A Customizable GeantV Calorimeter Application

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Advised by Sofia Vallecorsa, Andrei Gheata

(honorable mention to Mihaly Novak)

Status: Early June

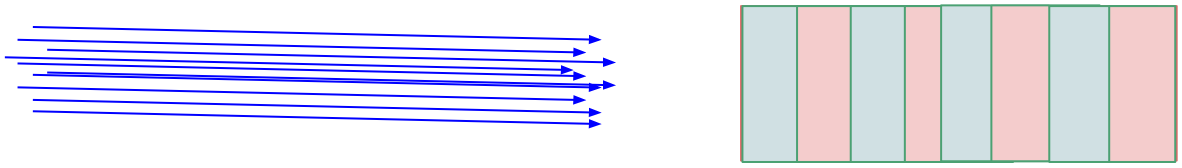
A physics simulation toolkit must support two fundamental user-defined inputs:

Incident Particles

- Type
- Energy
- Direction

Detector

- Materials
- Geometry



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(e-, e+, p, etc.)

Detector
(Calorimeter, Tracker,
CMS/Atlas geometry, etc.)

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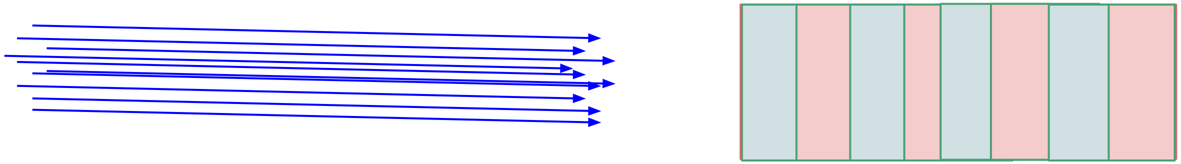

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Detector
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GeantV can’t do this by itself!
(circa June 2017)

June Workflow: Defining and testing a calorimeter

Define calorimeter parameters

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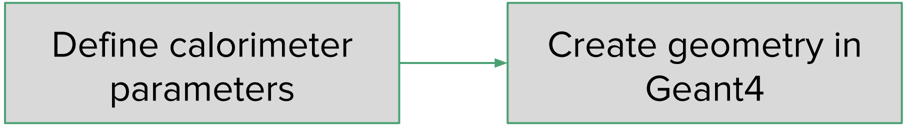
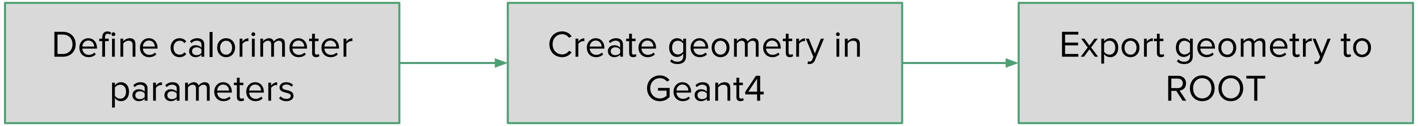


Define calorimeter parameters

Create geometry in Geant4

June Workflow: Defining and testing a calorimeter



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Export geometry to ROOT

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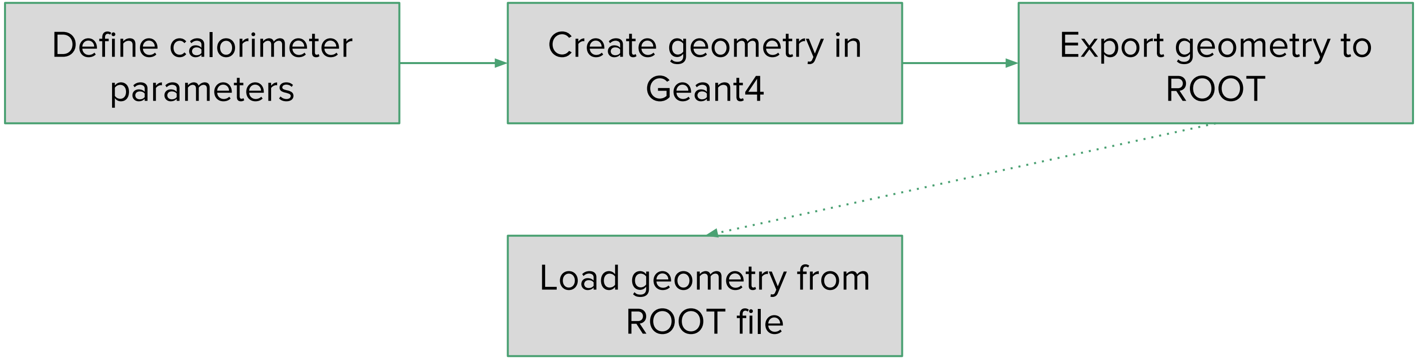

