

# SMARTHEP

REAL-TIME ANALYSIS FOR  
SCIENCE AND INDUSTRY

## Coordinator's report

Mid-term check,  
9-10/01/2023

**Caterina Doglioni**  
(coordinator and interim PM)



SMARTHEP is funded by the European Union's Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086



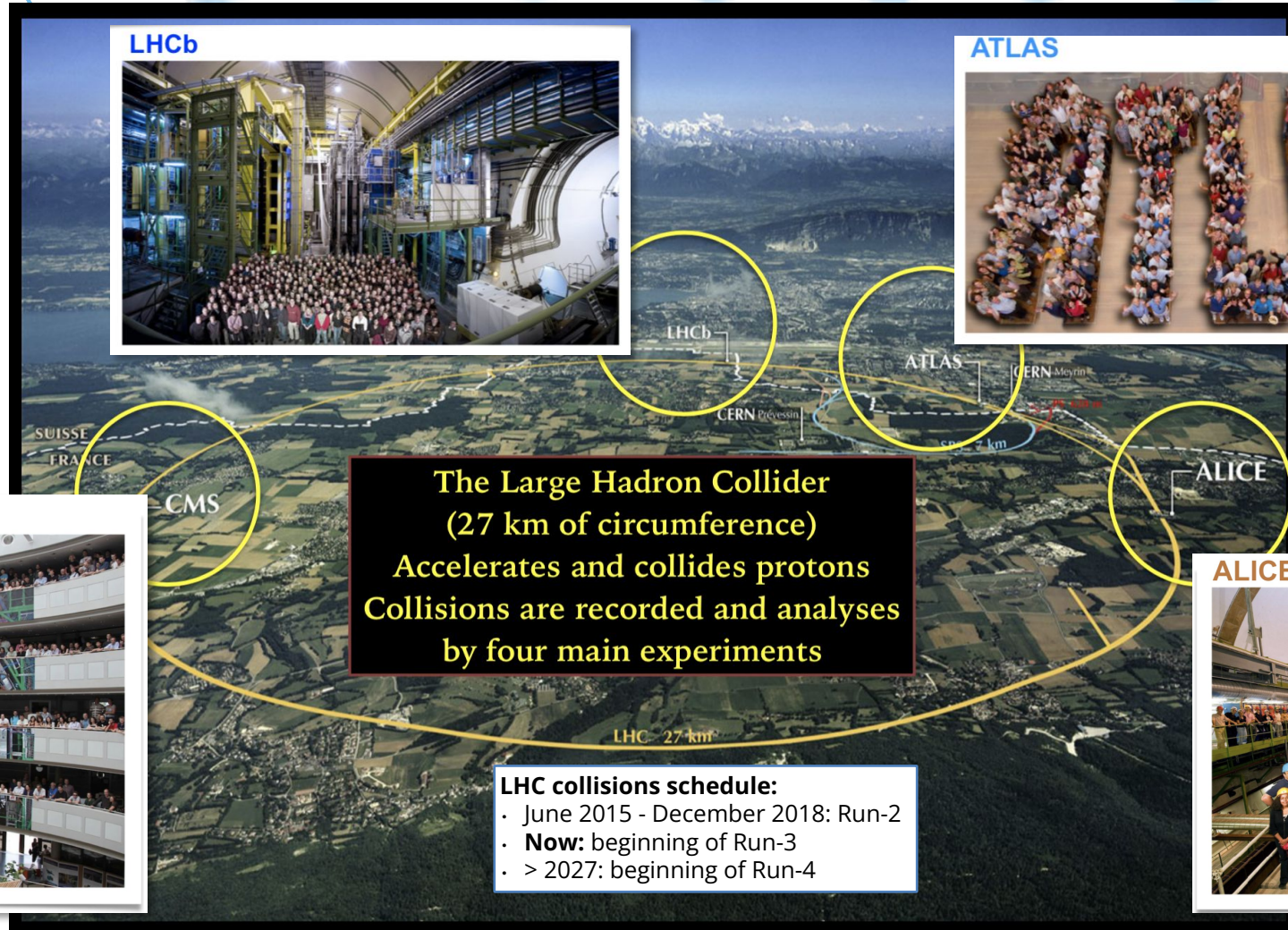
# Outline

- Scientific introduction
- Description of the network and its set-up
- Results, communication and dissemination so far
- Network activities up to now

# Scientific introduction

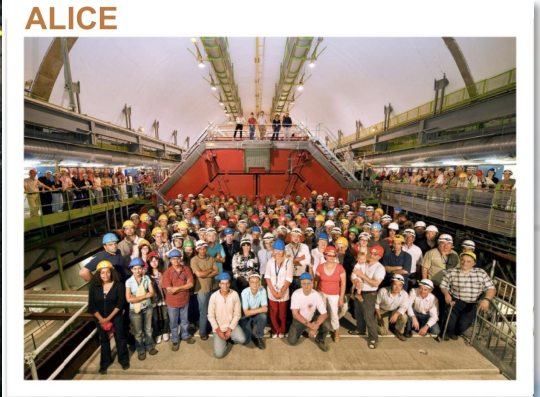
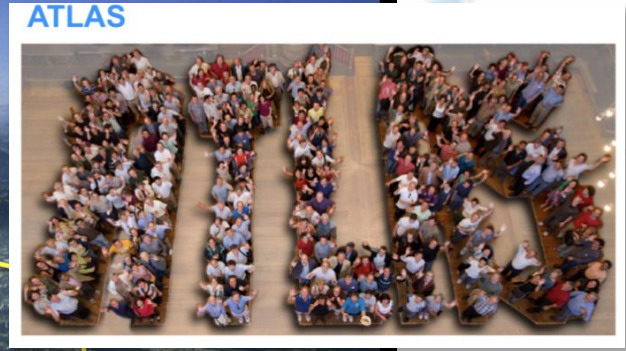


# The Large Hadron Collider and its experiments



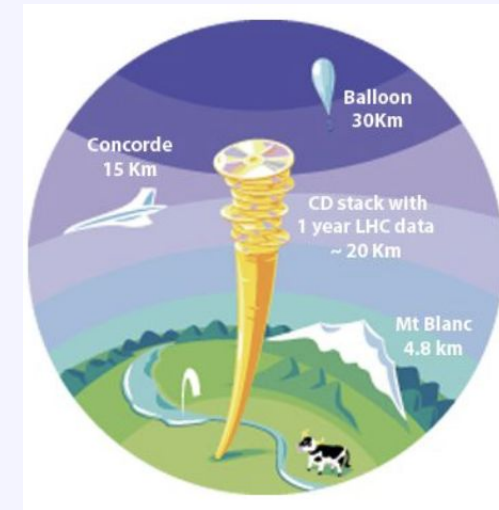
The Large Hadron Collider  
 (27 km of circumference)  
 Accelerates and collides protons  
 Collisions are recorded and analysed  
 by four main experiments

- LHC collisions schedule:**
- June 2015 - December 2018: Run-2
  - **Now:** beginning of Run-3
  - > 2027: beginning of Run-4



