AI task force – report summary

Wouter Verkerke

Nikhef AI/ML - task force report & conclusions

- **AI/ML task force has delivered its final report November last year**
- **1 - Overview of the current state of AI/ML activities**
  - Current AI/ML activities over the various Nikhef physics programs
  - Planned AI/ML activities in programs in short/medium term future
  - Expertise in AI/ML activities (or lack thereof) in programs
  - Partnerships nationally and internationally on AI/ML activities (current, and potential future)
  - Comparison of activities and expertise with international competitors
  - Survey on required expertise, infrastructure and person power needed in future

- **2 – Recommendation for future AI/ML at Nikhef**
  - Creation of an AI/ML group at Nikhef - goals and structure
  - Assisted in funding of this recommendation through preparation of AI/ML proposal for NWO-I Strategic Innovation granting scheme (submitted July, awarded Dec)

Members

- Wouter Verkerke (chair)
- Sascha Caron — ATLAS — Radboud University
- Mengqing Wu — ATLAS / R&D — Radboud University
- Gerhard Raven — LHCb — Vrije Universiteit
- Jacco de Vries — LHCb — Universiteit Maastricht
- Marta Verweij — Alice — Universiteit Utrecht
- Roel Aaij — PDP — Nikhef
- Chris v/d Broeck — Grav. Waves — Universiteit Utrecht
- Jelle Aalbers — Dark Matter — Universiteit Groningen
- Aart Heijboer — Neutrinos — Nikhef
- Melissa van Beekveld — Theory — Nikhef

1 - Overview of the current state of AI/ML activities

Process

- **Information gathered from all physics groups through a questionnaire and follow-up by task force members by group**
  - Information gather period was spring 2025
  - Full results available on task force agenda https://indico.nikhef.nl/event/6613/
  - Prepared overviews by topic over all programs (example below)
  - Information shown here is digested summary of those summaries

Current AI - production use

(1.1)	Object reco	Object ID	Calibration	Sig/Bkg discrimination	Anomaly/ Glitch detection	Stat. analysis/ param est
Alice	Tracking ITS & MFT (cellular automaton)	Flavor tagging with DNN	Jet energy with DNN	Simple models	Unsupervised, reinforcement learning	
ATLAS	Boosted objects with GNN	Flavor tagging with GNN	Mass regression of heavy objects	Wide range, including DNNs,	Variety of methods	LR of MVA score NSBI methods high-dim NN (SUSY)
LHCb	Small/fast track reco models	Simple classifiers	Simple classifiers			
GW					DeepExtractor	FlowMC, JIM, Jester (JAX), Flex.
DM	NN event reco (lightweight to GNN)	NN classification (lightweight to GNN)				Neural posterior estimation
Pierre Auger	DL shower reco (RNN/GNN)	-	-	-	-	-
Neutrino	-	-	-	-	-	-
eEDM	-	-	-	-	-	-
Theory	Jet substructure	Jet tagging				SMEFT, WEFT, PDFs etc with (G)NN

Summary of observations – AI use & user base

- **Current AI use in production**
  - **Clear 'front-runner' group: ATLAS+Alice+LHCb+GW+DM** where AI is pervasively in use
  - Second group Auger+eEDM+Neutrino+Theory*, with more limited AI use at the moment
    (but all with interest to catch up)
  - Most AI use currently in object-level reconstruction/identification and event-level discrimination tasks.
  - Limited use of AI in inference (limited use in GW ATLAS at present) and in simulated data generation

- **Level of AI involvement in Nikhef programs divides along same groups**
  - Strong multi-front involvement in front runner group
  - Limited (end-user) use in second group

- **We have a quite sizeable group of scientists involved across programs!**
  - About **15 staff** – with expertise ranging from top-tier (Sascha) to 'limited, but with strong interest'
  - Another **20 PhD/PD** closely involved with AI application, plus a few more on AI method development

