Neutron Detector Systems For The Spallation Neutron Source

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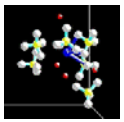
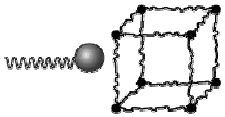
July 2003

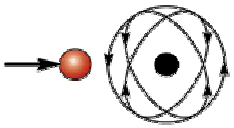
Neutron Scattering



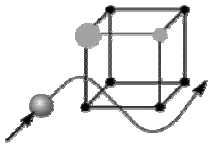
1. Neutrons have the right wavelength



2. Neutrons measure the Velocity of Atoms



3. Neutrons see the Nuclei

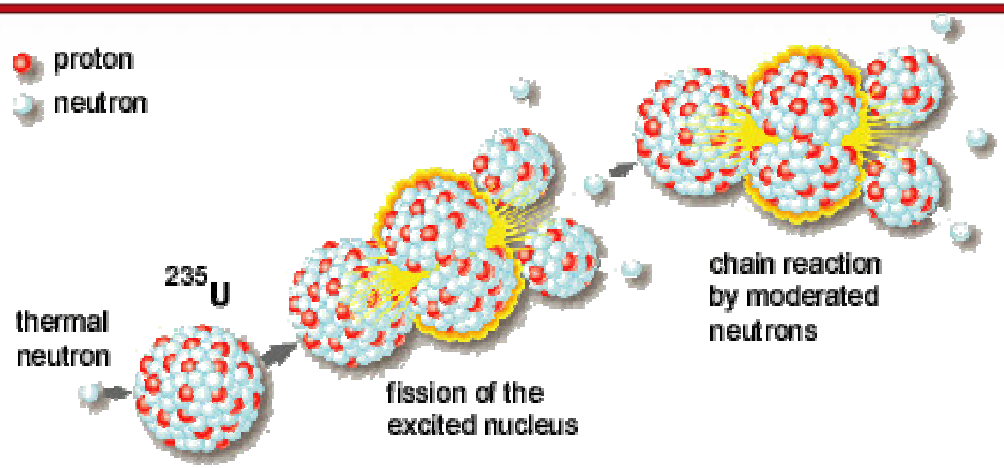


4. Neutrons see light Atoms next to Heavy Ones

5. Neutrons penetrate deep into Matter

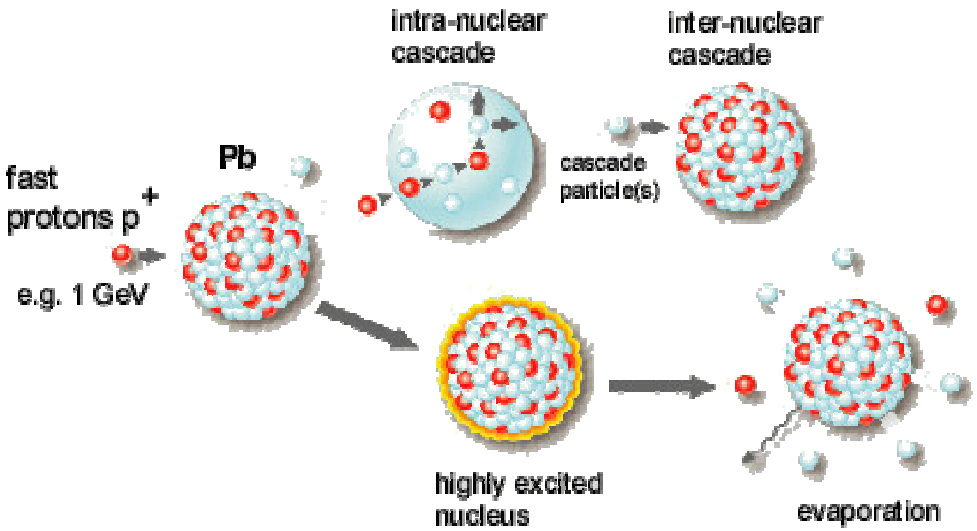
6. Neutrons see Elementary Magnets

How do we produce neutrons?



Fission

- chain reaction
- continuous flow
- 1 neutron/fission
- 180 MeV/neutron



Spallation

- no chain reaction
- pulsed operation
- 40 neutrons/proton
- 30 MeV/neutron

SNS


Front-End Building
Klystron Building
Central Helium Liquefaction Building
Linac Tunnel
Ring
Radio-Frequency Facility
Target
Future Target Building
Support Buildings
Central Laboratory and Office Complex
Center for Nanophase Materials Sciences
Joint Institute for Neutron Sciences
01-04517/arb

