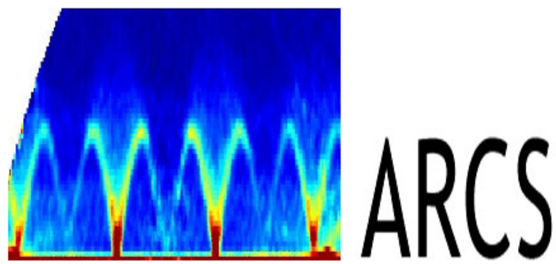


Overview of the ARCS Concept

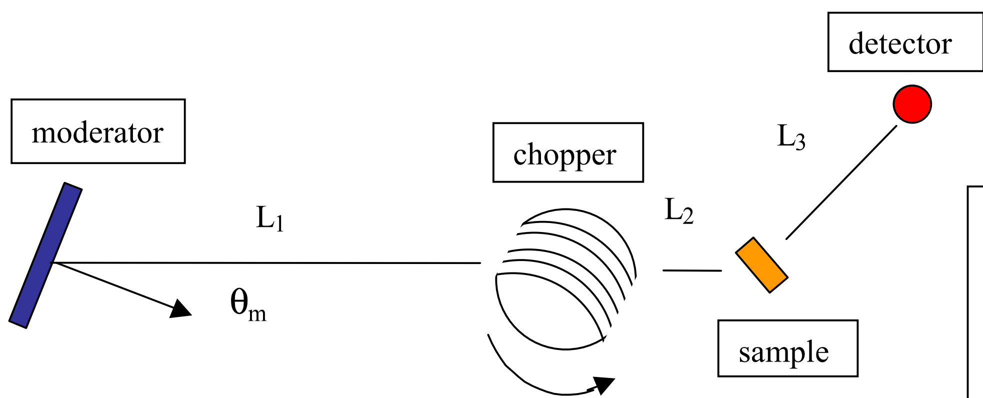
Doug Abernathy
ARCS Instrument Scientist

SNS User Feedback - Inelastic Scattering Workshop 11/1/99

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

Chopper Spectrometer Basics



Parameters

L_1	Moderator-Chopper distance
L_2	Chopper-Sample distance
L_3	Sample-Detector distance
Δt_m	Moderator pulse width (FWHM)
Δt_{ch}	Chopper pulse width (FWHM)
t_1	Moderator-Chopper flight time

Chopper Resolution and Flux

Resolution

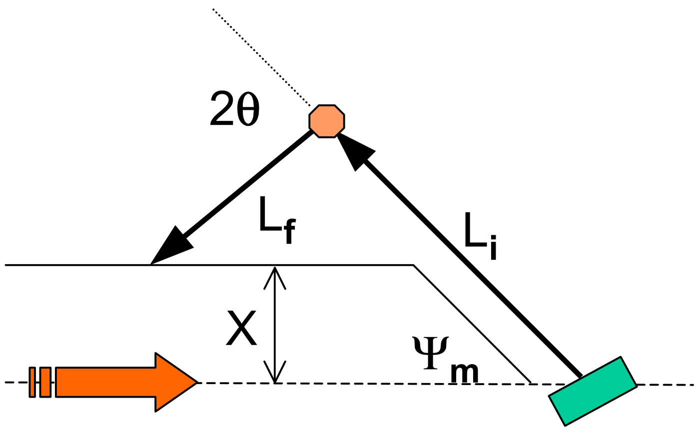
$$\frac{\Delta\varepsilon}{E_i} = 2\left\{\left[1+\left(\frac{L_2}{L_3}\right)\left(\frac{E_f}{E_i}\right)^{3/2}\right]^2 \frac{\Delta t_m^2}{t_1^2} + \left[1+\left(\frac{L_1+L_2}{L_3}\right)\left(\frac{E_f}{E_i}\right)^{3/2}\right]^2 \frac{\Delta t_c^2}{t_1^2}\right\}^{1/2}$$

$$\Delta t_c = \left\{\left(\frac{d}{2r\omega}\right)^2 + \left(\frac{W_m}{\omega L_1}\right)^2\right\}^{1/2}$$

Flux

$$I(E_i) \propto \left(\frac{d}{d+s}\right)\frac{d}{L_1^3}$$

Geometric constraints



$$X = L_i \sin\Psi_m - L_f \sin(2\theta - \Psi_m)$$

Accessible regions in L_f lie below a straight line in (L_i,L_f) plane

BL18: $X = 5$ m $\Psi_m = 35°$

For $2\theta > 125°$ & $L_f = 2.5$ m , $L_i = 13.0$ m

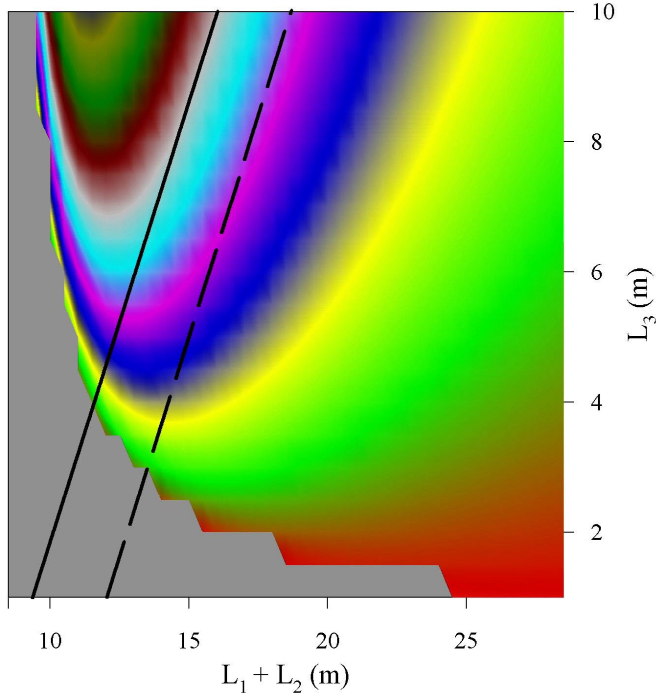
For $2\theta = 60°$ & $L_f = 6.0$ m , $L_i = 13.1$ m

