# NIST Nuclear Data Standards Measurements Including other Standards Activity

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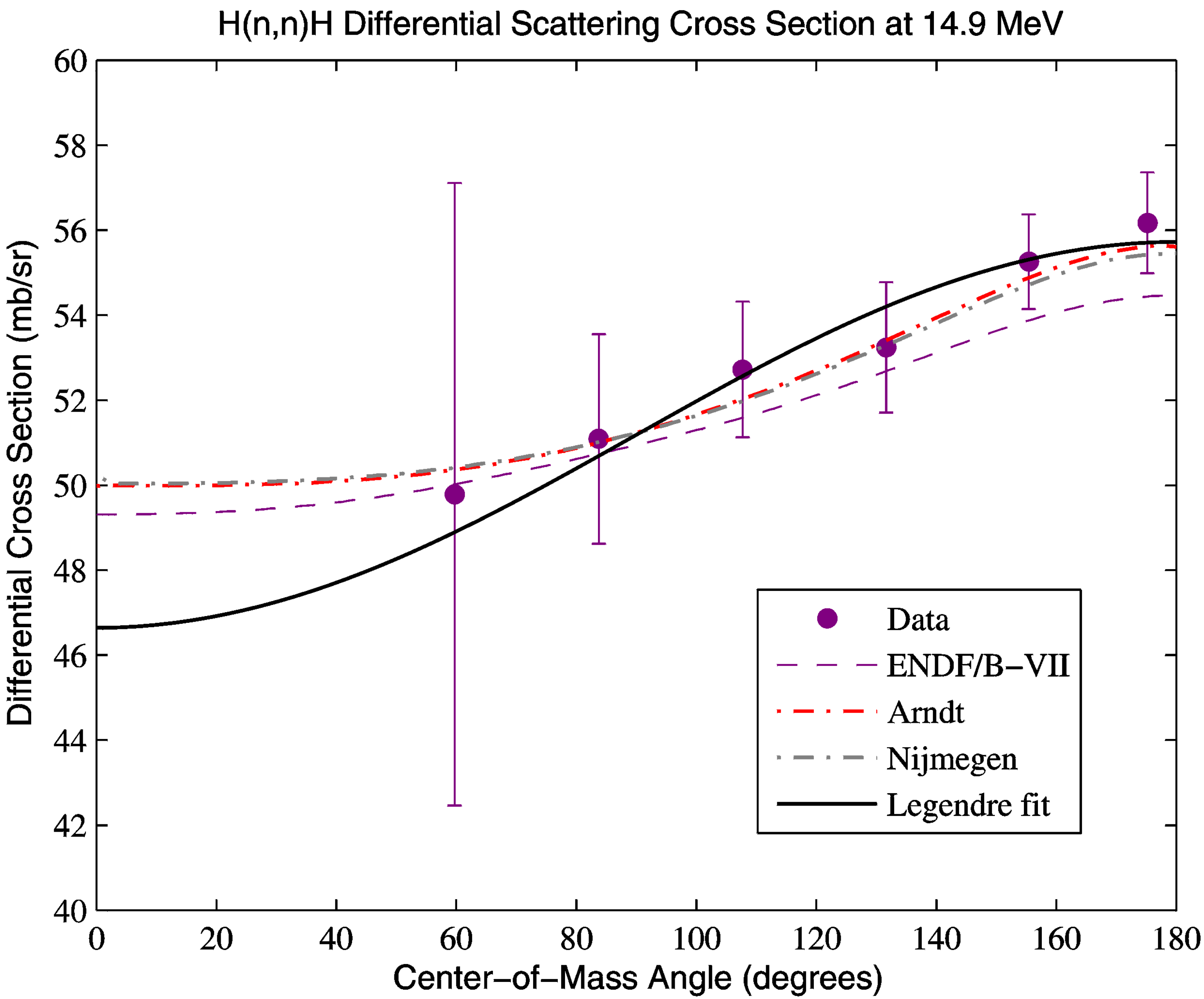
## H(n,n)H Angular Distribution Work

•Measurements were made at laboratory angles of 0 degrees, ± 12 degrees (one on each side of the beam direction), ± 24 degrees, ± 36 degrees, ± 48 and ± 60 degrees at the Ohio University accelerator facility. A paper on this work was given at the ND2007 conference. The data are obtained at 14.9 MeV neutron energy.

•Plans are being made to continue this type of work using a Time Projection Chamber which will provide higher counting rates than are possible with the scattering chamber now being used.
(collaboration with Ohio University, LANL and the University of Guelma)

