Fermilab

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# Fermilab, AI and DOE's Genesis Mission

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Fermi National Accelerator Laboratory is managed by FermiForward for the U.S. Department of Energy Office of Science

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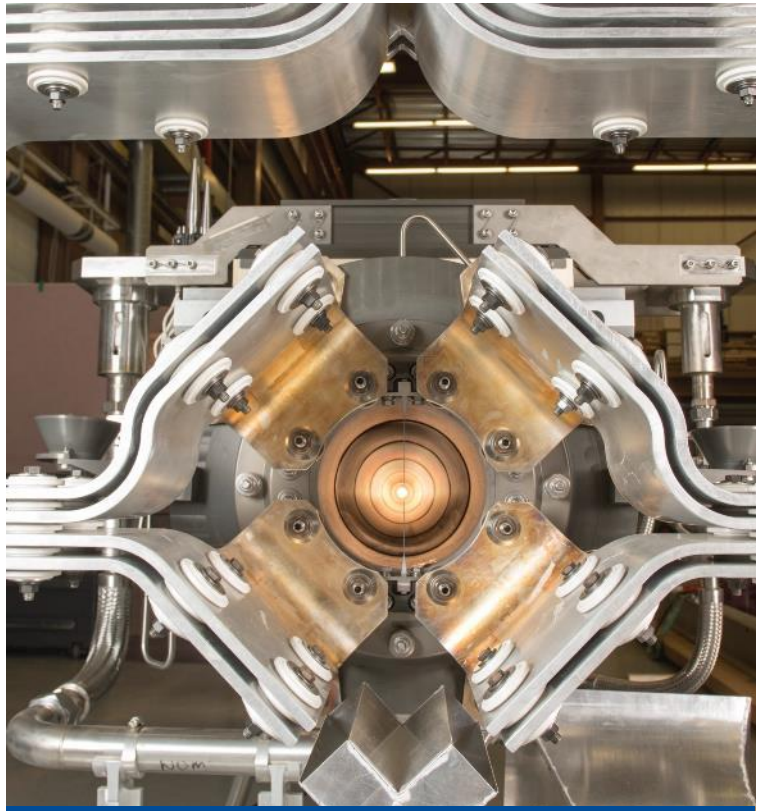
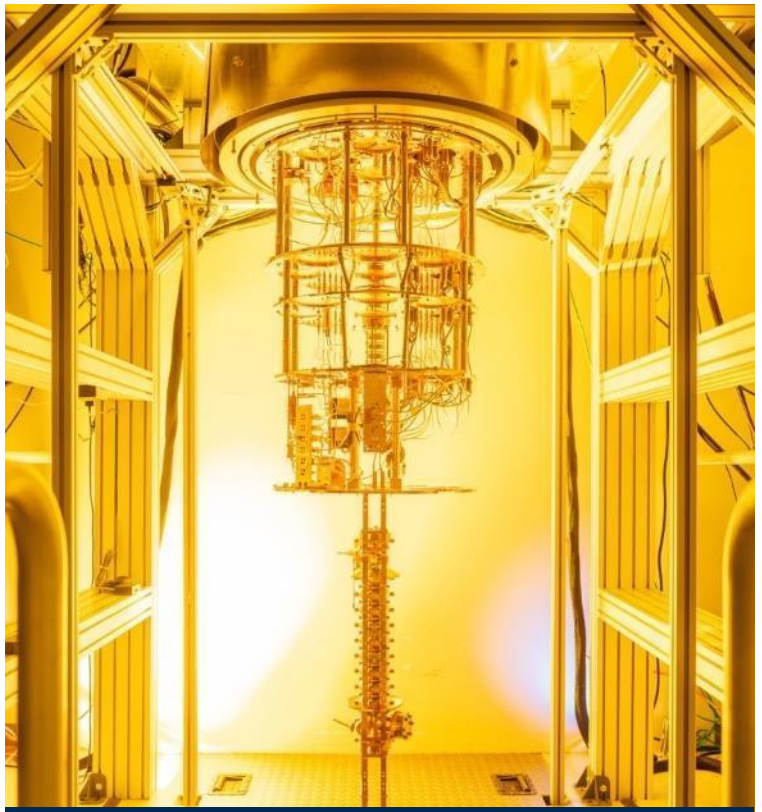
# Our top priorities

