# ATLAS ITk Outer Endcap Local Support Production Database Qualification Task

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## Contents

# 1 Introduction

As we can find in welcome page of the ITk Production Database website [1] the ITk Production Database (ITkPDB) is an information system for registering all components used in the CERN Inner Tracker of the ATLAS experiment. The Inner Tracker (ITk) consists of approximately 500k components and its construction will take several years. The Inner Tracker will run for about 10 years and data should be available for a period of 20 years.

So, due to this huge amount of objects, the ATLAS ITk collaboration have decided to set up a Production Database that will allow each construction and testing site to keep track of every component, elementary or assembled, and the results of the test on such components. My work on the ITk Production Database was focused on the implementation of the ITk Pixel Outer Endcap (OEC) Local Support, work done as ATLAS qualification task.

A first FDR (Final Design Review) was held on 2020: you can find the ITk Production Database FDR1 on `https://indico.cern.ch/event/932846/`

This document is divided as follows:

1. Chapters [2-5] concern the ITk Production Database implementation: which components were instantiated, which test and stages, components identification codes and properties.
2. Chapter [6] describes the ITk Production Database test for the OEC. The whole components of a OEC Local Support were inserted inside the Database and then these components were assembled inside the database to compose the final Local Support Assembly.

## 2 Outer Endcap Local Support Structure

Starting from the Outer Endcap Local Support Assembly Breakdown Structure (ABS) [2], a tree structure was created.

As it's shown in Figure 1, every Half-Rings is composed of a Bare Half-ring, the naked carbon structure, on which are assembled the Type-0 Tape, a Low Voltage and High Voltage End of Stave Cards (LV/HV EoS), a Power and Data Pigtail and in the end a certain number of Quad Modules glued with their Adhesive.

There were also included two Reusable objects as Handling Frame and Transport box. It was chosen to link both of them at the Half-Ring Assembly level to simplify the disassembling process when the Half-Ring will be moved from the Handling Frame into the Shell for the final installation into the Endcap Shell. In the same way it was produced the tree structure for the Bare Half-Ring Assembly shown in Figure 2.

In both assembly structures some components are independent from the layer, while others are layer dependent or orientation dependent (orientation means that the object will be install in right or left shall). For this reason in tree structure Figure (1 and 2) the wording *L2* has been left before the component names, likewise the *Right-handed* wording, to specify which components are layer/orientation dependent and which are not. It is important to specify that the orientation of the Half-Ring Assembly comes from the gluing of the Type-0 Tape on the Half-Ring surface. Indeed, before the Type-0 Tape the Bare Half-Ring is totally symmetric and it can be both right and left.

It is important to specify how these components are not dependent from the Outer EndCap side (*A-side* or *C-side*) because on both side they are identical but mirrored.

## 3 ITk Production Database Components

As just said in previous chapter, my work on Production Database was started with the instantiation of whole Outer EndCap Local Support components inside the Database. The total list of components is the following:

1. Half Ring Assembly
    - 1.1. Bare Half Ring Assembly
        - 1.1.1. Co-cured Half Sandwhich
            - 1.1.1.1. Carbon Foam Trapezoids
            - 1.1.1.2. Pre-Preg Foil
        - 1.1.2. Evaporator