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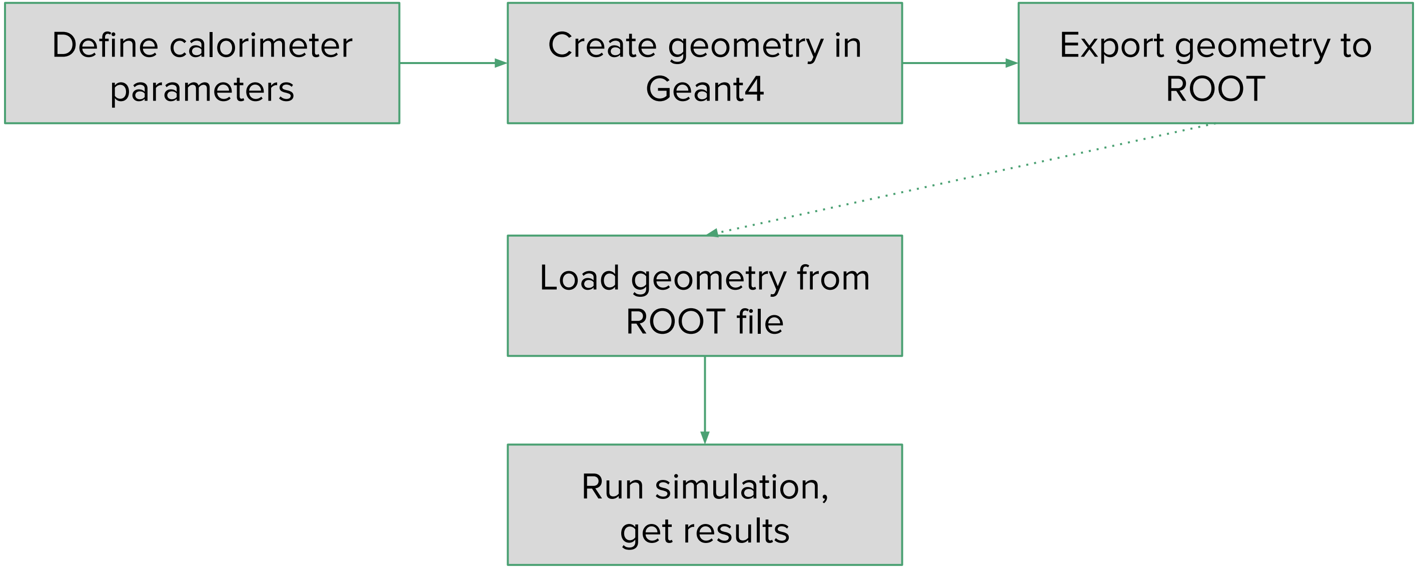

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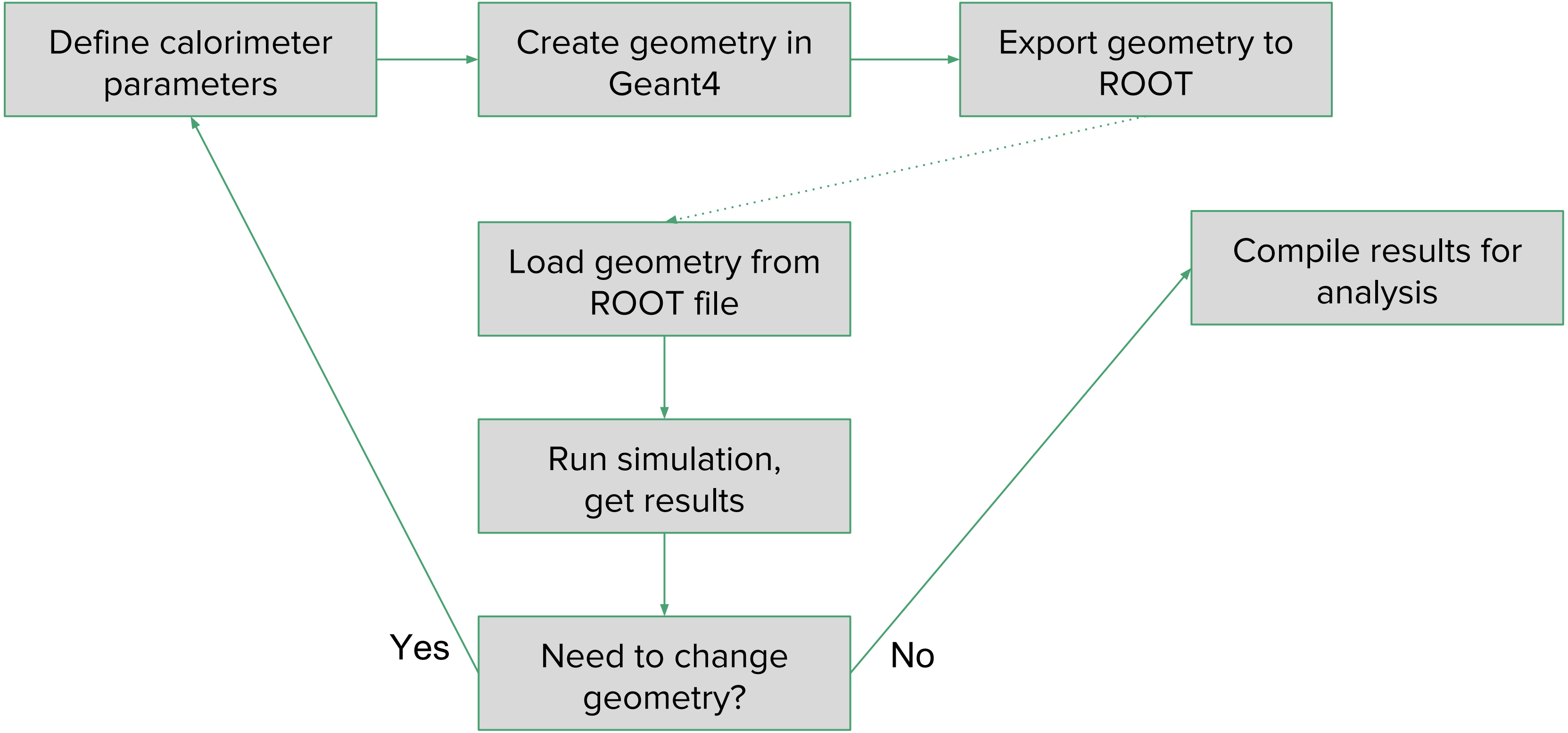

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Need to change geometry?

