Nuclear Data Experimental Activities at ANL

Filip G. Kondev

Applied Physics & Nuclear Data
Nuclear Engineering Division

(supported by the Office of Nuclear Physics, US DOE)

Highlights

❑ **Decay studies of selected actinide nuclei** (with I. Ahmad & J. Greene, ANL-PHY & A.L. Nichols & M.A. Kellett, IAEA) **-** part of the ANL commitment to the IAEA-CRP on *"Updated Decay Data Library for Actinides"*

- ✓ studies of **^{233}Pa, ^{237}Np, ^{240}Pu, ^{242m}Am, ^{243,244,245,246}Cm & ^{249,250}Cf** using α–decay and γ–ray spectroscopy techniques and mass separated sources

Pγ (312 keV;^{233}Pa)=**38.6 (5)%** by Gehrke et al., but **41.6 (9)%** by Harada et al. – **7.7%** difference!!

Journal of NUCLEAR SCIENCE and TECHNOLOGY, Vol. 43, No. 11, p. 1289–1297 (2006)

Emission Probabilities of Gamma Rays from the Decay of ^{233}Pa and ^{238}Np, and the Thermal Neutron Capture Cross Section of ^{237}Np

Hideo HARADA[1,*], Shoji NAKAMURA[1], Masayuki OHTA[1], Toshiyuki FUJII[2] and Hajimu YAMANA[2]

[1]*Nuclear Science and Engineering Directorate, 2-4 Shirane, Shirakata, Tokai-mura, Naka-gun, Ibaraki 319-1195, Japan*
[2]*Research Reactor Institute, Kyoto University, Kumatori-cho, Sennan-gun, Osaka 590-0494, Japan*

❑ **Standardization of ^{177m}Lu decay data** – calibration standard for the novel gamma-ray tracking detectors – also of relevance to the super-inelastic CS data

Two new projects funded by the Office of Nuclear Physics, Office of Science (ARRA)

✓ **MANTRA ($2M)** – in collaboration with INL

✓ **Decay data measurements & evaluations for decay heat calculations ($2M)** – in collaboration with UML (P. Chowdhury) and ANL-PHY (C. Lister)

MANTRA (Measurement of Actinide Neutronic Transmutation Rates with Accelerator mass spectroscopy)

INL: Gilles Youinou, G. Palmiotti, INL: M. Salvatores
ANL: F.G. Kondev, R. Pardo
ISU: G. Imel.

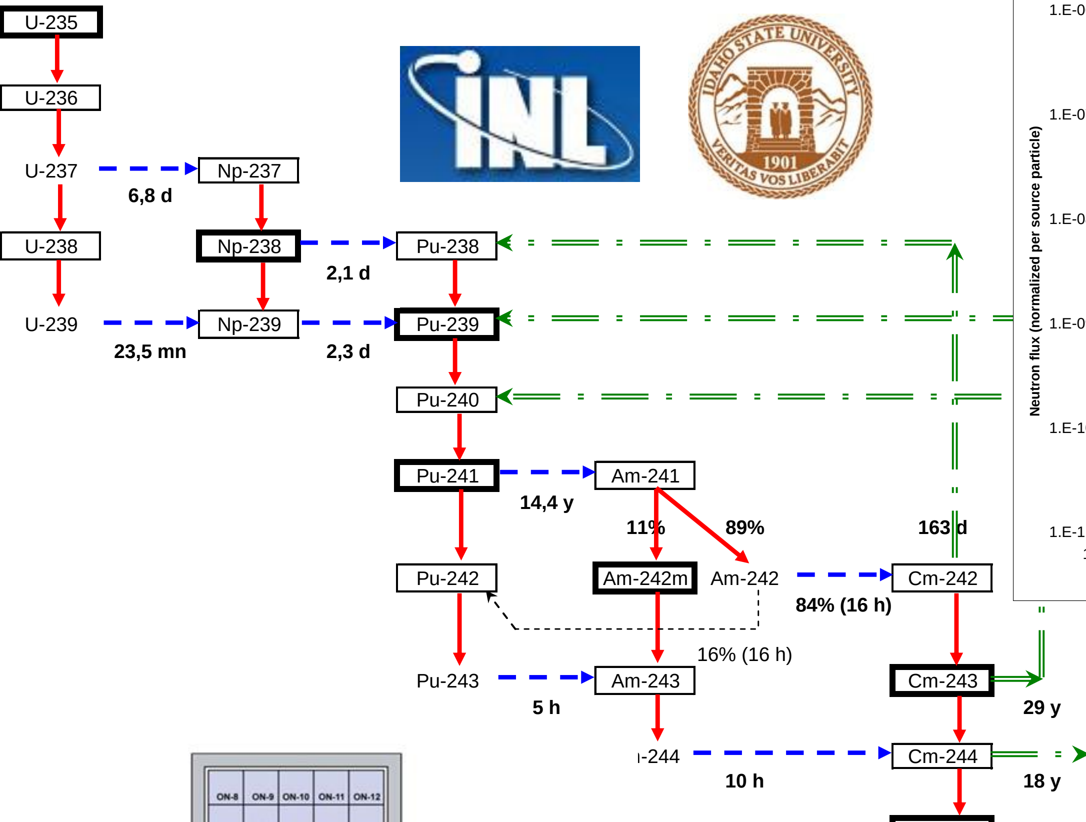
Basic Concept:

