Big Data Challenges in Particle Physics

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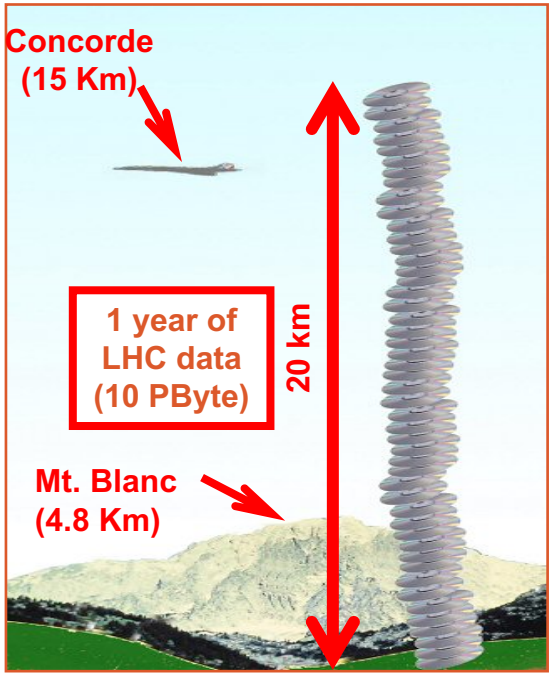
Dealing with large data sets...

- In every single research discipline there is more and more discussion about big data
  - Try googling ‘Big Data’ !!

- In High Energy Physics there is a long tradition of dealing with large data sets
  - Big HEP Experiments – e.g. LHC, Lep (CERN), Tevatron (Fermilab), etc.
  - Simulation of Monte Carlo events for future studies – e.g. Linear Collider, future neutrino programme, etc.
  - Grid computing – interconnected computers used to analyse large data sets

- During the years there has been a lot of development of advanced statistical techniques to deal with the analysis of large data sets



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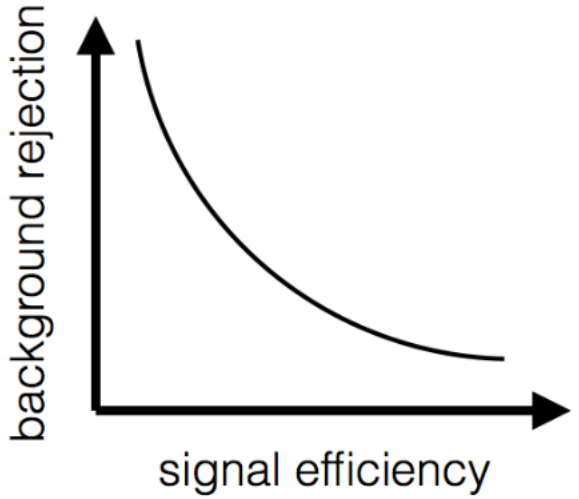
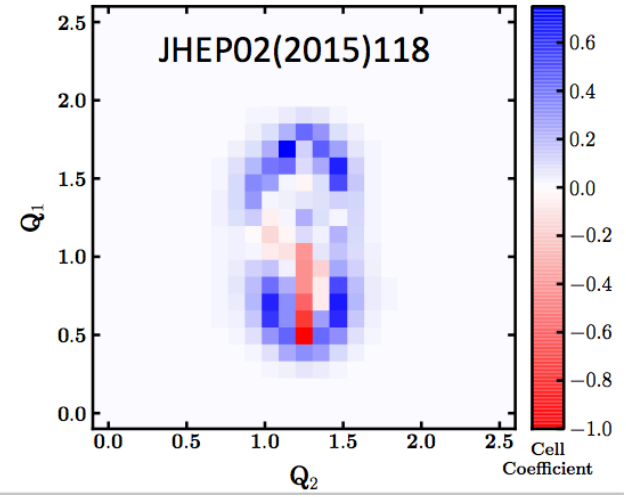
Using advanced analysis techniques

