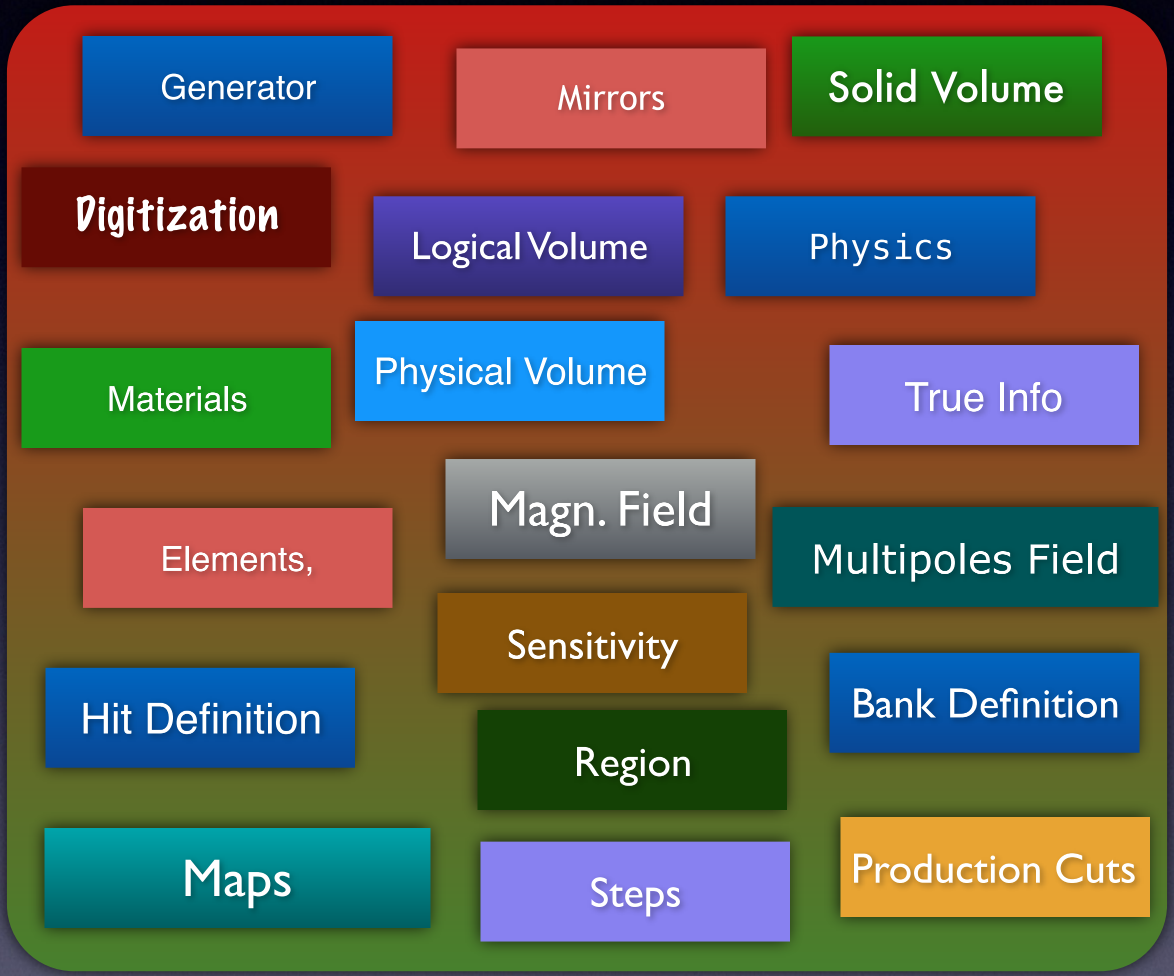
GEant4 Monte Carlo

Overview/Outlook of the GEMC framework

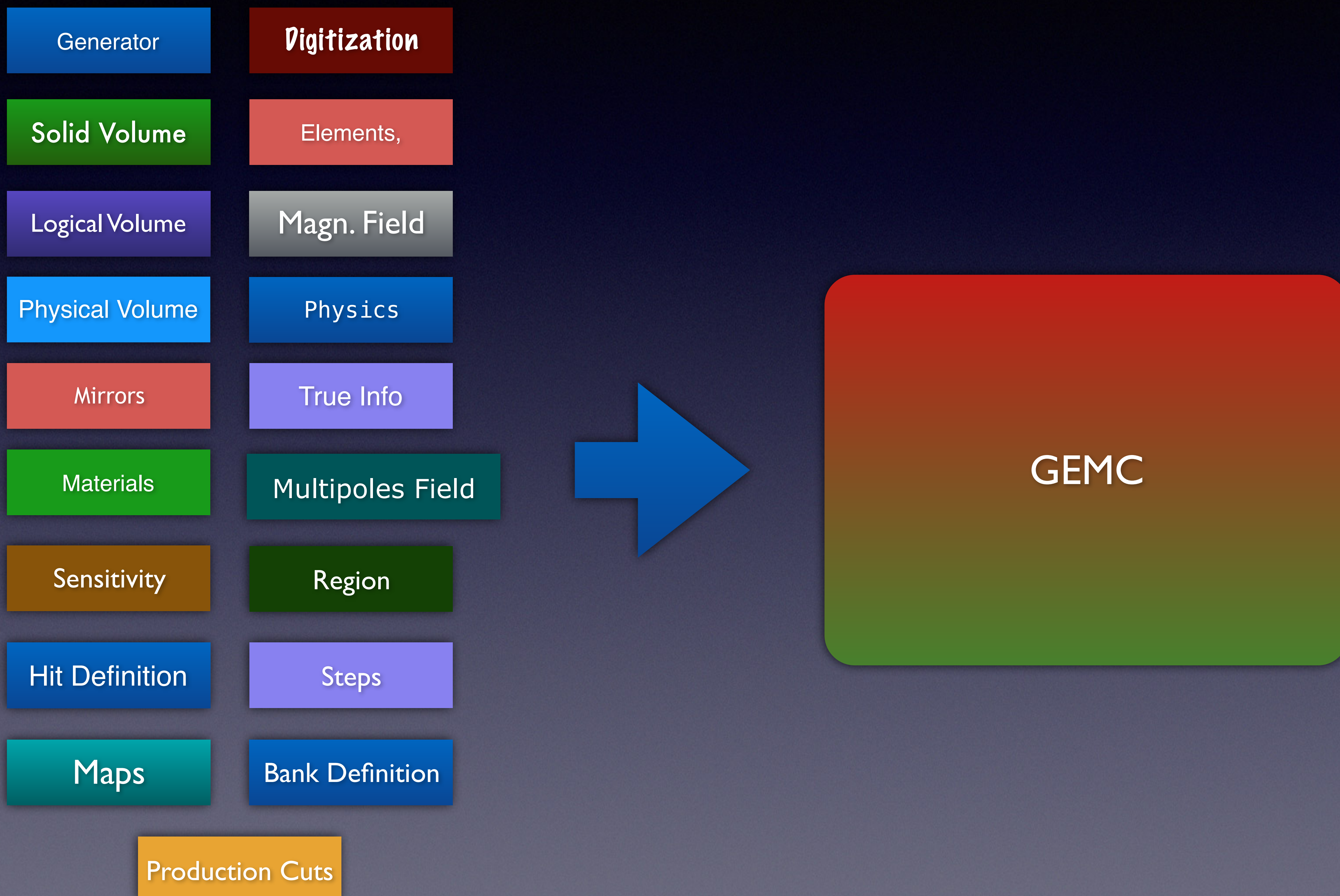
gemc portfolio



Ingredients to cook a geant4 simulation

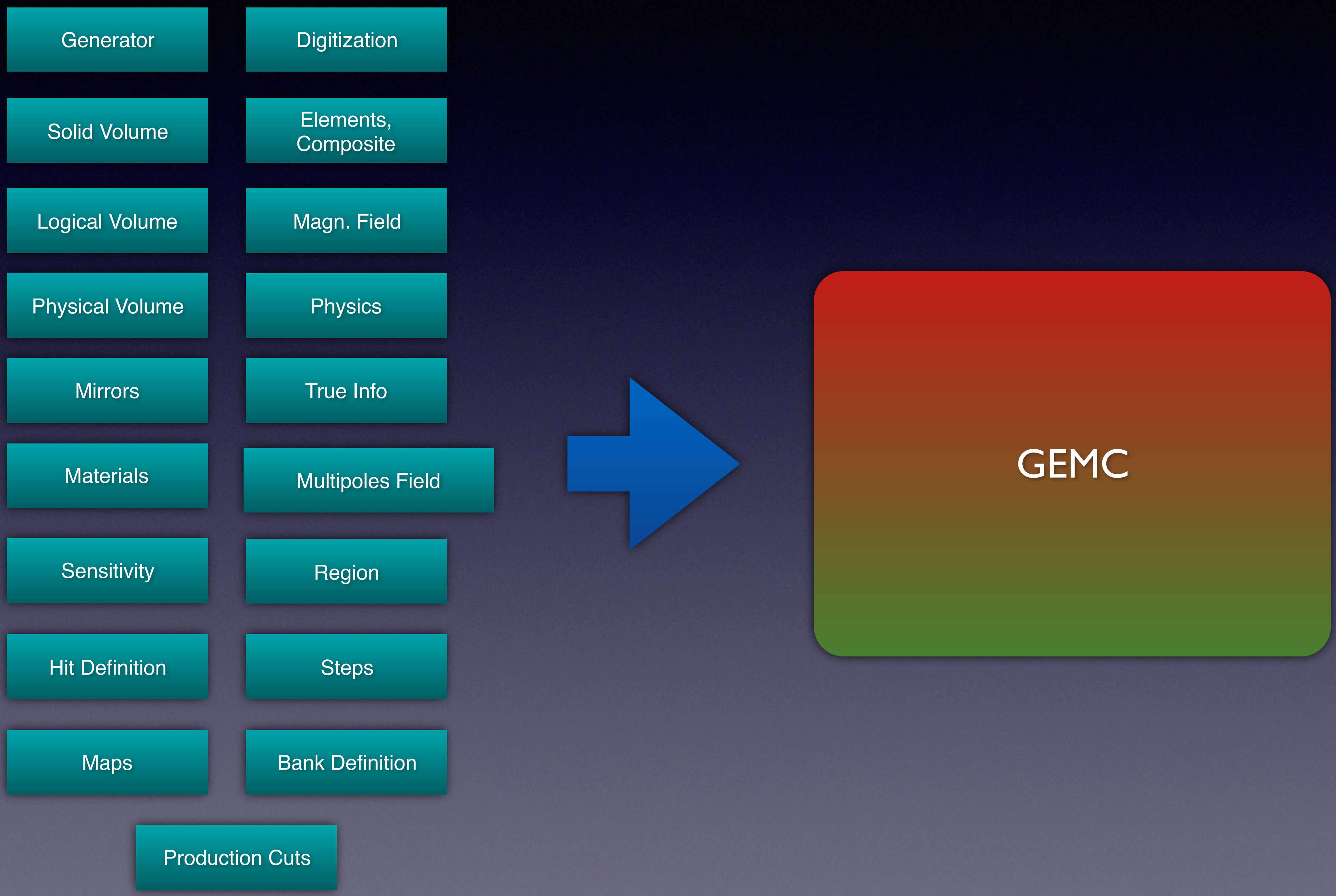
gemc portfolio

abstraction of "detector" to table of parameters



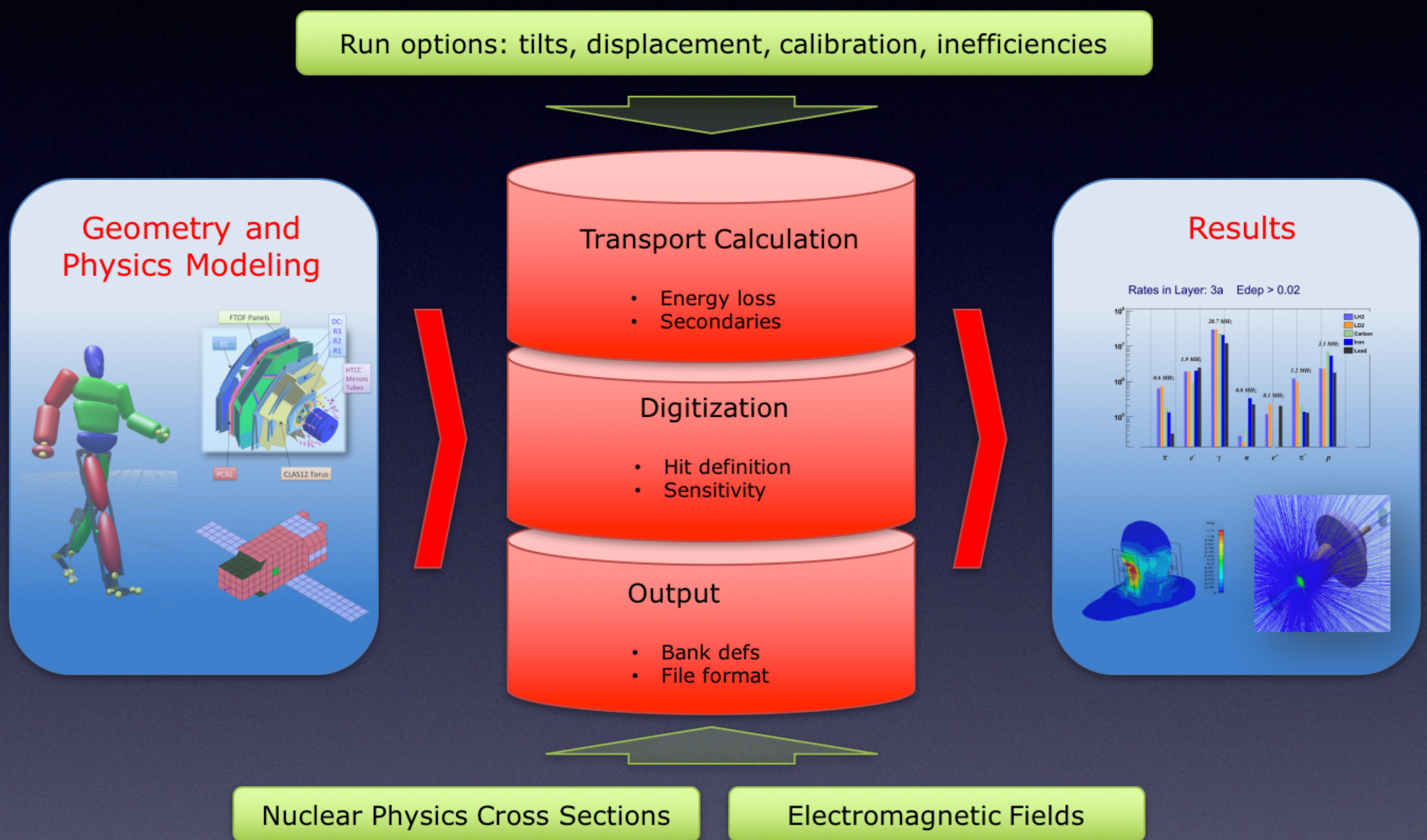
gemc 2 portfolio

standardized api for all components



