FONDAZIONE BRUNO KESSLER | SENSORS AND DEVICES

# The Detector Data Acquisition System of the European Spallation Source

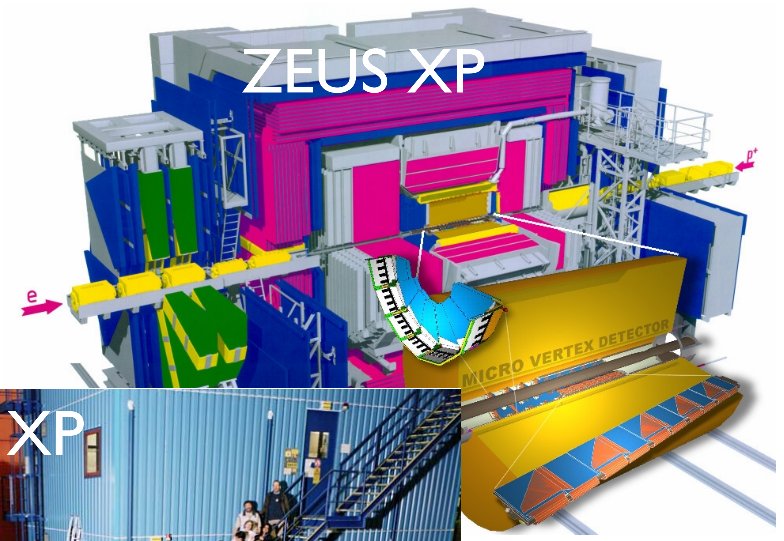
Prof. Richard Hall-Wilton

*FBK-SD director*

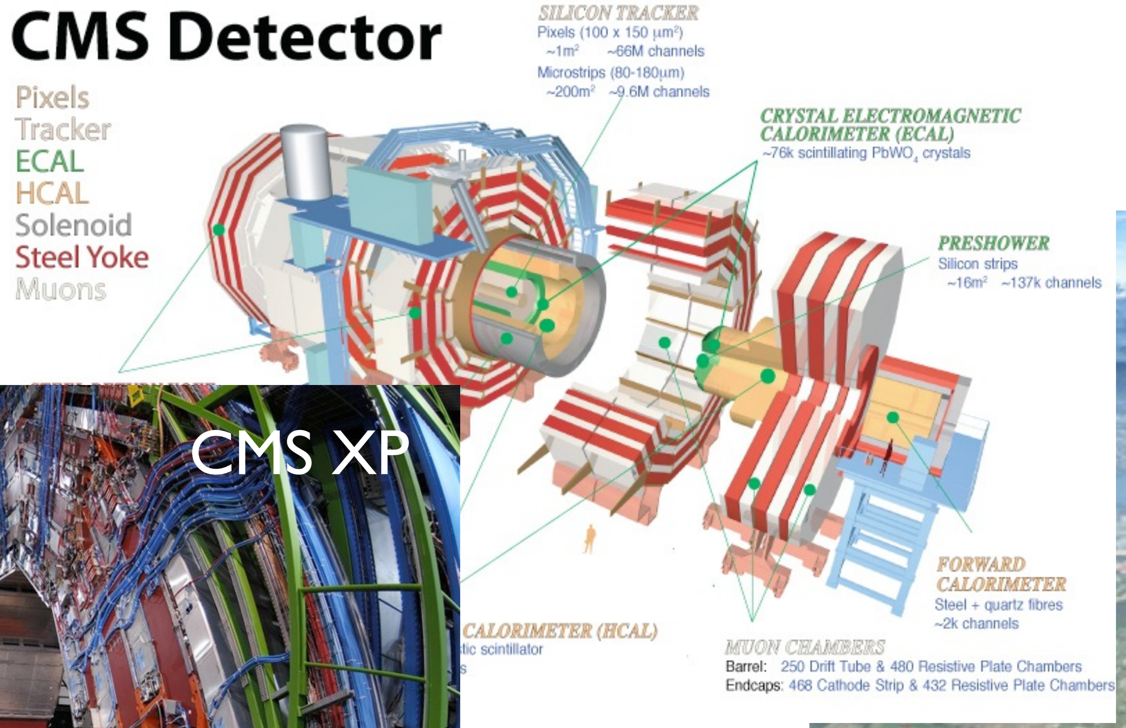
It’s been a strange past 2-3 years …

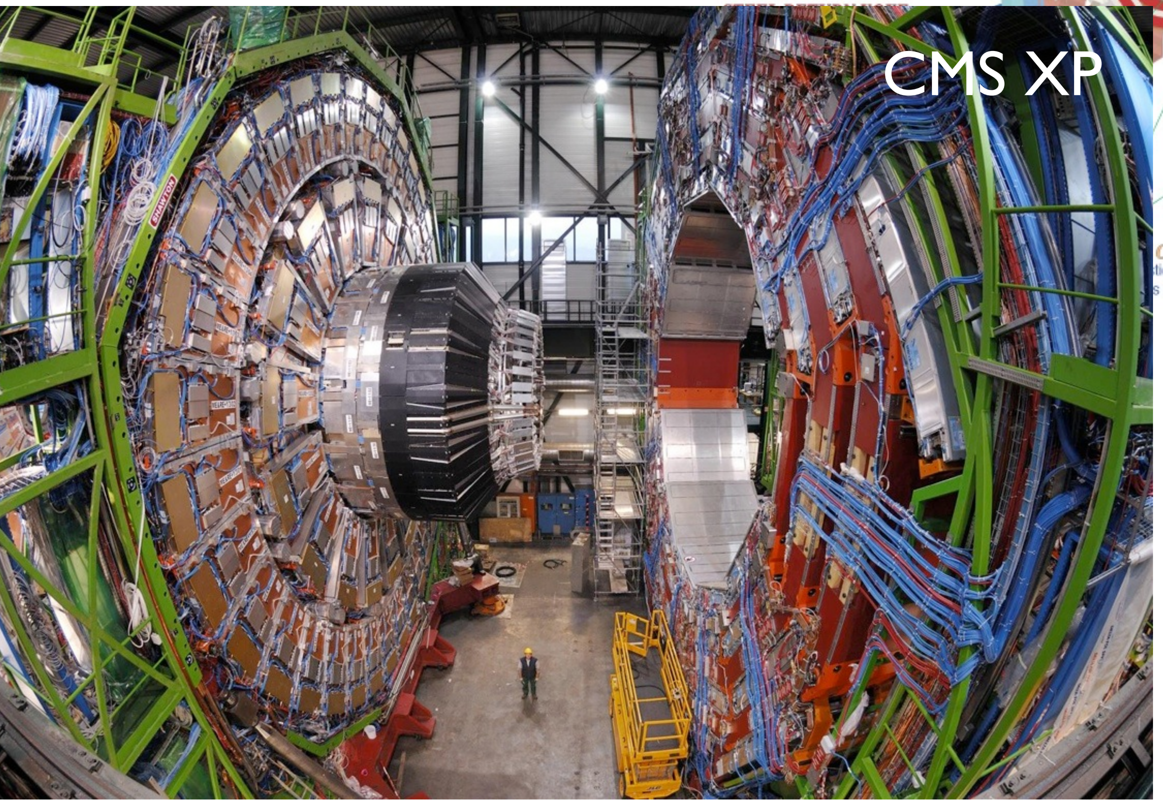

It’s really exciting that we can (re-)start to meet in person again and meet each other …

# Projects that I have worked on …

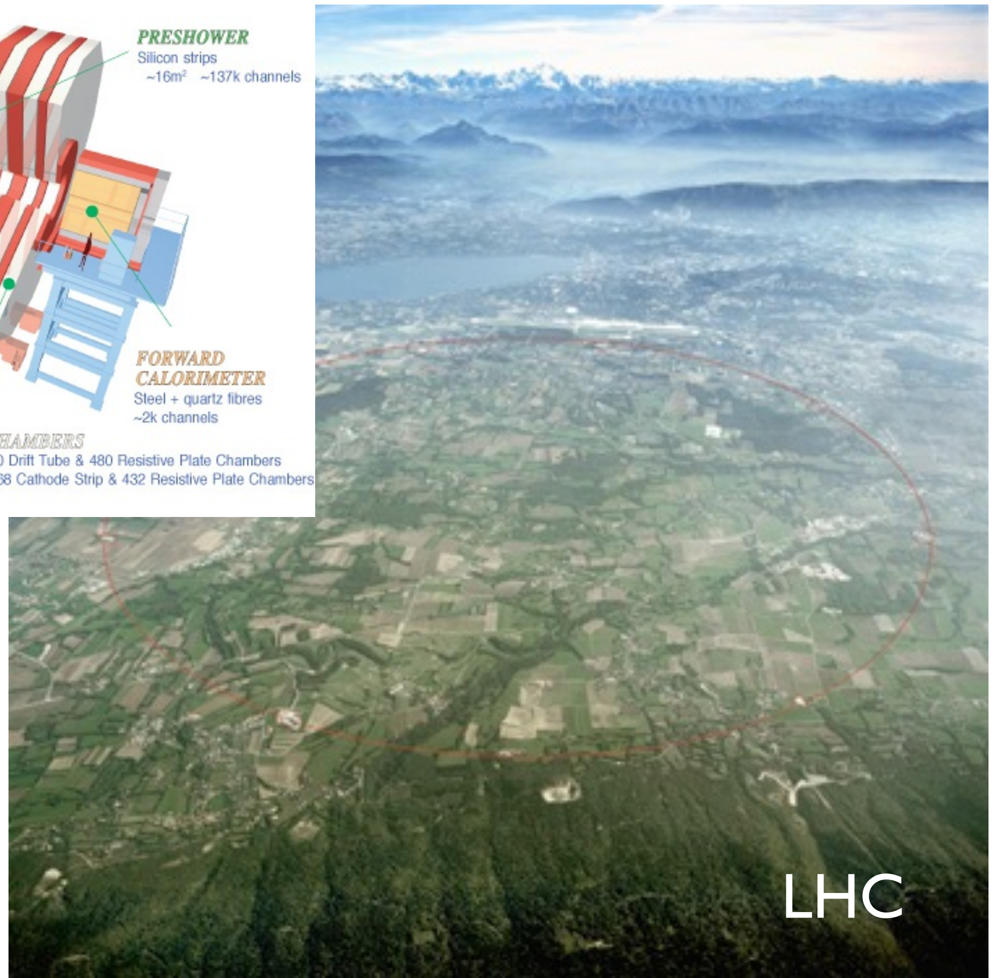




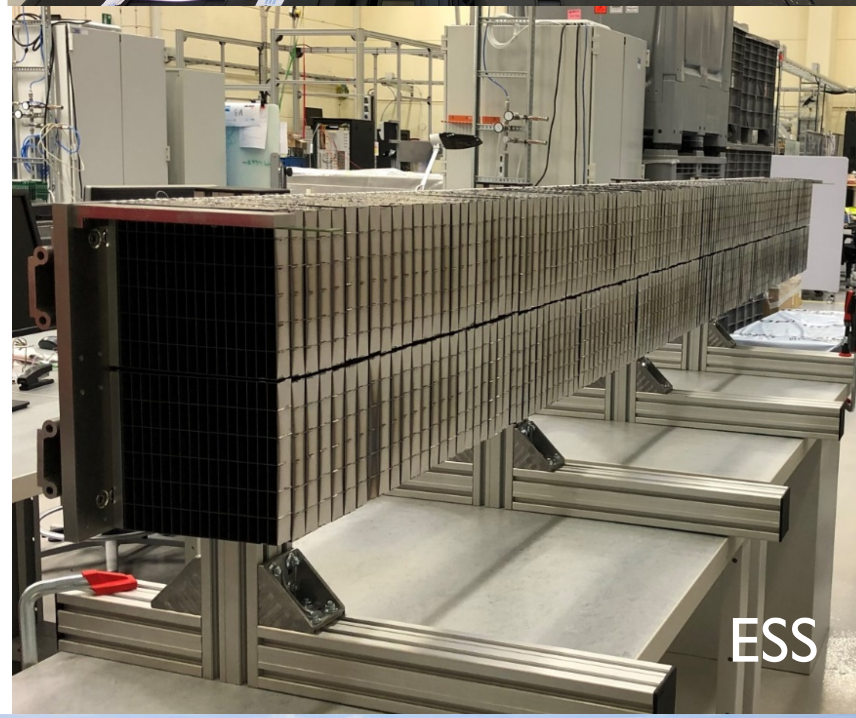




- RD42 Collaboration (Diamond Detector Development) (1995-6, 2006-11)
- ZEUS Collaboration for HERA at DESY (1995-2006)
- LHC Machine-Experiment Interface group (2005-2008)
- CMS Collaboration for LHC at CERN (2006–11)
- RD51 Collaboration (Micro Pattern Gaseous Detectors) (2013—)
- European Spallation Source (2011-2022)









# Caveat Emptor

… the contents of this talk are reflections from personal experience …

EUROPEAN
SPALLATION
SOURCE

# What am I going to talk about …

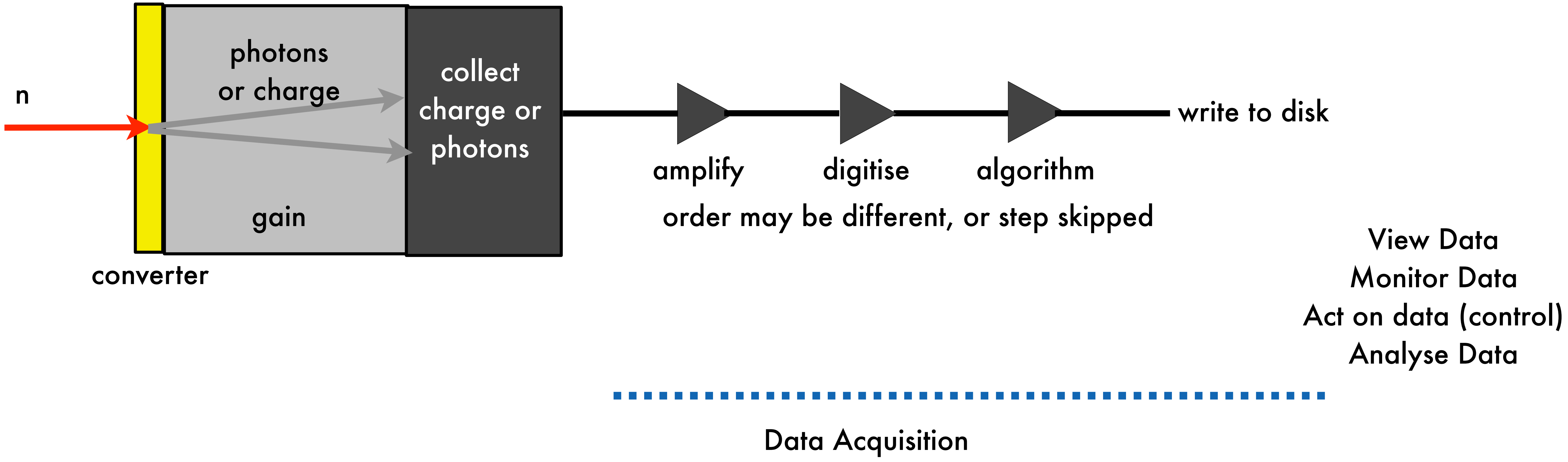
- You have been learning about: Systems-on-Chip Based on FPGA for Scientific Instrumentation and Reconfigurable Computing
- Detailed courses on how to perform a very particular and valuable technical skill

- Here, I am going to give a bird's eye view of how a large data acquisition system might look, utilising these skills you have been looking at …
- Am going to go through - with very broad strokes and very little detail - what needs to be taken into account in the design of the data acquisition system ….

- Like everyone, I will show this from my own experience - of the detector data acquisition system for the European Spallation Source …

# Basic Principles of Neutron Detectors

- Need to produce a measurable electric signal
- Not possible to directly detect slow neutrons - energy is too low
- Need to use nuclear reactions to convert neutrons into charged particles
- Then indirectly detect the charged particles in a charged particle detector
- Amplify, digitise, process as needed.
- Store data on disk




What is your end goal?

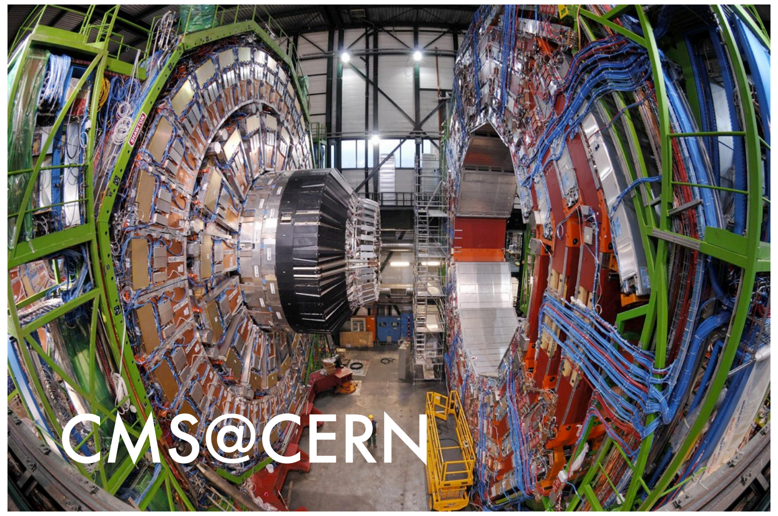
“horses for courses”

- Data acquisition is about being able to extract the information from the sensors to be able to carry out the measurements of interest as simply and **best** as possible
- Optimisation can be done for performance, cost, simplicity, off-the-shelf, size, energy usage, …

# Instrumentation


What camera you use has a big impact on the quality of photos that you get out of it …

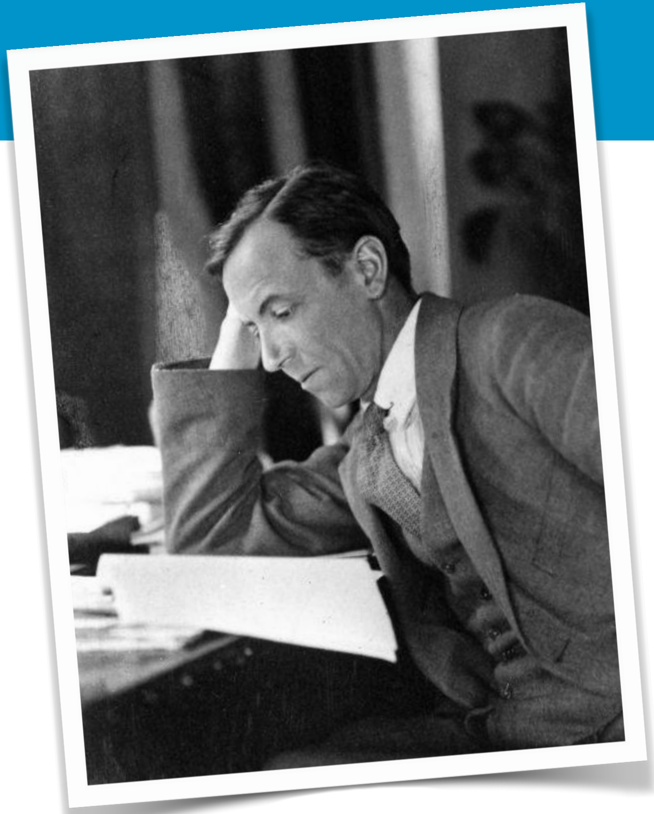





Bleeding edge Instrumentation enables novel and future science

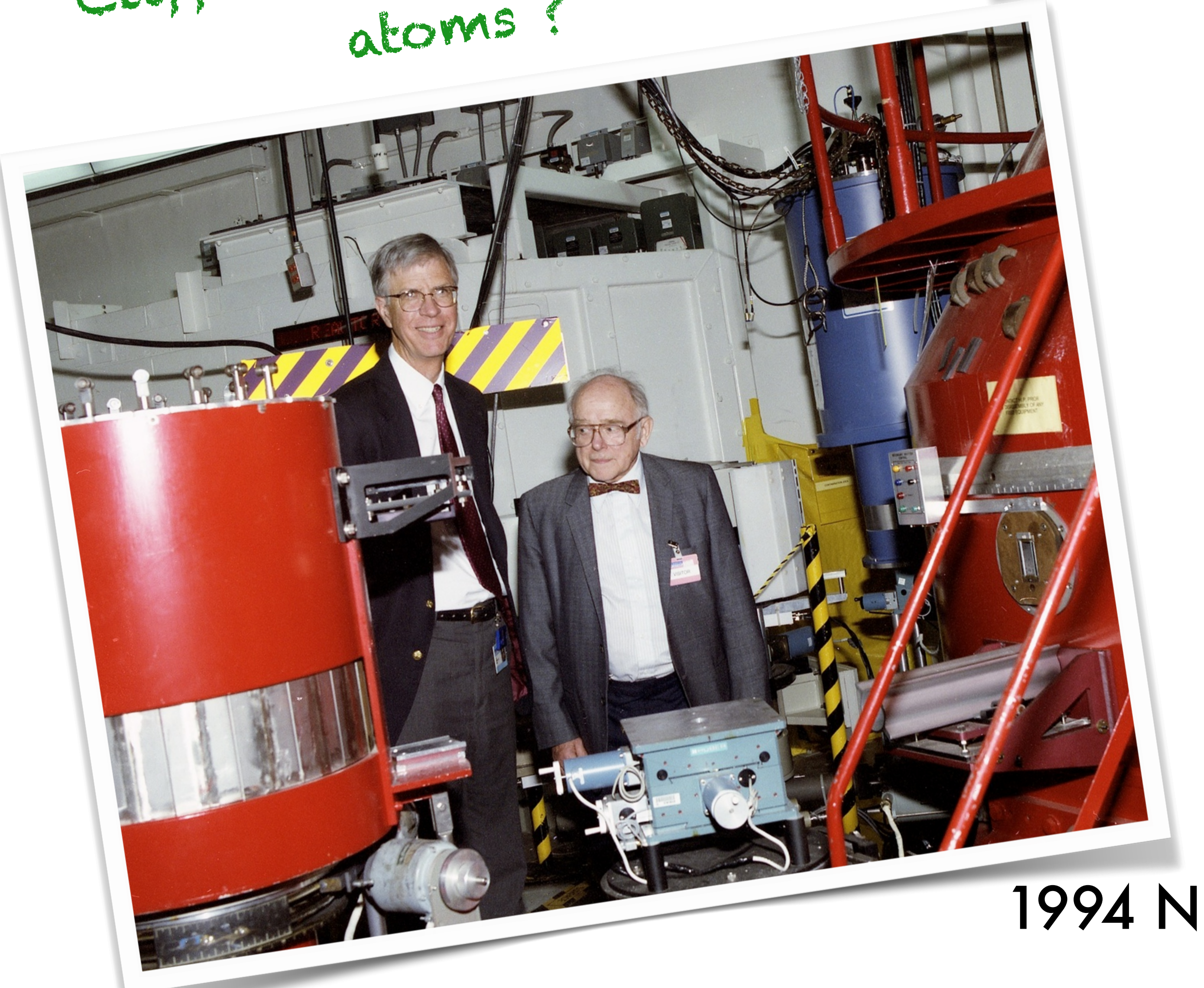
# What is the aim of the European Spallation Source?

# Neutrons



1932: Chadwick discovers "a radiation with the more peculiar properties", the neutron.

Cliff Shull: where are the atoms ?



Bert Brockhouse: what do they do ?

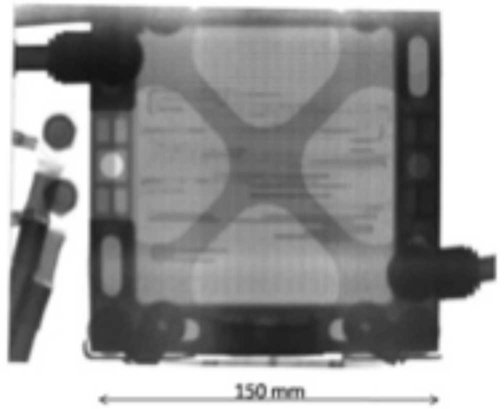
1994 Nobel Prize in Physics


Lighting
New materials
Solar energy
Food
Medicine
Tailor made materials
Pacemakers
Mobile phones
Cosmetics
Bio fuels
Implants
Transportation
Geo science

# Applications of Neutron Science

## Charge neutral

### Deeply penetrating

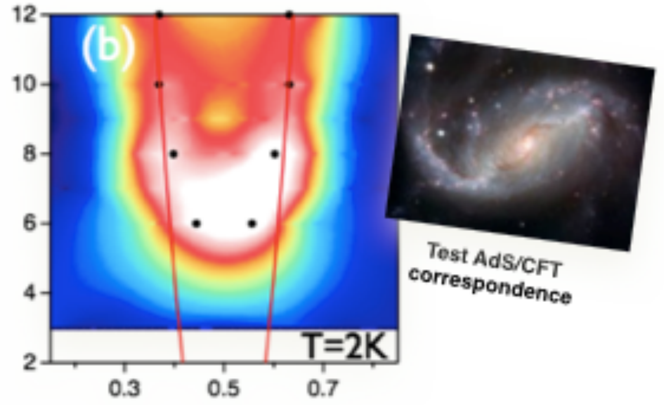



### Li motion in fuel cells

### Help build electric cars

## S=1/2 spin

### Directly probe magnetism

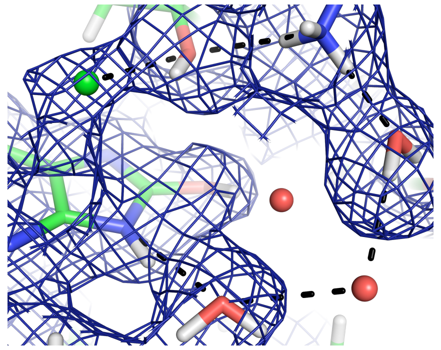



### Solve the puzzle of High-Tc superconductivity

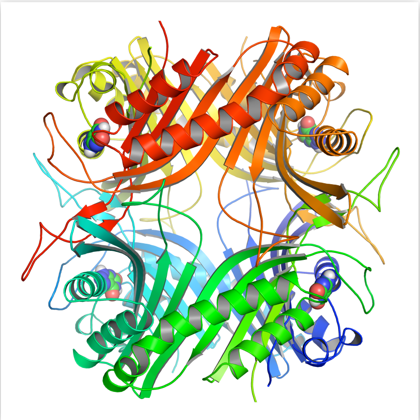
### Efficient high speed trains

## Nuclear scattering

### Sensitive to light elements and isotopes



### Active sites in proteins

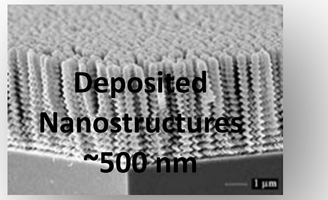


### Better drugs

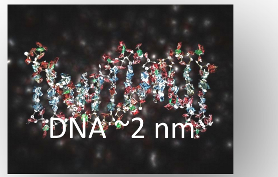
*Urate oxida*

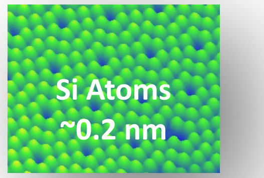
## Probing length scales and dynamics



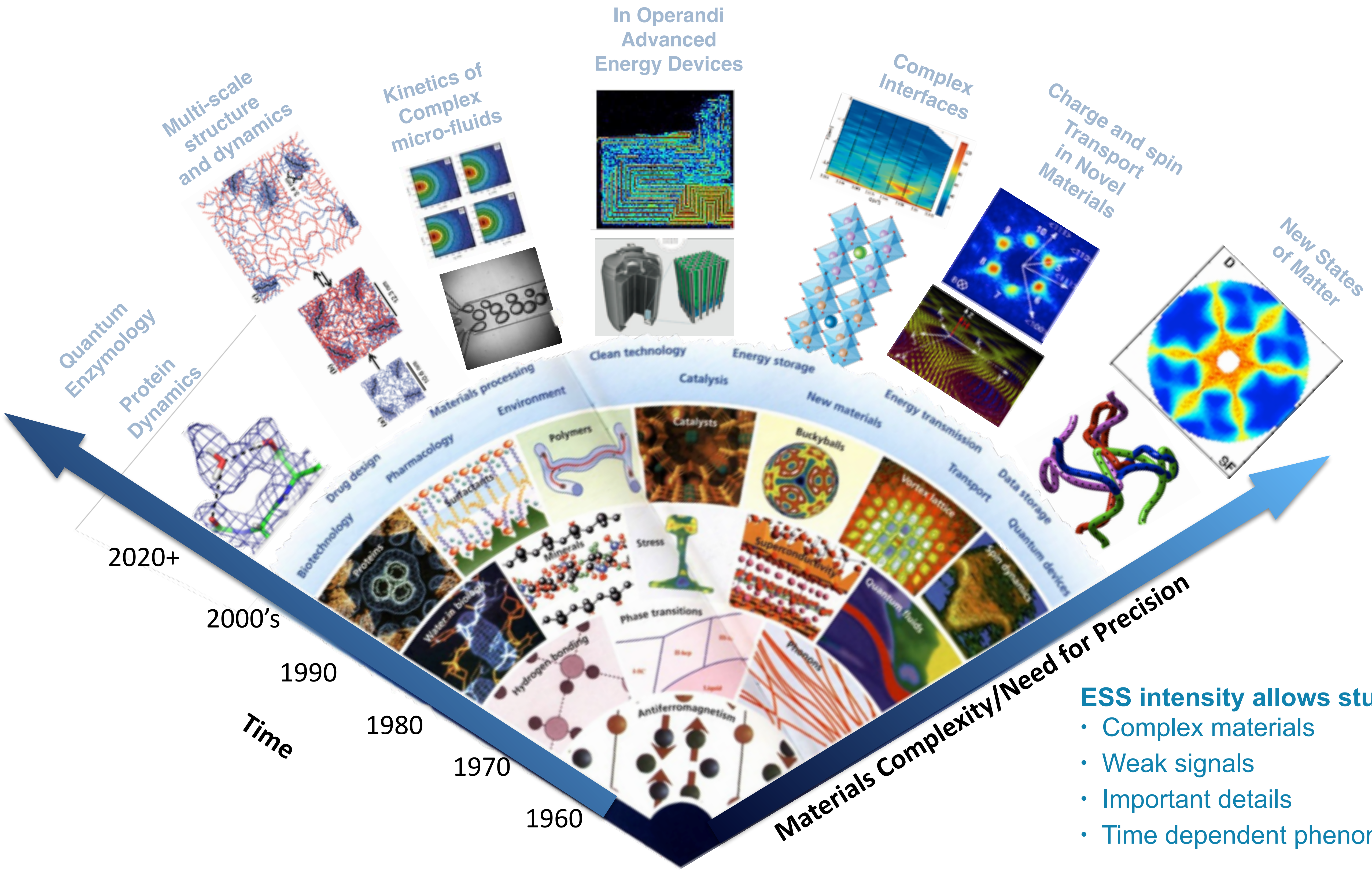






# Neutron Science Pushes the Boundaries



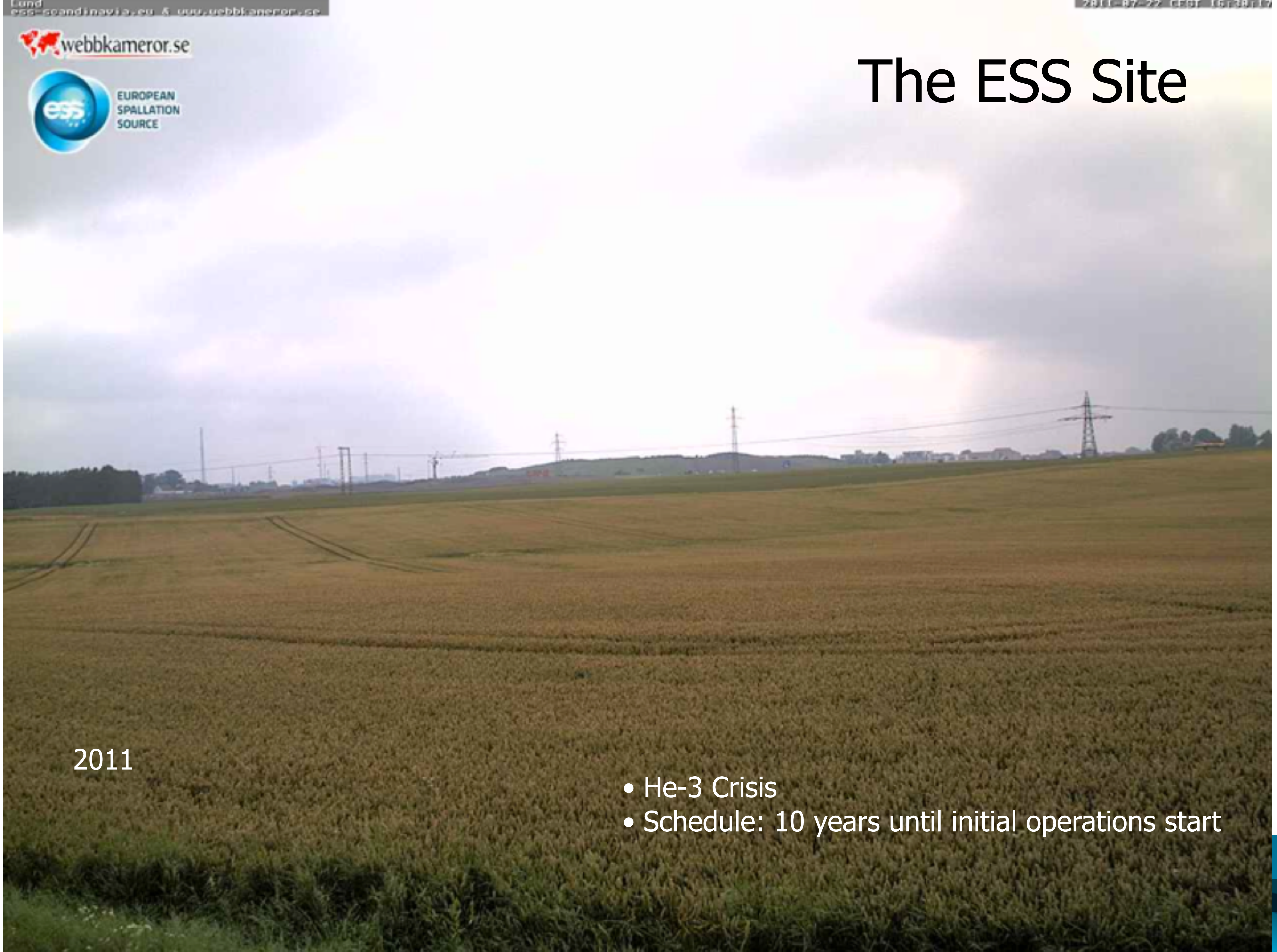

**ESS intensity allows studies of:**

- Complex materials
- Weak signals
- Important details
- Time dependent phenomena

