# Migration of Examples and User Application Code to MT

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# Outline

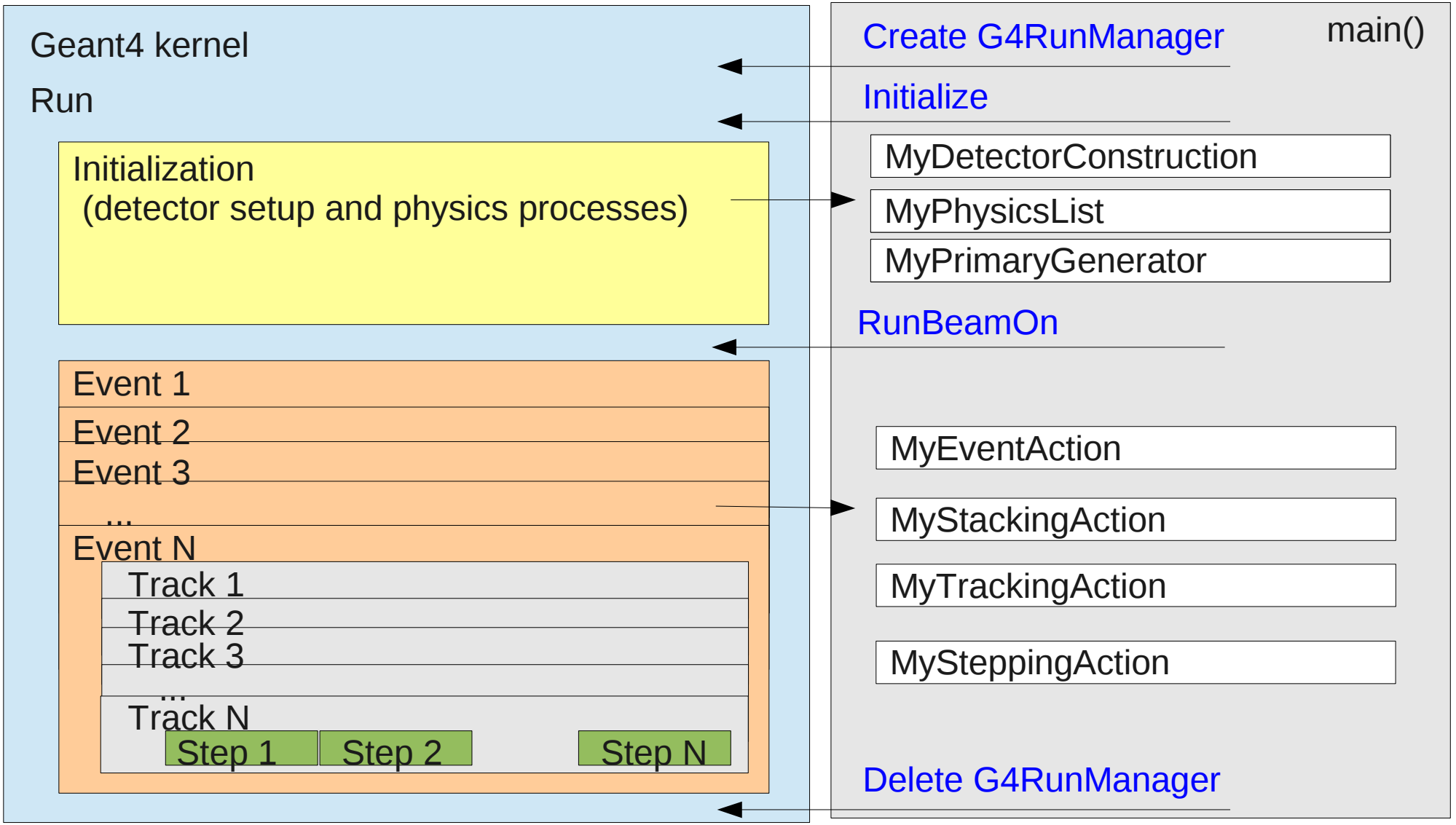
- Where to start
- Basic understanding of MT mode
- MT migration of  a basic application in 5 steps
- Other items for migration
- Tips for building & testing application in both modes

