Introduction to Scientific Computing I

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What do *I* do ?

Was the Universe an Accident?

Artificial Intelligence may find the answer in data from the Large Hadron Collider

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ATLAS EXPERIMENT

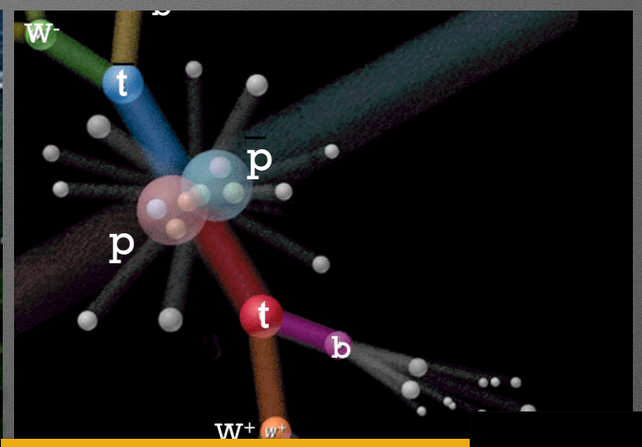
DUNE DEEP UNDERGROUND NEUTRINO EXPERIMENT

What is HEP ?

Large Hadron Collider (LHC)

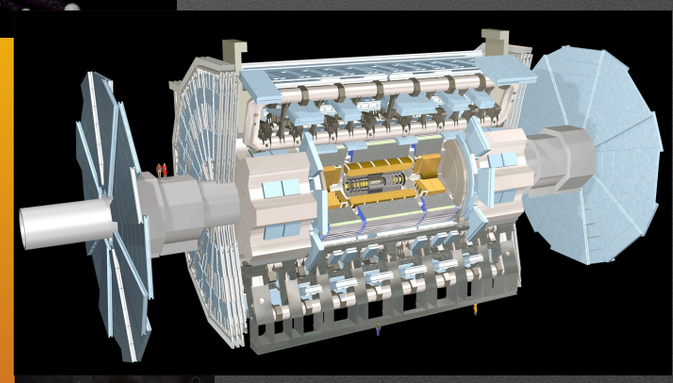
Largest Machine Ever Built

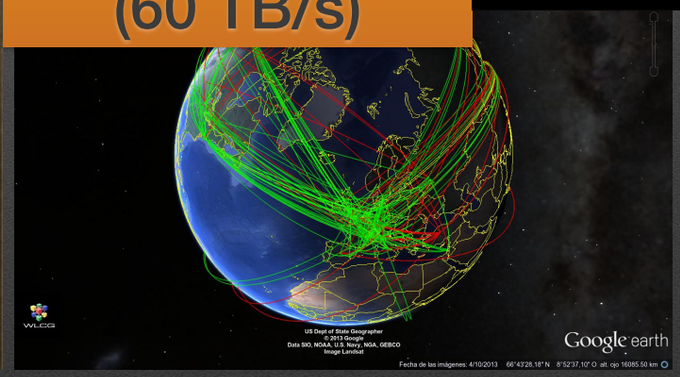
10^{11} Protons Collide 40 Million Times per Second



Create New Particles
Only 1 in 10^{11} are "interesting"

Record with 5 Story 100M Channel "Camera" (60 TB/s)





Processed by 300k Cores Around the World

Higgs Discovery - Nobel Prize Physics 2013

Physics Letters B 716 (2012) 1–29

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Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC ☆

ATLAS Collaboration *

This paper is dedicated to the memory of our ATLAS colleagues who did not live to see the full impact and significance of their contributions to the experiment.

