(γ,*x*n) Cross Section measurements at ALBA's γ-Ray Beam Line

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Needs for photonuclear data (i)

Photonuclear reaction data are important for understanding both the structure of nuclei and nuclear reaction mechanisms. In addition, they are needed for a variety of current or emerging applications:

Radiation shielding design, dose calculations, physics and technology of fission reactors, activation analyses, safeguard and inspection technologies, nuclear waste transmutation and astrophysical nucleosynthesis.

There is a wide list of materials for which photonuclear data are needed (IAEA - *Handbook on photonuclear data for applications*)

•Structural, shielding (**for example the beam dump of our beam line**) and bremsstrahlung target materials

Be, Al, Si, Ti, V, Cr, Fe, Co, Ni, Cu, Zn, Zr, Mo, Sn, Ta, W, Pb

•Biological materials

C, N, O, Na, S, P, Cl, Ca

•Fissionable materials

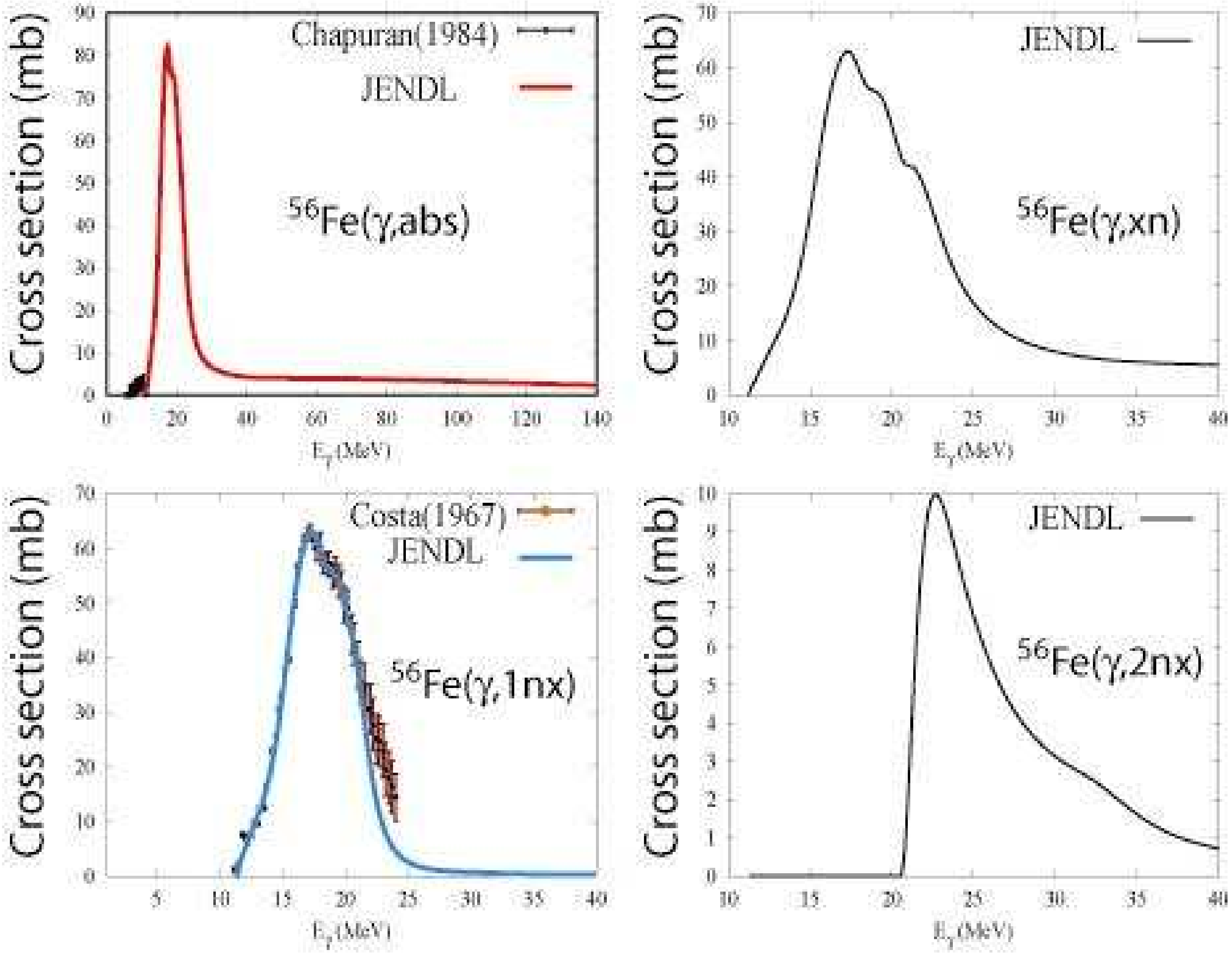
Th, U, Np, Pu

•Other materials

H, K, Ge, Sr, Nb, Pd, Ag, Cd, Sb, Te, I, Cs, Sm, Tb

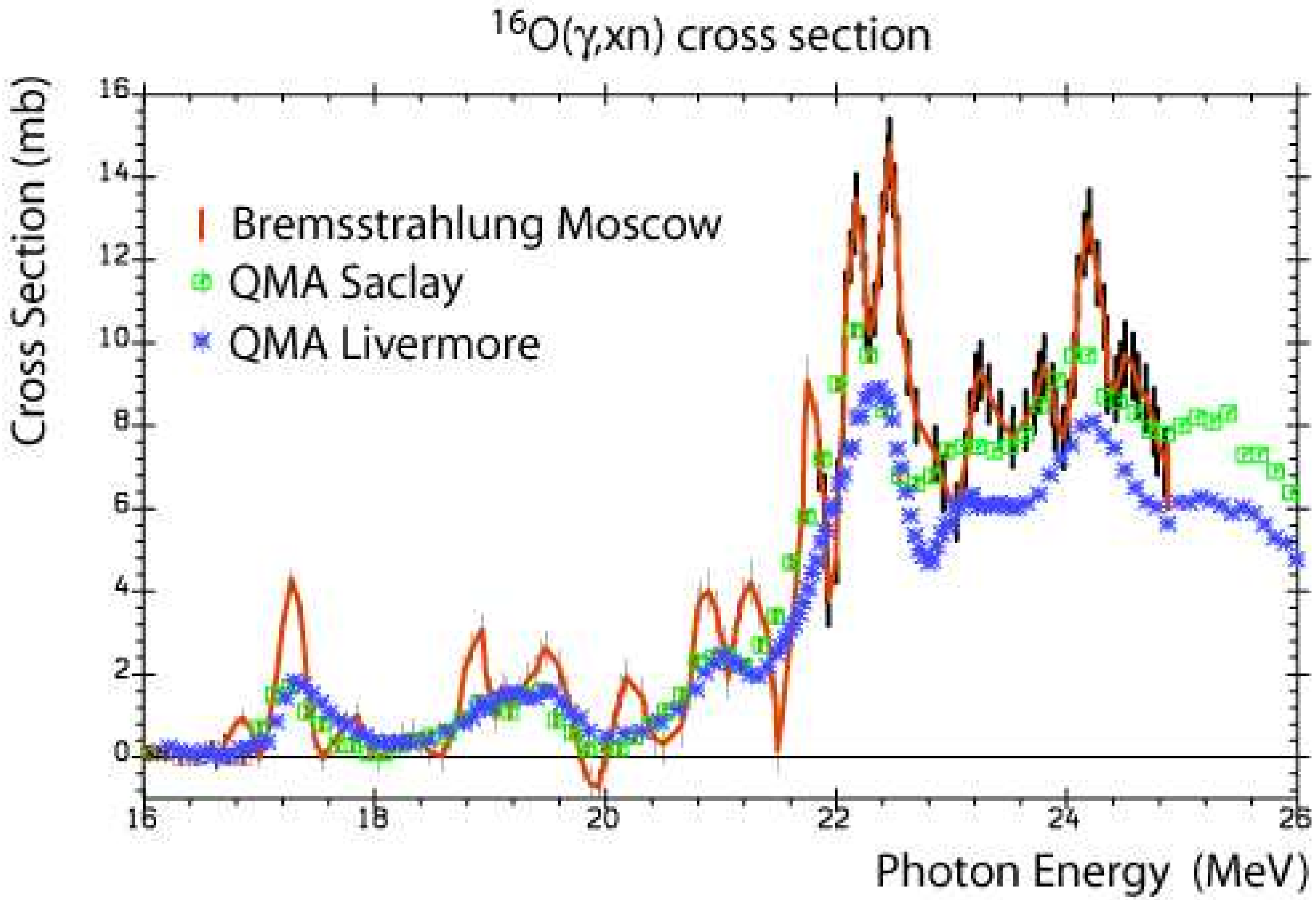
Needs for photonuclear data (ii)

Photonuclear data are scarce, even for common materials.

