

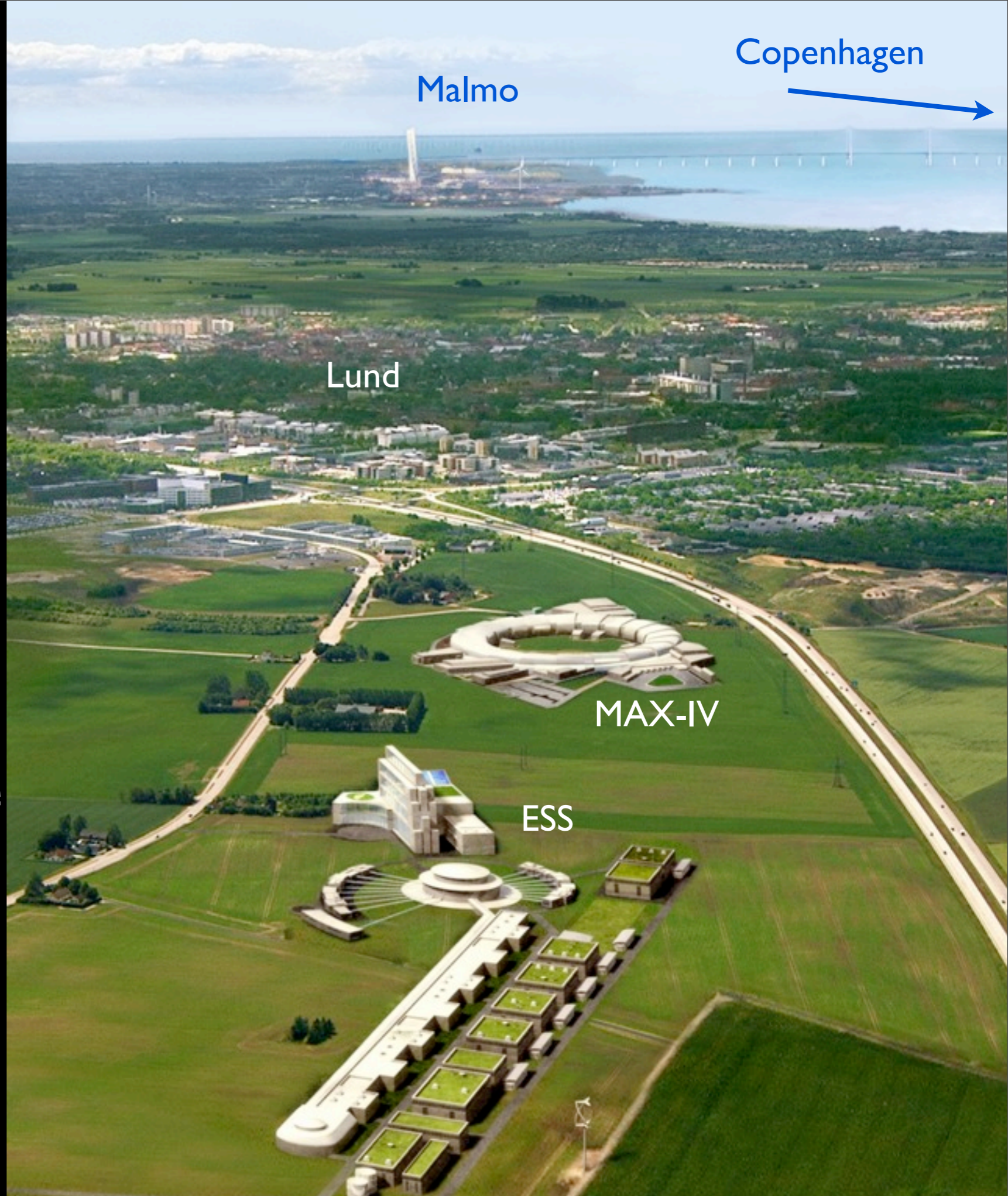


EUROPEAN  
SPALLATION  
SOURCE

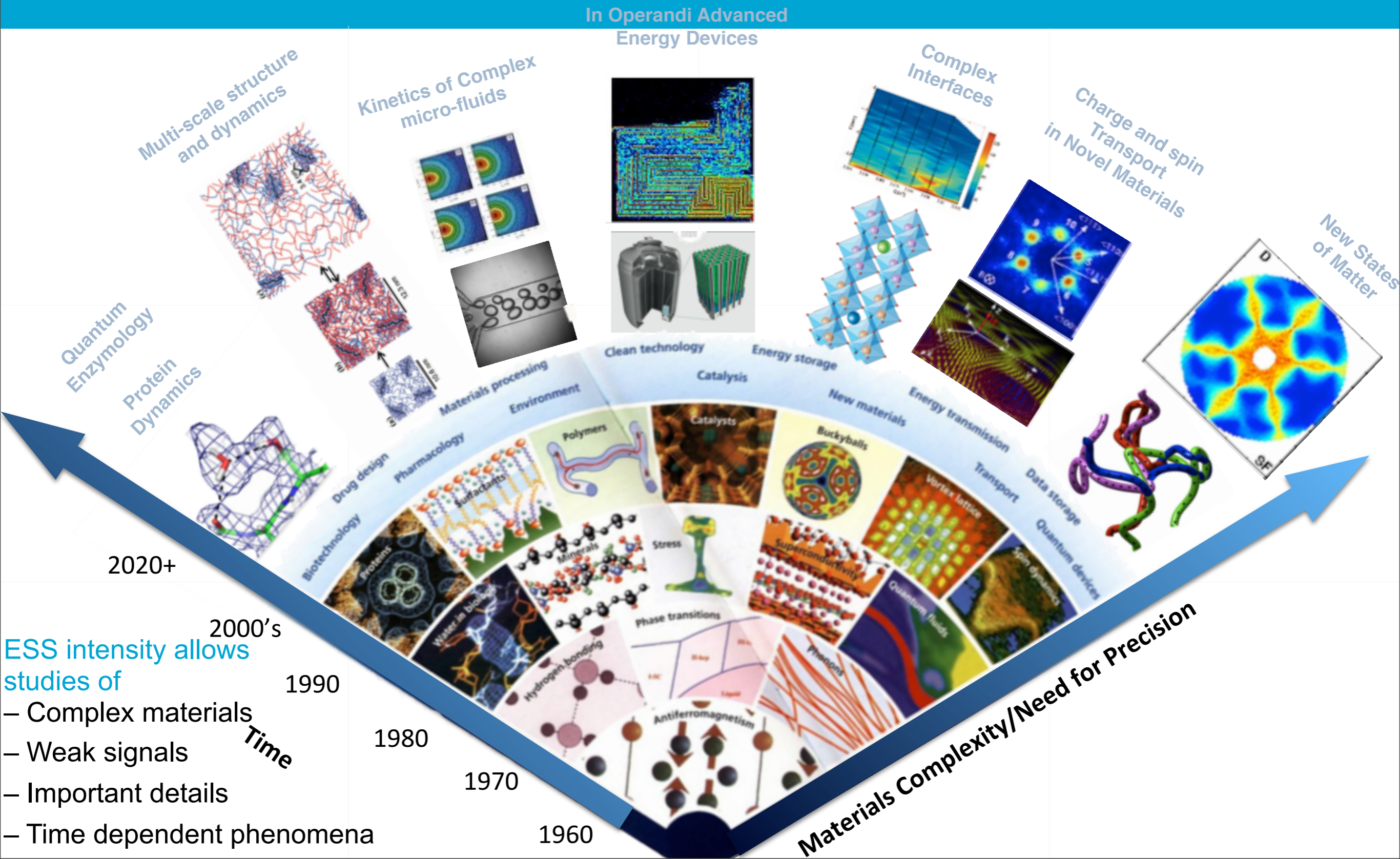
# Neutron Detectors for the European Spallation Source

- Neutron Scattering
- Status of the ESS
- The challenge for detectors
- A snapshot of where we are today

Richard Hall-Wilton  
Detector Group Leader



# Neutron Science Pushes the Boundaries

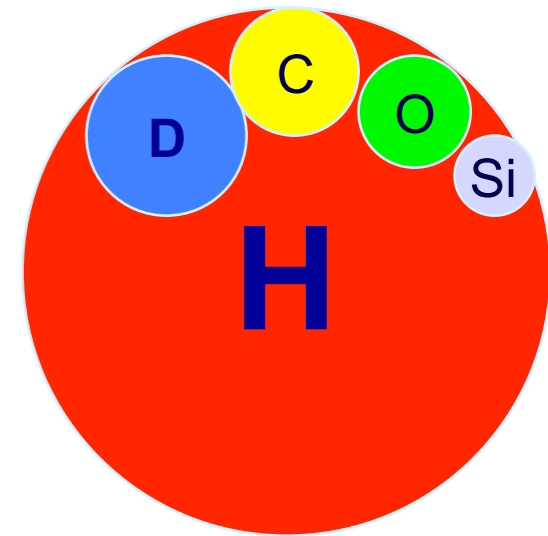


# Why Neutrons?

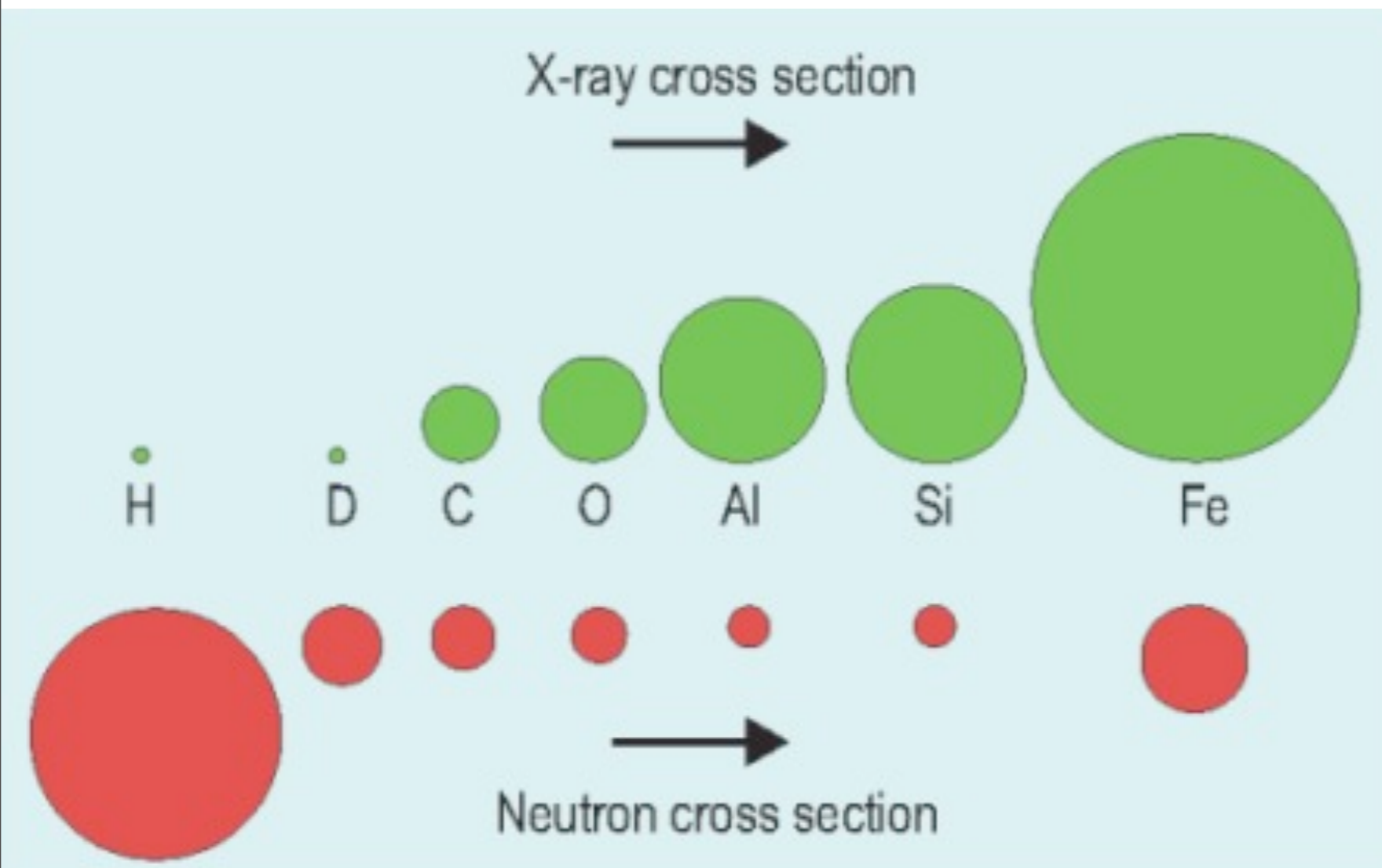
## Neutrons are

- low energy
- non-damaging
- penetrating
- broad wavelength range

- 1) Ability to measure both energy *and* momentum transfer  
Geometry of motion
- 2) Neutrons scatter by a nuclear interaction => different isotopes scatter differently     H and D scatter very differently
- 3) Simplicity of the interaction allows easy interpretation of intensities  
Easy to compare with theory and models
- 4) Neutrons have a magnetic moment



thermal and cold neutrons  
meV  
"with a small m"  
wavelength ca. Å



# Neutrons are special

Charge neutral

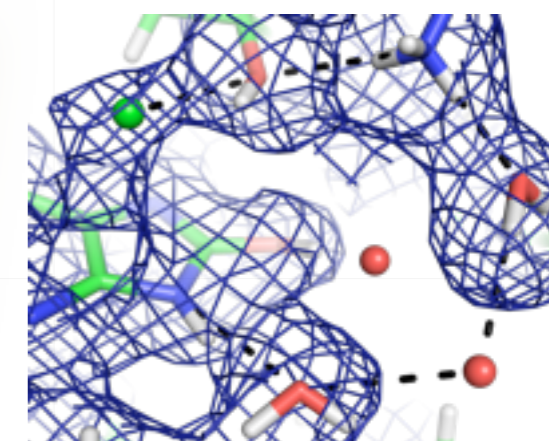
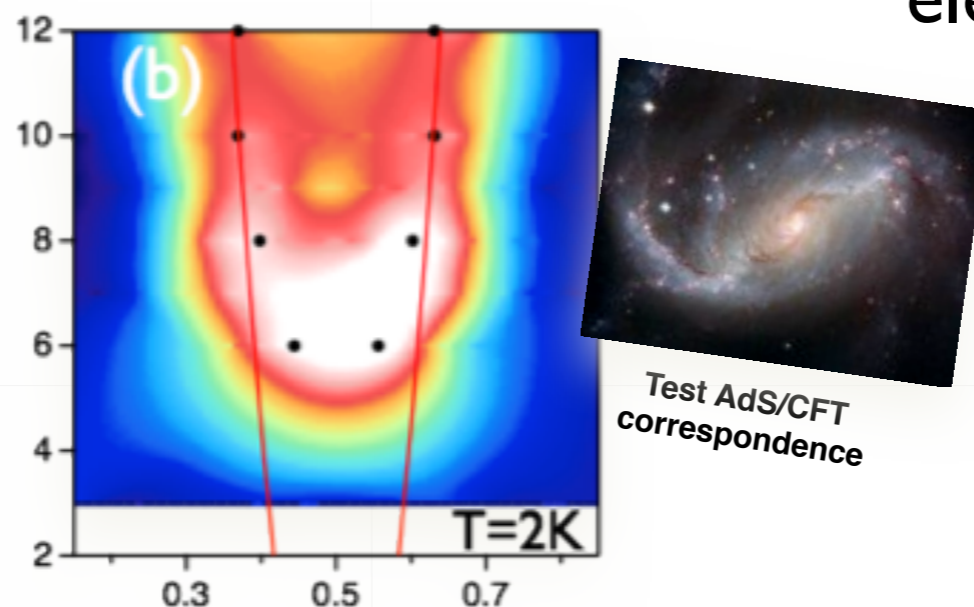
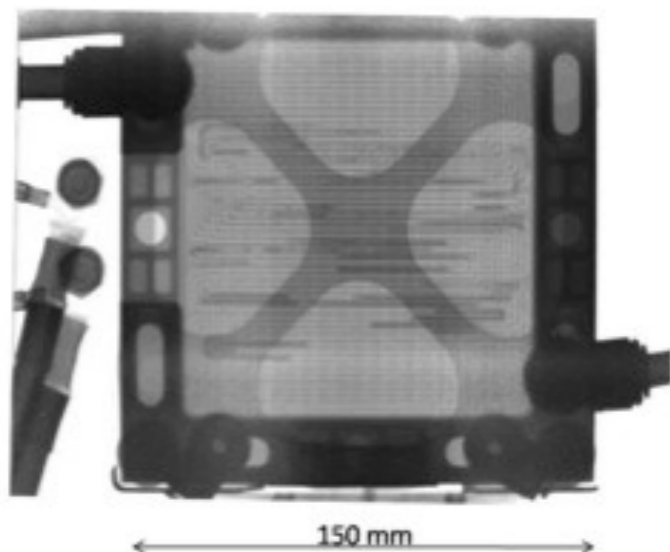
$S=1/2$  spin

Nuclear scattering

Deeply penetrating

Directly probe magnetism

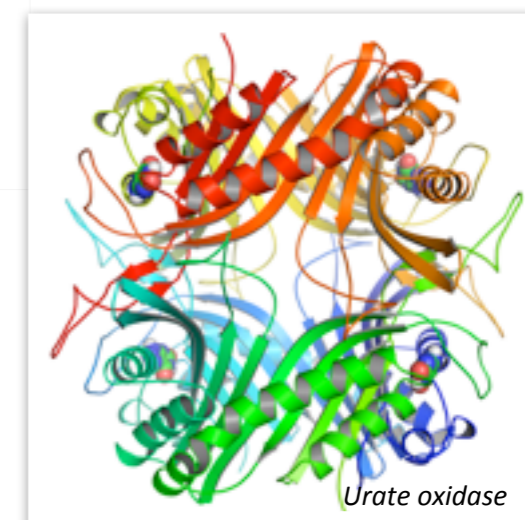
Sensitive to light elements and isotopes



Solve the puzzle of High-Tc superconductivity

Active sites in proteins

Li motion in fuel cells



Help build electric cars

Efficient high speed trains

Better drugs

# What is the European Spallation Source?



Europe 2019: The European Spallation Source (<5 MW)

Lund, Sweden



Japan 2008:  
JPARC (<1MW)



USA 2006:  
SNS (<1.4 MW)

- One of Europe's largest planned research infrastructures. 1.843 B€.
- For physics, chemistry, life science and more.
- For academia and industry.
- 17 countries plan and build together.
- The world's most powerful linear proton accelerator, and the most powerful source of neutrons for science.
- Ground-break/site preparations June 2014.
- Neutrons & first instruments by the end of the decade.
- ~ 500 employees; ~2500 users/yr.

# European Joint Ownership



**Sweden,  
Denmark and Norway:  
50% of construction  
15-20% of operations**



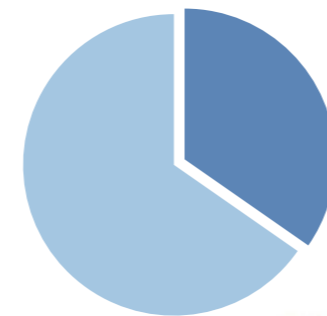
**European partners:  
50% of construction**

**Plus discussions with countries that might join after construction start**

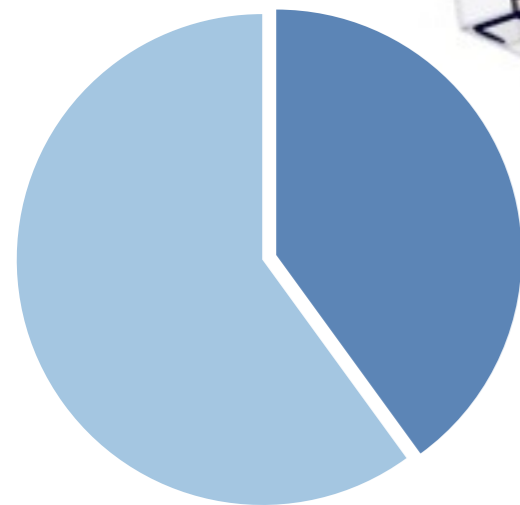
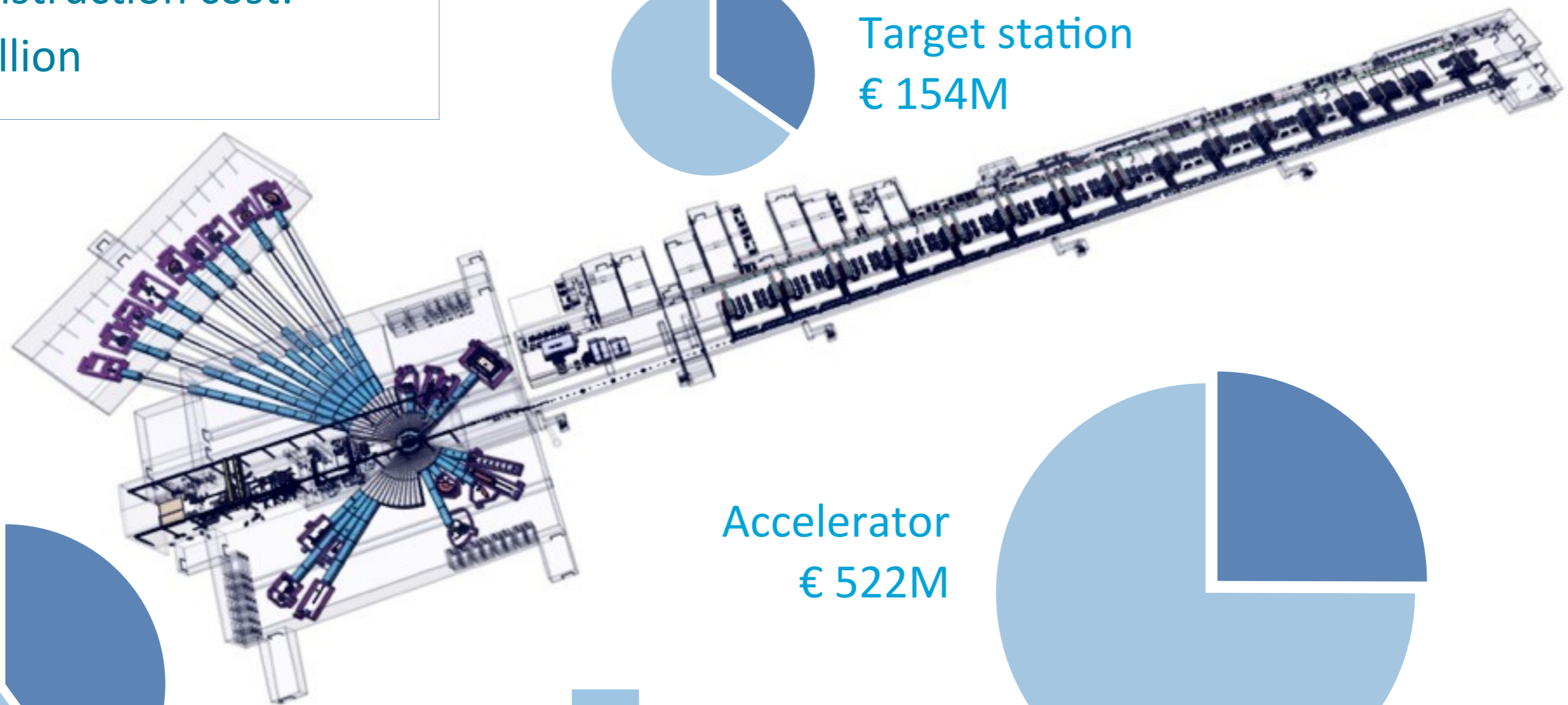
Belgium, Finland, Israel, Portugal, Russia, Singapore.....?

