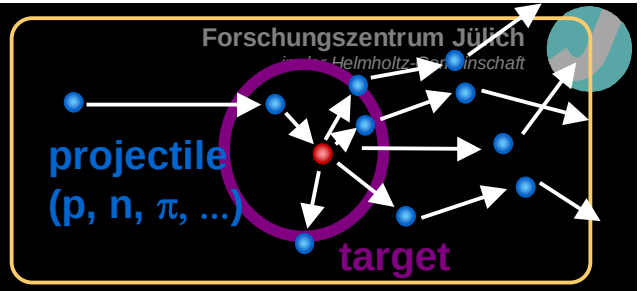
What is Spallation ???



Definition found in Nuclear Physics Academic press:

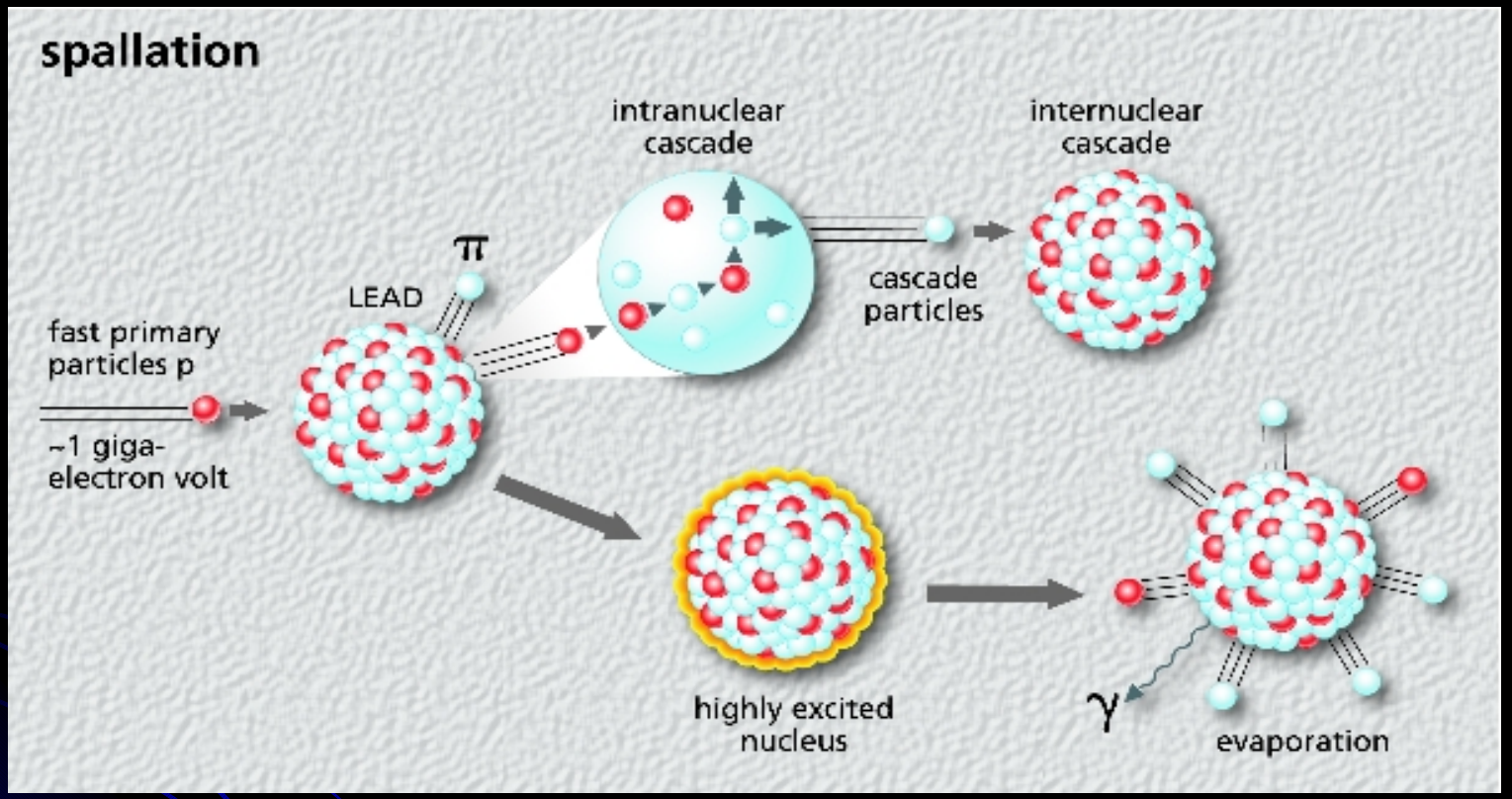
"Spallation---a type of nuclear reaction in which the high-energy level of incident particles causes the nucleus to eject more than three particles, thus changing both its mass number and its atomic number."

