# Theory Perspective on AI

Koji Hashimoto (Kyoto U.)
Director of MLPhys, Director of ARiSE AI4MP



The challenge is:
to find a way to develop physics,
in the collaboration of
Experimentalists-Theorists-AI

Contents

1. MLPhys Japan, some outcome
2. Recent ability of AI on theory
3. Proposal : WG for community



# MLPhYs

Foundation of "Machine Learning Physics"





# Format of MLPhys (2022-2027, 6M USD)

Steering committee

B01: ML models for physics

B02: Numerical sampling efficiency

B03: Topology and ML

A01: AI computational physics

A02: AI particle physics

A03: AI condensed matter physics

A04: AI quantum + gravity

MLPhys

# Giving-up Interpretability, while bridging

AI hep-lat : Spin MC by transformer

AI hep-ph : Jet tag by transformer

AI cond-mat : Superconductor wave fn

AI hep-th : Emergent spacetime

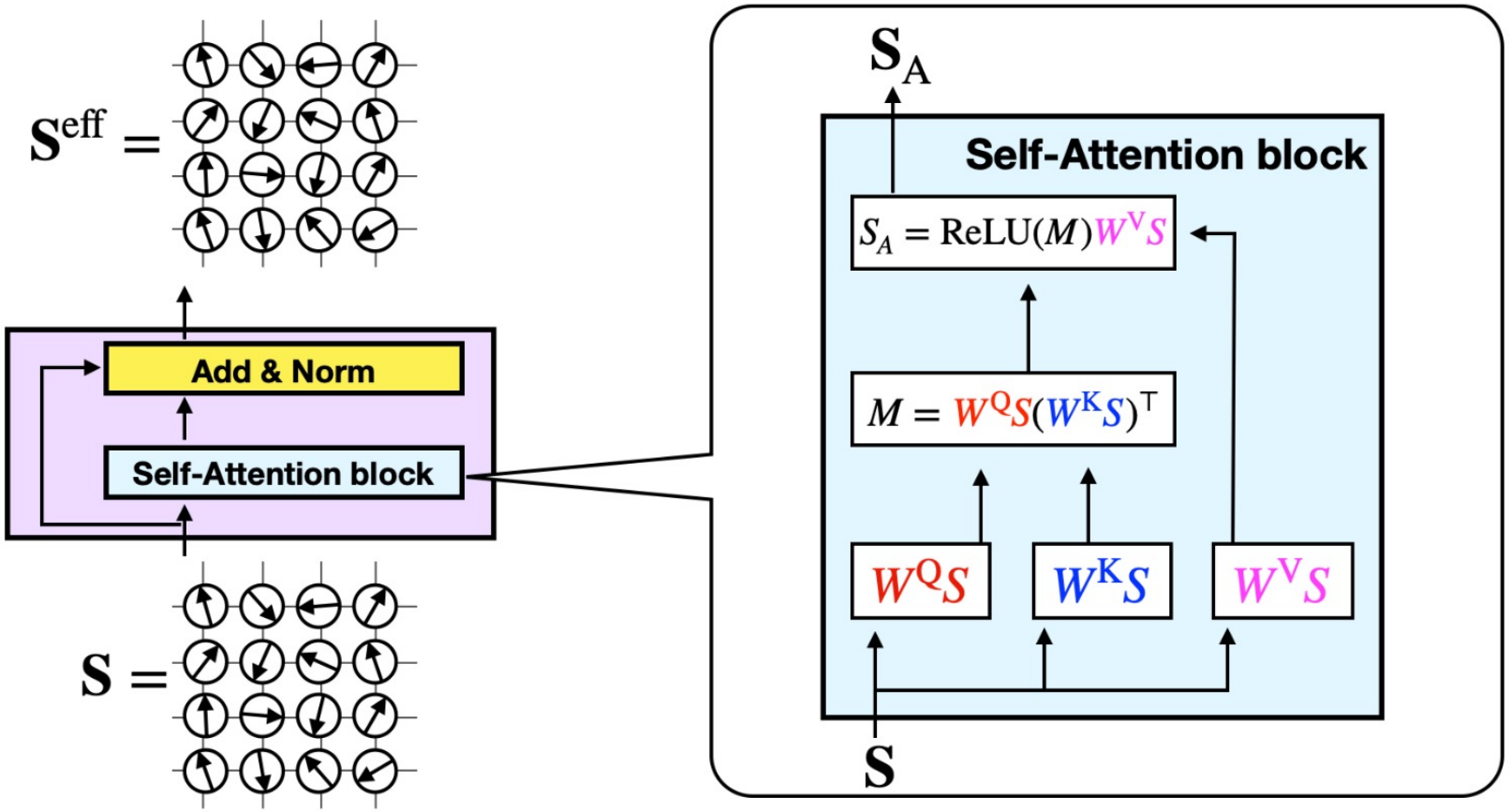
AI stat-mech : Diffusion model is QM

# AI hep-lat : spin MC by transformer

**A01**

Attention mechanism describes nonlocality

**[Tomiya, Nagai, *PoS* LATTICE2023 (2024) 001]**

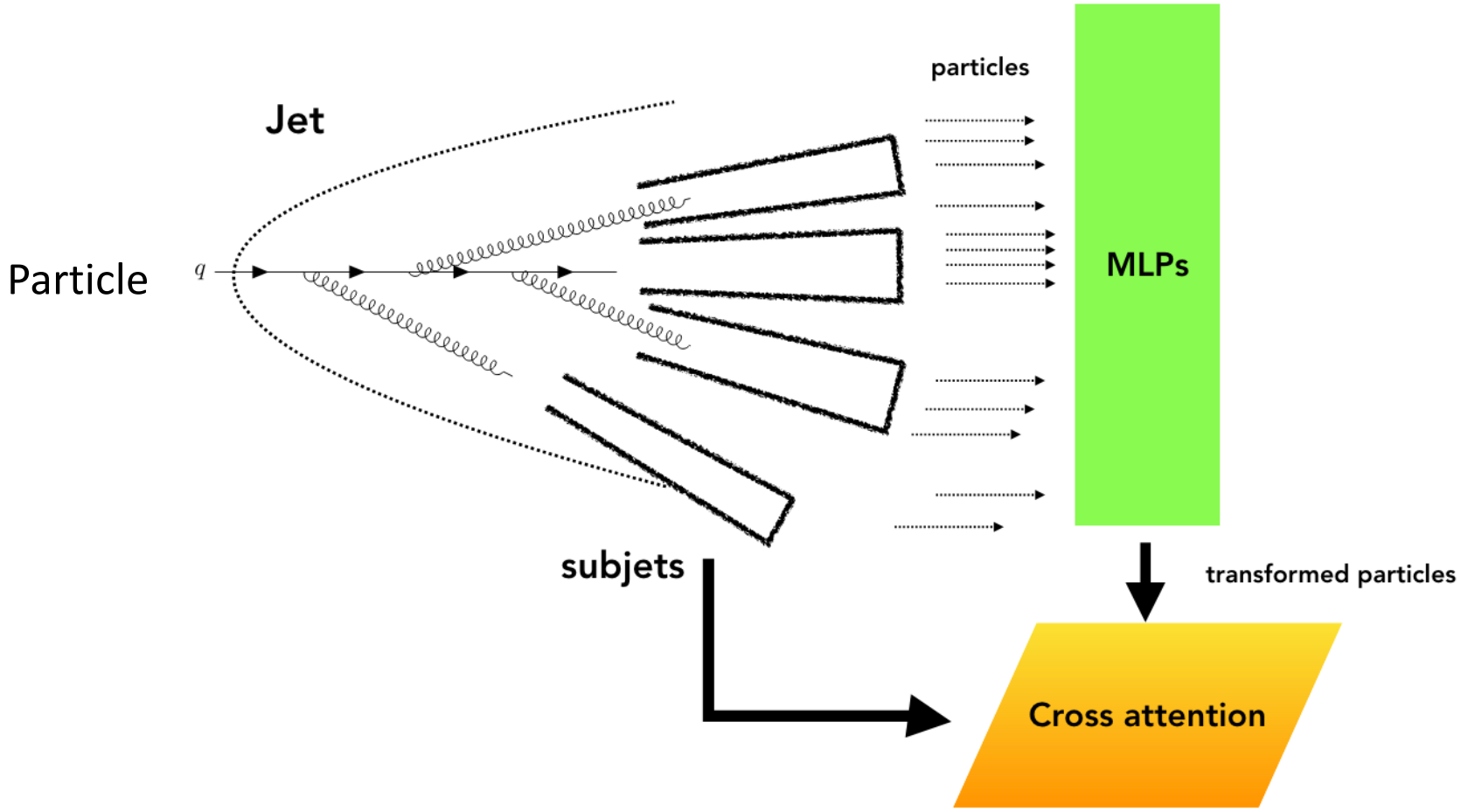


# AI hep-ph : jet tag by transformer

A02

[Hammad, Nojiri, JHEP 06(2024)176, JHEP 03 (2024) 114]

