interTwin


# The interTwin Digital Twin Engine: a platform for building and managing scientific Digital Twins

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Funded by the European Union

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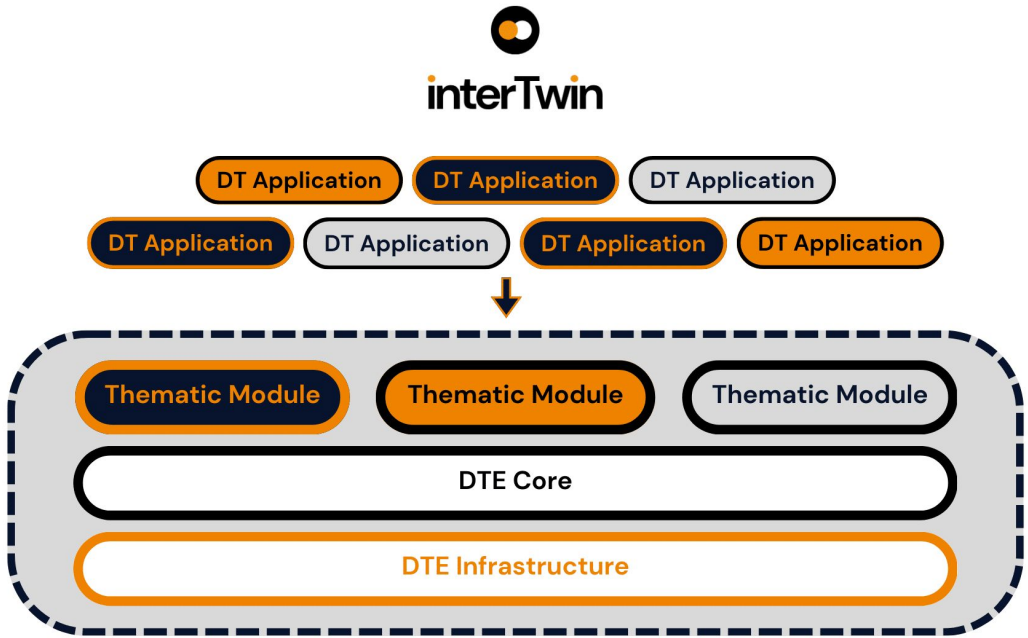
# interTwin - Digital Twin Engine for science

Co-designs and implements the prototype of an **interdisciplinary Digital Twin Engine**

**Open-source** platform based on **open standards**

Piloted by a large spectrum of **diverse use cases** from **physics** and **environmental** sciences



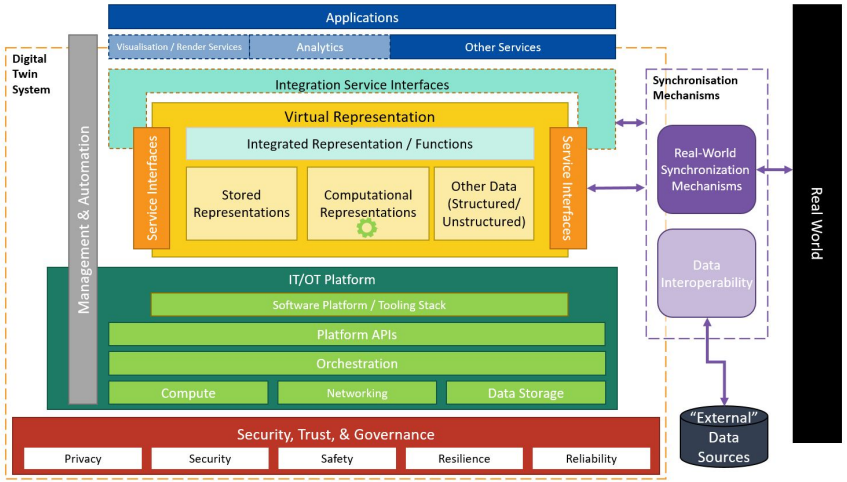

The interTwin Digital Twin Engine (DTE)

# Digital Twins definition(s)

A **Digital Twin (DT)** is a **virtual** representation of a **physical object**, **process**, or **system**. It is created and sustained with information derived from one or many sources of data such as sensors or models considering historical as well as real-time data.

