REQUIREMENTS MANAGEMENT FOR DETECTOR SYSTEMS

Electron Ion Collider

OVERVIEW

This document describes the general format, structure and syntax for the requirements being developed for the Electron Ion Collider Detector systems. The numbering format described in this document draws heavily from the material provided by Russo, Cullen and Rochford at Brookhaven National Laboratory.

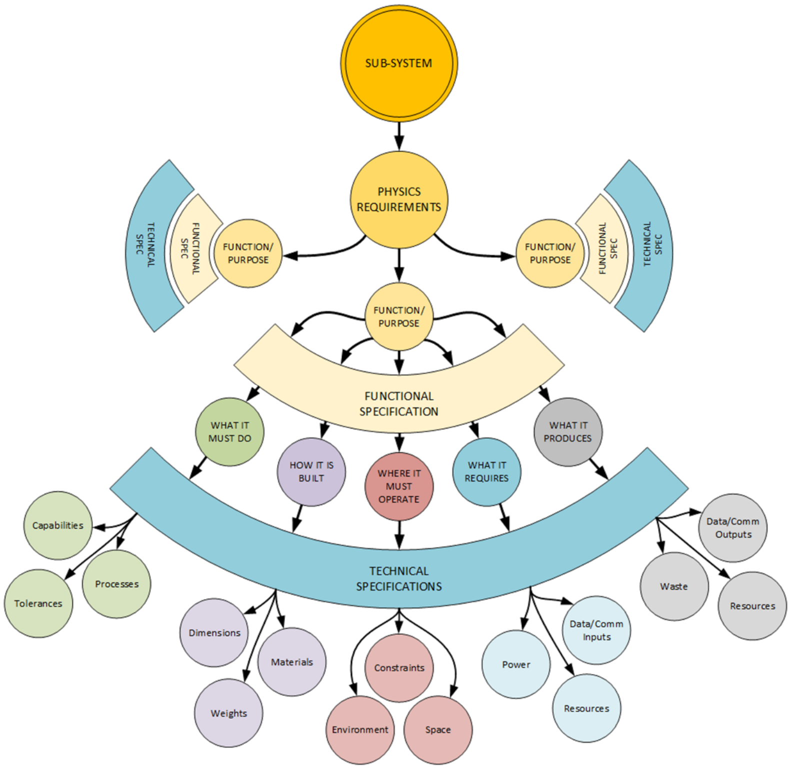
At a fundamental level, system requirements are treated as *line item* entries that identify all of the physics requirements, functional requirements and technical specifications. These requirements are conceptually gathered into a tree structure with physics requirements at the top and technical requirements at the bottom. All lower level requirements must have relationships that directly link them to higher level requirements. For instance, all technical requirements must be associated with one or more functional requirements and all functional requirements must be associated with one or more physics requirements.

A numbering scheme, based on the Brookhaven approach, is documented here that will ensure that each requirement has a unique identifier that can be used for reference. In addition to being used to provide references between levels, these identifiers may be employed later as indices when the requirements are stored in a database.

This document will identify the three layers of requirements that are being used and will identify the type of information that should be included at each level. Further, it will define the structure of the numbering scheme and how it should expand as the number (and depth) of requirements grow. Finally, it will suggest future solutions that may be implemented to index and catalog the requirements for ease of access.

LEVELS OF REQUIREMENTS

As described earlier, detector requirements are broken into three groups: physics requirements, functional requirements and technical specifications. The diagram at right provides a conceptual hierarchy describing the types of information that will be included in each level.



Physics Requirements

These are the highest level requirements for a system or sub-system. They should provide a general description of the function or purpose of this (sub)system within the context of operating environment. Like all requirements, these should be brief and specific. If a (sub)system performs more than one function or is multi-purposed, then each of those requirements should be listed as a separate line item.

Functional Requirements

Where the physics requirements identify the purpose of the sub-system, the functional requirements identify how the sub-system will satisfy that purpose. Again, functional requirements are brief and specific, but do not contain implementation details or performance requirements. Some of the areas that may be covered in the functional requirements for a sub-system might be:

- What the sub-system must do

  Example: The device must transform A/C power to support sub-systems in the barrel detector.