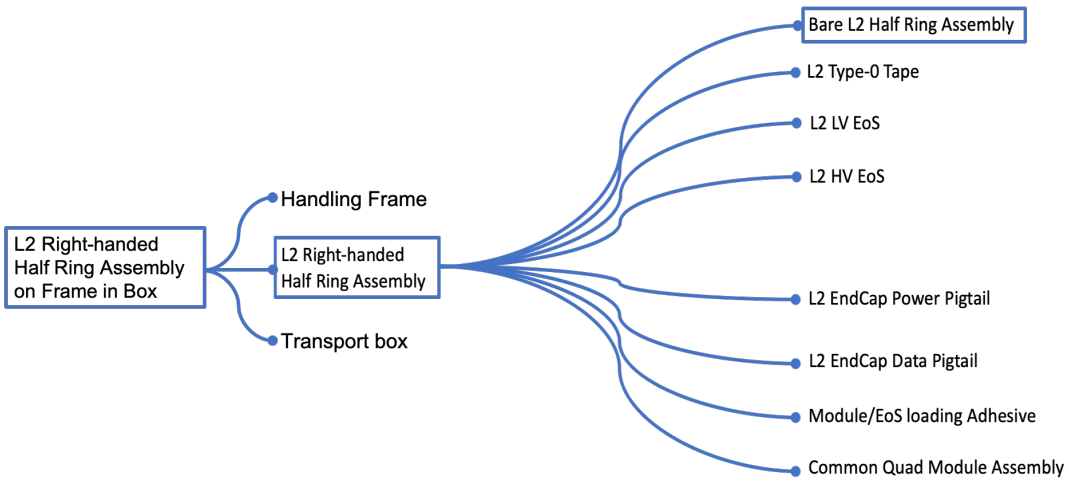


Figure 1: Half-Ring Structure

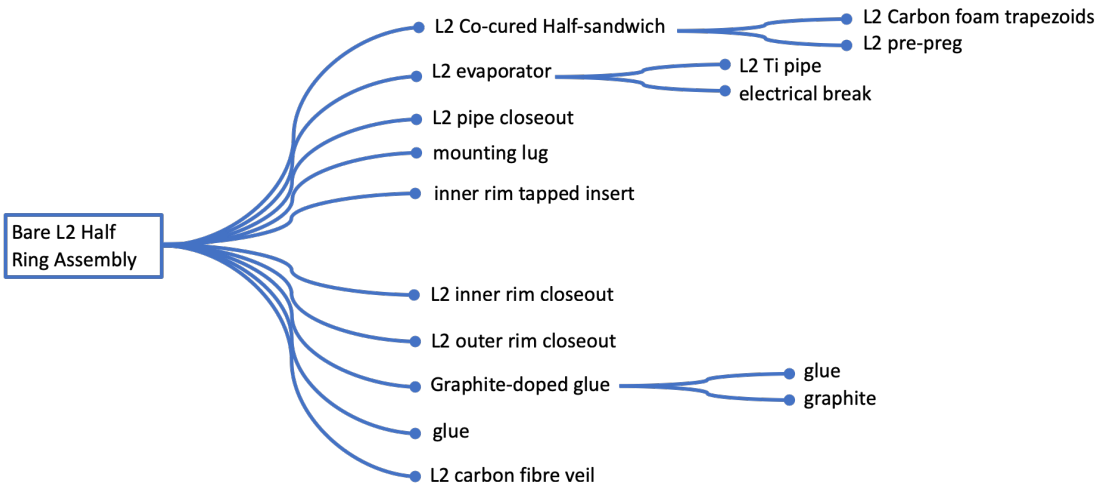


Figure 2: Bare Half-Ring Structure

1.1.2.1. Titanium Pipe
1.1.2.2. Electrical Break
1.1.3. Mounting Lug
1.1.4. Inner Rim Tapped
1.1.5. Inner Rim Closeout
1.1.6. Outer Rim Closeout
1.1.7. Graphite-doped glue
1.1.7.1. Pure Glue
1.1.7.2. Graphite powder
1.1.8. Pure Glue
1.1.9. Carbon Fibre veil
1.2. Type-0 Tape
1.3. End of Stave Cards
1.4. EndCap Pigtail

2. Handling Frame
3. Transport Box

All of these components were named inside the database with OEC (that stands for Outer EndCap) + components name, to distinguish the OEC components from the Outer Barrel (OB) components.

## 3.1 Types

Some of these components have got different *Components Types*. In fact, the database is structured such as to have only one component with certain name, but different types of the same component can be instantiated for each component once defined. In this way we have, for example:

- OEC Half Ring
  - HR Layer 2-Right Handed (HRL2R)
  - HR Layer 2-Left Handed (HRL2L)
  - HR Layer 3-Right Handed (HRL3R)
  - HR Layer 3-Left Handed (HRL3L)
  - HR Layer 4-Right Handed (HRL4R)
  - HR Layer 4-Left Handed (HRL4L)

And each type of OEC Half Ring Assembly has its own children connected:

- HRL2R

  - L2 Bare Half Ring
  - L2 Type-0 Tape
  - L2 EoS Cards
  - L2 Pigtail
  - Quad Module
  - Module/EoS loading Adhesive

There were also included different type of End of Stave Cards (EoS):

- OEC EoS
  - OEC HV EoS
  - OEC LV EoS

and different Pigtail types:

- OEC Pigtail
  - OEC Power Pigtail
  - OEC Data Pigtail

## 3.2 Components Categories

Inside the Production Database the components are divided in *Categories*. For each component you have to choose which category it belongs to.
Inside the Production Database there are several different Components Categories, but in my work I've use 5 categories: *Assembly*, *Item*, *Bulk*, *Material* and *Reusable*.

### 3.2.1 Assembly

By definition Assembly Component is: *something that consists of several children components being combined together*.
Outer EndCap Components that belong to Assembly Category are

- OEC Half-Ring
- OEC Bare Half-Ring
- OEC Half-Sandwich
- OEC Evaporator
- OEC EoS for Half-Ring
- OEC Type-0 Tape

For example, Each Bare Half-Ring is composed by several different components, as we can see in the list in the sec. 3. This dependency between the Assembly and their *children* allows to record which components have been used to compose the Assembly.

