Track Extrapolation and Muon Identification with GEANT4e in Belle II Event Reconstruction

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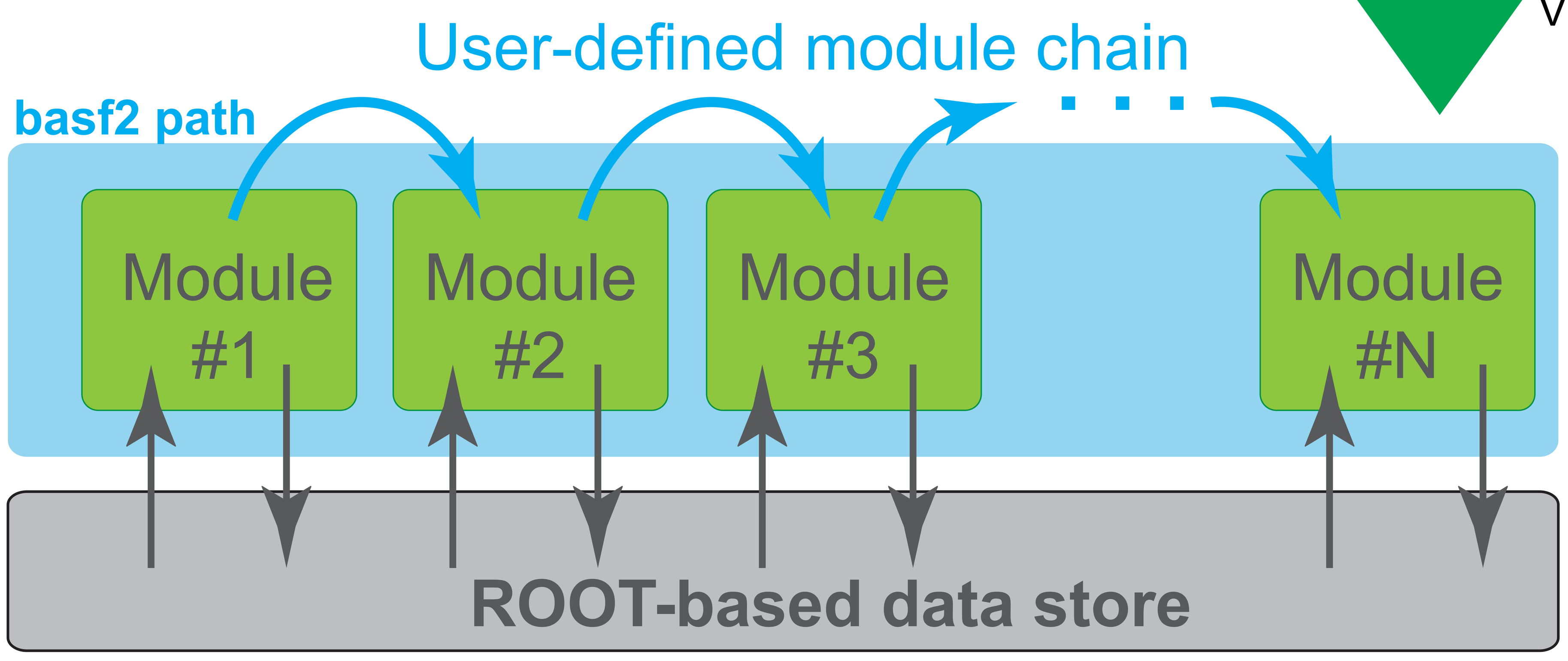
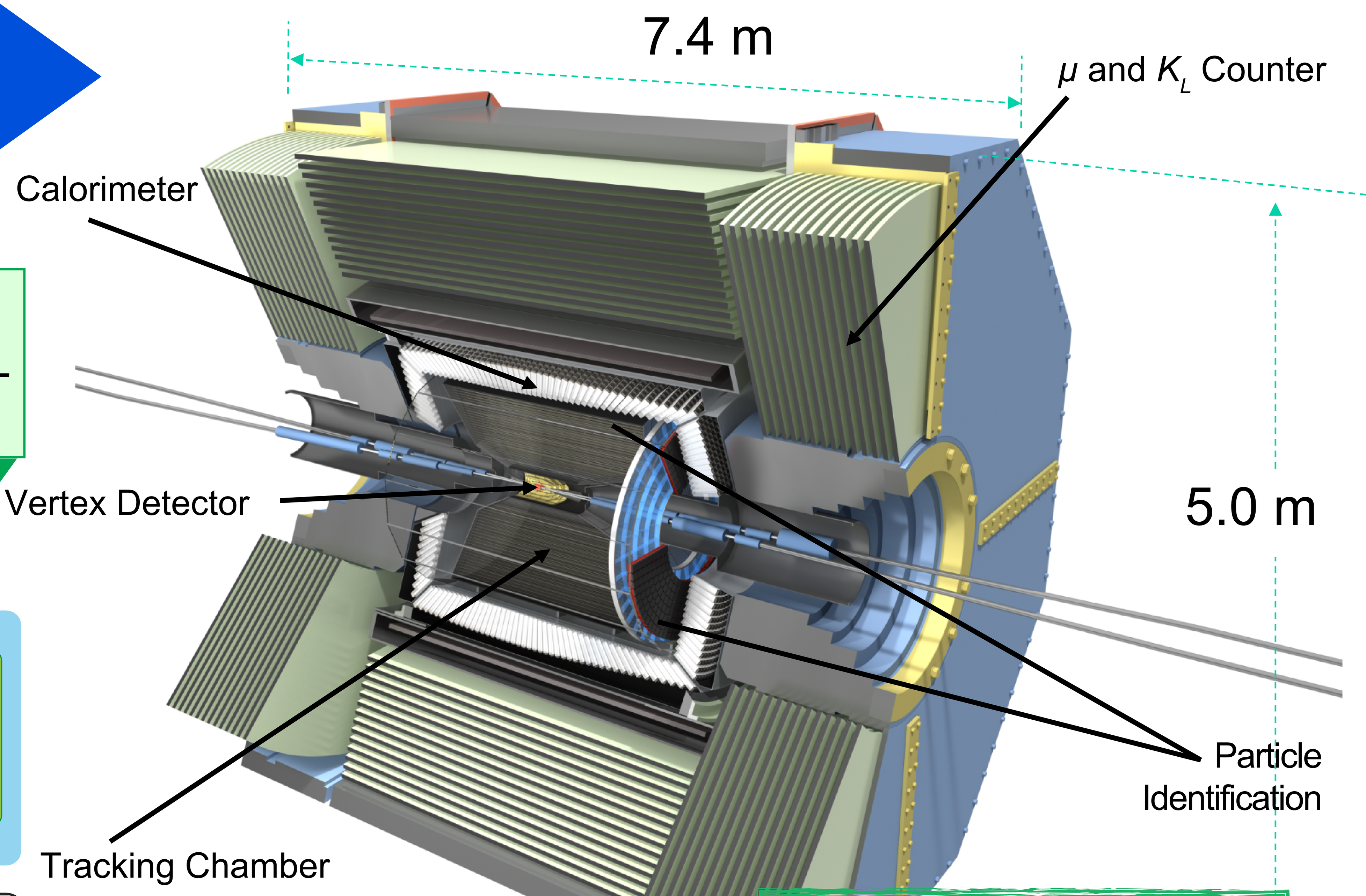