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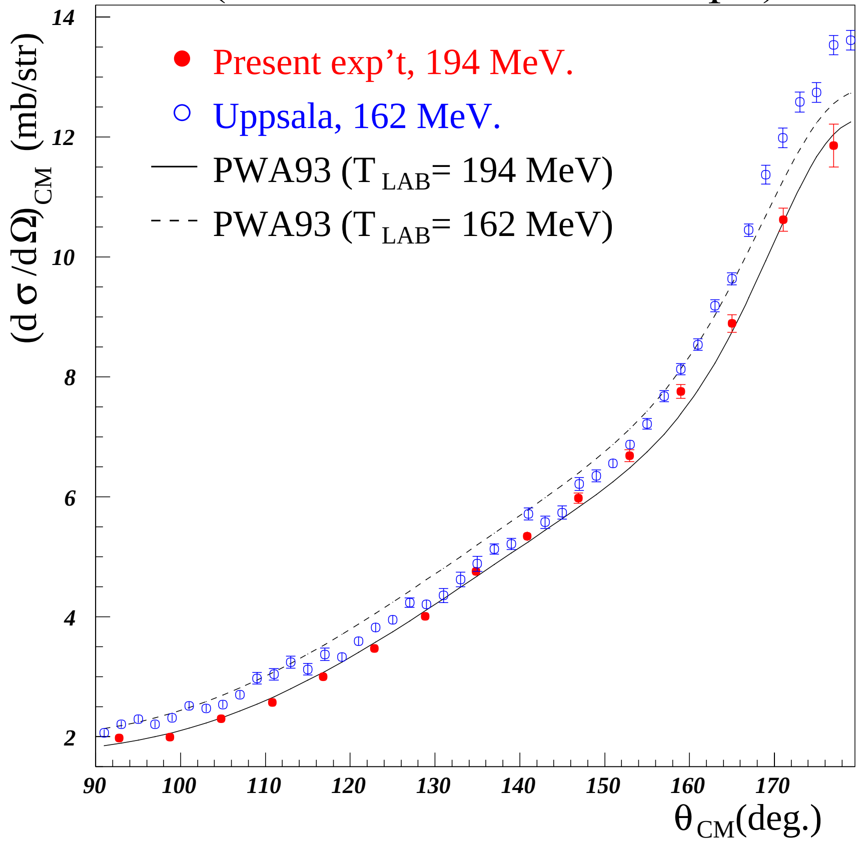
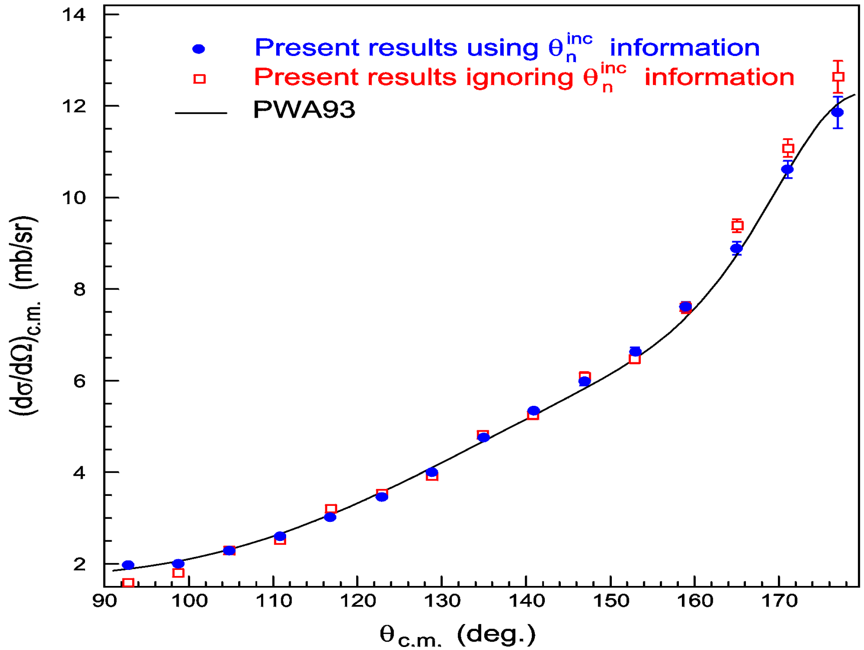
# H(n,n)H Angular Distribution Work at ~200 MeV

•There is a discrepancy between the results of the Uppsala University and Indiana University measurements (shown here as Present exp't).



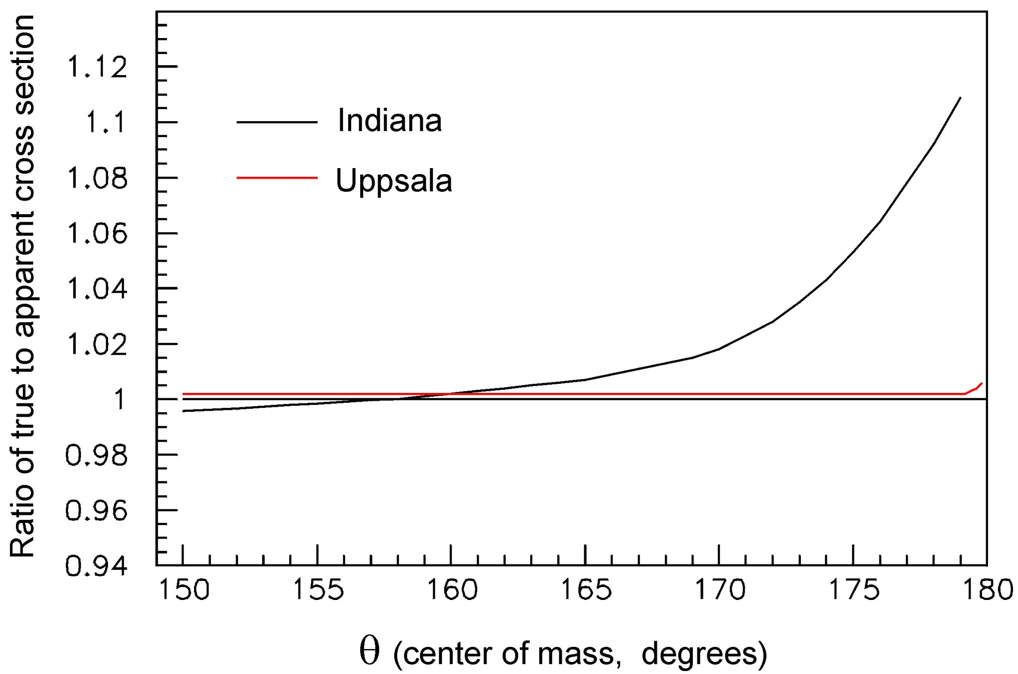
# H(n,n)H Angular Distribution Work at ~200 MeV (cont.)

