

AN ACCELERATOR DESIGN TOOL FOR THE INTERNATIONAL DESIGN STUDY FOR THE NEUTRINO FACTORY

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Abstract

A tool has been developed to simplify the accelerator design process from the lattice design, through tracking simulations with engineering features, to costing the facility. The aim of this tool is to facilitate going through the design loop efficiently and thus allow engineering features to be included early on in the design process without hindering the development of the lattice design.

The tool uses a spreadsheet to store information about the accelerator and can generate MADX input files, G4beamline input files and interfaces with the costing tool developed by CERN. Having one source for the information simplifies going between lattice simulations, tracking simulations and costing calculations and eliminates the possibility of introducing discrepancies in the design.

The application of this tool to cost the Neutrino Factory, which is part of the IDS-NF and EUROnu studies for delivering the Reference Design Report, will be presented.

INTRODUCTION

The International Design Study for the Neutrino Factory (IDS-NF) [1] aims to deliver a reference design report of the whole facility by the end of 2013. This report will contain a detailed cost breakdown to inform a decision to build the facility. The effort to cost the Neutrino Factory is also part of the EUROnu [2] project which will compare a next-generation superbeam, the Neutrino Factory and a β -beam based on physics reach, accelerator and detector performance and cost. In order to do the cost evaluation in a consistent way for all the facilities a costing tool developed at CERN is being used. This allows a breakdown of the project to be defined and costs of the components to be specified.

Whilst much of the design of the Neutrino Factory is well advanced, there are certain areas where the design still needs to be fully specified. This means that the costing of the accelerator needs to be done in a flexible way and past experience has taught us that engineering and cost considerations will also impact the basic design of the accelerator facility. So an iterative approach needs to be taken in order to arrive at the final design. Much of the information used to specify the lattice design, perform tracking simulations and cost an accelerator is the same. By organising this information in a common format considerations from one aspect can easily be fed into another aspect, e.g. a small decrease in the aperture may lead to a significant cost saving and this can then be fed back to the lattice design.

A tool has been developed to facilitate the exchange of information between accelerator physicists and engineers in order to include engineering and cost considerations at an early stage of the design process. This tool uses a spreadsheet to store information in a common format which can then be used to automatically generate input files for MADX [3] and G4beamline [4] as well as interfacing to the CERN Costing Tool (CCT) [5]. This paper describes the organisation of information within the tool and the interfaces to MADX, G4beamline and the CCT. The decay ring of the Neutrino Factory will be used as an example to demonstrate the usage of the tool.

THE ACCELERATOR DESIGN TOOL

Typically, the design of an accelerator facility will start with the lattice design and follow a design loop as shown in Figure 1. Once the lattice design has been developed en-

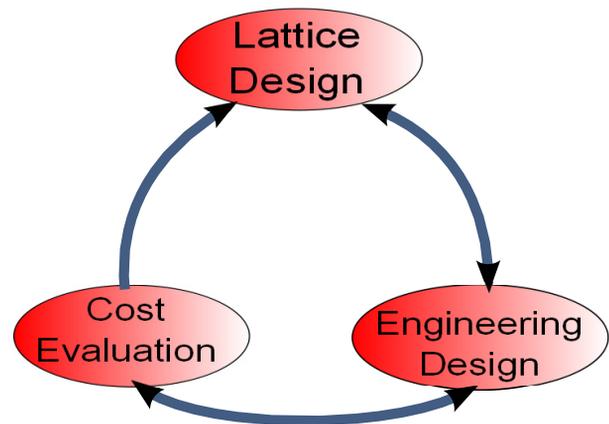


Figure 1: Figure showing the different phases of the design process and the paths that can be taken in going from one phase to the other.

gineering features will be added such as realistic distances between optical elements (e.g. to account for realistic cryomodule dimensions). This type of detail can be included in the lattice design but will depend on the experience of the accelerator physicist. The costing phase of the design process will then include many items needed to run the accelerator, e.g. vacuum valves and diagnostic equipment. Depending on the complexity of the design, the inclusion of such features could affect the lattice design and then this would need to be modified. So to reach the final design it may be necessary to go through this design loop several

times. In going between each phase, the exchange of information between accelerator physicists and engineers could be cumbersome and the conversion of information between different formats could lead to errors or omissions.

The aim of the accelerator design tool (ADT) is to provide a common structure for the information required and to provide the interfaces to do the lattice design, perform tracking simulations and to include details to cost the accelerator. The beam optics code MADX and the particle tracking code G4beamline were chosen to interface to as they are commonly used within the IDS-NF. The CCT is an Oracle database with a web-based form interface and an Excel spreadsheet interface. So for simplicity and ease of use, Excel was chosen as the format to store the information in. The information in the spreadsheet is parsed using a set of Visual Basic for Applications (VBA) Macros that are used to generate input files for MADX and G4beamline and to generate spreadsheets for the CCT.

Common Information Structure

The information needed to describe an accelerator in the ADT is broken down into three basic levels. These correspond to a physical hierarchy of building, module and component. Components (level 3) can be beamline elements such as magnets, RF cavities, etc. Modules (level 2) contain components and their dimensions reflect the space needed to have the component in the beamline, e.g. the size of a module for a magnet will include its yoke and support structure not just the size of the field volume. A building (level 1) contains modules and its dimensions reflect space needed for ancillary equipment such as vacuum gate valves, magnet power supplies, etc. Additional levels below the component level contain details for tracking simulations (level 4) and for costing purposes (level 5). This hierarchy is implemented in the spreadsheet using groups, see Figure 2. The buttons on the left-hand-side and on top of the spread sheet marked with a + or – respectively hide or show lower level groups, which prevents the screen from getting cluttered with unnecessary information.