Cross-attention learns
Physical energy scales

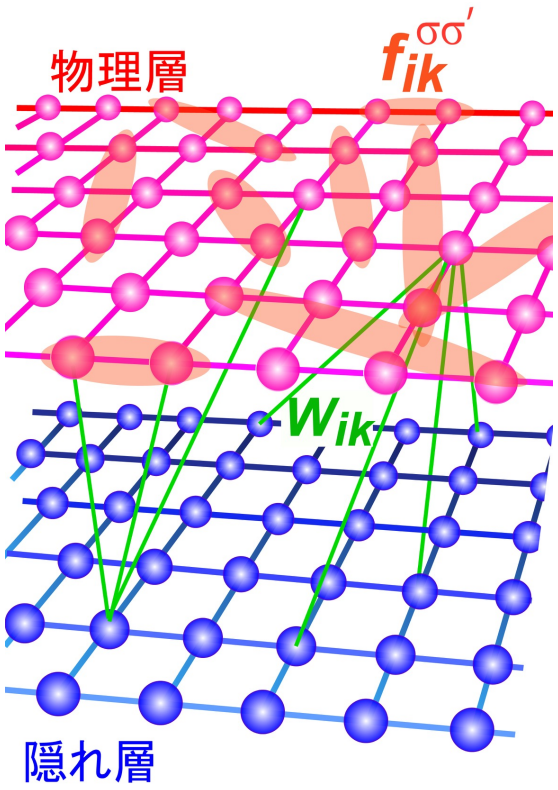


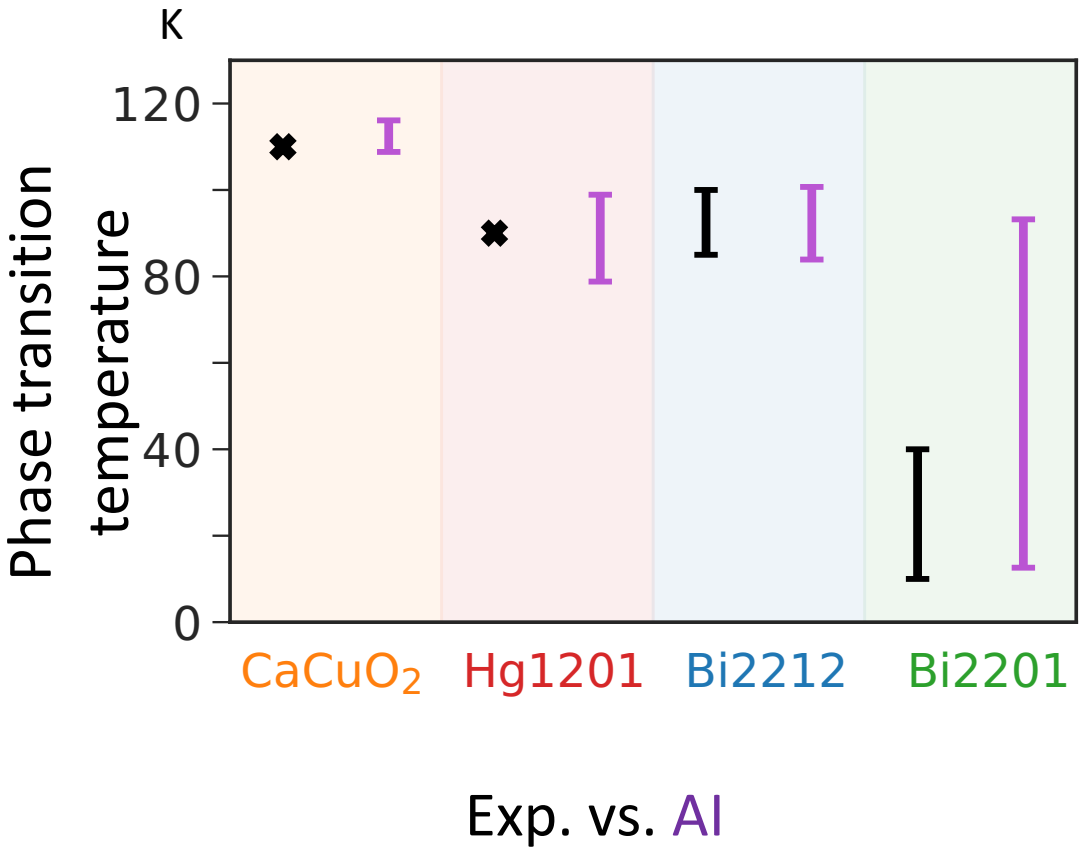
# AI cond-mat : superconductor wave fn

**A03**

Quantum many-body wave functions by Boltzmann machine

**[Schmid, Morée, Kaneko, Yamaji, Imada, Phys. Rev. X 13, 041036 (2023)]**



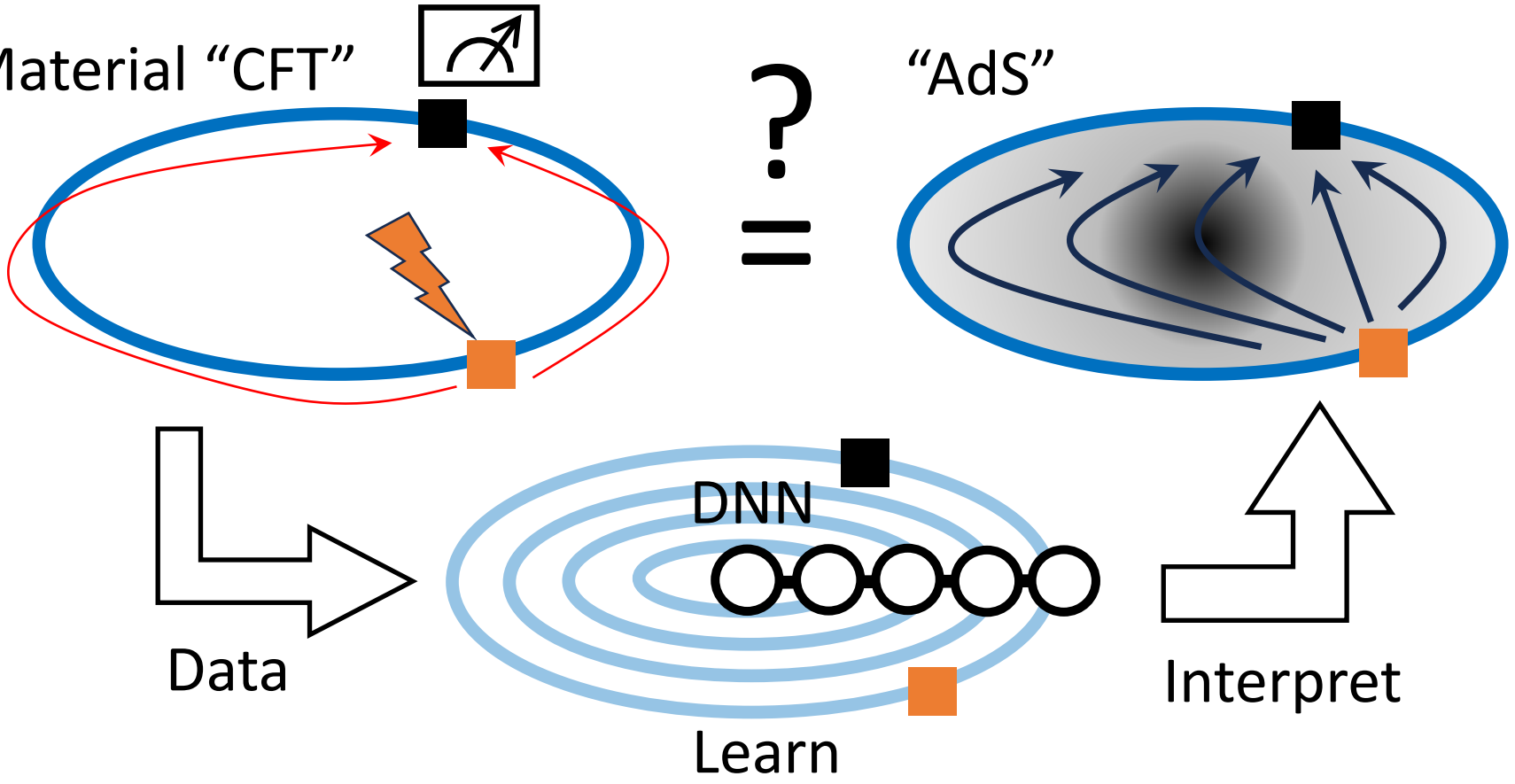



# AI hep-th : emergent spacetime

A04

NN derives emergent bulk spacetime from data on material

[Hashimoto, Matsuo, Murata, Ogiwara, Takeda, ICML 2024 workshop poster]

