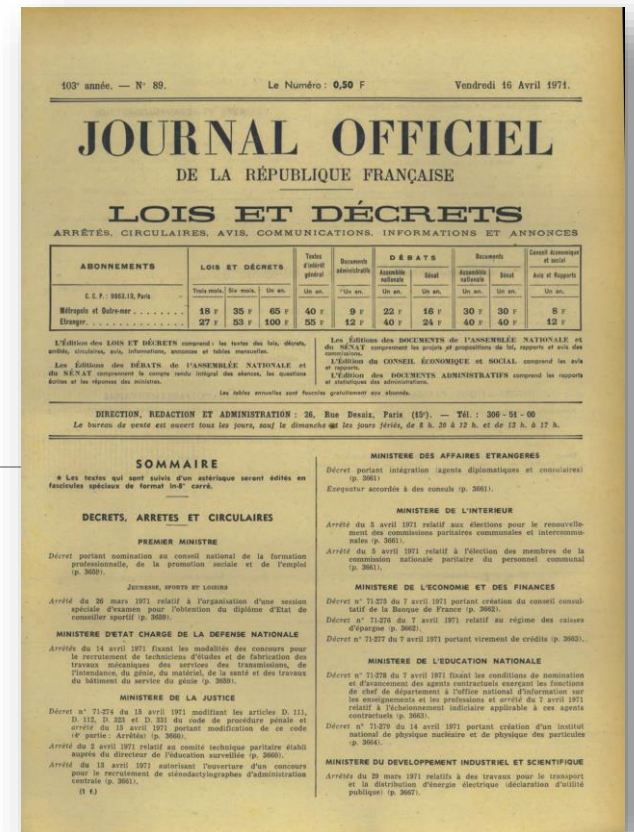


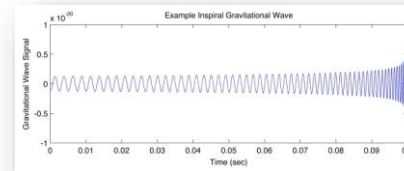
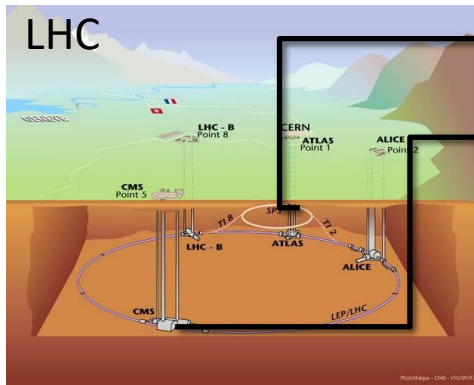
The two infinities and the universe of algorithms

50 ANS DE L'IN2P3 AU L2IT

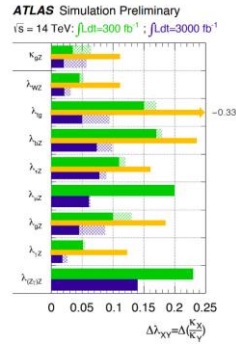
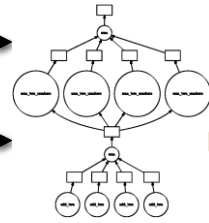
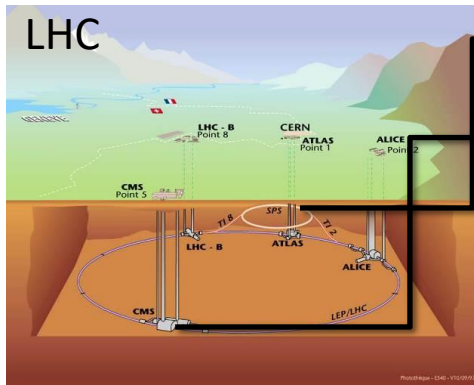
G. WATTS (UW/SEATTLE, IRIS-HEP, CPPM)



