Radiation dose in the PS dipoles

Status Report

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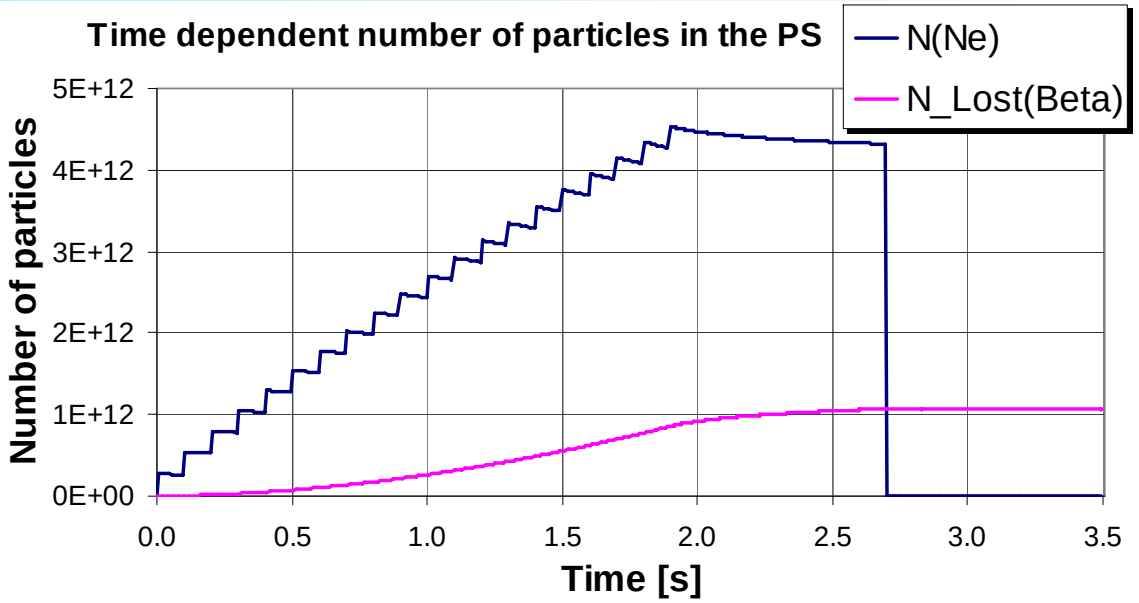
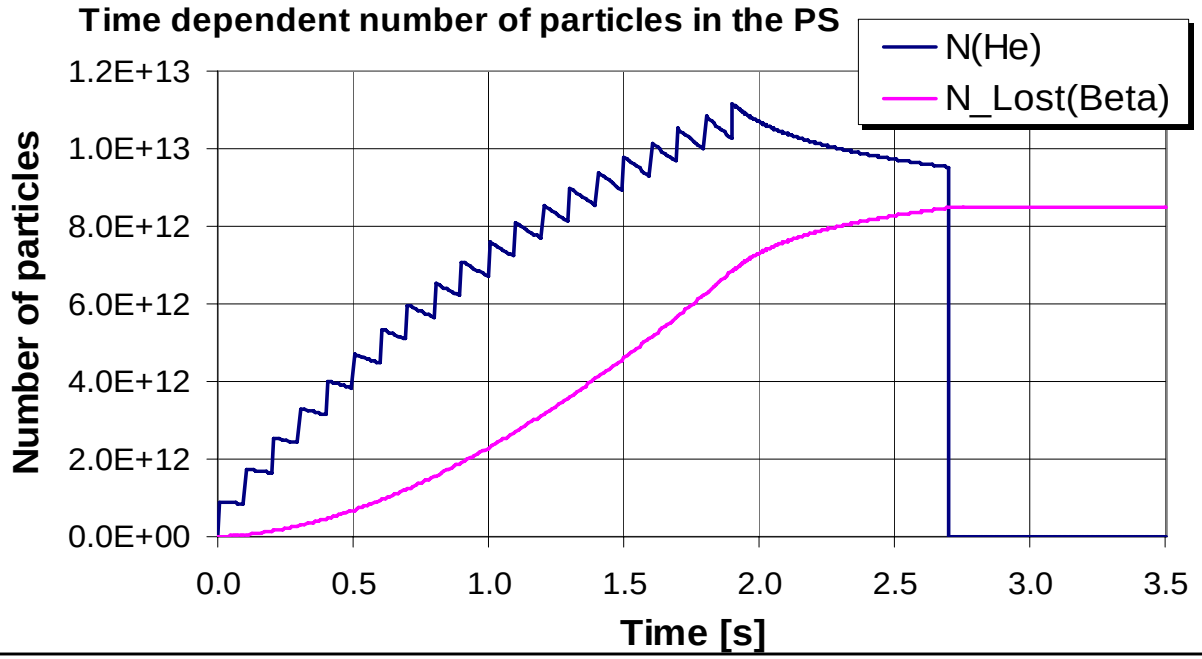
Contents

- Review of Beam Losses
- Simulation Components, Geometry & Materials
- Stopping Ranges & Dose Patterns
- Summary & Outlook

