HYSPEC

S.M. Shapiro (PI), I. Zaliznyak (PI), L. Passell, V.J. Ghosh, W.J. Leonhardt, A.Ruga, CMPMS Department, B.N.L.

M. Hagen, Experimental Facilities Division, SNS, O.R.N.L.

BROOKHAVEN NATIONAL LABORATORY

SNS

Scientific Mission

HYSPEC will be a world class inelastic-scattering instrument with neutron polarization analysis capabilities, making it unique among the instruments being installed at the SNS.This instrument will meet the challenge posed for neutron inelastic spectroscopy in a wide range of science applications, including complex alloys (high Tc superconductors, spin valves, and photonic switches), nanosize magnetic molecules (spintronics and quantum computing), functional materials (superconducting cuprates and colossal magnetoresistance), strongly correlated electron systems, and quantum magnetism.

CAPABILITIES

Desire to measure lattice and spin dynamics in small single crystals:

- Need high flux at sample position.
- Low background

Science Needs:

- Polarized neutrons
- Sophisticated and/or extreme sample environment

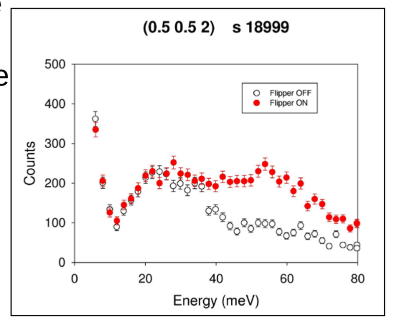
MAGNETIC FIELD

POLARIZED NEUTRONS

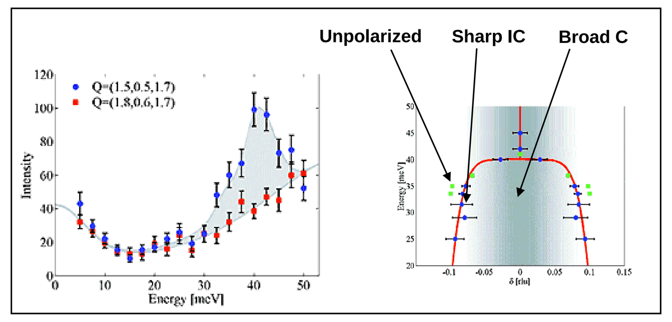
EXAMPLES OF INEALSTIC POLARIZED NEUTRON STUDIES:

CMR Material $La_{2/3}Ca_{1/3}MnO_3$ (Fernandez-Baca & Hagen).

Measured at zone boundary (0.5,0.5,2) The red data points are phonon + magnon scattering while the open data points are phonon only.



High T_c: $YBCO_{6.85}$ (Regnault et al.)



PROPOSED PROJECTS FROM HYSPEC IDT MEMBERS

- Spin Dynamics in Nanostructures (J. J. Rhyne, LANL)
- Nanoscale Features of Functional Materials (V. Kiryukhin, Rutgers U.)
- Anomalous Phonon Behavior (S. Shapiro, G. Shirane, BNL)
- Complex Phases in Intermetallics (C. Stassis, R. McQueeney, Iowa State U.)
- Correlated Phases in Many-Electron Systems (I. Zaliznyak, J. Tranquada, BNL)
- Strongly Correlated Electron Materials (G. Lander, EITU, S. Nagler, ORNL, Y. Lee, B. Khaykovich, MIT)
- High-Tc Superconductors (L.-P. Regnault, CEA,J. Tranquada ,BNL)
- New Transition Metal Oxides (M. Greven Stanford U.)
- Quantum Critical Points (R. Osborn, ANL)
- Geometrically Frustrated Magnets (B. Gaulin, McMaster U., J. Gardner, BNL)
- Quantum Spin Systems (A. Zheludev, ORNL)
- Colossal Magnetoresistance Materials (J. Fernandez-Baca, M. Hagen, ORNL)

Instrument Design

The HYSPEC spectrometer is one of five instruments in the SING (SNS Instruments Next Generation) project currently being designed for installation at the Spallation Neutron Source (SNS). It was proposed by an IDT (Instrument Development Team, see bottom left for members) led by staff from the Center for Neutron Science at BNL. The design and construction of HYSPEC is being carried out jointly between a design team working at BNL and members of the Experimental Facilities Division at the SNS.

