Diffraction detectors for ESS: challenges and strategy

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Goals and challenges

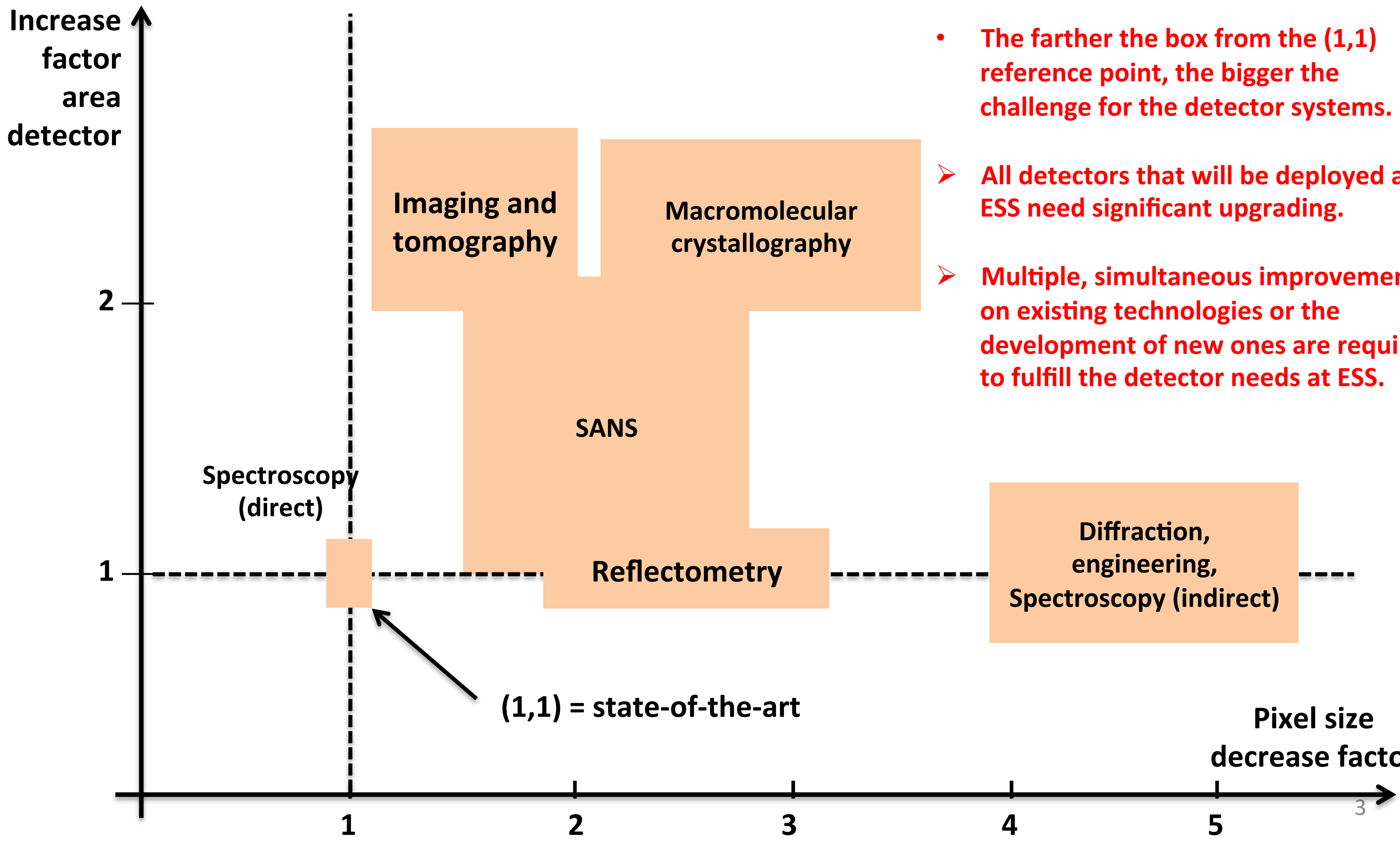
ESS goal: build a facility capable to provide the most intense neutron beam world-wide that will be use to:

- ➔ Measure very small samples, investigate kinetics
- ➔ Perform fast measurements
- ➔ Combine multiple methods in one instrument (e.g., PD+SANS+NI)
- ➔ etc.

