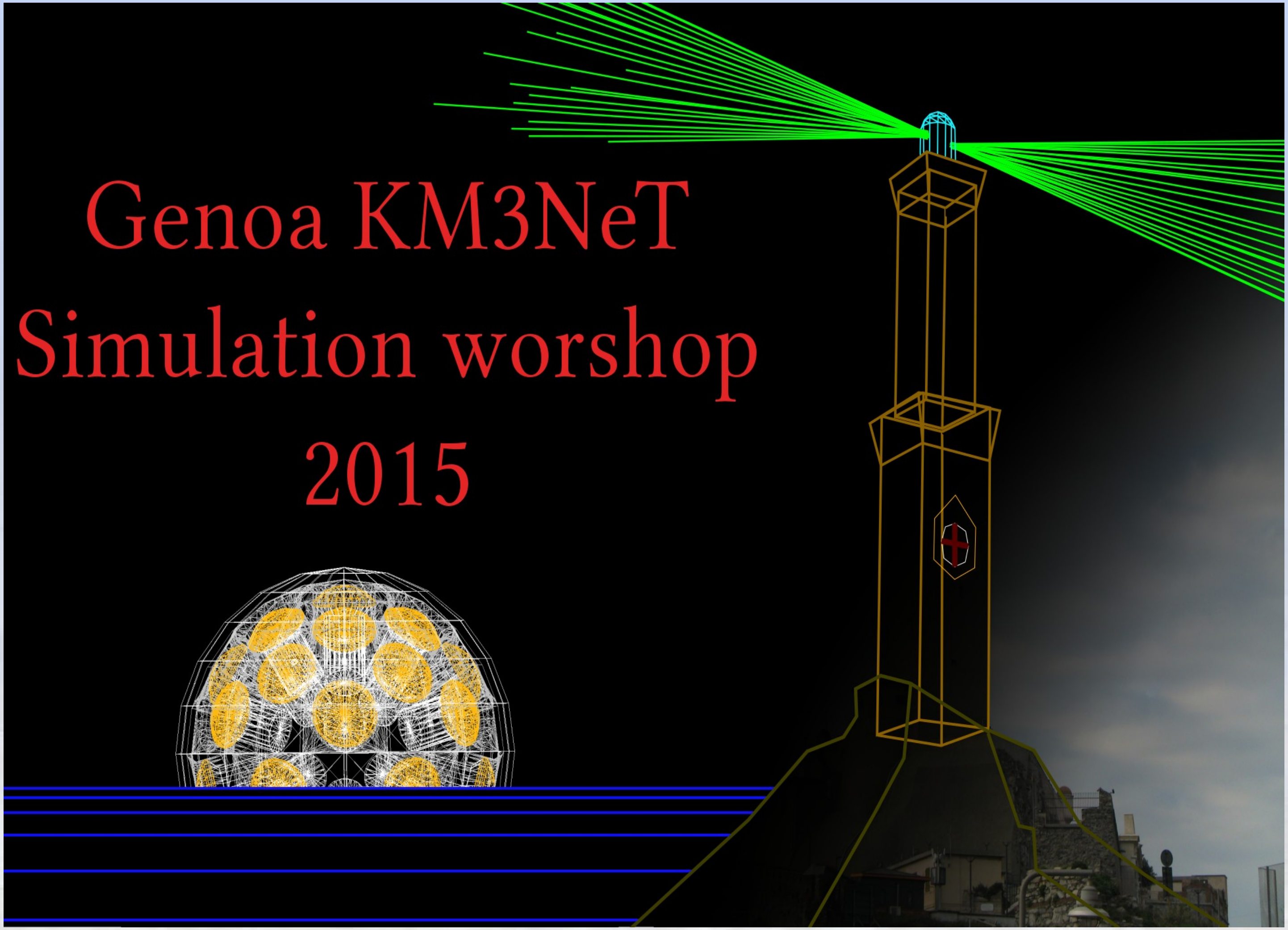
How to use the simulation



INFN Istituto Nazionale di Fisica Nucleare Genova KM3NeT

Overview

- The GEANT4 library principle
- The physical processes
- Define a material in KM3RTSim
- Define the phototube
- Define the OM
- The mac scrip
- The output
- How to define a custom output/analysis manager
- Create the detector
- The compilation and execution

Get the package

```
svn repository:

svn co --username=km3net http://svnserver.ge.infn.it/KM3Sim
KM3Sim
Password: Capopassero
```

The compilation

!dependency on GEANT4, ROOT and libconfig++!

