Optimisation Opportunities

Robert Dalgliesh

Tuesday 14th August 2018

RAL

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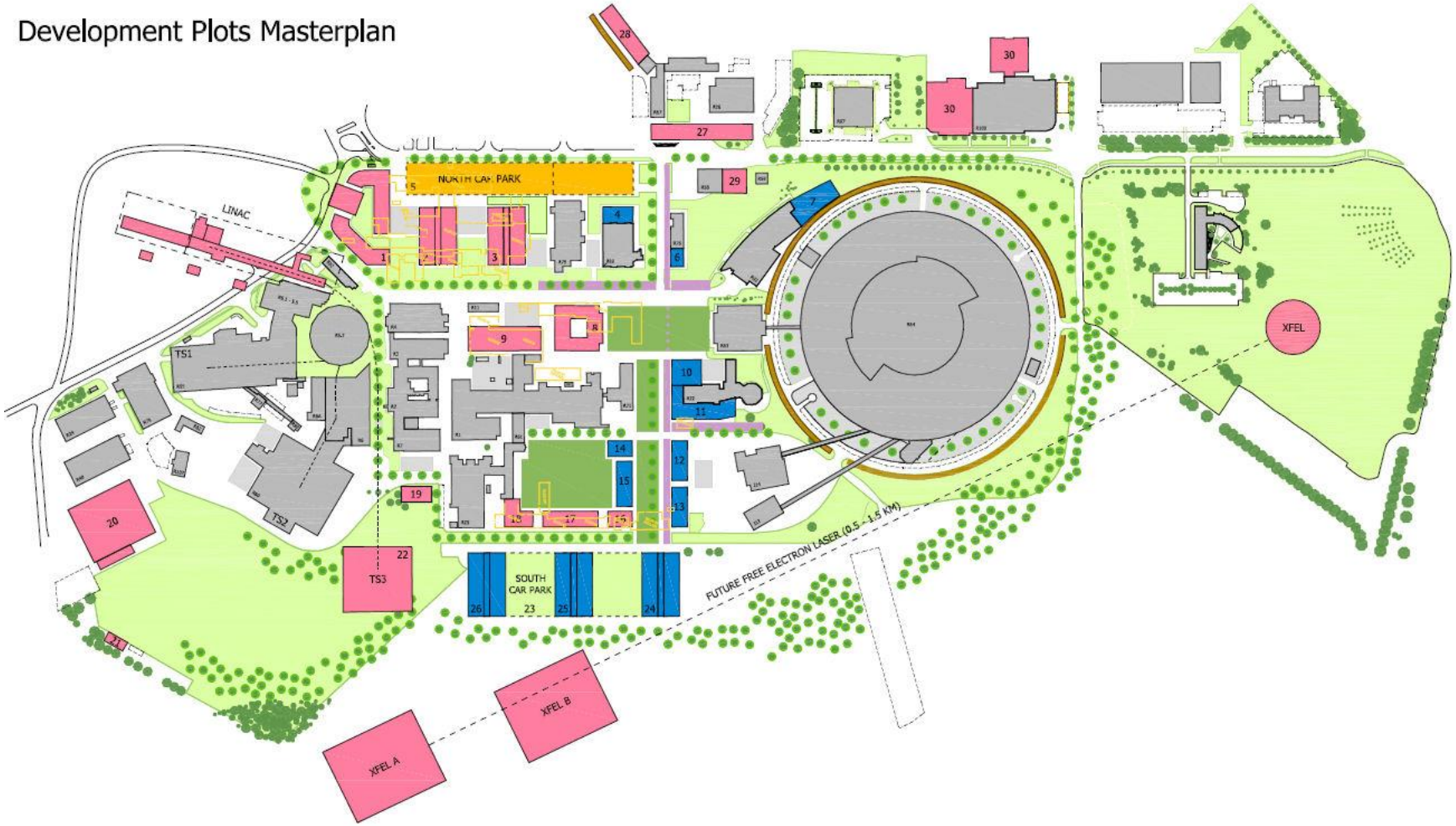

- How do we decide what to build?
- What can we optimise?
- What do we need?

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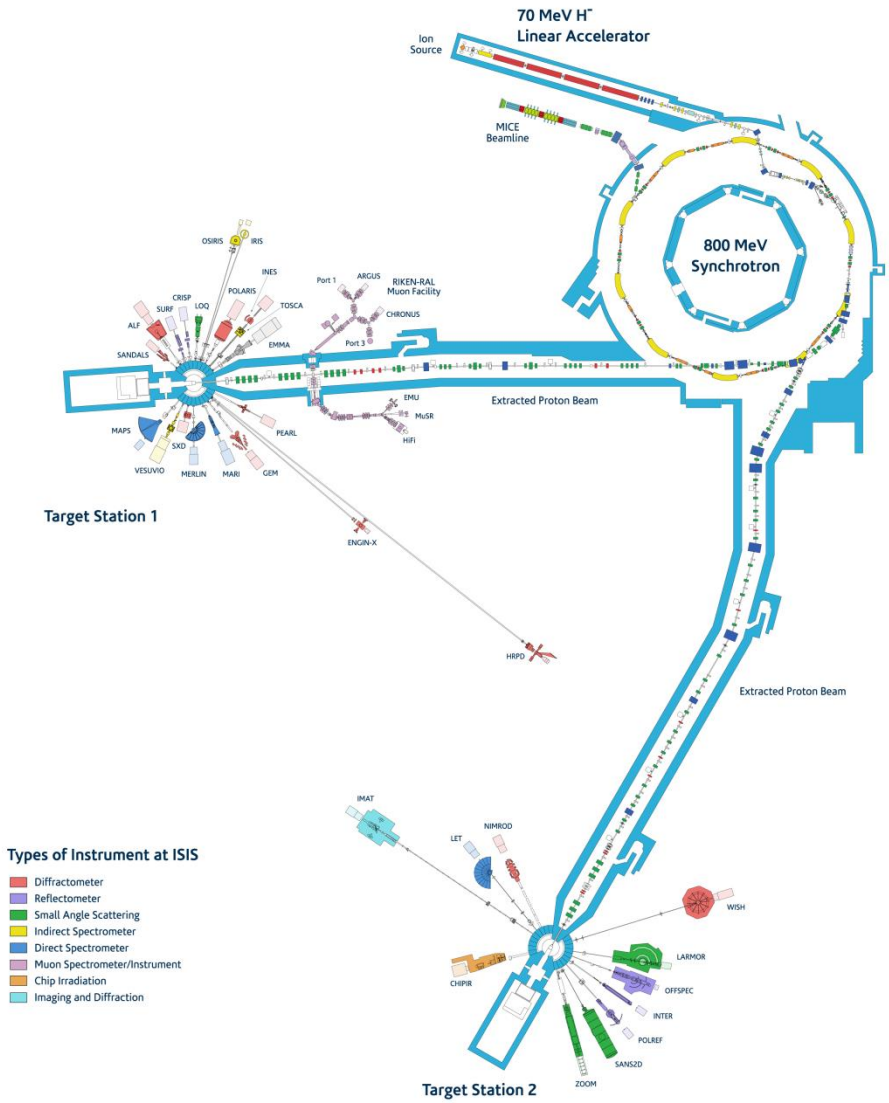
TS1 and TS2

- TS1
  - High resolution, short pulse target
  - A lot of compromises
  - Ageing technology (It is 30!)
  - World class with numerous upgrade opportunities
- TS2
  - Medium resolution, short pulse target
  - Compromises in moderator choices
  - World class also with new instrumentation and upgrade opportunities

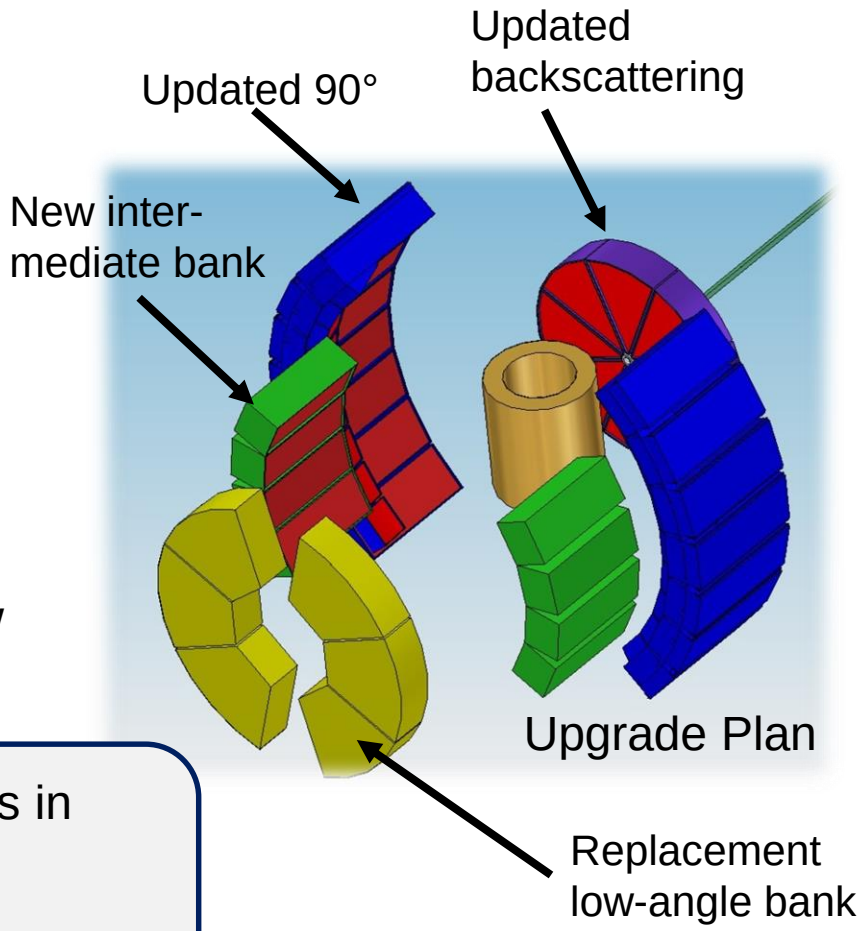


What could we do now?

