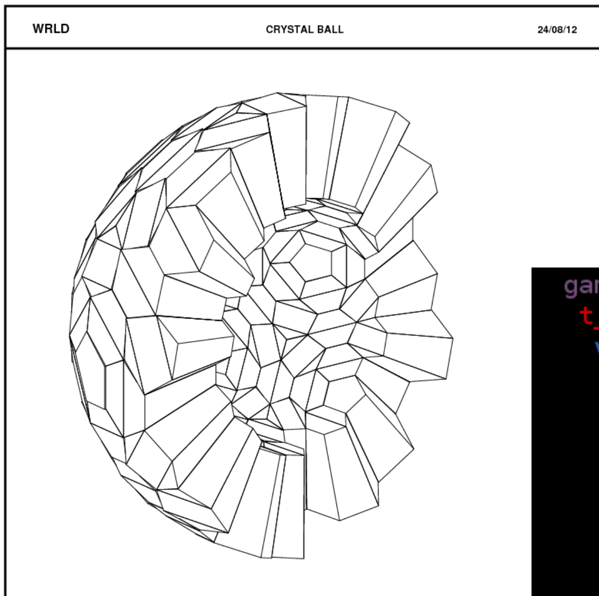
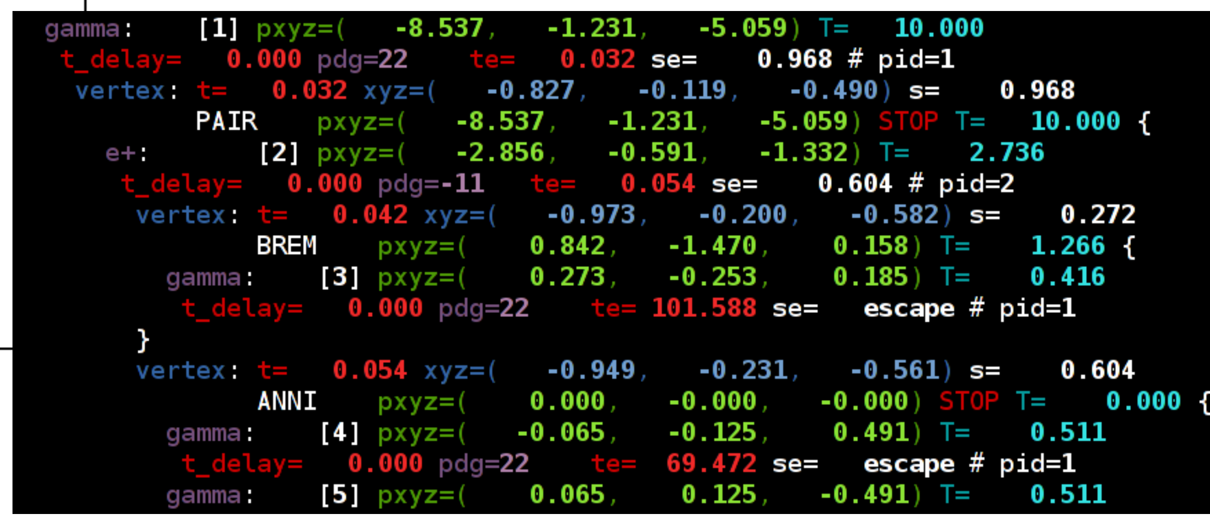
Command line *simulations*





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IEM-CSIC, December 2012

Outline

Example

Simulation flow overview

Interfacing with GEANT3/4

Digitisation

Parametrised detectors

Versatile particle gun

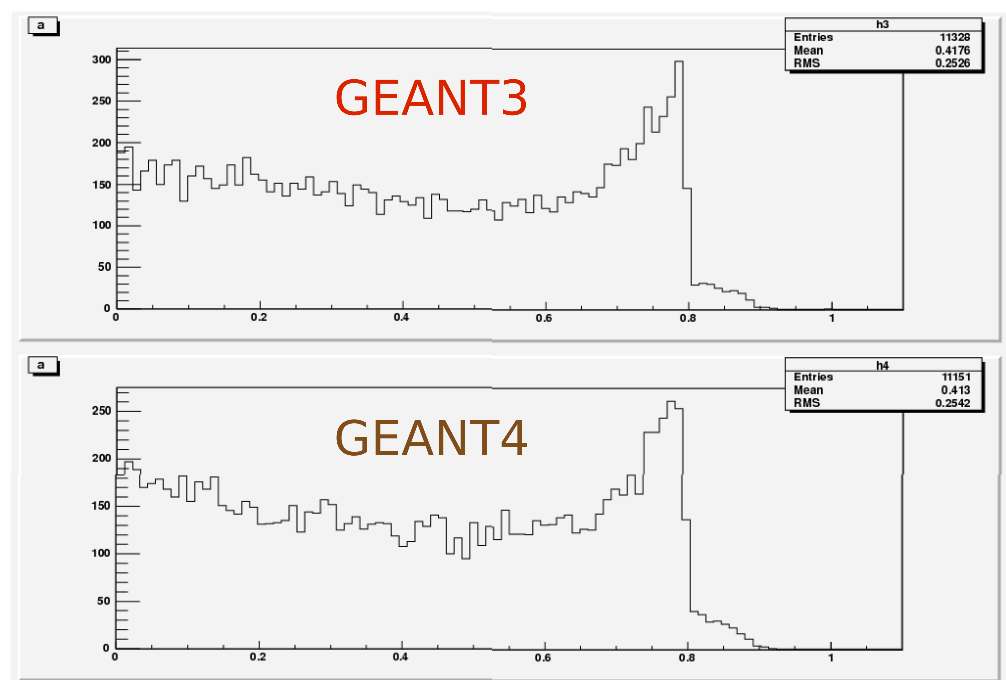
Vertex & hit dump

Wrapping up

Same command line for GEANT3 & 4

```
./land_geant3 --test=d=1cm,z0=2cm,type=plastic,out_col=0 \
  --gun=T=1MeV,gamma,isotropic --events=1000000 | \
  grep TSTDMP | sed -e "s/.*://" > test3.txt

./land_geant4  . . .  > test4.txt
```

```
test3.txt:          test4.txt:

    0.71876             0.21737
    0.05768             0.77376
    0.00663             0.09234
    0.68386             0.08010
    0.06915             0.77861
    0.79547             0.60840
    0.61802             0.78068
    0.69747             0.64339
    0.07892             0.69145
...                 ...
```




```
TTree t3, t4;
t3.ReadFile("test3.txt","a");
t4.ReadFile("test4.txt","a");
TCanvas c1;c1->Divide(1,2);
c1->cd(1);t3->Draw("a>>h3(100,0,1.1)");
c1->cd(2);t4->Draw("a>>h4(100,0,1.1)");
```

Data flow

Reconstruction flow: ↓

Simulation starts at the level where analysis ends;

