LUXE GEANT4 Simulation Output

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GEANT4 simulation output

GEANT4 simulation output:

- File(s) with trees (Ttree):
  - each thread writes it own tree to the file marked with a suffix *_tN.root, where N = 0, 1... is a thread number;
- File with histograms:
  - Same name without suffix. Histograms from different threads are merged in the end of run and saved to a separate root file.

There are 4 trees:

```
[oborysov@naf-ilc11 lxmacro]$ root -l /nfs/dust/ilc/user/oborysov/runjlx/hics/lxsim_hics_48d22e1b/run_2/luxe_hics_signal_165gev_20000nm_cv7emstd_1umstep_tv31_hv1_184_t0.root
root [0]
Attaching file /nfs/dust/ilc/user/oborysov/runjlx/hics/lxsim_hics_48d22e1b/run_2/luxe_hics_signal_165gev_20000nm_cv7emstd_1umstep_tv31_hv1_184_t0.root as _file0...
(TFile *) 0x2315190
root [1] _file0->ls()
TFile**         /nfs/dust/ilc/user/oborysov/runjlx/hics/lxsim_hics_48d22e1b/run_2/luxe_hics_signal_165gev_20000nm_cv7emstd_1umstep_tv31_hv1_184_t0.root
 TFile*         /nfs/dust/ilc/user/oborysov/runjlx/hics/lxsim_hics_48d22e1b/run_2/luxe_hics_signal_165gev_20000nm_cv7emstd_1umstep_tv31_hv1_184_t0.root
  KEY: TTree    lxtsim;1        Bremsstrahlung photons at IP
  KEY: TTree    Tracks;1        Tracks hitting volumes marked for track interception
  KEY: TTree    Hits;1  Hits in sensitive detectors
  KEY: TTree    HitTracks;1     Tracks which produced hits in sensitive detectors
  KEY: TTree    DetSettings;1   Sensitive detector settings
```

Reconstruction:

Energy deposited in sensitive elements of the detectors (hit):
Hit identified by sensitive element (cell_x, cell_y, layer, detector_id)
Cluster collection of hits of the same detector_id and layer presumably related to the same particle

Reconstruction in experiment

Reconstruction approach:

- Energy deposited in sensitive elements of the detectors (hit):
  - Hit identified by sensitive element (cell_x, cell_y, layer, detector_id) and deposited energy (e_dep);
- Cluster collection of hits of the same detector_id and layer presumably related to the same particle (but necessarily);
- Combining clusters and to assign them particle tracks or shower in calorimeter:
  - Clusters needs to be translated to global reference frame.

Output of hits and tracks

```
->CreateNtuple("Hits", "Hits in sensitive detectors");
->CreateNtupleIColumn(2, "eventid");
->CreateNtupleIColumn(2, "detid");
->CreateNtupleIColumn(2, "layerid");
->CreateNtupleIColumn(2, "cellx");
->CreateNtupleIColumn(2, "celly");
->CreateNtupleDColumn(2, "edep");
->CreateNtupleIColumn(2, "hitid");
->CreateNtupleIColumn(2, "track_list", fvHitTrackList);
->CreateNtupleDColumn(2, "trackx", ftrackx);
->CreateNtupleDColumn(2, "tracky", ftracky);
->CreateNtupleDColumn(2, "trackz", ftrackz);
->CreateNtupleDColumn(2, "weight");
->FinishNtuple(2);
```

```
->CreateNtuple("HitTracks", "Tracks which produced hits in sensitive detectors");
->CreateNtupleIColumn(3, "eventid");
->CreateNtupleIColumn(3, "trackid", fvTracks);
->CreateNtupleDColumn(3, "vtxx", fVtxx);
->CreateNtupleDColumn(3, "vtxy", fVtxy);
->CreateNtupleDColumn(3, "vtxz", fVtxz);
->CreateNtupleDColumn(3, "px", fPx);
->CreateNtupleDColumn(3, "py", fPy);
Column(3, "pz", fPz);
Column(3, "E", fE);
Column(3, "pdg", fPDG);
Column(3, "pproc", fPhysProc);
Column(3, "ptid", fPTId);
Column(3, "weight");
3);
```

```
CreateNtuple("DetSettings", "Sensitive detector settings");
CreateNtupleIColumn(4, "detid");
CreateNtupleSColumn(4, "det_name");
CreateNtupleIColumn(4, "layerid");
CreateNtupleIColumn(4, "n_cell_x");
CreateNtupleIColumn(4, "n_cell_y");
CreateNtupleDColumn(4, "size_x");
CreateNtupleDColumn(4, "size_y");
CreateNtupleDColumn(4, "size_z");
CreateNtupleDColumn(4, "translation_x");
CreateNtupleDColumn(4, "translation_y");
CreateNtupleDColumn(4, "translation_z");
CreateNtupleDColumn(4, "e_phi");
CreateNtupleDColumn(4, "e_theta");
CreateNtupleDColumn(4, "e_psi");
CreateNtupleDColumn(4, "mass");
CreateNtupleSColumn(4, "material");
CreateNtupleDColumn(4, "density");
```

MC weight with scaling possibility

```
#-------------------------------------------------------------------------------------------------------------------------------------------
#  Final state particles translated back to IP.
#-------------------------------------------------------------------------------------------------------------------------------------------
#  Electron energy =  17.5000 +/-  1.00% GeV,  Sigma_xyz =     5.00    5.00   24.00 microns,  Emit_xy =     1.40    1.40 mm mrad
#  Laser Intensity =     0.29 x10^18 W/cm^2,  Wavelength =   800.00 nm,  pulse length =    35.00 fs,  spot size =   100.00 micron^2
#  Pulse peak RMS xi =    0.2601,  chi_e =    0.0489
#-------------------------------------------------------------------------------------------------------------------------------------------
#    E (GeV)          x (um)          y (um)          z(um)          beta_x          beta_y          beta_z          PDG_NUM     MP_Wgt
#-------------------------------------------------------------------------------------------------------------------------------------------
   17.489827      -0.25782554      -3.3345040       99.074567      -0.20330518E-09  -0.51889493E-10 0.99999999957319          11  0.600000E+07
   17.509677       -4.1768816       3.7983398       84.873957      -0.18117282E-11  -0.34784953E-11 0.99999999957415          11  0.600000E+07
   17.502719       -3.5429774       0.98079059      176.58908      -0.85629521E-11   0.72966633E-11 0.99999999957381          11  0.600000E+07
   17.486677        8.6149945      -0.77613691      139.35807      -0.30454675E-11   0.12188028E-11 0.99999999957303          11  0.600000E+07
   17.484707        2.2870494      -12.375114       110.07753      -0.20962565E-11   0.49475979E-11 0.99999999957294          11  0.600000E+07
```