Some examples.

HRPD+ Diffractometer

- All detectors replaced
- New electronics and sample tank
- Add new incident beam collimation
- Radial collimator around sample position
- Allow use of magnets up to 10 T
- Optimised design has been finalised



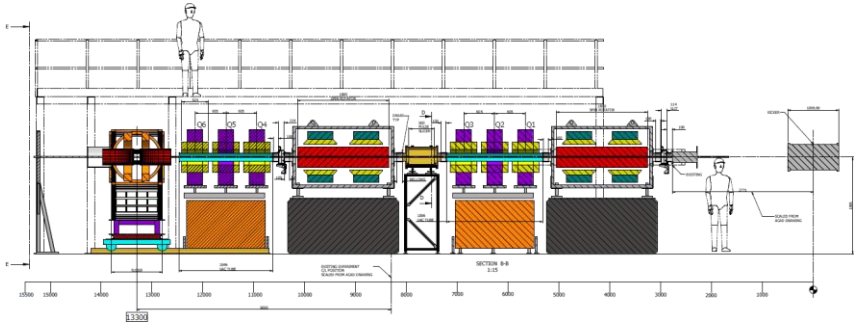
Solid angle increases: backscattering ~ 5x, 90 degrees ~22x, low-angle ~30x, plus new intermediate bank.

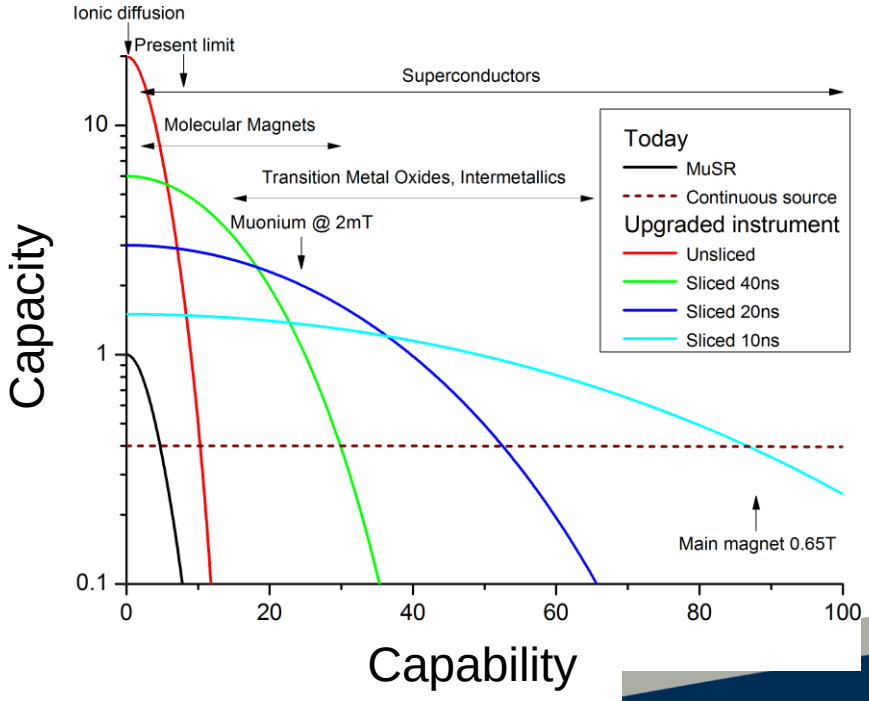
This will significantly enhance the capabilities in general, but most significantly for:

- complex sample environments e.g. high pressure
- small sample volumes
- large unit cell materials
- subtle structural distortions
- studies of magnetism

Super-MuSR

- Increase time resolution ~10x
  - Pulse slicer gives shorter muon pulse
  - Broadens range of materials, with higher quality data than today
- Increase count rate 15-20x
  - Highly-segmented detector array maximises information collected per muon
  - Improves sensitivity to weak signals
  - Enables parametric studies of quantum materials and energy materials
- Higher transverse fields
  - Rotating the muon spins in flight means measurement field doesn't deflect the beam
  - Makes use of the increased resolution for studies of superconductors, semiconductors, and organic materials





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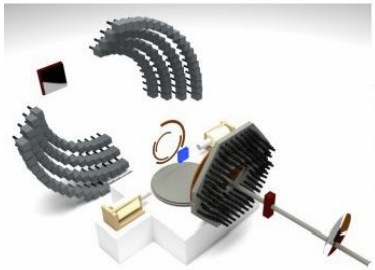
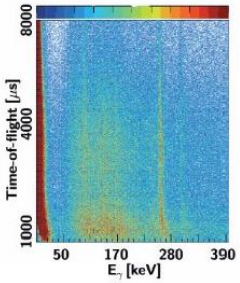
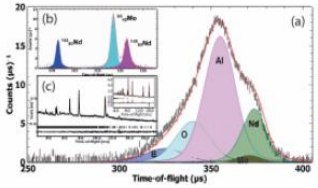
Molecular Spectroscopy

ETNA







METALYSIS

mta

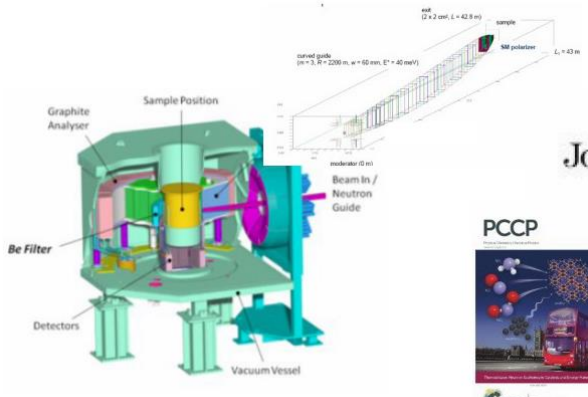
Sainsbury's

Consiglio Nazionale Ricerche

CENTRO FERMI

JAEA

OSIRIS++



sasol
reaching new frontiers

Consiglio Nazionale Ricerche

JM
Johnson Matthey

PCCP

EVONIK

TOYOTA

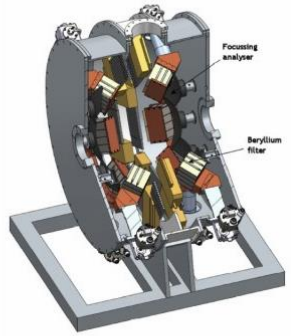
GM

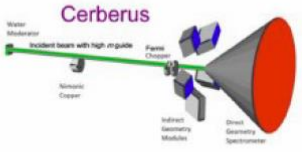
CatalysisHub

Vetenskapsrådet

Lucite International

TOSCA++





- Detector, guide and other instrumentation upgrades
- Order of magnitude+ gains in performance
- Smaller samples, kinetics

