Plan for CEPC Software Development

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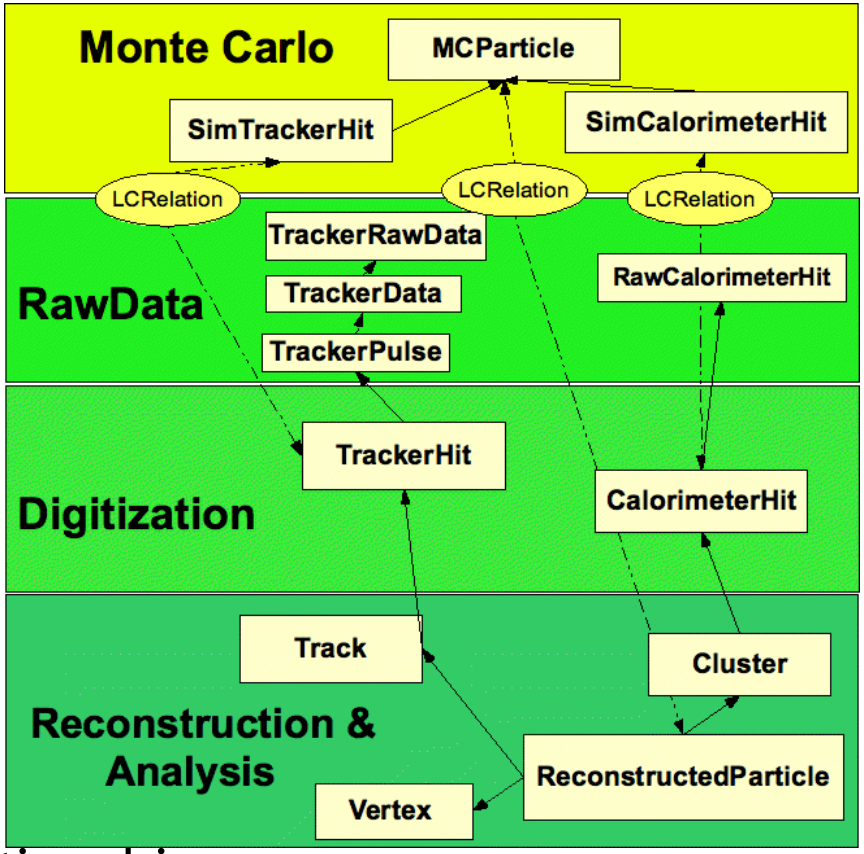
Software Environment

- Requirements from ACTS:
  - gcc (>= 6.2), cmake (>=3.7), boost (>=1.62), ROOT (>=6.10)
- Requirements from TensorFlow and multi-threaded Gaudi
  - TensorFlow: gcc >= 8
  - Gaudi v32.0: gcc >=7
- Plan to move from LCG_94 to LCG_96b

	Current	Update
LCG	LCG_94	LCG_96b (latest)
gcc	6.2.0	8.3.0
binutils	2.28	2.30
cmake	3.8.1	3.8.1
Boost	1.66.0	1.77.0
ROOT	6.14.04	6.18.04
Gaudi	v29r2	32.0

Association Relationships in EDM

- Association
  - TrackerHit
  - SimTrackerHit
  - CalorimeterHit
  - SimCalorimeterHit
  - ReconstructedParticle
  - MCParticle



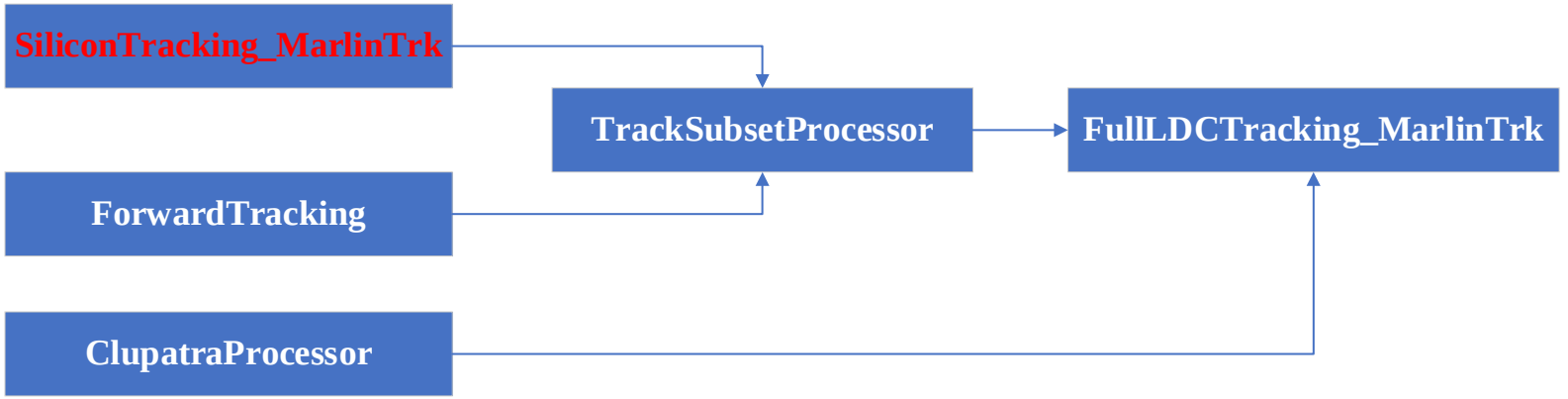
- Aggregation
  - A subtype of association relationship
  - In our case, upstream objects can access their own downstream objects: ReconstructedParticle → Track → TrackerHit → TrackerPulse

Plan for Event Navigation

- Requirements to Event Navigation
  - Needed by digitization algorithms and tracking algorithms for performance evaluation particularly in the development stage
- Problems with PLCIO
  - Object IDs are used in Association and Aggregation
  - Not straightforward to retrieve an object with its Object ID
- Plan
  - Develop helper classes or Gaudi services to facilitate event navigation between
    - TrackerHit and SimTrackerHit
    - CalorimeterHit and SimCalorimeterHit
    - ReconstructedParticle and MCParticle

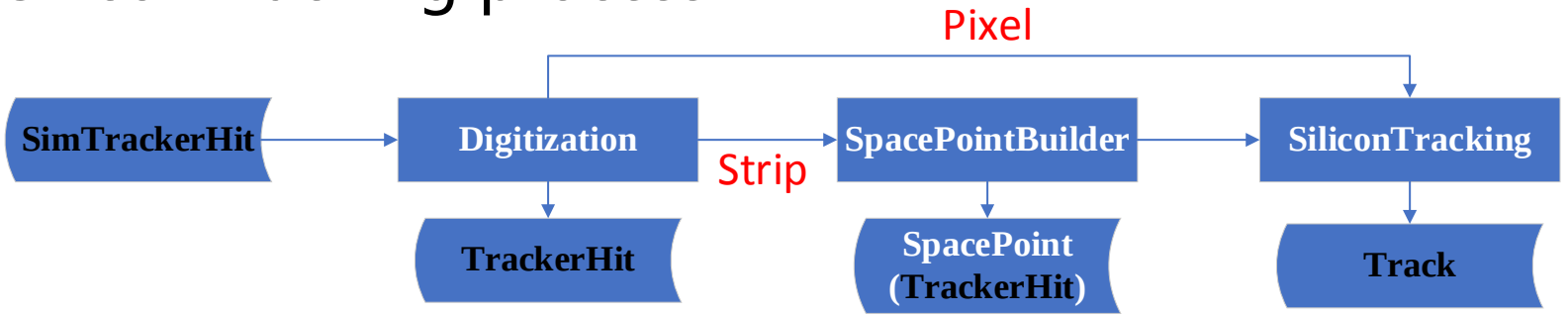
Porting tracking algorithm

- Tracking process (Marlin)



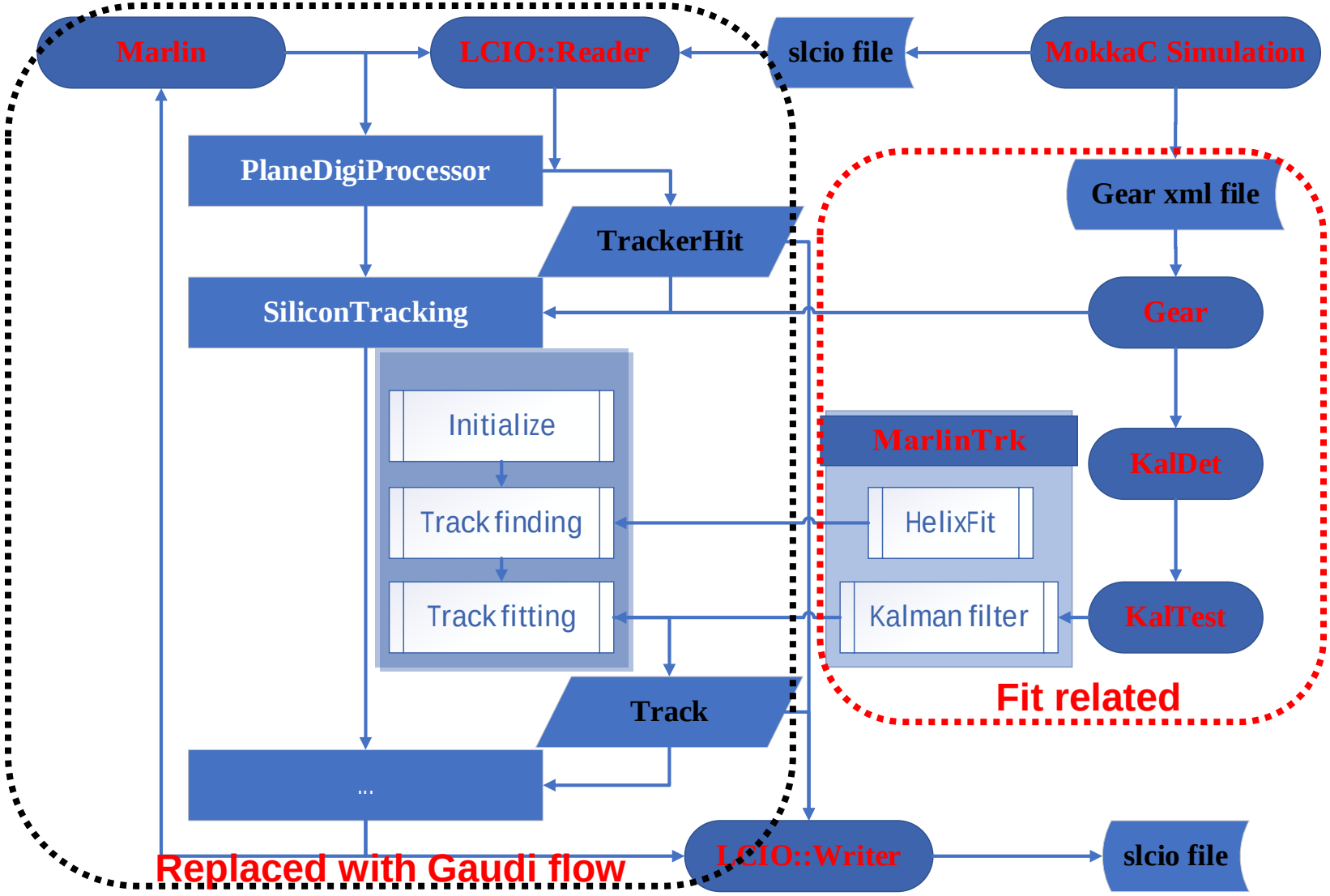
SiliconTracking_MarlinTrk is chosen as the first migrated reconstruction, since it has less dependency and the tracking for silicon detector is more simple than TPC.

- SiliconTracking process



SiliconTracking for vertex detector (pixel VXD) only (without strip SIT) is most simple option.

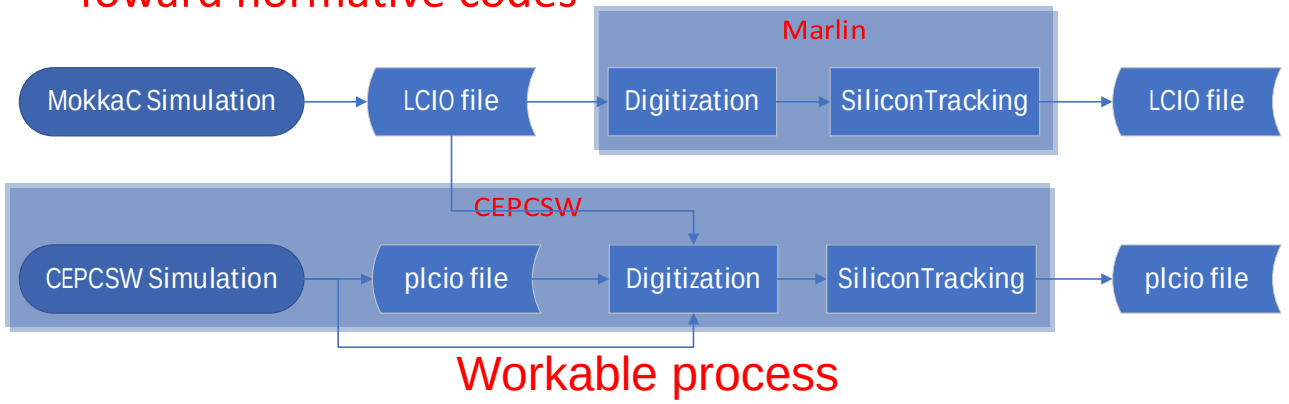
Working flow



Since CEPCSW's itself Geometry and Track fitting (Kalman filter) services have not bee ready, they are kept as external packages.

Status

- One reconstruction algorithm —— SiliconTrackingAlg
  - Dependencies
    - TrackSystemSvc (service): ready
    - TrackSystemSvcLib (library): ready
    - KalDet (external): ready
    - KalTest (exrernal): ready
    - GEAR (service): ready
    - Data input (LCIO file convert to plcio): ready
    - Data conversion (digitization): ready
  - Algorithm
    - Temporary solution scheme: ready
    - Toward normative codes

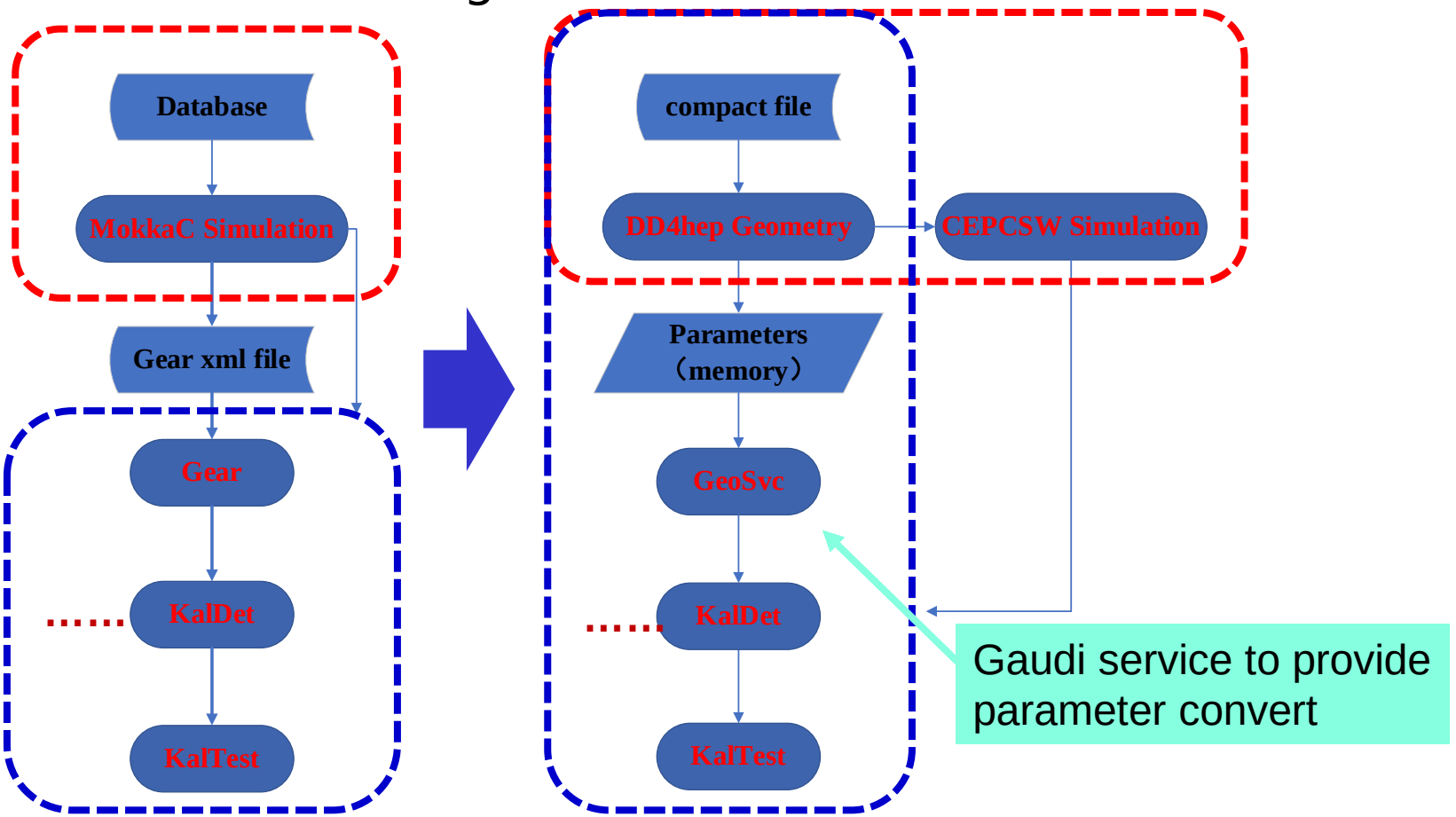


Plans for Tracking Algorithms

- Migration algorithms from Marlin to CEPCSW and Validation
  - Tracker
    - Silicon — Fu Chengdong
    - TPC + — Zhang Yao / Zhao Mingrui / Zhang Shunan
  - PFA
    - Arbor — Ruan Manqi, …
    - Pandora — Guo Fangyi, Li Gang, …
  - Jet / Flavor — Li Gang, …
  - Validation: Time consumption, manpower, computing resource…
- ACTS: A Common Tracking Software
  - Benefit from software upgrade projects for international experiments
  - Long term using ACTS as CEPC tracking (track finding)
  - HL-LHC: focus improving computing performance
  - CEPC: only O(10) tracks, focus the efficiency and precision
  - FATRAS: an option of tracker fast simulation tool for CEPC

Update of Geometry Manager

- Easy to manage geometry version
  - Compact files + gear file ⇒ compact files
- Run reconstruction together with simulation

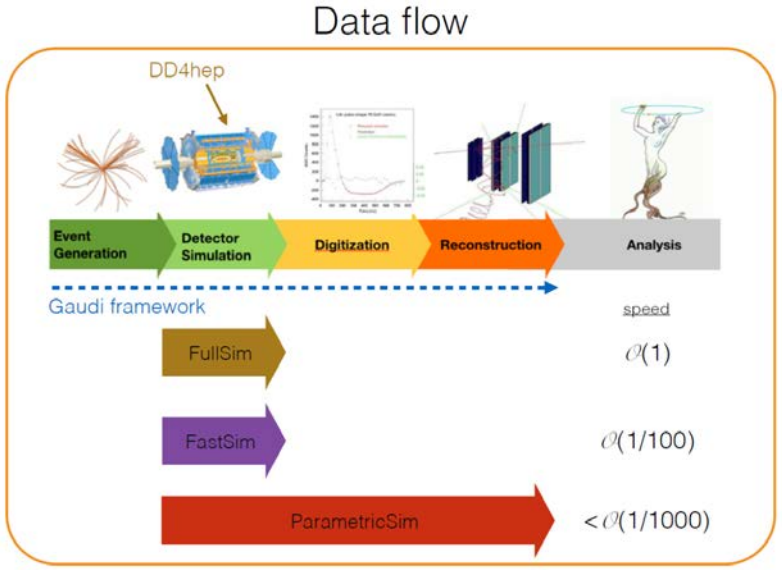


Tracking on Baseline Detector Migration

- Tracking related packages(red: TPC related, first stage, green: done/framework independent, blue: other subdetector related, second stage):
  - Digitization: TPCDigi(TPC), FTDDigi(FTD), VTXDigi(VTX, SIT, SET)
  - Fitting packages: KalTest, KalDet
  - Wrapper: MarlinTrk
  - Supporting packages: KiTrack
  - Track finding packages: clupatra(TPC), ForwardTracking(FTD), SiliconTracking_MarlinTrk(VTX, SIT, SET, FTD)
  - Selector and Merger: TrackSubsetProcessor, FullLDCTracking_MarlinTrk
  - Utility
- Plan and manpower
  - First stage: TPCDigi(Zhang Yao), Clupatra(Zhao Mingrui), Validation(Zhang Shunan)
  - Second stage: other packages(Zhang Yao, Zhao Mingrui, Zhang Shunan)

Fast Simulation

- Three types of simulation
  - Full simulation (Geant4) $\mathcal{O}(1)$
  - Fast simulation $\mathcal{O}(1/100)$
  - Parametric simulation $\mathcal{O}(1/1000)$
- Plan to develop a coherent simulation framework
  - Allow mixing of full and fast simulations
  - When a particle enters a certain detector region, user-defined simulation tool will be used.



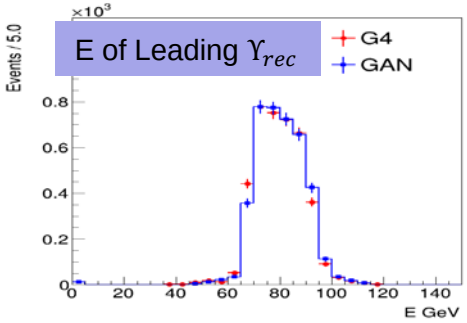
ATLAS ISF (Integrated Simulation Framework)

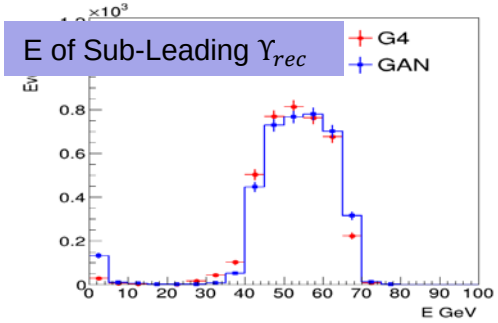
Fast Simulation Tool Development

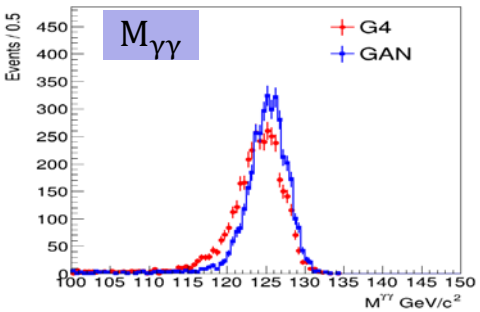
- Tracker
  - Fatras package in ACTS project used for test the tracking algorithm
  - Hit level fast simulation
  - Supports DD4HEP and uses the same detector description of GEANT4
  - Includes most interaction between particles and materials
    - Multiple coulomb scattering
    - Ionization loss
    - Radiation loss
    - Limited nuclear interaction processes
  - Manpower: Gang LI + ??
- Calorimetry
  - Physics analysis
    - Frozen library: GEANT4 and/or test beam
    - Generative Adversarial Network (GAN)
    - Parametric simulation?
  - Sub-detector performance
    - GEANT4
  - Manpower: Wenxing FANG, Tao LIN, Gang LI?