gemc core blind to detector details

geometry

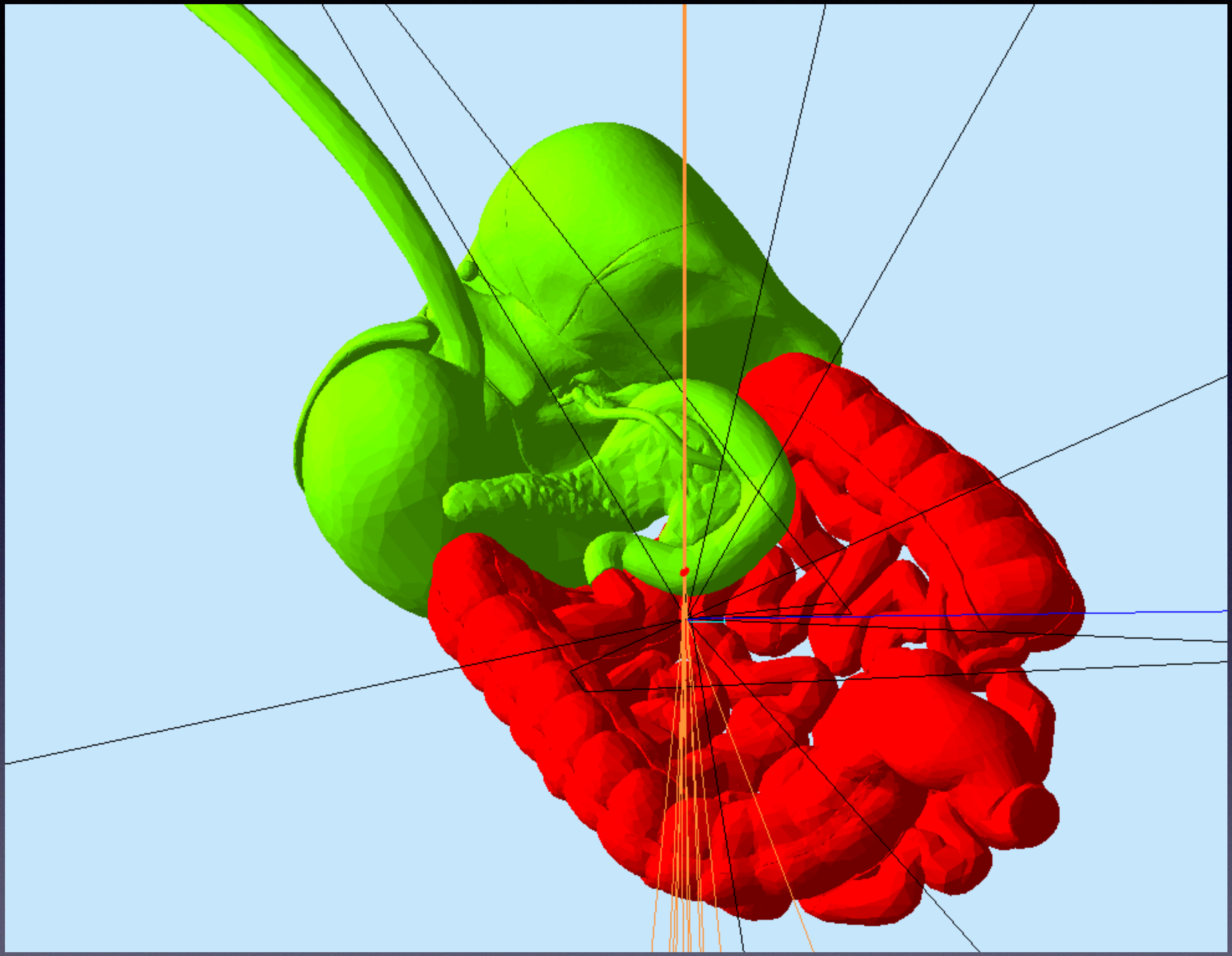


The architecture of gemc

- Complete description of a detector outside code.
- detector is a c++ "object"
- current APIs:
  - perl
  - python (almost completed)
  - java (working prototype for CLAS)
  - wanted: root?

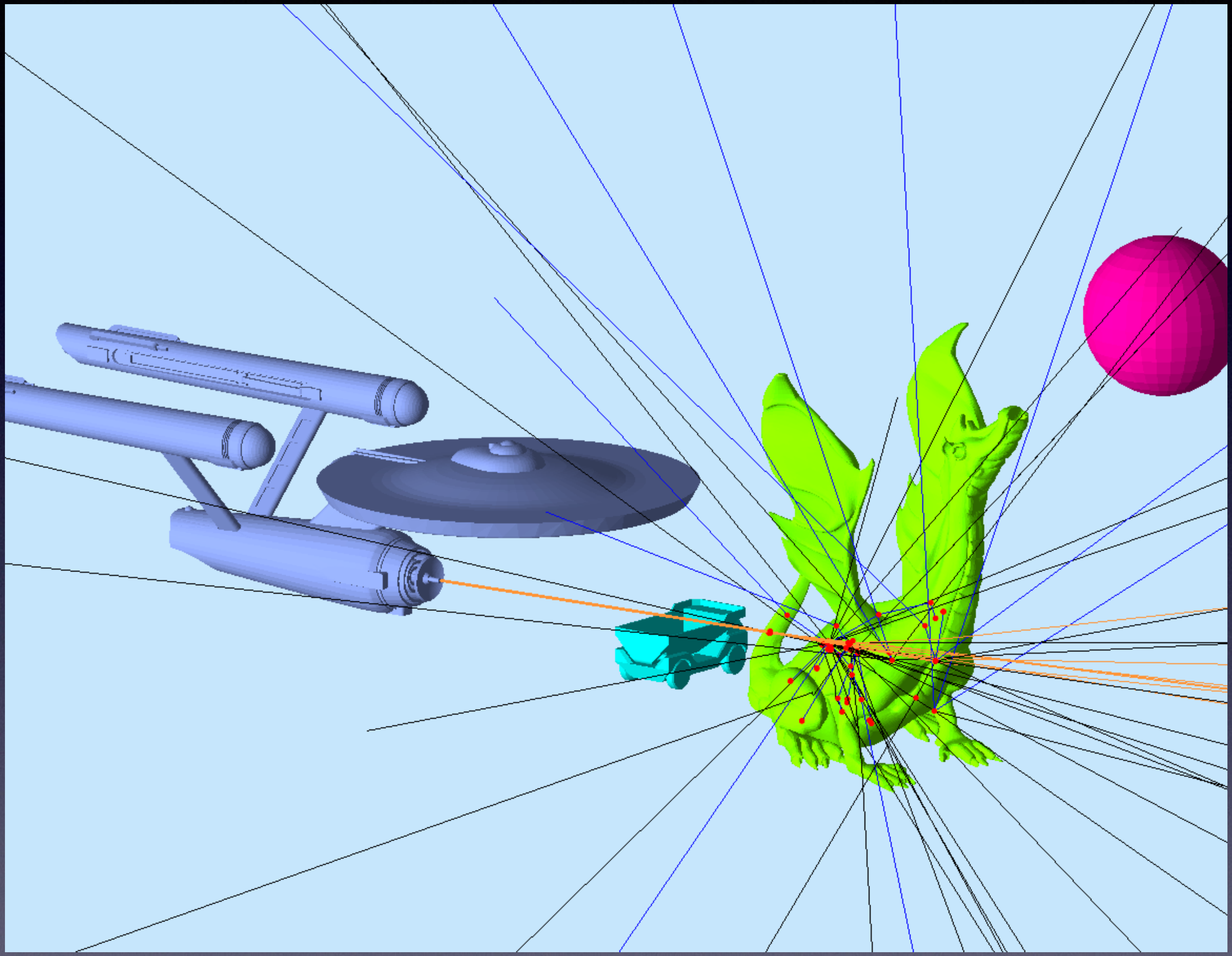
Geometry Database: CAD (STL, PLY, OBJ), GDML, TEXT and MYSQL.

