SMARTHEP

REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

Introduction

SMARTHEP yearly event @ Lund, 27/11/2023

Caterina Doglioni (coordinator),
Andrew Carey (project manager)
University of Manchester

Slide template by D. Wilson-Edwards (PhD student, UofM)
Graphics by Nectar Creative UK

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

MARIE CURIE ACTIONS

Outline

- Introduction to the network (mainly for the Advisory Board members)
  - Goals of the network
  - Description of the network and its set-up
- In the following contributions
  - Results, communication and dissemination so far (A. Carey)
  - Logistics for this week (A. Ohlson, O. Smirnova)

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Scientific introduction

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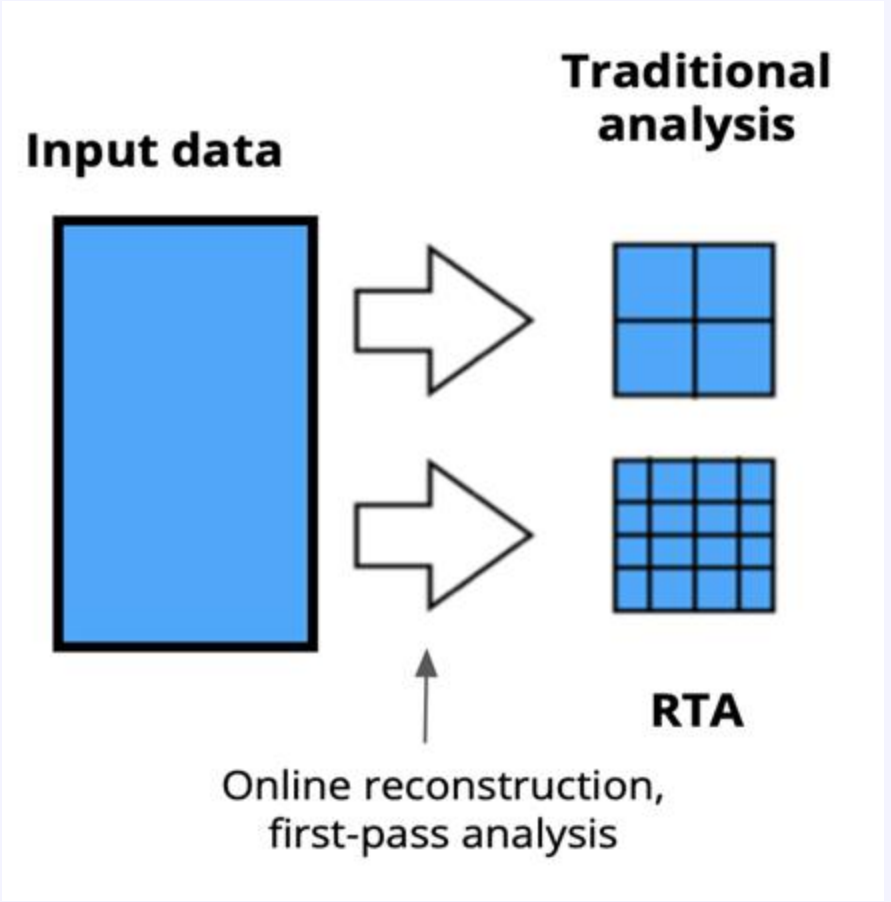
Main network focus

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

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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?

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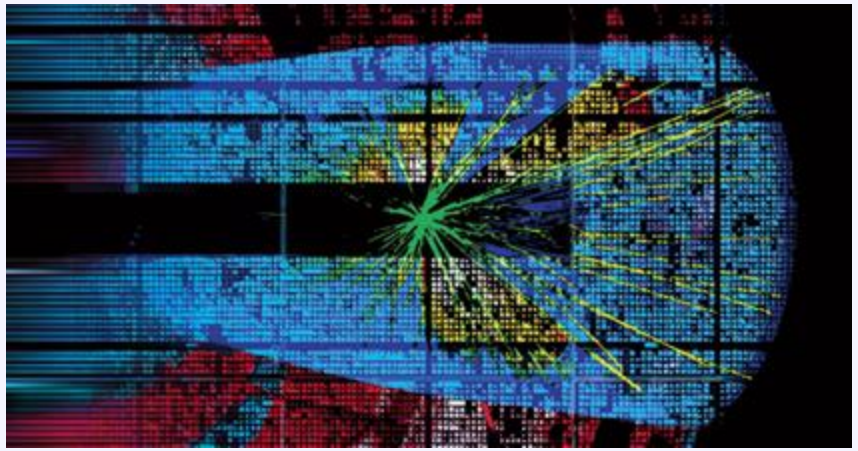
Tools: machine learning

