Polarized Beam Mode for the Hybrid Spectrometer (HYSPEC) at the Spallation Neutron Source.

Igor Zaliznyak

Neutron Scattering Group, Brookhaven National Laboratory

HYSPEC Instrument Design Team

V. Ghosh, L. Passell and S. Shapiro (BNL), M. Hagen (SNS/BNL)

Outline

- BNL's HYSPEC project and its place in the SNS instrument suite
- HYbrid SPECtrometer's layout and principal features
- Polarized beam setup: principle, specific features and components
- Performance and optimization of the (Fe/Si) transmission polarizer for different neutron energies
- Summary, work in progress and open questions

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Spallation Neutron Source (SNS) at ORNL

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http://www.sns.gov/
http://www.sns.gov/partnerlabs/partners.htm

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HYSPEC timeline: history of the project

- March, 2004
  - M. Hagen (instrument scientist) and W. Leonhardt (engineer) join the project
- May, 2003
  - DOE CD0, part of the SING project
- 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

HYSPEC Instrument Development Team and Design Team.

IDT Members (US) and their Affiliations

S. M. Shapiro, co-PI	BNL
I. Zaliznyak, co-PI	BNL
G. Shirane	BNL
J. Tranquada	BNL
L. Passell	BNL
D. Abernathy	SNS
L. Daemon	Los Alamos
M. Greven	Stanford
B. Gaulin	McMaster
V. Kiryukhin	Rutgers
S.-H. Lee	NIST
Y. Lee	MIT
R. MQueeney	Ames/Iowa St.
S. Nagler	ORNL
R. Osborn	ANL
J. Rhyne	U. Missouri
A. Zheludev	ORNL

HYSPEC Instrument Design Team

- *I. Zaliznyak (BNL)*
- *S. M. Shapiro (BNL)*
- *L. Passell (BNL)*
- *V. J. Ghosh (BNL)*
  Monte-Carlo simulations
- *W. Leonhardt (BNL)*
  Project Engineer
- *M. Hagen (SNS/BNL)*
  Instrument scientist

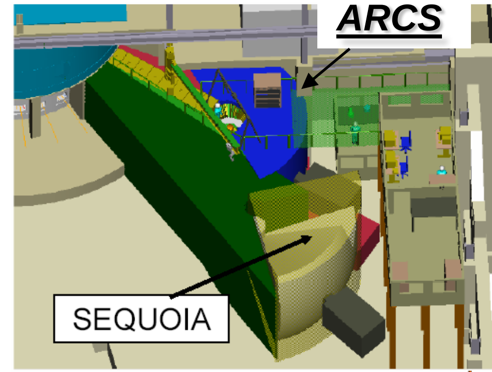
HYSPEC's place in the SNS inelastic instruments suite.

epithermal

High energy transfer

10-1000 meV Fermi Chopper Spectrometer

- E = 10 - 1000 meV
- Q = 0.1 – 22 Å^{-1}

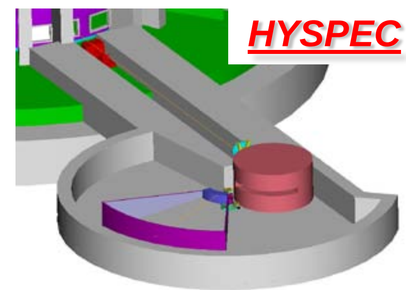


thermal

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}

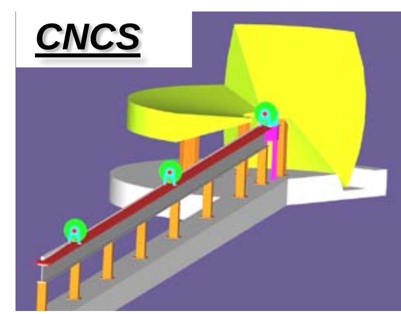


subthermal

High resolution and low energy transfer

10-100 μeV Multichopper Spectrometer

- E = 2 - 20 meV
- Q = 0.1 - 4 Å^{-1}



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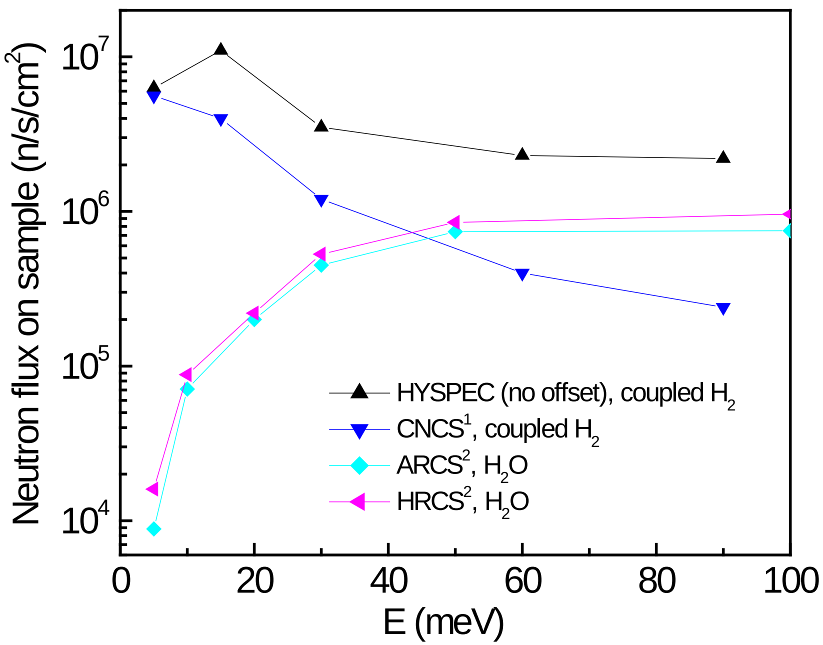
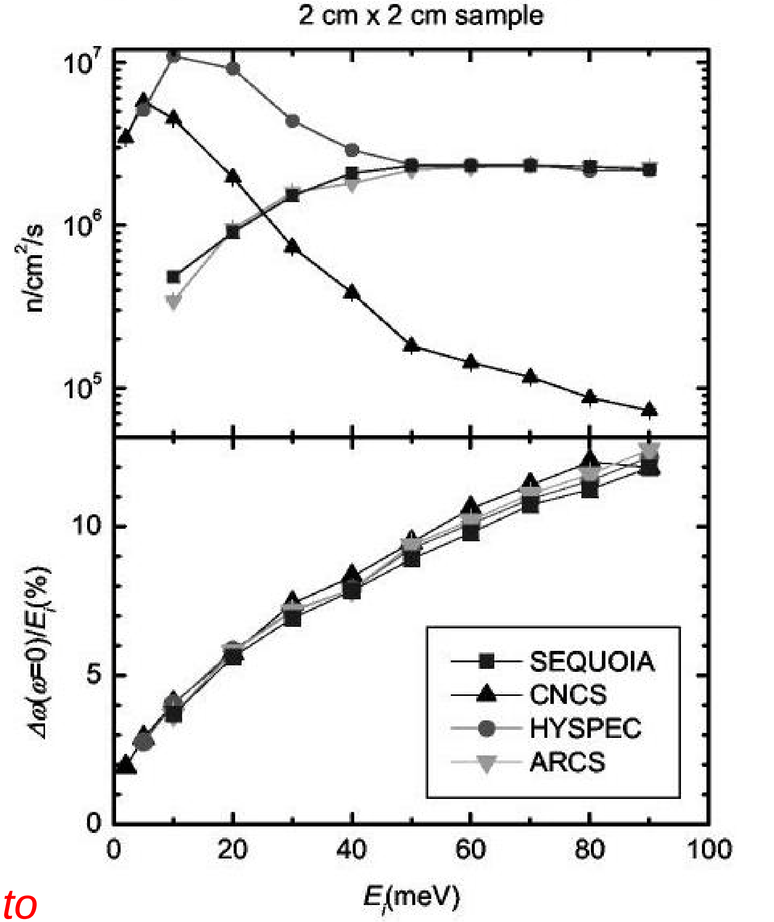
Comparison of the HYSPEC performance with other inelastic instruments planned for the SNS

MCSTAS simulations by HYSPEC IDT (V. Ghosh), with different re-scaling for ARCS and SEQUOIA



[1]CNCS model based on "Optimization...",J.V.Pearce et al.
[2]G.Granroth, Private communication

MC simulations by SNS (G. Granroth and D. Abernathy)



CNCS, ARCS and HRCS intensities were re-scaled to the same, coarser energy resolution as HYSPEC (this over-estimates their actual intensity)