### 3.2.2 Item, Bulk and Material

By definition Item Components are: *individual items with no components assembled into it.*
I've used this kind of category to instantiate "elementary" components that have to be tested piece by piece individually. The following components belong to this category:

- OEC Electrical Break for Ti Pipe
- OEC Pigtail
- OEC Ti Pipe

Bulk Component Category are: *components that arrive in batch and have no sub-type.*
This kind of components is grouped in batch and for the assembly purpose there is no need to identify every single component. Inside the Production Database only the batch is stored with an identification code, the *Batch Number*. The following components belong to Bulk category:

- OEC Inner Rim Closeout
- OEC Inner Rim Tapped Insert
- OEC Mounting Lugs
- OEC Outer Rim Closeout
- OEC Pipe Closeout

Material Components are defined as follows: *a pile of material from which a number of objects can be made without knowing precisely how many.*
In particular, the Outer EndCap components included inside the Production Database are the following:

- OEC Graphite Doped Glue
- OEC Graphite Powder
- OEC Carbon Fibre Veil
- OEC Carbon Foam Trapezoids
- OEC Glue
- OEC Loading Adhesive
- OEC Pre-preg
- OEC Foam Blocks

### 3.2.3 Reusable

Reusable Components are: *objects which need to be traced during production, but do not actually go into the detector.*
This kind of components is used several times, for example to ship Half-Ring from one institute and another, so it's important to register them inside the database to track their position. I've instantiated only two components in Reusable Category: OEC Handling Frame and OEC Transport Box.

# 4 Stages and Test

For each component I've included several stages. In the context of the Production Database, Stage means *The stages collect the information about the current state of an object.* So, in order to cover all the possible components status, I differentiated between Assembly component category, Reusable and the other categories (Item, Bulk and Material).
In Table 1 you can find the complete stages list divided by component category.

| | **Assembly** | **Reusable** | **Item-Bulk-Material** |
|---|---|---|---|
| **Reception** | Yes | Yes | Yes |
| **Assembly** | Yes | No | No |
| **QC Test** | Yes | Yes | Yes |
| **Package** | Yes | Yes | No |
| **Shipping** | Yes | Yes | No |

Table 1: OEC Local Support component stages table

The first stage is the Reception Stage. Every component has as first stage the Reception Stage. During this stage some components are tested through a visual test.
For the Assembly Components, the second stage is the Assembly stage, in which the component is assembled.
The second stage for Reusable, Item, Bulk and Material components is the QC Test stage, in which the components are tested.
In the end, Assembly and Reusable are moved to Package and Shipping stage (the name of the stages is explanatory of the stage itself).

As it has been said, during Reception Stages and QC Test Stages components are tested. Several test are already included inside the Production Database.
You can find the whole test list for each components in Table 4.

| Assembly | Item | Bulk | Material | Reusable |
|---|---|---|---|---|
| **Half Ring** | **Electrical Break for HR Ti pipe** - Visual inspection, Ohmich | **Inner Rim Closeout** | **Graphite Doped Glue** - Weight, viscosity | **Transport Box** |
| **Bare Half Ring** - Jig, thermal, grounding and shielding, metrology | **Pigtail** | **Inner Rim Tapped Insert** | **Graphite Powder** | **Handling Frame** |
| **Half-Sandwich** - Dimension, space between trapezoids | **Ti pipe** - Jig, diameter measurement, visual | **Mounting Lugs** - Jig | **Carbon Fibre Veil** | |
| **Evaporator** - Jig, leak test | | **Outer Rim Closeout** - Jig | **Carbon Foam** Trapezoids – Dimension, density | |
| **EoS for HR** - Ohmic, functionality | | **Pipe Closeout** - Jig | **Glue** - weight, viscosity | |
| **Type-0 Tape** - Ohmic, functionality | | | **Loading Adhesive** | |
| | | | **Pre-preg** - weight, dimension | |

Table 2: OEC Local Support Tests

# 5 Serial Number, Batch Number and Properties

To identify components placed into ITk Production Database, they are identified through a Serial Number or Batch Number.
The basic difference between a Serial Number and Batch Number lies in the fact that Serial Numbers are self-generated by the Production Database (with the code schema chosen by the community) while the Batch Number could be chosen case by case by the shifter maintaining the code uniqueness.
The ITk Production Database identifies with a Serial Number the Assembly, Item and Reusable components, while the Material and Bulk components are identified by Batch Number.
A document on Local Support Serial Number is being written by the community. You can find it on `https://cds.cern.ch/record/2746044`

## 5.1 Serial Number

The Local Support Serial Number is an unique identifier code automatically assigned by the system to each components.
The Serial Number has got this form: $\mathbf{20UPEXXN_1N_2N_3N_4N_5N_6N_7}$.
To better understand what the singular parts of the code means, I report it's rules below:

- The Serial Number begins with the code **20U**, where **20** is the ATLAS Number, while **U** is the Upgrade Identifier.
- The code **PE** identifies the Pixel Outer EndCap components.
- **XX** is the Components Identifier. These two letters univocally recognize the components types (eg: for the component OEC Half-Sandwich the Components Identifier is **HS**).
- $\mathbf{N_1}$ is the Layer Number. This number can assume the following values: 2, 3, 4 (the only three possible layer for the OEC Local Support Components) and 9, which means that this particular components is the same for every layer.
- $\mathbf{N_2}$ is the Production Type number. This number can assume the following values:
  - Pre-Production = 0;
  - Production = 1;
  - Prototype = 2;
  - All = 9;
- $\mathbf{N_3}$...$\mathbf{N_7}$ count the N'th object.

