Optimization of Higgs Boson Measurements at a Future Particle Collider

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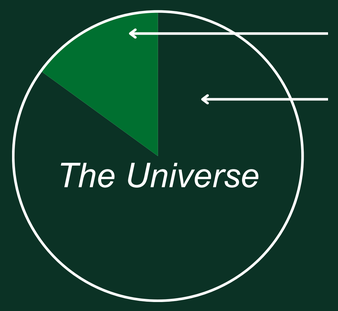
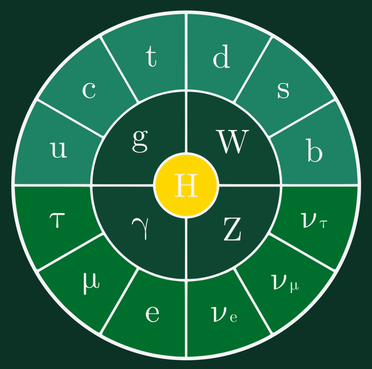
Dark Matter & the Higgs Boson



- Invisible
- Observed through gravity
- ~ 5-6x more abundant than RM
- Candidate to understand DM: **The Higgs Boson**

The Higgs Boson

- Discovered in 2012
  - ATLAS & CMS
- Gives fundamental particles their mass
- Higgs Boson → Dark Matter
  - New particles?



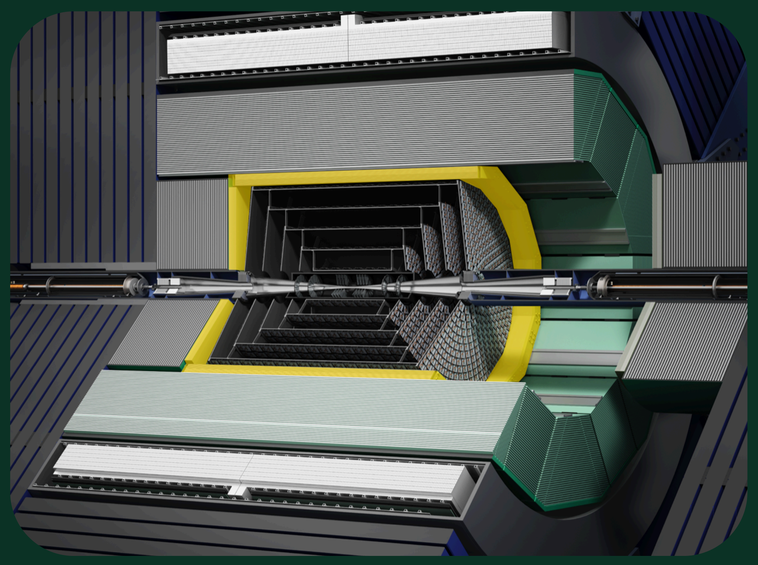
Higgs Factories & The International Linear Collider

A Higgs factory is a particle accelerator specially designed to produce relatively clean datasets of Higgs bosons with limited background.

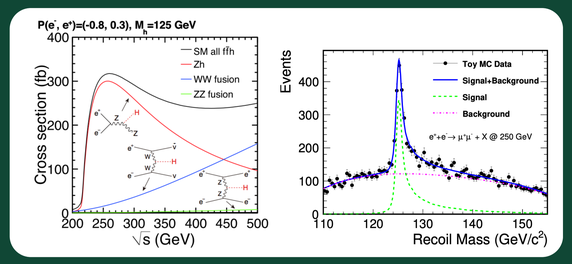
The **International Linear Collider** (ILC) is a frontrunner design for a Higgs factory

- 250 GeV e^- e^+ collider
- 31 km (19.26 mi) long

Our research focuses on optimizing the **Electromagnetic Calorimeter (ECal)** inside the Silicon Detector (SiD).



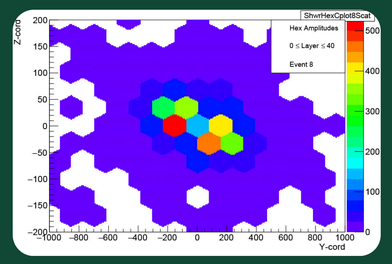
Higgs Detections Using the ILC



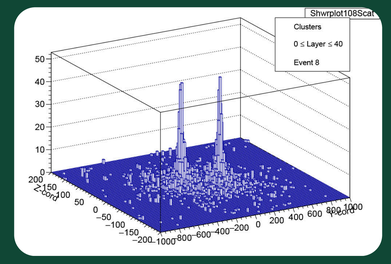
Left: Cross sections for the three major Higgs production processes as a function of center of mass energy.
Right: Recoil mass spectrum at 250 GeV. Signal $e^- e^+ \rightarrow Zh$. Background $Z \rightarrow \mu^- \mu^+$.

Given that the ILC collides leptons, the resulting events produce less signal events than the LHC at the Higgs recoil mass energy.

MAPS Upgrade



TDR Technology (Old Concept)



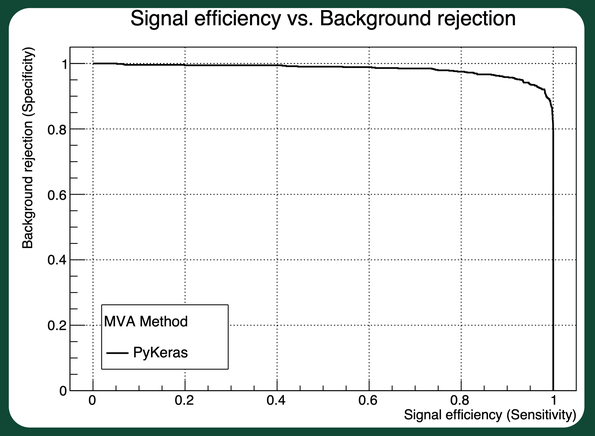
MAPS Technology (New Concept)

Proposed upgrade of the 13 mm² hexagonal pixel design to a novel 25 x 100 μm² design utilizing MAPS (Monolithic Active Pixel Sensors), improving event granularity as is seen in the plots.

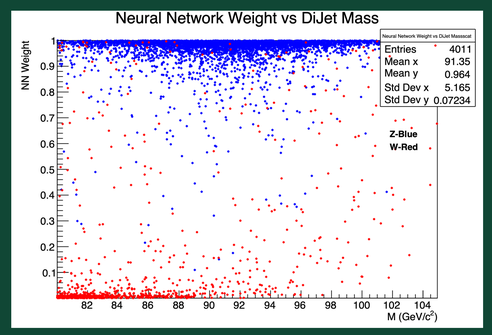
Signal Purification Using a Neural Network

The aim of this research is to use machine learning and neural networks in order to obtain the best signal (Higgstrahlung) to background (such as W-pair) event identification percentage, or resolution, from Monte Carlo simulations of the ILC.

A balance has to be achieved between how much background is cut from the data and how sensitive the detector is, as shown in the plot. To do so, we optimize the Higgs boson measurements as best as we can.



W & Z Boson ML Separation



Impact of DiJet mass on ML training. Scatterplot shows how the neural network evaluated the invariant mass values of the dijets for each event.

Results

By optimizing different parameters of our measurements using a variety of methods, in this case by training a neural network, we're able to slowly but surely improve the sensitivity of the ECal while rejecting as much of the background data as we can.

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