Site Photograph 4-03

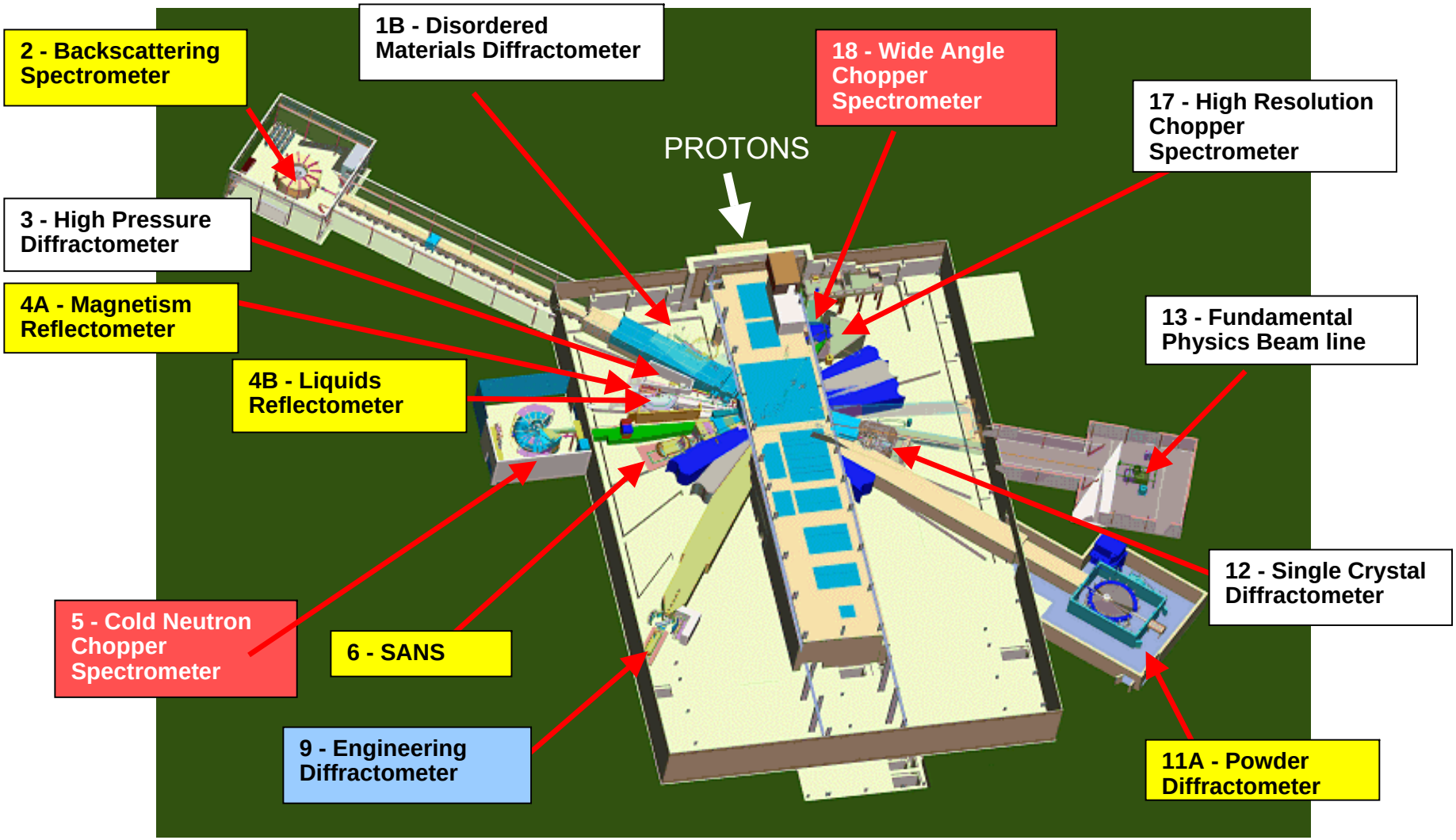
July, 2003

Central Lab 5-03

Target Building 5-03

Shielding Components

SNS Instrument Layout



Neutron Detection

- Detect daughter products from neutron capture
  - $^{3}He(n,p)t$
  - $^{6}Li(n,\alpha)t$
  - $^{10}B(n,\alpha)^{7}Li$
  - $^{157}Gd(n,gamma)^{158}Gd$
- No zero crossing signal for gating
  - Gate widths are ms
  - Timing accuracy is ~μs
  - Protons on target provides neutron energy
- High pixel rates from Bragg peaks
- No track fitting
- No high level triggers
  - Every neutron is sacred

General Detector Comments

Comments

- Due to high rates almost every instrument needs detector R&D
- A great deal of good science awaits new detectors
- “A program for neutron detector research and development”
- http://www.sns.gov/documentation/Neutron_Detector_White_Paper_March_03.pdf
- Upgrades will be necessary
- Purchase systems when possible

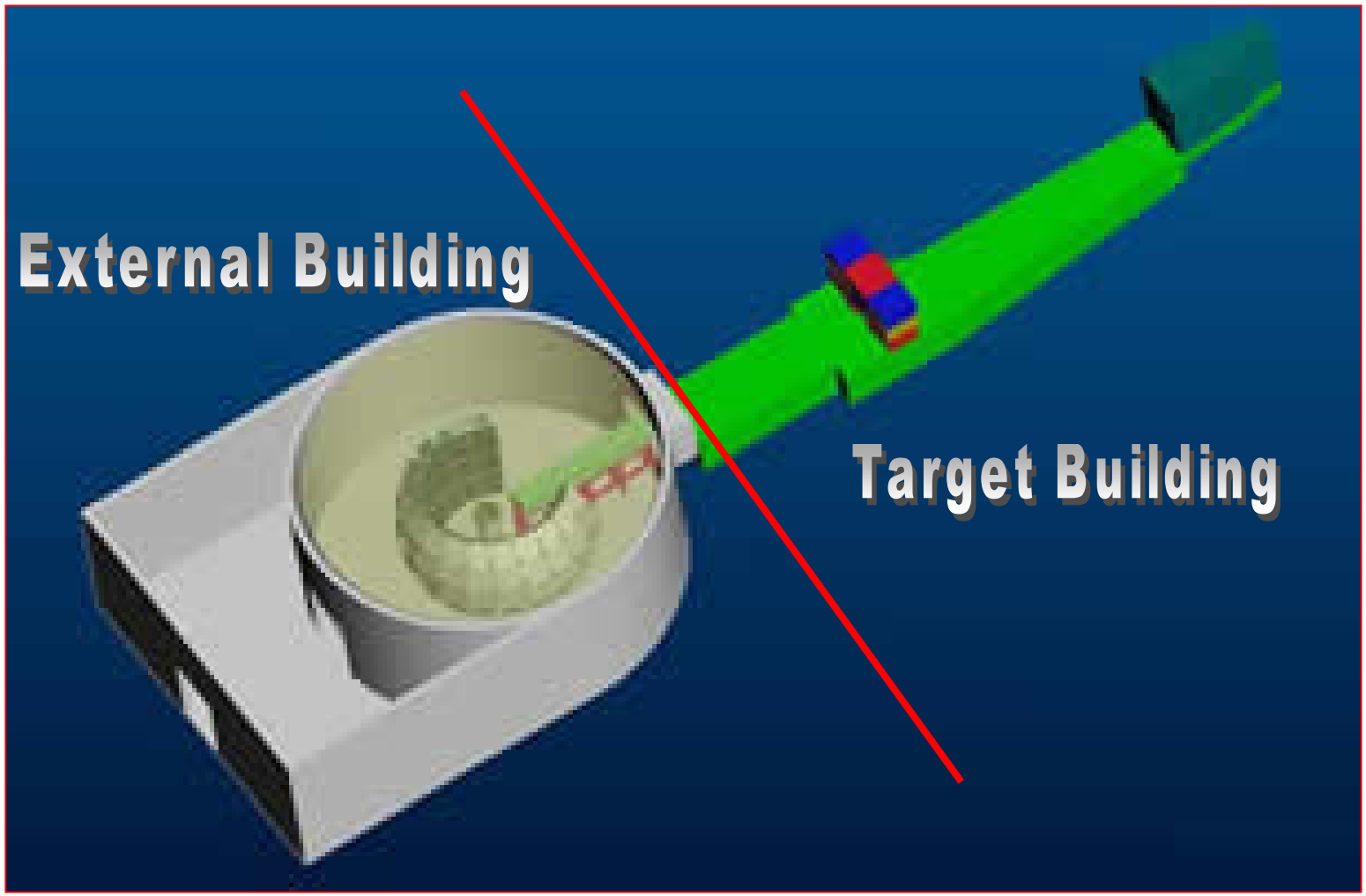
Requirements

- Time resolved data
- Save position and time of each neutron event
- PC based, crateless architecture
- Optical communication
- Enforce compatibility requirements

Inelastic Instruments

- Measure energy transfer
- Seven of first 16 instruments
  - Large area detector coverage 1 – 60 m^2
  - Large pixels ~ cm^2
  - Gamma rejection is very important
  - Long term stability
  - 50% efficiency for 1 eV neutrons
  - Detectors in vacuum or inert atmospheres