# Layout, Planning & Budget & In-kind potential

Total construction cost:  
€ 1,84 billion



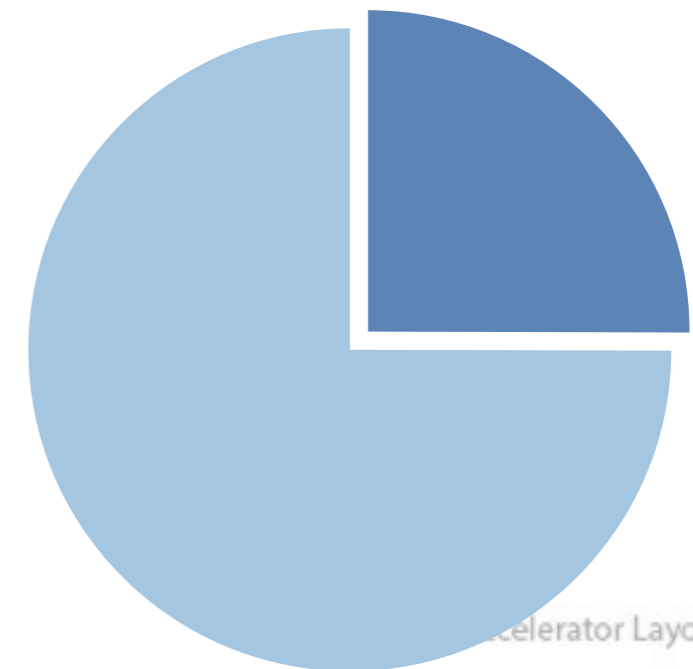
Target station  
€ 154M



Instruments  
€ 350M

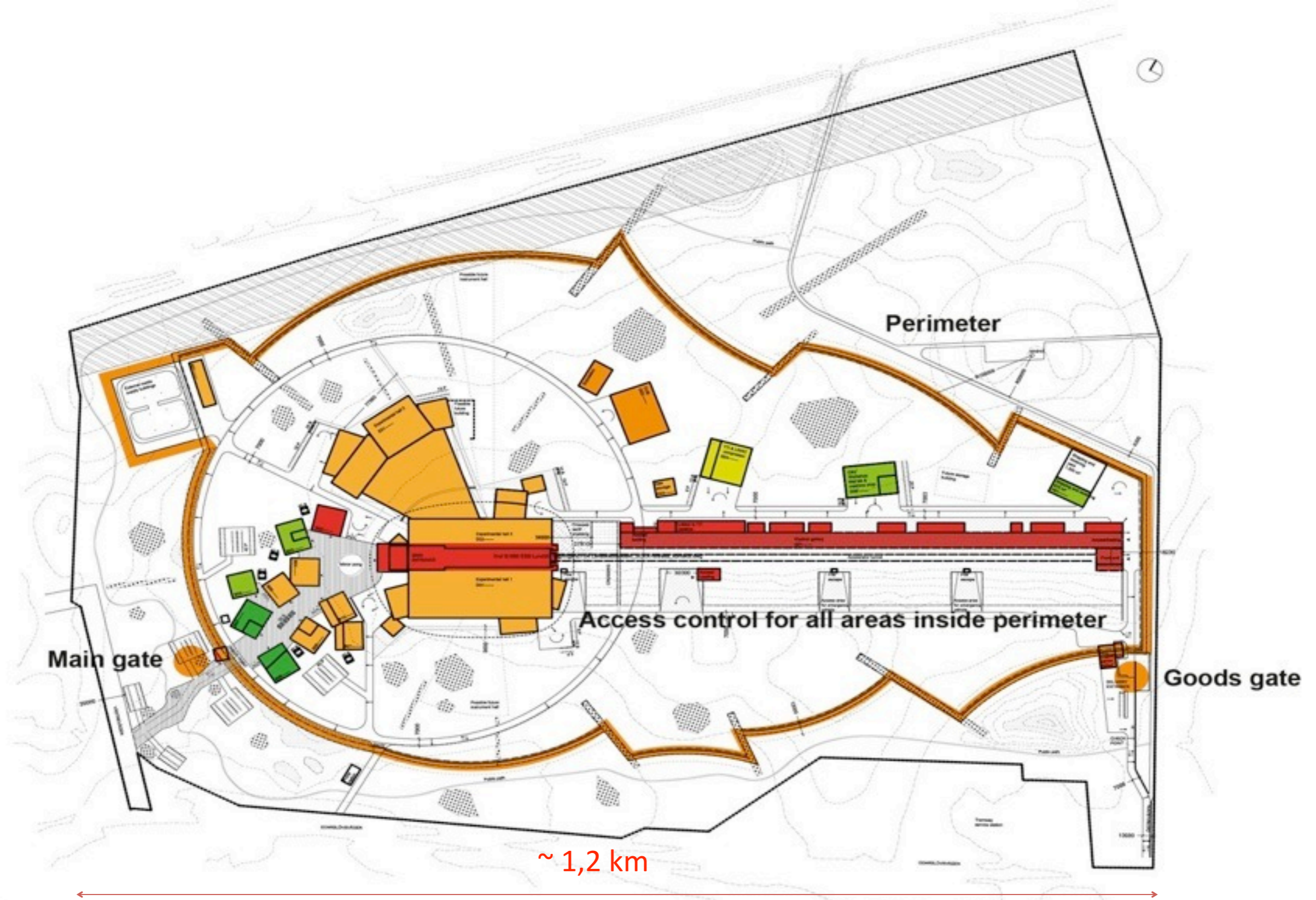


Accelerator  
€ 522M



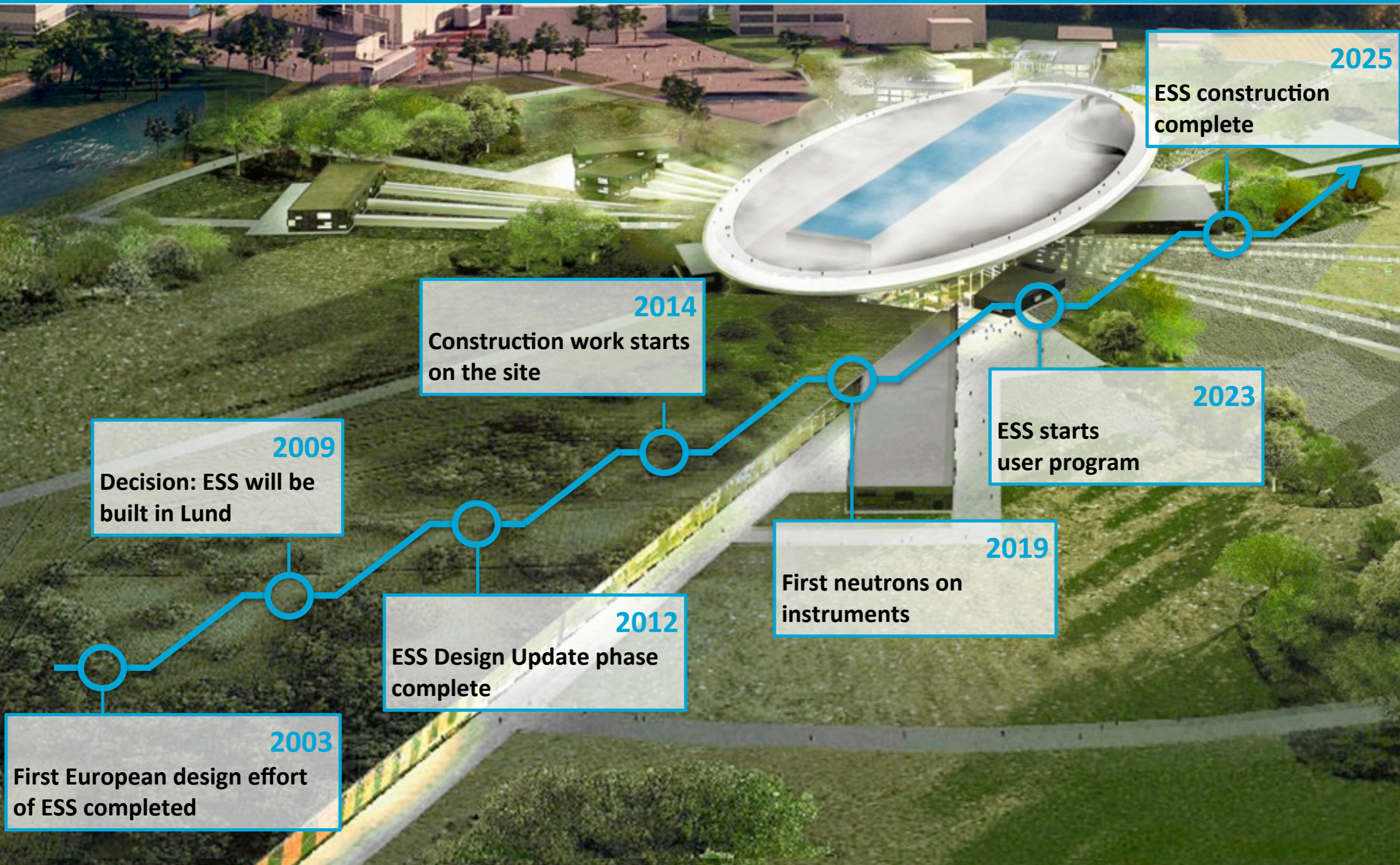
Accelerator Layout Nov 22, 2012

# The ESS Site Covers 75 Hectares

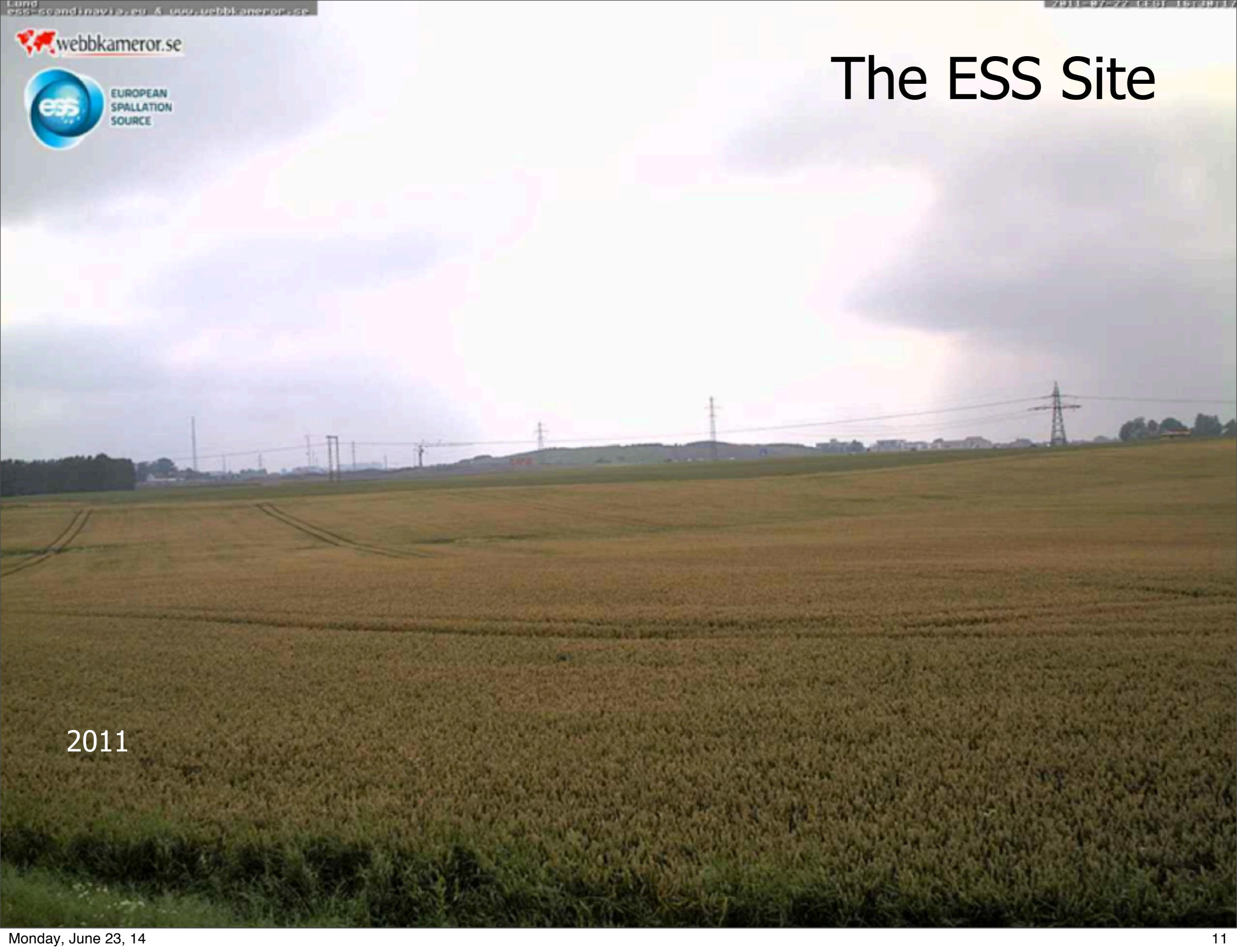




# The road to realizing the world's leading facility for research using neutrons



# The ESS Site



2011

# The ESS Site



23 October 2012



# Current status

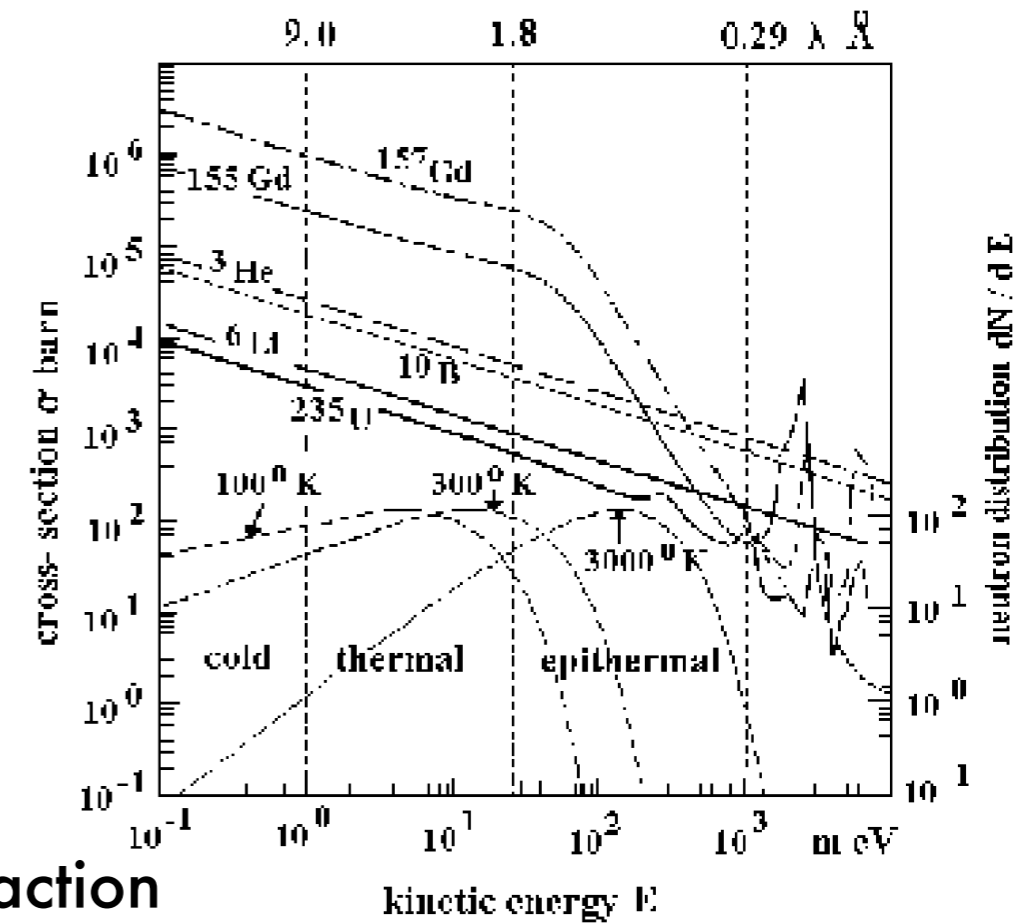
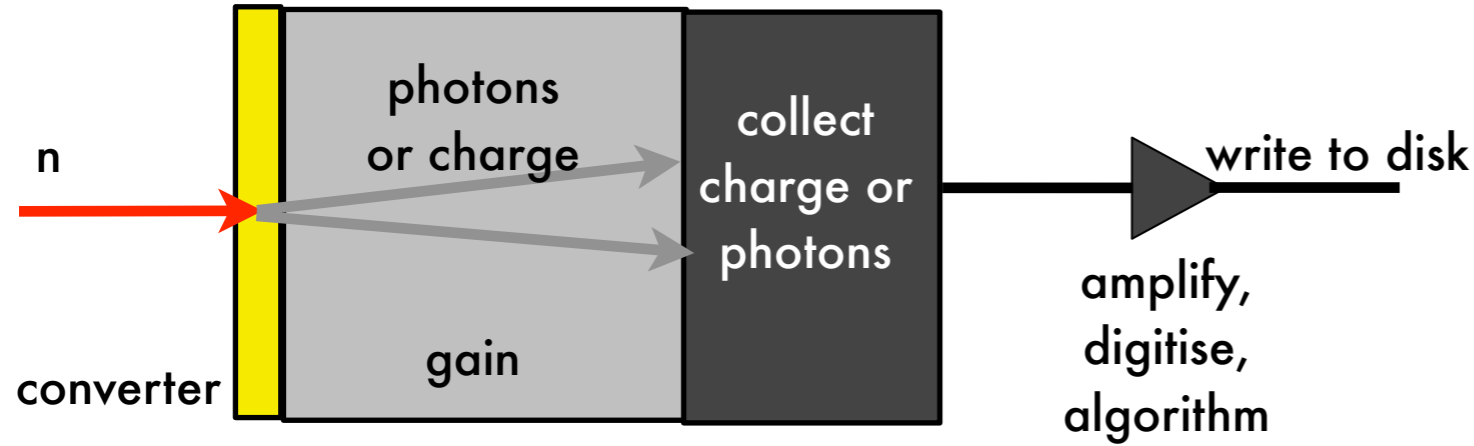
- 3 instrument concepts have entered Construction Phase 1 – preliminary engineering design.
- 16 new instrument concepts have been proposed and reviewed by our independent advisory bodies, the STAPs and the SAC. The SAC will soon be making a recommendation on which ones to build and in what order.
- The construction licensing process is in its end stages.
- National funding negotiations are nearly finished; countries are committed.
- The archaeological survey of the land has been completed, and test piling etc. is on-going.
- Site-preparation has started; contractors on-site
- Official ground breaking end of the summer!



- Lets start by looking back to pre-history ...
- ... where were we in 2011 ... start of the design update ...

# Basic Principles of Neutron Detectors

- Not possible to directly detect slow neutrons
- Use nuclear reactions to convert neutrons



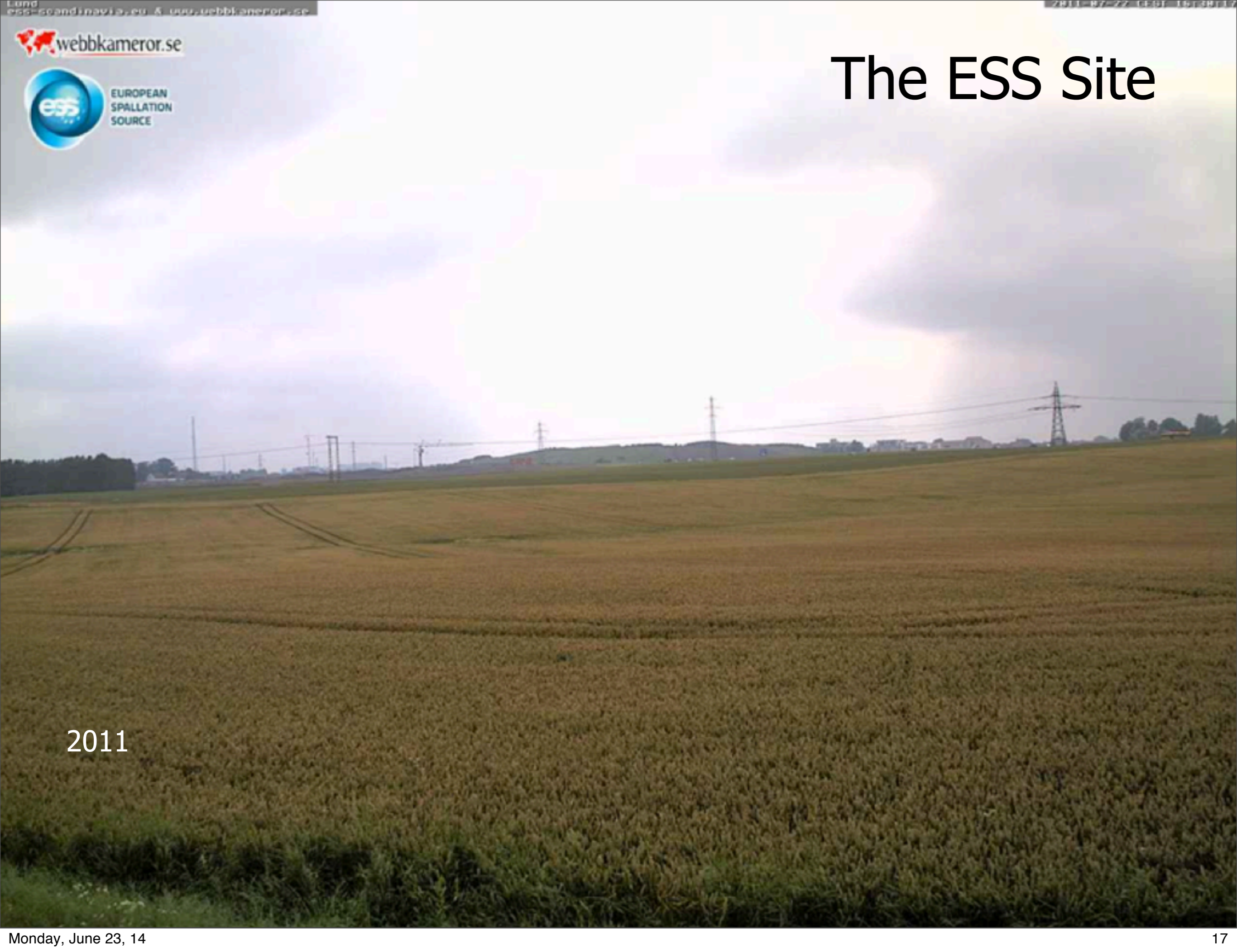
- Count neutrons: all other information lost in nuclear reaction

reaction	energy	particle	energy	particle	energy
$n (^3\text{He}, p) ^3\text{H}$	+0.77 MeV	p	0.57 MeV	$^3\text{H}$	0.19 MeV
$n (^6\text{Li}, \alpha) ^3\text{H}$	+4.79 MeV	$\alpha$	2.05 MeV	$^3\text{H}$	2.74 MeV
93 % $n (^{10}\text{B}, \alpha) ^7\text{Li} + 2.3 \text{ MeV} + \gamma (0.48\text{MeV})$		$\alpha$	1.47 MeV	$^7\text{Li}$	0.83 MeV
7 % $n (^{10}\text{B}, \alpha) ^7\text{Li}$	+2.79 MeV	$\alpha$	1.77 MeV	$^7\text{Li}$	1.01 MeV
$n (^{235}\text{U}, \text{Lfi}) \text{Hfi}$	+ ~ 100 MeV	Lfi	$\leq 80 \text{ MeV}$	Hfi	$\leq 60 \text{ MeV}$
$n (^{157}\text{Gd}, \text{Gd}) e^-$	+ $\leq 0.182 \text{ MeV}$	conversion electron			0.07 to 0.182 MeV

