Nanosecond ML for calorimeter segmentation
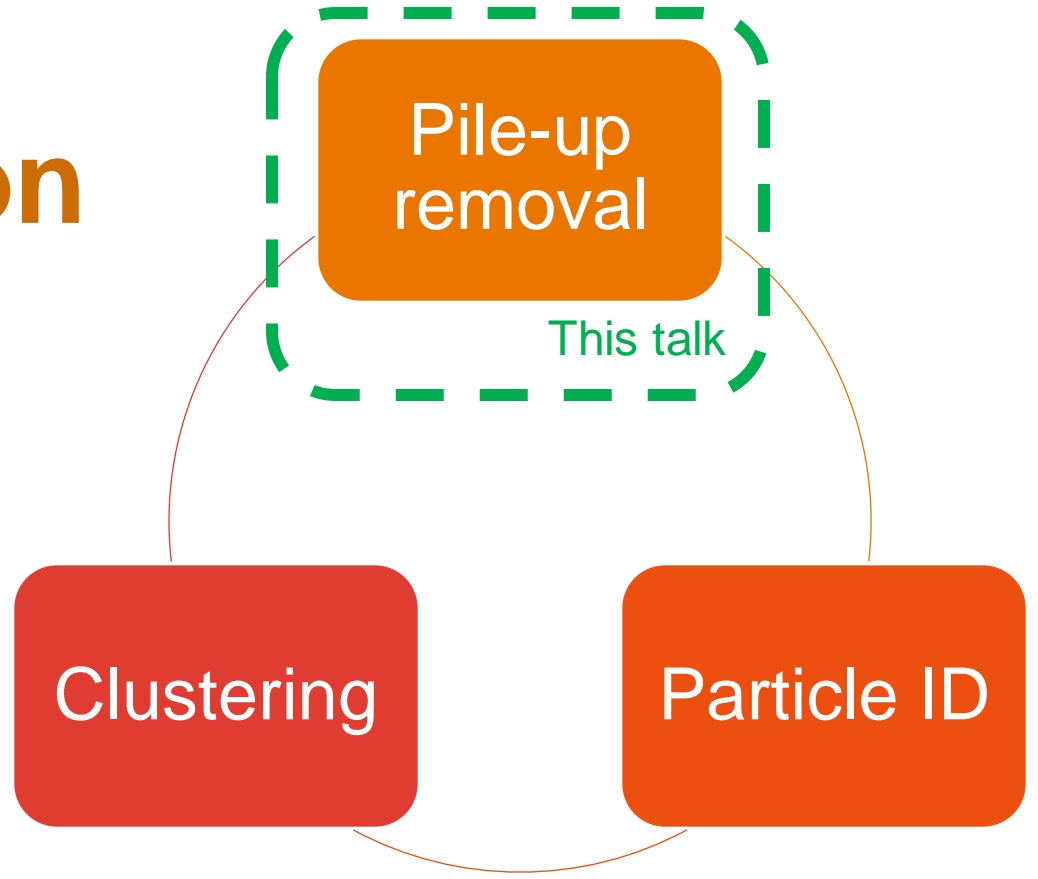
Noah Clarke Hall, Nikos Konstantinidis, Alex