Nuclear Data

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Medical Physics Working Group Meeting
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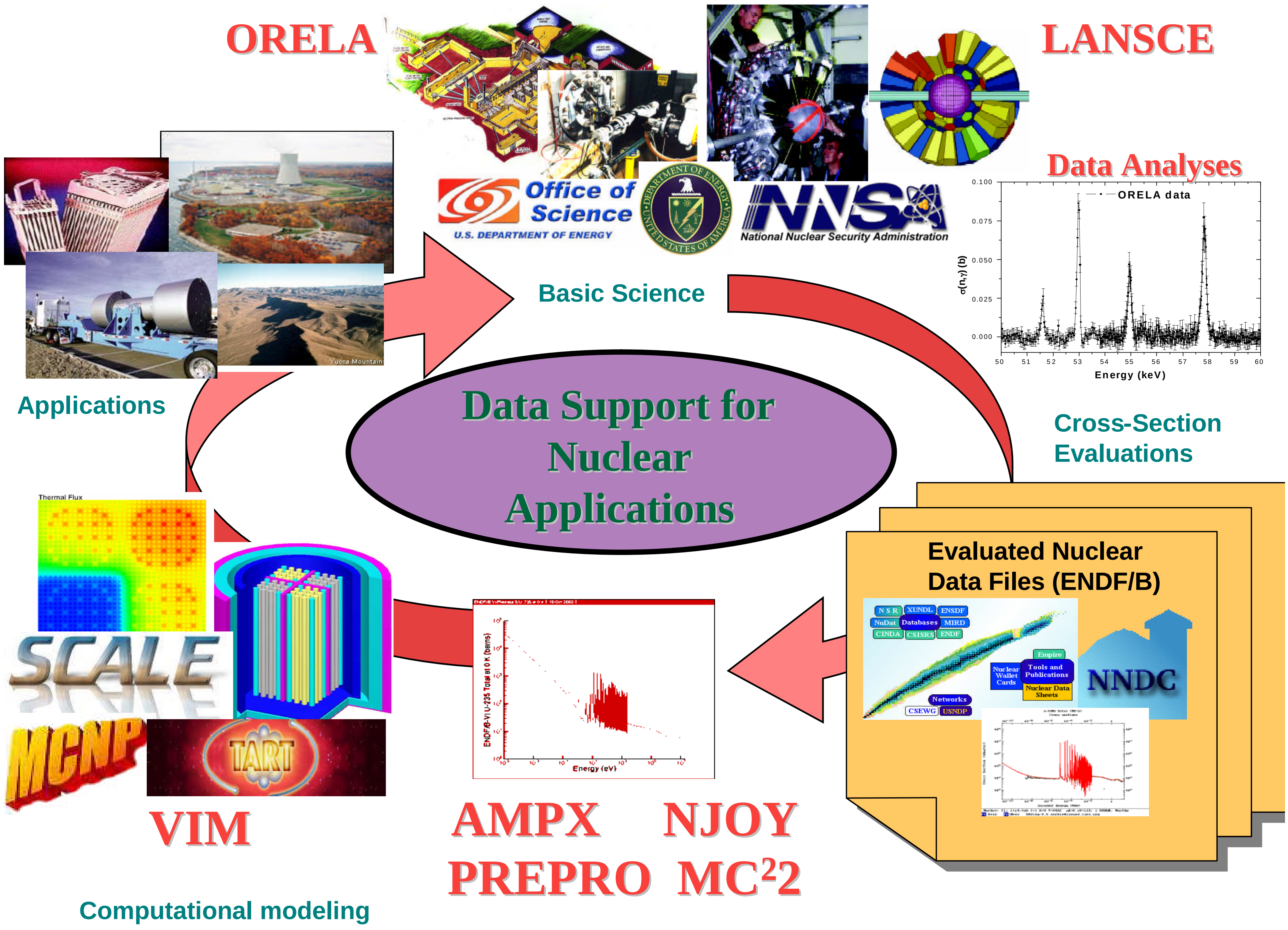

ORELA
LANSCE
Office of Science
U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration
Data Analyses
ORELA data
0.100
0.075
0.050
0.025
0.000
σ(n,γ) (b)
50 51 52 53 54 55 56 57 58 59 60
Energy (keV)
Basic Science
Applications
Yucca Mountain
Data Support for Nuclear Applications
Cross-Section Evaluations
Evaluated Nuclear Data Files (ENDF/B)
NSR
XUNDL
ENSDF
NuDat
Databases
MIRD
CINDA
CSISRS
ENDF
Empire
Nuclear Wallet Cards
Tools and Publications
Nuclear Data Sheets
Networks
CSEWG
USNDP
NNDC
Thermal Flux
SCALE
MCNP
TART
Energy (eV)
VIM
AMPX
NJOY
PREPRO
MC²2
Computational modeling

