

The SMARTHEP European Training Network

*Synergies between **MA**chine learning, **R**eal-**T**ime analysis and **H**ybrid architectures for efficient **E**vent **P**rocessing and decision making*

Jamie Gooding  technische universität
dortmund

On behalf of the SMARTHEP Network

Track 8 | CHEP 2023 | 9th May 2023



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



What is **SMARTHEP?**

European
Training
Network



What is **SMARTHEP?**

The SMARTHEP network



- EU Horizon funded training network running until late 2025
- 12 Early Stage Researchers (ESRs) across Europe
- 18 institutes involved, including:



The SMARTHEP network



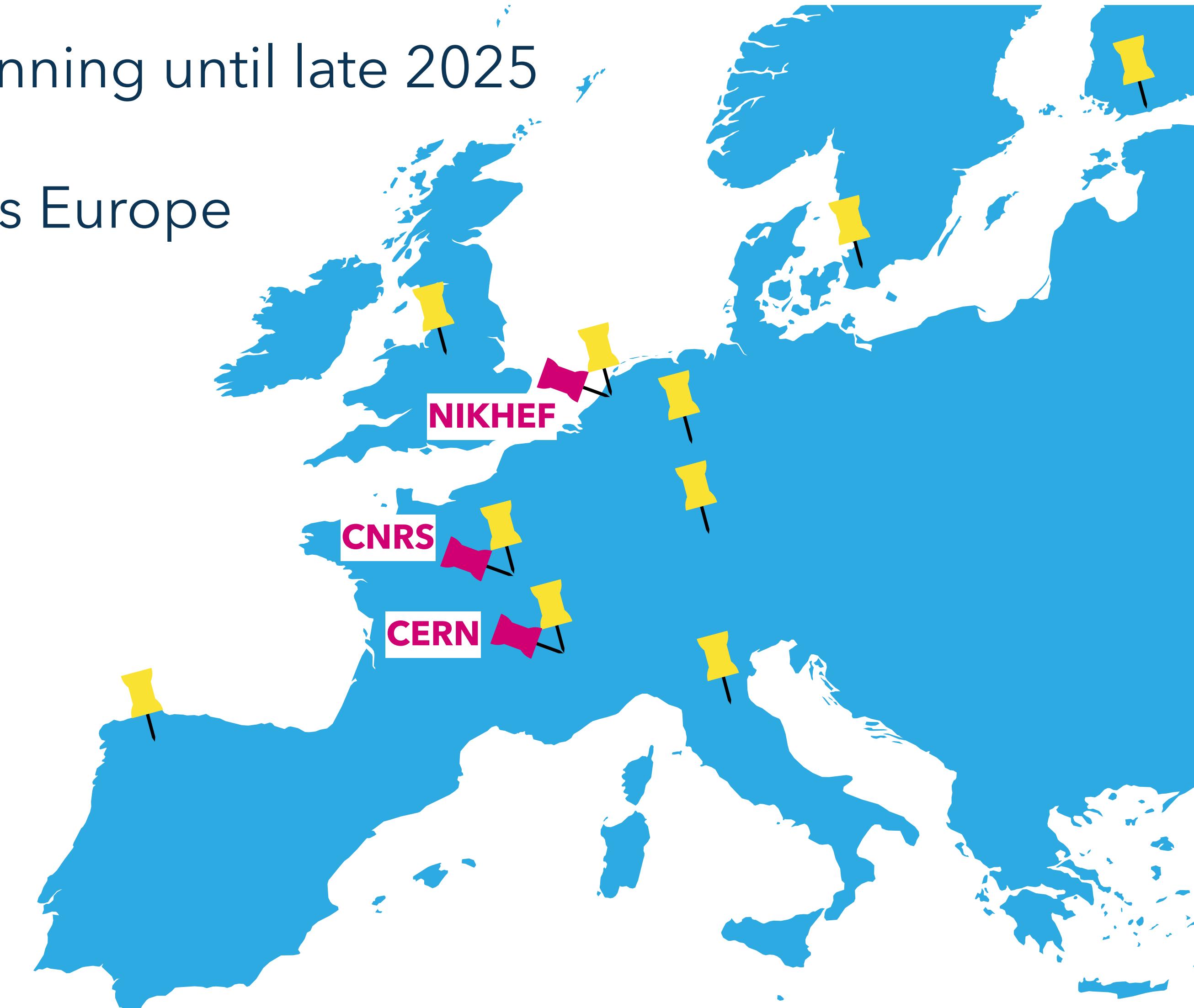
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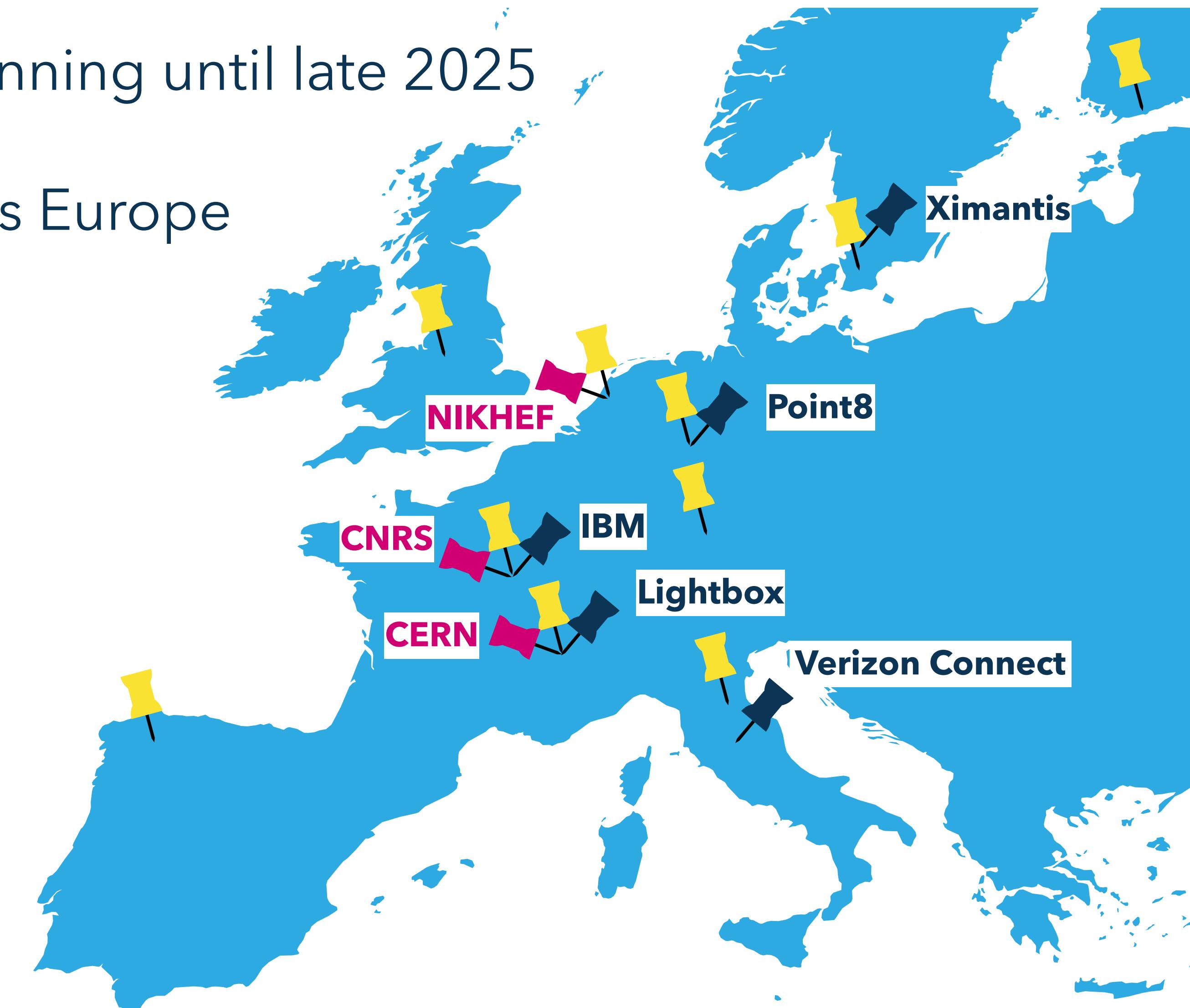
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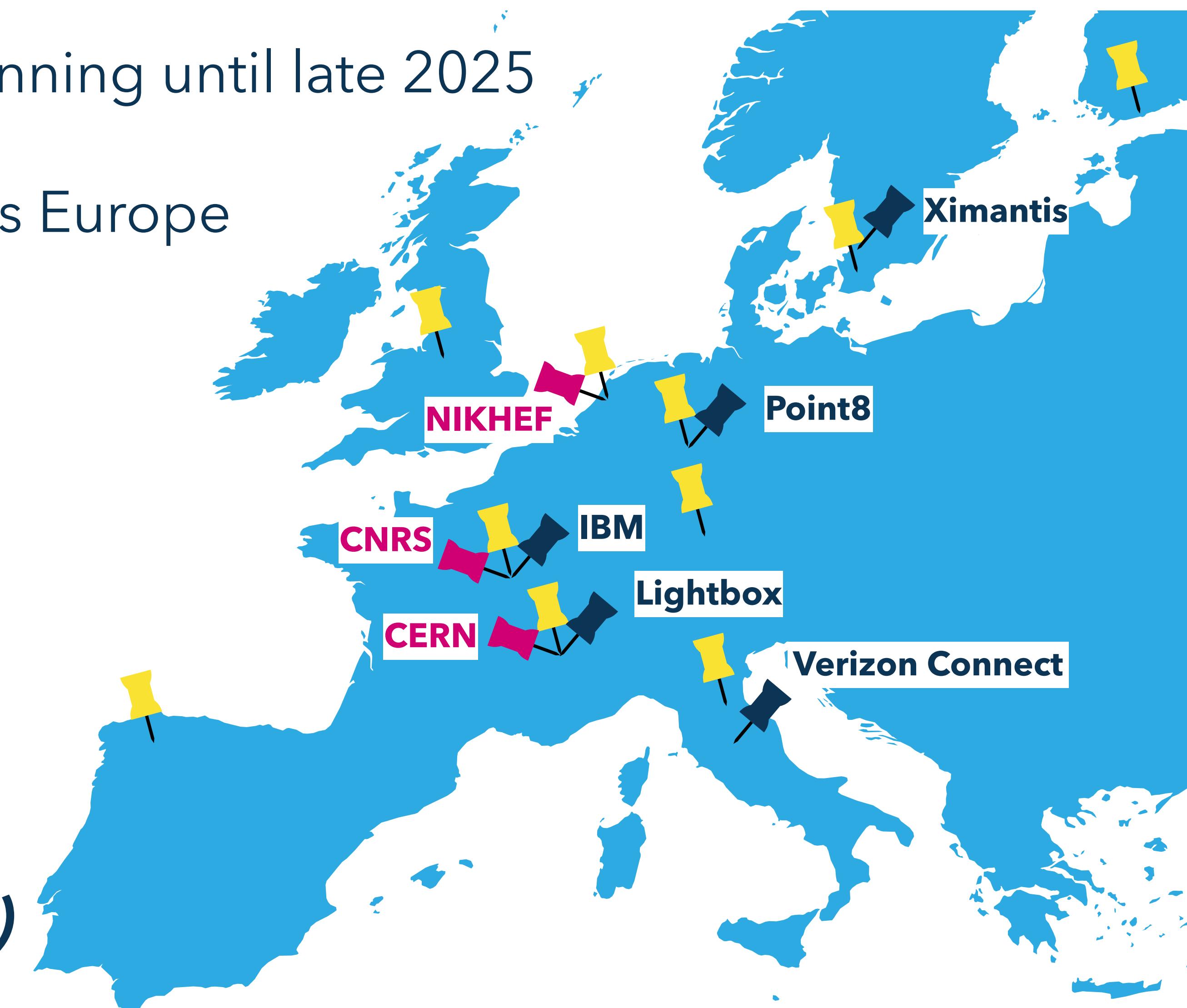


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The aim: bring together the **tools** and
expertise of **Real-Time Analysis (RTA)**