**Table 1: Commonly used isotopes for thermal neutron detection, reaction products and their kinetic energies.**

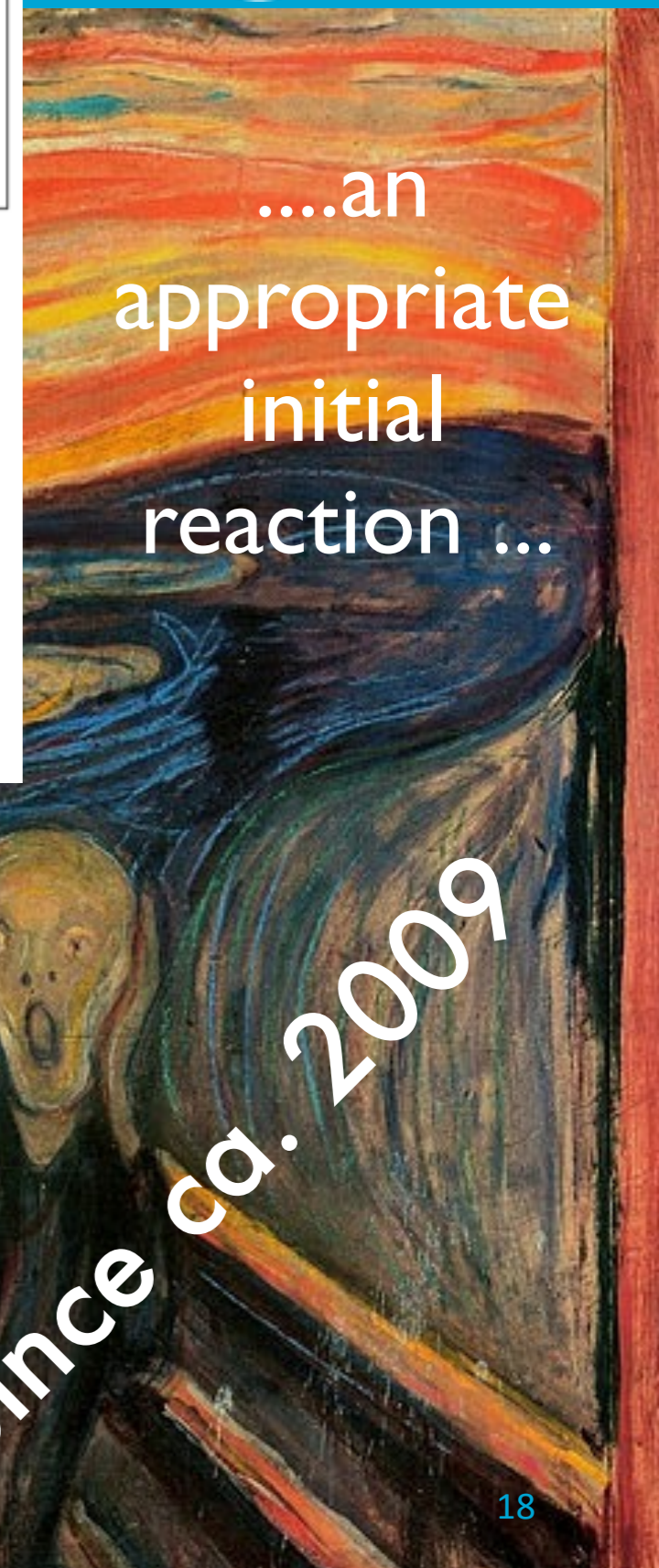
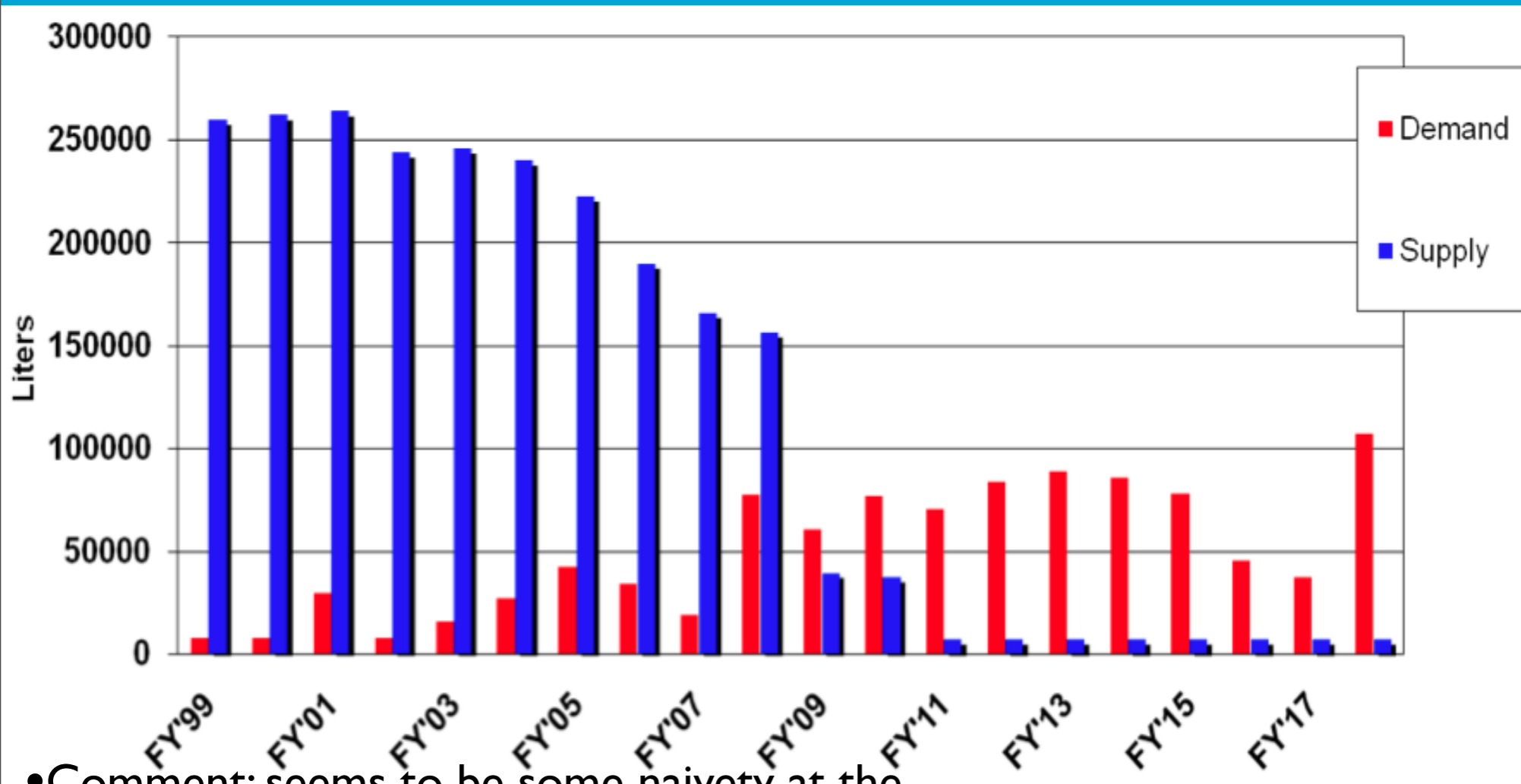
so far ...

# The ESS Site



2011

# Helium-3 Crisis



- 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 instrument classes,  
detectors are a limitation on  
performance**

# Context

Learn the lessons from other facilities

## Collaboration

Home

Collaboration

Working Groups

Publications

News & Events

Imprint

### Participating Facilities

ESS	European Spallation Source, Sweden
FRM II	Forschungs-Neutronenquelle Heinz Maier-Leibnitz, Germany
HZB	Helmholtz Zentrum Berlin, Germany
ILL	Institut Max von Laue – Paul Langevin, France
ISIS	Science and Technology Facilities Council, UK
JCNS	Jülich Centre for Neutron Science, Germany
J-PARC	Japan Proton Accelerator Research Complex, Japan
NIST	Centre for Neutron Research, USA
ORNL	Neutron Science Directorate, Oak Ridge National Laboratory, USA

new: plus PSI

### Coordination

K. Zeitelhack, FRM II, GER; E-Mail: [✉ karl.zeitelhack@frm2.tum.de](mailto:karl.zeitelhack@frm2.tum.de)

### Working Group Coordination

Scintillation detectors: N.J. Rhodes, STFC, UK; E-Mail: [✉ nigel.rhodes@stfc.ac.uk](mailto:nigel.rhodes@stfc.ac.uk)

B10 – detectors: B. Guerard, ILL, France; E-Mail: [✉ guerard@ill.fr](mailto:guerard@ill.fr)

BF3 – detectors: T. Wilpert, HZB, GER; E-Mail: [✉ wilpert@helmholtz-berlin.de](mailto:wilpert@helmholtz-berlin.de)

(... but no BF3 detectors for ESS ... safety !!)

ESS cannot cover all technologies

ESS in-house will concentrate on B-10 detectors

Rely on others for Helium-3, Scintillator detectors

ESS will need all 3 detector technologies for the suite as a whole

# Example of Challenges: Rates for Reflectometry

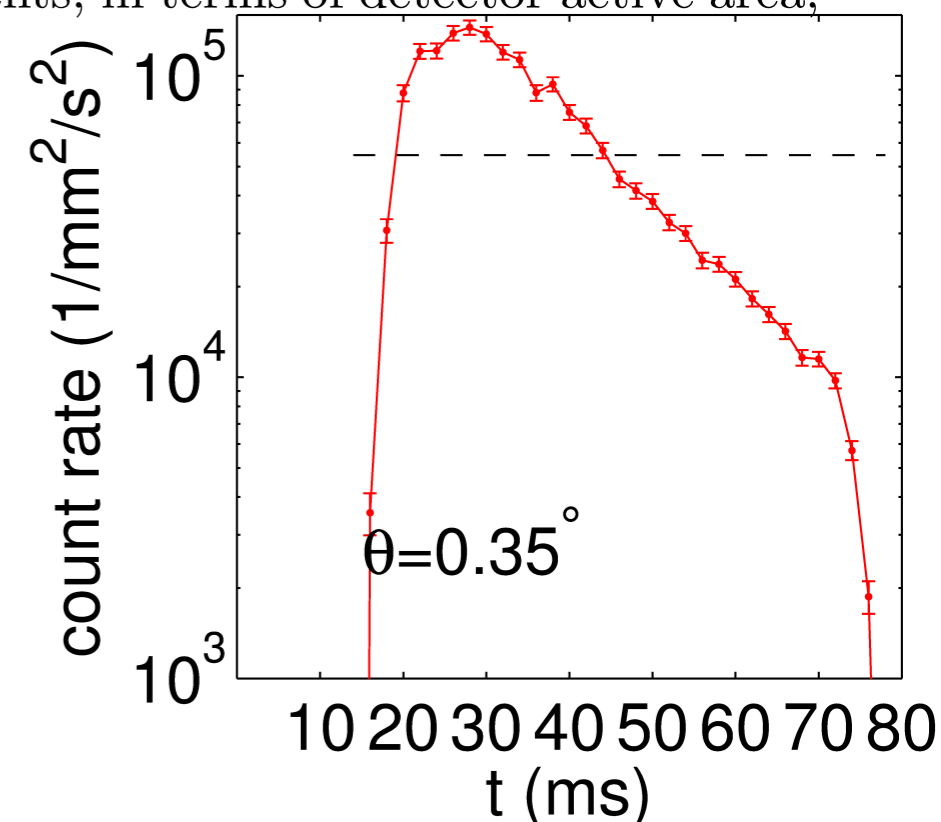
Instrument		area ( $mm \times mm$ )	$\Delta x$ ( $mm$ )	$\Delta y$ ( $mm$ )	global rate ( $s^{-1}$ )	local rate ( $s^{-1}mm^{-2}$ )
ESTIA [2]	min	$500 \times 170$	$\leq 2$	$\geq 2$	-	-
	ideal	$500 \times 500$	$\leq 0.5$	$\geq 0.5$	$\sim 10^7$	$3 \cdot 10^4$
FREIA [3]	min	$500 \times 500$	8	1	-	-
	ideal	$500 \times 500$	$\leq 8$	$\leq 1$	$\sim 5 \cdot 10^5$	$\sim 3.5 \cdot 10^3$
THOR [4]	min	$500 \times 500$	2	-	-	-
	ideal	$500 \times 500$	$\leq 2$	-	-	-
VERITAS [5]	min	$500 \times 500$	2	2	-	-
	ideal	$500 \times 500$	$\leq 2$	$\leq 2$	$5 \cdot 10^5$	$5 \cdot 10^2$

Table 1: Detector requirements, for both ideal-world and minimal requirements, in terms of detector active area, spatial resolution, global and local rates for reflectometer proposals at ESS.

(preliminary)

Factor >100-1000 higher than  
state-of-art detectors today

NEUTRONS@ESS: RATE IS AS BIG A  
PROBLEM AS HELIUM-3 AVAILABILITY



# Helium-3 Update



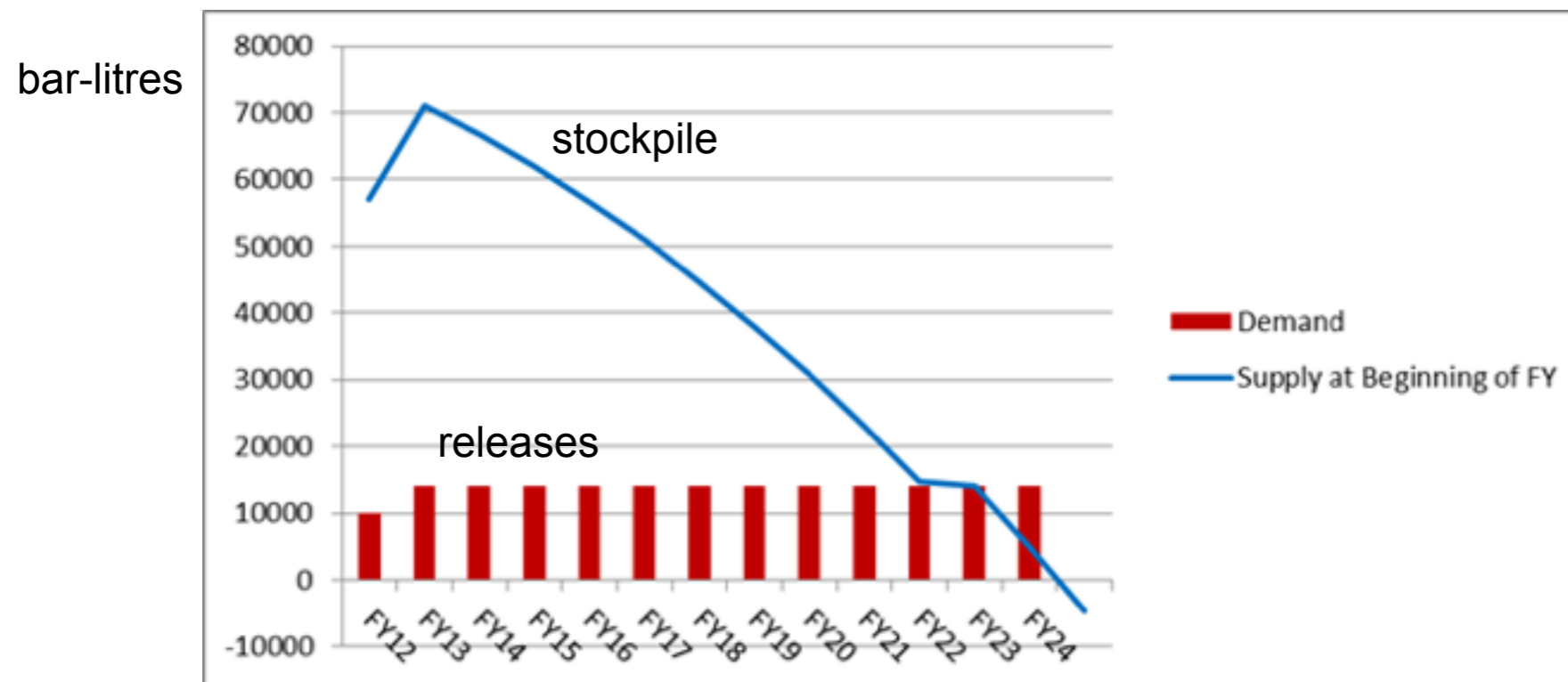
# $^3\text{He}$ Supply Forecast

Update from R. Kouzes, "End of He-3 As We Known It", IEEE NSS 2013

## ➤ Current intent for U.S. $^3\text{He}$ supply

- About 10k liter/year allocation for government use
- About 4k liter/year for auction \*\*\* this is what we can bid for \*\*\*
- About 10k liters added annually (diminishing)
- Supply is gone in ~2024

## ➤ DOE is relying on industry to develop new supply















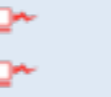














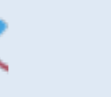











































Plot From Jehanne Gillo, DOE Office of Nuclear Physics, Dec 2012









# Detector Requirements and Strategy



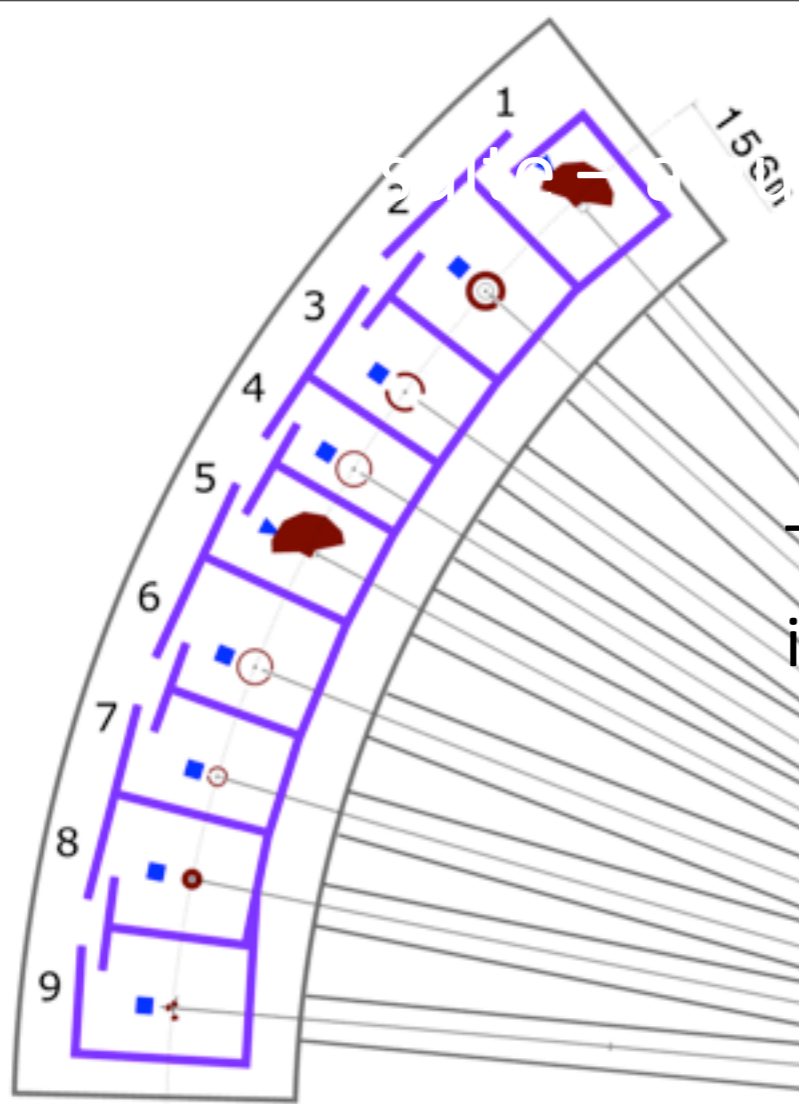
# Science Drivers for the Reference Instrument Suite from the Technical Design Report

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	

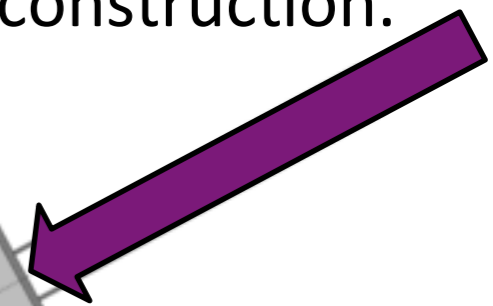
	life sciences		magnetism & superconductivity
	soft condensed matter		engineering & geo-sciences
	chemistry of materials		archeology & heritage conservation
	energy research		fundamental & particle physics

# TDR Reference Suite of Instruments



Wide-Angle Spin Echo  
 Horizontal Reflectometer  
 Broad-Band High Flux SANS  
 High-Resolution Spin Echo

These instruments are gradually being replaced by instrument concepts selected for construction.

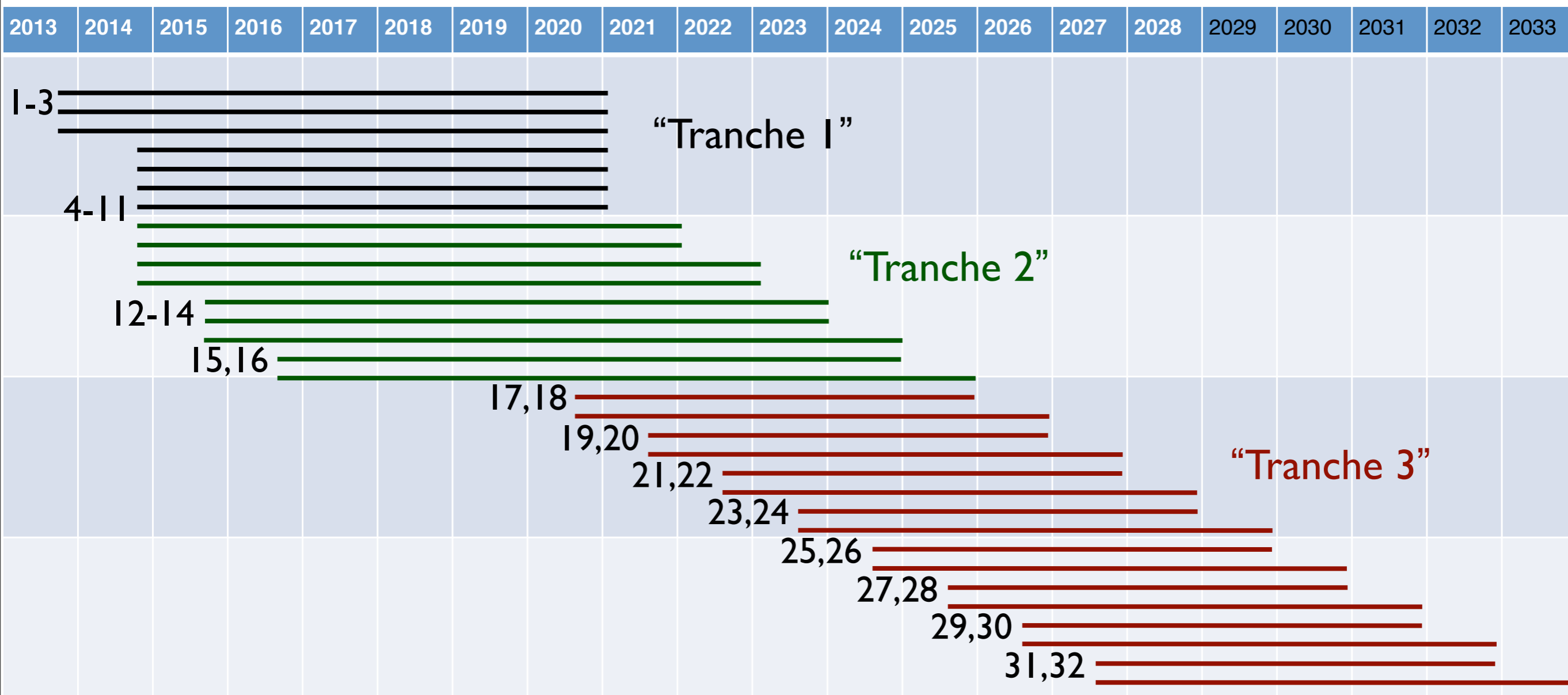


1. Cold Chopper Spectrometer
2. Backscattering Spectrometer
3. Materials Science & Engineering Diffractometer
4. Thermal Powder Diffractometer
5. Thermal Chopper Spectrometer
6. Extreme Conditions Instrument
7. Single-Crystal Magnetism Diffractometer
8. Cold Crystal-Analyzer Spectrometer
9. Macromolecular Diffractometer

