
# AIM for a Higgs Factory

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# Scope of the AI/ML L3 area

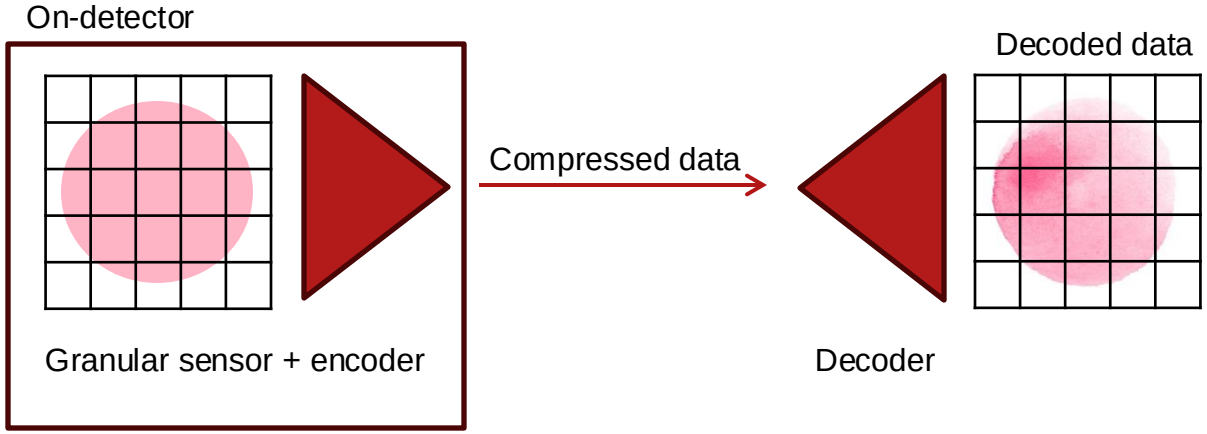
- Using AI/ML **on-detector**
  - Connection to microelectronics, TDAQ
- Using AI/ML for **detector design/optimization**
  - For a specific subsystem (e.g. tracker, calorimeter)
  - For the detector as a whole (connection to integration)
- Have other ideas? Please share!

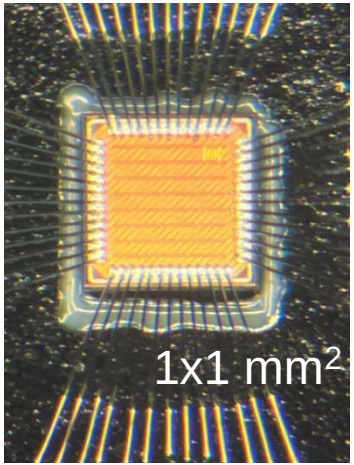
# On-detector: what is it for?

- Reduce data rates from detectors with many channels by using ML to do some processing at the edge
- Goal: maximize performance and flexibility of a ML algorithm in a highly resource-constrained environment
  - Power, area, latency
- How? Implement a digital NN on-ASIC, eFPGA
  - What can be done with pure analog? This is also being explored
  - Can this be done on a monolithic pixel detector? Probably, but let's try

# On-detector: what is it for?

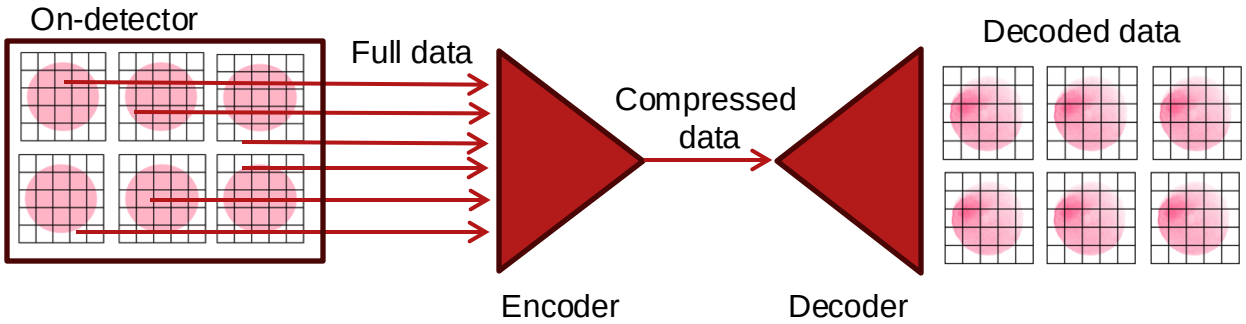
- Reducing bandwidth via compression with an auto-encoder
  - To transfer highly granular sensor data off-detector (example with eFPGA)

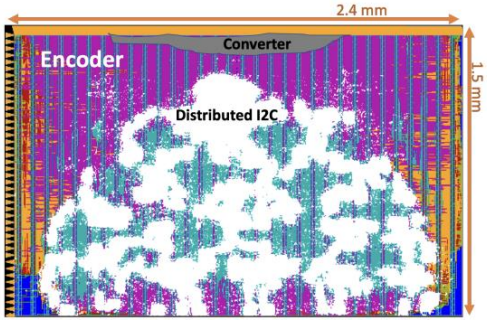


# On-detector: what is it for?

- Reducing bandwidth via compression with an auto-encoder
  - To concentrate data from many modules (e.g. CMS HGCAL: ECON-T)

