REST v2.0

A data analysis and simulation framework for micropatterned readout detectors.

J. Galan
Shanghai Jiao Tong University (SJTU)

In collaboration with the University of Zaragoza

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Rare Event Searches for TPCs software

REST arises as a need to unify common codes for simulation and data processing within the group at University of Zaragoza.

REST is motivated by its use in different projects and experiments (as TREX-DM, IAXO-D0, PandaX-III, …).

It defines a common collaborative framework allowing for transferable event data, reproducible results and data versus simulation comparison.

REST is an initiative from the University of Zaragoza, and it is developped with the experience gained by the group during the last years, and it is strongly supported by PandaX-III collaboration for its use on detector simulation, data analysis and detector response studies.

REST in a nutshell

REST defines a ROOT-ified and encapsulated metadata and data format.

Fixes basic event data structures : HitsEvent, TimeSignalEvent, TrackEvent

Prototypes the implementation of processes that allow to transform event data.

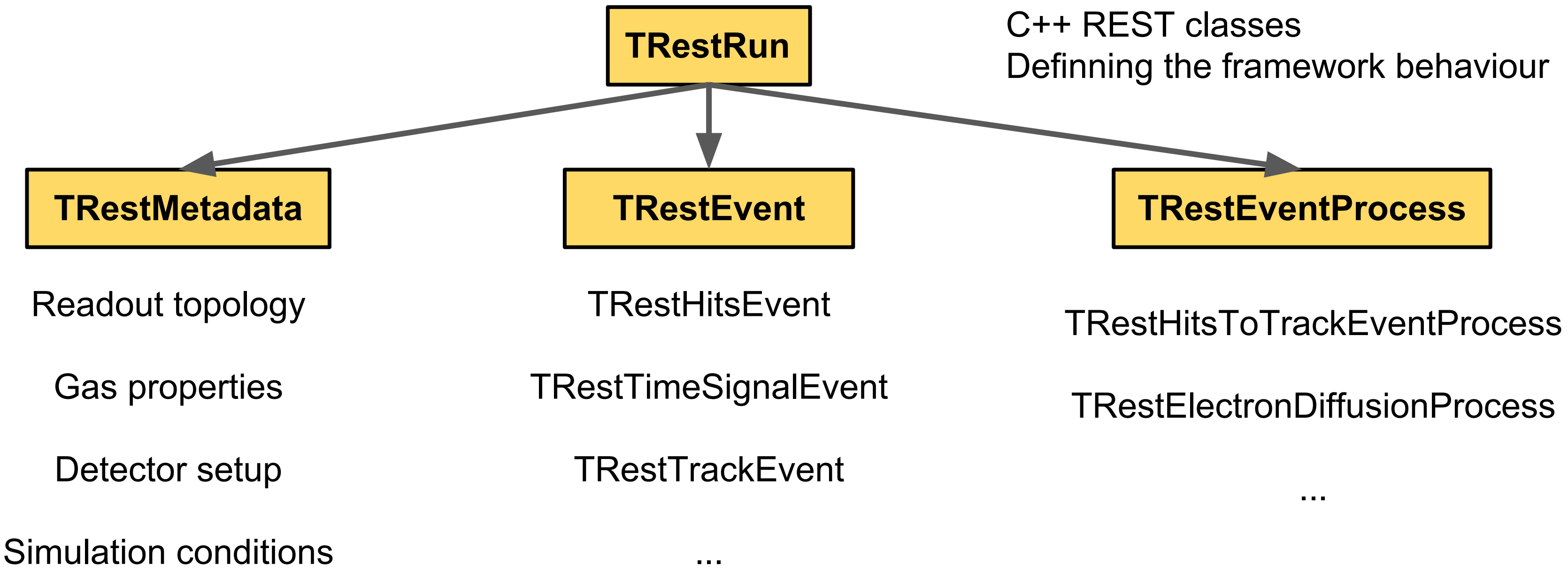
Defines how metadata information is stored and given to the framework to define the behaviour of the framework (allowing to define for example, processes parameters, simulation conditions, detector readout topology, etc).

REST includes pre-defined metadata (readout topology - gas properties) structures and processes that can be used for gas Micropatterned readout detectors.

REST Framework scheme

All the **event data and metadata** access (I/O) is managed/centralized in TRestRun.

TRestRun is also responsible to manage **event processing**.



Framework scalability and structure

REST **offers scalability and integration** of new metadata, event data types and event processes provided by the user.

Although common event types, metadata structures and processes related to event reconstruction, detector response and track analysis **are already existing** inside the framework.

REST framework

Defines basic event types, metadata classes, and basic event data transformation.

+ visualization tools, process manager, common plotting tools, analysis tree, etc

Track processing package

Signal processing package

....

+ user defined

The functionality of the framework is extended using packages that contain related processes.

I.e. adding signal noise, signal deconvolution, signal shaping, etc.

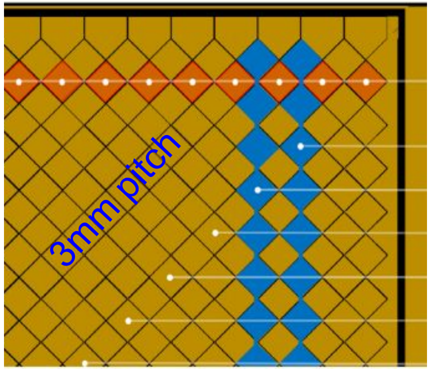
TRestReadout metadata definition (hits ↔ signal)

Advanced features in configuration scheme defined by TRestMetadata allows for complex readout topology definitions.

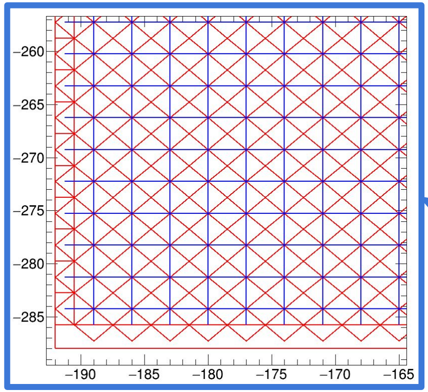
Using FOR loops or complex mathematical expression evaluation.

