EUROPEAN SPALLATION SOURCE

Accelerator Integration

Dave McGinnis

AD Chief Engineer

www.europeanspallationsource.se

1 April 2015

Purpose

- The Accelerator Integration Group is responsible for the integrated technical design of the ESS Linac
- The integrated technical design is defined by set of specifications organized in an hierarchical structure.
  - L1 - Linac Power and Flux specifications
  - L2 - Linac Energy and Peak Beam Power specifications
  - L3 - Linac sub-system specifications
  - L4 -Engineering discipline specifications
    - Electromagnetic resonators, proton beam instrumentation, beam magnets and deflectors, vacuum, cryogenics, radio frequency systems, power convertors, physical plant, control system
- The main task of Accelerator Integration Group is to:
  - Ensure a complete set of specifications for the integrated technical design is available.
  - Verify that the complete set of specifications for the integrated technical design are met in the specific engineering design of the ESS Linac sub-systems.

Staff

- Dave McGinnis - Chief Engineer
- Eugene Tanke - Systems Engineer
- Stephen Molloy - Accelerator Engineering Section Leader
  - Edgar Sargsyan - Lead Engineer RFQ, DTL
  - Aurélien Ponton - Lead Engineer ISRC, LEBT, MEBT
  - Inigo Alonso - Lead Engineer HEBT
  - Steve Molloy - Lead Engineer SPK, MBL, HBL, A2T
  - Enric Bargalló - Lead Engineer RAMI
- Nick Gazis - Design Integration Section Leader
  - Carl-Johan Hardh - Design Engineer (Design office)
  - Daniel Lundgren - Design Engineer (Design office)

Responsibilities

- Chief Engineer:
  - Coordination of the Physical Plant Working Group*
  - Editor of the ESS Linac Parameter Book
- System Engineer:
  - Specification System**
  - Installation Planning
- Accelerator Engineering Section*
  - Engineering discipline specifications*
  - AD-ICS Vertical Integration Tests*
- Design Integration Section*
  - Integrate in the ESS 3D master model (ESS-0016885) with
    - In-Kind Contributions and other design input produced inside & outside ESS.
    - In-Kind Drawing Exchange Solution

* essreviewer, TAC112015

** Train1, DOORStr1

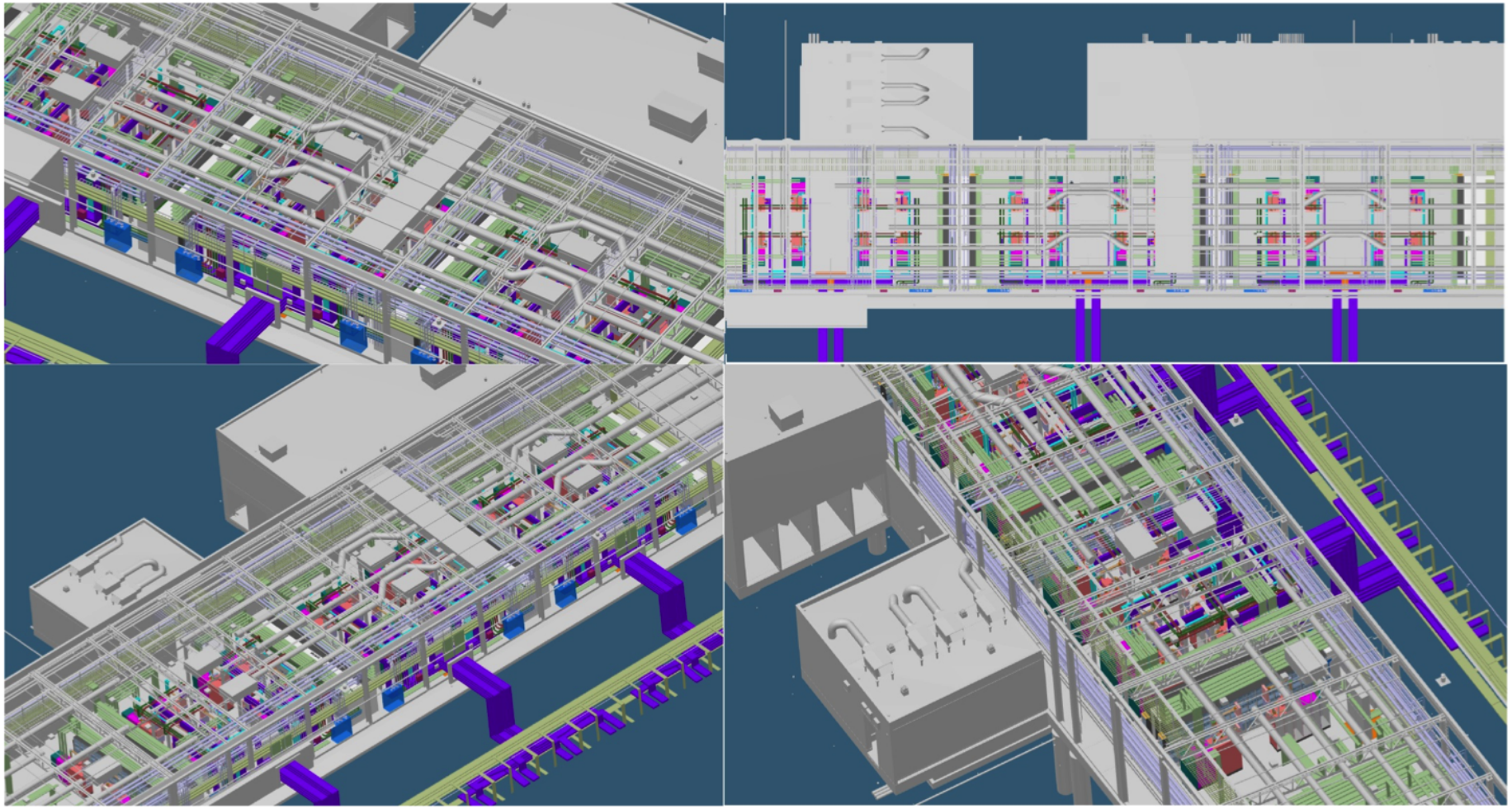
Physical Plant Working Group

- Goal
  - Coordinate accelerator equipment installation with conventional facilities
  - WIKI*
  - Issue Board*
- Members
  - Accelerator Safety - Lali Tchelidze
  - Cables and Cable Trays - Evangelia Vaena - AD-TS
  - CF Liaison - Karin Svedin - CF
  - Conventional Power - Frithiof Jensen - AD-TS
  - Cooling - Anton Lundmark - AD-TS
  - Cryogenics and Test Stands - Wolfgang Hees - AD-TS
  - Gallery Layout - Morten Jensen - AD-RF
  - Protection Systems - Stuart Birch - ICS
  - Radiation calculations - Luisella Lari AD-MGMT
  - Target Interface - Stephen Molloy - AD-AIG
  - System Engineering - Eugene Tanke - AD-AIG
  - Tunnel Layout - Nick Gazis - AD-AIG

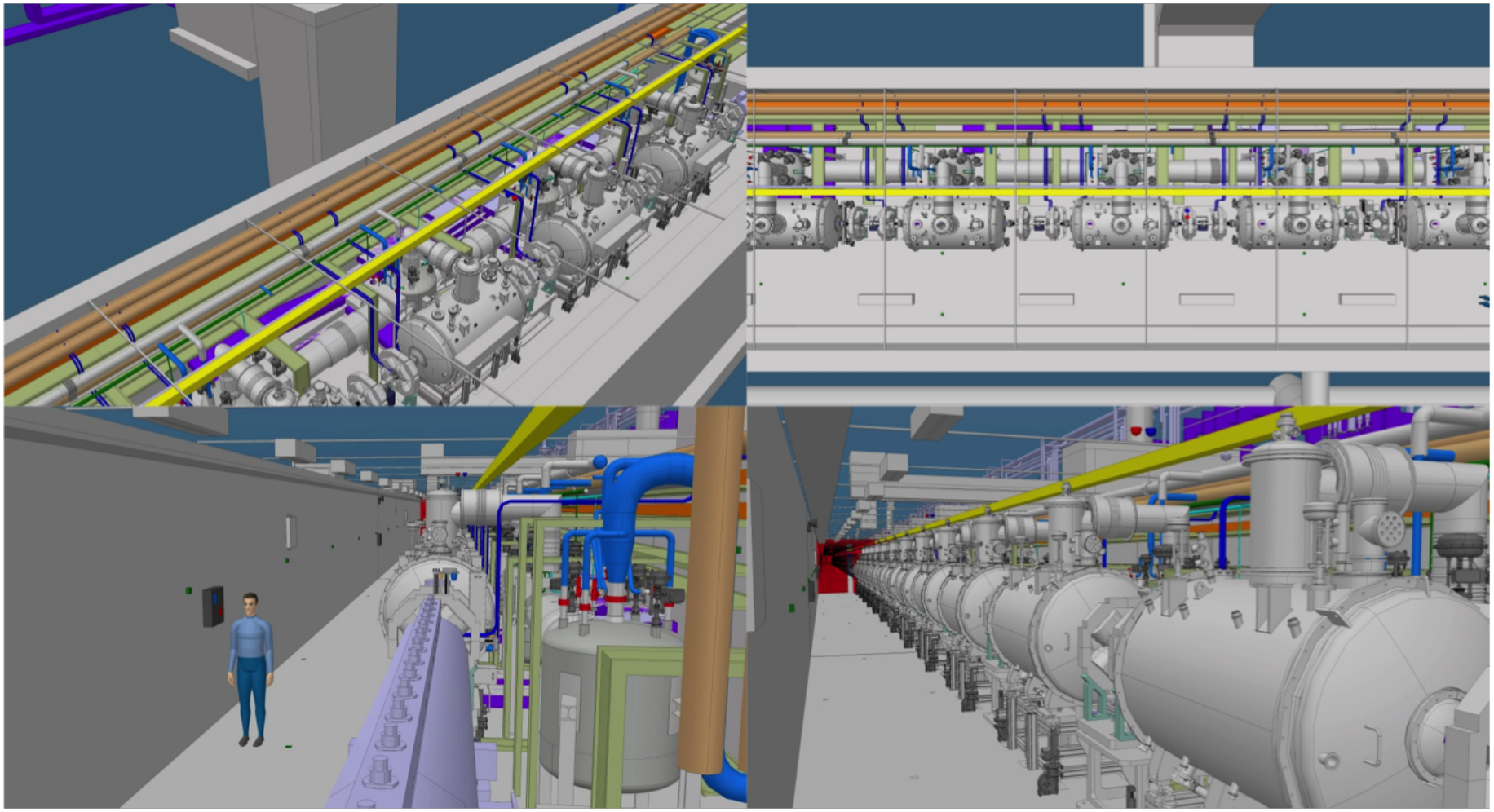
* essreviewer, TAC112015
** Train1, DOORStr1

PPWG:

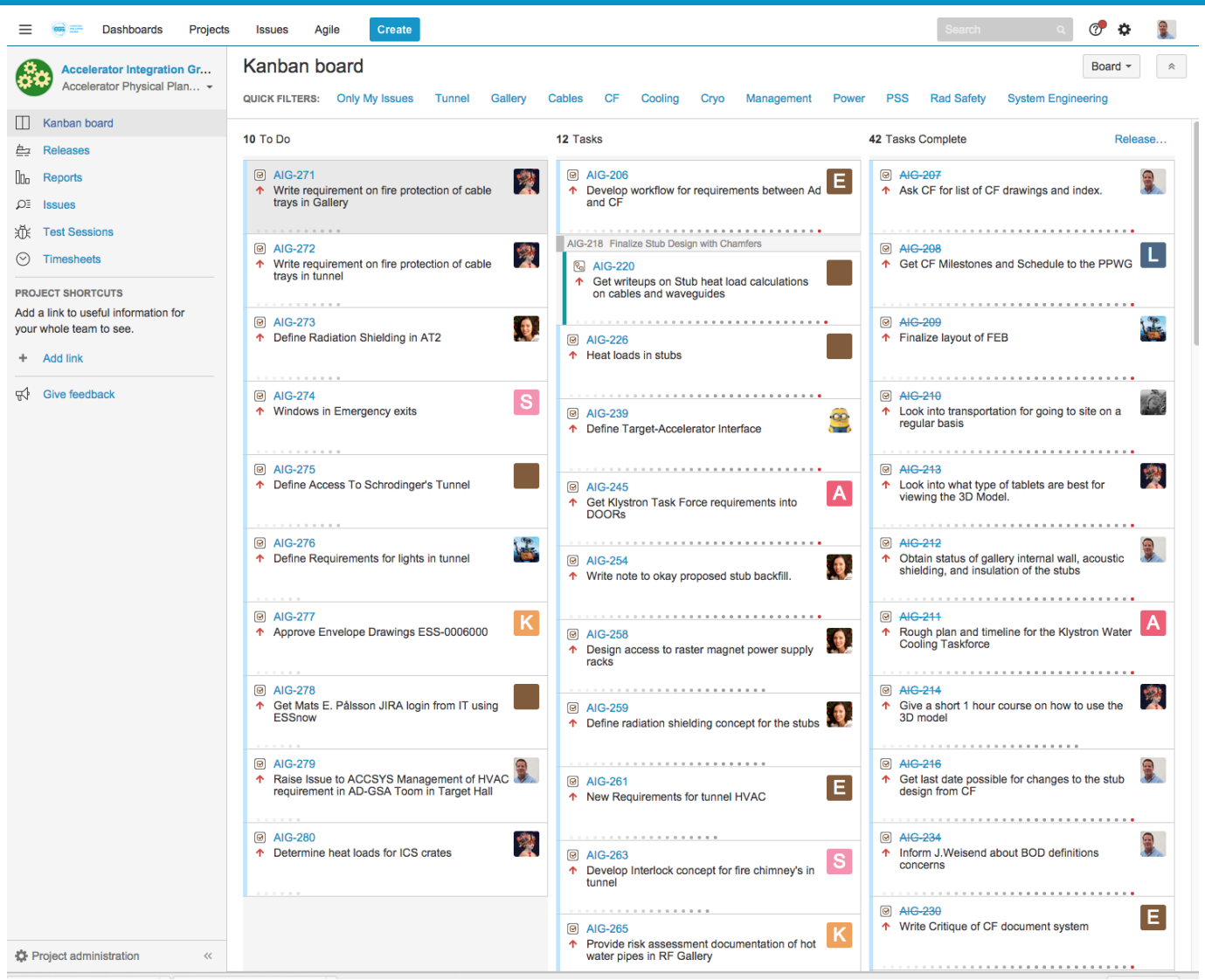
Example Klystron Gallery Equipment: Spoke Section



PPWG:
Example Tunnel Equipment: Spoke Section



PPWG JIRA Issue Board*



* essreviewer, TAC112015
** Train1, DOORStr1

PPWG Major Issues

- Klystron Collector Water cooling system
- Tunnel HVAC system
- Tunnel Drainage
- Tunnel Smoke Evacuation System
- HEBT Loading Bay Vertical Height Clearance
- No documented baseline to review against AD specifications
- Unclear change control process

L4 Specification Status

- The Level 4 Specifications
  - which describe the specifications for the engineering disciplines
  - are the responsibility of the Lead Engineers
- The Level 4 Interface Specifications
  - which describe how engineering disciplines will interact
  - are the responsibility of the workpackage leaders
- The Level 4 Specifications and Interface Specifications and Specifications will be major component of the technical annexes of the in-kind contracts
- **The in-kind contracts cannot be considered complete until these specifications are written**

L4 Specification Status

- ESS has held two CDRs in the past 6 months with three more planned in the next 4 months. At the first two CDRs,
  - The list of specifications were incomplete.
  - The interface specifications between Accelerator Disciplines were non-existent, incomplete or not ready.
- Since the AIG is purely an advisory group it does not have the authority to:
  - enforce work package leaders to follow L4 specifications
  - require work package leaders to author L4 interface specifications

Internal Vertical Design Reviews (IVDRs)

- To try to prevent these types of gaps of information at future CDRs,
  - the AIG will hold a two day internal review of the status of the L4 specifications of a specific L3 Accelerator system
  - every three weeks for the rest of 2015.
- For each review, the AIG will issue a report
  - To the ACCSYS Project manager
  - reporting the status of the L4 specifications
  - ***advising*** whether
    - a CDR should be held
    - the in-kind contract technical annex is ready.
- The charge, agenda, and schedule was presented at the Technical Board 12

IVDR Schedule

System	Date	Lead Engineer	Comments
RFQ	28-Apr-2015	E. Sargsyan	
DTL	19-May-2015	E. Sargsyan	
A2T	9-Jun-2015	S. Molloy	Addresses WP6 beam delivery systems
HEBT	30-Jun-2015	I. Alonso	Focuses on LWUs
SPK	8-Sep-2015	S. Molloy	
MEBT	29-Sep-2015	A. Ponton	
ELP	20-Oct-2015	S. Molloy	
ISRC	10-Nov-2015	A. Ponton	
DMP	1-Dec-2015	S. Molloy	

System Integration Tests (Blinky Light Tests*)

- AD and ICS have organized two simple system tests to integrate accelerator devices into the control system.
- Two simple configurations were intentionally selected
  - in order to pioneer the procedures and tools
  - rather than spend time on complex integration tasks.
  - The tests are nick-named "Blinky Light Tests"
    - because we will have achieved our goal
    - if we can make a red light blink using our tools and procedures.
- The two accelerator systems to be tested are:
  - A powered electromagnet (e.g. an accelerator quadrupole, dipole corrector, etc.).
  - A vacuum system containing examples of many (most?) of the technologies planned for deployment in the accelerator vacuum system.

* essreviewer, TAC112015
** Train1, DOORStr1

Blinky Light Test Goals

- Demonstrate how the Accelerator and Controls expert work together
  - Identify the key documents
  - Identify the key roles
  - Identify obstacles. These are the processes and tasks that were difficult and caused major delay.
  - Track the actual time for the tasks (i.e. requirements, procurement, integration, etc.) to use as a datapoint for future estimates.
- Expose the in-house people to the specifics of EPICS integration.
  - The tests are to be technically simple, such that a person inexperienced in EPICS can do the integration.
  - The tests are to be implemented via the agile methodology, with product owners and scrum masters.
  - The tests are intended to expose the WPL's to the issues of integration.
- Demonstrate that a simple integration can be completed with the hardware and software we have chosen?
  - Identify and demonstrate a basic and standard Control Box configuration.
  - Exercise the ESS standard Configuration Management, Services, and Development Environment software.

RF Test Stand

- The Blinky Light tests have already uncovered a number of important unforeseen issues on just simple systems.
- It is likely that many other unforeseen issues would be uncovered with more complicated systems.
- The RF system is the single most costly and complicated system for the ESS Linac.
- A complete system test of an RF system ***in Lund*** would be invaluable in:
  - Uncovering unforeseen interface issues
  - Developing logistics and infrastructure
  - attracting experienced staff

RF Test Stand

- The ATAC has on numerous occasion strongly recommended an RF test stand in Lund
- The RF test stand will require additional staff that is not in the AD staff plan
  - One power convertor engineer, two power convertor technicians
  - One RF engineer, one mechanical technician, one RF technician.
  - ATAC has also recommended increasing the staff of the RF group in proportion to other groups
- The RF Test stand would contain:
  - 704 MHz klystron with a peak power of 1.5 MW
  - pulsed modulator with 140 kVA of power
  - High voltage dummy load, RF dummy load
  - 704 MHz circulator and waveguide distribution

RF Test Stand Sources of Equipment

- Stage 1
  - 140 kVA multi-level topology being currently developed at LTH (ready for klystron tests beginning Q1 2016 - this R&D project could require extra time.)
  - 704 MHz being procured from Thales (late Q1-early Q2 2016)
- Alternative
  - Borrow ESS modulator from CERN (already commissioned)
  - Borrow CERN 704 MHz Klystron (under tests)
  - Install at ESS late Mid Q3 2015 (9 month advance over Stage 1)
  - Return CERN equipment in Q2-Q3 of 2016

RF Test Stand Locations

- Southern Hall in M-Building
  - Availability: from now on (ESS is already renting this space);
  - Total area of 375m^2;
  - 5 tons crane available that covers this entire area;
  - The clearance on the front gate is enough to transport any modulator inside. A klystron can also pass through if in horizontal position. In vertical position it's not possible;
  - The ground floor is concrete with 50 cm thickness
  - There is enough power in the underground substation,
    - We have already requested the university to bring up a power cable for 150kVA.
  - Price for renting the hall: 220kSEK per year;
    - Price to install one 150kVA cable + circuit breaker + power meter in the hall: 135 kSEK;
  - There is no primary cooling capability in the close area in that part of the building ,
    - We have launched a Request For Quotation to rent one for 150kW cooling capability for one year.
- Scheelevagen
  - Space will be rented by ESS, which is available from May or June;
  - The total area is 700 m^2;
  - The clearance in the main gate is enough both for modulators and klystrons;
  - No crane is available;
  - 220kVA of power is available.
  - There is a primary cooling circuit in the building with a capacity of at least 150kW;
  - There is always a possibility to rent an autonomous cooling station if needed

AIG Summary

- AIG has focussed the last 6 months on developing integration tools (DOORs, JIRA, LinacLego, and IDES)
- Specification gathering
  - has been an exercise in frustration
  - but will try to solve the lack of progress with IVDRs
- The PPWG
  - has been effective at uncovering a number of significant issues with the interfaces between Conventional Facilities and Accelerator Division
  - but has not made much progress in achieving remedies.
- The AIG would like to transition
  - from office work
  - to hardware tests of systems
    - Blinky Light Project
    - RF Test Stand

EUROPEAN SPALLATION SOURCE

Installation plans for the ESS Linac

Eugene Tanke

AD Systems Engineer

Dave McGinnis

Chief Engineer

www.europeanspallationsource.se

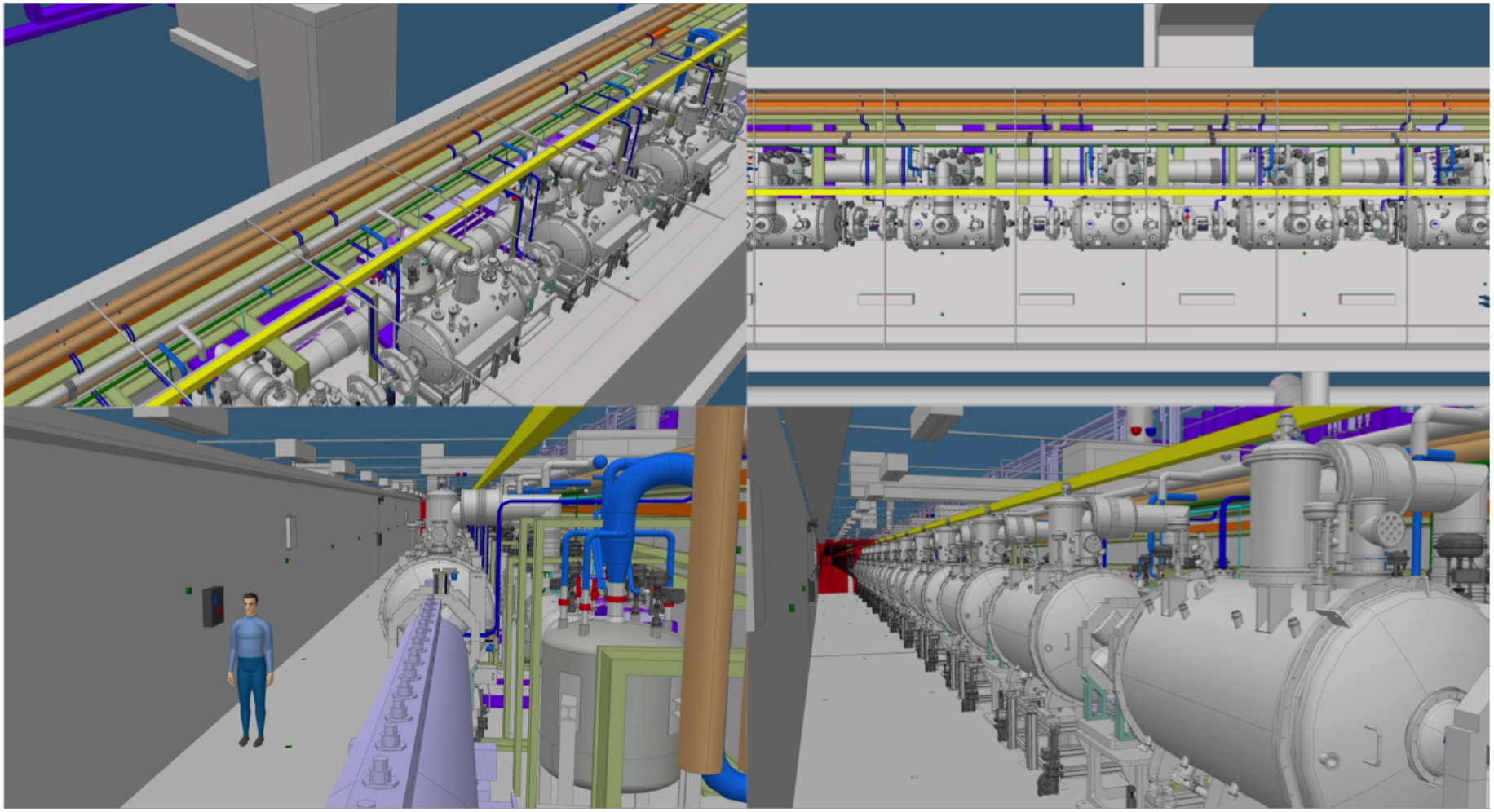
1 April 2015

Outline

- Basis for an integrated accelerator Installation, Testing and Commissioning plan
- Proposed sequence
- Next steps
- Open issues

