Introduction to HYSPEC: Overview of the Conceptual Design and Top Level Specifications.

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Outline

- Overview of the HYSPEC layout and principal features
- Guiding principles of the instrument design
- An overview of the important design choices
- Instrument specific features and components
- Summary, work in progress and open questions

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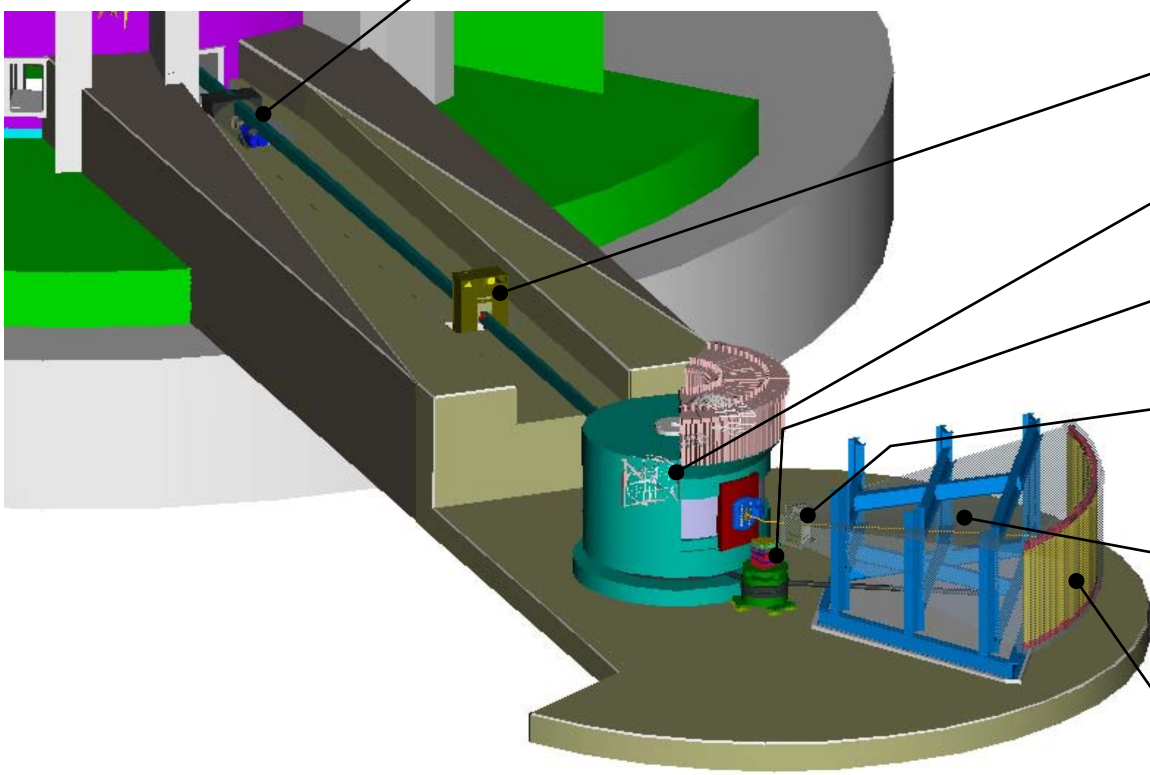
HYSPEC Layout and principal features

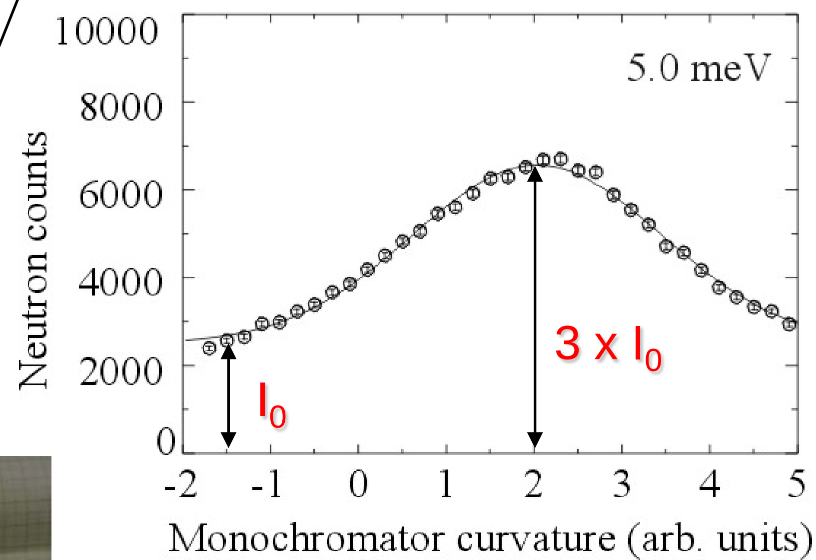
Part 2. Conceptual design and Top Level Specifications

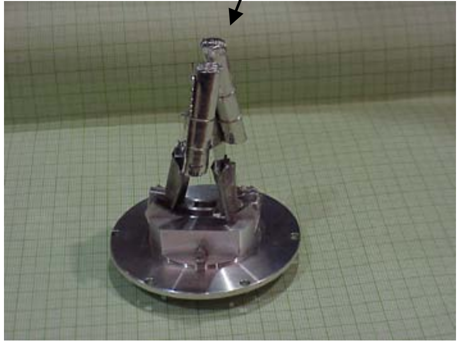


Why HYSPEC design is the best choice for thermal neutron inelastic spectrometer for single crystal studies at SNS.

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

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





HYSPEC design objectives.

Major unresolved issues in TOF instruments:
(i) efficient focusing neutron optics, (ii) polarized beam.

- ✓ Efficiently use large incident neutron beam by focusing it on the sample
- ✓ Minimize the background: scattering volume seen by a detector should be well defined and easily adjustable
- ✓ Envisage an easy setup of the polarized beam option
- ✓ Optimize the instrument for high throughput at moderate resolution
- ✓ Avoid direct view of the moderator by the sample and its environment
- ✓ Throughput and resolution should be easily traded and vary smoothly over a substantial energy interval, typically from 2.5 meV to 90 meV
- ✓ Both energy and wave vector resolutions should be flexible and easily adjustable, typical resolutions are 1% to 10%
- ✓ Accessible range of scattering angles should be as large as possible

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: moderator

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

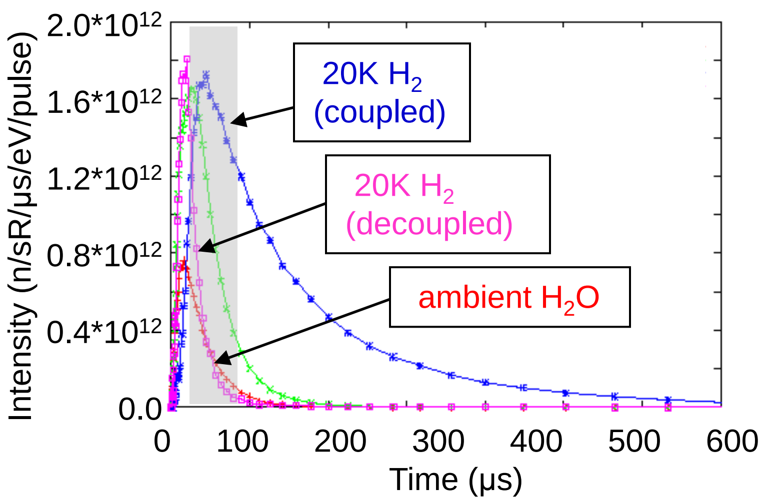
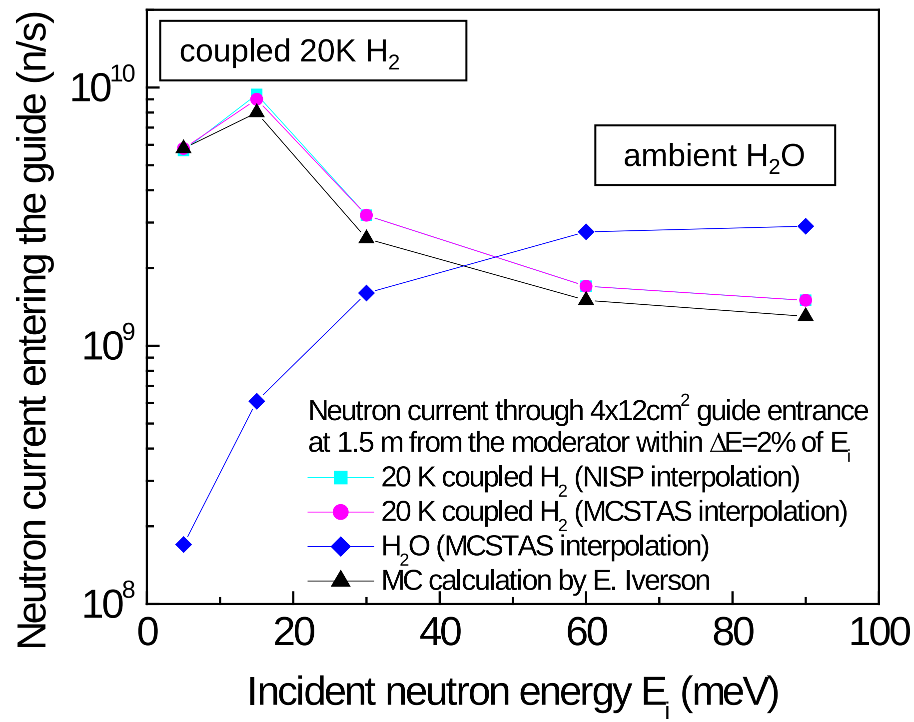


Figure of merit is the total flux within Δt = 40-80 μs time window accepted by the spectrometer.