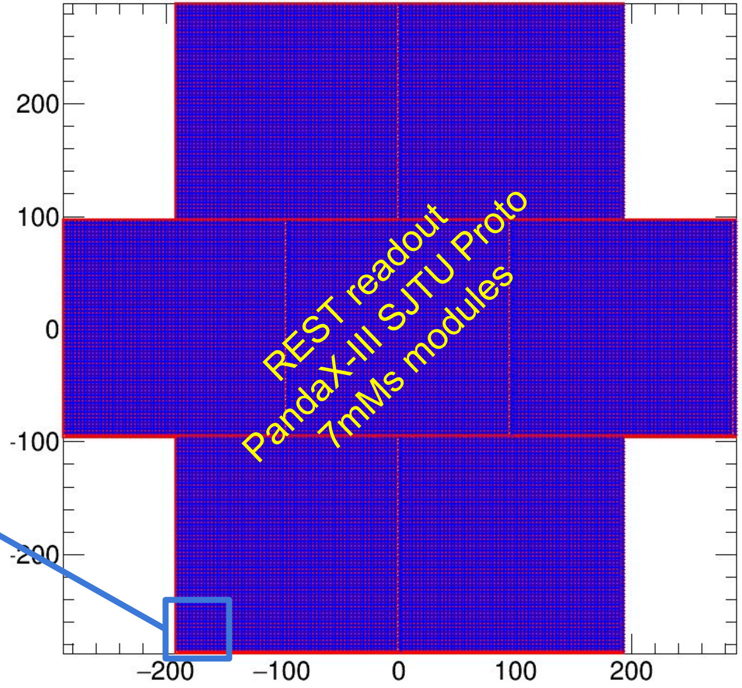
The readout is made of readout pixels - readout channels - readout modules

Gerber design from PandaX-III microbulk detectors



REST readout visualization





restG4 package (simulation input from Geant4)

restG4 is a package allowing us to generate a first dataset in the REST event data and metadata format.

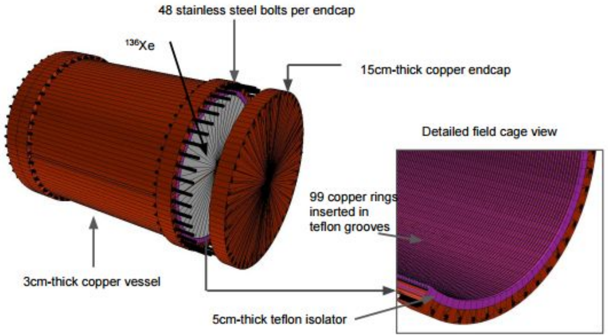
It requires :

- A description of the simulation conditions through an REST configuration file.

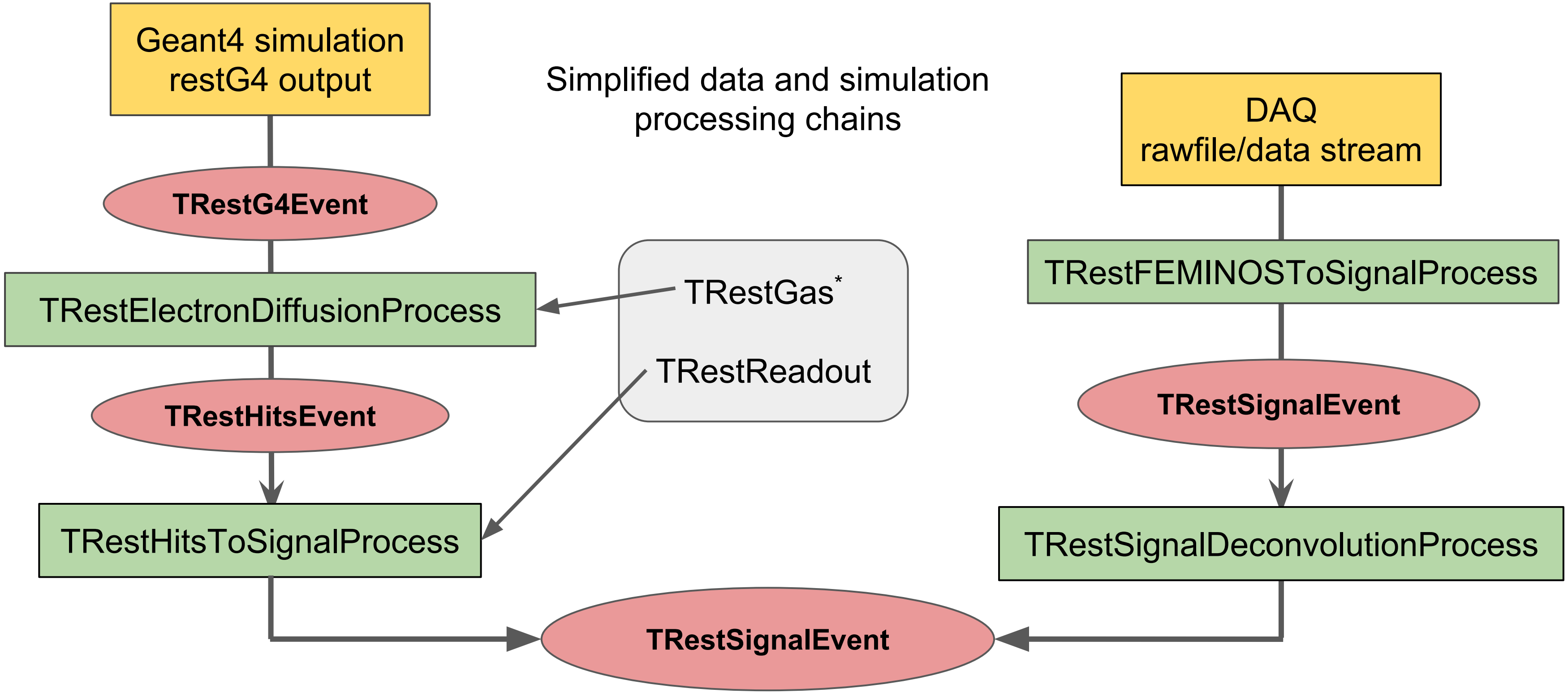
- A geometry definition in GDML compatible with ROOT.

