

# Lesson learned when migrating the IDEA tracker software to EDM4hep

**Lia Lavezzi**

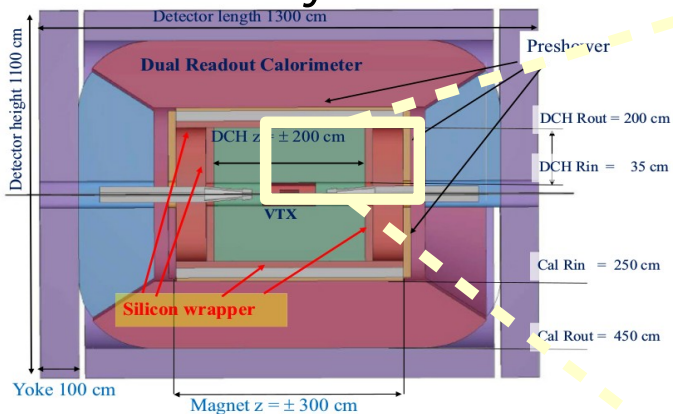
*for the working group*

University of Torino and INFN

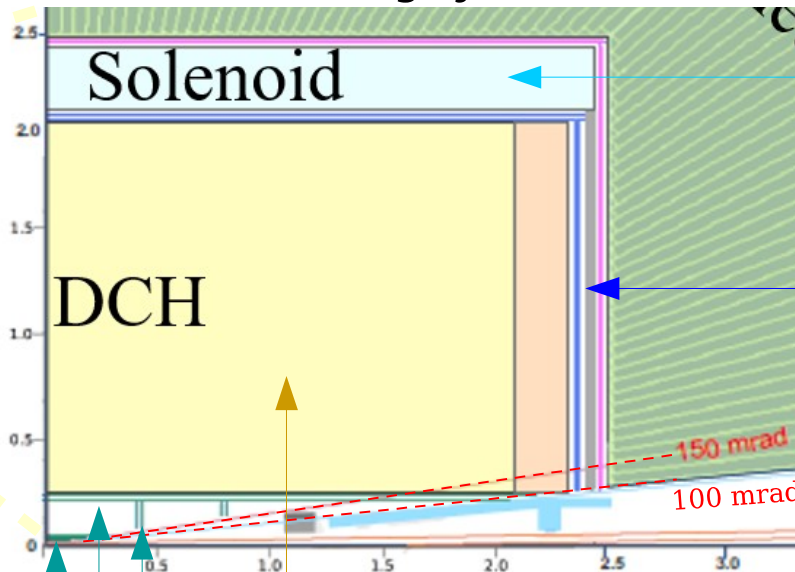


# IDEA Tracking System

IDEA layout



Tracking Systems



**Solenoid**  
 mag field 2 T  
 length 5 m  
 radius 2.1 - 2.4 m  
 rad length  $0.74 X_0$

**Vertex**

- inner** - 3 single Si pixel ( $20 \times 20 \mu\text{m}^2$ ) layers of  $0.3\% X_0$
- outer** - 2 single Si pixel ( $50 \times 50 \mu\text{m}^2$ ) layers of  $0.5\% X_0$
- forward** - 4 single Si pixel ( $50 \times 50 \mu\text{m}^2$ ) layers of  $0.3\% X_0$

**Drift Chamber**

56448 ( $\sim 1.2$  cm) cells  
 He: $i\text{C}_4\text{H}_{10}$  (90:10)

**Si Wrapper**

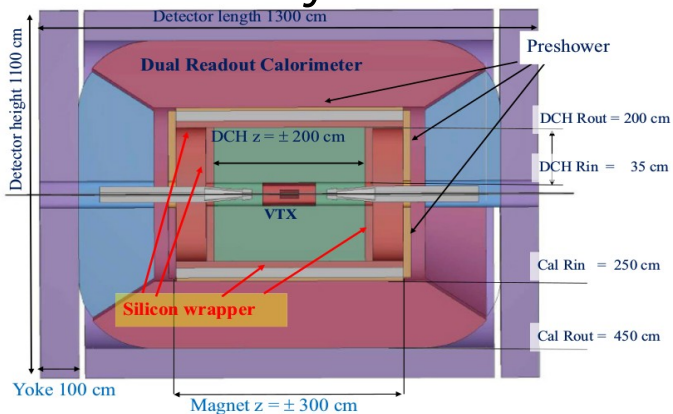
2 layers of microstrips ( $50 \mu\text{m} \times 1$  mm)  
 both barrel and forward regions