CMake base:

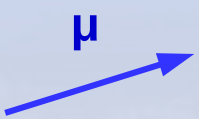
```
mkdir build
cd build
cmake .. [-DDEBUG=1] [-D__NEW_TESTING_ALGO=1] [-DFULL_OPTIMIZATION=1]
```

The GEANT4 physical processes

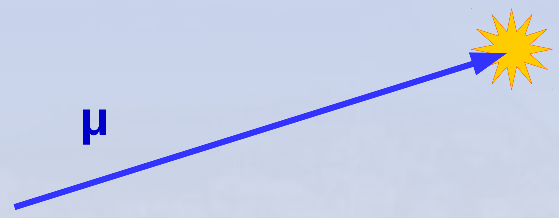
- Discrete processes
  - They provide a length (therefore a probability), they occur punctually, as scattering, absorption... and generally define the step length
- Along step processes
  - Once the step length is calculated, they are applied along the particle path. If they change the energy over a threshold, a correction will be applied to the step length
- Boundary processes
  - In fact a discrete processes with infinite interaction length, they trigger when the particle change its medium. Mostly used in optics (index, thin layer model...)
- Other
  - The various processes dependent on a lifetime (decay) etc. Not used in optics (but can be useful in specific cases)

The GEANT4 principles: illustration

1) The particle is produced with an impulsion in a medium



The GEANT4 principles



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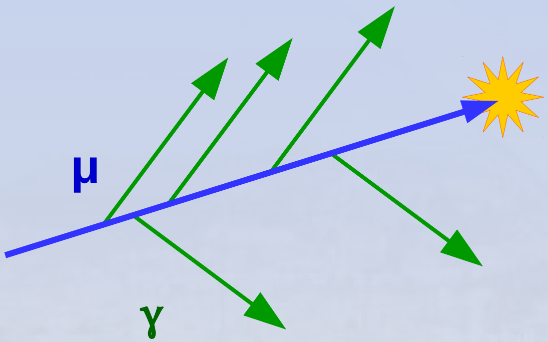
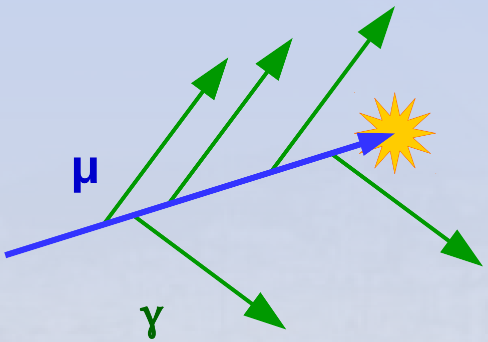
The GEANT4 principles



1) The particle is produced with an impulsion in a medium
2) The interaction length is calculated with the total of discrete processes. the a random number is taken to choose the effective distance
3) The along step processes are produced (eg. Cerenkov)

The GEANT4 principles



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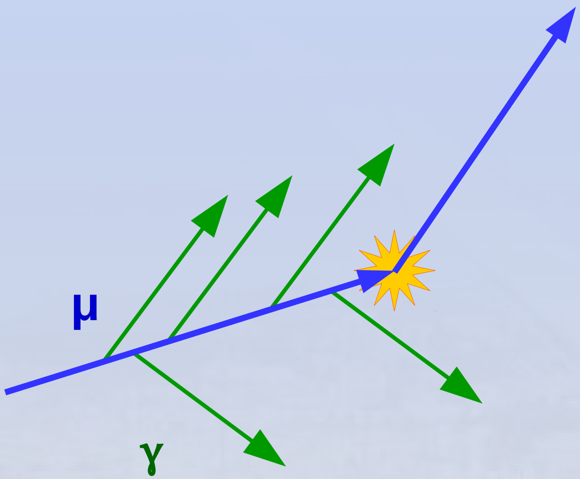

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5) The discrete process is chosen randomly in function of the processes interaction lengths (eg. Elastic scattering)

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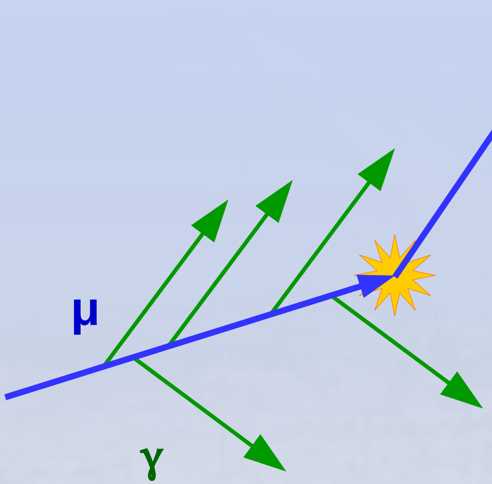

