

# H1 data preservation



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MAX-PLANCK-INSTITUT  
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DPHEP meeting  
October 2024



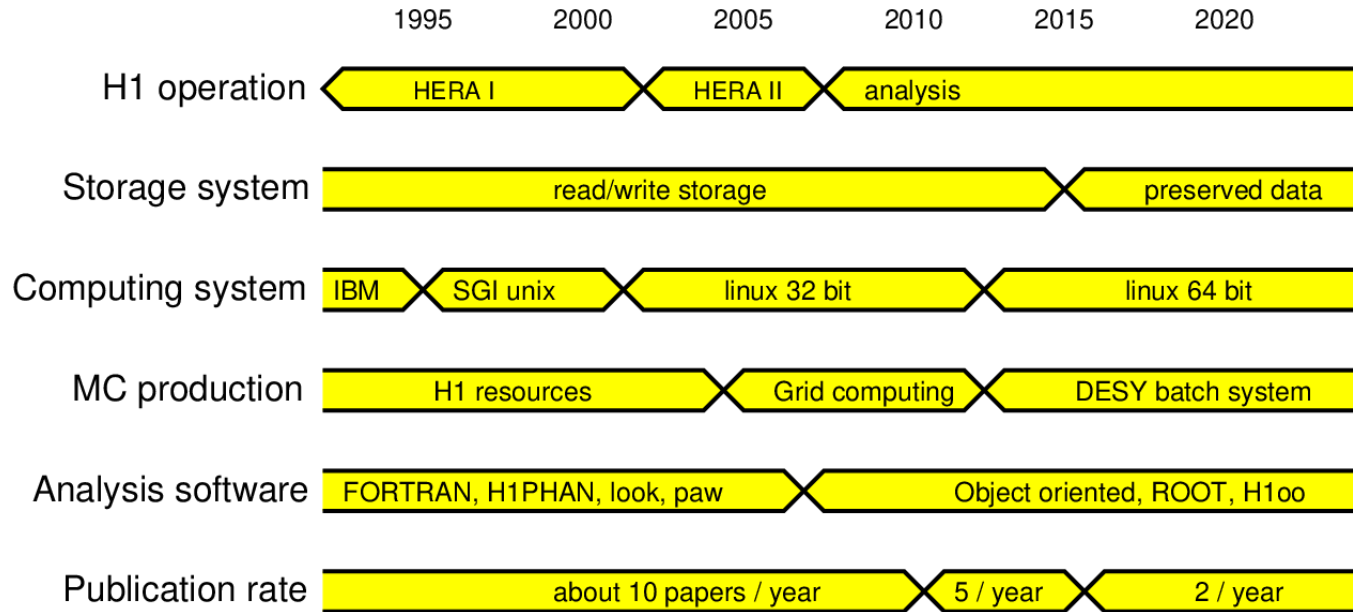
## Outline:

- H1 storage and analysis model
- Recent physics highlights
- DPHEP status and recent developments