- **Machine learning** is revolutionising high energy physics, industry and society
  - Use of ML is ubiquitous in all of these



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-EVENTS-2021-004-2/M Rayner
CERN Courier

- 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

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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

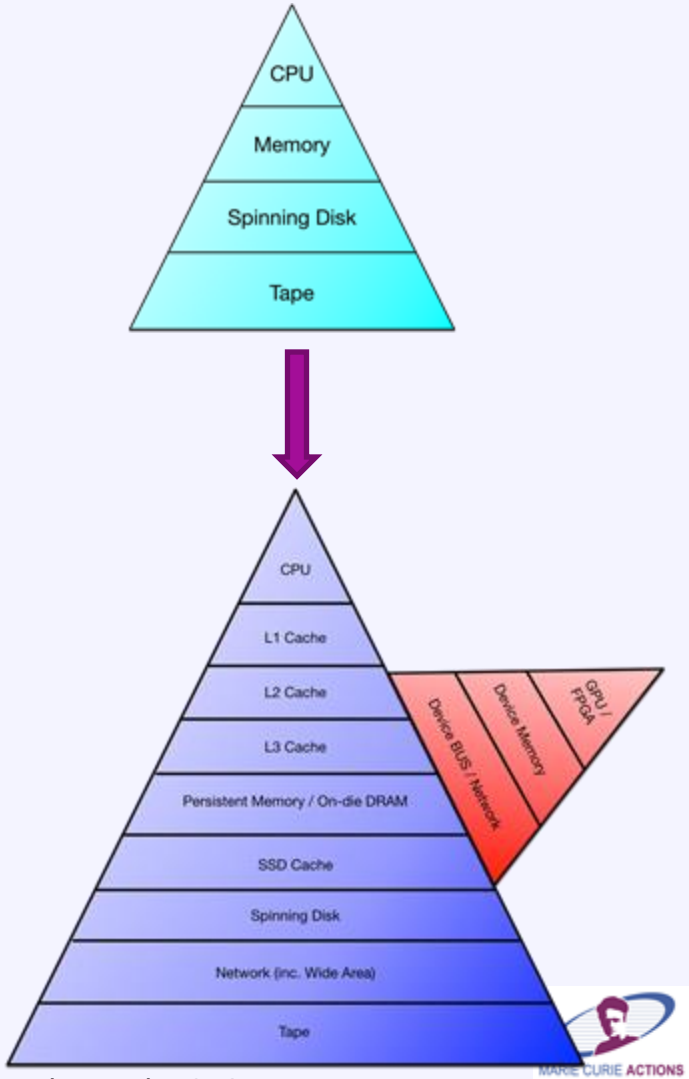

Diagram by G. Stewart

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

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The network and its set-up

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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) + Lund University
- The Pufendorf Institute for Advanced Studies (Sweden)
- The Institut Pascal (France)