geometry examples



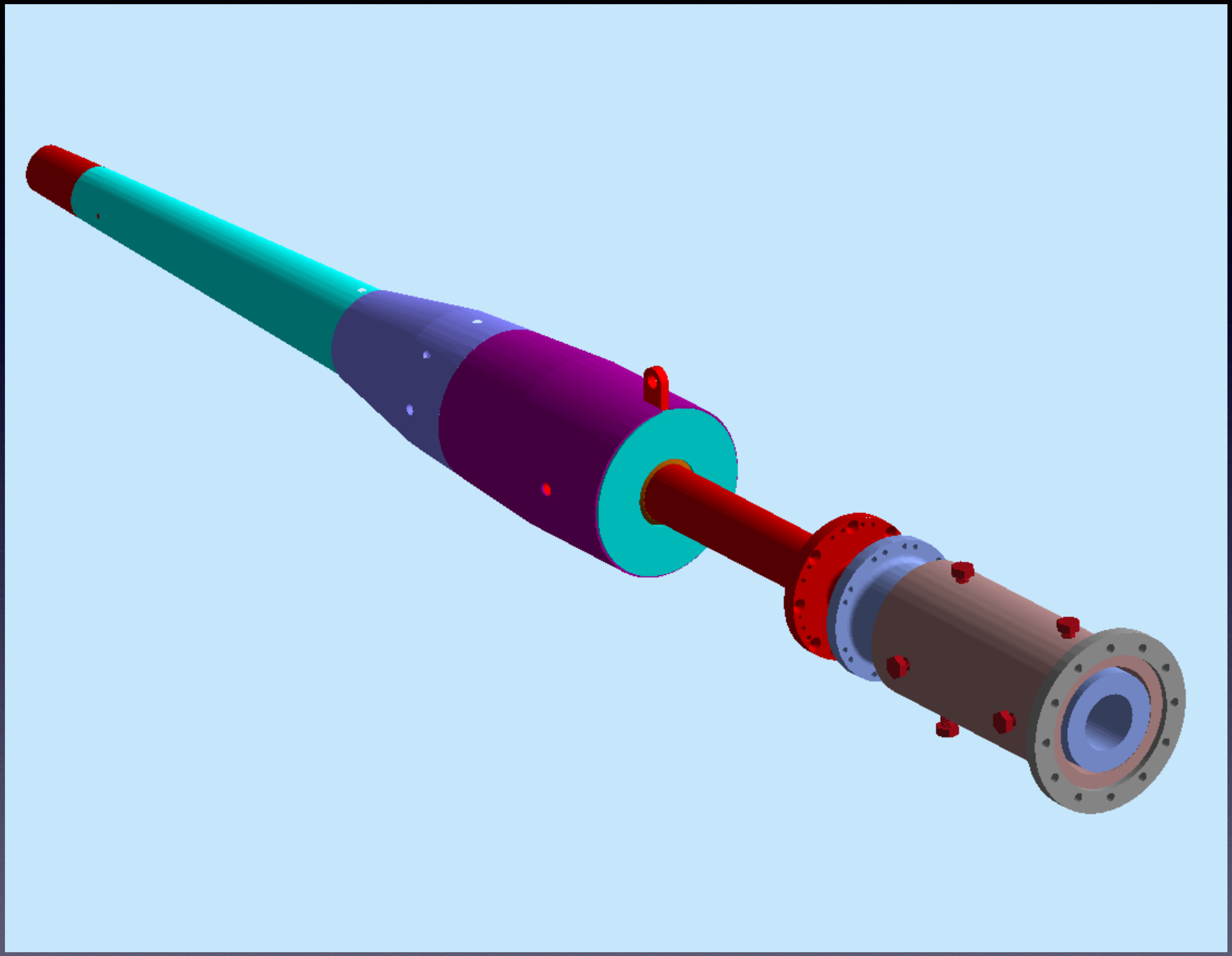
CAD: objects can be made sensitive at run time.
Many attributes (material, mother volume, position, rotation, touchable ID) can be assigned at run time.

geometry examples



A CAD Enterprise shooting a “sensitive” CAD dragon while a GDML truck and a GDML sphere are watching.

geometry examples



Beam line, support and shielding imported directly from the engineering model (STEP files)

geometry examples

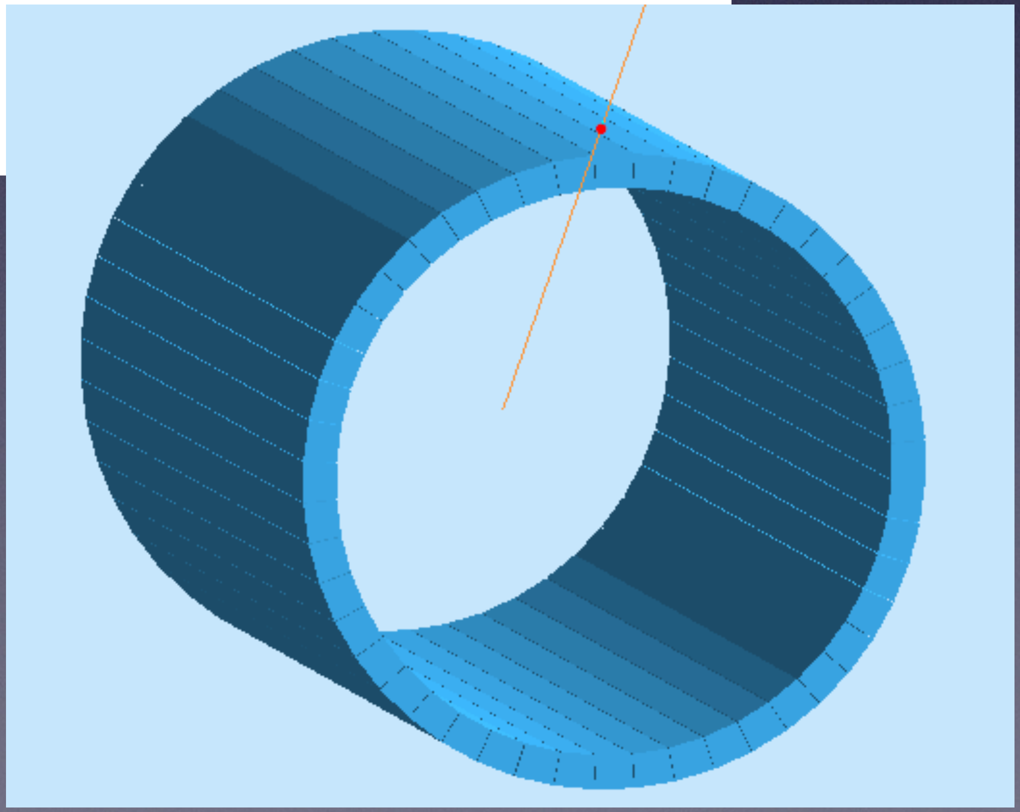
```
my $dtheta  = 360/$NUM_BARS
my $R = 25;

for(my $n=1; $n<=$NUM_BARS; $n++)
{
        my %detector = init_det();

        $detector{"name"}       = "paddle_$n";
        $detector{"type"}       = "Trd";
        $detector{"dimensions"} = "1.8*cm 1.5*cm 32*cm 32*cm 1.6*cm";

        # positioning based on $R
        my $theta  = ($n-1)*$dtheta;
        my $x      = sprintf("%.3f", $R*cos(rad($theta)));
        my $y      = sprintf("%.3f", $R*sin(rad($theta)));
        my $z      = "0";
        $detector{"pos"}        = "$x*cm $y*cm $z*cm";

        # rotate the trapezoid by 90 degrees
        my $theta2 = $theta + 90;
        $detector{"rotation"}   = "90*deg $theta2*deg 0*deg";

        print_det(\%configuration, \%detector);
}
```