# Where to Start

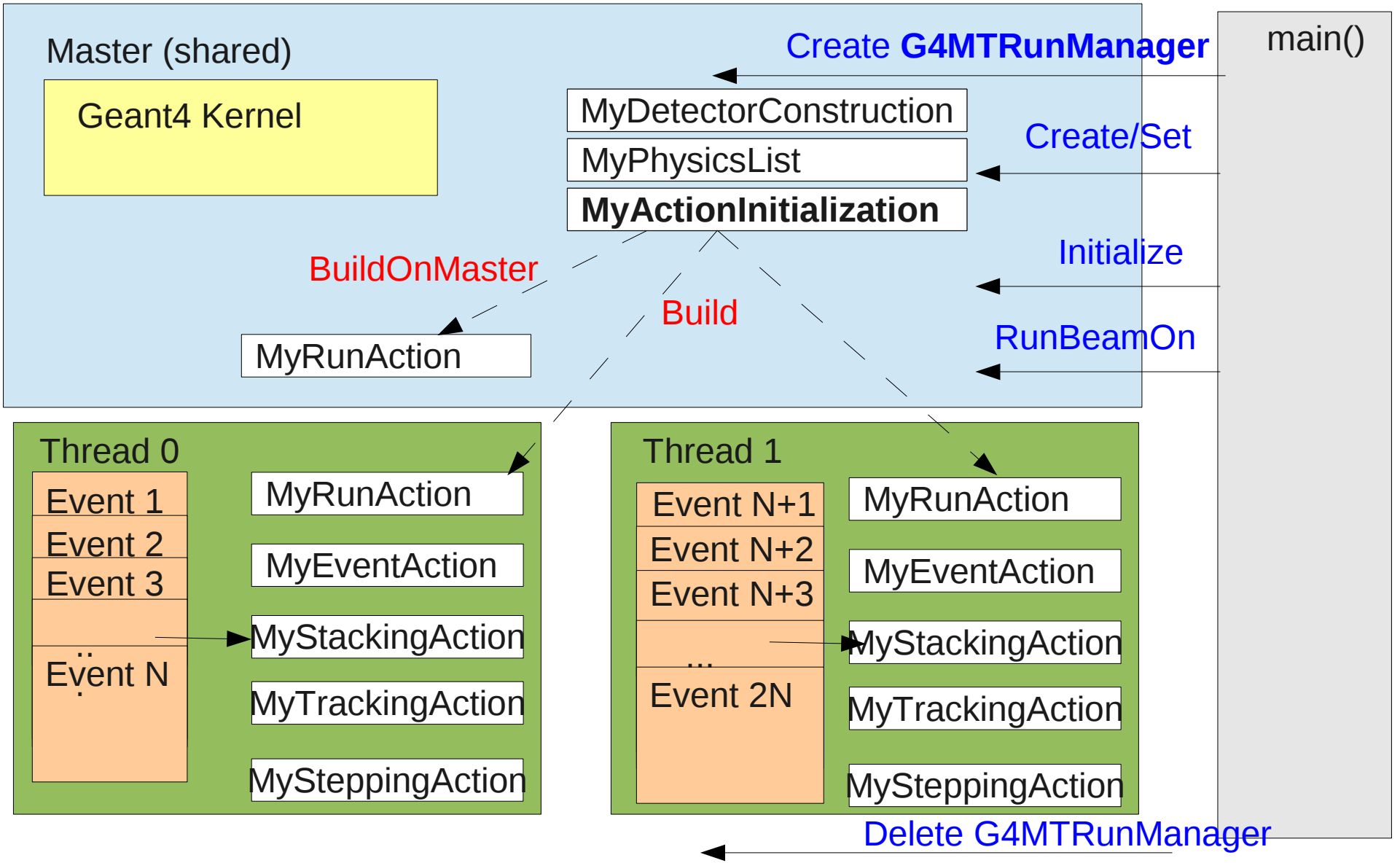
- Basic examples - already migrated to MT
  - Cover most frequently used features
- Geant4 MT For Application Developers wiki page:
  - https://twiki.cern.ch/twiki/bin/view/Geant4/Geant4MTForApplicationDevelopers
  - Very detailed instructions covering all aspects
- This presentation

