Elemental Analysis of Carbon Disks Using Proton Induced X-ray Emission

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$D_{ko} + T_{fuel} \rightarrow \alpha + n^{**}$

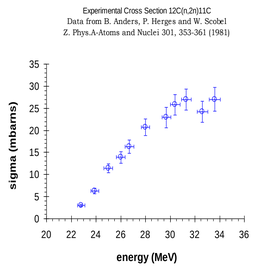
$n^{**} + {}^{12}C \rightarrow 2n + {}^{11}C$

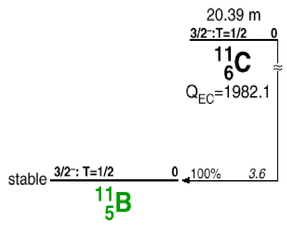
${}^{11}C \rightarrow {}^{11}B + e^{+}$

$e^{+} \rightarrow 2\,\gamma_{511KeV}$

Our Goal

To develop a fuel compression measurement using **tertiary neutrons** produced from an **ICF** "burn" which is:
-Sensitive to the fuel density-radius product $(\rho r)^2$
-Insensitive to **primary & scattered neutron**
-Robust, inexpensive, reusable and reliable

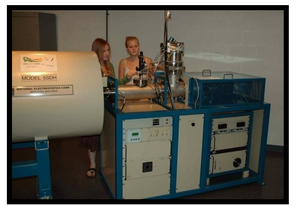




View of the 15 deg beam line on the 1.7 MV Tandem pelletron accelerator

View of the control room

Brand new 1.7 MV Tandem Pelletron accelerator



View of the source on the 1.7 MV Tandem Pelletron accelerator

Thermonuclear Reactions in a confined plasma

$D_{fuel} + T_{fuel} \rightarrow \alpha + n_{14.1\ MeV}$

All primary neutrons are 14.1 MeV

$n_{14.1\ MeV} + D_{fuel} \rightarrow n^{*} + D_{ko}$

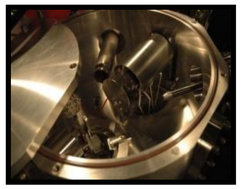
Producing 0 – 12.5 MeV knock-ons

$D_{ko} + T_{fuel} \rightarrow \alpha + n^{**}$

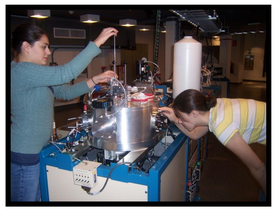
Producing 12 - 30 MeV tertiary neutron
The number of tertiary neutrons is related $(\rho r)^2$ or ρr

Motivation for using PIXE

To use proton induced x-ray emission (PIXE) as a technique for determining trace amounts of contaminant elements in the carbon disks used to measure the yield of tertiary neutrons.