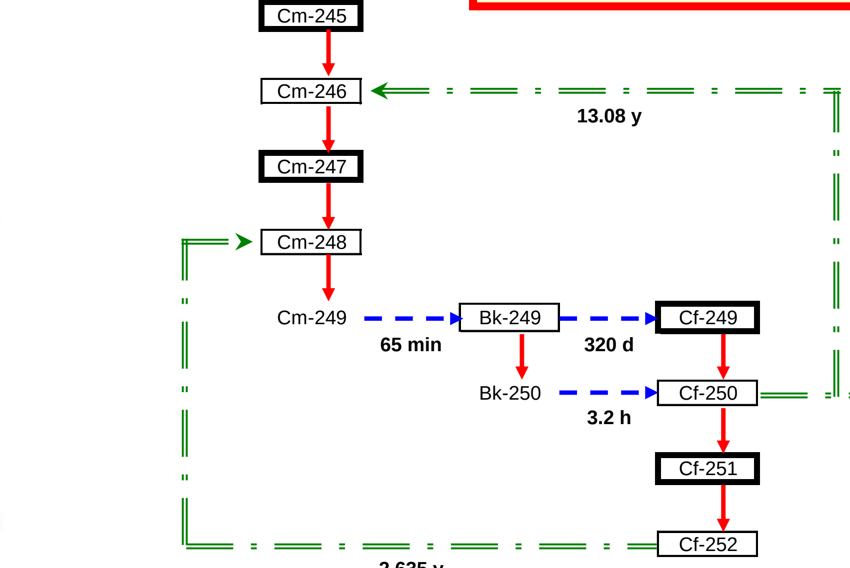
- ✓irradiating (small) samples of pure MA at the ATR facility at INL
- ✓measurements using the AMS technique at the ATLAS facility ANL

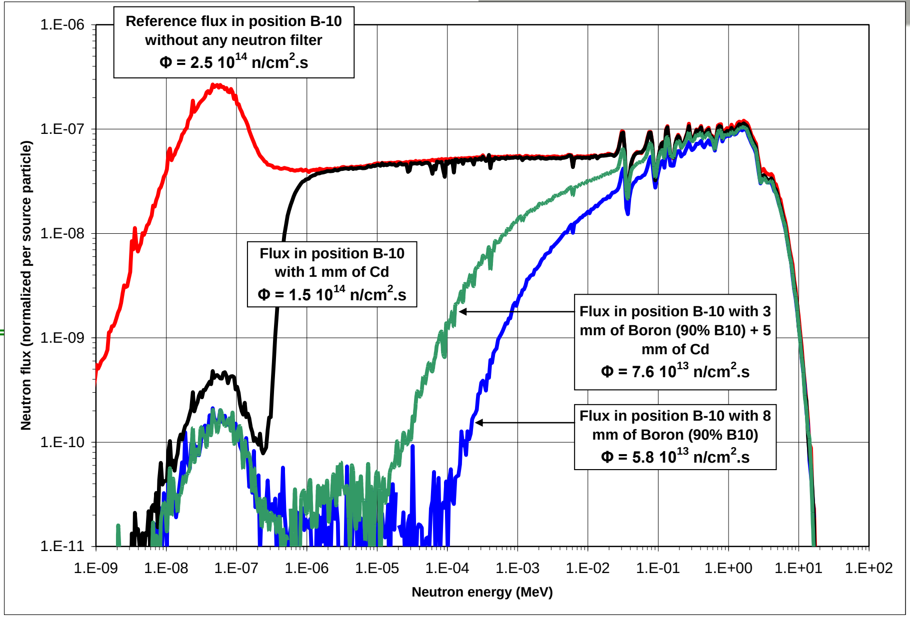
A shift toward science

■ INL's primary focus is still engineering, but the lab is incorporating more fundamental science.