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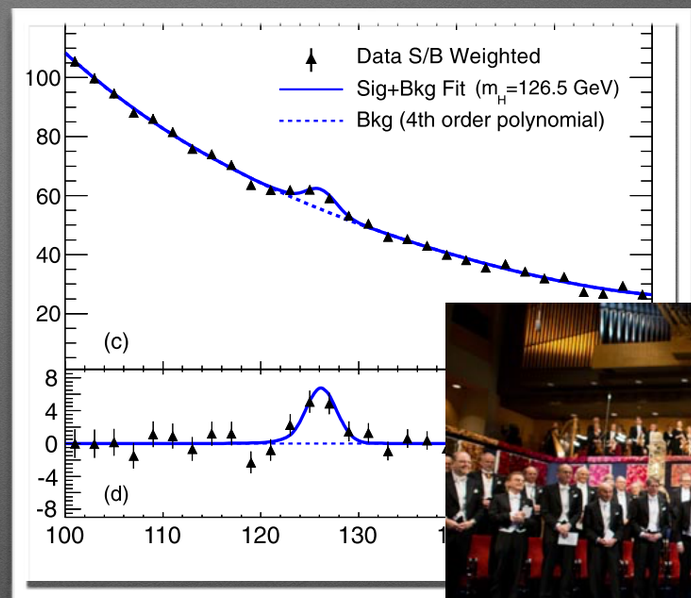
ABSTRACT

A search for the Standard Model Higgs boson in proton–proton collisions with the ATLAS detector at the LHC is presented. The datasets used correspond to integrated luminosities of approximately 4.8 fb^{-1} collected at $\sqrt{s} = 7$ TeV in 2011 and 5.8 fb^{-1} at $\sqrt{s} = 8$ TeV in 2012. Individual searches in the channels $H \to ZZ^{(*)} \to 4\ell$, $H \to \gamma\gamma$ and $H \to WW^{(*)} \to e\nu\mu\nu$ in the 8 TeV data are combined with previously published results of searches for $H \to ZZ^{(*)}$, $WW^{(*)}$, $b\bar{b}$ and $\tau^+\tau^-$ in the 7 TeV data and results from improved analyses of the $H \to ZZ^{(*)} \to 4\ell$ and $H \to \gamma\gamma$ channels in the 7 TeV data. Clear evidence for the production of a neutral boson with a measured mass of 126.0 ± 0.4 (stat) ± 0.4 (sys) GeV is presented. This observation, which has a significance of 5.9 standard deviations, corresponding to a background fluctuation probability of 1.7×10^{-9}, is compatible with the production and decay of the Standard Model Higgs boson.