**plus**

- pre-shower  $\mu$ -RWELL
- muon  $\mu$ -RWELL

# IDEA Tracking Software

## IDEA layout



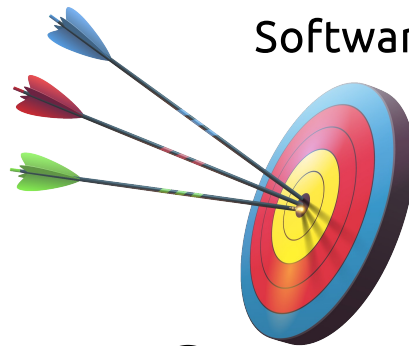
## Standalone Software

- Simulation based on GEANT4
- Reconstruction based on ROME

[M. Schneebeil, R. Sawada, S. Ritt, *ROME - A universally applicable analysis framework generator*, proc. CHEP06]



## Software Framework



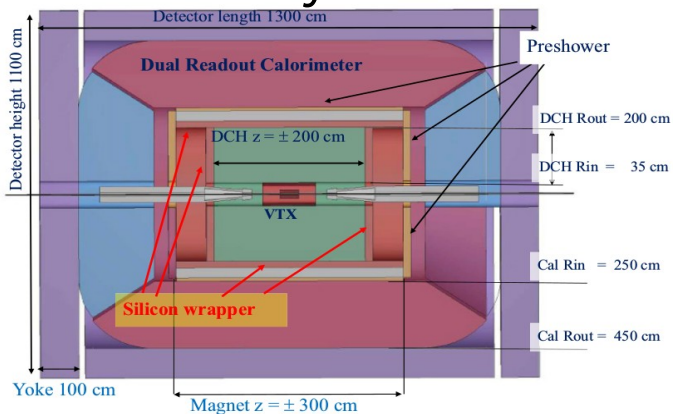
- FCCSW
- Key4hep



See talk by C. Helsens on 11 Feb

# IDEA Tracking Software

## IDEA layout



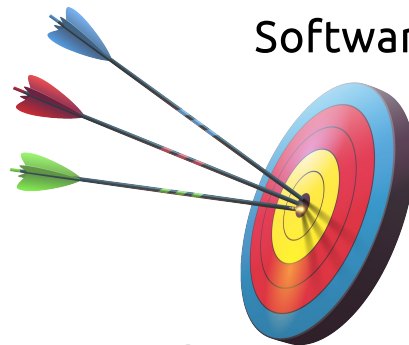
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- 
- port the geometry
  - port the algorithms
  - port the the data format

## Software Framework



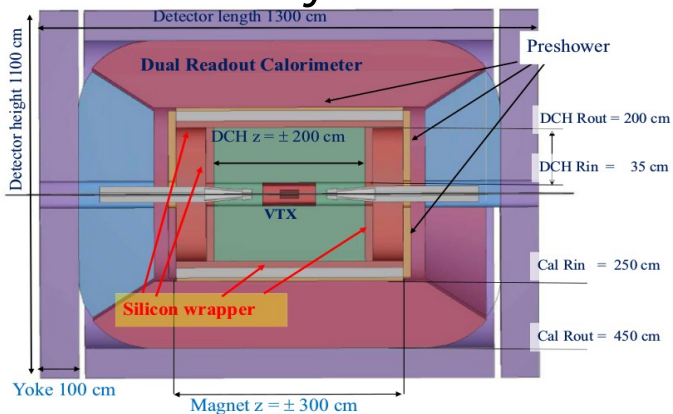
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# IDEA Tracking Software

## IDEA layout



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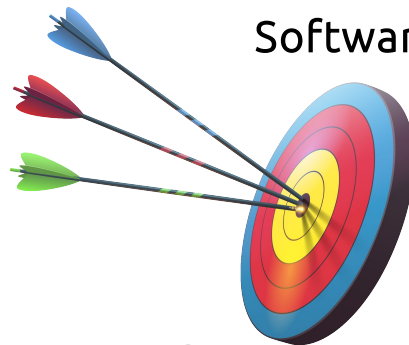
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- FCCSW
- Key4hep