## 5.2 Batch Number

Batch Number allows grater freedom of choice, so as to adapt the object numbering with contingency. For example, the Batch Number could be the vendor batch identifier.
At the moment with this criteria was chosen the OEC Foam Blocks and OEC Foam Trapezoids Batch Numbers. Using the Batch identifier with which the vendor named the Foam Blocks shipped to the laboratories in Genoa, the Batch Numbers of these components have been decide:

- OEC Foam Blocks Batch Number is **SNXX-LotYY**, where **XX** and **YY** are the Foam Block vendor chosen serial number and lot number respectively.
- OEC Foam Trapezoids inherit the Batch Number from the Foam Block from which they are produced, plus a number **ZZ** ranging from 0 and 99: **SNXX-LotYY-ZZ**.

## 5.3 Properties

For each component inside the Production Database you can define some properties. Properties are additional information that help the shifter to better store information about the component in the database.
During the development phase, the following properties for the components were chosen:

- Assembly, Item and Reusable components:
  - Shifter Name: the name of who insert this components into the database
  - Layer Number: the number of the layer for which the component is assembled. This information is stored into the Serial Number as Layer Number ($N_1$). I've used `codeTable` data type for this property.
  - Production Type: this property stores the information about the type of production for which the component is being assembled. Production Type can only assume values 0, 1, 2 and 9 as mentioned in the section concerning serial numbers (sec. 5.1). Also this information is stored into the Serial Number as Production Type Number ($\mathbf{N_2}$). I've used `codeTable` data type for this property.
  - Part Number: it is an Alternative ID and is a "human readable" serial number. This property is useful for shifters to find objects into the database without having to use the Serial Number.
- Material and Bulk components:
  - Shifter Name: the name of who insert this components into the database

– Batch Number: this property is the Batch Number identifier explained in sec. 5.2. This property is an Alternative Identifier and also Unique. It's data type is a `string`.

– Part Number: it is an Alternative ID and is a "human readable" serial number. This property is useful for shifters to find objects into the database without having to use the Serial Number.

# 6 Bare Half-Ring Assembly inside Production Databse

In order to test my work, I started to insert components that are actually present in the Genova laboratory and then assemble a first Bare Half-Ring.
I've started with OEC Foam Blocks SN20-Lot12 and OEC Foam Trapezoids L4 from which they are produced: SN20-Lot12-[01,..,25]. For these particular Foam Trapezoids, the density of been measured for each of them,rather then inherit the one from the parent block, and I've also included inside the Production Database the results of these test. Adding the OEC Pre-preg L4, I have assembled these components into two different OEC Half-Sandwich L4.
In Fig. 3 a picture of one of these OEC Half-Sandwich L4 produced by Genova is shown.

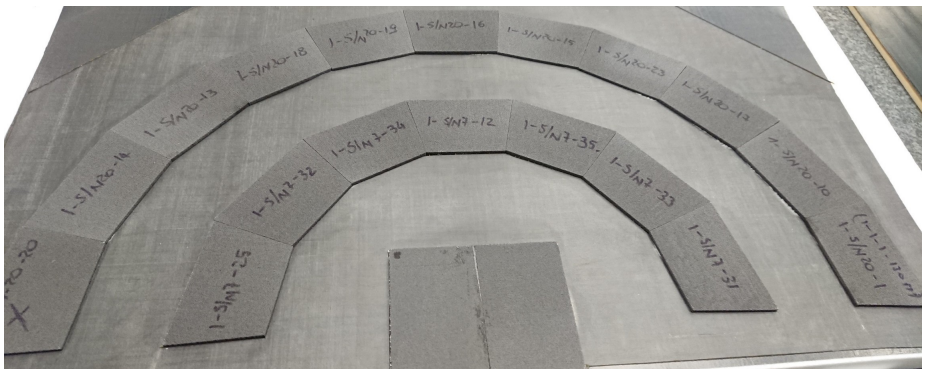


Figure 3: Half-Sandwich assembled

To assemble an Half-Sandwich (HS) into the Production Database you have to link the HS children with the HS itself.
In order to preserve the information of individual Foam Trapezoid placement on the HS, each trapezoid is linked in the following order into the list of children of the HS:

- Look at the HS on the table with the concavity facing down (as you can see in Fig. 3).

- Trapezoids, with their name visible, are linked from left to right.

I've also included into the database the picture of the HS with the trapezoids name visible.