- The environment in which the sub-system must operate

  Example: The temperature and humidity ranges must be within the transformer manufacturer's specification –or- the transformer must be able to operate within existing temperature and humidity thresholds.

- Structural/material requirements that are driven by its function or environment

  Example: The casing of the device must be made from non-magnetic material.

- Input requirements

  Note: the input/output requirements are where the interface specifications are documented. For each system that must interconnect with another system or outside service, an interface must be identified here and its technical requirements must be explicitly detailed in the technical specifications.

  Example 1: The sub-system must receive power from an exterior source.

  Example 2: The sub-system must have an interface that connects it to another sub-system.

  Example 3: This sub-system must be able to receive and process data from another sub-system.

- Output requirements

  Example 1: Waste heat from the sub-system must be removed from the central detector.

  Example 2: This sub-system must produce data that is compatible with another sub-system.

Technical Specifications

Technical specifications are specific values that refine the information provided in the functional requirements. Each of the line items in a technical specification should relate directly to one or more of the functional items and must provide a quantitative description of how the functional requirement will be satisfied. Technical specifications will contain specific dimensions, weights, ranges of operation and performance specifications that, if met, will assure that the sub-system satisfies its function or purpose.

Note that this is the dividing line between the system specifier and the system designer. The technical specifications provided here should provide a full accounting of all of the technical requirements that are necessary to build an operable system. Accordingly, if ALL of these technical specifications are satisfied, then the system should function – regardless of the method of implementation by the system designer.

RELATIONSHIPS

The identifier indexed hierarchy (or taxonomy) is used to uniquely identify each requirement and to assist in identifying relationships between entries up and down the tree, as well as entities in other sub-systems. To maintain continuity, the development of the requirement tree should focus on maintaining a complete hierarchy from top to bottom, and on avoiding orphaned requirements within the hierarchy.

- Hierarchy: When the requirements document is complete, in the end all physics and functional requirements MUST have subordinate technical requirements. However, early in the design many lower level requirements will have not been identified yet. As a result, there may be physics and functional requirements that are *placeholders* for future expansion.

- Orphans: All functional and technical requirements must have a parent. Orphaned requirements, those that are not linked to a parent, should be relocated, removed or a viable parent must be added at a higher level.

TAXONOMY

Requirement Type Prefix

The requirements system recognizes three categories of requirements. Accordingly, each requirement line item number is prefixed by a character that identifies which type of requirement it is.

P = Physics Requirement
F = Functional Requirement
T = Technical Specifications

Major System Identifier

Each of the major systems in the EIC has a unique abbreviation that identifies it. The major system identifier for the detector system is **DET**. This will be coupled with the requirement type (separated by a hyphen) to produce a unique prefix for each category of requirements for the major system.

P-DET = Physics Requirements for the Detector system
F-DET = Function Requirements for the Detector system
T-DET = Technical Specifications for the Detector System

Sub-System Identifier

Below the major system, there is a hierarchy of sub-systems. As with the major system identifier, each level of the sub-system is separated with a hyphen. The following are examples of different sub-system identifiers.

P-DET-ECAL = Physics requirements for all electromagnetic calorimetry in the detector.
F-DET-PID = Functional requirements for particle identification sub-system of the detector.
T-DET-PID-BACK-TOF = Technical specifications for the time-of-flight detector in the backward region of the particle identification sub-system of the detector.

As can be seen from these examples, sub-system identifiers can remain unique and be arbitrarily deep as long as the system abbreviations are separated by a common delimiter (the hyphen) and the names are unique at each branch of the hierarchy.

Requirement Numbering

Each line item must include a requirement number. Requirement numbers are separated from the sub-system identifier by a period. Numbering for the requirements within each sub-system identifier starts at 1 and proceeds upward incrementally. The following are examples of number requirements.

T-DET-ECAL-BARREL.1 = the barrel electromagnetic calorimeter will consist of 24 independent segments.
T-DET-ECAL-BARREL.2 = each barrel EMCal segment will have 240 crystals in the hadron direction.
T-DET-ECAL-BARREL.3 = each barrel EMCal segment will have 320 crystals in the lepton direction.

