A High Performance Instrument for the Single Crystal Spectroscopy at the Pulsed SNS.

Neutron Scattering Group

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Outline

- *What is the spectrometer we want and what is its place in the proposed SNS instrument suite?*
- *Main criteria for the optimal design of an instrument at the pulsed source.*
- *Hybrid (crystal monochtomator) versus chopper spectrometer: general considerations and Monte-Carlo results.*

Neutron spectrometer for studies of the low-energy coherent excitations in single crystals.

Common requirements for a single crystal neutron spectrometer:

- *Transmission function for both primary (monochromator) and secondary (analyzer) spectrometers should be close enough to 1 within the acceptance range, and vary smoothly over a substantial energy range, typically from 5meV to 100meV.*
- *Both spectral (energy resolution) and angular (~ wavevector resolution) acceptances of the monochromator and analyzer should be flexible and easily adjusted, typical resolutions are 1% to 5%.*
- *Scattering volume seen by a detector should be well defined and easily adjustable depending on the sample size, to minimize the background.*
- *Efficient use of the large incident neutron beam by focusing it on the sample is very important, and should be previewed.*

SNS workshop on Inelastic Neutron Scattering: where is the instrument we want?

Table I : Instruments Discussed

Category	Instrument
A.1	indirect geometry spectrometer, (backscattering), resolution 2 μeV (elastic position)
A.2	Direct geometry spectrometer (chopper), resolution ΔE/E ~ 1% (elastic position), E ~10 – 1000 meV, continuous angular coverage
A.3	Spectrometer with 10 – 100 μeV resolution
B.1	Chopper , ΔE/E ~ 5% (elastic position), large angular coverage
B.2	Inverse geometry spectrometer, time focussed, ΔE/E ~ 1%
B.3	Triple axis-like instrument with high signal to noise
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

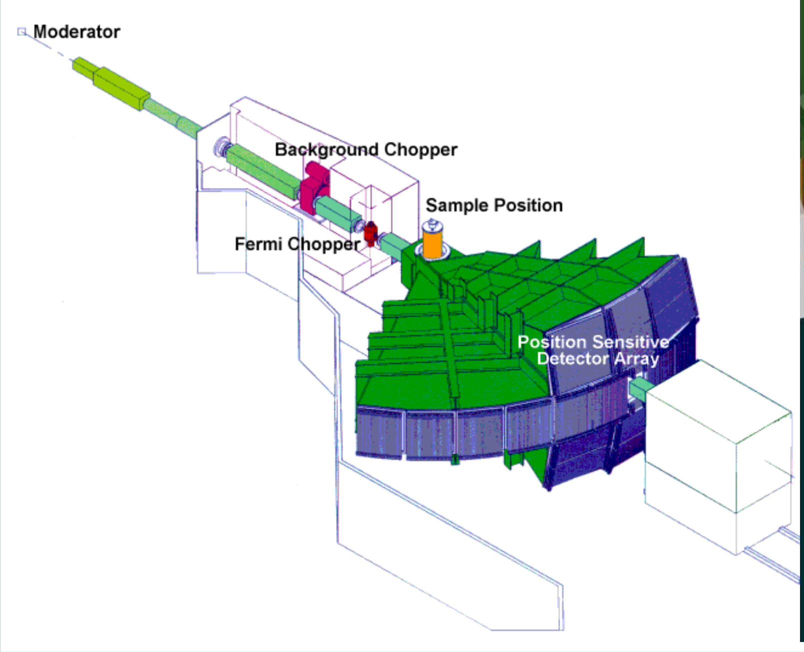
What is a flagship inelastic instrument at a spallation neutron source?