➔ A large number of new components (including detectors) must be developed.

Goals	Implications for detectors
Small samples	Small pixel sizes, large area, low background
Fast measurements	Fast detector response, readout electronics, DAQ
Multiple methods in one instrument	Several types of detectors must be integrated

Detectors for ESS: *sky is the limit*



- The farther the box from the (1,1) reference point, the bigger the challenge for the detector systems.

- All detectors that will be deployed at ESS need significant upgrading.
- Multiple, simultaneous improvements on existing technologies or the development of new ones are required to fulfill the detector needs at ESS.

Detectors for ESS: strategy

Instrument class	Instrument sub-class	Instrument	Key requirements for detectors	Preferred detector technology	Ongoing developments (funding source)
Large-scale structures	Small Angle Scattering	SKADI	Pixel size, count-rate	Scintillators	SonDe (EU SonDe)
		Loki		^{10}B-based	BandGEM
	Reflectometry	Freia	Pixel size, count-rate	^{10}B-based	MultiBlade (EU BrightnESS)
		Estia			
Diffraction	Powder Diffraction	DREAM	Pixel size, count-rate	^{10}B-based	Jalousie
		Heimdal		*Scintillators*	
	Single-crystal diffraction	MAGIC	Pixel size, count-rate	^{10}B-based	Jalousie
		NMX	Pixel size, large area	Gd-based	GdGEM uTPC (EU BrightnESS)
Engineering	Strain scanning	BEER	Pixel size, count-rate	^{10}B-based	AmCLD, A1CLD
	Imaging and tomography	Odin	Pixel size	Scintillators, MCP, wire chambers	
Spectroscopy	Direct geometry	C-SPEC	Large area (^{3}He-gas unaffordable)	^{10}B-based	MultiGrid (EU BrightnESS)
		T-Rex			
		VOR			
	Indirect geometry	BIFROST		^{3}He-based	
		MIRACLES			
		VESPA			

Key requirement for the ESS diffractometers

- Absolutely key to be clear about requirements for the design.

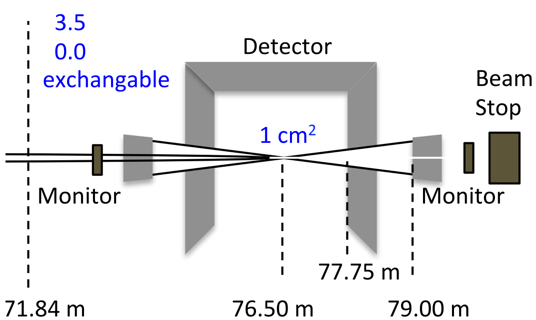
Instrument	Position resolution (H x V)	Area detector	No of detector pixels	Integrated flux on sample, HI mode ($n/s/cm^2$)	Δd/d (90°)	Detector technology	
						Comments	Options
DREAM	4 mm x 4 mm	6.2 sr ($9.7\ m^2$)	$6*10^5$	$3.4*10^8$ (calculated)	0.006	^{3}He tubes ruled out by the position resolution requirement. Rate capability of current technologies could be a challenge.	Scintillators, ^{10}B-based gas detectors
HEIMDAL	< 3 mm x 10 mm	1.8 sr ($4.7\ m^2$)	$1.5*10^5$	$2*10^9$ (calculated)	0.01		
BEER	< 2 mm x 5 mm	1 sr ($4\ m^2$)	$4*10^5$	10^9 (calculated)	0.01		^{10}B-based gas detectors
WISH@ISIS	8 mm x 8 mm	2.8 sr ($13.8\ m^2$)	$2.1*10^5$	$1.1*10^8$ (experimental)	0.005	^{3}He tubes	
IMAT@ISIS	4 mm x 100 mm	1 sr ($4\ m^2$)	10^4	10^7 (calculated)	0.7	ZnS-based scintillators, crossed WLS fibers under construction	

➔ see Nigel's talk

Diffraction detectors for ESS

DREAM

Bi-spectral powder diffractometer



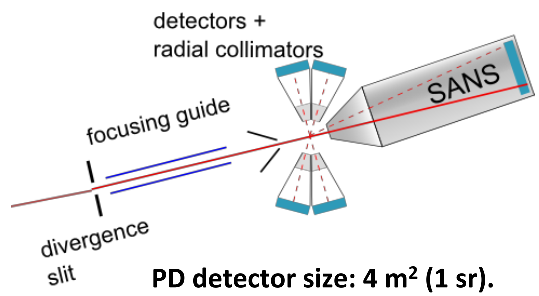
PD detector size: ~9.7 m² (6.2 sr).
Pixel size: 4 mm x 4 mm.