Martynwood, Naoki Kimura
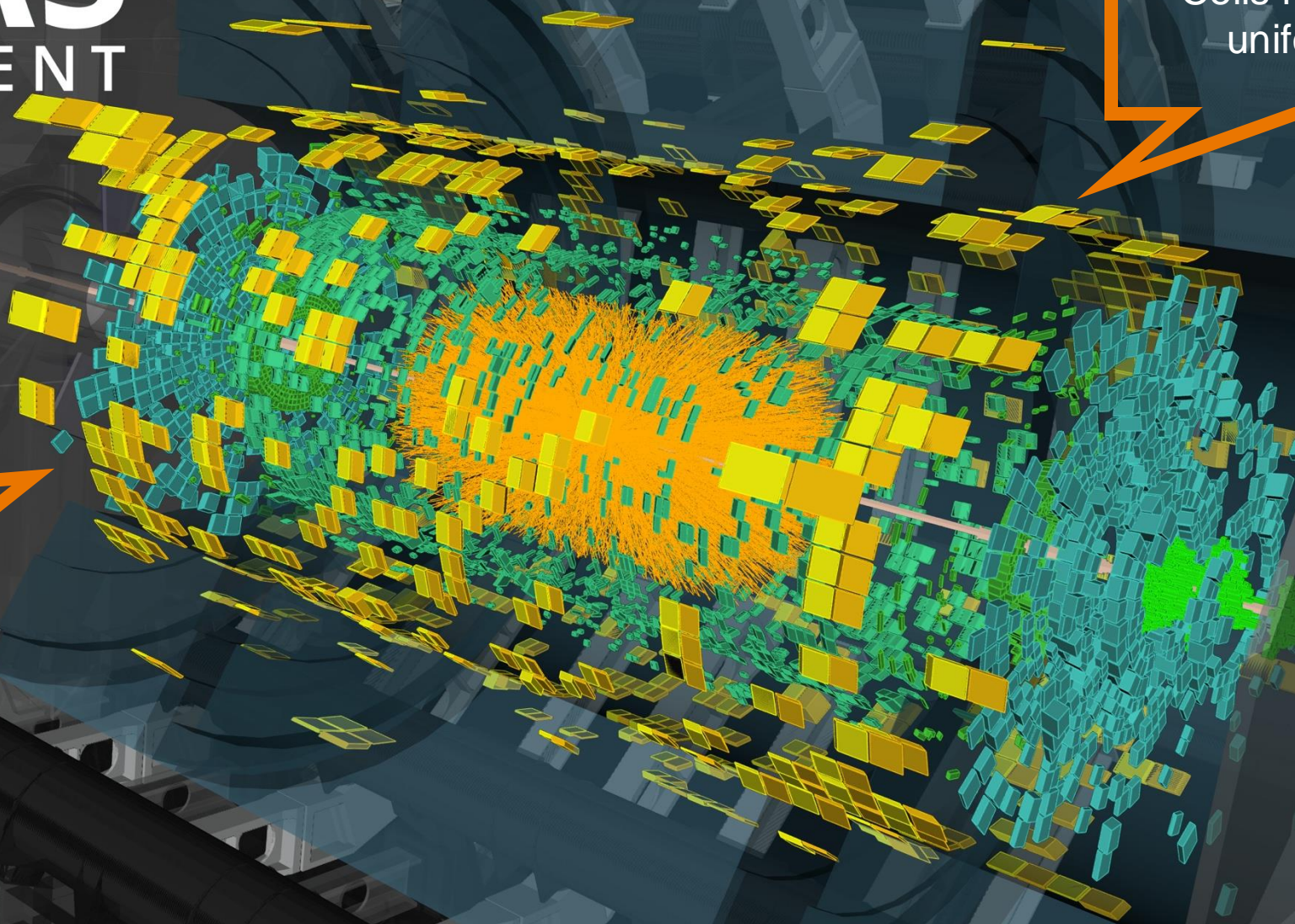
Pile-up removal
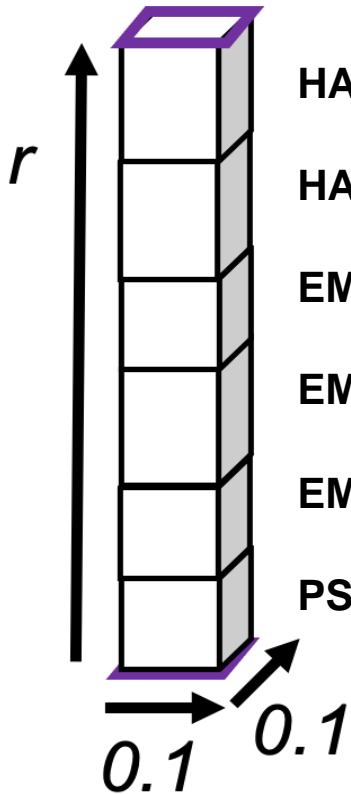
This talk