Yes

No

Compile results for analysis

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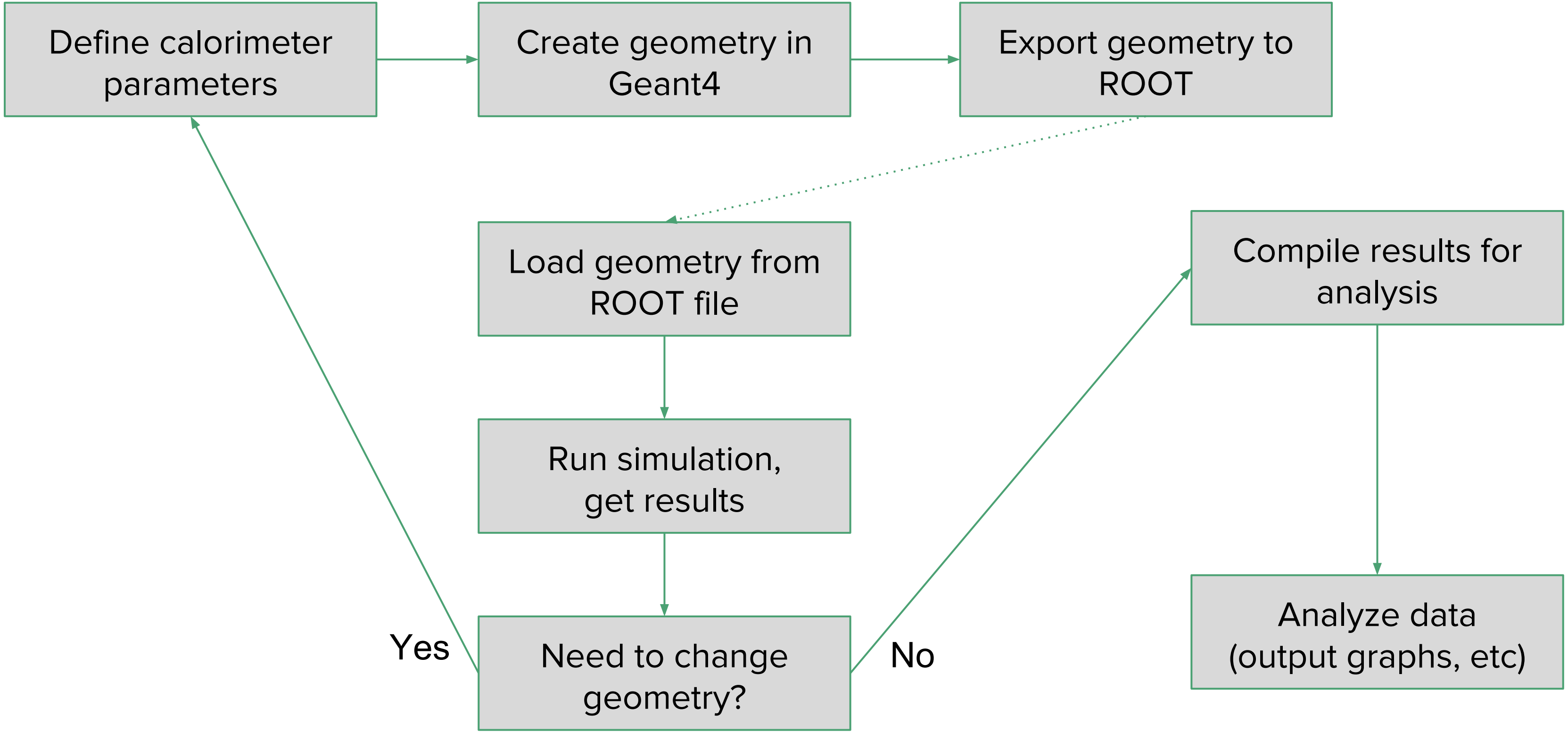