Moderators useful neutron flux



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

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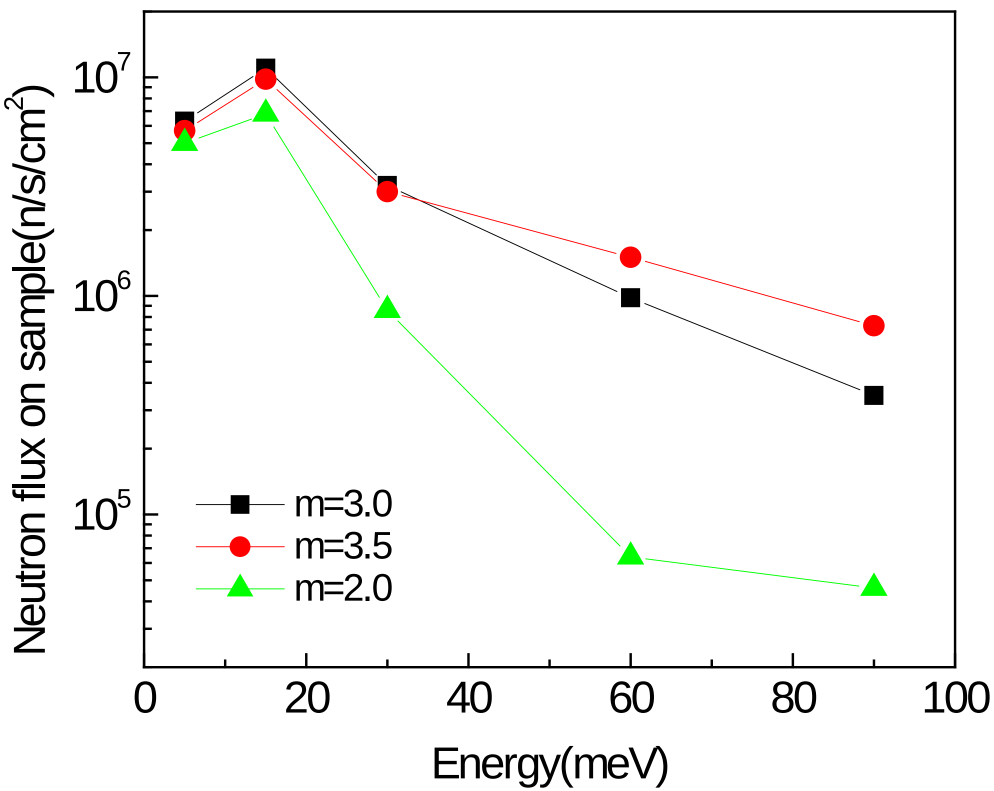
HYSPEC design choices: guide coating

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



- ❑ m=3 supermirror provides good performance, and is important

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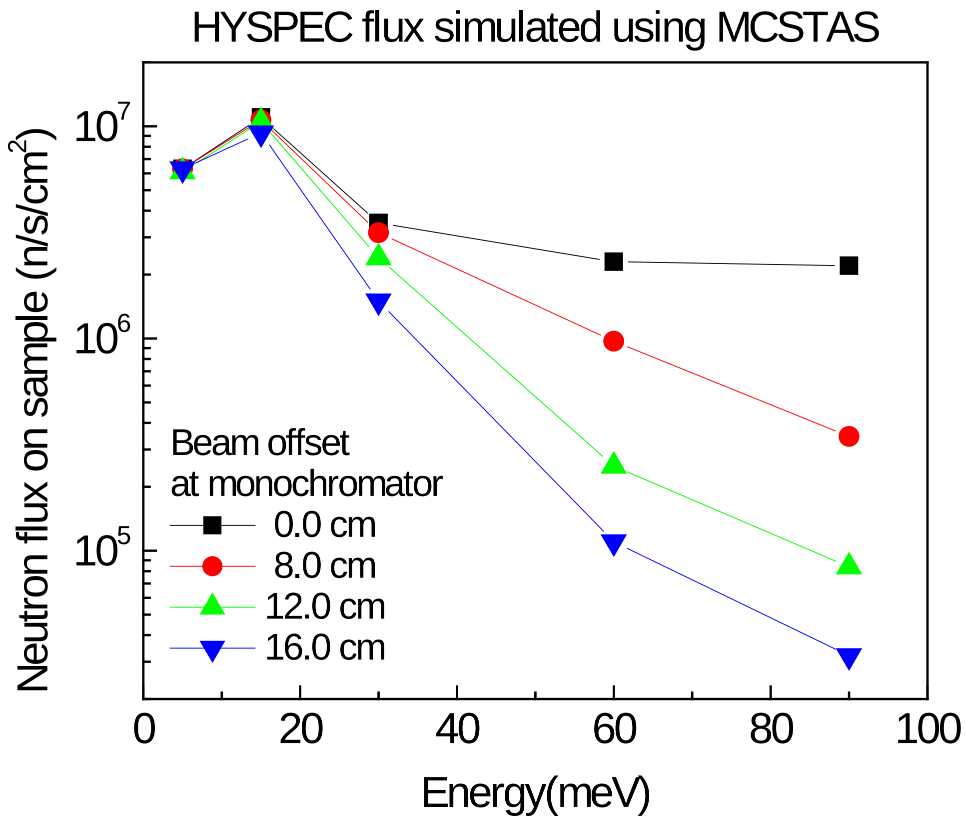
HYSPEC design choices: guide curvature

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

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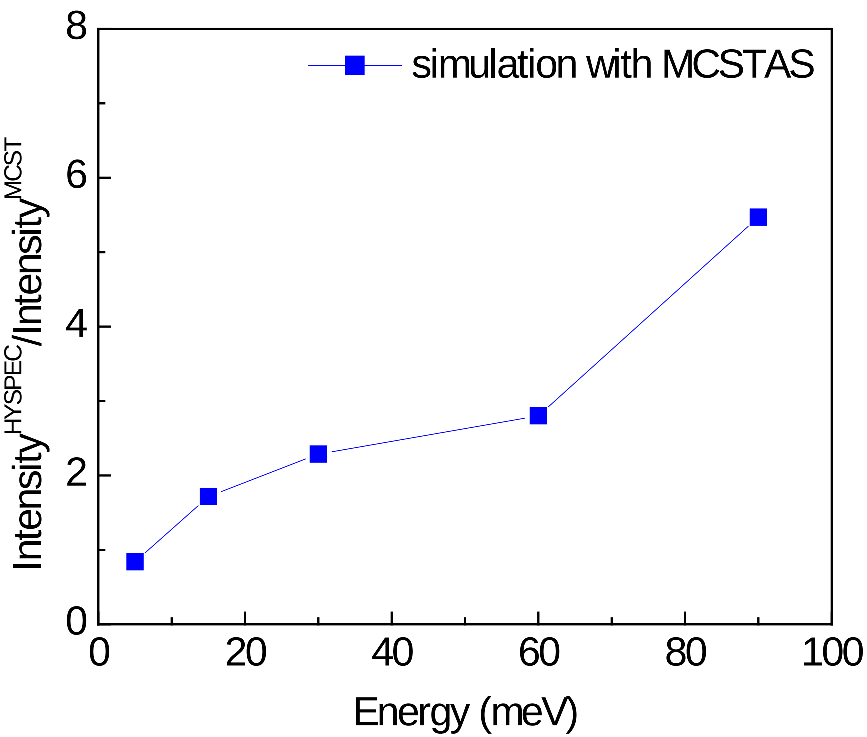
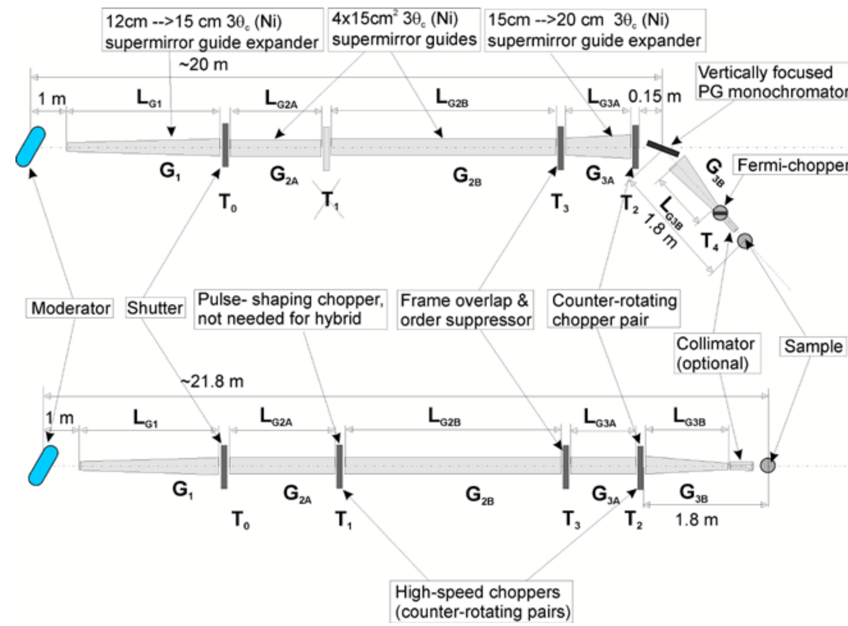
HYSPEC design choices: vertical focusing gain





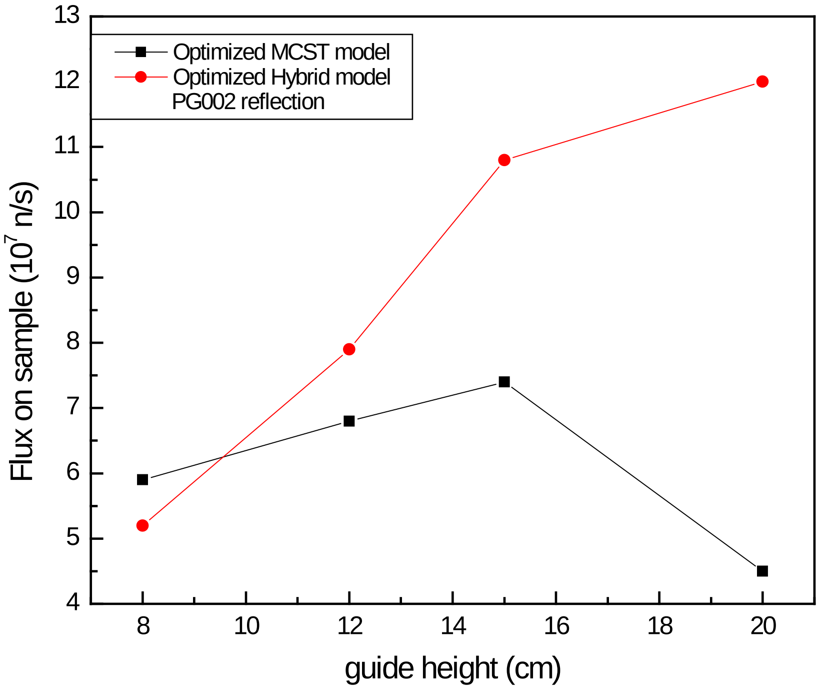
Crystal-monochromator hybrid spectrometer (HYSPEC, top scheme) vs traditional "straight-through" TOF setup (MCST, bottom scheme).