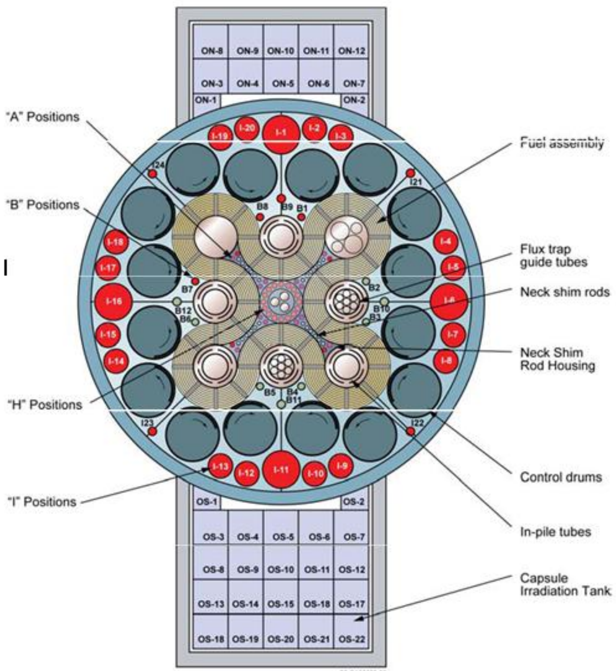
P. Fink (INL): " … using a science-based approach to obtain better nuclear data…"