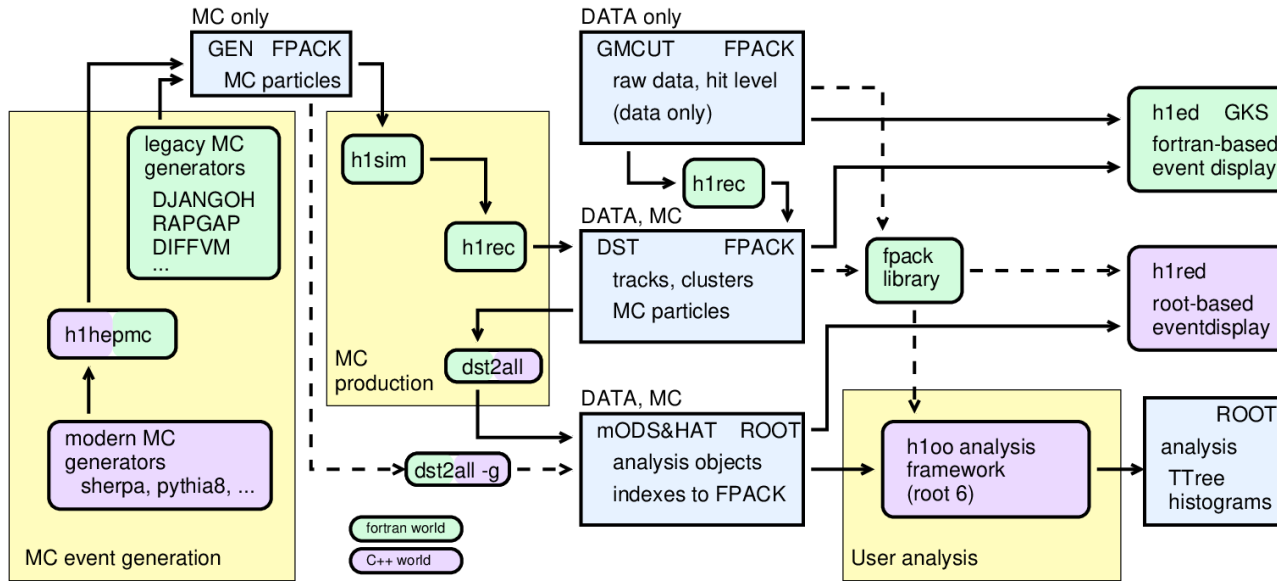
# The H1 collaboration

- $\sqrt{s}=320$  GeV ep collider HERA at DESY, data taking 1992-2007
- Once 400, today still 150 members. About 2 papers per year



- Have seen many computing environments come and go
- Our model: keep the H1 software alive (Level 4 data preservation)

# Present H1 storage and analysis model



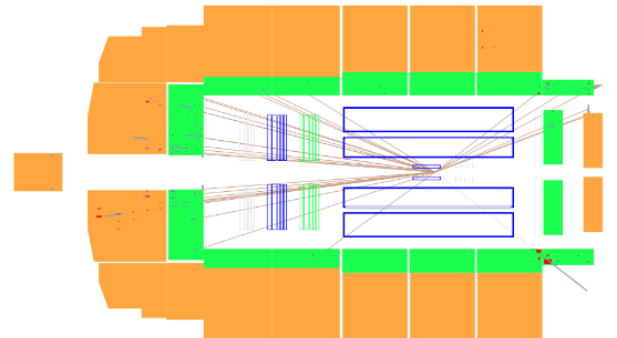
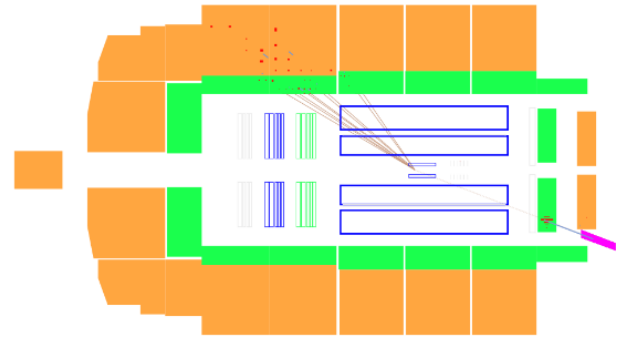
- User-level: Root based analysis
- On-the-fly access to FORTRAN objects from object-oriented program (track segments, hits, etc)
- Simulation is interfaced to HEPMC3

- Detector simulation “h1sim”: based on GEANT3, written in fortran
- Reconstruction “h1rec”: written in fortran

# Recent physics results (2024)



- As Electron-Ion Collider effort ramps up, interest in HERA data has increased significantly
- Useful for training students, applying new tools from data science. Level-4 preservation is ideal
- Theory of jet physics has advanced significantly since 2007!
- Thus recent H1 results have focused on investigations of the hadronic final state