# Visions for the coming decade …

# The European Spallation Source: view to the Southwest in 2025

# The ESS Site




2011

- He-3 Crisis
- Schedule: 10 years until initial operations start

# ESS Construction - October 2020

# Helium-3 Crisis

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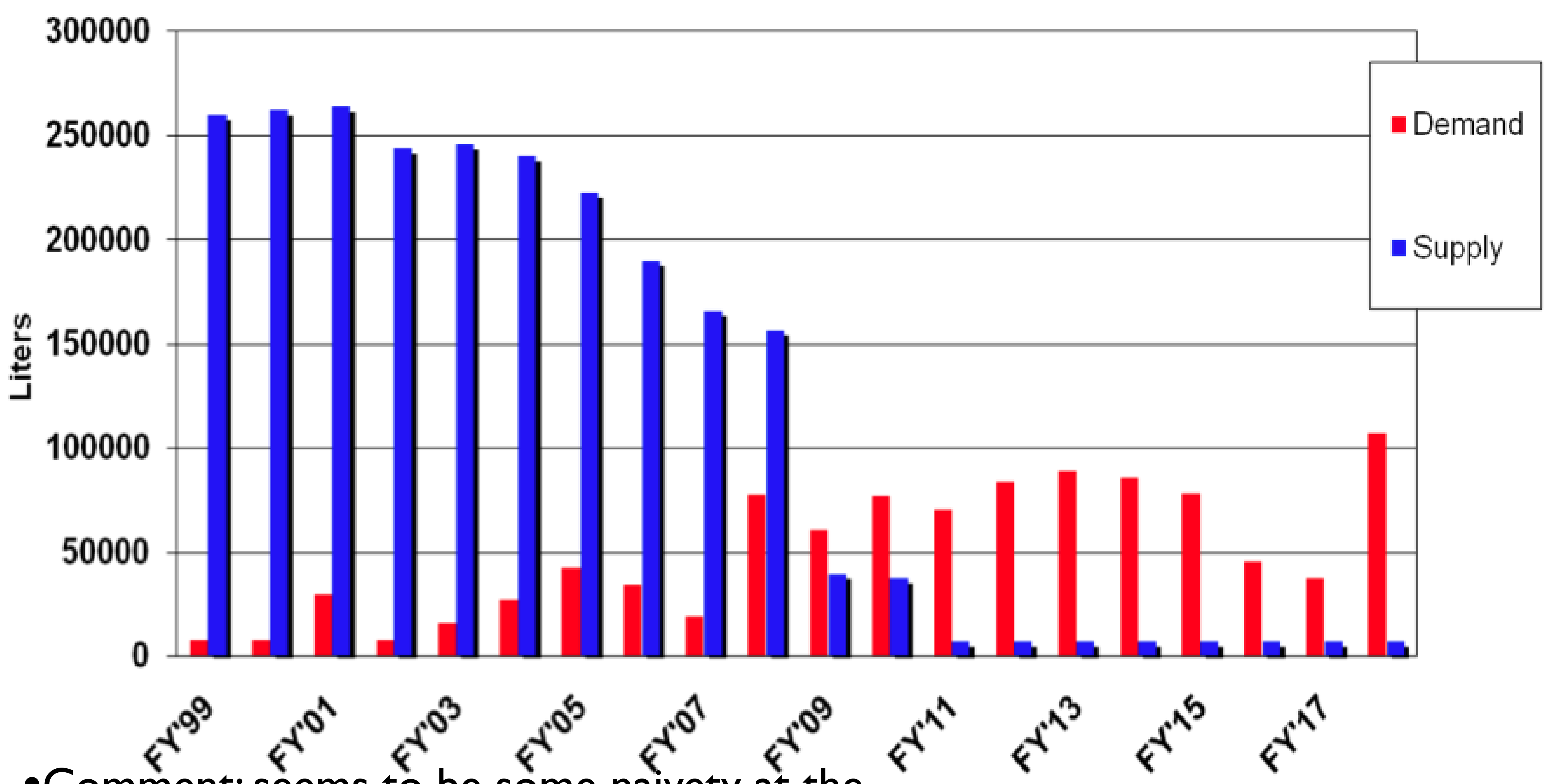
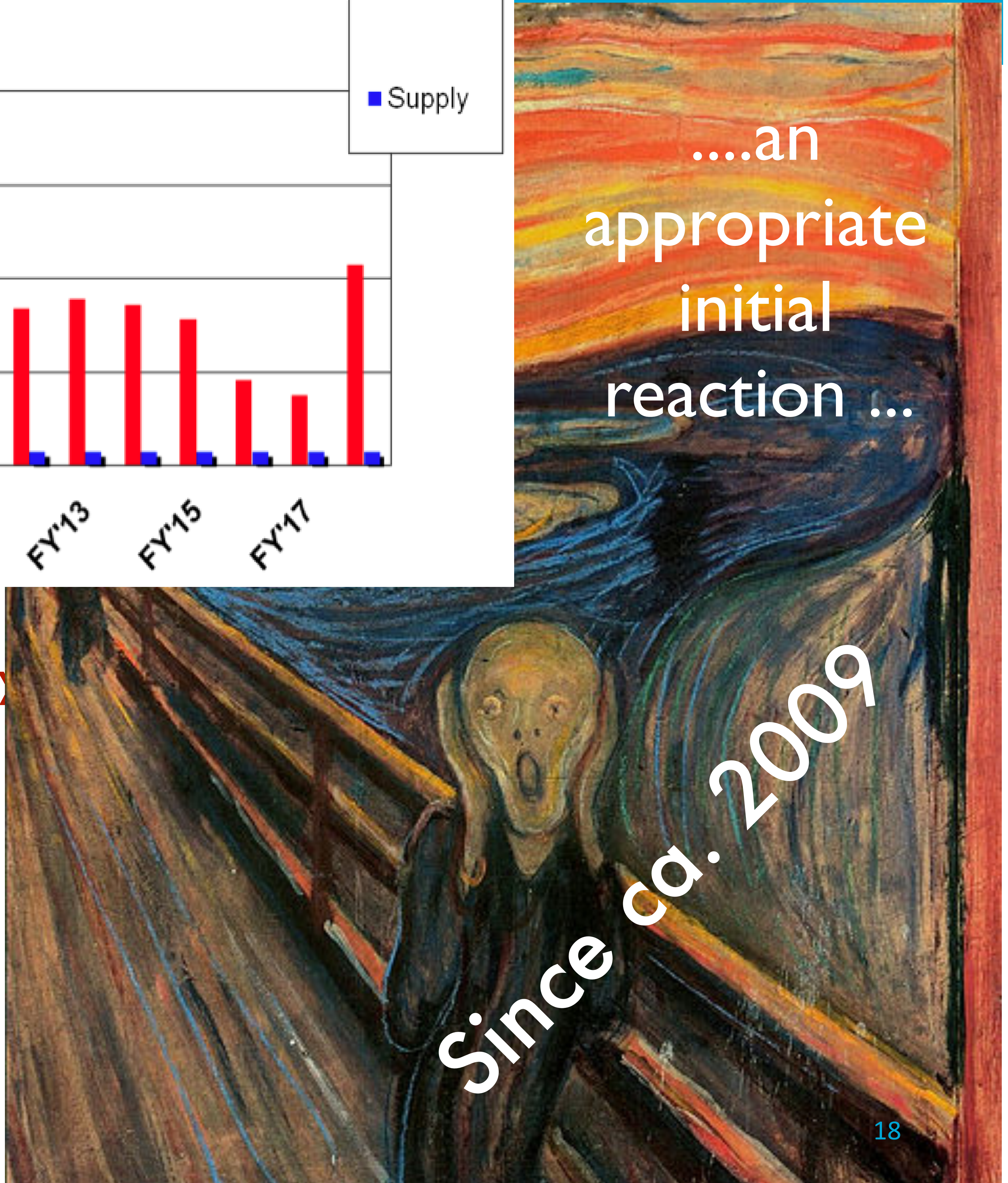



- Comment: seems to be some naivety at the moment as stocks are being emptied rapidly

Aside … maybe He-3 detectors are anyway not what is needed for ESS?
eg rate, resolution reaching the limit …

Crisis or opportunity … ?

For almost all instruments, detectors are a limitation on performance
Opportunity to implement modern DAQ

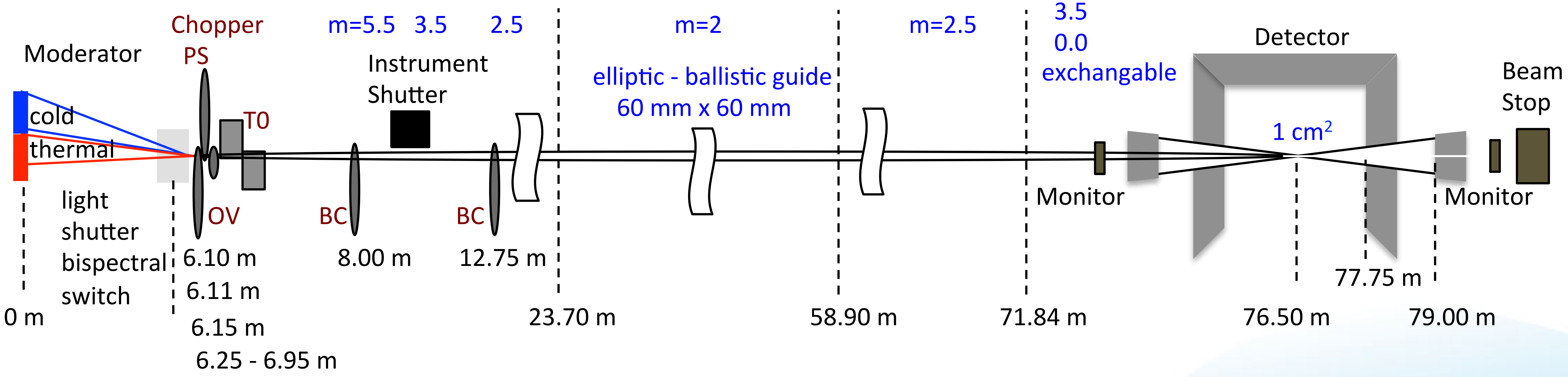
# Schedule …


- 10 years until first neutrons …

# Instruments and their Requirements

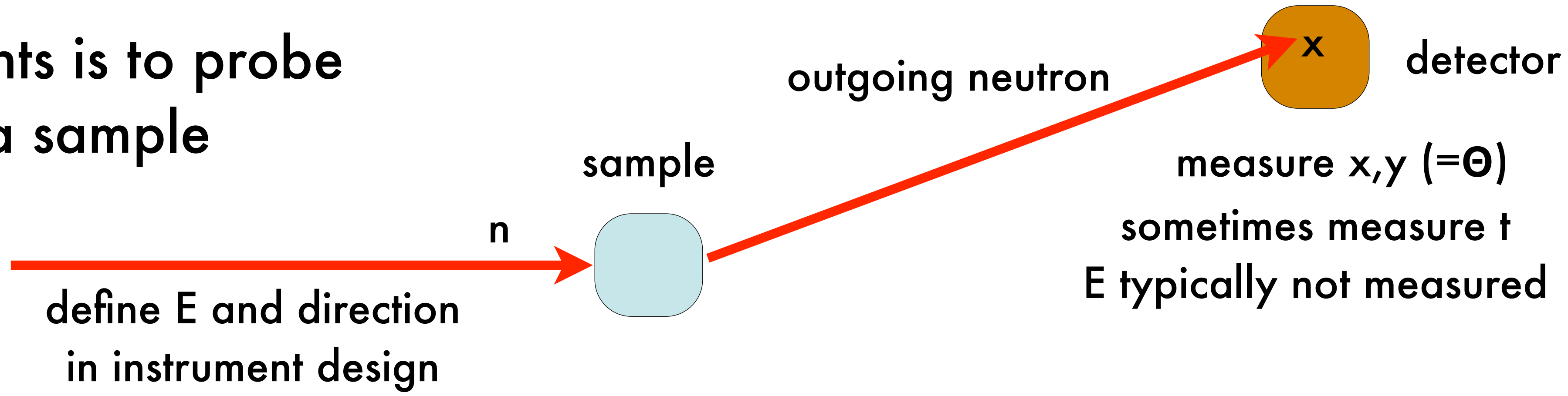
# Instrument Design

- Instrument Design is about selecting the phase space of interest and maximising that
- Phase space here primarily means flux (6D: position, divergence) and neutron energy/ wavelength
- Remember that as the neutron energy is not measurable, need to use time-of-flight or diffractive scattering to determine neutron energy
- Remember Liouville's theorem:
  - Phase space density is constant for conservative force fields
- It implies that high resolution measurements are low flux and vice-versa



# Why?

- The purpose of the instruments is to probe with neutrons some aspect of a sample




- Very generically, this can be divided into elastic and inelastic categories
  - elastic: gives information on where atoms are
  - inelastic: gives information on what atoms do (ie move)
- This is measuring the cross sections:

elastic

$$\frac{d\sigma}{d\Omega}(\lambda, 2\theta, \psi)$$

- cross section / scattering probability into a solid angle, as a function of wavelength, scattering angle and aximuthal angle

inelastic

$$\frac{d^2\sigma}{d\Omega dE}(\lambda_{in}, \lambda_{sc}, 2\theta, \psi)$$

- double differential cross section / scattering probability into a solid angle, as a function of wavelength, scattered wavelength scattering angle and aximuthal angle

# Science Drivers for the Reference Instrument Suite from the Technical Design Report

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- Multi-Purpose Imaging
- General-Purpose SANS
- Broadband SANS
- Surface Scattering
- Horizontal Reflectometer
- Vertical Reflectometer
- Thermal Powder Diffractometer
- Bispectral Power Diffractometer
- Pulsed Monochromatic Powder Diffractometer
- Materials Science Diffractometer
- Extreme Conditions Instrument
- Single-Crystal Magnetism Diffractometer
- Macromolecular Diffractometer
- Cold Chopper Spectrometer
- Bispectral Chopper Spectrometer
- Thermal Chopper Spectrometer
- Cold Crystal-Analyser Spectrometer
- Vibrational Spectroscopy
- Backscattering Spectrometer
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo
- Fundamental & Particle Physics

life sciences

magnetism & superconductivity

soft condensed matter

engineering & geo-sciences

chemistry of materials

archeology & heritage conservation

energy research

fundamental & particle physics

# NSS Project scope: *15 neutron instruments + test beamline + support labs*

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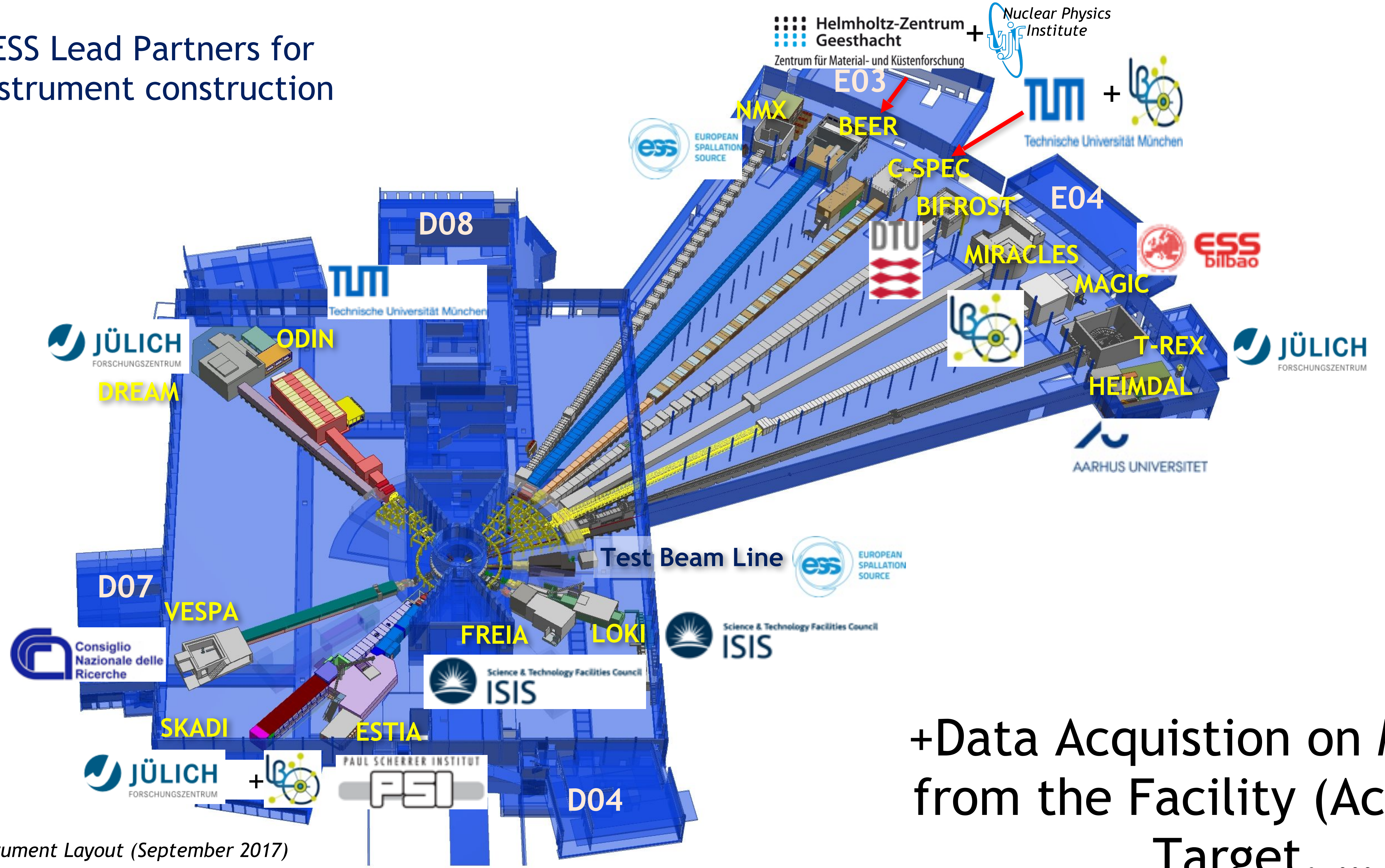
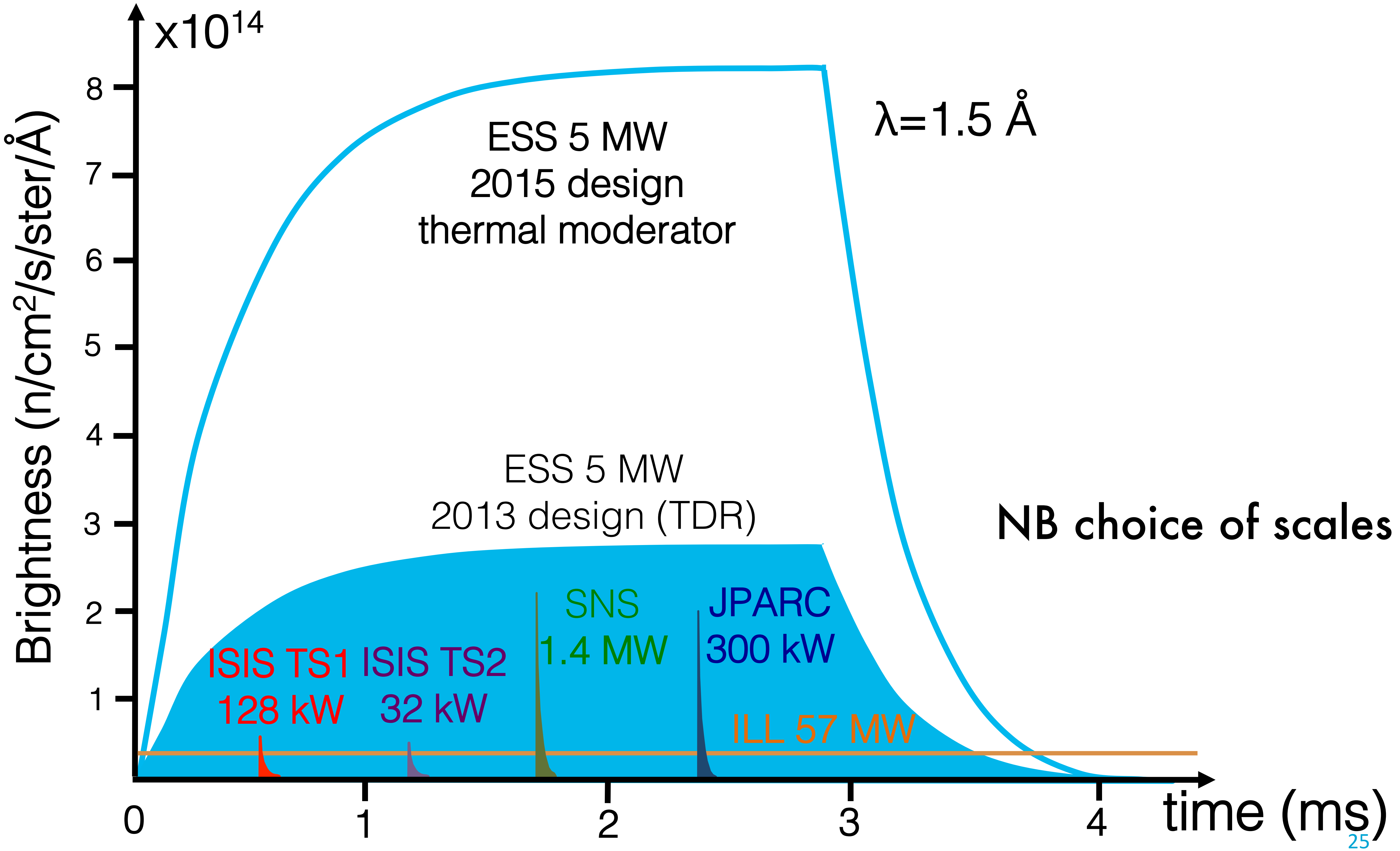
ESS Lead Partners for instrument construction




*ESS Instrument Layout (September 2017)*

+Data Acquistion on Monitoring from the Facility (Accelerator, Target, …

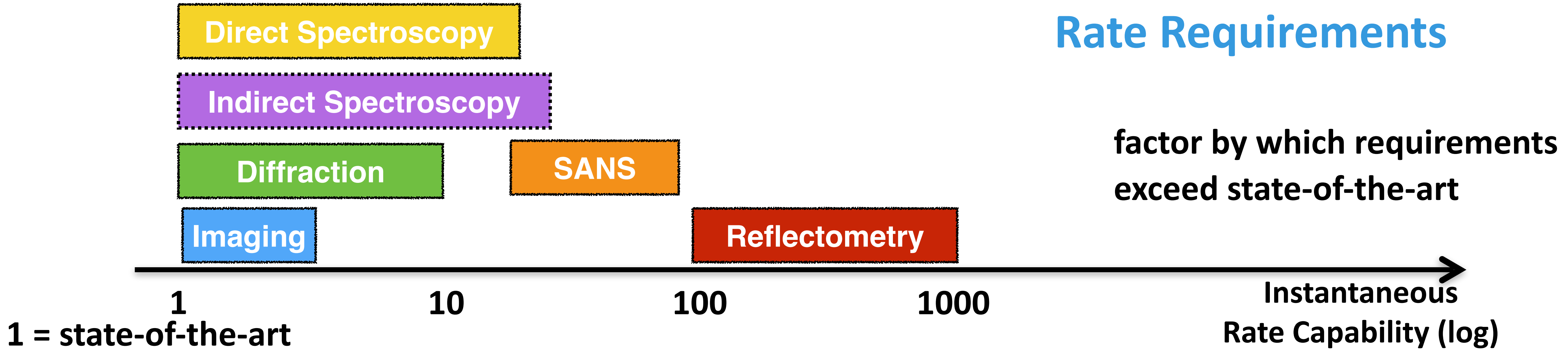
# Source BrightnESS



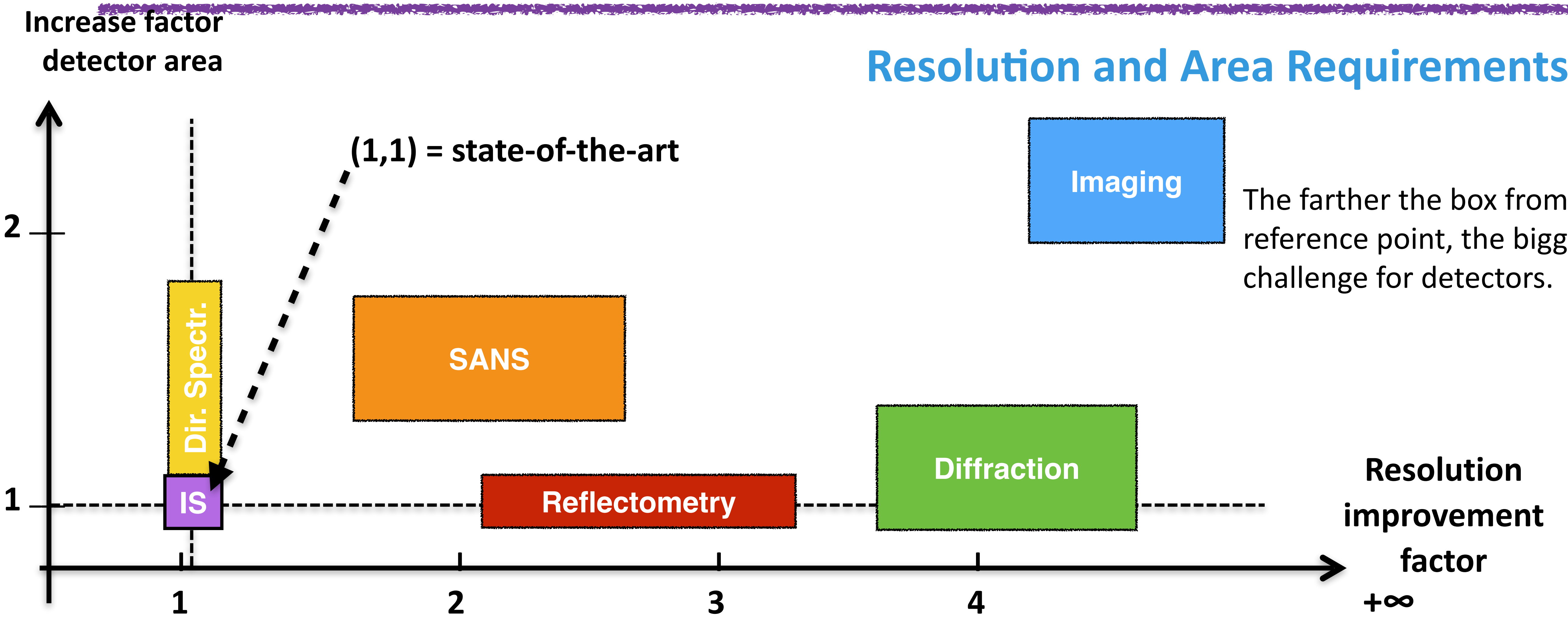
# Requirements Challenge for Detectors for ESS: *beyond detector present state-of-the art*

EUROPEAN SPALLATION SOURCE

## Rate Requirements




## Resolution and Area Requirements




The farther the box from the (1,1) reference point, the bigger the challenge for detectors.

# Typical Detector Requirements

- Size: from 0.25mˆ2 up to 30mˆ2
- Position resolution: 100um - 10mm
- Time Resolution: <1us

- Rate and DAQ requirements very much defined by the instrument and data topology
- Can be >MHz/channel instantaneous in some cases
- Average rates much lower

- Every instrument is very much a bespoke individual design …
- For a good user experience …
- … It's important to design the detector to the individual detector
- … it's important to make sure that the DAQ can cope with the, and has a homogeneous look and feel

# Instrument Control System Design

- Need a modular system to cope with diversity in design

- Use EPICS as the control system for the DAQ
- Use accelerator timing system: only 1 timing system needed for the facility
- Can access monitoring & diagnostic data across the facility data

- High rate & high number of channels = high data volume
- Use a dedicated data interface

- Unify the data where you actually want to utilise it

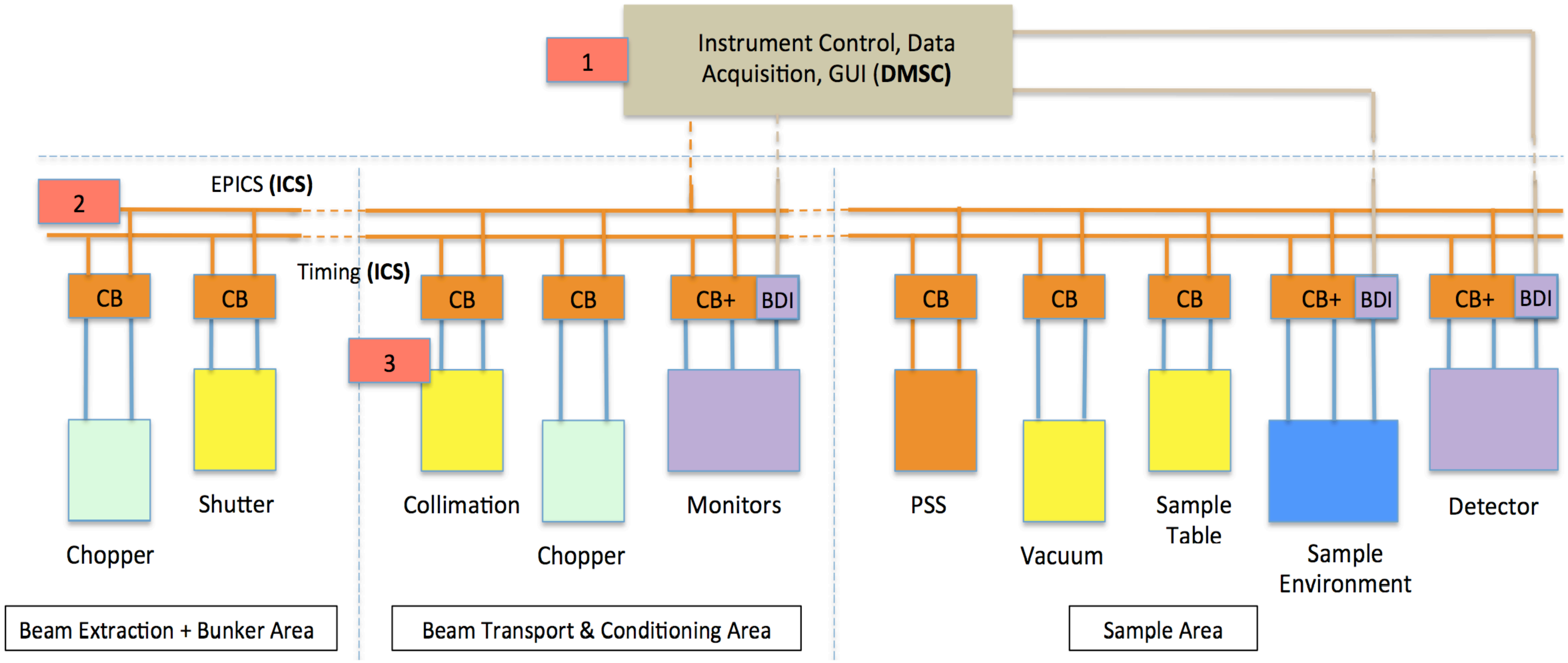
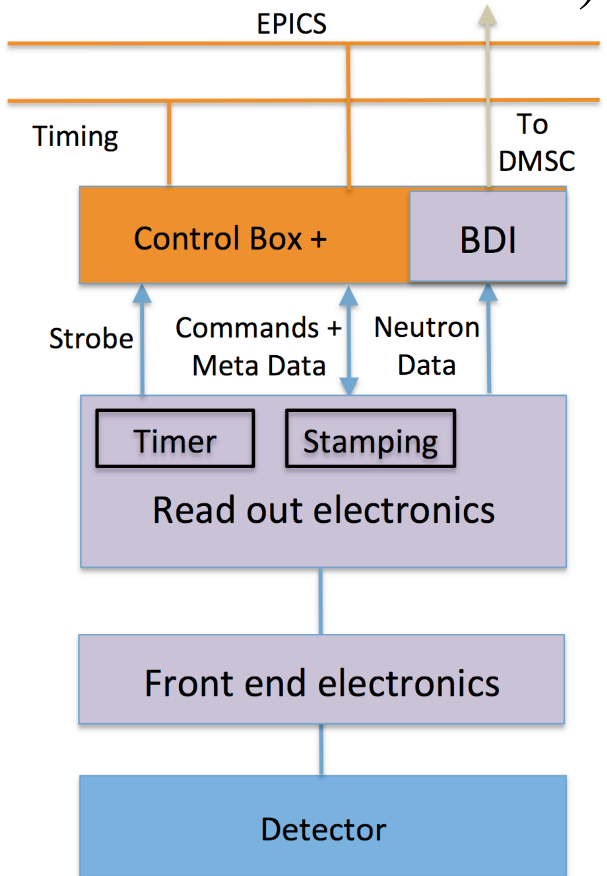



**Figure 3.** Topology of the modular instrument control concept for a 160m long Neutron Scattering Instrument at ESS. (CB = Control Box, BDI = Bulk Data Interface).




- Where possible use network equipment & standard PCs: lower the expert knowledge needed
- Use FPGAs only where performance needed ...