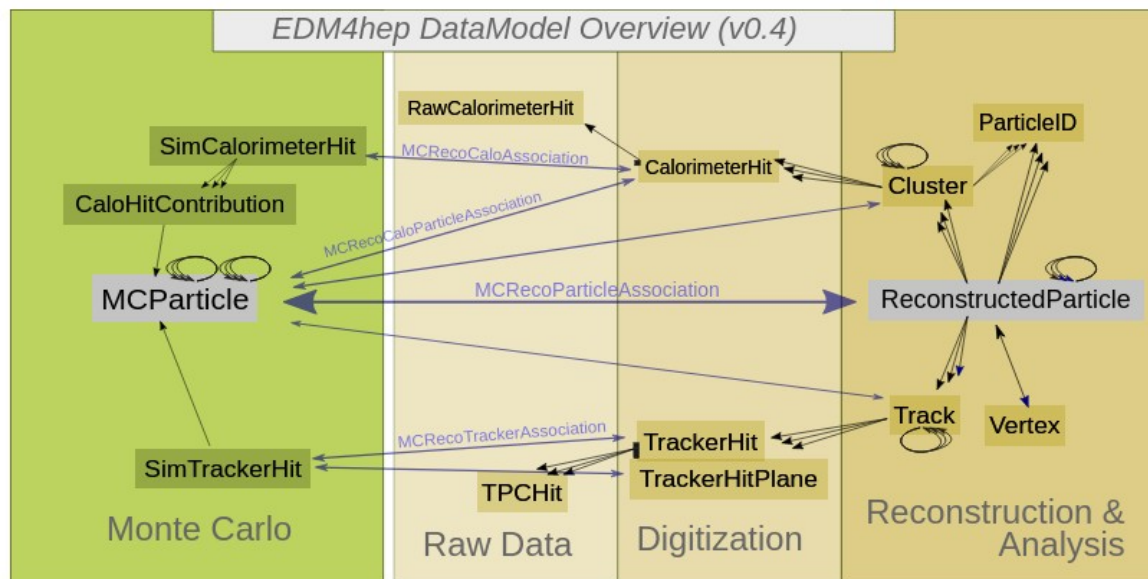


See talk by C. Helsens on 11 Feb

# EDM4hep - PODIO

## Temporary Solution

simulation from the standalone → transform the GEANT4 Monte Carlo hits into EDM4hep  
reconstruction from the standalone → transform the reconstructed tracks into EDM4hep



PODIO - a generic EDM toolkit  
automatic code generator from a  
high level description in YAML  
format → free the users from the  
implementation details

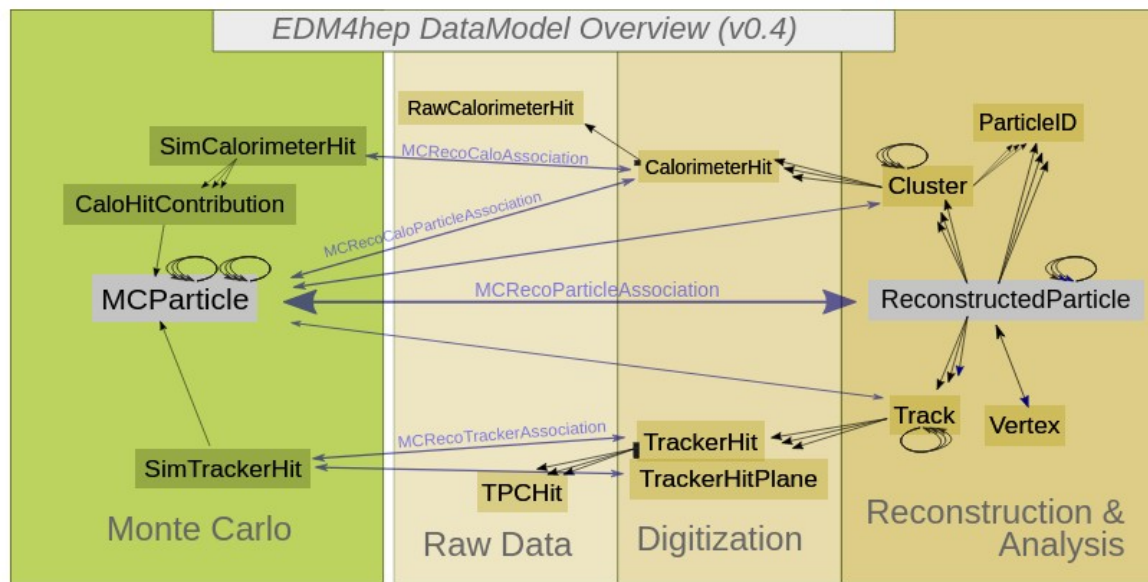
thanks to I. Vivarelli for the recipe

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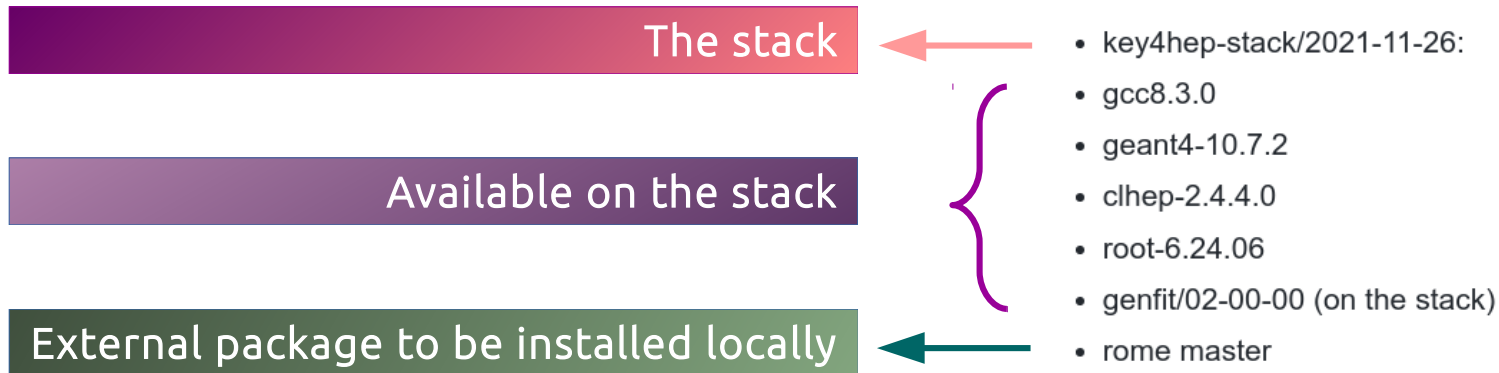
Temporary solution to use IDEA with the common analysis tools



# Standalone Code on the Stack

- The standalone code was adapted for compilation on Key4hep stack (thanks to G. Tassielli)
- It works with the latest Key4hep stack on CERN **lxplus** machines  
<source /cvmfs/sw.hsf.org/key4hep/setup.sh>

## Everything is working with these versions



- Contacted FCCSW developers to plan how to distribute the code



# How to Install

<https://github.com/lialavezzi/DriftChamberPLUSVertex/tree/uptodate>

standalone previous structure  
+  
converter/ directory  
+  
install\_standalone.sh

lialavezzi Update README.md		b149f75 7 hours ago	🕒 52 commits
📁 DCHDAQ	initial commit		13 months ago
📁 DCHDataReade	initial commit		13 months ago
📁 analyzer	fix on zlib path to use latest key4hep stack, switch rome to ma...		7 days ago
📁 converter	moved converthits to the converter directory		7 hours ago
📁 simulation	moved converthits to the converter directory		7 hours ago
📄 README.md	Update README.md		7 hours ago
📄 install_standalone.sh	fix on zlib path to use latest key4hep stack, switch rome to ma...		7 days ago
📄 key4hep_setup.sh	fix to use key4hep stack 2021-09-01		11 days ago

## INSTALLATION via installer

Instructions:

- Download the file [install\\_standalone.sh](#)
- Edit it and set STANDALONE\_INSTALL\_DIR to the directory where you want to install everything
- Make it executable with: `chmod u+x install_standalone.sh`
- Execute it with: `./install_standalone.sh`

In order to run the code, go directly [here](#)

# Conversion of MC Hit

## GMCG4TrackerHit *original GEANT4 hit*

```
G4int      fTrackID;
G4int      fChamberNb;
G4int      fChannelNb;
G4double   fEdep;
G4double   fNoIEdep;
G4double   fGlobalTime;
G4double   fProperTime;
G4ThreeVector fPos;
G4ThreeVector fPosEnding;
G4ThreeVector fMomentum;
G4double   fStepLength;
G4String   fProcessCode;
```

```
#----- SimTrackerHit
edm4hep::SimTrackerHit:
  Description: "Simulated tracker hit"
  Author : "F.Gaede, DESY"
  Members:
    - unsigned long long cellID //ID of the sensor that created this hit
    - float EDep //energy deposited in the hit [GeV].
    - float time //proper time of the hit in the lab frame in [ns].
    - float pathLength //path length of the particle in the sensitive material that result
    - int quality //quality bit flag.
    - edm4hep::Vector3d position //the hit position in [mm].
    - edm4hep::Vector3f momentum //the 3-momentum of the particle at the hits position in [GeV]
  OneToOneRelations:
    - edm4hep::MCParticle MCParticle //MCParticle that caused the hit.
  ExtraCode :
```

## SimTrackerHit *EDM4hep tracker hit*

- The class **convertHits** translates GEANT4 hits to EDM4hep tracker hits
- The EDM4hep hit is at the moment the SimTrackerHit defined in:  
<https://github.com/key4hep/EDM4hep/blob/master/edm4hep.yaml>
- EDM4hep people encourage feedback

# Conversion of MC Hit

Si vertex tracker, drift chamber, Si wrapper & pre-shower

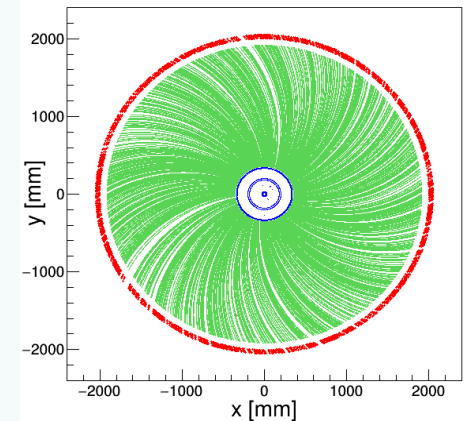
Example of simulation

particle

- 1000 events
- 1 muon/event
- $\theta \in [88.5^\circ, 90.5^\circ]$
- energy = 1 GeV

geometry

- beam pipe
- SVX
- DCH
- PSHW (w/ SW)
- magnetic field = 2.0 T



The other steps

- porting of **DR calo hits** to EDM format [I. Vivarelli / L. Pezzotti]
- adding them to the standalone and merging the two pieces of code [W. Elmetenawee]
- adding the geometry of the **muon chambers** [I. Garzia]



See talk by Sang Hyun Ko right after this



See talk by W. Elmetenawee tomorrow



See talk by G. Mezzadri on 8 Feb

Hits are not enough for inserting IDEA in the analysis.  
Also reconstruction is standalone for now → need reconstructed tracks in EDM4hep!

# Conversion of Reconstructed Track

The class `convertTracks` translates standalone reconstructed tracks to EDM4Hep model

## Track from standalone reconstruction

Int_t	TrkID	Track ID
Double_t	x0,y0,z0	Track Vertex x,y,z coord
Double_t	err_x0, err_y0,err_z0	Error On the Track Vertex x,y,z coord
Double_t	theta	polar angle
Double_t	err_theta	Error on the Track Vertex theta
Double_t	phi	azimuthal angle
Double_t	err_phi	Error on the Track Vertex phi
Double_t	Momentum	Track Momentum
Double_t	Err_Momentum	Error on the Track Momentum
TVector3	mom	Fitted Momentum
TMatrixDSym	cov	Covariance Matrix
Int_t	hitindex	Index of the hit used for the track fit
Int_t	detid	detector ID
Bool_t	Skipped	Flag for skipped track
TVector3	StateVector	State vector
Int_t	nhits	number of hits
Int_t	ngoodhits	number of good hits
Int_t	nhitsdch	number of hits in dch
Int_t	ngoodhitsdch	number of good hits in dch
Int_t	nhitssvx	number of hits in svx
Int_t	ngoodhitssvx	number of good hits in svx
Int_t	nhitsspshw	number of hits in pshw
Int_t	ngoodhitsspshw	number of good hits in pshw
Double_t	chi2	chi2 of the track fit
Int_t	dof	Degrees of freedom
Bool_t	IsFitted	Flag indicating if the track has been already fitted

## EDM4Hep reconstructed track

```
#----- Track
edm4hep::Track:
  Description: "Reconstructed track"
  Author : "F.Gaede, DESY"
  Members:
    - int type //flagword that defines the type of track.Bits 16-31 are used internally
    - float chi2 //Chi^2 of the track fit
    - int ndf //number of degrees of freedom of the track fit
    - float dEdx //dEdx of the track.
    - float dEdxError //error of dEdx.
    - float radiusOfInnermostHit //radius of the innermost hit that has been used in the track fit
  VectorMembers:
    - int subDetectorHitNumbers //number of hits in particular subdetectors.Check/set collection variable
    - edm4hep::TrackState trackStates //track states
  OneToManyRelations:
    - edm4hep::TrackerHit trackerHits //hits that have been used to create this track
    - edm4hep::Track tracks //tracks (segments) that have been combined to create this track
```

# Conversion of Reconstructed Track

## Track description

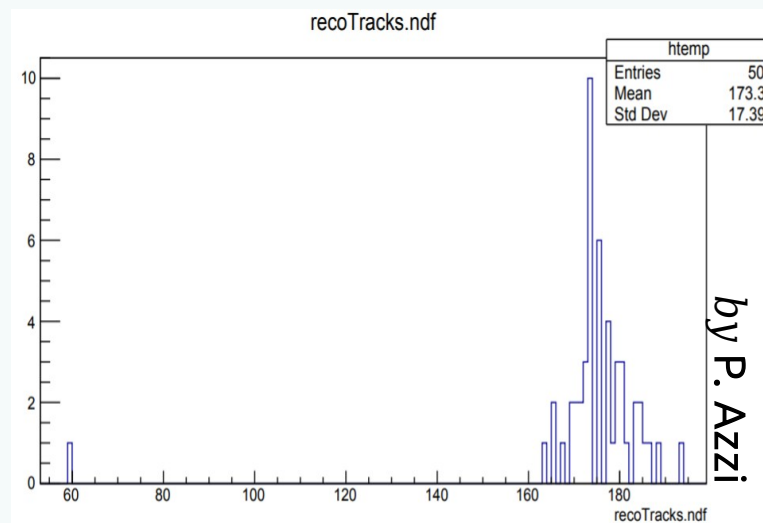
- track parameters @ poca to the beamline
- state vector
- covariance matrix

## Jacobian for reference frame conversion

EDM4hep

$$J = \frac{\partial(k, \varphi, \rho, ctg(\theta), z_0)}{\partial(x, y, z, p_x, p_y, p_z)}$$

Standalone



## particle

- 50 events
- 1 particle / event
- energy = 1 GeV

Will need to accommodate the cluster counting variable  $dN/dx$



See talk by F. Grancagnolo on 8 Feb

# Conclusions

- The code is available on <https://github.com/lialavezzi/DriftChamberPLUSVertex/tree/uptodate> and it is installable on **lxplus** machines with a **script**
- It does the following, with IDEA detector:
  - standalone simulation, with SVX, DCH, SWR, PSHW (DRCALO and MUC *in progress*)
  - standalone track reconstruction
  - hit / track conversion to EDM4hep

Usable as interface between IDEA detector and FCC analysis tools for now  
→ *meanwhile the geometry and reconstruction will be implemented in the framework*

## Ongoing

- Under test in order to be used soon
- Soon (I hope) will be made available to everyone
- Soon (I hope) merged with the latest developments from DRCALO & MUC

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thank you for the attention