Reactor & Spallation Neutron Sources

EUROPEAN SPALLATION SOURCE

Oxford School of Neutron Scattering

Oxford, 2011-09-06

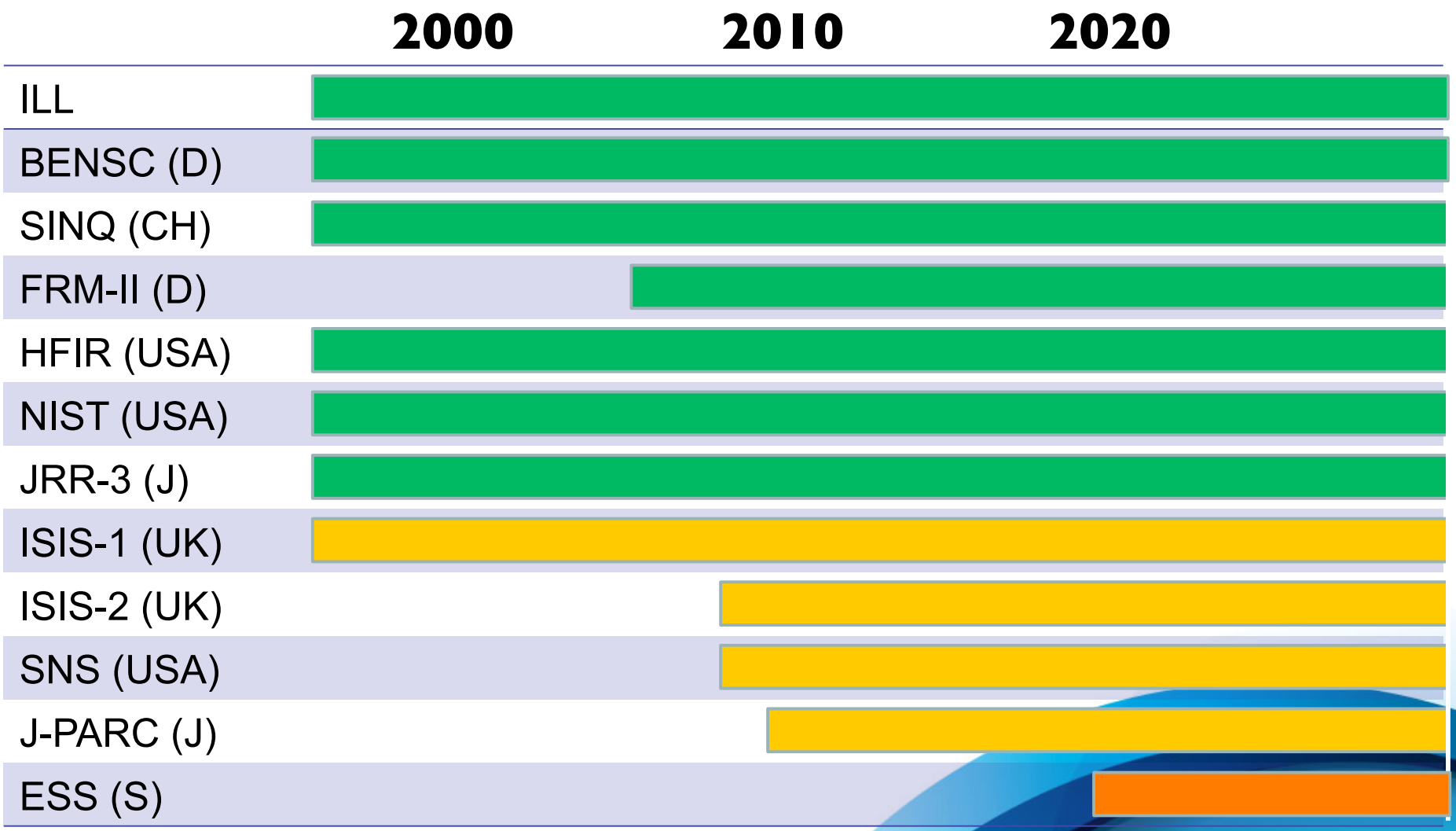
Ken Andersen

ESS Instruments Division

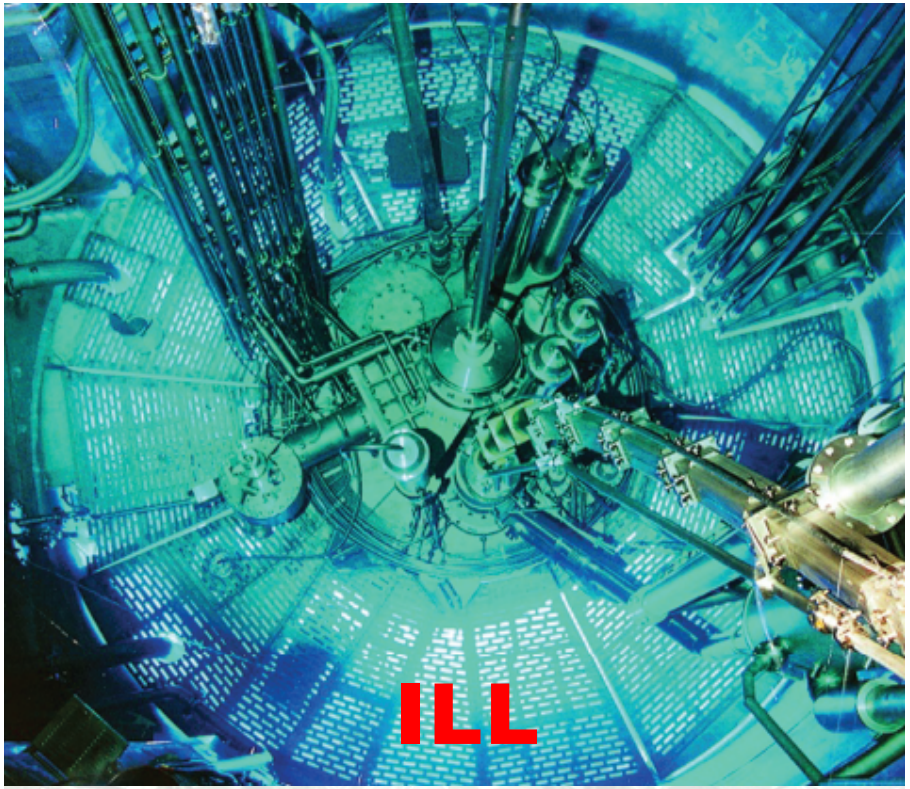
EUROPEAN
SPALLATION
SOURCE

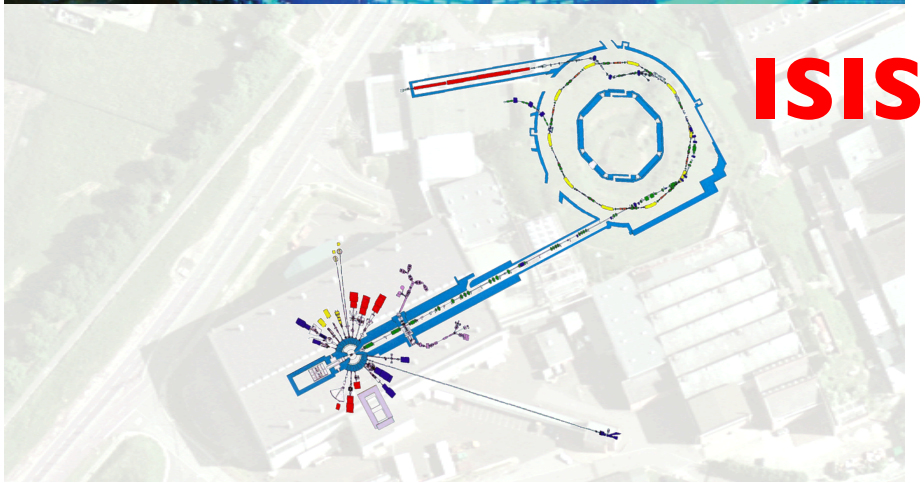
EUROPEAN SPALLATION SOURCE

Time evolution: Major neutron sources



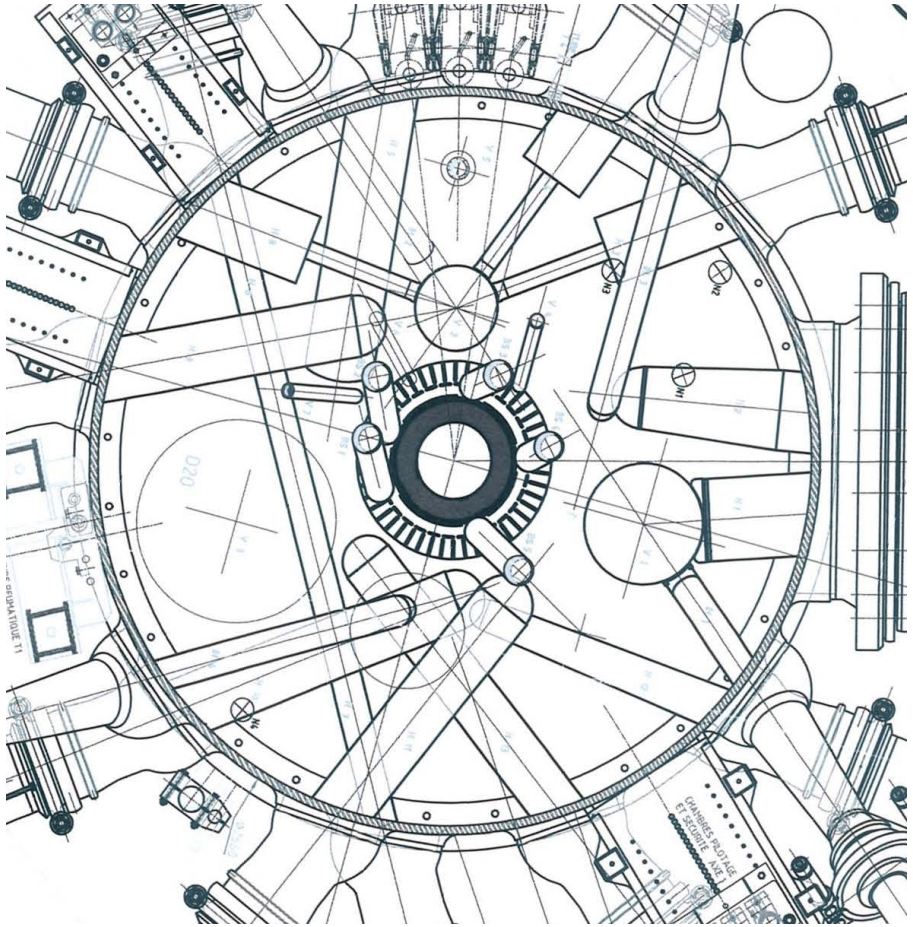
Neutron Sources





- About 10 major neutron facilities worldwide
- Fission (continuous)
- Spallation (pulsed)
- User facilities
- Number 1 is Institut Laue-Langevin (ILL) in Grenoble, France
  - 40 instruments
  - 700 experiments a year
  - Mainly condensed-matter physics, but increasingly also chemistry and biophysics

ILL Reactor Neutron Source

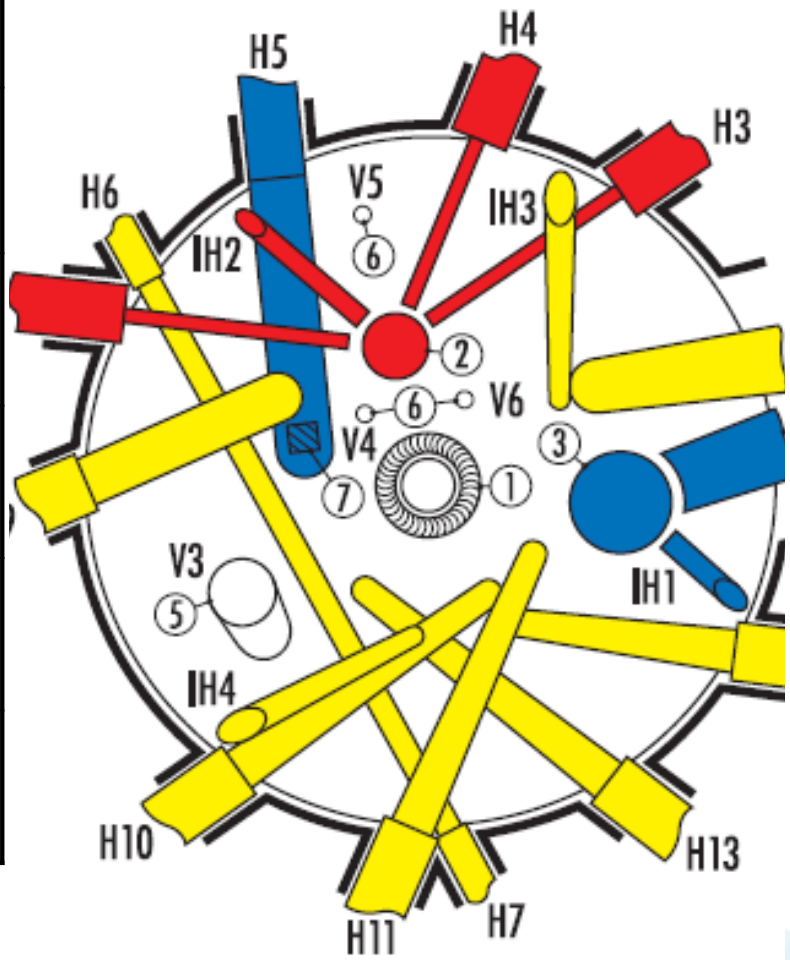


2.5 m

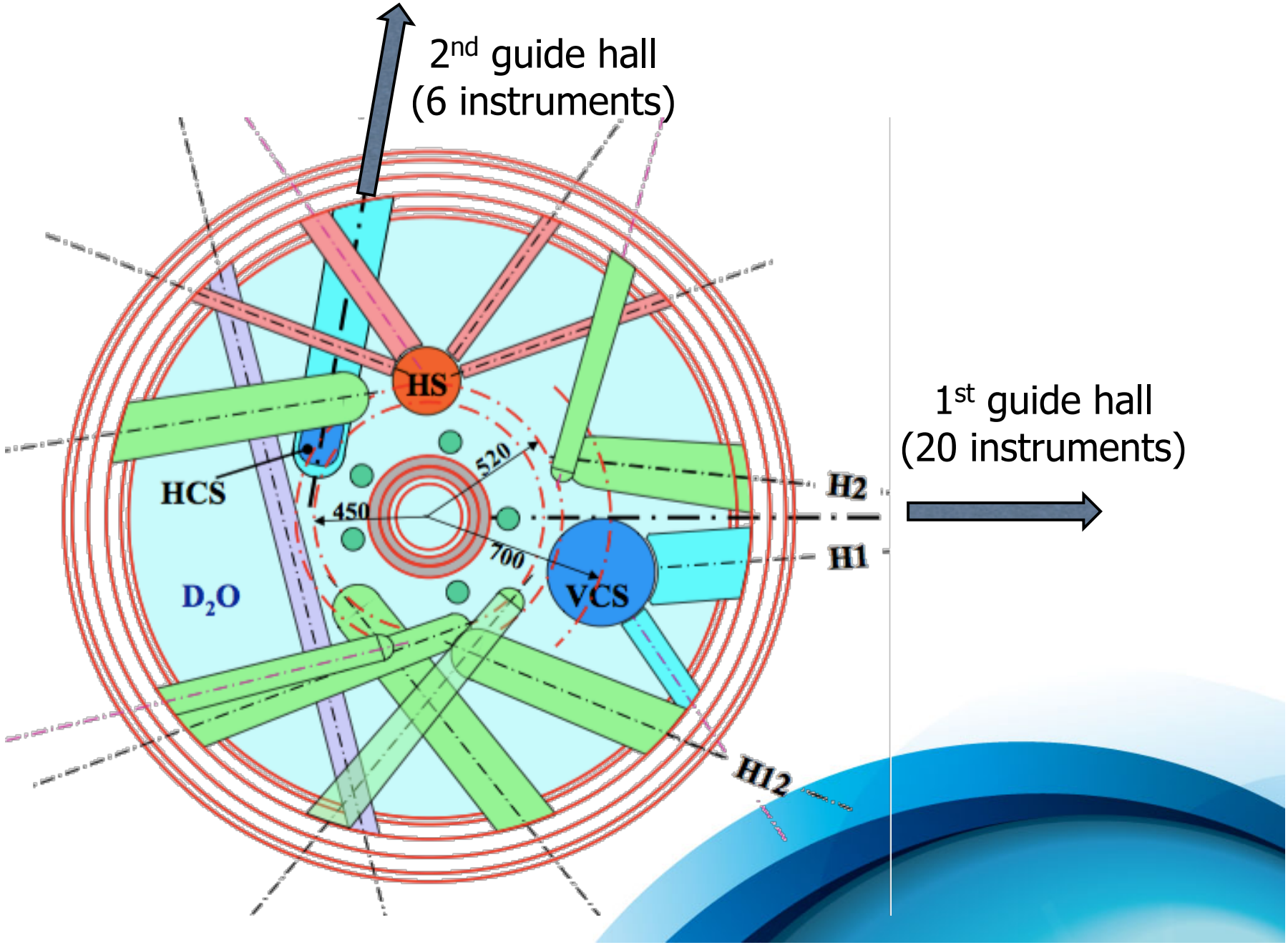
- Highly-enriched uranium
- Compact design for high brightness
- Heavy-water cooling
- Single control rod
- 57MW thermal power