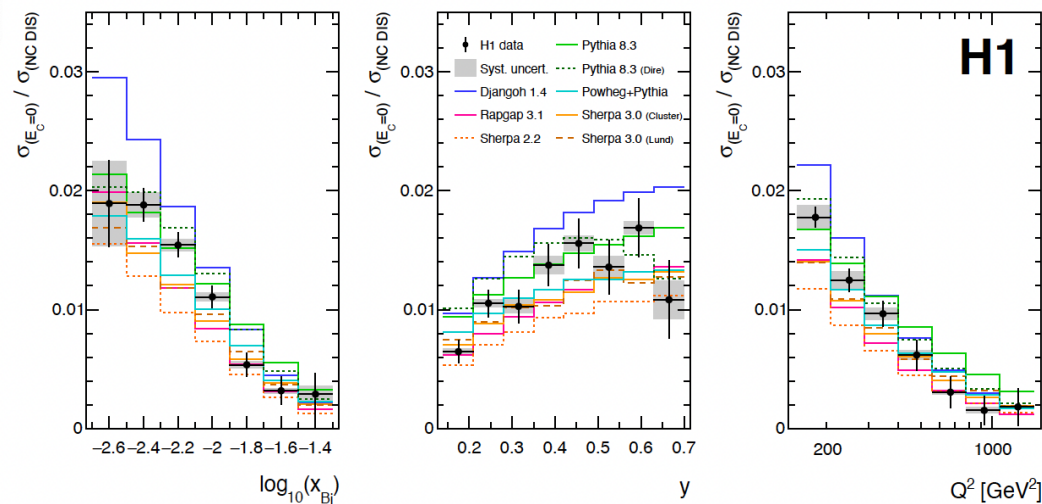


# Recent physics results (2024)



- Recent H1 results: investigations of the hadronic final state

- Jet substructure (2023)
- Angular moments (2023)
- Empty hemisphere events EPJ C84 (2024), 720 [2403.08982]
- 1-jettiness eventshape
- Groomed eventshapes

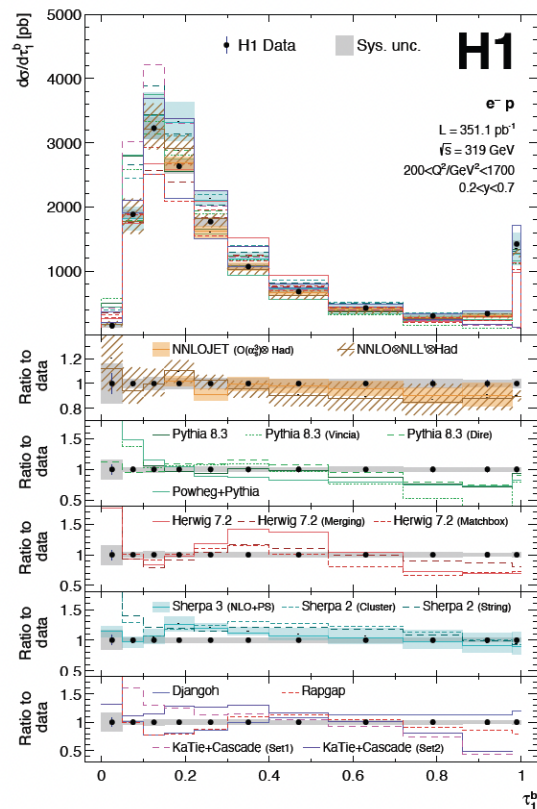


Fraction of empty hemisphere events (Breit frame) is measured for the first time. Models perform reasonable in terms of shape, less so in normalisation.