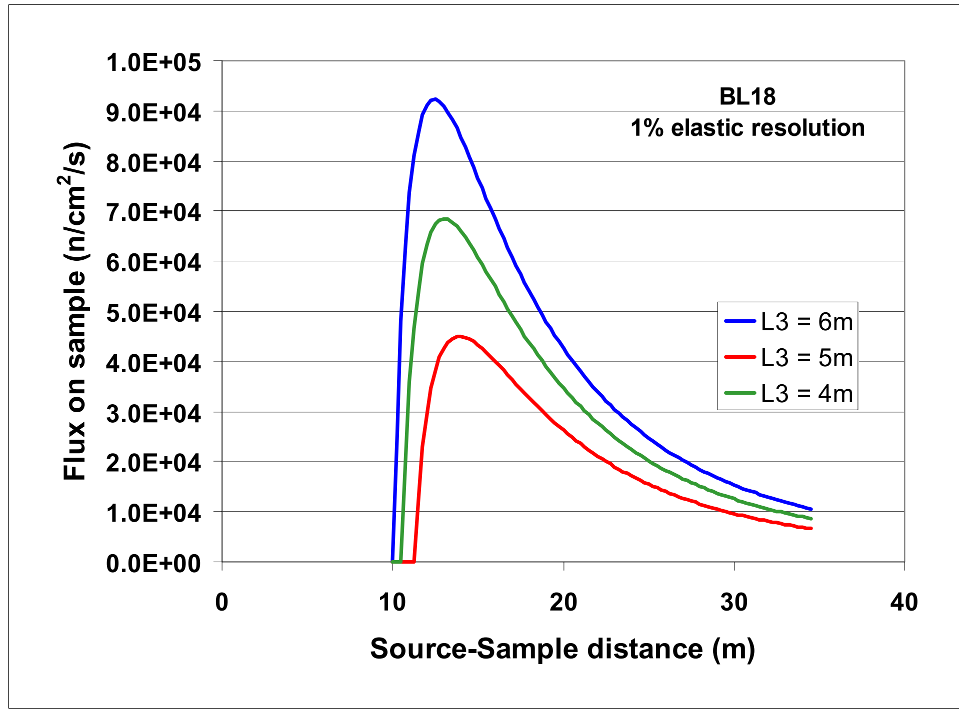
BL9: $X = 6.5$ m $\Psi_m = 35°$

For $2\theta > 125°$ & $L_f = 2.5$ m , $L_i = 15.7$ m

For $2\theta = 60°$ & $L_f = 6.0$ m , $L_i = 15.8$ m

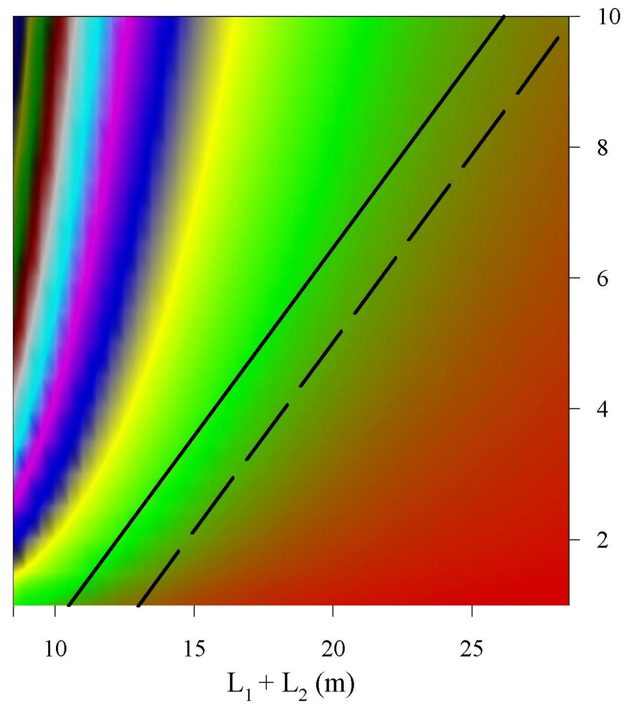
Flux on sample at 200meV - 1% elastic resolution