# Data at the LHC

- The LHC **collides protons** every 25 ns, and can **produce other/new particles**
- **Research goals:** measure fundamental properties of matter, discover new phenomena not included in the current theory
- The **signals** we are looking for are **rare**  
→ need enormous number of collisions to produce them
- Their **backgrounds** often look the same and are **much larger**
- **Problem:** recording all LHC data takes 400000 PB/year [\[Ref\]](#)
  - up to 30 million proton-proton collisions/second (MHz)
  - ~ 1-1.5 MB/data per collision event, including raw data



after selection of "interesting" data

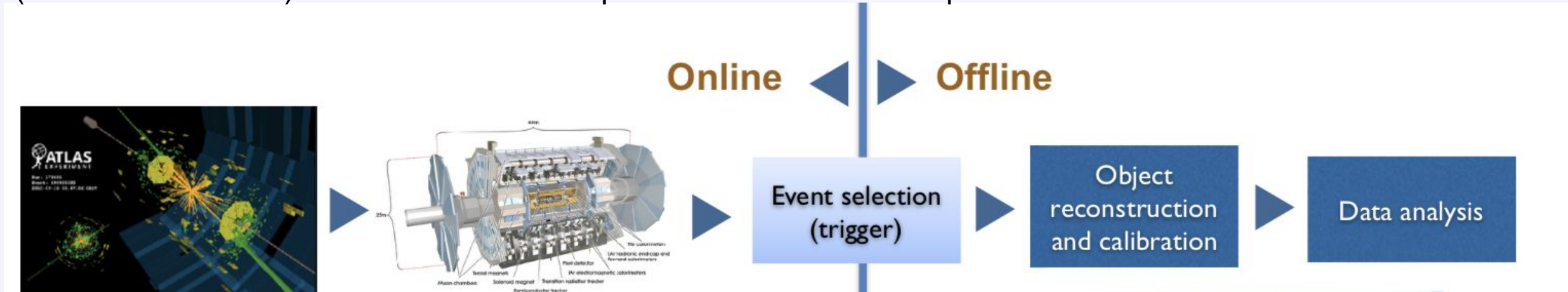
# Triggering on data

LHC experiments have to select "interesting" events (=trigger) in **real-time** (milli/microseconds)

Collisions at ~30 MHz  
 (~1 MB of info each)

**Hardware trigger**  
 outputs ~100 kHz

**Software trigger**  
 outputs ~1 kHz

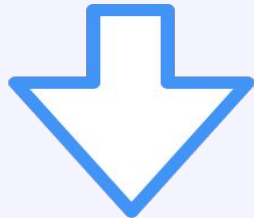


Most data gets discarded...are we discarding some kinds of **signal** as well?

# Main network focus

Traditional data analysis is  
**asynchronous:**

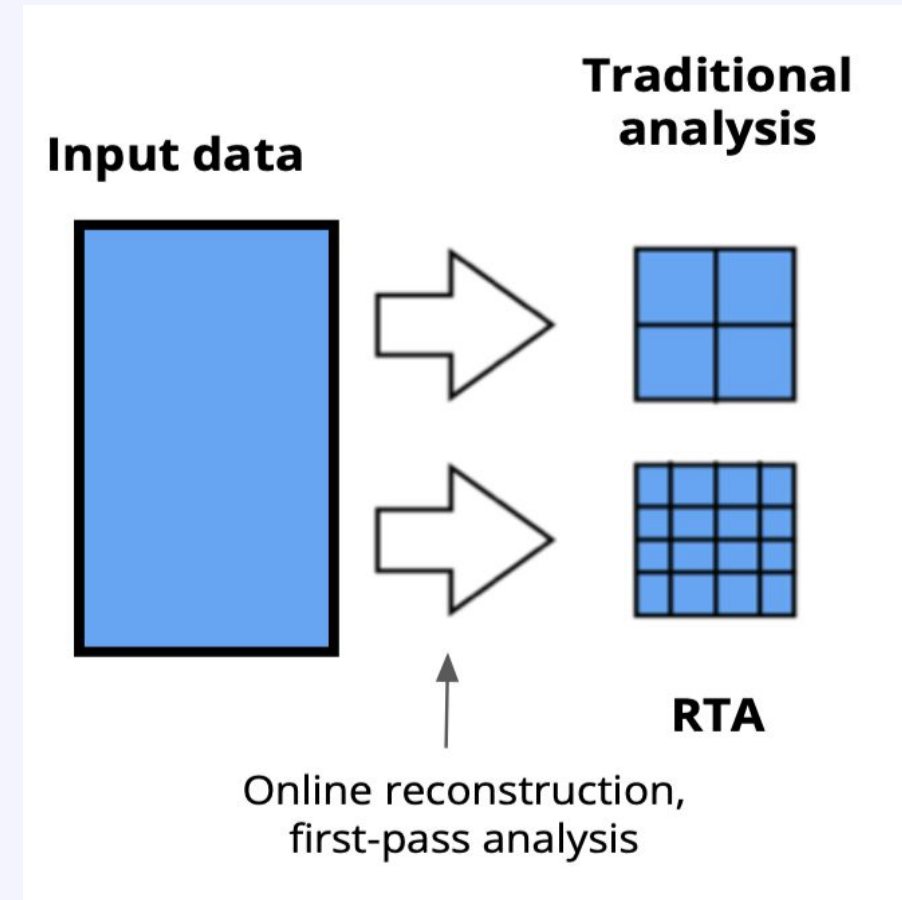
*First record and store data,  
then reconstruct/analyze it*



**Real-time** data analysis

*Analyse data as soon as it is collected*

- only store (smaller) final-state information
- reduce time-to-insight
- accelerate decision making



*only store (smaller) final-state information:  
useful for saving more data in LHC experiments*

# Where SMARTHEP comes from

All four main **LHC experiments** use **Real-Time Analysis** techniques

**ALICE:** [online reconstruction \(O2\)](#) **ATLAS:** [Trigger Level Analysis](#)  
**CMS:** [Data Scouting](#) **LHCb:** [Turbo stream](#)

+ the *trigger* system is a real-time decision making system

**“Too much data” & “need to analyse data ASAP”** problems  
**not unique** to particle physics

+ use cases in financial transactions, fleet & traffic management, predictive maintenance...

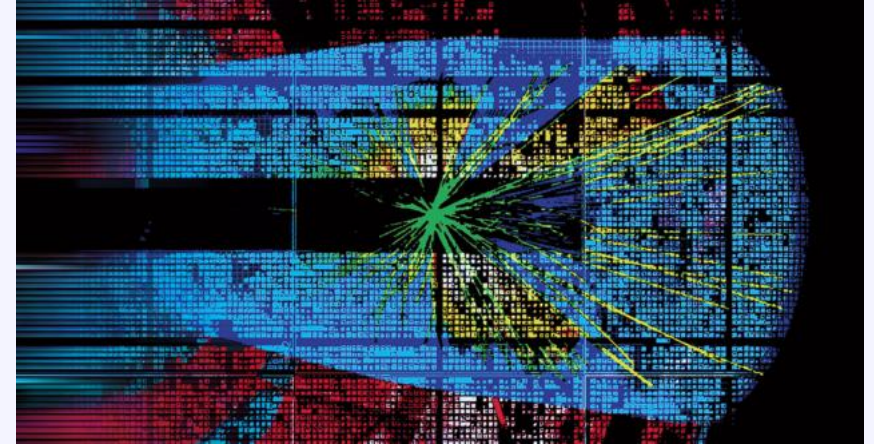


Given these common needs,  
how do we **collaborate** to advance RTA at the LHC and beyond?