Definition (Encyclopedia Britannica): "high-energy nuclear reaction in which a target nucleus struck by an incident (bombarding) particle of energy greater than about 50 million electron volts (MeV) ejects numerous lighter particles and becomes a product nucleus correspondingly lighter than the original nucleus. The light ejected particles may be neutrons, protons, or various composite particles equivalent…"

*has to be specified in the context of accelerator driven systems or high intense neutron sources. Here spallation is the disintegration of a nucleus by means of high energetic proton induced reactions. Typically approximately 20 neutrons are created per incident GeV proton.

- Nonelastic nuclear interaction induced by a high energy particle (> 50 MeV) producing numerous secondary particles.

The Spallation Process (1)



- High energy hadron causing an intra-NC on a time scale ≈10^{-22}s
- secondary particles (n,p,π) themselves produce secondaries creating an inter-NC placing many individual nuclei into highly excited states
- Release energy by evaporating n, p, d, t, α, γ… on a time scale ≈ 10^{-18} 10^{-16}s

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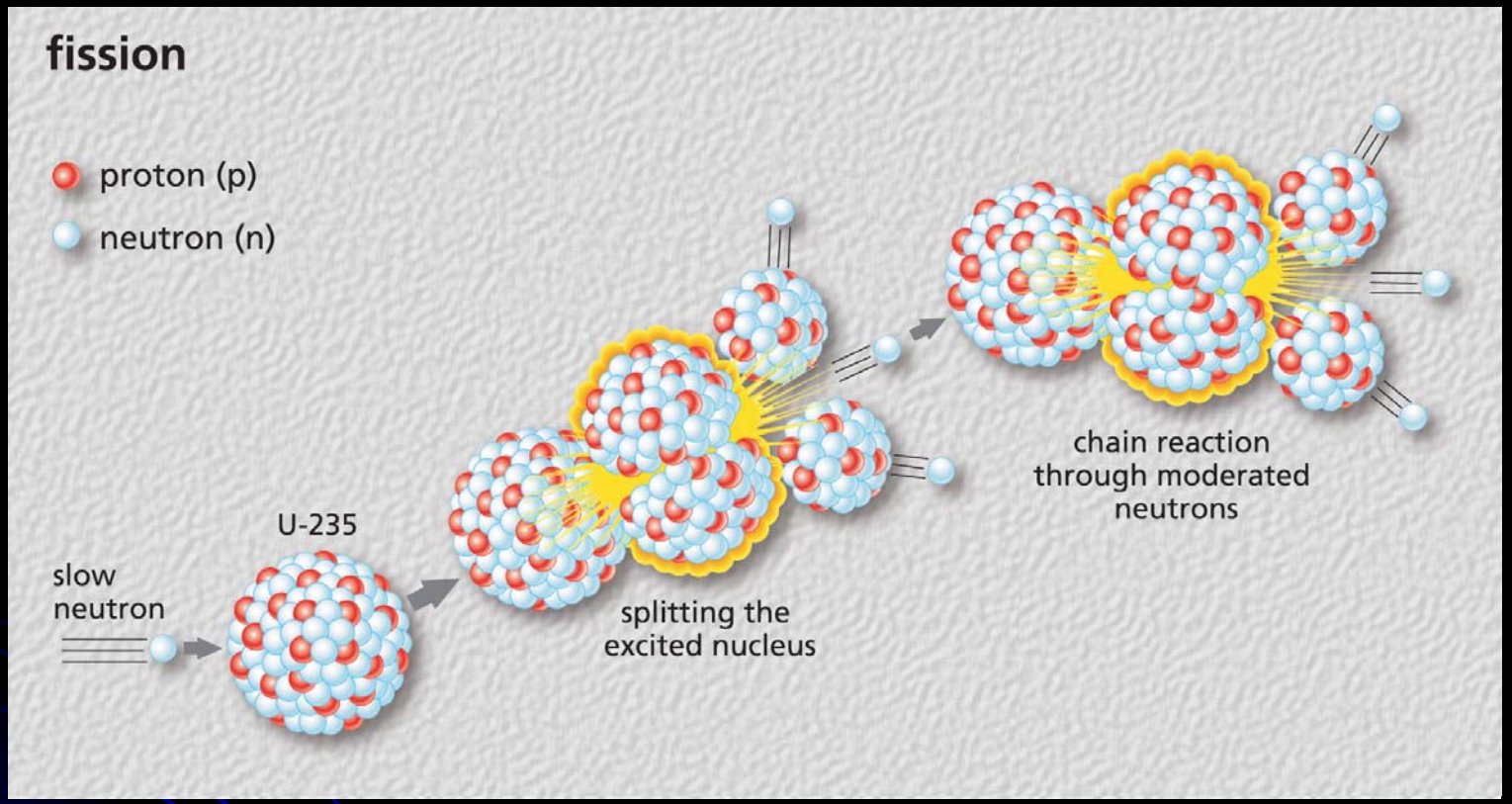