We are **one lab.** We all work for **science.** We **focus.** We **collaborate.** We **execute.**



**Beam to LBNF/DUNE-US by 2031**

**HL-LHC**



**Driving Innovation**

## DRIVING INNOVATION

# Apply World Leading Capabilities to Deliver Innovative Technologies and Enhance National Competitiveness

# Integrating Storage, Data Service, and AI

- Fermilab serves computing needs of CMS, DUNE, and many other experiments
- **Leading networking & storage capacity**
  - **Over 1 exabyte storage**
  - **2.4 Tb/s ESnet networking with over 1 exabyte served last year**
- Development and stewardship of software frameworks for CMS and DUNE
- Created Fermi Data Platform (FDP) for American Science Cloud

1 of 7 tape libraries (100+ PB each)

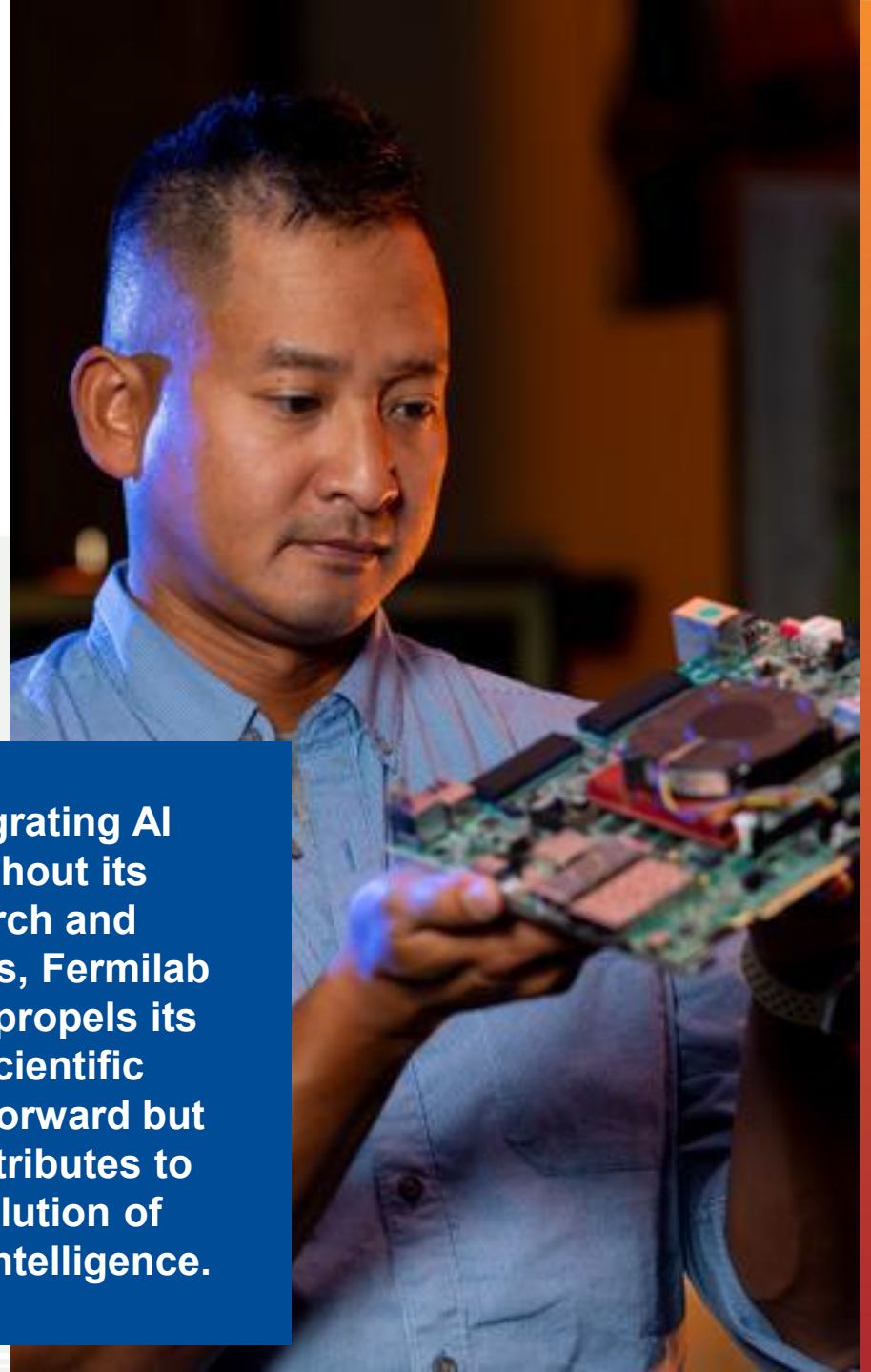

**Bringing CMS/DUNE data capabilities to the Genesis Mission**

# How AI enhances scientific goals of particle physics

**Advancing discovery in high-energy physics