ILL Reactor Neutron Source

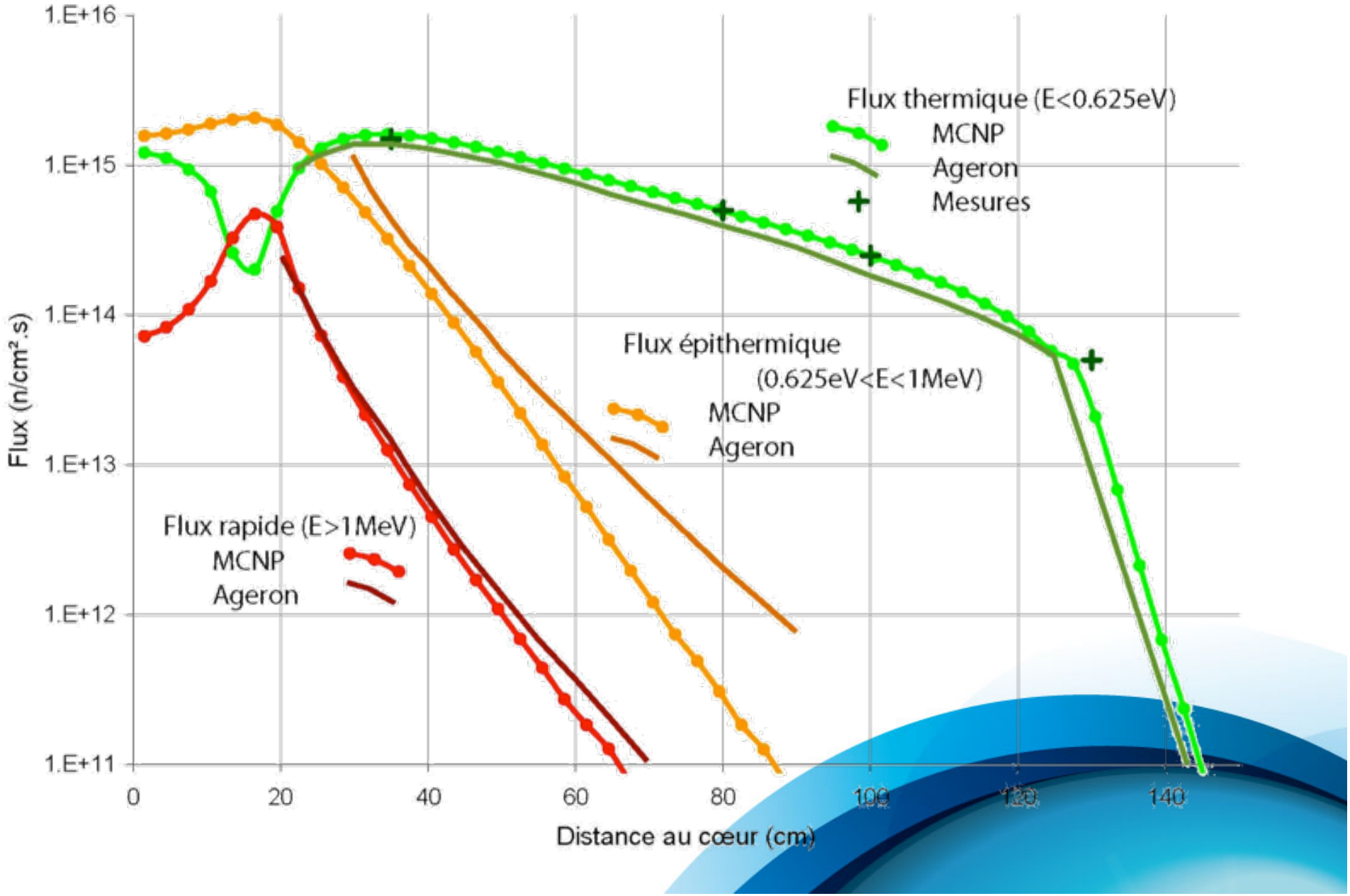
	cold	thermal	hot
moderator	liquid D_2	Liquid D_2O	graphite
moderator temperature	20K	300K	2000K
neutron wavelength	3→20Å	1→3Å	0.3→1Å
sample lengthscale	1Å→100 nm	0.3→5Å	0.1→2Å
sample timescale	1kHz→1 THz	0.1→10 THz	1→100 THz



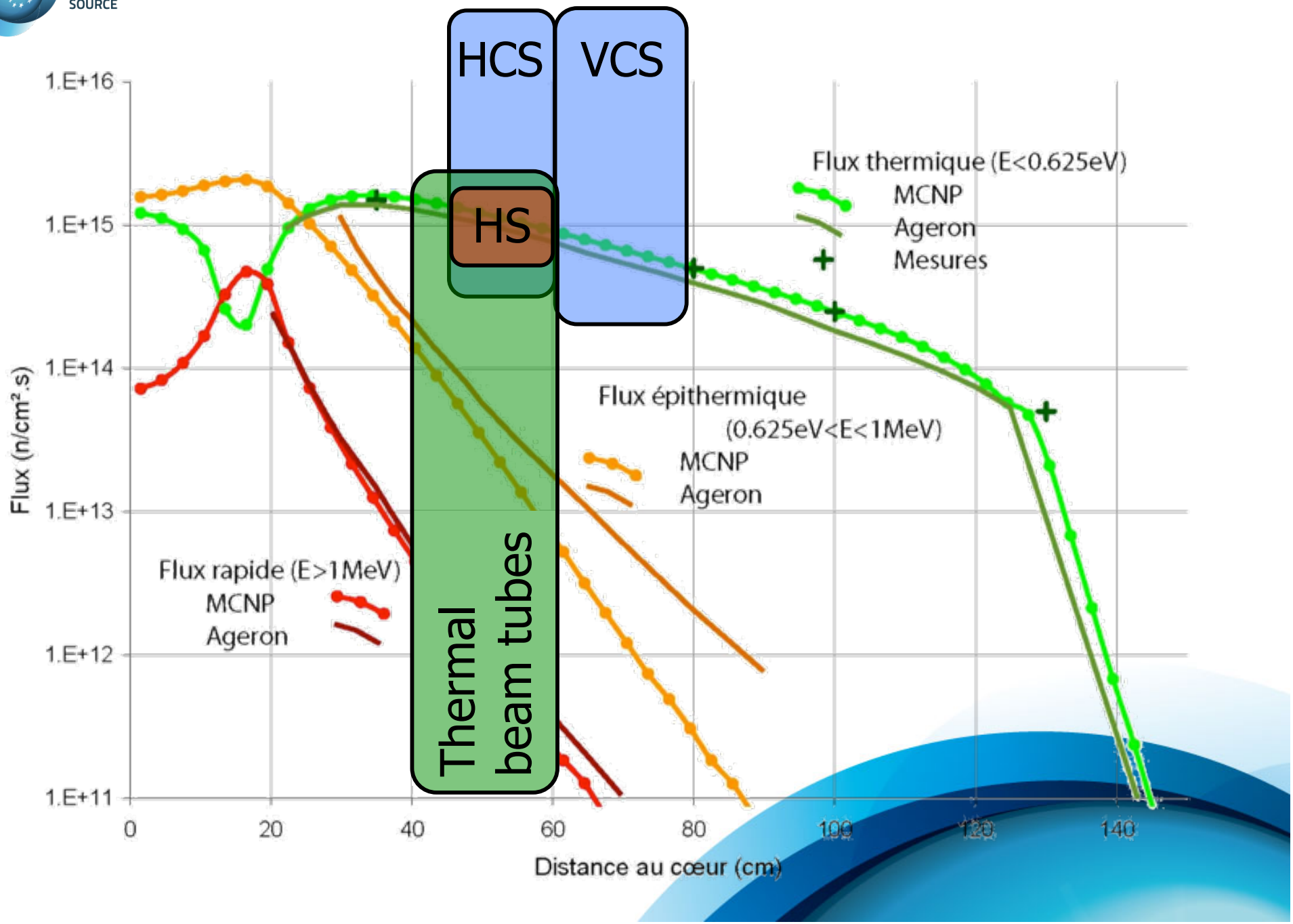
ILL Reactor Neutron Source



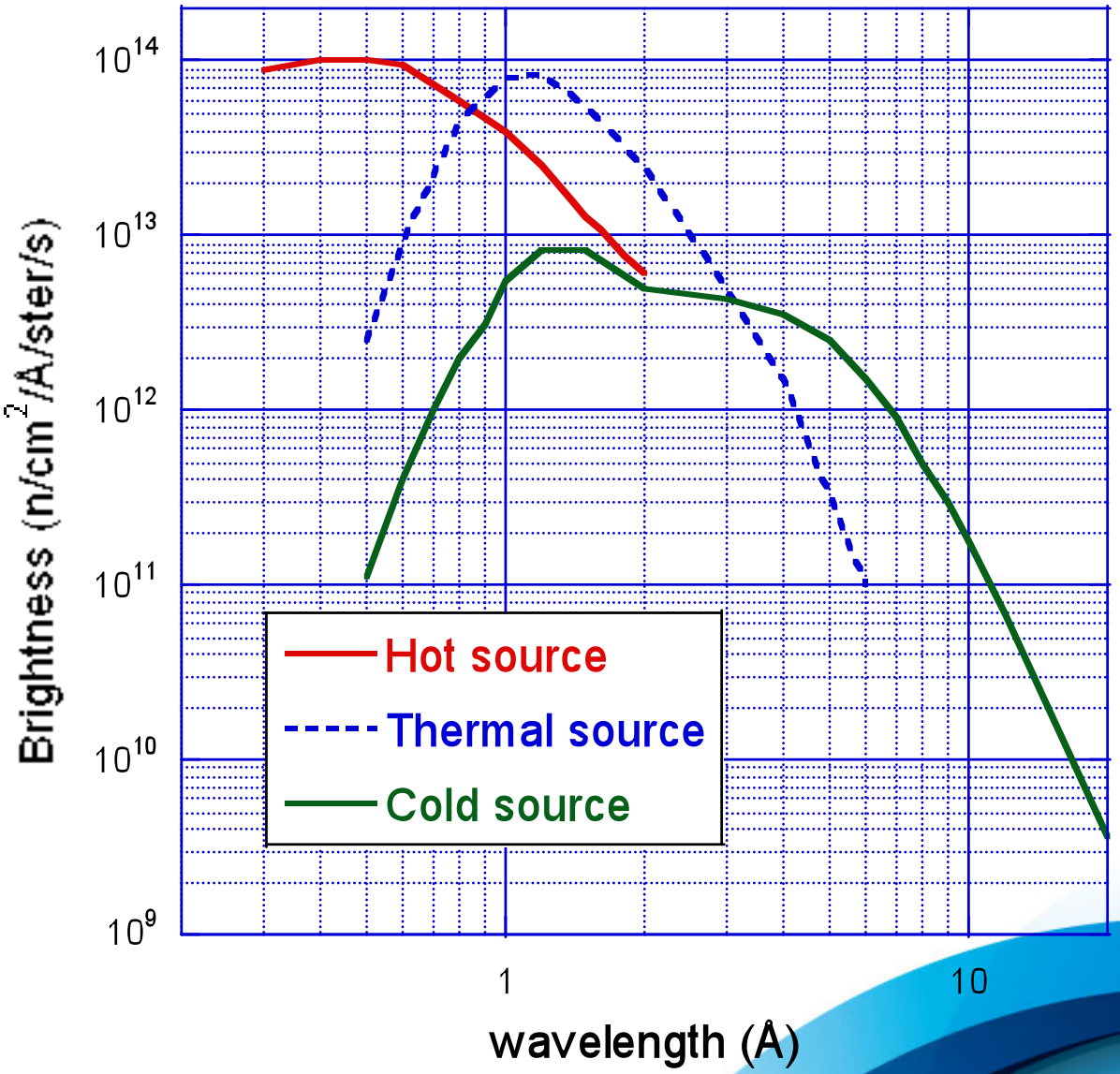
ILL Reactor Neutron Source



ILL Reactor Neutron Source



Neutron Moderators at the ILL



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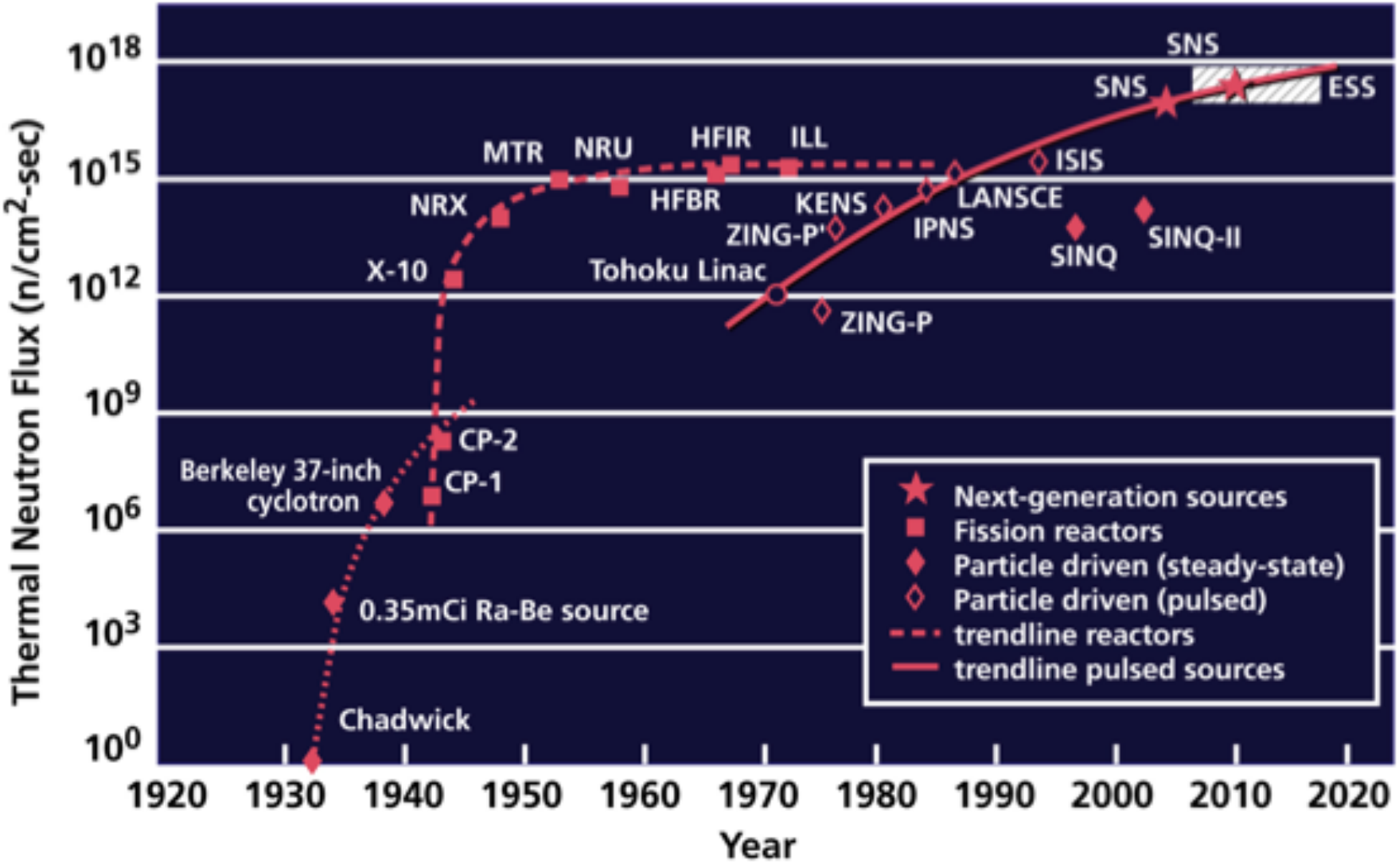


(Updated from *Neutron Scattering*, K. Skold and D. L. Price: eds., Academic Press, 1986)

Spallation Sources

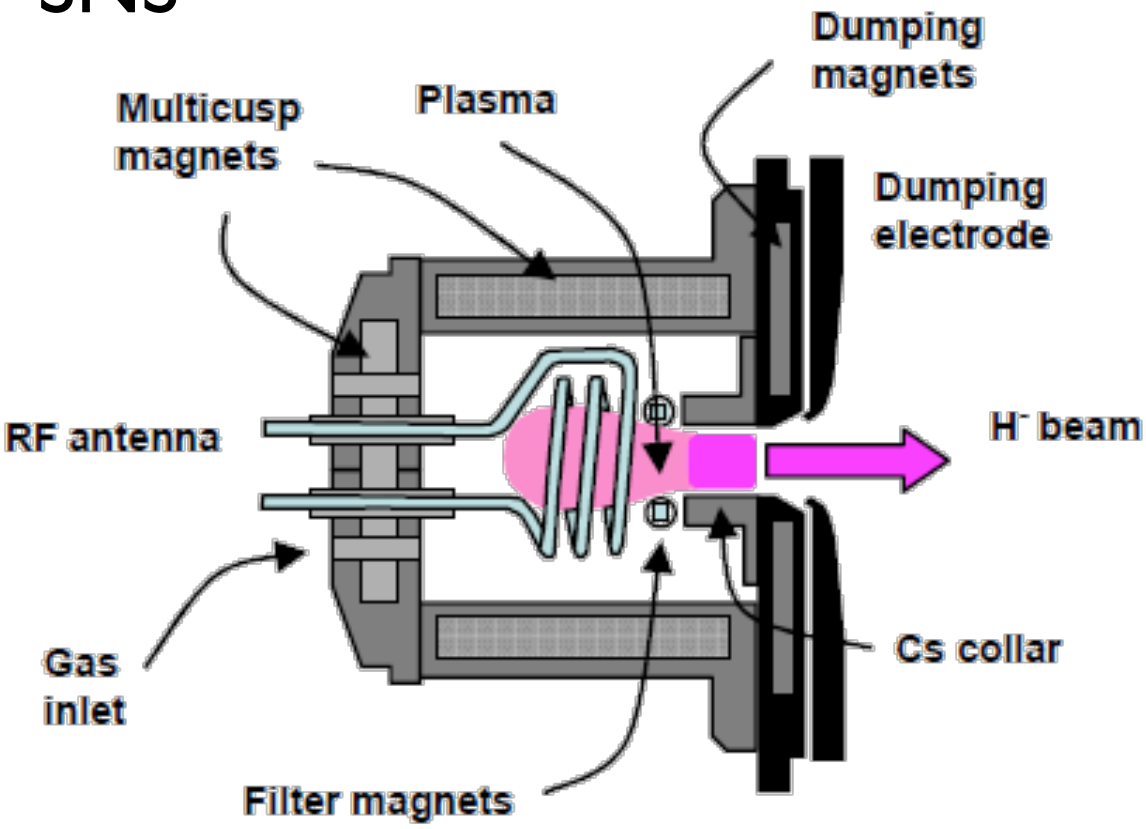
- Spallation: 10x more neutrons per heat than fission
- 5MW spallation source = 50MW reactor
  - Confusion: Heat input or output
  - accelerators 10-20% effective
- Pulsed nature gives information which allows lower time-integrated flux
- P = IxV = 0.2-1MW
  - efficient spallation requires proton E > 0.5 GeV
  - => I = 0.2-1mA

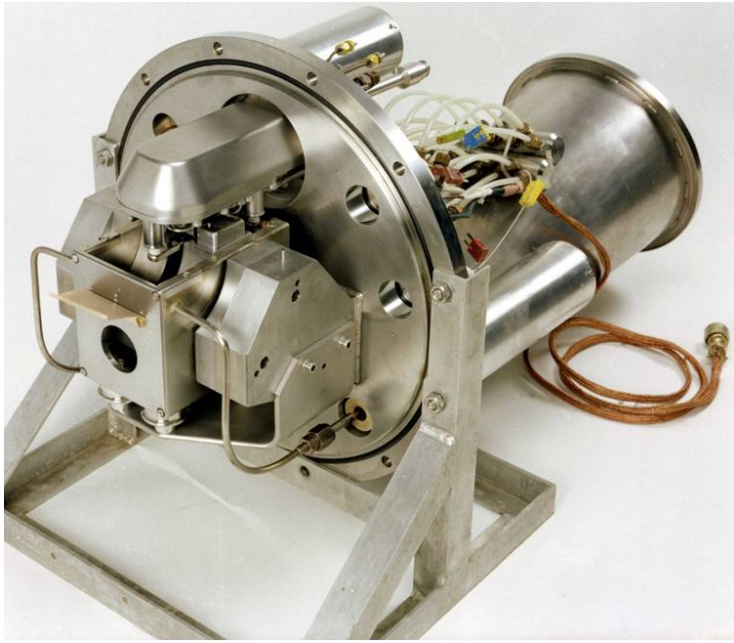
Spallation Sources

- Continuous spallation source: SINQ at PSI in Switzerland
- Short-pulse spallation sources: ISIS, SNS, J-PARC
  - H- Ion source
  - Linear accelerator (normal- or super-conducting)
  - Stripper converts H- to H+
  - Synchrotron
- Target
- Reflector
- Moderators