Intensity during Machine Cycle

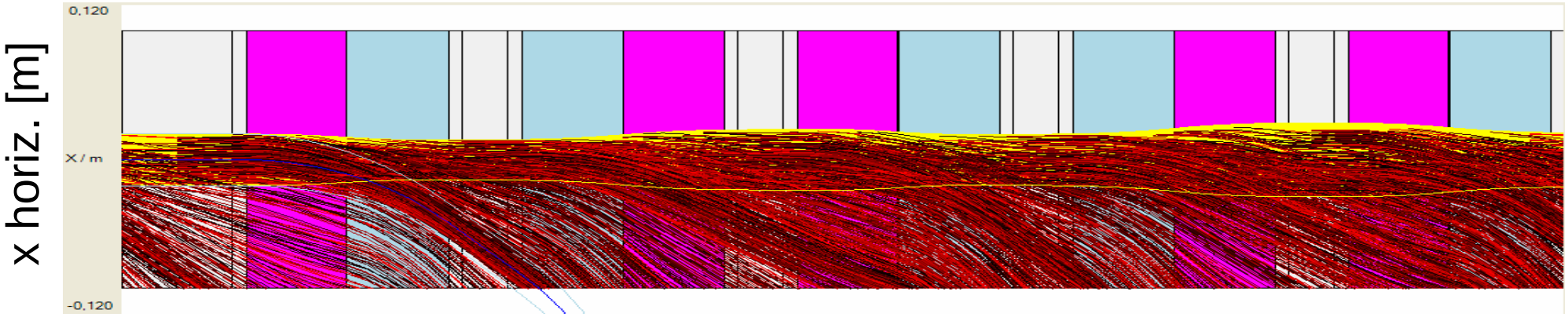




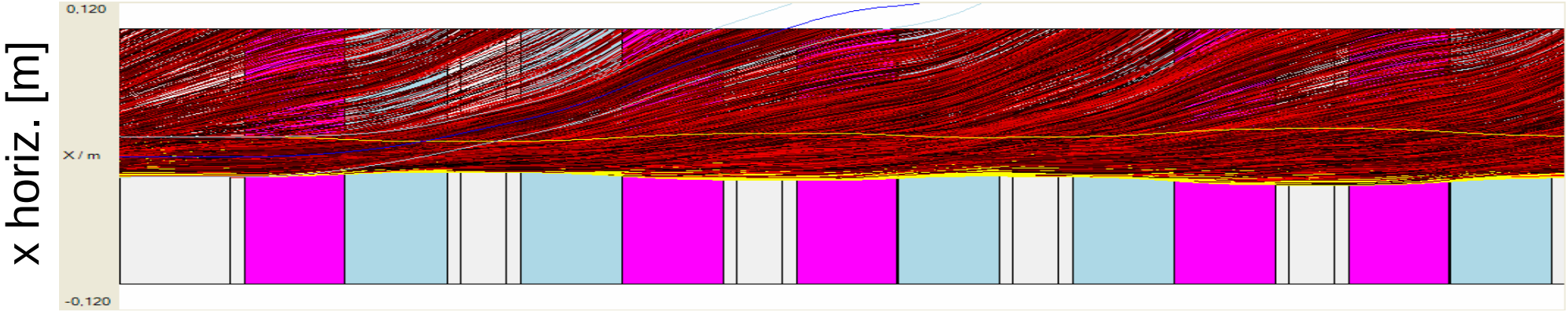
Decay Product Trajectories

Beta Beams in EURISOL

He_β beam: $^{6}Li^{3+}$