research**

**Developing national AI capabilities that build on the challenges of particle physics and technologies**

**Fostering collaboration to address interdisciplinary AI challenges and share insights with scientific and technology partners**



**By integrating AI throughout its research and operations, Fermilab not only propels its own scientific mission forward but also contributes to the evolution of artificial intelligence.**

# A symbiotic relationship

AI plays a key role across many of our **core research and mission areas**:

- Neutrino experiments
- Accelerator research
- Quantum information science
- Smart detectors and sensors
- Particle physics at colliders
- Astrophysics
- Business operations

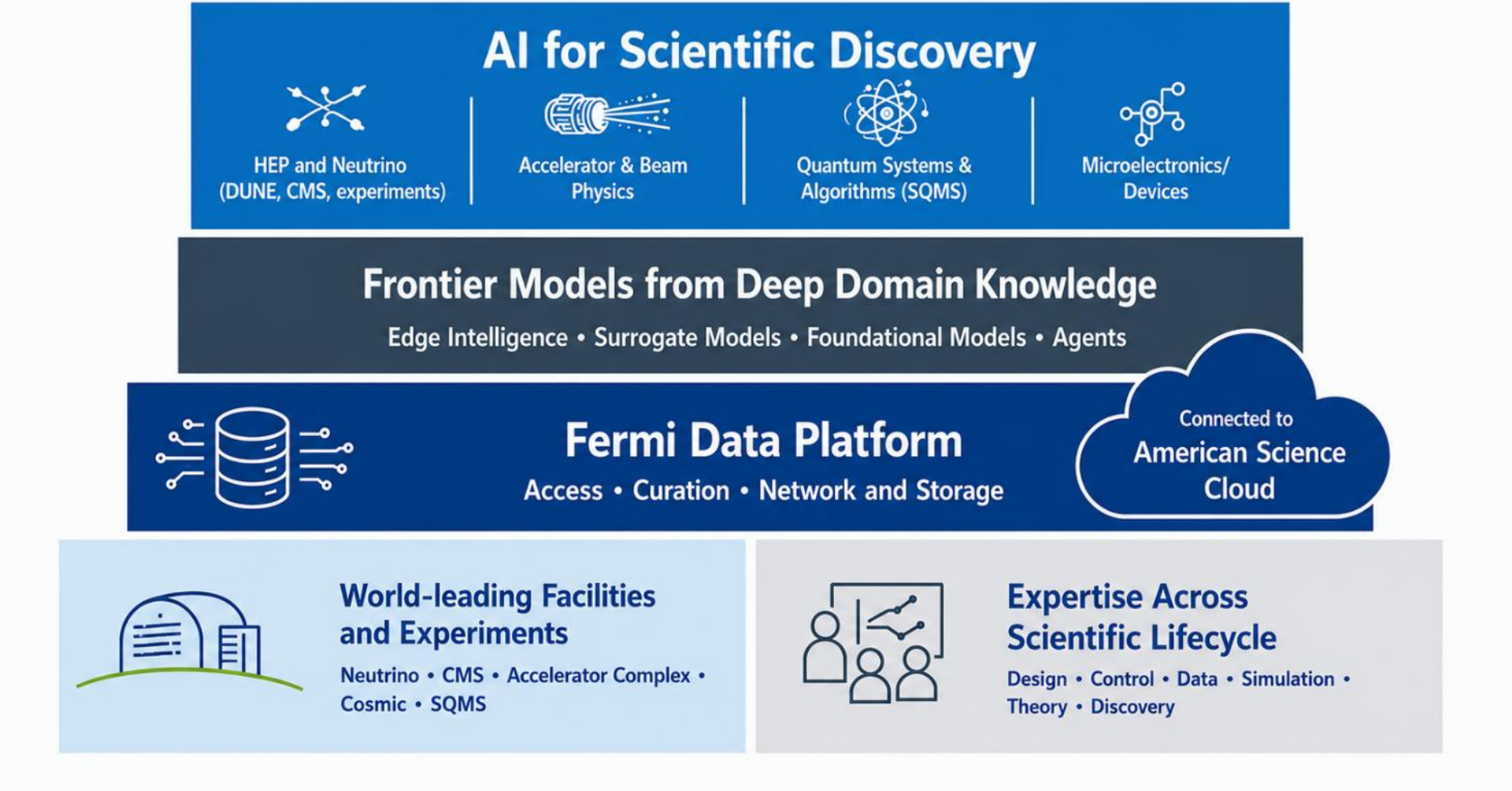
Fermilab plays a central role in the **DOE's Genesis Mission**, a national initiative to **double U.S. scientific productivity through AI,** quantum technologies and advanced computing.