- **AI is commonly used in MSc/BSc projects in 'front runner group' (50-70%?)**
  - **Generally (very) positive experiences for those participating**
  - Also embedding of CS/AI students in several programs

- **Use of coding tools (co-pilot, ChatGPT) still quite limited**
  - A handful of users in each program (including groups that otherwise don't use much AI)

Summary of observations – AI in near future

- **Expected future use to increase all experiments**
  - Overall use expected in become more pervasive.
  - General move to **larger models** with more **ambitious goals** (transformer models directly using all data) in experiments already deploying AI (➔ foundation models)
  - Use of AI for **highly complex data** (HL-LHC tracking, ET GW signals)
  - Production deployment of AI methods in statistical **inference**/parameter estimation (NBSI), and fast event **simulation** (GANs etc), **anomaly detection**
  - Use of AI in low-latency online environment (trigger) ➔ **FPGA** implementation (Alice, ATLAS, eEDM)
  - Interest in AI-assisted experimental **design optimization**

- **Required infrastructure/resources**
  - Most ambitious R&D projects (ATLAS/Alice tracking) require state-of-the art GPUS (nVidia H100/H200), available in Snellius, not locally. LHCb needs GPU in trigger/online farms
  - GW purchased already nVidia L40S for medium-term needs
  - All other Nikhef applications likely (much) less demanding, but not always clear

Summary of observations – AI ambitions

- ## AI ambitions of Nikhef groups
  - 'front runner' experiments: to have leading involvement AI application development in many areas (tracking, object identification, regression of object properties, statistical inference, anomaly detection, physics-inspired models)
  - 'second group' experiments: deployment in reconstruction and data analysis

- ## Leading institutes in AI in HEP world-wide
  - Many relatively small groups (1 staff + PhD/PD) at universities in US and Europe.
  - Little overlap between leading institutes per experiment → few seem to on multiple experiments?
  - Main exception – UW Data Science center / Kyle Cranmer – 20 FTE. (KC is also former supervisor many of the current strong senior scientists with groups in ATLAS)

- ## Comparison of leading institutes with Nikhef
  - Often O(1) staff – thus comparable in size and expertise with Nikhef groups (with a bit of spread)
  - Several groups have better connection to non-HEP AI/CS/Math experts
  - Often have more sizeable PhD/PD groups working on AI projects
  - In certain countries access to vastly larger computing resources (notably US, Spain in future?)

Summary of observations – AI ambitions

- **Inter(national) partners in AI development**
  - national entities: SURF, eScience center
  - non-HEP groups at NL universities: Grappa@Uva, AI@Radboud, DACS@Maastricht
  - *But mostly through personal contacts of a few individuals or locations (Sascha, Maastricht)*
  - International universities: handful of universities in Europe and US, O(1-2) per group

- **What are we missing to realize our ambitions?**
  - Education/training/expertise (mostly in the '2nd group')
  - Close connections to domain experts in CS/AI, math/statistics
  - Sufficient in-house GPU compute power, access to large-scale NL and EU AI centers
  - PhD/PD person power

- **Expectations on future of coding assistance**
  - Expected to generally grow and importance and use
  - Emphasis/concerns on secure (in-house) services for use on private data and/or information
  - Institutional support

Summary of observations – AI long-term ambitions

- **Long-term goals that may be realizeable with AI**
  - Large-scale data reconstruction from low-level data (HI PbPb tracking)
  - AI-assisted (re)design of software structure and analysis pipelines ('end-to-end optimization')
  - AI-assisted design – from sensors to entire detectors / observatories
  - Large Physics Models as evolution of foundation models (trained on low-level data, allows for high-level physics queries)
  - AI Lattice QCD