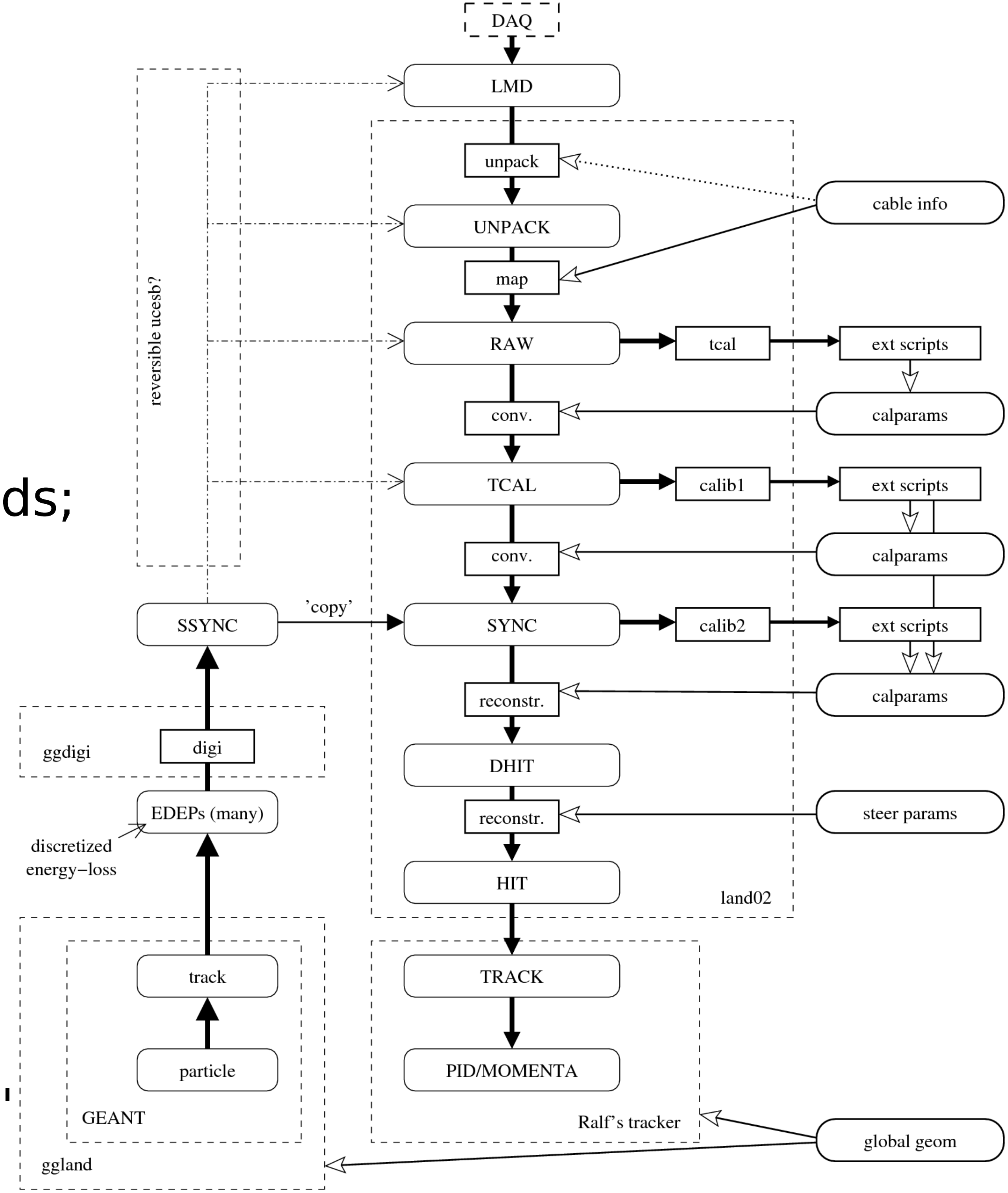
Simulation flow: ↑

Flow ↑ until suitable handover point:

(land02-speak:) SYNC level

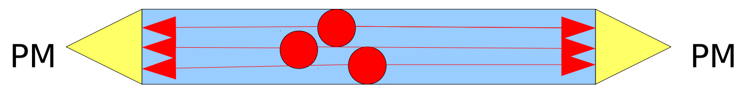
`ggland`: wrap GEANT3/4

`ggdigi`: combine 'δE-hits'



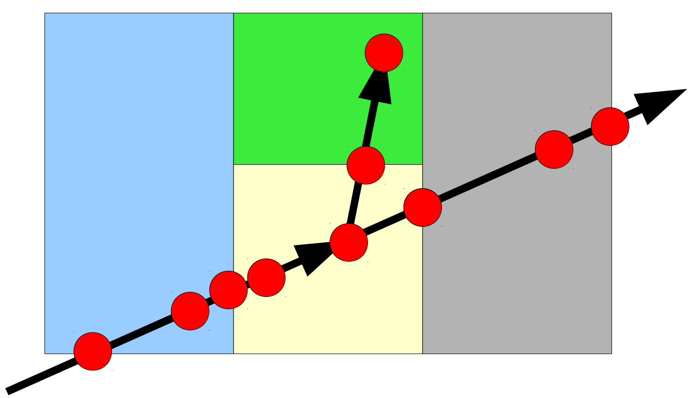
Read this way

SYNC level data (t,e) → land02



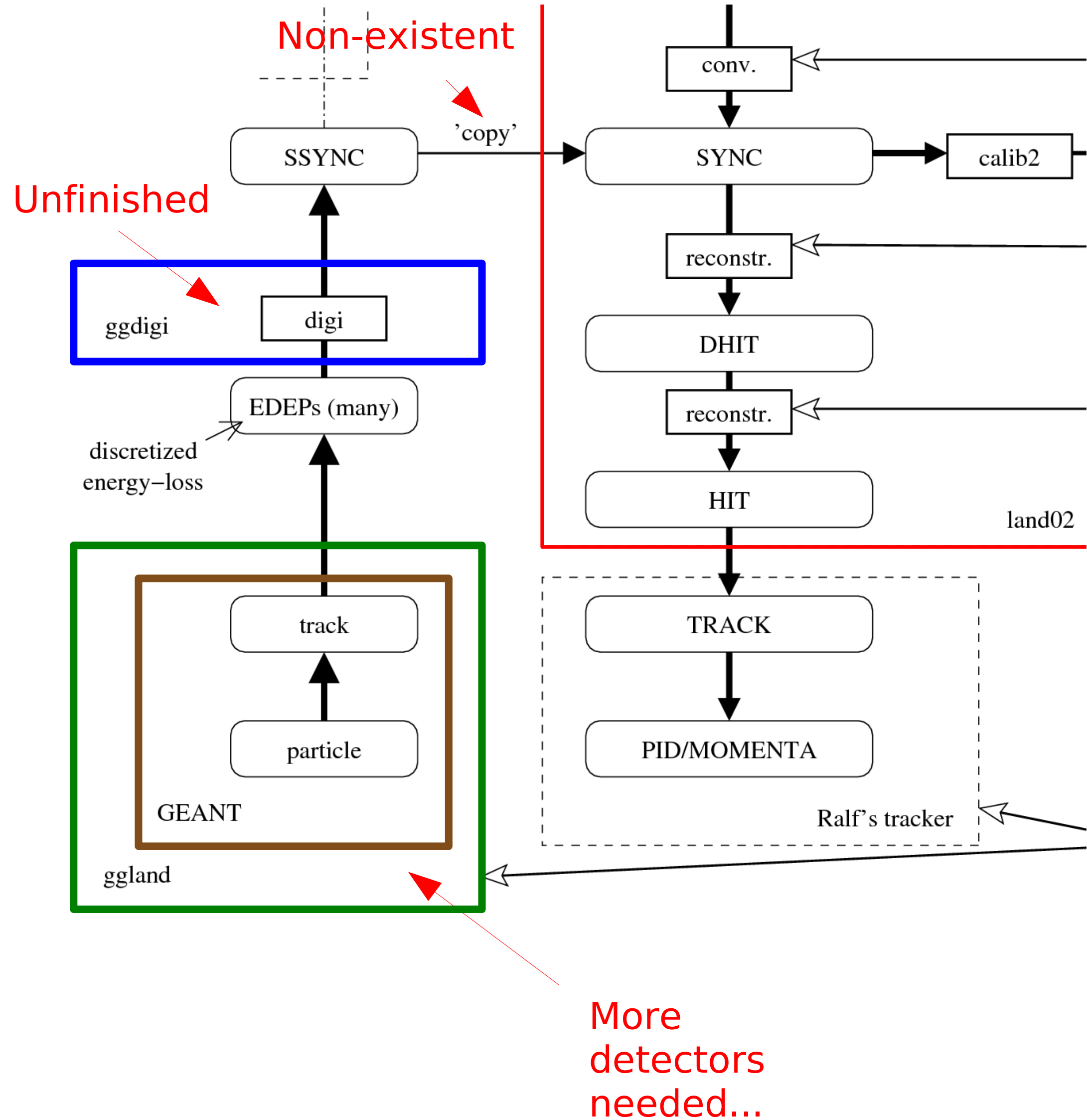
ggdigi: propagate δE-signals to readout, sum & discriminate