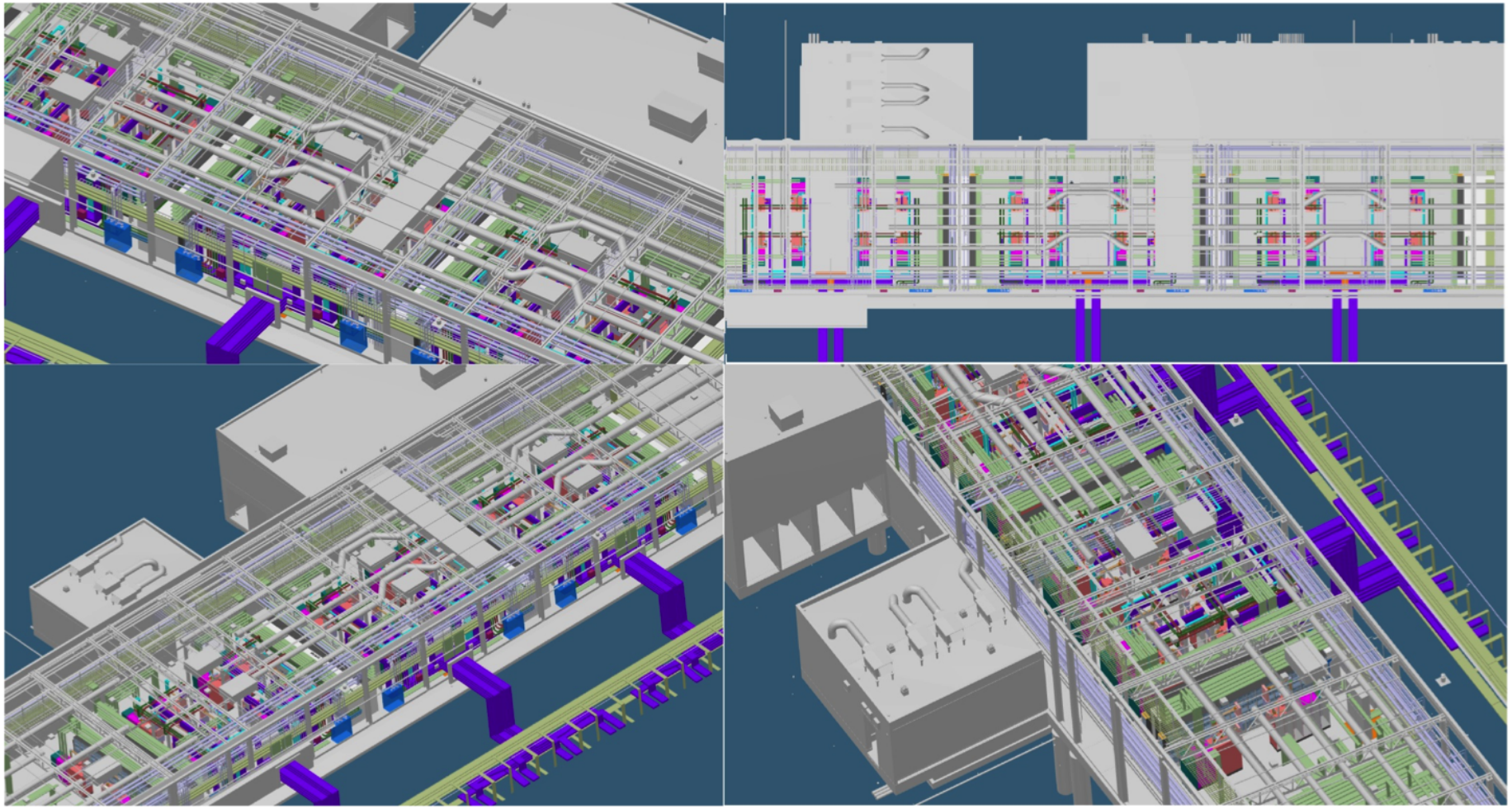
The Task Ahead

Example Tunnel Equipment: Spoke Section



The Task Ahead:

Example Klystron Gallery Equipment: Spoke Section



Sectioned Commissioning

- ESS linac will be commissioned in sections
  - Driven by schedule
  - Minimize risk
- This requires dovetailing Installation, Testing and Commissioning
- Installation will be a challenge due to the high density of equipment, both in the tunnel and in the klystron gallery
- Low energy end of the linac is critical, e.g. because of
  - Space charge and space charge compensation
  - Large angles in beam
  - Phase advance

Planning Definitions

- Phases related to Installation, Testing and Commissioning (ITC) have been defined in ESS-0025640*:
  - ITC Phase A: Installation
  - ITC Phase B: Local testing without beam and without ICS
  - ITC Phase C1: Local testing without beam, with ICS
    - Local test including controls,
    - e.g. controlling a power supply
  - ITC Phase C2: Integrated testing without beam, with ICS
    - End to end test including controls,
    - e.g. controlling a power supply, concomitant magnet, water cooling, interlocks etc
  - ITC Phase D1: Testing diagnostics with beam
    - Will typically make use of a “probe” beam
  - ITC Phase D2: Beam commissioning
    - Goal during this phase is to prepare and deliver the required beam

*Document is not yet approved

Installation/testing/commissioning steps: A preliminary sequence

- Goal:
  - Reach Master Schedule milestone for beam on target
  - 28-Jun-2019 for 570 MeV on target (MS milestone 1G4910)
- Path:
  - Understanding boundary conditions, optimizing sequencing
  - Requires multiple iterations
  - This presentation does not represent the final solution and is far from "complete"!
  - Start with understanding RFI (Ready For Installation) dates

Proposed Integration Process with P6

- Use Ready For Installation (RFI) dates
  - from official P6 ACCSYS 11 schedule
  - as well as durations as needed
- Optimize the installation/testing/commissioning sequence
  - in OpenProject based on the above RFI dates
  - Currently 500+ lines in OpenProject
- Push plan output to the newly created P6 ACCSYS 11 I schedule
  - After a transition period, the ACCSYS 11 I schedule will become the reference

RFI and Installation Dates

Deliverables Tunnel (RFI)	1,239 days	2017/10/02 8:00 AM
ISrc and LEBT	0 days	2017/11/01 9:00 AM
RFQ	0 days	2018/06/20 8:00 AM
MEBT	0 days	2018/05/31 8:00 AM
DTL4	0 days	2017/10/02 8:00 AM
DTL3	0 days	2018/02/01 8:00 AM
DTL1	0 days	2018/06/01 7:00 AM
DTL2	0 days	2018/10/01 8:00 AM
DTL5	0 days	2019/02/01 8:00 AM
SPK Cryomodule 1	0 days	2018/01/08 9:00 AM
SPK Cryomodule 2	0 days	2018/02/01 9:00 AM
SPK Cryomodule 3	0 days	2018/03/01 9:00 AM
SPK Cryomodule 4	0 days	2018/04/02 8:00 AM
SPK Cryomodule 5	0 days	2018/05/01 8:00 AM
SPK Cryomodule 6	0 days	2018/06/01 8:00 AM
SPK Cryomodule 7	0 days	2018/07/02 8:00 AM
SPK Cryomodule 8	0 days	2018/08/01 8:00 AM
SPK Cryomodule 9	0 days	2018/09/03 8:00 AM
SPK Cryomodule 10	0 days	2018/10/01 8:00 AM
SPK Cryomodule 11	0 days	2018/11/01 9:00 AM
SPK Cryomodule 12	0 days	2018/12/03 9:00 AM
SPK Cryomodule 13	0 days	2019/01/07 9:00 AM
MBL Cryomodule 1	0 days	2018/09/03 8:00 AM
MBL Cryomodule 2	0 days	2018/10/02 8:00 AM
MBL Cryomodule 3	0 days	2018/11/02 9:00 AM
MBL Cryomodule 4	0 days	2018/12/03 9:00 AM
MBL Cryomodule 5	0 days	2019/01/07 9:00 AM
MBL Cryomodule 6	0 days	2019/02/04 9:00 AM

- RFI dates are not necessarily installation dates
- Actual required installation dates may still change as a function of the sequence optimization
- Suggest to not alter current Ready For Installation (RFI) dates

Example of data currently in OpenProj derived from Master Schedule

Definitions of Building Access

- Early Access:
  - The building is weather protected and CF contractors are still doing construction works.
  - Other Division can start to install their equipment, but all works have to be approved and coordinated by CF Contractor.
  - The CF Contractor is responsible for OHS and all works have to be in accordance with the rules and regulations on site.
  - Experience from SNS: Early Access not always useful when overhead work still ongoing
- Full access: (Beneficial Occupancy Date or BOD)
  - CF has handed the building over to ESS Operations.
  - For ACCSYS this means ACCSYS controls access to that particular ACC building; ACCSYS can start installation

Will use Early Access dates as needed

- Access dates for ACCSYS defined
  - Tunnel Full Access 2-May-2017
  - Klystron Gallery (along FE+SPK stubs) Early Access 1-Dec-2017*
  - Klystron Gallery Full Access 31-May-2018
  - Test stand and cryoplant dates consistent with schedule

	Early Access	Full Access
Compressor bldg.	9-Sep-2016	1-May-2017*
Coldbox bldg.	7-Oct-2016	1-May-2017*
KG (Test stand)	7-Oct-2016	1-May-2017*

- Usage of Early Access and Full Access dates
  - Example use cases for early access: setting up the alignment network, start drilling holes for bolting down equipment
  - Adjust as needed & possible to match ACCSYS requirements

*Preliminary dates, being negotiated with CF

Install Utilities
(1 out of 18)

- Preliminary installation sequence for ACC “utilities” in the tunnel established