In order to assembly a complete OEC Bare Half Ring L4, I've stored into the database the remaining components that compose the Bare Half Ring (BHR). I've started with a OEC Titanium Pipe L4 and two OEC Electrical Break for HR Ti Pipe, so as to assemble them in an OEC Eveporator L4.
At last, the remaining components was added:

- OEC Glue for HR,
- OEC Doped Glue for HR, assembly composed by the OEC Glue and the OEC Graphite Powder,
- OEC Inner Rim Closeout for HR L4 and OEC Outer Rim Closeout for HR L4,
- OEC Inner Rim Tapped Insert for HR,
- OEC Pipe Closeout for HR L4.

At this point all these components were linked ad children to the BHR. As the only precaution, the HSs were added as children in numerical order, i.e. by first adding the HS with the lowest Serial Number. This HS will be the "face up" of the BHR. In Fig. 4 it's shown the real BHR assembled by Genova.

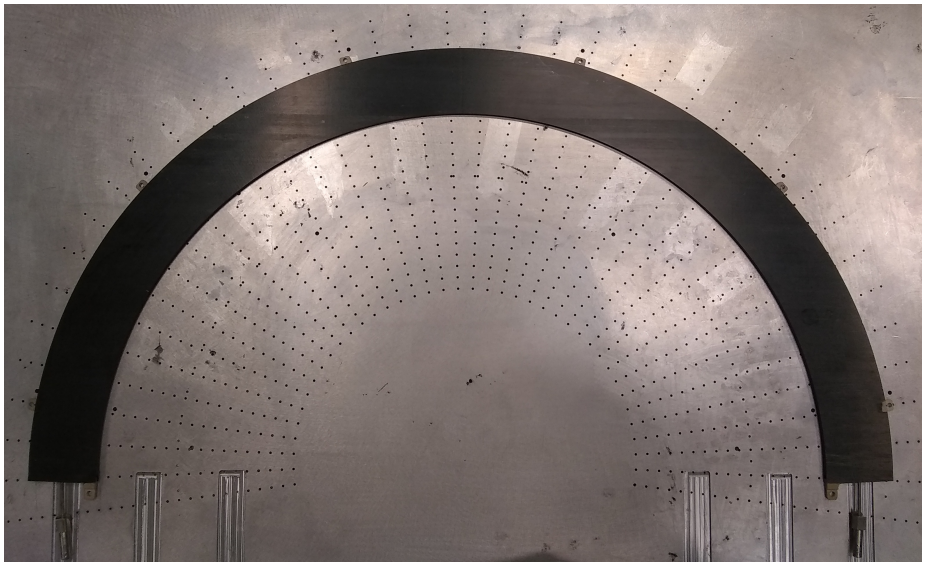

Figure 4: Bare Half-Ring assembled

When the OEC Bare Half Ring is assembled, being this totally symmetrical, it can be installed in any of the 4 Half-Shells that will enclose ITk's Outer Endcap. Only the gluing of Type-0 Tape on the Bare Half Ring paces will brake this symmetry making the HR permanently "right" or "left", as shown in Fig. 5.

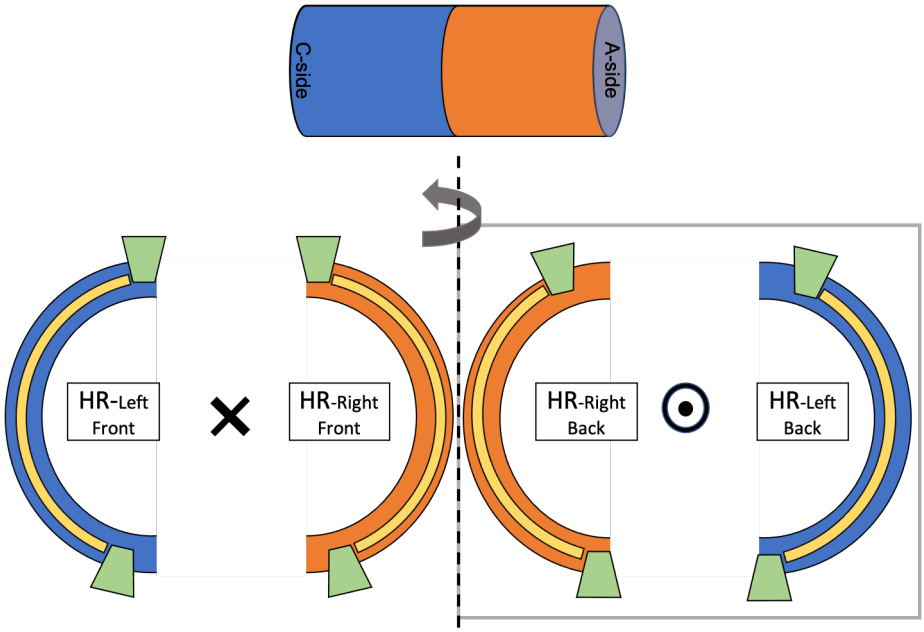


Figure 5: schematic reproduction of an HR to which the Type-0 Tape has been added. As you can see, the tape breaks the symmetry and makes the HR "left" or "right".