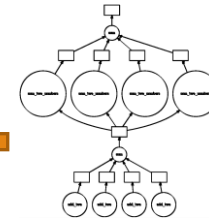
Algorithms: Gateway to Science



Algorithms: Gateway to Science



Location,
type,
mass

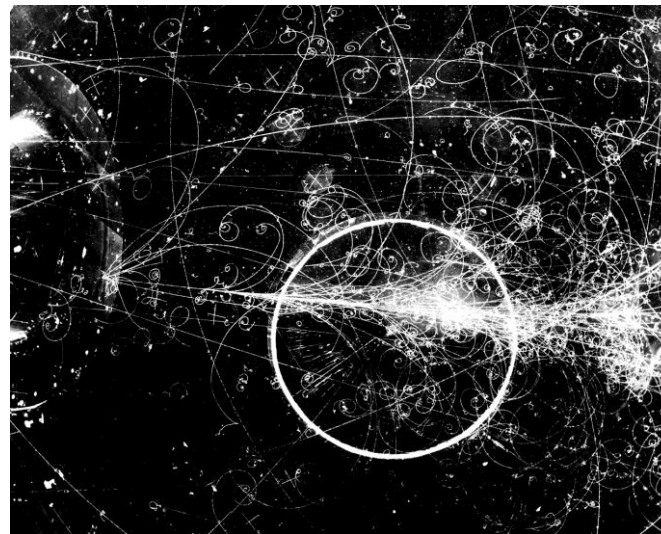
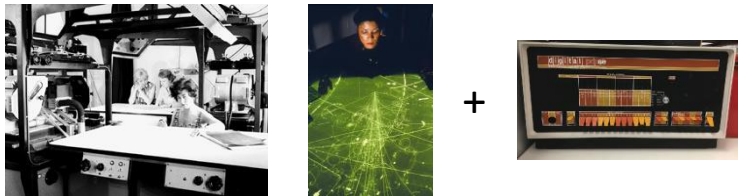


Algorithms: Gateway to Science



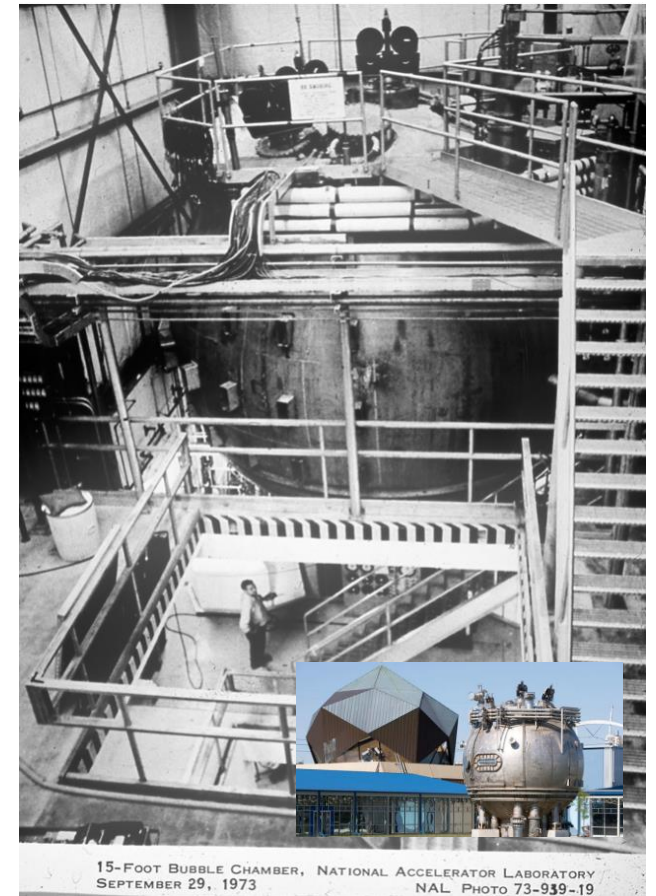
Track Finding

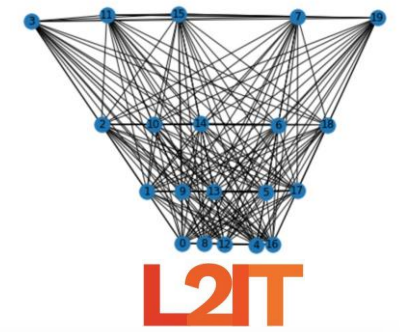
Bubble Chambers (~1970)



Bubble Chambers (late 1970's)