For each beamline element you can specify a type, size, relative location and rotation. The type at level 3 and 4 has to be a keyword and is used to generate input files for MADX and G4beamline. For other levels, type is a descriptive name. Sizes and positions are specified in Cartesian coordinates and units of metres. Rotations are about the axes of the coordinate system of the containing object and are given in degrees. The right-most section of the spreadsheet (from the column labelled “Other Parameters”) contains keyword-value pairs used to specify parameters for MADX and G4beamline. Figure 2 shows an example of a simple beamline.

MADX Interface

The ADT can create a MADX sequence file from the information stored in the spreadsheet. A VBA macro parses

Figure 2: Screen snapshot of the ADT showing a simple beamline. The buttons on the left-hand-side and on top of the spread sheet marked with a + or – respectively hide or show further details.

the spreadsheet and creates a series of sequences that follows the level 1, 2 and 3 structure of the spreadsheet. Higher levels are ignored. The type of a level 3 entry must correspond to a known type and specifies what beamline element to include in the sequence. For example, if the type is “rfcavity” then an “LCAV” will be included in the sequence at the specified position and with the specified size. The other parameters needed to specify an “LCAV” in a MADX sequence (e.g. the frequency) need to be given in the “Other Parameters” columns. Figure 3 shows the MADX sequence generated for the spreadsheet shown in Figure 2.

Figure 3: Screen snapshot of the ADT's MADX sequence file for the simple beamline shown in Figure 2.

G4beamline Interface

A VBA macro has also been written to generate input for G4beamline from the spreadsheet. Here the G4beamline input follows a linear format and does not have the level 1, 2 and 3 hierarchy other than implicitly in the names automatically generated for each beamline element. Certain level 3 entries must be followed by additional entries at level 4 in order to provide required information

for G4beamline. For example, the row “solenoid” must be followed by two level 4 rows with type “solParams” and “coil”. These entries provide the information needed by the “solenoid” command in G4beamline and maintains the ability to use the same coil definition for solenoids with different currents. There is also the option to have a header section that can be used to specify other parameters of the simulation such as the input beam, etc. Figure 4 shows the G4beamline input generated for the spreadsheet shown in Figure 2.

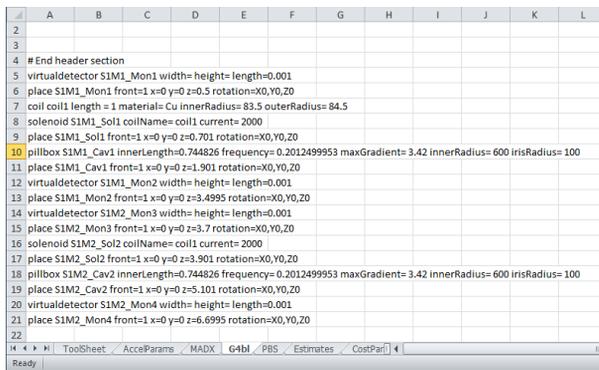


Figure 4: Screen snapshot of the ADT’s G4beamline input file for the simple beamline shown in Figure 2.

CERN Costing Tool Interface

Within the CCT a project is broken down into sets of grouped components. This structure was chosen to be the same as the hierarchy defined for the ADT. Each component is then split into three phases. The first phase, called industrialisation and tendering, is when the tender document is written. The next phase is called procurement and is when the item is ordered and manufactured. The last phase is called reception and is when the item is installed on-site and commissioned. Each phase has its own associated material costs and technician and engineering manpower. All this information needs to be provided to the CCT as well as other information such as the phase start date and duration, item multiplicity, etc. The information that needs to be provided to the CCT has been grouped into higher level columns and rows within the ADT. Thus, these can be hidden when only the physics or engineering design is being considered. A VBA macro is used to translate the information in these higher levels into the format required by the CCT. The order in which the items appear and the level they are in determines the unique code used by the CCT for that item, which gives the breakdown structure of the project. Entries at all levels except level 4 must specify a cost ID, which identifies if that item is to be costed or if the cost is the same as a previously specified item. If the same cost ID has been used previously then the multiplicity of that item is incremented otherwise a new item will be added to the project breakdown structure and cost information will be copied.

Additional Features

Additional features have been added in order to make the ADT more useable:

- A macro to copy and link sections, which is useful for repeating structures.
- The use of a parameters sheet and named cells to store variables in a compact location.
- A macro to automatically highlight rows at the appropriate level, which makes reading the spreadsheet easier.
- The use of filters. Useful for viewing on certain objects, e.g. to only look at solenoids.
- Copy and paste macros to copy non-contiguous areas. Useful for pasting values from an external source to a filtered region.

CONCLUSION

The ADT has been developed to facilitate the exchange of information between the various design phases as illustrated in Figure 1. The ADT is able to convert the description of the accelerator facility, stored within its spreadsheet, into a MADX input file, a G4beamline input file and into the spreadsheet format used by the CCT.

The primary reason for developing this tool is to help with costing the Neutrino Factory. Work is already underway to implement ADT spreadsheets for the different sections of the Neutrino Factory accelerator facility and the results of this costing exercise will be presented in the reference design report of the IDS-NF.

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