GEANT: gives 'δE-hits' (●)



GEANT: particles & tracks

ggland: minimalistic interface

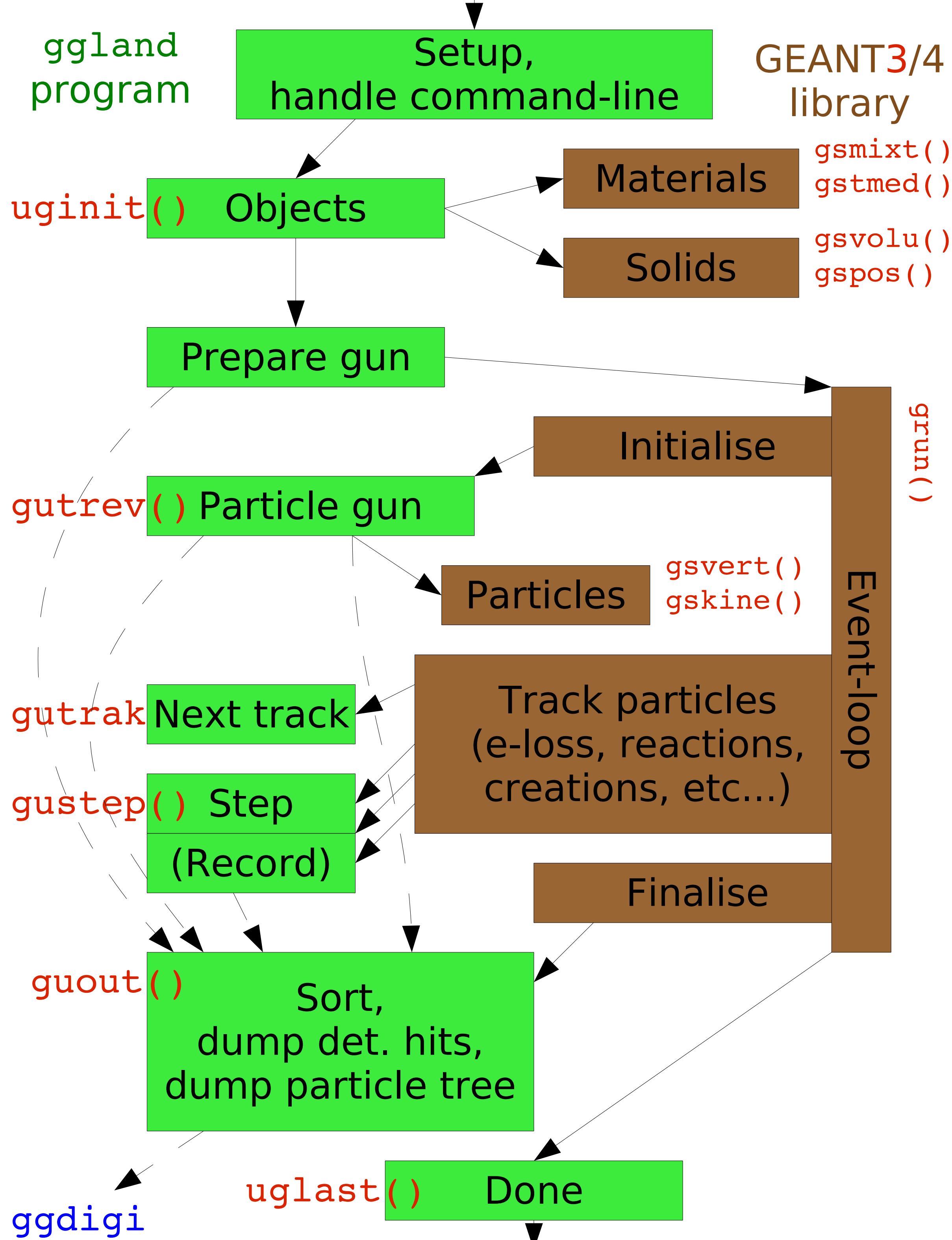


ggland & ggdigi

ggland: Interfacing with GEANT3/4

Interface to GEANT3:
6 user-defined functions
(FORTRAN, easy to call
From C).

GEANT4 has similar
'mechanics', but more
flexible and C++.



ggdigi: Generic digitisation

Simulation generates list of energy deposits in volumes

```
*** EVENT 5 *** # seeds: 885310761,1134865903
hits: LAND: #       3,      2 sections
  1/18: # LAND, 2 hits (E=18.792)
        t=    41.189 p=-99.97 dE=  10.906 ds= 0.865
        t=    41.209 p=-99.29 dE=   7.886 ds= 1.125
  1/19: # LAND, 1 hits (E=3.674)
        t=    41.280 p=-99.35 dE=   3.674 ds= 0.490
# total E=22.466
```

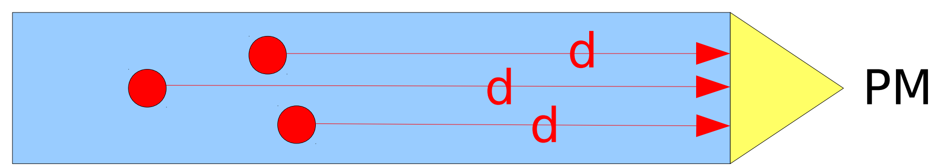
Often many!
Depends on discretization.

```
hits: TEST: #    49,    1 sections
  1: # TEST, 49 hits (E=9.073)
        t=    0.032 p= -0.49 dE=   0.000 ds= 0.000 # 2
        t=    0.032 p= -0.49 dE=   0.000 ds= 0.000 # 7
        t=    0.032 p= -0.49 dE=   0.000 ds= 0.968 # 1
        t=    0.035 p= -0.51 dE=   0.316 ds= 0.072 # 2
        t=    0.037 p= -0.56 dE=   0.173 ds= 0.057 # 2
        t=    0.038 p= -0.58 dE=   0.185 ds= 0.051 # 2
        t=    0.038 p= -0.58 dE=   0.852 ds= 0.183 # 7
        t=    0.040 p= -0.59 dE=   0.197 ds= 0.043 # 2
        t=    0.041 p= -0.58 dE=   0.161 ds= 0.039 # 2
        t=    0.042 p= -0.58 dE=   0.022 ds= 0.009 # 2
        t=    0.043 p= -0.58 dE=   0.113 ds= 0.035 # 2
        t=    0.044 p= -0.57 dE=   0.716 ds= 0.163 # 7
        t=    0.044 p= -0.58 dE=   0.129 ds= 0.035 # 2
        t=    0.045 p= -0.57 dE=   0.126 ds= 0.035 # 2
        t=    0.047 p= -0.56 dE=   0.108 ds= 0.035 # 2
        t=    0.048 p= -0.54 dE=   0.107 ds= 0.035 # 2
        t=    0.048 p= -0.55 dE=   0.000 ds= 0.000 # 8
        t=    0.048 p= -0.55 dE=   0.622 ds= 0.127 # 7
        t=    0.049 p= -0.55 dE=   0.024 ds= 0.014 # 8
        t=    0.049 p= -0.57 dE=   0.118 ds= 0.035 # 2
        t=    0.050 p= -0.58 dE=   0.000 ds= 0.000 # 9
        t=    0.050 p= -0.58 dE=   0.388 ds= 0.063 # 7
        t=    0.051 p= -0.57 dE=   0.113 ds= 0.035 # 2
        t=    0.051 p= -0.59 dE=   0.038 ds= 0.011 # 9
        t=    0.052 p= -0.56 dE=   0.123 ds= 0.035 # 2
        t=    0.054 p= -0.56 dE=   0.000 ds= 0.000 # 4
        t=    0.054 p= -0.56 dE=   0.000 ds= 0.000 # 5
        t=    0.054 p= -0.56 dE=   0.143 ds= 0.012 # 2
```

