BDSIM simulation model of ATF2 & Background Studies for the Vertical Collimator System

Anne Schütz ¹, S. Boogert ², L. Nevay ², J. Snuverink ², N. Fuster Martinez ³

ATF staff ⁴ & ATF2 collaboration, G. White ⁵

¹DESY, KIT ²RHUL ³IFIC ⁴KEK ⁵SLAC

March 14, 2017
Table of contents

1 BDSIM update
   • Thin Multipoles
   • Dipole Fringe Fields and Pole Face Rotation
   • Magnetic Fields outside the Tracking Volume
   • Matching Magnetic Poisson Fields to BDSIM Fields
   • Modelling the ATF2 Tunnel and outer volumes with PyGDML

2 Background studies for the Vertical Collimator System
   • Background Measurements at ATF2
   • BDSIM simulation of the Backgrounds at ATF2
   • Outlook
RHUL efforts for BDSIM and the ATF2 geometry model
Most recent BDSIM version: 0.95

Easy to install and run thanks to the detailed manual:

BDSIM is a MC simulation tool for simulations of particle accelerators:

- C++ program utilising the Geant4 toolkit
- simulating the transport of particles in an accelerator
- simulating the interaction of particles with the accelerator material
- simulating detector backgrounds from the beam halo and machine background sources
- Geant4 geometry dynamically and easily built

Example applications are background studies for ATF2, CLIC, LHC, ...
Ongoing development for:

- Thin magnets/multipoles (difficult in Geant4)
- Dipole fringe fields and pole face rotation
- Magnetic fields outside of tracking volume (beampipe)
- Matching Poisson fields to BDSIM fields
- Modelling the ATF2 Tunnel and outer volumes with PyGDML
BDSIM: Thin Multipoles

Thin Multipole momentum kick:\(^1\):

\[
P = \Delta K_0 L - K_0 L \frac{p_t}{\beta} + \sum_{n=1}^{\infty} K_n L \frac{(x + iy)^n}{n!}
\]

- \(x_2 = x_1, \quad p_{x2} = p_{x1} - \Re P\)
- \(y_2 = y_1, \quad p_{y2} = p_{y1} + \Im P\)

- \(K_n = \) multipole coefficients (normal and/or skewed).
- Built in BDSIM as 1 \(\mu\)m thick non-physical component.

Example thin multi-pole with quadrupolar component, between two drifts:

Horizontal focussing:

![Horizontal focussing diagram]

Vertical defocussing:

![Vertical defocussing diagram]

1: MAD 8 Manual (V8.13)., F. Iselin, 1994
BDSIM: Dipole Fringe Fields

Fringe field momentum kick
\[ x_2 = x_1, \quad p_{x2} = p_{x1} + \frac{1}{\rho} \tan \psi_i \]
\[ y_2 = y_1, \quad p_{y2} = p_{y1} - \frac{1}{\rho} \tan \psi_i \]
\[ \psi_i = E_i - \frac{g}{\rho} I_1 (1 + \sin^2 E_i) \]

- \( E_i \) = Poleface rotation angle,
- \( g \) = Dipole vertical gap,
- \( I_1 \) = Fringe field integral.

Built in BDSIM as 1 um thick non-physical magnet(s) at the entrance/exit polefaces.

Horizontal defocusing, vertical

1: MAD 8 Manual (V8.13), F. Iselin, 1994
BDSIM magnet elements (fields outside vacuum)

Generated from LANL Poisson Superfish file

Poisson also used for Numerical Solution of B field – Poisson solution is used as BDSIM input

Multipole strengths (k parameters) given as an input parameter for complete description.

\[
\frac{e}{cp} B_y = \kappa_x + kx + \frac{1}{2} mx^2 + \frac{1}{6} rx^3 + \frac{1}{24} dx^4 + ...
\]

\[
\frac{cp}{e} = |B| \rho
\]
Fitting Magnet Elements

- The strength of a magnet’s multipole effect on the beam related to Field Gradient of Magnet by Equation 2, where \( s_1 = \text{Quadrupole}, \ s_2 = \text{Sextupole} \) etc.