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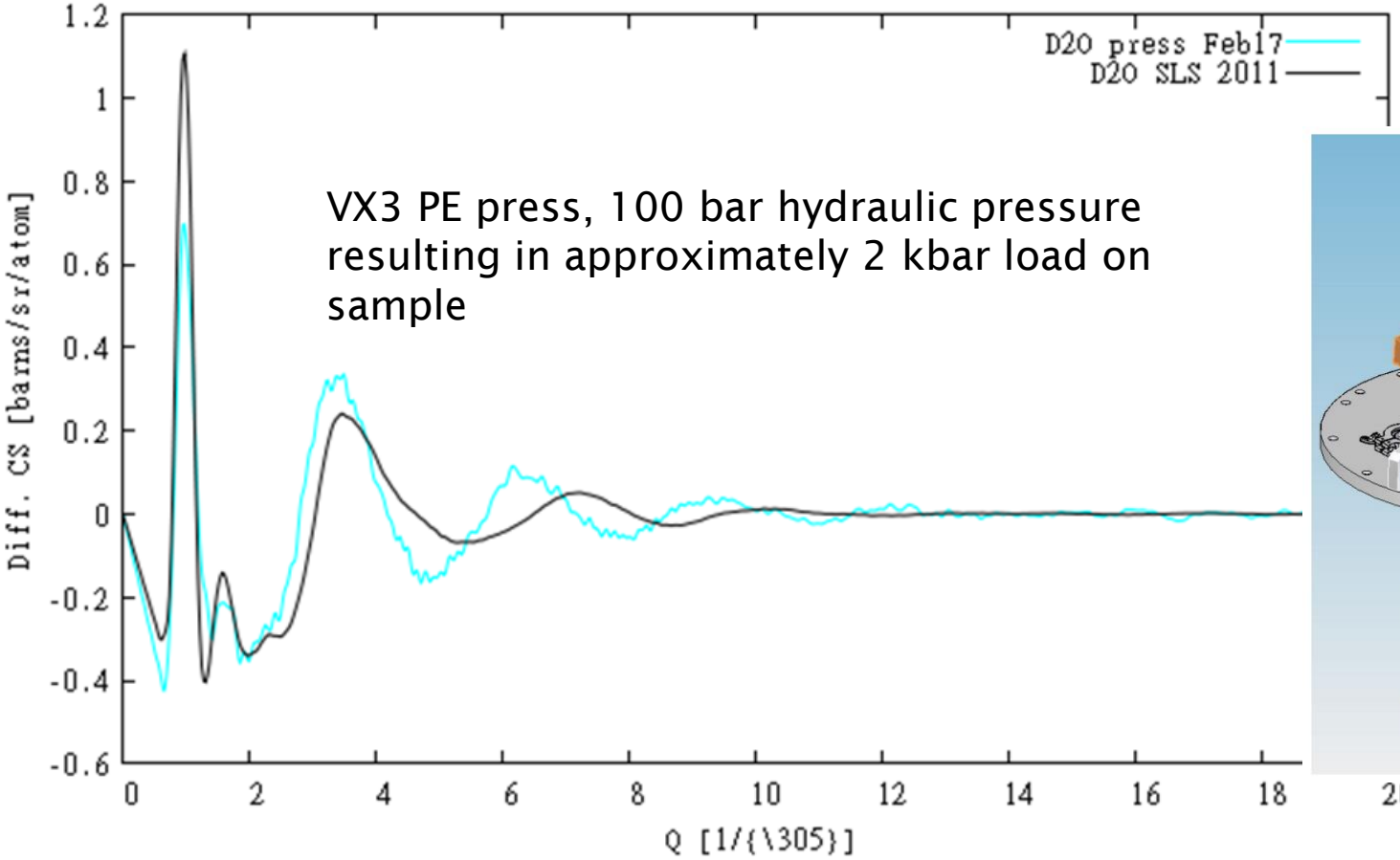
The MUSHROOM spectrometer concept

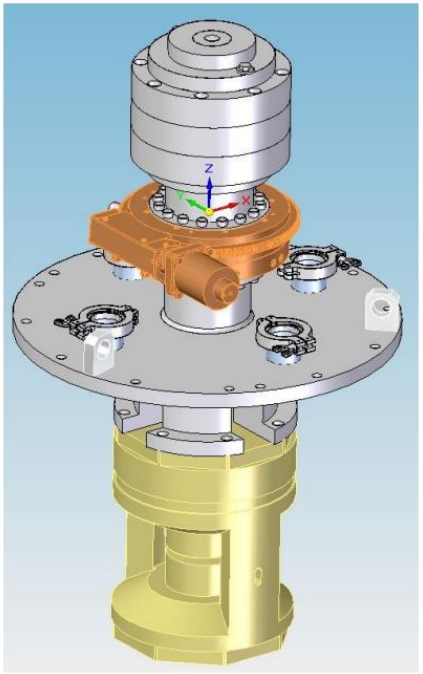
- Very high count rates. **50 x LET** for same energy resolution
- Smaller, cheaper detector footprint while maintaining angular coverage
- Double elliptic guide to focus on small samples ≤ 1 cm^3
- Large dynamic range -1.2 to +20 meV in one shot

- Small samples (<10 mg) of new materials, could even be used for thin films.
- Parametric studies (including difficult tuning parameters like strain), e.g. skyrmions. Could be used with a Paris-Edinburgh type cell

SANDALS



VX3 PE press, 100 bar hydraulic pressure resulting in approximately 2 kbar load on sample



- Collimation changes and detector upgrades
- Factor of 5 increase in performance
- Smaller samples – new science
- Increase capacity

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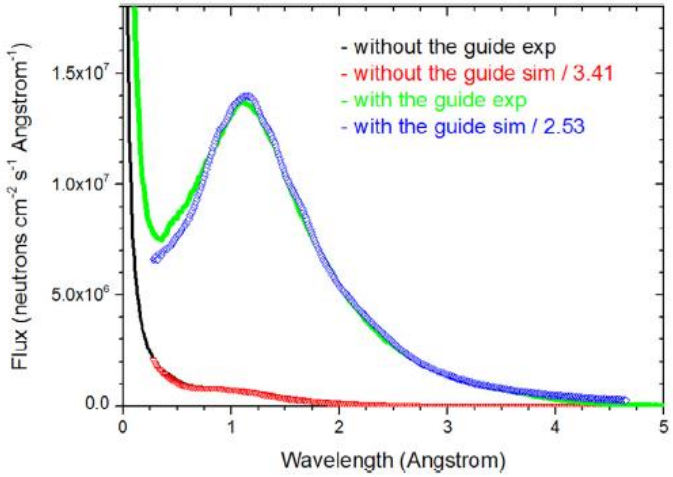
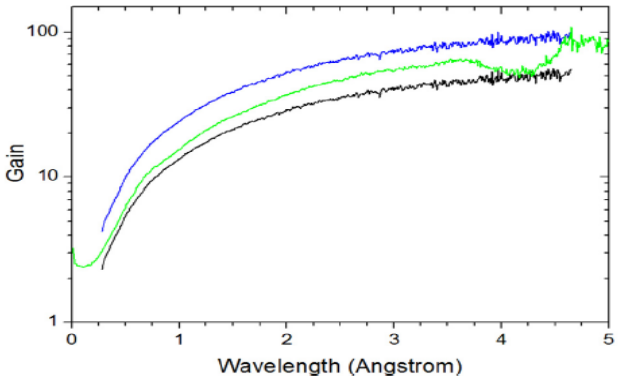
What have we done most recently?

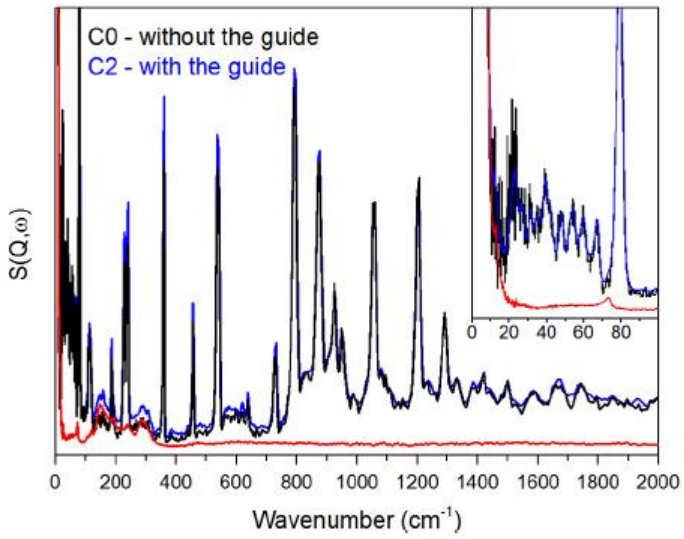
A couple of examples.

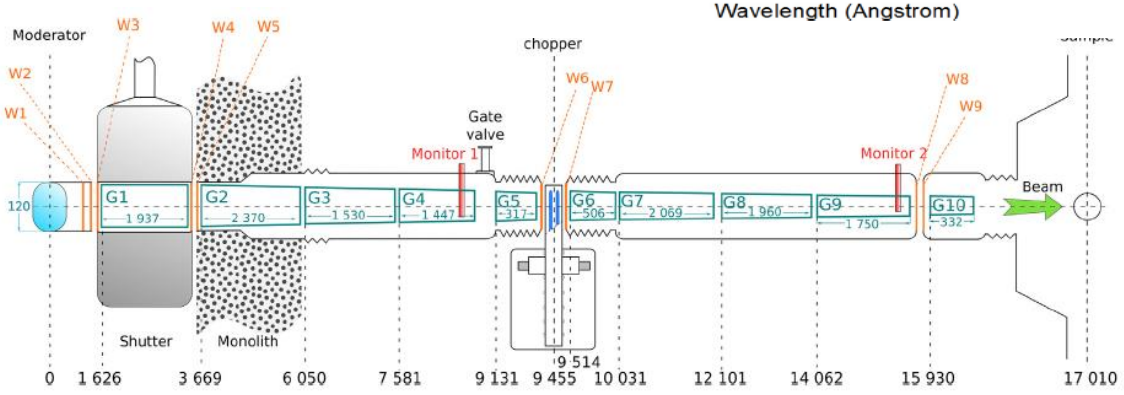
TOSCA Upgrade

- New Guide installation completed in October 2016
- Large gains in flux across the whole dynamic range.
- Faster measurements and smaller samples – New Science



