Isotopes Project

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Guests: E. Browne, H. Choi (Korea)
Visitor: M. Krticka (Charles University, Prague)

Isotope Project Activities

- Mass chain/Isotope evaluations
- Evaluated Gamma-ray Activation File (EGAF)
- IAEA CRP neutron activation σ_0/k_0 comparisons
- Decay Data Evaluation Project (DDEP)
- Measurements and basic research

USNDP Meeting, Brookhaven National Laboratory, November 3-6, 2009

Mass Chain, Isotope Evaluations

Permanent mass chain responsibility: A=21-30, 59, 81, 91-93, 166-171, 184, 186, 187, 189, 210-217

Published: A=25, 81, 119*, 145*, 179, 229*

In the pipeline: A=66*, 93, 168, 184, 192

Isotope evaluations: "Island of Inversion" (^{30}Si, ^{30}Al, ^{30}F, ^{29}Al, ^{29}Mg, ^{29}F, ^{28}Mg, ^{28}Na, ^{28}F, ^{27}Na, ^{27}Ne, ^{27}F, ^{26}Ne, ^{26}F, ^{25}Ne)

* Funded by the NNDC

Evaluated Gamma-ray Activation File (EGAF)

EGAF is an LBNL/IAEA database of thermal neutron capture γ-ray cross sections. A second edition of EGAF is being evaluated and will include an activation data file and total radiative neutron cross sections σ_0.

Relevant publications:

• *Database of Prompt Gamma Rays from Slow Neutron Capture for Elemental Analysis*, R.B. Firestone, H.D. Choi, R.M. Lindstrom, G.L. Molnar, S.F. Mughabghab, R. Paviotti-Corcuera, Zs. Revay, V. Zerkin, and C.M. Zhou, IAEA STI/PUB/1263, 251 pp (2007).

• *Handbook of Prompt Gamma Activation Analysis with Neutron Beams*, Zs. Revay, T. Belgya, R.M. Lindstrom, Ch. Yonezawa, D.L. Anderson, Zs. Kasztovsky, and R.B. Firestone, edited by G.L. Molnar (Kluwer Publishers, 2004).

The EGAF database is at http://www-nds.iaea.org/pgaa/pgaa7/index.html

LLNL/LBNL ENDF Neutron Capture Gamma Library

Collaborators

LBNL – R.B. Firestone, S. Basunia, H. Choi
LLNL – B. Sleaford, N. Summers, D. Dashdorj, J. Escher, A. Hurst
Budapest – Zs. Revay, T. Belgya
Prague (Charles University) – M. Krticka

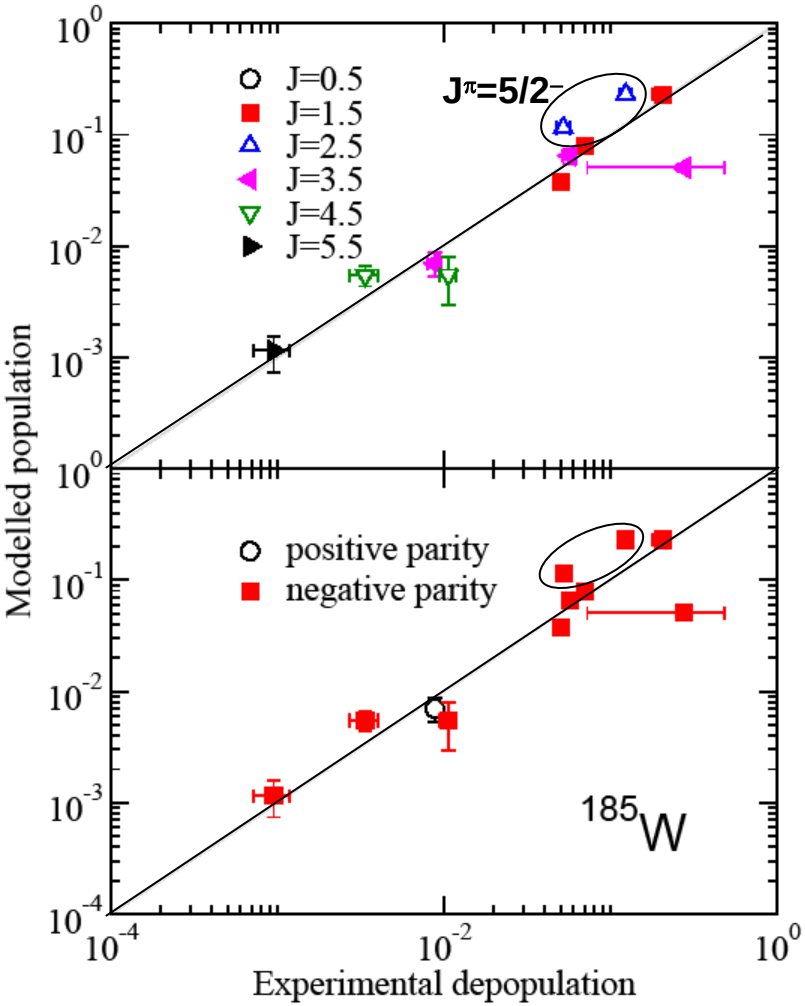
Neutron Capture Gamma Library: ENDF data libraries funded at LLNL by NA-22. Data for Z=1-19 completed. Fe, Eu, Gd, W evaluations in progress.