\[
s_n = \frac{e}{cp} \frac{\partial^{n-1} B_y}{\partial x^{n-1}} |_{x,y=0}
\]

- Field Gradient not taken as BDSIM input, but approximated from field-map using a 4-point central difference formula, the second (and higher) derivatives of the field being found by the same method in terms of lower order derivatives.

\[
f'(x) = \frac{f(x - 2h) + 8f(x + h) - 8f(x - h) - f(x + 2h)}{12h}
\]

\[
\frac{\partial^n f(x)}{\partial x^n} = \frac{\frac{\partial^{(n-1)} f(x-2h)}{\partial x^{(n-1)}} + 8 \frac{\partial^{(n-1)} f(x+h)}{\partial x^{(n-1)}} + 8 \frac{\partial^{(n-1)} f(x-h)}{\partial x^{(n-1)}} + \frac{\partial^{(n-1)} f(x+2h)}{\partial x^{(n-1)}}}{12h}
\]

- This gives the ratio between the strength of the BDSIM magnet and the strength of the map, allowing linear scaling to fit the map to the known magnet strength.
ATF2 Tunnel

- Programmatically generated in GDML format using the PYGDML module
- Realistic features, dimensions and materials
- Ready for loading in Geant4 and BDSIM
Background studies
for the Vertical Beam Halo Collimator
The Vertical Beam Halo Collimator and the RHUL Cherenkov detector

Diamond Sensor (DS)

IPBSM Background Monitor

Vertical Beam Halo Collimator

RHUL Cherenkov detector

Anne Schütz (DESY)  ILC & Background Simulations  March 14, 2017
Background Data taken with the RHUL Cherenkov detector

Symmetric jaw movement

Jaws moving separately

Background is reduced, but then rises again when collimator jaws are driven closer into the beam halo.

Individual jaw movement gives conflicting results.
The collimator was modelled with **PyGDML** according to the technical drawings provided by Nuria Fuster Martinez. Its jaws can be placed as desired. ⇒ Individual jaw movement is now possible!
First data to MC comparison is not satisfactory. More statistics of the MC is needed, and the ATF2 model in BDSIM needs to be reviewed.
Study of the ATF2 components producing secondary particles

Number of particles created in the components of the ATF2 beam line.
Study of the ATF2 components producing secondary particles

Number of Particles created in the ATF2 beam line components

- Open Vertical Collimator
- Closed Vertical Collimator
Study of the ATF2 components producing secondary particles
Study of the ATF2 components producing secondary particles

Number of Particles created in the ATF2 beam line components

- Open Vertical Collimator
- Closed Vertical Collimator
Study of the ATF2 components producing secondary particles

Number of Particles created in the ATF2 beam line components

- Open Vertical Collimator
- Closed Vertical Collimator
Study of the ATF2 components producing secondary particles, sampled in the Vertical Collimator

These components create particles hitting explicitly the Vertical Collimator:
Background studies for the Vertical Collimator System

BDSIM simulation of the Backgrounds at ATF2

Study of the ATF2 components producing secondary particles, sampled in the RHUL detector

These components create particles hitting the RHUL detector plane:
Study of the ATF2 components producing secondary particles, sampled in the IP

These components create particles that reach explicitly the IP:
BDSIM simulation: Outlook

Plans for further BDSIM simulations in collaboration with RHUL:

- Reviewing the BDSIM geometry model of ATF2
- More accurate Aperture Model of ATF2
- Put together all new component models for a more accurate ATF geometry model
- Improve the Vertical Collimator model
- Introduce beam bumps in simulation to study effect of beam orbit changes on background level at the RHUL cherenkov detector and the IP
- Change vacuum pressure in the simulation to also compare these data taken
Thank you very much!

どうもありがとうございます。