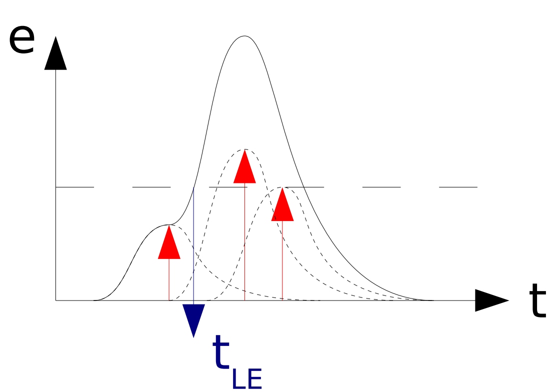
Analysis needs single data per readout channel (like real data)

Digitiser propagates to readout:

- Time-delay   `t += d * v`$_{eff}$
- Attenuation   `e *= exp (-d/l`$_{att.len.}$`)`



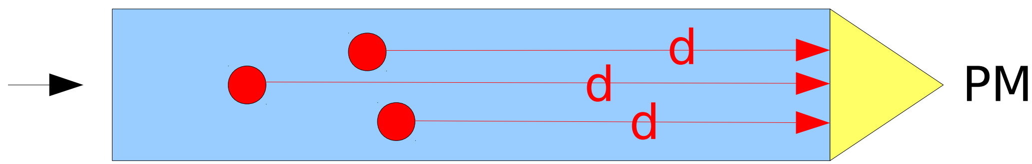
- Each hit contributes to readout pulse.
- Final time-signal after CFD (or LE) mimic

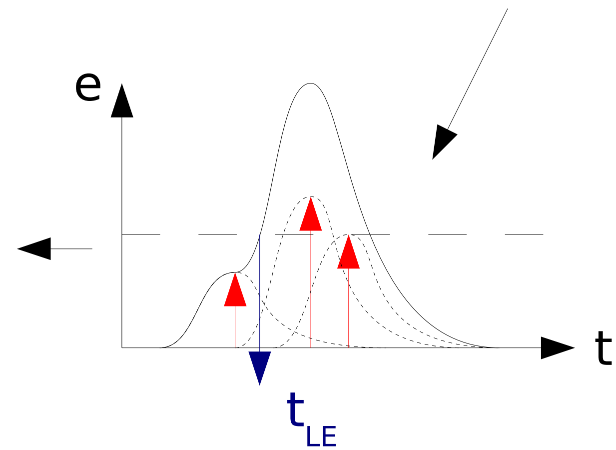


Propagation and CFD based on
`R3BConstantFraction.{h,cxx}`
By Johan Gill & Staffan Wranne

ggdigi: Generic digitisation II

```
*** EVENT 5 *** # seeds: 885310761,1134865903
hits: LAND: #     3,     2 sections
  1/18: # LAND, 2 hits (E=18.792)
        t=    41.189 p=-99.97 dE=   10.906 ds= 0.865
        t=    41.209 p=-99.29 dE=    7.886 ds= 1.125
  1/19: # LAND, 1 hits (E=3.674)
        t=    41.280 p=-99.35 dE=    3.674 ds= 0.490
# total E=22.466
```






```
*** EVENT 5 ***
# LAND 2 sections 3 hits
 1/18: t1=   35.189 e1=   10.079 t2=   47.202 e2=   35.039
 1/19: t1=   35.295 e1=    1.975 t2=   47.265 e2=    6.836
```

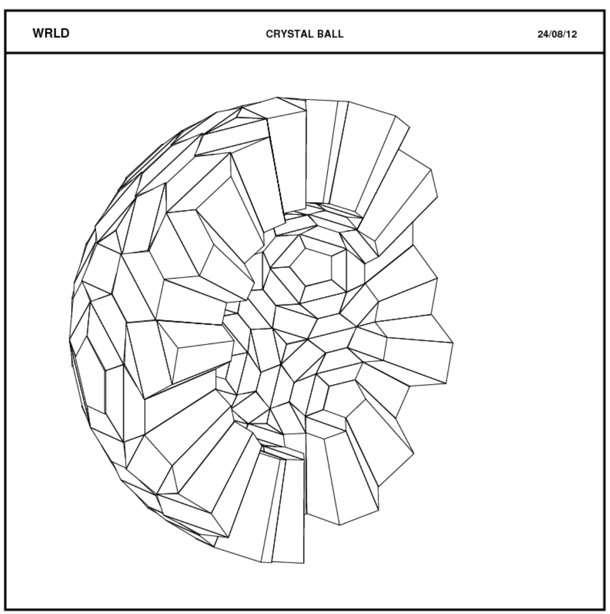
ggdigi: Separate process, same routine for all detectors!