# Collaborations


Everyone should play to their strengths

# ESS Partners on Detectors

EUROPEAN SPALLATION SOURCE

ILL

CERN

SNS SPALLATION NEUTRON SOURCE

LiU LINKÖPING UNIVERSITY

ESS bilbao

LUNDS UNIVERSITET

UNIVERSITAS BERGENSIS

Science & Technology Facilities Council

Science & Technology Facilities Council ISIS

BNC Budapest Neutron Centre

Wigner

Consiglio Nazionale Ricerche

IFP

UNIVERSITÀ DEGLI STUDI DI MILANO BICOCCA

INFN Istituto Nazionale di Fisica Nucleare

JCNS Jülich Centre for Neutron Science

DENEX Detektoren für Neutronen GmbH
Stöteroggestraße 71 | 21339 Lüneburg
Tel.: +49 (0) 4131/248932

IEAP

CDT GmbH CASCADE Detector Technologies

UJF

FZÚ

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

Risø DTU
National Laboratory for Sustainable Energy

ideas

COSYLAB

IFE Institute for Energy Technology

JÜLICH FORSCHUNGSZENTRUM

Mittuniversitetet MID SWEDEN UNIVERSITY

icnd.org { ILL ESS FRM II Forschungs-Neutronenquelle Heinz Maier-Leibnitz HZB Helmholtz Zentrum Berlin ISIS J-PARC JCNS NEUTRON SCIENCES }

INTERNATIONAL COLLABORATION FOR THE DEVELOPMENT OF NEUTRON DETECTORS

# Detectors for ESS Instruments

| Instrument | Neutron Converter | Detector Type | Gas Gain | Number of Channels | Front-End Type/ASIC |
|---|---|---|---|---|---|
| CSPEC | 10B4C | MWPC | ca. 10 | ca.20k | VMM3A |
| TREX | 10B4C | MWPC | ca. 10 | ca. 15k | VMM3A |
| ESTIA | 10B4C | MWPC | ca. 10 | ca. 6k | VMM3A |
| FREIA | 10B4C | MWPC | ca. 10 | ca. 4k | VMM3A |
| NMX | Gd | GEM | ca. 1000 | ca. 15k | VMM3A |
| DREAM | 10B4C | MWPC | <100 | 400k | CDT/CIPIX |
| MAGIC | 10B4C | MWPC | <100 | 165k | CDT/CIPIX |
| HEIMDAL | 10B4C | MWPC | <100 | 250k | CDT/CIPIX |
| LOKI | 10B4C | Straws | >1000 | 5k | Discrete Preamp/ CAEN R5560 |
| BIFROST | 3He | Tube | >1000 | ca. 100 | Discrete Preamp/ CAEN R5560 |
| VESPA | 3He | Tube | >1000 | ca. 100 | Discrete Preamp/ CAEN R5560 |
| MIRACLES | 3He | Tube | >1000 | ca. 100 | Discrete Preamp/ CAEN R5560 |
| SKADI | 6Li | Scintillator | N/A | 25000 | IDEAS/IDE3465 |
| ODIN | 6Li | Various | N/A | ca. 1M | TIMEPIX4 |
| BEER | 10B4C | MWPC | >100 | 40 | Delay Line + Custom FPGA |
| Beam Monitors | Various | MWPC/GEM/IC | 1-100 | 50 | Discrete Preamp / ADC OHWR FMC-ADC-100m14b4Cha |
| TestBeam Line | 10B4C | MWPC | ca. 10 | ca. 1k | VMM3A |

- Step change # channels cf. current instruments
- From 100's to 10k's

- Need for using ASICs to handle large channel count at moderate cost
- Different detector partners means a variety of choices for front-end

- Key requirement for DAQ system is to be able to integrate a multiplicity of detector types and approaches
- Unify the "look and feel" within the electronics DAQ

# Detectors for ESS Instruments

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| TestBeam Line | 10B4C | MWPC | ca. 10 | ca. 1k | VMM3A |

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Have managed to settle on 3 main front ends for 13/16 instruments:

- CAEN R5560 for detectors using charge division (He-3 PSDs and Boron Straws). 4 instruments.
- CIPIX for diffraction detectors using CDT Jalousie detectors. 3 instruments.
- VMM3A for Boron wire detectors (MultiGrid, MultiBlade and GEM detectors). 6 instruments.

# Detector Electronics Integration Models

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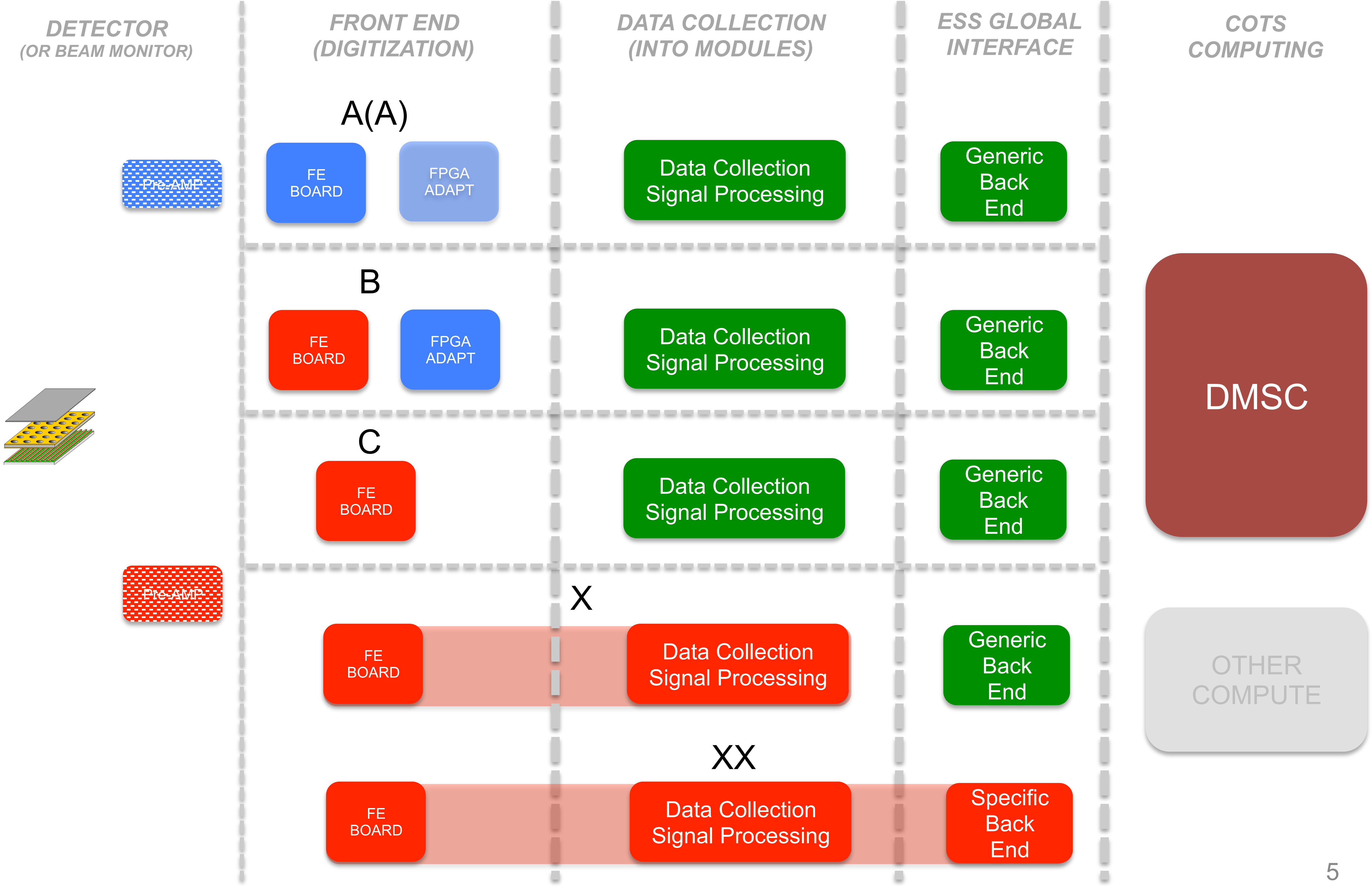


# Data

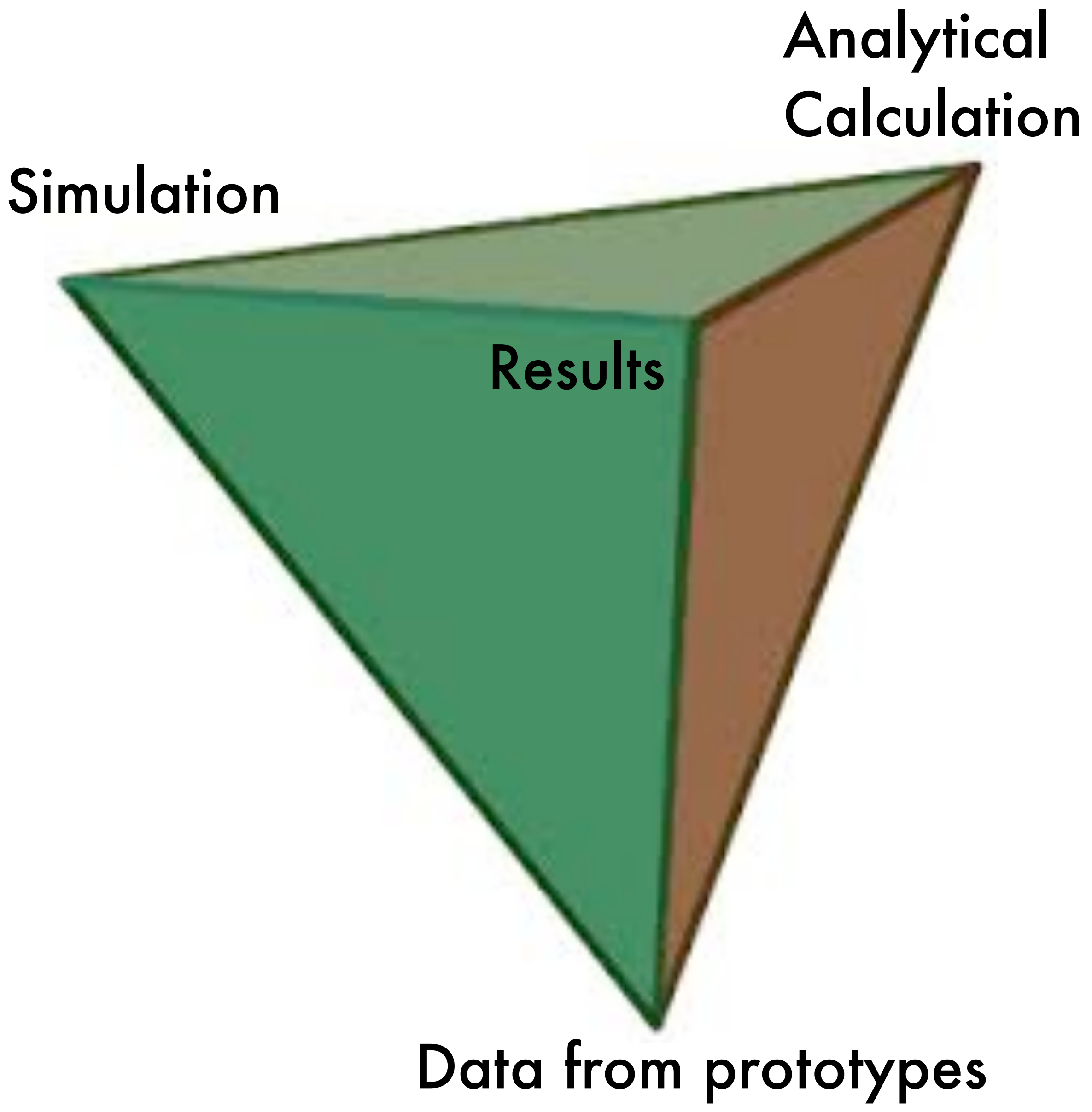
# Data: Calculation, Simulation, Prototype Data

- As you have heard, simulation is a very powerful tool
- … but the computer will always lie to you …

- Data from prototype tests is golden
- Lack of ability to trigger independently on the neutron means some degree of arbitrariness in defining the measurement
- Checking that your measured data is correct is complicated

- Additionally, always try and calculate analytically or "back of envelope" what your expectation is
- (Or at least upper and lower limits)

- Use all 3 of these **together** to understand the performance of your prototypes
- Expect "features" and non-agreement and investigate them
- Iterative



# Definitions and Standards

# Detector Rate and Data Rate

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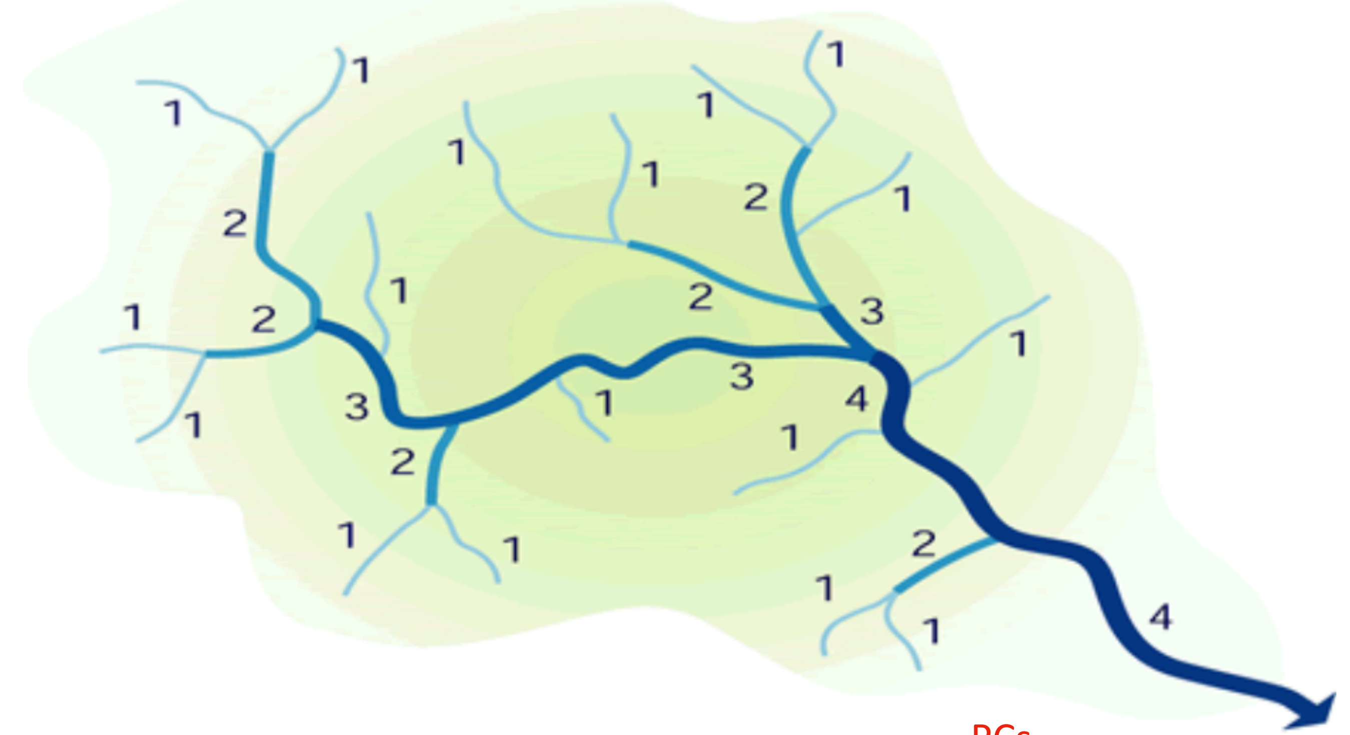
Important to define what is meant by rate when it is quoted:

- **Global time-averaged incident/detection rate**: the total number of neutrons per second entering/recorded by the entire detector
- **Local time-averaged incident/detection rate**: the total number of neutrons per second entering/recorded in a detector pixel, channel or unit
- **Global peak incident/detection rate**: the highest instantaneous neutron incident/detection rate on the whole detector
- **Local peak incident/detection rate**: the highest instantaneous neutron incident/detection rate on the brightest detector pixel, channel or unit

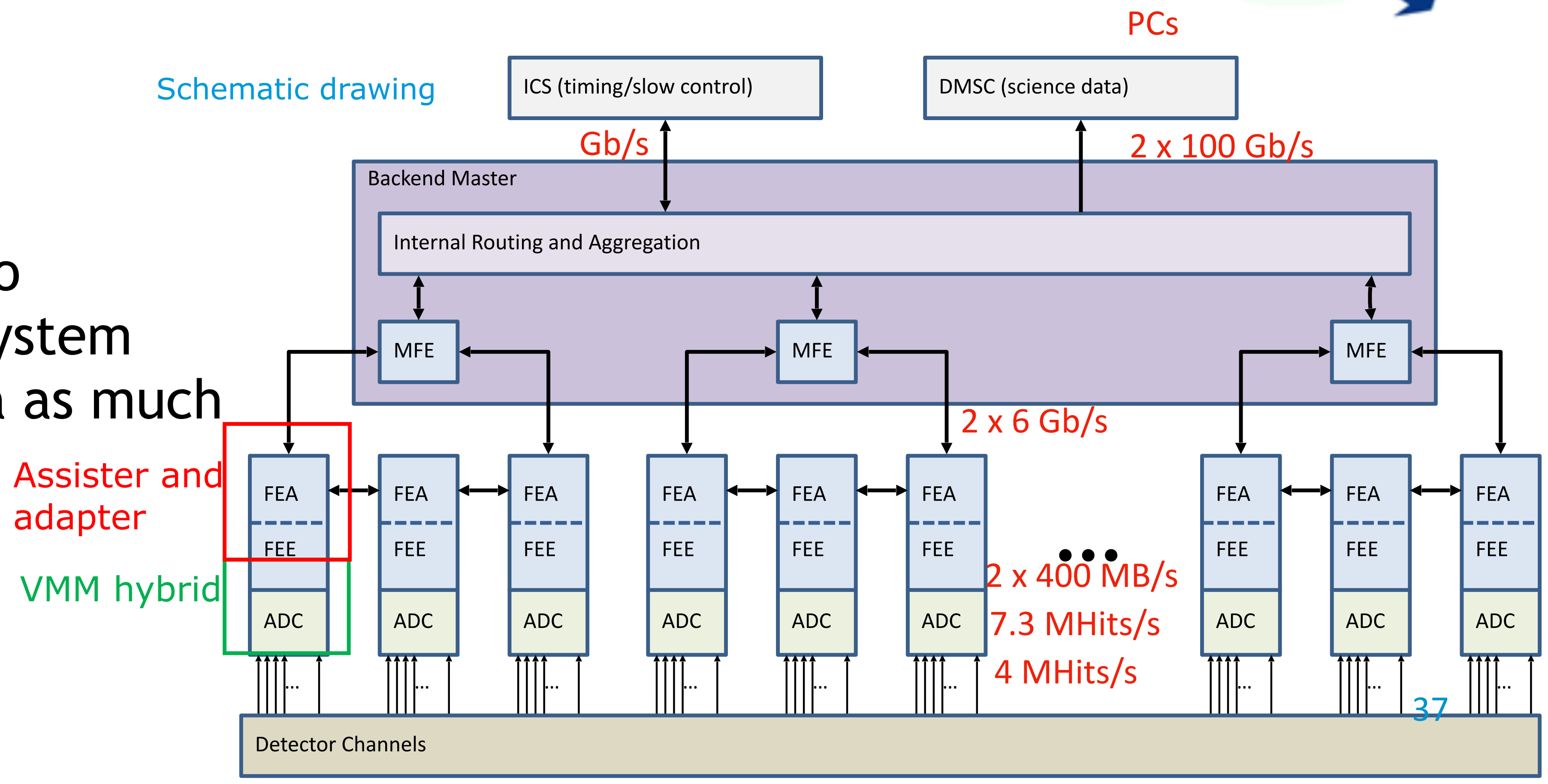
*I. Stefanescu et al., JINST12 (2016) P01019

River Network



- Any DAQ system is vulnerable to “flooding" at any point in the system
- Important to with realistic data as much as possible
- Pattern & quantity

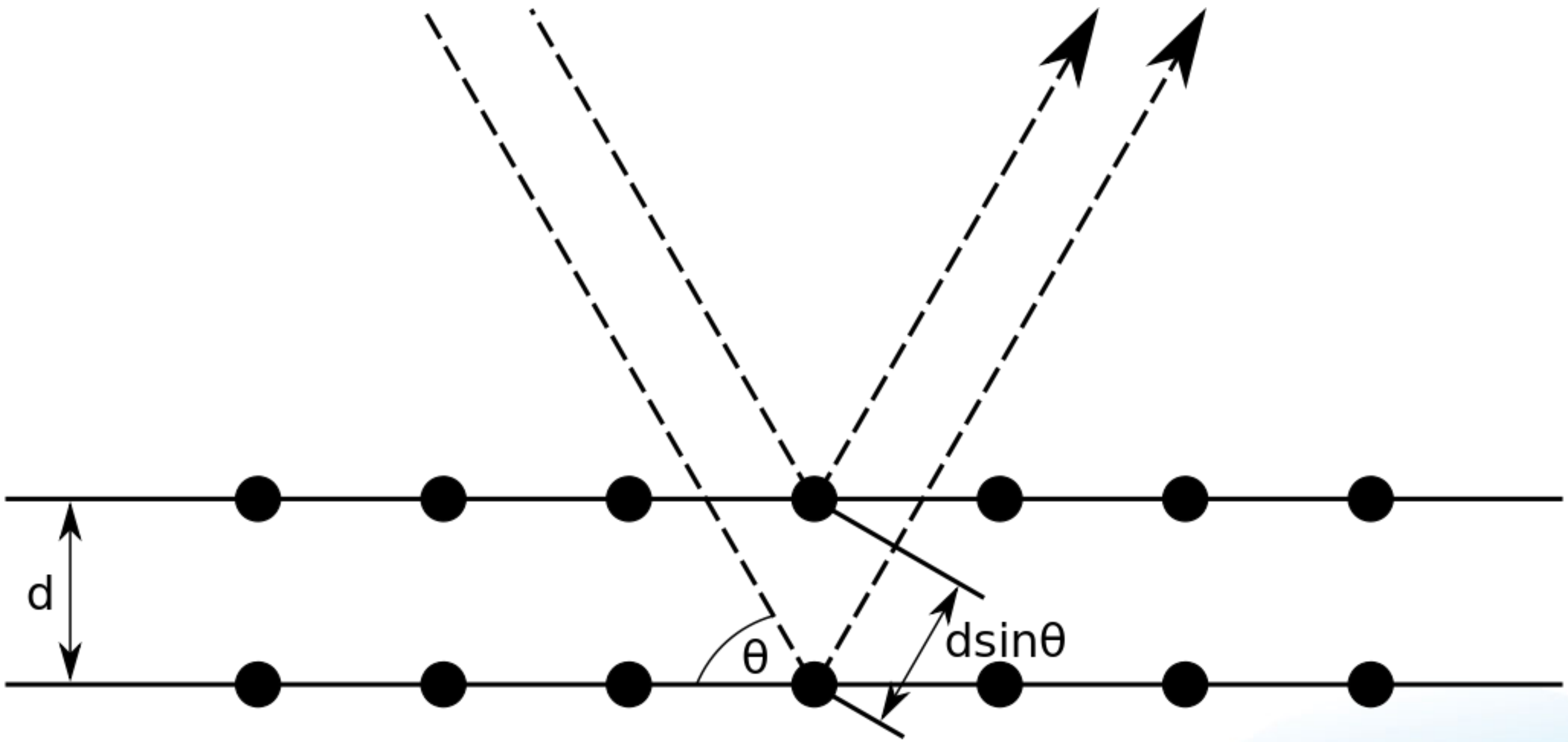
Schematic drawing




Readout Architecture is described in BrightnESS Deliverable D4.1:
https://dx.doi.org/10.17199/BRIGHTNESS.D4.1

# Diffraction

Sizes probed = "atomic structures" = 0.1 nm - 10 nm

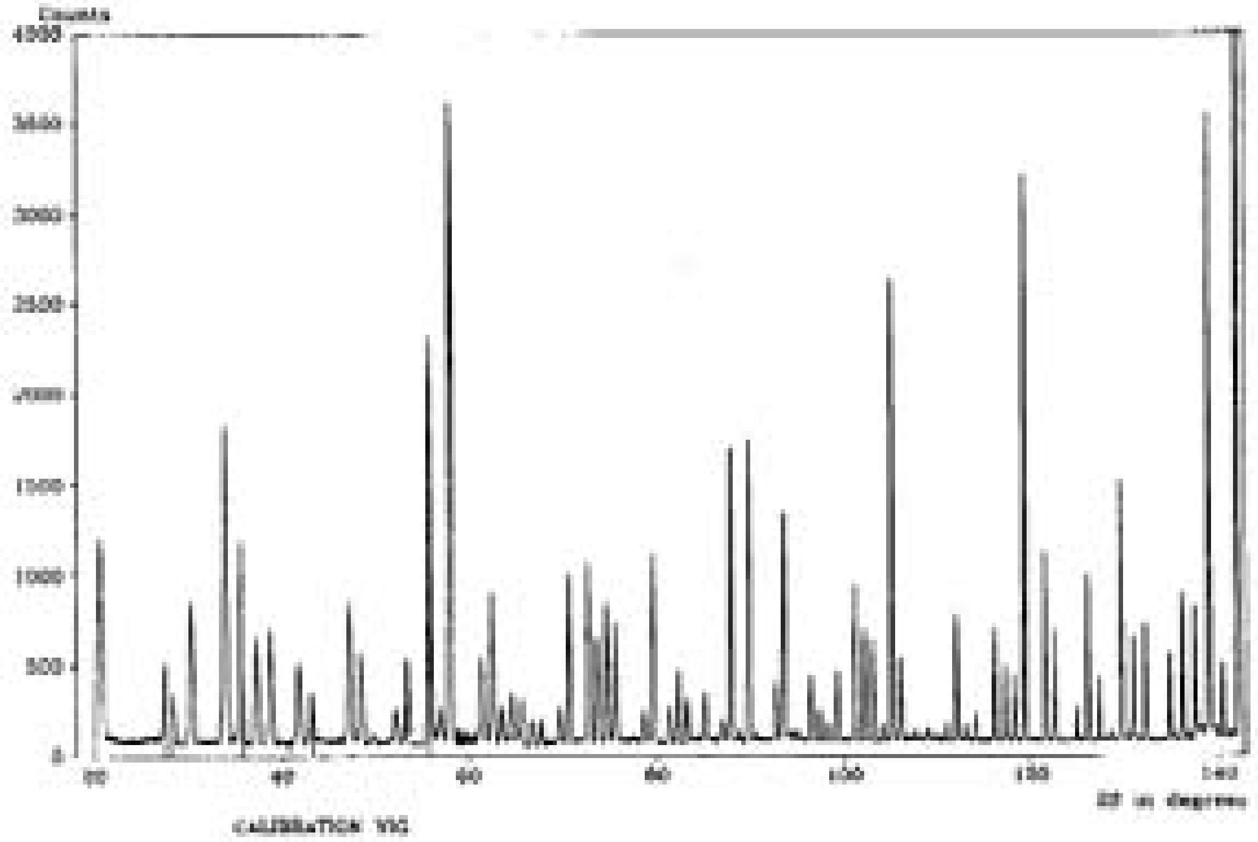



Position and intensity of diffraction peaks gives atomic positions

# Detectors are tools

Basically, in some form,
you want to measure
Bragg's equation

$$n\lambda = 2d \sin\theta$$



Define the neutron wavelength with your instrument design

Detectors allow you to measure theta

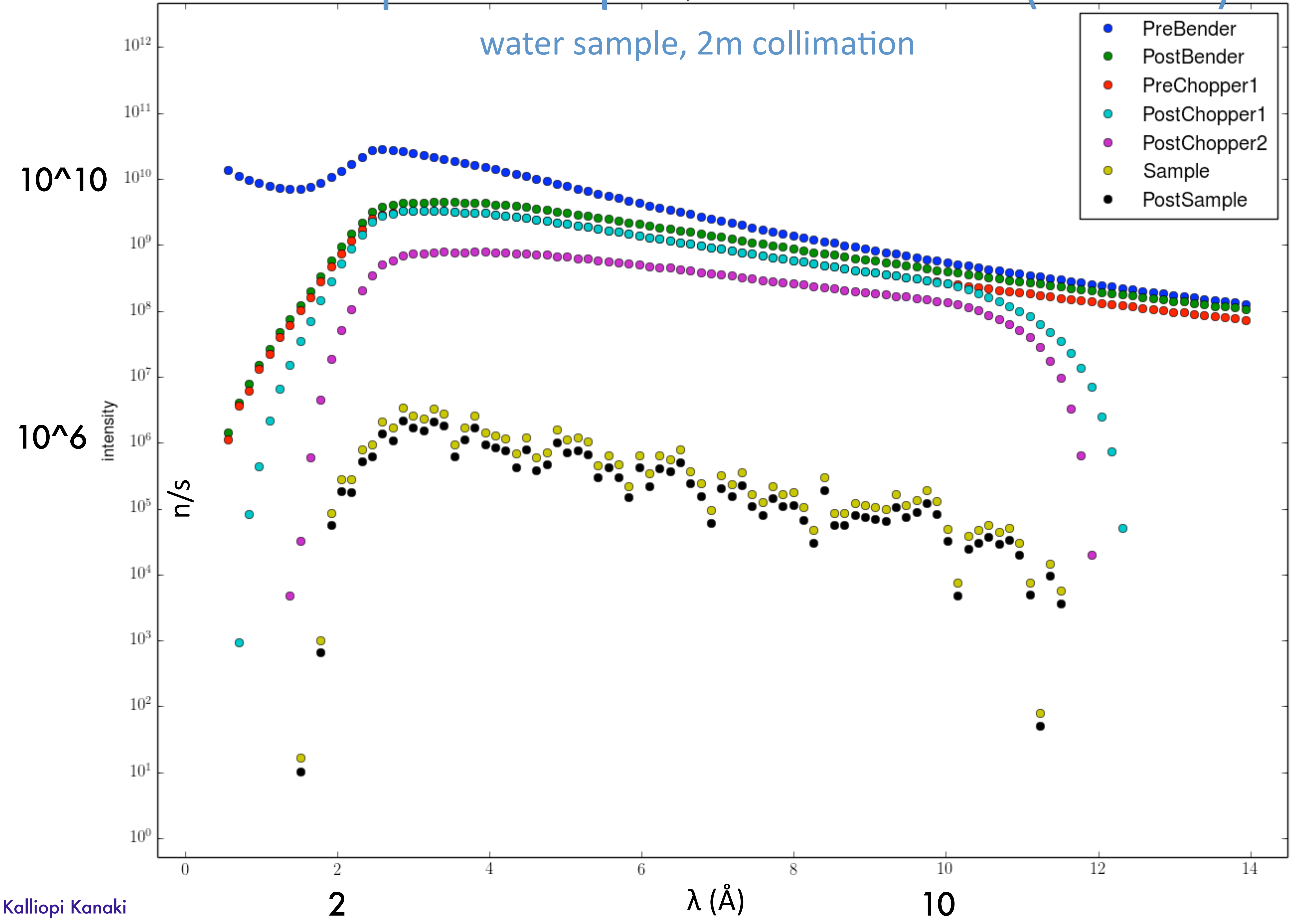
It means that you can calculate "d"

Therefore the detector should be designed to give you the most appropriate measurement of scattering angle for a instrument class

"horses for courses "

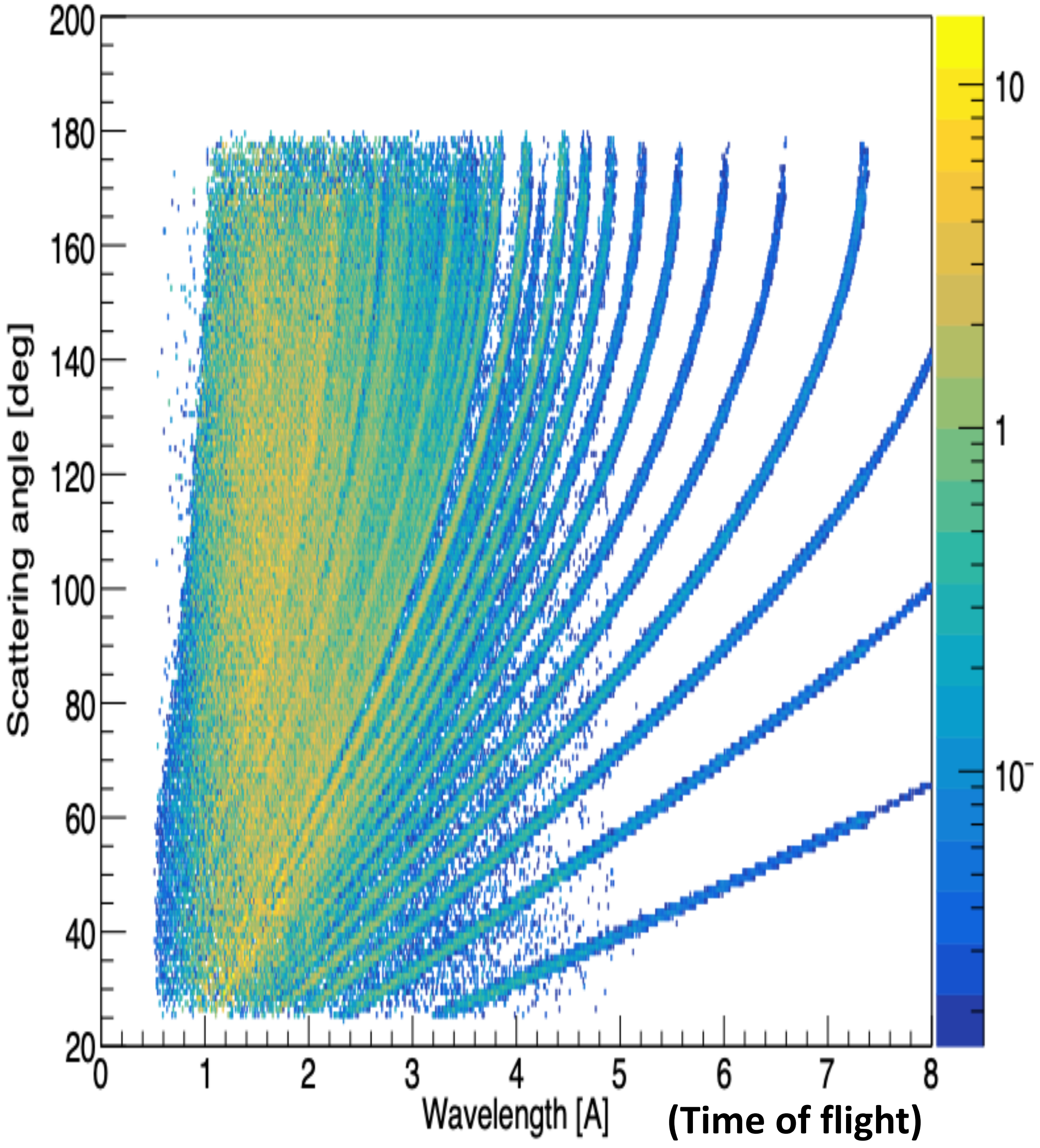
# Selecting phase space ...

