ESS Strategy for Detectors for the Neutron Reflectometry Instrument Class

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Abstract

The future high-performance reflectometers at ESS are a challenging class of instruments. The main requirement for specular reflectometry at ESS is a high counting rate capability ($\geq 1kHz/mm^2$). In addition, high spatial resolution ($\leq 1mm$) is required in some cases, primarily for angular-dispersive measurements (ESTIA), and for off-specular and grazing-incidence SANS (GISANS) experiments (all reflectometers). These needs can in general not be met with the technologies available at present. Detector performance is already a challenge on reflectometers at existing sources, and further development is therefore essential at ESS. This document outlines a strategy to meet the requirements, based on currently ongoing work in and planned technological developments. These include scintillation detectors with WLS (Wavelength shifting) fibre and directly-coupled readout, Multi-Blade gaseous detector based on ^{10}B layers, Micro Pattern Gaseous Detectors (MPGS - like Gas Electron Multiplier, GEMs, and Micromegas) and Restive Plate Chamber detectors. A realistic timeline is presented for the development of suitable detector technologies that match the requirements of the instrument concepts currently being evaluated for ESS reflectometers. Based upon this schedule and the current state of developments, it is realistic to anticipate detector performance to allow, *from a detector point of view*, a world-leading reflectometry instrument to be part of the first tranche of instruments entering hot commissioning.

1 Introduction

The peak brightness of ESS will be higher than that of any of the existing pulsed sources, and it will be more than one order of magnitude higher than that of the ILL, the world's leading continuous source [1].
The ESS instrument suite will include several reflectometry instruments; in the 2013-2014 instrument proposal round 4 instrument proposals were submitted for consideration: ESTIA [2],

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FREIA [3], THOR [4] and VERITAS [5]. This review was assembled at the behest of the reflectometry STAP, who requested advice from the ESS detector group as to the strategy for detectors for reflectometry instruments at ESS, and in particular whether *a performant and reliable detector system is foreseen by 2019, such that the first reflectometry instrument at ESS can be considered as a day 1 instrument.* The advice was requested in the context that at other sources, particularly at the current leading spallation sources, saturation due to rate effects, in particular charge accumulation, is a known problem even without the anticipated increase in rates expected for ESS reflectometry instruments.
A strategy for reflectrometry instruments at ESS is presented that outlines a path to 2019 or developments and demonstration of these developments. This focusses on rate performance, in particular local rate performance, and on moderate gains in spatial resolution for the detectors. *In summary, if the strategy outlined following is executed, it is realistic to anticpate that a day 1 reflectometry instrument can have a detector with adequate performance, demonstrated to the point where it can be considered a mature detector technology* [6].

2 Reflectometry at ESS

A neutron detector for a reflectometry instrument is in general compact in size ($< 1m^2$) and the spatial resolution required to achieve the appropriate angular resolution is of the order of $1mm$. Specular neutron reflection is measured as a function of the momentum transfer q in the direction perpendicular to the reflecting surface, and high spatial resolution is only needed in one direction and the other coordinates are generally integrated over. Nevertheless a two-dimensional detector is necessary for background correction of the measured specular reflectivity [5]. Moreover, a position-sensitive detector (PSD) is necessary to observe any off-specular reflections arising from the presence of in-plane structures, including the surface roughness and often other unexpected features observed in specular experiments due to a PSD.
In many areas of soft and hard condensed matter science, the amount of material to investigate is rather limited and it will be important to optimize reflectometers for small samples [2] at ESS. In such cases, the small sample area means that the measurement times are flux-limited, giving rise to a need for detectors with high efficiency. There is also a great deal of interest in expanding the applications of time-resolved reflectometry studies [3]. These studies typically use large samples and lower resolution, or refractive encoding [7, 8], which require high count rate capability on the detector. This will not be the case at ESS where the wavelength-position encoding of the neutron energy will provide a large gain in useful neutron flux [2].
In conclusion, a PSD is necessary for all reflectometry instruments. It should tolerate intense fluxes in a relatively small beam area and provide a high spatial resolution for off-specular/GISANS studies as well as angle-dispersive [2] and possible refractive encoding measurements [7, 8].

