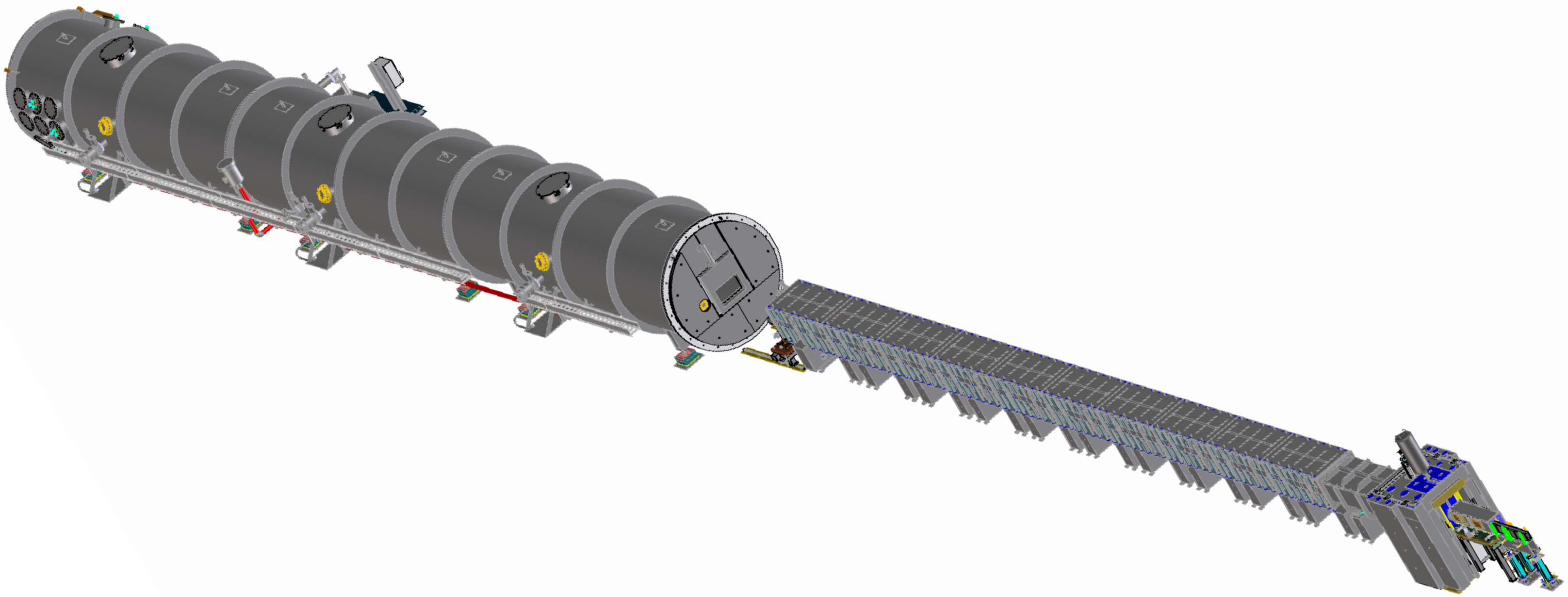
VSANS

The Very Small-Angle Neutron Scattering (VSANS) Diffractometer at NIST



November 19th, 2014

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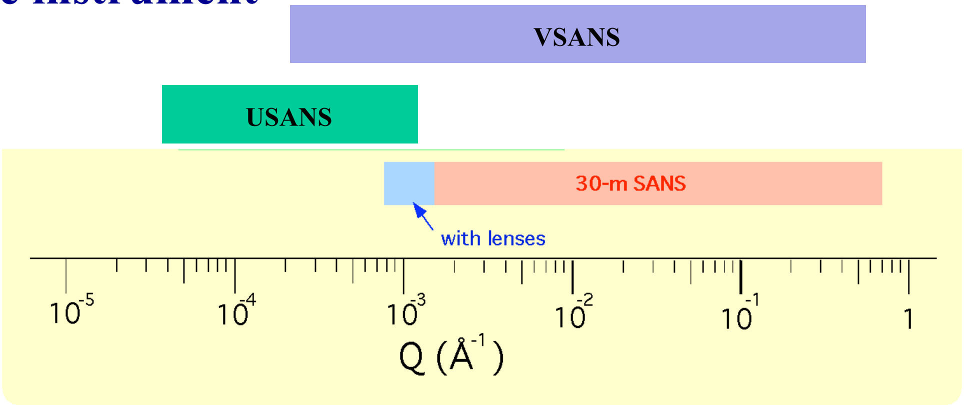
NIST Center for Neutron Research
Gaithersburg, Maryland

VSANS Instrument

Why VSANS ?

- **To improve measurement efficiency**
  - **extending the q-range of the 30 m NIST SANS instruments would enable most SANS experiments to be completed on one instrument**



- **To add new measurement capabilities**
  - **2% or 12.5 % or "white" Beam (4 Å ≤ λ ≤ 8 Å) wavelength band**
  - **expandable (~2 m) sample staging area**
  - **multiple detectors to extend q-range of a single measurement**

Comparison of Count rates: USANS vs SANS w Lenses: q_{min} = 0.001 Å^{-1}

$$\frac{C_s}{C_u} \approx \frac{N_{col}\,\Delta q_{pixel}}{\Delta q_u}\left(\frac{\lambda_s}{\lambda_u}\right)^2 \frac{I_s}{I_u}$$

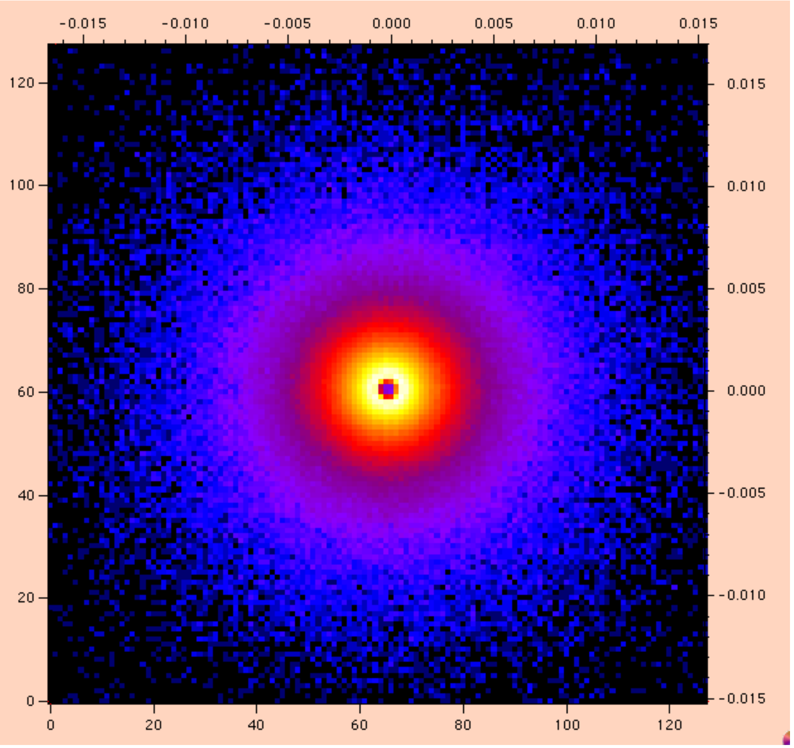
$$128 \text{ x } \frac{2.5e-4}{2e-5}\left(\frac{8.1}{2.38}\right)^2\left(\frac{17,000}{25,000}\right) = 12,000$$

Obtain same statistics 10,000 Times faster on SANS vs USANS

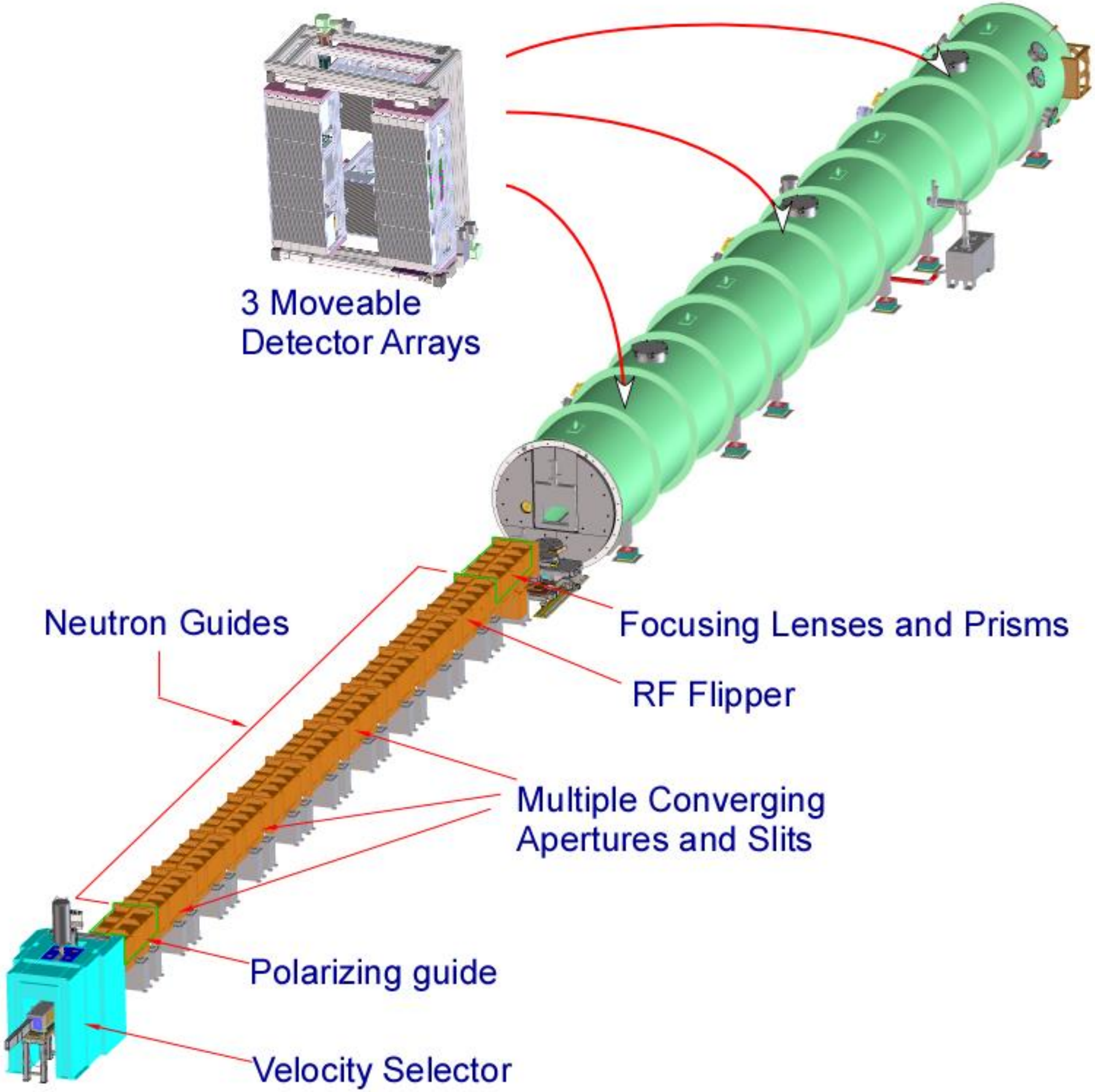
Assumptions:

- **Same sample thickness and transmission**
- **Same 8 mm radius sample aperture**

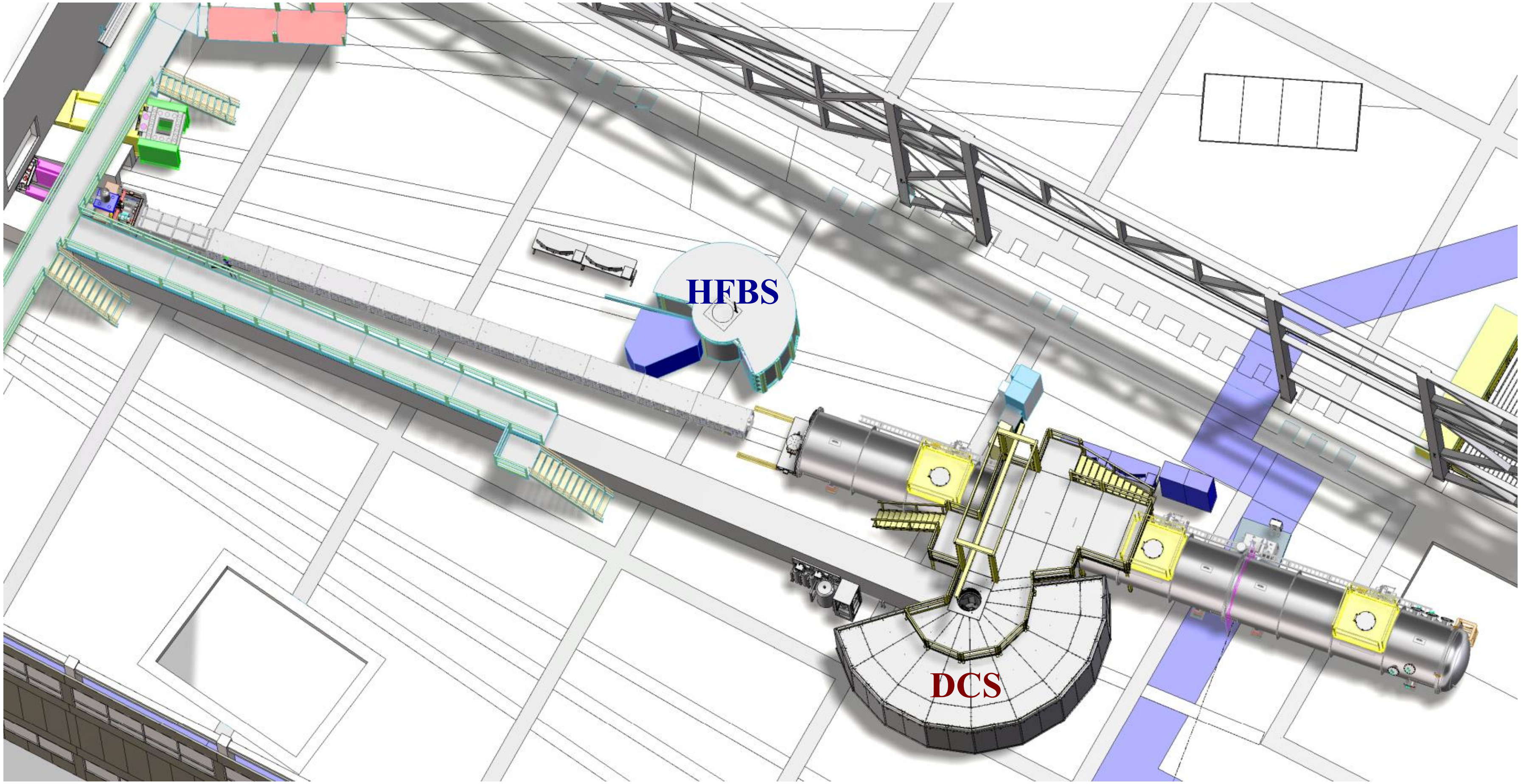
R. Triolo Marble: 10 min time
Lens Config.(SDD= 15 m, λ = 8.1 Å)



VSANS: q_{min} = 2e-4 Å^{-1}: **Narrow slit collimation → 100,000 times faster …**
Converging beam collimation → 1,000 times faster

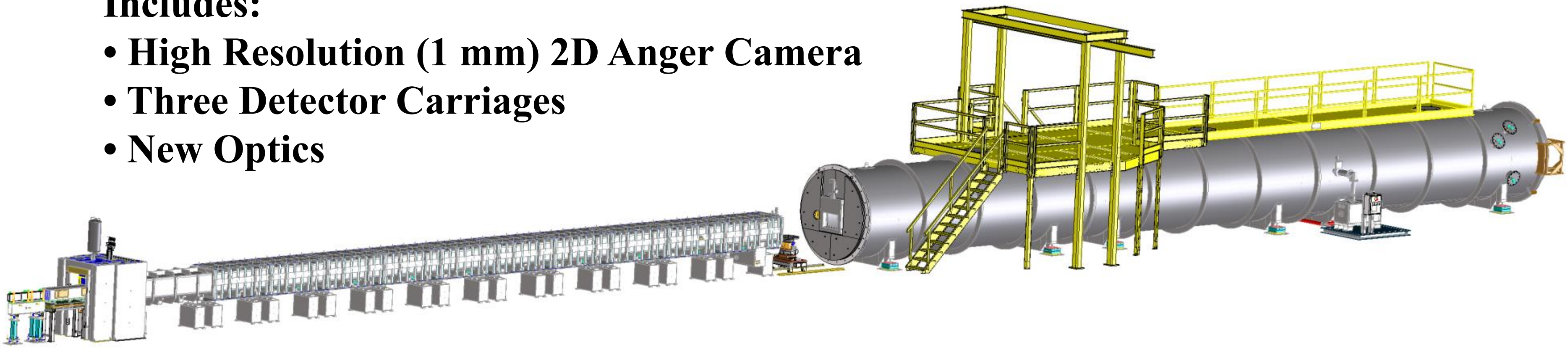

3 Moveable
Detector Arrays
Neutron Guides
Focusing Lenses and Prisms
RF Flipper
Multiple Converging
Apertures and Slits
Polarizing guide
Velocity Selector

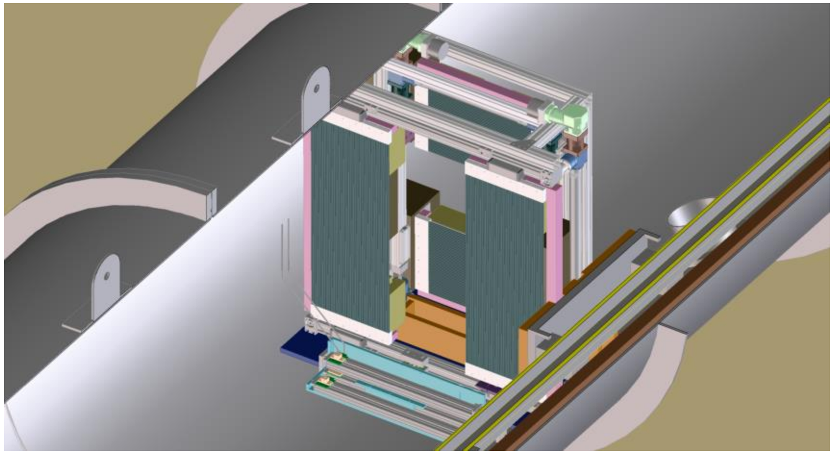
Plan View of VSANS Instrument in Guidehall

