Science & Technology Facilities Council
ISIS

ISIS Neutron and Muon Source

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ISIS Neutron and Muon Source
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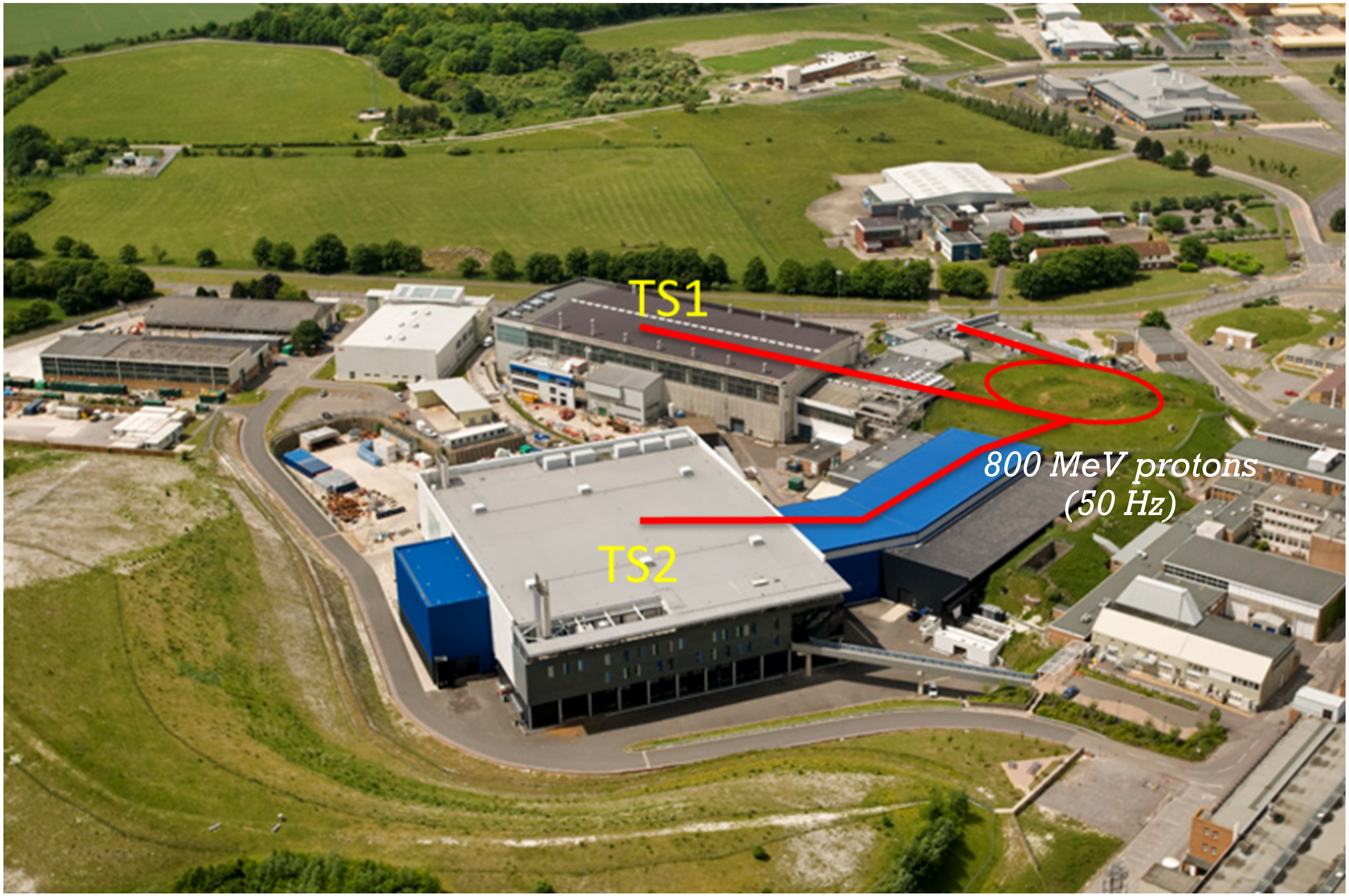
Target Station 1 (TS1) up and running by 1985 and Target Station 2 (TS2) following in 2008

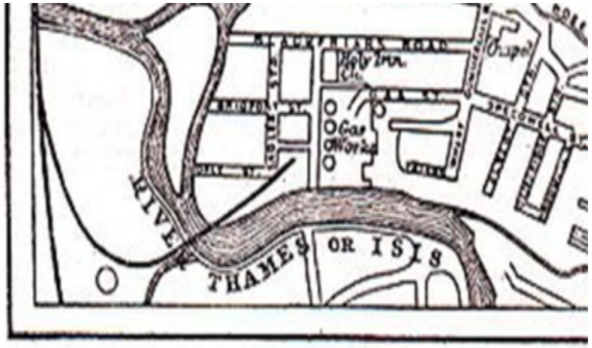


But first, NIMROD…

Nimrod was a 7 GeV proton synchrotron operating in the Rutherford Appleton Laboratory between 1964 and 1978. It was used for studies of nuclear and sub-nuclear phenomena.

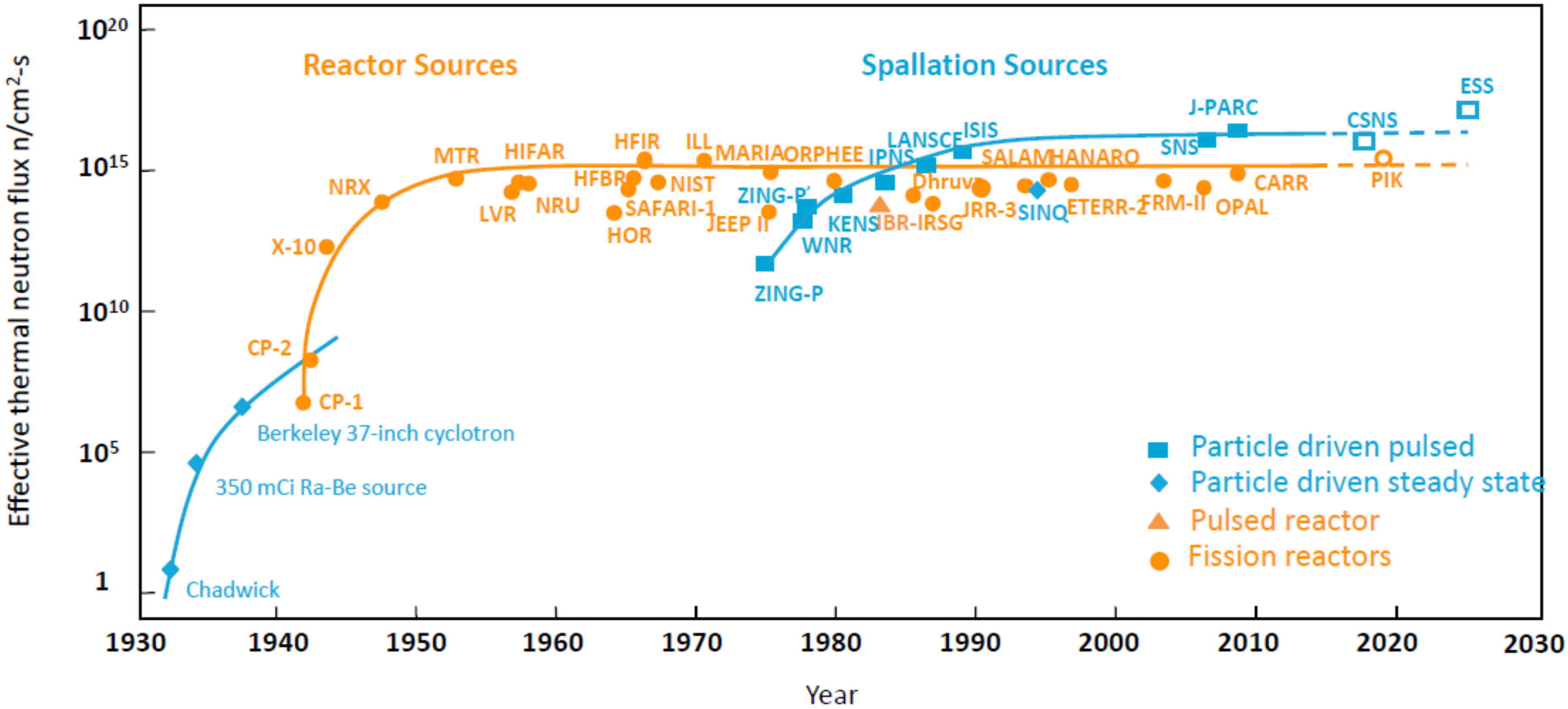
Nimrod was dismantled and the space it occupied reused for the synchrotron of the ISIS neutron source.

… and then, ISIS

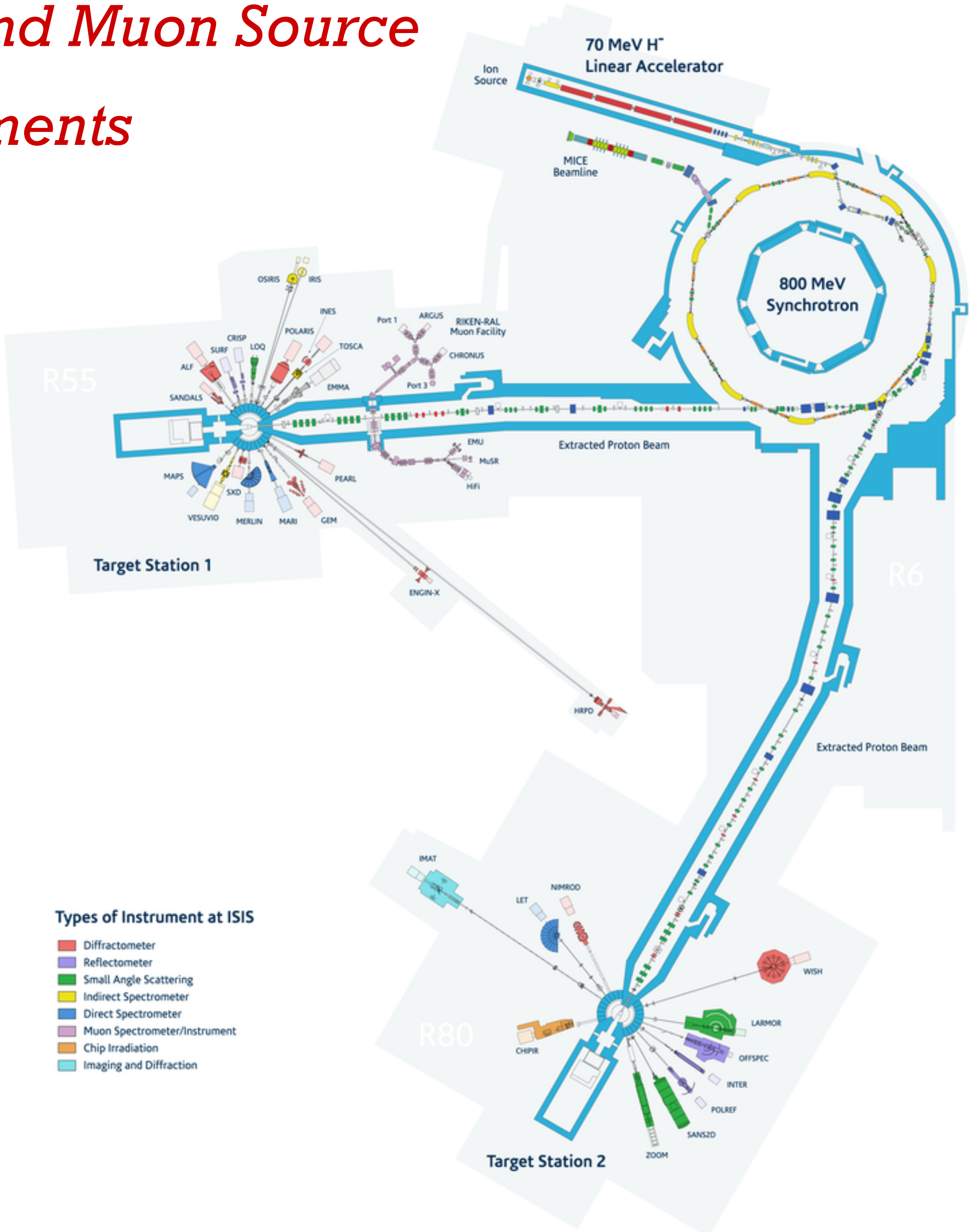


The name ISIS is not an acronym: it refers to the ancient Egyptian goddess and the local name for the river Thames. The name was selected for the official opening of the facility in 1985, prior to this it was known as the SNS, or Spallation Neutron Source. The name was considered appropriate as Isis was a goddess who could restore life to the dead, and ISIS made use of equipment previously constructed for the NIMROD and NINA accelerators.

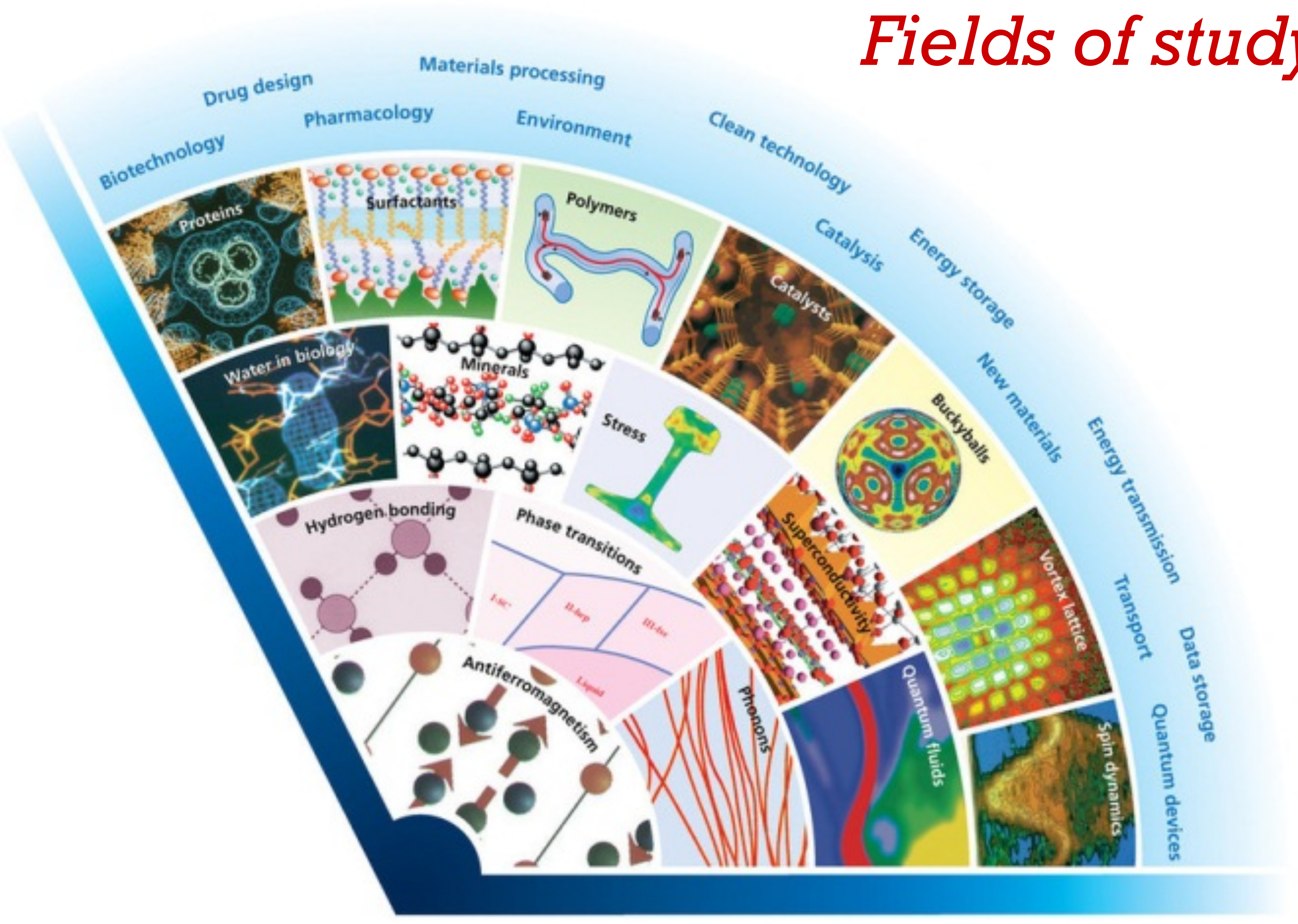
A bit of context: Neutron facilities around the world



ISIS Neutron and Muon Source instruments



Fields of study



Fields of study: Neutrinos?

