HYSPEC: Our Instrument at the Spallation Neutron Source.

Igor Zaliznyak

Neutron Scattering Group, Brookhaven National Laboratory

Outline

• Spallation Neutron Source (SNS) and the BNL
• Overview of the SNS instrument suite
• General features of a design and an operation of a spectrometer at a pulsed neutron source
• HYSPEC layout, principal features design and important design choices
• Instrument specific features and components
• Summary, work in progress and open questions
Spallation Neutron Source (SNS) at ORNL

Front-End Systems (Lawrence Berkeley)
Accumulator Ring (Brookhaven)
Target (Oak Ridge)
Linac (Los Alamos and Jefferson)
Instrument Systems (Argonne and Oak Ridge)

http://www.sns.gov/
http://www.sns.gov/partnerlabs/partners.htm
SNS accumulator ring built by BNL

http://sns.bnl.gov/
http://sns.bnl.gov/ap_group/ring.html
Recent view of the SNS construction site
SNS target station: getting closer!
SNS construction: the middle of the way is passed (and the funding ramps down).

The heaviest lift in the construction: the core vessel is installed!
Current status of the SNS instrument suite

2 - Backscattering Spectrometer – SNS Funded – Commission 2006

3 - High Pressure Diffractometer – DOE Funded (SING) – Commission 2007


5 - Cold Neutron Chopper Spectrometer – IDT DOE Funded – Commission 2007

6 - SANS – SNS Funded – Commission 2007

9 - Engineering Diffractometer – IDT CFI Funded – Commission 2008

10 - Chemical Spectrometer


12 - Single Crystal Diffractometer – DOE Funded (SING) – Commission 2009

13 - Fundamental Physics Beamline – IDT Funding TBD – Commission TBD

14B - Hybrid Spectrometer – DOE Funded (SING) – Commission 2011

15 - Spin Echo

17 - High Resolution Chopper Spectrometer – DOE Funded (SING) – Commission 2008

18 - Wide Angle Chopper Spectrometer – IDT DOE Funded – Commission 2007
Neutron spectrum produced by SNS vs reactor

Neutron current through 4x12cm guide entrance at 1.5 m from the moderator within $\Delta E/E = 2\%$

- 20 K coupled $\text{H}_2$ (NISP interpolation)
- 20 K coupled $\text{H}_2$ (MCSTAS interpolation)
- $\text{H}_2\text{O}$ (MCSTAS interpolation)
- MC calculation by E. Iverson

MC calculation for NIST cold source normalized to same intensity at low E
Setup of a scattering experiment

Elastic. The scattered neutron’s wave vector is large.

Inelastic. The scattered neutron’s wave vector is large.
Phase space overview of a TOF experiment
Two-spinon continuum in SrCuO₂: direct measurement

MAPS@ISIS, $E_i = 98$ meV.

Color contour map of the scattering intensity. White lines are gaps in the detector array. Vertical lines at $l = n/2$ are spinons.

MAP0336_9CARDS_4_4TO1.SPE, c⁺ perp ki, $E_i=98.13$ meV, $s=2$

$u=[1 0 0], v=[0 0 1], \Psi(u,ki)=0$

slice $-4<k<4$, $l=-2:0.02:4$, $E=0:2:100$

$q_{\text{chain}}/2\pi$
Two-spinon continuum in SrCuO$_2$: direct measurement

MAPS@ISIS, $E_i = 241$ meV.

Color contour map of the scattering intensity.
Two-spinon continuum in SrCuO₂: direct measurement

MAPS@ISIS, $E_i = 520$ meV.

Color contour map of the scattering intensity.
Spin part of one-dimensional electrons

Triplet spectrum of two-spinon states, combined set of 4 measurements on MAPS at ISIS

- Effective single-band Hubbard model at half-filling
- Spin-charge separation
- Holon gap
  \[ m \approx 0.75 \text{ eV} \]
- Optic gap
  \[ \Delta = 2m \approx 1.5 \text{ eV} \]
- Two-spinon band
  \[ \pi J \approx 0.7 \text{ eV} \]
HYSPEC: place in the SNS inelastic instruments suite.

**High energy transfer**
10-1000 meV Fermi Chopper Spectrometer
- E = 10 - 1000 meV
- Q = 0.1 – 22 Å⁻¹

**High intensity at moderate resolution and medium energy transfer + polarized beam**
Crystal Monochromator Hybrid Spectrometer
- E = 2.5 - 90 meV
- Q = 0.1 – 8 Å⁻¹

**High resolution and low energy transfer**
10-100 µeV Multichopper Spectrometer
- E = 2 - 20 meV
- Q = 0.1 - 4 Å⁻¹
HYSPEC timeline: history of the project.

- **May, 2003**
  - DOE CD0

- **December, 2002**
  - HYSPEC proposal submitted to DOE

- **January, 2002**
  - HYSPEC IDT filed Letter of Intent with SNS

- **Fall, 2001**
  - Instrument Development Team formed
  - Workshop on the Hybrid Spectrometer held at BNL
  - Refined HYSPEC concept presented to EFAC

- **March, 2001**
  - Draft proposal of a Direct Geometry Hybrid Spectrometer first presented to EFAC, received positive reply

- **December, 2000**
  - Completed review of the possible instrument designs
  - Concept of the Hybrid Spectrometer formulated and adopted

- **Fall, 1999**
  - Center for Neutron Science and Neutron Scattering Group at BNL initiate an effort to design a spectrometer for the SNS
HYSPEC Instrument Development Team and Design Workgroup.

**IDT: Current Members and their Institutional Affiliations**

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Zaliznyak</td>
<td>BNL</td>
</tr>
<tr>
<td>S. M. Shapiro</td>
<td>BNL</td>
</tr>
<tr>
<td>G. Shirane</td>
<td>BNL</td>
</tr>
<tr>
<td>J. Tranquada</td>
<td>BNL</td>
</tr>
<tr>
<td>L. Passell</td>
<td>BNL</td>
</tr>
<tr>
<td>D. Abernathy</td>
<td>SNS</td>
</tr>
<tr>
<td>L. Daemon</td>
<td>Los Alamos</td>
</tr>
<tr>
<td>M. Greven</td>
<td>Stanford</td>
</tr>
<tr>
<td>B. Gaulin</td>
<td>McMaster</td>
</tr>
<tr>
<td>V. Kiryukhin</td>
<td>Rutgers</td>
</tr>
<tr>
<td>Y. Lee</td>
<td>MIT</td>
</tr>
<tr>
<td>S. Nagler</td>
<td>ORNL</td>
</tr>
<tr>
<td>R. Osborn</td>
<td>ANL</td>
</tr>
<tr>
<td>J. Rhyne</td>
<td>U. Missouri</td>
</tr>
<tr>
<td>C. Stassis</td>
<td>Ames/Iowa St.</td>
</tr>
<tr>
<td>A. Zheludev</td>
<td>ORNL</td>
</tr>
</tbody>
</table>

**HYSPEC Instrument Design Workgroup**

- I. Zaliznyak (BNL)
- S. M. Shapiro (BNL)
- L. Passell (BNL)
- V. J. Ghosh (BNL), Monte-Carlo simulations
- S. Doran (SNS/ANL)
- Engineering design concept

HYSPEC Layout and principal features

Part 2. Conceptual design and Top Level Specifications

- T₀ Chopper
- Disc Chopper
- Monochromator
- Goniometer
- Radial Collimator, or Bender Polarizers
- Flight Chamber (evacuated or Ar/He filled)
- Detectors