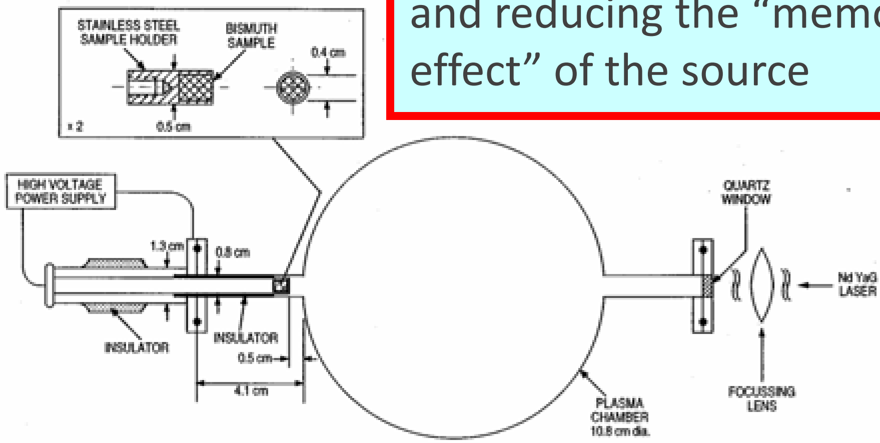


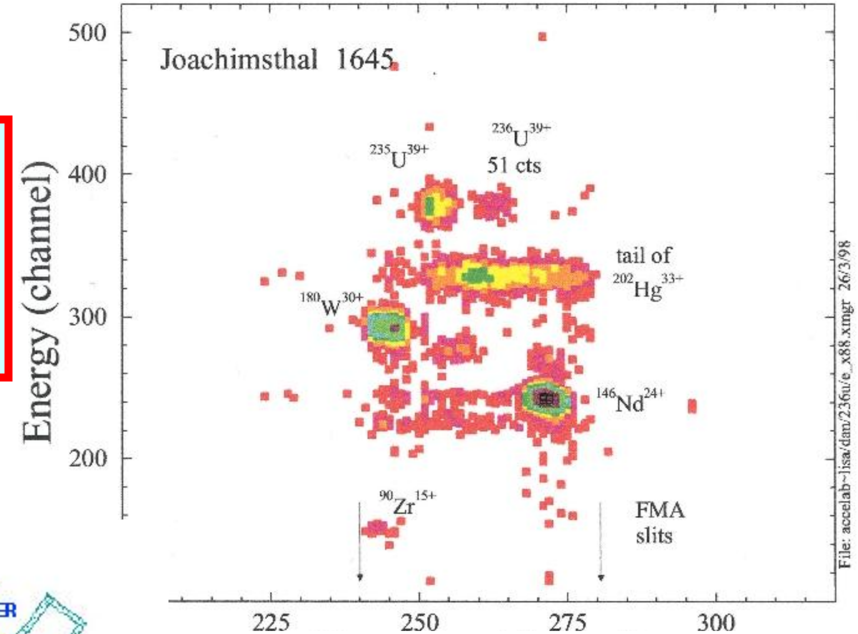


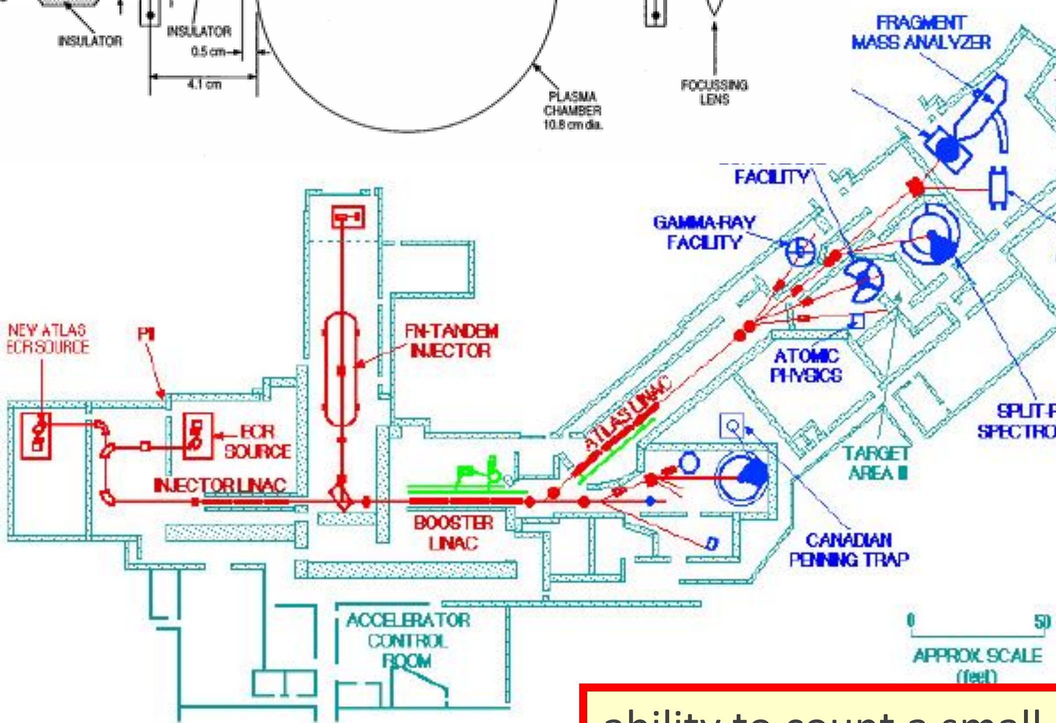
✓ irradiation of samples under different conditions at the ATR facility at INL

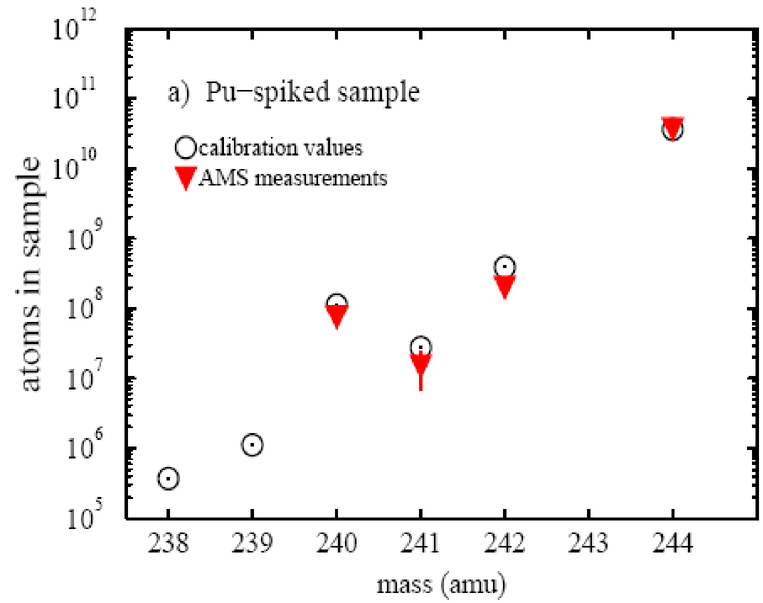


develop laser ablation capability – smaller samples and reducing the “memory effect” of the source





