Logistics of the Advanced Photon Source upgrade

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ABSTRACT

The Advanced Photon Source Upgrade (APS-U) is a very large-scale project that involves high accuracy and superior organization in the logistics of it. With thousands of parts that need to be kept track of, a consistent nomenclature is necessary in the bill of materials (BoM); thus, a large portion of this stage of the project involved making all datasheets and BoMs consistent with each other and the Argonne Component Database (CDB). In addition to consistency, another part of this stage of the project involves modeling portions of the storage ring to ensure the safety of the Argonne staff as the bending magnets keeping the electron beam in the storage ring decay. The pipeline was modeled using OpenSCAD and Python was used to automate the process. The created model can be used to ensure that the electron beam will not enter the enter the X-ray pipeline as the bending magnets decay. The APS-U is carried out with emphasis on LEAN manufacturing techniques by reducing waste and ensuring that all actions done on the project are done only once to save time and resources. Many aspects of the project have LEAN manufacturing as an integral part of the process; for example, the jigs designed to hold fasteners show the type of nuts to be used and the type of gasket the fasteners go on displayed on the jig itself along with a QR code showing how to use each bolt. The jigs were designed using LEAN and are made with the intent to reduce mistakes and save time and confusion in the assembly process.

INTRODUCTION

The APS at Argonne National Laboratory is a large synchrotron which was brought into operation in 1995. With the discovery of a more efficient synchrotron design, the 26-year-old synchrotron is going to be torn up and replaced with the improved design. The device being as large as it is, however, it is a massive endeavor to replace the whole machine. Any project of this scale requires precision and efficiency from the engineers and technicians in charge. The logistics of the APS-U require the implementation of manufacturing methodologies employed by some of the most efficient companies in the world such as the Toyota Production System also known as LEAN manufacturing.

Figuring out and employing the methods that can be used to maximize efficiency in the APS-U involves understanding LEAN manufacturing techniques and applying them to every aspect of the project. With as big of a project as the APS-U is, all BoMs require consistent nomenclature such that any engineer or technician can look at the BoMs and be able to find the exact part necessary in the CDB as well as in the warehouse. Additionally, to reduce the likelihood of mistakes in the assembly process, jigs were designed with LEAN manufacturing in mind. Safety is also of top priority and thus attention was directed to the storage ring where bending magnets turn the electron beam along the circular pipeline. The points that the beam turns and an X-ray beam is released were modeled to ensure that, as the bending magnets decay, the beam does not go down the wrong pipe to ensure the safety of the workers downstream.

USING JIGS TO MINIMIZE MISTAKES

There are many flanges and gaskets used in the APS-U. The number of different combinations of flanges, gaskets, nuts, and bolts is enough to leave any technician confused and leaves the assembly process prone to errors. Errors in gasket placement can be catastrophic to the function of the synchrotron as the wrong flange could block the path of the electron beam. To combat this problem and reduce the risk of errors and waste down the line, 24 separate jigs - lettered A through X - were created for each combination. The jigs were modeled in the open-source CAD software OpenSCAD, which uses a coding-based interface to model in the program. The code is written out so that just by changing the letter of the jig, the model would update for that specific jig. Each jig is designed to have the letter of the jig, the appropriate number of holes to hold the correct length bolts, a storage tray for nuts and washers along with a picture for reference, the picture and the name of the gasket required, and a QR code with instructions on how to assemble the parts. A picture of the model can be seen in Figure 1 showcasing each of the above aspects. The completed OpenSCAD models were saved as STLs and sent to be 3D printed as prototypes. Future iterations will be used during the assembly stage as lean manufacturing is employed.

CREATING A CONSISTANT NOMENCLATURE

Each beamline along the synchrotron requires different parts as well as a different number of parts. The original documents from when it was first constructed do not have a consistent nomenclature resulting in an organizational mess. Beamlines 4ID, 8ID, 9ID, 19ID, 20ID, 25ID, 28ID, 33ID, and 34ID needed to be cataloged using engineering ESDs to find components along the beamline and organize them in a way to transfer it over to the CDB. This involved looking closely at ESDs as well as beamline diagrams such as the one shown in Figure 2 to create a list of components ordered based on distance along the beamline. In cases where the ESD did not provide enough information to complete the spreadsheet, the diagram of the beamline was used, especially in the cases of smaller components or less obvious parts such as bellows, ion pumps, gate valves, and shielded transports. To comply with the wants and preferences of the other engineers, after each iteration of a beamline, the sheets were sent to be reviewed and feedback was used to further improve each list of materials. A constant back and forth was maintained with the other engineers until an agreed upon version was reached. A consistent nomenclature and method of organization places the APS-U leagues ahead of the original installation and will provide an easier process for future upgrades at the APS. With the necessary beamlines documented and reviewed they were ready to be put into CDB for reference. By utilizing LEAN manufacturing in this stage of the project, the ease of assembly can be ensured as well as the ease of design and assembly the next time the APS gets upgraded in roughly the next 25 years.