Calorimeter Simulation with GAN

- Full simulation with Geant4 :
  - The most accurate approach, but also the most computationally intensive.
  - Computing time scales roughly linearly with both the incident particle energy and the number of incident particles.
  - Calorimeter simulation is one of bottlenecks.
- Simulation with Generative Adversarial Networks (GAN) is one of fast simulation methods
- Current status:
  - Trained GAN for electron and photon using particle gun samples.
  - Checked its performance using $e^+e^- \to Z(\nu\nu)H(\gamma\gamma)$ mc samples.
  - Compared some properties of reconstructed gamma from Geant4 and GAN.
- In general, the results from GAN looks good and shows its potential for fast calorimeter simulation.
- Lots of work need to be done



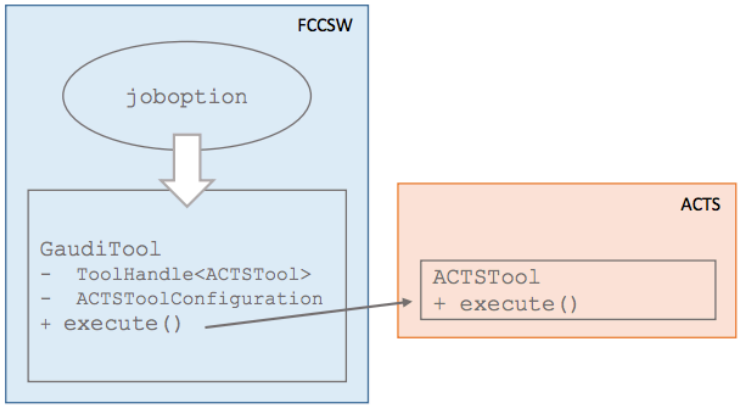




  - Looks fine, has room for improvement.

Integration with ACTS toolkit

- Acts toolkit includes several repos:
  - acts-core: detector independent; acts-fatras: fast track simulation; acts-data: data needed to run examples; acts-framework: a small event processing framework. Acts-framework will be replaced by Gaudi.
- Gaudi-based algorithms, services and tools will be developed:
  - RecTrackAlg: a generic tracking algorithms.
  - TrackingGeoSvc: provides the Acts-based geometry, converted from DD4hep.
  - ITrackSeedingTool and ITrackFittingTool: used by RecTrackAlg, implemented by Acts toolkits.
  - Keep the interfaces compatible with FCCSW.



http://acts.web.cern.ch/ACTS/integration_fcc/

Plan for Multi-threading Testing

- Framework Testing
  - Update Gaudi to the latest version of V32.0
  - Detector simulation chosen to be Multi-threaded application
- Testing of Event Store
  - To check whether it is thread-safe or not
- Event Data IO Testing
  - Data synchronization and performance measurements
- Performance optimization

CEPCSW Version Release in 2020

- First Version (May-Release)
  - Software environment
  - EDM: relationship
  - Uniform geometry: Simulation and Reconstruction
  - Tracker: silicon / TPC
- Second Version (October-Release)
  - PFA: Arbor and/or Pandora
  - Jet / Flavor tag
  - Integration of ACTS
  - Geometry: DD4Hep
  - Fast simulation framework: tracker and/or calorimeter
  - Multi-threading testing / EDM performance optimization
  - Detector design
  - Visualization ?

Plan of Next 3 Years

- 2021
  - PLCIO ➔ EDM4Hep
  - Support data analysis of beam test
  - Fast simulation: data production and physics analysis
  - Non-uniformity of magnetic field, noise and background mixing: optimization of reconstruction algorithm and physics analysis
- 2022
  - Integration with Key4Hep
  - Optimization, performance and validation of reconstruction algorithms, physics analysis
  - Online event filter
  - Parallel computing
  - Application of Machine learning in Reconstruction

Thank You !

謝謝