3 Requirements for Reflectometry instruments at ESS

Reflectometry needs PSDs with high counting rate capability and good a spatial resolution [6]. Table 1 summarizes the detector features for the four conceptual instruments proposed for ESS, as submitted in the 2013-2014 instrument proposal round. In the proposals, ESTIA [2], FREIA [3], THOR [4] and VERITAS [5], both ideal and minimal detector requirements are reported. These proposals as submitted are taken to be generally indicative of the requirements

for reflectometry.
The detector requirements can be expressed by specific features and defined as follows:

- **Detector area:** is the detector active area where it is sensitive to neutrons.

- **Spatial Resolution:** is the ability to distinguish between two events as a function of the distance they hit the detector. Some events at a certain position on the detector will generate a continuous distribution in space. A widely used criterion is to define the spatial resolution as the FWHM of a distribution of those events. A FWHM is (in the gaussian case) the 88% of probability to identify correctly an event belonging to the right distribution.

- **Global Rate:** is the total counting rate the whole detector is exposed to.

- **Local Rate:** is the rate, defined over an area of a mm^2 or a cm^2, that the detector should handle. The local rates for detectors employed in reflectometry are usually given per tube, in the case of ^{3}He detectors, or for a strip because one direction is generally integrated over. For simplicity we normalize the local rates to a mm^2.

Both global and local rates are shown in Table 1. Both rates are reported for the peak flux within the neutron wavelength range from about 2Å and 15Å. For ESTIA the peak flux is at 5Å, for FREIA is about at 3.5Å. **The reported rates are for direct beam intensities**, which need to be measured ideally on the detector for rigorous normalisation. *The reflected rates are up to 6 orders of magnitude lower than this.* Direct beam measurements can performed up to an extent by using an attenuator, but this needs to be wavelength independent and has limitations on the maximum achievable attenuation (3-4 orders of magnitude).
The count rate as a function of the time-of-flight for FREIA [3] is shown in Figure 1. The peak rate at sample is about $1.5 \cdot 10^5\, Hz/mm^2$ and the time-averaged over the pulse length ($64ms$) is about $5.5 \cdot 10^4\, Hz/mm^2$. Note that these temporal rate variations are not fully represented in the definitions of rate given above, due to the complexity of the effects, which are highly dependent upon detailed aspects of the detector design. A more generic definition is being worked upon.

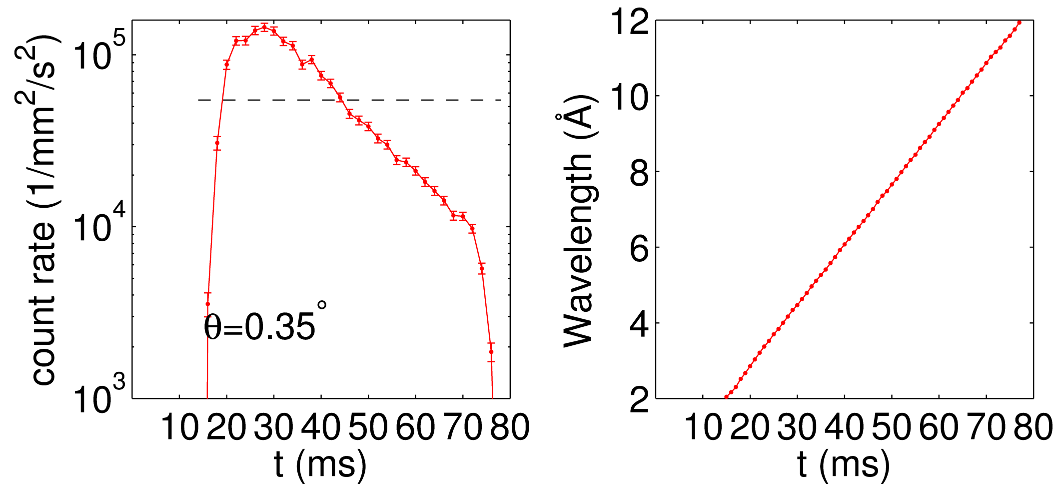

Figure 1: The neutron pulse intensity as a function of the time-of-flight (left) and the corresponding neutron wavelength as a function of time (right) [3].

