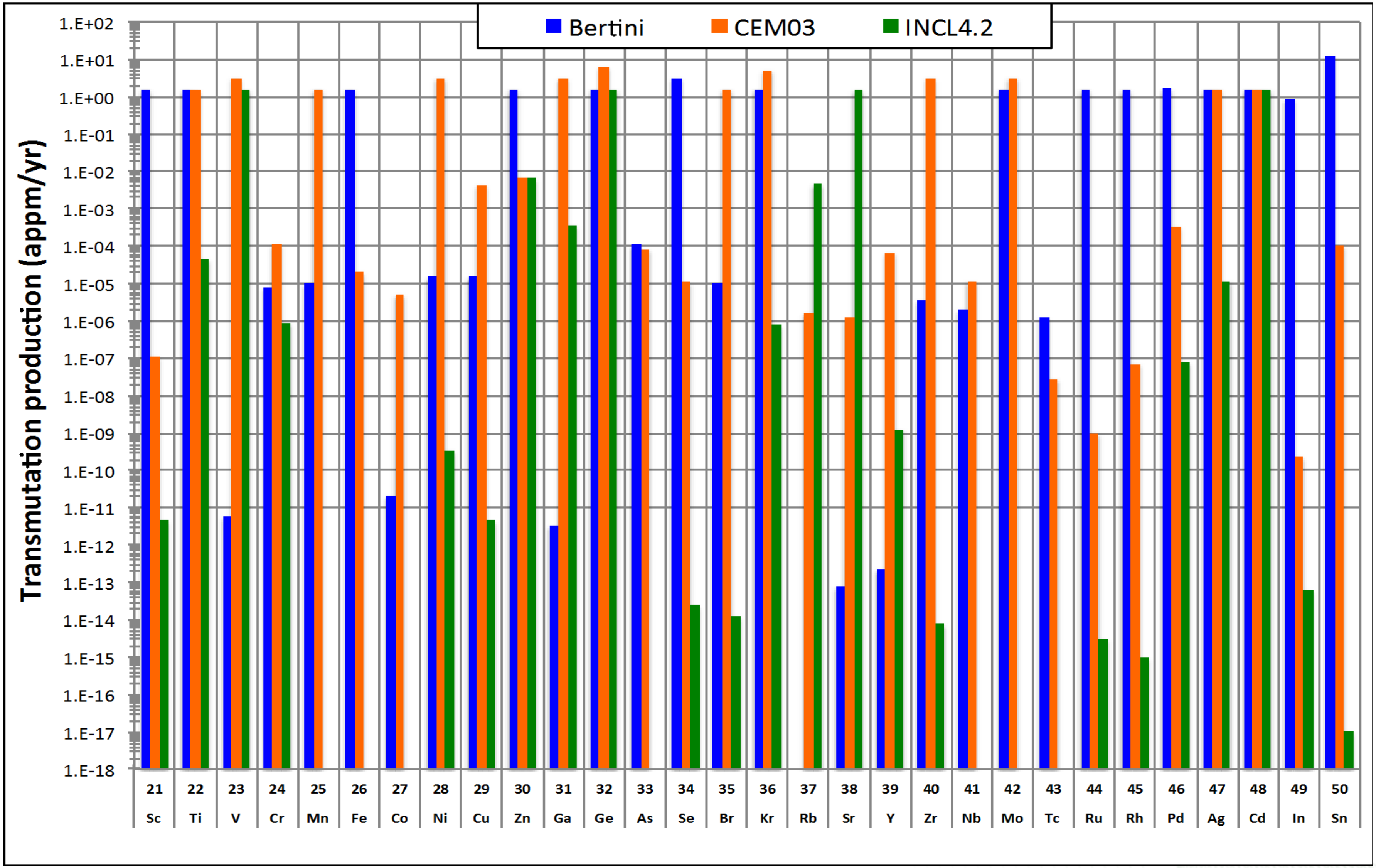
Transmutation products at FMITS - tungsten