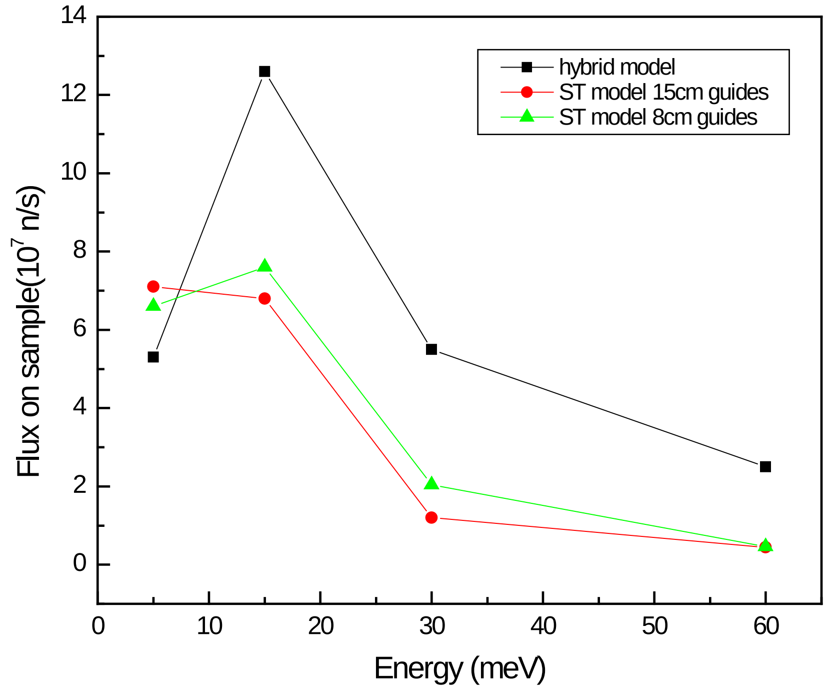
- HYSPEC wins except at 5 meV, where both concepts are roughly equal.

HYSPEC design choices: guide height

Where does the HYSPEC gain comes from?

✓ *Efficient use of the tall guide.*





✓ *Relative performance of the hybrid instrument at lower energies will be even better for a cheaper, m=2.5 or m=2 guide coating*

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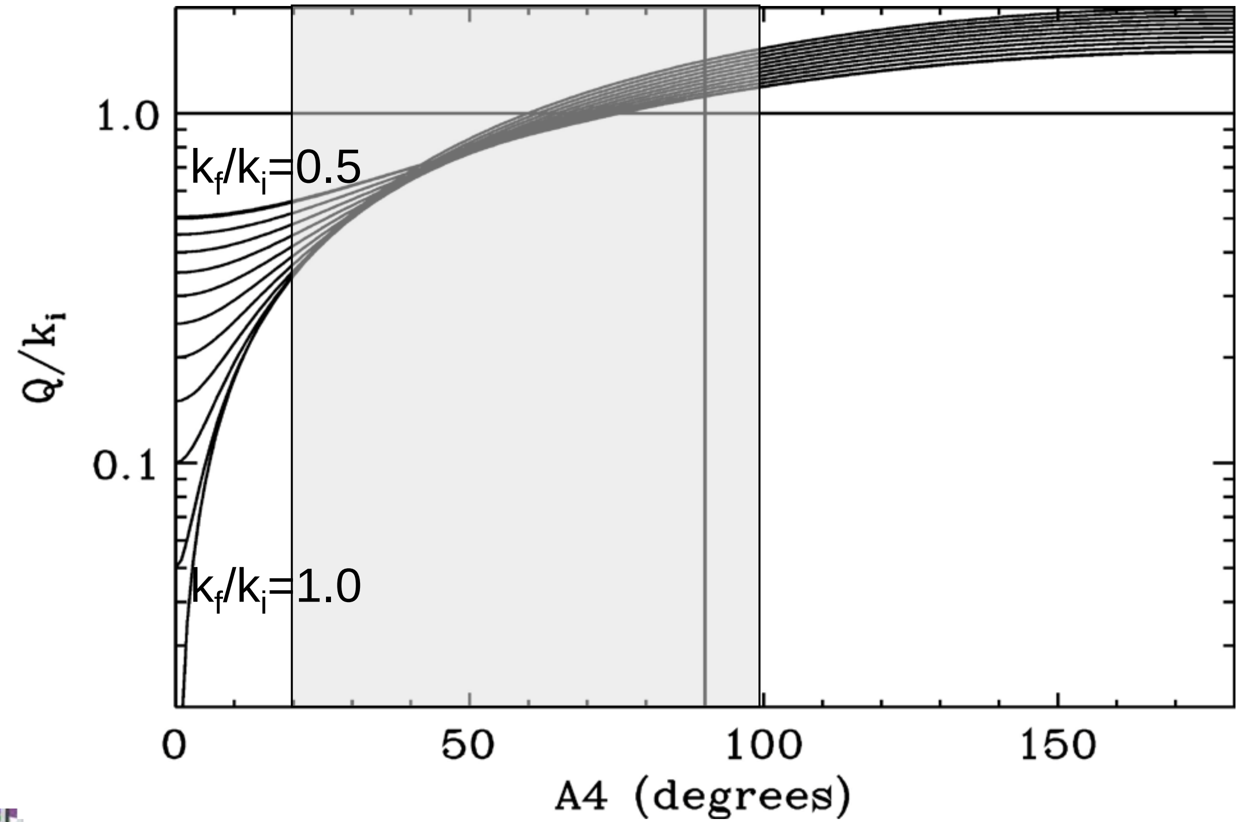
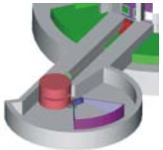
HYSPEC design choices: analyzer angular coverage.

- Our design goal is to cover at least *one* typical Brillouin zone.
- 60° - 90° coverage of the scattering angle by the detector array gives simultaneous access to an interval in Q for $0.5<k_f/k_i<1$.
- *Moving the analyzer is cost-effective!*





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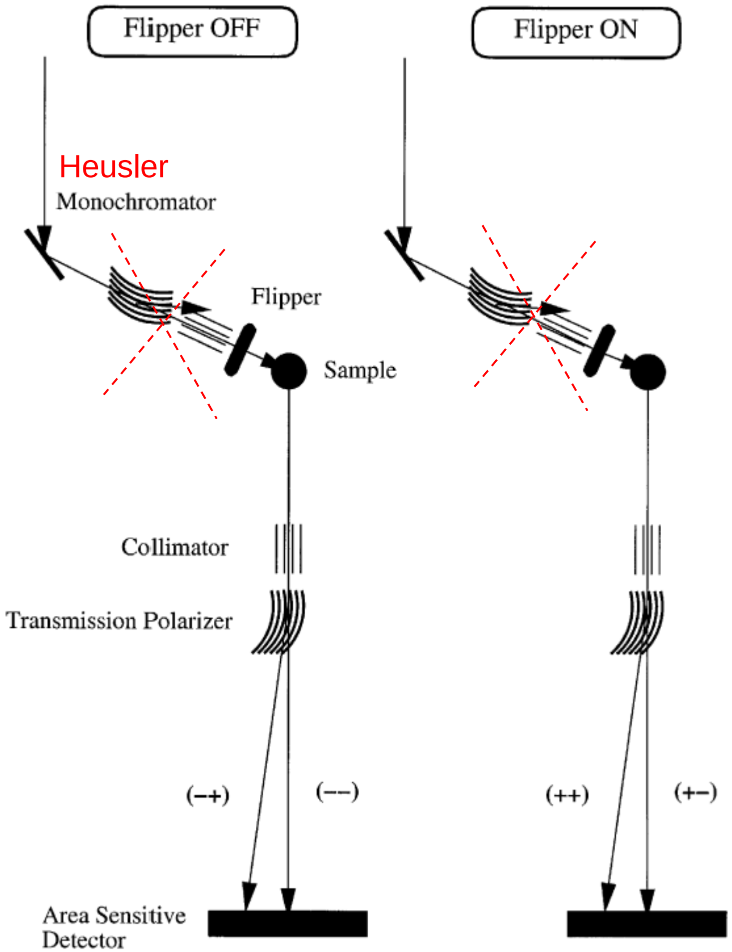
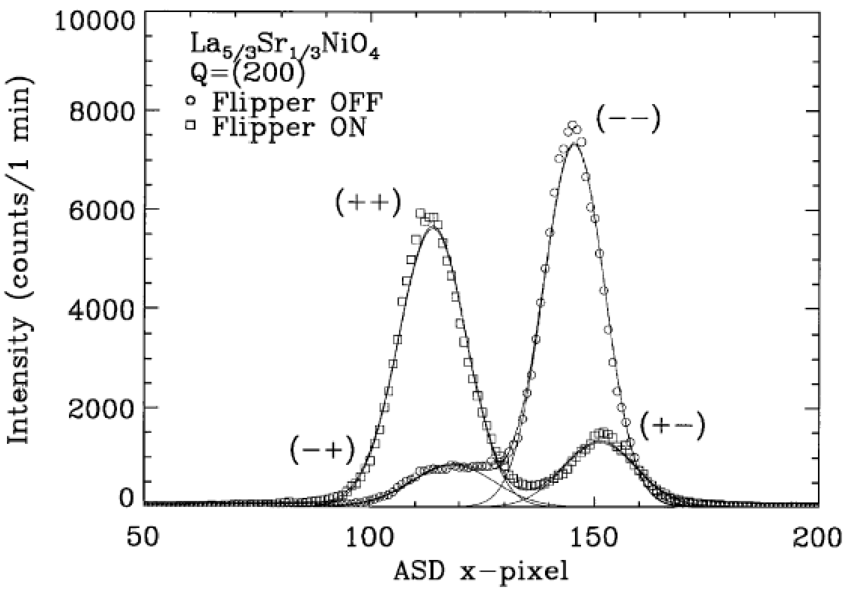
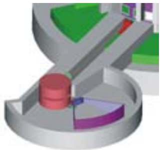
HYSPEC polarization analysis scheme: experimental demonstration