We use Machine Learning (ML) techniques in all aspects of our analyses

- Optimisation of our signal selection
- Teaching to the algorithms how to learn
  - using physics knowledge to improve performances
- Learning from what the algorithm has learned
  - extract information about whether or not the algorithm is learning
  - use this information to design new variables
    - Visualisation can be a key component





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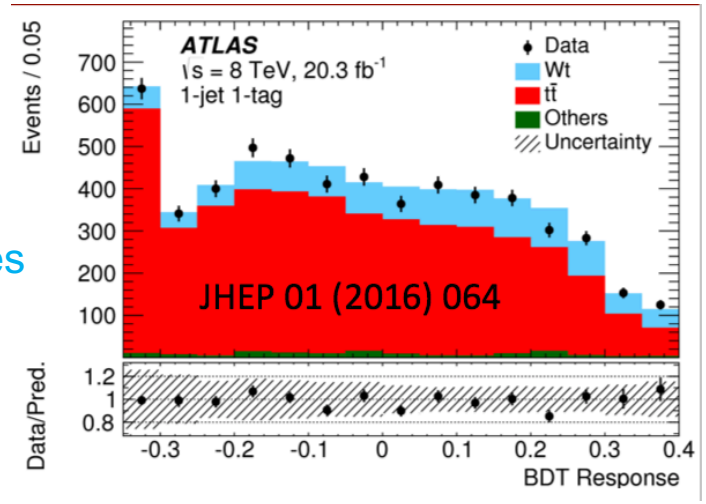
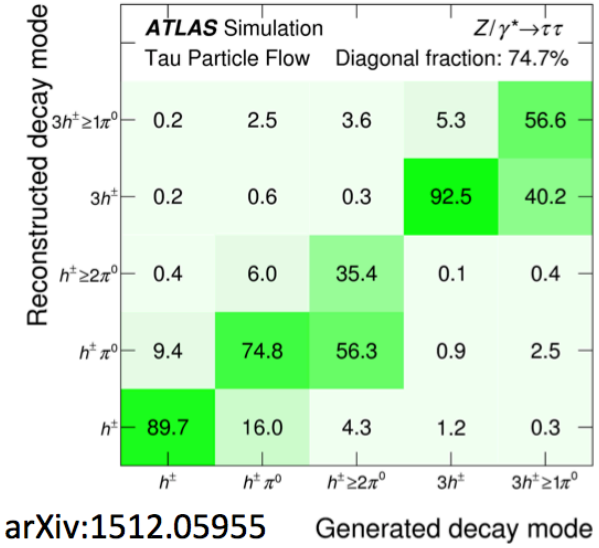
Many applications of ML in HEP

- Analysis –
  - separation of signals from backgrounds
  - reconstruction/identification of complex states
    - e.g. unstable particles, long decay chains
- Detector reconstruction –
  - Energy calibration
  - Particle identification
- Computing –
  - Estimate needed number of simulated data for meaningful statistical comparison with ‘real’ data