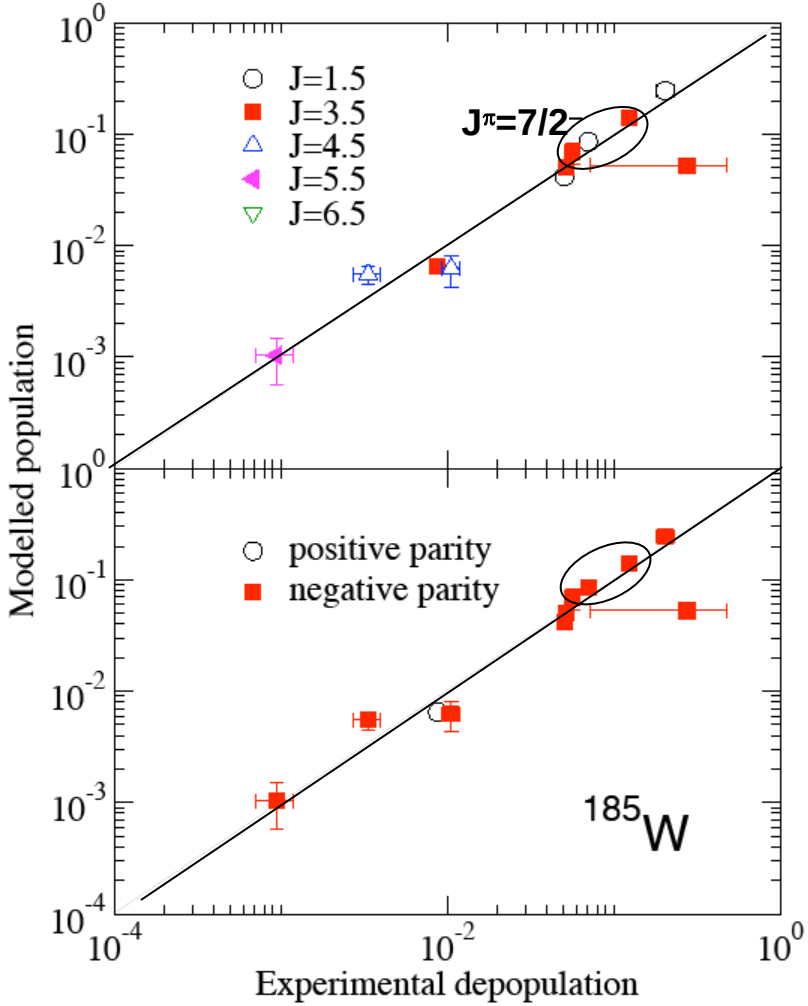
Thermal capture σ_0 evaluations: DICEBOX statistical model calculations normalized to EGAF (n,γ) data. Results are published in the literature, e.g.

Thermal neutron capture cross sections of the Palladium isotopes, M. Krticka, R.B. Firestone, D.P. McNabb, B. Sleaford, U. Agvaanluvsan, T. Belgya, and Z.S. Revay, Phys. Rev. C 77, 054615 (2008).

Reaction Input Parameter Library (RIPL): Improved nuclear structure data from statistical analysis will be fed back into RIPL and ENSDF.

DICEBOX Population/Depopulation plot for $^{184}W(n,\gamma)^{185}W$ data. Levels at 66- and 188-keV have $J^{\pi}=5/2^{-}$ in RIPL (ENSDF). Statistical model calculations indicate that both levels are only consistent with $7/2^{-}$. Many other "definite" J^{π} values in ^{185}W must be revised.





