Coupling between FLUKA and BIG2

Workshop on coupling simulation of beam impact on accelerator components

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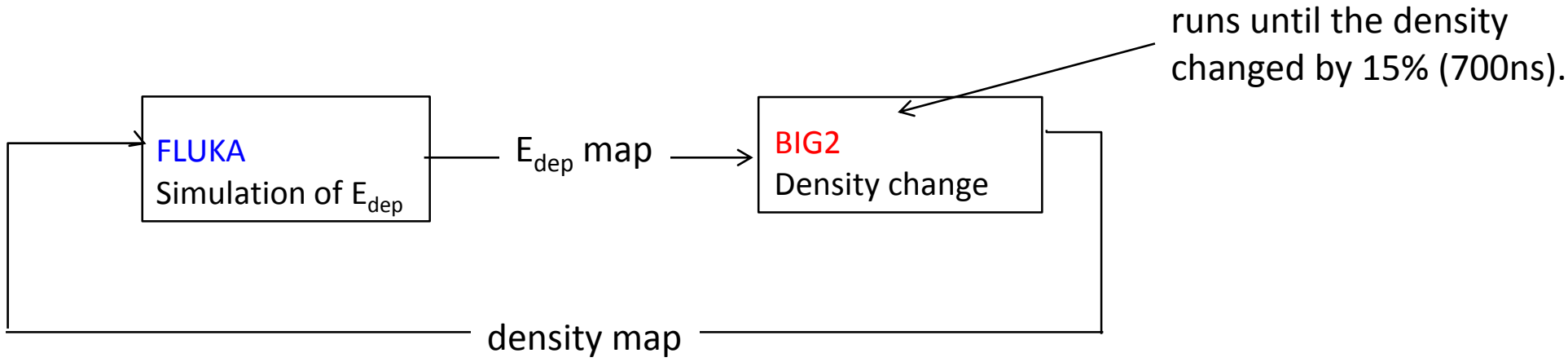
A bit of history:

- Before 2011: Collaboration between N. Tahir (GSI), R. Schmidt and Juan Sancho.
  - First LHC related simulations, first LPROT (HiRadMat - copper cylinder experiment) simulations
- 2011: I joint and Juan left the team.
  - LPROT simulations with real beam parameters and bunch / bunch train spacing.
  - First FCC graphite beam dump simulations
  - First FCC water beam dump simulation
- 2017: I left to DESY.

- Very fruitful collaboration: many journal papers (Physics of plasma, Journal of applied physics, Phys. Rev. E, High energy density physics, etc…) , 2 PhD theses.

Coupling between FLUKA and BIG2

- Alternating simulation with FLUKA and BIG2 (N. Tahir, GSI).
- Energy deposition of 440 GeV protons in the target is calculated using FLUKA code.
- Energy deposition data is used as input to a two–dimensional hydrodynamic code BIG2, to study the thermodynamic and the hydrodynamic response of the target due to the beam impact.
- Density distribution from BIG2 used as input for next FLUKA iteration.



General routine:

1. FLUKA simulation with the required beam and material paramters.
2. Get out an Energy deposition (GeV/cm^3/p)
3. Data – Ordering with MATLAB script.
4. Energy deposition map to N. Tahir
5. BIG2 is running until density change ~ 15%, otherwise unrealistic fluctuations.
6. Density map.
7. Translation into FLUKA input file via python script.
8. Start new FLUKA simulation.
9. … repeat until density decrease moves with constant speed
10. Extrapolation to final number of bunches.

3.) Data-ordering (MATLAB), BIG2 needs a special data format

Header: Size of target and number of bins, etc.