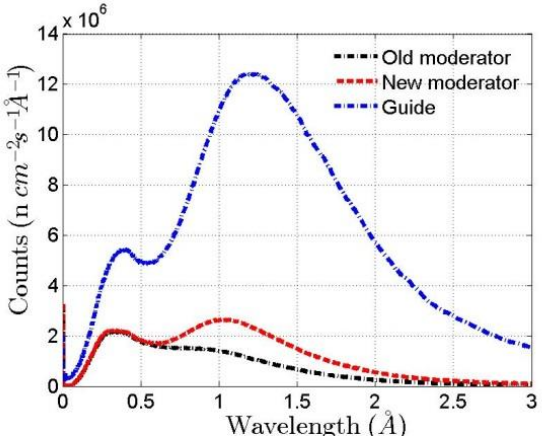


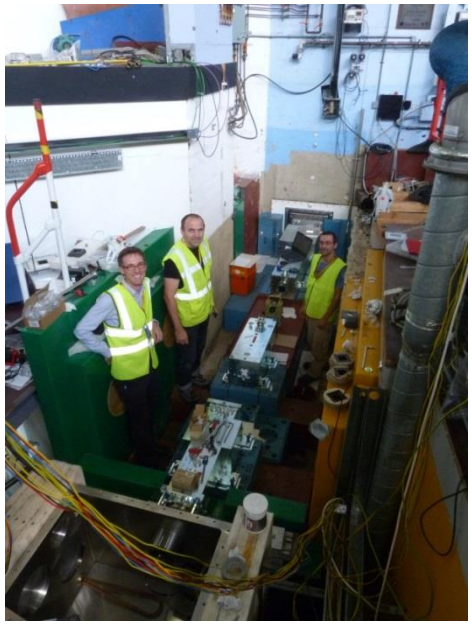


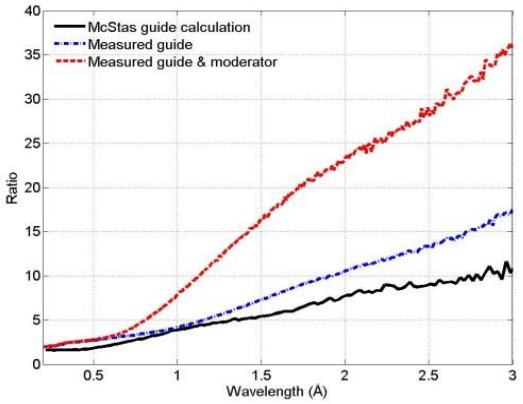


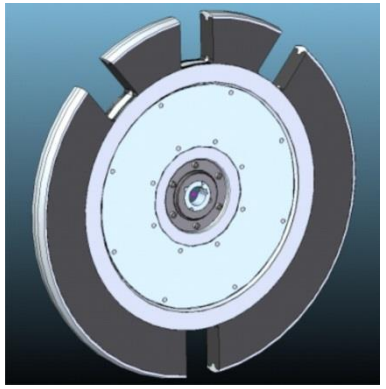
MAPS Upgrade

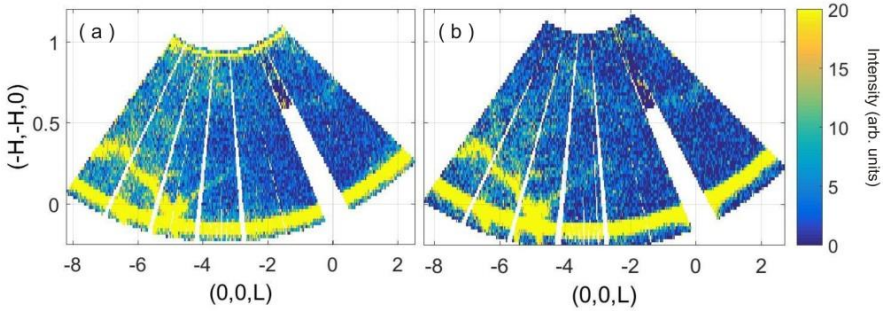
- 3 component project
  - Replacement moderator
  - New Guide
  - New chopper
- Completed December 2017

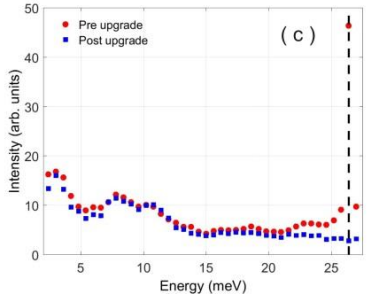












- More flux
- Reduced backgrounds for high temperature samples

Summary part 1

- Almost every instrument on TS1and some on TS2 could be upgraded resulting in significant performance increases.
  - Detectors, guides, moderators, background suppression
- Simulated gains match closely to reality.
- The gains would be larger even if we started again with the same source power.
  - New target and moderator concepts, new instrument concepts, better shielding, improved source – guide coupling
- On a new 1MW+ source with more complete optimisation expect at least a factor of 5 in all cases. Where guides and further instrumental gains are possible 2 orders of magnitude could be possible over existing TS1.

What can we learn from other facilities?

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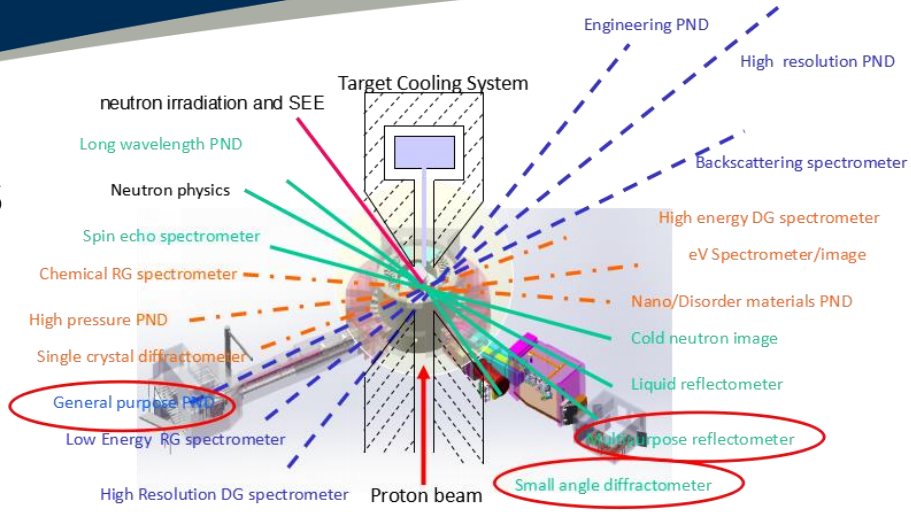
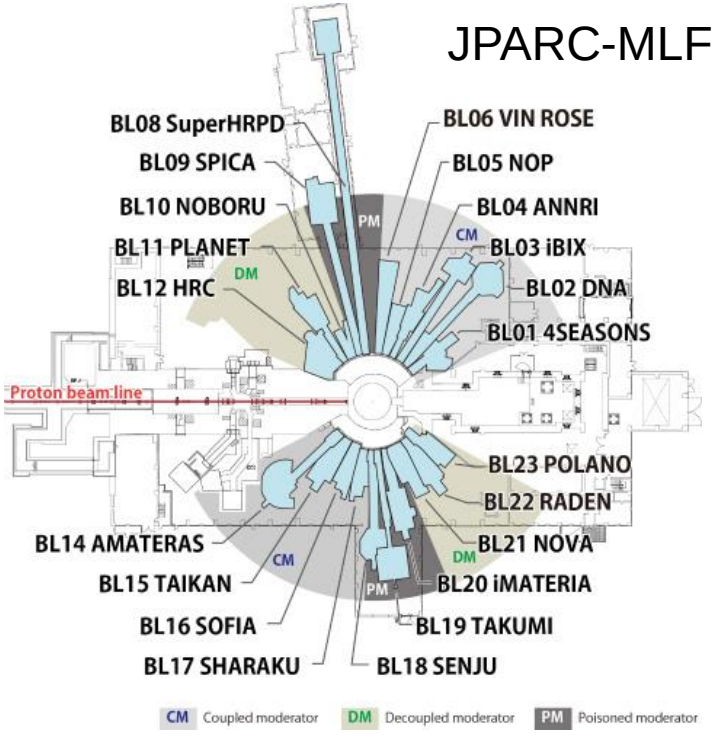
High power sources

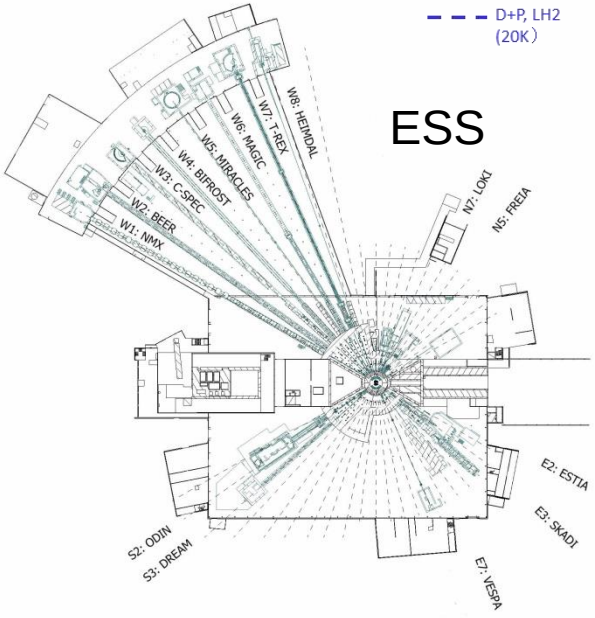
CSNS



JPARC-MLF



ESS



SNS

MW Class facilities

- JPARC, SNS mercury targets and moderators
  - Performance can be improved
  - SNS STS and ESS compact rotating wheels will provide enhanced flux for the same reasons as the TS2 target
- ESS and SNS STS
  - Guide coupling and moderator geometry optimisation provide significant gains.
  - Shielding improvements are critical to ESS.
- ESS and SNS STS
  - In monolith beamline technology such as choppers, shutters and complex optics will provide new opportunities.