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







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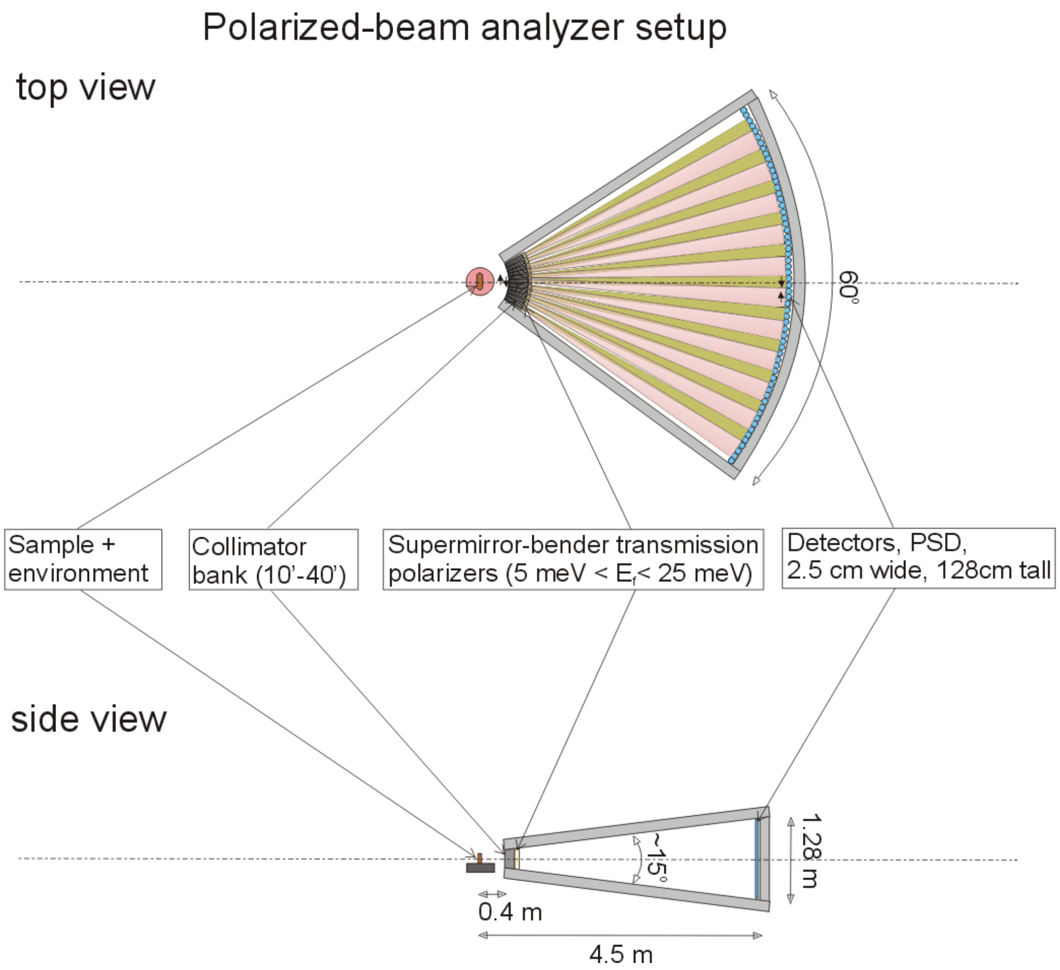
HYSPEC setup for polarization analysis

- 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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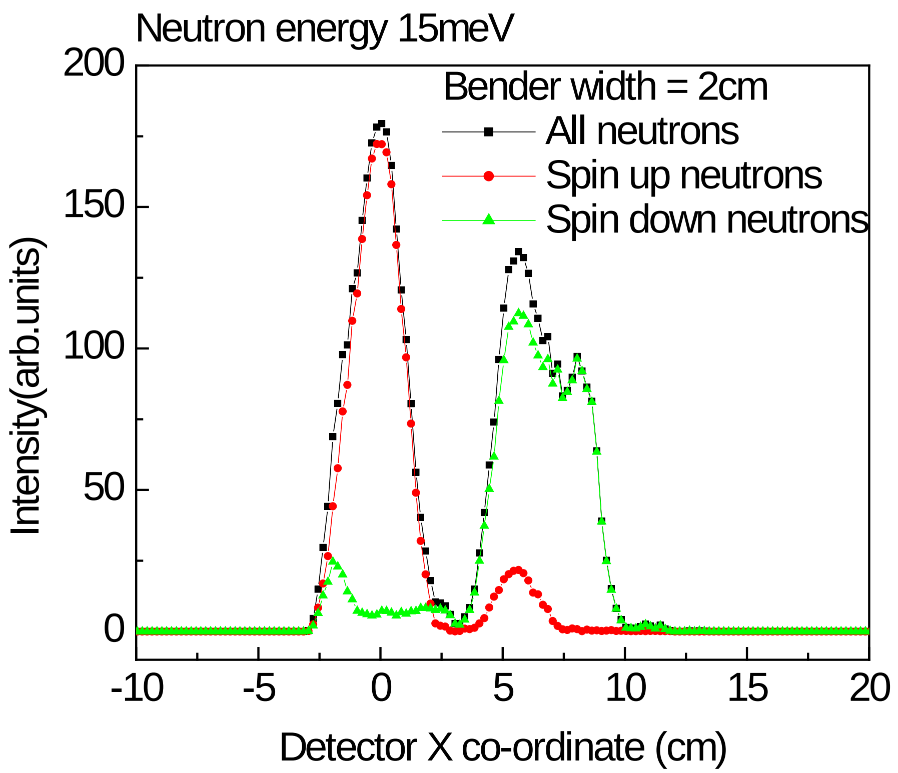
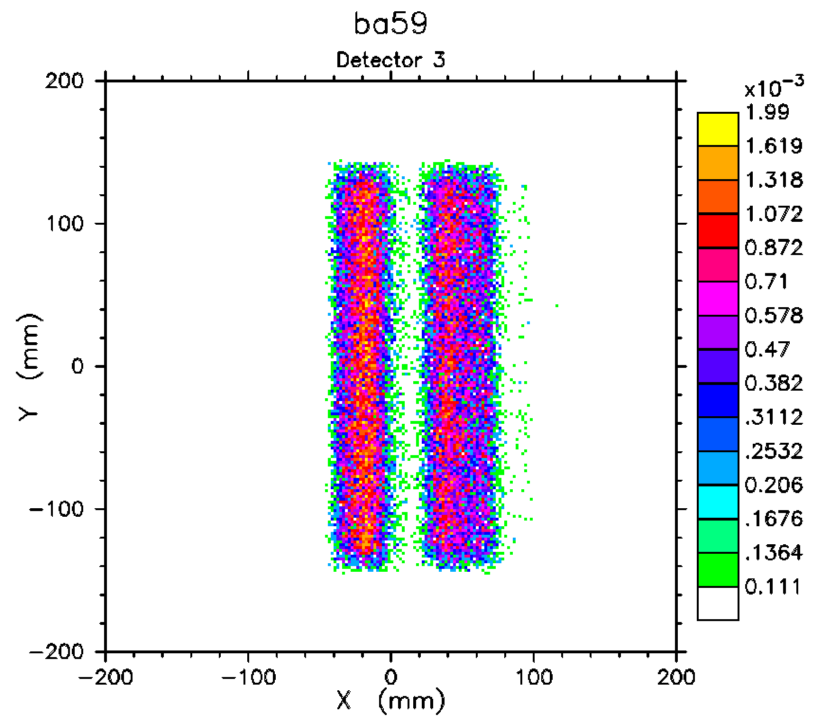
HYSPEC performance in the polarized beam mode





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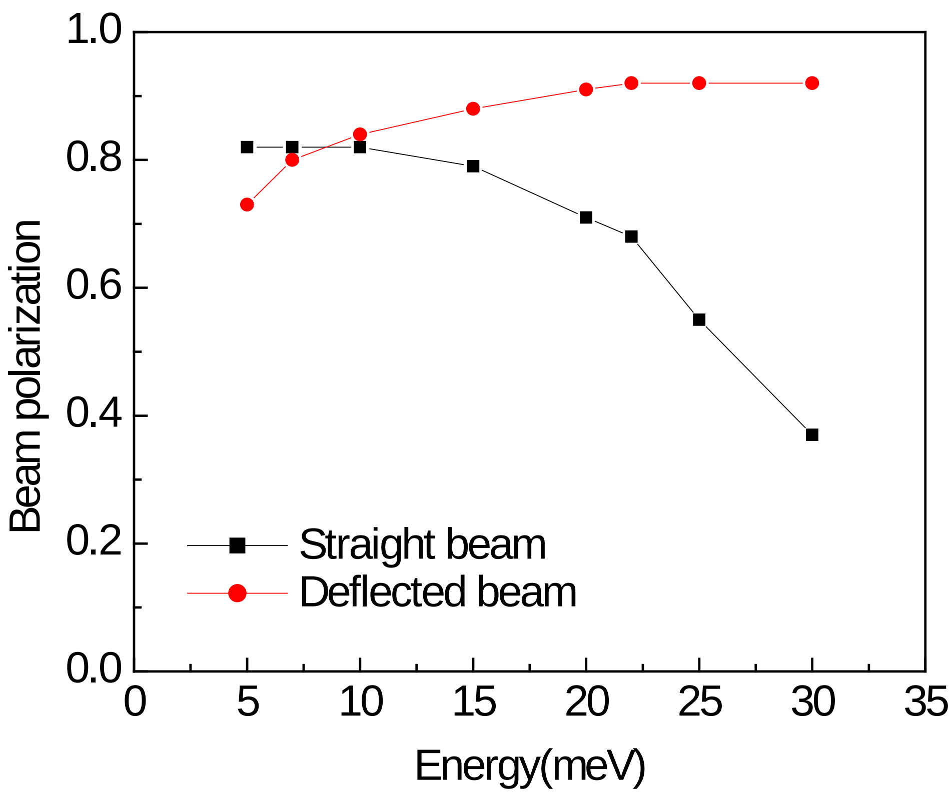
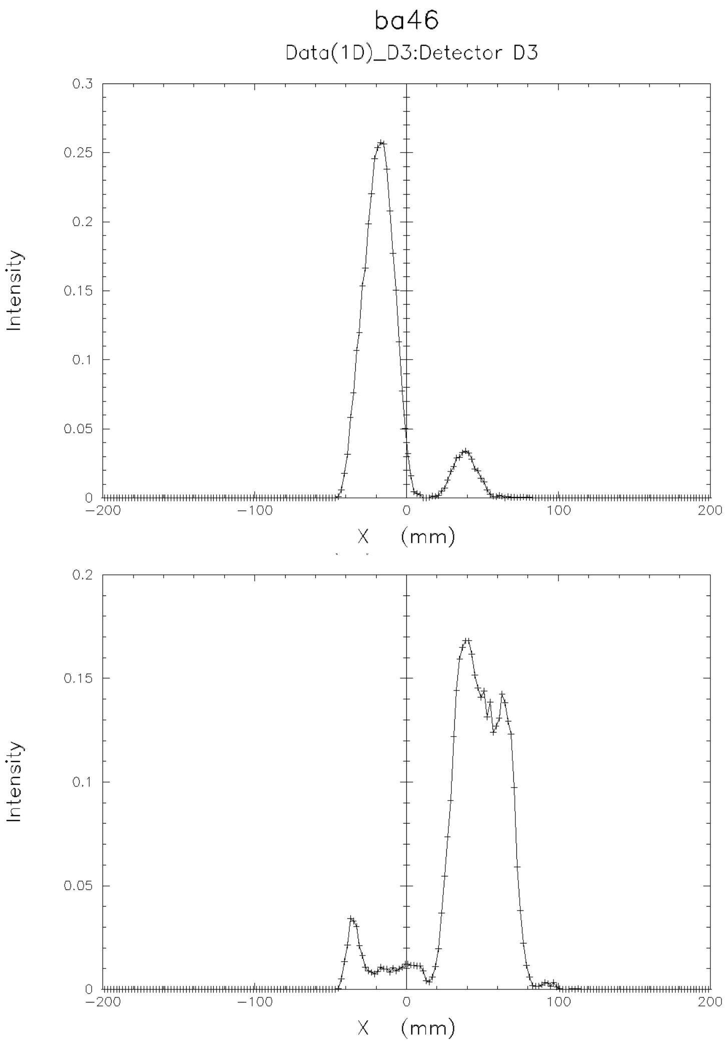
HYSPEC performance in the polarized beam mode