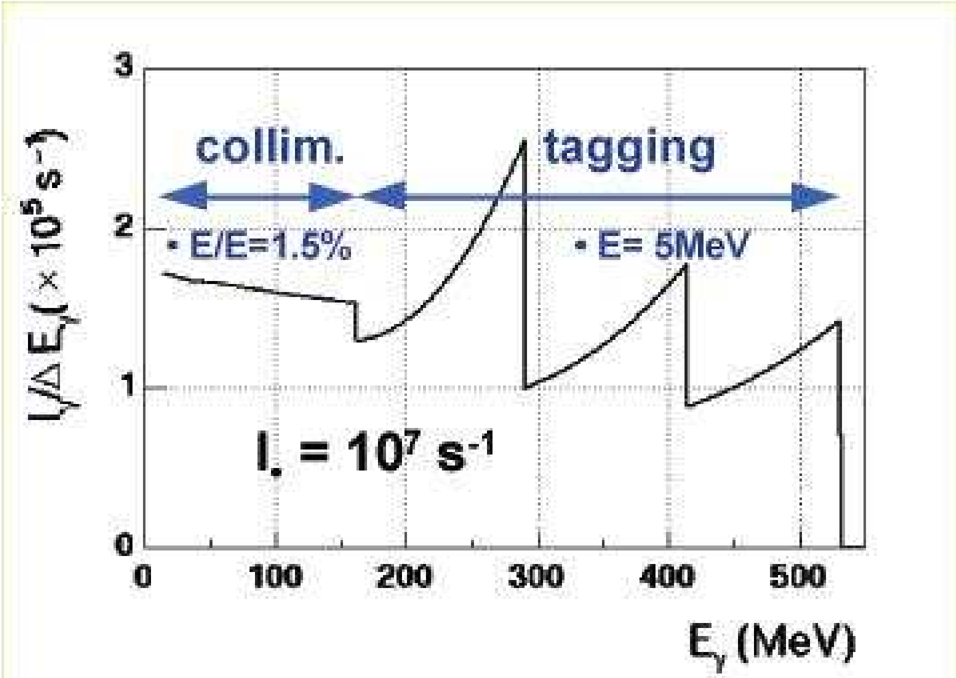


Accuracy of photonuclear data

Photonuclear (γ,*x*n) cross sections measured at Bremsstrahlung and Quasi Monoenergetic Annihilation facilities show systematic differences, mainly due to the non-monochromaticity of the QMA γ–beam (*Ishkhanov et al*). Data from ALBA-like γ–ray sources suffer of less systematic uncertainties.



Main characteristics of ALBA's γ-Ray Beam Line



15 MeV < E_γ < 150 MeV

Monochromatic beams due to collimation. Pointwise cross section measurements by tuning the laser energy. Determination of the neutron energy by spectroscopic information.

E_γ > 150 MeV

Tagging technique. Determination of the neutron energy by TOF + spectroscopic information.

The GDR maximum is within this γ energy range for the lighter nuclei (Cu).

Future Improvements

•In 5 years from now, a more advanced laser system (OPO) could extend the range of the monochromatic beams to lower energies.

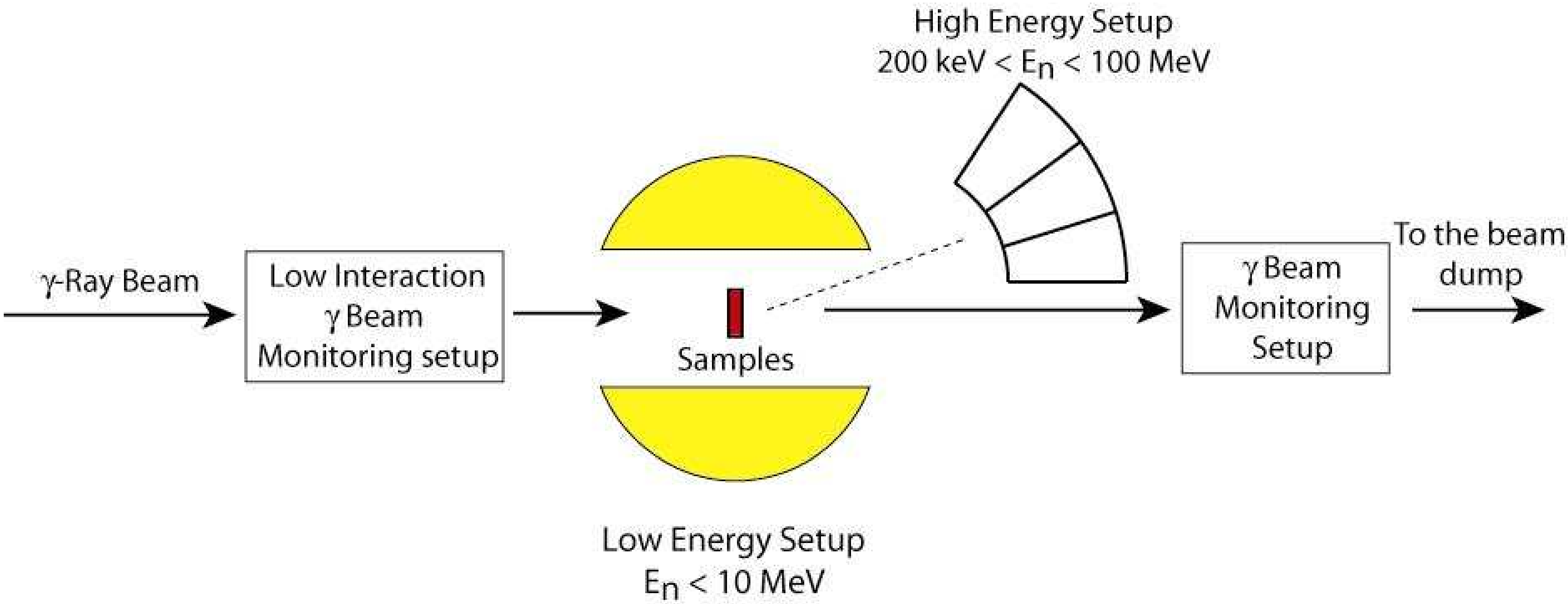
•Build a Free Electron Laser. Very interesting possibilty!!!

