

# Physics Software & Computing

## US HFCC Level-2 Area

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(Level-2 Managers)

# Physics Software & Computing

Dual mandate for this group:

- Development of software and computing resources for Higgs Factories
- Increasing engagement of US physicists in Higgs Factories through training and documentation

Current focus: identifying interested people/groups; developing resources for new users; and understanding where the US can/should engage more in existing international PS&C efforts

See kickoff meeting for more details on some specific target areas, including:






- Physics SW
- Core SW
- Computing

# Parallel session agenda

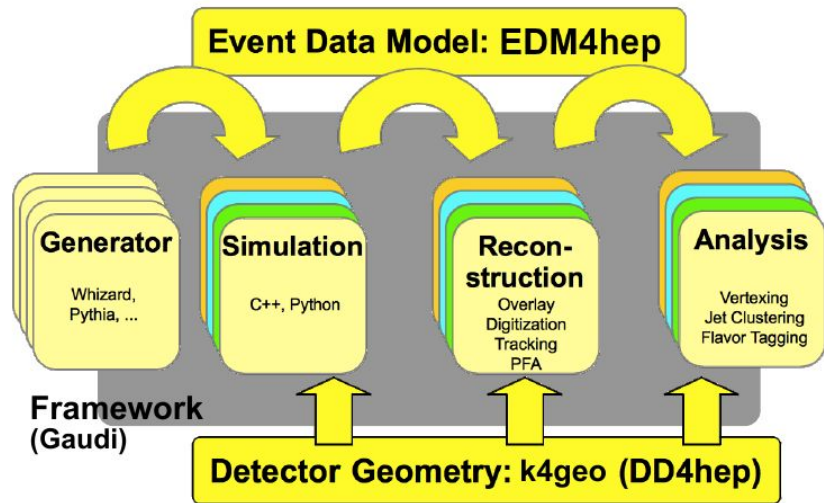
**10:45 AM** → 12:30 PM **Parallel: Physics Software & Computing** 53/2-2002 - Berryessa

Zoom room: <https://stanford.zoom.us/j/94300744053?pwd=ImDSE2uTaS2lt8yy3lUqmlqWFcq2uK.1>

**Conveners:** Lothar Bauerdick (FNAL), Mike Hance (UCSC)

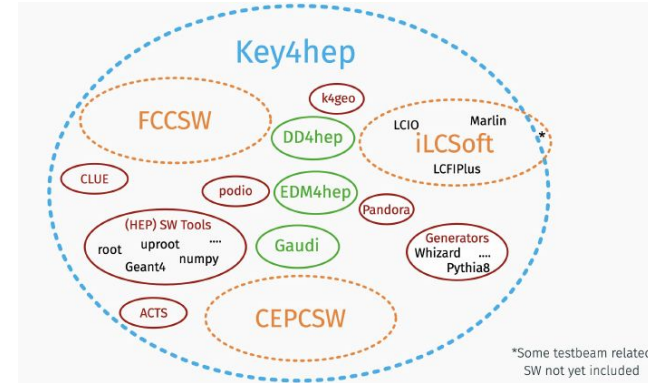
- 10:45 AM** **Introduction** 5m  
**Speakers:** Lothar Bauerdick (Fermilab), Michael Hance (UC Santa Cruz)  
 2024-12-19 SLAC P...
- 10:50 AM** **Key4HEP overview** 30m  
**Speaker:** Juan Miguel Carceller (CERN)  
 20241219-key4hep...
- 11:25 AM** **MC Generators for Higgs Factory studies** 20m  
**Speakers:** Prof. Saptaparna Bhattacharya (SMU), Saptaparna Bhattacharya (Northwestern University)  
 FCCee\_Generators...
- 11:50 AM** **Core Software, from LHC to Higgs Factories** 20m  
**Speaker:** Vakho Tsulaia (LBNL)  
 CoreSW4HiggsFact...
- 12:10 PM** **Analysis Software in Key4HEP and beyond** 20m  
**Speaker:** David Lange (Princeton)  
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- **Turnkey software for future colliders**
- **Share components** to reduce maintenance and development cost and allow everyone to benefit from its improvements
- **Complete data processing framework** from generation to data analysis
- Community with people from **many future experiments**: FCC, ILC, CLIC, CEPC, EIC, Muon Collider, etc.
- Open [biweekly](#) meetings



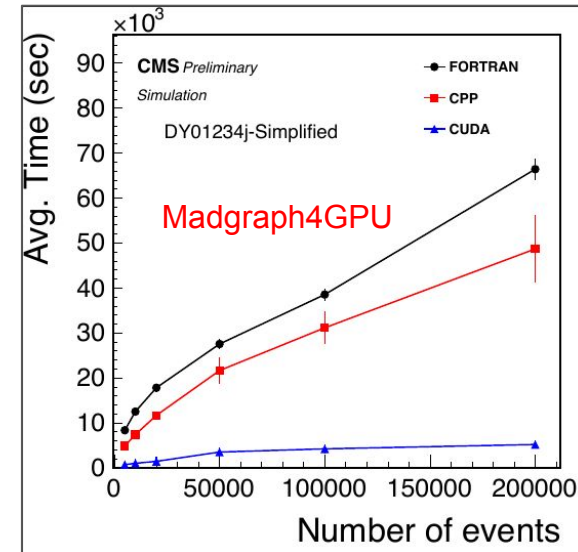
# Key4Hep

- Significant progress in past ~year within Key4Hep:
  - Stabilizing interfaces, data model (EDM4hep)
  - Wrappers for event generators
  - Improved tools for detector modeling
  - Increased buy-in from EIC, CEPC, Muon Collider
- Still significant work to be done, especially in areas of US strength:
  - Core SW: Gaudi framework; multithreading/MPI support
  - Reconstruction software, especially for FCC-ee: ACTS integration
  - Analysis SW: python ecosystem



# Generators for Higgs Factories

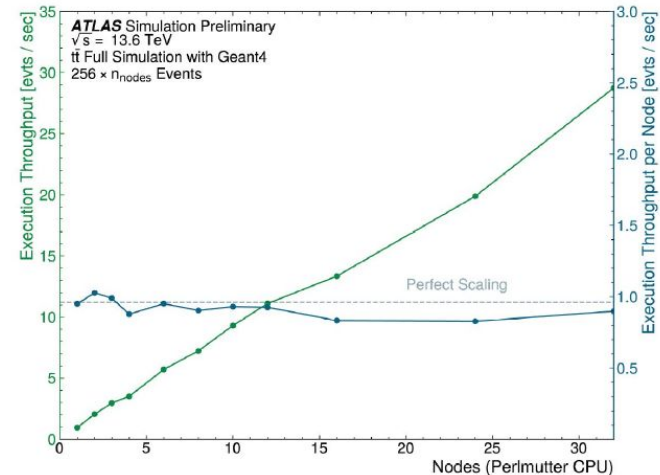
- Requirements for physics event modeling at Higgs Factory:
  - Precise computation of  $\alpha_s$
  - NnLO and NnLL resummation
  - High-precision electron PDFs (collinear/soft photon emissions)
  - To fully exploit Tera-Z program at FCC-ee, need:
    - At least NNLO EWK needed for almost all computations
    - For Bhabha scattering: N<sup>3</sup>LO for luminosity
- Tour of Event Generators
  - Pythia, Herwig
  - Sherpa (now with parallelization [PEPPER])
  - MadGraph (now with GPU support for matrix element [Madgraph4GPU])
  - Whizard, BabaYaga
  - parton-level calculators



# Core SW from LHC to Higgs Factories

Key4Hep uses Gaudi event processing framework, like ATLAS and LHCb

- Some evolution of Gaudi has brought substantial new features:
  - Multithreading support: GaudiMT
  - Soon “Heterogenous Gaudi” for CPU+GPU jobs (“Asynchronous Algorithms”)
- Experiments add a lot of functionality in layers on top of Gaudi that would need effort to move into Key4Hep
  - e.g. MPI support; full utilization of multithreading support; many others
- Significant US expertise in core SW that will have broad impact on Higgs Factory simulation, digitization, reconstruction



# Analysis Software

- [Existing FCCAnalysis tools](#) are based on ROOT's `RDataFrame` (python steering with C++ routines for on-the-fly calculations)
- US (IRIS-HEP, FNAL) has led development of “python ecosystem” tools for LHC physics analysis
  - Increasingly popular with LHC users, Compatible with existing analysis facilities at FNAL, UChicago, others
- [HSF-India project](#) to add support (schema) for EDM4hep in coffea (Prayag Yadav, Hyderabad)

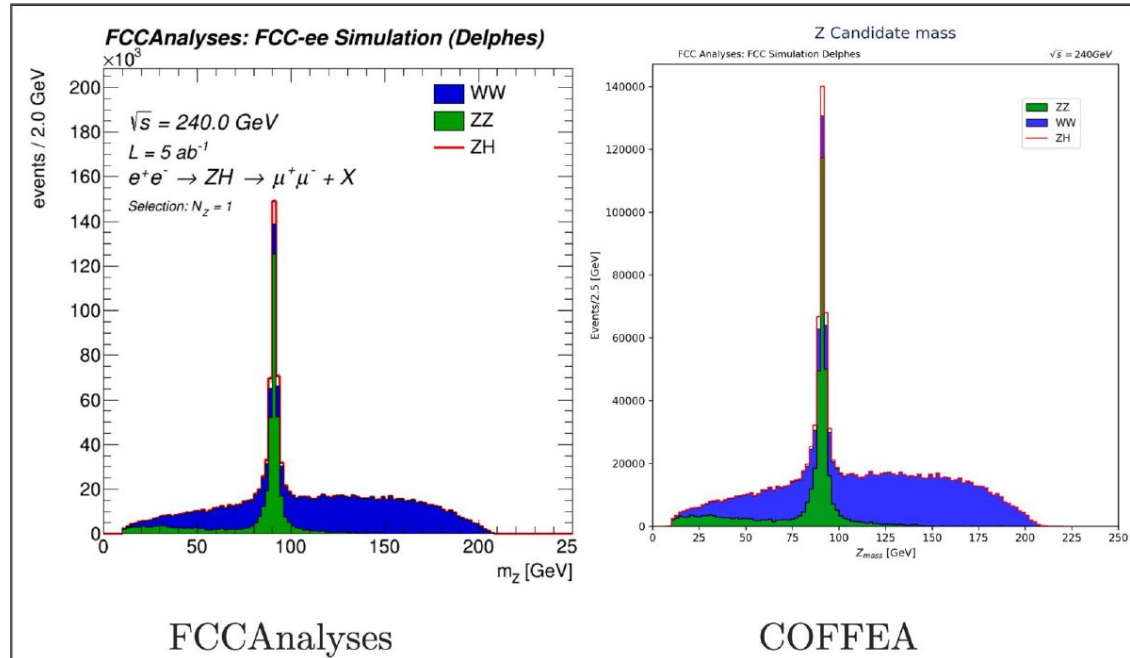


- **Uproot** to read and write root files.
- **Awkward Array** to manipulate HEP data in a numpythonic way.
- **Dask** to for scaling-out
- **Hist** for histogramming
- **MPLHEP** for plotting
- **Numba** for just-in-time compilation
- and other useful packages ...



# Analysis Software

- New schema works well, and has competitive (possibly better) performance than `RDataFrame`-based analysis tools



# Computing Resources

From shared AIM/TDAQ/PS&C parallel session, as well as plenary session on simulation, it is clear there is a need for computing resources that US users can access for detector design/optimization studies.

- CPU and GPU for compute, shared/globally accessible storage for collaborative efforts

Short-term plans:

- PS&C will request time on HPCs (e.g. Perlmutter) for HFCC work
- Some institutional clusters exist and may be useful for specific tasks
- “Analysis Facility” model at LHC has been extremely successful, consider investing in a shared facility for US HFCC users

# Physics Support

Clear demand for documentation and training resources:

- Reduce the barrier to entry for simulation, analysis studies
- Expand/strengthen community of FCC analyzers in the US

Together with some “strategic” investments to provide shared storage/data access and open up access to opportunistic computing resources (HPC, OSG/Path), investing some dedicated effort in this area would likely have the largest impact to enable the US community to grow participation in HF

We will soon have a funding proposal, following up on our request at Stony Brook

# Proposed Workshop / Training in March at Princeton

“Software & Computing: From LHC to Future Colliders”, (co-) sponsored by IRIS-HEP

Details to be discussed; possible goals for questions to answer:

- Needs:

- US community needs in terms of software and computing for Future Collider studies

- Resources:

- Are there opportunities for the future collider effort to align with and/or leverage existing S&C projects (HEP-CCE, IRIS-HEP, etc.)?

- What similar collaborations are possible with CERN and other international efforts?

- Near term goals:

- What concrete things could be accomplished over the next 12 months?

- An associated training event could cover modern software tools, Key4Hep, etc.