Example with primaries definition : **U238** launched from volume **vessel** existing in GDML geometry

```
<parameter name="gdml_file" value="pandaXIII_Setup_WT12m.gdml"/>

<generator type="volume" from="vessel" >
    <source particle="U238" fullChain="on">
        <angularDist type="isotropic" />
        <energyDist type="mono" energy="0" units="keV" />
    </source>
</generator>
```

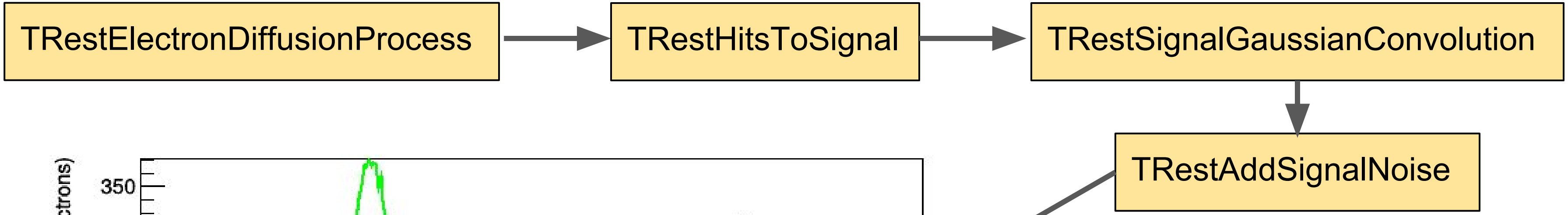


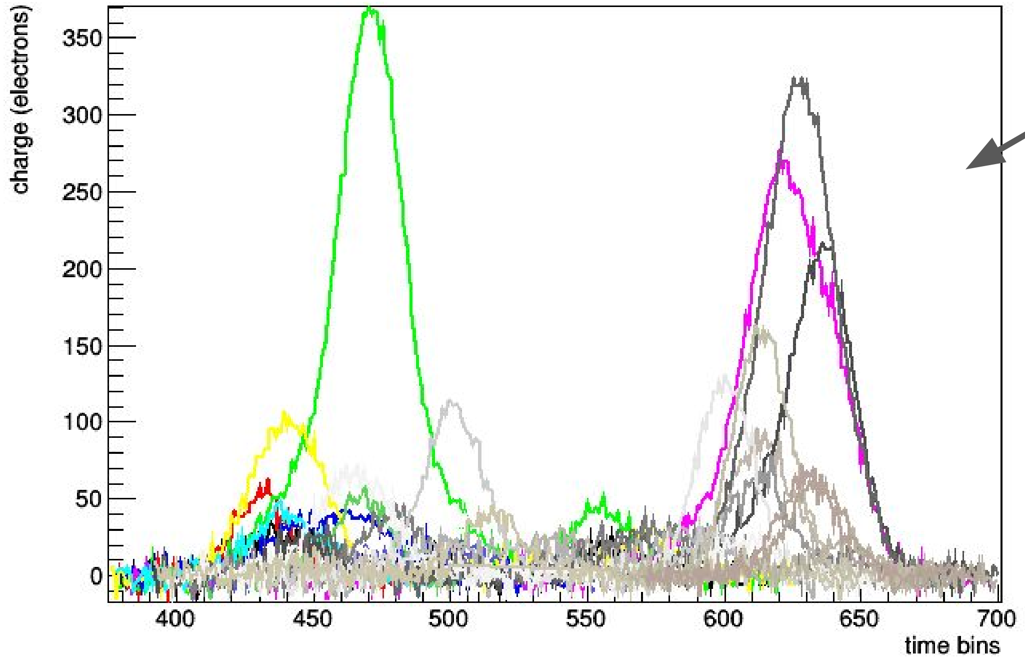
Towards comparison of rawdata and simulation data



* Gas parameters as drift velocity or gas diffusion can be directly given to processes.
TRestGas allows to define the properties of any gas mixture by using the Garfield++ interface to Magboltz.

Daq event like simulation data

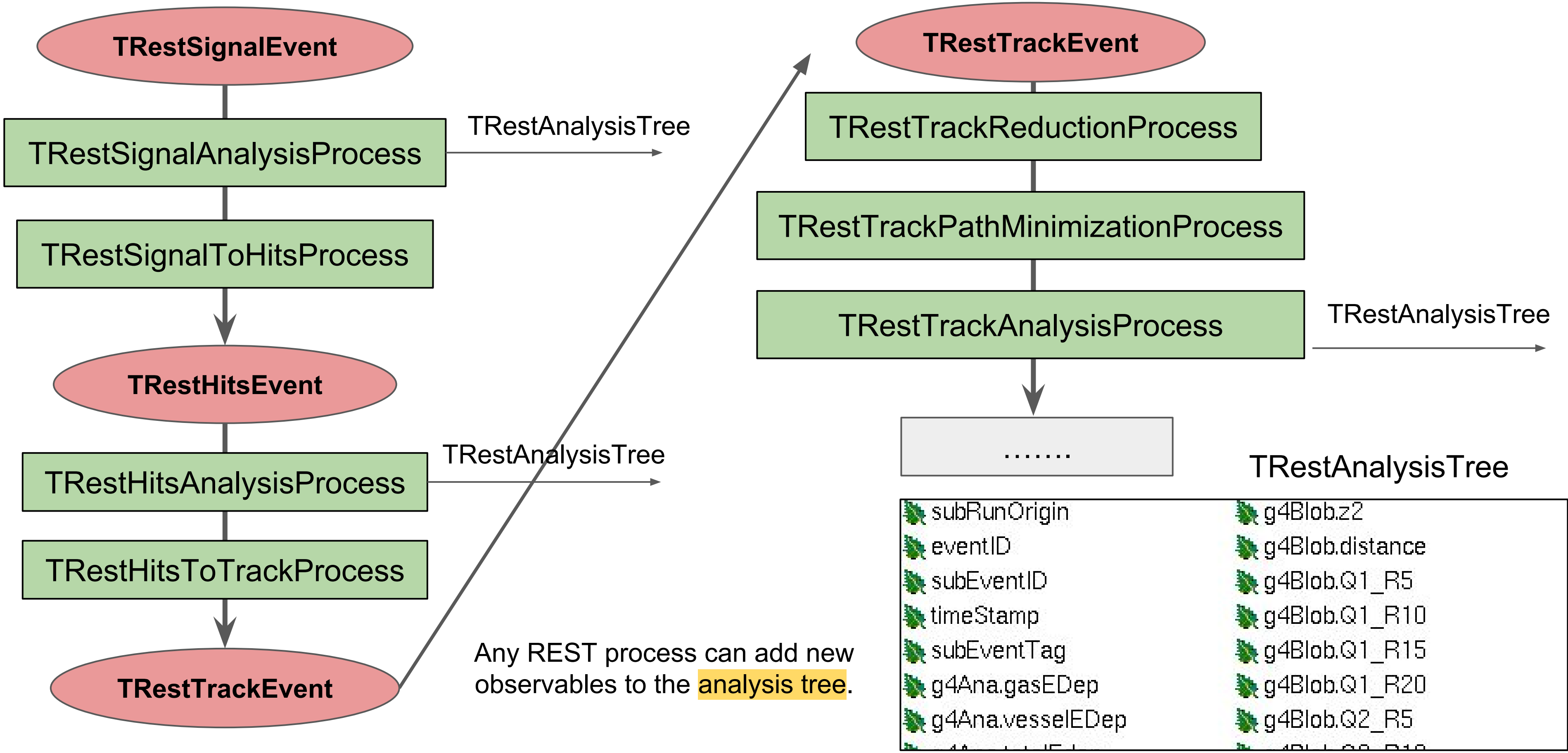




The main goal is to reach one point where the processing and analysis of events for simulated data and real data is similar.