# Understand How It Works

# User Application and Geant4 Kernel In Sequential Mode



# User Application and Geant4 Kernel In MT Mode



# In MT Mode

- It is important to know which objects are thread-local and which are shared
  - For details see MT guidelines on Wiki page
- When you are in doubt you can quickly check by printing the object pointer:

```
G4cout << "Logical volume: " << fLogicChamber
       << " SD: " << aTrackerSD << G4endl;
```

  - Objects on thread have longer address:

```
G4WT0 > Logical volume: 0xa5feb0 SD: 0x7f5d380e7940
```

# MT Migration of A Basic Application in 5 Steps

# 5 Steps
# to Migrate Basic Applications

1. Create Action Initialization class
2. Update main()
3. Update Detector Construction class
4. Update RunAction
5. Update G4Allocator declarations (if present)

# 1. Action Initialization

- *Move user actions classes from main() to a new ActionInitialization class*

exampleB1.cc 9.6.p02

```
// Detector construction
runManager->SetUserInitialization(new B1DetectorConstruction());

// Physics list
G4VModularPhysicsList* physicsList = new QBBC;
runManager->SetUserInitialization(physicsList);

// Primary generator action
runManager->SetUserAction(new B1PrimaryGeneratorAction());

// Stepping action
runManager->SetUserAction(new B1SteppingAction());

// Event action
runManager->SetUserAction(new B1EventAction());

// Run action
runManager->SetUserAction(new B1RunAction());
```

Keep in main

Move to new class

# Action Initialization (cont.)

B1ActionInitialization.hh - 10.00

```
#include “G4VUserActionInitialization.hh”

class B1ActionInitialization :
  public G4VUserActionInitialization
{
 public:
   B1ActionInitialization();
   virtual ~B1ActionInitialization();

   virtual void BuildForMaster() const;
   virtual void Build() const;
};
```

B1ActionInitialization.cc - 10.00

```
void B1ActionInitialization::BuildForMaster() const
{
 SetUserAction(new B1RunAction);
}


void B1ActionInitialization::Build() const
{
 SetUserAction(new B1PrimaryGeneratorAction);
 SetUserAction(new B1RunAction);
 SetUserAction(new B1EventAction);
 SetUserAction(new B1SteppingAction);
}
```

In MT: both functions are called
In S: only Build() is called

See basic/B1 example

# 2. main()

- *Instantiate G4MTRunManager and replace the code moved in Action Initialization with use of this class*

exampleB1.cc 10.00

```
  // Construct the default run manager
#ifdef G4MULTITHREADED
  G4MTRunManager* runManager = new G4MTRunManager;
  runManager->SetNumberOfThreads(8);
#else
  G4RunManager* runManager = new G4RunManager;
#endif

  // Detector construction
  runManager->SetUserInitialization(new B1DetectorConstruction());

  // Physics list
  G4VModularPhysicsList* physicsList = new QBBC;
  runManager->SetUserInitialization(physicsList);

  // User action initialization
  runManager->SetUserInitialization(new B1ActionInitialization());
```

See basic/B1 example

# 3. Detector construction

- *Separate creation of **sensitive detectors**, if present, in a new function CreateSDandField()*

