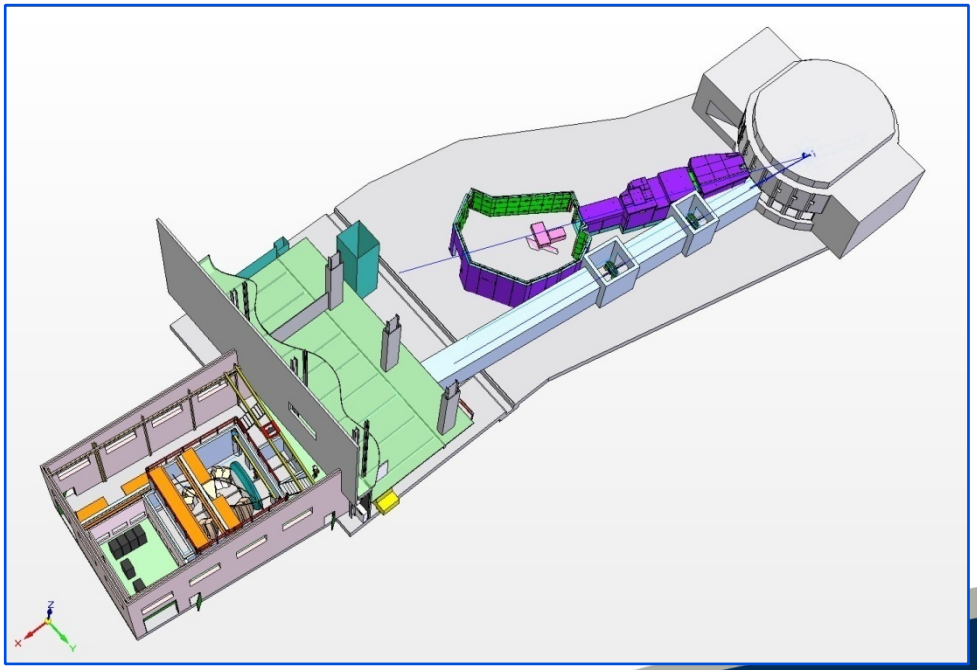
# IMAT: Instrument overview
# &
# Performance parameters



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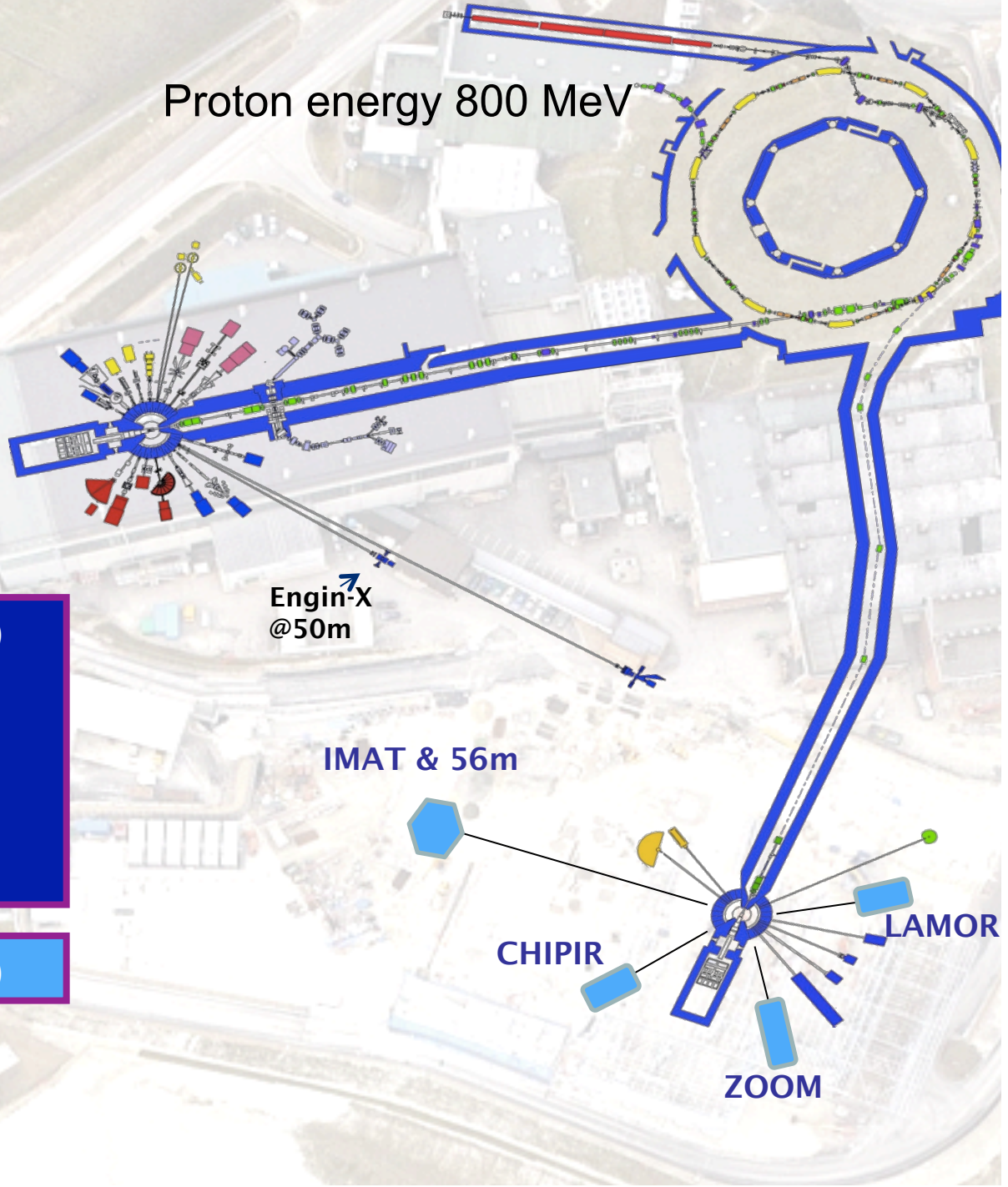
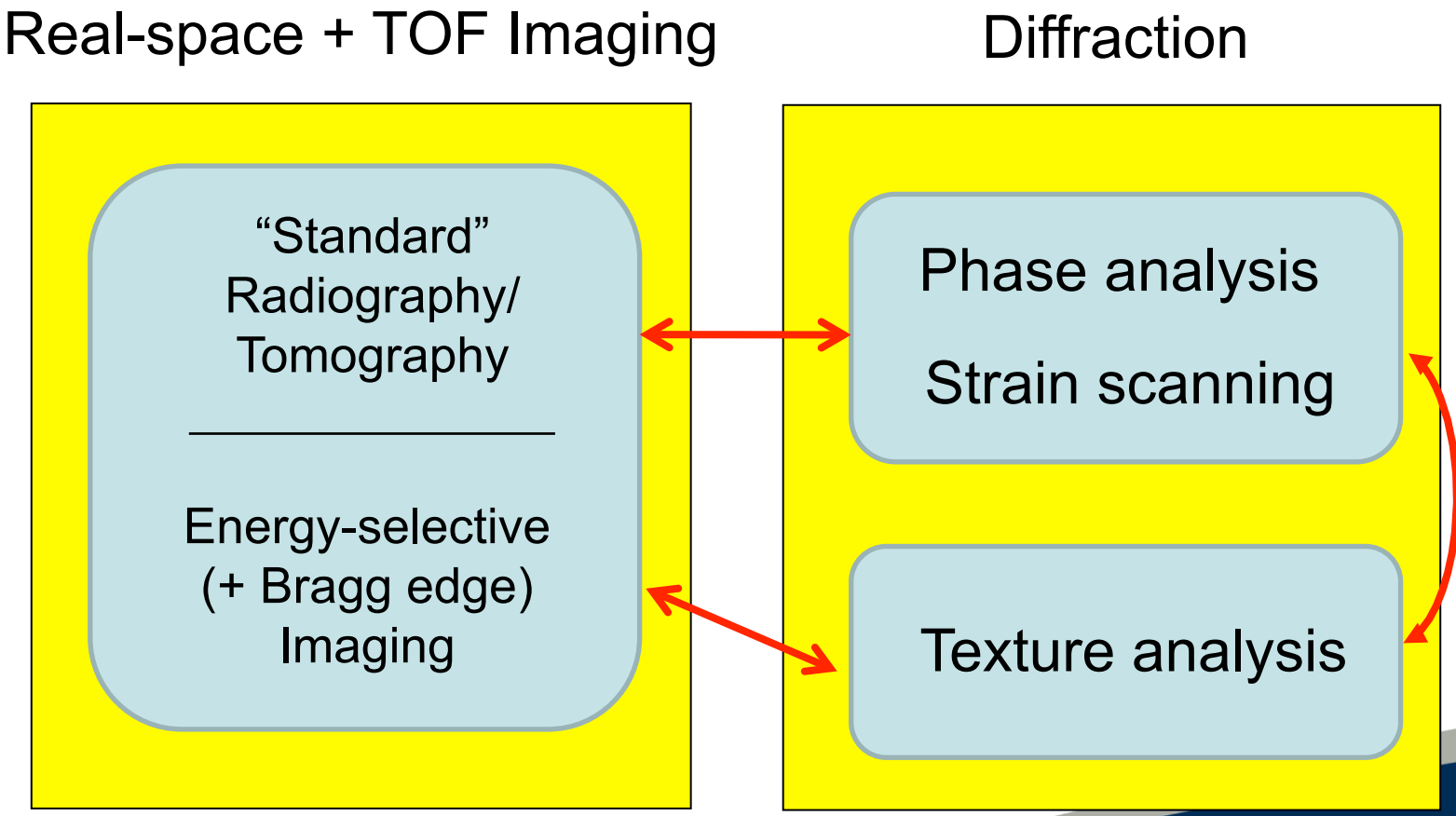
TS-I
20 instruments
40 Hz
Target: W, clad in Ta
150 kW
160 μA (240 μA)

TS-II: Phase-1 instruments (7)
10 Hz
Target: W, clad in Ta
(∅ 6.6, 27 cm)
48 kW
40 μA (60 μA)

TS-II: Phase-2 instruments (4)



# IMAT Methods



# IMAT Requirements

## Real-space + TOF Imaging

Large screen imaging detector
(maximum 200x200mm)

Pixellated Bragg edge detector
(TOF capable)

L/D aspect ratio: variable; at least 500
(high intensity versus high resolution)

## Diffraction

Short wavelengths;

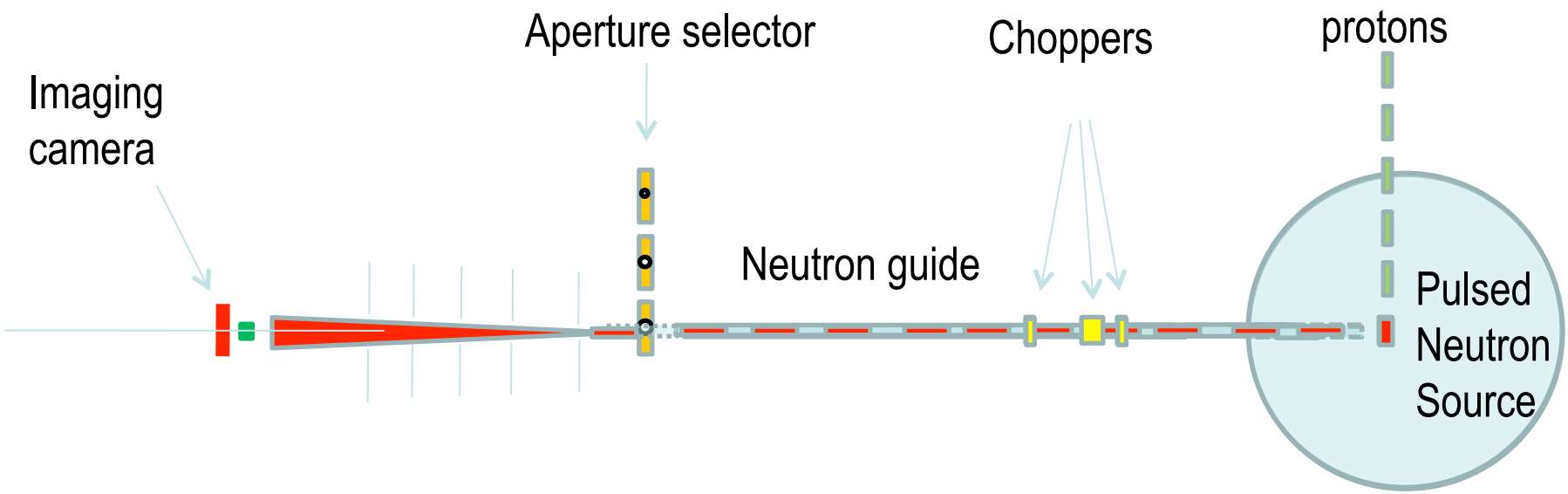
Small beam (minimum 1x1 mm)

Sufficient strain resolution

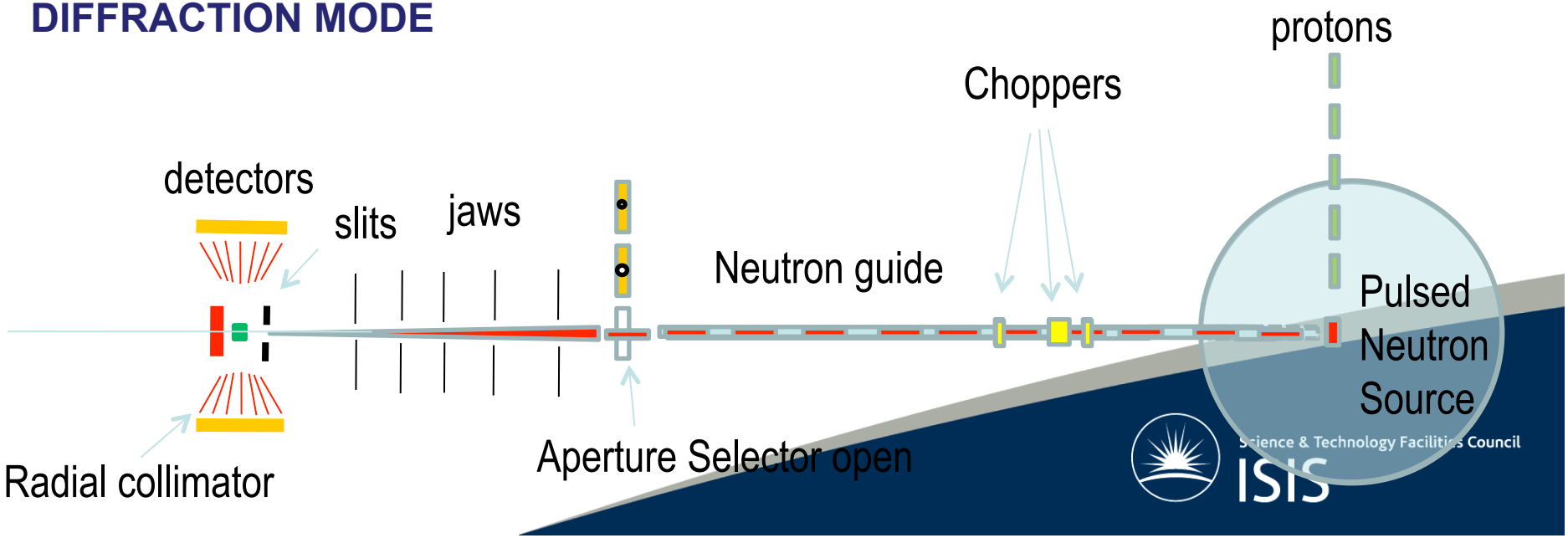
High detector coverage; pixellated

- Fast switching from imaging to diffraction
- Complementarity to ENGIN-X
- In-build flexibility
  (rapidly changing imaging camera technology; small samples; large samples)

