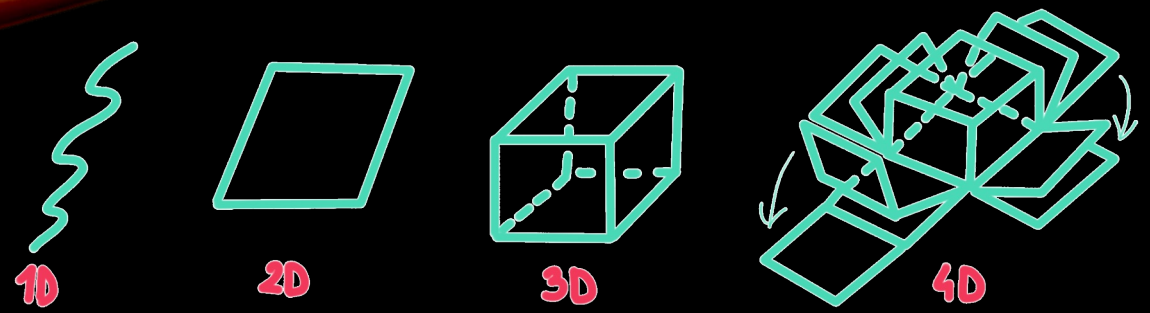


Time-assisted reconstruction

Valentina M.M. Cairo

CERN

Polarized Perspectives: Tagging and Learning in the SM

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

COMETA

REMINDER OF COMETA GOALS

Comprehensive Multiboson Experiment-Theory Action

Establish a long-lasting and multi-directional knowledge exchange among experts (theorists, experimentalists, machine learning experts, etc) in:

- the measurement of processes with single and multiple gauge and Higgs bosons at the LHC;
- the reconstruction of physics objects from detector hits;
- higher-order calculations for multi-boson processes and modelling of polarised weak bosons;
- the formulation and phenomenology of BSM models of EWSB, as well as SMEFT and HEFT;
- the development of Monte Carlo and Parton Shower codes for collider simulations;
- The development of state-of-the-art ML/DL methods (in academia and industry) and their application to HEP.

https://www.cost.eu/actions/CA22130

REMINDER OF COMETA GOALS

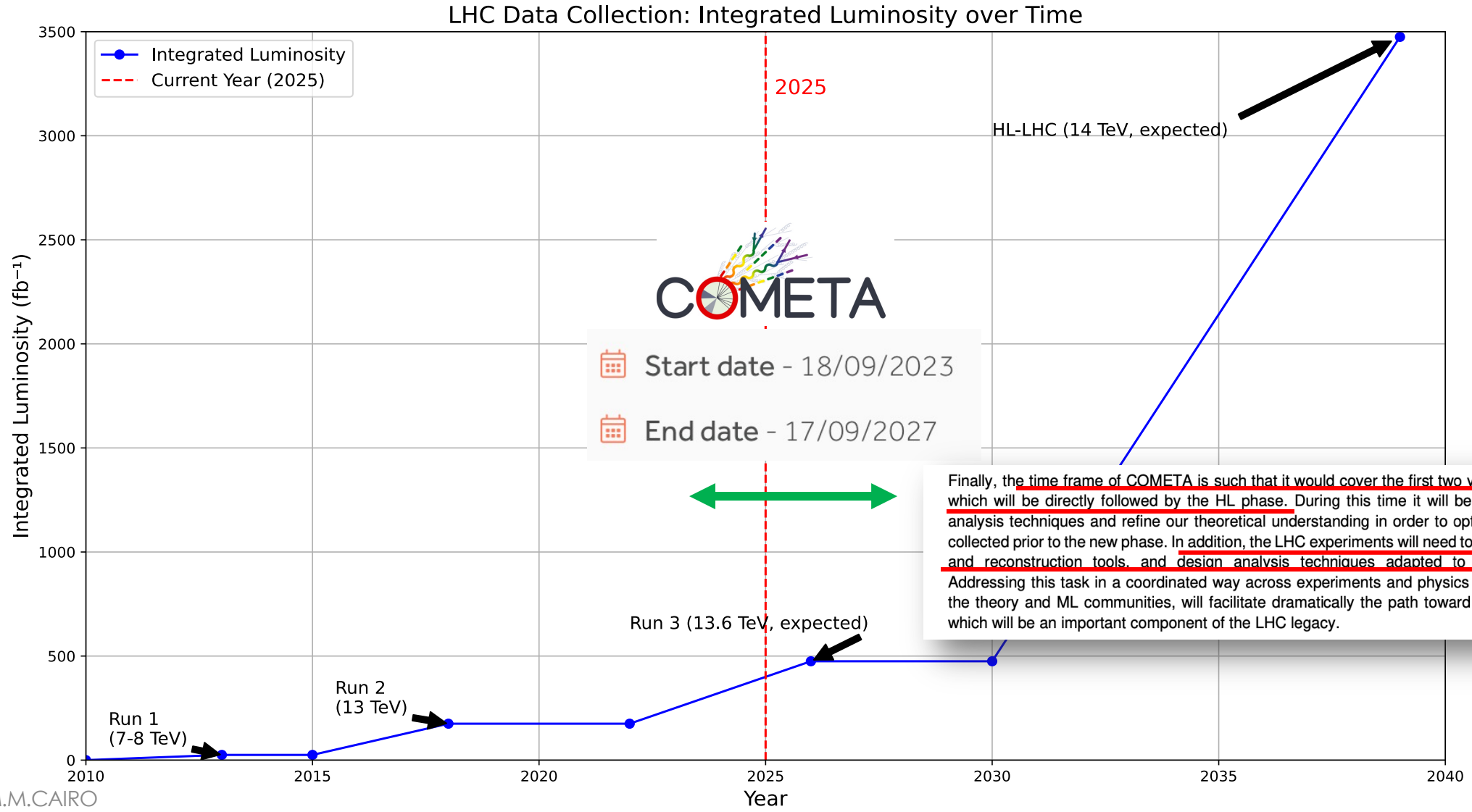
a. COMETA will promote the development of **optimised trigger designs for the HL-LHC** that will ensure higher event yields and allow lower momentum thresholds for leptons. These algorithms will use topological information on the events and benefit from some recent ML developments for jet-tagging and object reconstruction, tailored to the foreseen hardware upgrades.

