Vacuum system basics
for Instrument Engineers

ISNIE Summer School

2018

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A word from our sponsor ISNIE ;)

How this course works …

maybe

Overall objectives

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To increase the **awareness** of engineers to the importance of considering the engineering constraints and **best practices** related vacuum systems as part of the design of neutron instruments.

....such that, designers are aware of **important issues**, may **avoid commonly occurring mistakes**, and **communicate effectively with system experts**,

....in order to produce neutron instruments which provide **superior scientific capability** at **lower installation and operational costs** (through improved maintainability).

Our approach to learning in this course

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Make it real …. And work from there

- Relevance
- Interaction
- Engagement

Real life examples

Exploration
Worked examples

Technique
And applied theory

In each implementation we will consider

Installation specific

System Requirements

- Vacuum level
- Pumped volume
- Cycles

Constraints

- Radiation hardness
- Serviceability

Installation specific

Analysis

- Techniques
- Theory

Solutions

- Equipment choice
- Packaging
- Sealing

Game plan

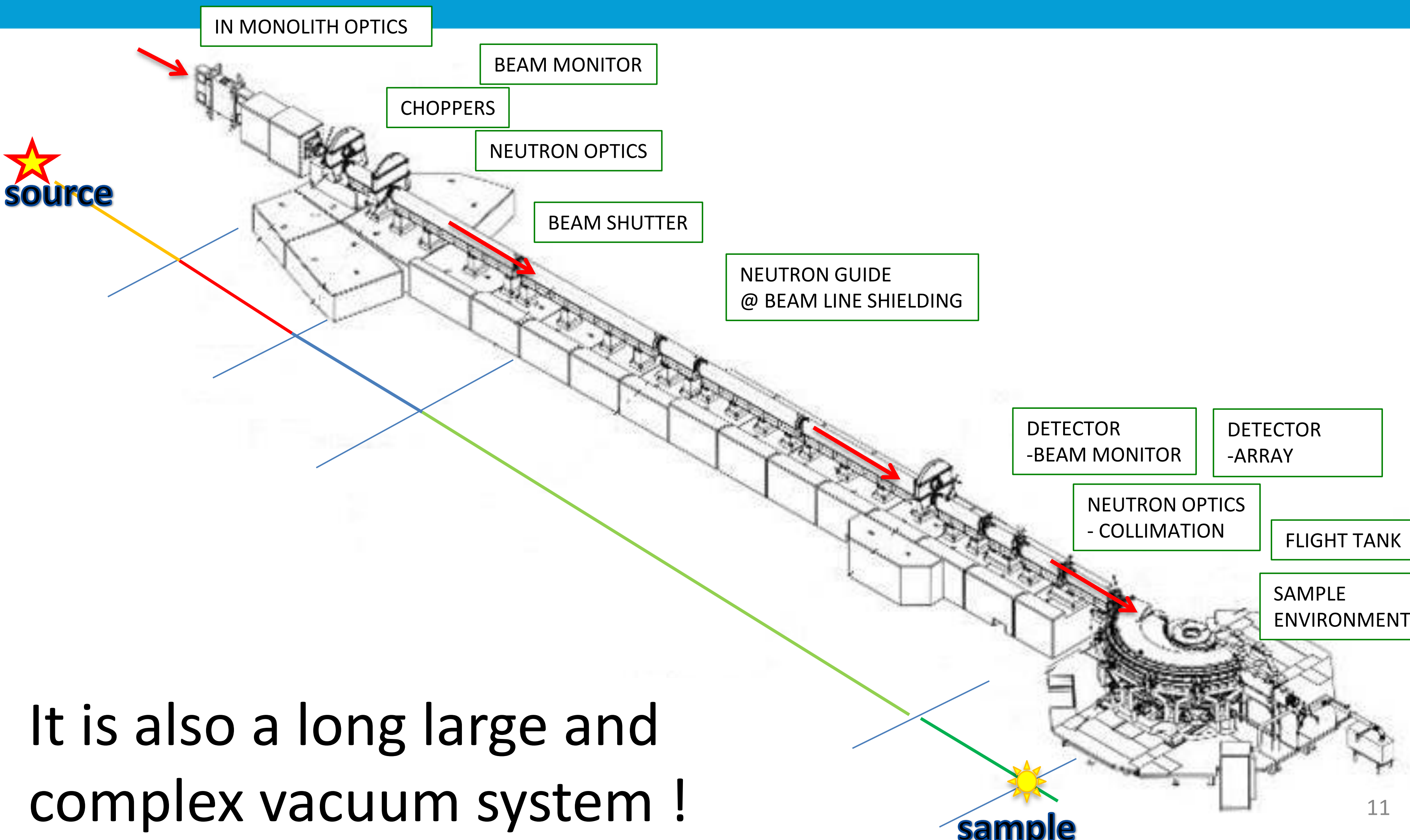
Part 1
Introduction (Iain)
30mn
- Context
- Case studies

Part 2 (Marcello & Lothar) 45mn + 30mn
Approach & Solutions
Vacuum technology

Part 3 Wrap up
(Marcello) 15mn
Take away

Neutron instruments
an introduction (?)

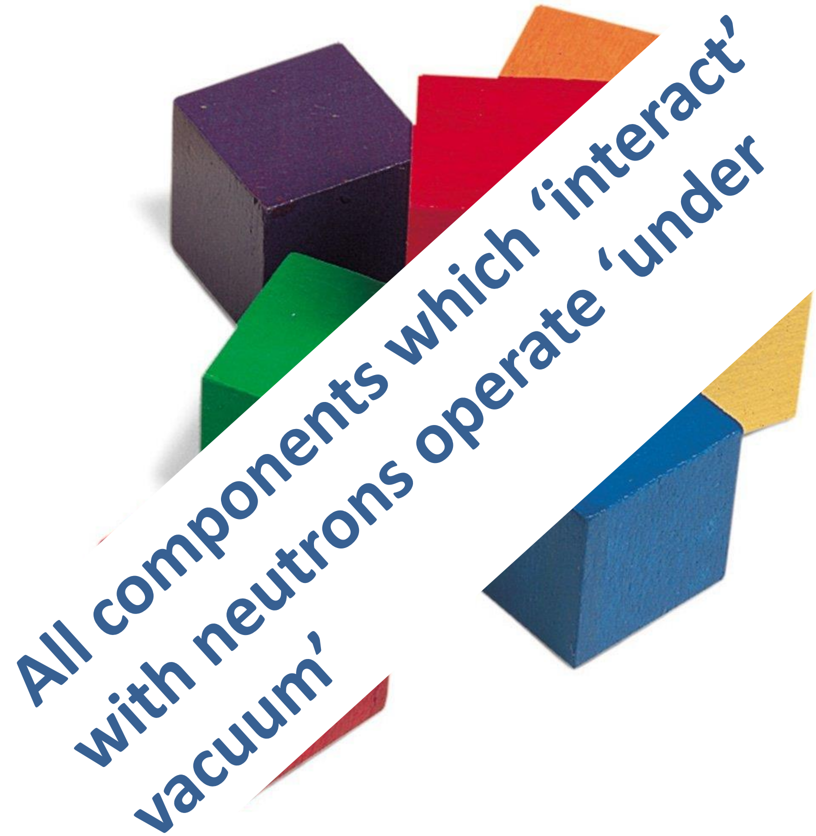
A typical neutron scattering instrument …



It is also a long large and complex vacuum system !