Imperial College London

Evaluation of neutron backgrounds for ZEPLIN-III at ISIS

Henrique Araújo (Imperial College London)

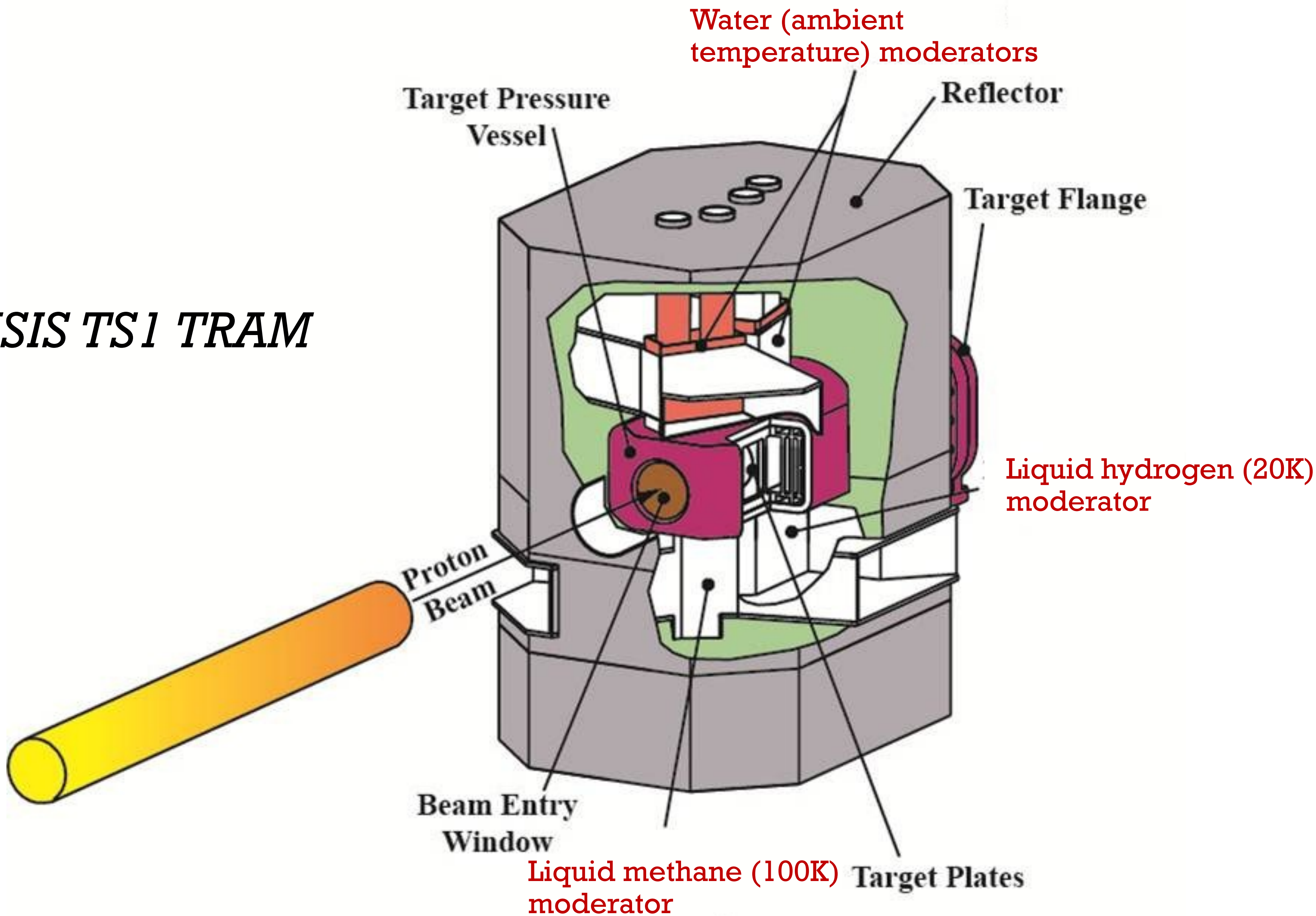
March 23rd, 2012 (v2.0)

Summary

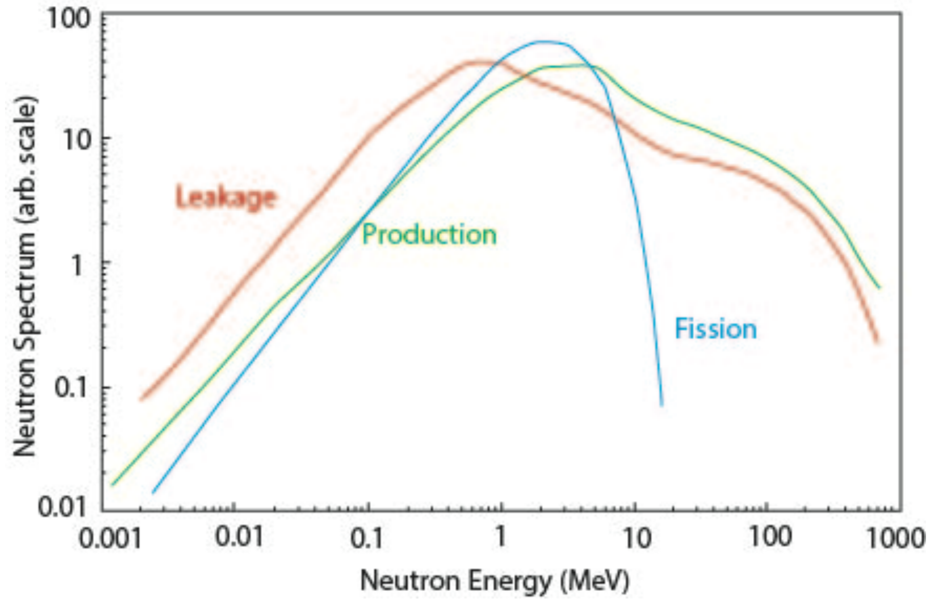
We assessed the viability of a measurement of coherent neutrino-nucleus scattering (CNS) with ZEPLIN-III at the ISIS facility analysing specifically the dominant neutron backgrounds. The signal rate expected in a 6 kg fiducial liquid xenon volume is 52 events per calendar year. Cosmogenic and internal neutrons contribute ~30 events per year in near-coincidence with the beam (un-vetoed nuclear recoils with energies of 0.1-10 keV) but can be further subtracted with an off-beam measurement. Beam-coincident spallation neutrons above 20 MeV appear to dominate the ambient neutron dose equivalent rate measured at the neutrino alcove. These would make a beam-coincident measurement at that location impossible even with additional shielding. A 1-μs delayed measurement (targeting muon-decay neutrinos only) would eliminate most of the prompt backgrounds (delayed neutrons can be shielded effectively) whilst retaining ~25% signal acceptance, or 13 events per year. This is deemed too low a rate to enable a discovery experiment with manageable risk.

Heart of a Spallation Neutron Source: Target, reflector and moderators (TRAM) assembly

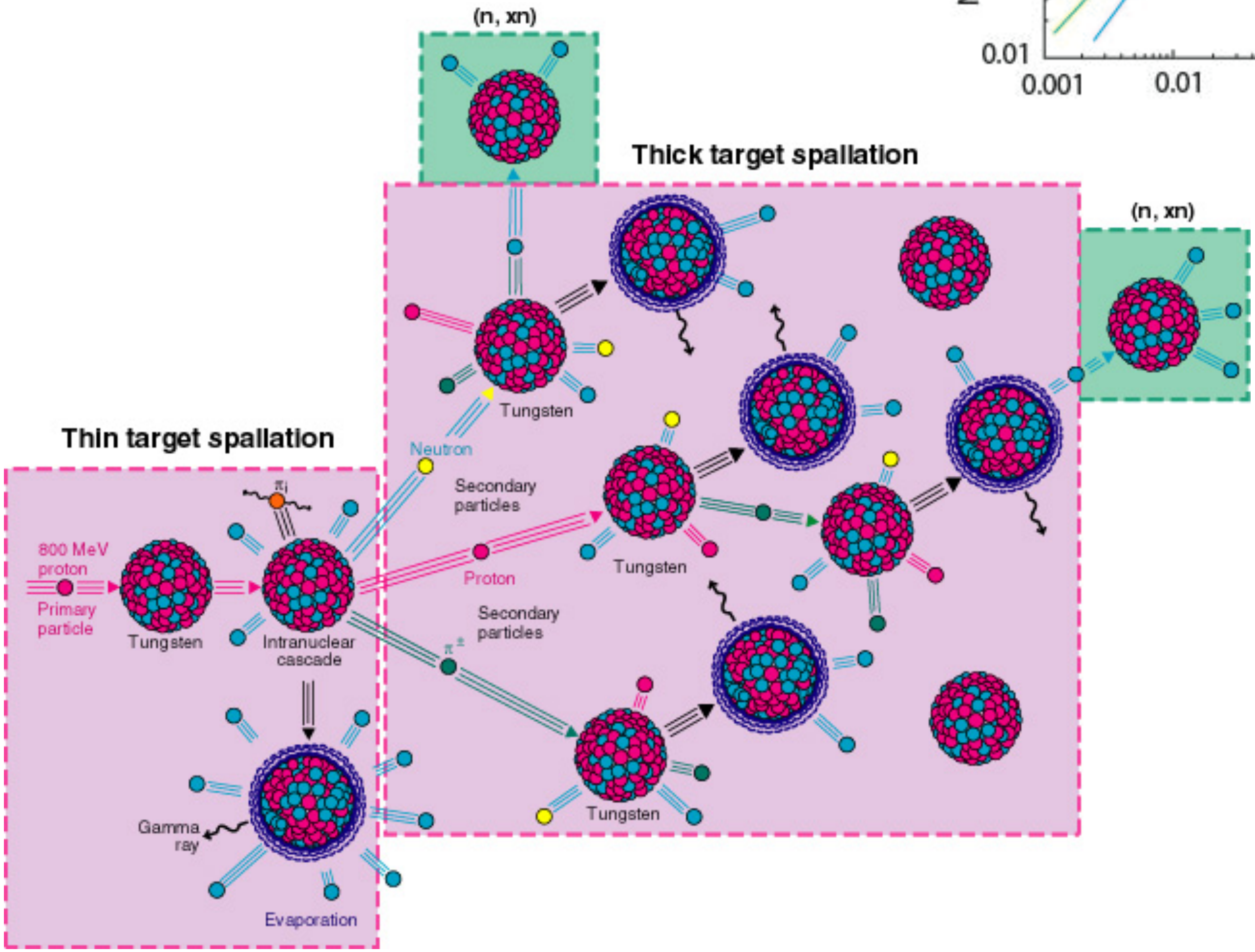
ISIS TS1 TRAM



Spallation



Neutron Spectrum (arb. scale)
Neutron Energy (MeV)
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
Leakage
Production
Fission

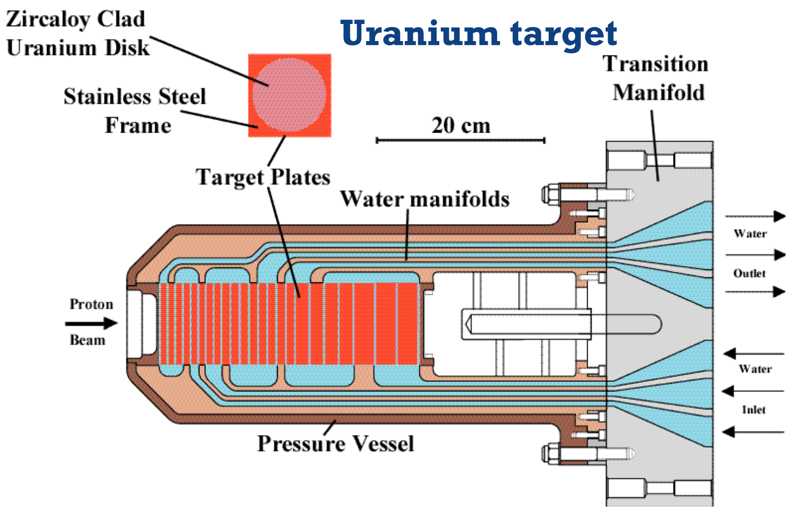


(n, xn)
Thick target spallation
(n, xn)
Thin target spallation
800 MeV proton
Primary particle
Tungsten
Intranuclear cascade
Evaporation
Gamma ray
Neutron
Secondary particles
Proton
Secondary particles
Tungsten
Tungsten
Tungsten