Detector Settings Tree

Settings for the sensitive detectors

```
CreateNtuple("DetSettings", "Sensitive detector settings");
CreateNtupleIColumn(4, "detid");
CreateNtupleSColumn(4, "det_name");
CreateNtupleIColumn(4, "layerid");
CreateNtupleIColumn(4, "n_cell_x");
CreateNtupleIColumn(4, "n_cell_y");
CreateNtupleDColumn(4, "size_x");
CreateNtupleDColumn(4, "size_y");
CreateNtupleDColumn(4, "size_z");
CreateNtupleDColumn(4, "translation_x");
CreateNtupleDColumn(4, "translation_y");
CreateNtupleDColumn(4, "translation_z");
CreateNtupleDColumn(4, "e_phi");
CreateNtupleDColumn(4, "e_theta");
CreateNtupleDColumn(4, "e_psi");
CreateNtupleDColumn(4, "mass");
CreateNtupleSColumn(4, "material");
CreateNtupleDColumn(4, "density");
```

```
root [4] DetSettings->Scan("detid:det_name:layerid:n_cell_x:n_cell_y:size_x:size_y:mass:material:density:translation_x:translation_y:translation_z")
************************************************************************************************************************************************************
*    Row    *     detid *  det_name *   layerid *  n_cell_x *  n_cell_y *    size_x *    size_y *      mass *  material *   density * translati * translati * translati *
************************************************************************************************************************************************************
*        0 *      3000 *   LysoCal *         0 *       300 *        25 *       300 *        50 *      2.25 *     LANEX *      7500 *       160 *         0 *     10890 *
*        1 *      3001 *   LysoCal *         0 *       300 *        25 *       300 *        50 *      2.25 *     LANEX *      7500 *      -160 *         0 *     10890 *
*        2 *      4000 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 * 8.512e-15 *  -139.016 * 13279.992 *
*        3 *      4001 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 * 98.299156 * -98.29915 * 13279.992 *
*        4 *      4002 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 *   139.016 *         0 * 13279.992 *
*        5 *      4003 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 * 98.299156 * 98.299156 * 13279.992 *
*        6 *      4004 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 * 8.512e-15 *   139.016 * 13279.992 *
*        7 *      4005 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 * -98.29915 * 98.299156 * 13279.992 *
*        8 *      4006 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 *  -139.016 * 1.702e-14 * 13279.992 *
*        9 *      4007 * LeadGlass *         0 *         1 *         1 *        38 *        38 *  2.508228 *    LG_TF1 *      3860 * -98.29915 * -98.29915 * 13279.992 *
*       10 *      2000 * ECalSenso *         0 *       110 *        11 *       550 *        55 * 0.0225544 *     G4_Si *      2330 *    304.13 *         0 *   4258.54 *
*       11 *      2000 * ECalSenso *         1 *       110 *        11 *       550 *        55 * 0.0225544 *     G4_Si *      2330 *    304.13 *         0 *  4263.042 *
*       12 *      2000 * ECalSenso *         2 *       110 *        11 *       550 *        55 * 0.0225544 *     G4_Si *      2330 *    304.13 *         0 *  4267.544 *
```

Output of hits and tracks

```
->CreateNtuple("Hits", "Hits in sensitive detectors");
->CreateNtupleIColumn(2, "eventid");
->CreateNtupleIColumn(2, "detid");
->CreateNtupleIColumn(2, "layerid");
->CreateNtupleIColumn(2, "cellx");
->CreateNtupleIColumn(2, "celly");
->CreateNtupleDColumn(2, "edep");
->CreateNtupleIColumn(2, "hitid");
->CreateNtupleIColumn(2, "track_list", fvHitTrackList);
->CreateNtupleDColumn(2, "trackx", ftrackx);
->CreateNtupleDColumn(2, "tracky", ftracky);
->CreateNtupleDColumn(2, "trackz", ftrackz);
->CreateNtupleDColumn(2, "weight");
->FinishNtuple(2);
```

```
->CreateNtuple("HitTracks", "Tracks which produced hits in sensitive detectors");
->CreateNtupleIColumn(3, "eventid");
->CreateNtupleIColumn(3, "trackid", fvTracks);
->CreateNtupleDColumn(3, "vtxx", fVtxx);
->CreateNtupleDColumn(3, "vtxy", fVtxy);
->CreateNtupleDColumn(3, "vtxz", fVtxz);
->CreateNtupleDColumn(3, "px", fPx);
->CreateNtupleDColumn(3, "py", fPy);
->CreateNtupleDColumn(3, "pz", fPz);
->CreateNtupleDColumn(3, "E", fE);
->CreateNtupleIColumn(3, "pdg", fPDG);
->CreateNtupleIColumn(3, "pproc", fPhysProc);
->CreateNtupleIColumn(3, "ptid", fPTId);
->CreateNtupleDColumn(3, "weight");
->FinishNtuple(3);
```

MC weight with scaling possibility

SQL query would be:

```
SELECT *
FROM Hits INNER JOIN HitTracks
        ON (Hits.eventid == HitTracks.eventid) AND (Hits.track_list == HitTracks.trackid)
```