# Recent physics results (2024)



- Recent H1 results: investigations of the hadronic final state
  - Jet substructure (2023)
  - Angular moments (2023)
  - Empty hemisphere events
  - 1-jettiness eventshape: [2403.10109], EPJ C84 (2024) 785
  - Groomed eventshapes



1-jettiness event shape is measured in the Breit frame at HERA for the first time

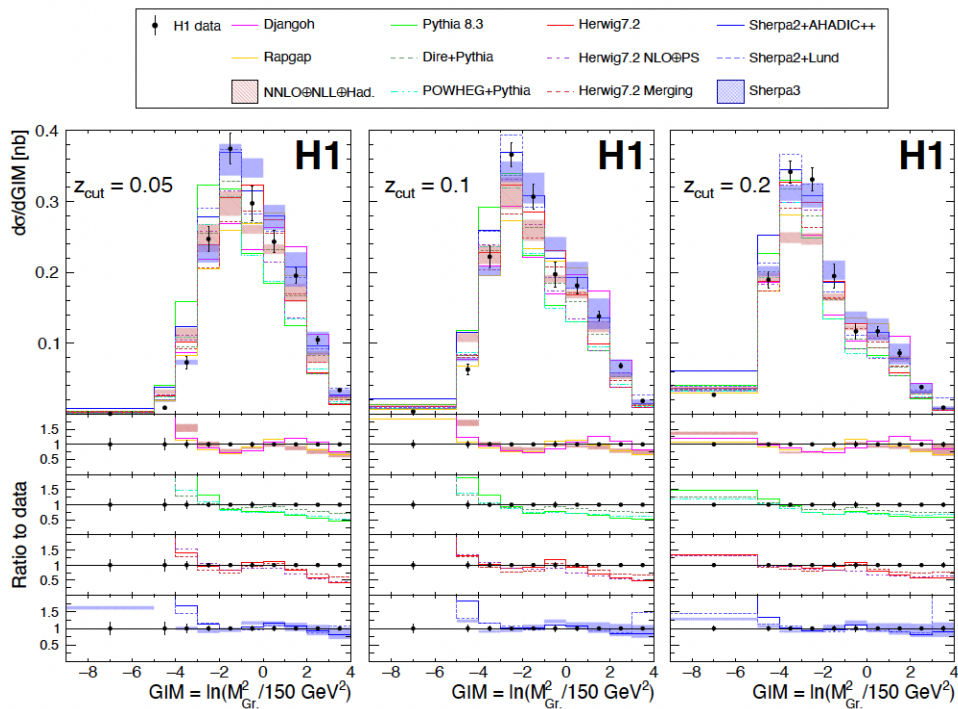
MC models do a reasonable job. These precision data can be used to tune the models in great detail (3D distributions are unfolded)

# Recent physics results (2024)



- Recent H1 results: investigations of the hadronic final state

- Jet substructure (2023)
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- Empty hemisphere events
- 1-jettiness eventshape
- Groomed eventshapes: [2403.10134], EPJ C84 (2024) 718



Groomed invariant mass and 1-jettiness are measured. First time grooming is tested in ep. Models have some difficulties to describe our data.

# DPHEP developments and status



- 2015: transition to DPHEP storage (read-only), selected data and MC sets
- 2017: transition from SL5 to SL6 (32 to 64 bit)
- 2019: revive GKS-based event display
- 2020: large-scale modernisation of software stack, including cc9, ROOT6, C++20, pythonic analysis, LCG compatibility, transition from SL6 to SL7 and from svn to git [[vCHEP2021](#)]
- 2024: transition to SL9 basically completed

Also can run SL5-SL7 binaries in containers



# Summary / Outlook



- H1 still is an active collaboration, lots of interest from people involved in Electron-Ion Collider @ BNL
- 3 papers in 2024, working of the 4<sup>th</sup>
- Recent development: transition to SL9
- Outlook: we have several results of unbinned unfolding, will have to find a clever way to present these  
(event lists with particle-level observables and a set of weights for obtaining uncertainties → users can do their own binning)