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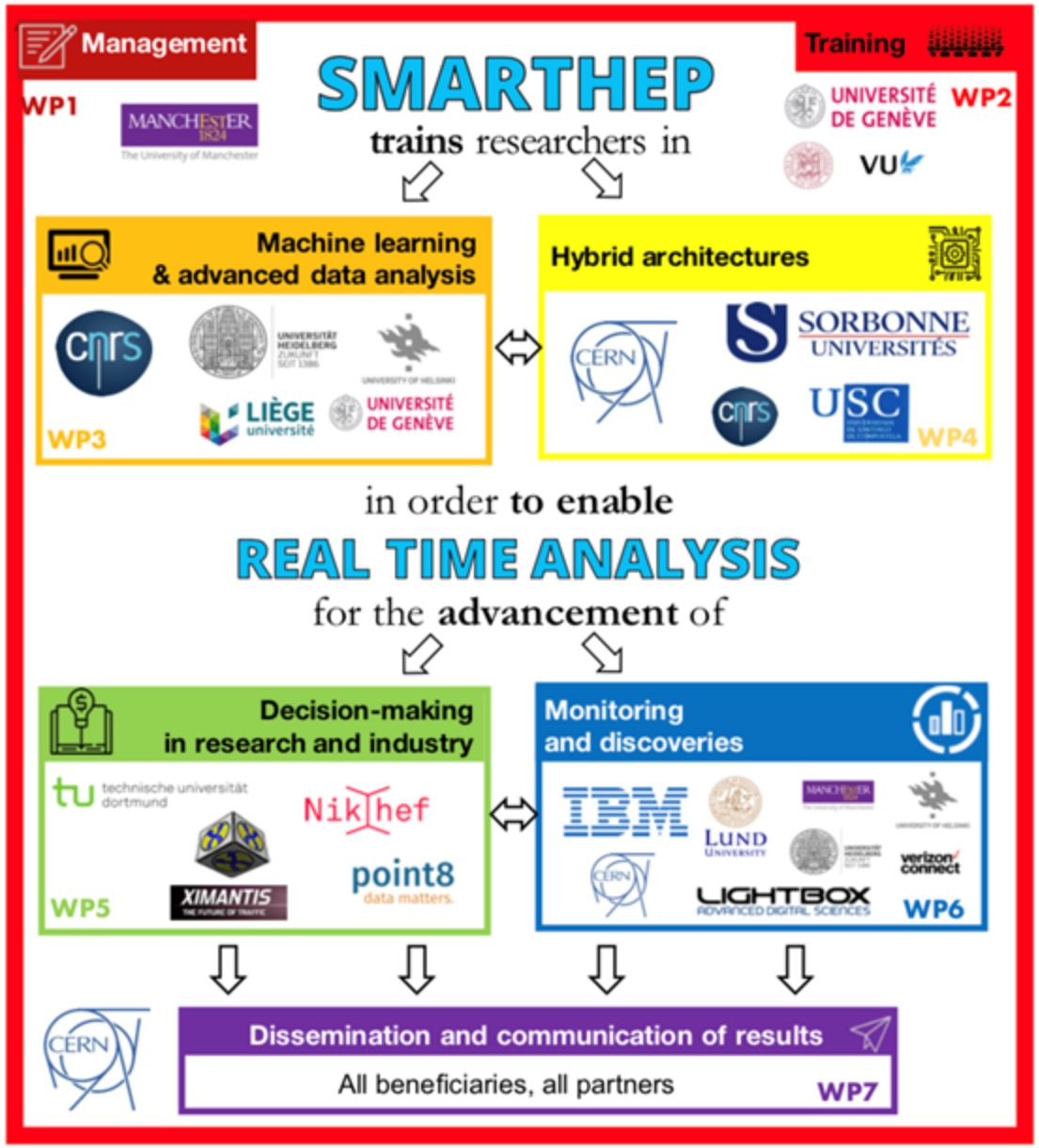

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Synergies between LHC & industry:

- 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)***

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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 and tomorrow!

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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 and tomorrow!

