

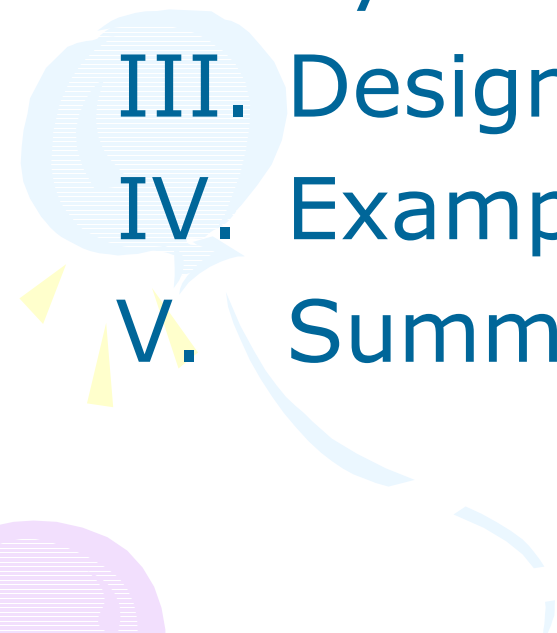

Development of an Interface for Using EGS4 Physics Processes in Geant4

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Outline

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 - II. System Analysis
 - III. Design Details
 - IV. Examples of User Session
 - V. Summary
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I. Introduction

Motivation

- The Geant4 framework has rich flexibility and expansibility;
 - Geant4 is designed to allow users to implement new processes in a generic/general way.
- Current Geant4 EM Physics
 - Standard EM
 - Low-Energy EM
- Why EGS4 now?
 - There are many EGS4 users especially in medical and space field.
 - **But, EGS4 has some difficulties;**
 - Implementing users' geometry is hard work, which makes them difficult;
 - to implement complex geometries.
 - to track particles in electromagnetic fields.
 - It is written in MORTRAN/FORTRAN!!
 - We can provide an easy-to-use system of EGS4 under the Geant4 framework.
- This interface provides...
 - EGS4 users can share Geant4 powerful resources, such as geometry description, tracking etc.
 - A common environment for comparison tests between EGS4 and Geant4 especially in users' application level.



Co-Workers

- This activity is proceeded under *KEK-SLAC collaboration*.
 - (not an activity of Geant4 Collaboration)
 - Persons involved
 - K.Murakami (KEK, Koichi.Murakami@kek.jp)
 - K.Amako (KEK)
 - T.Sasaki (KEK)
 - M.Asai (SLAC)
 - T.Koi (SLAC)
- and *EGS4 developers* (technical advice and benchmark)
- H.Hirayama (KEK)
 - Y.Namito (KEK)

The background features several large, stylized, overlapping shapes in shades of purple, green, and blue. These shapes are composed of thick, curved lines and arrows, suggesting a process or flow. Interspersed among these shapes are numerous small, yellow, triangular arrowheads pointing in various directions, creating a sense of dynamic movement and energy.

II. System Analysis

Geant4 Process Scheme

- All actual processes (*classes*) inherit from *G4VProcess*, in which **generic protocols** to invoke interactions are defined.
- There are three types of processes;
 - *AtRest*
 - *AlongStep*
 - *PostStep*
 - *any combinations*
- Each type of process defines two mandatory methods to be implemented;
 - GPIL (GetPhysicalInteractionLength)
 - limits the step size
 - calculates when an interaction will occur using cross section
 - DoIt
 - gives actual change of a track
 - generates secondaries
 - ,which are described in terms of *G4ParticleChange*

Analysis of EGS4 System

- in terms of difference from Geant4-

- **Our policy** is that we should care for **NOT to change** *algorithms and prescriptions* which are used in the EGS4 system.
- **Issue-1:** Determination of step size and process selection
 - In Geant4, each process has its own fate in terms of *NIL* (*N of Interaction Length*). Then, a process having minimum fate will occur.
 - In EGS4, the next step size is calculated based on the total cross section. Then, which process will occur is chosen at the rate of branching fraction.

Good!! In principle, these are performed in the same manner.