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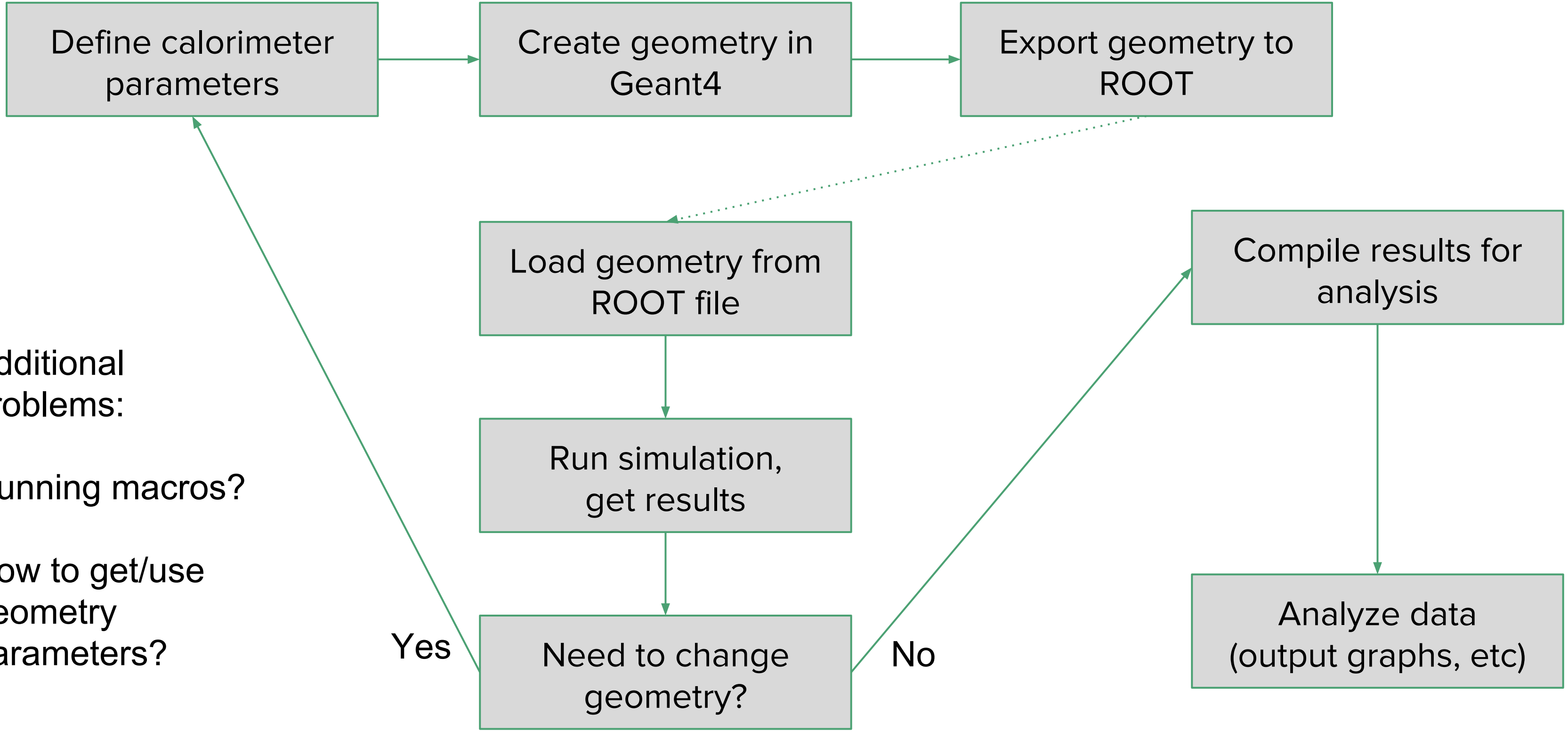
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Additional problems:

Running macros?

How to get/use geometry parameters?

Project Goals:

- Provide an implementation of a **user-defined detector**, including geometry and materials

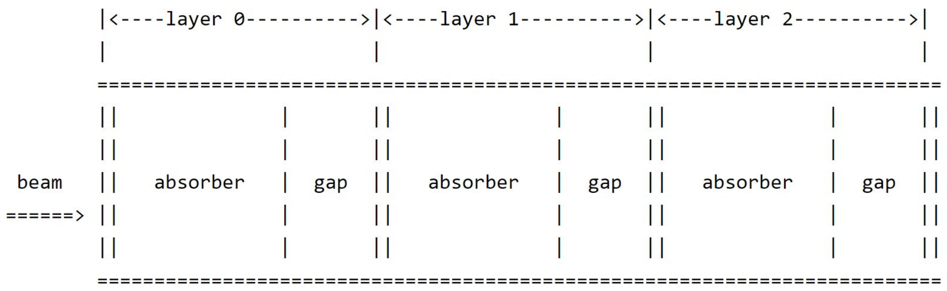
- Allow for this detector to be **fully customizable** without need to recompile

- Use “**real physics**” (as opposed to tabulated physics)

- Implement **new data structures** which allow for outputs to be associated with individual primaries

GeantV Calorimeter: User Detector Construction

Goal: Develop an example detector construction which can be easily grasped by users familiar with Geant4



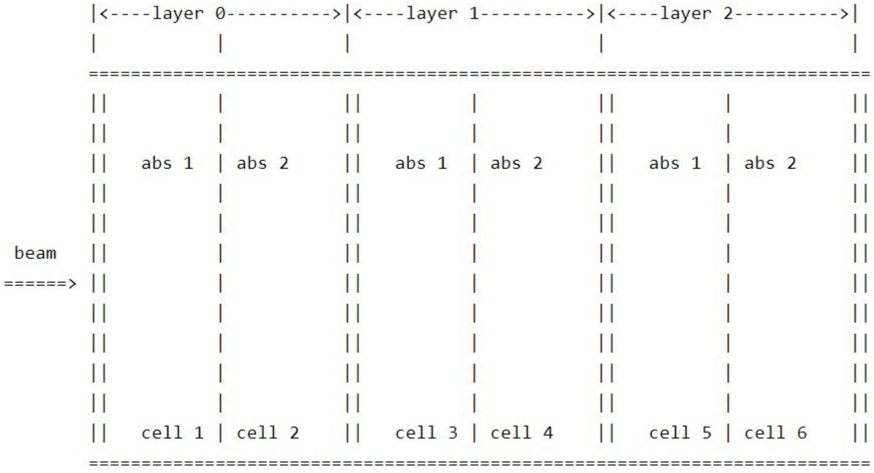
```
        |<----layer 0---------->|<----layer 1---------->|<----layer 2---------->|
        |                       |                       |                       |
        ==========================================================================
        ||              |       ||              |       ||              |       ||
        ||              |       ||              |       ||              |       ||
 beam   ||   absorber   |  gap  ||   absorber   |  gap  ||   absorber   |  gap  ||
======> ||              |       ||              |       ||              |       ||
        ||              |       ||              |       ||              |       ||
        ==========================================================================
```