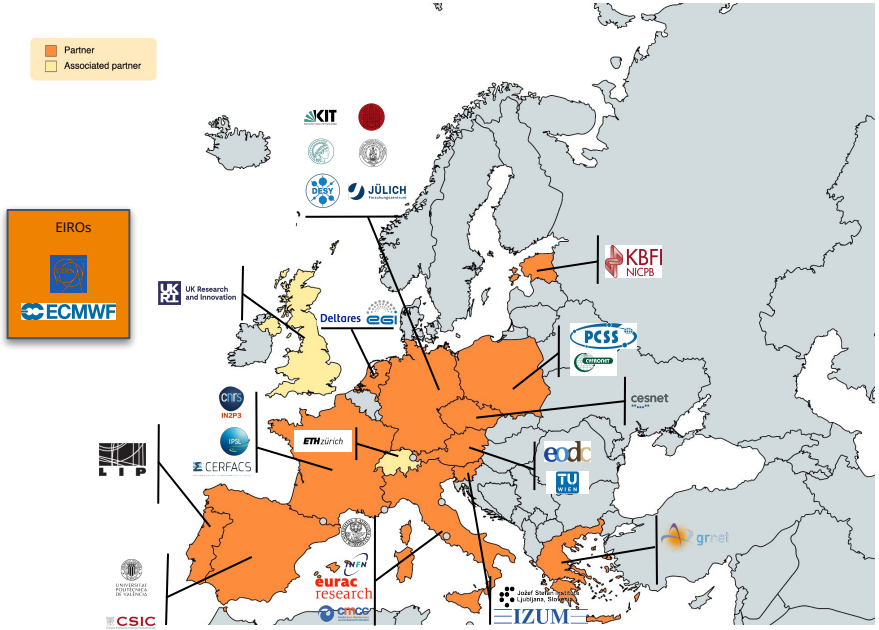
https://www.digitaltwinconsortium.org/glossary/glossary

https://www.deltares.nl/en/expertise/projects/digital-twins




| Type | Industry | Cities & (air)ports | Environment |
|---|---|---|---|
| Goal | Life cycle management | "Smart" cities & (air)ports | Decision support, risk management & dissemination |
| Interventions | Adaptive design | Spatial planning and policymaking | System operation (e.g. sluices & locks) & policymaking |
| Cost reduction | R&D, construction & maintenance costs | Design, construction & maintenance costs | Disaster risk reduction, climate adaptation & biodiversity protection |
| System representation | Single object with many components | Many objects | Many systems |
| Timespan | Seconds - 5 years | Days - 10 years | Days or decades |

# Consortium




1.09.22 - 31.08.25

Budget 11,7 M euro

EGI Foundation as coordinator

**30** **Participants**, including 1 affiliated entity and 2 associated partners

## Consortium at a glance

**10**
**Providers**

cloud, HTC , HPC resources and access to Quantum systems

**11**
**Technology providers**

delivering the DTE infrastructure and horizontal capabilities

**14**
**Community representants**

from 5 domains requirements and developing DT applications and thematic modules

**Objective 1. Co-design, develop and provide a Digital Twin Engine that simplifies & accelerates the development of complex application-specific DTs that benefits researchers, business and civil society**

**Objective 2. Co-design a Digital Twin Engine blueprint architecture that provides a conceptual framework for the development of DTs supporting interoperability, performance, portability & accuracy.**

**Objective 3. Extend the technical capabilities of the European Open Science Cloud with modelling & simulation tools integrated with its compute platform**

**Objective 4. Ensure trust and reproducibility in science through quality, reliability and verifiability of the outputs of Digital Twins**

