Lepton Jets at CMS

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Outline

- Background to Theory

- Theoretical Model

- Previous Searches

- Our Model

- Simulation Benchmarks

- General Analysis Strategy

- Selecting Electron Jets

- Summary

Theoretical Background

- The positron fraction of cosmic rays rises between 20-200 GeV, without any antiproton fraction excesses
  - Not from secondary production processes resulting from cosmic ray nuclei interacting with the interstellar gas
  - As seen by many experiments including PAMELA satellite
    - arXiv:0810.4995
  - The FERMI LAT space telescope satellite
    - arXiv:1109.0521

- Also excess in the electron+positron spectrum
  - Seen by various experiments including MAGIC, an Imaging Atmospheric Cherenkov Telescope
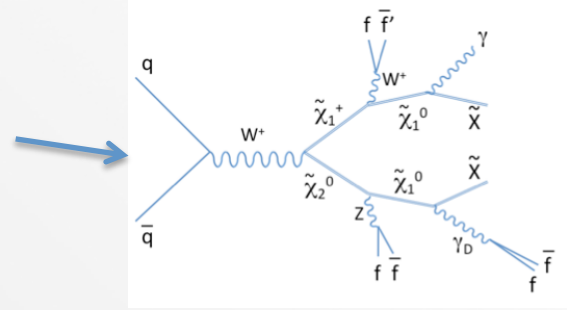   - arXiv:1110.4008
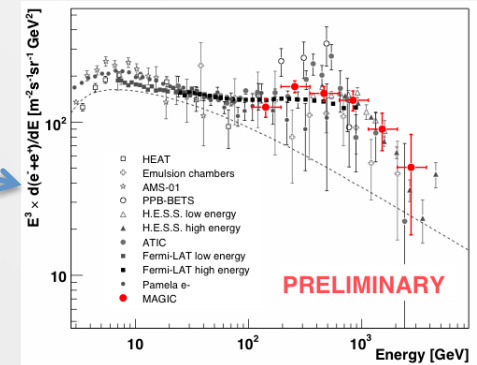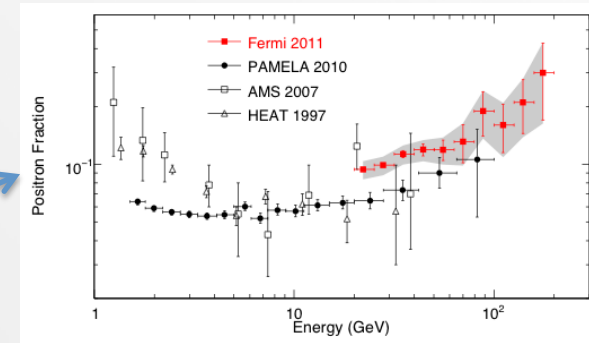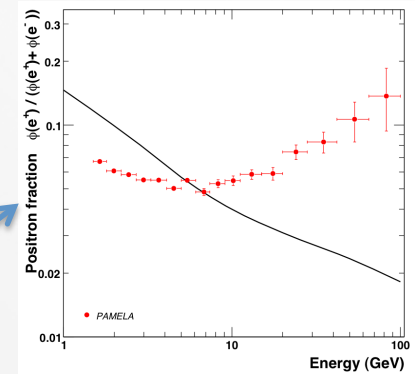
Theoretical Model