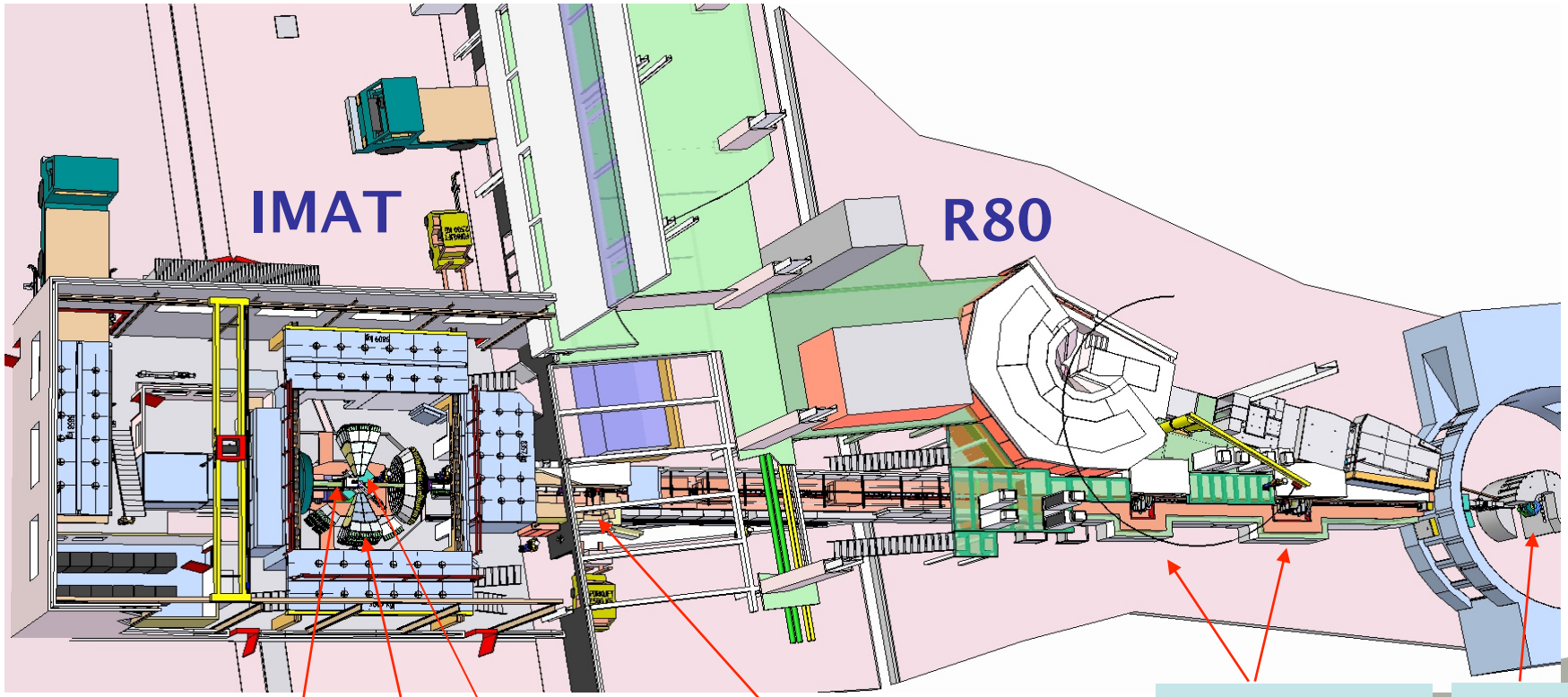
## IMAGING MODE




## DIFFRACTION MODE



# IMAT: Imaging and Materials

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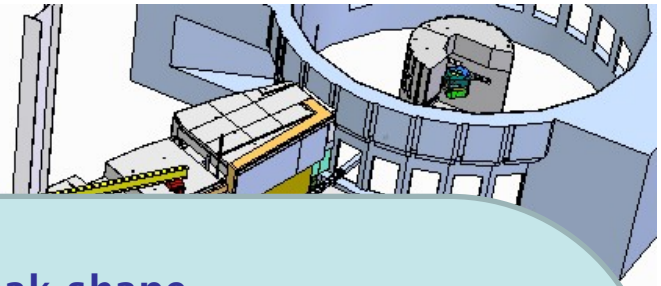
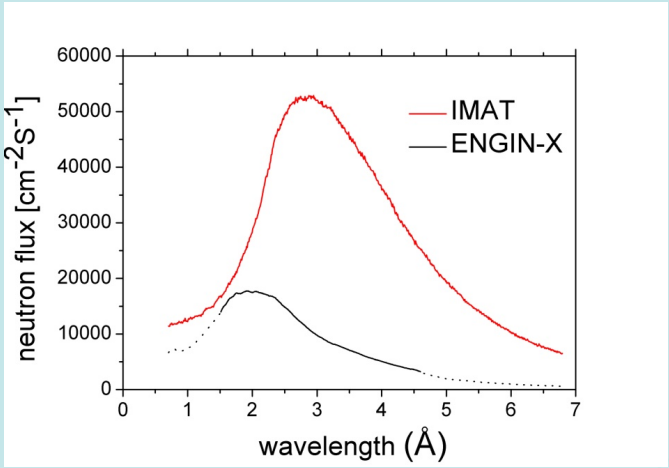
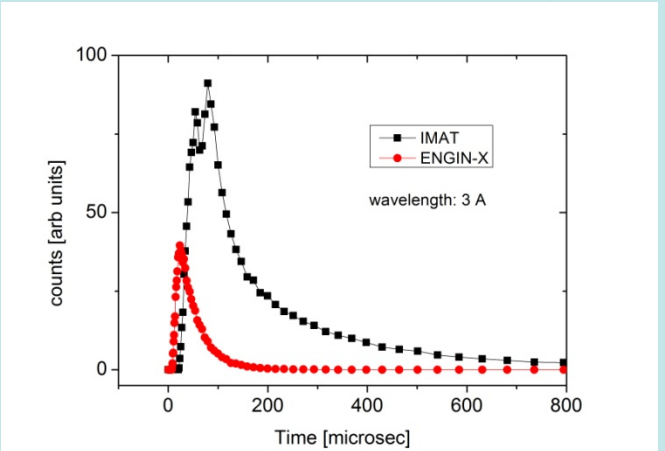
# Pulsed Source/ Moderator



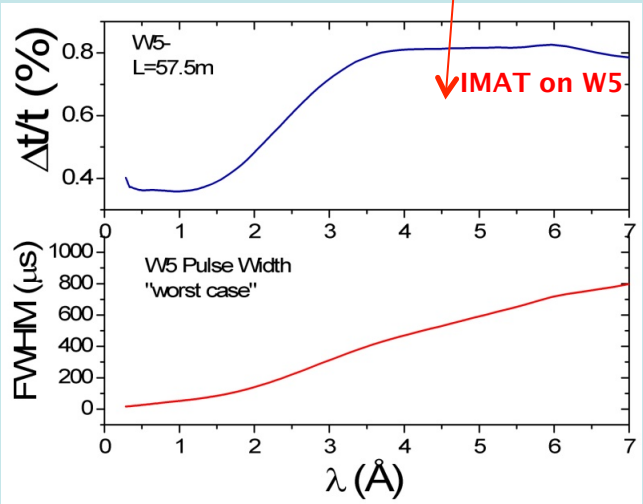
## Neutron Flux



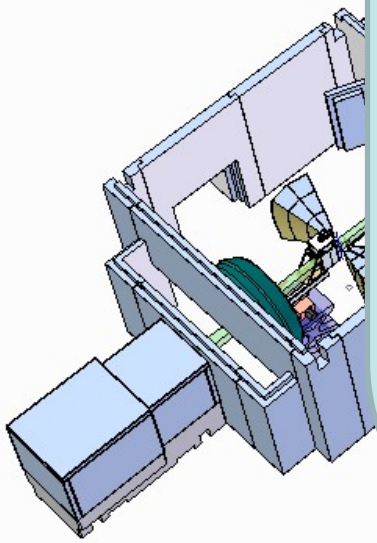

## Peak shape



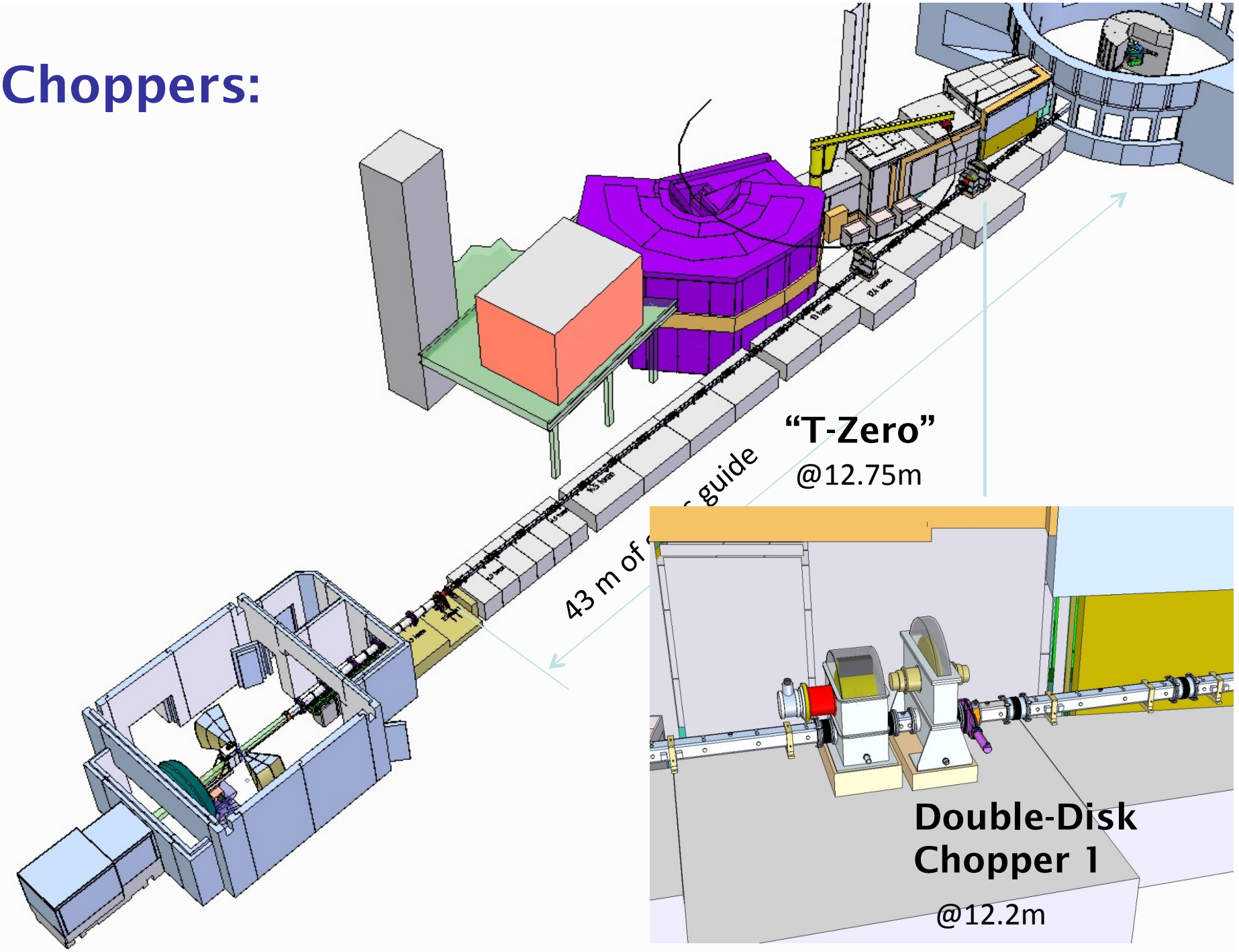

## Resolution




- 10 pulses / sec
- High-flux
- Broad peakshape

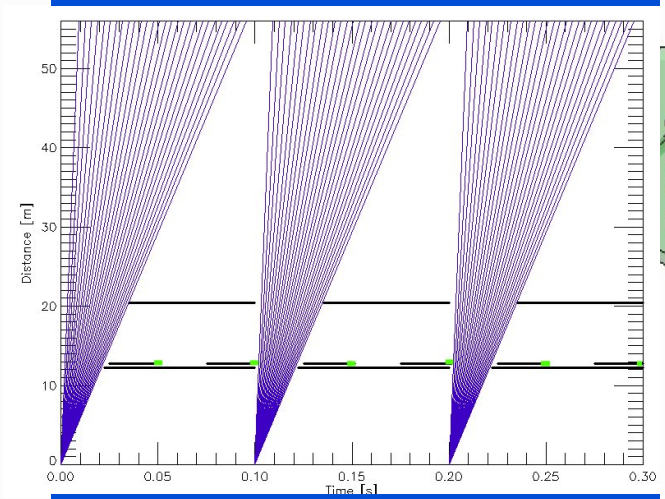


# Choppers:

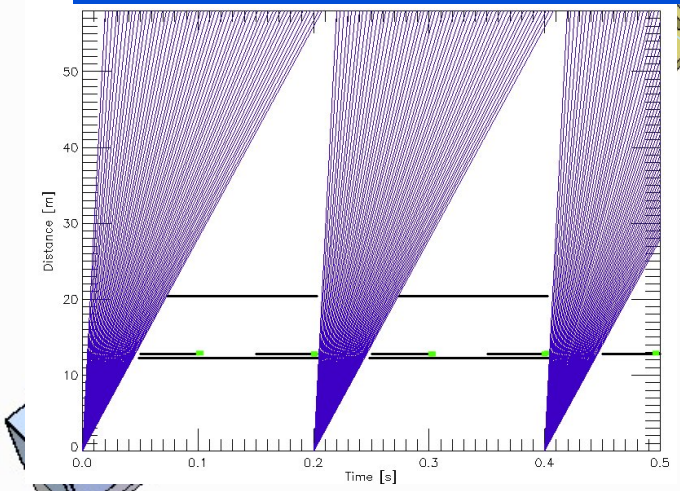


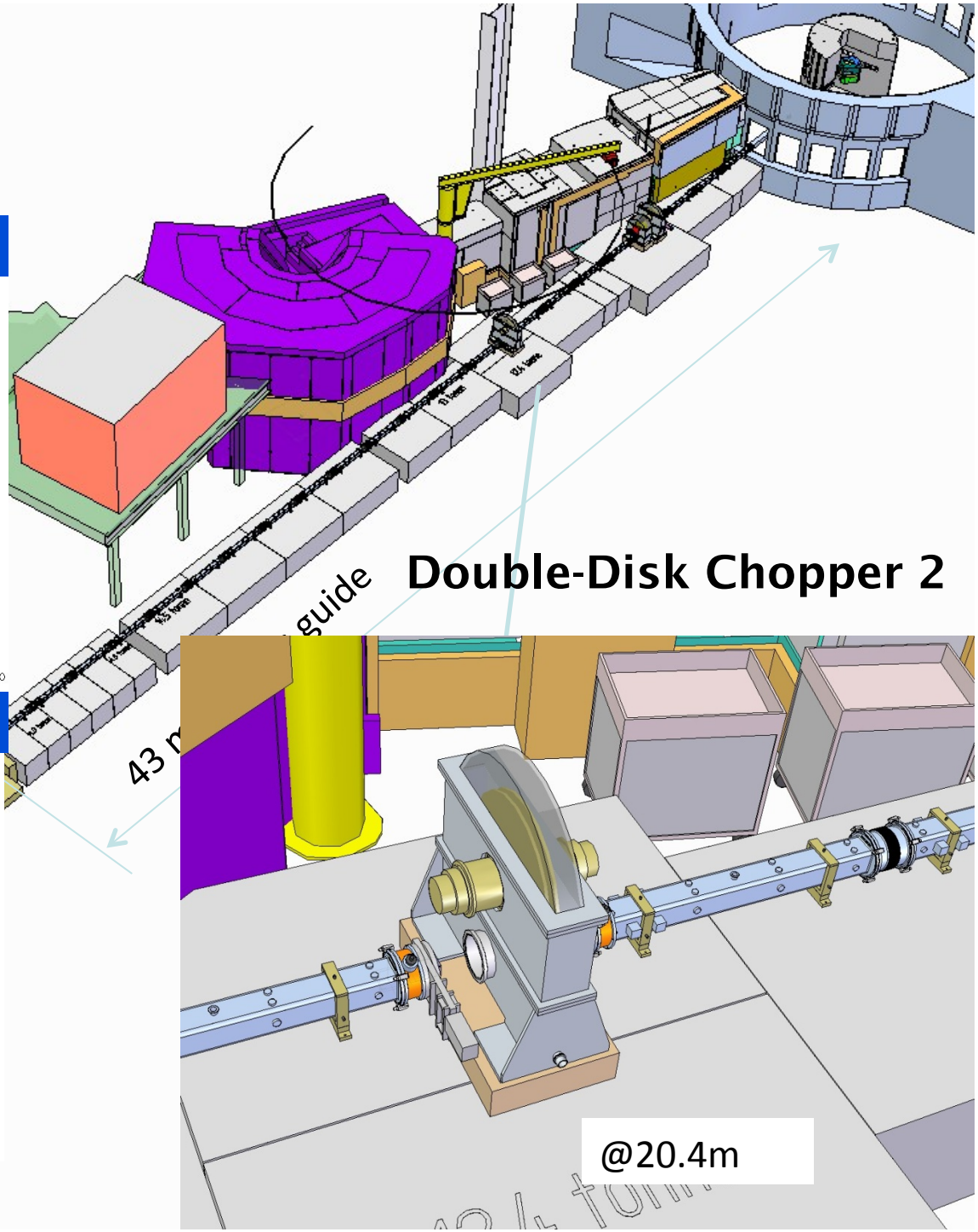
# Choppers:

**10 Hz → λ: 0.67 – 6.7 Å**



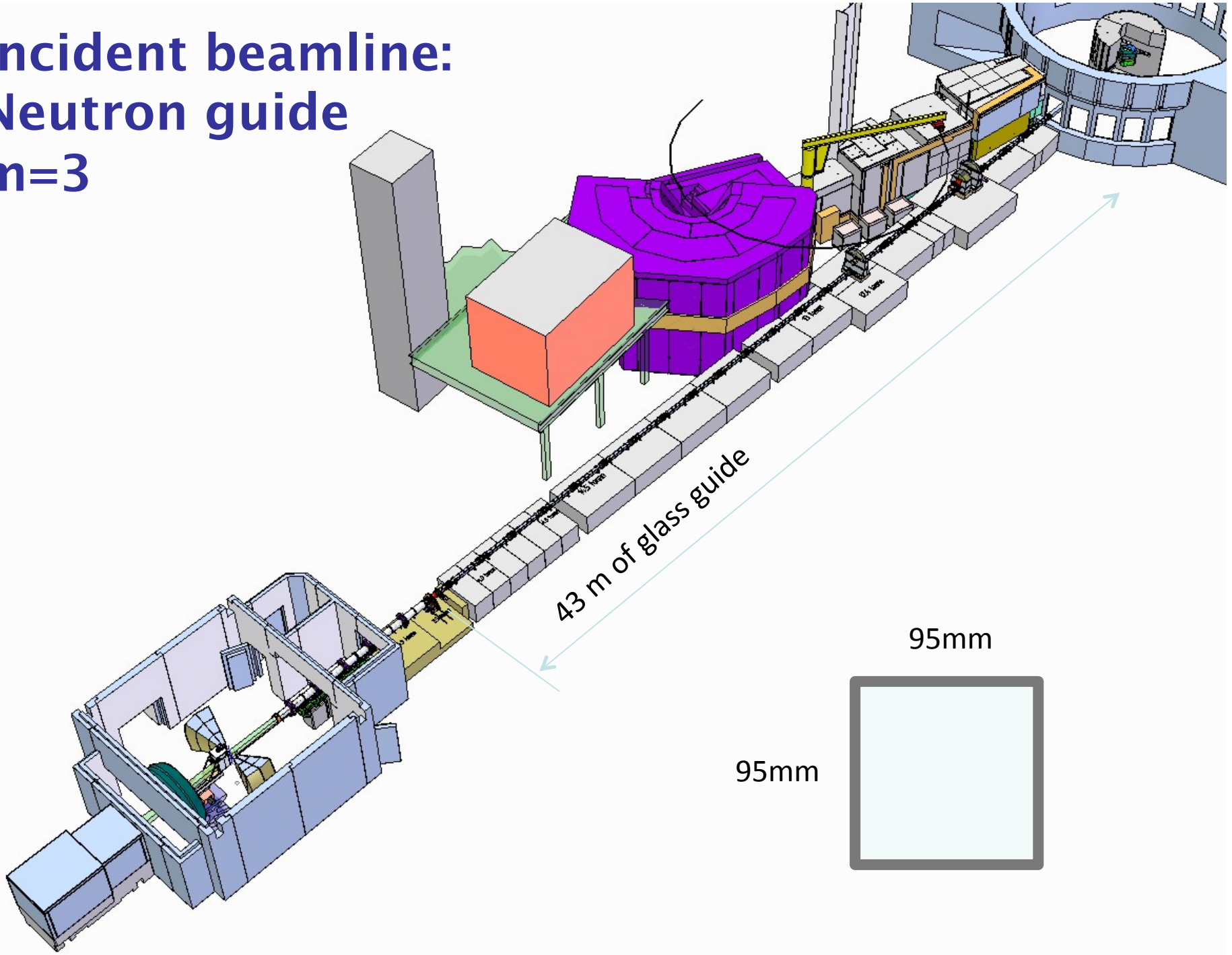

**5 Hz → λ: 1.4 – 14 Å**




**Double-Disk Chopper 2**

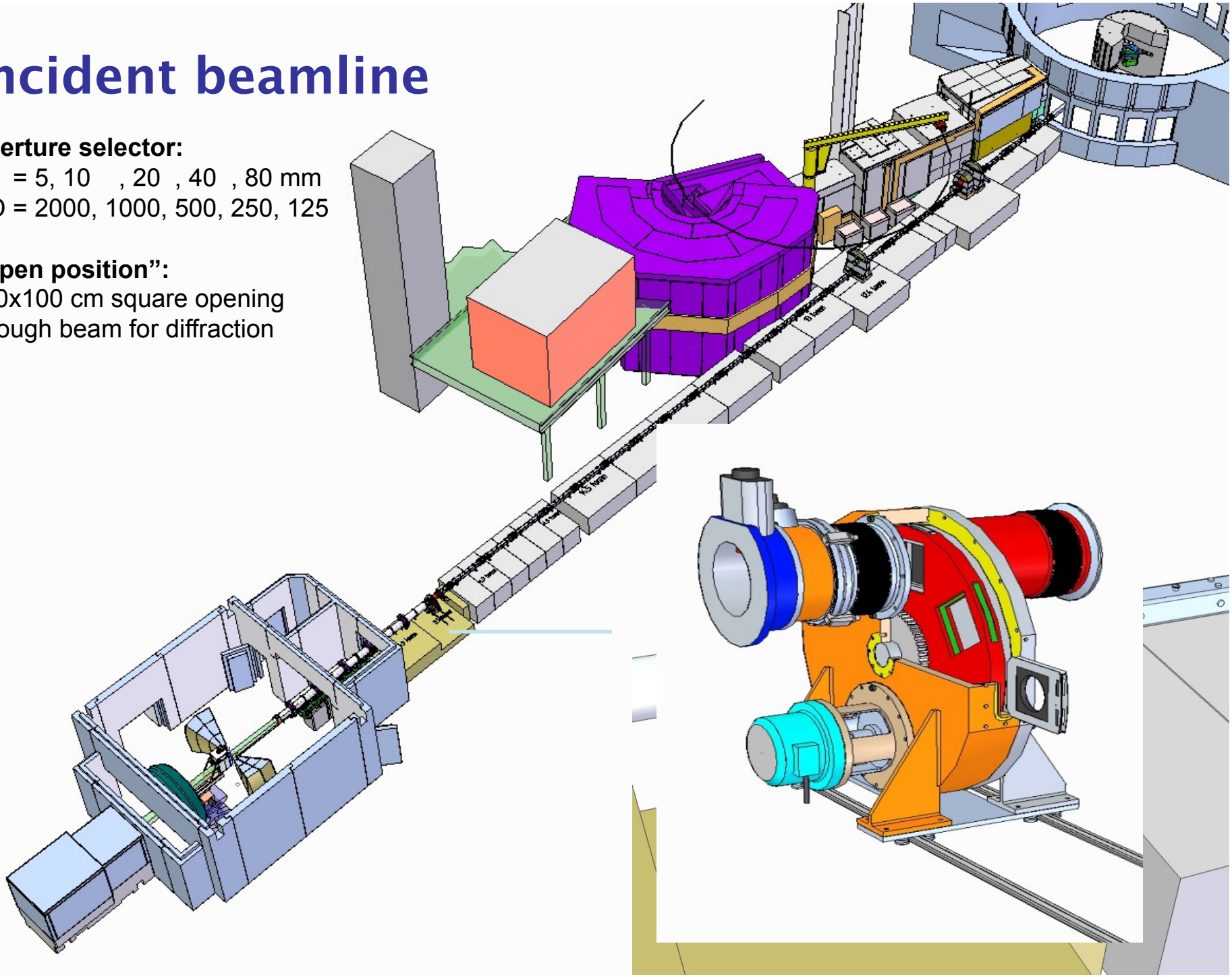
# Incident beamline: Neutron guide m=3



# Incident beamline

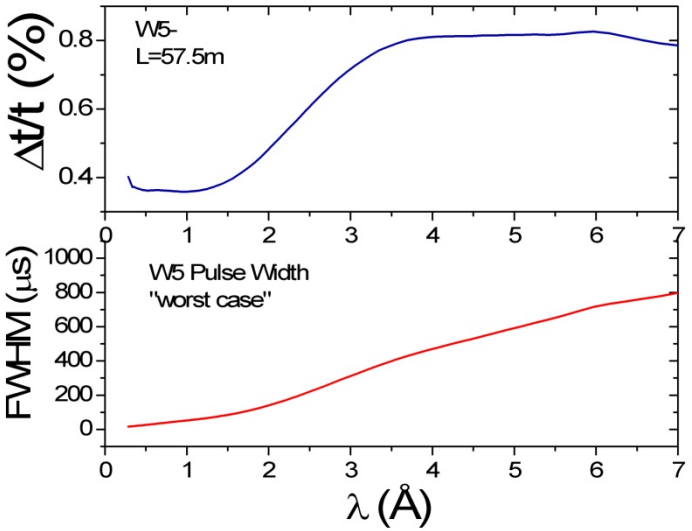
**Aperture selector:**
D = 5, 10 , 20 , 40 , 80 mm
L/D = 2000, 1000, 500, 250, 125

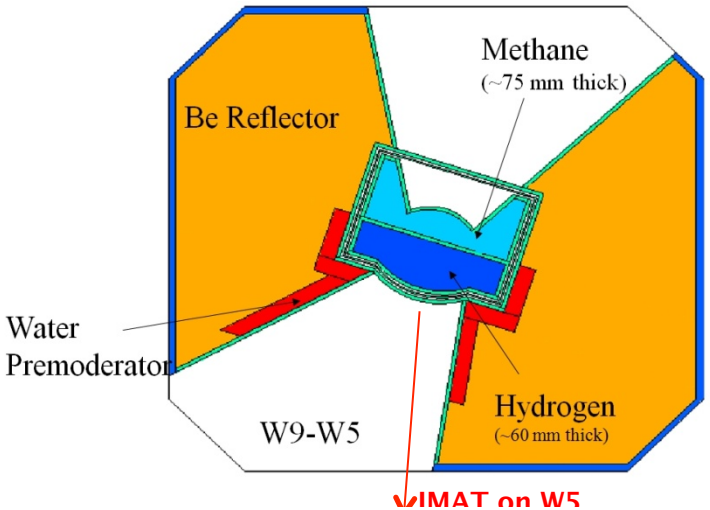
**“Open position”:**
100x100 cm square opening
through beam for diffraction

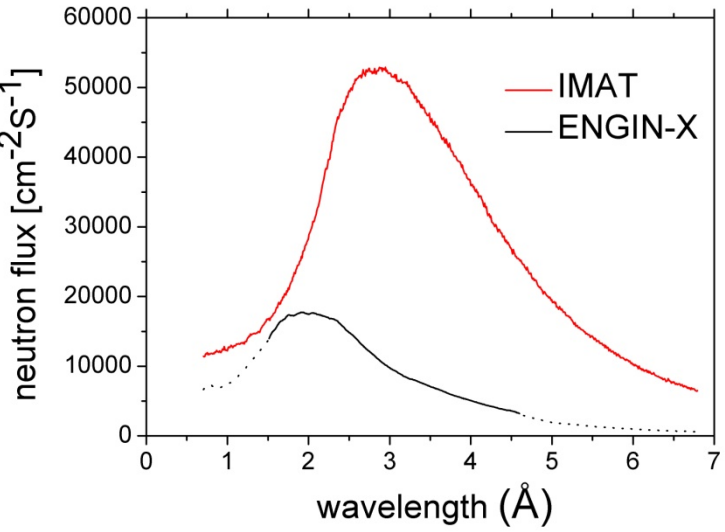


# Incident beam: parameters

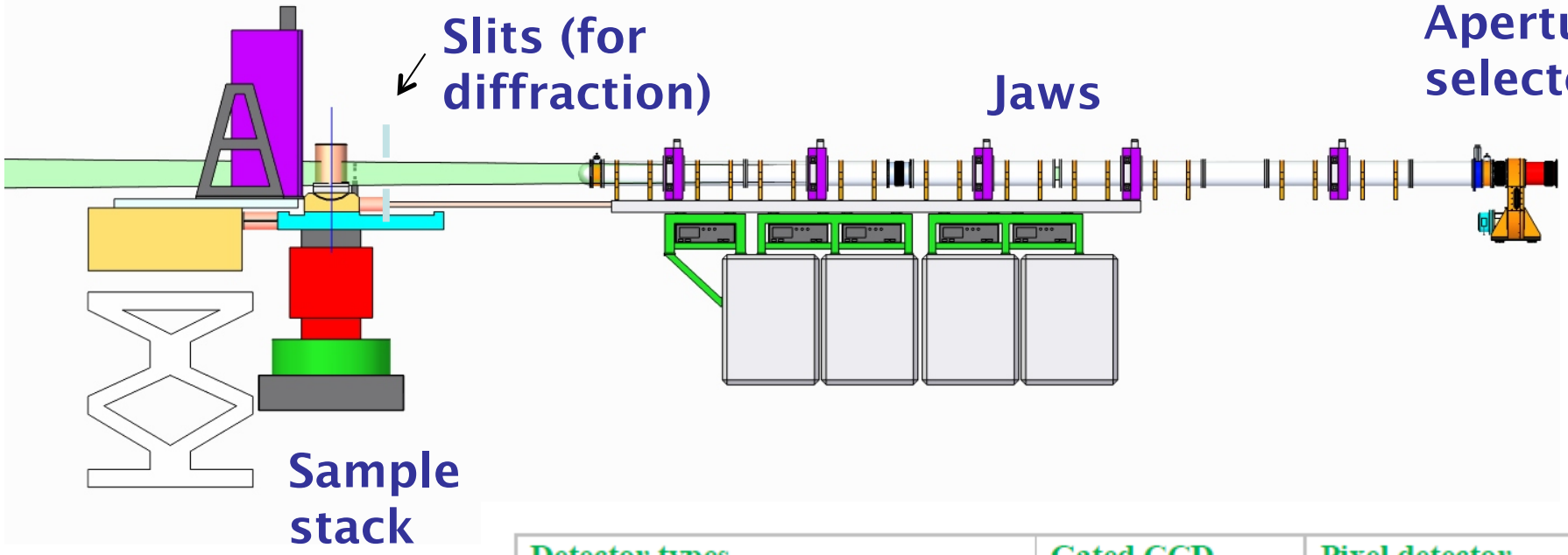
| | |
|---|---|
| **Source repetition** | 5, 10 Hz |
| **Moderator** | Liquid H2 / solid $CH_4$ coupled |
| **Neutron guide** | m=3 straight, square, 95x95 mm |
| **Single/Double frame bandwidth** | 0.67 - 6.7 Å / 2 - 14 Å |
| **Flight path to sample** | 56 m |



# Imaging on IMAT



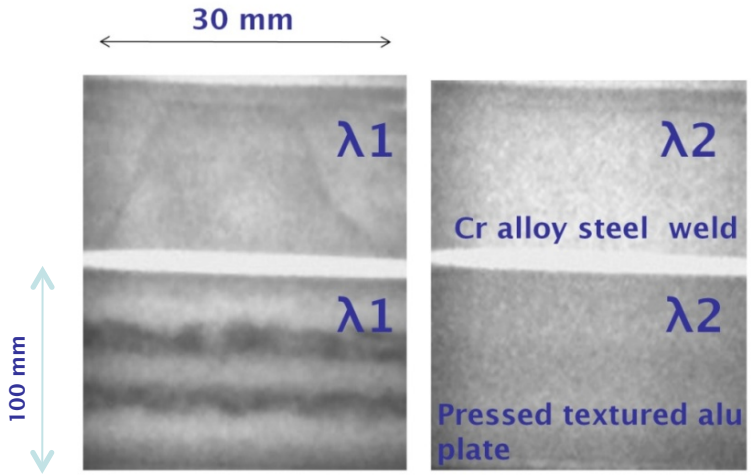

| Detector types | Gated CCD camera | Pixel detector |
|---|---|---|
| Field of View [mm$^2$] | 200x200 | 30x30 |
| Best spatial resolution [μm] | 50 | 50 |
| Timing resolution [μs] | 100 | 1 |
| Energy resolution | $\Delta E/E < 0.8$ % | |
| Neutron flux (L/D=500) n/cm$^2$/sec | $10^7$ | |

# Imaging camera 1

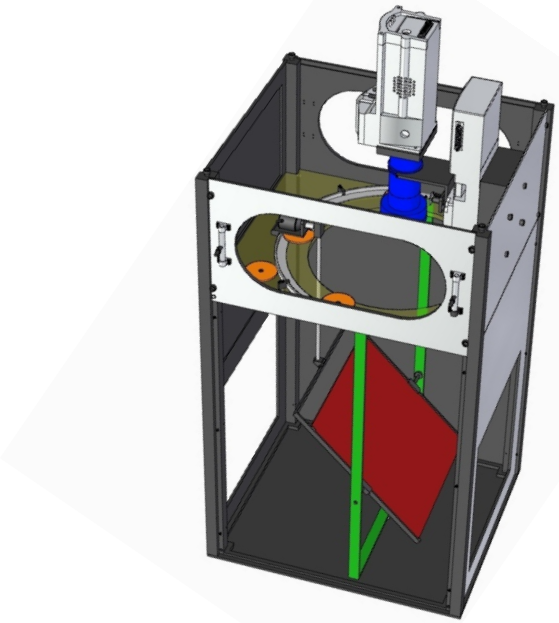
Collaboration with F. Aliotta, CNR Messina , Italy,
in the frame of the ISIS-CNR PANAREA project

Wavelength dependent imaging + tomography

**Gated CCD camera: 200x200 mm$^2$**
Design and construction by CNR Messina




Texture variations by energy-selective imaging
with prototype CCD camera (F. Aliotta, Messina)



| Best spatial resolution | |
|---|---|
| FOV=200x200 mm$^2$ | 200 µm + above |
| FOV=100x100 mm$^2$ | 100 µm |
| FOV=80x80 mm$^2$ | 80 µm |
| FOV=50x50 mm$^2$ | 55 µm |

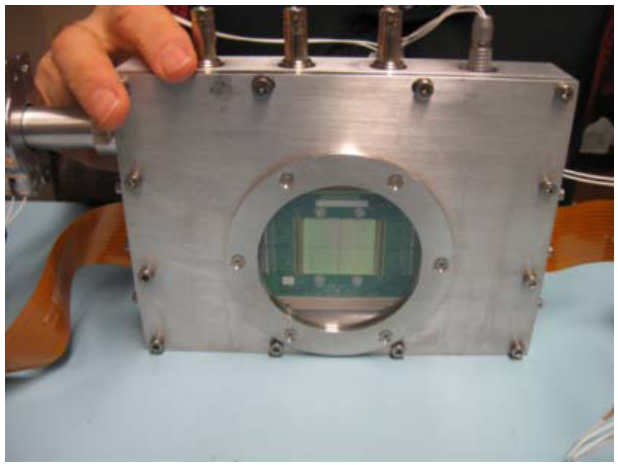
# Imaging camera 2

Collaboration with A Tremsin, Space Science Department, Berkeley, San Francisco, USA

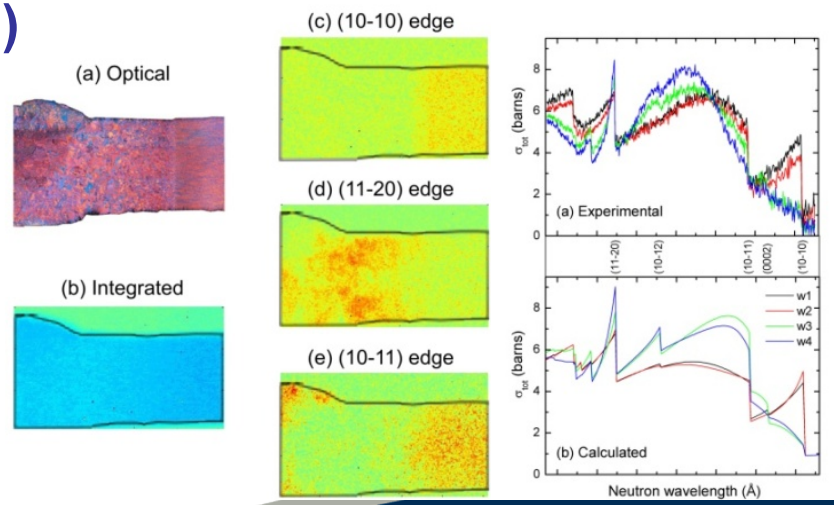
| | |
|---|---|
| Max. Field of View (FOV) | 30 x30 $mm^2$ |
| Best spatial resolution | 50 µm |
| Timing resolution | < 1 µs |