PEPR +



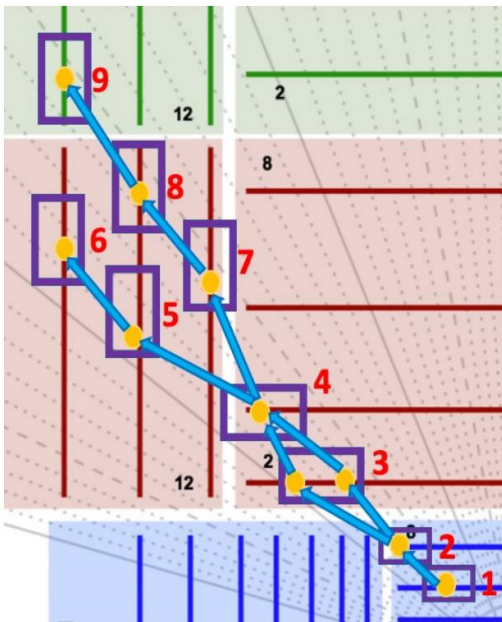


Algorithms: Gateway to Science

Graph Neural Networks

➔ Well suited to working in more than 2 dimensions!

Well suited to track finding in a HEP experiment!

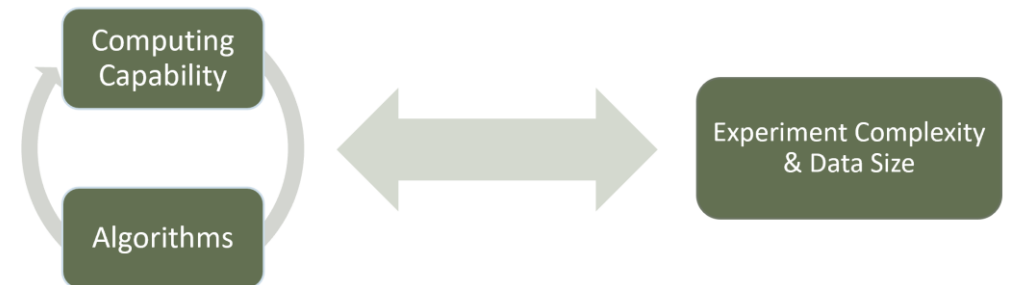


Use physics to modify a standard algorithm.

vCHEP
2021

Towards a realistic track reconstruction algorithm based on graph neural networks for the HL-LHC

Charline Rougier (charline.rougier@l2it.in2p3.fr)





A Plan for Scientific Software in the 2020's

Many workshops, involving a diverse group

- International participants
- Computing Management from the Experiments and Labs
- Individuals interested in the problems
- Members of other compute intensive scientific endeavours
- Members of Industry
- Run by HEP Software Foundation
- <http://s2i2-hep.org/>
- <https://hepsoftwarefoundation.org/>

Grassroots Effort

January 2017 UCSD - USA



June 2017 Annecy





A Plan for Scientific Software in the 2020's

arXiv.org > physics > arXiv:1712.06982

Search... All fields Search

Help | Advanced Search

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 Granshaw, Leonardo Cristella, David Crooks, Sabine Crépe-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 Dziejniewicz-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 et al. (210 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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(USA/NSF)

Institute for Research & Innovation
in Software for High Energy Physics

HEP-Center For Computing Excellence
(USA/DOE)

SWIFT-HEP (UK/STFC)

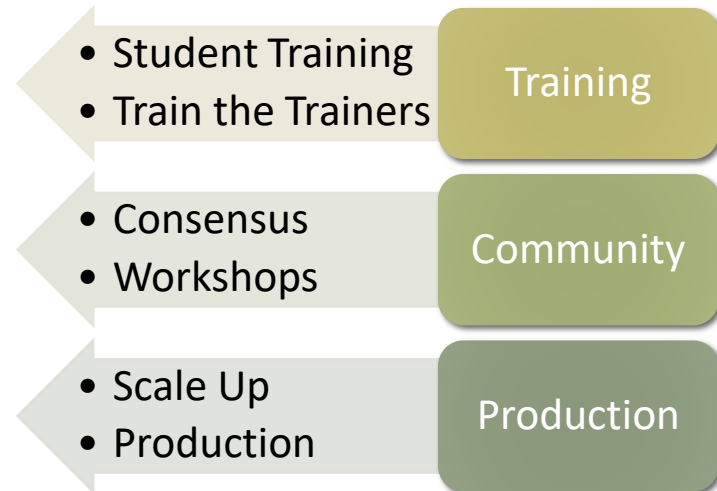
HEP Software Foundation's R&D Plan (CERN)
And CERN R&D



