HYSPEC - Hybrid Spectrometer for the Single Crystal and Polarized Neutron Studies at the SNS

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Brookhaven National Laboratory

- Unique in its class
- Highest flux on small samples
- Easily adapted for polarized neutron studies

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Outline

- Motivation (SMS)
- Science Case (SMS)
- IDT and Budget (SMS)
- Conceptual Design (IZ)
- Performance and Comparison(IZ)
- Summary (IZ)

Status

- Fall, 1999
  - BNL initiates an effort to design a spectrometer for the SNS
- December, 2000
  - Concept of the Hybrid Spectrometer formulated and adopted
- March, 2001
  - First presented to EFAC. Received positive reply
- Fall, 2001
  - Instrument Development Team formed
  - October: Workshop on the Hybrid Spectrometer held at BNL
  - Refined HYSPEC concept presented to EFAC
- January, 2002
  - HYSPEC IDT filed Letter of Intent with SNS
- April, 2002
  - Formal presentation to EFAC
- July, 2002
  - Letter of Intent accepted; Submit Scientific Proposal to EFAC

Motivation

SNS Inelastic Neutron Scattering Workshop[1]

Argonne (11/99)

Category	Instrument	
A.1	indirect geometry spectrometer, (backscattering), resolution 2 μeV (elastic position)	BS
A.2	Direct geometry spectrometer (chopper), resolution ΔE/E ~ 1% (elastic position), E ~10 – 1000 meV, continuous angular coverage	HRCS
A.3	Spectrometer with 10 – 100 μeV resolution	CNCS
B.1	Chopper , ΔE/E ~ 5% (elastic position), large angular coverage	ARCS
B.2	Inverse geometry spectrometer, time focussed, ΔE/E ~ 1%	
B.3	Triple axis-like instrument with high signal to noise	HYSPEC
B.4	High Q chopper spectrometer with small ΔE/E	
C.1	Spin echo spectrometer ΔE ~ 1 neV to 2 μeV	
C.2	Brillouin scattering spectrometer, small Q, intermediate E	
C.3	PRISMA-like spectrometer	

- A and B category top priority - **"potential day-one instrument"**

- [1] Report on the SNS Inelastic Neutron Scattering Workshop, SNS Document IS-1.1.8.2-8004-MM-A-00 (2000).

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Motivation from Workshop

- Small single crystal samples
  - **Focussing Bragg optics**
- Broad range of standard sample environments
  - **Use of collimators and beam definers**
  - **Sample environment separate from detector vacuum**
- Low background
  - **Time of flight**
  - **Sample area out of direct beam**
  - **Use of collimators**
- Vector **Q** in single crystals
  - **Moveable detector and rotatable sample**
- Polarization Analysis
  - **Proven and maintenance-free technology**

Motivation from Workshop

- Page 5 of Report:

"This [high time averaged flux] opens up the possibility of utilizing triple-axis like methods to examine details of excitations when the important physics can be found at specific, well defined regions of **Q** and E space"

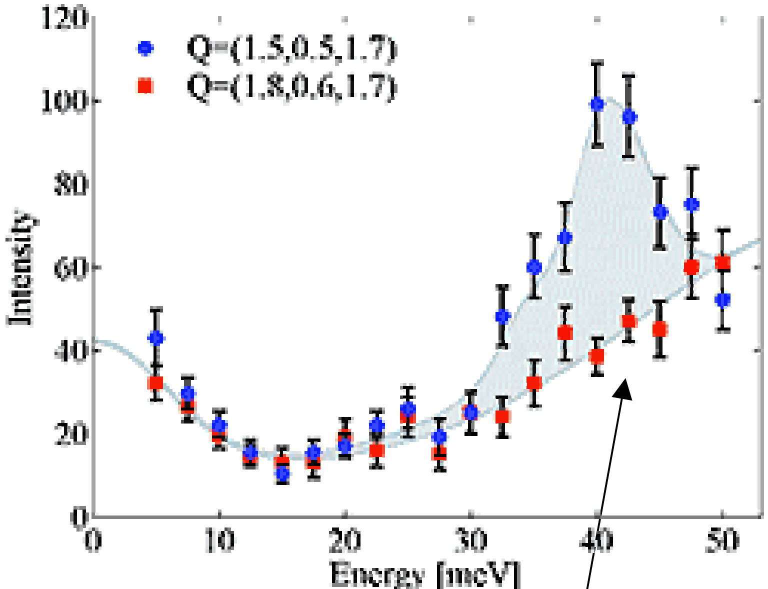
- Recommended: "potential day-one instrument"

Science Case

- Quantum critical points
- Low-D magnetism
- Nanomagnetism and complex systems
- Disordered and weakly ordered phases
- Anomalous phonon behavior
- Strongly correlated electron systems
  - Hi T_c: YBCO experiment performed at ILL - IN22

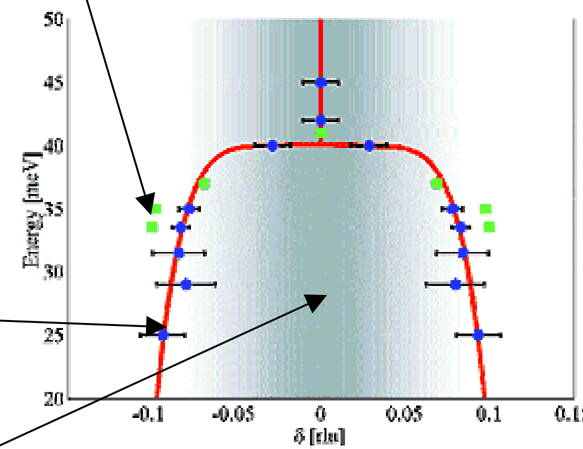
Polarized Neutron Study on Resonant Mode in $YBCO_{6.85}$ (L.P. Regnault et al.)

IN22
Spin Flip
P // Q



Rise due to increased counting time

Unpolarized



Sharp IC

Broad C

- **Much faster data collection**
- **Open new areas for polarized beam use**

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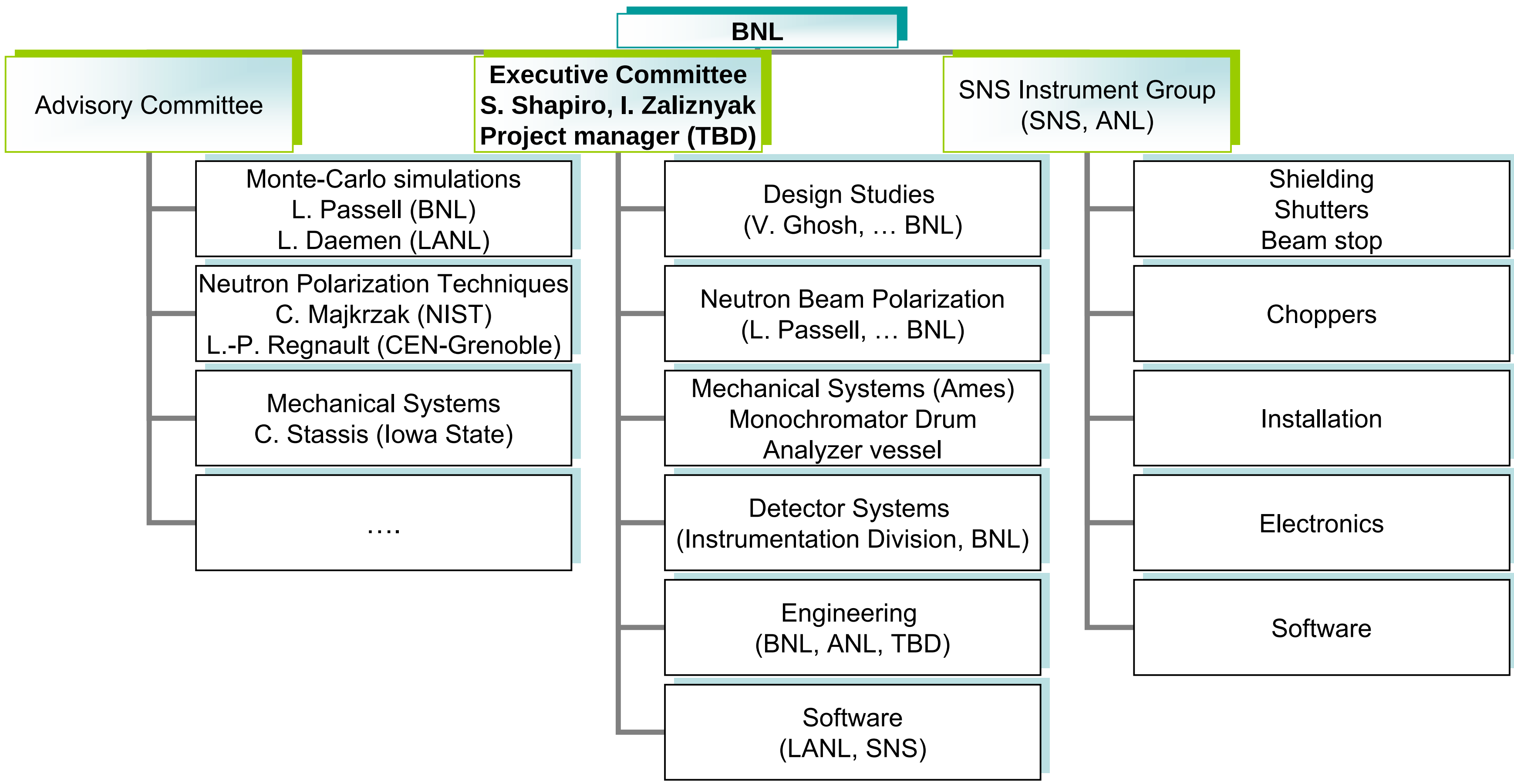
IDT Membership