## Bragg Edge detector (30x30 $mm^2$)

Developed and built by Berkeley



## Strain and texture mapping with high spatial resolution




Bragg edge transmission with Berkeley MCP detector on ENGIN-X.
Santisteban, Tremsin et al., J. Nuclear Materials, 2011)

# Imaging instrument

High flux moderator

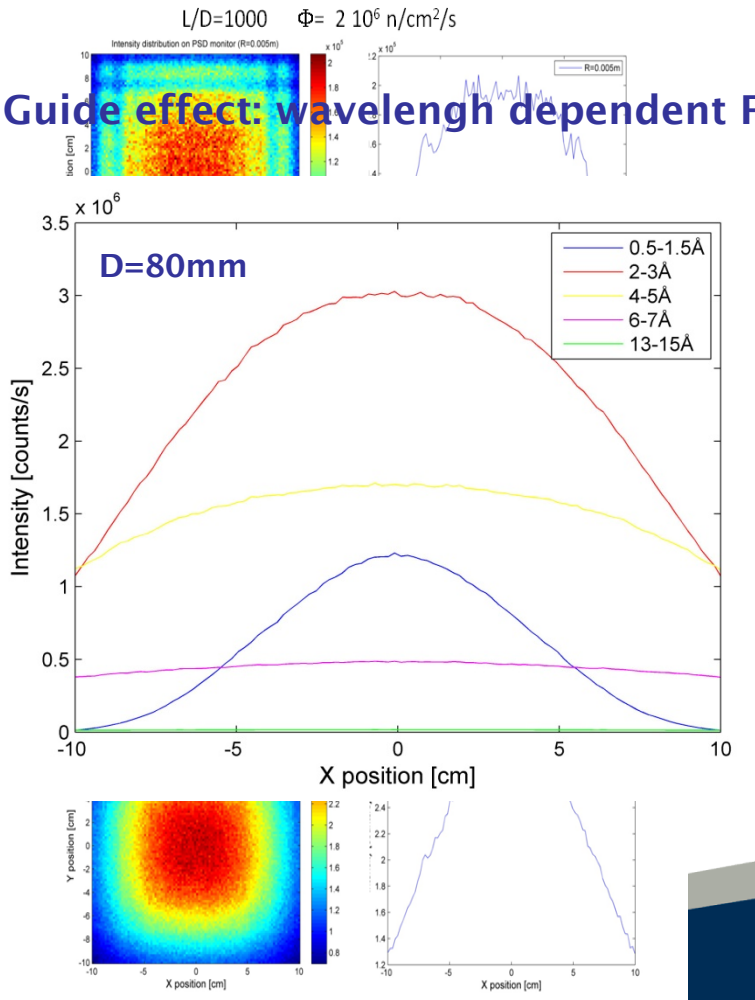
Gated CCD: 200x200 mm$^2$

Pixel camera: 30x30 mm$^2$

Potential second imaging position

| | |
|---|---|
| **Primary flight path** | 56 m |
| **L: pinhole-detector** | 10 m |
| **D: pinhole sizes** | 80, 40, 20, 10, 5 mm |
| **L/D** | 125, 250 , 500, 1000, 2000 |
| **Spatial resolution** | Standard: 200-400 μm<br>Minimum: 50 μm |
| **Wavelength resolution** | < 0.8%<br>(0.7 % at 3Å) |
| **Neutron flux (L/D=250)** | 4 10$^7$ neutrons/cm$^2$/s |
| **Max. field of view** | 200 x 200 mm |

## Guide effect: wavelengh dependent FOV

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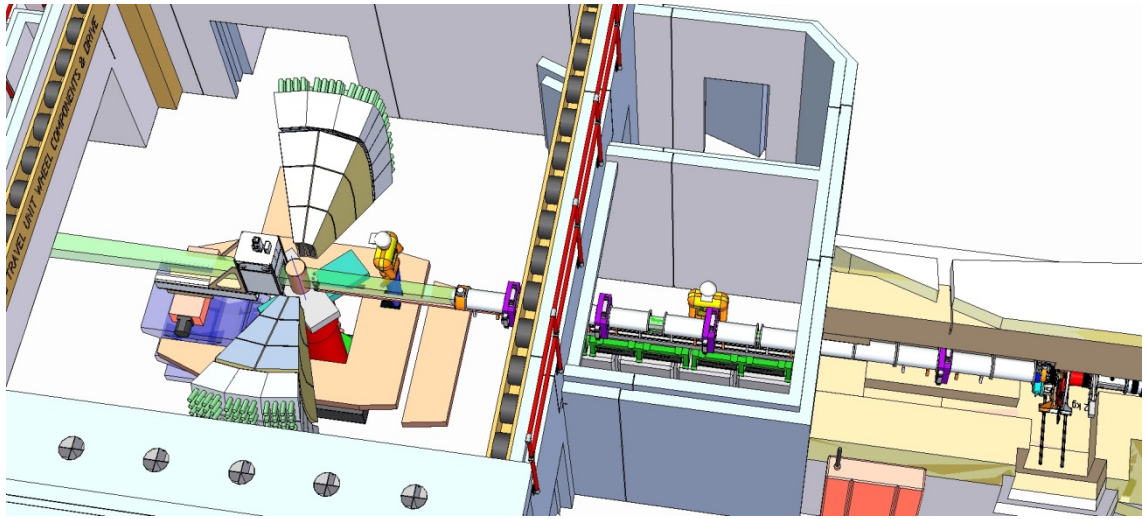
# IMAT diffraction



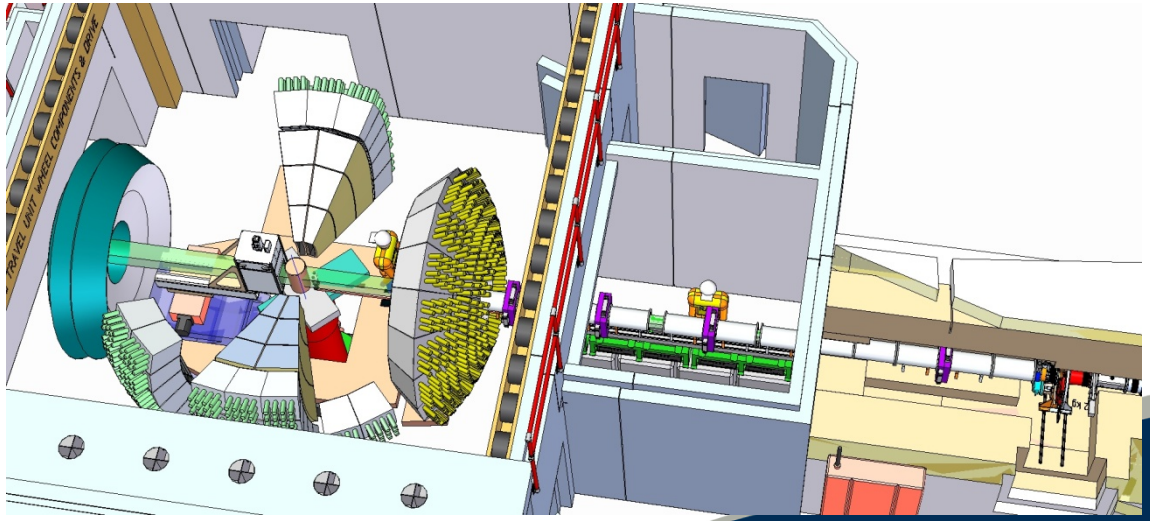
Stage 1:

Two diffraction detectors (at 90°)

Imaging, phase and strain analysis

Initial coverage:
4 $m^2$ ~ 1 sterad

Radial collimators 1, 2, 5, mm



Stage 2:

Additional diffraction detectors at forward and backscattering angles

Final coverage:
18 $m^2$ ~ 1 sterad

# Diffraction mode

Stage 1: 90 degree detectors
Stage 2: Large detector coverage

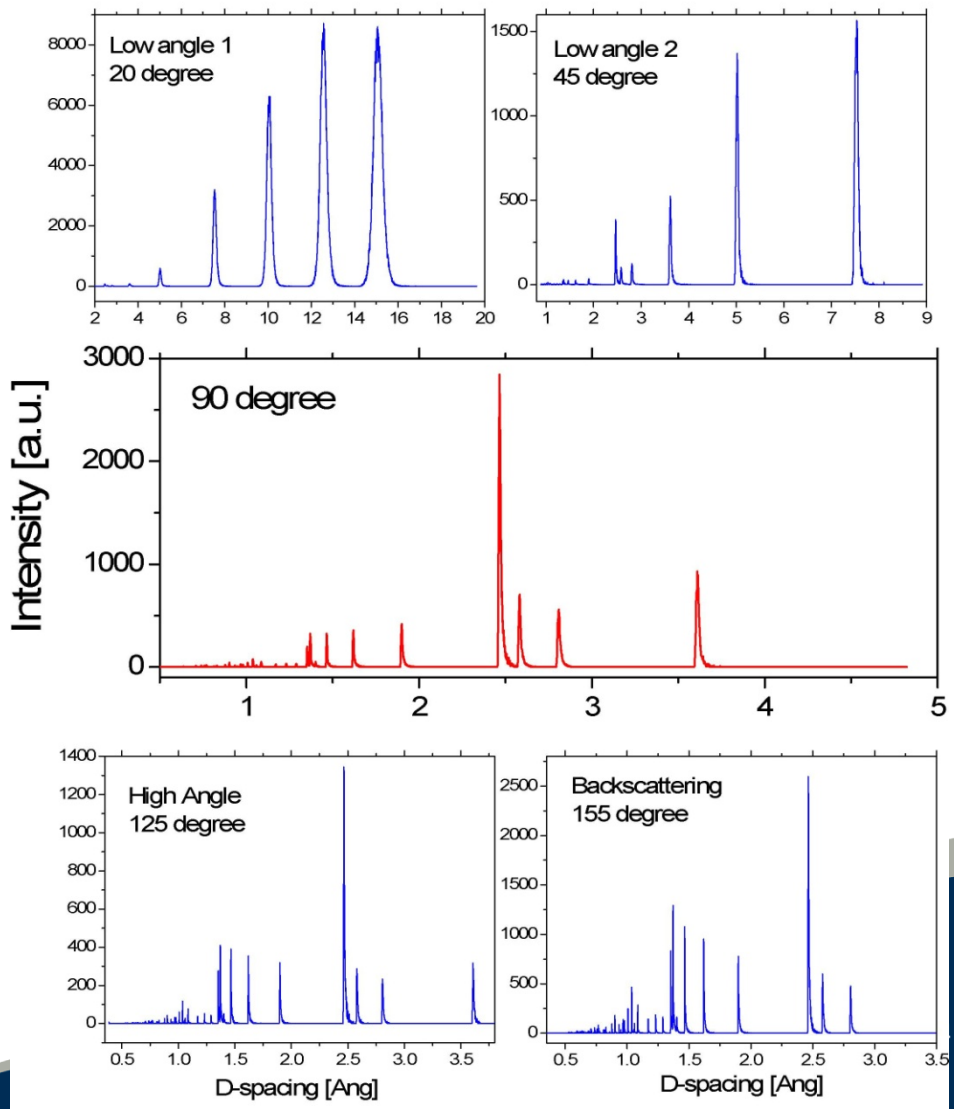
Scintillation detectors (ZnS/LiF); wavelength shifting fibres

Highly pixellated;
each pixel 4x100 mm$^2$ (<5 deg)

medium spectral resolution

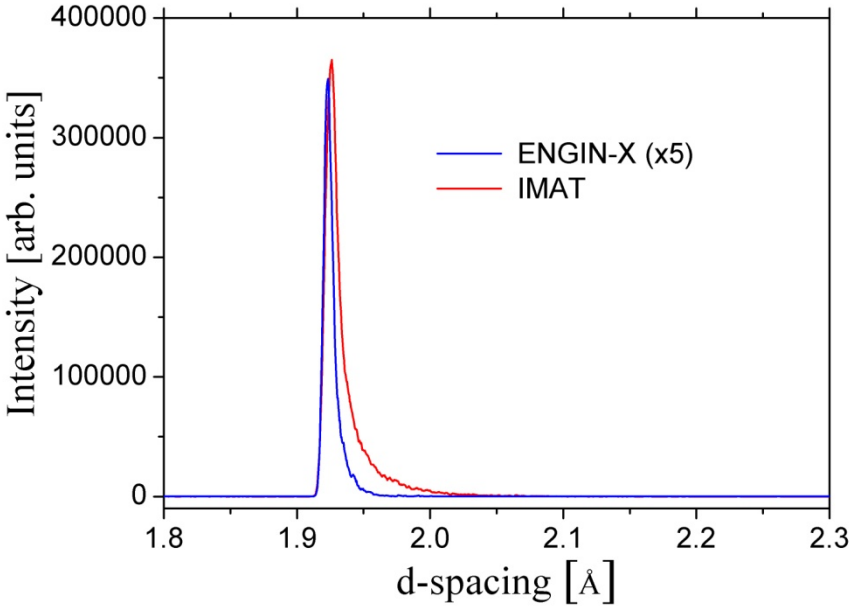
| | |
|---|---|
| **Primary Flight path** | 56 m |
| **Secondary flight path** | 2.0 m |
| **Single frame d-range** | 0.5 -4.8 Å (90 deg) |
| **Neutron flux** | $1 \cdot 10^7$ n/cm$^2$/sec |
| **Gauge size** | 1, 2, 5 mm |
| **Spectral resolution** | 0.7 at 3Å / 90 deg |
| **Strain resolution** | 70 microstrain |

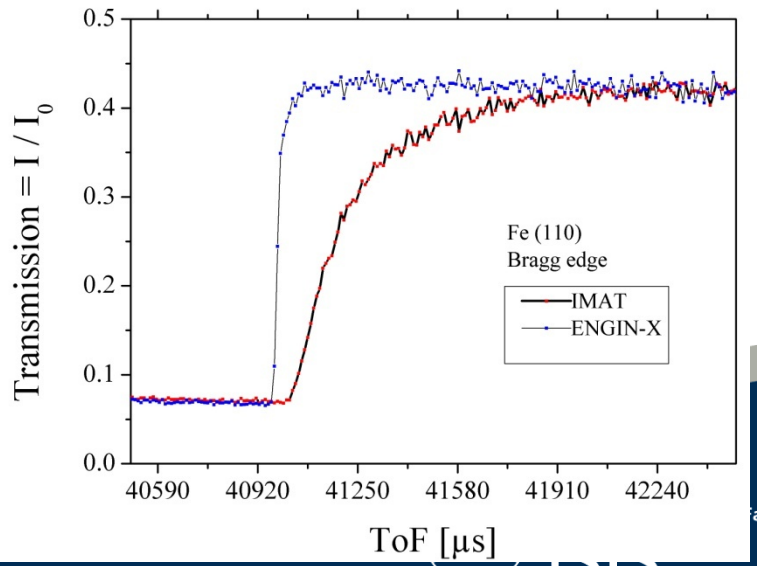
## Simulated diffraction patterns



## Strain analysis performance

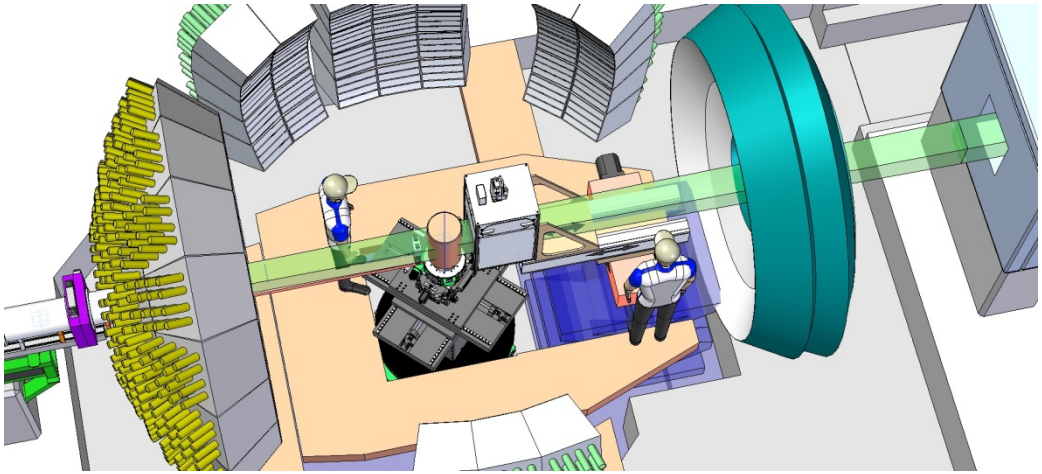
| | IMAT | ENGIN-X |
|---|---|---|
| Moderator | “broad” | “sharp” |
| Diffraction resolution (3Å/90º) | 0.69 % | 0.33 % |
| strain resolution [microstrain] | 70 | 50 |
| Bragg intensity 3 Å [a.u.] | 8.5 | 1.0 |



