

# EXPLORE: a multi-experiment open-access platform for education and training with LHC open data

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T 96.4: Outreach II



## EXPLORE within PUNCH4NFDI

### PUNCH4NFDI

NFDI consortium for  
Particle • Astro-particle • Hadron & Nuclear  
Physics • Astronomy

- ~9000 scientists in Germany
- Universities, Max Planck, Leibniz & Helmholtz institutions
- Part of the Nationale Forschungsdateninfrastruktur (NFDI)

### Enabling Open & FAIR Physics

- Federated & FAIR Science Data Platform (PUNCH-SDP)
- Infrastructure for data & computing access
- Support for big data, open data & FAIR workflows

Georg-August-Universität Göttingen a partner of PUNCH4NFDI

**TA2** – Compute4PUNCH (federated computing)

**TA6** – Services in Big Data Management → **EXPLORE**

**TA7** – Training, Education & Outreach

Designed as an open-access service - not restricted to collaboration members.

## What High Energy Physics Provides

- Strong commitment to **FAIR data principles**
- Large volumes of **LHC Open Data publicly released**
- Long-term data preservation efforts
- Open access via CERN Open Data Portal

## What Still Limits Broader Use

- Complex experiment software environments
- Infrastructure requirements (storage & compute)
- Non-trivial workflow setup
- Tools not easily accessible to outsiders
- Access often tied to collaboration or institutional affiliation



**FAIR data is available - but access and usability remain limited.**

## A Gateway to LHC Open Data







### Under the Hood

- Tier-2 ATLAS computing site
- Distributed batch system
- Containerized environments
- Secure data access

### For the User

- No installation
- No framework setup
- No local downloads
- Scalable compute access
- No CERN collaboration membership required
- No university affiliation required

### Who Is EXPLORE Designed For?

-  University & high-school teachers
-  Students (high school & university level)
-  Theorists without LHC experiment access
-  Open to users without CERN collaboration membership.

**Research infrastructure - simplified for open access.**

## ATLAS & CMS Open Data on EXPLORE

- **Support ATLAS Open Data (2020 & 2025)**
- **146 samples prepared for execution on EXPLORE**
- 13 TeV proton–proton collision data
- Educational & analysis-level formats
- Ready-to-run tutorial workflows

### How Users Progress

- Start with guided tutorials
- Build custom workflows
- Execute at scale on cluster resources
- Comprehensive documentation, Structured tutorial repository, Dedicated support team

### What Users Can Execute

- Pre-configured, executable physics workflows:  $t\bar{t}(\ell+\text{jets})$ ,  $H \rightarrow \gamma\gamma$ ,  $H \rightarrow ZZ$ , ...
- Object kinematics studies, event topology
- Full analysis chain

### CMS Open Data Status

- Selected 13 TeV CMS Open datasets validated
- Scalable execution demonstrated
- Additional datasets under evaluation
- Expansion planned in coming months

Education-ready entry point. Research-level scalability.

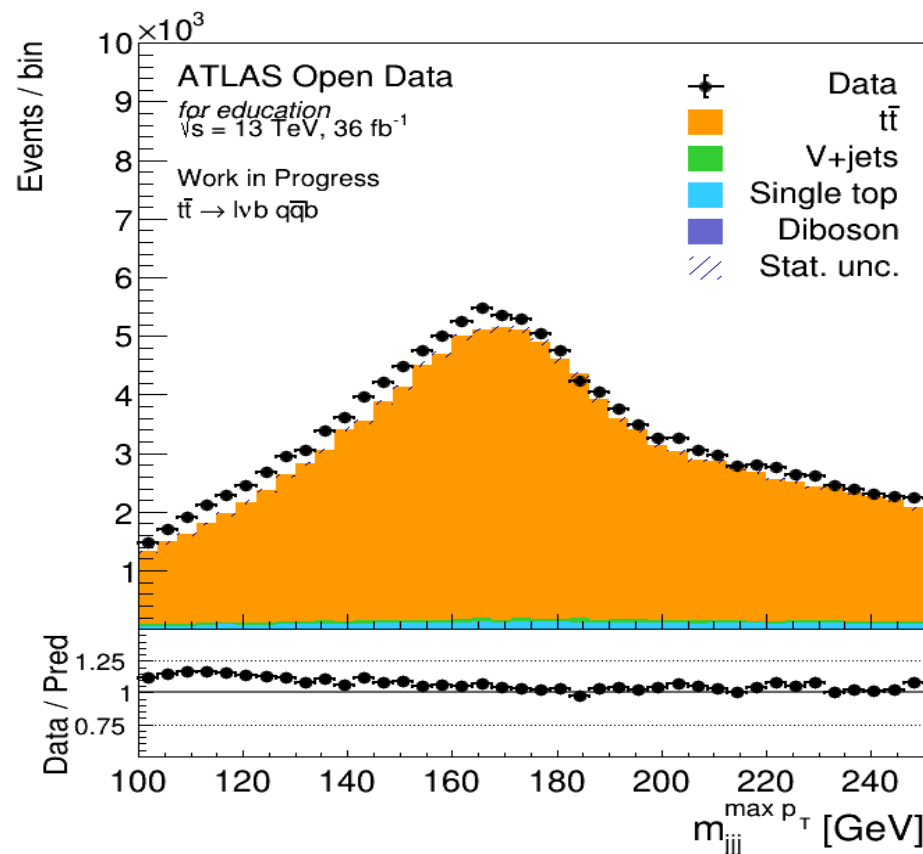
## ATLAS Open Data Tutorial @CERN (Nov. 2025)