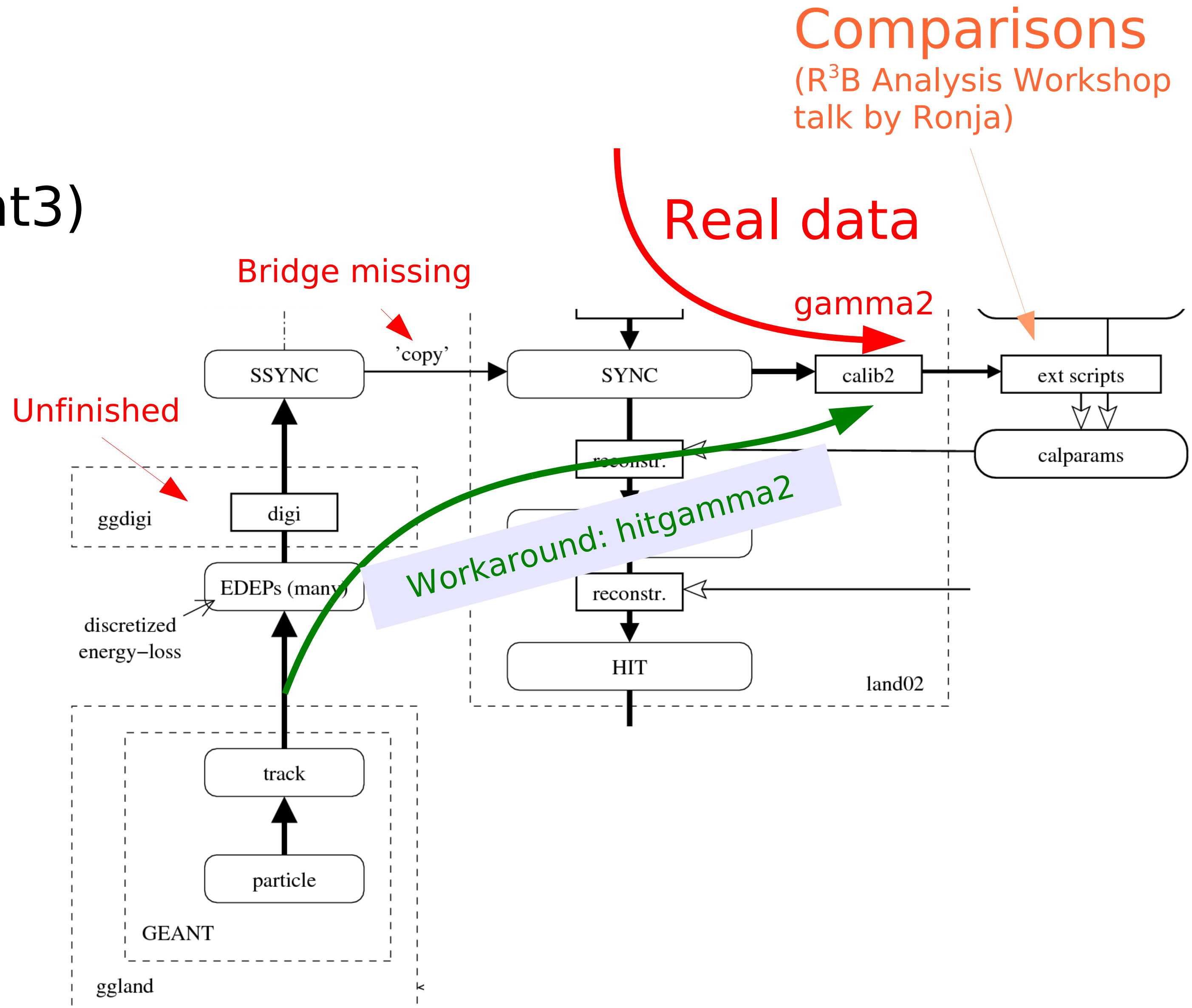
Customised by:

- Relevant propagation coordinate
- Speed of signal, e.g. v_{eff} of scintillation photons
- Attenuation length
- (To handle Birk's law – light output saturation)

Production-ready pieces

- Particle gun
- Test volume
- Crystal ball (geant3)





Parametrised detectors

Existing:

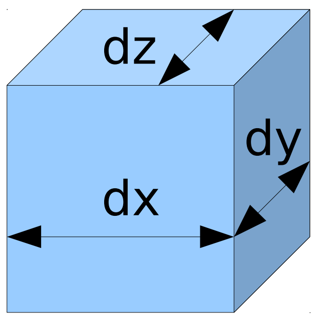
```
--land
--sciland
--xb
--csi
--cave
--boxcave
--test
--world
```

Detector volumes created by C code,
by calling wrappers for GEANT3/4.

Dimensions and aspects variable controlled.
Defaults give 'normal' detectors.
Override on command line.

```
--xb=help

rot{x,y,z}|x0|y0|z0           0 1|cm   Rotation | Location.
r1                           25 cm     Inner radius.
r2                           45 cm     Outer radius.
right                         1        Right half (1-81,!77,!81).
left                          1        Left half (83-162,!82).
forward                       0        Forward crystal (81).
backward                      0        Backward crystal (82).
bottom                        0        Bottom crystal (77).
all                           0        Enable all crystals.
crystal                     NaI        Crystal material.
```

TEST volume




```
--test=help

rot{x,y,z}|x0|y0|z0      0 1|cm  Rotation | Location.
d                        1 cm    Half width (if none of dx,dy,dz given).
dx                       1 cm    Half width (x).
dy                       1 cm    Half width (y).
dz                       1 cm    Half width (z).
dm                     nan g/cm2 Thickness (if none of dx,dy,dz given).
dmx                    nan g/cm2 Thickness (x).
dmy                    nan g/cm2 Thickness (y).
dmz                    nan g/cm2 Thickness (z).
out_col                 -1       Output column.  (Text dump.)
stepprint                0       Debug printing from the step function.
type             undefined       Test material.
```

Material must be given for test volume:

`--list-materials`

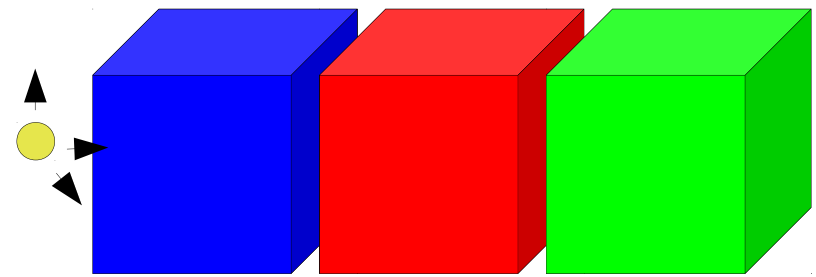
Energy sum per event.
First column is 0.
(Only non-0 events printed.)
For ROOT's `Ttree::ReadFile()`

test3.txt:

```
0.71876
0.05768
0.00663
0.68386
0.06915
0.79547
0.61802
0.69747
0.07892
...
```