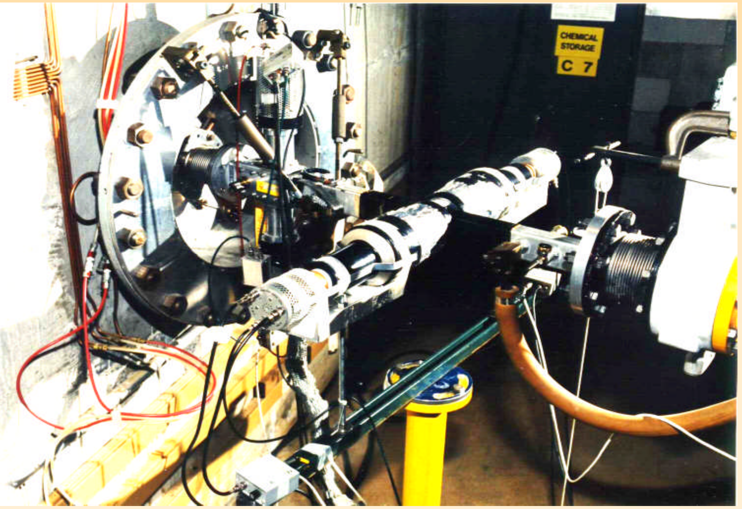
Cross Section Measurement Capabilities

Facility Parameters	United States				Europe	
	ORELA	LANSCE	IPNS	RPI	GELINA	n_TOF
Source	e^- linac	p spallation	p spallation	e^- linac	e^- linac	p spallation
Particle E (MeV)	140	800	450	>60	120	20000
Flight Path (m)	10-200	7-55	~6-20	10-250	8-400	185
Pulse Width (ns)	2-30	125	40	15-5000	1-2000	7
Max Power (kW)	50	64	6.3	>10	11	45
Rep Rate (Hz)	1-1000	20	30	1-500	Up to 900	0.278-0.42
Best Intrinsic Resolution (ns/m)	0.01	3.9	2.0	0.06	0.0025	0.034
Neutrons/s	1×10^{14}	7.5×10^{15}	8.1×10^{14}	4×10^{13}	3.2×10^{13}	8.1×10^{14}

ORELA Measurement Capabilities

- Unique measurement facility in U.S.
- High flux (10^{14} n/sec) => gram-sized, affordable samples
- Excellent resolution (Δt=4-30 ns) => good S/N facilitates better evaluations
- "White" neutron spectrum from E_n ~ 0.01 eV - 80 MeV => reduces systematic uncertainties
- Measurement systems well understood => very accurate data.
- Simultaneous measurements => (n,γ), (n,α), (n,n'), and σ_{total} experiments at the same time on different beam lines
- Electron, γ-ray, and neutron irradiations possible

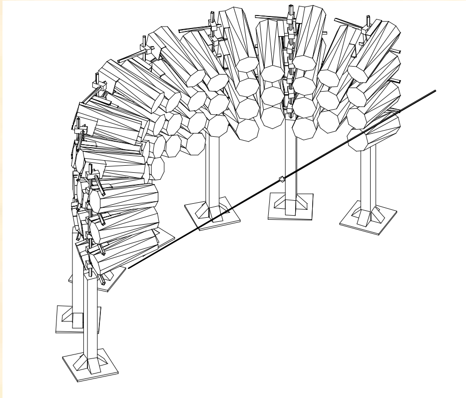
ORELA Accelerator



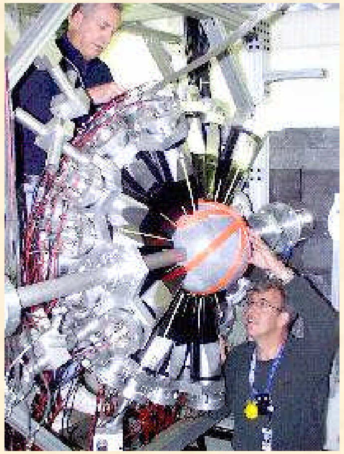
Selected LANSCE Measurement Capabilities

GEANIE (n,xγ)

FIGARO (n,xn+γ)



DANCE (n,γ)