•The Indiana experiment used tagging so the neutron's incidence angle is determined. If that angle is not known, the yield at small outgoing proton angles can be dominated by incident neutrons in the divergence of the beam. The incident neutron angle is not known for the Uppsala work. An analysis of the Indiana University data ignoring the neutron's incidence angle was done to determine this effect.



## H(n,n)H Angular Distribution Work at ~200 MeV (cont.)

•The Uppsala group wrote an analysis code with the objective of correcting their data for this effect. Using the details of their experimental setup, they found the effect was very small (0.2%-0.6%). They also calculated the effect for the Indiana experiment and obtained results consistent with those obtained by the Indiana group.



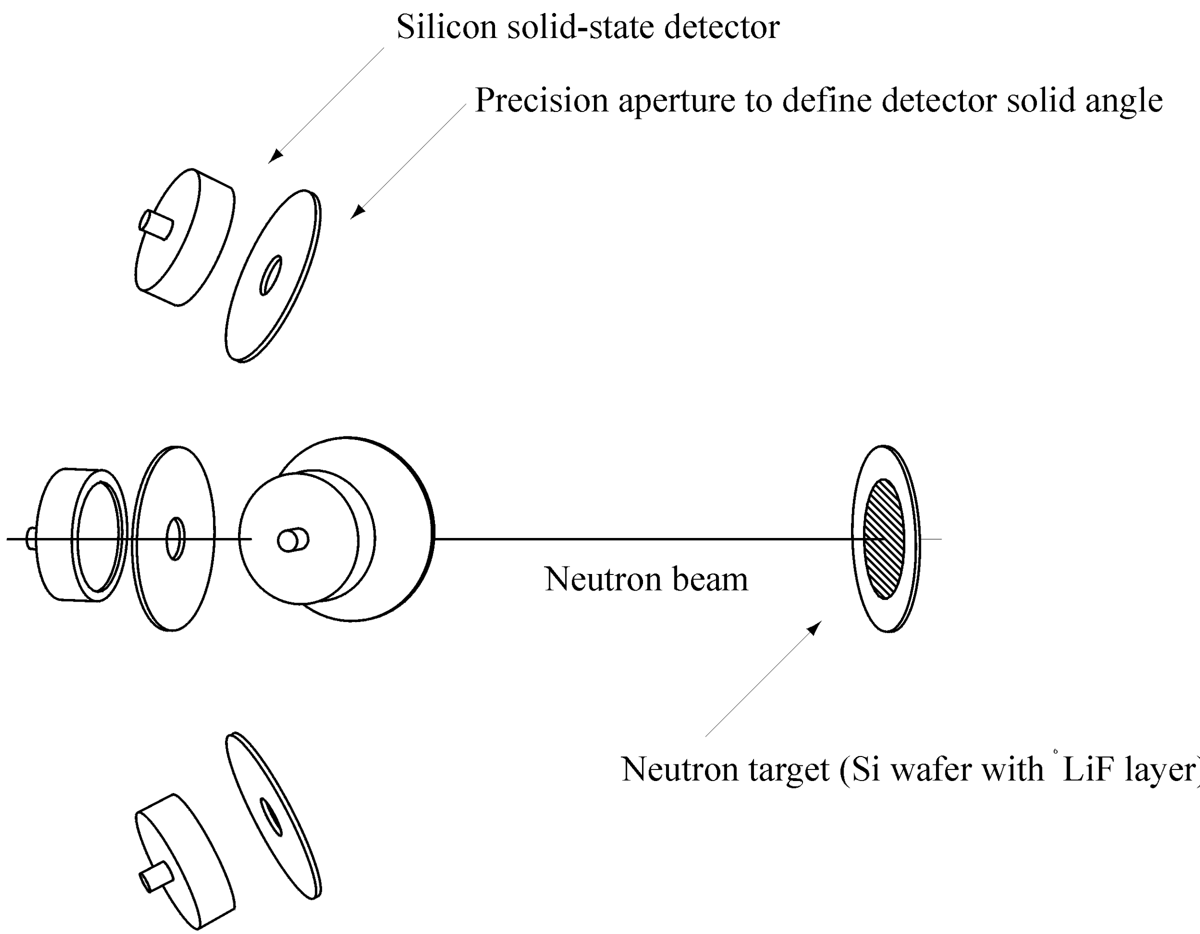
# $^3$He(n,p) Work

•An NIST collaborative experiment employing polarized neutrons and a polarized $^3$He beam has been designed. This measurement will allow separation of the real part of the two spin channels of this interaction.  These data can be used in R-matrix evaluations to improve the $^3$He(n,p) standard cross section. (collaboration with Indiana University and the University of North Carolina)

## $^6$Li(n,t) Work

•NIST collaborative measurements are being made of the $^6$Li(n,t) cross section standard at ~ 4 meV. These are the first direct and absolute measurements of this cross sections in this neutron energy range using monoenergetic neutrons.