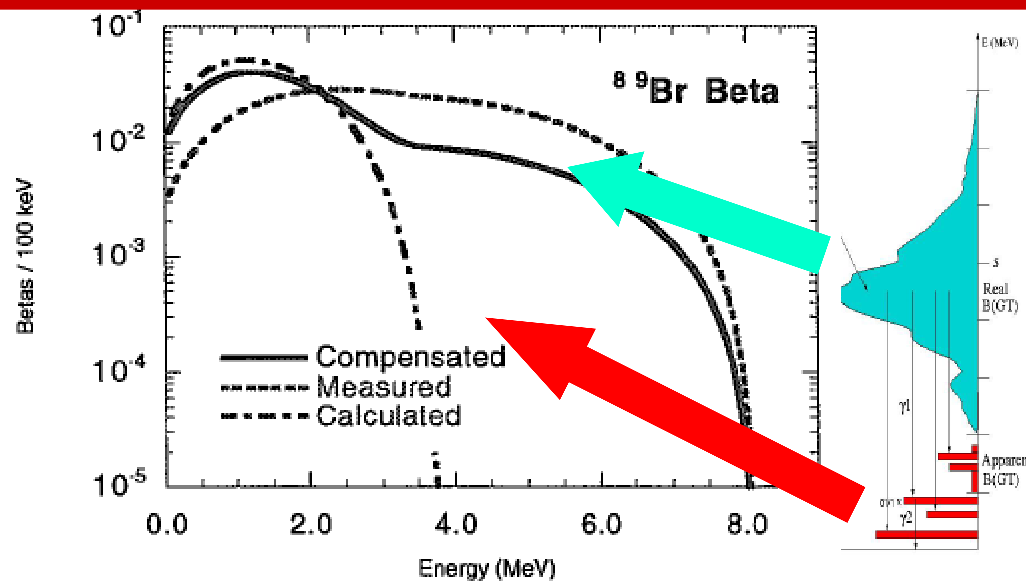




ability to count a small amount of material – e.g. 10^6 atoms sensitivity exceeds 1 in 10^{12}

ND Needs for Decay Heat calculations

- Many aspects of the nuclear fuel cycle require a detailed knowledge of the energy release, and corresponding heat from the decay of the radioactive nuclides
- Advanced fuel applications – assessments of decay heat for short cooling times are performed by means of **the microscopic summation method** – **decay and build-up of FPs** – input data: **fission yields and decay data**



J. Katakura *et al*., JNST, Suppl. 2 (2002) 444

- JENDL FP (based on ENSDF) - “contaminated” by Gross Beta-decay Theory for ~500 FP (almost half of all FP)!
- there are significant differences between various libraries, e.g. JEFF vs. JENDL vs. ENDF

- Accurate FP decay data are also important for other applications:
  - ✓ nuclear astrophysics
  - ✓ National Security – LLNL cargo inspections
    (NIM. A521 (2004) 608)

- about 50 cases studied using TAGS, but there are also drawbacks
- only a handful of cases studied with modern γ–ray arrays (e.g. GSI)

IAEA
International Atomic Energy Agency

INDC(NDS)-0499
Distr. SD

INDC International Nuclear Data Committee

Summary Report of Second Consultants' Meeting

Beta-decay and decay heat

held in collaboration with WPEC Subgroup 25
Validation of Fission Product Decay Data for Decay Heat Calculations
OECD/NEA, Paris, Fra...

NEA Data Bank, Paris, Fr...

3 May 2006

Prepared by

Alan L. Nichols
IAEA Nuclear Data Se...

June 2006

IAEA Nuclear Data Section, Wagramer Strasse 5, A-1400 Vienna, Aus...

Nuclear Science
2007

OECD

Assessment of Fission Product Decay Data for Decay Heat Calculations

International Evaluation Co-operation, Volume 25

AEN
NEA

NUCLEAR • ENERGY • AGENCY

IAEA
International Atomic Energy Agency

INDC(NDS)-0551
Distr. EN,ND

Total Absorption Gamma-ray Spectroscopy (TAGS), Current Status of Measurement Programmes for Decay Heat Calculations and Other Applications