European
Training
Network

Real-Time
Analysis

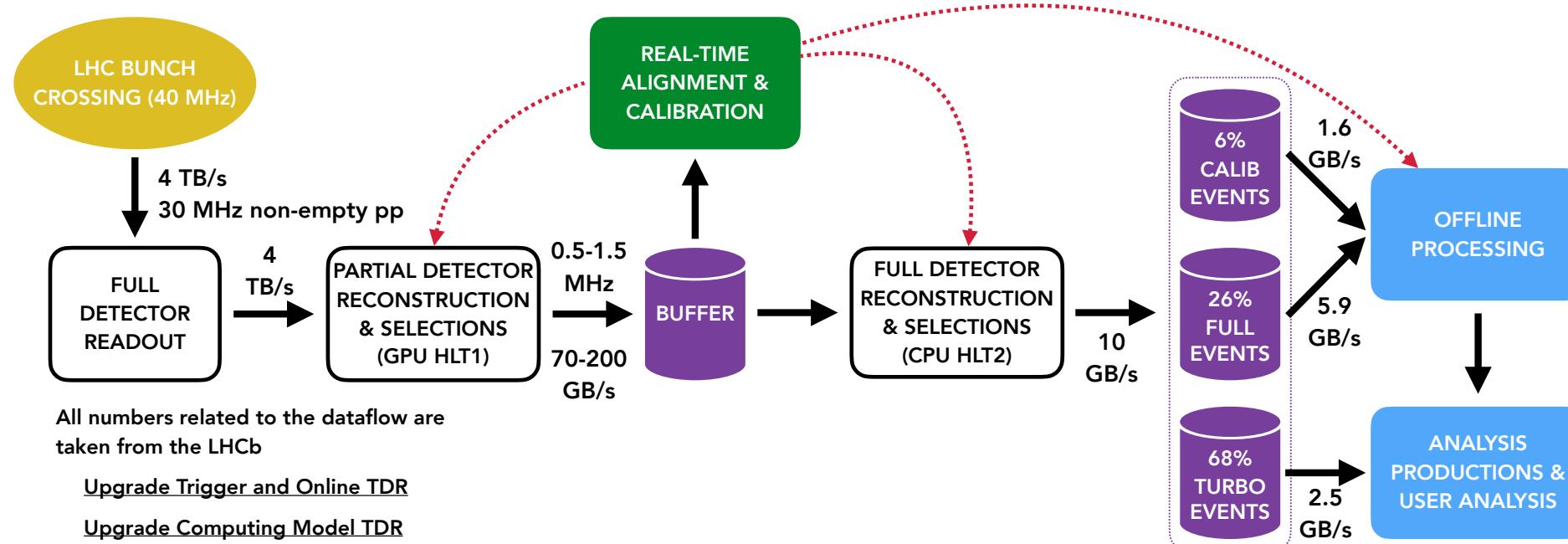
What is **SMARTHEP?**

Real-Time Analysis: Principles

The problem: too much data and not enough time to process it!

HEP problem

Large amounts of data to be processed immediately



LHCb Run 3 Dataflow, LHCb-FIGURE-2020-016

e.g. LHC event triggering

Industry problem

Detailed results required with short time-to-insight

Two sides of
the same coin¹



e.g. real-time vehicle monitoring

Real-Time Analysis: Principles

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...or how to drink from a firehose

C. Fitzpatrick, Mar. 2017

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↑ **But how do we get here?** ↑

Real-Time Analysis: Tools



The problem: too much data and not enough time to process it!

Principle is to process data online (as it is received); two tools at the heart of this:

Real-Time Analysis: Tools



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Principle is to process data online (as it is received); two tools at the heart of this:

Machine Learning

- Algorithms developed to **learn from data**.
- **Decisions** on **complex data** can be made more rapidly.²
- **Patterns/anomalies** can be recognised by models trained on **well-understood rules**.

Real-Time Analysis: Tools



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Hybrid architectures

- Often tasks highly parallelisable.
- Field Programmable Gate Arrays (**FPGAs**) ideal for **shorter bespoke tasks**.³
- Graphical Processing Units (**GPUs**) well-suited to **computationally intensive tasks**.⁴

Real-Time Analysis: Tools



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Our approach: train 12 ESRs in the RTA state-of-the-art from HEP and industry

European
Training
Network

Real-Time
Analysis

12 Early Stage
Researchers

What is **SMARTHEP?**

Early Stage Researchers



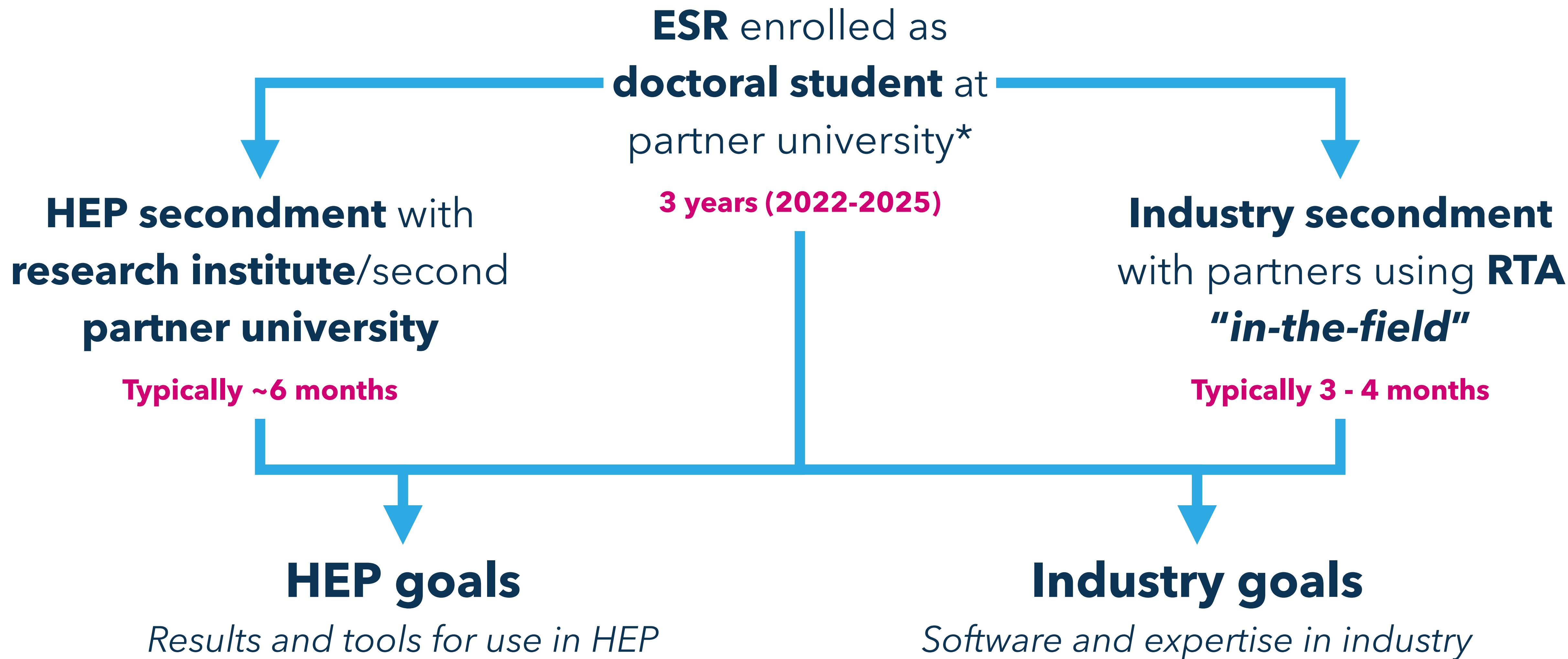
ESR enrolled as
doctoral student at
partner university*