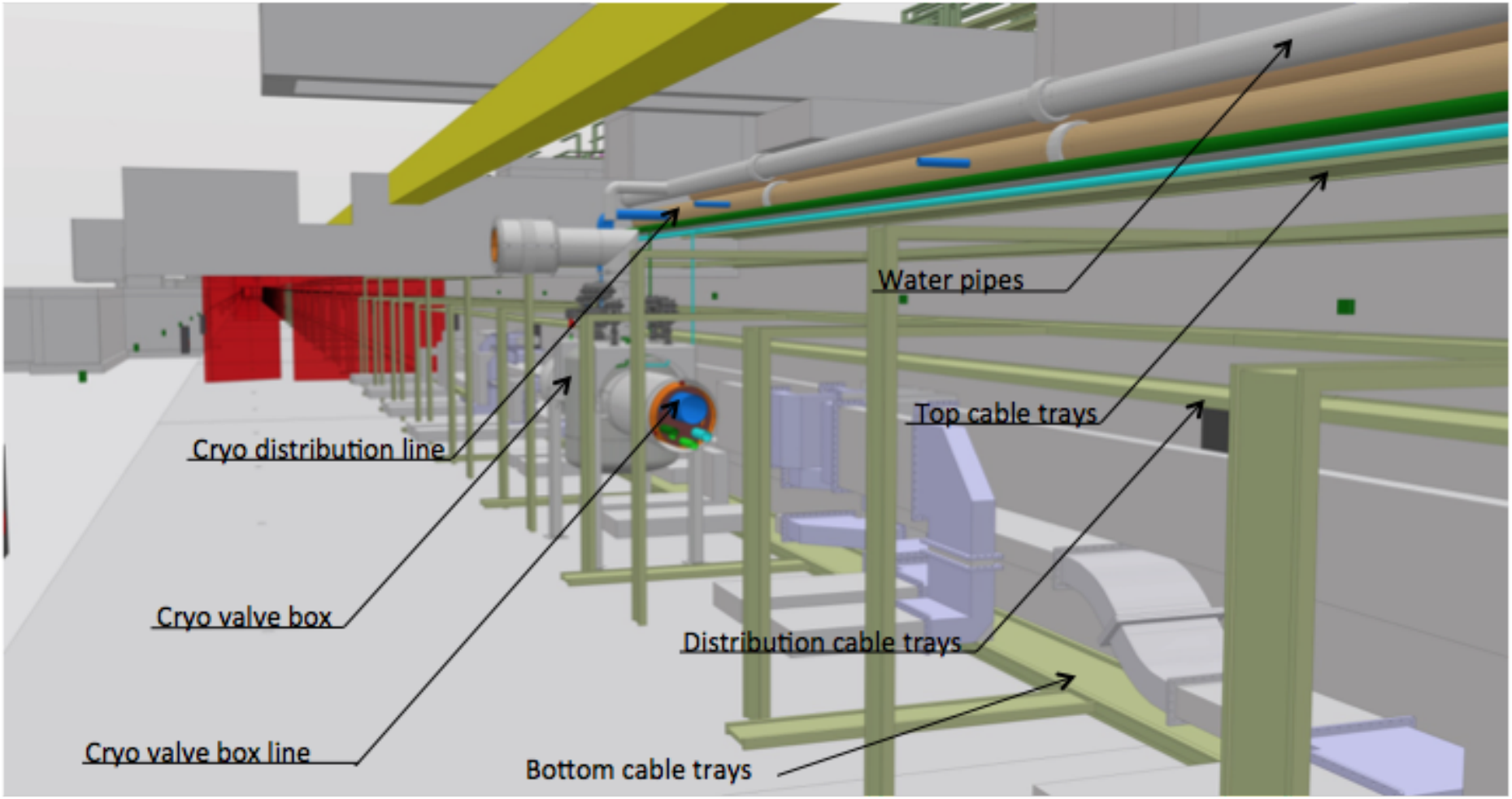
Installation in ACC tunnel	Preferred	
	Option 1	Option 2
Cable Tray	1	2
Water	2	1
Cryogenics Distribution	3	3
Waveguide in Stub*	4	4
Cables	5	5
Waveguide to CM (without final connection)	6	6

* not or barely sticking out into tunnel

- Also for the klystron gallery and stubs a preliminary installation sequence for ACC “utilities” has been established

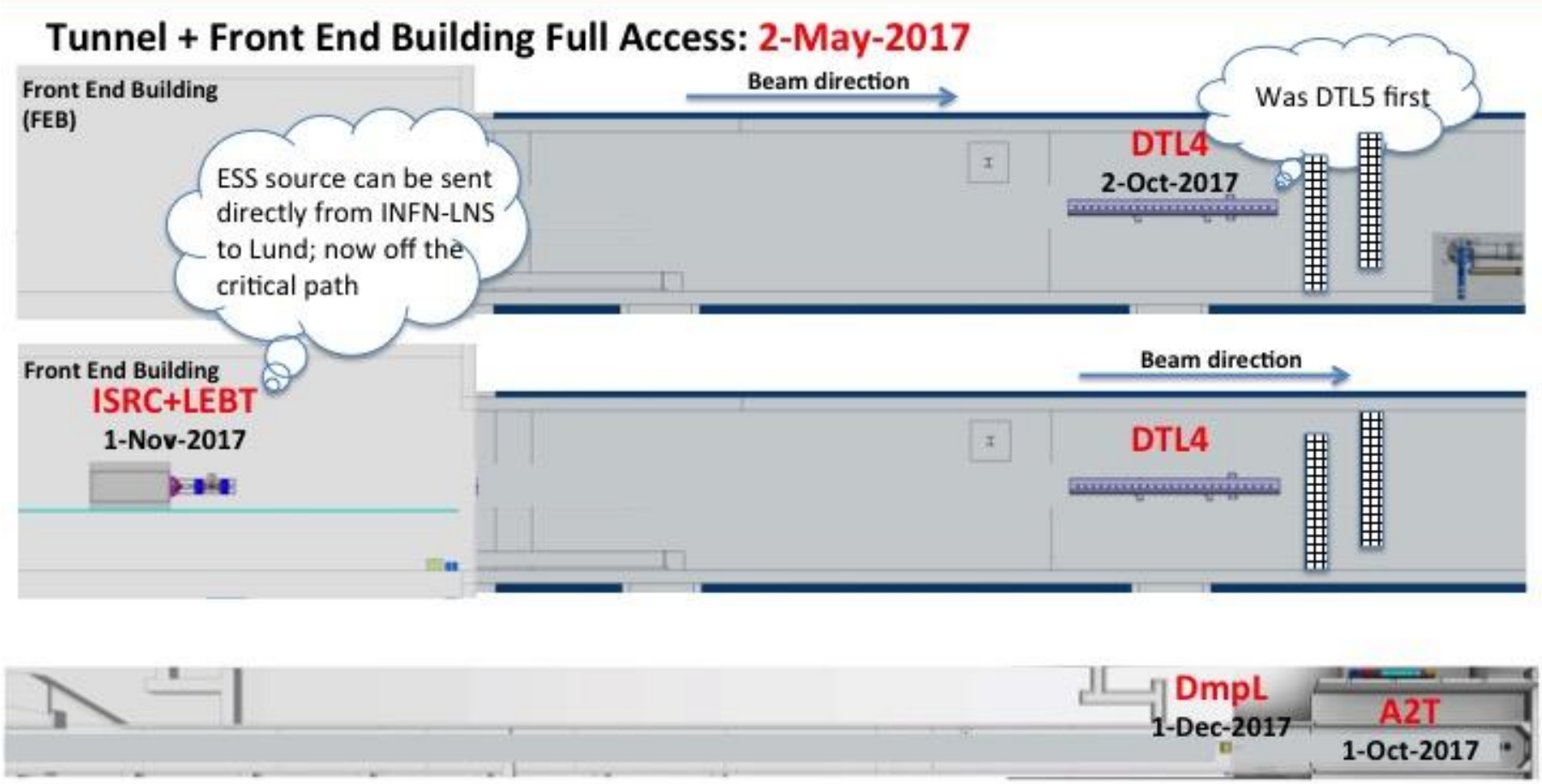
Begin Installing Utilities

Step 1/18: Date 2-May-2017



Install Ion Source and DTL4

Step 2/18: Date 1-Nov-2017

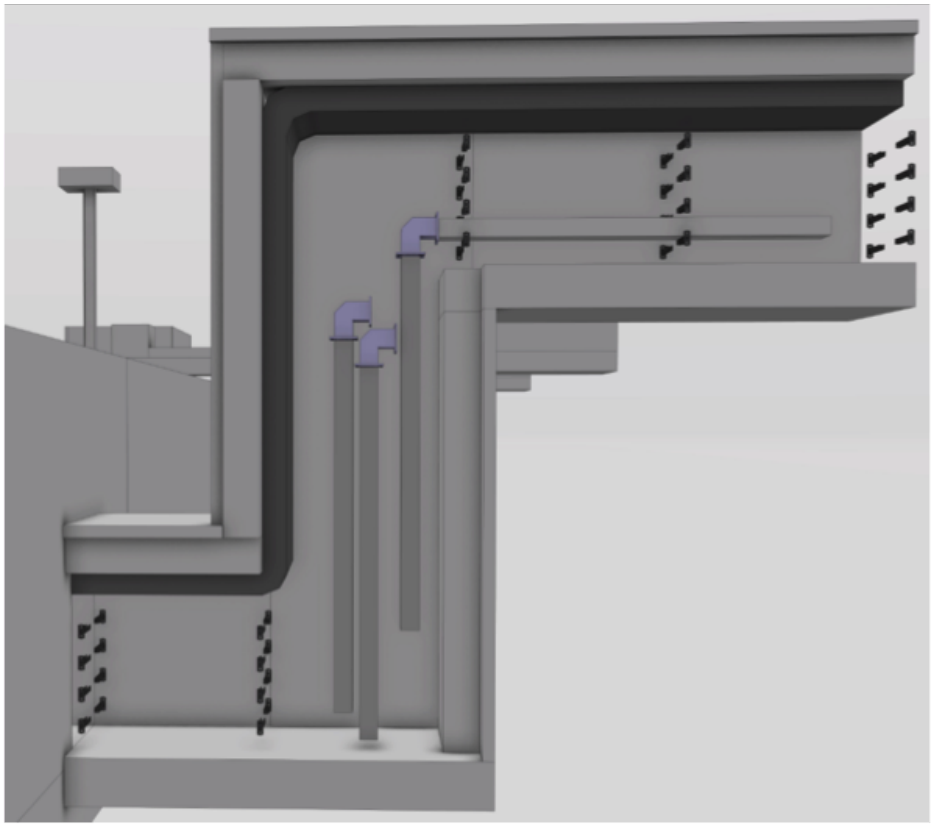


Dates are (approximated) installation start dates

Install RFQ and DTL RF Waveguides in Stubs

Step 3/18: Date 17-Jan-2018

Klystron Gallery BOD in ACC schedule: **31-May-2018**
Planning to use Early Access ~ **1-Dec-2017***



- Mount RF waveguide in stubs
  - RFQ-DTL completed by 17-Jan-2018
- Ready For Installation (RFI) dates for some equipment earlier than building Early Access date
  - MEBT RF amps 9-May-2017
  - RFQ klystron 8-Sep-2017
  - First DTL klystron 2-Oct-2017
- RFI dates are based on input from Master Schedule

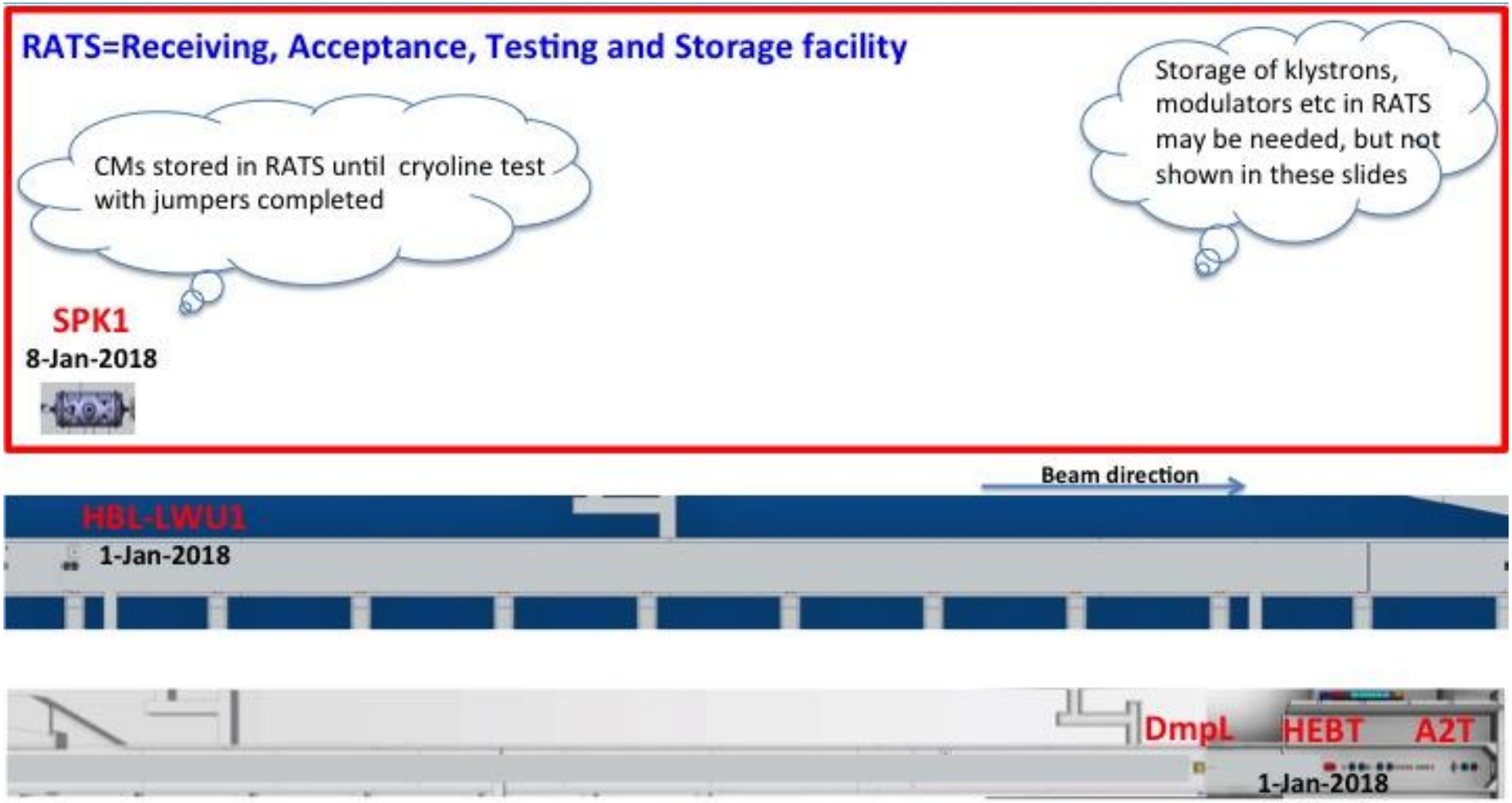
*Meetings are being held with SI scheduler to optimize building access dates as needed