• SNS should be equipped with the top of the line instruments, which will be the best performers in their class

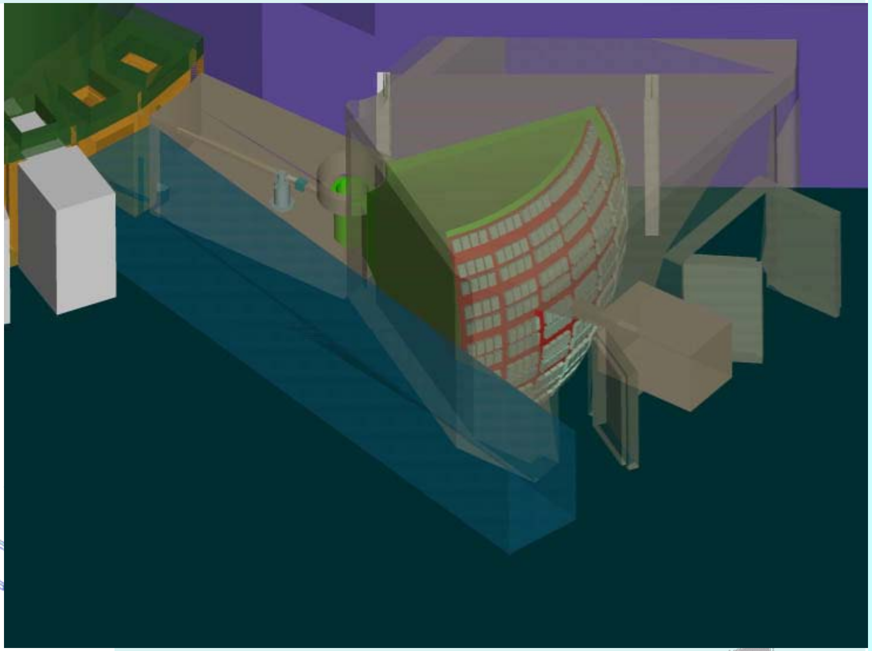
• SNS spectrometers should rely on the latest technology, and feature original and innovative design

Direct geometry chopper spectrometer?

MAPS at ISIS



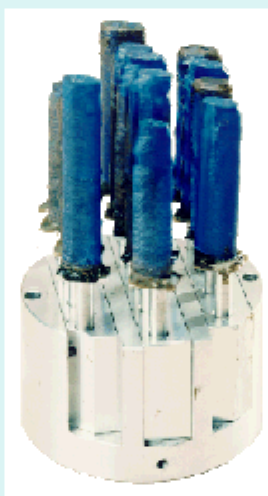
Proposed chopper spectrometer at SNS

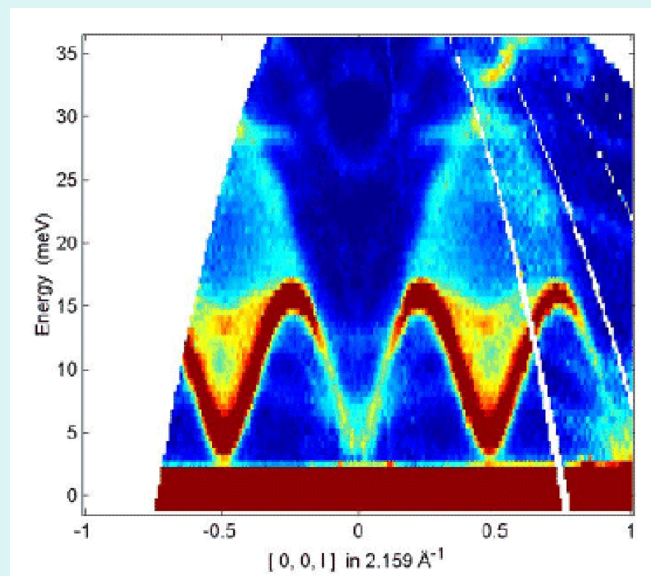


What is it that we want to study?