3 years (2022-2025)

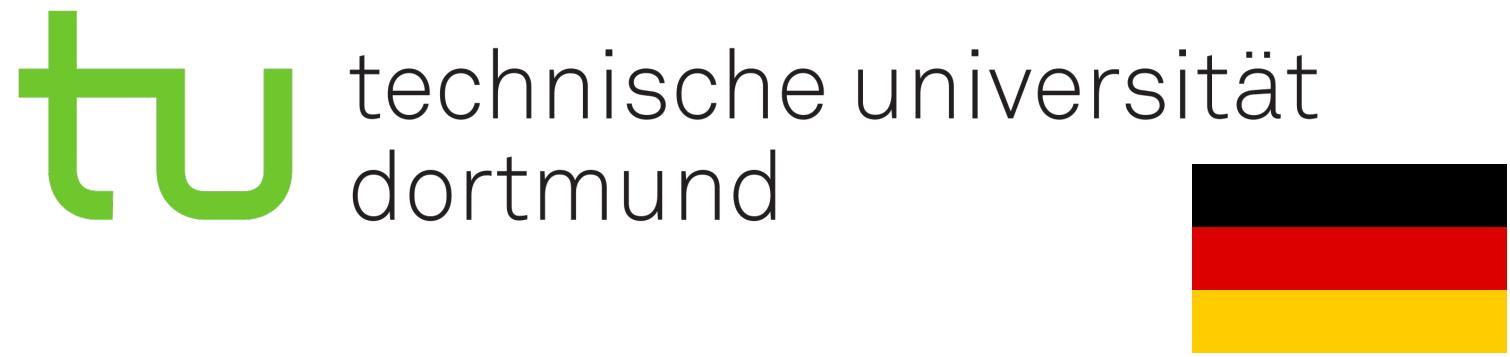
Early Stage Researchers



Early Stage Researchers

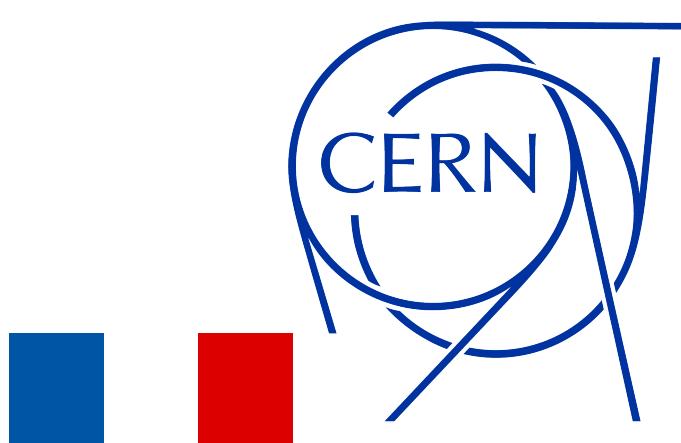
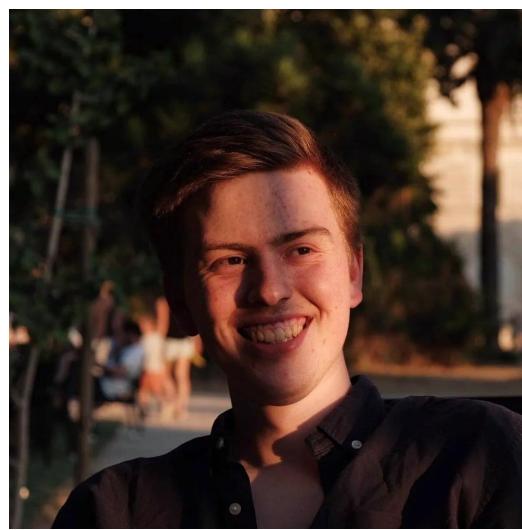


Example ESR: ESR7 (Me!)



*Studying at TU Dortmund,
working on the LHCb Experiment*

Example ESR: ESR7 (Me!)