- **Issue-2:** The scheme of describing material information
 - In Geant4, material information can be given in users' code.
 - In EGS4, users have to prepare a material file to be read in by executing **PEGS**, which is an external program, preceding to execution of a EGS4 program.
 - Additional information related to “processes” (cutoff, parameters/coefficients of formulas) are described in material.

Analysis of EGS4 System (Cont'd)

We gave up treating materials of EGS4 under the G4 system.

- Users have to **execute PEGS externally** to prepare materials to be used in EGS4.
- Our interface manages materials listed in the PEGS output file.
- A material is described/instantiated **in terms of both Geant4 and EGS4.**

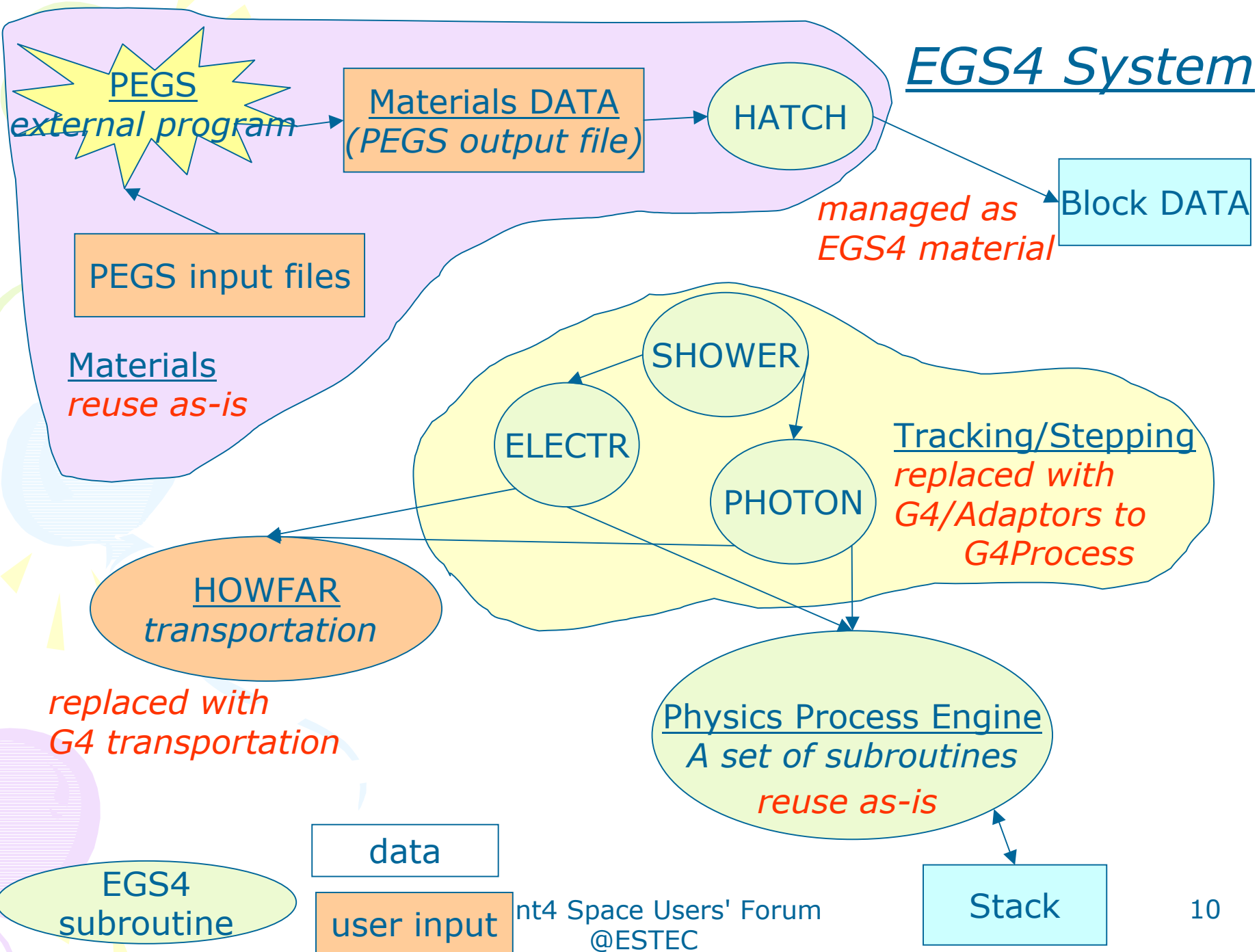
- **Issue-3: Cutoff scheme**

- In Geant4, there is **no cutoff** energy. Particles basically will be transported until they have zero kinetic energy.
- An idea of **production cut** is instead introduced.
- In EGS4, an idea of cutoff energy is applied. Particles below cutoff energy will be discarded.
- Each material has its own cutoff energy for electron/photon.

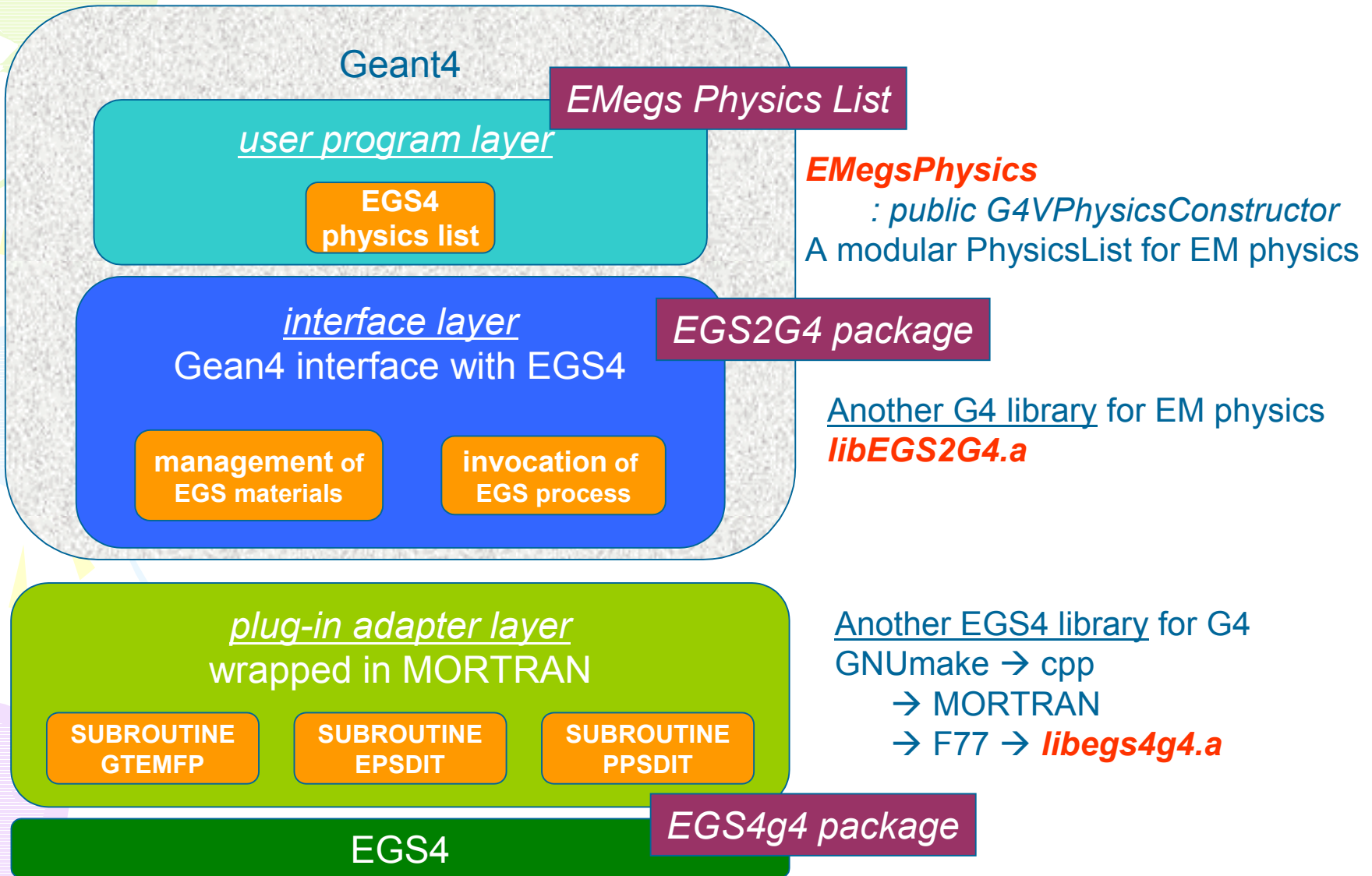
We should not change the EGS4 treatments *in order to get the same output* as obtained by EGS4 itself. (**Our Policy**)