HYSPEC PARAMETERS

Beamline: **14B**

Moderator: **Cryogenic coupled H2 moderator**

Moderator-monochromator distance: **37 m**

Monochromator-sample distance: **1.4-1.8m**

Sample-detector distance: **4.5m**

Incident energy range: **3.6meV < E_i < 90meV**

Incident energy resolution: **$\Delta E_i/E_i$ ~ 1.5%**

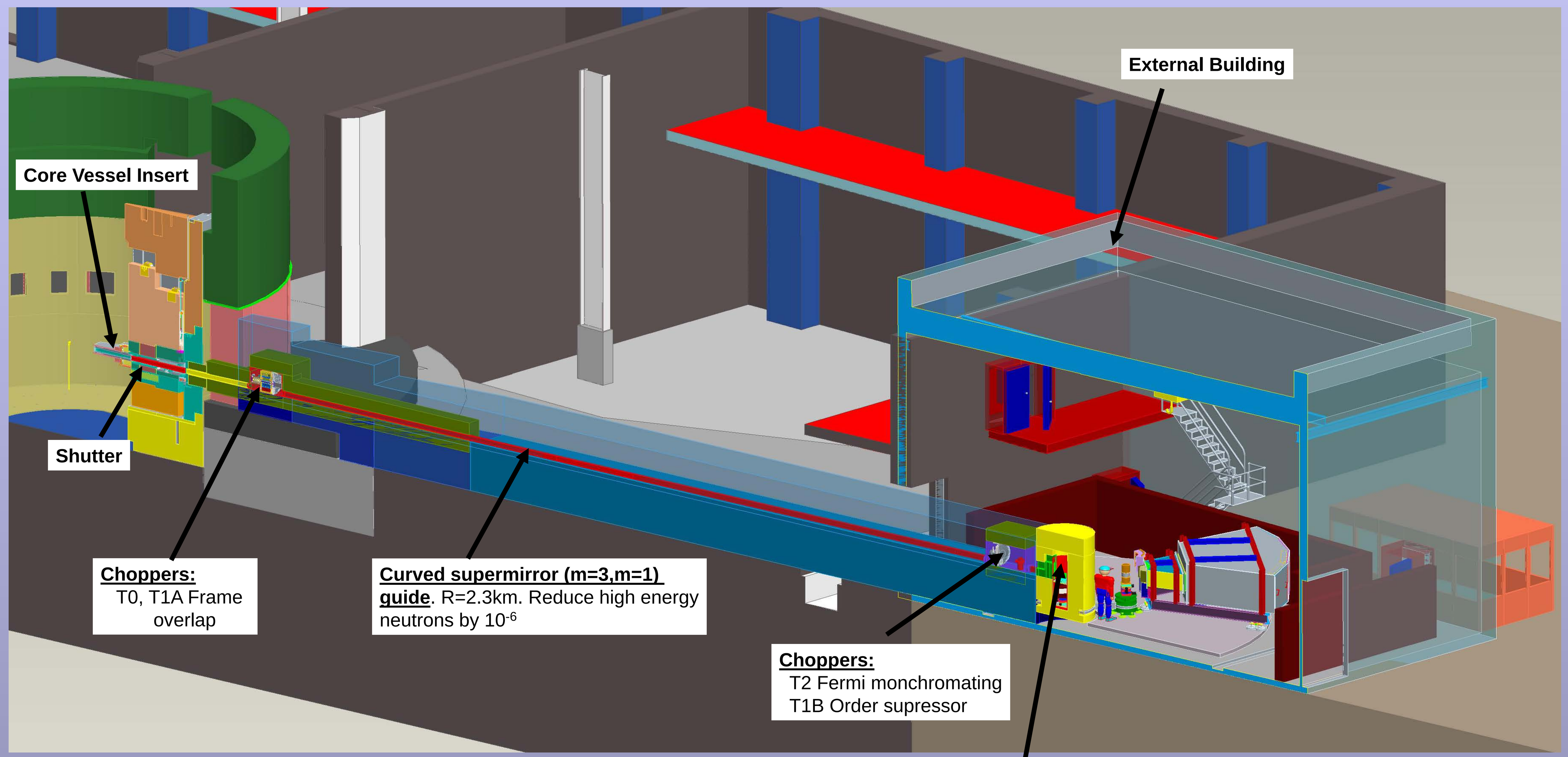
Final energy resolution: **$\Delta E_F/E_F$ ~ 5% - 8%**