IAEA CRP - *Reference Database for Neutron Activation Analysis*

IUPAC k_0 (*Pure Appl. Chem*. **76**, 1921 (2004)), σ_0 (Atlas of Neutron Resonances), σ_γ (Budapest reactor), and P_γ (DDEP, ENSDF) data are being evaluated to develop a new k_0/σ_γ database for Neutron Activation Analysis.

$$(k_{0,Au})_\gamma = \frac{M_{Au}\theta_x\sigma_{0,x}P_\gamma}{M_x\theta_{Au}\sigma_{0,Au}P_{Au}}$$

Discrepant Results					
Reaction	**σ_0 (Atlas)**	**σ_0(Adopted)**	**E(γ) (keV)**	**k_0 (IUPAC)**	**k_0 (Adopted)**
^{23}Na(n,γ)	517(4) mb	541(4) mb	1368.6 2754.0	0.0468(3) 0.0462(4)	0.0492(5) 0.0491(5)
^{40}K(n,γ)	30(8) b	90(3) b			
^{64}Zn(n,γ)	790(20) mb	780(20) mb	1115.5	0.00572(2)	0.00608(16)
^{99}Tc(n,γ)	22.8(13) b	26(1) b	539.5 590.8	No data	0.0359(14) 0.0292(13)

A CRP - *Reference Database for Neutron Activation Analysis*

New P_γ values and decay branching ratios

Reaction	E(γ) (keV)	P_γ (old)	P_γ (new)
^{30}Si(n,γ)	1266.16	0.00050(4)	0.000544(15)
^{37}Cl(n,γ)	1643.43	0.333(5)	0.319(6)
	2167.54	0.444(9)	0.430(8)
^{41}K(n,γ)	1524.6	0.1808(9)	0.173(3)
^{104}Rh(n,γ)	555.81	0.0199(5)	0.0221(8)
^{128}I(n,γ)	442.901	0.1261(8)	0.113(3)
Isotope	**$t_{1/2}$**	**Old branching**	**New branching**
^{114m}In	49.51 d	IT=96.75(24)%	IT=95.72(7)%
		EC+β^+=3.25(24)%	EC+β^+=4.28(7)%

Decay Data Evaluation Project

Contributors 2004-2009 – M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, C. Baglin, V. Chechev, N. Kuzmenko, R. Helmer, F. Kondev, D. MacMahon, K.B. Lee, A. Pearce, E. Schönfeld, R. Dersch, H. Xiaolong, W. Bausong, M. Galan, A Pearce, A. Luca, X. Mougeot, A.L. Nichols, A. Arinc

E. Browne, DDEP International Coordinator and Editor

Recommended values of nuclear and decay data for 156 radionuclides available from the Bureau International des Poids et Mesures
http://www.bipm.org/en/publications/monographie-ri-5.html