ACCSYS Temporary "RATS"Facility
Receiving, Acceptance, Testing and Storage Facility

- SNS had RATS facility:
  - ~5600 m^2 including 50 offices
  - Truck access (2) and loading docks (2)
  - 20 ton crane
  - Heavily used prior and after BOD tunnel/KG
    - Project Receiving/Material accountability
    - Magnet measurements & ion source testing
    - Mock-ups
    - Cryoline, DTL&CCL assembly
    - PS and low power RF testing
- ESS ACCSYS is establishing detailed needs for a similar facility for acceptance testing, assembly, storage etc.

Receive Spoke Cryomodules in RATS

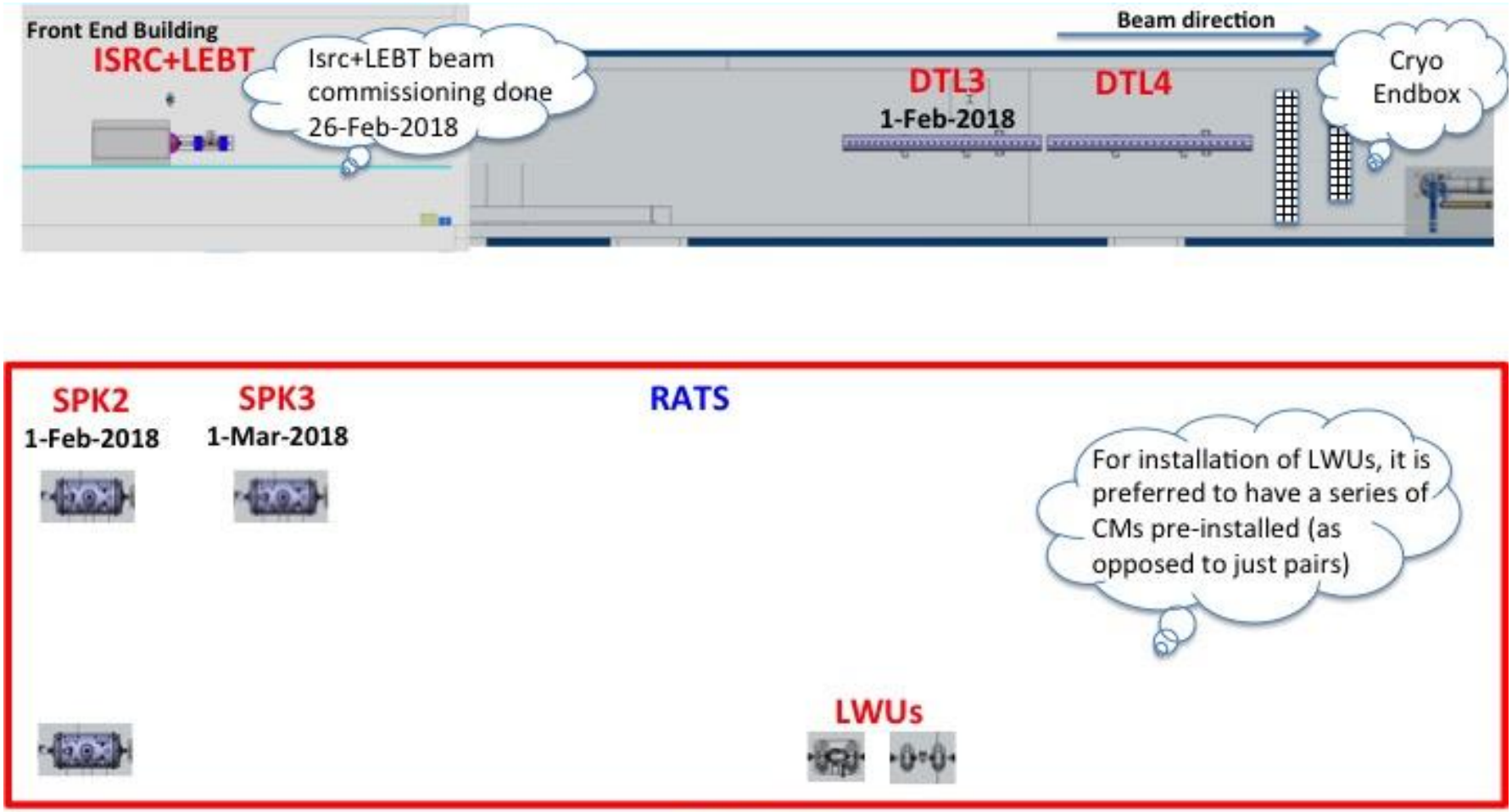
Step 4/18: Date 8-Jan-2018



Dates are (approximated) RFI dates for equipment in RATS, installation dates for the tunnel

Commission ISRC & LEBT and Install DTL3

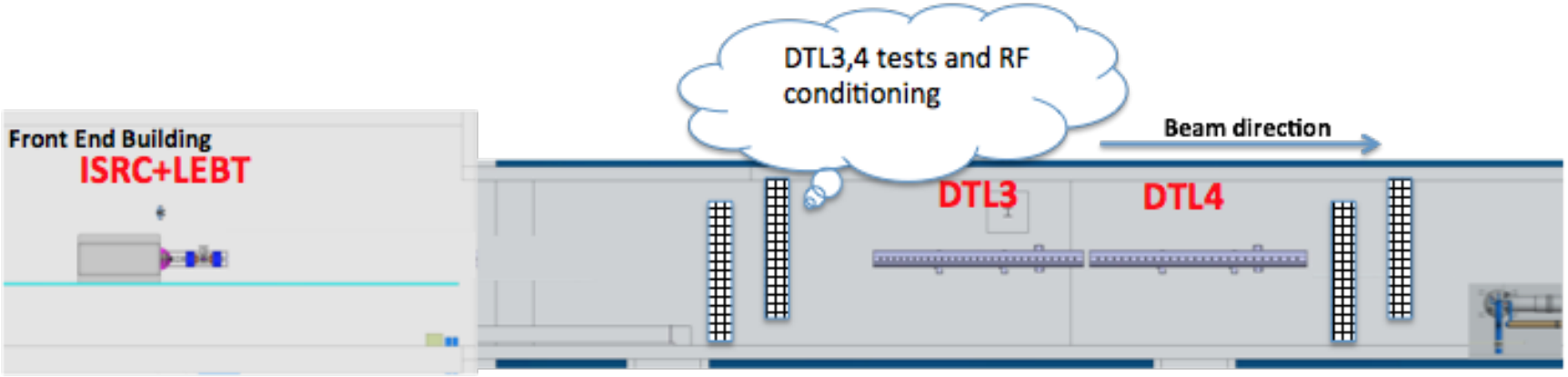
Step 5/18: Date 26-Feb-2018

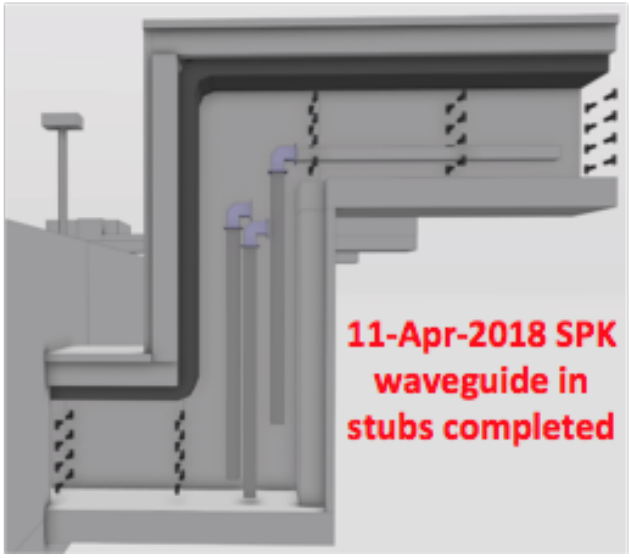


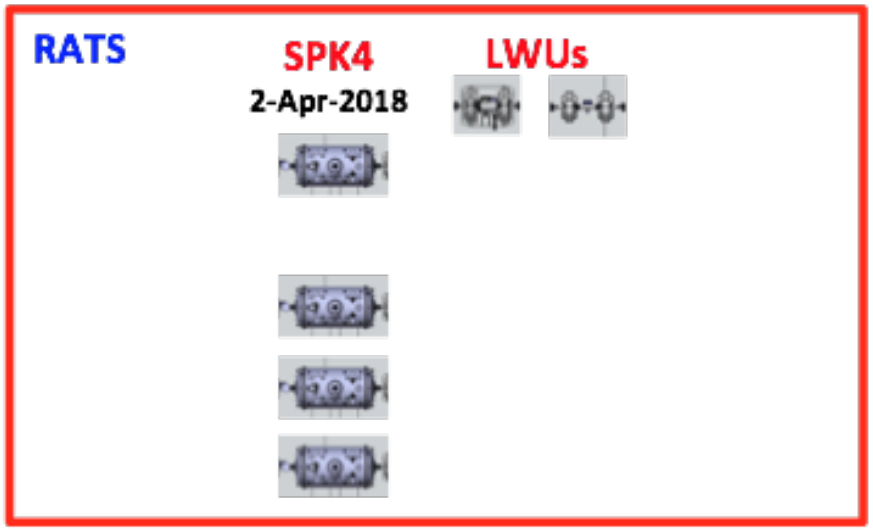
Dates are (approximated) RFI dates for equipment in RATS, installation dates for the tunnel

