Response to ESS Accelerator Technical Advisory Committee April 2014 Recommendations

TABLE OF CONTENT **PAGE**

1. GENERAL

1.1. Revise planning as soon as situation of IKCs gets better defined

Update on In-Kind planning to be presented in Accelerator Progress and Plans presented by Mats Lindroos at plenary section of the 10th Technical Advisory Committee meeting.

1.2. Allocate sufficient time and resources in schedule for individual system tests (= commissioning without beam)

In Progress. Marc Munoz of the AD-Beam Physics group held a Workshop on Beam Commissioning April 8-9, 2014. A draft commissioning plan has been prepared. The final version is in process. The draft is available on request. In addition, Eugene Tanke (AD/ System Engineer) is revising the ACCSYS installation plan. The draft plan is due by the end of Calendar 2014. The final version will be ready for the 2015 ESS Annual Review.

1.3. Allocate sufficient time and resources in schedule for commissioning with beam.

See Recommendation 1.2

1.4. Consider early access to tunnel front-end for staged installation & commissioning

Because the target date of neutrons by the end of 2019 is extremely aggressive, it is very unlikely that there will be enough time for a staged installation and commissioning plan. See Recommendation 1.2

1.5. Consider possibility of practical training of newly recruited technical staff at existing experimental facilities in partner institutes.

This is a good concept in theory but difficult to implement in practice. The aggressive schedule along with the minimal staff size make it very difficult for the staff to allocate time for training at other laboratories and meet schedule milestones at the same time. Another approach would be to hire experienced staff from other laboratories. Because of limitations in the local labor market, this approach has been problematic.

1.6. Strive to secure IKCs identified as likely, and estimate from the results the likelihood of achieving full 75% target; revise ACCSYS IKC plans accordingly

See Recommendation 1.1

1.7. Plan combined& intertwined operation/construction activities in 2020-2025 in terms of schedule and resources

Agreed, this should be done. Current focus has been developing plan for construction.

1.8. Report qualitatively and quantitatively on progress of the different tasks

ACCSYS follows a well-defined project management plan (available on request). This plan requires each work package to report monthly on schedule, cost, technical milestones, and issues and risks (available on request). These reports are collated into an overall monthly project report that is submitted to ESS management (available on request). In addition each work package is audited at least annually by ACCSYS management. These reports of these audits are also available on request. Appendix 1 shows the ACCSYS milestones to be met in the next 12 months and the EVM curve for 2014.

1.9. Provide a presentation on availability answering the questions raised by the Annual Review, on the next TAC agenda

The first step in this process is to have a facility wide agreed upon definition for reliability and availability. Because of the different needs of the users, this task has been difficult. Enric Bargalló will present at the Fall 2014 ATAC meeting a definition of reliability and availability proposed by the Accelerator Division that is currently under review by ESS management. However, even with the new proposed definitions, it is problematic to define specific and verifiable reliability and availability requirements for accelerator subsystems and hence, will not be included in ACCSYS Level 3 and below requirements.

1.10. Aggressively follow prototype activities, esp. with spoke and medium beta cryomodule development and associated RF sources

Agreed. The spoke and medium beta are pre-series production models that are on the critical path for beam in 2019. There will be a presentation on the spoke cryomodule status and another on the spoke RF power amplifier at the Fall 2014 ATAC meeting.

1.11. Pursue early tunnel occupancy for the front end to start staged commissioning in Lund

See Recommendation 1.4

2. BEAM SHIELDING

2.1. Use the error analysis framework as a basis for determining instrumentation needs, correctors, and other equipment related requirements. It may be possible to relax certain constraints

The current tolerances are set assuming functionality of the beam diagnostics that could be used with a full power beam (BPMs are the only ones). The floor has been considered to have reached a reasonably stable stage and have not been considered. Field flatness in the SC cavities are not yet included in the error simulations, The process had though started to formulate the requirements for fields. The higher order components of the magnets was not part of the early error studies, the process is started recently.