- **We don't disturb the cutoff treatment carried out in EGS4.**

EGS4 System



Product Hierarchy





III. Design Details

Parts List

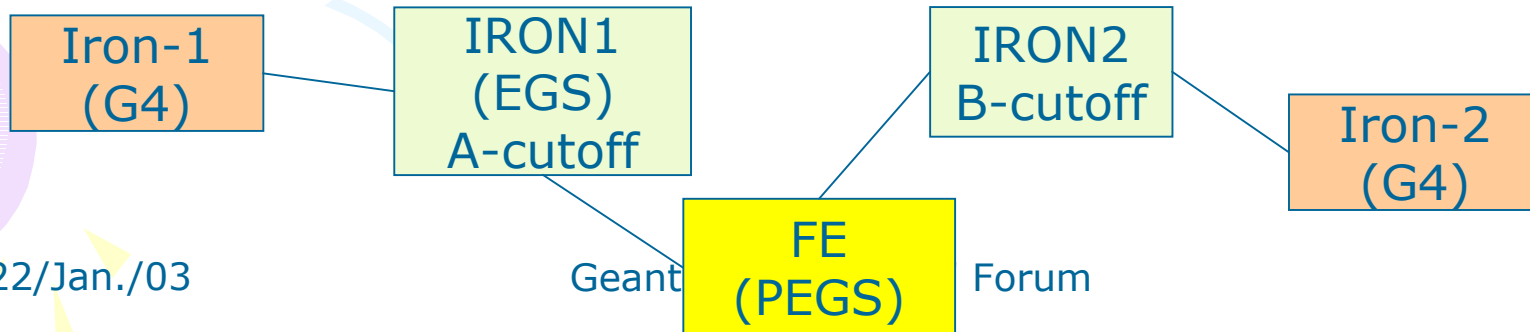
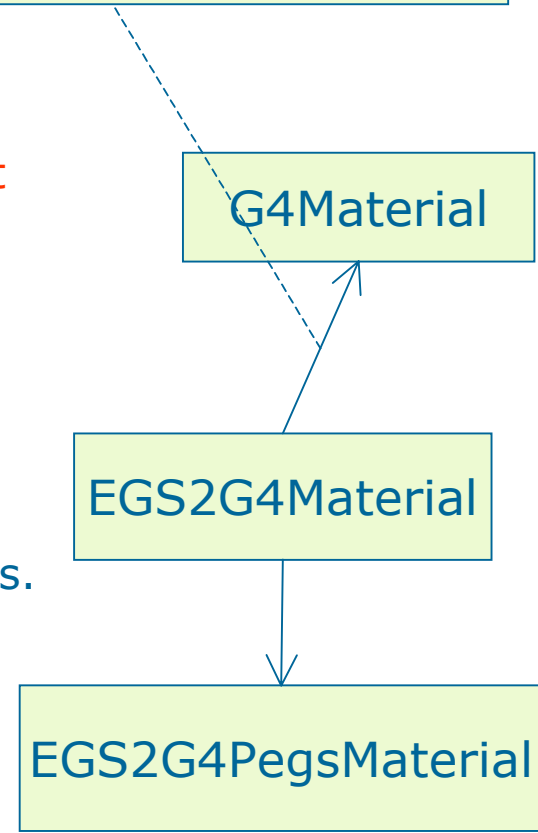
Prefix of classes is “EGS2G4”.