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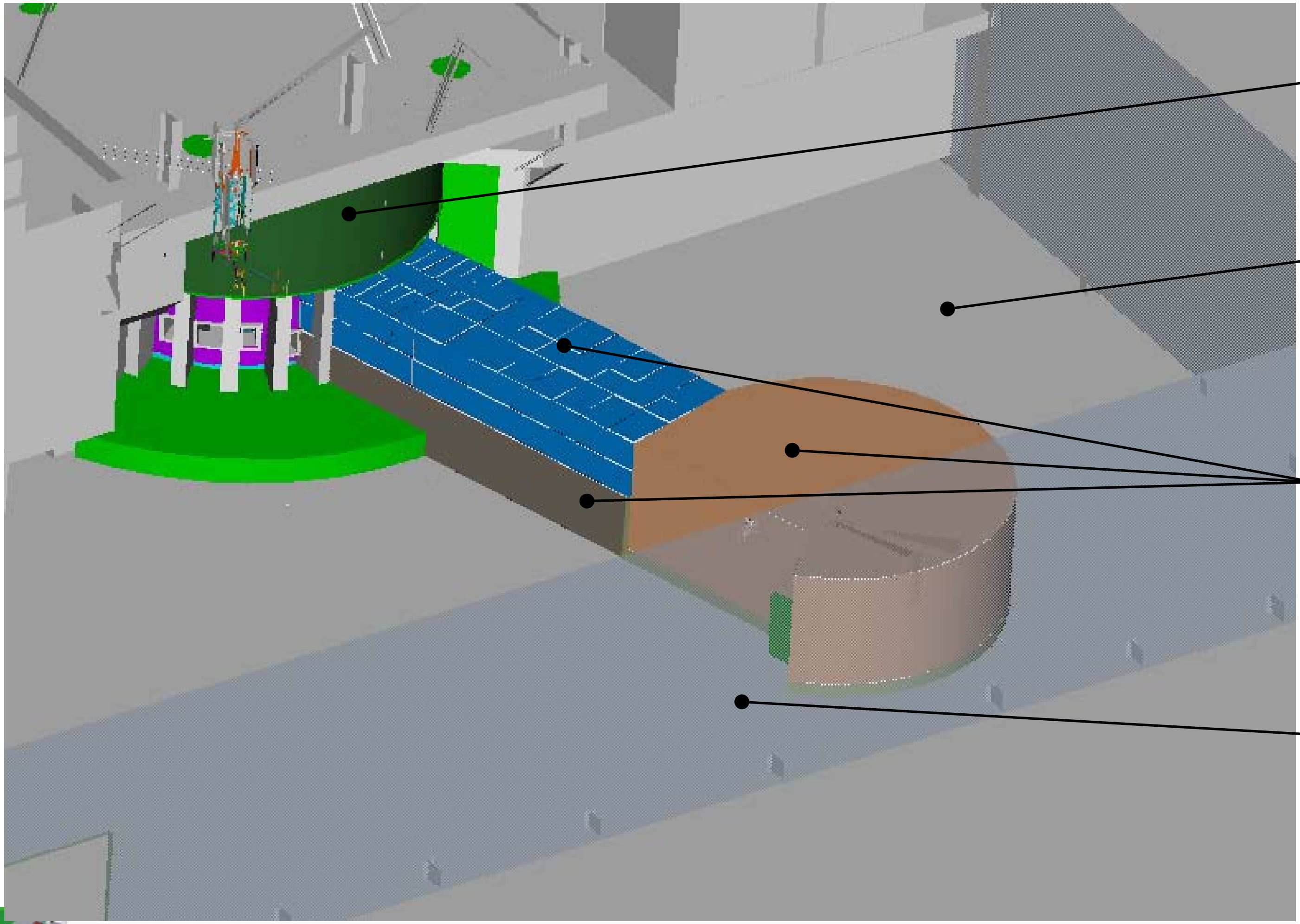
Hybrid Spectrometer conceptual design: shielding and general floor layout.

Beamline 14B, sample at ~25 m from the moderator, secondary flightpath 4.5 m



- Target Monolith
- SNS Building Floor
- Instrument Shielding 14' Tall x 14' Wide
- SNS Building Wall

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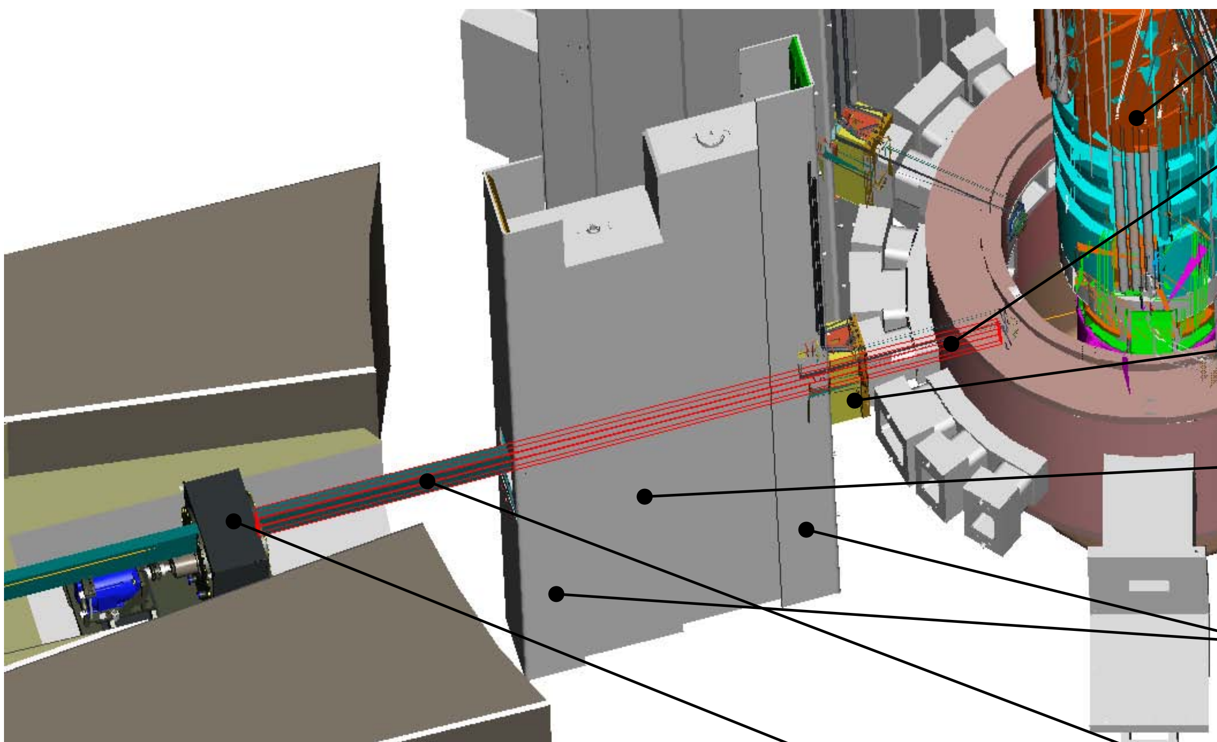
Hybrid Spectrometer conceptual design: interface with the moderator.



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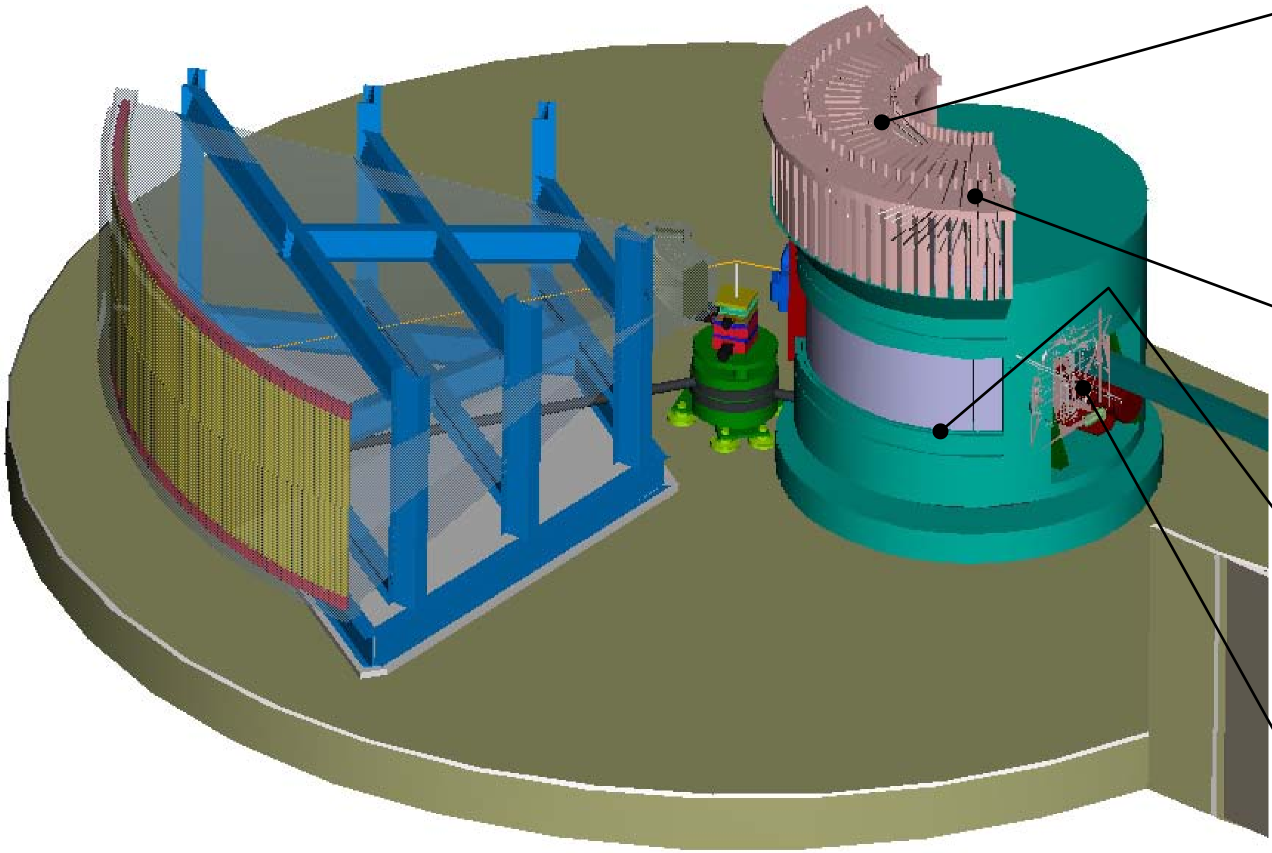
Hybrid Spectrometer conceptual design: setup of the analyzer and experimental area.



