AI and Emerging Technologies

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on behalf of AI Working Group

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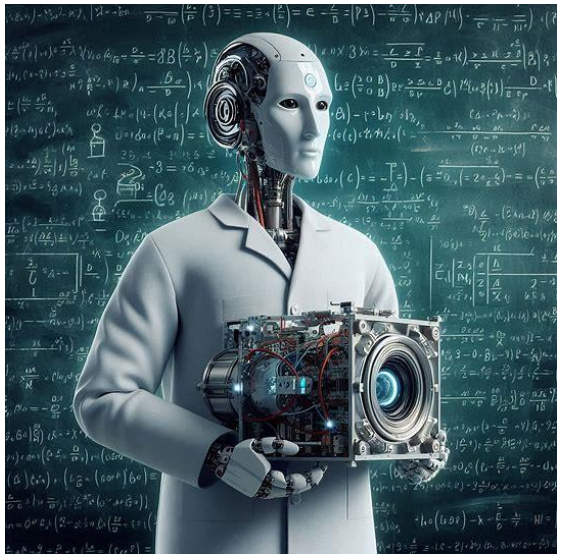
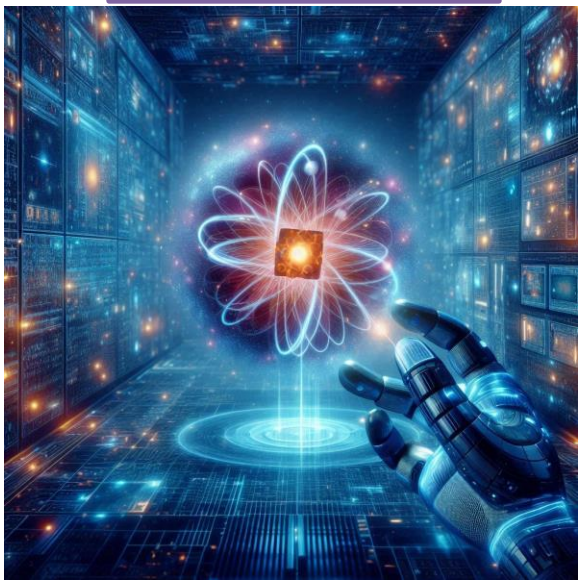
Overview

- Outline
  - Importance of AI
  - Progressing further?
  - Enabling AI in HEP
  - Challenges, barriers and opportunities:
    - Software, hardware and AI-ops
    - Skills/training and capacity building
    - Knowledge-exchange within/beyond HEP
  - Emerging Technologies
  - Next-steps and summary

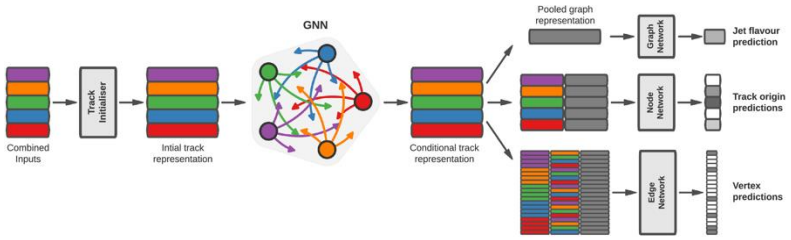


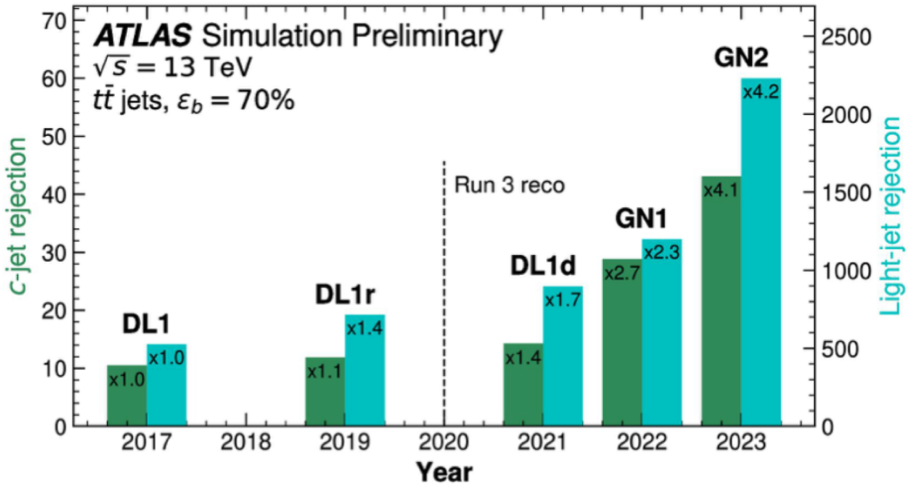
CoPilot ‘AI in HEP’



