WPEC Subgroup 35

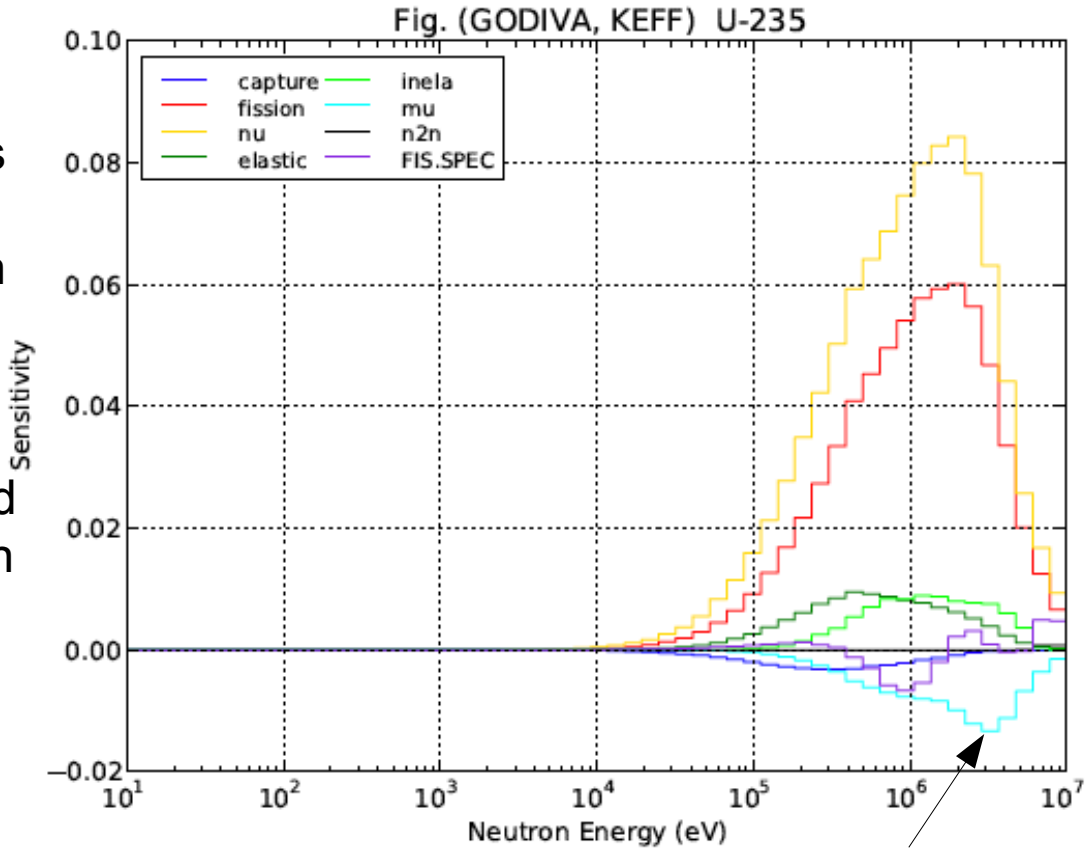
Scattering Angular Distribution in the Fast Energy Range

Status Report

T. Kawano
LANL, Theoretical Division

About SG35

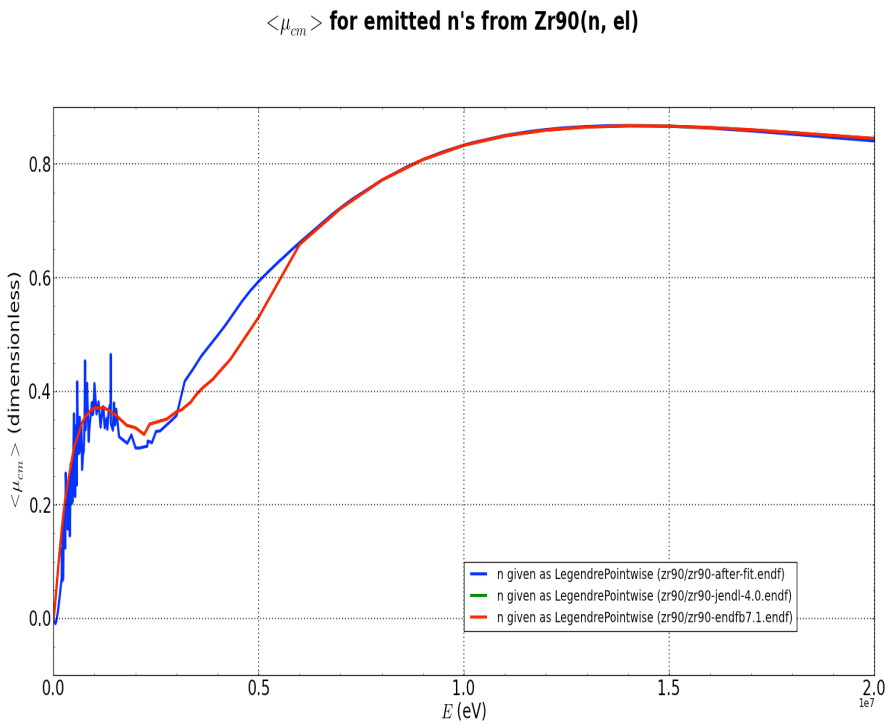
- Improve evaluation method of scattering angular distributions
- Identify integral benchmarks in which the scattering data play important role
- Provide better evaluations, and help experimentalists to design and conduct new scattering measurements