Instrument		area ($mm \times mm$)	Δx (mm)	Δy (mm)	global rate (s^{-1})	local rate ($s^{-1}mm^{-2}$)
ESTIA [2]	min	500×170	≤ 2	≥ 2	-	-
	ideal	500×500	≤ 0.5	≥ 0.5	$\sim 10^7$	$3 \cdot 10^4$
FREIA [3]	min	500×500	8	1	-	-
	ideal	500×500	≤ 8	≤ 1	$\sim 5 \cdot 10^5$	$\sim 3.5 \cdot 10^3$
THOR [4]	min	500×500	2	-	-	-
	ideal	500×500	≤ 2	-	-	-
VERITAS [5]	min	500×500	2	2	-	-
	ideal	500×500	≤ 2	≤ 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.

In addition to the features listed in Table 1, the uniformity of the detector and ageing are important characteristics to be taken into account. The uniformity variation along the detector surface should not exceed 1% according to [2]. By considering the wide dynamic range in neutron counting, the detector is exposed to, adjacent pixels can receive a widely different flux in the same measurement that can vary more than six orders of magnitude. In these conditions ageing can be an important issue that degrades the detector uniformity. These non-functional requirements are also very important, however they are not discussed further in this strategy paper.
Background (background neutrons and γ-rays) suppression is also an important feature the detector should compromise with respect to the efficiency. A suitable detector shielding should prevent the detector from counting background neutrons from the environment. Depending on the γ-ray background on the instrument, a detector should provide a γ-ray rejection down to 10^{-7}.
The range of neutron wavelength range interesting for reflectometry is from about 1 Å and 30 Å. Reasonable detector efficiency of the detector is required in this range. The distance between the sample and the detector is on average $2m$ but it can vary from $1m$ up to $8m$ for specific applications. The size of the pixel, in one direction only, should match the angular resolution of the instrument. This, in terms of spatial resolution on the detector area, is of the order of $1mm$.
For its specific scientific case ESTIA [2] needs the best spatial resolution with respect the other proposals, the goal is to achieve $0.5\,mm$. High uniformity (efficiency variations below 1%) along the detector surface is also a strong requirement for ESTIA as well as a long stability in time. A wide dynamic range is a requirement for all the proposed concepts: regions of the detector should be able to measure fluxes of the order of $10^8\,Hz$ and simultaneously other sectors must measure down to about $1\,Hz$.

In addition to the requirements listed above, there is also a need for small area beam monitors capable of continuously measuring the direct beam in order to detect source variations. It is likely that 2 or 3 monitors with different efficiencies are needed to cover different measurements. Developments are foreseen, but are not strictly connected to the main detectors which are essential to the listed proposals but also also a common requirement of all instrument proposals at ESS.

3.1 Summary of Detector Requirements for Reflectometers at ESS

The suite of reflectometry instruments proposed at ESS have many common features. The detector needs are summarised in Table 2. Global and local rates are given for the peak flux in the neutron wavelength range from about 2Å and 15Å.

area ($mm \times mm$)	spatial resolution ($mm \times mm$)	global rate (s^{-1})	local rate ($s^{-1}mm^{-2}$)
500×500	$[\leq 0.5, 2] \times 2$	$[5, 100] \cdot 10^5$	$[5, 300] \cdot 10^2$

Table 2: Summary of generalised detector requirements for refletometry instruments at ESS in terms of spatial resolution, global rate capability and local rate capability.

Although global rates can be just about achieved by technologies at present, the local counting rate capability required is at about 2 orders of magnitude higher of what can be held by detector technologies at present. The development of a higher counting rate capability technology is strictly necessary to fulfil the reflectometry instrument requirements at ESS. Although an ^{3}He-tube detector can meet the detector requirements for FREIA [3] in terms of spatial resolution, the main requirement for the instrument is the high counting rate capability that can not be achieved by this technology. Concerning the local counting rate capability, there is an extra issue arising from the dynamic range of 8 orders of magnitude between different regions of the detector.
A secondary need requiring attention and development is the spatial resolution beyond present state of the art. The detectors needed are compact in size and do not exceed $500 \times 500\, mm^2$ with spatial resolution of about $0.5 \times 2\, mm^2$. Although a more relaxed spatial resolution can be accepted in many cases, the goal of $0.5\, mm$, at least for one direction, would improve the instrument performance and would allow off-specular/GISANS measurements with shorter sample-detector distances (which would allow a broader wavelength band to be used).
The efficiency of detectors at present is enough to assure the instrument performance, and should remain high in new detector developments.