RF Condition DTL3 & DTL4 & Install SPK Waveguides

Step 6/18: Date 11-Apr-2018



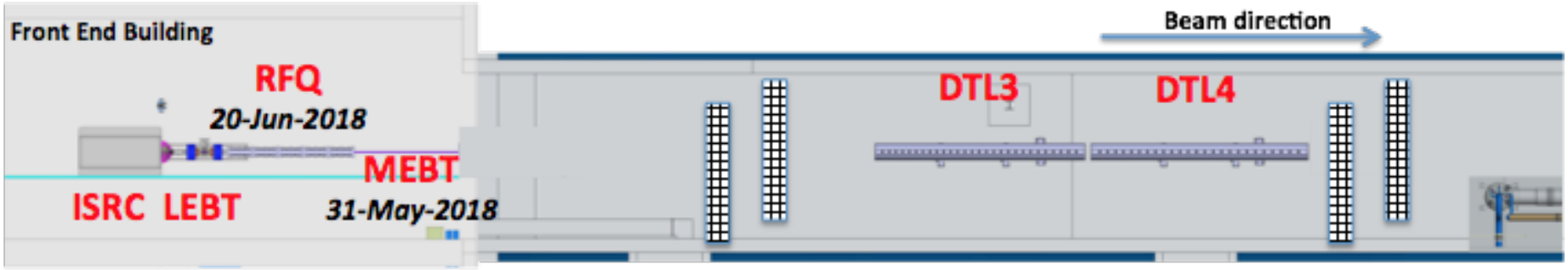


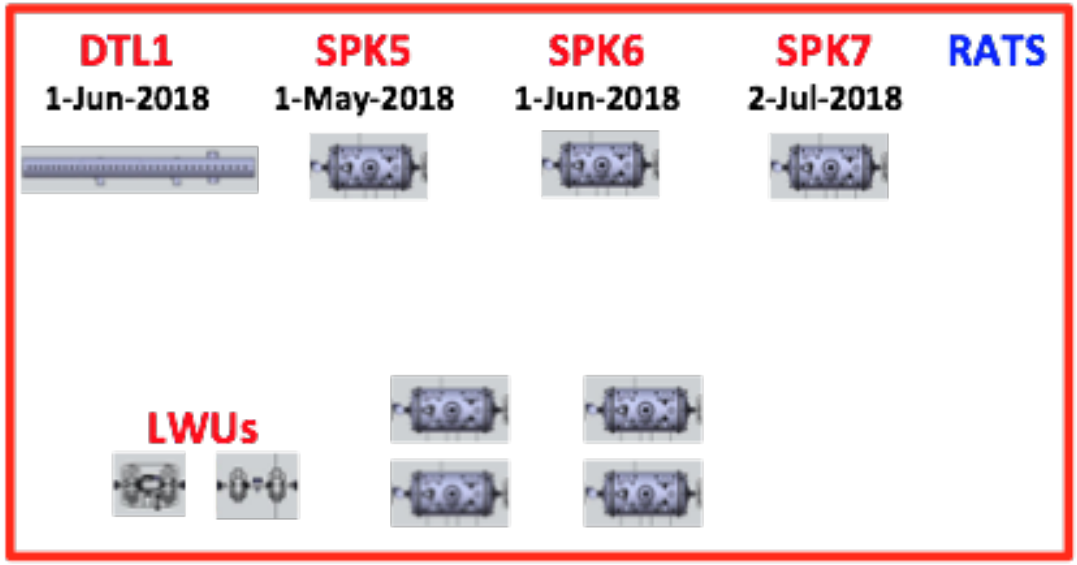


Dates are (approximated) RFI dates for equipment in RATS, installation dates for the tunnel

Install RFQ and MEBT

Step 7/18: Date 20-Jun-2018

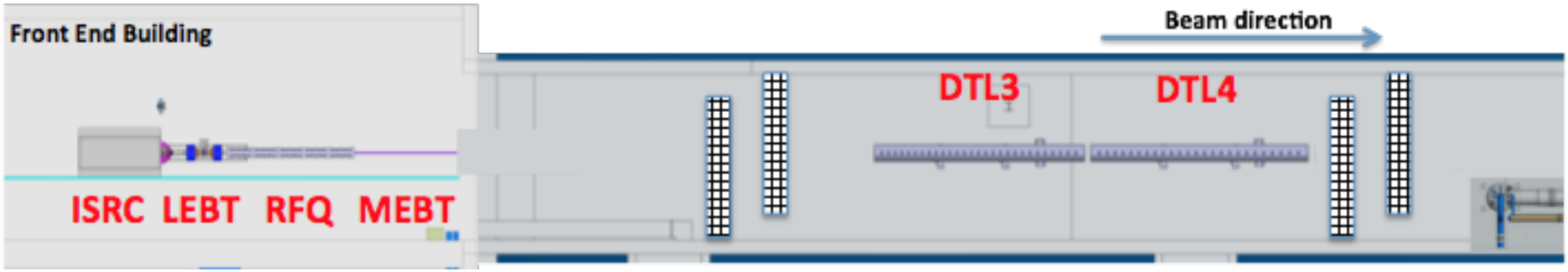




Dates are (approximated) RFI dates for equipment in RATS, installation dates for the tunnel

Commission RFQ and MEBT

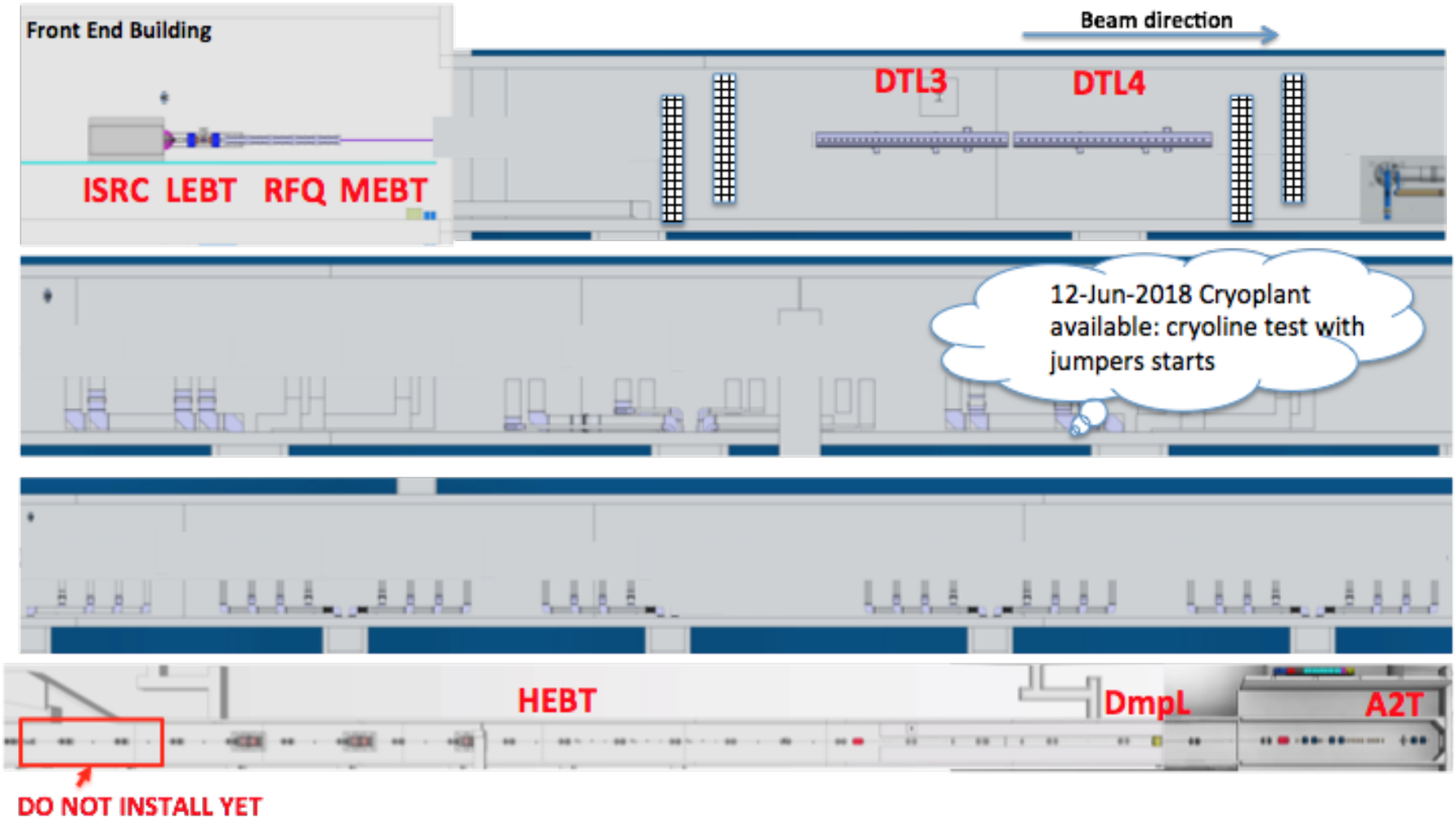
Step 8/18: Date 22-Oct-2018



- RFQ and MEBT phase D: beam commissioning
  - with inline MEBT diagnostics and low power end cup/beam stop
  - RFQ and MEBT beam commissioning for 6 weeks
  - RFQ+MEBT beam commissioning completed by 22-Oct-2018
  - Will use additional (borrowed) diagnostics behind MEBT