- Hidden Valley models can give a unified explanation of these anomalies
  - If the dark sector is light at GeV scale
- Introduce a light hidden/dark gauge sector which couples weakly to the SM
  - Dark Matter annihilates into the dark sector
  - Dark photon, through mixing with the SM photon, goes to leptons or hadrons depending on the its mass
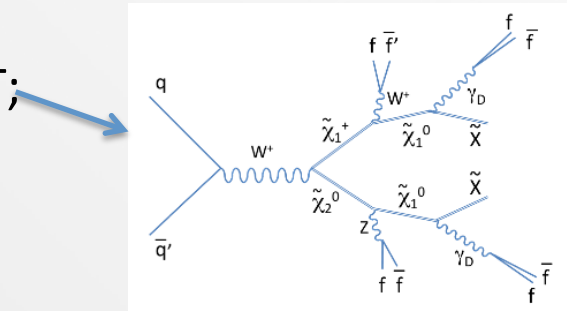 - Cascade decays in the dark sector can produce impressive signatures
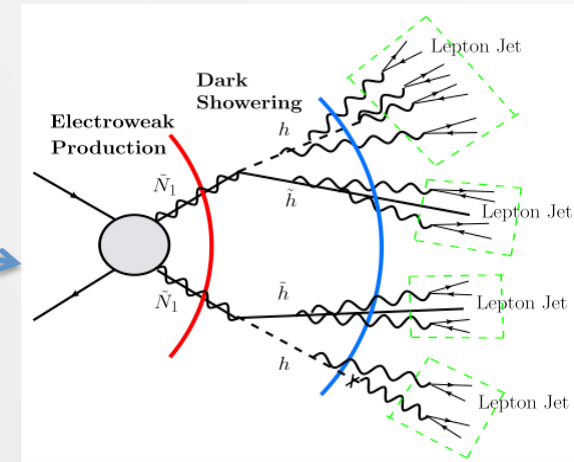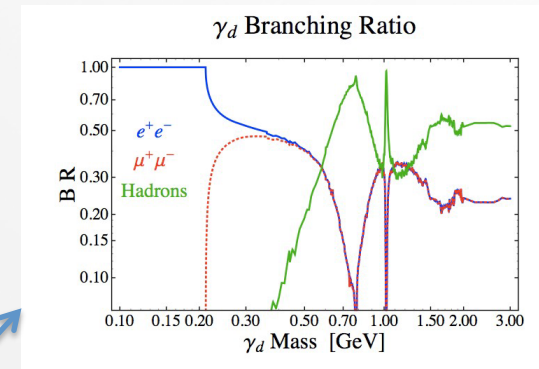
Previous Searches

- ## D0
  - arXiv:0905.1478: 4.1/fb; Photon+2 leptons +MET; no evidence found -> set limits
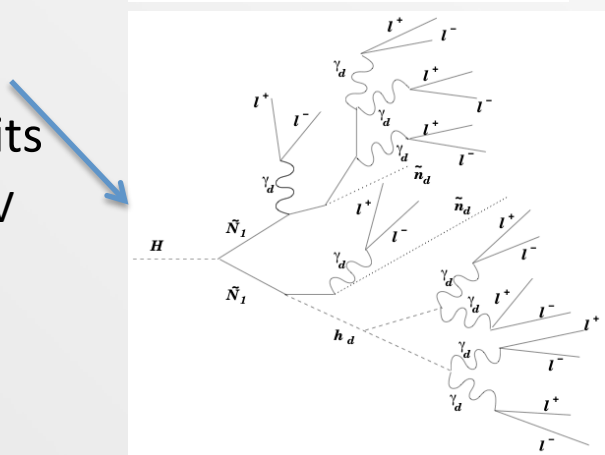   - Evade: Models without photons/high multiplicity
  - arXiv:1008.3356: 5.8/fb; 2x(2 leptons)+MET; no evidence found -> set limits
    - Evade: fat lepton jets/high multiplicity
- ## CDF
  - arXiv:1202.1260: 5.1/fb; V+ counting many low E leptons; no evidence found -> set limits
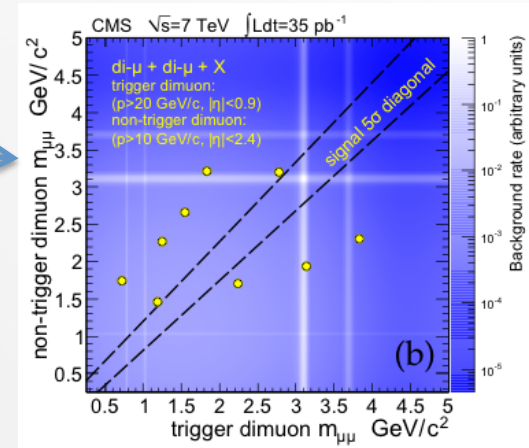   - Evade: Low lepton multiplicity/No leptonic V
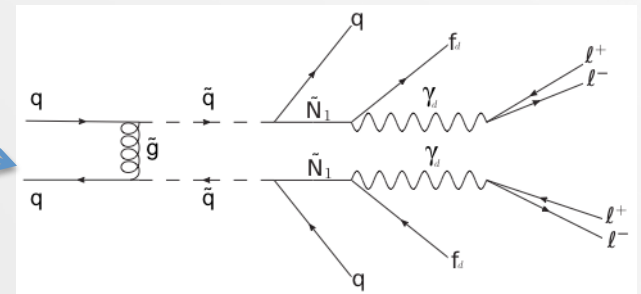
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Previous Searches