Preliminary drawing for the DREAM sample area.

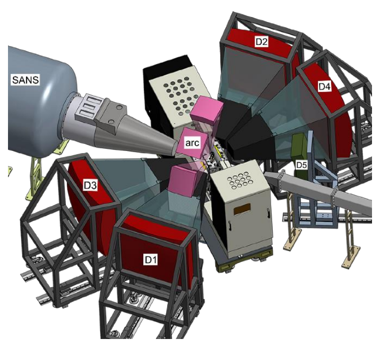
W. Schweika et al., ESS Instrument Construction Proposal DREAM (POWHOW), 2014.

BEER

Engineering diffractometer



PD detector size: 4 m² (1 sr).
Pixel size: < 2 mm x 5 mm.

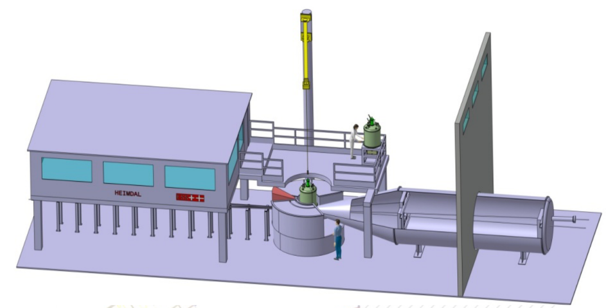


Preliminary drawing for the BEER sample area.

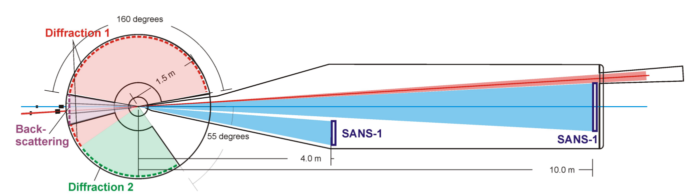
A. Schreyer et al., ESS Instrument Construction Proposal BEER, 2014.

HEIMDAL

Thermal powder diffractometer



PD detector size: ~4.7 m² (1.8 sr).
Pixel size < 3 mm x 10 mm.



Preliminary drawing for the HEIMDAL sample area.

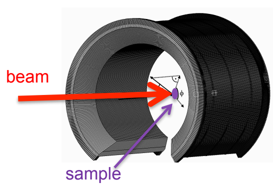
M. Christensen et al., ESS Instrument Construction Proposal HEIMDAL, 2014.

Diffraction detectors for ESS

EUROPEAN SPALLATION SOURCE

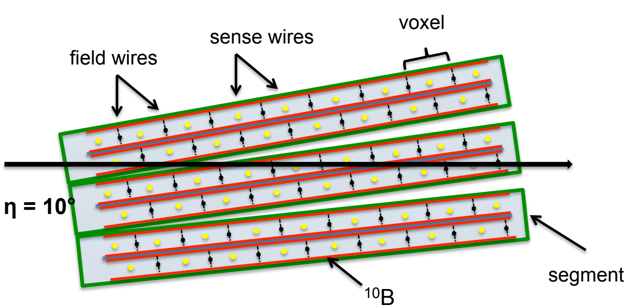
DREAM

The Jalousie detector concept was designed by CDT Heidelberg for the POWTEX diffractometers at FRM2.



"the Jalousie detector"

^{10}B-layers @ 10°, ε_{det} ~ 53% @ 1 Å.



The same detector technology will be used by the MAGIC – XSD @ ESS.

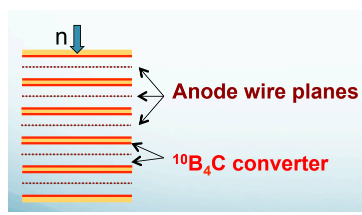
M. Henske et al., The ^{10}B-based Jalousie neutron detector – An alternative for ^{3}He-filled position sensitive counter tubes, NIMA 686 (2012) 151.