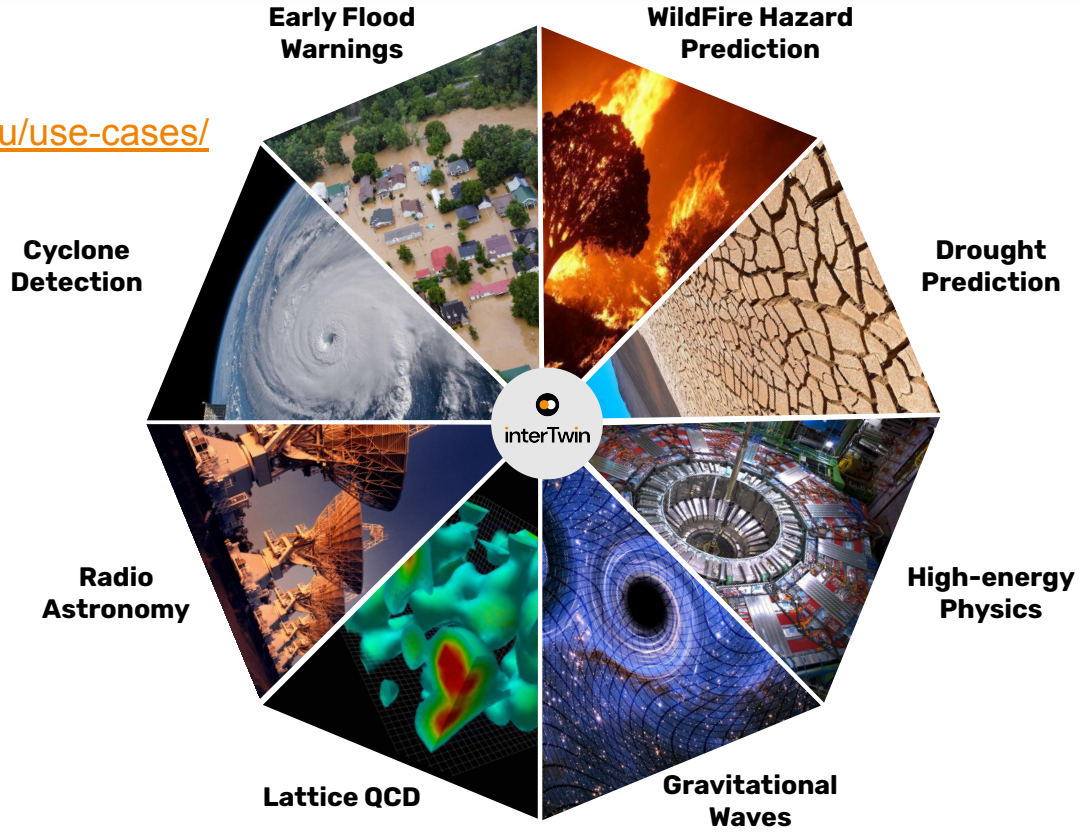
**Objective 5. Demonstrate data fusion with complex modelling & prediction technologies**

**Objective 6. Simplify DT application development with tools to manage AI workflows and the model lifecycle while reinforcing open science practices**

# interTwin Specific Objectives

# interTwin use cases

https://www.intertwin.eu/use-cases/



# Climate research and Environmental Monitoring Use Cases

**Cyclone Detection**
CMCC, CNRS, Univ. of Trento


**WildFire Hazard Prediction**
CMCC, CNRS, Univ. of Trento

ML4Fires: A Digital Twin Component for Wildfire Danger Analysis via Global Burned Areas Prediction on Climate Projection Data
3rd Oct 10:20