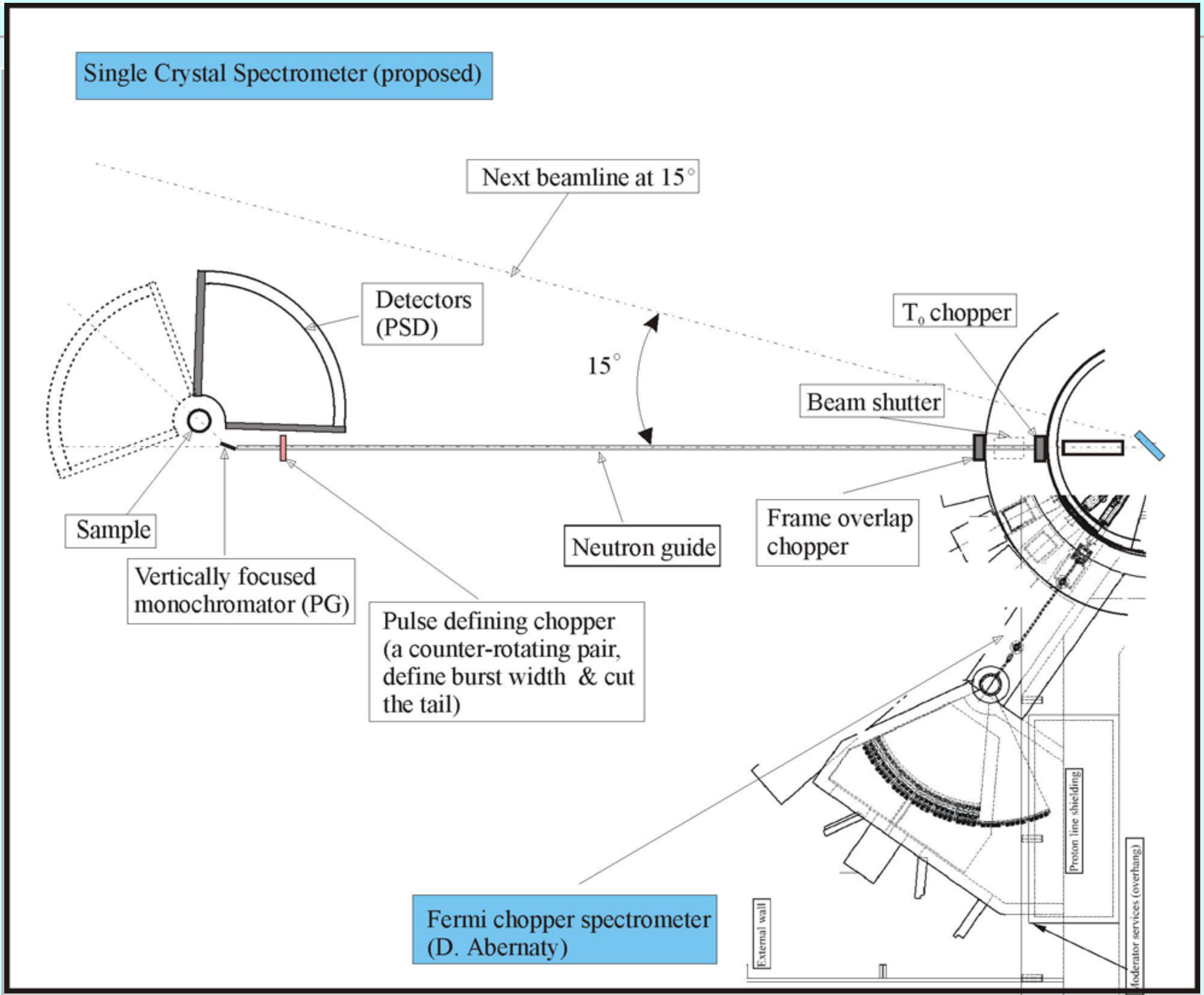
- *Coherent low-energy excitations in single crystals*
- *Different coherent static phases, ordered and weakly disordered states*
- *Magnetic vs structural scattering: polarization-dependent cross-section*
- *Reasonably small samples*

CuGeO3 sample from Masa Arai group, used for measurements on MAPS





How does the instrument we discuss fit SNS floor layout?



Follows a long, 30 m to 50 m neutron guide.

10-1000meV direct geometry high resolution (~1%) chopper spectrometer (Abernaty) is more compact (at ~11m guide).