b. The **reconstruction of jets** requires a proper combination of inputs from various calorimetry and tracking sub-detectors, which record the distinct time and space evolution of showers from different particles. In order to efficiently exploit these inputs, 3D localisation ML/DL algorithms are required. For both physics and ML communities, combination of heterogeneous information and the presence of symmetries play a fundamental role. Geometric DL encodes them using mathematical methods such as graph computations and GNNs, making it possible to study complex systems, for instance by removing symmetry-duplicated data. On the other hand, recently developed techniques in Lie Algebra NNs (or Group NNs) could instead help learning unknown symmetries of a complex system. Both scenarios would potentially lead to a more complete physical understanding of the problem.

A deep interaction between the HEP and ML communities will enable the development of optimised tools by exploiting at best the expertise of both groups.

c. COMETA's physics goals will be crucially supported by the development of improved **algorithms to tag forward jets** characteristic of VBF/VBS topologies and to provide **central hadronic activity veto**, to help suppress QCD-induced backgrounds. The forward region is the most challenging for hadronic final states due to limited tracking coverage, radiation damage, and pileup. This condition will get significantly worse at the HL-LHC, where an improved understanding of the tagged jets using ML/DL will be indispensable to enable the vast majority of VBF/VBS studies, and in particular VBF HH searches.

TIMESCALE

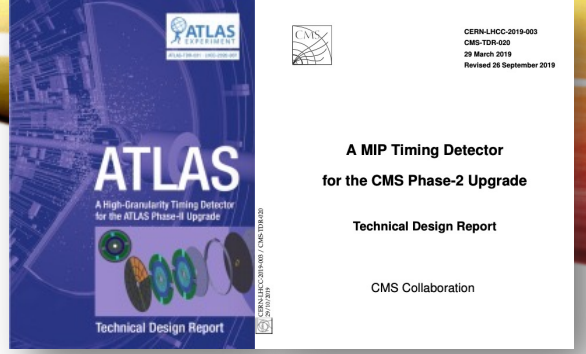


Finally, the time frame of COMETA is such that it would cover the first two years of Long Shutdown 3, which will be directly followed by the HL phase. During this time it will be important to improve the analysis techniques and refine our theoretical understanding in order to optimally profit from the data collected prior to the new phase. In addition, the LHC experiments will need to develop new identification and reconstruction tools, and design analysis techniques adapted to the upgraded detectors. Addressing this task in a coordinated way across experiments and physics groups, with support from the theory and ML communities, will facilitate dramatically the path toward combined interpretations, which will be an important component of the LHC legacy.

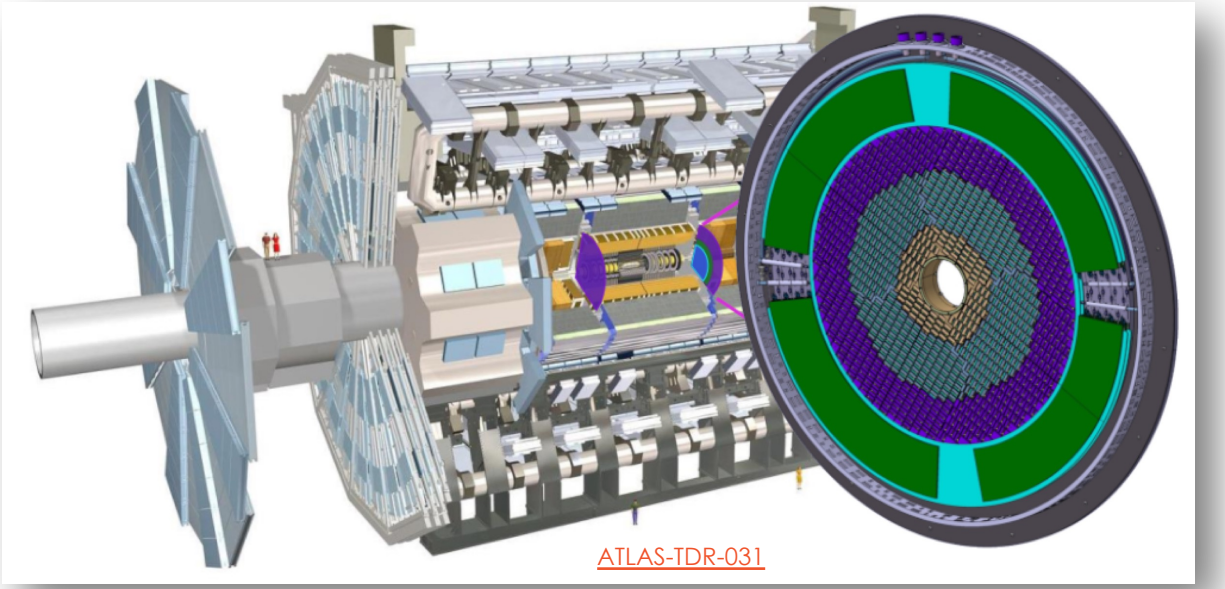
UNFOLDING A NEW DIMENSION

Addition of timing layers to HEP detectors growing area of interest

- At the LHC, main goal is pile-up mitigation



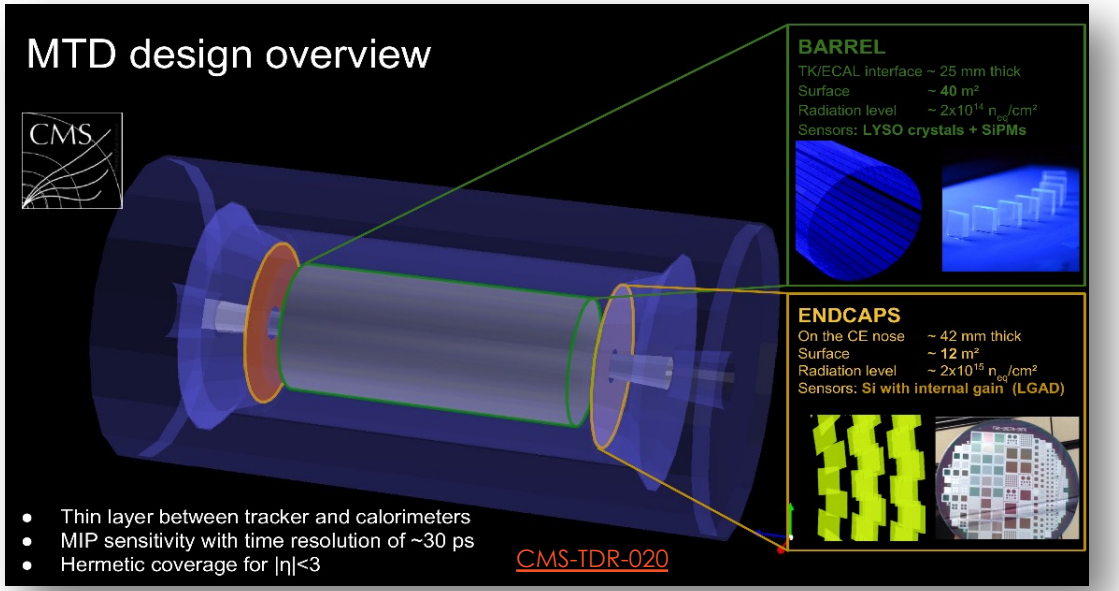
ATLAS High Granularity Timing Detector



ATLAS-TDR-031

LGADs to cover the
forward pseudorapidity region $2.4 < |\eta| < 4.0$

CMS MIP Timing Detector



CMS-TDR-020

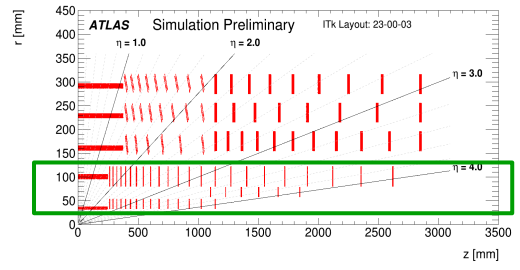
LGADs and crystals for hermetic coverage
up to $|\eta| < 3.0$

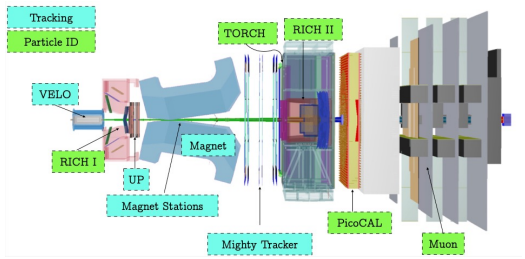
4D TRACKING

Next step in advancing technologies are real 4-dimensional silicon trackers
with resolution of $O(10\ \mu m)$ & $O(10\ ps)$

- **Interesting opportunities during HL-LHC and, in particular, for future energy frontier trackers**