I. Zaliznyak, co-PI	BNL
S. M. Shapiro, co-PI	BNL
G. Shirane	BNL
J. Tranquada	BNL
L. Passell	BNL
D. Abernathy	SNS
L. Daemen	Los Alamos
M. Greven	Stanford
B. Gaulin	McMaster
K. Hirota	ISSP
V. Kiryukhin	Rutgers
G. Lander	EITU
Y. Lee	MIT
C.Majkrzak	NIST
S. Nagler	ORNL
R. Osborn	ANL
L. P. Regnault	CEN-Grenoble
J. Rhyne	U. Missouri
C. Stassis	Ames/Iowa St.
A. Zheludev	ORNL

HYPSEC INSTRUMENT
DESIGN WORKING GROUP

I. Zaliznyak (BNL)
S. Shapiro (BNL)
L. Passell (BNL)
V. Ghosh (BNL)
(Monte Carlo Simulations)
S. Doran (SNS/ANL)
(Engineering Design)

HYSPEC IDT Organization Chart



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HYSPEC Budget Estimate

Primary Flight Path			
	Choppers		1400
	Incident beam shielding		2300
	Supermirror guides		500
	Beam monitors		100
		SUB	4300
Monochromator			
	Shielding		1000
	Crystals and holder		400
	Collimators		50
		SUB	1450
Sample Stage			
	Goniometer, sample table		160
	Ancillary equipment		250
		SUB	410
Analyzer, detector			
	Collimator sets		200
	Polarization benders		1000
	PSD, electonics mounts		900
	Beam Controls-DAQ		140
	Detector vessel		1500
	Beam stop/get lost pipe		200
		SUB	3740
	CAPITAL TOTAL		9900
	LABOR (1/3 Capital)		3300
	TOTAL		13200

Budget estimates from:

- SNS engineering group (11/01)
- HRCS Summary (7/02)

Time Estimate:

- 5 years from funding

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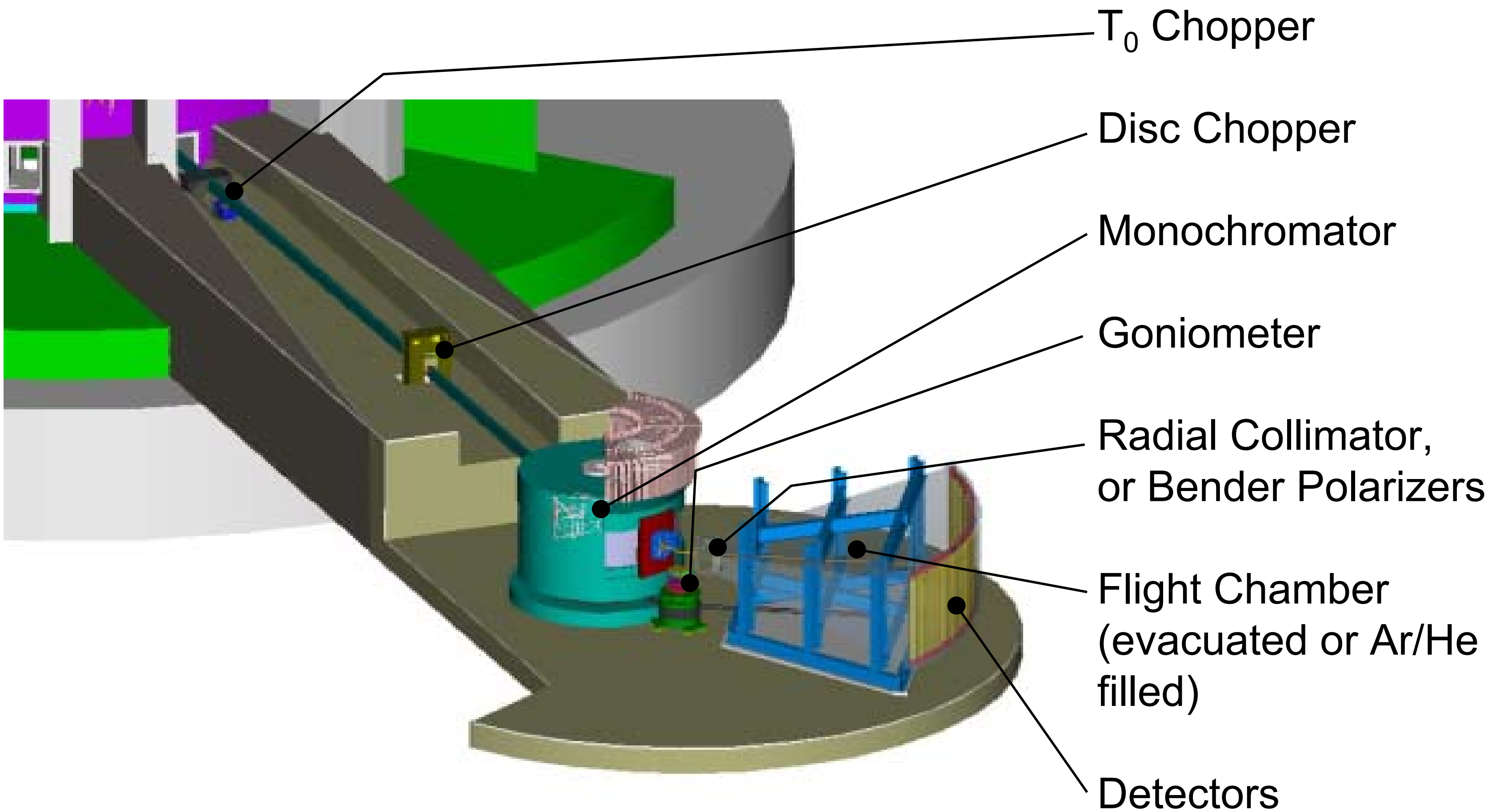
HYSPEC: A Proposed Crystal-Time-of Flight Hybrid Spectrometer for the Spallation Neutron Source