Output configuration

```
CreateNtuple("Tracks", "Tracks hitting volumes marked for track interception");
CreateNtupleDColumn(1, "E");
CreateNtupleDColumn(1, "x");
CreateNtupleDColumn(1, "y");
CreateNtupleDColumn(1, "z");
CreateNtupleDColumn(1, "t");
CreateNtupleDColumn(1, "vtxx");
CreateNtupleDColumn(1, "vtxy");
CreateNtupleDColumn(1, "vtxz");
CreateNtupleDColumn(1, "px");
CreateNtupleDColumn(1, "py");
CreateNtupleDColumn(1, "pz");
CreateNtupleDColumn(1, "theta");
CreateNtupleDColumn(1, "phi");
CreateNtupleIColumn(1, "pdg");
CreateNtupleIColumn(1, "physproc");
umn(1, "detid");
umn(1, "xlocal");
umn(1, "ylocal");
umn(1, "zlocal");
umn(1, "eventid");
umn(1, "trackid");
umn(1, "weight");
```

```
/luxe/run/dump_geometry  false

/luxe/run/add_intercept_volume  OpppDetContainer:1000
/luxe/run/add_intercept_volume  ComptonDetContainer:2000
/luxe/run/add_intercept_volume  GammaCalo:3000
/luxe/run/add_intercept_volume  Shielding:4000

/run/initialize

/luxe/run/add_sensitive_volume  OpppTracker:1000:1:0
/luxe/run/add_sensitive_volume  ComptonTracker:2000:1:0
/luxe/run/add_sensitive_volume  GammaCalo:3000:1:0
```

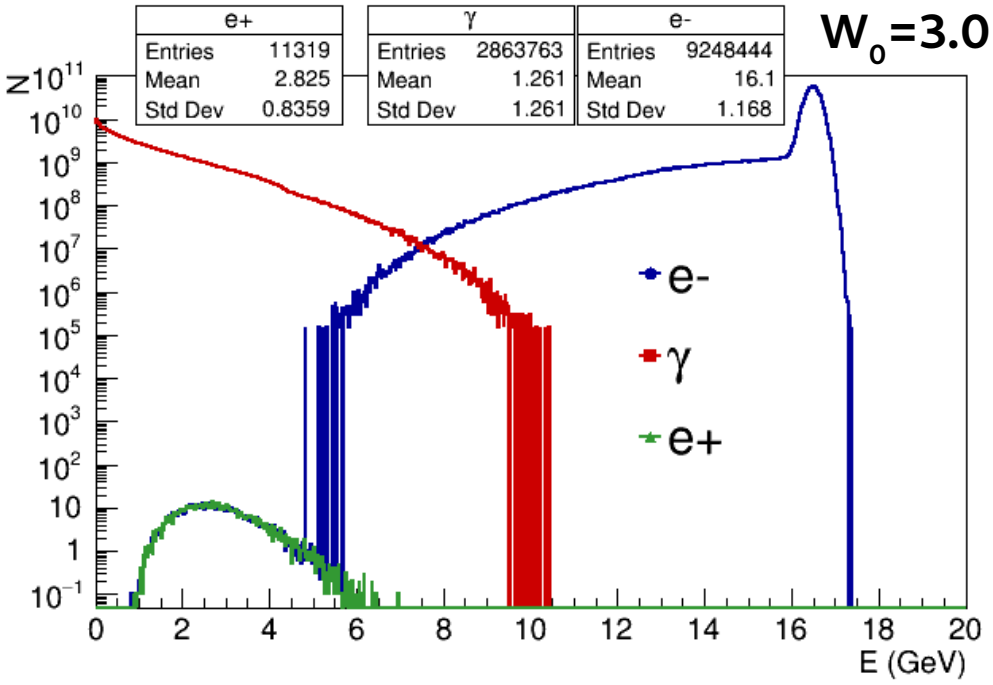
```
->CreateNtuple("DetSettings", "Sensitive detector settings");
->CreateNtupleIColumn(4, "detid");
->CreateNtupleSColumn(4, "det_name");
->CreateNtupleIColumn(4, "layerid");
->CreateNtupleIColumn(4, "n_cell_x");
->CreateNtupleIColumn(4, "n_cell_y");
->CreateNtupleDColumn(4, "size_x");
->CreateNtupleDColumn(4, "size_y");
->CreateNtupleDColumn(4, "size_z");
->CreateNtupleDColumn(4, "translation_x");
->CreateNtupleDColumn(4, "translation_y");
->CreateNtupleDColumn(4, "translation_z");
->CreateNtupleDColumn(4, "e_phi");
->CreateNtupleDColumn(4, "e_theta");
->CreateNtupleDColumn(4, "e_psi");
->FinishNtuple(4);
```