4 State of the art: what is possible with today technologies

^{3}He and ^{6}Li scintillators are the two main technologies used in neutron detectors for reflectometry instruments at present. Because of the limited counting rate capability, scintillators are in general a secondary choice for high flux reflectometers and they are used as support detectors.

4.1 Helium-3 Detectors

In terms of counting rate capability, neutron detection efficiency and γ-ray sensivity, ^{3}He is a superior to scintillators. Most existing reflectometers, summarised in Table 3 use this technology. Gaseous detector have several designs and performances, typically for cold neutrons (2.5-30Å), ^{3}He detectors have efficiencies of $50 - 90\%$, global count rates of 20kHz-30MHz, and local count rates of $200 - 300 Hz/mm^2$. Figure 2 shows an example of the FIGARO [9] Al mono block detector and a Denex detector [10].

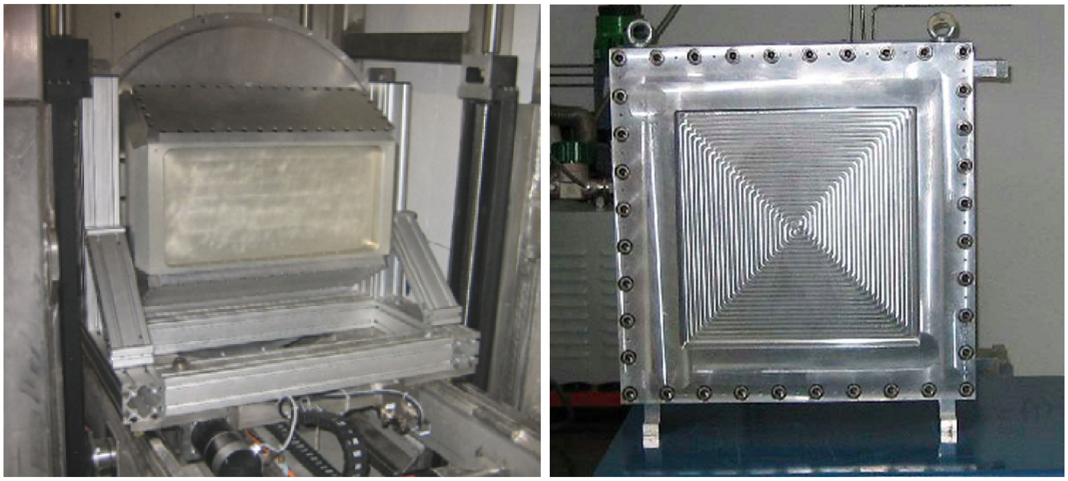

Figure 2: The Figaro detector [9] installed on the instrument (left) and a Denex detector [10] of active area of $300 \times 300\, mm^2$ (right).

Instrument	Facility	techn.	area ($mm \times mm$)	spatial res. ($mm \times mm$)	efficiency	global rate (s^{-1})	local rate ($s^{-1}mm^{-2}$)
FIGARO [9]	ILL	^{3}He	512×256	$\sim 2 \times 7.5$	$\sim 63\%$ @ 2.5Å $\sim 90\%$ @ 10Å $\sim 80\%$ @ 30Å	$3 \cdot 10^7$	230
SuperADAM [11]	ILL	^{3}He	300×300	2.8×2.8	76% @ 4.4Å	$2 \cdot 10^5$	-
REFSANS [12]	FRM2	^{3}He	500×500	$\sim 2 \times 2$	58% @ 10Å $\geq 50\% \in [5, 18]$Å	$2.2 \cdot 10^5$	300
INTER [13]	ISIS	^{3}He,^{6}Li	200×200	$\sim 1 \times 1$	-	-	-
POLREF [14, 15]	ISIS	^{3}He	200×200	$\leq 1 \times 1$	-	-	-
BIOREF [16]	HZB	^{3}He	300×300	2×3	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
LR	SNS	^{3}He	200×200	1.3×1.3	-	-	-
MR	SNS	^{3}He	210×180	1.5×1.5	-	-	-
Platypus [17]	OPAL	^{3}He	500×250	1.2×1.2	$\sim 60\%$ @ 10Å	$2 \cdot 10^5$	300
SOFIA [18, 19]	J-PARC	^{3}He ^{6}Li	128×128 256×256	2×2 4×4	- -	- -	300 300

Table 3: Detectors features on instruments at existing facilities, where figures are publically available.