To preserve the information chain on *which Foam Trapezoids is in which place* on each HR, it is therefore essential to keep track of which tape has been glued onto which Half-Sandwich.

# 7 Conclusion

The Production Database is now usable to store the Pixel OEC Local Support components. It is now possible to store the components information inside the Production Database with some test result too.

Soon I will work to finalize the GUI, to make it totally usable for the Outer EndCap community.
With the FDR finalization the tests that will be chosen by the construction site will be included inside the database.

# Appendice

# A ITk Production Database Implementation instruction

## A.1 Log In

To move the first step into the Production Database you must register a new account. Following the guide (`https://twiki.cern.ch/twiki/pub/Atlas/PixelDatabase/DBTutorial_GettingStarted.pdf`) you can sing up on ITk Production Database. If you need to add new components into the database, you have to ask the administration rights.

## A.2 Components Implementation

Once you sign up and your rights are granted you can start adding new components. In section Component Types click on the box with the + symbol. In Basic Properties you have to fill the following fields:

- Code: I suggest to fill this filed with the name of the components that you intend to add, with underscores between the word (instead of space)
- Name: the name of the components. If a component with the same name is already inside the database, you might use, before the name of the component, the code of the subsystem to which the component belongs (eg: OEC Half Ring)
- Category: you have to chose between some category: Item, Assembly, Bulk, Wafer, Panel, Material and Reusable.
- Subprojects: you can chose between Inner, Outer Barrel, Endcaps and Pixel general.

If you have filled the category field with Assembly, Item, Panel, Wafer or Reusable, you have to tick the ATLAS Serial Number box. In this case you should also fill the SN Component Identifier field, i.e. two letters that identify that component.
In Fig. 6 you can find this first page completely filled with the Bare Half-Ring information.

By clicking on the "Next" button at the bottom right, you will pass to the "Types" page. Different types of the same component are, for example, the different destination layer. The component are conceptually the same, but due to this different final destination, every type hosts different children. In Fig. 7 is shown the Bare Half-Ring Types page. As it shown in that picture, the Bare

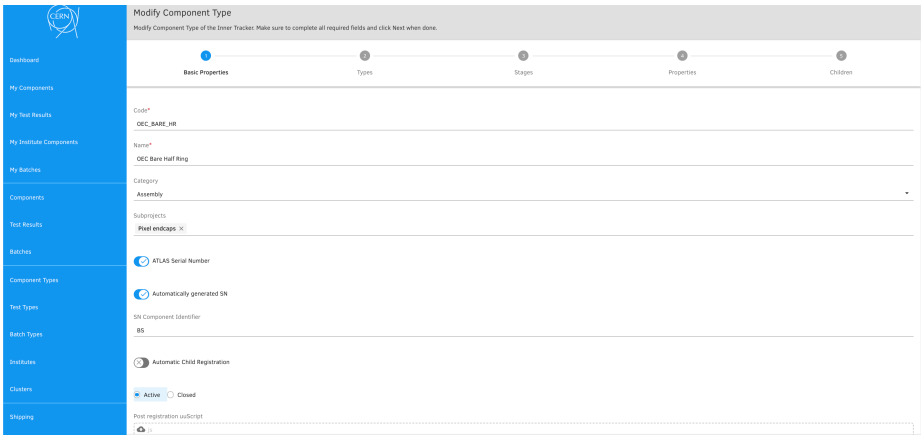


Figure 6: Basic Properties database page. This is the first page of fields must be filled in to register a new component.

Half-Ring has got 3 different types for each layer in which it will be installed (plus a prototype types that it was helpful for tests).

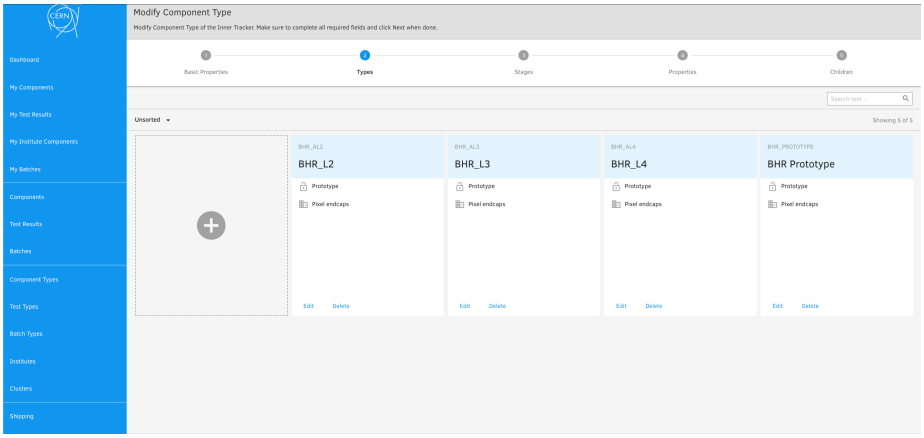


Figure 7: Types database page. In this page you can register the different types in which the particular component will be assembled (or purchased if it is not an Assembly).

