

The ROOT file of Simulation Output: a short How-To

Milano & Roma 1

Introduction

This (very) short tutorial is meant to explain how to use the MC data output produced for FOOT. The main topics are:

- The structure of the root data produced by MC
- A skeleton code/macro to perform a minimal analysis on MC data: AnaFOOT.h, AnaFOOT.cpp (more professional and complete code to be developed within the general framework software)
- Give some basic infos specific of MC simulation (FLUKA) that everybody needs to know

The setup in simulation (at this time)



The setup in simulation (at this time)



The B-field map for tracking



Example of one interesting fragmentation event in the target





Building our taylored MC Output

We have configured some user routines of FLUKA to produce an "ad hoc" event-by-event output written as an ASCII file (*TXT.dat)

Those ASCII files contain information about all the particles and interaction simulated. A simple and portable code reads these txt's and outputs ROOT files



The first goal of this meeting is to start to get familiar with the Tree structure of our output. A simple macro will be used to perform some exercises

The second goal is to allow people to start working seriously on event reconstruction by means of the proposed framework software for both real and simulated data

Example prepared for this meeting

Root file: FOOT_EMFon*.root **500K events of** ¹⁶O on C₂H₄ target (only events with inelastic interaction in the target where written on output, for compactness)

Simple macro for root: **AnaFOOT** (compiled)

A few things specific of FLUKA MC that are useful to know

Default units

the most important are: time \rightarrow s, length \rightarrow cm, energy \rightarrow GeV, masses \rightarrow GeV/c²

- Reference frame: (cartesian, right-handed) z is primary beam direction
- y is pointing upwards



Particles:

each particle is identified by a number

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Quick launch: Download Mailing list Manual Online Courses Flair Contact us <u>Last version:</u> FLUKA 2011.2c.4, April 17th 2016 (last respin) flair-2.2-3 20-Sep-2016 <u>News:</u> <u>Next Course</u> (<i>17.06.2016</i>) The 18th FLUKA Beginners Course will be held at the Shanghai Proton and Heavy-lon Center (SPHIC), China, on Nov 21-25, 2016.	A A A FLUKA On FLUKA On List of content INTRO Index of the FLUKA ma 0} What is FLUKA? 1) A quick look at FLUK 2) A FLUKA beginner's 3) Installation 4) FLUKA modules (Fo 5) Particle and material 6) General features of I 7) Description of FLUK 8) Combinatorial Geom 9) Output	line man S: anual on-line (A's physics, struc guide rtran files) codes -LUKA input A input options letry	ual	5		index]
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Manual can also be accessed within Flair: press F1

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-	7.18.23 Rigsing options for low of	SIGMA+	21	Positive Sigma	3222		

Since we are mostly interested to nuclear fragments, notice that:

for p, n, d, t,³He, ⁴He there is a specific FLUKA particle number

For A>4: FLUKA particle numbers is always -2, and nucleus is identified by Z and A

Fragments and nucleons originating in the "nuclear evaporation" phase are identified with particle number in the range from -30 to -7. Again identified by Z and A.

there would be also a way to identify isomers, but we can omit this now

The concept of Region

- FLUKA makes use of "Combinatorial Geometry" (originally from Oak Ridge and later extended/modified)
- Basic objects called bodies (such as cylinders, spheres, parallelepipeds, etc.) are combined to form more complex objects called **Regions**



- 1 complex object = **REGION**
- internally identified by a number
- to each region is assigned a single Material (chemical element or compound or mixture)

3 basic objects

Example

"Air" is one region, filled with air (N, O, Ar @ STP)

×



Region numbering in (present) FOOT simulation



The root data by FLUKA

The data are stored in a root file with several block in the structure EVENTO_STRUCTPIX (defined in the file EventStructPix.h):

- The particle block: kinematics information of the produced particles
- The detector block: information about the detector outputs of the event and namely about energy releases and hits + links to "MC truth".
- The crossing block: informatioon about the particle that cross different regions of the setup (both inactive and active)

The particle structure

for each of the produced particles we register the info in arrays: i.e. trmass[2] is the mass of the 3rd produced particle