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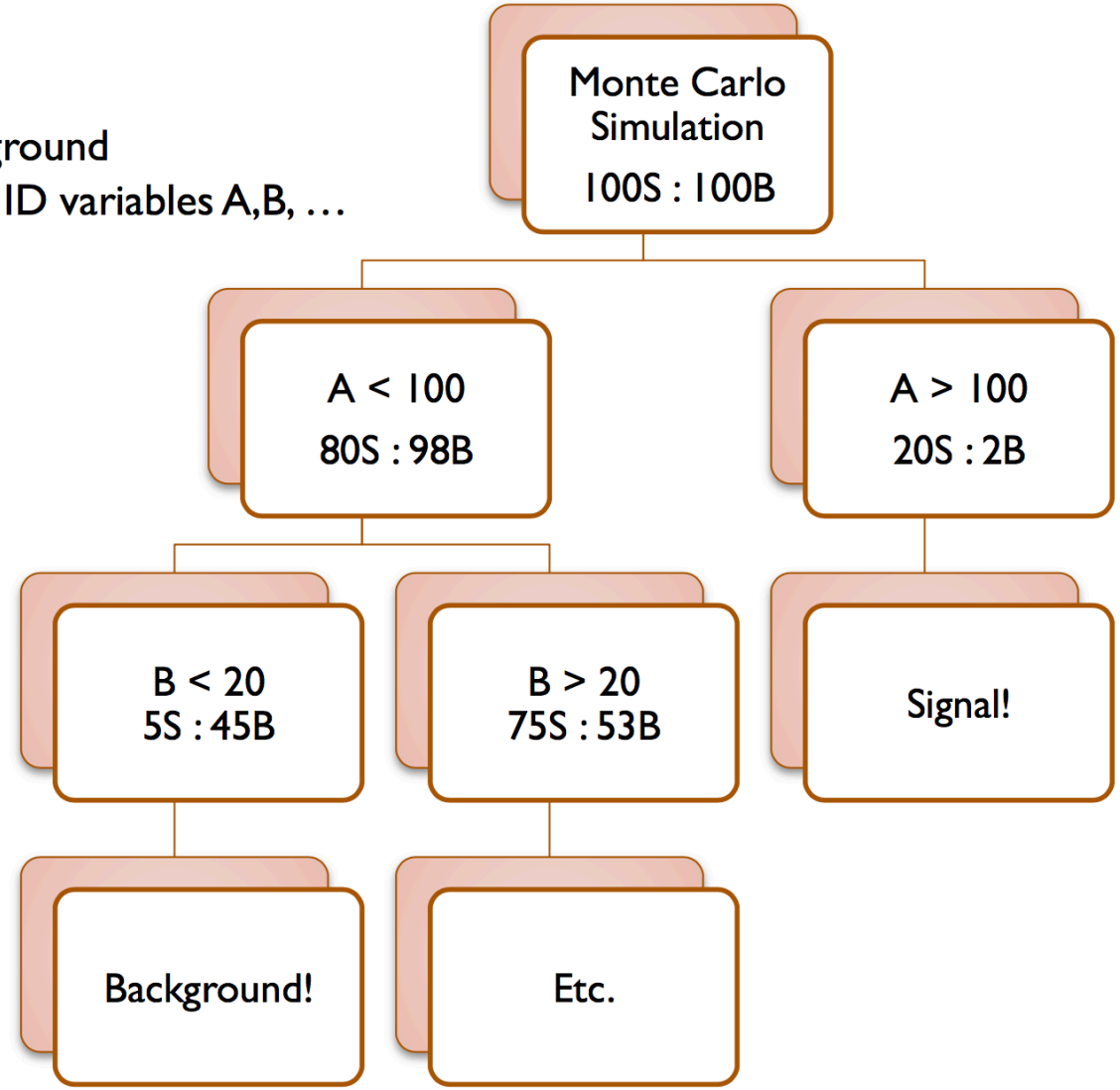
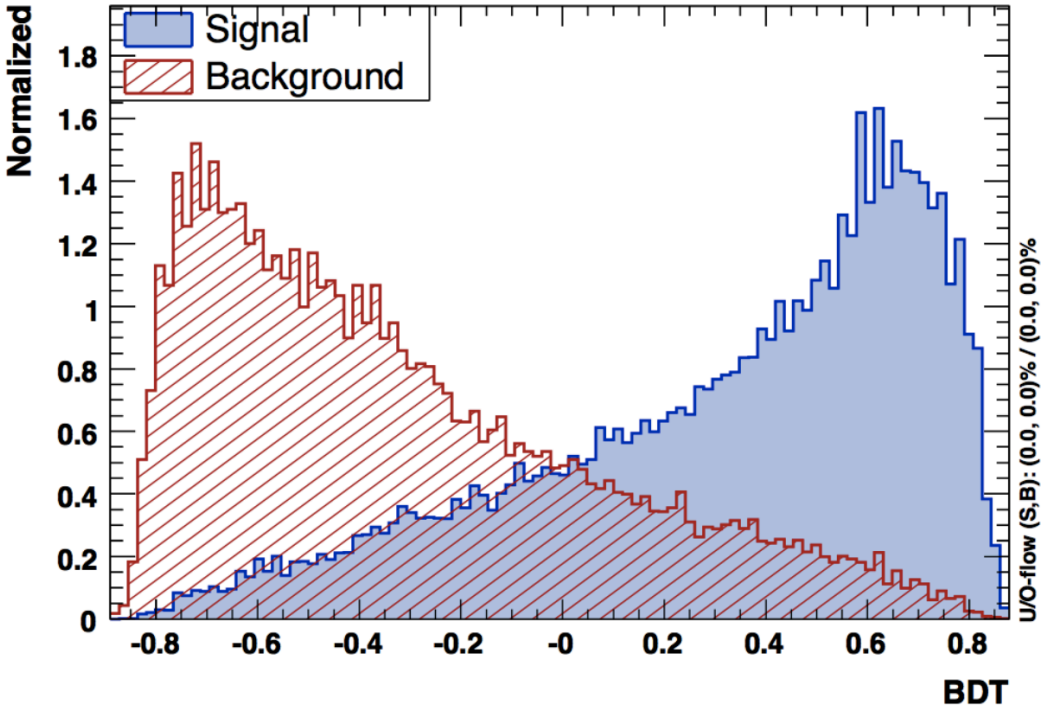
Boosted Decision Trees (BDT)