Summary Report of Consultants' Meeting

Prepared by

A.L. Nichols
International Atomic Energy Agency, P.O. Box 100, Vienna, Austria

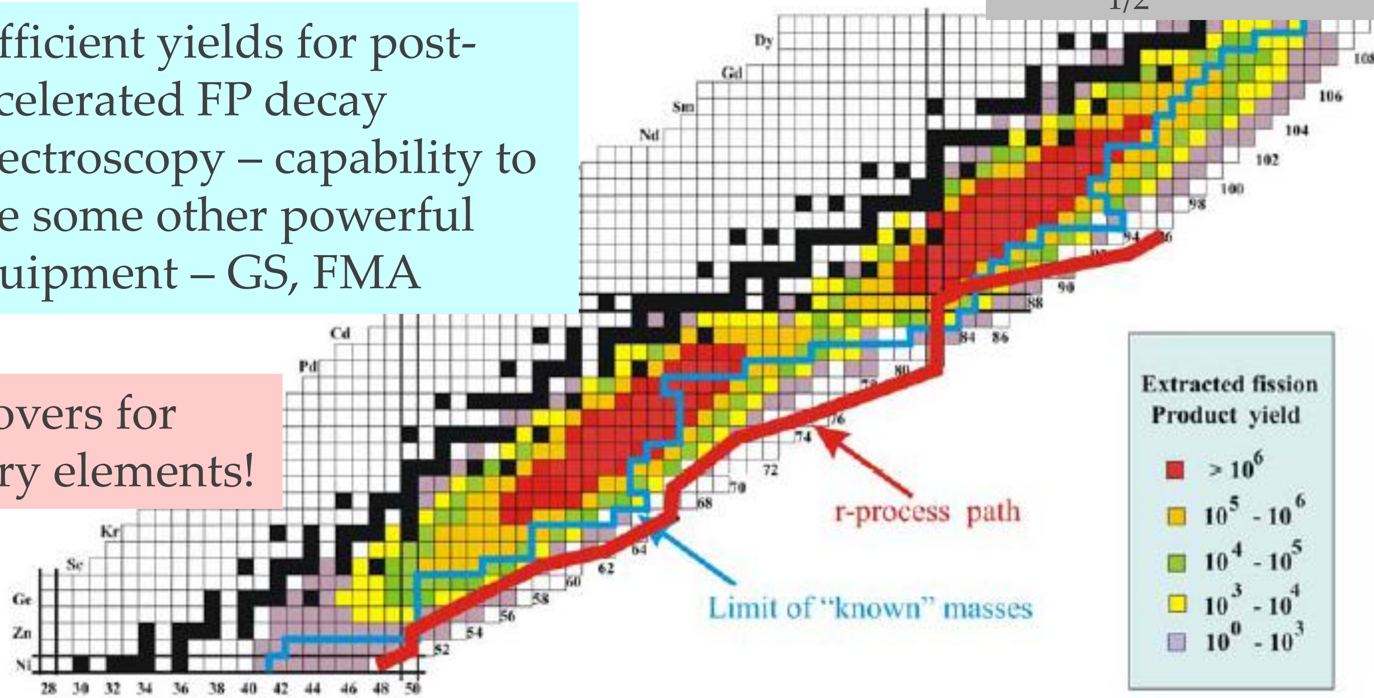
C. Nordborg
OECD, Nuclear Energy Agency, 12 Boulevard des Iles, Issy-les-Moulineaux, France

IAEA Headquarters, Vienna, Austria
27 – 28 January 2009

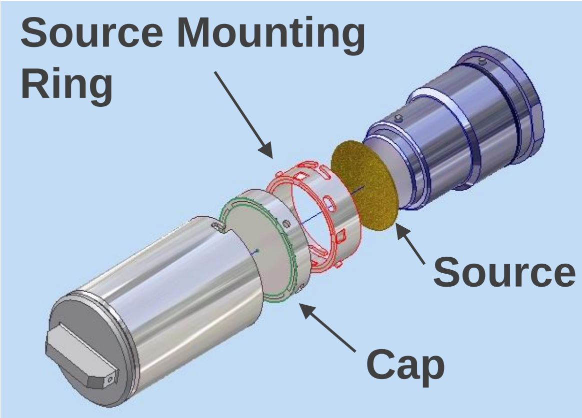
Opportunities at ANL - CARIBU

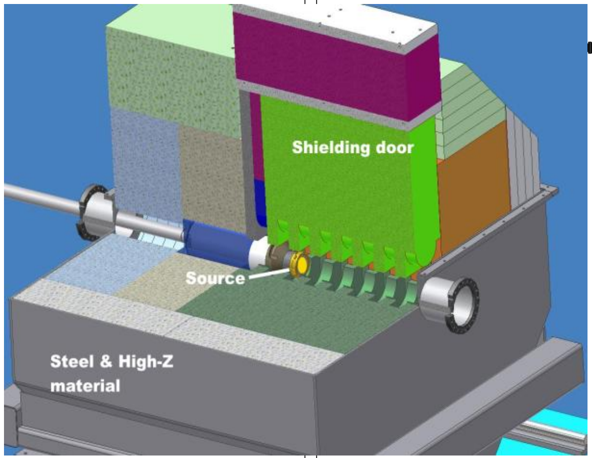
- **CA**lifornium **R**are **I**on **B**reeder **U**pgrade (**CARIBU**) of ATLAS – 1 Ci ^{252}Cf spontaneous fission source (~20% of total activity extracted as ions) - gas catcher and isobar separator (with or without post acceleration) – large improvement over existing ISOL-based facilities