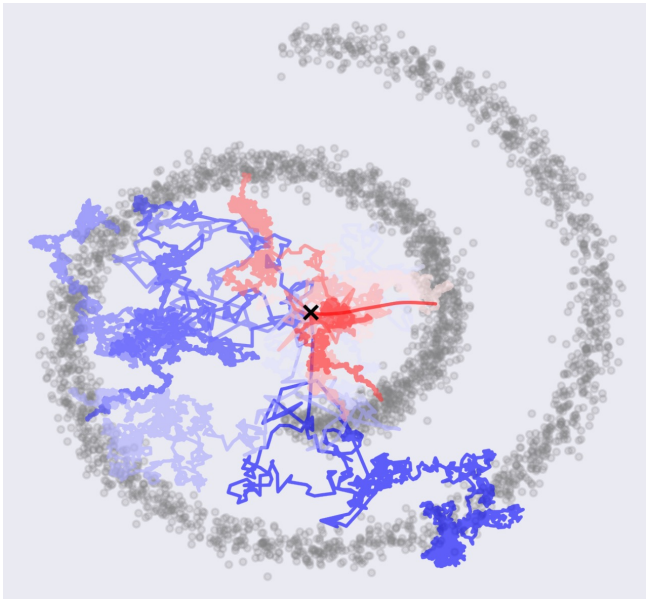


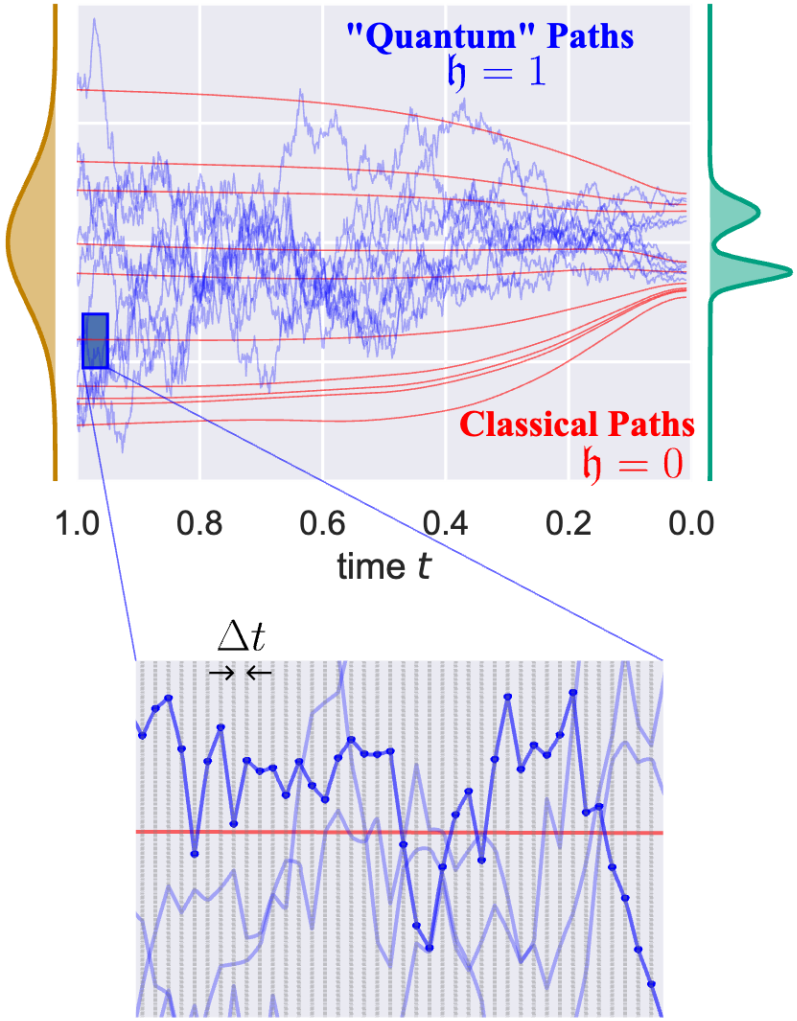
# AI stat-mech：Diffusion model is QM

**B01+B03**

[Hirono, Tanaka, Fukushima, ICML 2024, arXiv:2403.11262]

Diffusion model for generative AI is rewritten by path-integral





# Summary, MLPhys 2026 conference (Jul 2026)

https://mlphys.scphys.kyoto-u.ac.jp/ic_mlphys2026/report_en.pdf

## What Does Giving Up on Interpretability Bring to Machine Learning Physics?

Lessons from International Conference on Machine Learning Physics 2026: Research Design Connecting Performance, Meaning, and Internal Understanding

Koji Hashimoto

Representative, Foundation of Machine Learning Physics

Kyoto University

July 2026

Abstract

When neural networks (NNs) are used in physics, at what point should human interpretability of their internal representations be a condition of success? This article takes

# Summary, MLPhys 2026 conference (Jul 2026)

https://mlphys.scphys.kyoto-u.ac.jp/ic_mlphys2026/report_en.pdf

Typical research progress in MLPhys

Step I (AI) : Neural network applied (Giving up Interpretability)