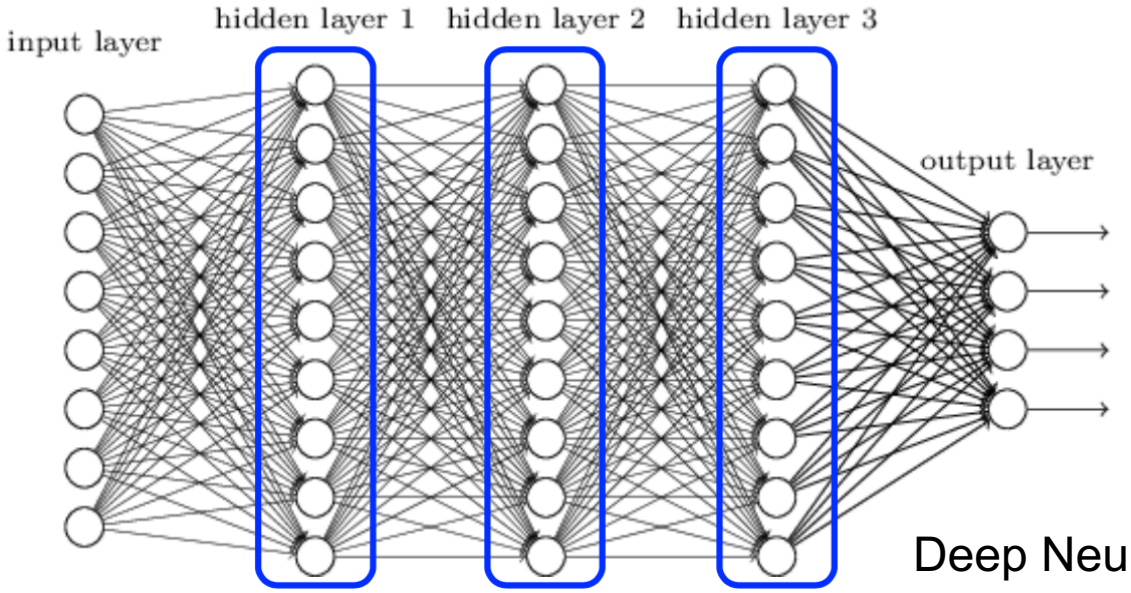
S: Signal
B: Background
Particle ID variables A,B, …