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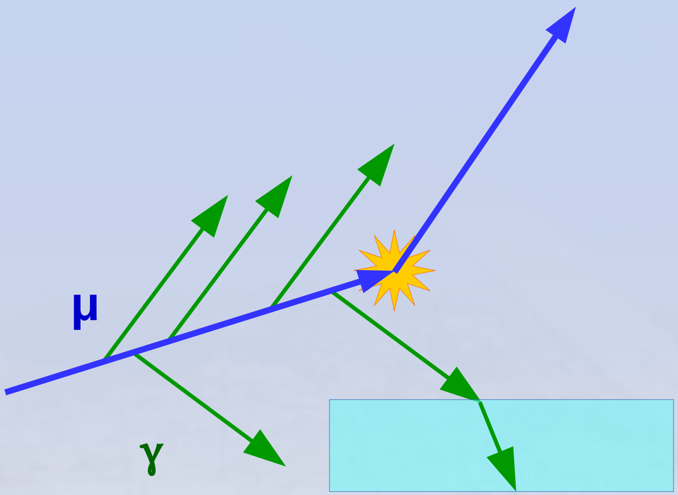
The GEANT4 principles



In the case where the interaction length is shorter than the distance to out of the medium, it does a step on the interface, executing the boundary processes (eg. Refraction of optical photons)

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6) When the primary particle is stopped, it does the secondaries ones

Create a new physical process

- Standard GEANT4 method, two examples:
  - KM3PetzoldScattering for the discrete process
    - Calculation of the length
    - Trigger
  - KM3PMTOpticalModel
    - Used for the photocathode properties
    - Limited to optical photons on boundaries

Should be integrated in the KM3PhysicsList

Define the detector with KM3RTSim: The material

- A tool exist at upper level than the GEANT4 library: KM3Material
- It allows to define the material thanks to a bench of auto-loaded configuration files:

INSTALL/common/data/KM3Mat*.dat

Define the detector with KM3RTSim: The material

Component list:
The GEANT4 material list
See GEANT4 documentation

The propreties list
Every GEANT4 properties plus:

- EFFICIENCY
  - QE of the photocathode
- KINDEX
  - Imaginary index ONLY FOR THE THIN LAYER MODEL
- THICKNESS
  - Thickness of the photocathode deposit in function of the center
- ANGULAR_EFFICIENCY
  - Angular collection efficiency for the PMT (photocathode)
- ANGULAR_EFFICIENCY_ERROR
  - For the estimation of the systematics

```
CREATE PTerphenyl

density 1.24

COMPONENTS
G4_H 14
G4_C 216
COMPONENTS

CREATE

PROPERTY RINDEX
OPTION wavelength
100 1.65
800 1.65

PROPERTY WLSTIMECONSTANT
OPTION constant
1.05e-9

PROPERTY WLSABSLENGTH
OPTION wavelength #(nm)  Molar
Extinction (cm-1/M)
OPTION shifter_density 5.4
#[Molar]=mol/dm3
219.74    16727
219.99    16411
220.24    15787
...
```

The density is relative

The option list are:

- Wavelength
  - For photon, will be converted in eV
- eV
  - The GEANT4 base for energy is the keV
- Constant
  - Not a vector of values
- Shifter density
  - Special for WLS, to manage the special dimensions

Define the detector with KM3RTSim: The material

- Anything can be added in the properties
  - To be used in your own physical processes
  - To be used in your analysis
  - …
- Some specific material names exists
  - AntaresWater (NEMOWater)
  - ...