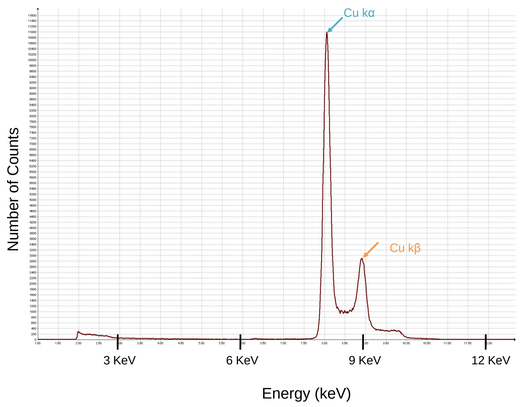


View of the inside of the target chamber

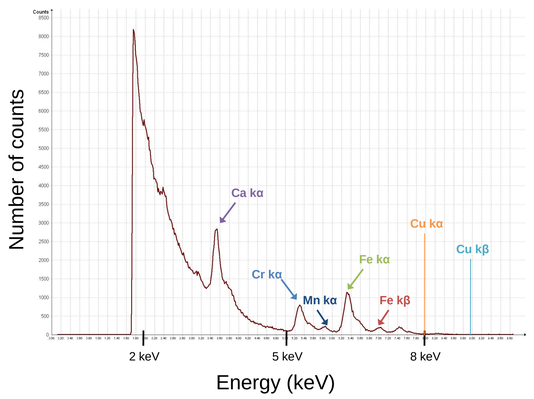


End station with PIXE detector

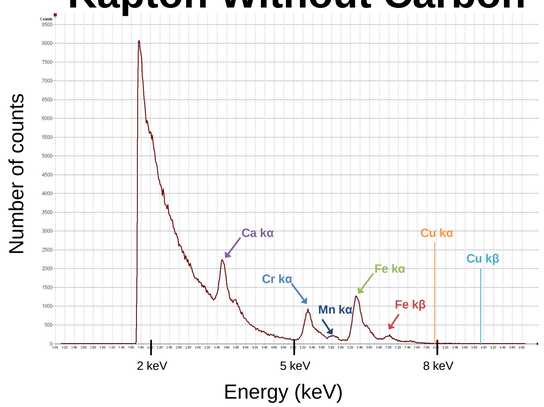
PIXE Spectrum of Copper for Calibration



PIXE Spectrum of Kapton With Carbon



PIXE Spectrum of Kapton Without Carbon



Predicted Neutron Yield

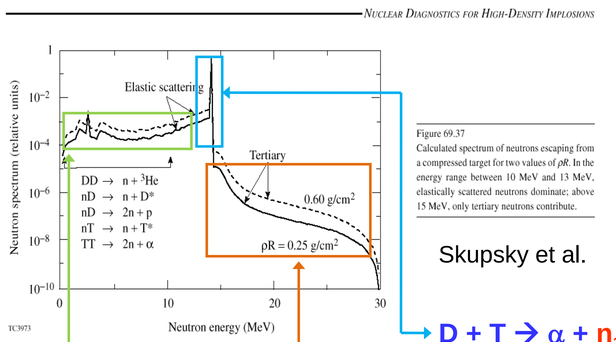


Figure 69.37
Calculated spectrum of neutrons escaping from a compressed target for two values of ρR. In the energy range between 10 MeV and 13 MeV, elastically scattered neutrons dominate; above 15 MeV, only tertiary neutrons contribute.

Skupsky et al.

$D + T \rightarrow \alpha + n_{14.1MeV}$ (primary)

$n_{14.1MeV} + D_{fuel} \rightarrow n^{*} + D_{ko}$

$D_{ko} + T_{fuel} \rightarrow \alpha + n^{**}$ (tertiary)

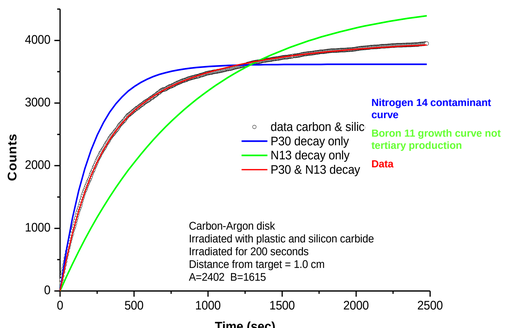
Trace Elements in Ultra Pure Graphite < 1ppm

Trace Element	Isotopic Abundance	MW (g)	Thermal Abs. Cross Section	Radioactive Isotope	Half-Life (min)	positron emitter
Mg-26	11.01%	24.305	3.60E-26	Mg-27	9.45	
Al-27	100.00%	26.98	2.33E-25	Al-28	2.25	
Si-30	3.10%	28.085	1.07E-25	Si-31	157.2	
S-36	0.02%	32.07	2.30E-25	S-37	5.05E+00	
S-34	4.21%	32.07	2.90E-25	S-35	1.26E+05	
Ca-48	0.19%	40.078	1.10E-24	Ca-49	8.72	
Ti-50	5.40%	47.88	1.77E-25	Ti-51	5.76	
V-51	99.75%	50.94	4.90E-24	V-52	3.76	
Cr-54	2.37%	51.996	3.60E-25	Cr-55	3.50E+00	
Cr-50	4.31%	51.996	1.58E-23	Cr-51	3.99E+04	e+
Mn-55	100.00%	54.93	1.33E-23	Mn-56	1.55E+02	
Fe-58	0.28%	55.847	1.20E-24	Fe-59	6.41E+04	
Ni-64	0.91%	58.69	1.52E-24	Ni-65	1.51E+02	
Ni-58	68.27%	58.69	4.60E-24	Ni-59	4.00E+10	e+
Cu-65	30.91%	63.546	2.17E-24	Cu-66	5.1	e+
Cu-63	69.09%	63.546	4.50E-24	Cu-64	7.62E+02	e+
Sn-122	4.63%	118.7	1.30E-25	Sn-123m	40.1	
Sn-124	5.79%	118.7	1.30E-25	Sn-125m	9.5	

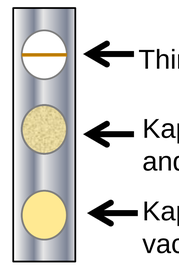
Carbon disk

View of the inside of the reaction chamber at LLE

Ultra pure graphite



Aluminum Target Holder and Targets



Plans for the Future

-Minimize contamination during carbon target preparation

-Precisely calibrate PIXE Energy spectrum

-Identify all contaminants in graphite sample

-Determine absolute contaminant levels in graphite