H- ion source

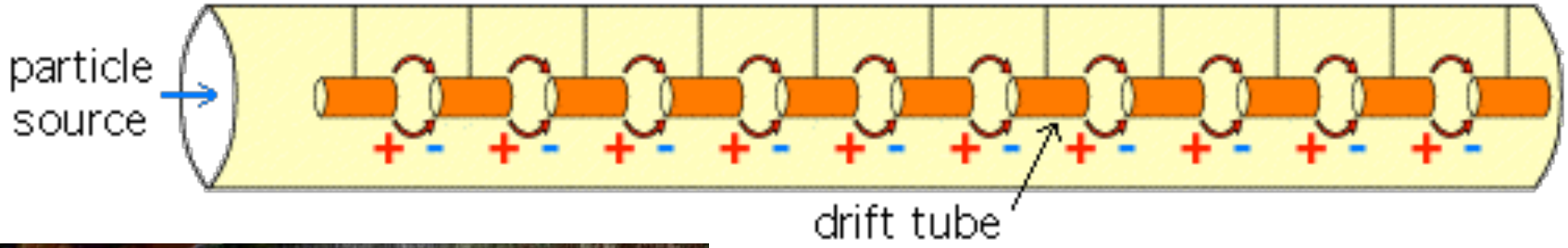
SNS





ISIS

Linac (drift tube)



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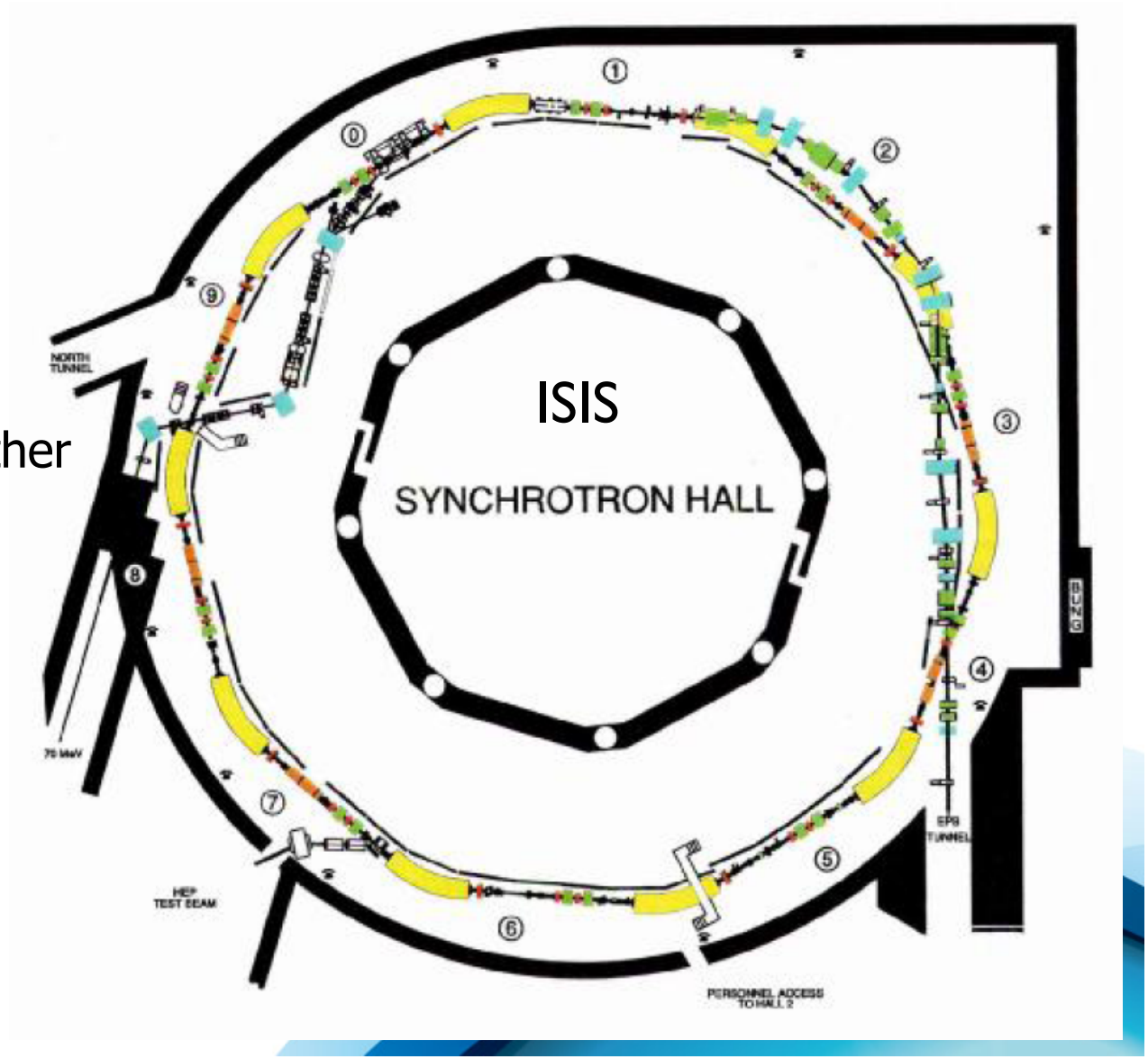
Synchrotron

- Synchronise:
  - B-field: bend
  - E-field: accelerate
  - E & B field: focus
  - Magnets to each other
- Injection
  - Stripper foil
- Extraction
  - Kicker magnet



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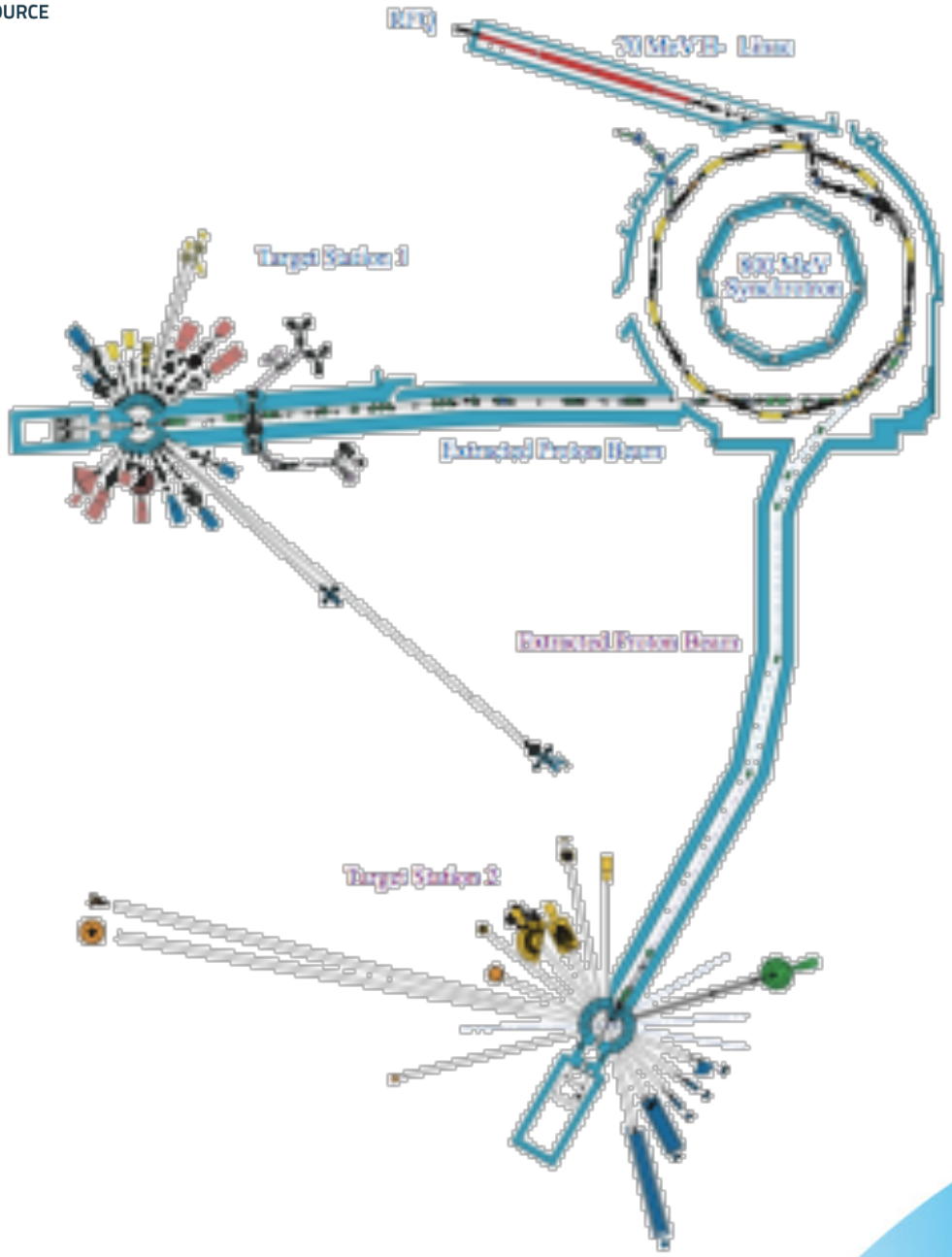
ISIS (200kW)



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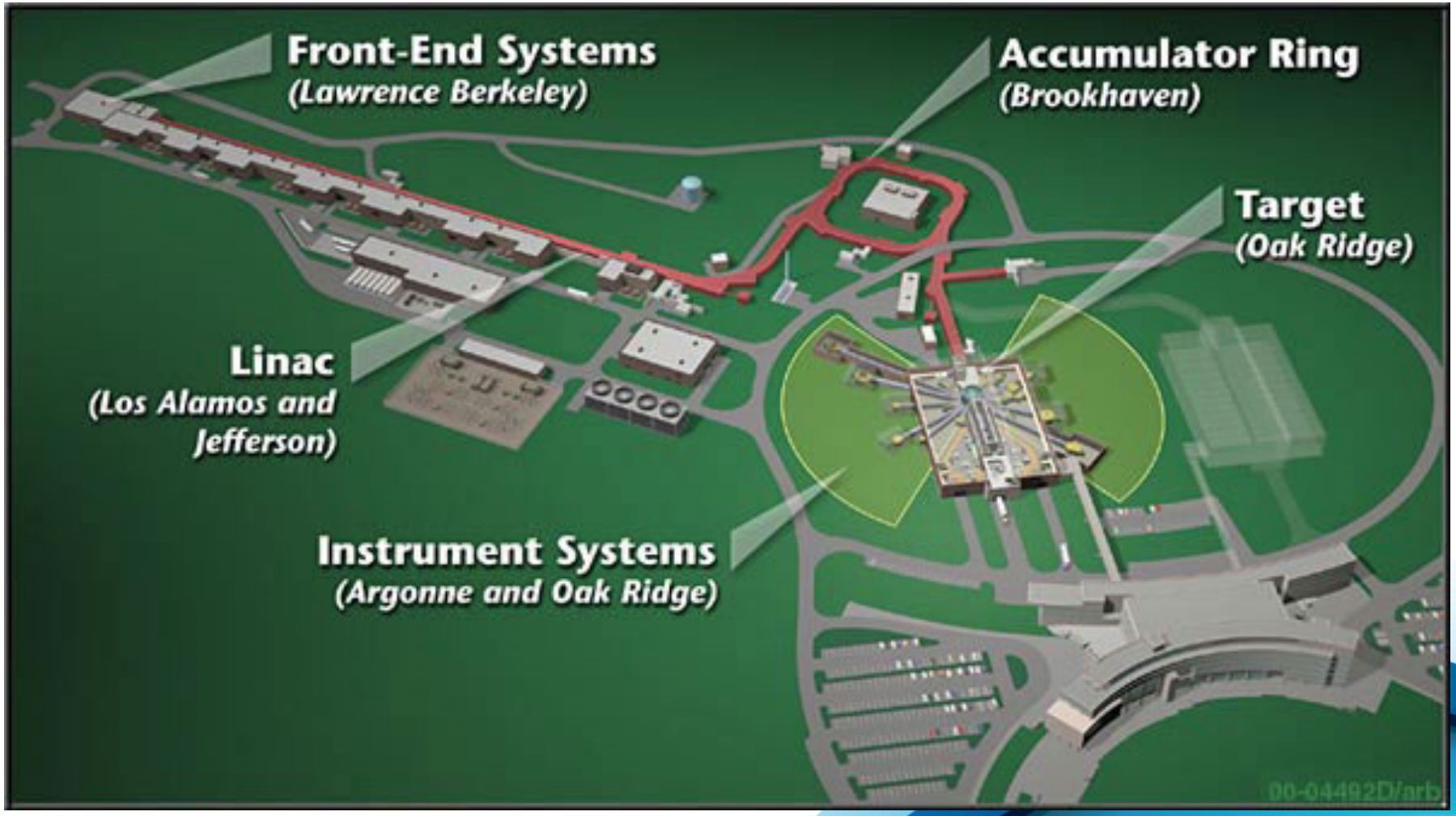
SNS, Oak Ridge, Tennessee, USA (500kW in 2010, 1MW in 2012)



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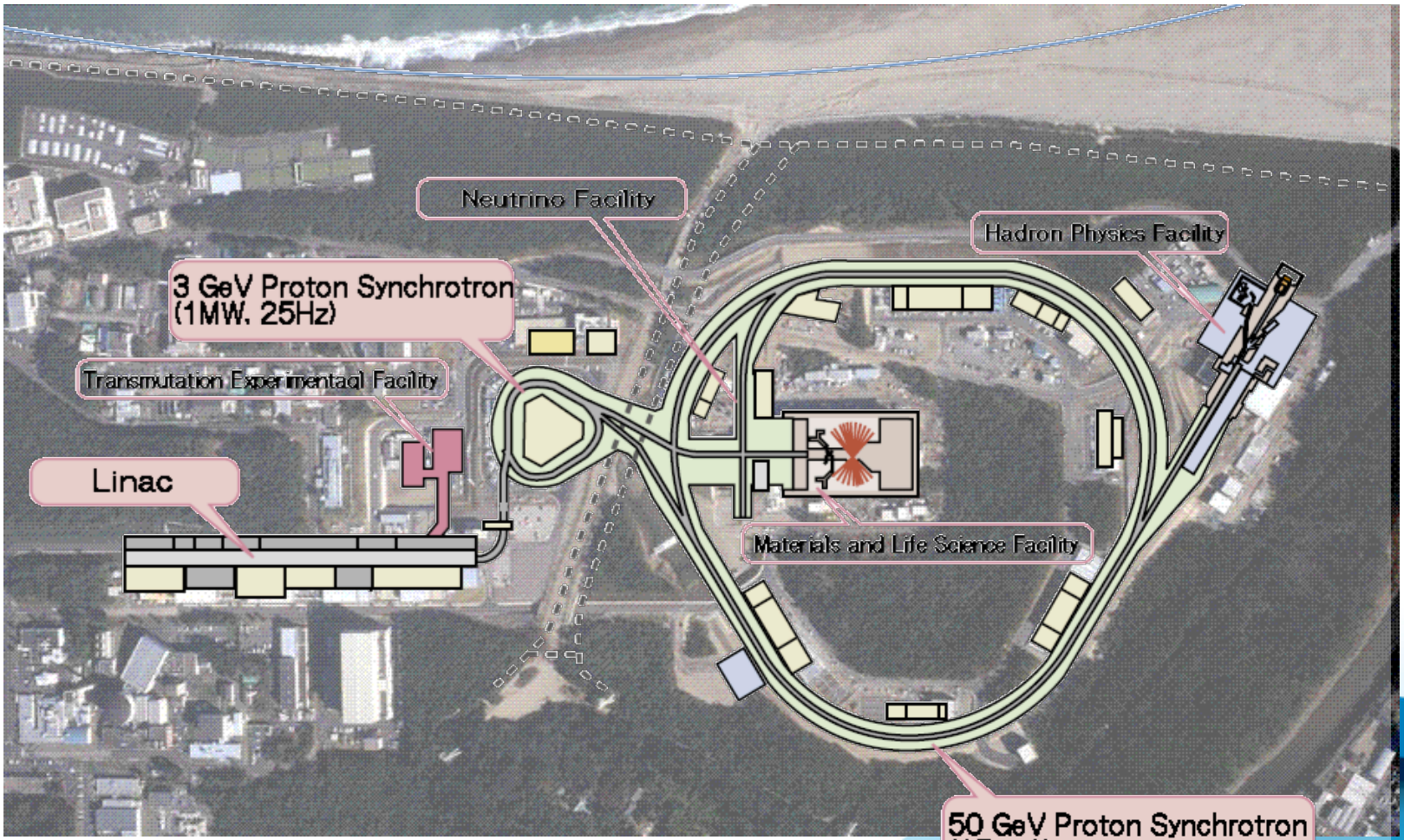
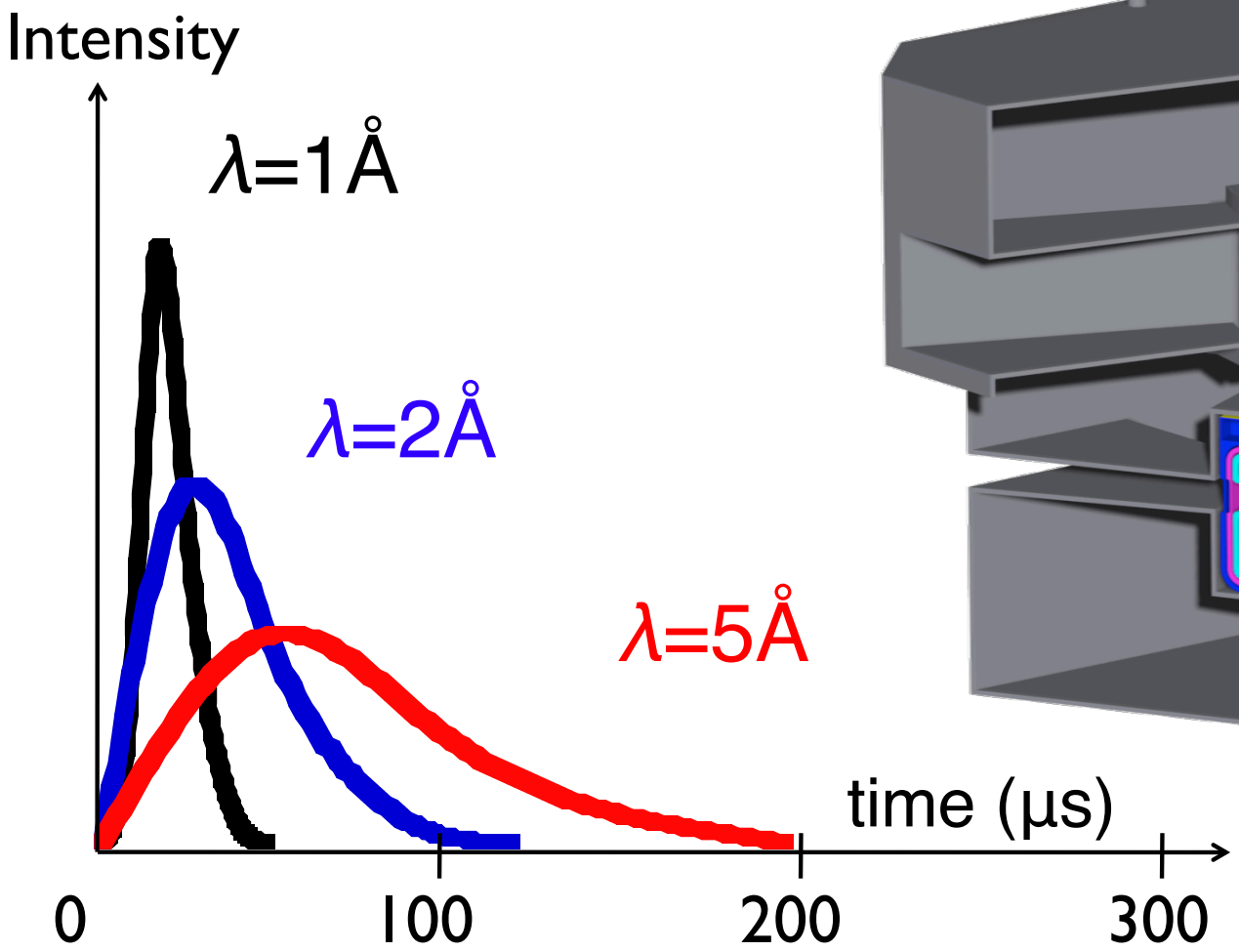
J-PARC, Tokai, Japan (100kW in 2010, 1MW in 2015)