Building blocks of neutron scattering instruments

- Neutron Source
- Neutron transport
- Neutron conditioning
- Sample exposure
- Detector
- Shielding
- Control
- Data collection
- Data Treatment



There to be used
High performance + high maintainability

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Complex Installed systems

Hazardous environment

Limited access opportunities

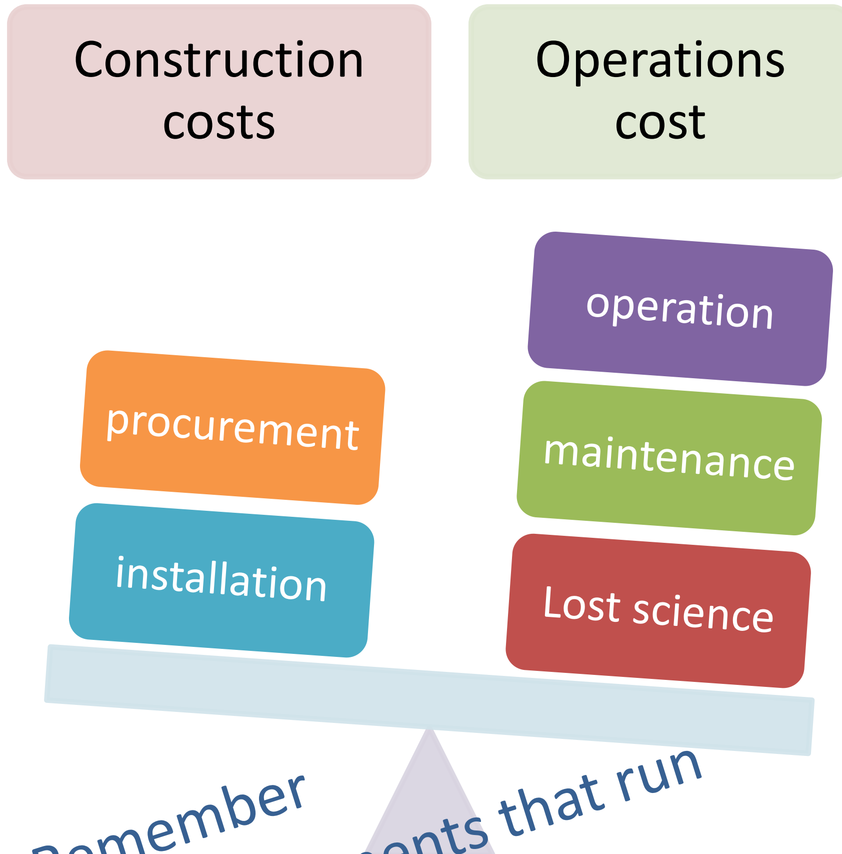
A challenging environment to operate equipment

A engineering balancing act

Construction cost / Operating cost

Scientific Performance / Availability

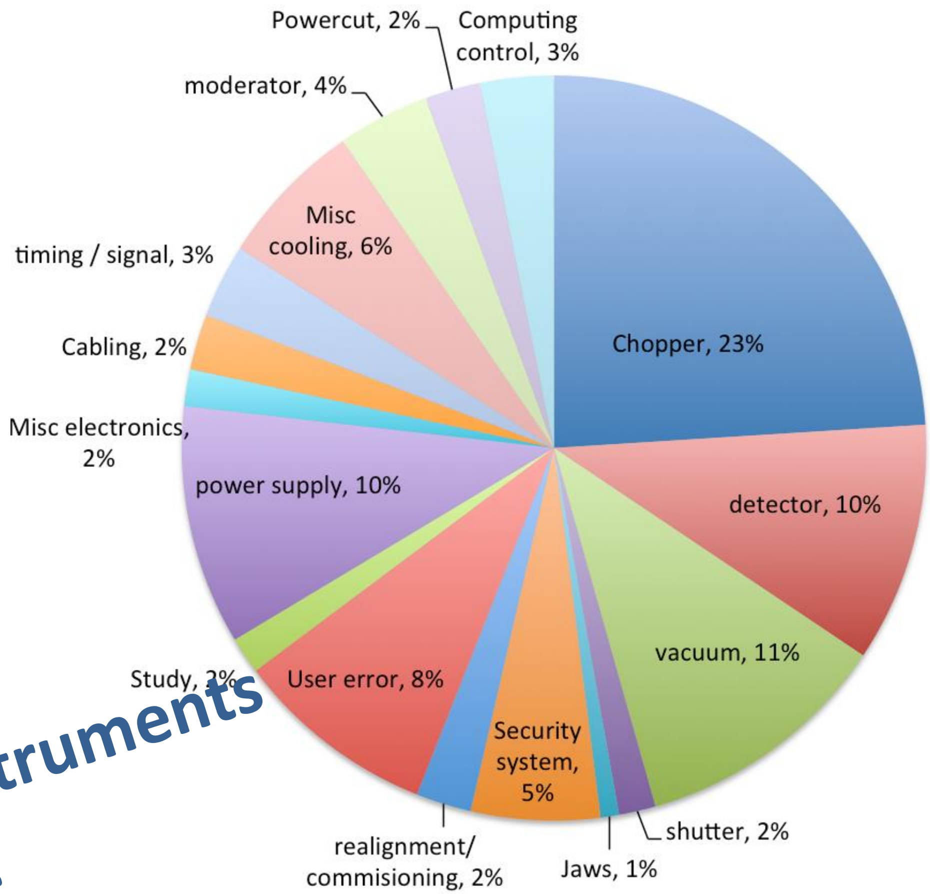
- Vacuum systems represent
  - 5-10% of the construction cost
  - But also 5-10% of maintenance costs



Remember
Only instruments that run produce science !

Down time

- Issues with vacuum are the #2 or #3 most frequent ‘cause’ of instrument shutdown.
- A significant part of downtime



Remember only operating instruments produce science !

Why vacuum?