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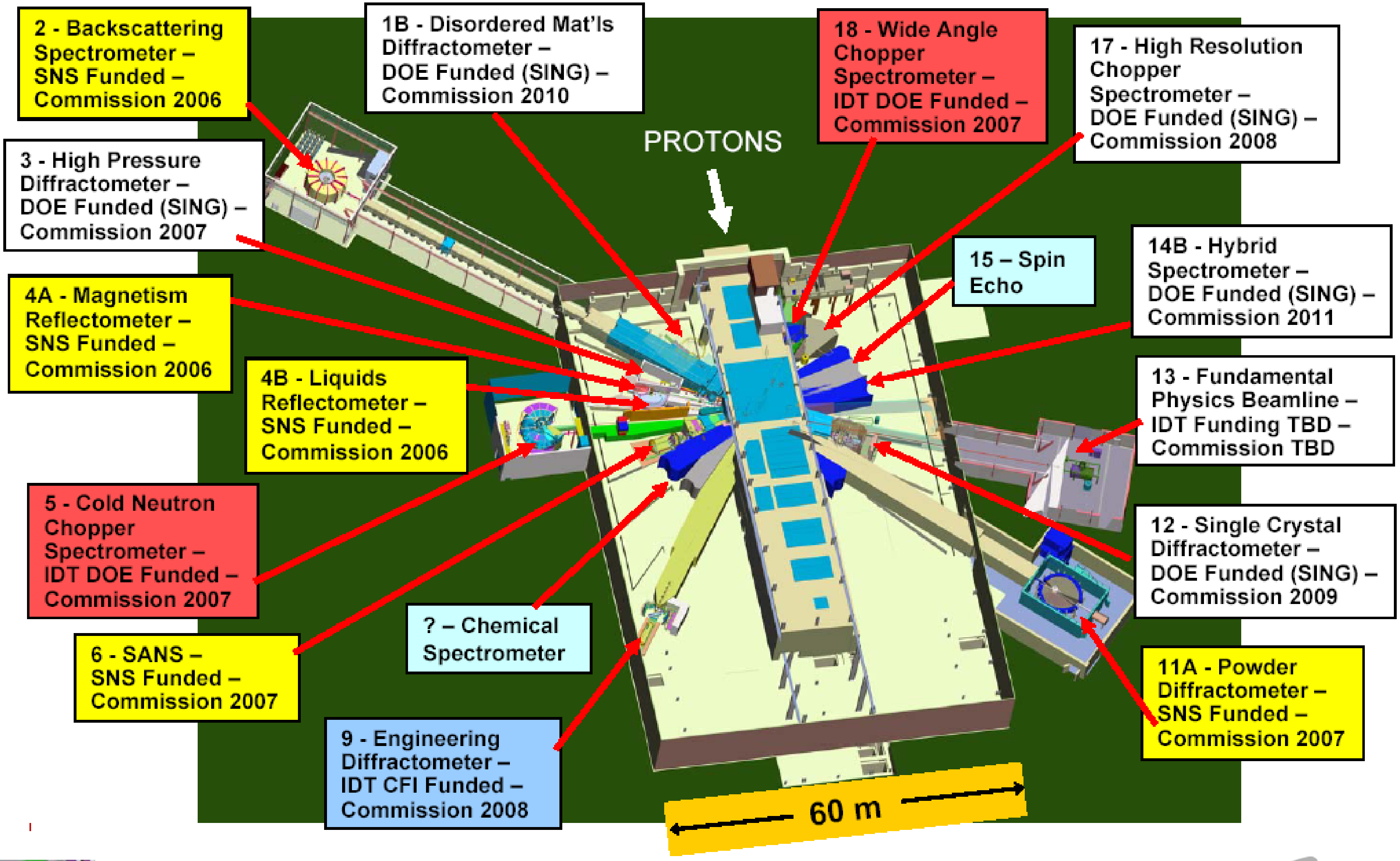
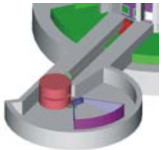
Current status of the SNS instrument suite





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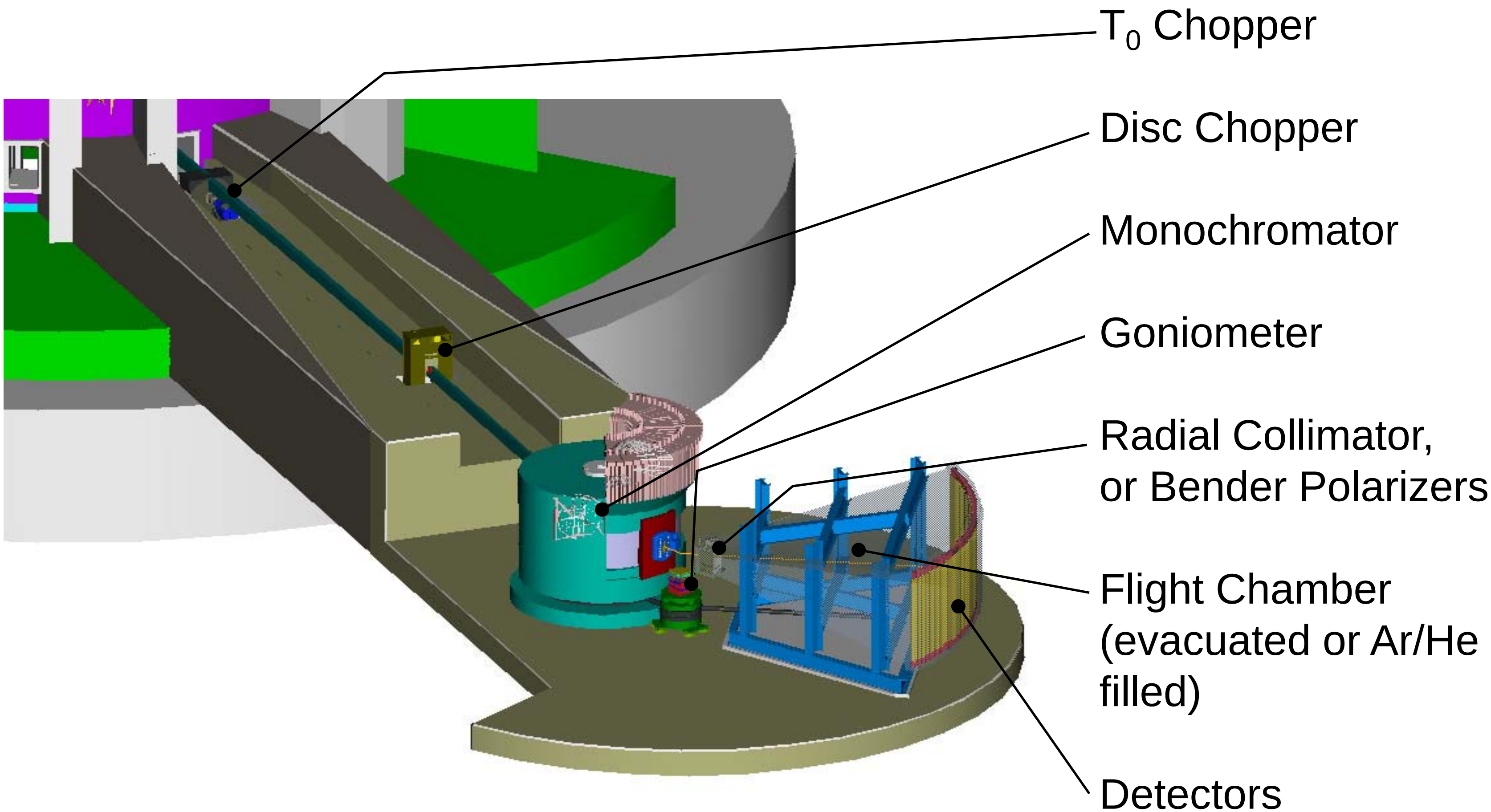
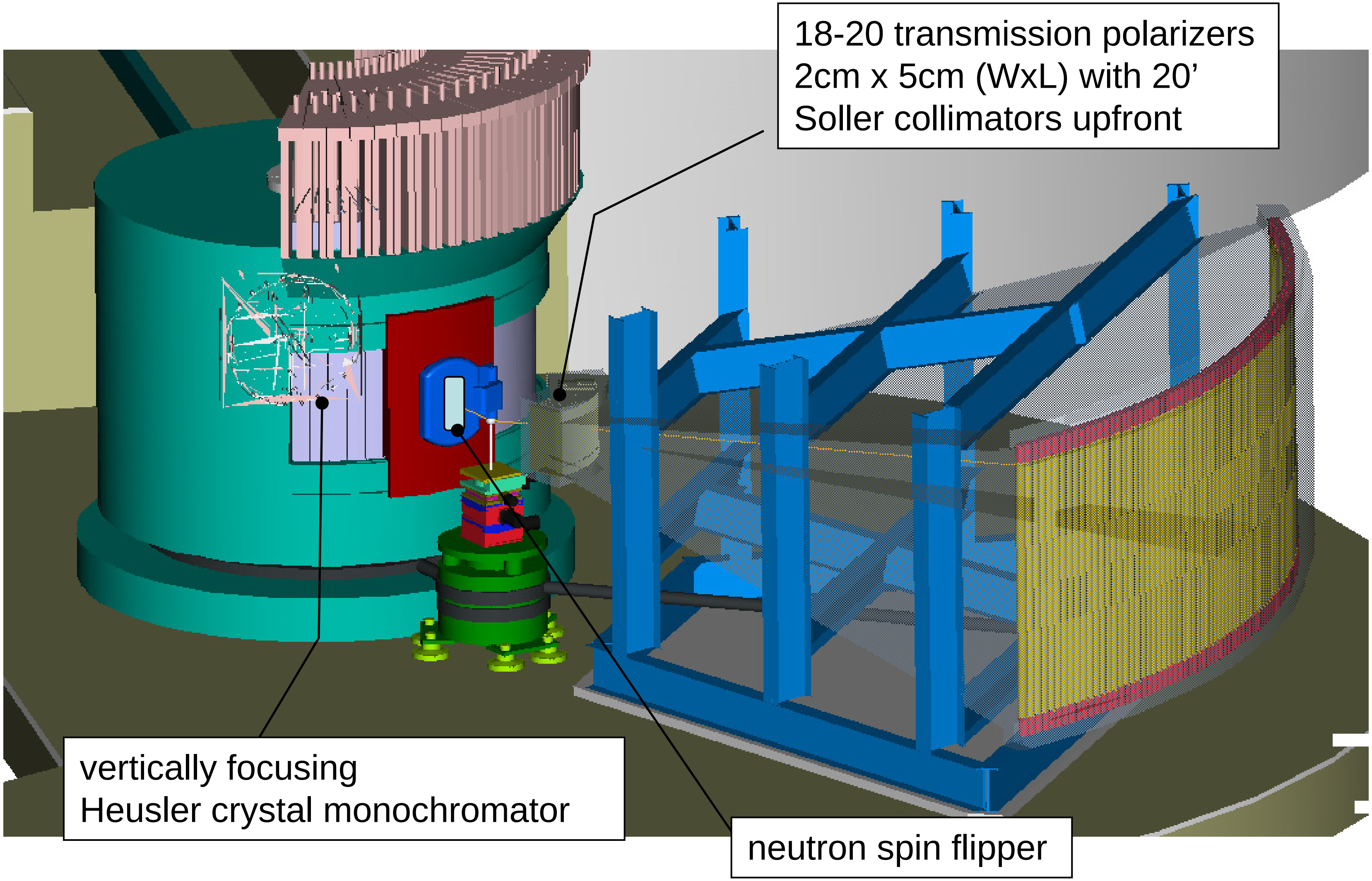
HYSPEC layout and principal features

