Institute for Research and Innovation in Software for High Energy Physics (IRIS-HEP)

Evolving the Innovative Algorithms area towards IRIS-HEP2.0

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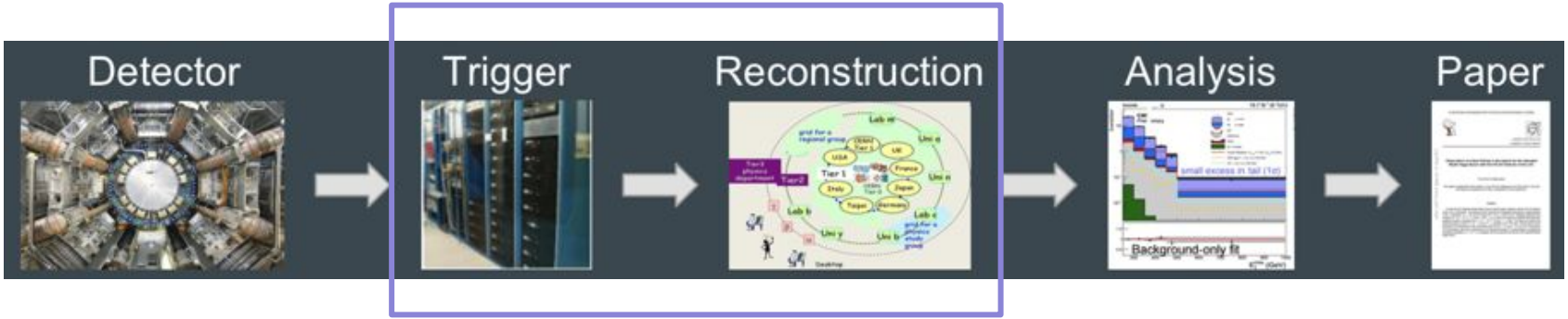
http://iris-hep.org

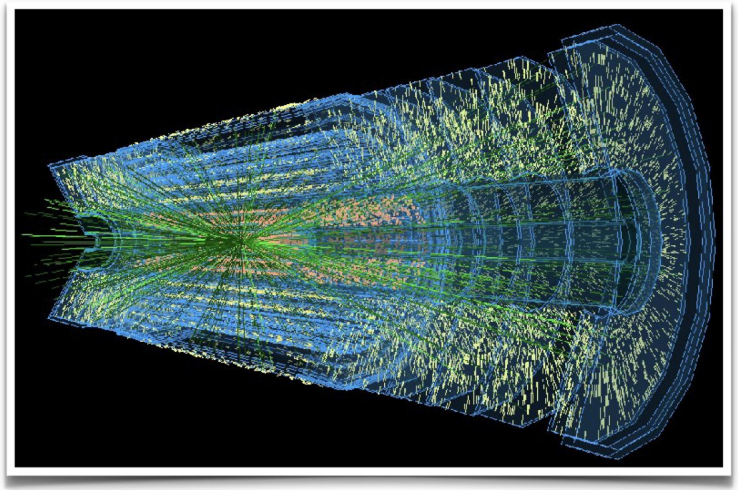
From Detector to Physics Analysis



- Pattern recognition of charged particles (**tracking**) is the most computationally demanding piece of event reconstruction.
- Need **faster** track reconstruction algorithms with **better physics** performance to **extend the scientific reach** of the HL-LHC