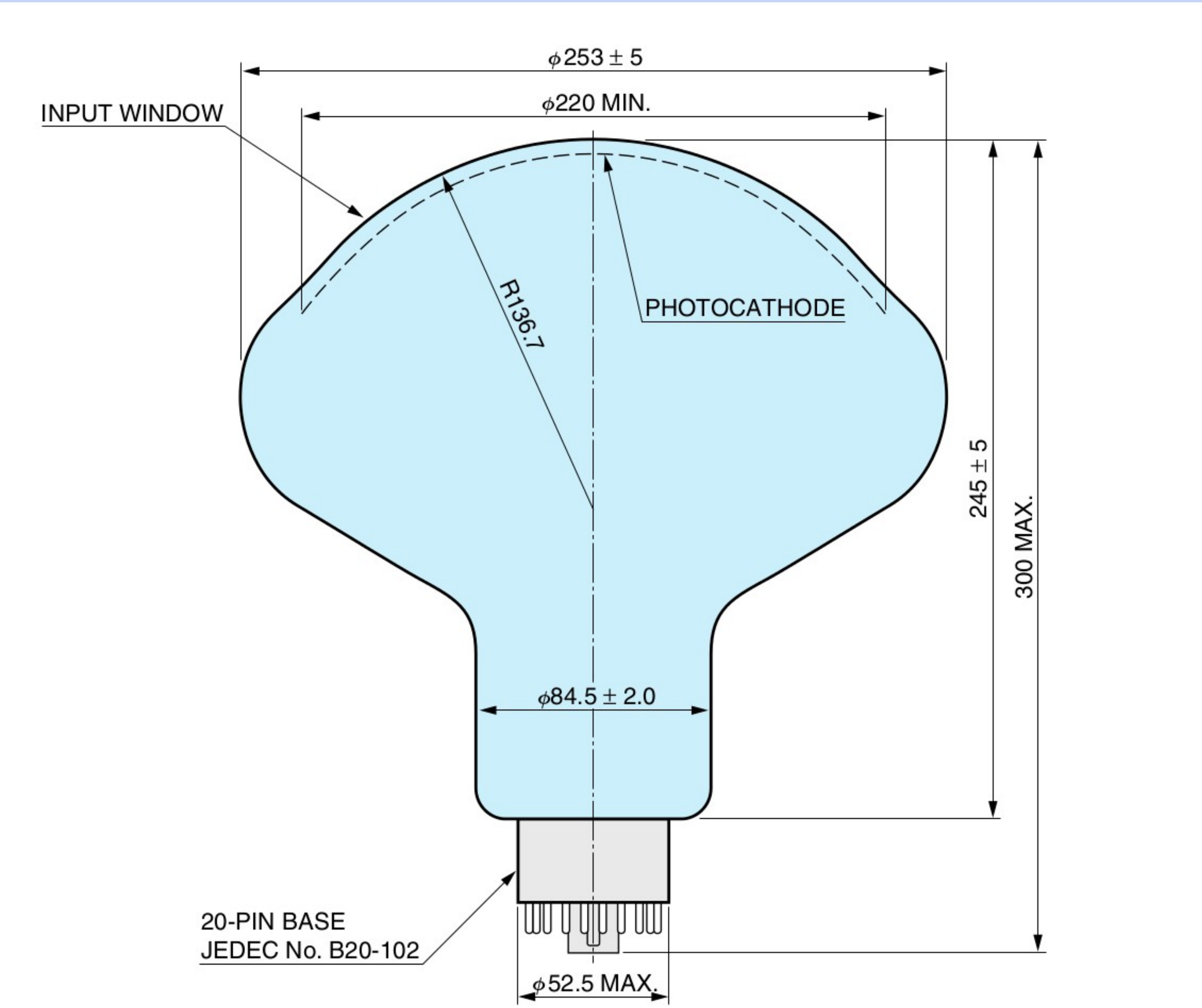
Define a phototube

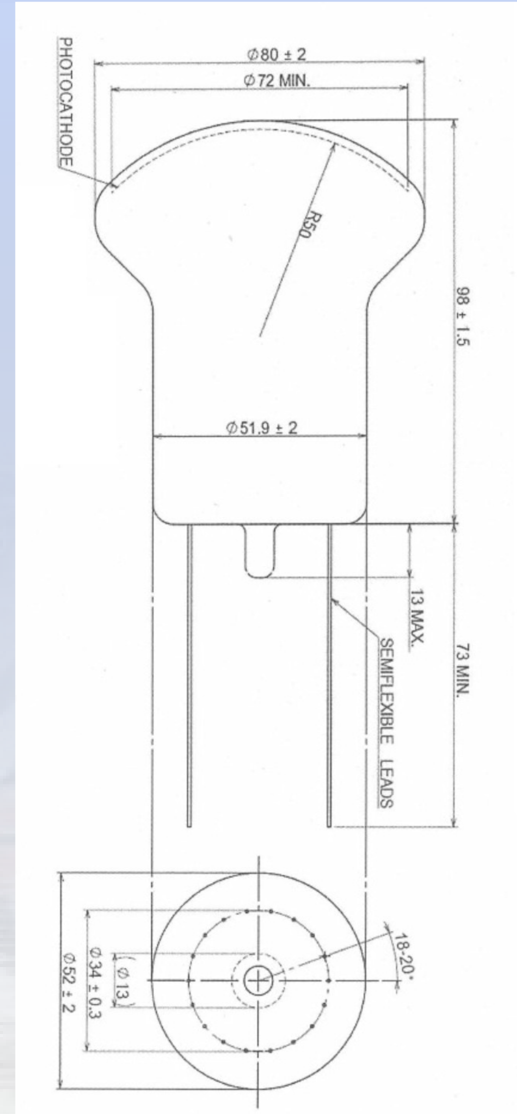
- A tool exist at higher level than the GEANT4 simulation:
  - KM3PhotoTubeMgr, reads automatically a list of phototubes in common/data/KM3PMT*.dat
  - Uses the “typical” constructor data