Multi-Purpose Imaging  
 Bi-Spectral Powder Diffractometer  
 Vibrational Spectroscopy  
 Fundamental & Particle Physics

General-Purpose Polarized SANS  
 Surface Scattering  
 Vertical Reflectometer  
 Bi-Spectral Chopper Spectrometer  
 Pulsed Monochromatic Powder Diffractometer

# Instruments Will Move into Construction a Few at a Time



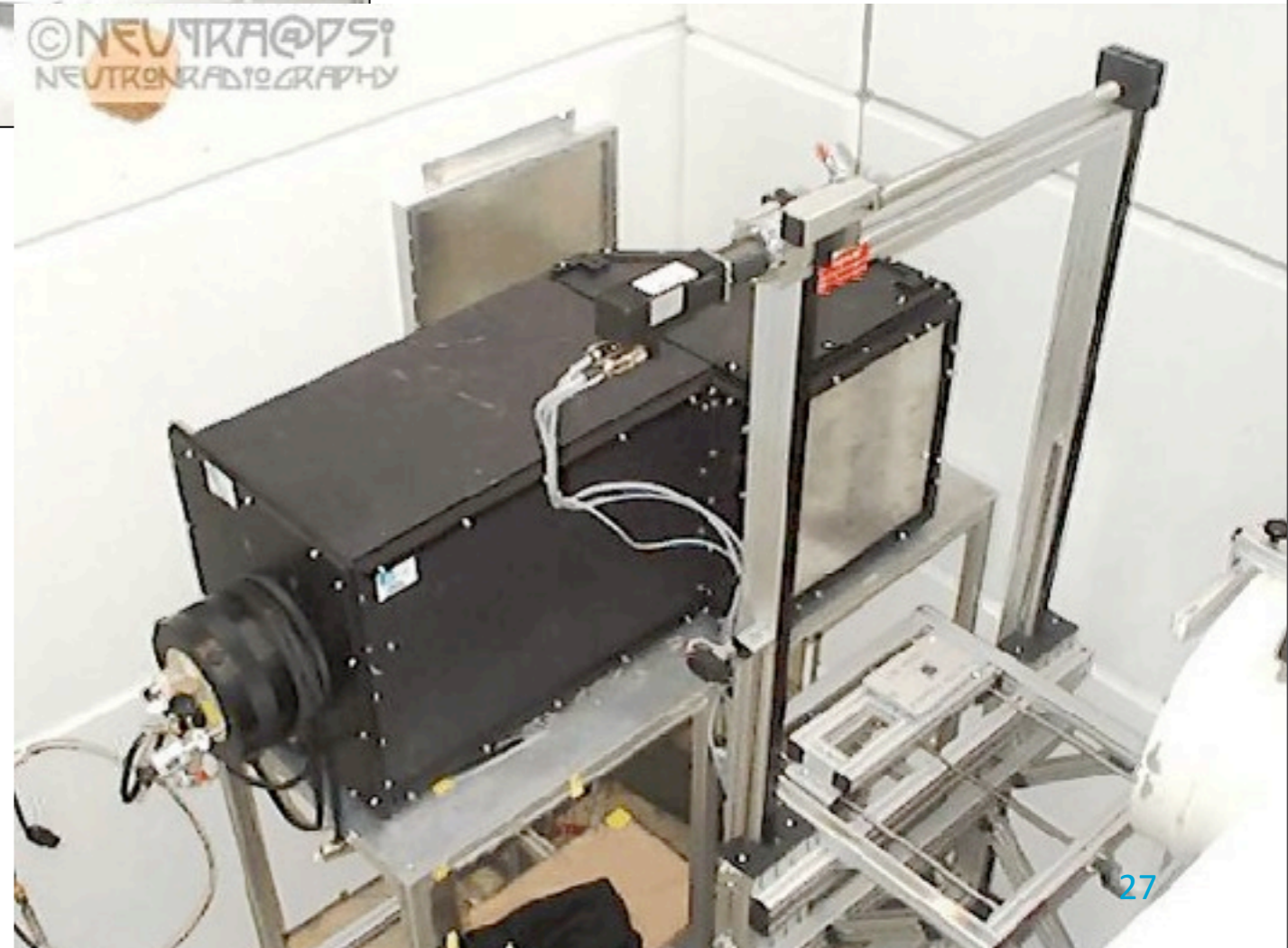


Simply put:

“get it done” (x22++)  
“get it done well”  
Keep’em working



build a technology and service  
group and facilities capable of  
doing this



# Scope: Detector Requirements for Instruments



Instrument	Detector Area [m <sup>2</sup> ]	Wavelength Range [Å]	Time Resolution [μs]	Resolution [mm]
Multi-Purpose Imaging	0.5	1-20	1	0.001 - 0.5
General Purpose Polarised SANS	5	4-20	100	10
Broad-Band Small Sample SANS	14	2-20	100	1
Surface Scattering	5	4-20	100	10
Horizontal Reflectometer	0.5	5-30	100	1
Vertical Reflectometer	0.5	5-30	100	1
Thermal Powder Diffractometer	20	0.6-6	<10	2x2
Bi-Spectral Powder Diffractometer	20	0.8-10	<10	2.5x2.5
Pulsed Monochromatic Powder Diffractometer	4	0.6-5	<100	2 x 5
Material Science & Engineering Diffractometer	10	0.5-5	10	2
Extreme Conditions Instrument	10	1-10	<10	3x5
Single Crystal Magnetism Diffractometer	6	0.8-10	100	2.5x2.5
Macromolecular Diffractometer	1	1.5-3.3	1000	0.2
Cold Chopper Spectrometer	80	1 -20	10	10
Bi-Spectral Chopper Spectrometer	50	0.8-20	10	10
Thermal Chopper Spectrometer	50	0.6-4	10	10
Cold Crystal-Analyser Spectrometer	1	2-8	<10	5-10
Vibrational Spectroscopy	1	0.4-5	<10	10
Backscattering Spectrometer	0.3	2-8	<10	10
High-Resolution Spin Echo	0.3	4-25	100	10
Wide-Angle Spin Echo	3	2-15	100	10
Fundamental & Particle Physics	0.5	5-30	1	0.1
<b>Total</b>	<b>282.6</b>			

• Specifications very varied

• Typically superior to what is presently state-of-the-art at existing sources

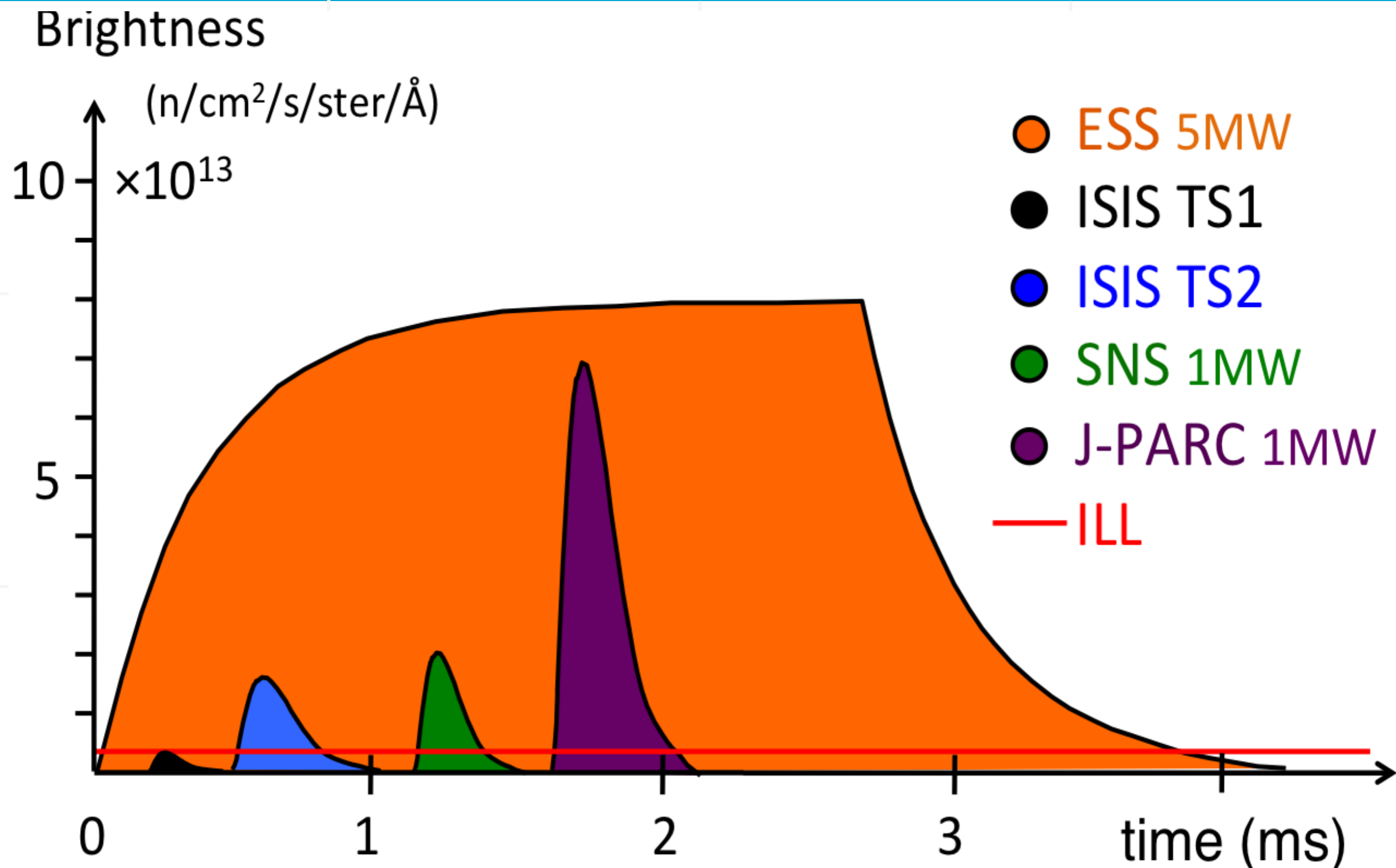
• In many cases, instrument performance dominated by S:B rather than raw specifications here

**COST!**

**RATE!**

• Updated soon with accepted instrument concepts submitted in this proposal round

# ESS is a Long-Pulse Source



# Detector Technologies for Baseline Suite

Instrument	Detector Technology						
	$^{10}\text{B}$ Thin Films		Scintillators		$^3\text{He}$	Micropattern	
	$\perp$	$\parallel$	WLS	Anger		Rate	Resolution
Multi-Purpose Imaging	-	-	-	-	-	o	+
General Purpose Polarised SANS	o	+	-	+	o	+	-
Broad-Band Small-Sample SANS	o	+	-	+	-	+	-
Surface Scattering	o	+	-	+	o	+	-
Horizontal Reflectometer	-	o	-	+	+	o	-
Vertical Reflectometer	-	o	-	+	+	o	-
Thermal Powder Diffractometer	o	+	+	-	-	o	-
Bi-Spectral Powder Diffractometer	o	+	+	-	-	o	-
P-M Powder Diffractometer	o	+	+	-	-	o	-
MS Engineering Diffractometer	o	+	+	-	-	o	-
Extreme Conditions Diffractometer	o	+	+	-	-	o	-
Single Crystal Diffractometer	o	+	+	-	-	o	-
Macromolecular Diffractometer	-	o	o	o	-	+	+
Cold Chopper Spectrometer	+	o	o	-	-	-	-
Bi-Spectral Chopper Spectrometer	+	+	o	-	-	-	-
Thermal Chopper Spectrometer	+	+	+	-	-	-	-
Cold Crystal Analyser Spectrometer	-	o	-	+	+	-	-
Vibrational Spectrometer	-	o	-	o	+	-	-
Backscattering Spectrometer	-	o	-	+	+	-	-
High-Resolution Spin Echo	-	o	-	o	+	+	-
Wide-Angle Spin Echo	-	o	-	o	+	+	-
Fundamental & Particle Physics	-	-	-	-	+	+	+

+ = favoured option  
o = option  
- = disfavoured option

- Most instruments have "He-3-free" options
- Requirement for He-3 significantly reduced

- An array of technologies will be used

- dependent upon a wide range of sources for detectors

Preliminary

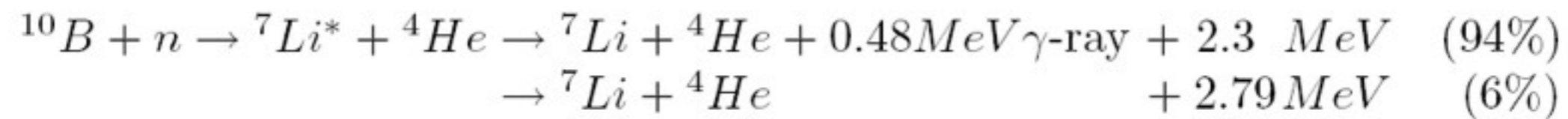
Collaborative and In-Kind needed to fulfill these needs

# The ESS Detector Group

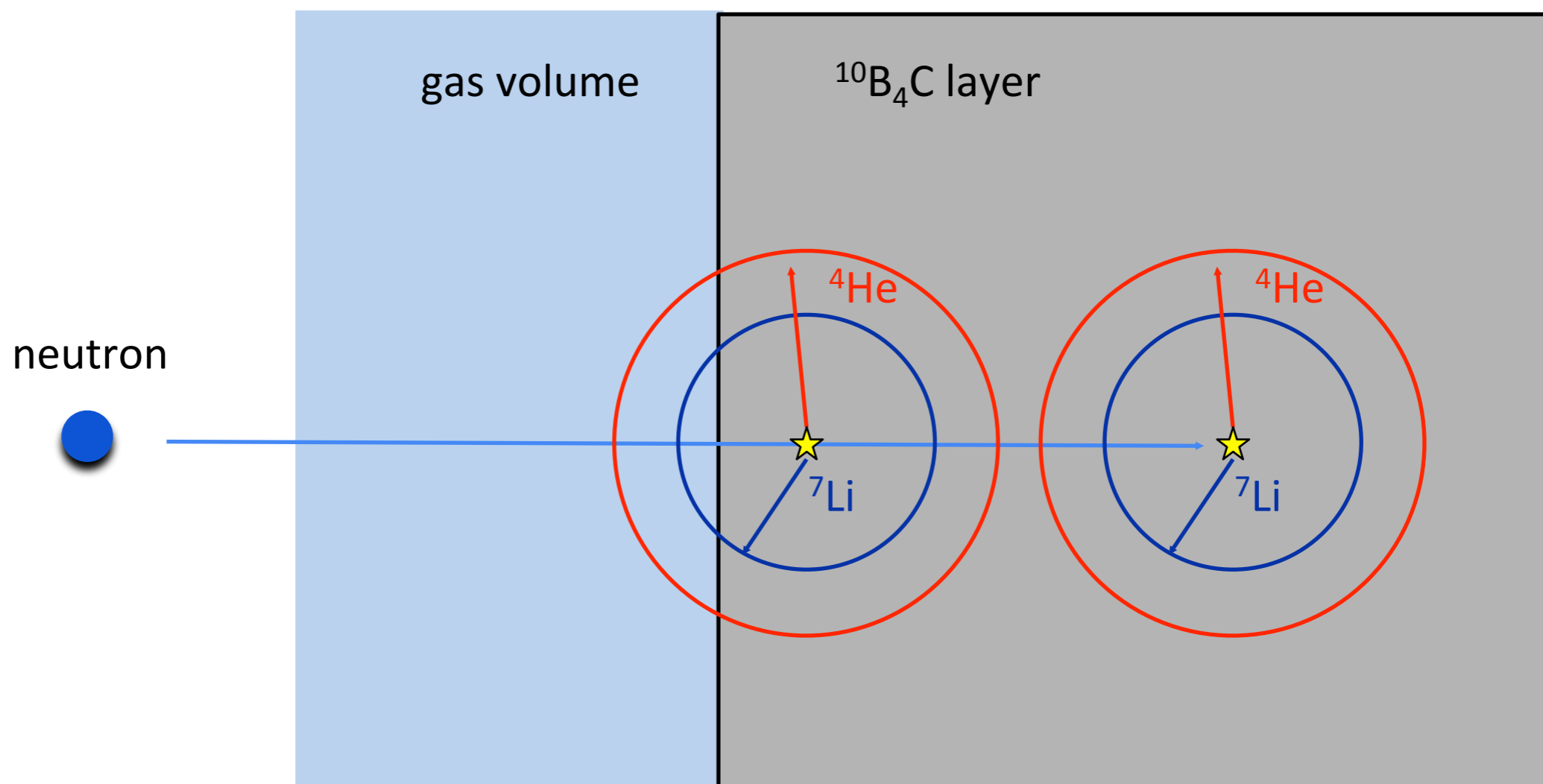


- **“No prototypes installed in ESS”**
- Standards developed to evaluate detectors
- Sufficient expertise to be able to engage with in-kind
  
- In terms of detector technology choices - specialise:
  - B-10 detector effort led from ESS in-house efforts with in-kind partners. ESS as a centre of excellence for the community to support developments where needed
  - All scintillator detectors, He-3 detectors, supplied by collaborating with in-kind partners
  - No BF3 detectors due to safety and performance issues
  
- Detector construction will be a primarily distributed effort, with many partners
- Development of support workshop facilities in Lund to ensure that detector development is efficient and cheap as possible, to support in-kind, and to ensure that detector group builds capacity to be ready for installation, and transmission to commissioning and operations

# $^{10}\text{B}$ -based Neutron Detectors



Efficiency limited at  $\sim 5\%$  ( $2.5\text{\AA}$ ) for a single layer

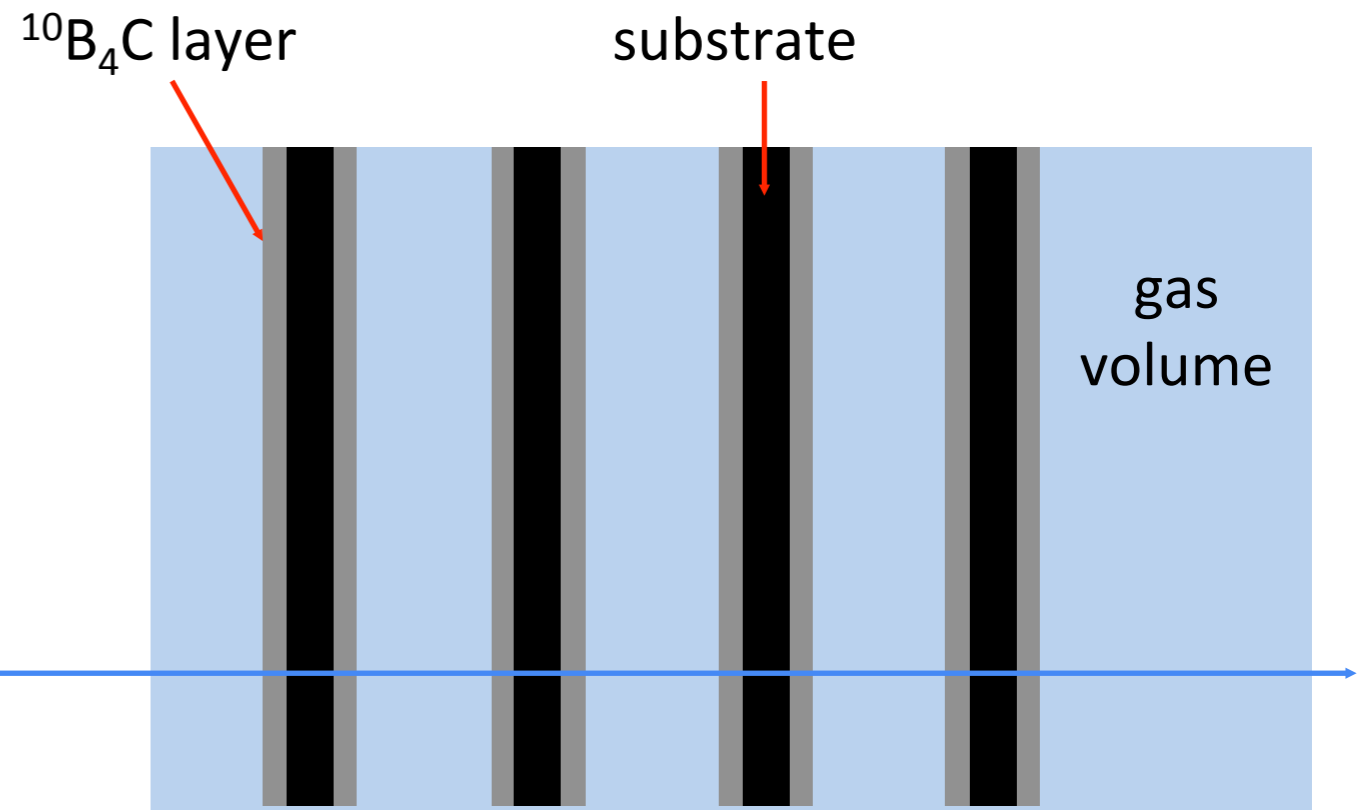


# $^{10}\text{B}$ -based Neutron Detectors

1

Multi layer

neutron

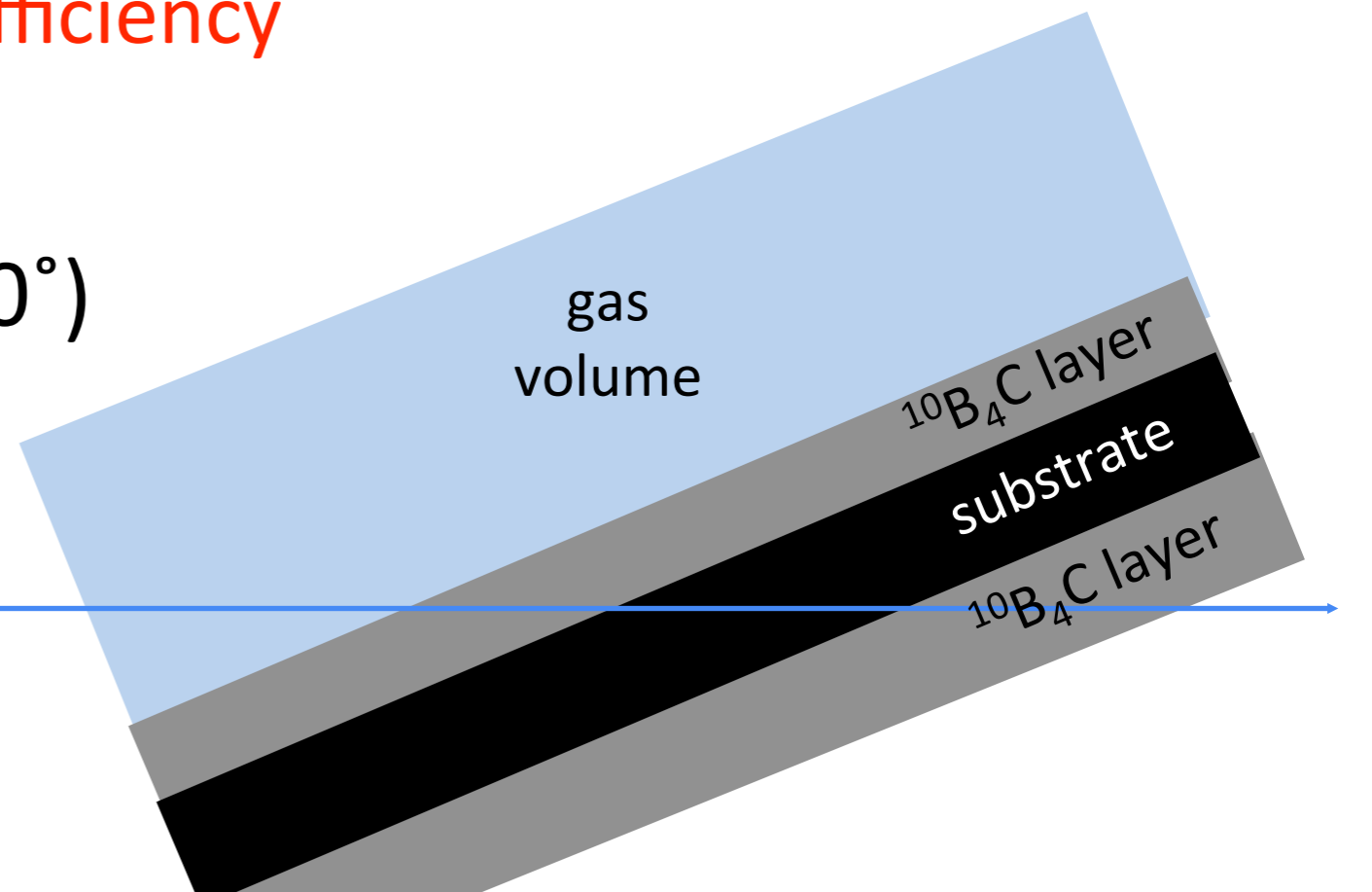


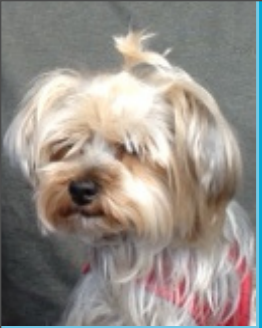
Generic approaches to improve efficiency