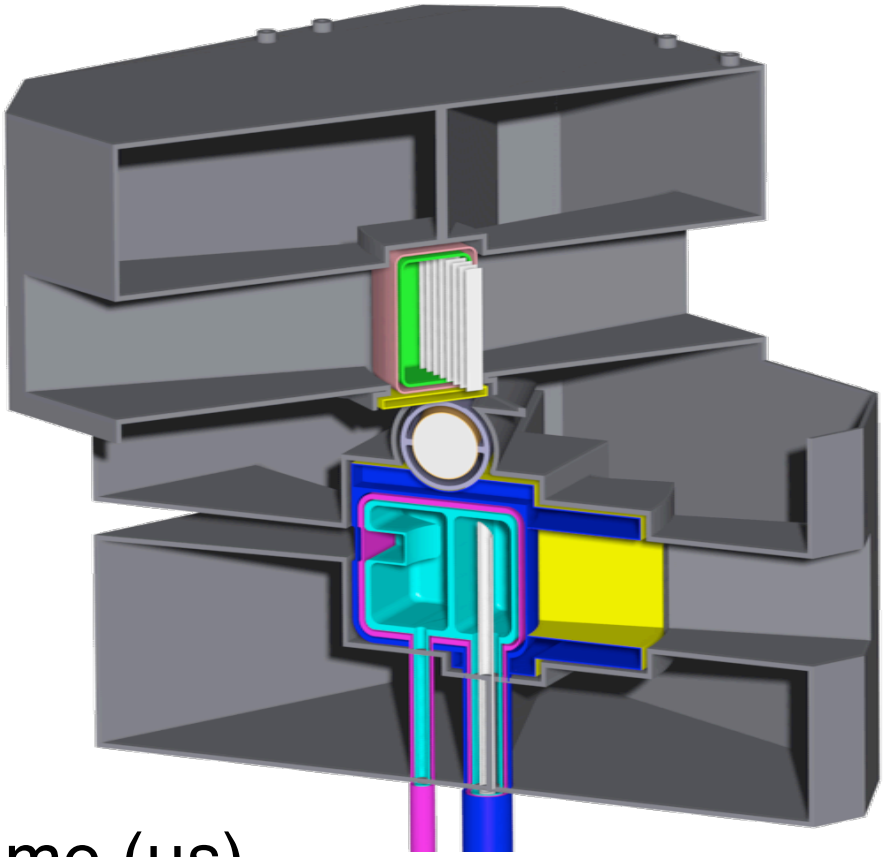
EUROPEAN SPALLATION SOURCE

J-PARC, Tokai, Japan (100kW in 2010, 1MW in 2014)

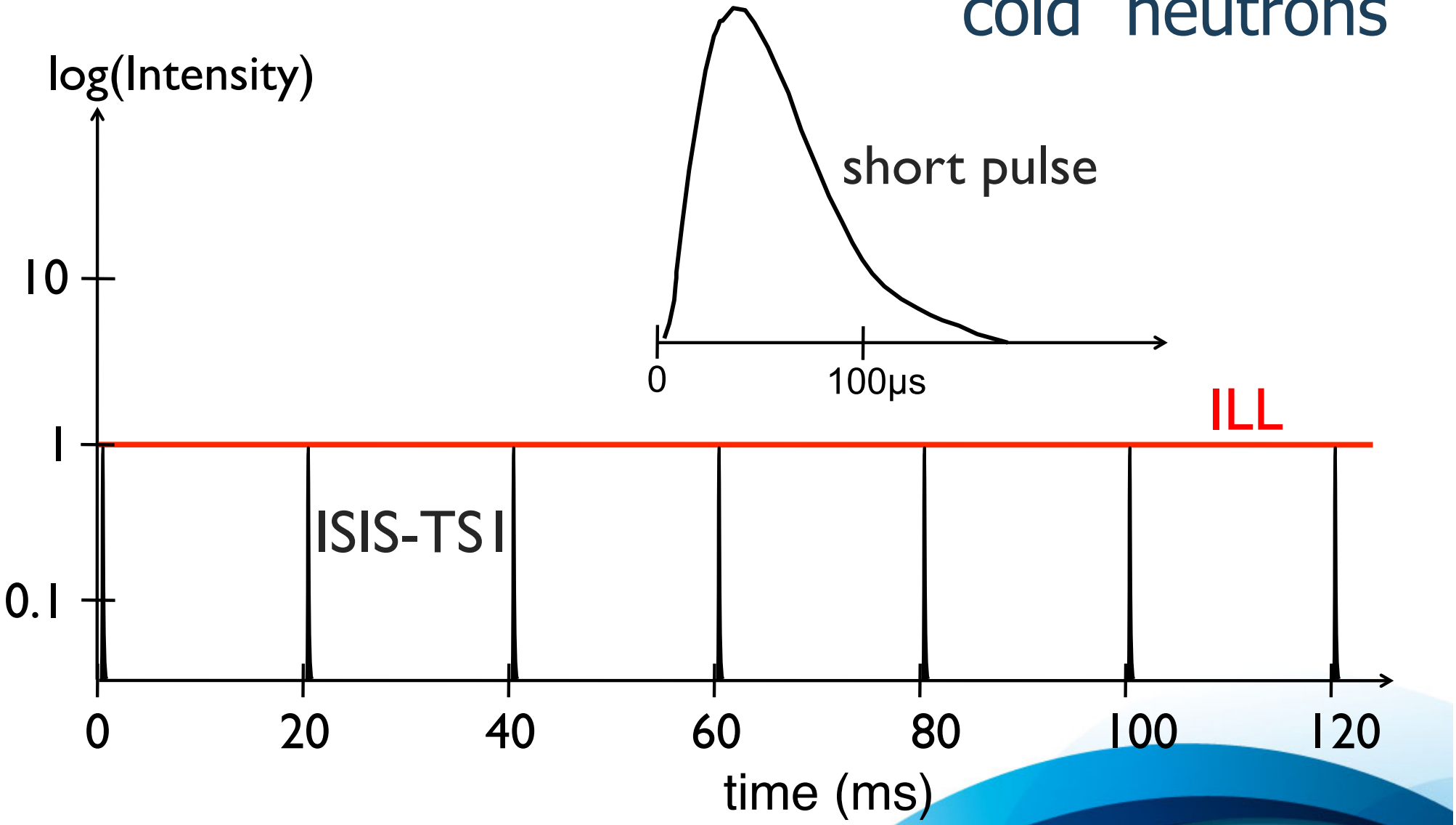


Pulsed-source time structure





Pulsed-source time structures cold neutrons



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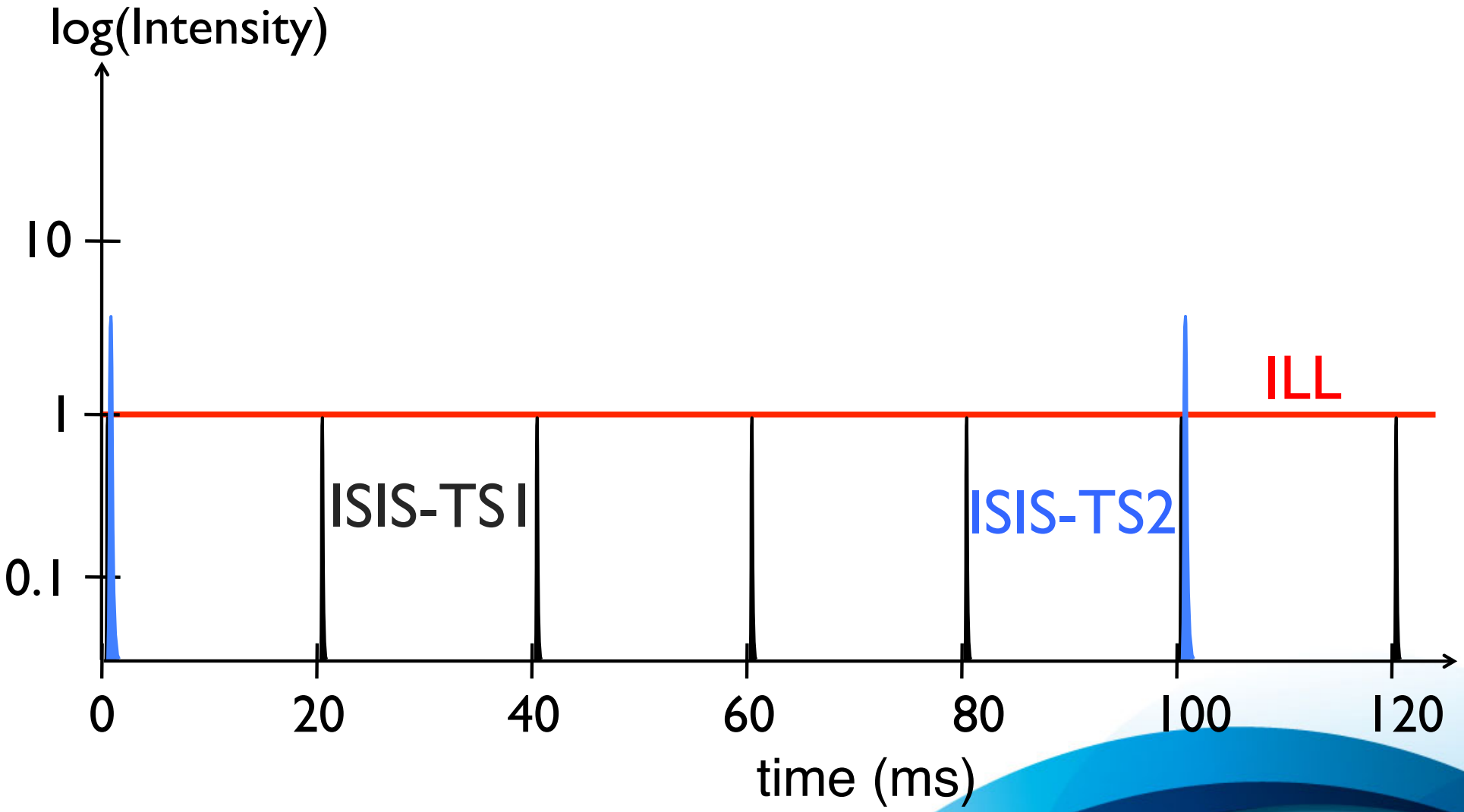

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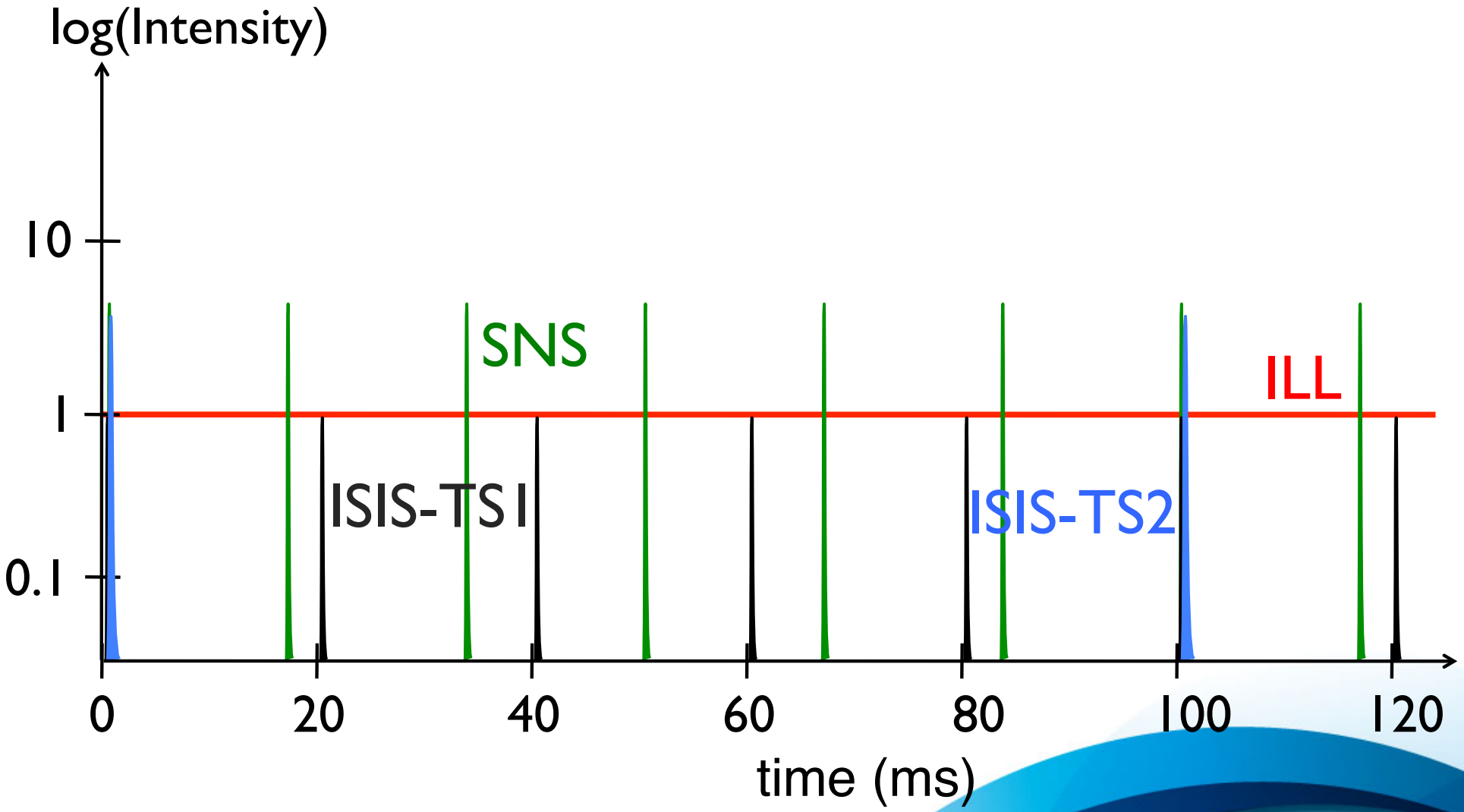
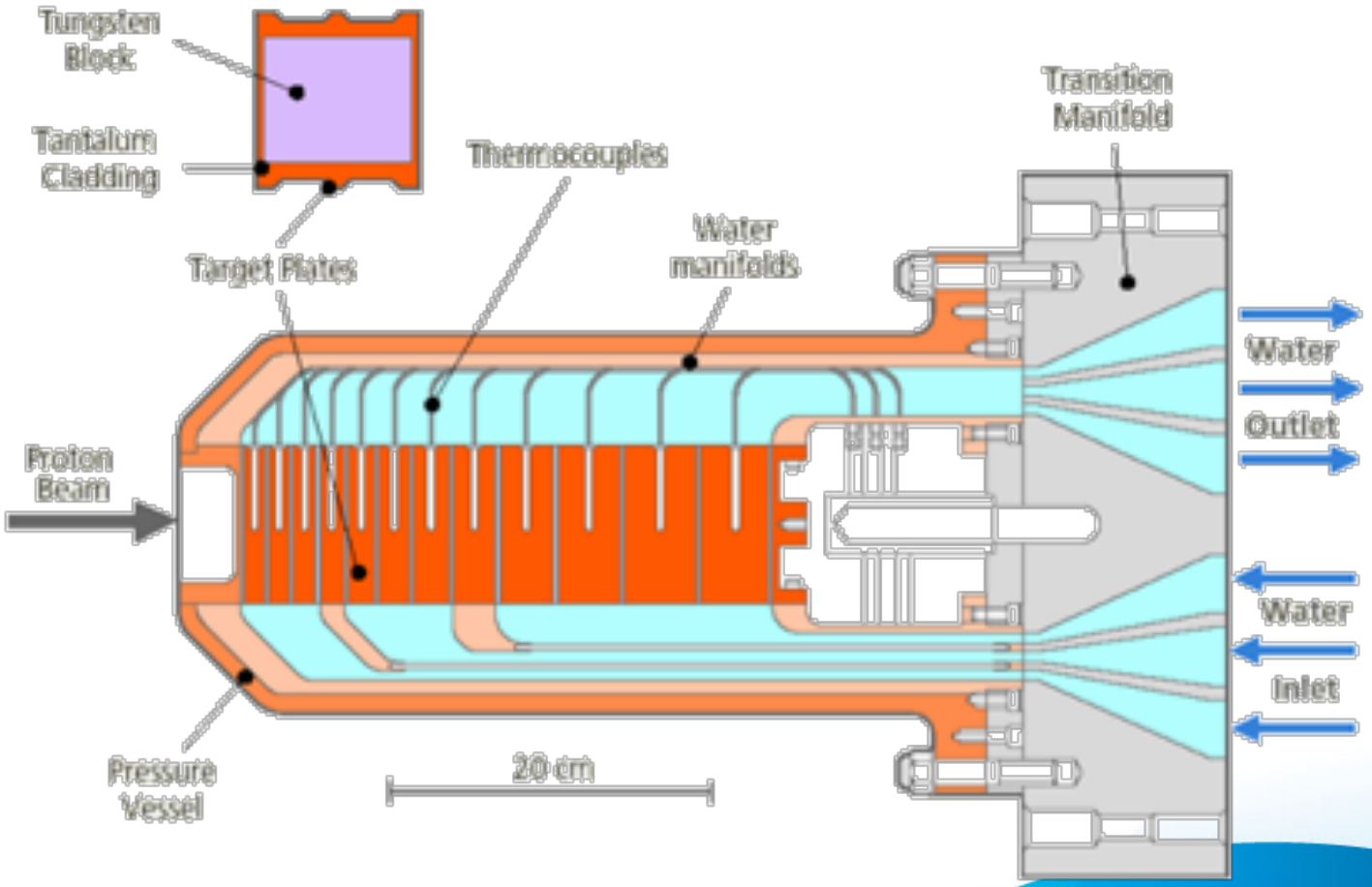