Step II (Human) : Discoveries interpreted by human



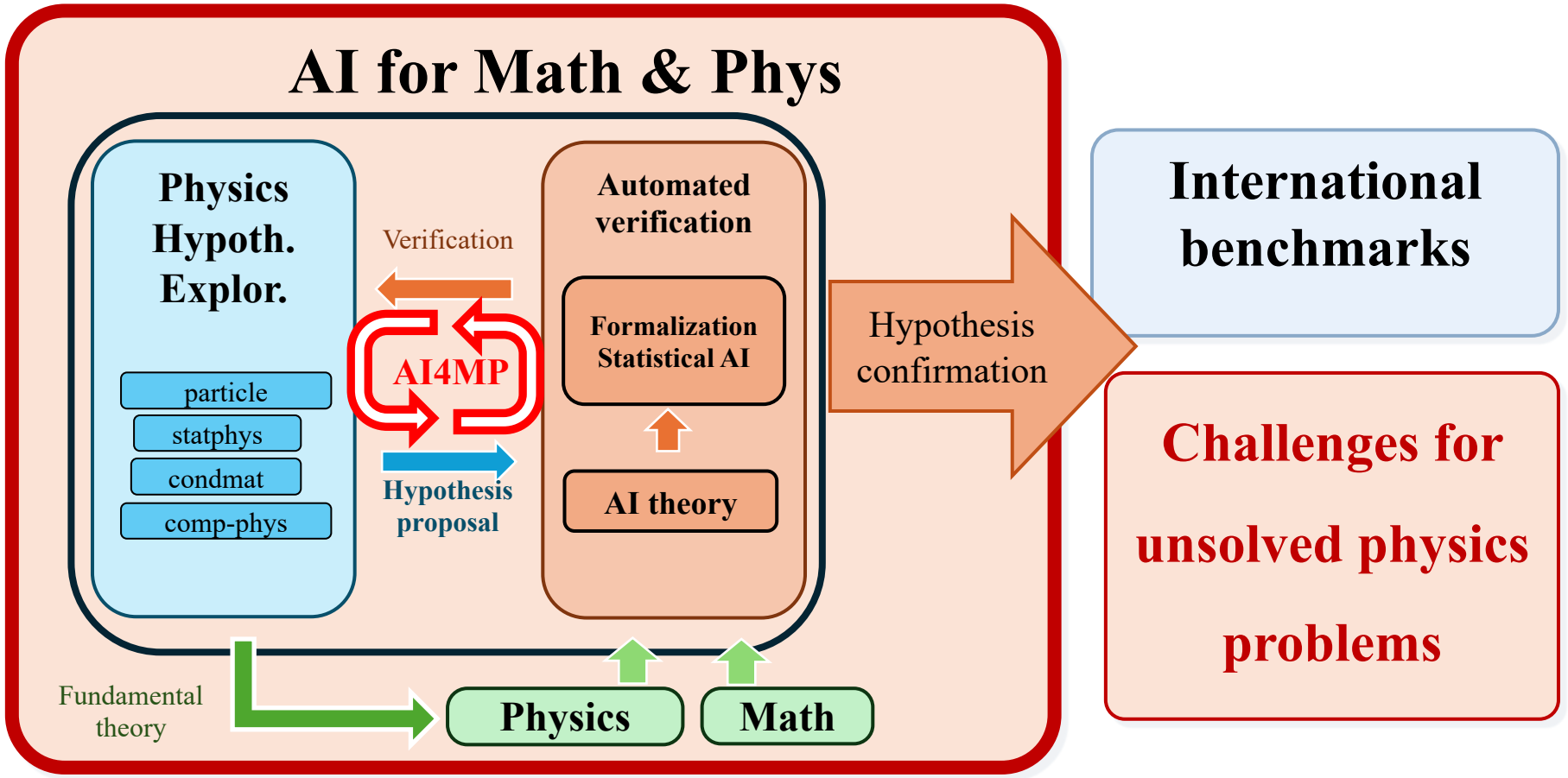
Step III (AI + Human) : Interpretable architecture applied

E.g. “Fermi machine” M. Imada (2024)

# ARiSE AI4MP (2026-2029, 4M USD)

Koji Hashimoto + Masataka Imaizumi
+ Tomiya + Otsuki + Nojiri + Kabashima + Sugiyama + Iso

**AI agents with math and physics verification for unsolved physics problems**



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Generated by Chat-GPT o3-mini-high, Feb 2025, 1 hour
(Unpublished)

# Emergent Bulk Geometry from Temperature-Dependent Magnetization Data in $Sm_{0.6}Sr_{0.4}MnO_3$ and $Sm_{0.6-x}La_xSr_{0.4}MnO_3$ via Deep Learning with a $\phi^4$ Potential

Your Name
*Your Affiliation*

(Dated: February 10, 2025)

We present a data-driven holographic modeling approach by mapping temperature-dependent magnetization versus magnetic field data onto boundary conditions for a bulk scalar field. Following the strategy of Hashimoto *et al.* [1], we recast the scalar field evolution in an asymptotically Anti-de Sitter (AdS) space as a discretized deep neural network whose trainable parameters are interpreted as components of the emergent bulk metric. In our analysis we include a $\phi^4$ potential term so that the evolution equation for the conjugate