The following page is the "Stages" one. The purpose of stages is well defined in sec. 4. In that section are also listed which stages were created for which category of component.
In Fig. 8 I report the Stages page of the Bare Half-Ring, in which four stages are present. The first stage in this case is the Assembly one because the Bare

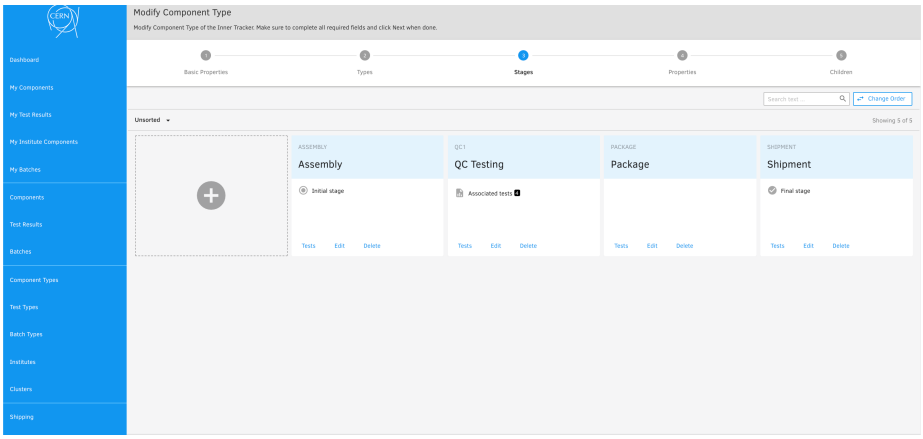


Figure 8: Stages database page. Different stages are created for the Bare Half-Ring components. Look at sec. 4 for detailed explanation of what kind of stages were chosen and why.

Half-Ring are assembled in construction site. Once assembled, the BHR moves on to the QC Testing stage. This stage has associated 4 test at the moment. I will cover the topic of how to create test in a next section.
The last two stages are the Package and the Shipment (the Shipment stage are marked as final stage).

Regarding the properties, I refer to the previous section. The logic with which I implemented the properties for each component category is the one reported in the sec. 5.3.

In the end, once all the components have been implemented into the Production Database, you have to link this components to the parent assembly. As you can see in Fig. 9, for each types of the same components you can add the total list of sub-components (child) that compose that assembly (parent). Obviously, you must to be careful to connect children of the same type as parents.

## A.3 Tests Implementation

Once the components are implemented into the Production Database and once related stage have been added to each component, you can implement tests. Clearly, you have to follow the QA/QC Final Design Review (FDR) in which there are all the tests that have been decided to perform on each component.
In order to add a new test to a component, you have to click on Test Types in the blue bar to the left of the database home page. You can find your components using the top right finding bar.
Now, once you find the component, click on the component box.
Clicking on the box with the plus button and you will be redirected on test

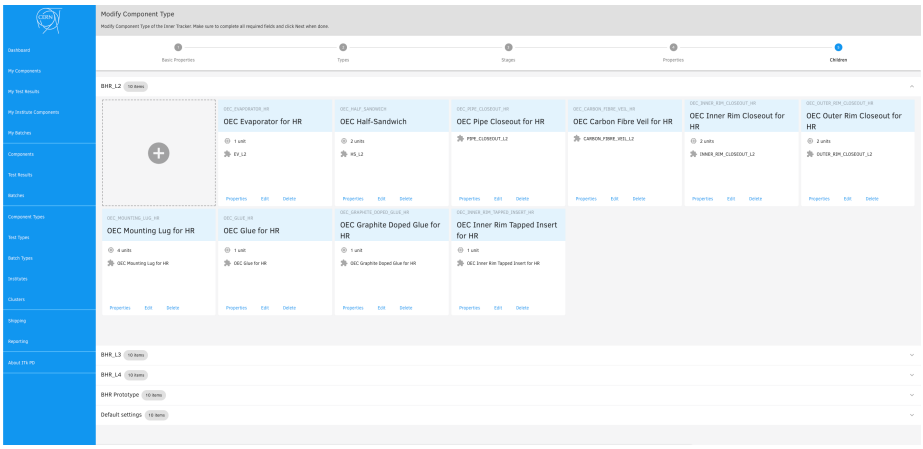


Figure 9: Child database page. For each parent types you have to link the children that compose it, being careful to connect children of the same type.

Basic Properties page. On this page you have to fill all the fields and remember to tick the "Active" box at the bottom of the page, as you can see in the first image of the Fig. 10.
On the Properties Page you can define with wich variable the test result will be loaded and a threshold (if there is one) that defines whether the test passes or fails.
In the end, you can add a chart to graph the data collected in the tests (last image of the Fig. 10).