- Manager
 - *EGS2G4Manager*
 - which is automatically instantiated/deleted from an actual process class.
 - Users don't have to take care of it.
- Management of material information
 - *EGS2G4Material* / *EGS2G4PegsMaterial*
 - *EGS2G4MaterialStore* / *EGS2G4PegsMaterialStore*
- Implementation of actual processes
 - *EGS2G4VProcess* / *EGS2G4eProcess* / *EGS2G4gProcess*
- Controller for user parameters/flags
 - *EGS2G4ParameterStore/EGS2G4TParameter*
 - All(?) parameters/flags can be accessed via G4 user commands at run time.
 - Users don't have to re-compile any EGS4 library.

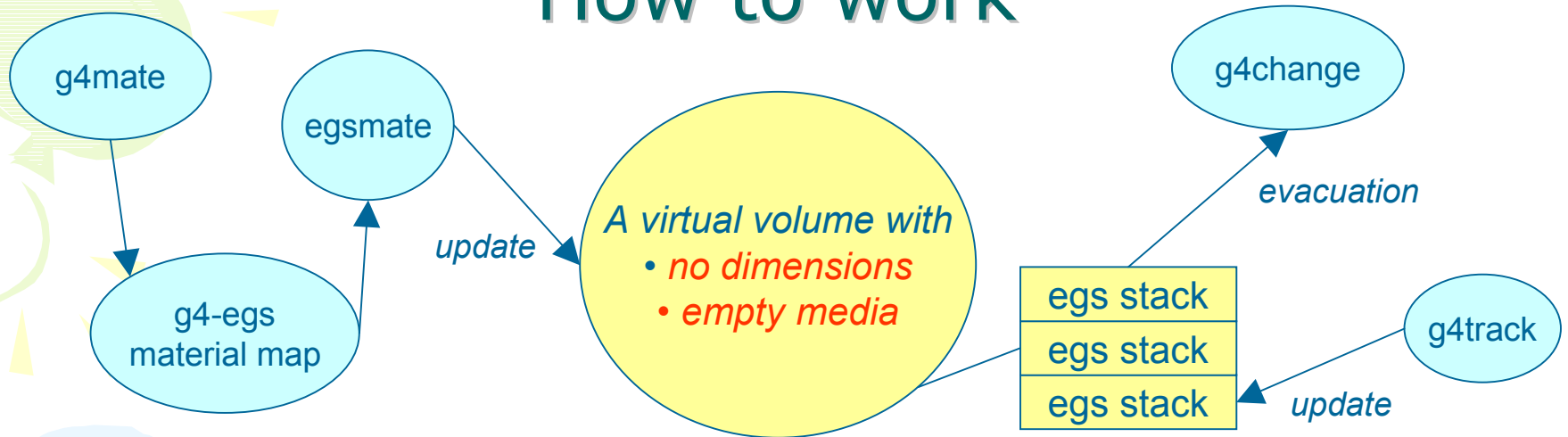
Materials Detail

```
EGS2G4Manager  
map<G4Material*,  
    EGS2G4Material> g4egsMap
```

- There are *three* classes describing materials:
 - **PEGSMaterial (as EGS2G4PegsMaterial)**
 - It describes materials *defined in a PEGS output*.
 - Its objects will be *instantiated from a PEGS output* at the initialization time.
 - **EGSMaterial (as EGS2G4Material)**
 - It works as a wrapper class of “*PEGSMaterial*”.
 - It has additional information, such as
 - user cutoffs, user density, user flags, ...
 - **G4Material**
 - A G4Material is assigned to A EGSMaterial by users.
 - A G4Material is converted to a EGSMaterial through *the g4-egs material map* at tracking time.
 - If no EGSMaterial is assigned, run-time exception occurs.



