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# Machine Learning and the needle in the needle stack **EPS 2025 Young Experimental Physicist Prize**





Streaming

#### Clissa et al. 10.3389/fdata.2023.1271639

#### Storage

data sources

Production



#### **Time to process**



#### **Production** frequency



What we're looking for is way down here somewhere!







#### 2) Discard > 99% of collisions within ~few µs

#### 2) Send reduced event info to L1 (5% of internet)

#### 1) Buffer data inside detector

A



# LHC (currently)



- Current trigger systems  $\bullet$ 
  - L1 trigger
    - Hardware-based, implemented in custom-built electronics
    - ala viva atav inita via atiana :16





### High Luminosity LHC



real and lerity no tracking information





# Geneva Lake

#### CMS

#### Fast ML inference on specialised hardware

LHCb

#### **ASIC** inference

#### **Detector:** Latency O(1) ns



#### **FPGA** inference

# Level-1 trigger: Latency O(10) ns



# nature machine intelligence

Quantized neural networks on the edge





Nature Machine Intelligence 3 (2021)











# 

# <u>JINST 13 P07027 (2018)</u> Mach. Learn.: Sci. Technol. 2 045015 (2021)

# - - LOST DATA SELECTED DATA - POSSIBLE NP SIGNAL

#### Trigger threshold



#### Are we keeping "the right" ones?

# **Anomaly Detection triggering**



#### **Trigger threshold**







... in 50 nanoseconds!



# **Outlier detection in analysis**



#### Before cut on anomaly score After cut on anomaly score

The CMS Collaboration 2025 Rep. Prog. Phys. 88 067802 Friday Track 9: Model-independent searches and anomaly detection at the CMS experiment, L. Moureaux



#### Setting limits on ~50 New Physics hypothesis in one go, many which have never been searched for!

The CMS Collaboration 2025 Rep. Prog. Phys. 88 067802 Friday Track 9: Model-independent searches and anomaly detection at the CMS experiment, L. Moureaux



E. Govorkova et al (2022)

#### P. Odagiu et al. 2024

#### **On-detector data** compression

### **10k ECONS with ML inside** in CMS HL-LHC



#### TWEPP, C. Suarez



#### ...and outside

#### **Colliding particles not cars: CERN's** machine learning could help selfdriving cars

CERN and software company Zenseact wrap up a joint research project that could allow autonomous-driving cars to make faster decisions, thus helping avoid accidents

25 JANUARY, 2023 | By Priyanka Dasgupta



#### N. Ghielmetti et al. 2022





- MLPerf tinyML benchmarking
- For fusion science phase/mode monitoring
- <u>Crystal structure detection</u>
- Triggering in DUNE

# satellites



- Accelerator control
- Magnet Quench Detection
- Food contamination detection
- <u>Quantum control etc....</u>



# 1-5 September 2025 fast machine learning for science

Real-time and accelerated ML for fundamental sciences

indi.to/fastml25







# Thank you very much!