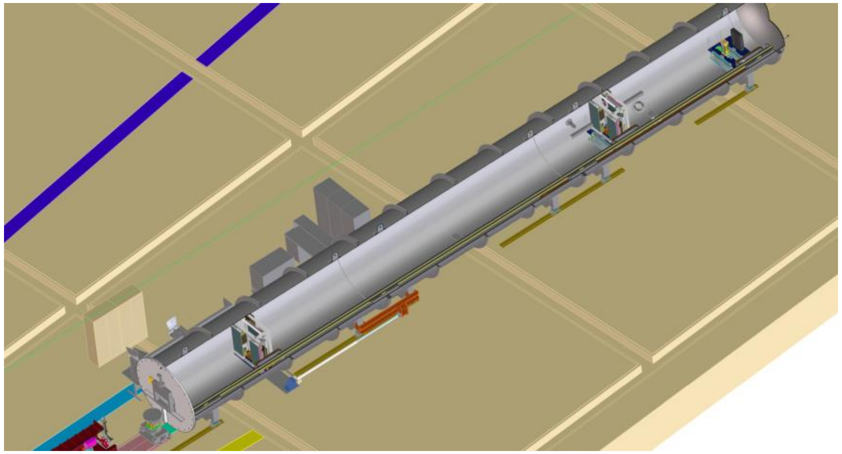


Initial Operation: Fall, 2016
45 m long
From outside, looks like a typical SANS instrument…
Includes:

- **High Resolution (1 mm) 2D Anger Camera**
- **Three Detector Carriages**
- **New Optics**





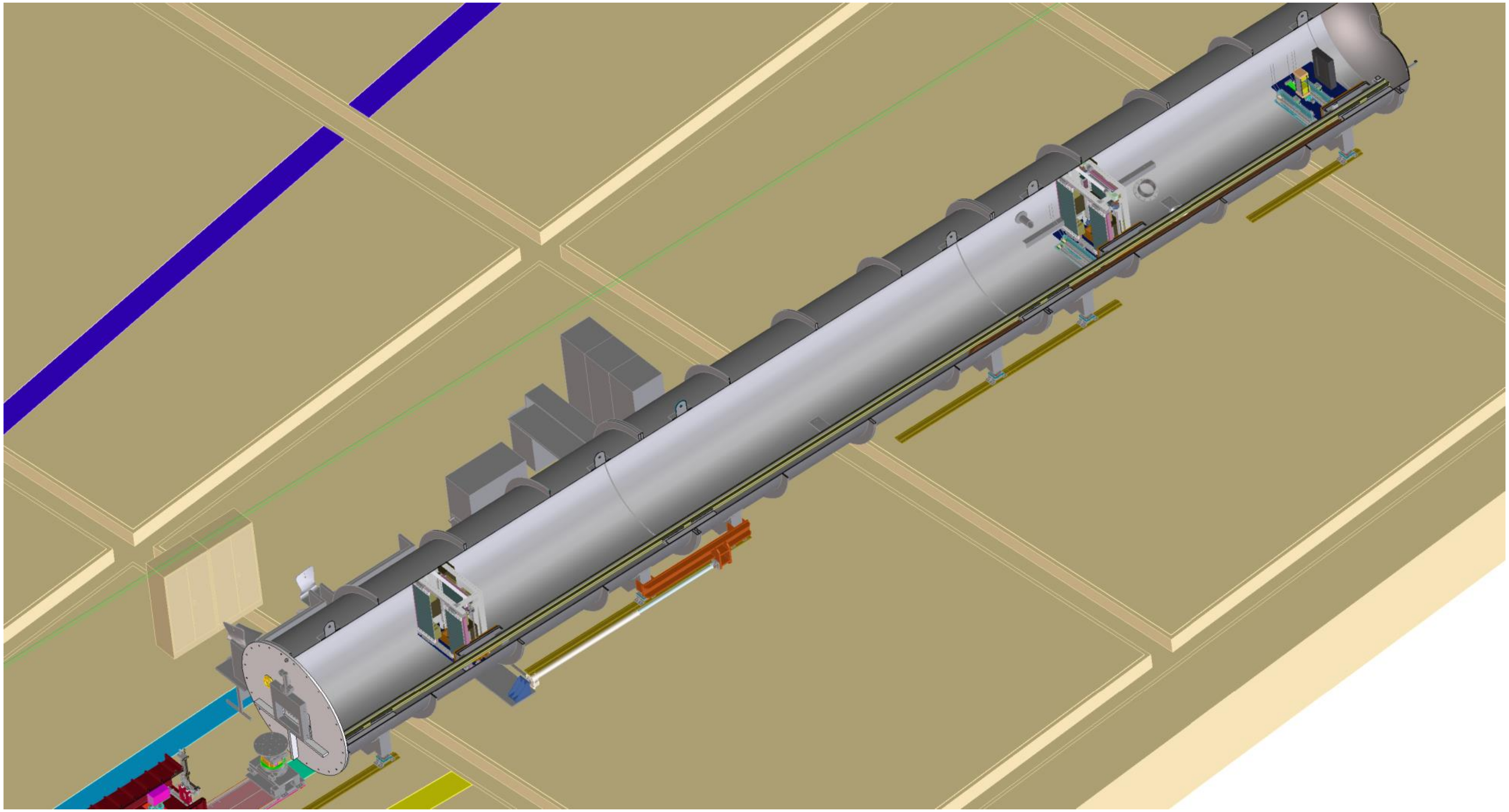


Instrument Characteristics (Blue → New or improved feature)

Source	Guide 60 mm wide x 150 mm tall
Wavelength Range	4 to 20 A
Wavelength resolution	2% (graphite), 12.5 % (Selector) and "White" Beam: 4 Å ≤ λ ≤ 8 Å
Source-to-sample distance	4 m to 22 m in 2 m steps
Sample-to-detector distance	0.6 m to 22.5 m continuous
Collimation	• Circular pinhole – several sizes up to 60 mm diameter
	• Rectangular XY slits – continuous range 0-60 mm x 60-150 mm
	• Multiple (18) Converging circular beams + lens + prism
	• Multiple (3) converging narrow rectangular beams + lens
Sample Size	• Circular: 1 mm to 30 mm diameter
	• Rectangular width 1 to 18 mm, height 12 to 75 mm
	• Converging beams: typically 35 mm x 72 mm
Q-range	**$2x10^{-4}$ A^{-1}** to 1.0 A^{-1} **{In one measurement}**
Detectors	1) **1.2 mm fwhm res., 2D, 150 mm wide x 450 mm tall**
separate carriages	2) 8 mm fwhm res. 2D (tubes), four panels: 384 mm x 1000 mm
	3) 8 mm fwhm res. 2D (tubes), four panels: 384 mm x 500 mm

Cutaway view of detector vessel showing **three** movable detector carriages

{ delivery spring 2016 }

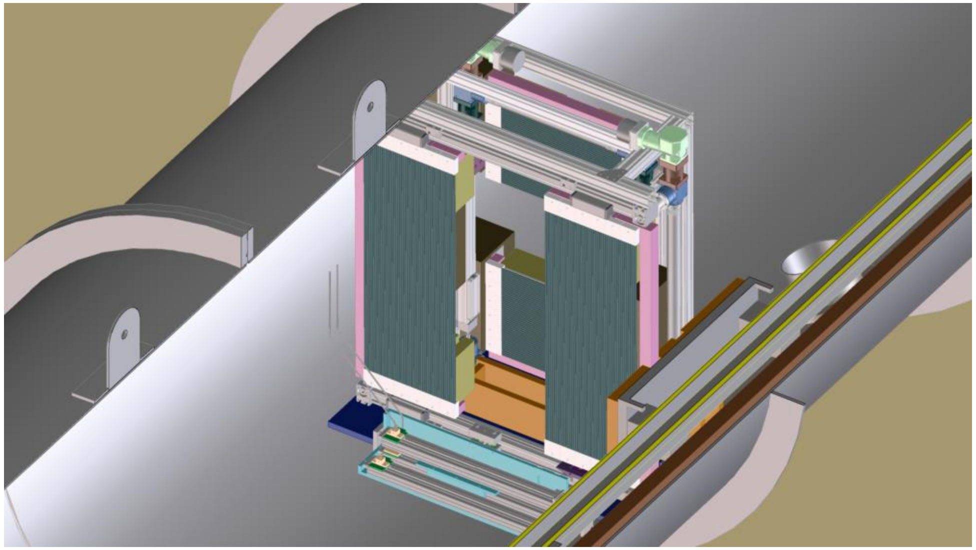


Movable 2D Detector Panels

to form a Picture Frame:

- **Side Panels 384 mm x 1000 mm**
- **Top/bottom 500 mm x 384 mm**
- **8 mm dia. He(3) Tubes, one layer**

Extends Q-range by factor of 30x



Other Multiple Carriage

Instruments:

- **D33, ILL Grenoble France**
- **BILBY, ANSTO, Australia**

Panels received from General

Electric in Feb, 2012

High Resolution Detector Procurement: fy 2015

SNS-type Anger camera → 15 cm x 45 cm

Instrument rotated 0.3° to avoid reactor core Gamma rays

Installation of Anger Cameras in SNAP.

Specifications

Active area: 15 x 15 cm

Scintillator: 2 mm GS20 Li glass

PMT: H8500; 9 PMTs, each with 64 anodes

Pixels gain compensated

Tileable

NIST Cold (T=32 K) Neutron vs "typical" Xray Source Brilliance

20 MW Reactor: 1e18 s^{-1} excess neutrons

1) Large emitting source surface ….