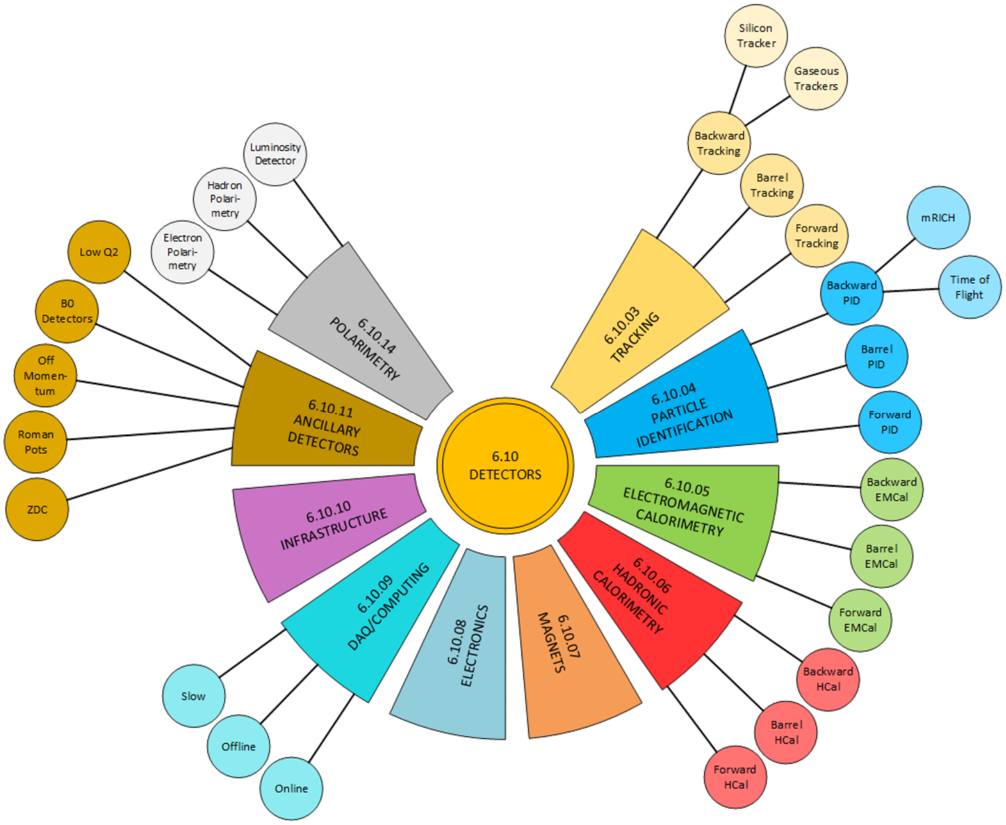
If necessary and desired, hierarchies of requirement line items may exist within a sub-system identifier. In the example below, the specifications for the hadron and lepton crystals are included immediately below the parent's described above.

T-DET-ECAL-BARREL.2.1 = hadron crystals will be constructed from lead tungstate glass.
T-DET-ECAL-BARREL.2.2 = hadron crystals will have a square face and a width of 4 cm.
T-DET-ECAL-BARREL.2.3 = hadron crystals will have a length of 30 centimeters.

T-DET-ECAL-BARREL.3.1 = lepton crystals will be constructed from lead tungstate glass.
T-DET-ECAL-BARREL.3.2 = hadron crystals will have a square face and a width of 2 cm.
T-DET-ECAL-BARREL.3.3 = hadron crystals will have a length of 20 centimeters.

HIGH-LEVEL TAXONOMY FOR DETECTOR SYSTEM

The high-level taxonomy for the detector system is derived from the WBS structure as shown in the illustration at right. The overall detector system is at the root of the system and it has all of the major sub-system as its direct children.



Many of these sub-systems (such as tracking, particle identification and calorimetry) have component systems that exist in each of the backward, barrel and forward regions of the central detector. For sub-systems that exist in two or more of these regions, the region tag BCK, BAR, or FWD will be included as part of the sub-system identifier to make it easier to determine which region the sub-system is in. In each of these cases, the sub-system abbreviation will follow the region tag, to uniquely identify which component system is being discussed.