negative sensitivity to k-eff

2013 Group Meeting Highlights

- **A. Plompen**
  - re-analysis of Na elastic scattering data at Geel
  - nD scattering experiments summary
- **Y. Danon**
  - neutron scattering experiments for Be, Mo, Zr, U238, Fe56
- **P. Archier**
  - elastic scattering angular distribution impacts on k-eff and sodium void reactivity
- **D. Brown**
  - Zr evaluation status, mu-bar fluctuation added
- **M. Ishikawa**
  - ZRP and FCA data analysis w/wo reflector
- **T. Kawano**
  - estimation of P1 from experimental total cross section

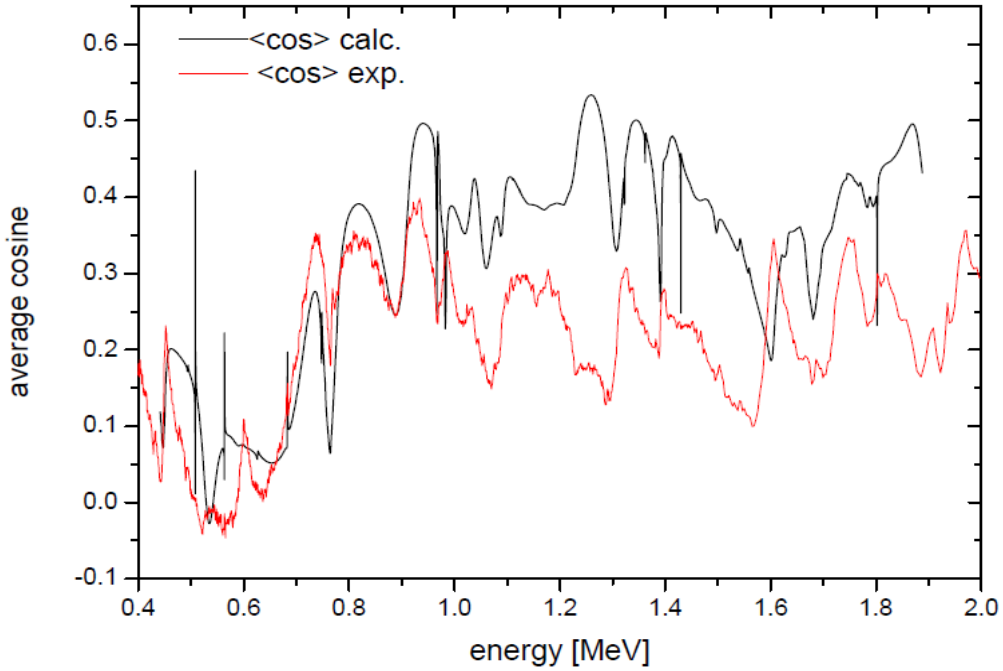


Recent Relevant Experimental Activities Summary

- **IRMM**
  - elastic and inelastic scattering
  - n+D experiments
    - angular distribution data request by Kozier
    - theory comparison on-going
- **U. Kentucky**
  - NEUP: Nuclear Energy University Program
  - Na elastic scattering measurement, reported at ND2013
- **RPI**
  - neutron scattering yield measurement at several angles
    - Fe56 and U238 data reported
    - data for other targets published too
  - semi-differential elastic scattering data for evaluation benchmark

Relevant R-matrix Resonance Parameters Discussed

- **Na23**
  - IRRM parameters available
  - calc. <cos> different from those directly obtained from experimental data
- **Fe56**
  - analysis on-going at ORNL
  - go beyond the first inelastic channel



Evaluation Methods for Scattering Angular Distributions

- **Resolved Resonance Region**
  - optical model
  - re-construct Legendre coefficients from resonances when R-matrix parameters are available
    - pre-processed, energy averaged, and store in MF4 MT2
    - NJOY2012
  - pre-processed data in new Ni isotope evaluations performed well, reported by Kahler at CSEWG 2012, HMF3.12 k-eff 1.009 → 0.998
- **Unresolved Resonance Region**
  - optical model
  - experimental data if available - e.g. V, Ti48, Fe56, Na23 in ENDF
  - estimate P1 from experimental total cross section (structural materials)

