

## Geant4 Fast Simulation Interface

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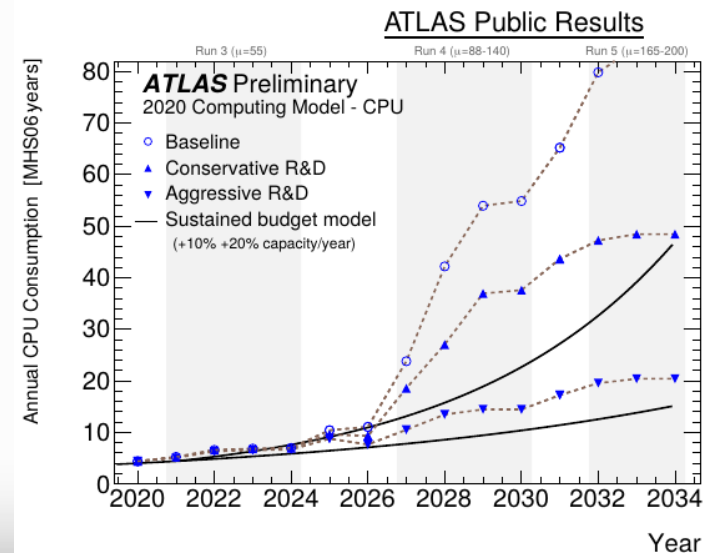
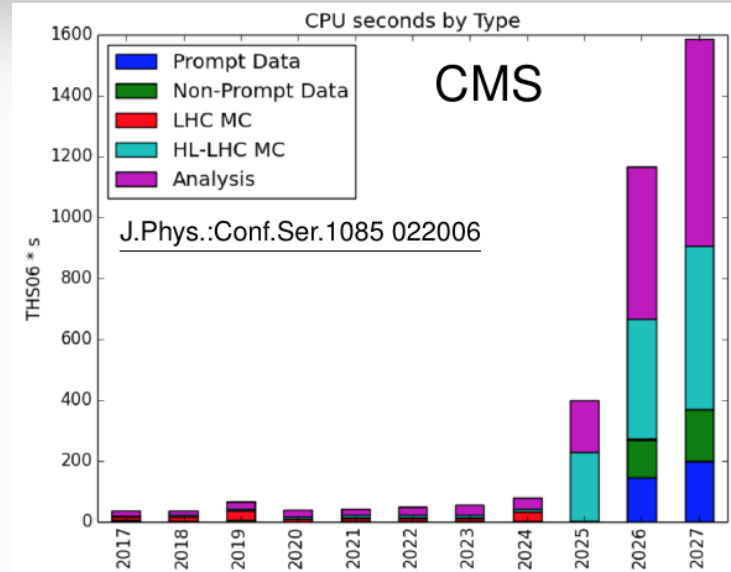
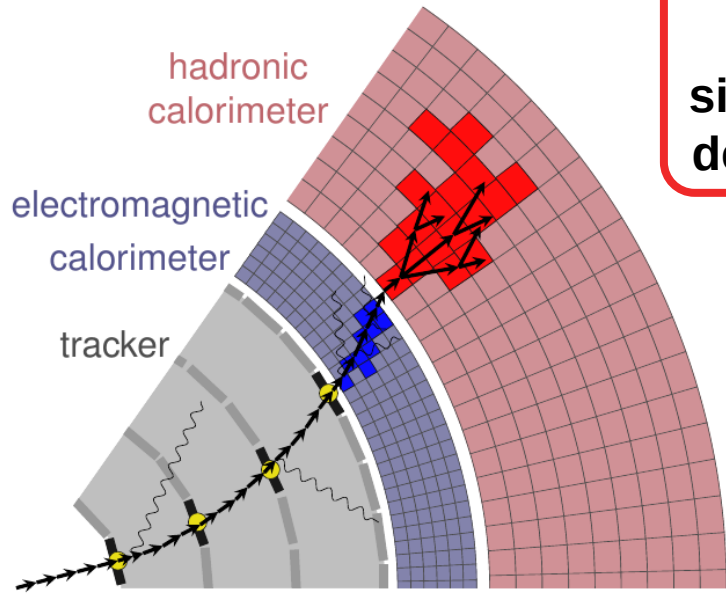
# Outline