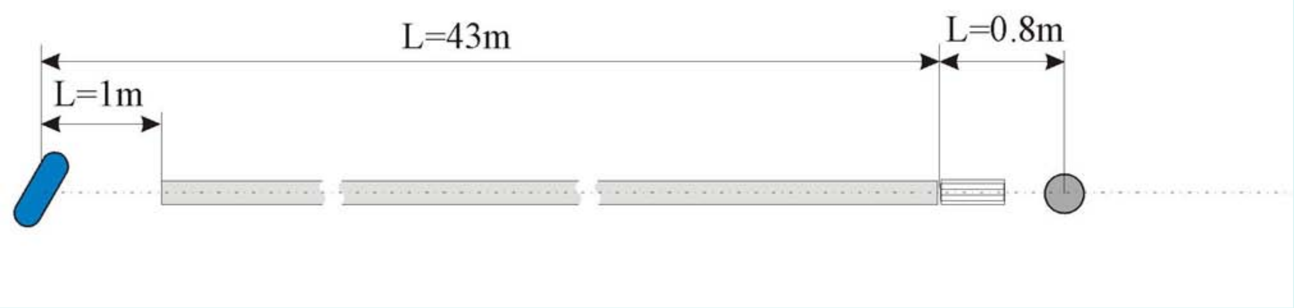
What are the general guidelines for the optimal design of an instrument at the pulsed spallation source?

- Pulsed nature of the neutron beam should be used
- The monochromatic “useful” neutron current through the sample should be maximized
- Solid angle accepted by the secondary spectrometer should be made as large as possible
- The direct view of the source by the sample should be avoided
- Scattering volume seen by a detector should be reduced to minimum, determined by the sample size

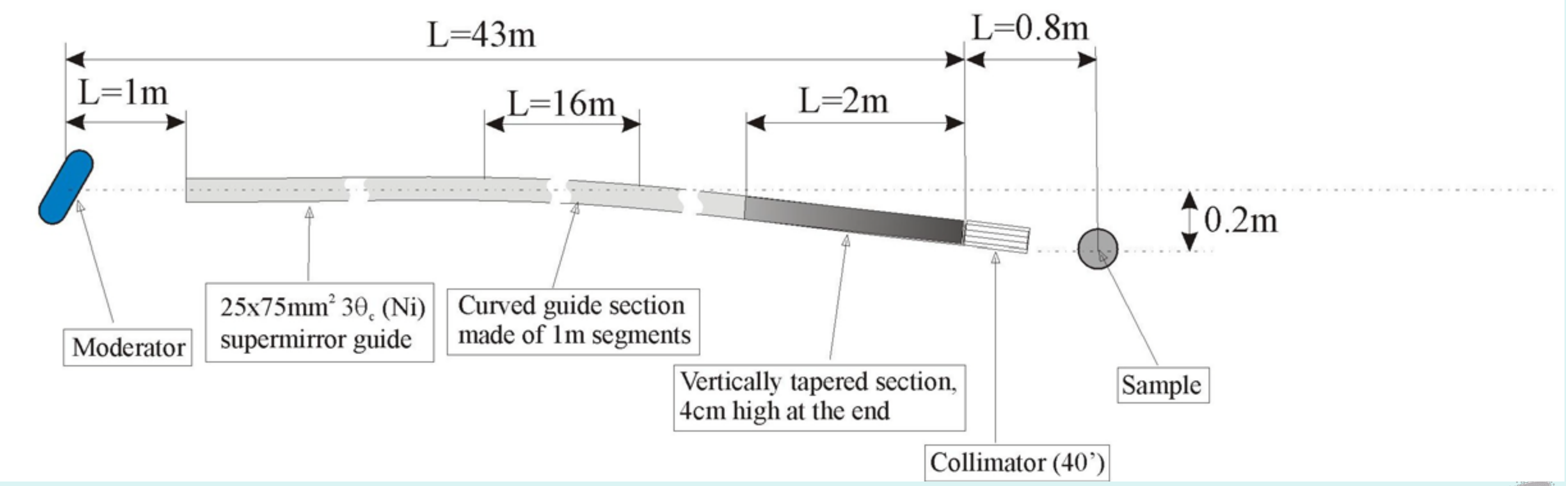
Note: once the time structure of the neutron beam is used for either the monochromator or the analyzer, no additional gain will result from using it for both.

Optimization of the neutron optics for the chopper spectrometer: MC results.

