Summary of IPM Simulation workshop CERN, 3-4 March 2016

Introduction:

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. However a number of phenomena which leadto the distortion of the image obtained on the detector with respect to the real beam distribution. 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. We propose to create panels to exchange information about the various existing codes and about benchmarking those codes against each other and against data.

The workshop webpage with all the presentations and additional documents is available at the following address: https://indico.cern.ch/event/491615

Present:

J. Storey, K. Satou, M Sapinski, B Dehning, E. B. Holzer, S. Udrea, P. Forck, R. Williamson, G. Tranquille, T. Cyrille, S. Damjanovic, S. Levasseur, J. Marroncle, H. Sandberg, R. Singh, R. Thurman-Keup.

Other interested parties:

C. Welsch, C. Wilcox, T. Giacomini, B. Walasek-Hoehne, J. Zagel

The presentations:

1. Peter Forck, “GSI code and its limitations.”
2. Mariusz Sapinski, “Modified pyECloud code and main results.”
3. Jacques Marroncle, “IPM space charge for LIPAc.”
4. Cyrille Thomes, “ESS code.”
5. Randy Thurman-Keup,” Fermilab code(s).”
6. Rob WIlliamson, “ISIS code.”
7. Kenichiro Sato, “The core of the new code.”

In addition S. Udrea presented a review of open source FEM codes.

Workshop Summary:

During the workshop the Ionisation Profile Monitors of CERN, GSI (also Bunch Shape Monitor and Beam-Induced Fluorescence Monitor), Fermilab, J-PARC, ISIS, ESS and IFMIF were presented. All the speakers presented their approach to simulate various phenomena related to IPM physics. They can be classified as follows:

- Treatment of beam space-charge effect for electron signal (M. Sapinski, , C. Thomas, K. Sato)
- Treatment of beam space-charge for ion signal (R. Williamson, J. Marroncle, P. Forck)
- Treatment of highly non-uniform electric fields (R. Williamson)
- Beam space charge correction procedures (J. Marroncle, M. Sapinski)
- Simulation of electron trajectories for various field configurations (R. Thurman-Keup, K. Sato, C. Thomas)
- Simulations for beam shape monitor, BIF, laser wire monitor etc. (especially P. Forck and R. Thurman-Keup).

The codes are summarized in the Table 1.

Table 1: The list of IPM simulation codes together with the most important properties.

Code	implementation	tracking	benchmarks	remarks
GSI	C++	E, B	None.	Bugs in the code (to be corrected), uniform external fields. Tracking 3D.Need to correct relativisitic part. Add Gaussian space charge dstn.
pyECLOUD	python	E, B	c.f. SPS/LHC IPM data; Not conclusive.	Uniform ex fields, relativistic.
FNAL	matlab	E, B	None.	Free space boundary conditions. 3D tracking.
ESS	matlab	E, B	Started c.f. Kenichiro’s code.	Free space boundary conditions. 3D tracking.
CEA	C++	E, ions	Correction of beam profile; Nice results at 90keV.	Round DC beam. Lorentz solver for E-field.
ISIS	C++	E	Correction of beam profile; Good in range 70 MeV - 800	Assumes DC beam. Import CST electric fields.

			MeV; beam sizes & intensities.	
Kenichiro	python	E, B	c.f. pyECLOUD - good agreement.	Field maps (CST/poisson), relativisitc beam. 3D tracking. Will soon introduce analytical gaussian beam.

In addition the commercial codes, like CST Studio and COMSOL were discussed. The investigation on CST carried out a year ago has shown that this package program cannot be used for IPM simulation purposes because of lack of options to generate realistic initial electron distribution and lack of beam space charge effects. However this should be reevaluated with the new version of CST. COMSOL is being evaluated as well (see Task list)

Electron and ion tracking is a key part of the code. For the moment only FNAL and ESS codes contain tracking which takes into account all field components, however GSI and Kenichioro codes are aiming to provide the same in the near future.

Benchmarking the codes against each other and comparing them to experiments is considered by the workshop participants as one of the most important goals of the IPM simulation community. Some benchmarking has been done in the past (e.g. Kenichiro code against pyECLOUD results), some are ongoing (e.g. Kenichiro vs. ESS). It has been agreed that several beam parameter sets, typical for various machines will be selected for codes benchmarking. The results will be published on the project wiki.

Future developments

The plans for the near future are result of particular interests of the laboratories, the available manpower and state of advance of respective codes.

In general it can be concluded that:

1. FNAL and ISIS are satisfied with their codes however:
    a. ISIS code is limited to nonrelativistic beams.
2. ESS, GSI and Kenichiro plan to keep developing their codes in the near future.
3. ESS and FNAL codes are sets of matlab scripts; development of these scripts towards a common, general purpose code seems to be not practical.
4. Original purpose of the pyECLOUD code is investigation of electron cloud development, future development towards general IPM simulation program requires a lot of effort and program restructurization towards a code structure which is anyway similar to Kenichoro code, therefore the further development of this code is not planned.
5. A future development of Kenichro code will be supported by CERN and GSI, resources are discussed.

The main remarks concerning the new common code concern its modularisation, good definition of the interfaces between modules (so they could be easily exchanged), use of available modules in parallel on in place of current modules and need of a good communication between the developers (not only common wiki but future meetings).

Action list

At the end for the workshop a list of action has been commonly defined.

1. James:

- Setup project Wiki and Github spaces @ CERN.

- Follow-up COMSOL simulation from Chalmers University.

- Make LHC IPM data available on wiki.

- Investigate using ions for LHC IPM.

- Investigate possibility for TECH/DOCT student.

2. Mariusz (and Peter):

- Investigate double differential cross section for Kenichiro code (and other codes if needed).

- Measure profiles in SIS-18 for different beam currents, compare against codes.

- Involve Dominik Vilsmeier in the project at a working student in GSI.

- Investigate the possibility of future meeting at GSI (after summer, probably early October).

3. Kenichiro:

- Implement non-relativistic beam.

- Submit first version to Github asap.

- Benchmark.

4. Cyrile:

- Benchmarking.

- Requirements / specification for the ESS IPM.

5. Rob:

- Make IPM data available on wiki.

- Include chaneltron simulations.

6. Jacques (with a postdoc starting in April):

- Study space-charge effect

- Benchmarking.

7. Serban:

- Include relatavisitic effects in GSI code.

- Benchmarking.

- GUI (for GSI code)

8. Randy:

- Benchmarking.

9. Rahul:

- look at OpenFEM solvers.