(γ,*x*n) Cross Section Measurement Setup

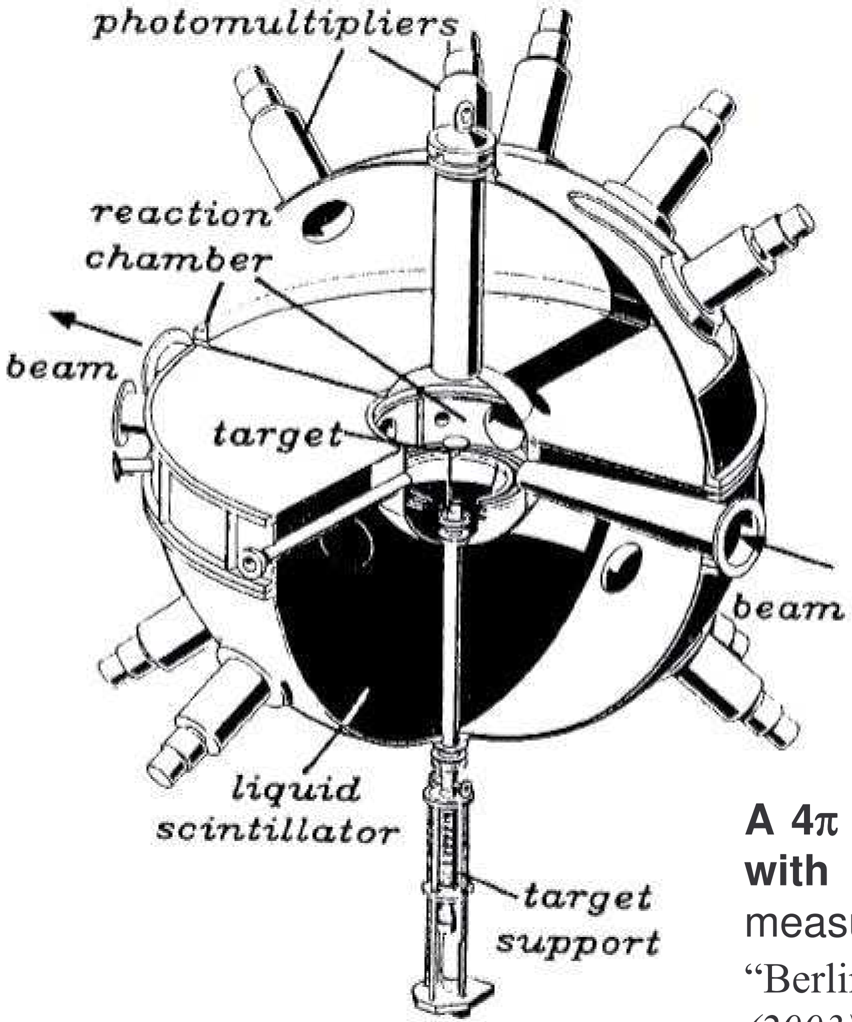
Different detection techniques depending on the neutron energy range and gamma ray beam energy:

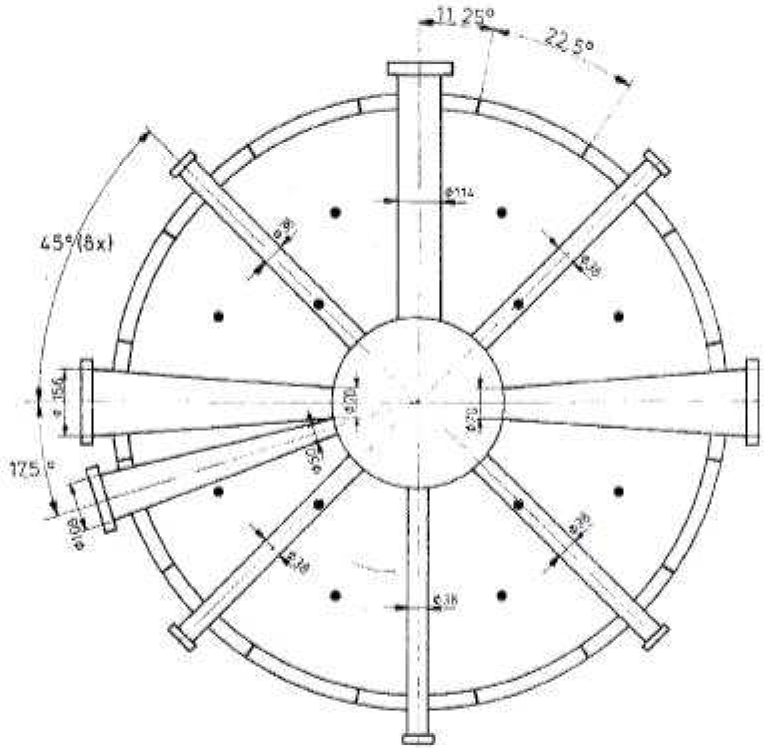
•Multiplicity measurements / neutron moderation + conversion

•Multiplicity measurements / TOF (if γ-ray tagging is available)