Because …

Increased instrument Performance

– Reduced transmission losses
  - Source – Sample
  - Sample - Detector

Increased Safety

– Reduced air activation

Increased operability

– Avoid corrosion

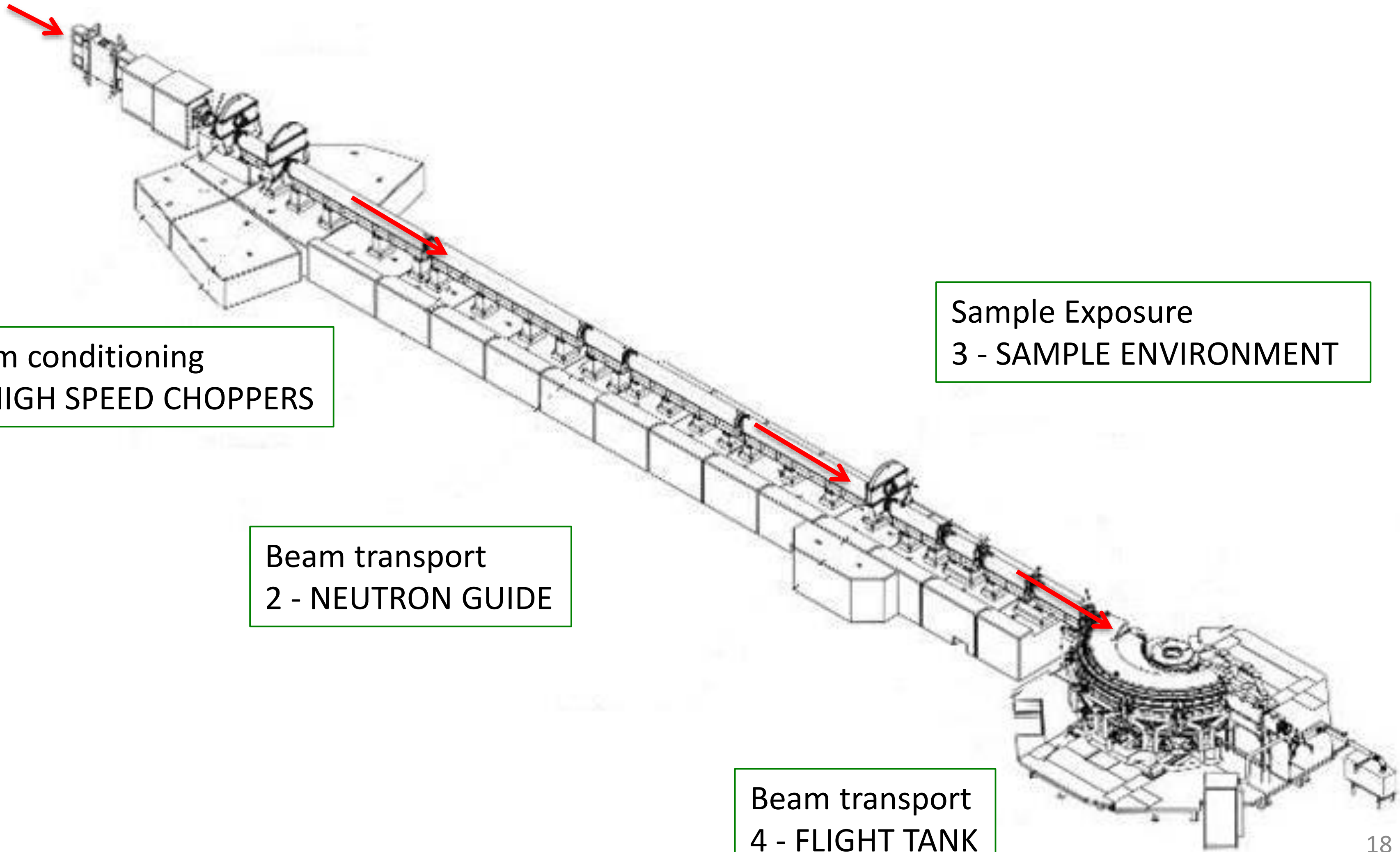
Vacuum systems make instruments better and helps keep them that way

Consideration of vacuum related issues in the design process is vital.

Reality

Case studies

Typical vacuum system implementations



Beam conditioning
1 - HIGH SPEED CHOPPERS

Sample Exposure
3 - SAMPLE ENVIRONMENT

Beam transport
2 - NEUTRON GUIDE

Beam transport
4 - FLIGHT TANK

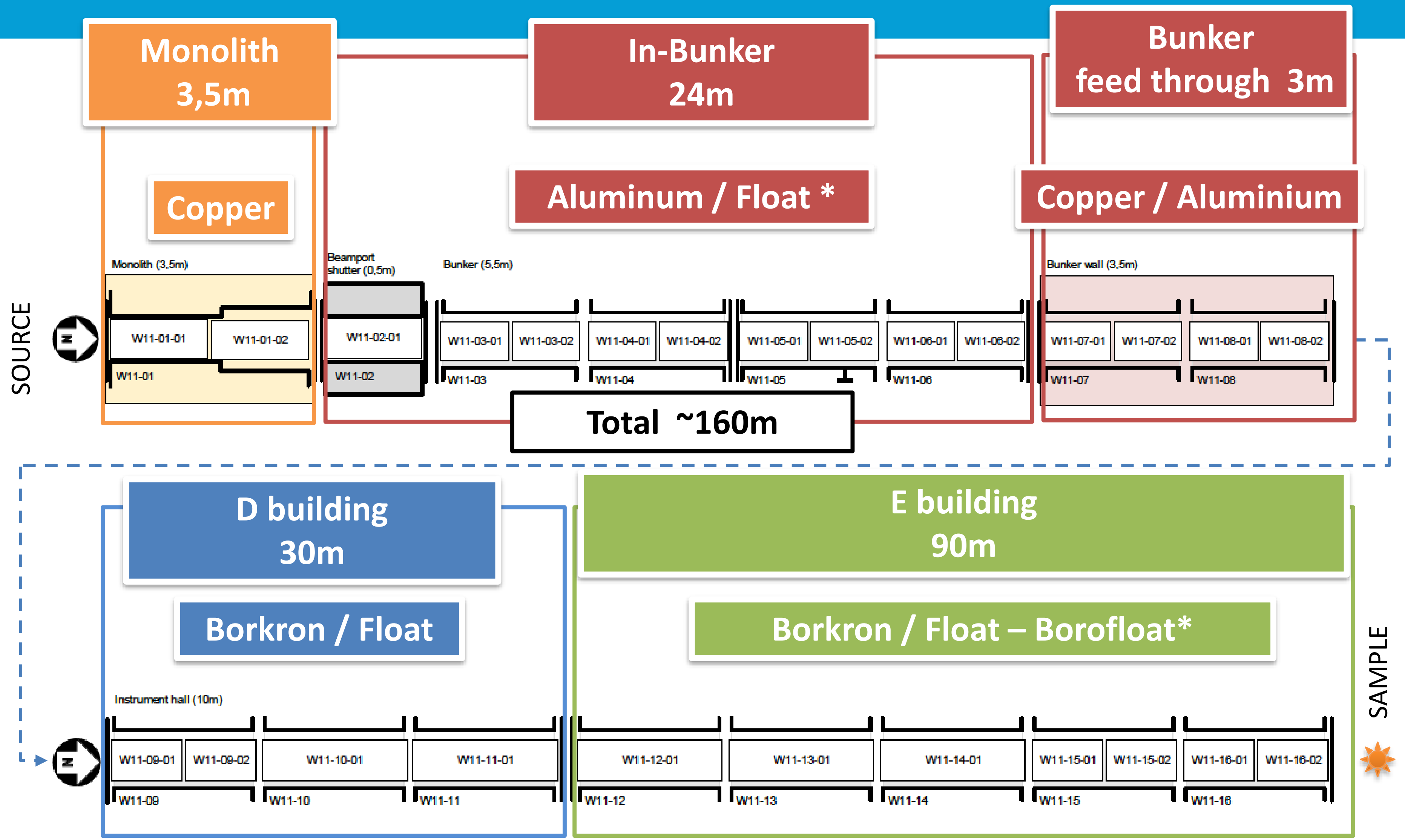
Instrument vacuum systems
Case study – Neutron guide systems