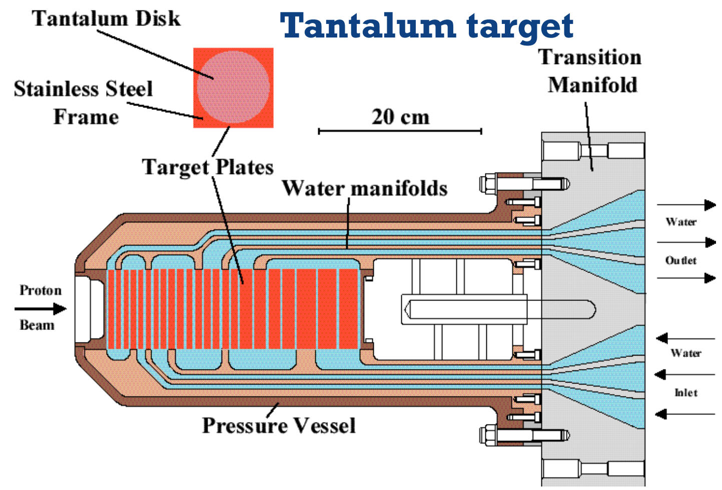
ISIS TS-1 targets

20th century

Uranium target

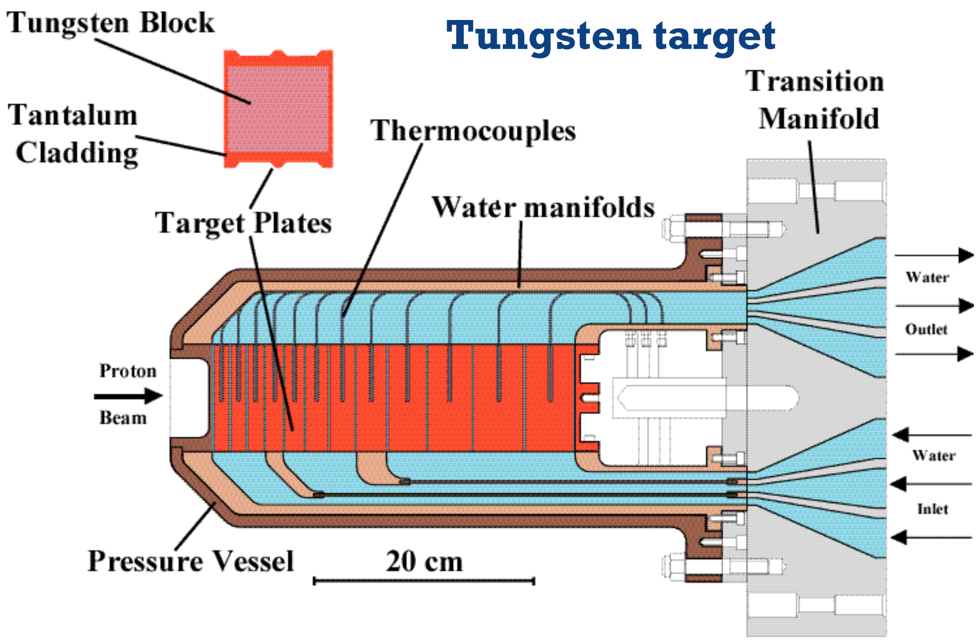


Tantalum target



Tungsten target

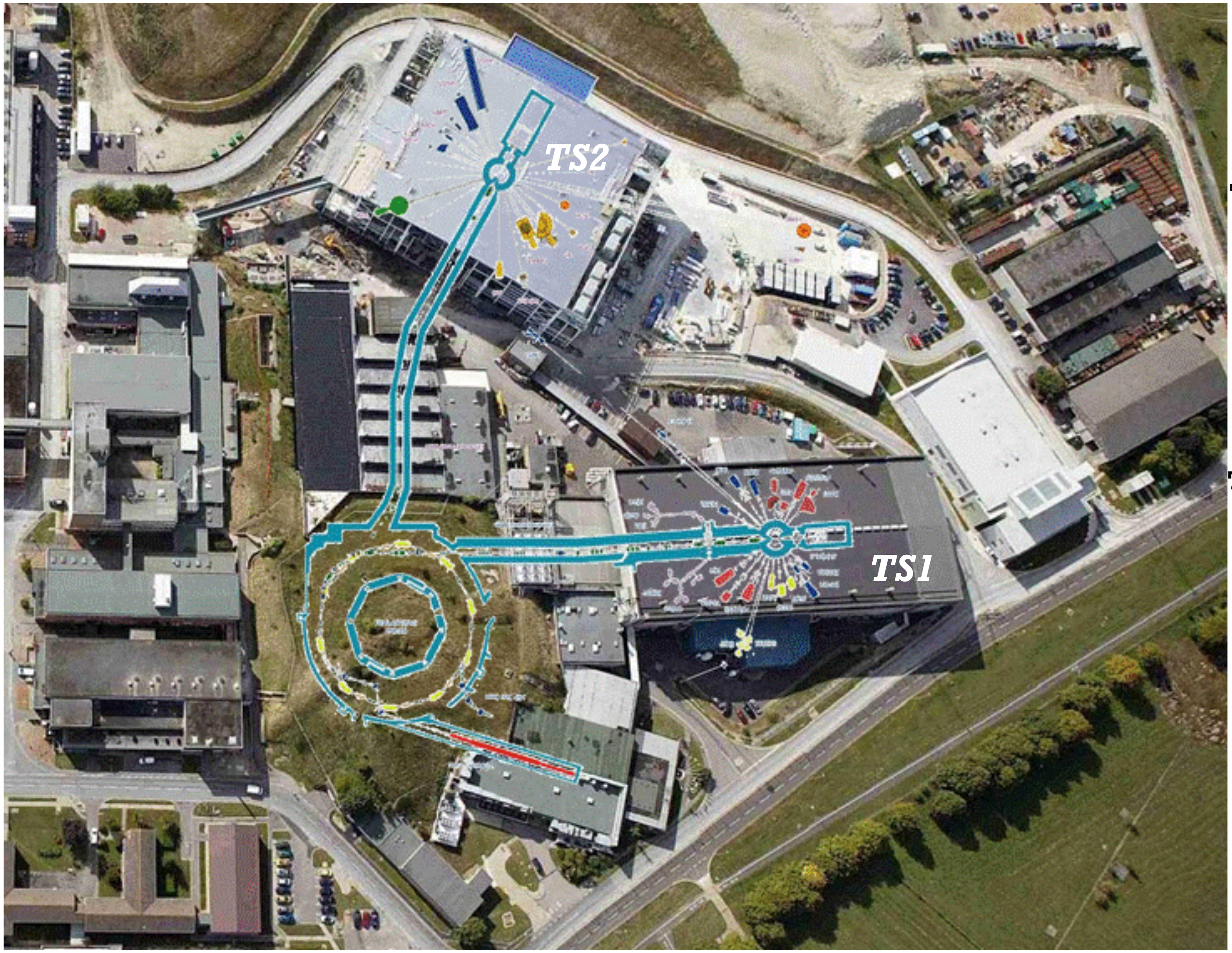
21th century



Current target – 12 tungsten plates (tantalum cladding)

Typically 160 μA (800 MeV protons)

ISIS Targets: History



ISIS TARGETS
DATES FITTED - REMOVED

TS1

...

TANTALUM #2 OCT 1994 – FEB 1995
URANIUM #9 MAY 1995 – JUN 1995
TANTALUM #2 JUN 1995 – SEP 1996
TANTALUM #3 NOV 1996 – APR 1999
TANTALUM #4 MAY 1999 – MAR 2001
TUNGSTEN #1 MAY 2001 – AUG 2005
TUNGSTEN #2 SEP 2005 – APR 2009
TUNGSTEN #3 APR 2009 – SEP 2014
TUNGSTEN #4 MAR 2015 –

TS2

TUNGSTEN #1 AUG 2008 – FEB 2010
TUNGSTEN #2 FEB 2010 – JUN 2010
TUNGSTEN #3 MAR 2011 – NOV 2012
TUNGSTEN #4 NOV 2012 – JUN 2014
TUNGSTEN #6 JUL 2014 – JUL 2015
TUNGSTEN #7 SEP 2015 –

BEAM PARAMETERS

800 MeV protons
50 Hz
Short pulse (~0.5 μs)
160 μA – TS1
40 μA – TS2

TS-1 W-4 target: irradiation history

Cycle: 2014/03 (first row, left table)

Cycle: 2016/04 (penultimate row, left table)

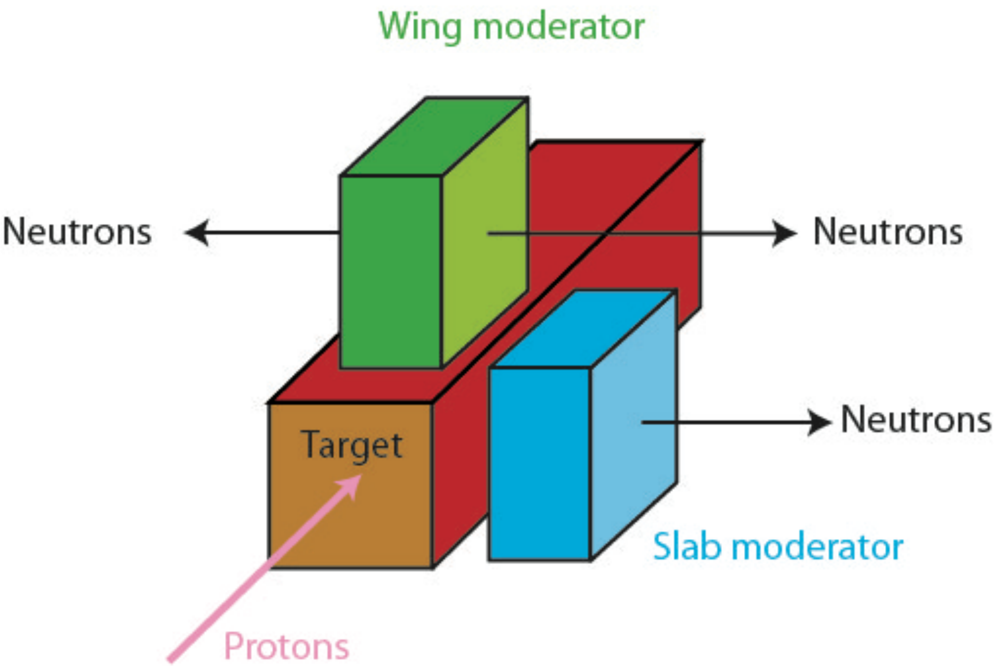
Beam Status	Number of days	Integrated current [mA-hours]	Beam energy [MeV]
on	47	171	700
off	30		
on	42	162	700
off	44		
on	38	139	700
off	16		
on	43	142	800
off	61		
on	16	53	800
on	22	72	700
off	17		
on	38	138	800
off	112		
on	15	41	800
on	30	83	700
off	14		
on	30	100	700
off	59		

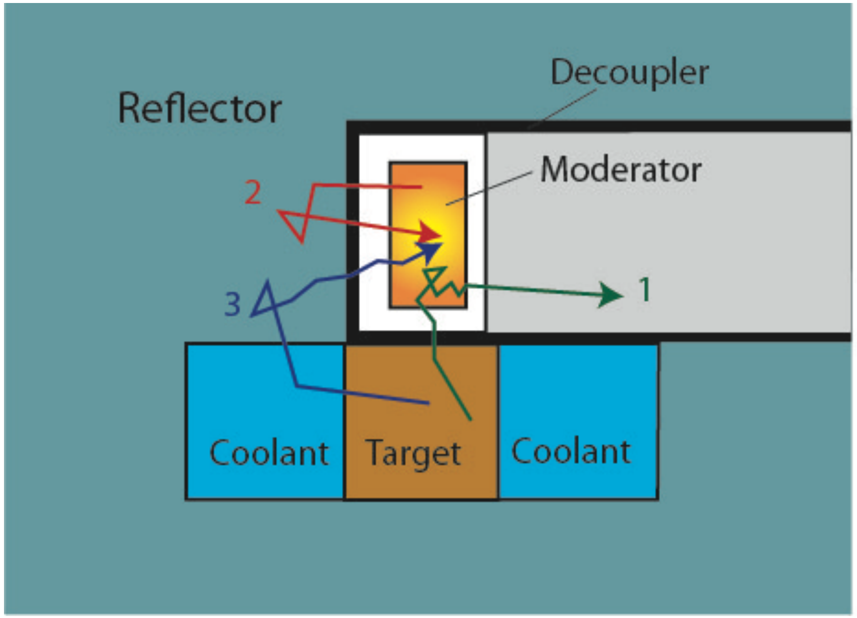
Cycle: 2016/05 (first row, right table)

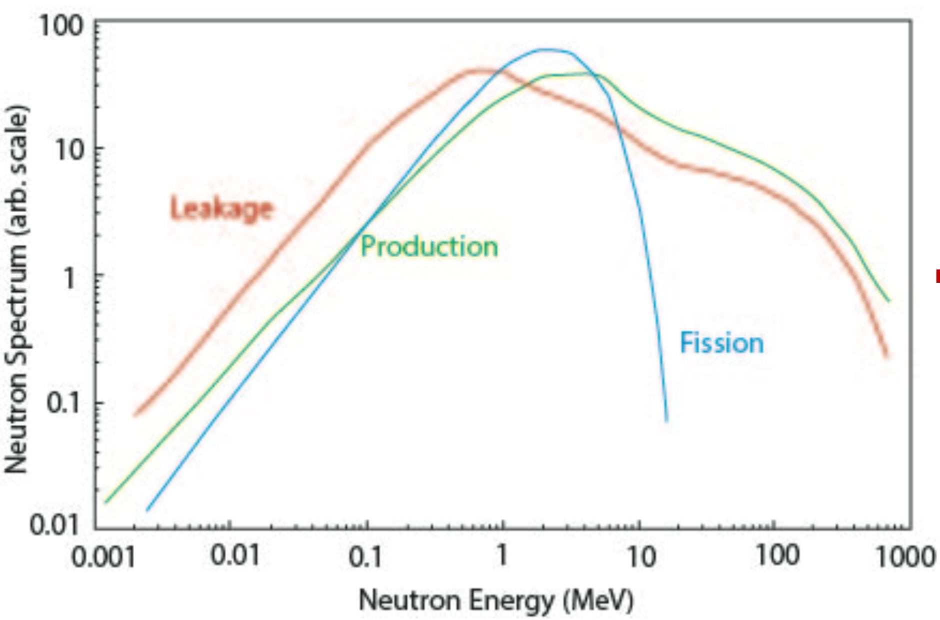
Cycle: 2018/03 (last row, right table)

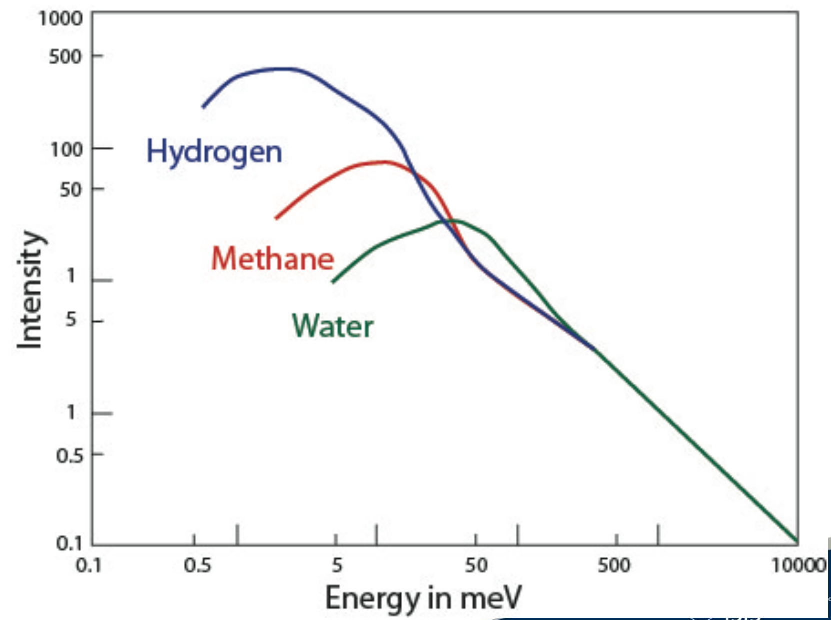
Beam Status	Number of days	Integrated current [mA-hours]	Beam energy [MeV]
on	12		800
on	33	151 (total)	700
off	31		
on	31	112	700
off	108		
on	30	104	800
off	24		
on	35	132	700
off	48		
on	47	180	700
off	23		
on	30	116	700
off	18		
on	38	155	700
off	60		
on	44	170	700
off	15		
on	40	140	700