MODELING THE VACUUM CHAMBER

As a final project during my time at Argonne, the vacuum chamber needed to be modeled to ensure that the electron beam will not enter the X-ray beamline as the bending magnets decay. Since this is a very important safety precaution, an accurate model of the vacuum chamber is necessary. Cross sections of the beamline were taken both parallel to and perpendicular to the chamber. The cross sections were taken as a series of points that can be opened in GnuPlot as seen in Figure 3. Using GnuPlot along with OpenSCAD, the straight sections of the vacuum chamber were modeled manually and fit to the lateral cross sections of the chamber, shown in Figure 4, making sure to consider inconsistencies in the model (these were also documented in their own files as seen in the appendix). The curved section of the vacuum chamber involved more work. A complex shape such as the curved section of the vacuum could not be done manually, instead the Python module SolidPython was used to automate the process. Using Python code to grab the data points from the cross-sectional data, the cross section was modeled then extruded along the path of the vacuum chamber. All the models were combined into one file and cut out of a large block. The models are shown in Figure 5. The model as is can be sent to the other engineers to perform simulations and ensure that the electron beam will not be sent down the wrong pipe.

CONCLUSION

The APS-U is a large project that will not be complete during my time at the laboratory, but the work that I have done during my 10 weeks will have an impact for roughly the next 25 years when the APS is upgraded again. Employing LEAN manufacturing techniques will make it so that when the assembly stage begins next year, the technicians will have no problems in the assembly process and the jigs that were designed and the BoMs uploaded to CDB will assist greatly in minimizing mistakes and creating a more efficient assembly process. The vacuum chamber that was modeled using the cross sections will also ensure that the danger of the electron beam going down the wrong pipe can be avoided as that could be catastrophic for the scientists and engineers downstream. Overall, I have learned a lot about cooperating with engineers and making decisions in a complicated environment such as a large-scale engineering project like APS-U. The skills I have gained in this area are extremely transferable and will help me in my career by enabling me to be a more effective communicator and get my ideas heard to push forward projects such as this one.

ACKNOWLEDGEMENTS

Project Supervisor:
[redacted]

Partner Intern:
[redacted]

Engineers Involved in the APS-U:
[redacted]