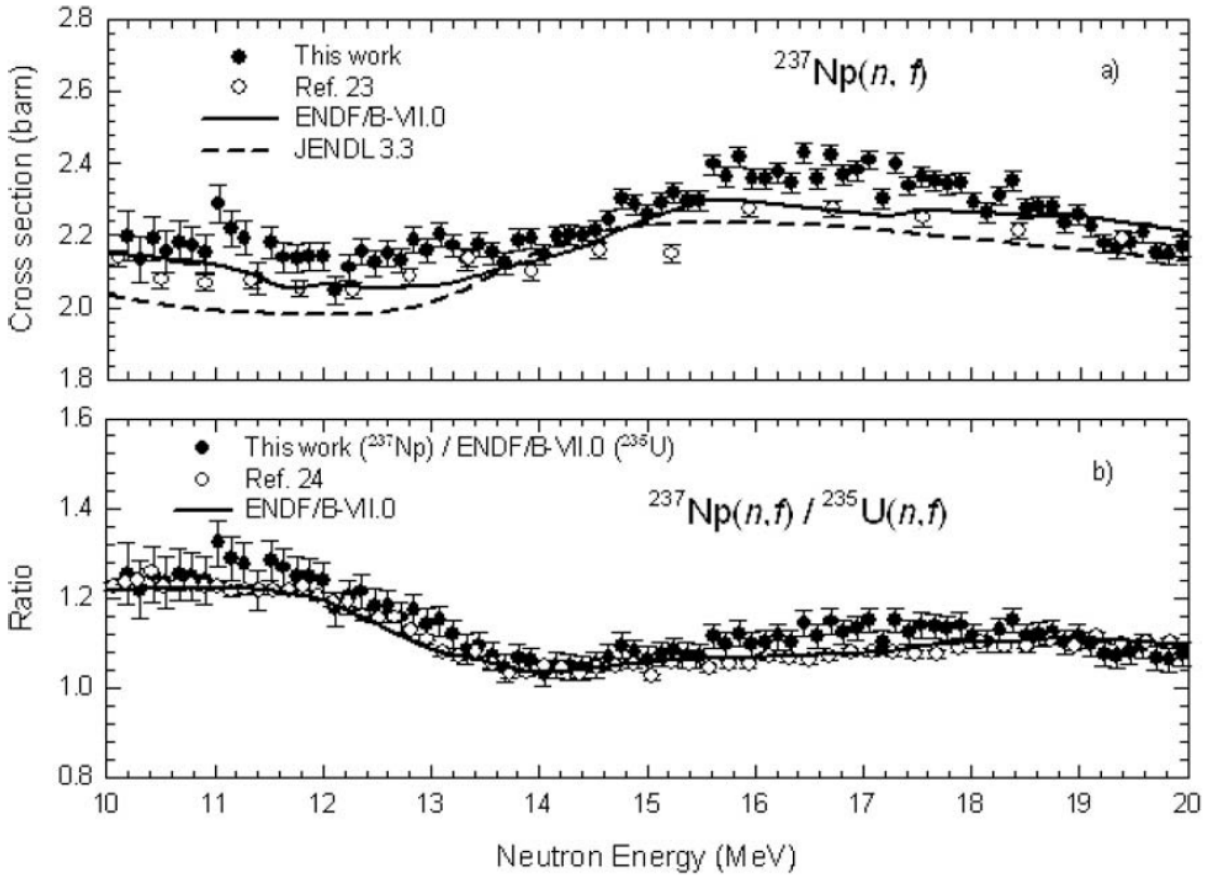
Isotopes Project Research

- Thermal neutron cross section measurements with neutron beams at the Budapest reactor.
- Surrogate reaction cross section at the Berkeley 88” Cyclotron
- Nuclear decay rates
- Terrestrial impacts and near-Earth Supernovae

Thermal neutron cross sections for Z=1-9

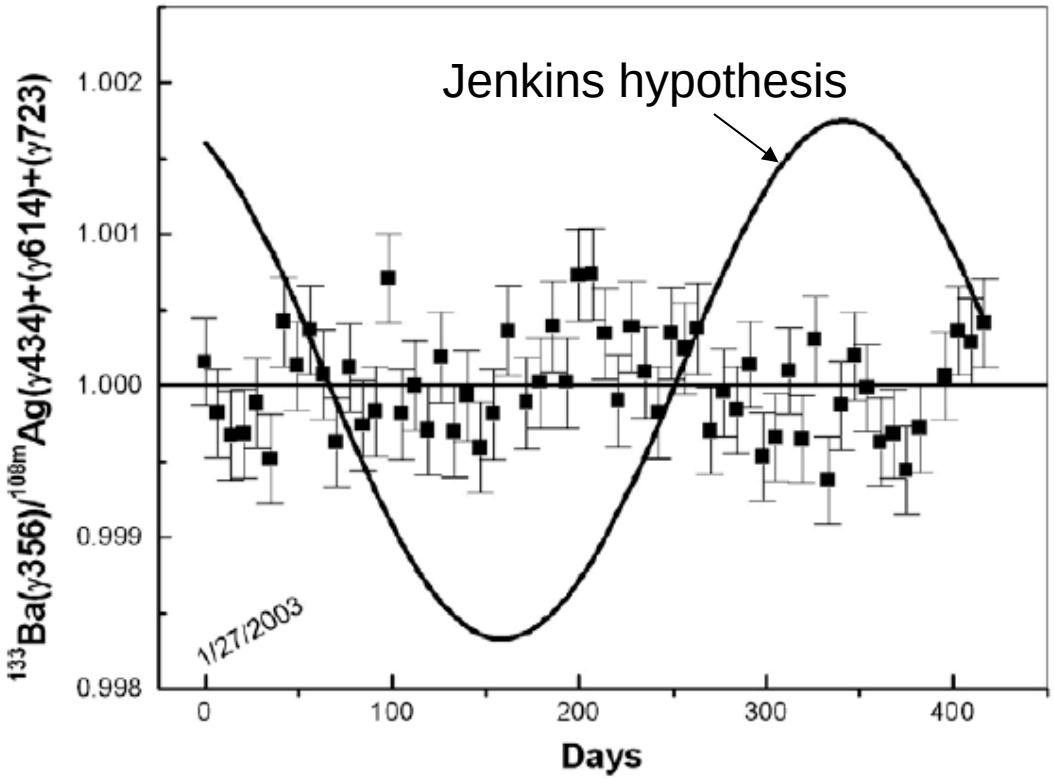
Reaction	σ_0(Atlas)	σ_0 (This work)
$^{1}H(n,\gamma)$	332.6(7) mb	=332.6(7) mb
$^{2}H(n,\gamma)$	508(15) μb	549(10) μb
$^{6}Li(n,\gamma)$	44.8(3) mb	52.6(22) mb
$^{7}Li(n,\gamma)$	45.2(14) mb	46.3(13) mb
$^{9}Be(n,\gamma)$	8.49(34) mb	8.8(4) mb
$^{10}B(n,\gamma)$	305(16) mb	393(10) mb
$^{11}B(n,\gamma)$	5.5(33) mb	9.06(20) mb
$^{12}C(n,\gamma)$	3.53(7) mb	3.84(6) mb
$^{13}C(n,\gamma)$	1.37(4) mb	1.51(3) mb
$^{14}N(n,\gamma)$	80.1(6) mb	80.3(8) mb
$^{15}N(n,\gamma)$	23(8) μb	39(3) μb
$^{16}O(n,\gamma)$	190(20) μb	197(7) μb
$^{19}F(n,\gamma)$	9.51(9) mb	9.36(12) mb