- **Why do we need fast simulations?**
- **What is fast simulation in Geant4?**
- **How to create Geant4 Fast Simulation Model?**
  - Which?
  - What?
  - Where?
- **Geant4 Fast Simulation Process definition and parallel worlds**
- **Applications**
  - Detector simulations
  - Machine Learning model
  - Channeling in crystals

# Why we need to simulate fast?

- To speed up simulations in order to generate more data within the same CPU time
- **More simulations** and data analysis will be **required** in the **future experiments**
- Economy of simulation resources
- Economy of electricity

**We need new models to simulate certain detectors faster**



# Why do we need any special interface in Geant4?

## What about G4Biasing?

- **G4Biasing** is a special class allowing one to **modify Geant4 processes** during simulation execution

In certain cases extremely useful, **but:**

- **G4Biasing works only for discrete processes**, it **does not work** for multiple scattering, bremsstrahlung, pair production (**continuous discrete processes**)

To simulate **electromagnetic calorimeter** with a different physics we need to **replace electromagnetic physics** in a **certain volume**, at **certain condition** and for **certain particles**

Sometimes we need to **replace the Geant4 processes** by an **external simulation code**

# Geant4 Fast Simulation Interface



**GEANT4**  
A SIMULATION TOOLKIT

# What we do mean by Fast Simulation in Geant4?

- **Fast simulation** is not a simulation that 'magically' produces results faster.
- **Fast simulation** is a **trade-off** between simulation **time** and **accuracy**.
- In **some regions** we do **not need** too **detailed simulations** => we can replace them by faster simulation processes, so-called **parameterisation**
- **Fast simulation** completely **stops** the **standard Geant4 processes** at the step of Fast Simulation model and then resumes them
- Is activated **only** in a **certain G4Region** at a **certain condition** and only for **certain particles**

# Fast Simulation Interface: where? which? what?

- **Where** the particles are parameterised, in which region?
- **Which** particles are parameterised?
  - static conditions (particle type, PDG, charge, . . . )
  - dynamic conditions (energy, direction, . . . )
- **What** happens instead of the detailed simulation:
  - where the particle is moved?
  - what are the created secondaries?
  - is the primary particle killed?
  - what (and where) energy is deposited?

# Where: in a G4Region defined in DetectorConstruction

## ● Add to DetectorConstruction::Construct()

```
//my volume
G4Box* MySolid = new G4Box("MyBox",SizeX/2,SizeY/2,SizeZ/2.);
G4LogicalVolume* MyVolumeLogic = new G4LogicalVolume(MySolid,MyMaterial,"MyVolume");
new G4PVPlacement(Rotation,Position,MyVolumeLogic,"MyVolume",logicWorld,false,0);

//my region (necessary for the FastSim model)
fRegion = new G4Region("MyRegion");
fRegion->AddRootLogicalVolume(MyVolumeLogic);
```

Volume declaration  
(completely standard)

G4Region declaration

Add Logic Volume to  
G4Region declaration

## ● Add to DetectorConstruction::ConstructSDandField()

```
void DetectorConstruction::ConstructSDandField()
{
    // ----- fast simulation -----
    //extract the region of the crystal from the store
    G4RegionStore* regionStore = G4RegionStore::GetInstance();
    G4Region* MyRegion = regionStore->GetRegion("MyRegion");

    //create the channeling model for this region
    MyFastSimModel* MyModel = new MyFastSimModel("ChannelingModel",MyRegion);

    //some options of the model...
}
```

Get G4Region

Declare your FastSim model

# How to create your own Fast Simulation Model?

## MyFastSimModel.hh

```
class MyFastSimModel : public G4VFastSimulationModel
{
public:
    //-----
    // Constructor, destructor
    //-----
    MyFastSimModel (G4String, G4Region*);
    MyFastSimModel (G4String);
    ~MyFastSimModel ();

    //-----
    // Virtual methods of the base
    // class to be coded by the user
    //-----

    // -- IsApplicable
    virtual G4bool IsApplicable(const G4ParticleDefinition&);
    // -- ModelTrigger
    virtual G4bool ModelTrigger(const G4FastTrack &);
    // -- User method DoIt
    virtual void DoIt(const G4FastTrack&, G4FastStep&);
};
```