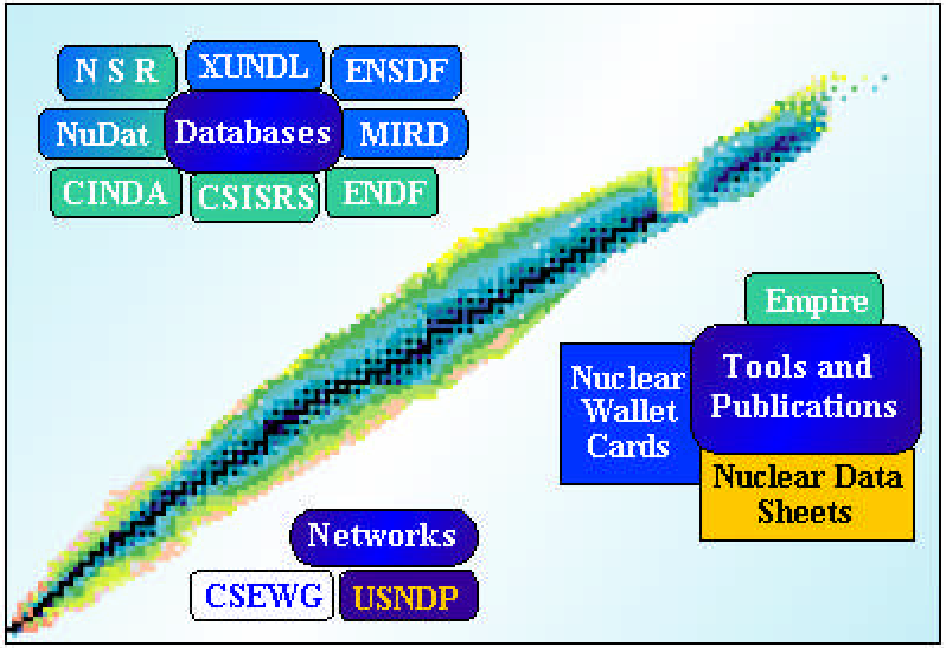
N,Z (n,charged particle)

Fission

Double Frisch-gridded fission chamber; also standard fission ion chamber

LSDS

Total cross sections



NNDC

National Nuclear Data Center

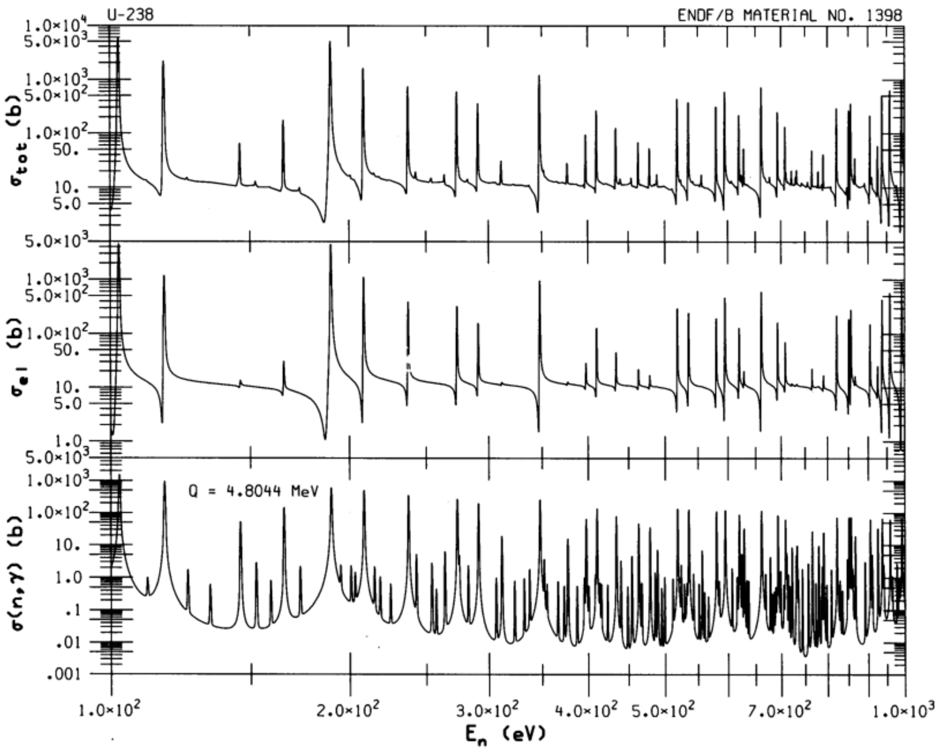
BROOKHAVEN NATIONAL LABORATORY

- Nuclear Structure and Decay Databases
- Nuclear Structure and Decay Tools
- Nuclear Reaction Databases
- Nuclear Reaction Tools
- Bibliography Databases
- Networks and Links
- About the Center
- Publications
- Meetings

http://www.nndc.bnl.gov/

- **Bibliography databases CINDA, NSR**
- **Experimental database CSISRS**
- **Evaluated database ENDF**