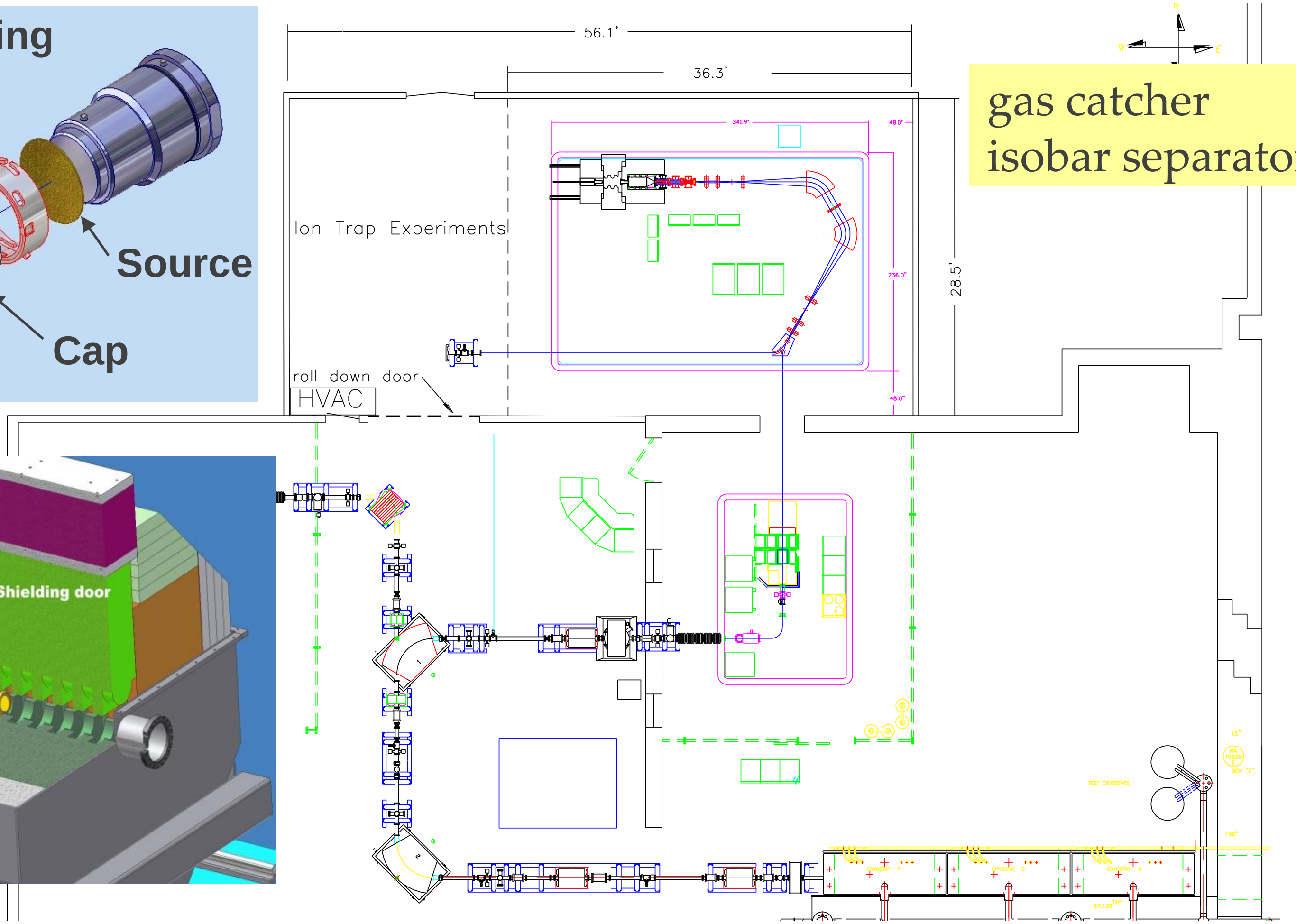
- ✓ not accelerated - short $T_{1/2}$ and more exotic
- ✓ sufficient yields for post-accelerated FP decay spectroscopy – capability to use some other powerful equipment – GS, FMA
- ✓ no stopovers for refractory elements!



CARIBU project - cont.







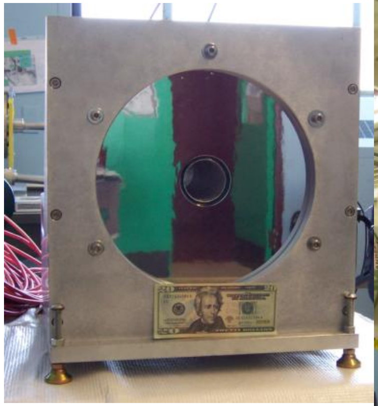
1Ci of ^{252}Cf is 1.9 mg; over an 3x6 cm ellipse area this yield a density of ~150 μg/cm2

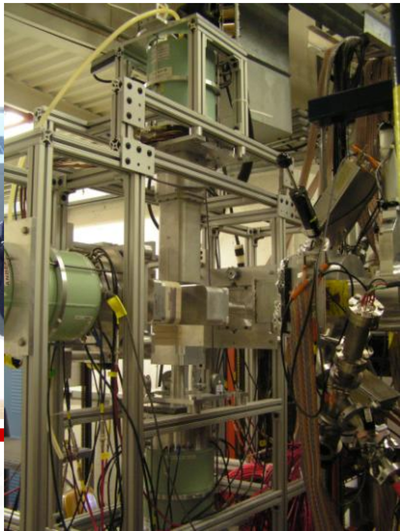
What does CARIBU offers?