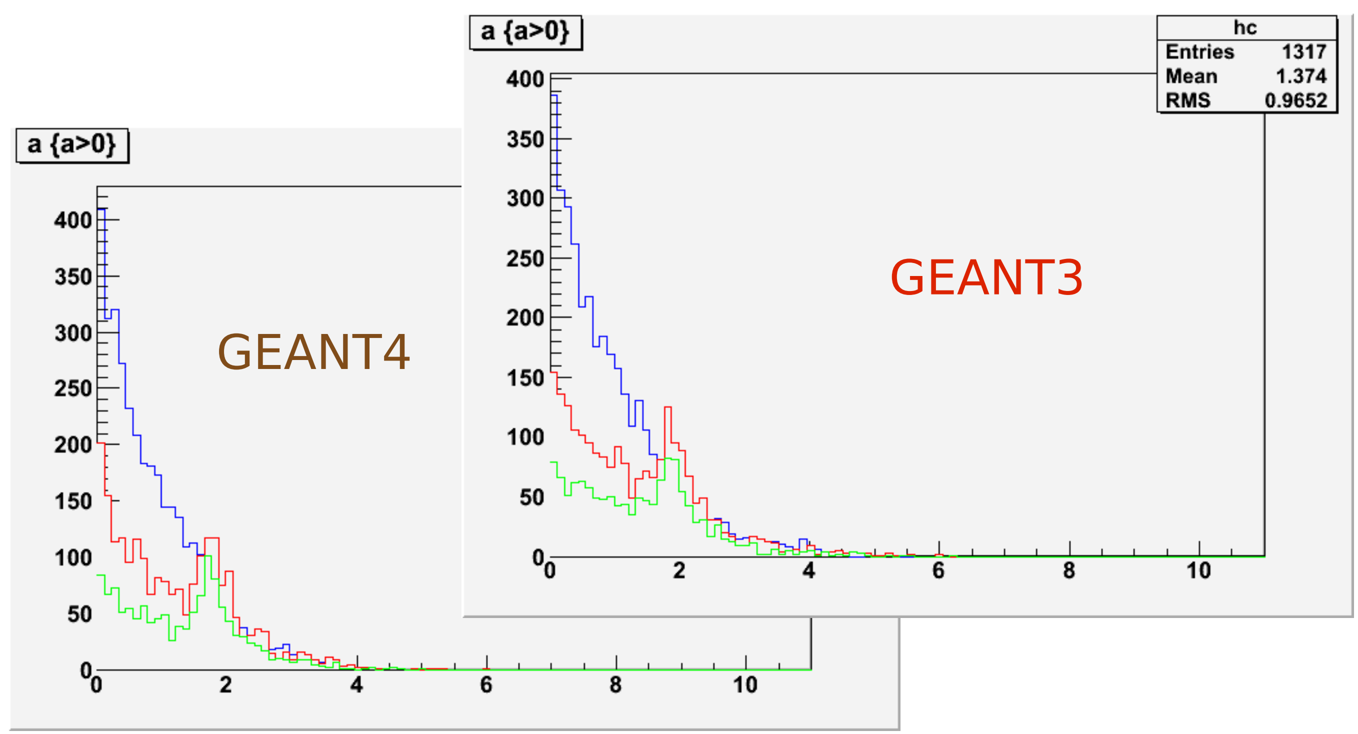
Multiple TEST volumes

```
./land_geant3
  --test-0=d=0.5cm,z0=1cm,type=plastic,out_col=0
  --test-1=d=0.5cm,z0=2cm,type=plastic,out_col=1
  --test-2=d=0.5cm,z0=3cm,type=plastic,out_col=2
  --gun=gamma,T=10MeV,dtheta=0.5pi --events=1000000 |
  grep TSTDMP | sed -e "s/.*://" > 3vols.txt
```



3vols.txt:

```
    2.26846    0.00000    0.00000
    2.14312    1.33287    0.00000
    0.95297    0.00000    0.00000
    0.07750    0.00000    0.00000
    0.27885    0.00000    0.00000
    0.00000    1.23321    0.00000
    0.53523    0.93503    0.00000
    1.06333    0.00000    0.00000
    0.00000    0.79065    0.00000
    3.89404    1.62902    0.00000
    0.14590    2.33030    1.07062
    0.00000    0.00000    0.47722
    0.00000    1.79729    2.36696
    0.93408    0.00000    0.00000
...
```



Instant .root-file

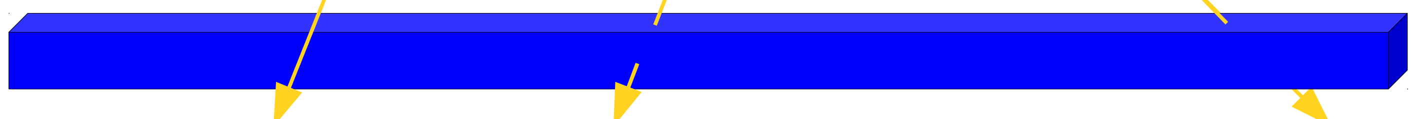
Back-of-the-envelope simulations

Create root-file with data from test volumes:

`sumE`

By rough 'digitizer': cluster by distance (currently sqrt(10) cm):

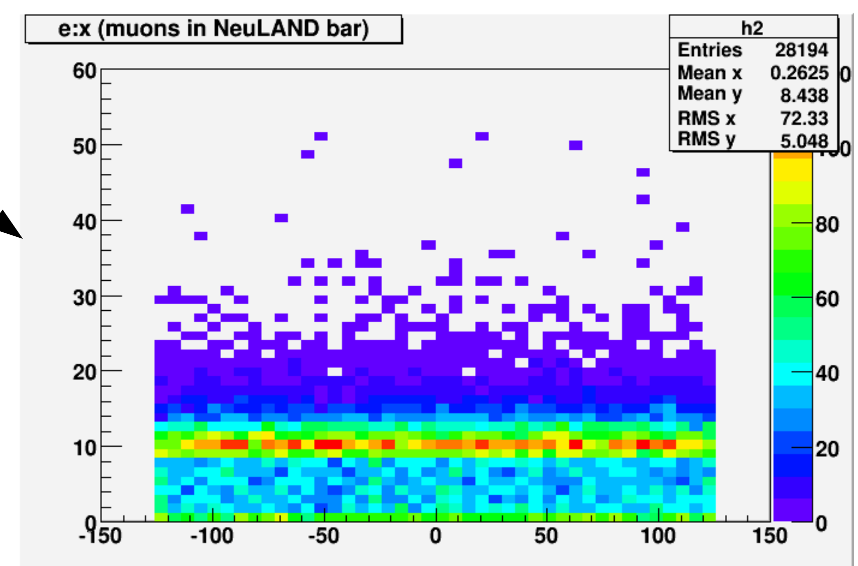
`n, x[n], y[n], z[n], t[n], e[n]`



```
./land_geant4 --test=dx=125cm,dy=2.5cm,dz=2.5cm,type=plastic,tree=1
   --gun=cosmmuonthetaE=250MeV,sr=130cm --test-tree=muons2.root
   --events=1000000
```

Include volume

h101->Draw(“e:x”)



Realistic muon source now
also gives corresponding real time.

```
Muon source (lowEcut=250.0 MeV, r=130.0 cm):
   avg time between ev. 0.0009705 s.
Muon source with 1000000 events, total time:
   970.5 s (= 0 h 16 m).
```

Vertex & hit list – markup: ggmark

```
--hits=vertex,- |
  ./ggmark |
  less -R
```

