Physics Software and Computing
Initial Plans for the US HFCC Level-2 Area

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Charge & Scope to the HFCC-PSC L2 working group

- Charge Item 4 to HFCC:
  - "Conceptualization of the software and computing framework that will be needed to advance physics studies and R&D efforts; and to collect, store, and analyze the large volumes of physics data at future collider experiments"
- Charge Item 6:
  - “**Ensure collaborations** by the U.S. with our partners are cost-effectively carried out to advance the future Higgs factory initiatives. (CPAD, ECFA, DRD, others)”
  - Should now add newly forming APS/DPF “Coordinating Panel for Software and Computing”

- Also, importantly,
  - provide infrastructure and computing resources in support of physics studies and R&D
  - provide software, computing, and user support to enable the US community to participate in and provide leadership to the future collider efforts

Addressing HFCC Priorities (RitchieP at ECFA)

Engage the **U.S. Community**

- US groups traditionally have deep expertise and a broad interest in S&C
- S&C is an enabling technology and key to achieve international leadership in data analysis / physics studies and detector simulation / reconstruction
- US agencies provide significant support for HEP S&C infrastructure, and the US Future Collider community should be put in a position to fully profit from and contribute to this ecosystem

Engage the **External Partners**

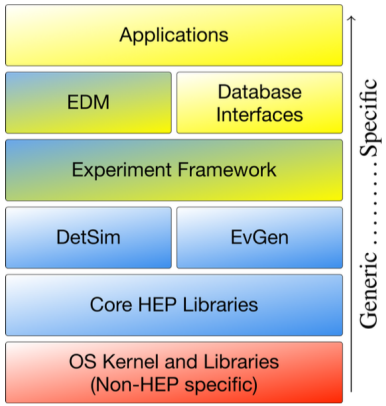
- PSC just started to interact with the larger international organizations, including the S&C coordinators of FCC and ILC, as well as PED leadership
- We also are starting to engage with the US computing ecosystem

Coordinate and Plan

- This requires some reasonable budget, at least at the level of seed funding
- Our approach aims to maximize leveraging existing expertise, efforts, and resources, to both provide some S&C support infrastructure and to start contributing to S&C deliverables, including core computing, access to resources, coordinating R&D and engineering efforts, etc

Requirements on Software and Computing Systems

Provide future experiments with a ready-to-use software ecosystem supporting all required workflows



source: 10.1051/epjconf/202024510002

- Allow for quick estimations, but also detailed performance studies
- Aid in detector design and optimization
- Support interoperability among the tools
- Allow different usage modes
  - Local running of Analysis, Simulation, Reconstruction, ...
  - Bulk processing / large productions
- Encourage developments and their quick distribution

These are well understood in HEP!

J.Smieško at ECFA w/s

Key4hep provides a “coherent set of packages, tools, and standards for different collider concepts” (including FCC, CLIC/ILC, MuC, EIC, and others)

Main ingredients across the HF and the broader HEP S&C ecosystem

- **Event data model**: EDM4hep, based on PODIO, AIDA project; “... is becoming mature”
- **Event processing framework**: Gaudi, used in LHCb, ATLAS, …, ILCDirac, ana4hep, …
- **Detector description**: DD4hep used in CMS,... AIDA project
- **Build system**, test, deploy, CI etc: Spack, suggested by HSF + CVMFS, experience throughout HEP

Essential Areas in S&C requiring engagement and support

Event Generators: Most generators are packaged in Key4hep, some tools exist

Simulation: Transition from parameterized (Delphes) to full simulation (Geant4)

Reconstruction: inclusion of leading-edge/modern algorithms → req. on f/w!

Analysis: initial analysis framework in Key4hep, interest in the Python ecosystem

Visualization: detector geometry visualization exists, moving to web-based event

Computing resources: interest in access to US facilities, data hosting needs, etc

User/Physics Support: including tutorials, documentation, etc

The U.S. is an International Leader in HEP S&C

US LHS operations programs play significant roles in designing, implementing, and operating software and computing systems across all areas of LHC experiments, including:

- Computing: data access/movement/storage; Tier-1/2/3 computing facilities; development of new platforms (e.g. HPC's, HW accelerators) for LHC workflows
- Software: core and detector-specific SW; IO and event data models; analysis tools
- Physics: generator development; detector simulation/digitization

US-ATLAS and US-CMS support S&C teams from 24 (ATLAS) + 19 (CMS) universities, and all DOE national labs working on the LHC, totaling 55+65 FTE's of funded effort, along with significant additional scientific effort from students, postdocs, and senior scientists.

Similarly, Belle, Rubin, LIGO, IceCube, Dune and other large US-hosted international science projects have significant S&C expertise and successfully support very large HEP user communities.

