Neutrino Platform – Detector Support System (DSS) review – 7th and 8th of November

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DSS review committee final conclusions:

The Review Committee acknowledges and thanks the Collaboration for the work done to prepare and present the documents for the review.

We were presented with a well-developed concept but the level of analysis is not sufficient for the committee to give a final judgment on the validity of the design.

According to the presented schedule, a definitive design has to be completed by Christmas this year. We advise detailed project milestones are drawn up to meet this general project schedule.
The resources required to meet the milestones must be immediately identified. We urge the management to allocate these necessary resources in order to meet the deadlines.

We advise before any material is procured that the following approved documentation is provided for review:

- Engineering specifications document drawn from the performance requirements.
- Detailed calculation notes which cover all the load cases for all steps of installation and operation and which demonstrate compliance with EU standards as indicated in the Annex 1.
- Fabrication production drawings
- Integration document that includes:
  - Sub-systems tolerances budget and adjustment possibilities
  - Definition and checks of the envelopes (static and dynamic) for all steps installation and operation and interferences checks.
  - Sign off from the affected sub systems that the interfaces are accepted (interfaces data (transferred loads, displacements, adjustment capabilities))
  - QA/QC plan and procedures.
- Detailed installation plan

The Committee will be able to answer the charge questions after the final analysis is done.
In Annex2, the review committee provides further comments, findings, and detailed technical recommendations.

Annex 1: Contents of the calculation note for the structural safety assessment

The requirements provided in the CERN Safety Regulation on mechanical equipment (SR-M) shall be followed.
In particular, the calculation note of the structural design shall include the following tasks:

1.1 Definition of the load cases, patterns and combinations

The load cases and patterns for the different constructional, installation and operational phases shall be defined according to the EN 1991: Eurocode 1 – Actions on structures. This provides guidance on action for structural design (e.g. density of materials, imposed loads on structures, cranes and machinery, accidental actions from impacts, etc.).
All the different load cases shall be combined according to the EN 1990: Eurocode 0 - Basis of structural design. The set of the partial safety factors shall be selected considering consequence class 2 (CC2) and, therefore, an execution class 2 (EXC2) in compliance with the EN 1090.

Note on the seismic action (to be discussed)
The seismic action on structures built at CERN, independently of the location, is defined as stipulated by the French law.
According to the 'Décret n°2000-892 du 13 septembre 2000 relatif à la prévention du risque sismique' new constructions or constructions submitted to important modifications in seismic regions shall comply with the applicable seismic design requirements.
According to the 'Décret n° 2015-5 du 6 janvier 2015 modifiant l'article D. 563-8-1 du code de l'environnement' CERN is classified as seismic zone 3, 'sismicité modérée'.
The seismic action at CERN is defined taking into account the indications of the 'Arrêté du 22 octobre 2010 relatif à la classification et aux règles de construction parasismique applicables aux bâtiments de la classe dite « à risque normal »' in particular:

- *reference peak ground acceleration on type A ground, a_{gR} equal to 1.1 m/s^2,*
- *design ground acceleration ag is equal to a_{gR} times the importance factor γ_I.*

The shape of the horizontal and vertical elastic response spectrum are defined in the NF EN 1998-1 and shall take into account the ground type.

1.2 Analytical and Numerical models' description and Performed Analyses

The adopted analytical and numerical models shall be representative of the mechanical and, in general, all the concerned physical phenomena. The details of such models shall be described and the compliance with the EN standards of the adopted values for the mechanical parameters shall be proven.
The adopted analysis methods shall be described. The results of the analysis runs in terms of internal forces, stress and displacements shall be presented for all the most worth noting load combinations.