Particle & vertex list

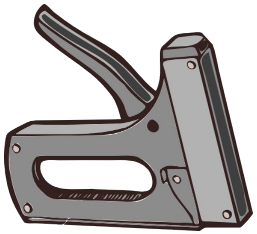
```
*** EVENT 5 *** # seeds: 55312060,333625511
# Vertices 7, particles 9
# bullet pdg=22    T=   10.000 theta=120.394deg phi=-171.797deg gamma
origin: t=   0.000 xyz=(    0.000,     0.000,     0.000) {
  gamma:     [1] pxyz=(    -8.537,    -1.231,    -5.059) T=   10.000
   t_delay=   0.000 pdg=22     te=   0.032 se=     0.968 # pid=1
    vertex: t=   0.032 xyz=(   -0.827,    -0.119,    -0.490) s=    0.968
                PAIR     pxyz=(    -8.537,    -1.231,    -5.059) STOP T=   10.000 {
      e+:        [2] pxyz=(    -2.856,    -0.591,    -1.332) T=    2.736
       t_delay=   0.000 pdg=-11    te=   0.054 se=     0.604 # pid=2
        vertex: t=   0.042 xyz=(   -0.973,    -0.200,    -0.582) s=    0.272
                    BREM     pxyz=(     0.842,    -1.470,     0.158) T=    1.266 {
          gamma:     [3] pxyz=(     0.273,    -0.253,     0.185) T=    0.416
           t_delay=   0.000 pdg=22     te= 101.588 se=    escape # pid=1
        }
        vertex: t=   0.054 xyz=(   -0.949,    -0.231,    -0.561) s=    0.604
                    ANNI     pxyz=(     0.000,    -0.000,    -0.000) STOP T=    0.000 {
          gamma:     [4] pxyz=(    -0.065,    -0.125,     0.491) T=    0.511
           t_delay=   0.000 pdg=22     te=  69.472 se=    escape # pid=1
          gamma:     [5] pxyz=(     0.065,     0.125,    -0.491) T=    0.511
           t_delay=   0.000 pdg=22     te=   0.069 se=     0.451 # pid=1
            vertex: t=   0.062 xyz=(   -0.916,    -0.169,    -0.804) s=    0.253
                        COMP     pxyz=(     0.192,     0.135,     0.078) T=    0.247 {
              e-:        [6] pxyz=(    -0.126,    -0.010,    -0.569) T=    0.264
               t_delay=   0.000 pdg=11     te=   0.062 se=     0.035 # pid=3
            }
        }
      e-:        [7] pxyz=(    -5.603,    -0.628,    -3.681) T=    6.242
       t_delay=   0.000 pdg=11     te=   0.071 se=     1.161 # pid=3
        vertex: t=   0.048 xyz=(   -0.794,    -0.314,    -0.546) s=    0.473
                    BREM     pxyz=(     1.088,     3.664,    -2.395) T=    4.028 {
          gamma:     [8] pxyz=(     0.007,     0.018,    -0.014) T=    0.024
           t_delay=   0.000 pdg=22     te=   0.049 se=     0.014 # pid=1
        }
        vertex: t=   0.050 xyz=(   -0.780,    -0.268,    -0.576) s=    0.535
                    BREM     pxyz=(     1.443,     0.913,    -3.707) T=    3.602 {
          gamma:     [9] pxyz=(     0.014,     0.010,    -0.034) T=    0.038
           t_delay=   0.000 pdg=22     te=   0.051 se=     0.011 # pid=1
        }
    }
}
```

Particle-hit association

Hit (δE) list

```
hits: TEST: #    49,    1 sections
 1: # TEST, 49 hits (E=9.073)
        t=    0.032 p= -0.49 dE=   0.000 ds= 0.000 # 2
        t=    0.032 p= -0.49 dE=   0.000 ds= 0.000 # 7
        t=    0.032 p= -0.49 dE=   0.000 ds= 0.968 # 1
        t=    0.035 p= -0.51 dE=   0.316 ds= 0.072 # 2
        t=    0.037 p= -0.56 dE=   0.173 ds= 0.057 # 2
        t=    0.038 p= -0.58 dE=   0.185 ds= 0.051 # 2
        t=    0.038 p= -0.58 dE=   0.852 ds= 0.183 # 7
        t=    0.040 p= -0.59 dE=   0.197 ds= 0.043 # 2
        t=    0.041 p= -0.58 dE=   0.161 ds= 0.039 # 2
        t=    0.042 p= -0.58 dE=   0.022 ds= 0.009 # 2
        t=    0.043 p= -0.58 dE=   0.113 ds= 0.035 # 2
        t=    0.044 p= -0.57 dE=   0.716 ds= 0.163 # 7
        t=    0.044 p= -0.58 dE=   0.129 ds= 0.035 # 2
        t=    0.045 p= -0.57 dE=   0.126 ds= 0.035 # 2
        t=    0.047 p= -0.56 dE=   0.108 ds= 0.035 # 2
        t=    0.048 p= -0.54 dE=   0.107 ds= 0.035 # 2
        t=    0.048 p= -0.55 dE=   0.000 ds= 0.000 # 8
        t=    0.048 p= -0.55 dE=   0.622 ds= 0.127 # 7
        t=    0.049 p= -0.55 dE=   0.024 ds= 0.014 # 8
        t=    0.049 p= -0.57 dE=   0.118 ds= 0.035 # 2
        t=    0.050 p= -0.58 dE=   0.000 ds= 0.000 # 9
        t=    0.050 p= -0.58 dE=   0.388 ds= 0.063 # 7
        t=    0.051 p= -0.57 dE=   0.113 ds= 0.035 # 2
        t=    0.051 p= -0.59 dE=   0.038 ds= 0.011 # 9
        t=    0.052 p= -0.56 dE=   0.123 ds= 0.035 # 2
        t=    0.054 p= -0.56 dE=   0.000 ds= 0.000 # 4
        t=    0.054 p= -0.56 dE=   0.000 ds= 0.000 # 5
        t=    0.054 p= -0.56 dE=   0.143 ds= 0.012 # 2
```

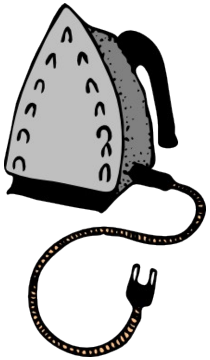
Versatile particle gun



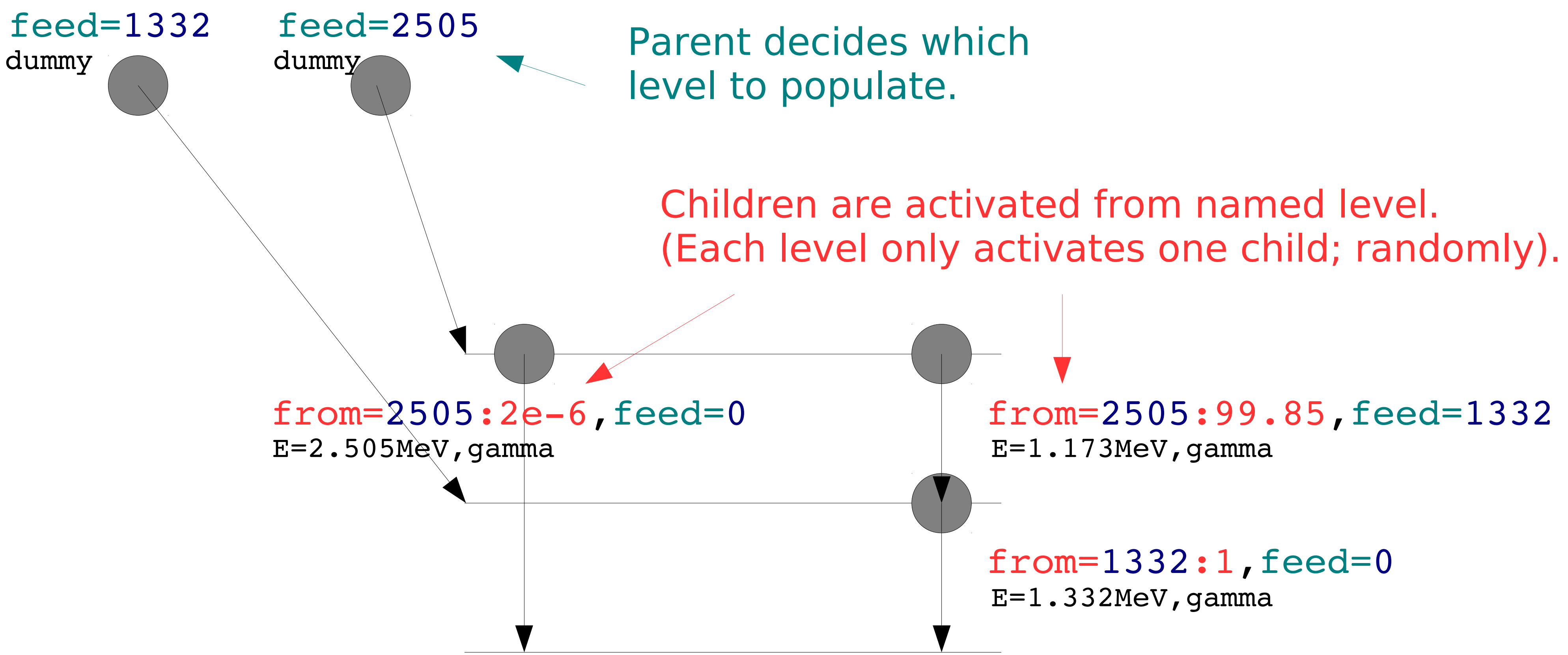
```
--gun=isotropic,gamma,E=5MeV

--gun=z0=10cm,sr=0.1cm,sphere,theta=45deg,
      dtheta=0.5pi,C12,T=200MeV/u
```

```
--gun=help
```

- Tree / conditional emission
- Source location & shape
- Direction and emission opening
- Energy / momentum
- Particle selection
- Phase-space / Lorentz boost



Particle gun 1: tree / conditional



feed=name	Activate subsequent particles (name for level).
prob=w	Probability, (e.g. 45% for percent, division and multiplication also allowed).
from=name:w	Given particle level with 'name' was activated as destination. Items are mutually exclusive.