## A.4 Registration of new components

Now you can start with the components registration!
In reference to this, I refer to an excellent guide that you can find at: `https://twiki.cern.ch/twiki/pub/Atlas/PixelDatabase/DBTutorial_Registration.pdf`

However, before proceeding with the registration of the components, one last step is required. You have to say to the Database wich kind of components are handled in your institute. To do this, click on the Institutes button on the blue border on the left and and search for your institution. Click on Edit and go to the second tab for your institution, namely Component Types. Here you have to add (manually) all the components that your institution may own, as you can see in Fig. 11. In this way you will enable the possibility to add those components in the Production Database.

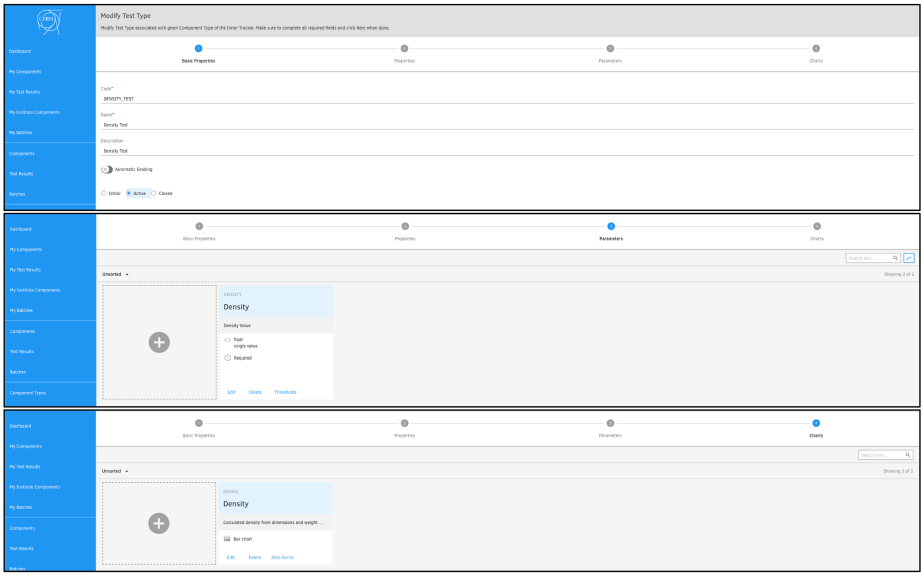


Figure 10: Test pages. The test's Basic Properties page is shown at the top. In the center, the Property page, where you can define with which variable the test result will be loaded and the possible thresholds of the test itself. Below, the Charts page where you can add a graph of the test results.

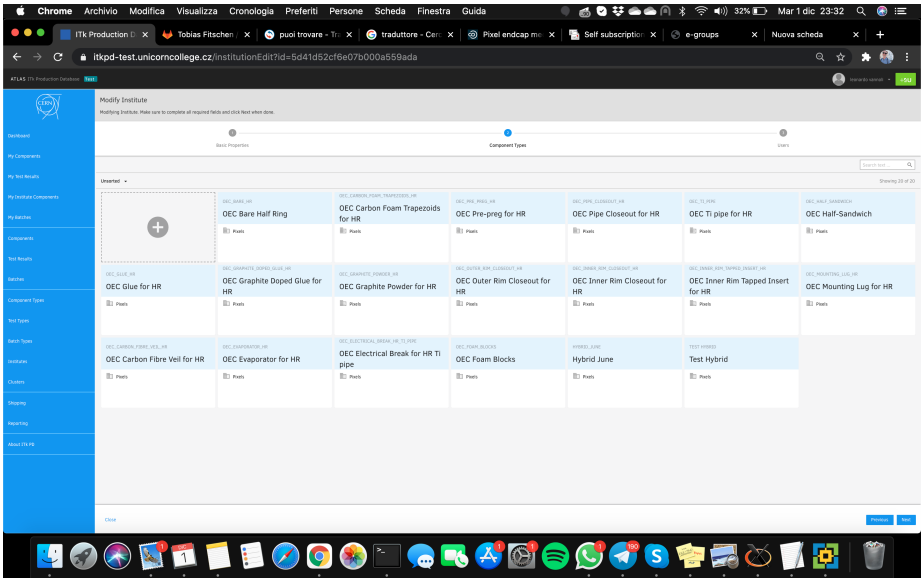


Figure 11: Genova institute Component Types. Those in the figure are all the components that the genoa laboratory must have to assemble a loaded HR.

# References


[1] https://uuos9.plus4u.net/uu-dockitg01-main/78462435-41f76117152c4c6e947f498339998055/book/page?code=home

[2] https://edms.cern.ch/ui/#!master/navigator/item?P:1494949617:100243432:subDocs

[3] The slides from which this report comes are available on https://indico.cern.ch/event/975503/contributions/4110594/attachments/2144310/3614543/PDB_Qualification_Task_Report_10-11-20pptx.pdf