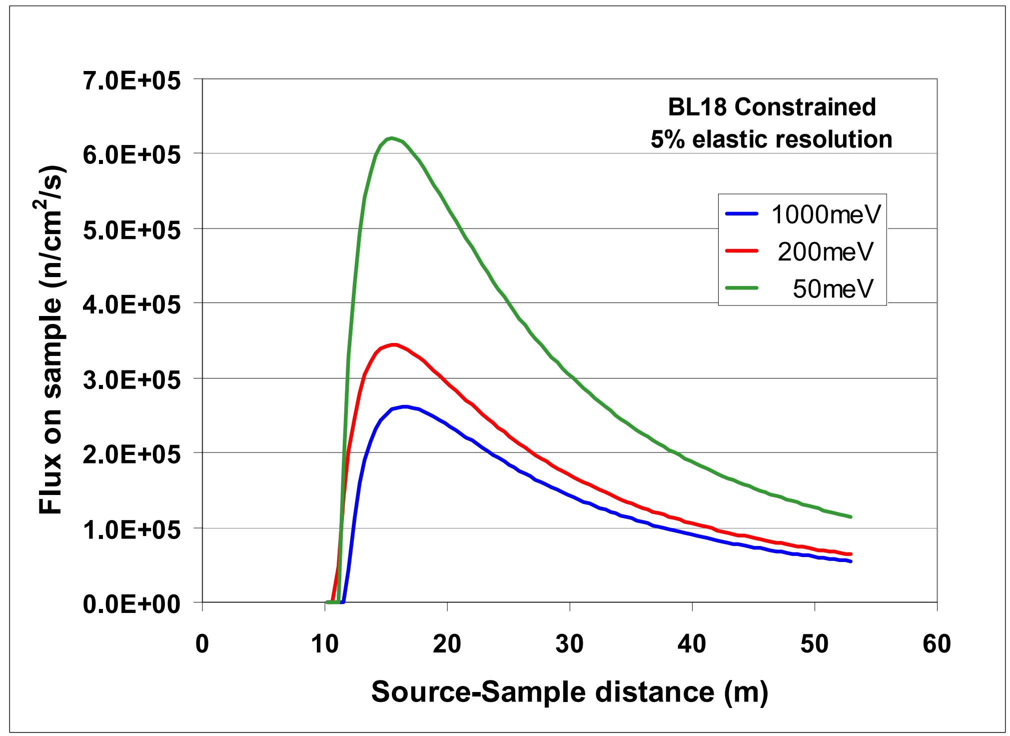




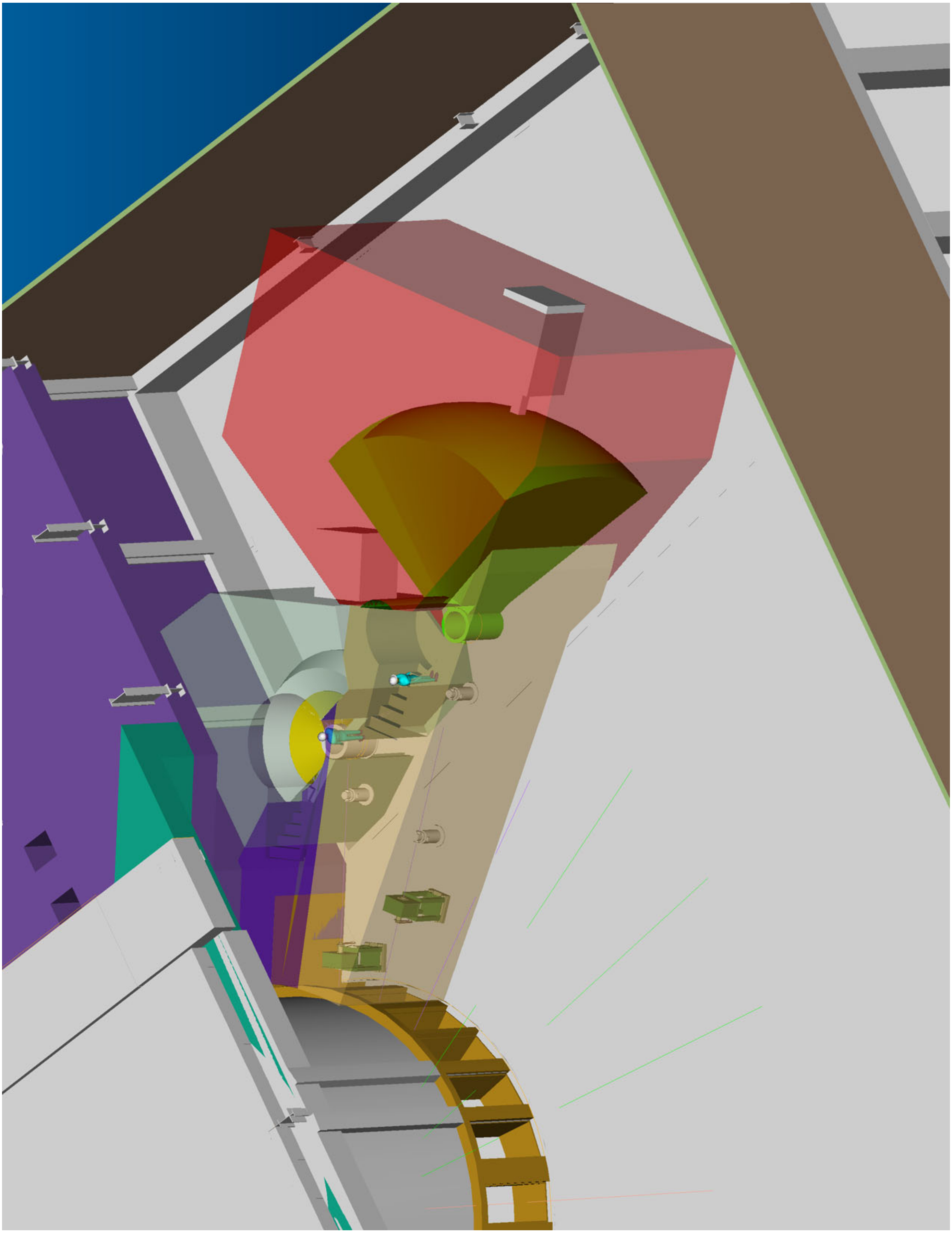
Can optimize flux for a given L_3 **that is not too large**

Flux on sample at 200meV - 5% elastic resolution





Optimum flux not accessible for any L_3



Summary and options (presented to EFAC 6/2000)

<u>Basic conclusions:</u>

Two world class chopper spectrometers can be built at the SNS, roughly corresponding to the desires of the user community.

Geometric constraints limit the placement of instruments for optimizing for high flux and low resolution.

Option 1: Build two!

Option 2: Try to force one instrument to accommodate all user desires.

Option 3: Build one, plan for second.

EFAC: Concepts valid, prefer high-resolution instrument first

ARCS – A medium-Resolution Chopper Spectrometer – Angular-Range Chopper Spectrometer

Intended for study of atomic-scale dynamics in the thermal and epithermal range with single crystal capability.

IDT headed by Brent Fultz
Scientist : Doug Abernathy

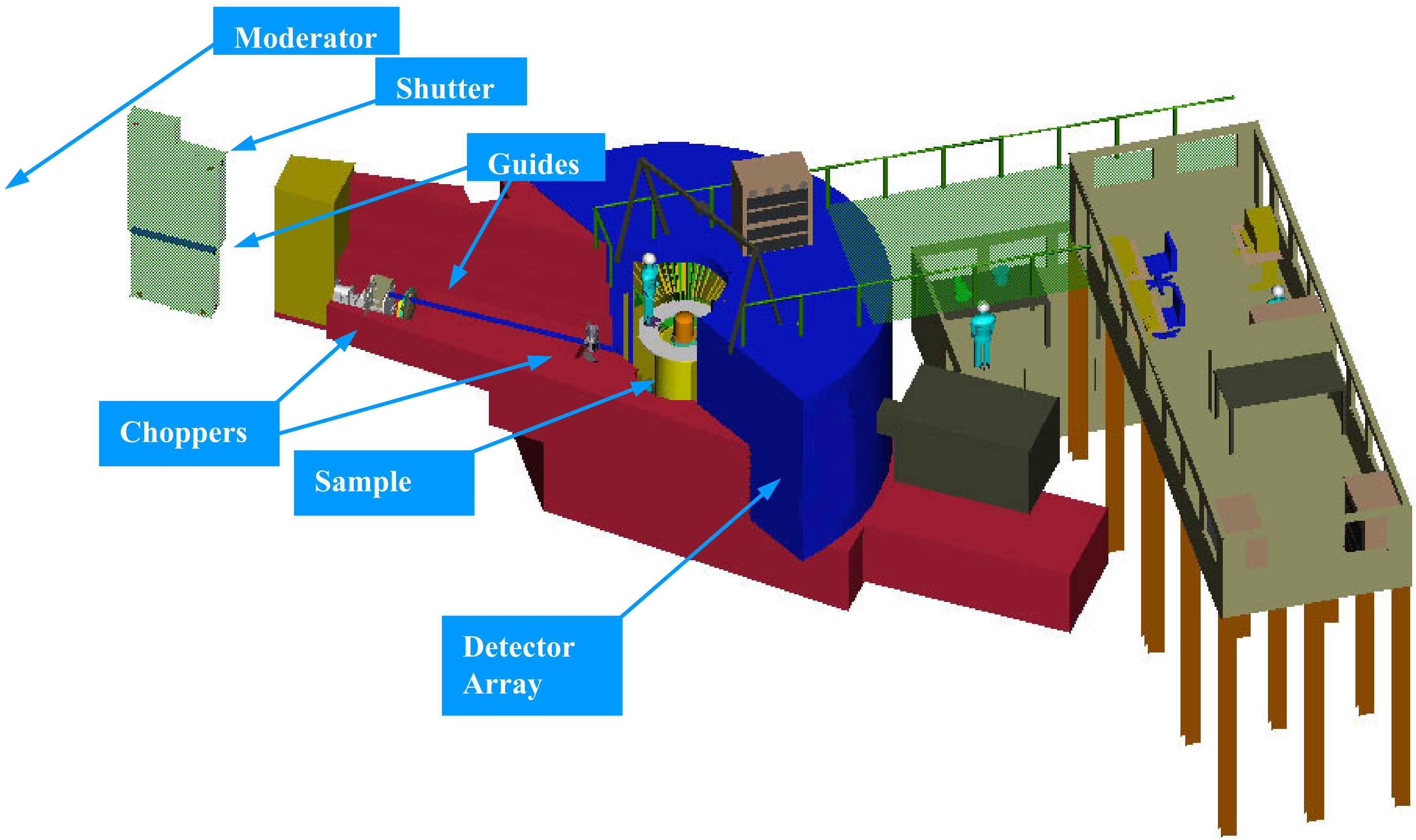
Moderator	decoupled poisoned water
Beam line	18
Source-sample	13.6 m
Sample-detector	3.0m