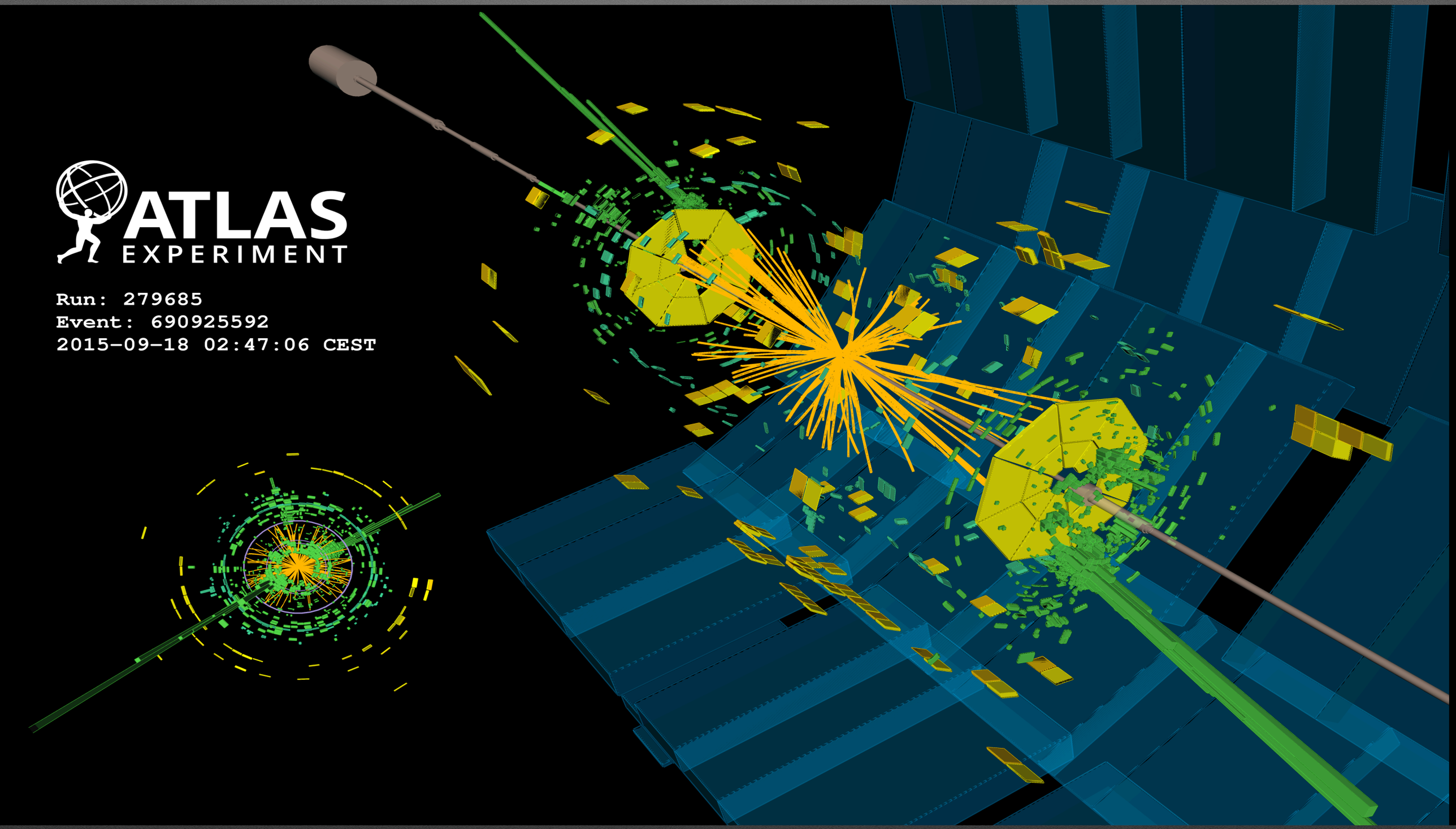
Last Piece of the Standard Model

Best Tested Theory… Ever.

Not Done… Higgs is Light! Possibilities:

- *Fine-tuned Theory*: Accident or Multiverse + Anthropic Principle
- *Mechanism*: Supersymmetry, Extra-Dimensions, Sub-structure
  - Focus of LHC
- *Design?*

Deep Learning in High Energy Physics



- Requires lots of computing
- Upgrade to LHC will give us 100x the data.
  - We won’t have 100x the computing power or storage.
- Use Artificial Intelligence and newest processors…

Animal Brains

- The brain takes in sensory data… ***builds hierarchical models of the world***.
- So effectively, a ***representation*** of the input is assembled in the brain.
  - Eyes see a limited window… but…
  - Location Cells
  - Imagining locations

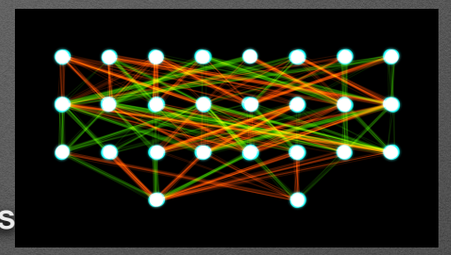
Brief History of AI

Artificial Intelligence

- Goal: Systems that reason and act as well as or better than humans
- Heuristic AI (1990's)
- Machine Learning AI
  - Knowledge learned from data
- Neural Networks ~ Brain inspired computing (1943)
  - Universal Computation Theorem (1989)
  - Multi-layer hidden networks (a.k.a. Deep) (1965)
  - Vanishing Gradient Problem (1991)

Deep Learning Renaissance (> 2007 - now)