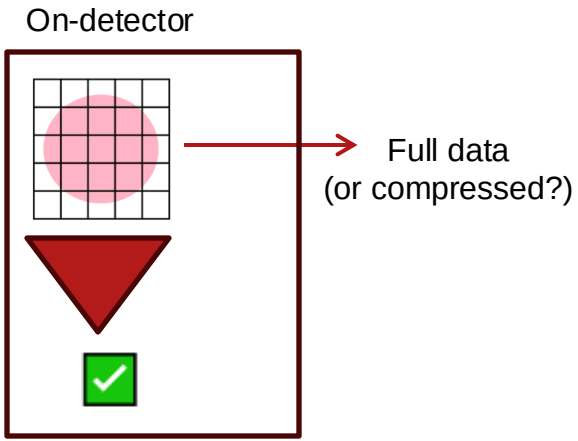


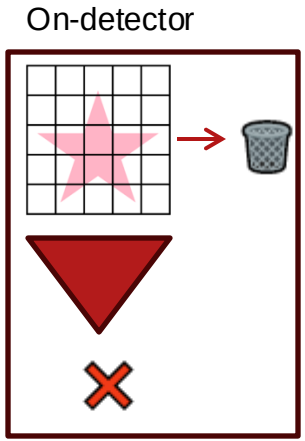
# On-detector: what is it for?

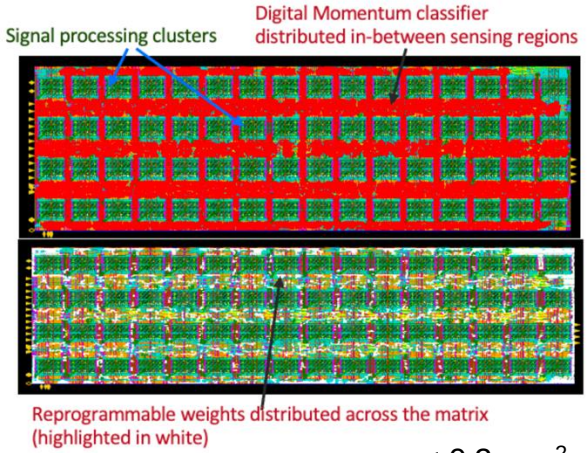
- Reducing bandwidth by filtering data
  - For example, based on estimated track momentum

High $p_T$ track




Low $p_T$ track

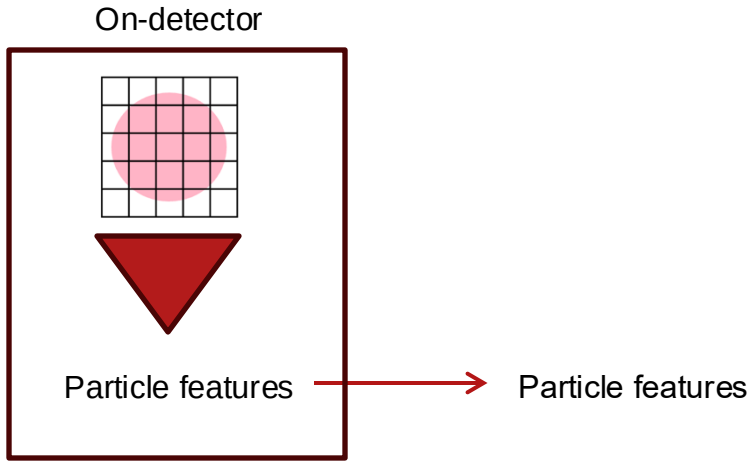



< 0.2 $mm^2$

# On-detector: what is it for?

- Reducing bandwidth by directly learning particle properties
  - For example, particle position and incident angle
  - Decouples size of data readout from e.g. pixel geometry



# On-detector: who is thinking about it?

- A3D3 (website)
- Fast ML (website)
- smartpixels (website)
- eFPGA at SLAC
- You? Let me know!

# On-detector: what does it require?

- Detailed simulations to use in training
  - Can simulated samples from detector groups be made public? 👀
- Algorithm development
  - Computing resources, person power
- Implementation and prototyping
  - Substantial engineering support, fabrication costs

# Design/optimization: what is it for?

- Detectors have a lot of design parameters ($\vec{x}$)
  - Geometry, material properties, power and data rates, etc.

$F(\vec{x}) =$ sensitivity

- Can use ML to find $\vec{x}$ that maximizes sensitivity to a physics process
  - Challenge: what do we optimize? What is the loss function of CMS or ATLAS?
  - Some examples can be found here

# Design/optimization: who is thinking about it?

- MODE Collaboration (website)
- You? Let me know!

# Design/optimization: what does it require?

- A simulation pipeline that is differentiable
  - There have been efforts to incorporate this feature into e.g. Geant
- Computing resources, person power

# Summary

- Work ongoing in multiple directions to implement AI/ML **on-detector**
  - So far, focus has been on reduction of data rate in pp scenario
  - Dedicated studies for ee should be strongly encouraged
- Interest in AI/ML for **detector design/optimization**
  - Very cross-cutting topic with substantial overlap with I of AIM group