CERN

Overview of the CERN-CEVA Project

Fast Inference Single Shot Detection

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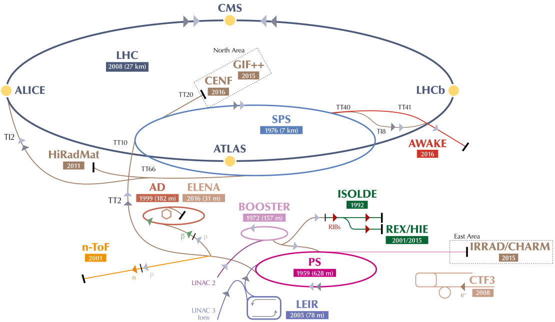
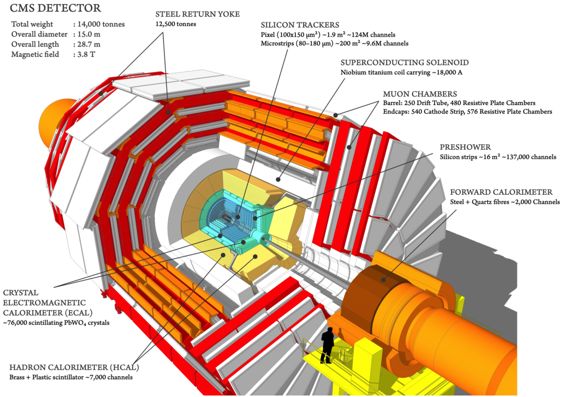
The CERN Large Hadron Collider



A view on the CERN's accelerator complex. From [1].

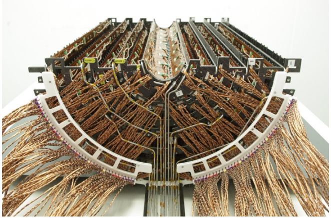
- 26.7 km long, the most powerful accelerator in the world.
- 14 TeV collision energy.
- Provides high rate of proton-proton or heavy-ion collisions (*events*).
- Bunch spacing of 25 ns (40 MHz rate of collisions yield).
- Four points where the two beams intersect are equipped with large experimental apparatuses in underground caverns (**detectors**).

The Compact Muon Solenoid Experiment



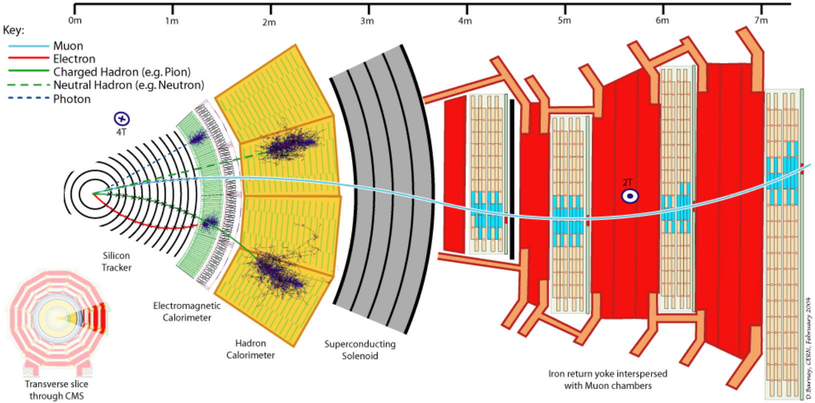
A cutaway diagram of the CMS detector. From [2].

- Designed to cover the widest possible range of physics at the LHC.
- Characterizes all the particles that were produced in a collision based on measurements of 3-**D positions** and **energy deposits**.
- Positions measured by tracking devices: silicon and muon detectors.
- Energy deposits measured by calorimeters.
- Powerful 3.8 T magnet completes the design.
- Trigger system selects interesting events.



A barrel pixel detector halves, assembled at Paul Scherrer Institute, with modules made by several European consortia. The photograph shows very lightweight mechanical support, very fine CO_2 cooling tubes and the impressive amount of cabling in a tight volume. From [3, 4].

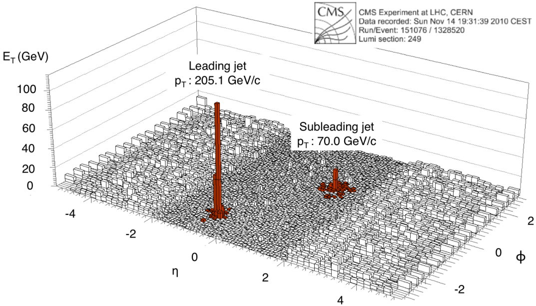
The CMS Calorimeters



A sketch of the particle interactions in a transverse slice of the CMS detector, from the collision point to the muon detectors. From [5].

- Calorimeters are devices that measure the energy of the particles.
- Neutral particles (e.g. photons) are not visible in tracking devices but revealed by the energy deposit they leave in the calorimeters.
- CMS has two types of calorimeters: electromagentic (ECAL) [6] and hadron (HCAL) [7].
- ECAL made of 76000 scintillating $PbWO_4$ crystals.
- HCAL made of brass and plastic scintillators.
- ECAL absorbs elections and photons; hadrons begin to lose energy in ECAL only to be stopped in HCAL.

- A *jet* is a collimated spray of particles.
- Used to probe the underlying elementary particle that initiates the cascade of particles.



Example of a dijet in a Pb-Pb collision event. Plotted is the summed transverse energy in the ECAL and HCAL vs. η and ϕ, with the identified jets highlighted in red, and labeled with the corrected jet transverse momentum. From [8].