More complex existing processes exploiting direct electronics response and noise reduction.

Common rawdata/simulation process chain

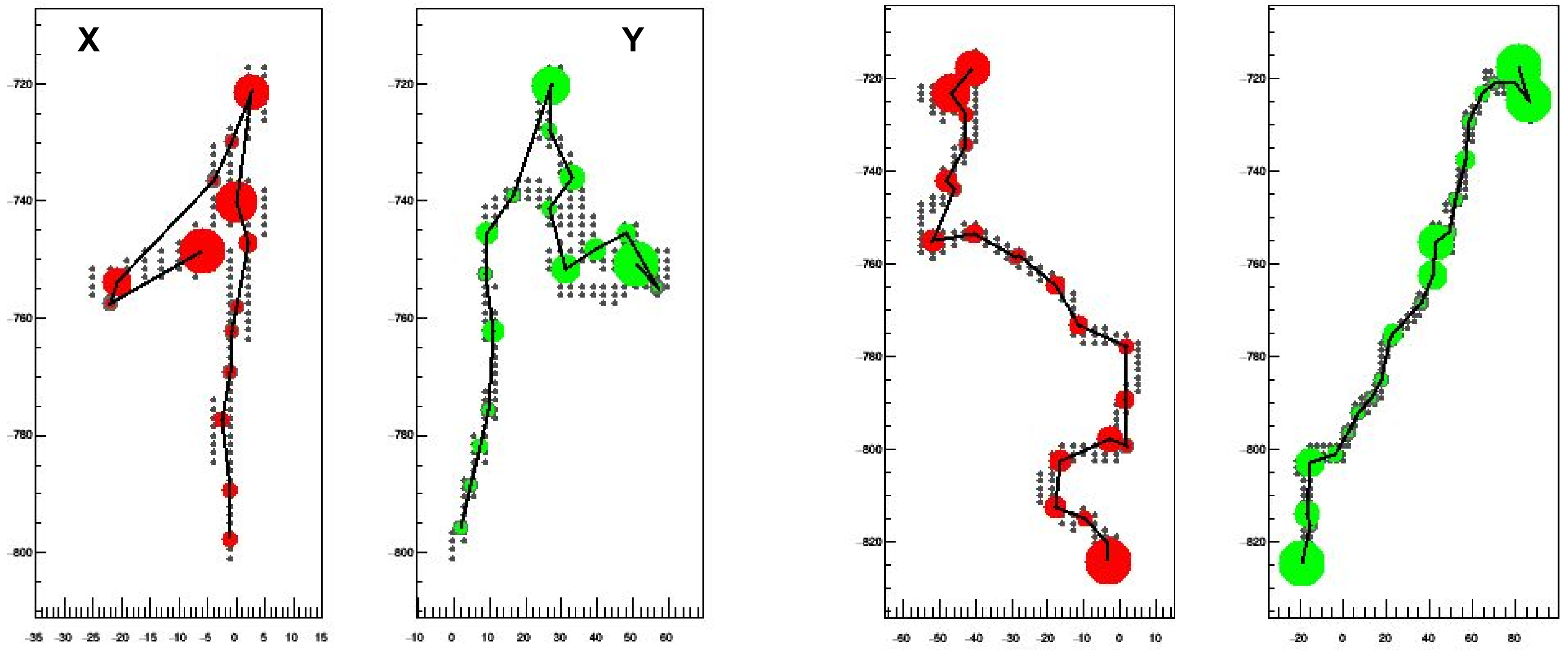


Any REST process can add new observables to the analysis tree.

The resulting processed track event

XZ and YZ track event projections for simulated events using PandaX-III stripped readout.

Sampling : 1 us
Pitch : 3mm



REST encapsulated ROOT data format

REST files are self content and keep full traceability of the event data processing metadata.

Typical REST file contents

```
TFile*         /home/javier/restData/Run_trackAnalysis_Xe136_00009_000
 KEY: TRestG4Metadata  HM0. restG4;1   Xe136
 KEY: TRestTrackAnalysisProcess       P0. tckAna;1    Track analysis
 KEY: TRestGeant4AnalysisProcess      HP0. g4Ana;1    Geant4 analysis
 KEY: TRestFindG4BlobAnalysisProcess  HP1. g4Blob;1   Find blobs in D
 KEY: TRestG4toHitsEventProcess       HP2. G4ToHits;1 G4Hits to Hits
 KEY: TRestHitsShuffleProcess  HP3. hitsShuffle;1      Shuffles the hi
 KEY: TRestHitsToTrackProcess  HP4. hitsToTrack;1
 KEY: TRestTrackReductionProcess      HP5. trackReduction;1   Merges
 KEY: TRestTrackPathMinimizationProcess       HP6. trackPathMinimizat
 KEY: TRestTrackReconnectionProcess   HP7. trackReconnection;1
 KEY: TRestFindTrackBlobsProcess      HP8. tckBlob;1  Find blobs in t
 KEY: TTree    TRestTrackEventTree;1   Simulations PandaX-III v1.0
 KEY: TRestAnalysisTree       TRestAnalysisTree;1      Simulations Pan
 KEY: TGeoManager      Default;1       Geometry imported from GDML
 KEY: TRestRun PANDA-X III run;1       Simulations PandaX-III v1.0
```