ISIS target 1: solid tungsten



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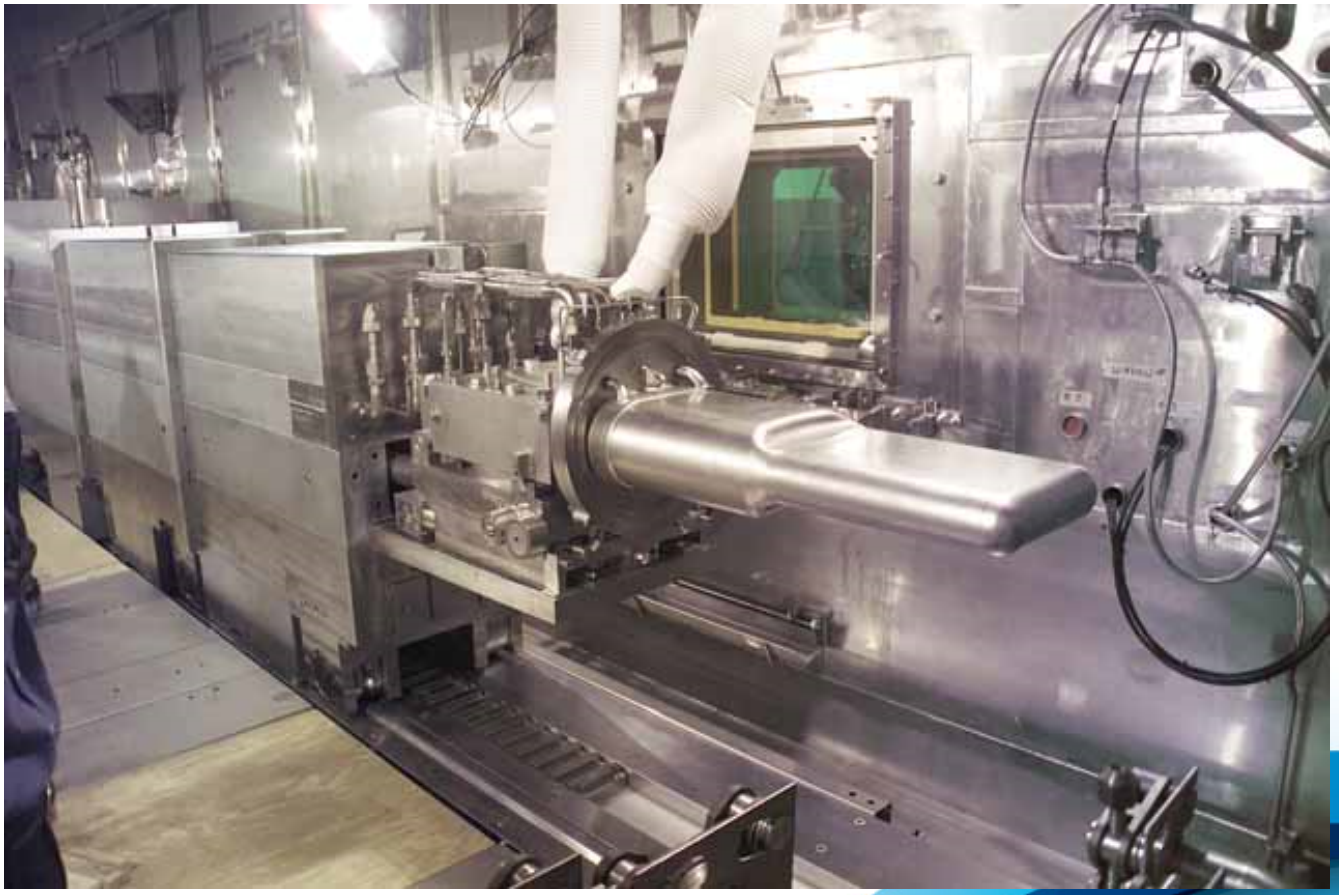
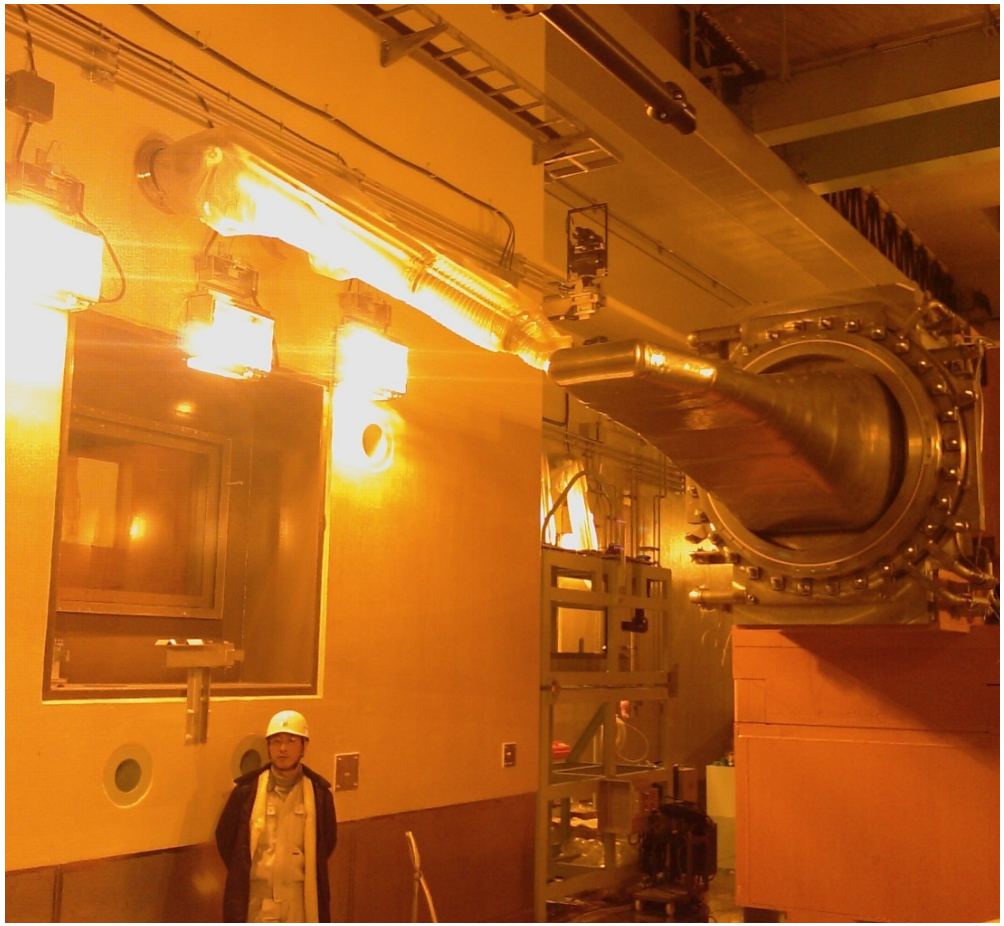
SNS target: liquid mercury



J-PARC target



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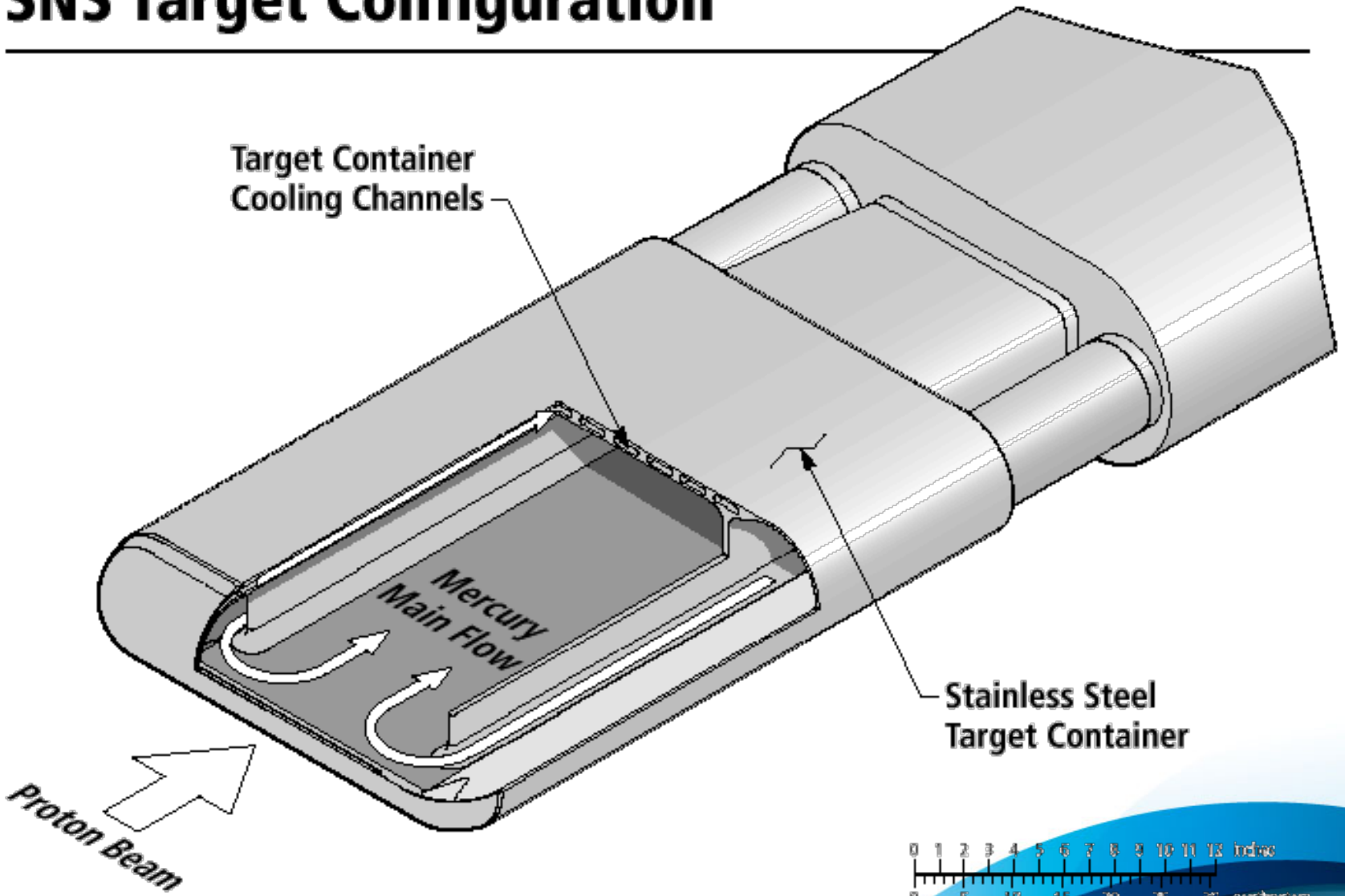
SNS Target Configuration



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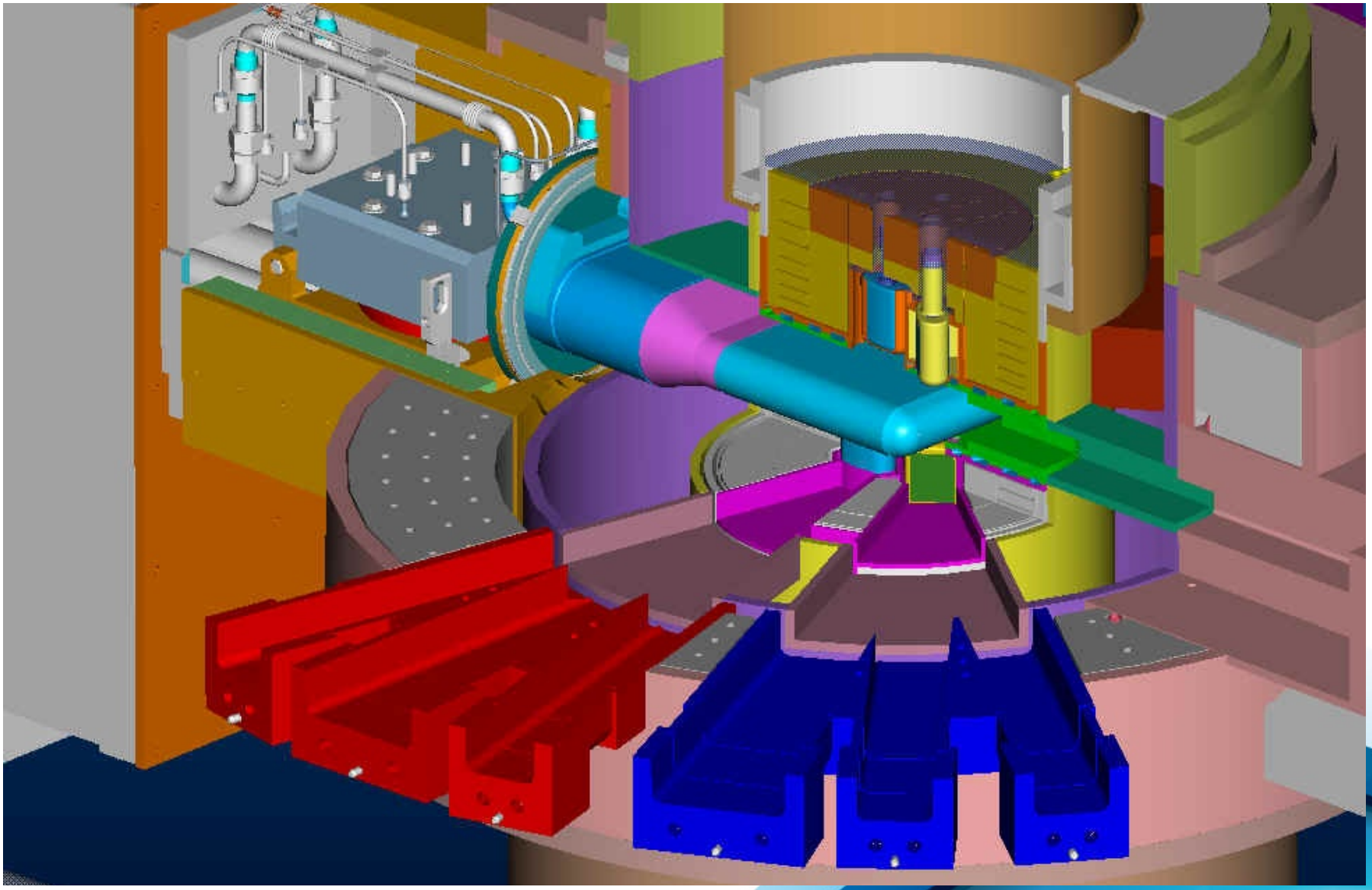
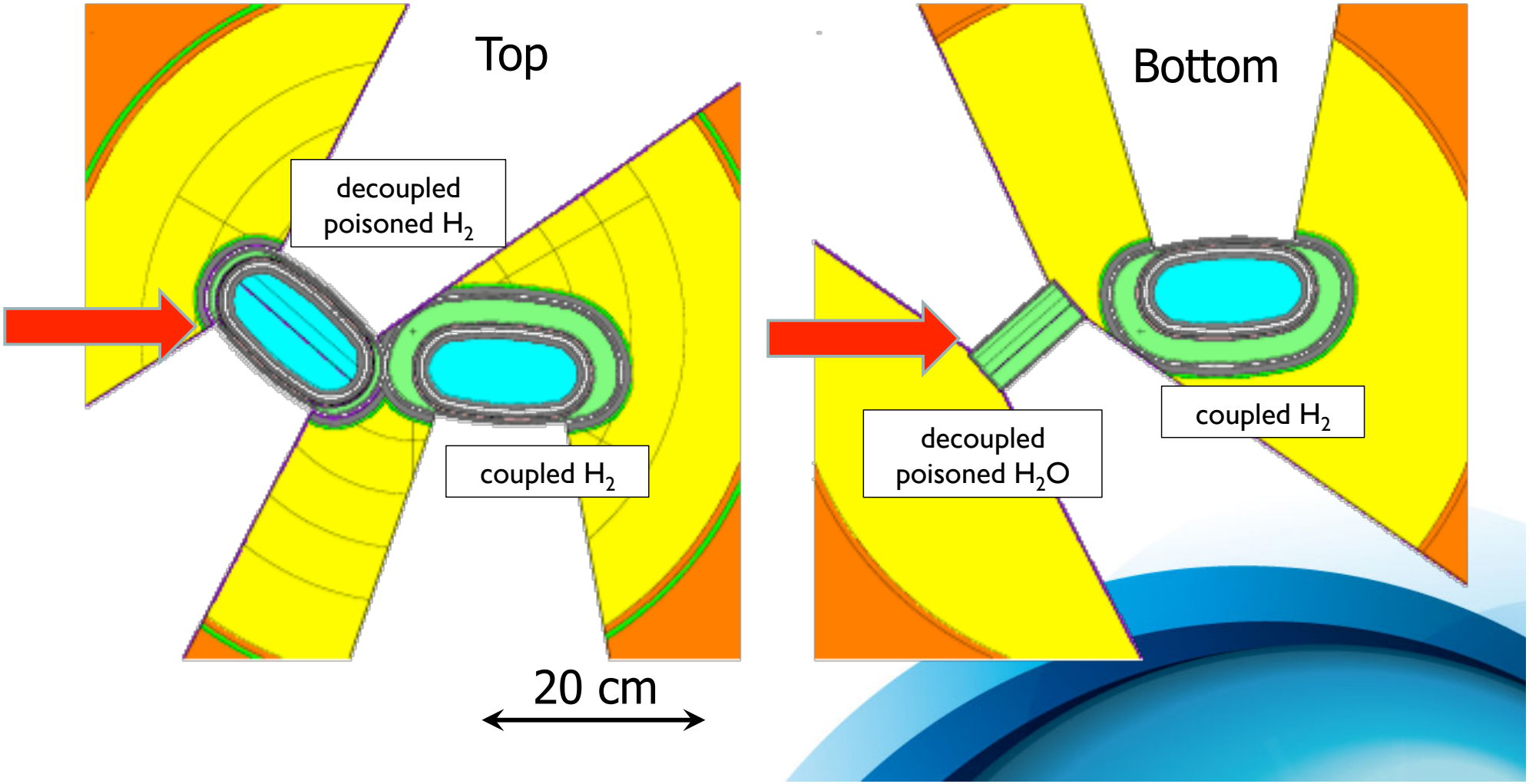
SNS target