**Early warning for Extreme events**
Deltares, EURAC, Technical Univ. of Wien

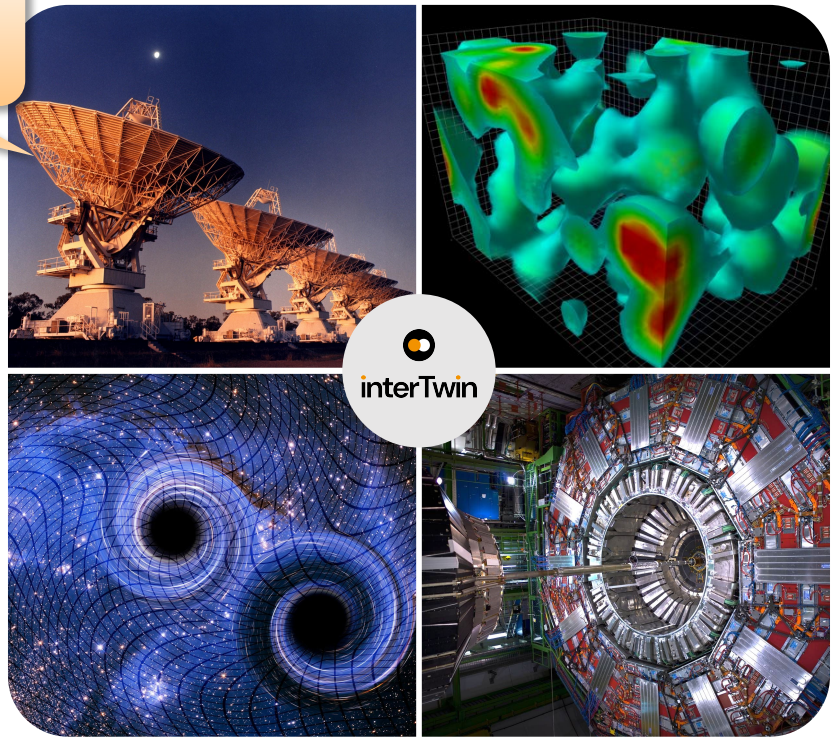
**Extreme events impacts**
CERFACS, EURAC, Deltares

A Digital Twin Application: Climate Extremes Detection and Characterization using Deep Learning
1st Oct 17:25

# Physics Use Cases

Detecting pulsar signals in vast real-time data streams with a machine learning / digital twin-based pipeline
1srt Oct 17:10

**Radio Astronomy Noise simulation**
Univ. of Heidelberg, Max Planck Society




**Lattice QCD Simulation DT**
CSIC, ETHZ

**VIRGO Gravitational Wave Interferometer DT**
INFN

**High Energy Physics Detector Simulation DT**
CERN, CNRS

# Timeline

## Project Year 1 — COMPLETED

**05 - 06.2023** — **DTE Design and specifications**

Deliverables: Report on requirements for all use cases and Design specs

**DTE blueprint architecture**

Deliverable: DTE blueprint architecture, functional specifications and requirements analysis v1

**08.2023** — **DT Applications Design**

Deliverable: First Architecture design of the DTs capabilities

## Project Year 2 — COMPLETED

**11-12.2023** — **Software Releases**

Deliverables: Software releases for all use cases and modules

**01.2024** — **DTE blueprint architecture II**

Deliverable: DTE blueprint architecture, functional specifications and requirements analysis v2

**04.2024** — **Validation**

Deliverables: DT application development and integration report

**09.2024** — **Design and specifications II**

Deliverables: Updated report on requirements for all use cases

## Project Year 3 — Focus now!

**10.2024** — **DTE blueprint architecture III**

Deliverable: DTE blueprint architecture, functional specifications and requirements analysis v3

**01-04.2025** — **Software Releases II**

Deliverables: Final Software releases for all use cases and modules

**07-08.2025** — **Validation II**

Deliverables:
DT application development and integration report
Report on software architecture concepts based on DestinE and InterTwin
Final Architecture design of the DTs capabilities

2023

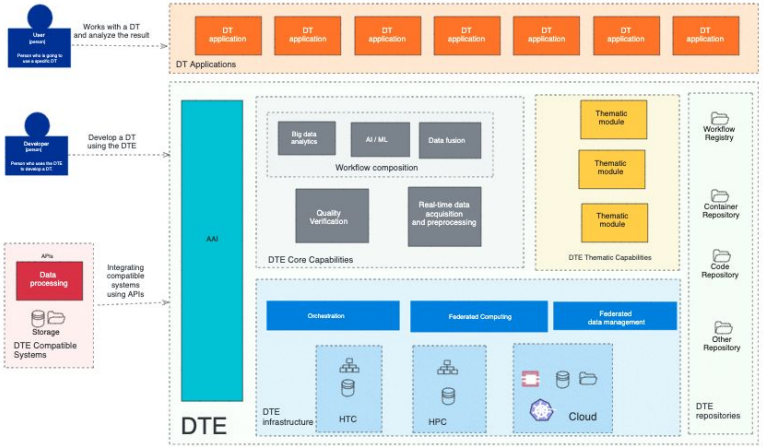
2024

2025

# DTE Blueprint and co-design

- Second version of the Blueprint architecture and design specifications is available in Zenodo