Moderated peak flux → 430 mm dia. sphere

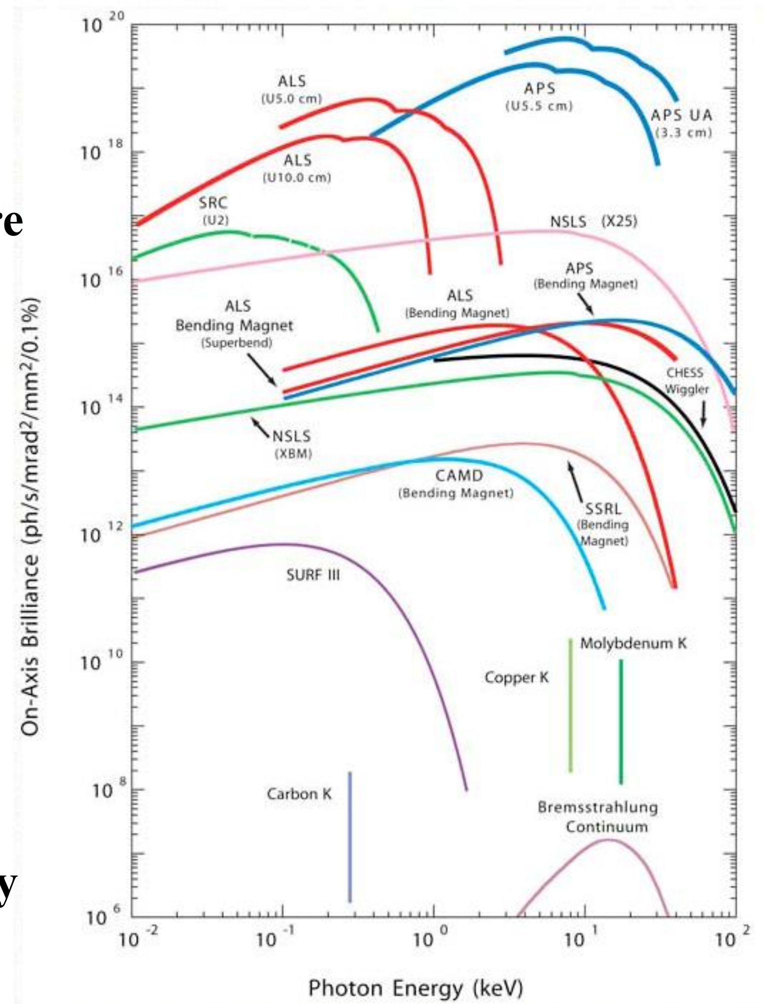
Moderated surface flux → 1.5e12 $mm^{-2}s^{-1}$

2) Isotropic source….

Per $mrad^2$ → 1.2e5 $mm^{-2}s^{-1}mrad^{-2}$

3) "White" (T=32 K) Maxwellian λ Distribution at λ = 3.5 Å

Per 0.1 % Δλ/λ → 20 $mm^{-2}s^{-1}mrad^{-2}0.1\%^{-1}$



Neutron Sources have up to 18 orders of Magnitude lower brilliance than some Xray Synchrotron sources !!!!

Larger samples → 2-3 orders gain

Larger bandwidth Δλ → 2 orders gain

←NIST neutron source →

$$I_B = \left(\pi/4\right)^2 \frac{D_1^2 D_2^2}{L_1^2}\left(\Delta\lambda/\lambda\right) f_{max}(\lambda) \propto q_{min}^2 A_{sample}$$

- **Circular Apertures $D_1 + D_2$:**

Longer instruments → larger samples

→Higher beam current

- **18 Converging Beams + lens:**

Gain = 18 x (10 mm/ 3 mm)^2 = 200

- **Narrow Slits: 150x5 + 75x2.5**

Gain = 1,400

'white' beam: 4 Å ≤ λ ≤ 8 Å

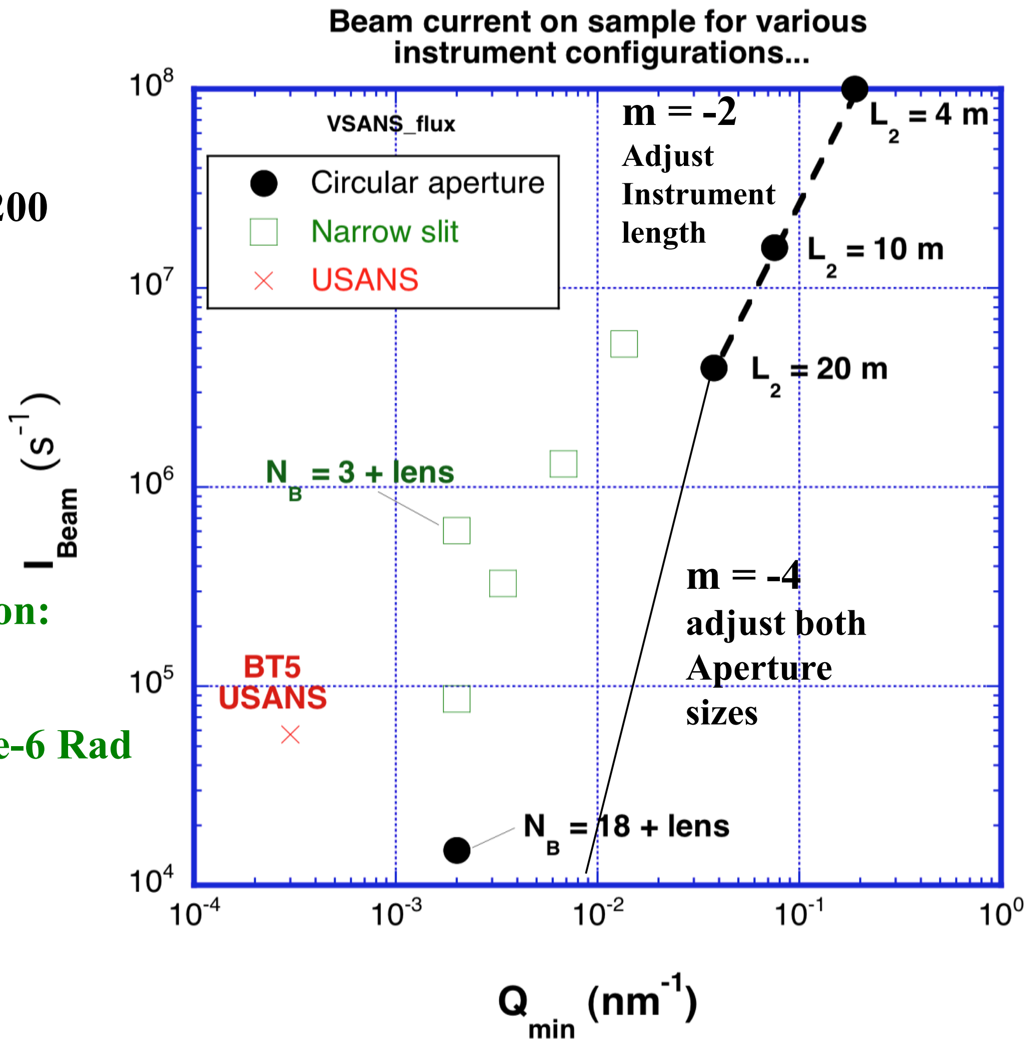
Additional gain → 5

Detector Solid Angle Comparison:

2D high res Detector vs USANS

0.15 m/22 m=6.8e-3 Rad vs 7.6e-6 Rad

Gain → 1,000

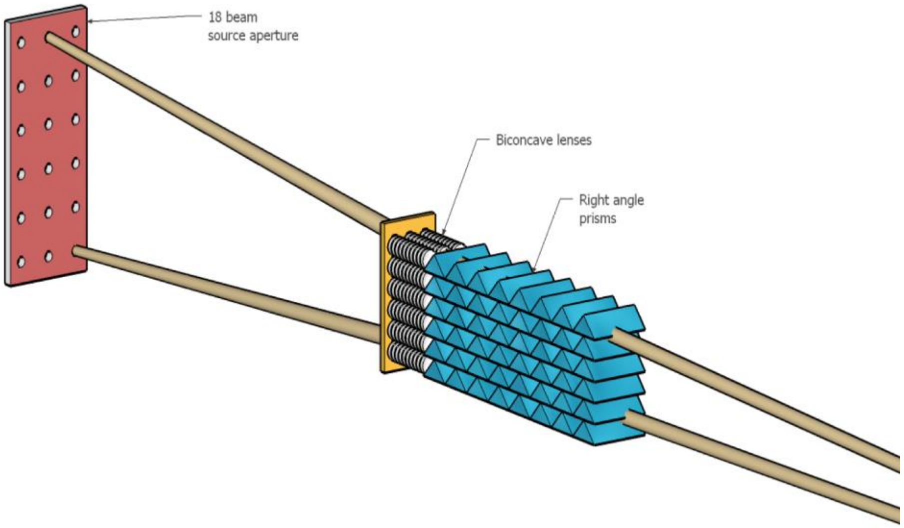


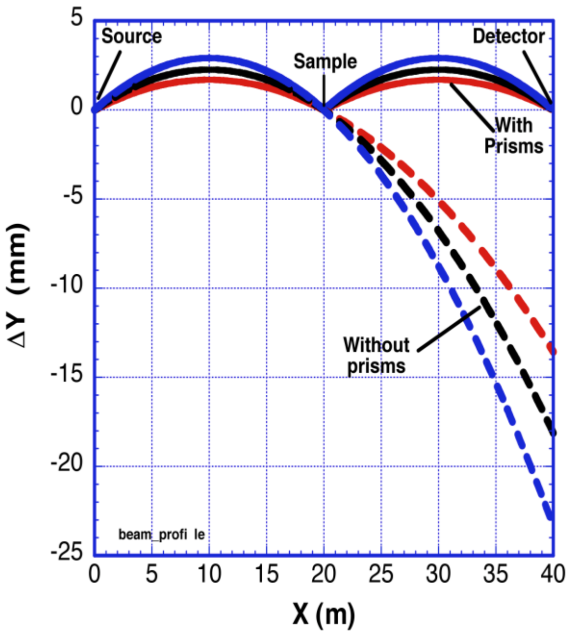
18 Converging Beams:

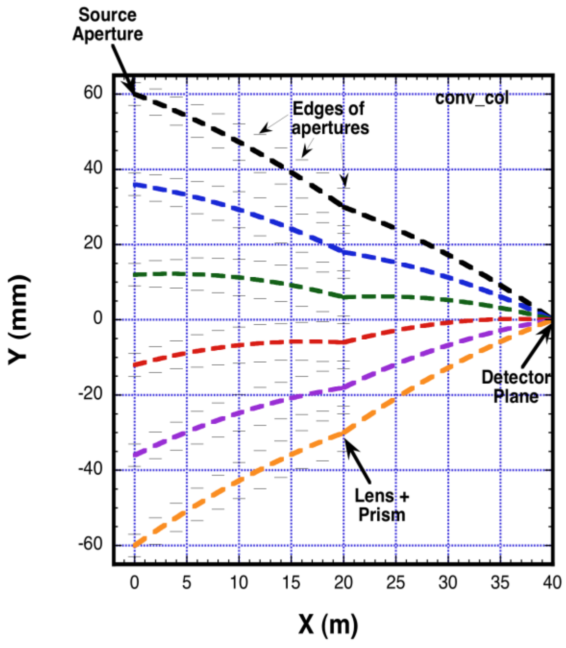
- Prisms to counter gravity
- Lenses for focusing
- Intermediate masks to stop crosstalk

Other Converging Beam Instruments:

Saclay, France + V16, Berlin, Germany

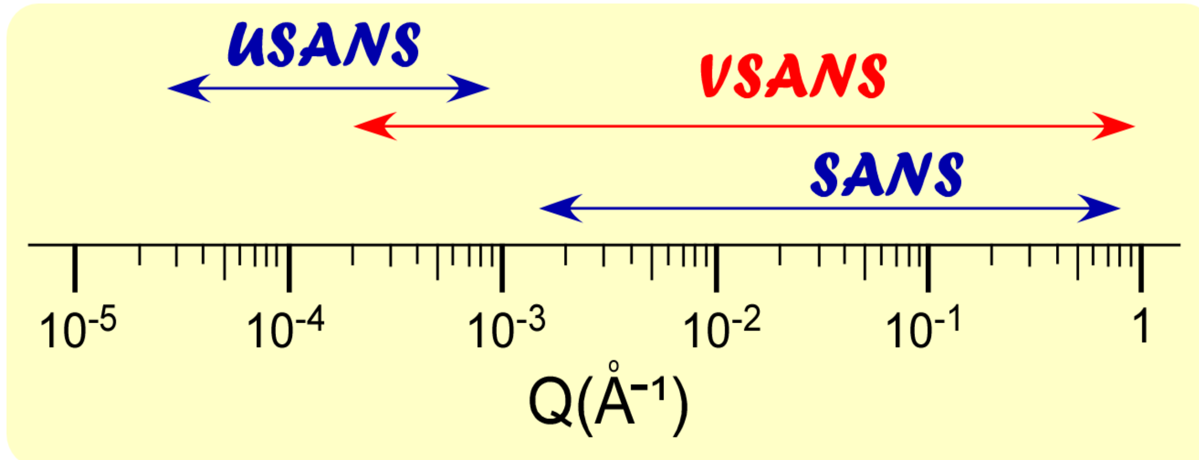






Extended Q-range: ~2e-4 to ~1 Å^{-1} in one measurement:

3 Collimation Options:
- **Narrow slit**
- **Converging Beams**
- **Large Pinhole**

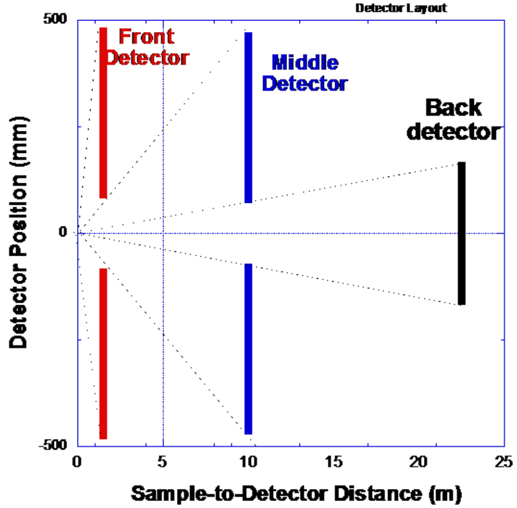


Detector Carriage	front	Middle	Back
Resolution (fwhm)	8 mm	8 mm	1 mm
Sample-to-Detector Distance	1.5 m	10 m	22.5 m
Panel Spacing	180 mm	160 mm	~

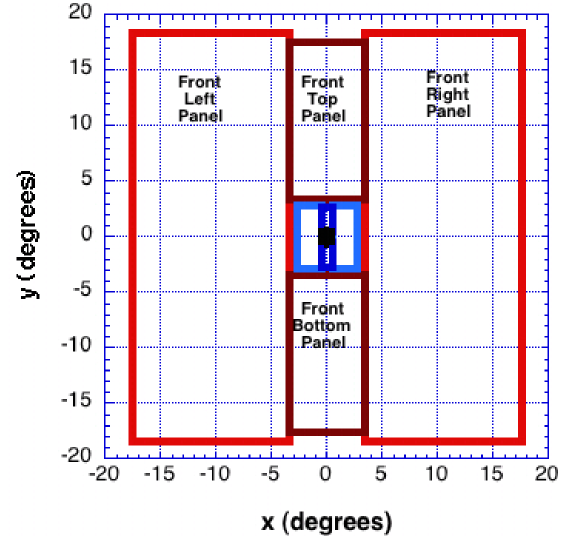
Front & Middle Carriages: 8 mm res.	Four Detector Panels Each:
Left & Right Panels	384 mm wide x 1000 mm Tall
Top & Bottom Panels	500 mm wide x 384 mm Tall
Back Carriage: 1 mm res. Anger camera	~ 150 mm wide x 450 tall mm

Collimation type	Narrow Slit	Converging Beams	Large Pinhole
Source Aperture	5 mm x 150 mm	6 mm dia,	60 mm dia.
Sample aperture	2.5 mm x 75 mm	35 mm x 72 mm	30 mm dia.
		{10 mm dia. Each}	
Beam stop	10 mm x 300 mm	10 mm dia.	120 mm dia.
Sample-to-detector	22.5 m	22.5 m	22.5 m
Wavelength	6 Å	7.5 Å	6 Å
Q_{min}	2.3e-4 Å^{-1}	1.9e-4 Å^{-1}	2.8e-3 Å^{-1}
Q_{max}	0.45 Å^{-1}	0.36 Å^{-1}	0.45 Å^{-1}
Beam Current	9.7e4 s^{-1}	9.0e3 s^{-1}	1.4e6 s^{-1}