What do we need to optimise?

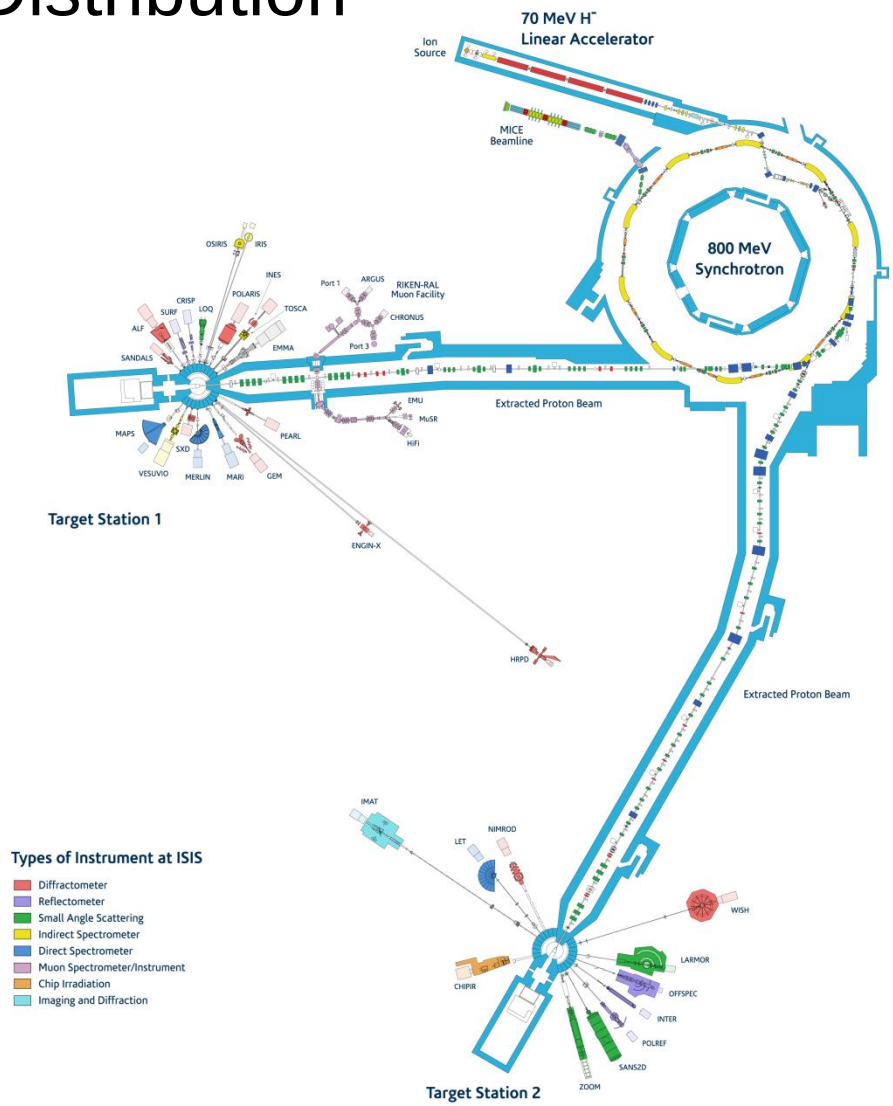
Source repetition rate

- High resolution diffraction and spectroscopy will still require a high resolution source with decoupled moderators
  - Useful wavelength band is short ~0-4Å
- CSNS and J-PARC operate at 25Hz to provide a balanced program with 1 target station. ISIS has TS2 operating at 10Hz.
- 40 or 50Hz should be optimised for flux vs shielding to reduce instrumental backgrounds

What do we need to optimise?

Instrument Distribution

- TS1
  - High resolution instruments
  - Diffraction
  - High energy inelastic
  - Spectroscopy
  - Muons
- TS2
  - “Medium” resolution
  - Small Angle Scattering
  - Reflectometry
  - Large d-spacing diffraction
  - Low energy inelastic
  - Imaging



What do we need to optimise?

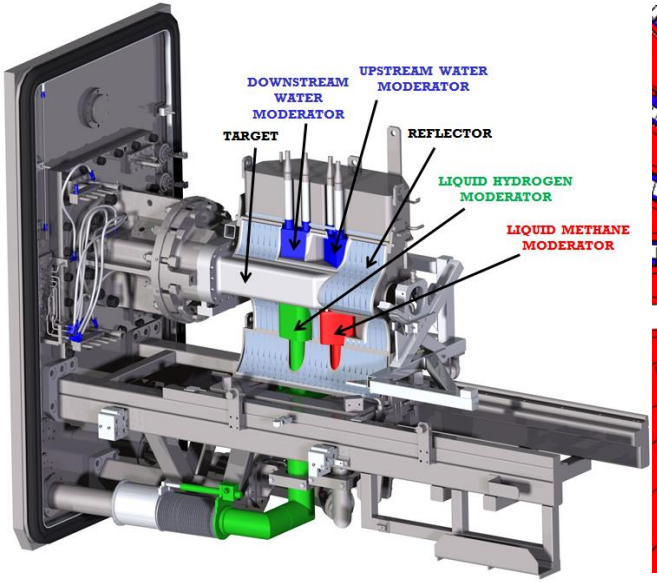
Muons

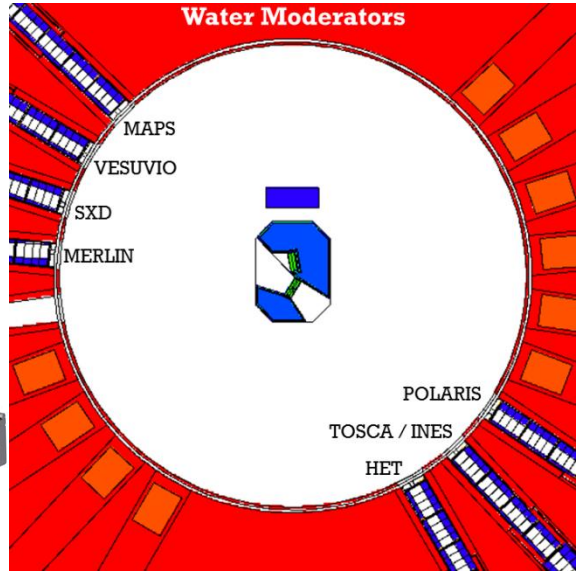
- 2 possible options
  - Extraction from the linac
  - Parasitic target on a TS3 as with TS1
- Extraction from the linac
  - Higher rep rate leading to a higher time averaged flux.
  - More flexible option for science.
  - More complex and very expensive.
- Parasitic target
  - Places strong constraints on the proton pulse length to the neutron target.
  - Similar flux gains to neutron source
  - Highly optimised instrumentation required to make the most of the opportunity. Such as Super-MuSR

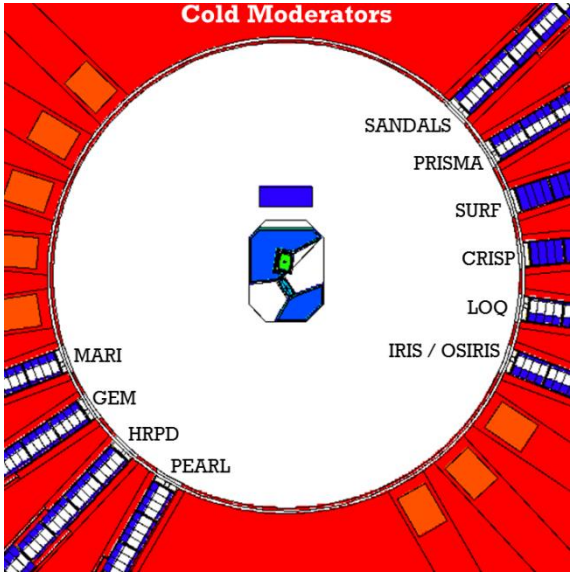
What do we need to optimise?

Moderators

- TS1 has a mixture of moderators
  - Water for high resolution and high energy
  - Methane for intermediate resolution and broader bandwidth
  - Hydrogen for intermediate resolution and long wavelengths
- A suite of new instruments are still likely to need similar options for a broad program but methane unlikely to be possible.
- Moderator development program required
- Small, bright moderators for optical gains with guides







What do we need to optimise?