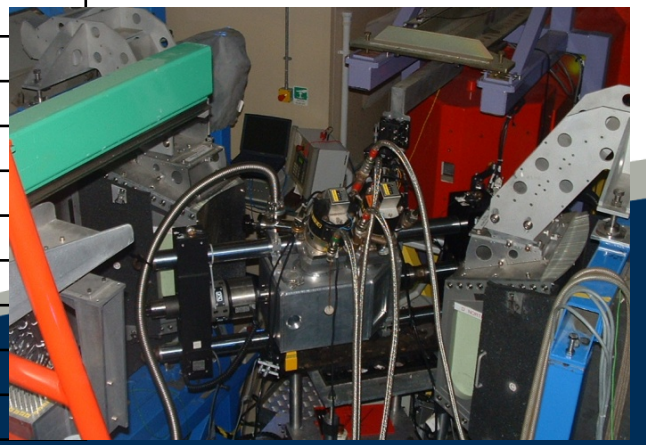
## IMAT sample stack

xyz-ω: heavy duty (1.5 t)
ω : tomography rotation



## IMAT sample environment

| | Stage-1 | Stage-2 |
|---|---|---|
| | | |
| **IMAT** | Furnace (1000 ºC) | 200 kN stress rig |
| | Sample changer | |
| | | |
| **Shared with ENGIN-X** | 50kN stress rig (uniaxial loading) | |
| | 100kN rig (uniaxial loading) | |
| | Cryogenic stress rig | |
| | Cybaman sample manipulator | |
| | | |
| **From ISIS pool** | CCR (10-300 K) | |
| | Cryostats (2 -300 K) | |
| | IGAn (for gravimetric studies) | |



# IMAT: Imaging and Materials Science

- Dual-use instrument: neutron imaging and diffraction

- New material analysis capabilities at ISIS
  - Conventional neutron radiography and tomography
  - Novel energy-selective (Bragg edge) imaging techniques
  - Combined imaging and diffraction experiments
  - Residual strain analysis
  - Texture analysis
  - Simultaneous strain and texture measurements

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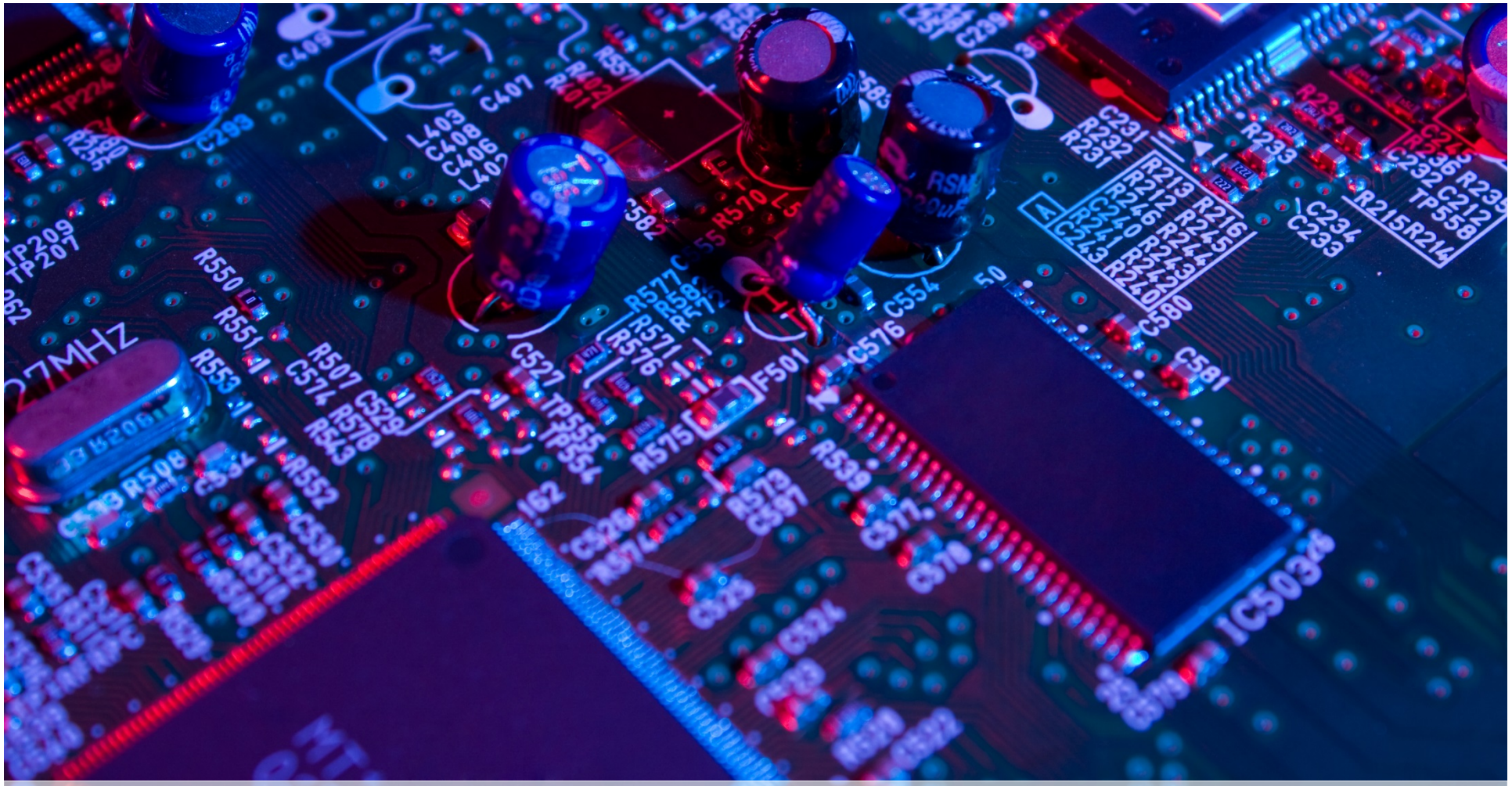

# When the Chips Are Down....

Christopher Frost

ISIS Facility

Science & Technology Facilities Council
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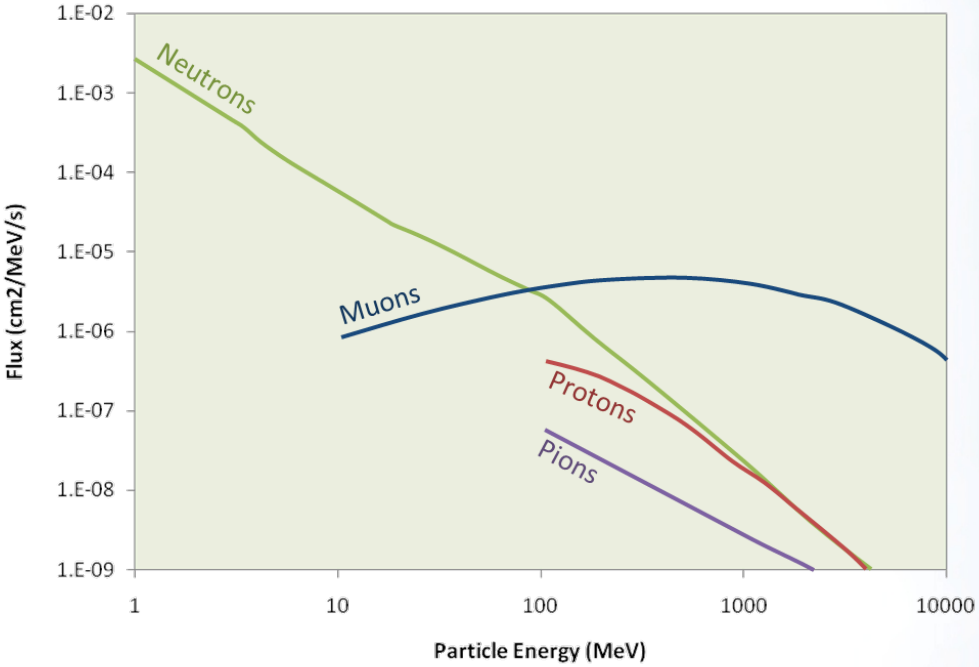




Reproduced from J.F.Ziegler et al IBM. J. Res. Develop. 40, 1996, p23

# Neutron Radiation from Cosmic Rays

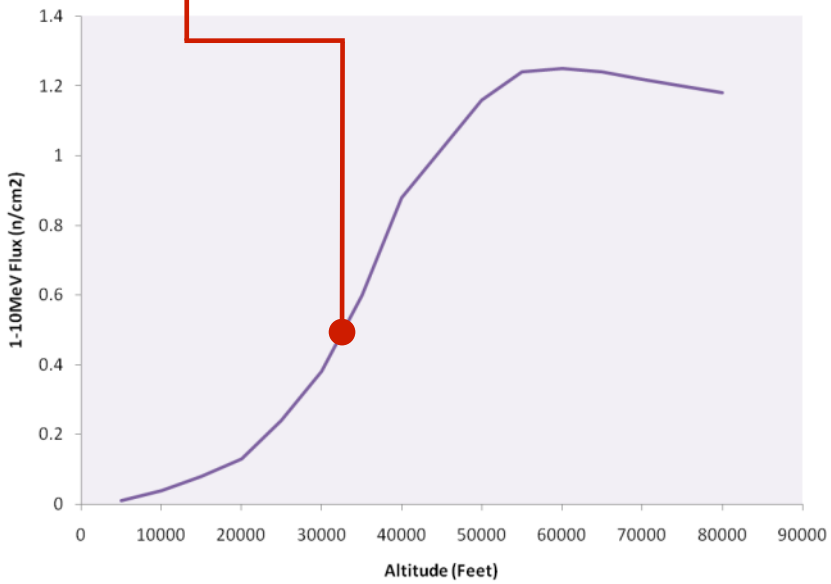

~ once a minute


E Normand and TJ Baker IEEE Trans Nucl Sci 40, 1484, (1993)

# Neutron Radiation from Cosmic Rays


~ 300 a minute

More neutrons at 35,000 feet





E Normand and TJ Baker IEEE Trans Nucl Sci 40, 1484, (1993)

# Neutron Radiation from Cosmic Rays


~ 300 a minute

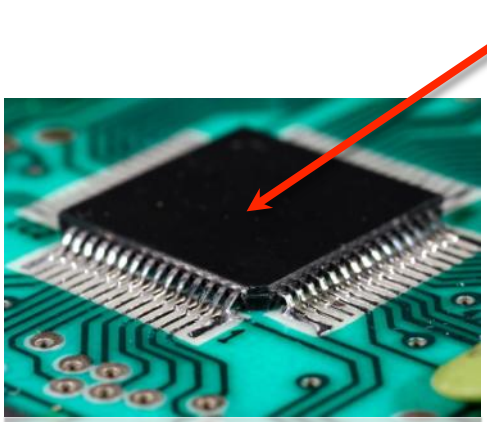
More neutrons at 35,000 feet

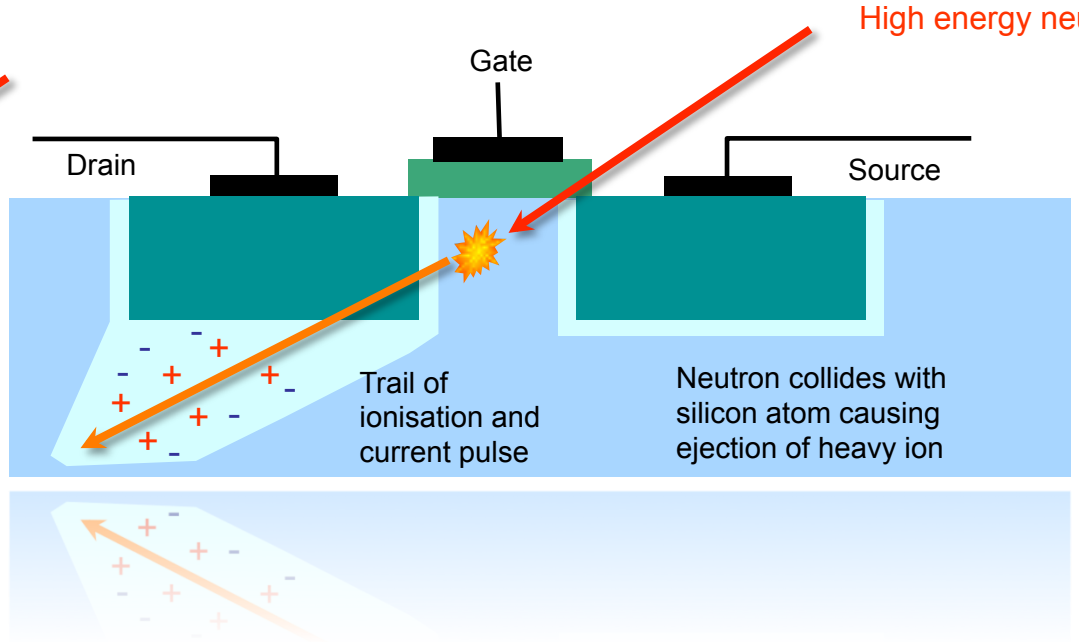
The dominant reliability issue in aircraft avionics

Becoming a dominant reliability issue in all advanced electronics


E Normand and TJ Baker IEEE Trans Nucl Sci 40, 1484, (1993)

**A Single Event Effect (SEE)** is when a highly energetic particle present in the environment, strikes sensitive regions of an electronic device disrupting its correct operation



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ISIS

**A Single Event Effect (SEE)** is when a highly energetic particle present in the environment, strikes sensitive regions of an electronic device disrupting its correct operation

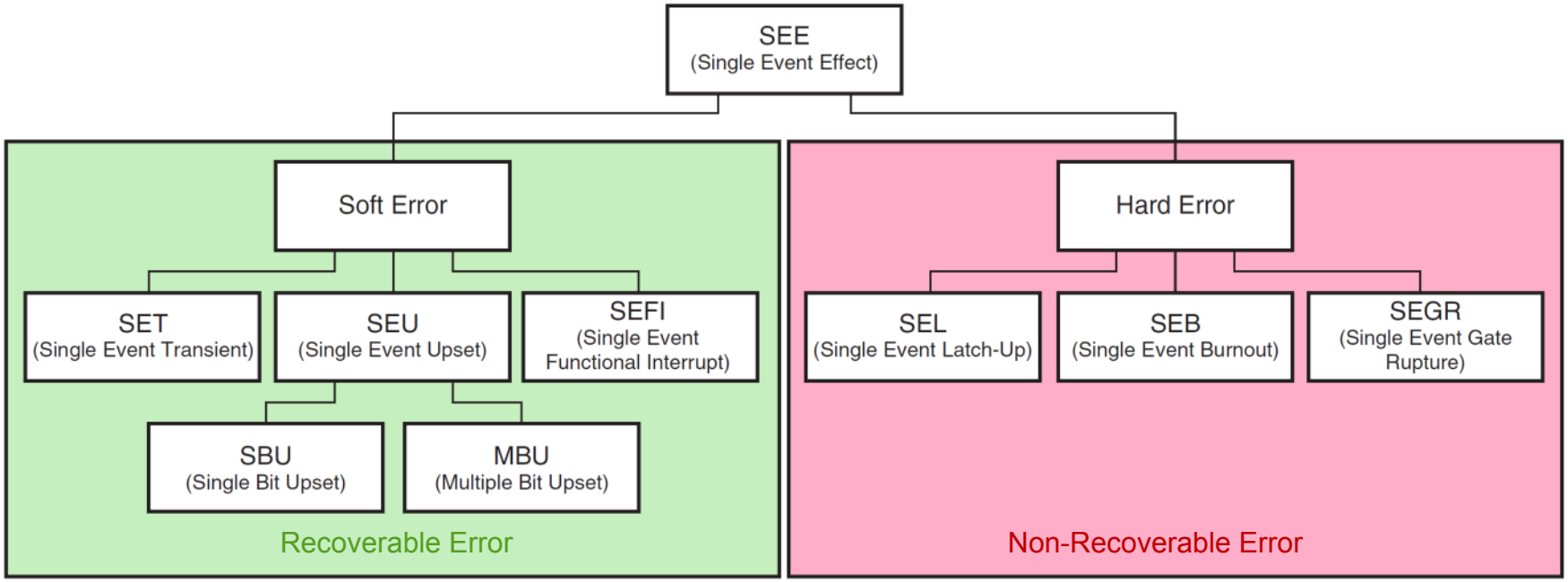


Diagram Courtesy: Xilinx

# ‘Real-world Incident’

7th October 2008 at 04:40:26

Flight Qantas QF72 – Singapore to Perth




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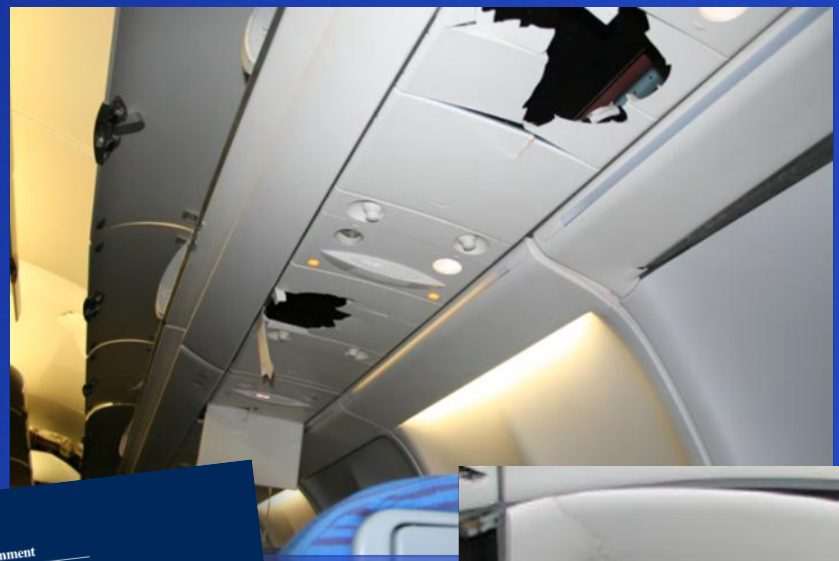
ISIS




ATSB TRANSPORT SAFETY REPORT Aviation Occurrence
Investigation AO-2008-070
Final

Science & Technology Facilities Council
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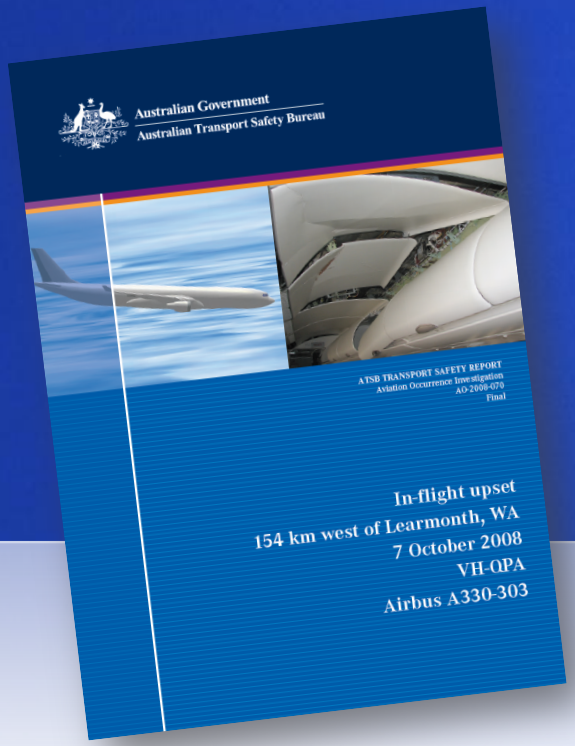
Blackpool Rollercoaster has a 213 ft drop

Science & Technology Facilities Council
ISIS

"It identified a number of specific lessons for the manufacturers of new, complex, safety-critical systems..."