- **Atlas of Neutron Resonances (New)**
- **Nuclear Reaction Model Code Empire**



ENDF/B Data Overview

File (MF)	Description	File (MF)	Description
1	General Information	10	Cross Sections for the Production of Radioactive Nuclides
2	Resonance Parameters	11	General Comments of Photon Production
3	Neutron Cross Sections	12	Photon Production and Multiplicities and Transition Probability Arrays
4	Angular Dist. of Secondary Particles	13	Photon Production Cross Sections
5	Energy Dist. of Secondary Particles	14	Photon Angular Distributions
6	Coupled Energy-Angle Dist. of Secondary Particles	15	Continuous Photon Energy Spectra
7	$S(\alpha, \beta)$ Scattering Law Data	23	Photon Interaction Cross Sections
8	Radioactive Decay and Fission Product Data	27	Atomic Form Factors or Scattering Functions
9	Multiplicities for Production of Radioactive Nuclides	30 – 40	Data Covariance Files

Available ENDF/B Data

- ENDF/B-IV released 1975
- ENDF/B-V released 1979
- ENDF/B-VI released 1990
- ENDF/B-VII scheduled for release December 2005

ENDF/B-VI Release 7

Evaluation Type	Number*
Radioactive Decay / Photo-atomic Interaction Evaluations	1204
Incident Neutron Evaluations	520
Thermal S(α, β) Evaluations	21
Total	**1745**

*Includes Multiple Releases of Same Nuclide

Nuclear Data for Medical Applications

- Photon production and transport
  - Medical accelerator head converts electron beam into x-rays
    - transport electrons high-Z material
    - production of photons and transport in accelerator
  - Beam modifiers providing tailored beam to patient
  - Radiation transport within patient
- Electron
  - High-energy x-rays set electrons in motion and electrons deposit dose
  - transport—electron energy loss and angular deflections
  - Evaluated Electron Data Library (EEDL)—Z (1-100), interaction, energy loss, etc.
  - Available in ENDF/B-VI Release 8
- Proton
  - Incident proton evaluations available with ENDF/B-VI Release 6 and later
  - Evaluations based on GNASH model calculations and EDA R-matrix code calculations
- Photoneutron
  - Absorption of photon by nucleus excite number of resonances—GDR dominates energy range of interest for medical accelerators
  - Neutron generation in medical accelerators and materials in therapy facilities
  - Fairly comprehensive (γ, n) data available—prepared during 1994—2001 timeframe
    - IAEA photonuclear data library 188 nuclide evaluations
    - Contributors: LANL, KAERI, JAERI, CNDC, IPPE, and CDFE
- Neutron
  - Extensive database of measured and evaluated neutron transport and production data
  - Concentrated effort devoted to improving data and providing cross-section uncertainty data—important for sensitivity/uncertainty analyses

Radiation Dose resulting from Material Activation

- Work by Rawlinson, Islam, and Galbraith—*Med Phys, Vol 29, April 2002*
  - Varian Clinac 21 EX accelerator Princess Margaret Hospital, Toronto
  - Principle isotopes contributing to therapist dose in treatment room:

Isotope	Material source	Half-life	Reaction	Principle γ energies (keV)
^{28}Al	Treatment couch	2.3 m	$^{27}Al(n,\gamma)\ ^{28}Al$	1780
^{56}Mn	Steel	2.6 h	$^{55}Mn(n,\gamma)\ ^{56}Mn$	847, 1811, 2113
^{24}Na	Concrete	15 h	$^{23}Na(n,\gamma)\ ^{24}Na$	1369, 2754
^{122}Sb	Lead shielding in accelerator head and gantry	2.8 d	$^{121}Sb(n,\gamma)\ ^{122}Sb$	511, 564