- Detector construction style inspired by Geant4 TestEm3
  - Includes a CreateMaterials() and CreateGeometry() method, following Geant4 convention
- VecGeom used as basis for geometry creation and placement
  - UnplacedBox = G4Box
  - LogicalVolume = G4LogicalVolume
  - world->PlaceDaughter() = G4PVPlacement
- Inherits from base class, so other detector types can be created

GeantV Calorimeter: User Detector Construction

Detector Features:

- Customizable inputs to geometry
  - Number of layers
  - Number of absorbers per layer
  - Absorber properties (thickness, material)
  - World size, Calo YZ cross-section, etc.
- Use of NIST and/or custom materials
- Detector Regions and Production Cuts
- Get/Set methods to receive detector properties as inputs and pass detector information to other classes (e.g. detThickness -> initial particle gun position)



```
        |<----layer 0----------->|<----layer 1----------->|<----layer 2----------->|
        |           |            |                        |                        |
        =============================================================================
        ||          |            ||          |            ||          |            ||
        ||          |            ||          |            ||          |            ||
        ||   abs 1  | abs 2      ||   abs 1  | abs 2      ||   abs 1  | abs 2      ||
        ||          |            ||          |            ||          |            ||
        ||          |            ||          |            ||          |            ||
 beam   ||          |            ||          |            ||          |            ||
======> ||          |            ||          |            ||          |            ||
        ||          |            ||          |            ||          |            ||
        ||          |            ||          |            ||          |            ||
        ||          |            ||          |            ||          |            ||
        ||          |            ||          |            ||          |            ||
        ||   cell 1 | cell 2     ||   cell 3 | cell 4     ||   cell 5 | cell 6     ||
        =============================================================================
```

Current GeantV Calorimeter Workflow

Create geometry in GeantV

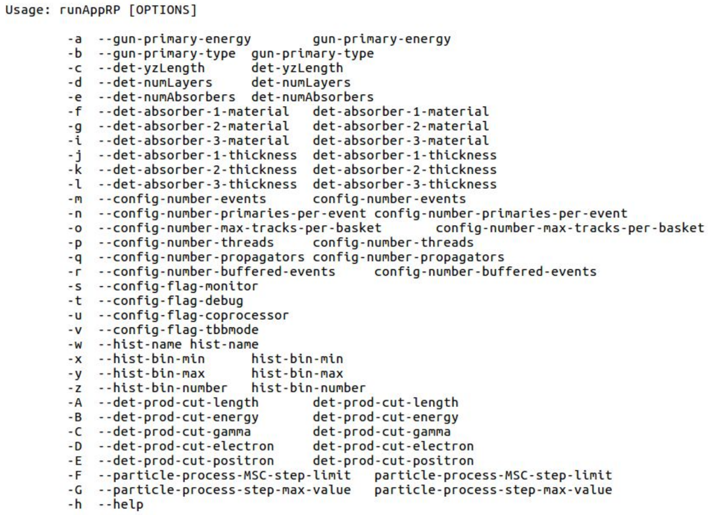
GeantV Calorimeter: Detector Inputs (Messenger)

Goal: Create interface which mirrors a messenger from Geant4, allowing users to set parameters from a macro

Since we don’t have an equivalent to a Geant4 messenger right now, this is handled manually:

- A user can run the application executable directly from terminal, using arguments to set parameters

- A user can run an executable macro in which all of the listed arguments may be set beforehand



```
Usage: runAppRP [OPTIONS]

        -a  --gun-primary-energy        gun-primary-energy
        -b  --gun-primary-type  gun-primary-type
        -c  --det-yzLength      det-yzLength
        -d  --det-numLayers     det-numLayers
        -e  --det-numAbsorbers  det-numAbsorbers
        -f  --det-absorber-1-material   det-absorber-1-material
        -g  --det-absorber-2-material   det-absorber-2-material
        -i  --det-absorber-3-material   det-absorber-3-material
        -j  --det-absorber-1-thickness  det-absorber-1-thickness
        -k  --det-absorber-2-thickness  det-absorber-2-thickness
        -l  --det-absorber-3-thickness  det-absorber-3-thickness
        -m  --config-number-events      config-number-events
        -n  --config-number-primaries-per-event config-number-primaries-per-event
        -o  --config-number-max-tracks-per-basket       config-number-max-tracks-per-basket
        -p  --config-number-threads     config-number-threads
        -q  --config-number-propagators config-number-propagators
        -r  --config-number-buffered-events     config-number-buffered-events
        -s  --config-flag-monitor
        -t  --config-flag-debug
        -u  --config-flag-coprocessor
        -v  --config-flag-tbbmode
        -w  --hist-name hist-name
        -x  --hist-bin-min      hist-bin-min
        -y  --hist-bin-max      hist-bin-max
        -z  --hist-bin-number   hist-bin-number
        -A  --det-prod-cut-length       det-prod-cut-length
        -B  --det-prod-cut-energy       det-prod-cut-energy
        -C  --det-prod-cut-gamma        det-prod-cut-gamma
        -D  --det-prod-cut-electron     det-prod-cut-electron
        -E  --det-prod-cut-positron     det-prod-cut-positron
        -F  --particle-process-MSC-step-limit   particle-process-MSC-step-limit
        -G  --particle-process-step-max-value   particle-process-step-max-value
        -h  --help
```