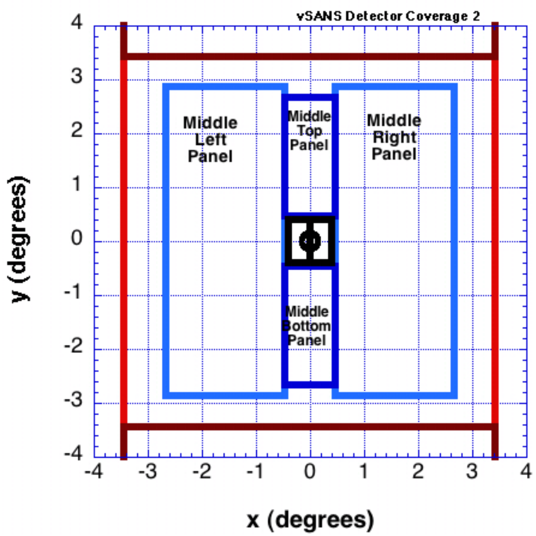
Side View



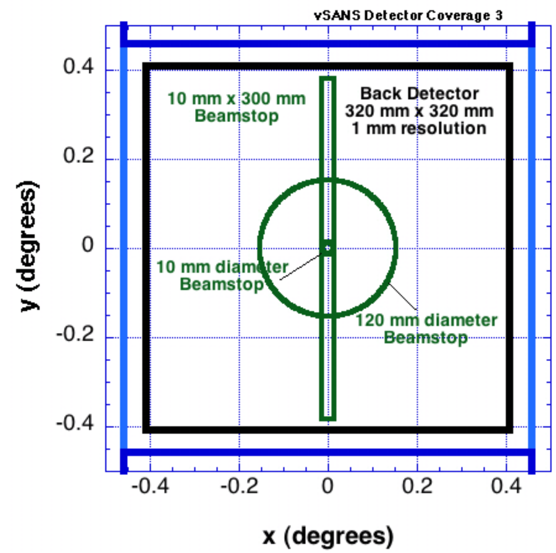
Front View



Front View at 5x



Front View at 50x

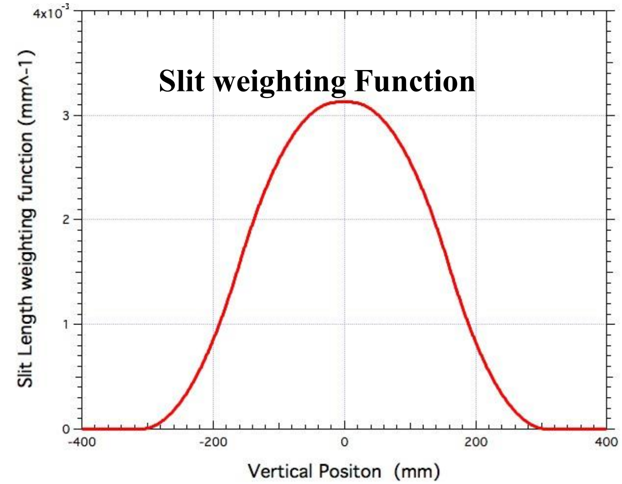


Narrow slits Option: Effect of Smearing

Source: 150 mm x 5 mm

Sample: 75 mm x 2.5 mm → triangle…

Detector: 320 mm → see graph →

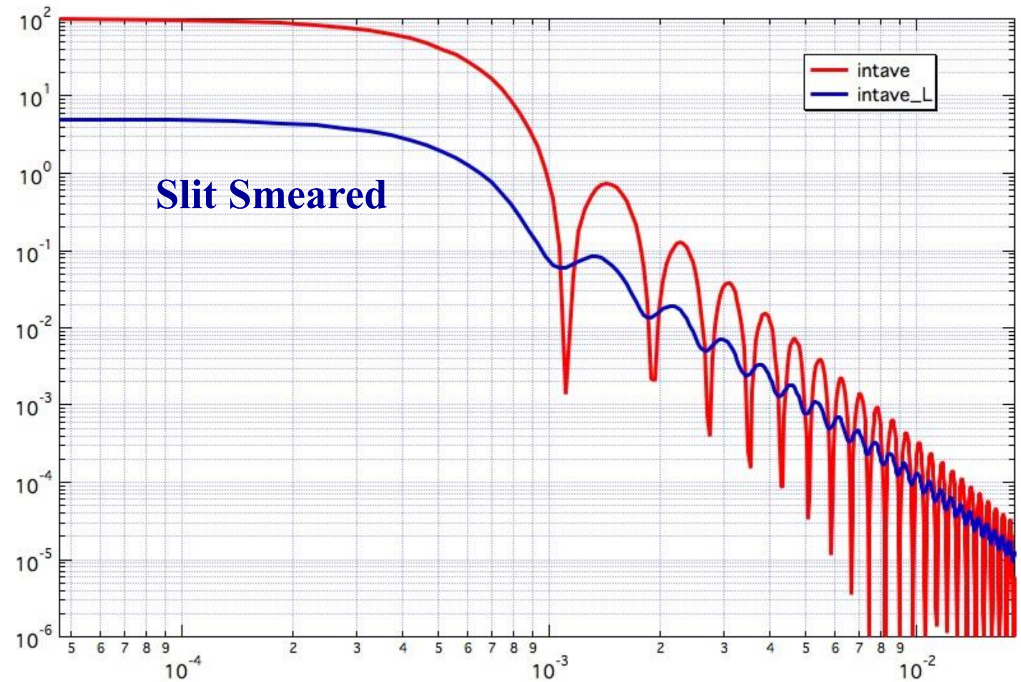


$$I_S(q) = \int P_L(u)\, I\left(\sqrt{u^2 + q^2}\right) du$$

Spherical Particles:

5,000 Å radius

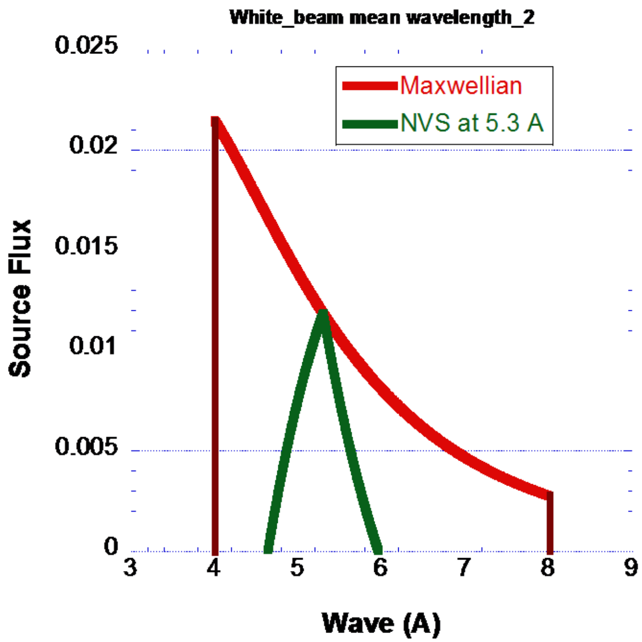
{ ignoring wavelength smearing }

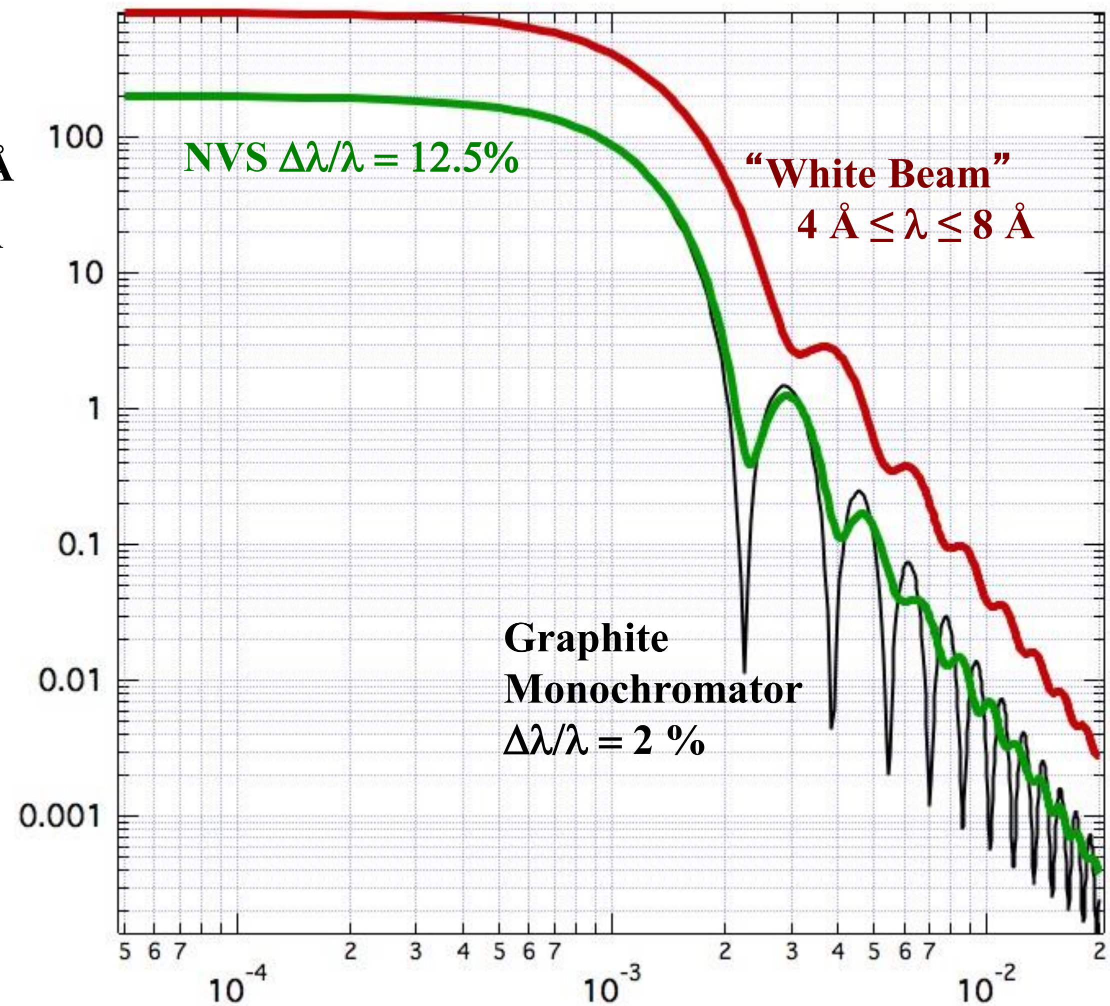


“White Beam Option”

- Beryllium filter cuts λ < 4 Å
- Cut-off Mirror cuts λ > 8 Å

Gain of factor 5 but with Additional smearing …





Options for larger liquid cells:

- Current Ti Cell → 19 mm diameter → $284\ mm^2$
- “medium” Ti-cell → 28 mm diameter → $616\ mm^2$

(1.25” window, 2 mm and 5 mm cells on order)

- Helma cell 404 → 18.5 mm x 38 mm → $703\ mm^2$
- Large Ti cell → 40 mm diameter → $1260\ mm^2$
- Custom quartz Cell → 35 mm x 72 mm → $2500\ mm^2$

Hellma – Precision in SpectroOptics Worldwide – Küvetten für Fluoreszenzmessungen 1/6/11 5:10 PM

Order Number	120-000-1-40
Type	120-QS
Material Color Code:	QS
Light Path:	1 mm
Volume:	280 µl
Outer Dimensions:	
Height:	
Width:	
Depth:	3,5 mm
Inner Dimensions:	
Width:	
Base Thickness:	
Number of windows:	2