2.2. Consider collimation options as an insurance against unexpected beam loss

Unexpected beam loss in the form of component failure causes losses that are very localized, to prevent these types of losses using a collimator system; one collimator should be added at each quadrupole doublet in between cryomodules which would be impractical. A presentation on the use of collimators in the ESS linac for halo reduction and beam loss will be presented at the Fall 2014 TAC

2.3. Ensure that the governing / licensing body endorses the assumed abnormal event basis used here.

Informal discussions between ESS and The Swedish Radiation Safety Authority (SSM - Strålsäkerhetsmyndigheten) have taken place. The SSM has given ESS a requirements document for achieving final licencing. ESS is preparing a response. There has not been a formal agreement on the accident or abnormal event criteria. Since the project has begun civil construction of the tunnel, this represents a project risk.

2.4. Check that localized hot spots > 1 W/m do not cause a problem at the site boundary, and consider mitigation if this is an issue (e.g. local shielding at the hot spots in the tunnel)

This work is on-going. Current state of the shielding studies can be found in:
Summary of Shielding and Activation analysis for the ESS Linac Tunnel

3. DIAGNOSTICS

3.1. Provide sequenced commissioning of the various linac sections, with temporary diagnostic stations.

As stated in Recommendation 1.4, schedule constraints will make staged commissioning very unlikely. Currently, there is no budget allocated for temporary diagnostic stations.

3.2. Make sure that both ESS team and IK partners contribute to installation, hardware and beam commissioning for gaining crucial expertise. This should be formalized in IK agreements.

See Recommendation 1.2

3.3. Relevant people from ESS (even if only professionals, in this phase) should join the in kind partner groups, during assembly, installation and testing of the accelerator components in the partner labs.

See Recommendation 1.2

3.4. Use opportunities to train the commissioning team also in collaboration with other facilities, as can be the LINAC4 commissioning at CERN in the near future.

See Recommendation 1.5

3.5. Define responsibility for the complete "inter-cavity" areas, from cavity flange to cavity flange

Agreed. In progress.

3.6. Include testing of all possible diagnostics equipment with beam in the agreement with IK partners, including this phase in the deliverable whenever applicable.

Many of the diagnostics are based on designs from other laboratories that have been tested with beam. For example, the BPM detectors, are based on the XFEL detectors, the BLMs are the same model as the LHC BLMs. There will be beam and instrumentation tests of the ion source and LEBT. There is a plan for beam testing the ion source, LEBT, LEBT, RFQ and MEBT at CEA. However, schedule constraints allow for little time for design iterations in this test and the RFQ is close to the critical path. Also, it would not be possible to meet the schedule if every prototype of instrumentation in the high energy end must be tested with beam.

3.7. The diagnostics team should take every opportunity to work in collaborating labs on the commissioning of new linacs, to gather experience and to better identify shortcomings and potential needs.

See Recommendation 1.5

3.8. As far as possible, prototypes for ESS should be tested with beam before going into series production.

See Recommendation 3.6

3.9. Provide explicit specifications so that all instrumentation will be compatible not only with the control system, but also any application programs.

This is part of the Level 4 requirements that are being written. Since the commissioning plan, which drives the requirements for the instrumentation, is not complete, these requirements are not complete resulting in the current specifications for instrumentation on a best guess method. Once the requirements are complete, the specifications will be updated.

3.10. ESS diagnostics team must take ownership of all instruments once in operation mode and will need the resources to do so.

It is the plan for ESS to take operational responsibility of all in-kind contributions. The operational staff plan for the Accelerator Division is shown in Appendix 3

3.11. Provide clear specifications for all diagnostics interfaces, and the electronics standard, which has to be used by the manufacturer. Order complete systems whenever possible.

See Recommendation 3.9

3.12. Define detection time for partial beam loss.

A Machine Protection Committee has been formed and this will be part of its charge.