2

Grazing angle ( $<10^\circ$ )

neutron





# Organisation - Detector Group June 14



ILL



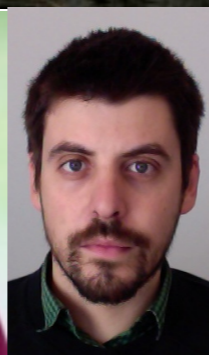
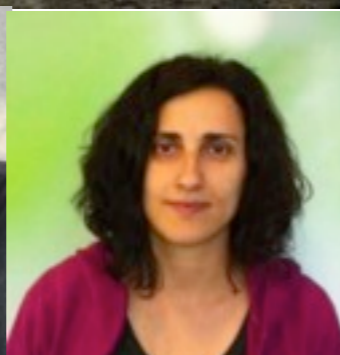
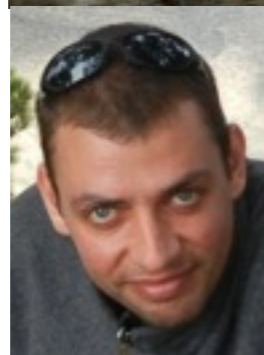
ESS



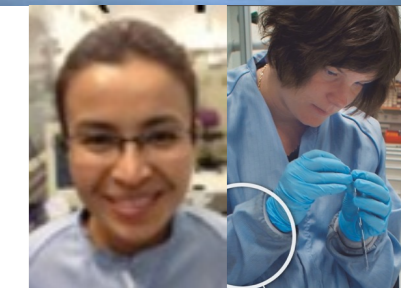
Linköping



Francesco Piscitelli

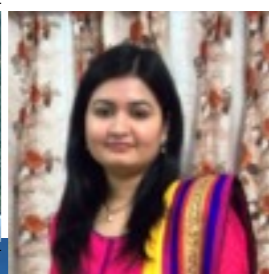


Richard Hall-Wilton  
Michail Anastasopoulos (sep)  
Robert Anderson  
Maddi Echegary  
Kalliopi Kanaki  
Anton Khaplanov  
Thomas Kittelmann  
Scott Kolya (deputy group leader)  
Luis Ortega (deputy work package manager)  
Irina Stefanescu



Carina Höglund  
Linda Robinson (sep)  
Mewlude Imam\*

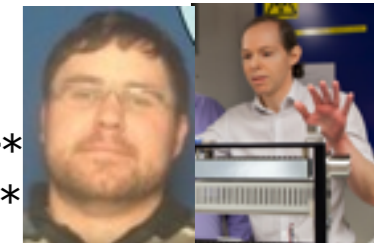
Isabel Llamas  
Xiao Xiao Cai  
Thomas Haraldsen



RED colour: ESS persons  
BLACK colour: local collaborators  
4 PhD Students (\*)  
(+5 bachelors/Masters Projects+2 interns)



Kevin Fissum  
Björn Nilsson  
Julius Scherzinger\*  
Vladimir Pastukov\*



IFE

Yashika Bansal\* (Bergen)

Dorothea Pfeiffer  
Filippo Resnati



CERN

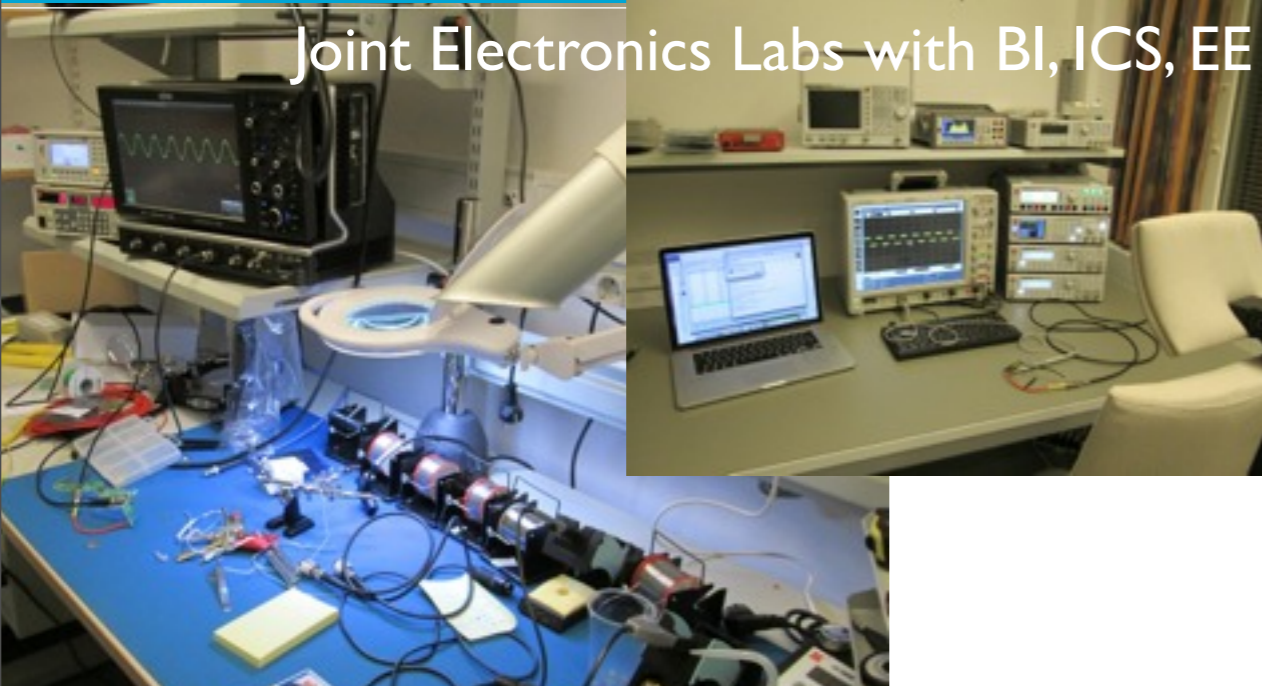


Lund U, LTH, MAXlab

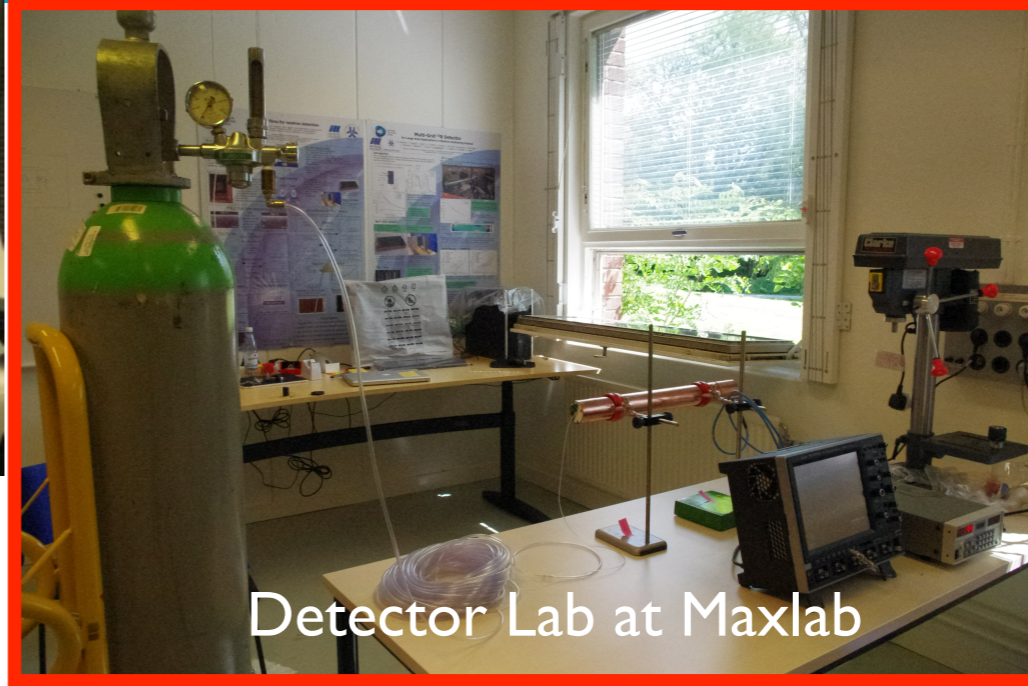
# 2014 - Labs - "Real things"

High quality facilities a priority (reminder: green field)

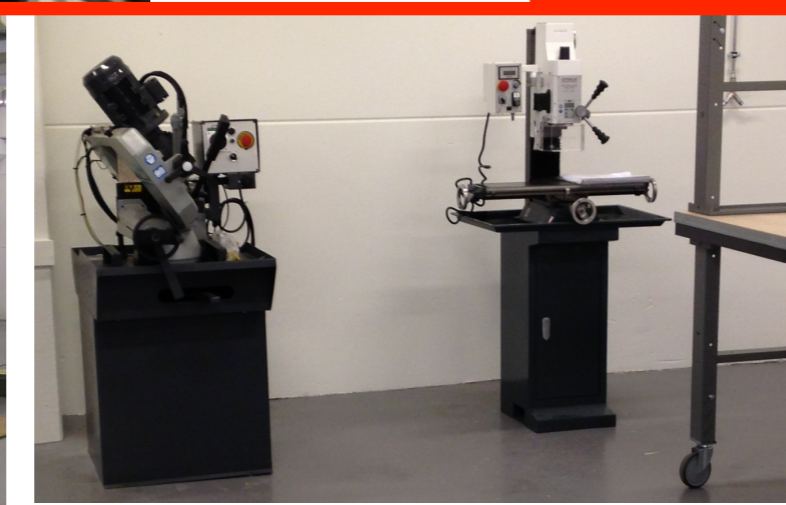
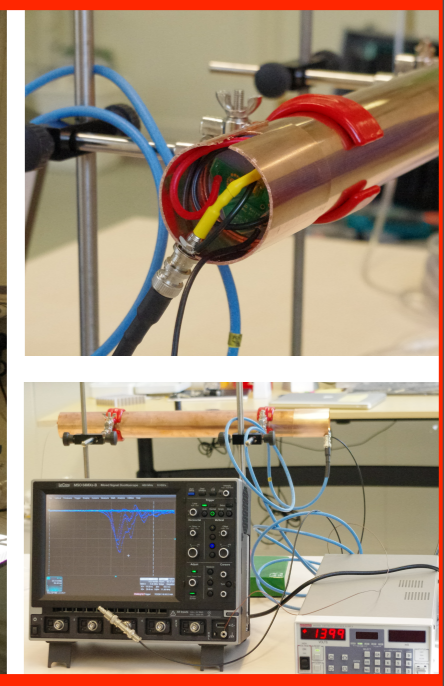
Synergies between groups



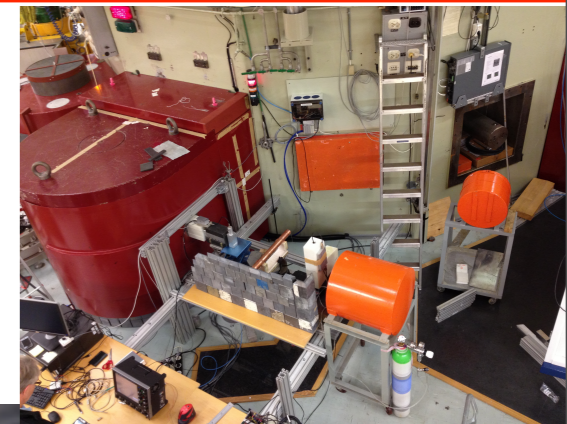
Joint Electronics Labs with BI, ICS, EE



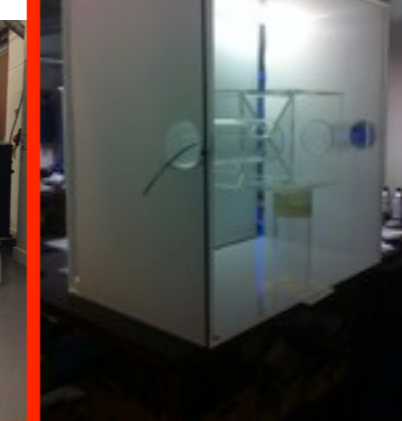
Detector Lab at Maxlab



• Beamline at IFE



Joint Neutron Technology Mechanical Lab

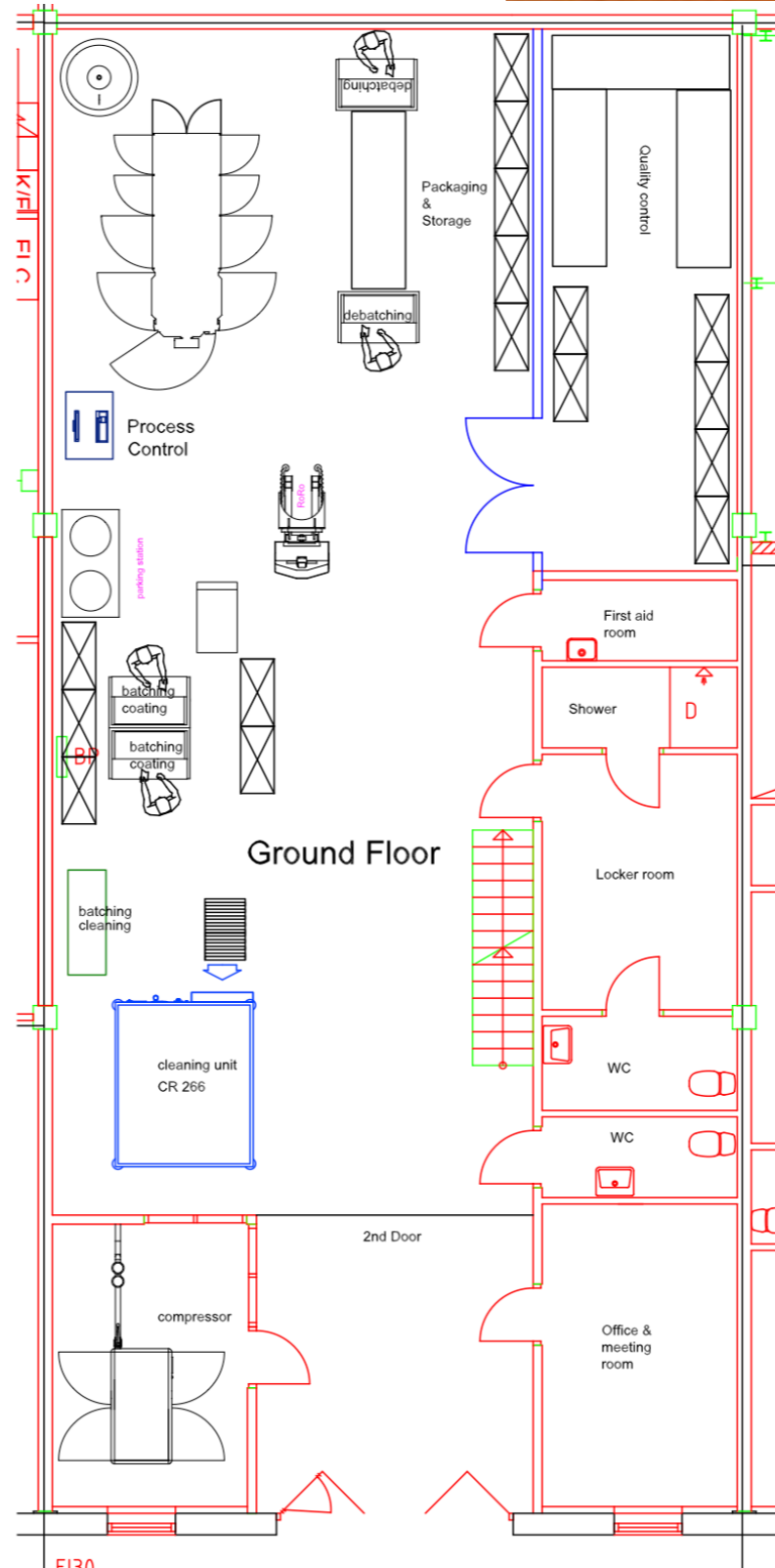
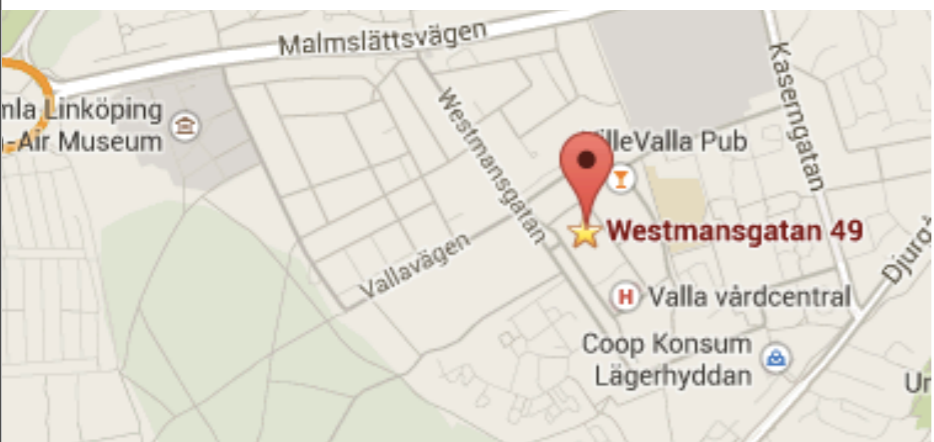
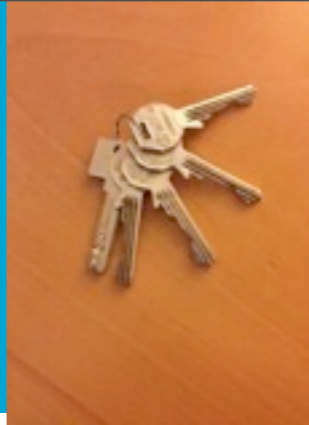


• Sources at Maxlab/ Lund U

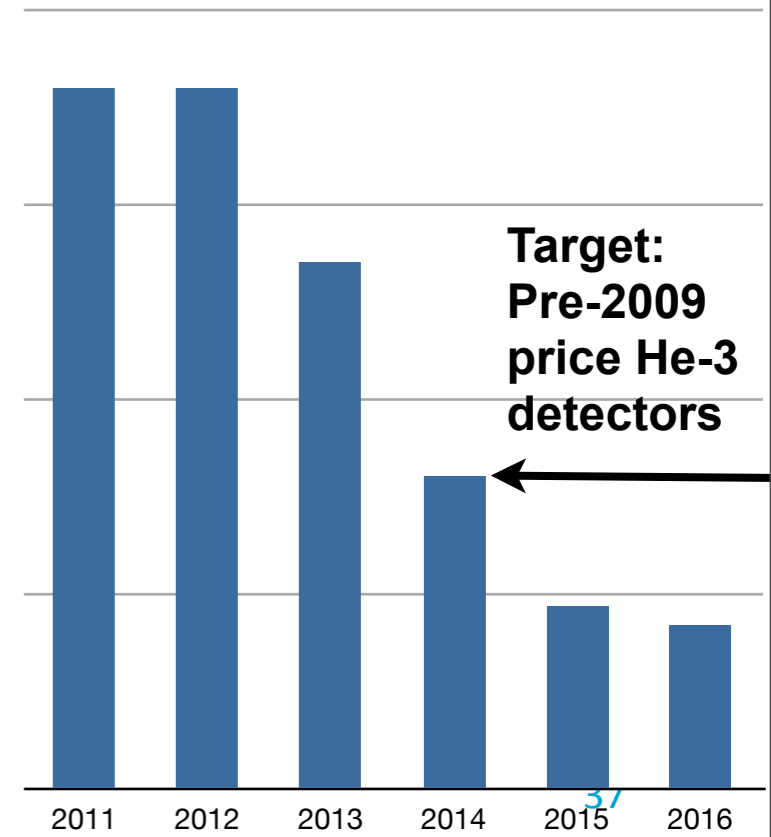
# Coating Facility in Linköping

## Turnkey Handover: next week

High quality enriched boron carbide coatings



Cost of B4C Coatings



# Developments and Standards



# “No Prototypes installed in ESS”: ensuring quality



Several competing technologies: Need to compare like-with-like

Develop Measurement Standards

Between neutron sources defines requirements are not defined in the same way

**We will write down draft standards, open for critique by Autumn 2014**

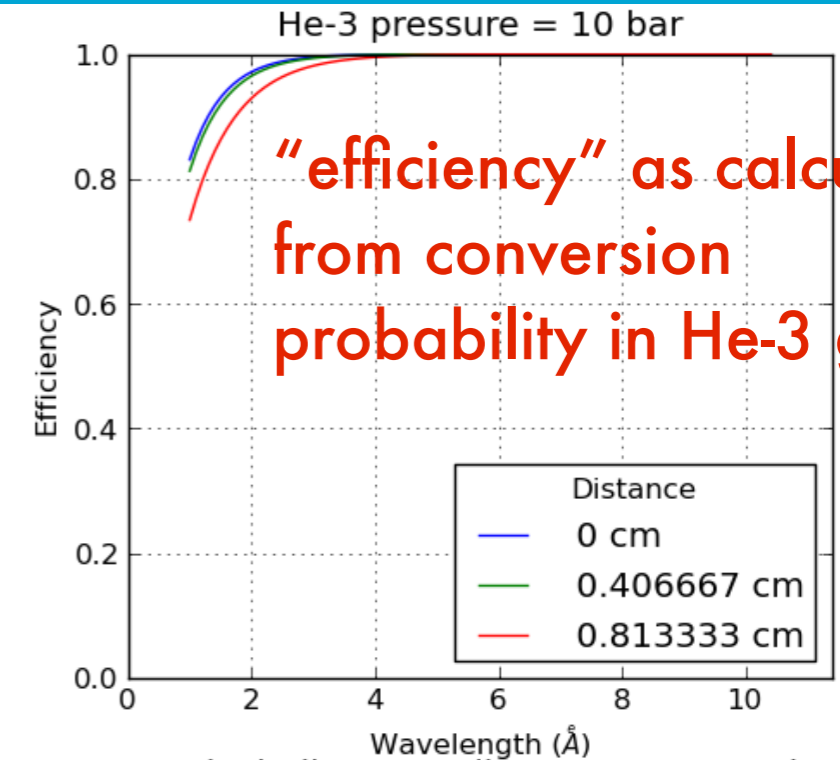
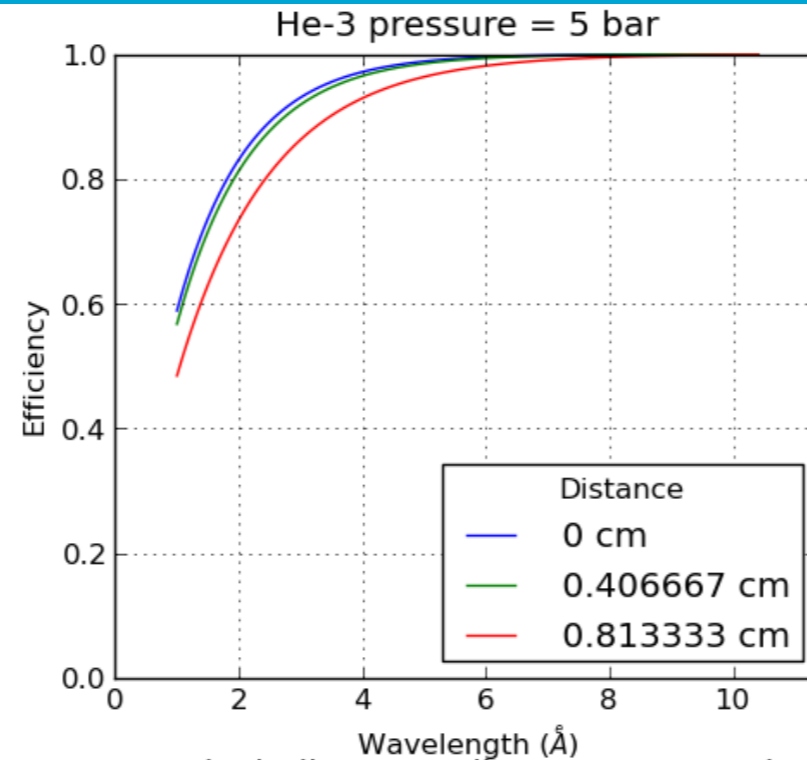
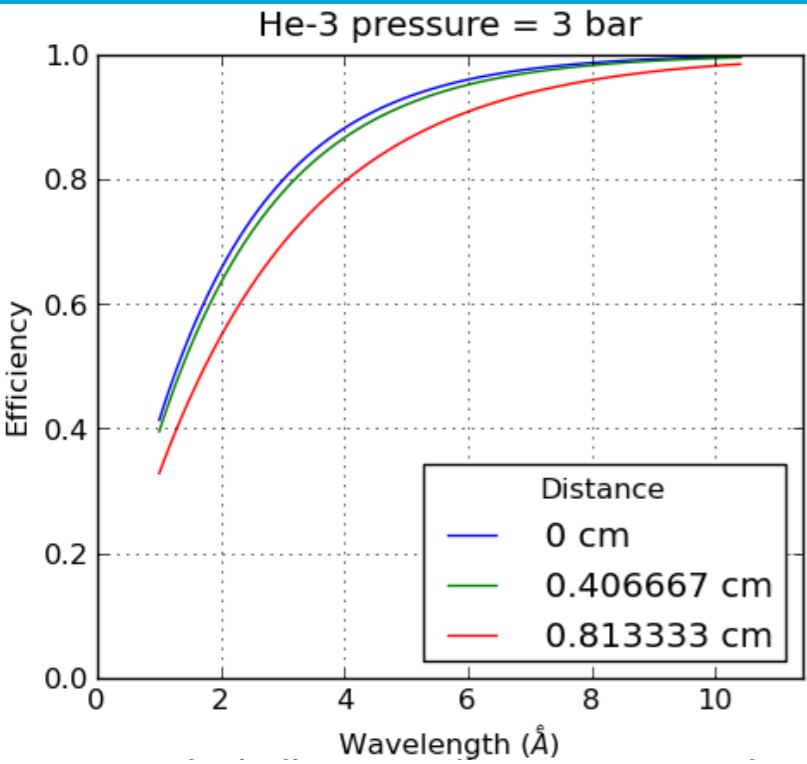
Prototype development also too long for instrument schedule  
(10 years from start to on beam)