Part 2: Conceptual design



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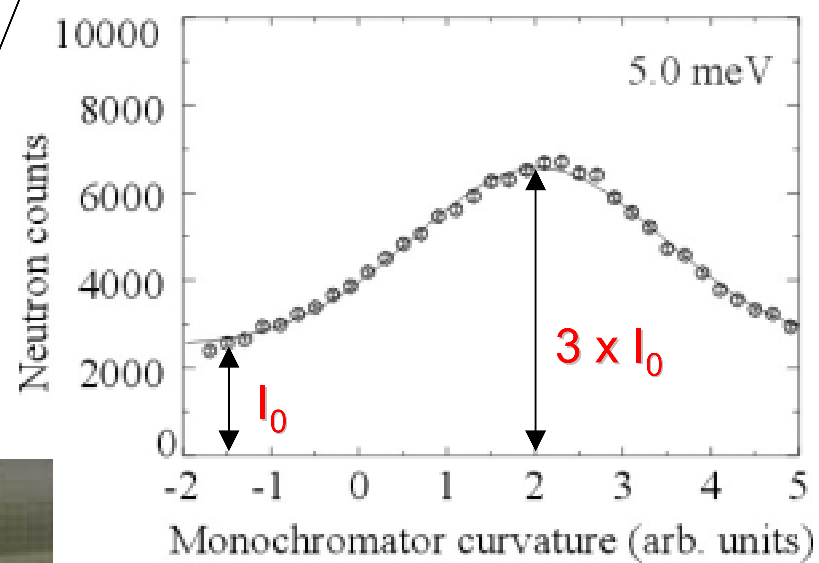
Why Hybrid Spectrometer?

- ❑ Science challenges
  - small samples
  - subtle features
  - polarization analysis
  - small signals, background-limited measurements
- ❑ Need intensity boost

❑ Monochromator vertical focusing gain on SPINS@NIST: factor ~3 even for m = 19 g sample (below)



HYSPEC design choices: moderator

Time-spectra of the neutron intensity from different moderators for E_i = 15.8 meV

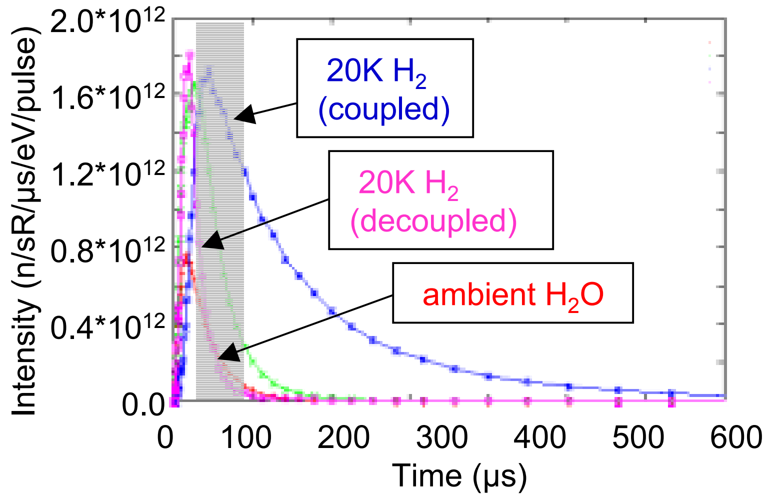
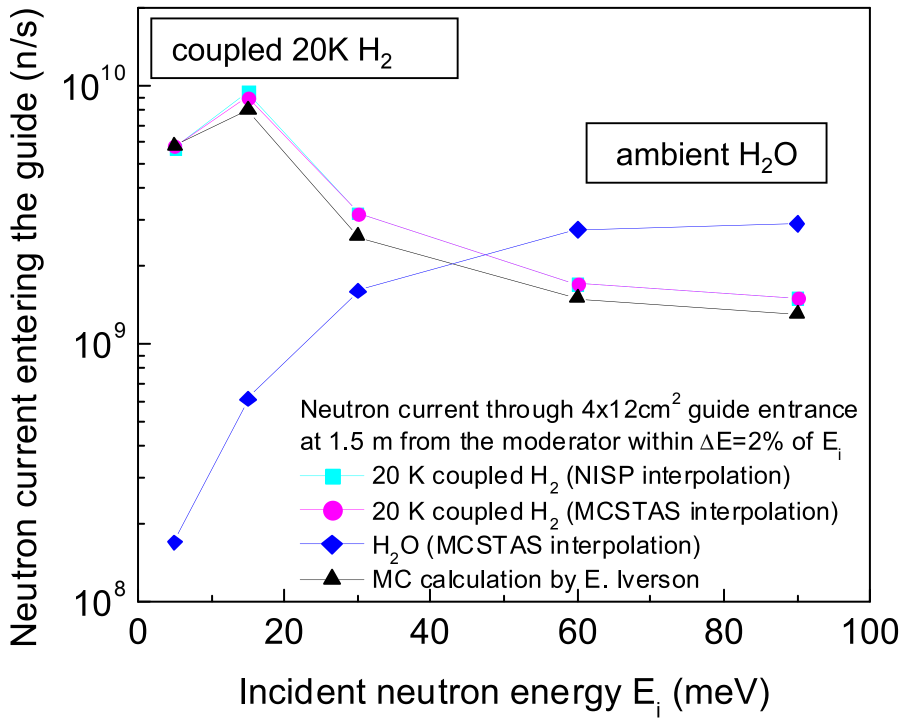


Figure of merit is the total flux within Δt = 40-80 μs time window accepted by the spectrometer.

Moderators useful neutron flux



- Coupled supercritical H_2 moderator wins in thermal neutron range E_i<45meV

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HYSPEC design choices: energy resolution

- For given incident pulse length Δt instrument energy resolution is determined by the analyzer flight-path

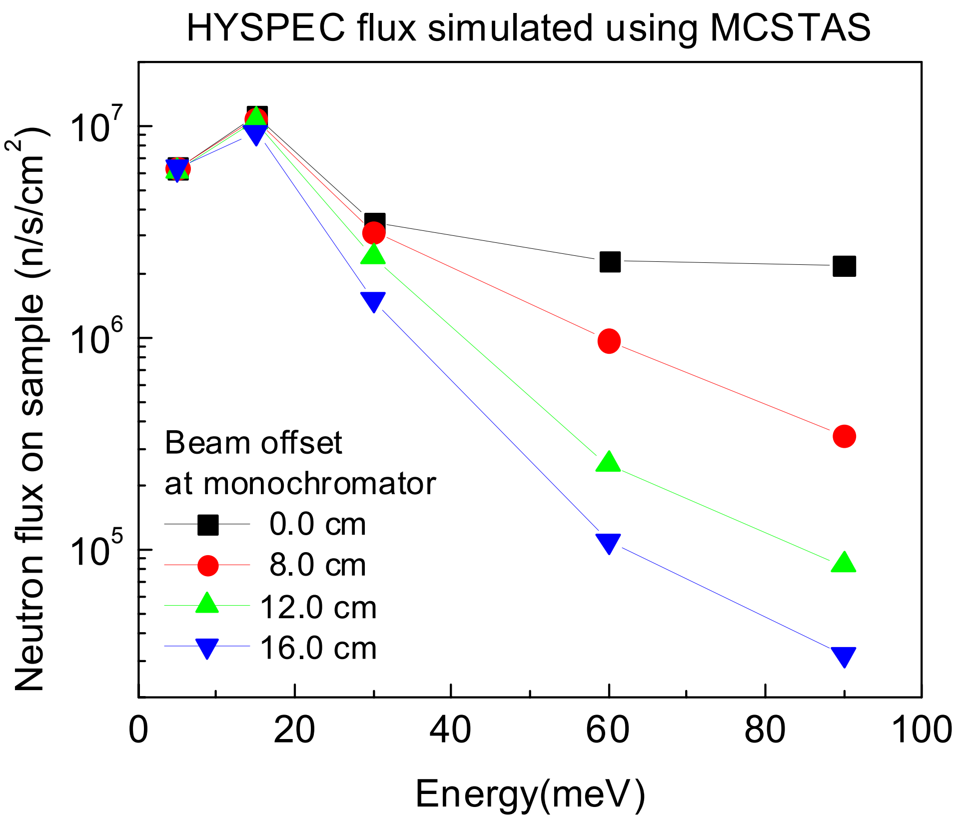
- Sample and detector size contribution to the instrument resolution is less than 0.5% each