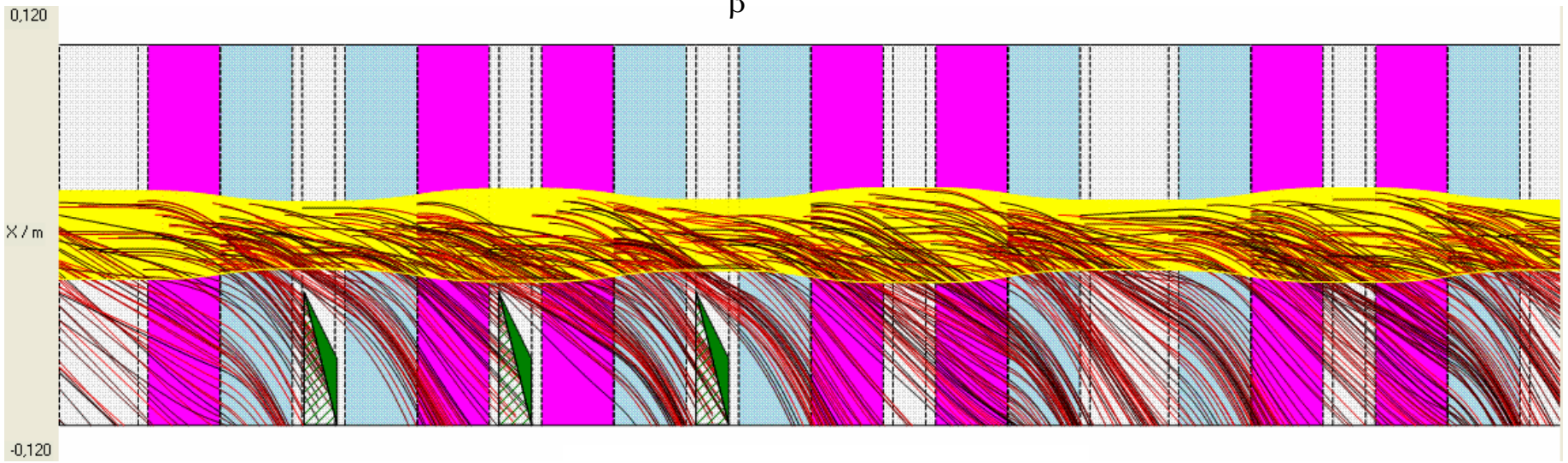
Ne_β beam: $^{18}F^{9+}$



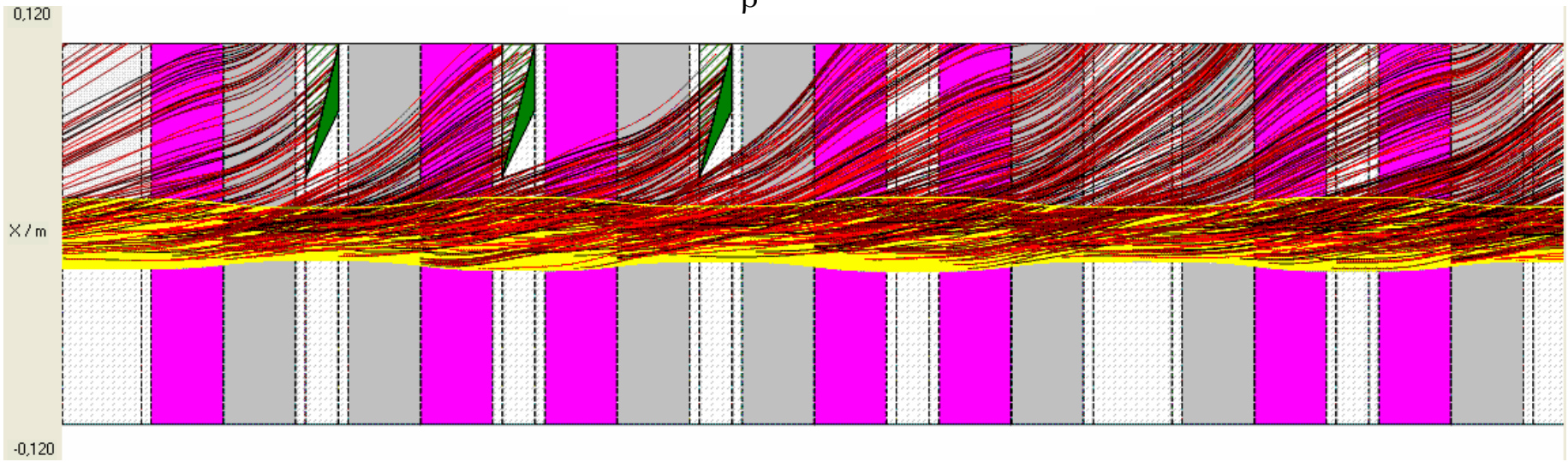
Decay Trajectories with Collimation

Beta Beams in EURISOL

He_β beam