Many areas of cross-group interest

- **AI classification strategies**
  - Pretty much every group
- **AI track/pattern reconstruction**
  - ATLAS+LHCb+Alice (+Neutrino?)
- **AI anomaly detection**
  - Known background, unknown signal
  - GW, ATLAS, Neutrino, PierreAuger, DM
- **AI physics-inspired model architectures**
  - LHCb, ATLAS, + ??
- **AI statistical inference / param estimation (NSBI etc) / stat properties of ML methods**
  - GW, ATLAS, LHCb, Neutrino, Theory + ??
  - Mostly powerful for physics problems with >>1 parameter of interest
- **AI deployment in FPGAs for trigger, or feedback loops**
  - ATLAS, Alice, eEDM
- **AI assisted optimization of data analysis pipelines and software ('end-to-end optimization')**
  - ATLAS, LHCb, DM + ??
- **AI foundation models / full event interpretation**
  - ATLAS, LHCb, Alice, + ??
- **AI assisted detector/observatory optimization**
  - ATLAS, PierreAuger, eEDM, Alice

2 - Recommendation for future AI/ML at Nikhef

Summary of recommendations

- **Establish AI/ML group at Nikhef**

- **Goals of the new group**
    1. Connect and coordinate AI/ML activities of (A)PP scientists within the Nikhef portfolio
    2. Collaborate with the broader AI/ML research community outside (A)PP
       at the national and the international level (own research agenda)
    3. Become a valued scientific partner and active participant in (future) national
       and European AI4Science coalitions for large-scale AI applications.

- **Funding of the new group**
    - Task force prepared grant proposal in NWO 'strategisch innovatiefonds' scheme (e1.4m)
      to fund establishment of this group (submitted July 2025, awarded Dec 2025)
    - Provides funding for 1 staff + 2 PD + some computing hardware
    - Recommends group be established with clear structure and embedding in the Nikhef organizational
      structure (OPL, SAC, Bronkhorst, Jamboree etc...)

Summary of recommendations

- **Establish AI/ML group at Nikhef**

- **Recommended structure**
  - **If Nikhef "AI and ML group" not (initially) formally a program, it should have many of its features, including**
    - Group leader and deputy group leader
    - Permanent representation at the OPL, SAC, Nikhef annual meeting, Bronkhorst management cycle
    - Dedicated office group for core members
    - Group budget for travel/expenses of core group members
    - Can draw (longer-term) on CT technical person power

  - **But also, some differences**
    - Due to the strong thematic connection of AI/ML with the physics programs, the group is expected to foster strong collaborations with scientists in the physics programs.
    - Over time, *scientists in physics program* may also wish to contribute part-time to the core research agenda of the AI group of general AI/ML methodology development for (A)PP, which case they can be added as *associate/part-time members to the AI/ML group*, in coordination with the relevant program leaders.
    - Similarly, scientists from groups or institute *outside the Nikhef partnership* can also be included as associate/part-time members, with mutual agreement, if they contribute to the core research agenda of group.

Summary of recommendations

- **Other considerations**
  - Much of the AI attention at the government level is directed towards industry, not academia. New government in formation may provide a timely window to influence the 'AI for science' strategy for the Netherlands. Nikhef should explore ways to exert influence here
  - Similarly, at a lower level, it is unclear what the NWO-I strategy is for AI in science. Most discussions are about AI as information retrieval tool ('chatgpt'), but not much strategy or discussion for AI as core data science tool for academia. Nikhef should explore ways to exert influence here
  - Same point for EU-level discussions for very-large-scale initiatives, which will be crucial for the success of the ambitions in building foundation models. A first success here with SCIANCE/RAISE, but still a long road to go. Can we have any influence closer to the political decision making?
  - How to influence CERN IT strategy? New IT head (Simone Campana) may provide new avenues to build closer ties and influence CERN strategy
  - Informal contacts with industry (e.g. ASML as reported in our last meeting) have proven somewhat difficult to navigate due to limited mandate of people involved from industry side (NDA's etc). A high-level agreement on the scope and boundaries of such cooperations may be needed to arrive at more fruitful practical cooperation.