•The neutron fluence measurements are based on counting prompt gamma-rays that originate from neutron capture in a totally absorbing boron target. The gamma-ray efficiency is known accurately from alpha-gamma coincidence measurements using a thin $^{10}$B target and also indirectly from measurements using a standard alpha source. A thin $^6$Li target whose geometry and target mass are both well known was used for the $^6$Li(n,t) cross section measurement. This procedure is capable of achieving an accuracy of ± 0.25%.
(collaboration with the University of Tennessee and Tulane University)



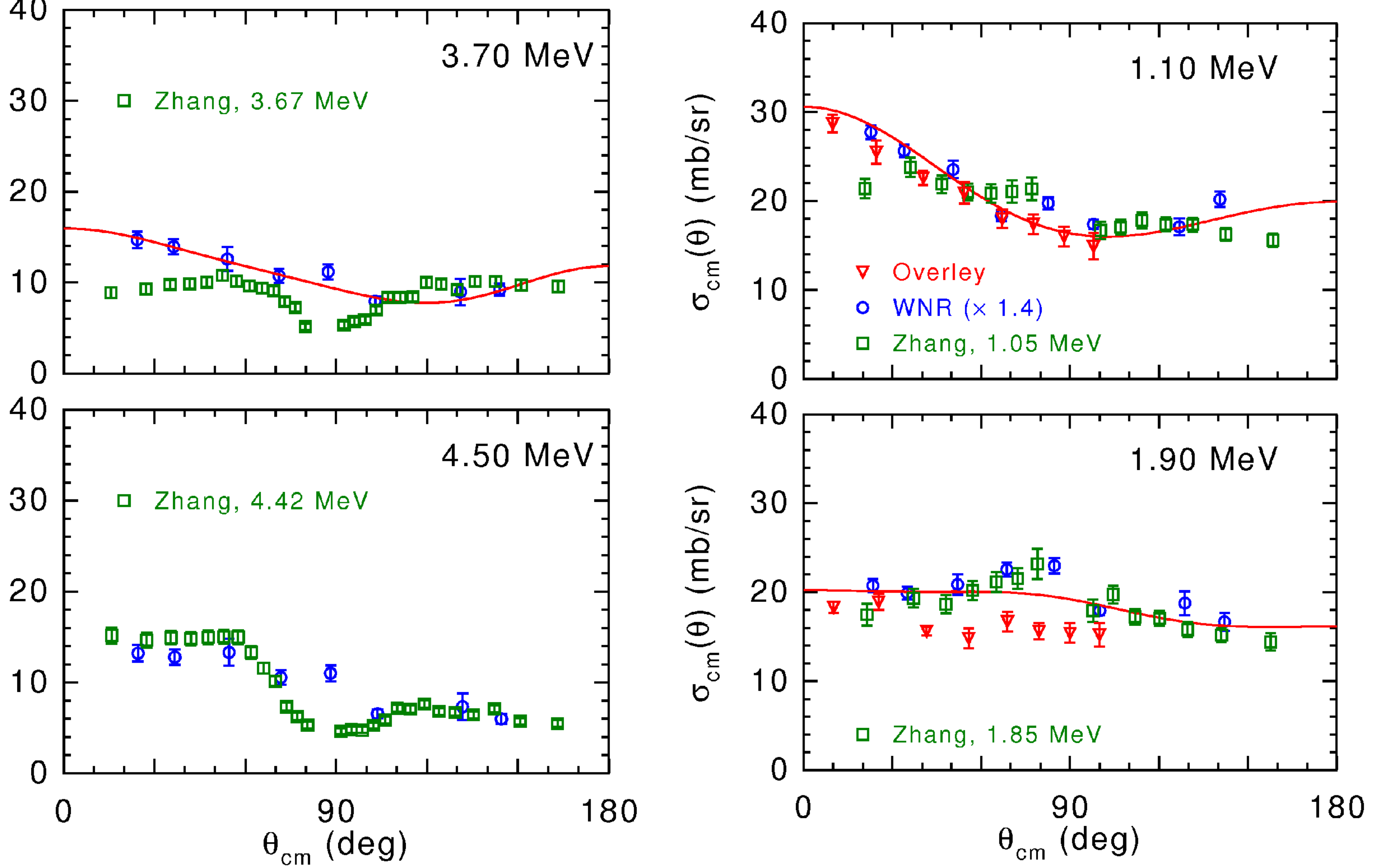

Experimental setup for the $^{6}$Li(n,t) reaction rate measurement
to obtain the 6Li(n,t) cross section

## $^{6}$Li(n,t) Work (cont.)

•The Frisch gridded ionization chamber work of Zhang et al. has been published. Angular distribution measurements were made at 1.05, 1.54, 1.85, 2.25, 2.67, 3.67 and 4.42 MeV. Integrated cross sections were obtained at 1.05 MeV and 1.54 MeV relative to the $^{10}$B(n,$\alpha$) standard; and at 1.85, 2.25, 2.67, 3.67 and 4.42 MeV relative to the $^{238}$U(n,f) standard.  Corrections are not made for the “particle leaking effect”; but the range of angles where the effect is present was calculated.