Neutron moderation



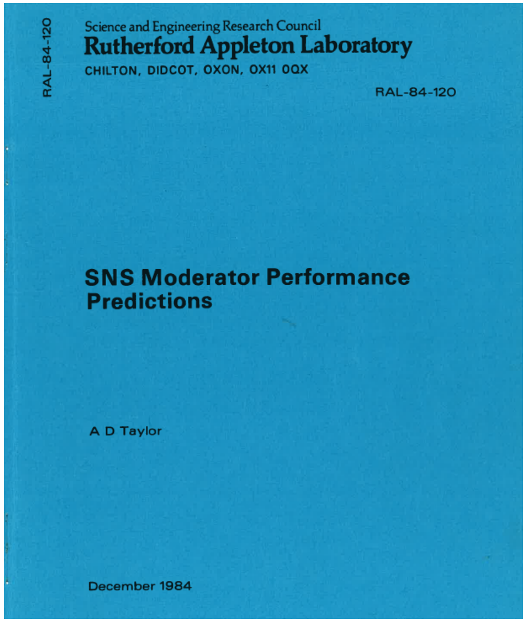


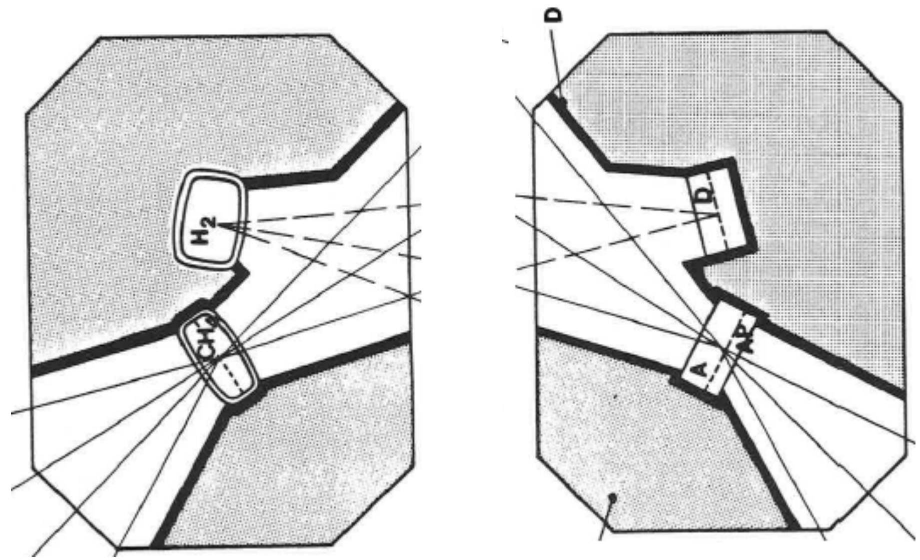




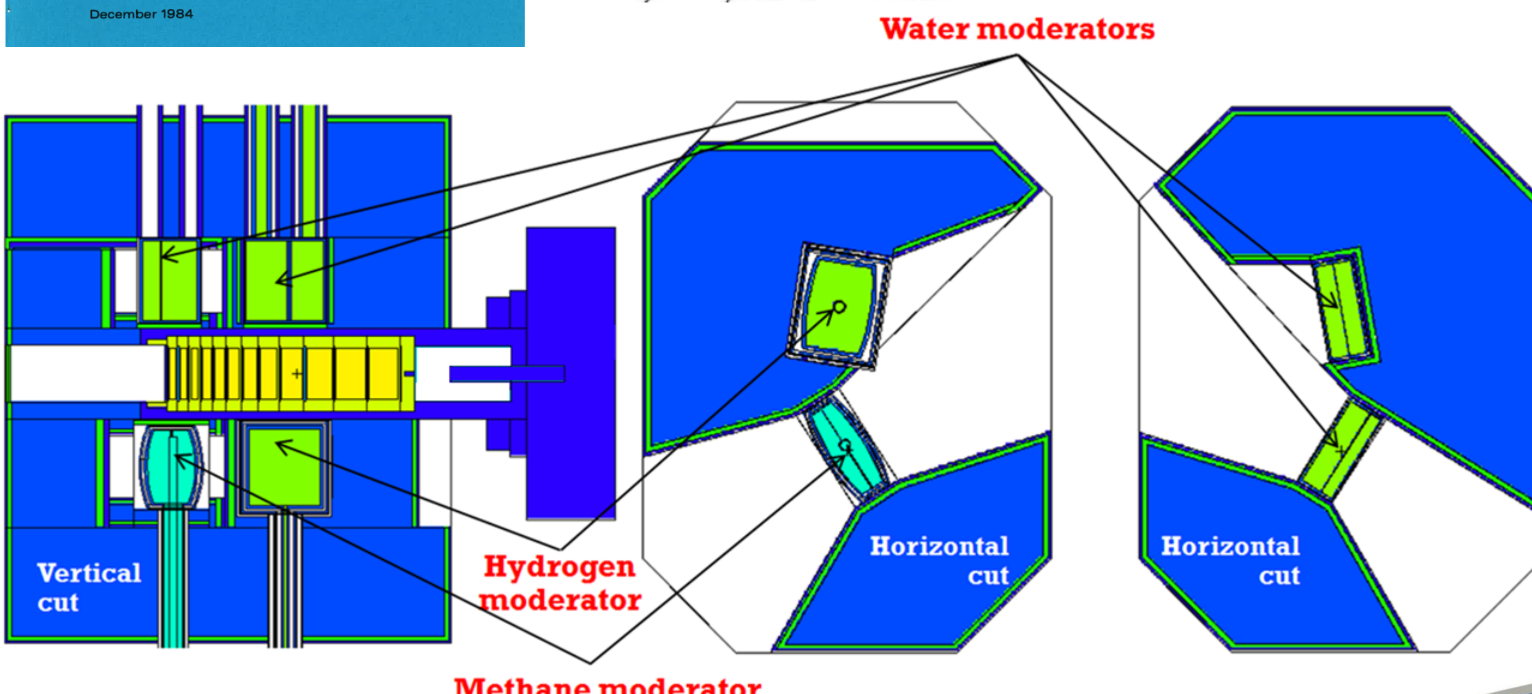
Target Station 1

1985



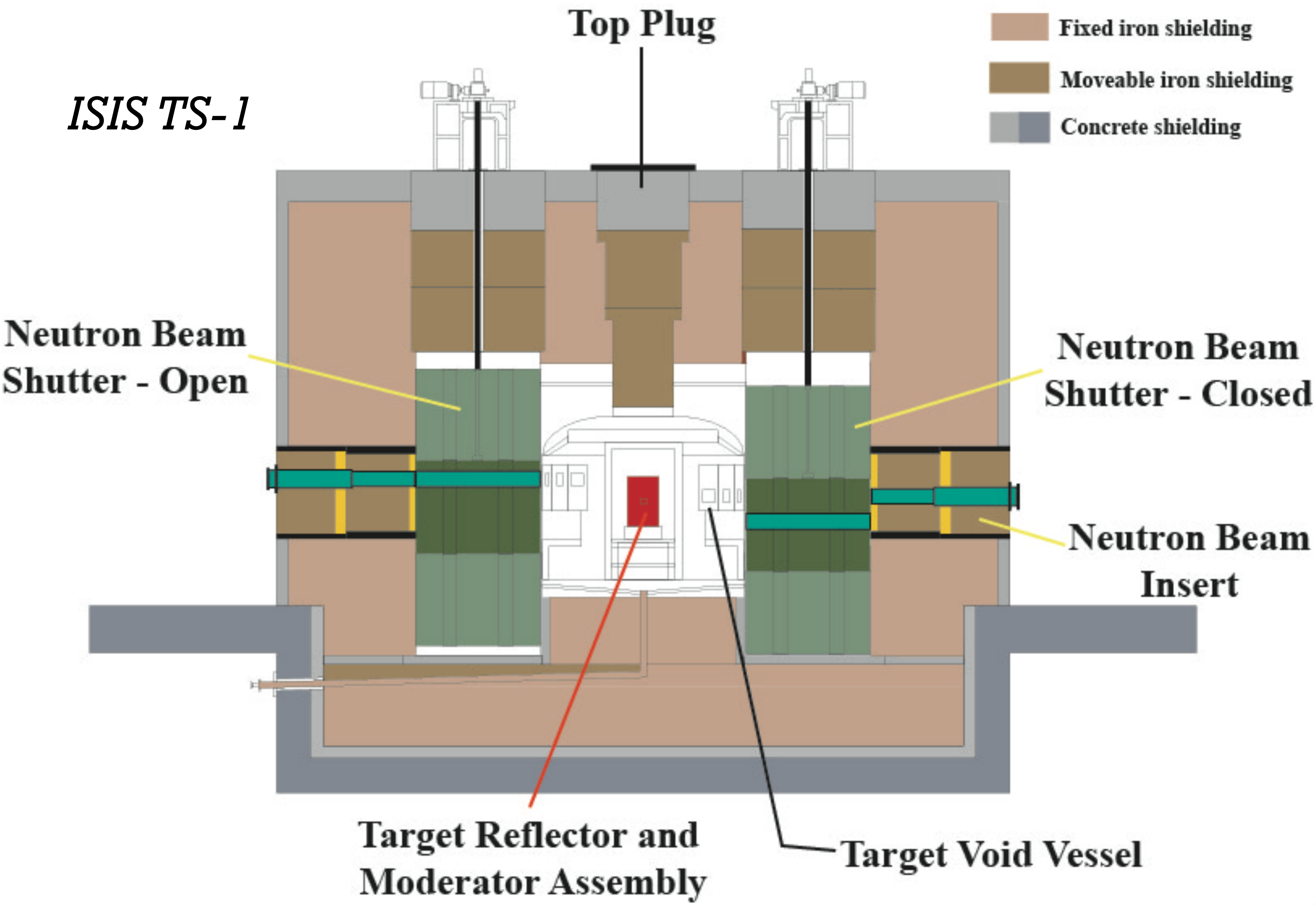


2019

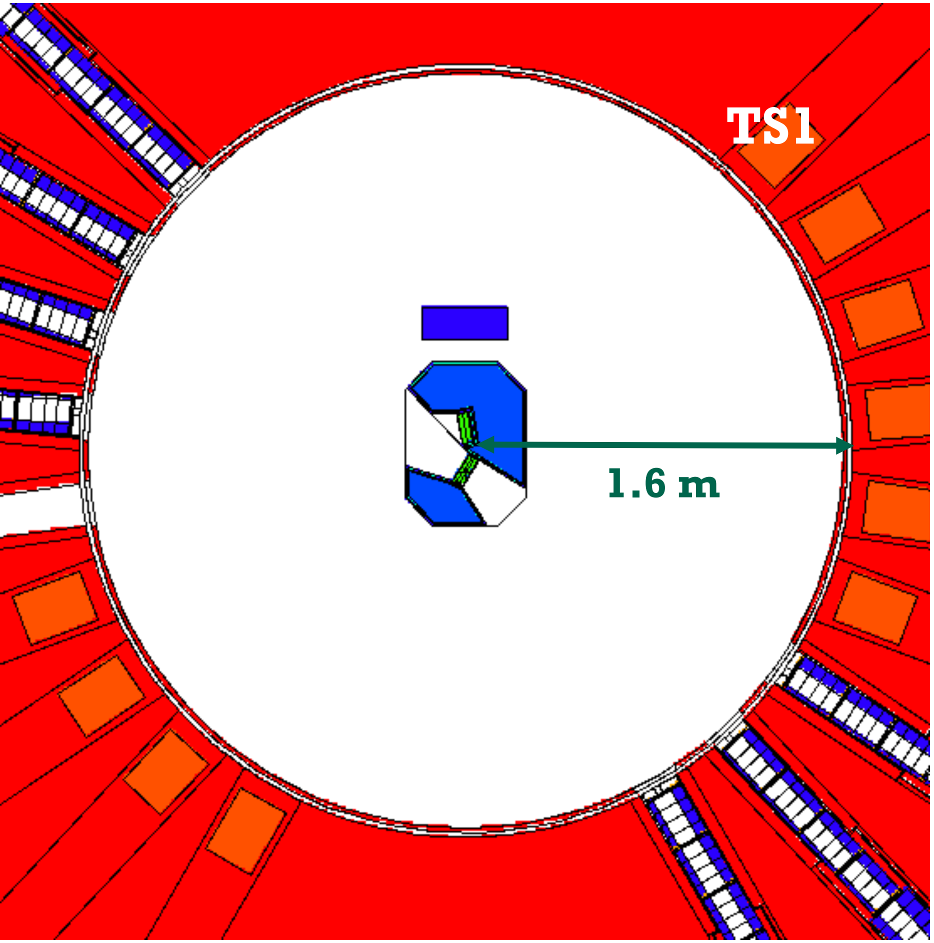


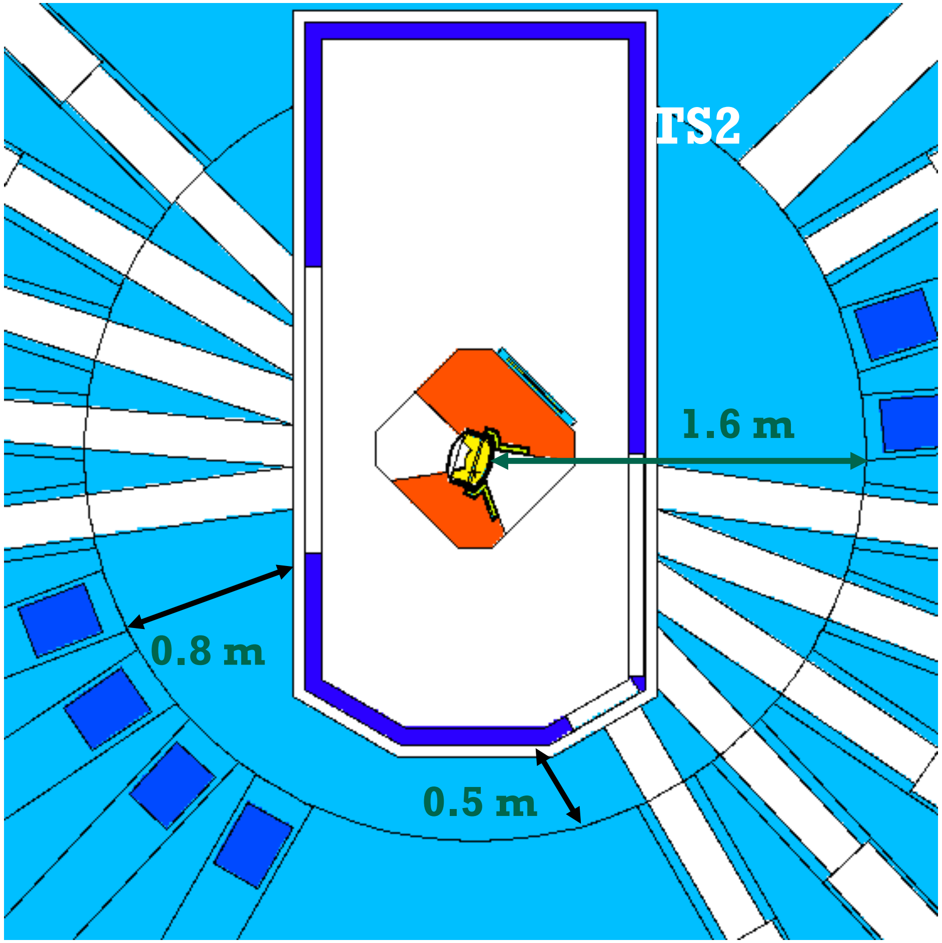
Neutron beamlines & shielding

ISIS TS-1



Shielding: TS1 / TS2





Nuclear (neutronics) physicist at a spallation neutron source

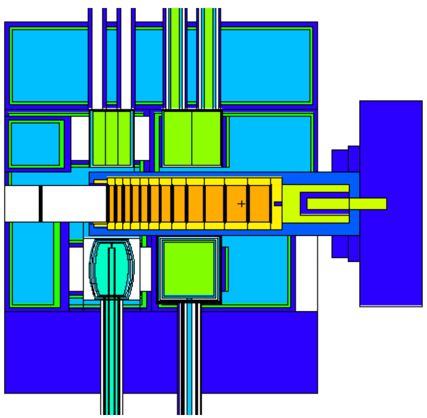
Job description:

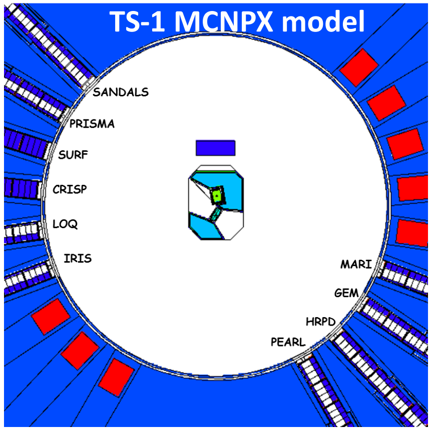
- *Building the neutronics Monte Carlo models of the Target Stations;*
- *Providing consultancy that allow instrument scientists to get maximum from their instrumentation;*
- *Calculations of the build-up of radionuclide inventories in activated materials;*
- *Robust measurements of particle fluxes and radiation dose rates in operational environments;*
- *Preparation of the future research and development programmes;*
- *Consultation, advisory and planning activities outside of home organization.*

TS-1 Project

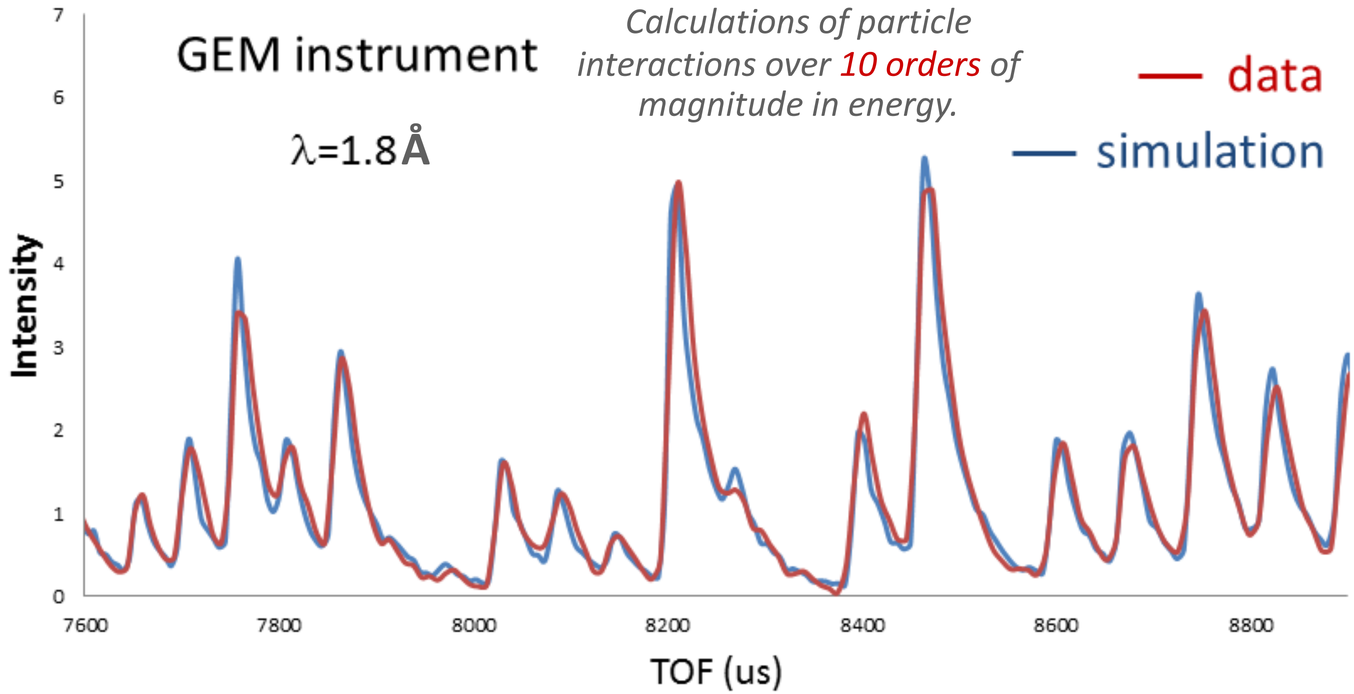
Monte Carlo model of current Target Station 1 has been created; an effort across ISIS to collect and document TS-1 characteristics.