Fermilab's leadership in AI-enabled research, quantum science, microelectronics, and the design and operation of some of the world's most complex scientific instruments will be essential to the success of Genesis.

# What is the Genesis Mission?

- Department of Energy initiative to bring together the national labs, industry and academia  to harness AI for breakthroughs in energy dominance, discovery science, and national security.
- Genesis Mission is initially tackling 26 national science/tech challenges, many of which align with Fermilab expertise and capabilities:
  - Fusion energy
  - Quantum algorithms and systems
  - Microelectronics
  - Enhancing Particle Accelerators
  - Unifying Physics from Quarks to the Cosmos

# The Genesis Mission at Fermilab




*Fermilab's strength in AI derives from its facilities and scientific expertise*

# Genesis AI for Science Early Wins

Genesis Mission

## Accelerated Microelectronics Design in Extreme Environments

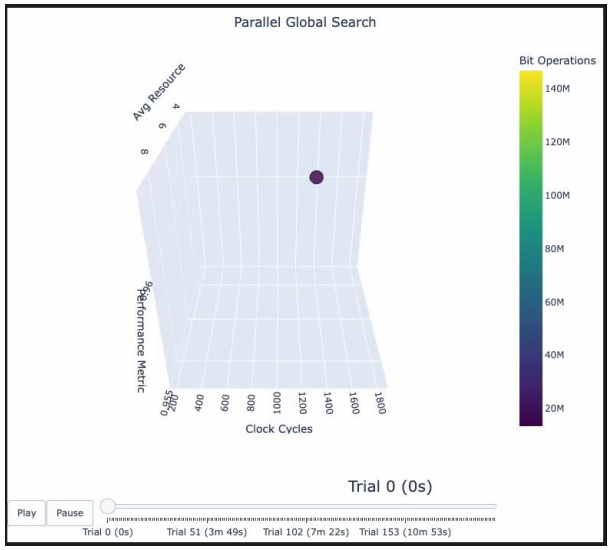
Speedup of circuit design from months to hours

AMD

SIEMENS

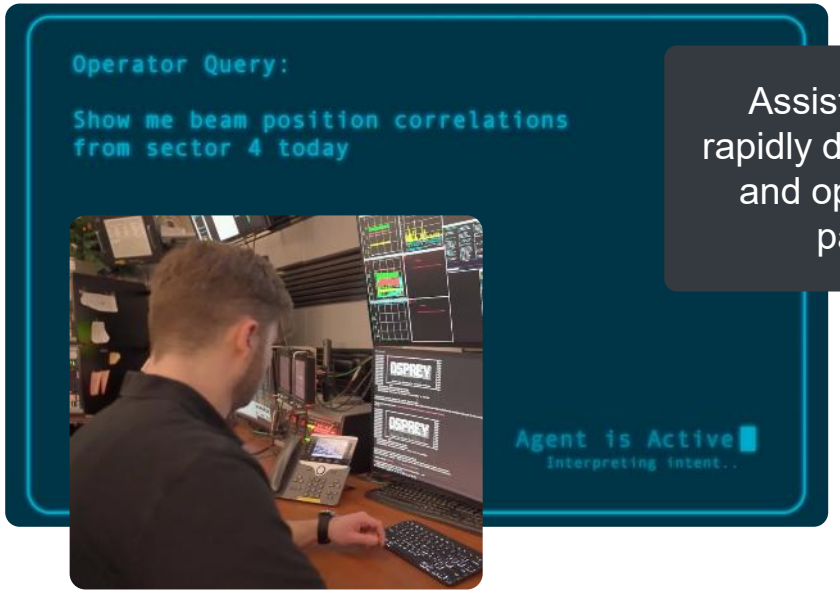
GlobalFoundries

Deploying novel AI surrogates on Genesis compute for 500x speed up in design exploration for qubit readout