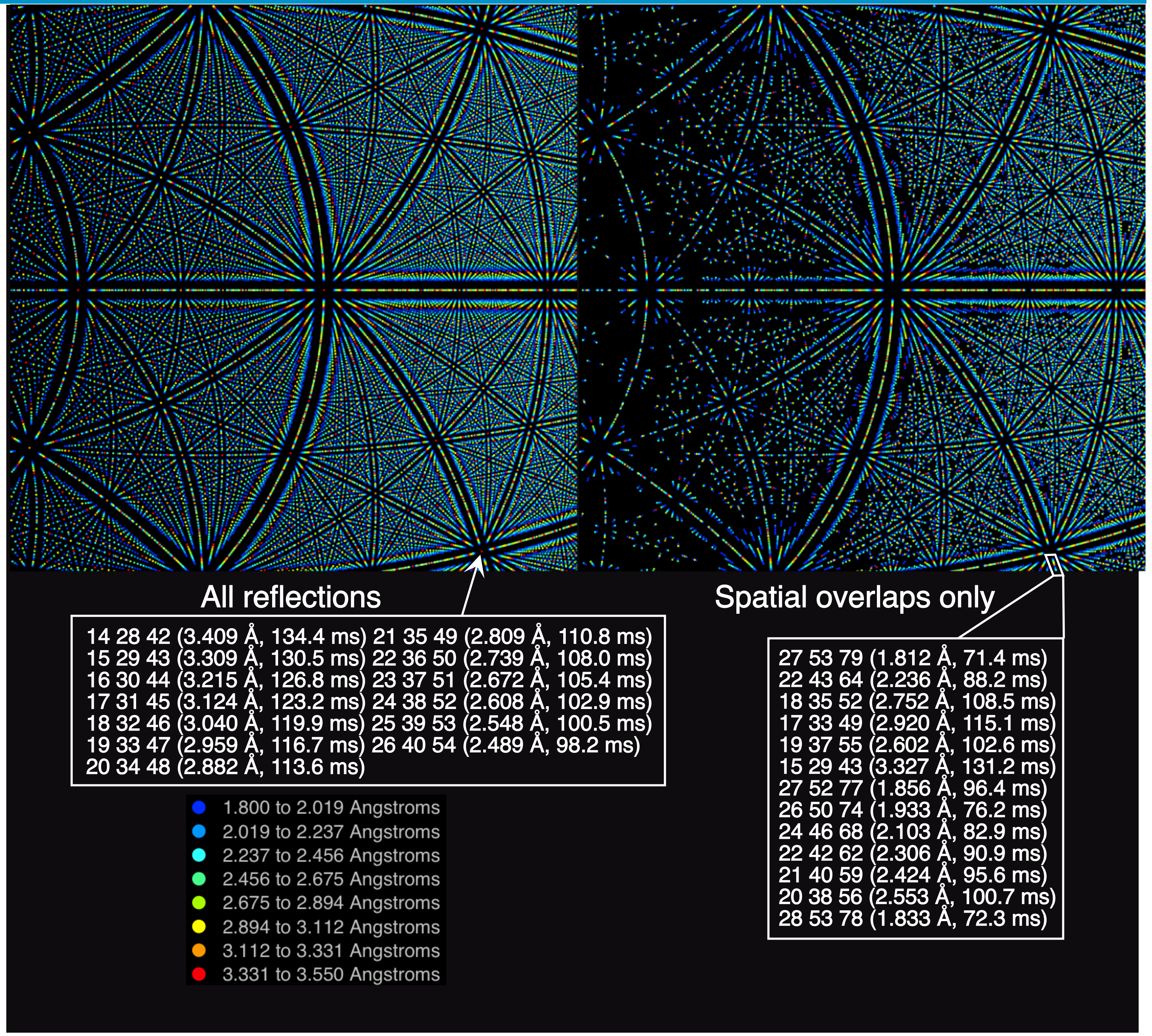
## Pre- and post sample λ distribution (McStas)



# What does data look like?

## Neutron Diffraction



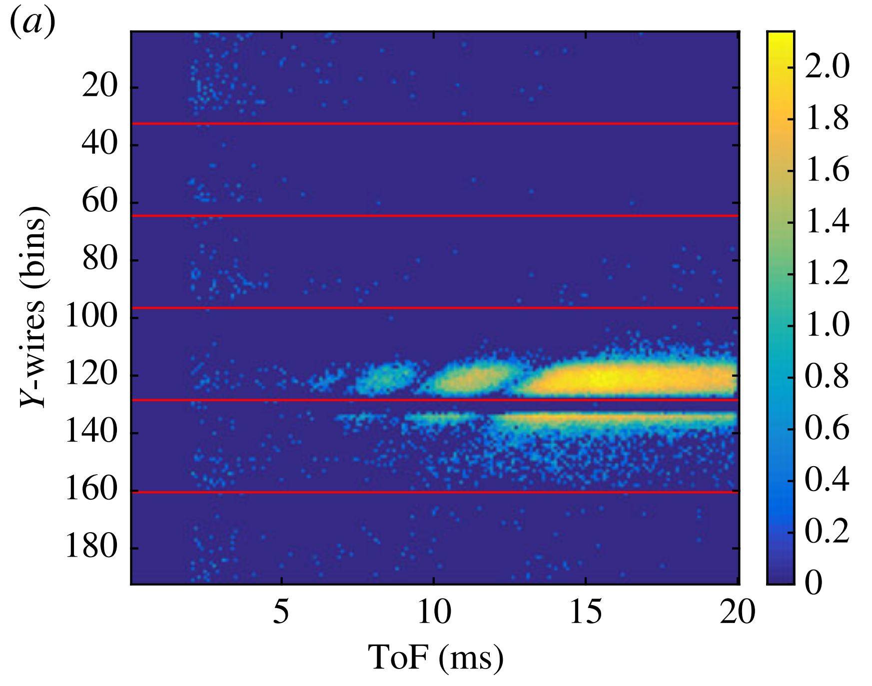

**Powder Diffraction** **Protein Diffraction**

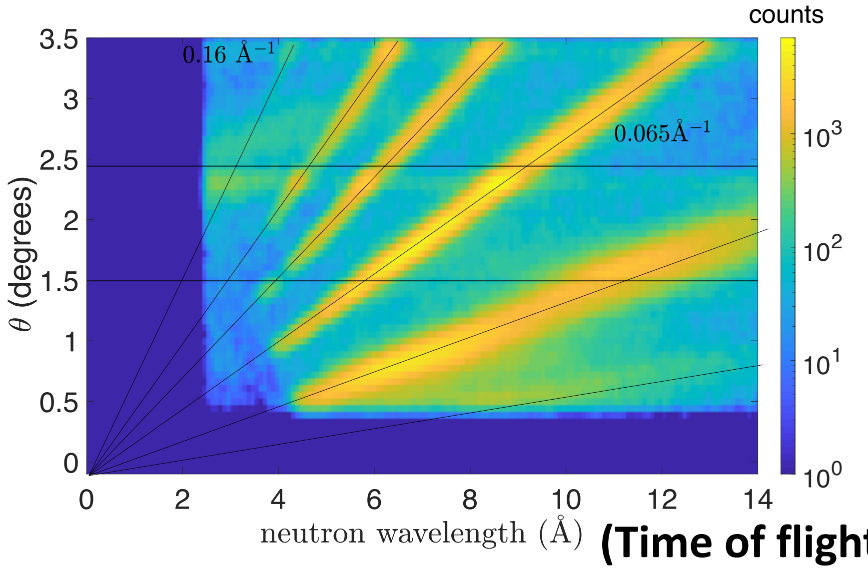


**Data is sparse and peaky**

# What does data look like?

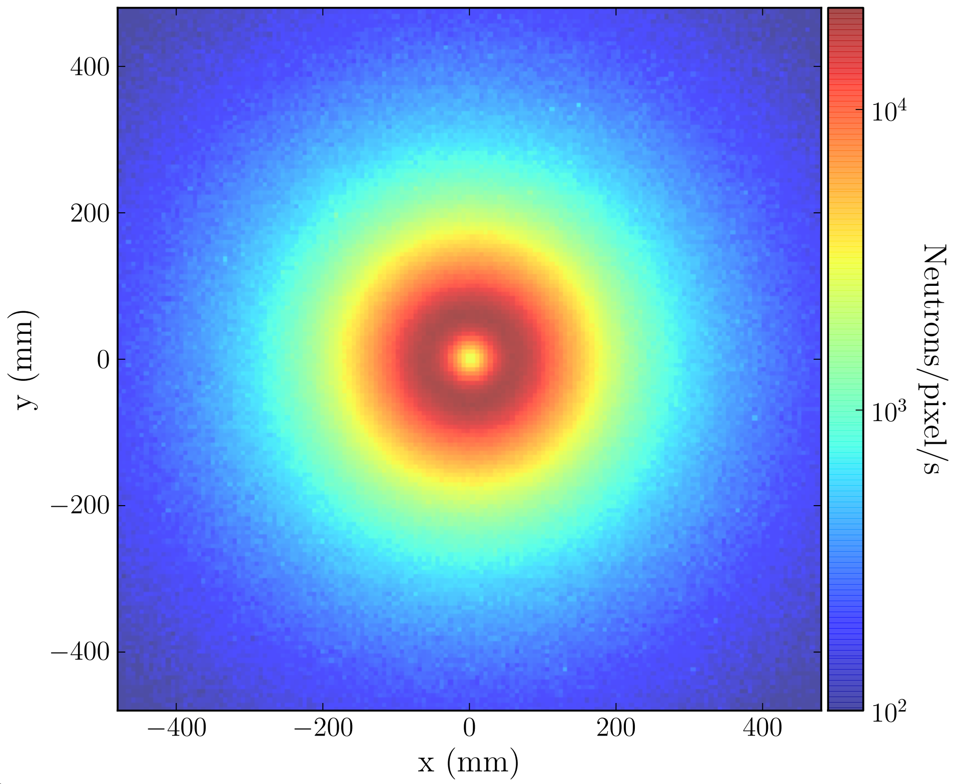
## Reflectometry, Small Angle Scattering, Spectroscopy



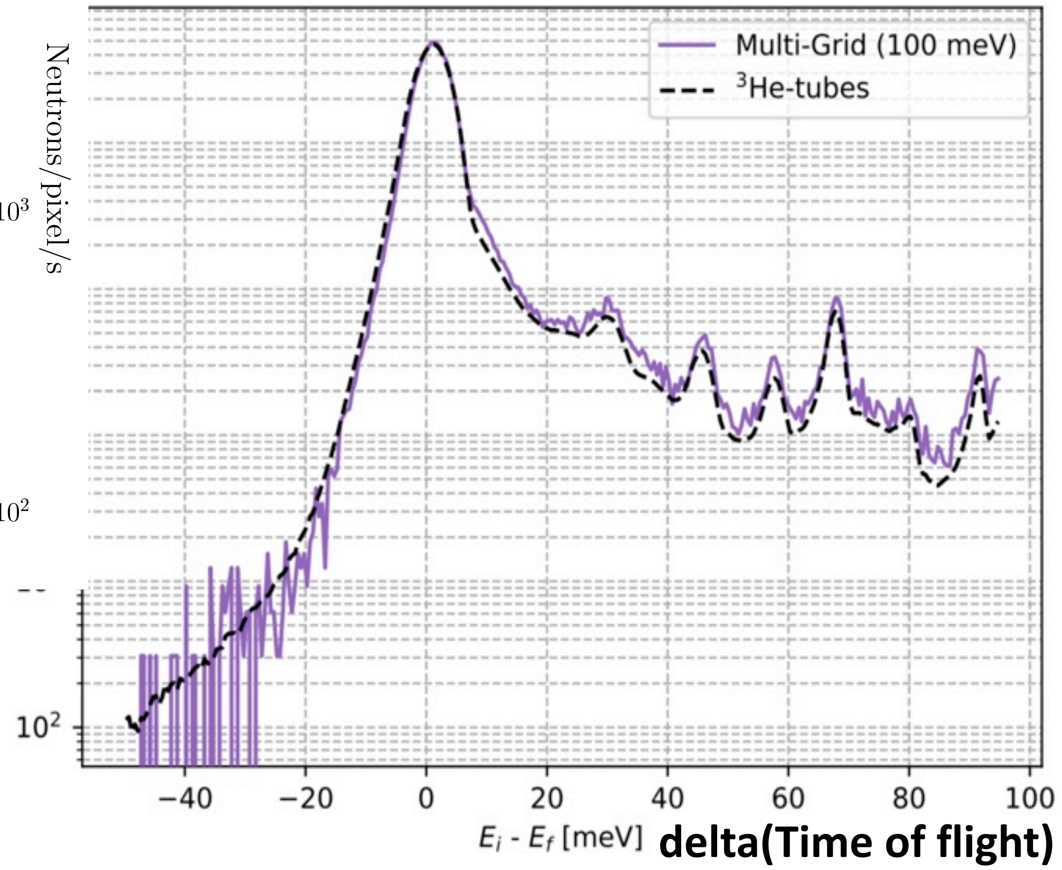




(Time of flight)

**Reflectometry**




**Small Angle Neutron Scattering**




**Spectroscopy**

**Different types of instruments have very different data characteristics**

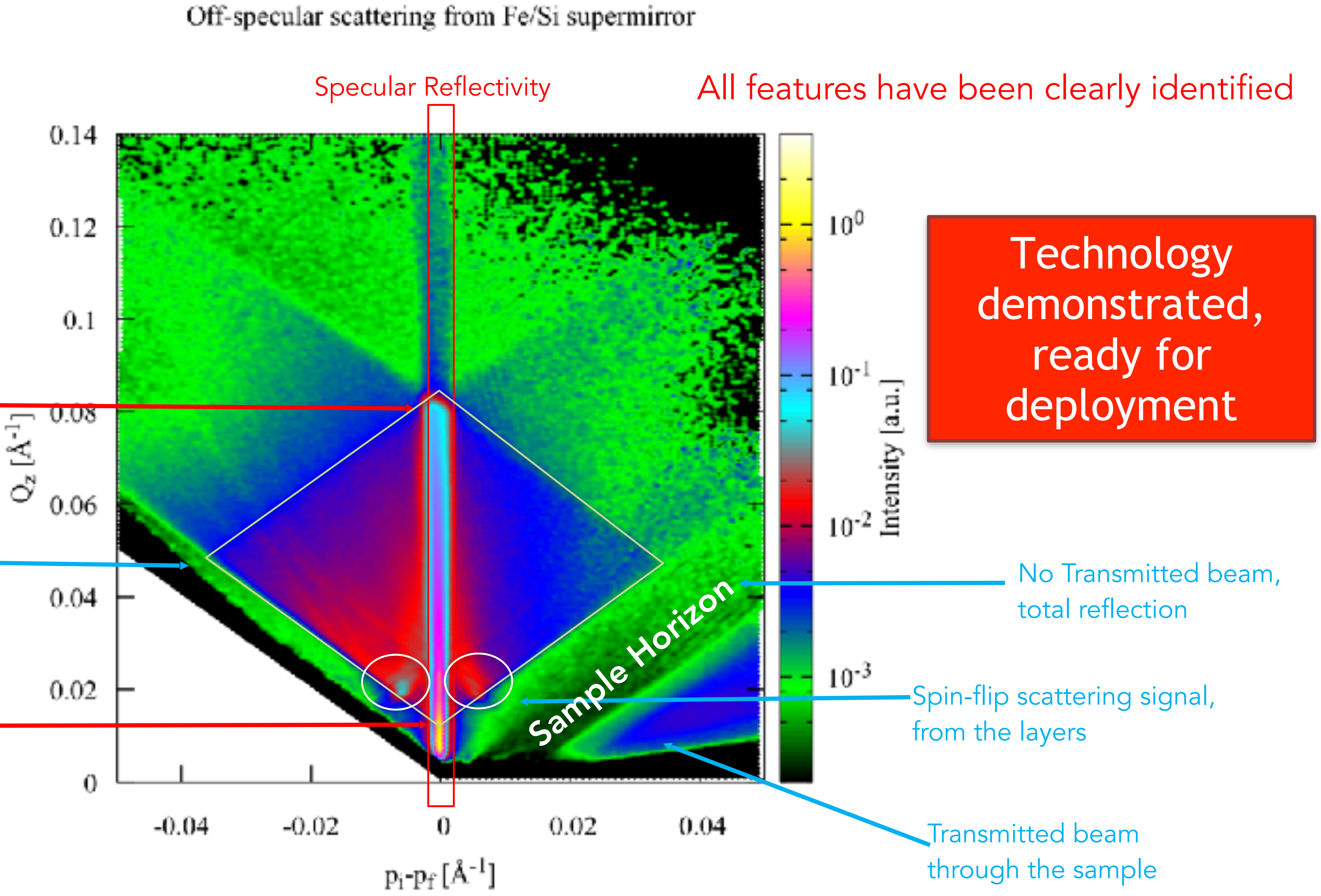
# Scientific Results from CRISP: Scattering from Fe/Si Supermirror

EUROPEAN SPALLATION SOURCE

<u>Results</u>

F. Piscitelli et al, Journal of Instrumentation13 P05009 (2018) arXiv:1803.09589

G. Mauri et al., Proc. Royal Society A474 (2018) 20180266 arXiv 1804.03962




All features have been clearly identified

**Technology demonstrated, ready for deployment**

BrightnESS is funded by the European Union's Horizon 2020 research and innovation programme under grant agreement No. 676548

brightness

# Detector Data Acquisition System

# Data Acquisition Chain for ESS Instruments

Most detectors for instruments are provided by in-kind partners

The integration of the DAQ for the instruments is done at the backend readout electronics

- Upstream the DAQ looks different for different instruments.
- In general ESS instruments have a very high number of channels
- However there was a desire to reduce the number of integrations: 3 main types.

- Downstream, there is a compute layer (the EFU: event formation unit) to form the events
- Aim is to do whatever can be done in standard PCs is done (i.e. reduce development effort in the electronics).

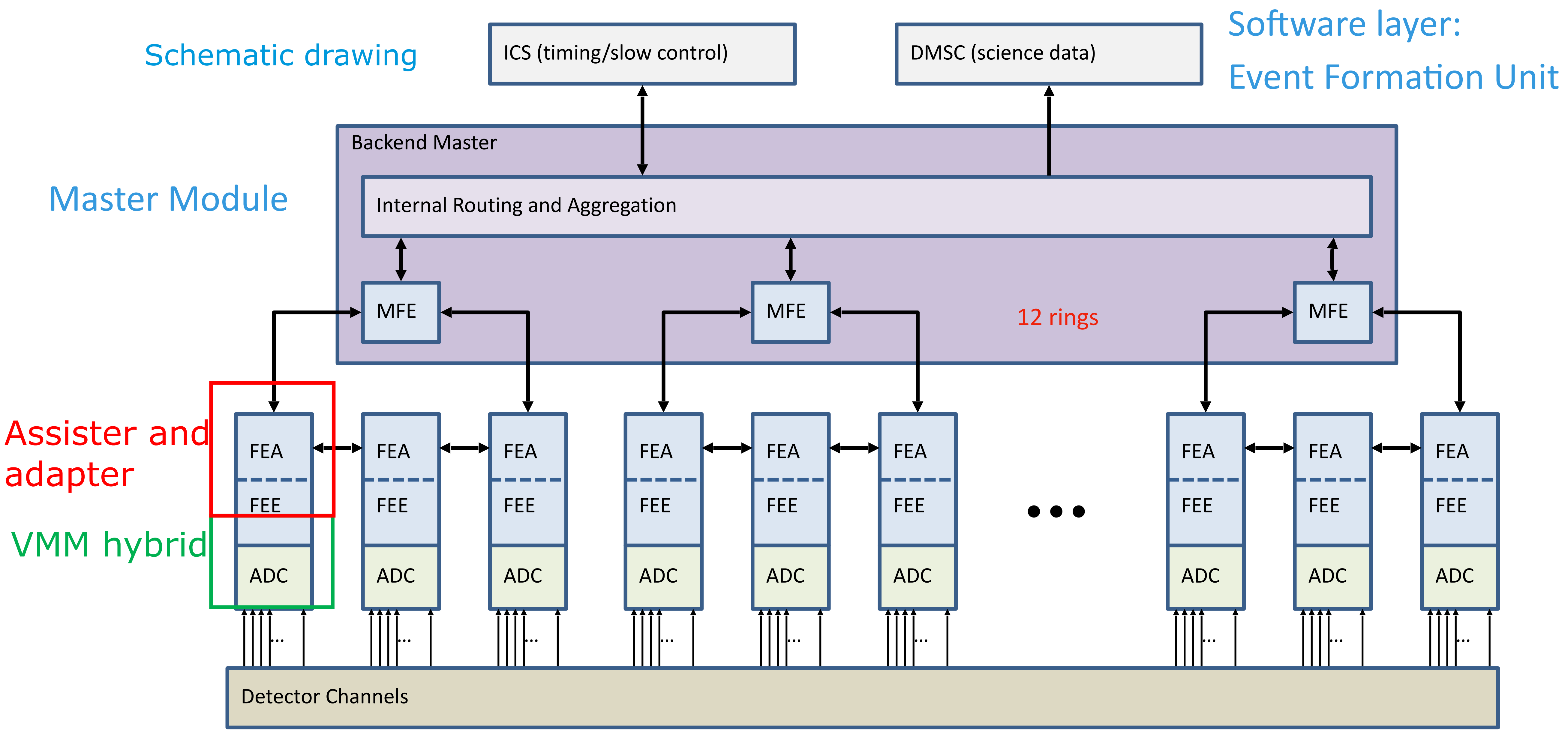
- Integration includes facility time (ICS timing) and slow control (EPICS)

Maintenance:

- Integration needs to be as simple as possible to reduce level of effort needed.

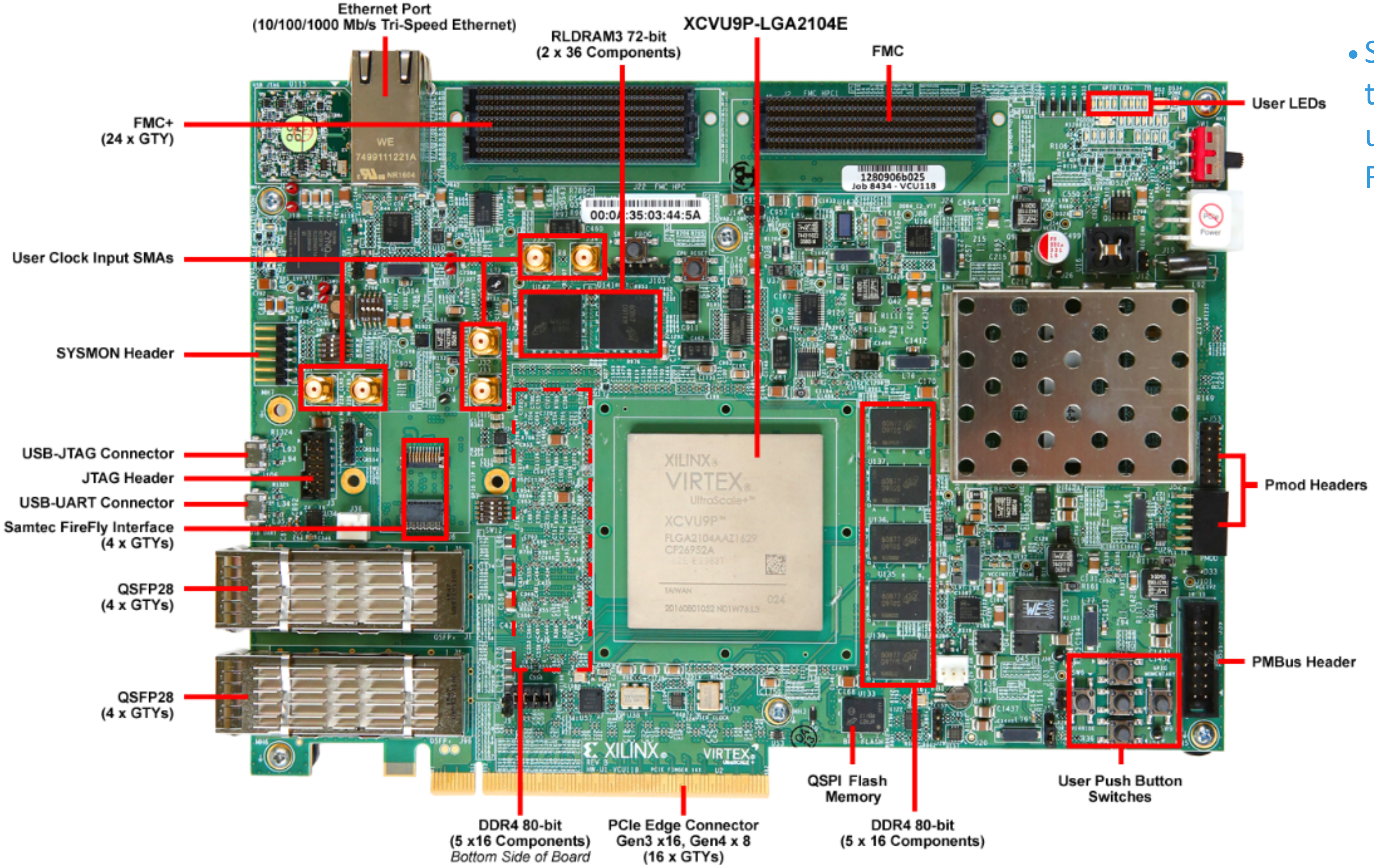
# Detector Electronics

- Standardised Instrument Data Acquisition at the Electronics Backend: All instruments will use the "Master Module" using a commercial FPGA dev board (VCU118)
- Front-ends handled using 12 data rings of “assistor" boards
- Facility ("accelerator”) timing distributed to the front-end via the rings



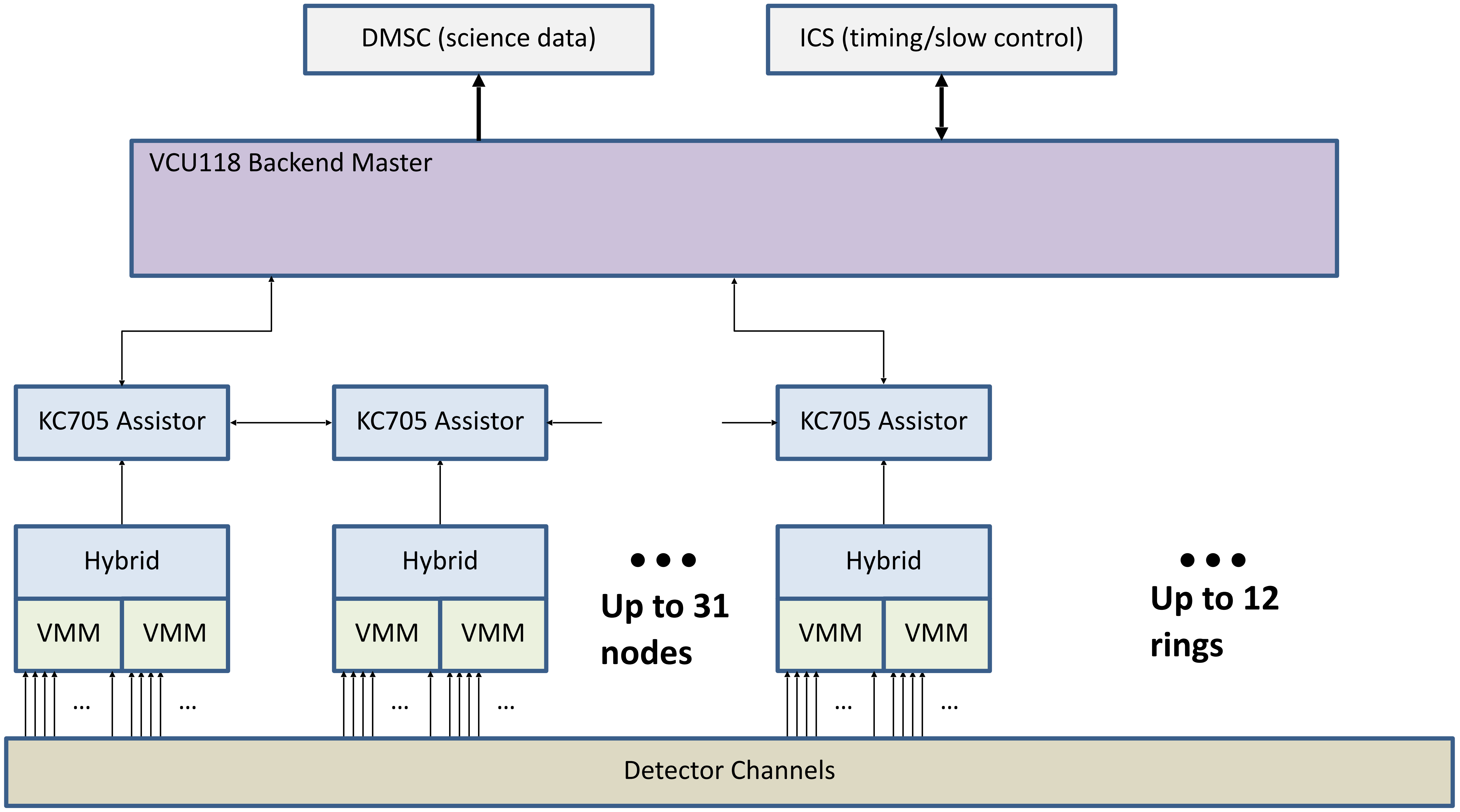

Readout Architecture is described in BrightnESS Deliverable D4.1:
https://dx.doi.org/10.17199/BRIGHTNESS.D4.1

# Master Module

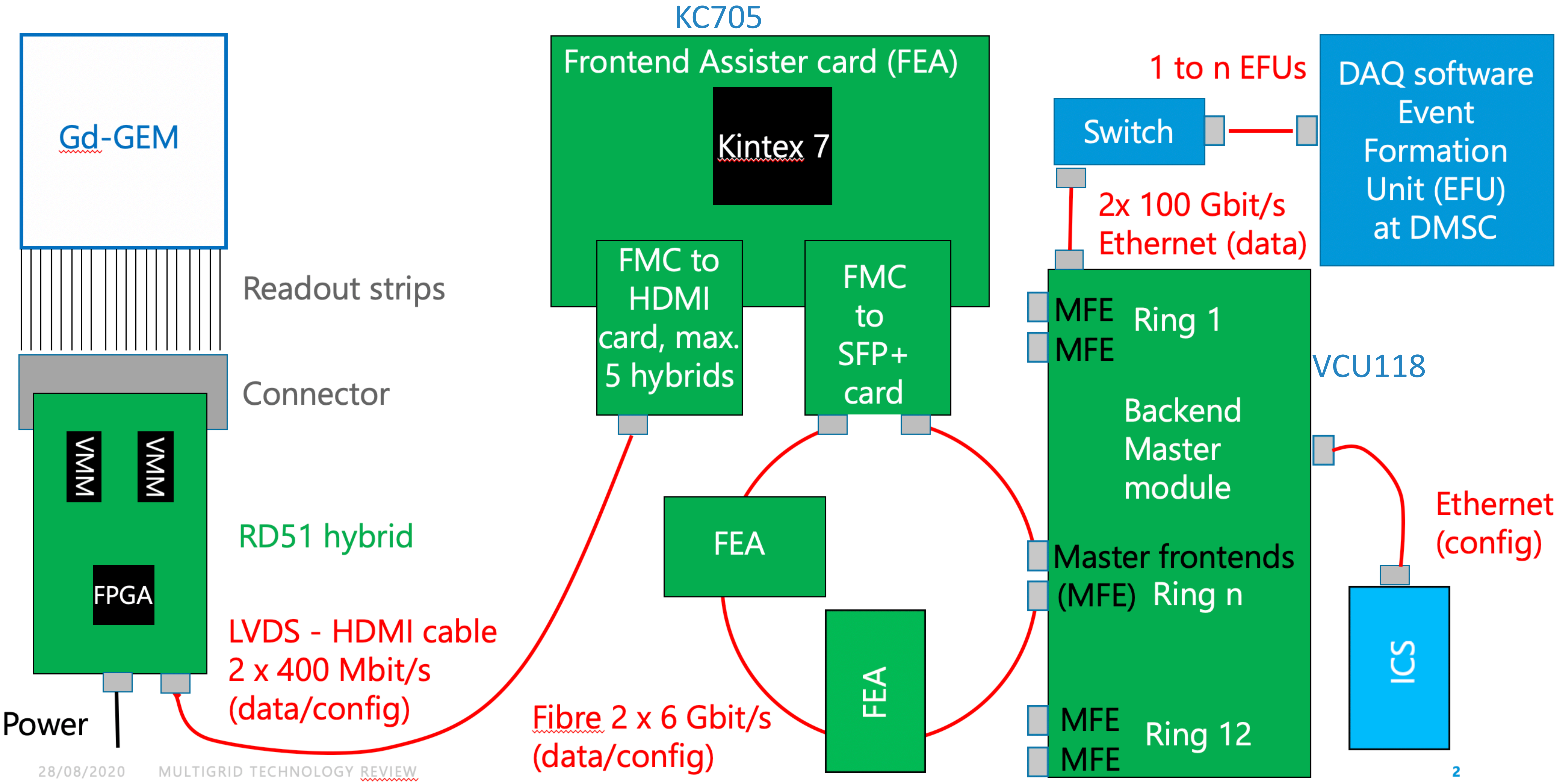



- Standardised Instrument Data Acquisition at the Electronics Backend: All instruments will use the "Master Module" using a commercial FPGA dev board (Xilinx VCU118)

# ESS Readout Architecture (VMM Implementation)



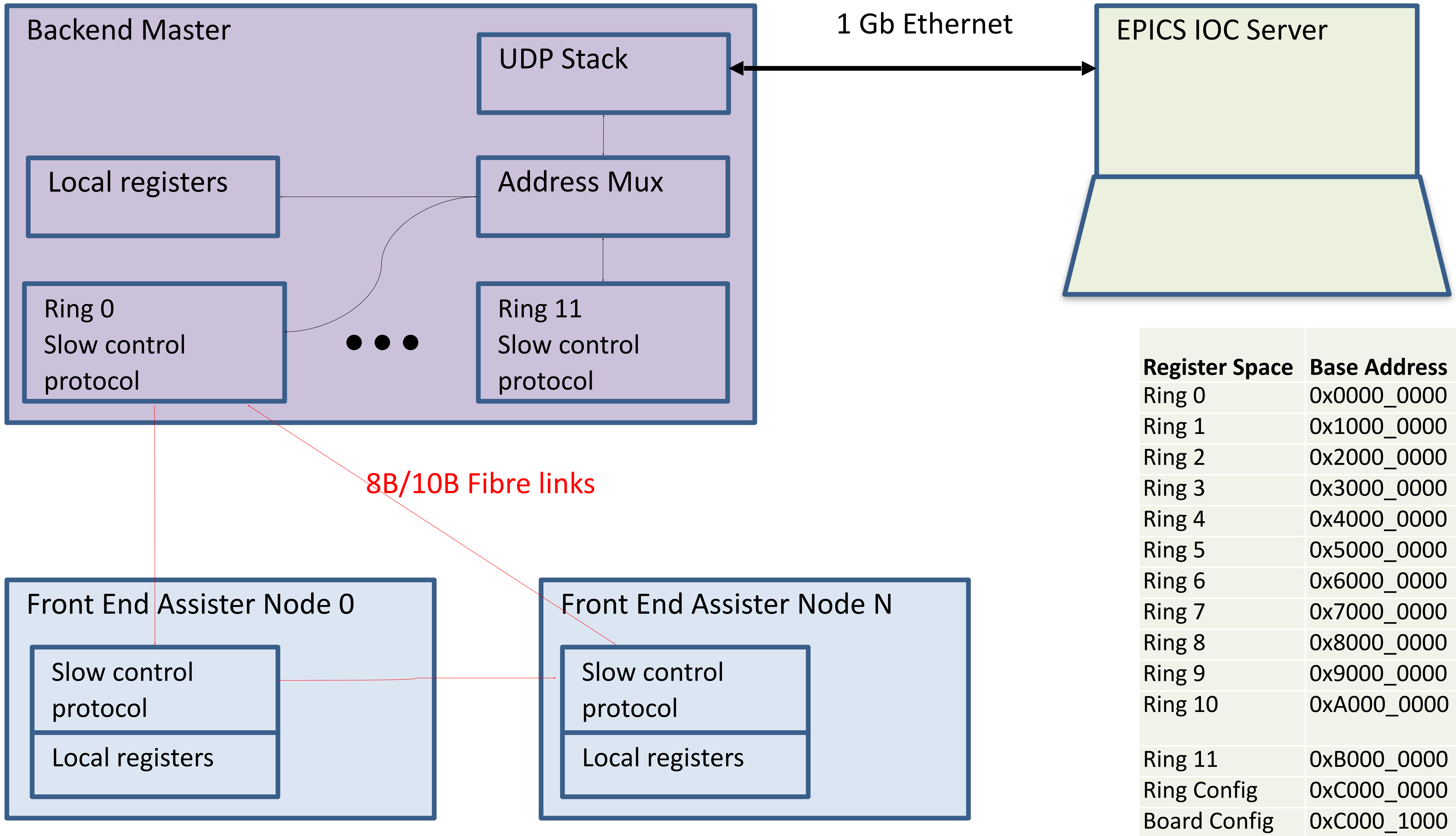
# Readout chain NMX



# ICS EPICS Slow Control Integration 1/2

- A very simple UDP-based Ethernet protocol has been implemented on the backend Master for configuration and monitoring of the entire readout system.
- UDP was selected instead of TCP for ease of firmware implementation. A Master-Slave configuration is adopted whereby the EPICS IOC is the Master, and every command must be acknowledged by the backend Master (which is actually the slave in this context). In other words, link reliability is achieved in the application layer of the stack.
- Each Instrument will have a dedicated IOC and a dedicated backend Master, provisioning a 32-bit address space for each readout system.
- The backend Master forwards read/write requests to the relevant register based on the address.
- To reduce cabling and simplify grounding, read/write requests to registers on front end nodes are sent over the same 8B/10B fibre used for timing distribution.
- ICS have implemented a baseline IOC which handles generic read/write requests, and are actively working on Instrument-specific functionality.