Neutron guides
What is it ?

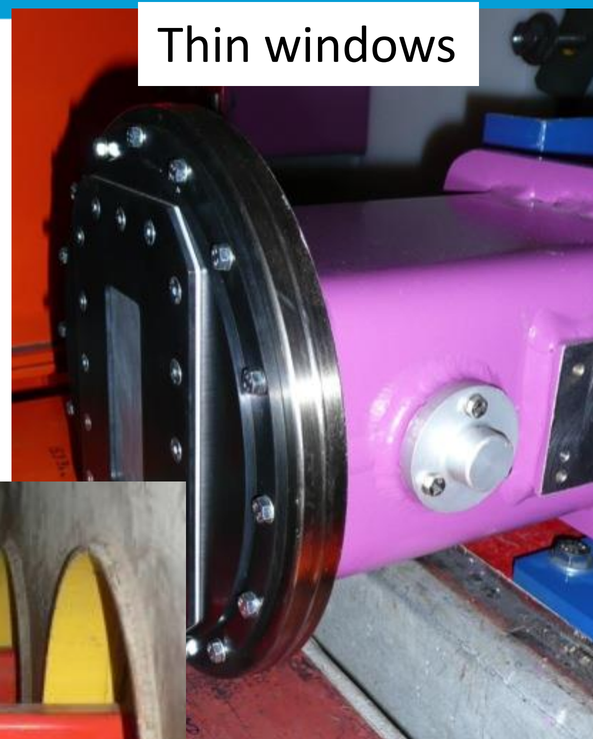
- Function
  - Beam transport
  - Energy selection
- How do they operate ?
  - reflection of neutron beam
- Why vacuum ?
  - Neutron transmission

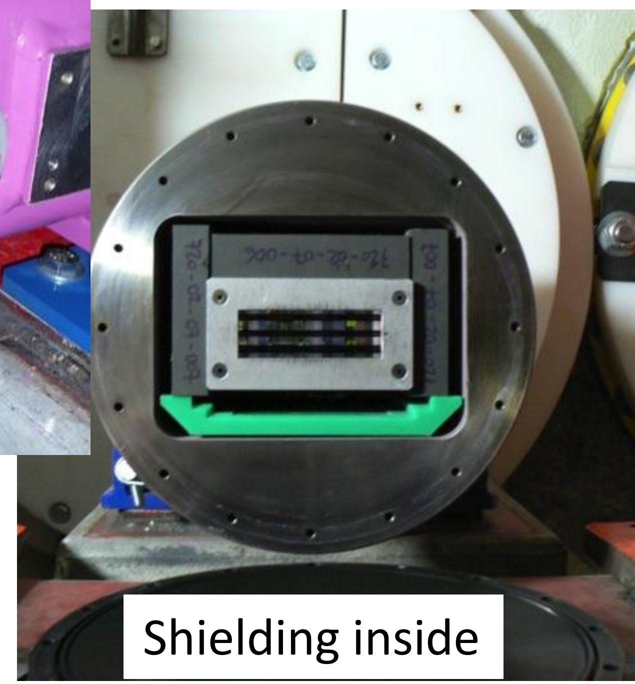
Neutron guides
What is it ?

Neutron guides



Details





Examples
A range of requirements and challenges for vacuum systems

Criteria	Neutron Guide
Vacuum level	Poor
Pumped volume	Moderate
Cycle time	V.Slow
Radiation hardness	High/Mod
Servicability	V.Low

Component type	Neutron guide system	
Example	ILL / H14	
Operating vacuum level	1e10-1	mbar
Pumped volume	5	m3
Cycle time	6 months	
Pump down	1 day	
Materials	Steel housing	
	Painted surfaces	
	Glass neutron guide	
	Rubber seals	
Radiation level	High	
Maintenance period	5 years	

Particularity

Housing has a section of 100cm2 and a length of 100m

Vacuum systems case study
- high speed neutron choppers

Neutron chopper
What is it ?

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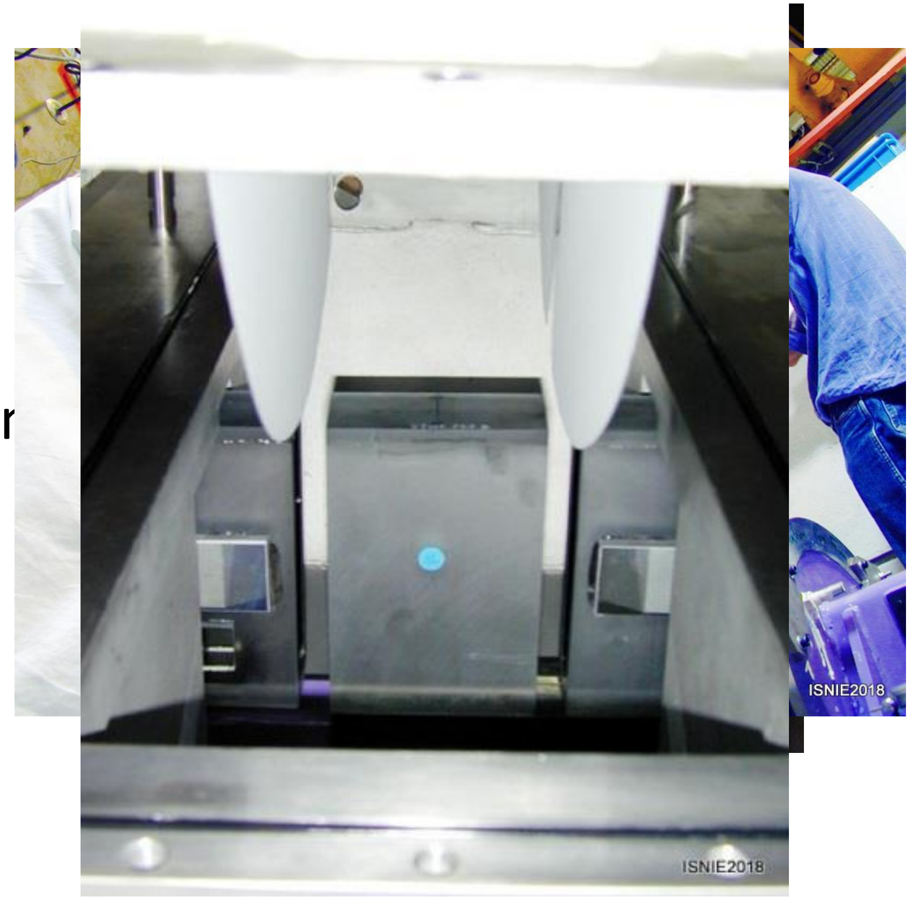
- Function
  - Pulse shaping
  - Energy selection
- How do they operate ?
  - Interception of neutron bear
- Why vacuum ?
  - Neutron transmission
  - Air friction



ILL IN5 CRD

Typical vacuum requirements
High speed choppers

Criteria	HS Choppers
Vacuum level	Good
Pumped volume	Small
Cycle time	V.Slow
Radiation hardness	High
Servicability	Low

Instrument vacuum systems

Component type	Sample environment	
Example		
Operating vacuum level	5e10-6	mbar
Pumped volume	0.1	m3
Cycle time	1 day	
Pump down	1 hour	
Materials	Steel housing aluminium	
Radiation level	High	
Maintenance period	months	

Instrument vacuum systems
Case study – Sample environment

Sample environments
What is it ?

- Function
  - Environmental conditioning
- How do they operate ?
  - Various !
- Why vacuum ?
  - Neutron transmission
  - Heat insulation
- Access
  - Good

- Cyrostat
- Furnace
- Cryomagnet
- Pressure cell
- …..

Sample environment
Installation context

- Where are they located in a beamline
- What is the installation context
- What are radiation levels
- How easy it is to access
- Why are they operating under vacuum?
- What are typical vacuum requirements for this type of system

Typical vacuum requirements
Sample environment

Criteria	Sample environment
Vacuum level	Very good
Pumped volume	V.Small
Cycle time	Fast
Radiation hardness	High
Servicability	High

Component type	High speed neutron chopper	
Example	ILL / IN5 CRD M-Chopper	
Operating vacuum level	5e10-4	mbar
Pumped volume	0,1	m3
Cycle time	6 months	
Pump down	1 day	
Materials	Steel housing	
	Painted surfaces	
	Glass neutron guide	
	Aluminium rotor	
Radiation level	High	
Maintenance period	5 years	

Instrument vacuum systems
Case study – Flight vessel

Flight vessels
What is it ?

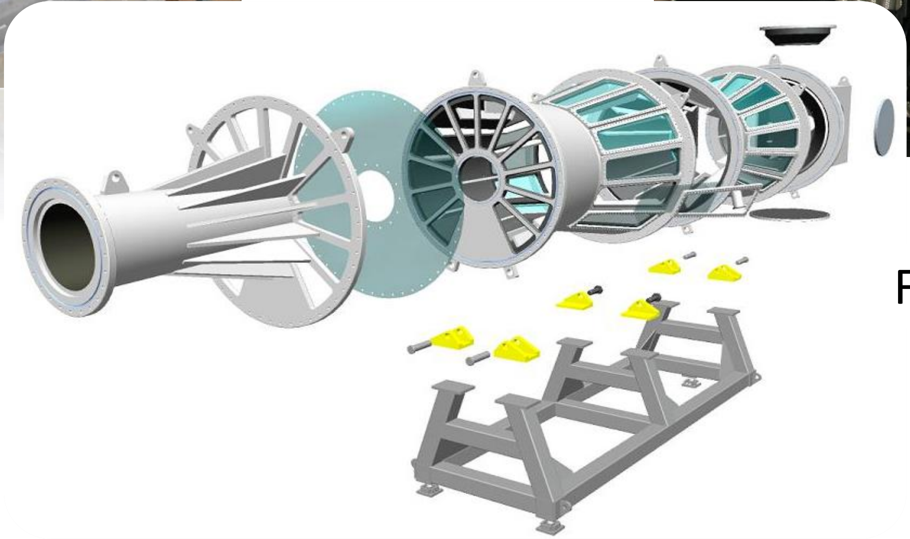
- Function
  - Avoid air scattering
- How do they operate ?
  - Evacuate flight path
- Why vacuum ?
  - Neutron transmission
- Access
  - Poor

Flight vessel
Issues

Thin windows

Full of 'stuff'

Feed throughs



geometry

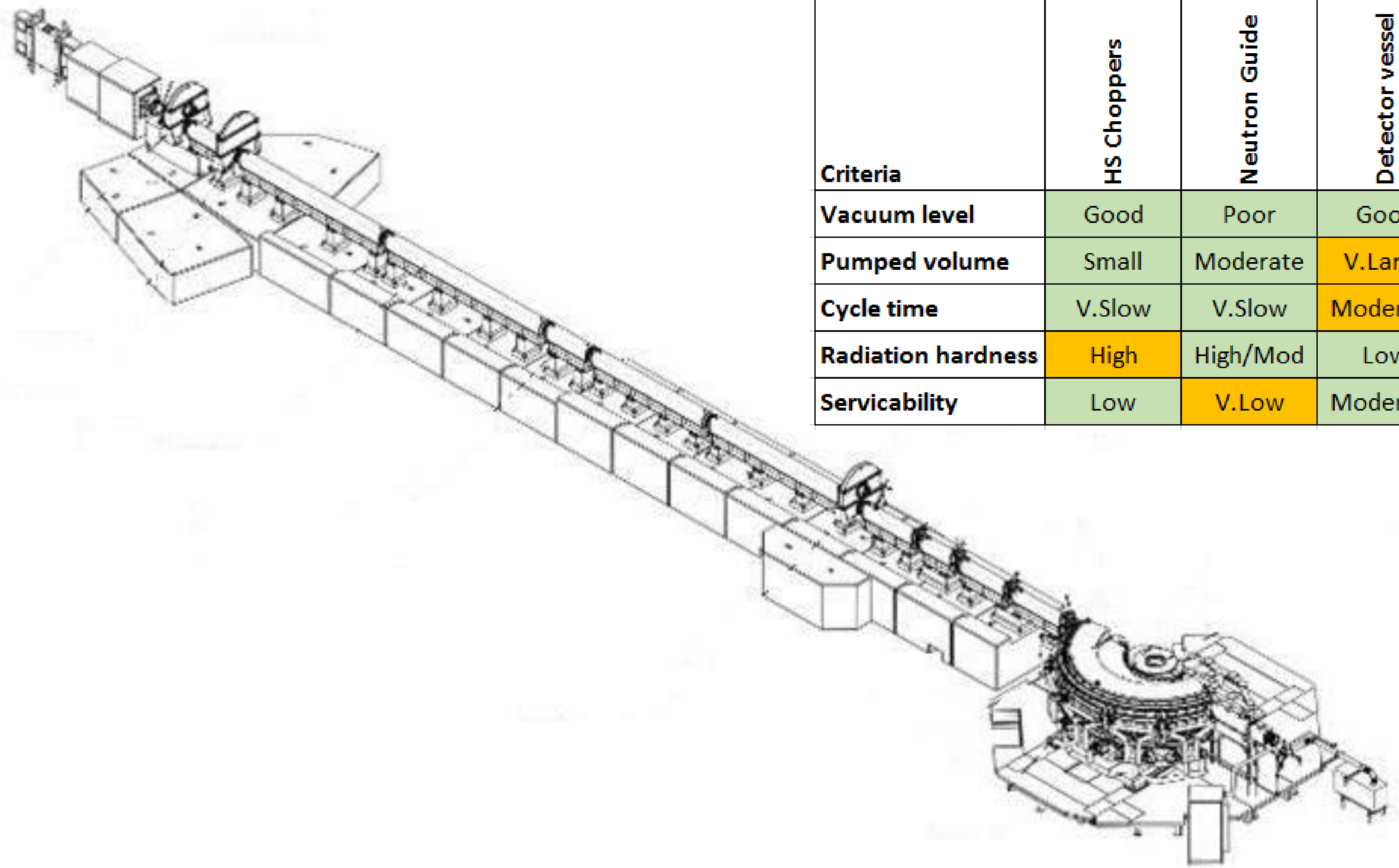
Typical vacuum requirements
Flight vessel