**Inheritance of  
G4VFastSimulationModel**



**Functions to compile:**



# How to create your own Fast Simulation Model?

## MyFastSimModel.cc

```
MyFastSimModel::MyFastSimModel(G4String modelName, G4Region* envelope)
: G4VFastSimulationModel(modelName, envelope)
{
}

//....ooo00000ooo.....ooo00000ooo.....ooo00000ooo.....ooo00000ooo

MyFastSimModel::MyFastSimModel(G4String modelName)
: G4VFastSimulationModel(modelName)
{
}

//....ooo00000ooo.....ooo00000ooo.....ooo00000ooo.....ooo00000ooo

MyFastSimModel::~MyFastSimModel()
{
}
```

**Constructor**

**Destructor**

# How to create your own Fast Simulation Model: which?

MyFastSimModel.cc

The model is applicable for these particles:

```
G4bool MyFastSimModel::IsApplicable(const G4ParticleDefinition& particleType)
{
    return
        &particleType == G4Electron::ElectronDefinition() ||
        &particleType == G4Positron::PositronDefinition() ||
        &particleType == G4Gamma::GammaDefinition();
    //& my particles ...
}
```

```
//....ooo0000ooo.....ooo0000ooo.....ooo0000ooo.....ooo0000ooo...
```

```
G4bool MyFastSimModel::ModelTrigger(const G4FastTrack& fastTrack)
{
    //my code:
    //...
    return MyCondition;
}
```

The model is activated at this condition

# How to create your own Fast Simulation Model: what?

## MyFastSimModel.cc

```
void MyFastSimModel::DoIt(const G4FastTrack& fastTrack,
                          G4FastStep& fastStep)
{
    //get some necessary information
    G4double Etotal = fastTrack.GetPrimaryTrack()->GetTotalEnergy();
    G4double mass = fastTrack.GetPrimaryTrack()->GetParticleDefinition()->GetPDGMass();
    G4double charge = fastTrack.GetPrimaryTrack()->GetParticleDefinition()->GetPDGCharge();
    G4ThreeVector MomentumDirection=fastTrack.GetPrimaryTrackLocalDirection();
    G4ThreeVector xyz = fastTrack.GetPrimaryTrackLocalPosition();
    G4double TGlobal = fastTrack.GetPrimaryTrack()->GetGlobalTime();
    //fastTrack.Get...

    //do very important simulations
    //my code ...

    //set new parameters:

    //set global time
    fastStep.ProposePrimaryTrackFinalTime(TGlobal);
    //set final position
    fastStep.ProposePrimaryTrackFinalPosition(xyz);
    //set final kinetic energy
    fastStep.ProposePrimaryTrackFinalKineticEnergy(Etotal-
        fastTrack.GetPrimaryTrack()->GetParticleDefinition()->GetPDGMass());
    //set final momentum direction
    fastStep.ProposePrimaryTrackFinalMomentumDirection(MomentumDirection);

    //kill a primary particle if necessary
    fastStep.KillPrimaryTrack();
}
```

Write your code

Get parameters

Propose new  
parameters

You may kill  
the particle

# Secondary particle production

## MyFastSimModel.cc

```
void MyFastSimModel::DoIt(const G4FastTrack& fastTrack,
                          G4FastStep& fastStep)
{
    //some code ...

    //there is a default but it is better to do:
    fastStep.SetNumberOfSecondaryTracks(MaxParticlesProducedPerStep);

    //particle declaration
    const G4DynamicParticle theGamma =
        G4DynamicParticle(G4Gamma::Gamma(), PhotonMomentumDirection, Ephoton);

    //generation of a secondary photon
    fastStep.CreateSecondaryTrack(theGamma, PhotonCoordinateXYZ, PhotonGlobalTime, true);
}
```

