US HFCC: **A**I, **I**ntegrated Detector Concepts, & **M**icroelectronics

L2 : Julia Gonski, Jim Hirschauer
L3 : Tim Andeen, Liza Brost, Jennet Dickinson, Loukas Gouskos

HFCC Detector Workshop: Day 2

This workshop

AIM

Introduction	*James Hirschauer et al.*	
53/4-4002 - Toluca, SLAC		10:45 - 10:55
Topics & Plans: AI	*Jennet Dickinson*	
53/4-4002 - Toluca, SLAC		10:55 - 11:15
Topics & Plans: Microelectronics	*Tim Andeen*	
53/4-4002 - Toluca, SLAC		11:15 - 11:35
Topics & Plans: Integrated Detector Concepts	*Liza Brost et al.*	
53/4-4002 - Toluca, SLAC		11:35 - 11:55
Brainstorming/Discussion		
53/4-4002 - Toluca, SLAC		11:55 - 12:30

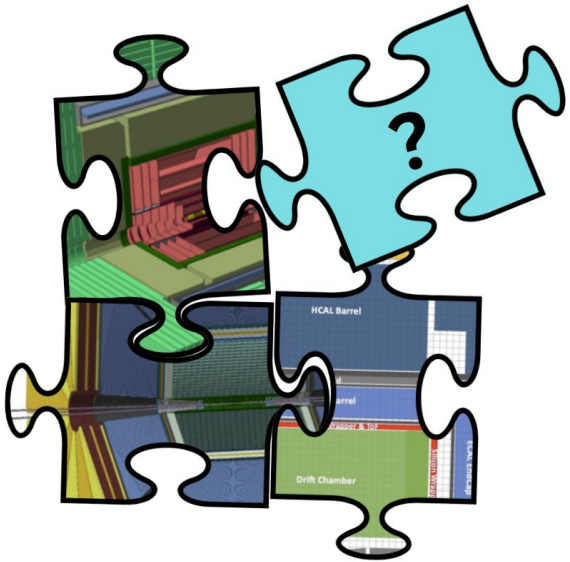
AIM + TDAQ + S&C

Overview	
53/4-4002 - Toluca, SLAC	14:00 - 14:05
Cross-Cutting Topic: Detector Design/Optimization Challenge	
53/4-4002 - Toluca, SLAC	14:05 - 14:50
Cross-Cutting Topic: AI for HF	
53/4-4002 - Toluca, SLAC	14:50 - 15:20
Miscellaneous/AOB	
53/4-4002 - Toluca, SLAC	15:20 - 15:30

Detector Challenge

Integrated Detector Concepts: Detector Challenge

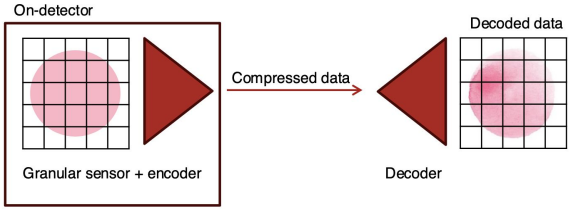
- Organized/self-contained sandbox for detector concepts and optimization
  - Enable community to explore new ideas for contribution to international efforts
  - **→ Collaboration among TDAQ, S&C, and AIM; involves & benefits all subsystem L2 areas**
- What we need:
  - Simulations: full detector (Delphes, Geant), subsystem digital level
  - **Resources: 0.5 FTE of student/postdoc to lead simulation development and compilation (with senior advising)**
- Next steps:
  - Organizing committee to finalize physics targets, compile simulation readiness & full Madgraph→plot pipeline

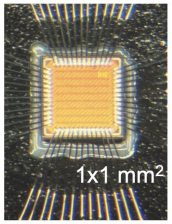


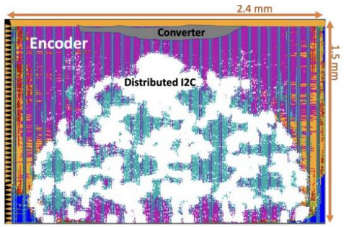
AI:

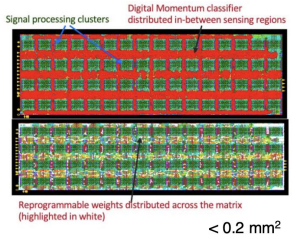
- Using AI/ML **on-detector** (Jennet)
  - Connection to microelectronics, TDAQ
- Using AI/ML for **detector design/optimization**
  - For a specific subsystem (e.g. tracker, calorimeter)
  - For the detector as a whole (connection to integration)

- Key challenges & priorities:
  - Subsystem-specific algorithms and DAQ studies
  - Power management, large data volumes
  - Analog computing (blue-sky)
  - Engagement with other communities: ASCR, EE, NP, industry
- Resources:
  - ASIC designs: engineering/physicist hours, M&S for tapeouts
  - Simulation: organized/curated central repository of digital level simulation
  - Test beams (for radiation characterization)









Microelectronics

- US expertise: Rad tolerance, low-power, low-noise, low-latency, cryogenic, AI/ML hardware
- Current priority R&D areas for HEP:

Research Area	Ongoing and future effort
AI/ML in ASICs, intelligence on detector	UT Austin, U Chicago, Cornell, UIC, UIUC, JHU, Kansas, ANL, LBNL, BNL, FNAL, SLAC, ORNL
Common IP for future MOSFET process nodes (28 nm e.g.)	LBNL, BNL, FNAL
3D / hybrid integration	USSC, LBNL, BNL, FNAL
Silicon photonics	ANL, LBNL, FNAL
High data density (including fast optical links	UPenn, ANL, LBNL, FNAL
Novel materials / devices	LBNL, FNAL
Novel design tools : open source, automated, AI/ML enhanced	UPenn, LBNL, BNL, FNAL, HEPIC
MAPS, 4D/5D sensor + ASICs, electronics for precision timing (now covered in Tracker L2 area)	U Michigan, ND, Oregon, UCSC, ANL, LBNL, BNL, FNAL, SLAC, ORNL

- HF would benefit most from investment in two high impact areas:
  - **AI/ML in on-detector electronics** to optimize physics precision, power, data volume, material
  - **HEP-accessible 3D/hybrid integration**: further minimize power and material (for on-detector intelligence e.g.) – complementary to MAPS
- Why should HF invest? **On-detector AI/ML** is HF-specific, **HEP-accessible 3D integration** will otherwise come too late (or not at all)

Conclusions

- AIM covers essential and cross-cutting topics in HF detector R&D: crucial to maintain involvement **across subsystem L2 areas**

- Priority #1: Proposed curation and organization of simulations via high-priority **“detector challenge”** will:
  - Facilitate R&D into new techniques including AI/ML
  - Maintain close coupling of all subsystems; propagation of subsystem R&D up to full detector concepts

- **AI and microelectronics** are cutting-edge technologies that can engage other funding sources and elevate HF detector designs to today’s state-of-the-art
  - Build on existing US leadership
  - Priority #2: AI-in-ASIC

- Drafting of EPPSU AI/microelectronics section underway