Energy deposition (GeV/g)

```
1
        "R - Z     binning n.   1  ""EdepGr    "" , generalized particle n. 208"
        R coordinate: from  0.0000E+00 to 7.000E+00 cm,  350 bins   ( 2.0000E- 02 cm wide)
        Z coordinate: from  0.0000E+00 to  1.4000E+03 cm,  560 bins   ( 2.5000E- 00 cm wide)
        axis coordinates: X = 0.0000E+00, Y =  0.0000E+00 cm
        Data follow in a matrix A(ir,iz), format (1(5x,1p,10(1x,e11.4)))

        accurate deposition along the tracks requested
2.5471E-01      2.0675E-01      1.3380E-01      6.8181E-02      2.8234E-02      1.1280E-02      4.6450E-03      2.6108E-03      1.7670E-03      1.3482E-03
1.0508E-03      8.8951E-04      7.3969E-04      6.3844E-04      5.4122E-04      5.0386E-04      4.1847E-04      3.8356E-04      3.4276E-04      2.9804E-04
2.8488E-04      2.4899E-04      2.1640E-04      1.9751E-04      1.8941E-04      1.7323E-04      1.6265E-04      1.4157E-04      1.4181E-04      1.2728E-04
1.2089E-04      1.1155E-04      1.0191E-04      9.7171E-05                                                                      7.2212E-05      6.8329E-05
6.5626E-05      6.2544E-05      6.0172E-05      5.9711E-05                                                                      4.6380E-05      4.6545E-05
4.2034E-05      3.9401E-05      3.9810E-05      3.7226E-05                                                                      3.3508E-05      3.2471E-05
3.3768E-05      3.2181E-05      2.8246E-05      2.8676E-05                                                                      2.3800E-05      2.2380E-05
2.1696E-05      2.2593E-05      2.3818E-05      2.1824E-05                                                                      1.9931E-05      1.9082E-05
2.1592E-05      2.0252E-05      1.7221E-05      1.7888E-05      1.7436E-05      1.6936E-05      1.8236E-05      1.8319E-05      1.7373E-05      1.7817E-05
1.6226E-05      1.5769E-05      1.4236E-05      1.3762E-05      1.4343E-05      1.3806E-05      1.3537E-05      1.3483E-05      1.2465E-05      1.2398E-05
1.3554E-05      1.2178E-05      1.2167E-05      1.1776E-05      1.2216E-05      1.3085E-05      1.2098E-05      1.1895E-05      1.0914E-05      1.1916E-05
1.1660E-05      1.1858E-05      1.1498E-05      1.1307E-05      1.2206E-05      1.1197E-05      1.1630E-05      1.0860E-05      1.0064E-05      1.0410E-05
9.6871E-06      1.0607E-05      9.7266E-06      1.0609E-05      9.9209E-06      9.8223E-06      8.9810E-06      8.9842E-06      8.7194E-06      8.9270E-06
8.2834E-06      8.3089E-06      8.4663E-06      8.6177E-06      8.9874E-06      8.1413E-06      8.8965E-06      8.0455E-06      7.8210E-06      7.3202E-06
7.6624E-06      7.8363E-06      7.9165E-06      8.1760E-06      7.7279E-06      7.3262E-06      7.2527E-06      6.9414E-06      7.4218E-06      7.2582E-06
```

MATLAB script

From FLUKA

Energy deposition

```
%for FCC Water


Table_corr=data(1:196560,3);
%%

for i=1:560 %radial
i = i*350; %1.Spalte
Table_corr(i,:)=[];
end
%%

Table0=reshape(Table_corr, [10,19600]);
Table_1=transpose(Table0);
%%
dlmwrite('FCCwater1300ns.txt',Table_1,'delimiter', '\t');
```

Re-ordering

BIG2

7) Translation into FLUKA input file (1/2) - MATLAB

During the water simulations, we had some artifacts from previous simulation in the density map from BIG2 (empty regions, first third of the target in the second third of the data set) → re-ordering with MATLAB

```
ddist=(d1300ns(56001:end,1:3)); %Copper weg

%% Regionen oberhalb R =7cm weg
for i=1:560;
ddist(i*751-((i-1)*400):(((i*751)+398)-((i-1)*400)),:)=[];
end

%% 1. Region oberhalb von R = 7 cm weg
ddist(1:399,:)=[];

%check
plot(ddist(:,2),'x')

%%
min_700 = min(ddist(:,3))
max_700 = max(ddist(:,3))
%%
```

```
%view(3)
%%
%%re-order Data
for i=1:351;
 density{i}=ddist(i:351:end,:);
end
%%

V=cell2mat((fliplr(density)));
 x=V(:,1:3:end);
s1=reshape(x,[196560,1]);
```

7) Translation into FLUKA input file (2/2) – python (~ 800 lines of code)

```
inp_file = density.txt
template_inp = Cylinder_template_new.inp
outputfile = Cutarget.inp
config_file = rhomap_conf_Copper02mm.cfg
outputfilemerge = CutargetMerge.inp

[target]
a = 63.546
rmin = 0.0
zmax = 150.0
rbins = 400.
zmin = 0.0
material = COPPER
rmax = 4.0
zbins = 1000.
rho = 8.96
z = 29.0

[algorithm]
maxreg = 100
regthreshold = 0.01
numparticles = 2000.0
maxregsize = 700

[rhomap_format]
Nz = 374
Nr = 2000
NumberRegions = 3
RegionOrder = [2,1,3]
NzR = [12,62,300]
NrR = [2000,2000,2000]
NzbR = [0.0417,0.0403,0.04]
NrbR = [1,1,1]

[beam]
energy = 440.0
fwhmy = .471
distribution = gaussian
particle = PROTON
```