EventNumber = FLUKA event number: trn= number of particles produced: max equal to

MAXNUMP = 1000

trpaid = index in the part common of the particle parent

- trcha = charge
- trbar = barionic number
- trfid = FLUKA code for the particle (es: photon, jpa=7)
- trgen = generation number

trix, triy, triz = production position of the particle
trfx, trfy, trfz = final position of the particle
tripx,tripy,tripz = production momentum of the particle
trifx,trfpy,trfpz = final momentum of the particle
trmass = particle mass
trtime = production time of the particle
trlen = track lenght of the particle

Int t EventNumber; Int t trm; Int trpaid[MAXNUMP]; Int t trgen[MAXNUMP]; Int ttrcha[MAXNUMP]; Int_t trreg[MAXNUMP]; Int t trbar[MAXNUMP]; Int tidead[MAXNUMP]: Int ttrfid[MAXNUMP]; Double t trix[MAXNUMP]; Double t trivi[MAXNUMP]; Double t triz[MAXNUMP]; Double t trfx[MAXNUMP]; Double t trfy[MAXNUMP]; Double t trfz[MAXNUMP]; Double t tripx[MAXNUMP]; Double t tripy[MAXNUMP]; Double t tripz[MAXNUMP]; Double t trfpx[MAXNUMP]; Double t trfpy[MAXNUMP]; Double_t trfpz[MAXNUMP]; Double t trmass[MAXNUMP]; Double t trtime [MAXNUMP]; Double t tof[MAXNUMP]; Double t trlen[MAXNUMP];

The individual detectors structures

For each detector with n energy releases the info are stored in arrays (x, p, De, time, etc...) with the i-th component related to the i-th release . Same syntax for all scint detector: "info""NAMEDETECTOR"[index of the release]

DETn = number of energy release in the detector DET

DETid = position of the particle responsible of the release in the particle block

DETinx, **DETiny**, **DETinz** = inizial position of energy release

DEToutx , DETouty , DEToutz = final position	"	"
DETnpx, DETinpy, DETinpz = inizial momentum	"	"
DEToutpx, DEToutpy, DEToutpz = final momentum	"	"
DETde = energy release		
DET = quenched energy release		
DETtime = initial time of the energy release		

Start Counter: st

Int t stn; Int t stid[MAXSC]; Double t stinx[MAXSC]; Double t stiny[MAXSC]; Double t stinz[MAXSC]; Double t stoutx[MAXSC]; Double t stouty[MAXSC]; Double t stoutz[MAXSC]; Double_t stinpx[MAXSC]; Double_t stinpy[MAXSC]; Double t stinpz[MAXSC]; Double_t stoutpx[MAXSC]; Double t stoutpy[MAXSC]; Double t stoutpz[MAXSC]; Double_t stde[MAXSC]; Double t stal[MAXSC]; Double t sttim[MAXSC];

Simple case of non-segmented detector

MAXSC = 500

Vertex tracker: vtx

This is instead a segmented (=pixelated) detector Additional variables are needed



Int t nIT; ... MAXIT = 500 Inner tracker: IT Int tiplaIT[MAXIT]; Int tirowIT[MAXIT]; Int ticolIT[MAXIT]; beam monitor (1st drift ch.): Int t nmon; ... MAXBM = 500 Int tilayer[MAXBM]; \rightarrow layer # mon Int ticell[MAXBM]; → cell # Int tiview[MAXBM]; \rightarrow view (0:x 1:y) 2nd drift ch.: 2dc Int t n2dc; ... MAX2DC = 500 Int tipla2dc[MAX2DC]; Int ticell2dc[MAX2DC]; Int tiview2dc[MAX2DC]; Int t nscint; ... MAXSCINT = 1000 scintillator: scint Int t Int t irowscint[MAXSCINT]; Int t icolscint[MAXSCINT]; crystal calorimeter: cry Int_t ncry; ... **MAXCRY = 2000** Int tirowcry[MAXCRY]; Int ticolcry[MAXCRY];

Energy releases and hits connection to particles

To find which particle released the energy of a detector energy release we need to build a pointer to the particle block. Given the j-th energy release in the detector DET, then we build:

pointer= DETid[j]-1;