Lattice dynamics
- Entropy and the effects of vibrational modes on stability and phase transitions of solids
- Excitations in disordered materials; effects of nanoscale features on vibrational entropy and thermodynamic stability
- Equations of state from measurements of the phonon density of states as a function of temperature and pressure
- Phonons in correlated-electron materials; coupling of lattice and electronic degrees of freedom in high T_c, heavy-fermion and mixed valence materials

Magnetic dynamics
- High temperature superconductivity
- Crystal field spectroscopy
- Low dimensional systems; 1D quantum magnets and low-dimensional conductors
- Magnetism in actinide materials
- Heavy fermion magnetism and superconductivity
- Metal-insulator transitions in oxides

Chemical Physics
- Deep inelastic neutron scattering studies of hydrogen
- Characterization of novel materials

ARCS Instrument Overview



Instrument parameters

Spectrometer	ARCS	High Resolution
Moderator and dimensions	Ambient H_2O decoupled poisoned 18BU 100mm(H) x 120mm(V)	
Angle	13.75° (possible 27.5°)	0° (possible 13.75°)
Geometry		
Source-chopper (L_1)	11.6m	15.5m
Chopper-sample (L_2)	2.0m	2m
Sample-detector (L_3)	3.0m	6m
Choppers		
T0 horizontal axis	Mechanical 60 Hz @ 9.0m	Mechanical 60 Hz @ 10.0m
Disk	Mechanical 60 Hz @ 9.5m	Mechanical 60 Hz @ 10.5m
E0 (Fermi) vertical axis	Magnetic 600 Hz @ 12.0m	Magnetic 600 Hz @ 15.5m
Guide		
Type	Tapered supermirror 3.6 θ_c	Tapered supermirror 3.6 θ_c
Length	~8.1 m	~11m
Apertures and collimators	2-4 Variable	2-4 Variable
After E0 (Fermi) chopper	Soller collimator	Soller collimator
Max. sample size	50mm(H) x 50mm(V)	50mm(H) x 50mm(V)