Criteria	Detector vessel
Vacuum level	Good
Pumped volume	V.Large
Cycle time	Moderate
Radiation hardness	Low
Servicability	Moderate

Instrument vacuum systems

Component type	Flight vessel	
Example		
Operating vacuum level	1e10-3 > 10e-6 ?	mbar
Pumped volume	30m3	m3
Cycle time	1 month	
Pump down	1 day	
Materials	Steel aluminium boron carbide rubber polyethene	
Radiation level	High	
Maintenance period	months	

A range of requirements and challenges for vacuum systems

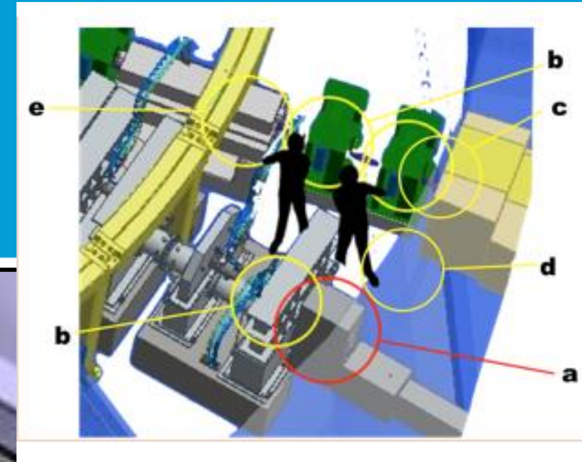


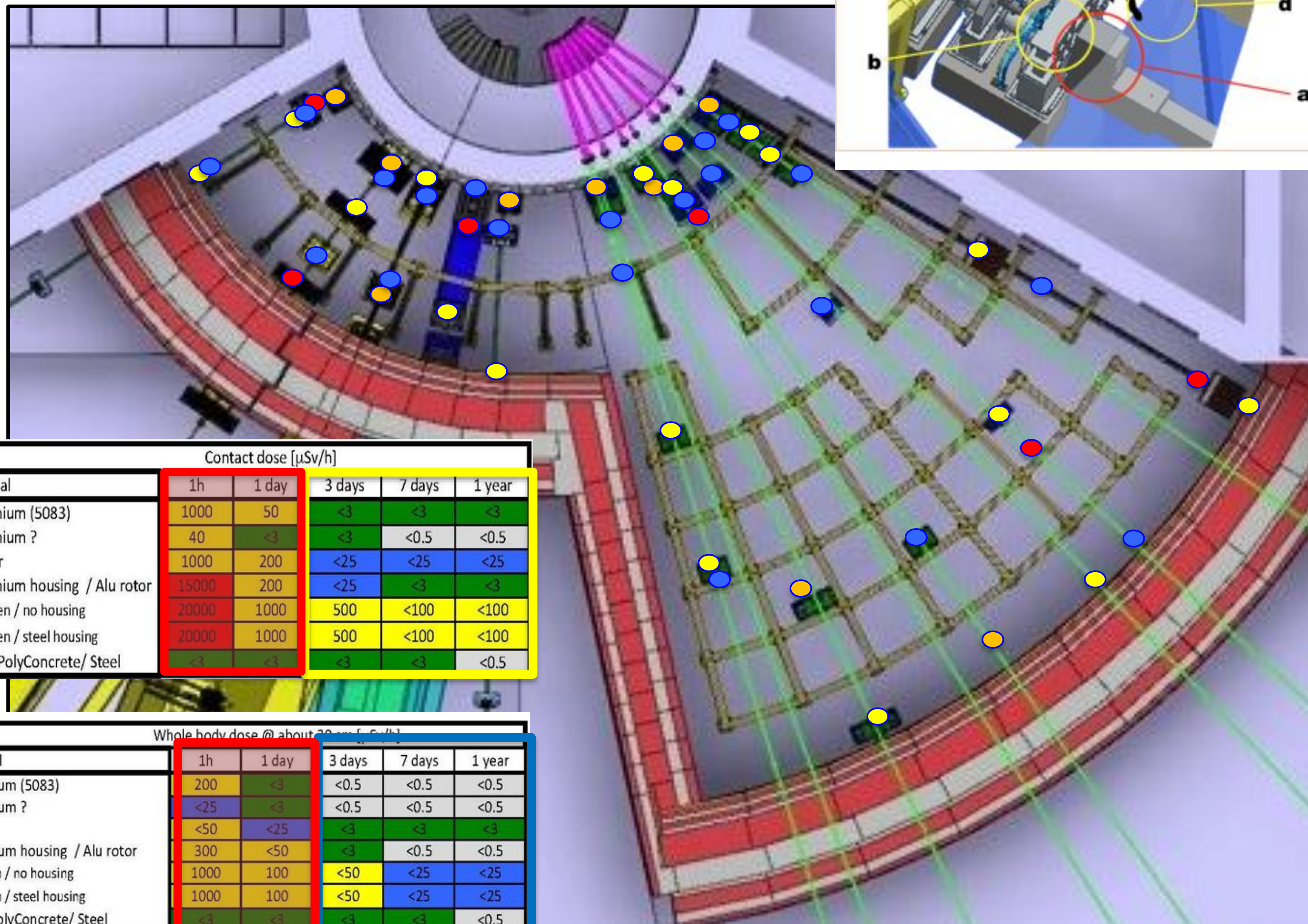
Criteria	HS Choppers	Neutron Guide	Detector vessel	Sample environment
Vacuum level	Good	Poor	Good	Very good
Pumped volume	Small	Moderate	V.Large	V.Small
Cycle time	V.Slow	V.Slow	Moderate	Fast
Radiation hardness	High	High/Mod	Low	High
Servicability	Low	V.Low	Moderate	High