- Final version is planned for Q4 2024

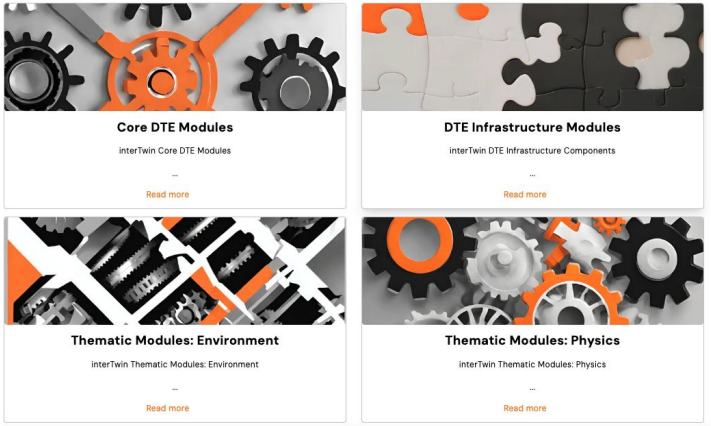



It also includes the analysys of relevant initiatives and projects (*Destination Earth, EOSC, ESCAPE, C-Scale, Digital Twin Consortium and EU Data Spaces, DT-GEO and BioDT*) to identify potential architectural components that can be incorporated within the interTwin context and where interoperability is desirable.

# interTwin DTE First Release

**interTwin** DTE first release available on our Website
https://www.intertwin.eu/intertwin-digital-twin-engine/

- 38 components in Total
- New components developed and extension to existing software
- https://github.com/interTwin-eu




# DTE Core components

Interoperable Workflow Efficiency: Exploring the Integration of OpenEO, CWL and EOEPCA for Seamless Data Processing and Modeling
1 Oct 2024, 15:55

Automated DT Validation in connection with workflow provenance

SQAaaS

yProv

Distributed data analysis embedded with specific workflow tools

COMMON WORKFLOW LANGUAGE

Connecting Real-time data with serverless processing

OSCAR

APACHE nifi

yProv: a Cloud-enabled Service for Multi-level Provenance Management And Exploration in Climate Workflows
3rd OCT 09:40

Quality Verification

Workflow Composition

Big Data Analytics

AI / ML

Data fusion

Real-time data acquisition and processing

TOSCA Templates Repository

ANSIBLE Artifacts Repository

Standardized deployment of Big Data Analytics tools

itwinai

mlflow

Generic ML / AI training framework with support to workflow management and model validation

Bridging Cloud and HPC for Scalable Event-driven Processing of AI Workloads
3rd Oct at 10:00

# DTE Infrastructure components

AAI

Elaborate deployment requests and use AI to find the best deployment strategies

INDIGO-DC PaaS Orchestrator

Enable complex simulation and modelling tasks to access different compute facilities, implementing also **transparent offloading** to HPC

kubernetes

openstack.

interLink

Based on **ESCAPE** Data Lake architecture and services, **Rucio**, **FTS** and HTTP accessed caches/storages.