Clustering

Particle ID

Cells form locally uniform grid

Cylindrical detector geometry

Towers & topoclusters

Tower (|η|<2.5)
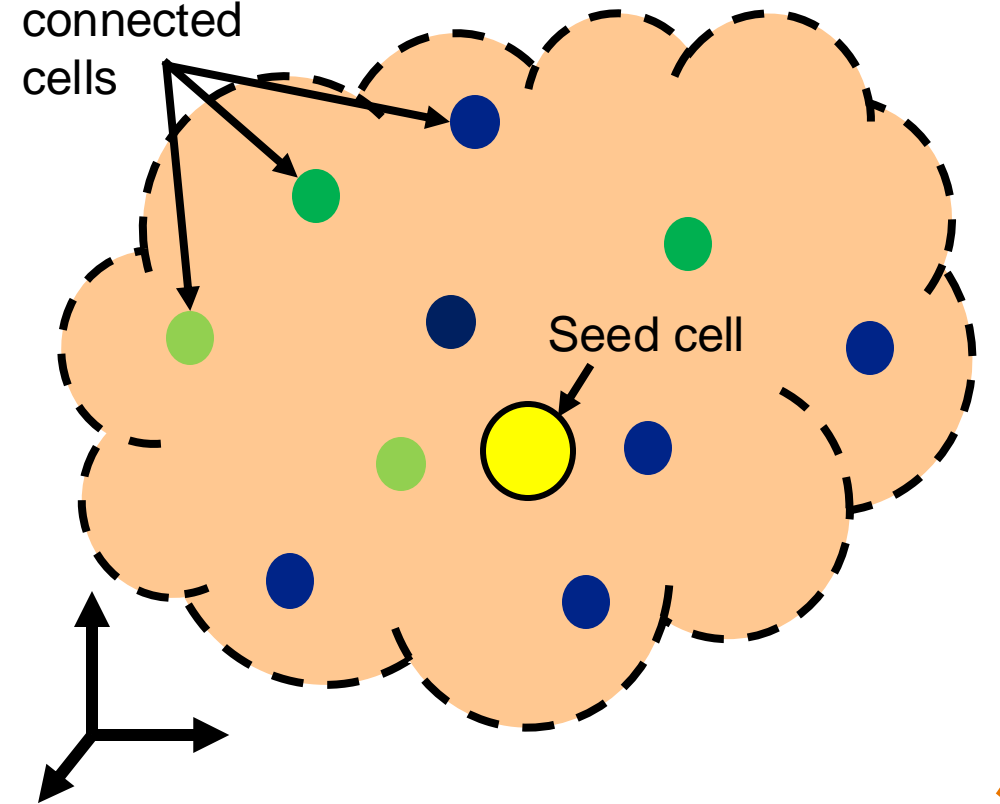
HAD2: Sum of 1 >2σ cells

HAD1: Sum of 1 >2σ cells

EM3: Sum of 8 >2σ cells

EM2: Sum of 16 >2σ cells

EM1: Sum of 32* >2σ cells

PS: Sum of 4 >2σ cells

Topologically connected cells

Topocluster (|η|<4.9)

Seed cell

Towers & topoclusters

Tower (|η|<2.5)

Image segmentation

HAD2: Sum of 1 >2σ cells

Sum of 1 >2σ cells

>2σ cells

cells

EM1:

PS: Sum of

0.1   0.1   0.1
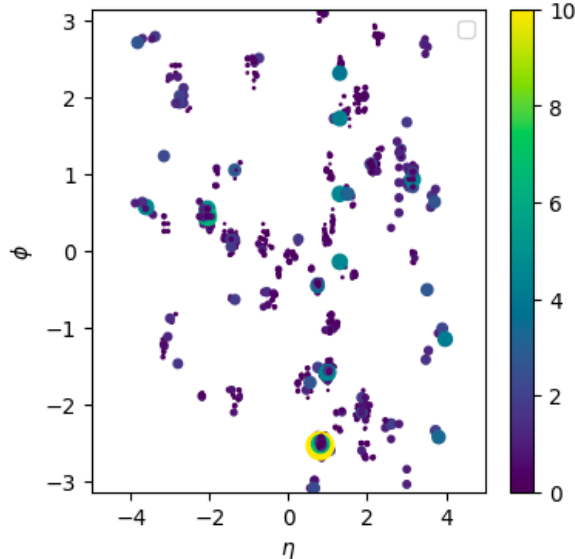
Topocluster (|η|<4.9)

Point-cloud classification

ell

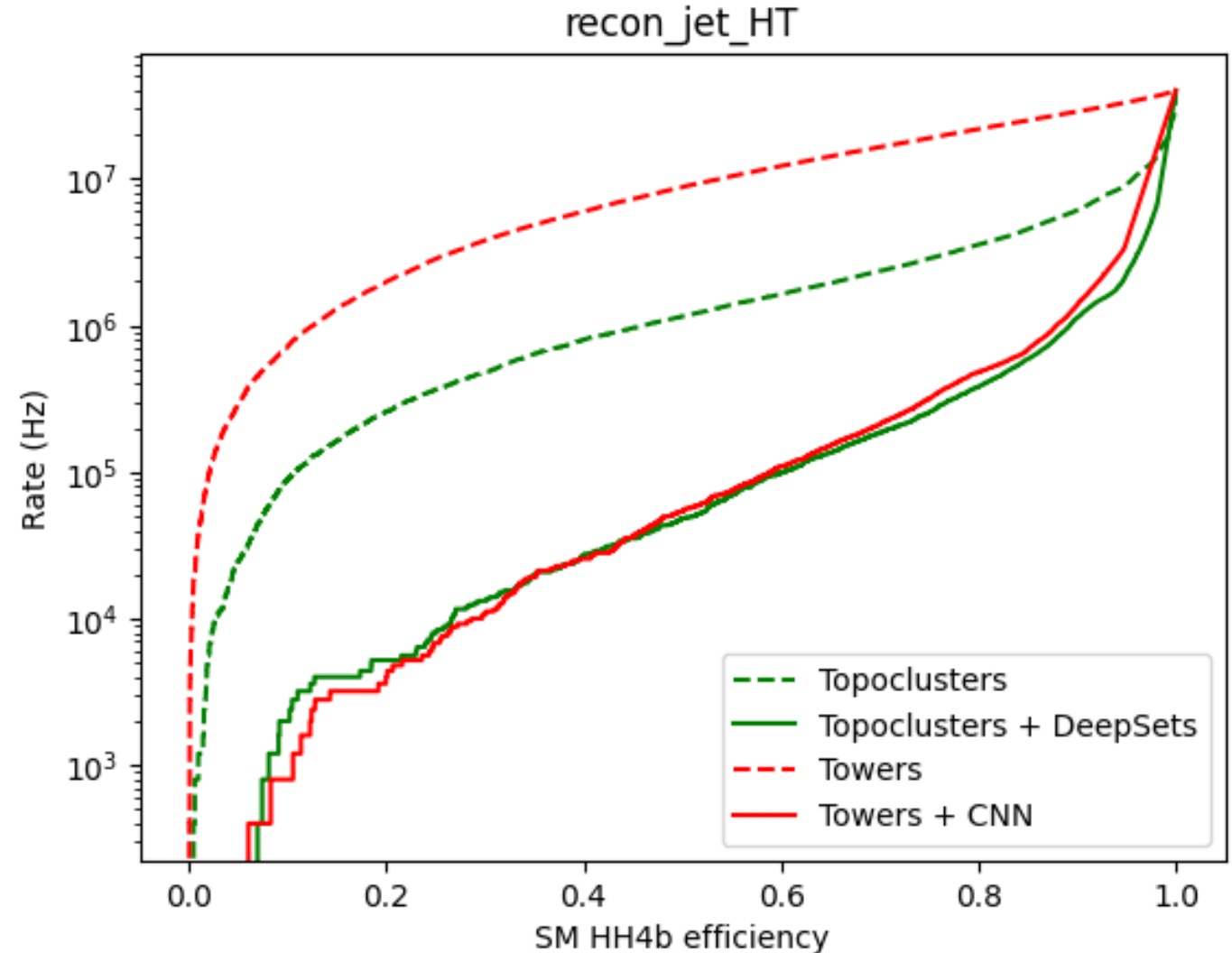# Two ML approaches

Image segmentation
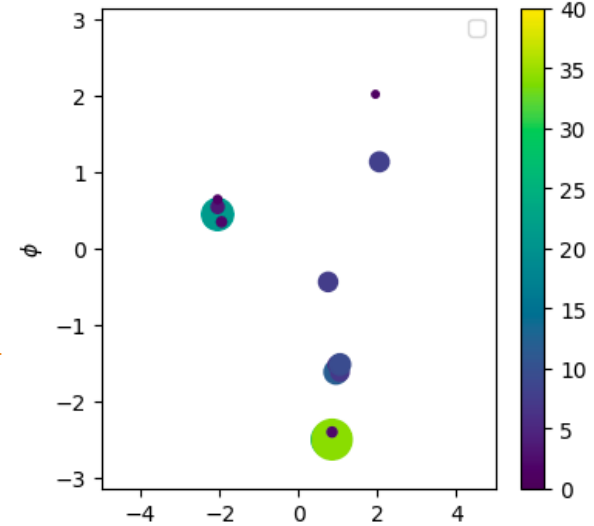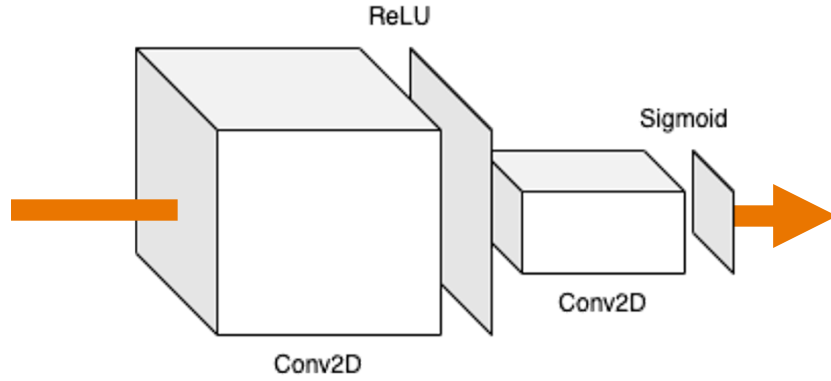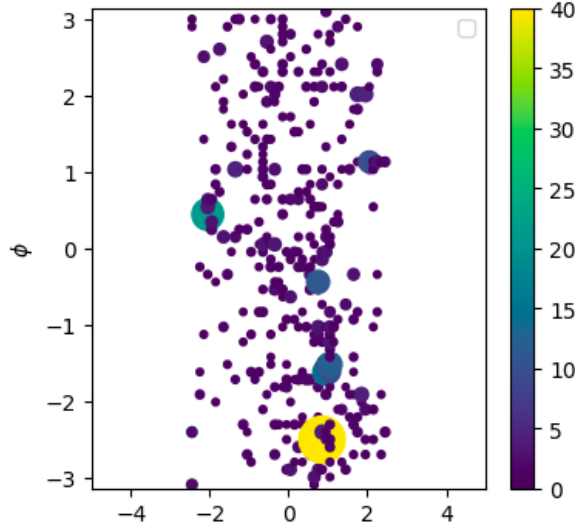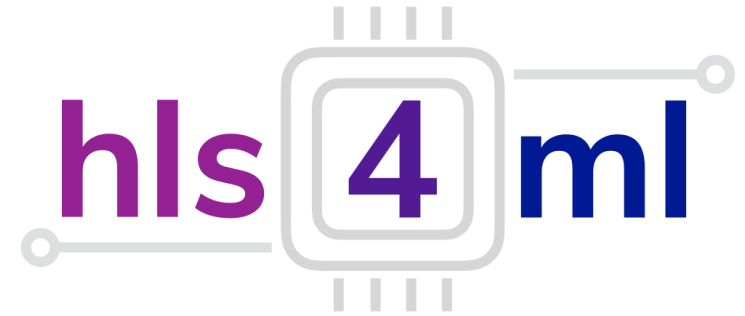