Then the features of the particles responsible of the release (for example the mass and the x coord of production) can be retrieved from the particle block as:

```
Massa = trmass[pointer];
```

```
Xprod = trix[pointer];
```



DETid(1)-1 = pointer to the particle in Particle Structure that originated hit=1 to access all infos (id, quantum numbers + kinematics) about that particle

The crossing data structure

This structure registers the info on the particles that cross the boundaries between the different regions of the setup (detector elements, air, target). At each crossing the info are stored in arrays

ncross = number of boundary crossing
idcross = position of the crossing particle in the particle block
nregcross = no. of region in which the particle is entering
nregoldcross = np. of region the particle is leaving
pxcross, pycross, pzcross = momentum at the boundary
crossing
xcross, ycross, zcross = position of the boundary crossing

tcross = time of the boundary crossing

chcross = charge of crossing particle

macross = mass of the crossing particle

Int_t ncross; Int_t idcross[MAXCROSS]; Int_t nregcross[MAXCROSS]; Int_t nregoldcross[MAXCROSS]; Double_t xcross[MAXCROSS]; Double_t ycross[MAXCROSS]; Double_t pxcross[MAXCROSS]; Double_t pycross[MAXCROSS]; Double_t pzcross[MAXCROSS]; Double_t pzcross[MAXCROSS]; Double_t mcross[MAXCROSS];

Double_t chcross[MAXCROSS]; Double_t tcross[MAXCROSS];

The simple code AnaFOOT

The code reads the root data from MC and produces some example histos. It's thought as an example/skeleton for more complex code specific to different analysis.

Compiling & Linking: make –f Makefile_AnaFlukaHIT (clean) Usage: can be seen typing "AnaFOOT –help" :

> AnaFOOT [opKons] with possible opKons

- nev value : [def=all] Numbers of events to process
- in file : [def=In.root] Root input file generated by FLUKA
- out file : [def=Out.root] Root output file with analysis histo
- iL

- : [def=none] input file is a list of files
- deb value : [def=0] Enables debugging

N.B To process multiple files make a list of files to be process in a list file (ex: lista.txt) and give the command:

./AnaFOOT -- iL -- in lista.txt -- out TotAnaFile.root

Let's look a little bit inside AnaFOOT.cpp

Just to be ready to make some simple exercise today...

Pointer to structure EVENTOPIX_STRUCT *pevstr = new EVENTOPIX_STRUCT; TFile *f_out = new TFile(Outname,"RECREATE"); Opens output root file status = Booking(f out); Books histograms. TFile *f input = new TFile(Inname); **Booking** is the routine where you have to book your custom histos f input->cd(); f input->GetObject("EventTree",ptree); EventoPix *Ev = new EventoPix(); Loads root tree with MC output status = Ev->FindBranches(ptree,pevstr);



return 0;

customized code: Example A

I want to retrieve the code and the mass of the particle that release energy in the start counter.

A particle may generate more than a single release in the detector (see the drawing): it's a good idea to consider the first energy release to retrieve the features of the impinging particle.

```
double massa;
int ipart_pointer, kpart_type;
If ((pevstr->stn)>0){
    ipart_pointer = pevstr->stid[0]-1;
    massa = pevstr->trmass[ipart_pointer];
    kpart_type = pevstr->trfid[ipart_pointer];
```



Example B

}

I want to know how many neutrons arriving at calorimeter have been generated inside the target

```
int neutron from target=0;
int neutron code = 8;
int target region = 3;
int first cry region = 254;
int last cry region = 354;
                                                           loops on all the crossings entering
Int ipart pointer;
                                                            a crystal and cheks if pointer in
for( int ii=0; ii<pevstr->ncross); ii++){
                                                            particle block is coming from
     if(pevstr->nregcross[ii]>=first cry region &&
                                                           target and if is a neutron
          pevstr->nregcross[ii]<=last cry region) {
               ipart_pointer = pevstr->idcross[ii]-1;
               if ( (pevstr->trreg[ipart pointer]==target region) &&
                (pevstr->trfid[ipart pointer]==neutron code) {
                   neutron from target++;
              }
```