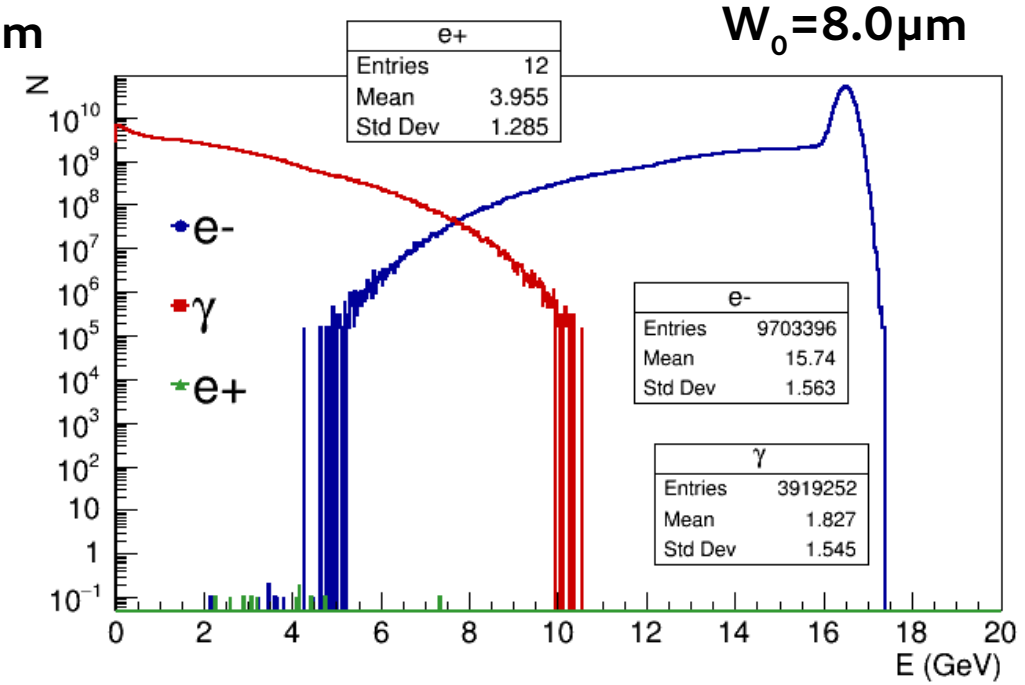
Spectra

Aug 2020 Data Runs, bunch/pulse crossings completed

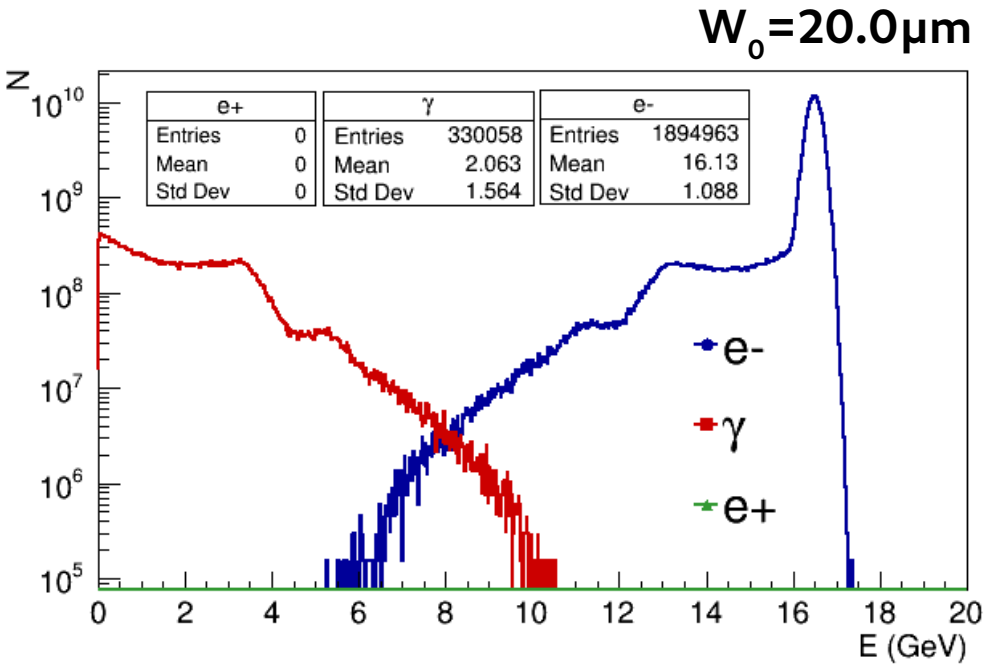
Experiment Config	$w_0 = 3\mu$m	$w_0 = 3.5\mu$m	$w = 0, 4.0\mu$m	$w_0 = 4.5\mu$m	$w_0 = 5.0\mu$m	$w_0 = 8.0\mu$m	$w_0 = 20.0\mu$m	$w_0 = 50.0\mu$m	$w_0 = 100.0\mu$m
peak SQED ξ	5.12	4.44	3.88	3.45	3.1	1.94	0.78	0.31	0.15
peak SQED χ (16.5 GeV)	0.9	0.79	0.69	0.61	0.55	0.34	0.138	0.055	0.028
JETI40 e-laser 16.5 GeV	939	951	946	949	938	1000	193	200	200
JETI40 e-laser 17.5 GeV	639	1000	1000	1000	1000	500			
JETI40 g-laser 16.5 GeV	1000	1000	999	1000	1000	1000			
JETI40 g-laser 17.5 GeV									
JETI40 misalignments									
JETI40 mCP production									

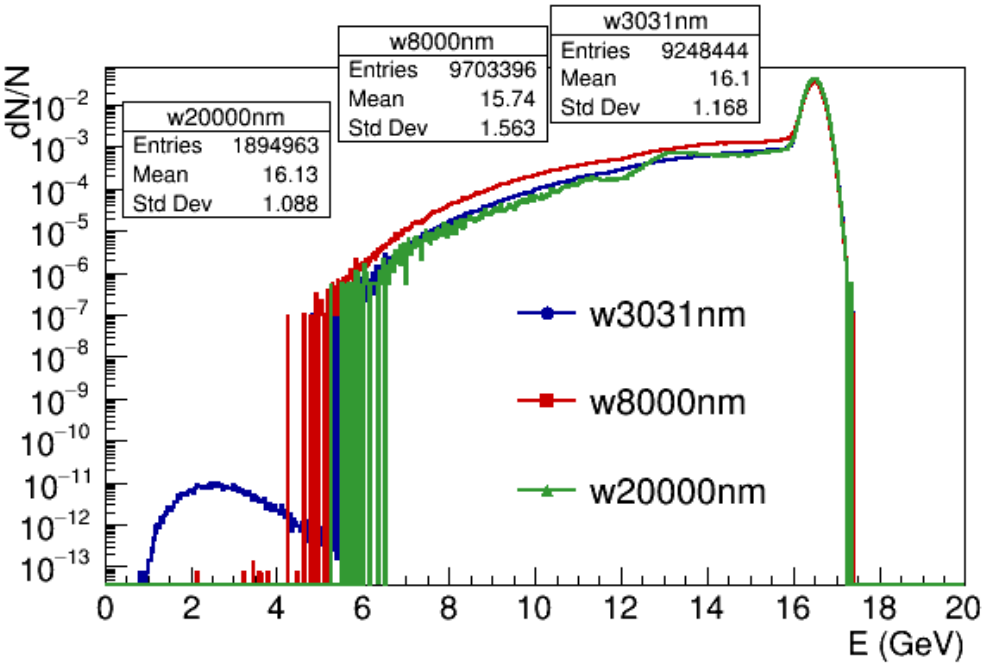
/afs/desy.de/group/flc/luxe/IPstrong_V1.1.00/JETI40/e_laser/16.5GeV/w0_3031nm
/afs/desy.de/group/flc/luxe/IPstrong_V1.1.00/JETI40/e_laser/16.5GeV/w0_8000nm