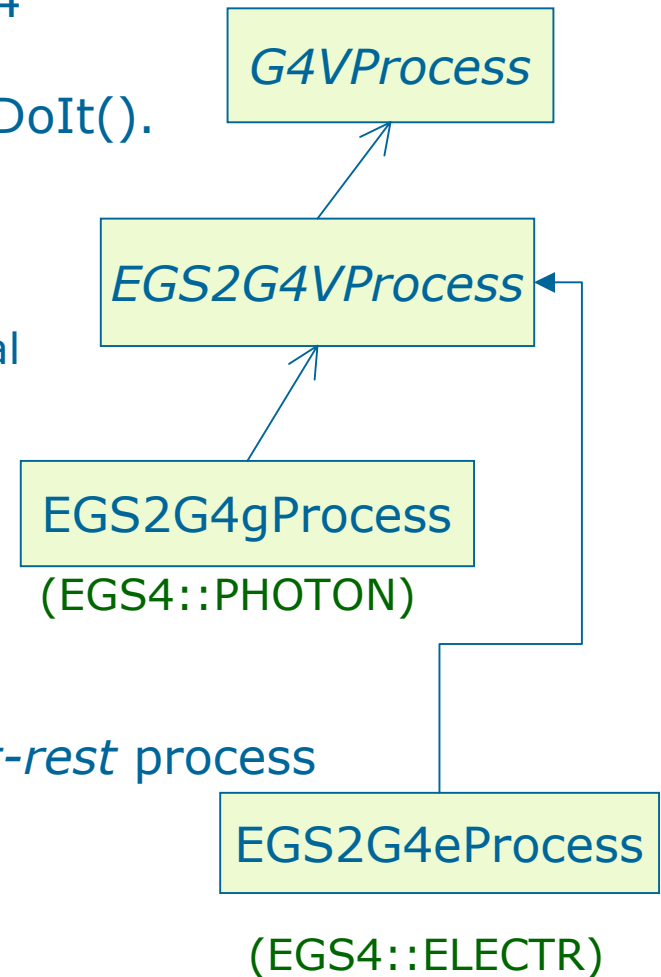
How to work



- In the EGS4 world, a single *virtual* volume with
 - **no dimensions** (transportation is a G4 job)
 - **empty medium** (dynamically updated)is prepared.
- At tracking time,
 1. Medium information of the EGS4 volume is updated at every step though the “*g4-egs*” material map.
 2. Kinematical information in the EGS4 stack is updated from G4 track
 3. A EGS4 process occurs.
 4. The stack information of EGS4 is evacuated to a G4 particle-change.

Implementation of Physics Process

- Single process per electron/photon respectively
 - easy to translate the flow control of EGS4
 - GPIL() is based on “total cross section”
 - Actual process selection is performed in DoIt().
- *EGS2G4VProcess*
 - has common utility methods;
 - conversion from G4Material to EGSMaterial
 - communication with the EGS4 stack...
- *EGS2G4gProcess*
 - implemented as a *discrete* process
- *EGS2G4eProcess*
 - implemented as a *continuous-discrete-at-rest* process



Process List

Photon processes

- Rayleigh scattering
- pair production
- photo-electric effect
w/ subsequent fluorescence
- Compton scattering

Electron processes

- multiple scattering
(momentum flip only)
- continuous energy loss
- Bremsstrahlung
- Møller scattering (e^-)
- Bhabha (e^+)
- positron annihilation (e^+)
(in-flight / at-rest)

As the first target, we started with interfacing with a plain EGS4 package. So, some extension components like *PRESTA* is not included yet.

(The treatment of displacement in multiple scattering is quite coupled with geometry.)

Treatment of Cutoff

- We don't disturb the cutoff treatment carried out in EGS4!! This is our policy.
- Basically, a particle below the cutoff will be discarded with depositing its kinetic energy.
- Positron will be stopped but still alive and followed by annihilation.
- Notes:
- There are two cutoff-s in EGS4.
 - *AP/AE* (for photon/electron)
 - which are given in PEGS and utilized as energy windows of cross section tables.
 - *AP/AE* works also as production thresholds for brems. / Moller.
 - For *UP/UE*, we provide a safety scheme not to exceed energy limit of cross section tables.
 - *PCUT/ECUT*
 - which are EGS user cutoff. (attributes of EGSMaterial)



IV. Examples of User Session

How to use

- PhysicsList (EM-module)
 - replaced with *EMegsPhysics*, which is provided as a modular PhysicsList for EM w/EGS4 processes.
- UserDetectorConstruction
 - Users don't have to modify any existing geometry code.
- Users have to execute *PEGS* by themselves.
 - define PEGS materials in PEGS input files.
 - execute PEGS to generate a cross section file (so-called PEGS output).
- All other operations can be performed via G4 command line interface.
 - assigning G4Material to EGSMaterial
 - setting users parameters
 - initialization, ...