# The last step: Fast Simulation Process registration

## Register FastSimulationPhysics

### ● Add to main:

```
G4FastSimulationPhysics* fastSimulationPhysics = new G4FastSimulationPhysics();
fastSimulationPhysics->BeVerbose();
// -- activation of fast simulation for particles having fast simulation models
// -- attached in the mass geometry:
fastSimulationPhysics->ActivateFastSimulation("e-");
fastSimulationPhysics->ActivateFastSimulation("e+");
// -- Attach the fast simulation physics constructor to the physics list:
physicsList->RegisterPhysics( fastSimulationPhysics );
```

That's it. Enjoy! :)

### Important:

- If any **condition** of the model is **not fulfilled** (IsApplicable, ModelTrigger), **standard Geant4** processes will be **active** just as usual
- If there are **several Fast Simulation models**, the **first** model in the list will be **activated** for which the conditions are fulfilled

# Parallel worlds for different types of particles

## ● Add to main:

### for mass and parallel geometry:

<examples/extended/parameterisations/Par01/examplePar01.cc>

```
FTFP_BERT* physicsList = new FTFP_BERT; // G4VModularPhysicsList
G4FastSimulationPhysics* fastSimulationPhysics = new G4FastSimulationPhysics(); // helper
fastSimulationPhysics->BeVerbose();
// - activation of fast simulation for particles having fast simulation models attached
↳ in the mass geometry:
fastSimulationPhysics->ActivateFastSimulation("e-");
fastSimulationPhysics->ActivateFastSimulation("e+");
fastSimulationPhysics->ActivateFastSimulation("gamma");
// - activation of fast simulation for particles having fast simulation models attached
↳ in the parallel geometry:
fastSimulationPhysics->ActivateFastSimulation("pi+", "pionGhostWorld");
fastSimulationPhysics->ActivateFastSimulation("pi-", "pionGhostWorld");
physicsList->RegisterPhysics( fastSimulationPhysics ); // attach to the physics list
```