- TOF analyzer energy resolution for the length of the secondary flight-path L_{SD}=4.5 m and pulse lengths 40 μs to 80 μs is in the range 1.7% to 15%

	Δt	$\Delta t/t_f$	$\Delta E/E_f$
E_f=5.0 meV			
	40 μs	0.0087	1.74%
	80 μs	0.0173	3.47%
E_f=15.0 meV			
	40 μs	0.015	3.0%
	80 μs	0.03	6.0%
E_f=30.0 meV			
	40 μs	0.021	4.25%
	80 μs	0.0425	8.5%
E_f=60.0 meV			
	40 μs	0.03	6.0%
	80 μs	0.06	12.0%
E_f=90.0 meV			
	40 μs	0.0368	7.36%
	80 μs	0.0736	14.7%

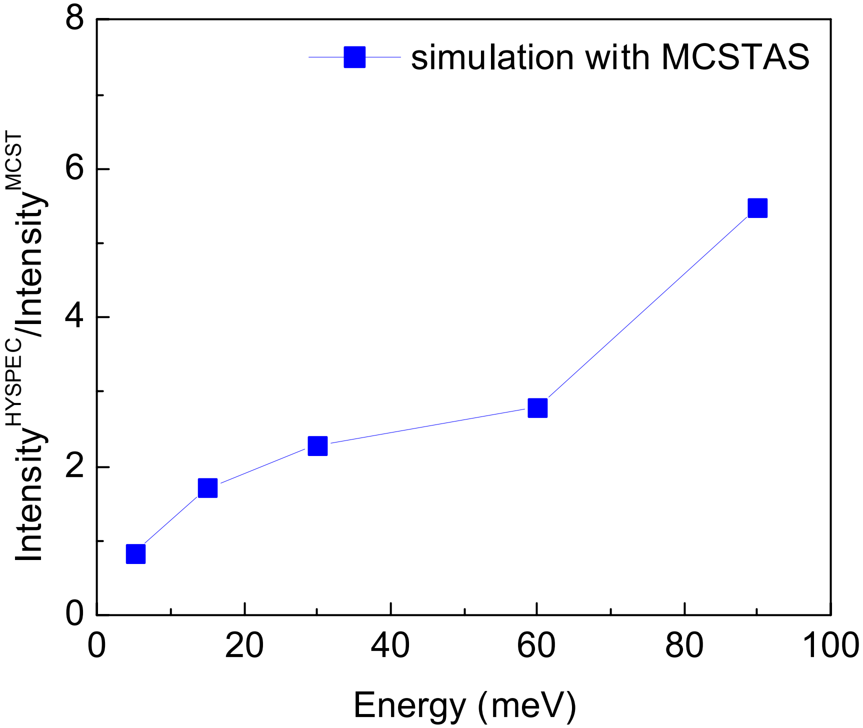
HYSPEC design choices: guide curvature

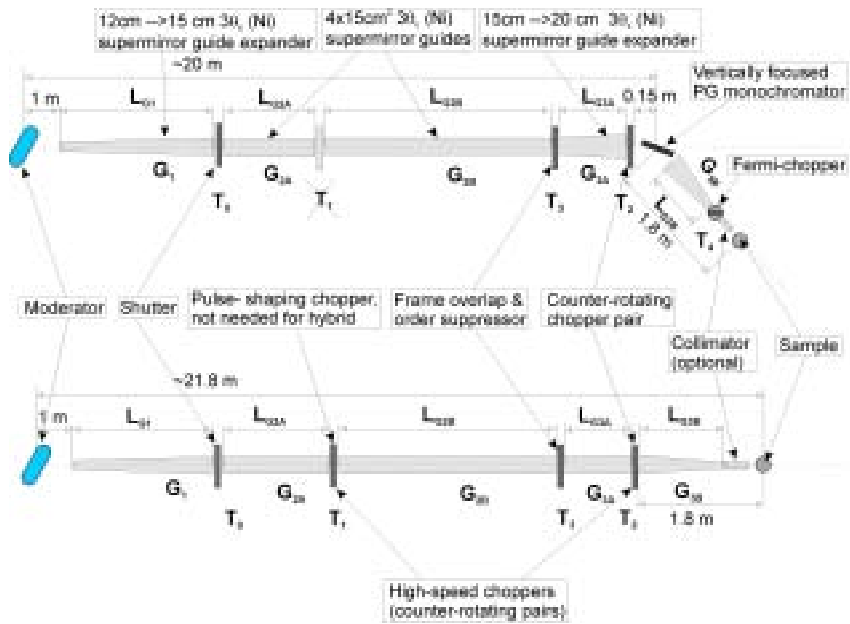
Flux on sample for different guide curvatures, parametrized by the corresponding offset at monochromator position.



- ❑ Straight guide with m=3 supermirror coating is an optimal solution

HYSPEC performance: vertical focusing gain





Crystal-monochromator hybrid spectrometer (HYSPEC, top scheme) vs traditional "straight-through" TOF setup (MCST, bottom scheme).

- HYSPEC wins except at 5 meV, where both concepts are rougthly equal.

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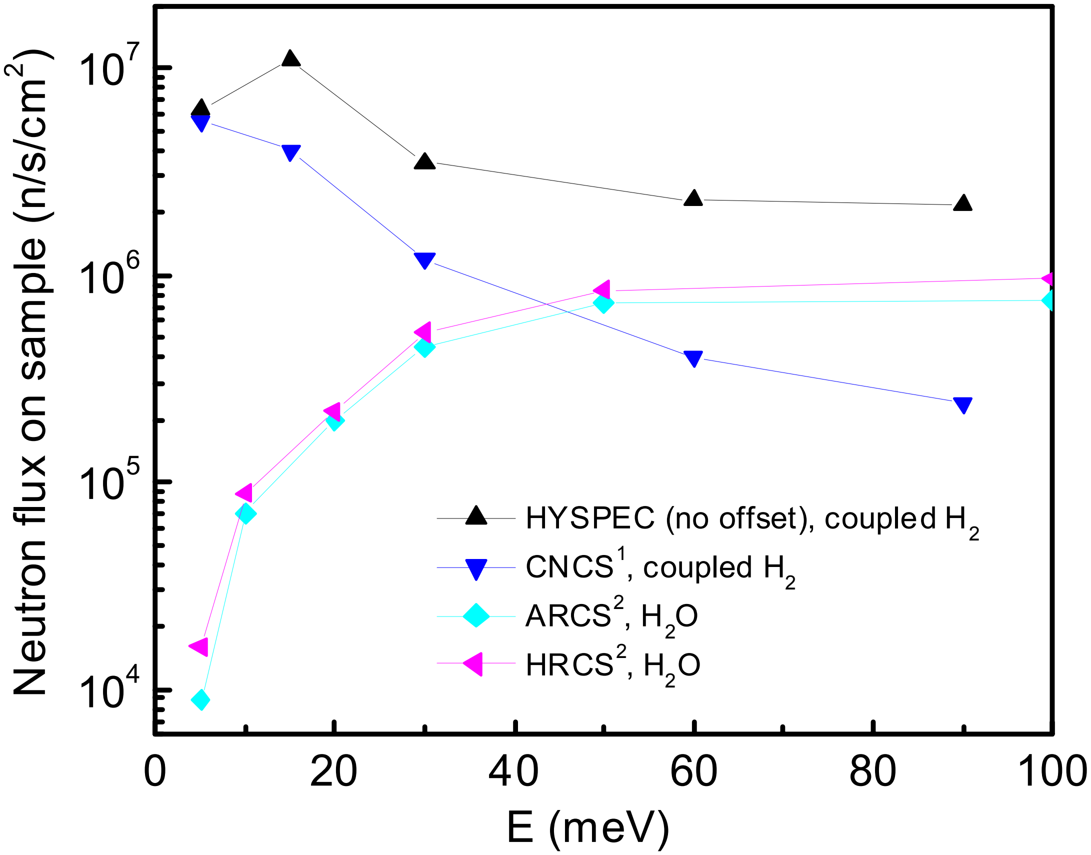
HYSPEC performance: comparison with other inelastic instruments planned for the SNS

- ❑ MC simulations by MCSTAS, V. Ghosh (2002)
- ❑ CNCS, ARCS and HRCS intensities are re-scaled to HYSPEC energy resolution (such rescaling may over-estimate the actual intensity)



[1]CNCS model based on "Optimization...",J.V.Pearce et al.