- Automating decision-making for fraud detection

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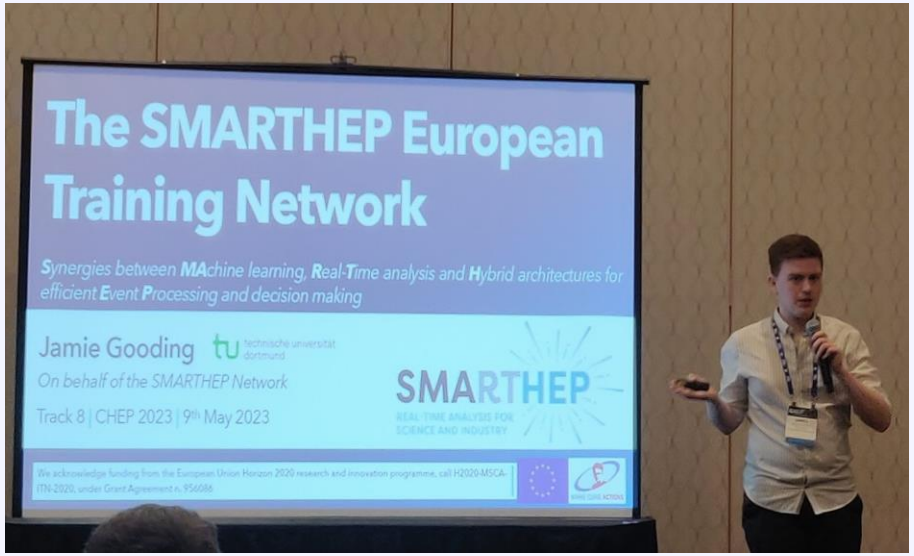
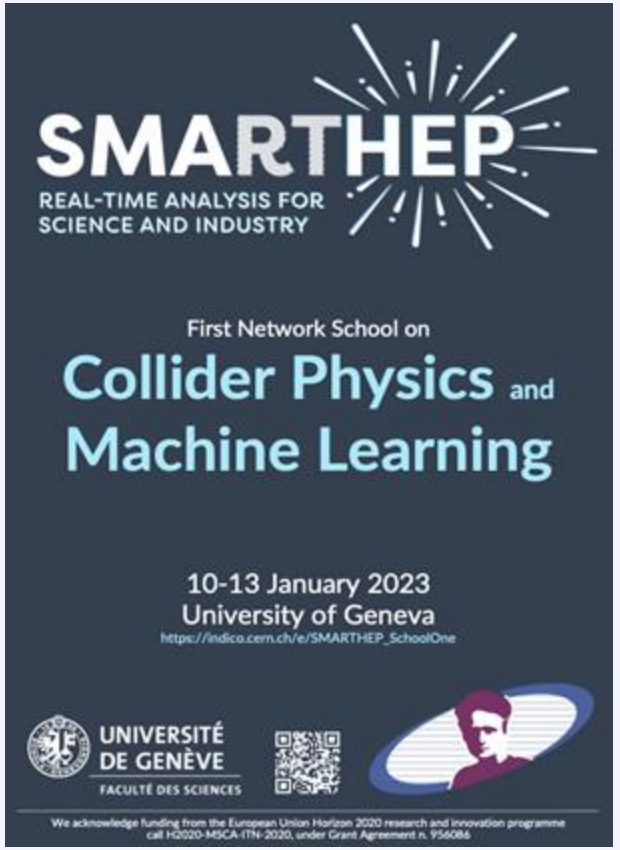
Network highlights so far

Kick-off at the University of Manchester, 11/2022

SMARTHEP presented at CHEP 2023



First network school at UniGe, 01/2023



C++ course at the University of Manchester, 08/2023

Real-time analysis sandpit at the University of Manchester, 10/2022

ovation programme under
MSCA-ITN-2020, under Grant Agreement n. 956086

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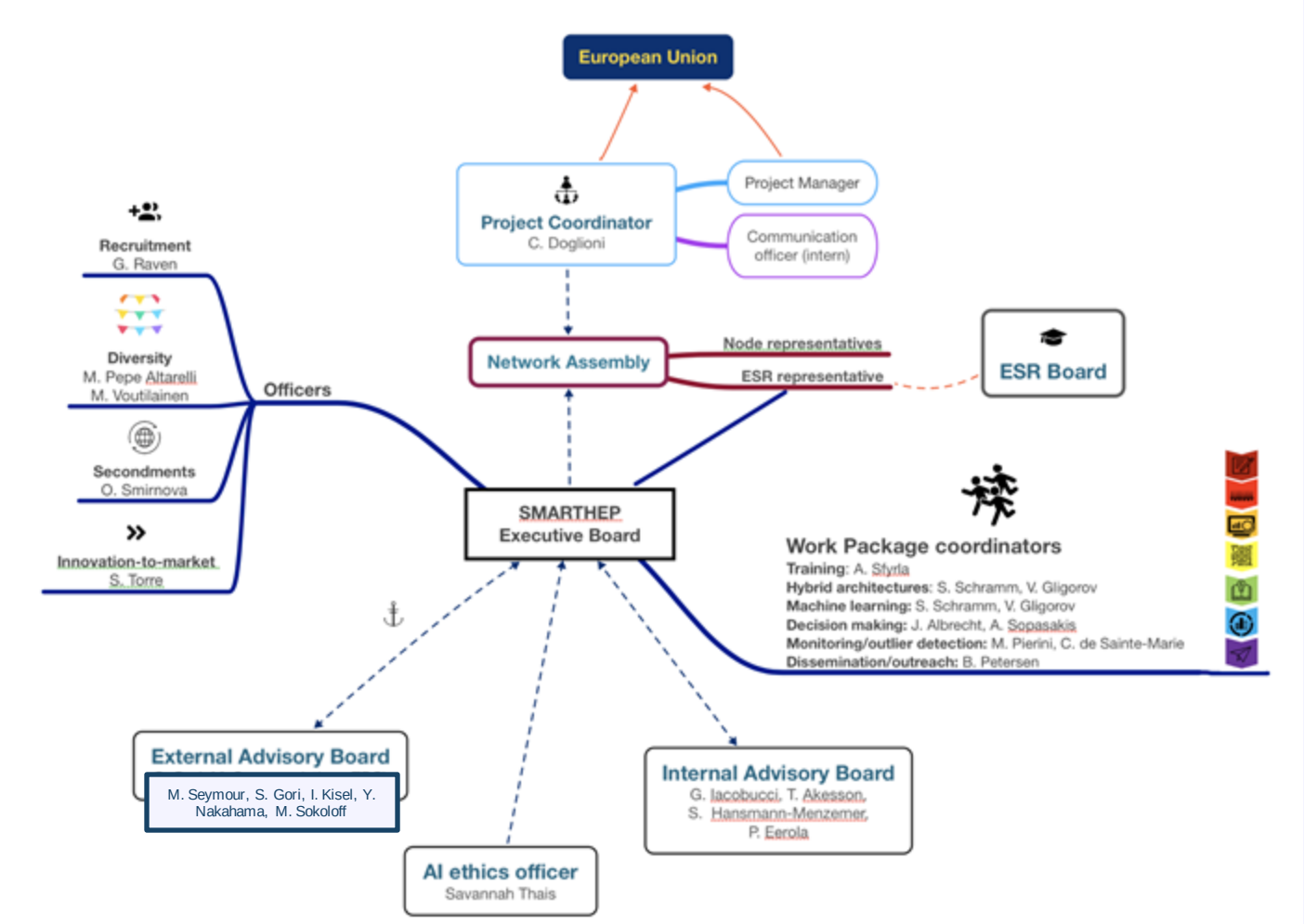
Who is who