BEER

The Am-CLD and A1-CLD detector concepts were developed by the HZG/Denex collaboration in the framework of the InKind contribution to the ESS design update phase (2011-2014) .

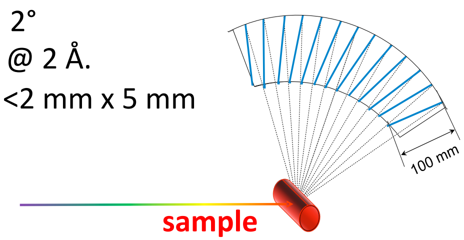
Powder and strain detectors: AmCLD

15 layers @ 90°
ε_{det} >60% @ 2 Å.
Pixel size <2 mm x 5 mm



Texture (arc) detectors: A1-CLD

1 layer @ 2°
ε_{det} >60% @ 2 Å.
Pixel size <2 mm x 5 mm



HEIMDAL

→ The instrument team favors the scintillator technology.

→ The ESS DG supports the intention of the Heimdal instrument team and welcomes the use of scintillator detectors in the ESS diffraction instrument suite.

→ The ability of the two detection technologies to work together, thereby mitigating the limitations of a single technology, is highly beneficial.

Risks

Instrument	Technological and engineering risks		Schedule risks	
BEER, DREAM, MAGIC	low	• Detectors based on MWPC, which is a mature technology. • Several laboratories are able to provide large quantities of high-quality ^{10}B-coatings at reasonable prices. • Validity of the BEER detector concepts was demonstrated and the first detector prototypes realized in a previous R&D project (2011-2014). A detector very similar to the DREAM detector is under construction for the POWTEX diffractometer at FRM2. • Detectors will be built by trusted industrial partners that already provided a number of detectors for use at instruments operational at existing neutron scattering facilities. • The detectors were designs by the same scientists who will built them. Issues related to the handing over the technology between the designers and manufacturers are avoided.	medium	• Delayed start of the project due to delay in funding. • Both companies consists of small teams of people that performs a very specialized type of work. There is a risk that unique workforce resources become unavailable when they are needed. • For DREAM (and MAGIC), any delays in the delivery of the POWTEX detector could lead to delays in starting the production of the components for the DREAM detector.
HEIMDAL	medium	• Some R&D work must be done in order to have a mature design that meets the requirements, assuming that one starts with an existing module.	high	• Due to the delay in deciding upon the technology, the detectors are subject to schedule risk.

➔ Today is about starting to reduce the risks by understanding the options

SANS detectors for Heimdal and BEER

Instrument	Position resolution (H x V)	Area detector	Integrated flux on sample, (n/s/cm²)	λ-range (Å)	Detector technology	
					Comments	Options
Heimdal, SANS	5 mm x 5 mm	1 m x 1 m 3 x 1 m x 0.5 m	~10^6 (calculated)	4 - 12	^{3}He tubes ruled out by the position resolution requirement.	Scintillators, ^{10}B-based MWPCs
BEER, SANS	5 mm x 5 mm	1 m x 1 m	~10^7 (calculated)	4.7 - 6.3		
SKADI	3 mm x 3 mm	1 m x 1 m	~10^9 (calculated)	4.5 - 40	Scintillators R&D ongoing under JCNS lead	
Loki (low-angle)	3 mm x 3 mm	~1 m²	~10^9 (calculated)	2 - 12	BandGEM R&D ongoing in Milan	
D22@ILL	8 mm x 8 mm	1 m x 1 m	~10^8 (experimental)	4.5 - 40	^{3}He tubes	
NGB30m@NIST	5 mm x 5 mm	0.64 m x 0.64 m	10^8 (experimental)	5 - 20	ORDELA MWPC (^{3}He)	
KWS1@FRM2	5.25 mm x 5.25 mm	0.64 m x 0.64 m	10^8 (experimental)	> 4.7	Anger cameras	

➔ Decision on the detector technology for the SANS add-on can be made later; several options will be available.