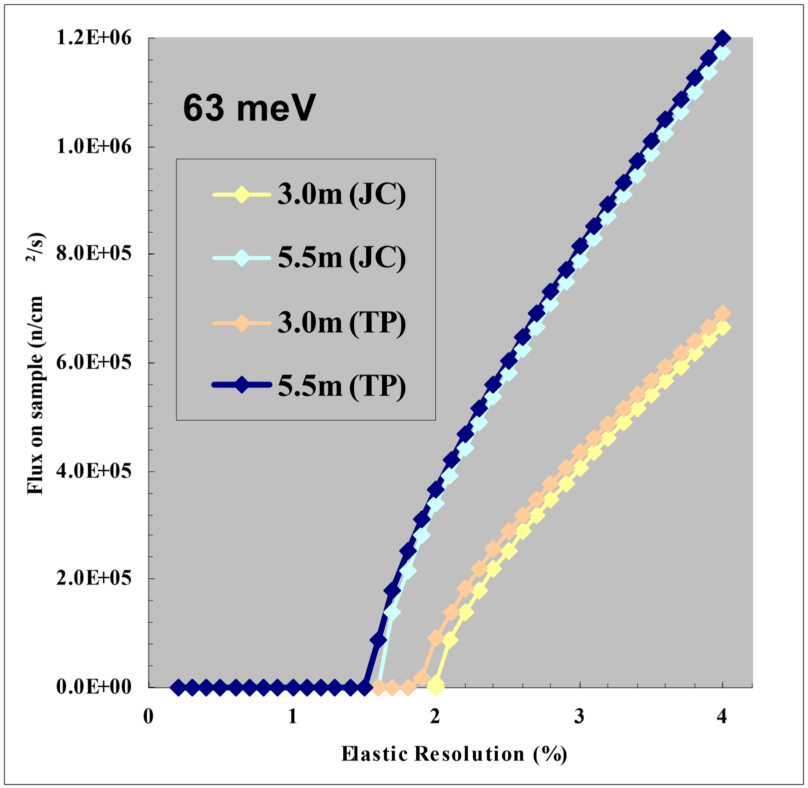
Instrument parameters

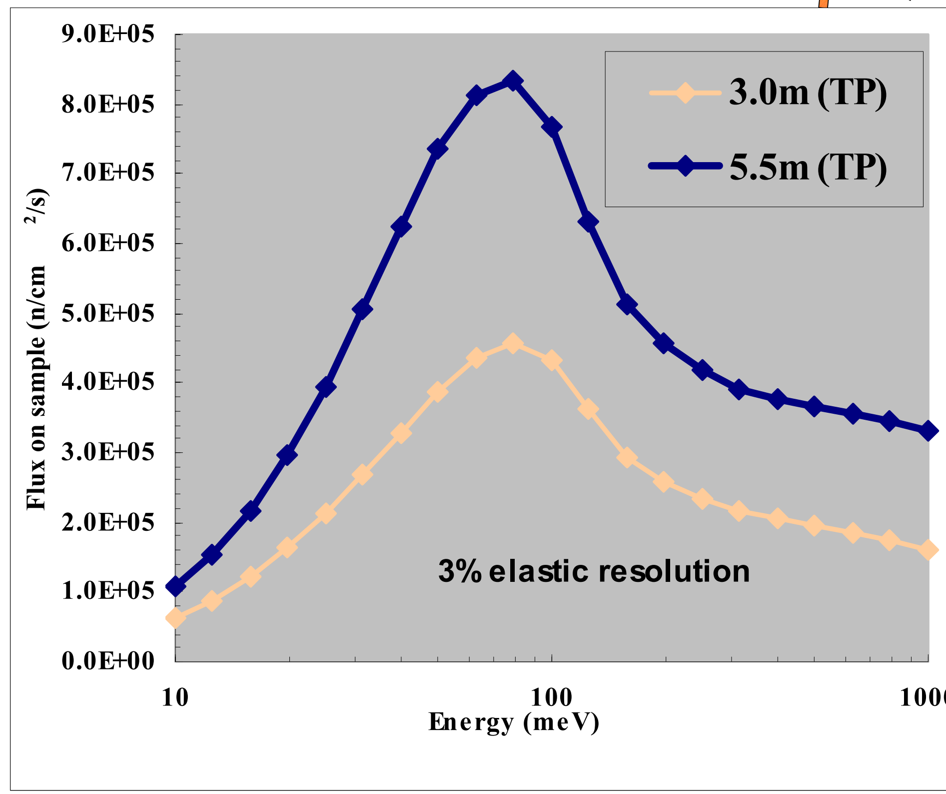
Spectrometer	ARCS	High Resolution
Scattering/sample chamber		
Radius sample-detector	3m	6m
Height	3m	6m
Vacuum at sample	$< 10^{-6}$ torr	$< 10^{-6}$ torr
Vacuum flightpath	$< 10^{-6}$ torr	$< 10^{-2}$ torr
Collimation	Oscillating radial collimator	Oscillating radial collimator
Shielding, inner	B_4C, 100m^2	B_4C, 200m^2
Shielding, outer	~0.5 m (TBD) thick, 200m^2	~0.5 m (TBD) thick, 400m^2
Linear PSDs		
Number	900	1200
Type	^{3}He 10 atm	^{3}He 10 atm
Diameter	25mm	25mm
Length	965mm (active)	965mm (active)
Resolution	25mm	25mm
Total pixels	35,000	50,400
Angular range, horizontal	-30° to -3°, 3°-150°	-30° to -2°, 2°-30° (low), 30°-60°(high)
Vertical, low bank	± 30°	± 30°
Vertical, high bank		± 10°
Low bank solid angle/area	2.95 sr / 26.7 m^2	0.70 sr / 26 m2
High bank solid angle/area		0.12 sr / 4 m2
Total area	26.7 m^2	30 m^2

Comparison to current chopper spectrometers

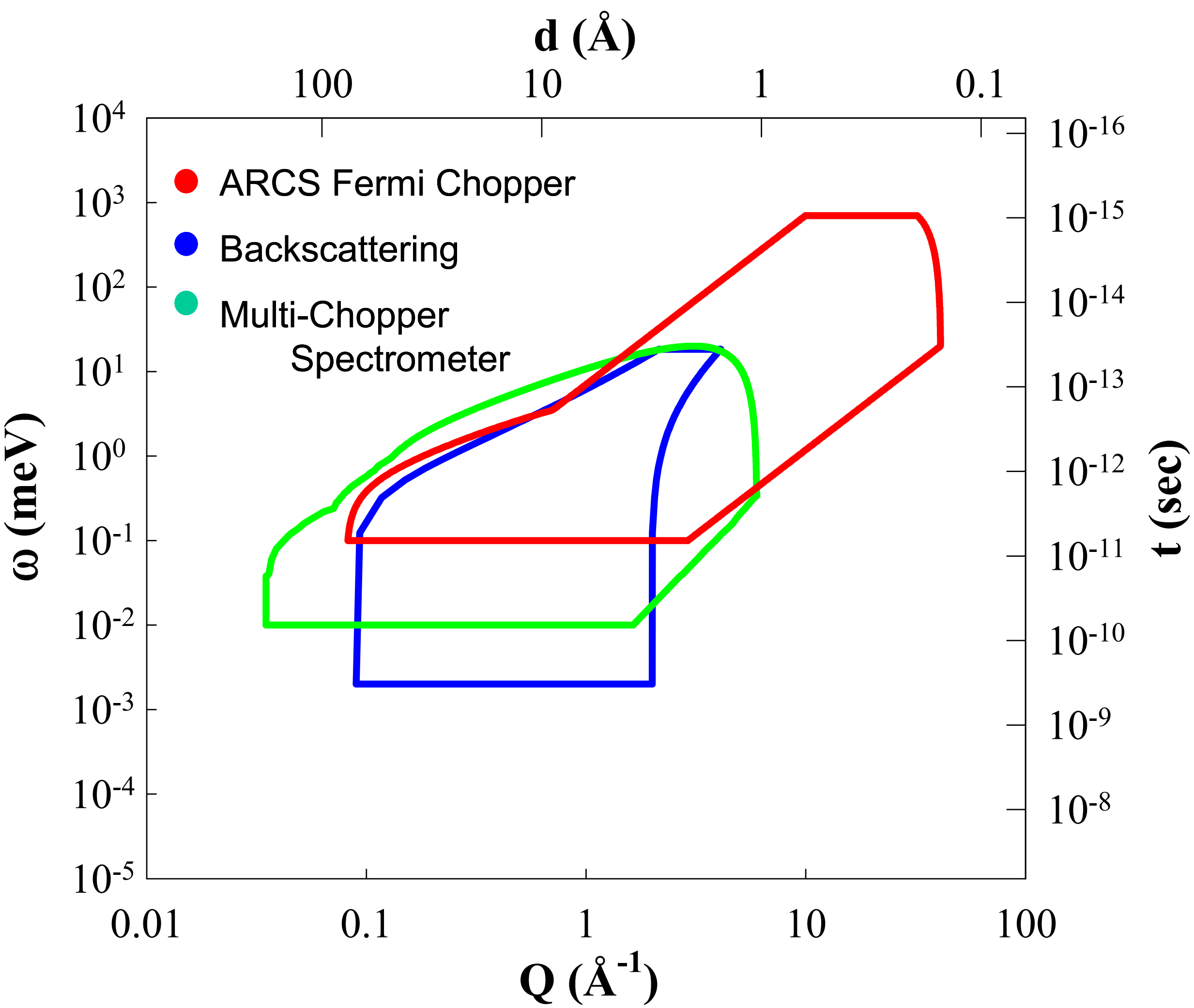
Instrument	L_1 (m)	L_2 (m)	L_3 (m)	Moderator, Tilt	% energy resolution	Angular Range (Hor)	Detector Solid Angle (sr)
LRMECS *ANL*	6.2	0.8	2.5	CH_4	2.5 – 7 %	3° - 120°	0.3
HRMECS *ANL*	12.7	1.1	4	CH_4	2 – 4 %	3° - 140°	0.5
HET *ISIS*	10	1.8	2.5/4	H_2O, 27°	2 – 4 %	3° - 30° 110° - 135°	0.1
MARI *ISIS*	10	1.7	4	CH_4, 13°	1 – 3 %	3° - 132°	0.1
MAPS *ISIS*	10	2	6	H_2O, 14°	1 – 3 %	3° - 60°	0.45
PHAROS *LANSCE*	18	2	4	H_2O , 15°	1.5 - 3%	1° - 140°	0.65
MERLIN *ISIS* (HET upgrade)	12	1.8	2.5	H_2O, 27°	2 – 4 %	3° - 150°	3.1
ARCS	11.6	2	3	H_2O, 14°	2 – 4 %	3° - 150°	2.9
SNS High res.	15.5	2	6	H_2O, 0°	1 – 1.5 %	2° - 60°	0.82