9.6.p02

```
G4VPhysicalVolume* B2bDetectorConstruction::Construct()
{
  // ...
  B2TrackerSD* trackerSD
     = new B2TrackerSD( "B2/TrackerSD", "TrackerHitsCollection" );
  G4SDManager::GetSDMpointer()->AddNewDetector( trackerSD );
  fLogicChamber->SetSensitiveDetector( trackerSD );
  // ...
}
```

10.00

```
G4VPhysicalVolume* B2bDetectorConstruction::ConstructSDandField()
{
  // ...
  B2TrackerSD* trackerSD
     = new B2TrackerSD( "B2/TrackerSD", "TrackerHitsCollection" );
  G4SDManager::GetSDMpointer()->AddNewDetector( trackerSD );
  fLogicChamber->SetSensitiveDetector( trackerSD );
  // ...
}
```

See basic/B2 example

# Detector construction (cont.)

- A new utility function G4VUserDetectorConstruction::SetSensitiveDetector can be also used:

```
G4VPhysicalVolume* B2bDetectorConstruction::ConstructSDandField()
{
  // ...
  B2TrackerSD* trackerSD
     = new B2TrackerSD( "B2/TrackerSD", "TrackerHitsCollection" );
  //G4SDManager::GetSDMpointer()->AddNewDetector( trackerSD );
  //fLogicChamber->SetSensitiveDetector( trackerSD );
  SetSensitiveDetector( “LogicChamberName”, trackerSD );
  // or
  SetSensitiveDetector( fLogicChamber, trackerSD );
  // ...
}
```

- Be careful if you define messenger classes to instantiate them at the right function
  - Messengers handling geometry data can stay in the constructor
  - Messenger handling SD (or Field) data should be also instantiated in the new method

# Detector construction (cont.)

- *Separate creation of a **magnetic field**, if present, in a new function CreateSDandField()*

9.6.p02

```
B2bDetectorConstruction::B2bDetectorConstruction()  {
  // ...
  fMessenger = new B2bDetectorMessenger(this);
  fMagField  = new B2MagneticField());
}
```

ref-07

```
G4VPhysicalVolume* B2bDetectorConstruction::ConstructSDandField()  {
   // ...
   fMagField  = new B2MagneticField();
   // ...
}

B2MagneticField::B2MagneticField()  {
   // ...
   fMagField  = new B2FieldMessenger();
   // ...
}
```

New magnetic field messenger class separated from B2bDetectorMessenger

# Detector construction (cont.)

- A new global field messenger class is available to define a uniform magnetic field with an interactive command for setting the field value
  - No B2 specific Magnetic field and Magnetic Field Messenger classes are needed anymore

10.00

```
G4VPhysicalVolume* B2bDetectorConstruction::ConstructSDandField()  {
  // ...
  G4ThreeVector fieldValue = G4ThreeVector();
  fMagFieldMessenger = new G4GlobalMagFieldMessenger(fieldValue);
}
```

See basic/B2 example

- If the field class has a cache mechanism, such field class object must be thread-local
  - See MT guidelines on Wiki page for an example

# 4. Run Action

- *Separate data representing accounted data (if present) from your RunAction class in a new Run class (derived from G4Run)*
  - Run action class is the only action which is instantiated besides workers also on master

```
class RunAction : public G4UserRunAction
{
  public:
    RunAction();
    virtual ~RunAction();

    virtual void BeginOfRunAction(const G4Run*);
    virtual void   EndOfRunAction(const G4Run*);

    void AddEdep (G4double e)
     { fEdep  += e; fEdep2  += e*e;};

  private:
    G4double  fEdep;
    G4double  fEdep2;
}
```

Move to Run class

# Run Action (cont)

10.00

```
class RunAction : public G4UserRunAction
{
  public:
    RunAction();
    virtual ~RunAction();

    virtual G4Run* GenerateRun();
    virtual void BeginOfRunAction(const G4Run*);
    virtual void   EndOfRunAction(const G4Run*);

    void AddEdep (G4double e);

  private:
    Run*  fRun;
}
```

```
class Run : public G4Run
{
  public:
    Run();
    virtual ~Run();

    void AddEdep (G4double e)
     { fEdep  += e;
       fEdep2  += e*e;};

     virtual void Merge(const G4Run*);

  private:
    G4double  fEdep;
    G4double  fEdep2;
}
```