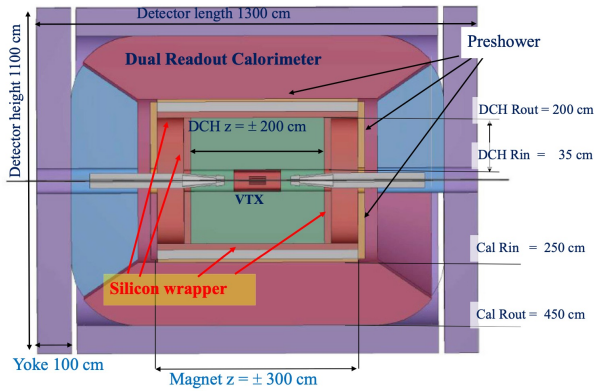
HL-LHC Beyond Run 4





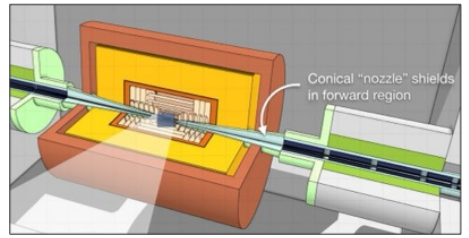
4D tracking for replacements/upgrades?

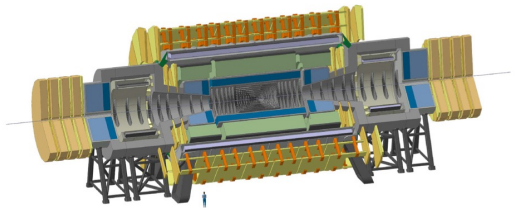
Electron-positron colliders



Timing layers for flavour tagging, particle ID, and LLP searches

Muon collider / hadron colliders





Beam-induced backgrounds (μ) and pile-up suppression (hh)

V.M.M.CAIRO 2035 2040s 2050s and beyond

2203.13900

4D TRACKING

Next step in advancing technologies are real 4-dimensional silicon trackers
with resolution of $O(10\ \mu m)$ & $O(10\ ps)$

- **Interesting opportunities during HL-LHC and, in particular, for future energy frontier trackers**

HL-LHC Beyond Run 4

4D tracking for replacements/upgrades?