To get more information, and for the project updates, please, visit
http://neutrons.phy.bnl.gov/hyspec

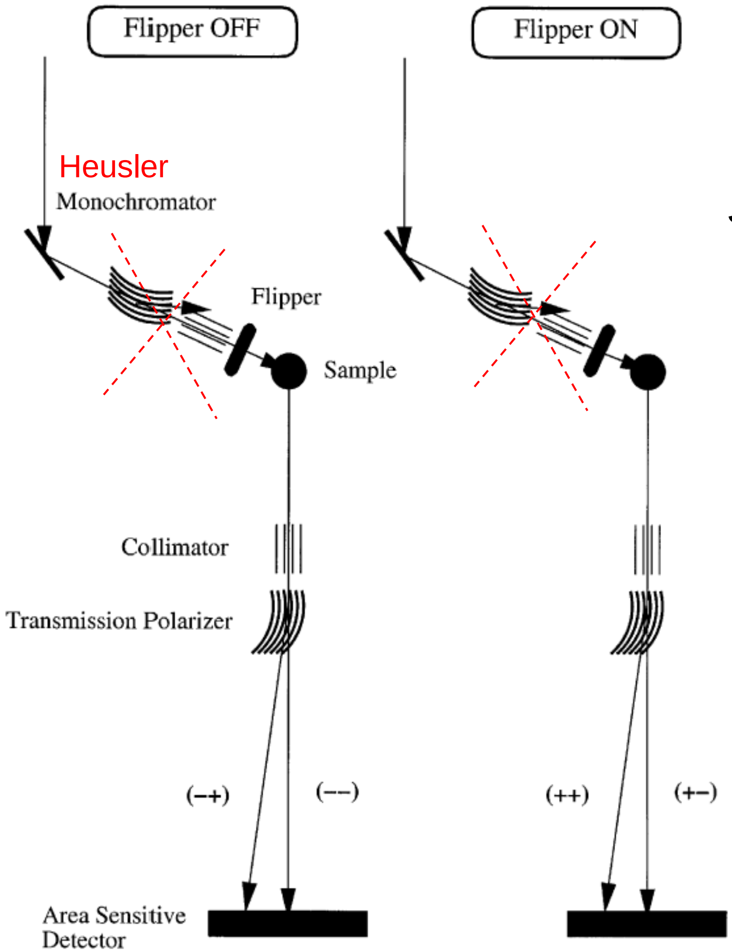


HYSPEC layout in the polarized beam mode

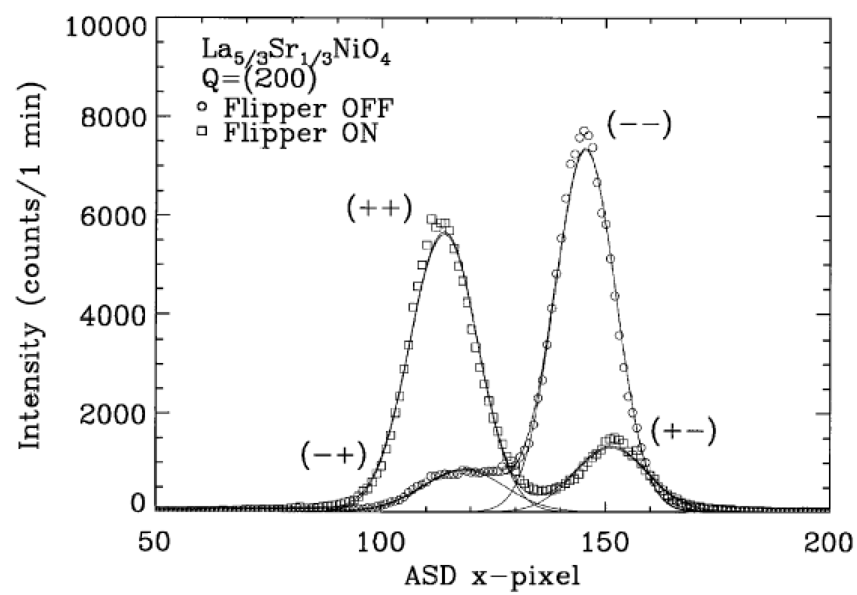


HYSPEC polarization analysis: principle and experimental demonstration on SPINS at NIST

Polarized beam Measurement with a Position Sensitive Detector (PSD)



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



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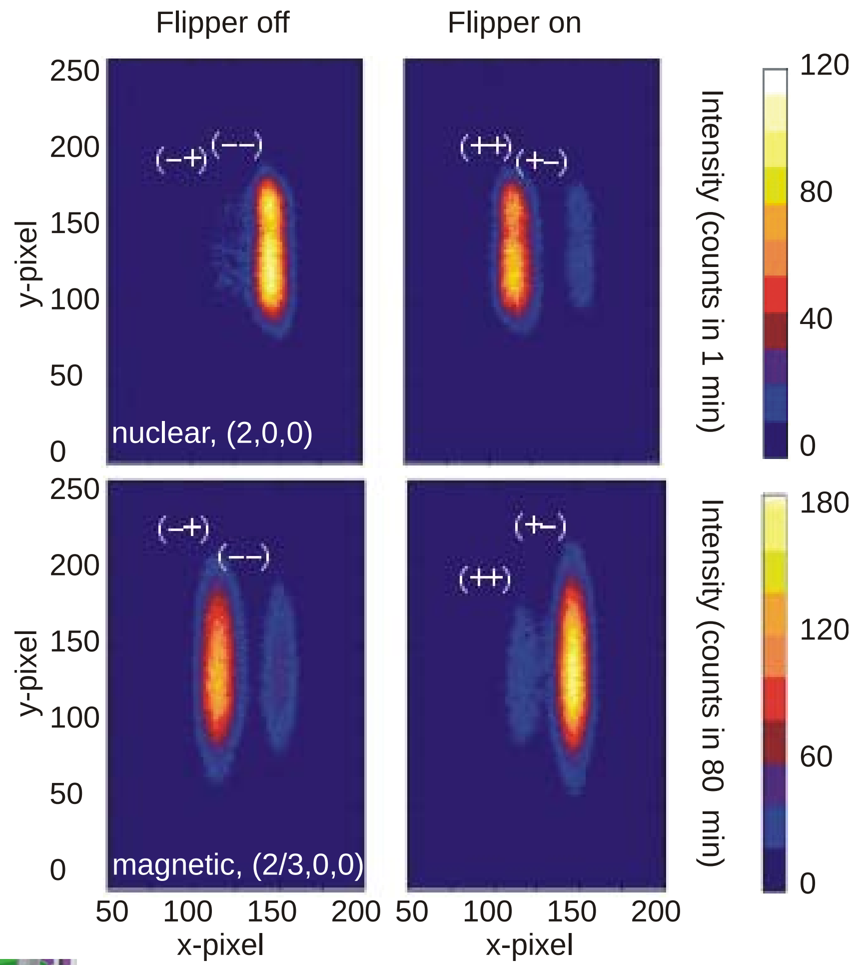
HYSPEC polarization analysis: experimental demonstration with PSD on SPINS

Nuclear and magnetic scattering intensities in $La_{5/3}Sr_{1/3}NiO_4$



I. A. Zaliznyak and S.-H. Lee, in Modern Techniques for Characterizing Magnetic Materials, ed. Y. Zhu (to be published by Kluwer Academic, 2004)

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HYSPEC setup for polarization analysis

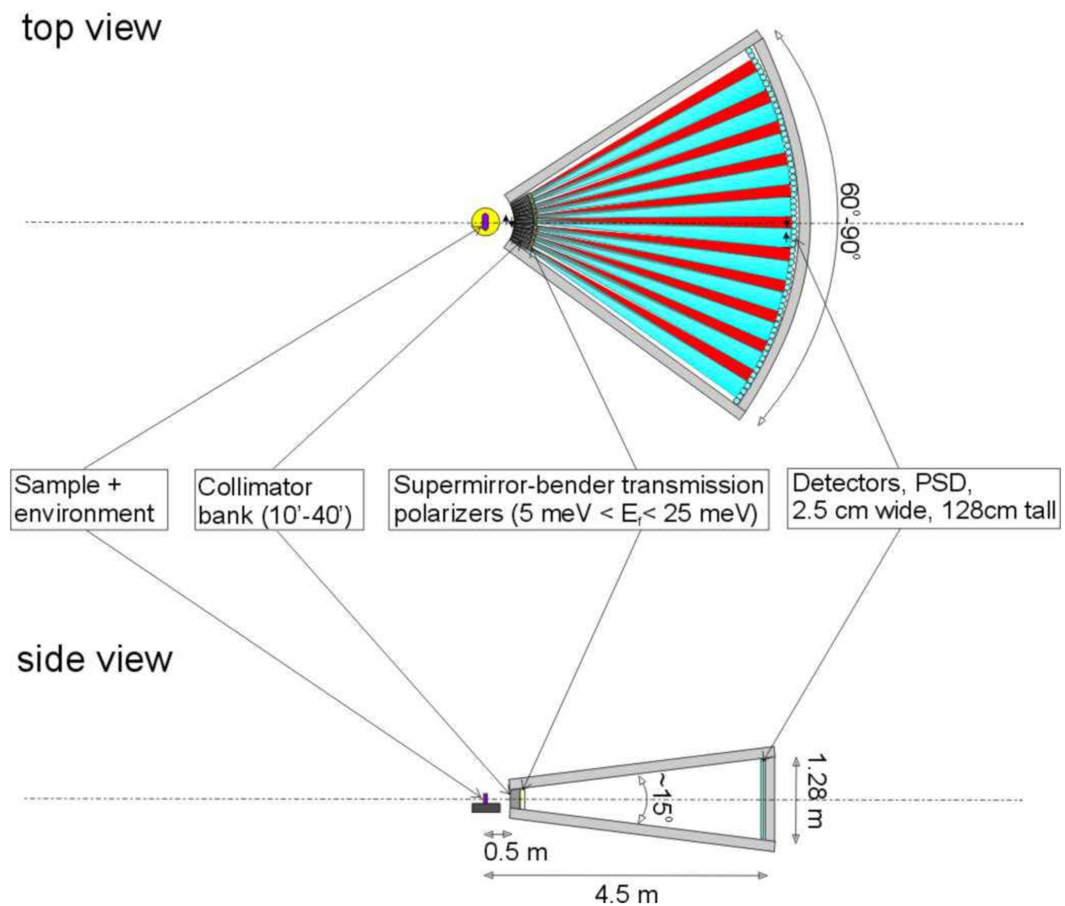
- Polarized incident beam is supplied by reflection from the vertically focusing Cu_2MnAl (Heusler alloy) crystal monochromator