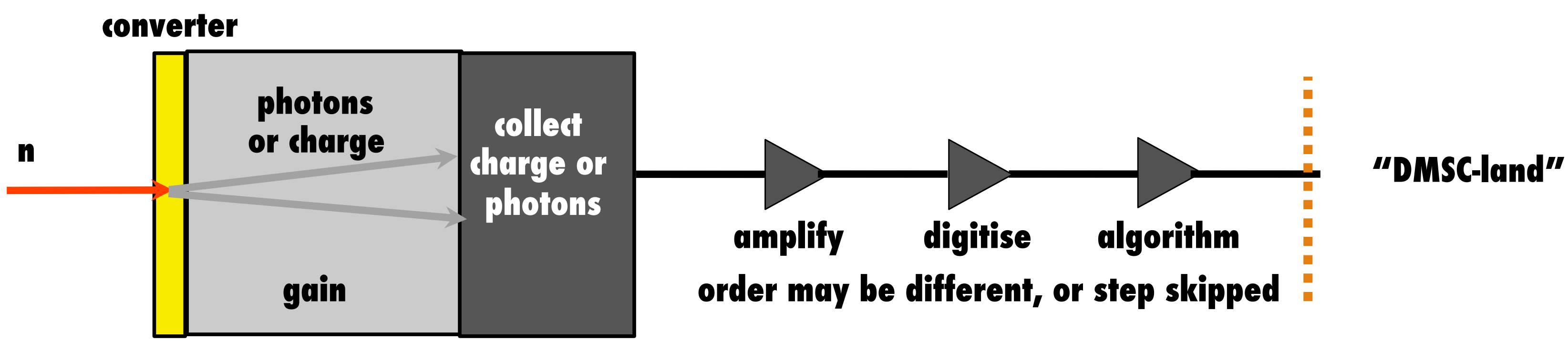
➔ See Giuseppe's talk on Loki

Conclusions and outlook

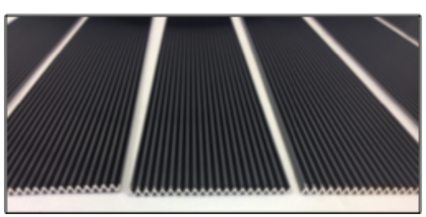
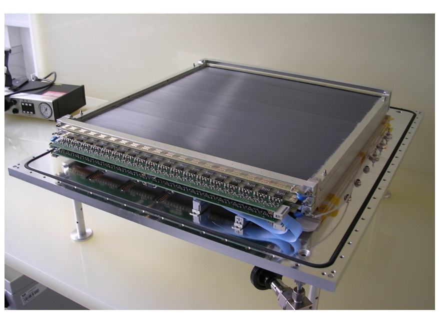
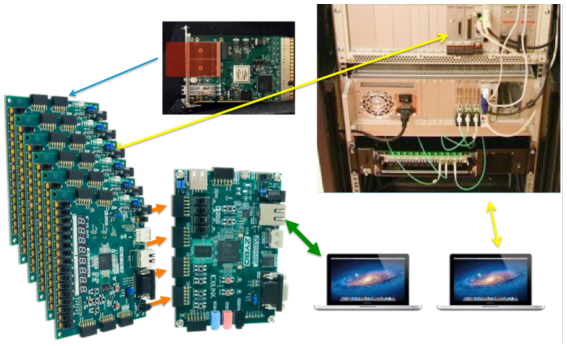
- The requirements for the powder diffraction detectors for ESS have demanding performance criteria which go beyond the state-of-the art limits.
- ESS diffraction instruments DREAM and BEER will employ ^{10}B-based detectors for the powder and texture studies, one of the very few technologies that can fulfill the challenging requirements in terms of pixel size, count-rate capability and detector area.
- We support using the scintillator technology for the Heimdal powder diffraction detectors and hope that a decision in that direction will be made at this meeting.
- The decision on the detector technology for the SANS add-on can be taken later. Several technological options are expected to become available in the next year or so.
- The instrument projects must enter the design phase with great forward momentum in order to meet the deadlines and budget.