- Driven by:
  - New NN Innovation
  - Big Data
  - Graphical Processing Units

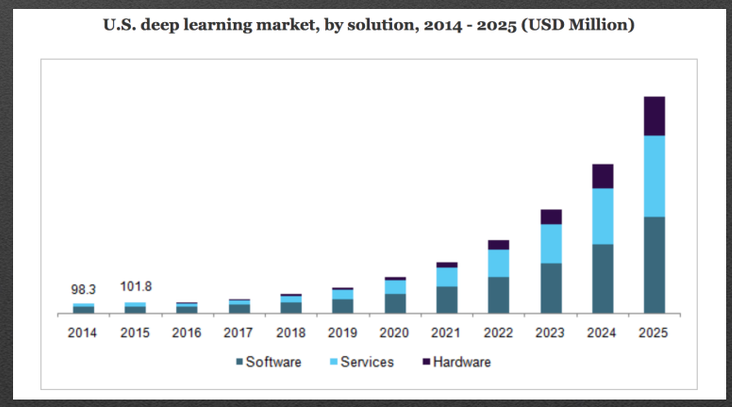


- Amazing Feats

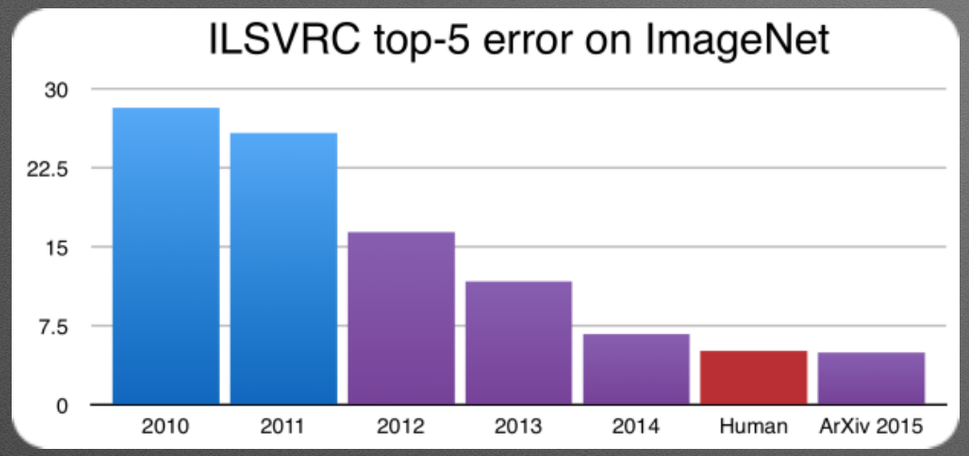
WIRED STAFF SCIENCE 06.26.12 11:15 AM

GOOGLE'S ARTIFICIAL BRAIN LEARNS TO FIND CAT VIDEOS

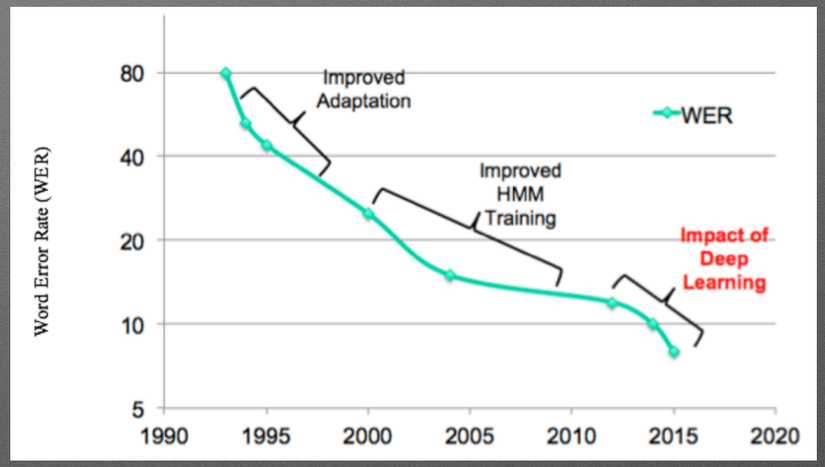
- Market Growth
- Industry Adoption



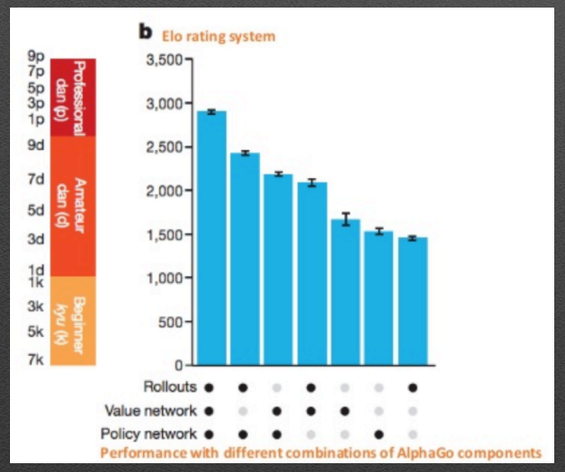
Amazing Feats : Some Examples



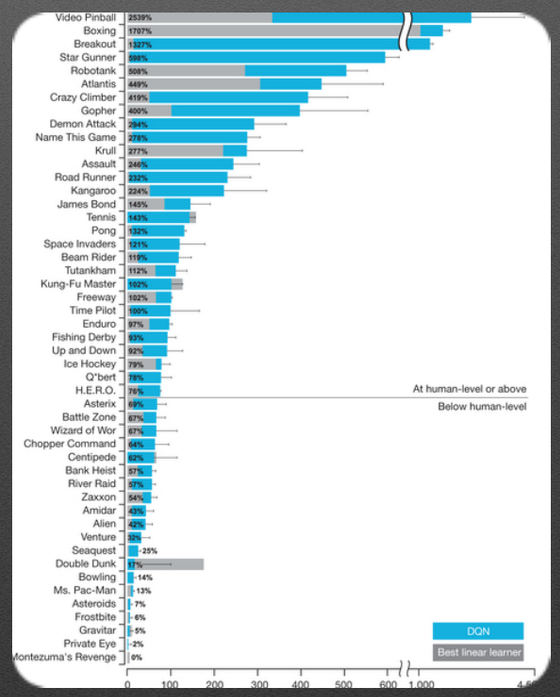
ImageNet Outperforms humans



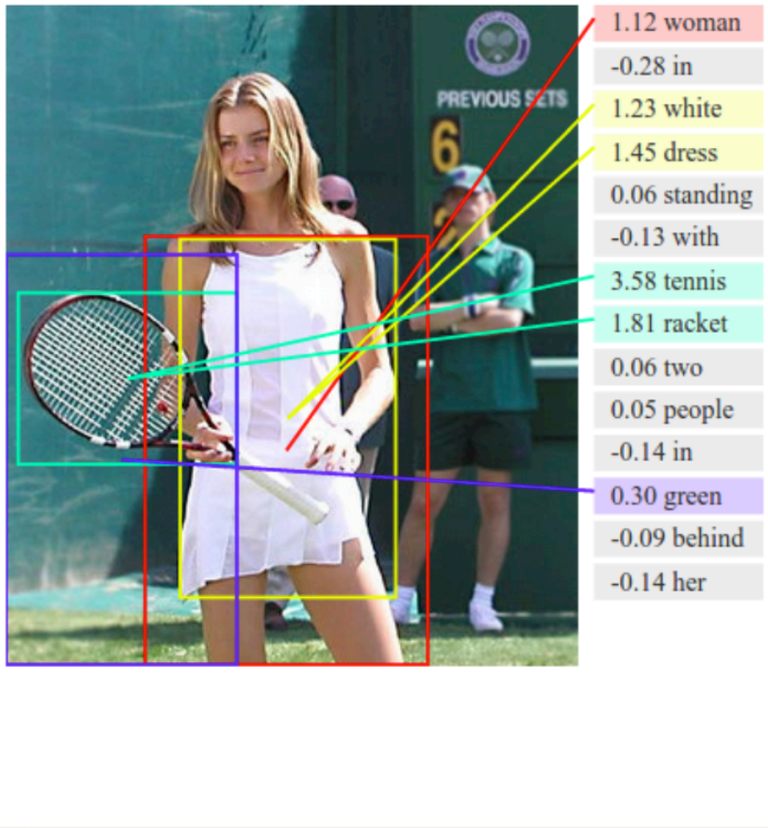
Rapid Advances in Speech Recognition

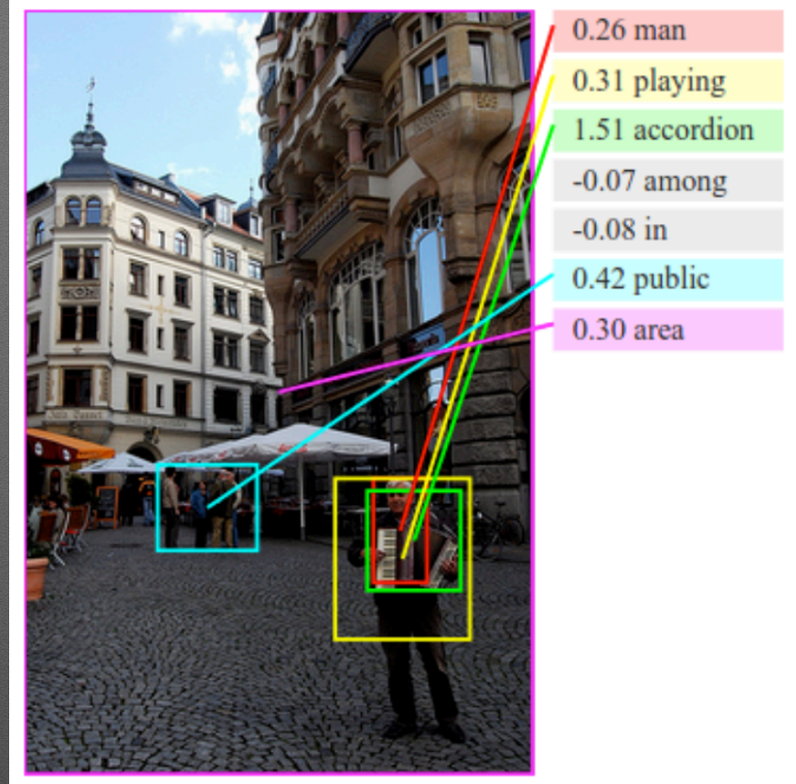


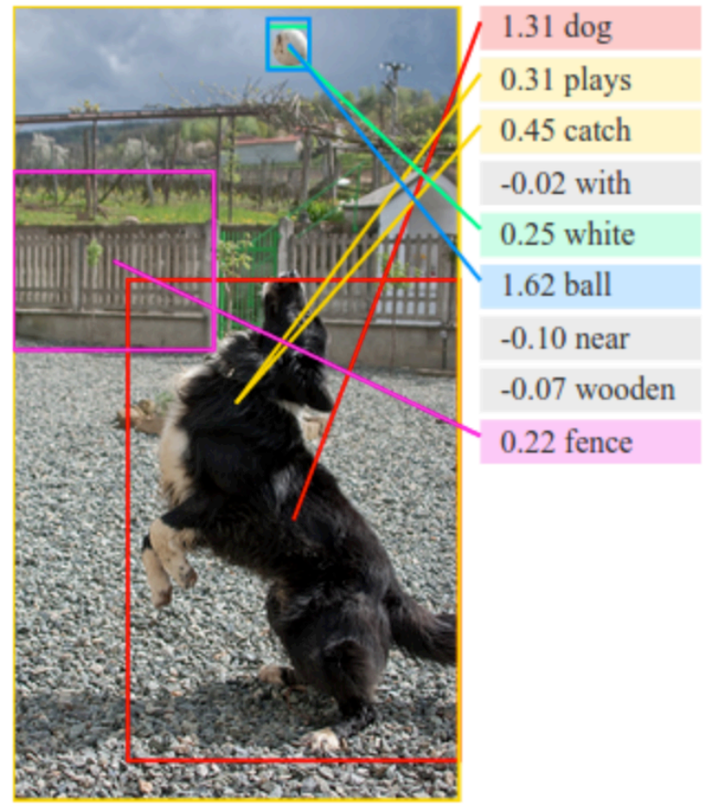
AlphaGo beats Lee Sedol