Unique name

Trapezoid dimensions

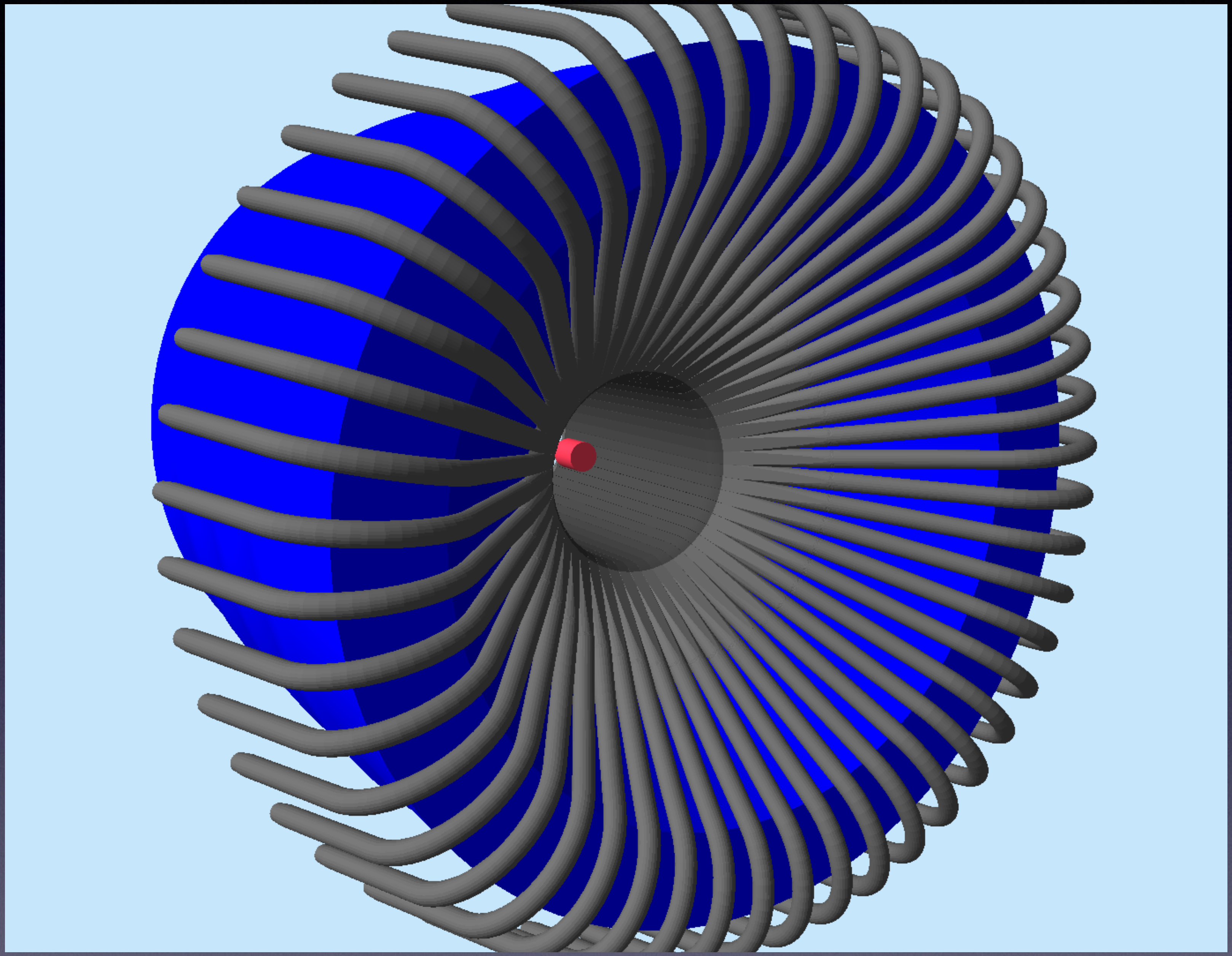
Position azimutally at r=$R

Rotate 90 deg so small base is the closest to the beam



Macro that produces geant4 trapezoid array.

geometry examples



Scintillator array + light guides imported directly from the engineering model (STEP files). The scintillators are much more complicated than simple trapezoids. The scintillators and light guides are impossible to describe using geant4 volumes.

geometry

Load geometry from different factories:

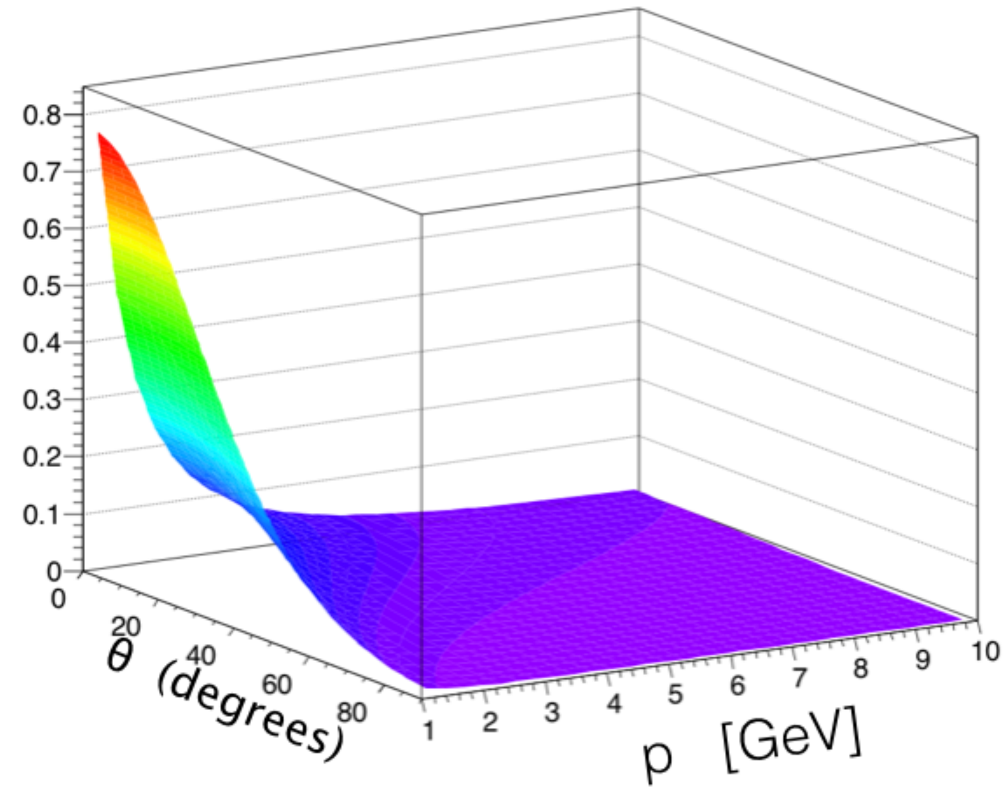
```
<detector name="drift_chambers" factory="TEXT" variation="lH2"/>
<detector name="target" factory="GDML"/>
<detector name="beamline/" factory="CAD"/>
```

Cosmic Ray Model

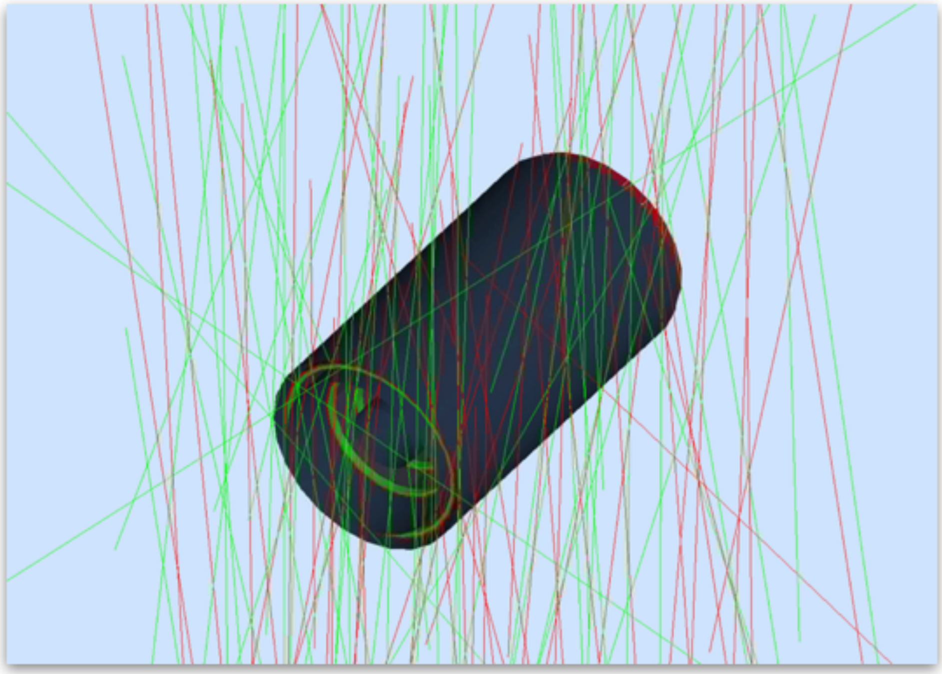
$$\frac{a^{cos(b*\theta)}}{p^2}$$

a =55.6
b=1.04
c=64
p >1 GeV

A. Dar, Phys.Rev.Lett, 51,3,p.227 (1983)



GEMC:
define parameters (or use "default"), p range
define target "AREA"
(x, y, z), R



Luminosity

Generating Background

To add background coming from the beam the following quantities must be defined

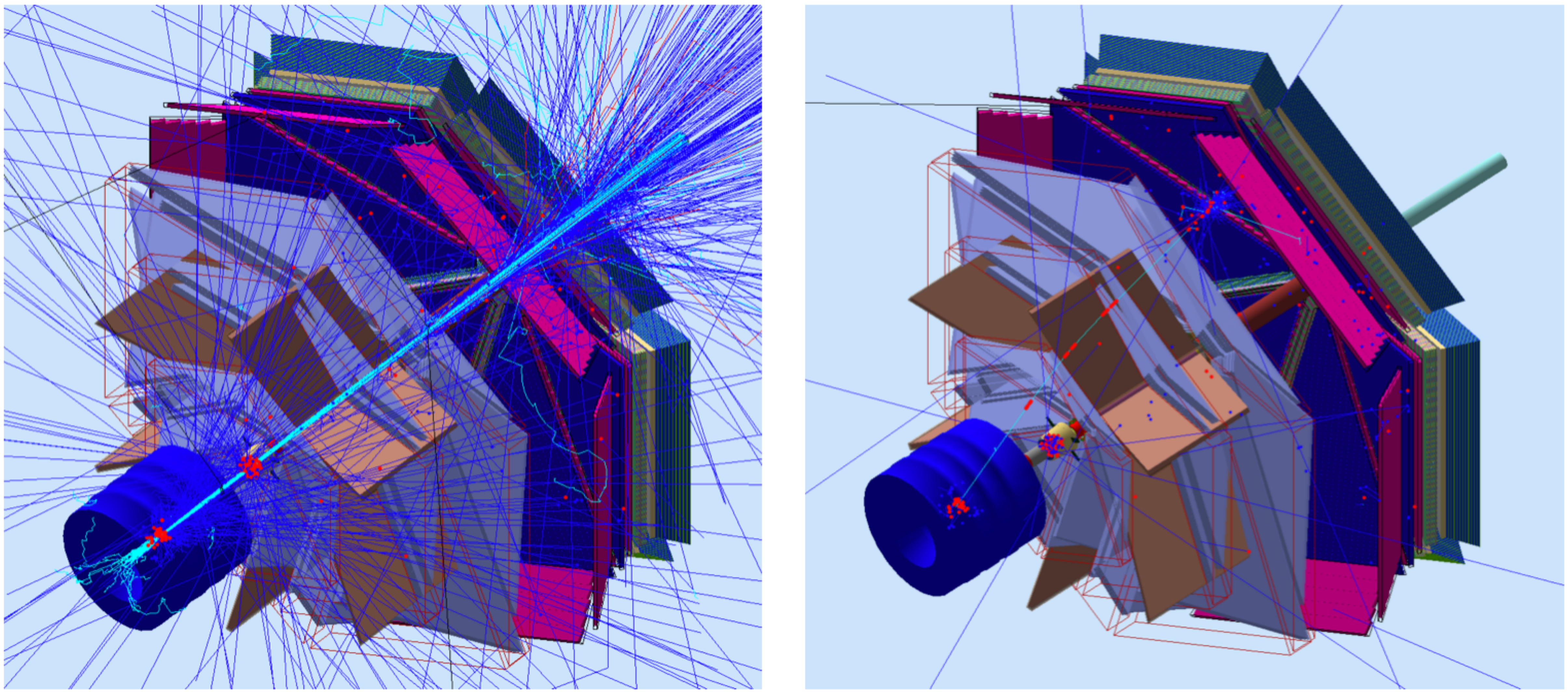
1. a time window: the total time of one event
2. the number of beam particles for each event
3. the number of beam bunches