HEP Secondment

6 months with CERN



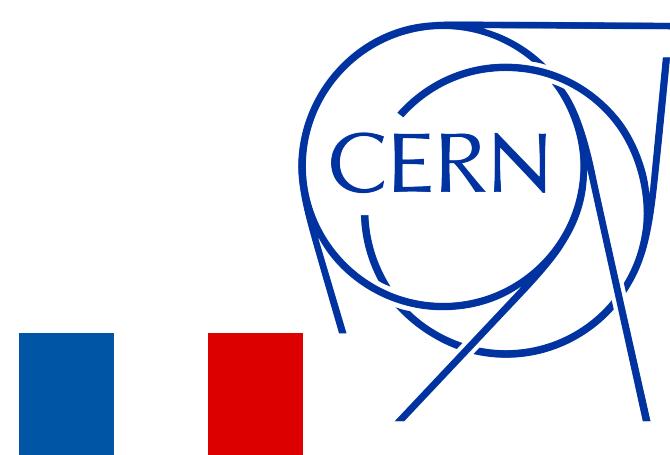
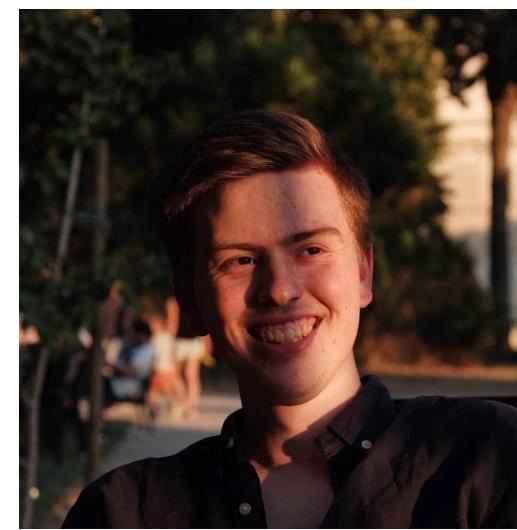
*Studying at TU Dortmund,
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Industry secondment

3-4 months with Ximantis

Example ESR: ESR7 (Me!)



HEP Secondment

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*Studying at TU Dortmund,
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x i m a n t i s



Industry secondment

3-4 months with Ximantis



HEP goals

Develop trigger algorithms for Lepton Flavour Violation searches at LHCb in Run 3



Industry goals

Develop algorithms for real-time traffic monitoring and forecasting.

A handful of our ESRs



| ESR | Main affiliation | HEP secondment | Industry secondment |
|-----------------------------|---------------------------|----------------|---------------------|
| ESR2 Laura Boggia | IBM S SORBONNE UNIVERSITÉ | cnrs | IBM |

Automated decision-making for fraud detection, collaboration detecting anomalies/patterns to classify HEP observations.

A handful of our ESRs



ESR

ESR2

Laura Boggia

ESR9

Carlos Cocha

Main affiliation

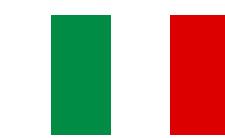
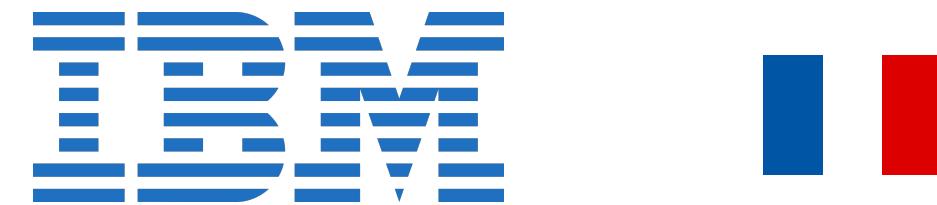


UNIVERSITÄT
HEIDELBERG
ZUKUNFT
SEIT 1386

HEP secondment



Industry secondment



Automated decision-making for fraud detection, collaboration detecting anomalies/patterns to classify HEP observations.

Real-time dark photon candidate selection at LHCb, collaboration processing vehicle video and sensor data in real-time.