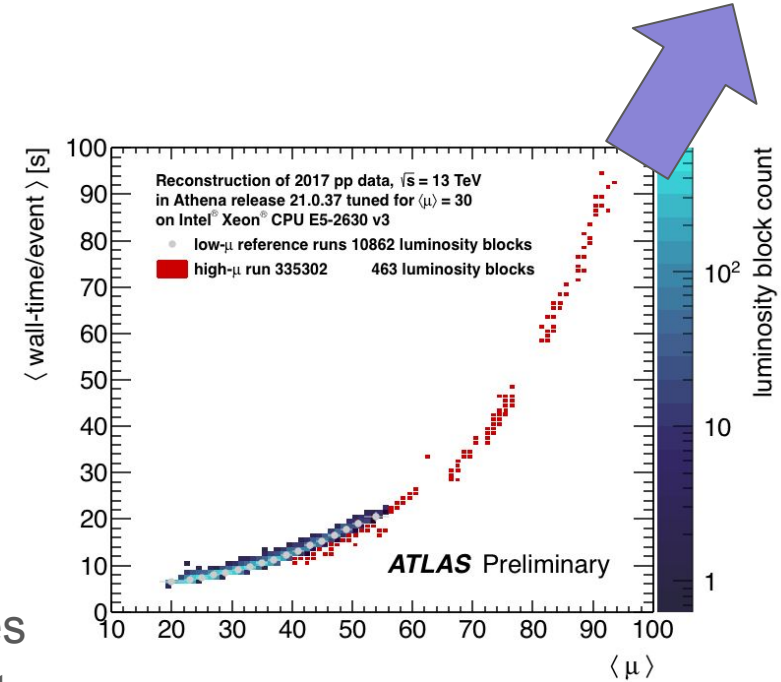
Tracking challenge for HL-LHC

- Online trigger will need to process **1 trillion events/yr** (10^{15} tracks)
  - 10x Run 3
- Up to **500 billion events/yr** will need to be processed offline
  - Up to 10x Run 3



Tracking Challenge for HL-LHC

- Upgraded accelerator
  - **non-linear increase** in collisions per bunch crossing (pileup)
- Detector upgrades
  - new detector technologies
  - additional **channels**
- Increased **event rates** due to trigger upgrades
- Evolving **heterogeneous** computing architectures

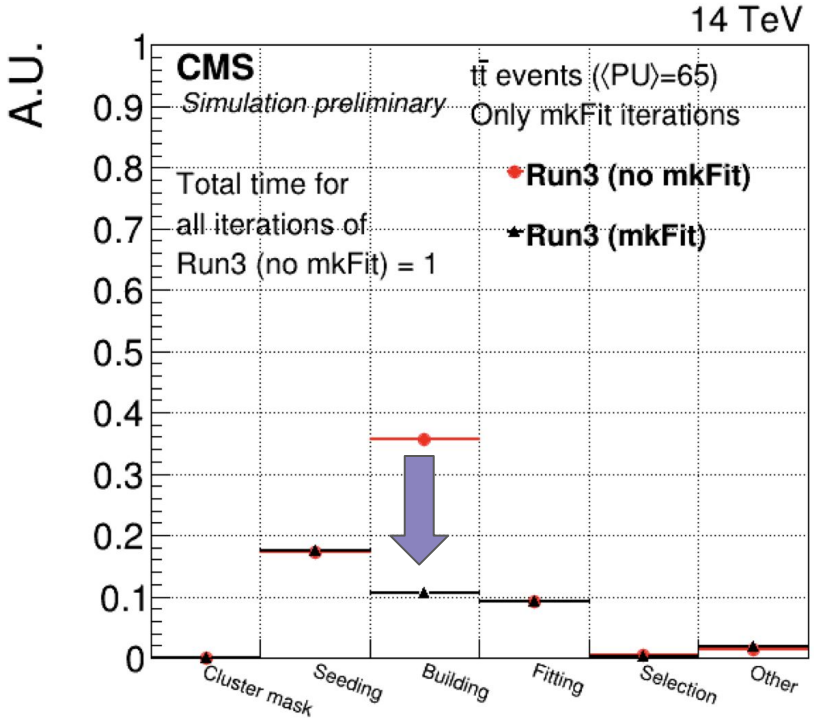


Our approach has been to pursue multiple R&D strategies

- Re-engineer existing algorithms for new technologies and new detectors
- Explore novel algorithms, e.g. using machine learning