Beam Extraction

- TS1 and TS2
  - The closest an optical element can be placed is in a shutter.
  - Positioning is not reproducible enough for complex optics.
- SNS STS, ESS, MLF-JPARC and compact sources
  - Guides can approach ~<2m from the source with high accuracy
  - Factor of 3-4 in solid angle
  - Huge number of extra neutrons. (If they can be used)

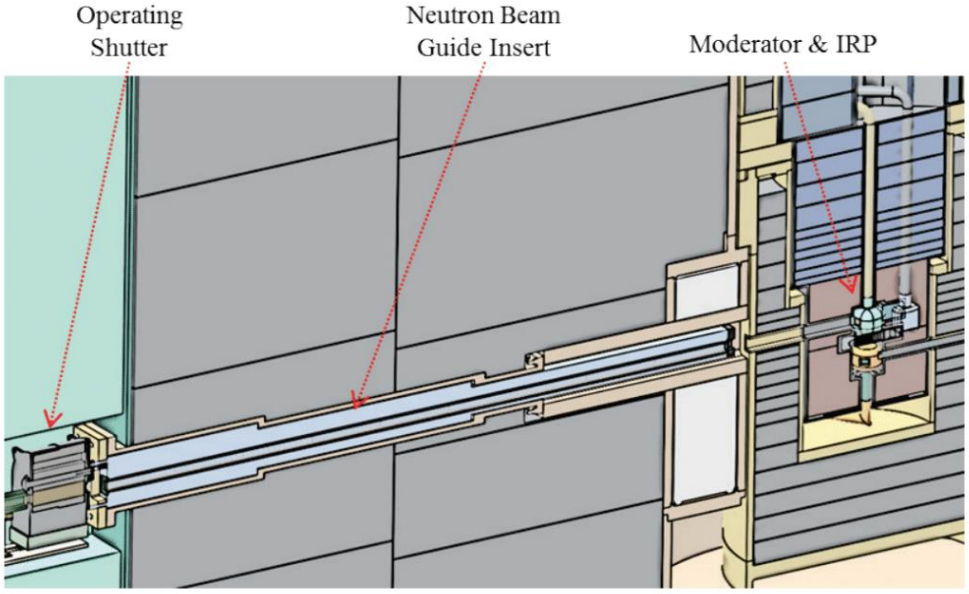
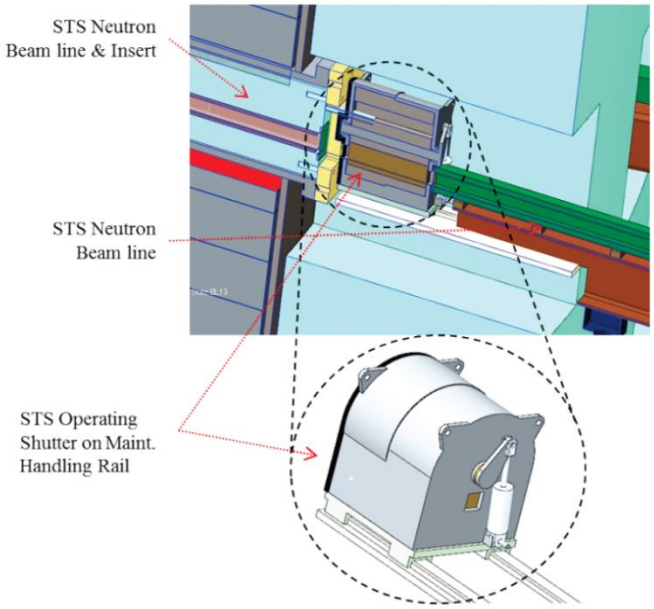


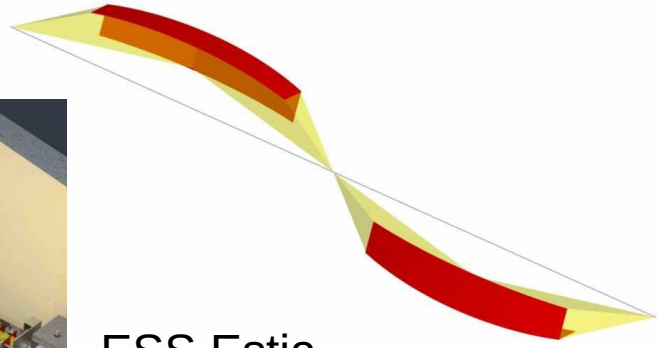
Fig. 4.61. STS neutron beam insert (installed in core vessel).



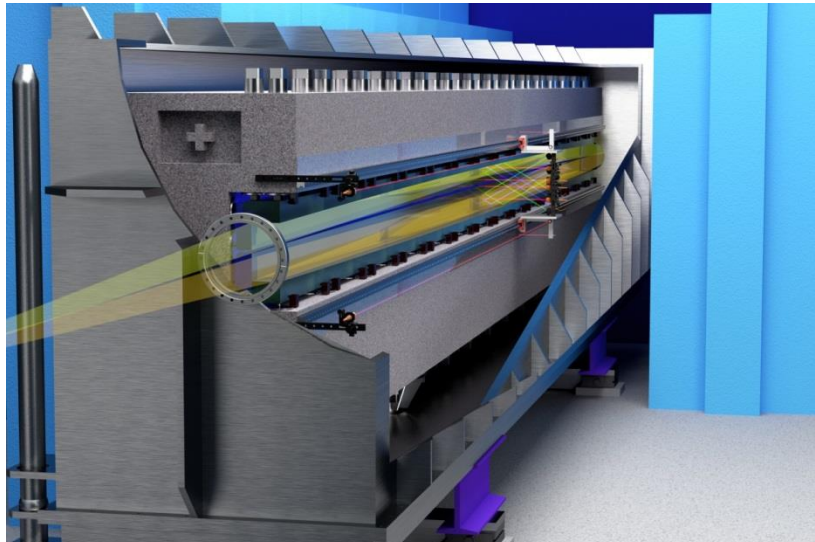
What do we need to optimise?

Guides and optics

- TS1
  - Majority of instruments built before guide technology was mature.
  - Moderators are not optimised with optics in mind
- New sources (most notably ESS and the proposed compact sources) show the value of exploring new instrument concepts and pushing engineering limits.
- Liouville's theorem cannot be avoided but bright, small sources provide new options for complex optics.



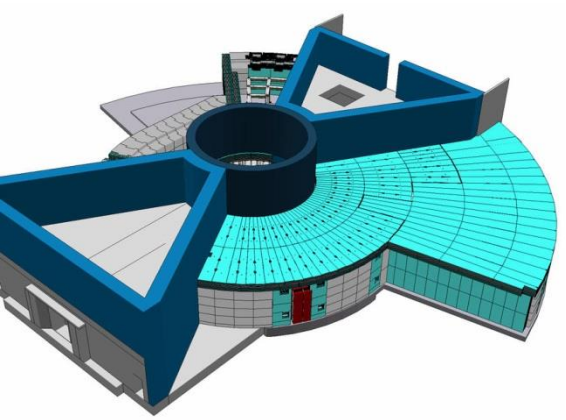
ESS Estia reflectometer



What do we need to optimise?

Shielding

- 1.2GeV, ~1.25MW, 50Hz beam
  - Shielding demands will be greater for radio protection but also to maximise signal to noise as with TS2.
  - MLF-JPARC and ESS illustrate what will be required.



ESS Bunker

MLF Bunker and instrument shielding

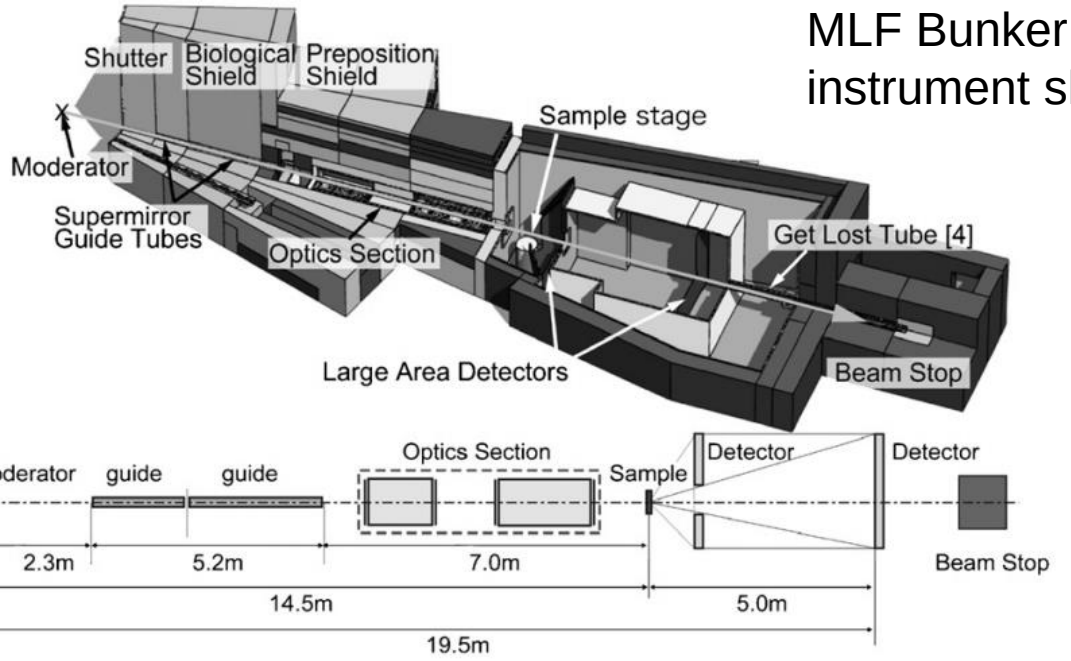


Fig. 1. The current design of the new TOF-SANS instrument HI-SANS in the MLF of J-PARC. The upper part shows the three-dimensional layout and the lower part the schematic illustration [4].