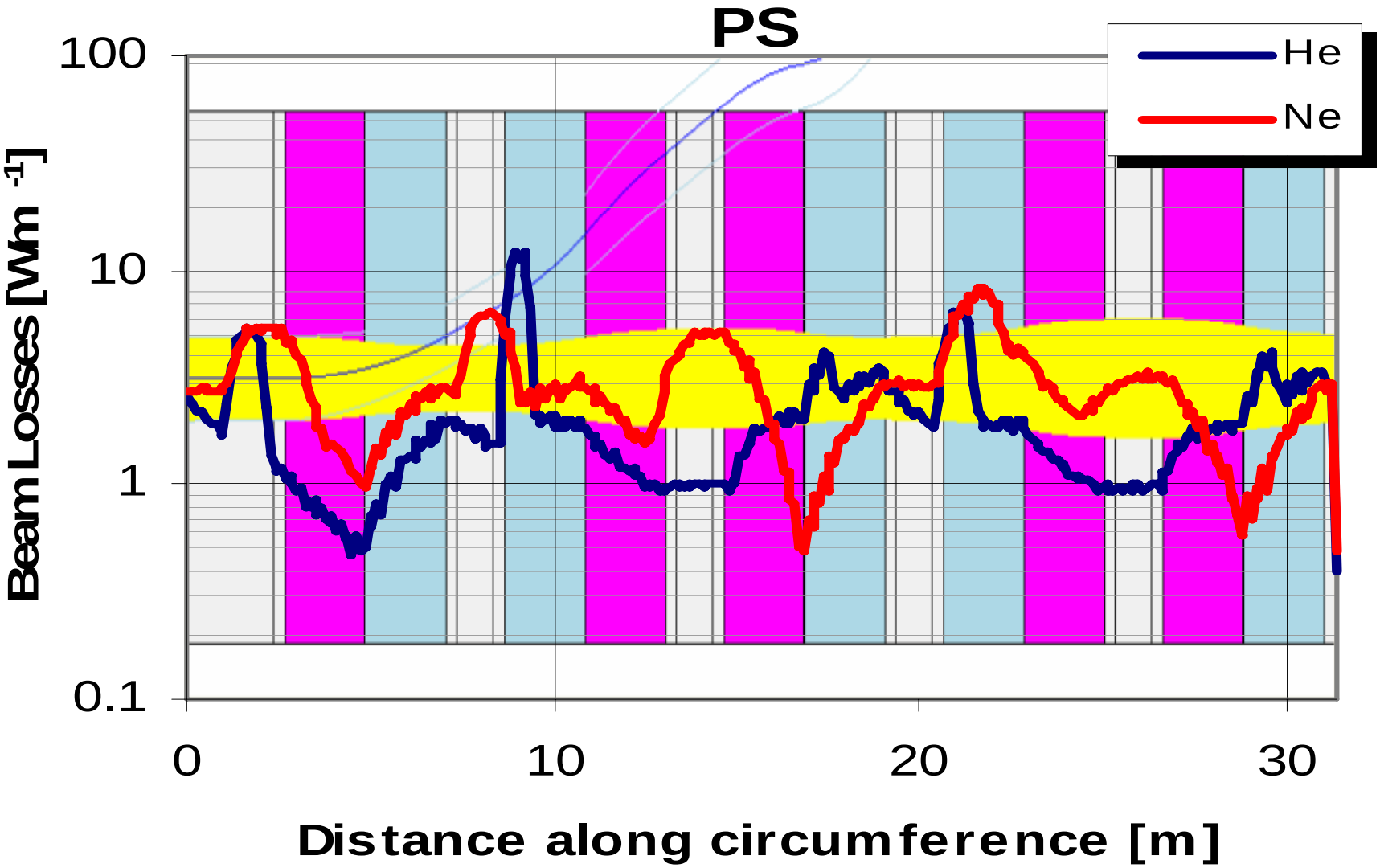
Ne_β beam



Loss Distribution

Beta Beams in EURISOL

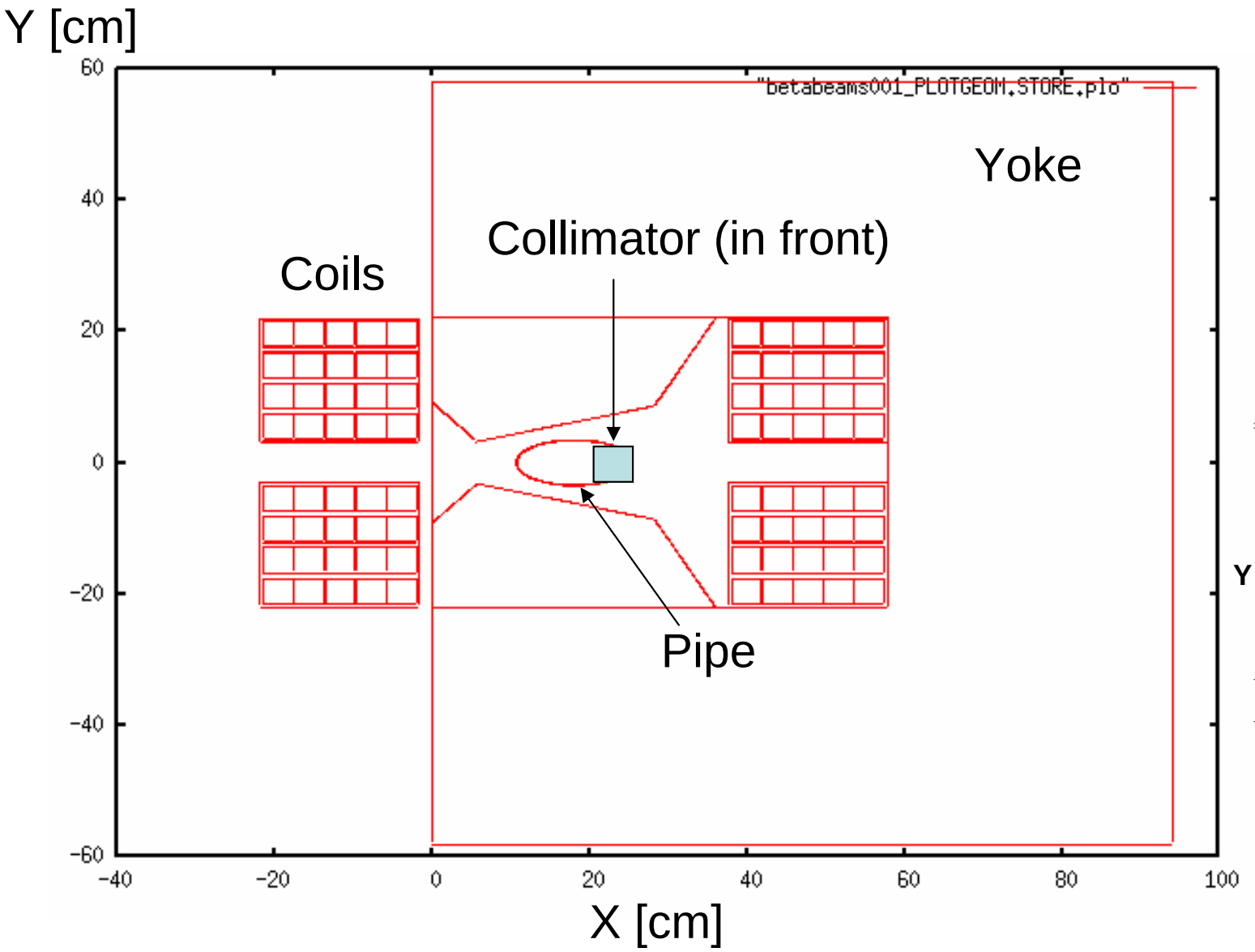
Beam loss power per unit circumference averaged over machine cycle