ARCS – Performance





SNS Spectrometers Summary – Q vs ω



Attempts to provide coverage of a broad area with flexible instruments and variety of resolutions

Design goals for vacuum vessel

- Provide cryogenic vacuum for sample with quick (< 1 hr) changeout and good access for special equipment
- Minimize/eliminate neutron windows (thin Al), particularly near sample
- Mount and provide access to neutron detectors (turnaround ~ several hours)
- Accept additional components – variable aperture, oscillating radial collimator
- Include internal neutron shielding (“crispy mix”)
- Allow for external neutron shielding to block background

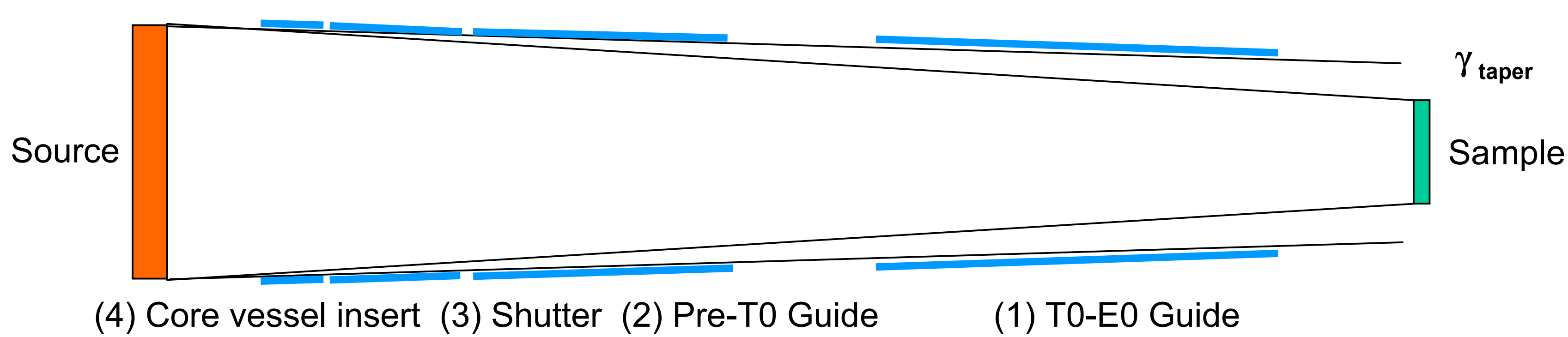
Choice: detectors outside or inside vacuum

- Outside:
  - Pro: Good access; proven approach
  - Con: Very large window area; implosion risk; venting for all sample or detector changes; tight tolerance on tank deflections
- Inside:
  - Pro: No large windows; better detector coverage; more tolerance for deflections
  - Con: Not proven detector operation; possibly more difficult detector access

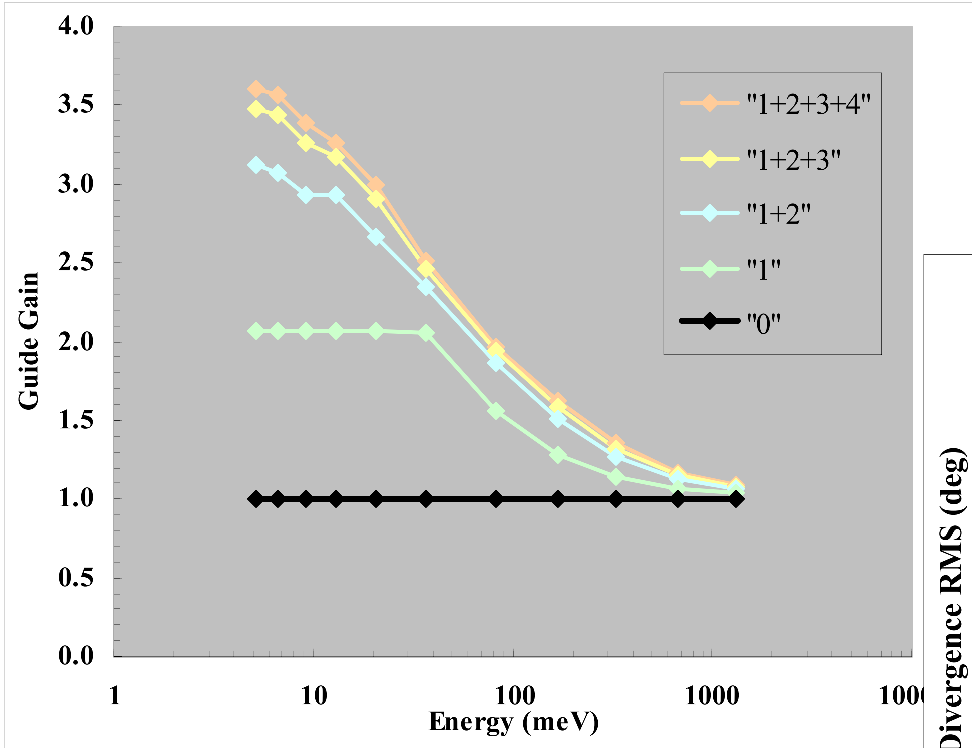
Guide calculations

Using acceptance diagram approach (1 - D)