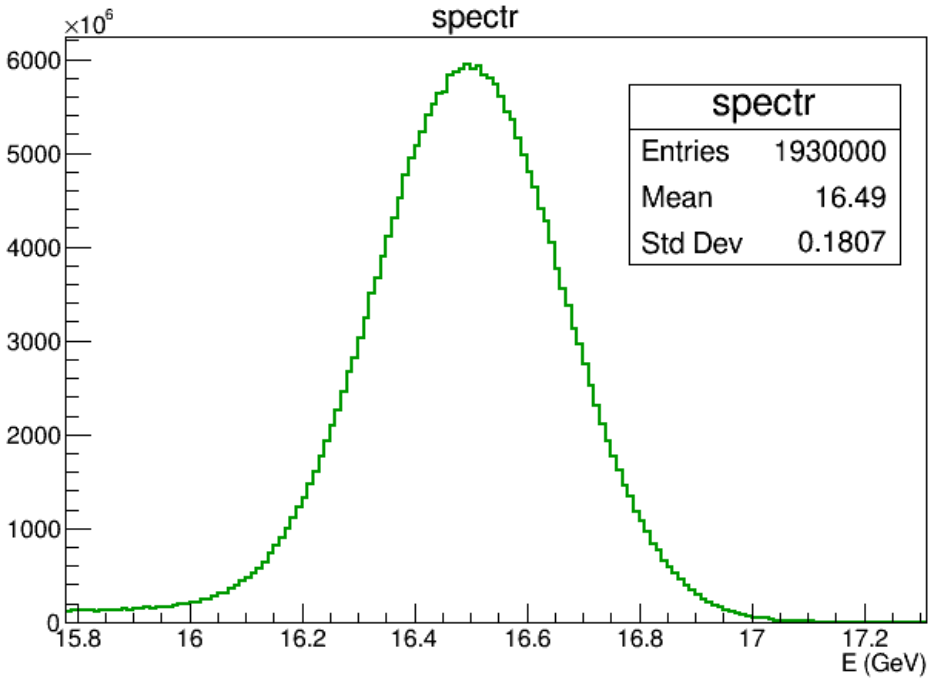


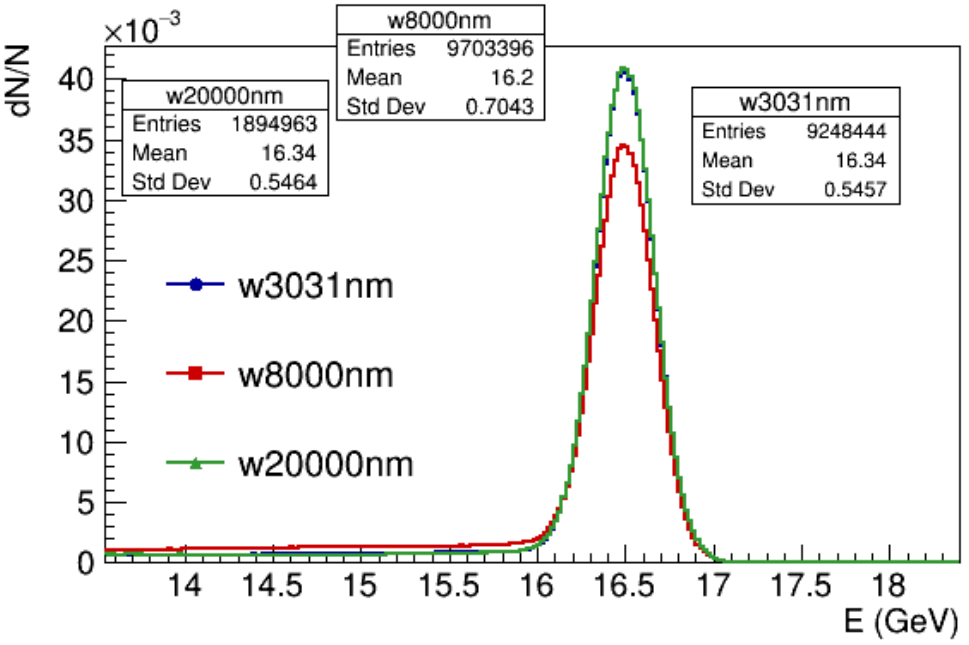


HICS spectra for different laser beam spot size









Backup

GEANT4 Simulation code

Repository:

https://stash.desy.de/projects/LXSIM/repos/lxsim/browse

git clone https://user_name@stash.desy.de/scm/lxsim/lxsim.git

Environment on naf:

```
. /cvmfs/sft.cern.ch/lcg/releases/LCG_97/Geant4/10.06.p01/x86_64-centos7-gcc8-opt/Geant4-env.sh
. /cvmfs/sft.cern.ch/lcg/releases/LCG_97/Geant4/10.06.p01/x86_64-centos7-gcc8-opt/bin/geant4.sh
# use cmake /cvmfs/sft.cern.ch/lcg/releases/LCG_97/CMake/3.14.3/x86_64-centos7-gcc8-opt/bin/cmake
```

```
cmake ./
make
```

```
./lxbeamsim  luxe_e_gamma.mac  1
```

Number of parallel threads

Runs simulation as configured in luxe_e_gamma.mac

```
./lxbeamsim
```

Usually starts qt GUI and then command
/control/execute vis_ev_e_v1.mac
opens geometry viewer/browser

Primary beam settings

```
# Primary beam settings
##########################################
#
#/lxphoton/gun/setDefault
#/lxphoton/gun/beamType    mono

#/lxphoton/gun/beamType    gaussian
#/lxphoton/gun/setSigmaX   5 um
#/lxphoton/gun/setSigmaY   5 um
#/lxphoton/gun/setFocus    8.1 m

/lxphoton/gun/beamType    mc
/lxphoton/gun/MCParticlesFile   test_data_0.out

#/lxphoton/gun/SpectraFile   spectra_test1.txt
#/lxphoton/gun/SpectraFile   spectra_test_compt.txt

/gun/particle    e-
/gun/energy      17.5 GeV
```

Fixed momentum beam

XFEL beam with fixed emittance and given $\sigma_{x,y}$ and focusing distance.