Surrogate Reactions



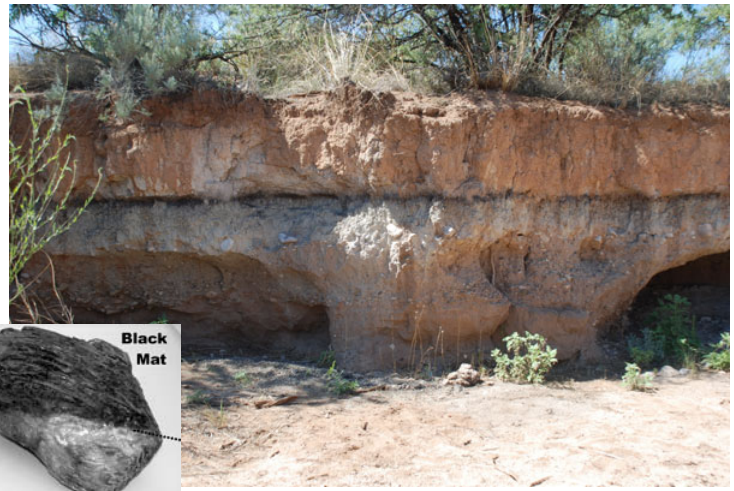
M. S. Basunia, R. M. Clark, B. L. Goldblum, *et al*, Nucl. Instrum. Meth. Phys. Res. B, **267**, 1899-1903, (2009).

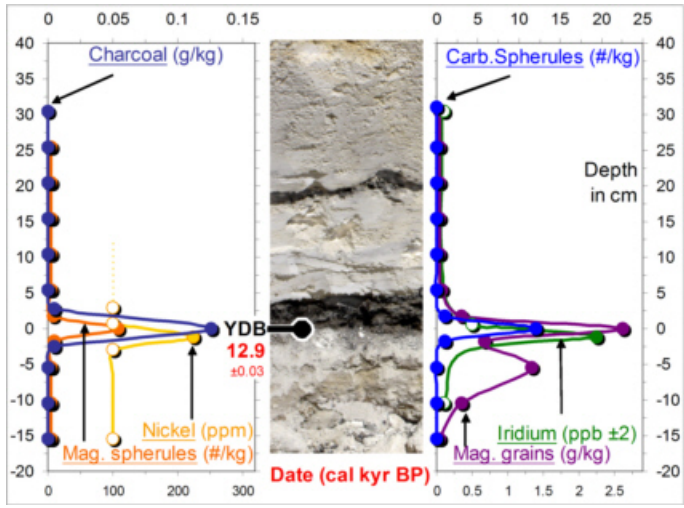
Decay rate oscillations

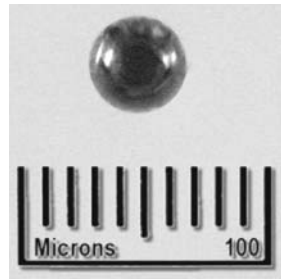


Evidence against correlations between nuclear decay rates and Earth–Sun distance E.B. Norman, E. Browne, H.A. Shugart, T.H. Joshi, R.B. Firestone, Astroparticle Physics **31,** 135–137 (2009).