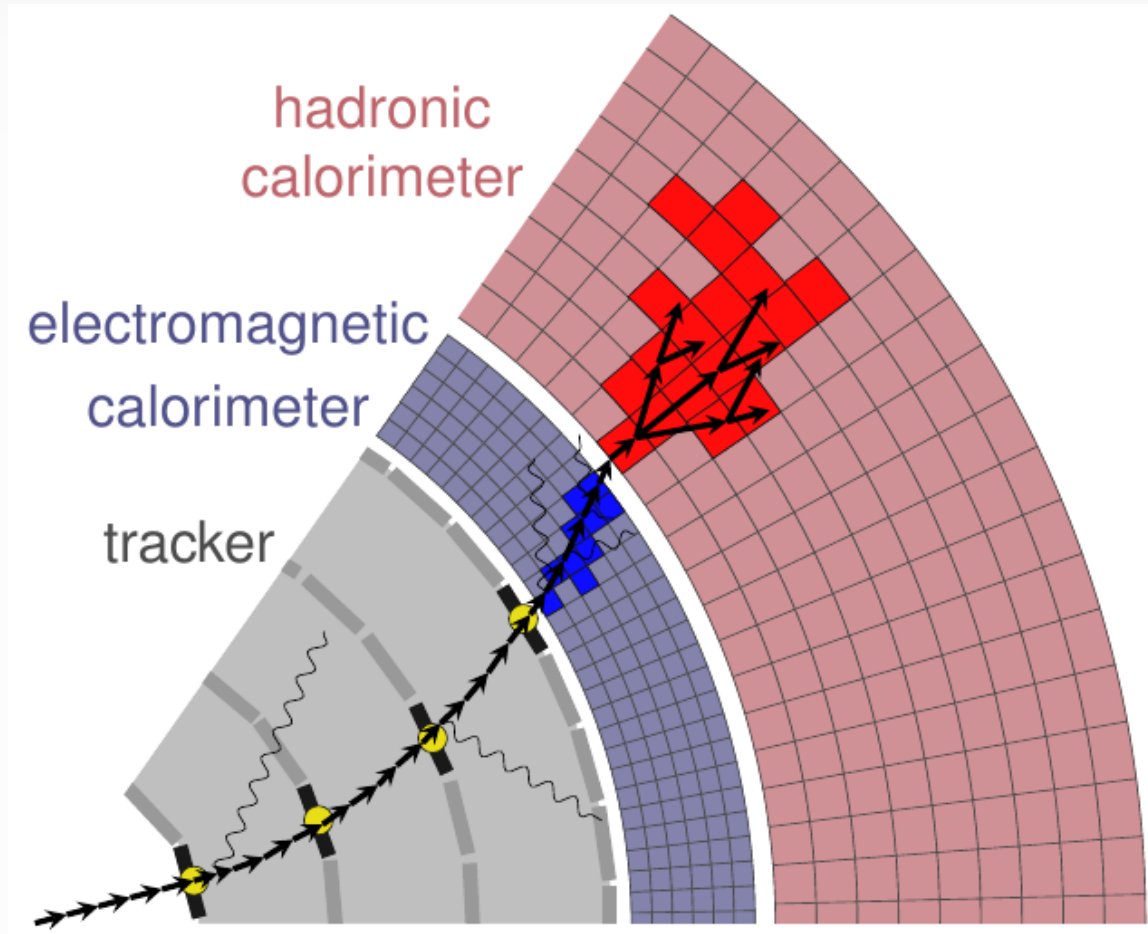
## ● Add to DetectorConstruction

### for parallel geometry:

<examples/extended/parameterisations/Par01/src/Par01ParallelWorldForPion.cc>

```
G4Region* ghostRegion = new G4Region("GhostCalorimeterRegion");
// ghostLogical is a G4LogicalVolume in parallel geometry, a box made of air encompassing
↳ both EM&H calorimeters
ghostRegion->AddRootLogicalVolume(ghostLogical);
```

# Applications

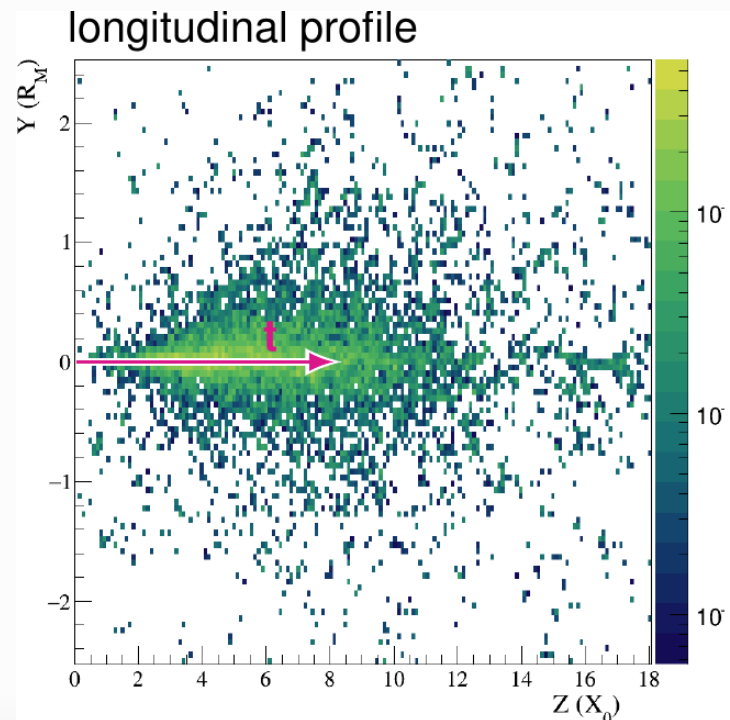
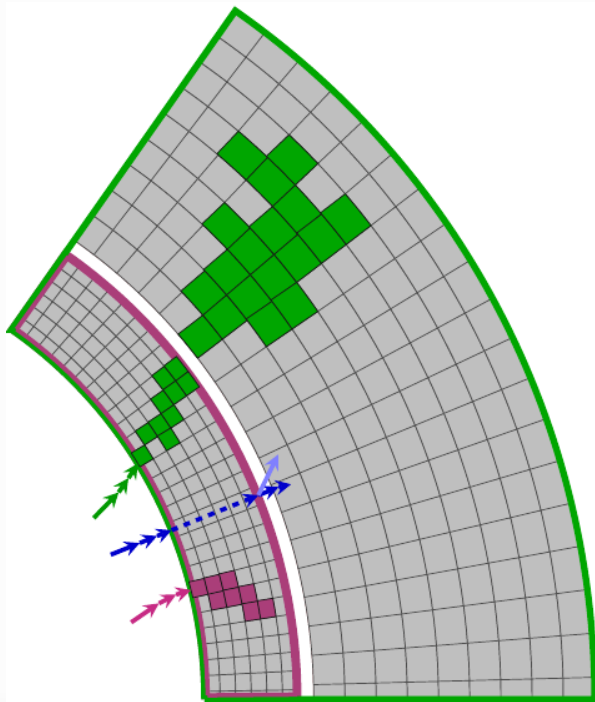