- Automated Shutter System For Monochrometer
- Dual Worm Drive Lifts
- Shutters, Each At 5 Degree Increments
- Counter Rotating Disk Chopper

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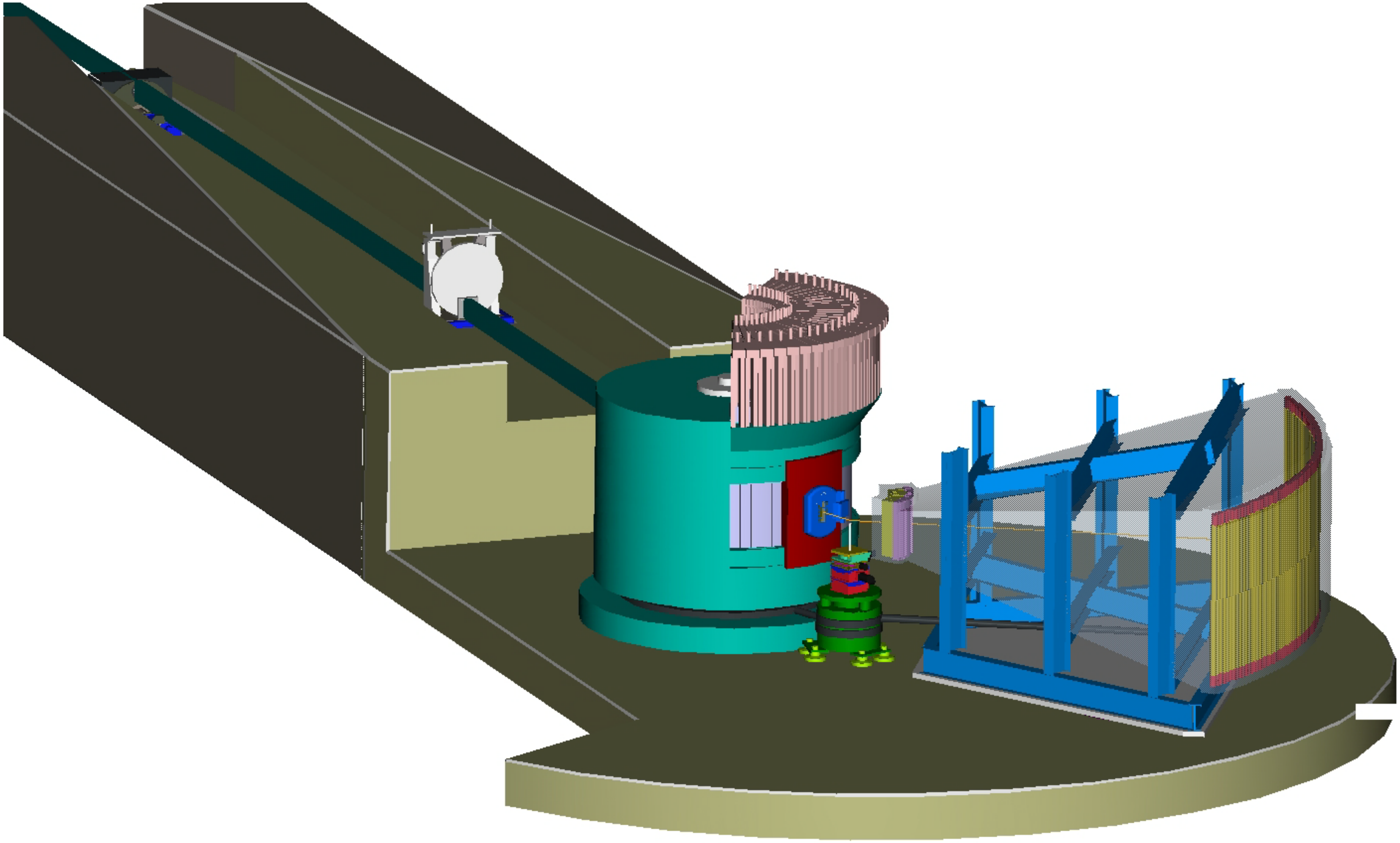
HYSPEC layout in the polarized beam mode



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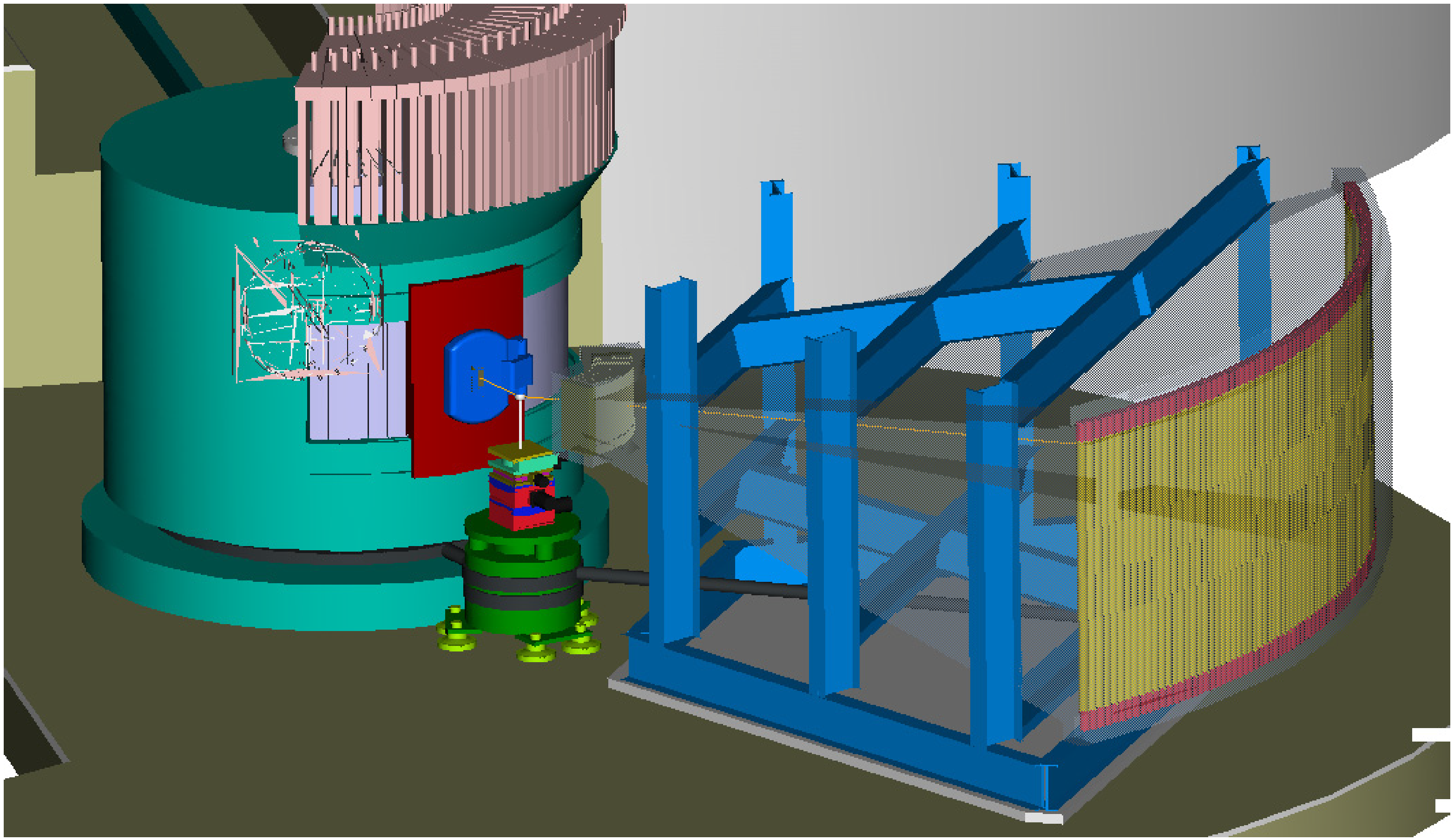
Hybrid Spectrometer conceptual design: typical experimental configuration.