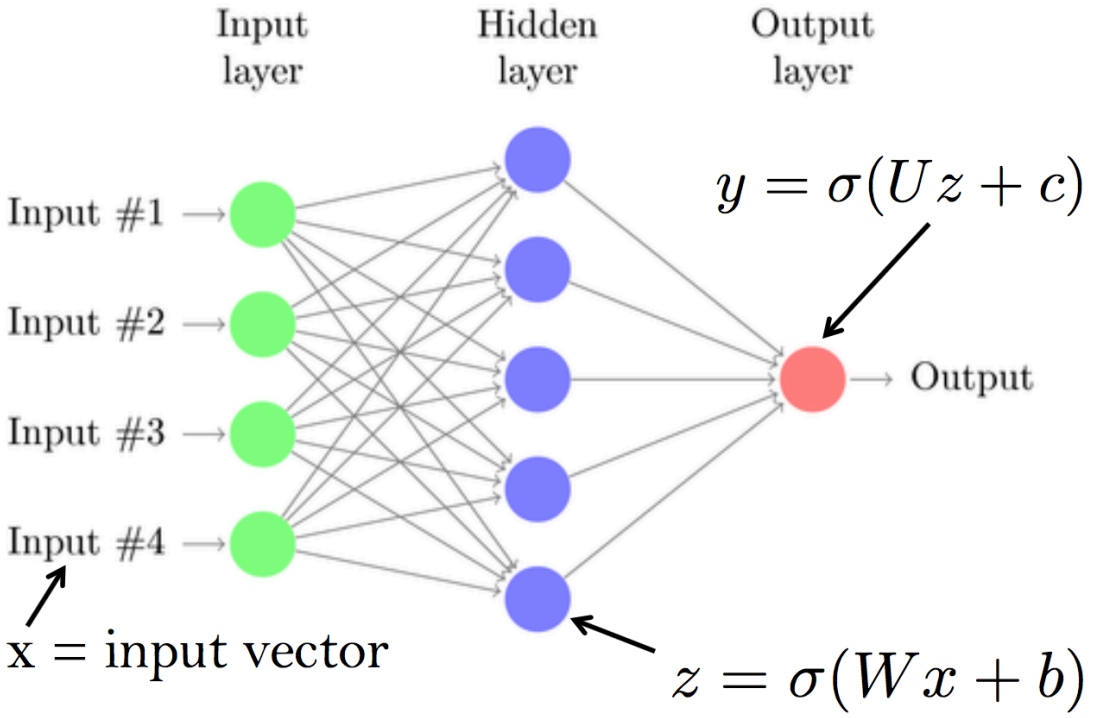


Neural Networks (NN)