CNCS Spectrometer



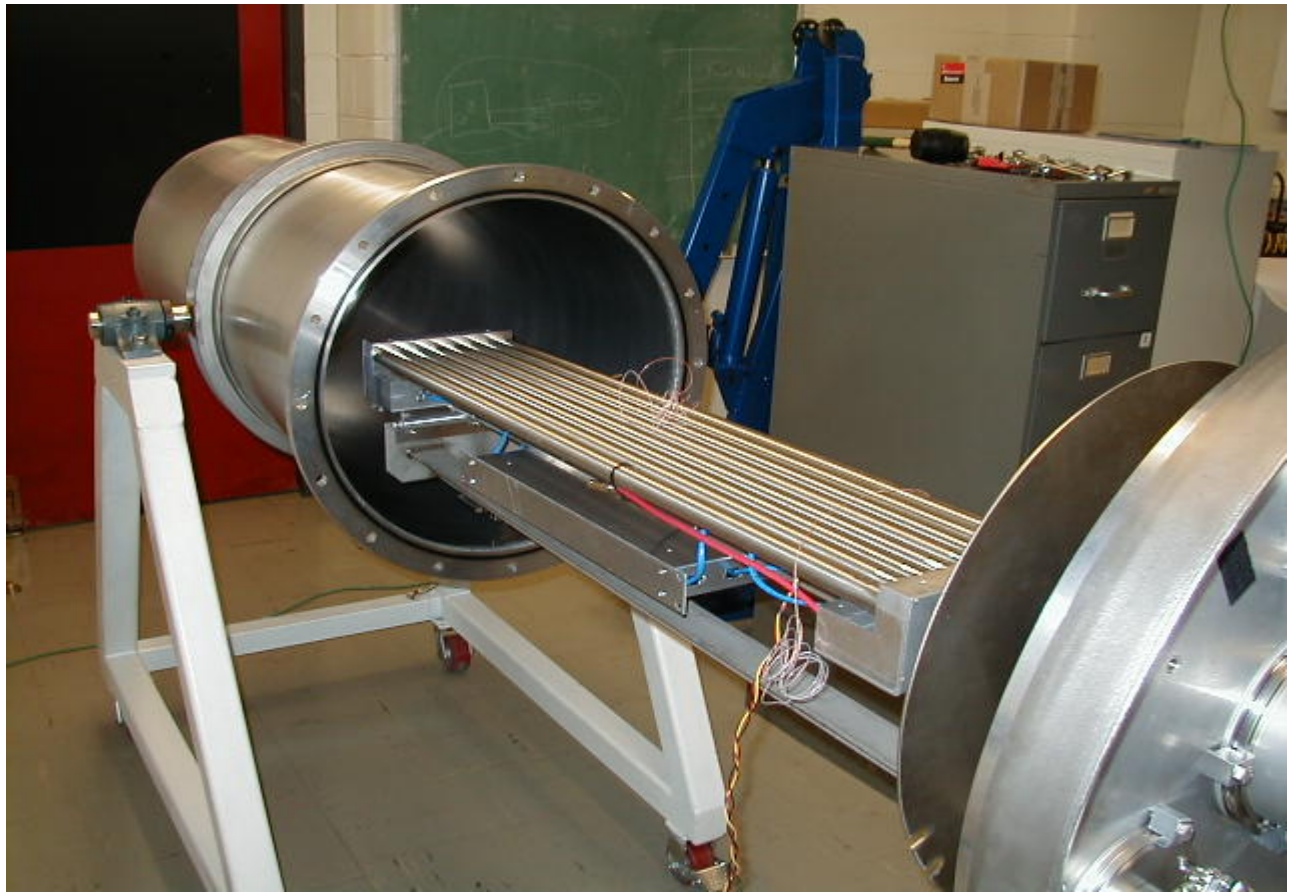
Detectors for Inelastic Instruments

- Linear position sensitive proportional counters (Reuter/Stokes)
- 10 Atmospheres of ^{3}He + quench gas
- 1m x 2.5cm tubes
- Low gas gain ~100
- Bragg peaks saturate tubes
- Good data comes in very slowly

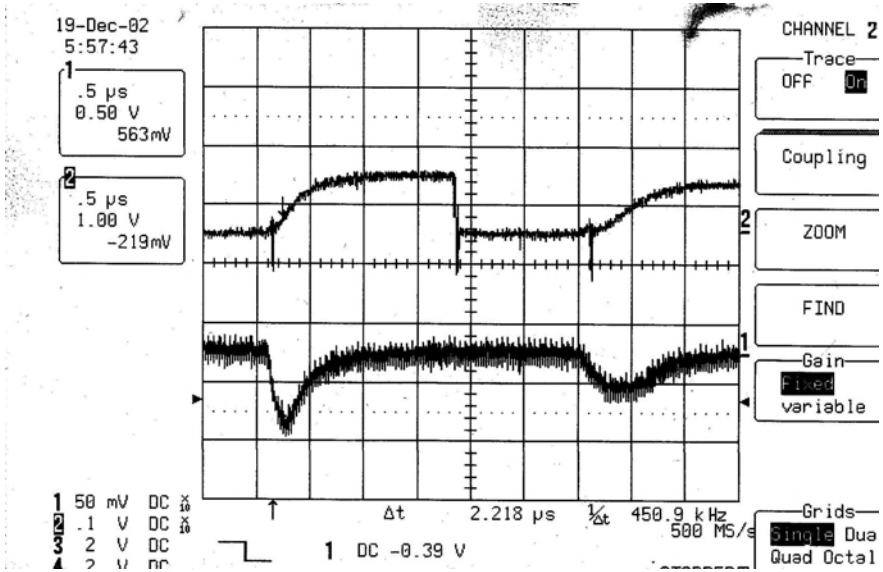
- Suggestions for alternatives that won't saturate?