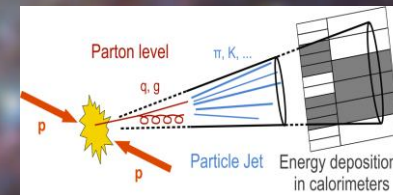
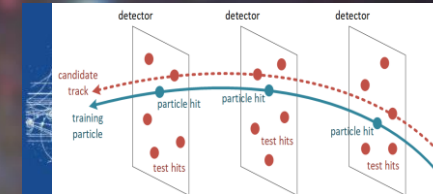
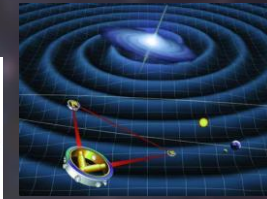
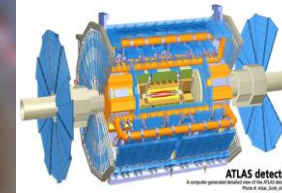


A Plan for Scientific Software in the 2020's

“Substrate”



Science and the Scientists are at the center...

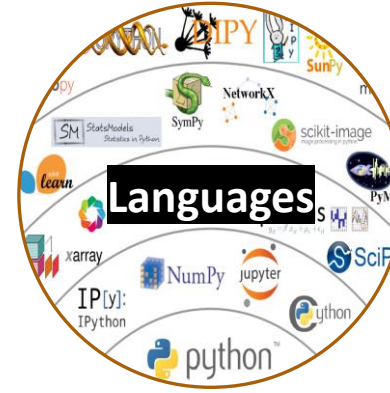




Algorithm Landscape



- Computing Centers
- Cloud Native
- Commercial Cloud



- C++

- Python
- Matplotlib
- Numpy
- Numba, JAX
- PyTorch

Ecosystem

- Julia, Dex, ...



- pyHF – Statistical Models
- Awkward Array – Big Data
- Hist
- ROOT

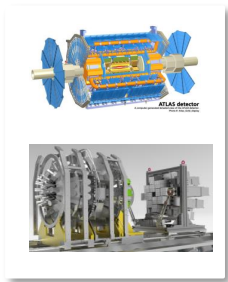


- Kafka - Streaming
- Airflow - Workflows
- DASK, RAY - Multiprocessing

“How do small teams have a large impact?”



Enabling New Techniques



Selection
(Physics Motivated)



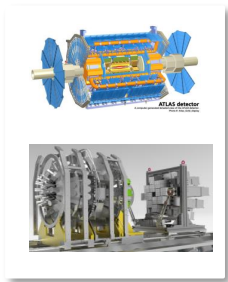
Neural
Network



Final Result

PyTorch
Optimize for S/\sqrt{B}

Enabling New Techniques



Selection
(Physics Motivated)



Neural
Network

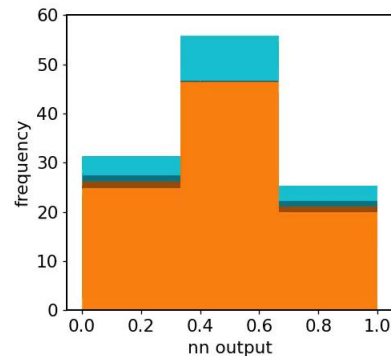
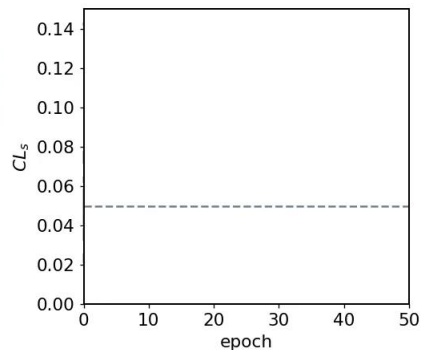
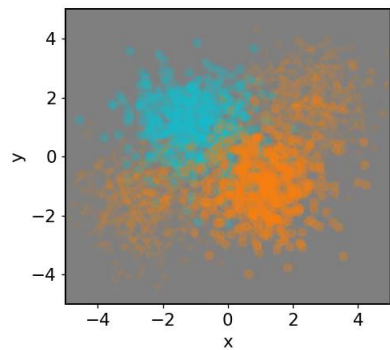