The following table provides the base high-level taxonomy that will be used for the central detector. Note that a question mark is included at the beginning of each identifier. This will be replaced with the appropriate prefix for whichever requirement type is being defined: physics, functional or technical.

Prefix	*System, Sub-System or Component System*
?-DET	Detector System
?-DET-TRAK	Tracking Systems
?-DET-TRAK-BCK	Backward Tracking Systems
?-DET-TRAK-BCK-SILICON	Backward Silicon Tracking Systems
?-DET-TRAK-BCK-GASEOUS	Backward Gaseous Tracking Systems
?-DET-TRAK-BAR	Barrel Tracking Systems
?-DET-TRAK-FWD	Forward Tracking Systems
?-DET-PID	Particle Identification Systems
?-DET-PID-BCK	Backward Particle ID Systems
?-DET-PID-BCK-mRICH	Backward mRICH Particle ID Systems
?-DET-PID-BCK-TOF	Backward Time of Flight Particle ID Systems
?-DET-PID-BAR	Barrel Particle ID Systems
?-DET-PID-FWD	Forward Particle ID Systems
?-DET-ECAL	Electromagnetic Calorimetry Systems

?-DET-ECAL-BCK	Backward EMCal Systems
?-DET-ECAL-BAR	Barrel EMCal Systems
?-DET-ECAL-FWD	Forward EMCal Systems
?-DET-HCAL	Hadronic Calorimetry Systems
?-DET-HCAL-BCK	Backward HCal Systems
?-DET-HCAL-BAR	Barrel HCal Systems
?-DET-HCAL-FWD	Forward HCal Systems
?-DET-MAG	Solenoid Magnet
?-DET-ELEC	Electronic Systems
?-DET-COMP	Data Acquisition and Computing Systems
?-DET-ECAL-OFFLINE	Offline DAQ and Computing Systems
?-DET-ECAL-ONLINE	Online DAQ and Computing Systems
?-DET-ECAL-SLOW	Slow Controls
?-DET-INFR	Infrastructure Systems
?-DET-ANC	Ancillary Detector Systems
?-DET-ANC-LOWQ2	Low Q2 Detectors
?-DET-ANC-B0	B-Zero Detectors
?-DET-ANC-OFFMO	Off-Momentum Detectors
?-DET-ANC-ROMAN	Roman Pots
?-DET-ANC-ZDC	Zero Degree Calorimeter
?-DET-POL	Polarimetry and Luminosity
?-DET-POL-EPOL	Electron Polarimetry
?-DET-POL-HPOL	Hadron Polarimetry
?-DET-POL-HPOL-HJET	Hadron Polarimetry: H-jet at IP-12
?-DET-POL-LUM	Luminosity Detector

POTENTIAL SOLUTIONS FOR COLLECTING AND MANAGING REQUIREMENTS

As noted earlier, we expect that most of the line item requirements will be written as compactly as possible and should be limited to individual dimensions or specifications. Because of this, documenting requirements is well suited to either a document, a spreadsheet or a database. Regardless of the initial format in which they're produced, they are likely to eventually reside in some format that allows for searching and sorting, and for creating relationships across major system boundaries.

