

WP 12 - Software for Future Detectors

Second Project Review Meeting

CERN, June 20, 2024

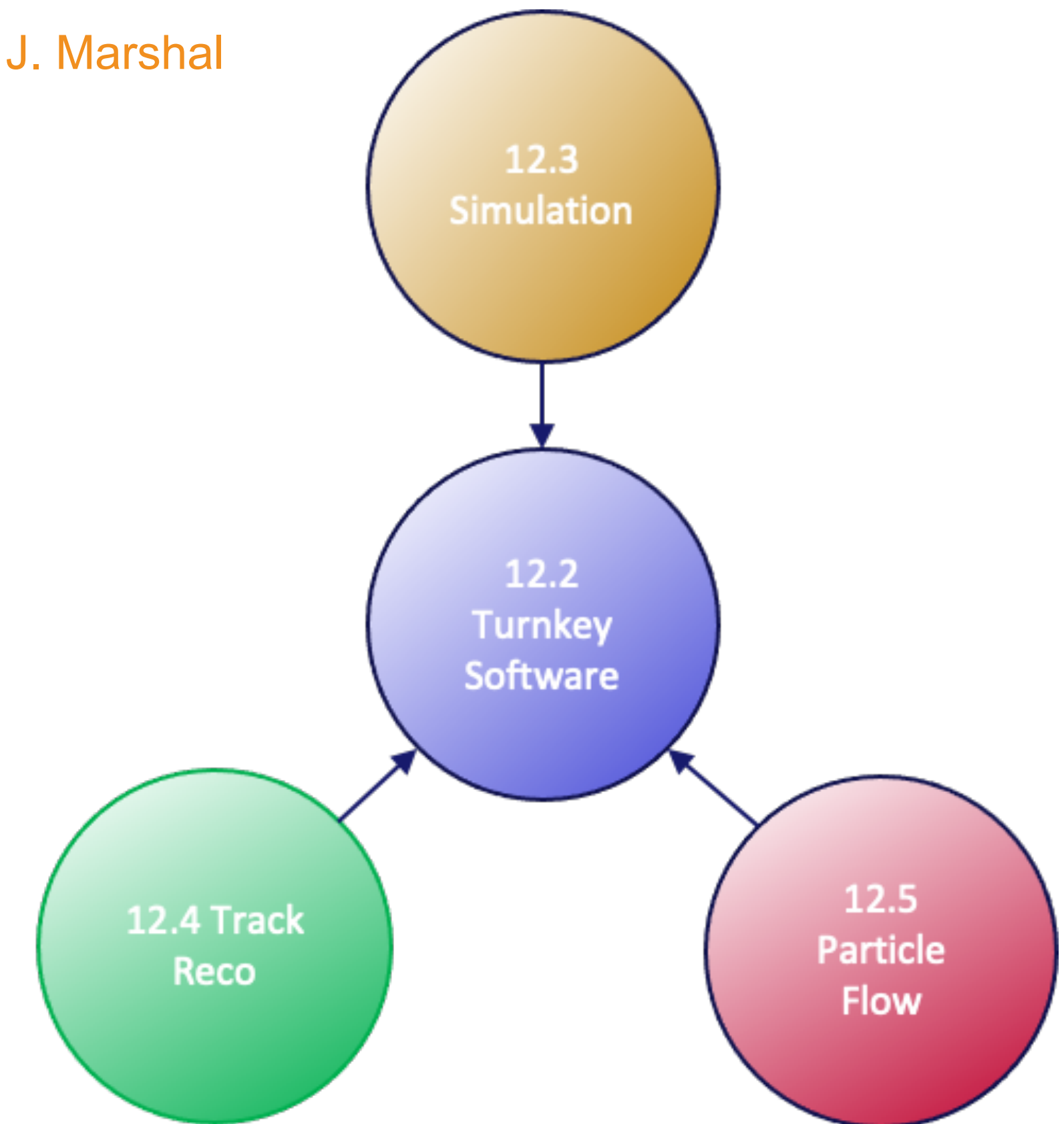
Frank Gaede, DESY, Graeme Stewart, CERN



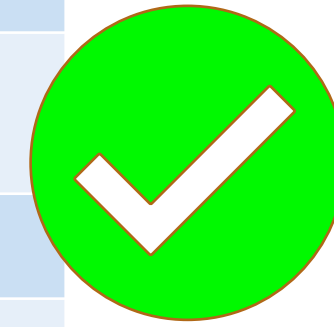
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101004761.

- **Task 12.1. Coordination and Communication (CERN, DESY)**
 - G.A.Stewart, F.Gaede
- **Task 12.2. Turnkey Software (DESY, CERN, INFN-PI, INFN-PD, INFN-BA, INFN-BO, IHEP, SDU)**
 - Turnkey Software Stack, for physics and performance studies, EDM4hep, PODIO and Digitisation toolkit
 - R&D study on frameworks to manage heterogeneous resources
 - T.Madlener, A.Sailer
- **Task 12.3. Simulation (CERN, DESY, CNRS-IJCLab, UNIMAN)**
 - Fast simulation techniques integrated into Geant4
 - Machine learning based calorimeter simulation toolkit for training and inference
 - A.Zaborowska
- **Task 12.4. Track Reconstruction (CNRS-IJCLab, CERN, DESY, INFN-FE, INFN-BO)**
 - complete track reconstruction with ACTS composable algorithms and for heterogeneous computing
 - Machine learning reconstruction algorithm for MPGD detectors
 - H.Grasland

- **Task 12.5. Particle Flow Reconstruction (UWAR, CERN, INFN-RM3, CNRS-LLR, CNRS-IP2I, UOS)**
 - PFA algorithms for DUNE and dual-readout calorimeters, APRIL PFA for hadronic jets
 - J. Back, J. Marshal



Milestone	Title	Due Date
MS48	LC reconstruction prototype in Key4hep	M21
MS49	Prototype of ML based shower simulation	M22
MS50	ACTS tracking algorithm prototypes	M23
MS51	New PFA prototypes	M23