10 meV < E_i^{pol} < 90 meV

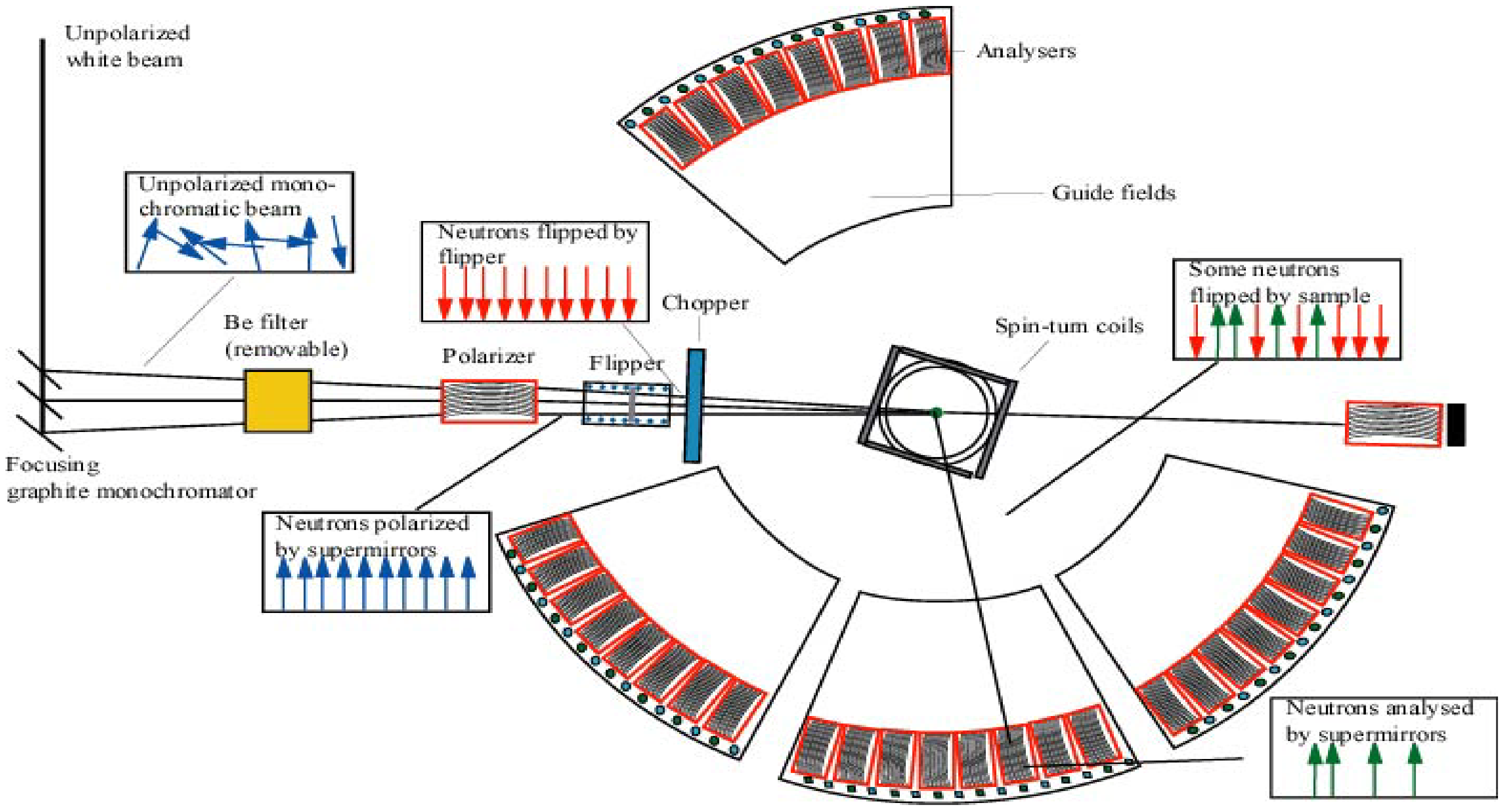
- Polarization analysis of the scattered neutrons is performed by a set of 18-22 supermirror-bender transmission polarizers, each 2 cm wide, 5 cm thick and 15 cm high,