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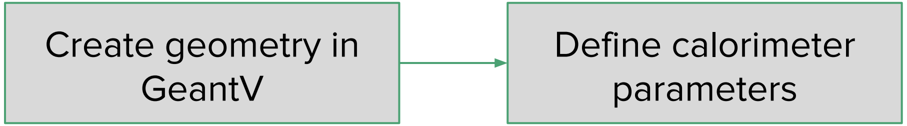


Create geometry in GeantV

Define calorimeter parameters

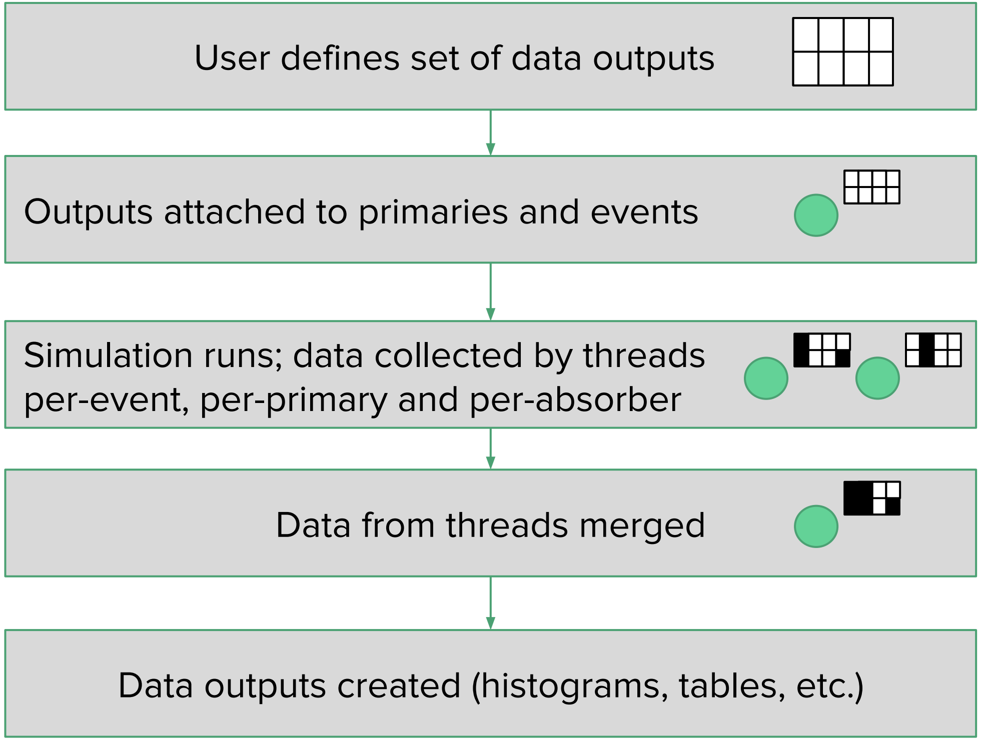
GeantV Calorimeter: Real-Physics Application

Goal: Create application which uses real physics and data structures which assign data to each primary

Derived an example application structure created by Mihaly (TestEm5)

- Adapted this for calorimeter application to allow data assignment to variable number of logical volumes

- Also created “legacy” application which outputs data in the old style (mean outputs only)


User defines set of data outputs

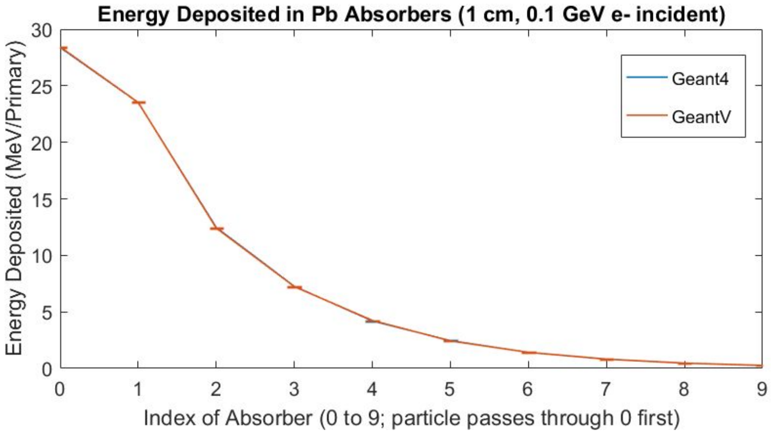
Outputs attached to primaries and events

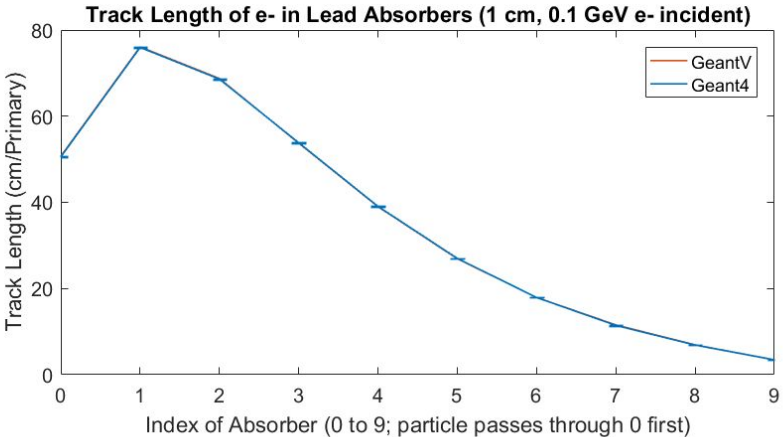
Simulation runs; data collected by threads per-event, per-primary and per-absorber