MC, typically Anthony's out file

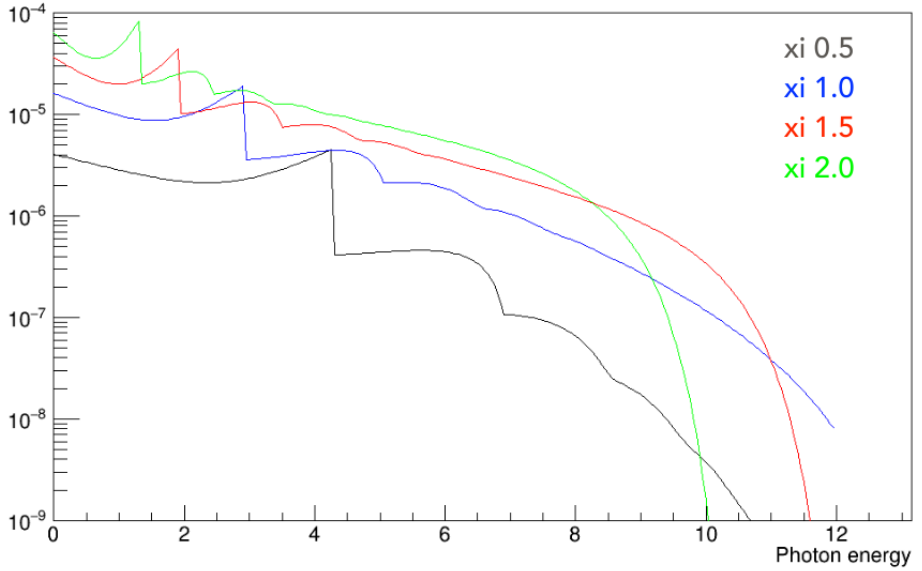
Arbitrary spectra which will be interpolated and used for generating particles

Ignored for MC

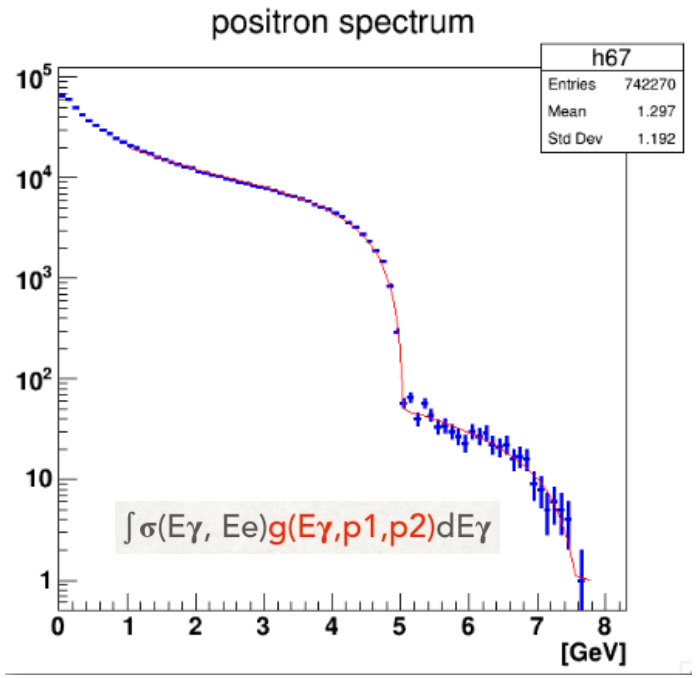
Primaries with a given spectra

Photon detector performance study w/o MC

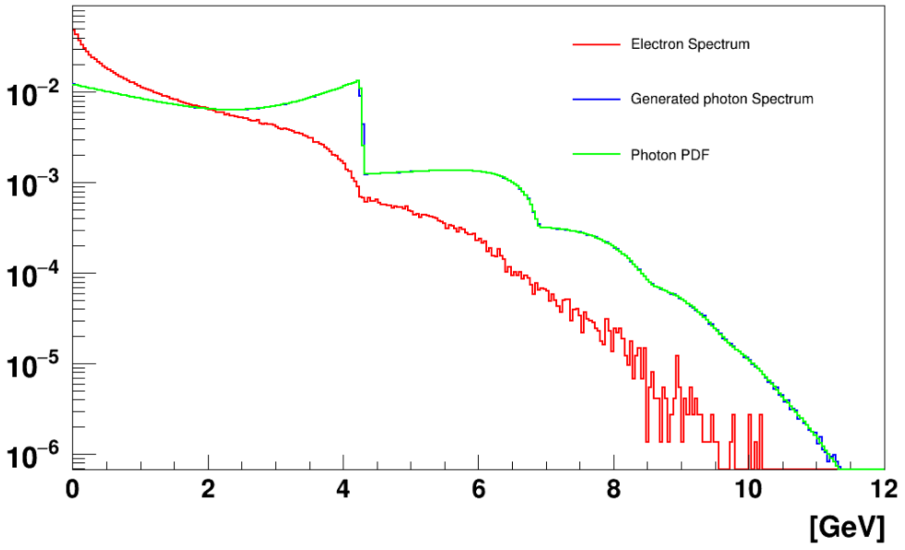
HICS spectra as tabulated function calculated by Anthony



GEANT4, primary and positrons after the target



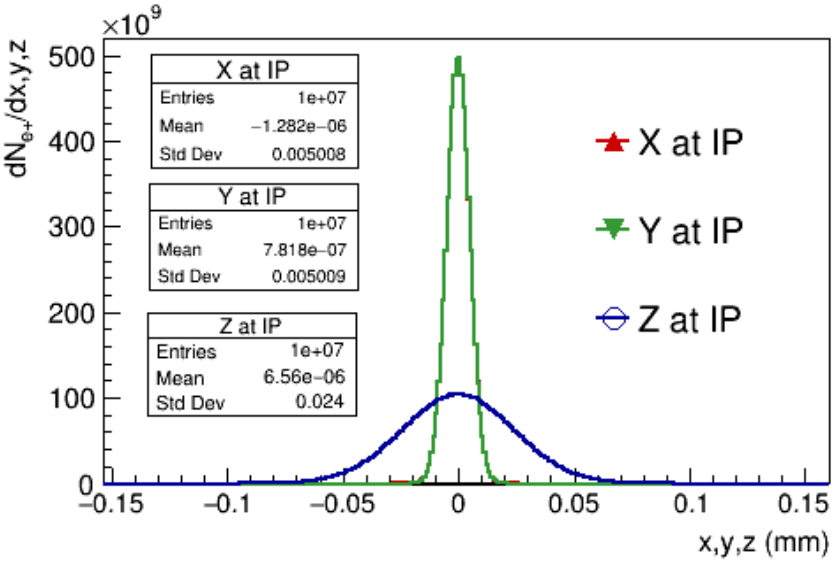
GAMMA AND ELECTRON SPECTRA FOR XI=0.5



Gaussian beam

$$f(x,x',z) = \frac{1}{2\pi\varepsilon}\exp\left[-\frac{(x-zx')^2}{2\varepsilon\beta^*} - \frac{\beta^* x'^2}{2\varepsilon}\right]$$