•New measurements are now being made by Devlin et al. at LANL.  Angular distribution data are being obtained from 0.2 to 10 MeV at eight laboratory angles using four E-$\Delta$E telescopes.  Also cross sections are being obtained with a detector system composed of two closely spaced silicon solid state detectors for the energy range from 0.1 to 8 MeV. Preliminary results from these experiments were reported at the ND2007 conference.

# $^{6}$Li(n,t) Angular Distributions



# $^{10}B(n,\alpha)$ Work

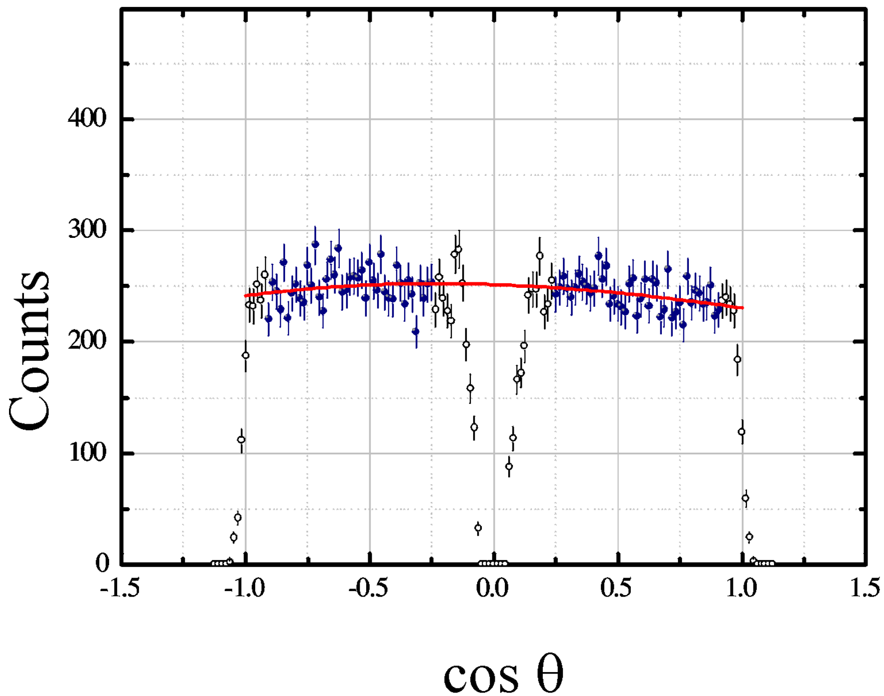
•The same basic experimental setup being used for the NIST collaborative measurements of the $^{6}Li(n,t)$ cross section at ~ 4 meV will be used to measure the $^{10}B(n,\alpha)$ cross section also.

•The angular distribution measurements of Hambsch were recently published. Data accumulation continues for the branching ratio experiment which is being extended to about 3 MeV. Plans have been made to make measurements of the $^{10}B(n,\alpha)$ and $^{10}B(n,\alpha_1\gamma)$ cross sections relative to the $^{235}U(n,f)$ standard up to about 3 MeV.

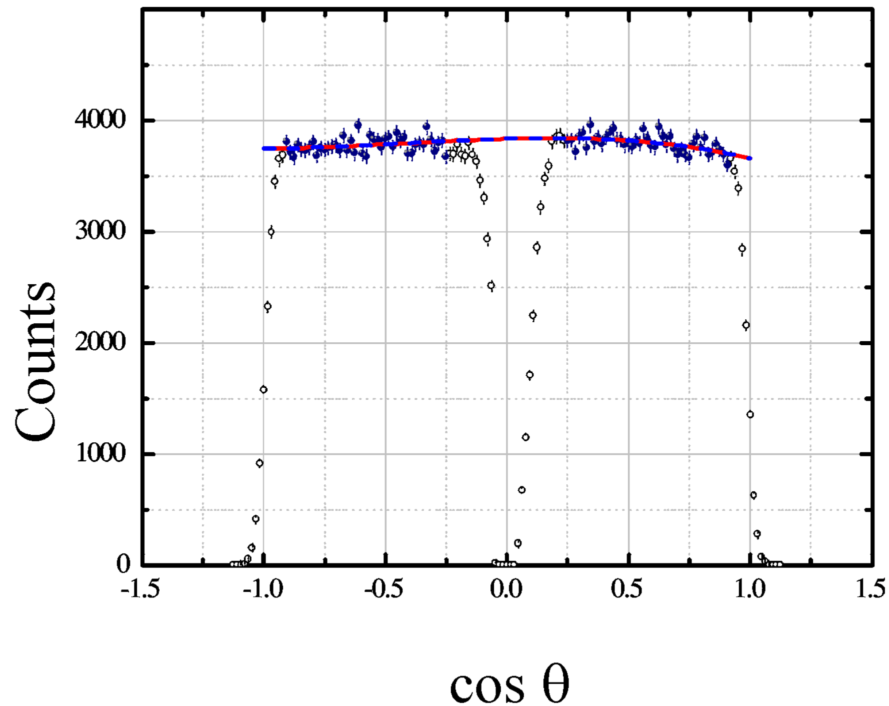
# Hambsch $^{10}B(n,\alpha)$ Angular Distribution Data