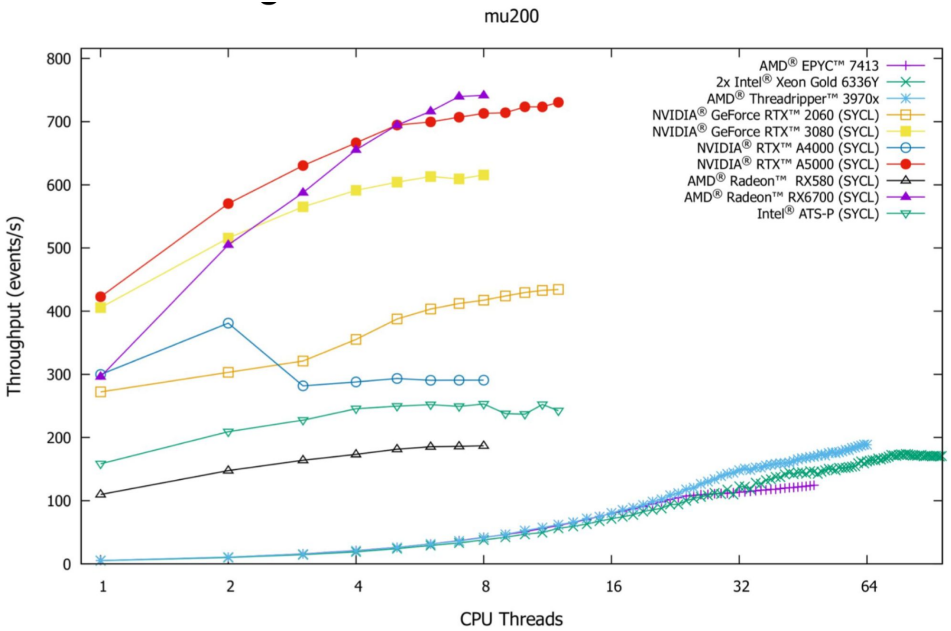
IRIS-HEP 1.0: MkFit

- Reengineered **Kalman Filter** tracking algorithm
  - Maintains physics performance
- **Track building** is most time intensive component
  - **scales** poorly with pileup
- **5x reduction** in track building time for Run 3 → Larger gains expected for HL-LHC
- **Deployed** for CMS for Run 3
- (S. Lantz *et al* 2020 *JINST* **15** P09030)



IRIS-HEP 1.0 ACTS

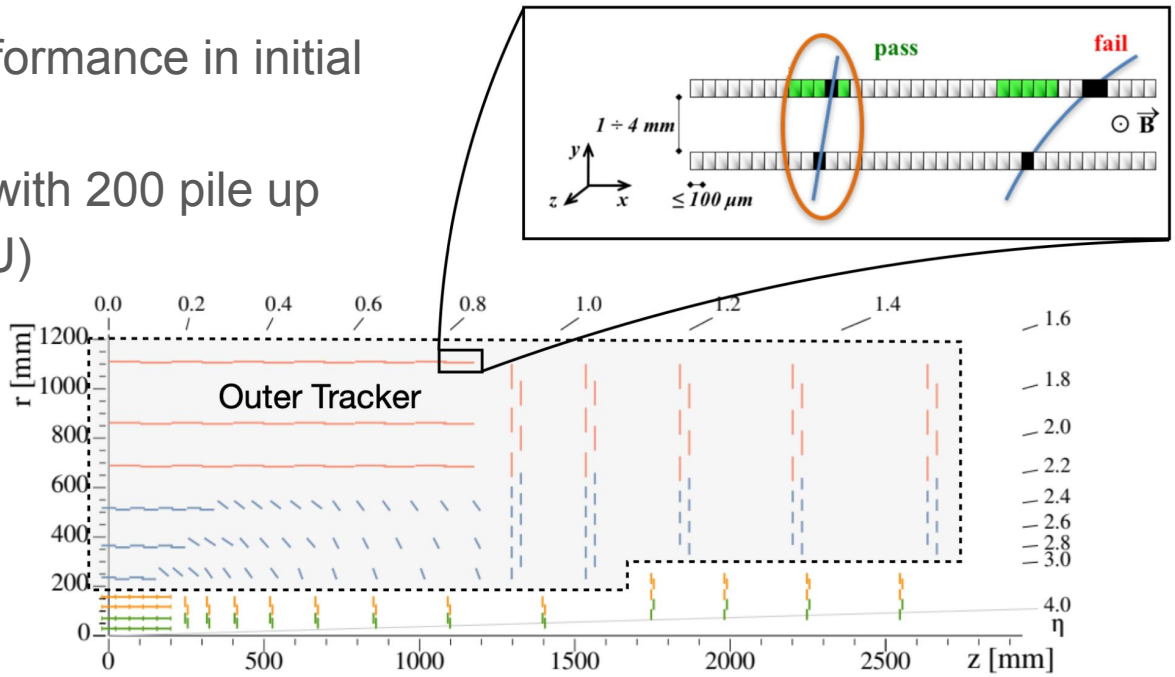
- **Experiment-independent** tracking code
- Key components (extrapolator and vertexing) **deployed** in ATLAS for Run-3
- Under evaluation as a **demonstrator** for ATLAS for Run-4
- Already used by experiments **beyond the LHC**: sPhenix, Belle-II, FASER, etc
- **X. Ai et al, CSBS 6 8, 2022**