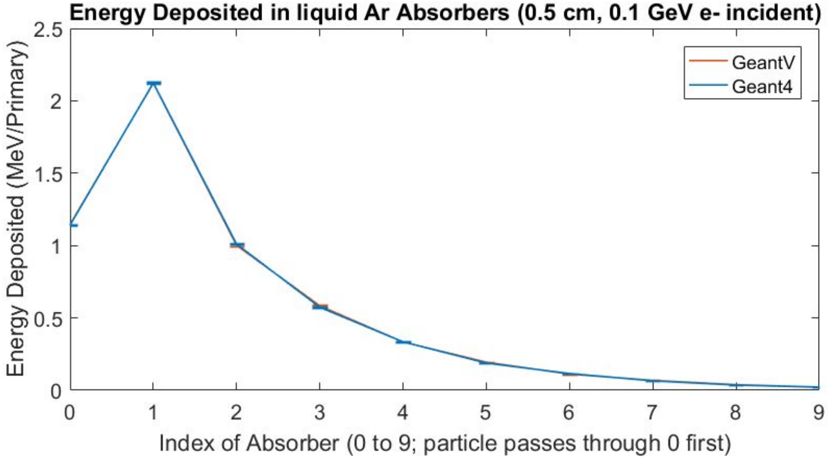
Data from threads merged

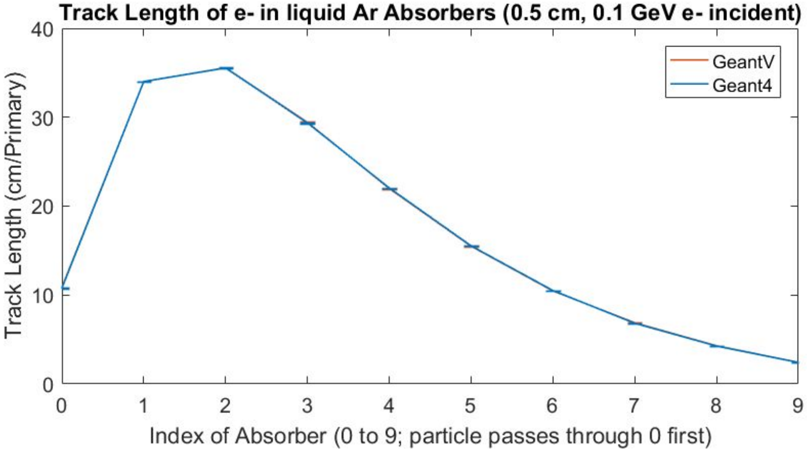
Data outputs created (histograms, tables, etc.)

Output comparison to Geant4 (TestEm3) -- Perfect match


Energy Deposited in Pb Absorbers (1 cm, 0.1 GeV e- incident)


Track Length of e- in Lead Absorbers (1 cm, 0.1 GeV e- incident)


Energy Deposited in liquid Ar Absorbers (0.5 cm, 0.1 GeV e- incident)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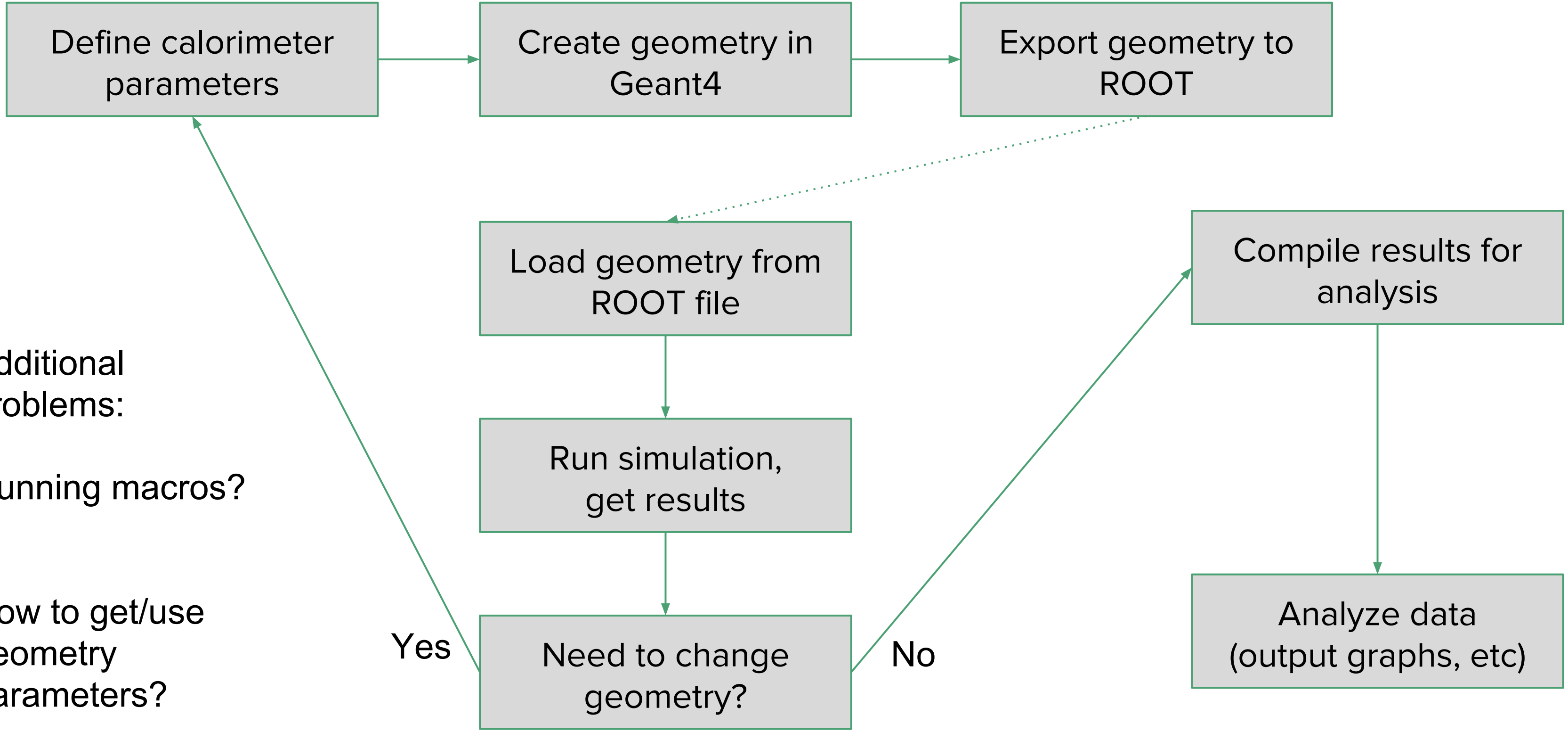