Example of Material Session

Command directory path : /process/egs4/material/

Guidance :

commands relevant to EGS materials

Sub-directories :

/process/egs4/material/pegs/ commands for PEGS materials

Commands :

create * create a EGS material
 setPegs * set a Pegs material to a EGS material
 assign * assign a material(G4) to a material(EGS)
 clearAssignment * clear assignment list of G4Material
 dump * dump EGS material information
 print * print EGS material information (EGS->G4)
 printMap * print EGS material information (G4->EGS)
 listG4Material * list materials(G4) defined
 erase * erase a EGS material
 clearAll * clear EGS materials
 setCuts * set cutoff energy (in MeV) for photon/electronto a EGS material
 setIRAYLR * set a flag of Rayleigh scattering
 setIEDGFL * set IEDGFL parameter (K-shell fluorescence)
 setRHOR * set user density (in g/cm3)
 setDefaultParams * set default parameters

```
# user macro to set up EGS matetials
# create EGS materials [egs nama] [pegs name] [g4 name]
/process/egs4/material/create AIR ! Air
/process/egs4/material/create PB PB Lead
/process/egs4/material/create PB-2 PB
/process/egs4/material/create NAI ! NaI
```

```
# assing g4 mate. to egs mate.
/process/egs4/material/assign Vacuum VACUUM
```

```
# set user cutoff
/process/egs4/material/setCuts NAI 0.1 0.7
```

```
/process/egs4/setPegsFile pegs.dat
/process/egs4/initialize
```

```
b00(Idle)[/process/egs4/material/]:dump NAI
```

```
-----
(@): EGS material name   -> PEGS medium name   -> G4Material name
-----
```

```
(o):NAI                  : "NAI                " : NaI
   @PEGS=0x8d06600
   AP*=0.010 , UP*=100.000 , PCUT=0.010 (MeV)
   AE*=0.521 , UE*=100.511 , ECUT=0.521 (MeV)
   URho/Rho*=3.667 /3.667 (g/cm3) =1.000
   IRAYL= 1, IRAYLM*= 1, IEDGFL= 0
```