3.13. Define diagnostics needs for beam commissioning.

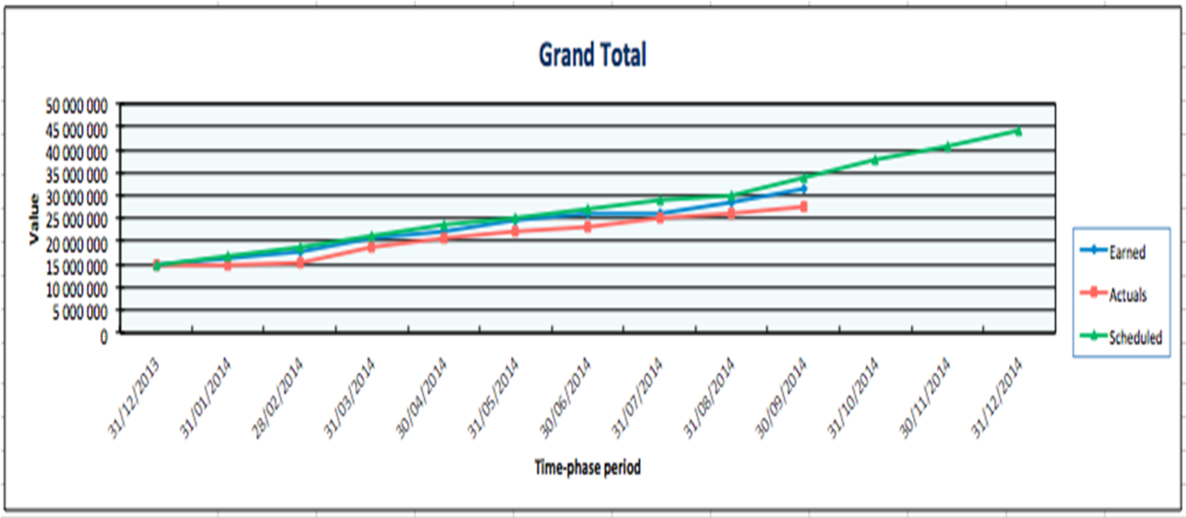
See Recommendation 3.9

3.14. Foresee "redundant" diagnostics in order to cope with non-available systems during start-up.

4. APPENDIX 1. ACCSYS MILESTONES FOR THE NEXT 12 MONTHS

ID	Name	# Activities leading up (All) / Completed	Planned Date	Current Forecast or **Actual**	Delay (W-days)
A50050	WP08. First IOT:s prototypes ordered	1/0	2014-04-25	**2014-09-30**	-86
A37160	WP08. First Klystron prototypes ordered	3/1	2014-04-25	2014-12-10	-137
A33670	WP05 Delivery of Drawings and complete project documentation for M-ECCTD (MS2)"	1/1	2014-06-28	2014-12-01	-90
A50080	WP02. Failure modes report	4/3	2014-08-28	2014-11-03	-47
A51550	INFN Catania/Legnaro IN-KIND agreement signed	0(0)	2015-01-01	2015-01-01	0
A48100	WP04. Spoke cavity prototype available for Uppsala test stand	3/0	2014-11-03	2014-12-23	-36
A32510	WP11. Accelerator Cryoplant ordered	8/5	2015-02-02	2015-02-12	-8
A37180	WP11. Heads of agreement between ESS AB and IKC signed for CDS eliptical section	4/2	2015-03-25	2015-01-19	+47
A46790	WP03. Proton Source #1 Beam test in Catania started	8/4	2015-03-30	2015-04-01	-1
A32550	Nb procurement starts for the spoke series	1/0	2015-11-18	2015-04-01	+140
A45230	Beam Commissioning Planning Front end	4/1	2015-04-15	2014-04-15	0
A31170	WP99. Integrated Installation Plan Complete	8/4	2015-06-18	2015-06-25	-5
A36780	WP08. Start of Modulator and klystron prototype testing	5+/2	2015-07-01	2015-10-27	-64

5. APPENDIX 2. ACCSYS EVM CURVE FOR 2014



Criteria1.Description	31/12/2013	31/01/2014	28/02/2014	31/03/2014	30/04/2014	31/05/2014	30/06/2014	31/07/2014	31/08/2014	30/09/2014
Earned	14 709 401	16 327 523	17 986 150	20 571 635	22 289 989	24 436 288	25 997 352	25 997 352	28 520 854	31 296 714
Actuals	14 709 401	14 592 405	15 385 740	18 709 012	20 500 629	22 299 956	23 250 184	24 999 981	25 875 951	27 699 381
Scheduled	14 709 401	16 671 835	18 713 058	21 174 285	23 531 255	25 301 194	27 205 880	29 028 858	30 152 017	33 960 619