### Real Training Environment

- Hands-on session using 13 TeV ATLAS Open Data
- No software installation
- No local data download

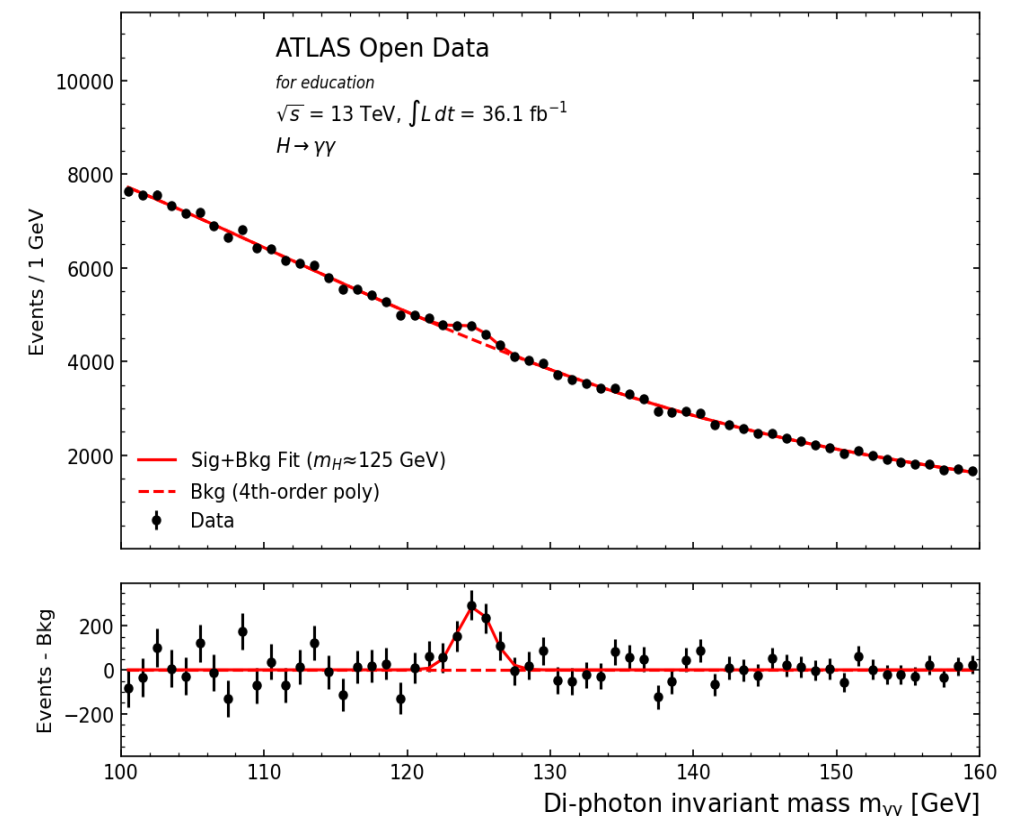
### Analyses Executed

- $t\bar{t}(\ell+jets)$  mass reconstruction
- $H \rightarrow \gamma\gamma$  invariant mass spectrum
- Object-level kinematic studies



### Top mass reconstruction ( $\ell+jets$ )

ATLAS Open Data (13 TeV) Beta Release – CERN Open Data Portal  
Workflow inspired by ATLAS Open Data tutorial, executed on EXPLORE



### $H \rightarrow \gamma\gamma$ invariant mass

ATLAS Open Data (13 TeV) Beta Release – CERN Open Data Portal  
Workflow inspired by ATLAS Open Data tutorial, executed on EXPLORE

