Comments from CRP PDR review 05/04/2022:

1) Could you prepare a summary table comparing the evolution and tested features in CRP1 through CRP5?

Tested features CRP1:

- Full size CRP
- anodes made of 6 pieces
- Assembly of 2 PCB layers over 3mx1.7m
- Composite structure made in 3 parts riveted together with 2 skins and molded fiber glass omega shape skeleton
- 48,0,90 orientation
- Shield plane
- Both TDE and BDE readout
- Filter boards

Evolution CRP2

- 30,-30,90 strip orientation
- Assembly of 2 PCB layers over 3.4mx1.5m
- Composite structure made of 2 parts bolted together with 2 skins and G10 profiles for the skeleton
- New channel count
- New layout of adapter boards
- Edge connectors for the strip connection to RO
- Full top readout
- Improved grounding of filter boards

Evolution CRP3

- Lighter composite structure made of 2 parts bolted together with 2 skins and G10 profiles for the skeleton

Evolution CRP4-CRP5

- Composite structure made of 2 parts bolted together with 2 skins and G10 profiles for the skeleton to accept the CE FEMBs
- Full bottom readout
- Connectivity through patch panels
- Mechanics of supporting feet

Features	CRP1	CRP2	CRP3	CRP4	CRP5
Full DUNE size CRP	✓	✓	✓	✓	✓
anodes made of 6 pieces	✓	✓	✓	✓	✓
Assembly of 2 PCB layers over 3mx1.7m	✓	-	-	-	-
Assembly of 2 PCB layers over 3.4mx1.5m	-	✓	✓	✓	✓
Strip orientations (Ind1, Ind2, Coll.)	48,0,90	30,-30,90	30,-30,90	30,-30,90	30,-30,90
Shield plane	✓	✓	✓	✓	✓
Electronic type	BDE / TDE	Full TDE	Full TDE	Full BDE	Full BDE
Composite structure : molded fiberglass skeleton with 2 skins (3 parts riveted)	✓	-	-	-	-
Composite structure :2 parts bolted together with 2 skins and G10 profiles for the skeleton	-	✓ Top version	✓ Light top version	✓ FEMBs space	✓ FEMBs space
Adapter boards with proper channel count and strip configuration	✓ Old channel layout	✓ new layout	✓ new layout	✓ new layout	✓ new layout
PCB Interconnection from strip to top electronic connectors or bottom FEMBs	Surface mount connector and pins	Edge connectors	Edge connectors	Edge connectors	Edge connectors
Bias Filtering board	✓	✓ Improved shielding	✓ Improved shielding	✓ Improved shielding	✓ Improved shielding
Suspended CRP structure	✓	✓	✓	In coldbox	
Mechanics of supporting feet	-	-	-	In module0	In module0
Connectivity through patch panels for bottom CRP	-	-	-	✓	✓

1) What are the features, i.e. the minimal set of requirements, that you consider necessary for the FDR?

- Assembly of PCB panels, gluing and silver printing with 30,-30,90 strip orientation
- Use of composite structure made of 2 parts bolted together with 2 skins and G10 profiles for the skeleton
- New layout of adapter boards
- Edge connectors for the strip connection to RO
- Latest bias filter board layout
- Latest shield plane filtering configuration
- Full bottom readout with connectivity through patch panels (tested at cold in US)
- Support system for bottom CRP
- Complete CRP specifications (bias HV, anode geometry) tested and validated in cold (CRP2 and CRP3)

2) What are the major risks leading up to the Module 0, which may have a significant impact on schedule or cost? What mitigation steps are taken to address these risks?

- Main risk could be delays in components to build the CRPs.
- Taking this risk into account we have ordered the CRP components well in advance (4 months)
  - CRP2: we have a margin of 2 months but most of the components (anodes +structures) are already received or ordered
  - CRP3: the anodes and mechanicals parts will be produced together with CRP2 parts and will be available by CRP2 time

  - CRP4: the anodes will come from spares of CRP2-3 mix with the ½ BNL CRP
  - CRP5 : we use the anodes originally foreseen for CRP4

For the composite: CRP2 and CRP3 use the same elements than can be mixed and available when the assembly is completed;

Composites 4 and 5 should arrive one after the other and in advance of the assembly

3) Could the assembly and test of CRP4 be moved earlier in time, eventually changing the order with CRP3, so that the results from this exercise could be fed into the FDR scheduled in November 2022?

Please clarify the bottlenecks (e.g., availability of BDE, of bottom support structures, etc.).

Reminder:

- ➢ CRP3 built in August/September and tested in October
- ➢ CRP4 built in October in US and tested in November (the parts are just come a few weeks after the ones from CRP3)

- The availability of the BDE and the US factory to assemble CRP4 should be guaranteed not before September.

- An other reason to avoid the swap is that the first CRPs to be installed in Module-0 should be CRP2 and CRP3 (full top); if we exchange the order we may add a delay in the installation of Module-0

- An unexpected delay on CRP4 can be absorbed by doing the assembly directly in Europe saving the transport time between the 2 continents: we considered about 2 months between Europe-US and US-Europe

- An other possibility to get enough time to feed the FDR with all CRP tests is to shift the FDR by some months n

4) What are the primary issues with the production of 3-segment panels?

Availability of commercial vendors that can produce such large segment panels
Attractiveness for the company to have a dedicated R&D is not immediate and has a much high initial cost (3x at least)

What is the strategy and timescale to pursue the 3-segment option further?

In 2022 continue to contact various companies to understand the feasibility and possible cost reduction.
If conditions are met for price and technical specifications by beginning 2023 we may have the possibility to build a prototype and test.

What is the timescale to decide on 3 vs 6 segment as the baseline for production?

We should define the final segment number in spring of 2023 depending on the previous point

5) In light of lack of adequate physics simulation studies, could design parameters such us strip pitch (strip width) be addressed in a dedicated extension of the test program in the 50 L prototype?

We understand that the design of the of the CRPs for Module 0 is substantially frozen, and we wonder whether additional studies could be performed in parallel in the smaller set-up.

- We don’t foresee to have additional dedicated tests with the 50L on the strip width
- The program is more to develop thorough simulation with the CRP strip configuration that is being implemented in the Module-0 (30,30,90).

- Based on the simulation results, additional tests can be developed with the 50L setup if experimental inputs are required

6) As already discussed, we suggest that more attention is devoted to QA/QC procedures and related documentation:
- Based on the successful building of CRP1, what are the criteria that you plan to assess as part of the QA/QC plan?
As mentioned in the CRP production document, the following criteria have to be controlled:

- tolerance of the PCB milling at the half lap joint
- tolerance on length and width of panels
- PCB production standards for the isolation of conducting surfaces
- electrical continuity at warm and cold,
- strip isolation
- PCB gluing process and alignment
- Cryogenic test of the assembled PCB panels
- Leakage current checks on adapter boards and bias boards

- We heard about electrical integrity test for the top CRPs, and about additional injected pulses and electronic noise checks for the bottom CRPs. Can some of the latter be envisaged for top CRPs?
It is also envisaged for the top CRP to inject pulses for the continuity and capacitance measurements
- Will mechanical integrity be tested in QA/QC?
Cold test of the assembled PCB will be part of the mechanical integrity especially for the gluing and silver printing
There will be control of the structure planarity at the factories before assembly and dimension measurements of the assembled stack

- Will the full QA/QC procedure be developed while constructing CRP2 and be applied to CRP3?
The plan is to use the CRP2 experience to develop and define in more details the QA/QC procedure for the following CRPs