***After 30 years ISIS community now has a** very fast **particle tracking model of the current TS-1** (with an unprecedented level of details).*

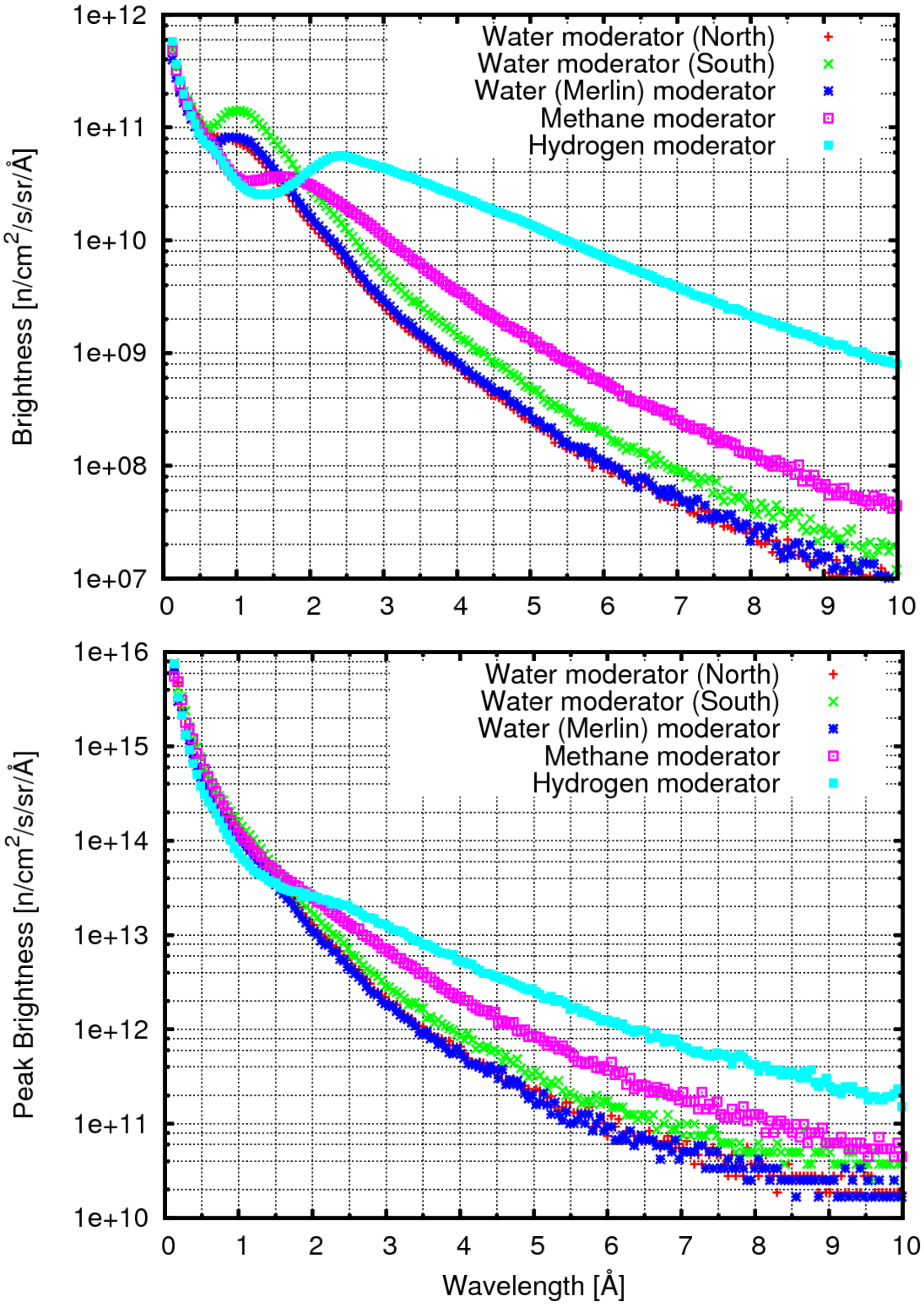




Calculations of particle interactions over 10 orders of magnitude in energy.



Unique in the world;
Invaluable as the basis for future upgrades of the TS-1.



Target Station 1

The mean and peak brightness of the current TS-1 moderators for beam current of 160 μA.

G. Škoro et al., 2017,
https://doi.org/10.1016/j.physb.2017.12.060

Gamma spectrometry

Applied Radiation and Isotopes 125 (2017) 1–3

Contents lists available at ScienceDirect

Applied Radiation and Isotopes

journal homepage: www.elsevier.com/locate/apradiso

Experimental verification of spallation inventory calculations

D.J.S. Findlay*, G.P. Škoro, G.J. Burns, S. Ansell[1]

ISIS, STFC, Rutherford Appleton Laboratory, Oxfordshire OX11 0QX, UK

TS-1 W2 target; 1946 mA-hours in fifteen irradiation ‘campaigns’ each ~30–50 days long; cooling time = 7.63 years – to coincide with the date on which the gamma-ray spectroscopy measurements were made.

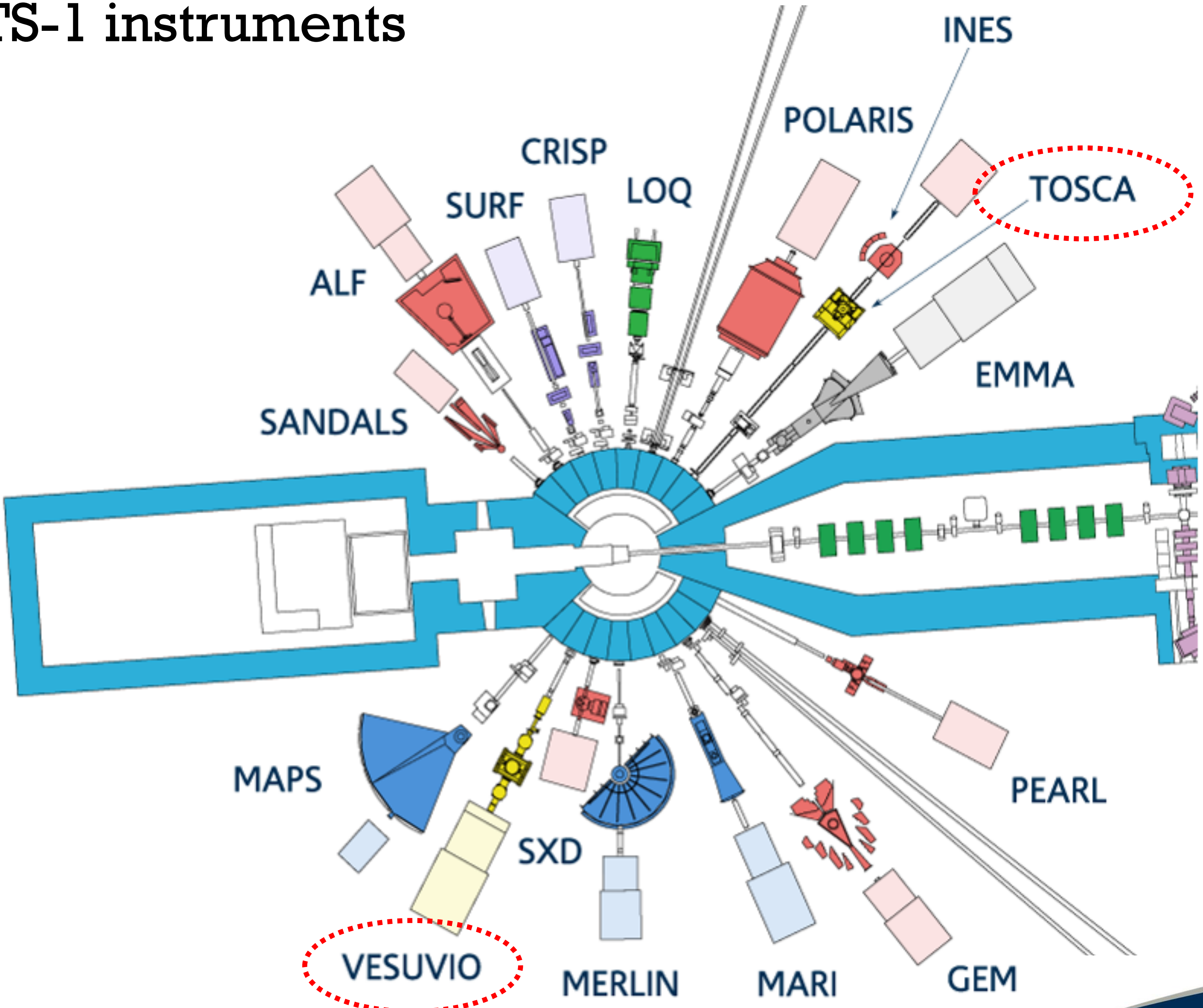
Table 2
Peak areas of identified lines in the gamma-ray spectrum measured outside the flask.

Counts/sec	±	Identif.	keV	Abund. %
0.1137	0.0670	Annihil.	511.00	
0.2286	0.0775	(Ra/Rn)	609.32	
0.1161	0.0458	Lu-172	1093.63	62.50%
5.5588	0.0546	Co-60	1173.23	99.85%
15.5114	0.1454	Co-60	1332.49	99.98%
0.0996	0.0033	K-40	1460.82	
0.0209	0.0035	Lu-172	1488.94	1.15%
0.0158	0.0021	Lu-172	1542.85	1.02%
0.0638	0.0048	Lu-172	1584.12	2.64%
0.0545	0.0038	Lu-172	1621.92	2.16%
0.0372	0.0028	(Ra/Rn)	1764.49	
0.0411	0.0027	Lu-172	1914.80	0.60%

Table 3
Comparison of absorption thicknesses with flask dimensions, and comparison of radionuclide activities from the gamma-ray spectrum and from the Monte Carlo inventory calculations. Uncertainties are statistical only.

Radionuclide	Pb thickness, cm		Activity, TBq	
	From spectrum	Flask wall	From spectrum	Monte Carlo
^{60}Co	18.25 ± 0.22	16.75	0.099 ± 0.015	0.087
^{172}Lu	26.97 ± 0.60		0.842 ± 0.315	0.791

TS-1 instruments



TOSCA

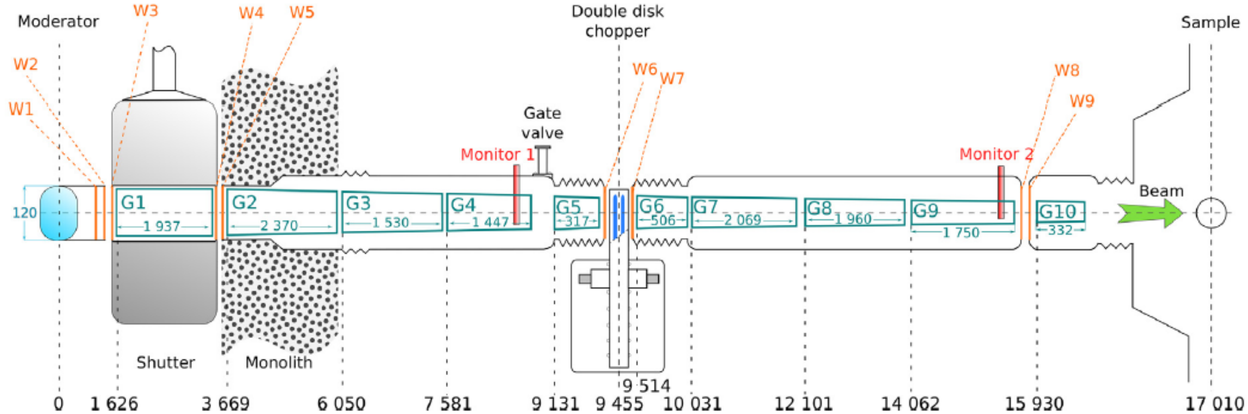
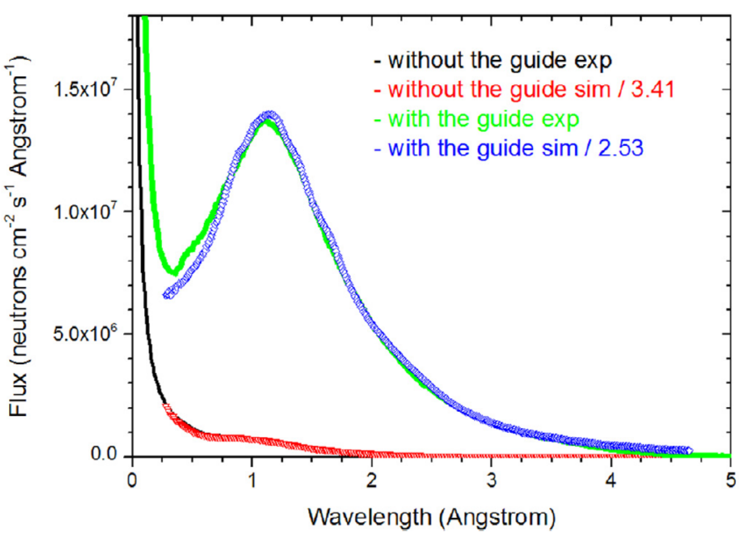


Fig. 1. Schematic representation of the side view of the TOSCA neutron guide as installed on the beamline. The guide sections are numbered in the order in which they appear along the flightpath. The starting position of each section, in relation to the moderator centre, as well as its length are provided (in mm units). Aluminium windows (W) are indicated by the orange vertical lines.