# Tools: machine learning

- **Machine learning** is revolutionising high energy physics, industry and society
  - Use of ML is ubiquitous in all of these
- Advantage for RTA: **decisions** based on **large, complex datasets** can be taken on a very **short timescale**
- Particular interest in **unsupervised methods**
  - Algorithms that "learn from the data" (including *rule induction*)
  - Necessary to remove theoretical prejudices on how new physics can look like



Artist's impression of an FPGA in the level-one trigger scanning for anomalies at a rate of 40 million events per second. Credit: S. Summer/CMS-PHO-EVE NTS-2021-004-2/M Rayner CERN Courier

# Tools: hybrid computing architectures (accelerators)

- CPU-based architectures (“computers” as we know them) are not the only option on the market, e.g.:
  - Field Programmable Gate Arrays (FPGA) for fast custom operations
  - Graphical Processing Units (GPUs) for parallel operations
- Advantage for RTA: **hybrid computing architectures** can significantly **accelerate** decision-making

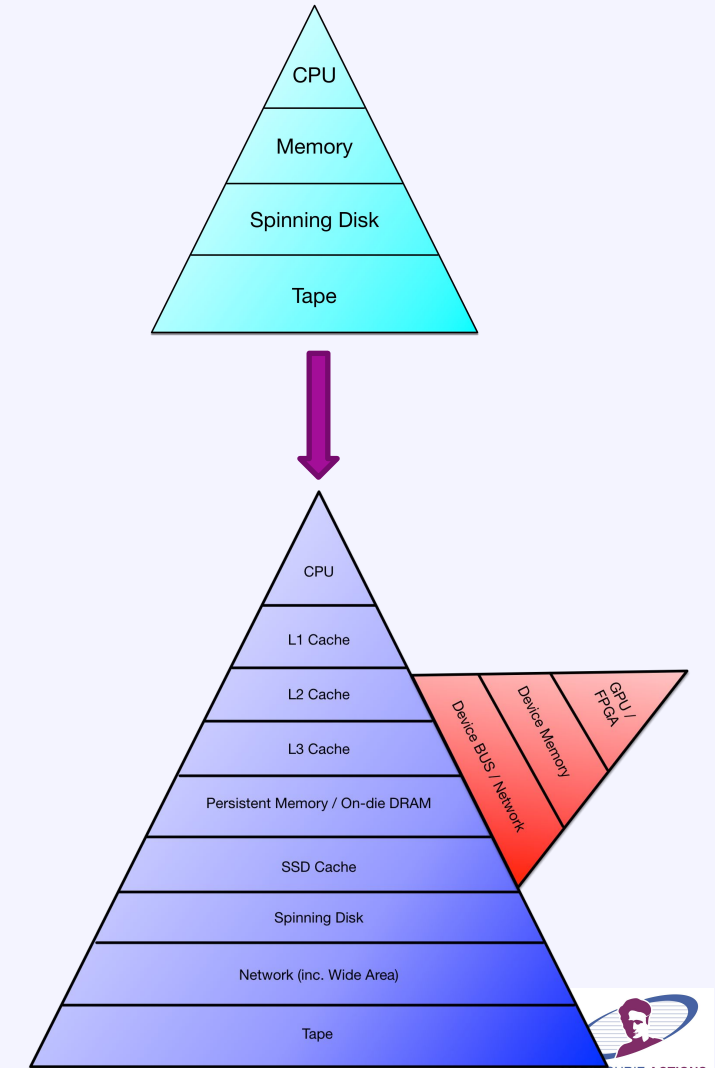


Diagram by G. Stewart



# SMARTHEP

REAL-TIME ANALYSIS FOR  
SCIENCE AND INDUSTRY

trains **Early Stage Researchers**  
in **Machine Learning**  
and **hybrid computing architectures**  
to advance **real-time analysis**  
in **science and industry**



SMARTHEP is funded by the European Union's Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086



# The network and its set-up



# The network, before/around the ITN



SMARTHEP kicks off at Lund - May 2017



RAPID Workshop - October 2018



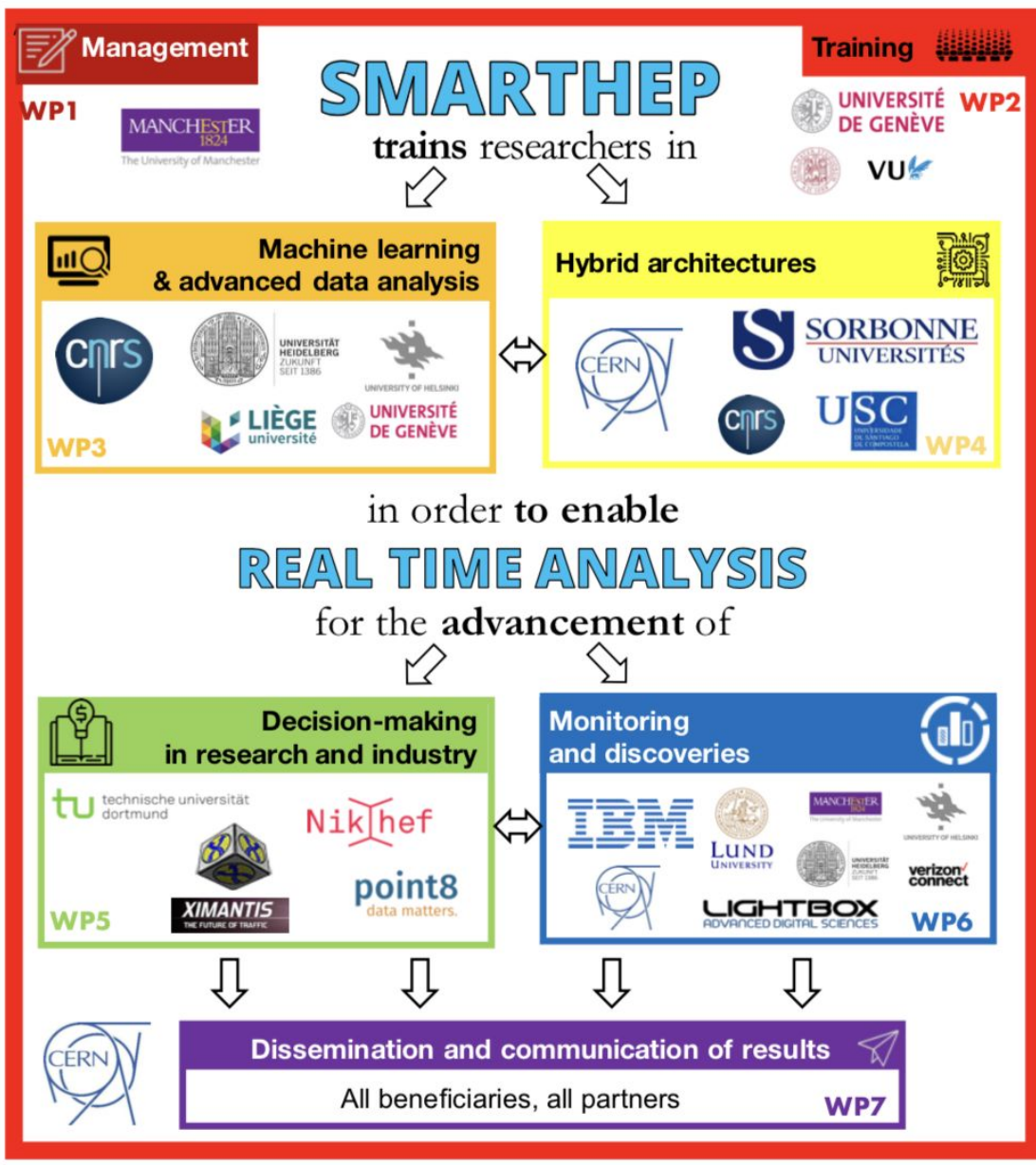
Institut Pascal "Learning To Discover" real-time analysis workshop - July 2019