[2]G.Granroth, Private communication

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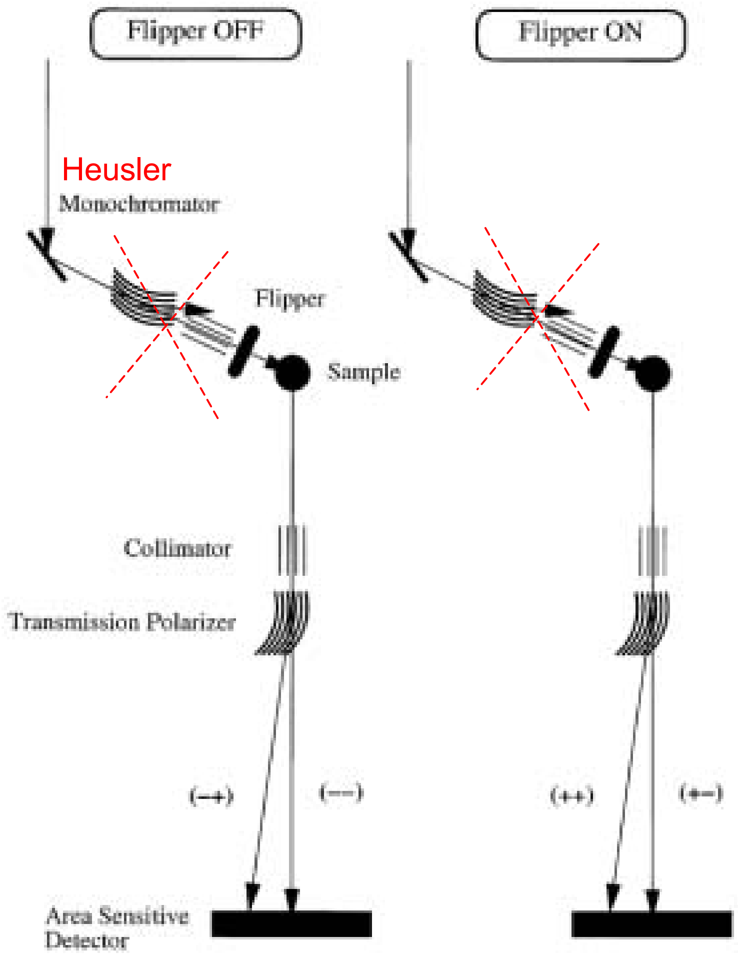
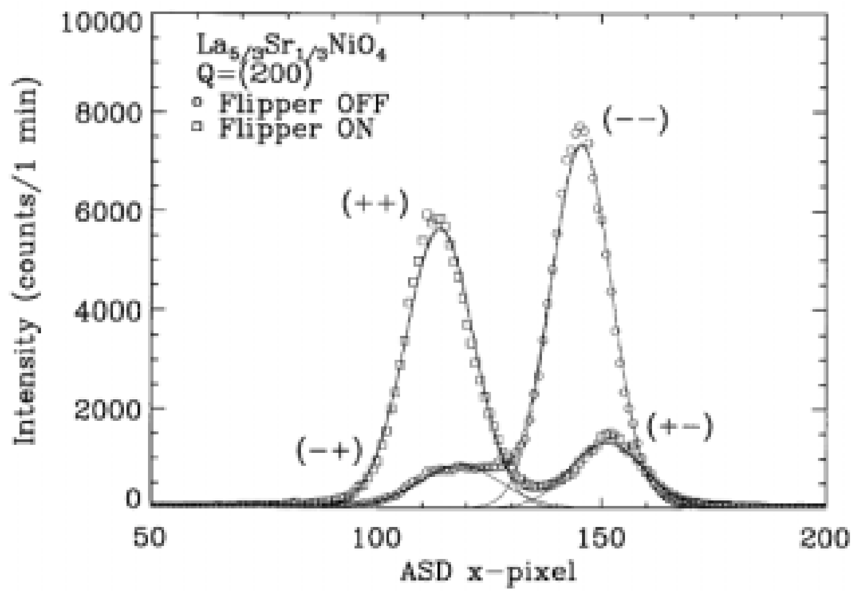
HYSPEC polarization analysis scheme: experimental demonstration

*S.-H. Lee, C. F. Majkrzak, Physica B **267-268**, 341 (1999)*





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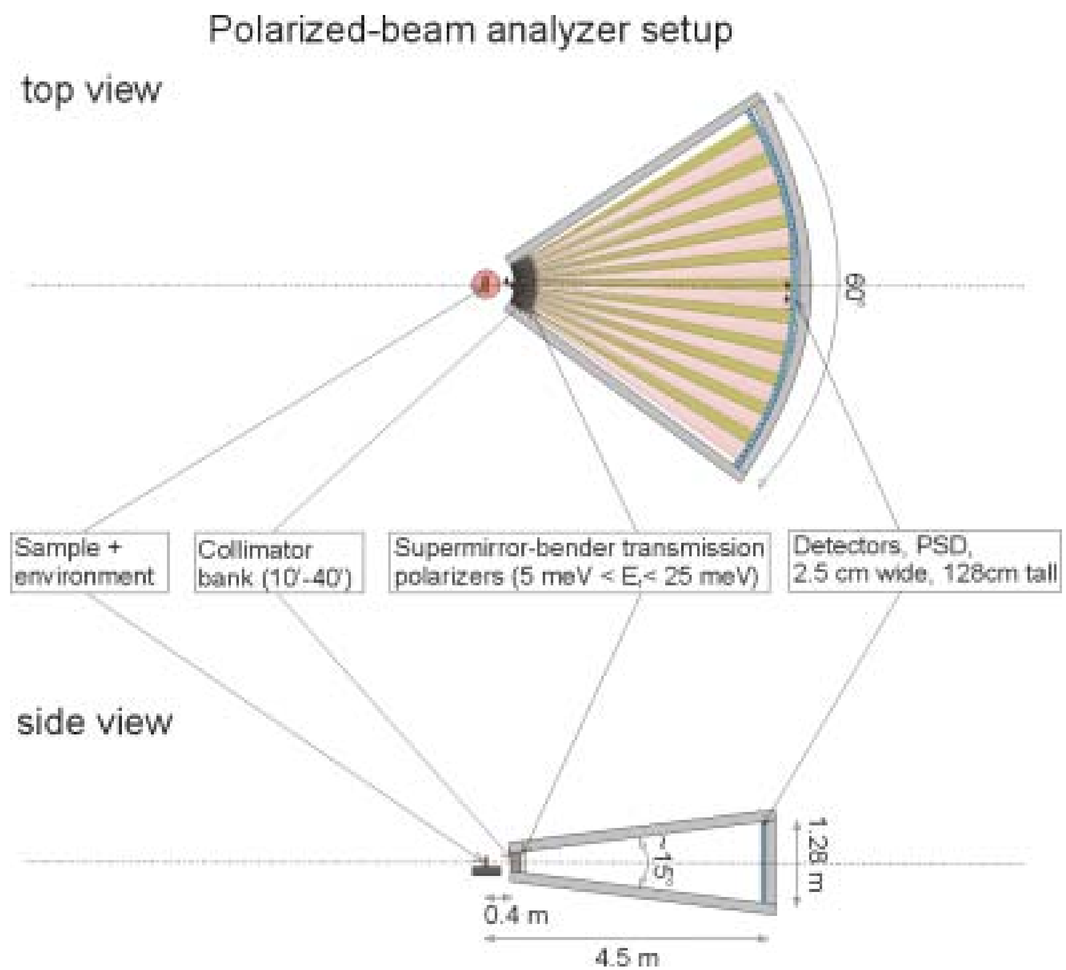
HYSPEC setup for polarization analysis