- ## CMS
  - arXiv:1106.2375: 35/pb; Find the γ_d resonance from pairs of muons; no evidence found -> set limits
   - Evade: If m(γ_d) is lower than m($\mu\mu$)/ dominated 3 body decays

- ## ATLAS
  - CONF-2011-076: 40/pb; 2x(2 muons); no evidence found -> set limits
   - Evade: If m(γ_d) is lower than m($\mu\mu$)/fat jets/ high multiplicity

Josh Ruderman

Our Model

- It is possible for the Higgs to decay, either directly or through SUSY, into a light hidden sector
  - arXiv:1002.2952
- A $m(\gamma_d)$ of 100 MeV decays exclusively to electrons
- Prompt decay of γ_d
  - i.e. not long lived decays
- 3 dark sector particles, shorter decays gives more MET
- V+Higgs->2 Electron Jets
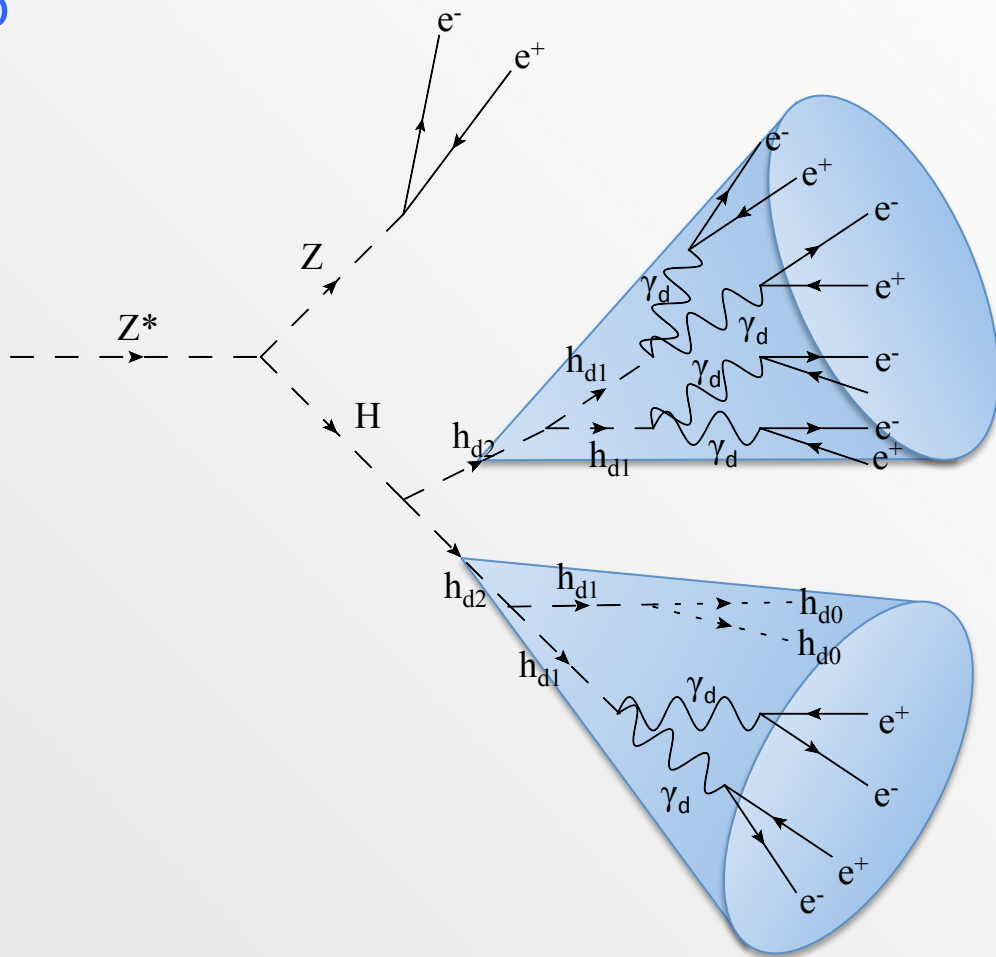
Simulation Benchmarks