$E_n < 400$ eV

$^{10}B(n,\alpha_0)$

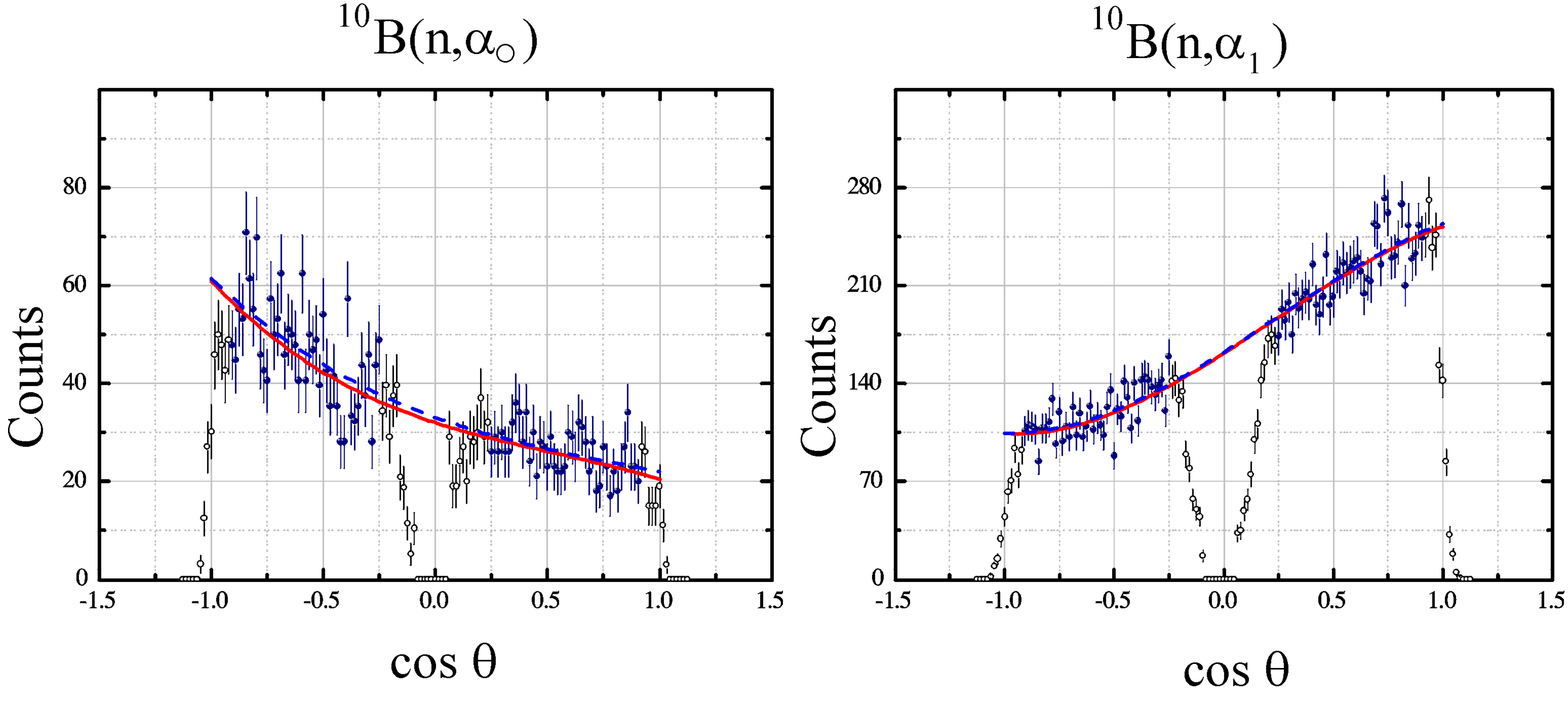



$^{10}B(n,\alpha_1)$



# Hambsch $^{10}B(n,\alpha)$ Angular Distribution Data

$E_n = 400$ keV



## Au(n,$\gamma$) Work

•Measurements of the capture cross section for Au have been made at the n_TOF facility by Massimi et al. with the objective of of adding the energy range from 1 eV to 10 keV to the standards energy region. Data obtained from 1 eV to 1 keV using two different detector systems were shown at the ND2007 conference. Analysis of the data should provide results to 1 MeV.