# ICS EPICS Slow Control Integration 2/2




| Register Space | Base Address | Range |
|---|---|---|
| Ring 0 | 0x0000_0000 | 256M |
| Ring 1 | 0x1000_0000 | 256M |
| Ring 2 | 0x2000_0000 | 256M |
| Ring 3 | 0x3000_0000 | 256M |
| Ring 4 | 0x4000_0000 | 256M |
| Ring 5 | 0x5000_0000 | 256M |
| Ring 6 | 0x6000_0000 | 256M |
| Ring 7 | 0x7000_0000 | 256M |
| Ring 8 | 0x8000_0000 | 256M |
| Ring 9 | 0x9000_0000 | 256M |
| Ring 10 | 0xA000_0000 | 256M |
| Ring 11 | 0xB000_0000 | 256M |
| Ring Config | 0xC000_0000 | 4K |
| Board Config | 0xC000_1000 | 4K |
| DMSC Config | 0xC000_2000 | 4K |
| Timing Config | 0xC000_3000 | 4K |
| 100 G Config | 0xC000_4000 | 8K |

# DMSC Neutron Event Integration 1/2

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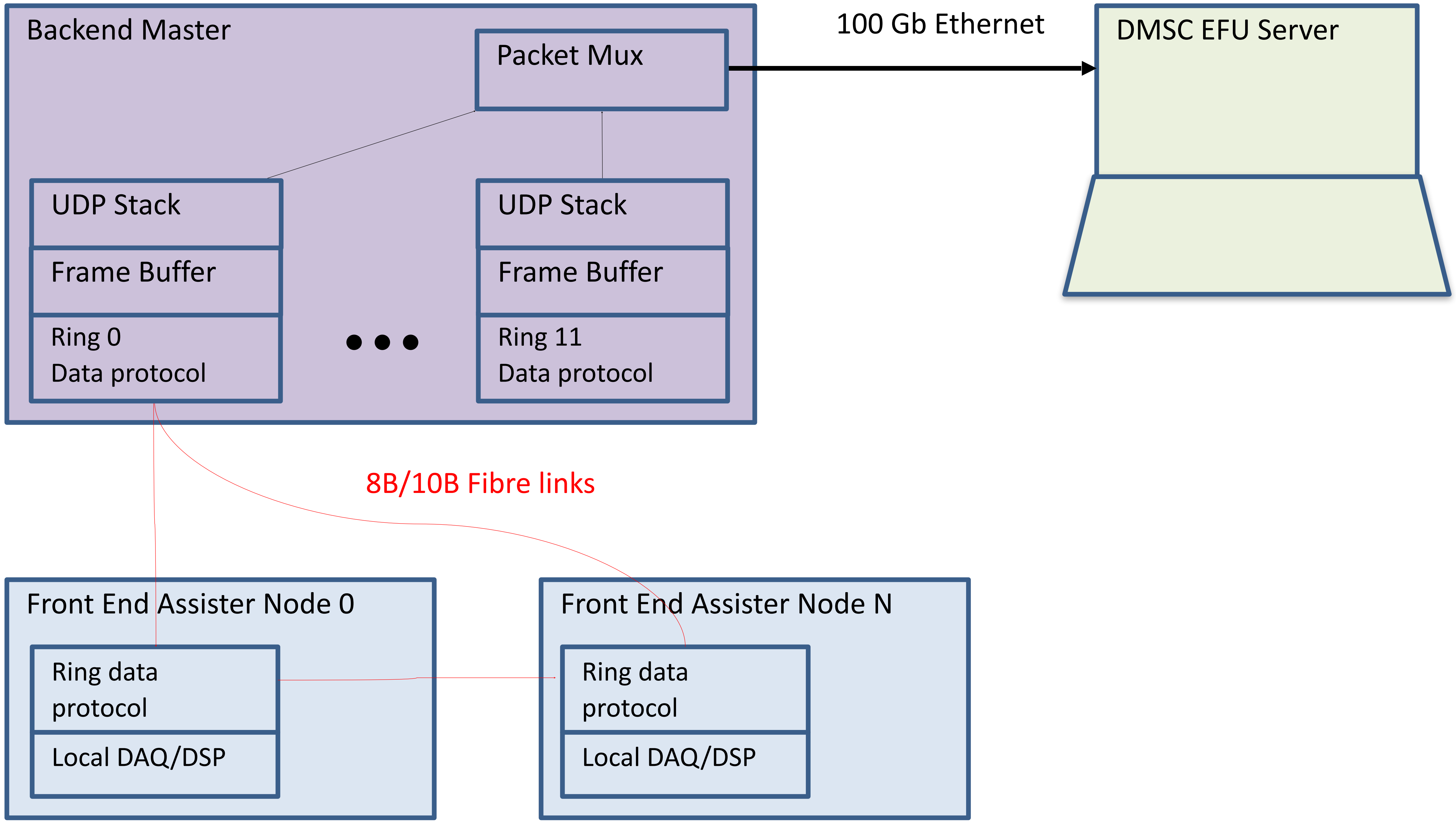
- The standardised “front end assistor” (FEA) firmware makes the ESS clock and timestamp available to the rest of the Instrument-specific “front end electronics” (FEE), which is responsible for detector data acquisition and signal processing.
- Timestamped neutron event data is transmitted over the 8B/10B fibre links to the backend Master.
- Each fibre ring can support approximately 10 Gbps: a 12-ring system can theoretically egress approximately 120 Gbps.
- The backend Master aggregates this data into jumbo frames associated with the current 14 Hz ESS accelerator pulse time, and these jumbo frames are then sent to the DMSC Event Formation Unit via UDP packets over one or two 100 Gb Ethernet links.

# DMSC Neutron Event Integration 2/2



# VMM Integration

- The VMM3A is the primary choice of ASIC for the MultiBlade, MultiGrid and NMX detectors in order to satisfy high channel count requirements.
- Significant development (the VMM Hybrid) already undertaken by CERN RD51 to read out and control this ASIC, but targeting the SRS readout system.
- Best solution in terms of design-reuse is to implement the FEA logic on a separate FPGA board – a so-called “Assistor Board”:
- The current assistor board is a commercial off-the-shelf Xilinx development board (the KC705).
- The SRS FEC firmware has been ported to the KC705, allowing the VMM hybrid to be controlled and read out using existing firmware. A new interface has been written to the ESS assistor logic.
- This work does not preclude the use of custom solutions in the future with smaller size/weight/power/cost.

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## Assister Specification Document

**Chess document: ESS-2055809**

- FEA assister is an FPGA which glues the integration together
- FEA (front end assister) firmware communicates with the ring/backend
- FEE (front end user firmware) communicates with frontend ASIC like VMM3a or ADC
- FEA and FEE part of firmware communicate via AXI4 streams

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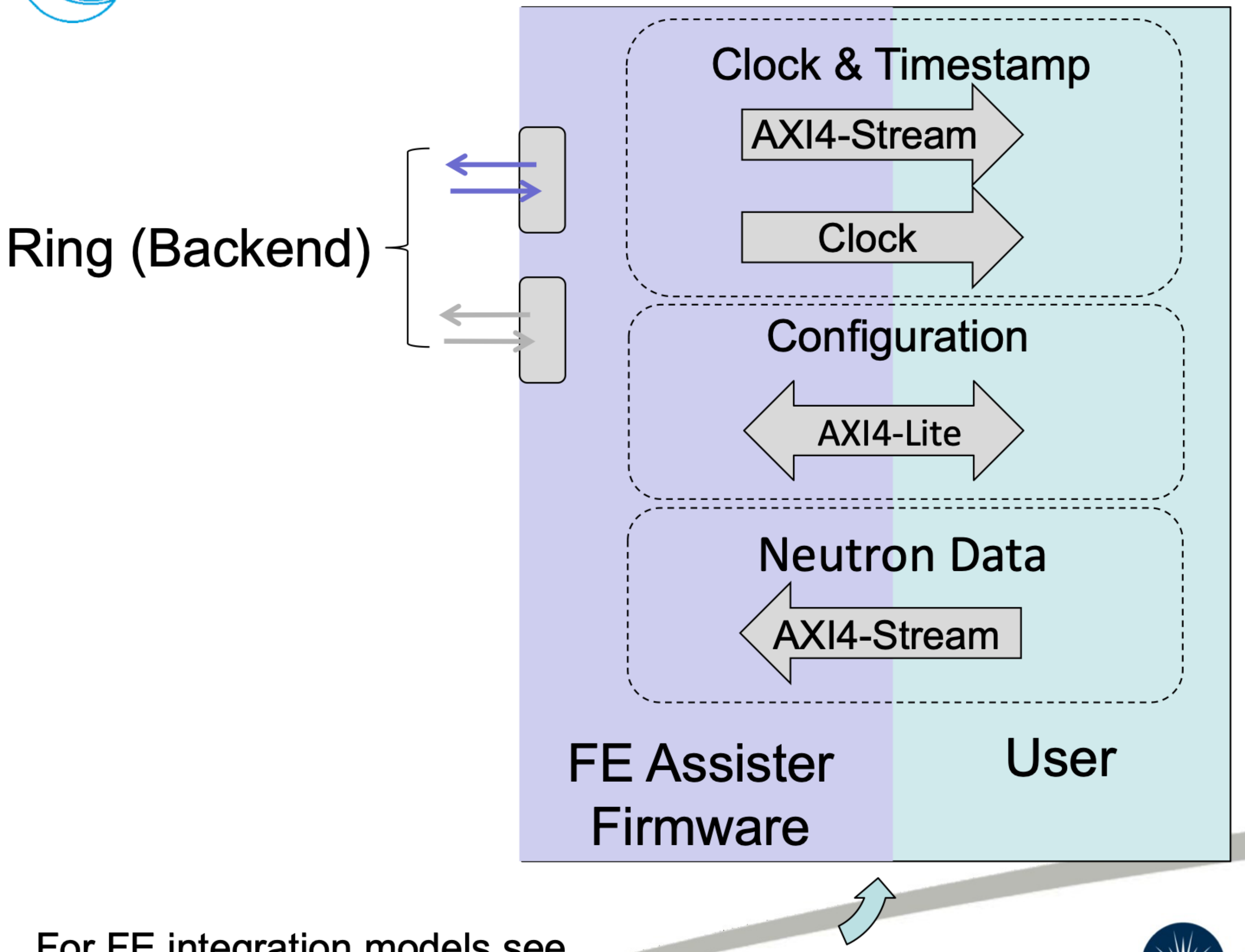
# Front End User Interface




For FE integration models see BrightnESS Deliverable Report: D4.1 – *Integration Plan for Detector Readout*. Scott Kolya et.al. 2017

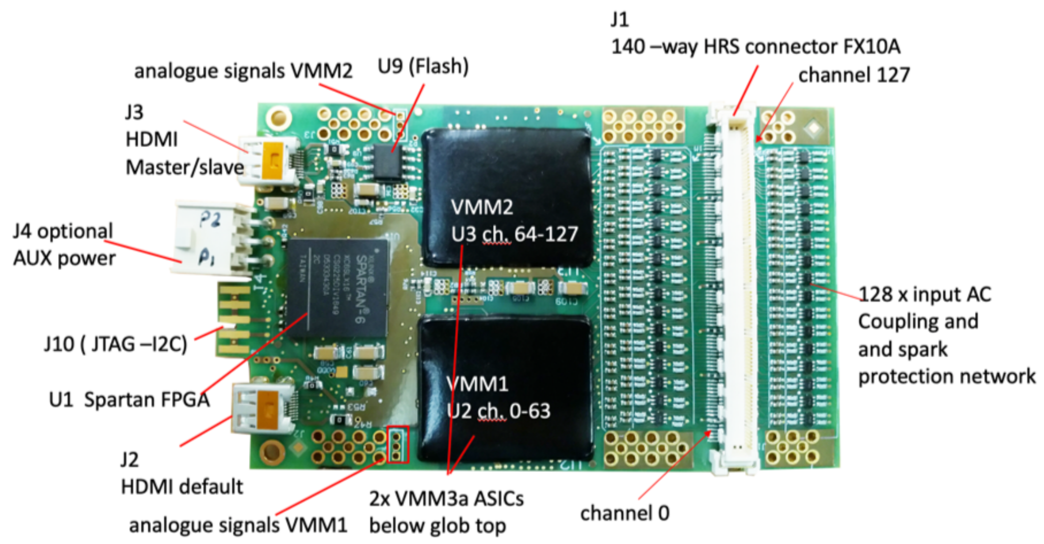
Science & Technology Facilities Council

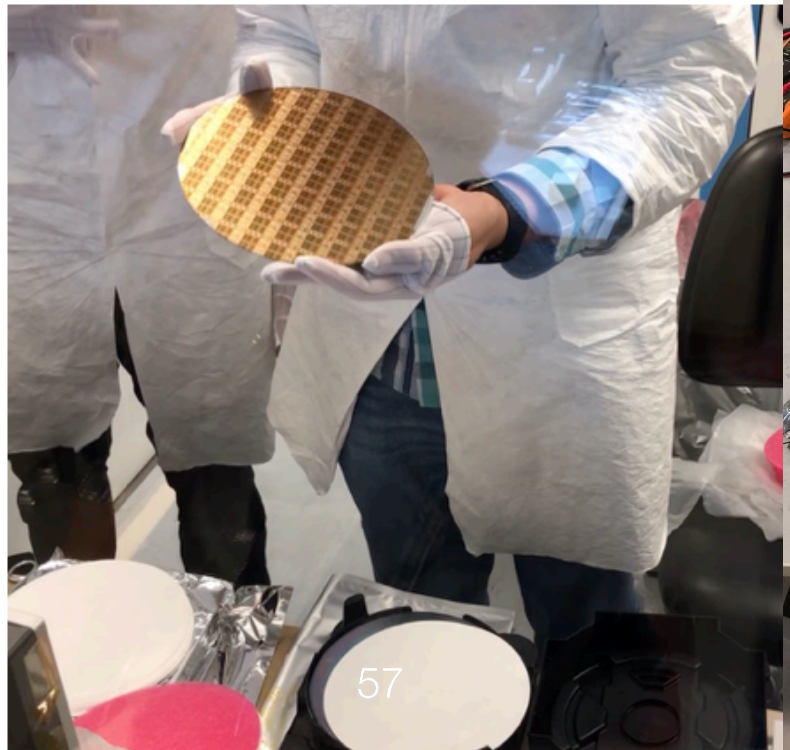
18

# Front End Electronics: VMM3A ASIC

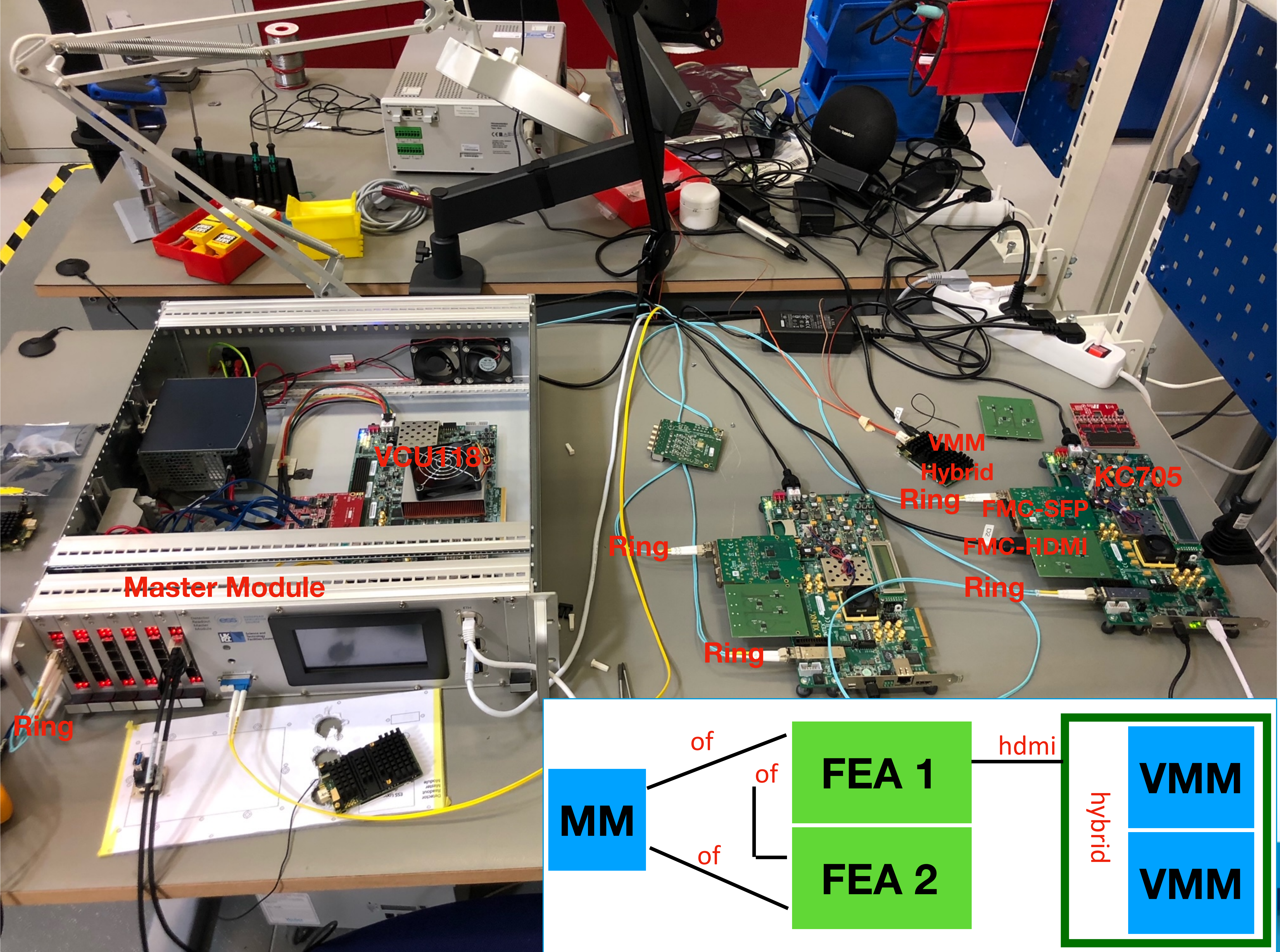
- VMM3a is the 4th version of an ASIC developed by Brookhaven National lab for the ATLAS New Small Wheel upgrade at CERN
- ASIC developed to read out Micro Pattern Gaseous detectors (MPGD)
- ASIC is high rate, sub-ns time resolution

- RD51 VMM3A hybrid common ESS-CERN project: successful integration of the VMM3a ASIC into the CERN Scalable Readout System (SRS) during BrightnESS
- 7.3 Mhits/s per VMM3a ASIC
- Per single VMM3a channel 4 Mhits/s
- Works well also for wire-based gaseous detectors



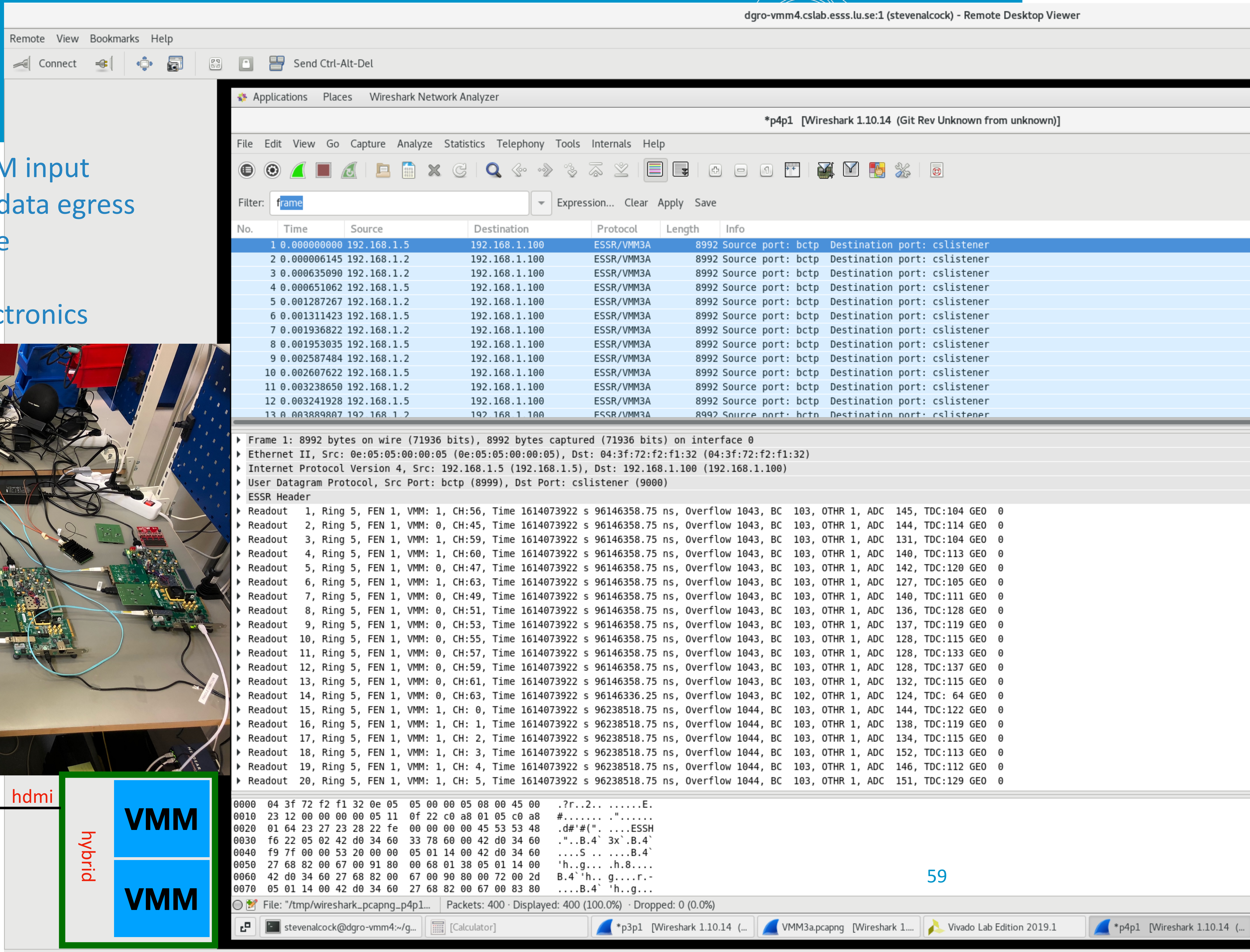



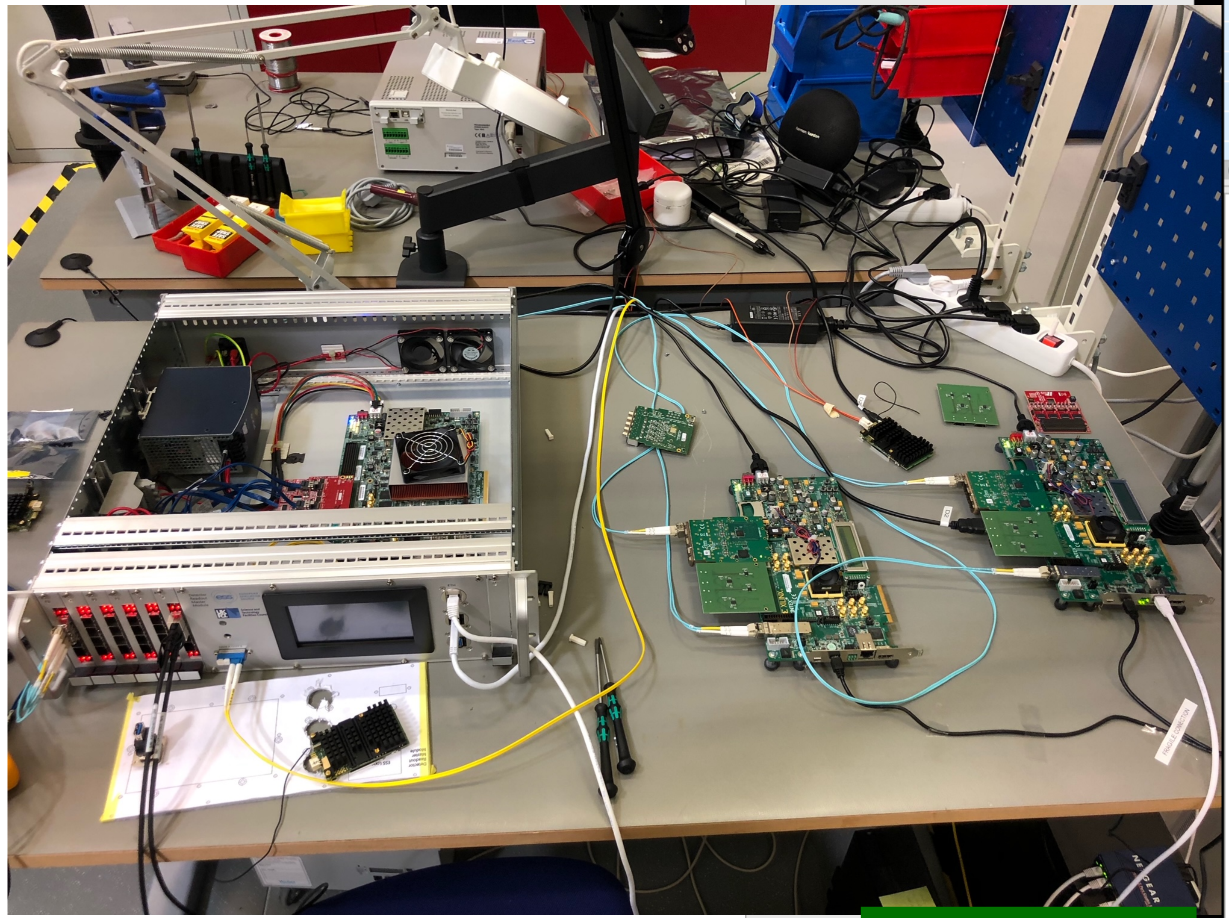
# VMM Integration

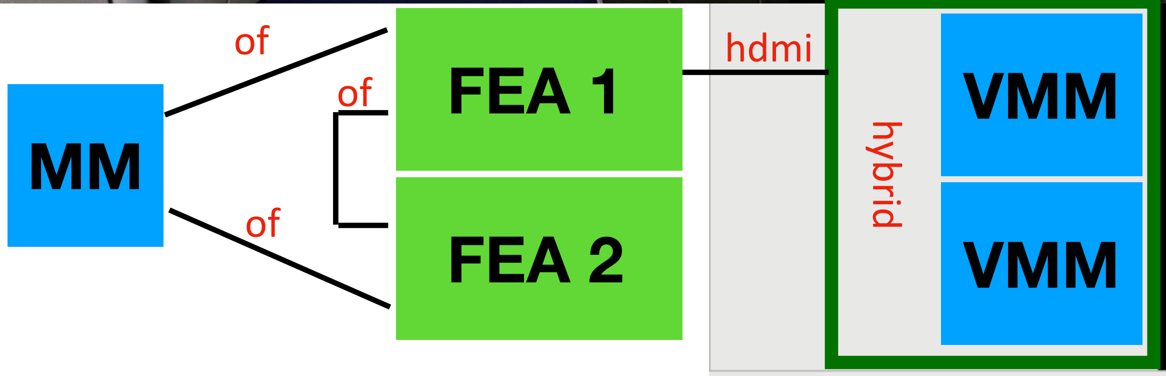


# VMM Integration

- Data seen from VMM input channel through to data egress from Master Module
- Through data rings
- End-end data in electronics

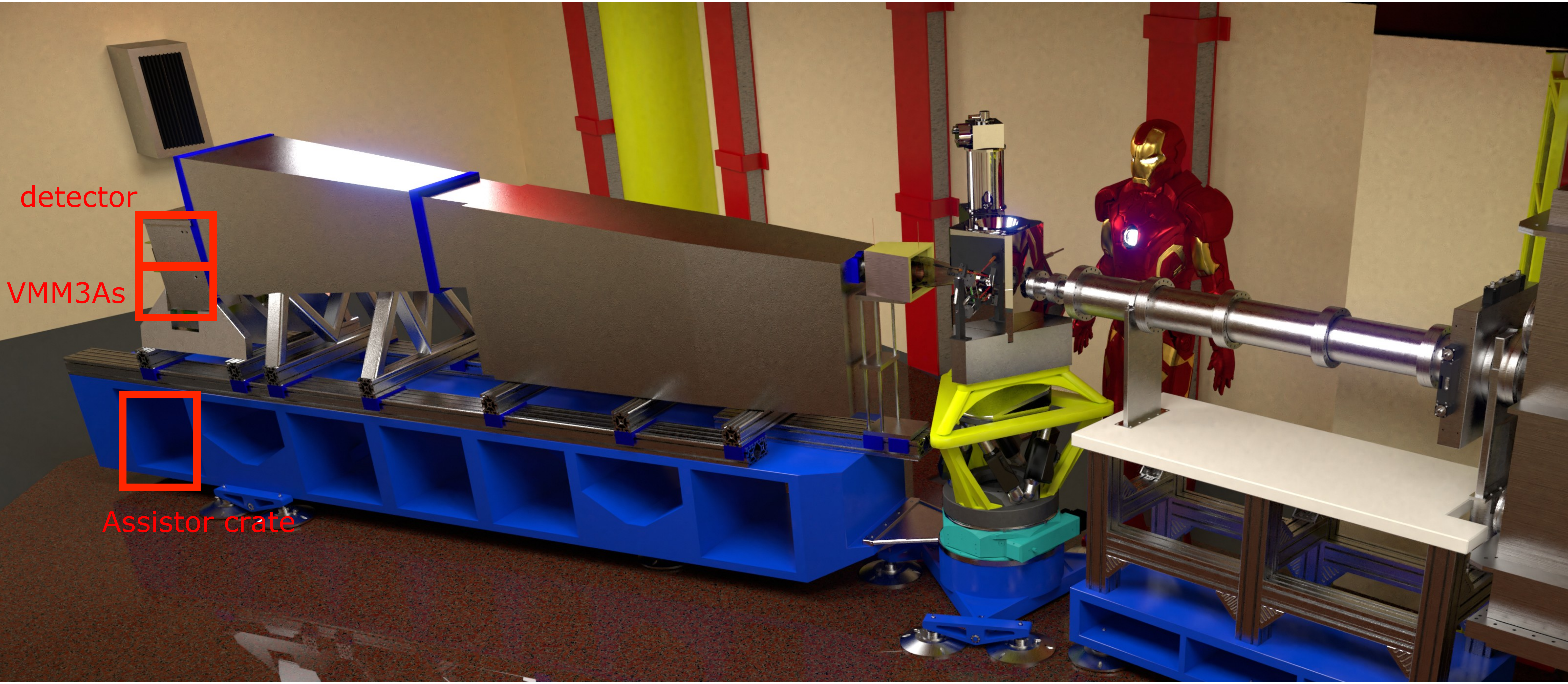




Engineering the whole system ...
It's not just digital ...
... or only about data transport and manipulation ...