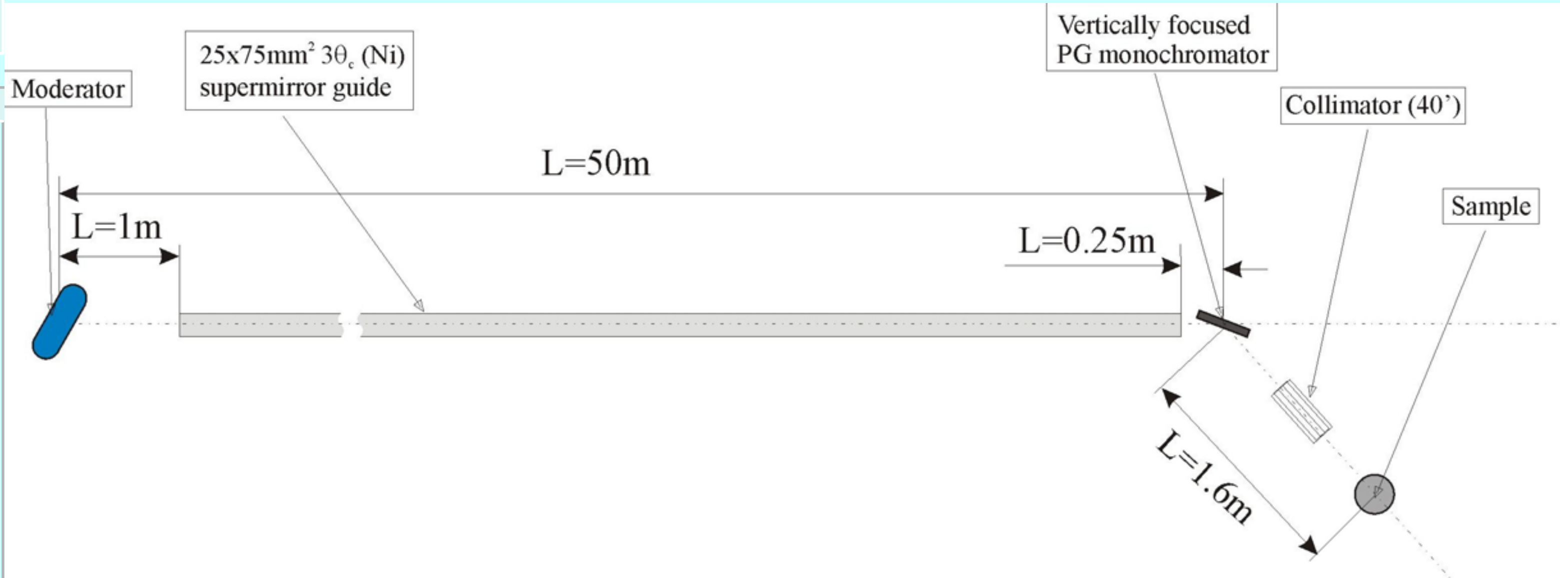
Basic layout for the direct geometry disc chopper spectrometer