$$\beta^* = \frac{\sigma^{*2}}{\varepsilon},$$



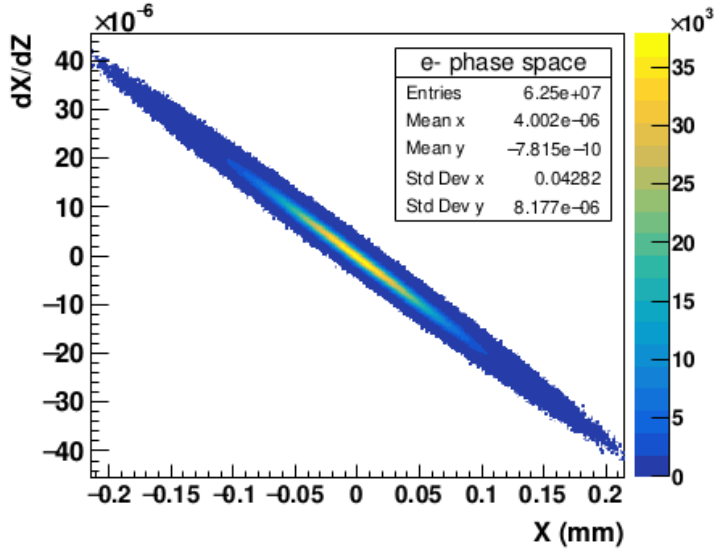


Figure 2: Phase space distribution of the primary electron beam 5.2 m upstream from interaction point.

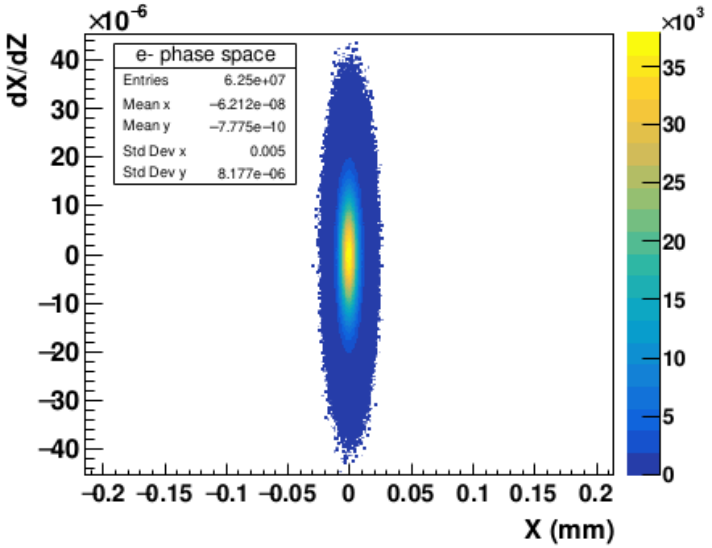


Figure 3: Phase space distribution of the electron beam at the interaction point.

Physics list settings

```
# Simulation settings
############################################
/lxphoton/phys/addPhysics  emstandard_opt0
#/lxphoton/phys/addPhysics local

/lxphoton/stepMax       1 um
#/lxphoton/stepMax       10 um
#
/run/setCut             1 um
#
```

```
if (name == "local") {
  AlterPhysicsList(name, new PhysListEmStandard(name));

} else if (name == "emstandard_opt0") {
  AlterPhysicsList(name, new G4EmStandardPhysics());

} else if (name == "emstandard_opt1") {
  AlterPhysicsList(name, new G4EmStandardPhysics_option1());

} else if (name == "emstandard_opt2") {
  AlterPhysicsList(name, new G4EmStandardPhysics_option2());

} else if (name == "emstandard_opt3") {
  AlterPhysicsList(name, new G4EmStandardPhysics_option3());

} else if (name == "emstandard_opt4") {
  AlterPhysicsList(name, new G4EmStandardPhysics_option4());

} else if (name == "emstandardSS") {
  AlterPhysicsList(name, new G4EmStandardPhysicsSS());

} else if (name == "standardSSM") {
  AlterPhysicsList(name, new PhysListEmStandardSSM());

} else if (name == "emstandardWVI") {
  AlterPhysicsList(name, new G4EmStandardPhysicsWVI());

} else if (name == "standardGS") {
  AlterPhysicsList(name, new PhysListEmStandardGS());

} else if (name == "empenelope"){
  AlterPhysicsList(name, new G4EmPenelopePhysics());

} else if (name == "emlowenergy"){
  AlterPhysicsList(name, new G4EmLowEPPhysics());

} else if (name == "emlivermore"){
  AlterPhysicsList(name, new G4EmLivermorePhysics());

} else {

  G4cout << "PhysicsList::AddPhysicsList: <" << name << ">"
         << " is not defined"
         << G4endl;
}
```

Visualization attributes

Nothing is in the code,
All settings for visualization are in mac files (essentially in one file vis_lx_color.mac)

vis_ev_e_v1.mac

```
# Draw geometry in surface mode with colors settings
/control/execute vis_lx_color.mac
```

vis_lx_color.mac

```
/control/alias bpipeColor   "0.5  0.5  0.5  1.0"
/control/alias vacuumColor  "0.0  0.4  0.4  1.0"
#/control/alias vacuumVisibility false
/control/alias vacuumVisibility true
/control/alias containerVisibility false
#/control/alias containerVisibility true
/control/alias containerColor  "0.3  0.3  0.3  0.0"
/control/alias bpipeWindowColor "0.0  0.9  0.9  0.8"
/control/alias fieldVolumeVisibility true
/control/alias fieldVolumeColor  "0.3  0.3  0.3  0.3"

/vis/viewer/set/style surface

/vis/viewer/set/lightsThetaPhi 130 30 deg

# Logical volumes settings
############################
```

.....