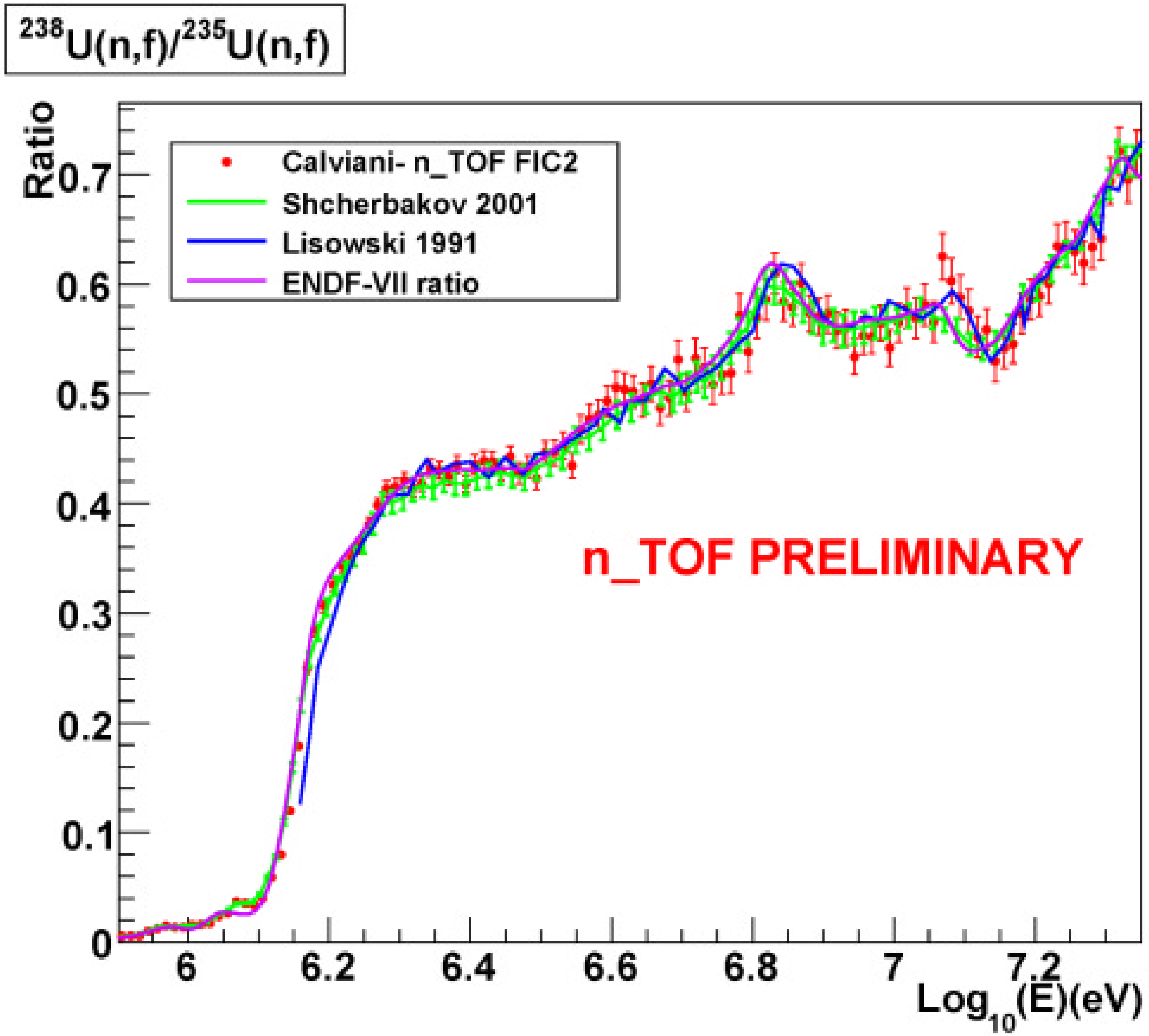
## $^{235, 238}$U(n,f) Work

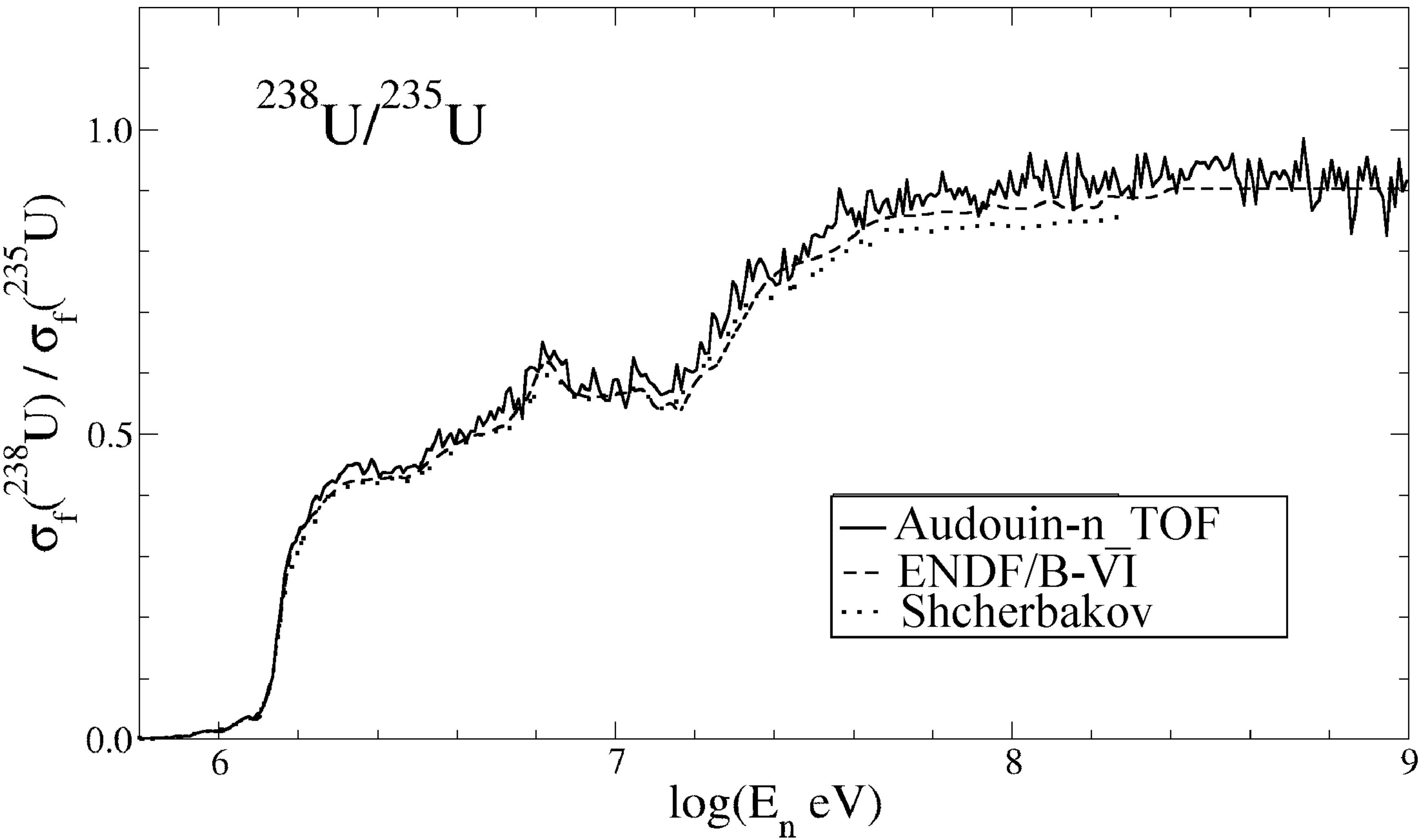
•The Nolte et al. $^{235}$U(n,f) and $^{238}$U(n,f) cross section measurements which extend from about 32 to 200 MeV were published this year. Some of the data were used in the standards evaluation.

•Measurements of the $^{238}$U(n,f)/$^{235}$U(n,f) cross section ratio have been made by two experimental groups at the n_TOF facility. Both groups gave papers on their work at the ND2007 conference.

- •Data from the Calviani et al. experiment were obtained with fission ionization chambers. Preliminary results of the data analysis are available to about 20 MeV. They are still working on the data in the very interesting region above 20 MeV (up to ~500 MeV) and hope to obtain results there soon.

- •Audouin et al. made measurements by detecting fission fragments in coincidence using Parallel Plate Avalanche Counters. The data extend to about 1 GeV. The data are preliminary.


$^{238}U(n,f)/^{235}U(n,f)$
Ratio
Calviani- n_TOF FIC2
Shcherbakov 2001
Lisowski 1991
ENDF-VII ratio
n_TOF PRELIMINARY
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
6
6.2
6.4
6.6
6.8
7
7.2
$Log_{10}(E)(eV)$



$^{238}U/^{235}U$
1.0
0.5
0.0
6
7
8
9
$\log(E_n\ eV)$
$\sigma_f(^{238}U) / \sigma_f(^{235}U)$
Audouin-n_TOF
ENDF/B-VI
Shcherbakov

# Additional Work Supporting the Standards

•Measurements are expected on the $^{239}$Pu(n,f) cross section in the MeV energy region with NERI funding. This work will use Time Projection Chambers for fission detection. Very accurate measurements should be possible with these detectors. It may be possible to also make measurements on the $^{235}$U(n,f) and $^{238}$U(n,f) standards.