❑ Polarized incident beam is supplied by reflection from the vertically focusing Cu_2MnAl (Heusler alloy) crystal monochromator

$10meV < E_i^{pol} < 90meV$

❑ Polarization analysis of the scattered neutrons is done by a set of 11-22 supermirror-bender transmission polarizers, each 2 cm wide, 5 cm thick and 15 cm high,

$5meV < E_f^{pol} < 25meV$



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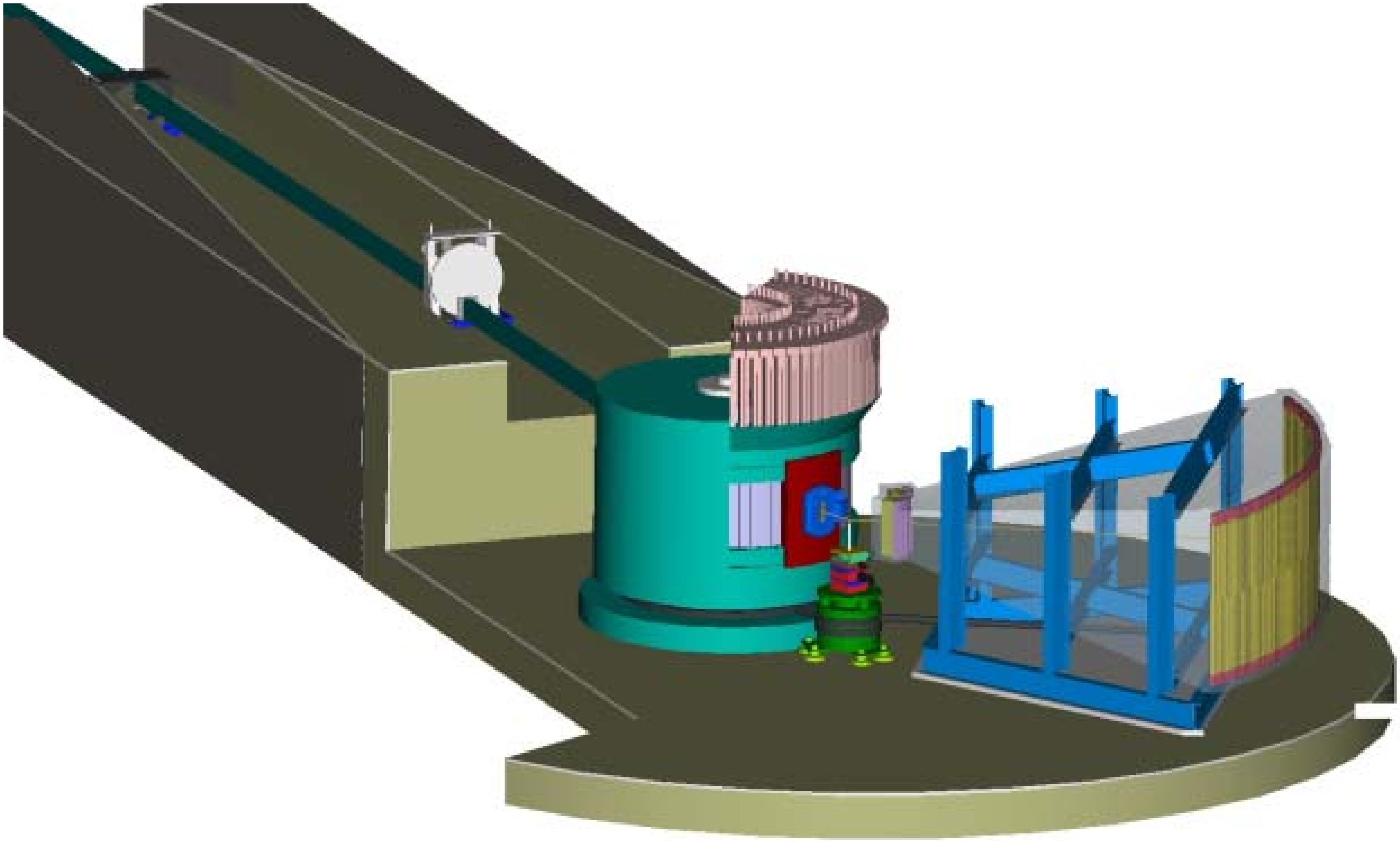
HYSPEC layout in the polarized beam mode



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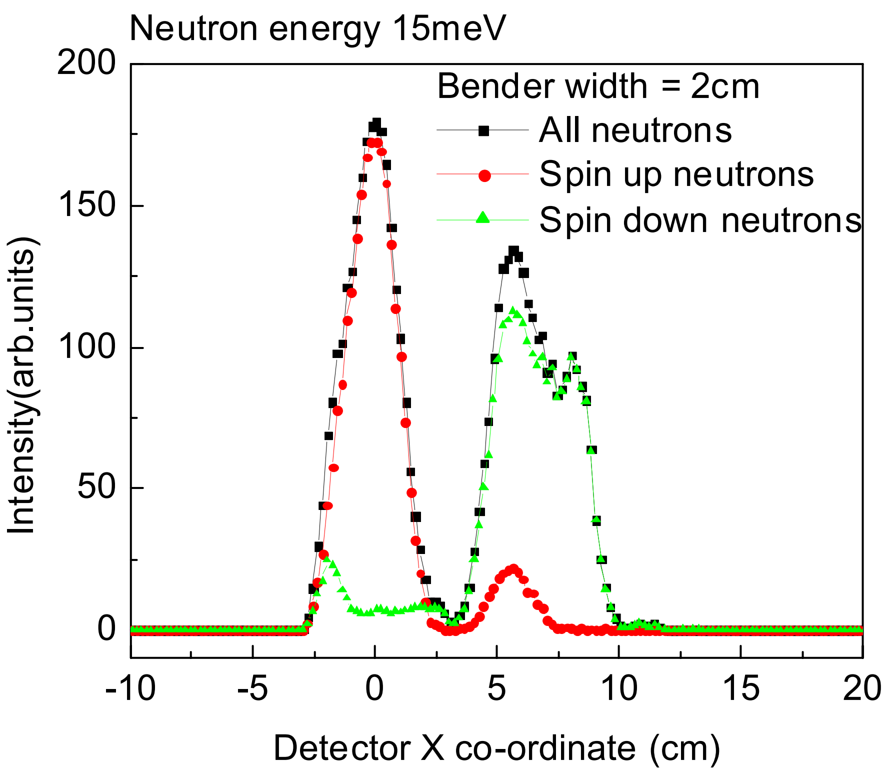
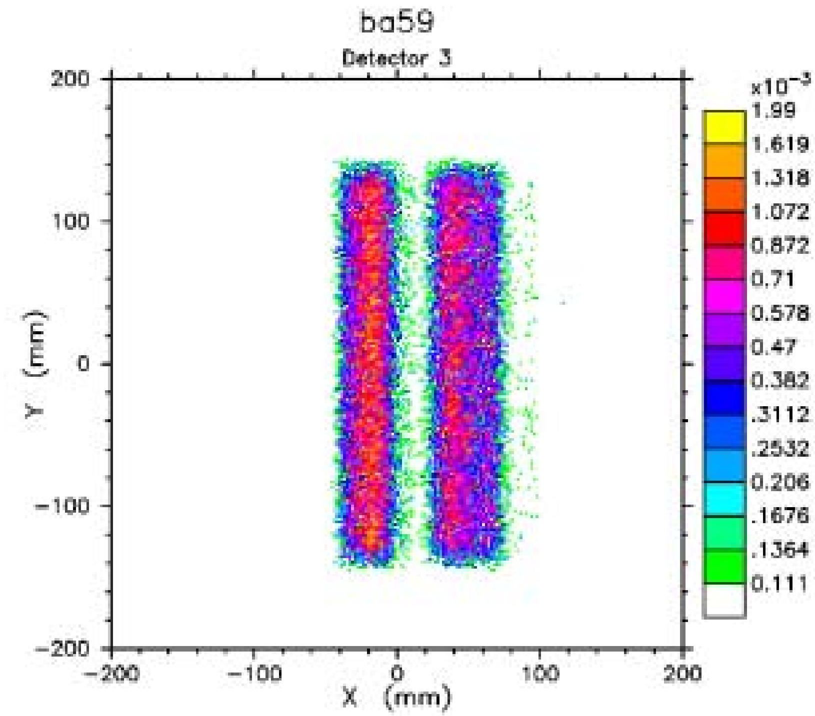
HYSPEC performance in the polarized beam mode