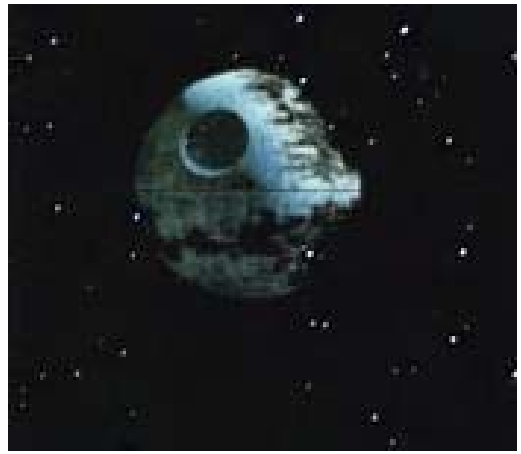


Magnet Geometry

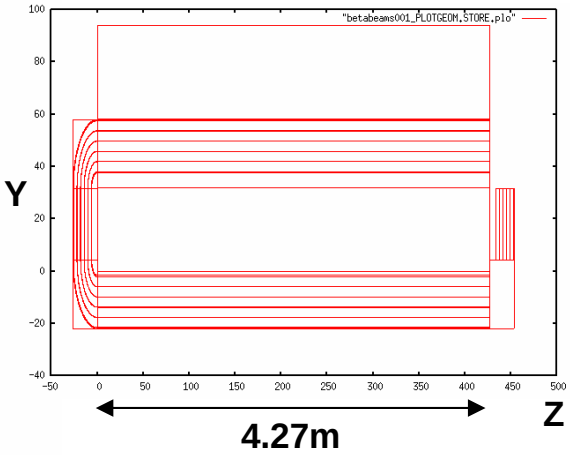
Beta Beams in EURISOL

FLUKA Geometry: PS combined function magnet





Horizontal slice through coils around upper pole (below)

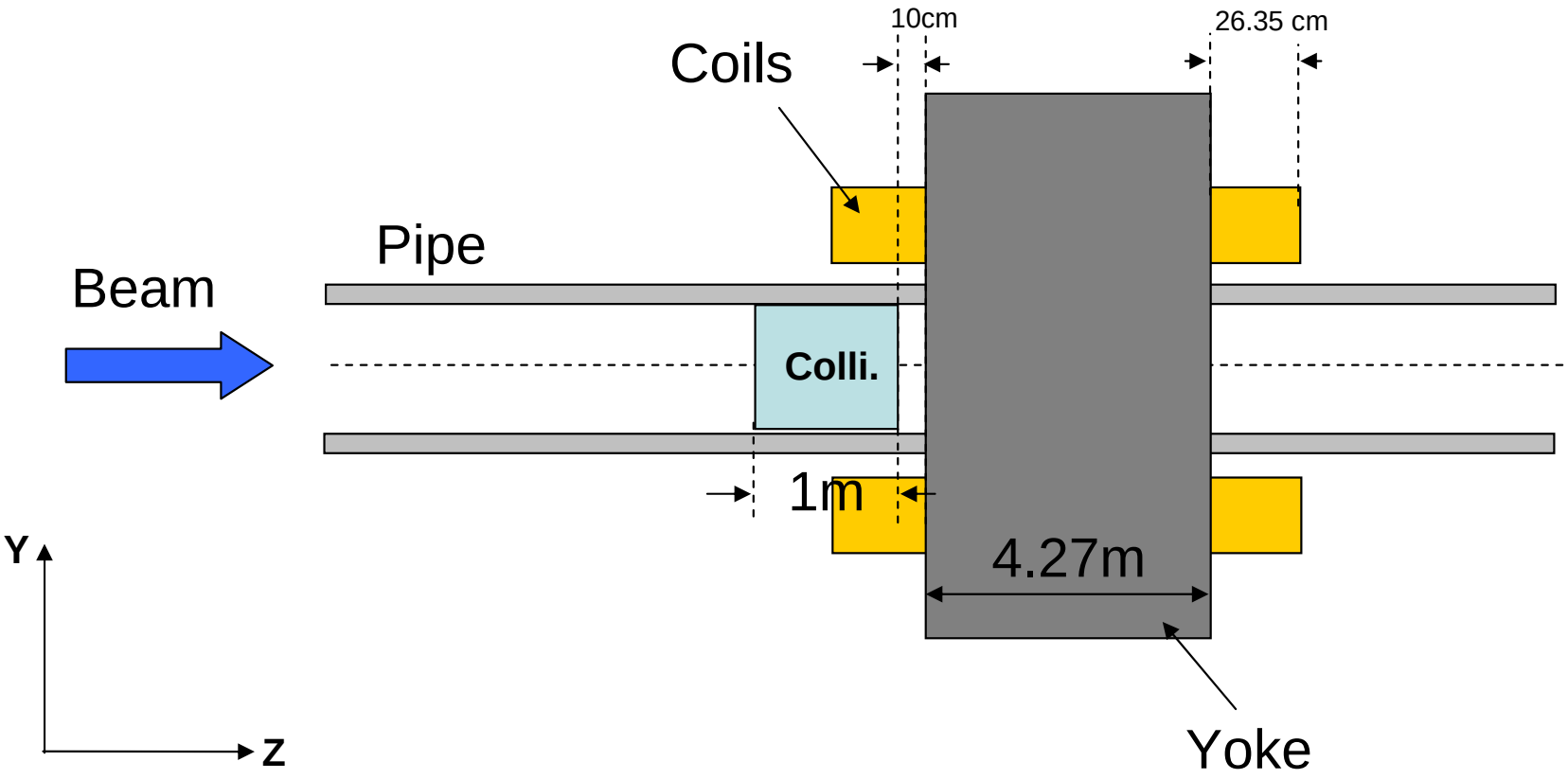


Whole Geometry

Beta Beams in EURISOL

FLUKA geometry: projection of beamline section around magnet

Initial beam distribution generated by StrahlSim (Omet)



Components

FLUKA geometry: main components

Coils:

- 2 pancakes coils per pole (copper)
- Holes in copper through which water flows
- Insulation: Epoxy Fibreglass (100% glass assumed)

Yoke:

- Iron
- Length 42.7 cm = (41.7+1)x10 such blocks (curvature neglected)
- Shape of poles approximated with flat surfaces

Beampipe:

- Stainless Steel
- Elliptical
- Outer dimensions: horiz. Rx=7.4cm, vert. Ry=3.5cm (0.1cm thick)

Insulation around the Coils

FLUKA materials

Coil insulation: Epoxy fibre glass resin (4mm thick)

Mainly consists of glass type E (80%). 100% assumed in model.