Geant4 simulation conditions

Processes metadata information

Event data

Analysis Tree

Geometry

Run metadata

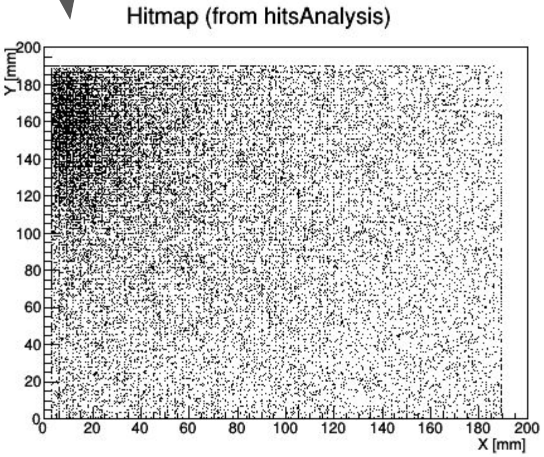
TRestAnalysisPlots

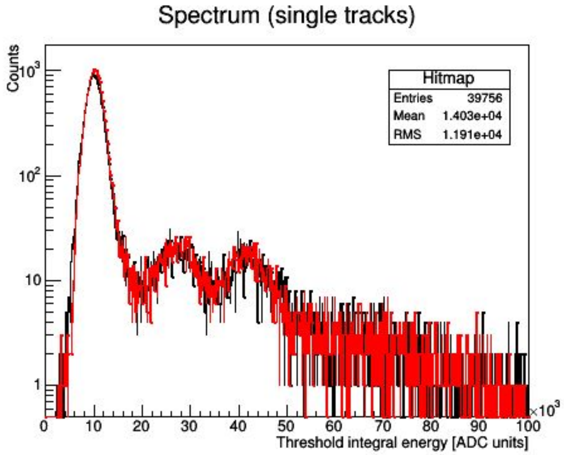
```
<plot name="Hitmap" title="Hitmap (from hitsAnalysis)" xlabel="X [mm]" ylabel="Y [mm]"
    logscale="false" save="/tmp/file3.png"  value="ON" >
    <variable name="hitsAna.yMean" range="(0,200)" nbins="1000" />
    <variable name="hitsAna.xMean" range="(0,200)" nbins="1000" />
</plot>
```

We can do 1D, 2D or 3D plots

```
<plot name="Hitmap" title="Spectrum (single tracks)" xlabel="Threshold integral energy [ADC units]" ylabel="Counts"
    logscale="true" save="/tmp/file4.pdf"  value="ON" >
    <variable name="sgnlAna.ThresholdIntegral" range="(0,100000)" nbins="1000" />

    <cut variable="tckAna.nTracksX" condition="==1" value="ON" >
    <cut variable="tckAna.nTracksY" condition="==1" value="ON" >
</plot>
```

We can apply specific cuts to each plot definition





TRestAnalysisPlots for quick look data production

TRestAnalysisPlot::
PlotCombinedCanvas()

It show a screen with all the plots defined in our plotAnalysis section.

<canvas size="(1000,800)" divide="(2,2)" />

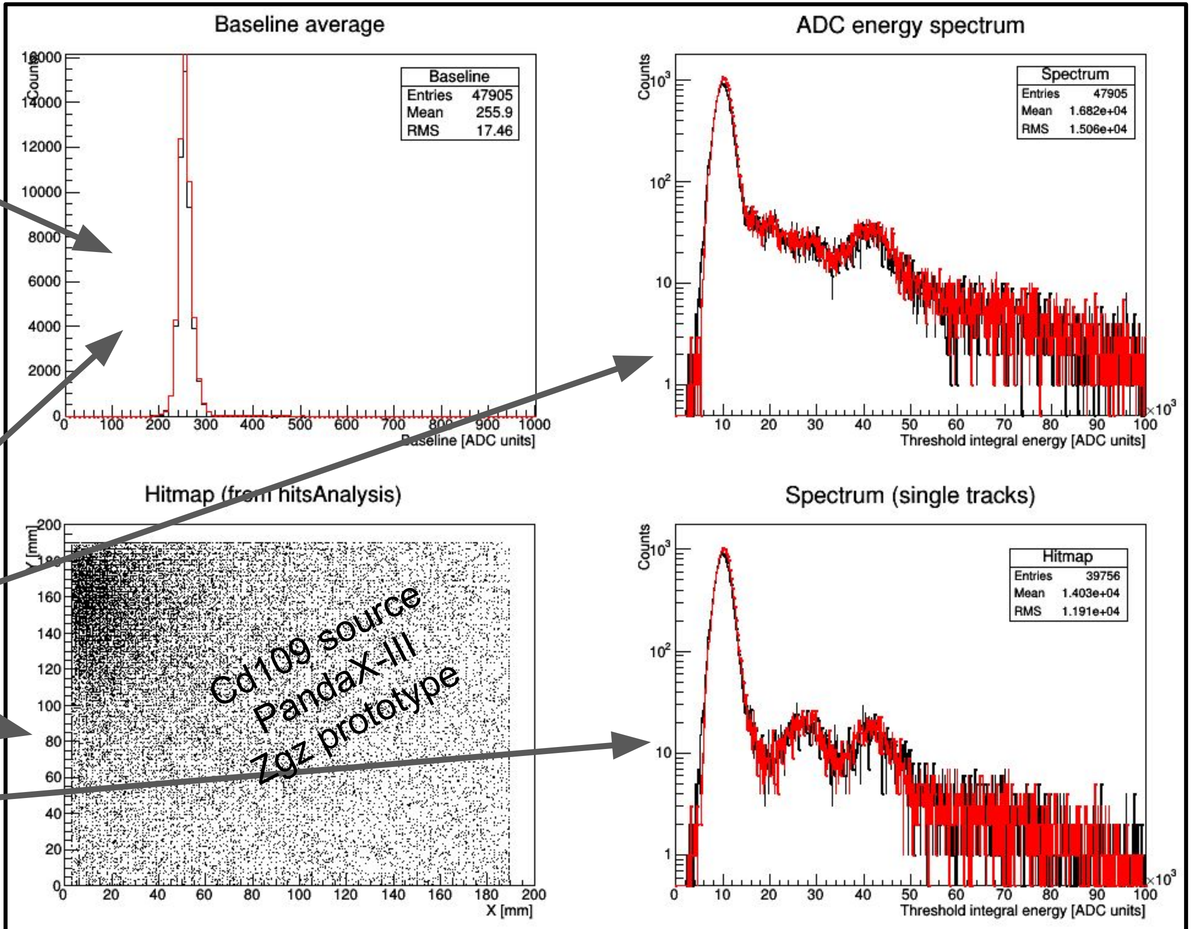
If the option save is enabled (we have provided a filename) each of the plots will be stored in the filename given.