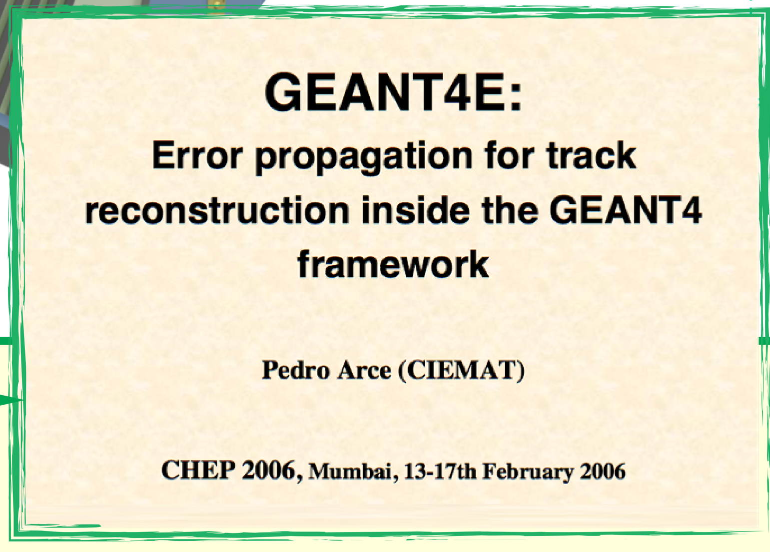
Track 2
Data Analysis – Algorithms & Tools

The Belle II experiment at the SuperKEKB colliding-beam $e^+ e^-$ accelerator in Tsukuba, Japan, studies the behaviour and symmetry properties of heavy quarks and leptons.