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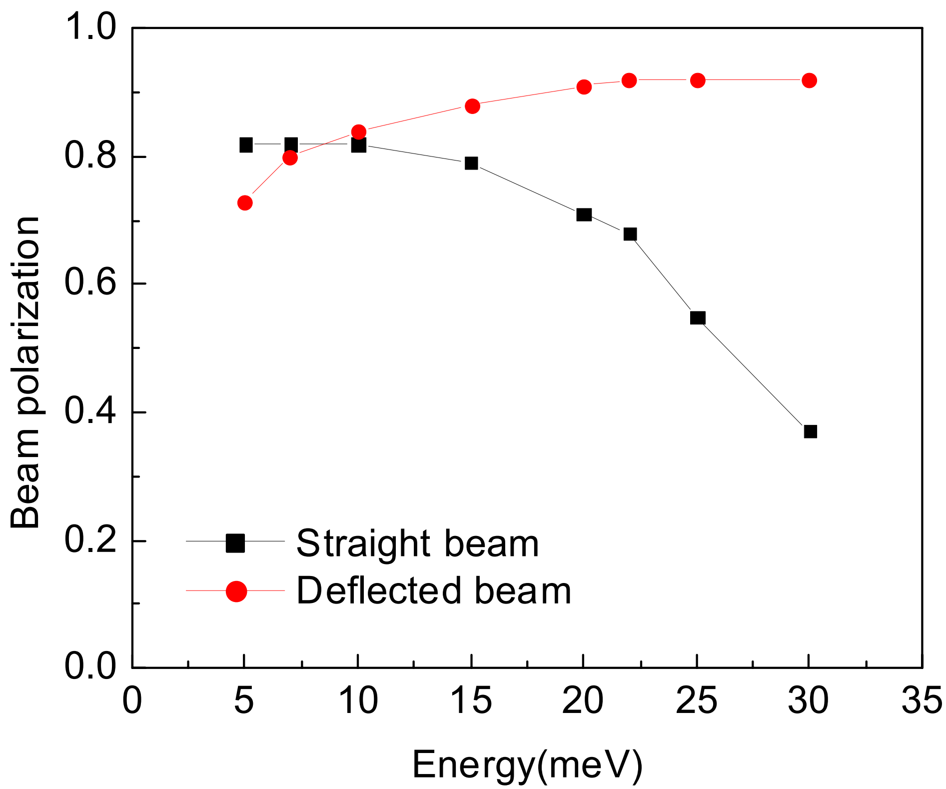
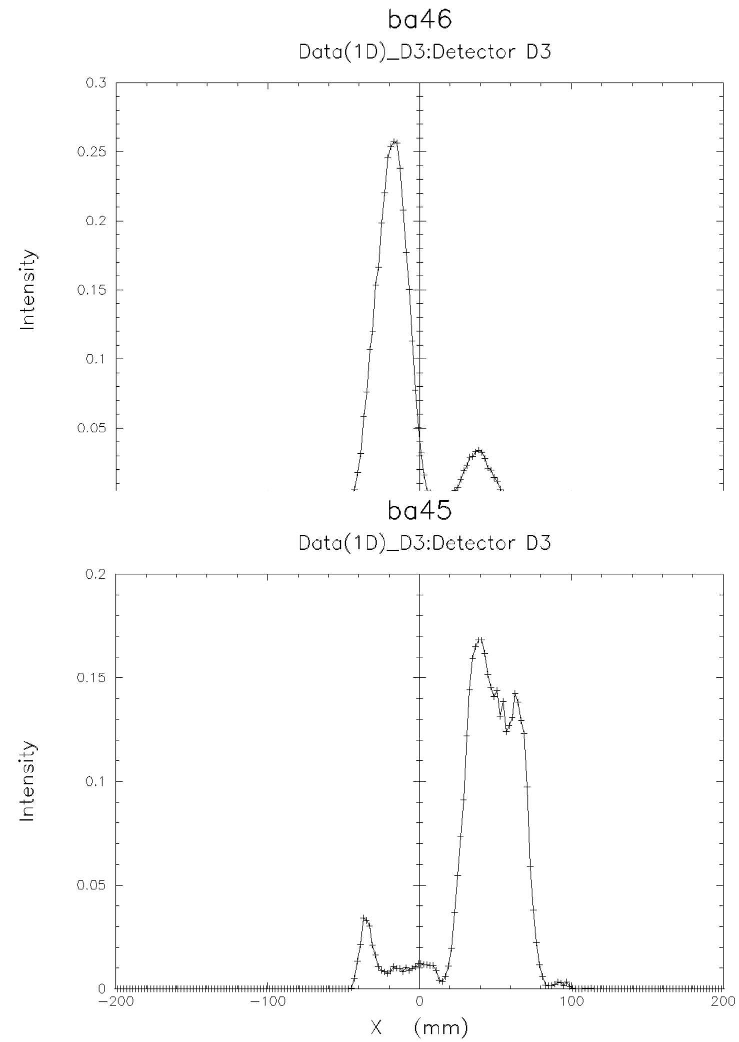
HYSPEC performance in the polarized beam mode





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HYSPEC place in the SNS inelastic instrument suite

	HYSPEC	CNCS	ARCS	HRCS
Incident energy range	5 – 90 meV	2 – 20(50?) meV	10 – 1000 meV	15 – 1000 meV
Maximum flux on sample	1.1×10^7 at 15 meV	5.6×10^6 at 5 meV	7.8×10^5 at 100 meV	9.6×10^5 at 100 meV
Energy resolution $\Delta E/E$	0.017 – 0.15	0.01 – 0.1	0.02 – 0.05	0.015 – 0.05
Polarized beam	Yes	No	No	No
Intended sample size	4 (w) x2 (h) cm^2	1.5 (w) x5 (h) cm^2	5 (w) x7.5 (h) cm^2	5 (w) x7.5 (h) cm^2
Moderator-sample dist.	21.8m	36.2m	13.6m	17.5m
Sample-detector dist.	4.5 m	3.5 m	2.5 m	6.0 m
Angular acceptance	0.27 – 0.41 sR		3.1 sR	1.2 sR
Beamline #	15	5	18	17
Guide coating	m = 3	m = 3.5	m = 3 – 3.5	m = 3 – 3.5
Guide Apertures (width x height, cm^2)	entrance 4x12.8 main 4 x 15 exit 4 x 10	entrance 5 x 10 main 5 x10 exit 1.5 x 5		

Summary

- HYSPEC will be a unique resource for probing correlations in condensed matter for