- By varying the masses of the particles in the hidden sector we can dramatically alter the characteristics of the Electron Jets

  - We are initially focussing on a 3 step decay (ie 3 dark sector masses)

- Used a Higgs particle gun simulation and adjusted the 3 masses

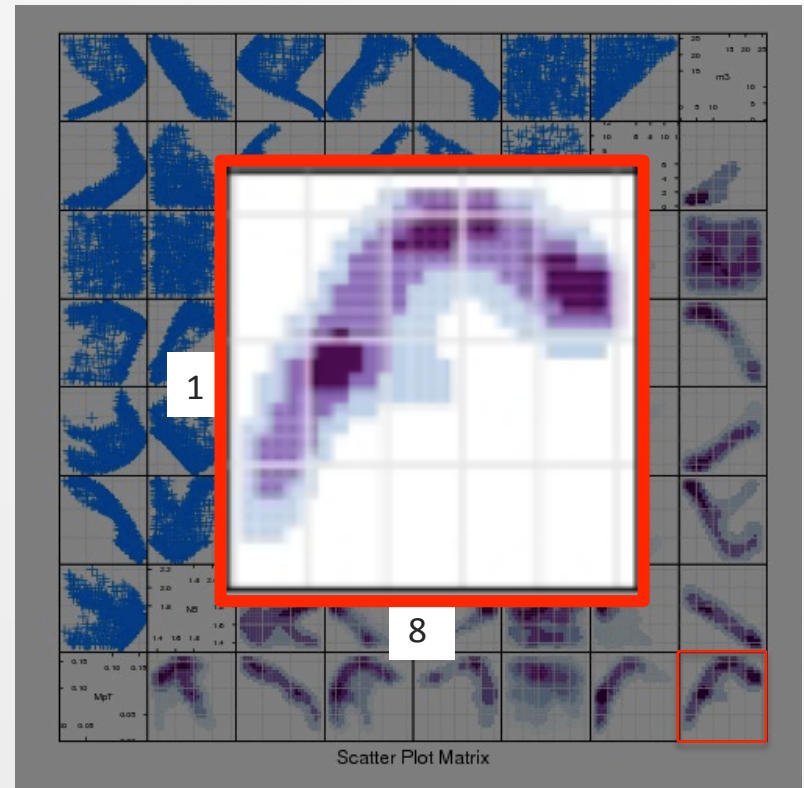 - Can try to cover as much phenomenological phase space as possible
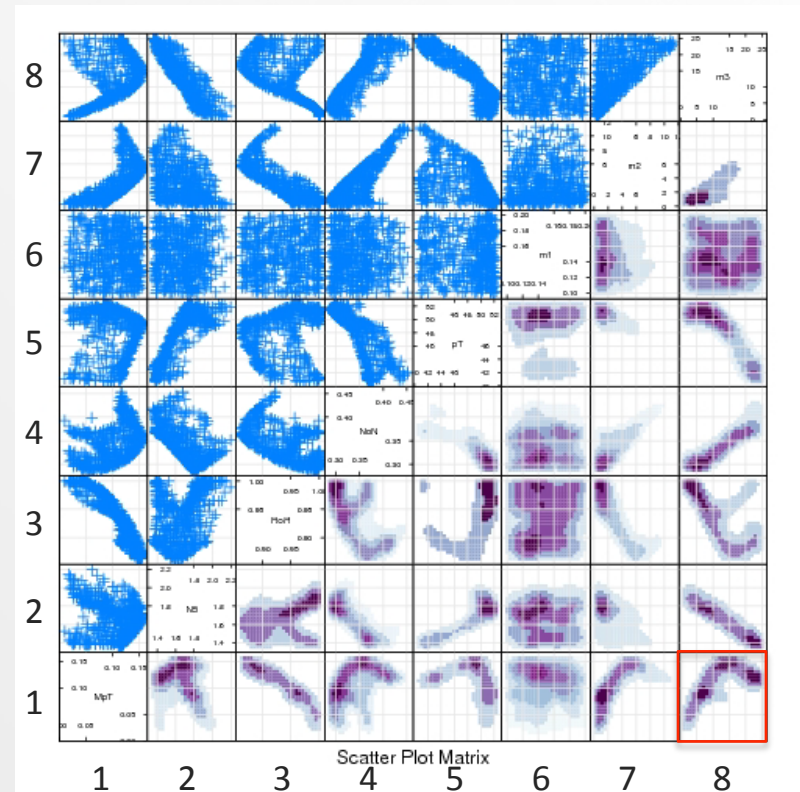
1) Jet mass/pt
2) Number of tracks with half of the jet energy
3) Energy in dR<0.25/energy in dR<0.5
4) Number of tracks with half of the jet energy/total number of jets
5) missing pt
6,7,8) 3 dark sector masses