momentum includes a nonlinear contribution. We consider two material systems: (i) $Sm_{0.6}Sr_{0.4}MnO_3$ (Material [2]) and (ii) $Sm_{0.6-x}La_xSr_{0.4}MnO_3$ with $x = 0.4$ (Material [3]). Synthetic boundary datasets at 10 K, 50 K, and 100 K are generated for each material and used to train the network. We extract the emergent bulk metric $h(\eta)$ and compare the results between the two systems. Our findings indicate that the emergent geometry is sensitive to both temperature and material composition.

Example of Generative Science

## I. INTRODUCTION

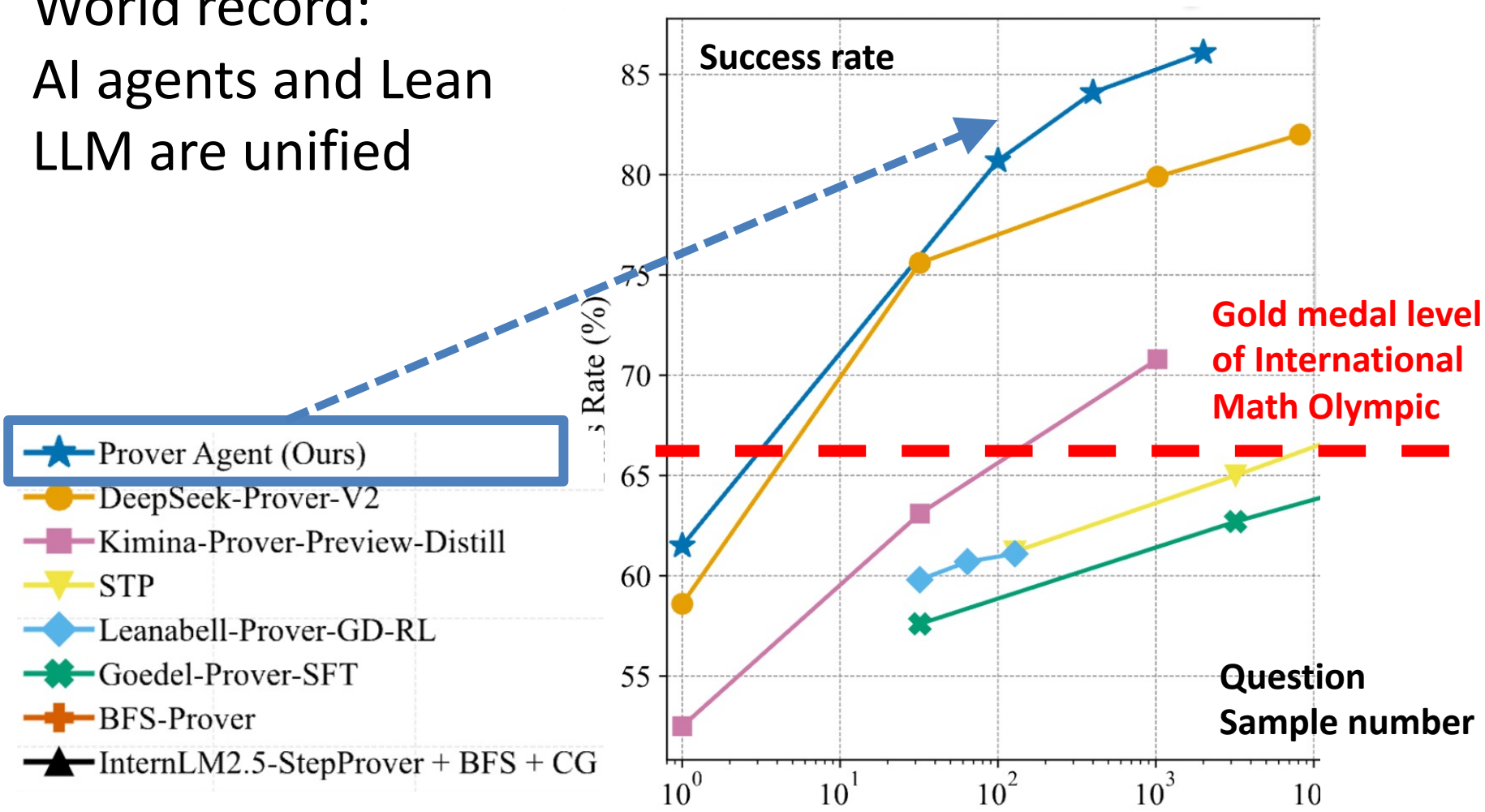
The Anti-de Sitter/Conformal Field Theory (AdS/CFT) correspondence has revolutionized our understanding of strongly coupled systems by establishing a duality between a gravitational theory in a $d+1$–dimensional AdS spacetime and a conformal field theory on its $d$–dimensional boundary [4–6]. Recently, Hashimoto *et al.* [1] introduced a novel method that recasts the bulk scalar field equations as a deep neural network, where the discretized radial coordinate is interpreted as network depth and the trainable weights represent components of the emergent bulk metric. This approach offers a new route for the inverse holographic problem—namely, reconstructing bulk geometry from boundary data.

Deep learning has found numerous applications in physics. For instance, Carleo and Troyer [7] showed that neural

# AI prover agent for auto-math

[Baba, Liu, Kurita, Sannai, ArXiv:2506.19923]

World record:
AI agents and Lean
LLM are unified



# Millenium problem on Navier-Stokes eq, OpenAI, 8 Sep 2026

## FINITE TIME BLOWUP FOR NAVIER–STOKES

OPENAI

Abstract. For every positive viscosity, we construct a solution of the three-dimensional incompressible Navier–Stokes equations that starts from rest and develops unbounded velocity in finite time while maintaining uniformly bounded kinetic energy.

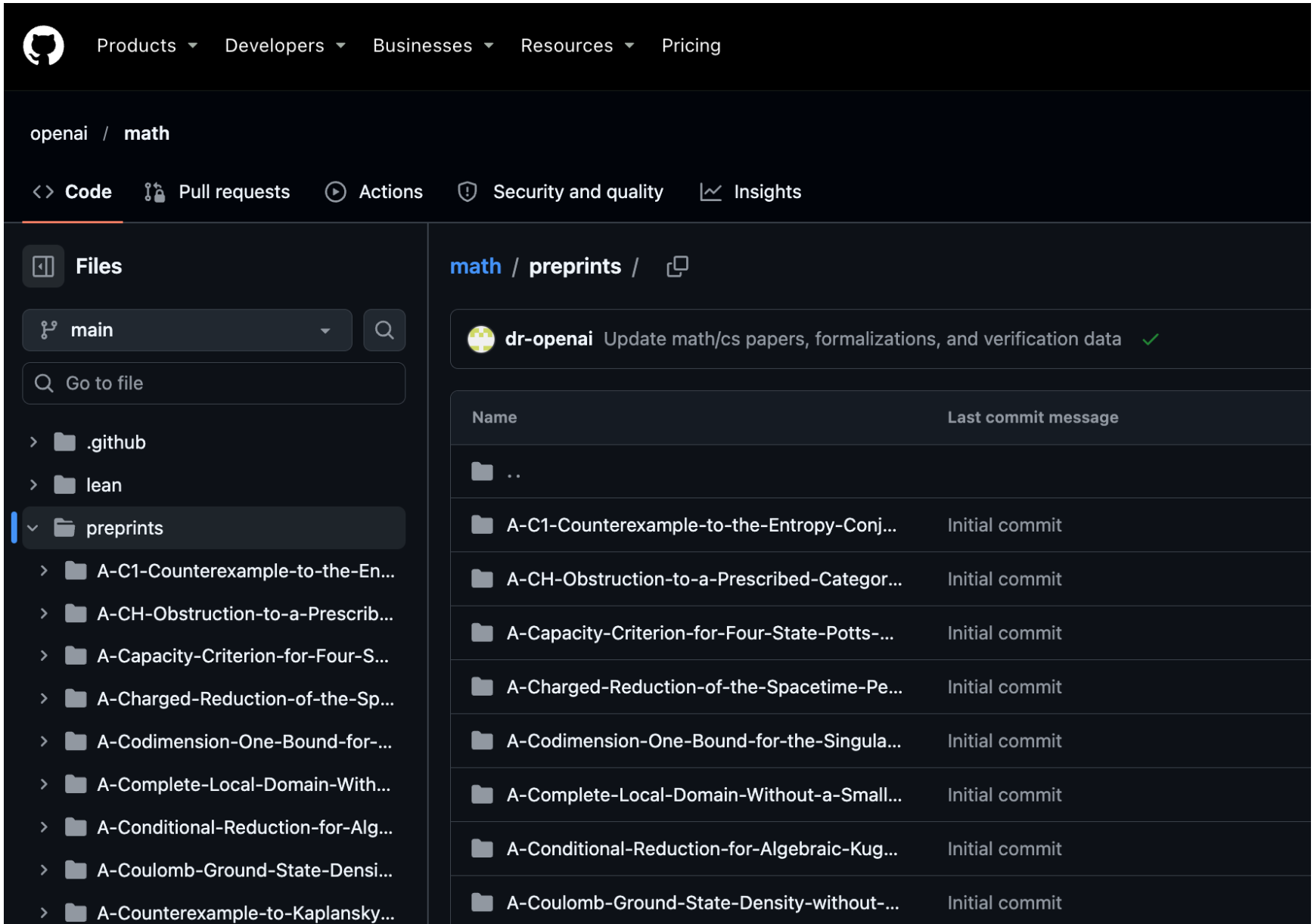
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### 1. Introduction