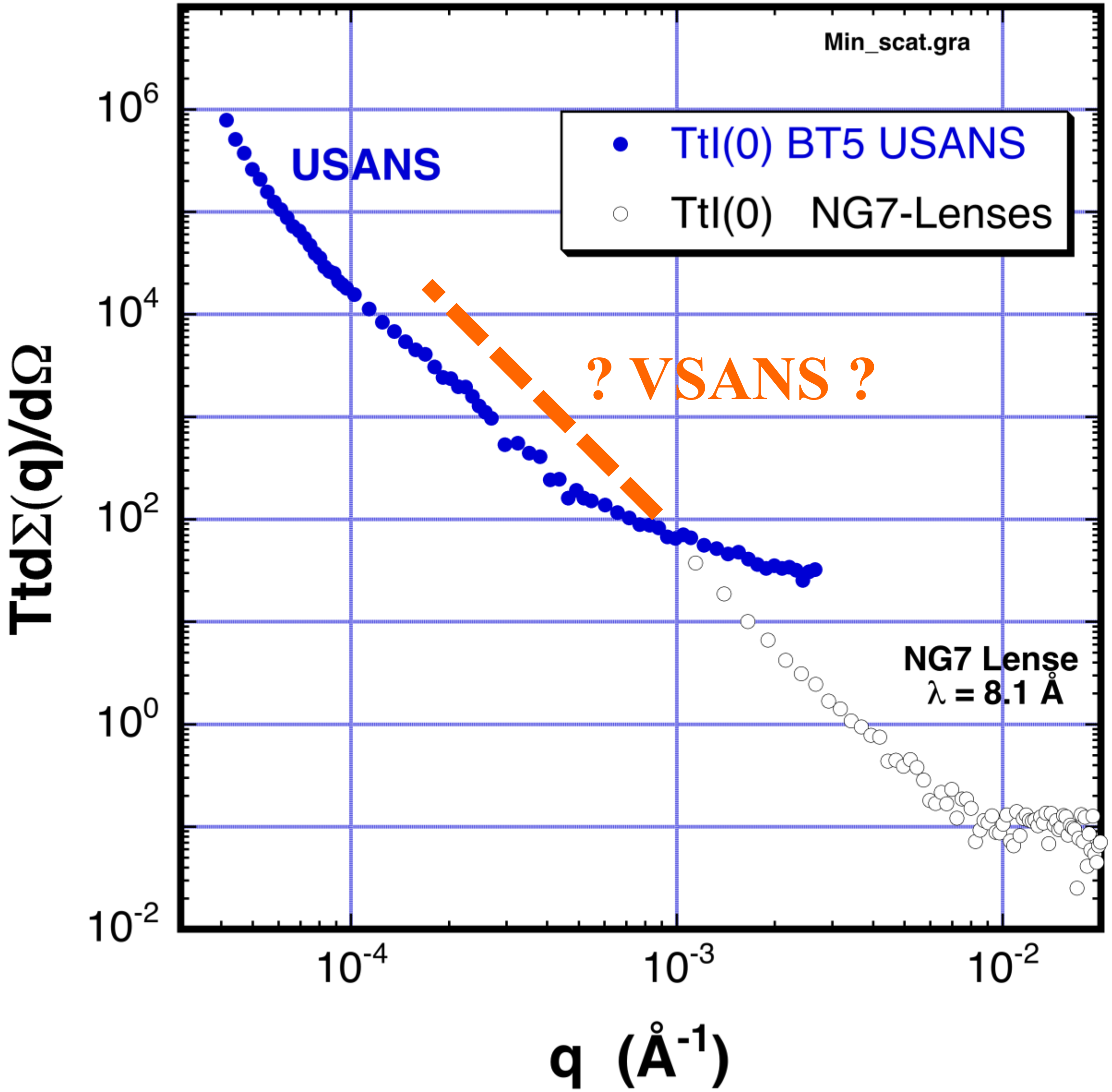
Print

Hellma – Precision in SpectroOptics Worldwide – Küvetten für Fluoreszenzmessungen 1/6/11 5:01 PM

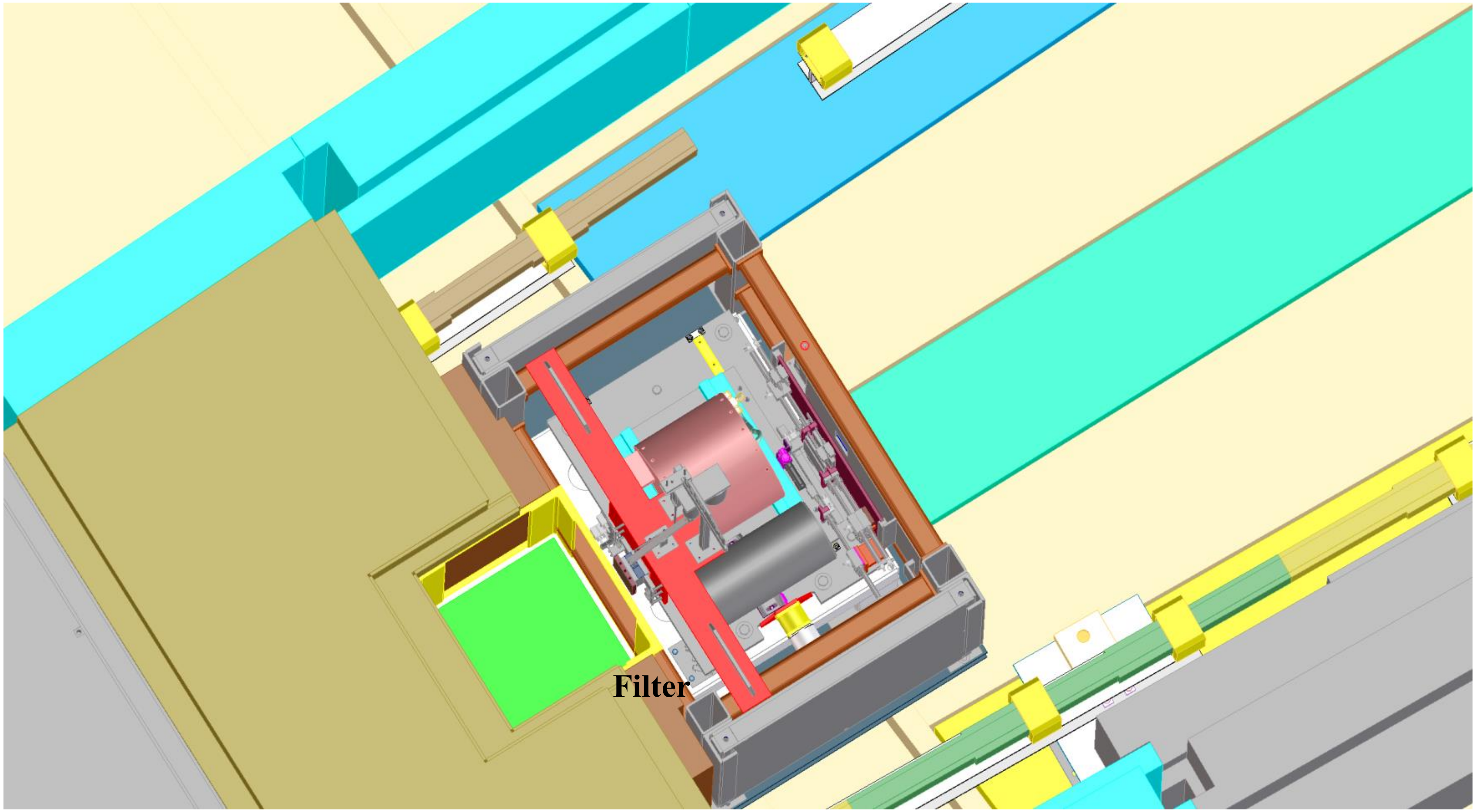
Order Number	404-1-46
Type	404.000-QX
Material Color Code:	QX
Light Path:	1 mm
Volume:	700 µl
Outer Dimensions:	
Height:	47,5 mm
Width:	23,6 mm
Depth:	3,5 mm
Inner Dimensions:	
Width:	18,5 mm
Base Thickness:	2,5 mm
Number of windows:	2

Print

Signal-to-Noise for VSANS Collimation:
How will it compare to USANS and Pinhole w Lens ??