## Agentic AI Accelerator Operations

FNAL high-power proton facility part of multi-lab, cross-facility/program team pushing state-of-the-art for accelerator AI assistant capabilities




Assists operators in rapidly diagnosing issues and optimizing beam parameters

## Genesis Model Teams working towards June showcase for America 250

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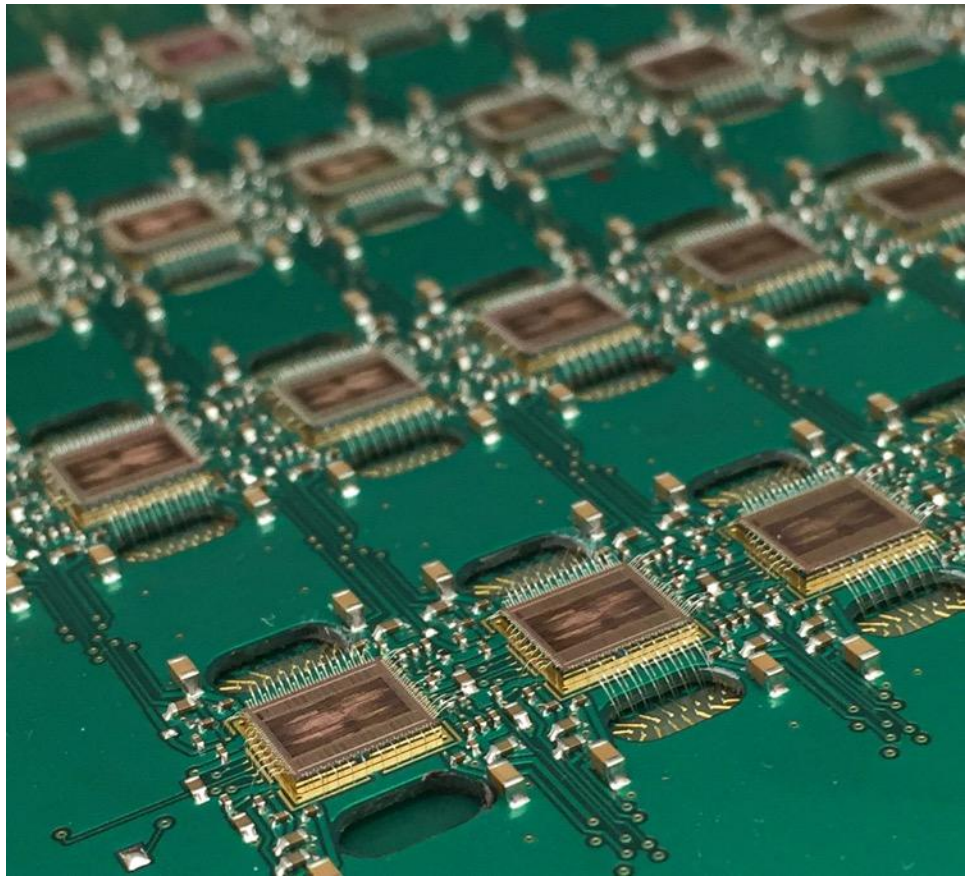
# Microelectronics: Novel sensing in extreme environments

**Motivation:** DOE science depends on chips that must work in harsh conditions—high radiation, extreme temperatures. Traditional design methods are slow.

**Approach:** We use AI to automate and dramatically speed up chip design for extreme environments.

**Impact:** AI enables 500× faster chip design, unlocking new capabilities for quantum systems, accelerators, and fusion energy.