The Belle II analysis software framework basf2 has a modular design with Python steering of on-demand dynamically-loaded C++ modules and event-based parallel-processing capability.

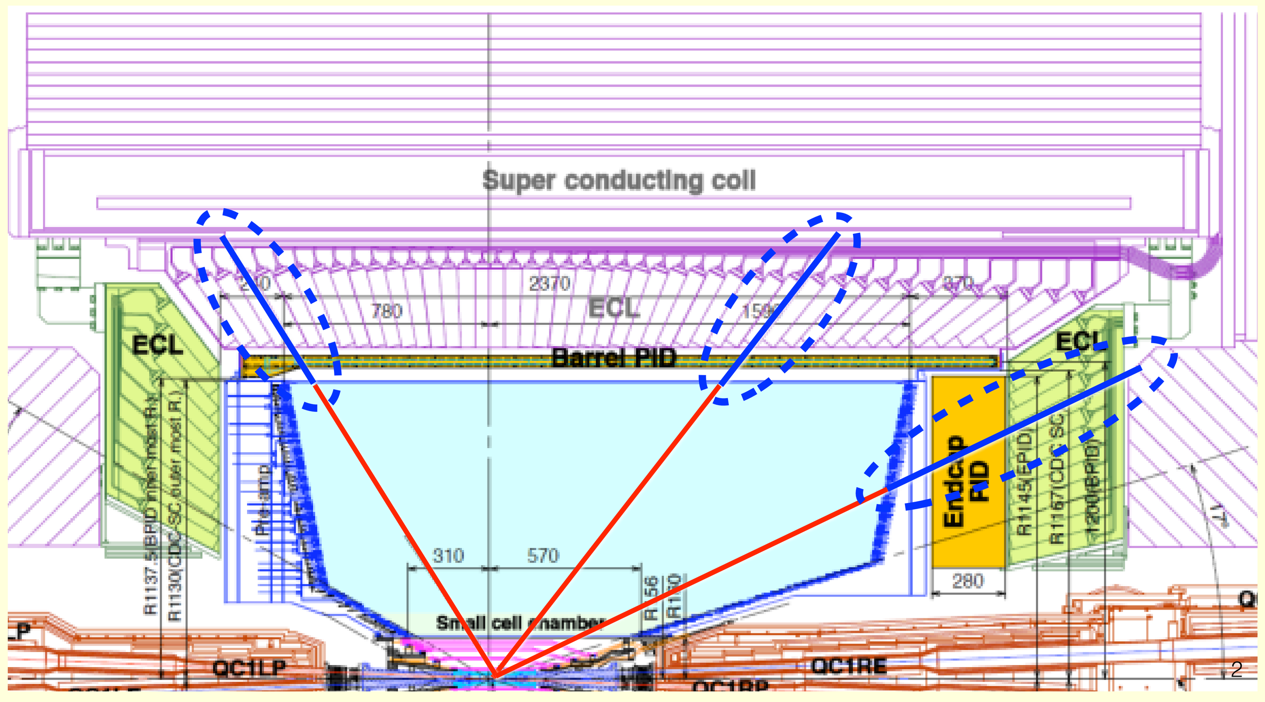




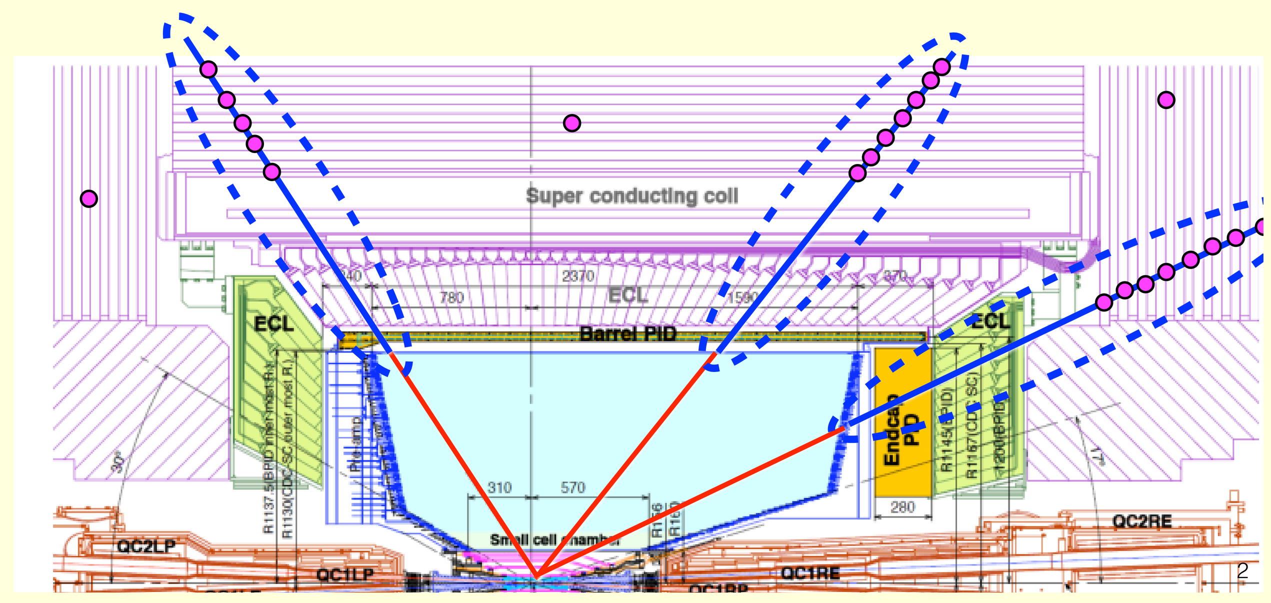

GEANT4E:
Error propagation for track reconstruction inside the GEANT4 framework
Pedro Arce (CIEMAT)
CHEP 2006, Mumbai, 13-17th February 2006

Two basf2 event-reconstruction modules for particle ID using GEANT4E

• ext
– extrapolates each reconstructed charged track outward
– assumes 6 particle-type hypotheses (e, μ, π, K, p, d) per track
– records crossings at each GEANT4 sensitive-volume boundary
– records time, position, momentum, phase-space covariance matrix



• muid
– extrapolates each track through the K_L–muon detector (KLM)
– assumes only the muon hypothesis
– applies a Kalman filter at each layer crossing; adjusts the extrapolated-track properties based on matching-hit location
– assigns particle-identification likelihood based on KLM's measured-vs-extrapolated range + transverse scattering



GEANT4 and GEANT4E coexistence in basf2

GEANT4E, as distributed, cannot be used with GEANT4:
- ⊠ incompatible particle lists
- ⊠ incompatible physics processes
- ⊠ conflicting usage of sensitive-detector geometry