3.7 meV < E_f^{pol} < 15-25 meV

Polarized-beam analyzer setup



A somewhat similar concept: D7 at ILL



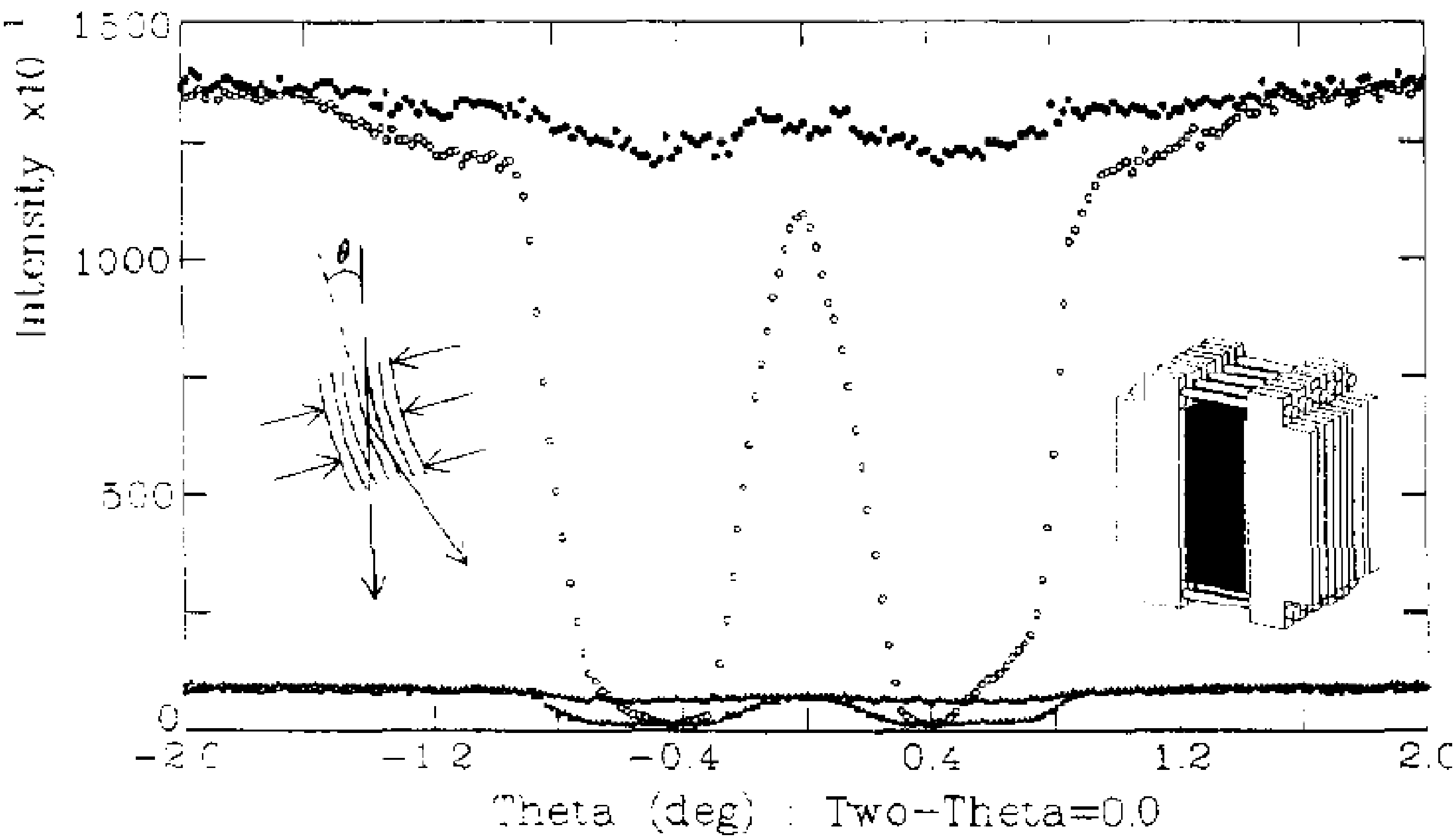
Important distinctions of the HYSPEC

– *optimized for using the straight-through transmitted beam*

– *both spin states are measured by the detector array*

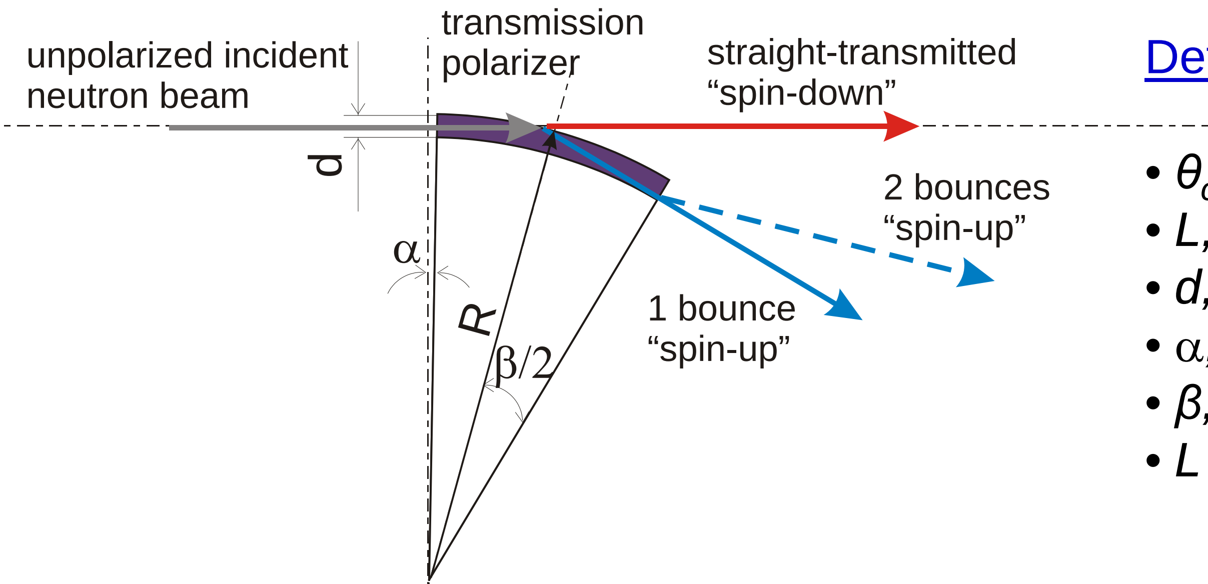
Most important question: can we expect the transmission polarizers to work up to 15-25 meV?

Performance of an optimized Fe/Si transmission polarizer for ~15 meV
C. Majkrzak, Physica B 213&214 (1995)



Yes, but fine-tuning of the polarizer tilt angle is necessary.

Optimizing the geometry of a single-bounce transmission polarizer



Defining parameters are:

- $\theta_c^{(up)}$ *and* $\theta_c^{(down)}$
- *L, length*
- *d, channel width*
- α*, tilt angle*
- β*, bend angle*
- $L \approx 2R \sin(\beta/2) \approx R\,\beta$

Optimization considerations and constraints

- $\theta_c^{(up)} = 3.0\ \theta_c^{(Ni)}$, $\theta_c^{(down)} = 0.6\ \theta_c^{(Ni)}$, => *best we can imagine for now*
- $L \approx 50$ *mm* => *maximum length is constrained by the transmission through Si*
- $d \le R(1-\cos\beta) \approx L\beta/2 \approx 0.25$ *mm* => *to remove the line-of-sight*
- *polarizer bend angle* β => *mechanically constrained, currently use* 0.57°
- *polarizer tilt angle* α => *must be optimized*

Simple optimization condition for a single-bounce device

$$(\alpha + \beta) = \theta_c^{(up)} = 3.0\ \theta_c^{(Ni)}$$

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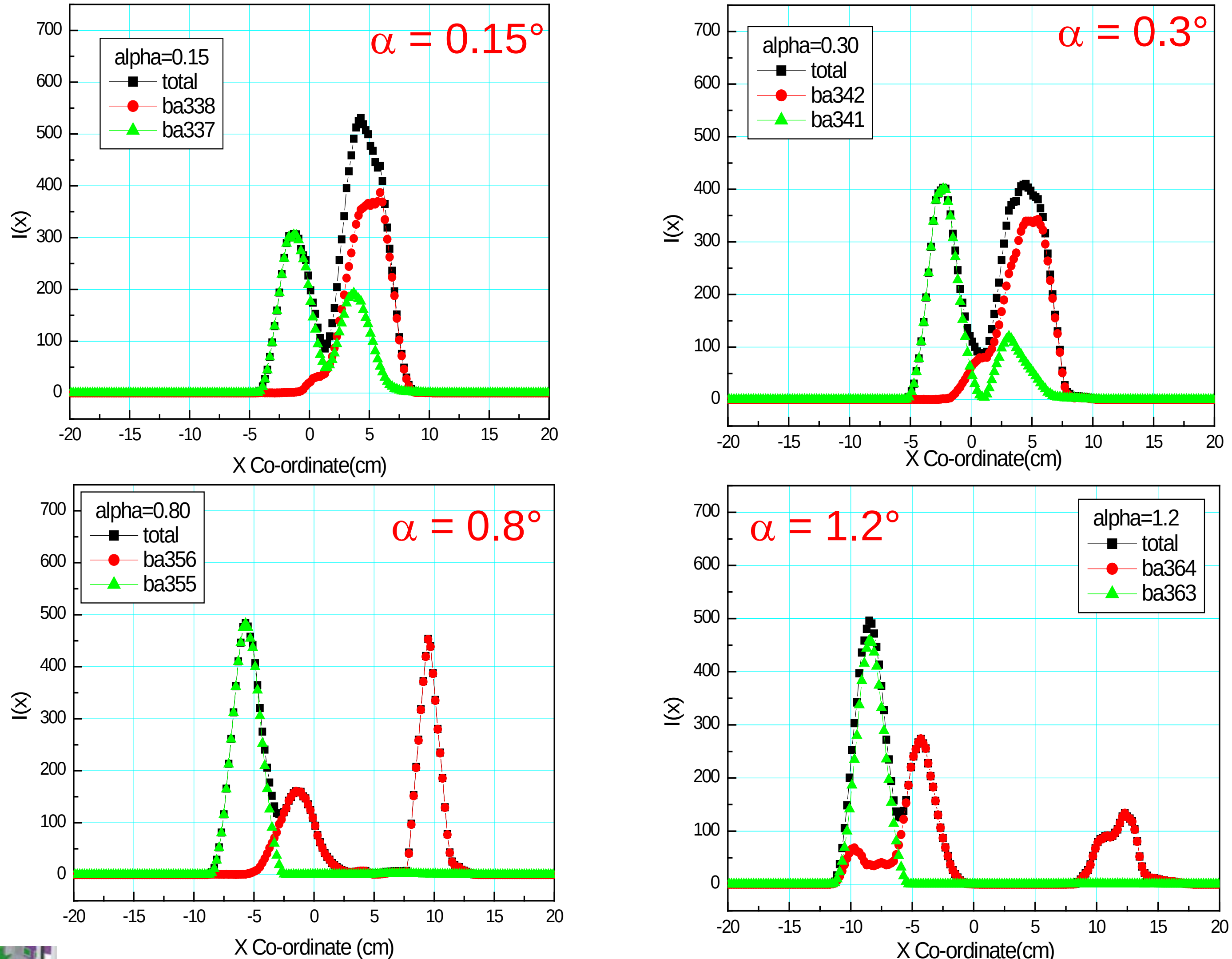
Optimizing the polarizer tilt angle at E = 3.7 meV

20' collimator in front



Neutron beam profiles on the detector

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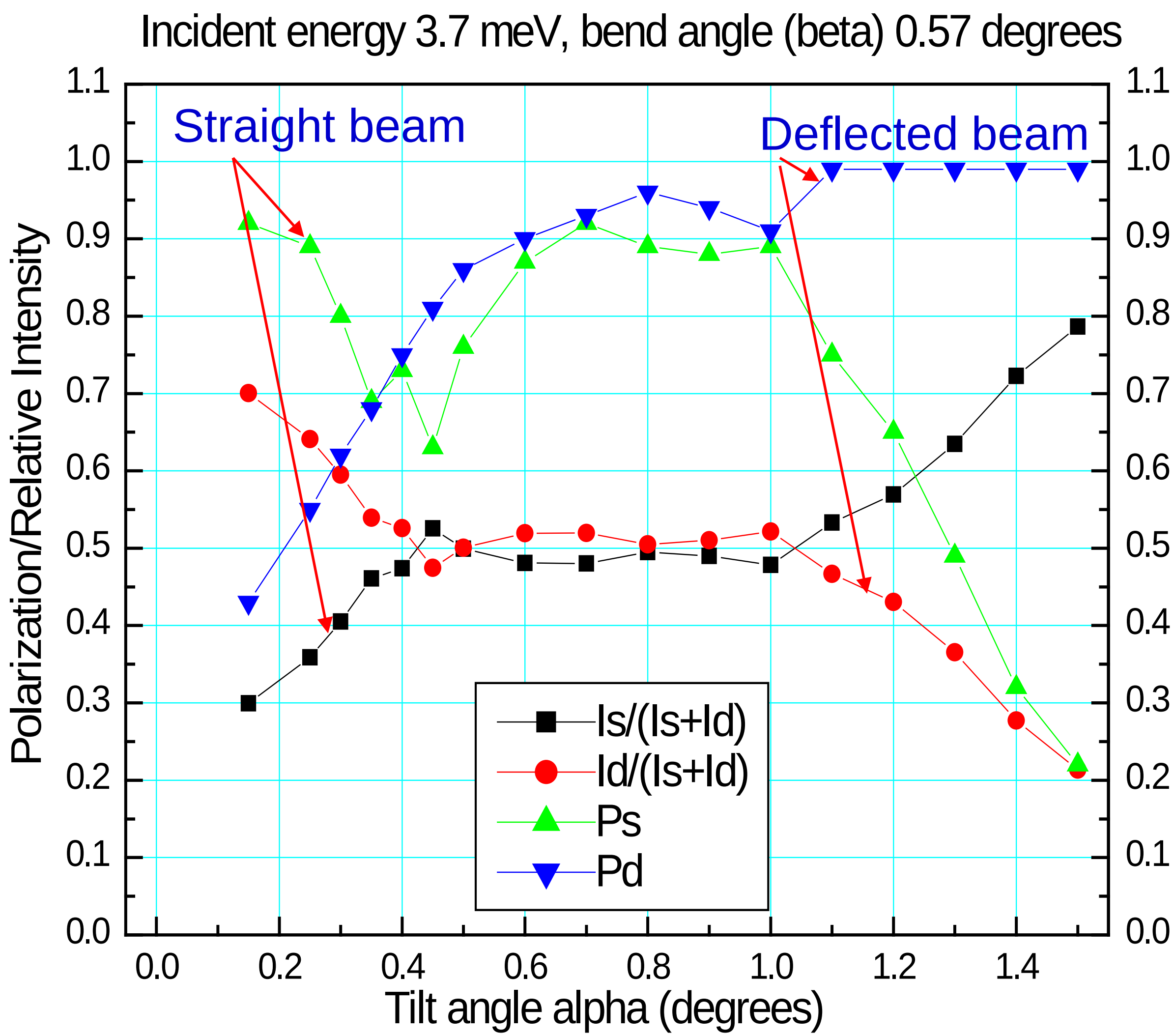
Optimizing the polarizer tilt: E = 3.7 meV is quite “forgiving”