P1 Approximation From Total Cross Section

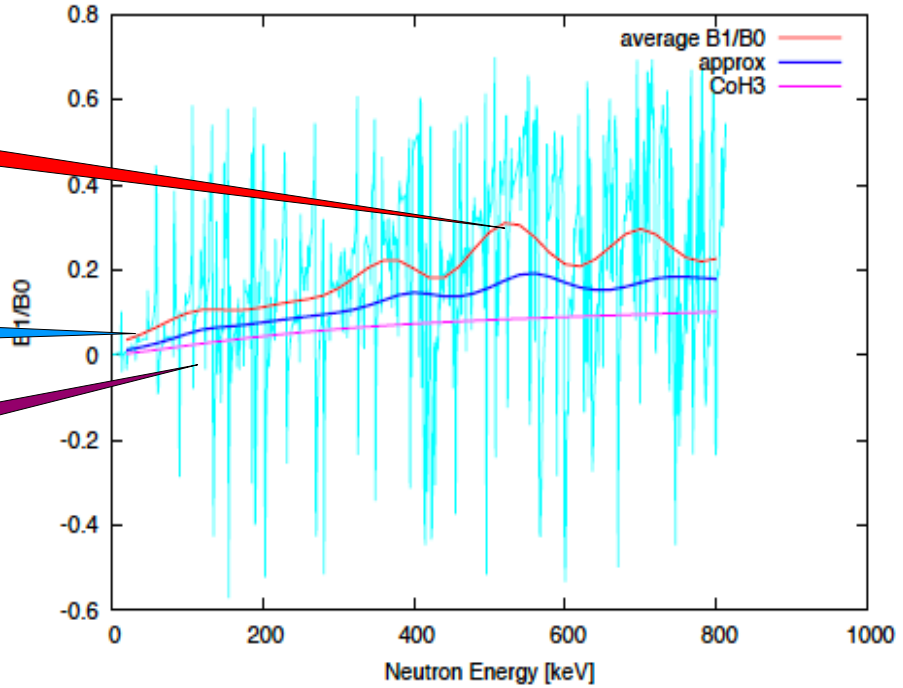
- New evaluation method developed to estimate P1 from experimental total cross section and optical model

$$P_1 \approx \frac{2\pi}{k^2 3(2I+1)\sigma_T}\frac{4}{3}\left\{3-(\Re S_1^{(1/2)}+\Im S_1^{(1/2)})-2(\Re S_1^{(3/2)}+\Im S_1^{(3/2)})\right\}$$

from R-matrix parameter

this method

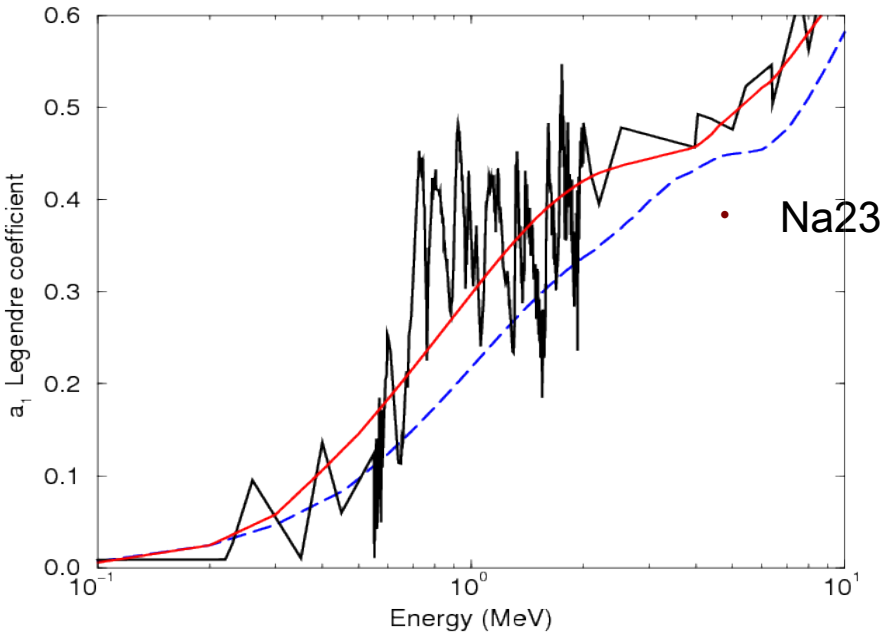
optical model



Neutron Energy [keV]

Is Fine Structure in P1 Important?

- **CEA Cadarache studied the impact of elastic scattering angular distributions on integral data**
  - Fe56 scattering angular distributions on k-eff
    - OM calc vs R-matrix
    - < 200pcm for mock-up benckmark, <10pcm for large core
  - Na23 on sodium void reactivity
    - optical model calc. gives a large deviation from R-matrix case
    - however, if average is adjusted, good agreement



It seems average behavior is more important

SG35 Conclusions

- Benchmark tests that have relatively high sensitivities to the scattering angular distributions identified (JAEA, Hokkaido U., Cadarache)
- P1 of Fe56 and Na23 tested at Cadarache
- Energy averaged P1 of Ni isotopes generated from resonance parameters, new evaluations provided (LANL)
- Active experimental programs and new proposals (IRMM, RPI)
- New method to estimate P1 from experimental total cross sections developed (LANL)
  - can be applied to Zr evaluation at BNL
- Final report will be prepared in this year
- We propose to close this subgroup