Innovation and US Technical Leadership In HEP S&C

The US has been a driver for innovations in HEP computing, certainly for the LHC and now the HL-LHC, but also in Astro-Particles (e.g. Rubin) and other areas.

Many US institutions are leaders and have significant expertise in leading-edge physics software and computing, in ML/AI application to physics software, in core software and computing infrastructure innovation, in algorithms like particle tracking, calorimeter clustering, simulation, as well as software architecture and libraries.

Together with Computational HEP projects like HEP-CCE and the IRIS-HEP Software Institute, the Open Science Grid, ESnet, projects like HTCondor, Globus and others, university and national lab's Tier-1 and Tier-2 computing centers and HPC providers, the US has a rich computing ecosystem and is very well connected with the international community, including the WLCG and CERN.

DPF is just starting a Coordinating Panel for Software and Computing, similar to CPAD

Vision/Strategy

Global efforts on PS&C for Higgs factories are coordinated separately by individual facilities (e.g. ILC and FCC), but with significant collaboration across facilities in some areas

- Software has been **consolidated in Key4HEP**, which provides a framework for simulation/digitization/reconstruction of MC samples for future Higgs Factories. This provides a coherent framework for all future collider software.
- But it will require **additional technical strength**, improvements in **usability**, and technical **innovations**, like those developed e.g. for the HL-LHC, to support the leading edge physics algorithms
- Computing is less well coordinated. Facilities are leveraging opportunistic resources for MC campaigns, and in some cases trying to identify **additional resources** to grow MC samples in the future. The US can make a big impact here.

Core Software Areas with Potential Large US Impact

- Framework software and related work is a US HEP core competency
  - Developing a concrete plan to kick-start US efforts in core software (“low-hanging fruit”)
  - Bring Gaudi and detector modeling experts into Key4HEP to improve performance and full-sim detector models – also, a LDRD proposal at Fermilab

- Work with our partners: CCE, IRIS-HEP, OSG, HPCs, etc
  - Define some key deliverables that are aligned with e.g. HL-LHC, Dune, etc
  - E.g. integration of the modern sim/reco algorithms require modernization of core software and software libraries, use of accelerators (GPUs, FPGAs), also s/w infrastructure

- Encourage outside proposals
  - LDRDs, ECAs, technology-focused FOAs, etc – already started at some labs and universities, to be discussed if it can be expanded

Analysis and Detector (sim, reco) Software

- We are collecting from the detector working groups concrete needs and ideas for getting credible efforts started
  - We note that the threshold for engagement with the existing tools is relatively high
  - Existing tutorials for users to generate/analyze data from Key4HEP stack are sometimes out of date, and somewhat too technical to enable easy entry into detailed physics and detector studies.
  - Need to improve the situation here, and let users familiar with LHC analysis transition easily into similar studies for Higgs Factories → e.g. Python data ecosystem a la Coffea, etc

- Detector Modeling
  - Work with L2 detector areas to support implementation of full-sim detector models
  - Can build on existing expertise in DD4hep detector geometry (but would need to find the effort)

Computing Resources, Analysis Support, etc

- Identify analysis computing resources for users where they can get training, easily start, and then scale up data analyses and physics studies
  - The Future Collider community should be enabled to profit from the emerging and growing Analysis Facility efforts e.g. in the LHC infrastructure and at the labs
  - We are developing ideas how we can organize user support and training

- Identify and bring grid US computing resources to facilities for MC production (in particular with the start of Full simulation) – requires work on job entry and provisioning of opportunistic resource, including OSG, HPCs etc
  - We are developing a plan for incremental resource procurements (in particular storage and data access infrastructure) at existing HEP installations, that can be managed “at the margin”, for use of US future collider community
  - Preparing an off-cycle ERCAP request for HPC resources (Perlmutter)

Strawman Budget Request

This strawman is a result of discussions and input from major stake holders

Next step is really to get more input from the US community at large

Project	Area	Institution	Person	FTE	M&S	Travel	Total
Gaudi for Key4HEP	Core SW	LBNL	Leggett/Tsulaia	0.2	$0		$100
Computing and Analysis Support	Core SW + Analysis SW	FNAL	T.B.D.	0.2	$0		$100
Computing resources, storage+processing	Computing	T.B.D.		0	$50		$50
User analysis tools	Analysis SW	Princeton	postdoc	0.5	$0		$50
Workshops, training events	Physics+Modeling	University (TBD)		0	$0	$50	$50
						Total	$350

SLAC Meeting

Discussion points for PS&C:

- Will have some speakers working on detector simulation to better understand bottlenecks and where we need to do more
- Discussion with e.g. AIM about how to engage more in full-detector optimization studies
- Talk on MC generators for Higgs Factories
- Possible tutorial, to be discussed