Still experimental, need the __ENABLE_TESTING__ flag

Stable release soon

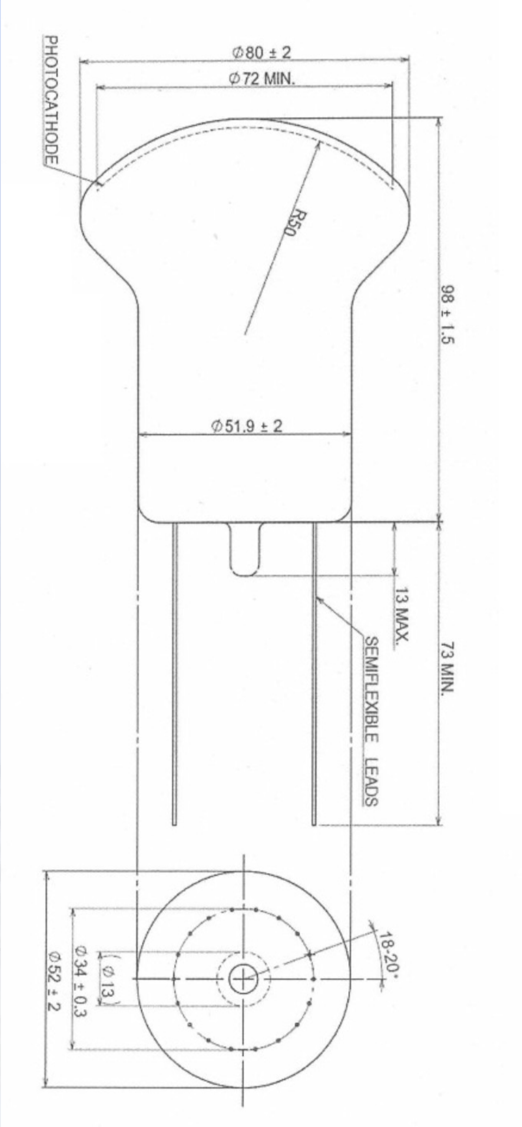
Define a phototube





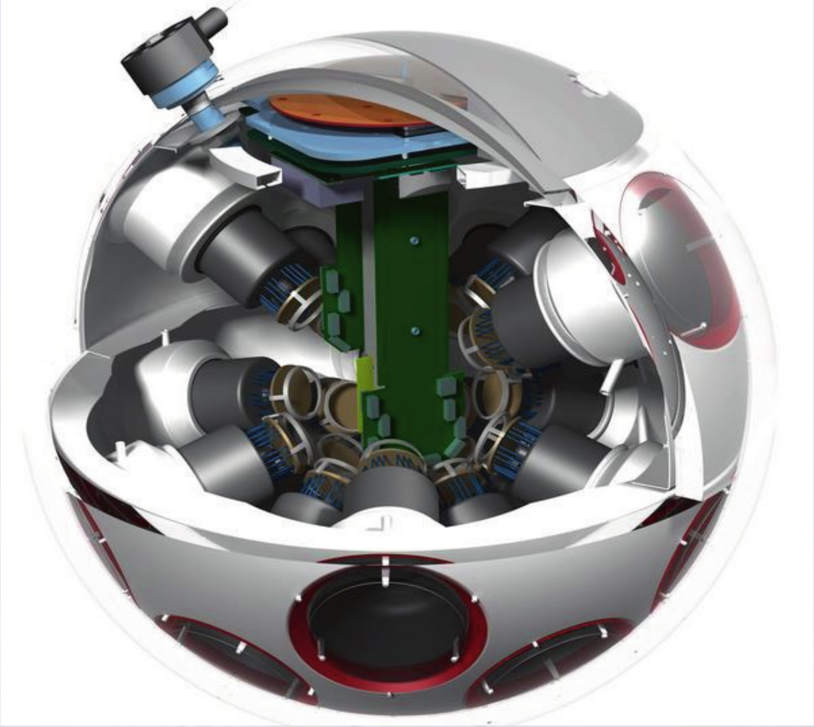
Define a phototube

```
Prefix = "DOM1"
Name = “3Inches”
//PMT input parameters
RadiusSphere   = 50.
BulbRadiusMin  = 72.
BulbRadiusMax  = 80.
BulbHeight     = 40.
ConeHeight     = 40.
TubeDiameter   = 52.
GlassThickness = 3.
TotalPMTHeight = 98
DinodsPos      = 0.
DinodsRadius   = 34.
DinodsHeight   = 30.

//overlaps checking
CheckOverlaps = false;

//The materials to get
GlassMaterial        = "PMTGlass";
PhotoCathodeMaterial = "photocathode3inches";
```