**S&T Challenge :** Advances Recentering Microelectronics in America with broad impact across DOE science.



**From slow, siloed design to AI-driven microelectronics innovation for the most demanding environments in science**

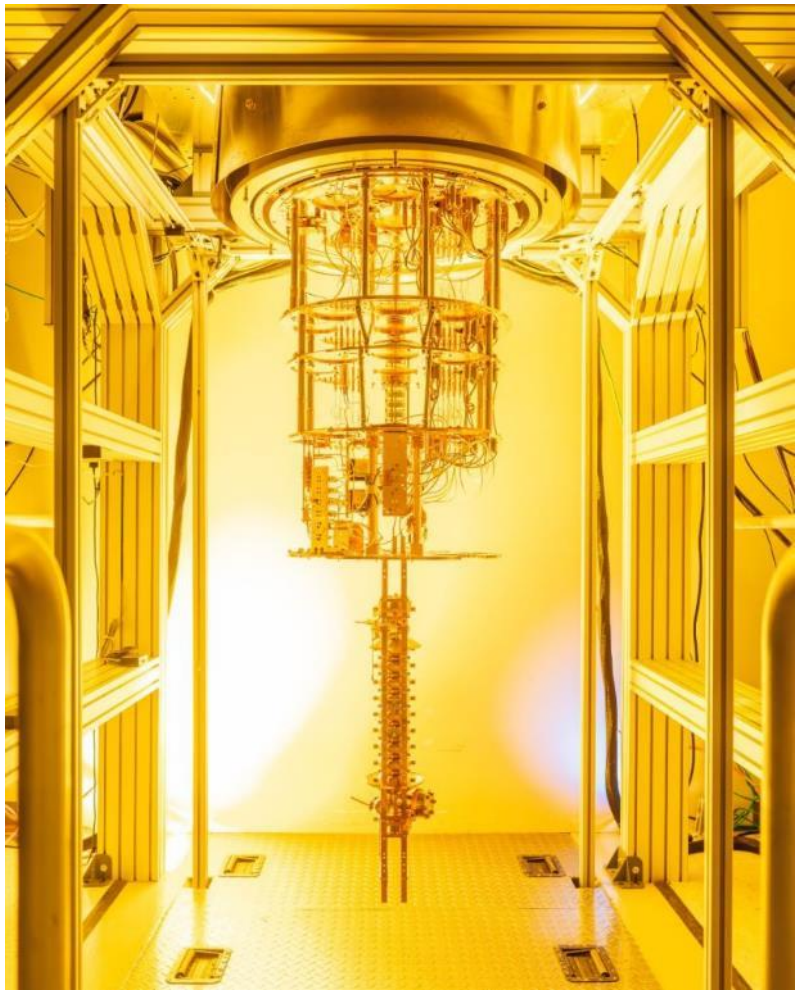
# AI-Ready Quantum Data Ecosystem for Discovery at the SQMS Center

**Motivation:** DOE's quantum research centers produce valuable data that sits in scattered, hard-to-access silos, limiting scientific discovery.

**Approach:** We build a shared, organized system that makes quantum data available and AI-ready across all centers.

**Impact:** Faster breakthroughs in quantum science and U.S. leadership in AI-powered quantum discovery.

**S&T Challenge :** Advances DOE priorities in Quantum Information Science and AI for Science at national scale.



**From fragmented quantum efforts to a unified, AI-powered national discovery ecosystem**

# AI-Driven Transformation of Particle Accelerator Design & Operations

**Motivation:** Particle accelerators are growing more complex, which limits performance and slows discovery.

**Approach:** AI systems like Osprey now operate at 8 DOE facilities, delivering over 100× faster operator interactions and smarter, more autonomous operations.

**Impact:** Faster scientific results, better performance, and innovations that benefit science, industry, and medicine.

**S&T Challenge :** Advances DOE's Enhancing Particle Accelerators for Discovery priority with wide-reaching impact.


***Genesis is transforming accelerators into intelligent, autonomous systems—delivering faster discovery and greater return on DOE investments.***

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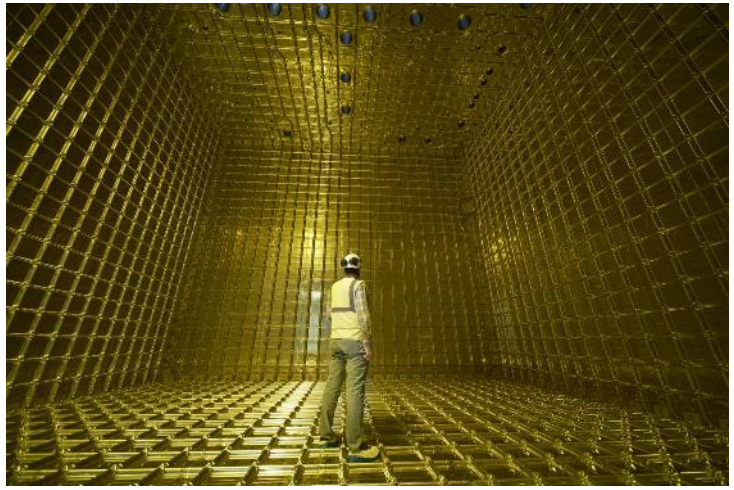
# Automating Complex High Energy Physics Workflows

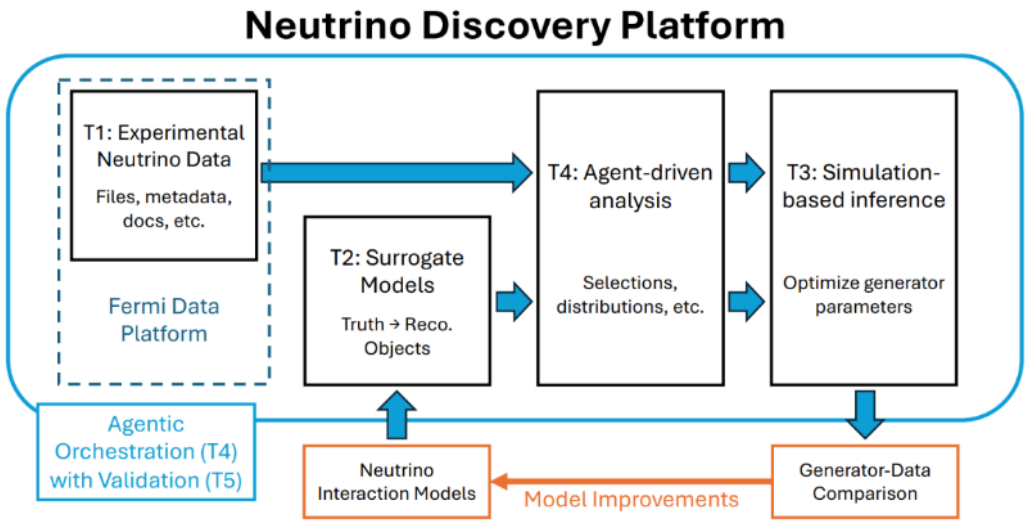
**Motivation:** Major physics experiments require many complex manual steps, slowing discovery and making results hard to reproduce.

**Approach:** AI agents automatically plan and carry out research workflows, tracking every step for full reproducibility.

**Impact:** Faster results at experiments like DUNE and the LHC by eliminating manual bottlenecks.

**S&T Challenge :** Advances Quark-to-Cosmos priorities with a unified AI framework applicable across DOE science.






**From manually orchestrated workflows to autonomous, AI-driven scientific discovery pipelines**

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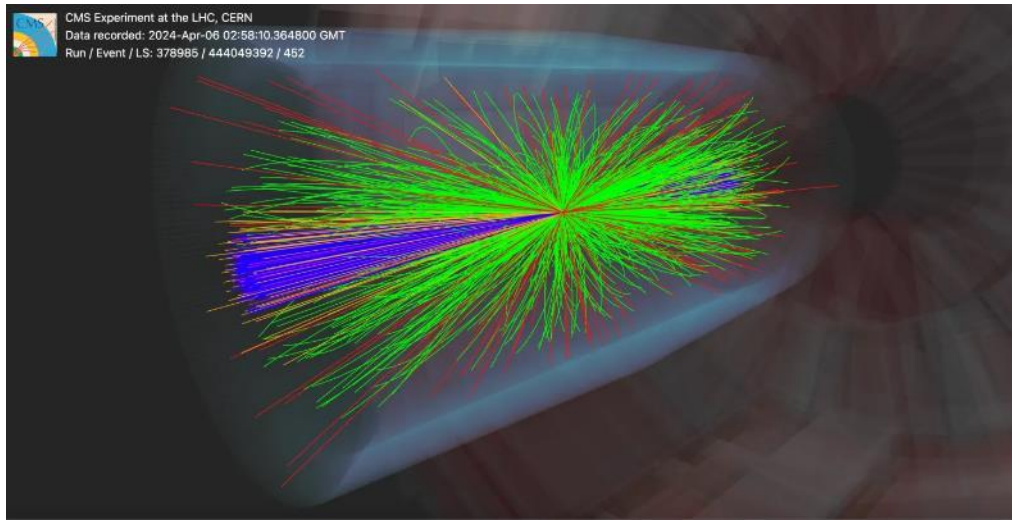
# Cross-Experiment Discovery for Particle Physics

**Motivation:** Data from different physics experiments is stored in incompatible formats, making it hard to combine and compare results.