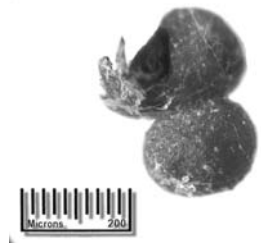
12.9 kyr BP Younger Dryas impact



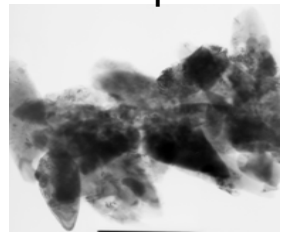




Fe/Ti microspherule



Carbon spherule



Nanodiamonds

Glass-like carbon

Impact markers found in a narrow sediment layer dated to 12.9 ka BP at >25 sites in North America and Belgium show that a 4.6-km comet exploded over the Laurentide Ice Sheet possibly creating the Great Lakes and causing

- Onset of >1000 years of Younger Dryas cooling
- Sudden extinction of mammoths and other megafauna

PGAA/NAA/XRF analysis shows that the comet was enriched in Ir and Fe/Ti and has a *similar composition to lunar Procellarum KREEP Terrane*.

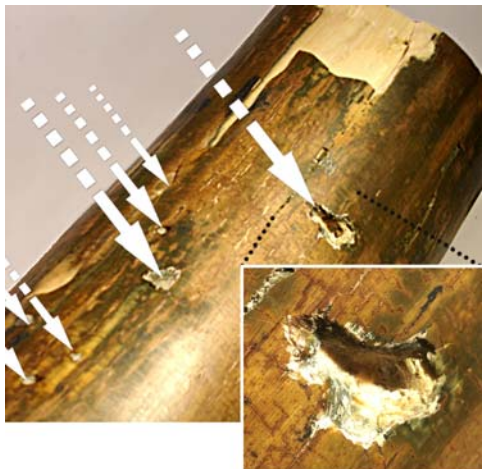
Radiocarbon analysis indicates that either the comet contained or the impact produced a *large excess of ^{14}C*.

R.B. Firestone, Journal of Cosmology **2**, in press (2009).

USNDP Meeting, Brookhaven National Laboratory, November 3-6, 2009

35 kyr BP impact into Mammoth tusks

Micrometeorite Impacts in Beringian Mammoth Tusks and a Bison Skull, R.B. Firestone, A. West, Zs. Stefanka, Zs. Revay, J.T. Hagstrum, 2007 AGU Fall Meeting, San Francisco.



7 mammoth tusks and bison skull dated to 34,000 BP

XRF/ICP-MS Analysis

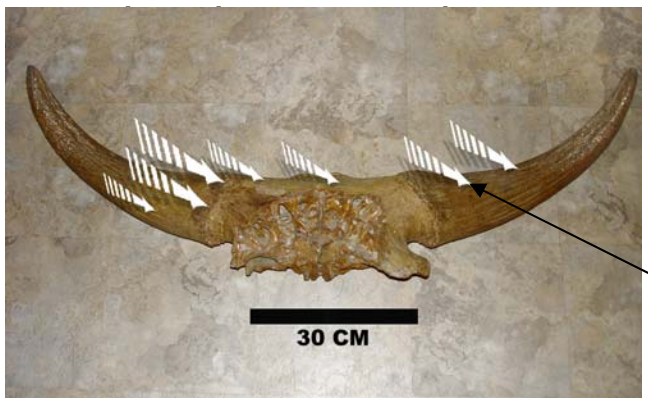
	(Ni/Fe)*	(Ti/Fe)*
Tusk 2	333	0.03
Tusk 3	190	0.003
Tusk 4	3	0.005
Tusk 5	22	0.005
Tusk 6	6	0.006
Bison	8.5	0.09
Average	94	0.02
Chondrite	51	0.02
Crustal	≡1	≡1