<plot name=”Baseline” …>

<plot name=”Spectrum” …>

<plot name=”Hitmap” …>

<plot name=”Spectrum2” …>

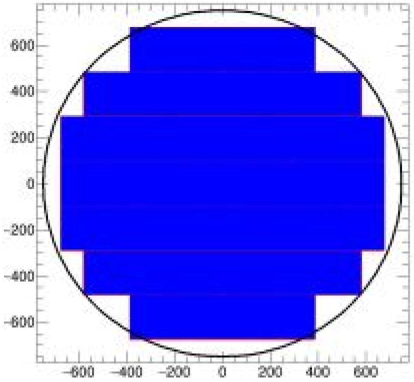


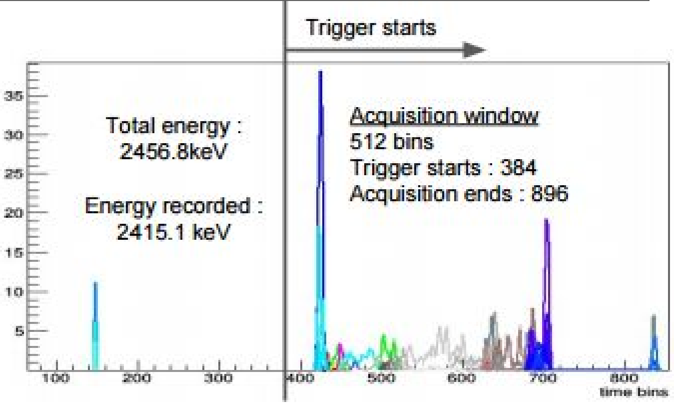
PandaX-III results produced with REST

The PandaX-III CDR was submitted to arXiv recently.

PandaX-III: Searching for Neutrinoless Double Beta Decay with High Pressure ^{136}Xe Gas Time Projection Chambers

https://arxiv.org/abs/1610.08883





Full event	Smearing (3% FWHM)	Time window	Active area
74.2%	70.8%	64.9%	54.2%

Background contribution and detector readout and time response was studied with existing REST processes and metadata structures.

Full study of different background contributions from different detector components.

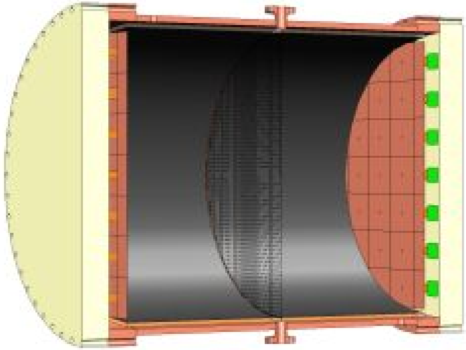
Component	Isotope	Background (10^{-5} c/(keV·kg·y))	
		BambooMC	RestG4
Water	^{238}U	-	0.23
	^{232}Th	0.56	0.63
Barrel	^{238}U	1.07	2.41
	^{232}Th	7.54	7.86
	^{60}Co	3.02	2.11
End-caps	^{238}U	0.30	1.26
	^{232}Th	3.89	4.16
	^{60}Co	2.98	0.76
	^{238}U	3.50	11.9

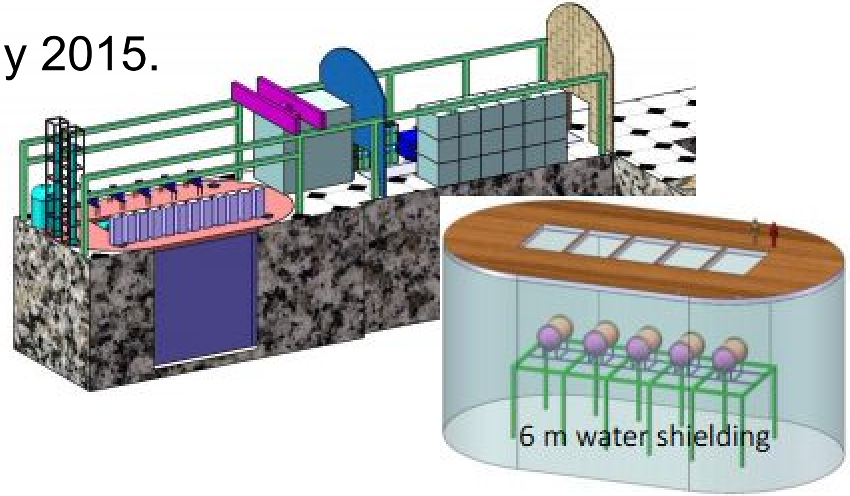
PandaX-III program

Panda X-III built based on the experience on Panda X-II (dark matter rare event search) and R&D progress on microbulk detectors operating at high pressure Xenon.

Aiming to the construction of 5 TPC modules 200Kg ^{136}Xe to reach 1-ton scale experiment by 2022.

Panda X-III community building up, since early 2015.



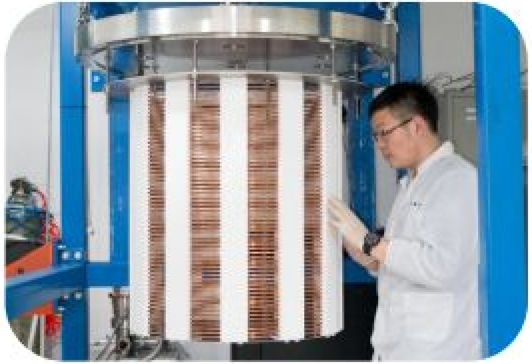


PandaX-III progress

New microbulk micromegas detectors designed and being tested.

Stripped pattern but higher granularity 3mm as baseline.

20x20 cm2
Modular readout



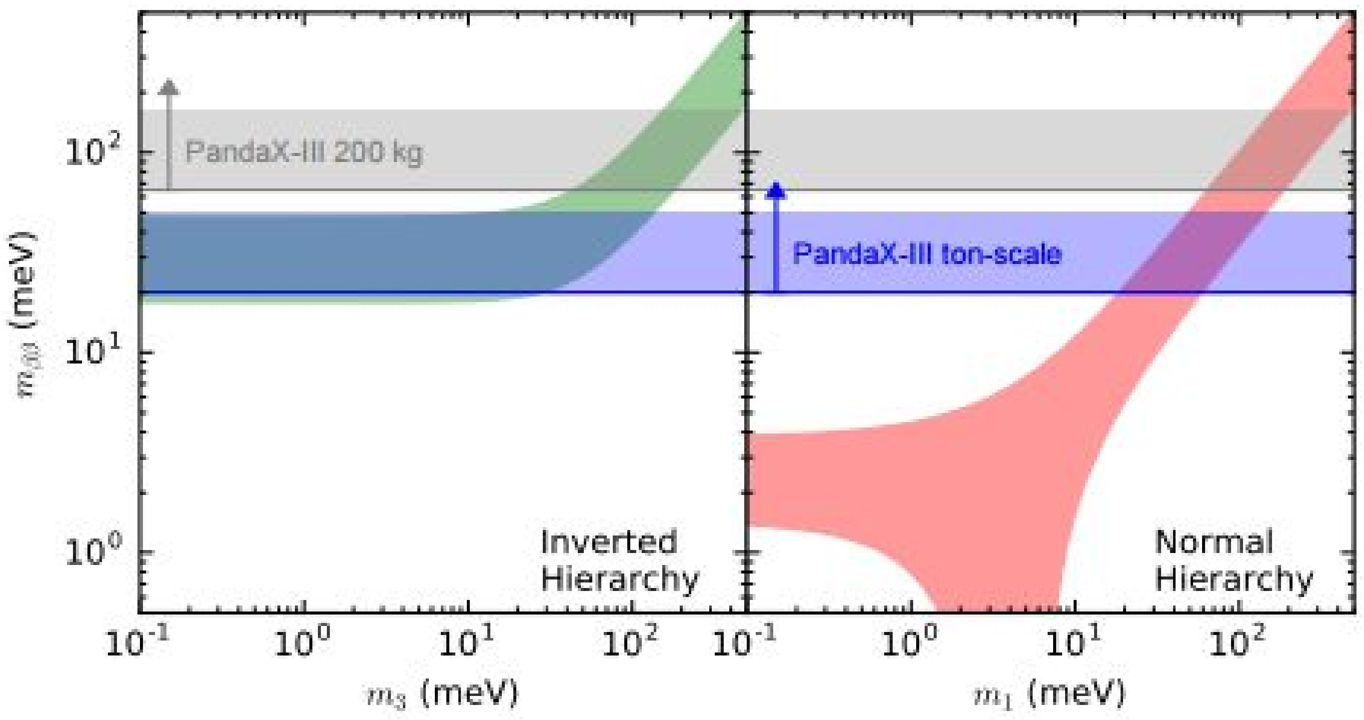
20 kg prototype TPC at SJTU built and taking data.