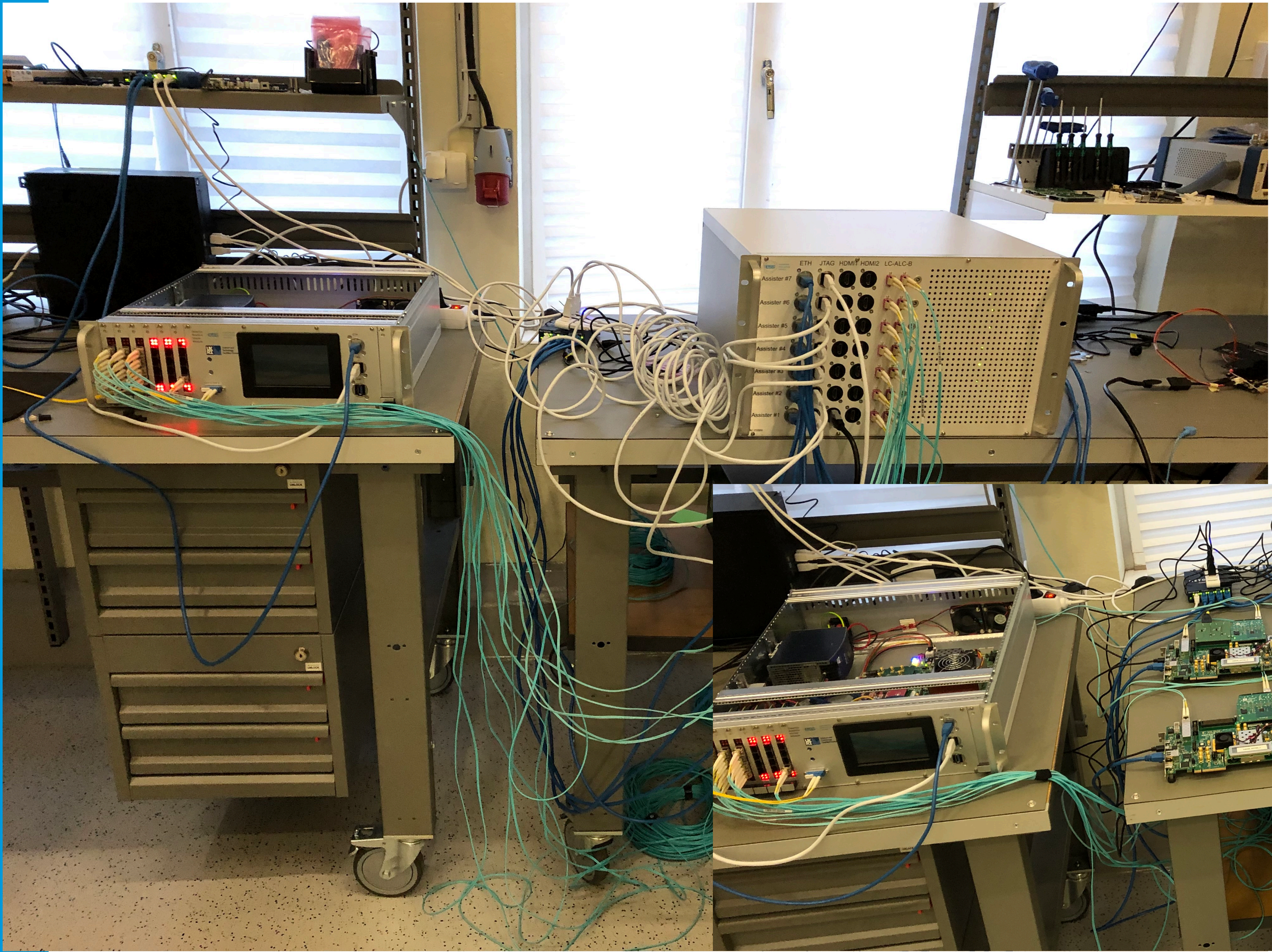
# MultiBlade

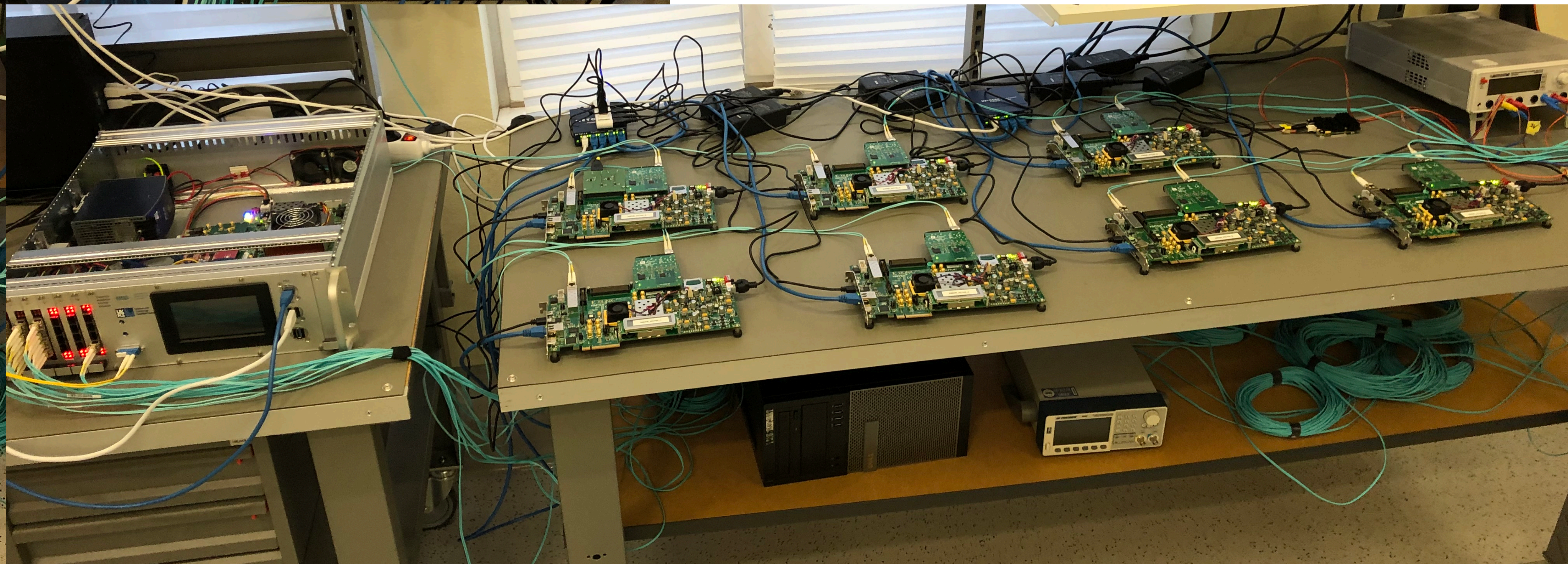



ca. 1-2m services path from VMM3As to Assistor crate

Detector rack ca. 15-20m distant

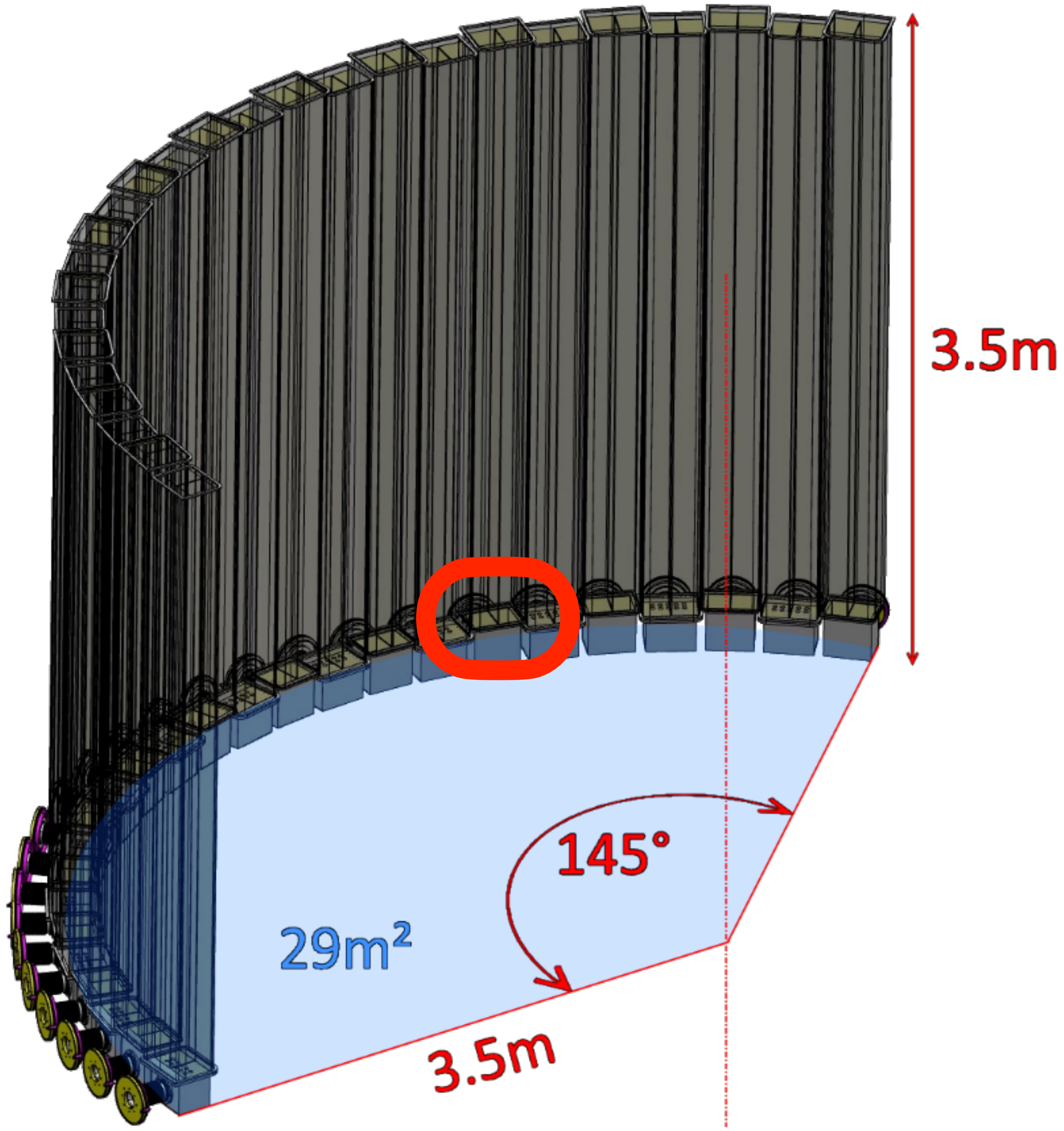
# Backend Readout Electronics

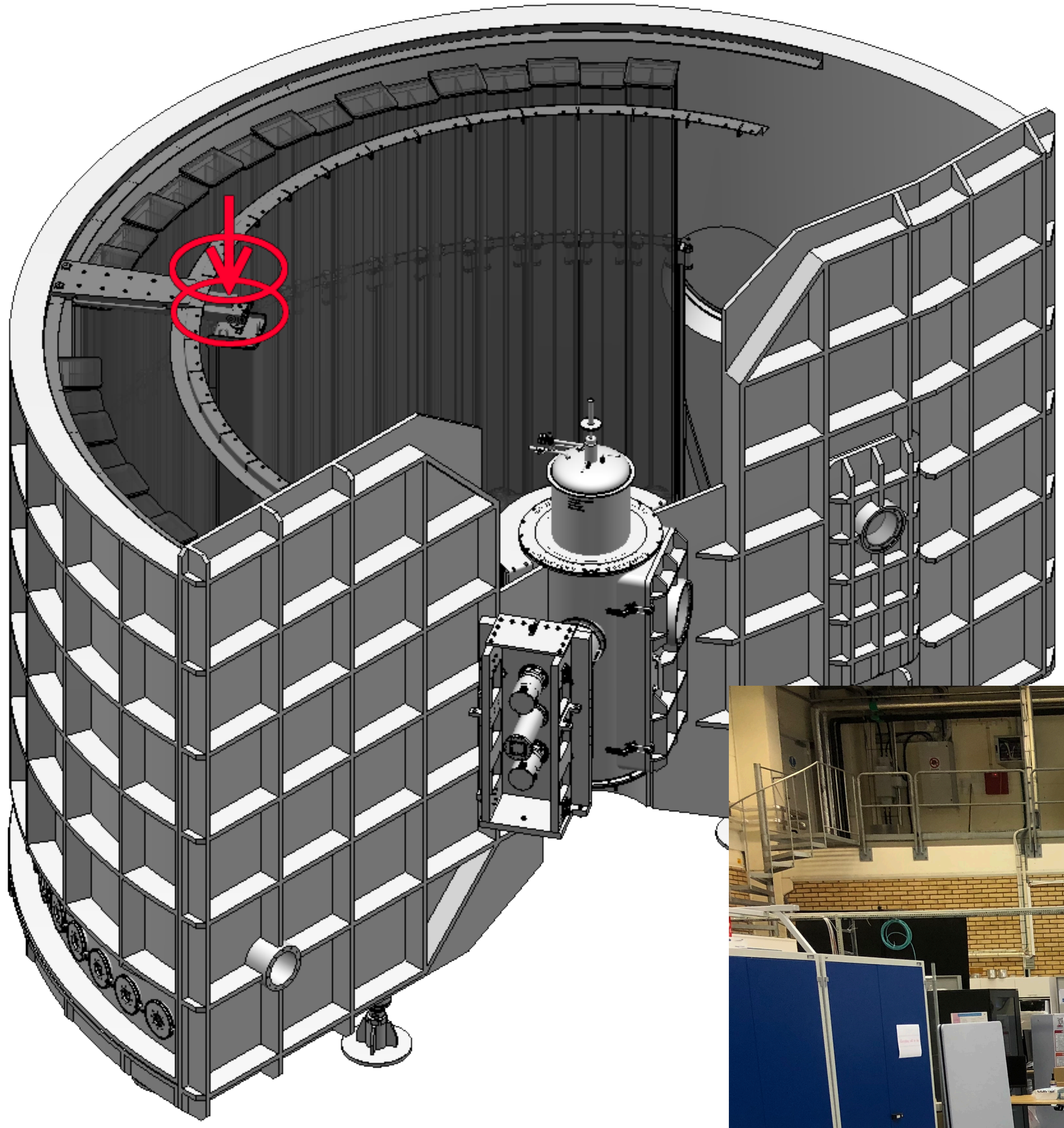




Electronics DAQ system works
Electronics DAQ system scales

# MultiGrid

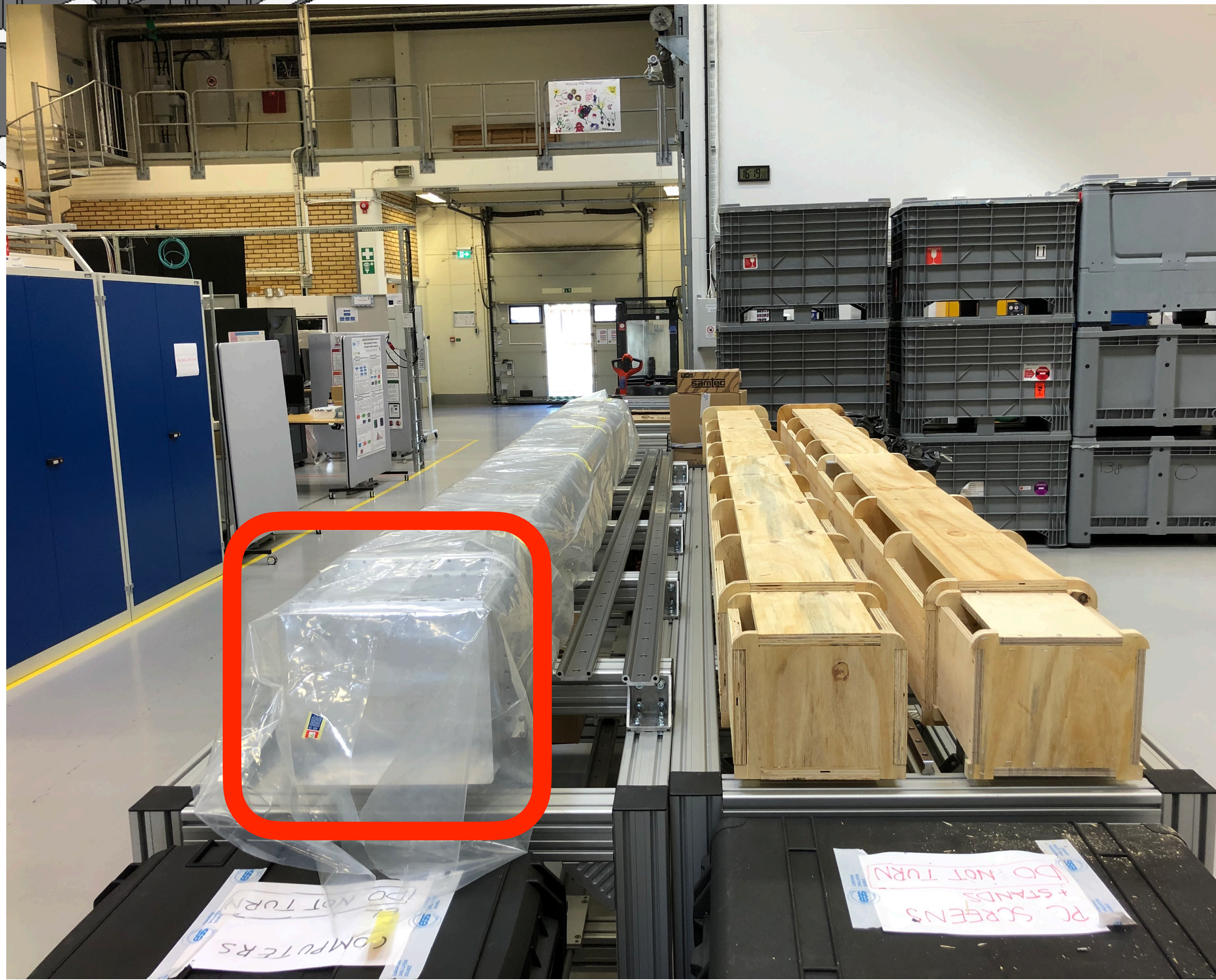


VMM3A and assister inside electronics box

ca. 50cm services path from electronics box to outside world.

Detector rack ca. 10-15m distant



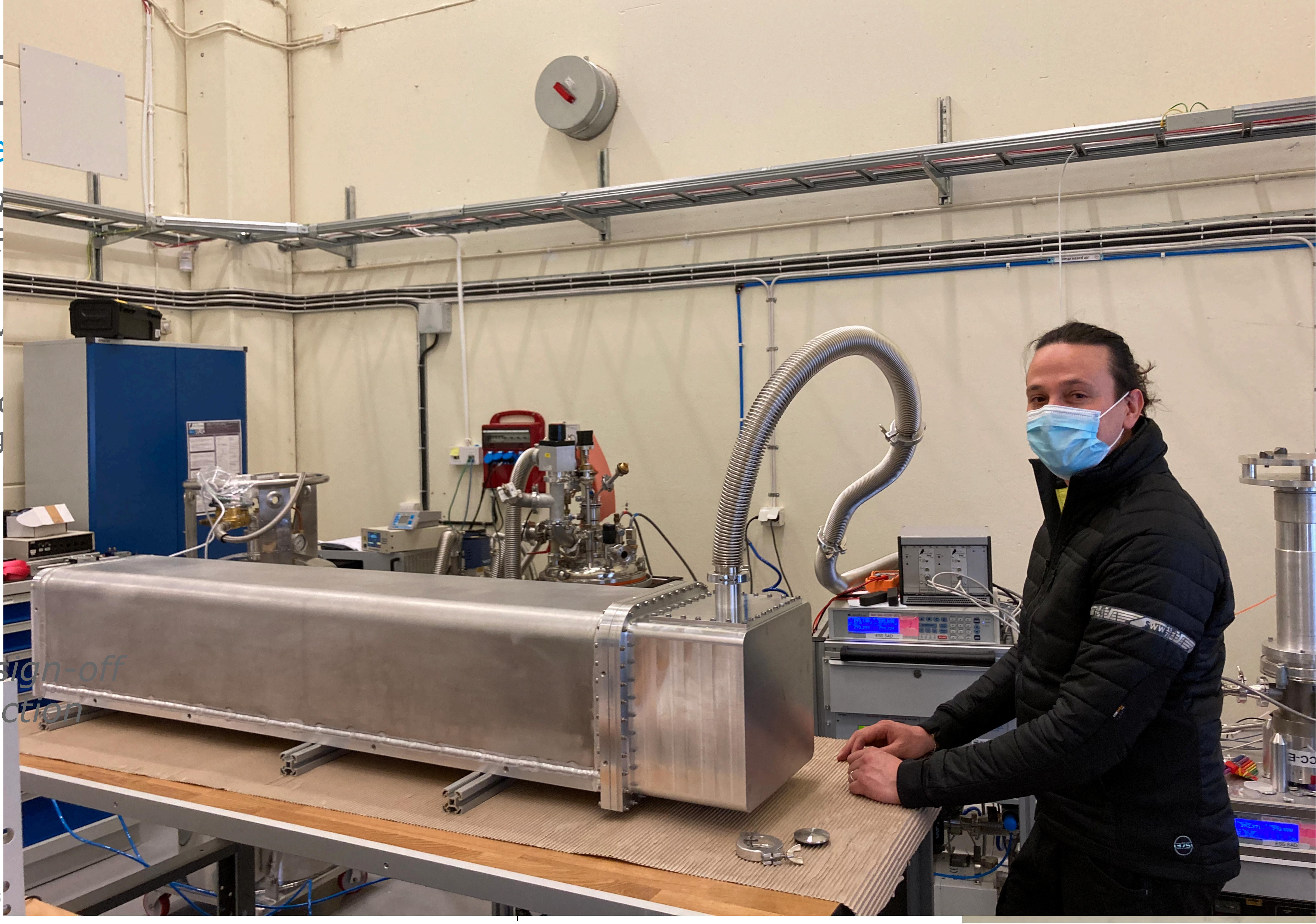
# Eg CSPEC instrument

# CSPEC D

## MultiGrid dete

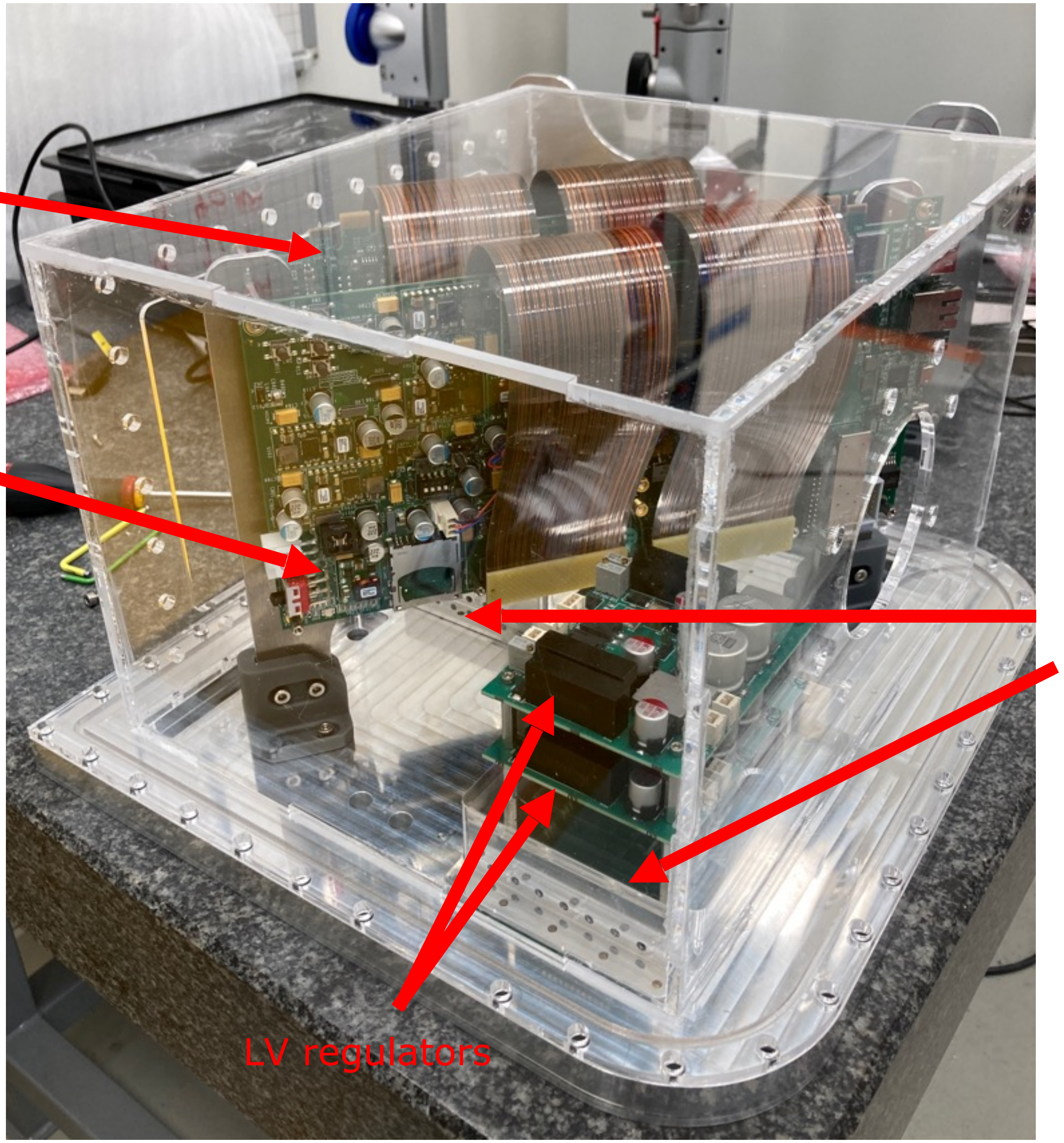
*Aim: Testing h*
*detector on LE*

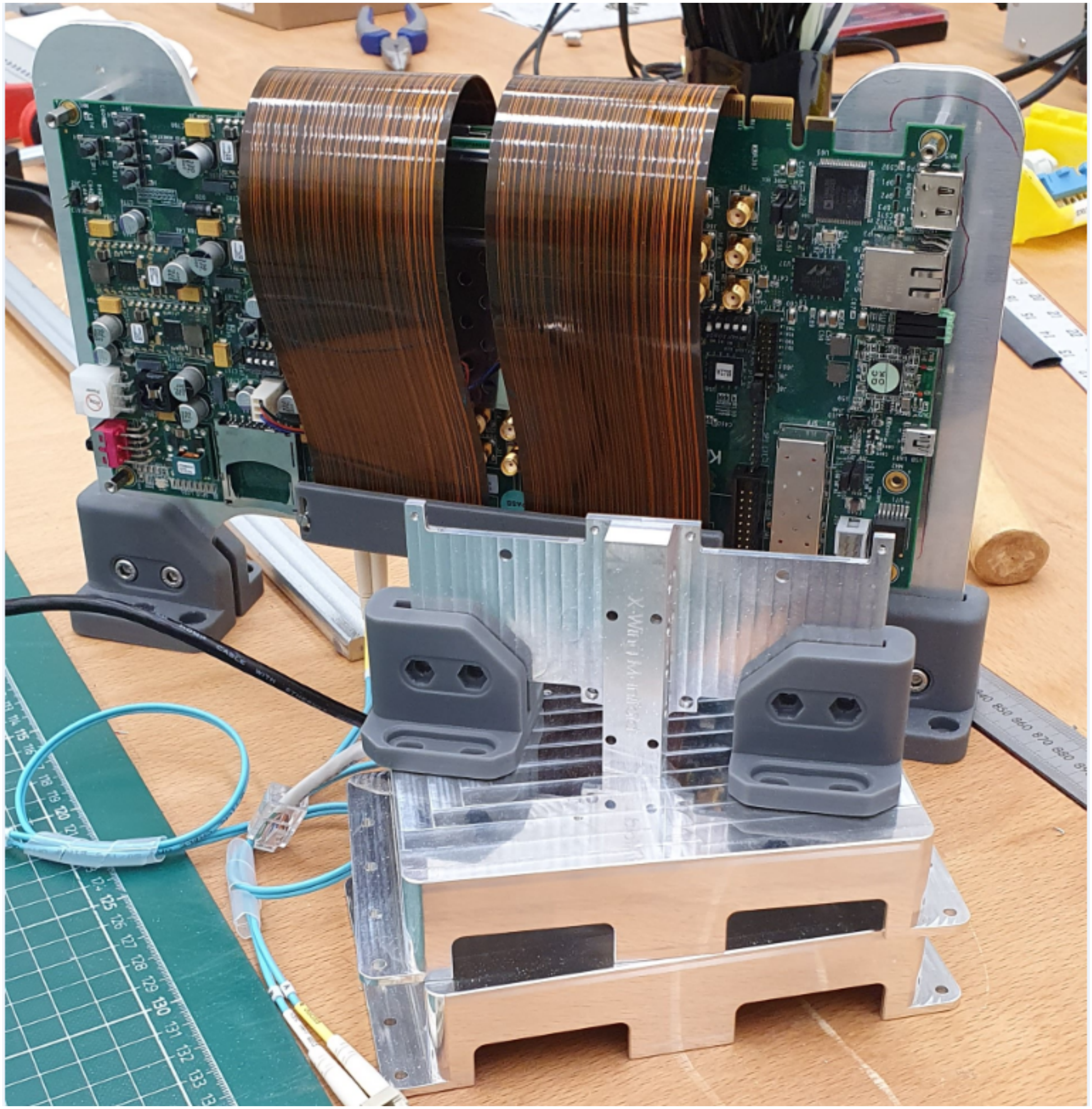
Status:
2x2 day test in M
Vessel ready
Coatings, Blade c
Preparation for g
Successful mock

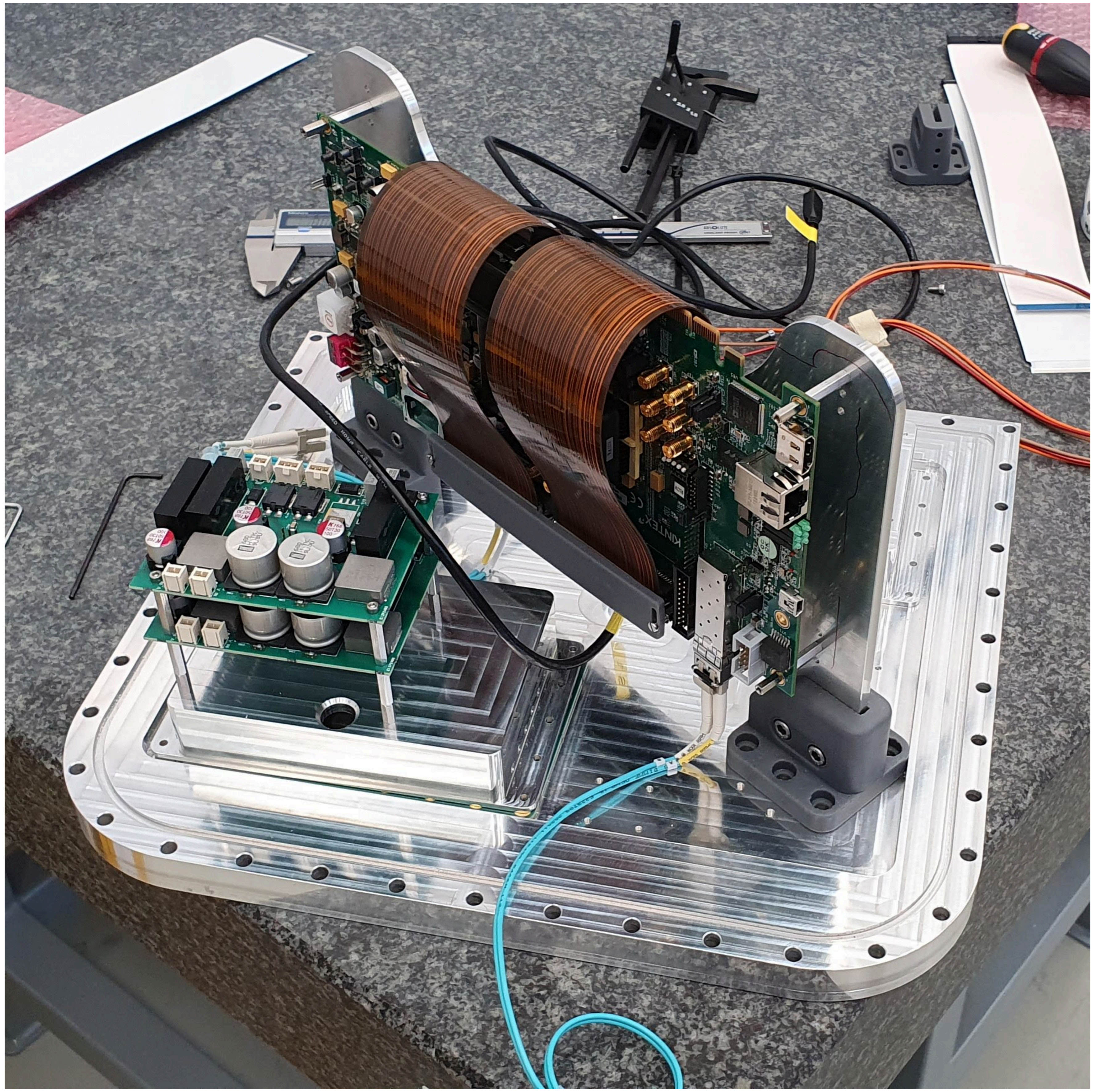


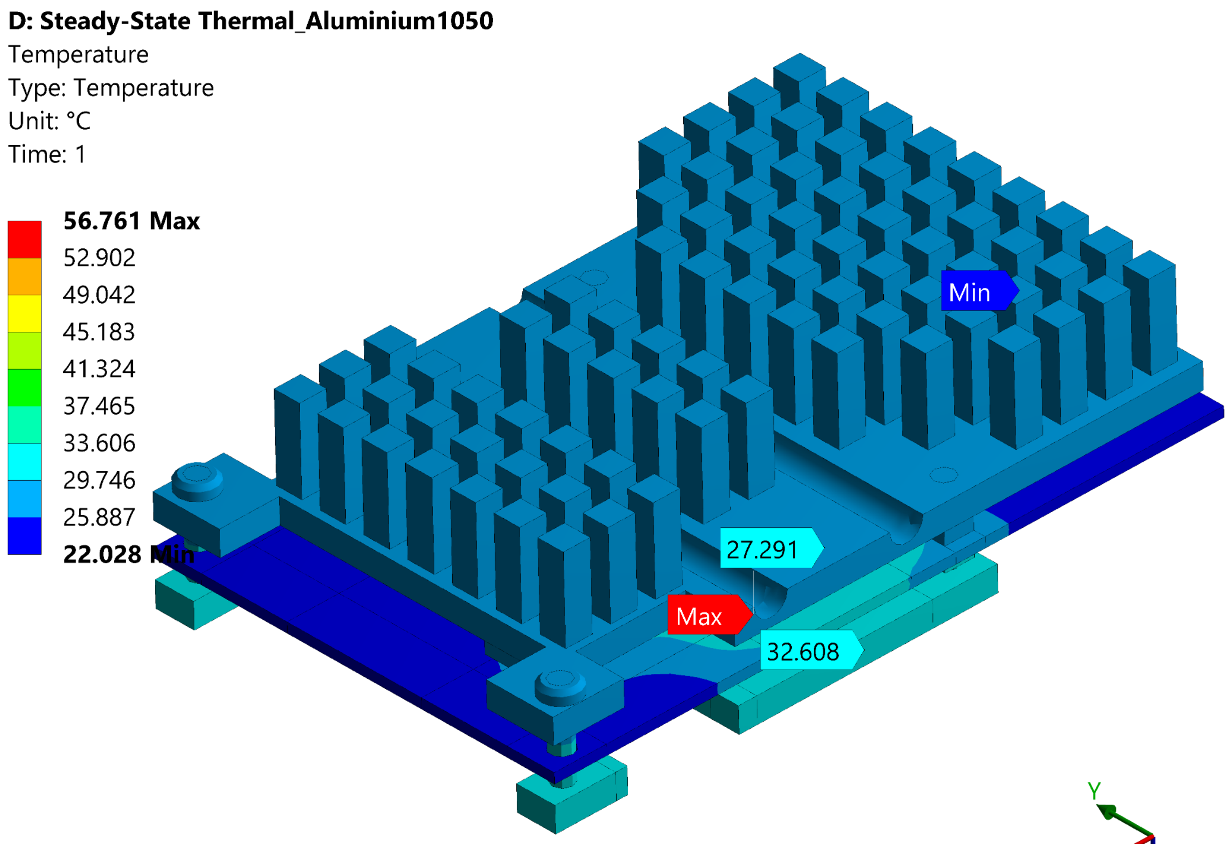
*Aim: final sign-off*
*for construction*