Wavevector transfer range: **~0.1Å^{-1} < Q < 8Å^{-1}**

Beam size: **A large beam (150mm x 40mm) from moderator is compressed (focused) down to a 2cm by 2cm sample area using (focusing) Bragg crystal optics.**

Guides: **A23.5 m curved m=3 supermirror guide lowers background by going away from and "out of the line sight" of the source. A high m-value supermirror preserves the thermal flux out to larger distances.**

Sample area:**There is a large area around the sample for specialized and/or bulky sample environment equipment.**



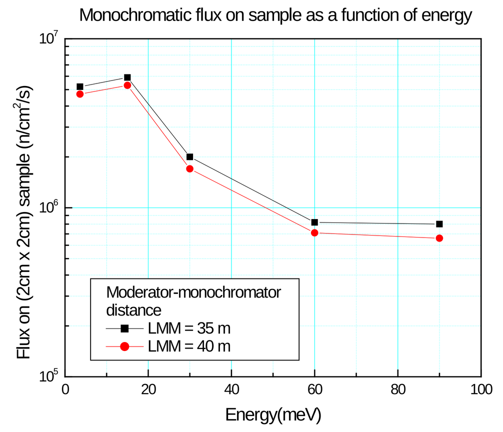
Choppers:
T0, T1A Frame overlap

Curved supermirror (m=3,m=1) guide. R=2.3km. Reduce high energy neutrons by 10^{-6}

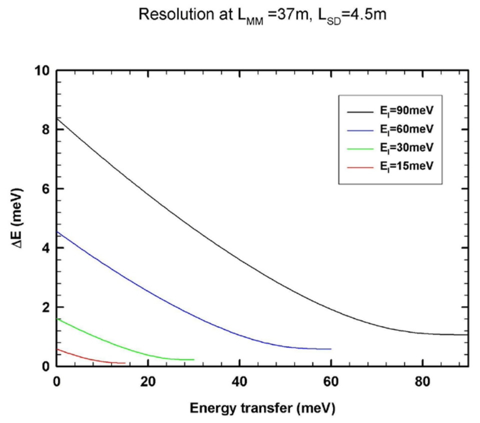
Choppers:
T2 Fermi monchromating
T1B Order supressor

FLUX AND RESOLUTION

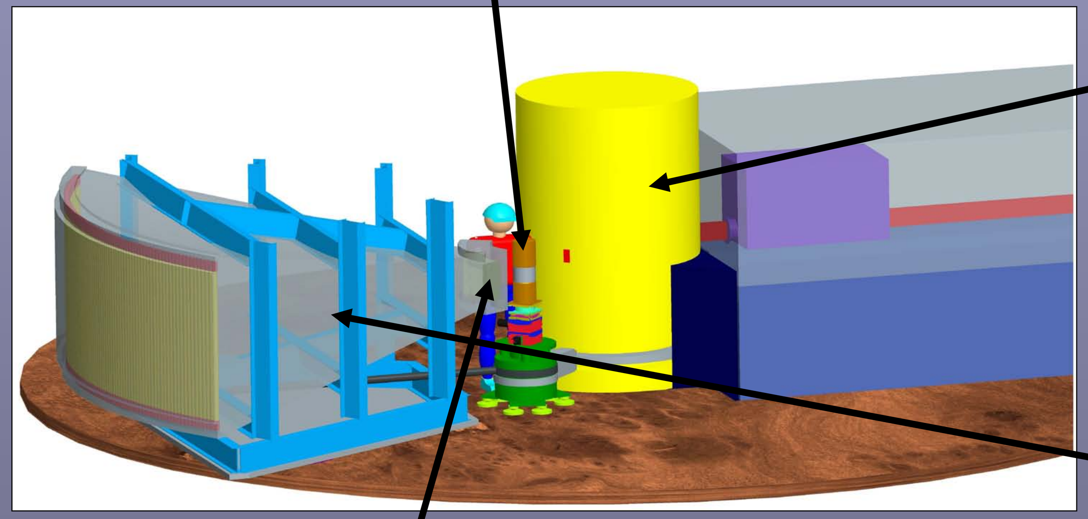
The flux at the sample position (in non-polarized mode), obtained from Monte Carlo simulations, for two different moderator to monochromator distances (LMM=35, 40m) is shown in the figure below as function of the incident energy.