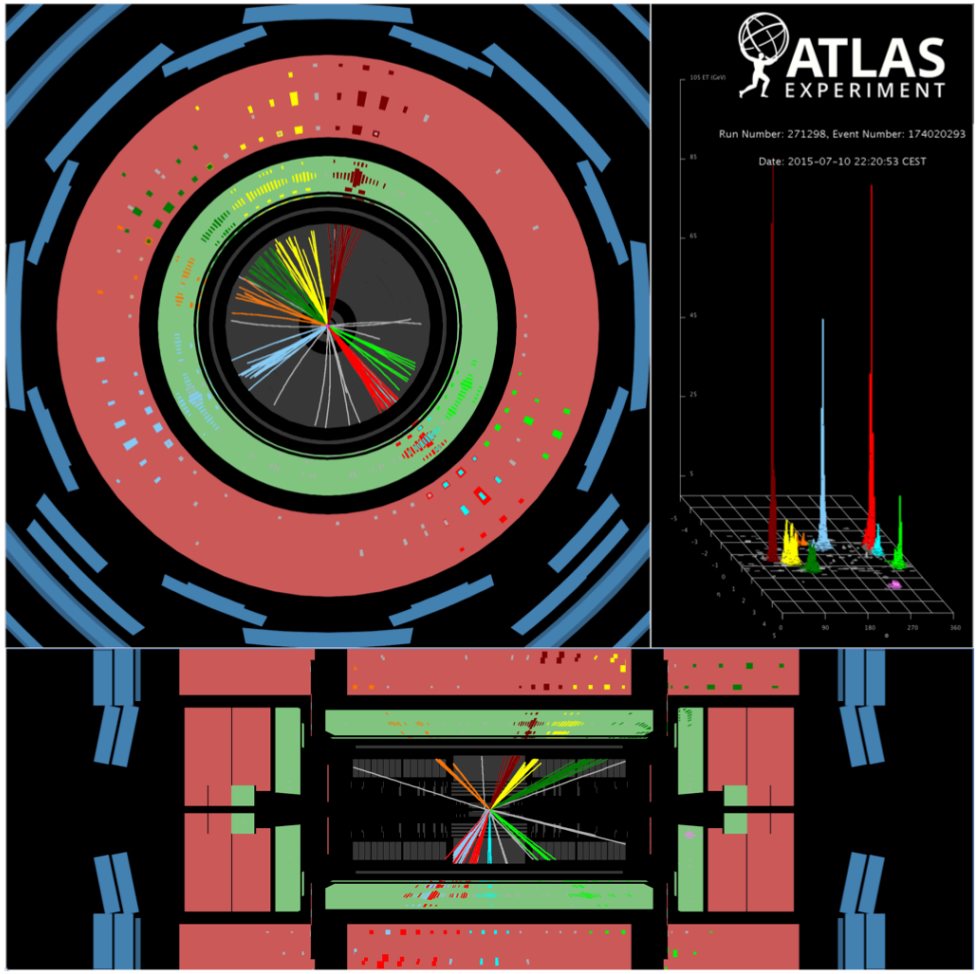
- Not a novel idea (I used them in my PhD thesis in 1998!)
- Care must be made to choose the correct variables to use
  - How many? Are they correlated?
- Important to know how many nodes in intermediate layer to avoid over-training

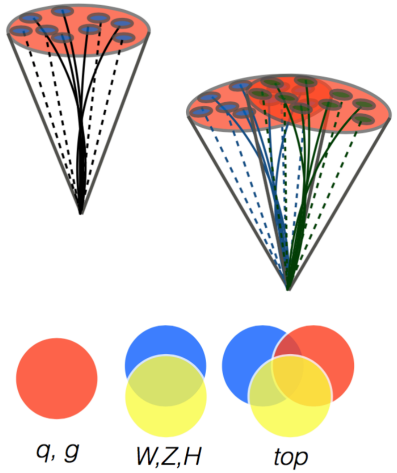


Deep Neural Networs (DNN)