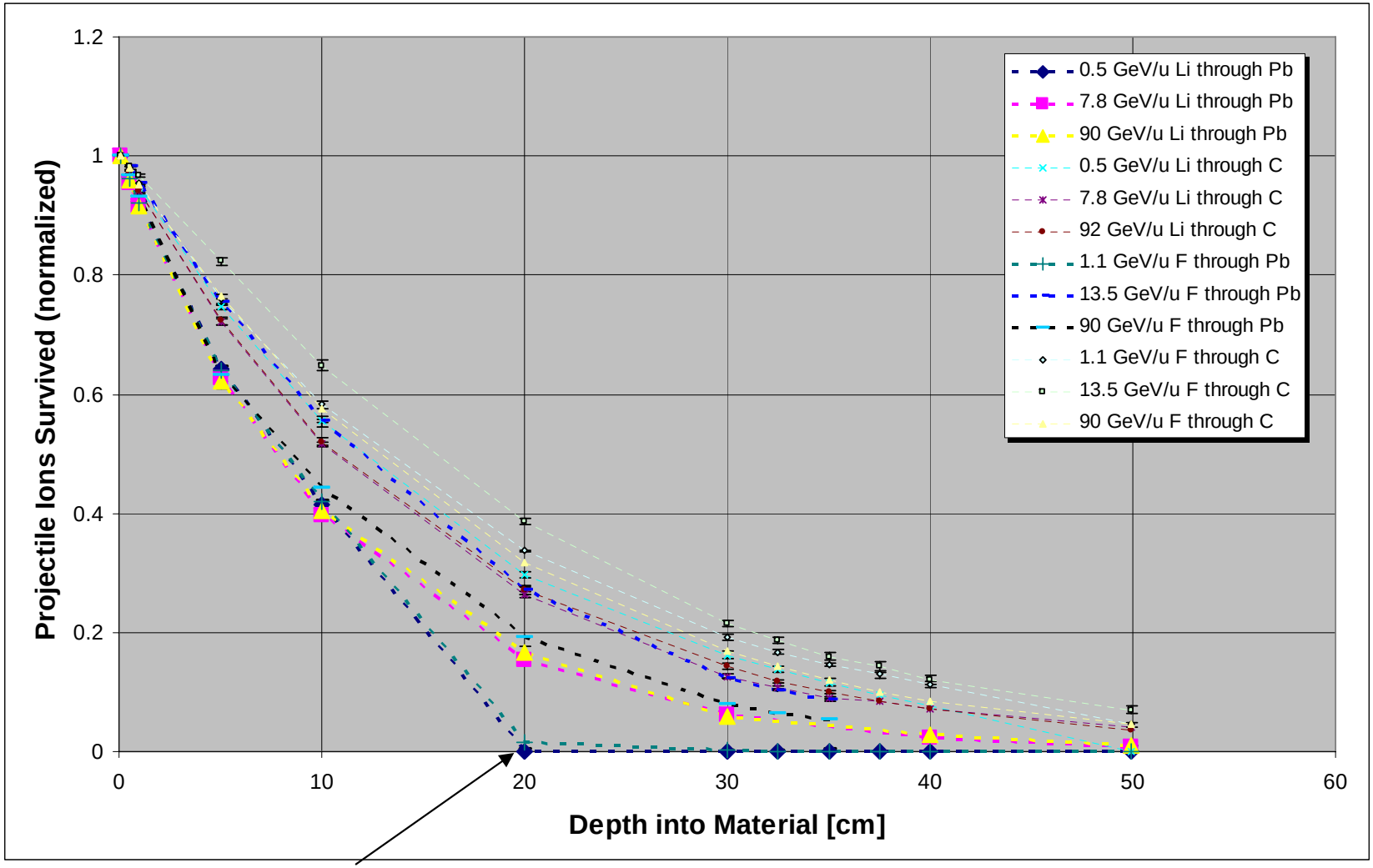
	Fraction of mass
SiO_2	**52-56 %**
Alkaline Oxides	0-2 %
CaO	**16-25 %**
MgO	**0-5%**
B_2O_3	**5-10%**
Al_2O3	**12-16%**
TiO_2	0-0.8%
Fe_2O_3	0.05-0.4%
F_2	0-1%

Projectile Ranges in Targets

Beta Beams in EURISOL

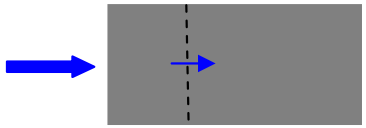
Plausible collimator dimensions: Block (X,Y,Z)=(16,20,50)cm

Transport with FLUKA code: Pencil beam along Z and orthogonal to block.



Cut-off in the tracking?

One way scoring:
heavy ions across boundary



Dose Distribution in Dipoles

Beta Beams in EURISOL

Z Colour: Dose [Gy/cm^3 per incident $^6Li^{3+}$]

X and Y [cm]

Test pencil beam directed normal to front face of magnet Hitting in region of black spot (picture).