Final Result

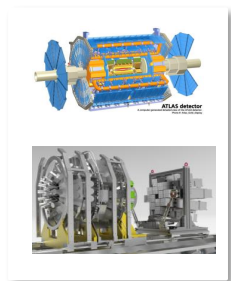


NEOS

Optimize for Sensitivity
(with **systematic errors**)



Enabling New Techniques



Selection
(Physics Motivated)



Neural
Network

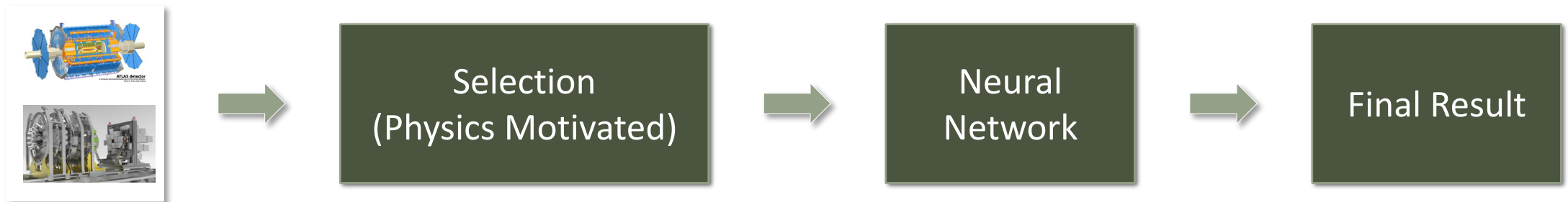


Final Result



Differentiable Programming
Optimize for Sensitivity
With systematic errors
With **Selections** and **Physics**

Enabling New Techniques



MODE Collaboration

Optimize for Sensitivity

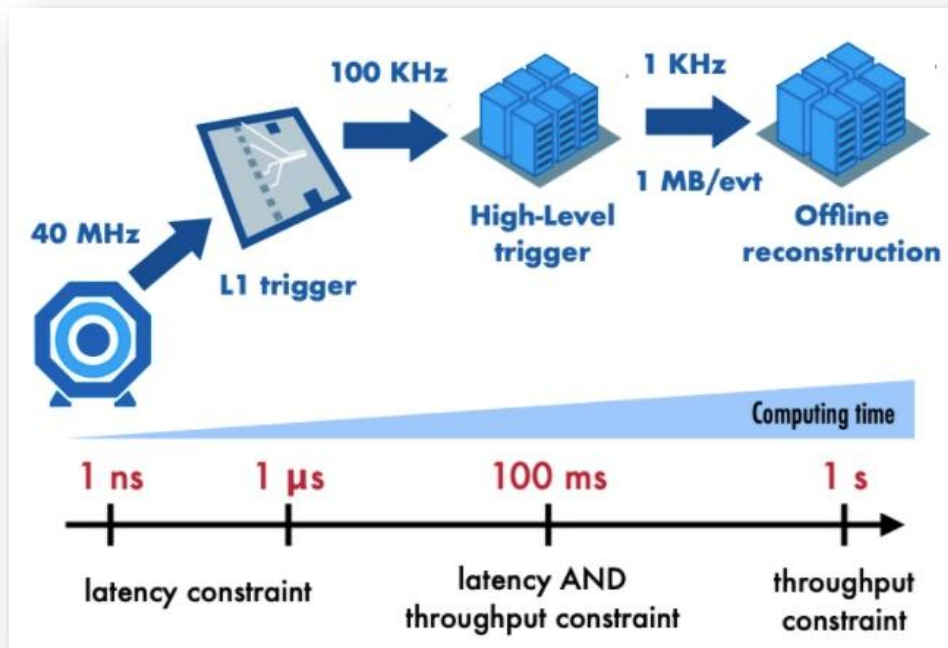
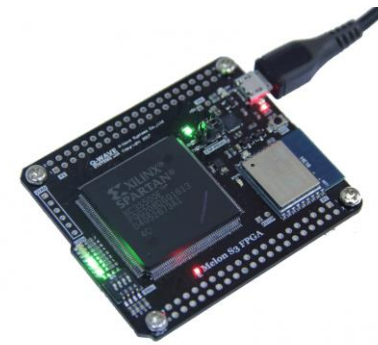
With systematic errors