1.3 Mechanical strength and buckling assessment of the structural elements

The assessment of the mechanical strength and buckling for all the structural elements for the most unfavourable load combinations shall be carried out according to the following standards:

- EN 1993-1-1 (Eurocode 3 - Part 1-1: General rules and rules for buildings)
- EN 1993-1-4 (Eurocode 3 - Part 1-4: General rules - Supplementary rules for stainless steels)

- EN 1993-6 (Eurocode 3 – Part 6: Crane supporting structures)

The results of such an assessment shall be presented in the calculation note.

1.4 Assessment of the joint connections between the structural elements

The structural assessment of the joint connections shall be carried out for the most unfavourable load combination according to the EN 1993-1-8 (Eurocode 3 - Part 1-8: Design of joints).

Annex 2: Reviewers comments and recommendations:

- Clarify the design strategy used to guarantee the Detector volume is within spec (better than the 1% level)

- Analysis of the DSS as a system should be done. The forces between members then extracted and used as input into detailed design of connections/trolley's etc.

- A detailed analysis is needed of all the connections (clevis, connection between beams, etc).

- Any analysis of the DSS as a system should include a load case with the lateral loads during installation phase of the sub systems.

- Please provide more details on the feed thru. How are they attached to the membrane and cryostat? Can they take a lateral load?

- The pinned connection between the runway beams and the hanging pipes does not allow a free rotation around both the axes. Consider to switch to a joint connection closer to a spherical hinge.

- Analyze the compatibility of the trolley system with the kinematic design of the bridge beam & runway beam finalizing the preliminary design.

- Which is the reason to have two pivot points very close instead of one single joint?

- Piet raised a question about whether the break and pivot in the middle of the bridge beams is really needed - this should be addressed, as it is potentially a mechanical weak point and we should be sure it is really necessary

- The feed thru flange are foreseen to be simply supported by the additional squared hollow section profiles. It can cause troubles for clearance and tolerances. Consider to weld it.

- The functionality of the thru holes present on the top flange used to compress the spring set should be detailed.

- Detail the mechanisms used to lock the location of the APA and CPA.

- Quantify the vertical adjustment required to align the APA and CPA

- Quantify the runaway beam parallelism needed to guarantee the trolley system functionality and describe the alignment procedure to meet that parallelism criteria.

- A better description of the friction behaviour at the interface between the connection clevis and the pins shall be given when the axial displacements of the runway beams are allowed.

- Which is the level of distortion allowed on the plan x-y of the DSS design?

- The Thermal deformations are on the same order of the requirements. Could you clarify the design strategy based on the estimated thermal deflections?

- Could you clarify the worst load case scenario or list the main critical load case scenario for the structural design?

- How much lateral movement is allowed on the vertical support rod for both constraint conditions? Constrain condition A: Not lateral support points applied. Constrain condition B: Lateral support points applied.

- The requirements for the hanging supports alignment on all axes for detector installation and positioning (beam plug, cathode panels connections, HV feed-through connection, mechanical interferences, APA connection and alignment, movements during installation, commissioning and operation) should be detailed.

- Define the status of each restrictor plate assembly during the installation, maintenance and operation conditions

- For a non-insider, the rationale of the beast_under_review was at times hard to understand from the presentations. This applies especially to the installation of TPC components, and the crucial role the DSS has to play herein. An explicit slideshow was cruelly missing.

- The design team is urged to change to the traditional coordinate system for fixed-target experiments without delay. It is understood that this system is already used by the DUNE physicists' community.
- While it is clear that the upstream-centre suspension point will be used for z (and x) fixation of the DSS w.r.t. the cryostat, it is not entirely understood how one will achieve the requested z ACCURACY IN OPERATION (cfr. beam plug).

- As said, the need of articulated beam joints is questionable. More generally, the individual suspension of TPC modules (the result of which being that they all "go their own way" to some extent) gives rise to a confusing set of possible backdoor effects. Even if not lethal, all of them should be understood, upper-bounded, etc. An example popping up during the session was that of the individual hang-down of each of the CPA modules, whereas, functionally, it would appear more straightforward to deal with them in pairs (because of the hinged field cage "doors"). In spite of the schedule pressure, this philosophy may need a "peaceful overhaul". Indeed, these issues may magnify out for DUNE. And since the main rationale of ProtoDUNE is exactly to serve as exercise (but possibly the LAST exercise), one would not want to defect on a principal goal. The (non??)requirement of vertical adjustment is intimately couple into this philosophy.