Example: finding jet of particles at LHC





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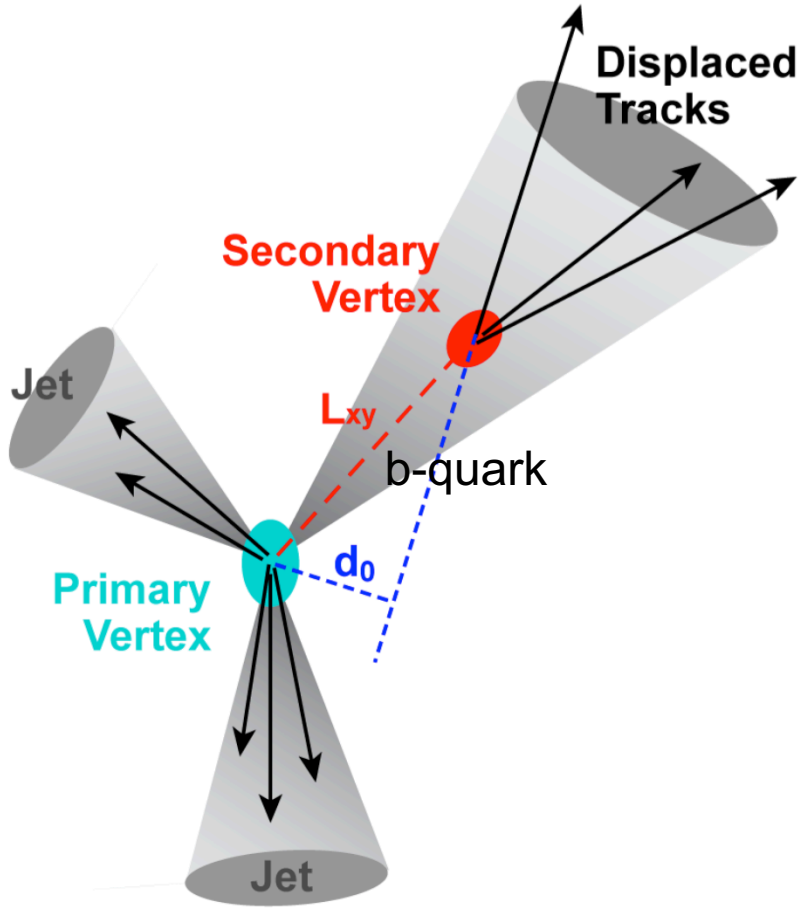
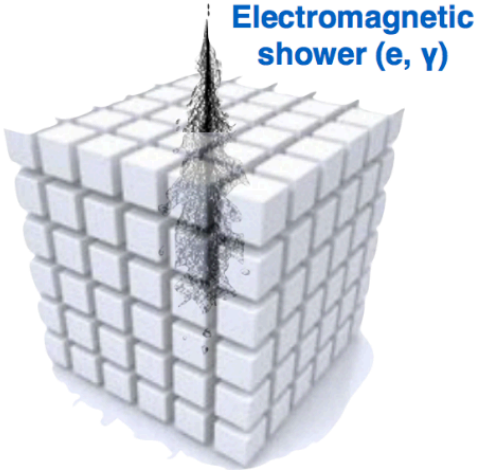
Identifying b-quark jets



Where can ML go next?

- A lot is being developed for using ML in HEP
  - use computer vision and imaging techniques to track particles very precisely within a detector volume



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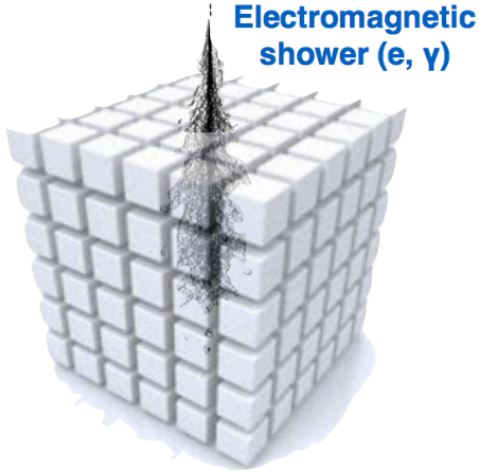
  - Anywhere were analysis of large datasets is required
    - health (malaria, HIV/AIDS, etc.)
    - environment (volcano watching, water quality, etc.)
    - electoral system data analysis
    - ……



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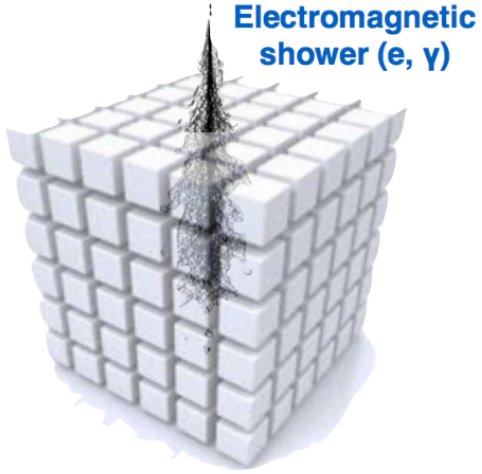