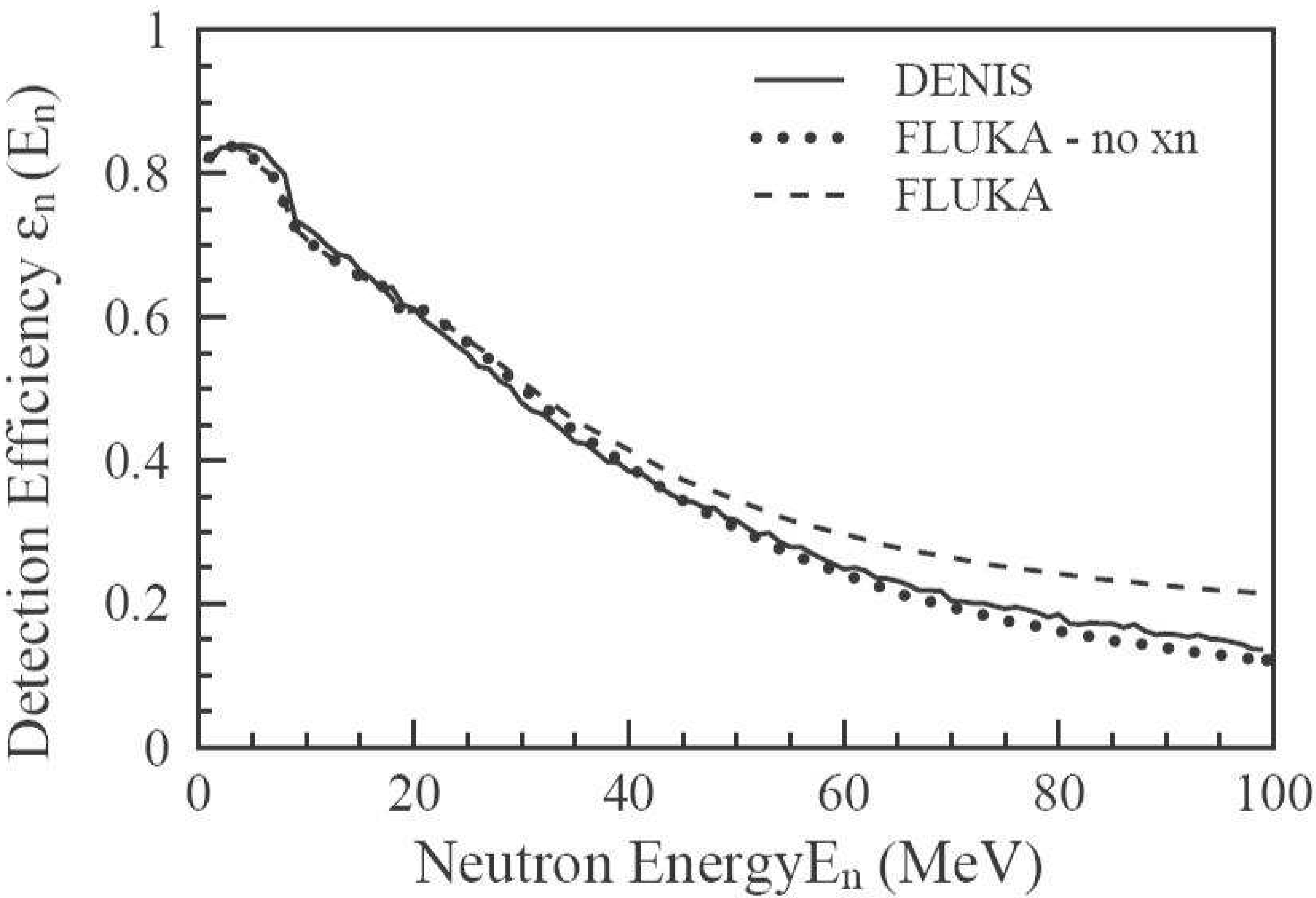
Low Energy Setup (E_n < 10 MeV)