^{3}He-based detector counting rate capability is limited by the space charge effect [20, 21, 22], as the ions created by each avalanche need more time, compared to electrons, to be evacuated. At high rates they tend to accumulate and consequently they decrease the actual electric field in the gas volume, decreasing the detection efficiency. ^{3}He detectors are also limited in spatial resolution because the anode wires for readout can not be mounted with a mm spacing in one direction, and because the spatial resolution along the wire by charge division is limited to about $2\, mm$ on a $30\, cm$ wire length, i.e. $\sim 0.7\%$. Another limiting factor is the gas pressure that can be reached within mechanical constraints, which leads to a general limit of around $1\, mm$ in the resolution the can be reached with this technique.

Although the quantity of ^{3}He needed for reflectometers at ESS would be available [23], [24], the spatial resolution and counting rate capability issues described above mean that these two main requirements can not be fulfilled with this technology. Neither issue prevents the instruments operation at ESS, but is not sufficient for realising their full potential as described in the current instrument proposals. The most important issue that can has to be addressed for reflectometers at ESS is the counting rate capability. The requirements exceed the performance of current ^{3}He technology by a factor of $10 - 100$.

4.2 Scintillator Detectors

Scintillators available and mostly used are ^{6}LiF/ZnS : Ag [25] and GS20 [26] (Lithium glass). The neutron detection efficiency for scintillators vary between 40% and 75% for 2.5 Å, which is slightly lower than standard ^{3}He tubes.The spatial resolution that can be achieved with scintillators in Anger camera type [27], [28] or WLS fibre readout [29], [30], [31] detectors is below $1\,mm$ and can easily fulfil the ESS requirements for reflectometers. However, $100\,kHz$ is the maximum count rate limit for scintillators coupled with a PMT, which can at best reach the same counting rate capability as ^{3}He and they are therefore not considered a good alternative as the main detector technology for reflectometers at ESS.

A new prototype has been developed at J-PARC for high-flux neutron reflectometers, in particular to fulfill the requirements for the SOFIA reflectometer [18]. The prototype is a Multi-Pixel Photon Counter (MPPC) coupled with a Zn/S :^{6} Li scintillator [32], [33]. This is a two-dimensional detector of $105 \times 128\,mm^2$ active area and it shows a spatial resolution of $5mm$ in one direction and in the other it can varies from $1.4mm$ to $2mm$. Uniformity of count along the detector surface is claimed to be in between the 10% variation. Local counting rate capability is about $400\,Hz/mm^2$, which is similar to the fastest existing ^{3}He detectors.

5 Strategy

Due to the ^{3}He shortage many groups in Europe and in the rest of the world are developing alternative detector technologies. Here, only the developments that have been ascertained to be relevant to reflectometry are mentioned. Most new developments are exploiting the ^{10}B technology, others WLS fibre readout coupled with scintillators. Possibilities that have been identified are:

- Multi-Blade [34], [35]
- Jalousie [36]
- Micro-Pattern Gaseous Detectors (MPGD) [37], [38], [39]
- A1-CLD [40]
- Semiconductors [41], [42].

These are described in the context of delivering high-performance detectors for ESS instruments for 2019.

5.1 Inclined Geometry Boron-10 Detectors

Perpendicular geometry ^{10}B detectors do not have good enough spatial resolution for reflectrometry applications. Therefore only inclined geometry detectors are considered here. The

Multi-Blade prototype [35] is a small area detector for neutron reflectometry applications. It is a Multi Wire Proportional Chamber (MWPC) operated at atmospheric pressure. The Multi-Blade prototype (see Figure 3) uses $^{10}B_4C$ [43] converters at grazing angle ($\sim 5deg$) with respect to the incoming neutron beam. The inclined geometry improves the spatial resolution and the count rate capability of the detector. Moreover, the use of the $^{10}B_4C$ conversion layer at grazing angle also increases the detection efficiency. The ^{10}B technology does not have any problems relating to gamma-sensitivity [44]. The Multi-Blade prototype is conceived to be modular in order to be adaptable to different applications. A significant concern in a modular design is the uniformity of detector response. The Multi-Blade should be implemented in a fixed geometry reflectometer because of the modular design; i.e. the detector-sample distance should be kept fixed.