Divide the technological developments out to support classes of instruments

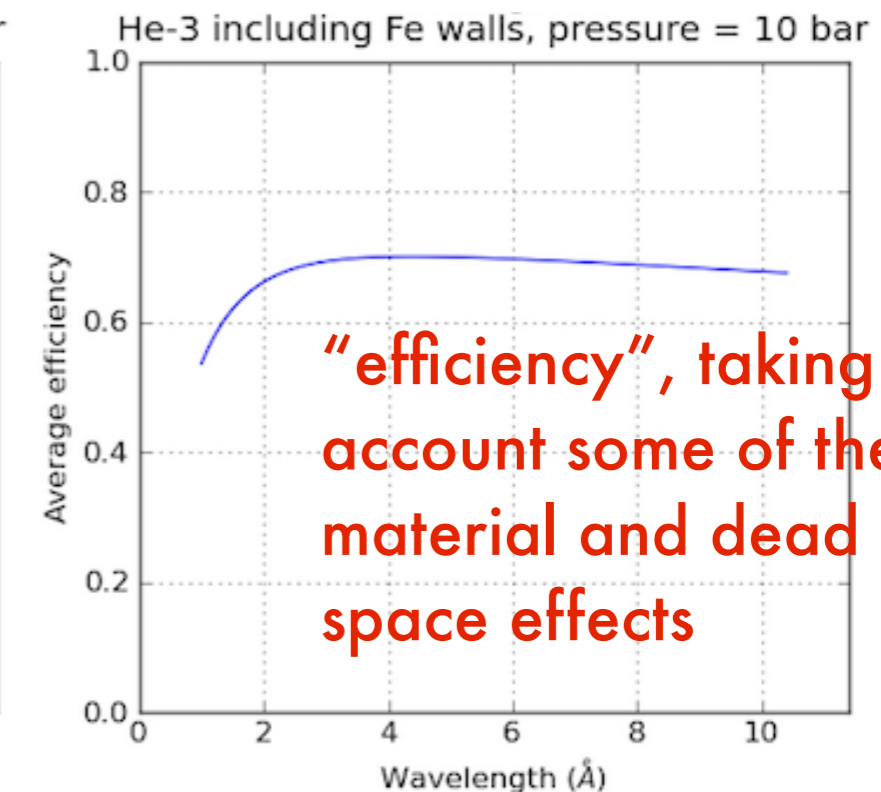
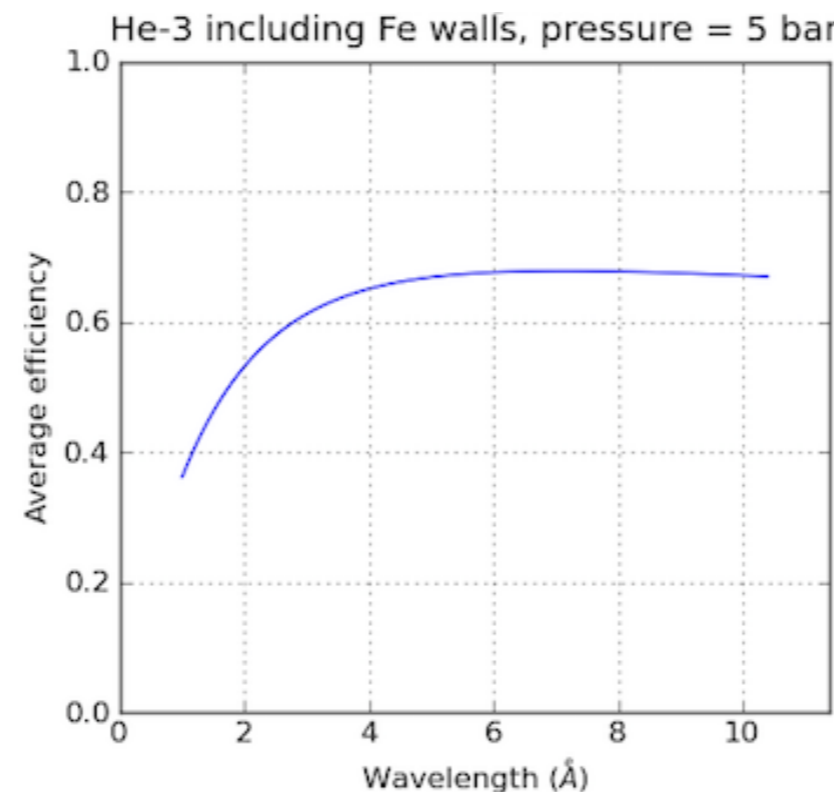
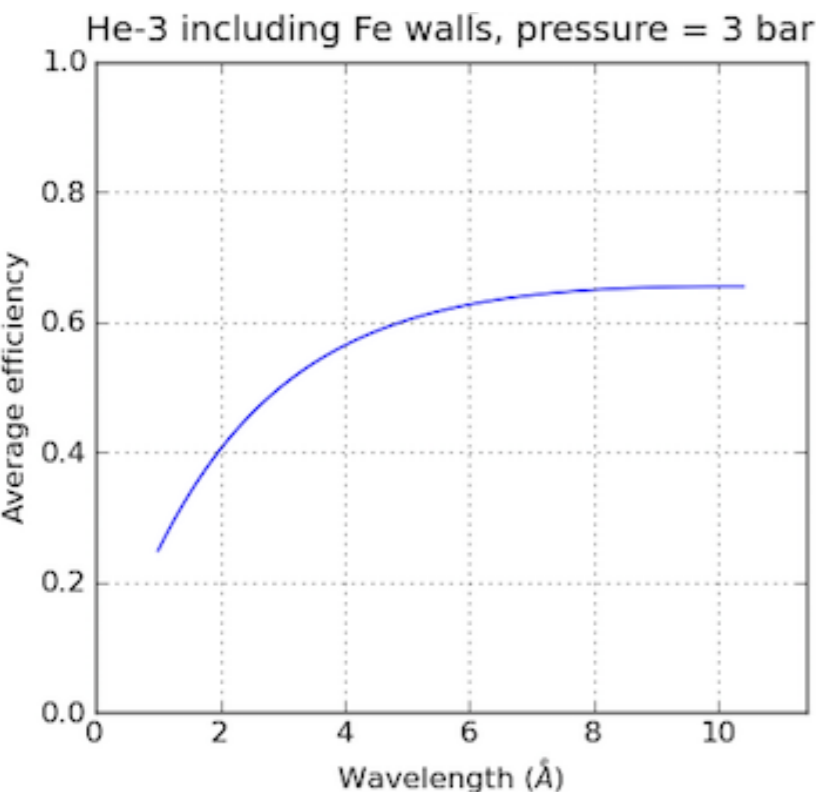
Everything fully prototyped and demonstrated BEFORE constructed and installed for ESS

# He-3 Efficiency

Example of typical large area application:



“efficiency” as calculated from conversion probability in He-3 gas

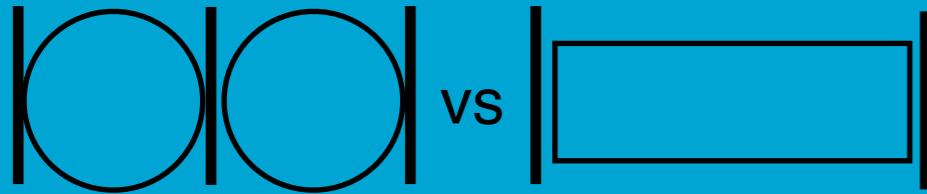


“efficiency”, taking into account some of the material and dead space effects

Important to compare like-with-like, in particular when looking at different technologies

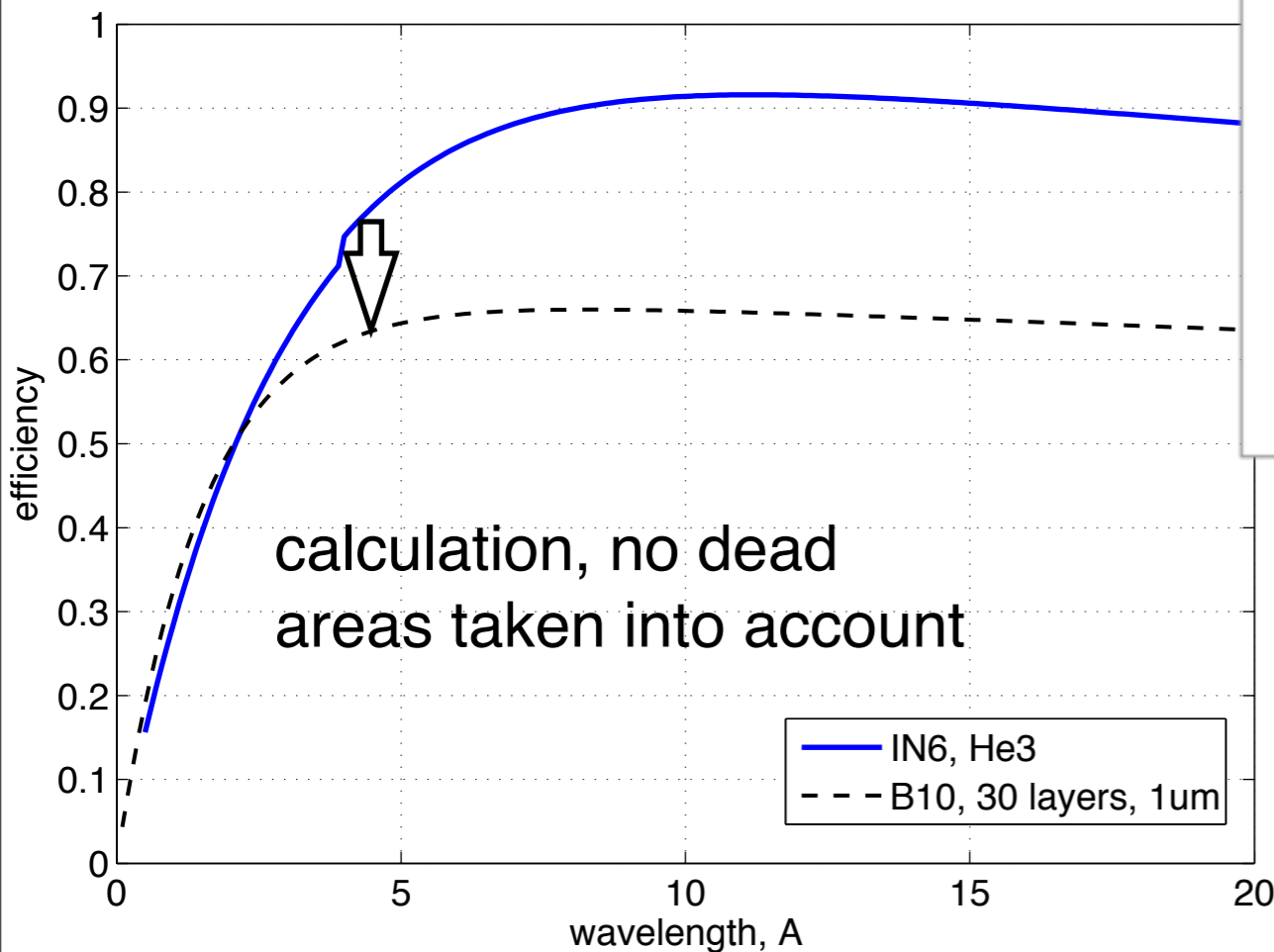
# Quality and Standards: Detection Efficiency

cartoon:

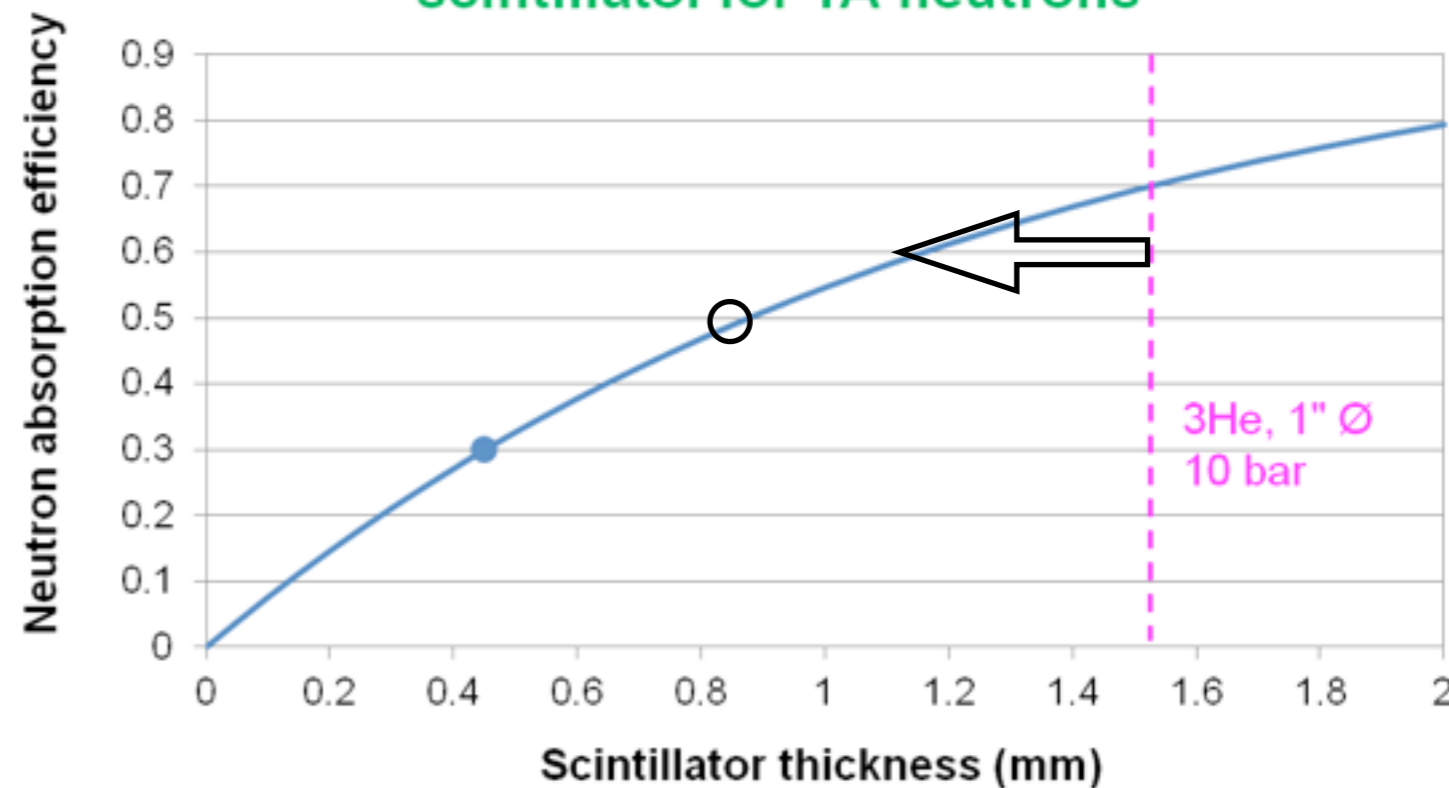


“boundary conditions matter”

- Helium-3 is the gold standard, in particular in terms of detection efficiency
- However, efficiency numbers have rarely compared like-with-like



## Absorption efficiency of AST 2:1 ZnS/LiF scintillator for 1Å neutrons



- Arrow indicate effect of dead regions into account with He-3 tubes
- Alternate technologies starting to approach raw efficiency numbers
- There is a need to compare like-with-like for the detailed instrument operating conditions
- Gamma rejection is a similar issue

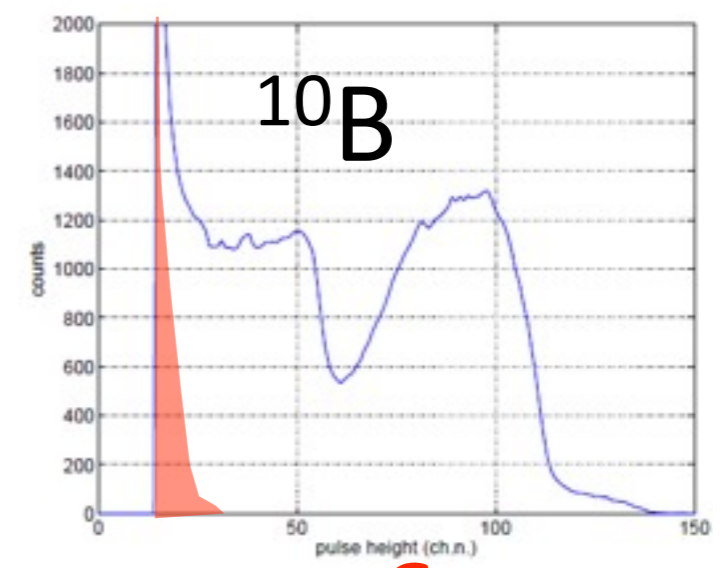
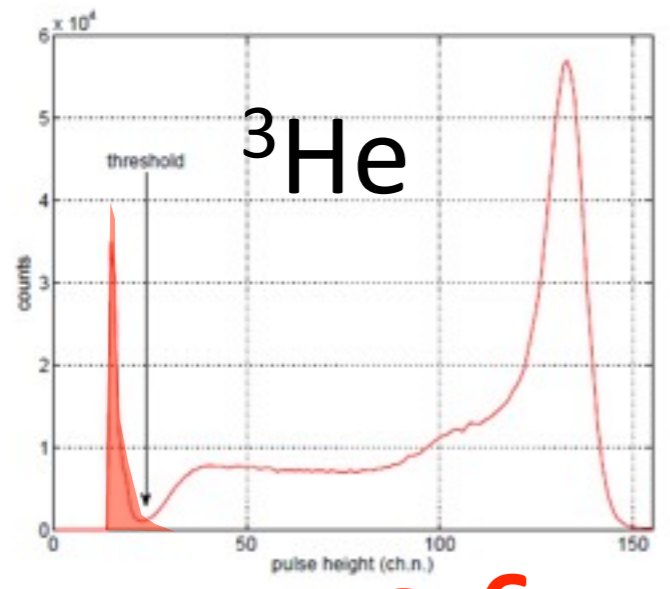
Standards definition key part of ensuring best cost/quality detectors