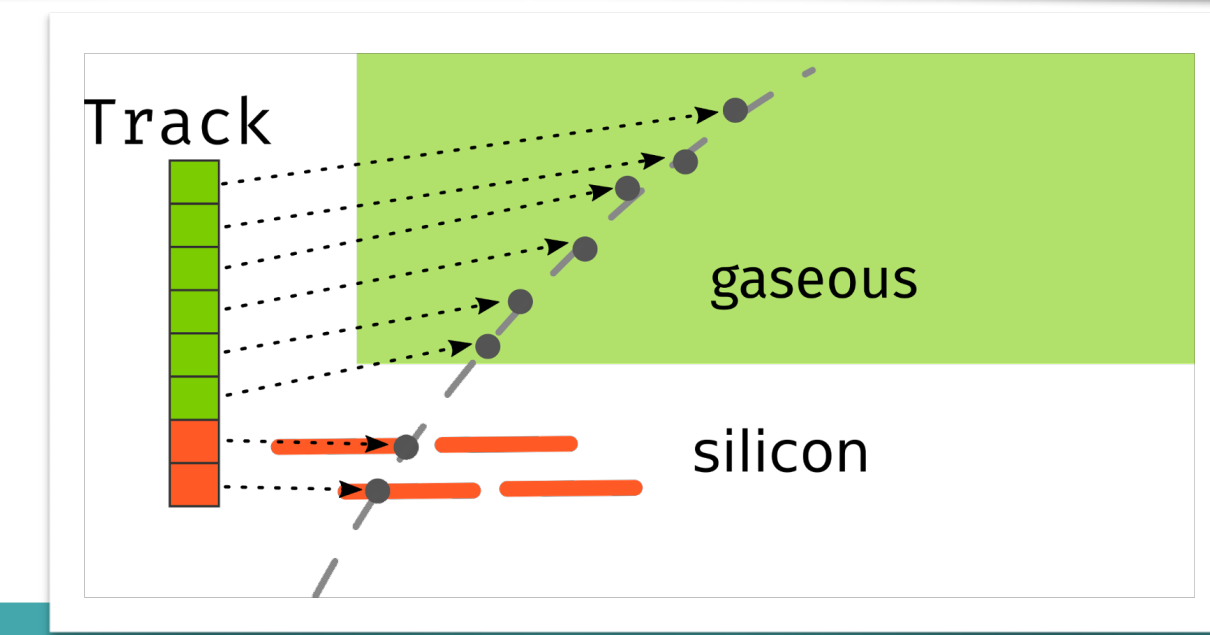
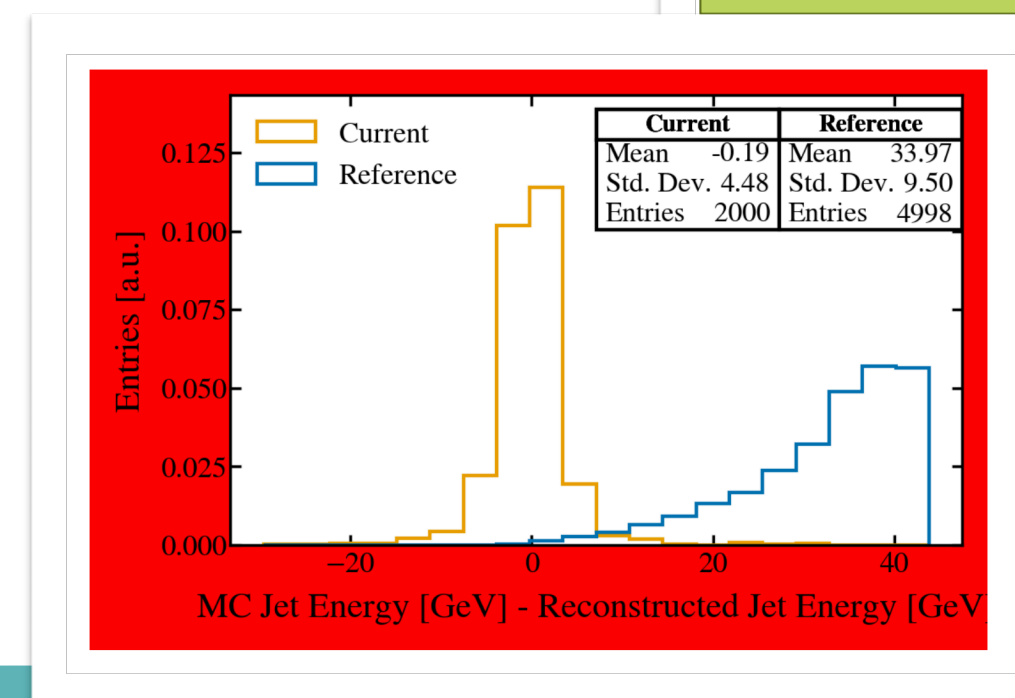
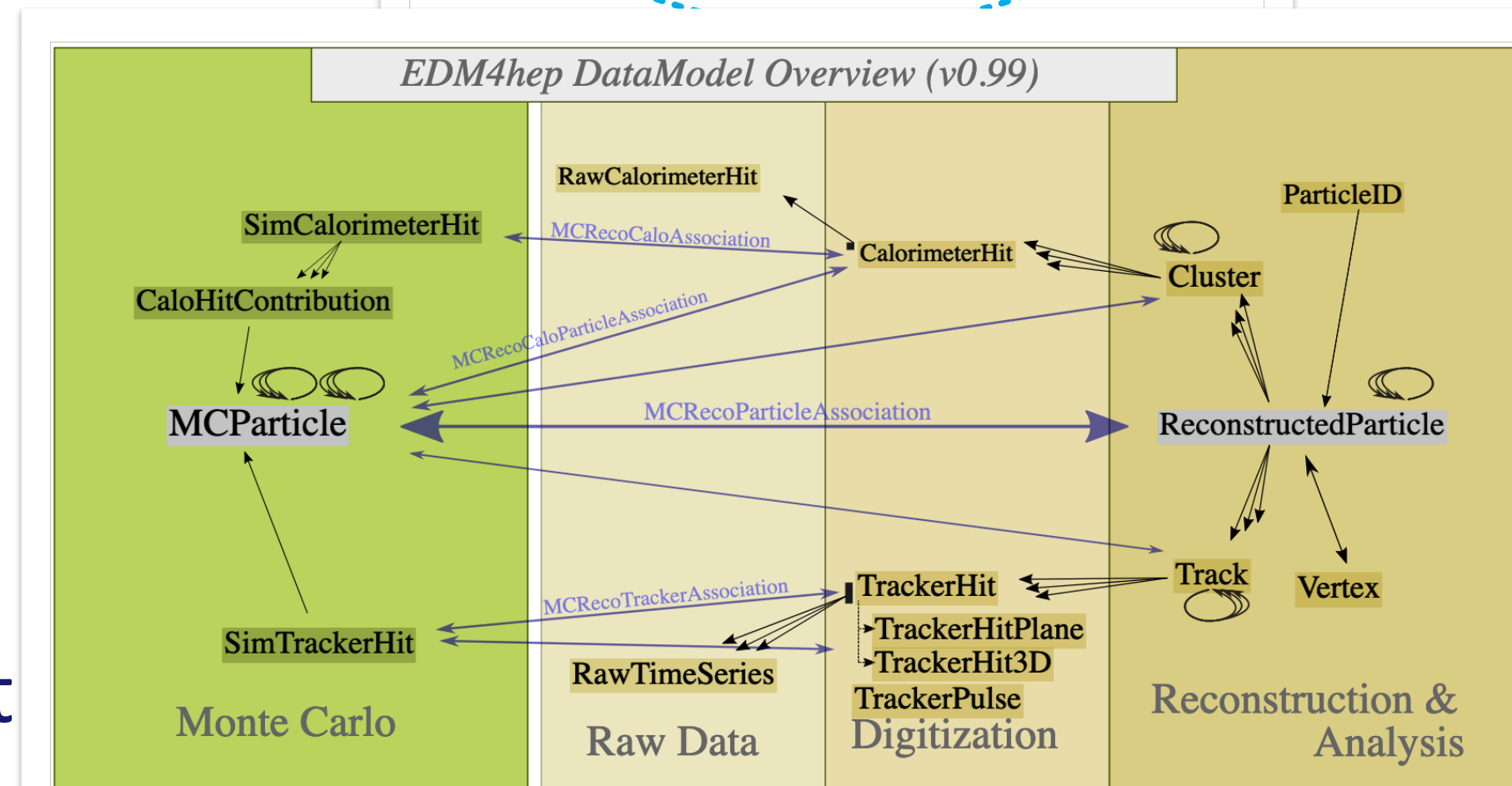
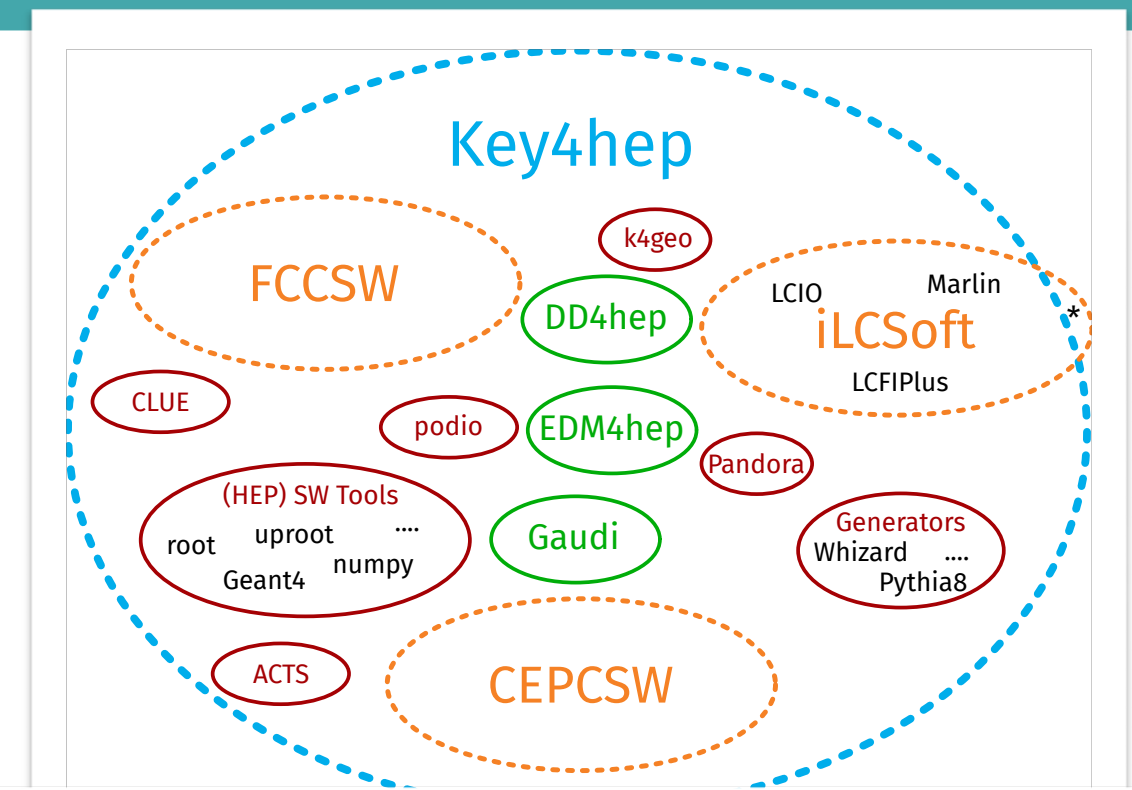
All milestones - with working prototypes - were achieved on time !

Well on track to achieve all deliverables - with final software toolkits - on time.

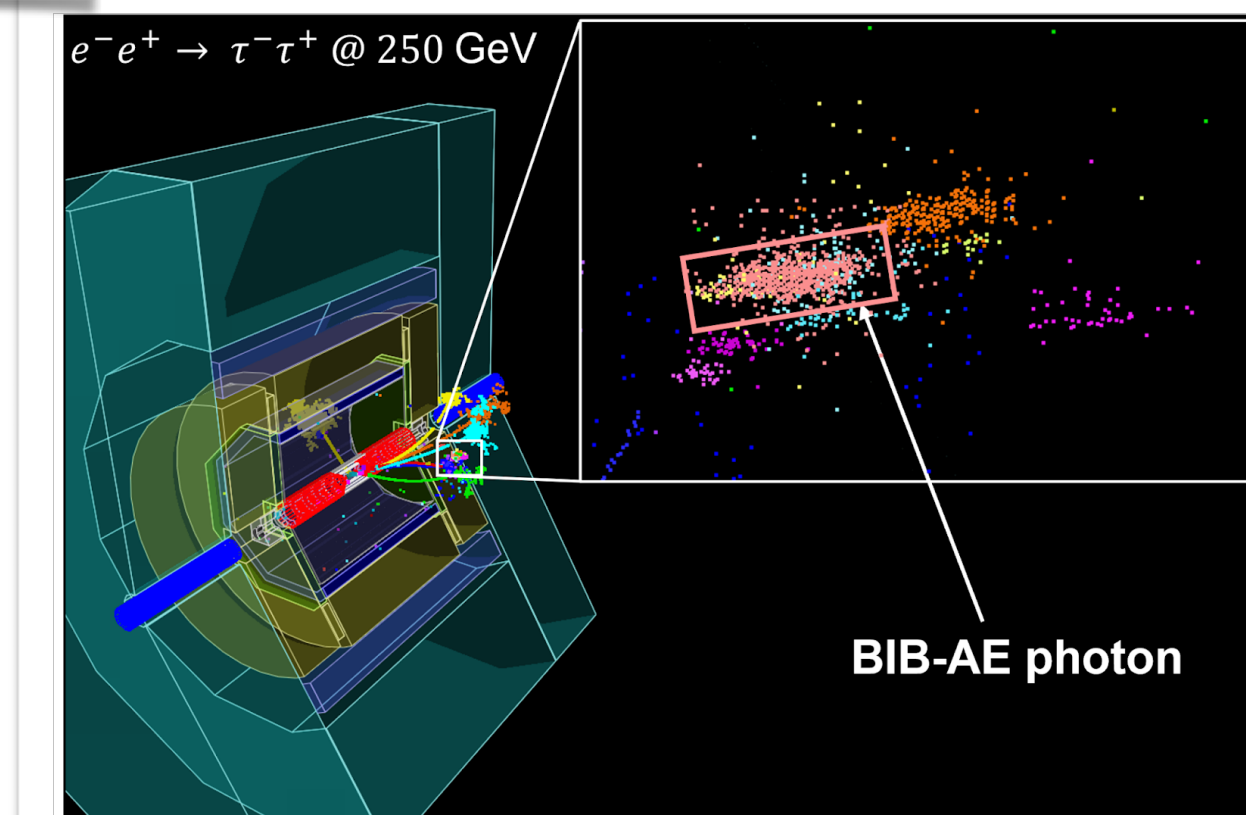
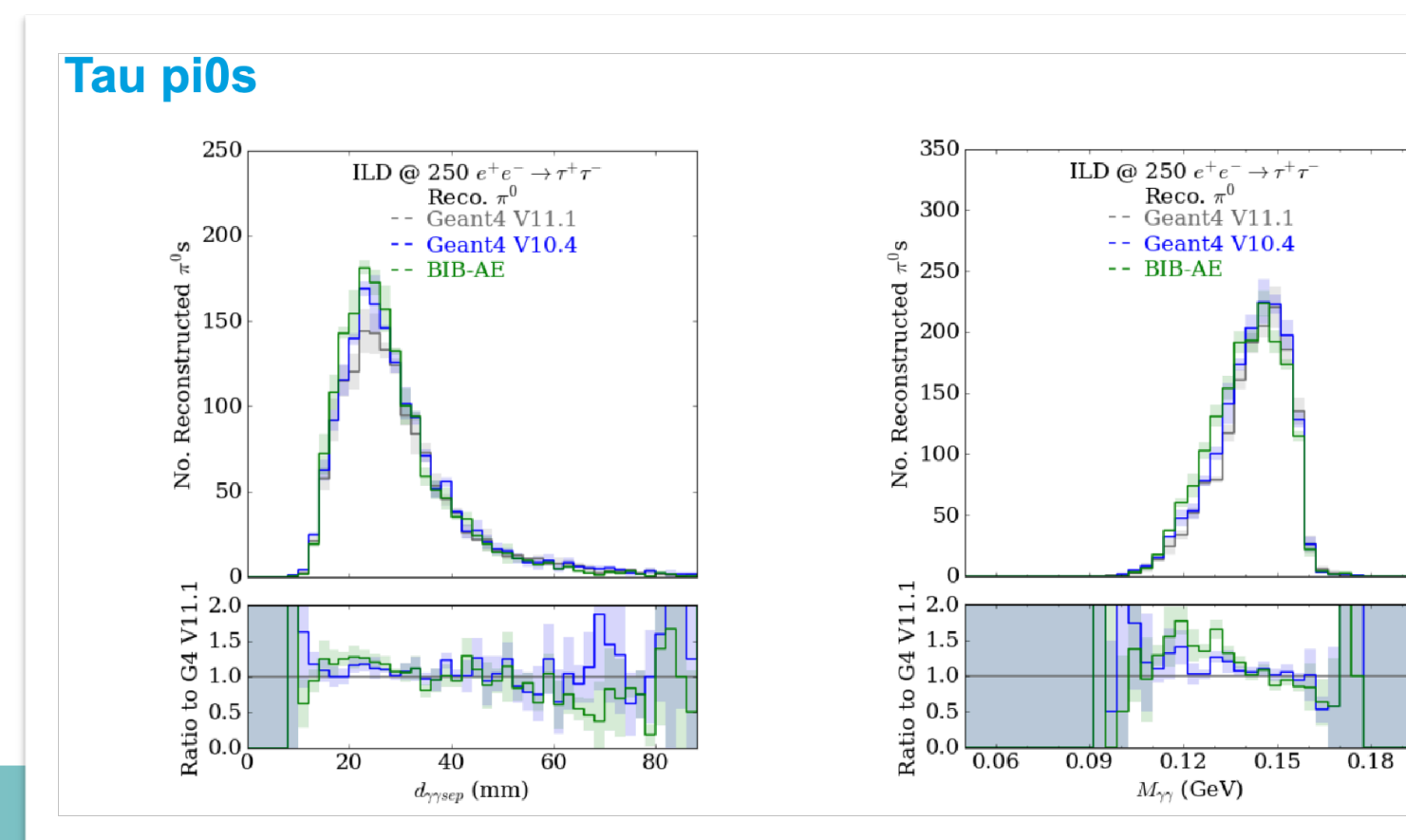
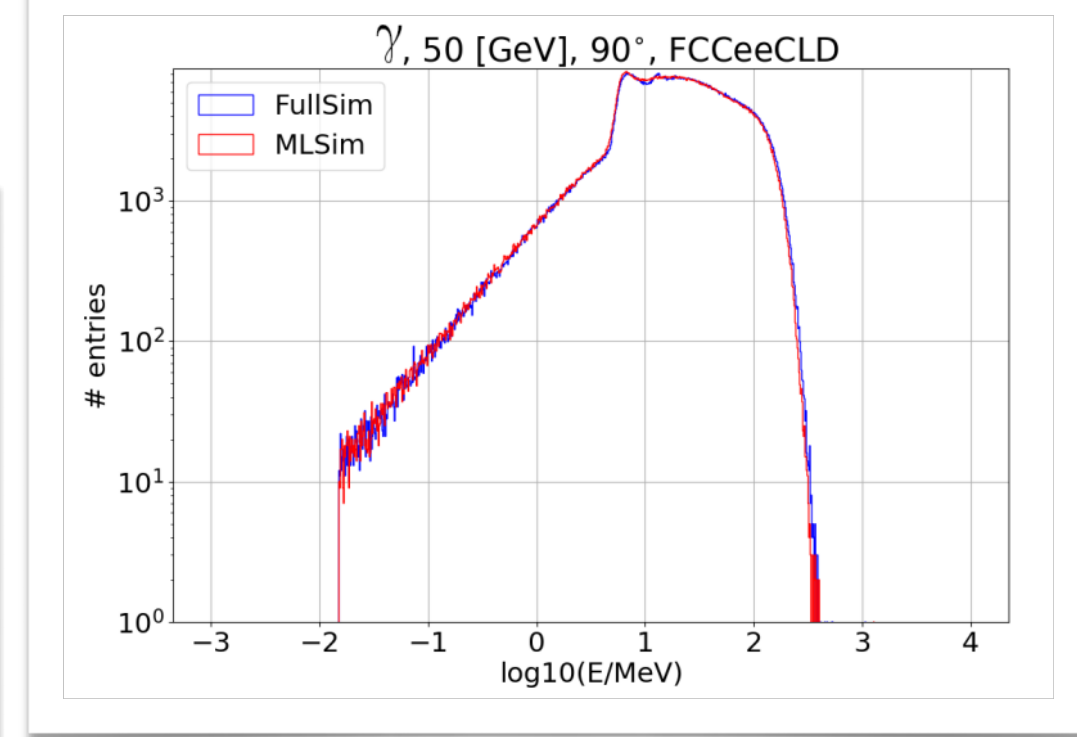
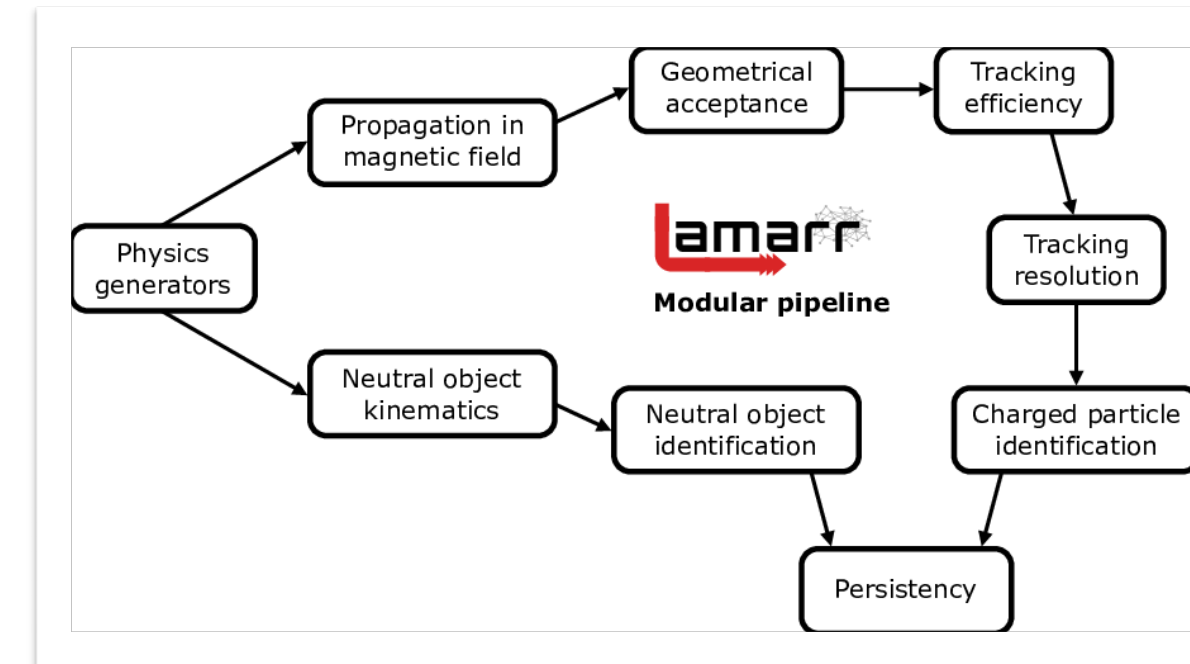
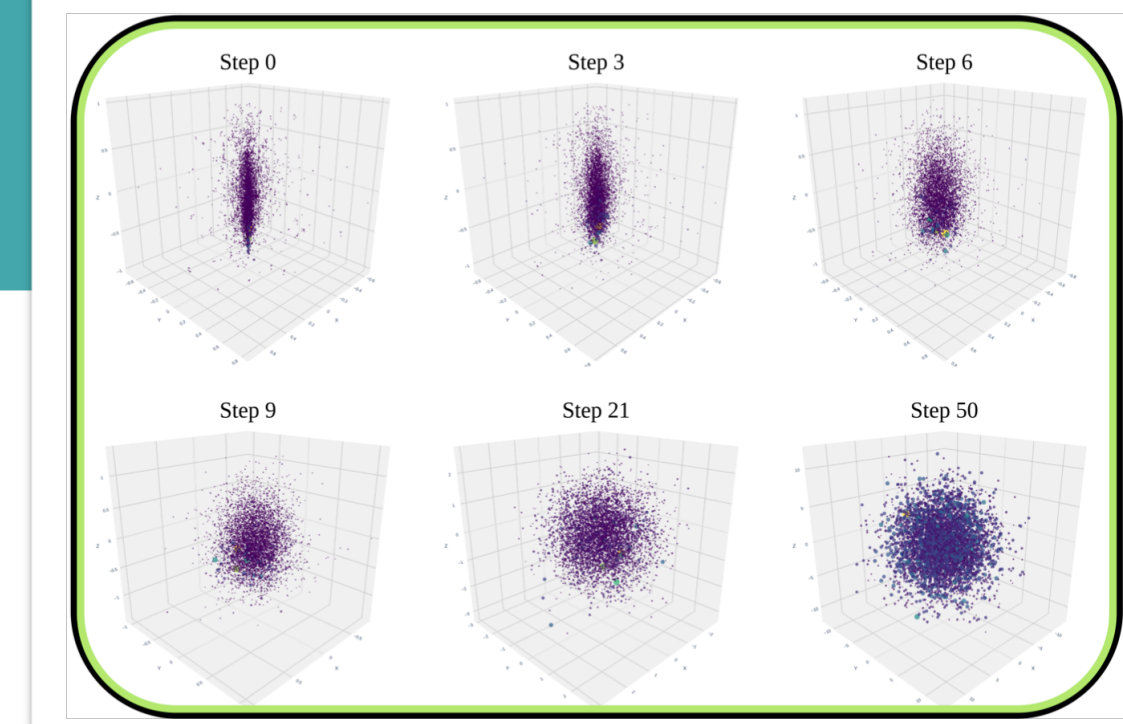
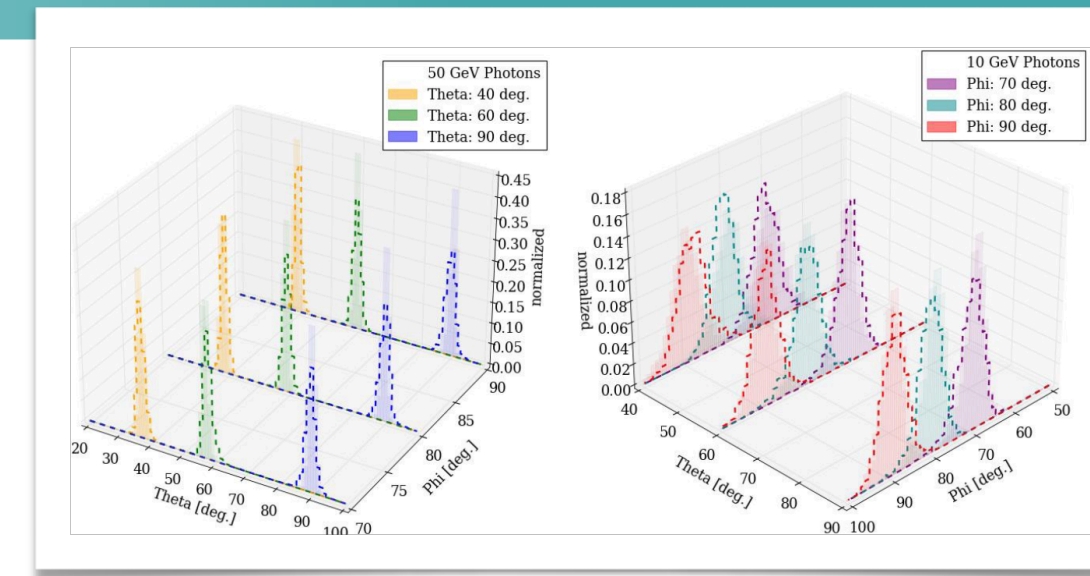
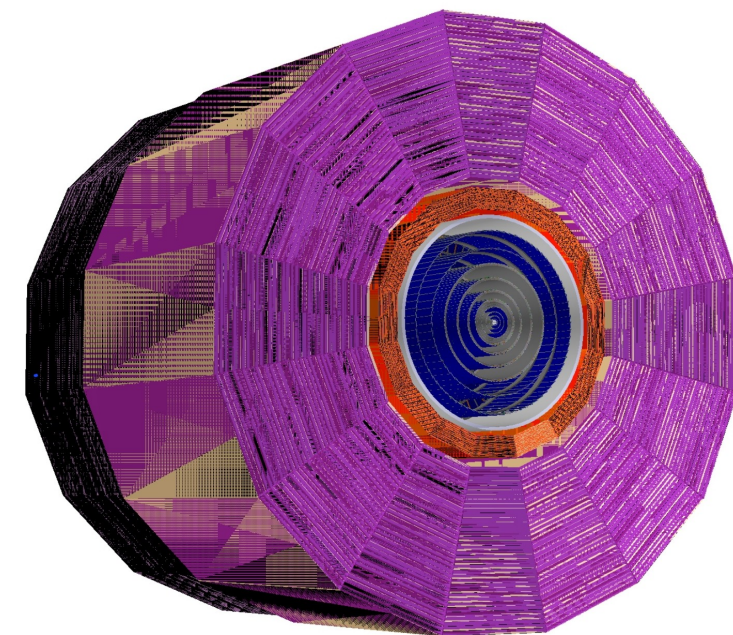
No concerns observed towards meeting this goal.

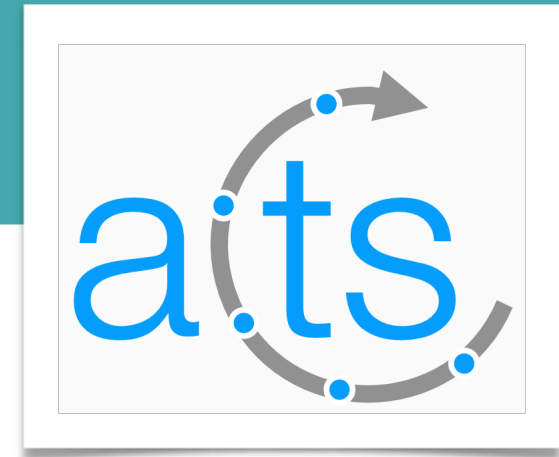
Deliverable	Title		Due Date
D12.1	Turnkey Software Stack (Key4hep)	Fully functional turnkey software stack (Key4hep) with simulation, track reconstruction and particle flow algorithms running for the linear colliders and the FCC , using the common event data model (EDM4hep), with documentation and examples	M46 (Jan 25)
D12.2	Fast shower simulation in Geant4	Fast shower simulation based on parameterisations and based on machine learning techniques fully integrated in Geant4, released with documentation and examples	M45 (Dec 24)
D12.3	ACTS tracking algorithms	Track reconstruction algorithms incorporated into ACTS, and fully documented , that manage the full tracking chain on CPU and non-CPU devices , with optional machine learning based algorithms available, also supporting MPGD detectors	M43 (Oct 24)
D12.4	PFA reconstruction	Improved and documented particle flow algorithms , including machine learning based algorithms , available in the PandoraPFA toolkit , suitable for detectors using new readout technology	M45 (Dec 24)

- Major progress in EDM4hep, e.g.
 - **Schema evolution**, RNTuple based backend, **Julia** code generation, new *Frame* based I/O
 - Event data Model finalised -> **v01-00 to be released soon**
- Prepared several **tutorials** for newcomers (CERN, DESY)
- Regular **software releases** and installations in cvmfs of complete software stack - using spack tool: ~500 packages !
- Key4hep is very actively used by **CEPC, CLIC, EIC, FCC and ILC**
- **Thread safety** via Gaudi functional
 - First native Key4hep reconstruction algorithms under development
ACTS tracking and PandoraPFA
- New **automated validation system**
 - **Nightly** checks of simulation and reconstruction

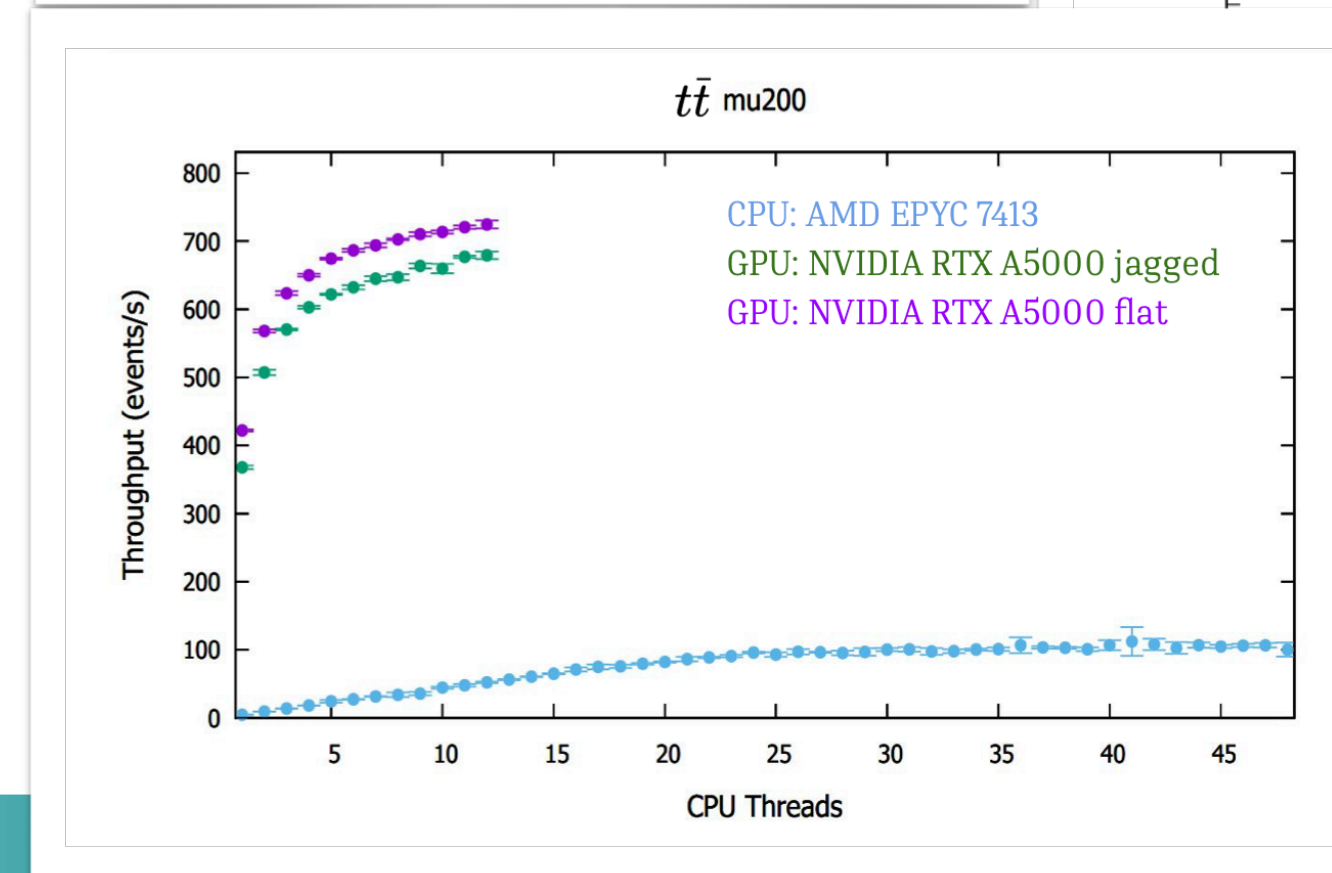
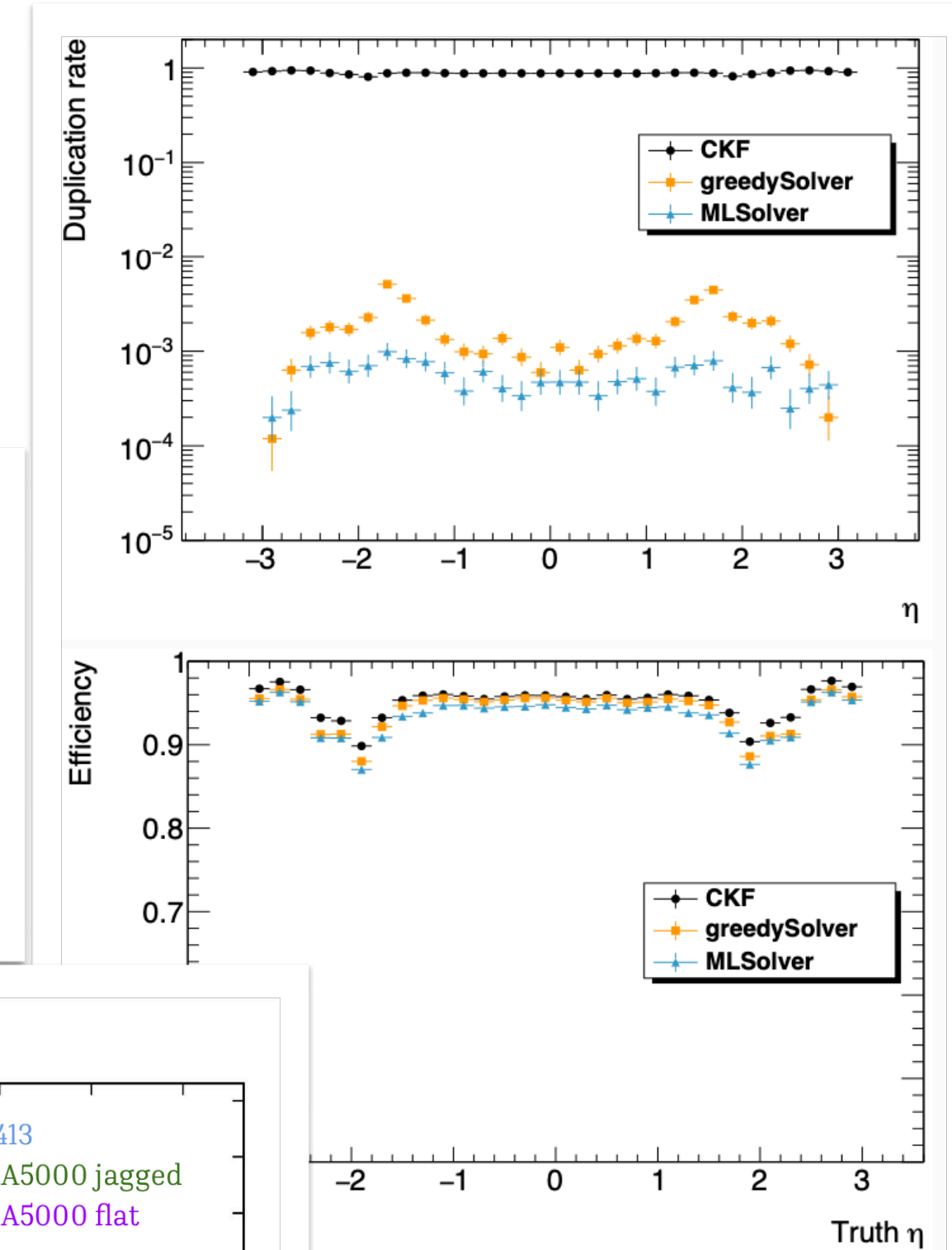
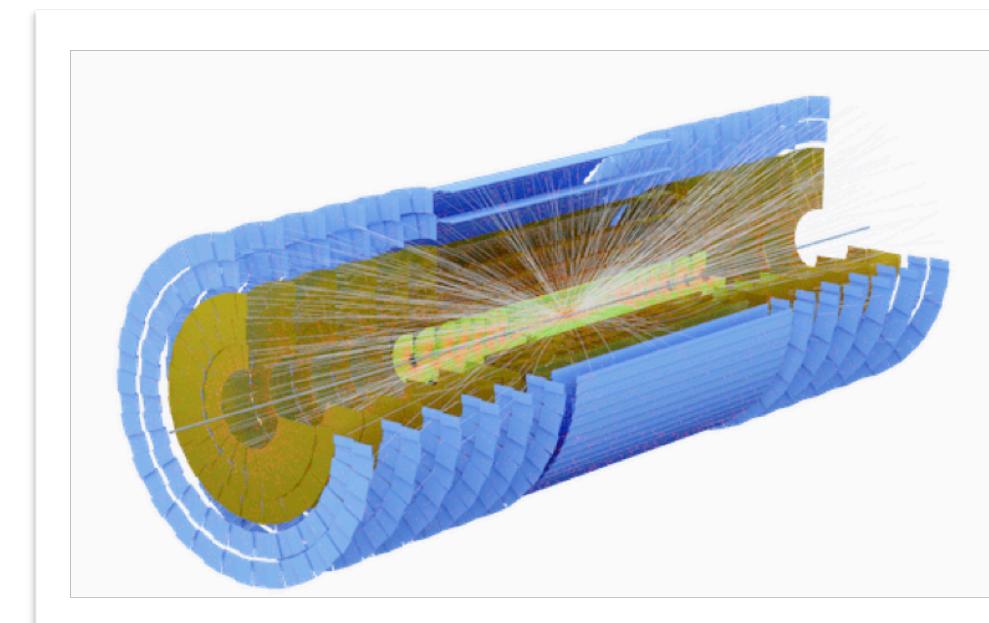
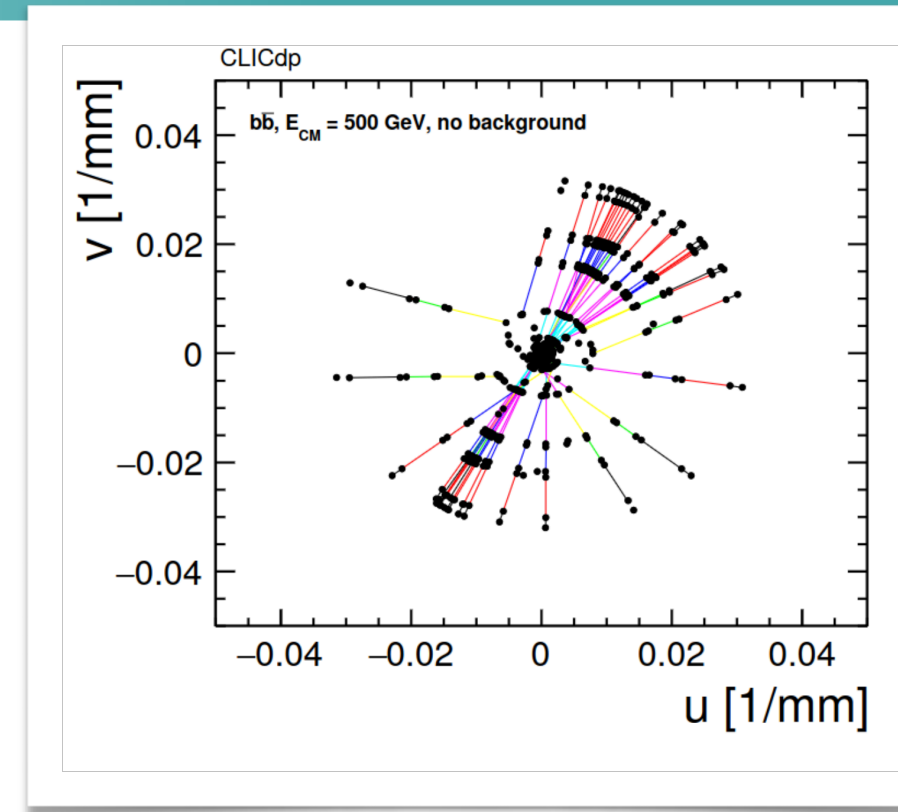


- Conditioned BIB-AE model on **two incident angles**
 - incl. application to physics events in ILD full sim
- Development of **ML fast sim library** for DD4hep
- New **diffusion models** for ILD and FCC
 - Point cloud and transformer based with high fidelity
- Conversion of *Lamarr* fast parameterised simulation tool (LHCb) to Key4hep
- Contribution to Open Detector
 - used for (ML) **fast sim validation**

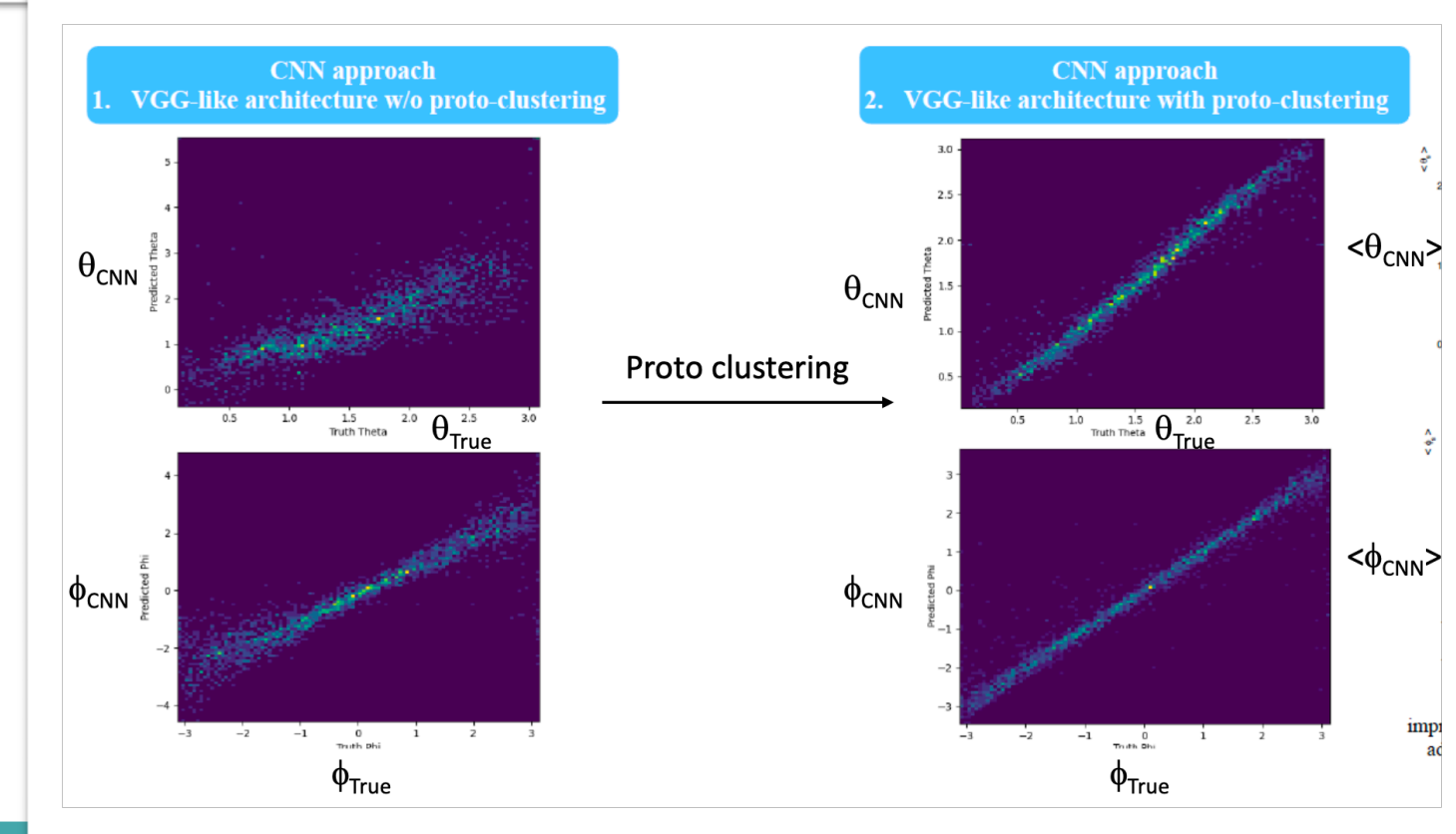
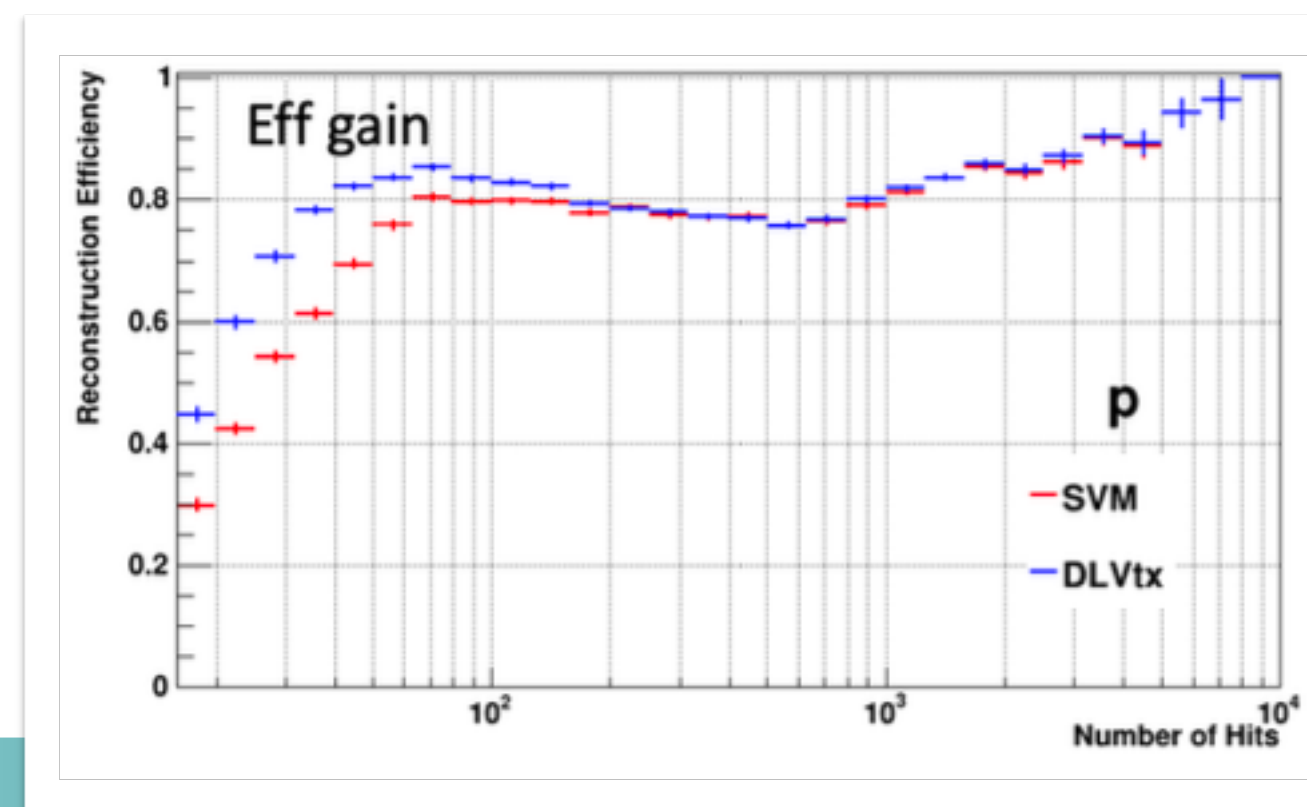
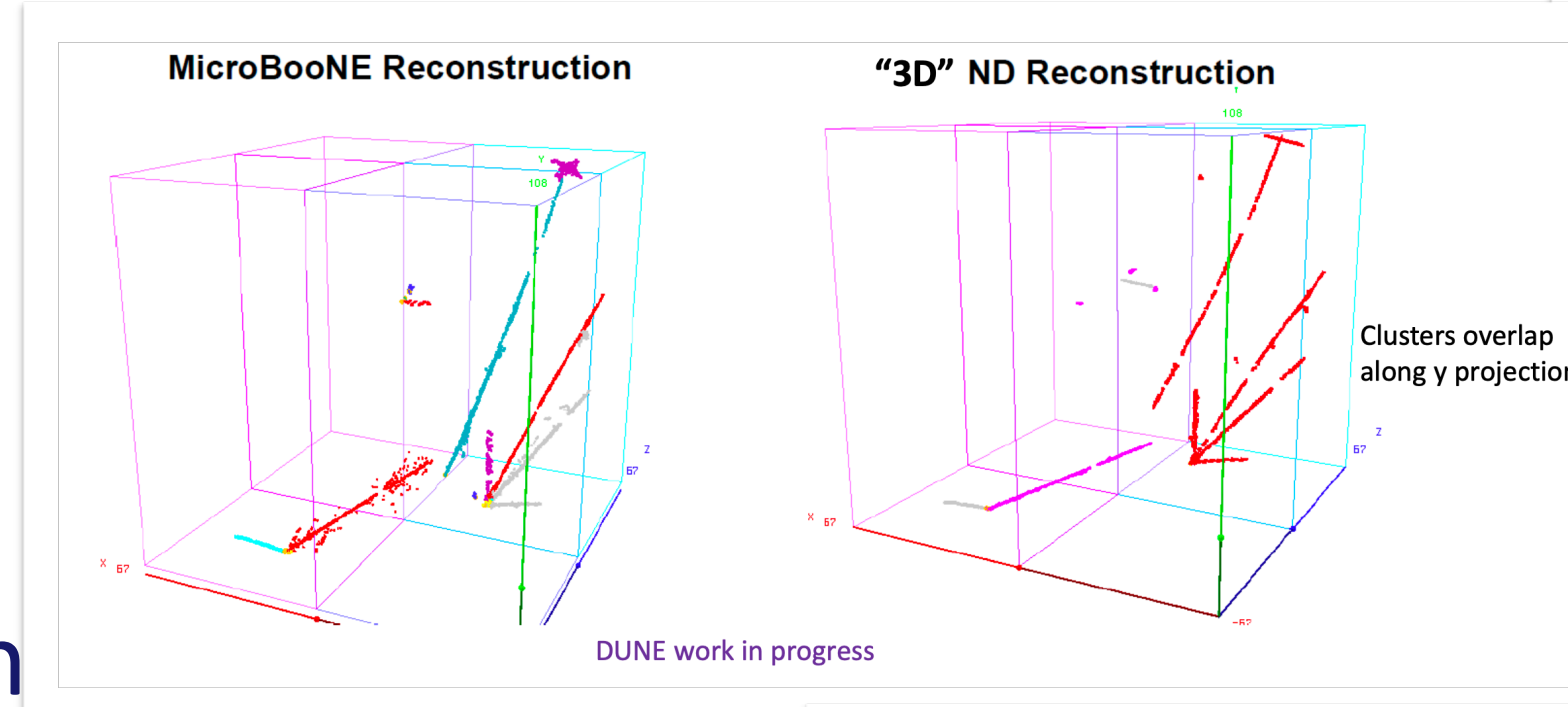
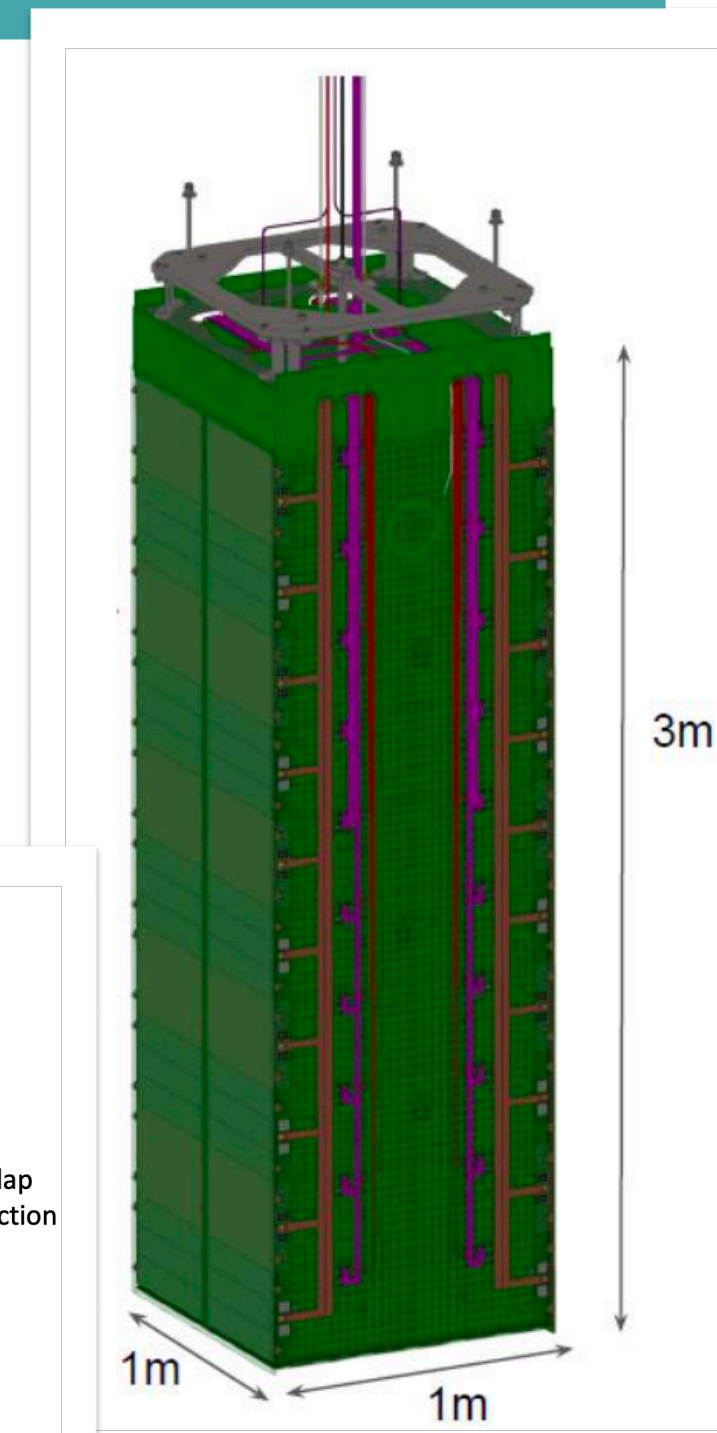
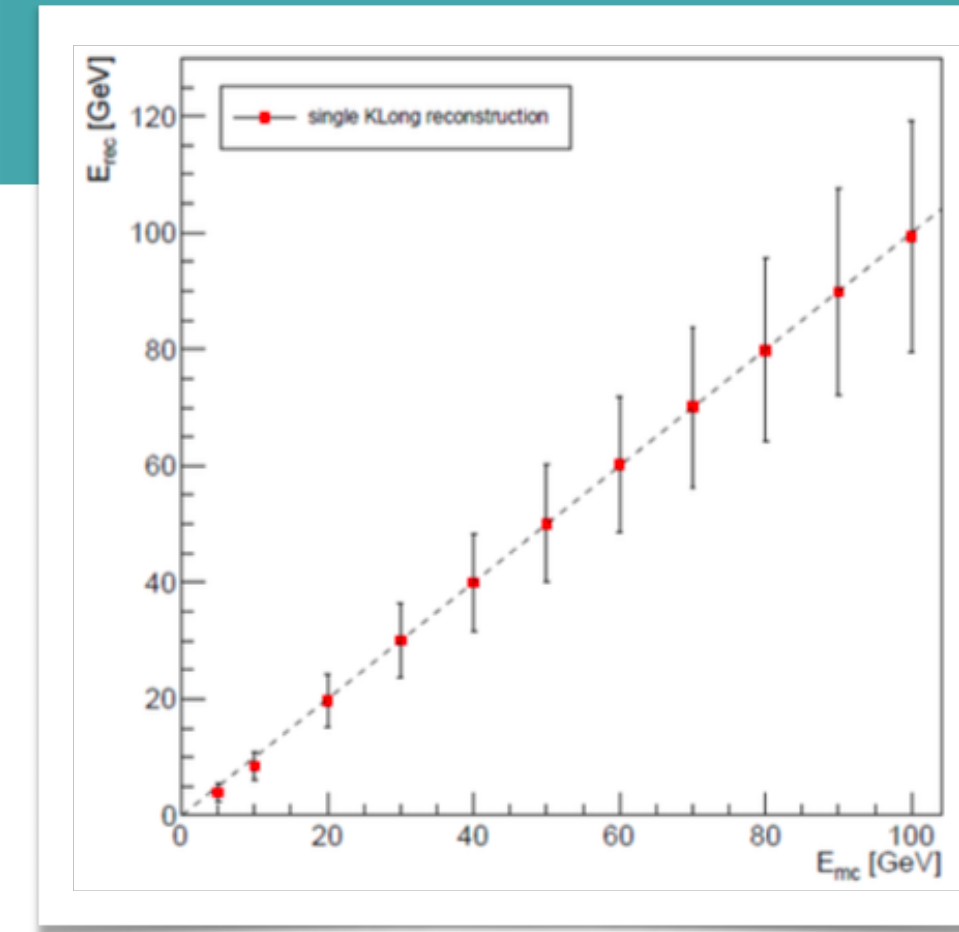




- **ACTS** now has a wide set of experiments either using or evaluating the toolkit: ATLAS, LDMX, ALICE, sPHENIX, FASER, ePIC, **CEPC**, STCF - **FCC** under development
- New global χ^2 fitter and **Gaussian Sum Filter** implemented
 - Important for best possible track fits for, e.g., electrons
- Public track EDM + **PODIO/EDM4hep support**
 - Links to EDM4hep changes allowing better description of TrackerHits
- Geometry support for GDML
- Improvements in **Open Data Detector** (work in conjunction with simulation team)
- **ML for ambiguity resolving and seed filtering** - prototype speeds up track fitting by $\sim 50\%$
- **GPU based track seeding** offers substantial speed-ups for high pileup events



- **APRIL-PFA**: developed new SDHCAL version in DDMarlinPandora
 - incl. correction for θ and ϕ to get Energy right
 - SDHCALContent **compatible with Pandora LCContent and APRILContent**
- Developed **PFA for Dune Near Detector (ND)**
 - combine 2d and 3d clustering techniques for ND
- Applied **DNN to vertexing** at Dune-ND
- Some Success in the application of **ML** to reconstruction **Dual-Readout Calorimeters**
 - Now re-scoping to improve final results by combining classical and ML ...



- Continued regular **zoom meetings of WP12**
 - roughly bi-monthly
- Dedicated sub-task meetings
 - e.g. tracking or fast simulation
- Held two more very productive **Hackathons** at AIDAinnova Annual Meetings in Valencia and Catania
- **Presentations** at international Conferences and Workshops
 - e.g. CHEP, ICHEP, IEEE, ACAT, LCWS, FCC-week,...
- **Publications** in peer-reviewed journals
 - e.g. EPJ, MLST, CSBS, MLST, JINST...



- WP12 is targeted at providing a **complete software stack** for future collider studies
- There has been **excellent progress** since the P1 review
- All **Milestones** have been **reached on time** and well on track to deliver the final deliverables on time
- Very **active development phase** with a strong focus on the integration of all prototypes and algorithms into the **Key4hep** stack
- The **future collider community** has full adopted the **Key4hep** stack as their development environment