REALTIME Advanced Study Group at the Pufendorf Institute of Advanced Studies - 2019/2020

*Support and funding in preparation for this ITN received by:*

- The Grace och Philip Sandbloms Fund (Sweden)
- The Pufendorf Institute for Advanced Studies (Sweden)
- The Institut Pascal (France)



## Synergies between LHC & industry:

- Different use cases
  - Different dataset size/ complexity  
→ Collaborate on **common tools**:
- 1. Machine learning (Work Package 3)**  
→ enables fast and efficient inference
  - 2. Hybrid computing architectures (WP4)**  
→ accelerate RTA w/ FPGA, GPU, multithreading
- Concrete outcomes in **decision-making (WP5)**, **monitoring and discoveries (WP6)**



# Sample physics outcomes

- Calibration of ALICE TPC for heavy-ion physics
- Improvements & optimization of the trigger system for Run-3 and High-Luminosity LHC
- Data analysis with real-time analysis workflows, e.g.
  - Lepton flavour violation analyses
  - New physics searches

*More in ESR talks  
this afternoon!*



# Sample industry outcomes

- Algorithms for real-time traffic prediction (Ximantis)

- Real-time analysis of videos and sensor data collected by dashcams (camera on vehicle)

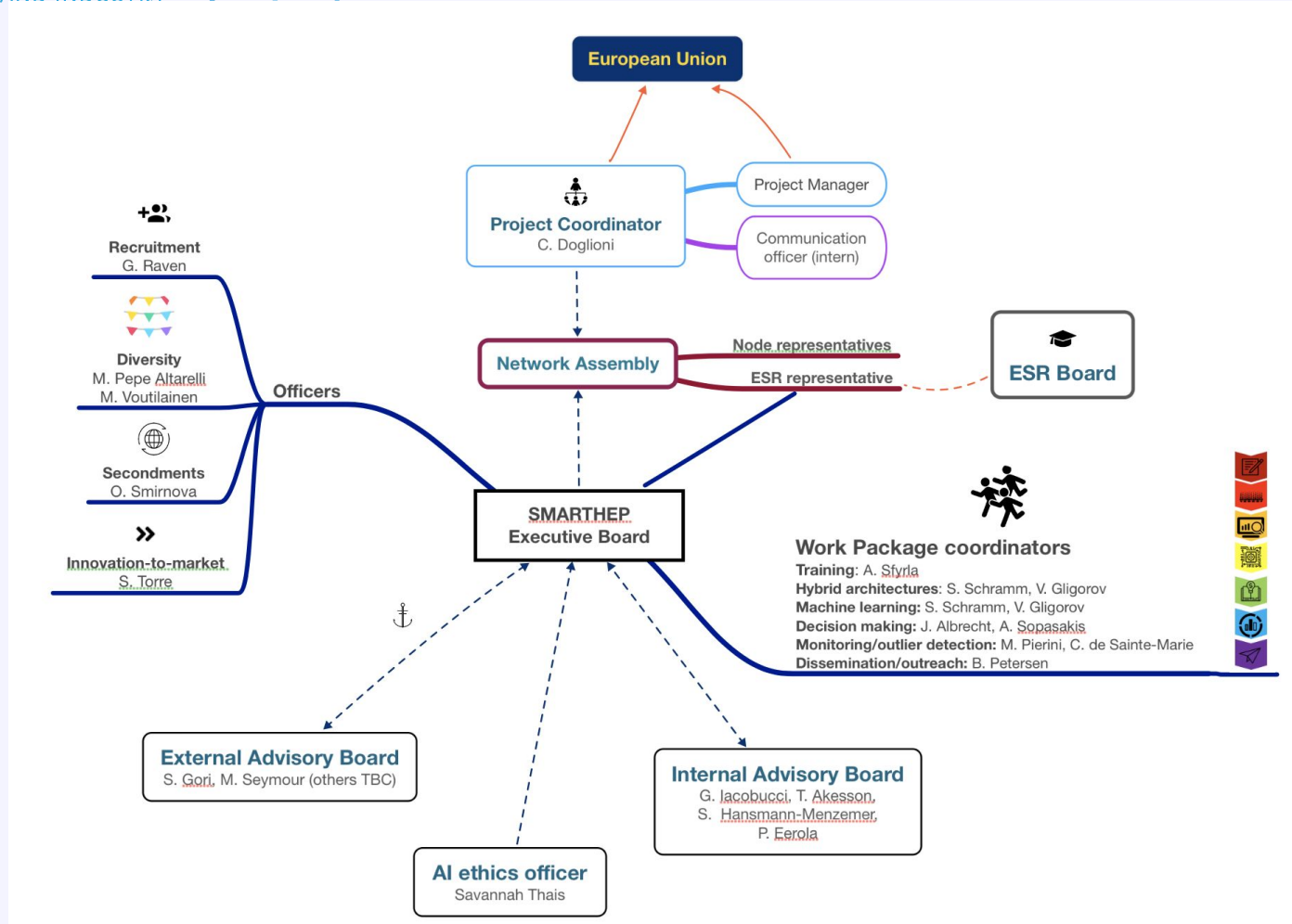
- Running fast analysis in embedded system

*More in ESR talks  
this afternoon!*

- Automating decision-making for fraud detection



# Who is who



## Network officers:

Experts who can advise the network and the ESRs on specific topics (including ethics)

## Work package coordinators:

SMARTHEP supervisors who follow and coordinate the work of each of the topics in the network (work packages also for management, training and dissemination)

## Network assembly:

Decision-making/voting body, includes ESR representation

## Executive board (EB):

Unless otherwise specified, EB has open meetings for anyone who wants to help with running the network

# Project manager: TBC

- Project manager hired at 0.5 FTE in January was ultimately not able to work on the project
  - Since hired PM was in a category protected by HR/university, we have not been able to open the position to hire a replacement
    - No costs incurred for the project as a consequence
  - Jonathan Masterson has been acting as interim PM, sharing tasks with coordinator (CD)
- Currently:
  - PM position is open and advertised, plan to have someone in post in Spring 2023
    - 35 months at 0.5 FTE (contract will finish when network reporting concludes)
  - Until then:
    - CD as acting PM to deal with administrative tasks, with JM's support
      - partial salary costs for CD charged to SMARTHEP
      - costs to remain within already-budgeted coordinator's share for PM
    - Intern to be hired to help with communication (website, twitter, network news)



# Work Package coordinators

## WP1: Management



**Caterina Doglioni**  
 U. of Manchester  
 (with **PM Andrew Carey**)

## WP2: Training



**Anna Sfyrta**  
 UniGe

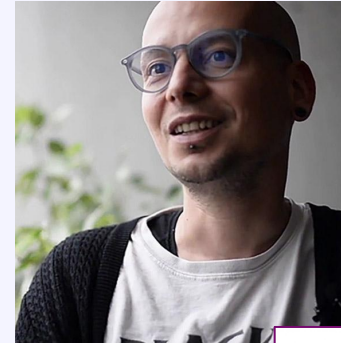
## WP5: Triggers



**Johannes Albrecht**  
 TUDO



## WP6: Discoveries with RTA



**Maurizio Pierini**  
 CERN



## WP7: Dissemination & Communication



**Brian Petersen**  
 CERN

## WP3: Physics and ML / WP4: Hybrid architectures



**Steven Schramm**  
 UniGe



**Vava Gligorov**  
 CNRS/Sorbonne



**Alexandros Sopsakis**  
 Ximantis



**Christian de Sainte-Marie**  
 IBM

# Officers & Ethics Advisor

## Secondments



**Oxana Smirnova**  
Lund

## Recruitment



**Gerhard Raven**  
NIKHEF/Amsterdam

## Equality, Diversity and Inclusion



**Monica Pepe Altarelli**  
CERN



**Mikko Voutilainen**  
Helsinki

## Ethics Advisor



**Savannah Thais**  
Columbia University

# Results, communication and dissemination so far

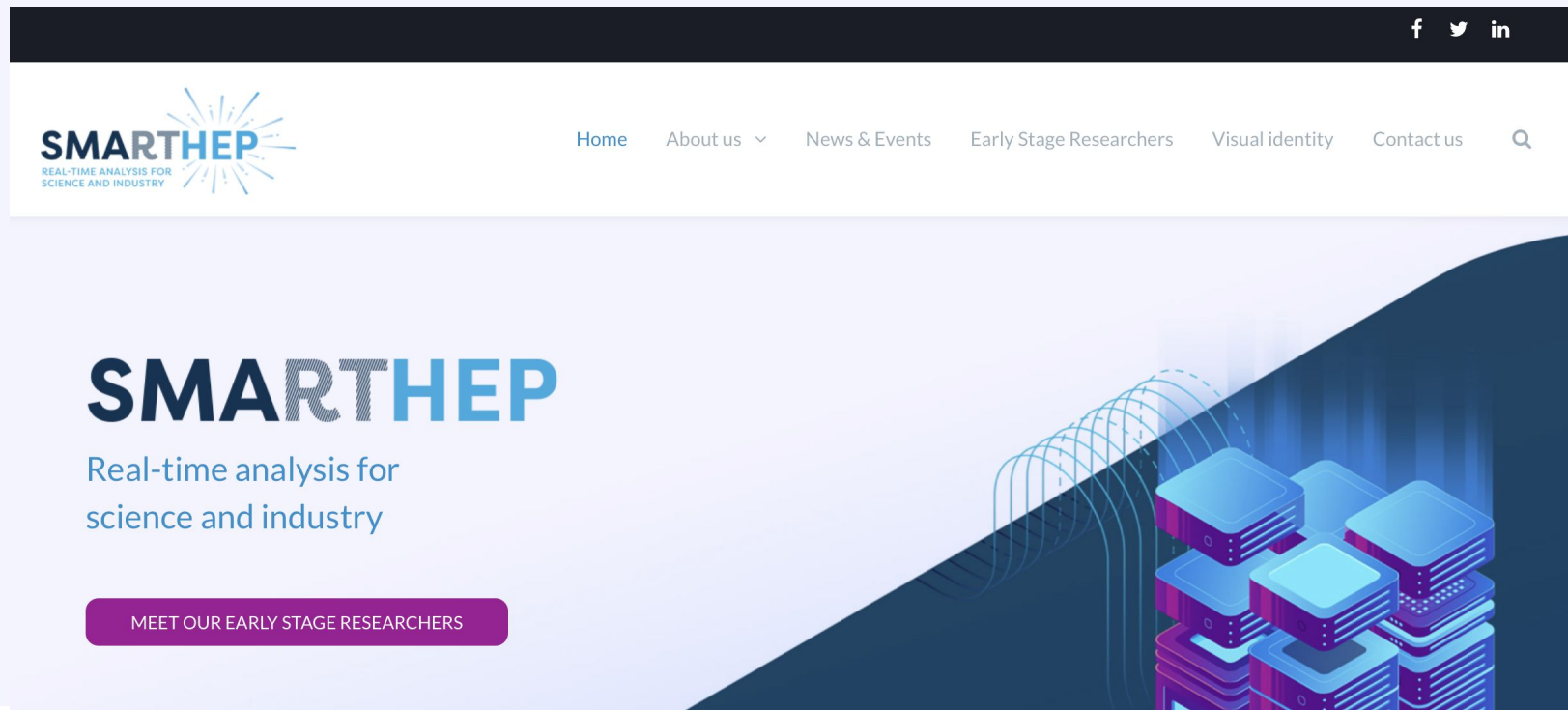




# The SMARTHEP website <https://smartheop.org>

Developed in collaboration with Nectar UK  
(who also provided logo and marketing strategy)

**Went online in January 2022, main source of information for recruitment**



SMARTHEP is funded by the European Union's Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086



# Open and FAIR data

Findable, Accessible, Interoperable, and Reusable digital assets.

**With SMARTHEP, we intend to be part of the effort to improve data *FAIR-ness* and *reproducibility & sustainability* of software**

Created and submitted first version of **Data Management Plan**

- LHC: following the CERN Open Data policy
- Individual discussions also involving Ethics Officer for industry beneficiaries and partners

Software discussions ongoing in high energy physics within the **HEP software Foundation** (talk by B. Hegner from coordination team at the kick-off meeting)

# Results, communication & dissemination opportunities

## Research community (papers and conferences)

- Whitepapers: state-of-the art, final results
- Individual physics/computer science/R&D results



SMARTHEP abstract to the biggest conference of **Computing for High Energy Physics** (CHEP) in Norfolk (USA) 2023 has been accepted  one of the ESRs (TBC) will give the talk

- (micro-)Blogs from the ESRs
- Specific activities for Masterclasses / World Wide Web day / data challenges

## Policy-makers

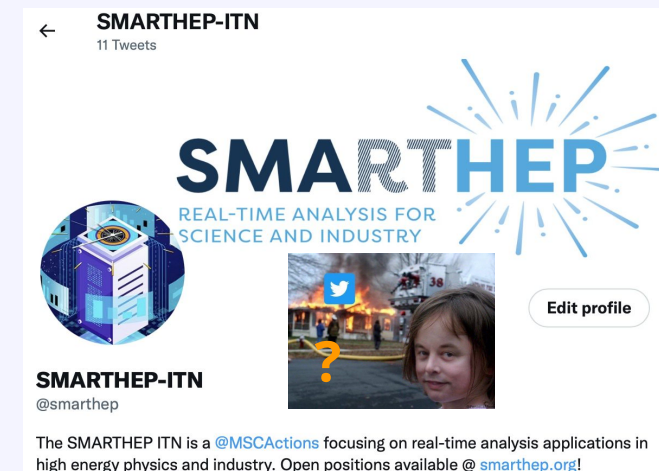
At the end of the network, possibility (w/o obligation) to write “best practices” papers, with a special interest on sustainable goals

## Industry and society

- Algorithms, software packages and patents from commercial research

## Twitter account

We have a distributed TweetDeck profile for SMARTHEP, waiting for Communication Officer