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

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Work Package coordinators

WP1: Management

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

WP2: Training

Anna Sfyrla
UniGe

WP7: Dissemination & Communication

Brian Petersen
CERN

WP3: Physics and ML / WP4: Hybrid architectures

Martino Borsato
Milan Bicocca (**WP3**)

Steven Schramm
UniGe (**WP3/4**)

Vava Gligorov
CNRS/Sorbonne
(**WP3/4**)

WP5: Triggers

Johannes Albrecht
TUDO

Alexandros Sopasakis
Ximantis

WP6: Discoveries with RTA

Maurizio Pierini
CERN

TBC this week (Nicholas/Pierre/Shubham)
IBM

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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

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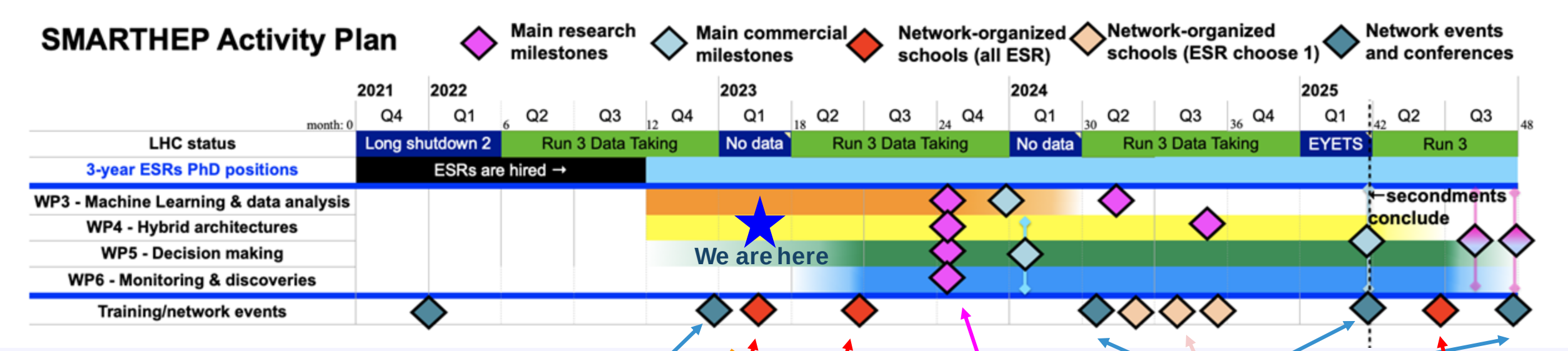
Our 4-year plan