7mMs Modules at Shanghai ready to be installed in the prototype.

Excavation of water pit finished. Finalizing layout of Hall B4 at CJPL-II.

Sensitivity prospects for PandaX-III

Sensitivity prospects for 3 years data taking period with 1 module 200Kg and 1-ton scale experiment.



Detector response expected background

3 10-3 keV-1 kg-1 y-1

After topological rejection

10^{-4} keV^{-1} kg^{-1} y^{-1}

Aiming to reach

$$T_{\frac{1}{2}} > 10^{26}\ yr$$

For 136Xe

Summary

REST defines a data analysis framework with tools to study micropatterned readouts, specially designed for Rare Event Searches TPCs.

It fixes data format, metadata management and event data types. Allowing for data exchange, re-processing, and analysis comparison.

Scalability of the framework allows for event data process connectivity. Allowing the user framework to introduce his own specific processes into the framework.

New version of REST already being used to produce results in **PandaX-III**. Data/metadata layout processing ready for large data management.

Full framework interface through configuration files allows for quick learn curve making it ideal for new students.

Plans for code distribution keeping open-source philoshophy.

Gas mixture description

Predefined REST gas mixtures described in RML

```
<section gas name="Gas-Xenon-TMA 1Pct" title="Xenon-TMA Mixture (1Pct TMA)">
    <parameter name="pressure" value="10" />
    <parameter name="temperature" value="293.15" />
    <parameter name="maxElectronEnergy" value="400" />
    <parameter name="ionizationPotential" value="10" />
    <parametere name="nCollisions" value="10" />
    <eField Emin="100" Emax="1000000." nodes="20" />
    <gasComponent name="xe" fraction="0.99" />
    <gasComponent name="n(ch3)3" fraction="0.01" />
</section>
```

Any gas available in Magboltz can be used in REST. The name convention can be found in Garfield++ user guide (Table B1).

http://garfieldpp.web.cern.ch/garfieldpp/documentation/UserGuide.pdf

Cosmic μ/γ generator config file

<generator type="**virtualWall**" position="(**0,400,0**)" units="mm" size="**200**" units="mm" rotation="(**90.,0,0**)">

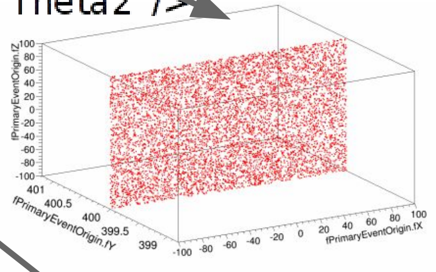
<source particle="**mu-/gamma**">

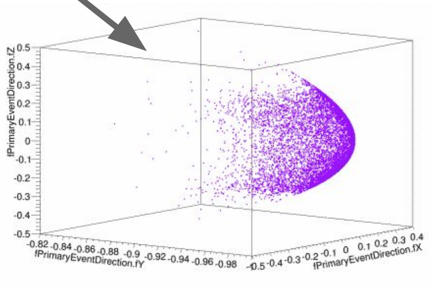
<energyDist type="**TH1D**" file="../../inputData/distributions/Muons.root" spctName="cosmicmuon" range="(0.1,350)" units="GeV" >

<angularDist type="**TH1D**" file="../../inputData/distributions/CosmicAngles.root" spctName="Theta2"/>

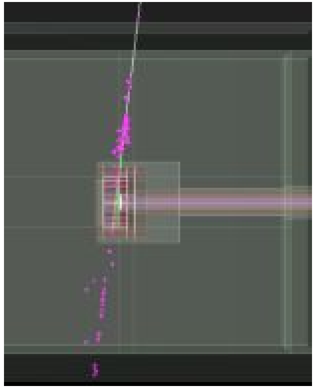
</source>

</generator>

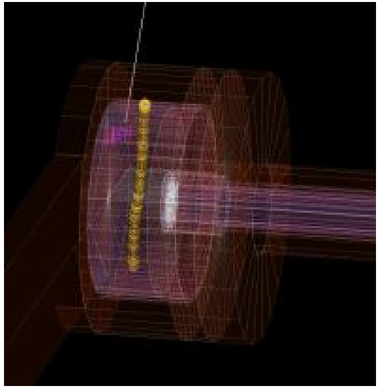




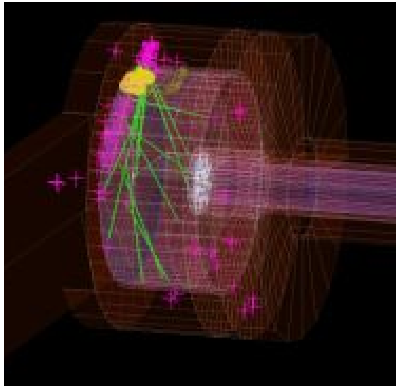
Cosmic muon



Low E cosmic Gamma (~MeV)



High E cosmic Gamma (~10GeV)



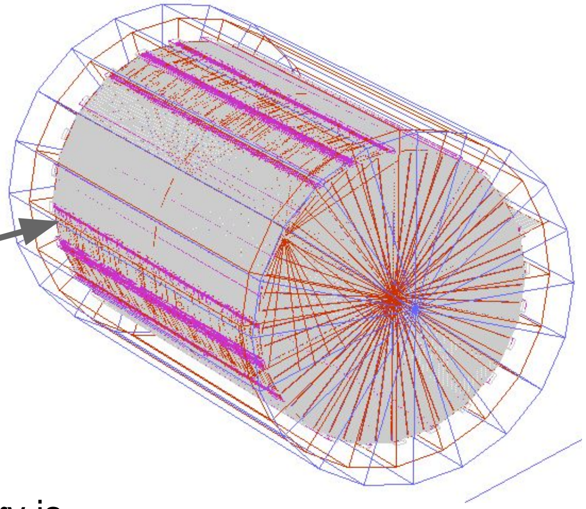
Simulations for IAXO detector by E. Ruiz Choliz/J. Gracia at Univ. of Zaragoza

restG4 uses GDML geometry definition.