Importance of AI

- AI is becoming increasing vital to a very wide range our physics programme
  - ➢ Can enhance almost all aspects of our experiments and some of theory:
    - Object reconstruction, event selection, simulation, event generation, data quality, detector control/monitoring, coding, trigger, hardware design, documentation….
  - ➢ Many examples where applying AI has been truly transformational





[GN2 Flavour Tagging on ATLAS]
- ATLAS Thesis Award
- 5 x ATLAS Outstanding Achievement Awards
- Result of in-depth AI training in STFC CDT Programme

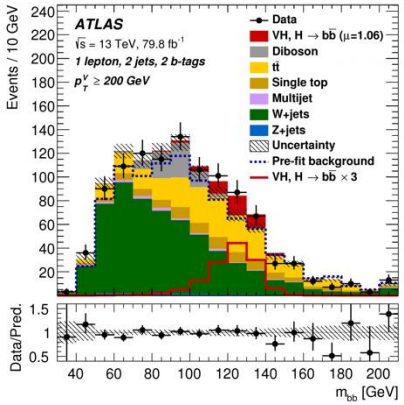
Progressing Further?

- AI has potential for further transformative change
  - ➢ Pushing the boundary:
    - Many (all?) students use AI tools to write code
      - Could envisage AI models that assist in the full analysis chain
        - *Focus more on physics rather than code frameworks?*

```
def calculate_met(px_list, py_list):
    """
    Calculate Missing Transverse Energy (MET).

    Args:
    px_list (list): List of x-components of transverse momenta (px) of all part
    py_list (list): List of y-components of transverse momenta (py) of all part

    Returns:
    float: Missing Transverse Energy (MET).
    """
    # Sum the px and py components
    sum_px = np.sum(px_list)
    sum_py = np.sum(py_list)

    # Calculate MET
    met = np.sqrt(sum_px**2 + sum_py**2)

    return met
```

ChatGPT: Write a function to calculate MET

ChatHEP: 'Produce a data/MC comparison plot with latest theory/exp corrections for H->bb'

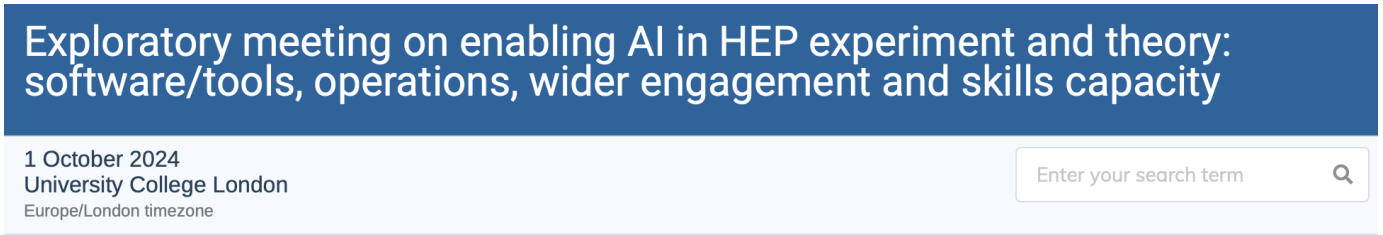


- Feed raw data into Large Language Models which can reconstruct objects
  - *Solve CPU issues?*
- Auto-encoders that can compress our data with little loss of information
  - *Assist with data storage issues?*
- Marking all our exams/course work…..

- Need to be able fully exploit this potential and opportunities (funding/impact)

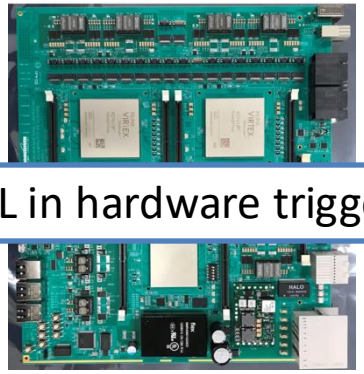
Enabling AI in HEP

- Initially via Swift-HEP and ExaTEPP started an initiative for enabling AI in HEP
  - Proposed a work package on AI in Swift-HEP 2.0
    - Launched an AI Working Group in the interim
      - **Enabling AI in HEP experiment and theory**
        - Community-wide endeavour
  - Focus on challenges, barriers and opportunities in:
    - Software, hardware and ML-Ops
    - Skills/Training and capacity building
    - Knowledge exchange and wider engagement
  - First exploratory workshop on 1st October@UCL
    - Please register to take part in the discussion (open to all):
      - https://indico.cern.ch/event/1450122/
    - Will be used to inform our input to ECFA on AI
    - Also engaging with STFC AI Strategy and other ECFA AI work