FTS

dCache

RUCIO

Software

Orchestrator

Federated compute

Federated data management

Hardware

HTC

HPC

Cloud

Data Repositories

Towards a compute continuum with interLink
1st Oct 17:40

The Evolution of INFN's Cloud Platform: improvements in Orchestration and User Experience
1st Oct 15:40

# DTE Thematic components examples

Thematic Modules for Physics include:

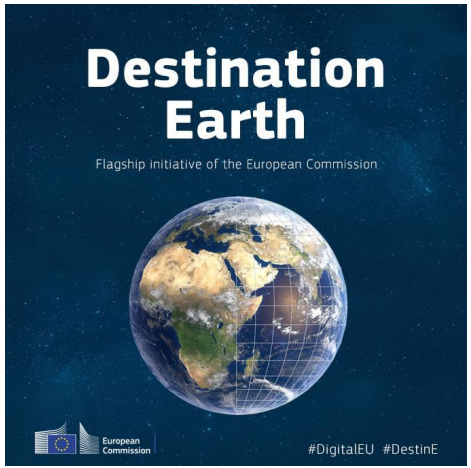
- Machine Learning based analysis for QCD simulation configurations and for time series
- Noise signals classification, noise analysis, de noising, and veto generation in Generative Adversarial Networks (GAN)
- Particle physics validation techniques capable of assessing different aspects of model performance
- Fast simulation of High Energy Physics detectors

Thematic Modules for Environment include:

- Data gathering, filtering, cleaning, harmonisation, augmentation. Event detection and attribution for Machine Learning
- Vector data processing, weather station data filtering and harmonisation
- Climate data downscaling
- STAC Medatada generation from raster datasets

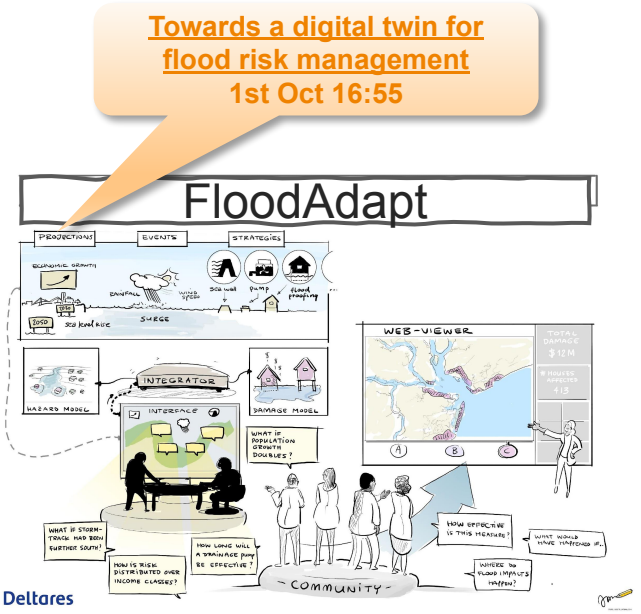
# Interoperability & Link with DestinE

**interTwin** has a dedicated activity of piloting with **DestinE** thanks to **ECMWF** as member of the project




ECMWF

**Pilots** of data handling across interTwin and DestinE Data Lake and Climate DT are under implementation in collaboration with **DELTARES**