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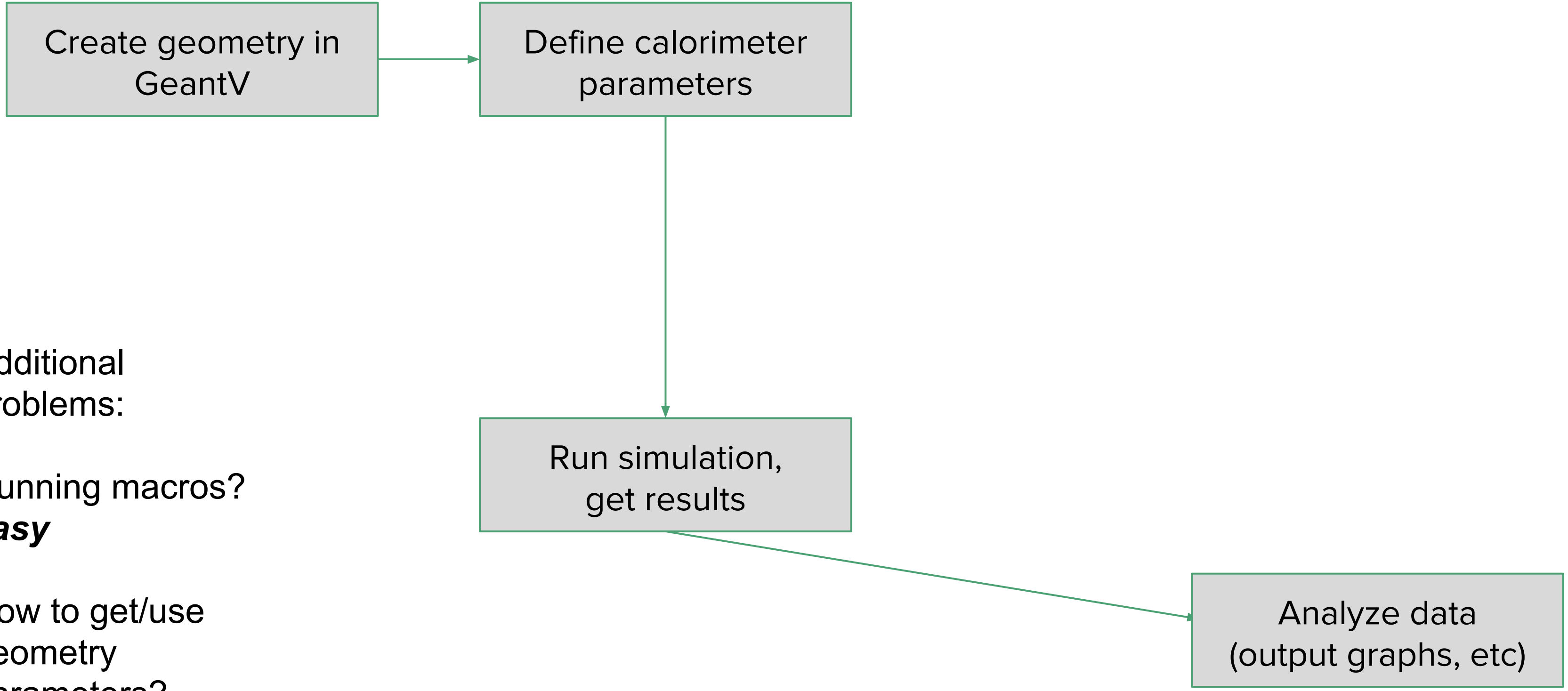

Create geometry in GeantV

Define calorimeter parameters

Run simulation, get results

Analyze data (output graphs, etc)

Additional problems:

Running macros?
easy

How to get/use geometry parameters?
Use get methods

Summary

With an Alpha release on the horizon, GeantV had an urgent need for the ability to define its own detectors

I have developed a fully customizable, self-contained calorimeter application using a user-defined detector, real physics, and new data structures

This example, with its simplified workflow and user-level syntax similar to Geant4, provides an important tool for teaching new users how to create detectors and applications in GeantV