These quantities are defined with the **LUMI_EVENT** option. For example for clas12 10^{35} luminosity on 5cm LH2 target:

```
<option name="LUMI_EVENT"      value="124000, 250*ns, 2*ns" />
<option name="LUMI_P"          value="e-, 11*GeV, 0*deg, 0*deg" />
<option name="LUMI_V"          value="(0.,0.,-10.)cm" />
<option name="LUMI_SPREAD_V"   value="(0.01, 0.01)cm" />
```

Adds 124000 e- in 250 ns time window, grouped in 2 ns bunches. That would produce 125 bunches with 992 particles each bunch. The beam is 100 micron wide and starts 10 cm upstream of the center of the target.

generating / merging background



3 GeV e- at 20 degrees merged with **realistic** background hits

generated background (slow) merged background (100x faster)

electronic noise

User implementation:

```
MHit* thisNoiseHit = new MHit(E, T, IDF, pid);
```

energy time identifier pid

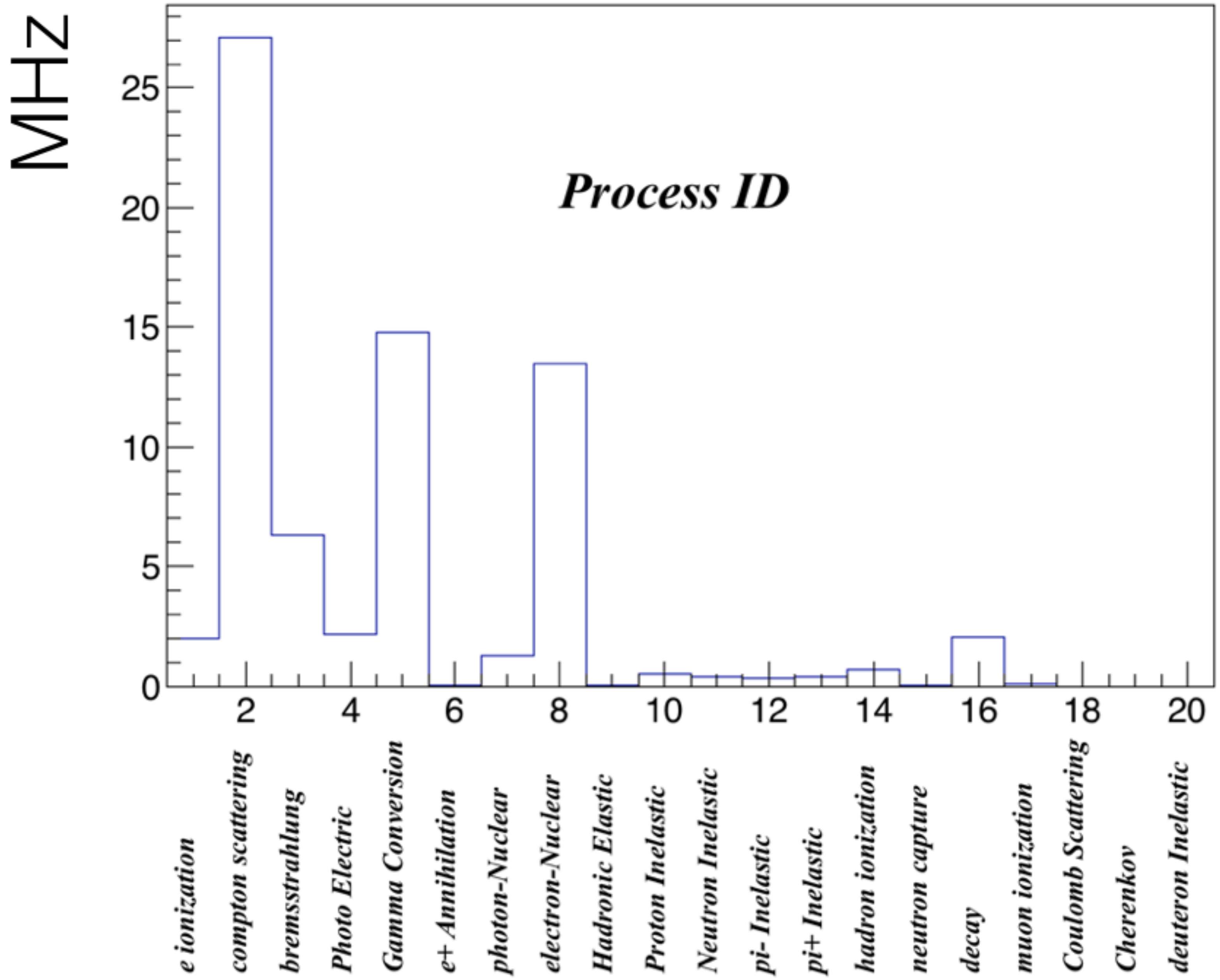
Electronic noise hits are added to the normal geant4 hits. Each process routine will have them available in the output.

Process Catalogue

Process Name	ID (int)
e ionization	1
compton scattering	2
e bremsstrahlung	3
Photo Electric Effect	4
Gamma Conversion	5
e+ Annihilation	6
photon-Nuclear	7
electron-Nuclear	8
positron-Nuclear	9
Hadronic Elastic	10
Proton Inelastic	11
Neutron Inelastic	12
pi- Inelastic	13
pi+ Inelastic	14
hadron ionization	15
neutron capture	16
decay	17
muon ionization	18
Coulomb Scattering	19
Cherenkov	20
deuteron Inelastic	21
muPairProd	22
ion ionization	23
hadron pair production	24
triton Inelastic	25
kaon- Inelastic	26
kaon+ Inelastic	27
kaon0 Inelastic	28
kaon0L Inelastic	29
alpha Inelastic	30
lambda Inelastic	31
sigma- Inelastic	32
hadronic bremsstrahlung	33
muon decay With Spin	34
na	90

procID is in the true info output bank

example from beam on target background



advanced digitization

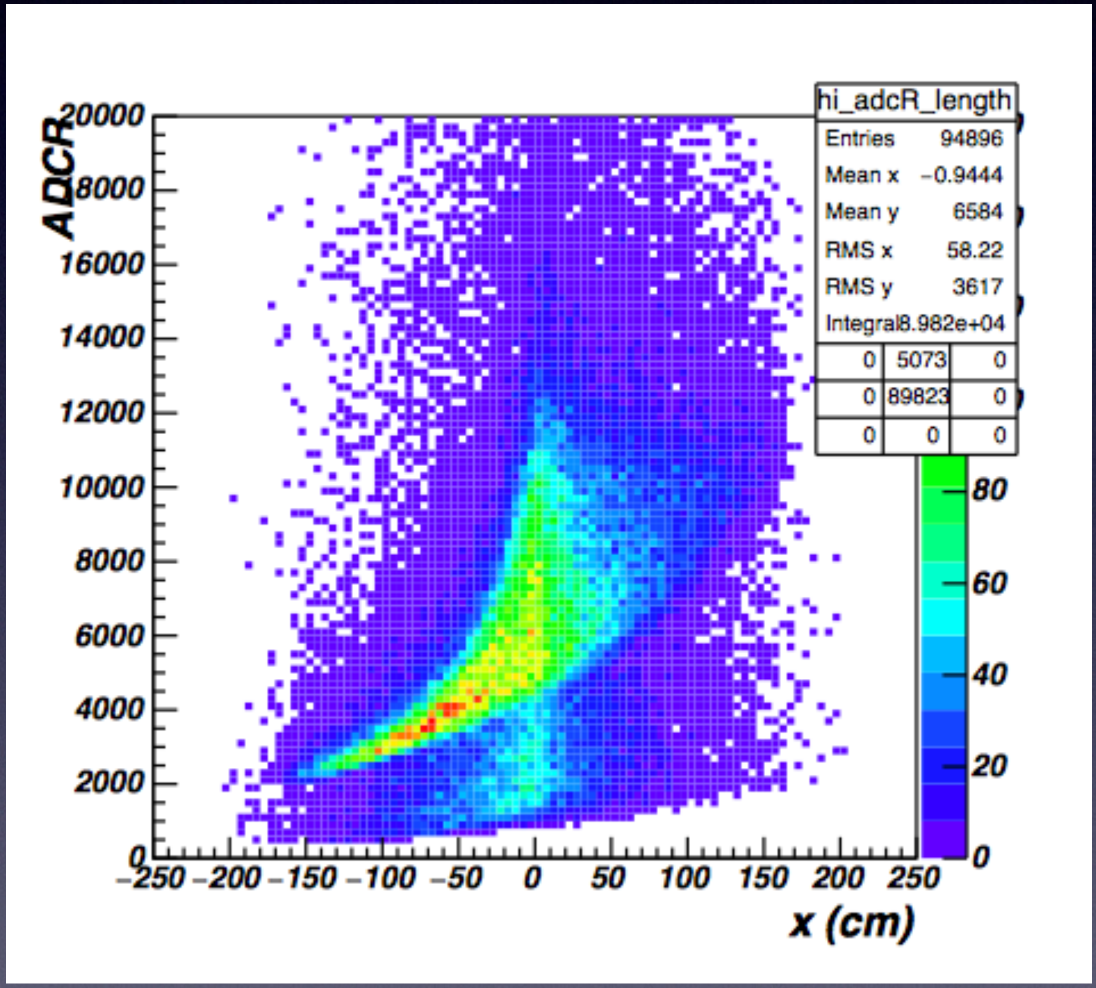
ADC:

- Attenuation according to exponential law
- Conversion from energy to ADC based on MIP signal (dEdxMIP=2 MeV/cm, countsForAMinimumIonizing=2000)

TDC:

- Delay due to light propagation in the paddle (effective velocity)
- Parameterized Time Walk
- Gaussian time spread based on parameters that will be matched to data ($\sigma2=\sigma02+\sigma12/\sqrt{EPMT}$ Conversion from time to TDC (time2tdc=20ns−1)

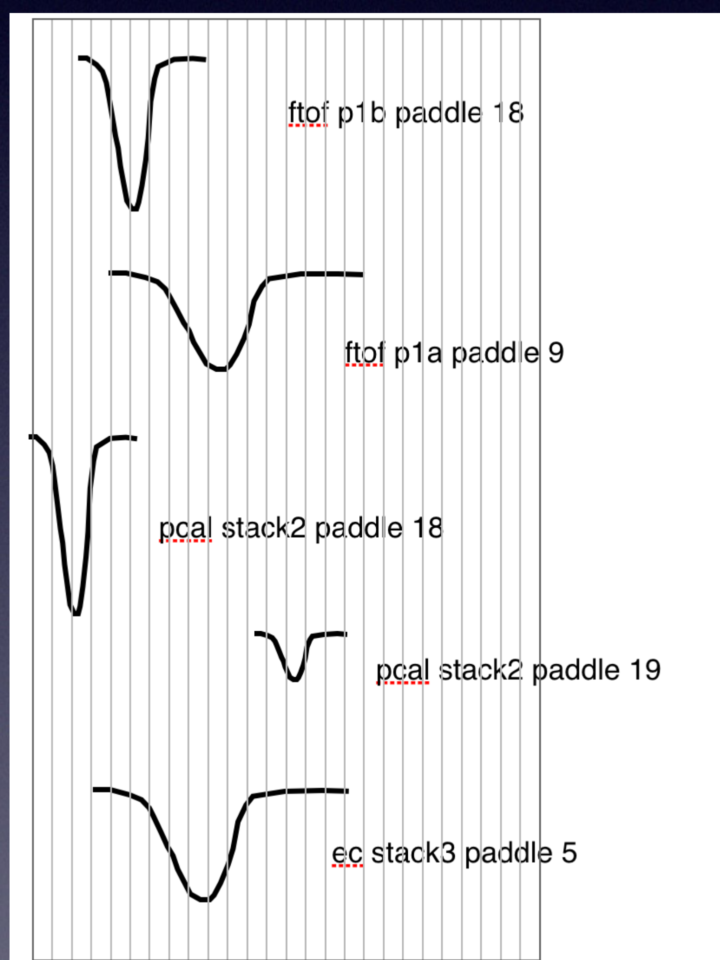
Output: both “smeared” and “unsmeared” TDCs