With Selections and Physics

With **Simulation & Reconstruction**

With **Detector Design**

Algorithms In Hardware

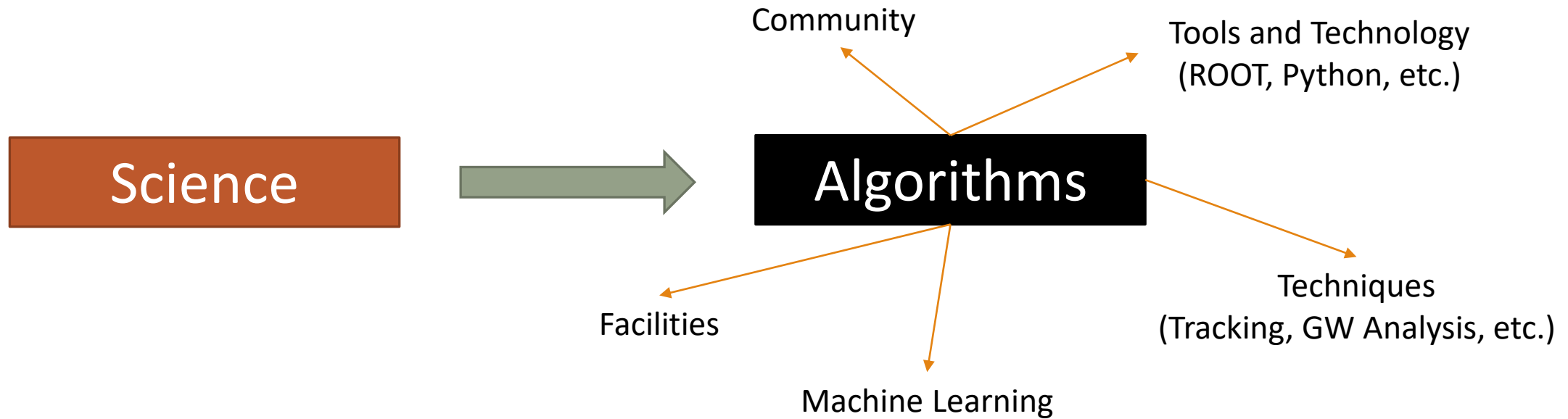


hls 4 mi

A3D3

- High Energy Physics
- Multi-Messenger Astronomy
- Neuroscience
- AI & Hardware Experts for “substrate”