Define an OM

```
PhotoTubeName = "3Inches"
Prefix = "OM1"
name = "DOM"
//Choice of the type, dom or om
DetectionUnitType="DOM"
//OM input parameters (ANTARES values)
SphereRmax       = 21.59
GlassThickness   = 15
//OM specific values
//AbsorberIn         = 0
//AbsorberOvertake = 0
//GelOvertake        = 14.5
//DistSpherePMT      = 5
//DOM specific values
AreThereReflectors = true
ReflectorAngle       = 30
ReflectorPosition  = 17 //fct of the PM bulb
RowAngles = [0, 30,...]
ColumnAngles = [0,...]
CheckOverlaps = false

//The materials to get, "classic" big PM by default
GlassMaterial = "AntaresGlass"
GelMaterial   = "AntaresOpticalGel"
```



In project: detector conf file definition

- On the same idea the experiment will be definable thanks to a config file:
- Water material
- Can size
- OM/DOM position/orientation

But for now the current new PM and OM definitions need to be finished and checked for the version KM3RTSim 0.9.1

Run an experiment

- For now a detector construction exist for each case:
  - K40DetectorConstruction
    - The 3 (D)OM are back to back in the volume
  - AADetectorConstruction
    - Only one (D)OM that can be rotated
  - WpropDetectorConstruction
    - Special case, no (D)OM, dedicated to NEMO LED calibration (see previous presentation)
- Everything is base on the GEANT mac file system for the run part

Run an experiment: the mac script

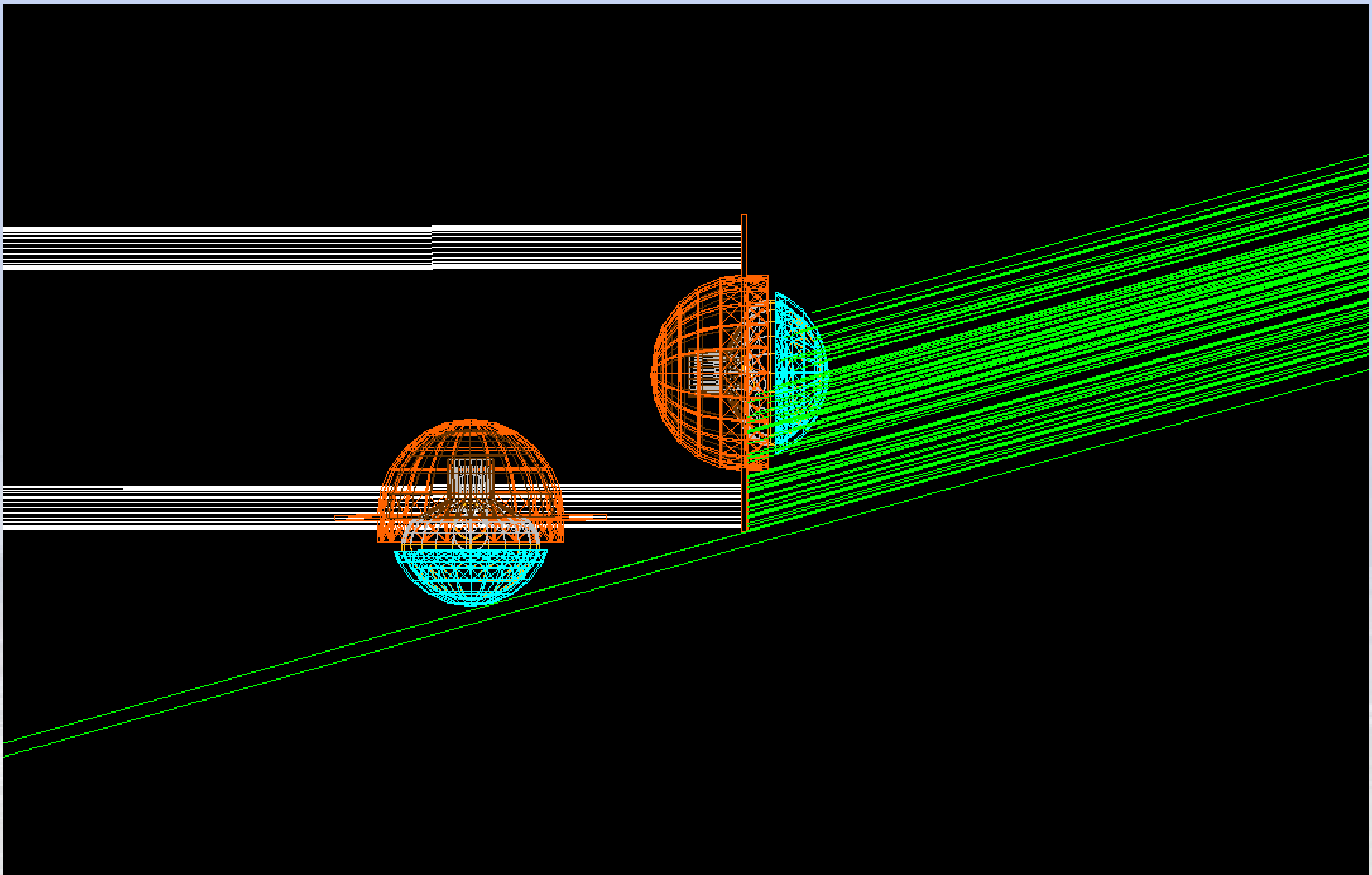
```
/KM3/XP/Type K40 #or AA or WProp

/KM3/det/setTargetScattering 1
/KM3/det/setTargetMaterial AntaresWater #or NEMOWater, IdealWater
/KM3/det/DontDraw absorber #some option to do not draw, deprecated
/KM3/det/setWorldLength 7  m #the can is 90% of the world

/KM3/GenType 2 #random genaration points, 1 for beams likes
#/KM3/det/setOpticalModuleTheta 33 deg
#/KM3/det/setOpticalModulePhi 0 deg
#orientation of the OM, only for scans

/run/initialize

/gun/particle ion #or opticalphoton, or electron...
/gun/ion 19 40
#for the case GenType 1, see gps generation in geant4 doc

#/gps/pos/type Beam
#/gps/pos/shape Circle
#...

/run/beamOn 100000
```