- One may reconsider the trolleys coupling the bridge-to-runway beams. Their essential role during TPC installation is beyond dispute. However, their use in operation ("accomodate motion during cooldown") is disputable. One could instead think of removing them after installation (hence removing a painstaking issue of tribology vs. cleanliness), and bolt the beams firmly down. The DSS would then present itself — to the TPC — as a homogeneous roof grid of austenitic steel, and

this is possibly the simplest, safest and least confusing concept. CTE mismatches to the composite-driven suspended equipment (CPA along z, FC along x) should be solved on the local level (and they probably are already).

- The requirements of vibration isolation should be spelled out and justified. In absence of that, one is urged to drop them.

- A detail integration/ static envelopes / interfaces analysis is required A breakdown of the required tolerances allocating them to each category is required.
- In particular: which is the clearance between the feed thru pipe and the support feed thru structure?

- Define a document that includes a detailed survey process in order to control As Built and As Installed configurations.

- The quantification of the order of distortions acceptable from the APA frames and CPA frames in all directions should be clarified and taken as specifications?

- The needs for all subsystems of horizontal and vertical adjustment need to be quantified and verified.

- The allowable relative displacements and distortions using a well- defined Cartesian coordinate system should be clarified.

- Could you clarify the organization of the technical documents such as the 3D models, the 2D drawings between the CERN and the US institutions and how to plan to mitigate the risk associate to the fact such documents might follow different standards?

- Verify the compatibility of the temporary construction opening with the final stage of the alignment and installation process of the DSS components.

- Describe the location and the lock system used for the spare bridge beams during the installation and DSS operation conditions.

- A 100% QC process on the major components will mitigate the engineering risks.

- Assure common components can be provided by multiple manufacturers

- The assembly sequence should be analysed in details, especially how the field-cage end walls are inserted and turned. Particularly for the Jura end because everything else will be more or less in place by then, so clearances are important, as is control of the available degrees of freedom of motion.

- Describe the alignment procedure of the APA and CPA along with CTE and roof sag compensations process.
- How accurately can they set the distance and parallelism between the beams? This will affect the detector installation.

- Please provide a description of the materials used for the sliding and rolling components. Is it possible to have table about frictions?

- There is an assumption that during cool down the trolleys will roll as the beams shrink. However, this can only occur if the rolling friction is overcome. This can only happen if the detector resists the lateral load. This should be considered.

- Can the CPA hanging scheme be modified to hang pairs of CPAs instead of individually? Then roof deflection won't affect the relative vertical alignment of pairs which are connected together.

- Please provide a description of how the hanging pipes are going to be flushed during commissioning and operation.

- The surface finish was described in the general document for the I beams. Are there any specifications about the finished roughness?

- Which is the functionality of the thru holes present on the top flange used to compress the spring set?

- Receipt inspection of the material should address verification of material type in addition to dimensional inspection.

- QC Plan should include verification of material properties for the trolleys and hanger material by review of CMTRs.

- Full size prototypes of the hanging supports and of the rollers should be realized and tested at the nominal working conditions (loads, displacements, temperatures).

- Recommend using torque wrench when installing the upper and lower flanges in the hanger system to ensure there is consistent torque around the flanges.

- Has a ground-loop analysis been performed for all detector elements, to check that the DSS ground scheme is compatible? When it is planned that the system is approved by the Grounding Committee?

- Please provide a description of the cleaning and handling procedures of the different materials.

- Please explain, if it was considered, what are the requirements during de-commissioning. The detector dismounting should be considered.