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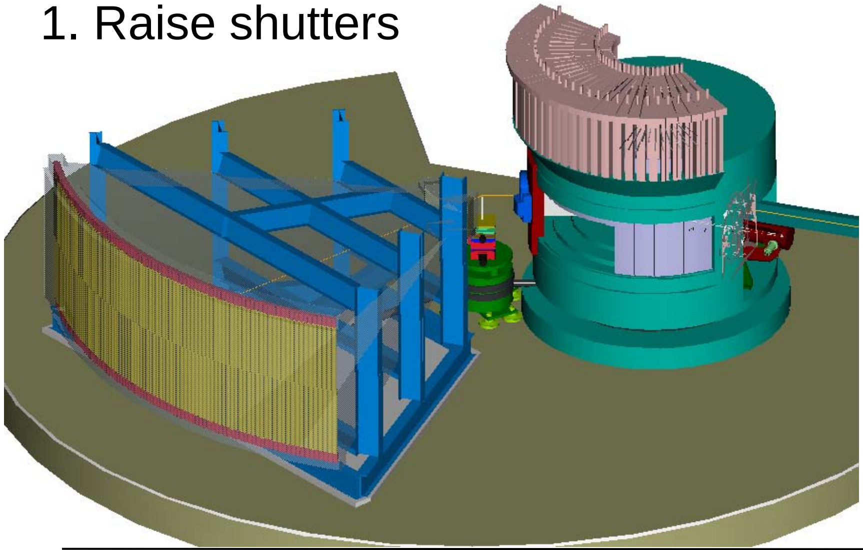
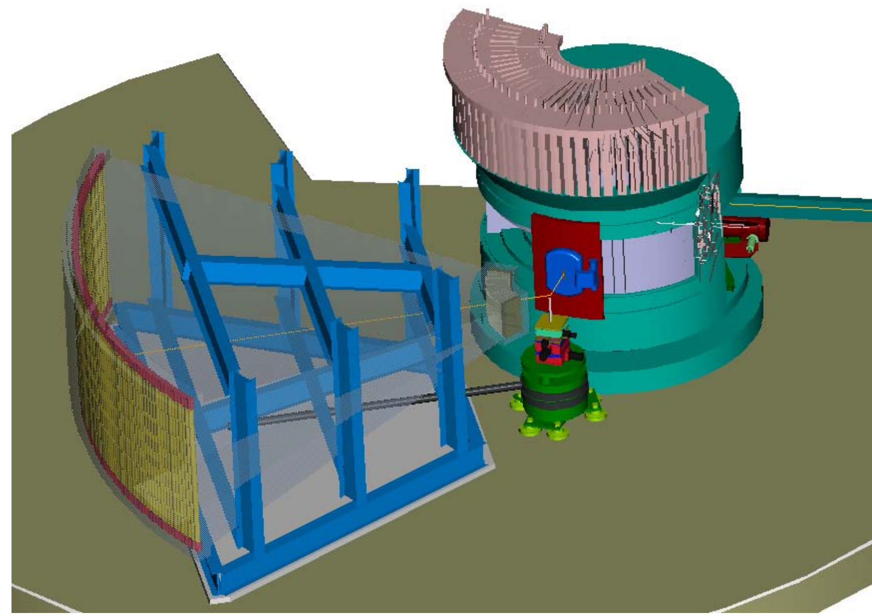
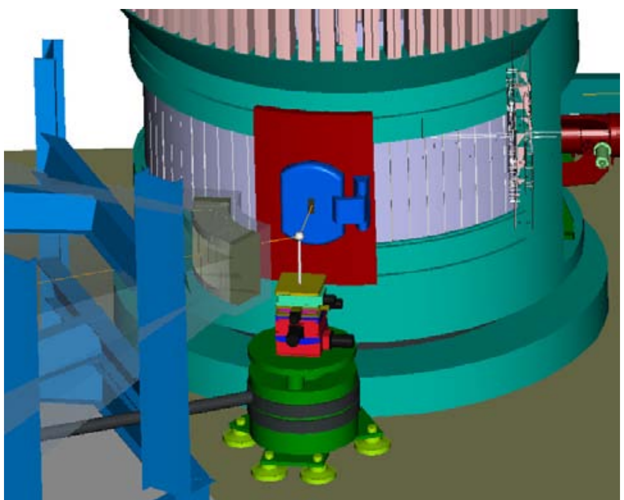
Hybrid Spectrometer conceptual design: some details of the operation.

1. Raise shutters



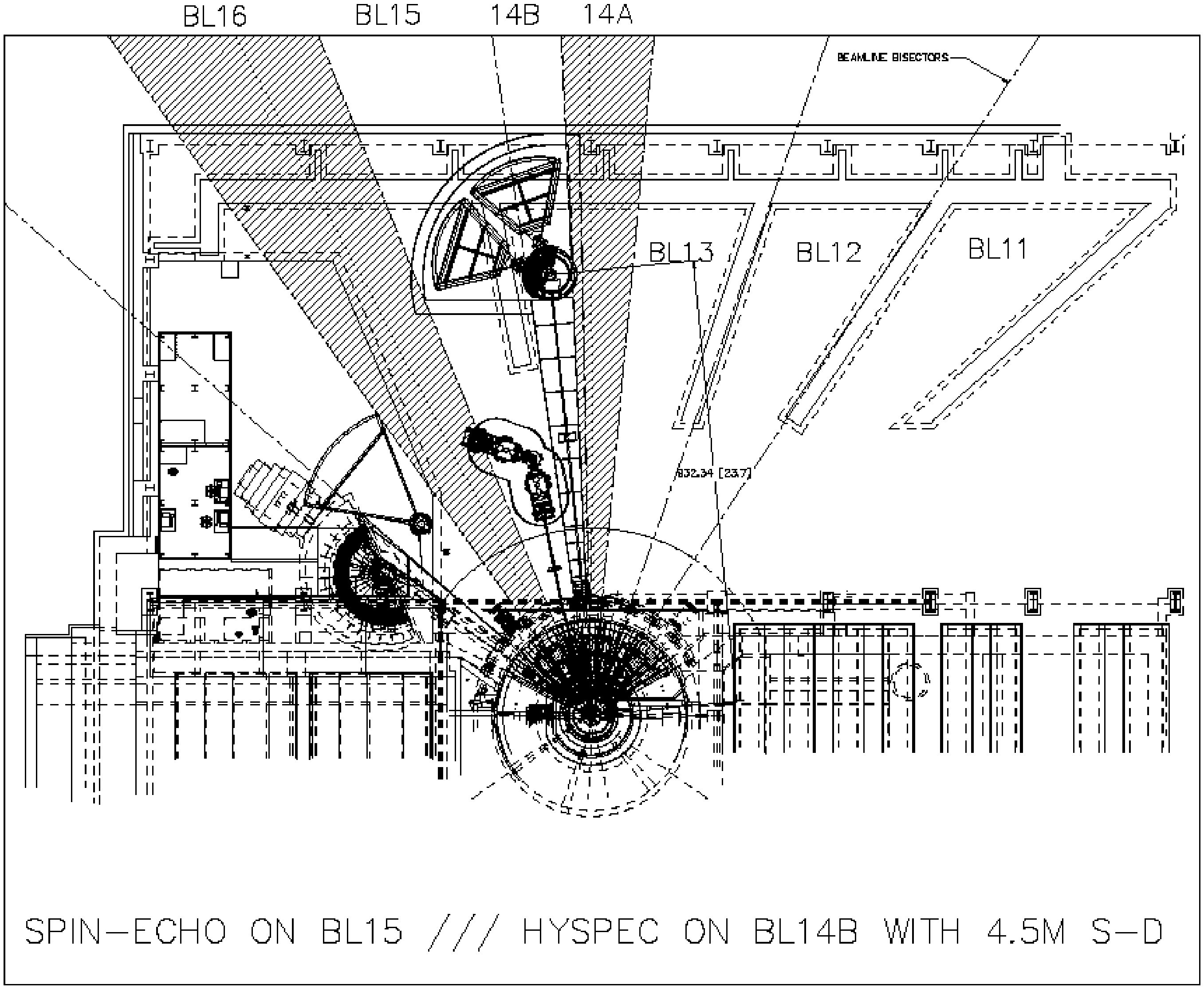
2. Swing sample and detectors (airpads?)





3. Close shutters

HYSPEC and Spin-Echo on SNS BL 14B, version 1.



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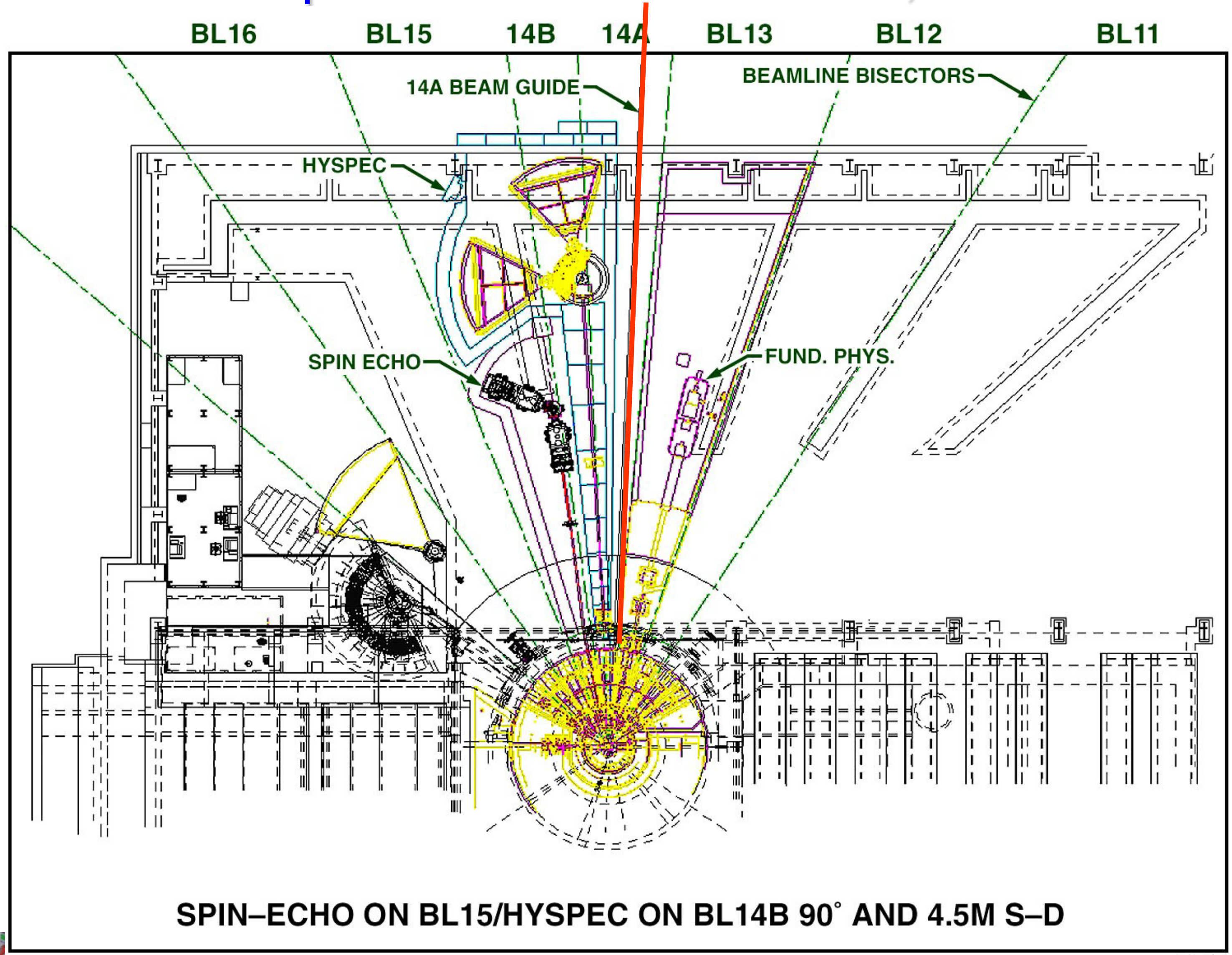
HYSPEC and Spin-Echo on SNS BL 14B, version 2.