Software, Hardware and ML-Ops

- Considerations:
  - Software
    - Do we have easy access to the latest libraries, tools and techniques?
    - Can we easily/effectively deploy the models we train?
      - Software stacks
      - Hardware (e.g. FPGAs)
    - Are we adhering to the FAIR principle?
    - Would HEP specific software be helpful?
  - AI-ops
    - Are our models reproducible?
    - Are they robust with changing conditions (detectors, beam, simulation)?
    - Do they cause undesirable biases?
    - Are they explainable?
  - Hardware
    - Do we have access to the necessary modern hardware for training, model development and deployment?
    - How can we make our usage more sustainable?
  - Do we have the necessary skills to exploit the hardware/software



Fast-ML in hardware trigger

Skills, Training and Capacity Building

- Need effective AI-training for HEP: model development, deployment, AI-ops…
  - Ability to bring in latest developments
  - What form should it take and how should it be provided?
    - Available for PhD, PDRAs, academics, technical staff?
    - In-depth courses available to PhD students at beginning of PhD?
      - STFC/UKRI CDT's great example of creating AI expert practitioners
      - View themselves as HEP and AI experts
        - Bring new tools/techniques into our field
    - Augment training with interactions with foundational/industry experts? Collaborate internationally? Hold in person to build national cohorts?...
- Capacity building: once we've trained world-leading AI practitioners….
  - Skillset that is in extremely high-demand in industry other research areas
    - Some leaving field good for wider socioeconomic impact
  - How do we ensure enough stay in the field?
    - Career progression opportunities and job security
    - Training (interactions with industry/foundational-AI experts)
    - Ability to stay at the cutting-edge (software/hardware)

Knowledge Exchange and Wider Engagement

- Several layers on which this can be considered:
  - Build into HEP - train fully fledged expert AI partitioners
    - Effective bridges between the AI and HEP communities (e.g. CDT)
  - Across HEP
    - Areas enriched in ML expertise, encourage KE:
      - e.g. AI forums, inter-disciplinary PhDs or co-supervision of PhDs (CDTs), develop common tools, mapping/linking expertise
      - PPTAP identified this as a key area to build upon
  - Foundational AI experts (e.g. Computer Science, Statistics….)
    - Many keen to engage providing a unique perspective
    - Better engage SciML and other expertise in Ada Lovelace Centre
  - Industry
    - Big possible gains from engaging with industry
      - Training, hardware access, tools/techniques, funding
    - Hartree and CDT programmes plus direct engagement already ongoing
      - Good examples to build upon and grow community-wide
- Effectively engaging KE can have a transformative effect upon our field
  - Can we improve our approach?

Emerging Technologies

- Focussed on AI as now a mature development
  - Need to make sure we horizon scanning for next breakthrough technologies
    - Ready to harness them
      - Understand potential, develop skills, build capacity
- Example: Quantum Algorithms (QA)
  - Potential for QA to have large impact in HEP
    - UK teams already exploring potential
      - e.g. tracking, parton-shower
    - No real funding for this work in the UK
  - Government priority area and large-scale funding being deployed
    - Significant long-term opportunities
- Need mechanisms to ensure we prepare for future breakthroughs

Next Steps

- AI is already a vital tool for our field and its importance will only grow
  - Can touch upon almost all areas of our entire programme
    - Provide truly transformational impacts
  - Vital that we are prepared to fully exploit the opportunities it affords
    - Enable/enhance our programme, more funding streams, enhanced impact
  - Need to similarly ensure we engage with other emerging technologies

- To ensure we can fully exploit AI need to focus on challenges and barriers in:
  - Training, skills and capacity building
  - Knowledge exchange and wider engagement (within, beyond, industry)
  - Software, hardware and AI-Ops
  - Other issues?

- All will be discussed in the exploratory meeting on enabling AI in HEP
  - Please register for workshop and take part in discussion
    - https://indico.cern.ch/event/1450122/
  - Help provide important input to ECFA submission on AI

Backup