FIGURES

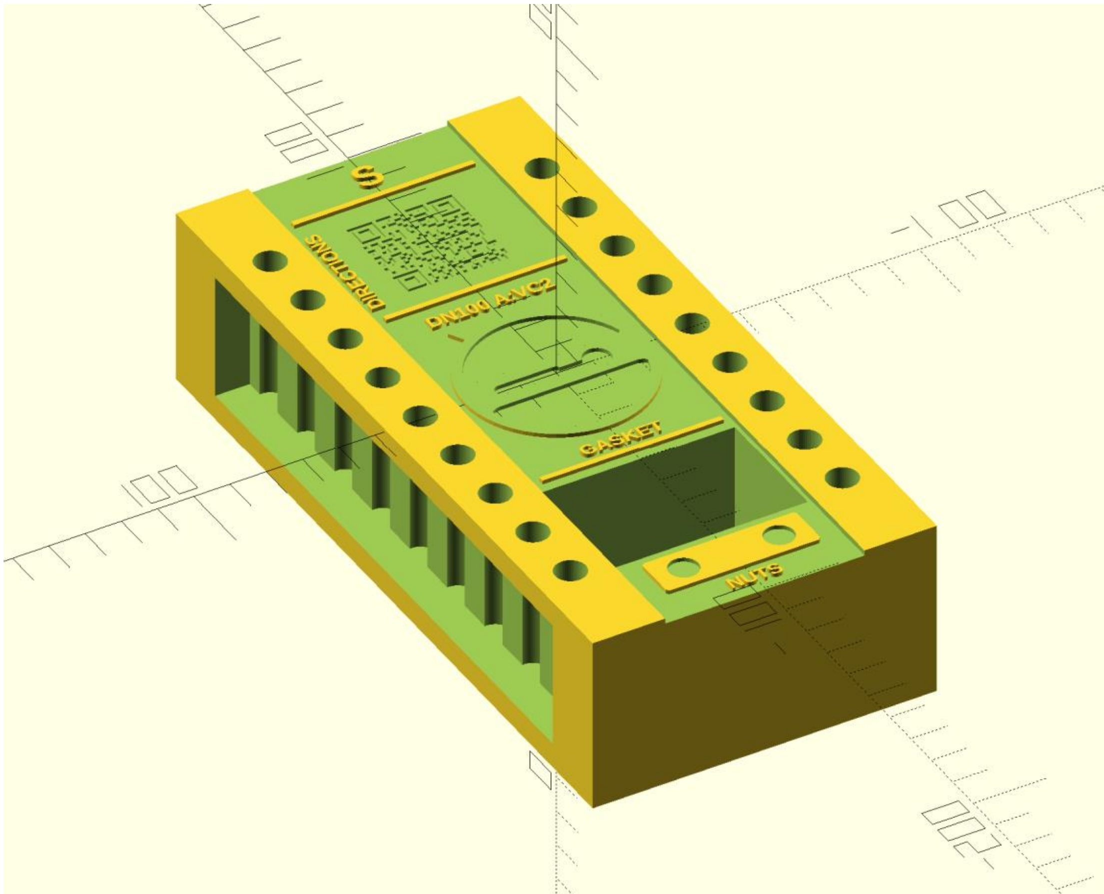

Figure 1: The label of the jig can clearly be seen at the top as "S." The QR code for the instructions is located below and the label and image of the required gasket is seen below that. Finally, at the bottom is the tray for the nuts and washers along with an image of the required item. The sides of the jig have holes to hold the correct number of bolts (in this case 18 bolts).

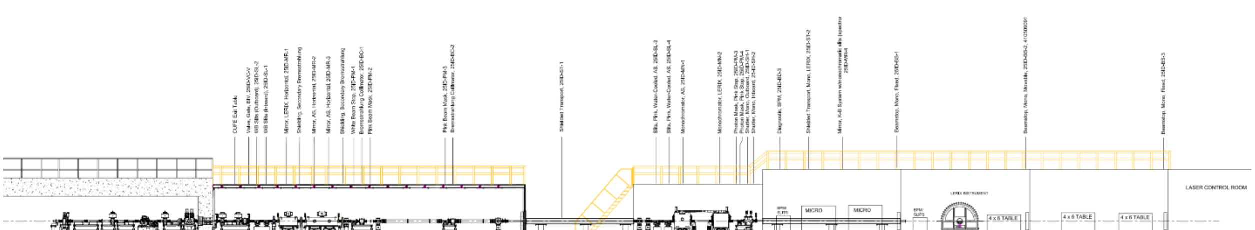

Figure 2: The entire length of the 25ID beamline is shown above. Certain components are only shown in this diagram such as the ion pumps at 25 and 25.7 and the gate valve at 26.2 as well as many more. The ESDs need to be compared with these diagrams to get an accurate account of components, another instance of inconsistent BoMs.