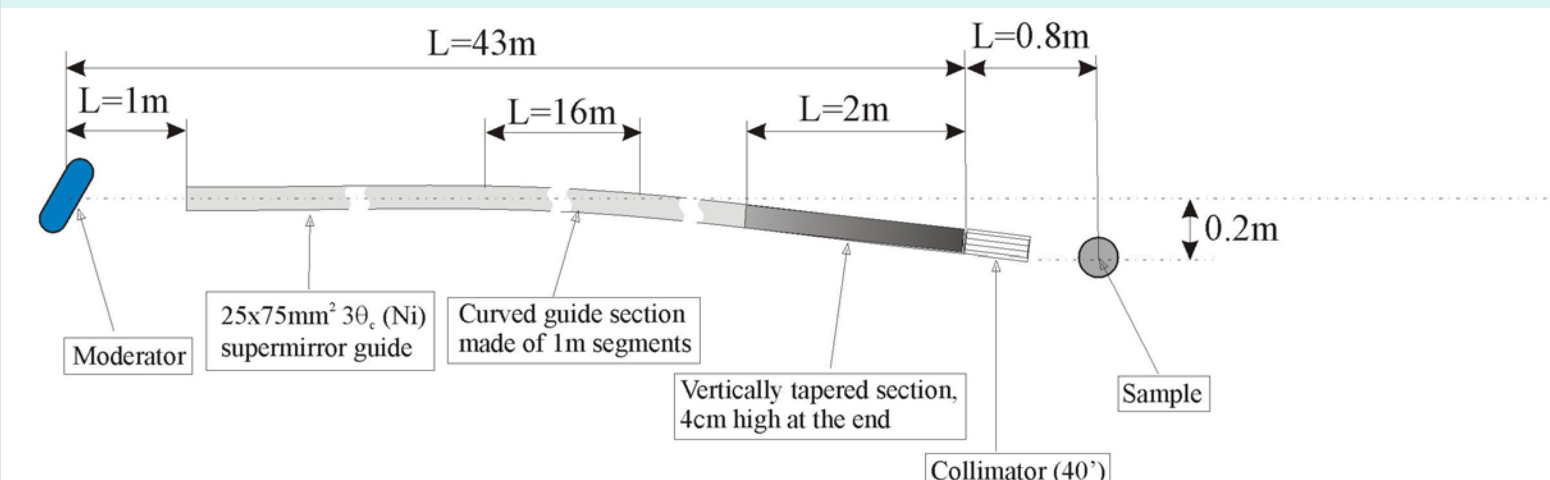


Optimized layout: curved guide loses ~6%, tapered section gain <1.4



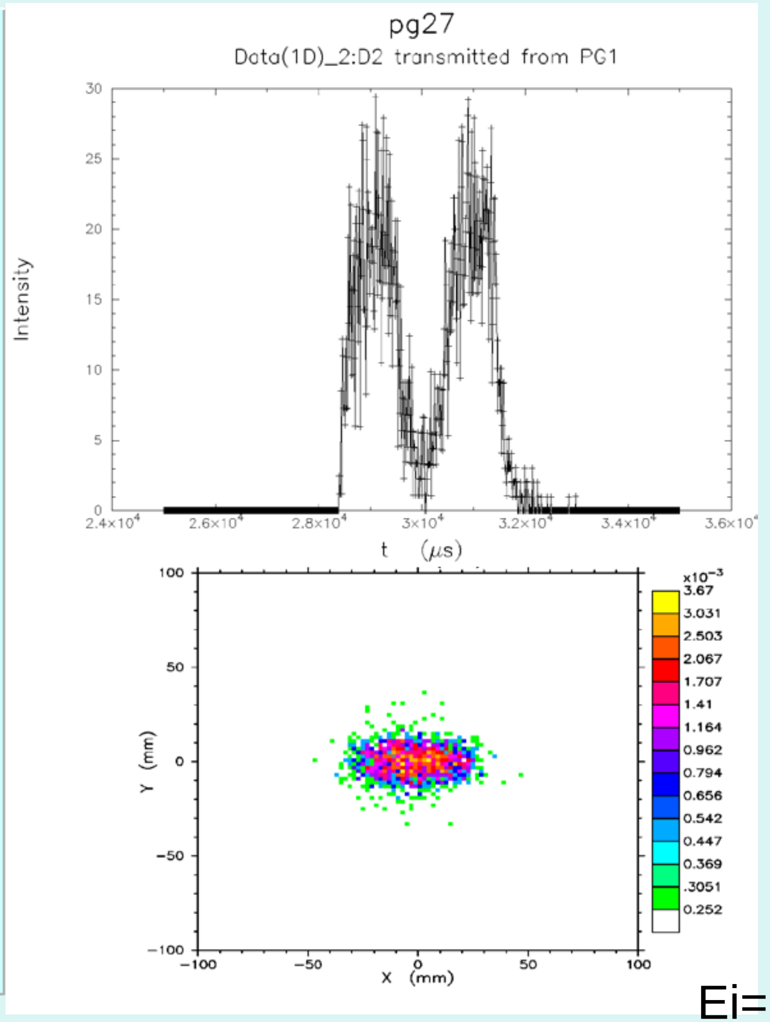
Two layouts for the low-energy direct geometry spectrometer: TOF vs PG crystal monochromator.