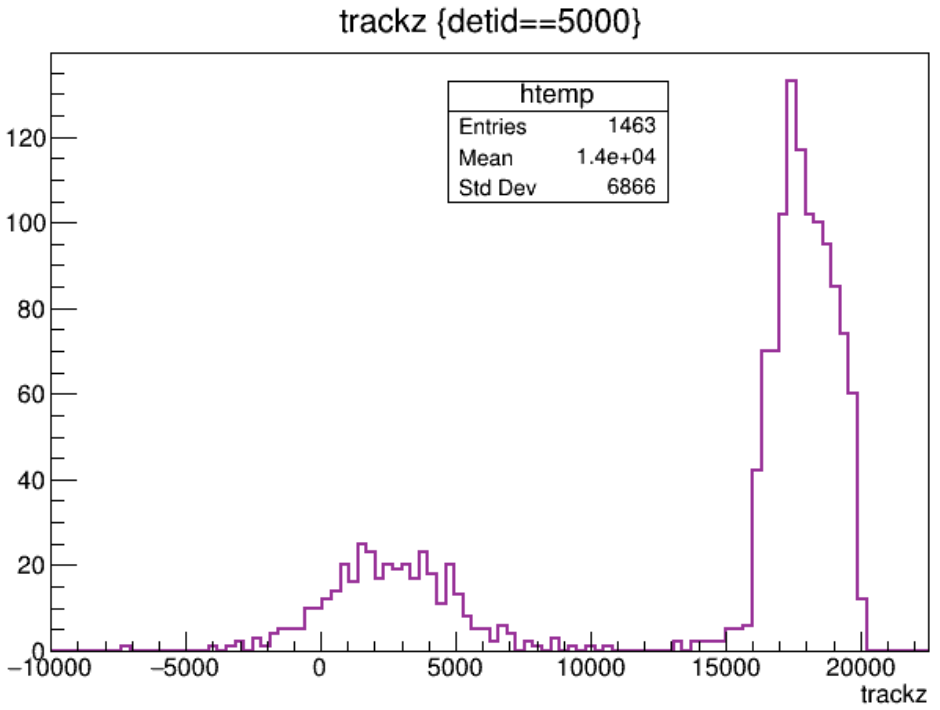
```
/control/loop ip_chmber_color.mac section 0 8 1
```

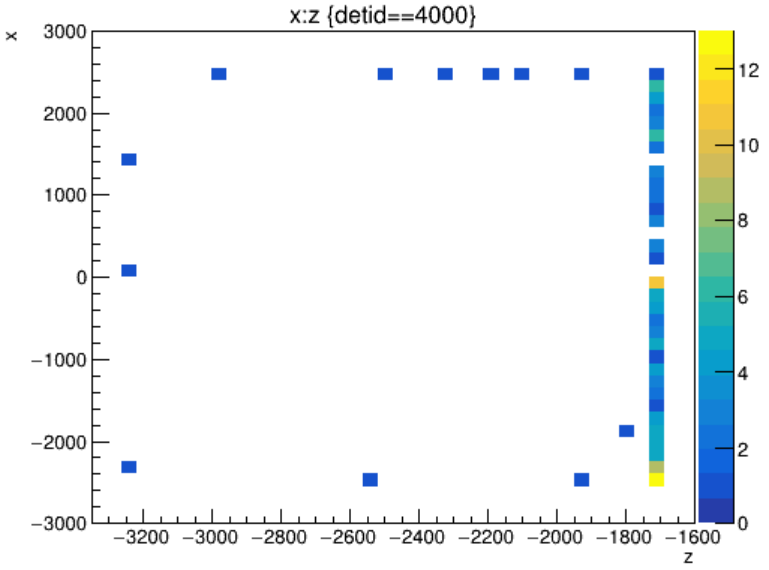
Simulation example

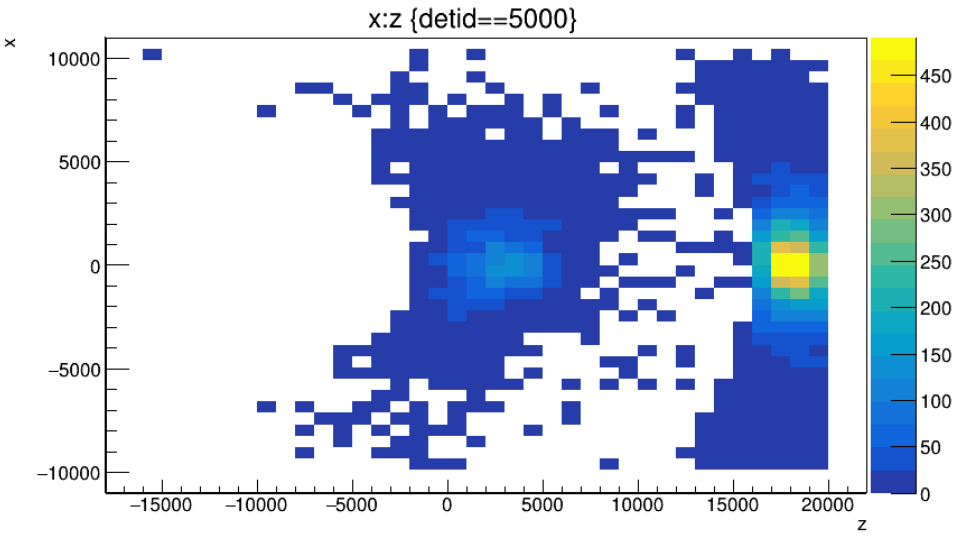
```
/luxe/run/add_intercept_volume  OpppDetContainer:1000
/luxe/run/add_intercept_volume  ComptonDetContainer:2000
/luxe/run/add_intercept_volume  GammaCalo:3000
/luxe/run/add_intercept_volume  Shielding:4000
/luxe/run/add_intercept_volume  Floor:5000

/run/initialize

/luxe/run/add_sensitive_volume  OpppTracker:1000:1:0
/luxe/run/add_sensitive_volume  ComptonTracker:2000:1:0
/luxe/run/add_sensitive_volume  GammaCalo:3000:1:0
/luxe/run/add_sensitive_volume  Shielding:4000:1:0
/luxe/run/add_sensitive_volume  Floor:5000:1:0
```







Add detector

```
#include "LxDetector.hh"

class LxDetectorGammaCalo: public LxDetector
{
  public:
    LxDetectorGammaCalo(DetectorConstruction *detc = 0): LxDetector(detc) {};
    virtual ~LxDetectorGammaCalo() {};
    virtual void Construct();

  protected:
    void AddSegmentation();
};
```

```
void DetectorConstruction::ConstructLuxeDetectors()
{
  fDetList["OpppDet"] = new LxDetectorOPPP(this);
  fDetList["ComptonDet"] = new LxDetectorCompton(this);
  fDetList["GammaDet"] = new LxDetectorGammaCalo(this);

  for (auto &nd : fDetList) { nd.second->Construct(); }
}
```