The CMS Trigger System

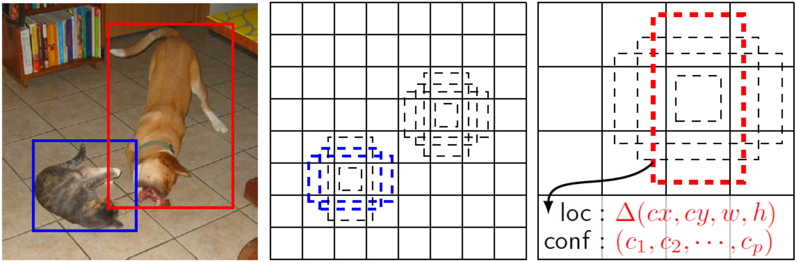
- Each event corresponds to around 1 MB in unprocessed form.
- The LHC operates at the rate of 40 million events per second.
- LHC is one of the largest sources of data in the world today.
- Trigger system selects interesting events due to storage constrains
- Trigger system is essentially a hierarchical set of algorithms.
- The Level 1 Trigger [9], reduces the 40 MHz input to a 100 kHz rate. Implemented on FPGAs and ASCIs. Approximately 3.2μs to decide.
- High Level Trigger [10] scales the 100 kHz stream from L1 Trigger rate down to 1 kHz. It is a collision reconstruction software running on a computer farm of about one thousand commercial processors. The decision has to happen in approximately 100 ms.

CERN-CEVA Collaboration

- LHC pushes for higher energy of collisions: an objective to collect 10x more data than in the initial design by around 2030.
- Urge to implement complex algorithms early in physics event selection process.
- Case study: jet detection using calorimeter energy deposit suitable for the trigger system time constraints.
- How: Single Shot Detection, Binary Neural Networks, CEVA's custom electronics.
- Next talk: HLS4ML.

SSD

- SSD (Single Shot Detector) is a technique to take *one single shot* to detect multiple objects within the image.
- Proposed in 2016, well establish technique in the community.
- For each location, we got k bounding boxes; For each of the bounding box, we compute c class scores and 4 offsets relative to the original default bounding box shape.



(a) Image with GT boxes (b) 8×8 feature map (c) 4×4 feature map

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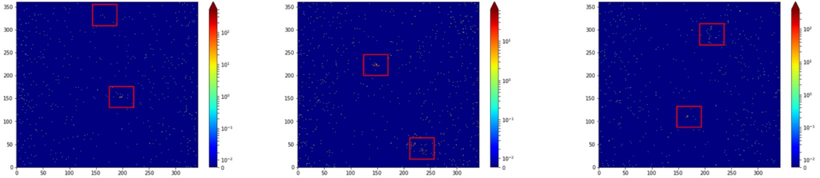
Method	mAP	FPS	batch size	# Boxes	Input resolution
Faster R-CNN (VGG16)	73.2	7	1	~ 6000	$\sim 1000 \times 600$
Fast YOLO	52.7	155	1	98	448×448
YOLO (VGG16)	66.4	21	1	98	448×448
SSD300	74.3	46	1	8732	300×300
SSD512	76.8	19	1	24564	512×512
SSD300	74.3	59	8	8732	300×300
SSD512	76.8	22	8	24564	512×512

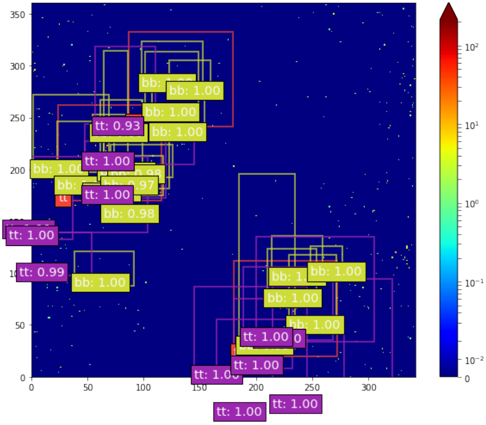
Inference Time

Case study: Dataset



- Calorimeter energy deposit represented as an 360x340 px image.
- 1-channel for ECAL only, 2-channels for both ECAL and HCAL.
- 4380973 events (images).
- 0.5 TB of data (in h5 files).
- Approximately 3.5 jets on average.
- Classes: `bb` (jet), `HH`, `WW`, `tt` (wide jets).

Case study: First Single Shot



Bottom Line: Challenges

- Fast inference neural networks suitable for the CMS trigger system.
- Transferring object detection techniques to non-natural images.
- Reaching high classification accuracy with binary networks.
- Distributed training for large datasets.

References

[1] CERN, "CERN's Accelerator Complex," 2016.

[2] F. Marcastel, "CMS Tent Point 5 Cessy," 2013.

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[4] K. Gill and EP-CMX, "CMS pixel upgrade: a truly global endeavor," 2017.

[5] S. R. Davis, "Interactive slice of the cms detector," 2016.

[6] C. Collaboration *et al.*, "The CMS electromagnetic calorimeter project," *Technical Design Report CMS. Geneva: CERN*, pp. 97–33, 1997.

[7] C. Collaboration, "The CMS hadron calorimeter project," *Technical Design Report CMS. CERN, Geneva*, 1997.

[8] S. Chatrchyan, "Observation and studies of jet quenching in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ tev," 2011.

[9] C. Collaboration *et al.*, "The TriDAS project: Technical Design Report, Vol. 1: The Trigger Systems, CMS TDR 6-1," tech. rep., CERN-LHCC-2000-038, 2000.

[10] C. Collaboration *et al.*, "The TriDAS project technical design report, volume 2: data acquisition and high-level trigger," *CERN/LHCC*, vol. 26, no. 6.1, 2002.

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