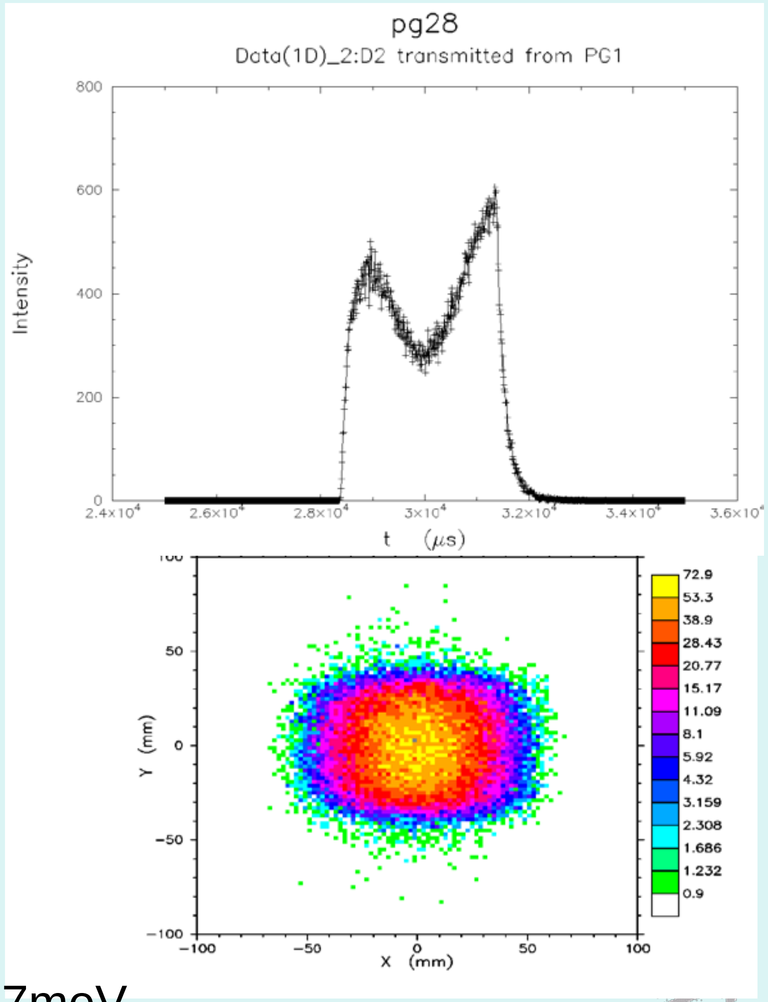


MC simulation for the PG(002) monochromator transmission and focusing properties.

Perfectly collimated beam



Beam from $3\theta_c$ supermirror guide



Ei=14.7meV

Punchline: pro's and con's of a crystal monochromator hybrid spectrometer.

Advantages

- The flux at the sample is maximized for all incident neutron energies by using the segmented crystal with vertical focusing
- Moving the sample and its environment out of the direct beam should significantly reduce the background in the detector bank
- The wavevector acceptance of the analyzer is very flexible and easily adjustable in the crystal reciprocal space (avoid the blank spots, etc.)
- The wavevector resolution may be easily controlled by adding collimators, a very high Q-resolution is possible
- The spectrometer is open for various kinds of the focussing options at the monochromator: 2D focusing, focusing with the asymmetrically cut perfect crystals, etc.
- The spectrometer can be fitted with the polarization analysis using the available technology: a Heusler crystal monochromator for the high-energy incident neutrons and an array of bender polarizers for the scattered neutrons.
- The pulsed time structure of the neutron beam is used in full

Punchline: pro's and con's of a crystal monochromator hybrid spectrometer.

Disadvantages

• Need to move an extremely bulky back end with detector bank, covering a significant solid angle
• Coupling between the resolution functions of the primary and secondary spectrometers
• Smaller than 1 and energy dependent reflectivity of the monochromator?
• Smaller solid angle coverage of the detector bank?