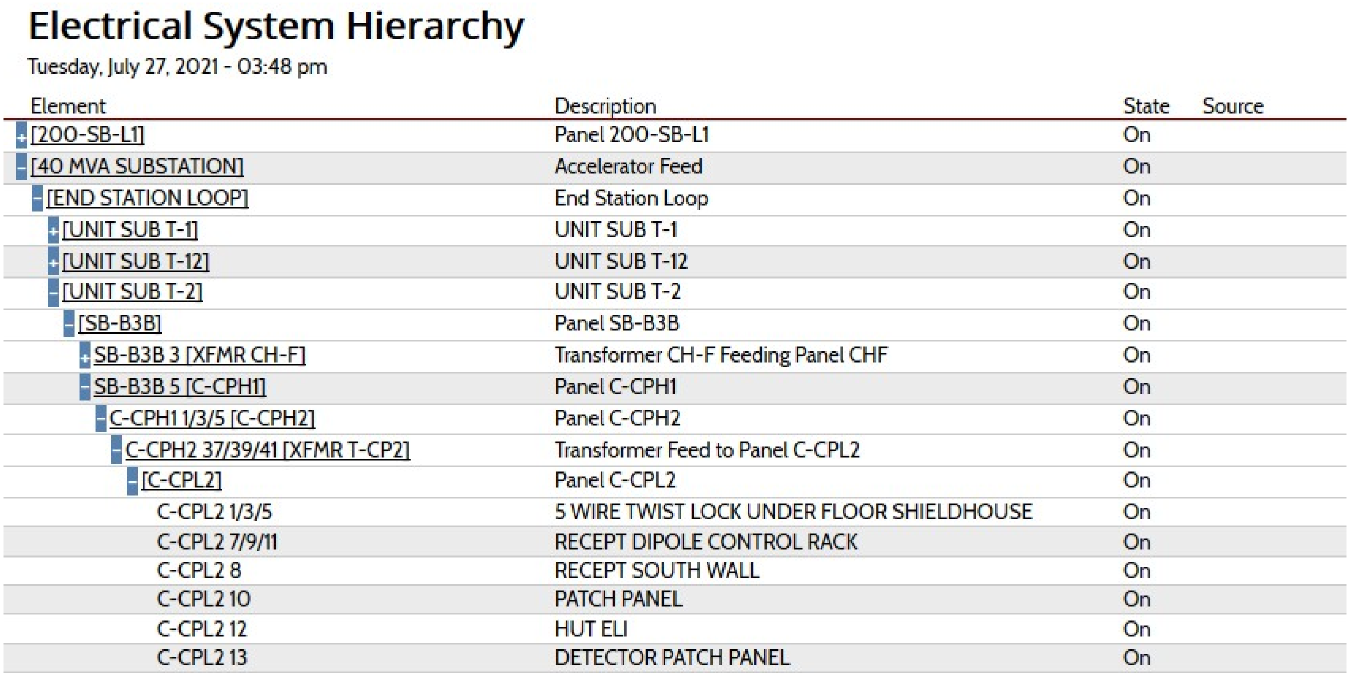
A decision regarding how the requirements will be collected should be made as soon as possible, so that requirements development will not be delayed. An input form may be developed for sub-system owners as either a document template or a pre-formatted spreadsheet. The collected information may then be transferred to a central repository to be collated into a master requirements table.

There are several web-based approaches that may be used for indexing the requirements for easy access. The following illustrations show approaches for system modeling of other hierarchies.

Web-Based Hierarchy

The line item requirements may be stored in a web-based hierarchy as shown in the illustration below. In this example, which is a model of an electrical system, each level of the hierarchy has an expandable list which can be opened to show the entries and additional levels below it. Using this approach, all of the data can be placed online and easily traversed from top to bottom, the hierarchy can be fully expanded to allow full text searches from within the web browser, or the data can be exported to a spreadsheet for offline analysis.

Existing libraries are available that would allow this type of hierarchy to be automatically generated using a centralized collection of spreadsheets or another online data source.