•Cross section measurements have been made using NBS-I as a standard neutron source. An independent determination of the neutron intensity of this source has been made to compare with the established value obtained from manganese sulfate bath measurements and calculations. The new determination is in principle only limited in accuracy by the uncertainty in nu-bar of $^{252}$Cf. The determination was made by measuring the neutron source intensity of a bare $^{252}$Cf source (from the fission fragment rate into a well defined solid angle measured with a solid state detector and nu-bar), comparing this source to a sealed $^{252}$Cf source (by relative counting with $^{3}$He neutron detectors) to determine the sealed source intensity, and comparing this result with that obtained from a calibration of the sealed source relative to NBS-I in a large manganese sulfate bath.

## Data Development Project Activities

•Pronyaev has worked on a new method for smoothing the Au(n,$\gamma$) cross section by using statistical model calculations. The objective is to remove non-physical fluctuations (structure) and maintain real structure such as the cusps that occur from competition with inelastic scattering. The model fit will be used in the standards database as shape input.

•Updating of the standards database.

•Investigating the possibility of developing an inelastic scattering cross section standard.

•Considering adding additional standards energy ranges for the Au(n,$\gamma$) cross section.

•Proposing updates for the evaluations of the $^{252}$Cf spontaneous fission neutron spectrum and the $^{235}$U thermal neutron-induced fission neutron spectrum.