Target-Reflector-Moderator Neutronics

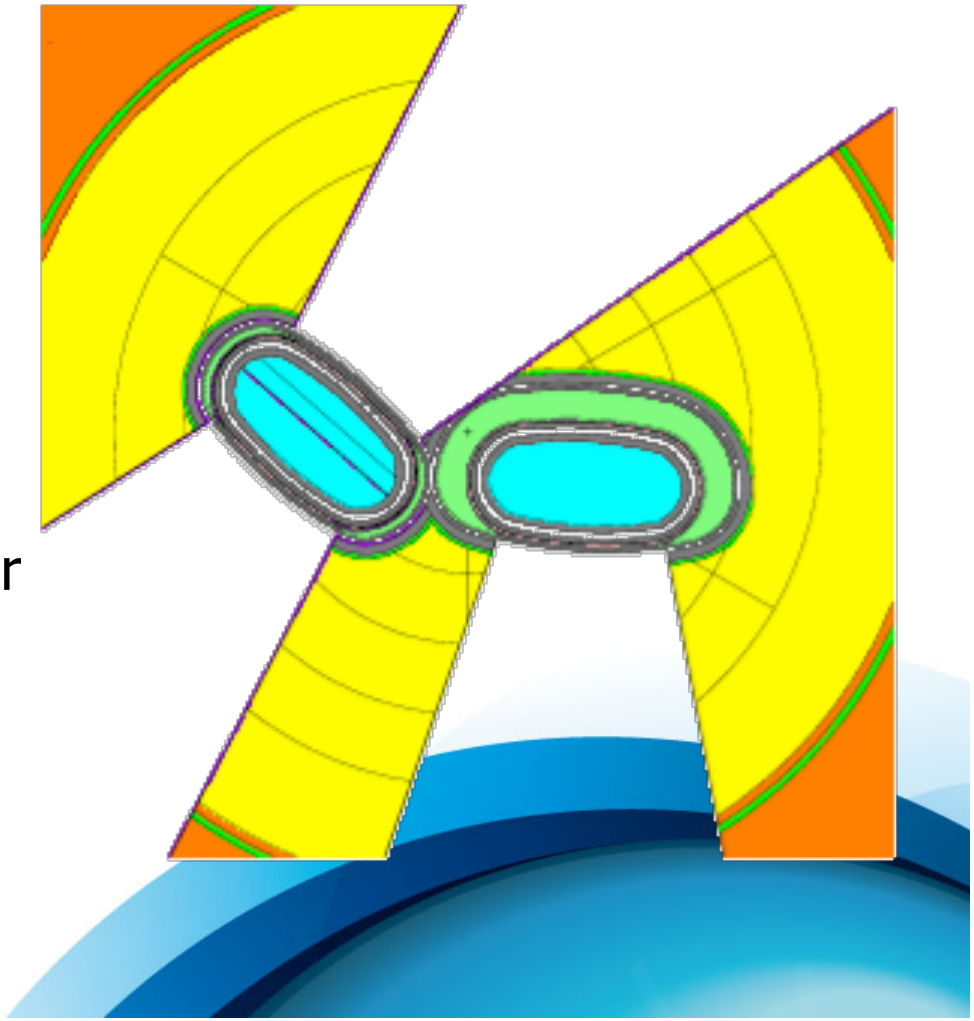
- Target produces neutron in MeV range
- Moderators contain H to thermalise neutrons
  - Largest scattering cross-section (80b)
  - Lowest mass
- Moderators embedded in reflector, usually D_2O-cooled Be
  - Minimal absorption
  - Large scattering cross-section (8b)
  - Little thermalisation

SNS moderators

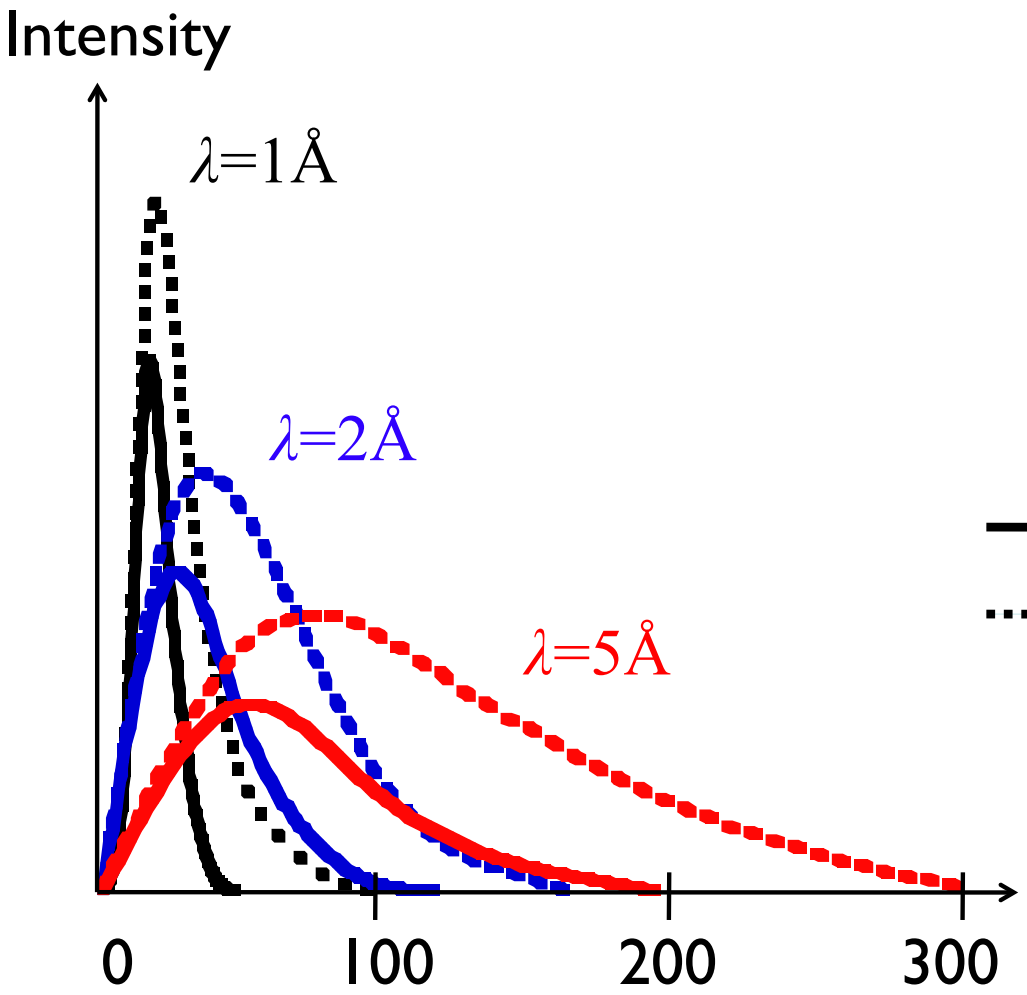


Target-reflector-moderator neutronics

- Proton pulse > 1 μs
- Neutrons moderated by H
  - Several cm depth of H required to thermalise
  - 4Å neutron speed: 1cm / 10 μs
  - Additional time-broadening: coupling between moderators and reflector
- Decoupling: Cd between moderator and reflector
  - Transparent above 0.3 eV
- Poisoning: Gd inside moderator



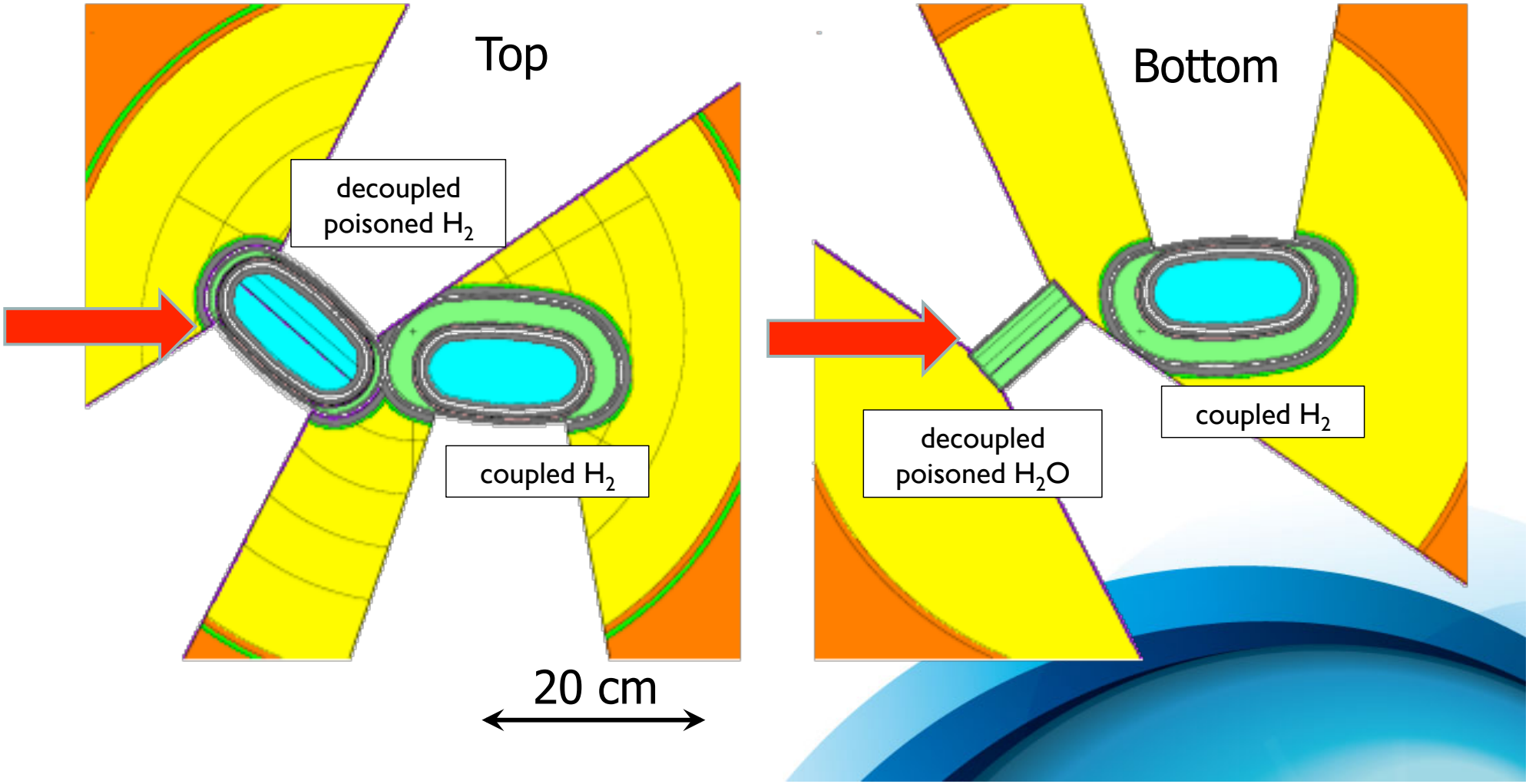
Pulsed-Source Moderators



decoupled

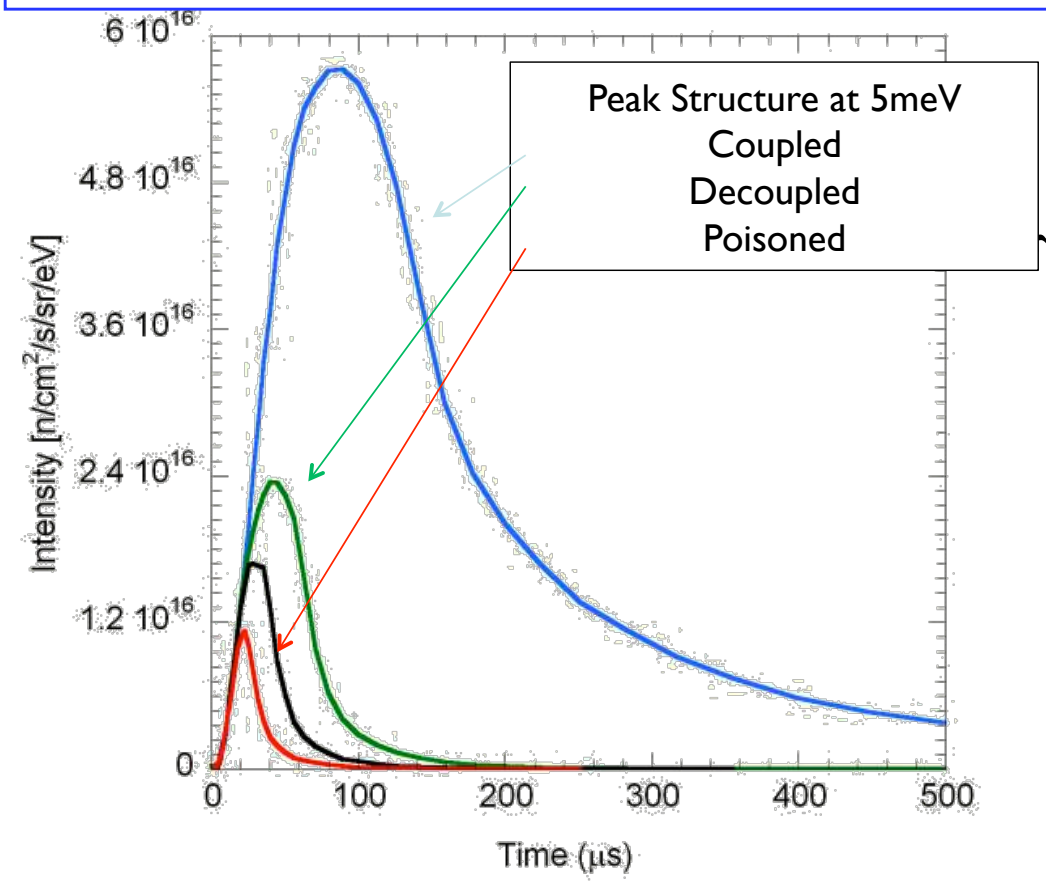
coupled

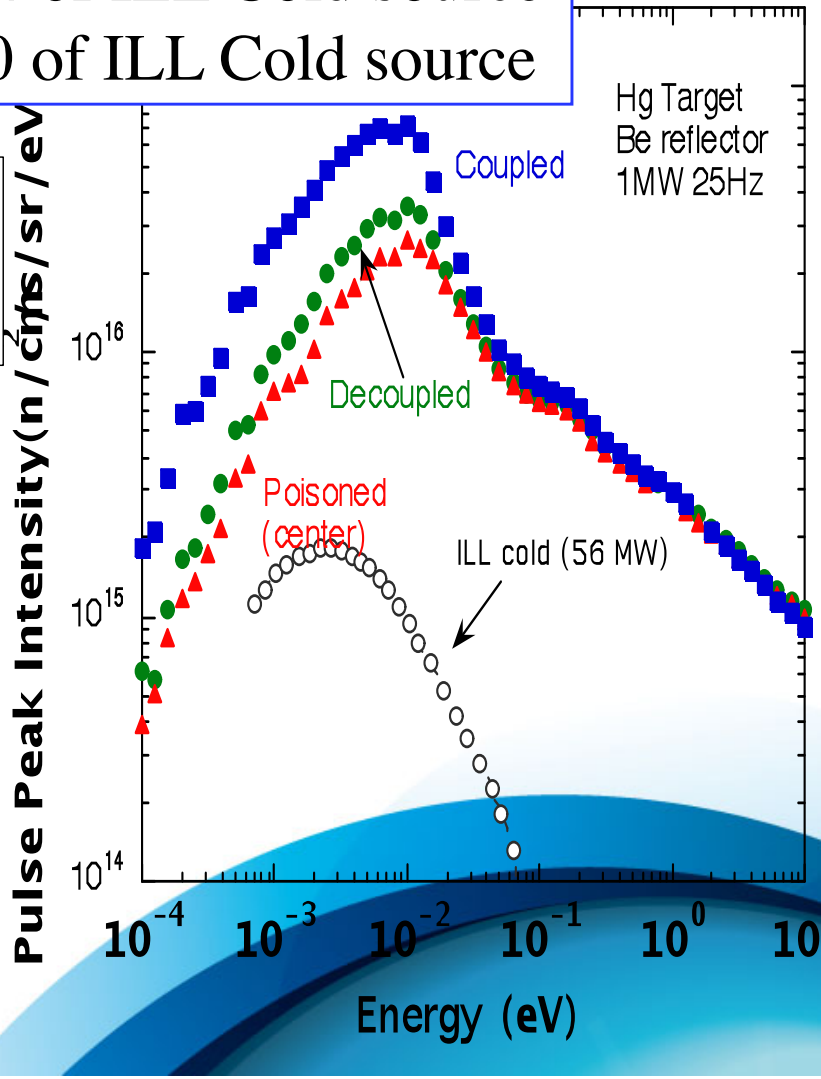
SNS moderators



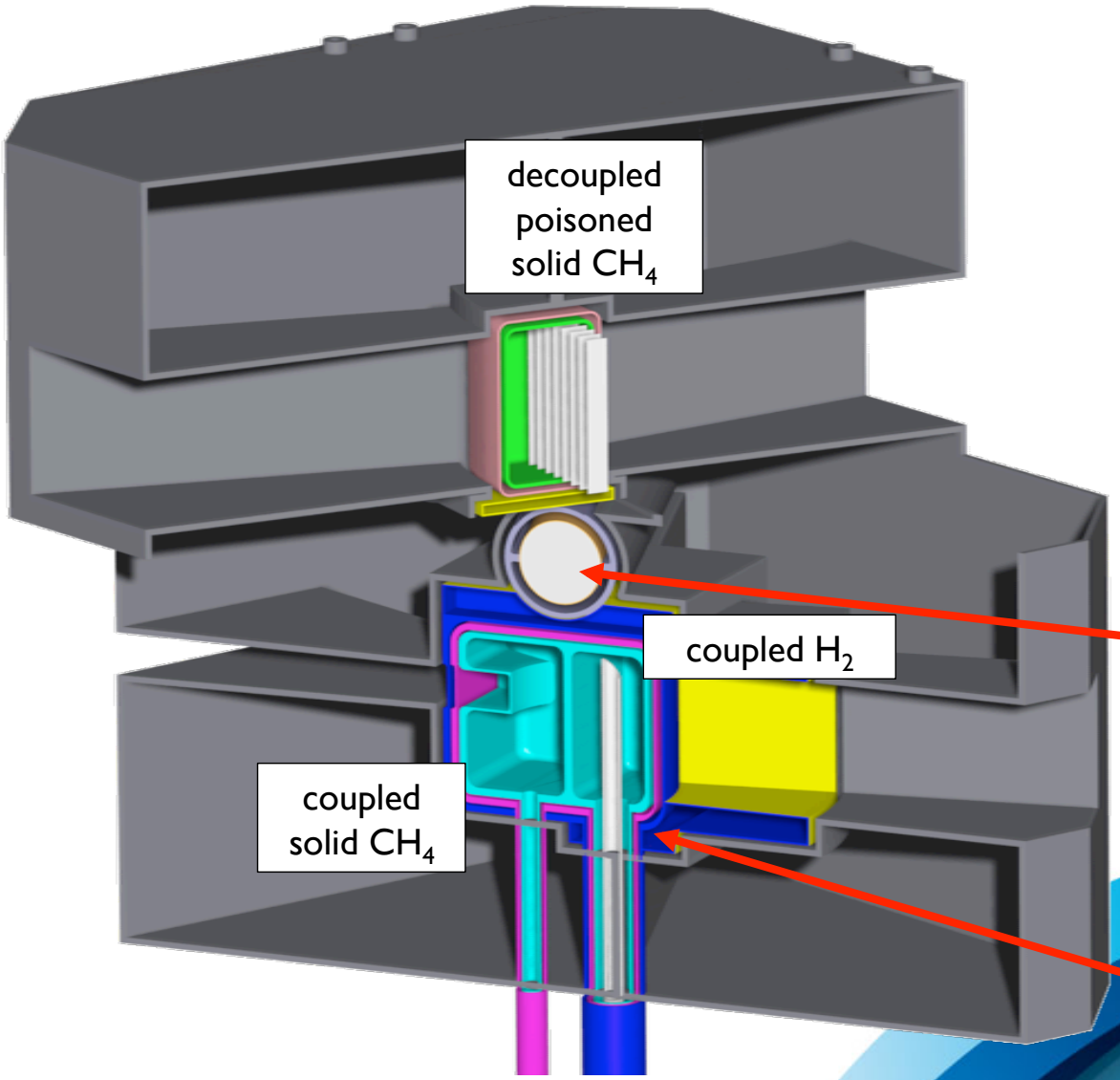
J-PARC coupled moderators

Time Averaged Intensity (for CM) :1/4 of ILL Cold source
Pulse Peak Intensity (for CM) ：~100 of ILL Cold source