The Chief Commissioner of the ATSB, Mr Martin Dolan
Media Report 19 December 2011




ATSB TRANSPORT SAFETY REPORT Aviation Occurrence Investigation AO-2008-070
Final

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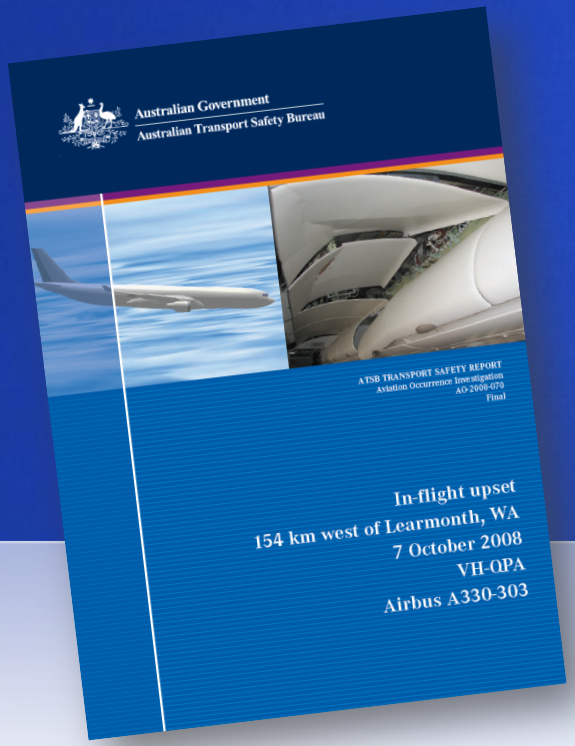
There were significant logistical difficulties in obtaining access to appropriate test facilities and developing test software and procedures.....




ATSB TRANSPORT SAFETY REPORT Aviation Occurrence Investigation AO-2008-070
Final

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Capacity of 3.5” Disk


Capacity of DVD

Capacity of human being’s functional memory

Zettabyte
1,000,000,000,000,000,000,000 bytes

Exabyte
1,000,000,000,000,000,000 bytes

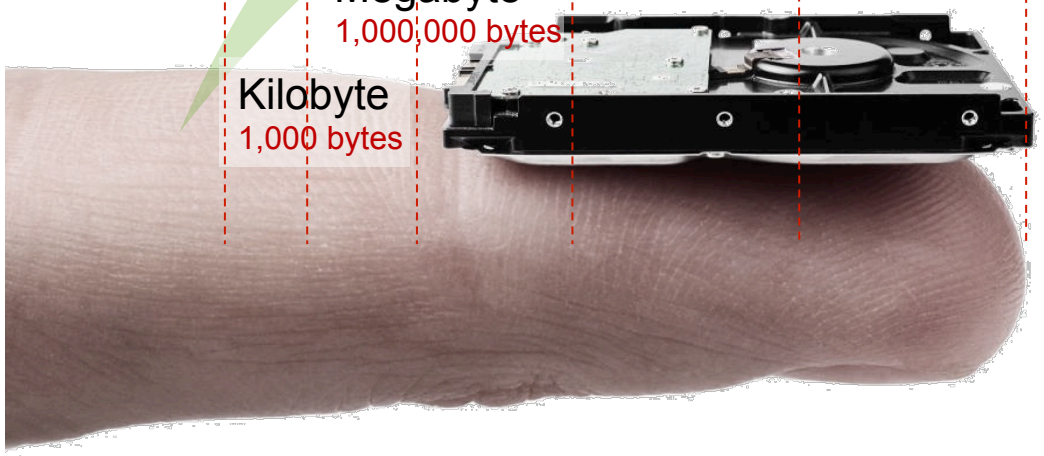
Petabyte
1,000,000,000,000,000 bytes

Terabyte
1,000,000,000,000 bytes

Gigabyte
1,000,000,000 bytes

Megabyte
1,000,000 bytes

Kilobyte
1,000 bytes



Amount of digitally stored information in the world (2010)

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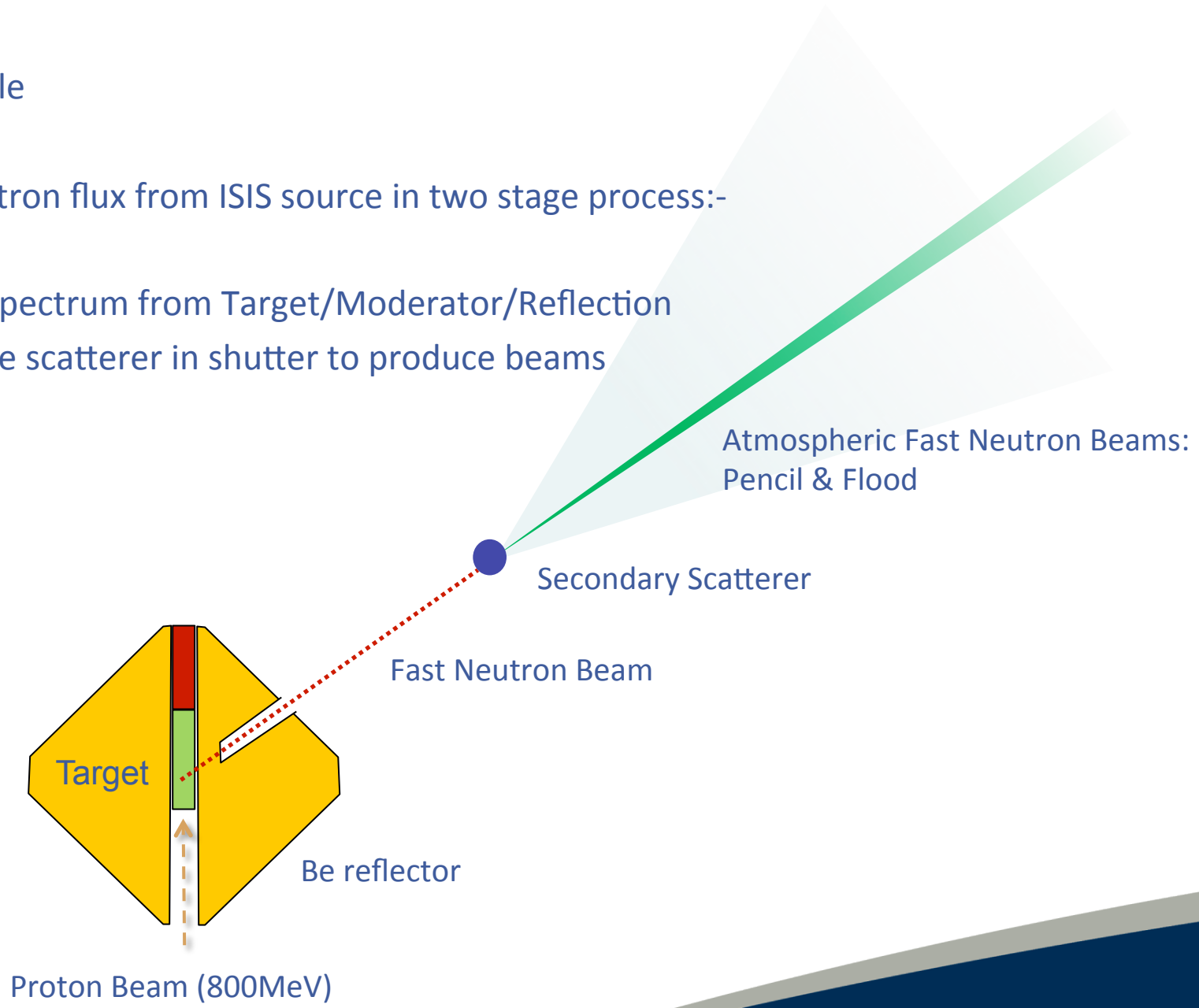
Source: Cisco


ISIS Neutron Source
Rutherford Appleton Lab

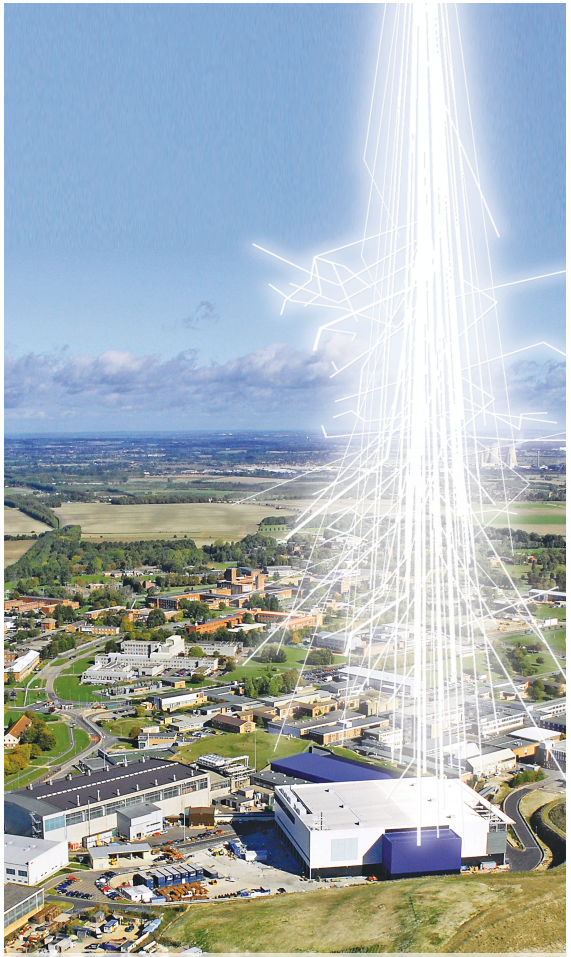
## Basic Principle

Use fast neutron flux from ISIS source in two stage process:-

- Harden spectrum from Target/Moderator/Reflection
- Illuminate scatterer in shutter to produce beams



| Primary Beam Specification |
| --- |
| An energy bandwidth of 0-800MeV |
| The fast neutron flux (>1MeV) should match the QinetiQ QARM model for the atmospheric neutron spectrum |
| The integrated flux above (10MeV) should be of the order of $1\times10^6$ n/cm$^2$/s |
| The thermal neutron flux should be of the same order $1\times10^6$ n/cm2/s and removable via filters |
| A highly collimated beam up to as large area beam as possible (currently of order 25cm×25cm) |
| The gamma-ray flux be less than 1krad/day, but ISIS should aim for <1krad/week |
| Variable collimation below a certain size (25cm×25cm) to down to a size of ~2x2cm$^2$ |
| A ‘flood’ beam with 2-3 sizes up to a maximum of 100cm×100cmwith flux of the order of $1\times10^4$ n/cm2/s |
| Ability to change to flux by two orders of magnitude (ideally $10^5$ – $10^7$ n/cm2/s integrated flux above 10MeV for the collimated beam and $10^3$ – $10^5$ n/cm2/s for the flood room) |



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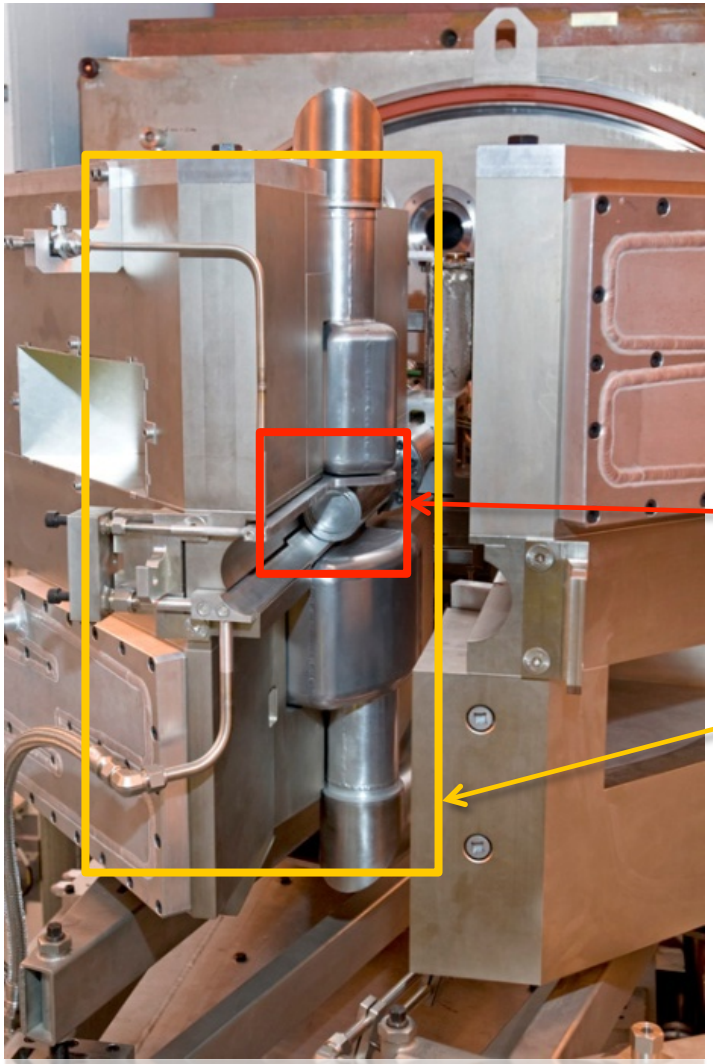
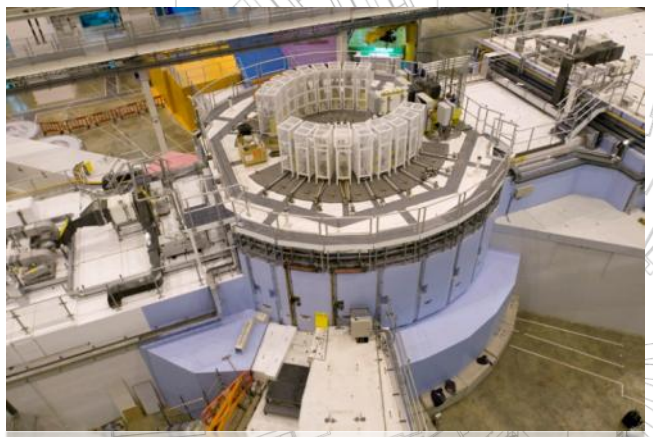
# ISIS Second Target Station: Fast Neutrons





Target

Be reflector

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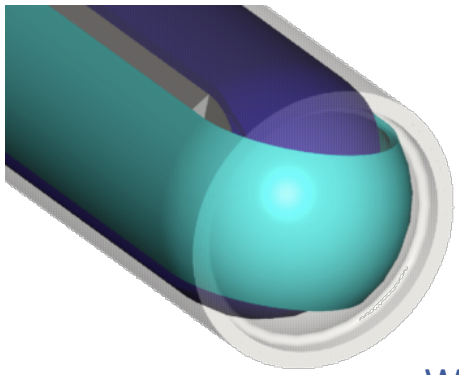
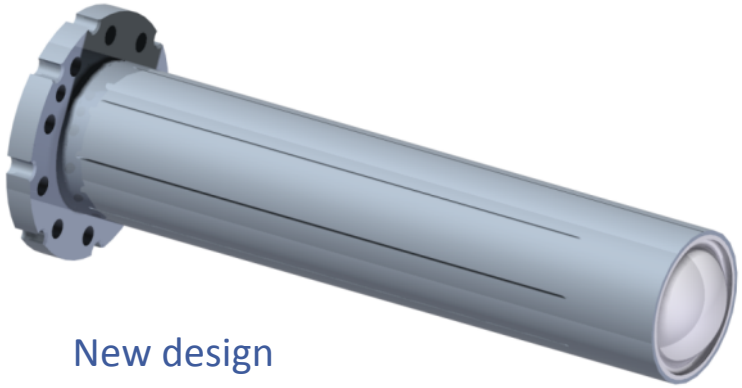
# ISIS Second Target Station: Fast Neutrons