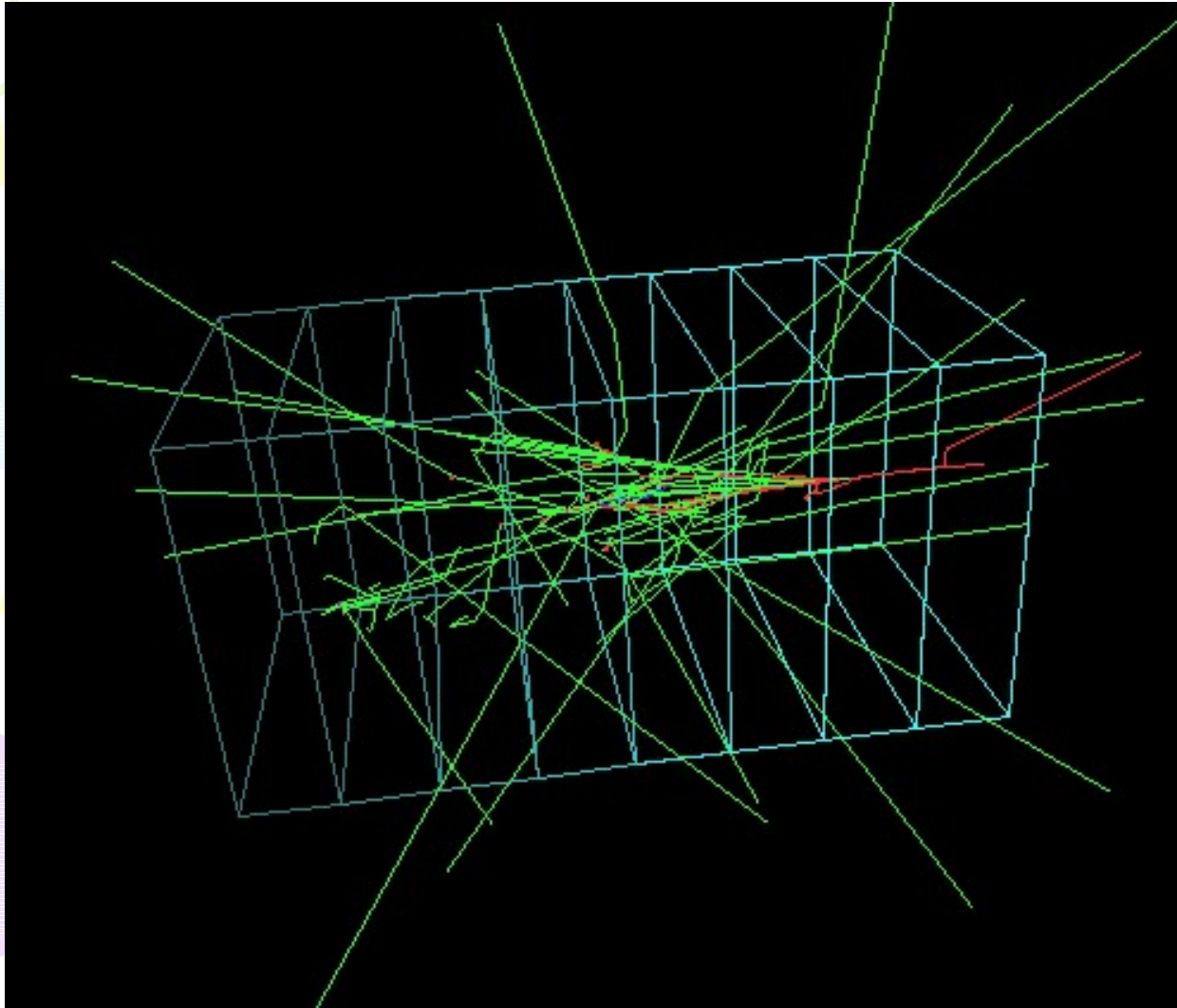
```
tb00(Idle)[/]:/process/egs4/material/printMap
```

```
-----
(@): EGS material name   -> PEGS medium name   <- G4Material name
-----
```

```
(o):VACUUM               : "VACUUM            " : Vacuum
(o):AIR                  : "AIR                " : Air
(-):n/a                  : "                   " : ArEthane
(o):PB                   : "PB                 " : Lead
(o):SCINTI               : "SCINTI             " : Scinti
(o):NAI                  : "NAI                " : NaI
```

Sample Event Display

- 5 electrons with $E_k=50 \text{ MeV}$ into a slab geometry composed of several materials.



w/ cutoff
EK=10 keV

Benchmarks

- Development environment
 - Linux
 - gcc/g77 ver. 2.95.3
 - Geant4 ver.4.1 patch-1
 - (will be updated to 5.0 soon)
- Robustness
 - several-M events in a simple geometry were successfully generated without crash.
- Detail benchmark tests were just started.

The background features several large, stylized, overlapping swirls in shades of purple, green, and light blue. Interspersed among these swirls are numerous small, yellow, triangular shapes that resemble confetti or starbursts, scattered across the white background.

V. Summary

Current Status and Plans

- First implementation was finished.
- Detail system check and benchmark tests are just started.
- We plan comparisons
 - between EGS4 itself and EGS2G4.
 - between EGS4 and EGS2G4 on a common environment.
- Information/documentation will be available on WWW in the near future. (by this spring)
- Technical studies for including extensive components like PRESTA are planned for fairer comparisons.

Conclusion

- We have successfully developed the first version of an interface between Geant4 and EGS4 based on OO-approach.
- This work is a proof of flexibility and expansibility of the Geant4 framework.
- By means of this interface, EGS4 users can share Geant4 powerful resources, such as geometry description, tracking etc.
- Further detail benchmarks are on going.
- We also plan to include some extension components so that as much functionalities as possible can be available.