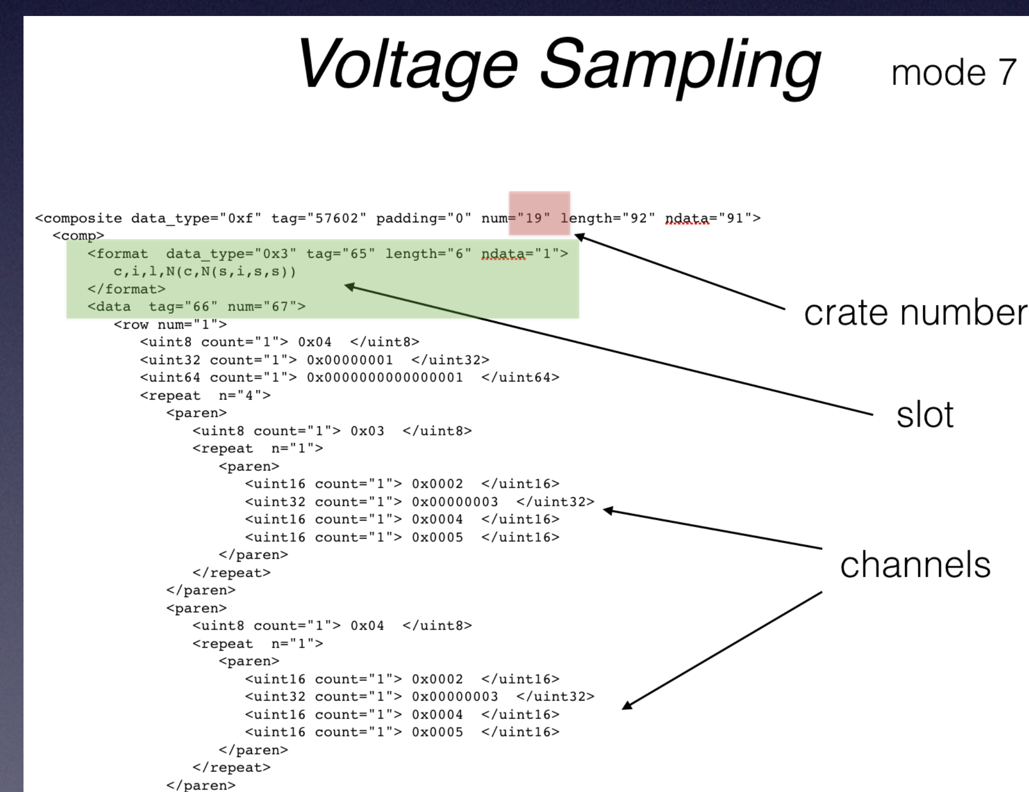
Status:
0 – fully functioning
1 – noADC
2 – noTDC
3 – noADC, noTDC(PMT is dead)
5 – any other reconstruction problem

translation tables, voltage sampling

Output organized by CRATE/SLOT/CHANNEL
Translation table SAME as real experiment



User defined voltage vs time function



output indistinguishable from real data

output, bank structure

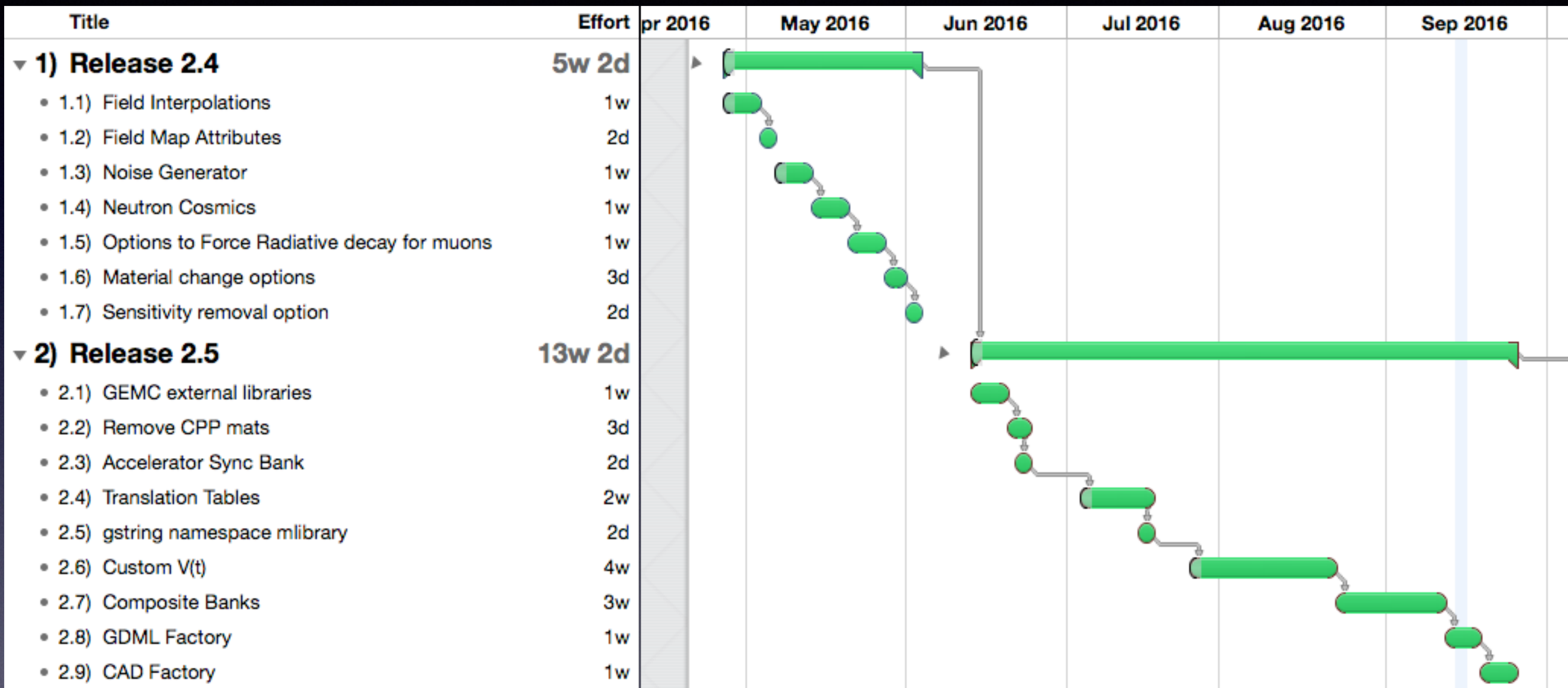
```
> BST  100, 0

  > True Step by Step infos  (101, 0)
    - Edep                   (101, 1)
    - Pid                    (101, 2)
    - positions              (101, 3)

  > Dgtz Step by Step infos  (102, 0)
    - ADCL                   (102, 1)
    - ADCR                   (102, 2)

  > True Integrated infos    (103, 0)
    - Edep                   (103, 1)
    - Pid                    (103, 2)
    - positions              (103, 3)

  > Dgtz Integrated infos    (104, 0)
    - ADCL                   (104, 1)
    - ADCR                   (104, 2)

  > Voltage as a function of time (105, 0)
    - Identifier                  (105, 1)
    - Time                        (105, 2)
    - Voltage                     (105, 3)

 > Trigger Bank              (106, 0)
    - Identifier             (106, 1)
    - Time                   (106, 2)
    - Voltage                (106, 3)
```

```
"pid",     "Ri", "ID of the first particle entering the sensitive volume");
"mpid",    "Ri", "ID of the mother of the first particle entering the sensitive
"tid",     "Ri", "Track ID of the first particle entering the sensitive volume"
"mtid",    "Ri", "Track ID of the mother of the first particle entering the sen
"otid",    "Ri", "Track ID of the original track that generated the first parti
"trackE",  "Rd", "Energy of the track");
"totEdep", "Rd", "Total Energy Deposited");
"avg_x",   "Rd", "Average X position in global reference system");
"avg_y",   "Rd", "Average Y position in global reference system");
"avg_z",   "Rd", "Average Z position in global reference system");
"avg_lx",  "Rd", "Average X position in local reference system");
"avg_ly",  "Rd", "Average Y position in local reference system");
"avg_lz",  "Rd", "Average Z position in local reference system");
"px",      "Rd", "x component of momentum of the particle entering the sensitiv
"py",      "Rd", "y component of momentum of the particle entering the sensitiv
"pz",      "Rd", "z component of momentum of the particle entering the sensitiv
“vx",      "Rd", "x component of primary vertex of the particle entering the se
"vy",      "Rd", "y component of primary vertex of the particle entering the se
"vz",      "Rd", "z component of primary vertex of the particle entering the se
"mvx",     "Rd", "x component of primary vertex of the mother of the particle e
"mvy",     "Rd", "y component of primary vertex of the mother of the particle e
"mvz",     "Rd", "z component of primary vertex of the mother of the particle e
"avg_t",   "Rd", "Average time");
"hitn",    "Ri", "Hit Number");
```