Virtual kick-off meeting

In-person 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

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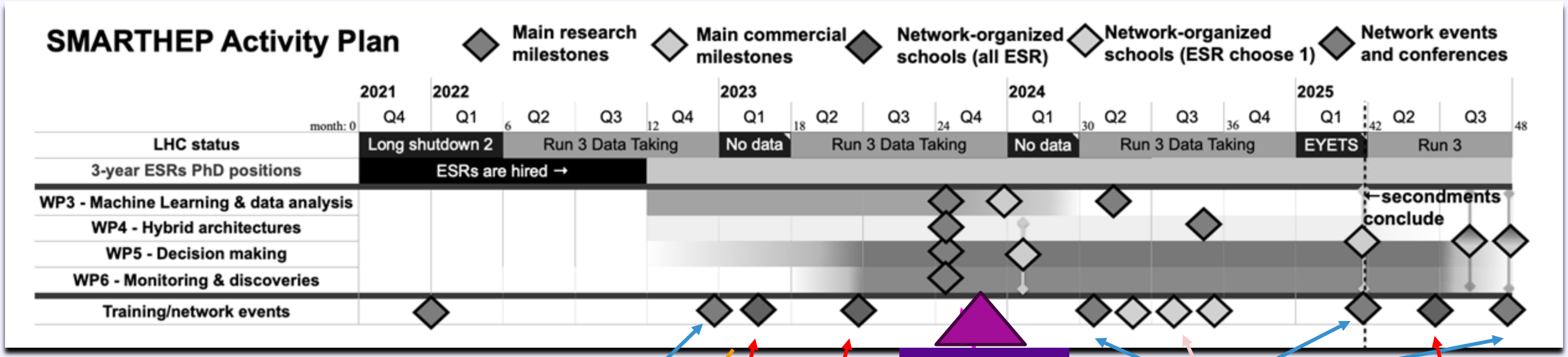
Our 4-year plan



Virtual kick-off meeting

In-person kick-off meeting

Mid-term check with the EU Project Officer

UniGe ML + Physics school

Advanced ML school

We are here

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

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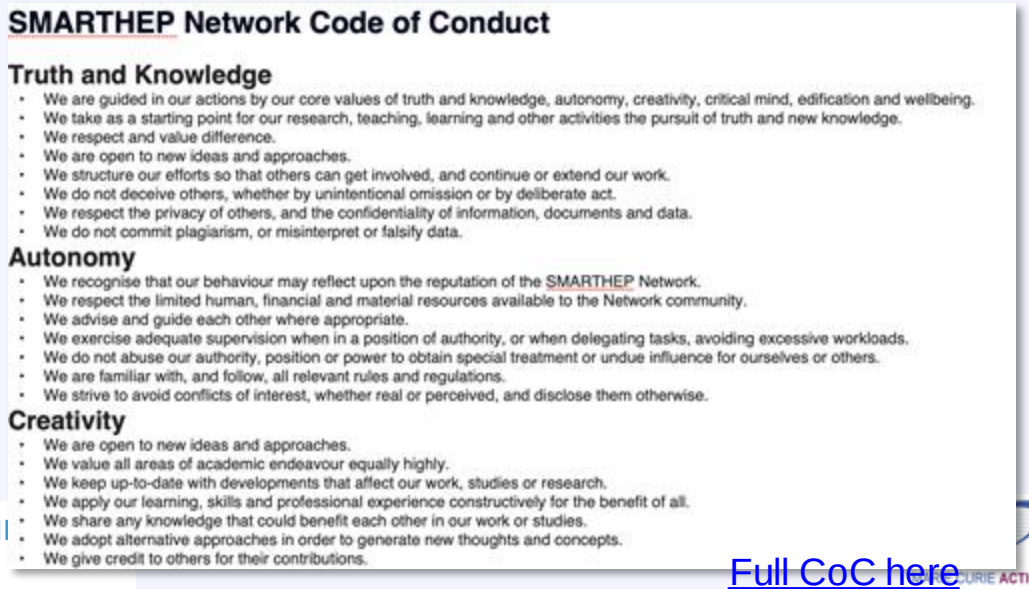
Code Of Conduct (applies to all events)

- 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 upon and pledging on 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.

Full CoC here

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Looking forward to more network activities and ESR results!

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Backup slides

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LUND UNIVERSITY

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17 May 2018

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If you have complaints regarding Lund University's processing of your personal data, you are always entitled to contact the relevant inspection authority, the Swedish Data Protection Authority.

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Print name: _____

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

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