A handful of our ESRs

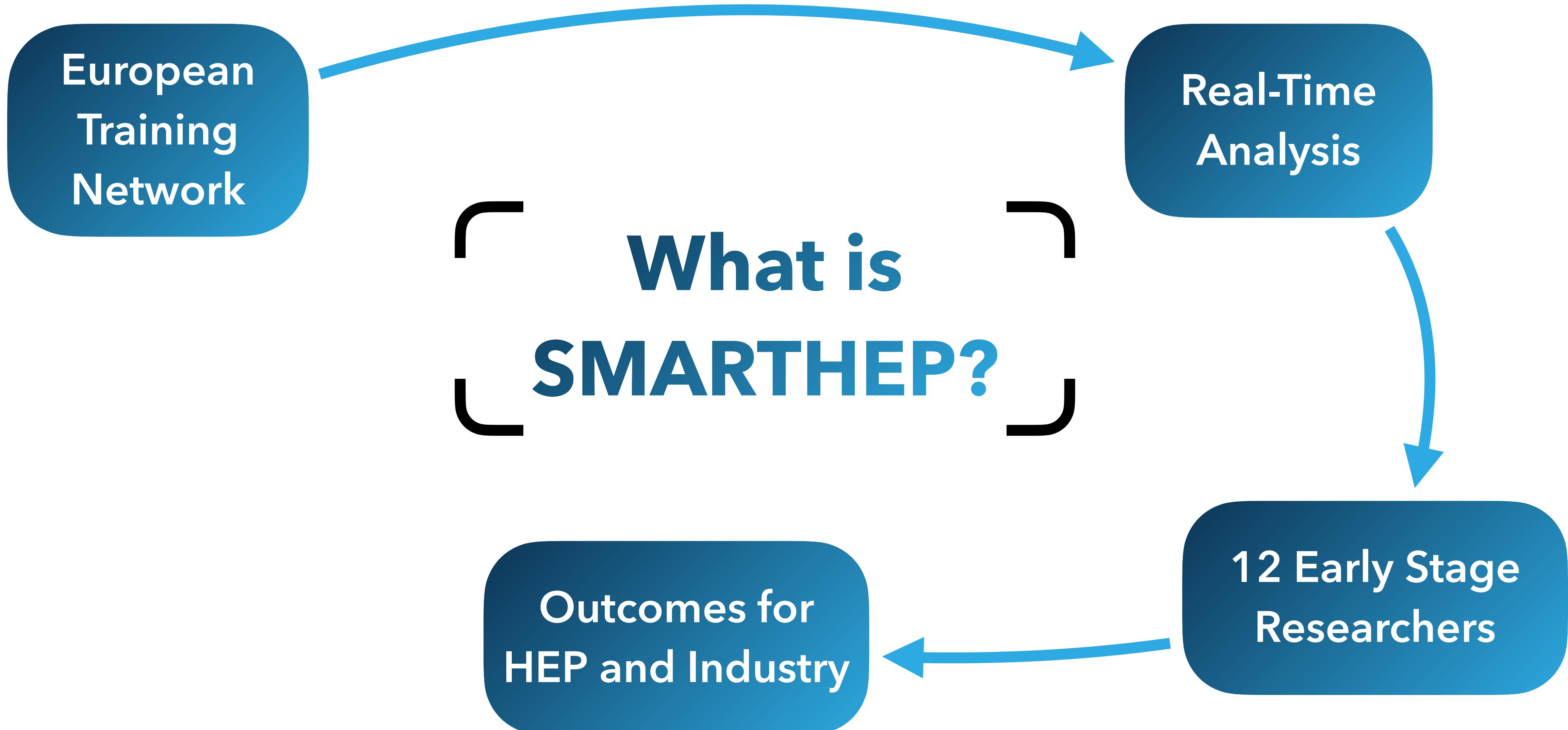


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| ESR2 Laura Boggia | IBM SORBONNE UNIVERSITÉ | cnrs | IBM |
| ESR9 Carlos Cocha | UNIVERSITÄT HEIDELBERG ZUKUNFT SEIT 1386 | tu technische universität dortmund | verizon connect |
| ESR10 Joachim Hansen | LUND'S UNIVERSITET | CERN | ximantis |

Automated decision-making for fraud detection, collaboration detecting anomalies/patterns to classify HEP observations.

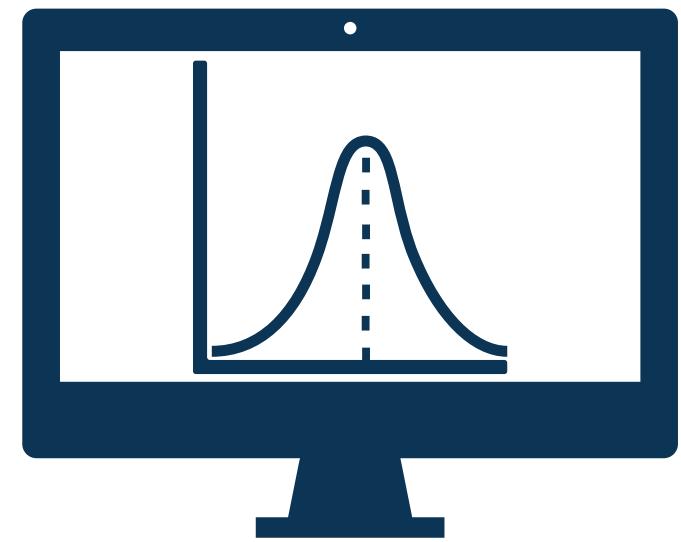
Real-time dark photon candidate selection at LHCb, collaboration processing vehicle video and sensor data in real-time.

Online calibration of ALICE time-projection chamber, collaboration with Ximantis monitoring/forecasting traffic information in real-time.



Network outcomes

Network outcomes

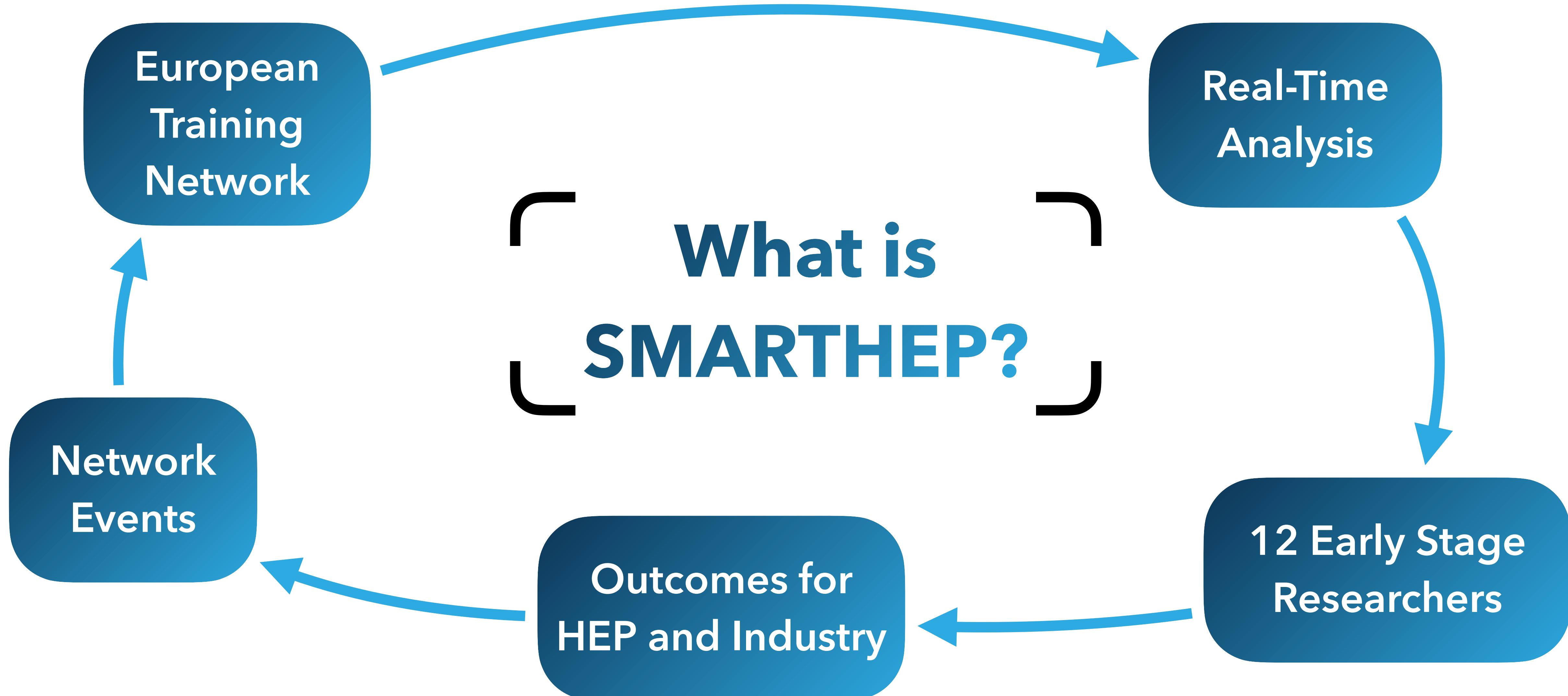


**Completed HEP
and industry
goals**

**Published
results and
whitepapers**

**Fully-trained
ESRs in RTA
state-of-the-art**

**Produced
software for
HEP/industry**



Network events

Events form backbone of ESR training and network cooperation:



- Participants' first chance to meet one another
- Review paper-writing course

- Outreach event for UoM students



- Lectures on particle physics
- Hands-on introduction to Machine Learning

- Seminars on ongoing experimental HEP efforts

Network events



Events form backbone of ESR training and network cooperation:



SMARTHEP Kick-off Meeting

21st - 25th Nov. 2022, Uni. of Manchester



First Collider Physics and Machine Learning School

10th - 13th Jan. 2023, Uni. de Genève

- Participants' first chance to meet one another
- Review paper-writing course
- Outreach event for UoM students

- Lectures on particle physics
- Hands-on introduction to Machine Learning

- Seminars on ongoing experimental HEP efforts

Coming soon:

- Annual Network Assembly
- Accelerator bootcamps

- Commercial applications school

Conclusions

- Hopefully now have a clear picture of what SMARTHEP is all about!
- Network runs until 2025; we hope to report achievements at future CHEPs.
- SMARTHEP(-adjacent) talks at CHEP
 - Machine learning based compression for scientific data, *Alex Ekman and Axel Gallen*, 14:30 – 8th May, Track 9.
 - The Run-3 ATLAS jet trigger, *Max Amerl*, 11:00 (right now!) – 9th May, Track 2.
 - Fast Inclusive Flavor Tagging at LHCb, *Claire Prouve*, 17:00 – 9th May, Track 9.