Transmutation products at FMITS - tungsten



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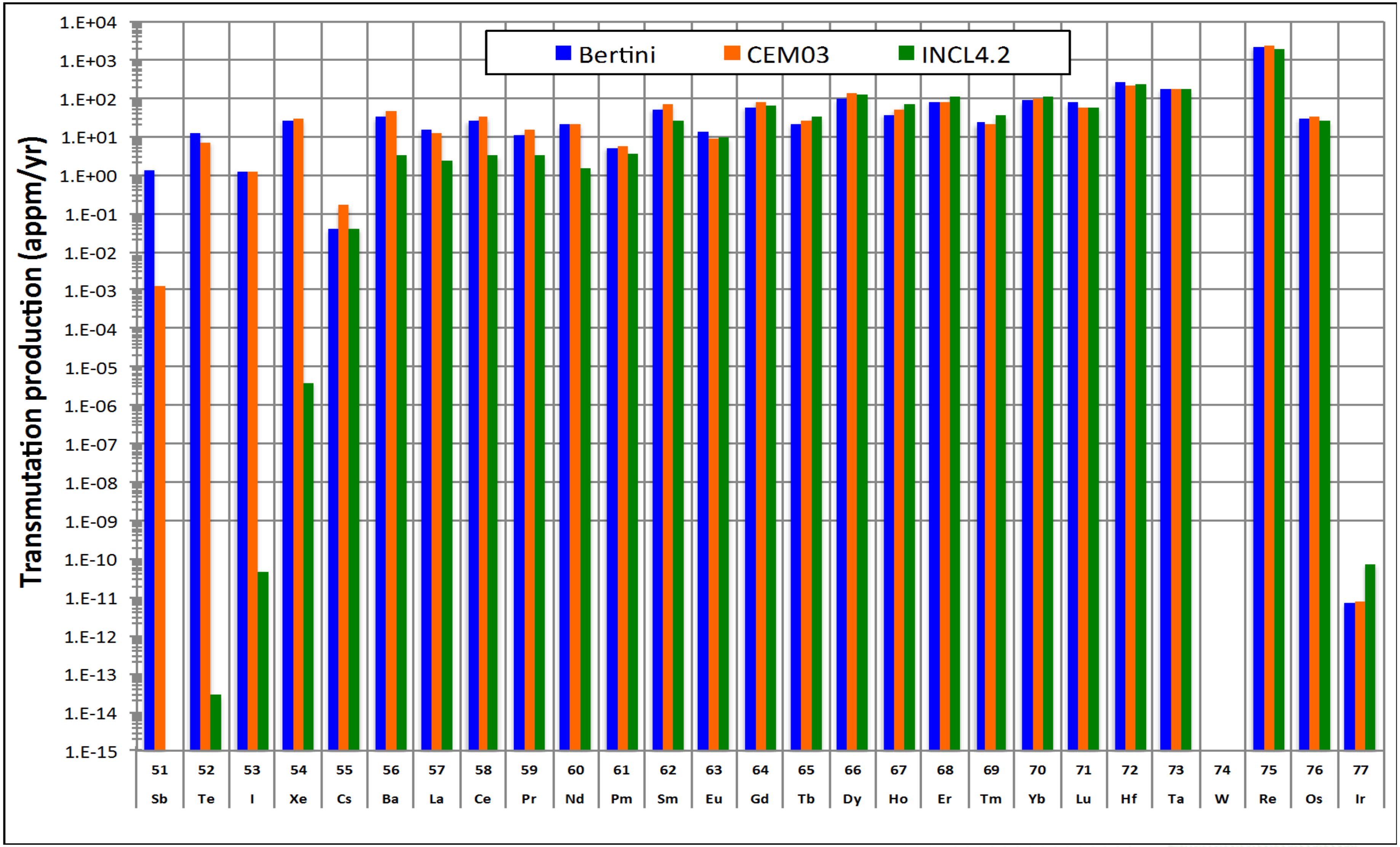
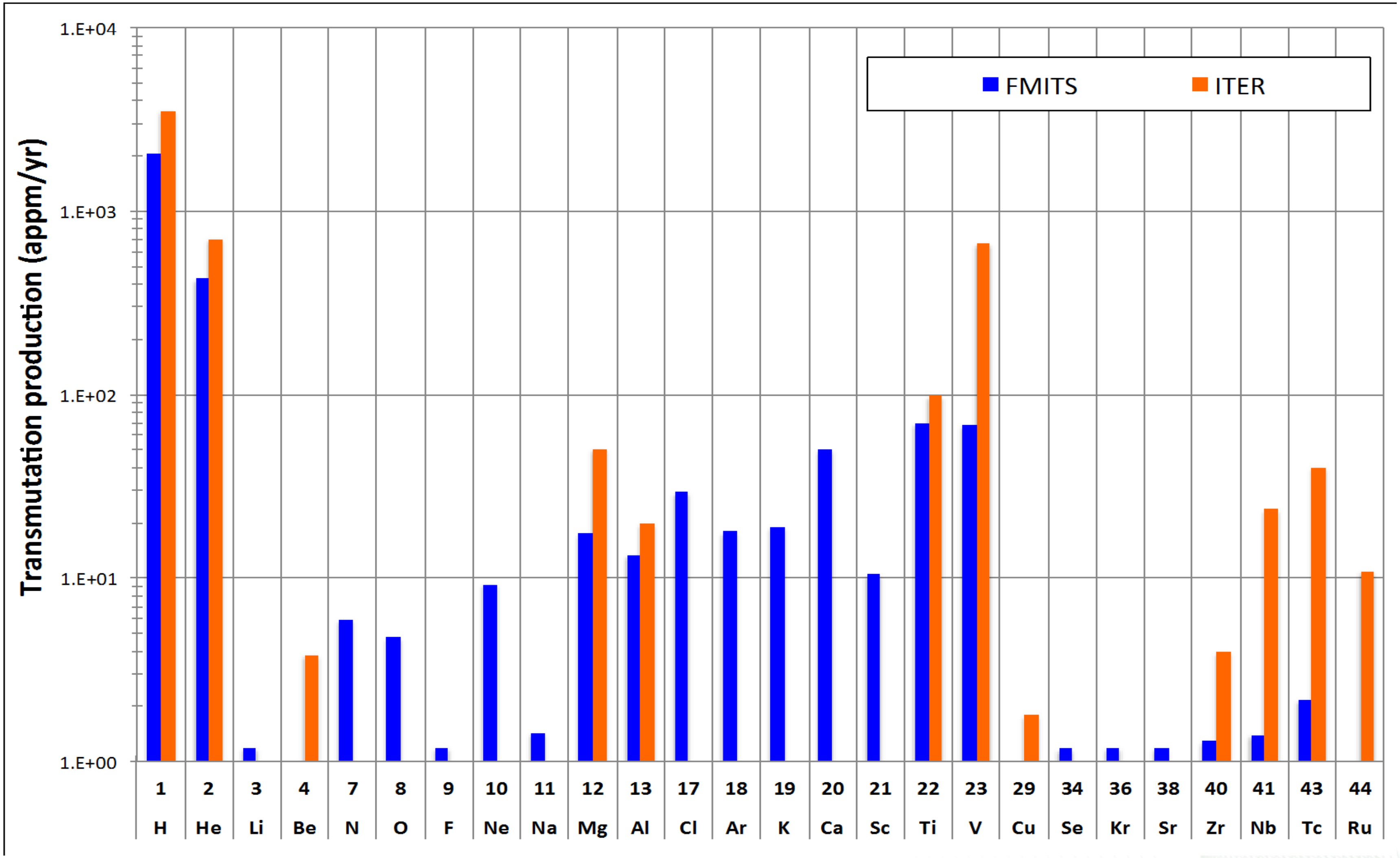