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- Application to industry
  - Image recognition (CCTV, Security screening, etc)
  - tests of combustion engines
  - Network security (see next slide)

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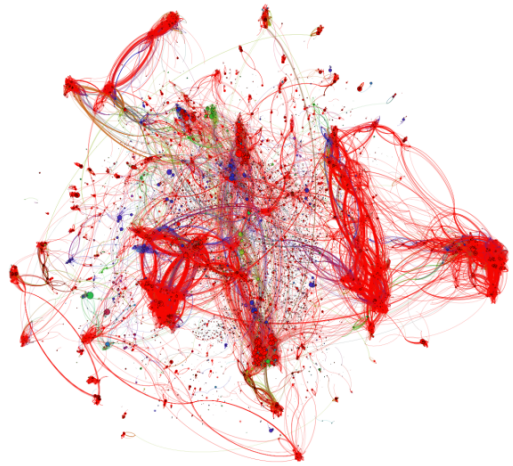
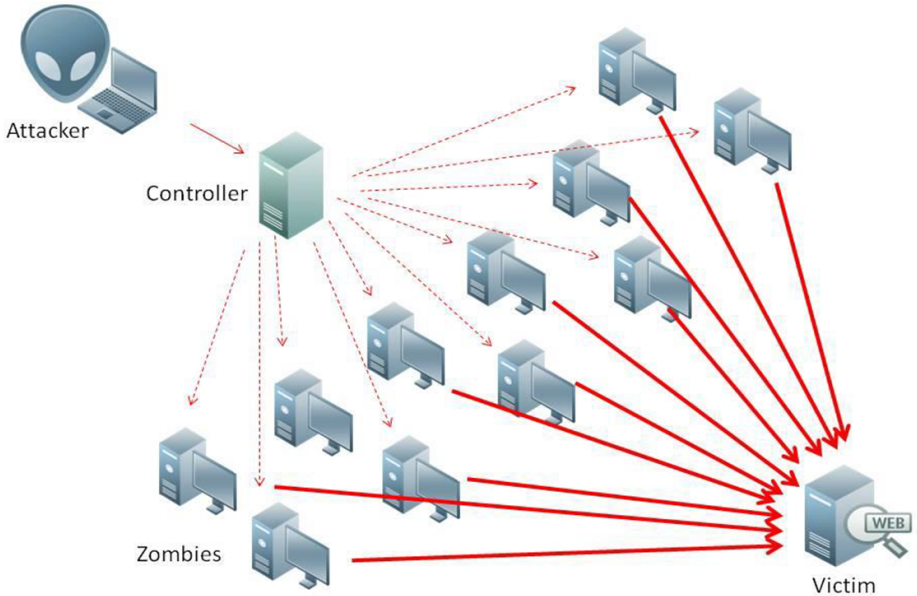
From the Higgs to Network security

- The ATLAS detector at the Large Hadron Collider collects data at enormous rates, then filters and saves it at 2 Gbps
- Sussex developed techniques and software (aka Trigger) to process data arriving at 200 Gbps
  - Innovative architecture, algorithms and machine learning techniques





- Similar data-rates are experienced in the largest cybersecurity DDOS attacks
  - Botnets are used to attack and flood computer systems
- With industry partners we are translating our expertise and IP to this pressing problem for society
  - Just obtained funding from STFC to pursue this line of research with our industrial partners

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Conclusion

- There is vast expertise in the PP group in handling and analysing large data set
- We use cutting edge statistical techniques that could find application in many other areas of reseach
  - Machine learning, Neural Networks, Grid, ….
- We are already looking to apply these techniques to pressing everyday problems in society
  - Network security
- We are confident that there are opportunities to start collaborating with other research group in the University
  - Hope to find some common ground at this meeting

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