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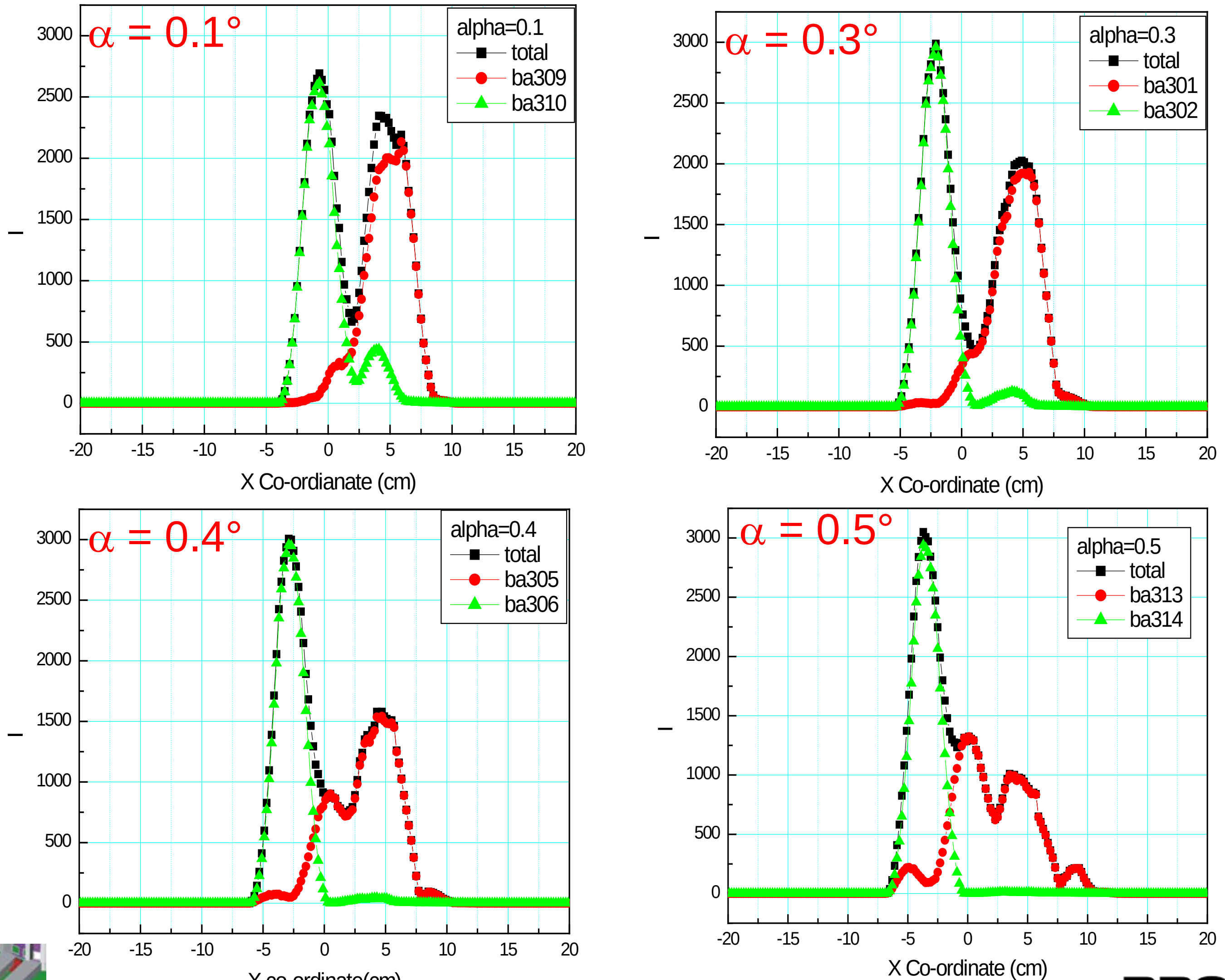
Optimizing the polarizer tilt angle at E = 10 meV

20' collimator in front



Neutron beam profiles on the detector

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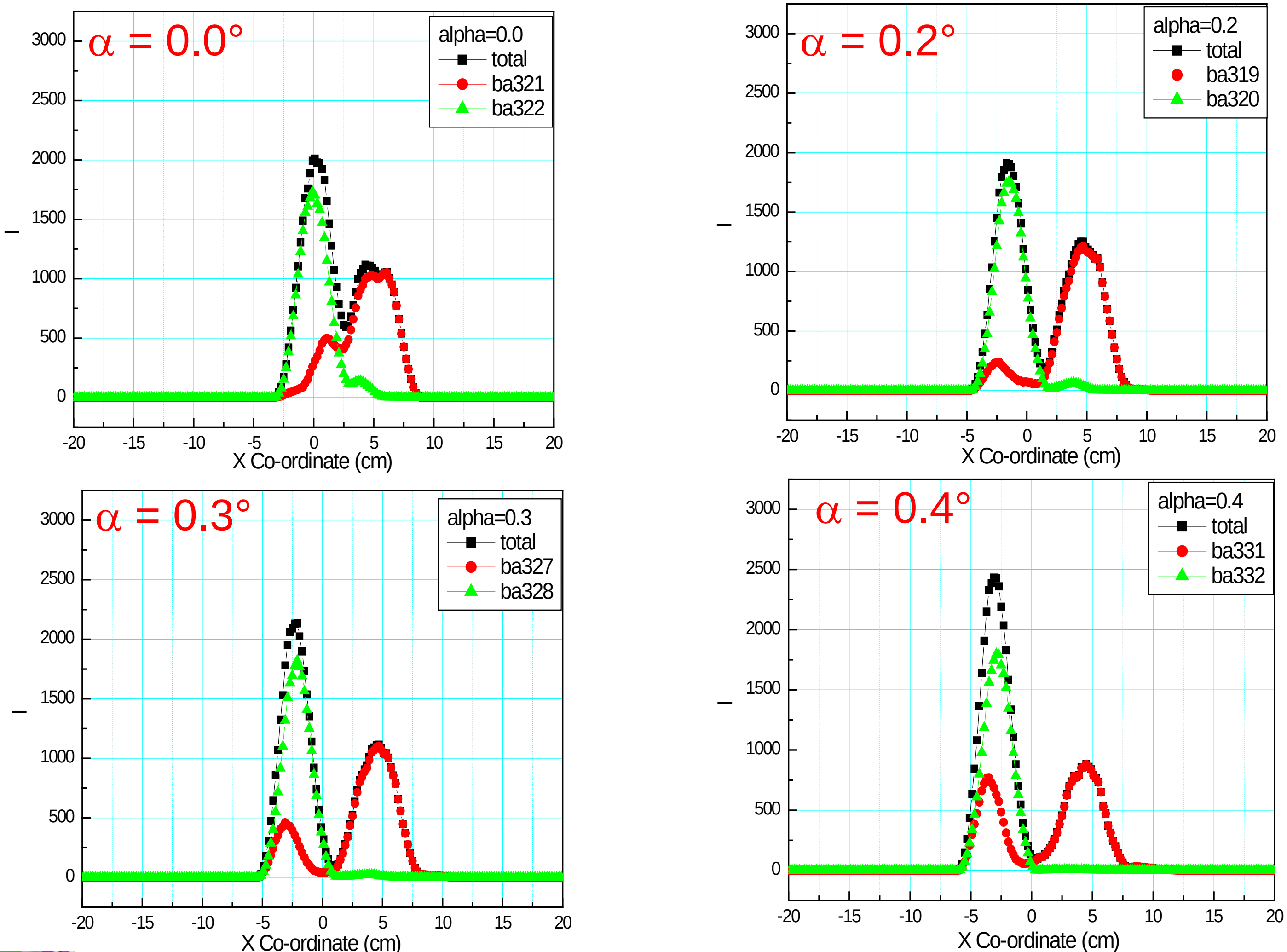
Optimizing the polarizer tilt angle at E = 20 meV