Neutron Detectors

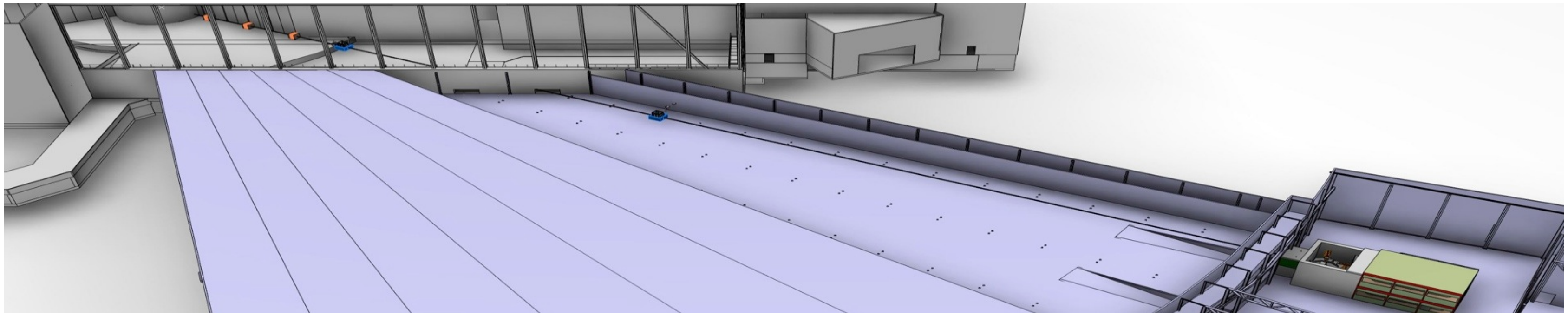
Efficient neutron converters a key component for neutron detectors