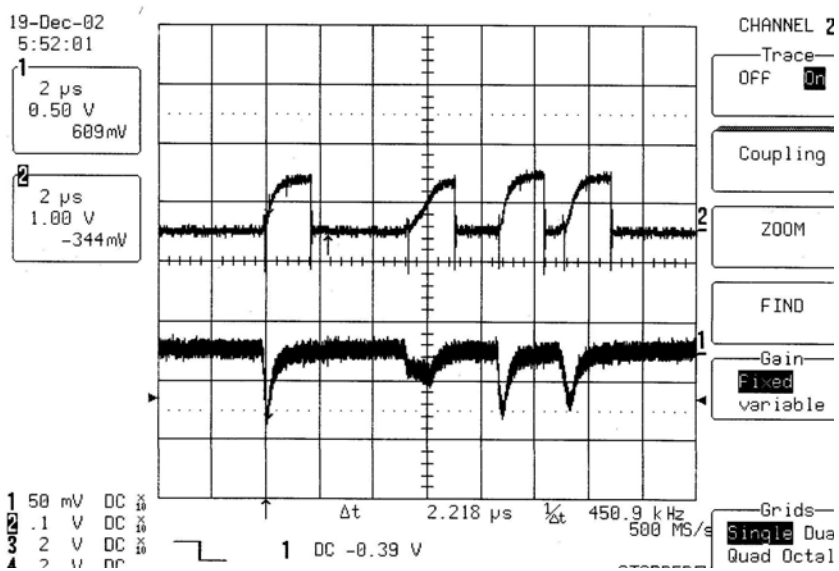
LPSDs

Eight pack vacuum test



LPSD Electronics

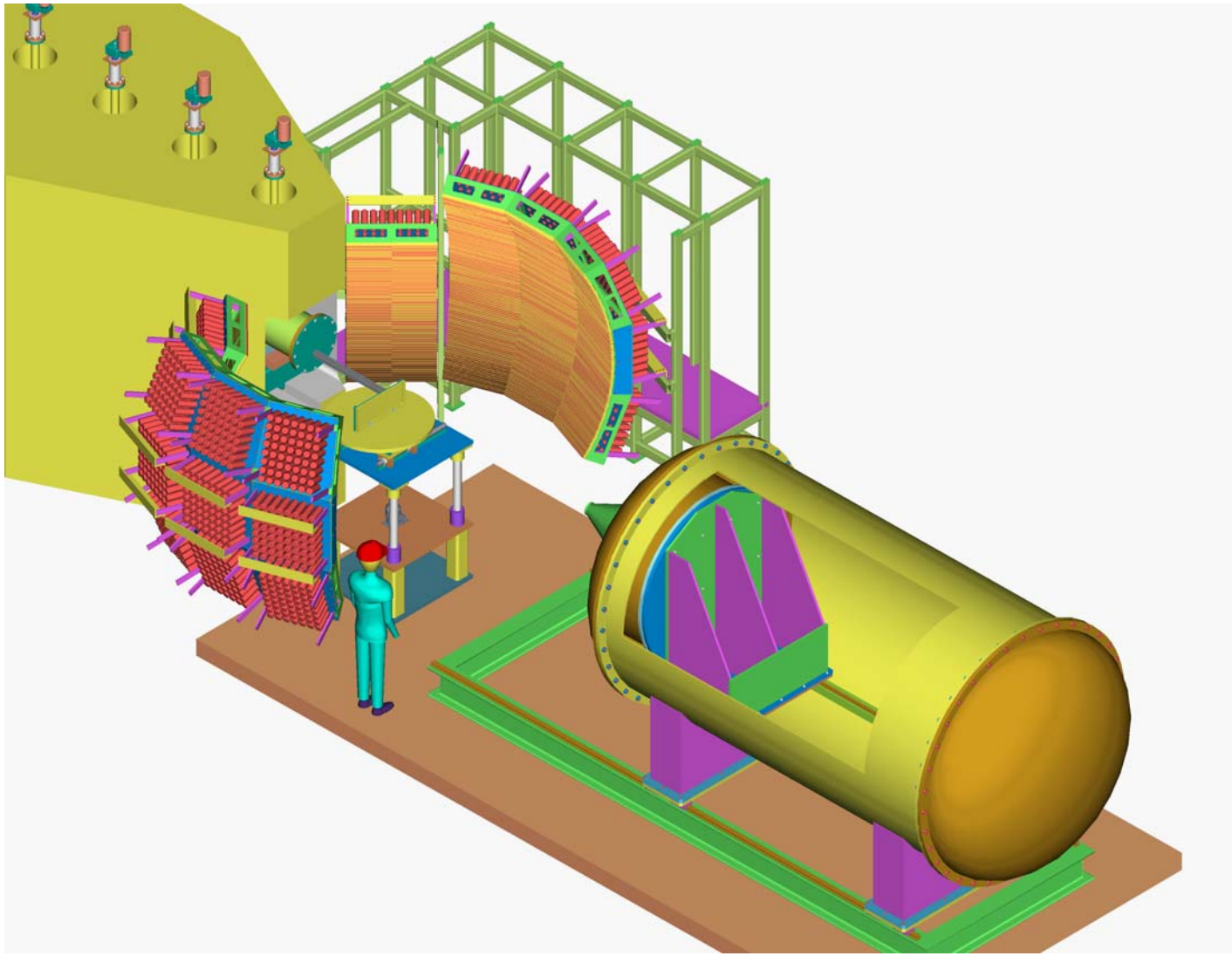




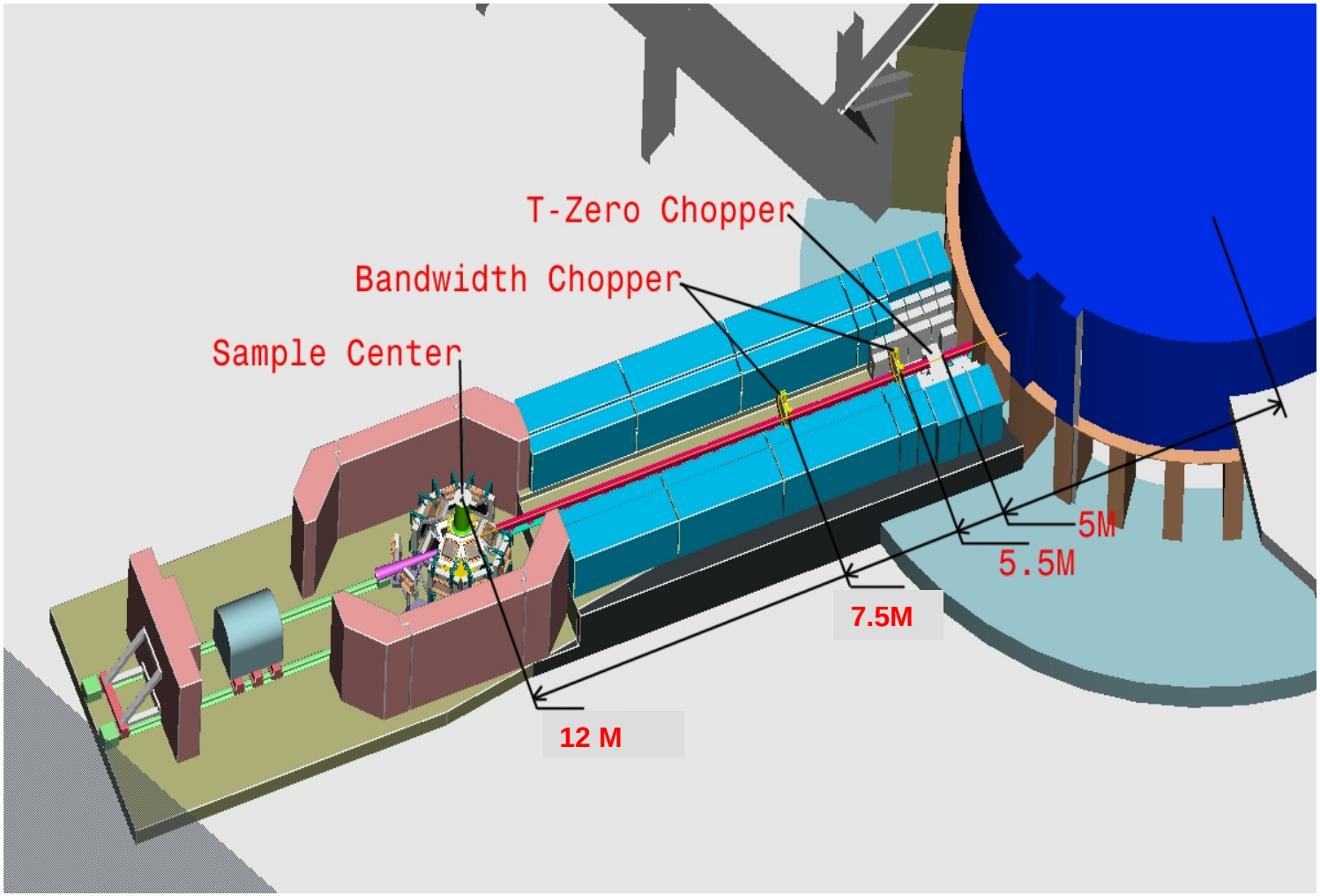
Diffractometers

- Measure structure of materials
  - Crystals, powders, glasses
- 5 of the first 16 instruments
  - Area coverage from 5 to 15 m^2
  - Position resolution from 1 mm^2 to > 2cm^2
  - Detect neutrons up to 50 eV

