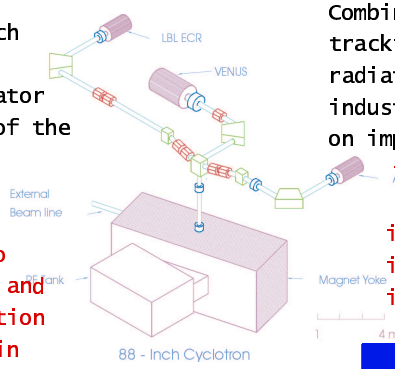
A Cyclotron-based Pulsed Fast-neutron Endstation for Research in Neutron-based Non-intrusive Inspection Techniques

The high-intensity light-ion (proton, deuteron) capabilities of the 88-Inch Cyclotron at LBNL make it an ideal candidate for generating monoenergetic beams of neutrons through deuteron breakup or (p,n) reactions. An Accelerator Improvement Project in the late 1990's successfully achieved a narrowing of the pulse width of the beam microstructure to 1-2 nanoseconds. [1]

We propose to build a multipurpose neutron facility at the Cyclotron. In DC mode the highest intensities would be available and could be used to measure (n,gamma) cross sections of interest to both nuclear astrophysics and stockpile stewardship, as well as for radiation effects testing and radiation biology. In pulsed mode, the facility would be used to make measurements in support of neutron-based non intrusive inspection techniques, in particular PFNA (nanosecond Pulsed Fast Neutron Analysis).

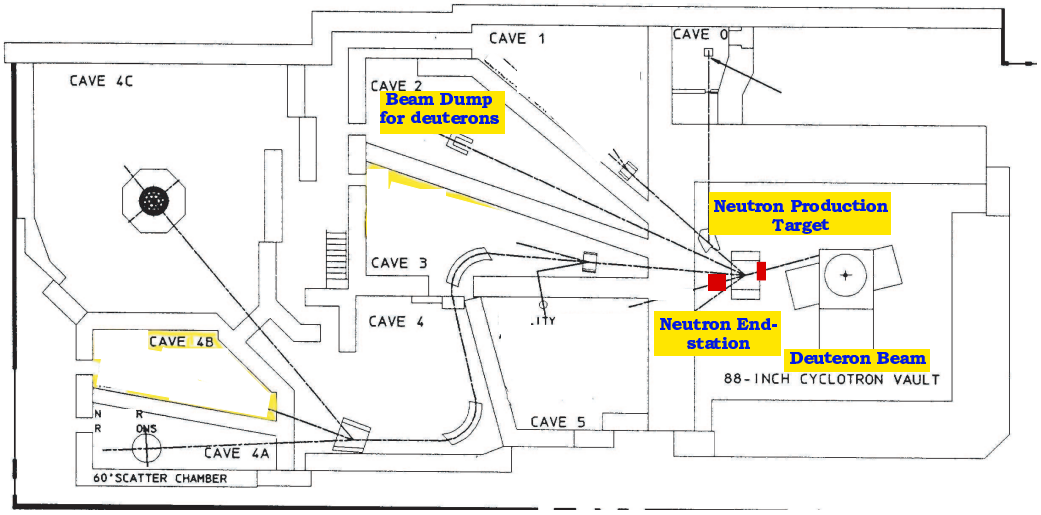


Combined with our local expertise in gamma-ray detection and tracking and our highly-reputed outside user program in radiation effects testing, we envision a facility at which industry and government can work together in studies focused on improving the sensitivity of neutron interrogation through:

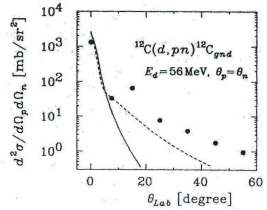
i) determination of the optimal energy for detection of the chemical elements and isotopes of interest,
ii) studies of different gamma-ray detection material,
iii) development of 3-dimensional imaging techniques, and
iv) minimizing long-lived activation products and radiation-induced damage to electronic components.

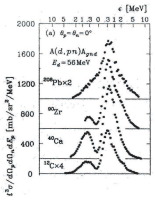
Properties of a neutron beam at the 88-Inch, generated in a deuteron breakup reaction:

DEUTERON BEAM: 1-65 MeV, 10 μA (1 μA at 1-2 nsec width)
PRODUCTION TARGET: 30 mg/cm^2 ^{12}C
NEUTRON BEAM: 0.5 - 33 MeV, 10^{11}/sec (10^{10} at 1-2 nsec)



Angular and Energy Distributions for 56 MeV deuterons [3]:



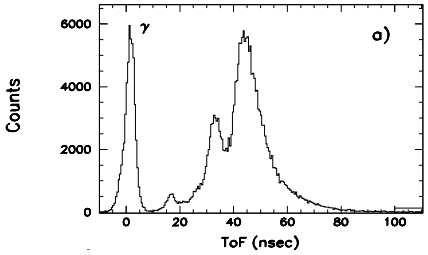


TIMING EXAMPLE: A deuteron beam of 28 MeV, with the pulse width reduced to 2 nsec, would produce 10 14 MeV neutrons/sec with a beam structure of 125 nsec between 2 nsec pulses. If desired, the time between pulses could be further reduced with the beam chopper, with an additional loss of intensity.

PROOF OF PRINCIPLE EXPERIMENT:

In 1996 pulsed low energy deuteron beams from the Cyclotron were used to measure (d,n) reactions for potential use in Boron Neutron Capture Therapy.[2] These experiments demonstrate the feasibility of using narrow pulse-width neutrons at the Cyclotron. For the example ^{13}C(d,n)^{14}N at a deuteron energy of 1.5 MeV, a TOF spectrum is shown below. The peaks in the TOF spectrum are associated with resonances in ^{14}N at 5.83, 5.32 and 2.31 MeV.

^{13}C(d,n)^{14}N, E_d = 1.5 MeV



REFERENCES:
1. "Phase width Reduction Project Summary", D.J. Clark, Z.Q. Xie and M.A. McMahan, LBNL-44339 Internal Report, Nov. 1999
2. "Measurements of low-energy (d,n) reactions for BNCT", N. Colonna, L. Beaulieu, L. Phair, G.J. Wozniak, L.G. Moretto, W.T. Chu and B.A. Ludewigt, Medical Physics 26, 793(1999)
3. "Strong evidence of the Coulomb-breakup of the deuteron at 56 MeV", H. Okamura, S. Hatori, N. Matsuoka, T. Noro, H. Sakai, H.M. Shimizu, K. Takesita, and T. Yamaya, Phys. Lett. B, 308 (1994).

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