Run an experiment: draw with JAS3

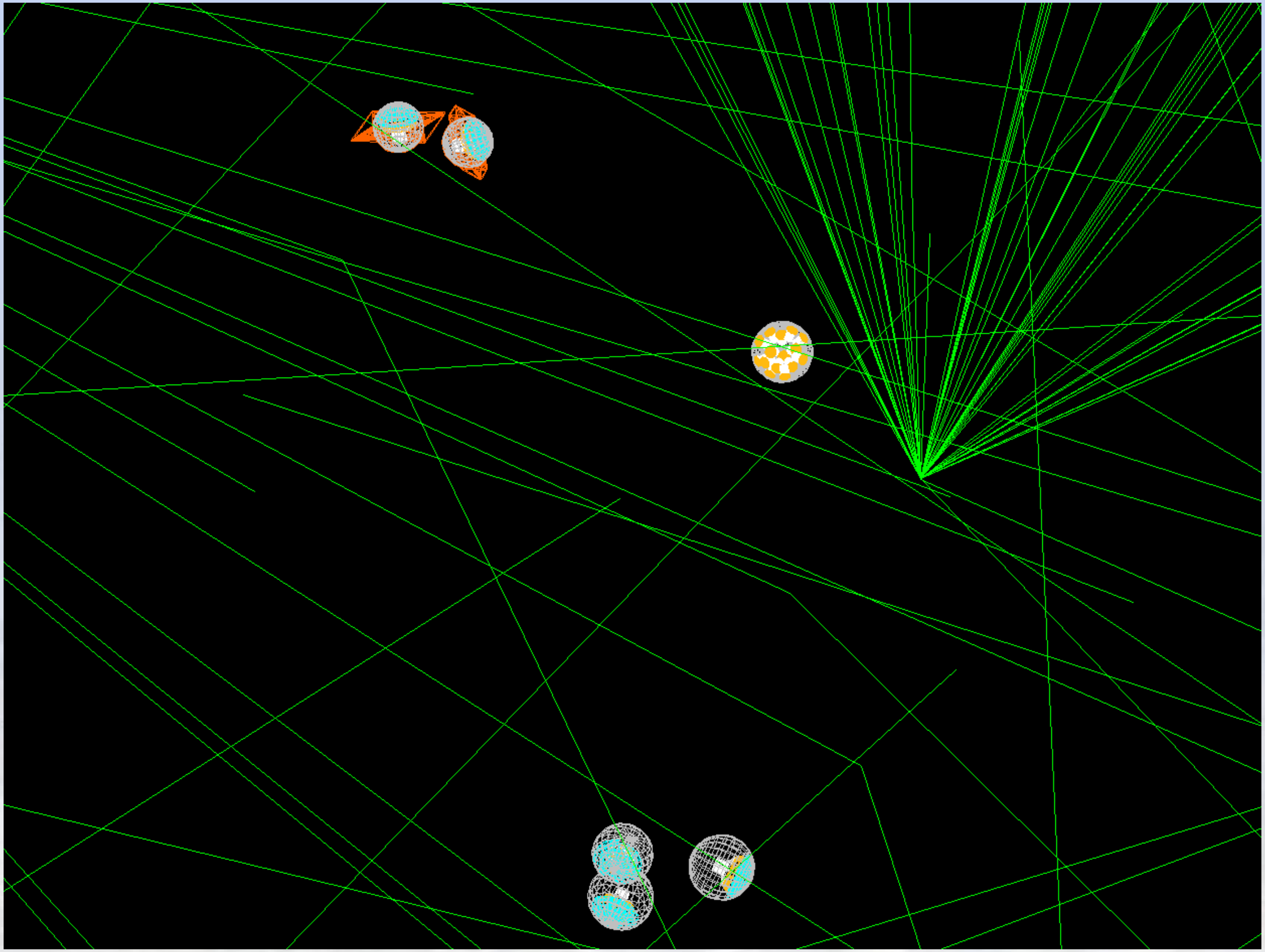
```
/vis/scene/create K40_Output.heprep.zip
/vis/open HepRepXML
/vis/scene/create
/vis/viewer/reset
/vis/viewer/zoom 200.
/vis/viewer/zoom 1.
/vis/viewer/set/viewpointThetaPhi 45. 45.
/vis/viewer/set/viewpointThetaPhi 90. 0.
/vis/drawVolume
/vis/scene/endOfEventAction accumulate 500
/tracking/storeTrajectory 1

/vis/drawVolume
```