TOSCA is an indirect-geometry inelastic neutron spectrometer optimised for high resolution vibrational spectroscopy in the energy transfer region between −24 and 4000 cm−1. The instrument has been operational for almost two decades and during that time has set the standard for broadband chemical spectroscopy with neutrons.



https://www.isis.stfc.ac.uk/Pages/INS-database.aspx

Nuclear Inst. and Methods in Physics Research, A 896 (2018) 68–74

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journal homepage: www.elsevier.com/locate/nima

ELSEVIER

The neutron guide upgrade of the TOSCA spectrometer

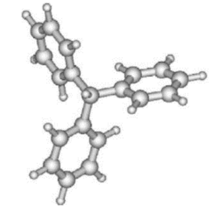
Roberto S. Pinna[a,b], Svemir Rudić[a,*], Stewart F. Parker[a], Jeff Armstrong[a], Matteo Zanetti[a,b], Goran Škoro[a], Simon P. Waller[a], Daniel Zacek[a], Clive A. Smith[a], Matthew J. Capstick[a], David J. McPhail[a], Daniel E. Pooley[a], Gareth D. Howells[a], Giuseppe Gorini[b], Felix Fernandez-Alonso[a,c]

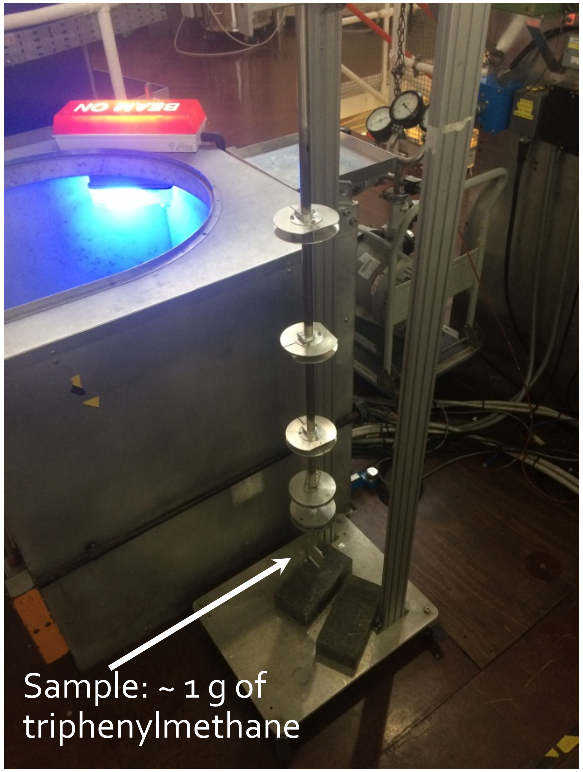
[a] ISIS Facility, STFC, Rutherford Appleton Laboratory, Chilton, Didcot OX11 0QX, UK
[b] CNISM, Universita' degli Studi di Milano-Bicocca, Piazza della Scienza 3, 20126 Milano, Italy
[c] Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, UK

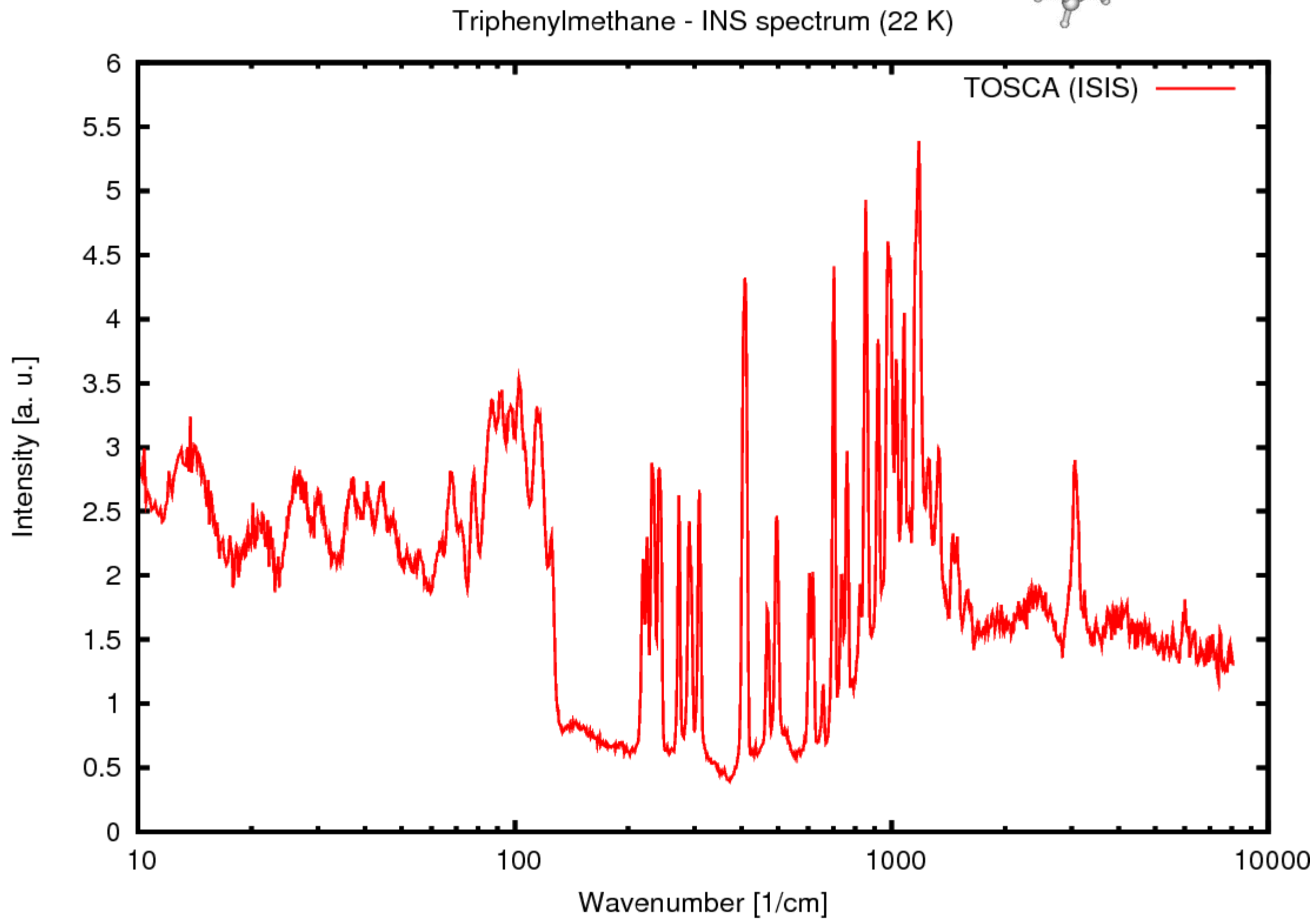
The primary flightpath of the TOSCA spectrometer has been upgraded recently with a high-m neutron guide in order to boost the neutron flux at the sample position.

Measurements of triphenylmethane DoS (TOSCA)

Two temperatures: 22 and 10 K.
Measurement time: ~2 hours per temperature.



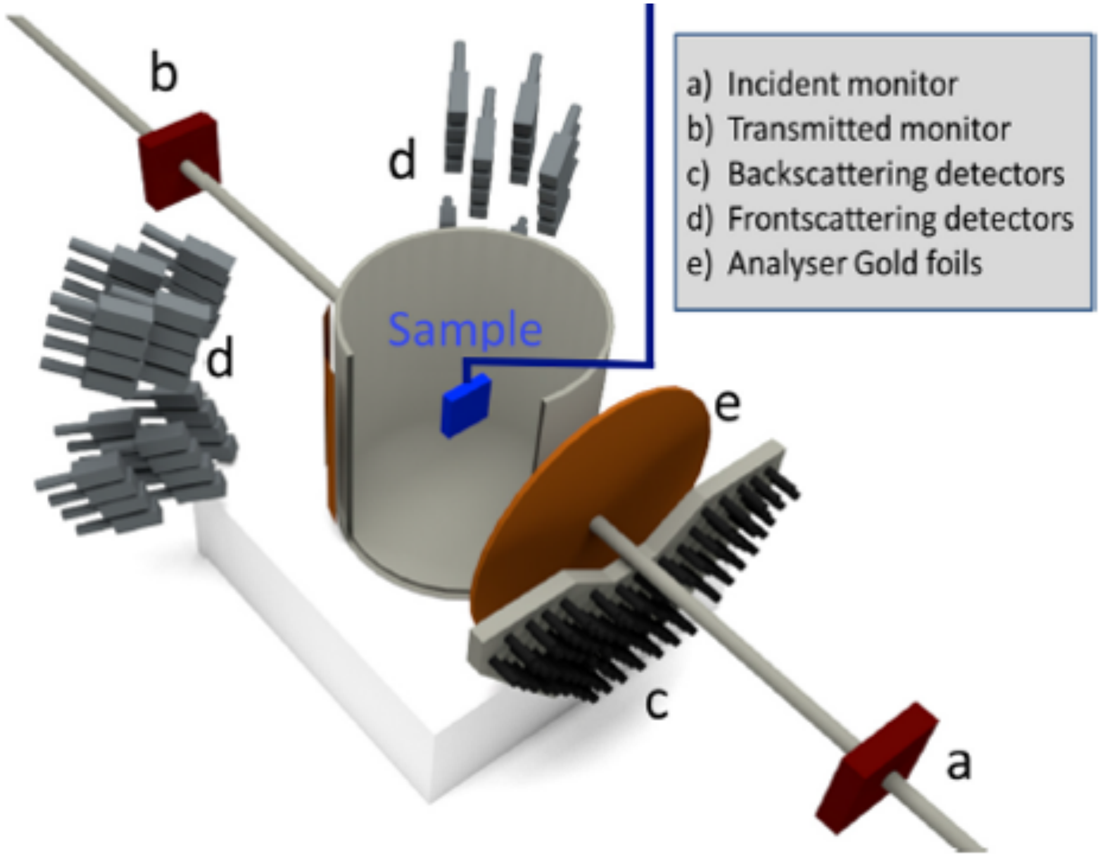




Very high number of excitations. In low frequency range the vibrations of three rings around of central atom appear, ring deformations dominate in the region between 350 and 1300 cm^{-1} and stretch vibrations in the higher frequency region.

VESUVIO (TS-1)

VESUVIO is an inverted-geometry spectrometer mainly employed for the determination of nuclear quantum effects in materials using Deep Inelastic Neutron Scattering. In recent years, VESUVIO has become an epithermal and thermal analysis station, where samples can be investigated through spectroscopy, neutron diffraction, and neutron transmission (NT) at the same time. The energy range accessible for NT spans 8 orders of magnitude, from a fraction of meV to tens of keV.



Samples are placed at 11 m from the ISIS TS1 water moderator. Incident neutron spectra were recorded using a GS20 6Li-doped scintillator at 8.57 m from the moderator, while the transmitted spectra were recorded using a similar detector at a distance of 13.45 m from the moderator. The neutron beam has a circular shape, with a maximum diameter of 4.5 cm.

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ELSEVIER

Measurement of the para-hydrogen concentration in the ISIS moderators using neutron transmission and thermal conductivity

Giovanni Romanelli[a,b,*], Svemir Rudić[a], Matteo Zanetti[a,c], Carla Andreani[b,e], Felix Fernandez-Alonso[a,f], Giuseppe Gorini[c], Maciej Krzystyniak[a,d], Goran Škoro[a]

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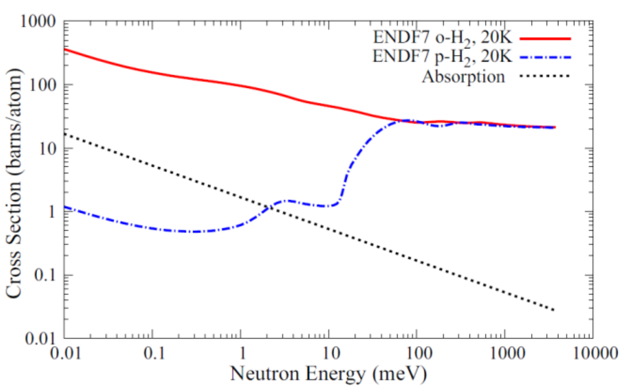
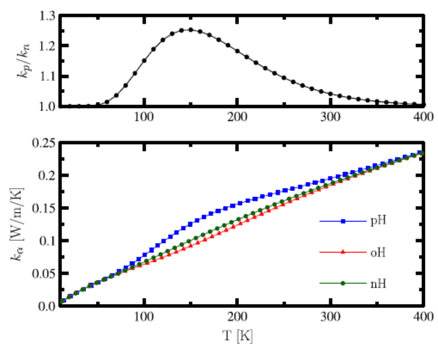
[b] Università degli Studi di Roma 'Tor Vergata', Dipartimento di Fisica and NAST Centre, Via della Ricerca Scientifica 1, 00133, Roma, Italy
[c] Università di Milano Bicocca, Piazza della Scienza 3, Milano 20125, Italy
[d] School of Science and Technology, Nottingham Trent University, Clifton Campus, Nottingham, NG11 8NS, UK
[e] Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi, Piazza del Viminale 1, Italy
[f] Department of Physics and Astronomy, University College London, Gower Street, London, WC1E 6BT, UK

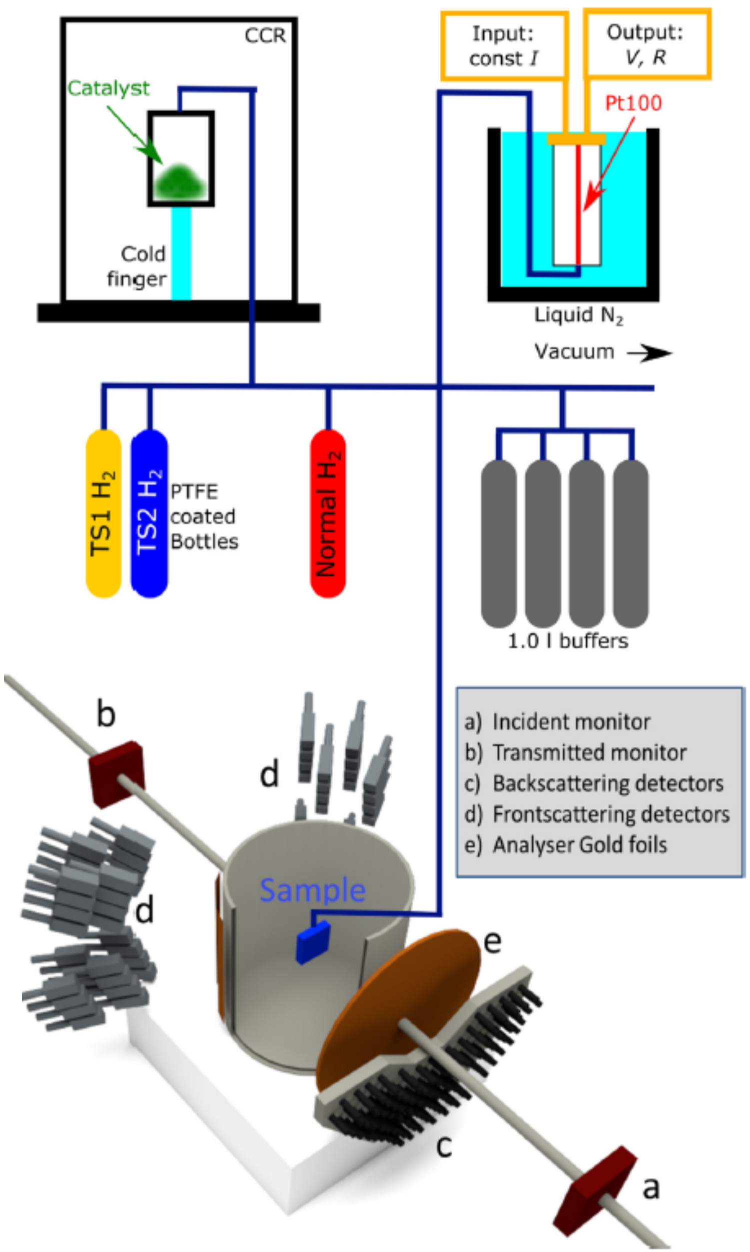




3. Thermal conductivity of nH (green circles), pH (blue squares), and oH (red triangles) in the gas phase (bottom panel), and the ratio of para-to-normal thermal conductivities (top panel). Results obtained using the models described in Ref. [32] at ca. 1 bar.

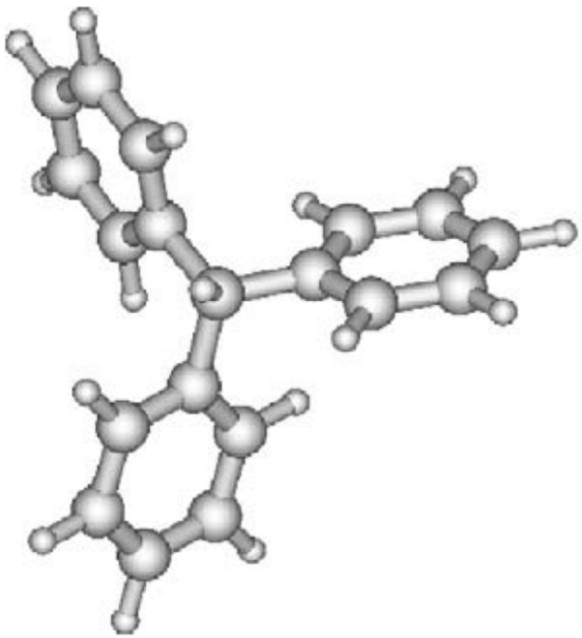
Table 1
Concentration of pH in the samples from the ISIS moderators as a function of the time spent in the PTFE-coated storage bottle.