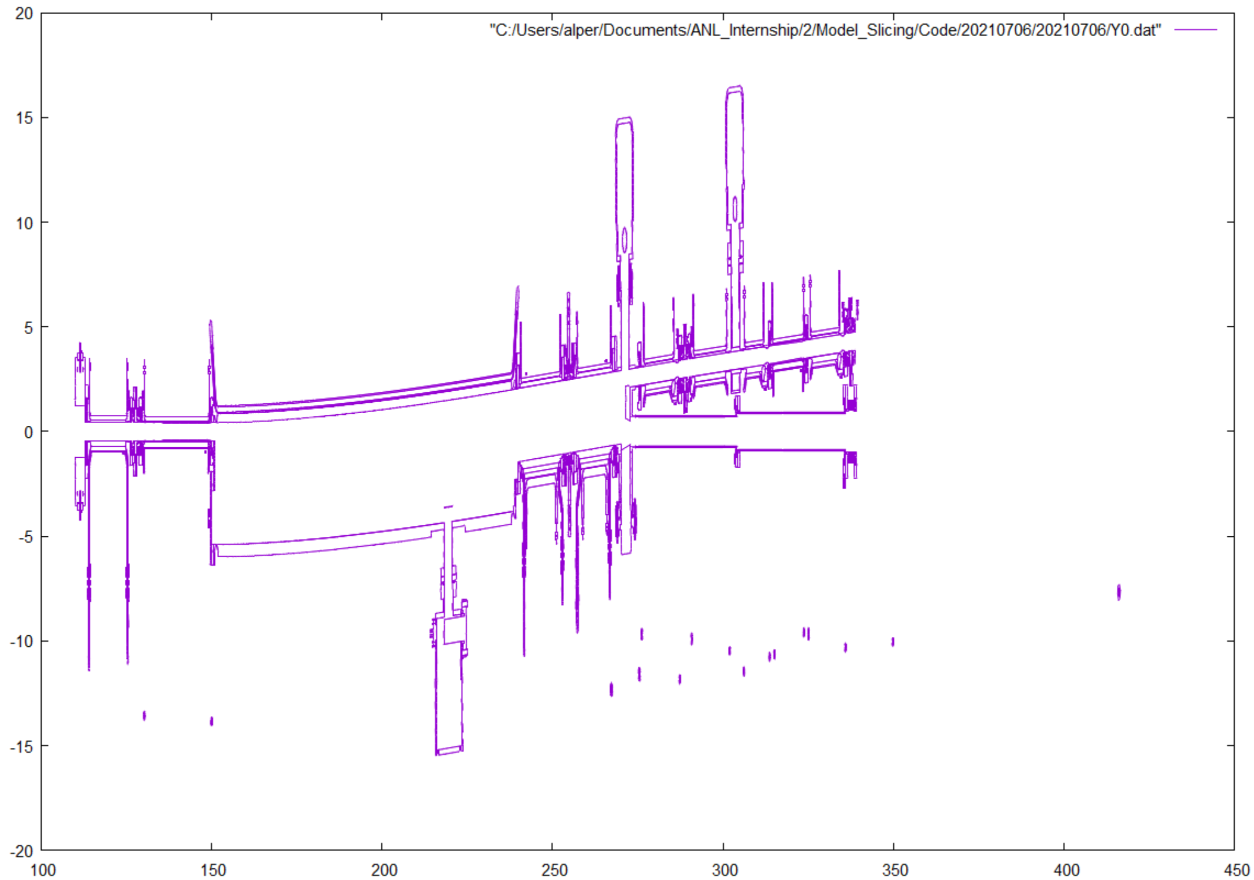

Figure 3: The points in the .dat files containing the cross sections are plotted in GnuPlot as seen in the plot above. This specific cross section is laterally right down the middle of the pipeline. The curved section is clearly visible from about 151 to 235 and the pipe for the electron beam is visible on top at roughly 275 to 340 along with the X-ray pipe on the bottom