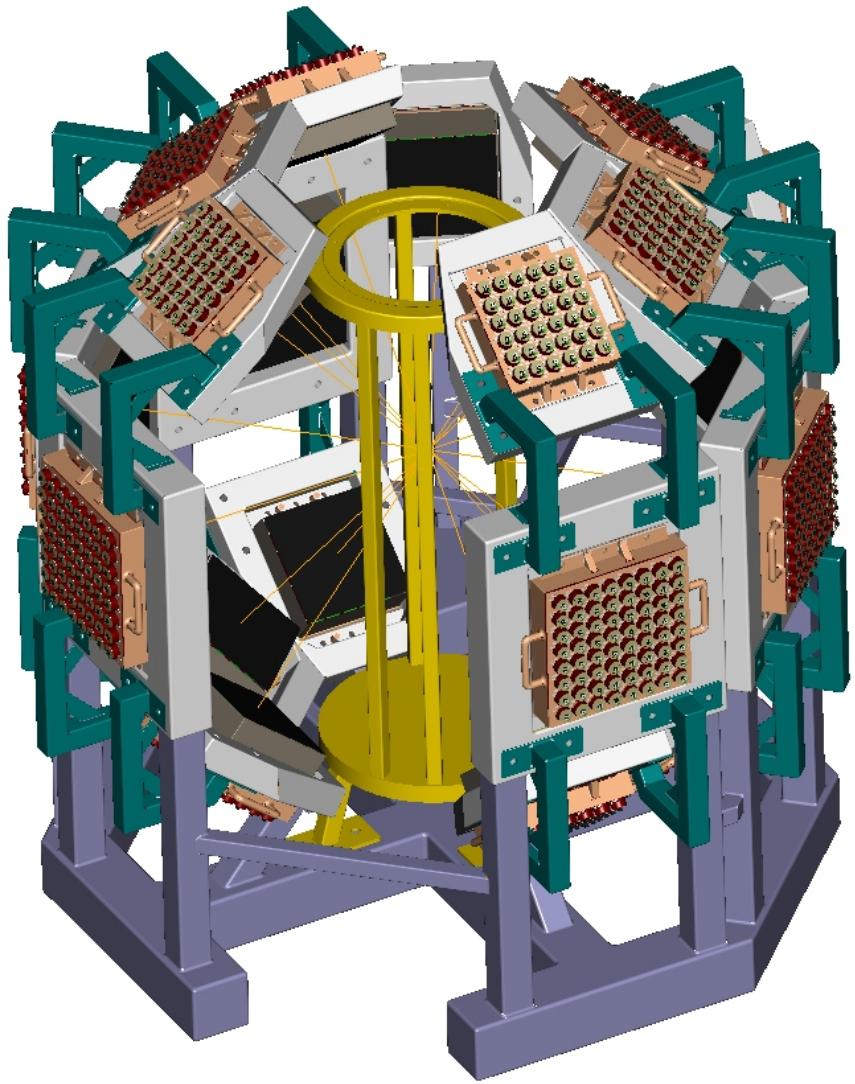
Engineering Instrument (Vulcan)



Single Crystal Diffractometer (SCD)



SCD Detectors



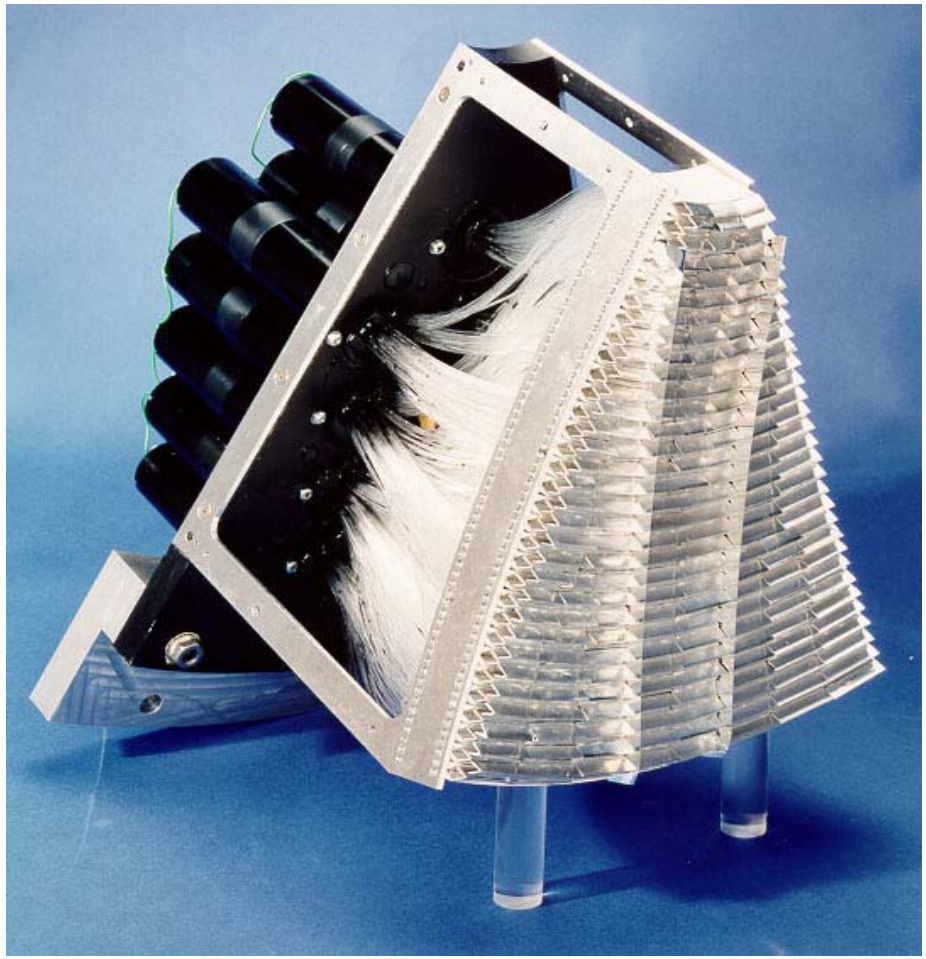
Detectors for Diffractometers

- Scintillators with fiber optic readout schemes
  - Head on fibers (ISIS)
  - Wavelength shifting fibers (SNS)
  - Multi-tube coincidences
  - Pulse shape gamma rejection