**compare like-with-like**

Especially necessary with commercial suppliers, to define what we want measured

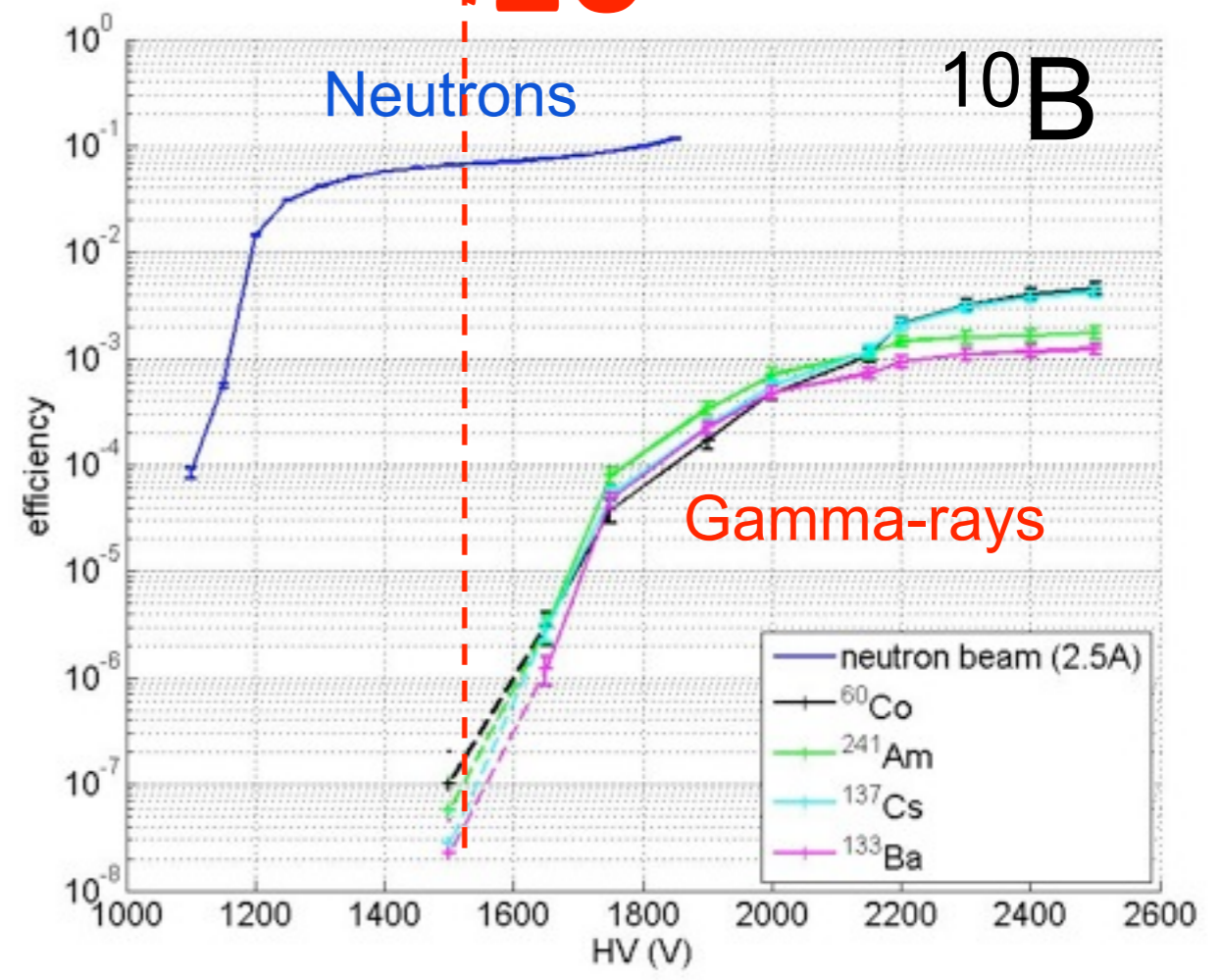
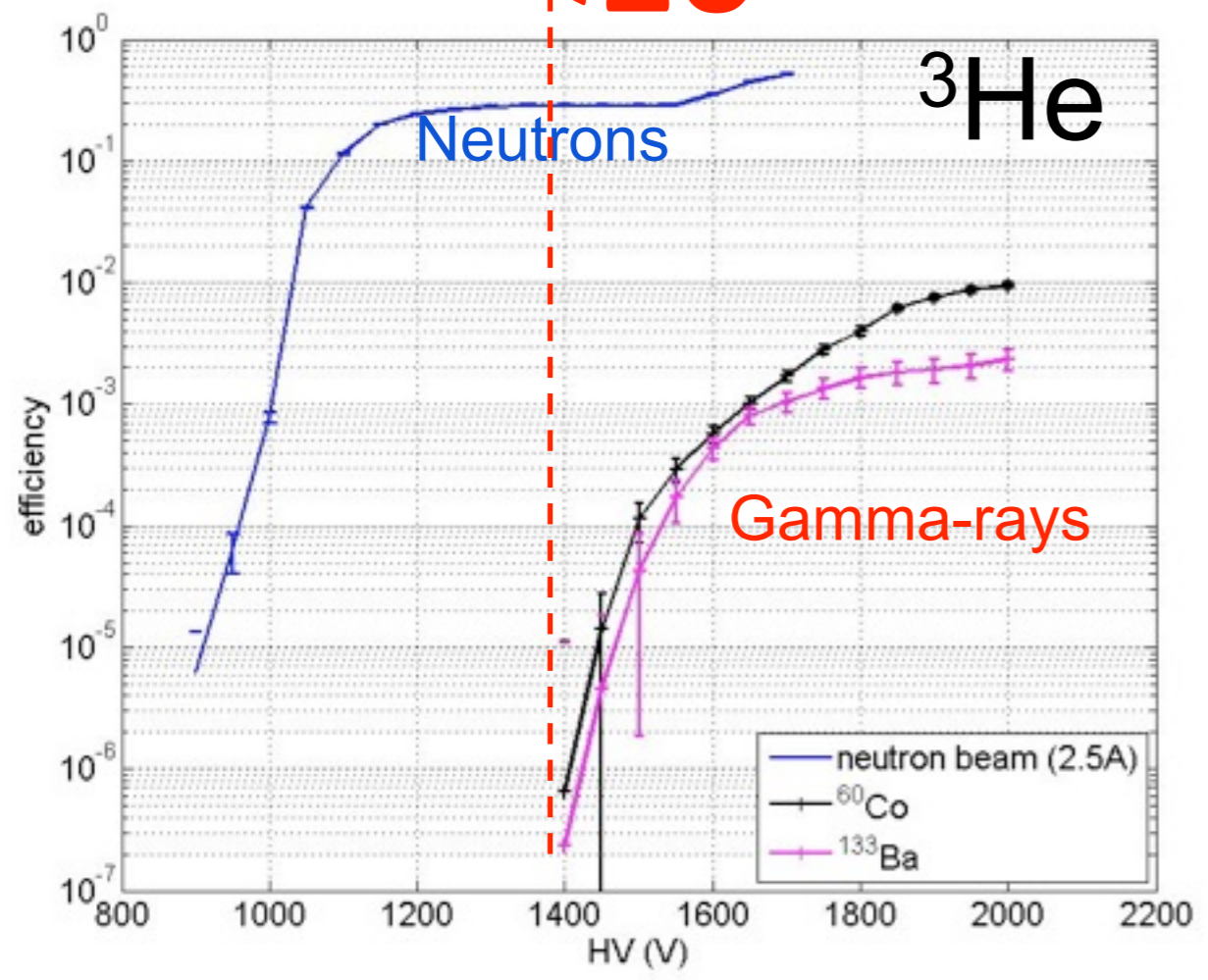
# $^{10}\text{B}$ -based Neutron Detectors: Gamma Sensitivity

A. Khaplanov, F. Piscitelli et al., JINST, v. 8, p. 10025, 2013



$<10^{-6}$

$<10^{-6}$



Gamma sensitivity



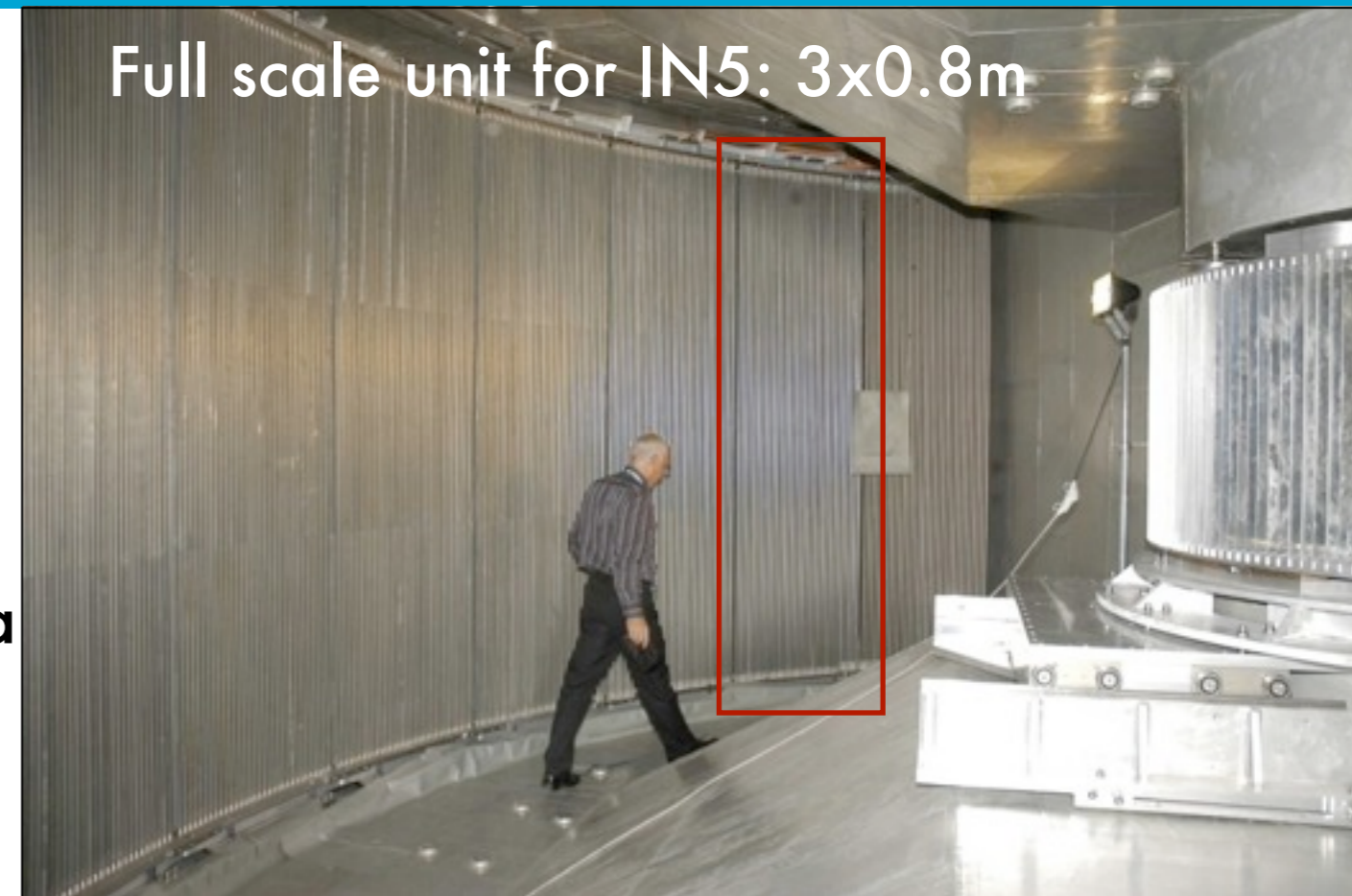
## **TEAMWORK**

**Share Victory. Share Defeat.**

- Everyone should play to their strengths

# Multigrid Design: ILL/ESS/LiU Collaboration

- This year: produce an IN5 equivalent module with the ILL Multigrid design
- Collaboration: ILL/LiU/ESS
- $>70\text{m}^2$  B-10 coating
- IN6 demonstrator results showed that performance roughly equivalent to Helium-3
- NB started ca. 2009: if this is used on a tranche 1 ESS instrument, it is a 10 year development to beam cycle



(slide from B. Guerard)

CLUSTER OF RESEARCH INFRASTRUCTURES  
FOR SYNERGIES IN PHYSICS

CRISP

Participants: ESS, ILL, LiU

# $^{10}\text{B}_4\text{C}$ thin film Multi-Grid detectors

The goal of the CRISP / WP15 work package is to show that the Multi-Grid concept +  $\text{B}_4\text{C}$  thin film converters is an alternative to  $^3\text{He}$  for large area detectors



Single column prototype  
200 cm x 8 cm

96 Grids and 60 wires readout individually

- 50% efficiency measured @2.5 Å
- $\text{B}_4\text{C}$  coating process validated
- Film characterization
- Simulation of the detector
- Centre Of Gravity localization in Y
- Gamma sensitivity measured
- Ar- $\text{CO}_2$  &  $\text{CF}_4$  tested at [0.2 - 1] Bar

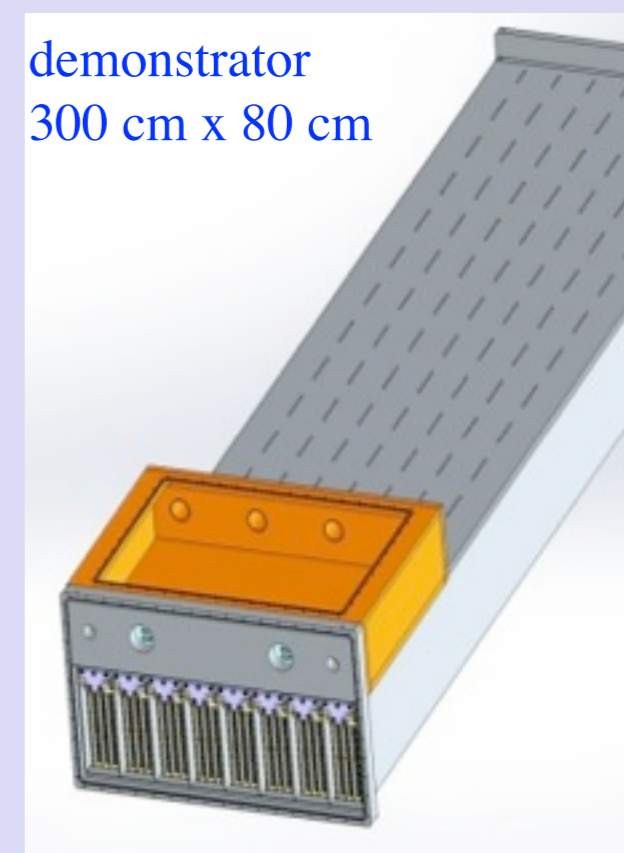
Where we were last year



IN6 prototype  
32 cm x 50 cm

- 96 grids and 360 wires
- Grids of same Y connected by 3 → 32 channels
- Wires  $X_n$  &  $X_{n+1}$  connected with resistors → 24 channels
- Measurements on IN6
- Background observed, solved
- back scattering measured
- Electronics validated
- Demonstrator in fabrication

What has been achieved since then



demonstrator  
300 cm x 80 cm

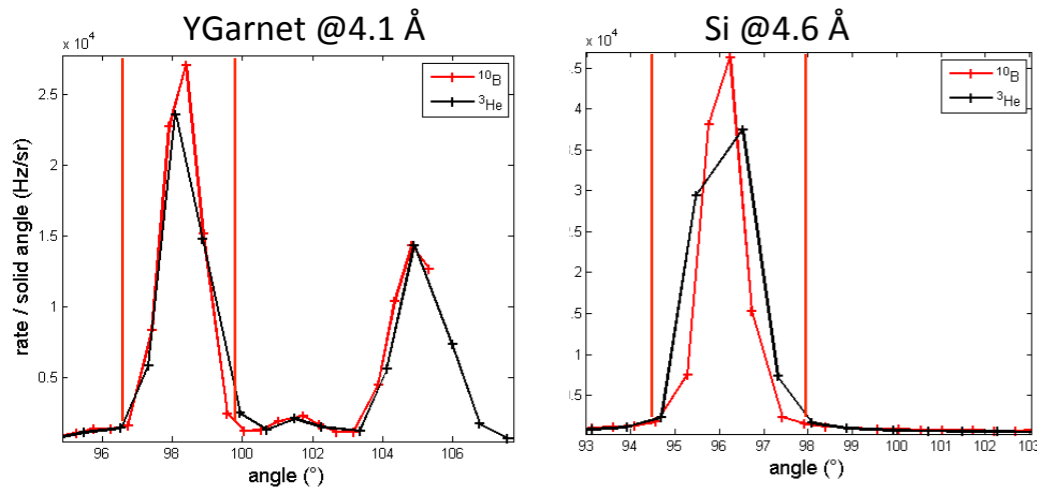
- 1024 grids/ 512 wires
- 256 x (4Grids) cath channels
- Wires  $X_n$  &  $X_{n+1}$  connected with resistors → 32 channels
- Pressure vessel tested
- Mass production of  $\text{B}_4\text{C}$  (70  $\text{m}^2$  !) and detector components
- real detector operational

Where we want to be next year

# Multigrid Design: IN6 Demonstrator



IN6 Demonstrator



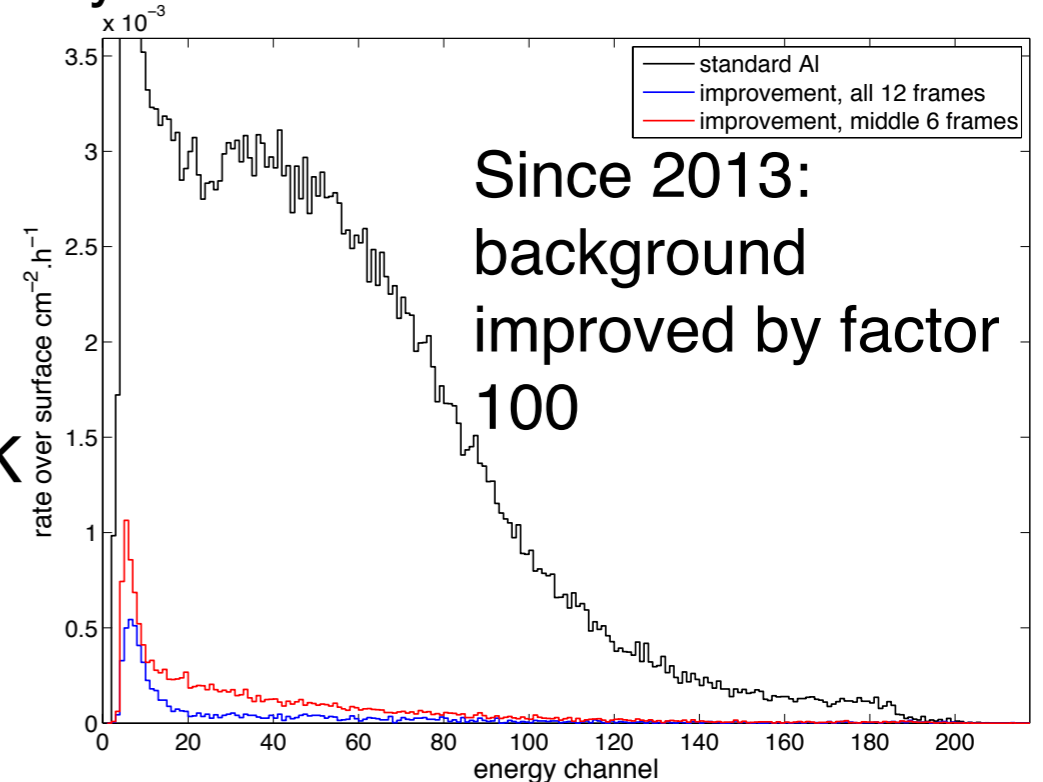
Ratio of integrated rates in Bragg peaks :

- 4.1 Å :  $\text{rate}^{(10\text{B})} / \text{rate}^{(3\text{He})} = 1.08$
- 4.6 Å :  $\text{rate}^{(10\text{B})} / \text{rate}^{(3\text{He})} = 0.97$

- background from alpha's in Al seen
- Plating or ultrapure Al solves it: now ok

• Performance basically matches Helium-3

- Efficiency - OK
- Data - OK
- Scattering - OK
- Gamma rej - OK
- t resolution - OK
- x,y resolution - OK

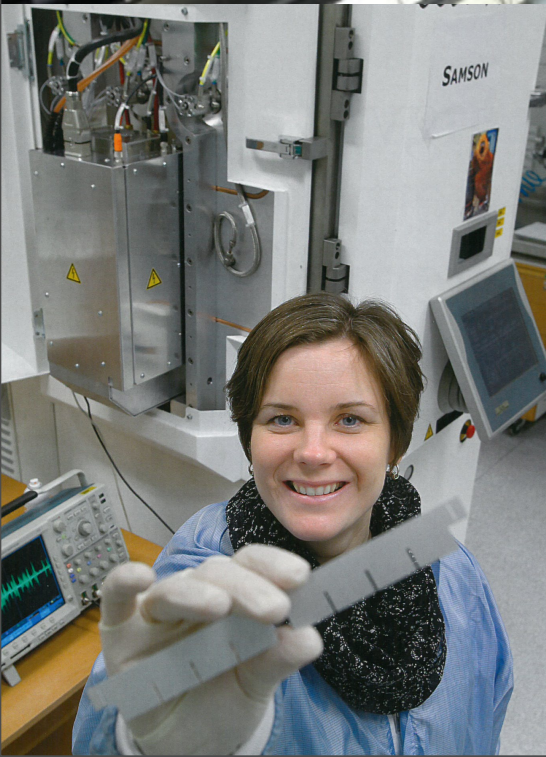
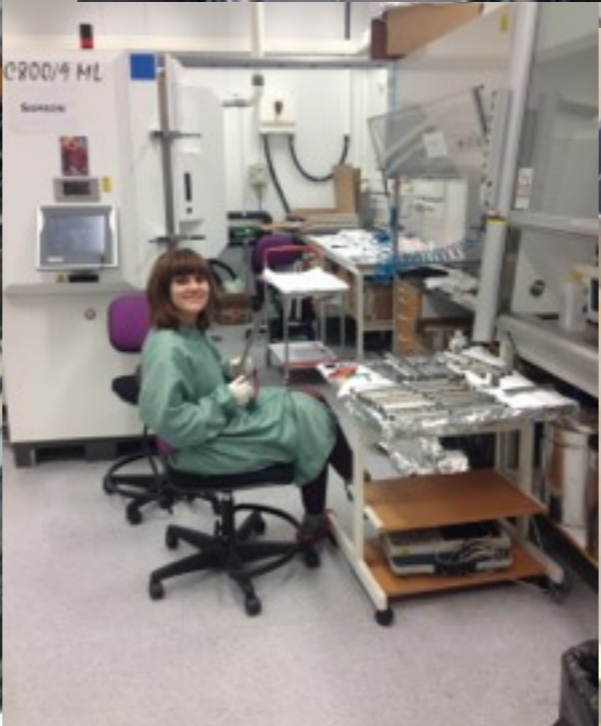
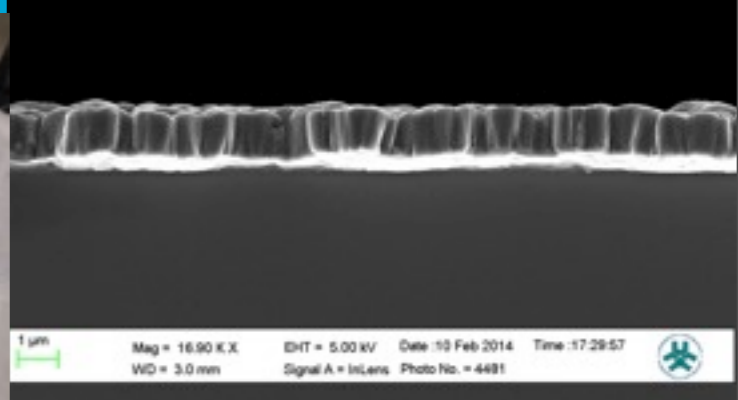
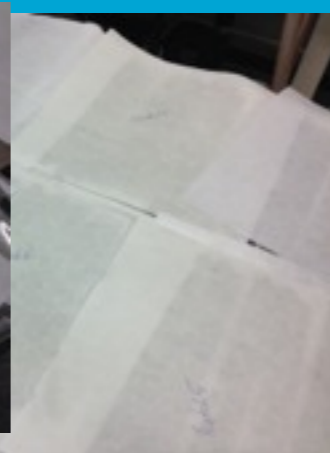