ISIS TS2



Target:
66mm W

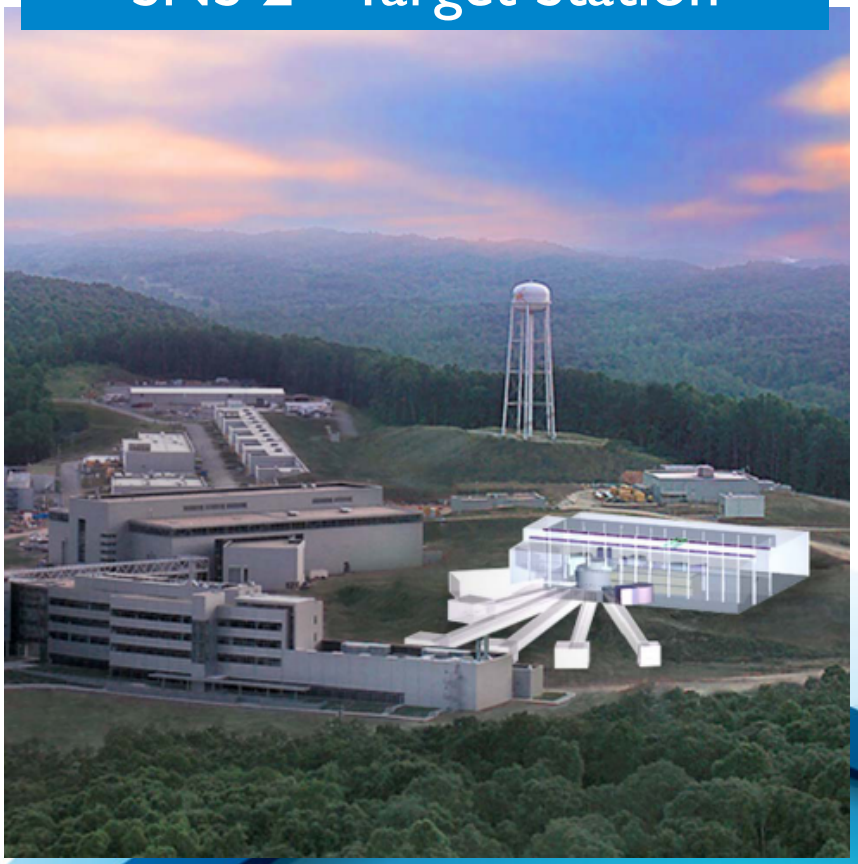
Water Jacket

EUROPEAN SPALLATION SOURCE

The future: Long-pulse spallation sources

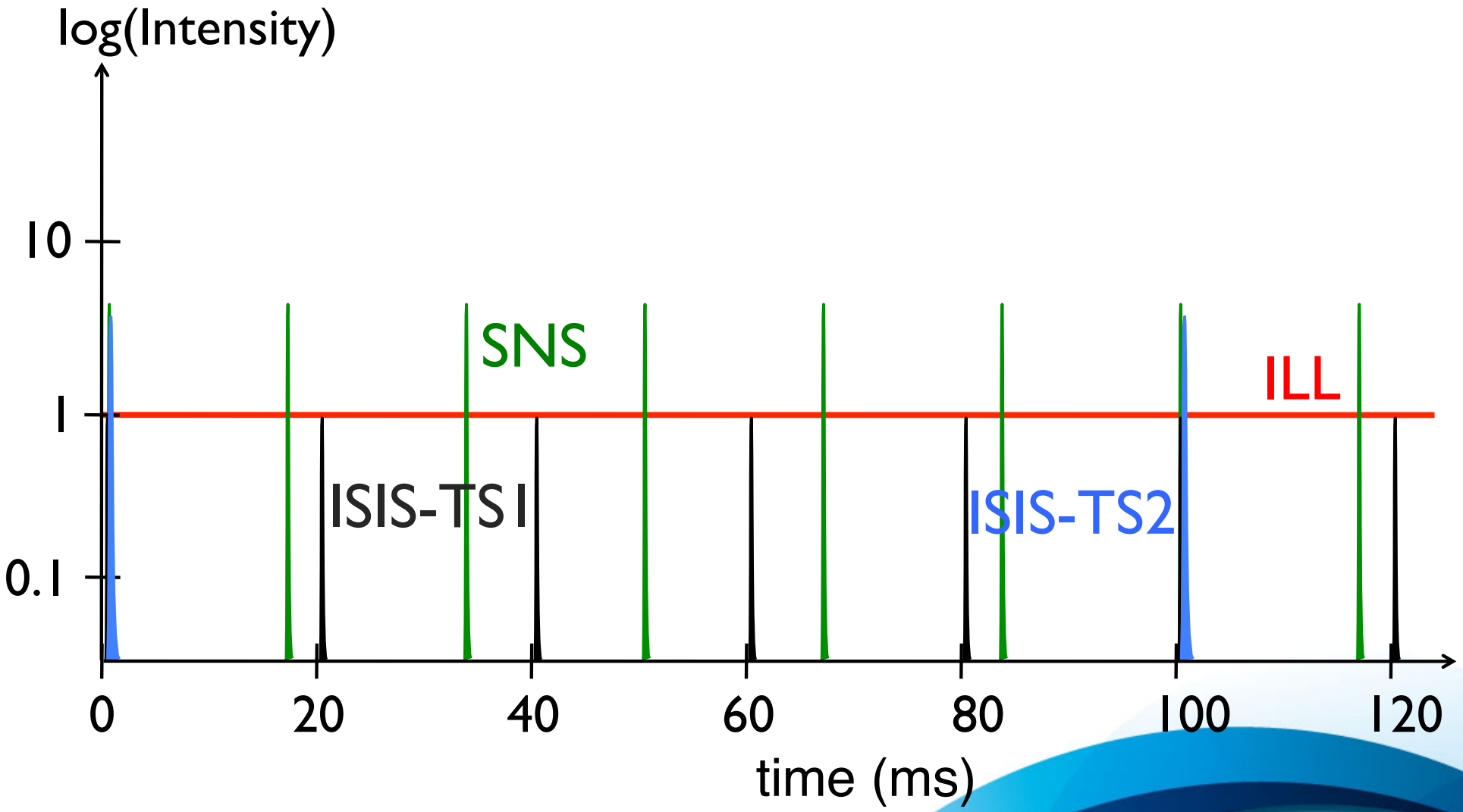
ESS, Sweden

SNS 2nd Target Station

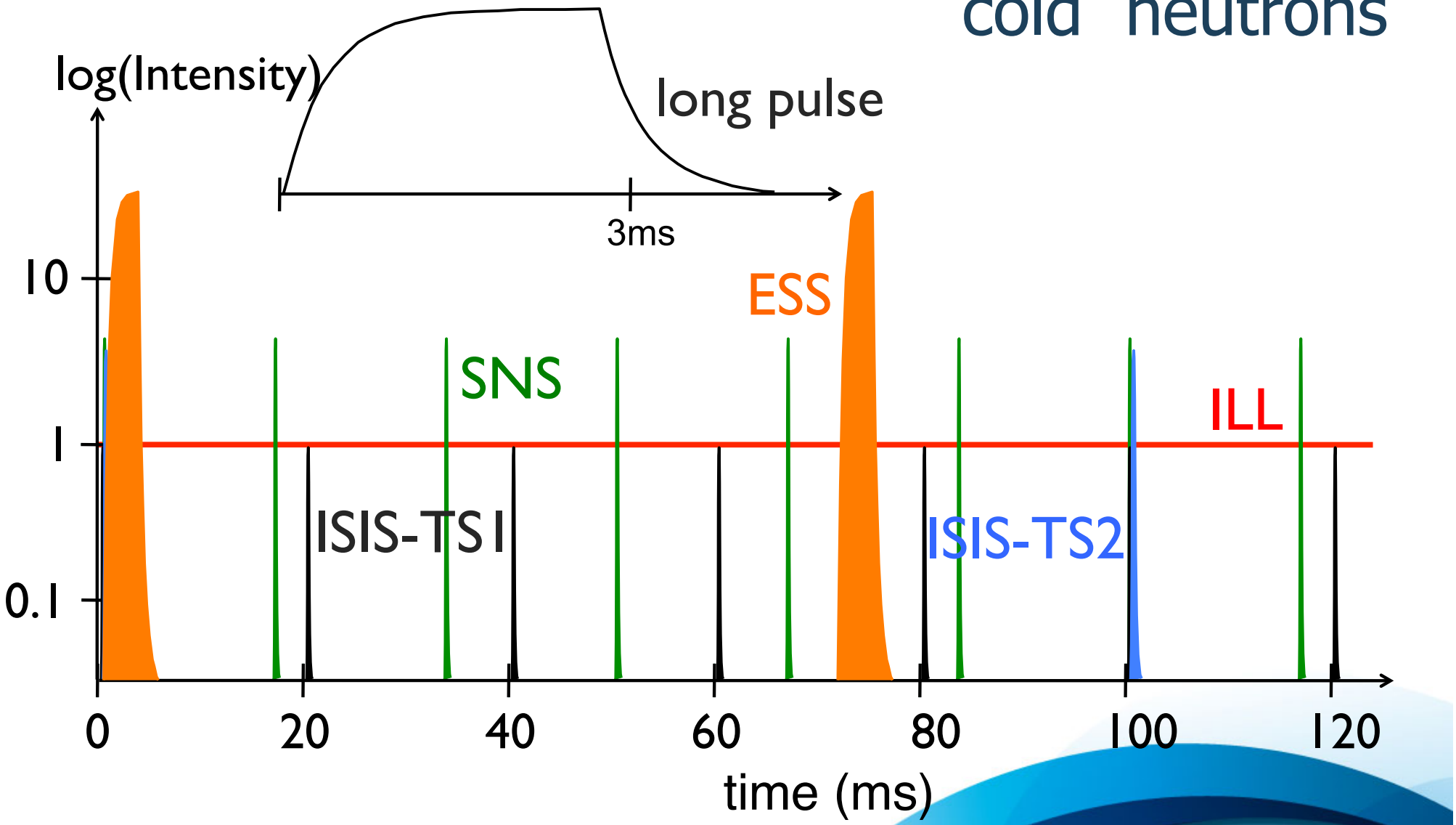


Long pulses: use only linac

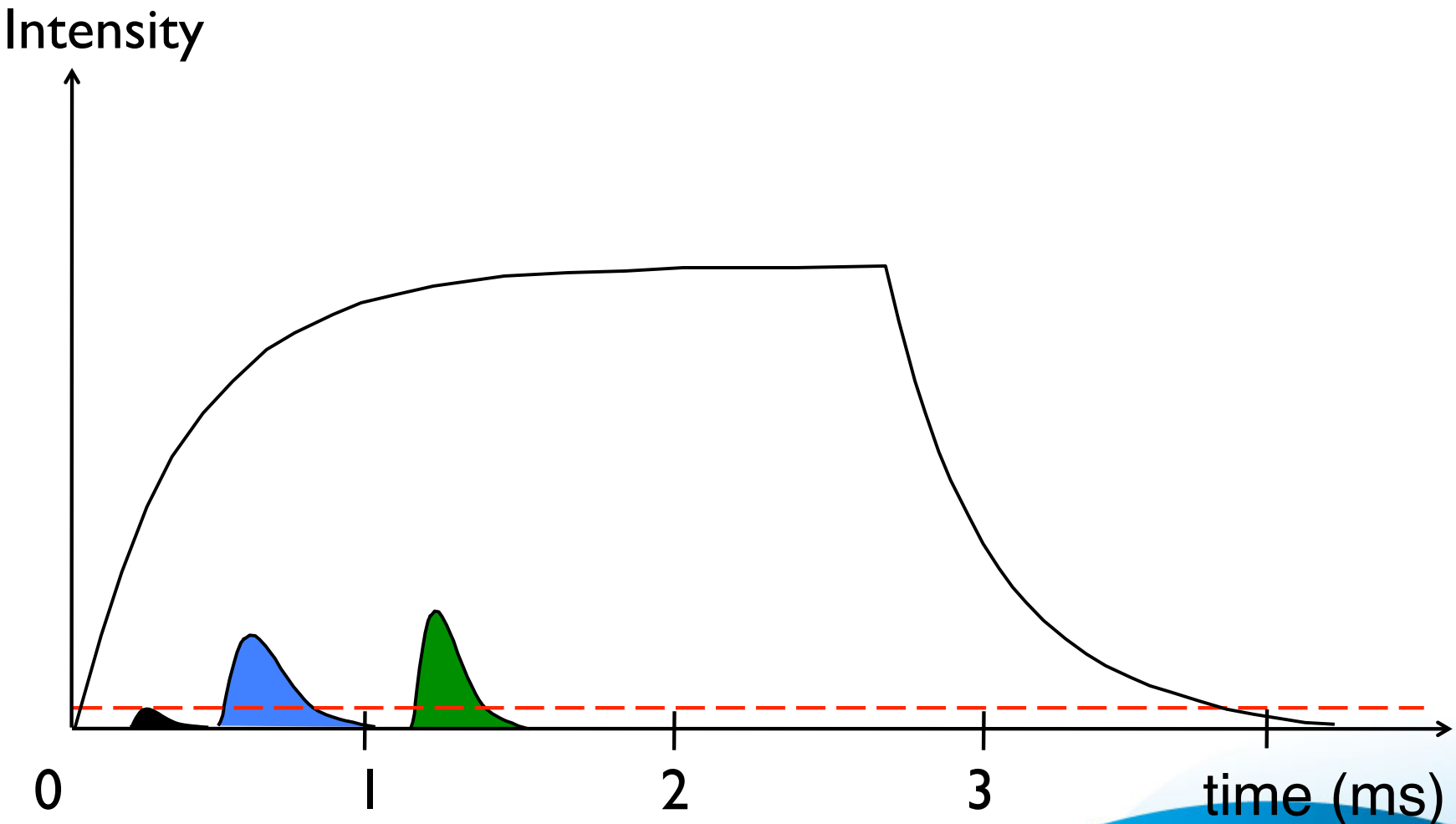
Pulsed-source time structures cold neutrons



Pulsed-source time structures cold neutrons



Long-Pulse Principle



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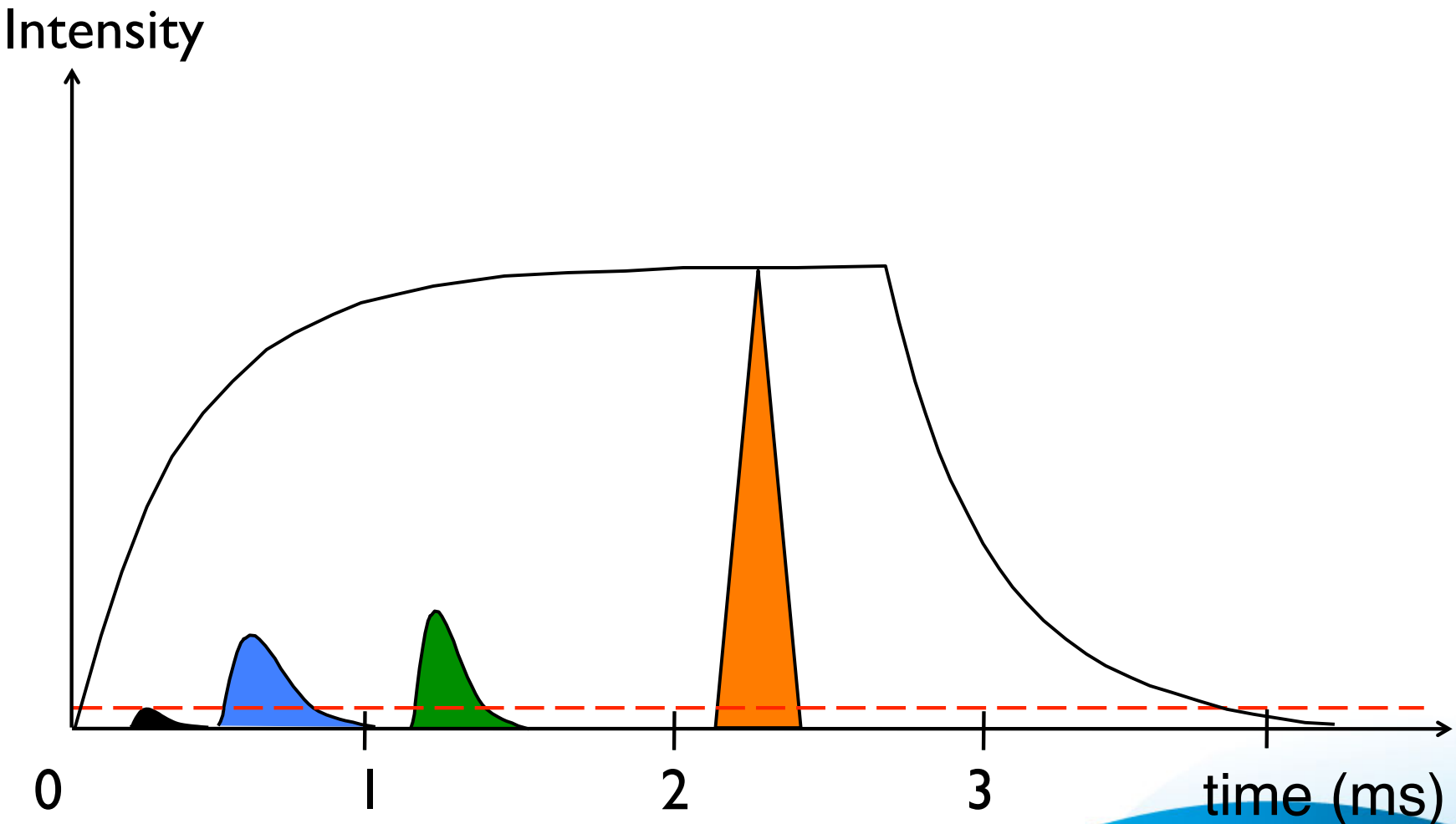