Human Level control in playing Atari games

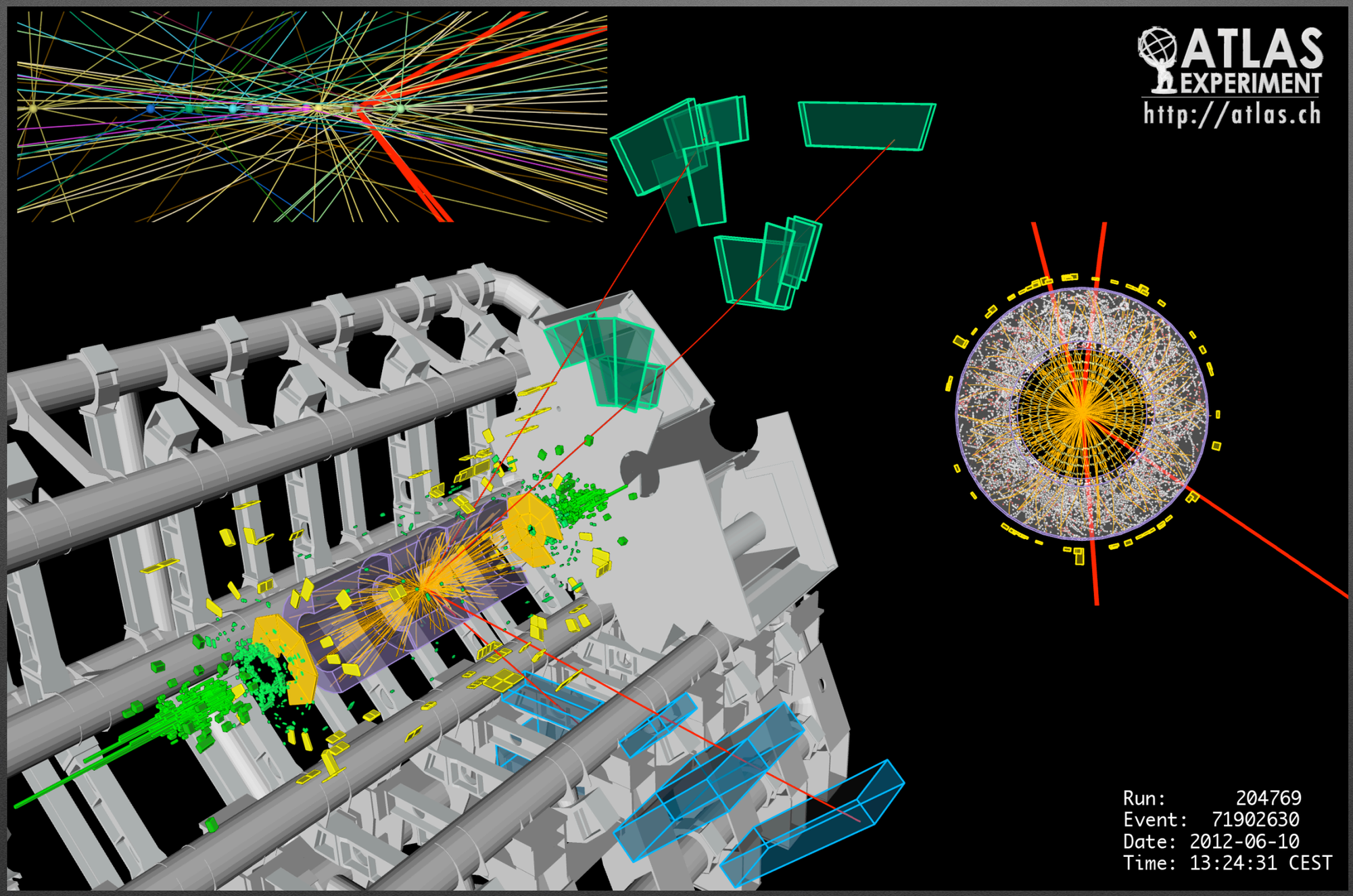






Deep Learning can be used to tell a story with context through data

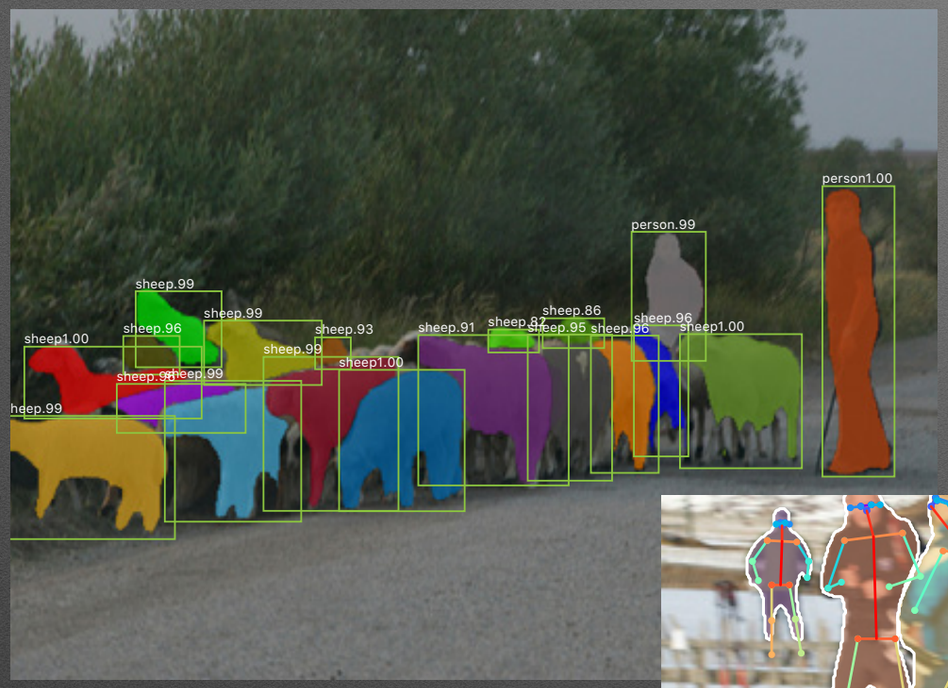
Used in HEP to understand what physics is happening