- Need new scintillator

GEM at ISIS

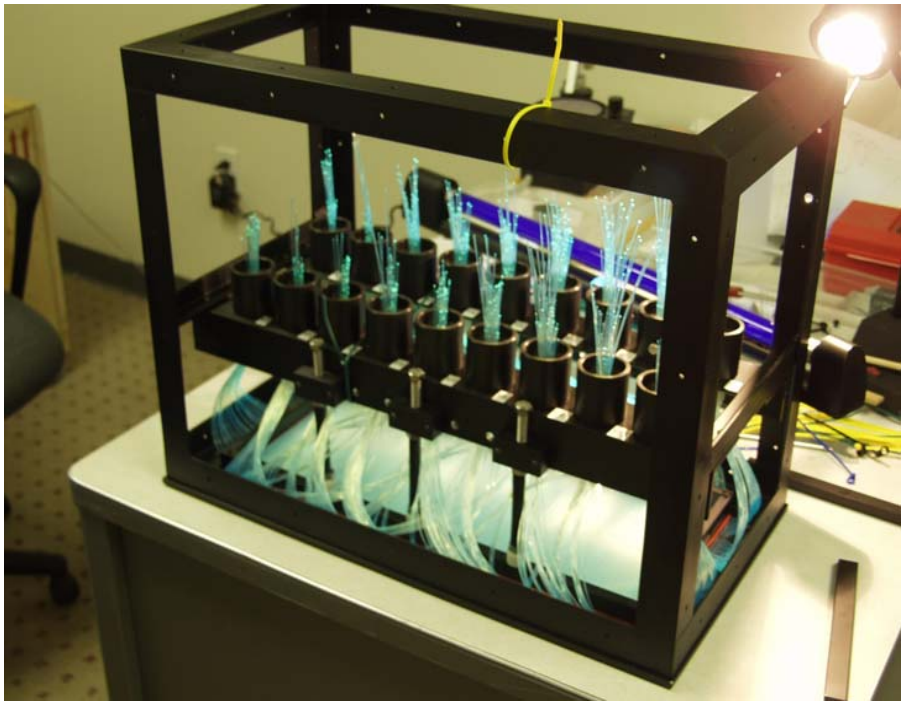
Diffractometer Detectors

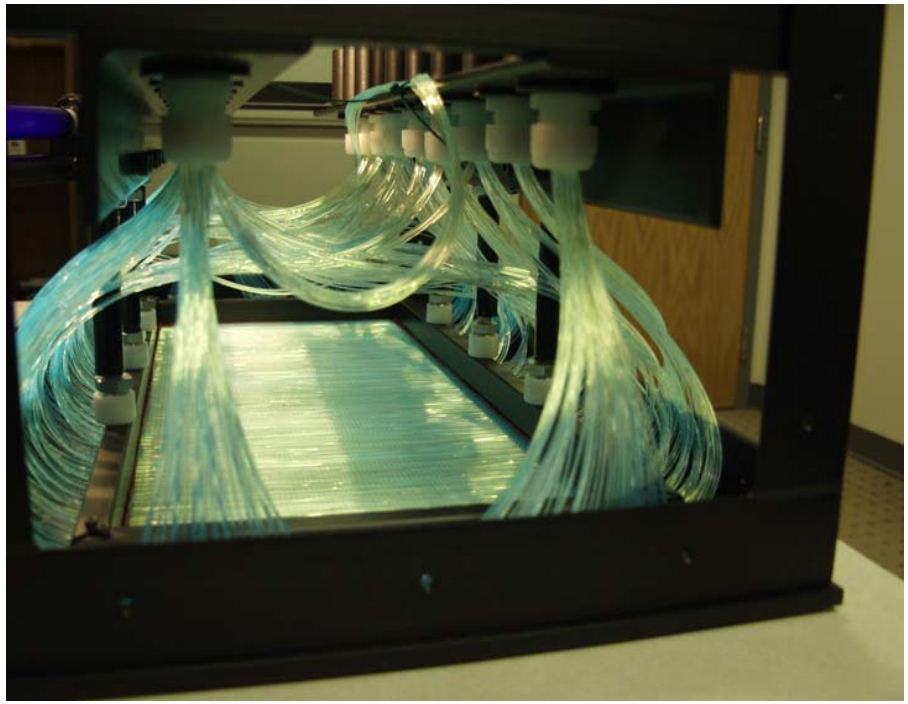


Detector unit for the GEM instrument at ISIS

Diffractometer Detectors

- Wavelength shifting fiber readout

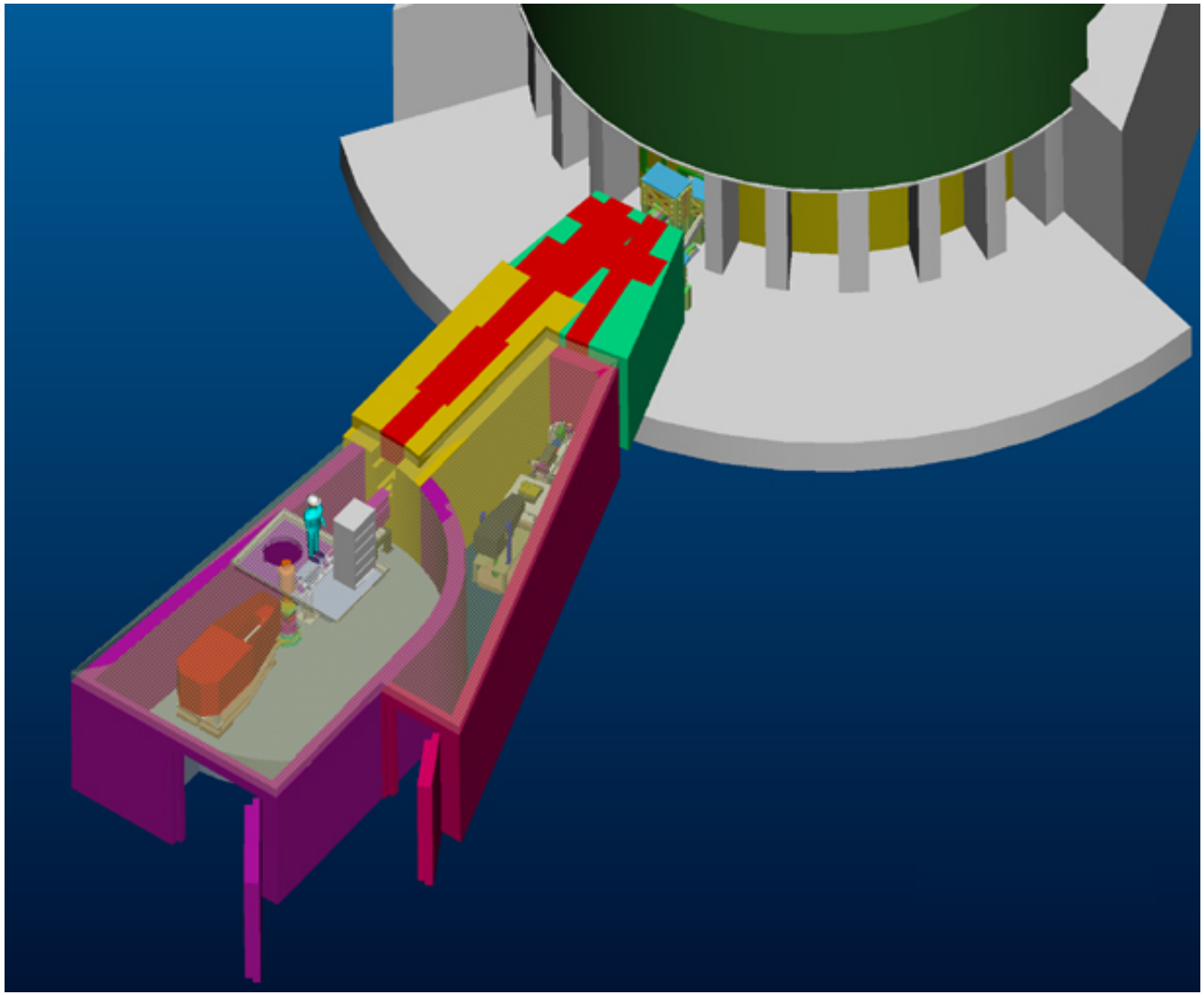




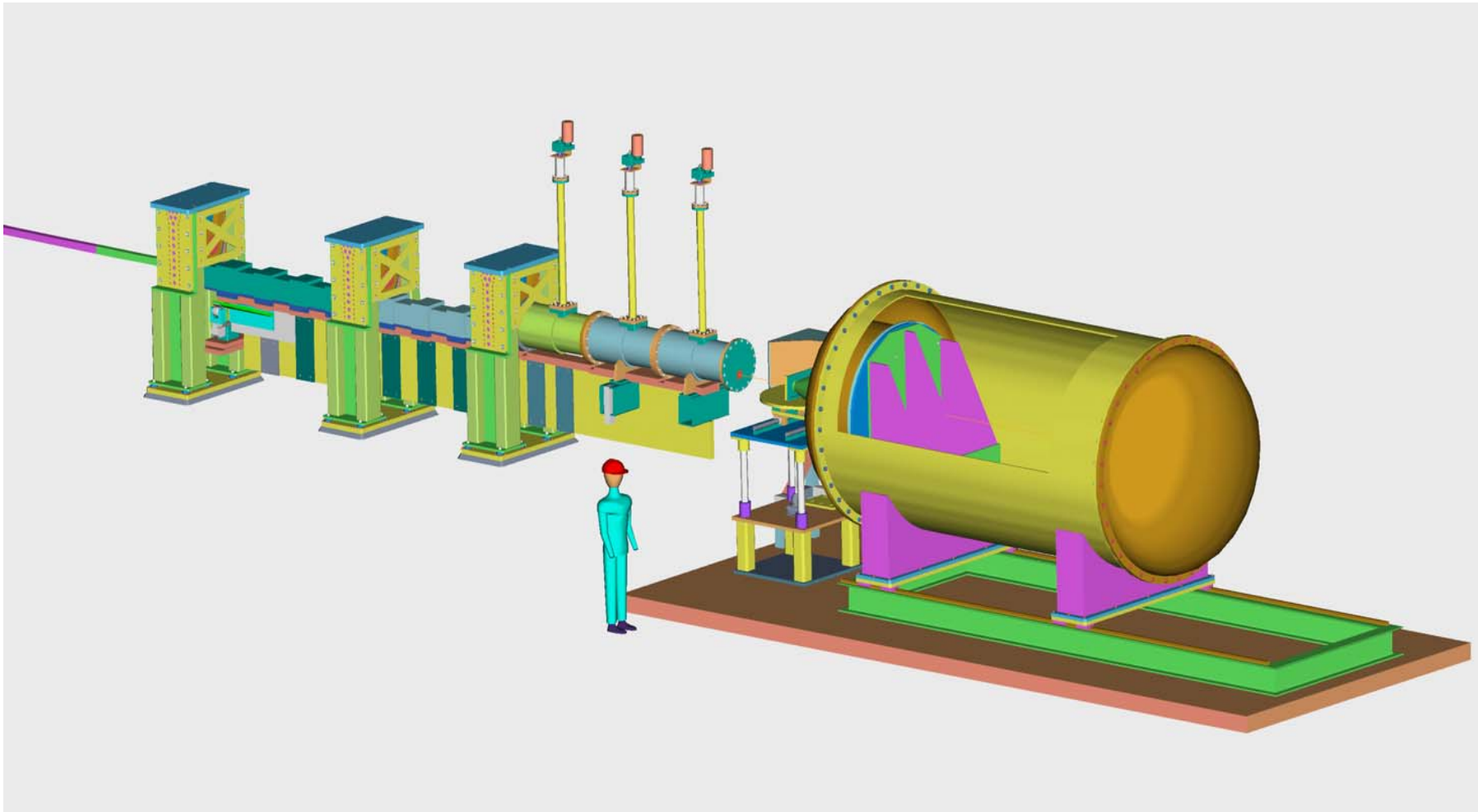
Small Angle Scattering and Reflectometer Instruments

- Measure biological materials and surface phenomenon on liquids and magnetic materials
- 3 of the first 16 instruments
  - Detector area ranges from $4cm^2$ to $1m^2$
  - Position resolution ranges from 0.1mm x 0.1mm to
  - 5mm x 5mm
  - Rate is 5×10^7 n/s for the detector
    - 2 orders of magnitude higher than is possible today
  - High magnetic fields
  - Very low gamma sensitivity