Since 2013:  
background  
improved by factor  
**100**

# Multigrid Design: IN5 Demonstrator

## Mass production possible?

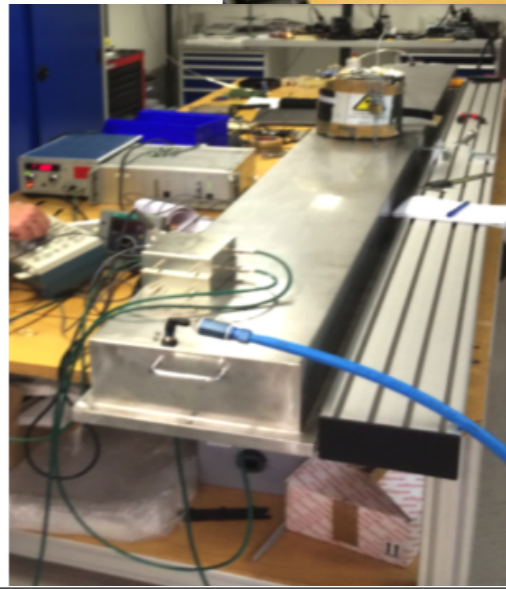
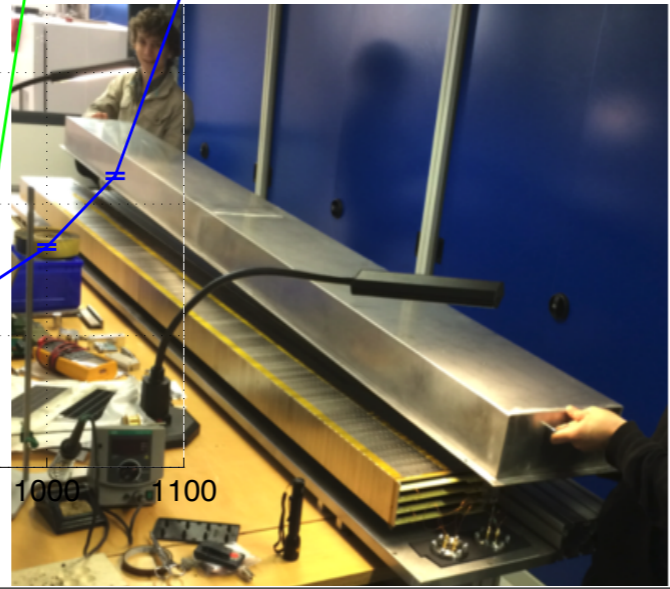
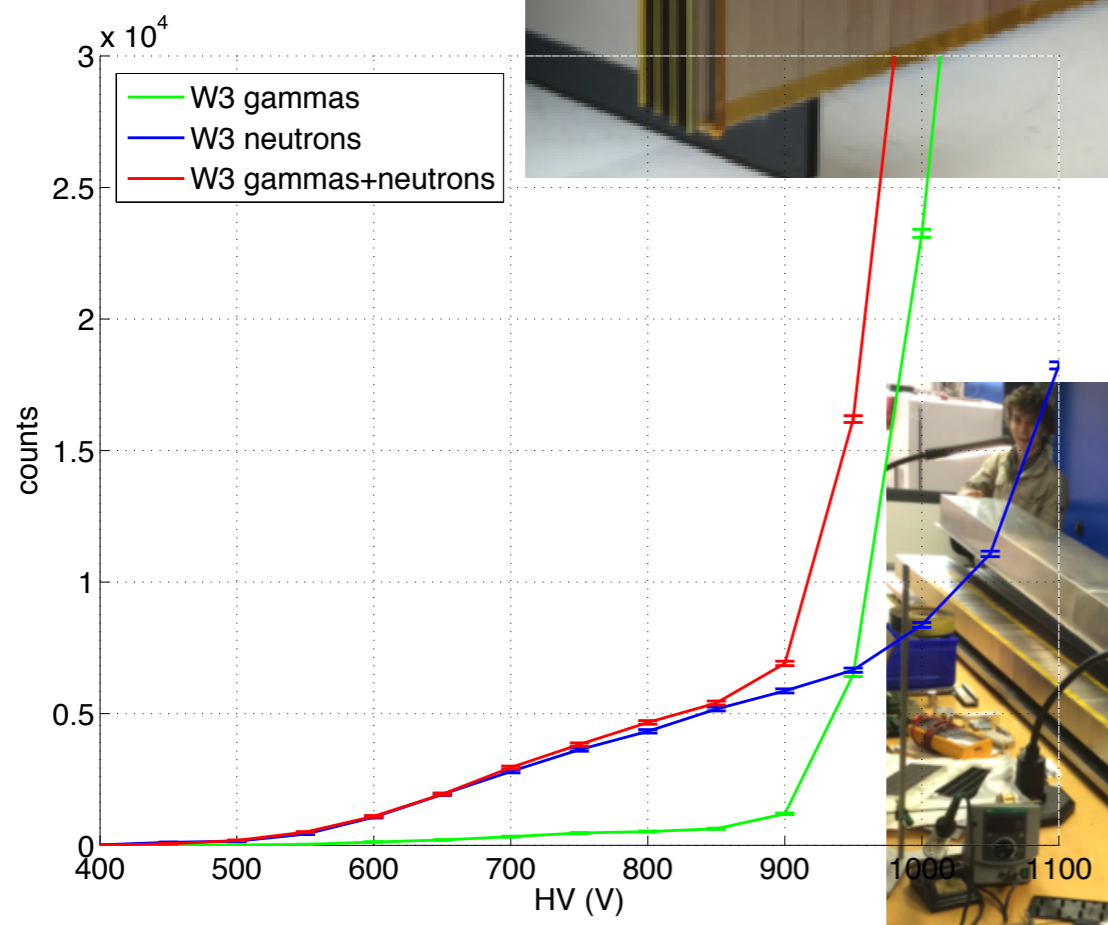
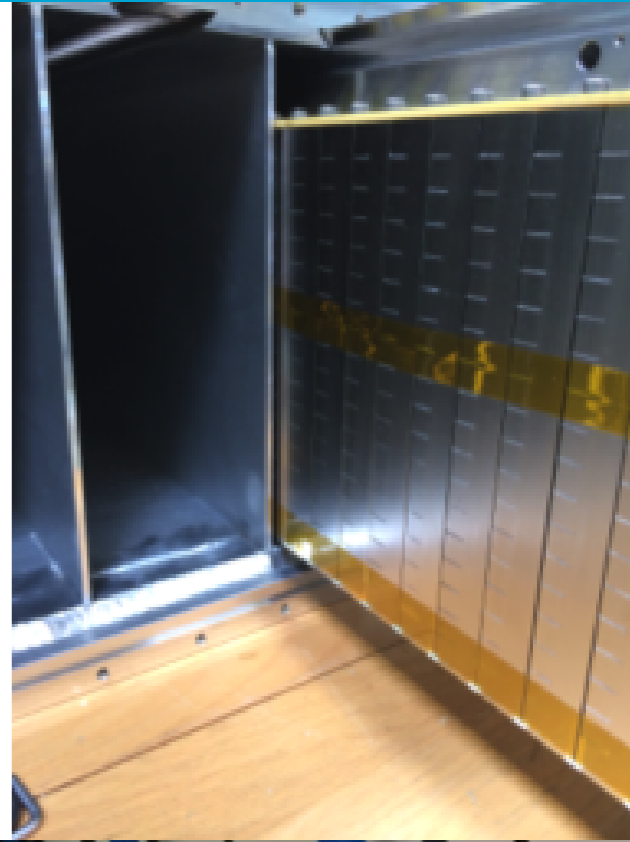
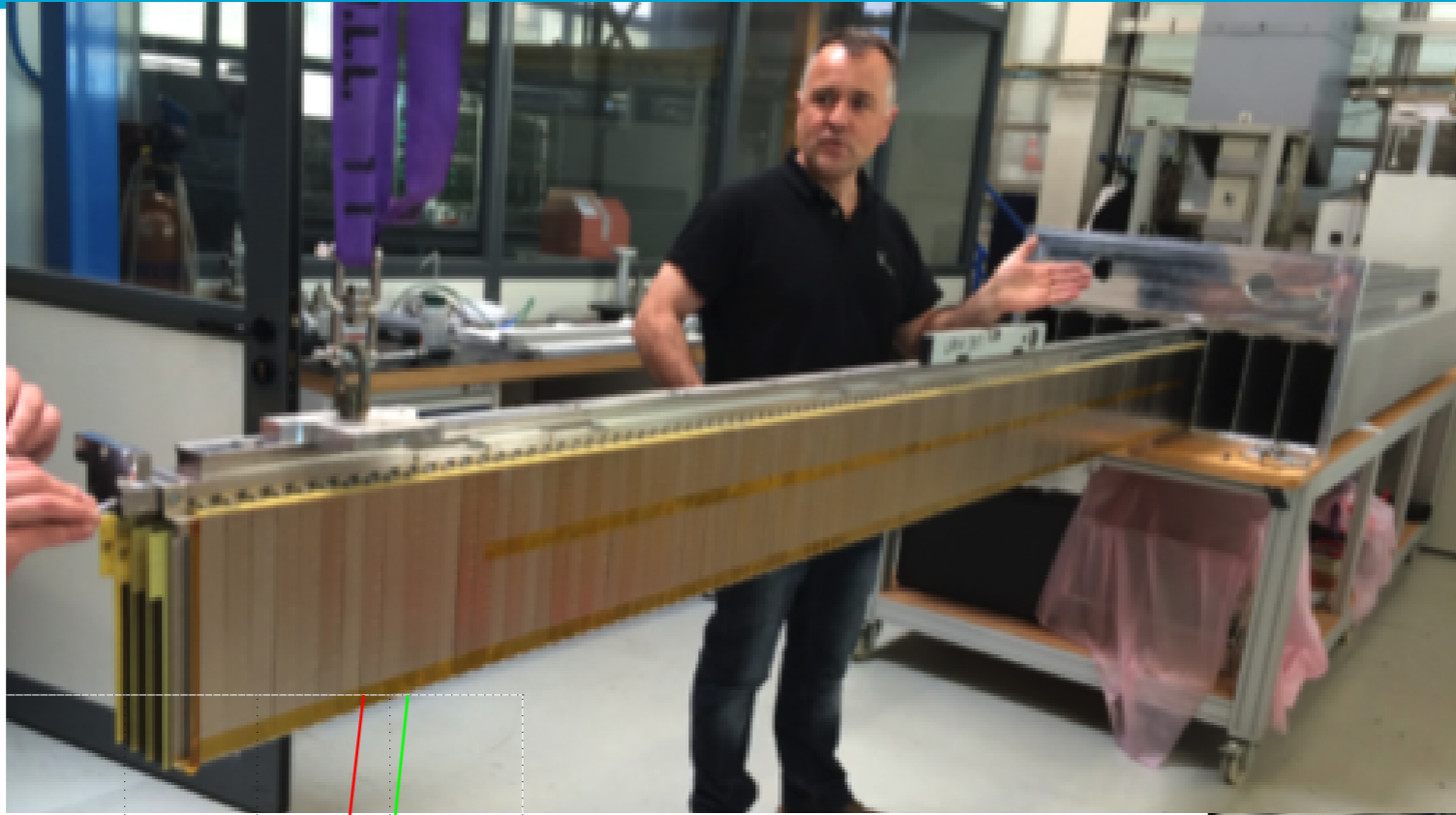
Full IN5-like module (3x0.8m)  
To be completed by Sep '14  
Coatings complete  
104m<sup>2</sup>  
All other items on track



# Multigrid Design: IN5 Demonstrator

## Large area neutron detectors possible again

ILL/ESS/LiU Collaboration

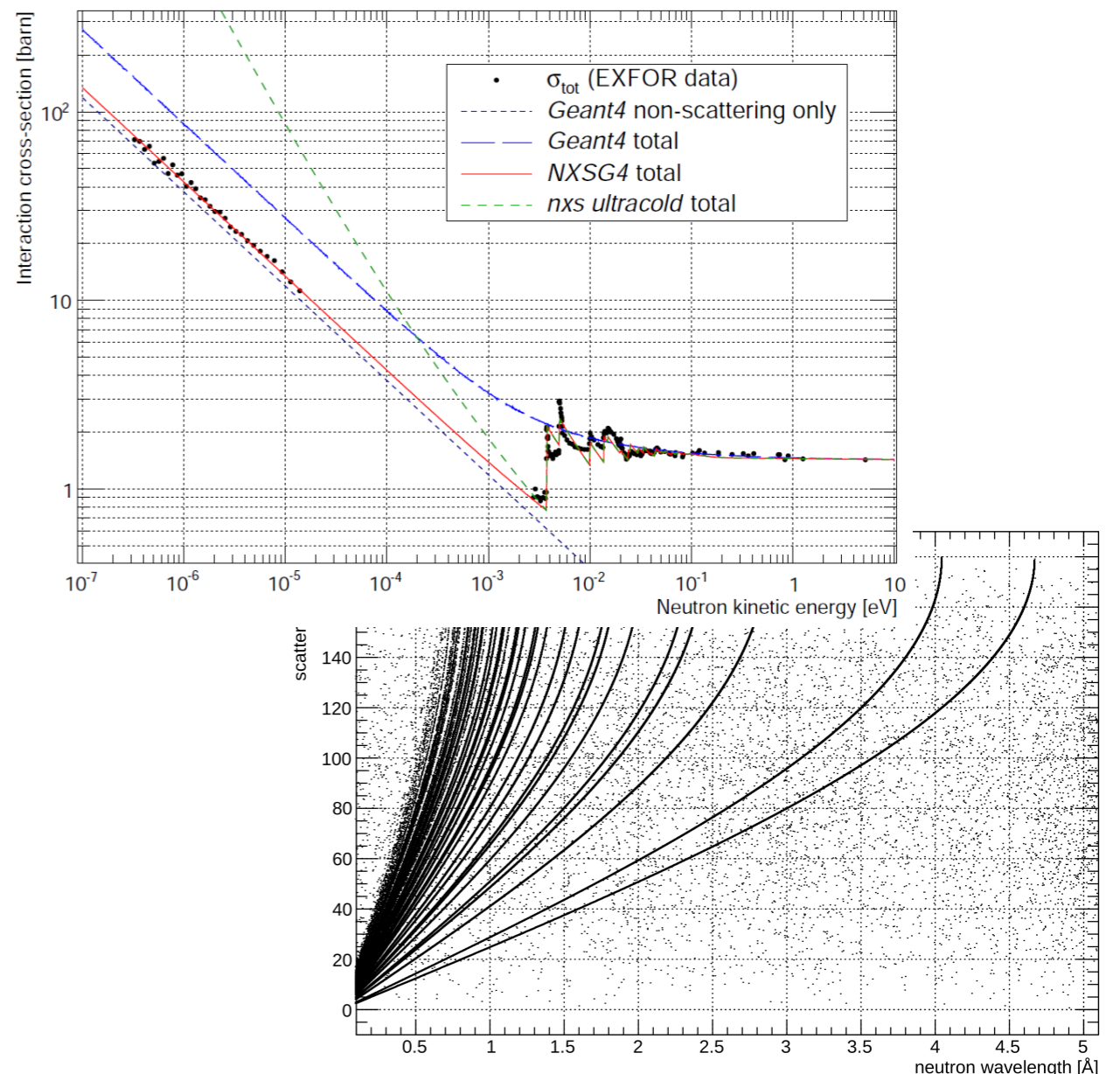
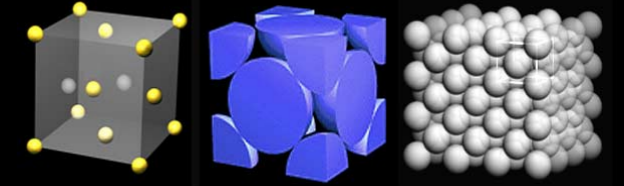


# Diffraction add-on for Geant4

T. Kittelmann, M. Boin

- Out of the box, Geant4 includes no capability for crystal diffraction.
- A new plugin, NXSG4, is provided which enables proper neutron diffraction in arbitrary polycrystalline materials:
- Based on the nxs library (used already in McStas, Vitess)
- Based on basic unit-cell parameters, just low-energy neutron scattering is overridden. All other Geant4 capability is retained, resulting in a rather complete tool for investigations of a multitude of phenomena at neutron facilities.
- Plugin freely available for non-commercial purposes at <http://cern.ch/nxsg4> and documented in paper (submitted).

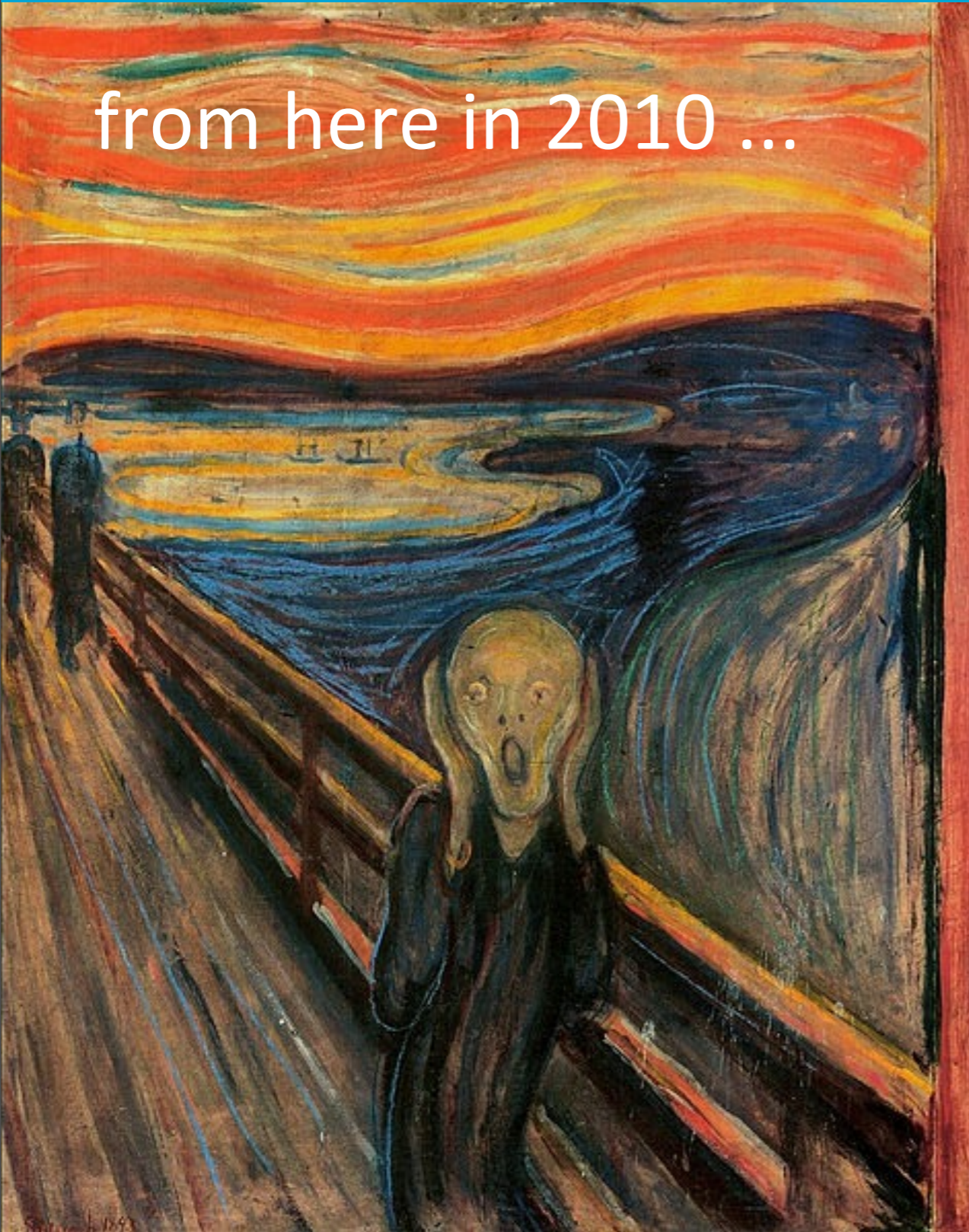
```
(tkittel@localhost data)> cat Al.nxs
space_group = 225
lattice_a = 4.049
lattice_b = 4.049
lattice_c = 4.049
lattice_alpha = 90
lattice_beta = 90
lattice_gamma = 90
[atoms]
add atom = Al 3.449 0.008 0.23 26.98 429.0 0.0 0.0 0.0
```



- Helium-3 detectors typically limited to a resolution of many mm - 5mm or greater typical
- Demand until recently for better resolution detectors was limited:
  - Sample size typically large, so better resolution not needed
  - ESS flux is likely to reduce sample size
- Safe to say that demands on resolution will increase: for proposed ESS instruments
  - Reflectometry: mm resolution or better
  - Neutron Macromolecular Crystallography: 200-500  $\mu\text{m}$
  - Imaging: 10-100 $\mu\text{m}$
- Availability of such detectors, with timing resolution, limited at the present
  - Existing detector-types being pushed in this direction
  - Gd(+CsI) MSGC detector (by HZB), with 200-500 $\mu\text{m}$  resolution
  - MCP, Coated silicon detectors: sub 10  $\mu\text{m}$  possible
- With time, and availability of such detectors, expect more demanding requirements on resolution

# Mood Message for the R+D so far ...

from here in 2010 ...



to here in 2014...



# Collaborations for Construction Phase

Instrument construction started for first 3 instruments

Challenge: select collaborative partners to build performant detectors



# Collaborations for the Construction Phase



In-kind will be competitive: oversubscribed by factor 2++

Focus no longer on R+D but rather on advanced stage development and building detectors for instruments

## In-Kind, Design Update



## In-Kind, Construction Phase (so far ...)

Remember: front weighted



## Collaborative Partners

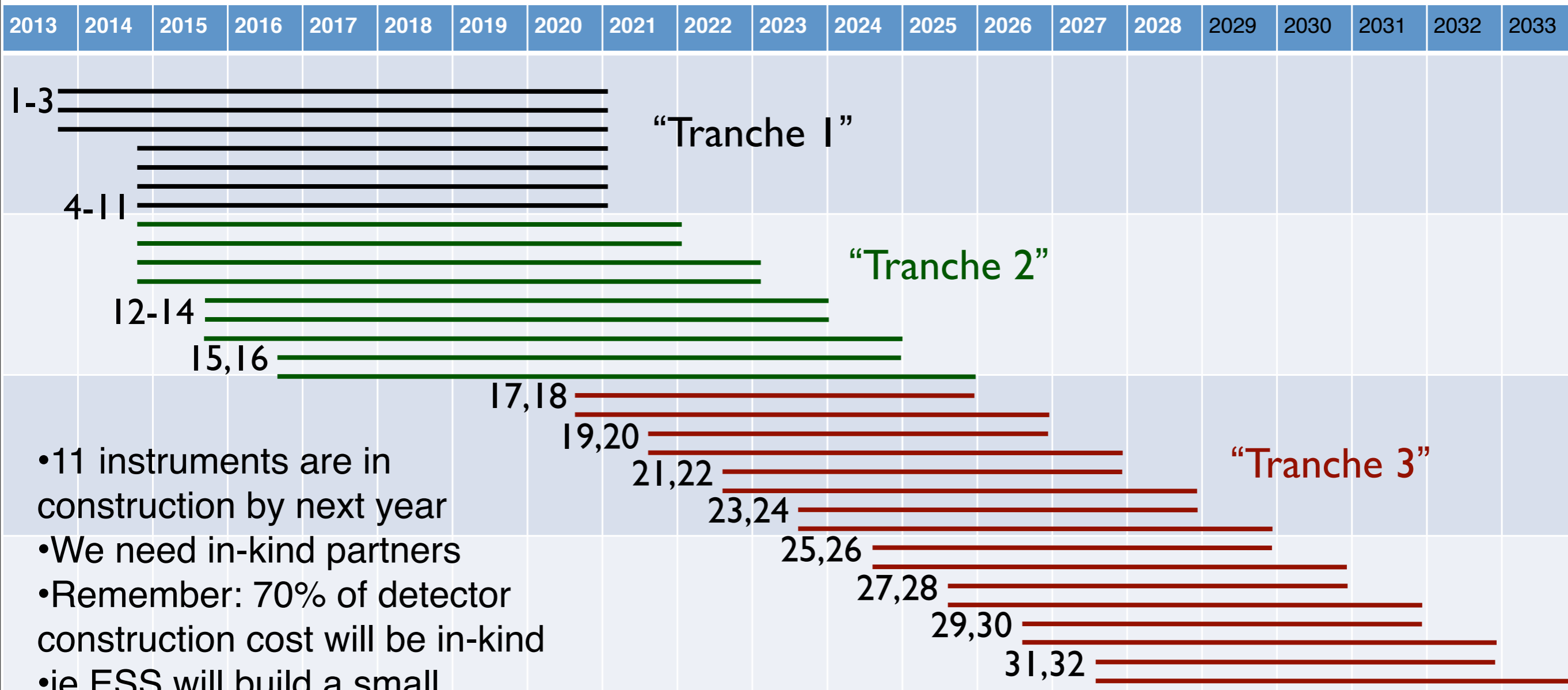


Need partners to build detectors

Commercial Partners

Working with many commercial partners

# Instruments Will Move into Construction a Few at a Time



- 11 instruments are in construction by next year
- We need in-kind partners
- Remember: 70% of detector construction cost will be in-kind
- ie ESS will build a small fraction of detectors ourselves
- we will enable as needed

# Summary

- Construction phase for ESS has started
- Huge progress from the community as a whole for solving the Helium-3 crisis
  - Very significant challenges still ahead for detectors ...
  - Instrument construction started ...
- We are just about ready for it for detectors ...
- Core of detector group and facilities exists ...
- Looking forward to facing the challenge together ...
- We need to utilise the considerable expertise that exists across Europe
- Challenge is only achievable using in-kind
- Need to build up centres of excellence in Europe rather than a large numbers of all-rounders
- Single take-away message: the ESS project needs extensive collaboration and partnership on detectors for success