- ChipIr is more sensitive to target/moderator/ reflector changes

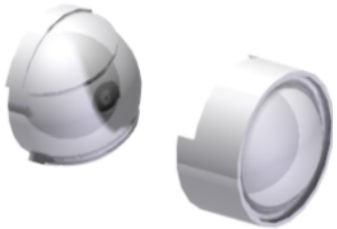


Water flow across front face



New design

which increases cooling on front face



Tantalum end cap and water flow guide

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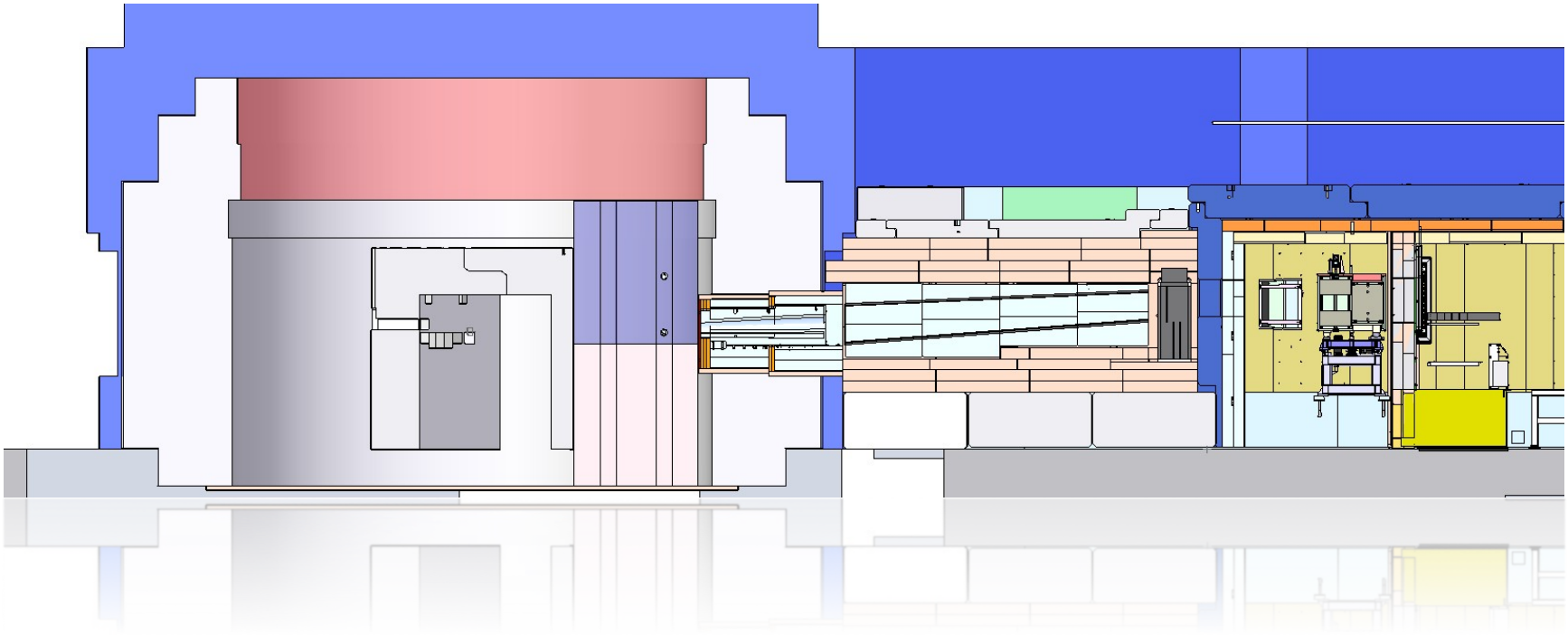
# ISIS Second Target Station: Fast Neutrons

- Target/moderator/reflector illuminated shutter/insert/front end
- Flux and spectrum optimised using Comblayer (Stuart Ansell) [MCNPX]



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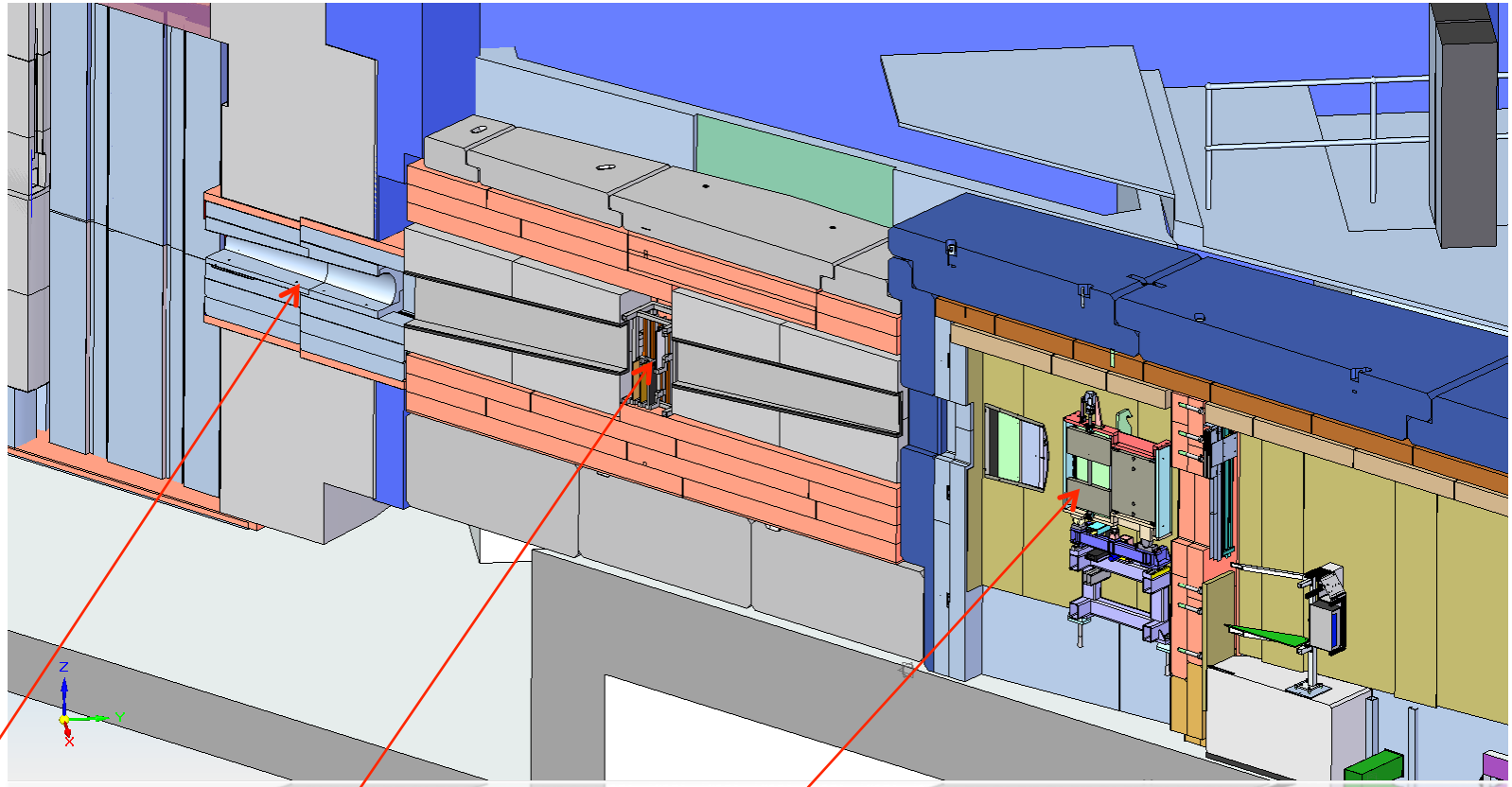
# ISIS Second Target Station: Fast Neutrons

- Shutter and Front End are illuminated by the fast neutrons




Inset

Filter Set

Collimator

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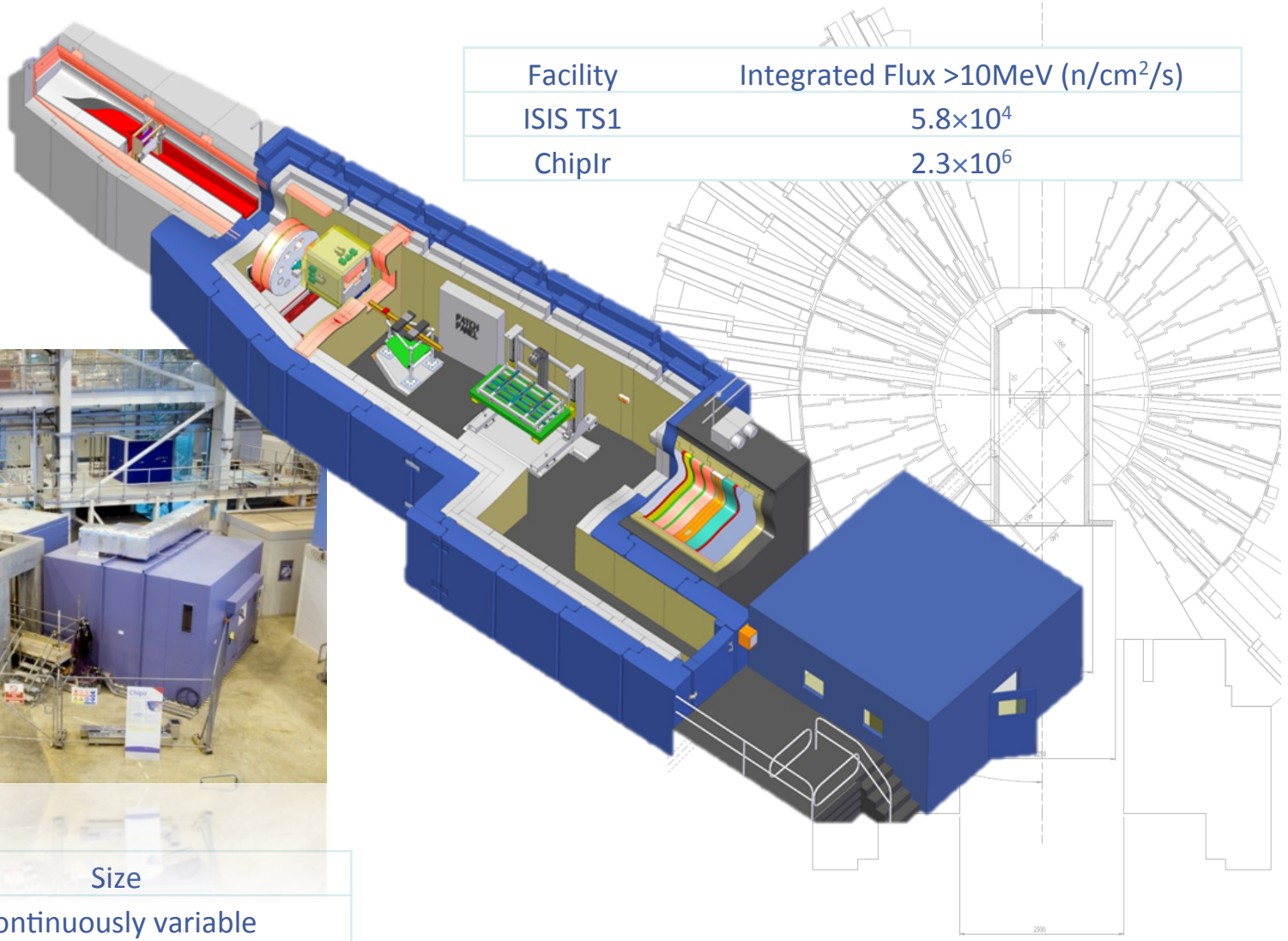
| Facility | Integrated Flux >10MeV (n/cm$^2$/s) |
|---|---|
| ISIS TS1 | $5.8\times10^4$ |
| ChipIr | $2.3\times10^6$ |



| Beam | Size |
|---|---|
| Collimated | Continuously variable<br>250mm×250mm<br>to 1mm×1mm |
| Flood | Fixed sizes<br>1000m×1000mm<br>500mm×500mm |

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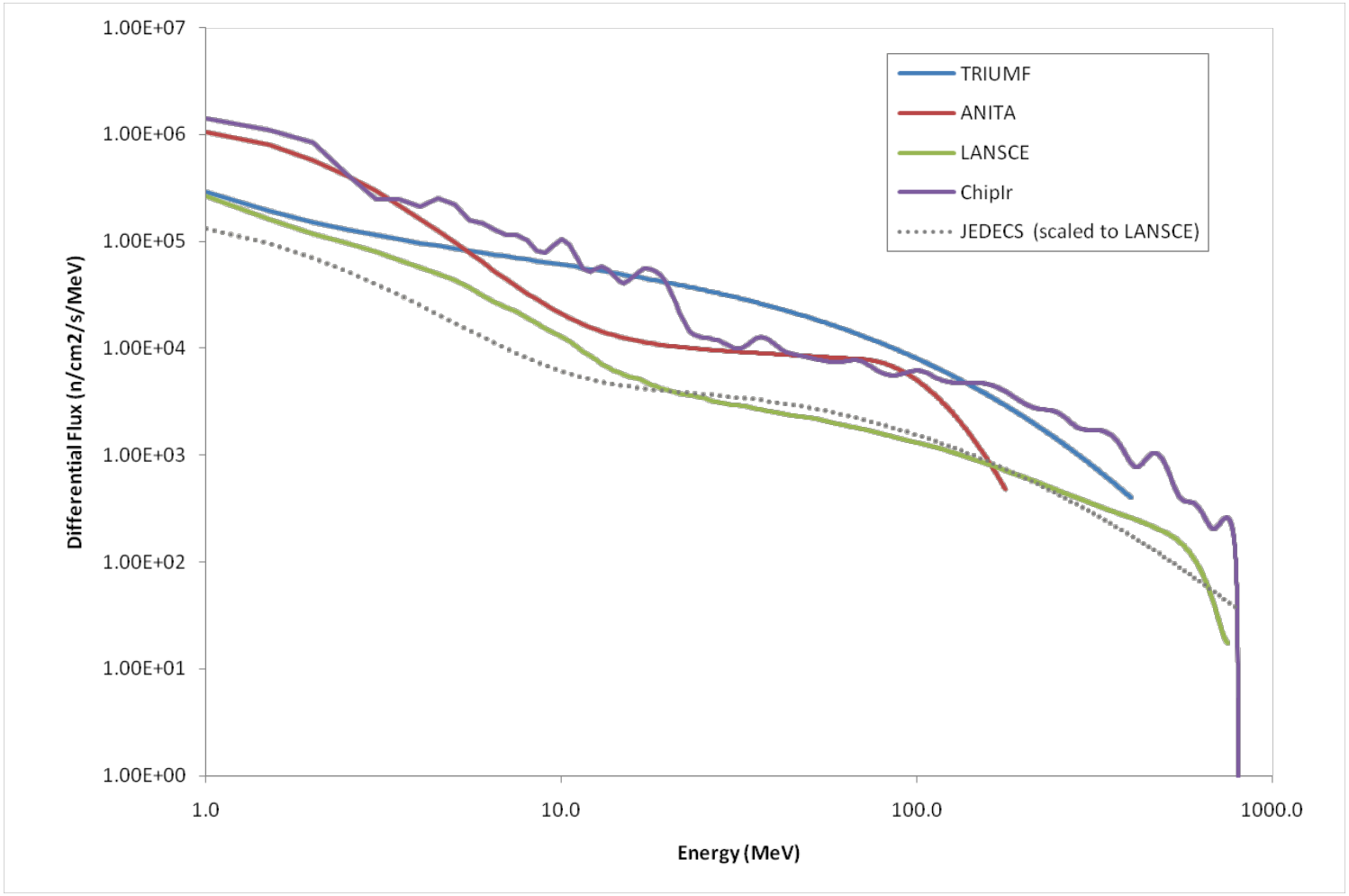


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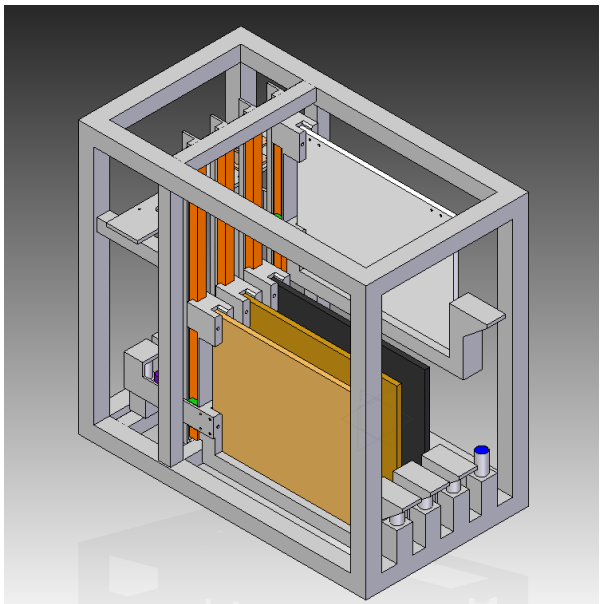
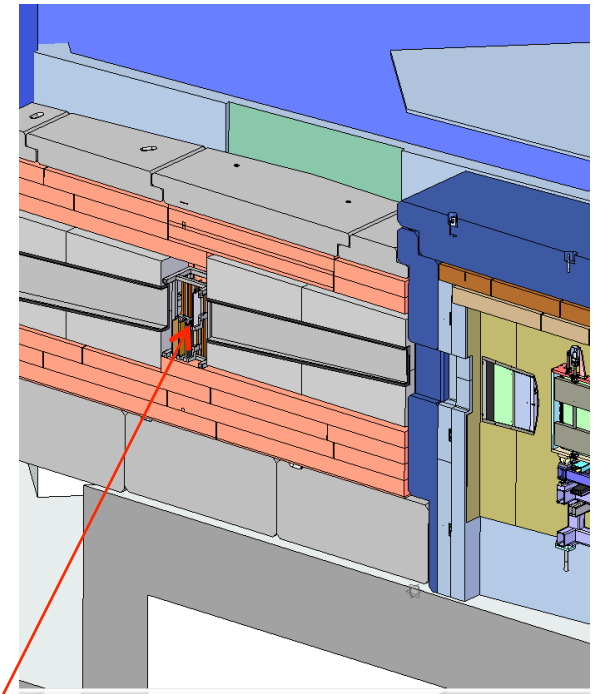
# ISIS Second Target Station: Fast Neutrons