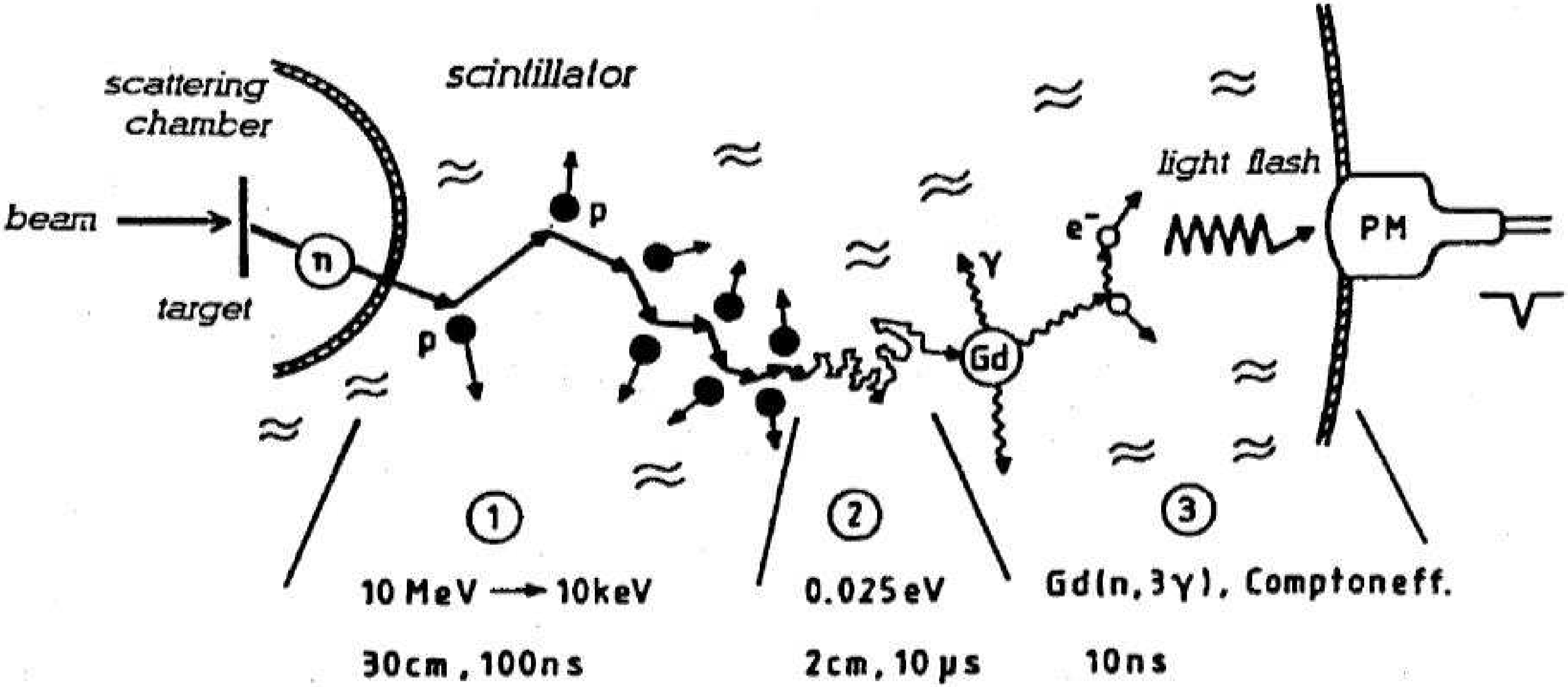




A 4π liquid scintillator (NE343) detector loaded with Gd (0.4% wt) for neutron multiplicity measurements up to 100 MeV (20% eff).