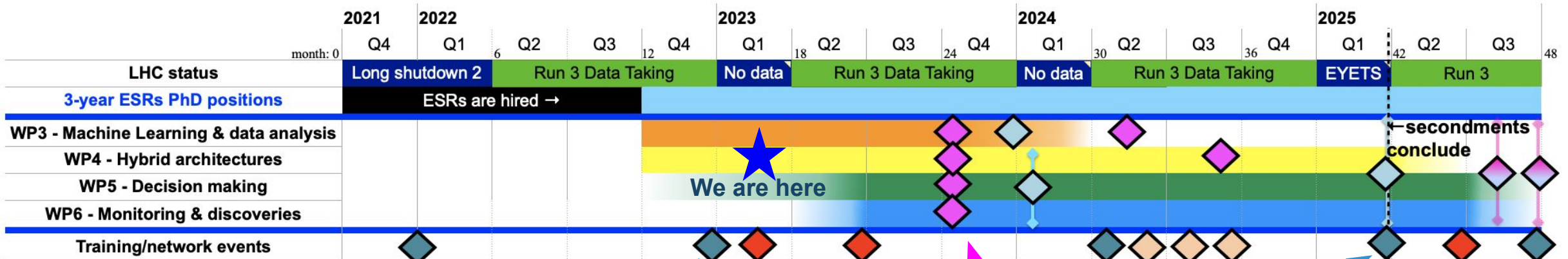
# Network activities so far



# The 4-year plan

## SMARTHEP Activity Plan

- ◆ Main research milestones
- ◆ Main commercial milestones
- ◆ Network-organized schools (all ESR)
- ◆ Network-organized schools (ESR choose 1)
- ◆ Network events and conferences



[Virtual kick-off meeting](#)

[This kick-off meeting](#)

Mid-term check with the EU Project Officer

[UniGe ML + Physics school](#)

Advanced ML school (TBC)

Whitepapers on state-of-the art [further research/commercial milestones: collections of papers and algorithms from individual projects]

Yearly network meetings

Accelerator boot-camps

Commercial applications school



SMARTHEP is funded by the European Union's Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086





## 12 PhD positions in Particle Physics and Computer Science - EU project SMARTHEP

Geneva, Switzerland

Full-time

### Company Description

The EU-funded Horizon 2020 programme has two main strategic objectives: to strengthen the scientific and technological base of European industry and to encourage its international competitiveness, while promoting research that supports EU policies.

In this context, the growing amounts of research data require new computing solutions to manage increased data storage, utilisation, and analysis capabilities.

*Synergies between Machine learning, Real-Time analysis and Hybrid architectures for efficient Event Processing and decision making (SMARTHEP)* is a European Training Network (ETN). SMARTHEP will train 12 Early Stage Researchers (ESRs) across 10 host institutions across Europe to use real-time decision-making effectively leading to data-collection and analysis becoming synonymous, aided by machine learning and hybrid computing architectures.

As part of SMARTHEP, you will join a dynamic research team that values science, technology, creativity and quality. We encourage the exploration of new ideas and innovations. You will work with a supportive international consortium which includes other enthusiastic young scientists as well as some of the world's leaders in the development of Real-Time Analysis (RTA) and key specialists from computer science and industry.

I'm interested

Refer a friend



Posted by  
**Ingrid Haug**

### SHARE THIS JOB



Powered by

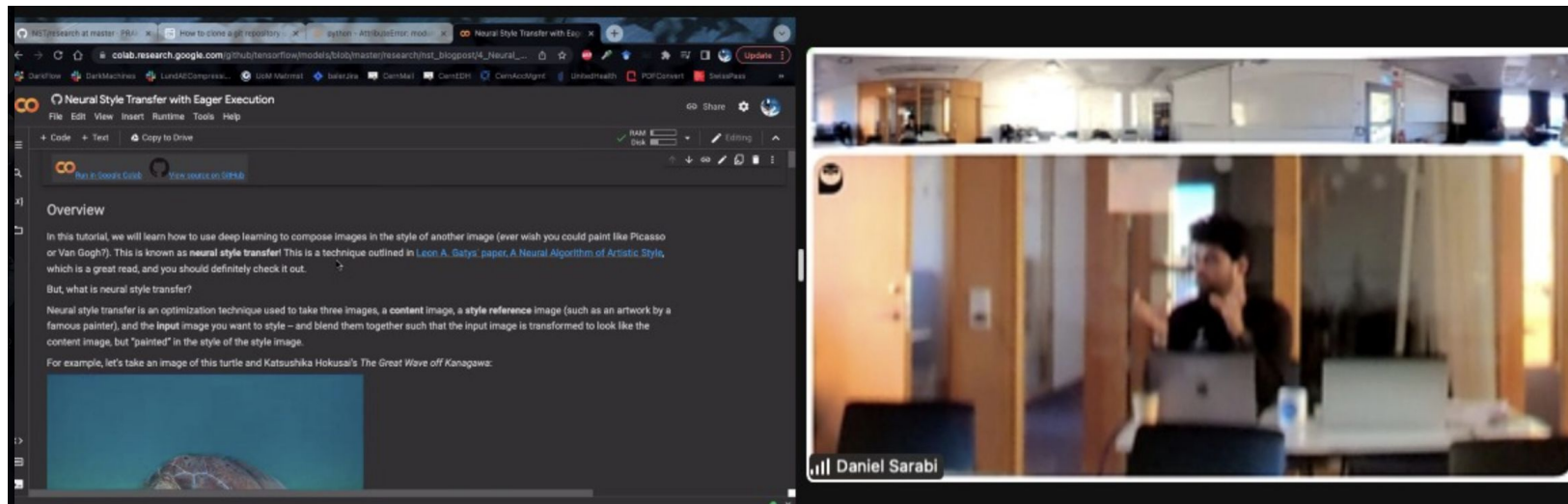
**SmartRecruiters** (Data Processor)

[Privacy Policy](#) and [Terms of Use](#)



# Highlights of ESR activities

- ESR contracts started in October 2022
  - ESRs still in preparation/ramping-up stage
- Some highlights (more in individual presentations):
  - In December 2022, ESR12 (Pratik Jawahar) taught the *“Reproducible and Interactive Data Analysis and Modelling using Jupyter Notebooks”* course at the COMPUTE graduate school at Lund University



# Kick-off meeting overview

## Monday November 21:

- Afternoon/evening:
  - ESR presentations
  - Social dinner

## Tuesday November 22:

- Morning:
  - In parallel: data management plan & individual ethics discussions
  - ESR self-assembly
  - Network Assembly
- Afternoon:
  - Networking event with other real-time analysis projects
  - Brief introduction to ML and ethics, Code of Conduct

## Wednesday November 23:

- Morning:
  - Visit to Jodrell Bank
- Afternoon:
  - Outreach event for final-year undergraduates
  - HEP Software Foundation talk
  - Preparation for writing course