- ⊠ distinct states when calling RunManager
- ⊠ distinct step-by-step Navigators
- ⊠ incompatible user actions (SteppingAction etc)

GEANT4E, as distributed, is limited:
- ⊠ propagates only electrons, positrons and photons

We have resolved these issues and limitations. All of our modifications are done <u>outside</u> the geant4(e) code base.

- ☑ The standard GEANT4E PhysicsList defines only three particles (gamma e+ e−) … and these are not compatible with geant4 usage during simulation

  Our modified ConstructParticle() defines the geant4 standard particles:

  gamma e+ e− mu+ mu− pi+ pi− pi0 kaon+ kaon− kaon0 kaon0L kaon0S proton anti_proton neutron anti_neutron geantino chargedgeantino opticalphoton *etc*

  plus geant4e–specific particles (all with PIDcode = 0)

  g4e_gamma g4e_e+ g4e_e− g4e_mu+ g4e_mu− g4e_pi+ g4e_pi− g4e_kaon+ g4e_kaon− g4e_proton g4e_antiproton g4e_deuteron g4e_antideuteron

- ☑ The distributed G4EnergyLossForExtrapolator defines energy-loss processes for electrons and positrons only. Our custom G4EnergyLossForExtrapolator extends these processes to μ, π, K, p and d (and their anti-particles).
- ☑ During GEANT4 simulation, G4SteppingManager calls user code to process steps through "sensitive" detector volumes and record the hits therein.