- New target/source approaches
  - ✓ gas catcher, isobar separator & ECR technology

    can be used to efficiently to turn a non-conventional source of n-rich isotopes, such as a spontaneous fission source, into a low-energy beam – no stopovers for refractory elements
- Very high acceleration efficiency
  - ✓ post-accelerator based on ATLAS
- Existing experimental equipment and infrastructure for radioactive beam physics
  - ✓ CPT, Gammasphere, HELIOS, FMA

TAGS & X-ray array





Yields for some nuclei of interest

- **N**on **A**ccelerated beams (~10^5-10^6 ions/sec)
- **AC**ellerated beams (10^4-10^5 ions/sec)

Nuclide	P	$Q_{\beta-}$, keV	Half-life	NA, ions/sec	AC, ions/sec
35-Br-86	1	7626 (11)	55.1 s	5.70E+04	2.10E+03
35-Br-87	1	6852 (18)	55.65 s	3.00E+05	1.10E+04
35-Br-88	1	8960 (40)	16.36 s	4.60E+05	1.70E+04
36-Kr-89	1	4990 (50)	3.15 min	4.70E+05	3.40E+04
36-Kr-90	1	4392 (17)	32.32 s	9.00E+05	6.60E+04
37-Rb-90m	2	6690 (15)	258 s	2.00E+05	7.40E+03
37-Rb-92	?	8096 (6)	4.49 s	9.30E+05	3.40E+05
38-Sr-97	2	7470 (16)	0.429 s	1.60E+06	5.40E+04
39-Y-96	?	7096 (23)	5.34 s	1.50E+05	5.40E+03
40-Zr-99	3	4558 (15)	2.1 s	3.30E+06	1.20E+05
40-Zr-100	2	3335 (25)	7.1 s	5.50E+06	2.00E+05
41-Nb-99	1	3639 (13)	15.0 s	2.50E+04	9.20E+02
41-Nb-100	1	6245 (25)	1.5 s	7.60E+05	2.80E+04
41-Nb-101	1	4569 (18)	7.1 s	3.50E+06	1.30E+05
41-Nb-102	2	7210 (40)	1.3 s	5.40E+06	2.00E+05
42-Mo-103	1	3750 (60)	67.5 s	4.00E+06	1.50E+05
42-Mo-105	1	4950 (50)	35.6 s	8.20E+06	3.00E+05

Nuclide	P	$Q_{\beta-}$, keV	Half-life	NA, ions/sec	AC, ions/sec
43-Tc-103	1	2662 (10)	54.2s	1.50E+05	5.60E+03
43-Tc-104	?	5600 (50)	18.3 min	1.20E+06	4.30E+04
43-Tc-105	?	3640 (60)	7.6 min	5.70E+06	2.10E+05
43-Tc-106	1	6547 (11)	35.6 s	5.90E+06	2.20E+05
43-Tc-107	2	4820 (90)	21.2 s	9.80E+06	3.60E+05
51-Sb-132	1	5509 (14)	2.79 min	1.90E+06	7.00E+04
52-Te-135	?	5960 (90)	19.0 s	4.80E+06	1.80E+05
53-I-136	1	6930 (50)	83.4 s	3.70E+06	1.30E+05
53-I-136m	1	7580 (120)	46.9 s	2.50E+06	9.20E+04
53-1-137	1	5877 (27)	24.13 s	4.20E+06	1.60E+05
54-Xe-137	1	4166 (7)	3.82 min	7.00E+06	5.10E+05
54-Xe-139	1	5057 (21)	39.68 s	9.40E+06	6.90E+05
54-Xe-140	1	4060 (60)	13.6 s	6.90E+06	5.00E+05
55-Cs-142	?	7308 (11)	1.69 s	6.80E+06	2.50E+05
56-Ba-145	2	5570 (110)	4.31 s	5.50E+06	2.00E+05
57-La-143	2	3425 (15)	14.2 min	2.80E+06	1.00E+05
57-La-145	2	4110 (80)	24.8 s	6.80E+06	2.50E+05

What makes studies at ANL unique?

- **the superiority of CARIBU**
  - ✓ intensity and purity of neutron-rich FP beams
  - ✓ gas-cell technology - no stopovers for refractory elements
  - ✓ FP can be delivered to other key instruments at ANL – CPT and FMA
- **combination of high-resolution γ–ray spectroscopy & TAGS**
  - ✓ discrete spectroscopy may suffer from "pandemonium", but TAGS cannot do it alone either – having capabilities to do both at a single facility is a "perfect marriage"
  - ✓ development of beta-delayed neutron measurements capabilities at ANL

- we are building multiple collaborations with interested participants from US, Europe, Australia, India, China & Japan
- we plan to organize a dedicated workshop in the second half of 2010 – experimentalists, data users & evaluators, industry and international organizations - we have an ambitious plan to make the newly coming data quickly available to the end users