Electron-positron colliders

Timing layers for flavour tagging, particle ID, and LLP searches

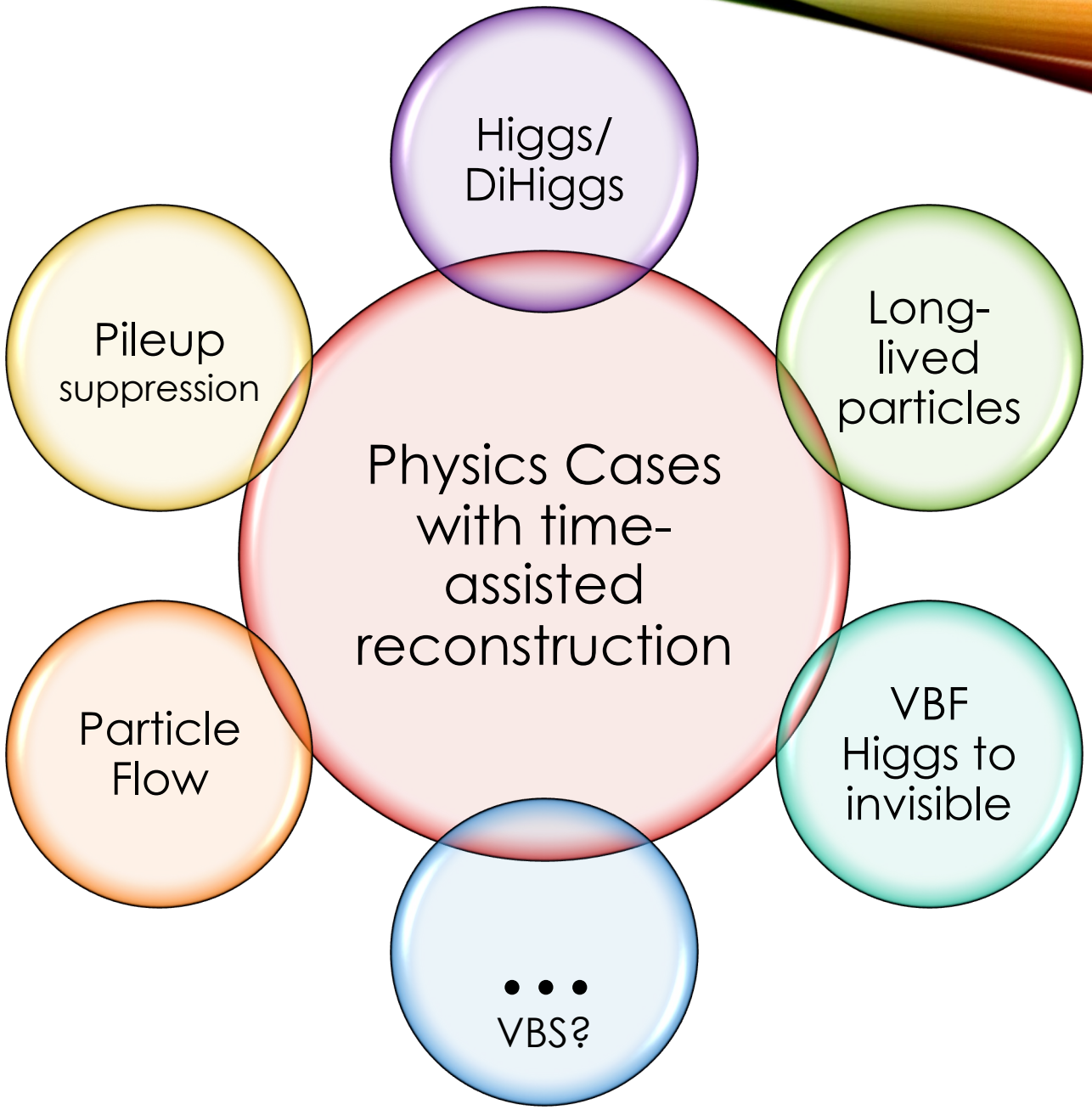
Muon collider / hadron colliders

Beam-induced backgrounds (μ) and pile-up suppression (hh)

The topic offers great opportunity for cross-experiment developments of cutting-edge algorithms
and
COMETA provides a unique venue to pursue them

2035 — 2040s — 2050s and beyond

2203.13900


Higgs/
DiHiggs
Pileup
suppression
Long-
lived
particles
Physics Cases
with time-
assisted
reconstruction
Particle
Flow
VBF
Higgs to
invisible
• • •
VBS?


Tracking
Trigger
Vertexing
Time-assisted reconstruction
Material/ Layout
Flavour Tagging
Digitization

AGENDA

09:35 **Track reconstruction with timing in ATLAS during the HL-LHC for Run 4 and beyond**

Speakers: Lorenzo Santi, Lorenzo Santi (CERN)

10:05 **Track reconstruction with timing in CMS during HL-LHC [remote]**

Speakers: Ksenia de Leo (INFN Trieste (IT)), Fabio Cossutti (Universita e INFN Trieste (IT))

10:35 **4D Tracking & Vertexing with ACTS**

Speaker: Pierfrancesco Butti (CERN)

Thanks for your attention!

Valentina M.M. Cairo

CERN