"Berlin Neutron Ball" *U. Jahnke et al, NIMA 508 (2003) 295 - 314*

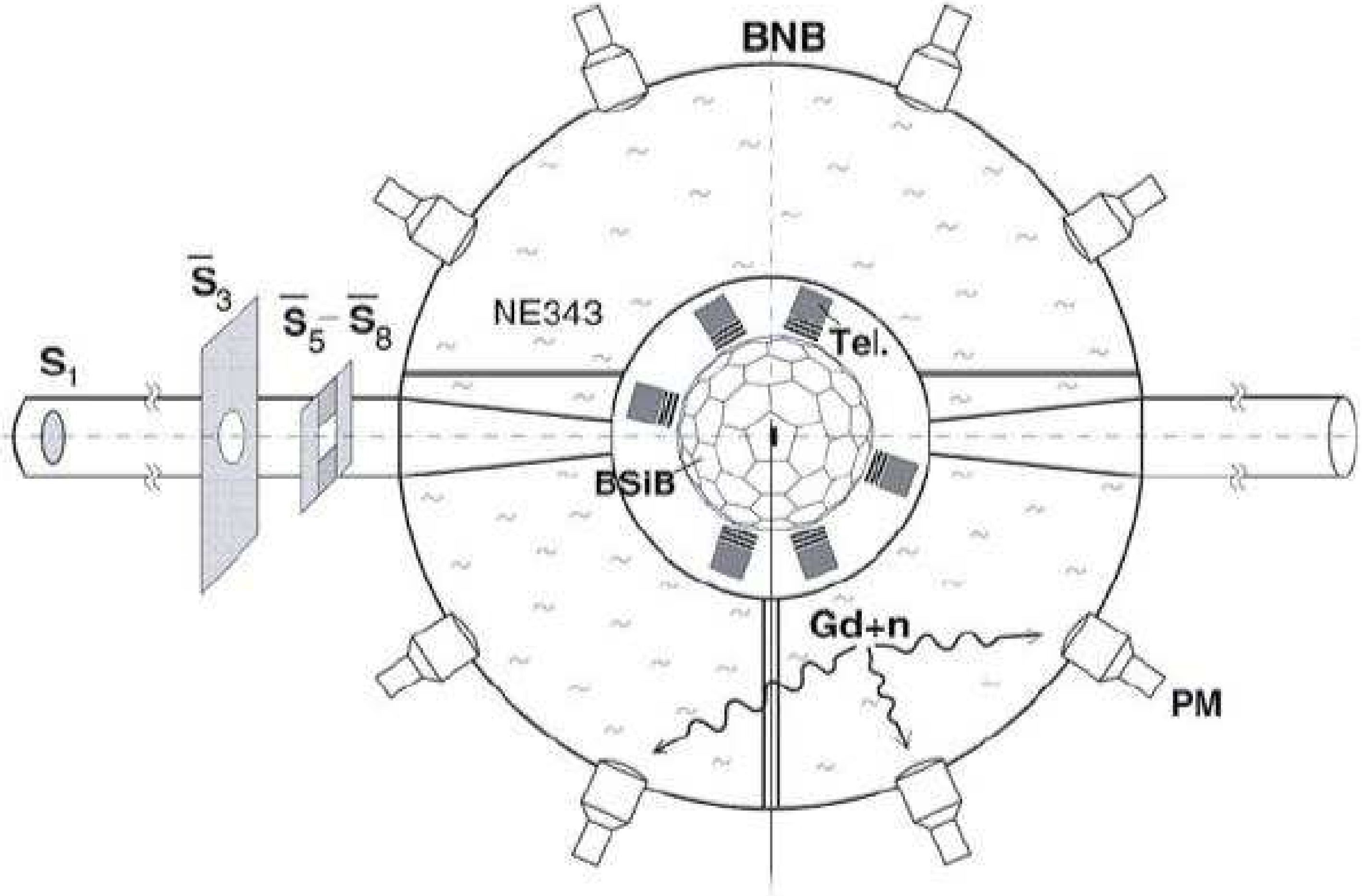

Detection Efficiency εn (En)
Neutron EnergyEn (MeV)
DENIS
FLUKA - no xn
FLUKA
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100

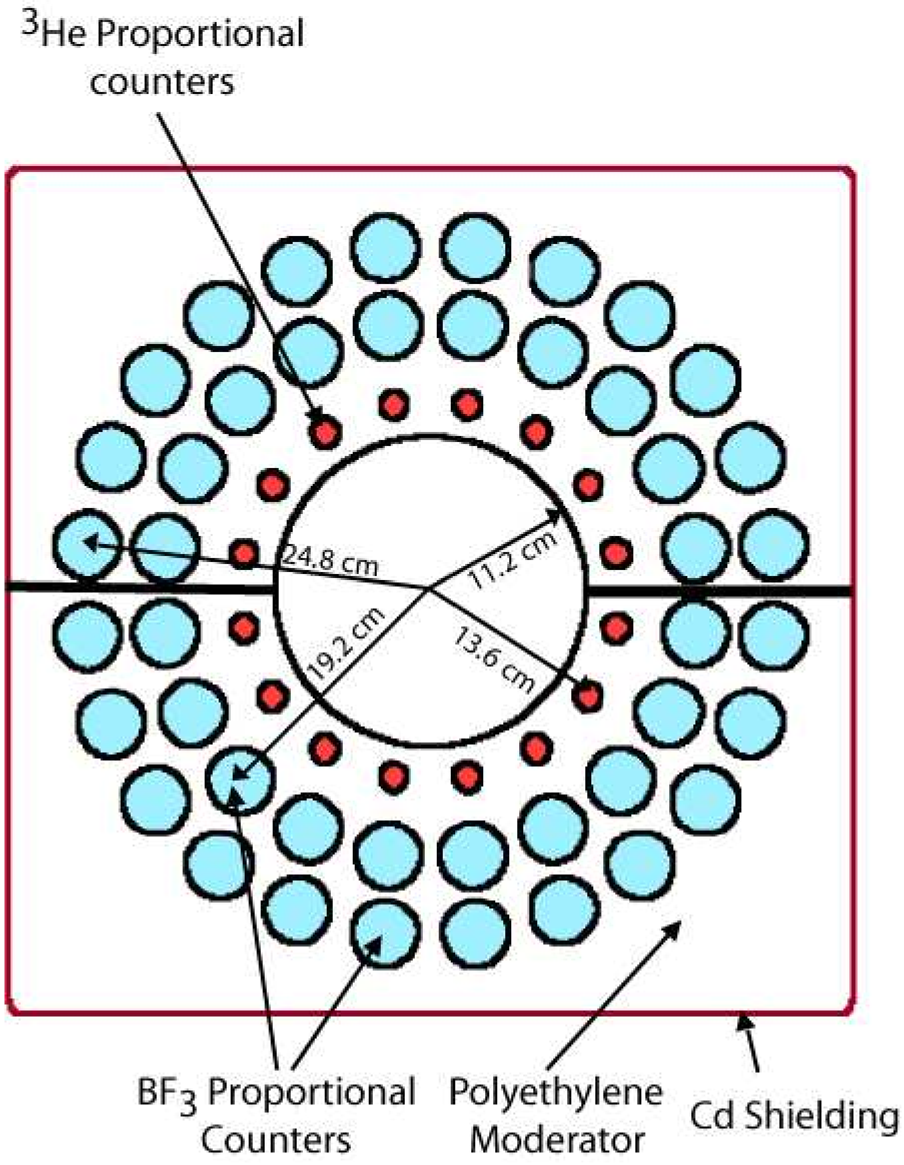


Is it the best kind of detector in a gamma ray environment? Calculate the sensitivity to scattered γ-rays by Monte Carlo simulation.

Such a detector can be operated in combination of a 4π detector for charged particle detection.

"Berlin Silicon Ball" **BSiB** *C.M Herbach et al, NIMA 508 (2003) 315 - 336*





Array of ^{3}He + BF_3 counters embedded in neutron moderator.