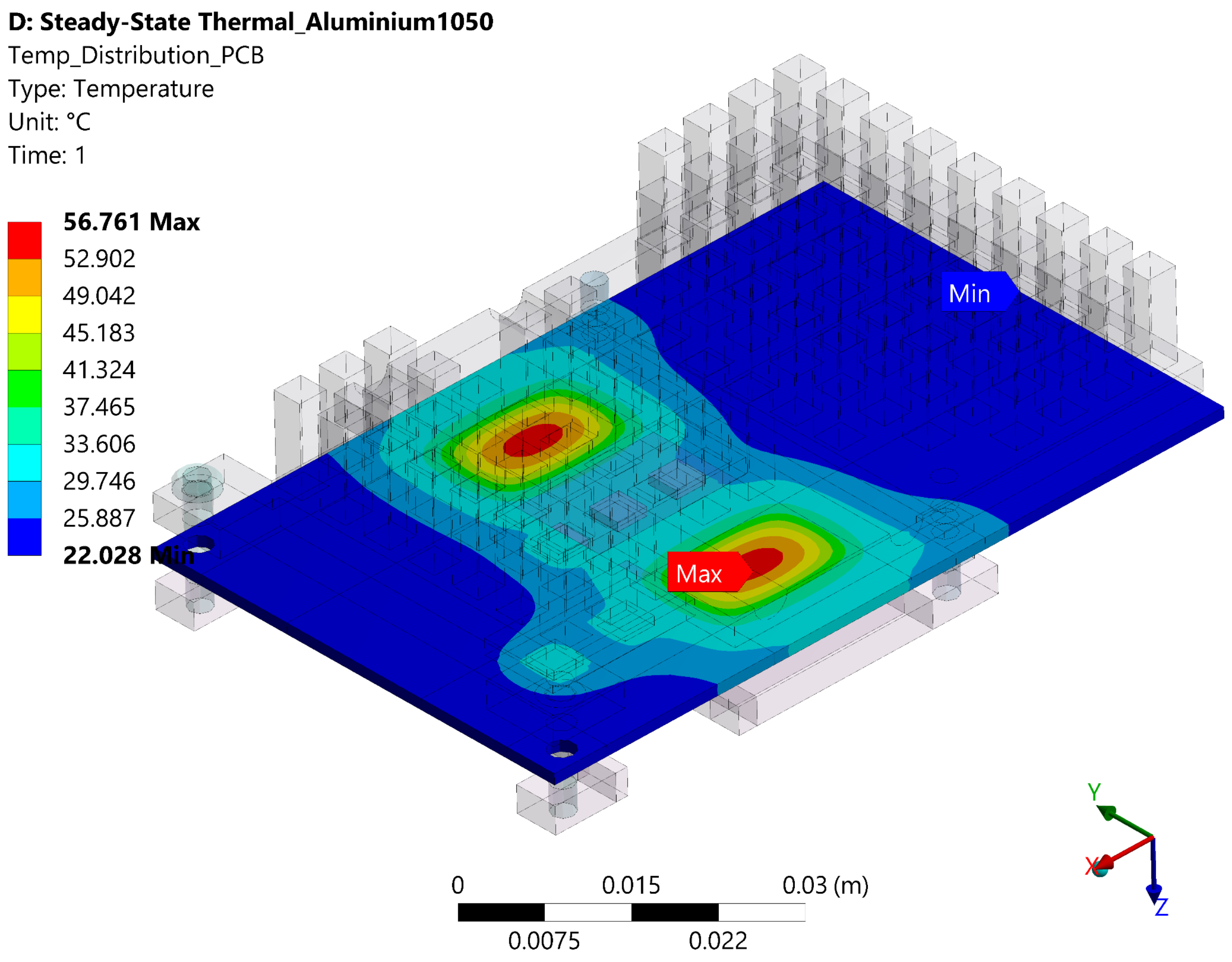
# MultiGrid Electronics Box

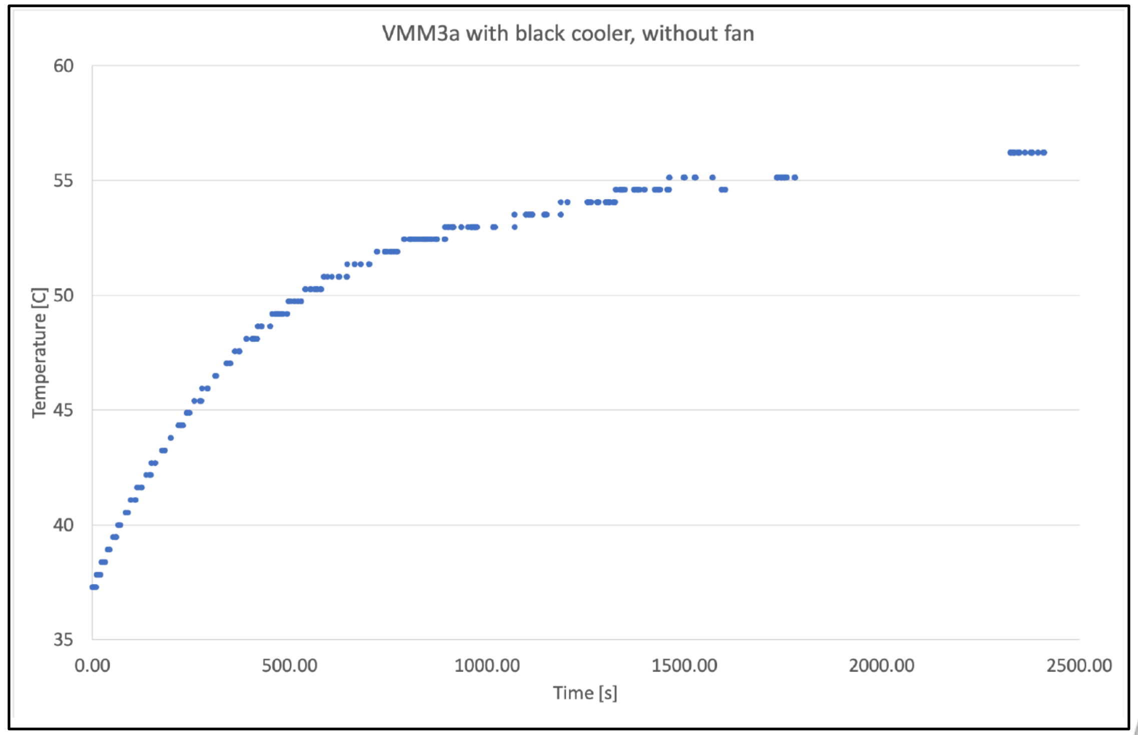


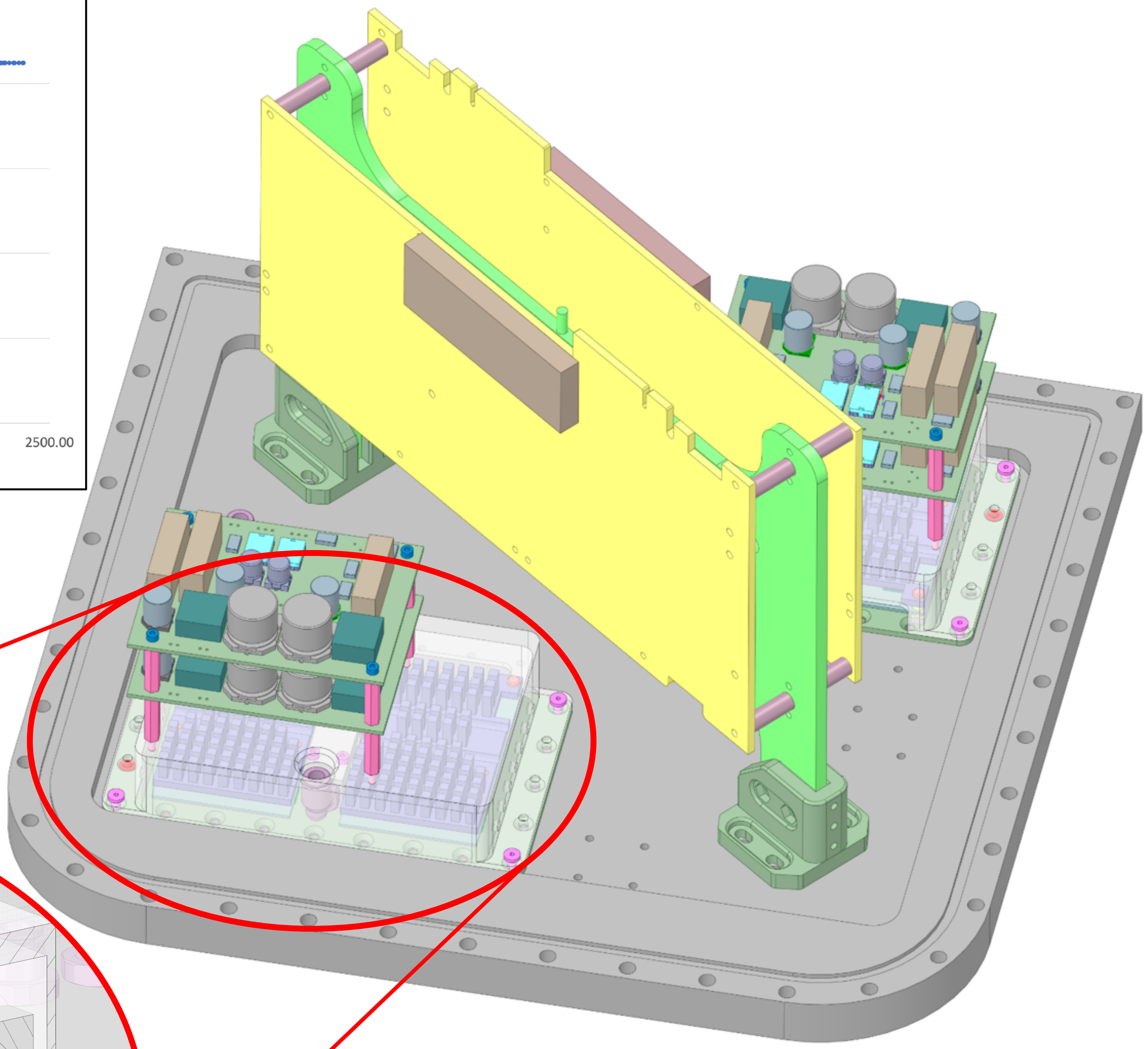


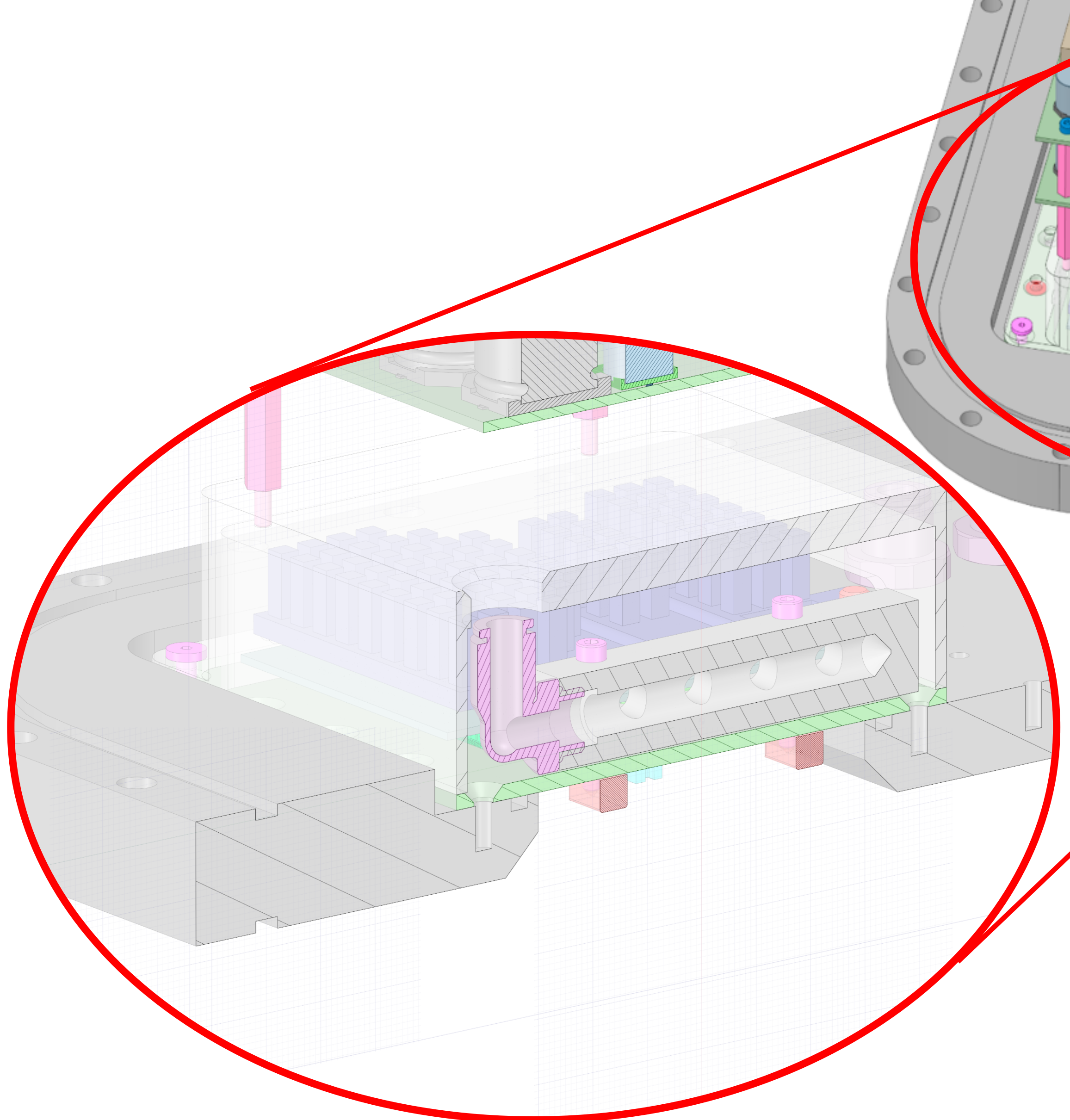



D: Steady-State Thermal_Aluminium1050
Temperature
Type: Temperature
Unit: °C
Time: 1
56.761 Max
52.902
49.042
45.183
41.324
37.465
33.606
29.746
25.887
22.028 Min
Min
Max
27.291
32.608
Y


D: Steady-State Thermal_Aluminium1050
Temp_Distribution_PCB
Type: Temperature
Unit: °C
Time: 1
56.761 Max
52.902
49.042
45.183
41.324
37.465
33.606
29.746
25.887
22.028 Min
Min
Max
0
0.015
0.03 (m)
0.0075
0.022
Y
X
Z


VMM3a with black cooler, without fan
Temperature [C]
60
55
50
45
40
35
0.00
500.00
1000.00
1500.00
2000.00
2500.00
Time [s]





# Principle

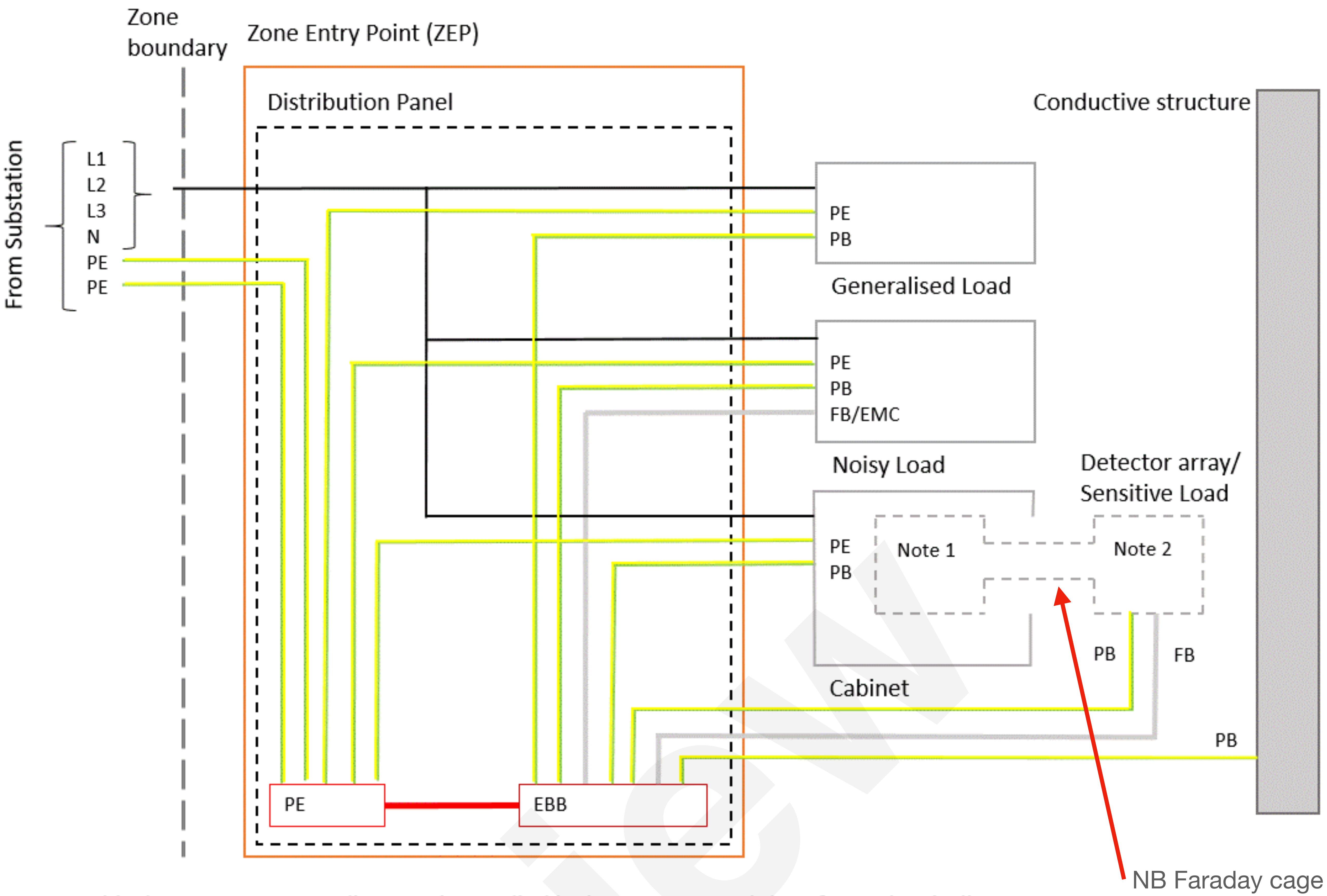
Sensitive part of detector will be surrounded by Faraday cage

i.e. Faraday cage encompasses from voltage supply (in rack) through detector sensitive element, through to Front End ASIC

For NMX this Faraday cage encompasses the detector module,
As this is the metallic object that surrounds readout plane
Therefore this should be isolated from robot/support

It is always wise to forsee bonding points at all isolated points - as it may be necessary to connect later

Details of NMX grounding will be drawn up Autumn this year




Note 1: This detector-corresponding part is supplied by its own UPS and therefore galvanically separated from the cabinet.
Note 2: The detector-complex is isolated from everything except the PB/FB connectors shown.

**Figure 9 Principle drawing of earthing and bonding in a generic zone. ZEP in orange frame.**

NB Caveat: indicative.
This diagram is not uptodate.
New version coming

NB all networks, & similar will be optically decoupled

# Rack electronics

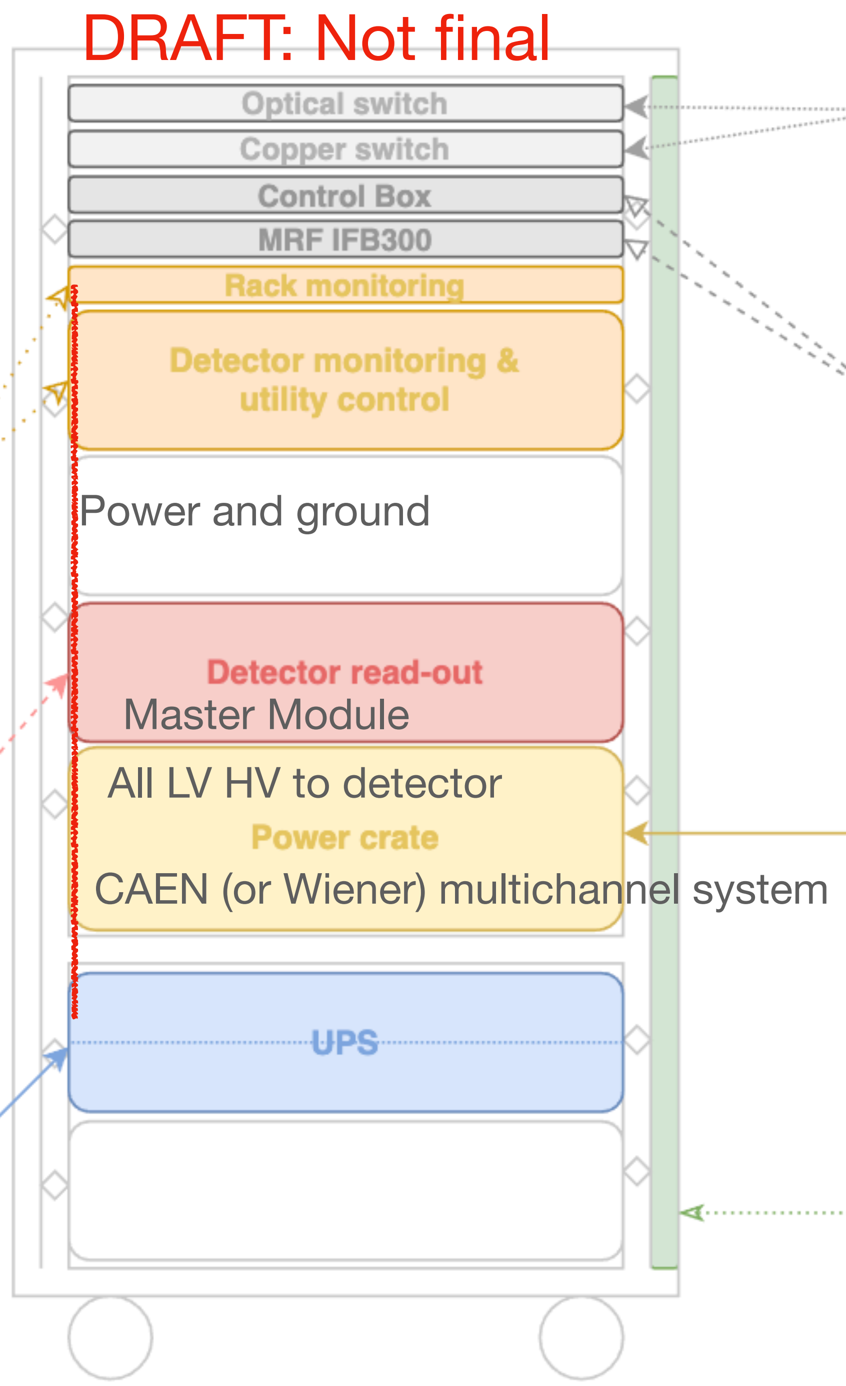
The standard detector rack is considered part of the readout back-end.

The rack environment will be monitored for e.g. humidity and temperature by use of a commercial-off-the-shelf system. Beckhoff terminals (3U–6U) are used to read and control detector parameters.

The ESS readout back-end provides a common interface for detector front-ends including controls and time distribution.

Six (6) horizontal units of space in the lower frame are reserved for the double-converting Uninterruptable Power Supply (UPS) which will be grounded through the mains input and supply floating ground for all downchain detector electronics.

Prototype Rack exists in Utgard and it is starting to be populated to determine configuration
Example for LOKI




Switches/patch panels to provide access to networks for timing distribution, event data, and controls. Only routed in via optical fibre.

Server to act as controls interface and to host the PCIe Event Receiver (EVR) and an interface board ("IFB300") to provide timing signal to ESS back-end readout system.

Up to eight (8) horizontal units in the upper frame will host the multichannel Low and High Voltage system, supplying e.g. bias for the detector(s).

A Power Distribution Unit (PDU) will take input from the UPS and feed power to all other detector components.

# Some Final Thoughts ...

# Mood Message for the Development so far ...

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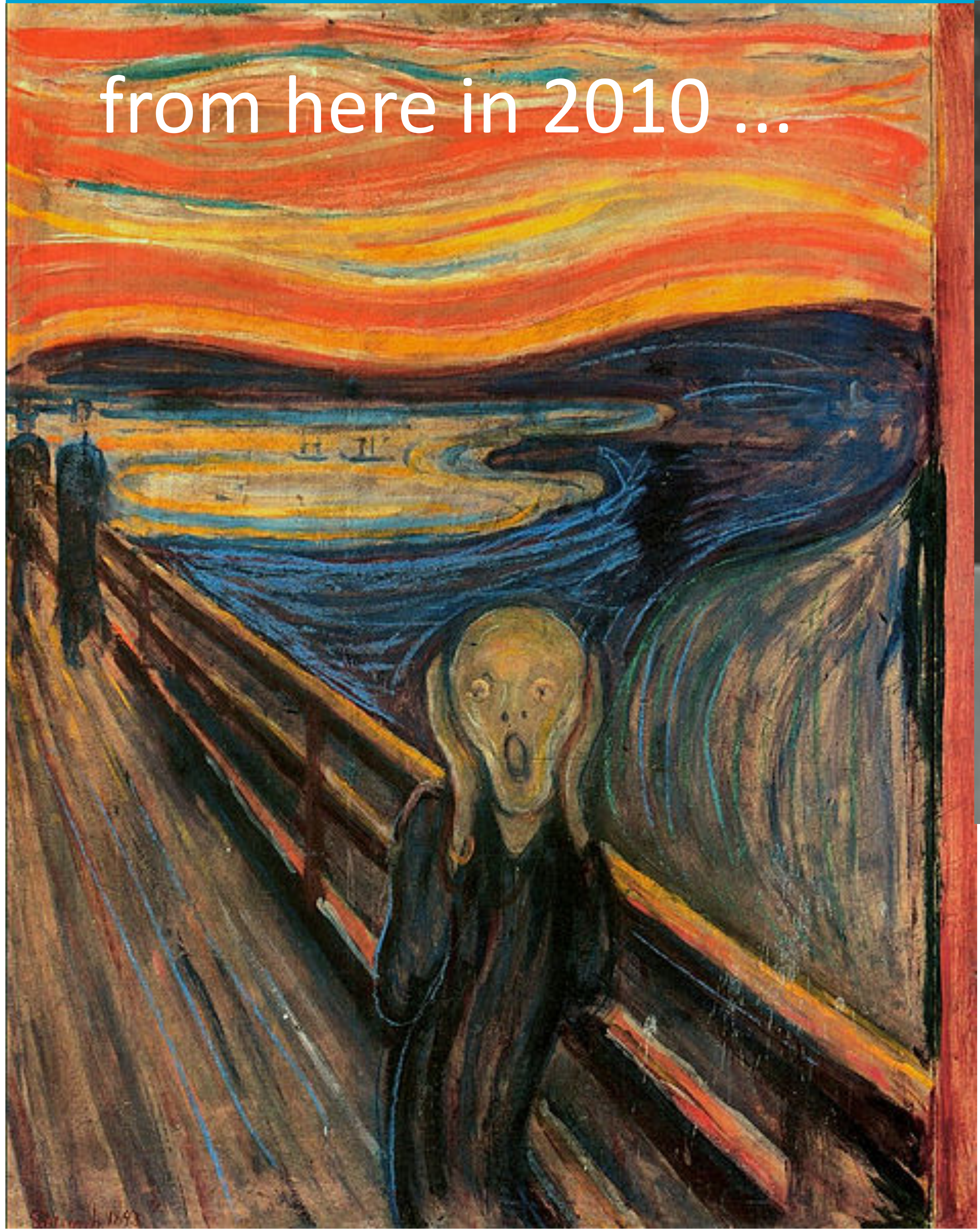
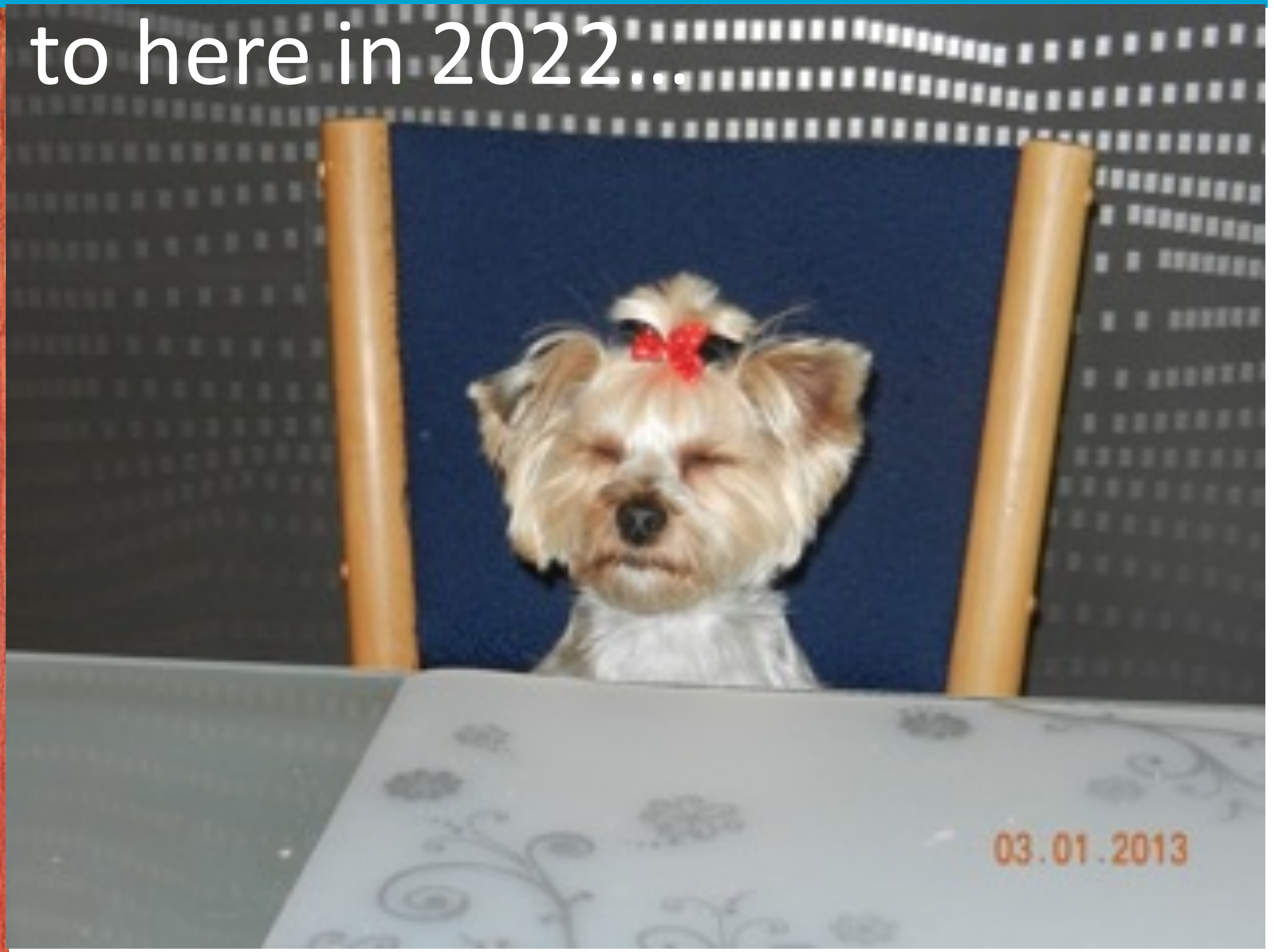
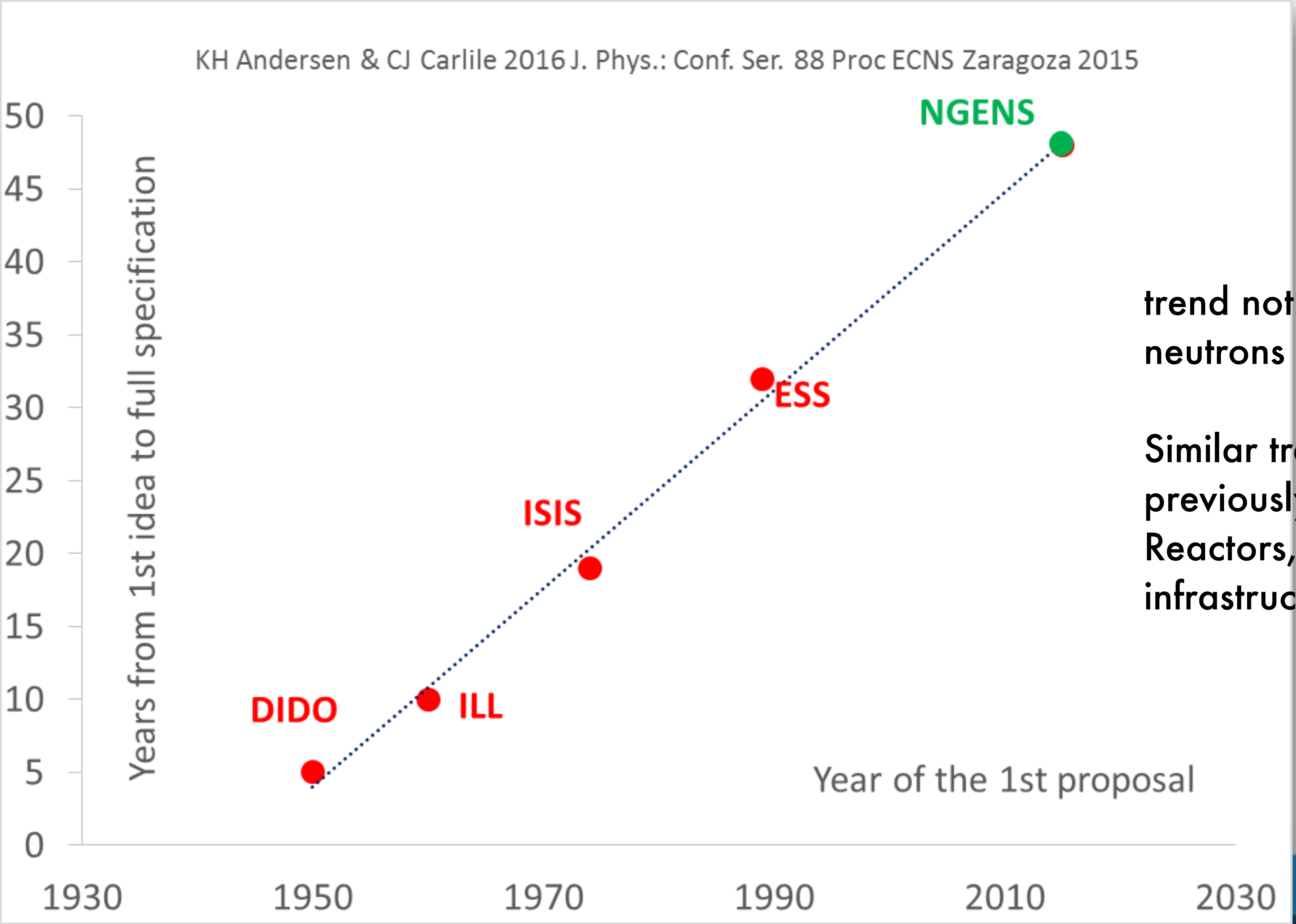



- Development time is long: typically 10 years from conception to utilisation
- Solve challenges one at a time, and remain calm

# Time from first proposal of a neutron source to operation at full specification




trend not unique to neutrons

Similar trends noted previously for Power Reactors, HEP, civil infrastructure, etc …

# Collaborations for Construction Phase

Big projects are very very difficult
- Berlin airport …
- Every military contract …
- Your local hospital …