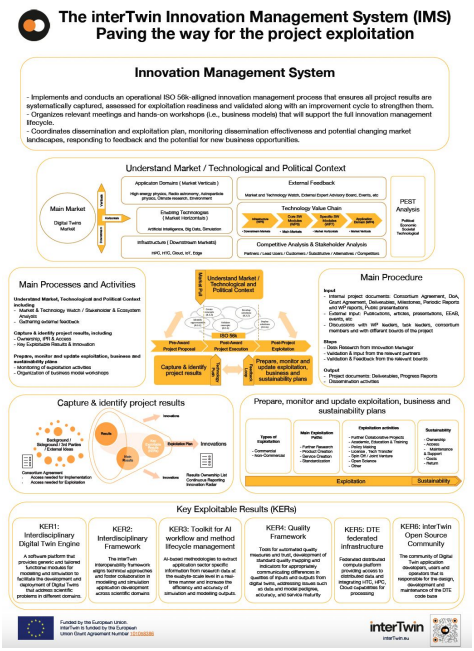


# Conclusions

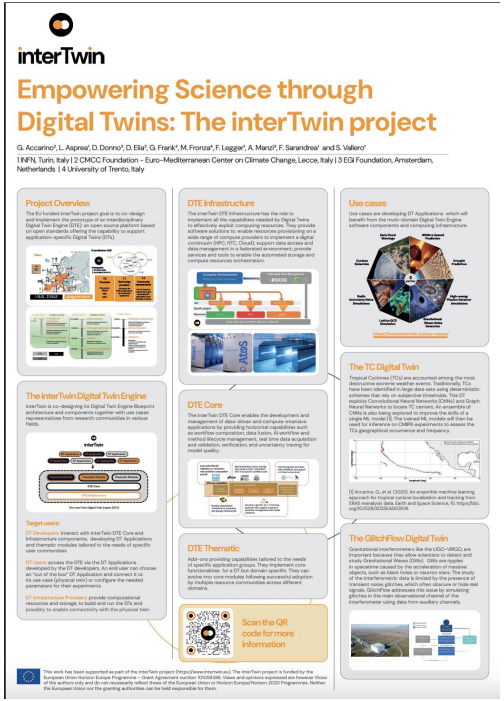
- Efficient co-design process with Communities use cases leading to Blueprint Architecture and DTE Components definition
- First Release available, new components opensourced in our Github community .https://github.com/interTwin-eu, Working towards final release in Q1/2025
- Transparent integration with HPC providers for AI/ML training and advanced simulations
- First DT Applications available since Q2/2024, Final DTs prototypes available online in Q2/2025
- Some of the components developed in the project are already included in new HE projects starting in 2025.