### What This Demonstrates

\* Infrastructure scales to multiple users

\* Ready for classroom deployment

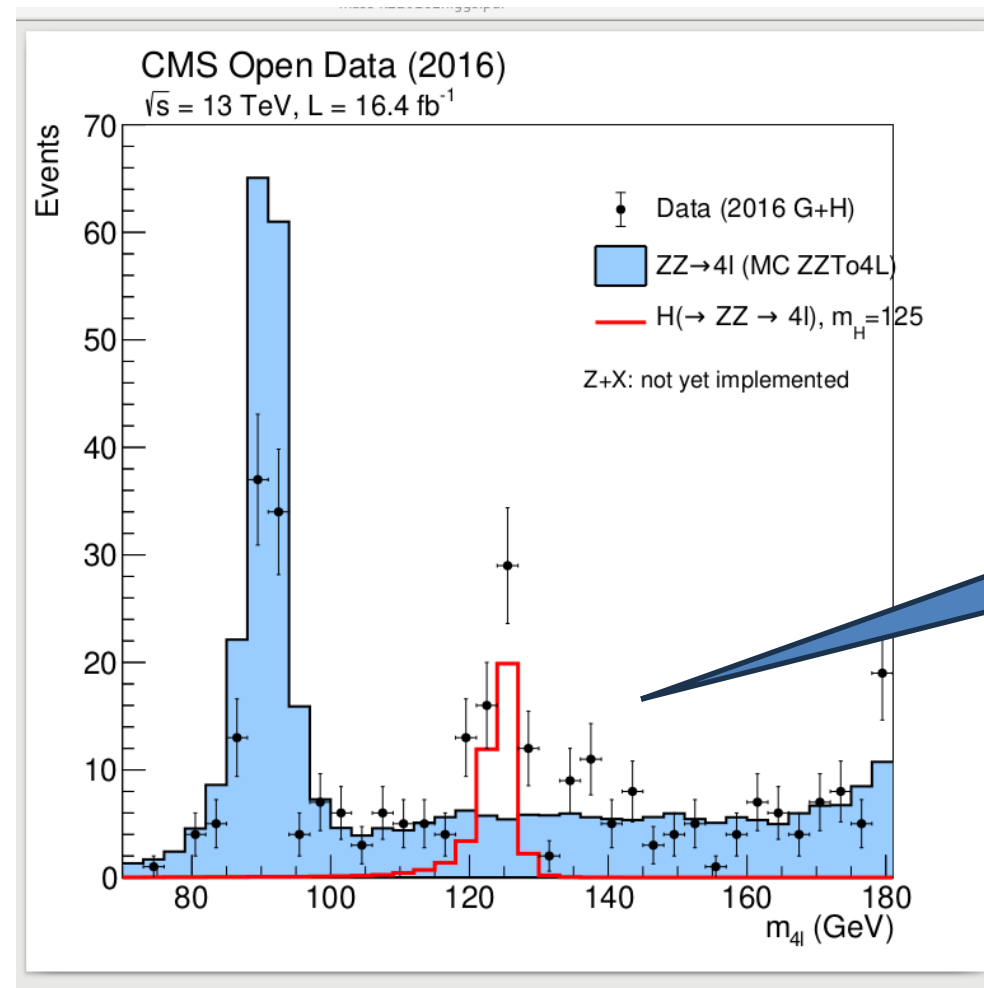
\* Reproducible analysis environments



# Beyond ATLAS: CMS Open Data

Can EXPLORE support CMS Open Data within the same scalable model?

■ **Physics Case**  
 $H \rightarrow ZZ \rightarrow 4\ell$  (2016)



**Higgs  
Peak**

**$H \rightarrow ZZ \rightarrow 4\ell$  invariant mass**

CMS Open Data (13 TeV) – CERN Open Data Portal  
Analysis workflow implemented on EXPLORE

## What This Demonstrates

- \* Not limited to one collaboration ecosystem
- \* Scalable & containerized execution
- \* Supports multiple Open Data formats
- \* Suitable for research-style studies

# Real LHC Data. Open to You



## Education

- Hands-on particle physics
- Real LHC collision data in class
- Suitable for university & high schools
- No IT infrastructure required



## Research

- Access to LHC Open Data
- No collaboration membership needed
- Test ideas on real datasets
- Scalable compute resources



## Open Science

- FAIR principles in practice
- Reproducible workflows
- Inclusive participation
- Lower barrier to entry

**From observing results → to performing analyses.**



**Real LHC data is ready to analyze - today.**

## Registration Takes Minutes

- Simple online registration
- No CERN credentials required
- Personal workspace provided
- Immediate access to datasets & workflows
- Scalable research computing included

**Try It in Your Class!**  
**Test It for Your Research!**

 <https://punchlogin.goegrid.gwdg.de>  
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**We welcome teachers, students, and researchers to join.**

**THANK YOU!**

# Acknowledgments & Links

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[PUNCH4NFDI.de](https://punch4nfdi.de)



[PUNCH4NFDI  
on ZENODO](#)



# BACKUP

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- [1] PUNCH4NFDI – <https://www.punch4nfdi.de>
- [2] HTCondor – <https://research.cs.wisc.edu/htcondor/>
- [3] COBaID <https://doi.org/10.5281/zenodo.1887872>
- [4] TARDIS <https://doi.org/10.5281/zenodo.2240605>
- [5] CVMFS – <https://cernvm.cern.ch/fs/>
- [6] Grafana – <https://grafana.com/>
- [7] OpenID Connect – <https://openid.net/connect/>
- [8] Helmholtz AAI – <https://www.helmholtz.de/en/aai/>
- [9] CERN Open Data – <https://opendata.cern.ch>
- [10] EXPLORE - CoRDI2025 presentation, Aachen  
<https://zenodo.org/records/16736008>
- [11] [Tutorial repository for EXPLORE users](#)
- [12] [EXPLORE presentation – PUNCHLunches](#), 2025
- [13] [EXPLORE Hands-on session at the ATLAS Open Data Tutorial, CERN, Nov. 2025.](#)

# EXPLORE setup @GoeGrid -Göttingen