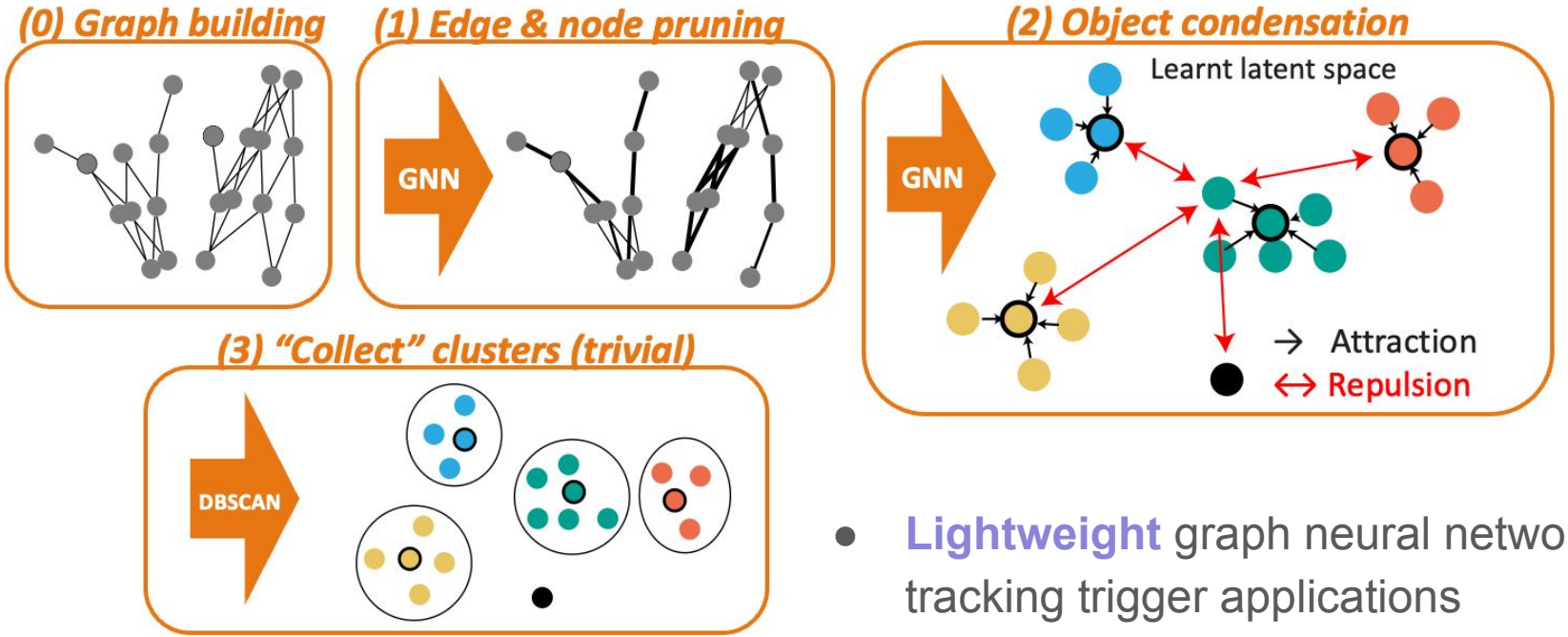
Seeding performance from traccc (GPU prototype of ACTS)

IRIS-HEP 1.0: Line Segment Tracking

- Designed for **GPUs** and CMS HL-LHC **tracker geometry**
- Good physics performance in initial CMS integration
- O(9ms)/event on with 200 pile up events (A100 GPU)



IRIS-HEP 1.0: Object Condensation Tracking (OCT)