- Less draw bugs
- More draw options
- See the demonstrations tomorrow

Draw type 1



Draw type 2



The output

```
//here some data to put in the
trees
//RunInfos tree
unsigned long fNbTrigg=0;

//Event tree
float fVertexX;
float fVertexY;
float fVertexZ;
float fVertexT;
float fVertexP;
float fOMHitX;
float fOMHitY;
float fOMHitZ;
float fOMHitT;
float fOMHitP;
float fPhotoX;
float fPhotoY;
float fPhotoZ;
float fPhotoT;
float fPhotoP;
short fOMId;
short fPMID;

//fast analysis tree
unsigned long fNbOM=0;
unsigned long fNbPhoto=0;
```

- The use of the KM3AnalysisManager is done by inheritance
- The KM3AnalysisManager contains a tree base data
- It can be completed by new branches or new TTrees (the EndOfEvents should be reinstanced)

The output simple example: ^{40}K

- Added in the FastAnalysis TTree a table containing the coincidences number between the Oms

- Unsigned coincidences [7][4]
  - Detection type null, inferior limit, mean, superior limit
  - Combinaison (nemo double, antares double, triplet, dom double, dom triple...)

The output example: Post analysis

- The post analysis is done in root
- No real clean code was done, only case by case but a base exist
- Work to do: Post-analysis for the most common cases (^{40}K, scans...)

Create the detector

- KM3DetectorConstruction: Classical GEANT4 detector construction with some messenger inputs
  - Target material: `/KM3/det/setTargetMaterial`
  - Scattering on/off and length /KM3/det/setTargetScattering
  - (D)OM angle: /KM3/det/setOpticalModuleTheta
  - Target length: /KM3/det/setWorldLength
- See the K40 and AA construction as example, they should cover most of the cases

The KM3RTSim core

- The main GEANT4 library elements are generated in a messenger KM3ExperimentTypeMessenger()
- The custom Construction, analysis etc... objects are instanced in function of the /KM3/XP/Type parameter: Your own experiment objects should be introduced here
- Project to use a factory with a dictionary

Summary to create your own simulation

Use the standard PMTs/OMs or

1)Implement the PMT dimensions

2)Implement the (D)OM dimensions

3)Implement the Materials (D)OM, medium etc.

4)Implement the photocathode properties

5)Create the Analysis manager

6)Integrate it in the ExperimentTypeMessenger

The execution

- The default binary source is in program

  KM3Sim [-s] script.mac output.root

- -s for “session”, for the draw
- The scripts examples are in INSTALL/script

- A custom executable can be added

Conclusion

- Simple geometry and physics implementations
- Most of the cases can be covered by the current status of the simulation
- A lot of improvement and refactorization are projected, but it takes time
- The documentation should be written! Under work (doxygen)

The schedule

Monday

- 10:00 Introduction
- 10:15 - 12:00 Physics, experiments and applications
  - Generalities
  - Results and application fields (water properties, the 40K...)
- 14:00 - 15:30 The physics of the PMT.
  - The principal challenge in PMT simulation will be presented
  - The physics of the PMT (photocathode, collection efficiency etc.)
  - The solutions used in KM3RTSim
- 15:30 - 17:30 A complete overview of the simulation and the "how to use it" will be developed.
- 17:30 - 18:00 An application of the simulation out of the Astrophysics: Detector of neutron for civil transportation control

Tuesday

- Morning - General Discussion about the simulation
  - The roadmap
  - The studied physics
- Afternoon - Application workshop: Demonstration and application to various cases (classical, and proposed while the discussion). Bring your laptop!

What to expect from this workshop

- To understand the “low level” optical modules simulation
  - The efficiency an the local properties of the detector

    but
  - No full detector reconstruction
  - No muon reconstruction
- To understand how it works and to be able to contribute to it
  - New application
  - Improvments
  - ...

The lunch

- Number of persons to go to the Fuorigrotta? (reservations)