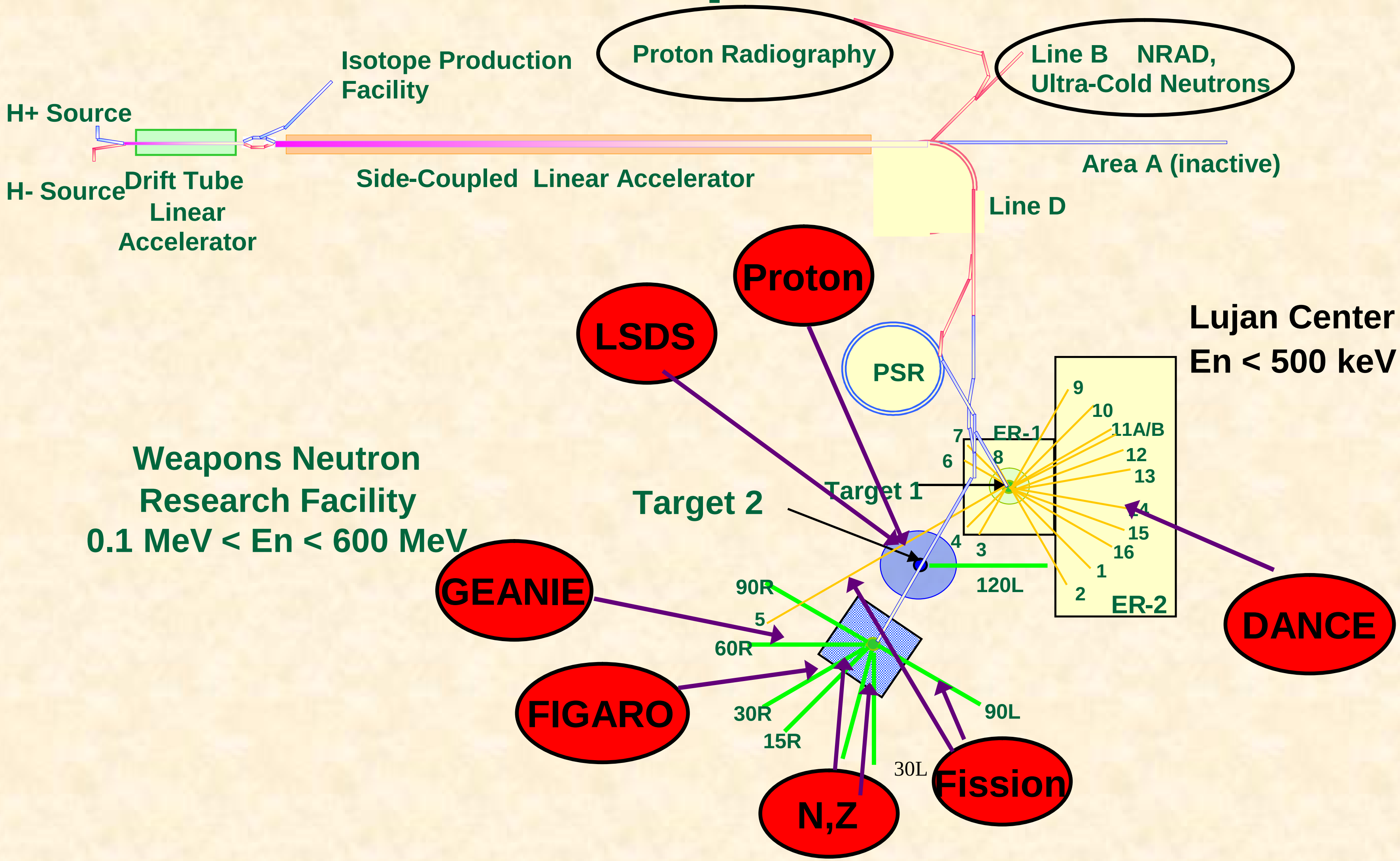
Radiation Dose resulting from Material Activation

- Study by Rawlison, et. al.
  - Importance of thermal (n, γ) reactions and cross-section data for modeling
  - High neutron capture materials anywhere in treatment room are potential sources
- Variation in facility construction/operation impact occupational dose
  - materials present—variation in concrete constituents
  - Types of treatment—IMRT, conventional radiation therapy
  - Amount of operation—number of treatments, duration, etc.
- Not sure that activation effects have been considered in treatment facility (room and equipment) design—may be changing with newer facility construction??

Nuclear Data Observations

- Effect of uncertainties in nuclear data and model parameters is not completely understood relative to the final calculated dose to the patient:
  - Uncertainties in cross-section data
  - Uncertainties in tissue composition and density
  - Uncertainties in accelerator design parameters
- What level of cross-section data accuracy needed for medical physics computational modeling?
  - Benchmark computational models & data against measurements at various treatment facilities
  - National laboratories have extensive experience in this type of work
- Sensitivity/uncertainty (S/U) analyses can be used to investigate impact of uncertainties on calculated quantities of interest
  - ORNL has developed S/U analysis tools based on adjoint perturbation theory
  - Primarily used for neutron transport
  - Recently performed S/U analyses for coupled neutron-gamma shield design work
- U.S. has integrated nuclear data program to respond to emerging application needs

LANSCE Measurement Capabilities



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