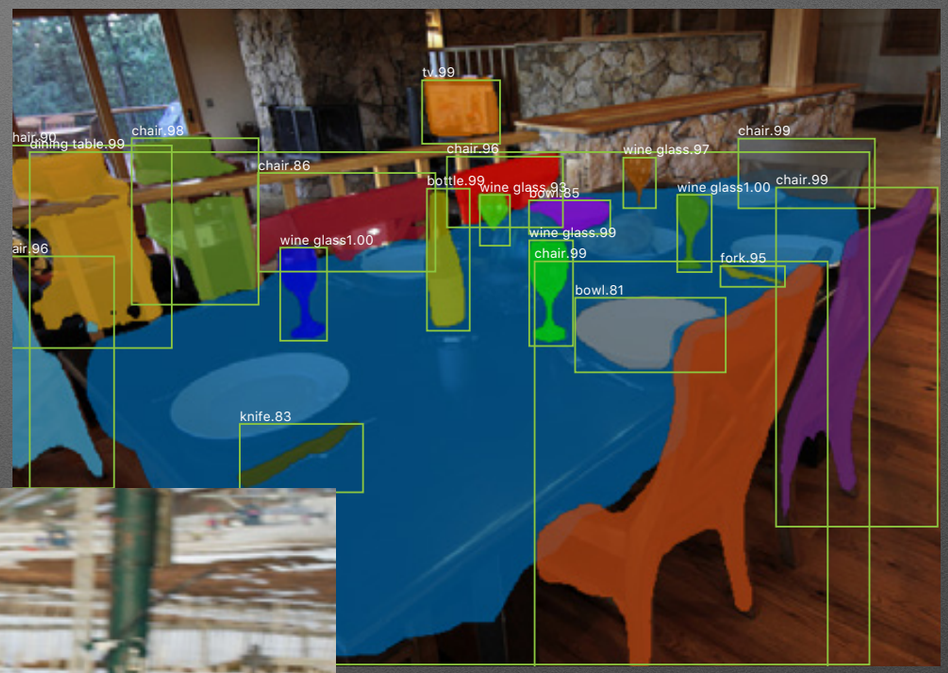


$H \rightarrow ZZ \rightarrow 4\ell$

We can use deep learning object tagging techniques in the data to find the decaying particle

Amazing Feats : Some More Examples





https://arxiv.org/pdf/1703.06870.pdf

Why go Deep?

Better Algorithms

- Better results
- Solution where there is none
- Make sense of complicated data

Easier Development

- Feature Learning, not Feature Engineering
- Save time and cost

Faster Algorithms

- DNNs Faster than traditional Algs
- Neuromorphic processors

Why Physicists ?

High Energy Physicists (HEP) ideally suited

- HEP Systems and Machine Learning and Deep Learning Systems confront similar challenges
- Decades of Experience at the Data Frontier
- Bridge between science and industry
- HEP scientists are also engineers by training

MOVE OVER, CODERS—PHYSICISTS WILL SOON RULE SILICON VALLEY

… it's happening across Silicon Valley. …, ***the things that just about every internet company needs to do are more and more suited to the skill set of a physicist***.

new wave of data science and AI is something that suits physicists right down to their socks.

"There is something very natural about a physicist going into machine learning … more natural than a computer scientist."

Physicists know how to handle data … building these enormously complex systems requires its own breed of abstract thought.