We consider the three-dimensional incompressible Navier–Stokes equations. A fundamental question about the nature of these equations is whether a solution starting from smooth data can develop unbounded velocity in finite time while its kinetic energy remains

# 722 preprints released by OpenAI, 6 Oct 2026



# One of OpenAI 722 preprints, on string theory

## The unique threshold bound state of the SU($N$) BFSS model

OpenAI

September 24, 2026

**Abstract**

For every finite $N \geq 2$, we prove that undeformed SU($N$) BFSS matrix quantum mechanics has exactly one normalizable zero-energy state after removing the center of mass. This establishes the threshold-bound-state conjecture.

## Contents

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# On the existence of QCD, OpenAI, 26 Oct 2026



October 26, 2026 Research Publication

# Working with academic communities to build scientific understanding

## Existence of quantum chromodynamics and completions of the Standard Model

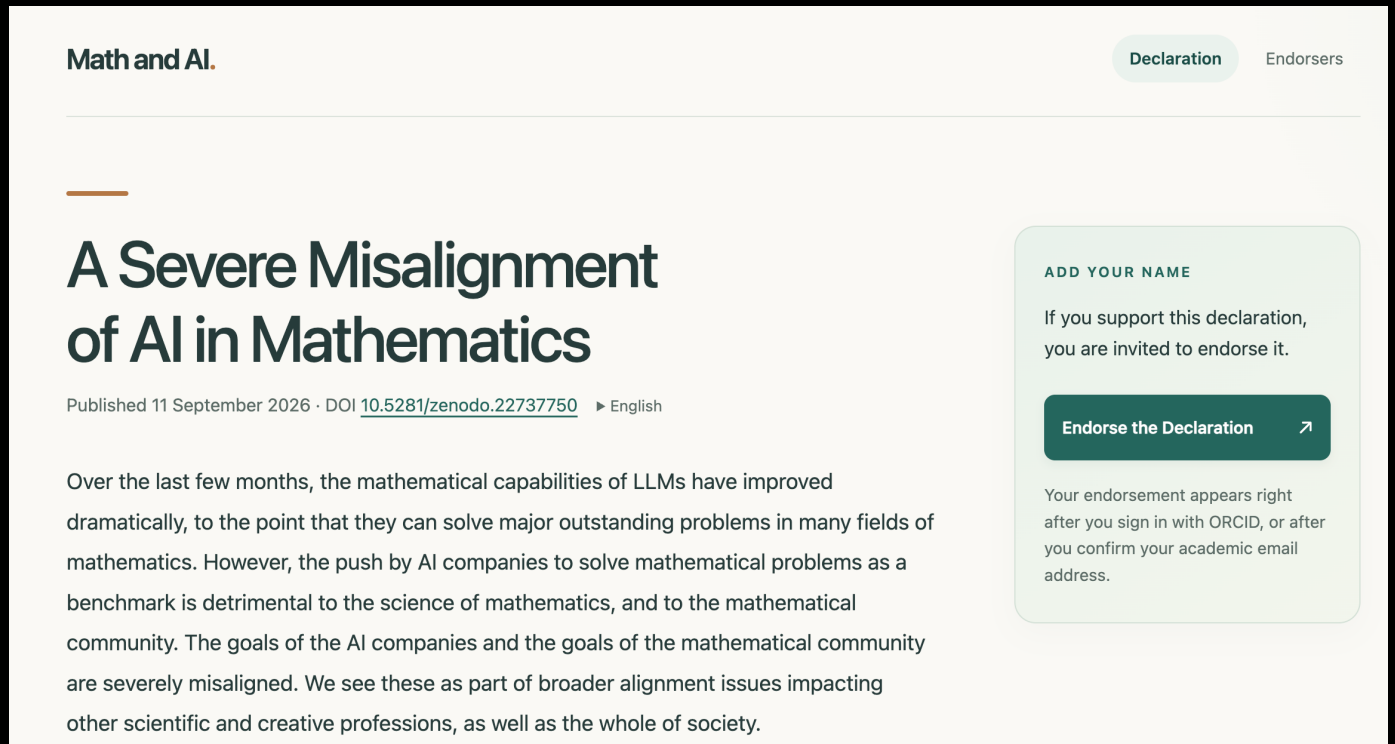
The physics collaboration will understand and explain a result that gives a mathematically rigorous existence proof of certain interacting quantum field theories containing gauge fields and fermions in four dimensions, including Quantum Chromodynamics (QCD) and a unified completion of the Standard Model of particle physics. Our work builds on Balaban's approach in constructive quantum field theory. As a subproblem, this work also includes a proof of the existence of pure Yang–Mills theory, which is part of the Quantum Yang–Mills Theory Clay Mathematics Institute Millennium Prize problem.

# Mass Petition from the Mathematics Community

https://mathandai.org/ 11 Sep 2026

"AI should support mathematical understanding and human creativity, rather than simply accelerate the production of benchmark solutions and formal results."

**A declaration signed by 8000 mathematicians, including 20+ Fields Medallists,** warning of a growing misalignment between AI development and the values of mathematical research.



# Early-Career Mathematicians on AI: Concerns and Recommendations

https://arxiv.org/abs/2610.40584 29 Oct 2026

**Study Summary**

- **268 early-career mathematicians** from 60 institutions in 5+ countries.
- **AI use is already common,** especially for search, checking, coding, and proof assistance.
- **70% became less likely to pursue academia**
- Most are **not anti-AI:** they see strong potential, but dislike how adoption is unfolding.

**Recommendations – Rebuild Evaluation-Education system**

- **Redesign hiring and promotion beyond Paper counts**
- **Preserve easy problems for Training young mathematicians**
- **Set clear rules for AI use**
- **Reward human understanding, explanation, and conceptual synthesis**

## EARLY CAREER RESEARCHER RESPONSES TO AI IN MATH

ANNA BRANDENBERGER, HANNA MULARCZYK, AND DORA WOODRUFF

ABSTRACT. We've heard a lot about AI in math from Fields medalists, AI labs, and established professors. However, the personal stakes are highest for early career researchers. Hoping to provide a platform for graduate students and postdocs to voice their opinions, concerns, and experiences, we wrote and distributed a survey on AI in math.