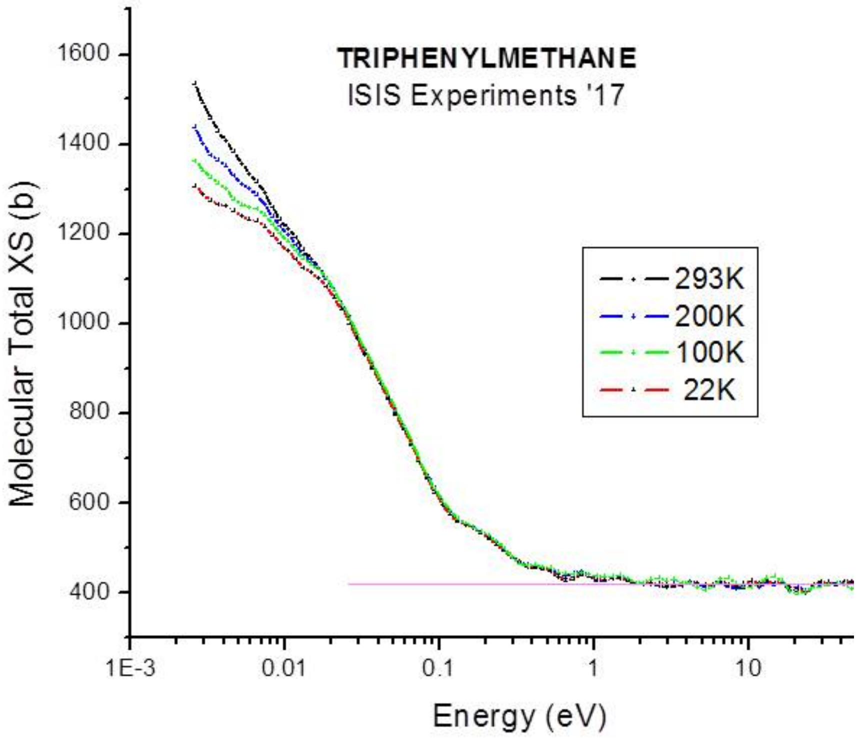
Time [weeks]	TS1		TS2	
	R [Ω]	p_α [%]	R [Ω]	p_α [%]
0	46.05	85 ± 5	45.59	92 ± 5
2	46.52	79 ± 4	45.92	87 ± 5
12	47.74	61 ± 4	46.79	75 ± 4

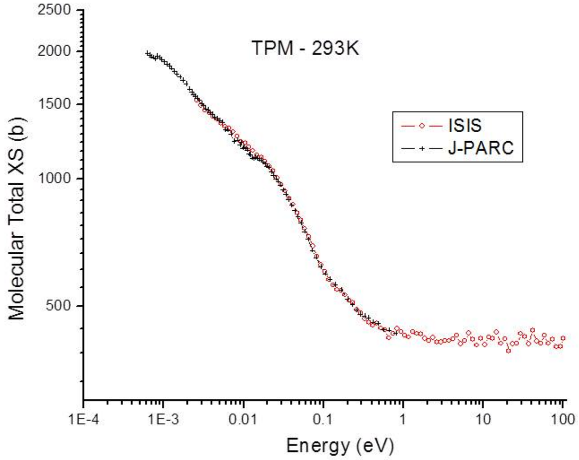


VESUVIO

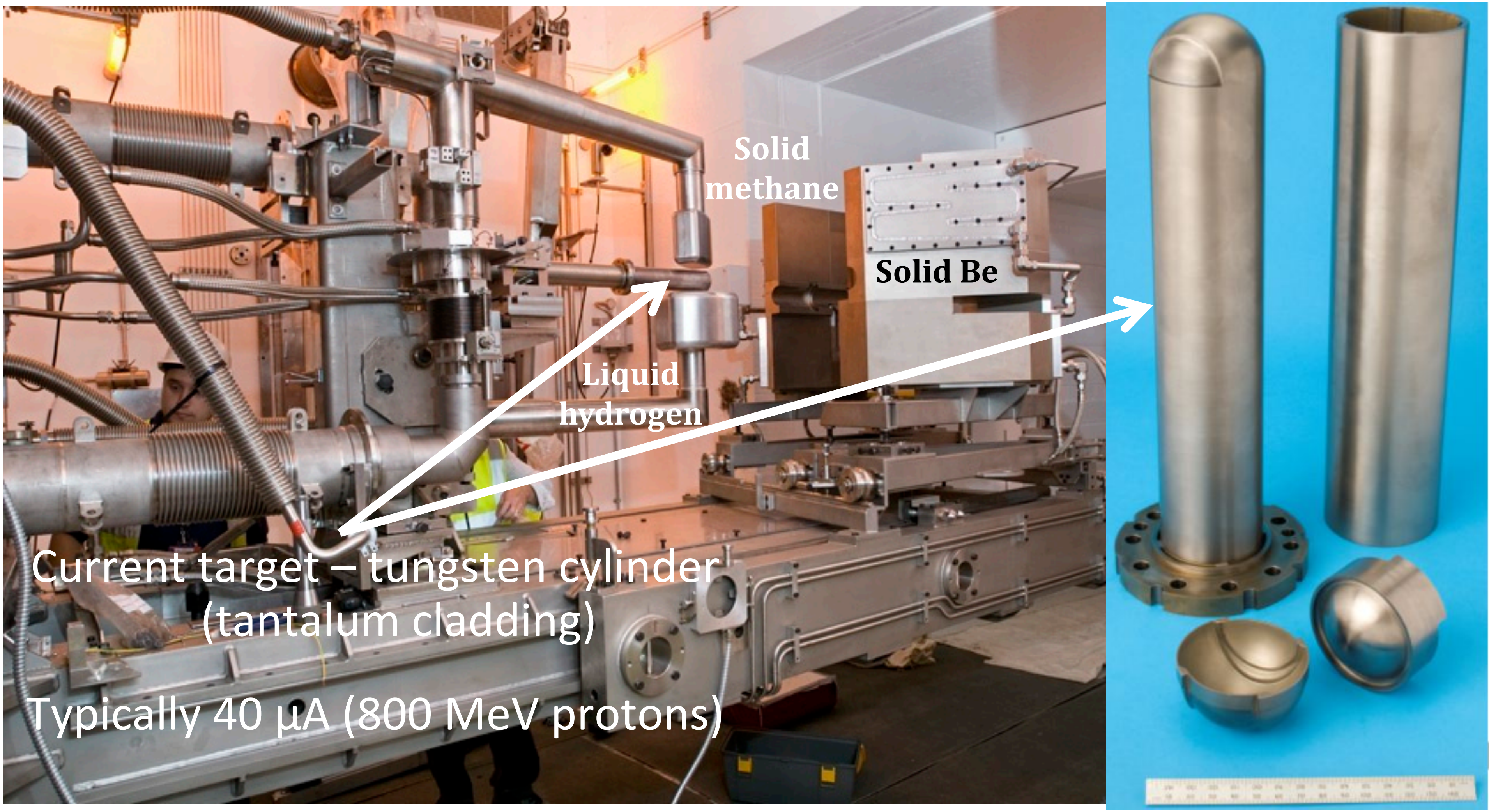
Measurements of triphenylmethane cross-section (VESUVIO)



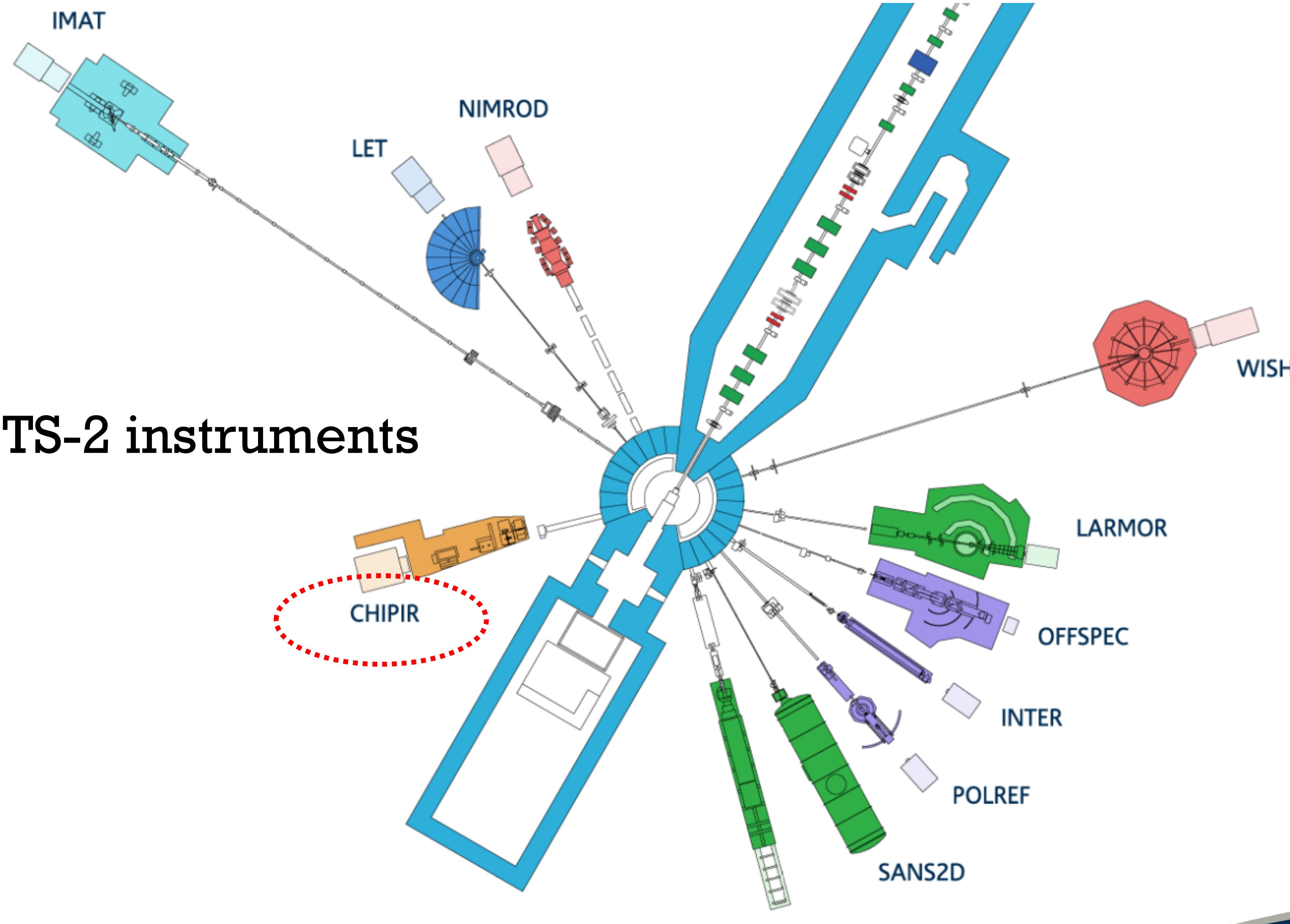




TS-2 TRAM

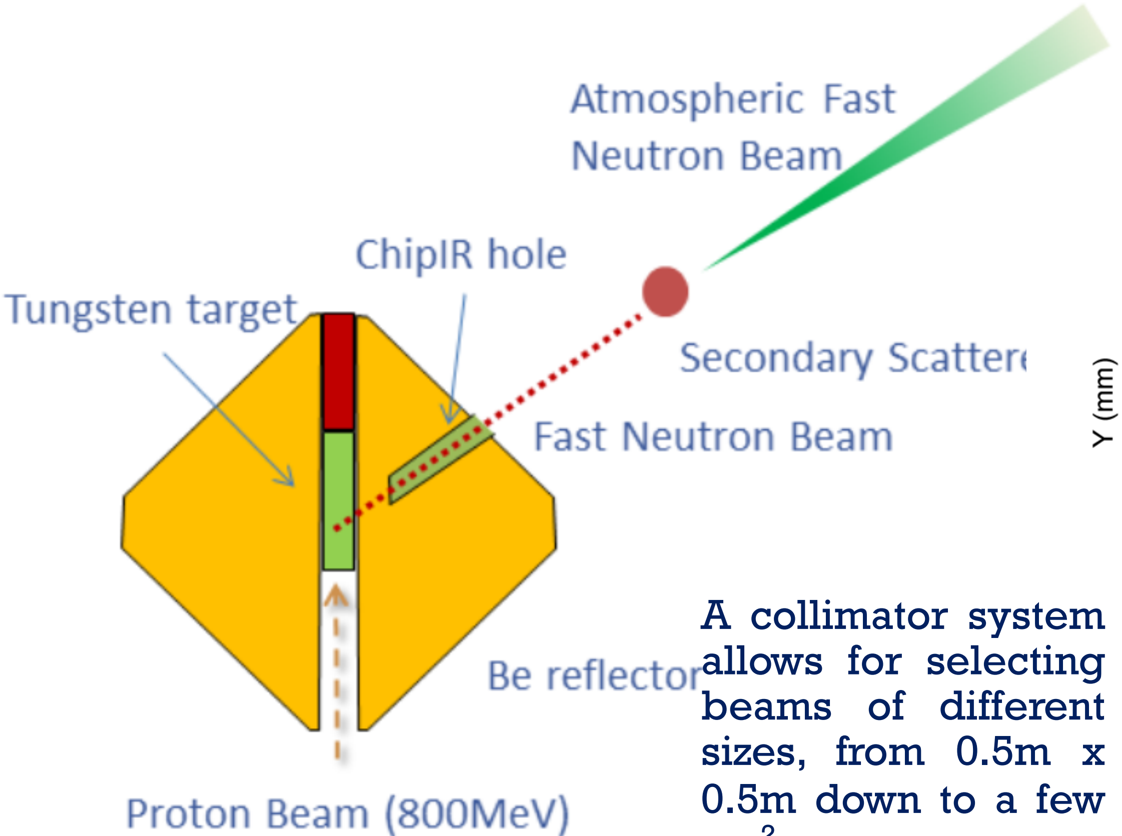

Solid methane
Solid Be
Liquid hydrogen
Current target – tungsten cylinder (tantalum cladding)
Typically 40 µA (800 MeV protons)

TS-2 instruments

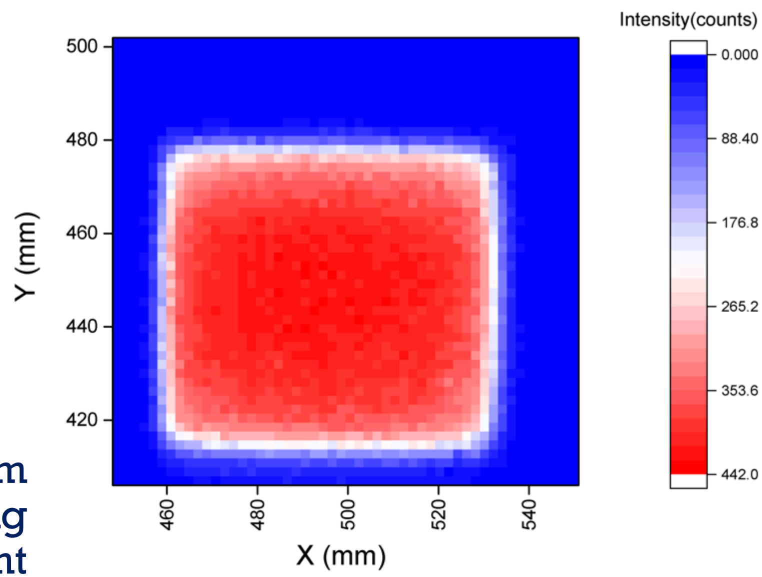


ChipIr (TS-2)

ChipIr is a new beamline dedicated to the irradiation of microelectronics with atmospheric-like neutrons. To extract a fast neutron beamline, a new section with a channel had to be inserted in the beryllium reflector for the ChipIr line of sight. Neutrons from this channel illuminate a secondary scatterer made to optimize the hard atmospheric-like neutron spectrum.