# Applications

- Existing examples: **examples/extended/parameterisations/**
- **examples/extended/parameterisations/Par01/src/**
  - Par01EMShowerModel.cc
  - Par01PionShowerModel.cc
  - Par01PiModel.cc
- **examples/extended/parameterisations/Par02/src/**
  - Par02FastSimModelEMCal.cc
  - Par02FastSimModelHCal.cc
  - Par02FastSimModelTracker.cc
- **examples/extended/parameterisations/Par03/src/**
  - Par03EMShowerModel.cc
- **examples/extended/parameterisations/Par04/src/**
  - Par04MLFastSimModel.cc
- **GFlashShowerModel**

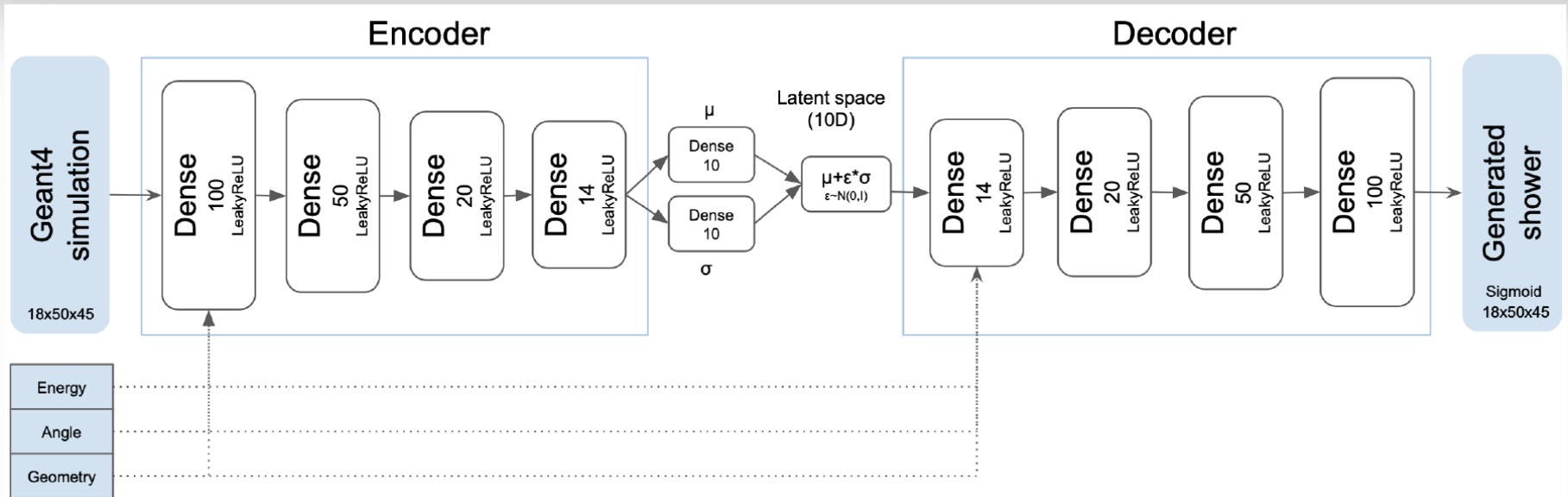
# Applications

- Simulation of **electromagnetic showers** in matter (**e.m. calorimeters**, ...)
- Simulation of **sampling calorimeters**
- **Machine Learning**
- Implementation of **external codes** into Geant4