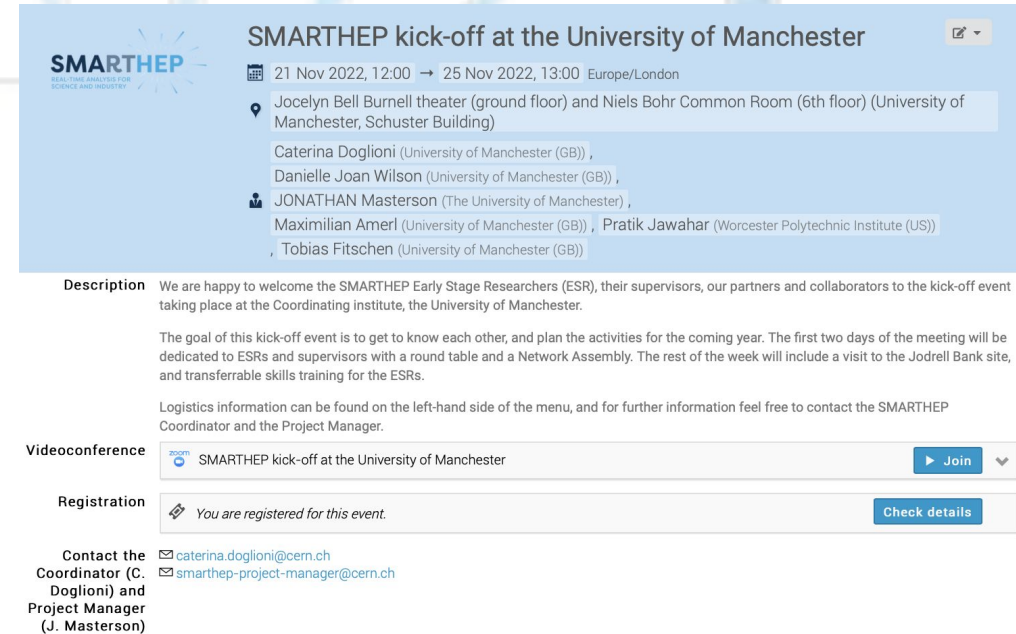
## Thursday November 24:

- Scriptoria course geared towards scientific reports and whitepapers

## Friday November 25:

- Closing words & departure

<https://indico.cern.ch/event/1204125/timetable/>



**SMARTHEP** kick-off at the University of Manchester

21 Nov 2022, 12:00 → 25 Nov 2022, 13:00 Europe/London

Jocelyn Bell Burnell theater (ground floor) and Niels Bohr Common Room (6th floor) (University of Manchester, Schuster Building)

Caterina Doglioni (University of Manchester (GB)),  
Danielle Joan Wilson (University of Manchester (GB)),  
JONATHAN Masterson (The University of Manchester),  
Maximilian Amerl (University of Manchester (GB)), Pratik Jawahar (Worcester Polytechnic Institute (US)),  
Tobias Fitschen (University of Manchester (GB))

**Description** We are happy to welcome the SMARTHEP Early Stage Researchers (ESR), their supervisors, our partners and collaborators to the kick-off event taking place at the Coordinating institute, the University of Manchester.

The goal of this kick-off event is to get to know each other, and plan the activities for the coming year. The first two days of the meeting will be dedicated to ESRs and supervisors with a round table and a Network Assembly. The rest of the week will include a visit to the Jodrell Bank site, and transferrable skills training for the ESRs.

Logistics information can be found on the left-hand side of the menu, and for further information feel free to contact the SMARTHEP Coordinator and the Project Manager.

**Videoconference** SMARTHEP kick-off at the University of Manchester [Join](#)

**Registration** You are registered for this event. [Check details](#)

**Contact the Coordinator (C. Doglioni) and Project Manager (J. Masterson)**  
[caterina.doglioni@cern.ch](mailto:caterina.doglioni@cern.ch)  
[smarthep-project-manager@cern.ch](mailto:smarthep-project-manager@cern.ch)

# Kick-off meeting: ESR presentations

ESR1 Patin Inkaew



ESR2 Laura Boggia



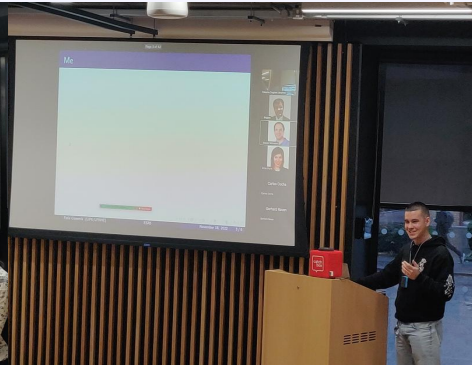
ESR3 Leon Bozianu



ESR4 Sofia Cella



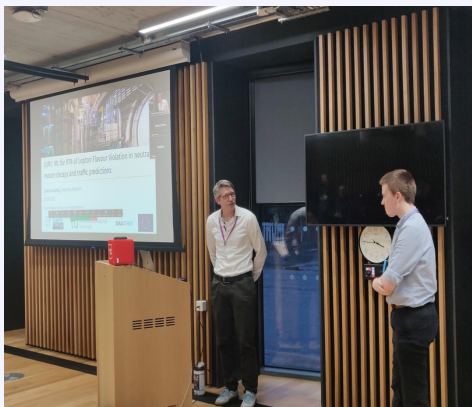
ESR5 Fotis Giasemis



ESR6 Daniel Magdalinski



ESR7 Jamie Gooding



ESR8 Micol Olocco



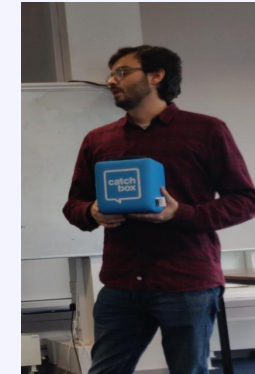
ESR9 Carlos Cocha



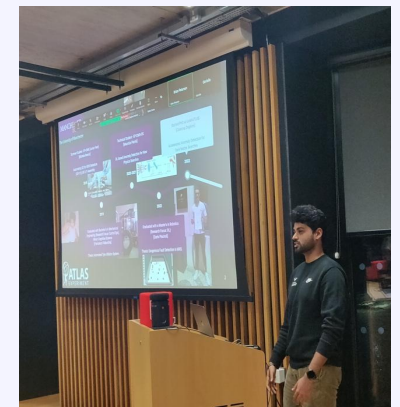
ESR10 Joachim Hansen



ESR11 Henrique Pineiro De Montegudo



ESR12 Pratik Jawahar

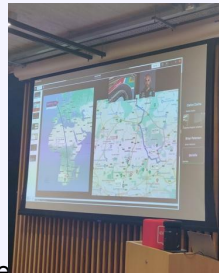


# Kick-off meeting: presentations by affiliated students

- The network also includes externally-funded students in beneficiary/partner PhD programs
  - PhD topic as strong synergies with network topics and goals
  - External students can participate in:
    - training activities (first-come first-serve basis, significant costs covered externally)
    - network research outcomes (ongoing collaborations exist within experiments, often also sharing supervisors/co-supervisors)



Maximilian Ameln



Danielle Wilson-Edwards



Joined since the kick-off meeting: Sten Astrand

- Schools can also open to external students, e.g. UniGe school has 25 participants (50% ESRs)

# Kick-off meeting: (pre-)local networking session

- Pre kick-off event related to network activities, organized by coordinating institute and advertised to network institutes:



- Providing seed funding for interdisciplinary collaborations built “on the spot”
- Groups who were awarded funding were asked to give a talk at the SMARTHEP kick-off meeting: engineering, medicine, finance, physics (including SMARTHEP institutes)



# Kick-off meeting: outreach event with UofM Physics Society

- Network event inviting 4th year students
  - Coordinator gave a presentation on what ITNs (Doctoral Networks) are and how to find / apply to them
  - Jamie Gooding (UofM alumni) gave a talk about his experience
  - Q&A session involving all ESRs



# Kick-off meeting: Visit to Jodrell Bank & social dinner



# Kick-off meeting: Code Of Conduct

- Discussed and agreed upon a code of conduct
  - Based on CoC from University of Helsinki / Kumpula Campus
  - Complementing the European Code of Conduct for Research Integrity and the MSCA Researchers Rights and Obligations
  - Reflecting and pledging conduct in terms of:
    - Truth and knowledge
    - Autonomy
    - Creativity
    - Critical Mind
    - Edification
    - Well-being

## **SMARTHEP Network Code of Conduct**

### **Truth and Knowledge**

- We are guided in our actions by our core values of truth and knowledge, autonomy, creativity, critical mind, edification and wellbeing.
- We take as a starting point for our research, teaching, learning and other activities the pursuit of truth and new knowledge.
- We respect and value difference.
- We are open to new ideas and approaches.
- We structure our efforts so that others can get involved, and continue or extend our work.
- We do not deceive others, whether by unintentional omission or by deliberate act.
- We respect the privacy of others, and the confidentiality of information, documents and data.
- We do not commit plagiarism, or misinterpret or falsify data.