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Scatter Plot Matrix

1) Jet mass/pt
2) Number of tracks with half of the jet energy
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Analysis Strategy

- Trigger off of the associated W/Z
  - +di-jets, +MET as thresholds change
  - Backup trigger of double electron with loose isolation
- Reconstruct the associated W/Z
- Run Electron Jet Identification over Particle Flow Jets
- Then count the number of events in a sliding m_{jj} window
- General strategy is to identify the Lepton Jets through the properties of the jets
 - Despite this, attempted a γ_d resonance search in the same manner as the muon analysis
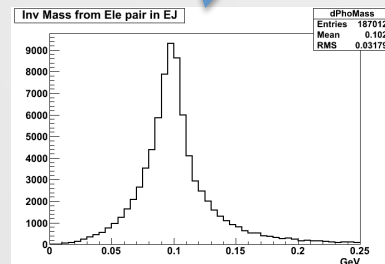
Electron Jet Identification

- Started with a general scheme of cutting on EMF and Jet ET/PT
  - As was used in arXiv:1007.3496
  - Found poor efficiency for signal and single electron backgrounds

- Then used Boosted Decision Trees in order to perform a discrimination of multiple classes
  - Boosted signal efficiency and decreased our background
  - But concerned over model dependence

- Multivariate Visualisation techniques independently confirmed the interesting variables found by BDT
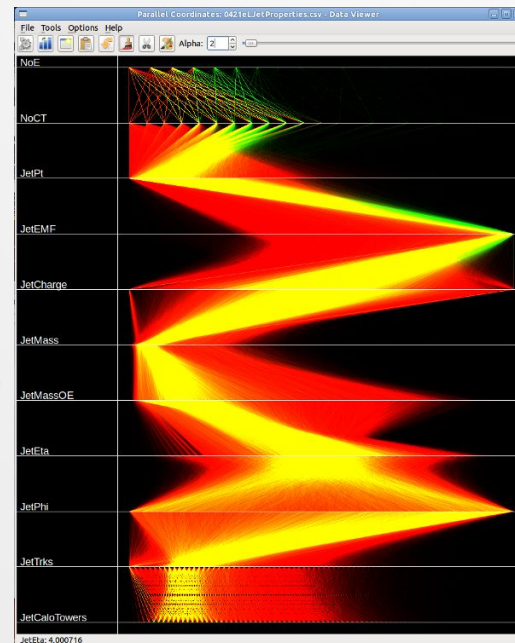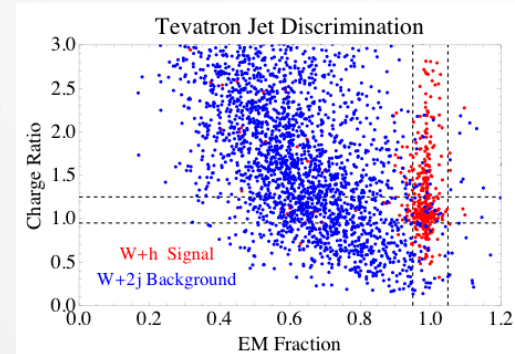
Electron Jet Identification