sector
SuperLayer
Layer
wire
LR
Doca
SDoca
time
Stime

gemc roadmap

full roadmap available at gemc.jlab.org

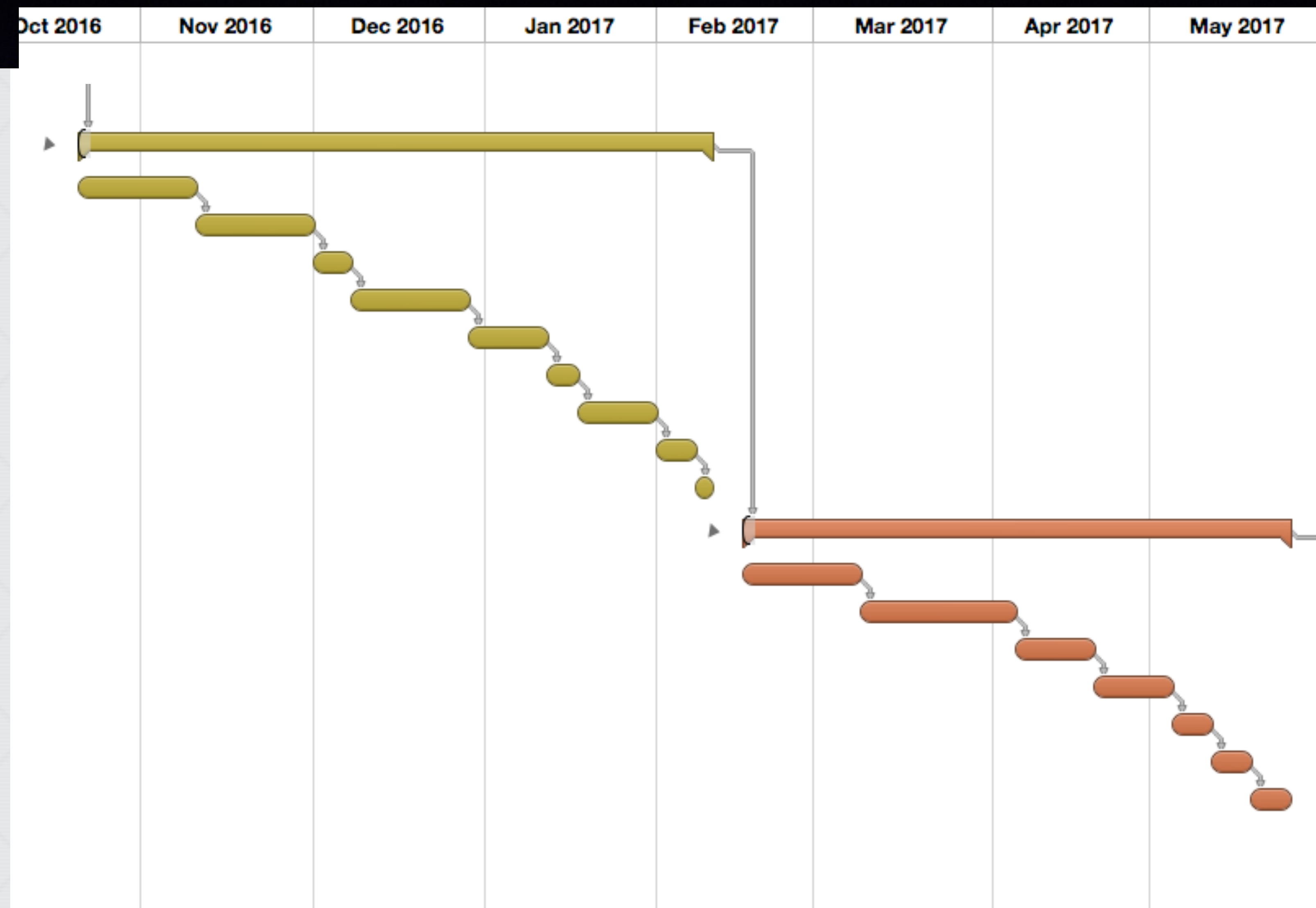


green = completed

gemc roadmap

full roadmap available at gemc.jlab.org

3) Release 2.6	**16w 1d**
3.1) G4 Analysis Tools	3w
3.2) Cross Sections Validations	3w
3.3) Finalize Replicas, Divisions	1w
3.4) Python API Implementation	3w
3.5) Use Run Action	2w
3.6) Add / Remove axis in GUI	4d
3.7) Linux Tarballs	2w
3.8) Detector Tests Template	1w
3.9) Active Rotations	2d
4) Release 2.7	**14w**
4.1) De-couple digitization from gemc	3w
4.2) Event Generator Lib	4w
4.3) proMC	2w
4.4) Redesign Generator Tab	2w
4.5) Culling options combobox	1w
4.6) Splash Screen library	1w
4.7) Pop up window for detector description	1w



G4 Analysis Tools. Finalize python API.

Event generator library (various inputs, pythia, proMC)

gemc roadmap

full roadmap available at gemc.jlab.org

- gemc being re-organized in libraries.
- gemc 3.0 is C++11 rewrite — geant4 multi-threads.
- geant4 transient data library - output to ROOT, ?

Existing libraries:

- translation table
- general options
- text progress bar
- string manipulation
- luminosity runs
- accelerator frequency sync

summary: gemc 2.5

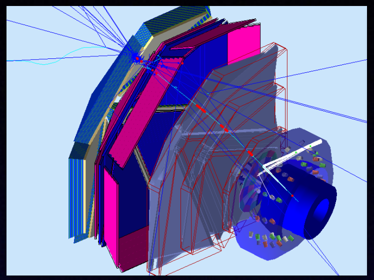
gemc.jlab.org

- Documentation (still work in progress)
- Examples
- Downloads
- Releases, Changelog.

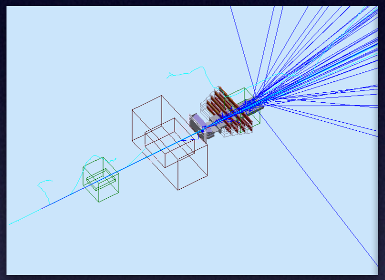
gemc 2.5 is a mac app (dmg)
Linux: still need compilation, but will be rpm
Windows: will be supported

gemc being re-organized in libraries that are not gems-specific. e.g. generator library, general geant4 transient data (but not only)

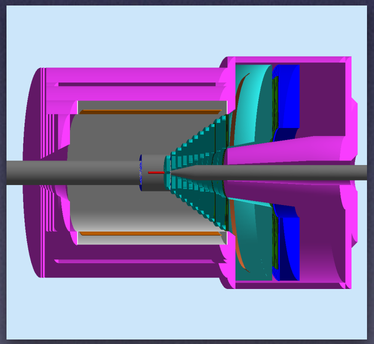
Clas12



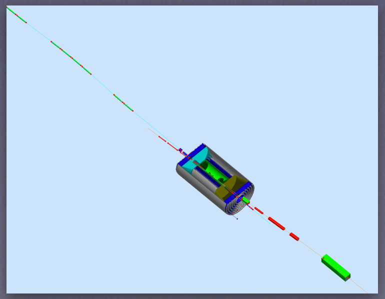
HPS Studies



Solid (Hall-A)



EIC beam line + detector



Optical Properties

- **surface**
- **type**
- **optical properties:**
  - photonEnergy
  - indexOfRefraction
  - reflectivity
  - efficiency
  - specularlobe
  - specularspike
  - backscatter

```
               polished:  smooth perfectly polished surface
    polishedfrontpainted:  smooth top-layer (front) paint
     polishedbackpainted:  same is 'polished' but with a back-paint

                  ground:  rough surface
      groundfrontpainted:  rough top-layer (front) paint
       groundbackpainted:  same as 'ground' but with a back-paint

     polishedlumirrorair:  mechanically polished surface, with lumirror
    polishedlumirrorglue:  mechanically polished surface, with lumirror & meltmount
             polishedair:  mechanically polished surface
       polishedteflonair:  mechanically polished surface, with teflon
          polishedtioair:  mechanically polished surface, with tio paint
        polishedtyvekair:  mechanically polished surface, with tyvek
       polishedvm2000air:  mechanically polished surface, with esr film
      polishedvm2000glue:  mechanically polished surface, with esr film & meltmount

       etchedlumirrorair:  chemically etched surface, with lumirror
      etchedlumirrorglue:  chemically etched surface, with lumirror & meltmount
               etchedair:  chemically etched surface
         etchedteflonair:  chemically etched surface, with teflon
            etchedtioair:  chemically etched surface, with tio paint
          etchedtyvekair:  chemically etched surface, with tyvek
         etchedvm2000air:  chemically etched surface, with esr film
        etchedvm2000glue:  chemically etched surface, with esr film & meltmount

       groundlumirrorair:  rough-cut surface, with lumirror
      groundlumirrorglue:  rough-cut surface, with lumirror & meltmount
               groundair:  rough-cut surface
         groundteflonair:  rough-cut surface, with teflon
            groundtioair:  rough-cut surface, with tio paint
          groundtyvekair:  rough-cut surface, with tyvek
         groundvm2000air:  rough-cut surface, with esr film
        groundvm2000glue:  rough-cut surface, with esr film & meltmount
```

Optical Properties

- **surface**
- **type**
- **optical properties:**
  - photonEnergy
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  - specularspike
  - backscatter

```
    dielectric_metal:  dielectric-metal interface
dielectric_dielectric:  dielectric-dielectric interface
      dielectric_LUT:  dielectric-Look-Up-Table interface
```