GDML in ROOT

Interactive root session:

```
TGeoManager *geo = new TGeoManager();
geo->Import("GeometrySetup.gdml");
geo->GetTopVolume()->Draw("ogl");
```

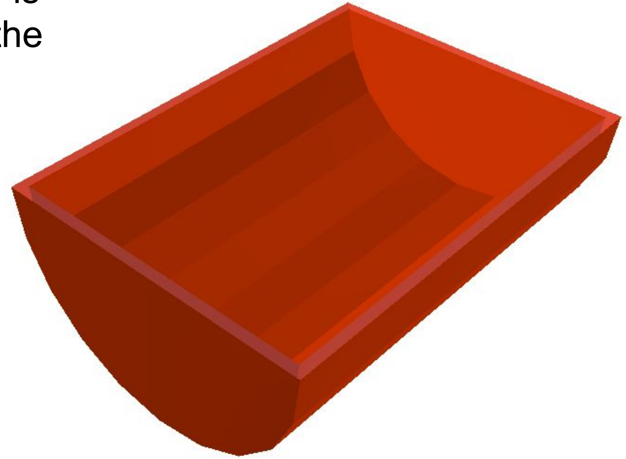


GDML Geometry in REST

Interactive root session:

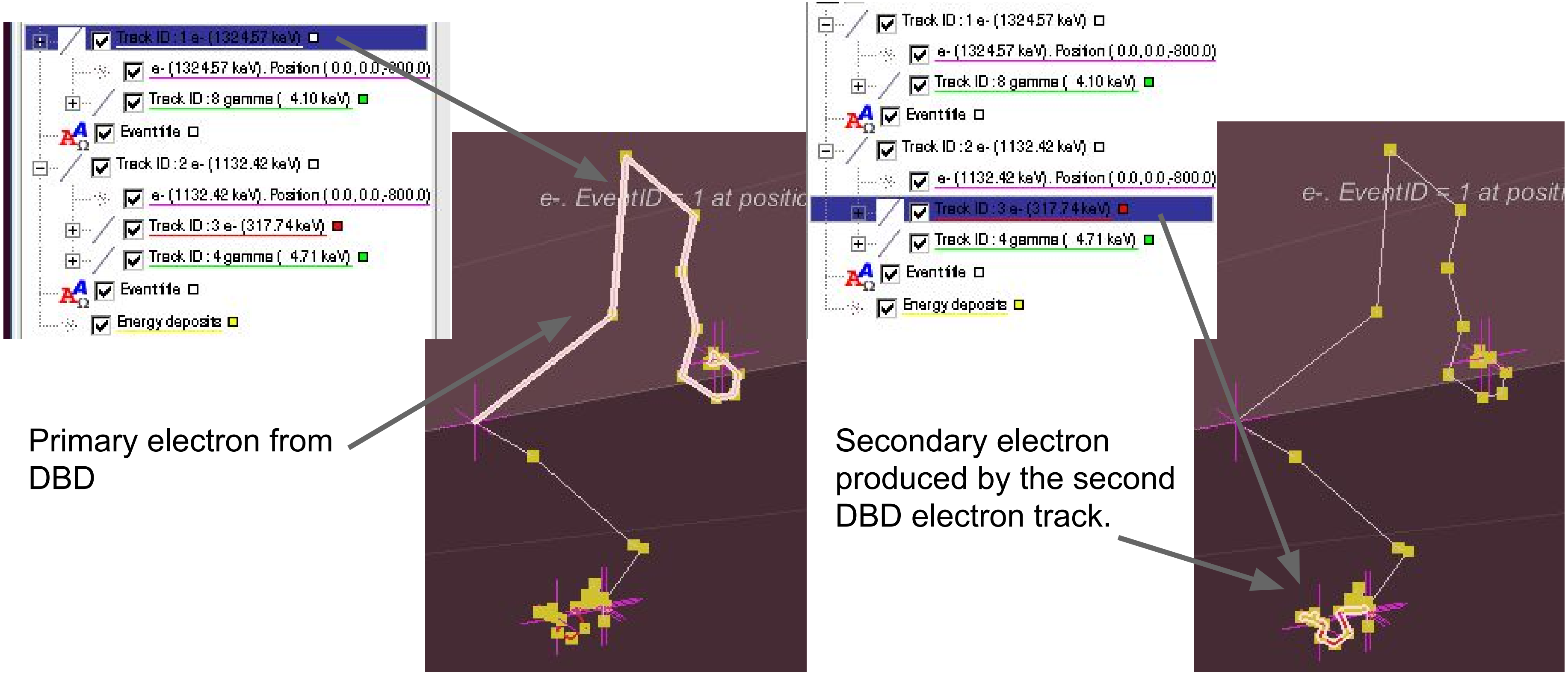
```
TRestRun *run = new TRestRun();
run->OpenInputFile("myRESTFile.root");
TGeoManager *geo = run->GetGeometry();

geo->GetVolume(3)->GetName();
>> (const char* 0x33343e9)"vesselVolume"

geo->GetVolume(3)->Draw("ogl");
```

The geometry is stored inside the REST file.



REST also provides visualizing tools for each basic event data type

The Eve Manager facilitates the Geant4 event inspection and track identification.



Readout PandaX-III Jinping

- Now we define readout planes.

- Each readout channel inside the readout is associated to a <u>unique</u> daqId -> decoding

A readout plane defines also its position, orientation and cathode position.

So that, now the definition of the readout is also the definition of the drift volume.

I.e. we can do readout->GetReadoutPlane(0)->isInsideDriftVolume(x, y, z);
This is now used in TRestElectronDiffusion

This is one readout plane. For the moment, we have just a 2D schematic readout viewer.