- backup

# Recent physics results (2023)



- Recent H1 results: investigations of the hadronic final state

- Jet substructure

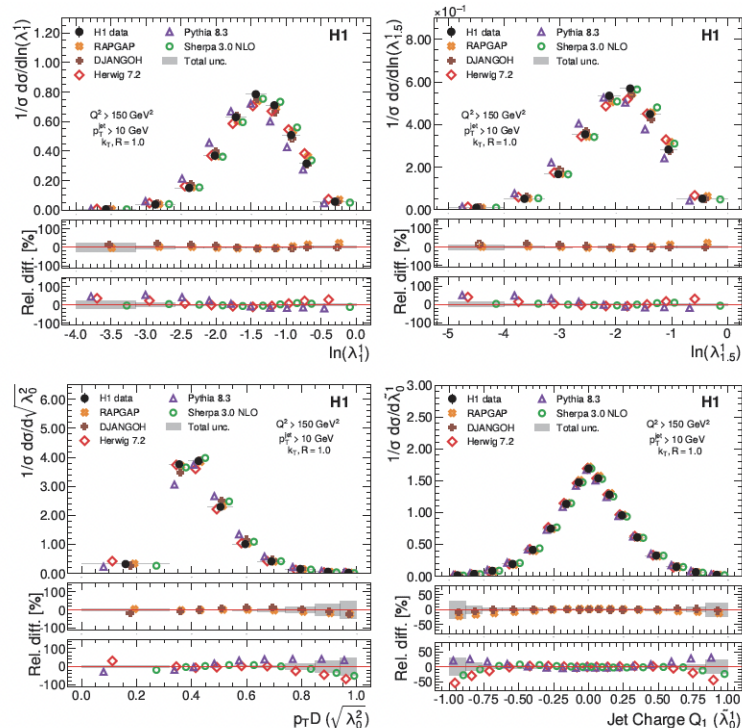
PLB844 (2023) 138101  
[arXiv:2303.13620]

- Angular moments

- Empty hemisphere events

- 1-jettiness eventshape

- Groomed eventshapes



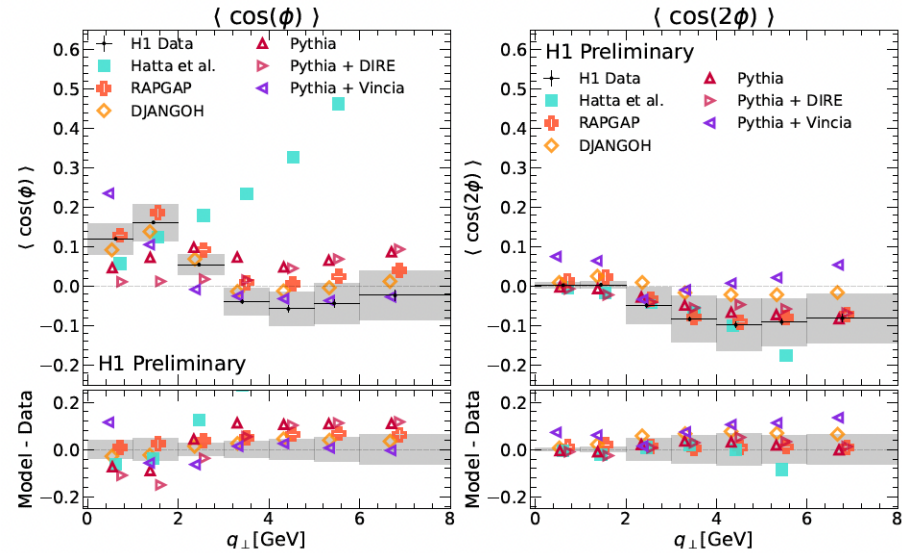
Unbinned unfolding using machine learning (multifold)

Six jet substructure variables are measured

# Recent physics results (2023)



- Recent H1 results: investigations of the hadronic final state
  - Jet substructure
  - Angular moments  
H1prelim23-031
  - Empty hemisphere events
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  - Groomed eventshapes



Unbinned unfolding using machine learning (multifold)  
Angular moments of the jet-lepton azimuthal angle are measured – sensitive to gluon radiation