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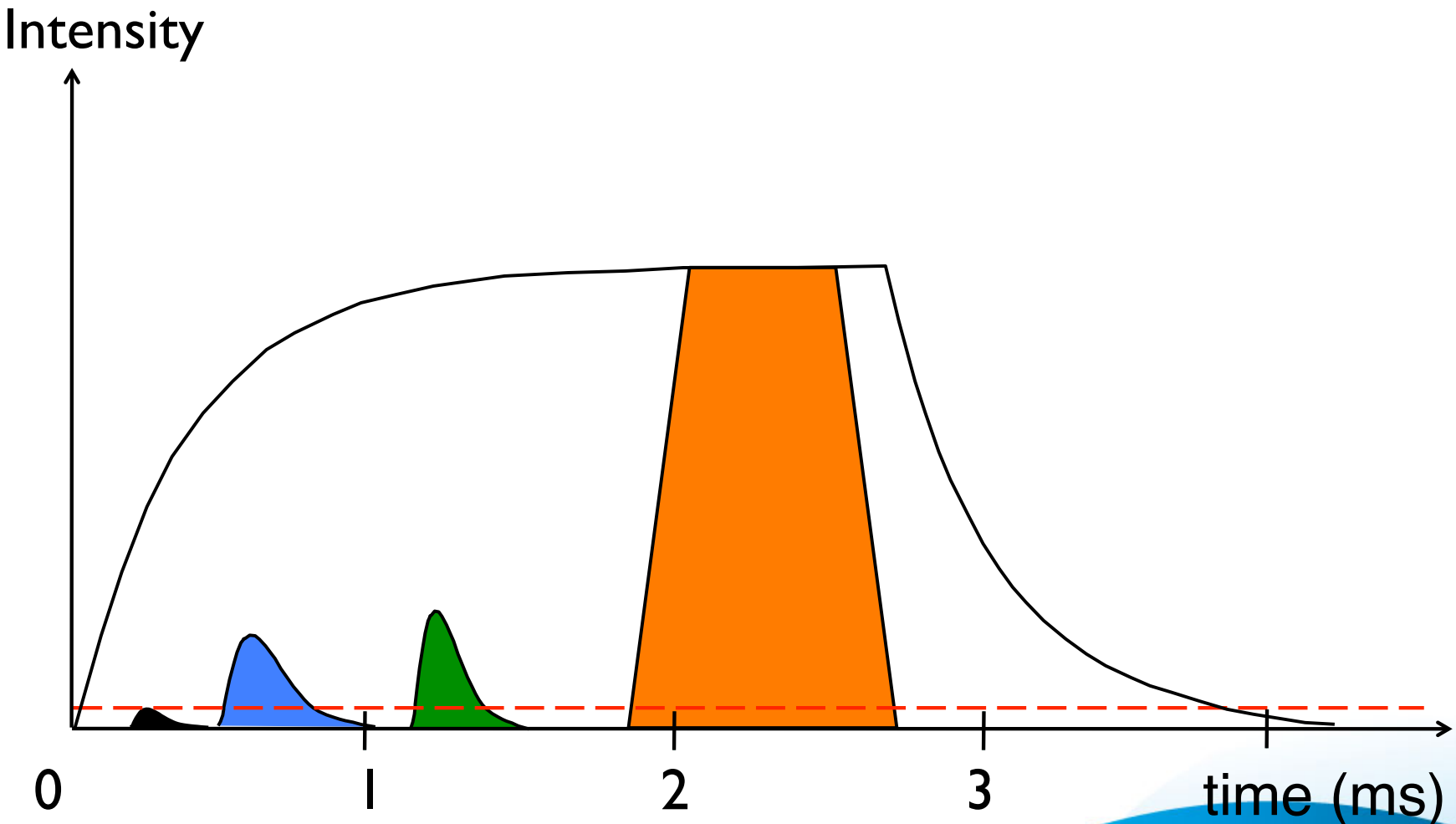

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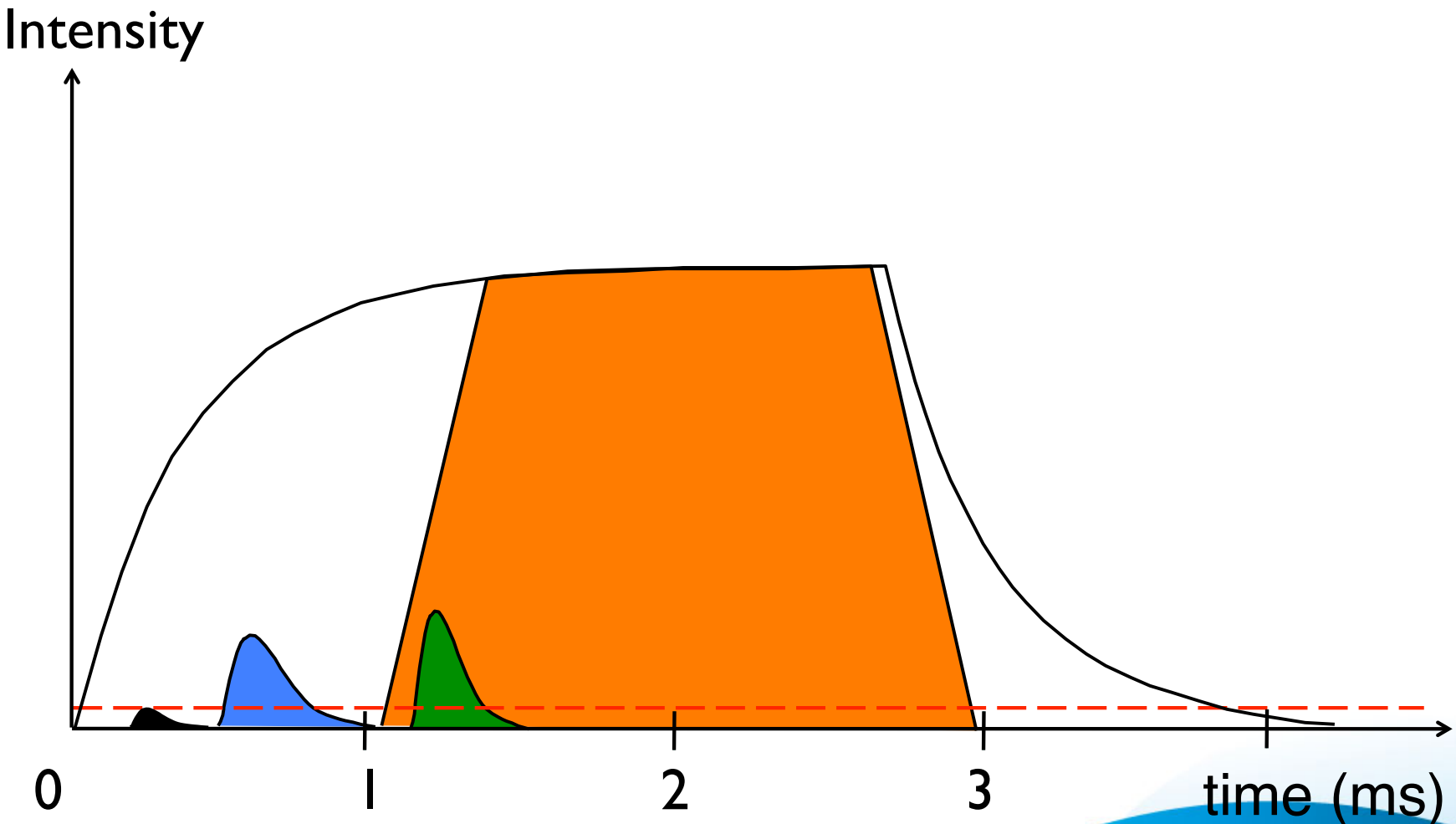
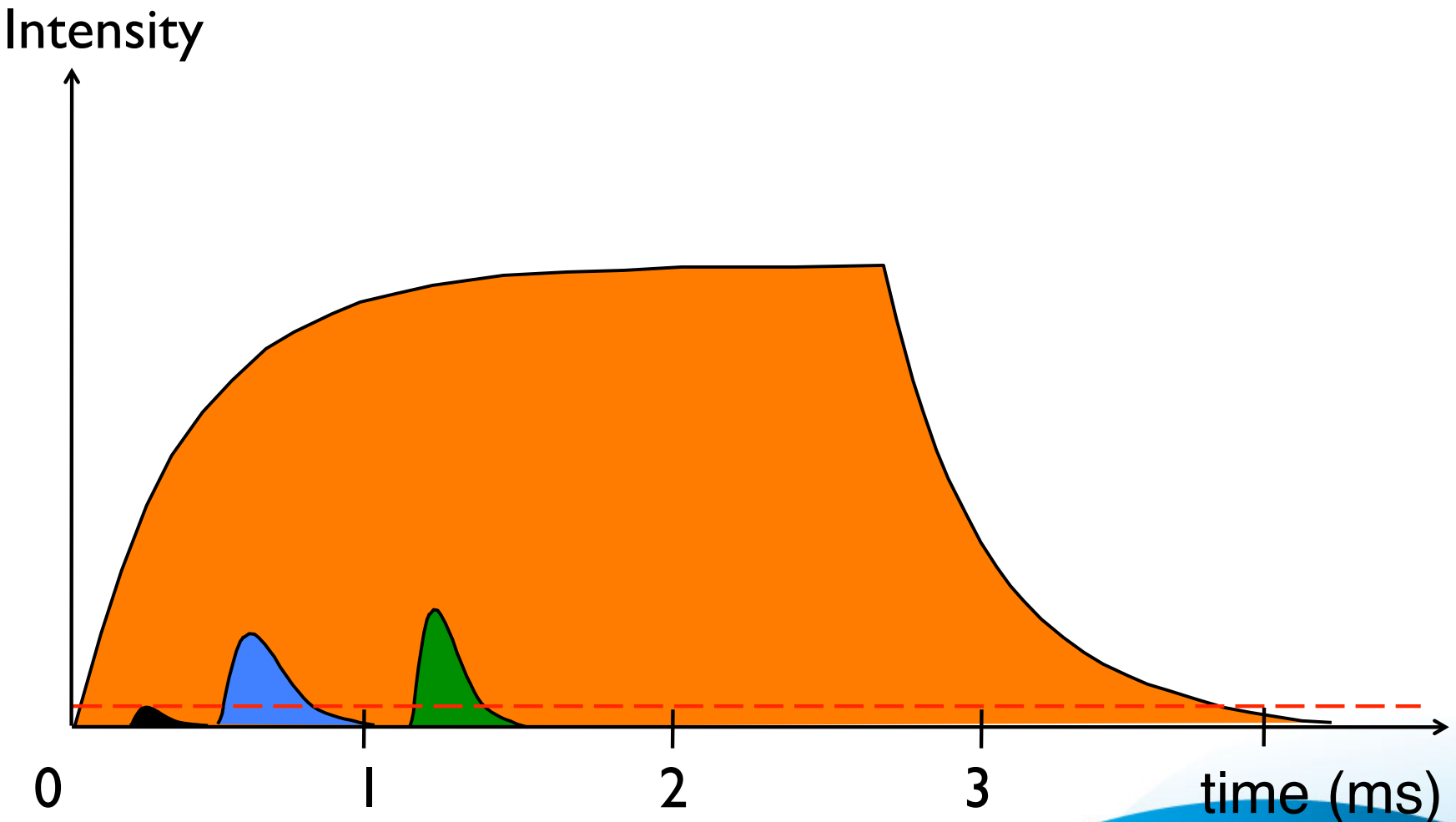


Long-Pulse Principle



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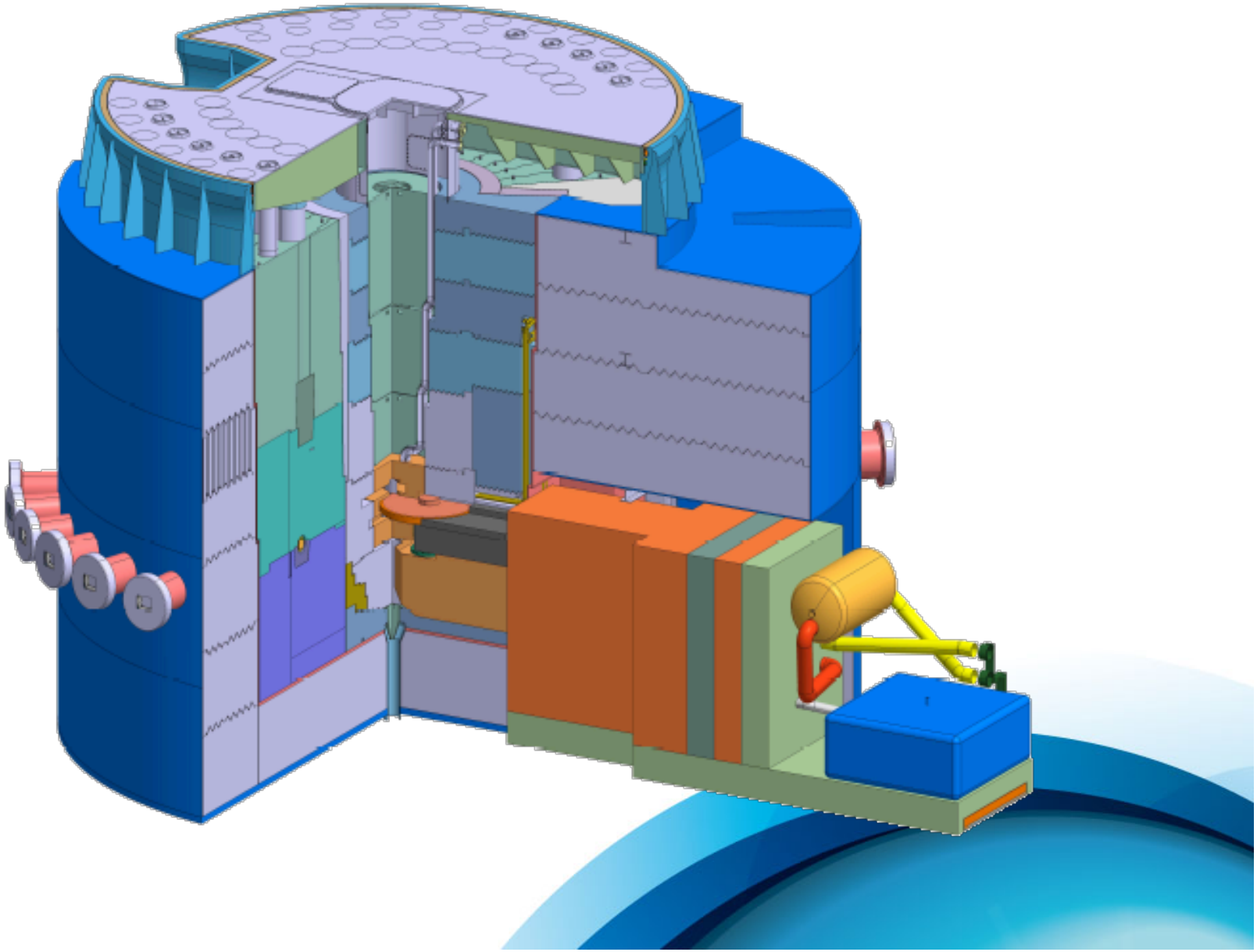
ESS Target Station



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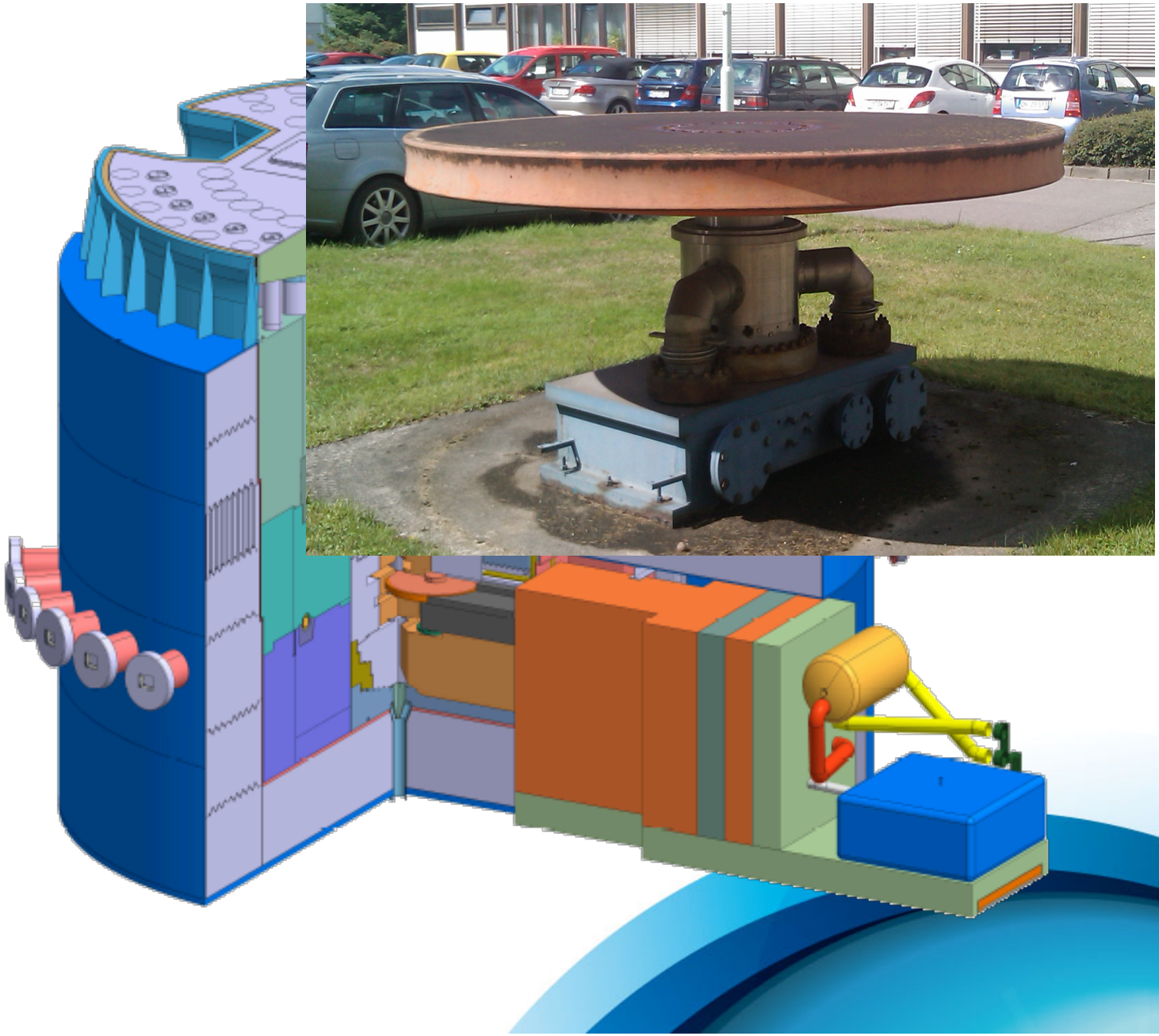

Thank you !

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Ken Andersen
ESS Instruments Division

Oxford School of Neutron Scattering

Oxford, 2011-09-06