6. Appendix 3. AD Long Term Staff Plan

AD Long Term Staff Plan	2014				2015				2016				2017				2018				2019				2020				2021			
29 April 2014	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
ACCELERATOR DIVISION	56	59	67	68	75	76	77	77	85	85	86	86	100	100	100	100	108	108	108	108	110	110	110	110	110	110	110	110	110	110	110	110
MANAGEMENT	4	4	4	4	4	4	4	4	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Head of Accelerator Division	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Deputy Head of Accelerator Division									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
PA to Head of Division	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Team assistant	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Team assistant									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Divisional planner	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ACCELERATOR SUPPORT	1	1	1	1	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Systems engineer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Safety engineer					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Reliability engineer					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Radiation protection engineer									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BEAM PHYSICS	6	6	6	6	7	7	8	8	8	8	8	8	8	8	8	8	9	9	9	9	10	10	10	10	10	10	10	10	10	10	10	10
Group leader	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Beam Dynamics																																
Accelerator phycisist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Phycisist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Phycisist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Accelerator phycisist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Accelerator phycisist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
High-Level Applications																																
Applications developer					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Applications developer							1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Operations management																																
Head of operations																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Deputy head of operations																					1	1	1	1	1	1	1	1	1	1	1	1
FRONT END	1	1	1	1	1	1	1	1	1	1	2	2	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Group leader													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Accelerator phycisist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, ion source											1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
SPECIALIZED TECHNICAL SERVICES	8	8	11	11	12	12	12	12	12	12	12	12	16	16	16	16	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Group leader	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Test Stands																																
Engineer, test stand project leader	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, test stand infrastructure	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cryogenics																																
Engineer, cryoplants linac	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, cryoplants target	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, cryoplants instruments/tests	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engineer, distribution and storage	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, cryogenics operations lead													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, cryogenic staff			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, operation													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, operation													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, operation													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, operation													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technician, operation																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technician, operation																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, maintenance																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, maintenance																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Vacuum																																
Engineer, vacuum lead	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, linac	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, linac			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, target			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Engineer, instruments			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technician, linac			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, workshop					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, target									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technician, target									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technician, instruments													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Technician, instruments													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

AD Long Term Staff Plan	2014				2015				2016				2017				2018				2019				2020				2021			
MECHANICAL ENGINEERING, TUNNEL SYSTEMS	**4**	**5**	**10**	**10**	**11**	**11**	**11**	**11**	**12**	**12**	**12**	**12**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**	**13**
Senior scientist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, electrical	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, mechanics	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, mechanics									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, mechanics													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, cooling systems		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, power systems	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, beam instrumentation					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, mechanics			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, mechanics			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, mechanics			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, mechanics			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, mechanics			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
BEAM INSTRUMENTATION	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**	**16**
Group leader	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scientist/Engineer, bam loss and energy deposition	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scientist/Engineer, beam current, position and phase	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scientist/Engineer, beam profile	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Scientist/Engineer, target diagnostics	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, Analog/RF	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, Analog	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, Digital/FPGA	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, FPGA development	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, Software/system integration	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, Software/EPICs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, Mechanica	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, Electronics/PCB	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, maintenace/repairs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, maintenace/repairs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, maintenace/repairs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
RF SYSTEMS	**14**	**16**	**16**	**17**	**18**	**19**	**19**	**19**	**22**	**22**	**22**	**22**	**29**	**29**	**29**	**29**	**33**	**33**	**33**	**33**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**	**34**
Group leader RF	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Master oscillator and low level RF																																
Accelerator scientist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, LLRF	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, LLRF									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, LLRF													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Interlock and control																																
Engineer	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, PLC programming	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
High power systems																																
Engineer, RF, senior	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, RF, RFQ/DTL/MB klystrons	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, RF, spokes	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, RF, HB IOTs					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, RF, solid state and drivers	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, RF power	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, RF power				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Modulators																																
Engineer, modulators, senior	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, modulators		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, modulators									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, modulators													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, modulators																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Magnets and power supplies																																
Engineer, magnets/power supplies, senior	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, magnets/power supplies									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, magnets/power supplies													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, magnets/power supplies																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Distribution																																
Engineer, RF, distribution	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, high power RF distribution						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
RF support																																
Engineer, tests/measurements/repairs	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, tests/measurements/repairs		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, racks/cables													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, racks/cables													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician interlock													1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, spares/assembly/conditioning																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, mechanical																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, mechanical																					1	1	1	1	1	1	1	1	1	1	1	1
SUPERCONDUCTING RF	**2**	**2**	**2**	**2**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**
Scientist, SRF	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineer, SRF	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, SRF					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Technician, SRF									1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1