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Summary: (tentatively) resolved issues

- Assignment of the beam line 14B on the cryogenic H_2 moderator
- Instrument fits within the SNS target building
  - reasonably short primary flight path, not too unbalanced
  - enough space for at least a 4.5 m secondary (analyzer) flight path: no sacrifice on the resolution
- Guides: m=3 supermirror coating, “ballistic” optimized vertical profile
- Choppers: T0, T1 (order suppressor), T2 (double disk), T3 (Fermi)
- Monochromator: PG, Heusler, mica(?), on a GMI-style frame with variable vertical cylindrical curvature
- Sample stage: standard triple-axis goniometer capable of supporting heavy environments, not integrated with the analyzer vessel.
- Mobile analyzer vessel with large (~15x~60 = VxH degrees) angular acceptance, evacuated or Ar filled.
- Detectors: ~2 cm lateral, ~128 cm tall ^{3}He PSD tubes

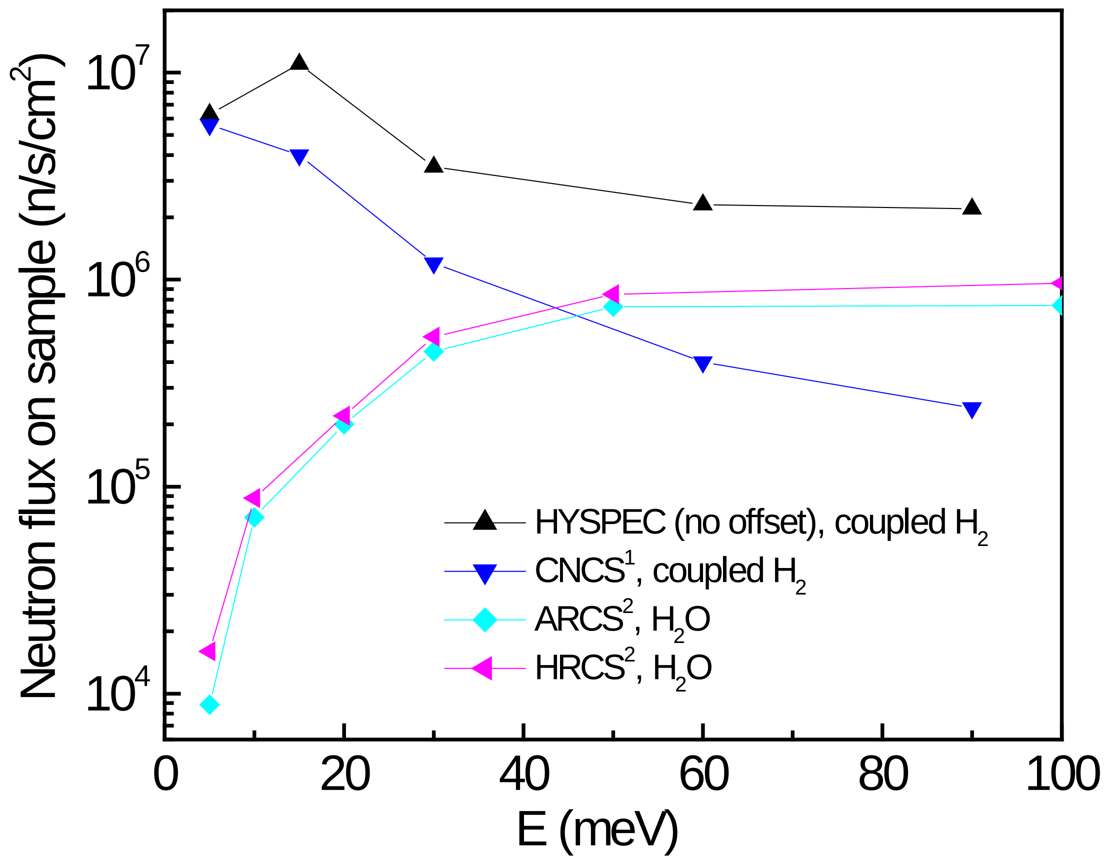
Summary: current issues and work in progress

- Guide horizontal profile
  - 4 cm wide (curved?) guide
  - continuously converging 10 cm → 4 cm (curved?) guide
- Shielding design for an instrument without a “get-lost” pipe
  - impact of filter(s)
  - (curved) guide impact and shielding requirements
  - monochromator drum shielding
  - use of the optimized composite shielding materials
- Choppers design
  - T0 multi-chopper: T0 chopper performance is critical
  - requirements on T2 counter-rotating pair disk chopper
  - straight slotted Fermi-chopper after the monochromator
- Mechanical systems: analyzer, monochromator drum movements
- Many of the issues are intertwined!

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 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 ΔE/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.	25.8m	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 #	14B	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		

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HYSPEC performance summary

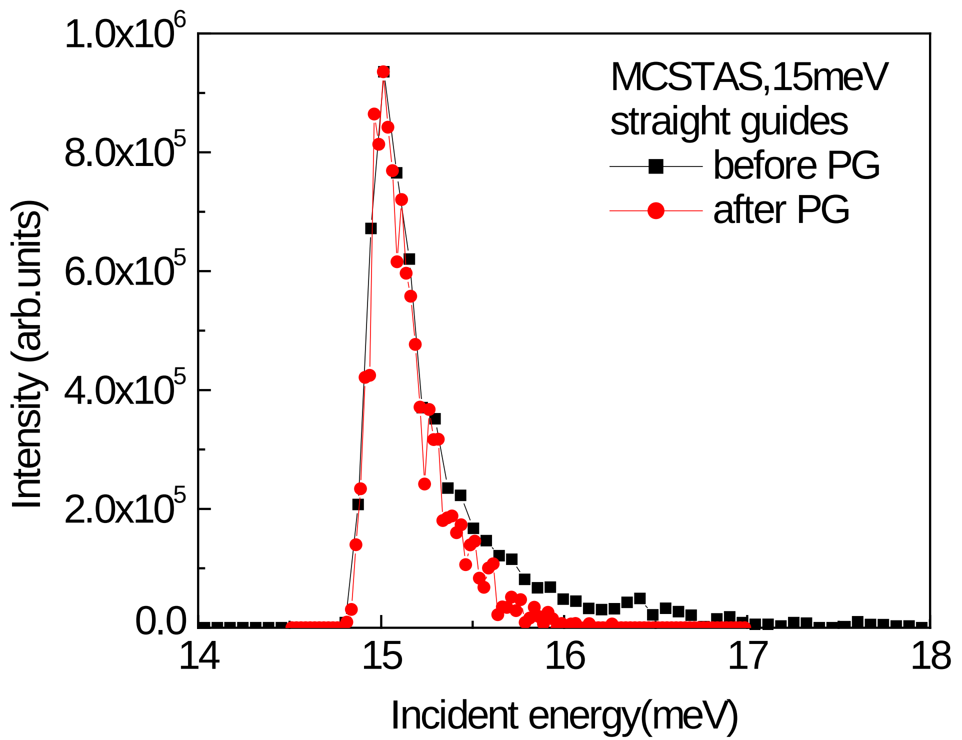
- HYSPEC will be a unique resource for probing correlations in condensed matter for

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

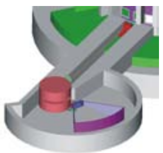
  $Q \in [0.3,10]$ Å^{-1} $\Delta Q/Q \in [0.005,0.2]$

- 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

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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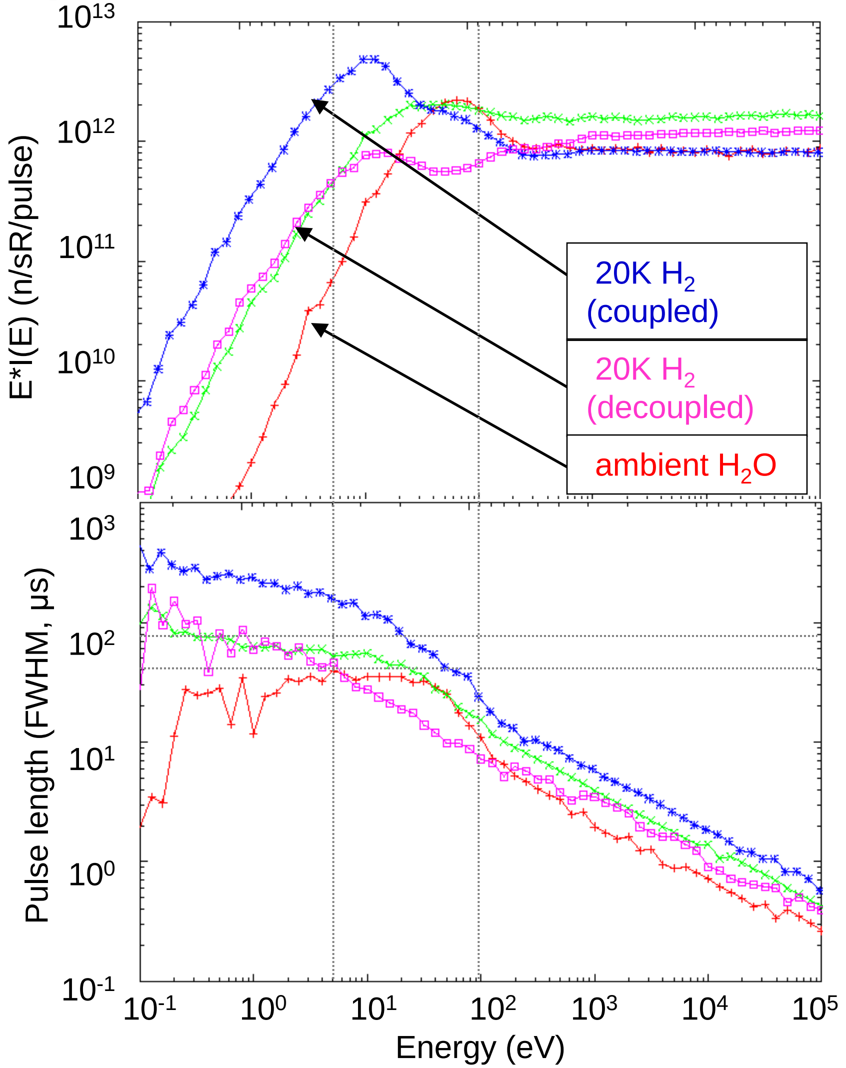
Appendix. Intensity and pulse length of SNS moderators



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