Algorithms





IN2P3

50 ANS DE PHYSIQUE DES DEUX INFINIS





Building Community

Formal Efforts

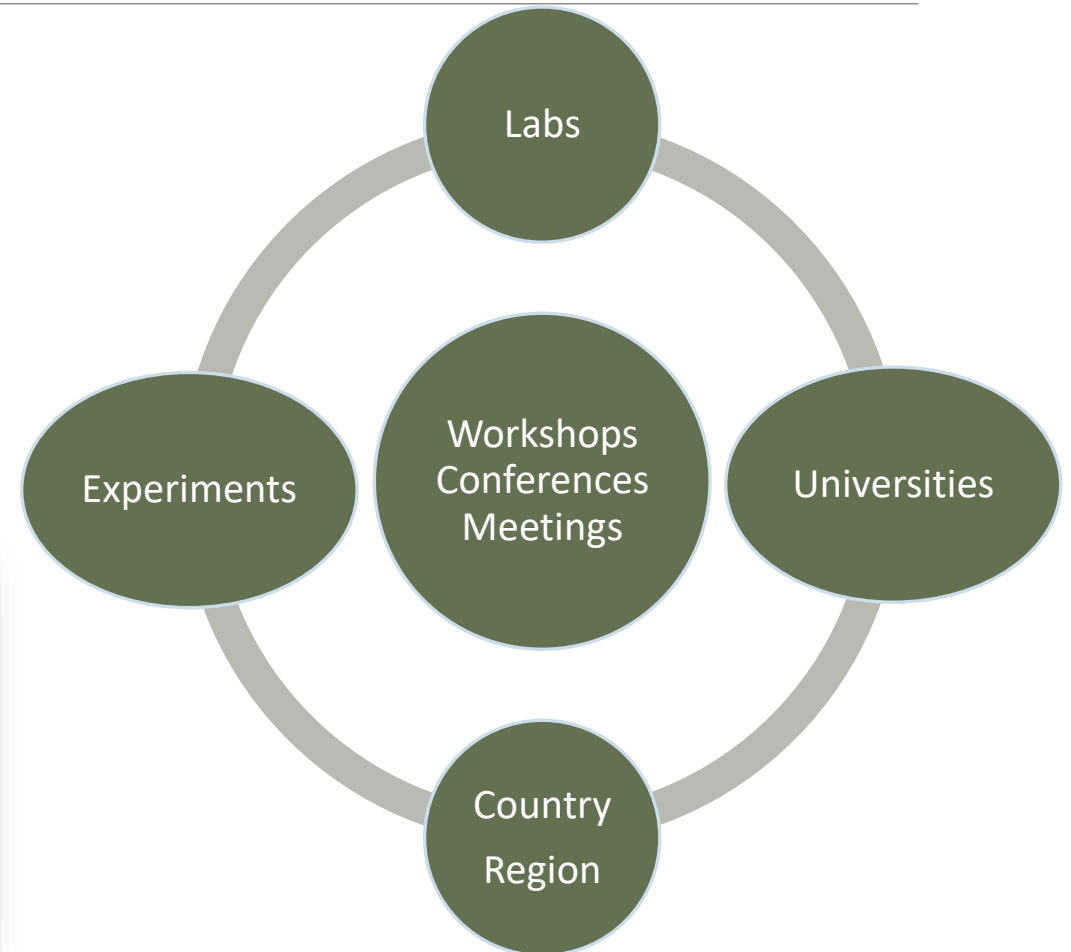
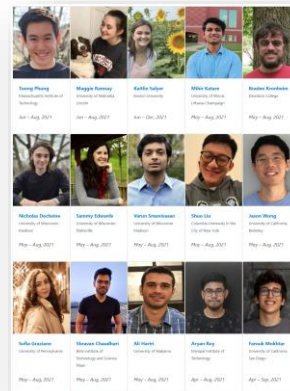
- Entry Level: Software Carpentries
- Domain Specific: Using common tools, ML schools
- Experiment Specific: Internal boot camps

Sponsored Efforts

- Weeklong training events (paid travel)
- Co-located with National Meetings
- Mentorship: Fellows programs (in person & remote)

Building the Field

- Job Market
- Citations & other forms of credit
- Job Promotions



Algorithms: Gateway to Science

CMS's High Granularity Calorimeter

Finer Grained Detector

15K → 6000K Readout Channels

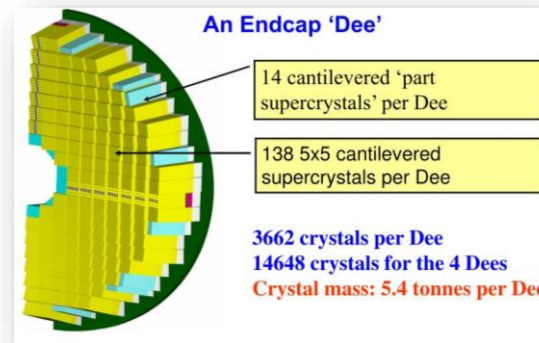
Unprecedented ability to study jet evolution

Algorithms & Computing

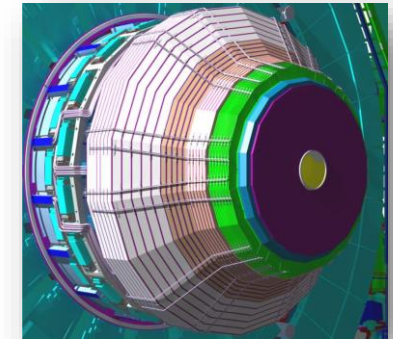
- Unprecedented jet reconstruction, resolution
- Jet evolution studies never before possible
- Energy measurement shorter than radiation length

New algorithms: Graphical Neural Networks!

If this works, likely the future of calorimeters in HEP



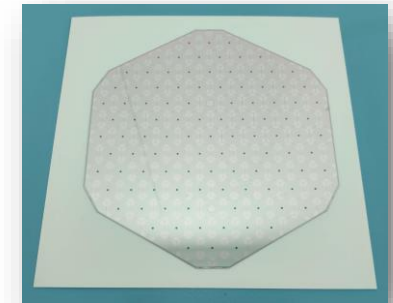
Run 2



Run 4



PbWO4 Crystals



Silicon Cells!