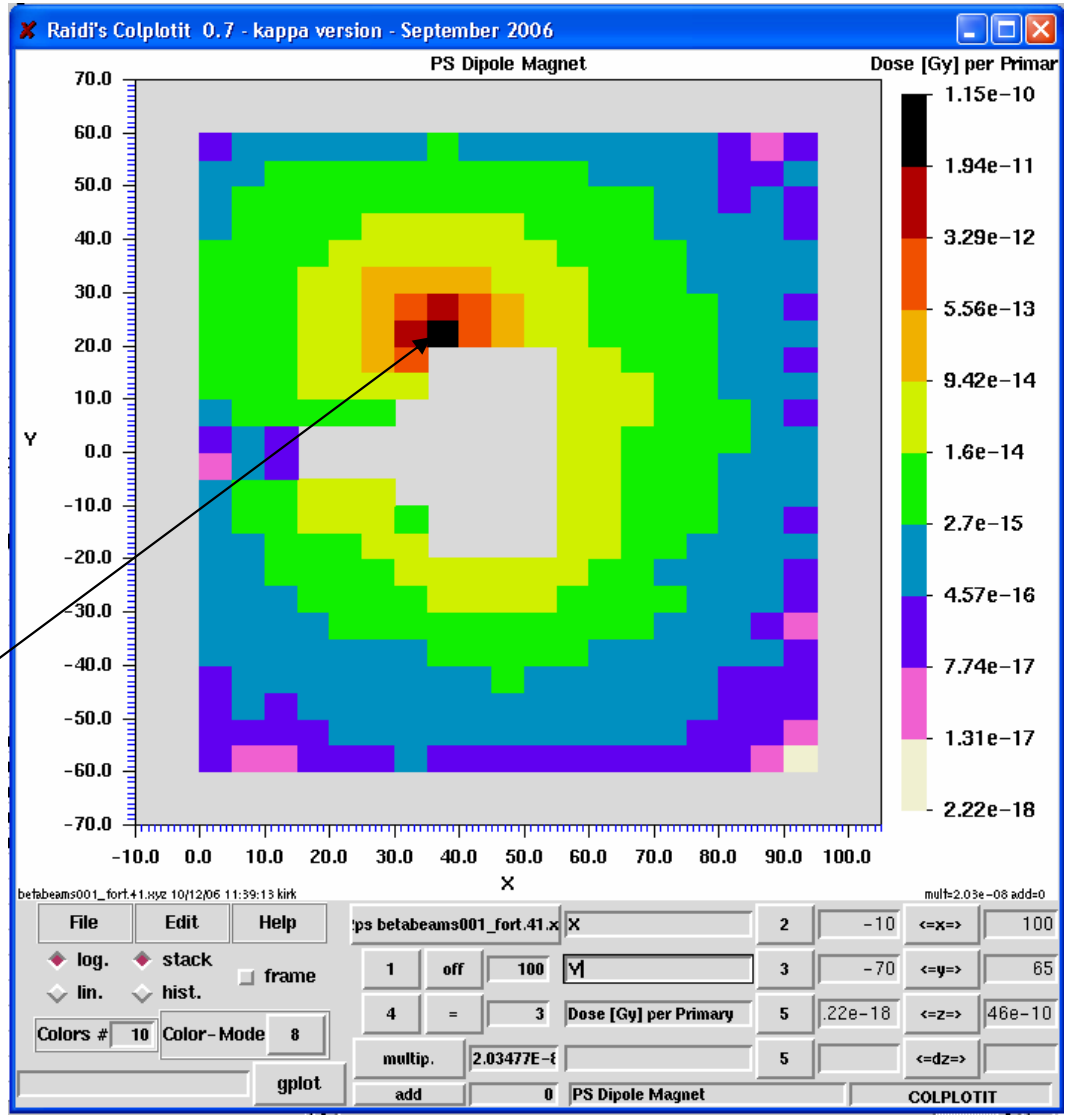
Slice shown to the right was taken at a depth of 3cm into magnet.

Time taken for impact region to reach 10 MGy is ~3.5 years.

Worst case!

Average dose over whole yoke

→ ~50 years.



Summary

- A worst case estimate for the degradation of the magnetic field due to radiation is ~3.5 years for continual He operation at 1 GeV/u. Nominal "lifetime" 10 MGy
- This worst case occurs if all beta decay daughters hit a point on the Yoke of a single magnet.
- However, if one considers the total dose in the Fe yoke then one gets an estimate of ~50 years instead.

Outlook

- Track primaries with plausible initial beam distribution through the complete environment. Viz., collimator beampipe, Magnet Yoke & coils.
- Track for bottom, top, and mean beam energy during the cycle. FLUKA can't change primary energy with time.
- Other than dose, more detailed activation studies still to be done.
- Eventual change to using C++ library is envisaged. Next 2 slides…