- Took lessons from BDT and developed a new scheme which was both efficient and model independent

  - Based on number of electrons & number of tracks found inside the Electron Jet, the EMF of the jet, and the number of tracks/pT

  - For the case where only one electron is successfully reconstructed apply an electron shape cut which is p_T dependant

  - Good efficiency for our 4 benchmark signal models

  - Also separates our signal from qcd and single electron backgrounds
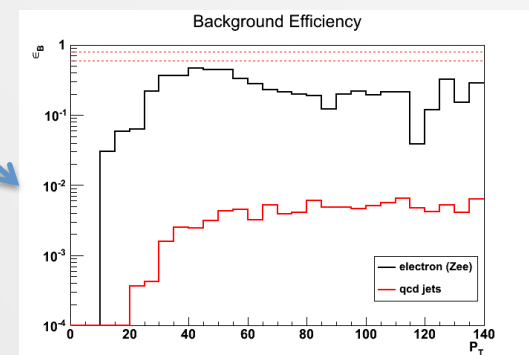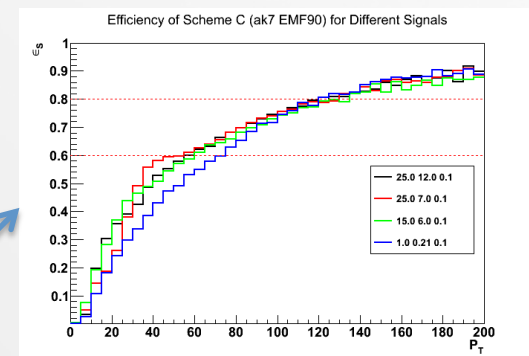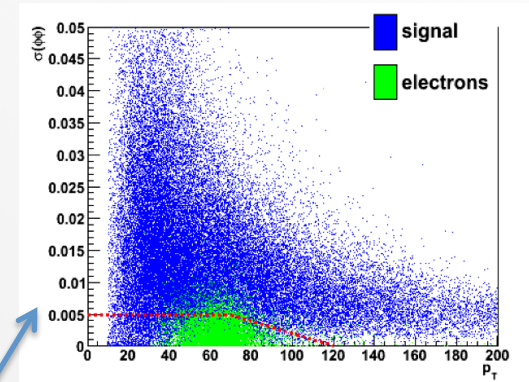
Electron Jet Identification

- Also from looking at the visualisation output, attempted a selection scheme based on the previous scheme
    - But in the case of reconstructing only one electron; use the relative isolation of that electron (expecting there to be more noise from the other electrons compared to background)
    - Not dependant on pT
    - Unfortunately this turns out to be model dependant as well
   - Perhaps by using different reconstruction techniques this selection might still work
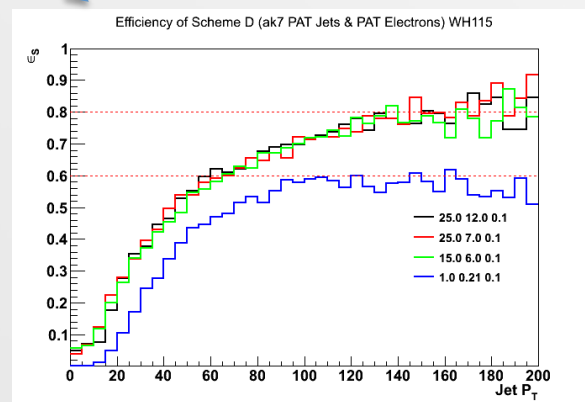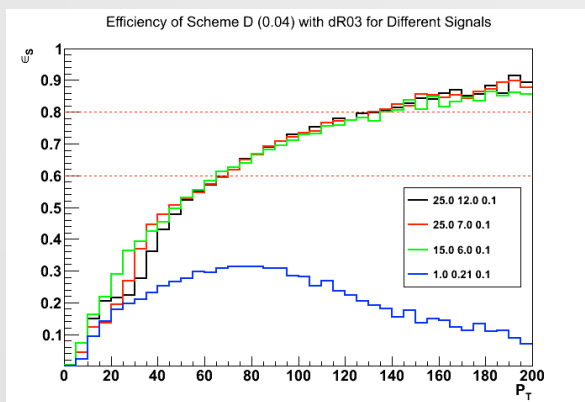
Summary