*Ratio to crustal ratio

PGAA Analysis of Bison Particle

Z	El	Wt(oxide)	±(%)
1	H	9.0%	*3.2*
5	B	7.4 ppm	*6*
6	C	36%	*5*
7	N	8.4%	*4.0*
9	F	10.4%	*5*
11	Na	0.34%	*5*
14	Si	0.35%	*13*
15	P	14.5%	*3.3*
16	S	0.33%	*9*
17	Cl	82 ppm	*5*
19	K	250 ppm	*20*
20	Ca	19.2%	*3.0*
22	Ti	120 ppm	*26*
23	V	150 ppm	*16*
24	Cr	0.08%	*14*
25	Mn	0.109%	*3.9*
26	Fe	1.01%	*4*
28	Ni	400 ppm	*18*

Mass of Fe=360 μg
Radius of micrometeorite ≈1 mm



Tusk micrometeorite with characteristic burn ring

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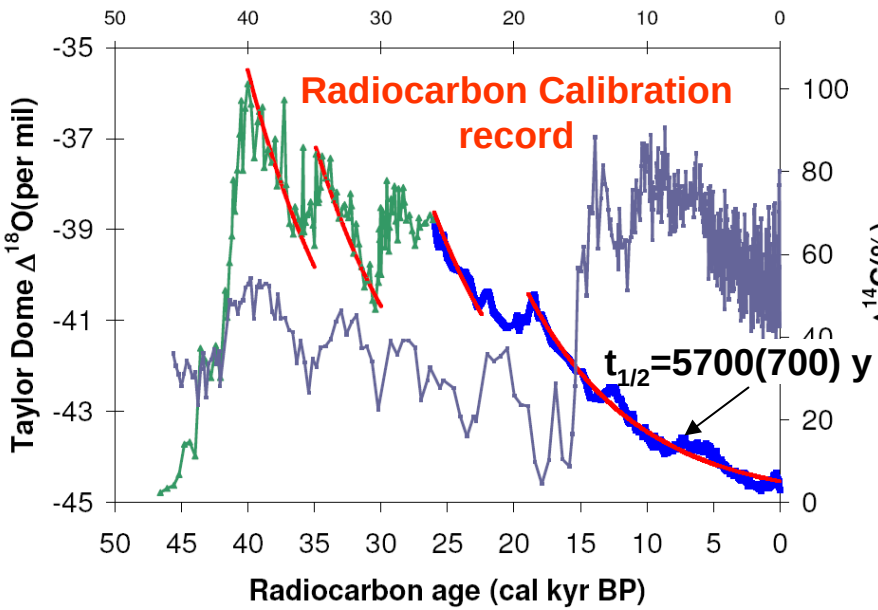
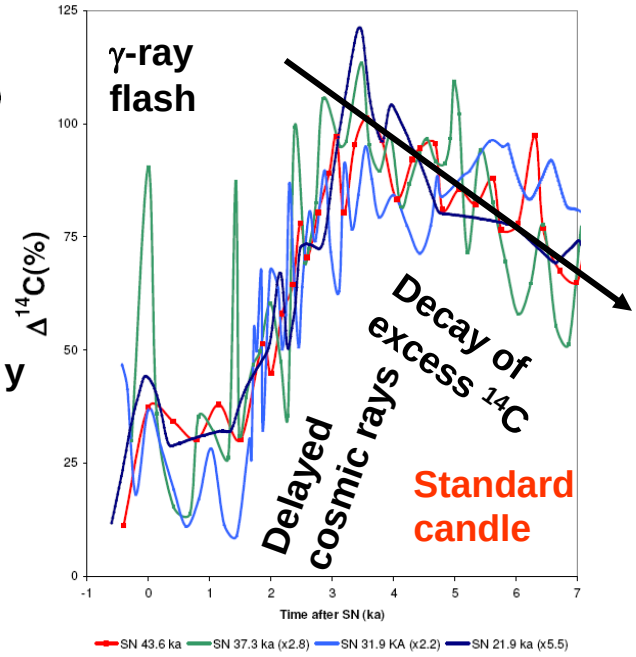
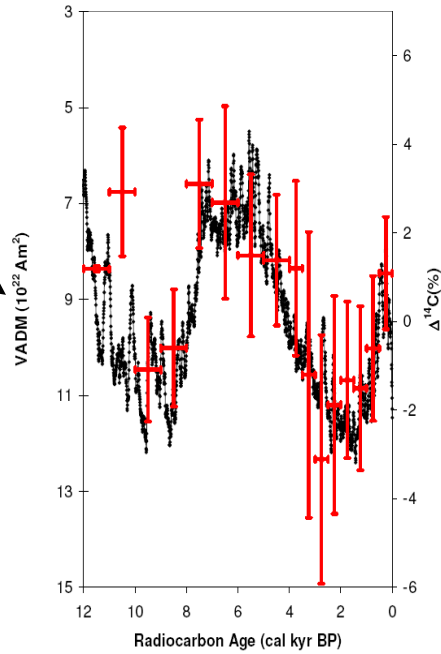
Discovery of 4 prehistoric near-Earth Supernovae