Electrical System Hierarchy

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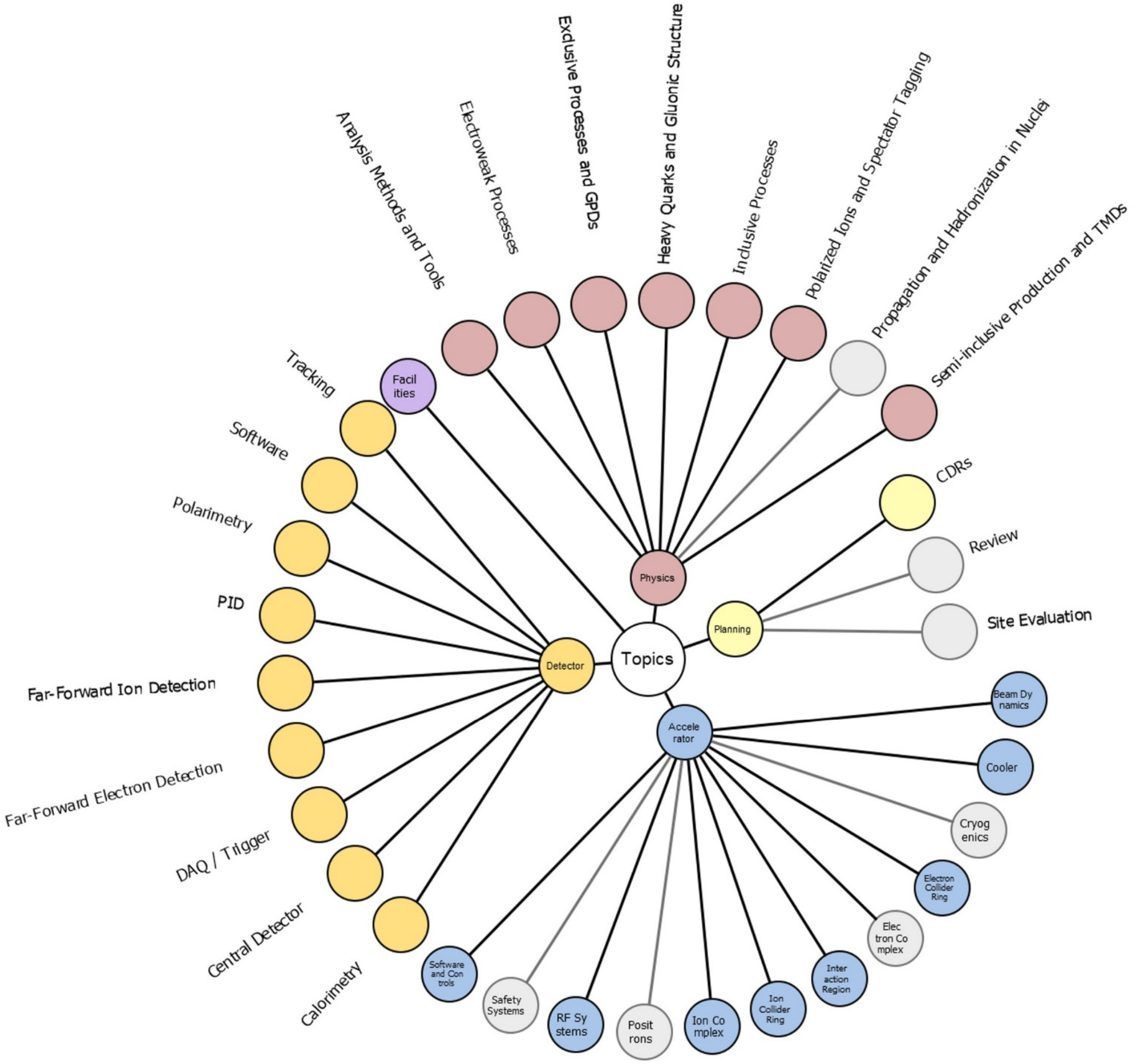
Element	Description	State	Source
+ [200-SB-L1]	Panel 200-SB-L1	On	
− [40 MVA SUBSTATION]	Accelerator Feed	On	
− [END STATION LOOP]	End Station Loop	On	
+ [UNIT SUB T-1]	UNIT SUB T-1	On	
+ [UNIT SUB T-12]	UNIT SUB T-12	On	
− [UNIT SUB T-2]	UNIT SUB T-2	On	
− [SB-B3B]	Panel SB-B3B	On	
+ SB-B3B 3 [XFMR CH-F]	Transformer CH-F Feeding Panel CHF	On	
− SB-B3B 5 [C-CPH1]	Panel C-CPH1	On	
− C-CPH1 1/3/5 [C-CPH2]	Panel C-CPH2	On	
− C-CPH2 37/39/41 [XFMR T-CP2]	Transformer Feed to Panel C-CPL2	On	
− [C-CPL2]	Panel C-CPL2	On	
C-CPL2 1/3/5	5 WIRE TWIST LOCK UNDER FLOOR SHIELDHOUSE	On	
C-CPL2 7/9/11	RECEPT DIPOLE CONTROL RACK	On	
C-CPL2 8	RECEPT SOUTH WALL	On	
C-CPL2 10	PATCH PANEL	On	
C-CPL2 12	HUT ELI	On	
C-CPL2 13	DETECTOR PATCH PANEL	On	

Graphical Hierarchy

An alternative approach to modeling the data is to construct a visual model that illustrates the hierarchy and allows the user to 'click-through' to access specific entries. In the past, such models have been created using image maps. Recently, though, scalable vector graphic (SVG) files have been developed which allow links to be embedded within the web-based map. As with the web-based hierarchy, libraries exist that allow SVG maps to be automatically generated using an external data source. The image below shows an SVG map representation of Topics within a DOC-DB site.