20’ collimator in front



Neutron beam profiles on the detector

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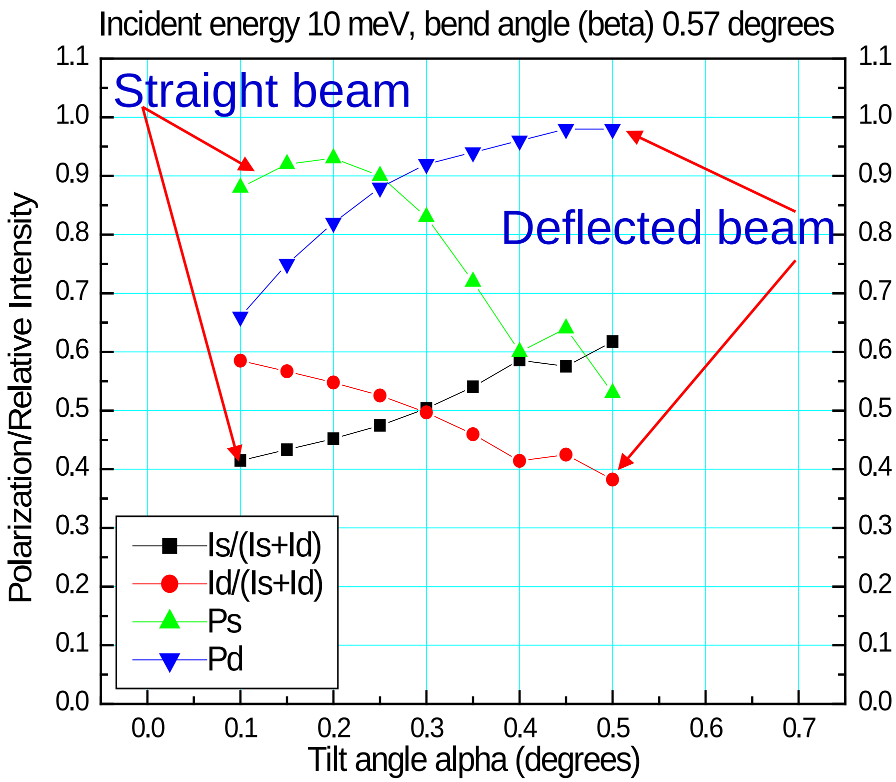
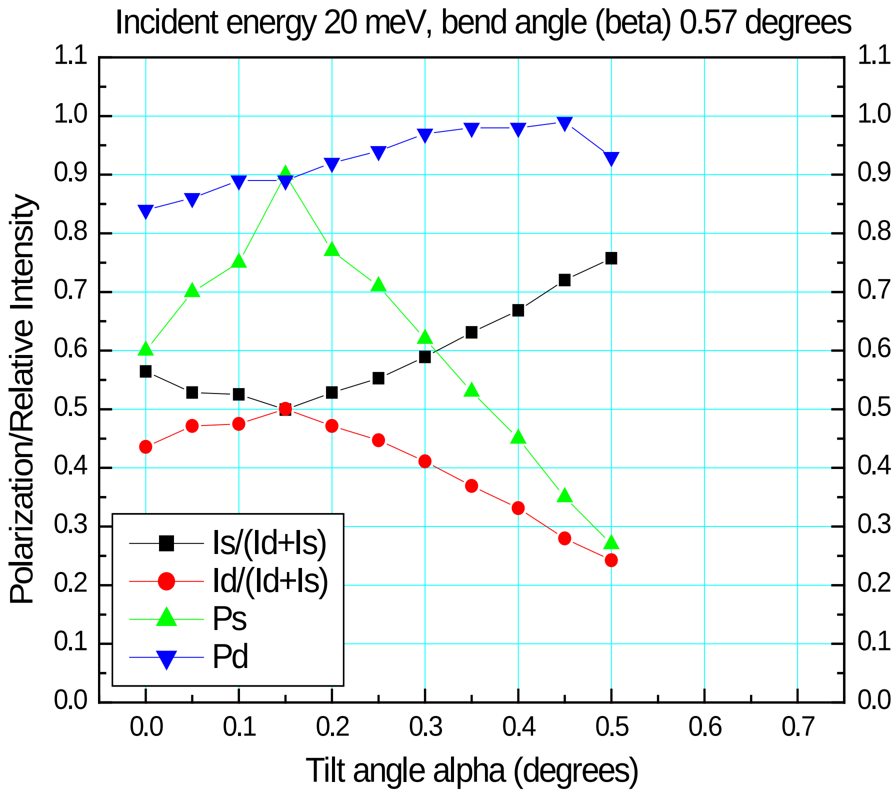
Optimizing the polarizer tilt: fine tuning is needed for higher energies





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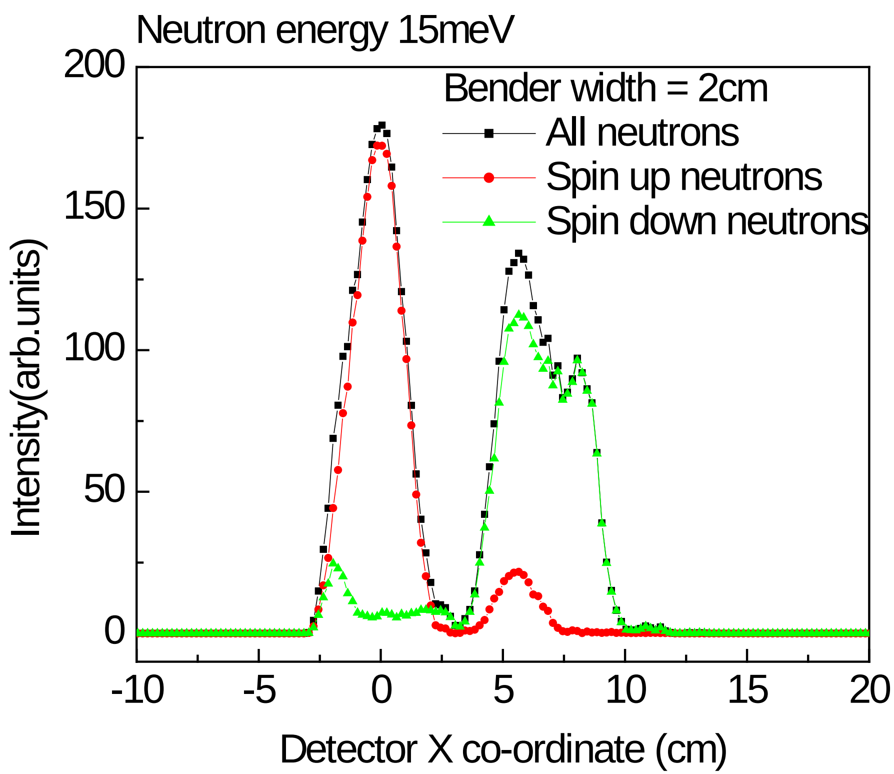
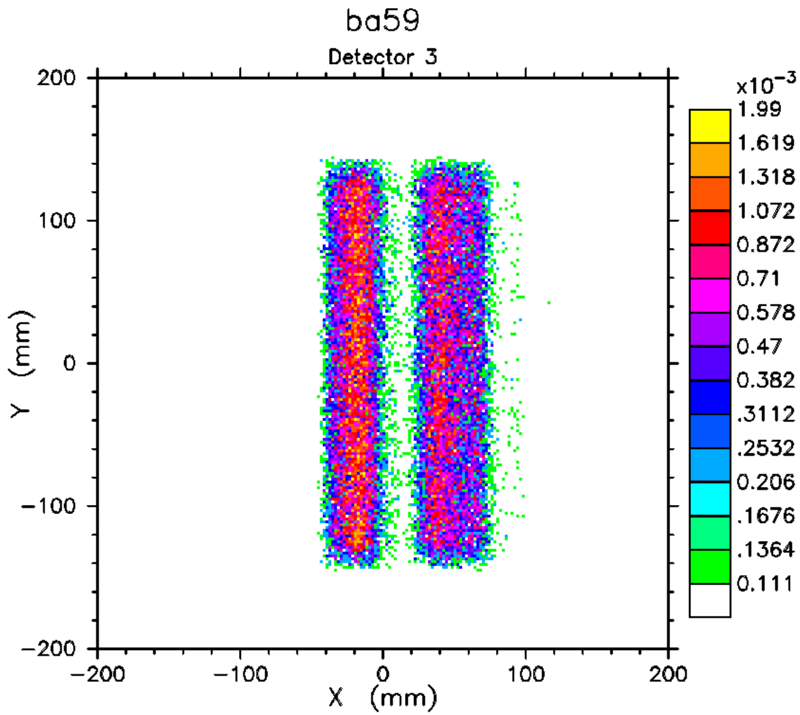
MC simulation (NISP) of the HYSPEC operation in the polarized beam mode: beam separation

Simulation for the bender geometry optimized for E=14.7 meV (C. Majkrzak, 1995)
Sample-to-detector distance L_{SD} is 4.5 m





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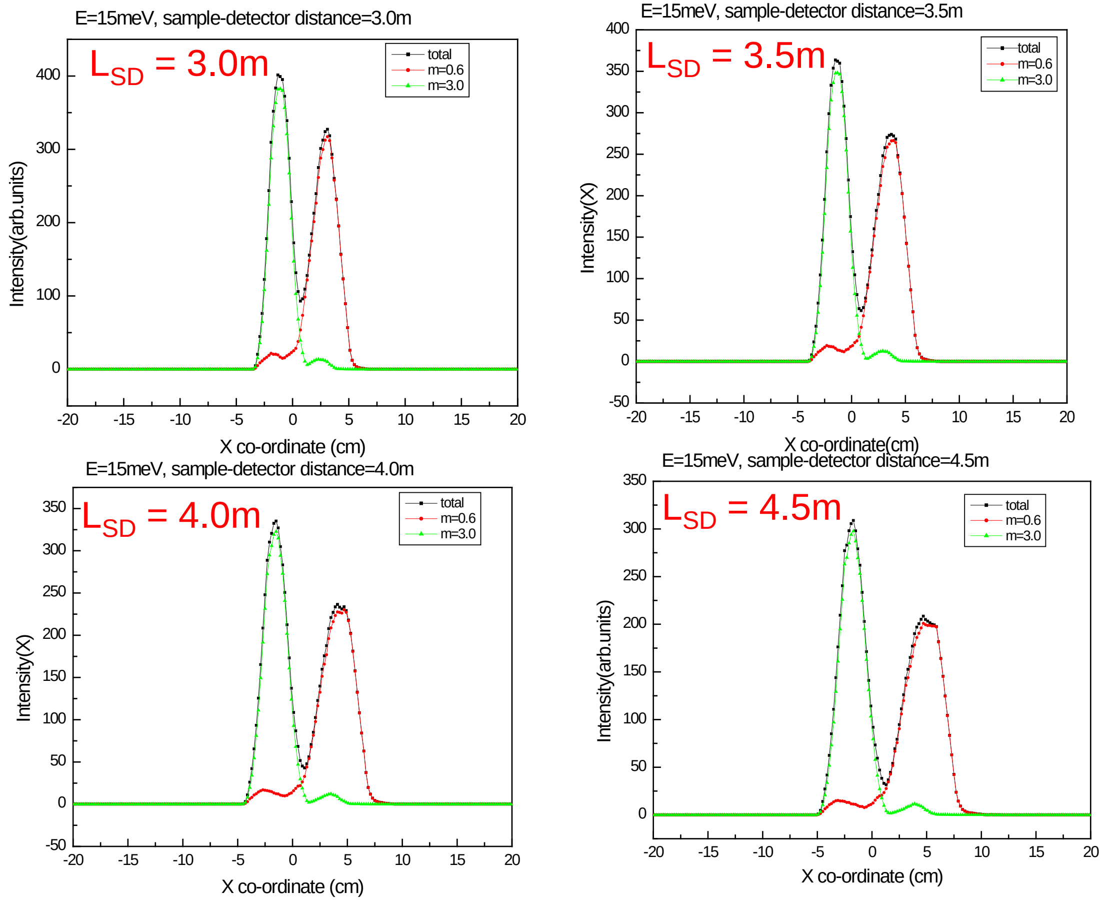
The spatial separation of two polarizations for different sample-to-detector distances