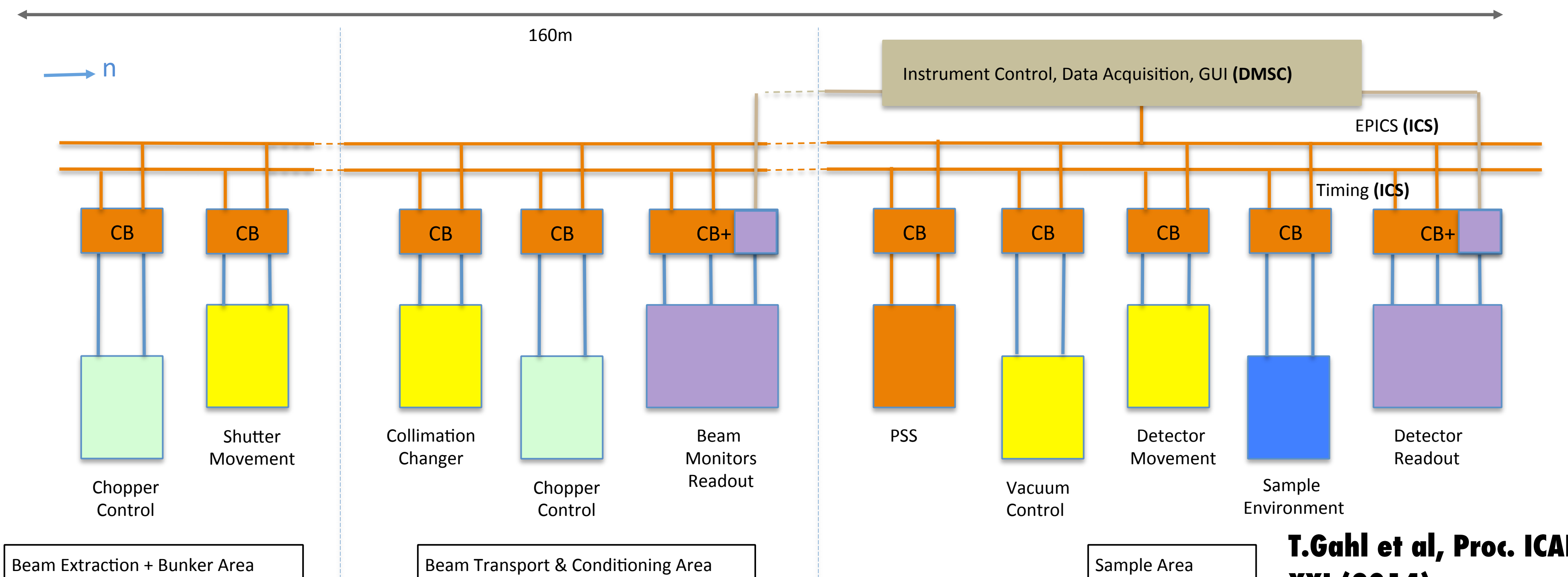


"Converter" *"Detector"* *"Electronics"*

 +  + 

Modular Instrument Control Concept

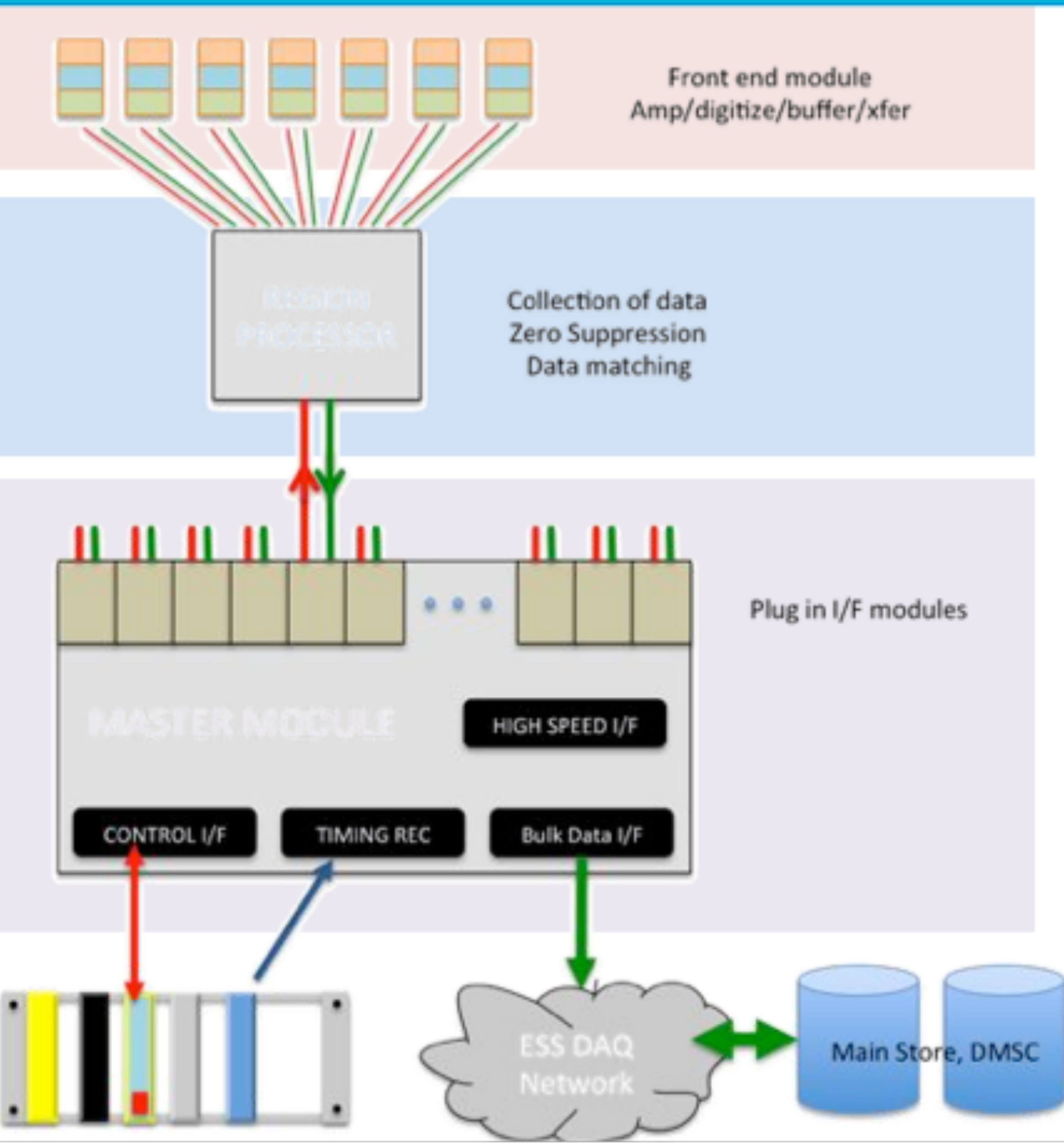




- **Modularisation to manage key interface**

T.Gahl et al, Proc. ICANS XXI (2014)
arXiv: 1507.01838

Modularisation for Detector Electronics



- **Modularisation to manage key interface**
- **Single in-kind partner (STFC, UK) for backend readout**
- **Example of synergy with existing European expertise to reduce developments needed by ESS**
- **Adapting rather than developing**

Diffraction detectors for ESS