Particle gun 2: location & shape

```
--gun=z0=10cm,sr=0.1cm,sphere,...
```

Location of source

Extent of source

x0, y0, z0	[0 cm]	Origin.
sx, sy, sz	[0 cm]	Source extent (box,ellipsoidals).
sr	[0 cm]	Source extent (disc,sphere,shell),
box/sphere/shell/disc		Shape of sx/sy/sz source extent. Disc perpendicular to nominal direction. (sphere is solid, shell is surface.)
shapenorot		Do not rotate source shape with theta & phi. Shape of sx/sy/sz source extent.
noverttochild		Do not give vertex to subsequent particle (feed). (Child using a source extent forces this.)

Particle gun 3: direction & opening

```
--gun=theta=45deg,dtheta=0.5pi,...
```

Direction

Default: z

Emission opening

Child direction relative to actual emission direction of parent particle.
(Facilitates 'anisotropic', 'backtoback' etc.)

```
ignoreparentdir               Ignore parent direction.
theta, phi     [0, 0]         Nominal direction, (e.g. 45deg for degrees).
dtheta         [0]            Spread of beam, (e.g. 45deg for degrees).
                              Or as dcostheta.  (dphi=2pi, always)
isotropic                     Shorthand for dtheta=1pi.
anisotropic=a2:a4             Anisotropic distribution (rel. to parent).
backtoback                    Generate in opposite direction to parent.
```

Used for ^{60}Co 1173 MeV + 1332 MeV decay.

Used for annihilation photons from β^+ sources.

Particle gun 4: energy

```
--gun=proton,T=100MeV

--gun=C12,T=200MeV/u

--gun=gamma,E=1MeV

--gun=gamma,E=1me

--gun=e-,beta=.99

--gun=gamma,E=0:10MeV
```

Choose particle momentum by giving a suitable energy or speed.

```
T,Tmin:Tmax     [MeV]    Kinetic energy, fixed or equidistributed min -- max.
                         Also as T/u and T/A, with MeV/u and MeV/A.
p,pmin:pmax     [MeV/c]  Momentum, fixed or equidistributed min -- max.
E,Emin:Emax     [MeV]    Total energy, fixed or equidistributed min -- max.
                         (Units [kev] or [me] also allowed.
beta,betamin:max         Beta, fixed or equidistributed min – max.
```

Particle gun 5: particles

`--gun=e+,...`

Particles from GEANT3/4
`--list-particles`

`--gun=C12,...`

`--gun=dummy,...`

No particle (not geantino).

`--gun=decay-Co-60`

'Realistic' predefined sources.
(Incl. branching probabilites, anisotropy.)

```
--gun=cosmmuonthetaE=200MeV,
      fromworldedge
```

Cosmic muon source.
(acc to: J. Kempa, A. Krawczynska,
Nucl. Phys. B (Proc. Suppl.) 151 (2006) 299-302.)

```
particle/isotope         The particle to generate (e.g. gamma,e-,p,n,d,t,Li6).
dummy                    Fire blank - no particle generated.

Predefined: decay-Na-22, decay-Co-60, decay-Cs-137

cosmmuonthetaE=lowEcut   Energy and angular distribution for cosmic muons.
fromworldedge            Move particle backwards to start from world edge.
```

Particle gun 6: phase-space & boost

```
--gun=T=2.28MeV,phasespace=nu,Zr90,e-,isotropic
```

Total energy

Phase-space distribution,
(sharing total energy)
(genbod algorithm – sequential two-body)

Last particle in
z / parent direction,
unless randomized

```
phasespace     Multiple particles share the given energy. (theta, phi,
               dtheta, isotropic applies to *last* particle).
               Particle can be followed by :setboost :dummy :feed.
```

```
--gun=beta=0.8,setboost,feed=A
--gun=from=A:1,boost,p
```

Inherit reference frame.
(Useful for beam-like emission.)
(Currently SEGFAULTs for uninvestigated reason.)

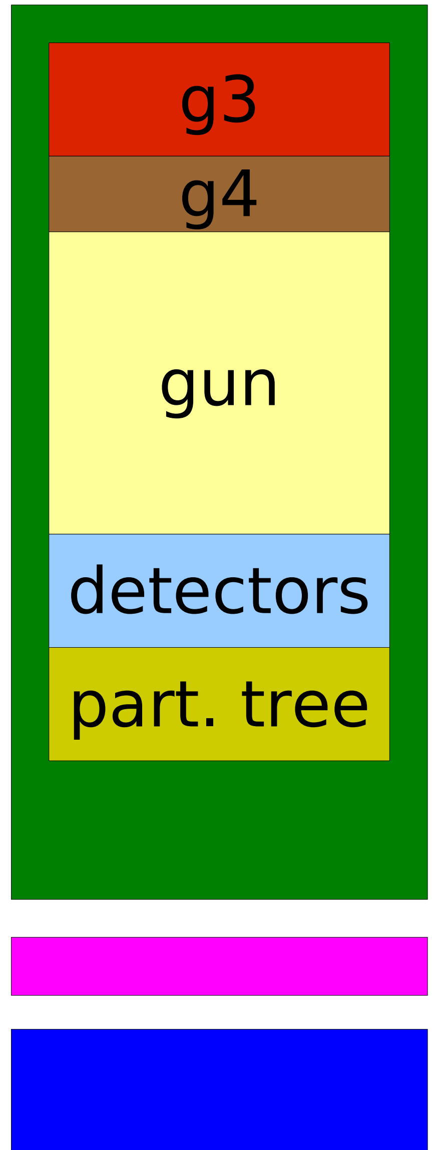
```
boost          Boost particle by set parent particle boost.
setboost       Use four-vector as boost source.
```

Fun-facts

land02-core: ~111 klines

ucesb-core: ~47 klines

`ggland:` 11,7 klines



GEANT3 interface.

GEANT4 interface.

Particle gun.

Detector geometry.

Vertex dump.

Other glue.

`ggmark:` 0,7 klines — Vertex dump markup.

`ggdigi:` 1,8 klines — Digitizer.

Sorry: ca 20 % blank lines
included in all numbers

Parallellisation

NEW

- Through process duplication:

  `fork()`

  (no threads – GEANT3/4 need not know)
- Master process distributes event seeds

TODO:

- Combine & sort output data (event “retirement”)
- “Farm-forking” using MPI

Finale!

Thank you!

A great deal of FUN!