- Filters allow modification of the beam



4 x Automatic Filter



Filters in Situ

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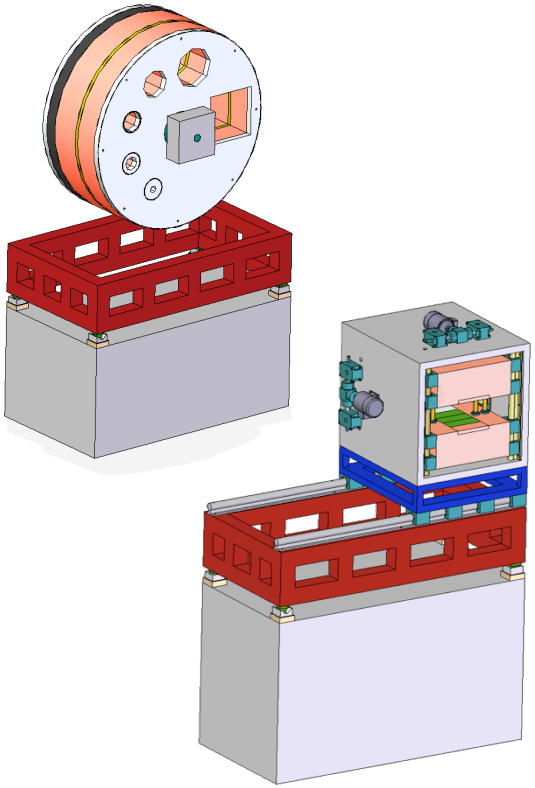

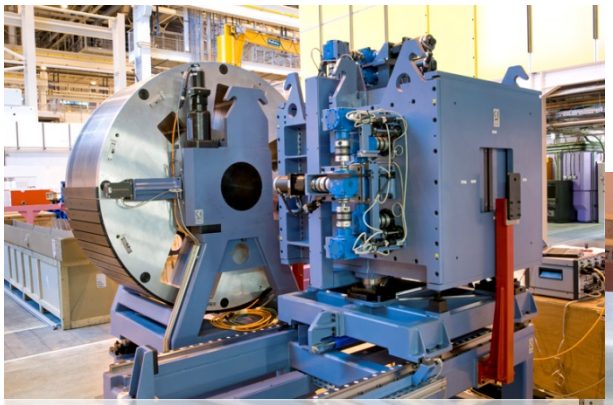

| Beam | Size |
|---|---|
| Collimated | Continuously variable<br>250mm×250mm<br>to 1mm×1mm |
| Flood | Fixed sizes<br>1000m×1000mm<br>500mm×500mm |

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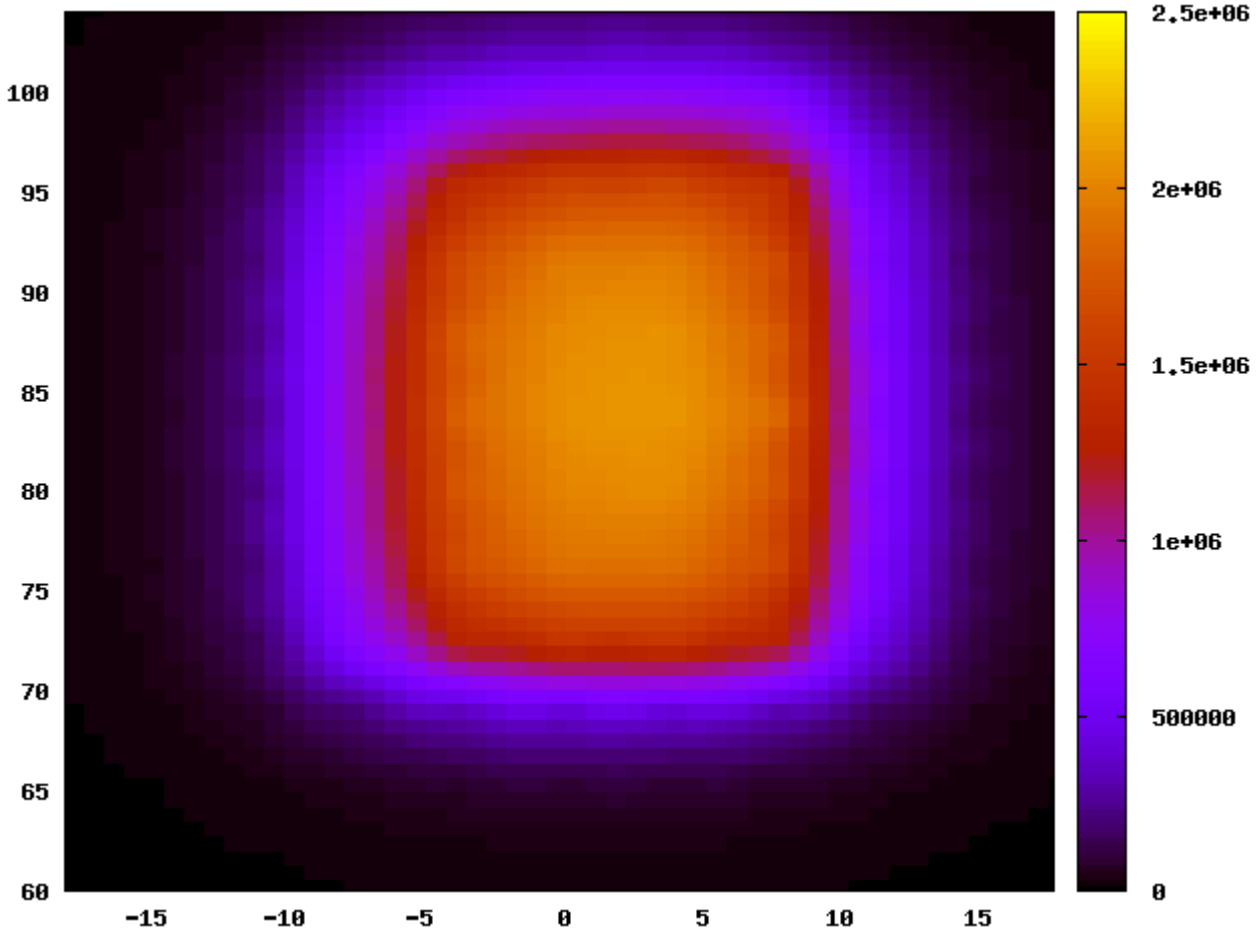


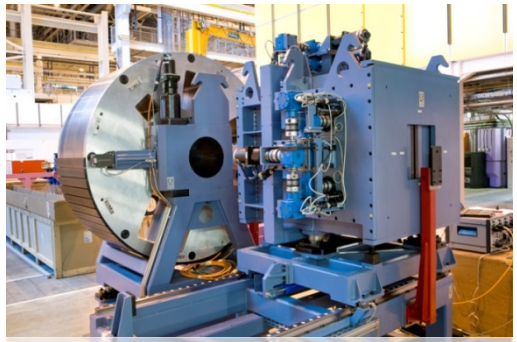

17cm by 25cm beam

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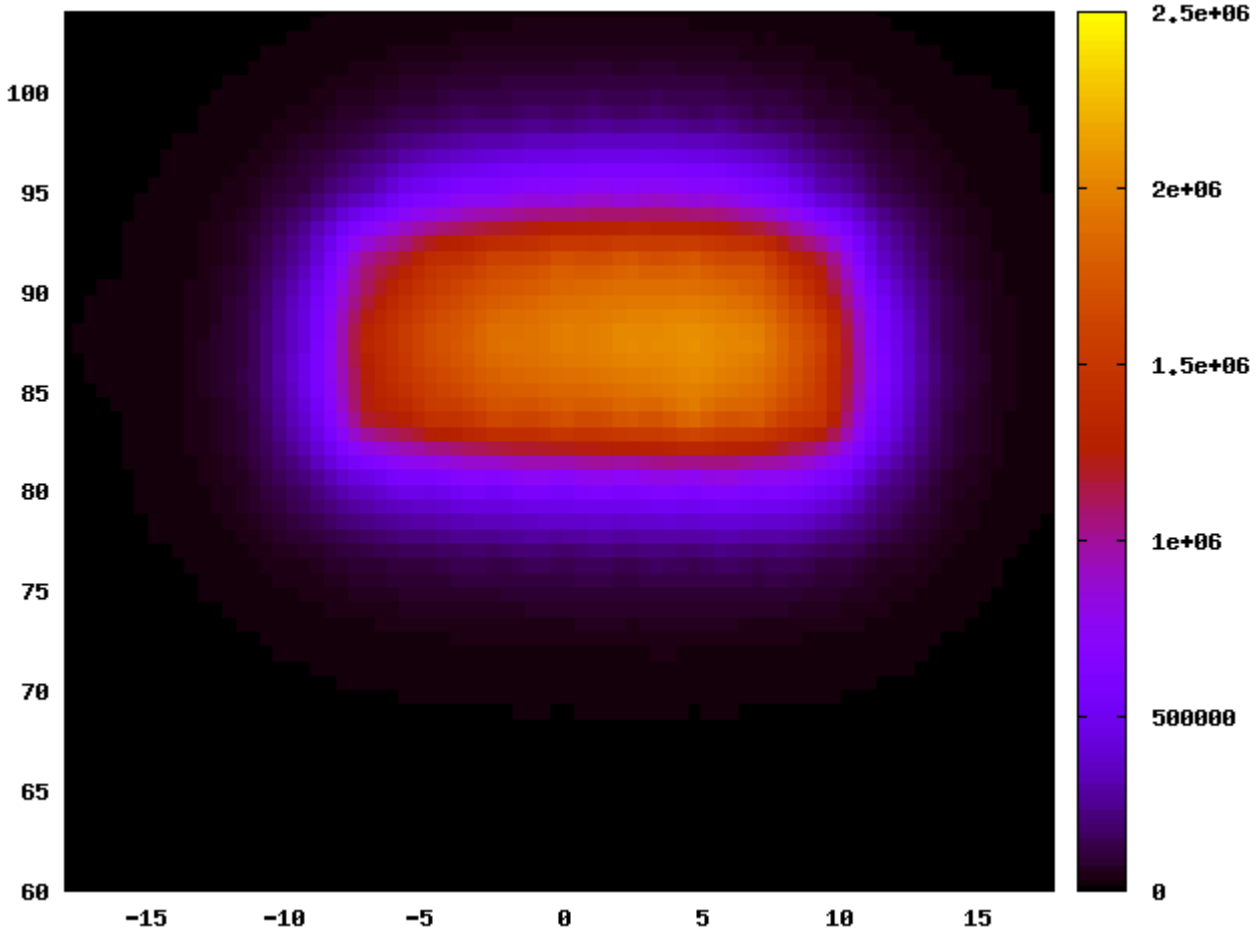


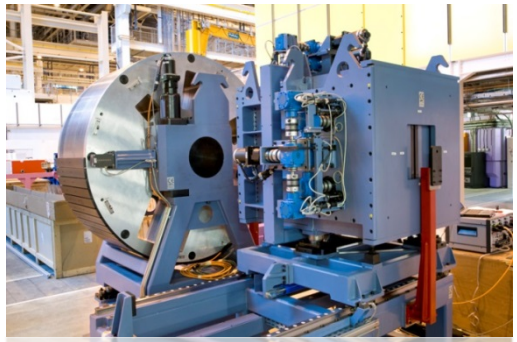

17cm by 12cm beam

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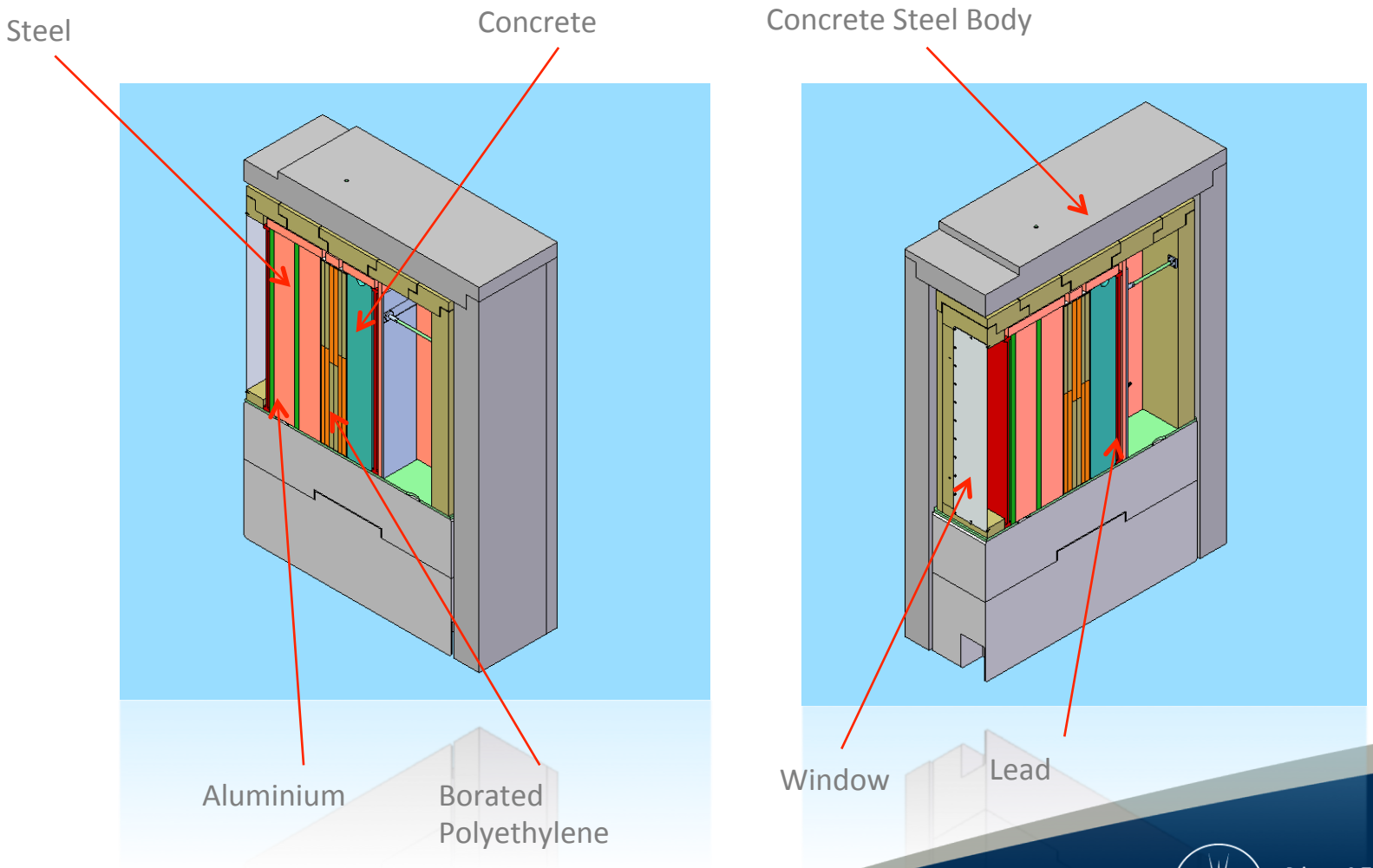
# ISIS Second Target Station: Fast Neutrons

- Beamstop aims to reduce background in the blockhouse

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# ISIS Second Target Station: Fast Neutrons

- Blockhouse: Low background in Hall

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# ISIS Second Target Station: Fast Neutrons

- Blockhouse: DUT positions/Collimator/Beamstop

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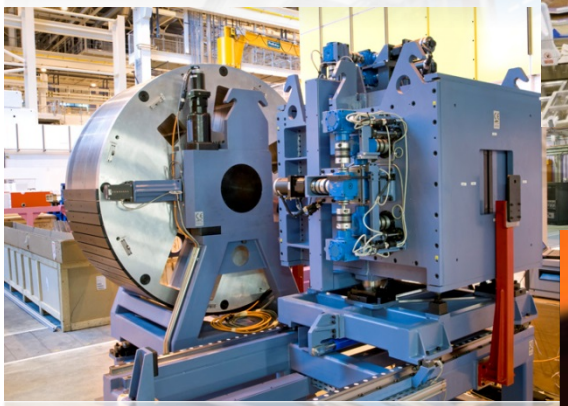
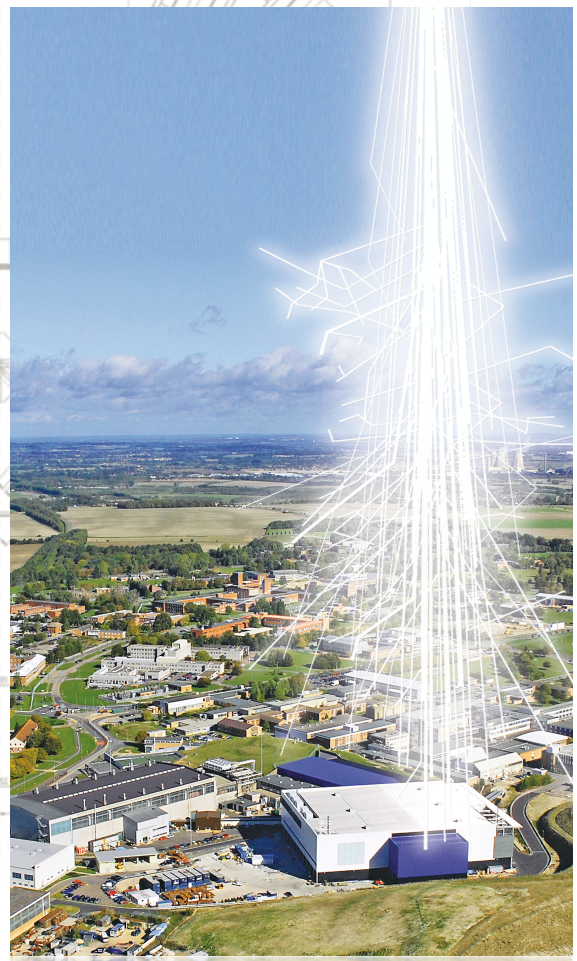
Under Construction




May 2014



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