DETECTOR LEVEL 2 REQUIREMENTS EXAMPLES

The following section contains a sample requirements hierarchy from the Detector Systems.

Identifier	*Requirement*
P-DET.1	The detector shall be installed in one of two available interaction points for the EIC, IP-6 or IP-8.
P-DET.2	The central detector shall consist of a barrel augmented by, a forward endcap and a backward endcap region forming the central detector to cover the rapidity range η between -4 and 4 for the measurements of electrons, photons, hadrons and jets.
P-DET.3	The central detector shall be augmented with detectors in the far backward region to measure scattered electrons at small angles.
P-DET.4	The central detector shall be augmented with detectors in the far forward region to measure proton and ion remnants at small scattering angles.
P-DET.5	The central detector shall have polarimetry and luminosity detectors that measure the electron and proton beam polarization and monitor the instantaneous collision luminosities.
F-DET.1	The EIC detector shall be capable to operate over the full range of Center-Of-Mass energy ($\sqrt{s}$ = 30 GeV to 141 GeV), at full luminosity, and for all ion species.
F-DET.2	The EIC central detector shall cleanly identify the electron-quark scattering process to TBD by a combination of tracking and calorimetry resolutions.
F-DET.3	The EIC central solenoid magnet shall provide the means to momentum-analyze the charged particles associated with the hadrons produced in electron-quark scattering process.
F-DET.4	The EIC central detector system shall have the resolution of 3σ separation for particle identification of pions, kaons and protons with momenta up to 10 GeV/c in the barrel region, up to 50 GeV/c in the forward endcap region, and up to 7 GeV/c in the backward endcap region.
F-DET.5	The EIC central detector shall allow for heavy flavor and other long living particle measurements through a vertex resolution of TBD.
F-DET.6	The EIC central detector shall allow for separation of single-photons from neutral-pion decay into two photons for a momenta up to XX GeV to a level of TBD.
F-DET.7	The EIC far-backward detector shall cover the low-Q2 electron scattering region to complement the central detector in the Q^2 range XX GeV to YY GeV.
F-DET.8	The EIC far-forward detector shall measure proton/ion remnants with momenta up to less than 1% different from the proton/ion beam momentum.
T-DET.1	The EIC central detector shall require a region free of interaction region magnets and other large collider equipment of at least 9 meters centered around the interaction point.
T-DET.2	The EIC central solenoid magnet combined with tracking detectors shall be capable of providing momentum resolution to a level of σ_{p_T}/p_T (%) = 0.05p_T **x** 0.5 in the barrel region and to 0.1p_T **x** 1 in the forward and backward region.
T-DET.3	The electromagnetic calorimeter in the central detector shall be capable of providing a resolution of $\sigma(E)/E \sim 10\%/\mathrm{sqrt}(E)$ **x** (1-3)% in the barrel and $\sigma(E)/E \sim 2\%/\mathrm{sqrt}(E)$ **x** (1-3)% in the backward region.
T-DET.4	The impact parameter resolution for heavy flavor measurements enabled by the vertex tracker shall be capable of providing a vertex resolution σ_{xy} of level 10/p_T **x** 5 μm.
T-DET.5	The hadronic calorimeter in the central detector shall be capable of providing a resolution of $\sigma(E)/E \sim 50\%/\mathrm{sqrt}(E)$ **x** 10% in the forward region.
T-DET.6	The angular acceptance of the far-forward detection shall be capable of providing 20 mrad for charged particles and 4.5 mrad for neutrons.
T-DET.7	The acceptance of the far-backward electron detection shall be able to reach 10^{-4} GeV < Q^2 < 0.1 GeV^2.

T-DET.8	The beam optics at the Interaction Point shall be capable to reach 0.1 (0.2) mrad horizontal (vertical) angular beam divergence to limit the transverse momentum resolution of the physics measurements.

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