### **Autonomy**

- We recognise that our behaviour may reflect upon the reputation of the SMARTHEP Network.
- We respect the limited human, financial and material resources available to the Network community.
- We advise and guide each other where appropriate.
- We exercise adequate supervision when in a position of authority, or when delegating tasks, avoiding excessive workloads.
- We do not abuse our authority, position or power to obtain special treatment or undue influence for ourselves or others.
- We are familiar with, and follow, all relevant rules and regulations.
- We strive to avoid conflicts of interest, whether real or perceived, and disclose them otherwise.

### **Creativity**

- We are open to new ideas and approaches.
- We value all areas of academic endeavour equally highly.
- We keep up-to-date with developments that affect our work, studies or research.
- We apply our learning, skills and professional experience constructively for the benefit of all.
- We share any knowledge that could benefit each other in our work or studies.
- We adopt alternative approaches in order to generate new thoughts and concepts.
- We give credit to others for their contributions.

# Kick-off meeting: writing training

- In preparation for the next network deliverables, students attended a course in scientific writing, including
  - Reading papers
  - Practical exercises



# Upcoming: whitepapers

- Main scientific deliverables in 2023: whitepapers on state of the art of tools and physics, necessary to set the scene for the work of the ESRs
  - One whitepaper per Work Package
- Whitepapers by WP coordinators/supervisors, and edited by ESRs
  - Authorship: anyone who is involved in writing/discussions will be an *author*, those making significant contributions will be *editors*
  - Publication on a peer-reviewed journal desirable, but not necessary
- Plan:
  - ESRs chose a "primary" whitepaper at the kick-off meeting
  - This week: refine the workplan and the contributors to each whitepaper



# Kick-off meeting: Code Of Conduct

- Discussed and agreed upon a code of conduct
  - Based on CoC from University of Helsinki / Kumpula Campus
  - Complementing the European Code of Conduct for Research Integrity and the MSCA Researchers Rights and Obligations
  - Reflecting and pledging conduct in terms of:
    - Truth and knowledge
    - Autonomy
    - Creativity
    - Critical Mind
    - Edification
    - Well-being

## **SMARTHEP Network Code of Conduct**

### **Truth and Knowledge**

- We are guided in our actions by our core values of truth and knowledge, autonomy, creativity, critical mind, edification and wellbeing.
- We take as a starting point for our research, teaching, learning and other activities the pursuit of truth and new knowledge.
- We respect and value difference.
- We are open to new ideas and approaches.
- We structure our efforts so that others can get involved, and continue or extend our work.
- We do not deceive others, whether by unintentional omission or by deliberate act.
- We respect the privacy of others, and the confidentiality of information, documents and data.
- We do not commit plagiarism, or misinterpret or falsify data.

### **Autonomy**

- We recognise that our behaviour may reflect upon the reputation of the SMARTHEP Network.
- We respect the limited human, financial and material resources available to the Network community.
- We advise and guide each other where appropriate.
- We exercise adequate supervision when in a position of authority, or when delegating tasks, avoiding excessive workloads.
- We do not abuse our authority, position or power to obtain special treatment or undue influence for ourselves or others.
- We are familiar with, and follow, all relevant rules and regulations.
- We strive to avoid conflicts of interest, whether real or perceived, and disclose them otherwise.

### **Creativity**

- We are open to new ideas and approaches.
- We value all areas of academic endeavour equally highly.
- We keep up-to-date with developments that affect our work, studies or research.
- We apply our learning, skills and professional experience constructively for the benefit of all.
- We share any knowledge that could benefit each other in our work or studies.
- We adopt alternative approaches in order to generate new thoughts and concepts.
- We give credit to others for their contributions.


SMARTHEP is funded by the European Union's Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086



# This week, at CERN/UniGe

- **9-13/1/2023**


- **Monday morning:** CERN visit, ethics in ML lecture
- **Monday 14:00 - Tuesday 13:00:** mid-term check meeting
- **Tuesday afternoon - Friday 15:00:** UniGe ML&Physics school
- **UniGe First Collider Physics and Machine Learning school** [[agenda](#)]
  - Particle physics (theory: T. Sjöstrand, experiment: A. Sfyrla)  
+ ML with hands-on component (M. Pierini)
  - Seminars (+ apero) on multimessenger astronomy & CERN experimental programme





**SMARTHEP**  
REAL-TIME ANALYSIS FOR  
SCIENCE AND INDUSTRY

First Network School on  
**Collider Physics and  
Machine Learning**

10-13 January 2023  
University of Geneva  
[https://indico.cern.ch/e/SMARTHEP\\_SchoolOne](https://indico.cern.ch/e/SMARTHEP_SchoolOne)



UNIVERSITÉ  
DE GENÈVE  
FACULTÉ DES SCIENCES



We acknowledge funding from the European Union Horizon 2020 research and innovation programme call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086



# Looking forward to more network activities and ESR results!





# SMARTHEP

REAL-TIME ANALYSIS FOR  
SCIENCE AND INDUSTRY

## Backup slides



SMARTHEP is funded by the European Union's Horizon 2020 research and innovation programme, call H2020-MSCA-ITN-2020, under Grant Agreement n. 956086



# Photo permission



## IMAGE RELEASE FORM

The University of Manchester often takes photographs or video film for publicity purposes. These images may appear in our printed publications, on our website, or both. We may also send them to the news media. We require your permission to do this. Please read the information below, then sign and date the form where shown.

**I agree to the use of my image(s), in printed publicity or promotional literature produced by The University of Manchester,** including leaflets, posters, newsletters and other display material; on The University of Manchester's website and other social media sites, including Facebook, Twitter and YouTube; and in any publicity material about our services sent to the news media. I understand that websites and other online media can be seen throughout the world, and not just in the United Kingdom, where UK law applies.

I have read and understood the above.

Forename

Surname

Email

Signature

Date

If you agree with photos that contain you to appear on Twitter/website, fill in this form

If you don't, tell Caterina and we'll make sure you're not in photographs

Your image is your personal data and it will be processed in accordance with data protection law based on the consent you provide in this form.

You have the right to withdraw your consent at any time please email

INTERNAL USE: THIS MUST BE COMPLETED BY THE PERSON ARRANGING PHOTOGRAPHY

and we will stop processing your image, however, please be aware that whilst we will make every effort to remove or take down your image from University communication channels it may have been copied by a third party.

Further information about your data protection rights including how to submit a request, is available here:  
<https://www.manchester.ac.uk/discover/privacy-information/data-protection>

Date/ref

M2285 05.18