Technical challenges
Radiation

Activation & Damage

Neutron Irradiation Damage & Activation





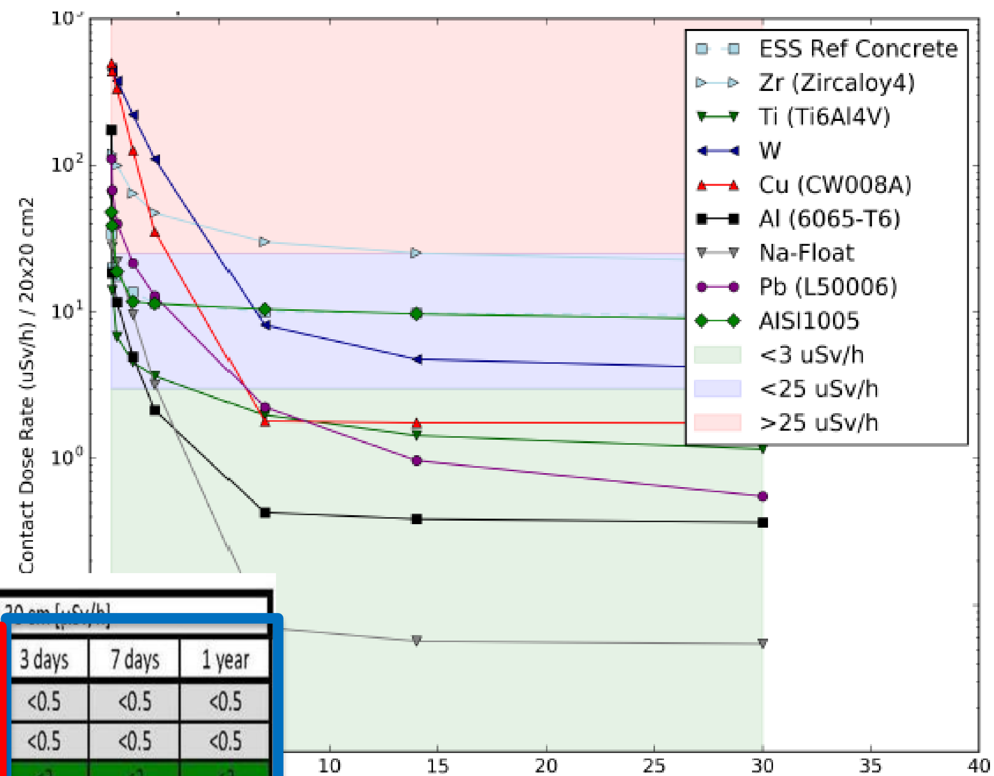
Contact dose [µSv/h]						
Delay following beam shutdown	Material	1h	1 day	3 days	7 days	1 year
Guide upstream of the 1st chopper	Aluminium (5083)	1000	50	<3	<3	<3
Guide downstream	Aluminium ?	40	<3	<3	<0.5	<0.5
Collimator (streaming)	Copper	1000	200	<25	<25	<25
Chopper (no steel)	Aluminium housing / Alu rotor	15000	200	<25	<3	<3
Heavy shutter	Tungsten / no housing	20000	1000	500	<100	<100
T_0 chopper (Tungsten hammer)	Tungsten / steel housing	20000	1000	500	<100	<100
Inside rear bunker wall (with lead)	Lead /PolyConcrete/ Steel	<3	<3	<3	<3	<0.5

Whole body dose @ about 30 cm [µSv/h]						
Delay following beam shutdown	Material	1h	1 day	3 days	7 days	1 year
Guide upstream of the 1st chopper	Aluminium (5083)	200	<3	<0.5	<0.5	<0.5
Guide downstream	Aluminium ?	<25	<3	<0.5	<0.5	<0.5
Collimator (streaming)	Copper	<50	<25	<3	<3	<3
Chopper (no steel)	Aluminium housing / Alu rotor	300	<50	<3	<0.5	<0.5
Heavy shutter	Tungsten / no housing	1000	100	<50	<25	<25
T_0 chopper (Tungsten hammer)	Tungsten / steel housing	1000	100	<50	<25	<25
Inside rear bunker wall (with lead)	Lead /PolyConcrete/ Steel	<3	<3	<3	<3	<0.5

Activation Material

Levers to pull

- Design
- Material choice
- … remote handling



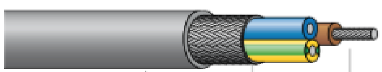
		Whole body dose @ about 20 cm [uSv/h]				
Delay following beam shutdown	Material	1h	1 day	3 days	7 days	1 year
Guide upstream of the 1st chopper	Aluminium (5083)	200	<3	<0.5	<0.5	<0.5
Guide downstream	Aluminium ?	<25	<3	<0.5	<0.5	<0.5
Collimator (streaming)	Copper	<50	<25	<3	<3	<3
Chopper (no steel)	Aluminium housing / Alu rotor	300	<50	<3	<0.5	<0.5
Heavy shutter	Tungsten / no housing	1000	100	<50	<25	<25
T_0 chopper (Tungsten hammer)	Tungsten / steel housing	1000	100	<50	<25	<25
Inside rear bunker wall (with lead)	Lead /PolyConcrete/ Steel	<3	<3	<3	<3	<0.5