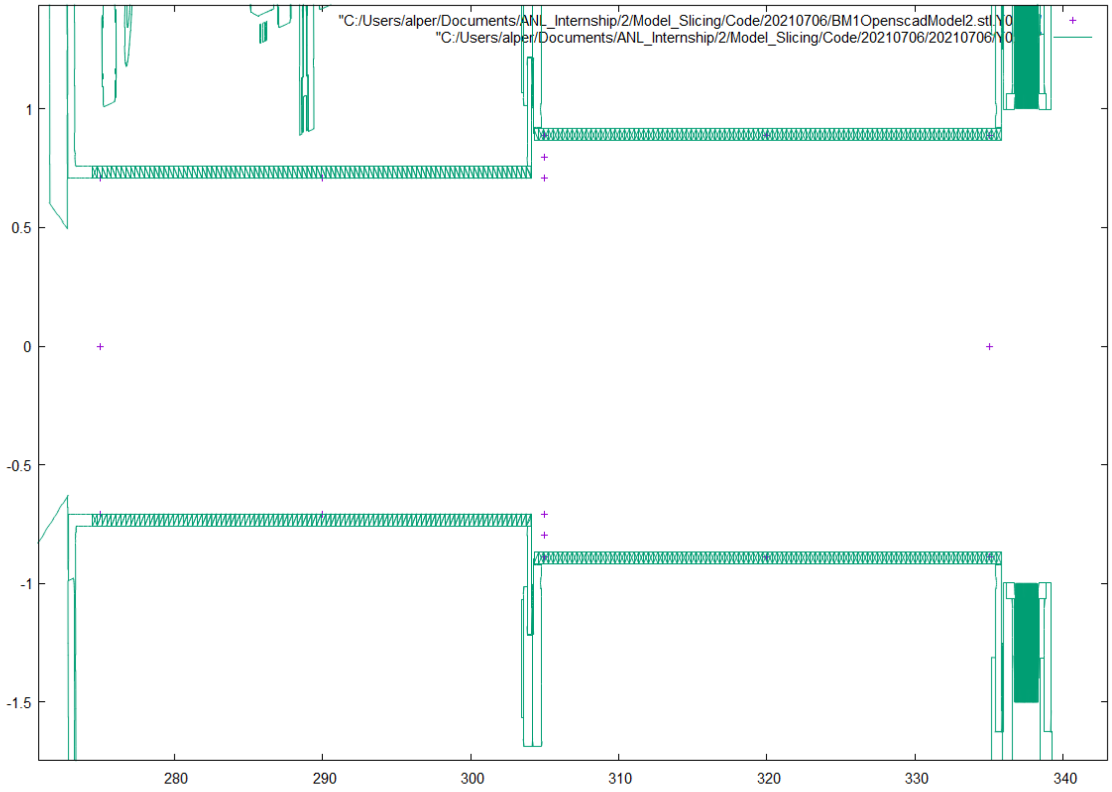

Figure 4: The above model compares a small section of the lateral cross section of the vacuum chamber (green) and the modeled sections of the vacuum chamber (pink). By comparing the two, the models can be iterated to account for areas where the pipeline changes shape and the model no longer is an accurate representation.

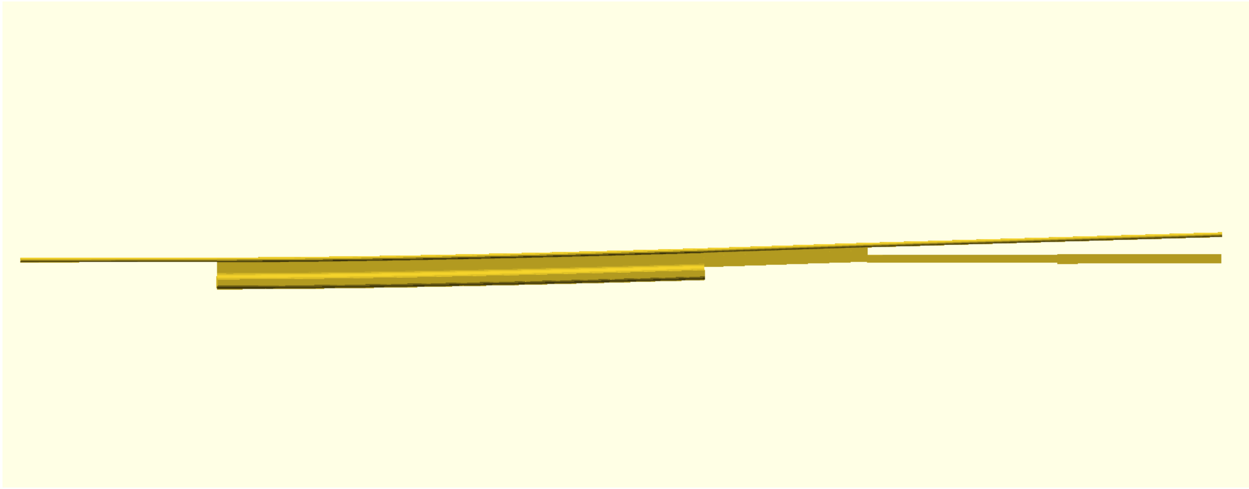

Figure 5a: The vacuum chamber can be seen modeled here with the straight section at the beginning entering the curved section, then the intermediate pipe between the curved section and the two pipes jutting off at the end for the electron beam (top) and the X-rays (bottom).

