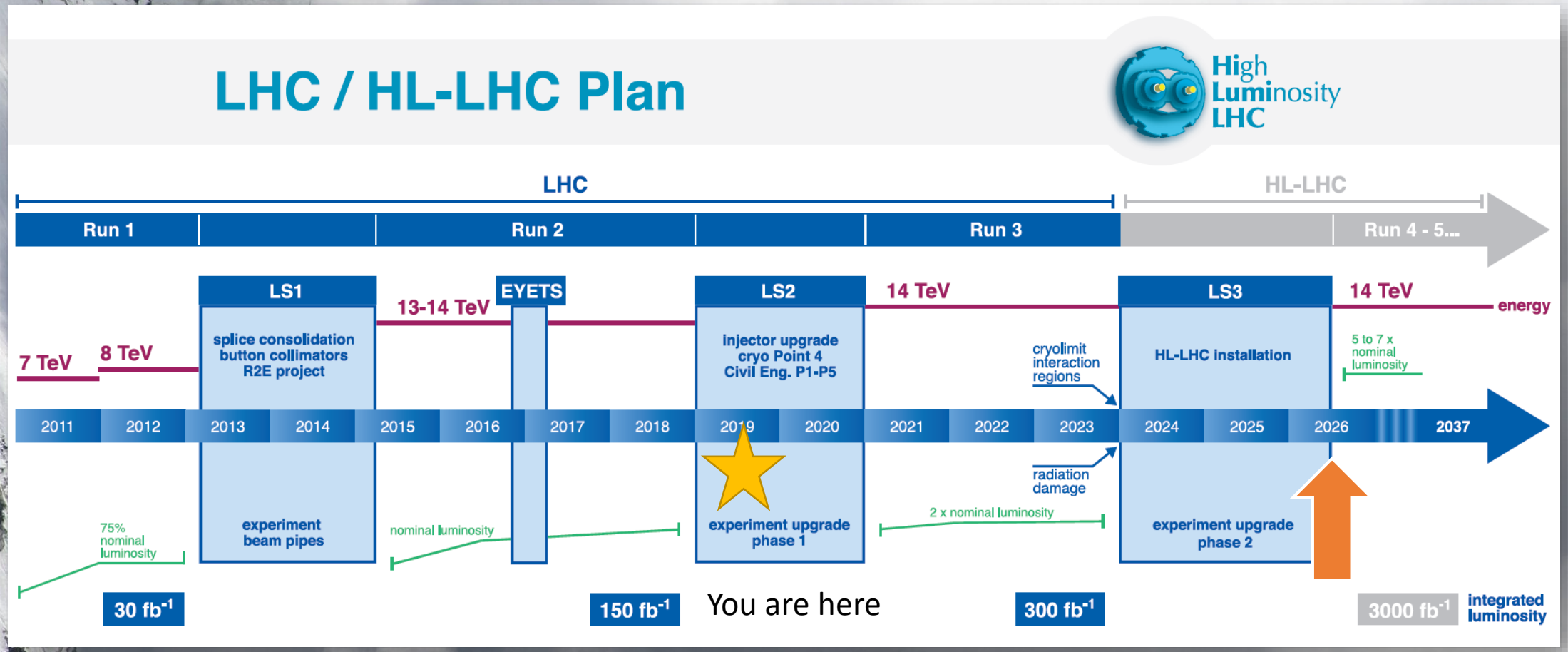
Beyond the Roadmap: HL-LHC HEP Software

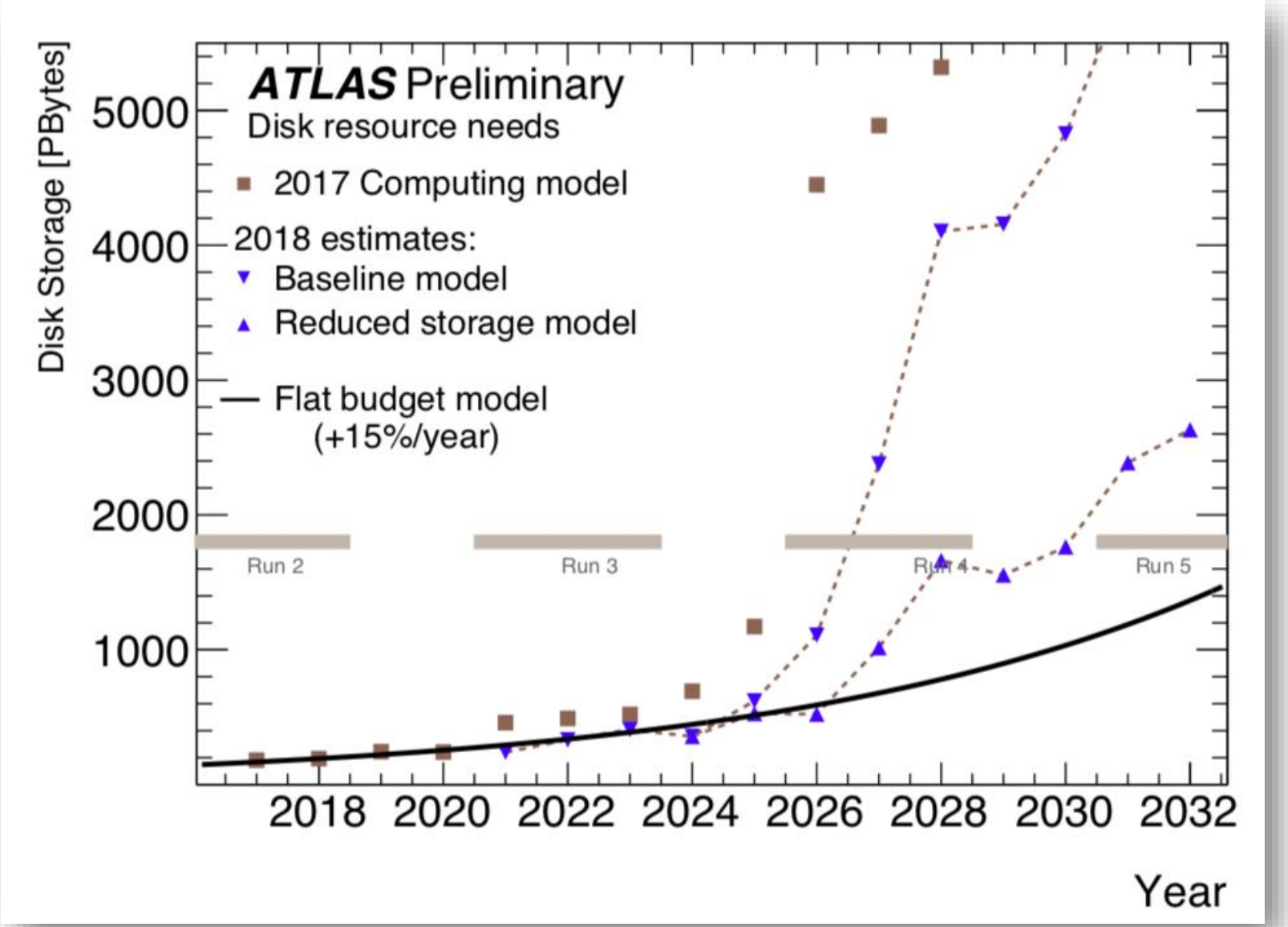
G. Watts (UW/Seattle)

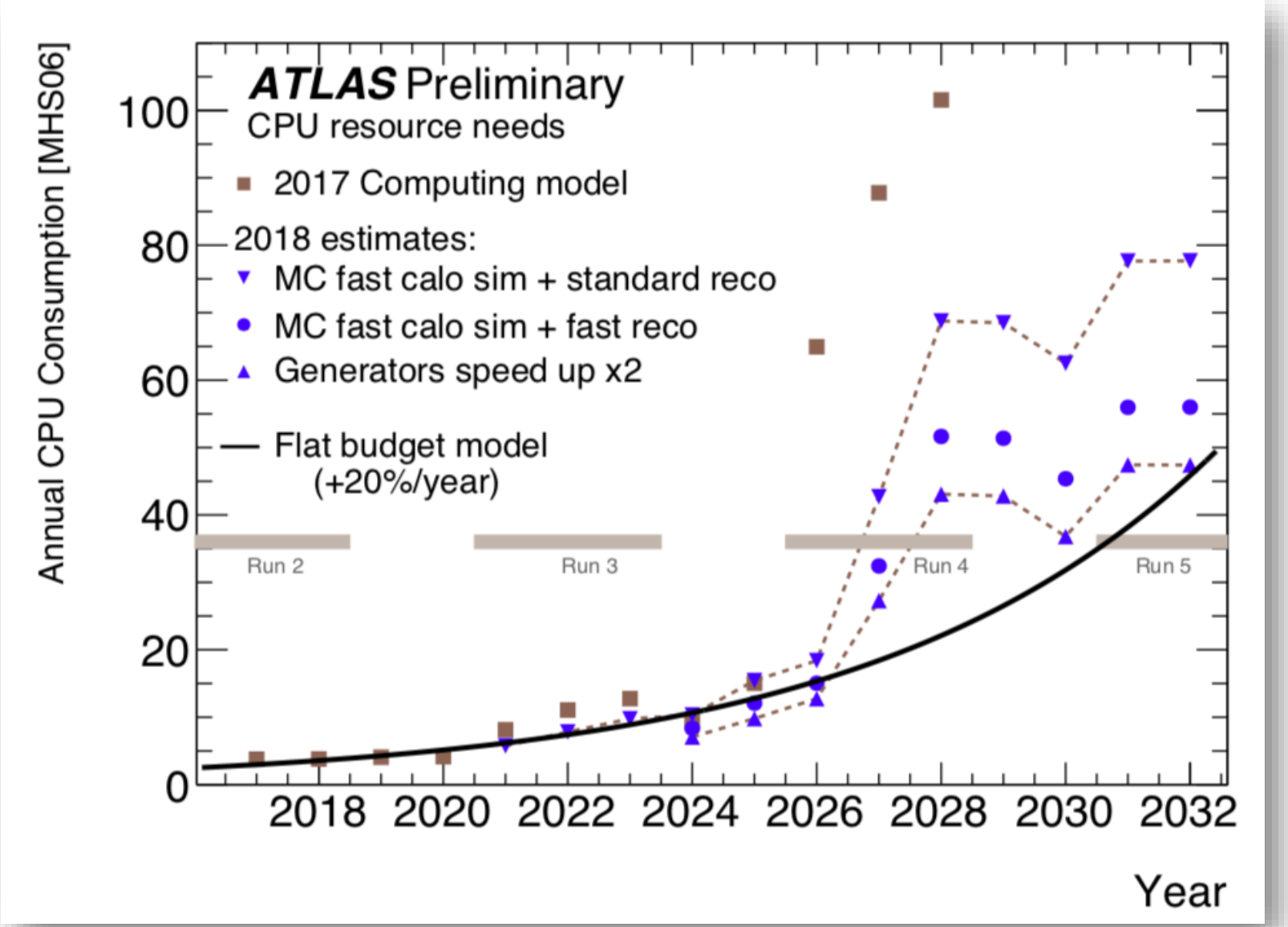
iris hep
Institute for Research & Innovation in Software for High Energy Physics

Why am I here talking about this?

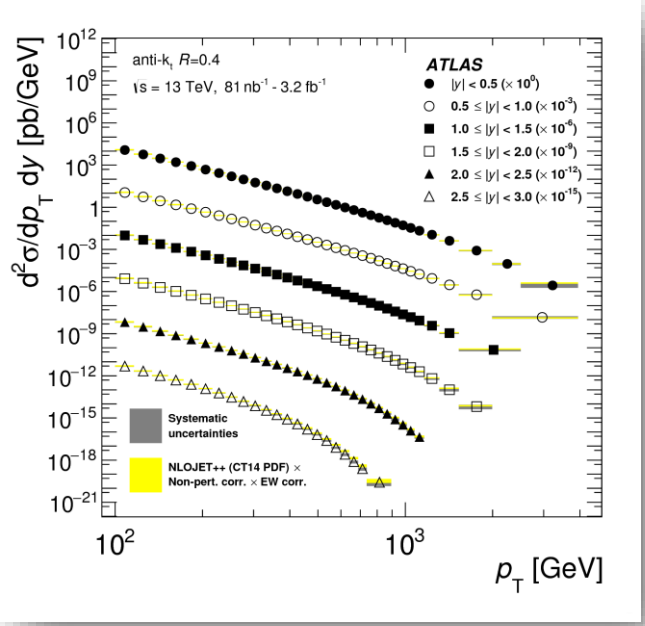


Run 4 Is Coming


ATLAS Preliminary
Disk resource needs
2017 Computing model
2018 estimates:
Baseline model
Reduced storage model
Flat budget model
(+15%/year)
Run 2
Run 3
Run 4
Run 5
Disk Storage [PBytes]
5000
4000
3000
2000
1000
2018
2020
2022
2024
2026
2028
2030
2032
Year


ATLAS Preliminary
CPU resource needs
2017 Computing model
2018 estimates:
MC fast calo sim + standard reco
MC fast calo sim + fast reco
Generators speed up x2
Flat budget model
(+20%/year)
Run 2
Run 3
Run 4
Run 5
Annual CPU Consumption [MHS06]
0
20
40
60
80
100
2018
2020
2022
2024
2026
2028
2030
2032
Year

Smaller or same number of people but more data!



The HL-LHC is a precision machine!

Size of a typical analysis moves from 100's of GB to 10's to 100's of TB

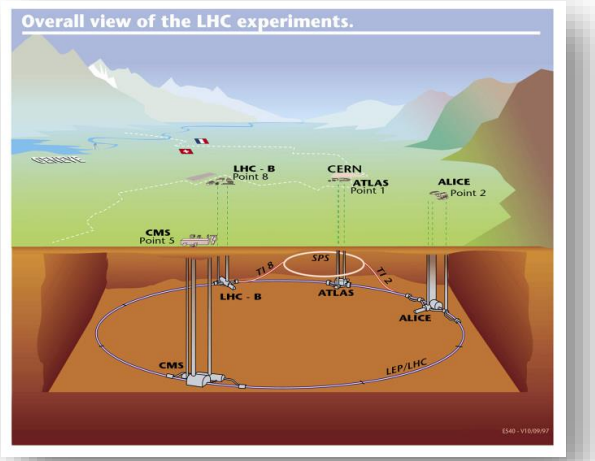
Maximal Exploitation of the LHC Means:

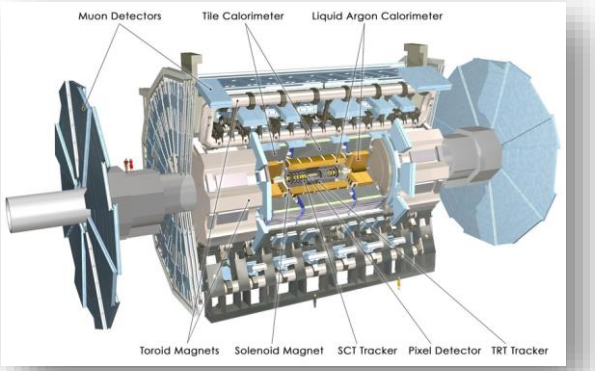
FASER

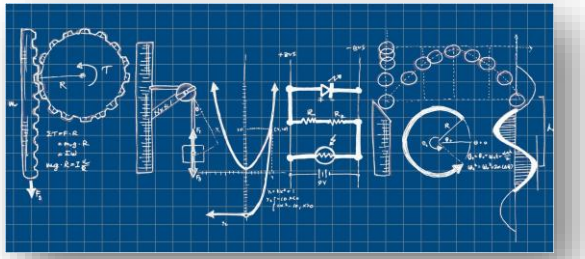
milliQan

SHiP
Search for Hidden Particles

MATHUSLA


Overall view of the LHC experiments.
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC


Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

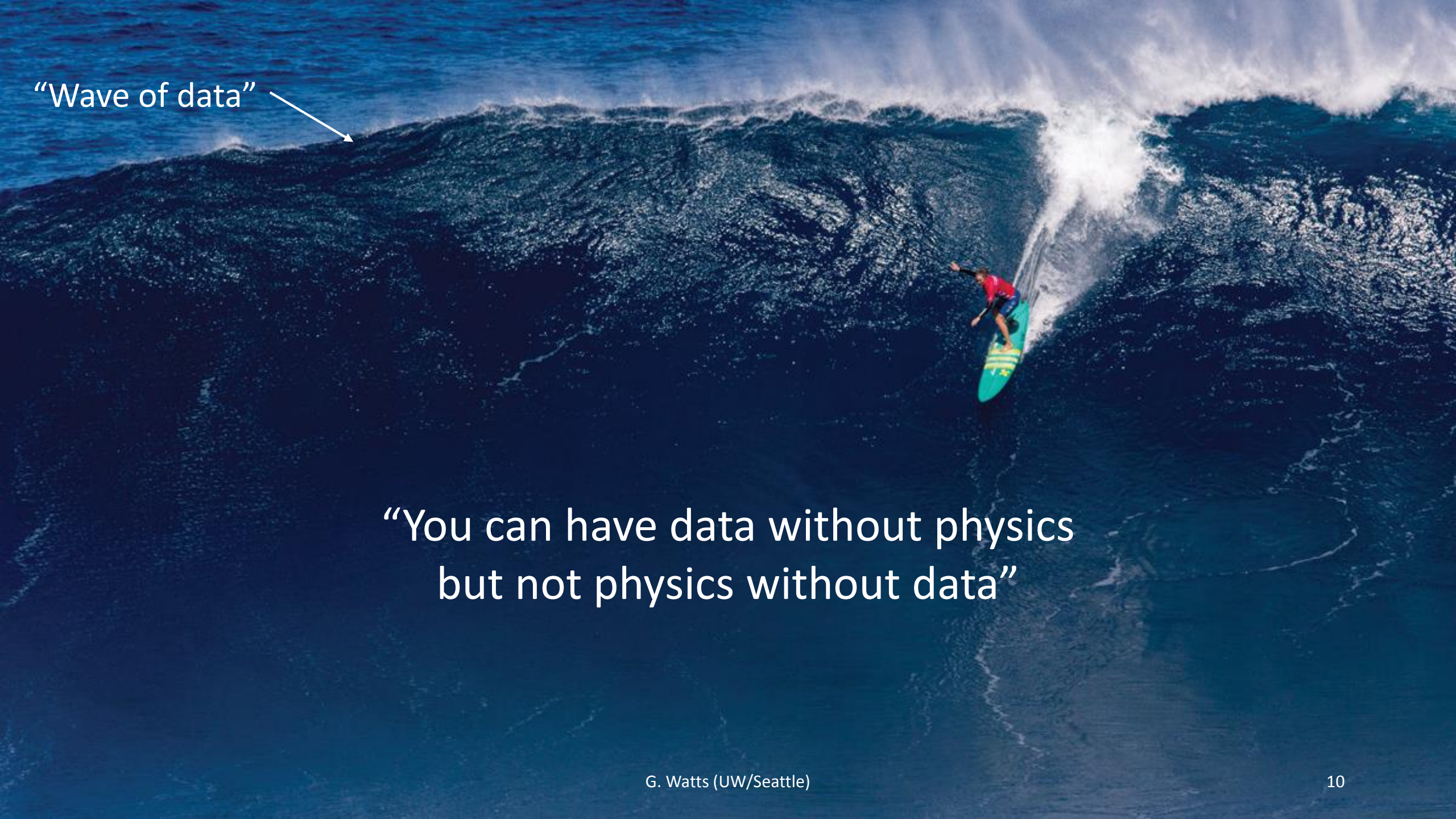


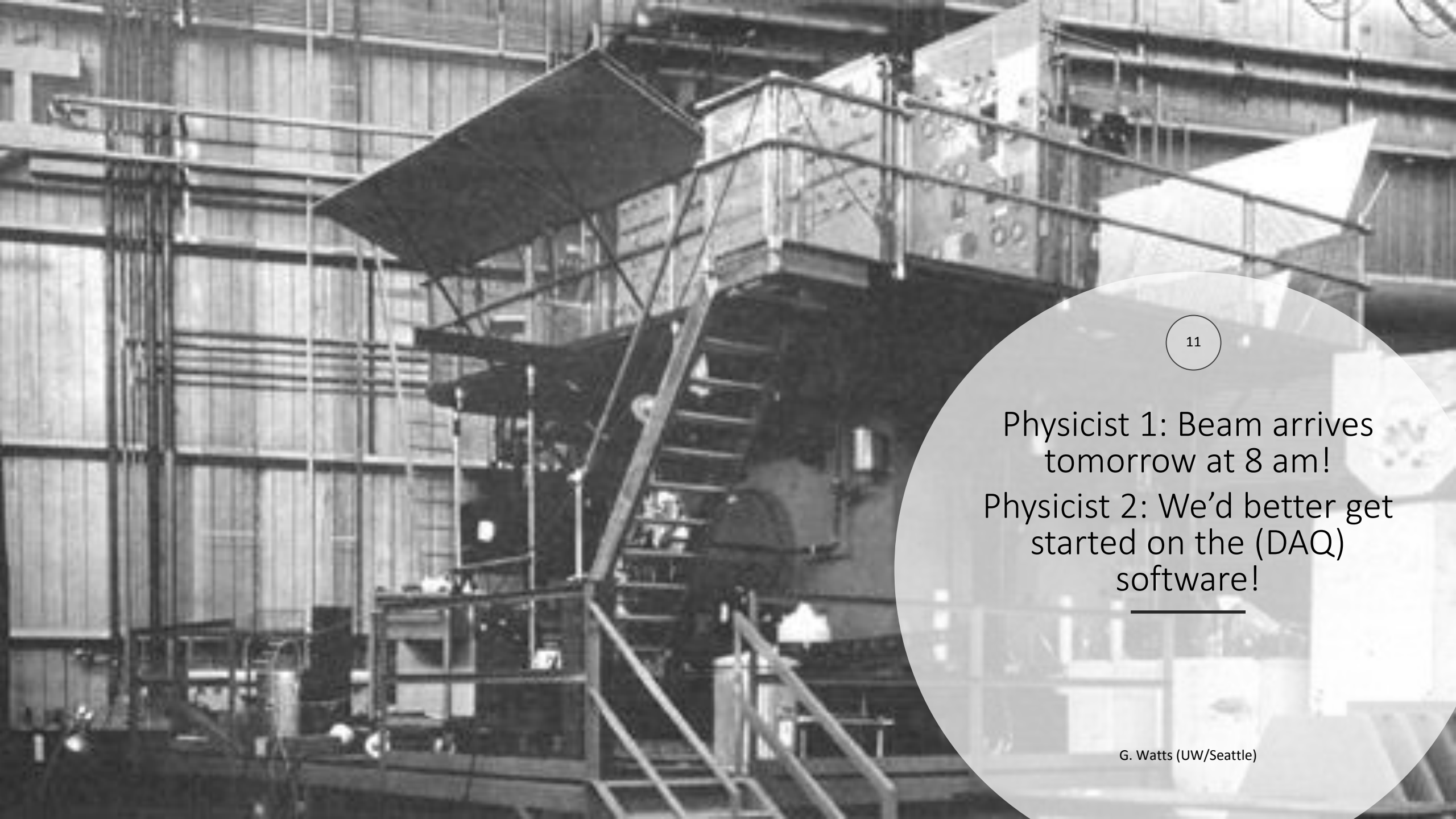
Physics

-or-

Our Tools

“You can have data without information
but not information without data”
- A. Lincoln

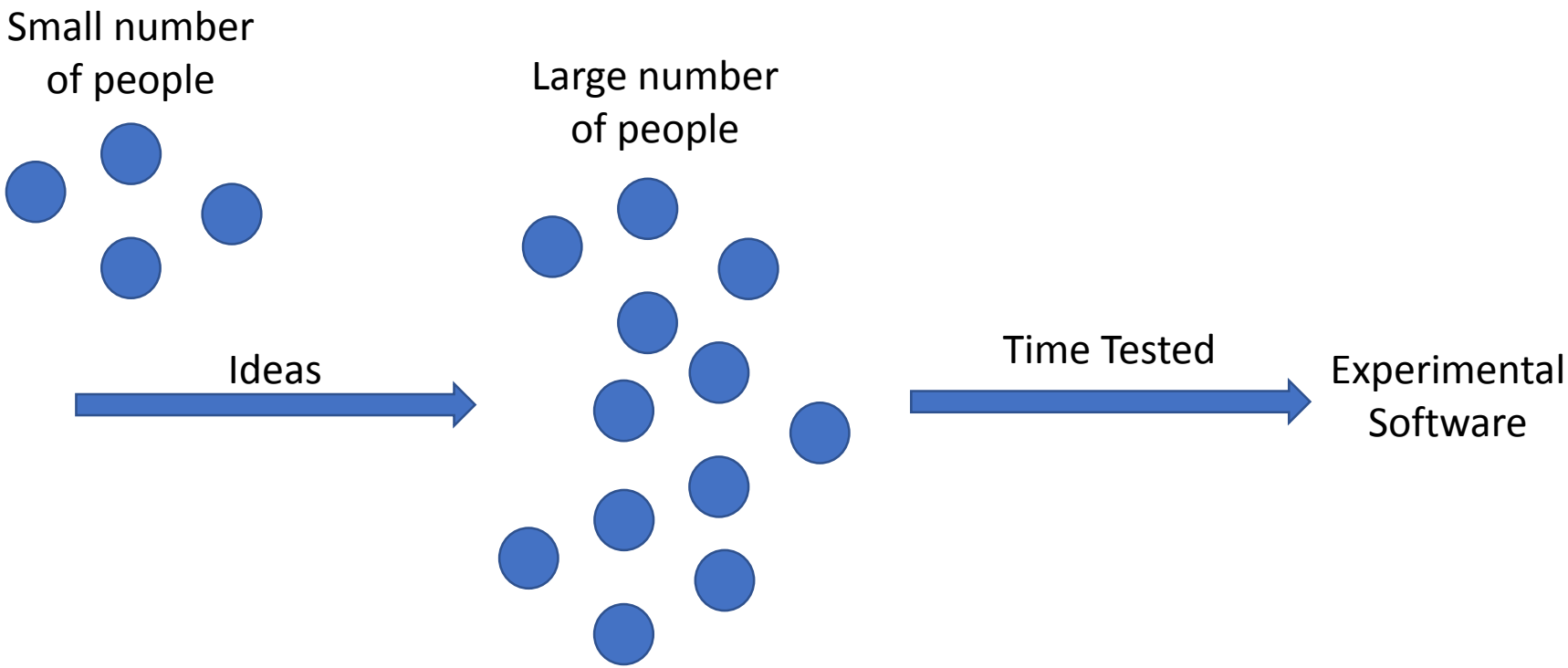

"Wave of data"
"You can have data without physics
but not physics without data"



Physicist 1: Beam arrives tomorrow at 8 am!

Physicist 2: We'd better get started on the (DAQ) software!

A Large LHC Experiment



Seniors + Teen-agers++ staying 5 to 8 years in HEP

Darkside-50, Mu2e, Noνa, etc.

LArSoft

DUNE, ICARUS, MicroBooNE, etc.

There is a whole new world outside of HEP now

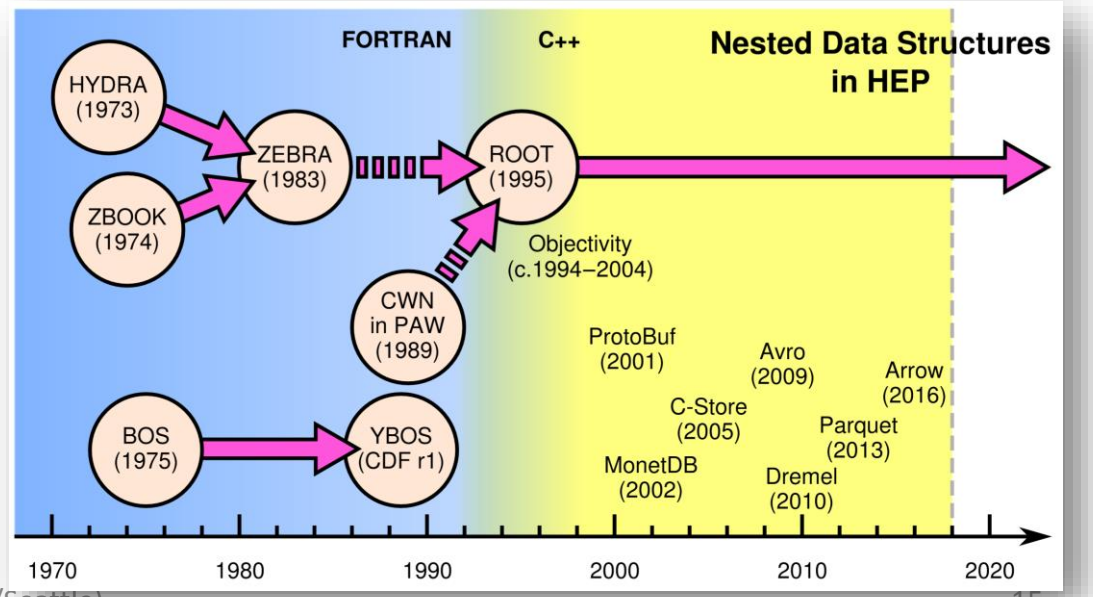
We've been working on tools for 50+ years
Web companies for about 10-15 years

c.f. Data analysis tools from within HEP and from industry
(J. Pivarski)

There are things missing in industry!

And us as well: Training

- c.f. Axel's talk on C++ 20
- New ML tools
- Vector and Array based processing

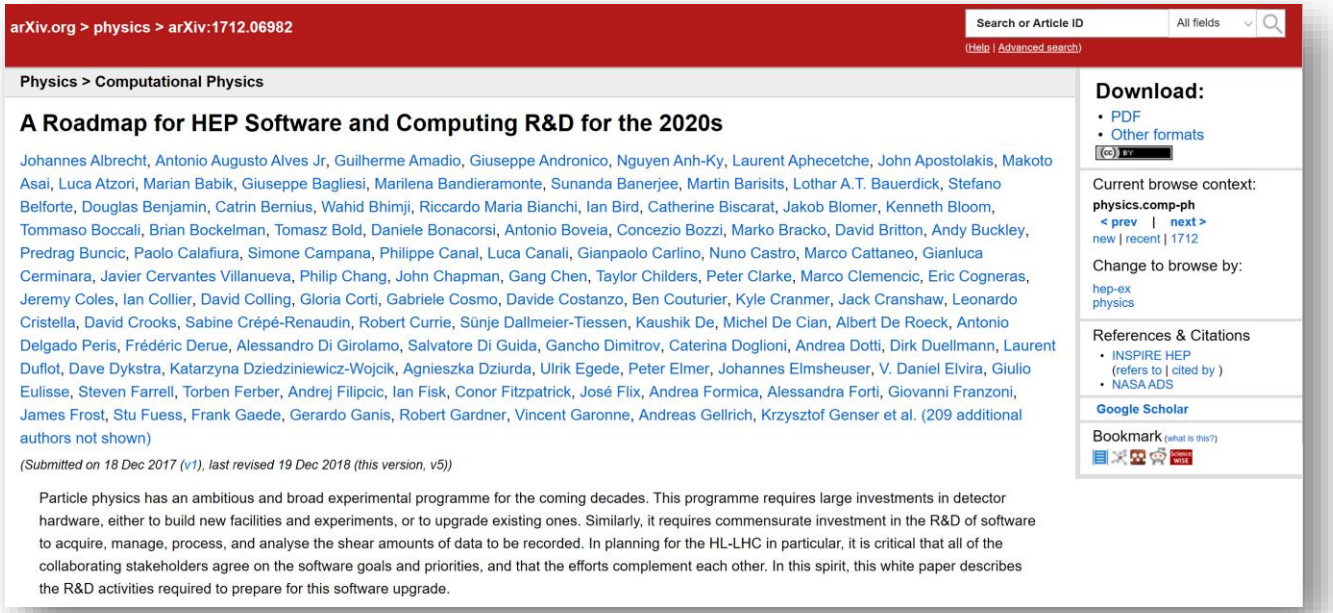


How can we tackle all these issues?

- Increased LHC dataset sizes and CPU requirements
- Flat budgets & stable or decreasing staffing
- New software tools and communities inside and outside HEP
- High turn-over inside HEP
- Educational Responsibility

Tackle them as a community!

The Community White Paper Process (2016-2017)



arXiv.org > physics > arXiv:1712.06982

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Physics > Computational Physics

A Roadmap for HEP Software and Computing R&D for the 2020s

Johannes Albrecht, Antonio Augusto Alves Jr, Guilherme Amadio, Giuseppe Andronico, Nguyen Anh-Ky, Laurent Aphecetche, John Apostolakis, Makoto Asai, Luca Atzori, Marian Babik, Giuseppe Bagliesi, Marilena Bandieramonte, Sunanda Banerjee, Martin Barisits, Lothar A.T. Bauerdick, Stefano Belforte, Douglas Benjamin, Catrin Bernius, Wahid Bhimji, Riccardo Maria Bianchi, Ian Bird, Catherine Biscarat, Jakob Blomer, Kenneth Bloom, Tommaso Boccali, Brian Bockelman, Tomasz Bold, Daniele Bonacorsi, Antonio Boveia, Concezio Bozzi, Marko Bracko, David Britton, Andy Buckley, Predrag Buncic, Paolo Calafiura, Simone Campana, Philippe Canal, Luca Canali, Gianpaolo Carlino, Nuno Castro, Marco Cattaneo, Gianluca Cerminara, Javier Cervantes Villanueva, Philip Chang, John Chapman, Gang Chen, Taylor Childers, Peter Clarke, Marco Clemencic, Eric Cogneras, Jeremy Coles, Ian Collier, David Colling, Gloria Corti, Gabriele Cosmo, Davide Costanzo, Ben Couturier, Kyle Cranmer, Jack Cranshaw, Leonardo Cristella, David Crooks, Sabine Crépé-Renaudin, Robert Currie, Sünje Dallmeier-Tiessen, Kaushik De, Michel De Cian, Albert De Roeck, Antonio Delgado Peris, Frédéric Derue, Alessandro Di Girolamo, Salvatore Di Guida, Gancho Dimitrov, Caterina Doglioni, Andrea Dotti, Dirk Duellmann, Laurent Duflot, Dave Dykstra, Katarzyna Dziedziniewicz-Wojcik, Agnieszka Dziurda, Ulrik Egede, Peter Elmer, Johannes Elmsheuser, V. Daniel Elvira, Giulio Eulisse, Steven Farrell, Torben Ferber, Andrej Filipcic, Ian Fisk, Conor Fitzpatrick, José Flix, Andrea Formica, Alessandra Forti, Giovanni Franzoni, James Frost, Stu Fuess, Frank Gaede, Gerardo Ganis, Robert Gardner, Vincent Garonne, Andreas Gellrich, Krzysztof Genser et al. (209 additional authors not shown)

(Submitted on 18 Dec 2017 (v1), last revised 19 Dec 2018 (this version, v5))

Particle physics has an ambitious and broad experimental programme for the coming decades. This programme requires large investments in detector hardware, either to build new facilities and experiments, or to upgrade existing ones. Similarly, it requires commensurate investment in the R&D of software to acquire, manage, process, and analyse the shear amounts of data to be recorded. In planning for the HL-LHC in particular, it is critical that all of the collaborating stakeholders agree on the software goals and priorities, and that the efforts complement each other. In this spirit, this white paper describes the R&D activities required to prepare for this software upgrade.

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Involved A Diverse
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- Individuals interested in the problems
- Members of other compute intensive scientific endeavors
- Members of Industry

Individual Papers on the arXiv:

Careers & Training, Conditions Data, DOMA, Data Analysis & Interpretation, Data and Software Preservation, Detector Simulation, Event/Data Processing Frameworks, Facilities and Distributed Computing, Machine Learning, Physics Generators, Security, Software Development, Deployment, Validation, Software Trigger and Event Reconstruction, Visualization

Community White Paper & the Strategic Plan

arXiv.org > physics > arXiv:1811.10309

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Physics > Computational Physics

HEP Software Foundation Community White Paper Working Group --- Visualization

Matthew Bellis, Riccardo Maria Bianchi, Sebastien Binet, Ciril Bohak, Benjamin Couturier, Hadrien Grasland, Oliver Gutsche, Sergey Linev, Alex Martyniuk, Thomas McCauley, Edward Moyse, Alja Mrak Tadel, Mark Neubauer, Jeremi Niedziela, Leo Piilonen, Jim Pivarski, Martin Ritter, Tai Sakuma, Matevz Tadel, Barthélémy von Haller, Ilija Vukotic, Ben Waugh

(Submitted on 26 Nov 2018)

In modern High Energy Physics (HEP) experiments visualization of experimental data has a key role in many activities and tasks across the whole data chain: from detector development to monitoring, from event generation to reconstruction of physics objects, from detector simulation to data analysis, and all the way to outreach and education. In this paper, the definition, status, and evolution of data visualization for HEP experiments will be presented. Suggestions for the upgrade of data visualization tools and techniques in current experiments will be outlined, along with guidelines for future experiments. This paper expands on the summary content published in the HSF \emph{Roadmap} Community White Paper~\cite{HSF-CWP-2017-01}

Subjects: **Computational Physics (physics.comp-ph)**; High Energy Physics - Experiment (hep-ex)

Report number: HSF-CWP-2017-15

Cite as: **arXiv:1811.10309 [physics.comp-ph]**

(or **arXiv:1811.10309v1 [physics.comp-ph]** for this version)

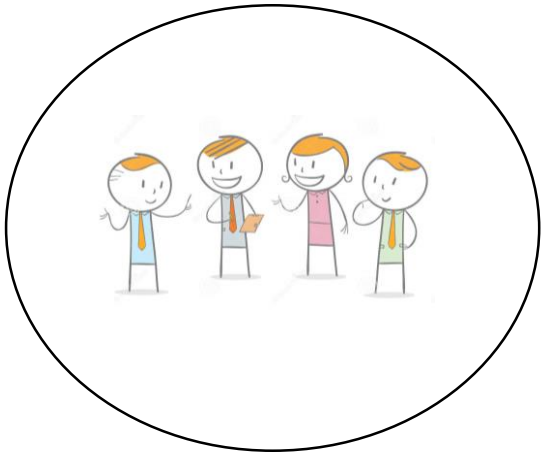
2 Current landscape

2.1 Event displays	Physics
2.1.1 Data access	Detector Development
2.1.2 Application development and distribution	
2.1.3 Geometry description and visualization	
2.2 Statistical data visualization	Analysis
2.2.1 Desktop solutions	
2.2.2 Web-based solutions	
2.2.3 Issues	Monitoring
2.3 Non-spatial visualization	

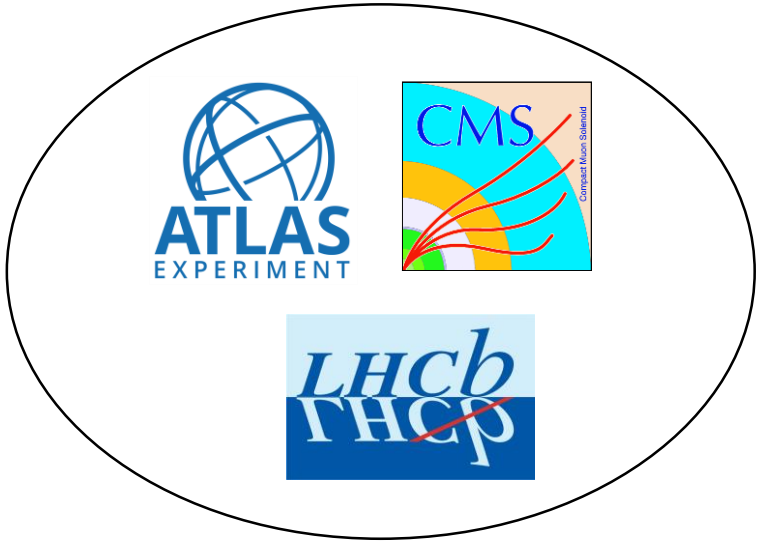
This is a lot of ideas!

(many of them from people in attendance today)

Conferences as Communities

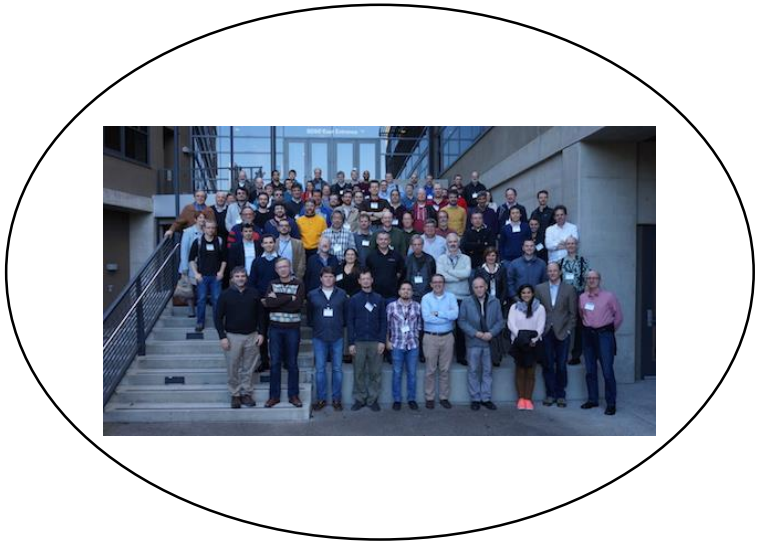


Groups



Experiments

HSF
HEP Software Foundation



Individuals

HEP Software Foundation

Labs

The HEP Software Foundation facilitates cooperation and common efforts in High Energy Physics software and computing internationally.

Link to the Community White Paper

Working Groups will be added to the activities listing of the HSF, can add material to the website and can have a dedicated mailing list and Indico category.

- Data Analysis
- Detector Simulation
- Frameworks
- Physics Generators
- Packaging
- PyHEP - Python in HEP
- Quantum Computing
- Reconstruction and Software Triggers
- Software/Developer Tools
- Training
- Visualization

One more bit missing…

Hardware

CERN: 950M CHF for 2015-2026

Other countries have individual contributions as well!

Some funding agencies have stepped up to address the call.

Groups

Experiments

Individuals

Labs

Funded by the National Science Foundation on September 1, 2018.

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"IRIS-HEP aims to develop the state-of-the-art software cyberinfrastructure required for the challenges of data intensive scientific research at the High Luminosity Large Hadron Collider (HL-LHC) at CERN, and other planned HEP experiments of the 2020's."

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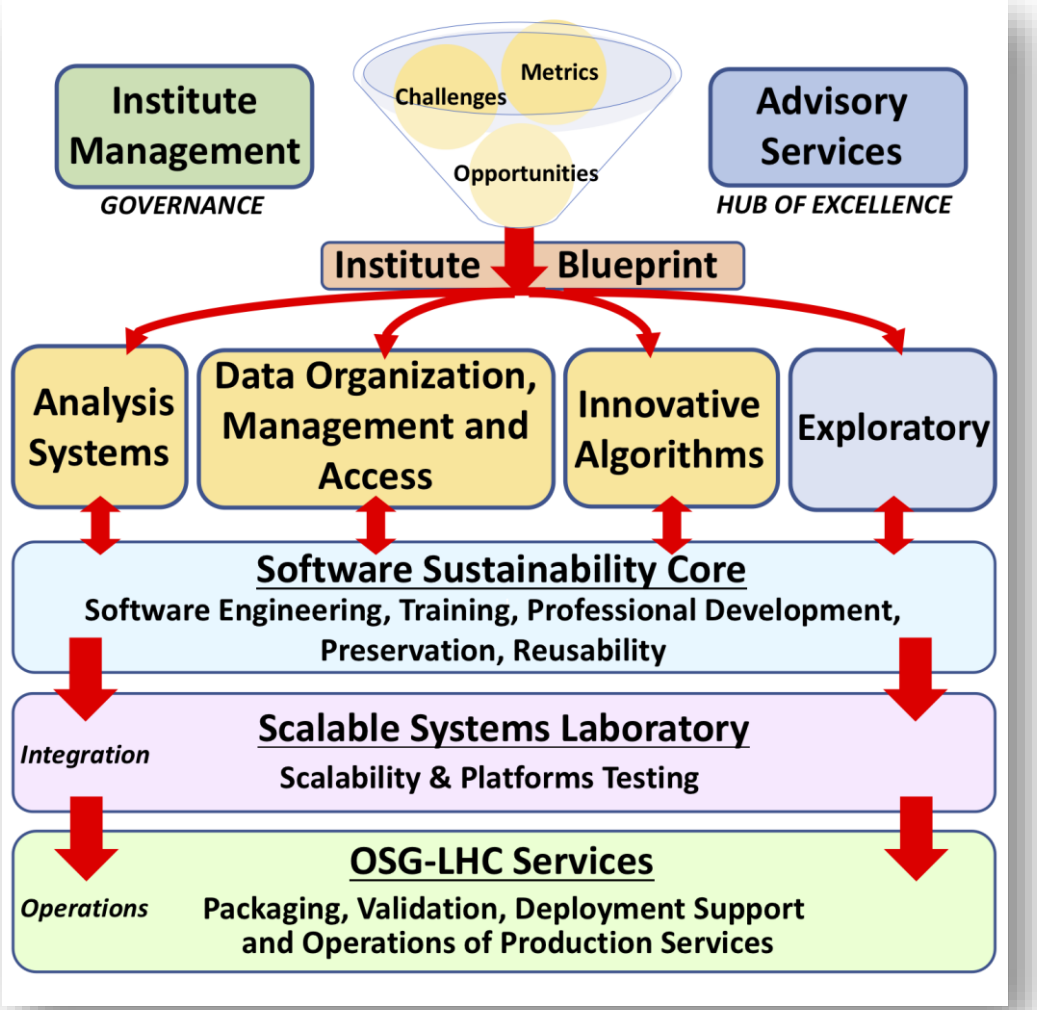

https://iris-hep.org

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Innovative Algorithms
Lead by Heather Gray (LBNL, Berkeley), David Lange (Princeton)
Trigger, Offline, Analysis Algorithms

Analysis Systems
Lead by Kyle Cranmer (NYU)
Preservation, diversification, declarative analysis

Data Management (DOMA)
Lead by Brian Bockelman (Wisconsin/Morgridge)
Distributed Infrastructure & Storage

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There are IRIS-HEP related talks here at ACAT already:

Parallelized Kalman-Filter-Based Reconstruction of Particle Tracks on Many-Core Architectures with the CMS Detector

Constraining effective field theories with machine learning

Nested data structures in array and SIMD frameworks

Aligning the MATHUSLA test stand detector: Using TensorFlow

A hybrid deep learning approach to vertexing

hls4ml: deploying deep learning on FPGAs for trigger and data acquisition

Summary

- C++20 will change how we write code
- Goals are simplicity, 0-cost, faster programs, common features in the library
- Implementations are on their way, most of C++17 already available

- General software development skills (carpentry!)
- Data analysis software skills
- Surveys of availible tools
- More advanced tool development skills

Done right should benefit the field and the individuals

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Topical and HSF Meeting

Expose HEP to new software techniques

Aimed at physicists and HEP computing folks that want to learn a bit more about what is out there

Vidyo only – and recorded and eventually posted to YouTube.

Subscribe to our announcements list to get notified of up coming lectures (or subscribe your calendar to the meeting iCal feed)

February 2019

- 25 Feb Analysis Description Languages NEW
- 18 Feb Integration of C++ Modules into CMSSW
- 13 Feb HLS4ML: Using ML on FPGAs to enhance reconstruction output
- 04 Feb Training for Software, Computing, Computational and Data Science in HEP

January 2019

- 28 Jan FuncX: High Performance Function as a Service for Science

Please let people at your institution know if you think they might be interested!

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Conclusions

- HEP software is facing a crisis
  - Data, CPU, staffing
- Develop further projects that can be used by multiple experiments
  - Data Management, Analysis Tools, Algorithms, Techniques
  - Healthy competition will always exist between the experiments.
- HEP Software Foundation
- IRIS-HEP
  - Tackling 3 large areas from the CWP
    - Innovative Algorithms, Analysis Systems, and DOMA
    - Training
    - OSG
  - Its success will be judged by its ability to build tools and algorithms that can be used by the community
- Collaboration between all these structures is key to the success of our community

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