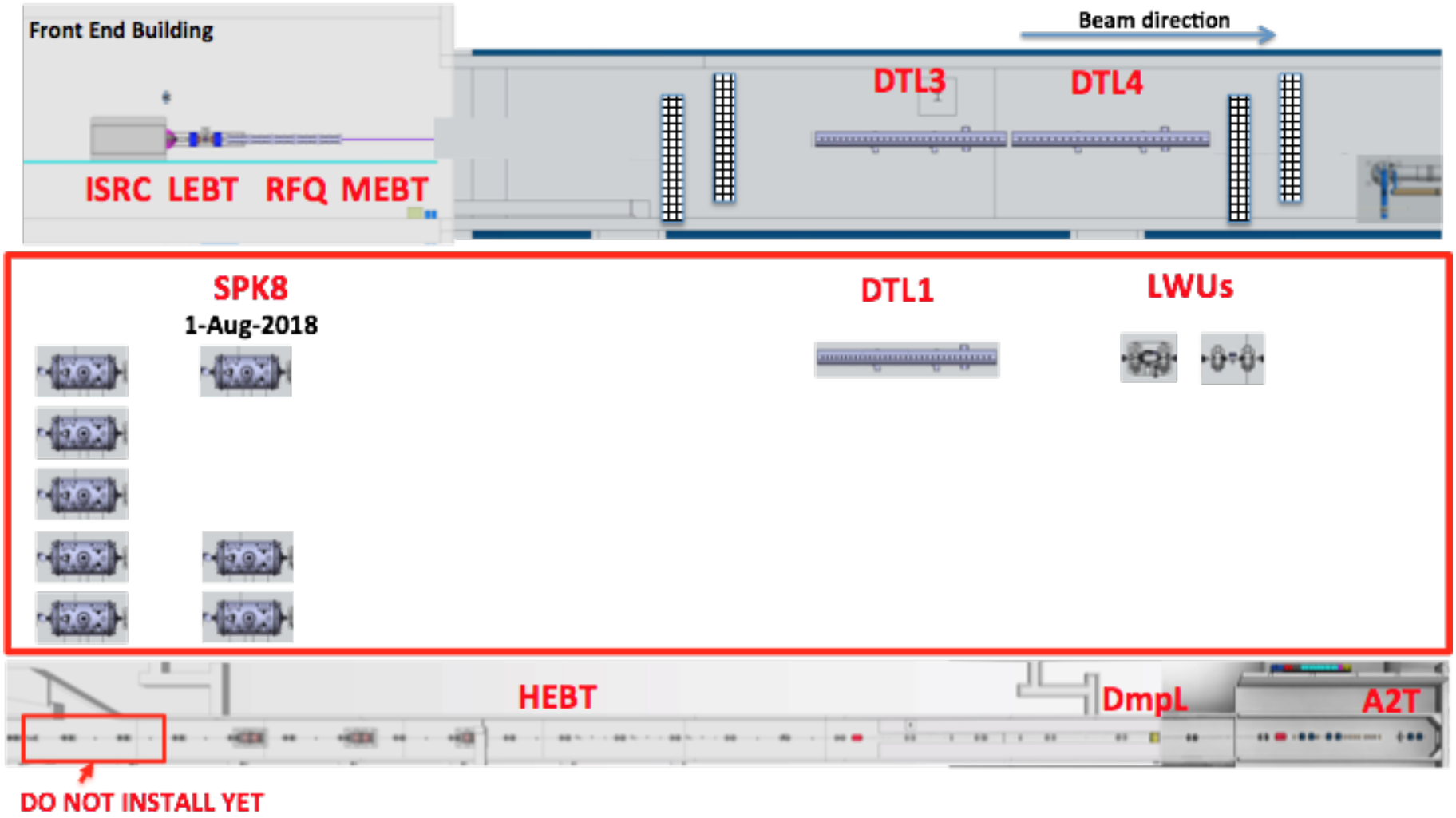
Begin Cryo Transfer Line Tests

Step 9/18: Date 12-Jun-2018



Complete Reception of First half of SPK Cryomodules

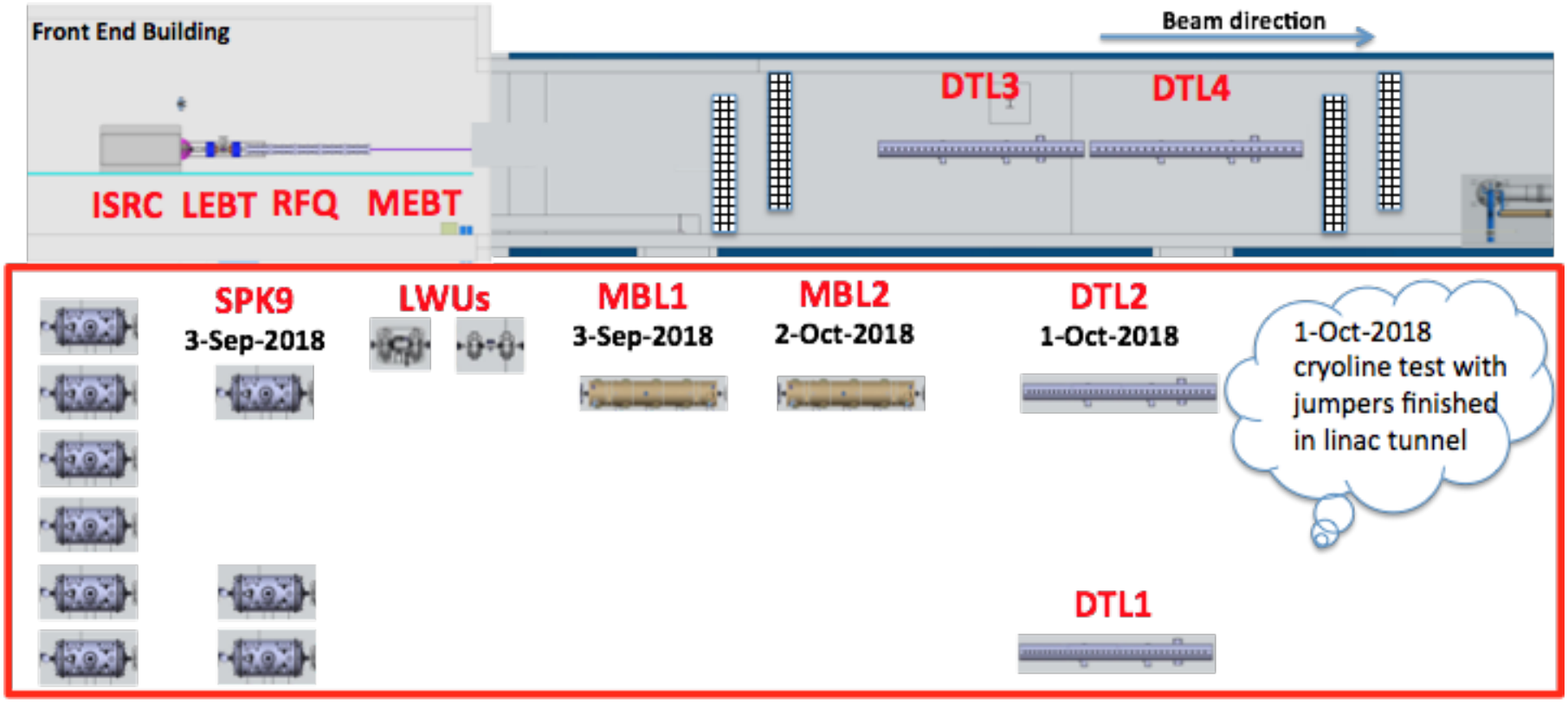
Step 10/18: Date 1-Aug-2018



Dates are (approximated) RFI dates for equipment in RATS, installation dates for the tunnel

Finish Cryo-line test & Receive MBL CRM

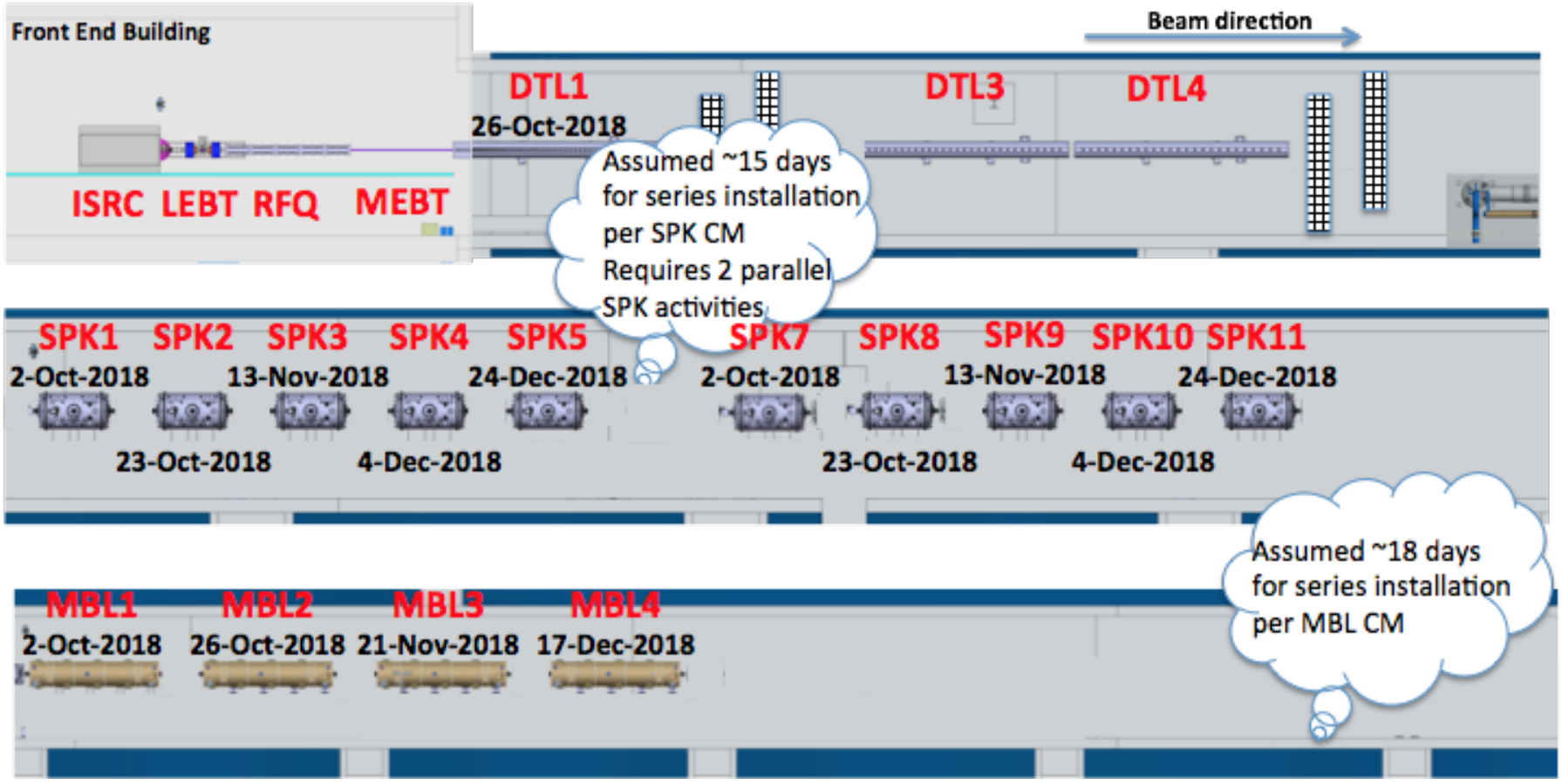
Step 11/18: Date 1-Oct-2018



Dates are (approximated) RFI dates for equipment in RATS, installation dates for the tunnel

Installation of Spoke Cryomodules

Step 12/18: Date 24-Dec-2018

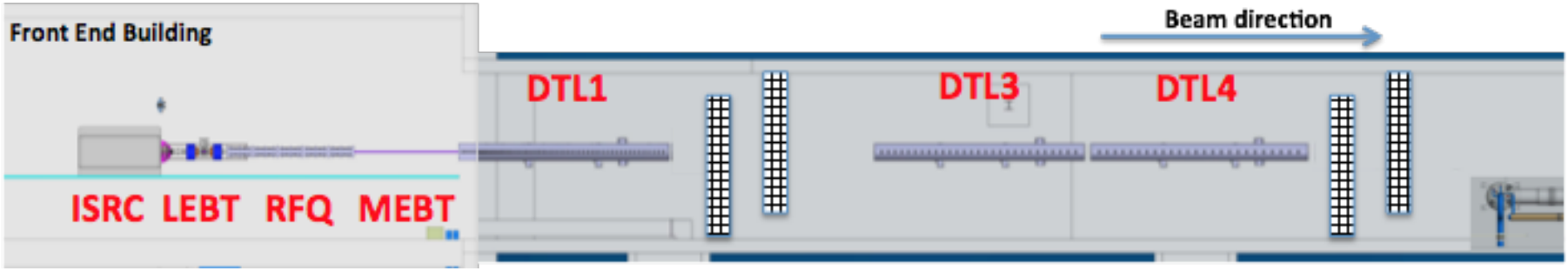


CMs have been pre-tested

Dates are (approximated) installation start dates

Beam Commissioning of DTL1

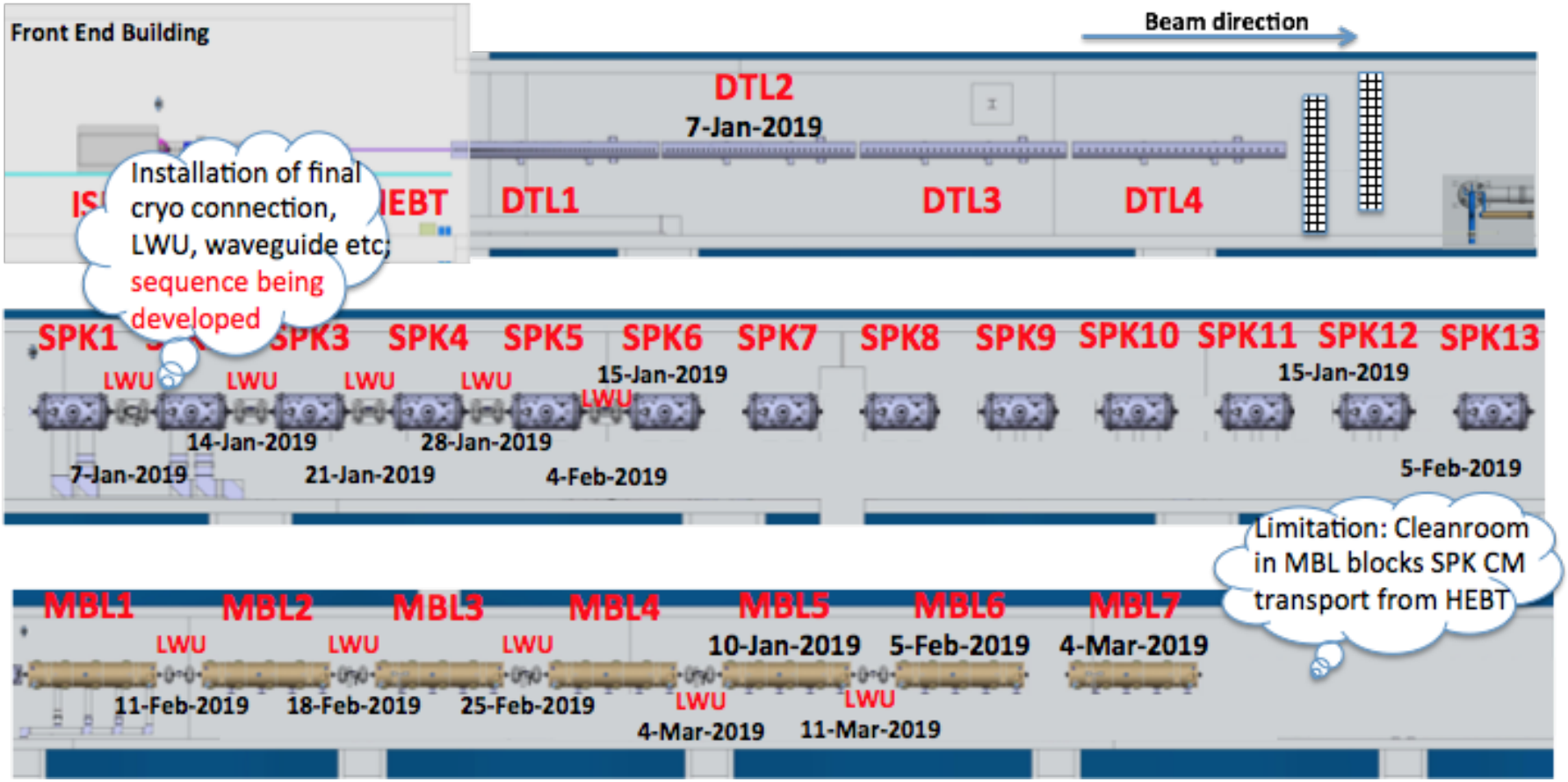
Step 13/18: Date 3-Jan-2019



- DTL1 phase D: beam commissioning with low power end cup/beam stop
  - Does not affect downstream installation/testing
  - Assuming 7 weeks of installation/testing
  - 2 weeks of commissioning with beam, completed by 3-Jan-2019
- Beam commissioning DTL tank 1 most critical of all DTL tanks; this has been recognized at other projects, e.g.
  - CERN Linac3, SNS DTL, CERN Linac4