# interTwin posters

## The interTwin IMS. Paving the way for the project exploitation




## Empowering Science through Digital Twins: The interTwin project



# Thank you!

# Questions?

www.intertwin.eu

info@intertwin.eu

intertwin_eu

intertwin

# Tropical Cyclones and Wildfires DTs

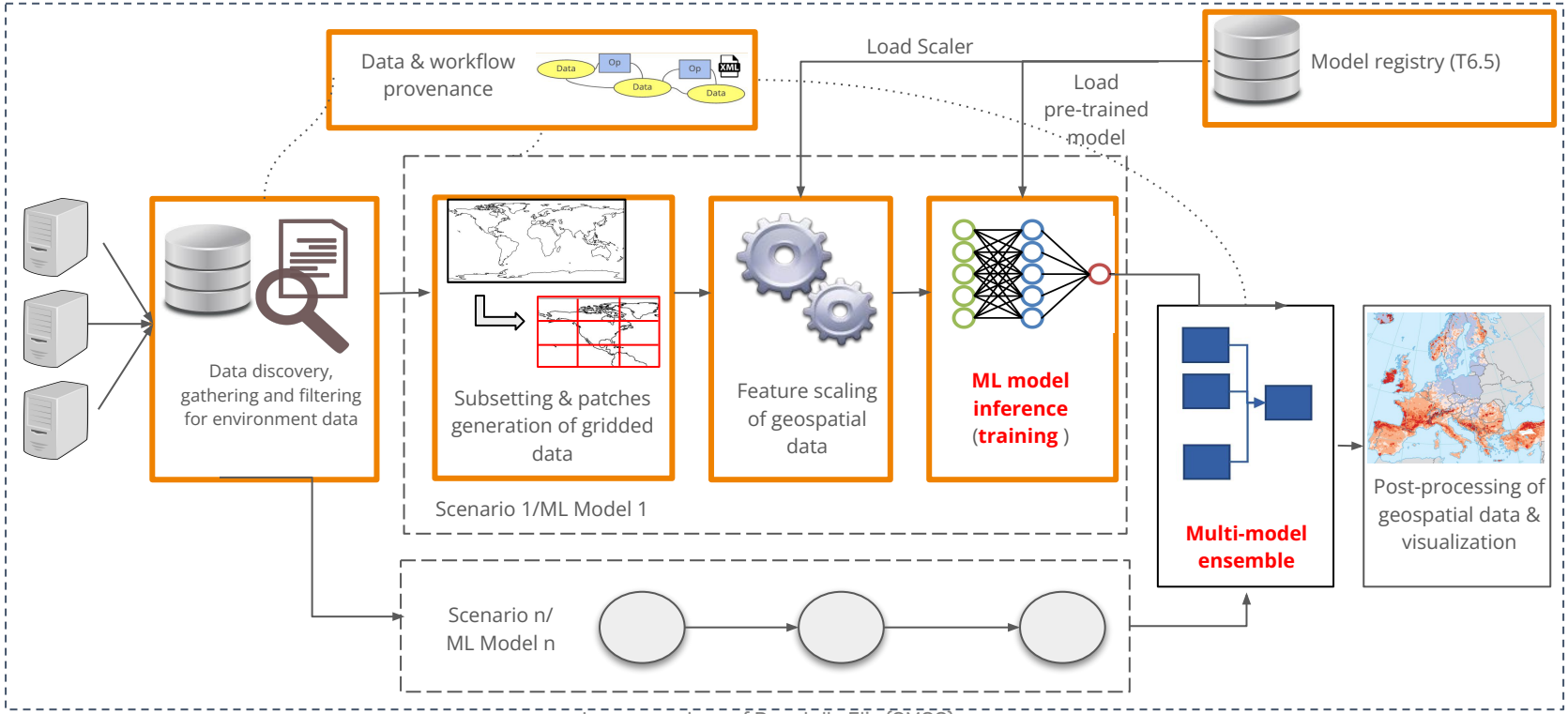



Image courtesy of Donatello Elia (CMCC)

# DT of Particle Detector

## Detector Prototyping & Optimization

Build data-driven tool that simulates detector response and integrates operation conditions from experimental setups (test-beams).

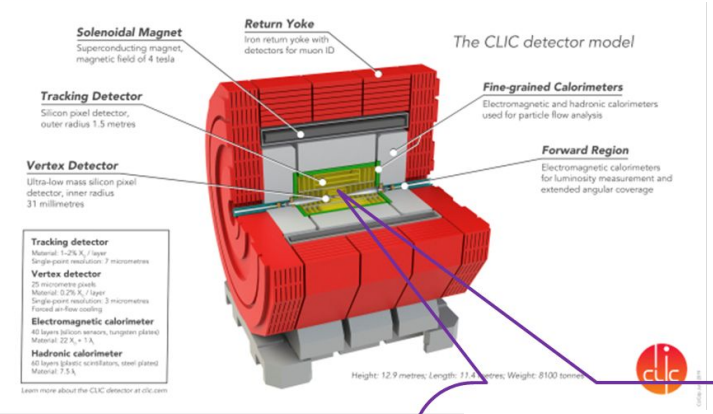
## Online ML for Detectors

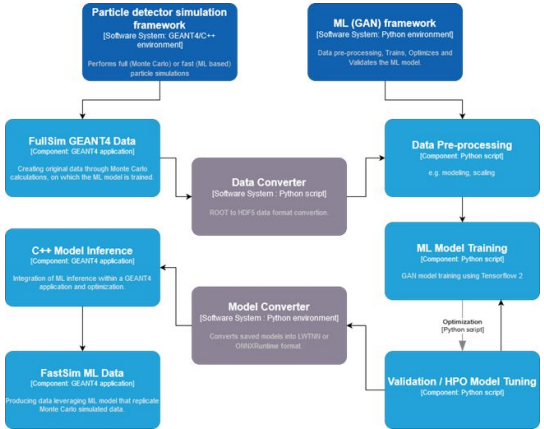
Adapt real-time detector and/or data acquisition configuration with respect to run conditions

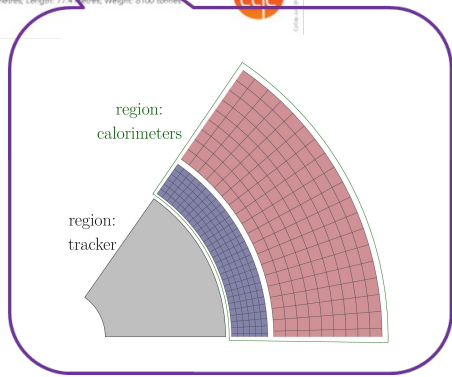
## Quality verification & Validation frameworks

Model convergence and accuracy of the generated data should be monitored.

Development of sample-based validation framework in collaboration with HEP community.






Images courtesy of Kalliopi Tsolaki (CERN)