Thanks to the inclined geometry, the Multi-Blade prototype can reach counting rates up to about 10 times larger than ^{3}He capability tubes at present (it would be about $2\,kHz/mm^2$), this would be only ten times smaller than the requirements for reflectometers at ESS. It has been shown that its neutron detection efficiency can be above 40% at 2.5 Å, similar to detectors used presently. The detector is operated at atmospheric pressure in a continuous gas flow. This implies that cost-effective materials can be used in the detector and that it can be operated easily in vacuum vessels.
Due to these advantages, the multiblade design is one that is favoured as a development path to be pursued for reflectometry. In terms of recent overviews of the R&D status of the ^{10}B Multi-Blade design, please see [35, 45, 46].

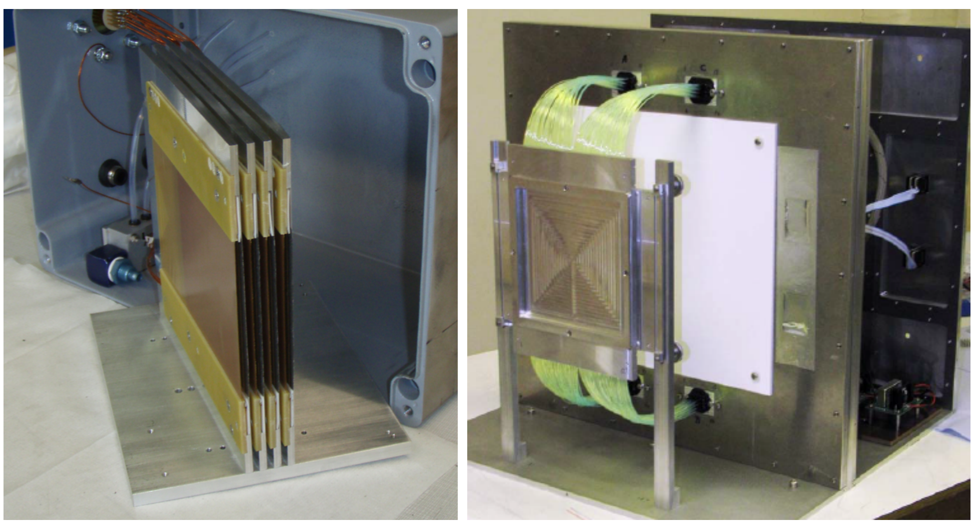

Figure 3: The Multi-Blade prototype developed at ILL (left). The WLS scintillating detector developed at ISIS (right).

The A1-CLD prototype [40] is a design update in-kind contribution for ESS from HZG/DENEX [10] and exploits the neutron conversion in one single layer operated at a very small grazing angle ($< 2.5deg$) to increase the detection efficiency. The efficiency is quoted to be $\sim 75\%$ at 5Å. Due to the extreme inclined angle, this geometry should offer higher rate capabilities than traditional ^{3}He gaseous devices by a factor of 20-50. There are many mechanical engineering challenges still left to realise this prototype concept as a demonstrated detector geometry, however, it has great potential for reflectometry applications if these hurdles can be overcome.

When neutron scattering is performed on soft matter samples, the incoherent scattering from hydrogen atoms gives a significant contribution to the total scattering signal. Single layers of the multi-layer boron based detector have neutron conversion efficiency, which is strongly dependent on the wavelength of the neutron. Therefore the depth of the interaction of the neutron with several layers in a detector carries statistical information about the energy of the detected neutron. In case of sufficiently statistics, this provides a coarse energy resolution, which can discriminate against this inelastic scattering. These developments are at their outset, however, may mature sufficiently to be implemented for detector geometries where there is more than one interaction layer.