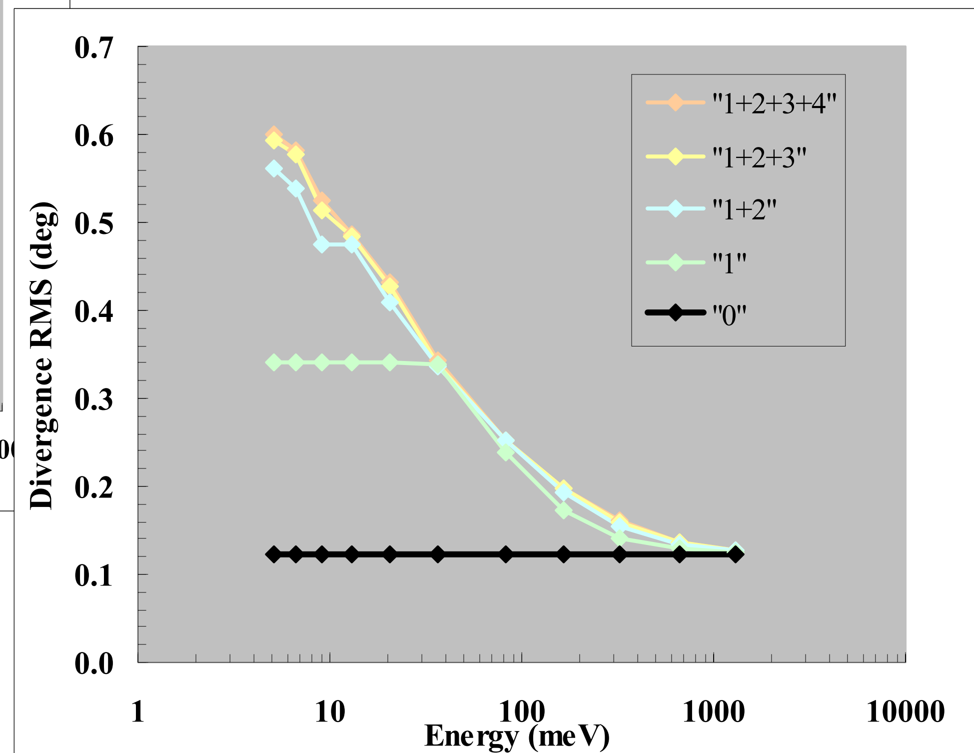
λ	γ taper		*Energy*	s_{source} (cm)	s_{sample} (cm)					
3.00	1.40		9.09	12.00	5.00					
Component	l (cm)	s_{in} (cm)	s_{out} (cm)	$n_{channels}$	c_{guide} (mradian/Å)	$n_{segment}$	*Start*	*Finish*	*S'in*	*S'out*
Source Tube	150.00	12.000	11.580	1	0.00	1	0.00	150.00	12.00	11.40
Core Vessel Insert	100.00	11.580	11.300	1	0.00	1	150.00	250.00	11.40	11.00
Shutter	200.00	11.300	10.740	1	6.23	1	250.00	450.00	11.00	10.20
Pre-T0 Guide	450.00	10.740	9.480	1	6.23	1	450.00	900.00	10.20	8.40
T0	150.00	9.480	9.060	1	0.00	1	900.00	1050.00	8.40	7.80
T0-E0 Guide	500.00	9.060	7.660	1	6.23	1	1050.00	1550.00	7.80	5.80
E0	50.00	7.660	7.520	1	0.00	1	1550.00	1600.00	5.80	5.60
Sample	150.00	7.520	5.000	1	0.00	1	1600.00	1750.00	5.60	5.00



Gain versus Length



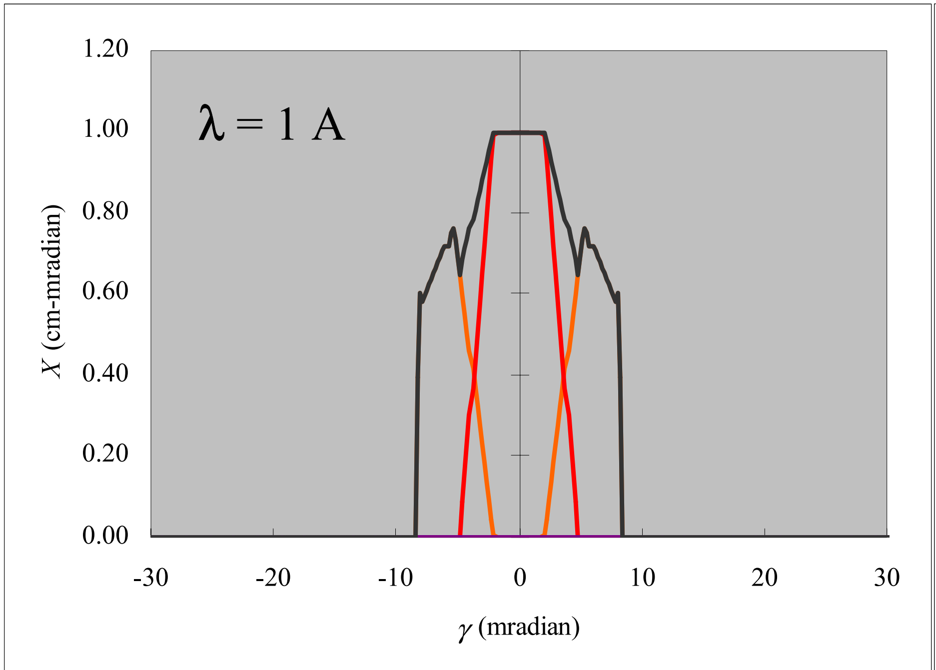
Section 1	T0-E0 Guide	5m
Section 2	Pre-T0 Guide	4.5m
Section 3	Shutter	2m
Section 4	Core Vessel Insert	1m