# Run Action (cont)

- Implementation of new or changed functions:

```
G4Run* RunAction::GenerateRun() {
   fRun = new Run();
   return fRun;
}

void RunAction::AddEdep (G4double edep) {
   fRun->AddEdep(edep);
}
```

```
void RunMerge(const G4Run* localRun);
{
 fEdep += localRun->fEdep;
 fEdep2 += localRun->fEdep2;
}
```

This function is called by the master run instance for each worker localRun instance

Data in master Run object

Data in worker Run object

See basic/B1, B3, B4b examples

# 5. G4Allocator

- *Make G4Allocator G4ThreadLocal*
- Typically G4Allocator is used in hit, trajectory and trajectory point classes

B2TrackerHit.hh 9.6.p02

```
extern G4Allocator<B2TrackerHit>* B2TrackerHitAllocator;
```

B2TrackerHit.cc 9.6.p02

```
G4Allocator<B2TrackerHit>* B2TrackerHitAllocator=0;
```

B2TrackerHit.hh 10.00

```
extern G4ThreadLocal G4Allocator<B2TrackerHit> B2TrackerHitAllocator;
```

B2TrackerHit.cc 10.00

```
G4ThreadLocal G4Allocator<B2TrackerHit>* B2TrackerHitAllocator=0;
```

See basic/B2 example

# MT Migration
# of More Advanced Applications

# Other Items For Migration (1)

- User defined physics list
  - G4GenericIon::GenericIonDefinition() has to be added in ConstructParticle()
  - All process objects have to be instantiated in ConstructProcess(), which is invoked for every thread
  - See extended/electromagnetic/TestEm4
- Random numbers
  - CLHEP::Random:: must be replaced with G4Random::
- Primary generation action reading input data file
  - Mutex locking mechanism is needed to share the same input data file on threads
  - See extended/runAndEvent/RE05

# Other Items For Migration (2)

- Static declarations in user code
  - Be sure that all static variables are used from threads as read-only
- Customize threading
  - Via G4UserWorkerInitialization class
- Advanced Tips & Tricks
  - https://twiki.cern.ch/twiki/bin/view/Geant4/Geant4MTTipsAndTricks

# Tips For Building & Testing Application in Both Modes

# Building Geant4

- Install Geant4 in both modes:
  - Keep a single version of geant4 source and create two build directories:
    - geant4_version_build,  geant4_version_build_mt
  - Build geant4 in each directory **with the same cmake options** but only added  -DGEANT4_BUILD_MULTITHREADED=ON for MT build
    - In some cases more options may be needed for MT build
  - Install each version in its installation area
    - geant4_version_install, geant4_version_install_mt

# Building Application

- Install your application (example) in both modes
  - Create two build directories:
    - my_example_build, my_example_build_mt
  - Build the application (example) from the same source against the relevant Geant4 installation:

```
cd my_example_build
cmake -DGeant4_DIR=/mypath/geant4_version_install/lib64/Geant4-10.0
/mypath/geant4_source/examples/my_example

cd my_example_build_mt
cmake -DGeant4_DIR=/mypath/geant4_version_install_mt/lib64/Geant4-10.0
/mypath/geant4_source/examples/my_example
```

  - You can also build each examples category or sub-category at once

# Testing Application

- Run your application in both build directories and compare the produced output (output analysis files, logs)
  - Tips:  you can redirect output from each thread in a file (and avoid their inter-laying):
    - /control/cout/setCoutFile fileName [ifAppend]
    - /control/cerr/setCerrFile fileName [ifAppend]
  - It is worth to test your application with different number of threads
  - gdb is working fine with MT mode, useful in case of crashes