5.2 Micro-Pattern Gaseous Detectors

The Micro-pattern gaseous detector class was invented at the ILL in 1988; this is probably neutron scattering biggest contribution to the wider interdisciplinary detector technology field. The Micro-pattern gaseous detectors (MPGD) [37] familiy includes Micro-Strip Gas Chambers (MSGC), Gaseous Electon Multipliers, GEMs, and Micromegas. In general these detectors offer intrinsic high rate capability ($\sim 1\, MHz/mm^2$) with excellent spatial resolution ($< 30\, \mu m$) [38]. These detectors are very widely used: from high energy physics, to space science (many MSGCs are used in satellites), to underground laboratories and beyond. In neutron scattering, the best known applications are the ^{3}He MSGC installed on D20, and the ^{10}B based CASCADE detectors [47], installed at the RESEDA instrument at FRM-II. Given their intrinsic rate and resolution capabilities, this technology is an obvious candidate to investigate for the detectors for reflectometry instruments under consideration at ESS. Technically this is not a category of detector by itself, but rather a variation on the Multi-Blade technology under development above. In order to increase the counting rate capability, the readout system can be replaced by GEMs and it might fulfil the requirements for ESS. There is no question as to the rate or resolution possible from such detectors, which exceeds the requirements necessary for the ESS instruments. Developments here, in parallel to those on the multiblade design, will focus on proving the appropriateness of such detectors in terms of scattering, dynamic range and stability. These developments are being pushed by a partnership with an in-kind contribution from Milan-Bicocca, CNR and INFN with CERN and ESS in-house effort.

5.3 Semiconductor Detectors

Microstructured semiconductor detectors represent a possible alternative as neutron detector for reflectometry applications. As shown in [42], they can reach a suitable detection efficiency (about 27% for thermal neutrons) with a good γ-ray rejection. Semiconductor detectors have a superb rate capability, well beyond the needs of ESS. Several efforts are ongoing, however, as they are all at the conceptual stage at the moment, they should not form a central part of the strategy here.

6 Schedule and Cost

6.1 Schedule

In the light of these developments which are ongoing, it is important to determine whether they are realistic to be deployed *as tested and mission-ready technologies.* Part of the overall strategy for detectors at ESS, to be able to contribute to the early success strategy of ESS as a whole, is that all detector technologies that are installed on ESS instruments should have been previously demonstrated elsewhere, and not be prototypes, i.e. *no prototypes installed at ESS.*

To determine whether this is realistic for a day 1 reflectometry instrument, the Multiblade detector design is taken as representative of the developments as a whole. This is so as to not overcomplicate the picture. The details of the timings of developments differ between the technologies under development, however in terms of steps to be demonstrated, they are the same. At the point where the technology choice needs to be taken for the instrument, the status of all relevant technologies would be reviewed, and the best option chosen.

The schedule for a hypothetical tranche 1 reflectometry instrument and for the detector developments targeted towards it, are shown in figure 4. The long time scale of the detector developments, which are already underway for 3 years, can be immediately seen from this figure. This underlines the necessity to keep a couple of technology options open, as outlined in the section above, in case of unexpected findings during the detector development process.

It can be seen that with the foreseen developments, it is possible to have fully proven and demonstrated the detector technologies such that they can be chosen in time and built for such an instrument. There is also some contingency in this schedule, but not a great deal. However, given the challenge for detectors as a whole for ESS, this is not unique to the reflectometry class. In summary, the schedule for developments looks realistic that detector technology availability should not inhibit the successful operation of a reflectometry instrument as a day 1 instrument at ESS, contributing to the early success strategy at ESS.

6.2 Cost

Whilst cost is always a driving factor in technology and design choices, for the reflectometers, it is not anticipated that detectors will be the major cost driver for the instrument. Given the modest area requirements for the reflectometers, this is expected to remain the case, even with the usage of new detector technologies. For example, the ^{10}B coatings can be mass produced very cheaply. Similarly, using developments in electronics will also drive these costs down significantly. These developments have shown that detectors can match pre-2008 price for ^{3}He detectors for large scale applications. For the smaller scale applications, like reflectometry here, it is difficult to pin down an exact price today, however it will not become a cost driver for the instrument.

7 Conclusion

Present detectors for reflectometry are at the limit and already inhibit instrument performance to some extent. The requirements for reflectometers at ESS go beyond present-day requirements and existing technologies. A realistic strategy for development has been outlined. Performance is or will be broadly comparable to ^{3}He [48]. The development programme, including technology demonstration on existing instruments look feasible to complete successfully for day-1 instruments to use tehse technologies in 2019. Therefore it is expected that the ambitious requirements expressed in the conceptual instrument proposals are realisable for day-1 instruments in 2019, and is compatible with the ESS early success strategy. *Finally, in overall summary, the availability and performance of detectors should not be an impediment to choosing a reflectometer for day-1 operation in 2019 at ESS.*