•Neutron multiplicity analysis

•Neutron energy analysis ??

•Presumably lower sensitivity to scattered γ-rays.

"NSCL - MSU" Low energy neutron detector *Schatz et al.*

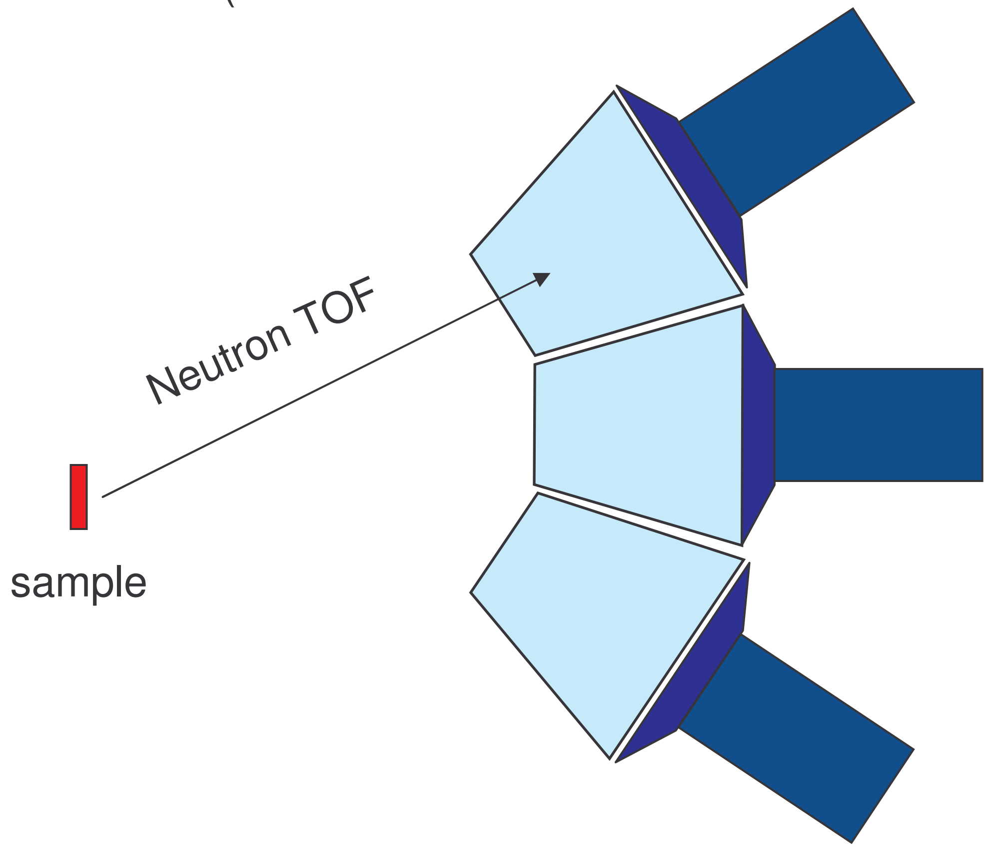
Both detection systems have slow time response (~100 μs), which means that the reaction rate has to be kept low < 10^4 r/s.

High Energy Setup (200 keV < E_n < 100 MeV)

Array of liquid scintillators

•neutron multiplicity analysis due to its segmentation

•neutron energy analysis due to TOF (7 ns/m at 100 MeV or 700 ns/m at 10 keV)



A “very” simplified beam time estimate!

For a moderation based neutron detector : $\tau_{moderation} \sim$ 100µs 🗁 Reaction Rate < $10^3 - 10^4$ s^{-1}

n[at/b] ☼ RR/($I_\gamma \cdot \sigma$) = 10^3 s^{-1}/(10^6 $\gamma s^{-1} \cdot 10^{-3}$ b) = 1 (~ 100mg – 1g of ^{27}Al)

For a TOF based neutron detector : largest TOF ~ 1µs 🗁 Reaction Rate < $10^5 - 10^6$ s^{-1}

n[at/b] ☼ RR/($I_\gamma \cdot \sigma$) = 10^5 s^{-1}/(10^6 $\gamma s^{-1} \cdot 10^{-3}$ b) = 100 (~ 10g – 100g of ^{27}Al)

Assuming detection efficiencies 1% < ε < 10 % 🗁 measurements will extend over a reasonable period of time (days or week)

Summary and conclusions

•There is a need for accurate photonuclear data (IAEA).

•Available photonuclear data are scarce.

•For many cases, there exist severe systematic differences between data sets obtained by different techniques: Bremsstrahlung versus Quasi Monochromatic Annihilation sources.Such problems can be attributed to the non-monochromaticity of the γ-beams.

•The γ-ray beam line at ALBA would be a "true" monochromatic source.

•The energy range between 15 MeV and 500 MeV is covered with a laser system available at present time. Such energy range includes the GDR of light nuclei (up to Cu). Future developments or the use of a Free Electro Laser would extend the energy range.

•(γ,*x*n) cross section measurements can be performed at ALBA's γ-ray beam line by means of two different kind of neutron detectors: 4π moderation based detectors (scintillator tanks or ^{3}He + BF_3 counters) or recoil based liquid scintillators.