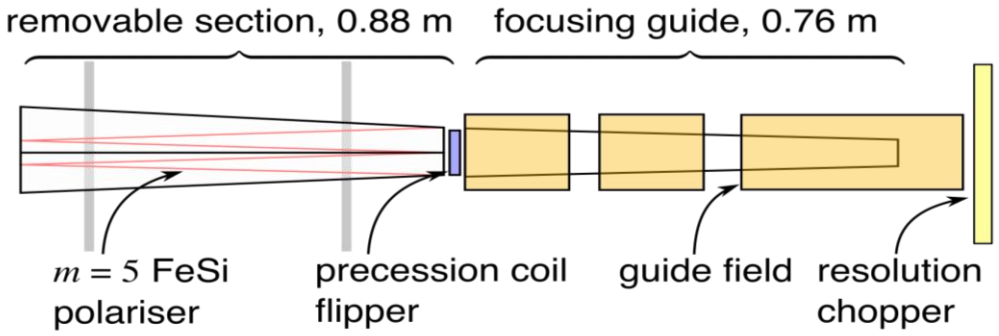
New Instrumentation Possibilities

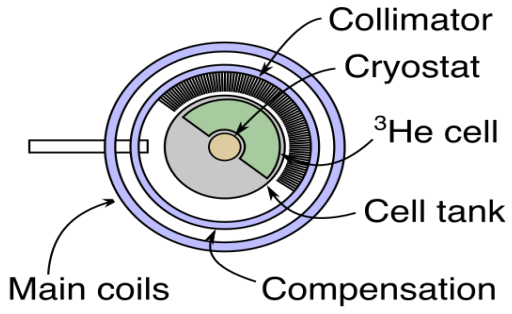
Some Examples

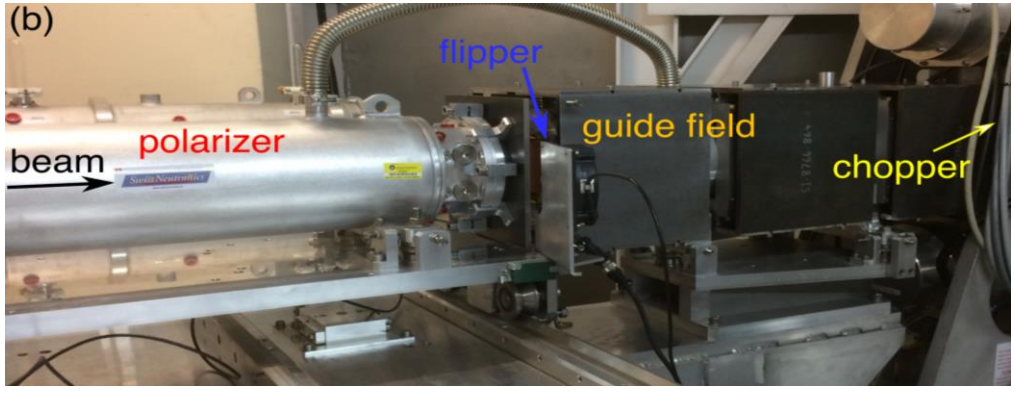
New Instrumentation possibilites

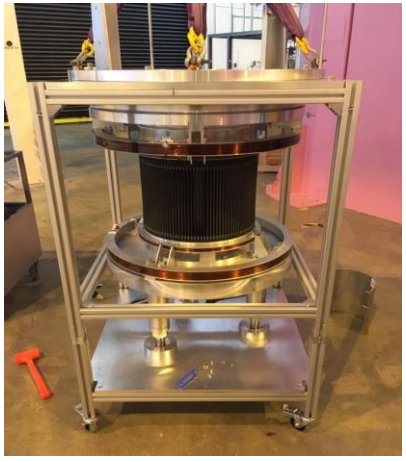
Polarisation and low flux techniques

- Polarised beams
  - Immediate flux loss of a factor of 2-4
  - Increased flux, optimised moderators and new optics will make new techniques possible





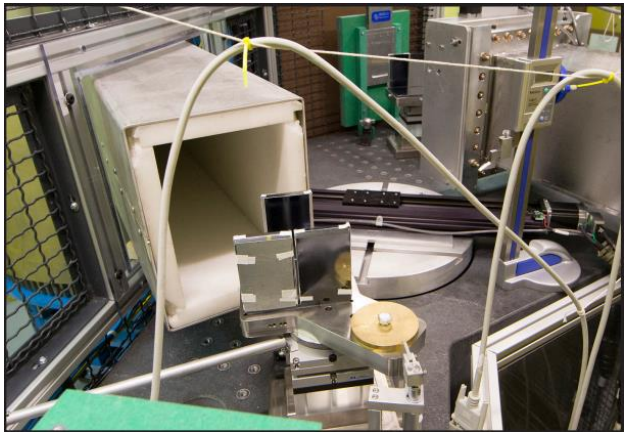


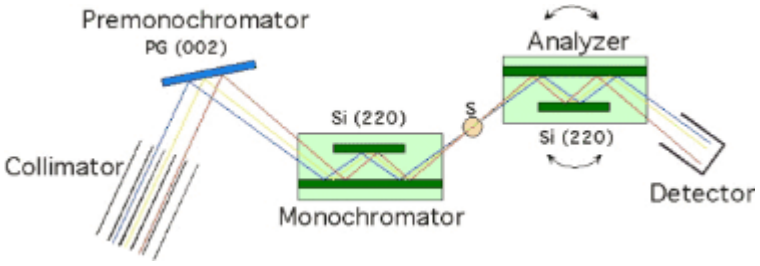


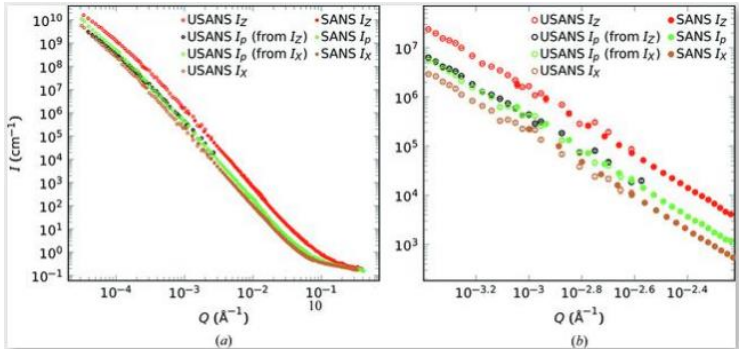
New Instrumentation possibilities

Polarisation and low flux techniques

- USANS
  - Severely flux limited technique with low information content
  - Requires contrast variation to extract useful information
  - 8hrs per measurement at NIST
  - Order of magnitude increase in available flux transforms the technique



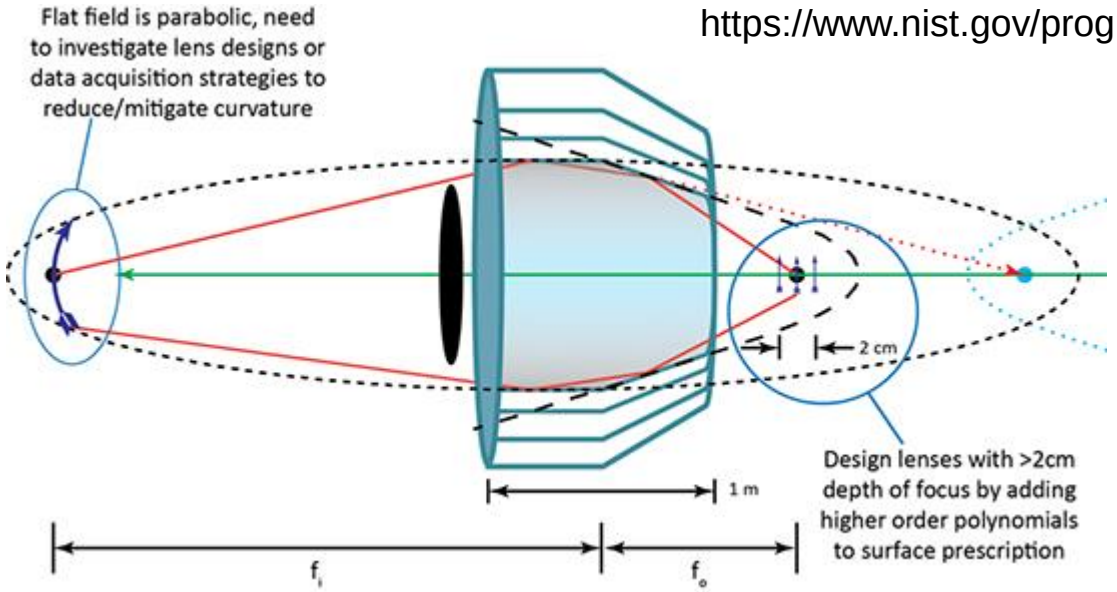




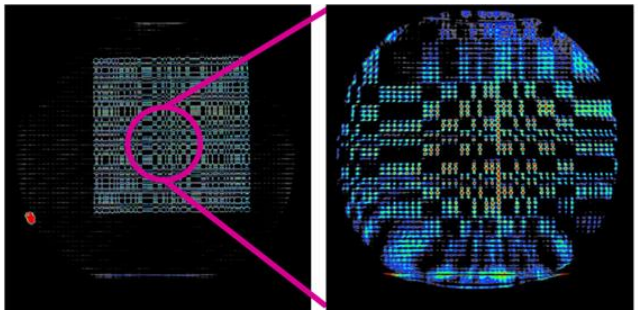
New Instrumentation possibilities

Polarisation and low flux techniques

- Neutron microscope
  - Requires a bright, divergent source of long wavelength neutrons.
  - Push below current imaging limit of ~100μm to a few μm
  - Mirror optics are based on X-ray telescope technology
  - Optics are expensive but are a new and improving technology
- Requires new detectors, optics and moderator optimisation.