From Anna Zaborowska presentation,  
[examples/extended/parameterisations/Par01](#)

# Machine Learning model



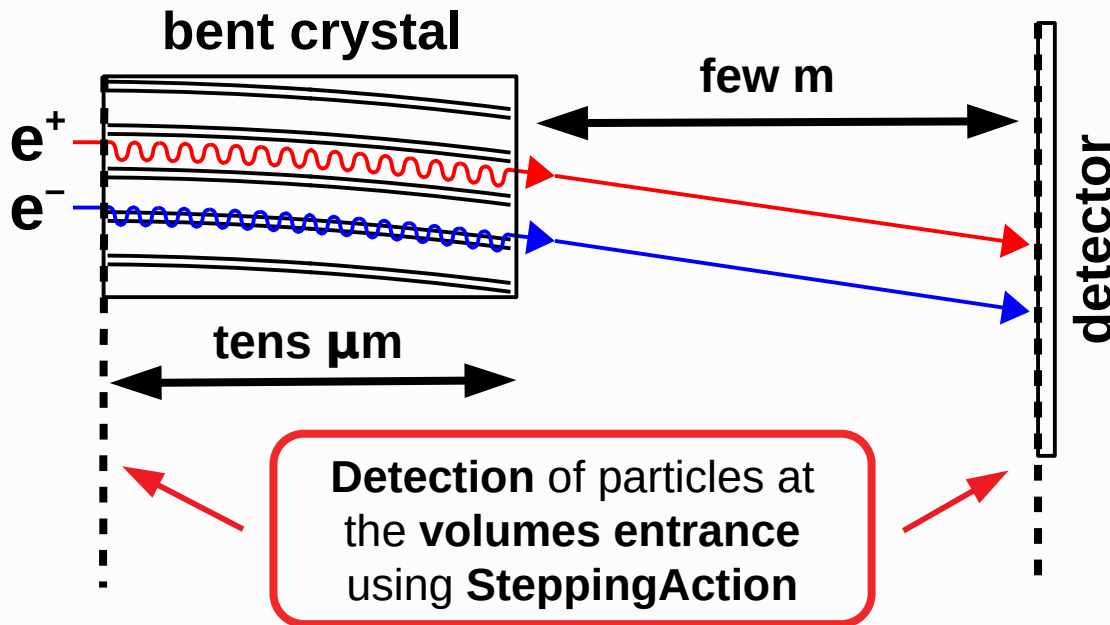
**Variational autoencoder** is one of the best way to randomly **generate** a distribution using initial parameters

**Fast Simulation Model** can upload the neural network parameters for **inference** using **Lightweight Trained Neural Network** or **Open Neural Network Exchange** libraries

# Channeling model: my next presentation



- Inspired by our experiments\* of 855 MeV electron beam deflection by an ultrashort bent crystal at Mainz Mikrotron MAMI



Beam setup in **run.mac** using **GPS** commands; all the **geometry** in **DetectorConstruction**

**Multithreading** works! Checked at the supercomputer **NURION@KISTI** (Korea)

**Output** both in **root** (only primary particles) and in **textfile** (all the particles) format



\*A. Mazzolari et al. Phys. Rev. Lett. 112, 135503 (2014)

A. Sytov et al. Eur. Phys. J. C 77, 901 (2017)

# Conclusions

- **Fast Simulation Interface** was created to **replace standard Geant4** processes during the code execution to **speed-up** the **simulations**.
- **Fast simulation** completely **stops** the **standard Geant4 processes** at the step of Fast Simulation model and then resumes them.
- It is activated **only** in a **certain G4Region** at a **certain condition** and only for **certain particles**
- It possesses a lot of **applications** such as simulations of a homogeneous and sampling **calorimeters, electromagnetic shower, Machine Learning** and so on. This provides considerable **speed-up** of **Geant simulations**.
- **Fast Simulation Interface** is the simplest way to implement an **external code** into Geant4.