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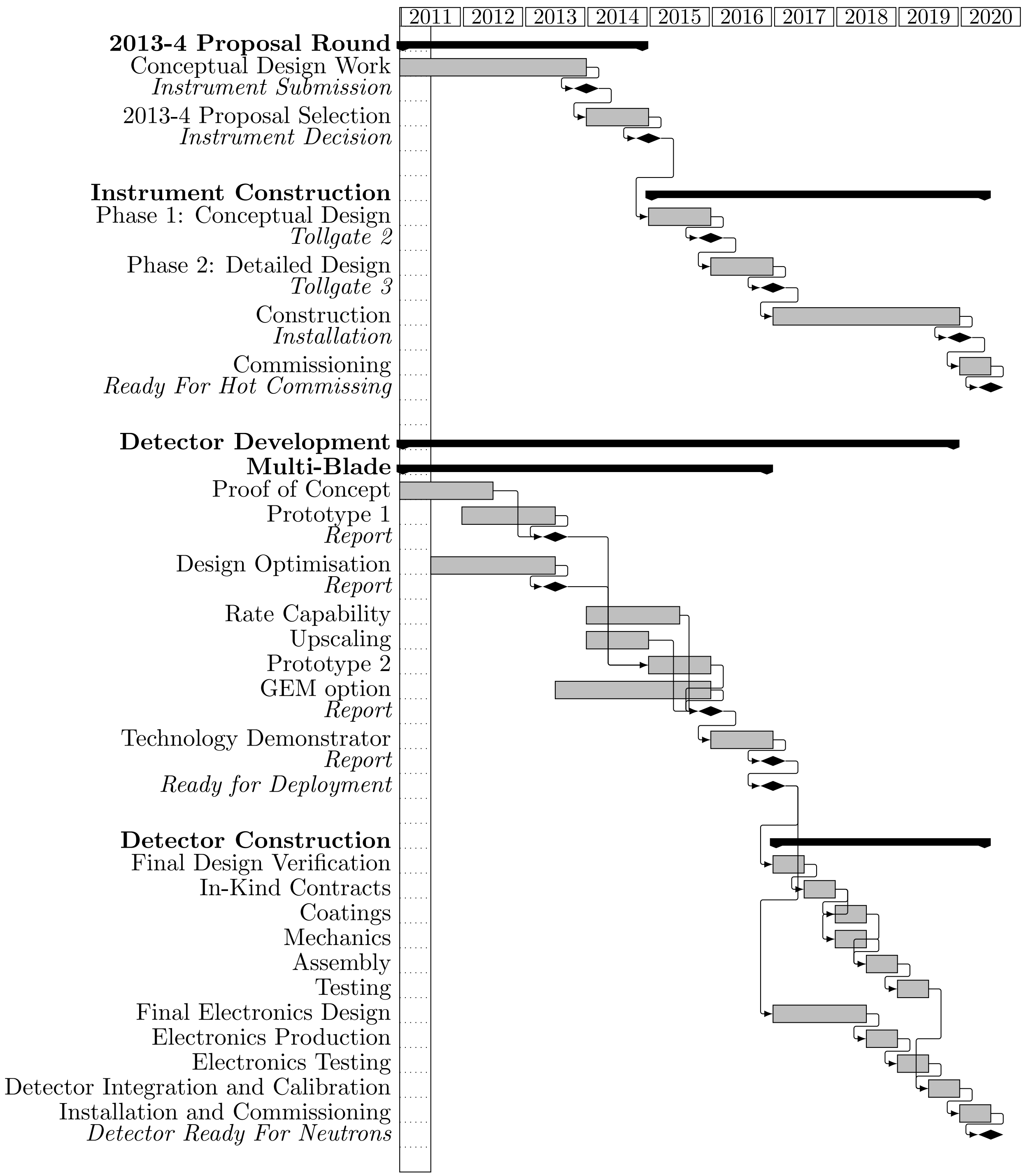

Figure 4: Simplified schedule for a hypothetical tranche 1 reflectometry instrument at ESS - a ”day one” instrument - and in particular the timeline for the detector development and technology choices for this instrument. The top part of the schedule shows the design update phase of the instrument and the instrument construction timeline for this instrument, assuming that it is chosen in this proposal round. The bottom part of the schedule shows how the timing of the detector development and the necessary prototyping stages fit in with the detector construction for this instrument. The MultiBlade design is taken here as representative of the various developments underway.