It's not going to be smooth …
… don't worry about this months crisis …

Focus on the goal and the vision and work towards this

# Timeline for detectors (schedule from 2012)

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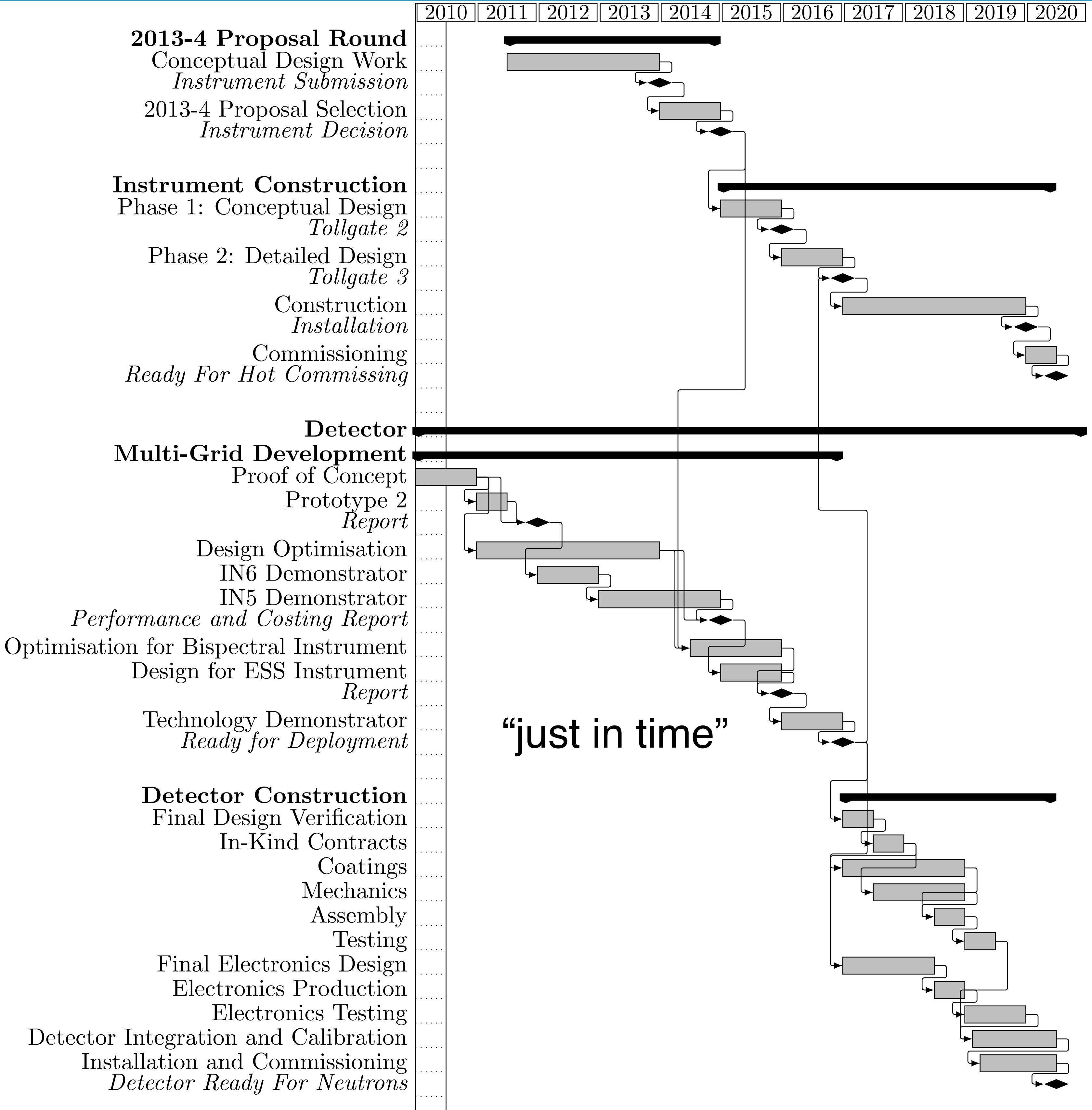



•Here is the timeline for a thermal chopper spectrometer with one concept for detector technology

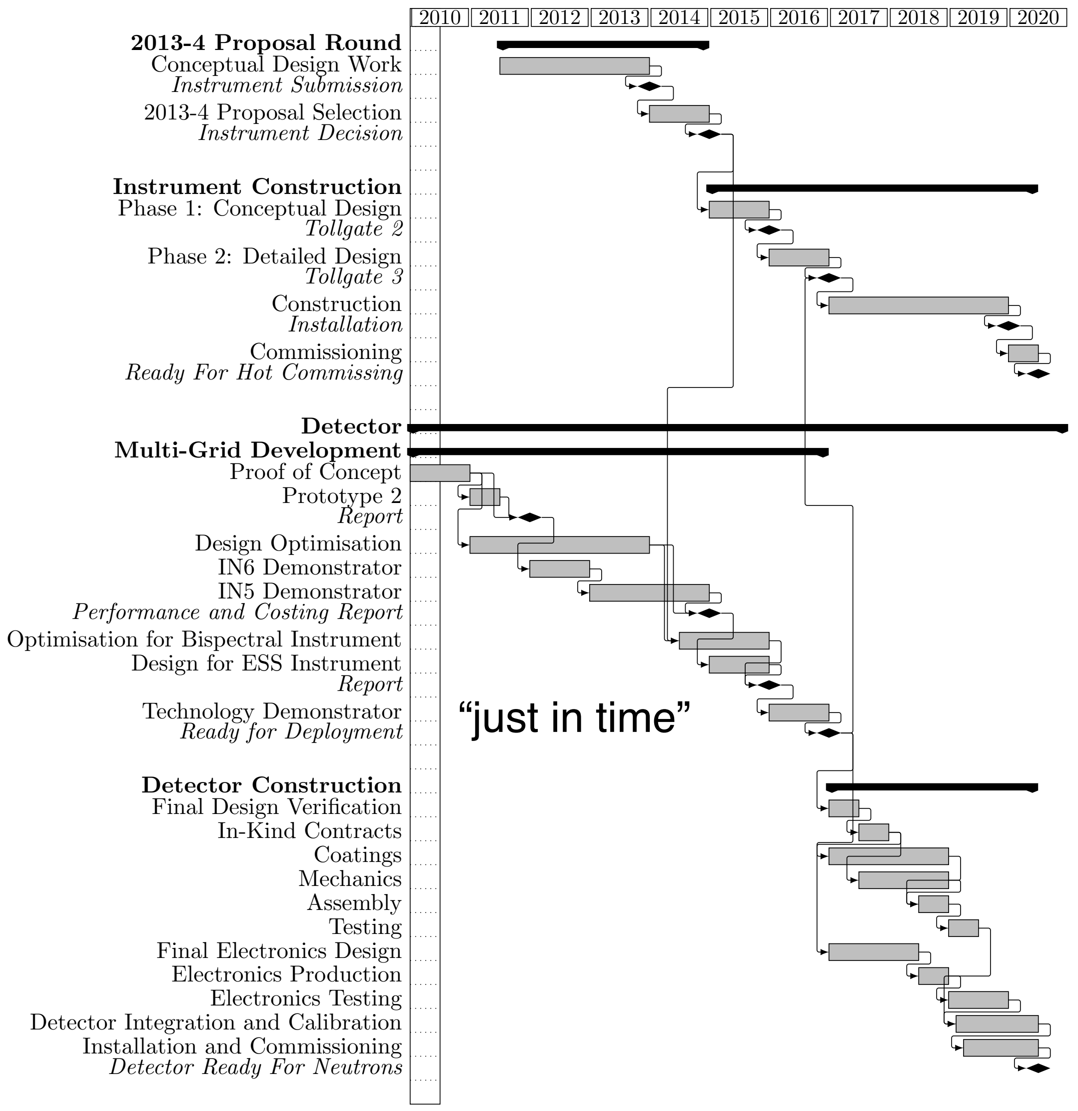
•note: 10 years from concept to (potential) utilisation

•note: neither the proof of concept nor construction phases dominate the timeline, but rather the numerous prototyping and demonstration phases in between

- Design friction: Only review decisions made if you really really need to
- I have seen many systems redesigned without any need to … wasted effort.

- Get it working - keep it working -
- and then only then improve it

# An aside on Project Management …



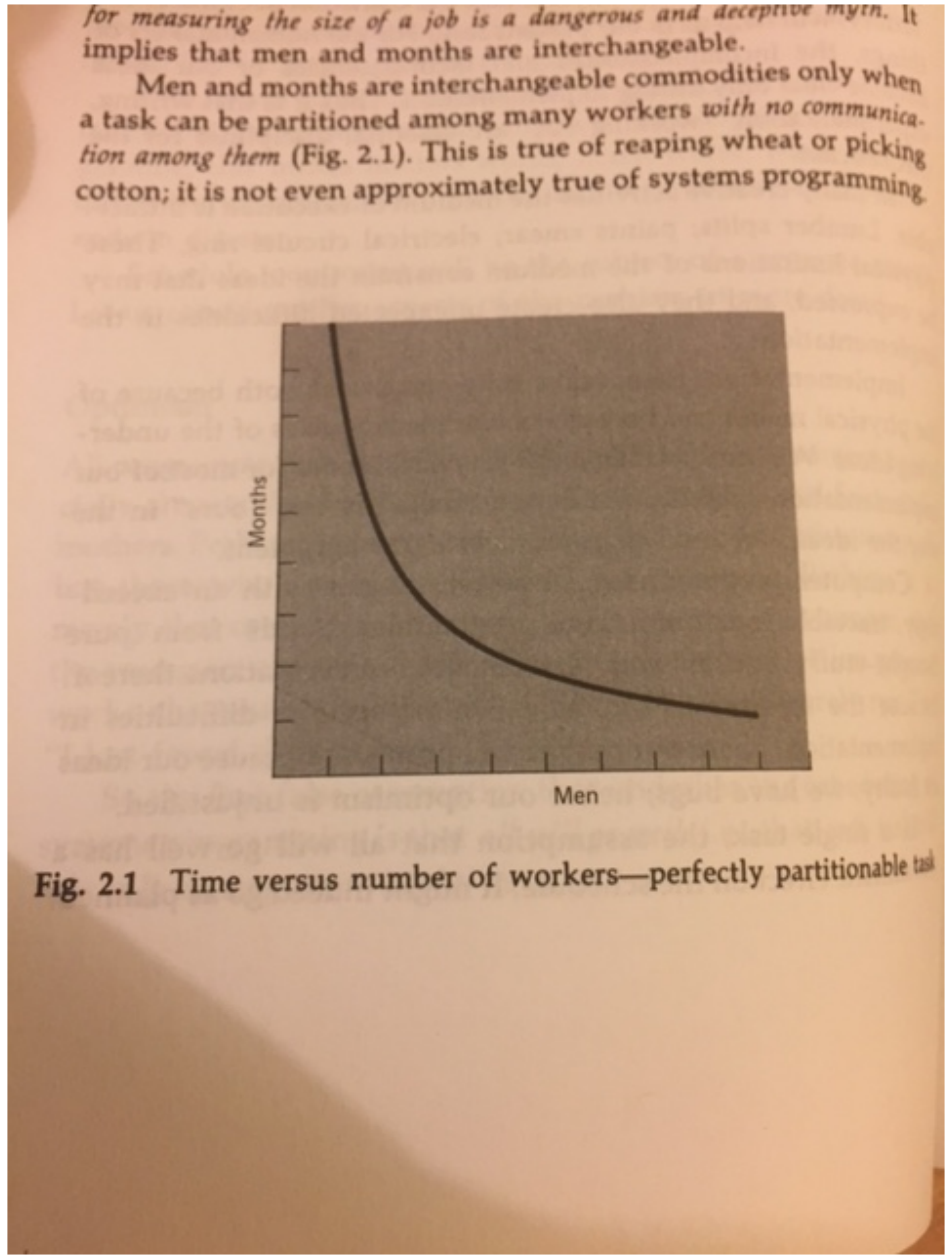

- You must to use "waterfall" project management
- (Gantt charts, etc).
- Most appropriate for "*known*" builds
- eg house…
- Focuses on immediate issues and critical path
- Use it to make sure that decisions are made, and interfaces understood and to understand progress

- However, detectors are very much a hi-tech item …
- … agile technique much better reflects actual work methodology
- You don't know what exactly you will achieve during R&D
- Be aware that this might better reflect day-day work

- 3rd method: "successive principle".
- Focus on the goal, and work back from these.
- Use non-experts to evaluate schedule given by experts …

- Making progress and getting things done is complex in big projects …

- From "the mythical man month"

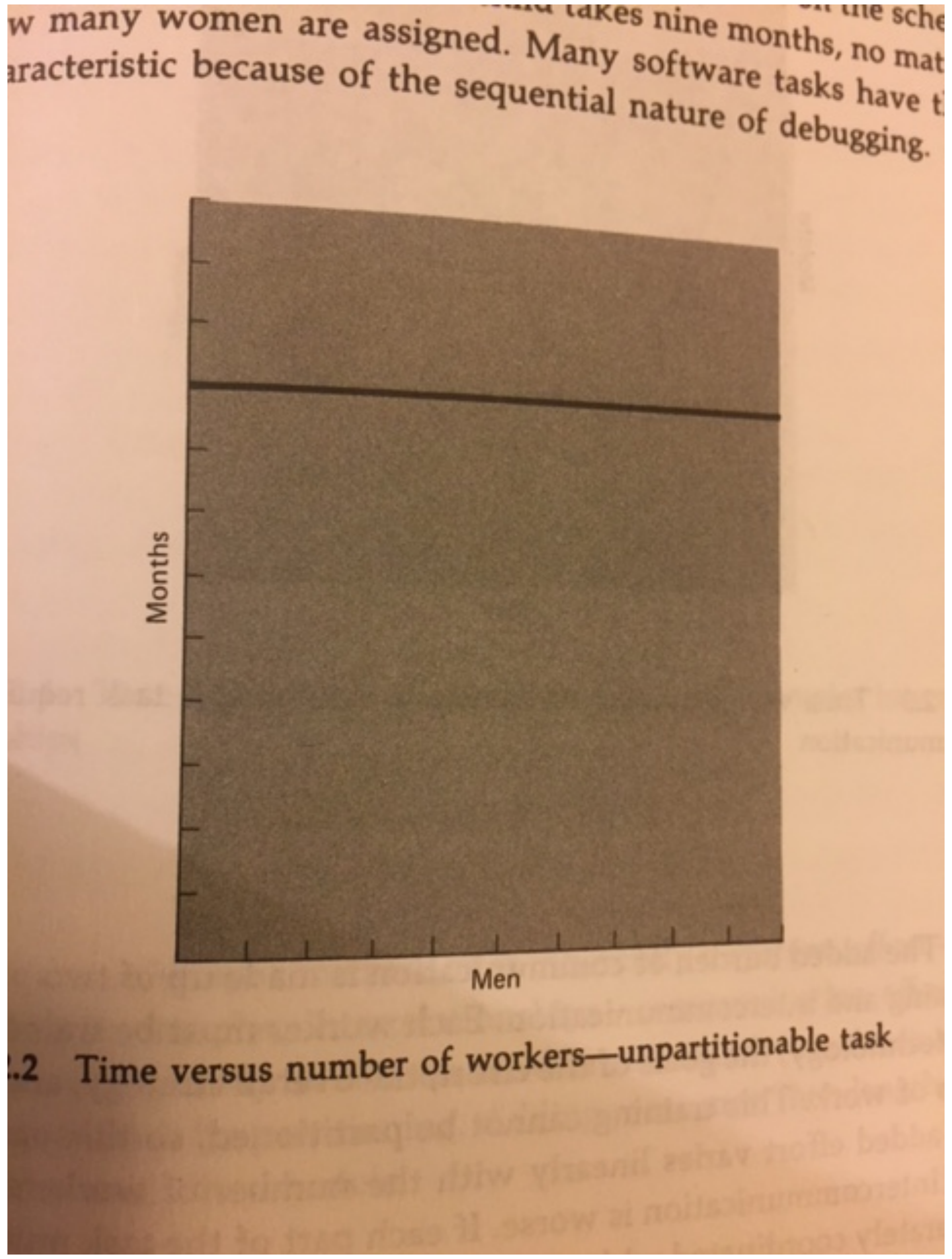


*for measuring the size of a job is a dangerous and deceptive myth.* It implies that men and months are interchangeable.

Men and months are interchangeable commodities only when a task can be partitioned among many workers *with no communication among them* (Fig. 2.1). This is true of reaping wheat or picking cotton; it is not even approximately true of systems programming.



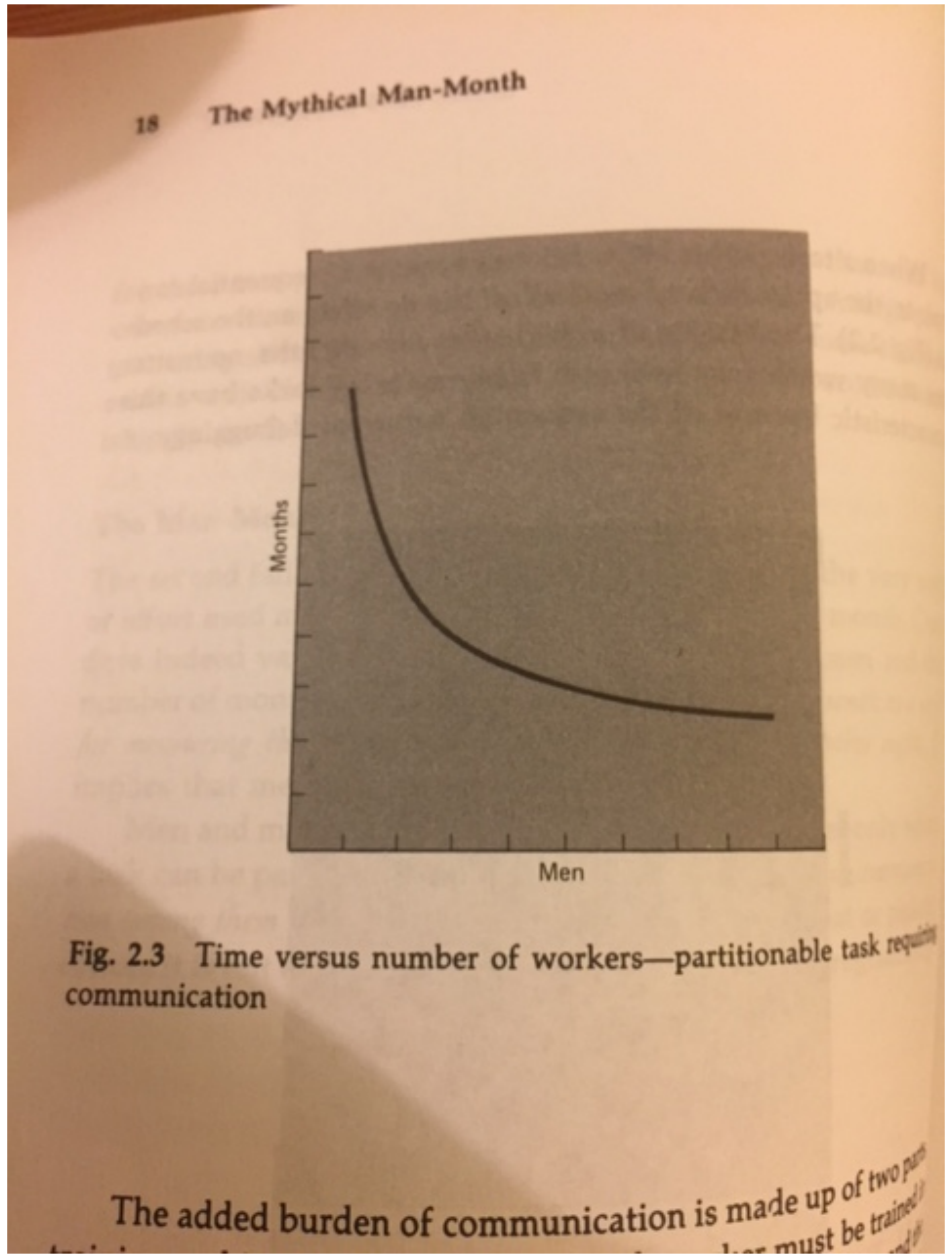
Fig. 2.1 Time versus number of workers—perfectly partitionable task



w many women are assigned. Many software tasks have t aracteristic because of the sequential nature of debugging.



.2 Time versus number of workers—unpartitionable task



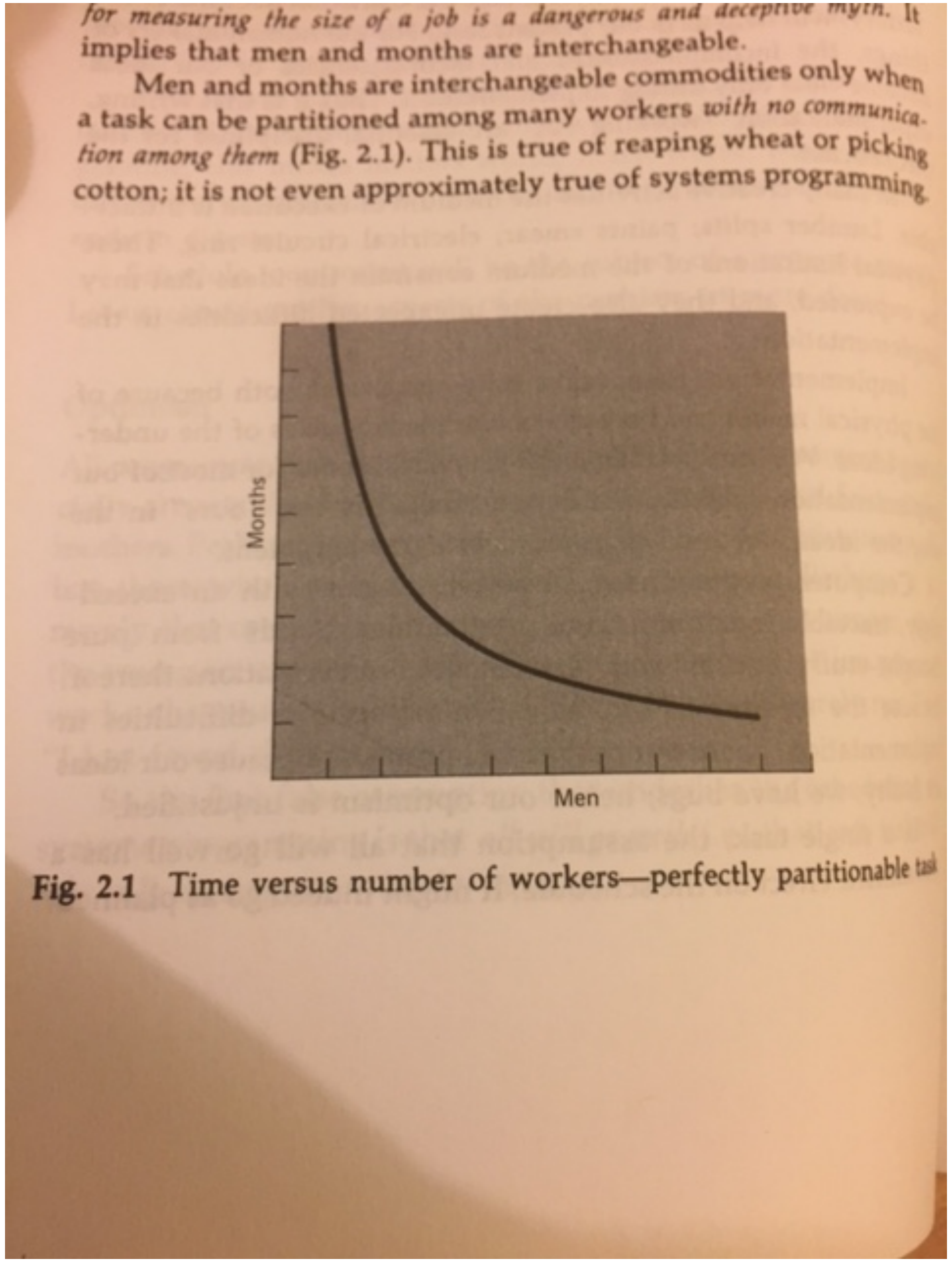
18 The Mythical Man-Month



Fig. 2.3 Time versus number of workers—partitionable task requiring communication

The added burden of communication is made up of two pa

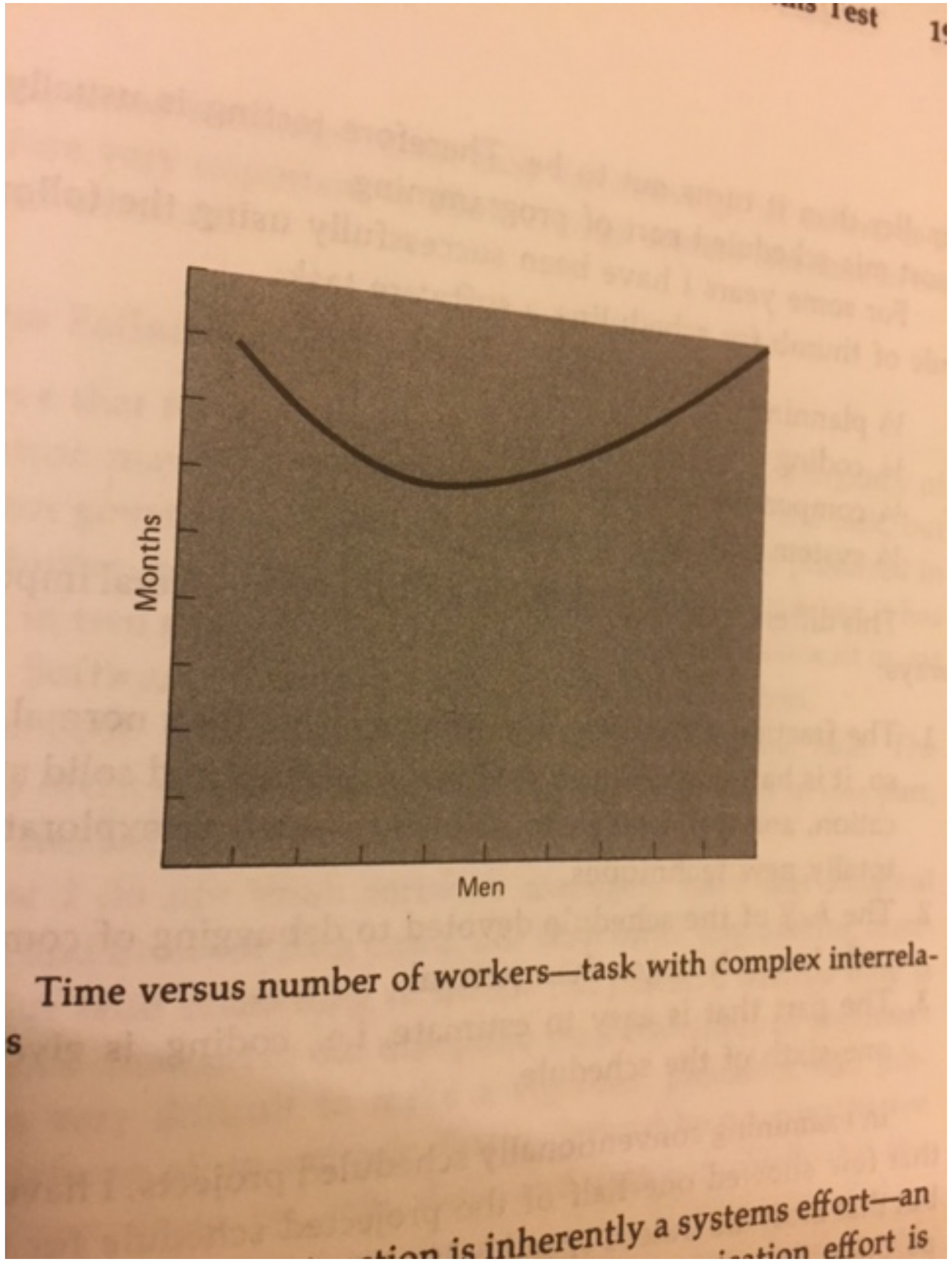
- From "the mythical man month"


*for measuring the size of a job is a dangerous and deceptive myth.* It implies that men and months are interchangeable.

Men and months are interchangeable commodities only when a task can be partitioned among many workers *with no communication among them* (Fig. 2.1). This is true of reaping wheat or picking cotton; it is not even approximately true of systems programming.



**Fig. 2.1** Time versus number of workers—perfectly partitionable tas


Test 19



Time versus number of workers—task with complex interrela-

tion is inherently a systems effort—an

ation effort is

# Teamwork …

- A pleasant working atmosphere …
- A working culture that is open to diversity
- Creativity …

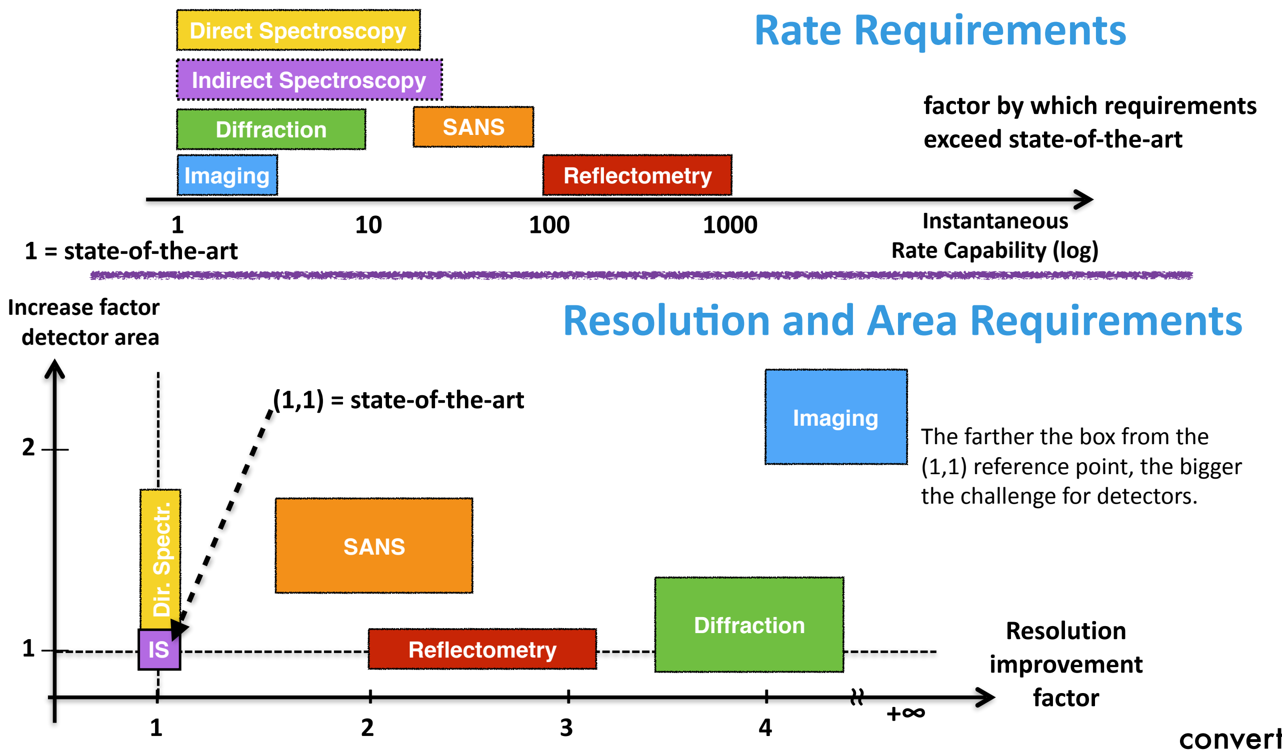
EUROPEAN SPALLATION SOURCE

# Thoughts …

EUROPEAN SPALLATION SOURCE

- Detector & DAQ development takes time
- Very difficult to go from concept to beam line in less than a decade
- e.g. Multi Grid started 2009/10. On ESS instrument ca. 2024/25
- Detector development time >> Instrument construction time

- This should be our aspiration level for a (every?) decade … :

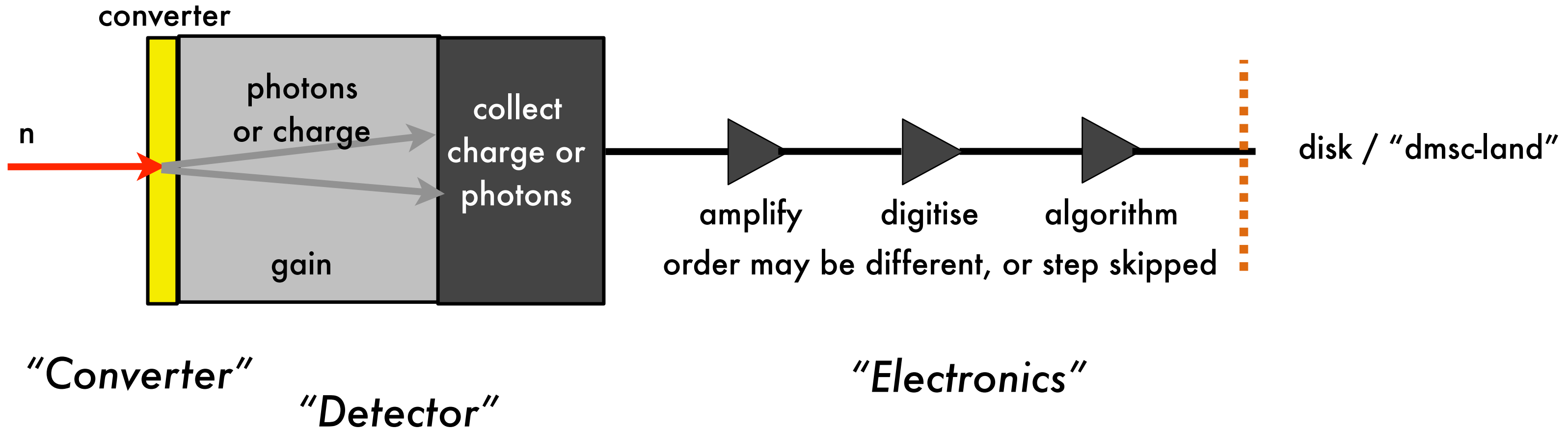



*…and cost improvement of a factor of few …*

- Computing and electronics have become ubiquitous and very cheap
- Future detectors will be much more designed around electronics
- Don't divide DAQ &detector efforts

- Simulation will play a much bigger role in design

- Specialisation and collaboration



# Summary

- Every DAQ system has different requirements: “horses for courses”
- Used ESS as an example for how a data acquisition system is designed
- What do you actually want to do with the DAQ system?
- What is important?

- Optimise your time. Recycle what you can
- You will underestimate the amount of time for changes (NRE).
- Only change what you need to.
- Don’t be afraid to take off the shelf solutions.

- What can go wrong?
- Remember: typically 10 years concept to implementation
- Don’t forget all the engineering factors … not just data transport …

- Make sure that you define what you want to measure clearly and unambigiously
- Publish what you do: too many of the best results remain forgotten and are redone 3-10 years later

- It’s all about people …
- … and how they work with each other

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*Thanks!*

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