$\theta_c^{(up)} = 3.0\ \theta_c^{Ni}$,

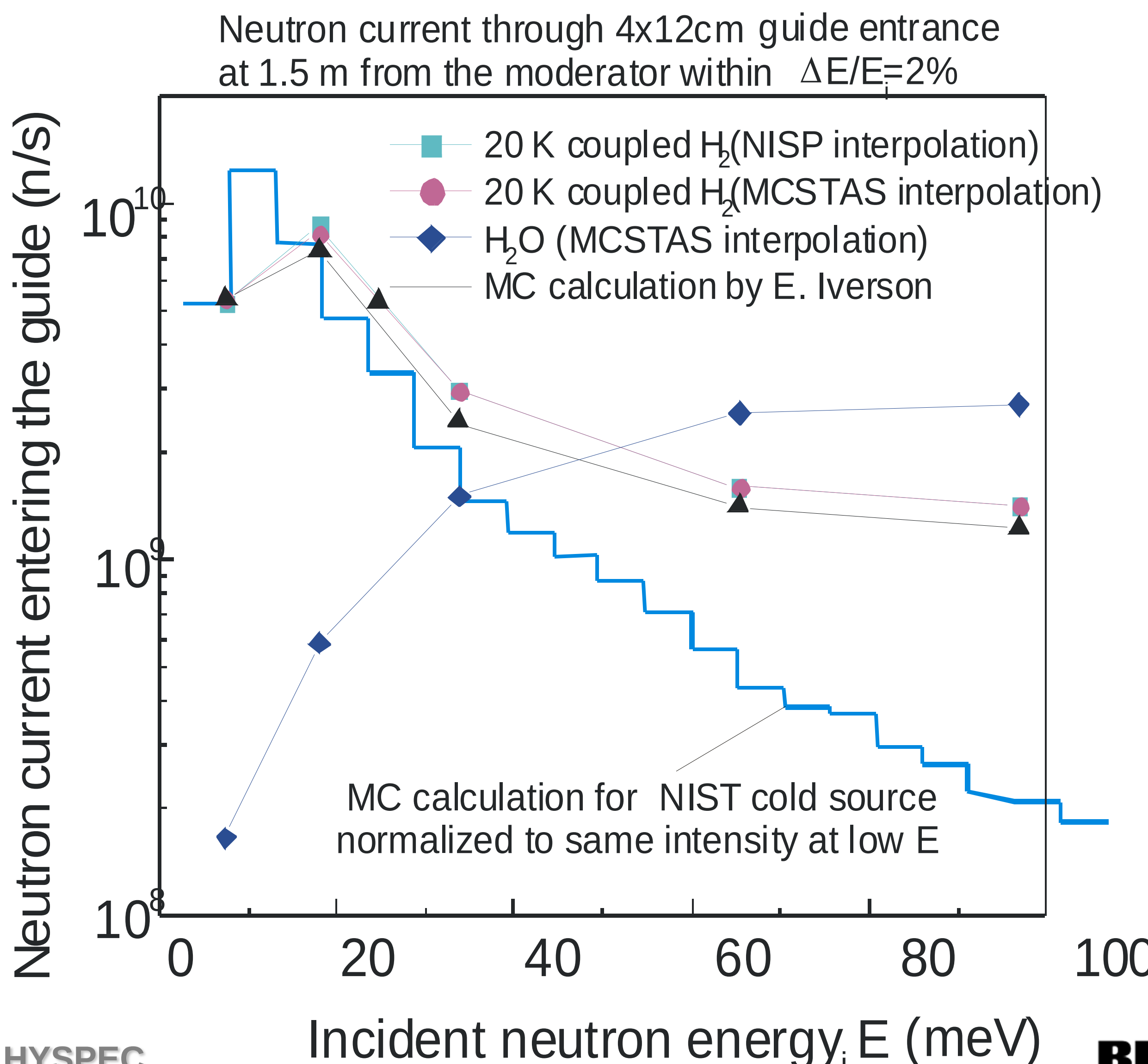
$\theta_c^{(down)} = 0.6\theta_c^{Ni}$.

The two polarizations only become sufficiently separated that they can be measured cleanly in the adjacent detector tubes for values of the secondary flight path L_{SD} > 4.0m.

Summary, work in progress, and open questions

- Heusler monochromator provides polarized incident beam
- Scattered beam polarization is determined by an array of transmission polarizers
  - Fe/Si, Co/Si, other?
  - straight-through transmitted beam is always measured
  - all scattering angles are covered
  - most of the detectors are efficiently used
  - price in intensity for using 20’ collimators also buys lower background and a somewhat better q-resolution
- Optimization of the polarizer geometry for the broadband operation
  - important to use the optimized tilt angle for every E_i, and E-range
  - curvature choice (possibly straight stack)?
  - fine tuning: length, channel width, collimation in front.
- Effect of a coarse (2-3 degrees) radial collimator behind the polarizers?

Neutron spectrum produced by SNS vs reactor



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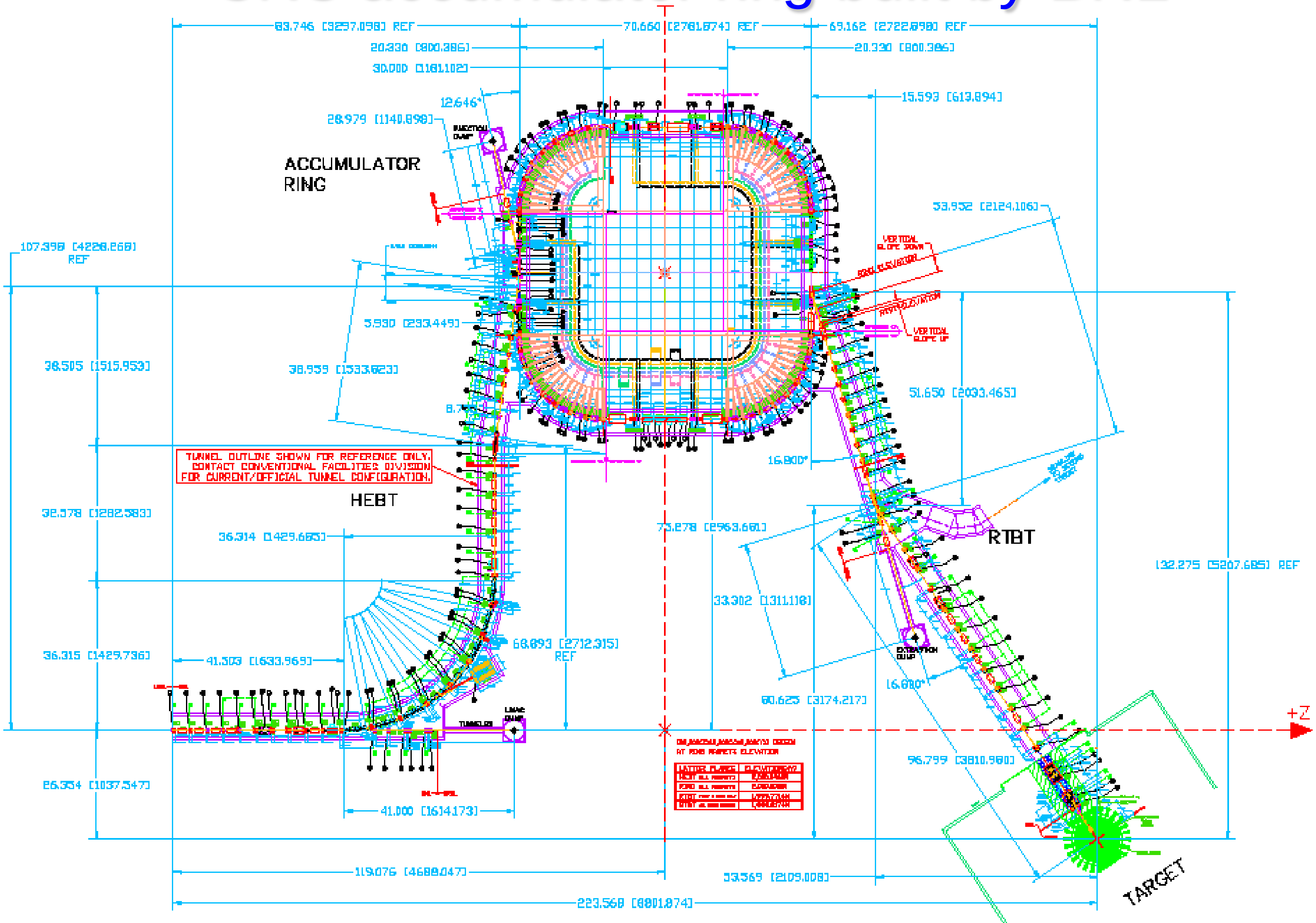
SNS accumulator ring built by BNL



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http://sns.bnl.gov/

http://sns.bnl.gov/ap_group/ring.html

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