Install DTL2 & Begin LWU Installation

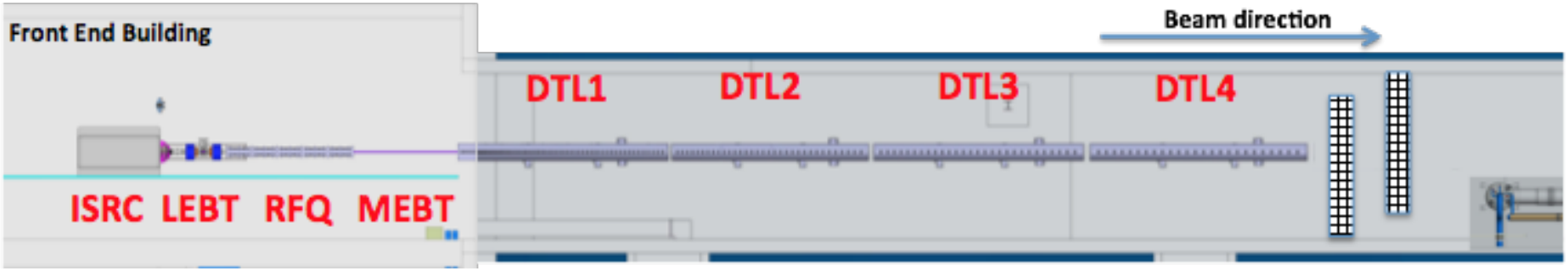
Step 14/18: Date 11-Mar-2019



Dates are (approximated) installation start dates

Beam Commission DTL1-4

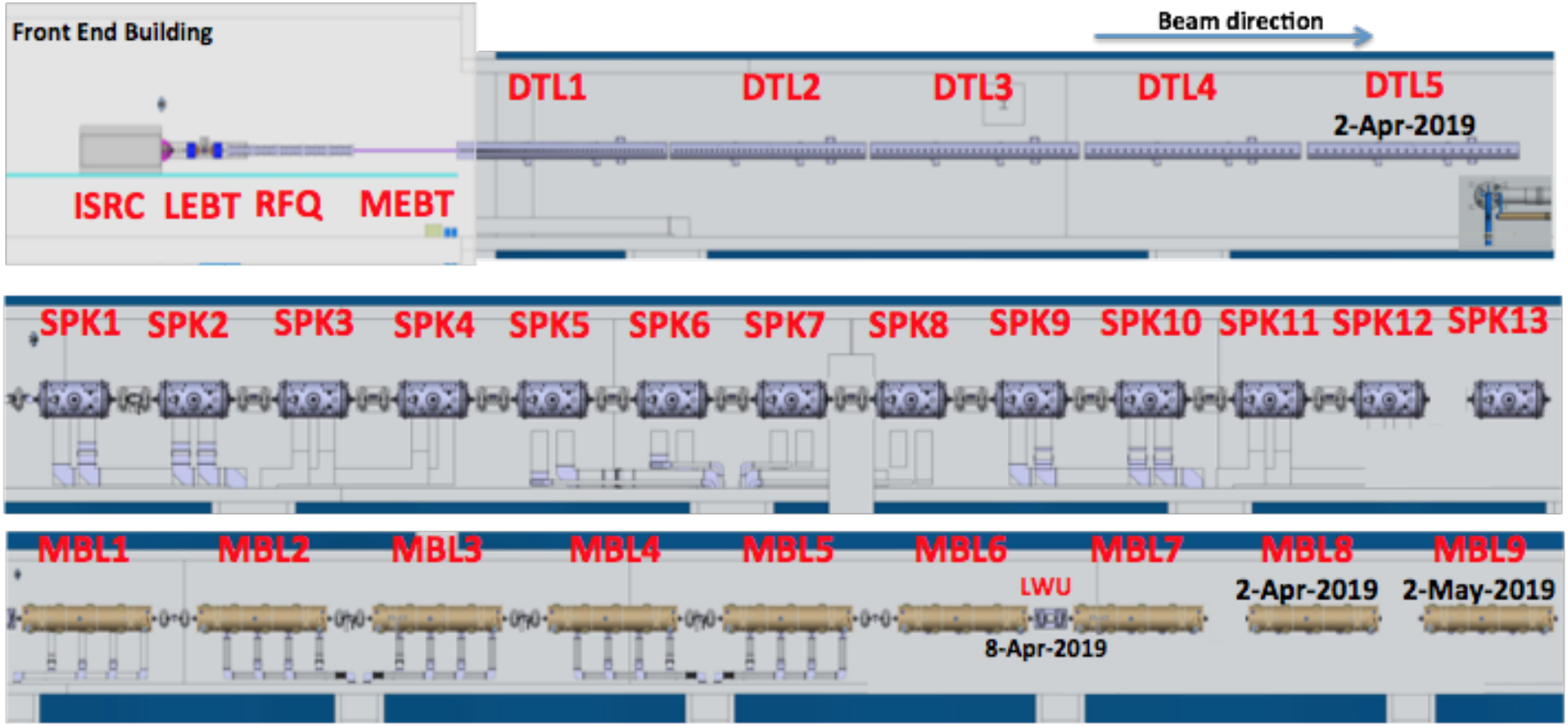
Step 15/18: Date 29-Mar-2019



- DTL1-4 phase D: beam commissioning with low power end cup/beam stop
  - Does not affect downstream installation/testing
  - Assume 7 weeks for installation and testing of DTL2 leaves 1 month for beam commissioning DTL1-4
  - DTL2-DTL3-DTL4 beam commissioning completed by 29-Mar-2019

Install DTL5

Step 16/18: Date 2-Apr-2019



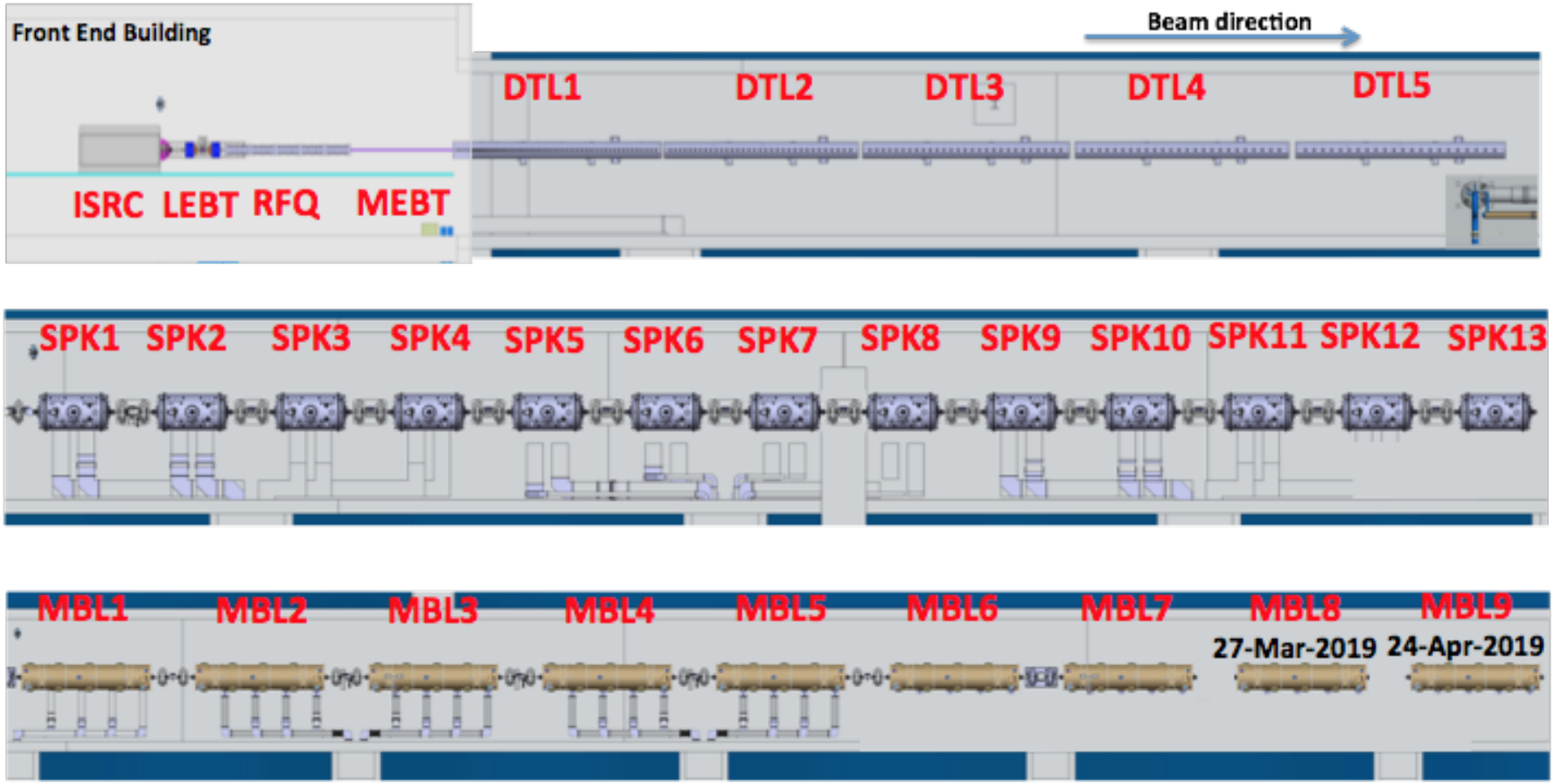
Dates are (approximated) installation start dates

MBL Production Rate and Final Test

- MBL installation schedule limited by MBL CM production rate and final test
- Could consider to test MBL CM8 and CM9 in final location in the tunnel
  - Would be able to produce neutrons with these last 2 CMs turned off
    - but 470 MeV protons, not 570 MeV on target
  - Finish installation last MBL by 24-Apr-2019
- Next steps assume this mitigation

Finish MBL Cryomodule Installation

Step 17/18: Date 24-Apr-2019



Dates are (approximated) installation **finish** dates

Begin Cryomodule Cool Down

Step 18/18: Date 2-May-2019

- In May 2019 CM cool down and testing could start, but…
  - All based on a success oriented, aggressive schedule
  - Concern about delivery schedule of LWUs
  - Different mitigation options are being looked into
- Less than one month for the following beam commissioning steps:
  - DTL5-SPK-MBL-HEBT beam to the linac beam dump
  - More than 500 m of structure containing 63 cavities and more than 120 quads and 120 steering correctors
  - HEBT-A2T beam to Target
- Beam on Target 30-Jun-2019

Next Steps

- Currently being prepared in OpenProject:
  - Klystron Building installation sequence is in but need
    - Verification of durations
  - Additional details on HEBT and A2T
  - Prerequisites: e.g. availability of AC power, water cooling etc
- Verification of logic in schedule and sensitivity analysis
- Data will be fed back from OpenProject into the newly created P6 ACCSYS 11 I schedule
- After a transition period, the ACCSYS 11 I schedule will become the reference

Open Issues

- Ascertain FE delivery dates
- Need to confirm Early Access dates with SI
  - Need to define access dates for A2T
- Adopt/further develop FE beam commissioning steps shown:
  - ISrc-LEBT
  - ISrc-LEBT-RFQ-MEBT
  - ISrc-LEBT-RFQ-MEBT-DTL1
  - ISrc-LEBT-RFQ-MEBT-DTL1-DTL2-DTL3-DTL4
    - Next steps would be DTL5 with cold linac (beam to dump, then to target)

It is not rare for haste to cause delay.
Olaf Hoenson