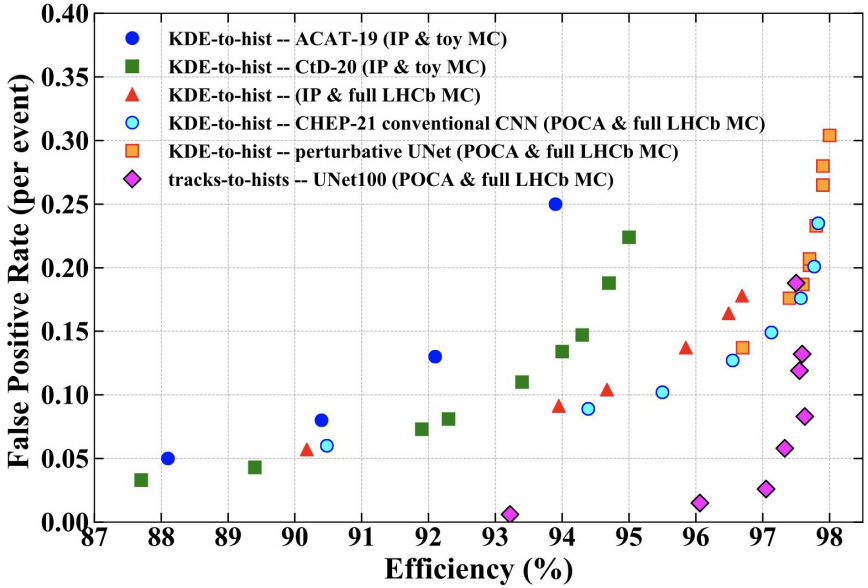


- **Lightweight** graph neural networks for tracking trigger applications
- Early stage of **R&D**; using trackML* dataset
- Potential **linear scaling** with pile up

*dataset made with ACTS

IRIS-HEP 1.0: PVFinder

- Identify tracks coming from common vertex using Machine Learning approach
- Under development for both LHCb and Atlas use cases
- Good physics performance achieved. Working to adapt codes to those appropriate for LHCb GPU trigger
- R. Bala Garg, CHEP presentation



Looking forward: Delivery and Feedback

Delivery:

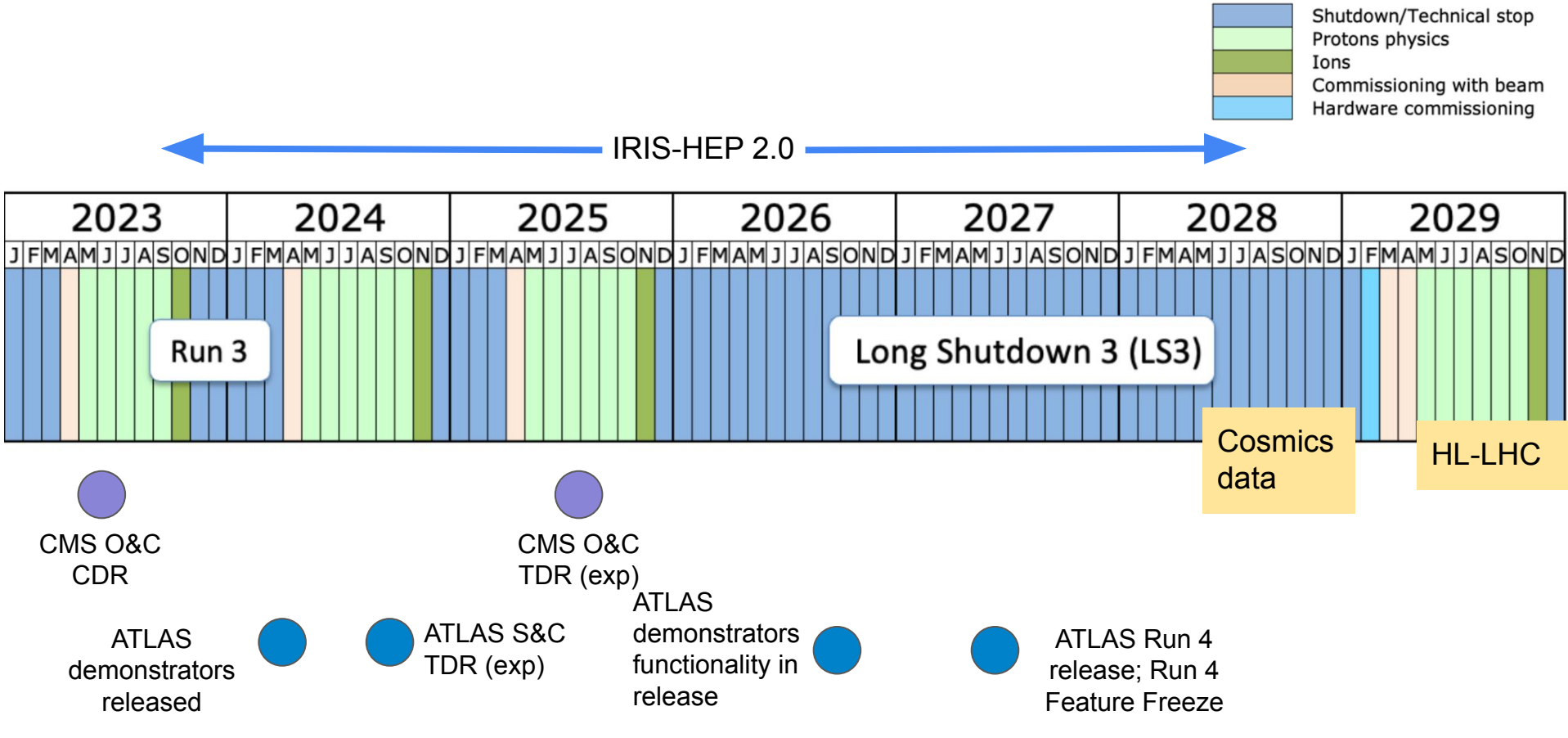
- Software must be **integrated** into experimental frameworks to be **used**
- Teams are experienced in integration
- Team members hold **key roles** within the experiments, e.g.
  - mkFit team includes **CMS tracking convener,** High Level Trigger contact, and **tracking upgrade coordinator**
  - ACTS team includes ATLAS **data preparation coordinator**, **upgrade tracking convener**, Event Filter L4 coordinator

Feedback:

- Experimental tracking **meetings**
- **Validation** campaigns
  - Tracking performance and impact on applications using tracks
  - Typically take **many months**

Project	IRIS-HEP FTE	US collaborators	International collaborators	Experiments engaged
ACTS	UC-Berkeley Stanford	USATLAS ops	CERN DESY	Atlas, EIC, Belle-II, sPhenix LDMX, …
mkFit/LST	UC-San Diego Cornell Princeton	USCMS-SW&C ops program base grants at UCSD Cornell FNAL via HEP-CCE (P2R) Formerly: Scidac		CMS
OCT	Princeton	GeorgiaTech CS (Miao/Li) UCSD physics (Duarte) Formerly: USCMS ops postdoc program		CMS
PVFinder	Cinnicati	NSF CSSI	MIT	LHCb, ATLAS

Timeline for reco/trigger algorithms through HL-LHC start



Maintenance and operation

- Personpower needs differ for **maintenance** vs **development**
  - Beyond IRIS-HEP, expect to rely on **research** (physics performance) and USATLAS and USCMS **operations** (software aspects) programs
    - e.g. ACTS/mkFit have already engaged with operations programs
- Maintenance will be necessary until **end of data taking**
  - Tasks organised by experiment **working groups**
    - Teams are well-integrated in these groups
  - Monitoring **physics** and **technical** performance during evolving conditions
    - Tracking efficiency, fake rate, simulation correction factors for each dataset
  - **Evolving software** given evolution in computing technologies and experimental frameworks

Summary

- IRIS-HEP plays a **crucial role** in the development of HL-LHC tracking solutions
  - mkFit has been **adopted by CMS** for Run-3
  - components of ACTS have been **adopted by ATLAS** for Run-3
- New avenues of R&D may lead to **novel solutions**
  - e.g. using machine learning or in the context of the software trigger
- We have a parallel session tomorrow for projects to discuss their plans (and more up to date achievements)
- IRIS-HEP 1.0 was successful in promoting **career development** for IRIS-HEP members working on tracking