Alternative Interface to FLUKA

Beta Beams in EURISOL

An alternative approach to FLUKA functionality via a C++ library

ROOT Macro to Define Materials and Geometry

```
//--- define some materials
   TGeoMaterial *matVacuum = new TGeoMaterial("Vacuum", 0,0,0)
   TGeoMaterial *matAl = new TGeoMaterial("Al", 26.98,13,2.7);
 //--- define some media
   TGeoMedium *Vacuum = new TGeoMedium("Vacuum",1, matVacuum)
   TGeoMedium *Al = new TGeoMedium("Root Material",2, matAl);
```

```
// Define the geometry using TGeo Class
 TGeoVolume *cave = geom->MakeBox("cave", Vacuum, 25., 25., 5.);
    cave->SetVisibility(kFALSE);
  TGeoVolume *pipe = geom->MakeBox("pipe", Al, 5., 20., 5.)
   pipe->SetLineColor(kBlue);
  Top->AddNode(pipe, 1, cave);
  TGeoVolume *pipe_vac = geom->MakeBox("pipe_vac", Al, 17.5, 5., 5.);
   pipe_vac->SetLineColor(kBlue);
   Top->AddNode(pipe_vac, 1, pipe);
```

```
********** MATERIALS **********
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7...
MATERIAL         1.0     1.008 9.990e-01       3.0                HYDROGEN
MATERIAL         6.0    12.011 9.990e-01       4.0                CARBON
MATERIAL         9.0    18.998 9.990e-01       5.0                FLUORINE
MATERIAL        13.0    26.982 9.990e-01       6.0                ALUMINUM
MATERIAL        14.0    28.085 9.990e-01       7.0                SILICON
MATERIAL        26.0    55.845 9.990e-01       8.0                IRON
MATERIAL        79.0   196.967 9.990e-01       9.0                GOLD
MATERIAL                       3.750e-03       10.0               AIR
COMPOUND   -0.235407       4.0 -0.019758       3.0 -0.744835       5.0AIR
```

```
********** TGEO MATERIAL ASSIGNMENTS **********
*
*...+....1....+....2....+....3....+....4....+....5....+....6....+....7...
* Assigning material:   air   to Volume: cave
ASSIGNMAT      10.0       1.0       0.0       0.0       0.0       0.0
* Assigning material:   carbon   to Volume: pipe1
ASSIGNMAT      11.0       2.0       0.0       0.0       1.0       0.0
* Assigning material:   vacuum   to Volume: pipevac1
ASSIGNMAT       2.0       3.0       0.0       0.0       1.0       0.0
```

GSI

Courtesy D. Bertini, GSI

Alternative Interface to FLUKA

Beta Beams in EURISOL

ROOT Macro for Fluka Physics process control

```
void Config()
        {
         // Set Random Number seed
         gRandom->SetSeed(12345);
        TFluka * gMC =   new  TFluka("C++ Interface to Fluka", 0);
         // Physics process control

         gMC->SetProcess("DCAY",1);
         gMC->SetProcess("PAIR",1);
         gMC->SetProcess("COMP",1);
         gMC->SetProcess("PHOT",1);
         gMC->SetProcess("PFIS",0);
         gMC->SetProcess("DRAY",1);
         gMC->SetProcess("ANNI",1);
         gMC->SetProcess("BREM",1);
         gMC->SetProcess("MUNU",1);
         gMC->SetProcess("CKOV",1);
         gMC->SetProcess("HADR",1);
         gMC->SetProcess("LOSS",2);
         gMC->SetProcess("MULS",1);
         gMC->SetProcess("RAYL",1);

         Float_t cut = 1.e-3;        // 1MeV cut by default
         Float_t tofmax = 1.e10;

         gMC->SetCut("CUTGAM", cut);
         gMC->SetCut("CUTELE", cut);
         gMC->SetCut("CUTNEU", cut);
         gMC->SetCut("CUTHAD", cut);
         gMC->SetCut("CUTMUO", cut);
         gMC->SetCut("BCUTE",  cut);
         gMC->SetCut("BCUTM",  cut);
         gMC->SetCut("DCUTE",  cut);
         gMC->SetCut("DCUTM",  cut);
         gMC->SetCut("PPCUTM", cut);
         gMC->SetCut("TOFMAX", tofmax);
```

Fluka input file

```
*Global process and cut settings
         *
         * --- DCAY --- Decays. Flag =     1
         * Decays are on by default
         *
         * --- PAIR --- Pair production by gammas, muons and hadrons. Flag =     1,
         PPCUTM =         0.001, PPCUTE =         0.001
         EMFCUT          0.0       0.0         0       3.0      15.0       1.0PHOT-THR
         *
         * +++ BREM --- Bremsstrahlung by muons/hadrons. Flag =    -1, BCUTM =
         0.001
         PAIRBREM        3.0         0     0.001       3.0      15.0
         *
         * --- COMP --- Compton scattering  Flag =     1
         EMFCUT          0.0       0.0       0.0       3.0      15.0       1.0PHOT-THR
         *
         * --- PHOT --- Photoelectric effect. Flag =     1
         EMFCUT           0         0         0       3.0      15.0       1.0PHOT-THR
         *
         * --- PFIS --- Photonuclear interaction  Flag =     0
         PHOTONUC        -1.0       0.0       0.0       3.0      15.0       1.0
         *
         * --- ANNI --- Positron annihilation. Flag =     1
         EMFCUT          0.0       0.0       0.0       3.0      15.0       1.0ANNH-THR
         *
         * --- MUNU --- Muon nuclear interaction. Flag =     1
         MUPHOTON         1.0     0.250     0.750       3.0      15.0       1.0
         *
         * --- HADR --- Hadronic interactions. Flag =     1
         *
         *Hadronic interaction is ON by default in FLUKA
         *
         * --- MULS --- Muliple Scattering. Flag =     1
         *
         *Multiple scattering is  ON by default in FLUKA
         *
         * --- RAYL --- Rayleigh Scattering. Flag =     1
         *
```

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Courtesy D. Bertini, GSI