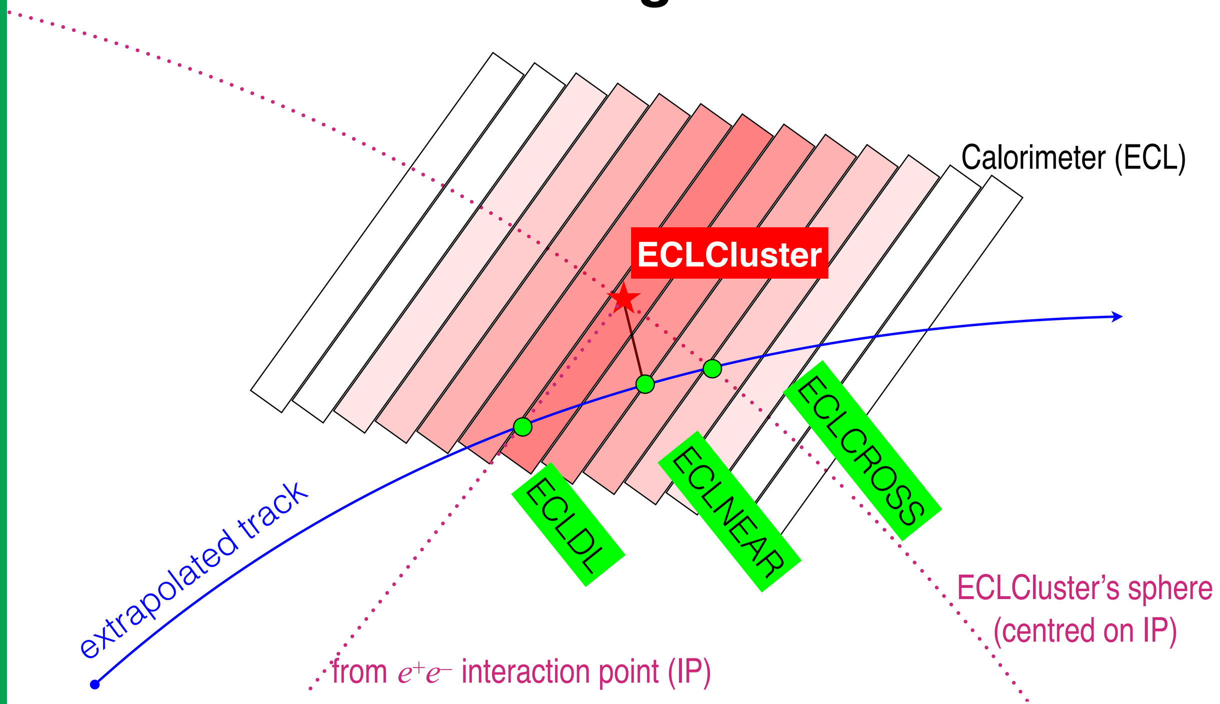
  During GEANT4E extrapolation, our custom version of StepLengthLimitProcess() disables this behaviour:

```
G4ParticleChange aParticleChange;

G4VParticleChange*
  ExtStepLengthLimitProcess::PostStepDoIt( const G4Track& track,
                                           const G4Step& )
{
  aParticleChange.Initialize( track );
  aParticleChange.ProposeSteppingControl( AvoidHitInvocation );
  return &aParticleChange;
}
```

- ☑ Avoid the special G4ErrorPropagationNavigator in GEANT4E. Instead, use the standard G4Navigator defined in GEANT4.
- ☑ GEANT4E requires a <u>*target surface*</u> (G4ErrorCylSurfaceTarget is an infinite-length cylinder). After each GEANT4E step, G4ErrorPropagationNavigator would have checked if track crossed this surface. Our steering code does this check.
- ☑ Our custom version of G4ErrorCylSurfaceTarget is a closed finite-length cylinder that includes the endcap surfaces.
- ☑ The distributed MagFieldLimitProcess in GEANT4E assumes that the magnetic field is along the z axis. Our custom MagFieldLimitProcess removes this assumption.

Track–cluster matching in the calorimeter:



Muon identification and hadron mis-ID: