



24th International Conference on Computing in High Energy & Nuclear Physics

4-8 November 2019, Adelaide, Australia

# CHEP 2019 Highlights

David Lawrence

Nov. 12, 2019



- Community converging around two message passing options
  - FairMQ for heavy ion experiments, ZeroMQ for everyone else
- Live monitoring is a CPU-expensive task
  - Huge amount of monitoring data (often histograms), updated frequently
  - Effort is being invested into reducing computing costs
- Increasing effort to reduce shifter dependencies
  - LHCb already requires minimal shifters due to being predominantly automated
  - CMS is developing DAQExpert to resolve DAQ-related problems faster than shifters
  - Belle II is working to automate PXD and SVD DAQ, ideally reducing shifters

- Trigger farms seem to increasingly be integrating GPUs
  - ALICE: farm is based upon GPUs, note that no actual “trigger” rather just data compression
  - CMS: HLT farm will contain 1x GPU per server
  - LHCb: full software trigger (no hardware trigger), first level potentially fully GPU-based
- Servers and their configurations are very complex to thoroughly optimize
  - Reading the server specifications is not even close to the full story
  - ALICE presented a very nice study showing dependencies on servers and their configurations
- Trigger networks primarily studying usage of 100 Gbps, mixture of RoCE and Infiniband
  - Very few places where 200 Gbps Infiniband is used

- Growing usage of GPUs and FPGAs in trigger applications
- Key use-case #1: track reconstruction on GPUs or FPGAs
  - Tracks are key to success in high-pileup environments
  - This is an expensive and slow process on CPUs  $\implies$  accelerate it!
  - GPU-based tracking planned by multiple groups in the coming years (more on this later)
  - CMS has shown a FPGA-based tracking study for the hardware trigger (running at 40 MHz) for the HL-LHC; FPGA tracking is working up to 300 simultaneous collisions
- Key use-case #2: machine learning in FPGAs
  - Regressions, classification, etc all appear very promising to improve trigger performance
  - Integration into currently-simplistic hardware trigger algorithms allows for large gains
  - FPGA implementations of NNs studied with several different approaches: HLS4ML or direct

# Common Problems, Common Solutions

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- LHC experiments do not dominate in data volume
- FTS is de-facto THE data transfer service
- Rucio is Breaking ATLAS Boundaries
  - missing functionality contributed by community

## 3<sup>rd</sup> Party copy (the problem)

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- GridFTP (Globus Toolkit) is not supported anymore (Dec 2018)
- Working alternatives are required at all sites ...
  - DPM, StoRM, dCache, XrootD, EOS, ECHO, Dynafed
  - FTS, Rucio, gfal ...



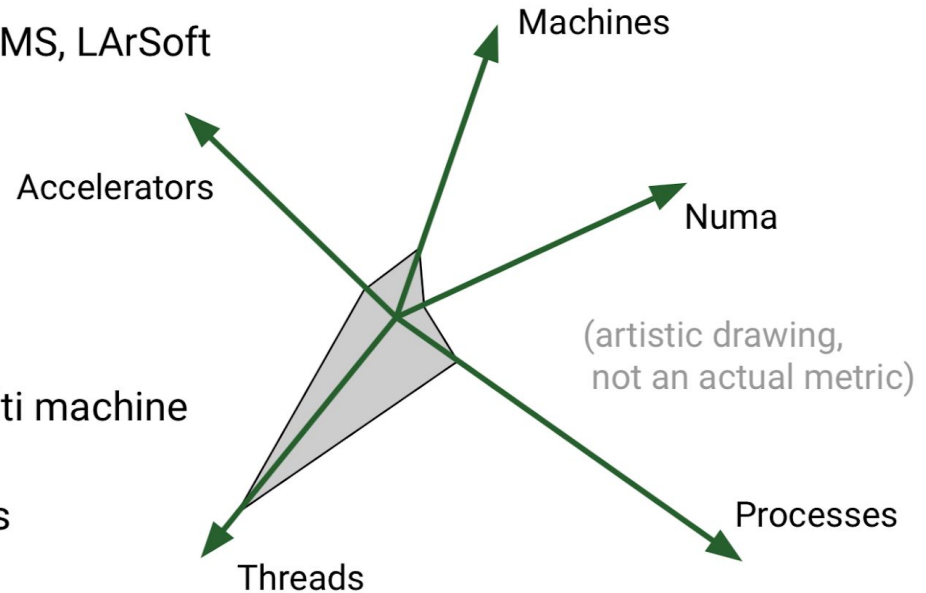
## Large effort to utilize all dimensions of performance

- multithreaded frameworks established
- thread performance by e.g. ATLAS, ILC, CMS, LArSoft
- GPU effort by e.g. LHCb, CMS, ATLAS

⇒ Shift to optimize in multiple dimensions

## Two complementary approaches

- monolithic framework augmented by multi machine workflow management (e.g. Raythena)
- loosely coupled microservice frameworks (e.g. ALFA, CLARA)

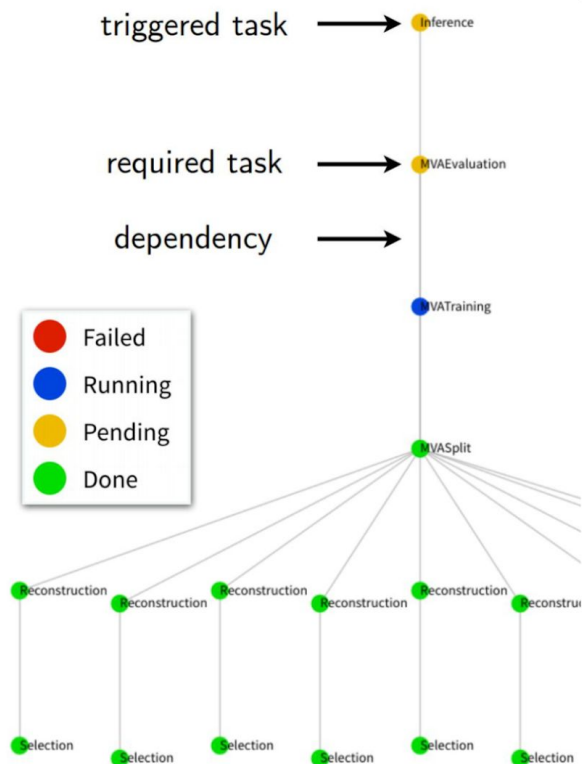






## Evolution in workflow management automation

- shift to more and advanced automated workflow decisions
- from early in the process (e.g. LHCb trigger configuration)
- up to analysis level (e.g. law)
- including the big frameworks (e.g. ATLAS, CMS, ALFA, CLARA, ...)





## Picking up momentum in HEP

- used by FCC, Key4HEP, SuperNEMO
- FAIR moving to spack
- CMS has proof of concept
- ATLAS considering but things still to be understood
- LHCb and Belle II willing to follow



[spack.io](https://spack.io)

## SpackDev: Multi-Package Development with Spack

“Coordinated build & test for integration, or initialize an environment for rapid build & test cycles of a particular package.”

- extension to Spack to help with development of interdependent packages

# Packaging: Other Options and Use Cases



Spack is not the only possible solution

- Gentoo Prefix and many more

## Conda and Conda Forge

The word 'CONDA' in a bold, green, sans-serif font. The letter 'C' is stylized with a white grid pattern.

“Reliably install ROOT in under 5 minutes on any machine”

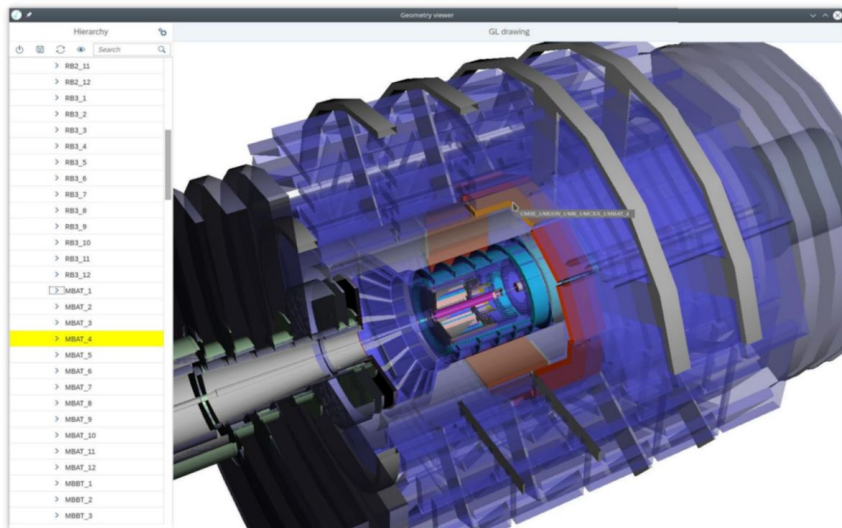
Chris Burr

- user centric software management
- increasing ease of use of many of our software packages

```
conda install python=3.8 root uproot boost-histogram
```



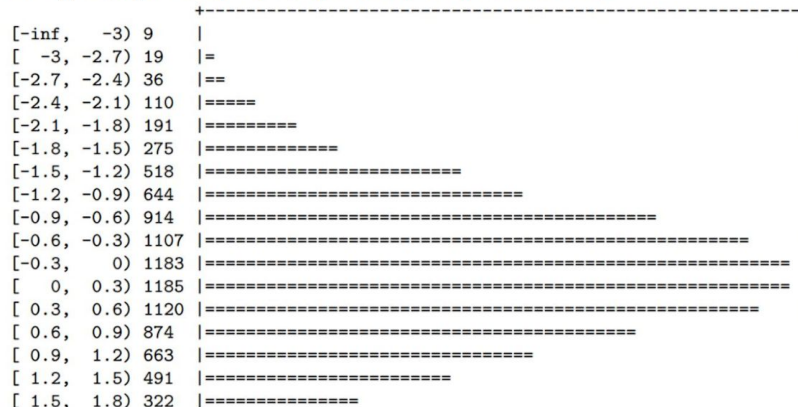
# High Level Libraries (and more)



Standalone, high-performance, header-only histogramming library added to boost

- good python bindings


```
histogram(regular(20, -3, 3, options=underflow | overflow))
```



ROOT moving to Web technologies for Visualization

- reduce dependency on system libraries
- experimental but feedback welcome!

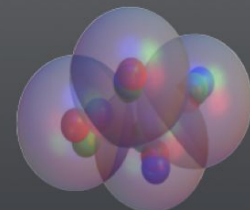
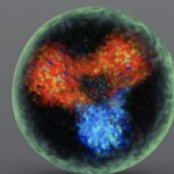
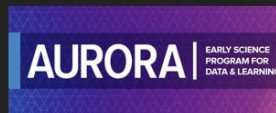
## MACHINE LEARNING FOR DATA ANALYSIS

- ▶ **Domain aware / physics informed / physics inspired ML algorithms**
- ▶ BSM physics searches at the LHC
  - ▶ Unsupervised ML for anomaly detection
  - ▶ Neural networks, reinforcement learning for jet tagging
- ▶ Nuclear physics track fitting  importing tools from HEP to NP
- ▶ ML-based Monte Carlo event generators
- ▶ High-dimensional ML inference - beyond summary statistics

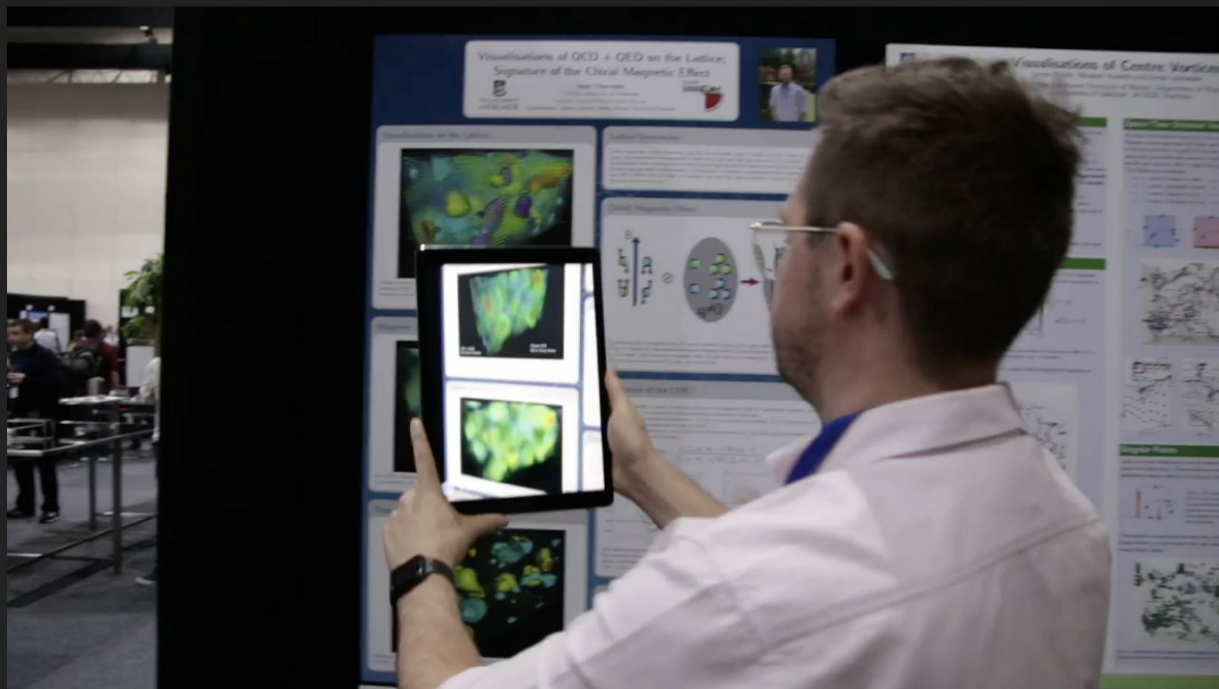


## LATTICE QCD

- ▶ **Hadron and nuclear physics from the Standard Model**
- ▶ **Extreme-scale computations**
  - ▶  $\sim 10^7$  GPU hours
  - ▶ 100-1000 GPUs in parallel
  - ▶  $>10\%$  of open-science supercomputing in e.g., USA
- ▶ **Era of precision calculations, fully-controlled uncertainties**
  - ▶ Hadron structure relevant to LHC, EIC
  - ▶ New physics searches e.g., muon  $g-2$
  - ▶ Moving towards nuclei for intensity frontier experiments



# TRACK 6 POSTER HIGHLIGHT – JOSH CHARVETTO (UNI OF ADELAIDE)



**Visualisations of QCD + QED on the Lattice;  
Signature of the Chiral Magnetic Effect**

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UNIVERSITY OF ADELAIDE  
Supervisors: James Zanotti, Ross Young, Waseem Karim

**Visualisations on the Lattice**

A basic lattice visualization illustrating the topological charge density of QCD, the magnetic field strength of QED and the QED magnetic field (represented) regions with lower topological charge density are not subject to topological fluctuations of instantons.

**Magnetic Field**

The QED magnetic field visualized with both the spin and color of the vectors representing the local strength of the magnetic field in a given direction.

**Topological Charge Density**

Regions of significant QCD topological charge density are contained in red through green-blue through spots by positive (negative) values of the density.

**Lattice Simulation**

Lattice quantum chromodynamics (QCD) has provided great insight into the nature of strong, spin-1/2 quark interactions. Quarks alone does not describe the nucleus in its entirety. Theoretical developments have introduced Quantum Chromodynamics (QCD) effects directly into the generation and QED effects are able to simulate for the first time evidence suggesting an interplay between these two fields.

**Chiral Magnetic Effect**

The generation of a magnetic field  $B$  causes quarks to align their spin depending on their relative charge. In regions of non-trivial topological charge density a net imbalance of chiral is indicated. This region with net topological charge density  $q$  will receive topological charge density with relative orientational current for the direction of  $q \neq 0$ .

**Signature of the CME?**

In order to quantify a local correlation between the magnetic field  $B$ , topological charge  $q$  and related vector  $J$  we need their corresponding correlation matrix. This linking of the relationship between  $J$ ,  $B$  and  $q$  we are able to measure  $J$  in the direction of  $q$  as a function of the magnetic field  $B$ .

By defining the correlation as a function of the distance  $R = |x - y|$  from any site on the lattice it is only after site we can find:

$$C(R) = \frac{\langle J_x^i B_x^i B_y^j q_y^j \rangle - \langle J_x^i B_x^i \rangle \langle B_y^j q_y^j \rangle}{\sqrt{\langle B_x^i B_x^i \rangle \langle B_y^j B_y^j \rangle \langle q_y^j q_y^j \rangle}}$$

Left: Left correlation of the topological charge density  $q$  of QED and QCD as a function of  $B$  calculated on various lattice volumes. For large enough volumes, a non-zero signal emerges for Right: correlation of  $B$  and  $q$  in the same direction. For large enough volumes, a non-zero signal emerges for  $C(R) > 0$  as well as the direction anti-correlation dip for regions  $R < 12$ .

**Download The Interactive Viewer!**

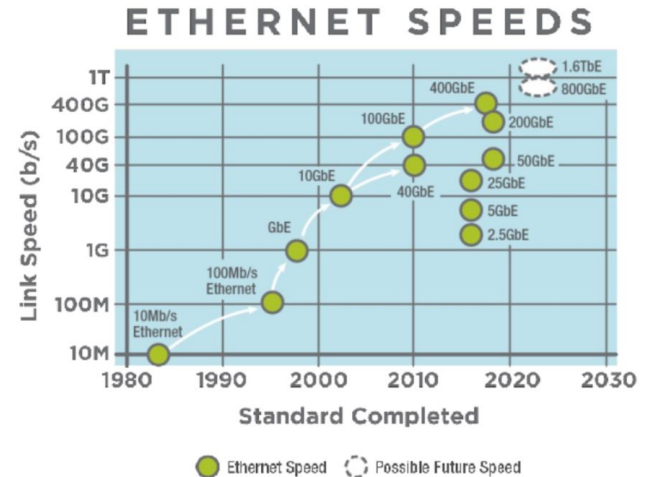
- Follow the QR code to download the CMEP Viewer browser
- Fully download the app, install it on your device and point it at any server with this URL: <http://10.10.10.10:8080>
- Supports for both Android and Apple devices available.
- Powered by WebGL and WebGL2.
- Referenced in this work available at the link.

## > Jupyter

- Increasing interest on the user side
  - > Interactive, fast learning curve
  - > Easy development and sharing
- Jupyterhub enables access to diverse HTP and HPC resources

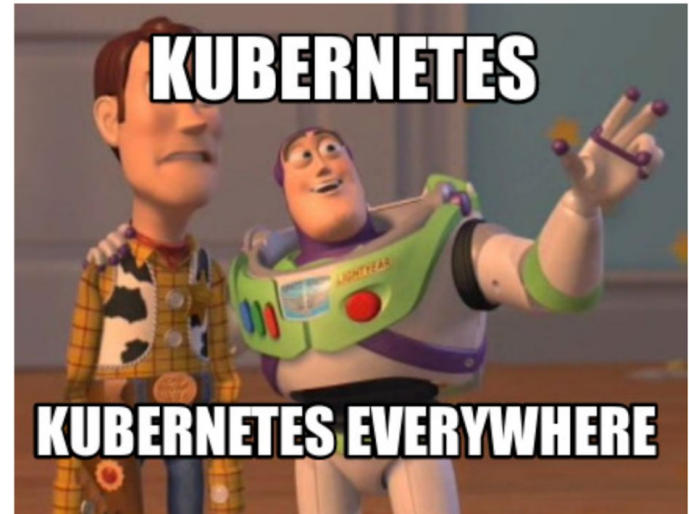
## > Overview by Hepix TechWatch working group

- Hyperscales (Google, Amazon) drive the market
- x86 market: AMD is back
- Magnetic disk: Market is shrinking
- Tape: Risks – essentially one company left for R&D
- Ethernet evolving very fast
  - > Pace of change exceeding IEEE standards process

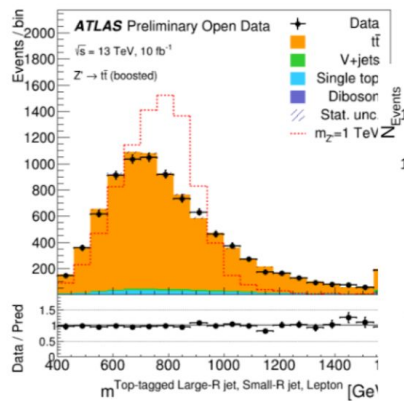




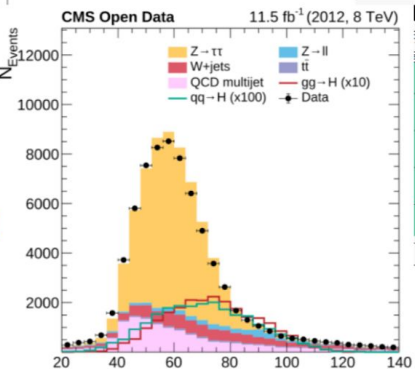
- > Kubernetes, kubernetes, kubernetes, ...
  - Intensive deployment of containers based on Kubernetes engine
  - Job scheduling without batch system, simply relying on Kubernetes  
-> effective and promising, aspect to simplifying site operations, no CEs...
  - Registry solutions to deploy container images is one of concerns
- > ScienceBox
  - Complete solution for scientific set of services from highly-scalable storage solutions (EOS) to user-friendly application, Jupyter notebook
  - All nicely packaged in containers
- > Container technology facilitates use of various resources
  - HPC, HTC, Grid resources, etc.
- > Moving CERN batch from Openstack VMs to Kubernetes
  - First benchmarks indicate 5% performance gain
- > All major experiments use containers in production



# Open data is growing



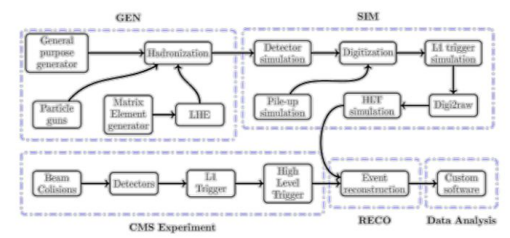
ATLAS



CMS



OPERA



## Experiments releasing more open data batches

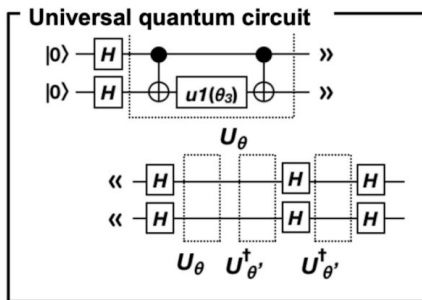
- ATLAS: New 13 TeV 2016 data samples
- CMS: Machine Learning, RAW/AOD/AODSIM
- OPERA: tau-neutrino events

## Growing use of open data for research

- Independent research papers on INSPIRE
- CMS released full provenance information as well as raw data samples

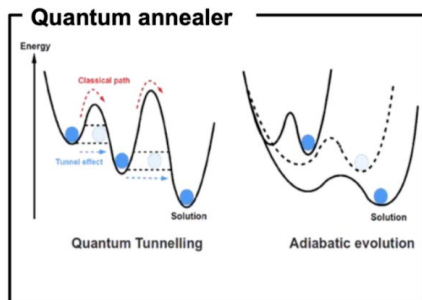
# Quantum Tracking

## Quantum Computer



- Arrange gates for each problem
- General-purpose computer

## D-Wave



- Find the minimum energy state of a given Hamiltonian
- Suitable for an optimization problem

Focus on quantum annealer

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## Results

1600 particles (20% of HL-LHC)  
- 11000 hits

Input

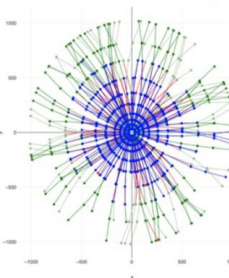
Doublet selection

390000 Doublets

Purity 0.22 %

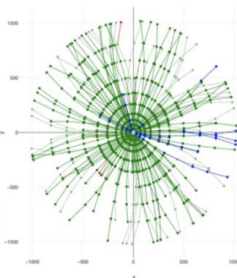
Efficiency 99.5 %

- Reconstructed high pT tracks
- Reconstructed low pT tracks
- Not reconstructed tracks
- Fake tracks



2445 Doublets

Annealing



1424 Doublets

Purity 98.5 %

Efficiency 96.4 %

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Not just a pipe dream!?

# Tracking ML challenge

## Leaderboard

RESULTS										
#	User	Entries	Date of Last Entry	score ▲	accuracy_mean ▲	accuracy_std ▲	computation time (sec) ▲	computation speed (sec/event) ▲	Duration ▲	
HEP people	1	sgorbuno	9	03/12/19	1.1727 (1)	0.944 (2)	0.00 (14)	28.06 (1)	0.56 (1)	64.00 (1)
	2	fastrack	53	03/12/19	1.1145 (2)	0.944 (1)	0.00 (15)	55.51 (16)	1.11 (16)	91.00 (6)
PH+CS	3	cloudkitchen	73	03/12/19	0.9007 (3)	0.928 (3)	0.00 (13)	364.00 (18)	7.28 (18)	407.00 (8)

Norfolk, Virginia, USA  
May 10-14, 2021



25<sup>TH</sup> INTERNATIONAL CONFERENCE

# CHEP 2021

Computing in High Energy & Nuclear Physics

LOCAL ORGANIZING COMMITTEE

Amber Boehnlein - Chair  
David Abbott

Mark Ito  
Brent Morris

Graham Heyes  
Rachel Harris



[chep2021.org](http://chep2021.org)

# Elizabeth River Waterfront, Norfolk

- Scenic, walkable downtown with restaurants, lodging, shopping, museum and entertainment conveniently located near a major airport
- Light Rail Line to access to additional restaurants and museums



# Social Activities

- Monday Night Reception will be held at the conference hotel
  - Feature Virginia Craft Beer and Virginia Wine: 4 excellent craft brewers and several vineyards in local area
- Banquet to be held at the Blue Moon Taphouse, Waterside
  - Music provided by Jae Sinnett, local Jazz legend
- Excursion/free afternoon options
  - Trips to the beach or seashore nature preserves
  - Norfolk Botanical Gardens
  - Geek tours: Port of Virginia and NATO Allied Command
  - Kayaking on the James
- Dining
  - Over 45 Restaurants near the Conference Hotel