Density map after Matlab

Target Parameters

Region threshold and number of regions

Binning of density map

Beam parameters

Region definition in FLUKA

```
BLKHOLE      5  +SPHBLK -SPHVAC
SURVAC       5  +SPHVAC -( +CILZ043 +PLAZ008 -PLAZ000 )
REG00001     5 +CILZ001 +PLAZ001 -PLAZ000
REG00002     5 +CILZ001 +PLAZ002 -PLAZ001
REG00003     5 +CILZ001 +PLAZ003 -PLAZ002
REG00004     5 +CILZ001 +PLAZ004 -PLAZ003
REG00005     5 +CILZ001 +PLAZ005 -PLAZ004
REG00006     5 +CILZ001 +PLAZ006 -PLAZ005
REG00007     5 +CILZ001 +PLAZ007 -PLAZ006
REG00008     5 +CILZ001 +PLAZ008 -PLAZ007
REG00009     5 +CILZ002 -CILZ001 +PLAZ001 -PLAZ000
REG00010     5 +CILZ002 -CILZ001 +PLAZ002 -PLAZ001
REG00011     5 +CILZ002 -CILZ001 +PLAZ003 -PLAZ002
REG00012     5 +CILZ002 -CILZ001 +PLAZ004 -PLAZ003
REG00013     5 +CILZ002 -CILZ001 +PLAZ005 -PLAZ004
REG00014     5 +CILZ002 -CILZ001 +PLAZ006 -PLAZ005
REG00015     5 +CILZ002 -CILZ001 +PLAZ007 -PLAZ006
REG00016     5 +CILZ002 -CILZ001 +PLAZ008 -PLAZ007
REG00017     5 +CILZ003 -CILZ002 +PLAZ001 -PLAZ000
REG00018     5 +CILZ003 -CILZ002 +PLAZ002 -PLAZ001
REG00019     5 +CILZ003 -CILZ002 +PLAZ003 -PLAZ002
REG00020     5 +CILZ003 -CILZ002 +PLAZ004 -PLAZ003
REG00021     5 +CILZ003 -CILZ002 +PLAZ005 -PLAZ004
REG00022     5 +CILZ003 -CILZ002 +PLAZ006 -PLAZ005
REG00023     5 +CILZ003 -CILZ002 +PLAZ007 -PLAZ006
REG00024     5 +CILZ003 -CILZ002 +PLAZ008 -PLAZ007
REG00025     5 +CILZ004 -CILZ003 +PLAZ001 -PLAZ000
REG00026     5 +CILZ004 -CILZ003 +PLAZ002 -PLAZ001
REG00027     5 +CILZ004 -CILZ003 +PLAZ003 -PLAZ002
REG00028     5 +CILZ004 -CILZ003 +PLAZ004 -PLAZ003
REG00029     5 +CILZ004 -CILZ003 +PLAZ005 -PLAZ004
REG00030     5 +CILZ004 -CILZ003 +PLAZ006 -PLAZ005
REG00031     5 +CILZ004 -CILZ003 +PLAZ007 -PLAZ006
REG00032     5 +CILZ004 -CILZ003 +PLAZ008 -PLAZ007
REG00033     5 +CILZ005 -CILZ004 +PLAZ001 -PLAZ000
REG00034     5 +CILZ005 -CILZ004 +PLAZ002 -PLAZ001
REG00035     5 +CILZ005 -CILZ004 +PLAZ003 -PLAZ002
REG00036     5 +CILZ005 -CILZ004 +PLAZ004 -PLAZ003
REG00037     5 +CILZ005 -CILZ004 +PLAZ005 -PLAZ004
REG00038     5 +CILZ005 -CILZ004 +PLAZ006 -PLAZ005
REG00039     5 +CILZ005 -CILZ004 +PLAZ007 -PLAZ006
REG00040     5 +CILZ005 -CILZ004 +PLAZ008 -PLAZ007
REG00041     5 +CILZ006 -CILZ005 +PLAZ001 -PLAZ000
REG00042     5 +CILZ006 -CILZ005 +PLAZ002 -PLAZ001
REG00043     5 +CILZ006 -CILZ005 +PLAZ003 -PLAZ002
REG00044     5 +CILZ006 -CILZ005 +PLAZ004 -PLAZ003
```

Some comments:

- Setting up the right FLUKA binning parameters (balance between simulation time and precision) and routine for a new simulation takes time (~ 1 - 1.5 month).
- FLUKA (~1 week) and BIG2 (couple of days) simulations need time.
- Data manipulation in between FLUKA and BIG2 can be done within 2 h.