  $E \in [5,90]$ meV $\quad \Delta E/E \in [0.05,0.15]$

  $Q \in [0.3,10]$ Å^{-1} $\quad \Delta Q/Q \in [0.005,0.2]$

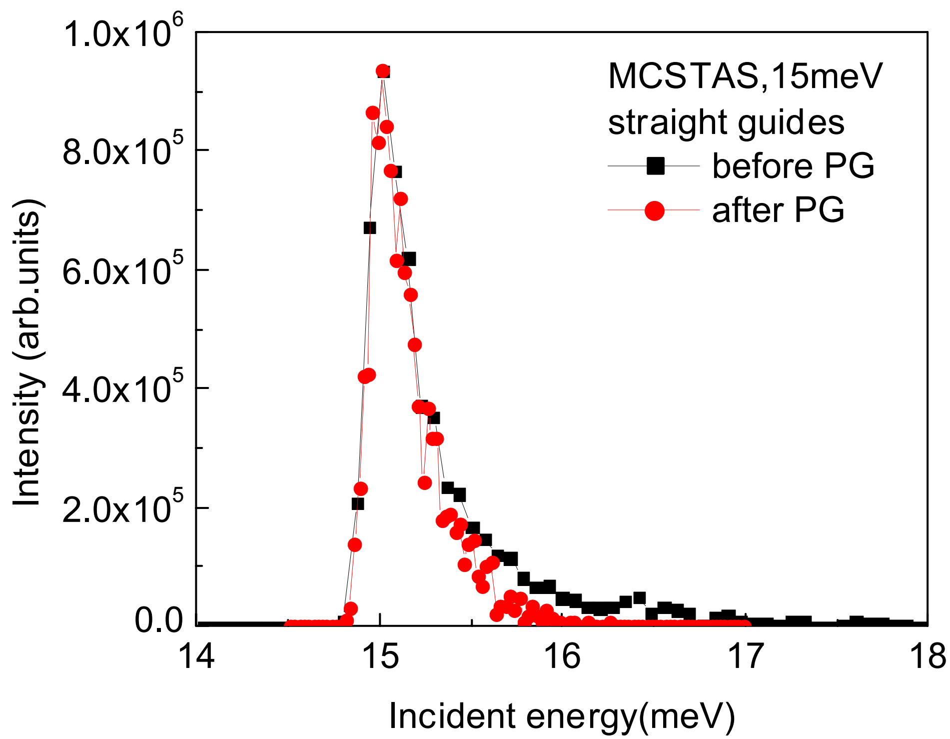
- Worlds most intense thermal neutron beam at a pulsed source
- Can optimize range of energy transfer and resolutions for experiment
- Independent variation of Q and E resolution
- Polarization analysis capability

The ultimate question: Do we need HYSPEC?

Lead: Do we need 2 to 5 times larger flux on sample compared to other SNS spectrometers and a polarized beam option?

Our answer: Yes, we do.

Appendix. HYSPEC performance: monochromator resolution function



- ❑ Significant part of the incident beam intensity - in the unwanted high-E tail
- ❑ Requires a pulse-shaping chopper in a standard TOF setup
- ❑ Is removed by reflection from the monochromator in HYSPEC

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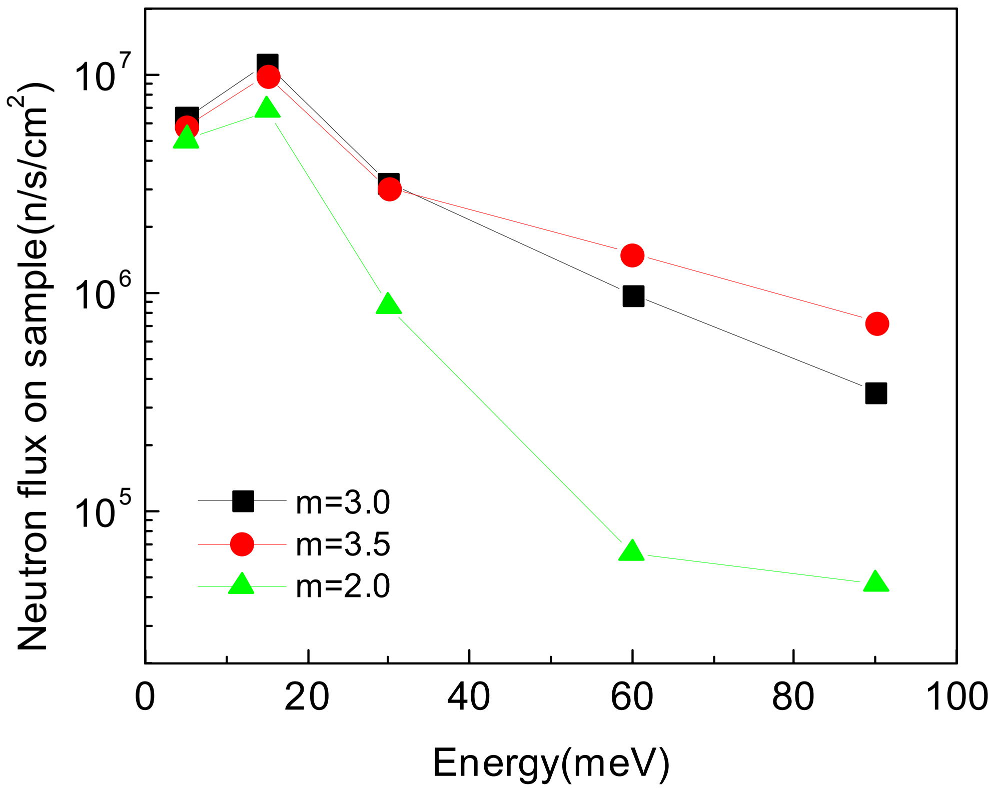
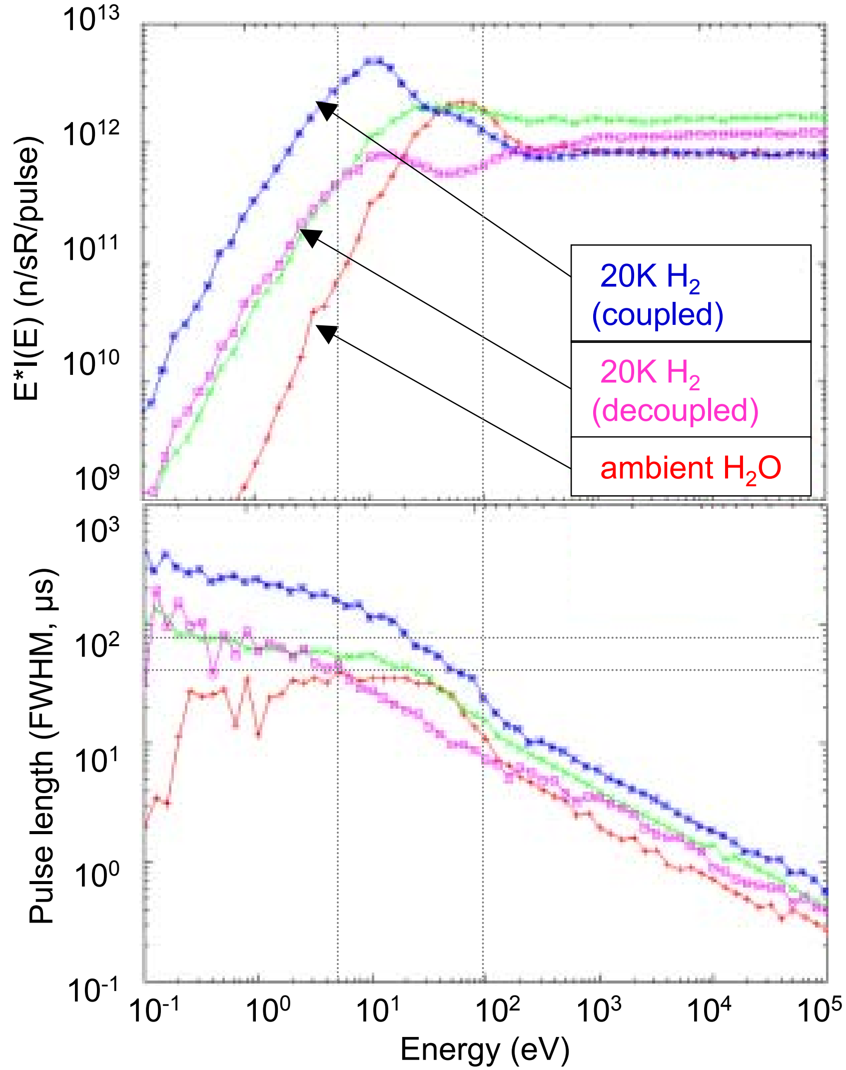
Appendix. HYSPEC design choices: guide coating

Flux on sample for m=2, 3, and 3.5 supermirror guides (for 8 cm offset at the monochromator position).



❑ Straight guide with m=3 supermirror coating is an optimal solution

Appendix. Intensity and pulse length of SNS moderators



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