Point cloud classification
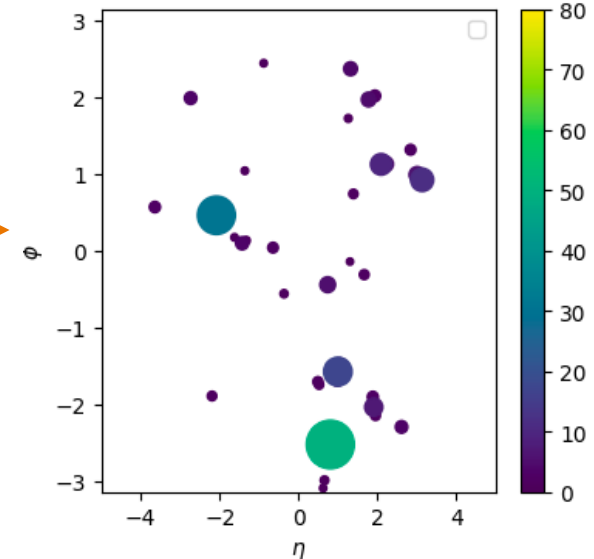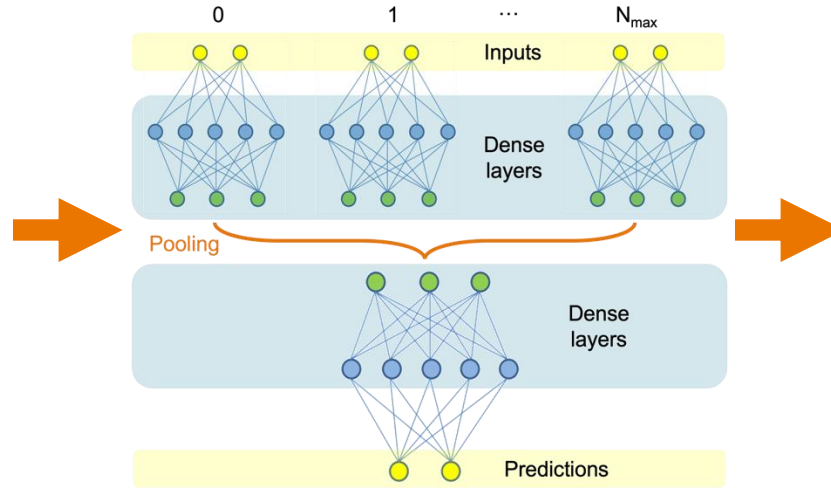
Physics performance

- Form anti-k_t central ($|\eta|<2.5$) jets

- Both approaches give similar physics performance

- Large improvement over baselines!

recon_jet_HT

Resources

QKeras: a quantization deep learning library for Tensorflow Keras

- Xilinx UltraScale+ XCU250

- 250 MHz clock

- CNN looks fast & light enough to be viable

- More optimisation needed

Resource/timing	CNN	DeepSets
Precision	Fixed <10,5>	Fixed <10,5>
# parameters	494	913
Latency (clk)	5	73
Interval (clk)	2	25
BRAM_18K	0	0
DSP	0	16
FF	1883	54478
LUT	33529	270742
URAM	0	0