Cool down

Damage
Hardened components

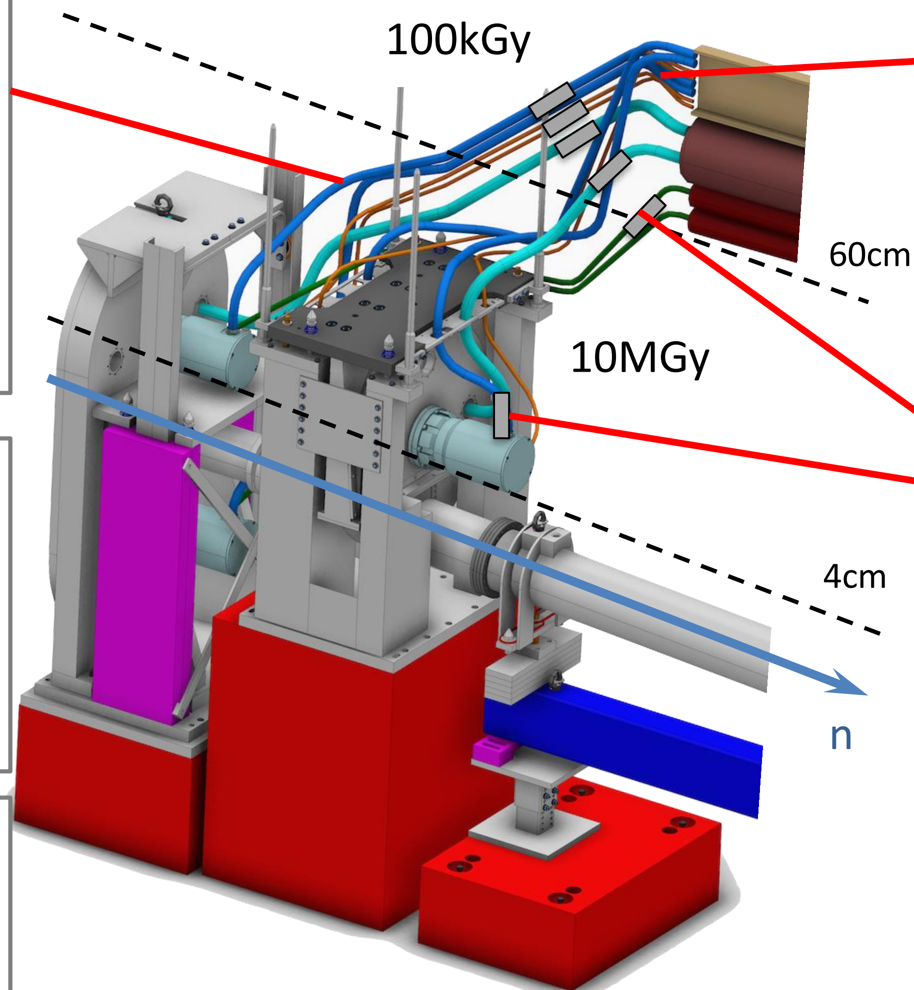
Cables
Radiation spec cables:
Huber Suhner RADOX 125
(3 MGy)

AXON Polyimide TPI
(20MGy)



Sensors
Vibration Sensor:
Vibro-Meter CA901
(10 MGy)

Switches
Mechanical limit switch:
Crouzet 83151 **(10 MGy)**



Cables
Standard cables, PU isolated
(100 kGy, **to be tested!**)

Connectors
Push-Pull, RH ability:
Lemo B-series (Materials:
SS AISI 303 + PEEK plastics)
(10 MGy, to be confirmed!)

Positioning Motors
Stepper motors:
Phytron VSS **(1 MGy)**

Brushless DC motors:
Wittenstein MRSR **(10 MGy)**

Damage material options

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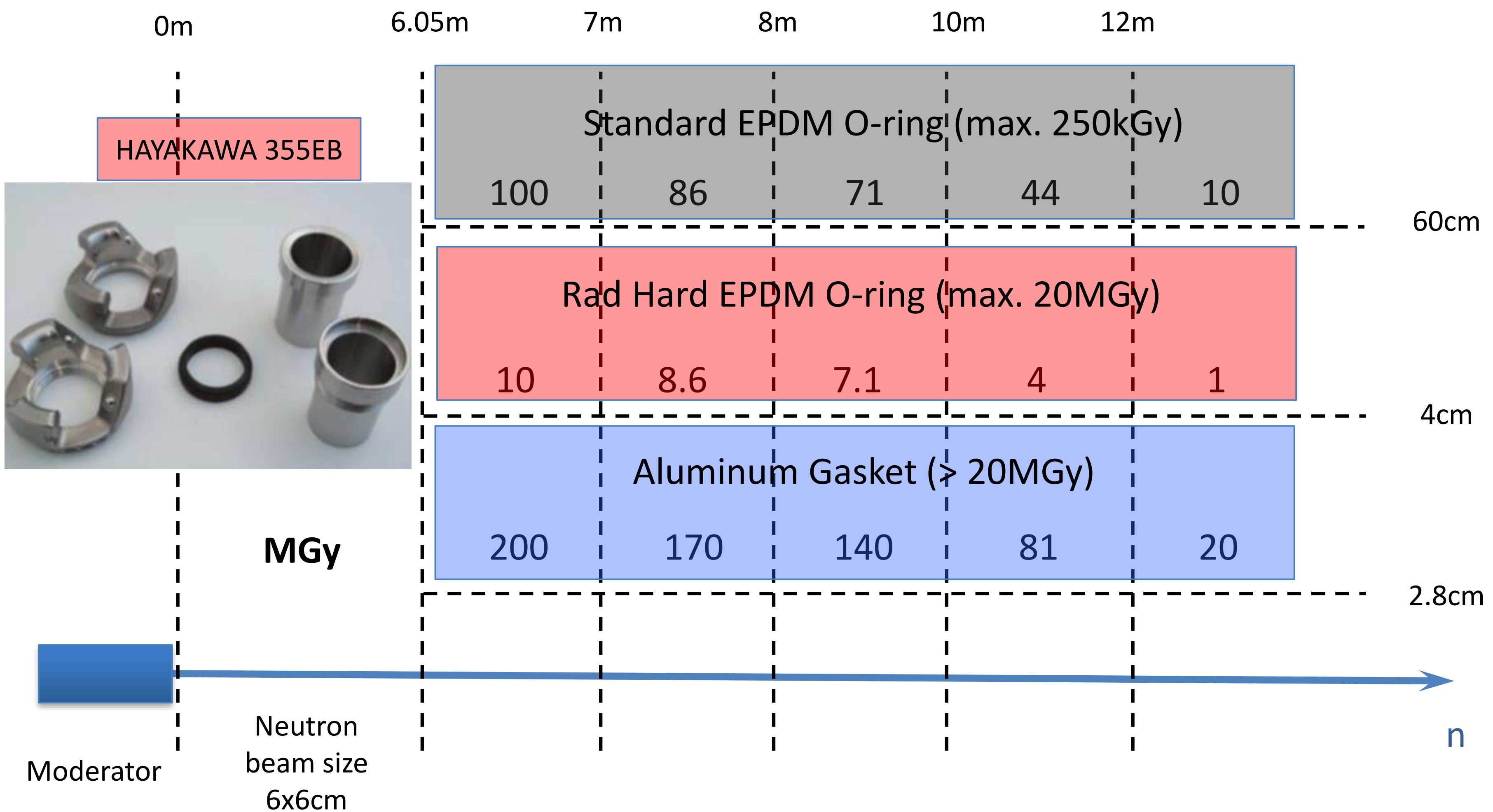

Requirement Specs ESS-0059912

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Thank you for your attention !