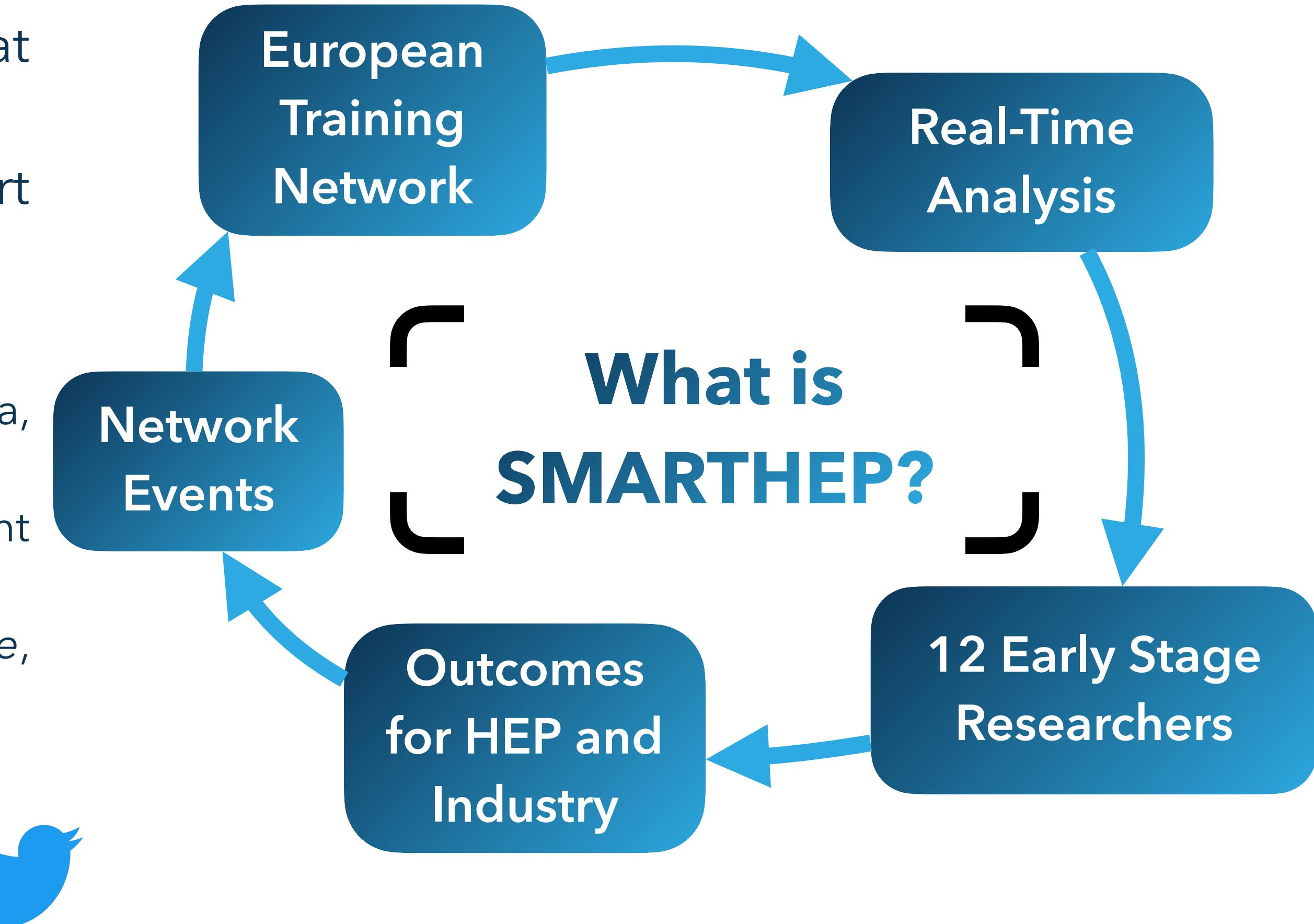
Get in touch



www.smartheponline.org

www.bit.ly/goodingjamie

@smartheponline
@goodingjamie

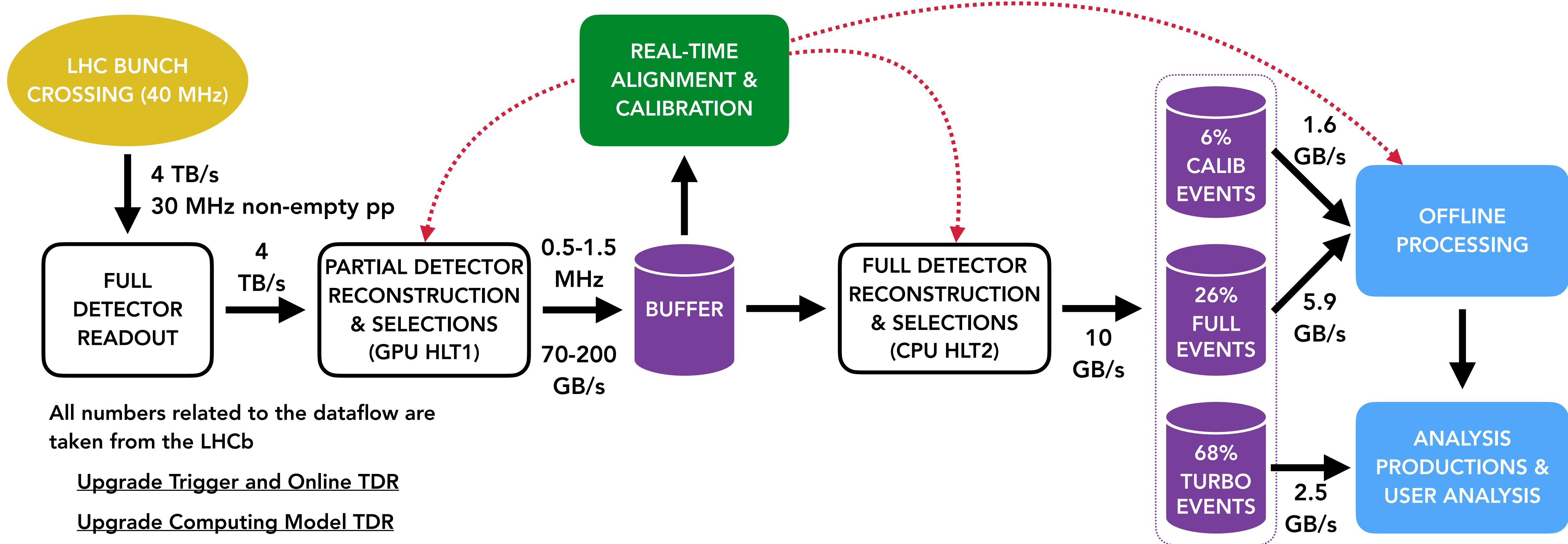


References

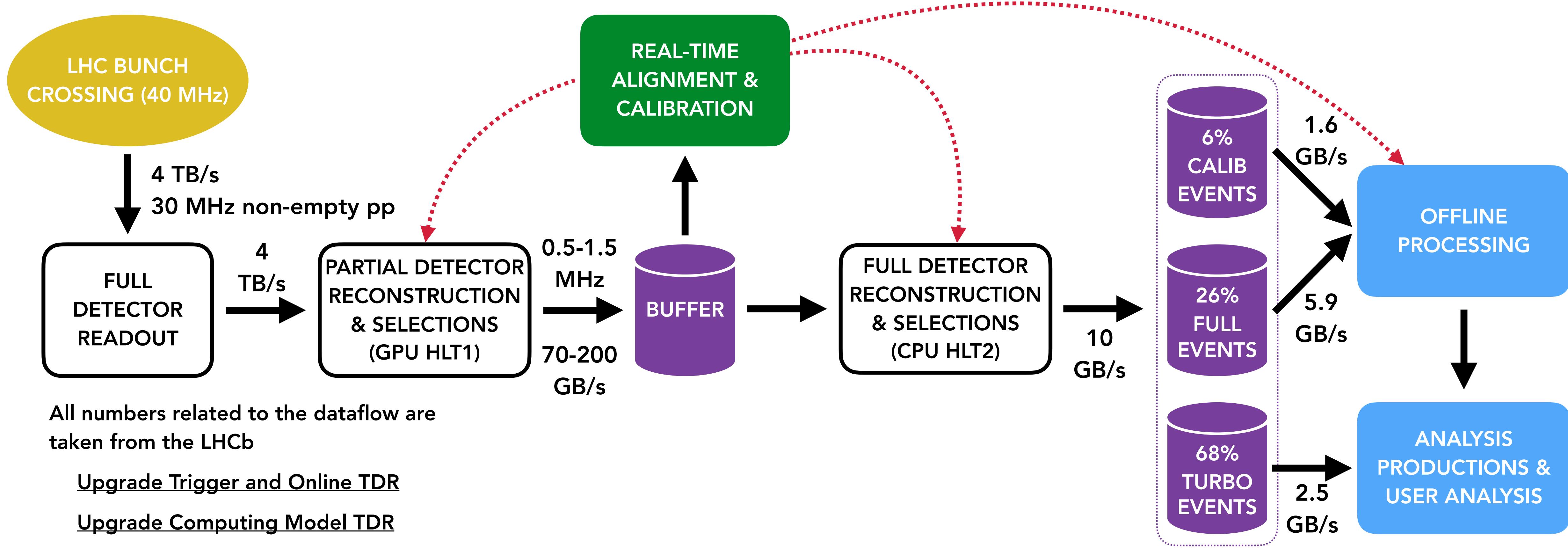
1. Hu et al. IEEE Access **2014**, 2, 652-687
2. Albertsson et al. J. Phys.: Conf. Ser. **2018**, 1086, 022008
3. Duarte et al. Comput. Softw. Big. Sci. **2019**, 3, 13
4. vom Bruch JINST **2020**, 15, C06010

Backup slides

Real-time triggering at the LHC



Real-time triggering at the LHC



All numbers related to the dataflow are taken from the LHCb

[Upgrade Trigger and Online TDR](#)

[Upgrade Computing Model TDR](#)

LHCb Run 3 Dataflow, LHCb-FIGURE-2020-016

SMARTHEP whitepapers



Series of 4 real-time analysis review papers (expected later this year):

Machine learning for real-time analysis

Summarising ML for RTA; focusing on SMARTHEP use cases/best practices for ML in HEP.

Hybrid architectures

Review of hybrid architecture (CPU+GPU) deployments in RTA; focus on SMARTHEP use cases.

Whitepapers

Trigger systems of the LHC

Review of the triggers of LHC collaborations and best practices for software in RTA applications.

RTA in LHC experiments

Review of use of RTA techniques by LHC experiments, including RTA-based searches and anomaly detection.

Open and FAIR data



As a network we are committed to data fairness:

Findable, **A**ccessible, **I**nteroperable, and
RReusable digital assets

Beyond this, we are committed to reproducibility & sustainability of software. Our work is most useful when it is made available to the community.