Liquids & Magnetism Reflectometers



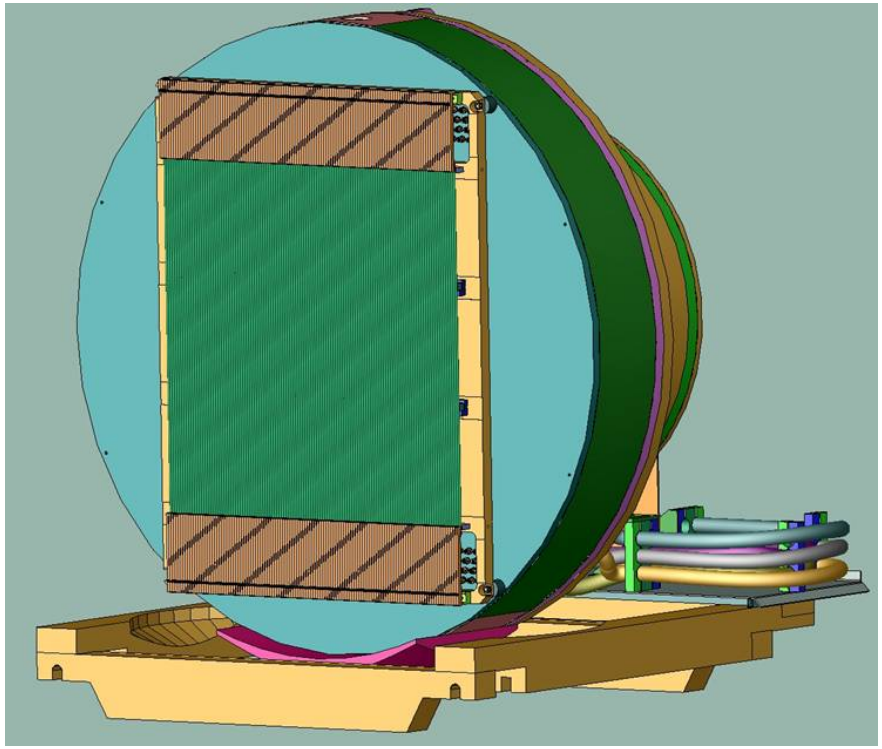
Extended-Q SANS

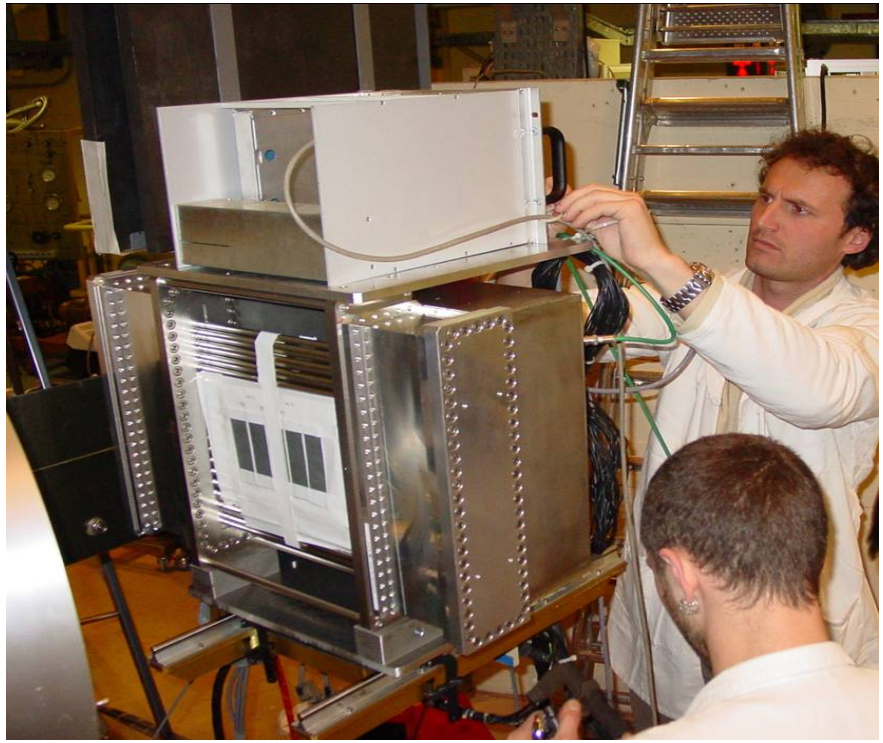


Detectors

- ^{3}He filled 2-D Position sensitive detectors (Several suppliers)
  - Only good to 5 x 10^{5} n/s
- Multiple tube arrays (ILL)
  - Only good to 5 x 10^{6} n/s
- Pixel readout ionization chambers (BNL/ORNL)
  - 40,000 pixels per detector
  - Need ASICs
  - Electronics in chamber
  - Heat transfer and gas purity are issues
- Semiconductor detectors with conversion foils for 0.1-mm resolution

ILL Multitube Detector

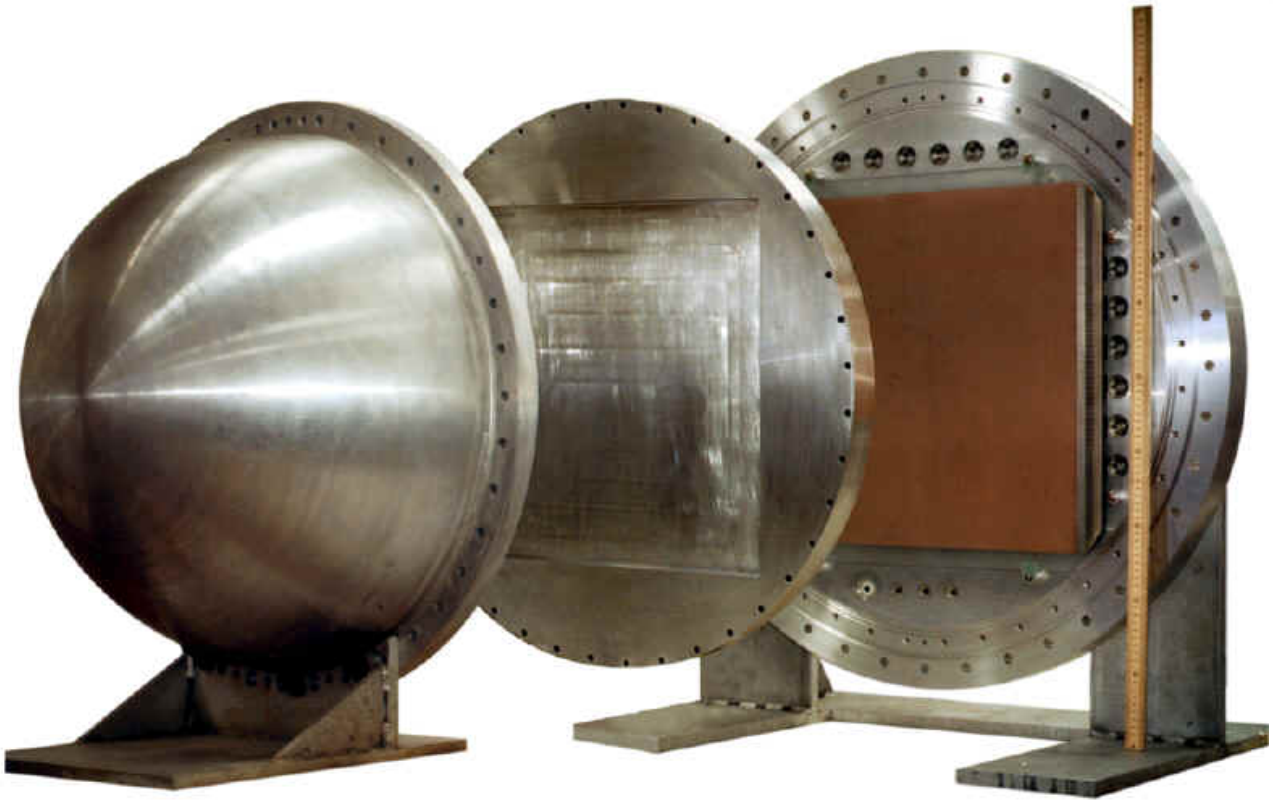




128 8-mm diameter, 1-m long
Tubes in a vacuum chamber

Prototype

BNL Detector



Typical proportional chamber that could be converted to ionization mode, pixel readout

Conclusion

- The SNS is on schedule to begin operation in 2006
- The detector systems that are available today do not meet the requirements of the SNS in most instances
- Electronics development is needed to minimize the saturation effects from Bragg peaks in linear position sensitive detectors
- ASICs are needed for parallel pixel readout schemes
  - Burst data at 60 Hz
  - Electronics in chamber gas
- We are soliciting ideas