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The Spallation Process (2)

inelastic interaction of a high energy hadron striking a nucleus of the material approaches the geometrical cross section of the nucleus.

review on interaction cross sections σ suggests for hadron energies larger 120 MeV empirical dependence $\sigma = 42A^{0.7} \times 10^{-27}[cm^2]$, A atomic number of target nucleus. Mean free path length (interaction length, nuclear collision length) $\lambda = A/(N\sigma)$, N Avogadro number. $\Rightarrow \lambda = 40 \times A^{0.3}\ \mathrm{g/cm^2}$

spallation processes are endothermic; incoming cp energy taken up as neutron separating and kinetic energy; up to about 1~GeV linear relation between total neutron production yield and proton energy; at higher p-beam energies π^0 production--``electromagnetic drain''; rapid decay (half-life 10^{-16}s) does not allow π^0 to take part in INC, although the π^+, π^- do; π^+, π^- decay time (26ns) sufficiently long to allow for further hadronic interactions. At still higher energies, well above 10GeV, other meson production channels open up which in addition deplete the cascade of energy

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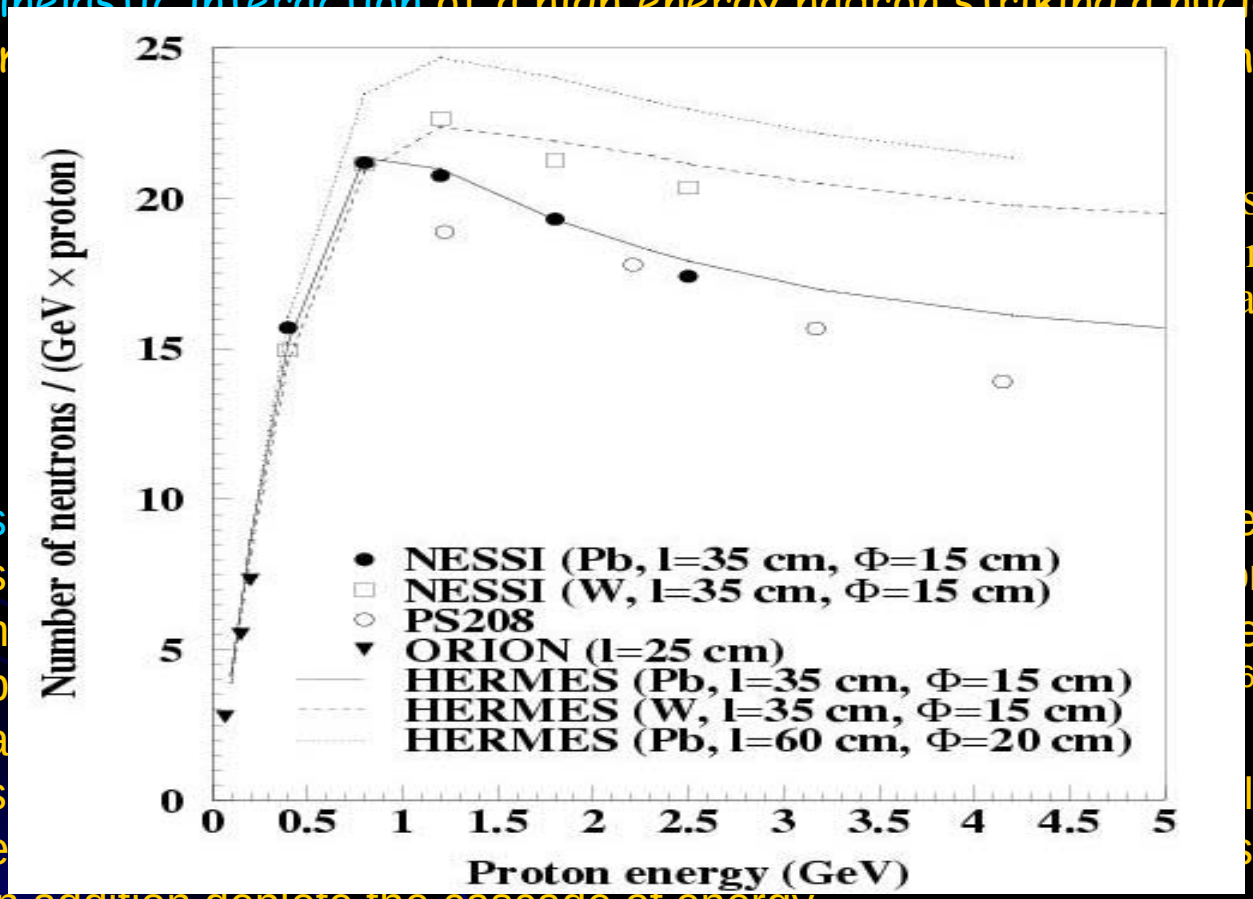

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Generalities

1947: E.O. Lawrence discovers that the number of emitted nucleons, especially neutrons, may be quite large depending upon the conditions of the spallation reaction.

90's: new interest for spallation reactions → they are of pivotal importance for the development of powerful neutron sources for various purposes:

- hybrid systems, be devoted to energy production or to incineration of nuclear wastes
- so-called multi-purpose spallation sources devoted to irradiation studies, material structure analysis, …
- future tritium production units

Other interest: the production of isotopes → spectroscopy
→ reaction mechanisms
→ astrophysics

Main aspects: • energy spectrum and angular distribution of emitted light particles
• production rate of residues

Spallation Sources

European Spallation Source (ESS) – EU → *http://www.neutron-eu.net/en/index.php*
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Spallation Neutron Source (SNS) – Japan → *http://jkj.tokai.jaeri.go.jp/*
(2007)

Spallation Neutron Source (SNS) – USA → *http://www.sns.gov*
(2006!)

Applications:

- chemistry
- complex fluids
- crystalline materials
- disordered materials
- engineering
- magnetism and superconductivity
- polymers
- ....

Note: a proton of 1 GeV on Pb target with a thickness of 60 cm produces about 25 neutrons!