Optical Properties

- **surface**
- **type**
- **optical properties:**
  - photonEnergy
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  - specularspike
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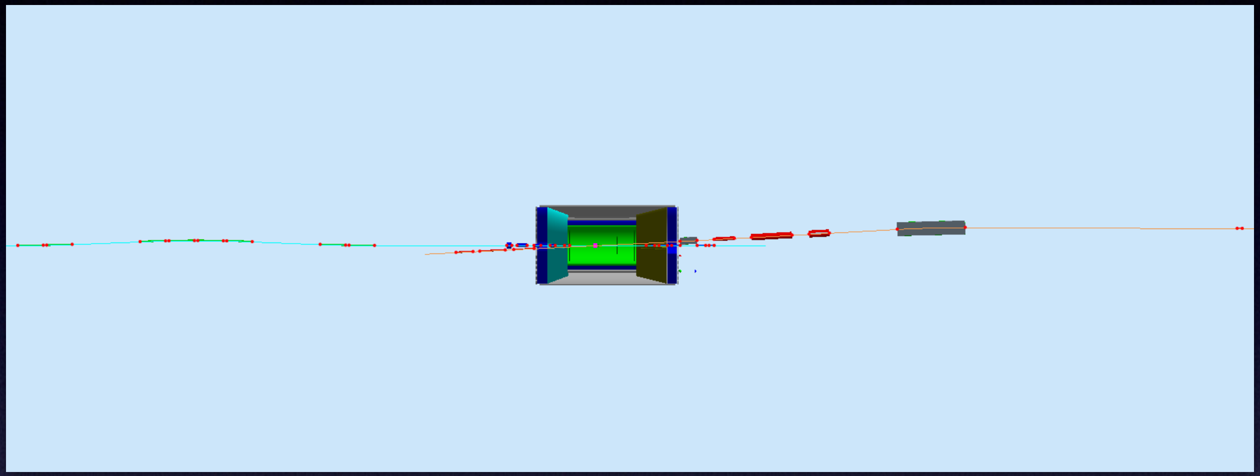
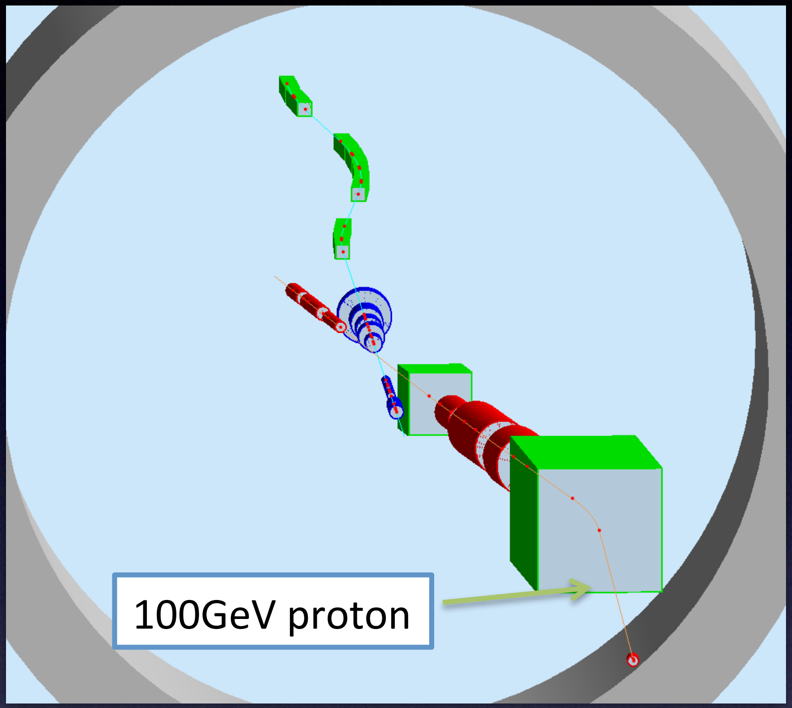
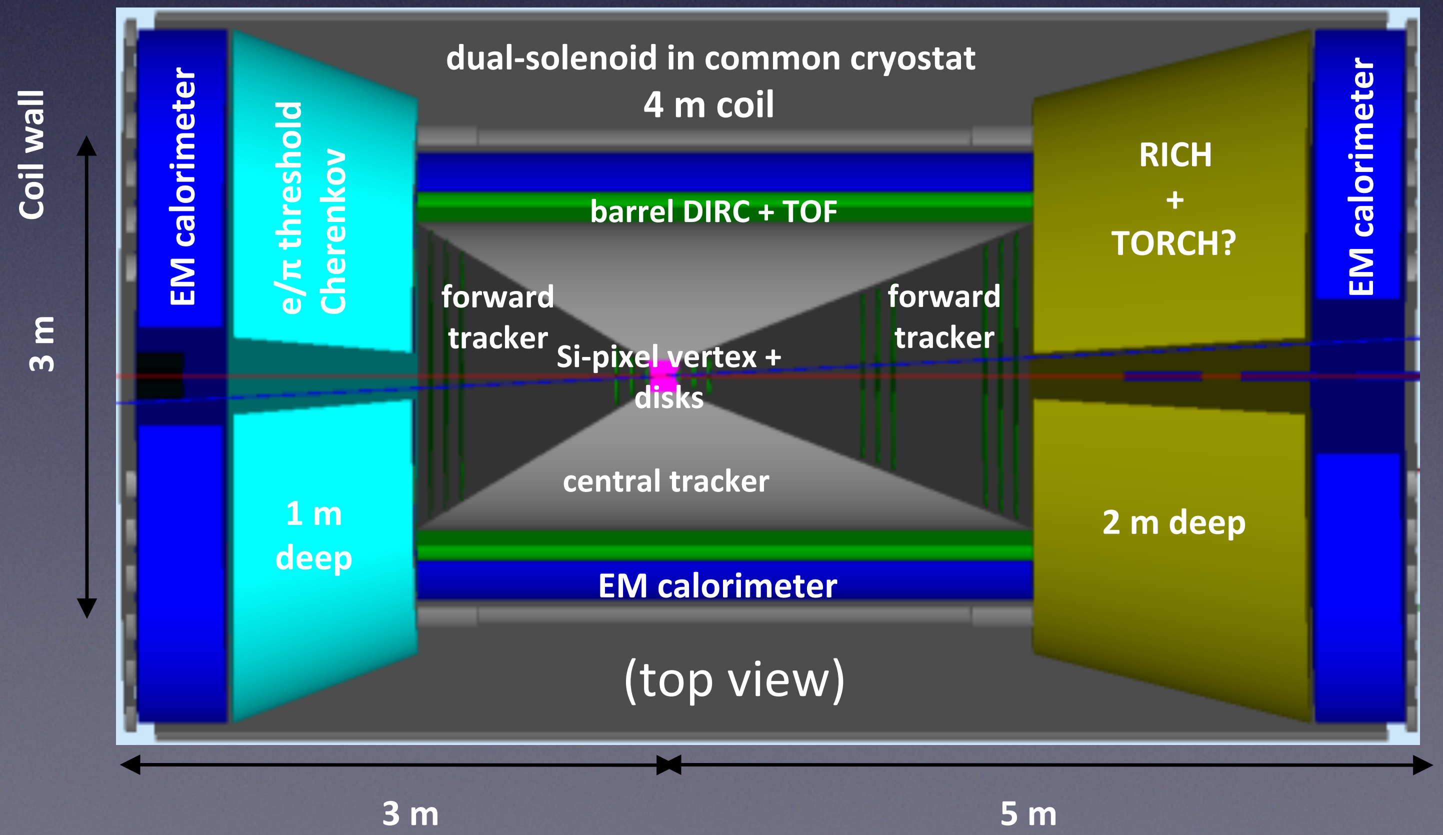
```
Table of optical photon energies (wavelengths) from 190-650 nm:

my $penergy =
"  1.9074494*eV  1.9372533*eV  1.9680033*eV  1.9997453*eV  2.0325280*eV " .
"  2.0664035*eV  2.1014273*eV  2.1376588*eV  2.1751616*eV  2.2140038*eV " .
"  2.2542584*eV  2.2960039*eV  2.3393247*eV  2.3843117*eV  2.4310630*eV " .
"  2.4796842*eV  2.5302900*eV  2.5830044*eV  2.6379619*eV  2.6953089*eV " .
"  2.7552047*eV  2.8178230*eV  2.8833537*eV  2.9520050*eV  3.0240051*eV " .
"  3.0996053*eV  3.1790823*eV  3.2627424*eV  3.3509246*eV  3.4440059*eV " .
"  3.5424060*eV  3.6465944*eV  3.7570973*eV  3.8745066*eV  3.9994907*eV " .
"  4.1328070*eV  4.2753176*eV  4.4280075*eV  4.5920078*eV  4.7686235*eV " .
"  4.9593684*eV  5.1660088*eV  5.3906179*eV  5.6356459*eV  5.9040100*eV " .
"  6.1992105*eV  ";

Reflectivity of AlMgF2 coated on thermally shaped acrylic sheets, measured by AJRP,
10/01/2012:
my $reflectivity =
"  0.8331038     0.8309071     0.8279127     0.8280742     0.8322623 " .
"  0.837572      0.8396875     0.8481834     0.8660284     0.8611336 " .
"  0.8566167     0.8667431     0.86955       0.8722481     0.8728122 " .
"  0.8771635     0.879907      0.879761      0.8831943     0.8894673 " .
"  0.8984234     0.9009531     0.8910166     0.8887382     0.8869093 " .
"  0.8941976     0.8948479     0.8877356     0.9026919     0.8999685 " .
"  0.9101617     0.8983005     0.8991694     0.8990987     0.9000493 " .
"  0.9065833     0.9028855     0.8985184     0.9009736     0.9086968 " .
"  0.9015145     0.8914838     0.8816829     0.8666895     0.8496298 " .
"  0.9042583 ";
```

gemc EIC

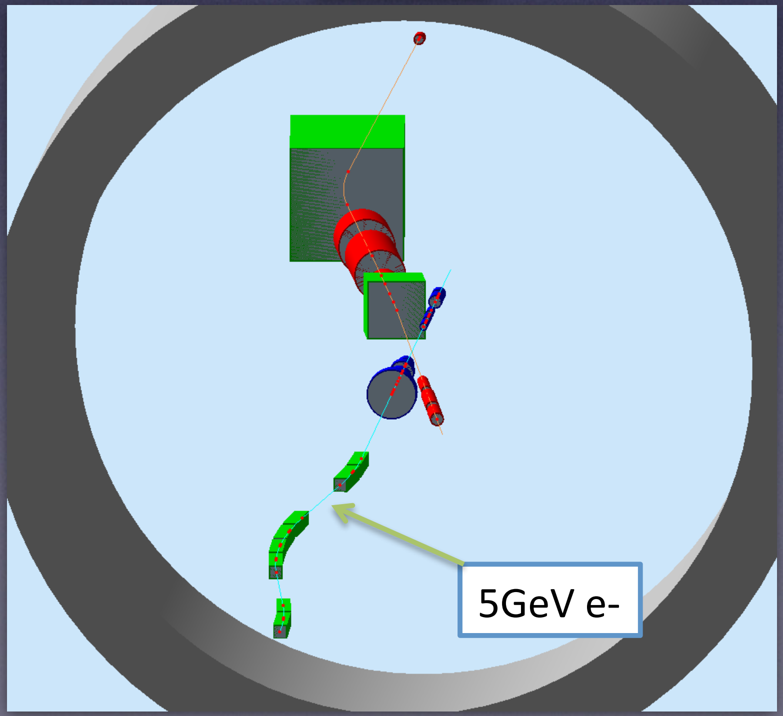


ion side





ele side



Modular Physics List

```
-PHYSICS="HADRONIC + <EM> + <HP> + <OPTICAL>"
```

Hadronic can be:

- CHIPS
- FTFP_BERT
- FTFP_BERT_TRV
- FTFP_BERT_HP
- FTF_BIC
- LHEP
- QGSC_BERT
- QGSP
- QGSP_BERT
- QGSP_BERT_CHIPS
- QGSP_BERT_HP
- QGSP_BIC
- QGSP_BIC_HP
- QGSP_FTFP_BERT
- QGS_BIC
- QGSP_INCLXX

EM can be

- STD
- EMV
- EMX
- EMY
- EMZ
- LIV
- PEN

HP: High Precision cross sections (e.g. thermal neutron, very low energy processes, etc)

Optical: Activate optical processes

Magnetic Fields

```
<mfield>
        <description name="clas12-torus" factory="ASCII" comment="clas12 superconducting torus"/>
        <symmetry type="phi-segmented" format="map" integration="RungeKutta" minStep="1*mm"/>
        <map>
                <coordinate>
                        <first  name="azimuthal"     npoints="61"   min="0"   max="30"  units="deg"/>
                        <second name="transverse"    npoints="126"  min="0"   max="500" units="cm"/>
                        <third  name="longitudinal"  npoints="126"  min="100" max="600" units="cm"/>
                </coordinate>
        <field unit="kilogauss"/>
        <interpolation type="none"/>
        </map>
</mfield>
0       0       100     0       0       0
0       0       104     0       0       0
```

```
<mfield>
   <description name="meic_ele_downstream_quadrupole4" factory="ASCII"
    comment="meic_det1_ele_downstream_quadrupole4"/>

   <symmetry type="multipole" format="simple" integration="RungeKutta" minStep="1*mm"/>

   <dimension Npole="4" scale="23.9743818" Bunit="T" x="0" y="0" z="-4.30"
    XYZunit="m" rot="0" ROTunit="rad" ROTaxis="Y"/>

</mfield>
```

Dipole, Quadrupoles, Multipoles