Collaborative project for IPM simulation code

January 19th, 2016

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Introduction

Measurement of transverse beam profiles in high-brightness accelerators is a difficult task. Intercepting devices, like wire scanners or SEM grids are damaged from interaction with the beam. Synchrotron radiation can be used only in case of high-gamma beams (electron beams or high-energy hadron beams).

Ionization profile monitors (IPMs, called also rest gas monitors or beam-gas ionization monitors) are non-intercepting beam profile measurement devices which use the rest gas ionization process. Electrons and ions liberated in ionization process are transported, using electric and magnetic fields, to a detector placed nearby the beam. The distribution of their position on the detector corresponds to the beam distribution.

There are three main phenomena which lead to the distortion of the image obtained on the detector with respect to the original beam distribution:

- Nonuniformities of the guiding fields.
- Beam space charge.
- Initial velocity distribution of the electrons (for beams with very small transverse size).

These effects are, in most cases, impossible to estimate without numerical simulations. Numerous codes have been written during the last 40 years. These codes are usually non-public, not maintained, not well documented and not complete.

Therefore we propose to create a general purpose simulation code together with a group of maintainers, which could be used by all current and future IPM designers and users. It will allow not only to design better devices, but also to understand impact of various processes on the measured profile.

Goals of the project

The project has the following goals:

1. Create a code which simulates beam-rest gas ionization process and transport of ions/electrons to the detector in realistic electric and magnetic fields.
2. Establish a group of code maintainers and developers.

3. Establish procedures to provide user support and to pass the code maintenance duties to future developers.

Typical use cases

Typical use cases for the planned code are:

1. Design the electrodes for new devices.
2. Simulation of field configuration to remove electron cloud from the device volume.
3. Simulation of profile distortion due to beam space charge and extraction field nonuniformities.

Interested parties

1. J-PARC, Kenichiro Satou – electron and ion-based IPMs.
2. GSI, Peter Forck, Mariusz Sapinski – both ion-based and electron based IPMs.
3. CERN, James Storey – mainly electron-based IPM.
4. ISIS, Rob Williamson – ion-based IPMs.
5. FNAL, Jim Zagel and Randy Thurman-Keup – electron-based IPMs.
6. BNL, Michiko Minty and Roger O'Connely – electron-based IPMs.
7. IFMIF, Jacques Marroncle – ion-based IPM.
8. ESS, Cyrille Thomas – ion-based IPM.

Sub-tasks

1. Parameterization of double-differential ionization cross-section:
   a. Various gas types.
   b. Large span of ion momenta, from 1 MeV/u up to 7 TeV/u (or more, include FCC?).
2. Rest gas/injected gas/gas jet relevant features:
   a. thermal motion,
   b. gas depletion,
   c. gas heating due to beam interaction, etc.
3. Background electrons (electron cloud).
4. Parameters scan for device optimization.
5. Additional signal due to synchrotron photons (aligned with the beam).
6. 3D-Tracking (or simpler 2D case for relativistic beams?) – core part.
7. Multiple-bunch simulation (case when ions will not have time to drift away before the next bunch arrival).
8. Graphical User Interface.
9. Tracking visualization.
10. Comparison with data, with other codes and with analytical calculations (for simple cases).
11. Manual.
12. Webpage (for instance sharepoint)
13. Code repository (cern svn? Git? github?).

Additional tasks

1. Electron tracking in electron beam scanner.
2. Simulations of BIF signal (simple).
3. Simulation of bunch-shape monitor signal distortion.
4. E-lens simulation (rather out of scope).
5. Detector module: parameterization of the MCP/Silicon detector efficiency, camera nonlinearity etc.
6. Influence of wakefields on electron trajectories