https://www.nist.gov/programs-projects/towards-neutron-microscope

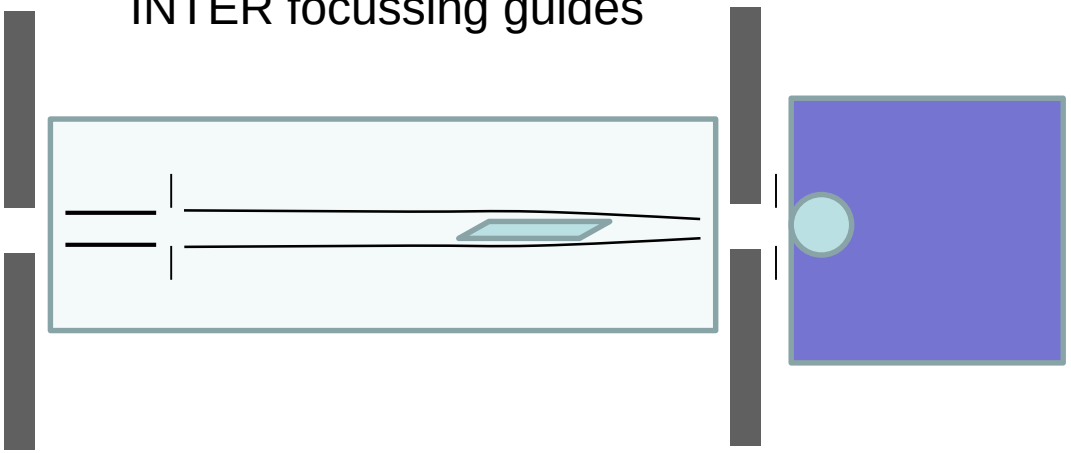


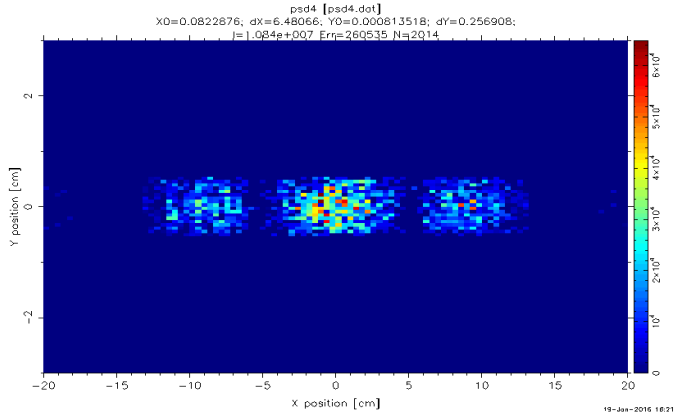
TS2

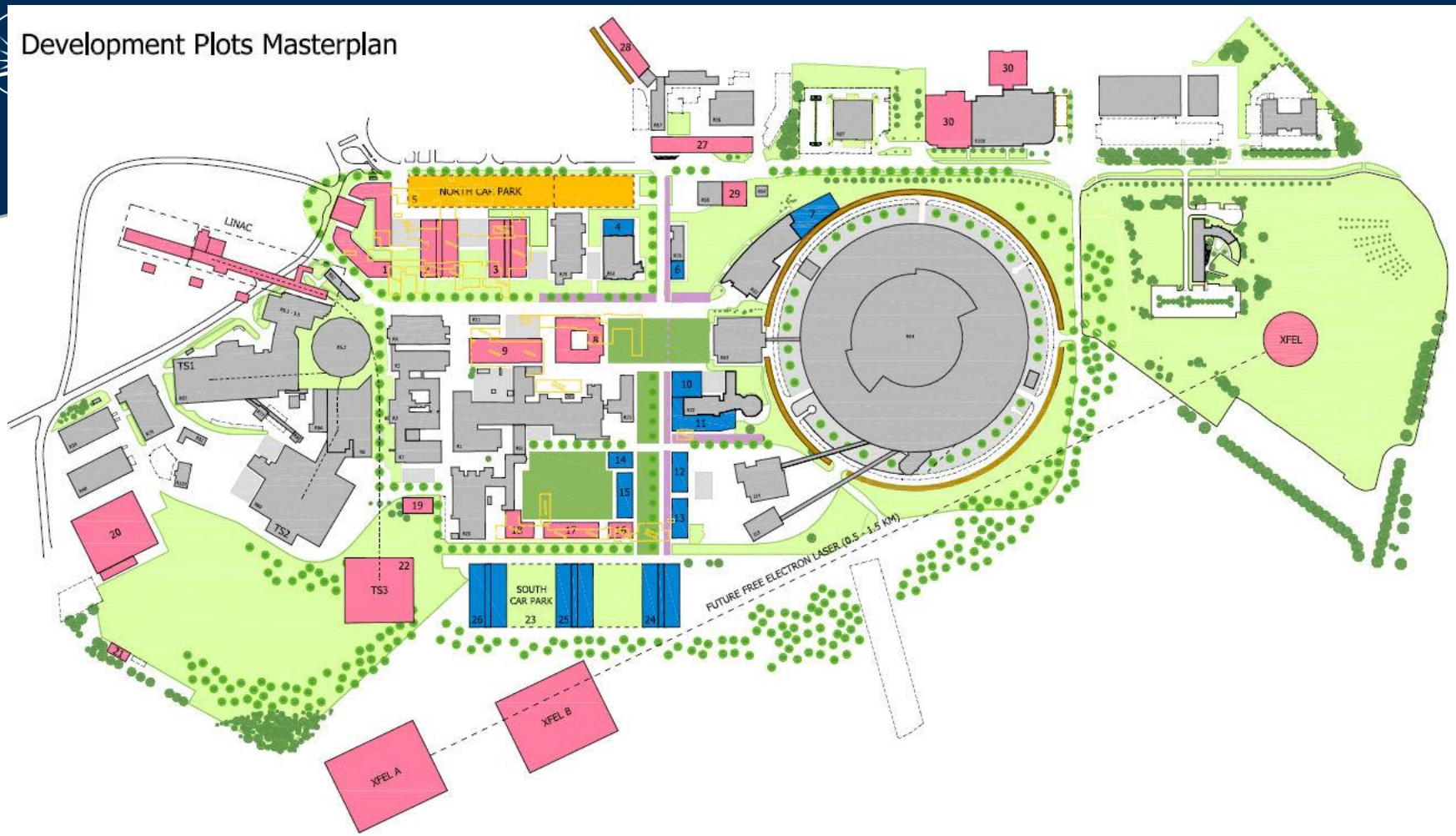
250kW upgrade

- Power upgrade would need to be combined with a new target, reflector and moderators.
- Factor ~5 gain in flux should be aimed for
- Combined with other instrumental optimisations
  - Reflectometers – already have upgrade plans for x10
  - SANS – need a brighter source at long wavelengths
  - WISH – Replacement for solid methane would be required.
  - Low dimensional moderators where appropriate.

INTER focussing guides







- TS1 and TS2 – Continuous renewal to retain and develop the world class science program.
- Develop any potential TS3 instrument suite in combination with an upgraded TS2 to maximise potential benefits.
- Start thinking now……. ESS will have been working on instrument concepts for nearly 15 years by the time it is running in 2025

Science & Technology Facilities Council
ISIS

Summary part 2

- ISIS-II would provide the UK with the world leading muon and high resolution neutron scattering facility. An optimised TS3 and upgraded TS2 would provide unique capabilities especially within Europe.
- To make the most of ISIS-II we need to maintain our vibrant community and continue to grow.
- Need to have an ongoing program of upgrades and new instruments
  - Continue to provide the community with what they need
  - We have world class instrumentation but the expertise required to maintain and continue to develop is highly specialised.
  - The next generation of instrument builders must continue to be trained
    - Qualified scientists and engineers will be needed in 2030.
- Need a moderator development program
  - Methane must be replaced, is hydrogen the only answer?
  - How can we be more efficient? We only use 0.001% of the neutrons we produce.

Thanks

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- Goran Skoro and Steve Lilley
- Many others

Thank you for your attention.