In this article, we share the responses to our survey. All responses are anonymous, and respondents came from almost 60 institutions and at least 5 countries. Our survey included both multiple choice questions and more open-ended free response questions.

# AI Concerns are already being discussed in HEP

https://arxiv.org/abs/2605.03185 4 May 2026

**"Physics community should preserve the core values of physics, protect PhD training as a process of developing independent researchers, and establish clear norms for AI-assisted research, publication, and peer review"**

**Community discussion from a KITP program,** involving more than 20 physicists and summarized in an arXiv paper.

physics.ed-ph] 4 May 2026

Discussion summary:
AI and the Research–Education Environment of Physics

December 11, 2025
Kavli Institute for Theoretical Physics, Santa Barbara
Based on discussions in the program
"Generative AI for High and Low Energy Physics"

**Abstract**

In the current era of AI transforming the research-education environment of physics, variety of issues and concerns arise. The KITP program "Generative AI for High and Low Energy Physics" offered a discussion session on this, and here presented is

# US HEP th+ph+lat blueprint paper

https://arxiv.org/abs/2610.28505 20 Oct 2026

- Build shared AI infrastructure for particle theory.
- Train an AI-ready theory workforce.
- It does not yet address how to sustain the theory community as AI takes on more theoretical research.

FERMILAB-PUB-26-0747-CSAID-T

## Blueprint for an AI-Enabled Particle Theory Community

George T. Fleming[1], Daniel C. Hackett[1], James Halverson[2], T. J. Hobbs[3], Stefan Hoeche[1], Brandon Kriesten[3], Konstantin T. Matchev[4], Tony Menzo[1,4], Stephen Mrenna[1], Benjamin Nachman[5], Prasanth Shyamsundar[1], David Shih[6], Jesse Thaler[7], Jure Zupan[8]

[1] Fermi National Accelerator Laboratory, [2] Northeastern University, [3] Argonne National Laboratory, [4] University of Alabama, [5] SLAC National Laboratory, [6] Rutgers University, [7] Massachusetts Institute of Technology, [8] University of Cincinnati

Prateek Agrawal[9], Jonathan Bagger[10], Yang Bai[11], Brian Batell[12], Sean Benevedes[13], Vedran Brdar[14], Matthew R. Buckley[6], Christopher Carone[15], Mu-Chun Chen[16], Kun Cheng[12], So Chigusa[7], R. Sekhar Chivukula[17], Neil Christensen[18], Timothy Cohen[19], Jonathan M. Cornell[20], Antonio Delgado[21], Radovan Dermisek[22], Jeff A. Dror[23], Anatoly Dymarsky[24], Jonathan L. Feng[16], Terrance Figy[25], Alexander Friedland[5], Dorival Goncalves[14], Craig Group[26], Tao Han[12], Mark Hertzberg[27], Samuel Homiller[12], Matheus Hostert[28], Philip Ilten[8], Zhong-Bo Kang[29], Can Kilic[30], Doojin Kim[31], William H. Kinney[32], Simon Knapen[33], Kyoungchul Kong[34], Graham Kribs[19], Shirley Li[16], Huey-Wen Lin[35], Zhen Liu[36], Ian Low[37], Pedro Machado[1], Kendall Mahn[35], Alexander Maloney[38], Liam McAllister[39], Djordje Minic[40], Bernhard Mistlberger[5], Sebastian Mizera[41], Moritz Münchmeyer[11], Ethan Neil[42], Nobuchika Okada[4], Sofia Palacios Schweitzer[6], Ian Pang[1,4], Andreas Papaefstathiou[43], Alexey Petrov[44], David Poland[45], Xiaolin Qi[40], Michael Ratz[16], Laura Reina[46], Thomas Rizzo[5], Nicholas Rodd[33], Alessandro Russo[47], Philip Schuster[5], Phiala Shanahan[7], Elizabeth H. Simmons[17], George Siopsis[48], Dejan Stojkovic[32], Shufang Su[49], Tim M. P. Tait[16], Lian-Tao Wang[50], Zhengkang Zhang[51]

v1 [hep-ph] 20 Oct 2026

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# Proposal

Establish an international WG of major HEP laboratories to define how AI is integrated without hollowing out a part of theory community.

**Issues WG should address:**

1. **Preserve Theory as a Strategic Capability**
2. **Protect the Next Generation of Theorists**
3. **Redefine What We Value in Theoretical Physics**
4. **Integrate and Govern AI—Rather Than Replace Theory with It**

**Roles of WG:**

- **Develop a joint statement on the role of theory in the AI era.**
- **Assess the impact of AI on the training and career pipeline.**
- **Recommend common principles for AI-era research and institutional policy.**

"What scientific capabilities, human expertise, and training ecosystem must HEP preserve and develop as AI capabilities rapidly change?"

## 1. Preserve Theory as a Strategic Capability

**Why:** AI can accelerate existing problem-solving, but HEP still needs people who decide which questions matter, how results are interpreted, and where the field should go next.

**Action:** Maintain theory groups and protect long-term, curiosity-driven theoretical research.

## 2. Protect the Next Generation of Theorists

**Why:** If junior positions and formative research tasks disappear, the field may lose theory people who will jointly provide future scientific judgment.

**Action:** Protect PhD, postdoctoral, and junior-theory positions, rebuild education, and preserve research experiences that develop intuition and independence.

## 3. Redefine What We Value in Theoretical Physics

**Why:** As AI makes calculations, proofs, and paper production cheaper, output volume becomes a poorer proxy for scientific value.

**Action:** Reward question formulation, conceptual advances, physical insight, connections to experiment, and long-term scientific direction—not simply publication counts.

## 4. Integrate and Govern AI—Rather Than Replace Theory with It

**Why:** AI can greatly strengthen HEP, but unmanaged adoption can weaken human scientific capacity and distort research incentives.

**Action:** Build Experiment – Theory - AI teams, establish shared AI norms, and treat AI investment as an augmentation of scientific capability.