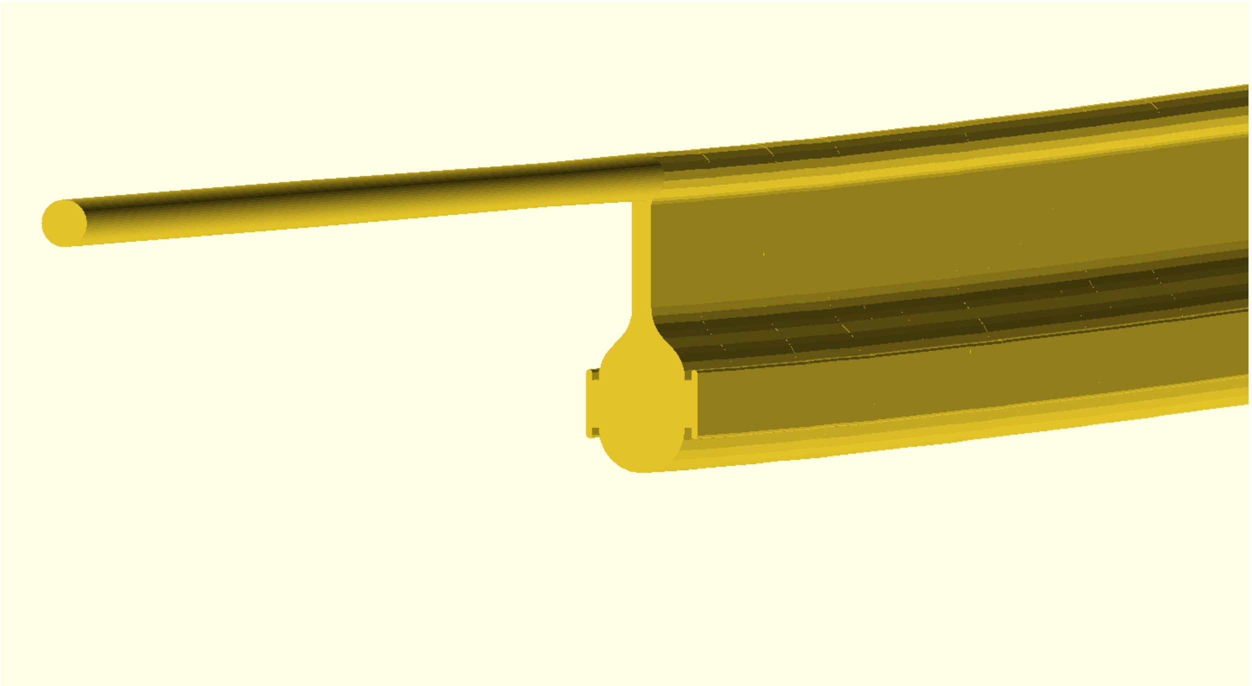

Figure 5b: A close up of the curved section of the vacuum chamber illustrating the unusual shape of the cross section to display why Python was necessary to model this part.

APPENDIX

A. Discrepancies in the X-cross sections

113: Pipe narrows significantly

127: pipe narrows slightly

128: instruments create openings

130: pipe narrows slightly

152: pipe connects to vacuum chamber

154-218: instruments inside vacuum chamber change its shape

219: Vacuum chamber splits to 2 pipes

225: Vacuum Chamber returns to normal shape

239: chamber changes shape and lower section shrinks

254-255: Pipe changes shape

168-272: chamber changes shape, instruments attach

273: Pipe splits into particle pipe and x-ray pipe

286: particle pipe is flattened on top and bottom

289: instruments change particle pipe

303: particle pipe changes shape

304: X-ray pipe gets larger briefly

312: particle pipe is flattened on top and bottom

335: Top and bottom of particle pipe become flattened

337: x-ray pipe becomes large and circular; instruments create openings in the particle pipe

B. Discrepancies in the Y-cross sections

109: Pipe sharply narrows to half size

123-127: Instruments create openings in pipe

127-149: Pipe gradually narrows slightly

149-150: Pipe opens up to size before gradual narrowing

150: Pipe opens up to large, curved vacuum chamber

219: Narrow pipe branches off of vacuum chamber

237: Vacuum chamber narrows slightly

238: Vacuum chamber narrows more

239: Vacuum chamber narrows to roughly half size and enters straight section

255: Instruments create openings in pipe

270: Pipe Branches off straight section

271: Pipe branches off into two pipes (one for the particle, one for x-rays), x-ray pipe narrows via nozzle, Particle pipe narrows but opens up again

272: X-ray pipe opens up sharply but only slightly

285: Particle pipe narrows slightly

290: Instruments create openings in particle pipe

302: External pipe connects to particle pipe; x-ray pipe opens up sharply

312: particle pipe narrows then opens up

313-320: Particle pipe gradually narrows

335: Particle pipe narrows

336: X-ray pipe widens

338: Instruments in particle pipe create openings in the pipe, grooves in x-ray pipe wall