Date (kyr BP)	Distance* (PC)	$\Delta^{14}C_{\gamma}$ (%)	ΔNO_3^- (%)	$^{10}Be/^{9}Be$ $\times 10^{-6}$	$\Delta^{14}C_{max}$ (%)
44	≈110	26	21	1.2	100
37	≈180	19	14	3.4	36
32	≈160	7	6	2.4	45
22 (Vela SN)	≡250±30	6	9	2.2	18

Evidence of four prehistoric supernovae <250 pc from Earth during the past 50,000 years, R.B. Firestone, paper PP31D-1386, American Geophysical Union Fall Meeting, December 2009.

USNDP Meeting, Brookhaven National Laboratory, November 3-6, 2009

ENSDF Mass Chain Publications

R.B. Firestone, ***A=25***, Nuclear Data Sheets **110,** 1691 (2009).

C.M. Baglin, ***A=81***, Nuclear Data Sheets **109,** 2257 (2008).

D.M. Symochko, E. Browne, and J.K. Tuli, ***A=119***, Nuclear Data Sheets **110,** 2945 (2009).

E. Browne and J.K. Tuli, ***A=145***, Nuclear Data Sheets **110,** 507 (2009).

C.M. Baglin, ***A=179***, Nuclear Data Sheets **110,** 265 (2009).

E. Browne and J.K. Tuli, ***A=229***, Nuclear Data Sheets **109,** 2657 (2008).

B. Singh and E. Browne, ***A=240***, Nuclear Data Sheets **109,** 2439 (2008).

Research Publications

O. Helene*, ***Parametric analysis of discrepant sets of data, Nucl. Instrum. Meth. Phys. Res.*** **604**, 701-706.

R.E. Marrs, E.B. Norman, J.T. Burke, R.A. Macri, H.A. Shugart, E. Browne and A.R. Smith, ***Fission-product gamma-ray line pairs sensitive to fissile material and neutron energy,*** Nucl. Instrum. Meth. Phys. Res. **A592**, 463 (2008).

R.B. Firestone and A. West, ***Impacts, mega-tsunami, and other extraordinary claims****, GSA Today*, e13 (2008).

E.B. Norman, E. Browne, H.A. Shugart, T.H. Joshi, and R.B. Firestone, ***Evidence Against Correlations Between Nuclear Decay Rates and Earth-Sun Distance,*** Astroparticle Physics **31**, 135 (2009).

R.B. Firestone, A. West, Zs. Revay, J.T. Hagstrom, A. Smith, and S.S. Que Hee, ***Elemental Analysis of the Sediment, Magnetic Grains and Microspherules from the Younger Dryas Impact Layer,*** AGU Fall Meeting, 15-19 December 2008, San Francisco, CA, Paper PP13C-1472.

D.S. Caron, E. Browne, and E.B. Norman, ***PABS: A computer program to normalize emission probabilities and calculate realistic uncertainties,*** LBNL-77567 (2009).

* Visitor 2008.

Invited Talks

Prehistoric Cosmic Catastrophes and Environmental Change, R.B. Firestone, Budapest Neutron Centre, November, 2009.

Mammoths, Meteorites, and Supernovae, R.B. Firestone, Northern California Geological Society, Orinda CA, February 25, 2009.

Mammoths, Meteorites, and Supernovae, R.B. Firestone, Peninsula Geological Society, Palo Alto CA, March 10, 2009.

Mammoths, Meteorites, and Supernovae, R.B. Firestone, Contra Costa Mineral and Gem Society, Concord CA, April 13, 2009.

The Influence of Nuclear Structure on Statistical Decay Properties, R.B. Firestone, 2nd Workshop on Level Density and Gamma Strength, Oslo, 11-15 May 2009.

Supernovae, Meteorites, and the Death of the Mammoths, R.B. Firestone, Joint Meeting of the Nuclear Theory & Modeling Group and the Experimental Nuclear Physics Group, LLNL, September 17, 2009.