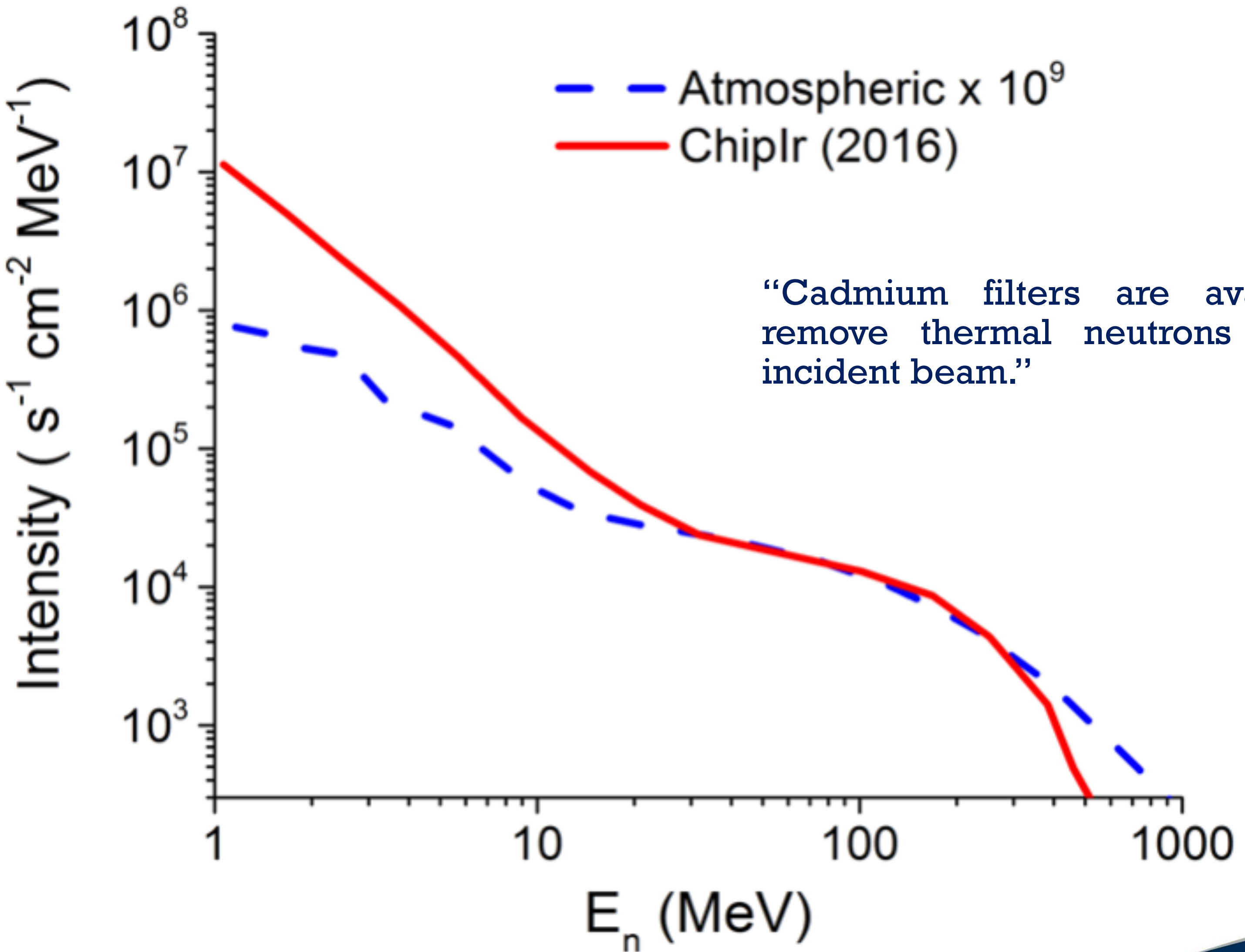
A collimator system allows for selecting beams of different sizes, from 0.5m x 0.5m down to a few cm^2.



Map of the 70 × 70 mm^2 ChipIr beam measured with a Diamond Detector.

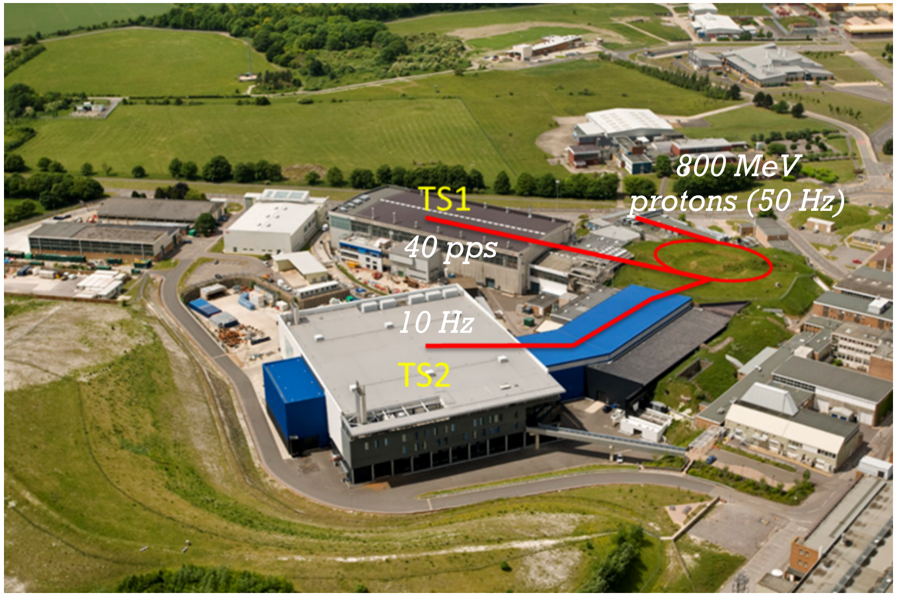
ChipIr (TS-2)

The ChipIr neutron flux (with E_n>10 MeV) has been measured to be $5 \cdot 10^6$ $cm^{-2}s^{-1}$.

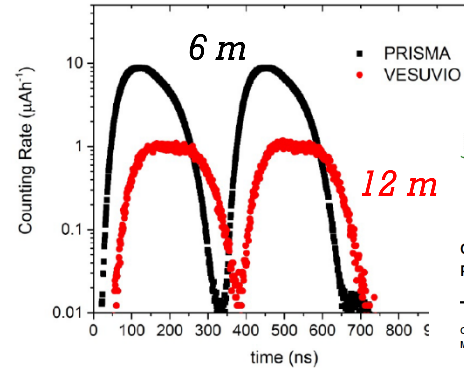


"Cadmium filters are available to remove thermal neutrons from the incident beam."

Proton beam and fast neutrons parameters



Synchrotron extracted beam time structure



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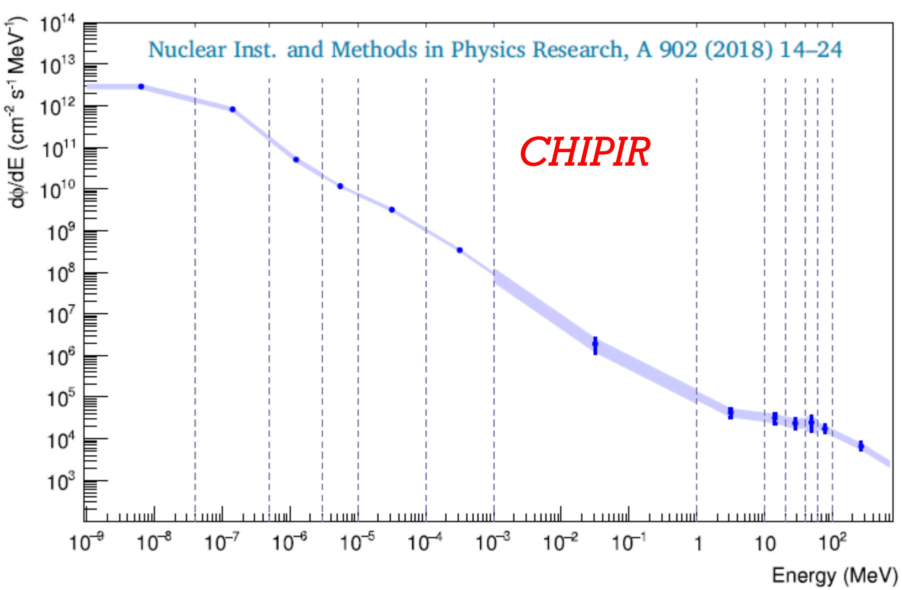
Characterization of the high-energy neutron beam of the PRISMA beamline using a diamond detector

C. Cazzaniga,[a,1] C.D. Frost,[a] T. Minniti,[a] E. Schooneveld,[a] E. Perelli Cippo,[b] M. Tardocchi,[b] M. Rebai[c] and G. Gorini[c]



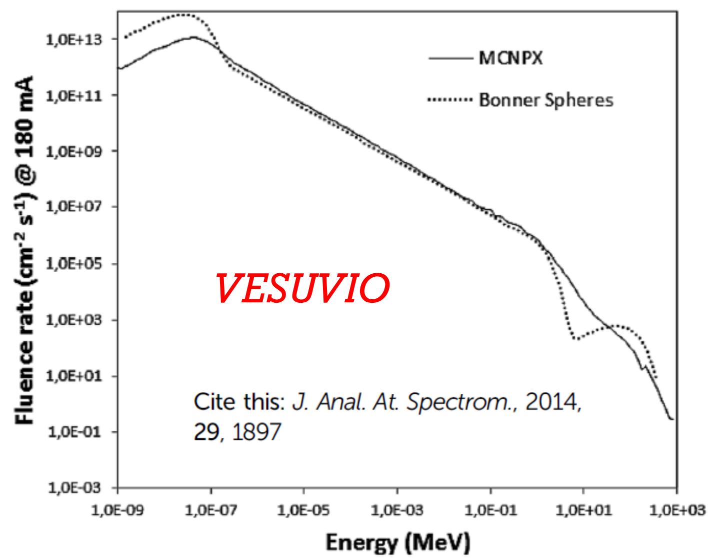
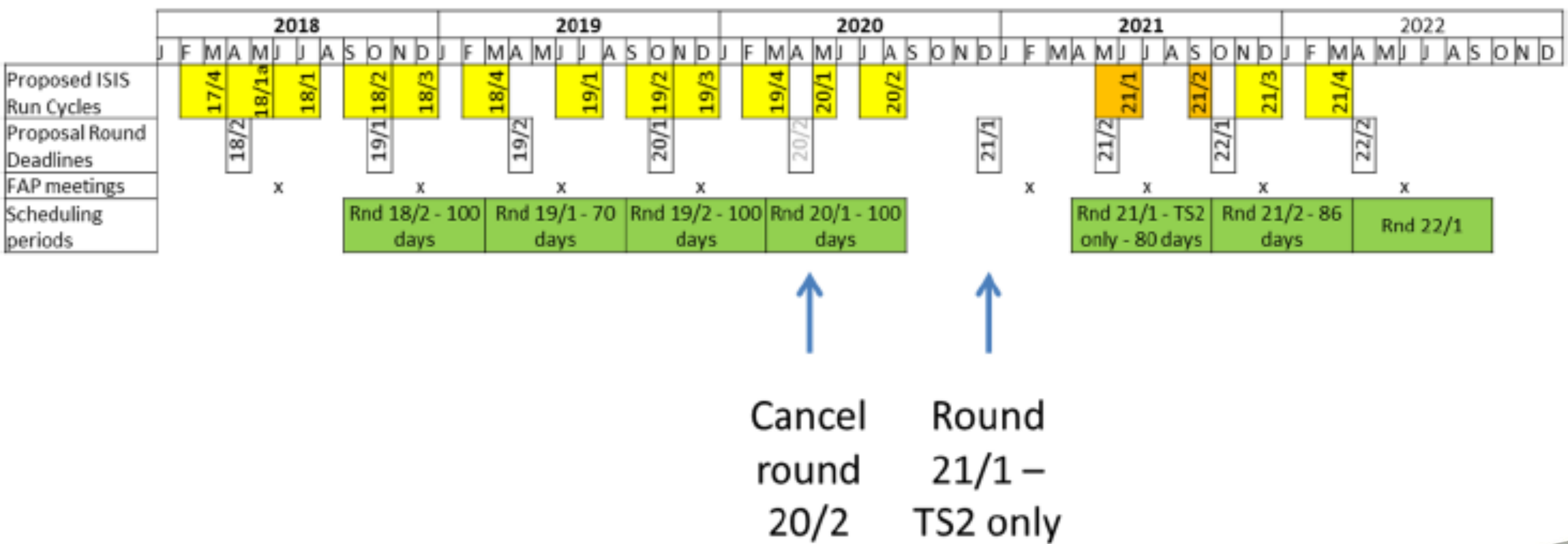


Fig. 1 Simulated and measured neutron spectra at the VESUVIO beamline.[3]

User programme

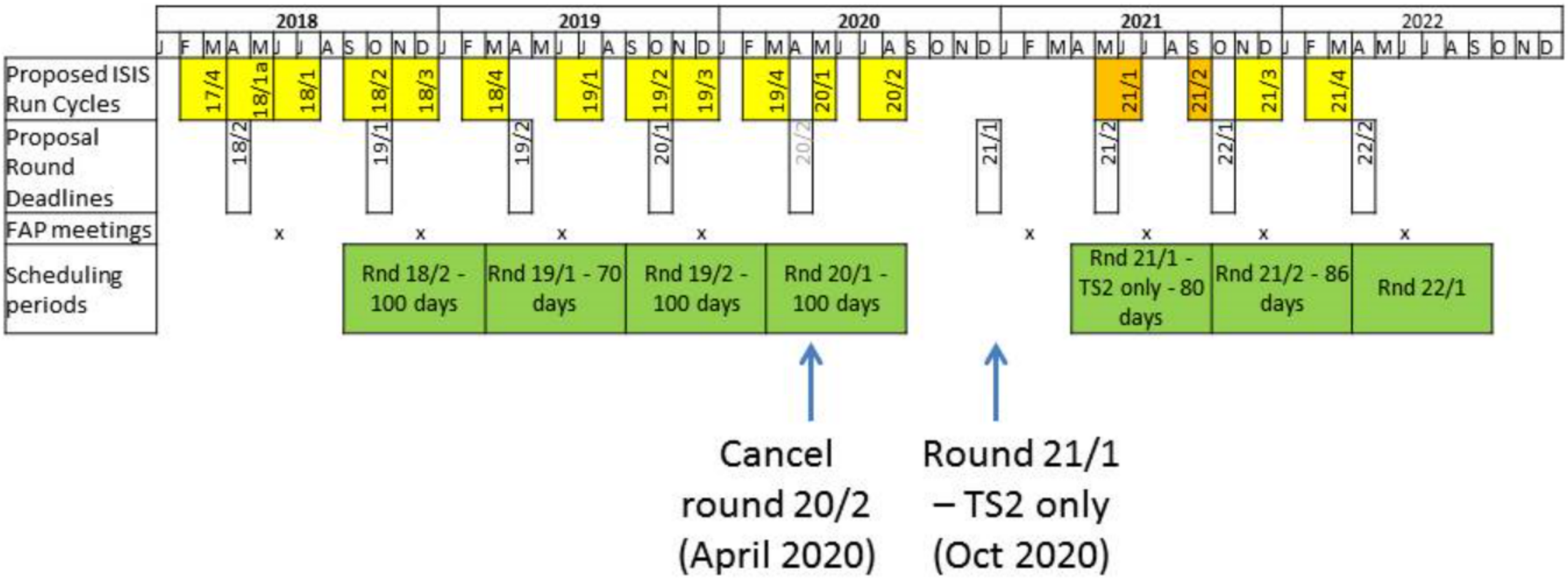
- 634 proposals across 31 instruments in latest round; over 600 for each of last 3 rounds.
- In addition about 80 Rapid proposals per year and also Xpress access.



Access

Long shutdown next year

- ISIS goes off for the long shutdown on 1 Sept 2020
- First beam to both target stations 2 Nov 2021
- TS2 is off for 8 months
- TS1 is off for 14 months (with possibly some beam after ~12 months)



Access routes

ISIS Proposal Routes – how to get beamtime

Name	What's it for?	How does it work?	When am I likely to get the beamtime?	Comments
Direct Access	All types of ISIS experiments	Submit a proposal - deadlines are the third Wednesday of April and October every year.	Normally 3-8 months after proposal submission	Discussion with ISIS scientist strongly advised before proposal submission.
Rapid Access	When beamtime is required more rapidly than is possible with Direct Access.	Submit a proposal any time	Normally 2 weeks – 2 months after proposal submission	Discussion with ISIS scientist is essential before proposal submission.
Xpress Access	A small amount of beamtime (not a full experiment). Must be a very simple measurement.	Submit a very short proposal any time	Data likely to be available from 1 week to a few weeks after submission.	Discussion with ISIS scientist is essential before proposal submission.
Industrial Access: Access mechanisms, in particular the ISIS Collaborative R&D scheme, are available for companies wishing to use neutrons at ISIS. Please contact the ISIS industry liaison, Dr Chris Frost (Christopher.frost@stfc.ac.uk) for details				

Access routes

Which Proposal Route for ISIS Beamtime do I need?

VESUVIO: Giovanni Romanelli

CHIPIR: Carlo Cazzaniga

...