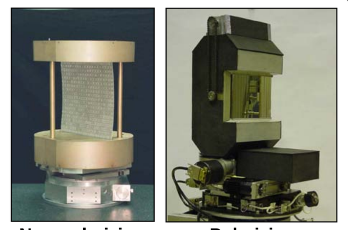
The resolution, as a function of energy transfer, is shown for 4 incident energies (E_i=15, 30, 60 and 90meV) below.



Sample area



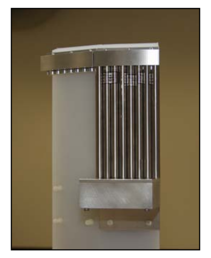
Focusing Crystal Optics
The large area of the neutron beam from the guide is "focused" to a small area by Bragg reflection from crystal arrays. For polarized neutron measurements the crystals used (Heusler) only reflects one neutron spin state (i.e. polarize the beam).



Non-polarizing HOPG(002)

Polarizing Heusler(111)

Detector Vessel
Data will be collected in a detector bank containing 160 linear position sensitive detector tubes covering 60° in the horizontal direction and 15° in the vertical direction. The vessel will contain an Argon atmosphere to reduce "air scattering" of the neutron beam. The vessel can be re-positioned to measure neutrons scattered at various angles from the sample.



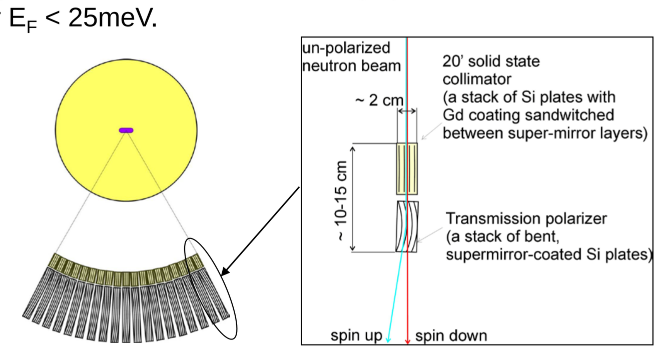
POLARIZATION ANALYZERS

The incident beam polarization is defined by the use of Heusler crystals (see Focusing Crystal Optics).

For the beam scattered from the sample we need to analyze how many neutrons are scattered with each spin state over a wide angular range (60° in the horizontal) and over a broad range of energies (1 < E_F < 80 meV). This does not necessarily have to be done with a single device, but could be done with a combination of devices. We are currently evaluating possible devices, two of which are shown in the panels on the right.

Polarizing Supermirror Benders

For neutron energies less than ~25meV the reflection from Fe/Si or Co/Si supermirror bender multilayers can be usedto split the neutron spin states. An array of such supermirror benders would be highly effective for E_F < 25meV.



Polarized ^3He Gas Cells

The neutron absorption cross-section of ^3He is highly spin dependent. Thus as a beam of neutrons passes through a gas of nuclear spin polarized ^3He one neutron polarization is selectively absorbed. Methods for polarizing ^3He gas cells exist, although they are highly sensitive to the magnetic field environment around them. Such a cell could cover an energy range 20 < E_F < 80 meV, and is a candidate for a spin polarization analyzer on HYSPEC.

Brookhaven National Laboratory is managed by Brookhaven Science Associates for the U.S. Department of Energy. For more information on HYSPEC please see the website http://neutrons.phy.bnl.gov/CNS/hyspec/index.htm