**Approach:** We unify detector data from multiple experiments and build AI models that can reason across all of them.

**Impact:** Deeper insights into fundamental physics—better Higgs measurements and new sensitivity to unknown physics.

**S&T Challenge :** Advances Quark-to-Cosmos priorities through projects like TREASURE on the American Science Cloud.




Example – **TREASURE project**
Tokenized Representations for Energy-frontier AI Searches via Understanding and Reasoning

**From isolated experiments to integrated,**
**AI-driven discovery across the global collider physics program**

# AI-ready Scientific Data Services

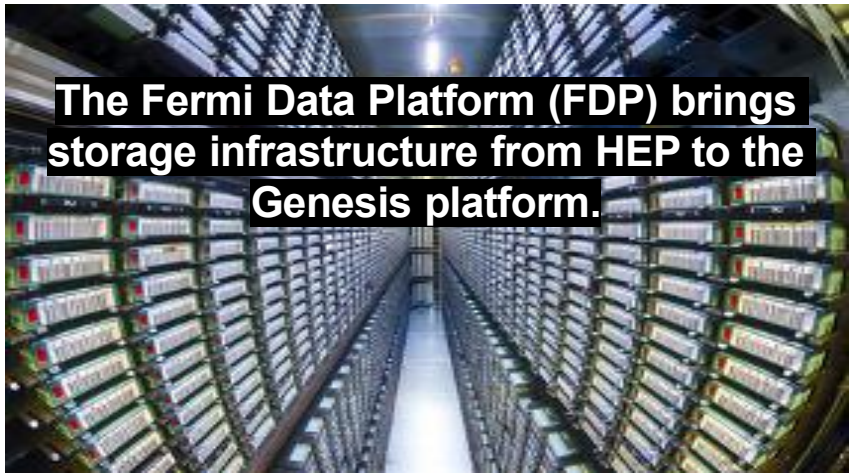
The Fermi Data Platform as an American Science Cloud Infrastructure Partner

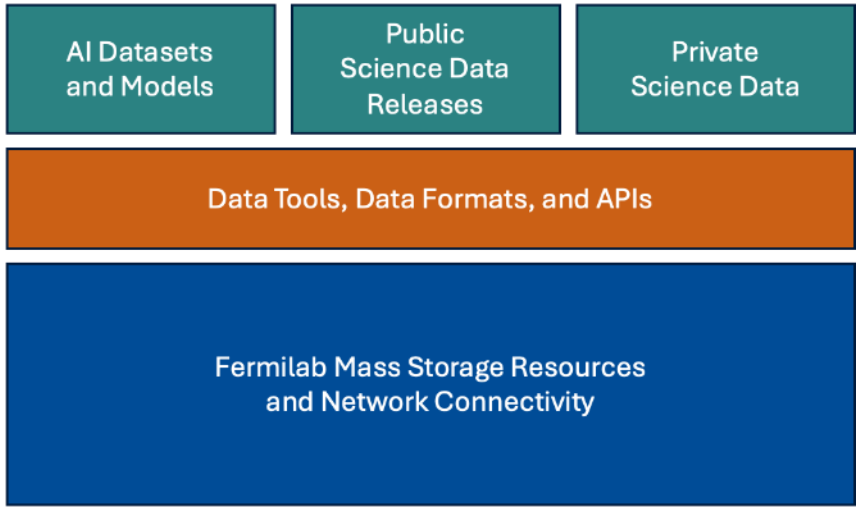
**Motivation:** AI-driven science needs fast, flexible access to large datasets across many labs—beyond what traditional systems can provide.

**Approach:** The **Fermi Data Platform (FDP)** delivers high-speed, shared data access across the DOE lab network, integrated with the American Science Cloud.

**Impact:** FDP already supports AI science across multiple programs, positioning Fermilab as a key national data provider.

**S&T Area:** Strengthens DOE's data infrastructure and Fermilab's role in the American Science Cloud ecosystem.




**AI for science requires the worlds largest data sets.**
**The Fermi Data Platform leverages HEP expertise to serve scientific data at unprecedented scales.**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