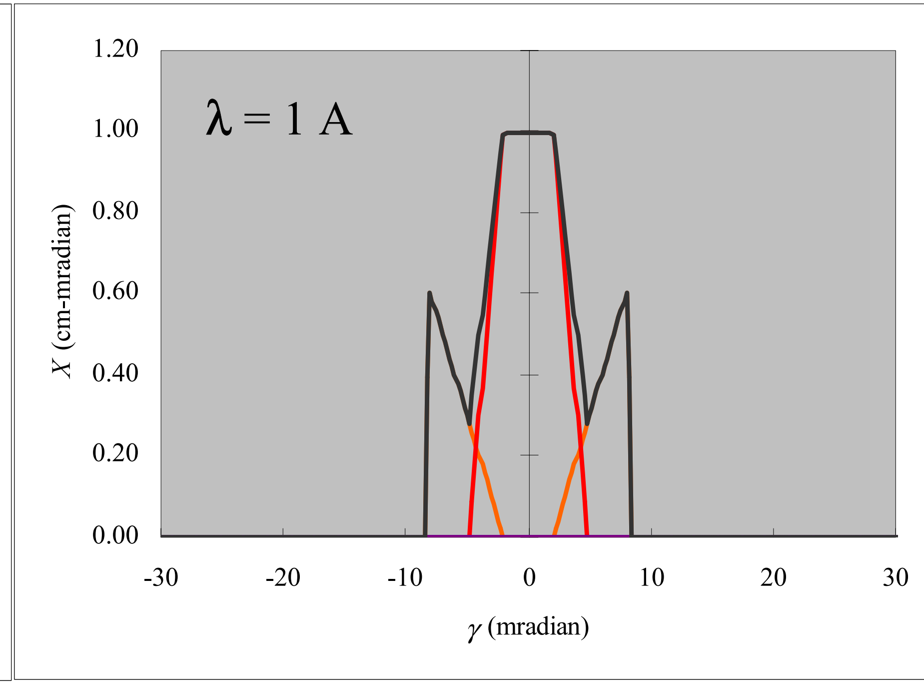


Source = 12 cm Sample = 5cm

γ_{taper} = 2 mrad (line-of-sight)

Divergence: Sections 1, 2 and 3 versus 1

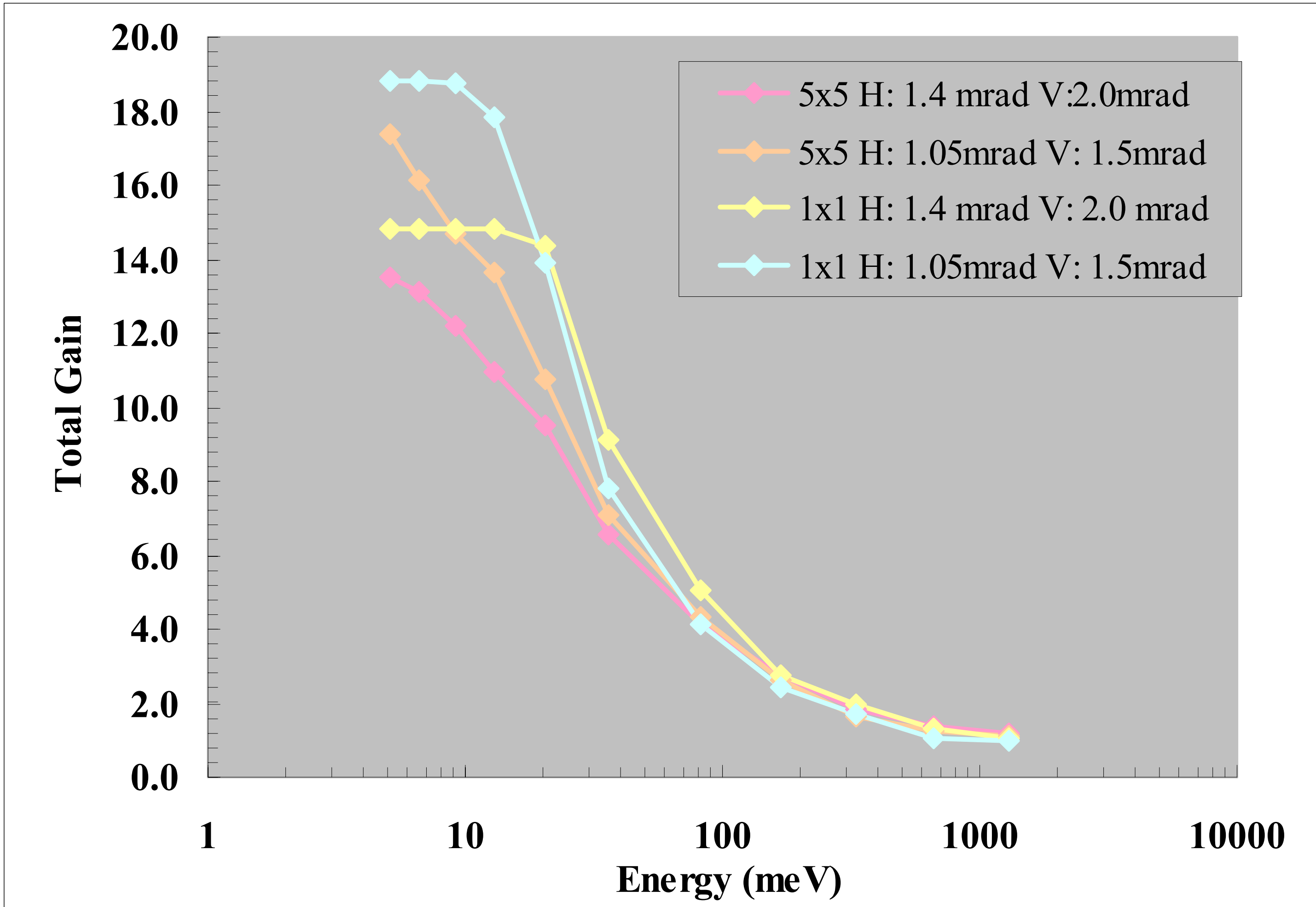




Source = 12 cm Sample = 5cm

γ_{taper} = 2 mrad (line-of-sight)

Total Gain: 5x5 cm^2 and 1x1 cm^2 sample



Major issues / risks for ARCS

- Detector mounting in vacuum
  - *Prototype testing plans underway*
- Vacuum vessel design
  - *Complete detector prototyping early*
  - *Use experienced design and manufacture firm*
- Guide design and shielding - effects on background
  - *Calculations and experience from others*
- Sample environment - allow for large systems, high fields, pressure
  - *Need more modeling of sample area to determine space constraints*
- Sample manipulation - on spectrometer or built into sample equipment
  - *Modeling of single crystal experiments; data analysis and visualization software to evaluate need*