INC models

- INCL results show lower gas (H & He) production, but it is not the most recent version and future work is required
- Compared to Bertini and INCL, CEM03 shows more a complete production spectrum especially at the light and intermediate-weighted nuclei.
- CEM03 results are used for comparison

FMITS vs ITER
- stainless steel



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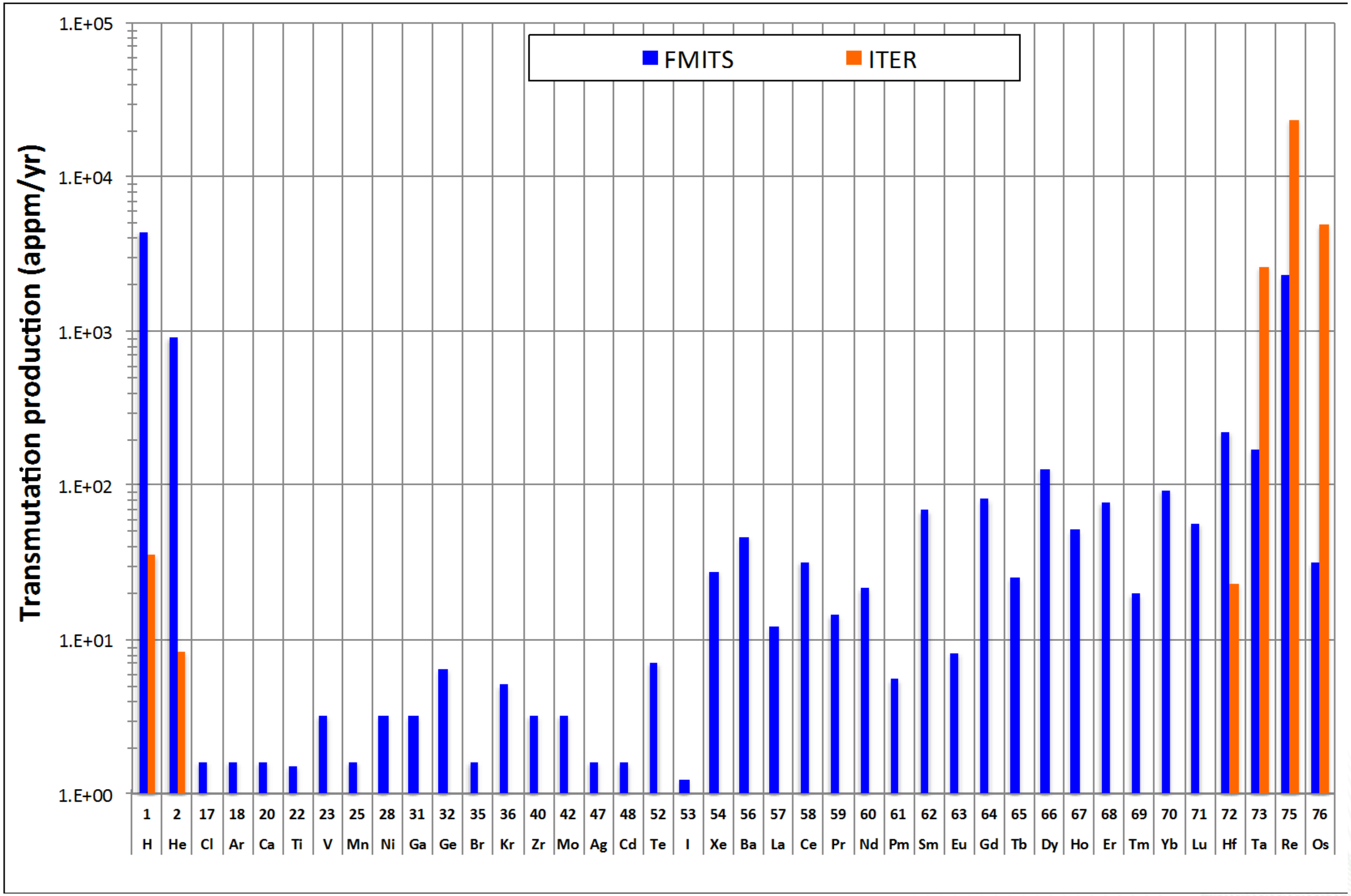
FMITS vs ITER
- tungsten



FMITS vs ITER

- Compared the fusion environment at ITER, samples at FMITS produce a much wider spectrum of transmutation products due to spallation reaction
- Stainless steel: the significant transmutation products at FMITS are generally lower than those at ITER. Most transmutation products unseen at ITER samples, except Ne, Cl, Ar, K, Ca, and Sc in the 10 appm/yr range, are insignificant.
- Tungsten: much higher H & He production at FMITS but lower heavy nuclei (Ta, Re and Os) production. FMITS produces ***Sm, Gd, Dy, Er, Yb*** and ***Hf*** in the 100 appm/yr.

Summary

- MCNPX/CINDER results for transmutation products at FMITS and ITER
- CINDER'08 shows consistent results compared to CINDER'90 with recent cross sections (considered more accurate) and improved algorithm
- The CEM03 results were tentatively adopted for the transmutation products at FMITS
- No significant unseen transmutation products presented in the stainless steel at FMITS, though for tungsten it is a different case
- Future work needed to use most recent version of INCL