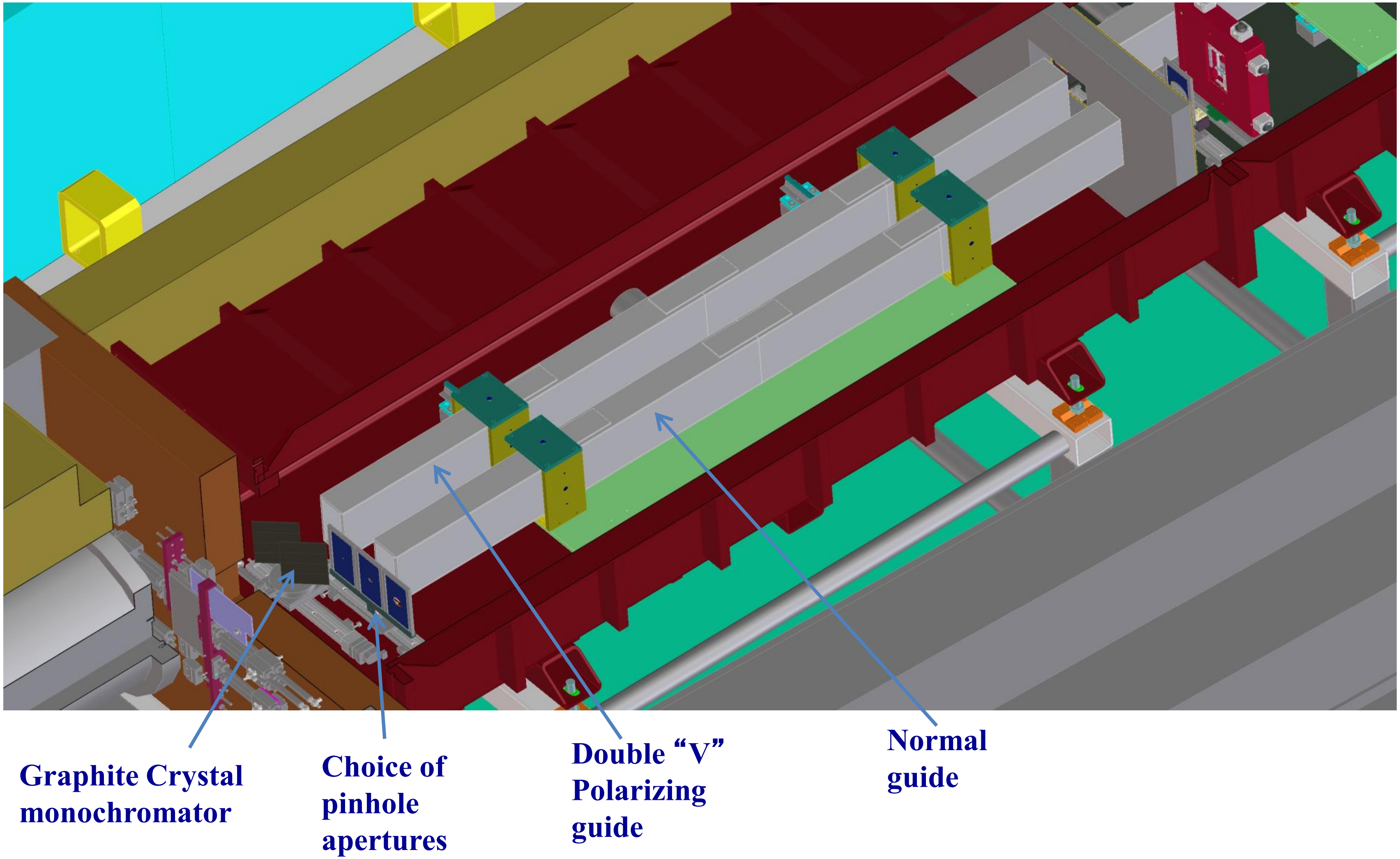


Filter + Velocity Selector Bunker
{ Installed, Nov 2014, Deflector in spring }

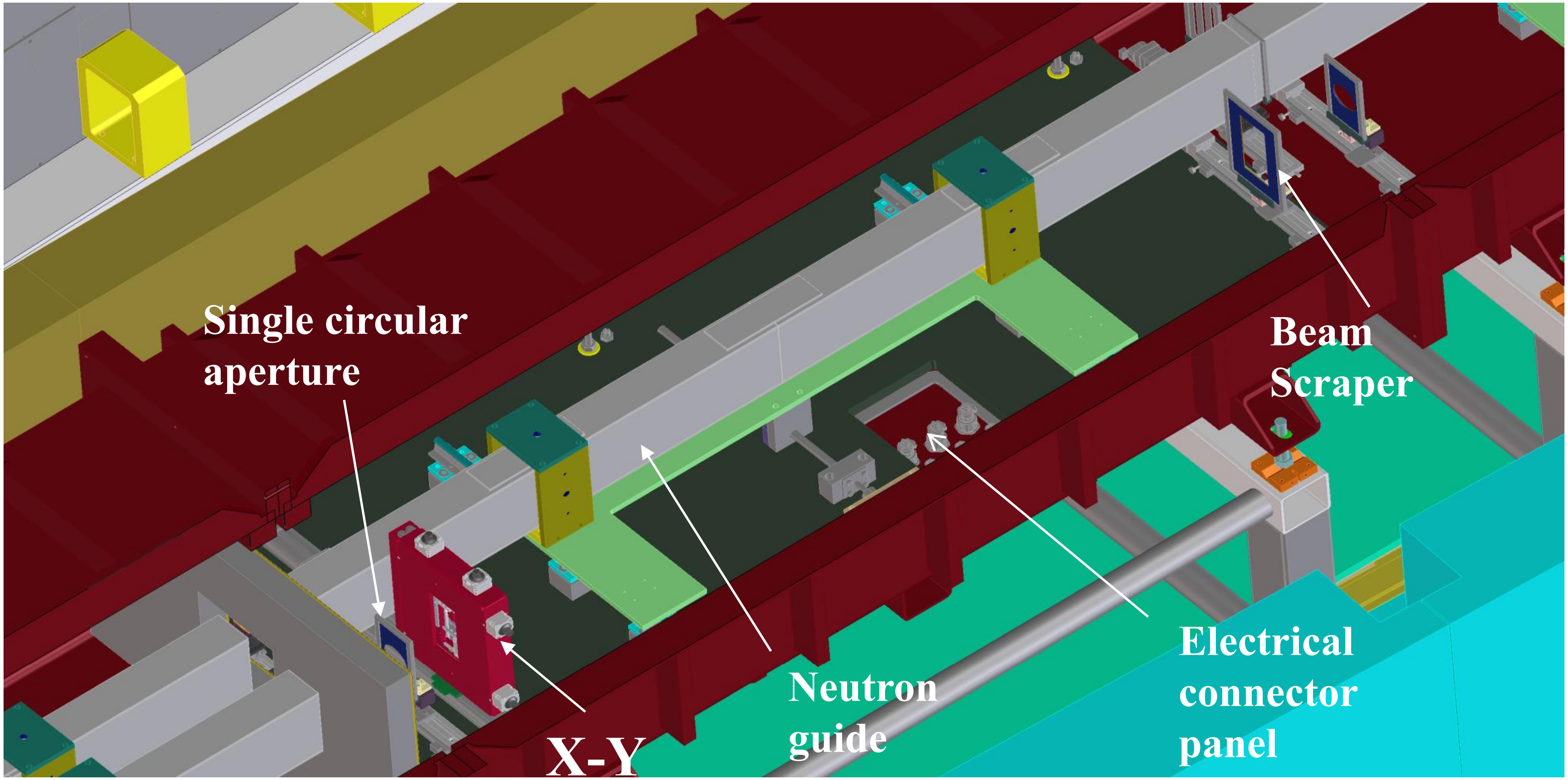


Cutaway view of first section of pre-sample vessel

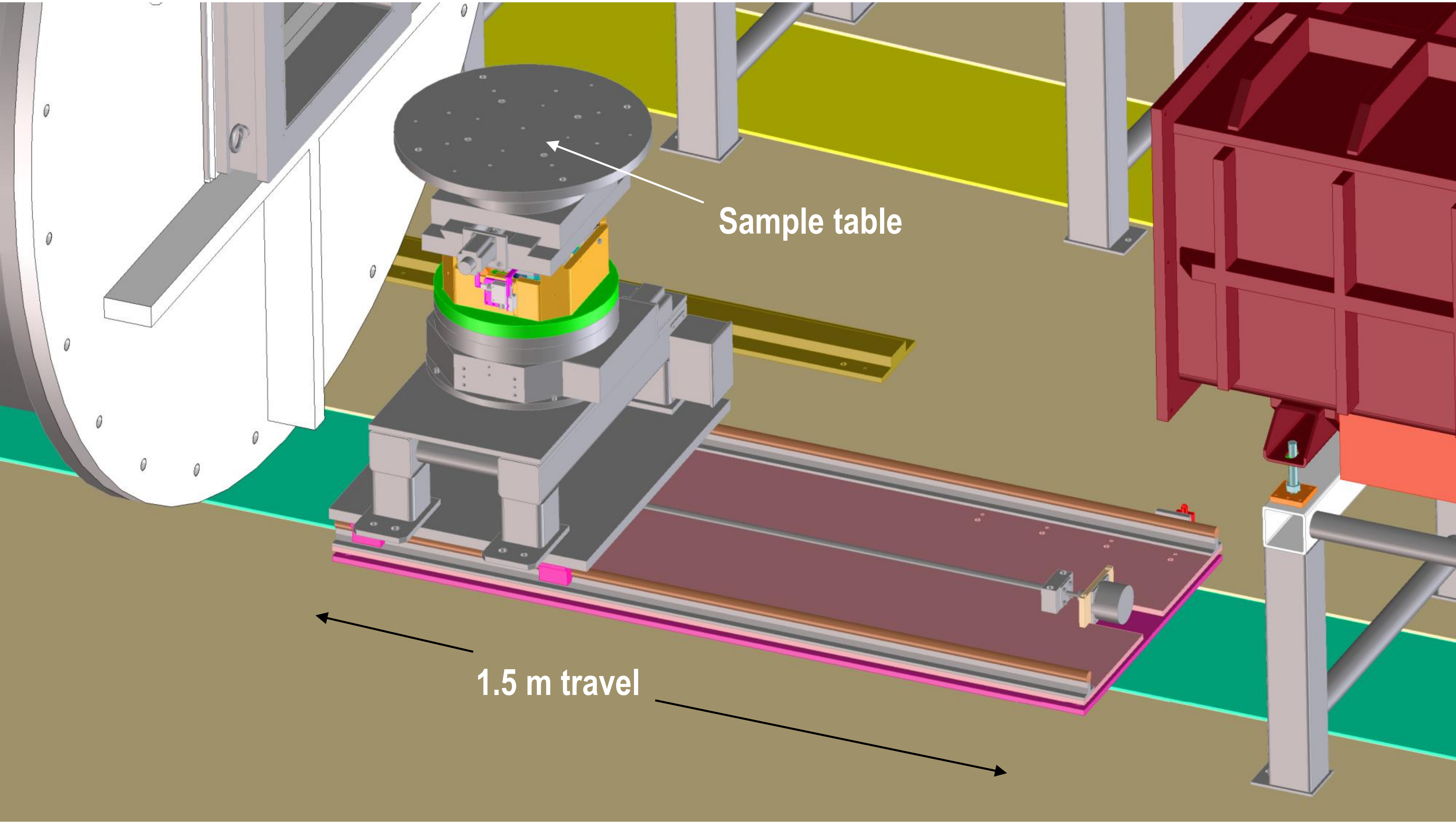
- All motion control devices are inside vacuum enclosure-



Cutaway view inside a typical 2-m long section of the VSANS pre-sample vacuum vessel



New vSANS sample Area→ No Sample Chamber



New Capabilities summary:

- Factor of four smaller q → higher resolution (1 mm) detector
- Higher beam current:
  - Converging beams → larger sample size (35 mm x 72 mm)
  - Narrow slits → additional smearing
  - "White" beam → additional smearing
- Extend q-range → three independent detector carriages → $q_{max}/q_{min} = 2{,}000$
- Larger sample area → 2 m
- Other Automated Optics:
  - Graphite monochromator $\Delta\lambda/\lambda = 2\%$
  - Double V polarizer $P > 99\%$ (w RF flipper + ^3He analyzer)

Predictions:

- Many experiments that have weak scattering or small samples will opt for Narrow slits / White beam to increase count rate.
- Signal to noise will not improve…