- Lepton Jets can be used to explain astrophysical results
- Currently concentrating on the case where the dark photon decays exclusively to electrons, producing Electron Jets
- We have created benchmarks for our Monte Carlo and now produced simulations
- Developed a selection criteria for Electron Jets
- We plan to have 2011 results within the next couple of months
- Can extended the analysis by including 5 step models, and also by changing the dark photon mass (e.g. looking at hadronic mode)
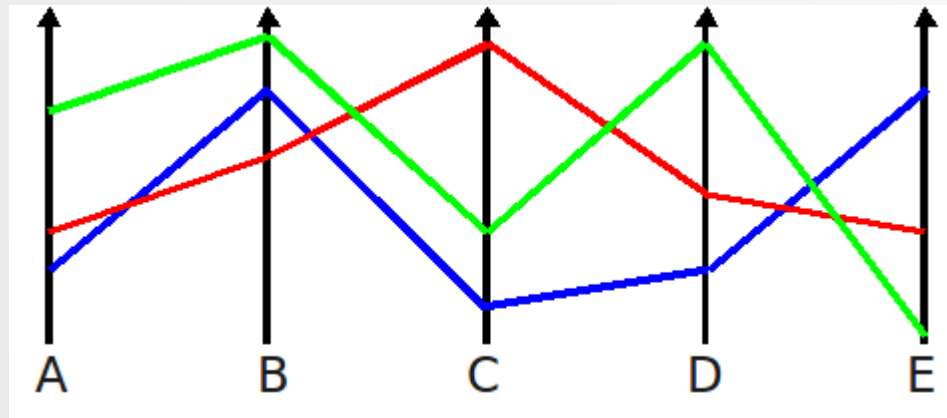
Bonus Level

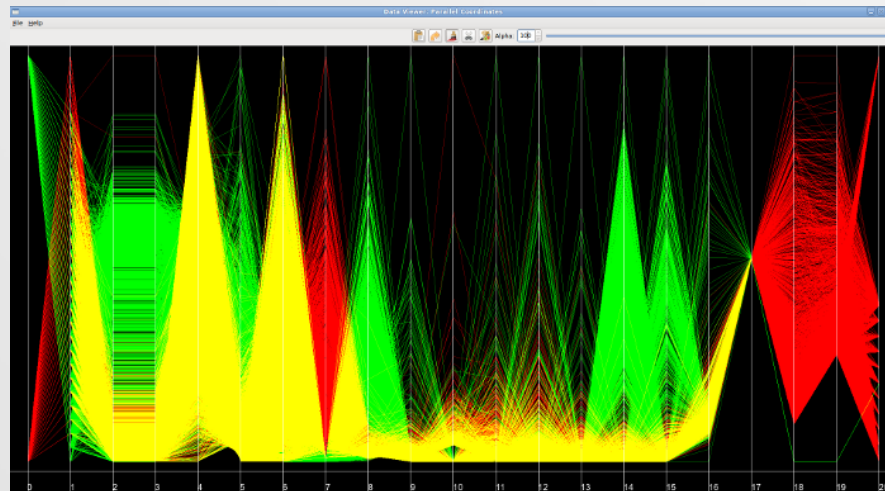- Multivariate Visualisation: Parallel Coordinates
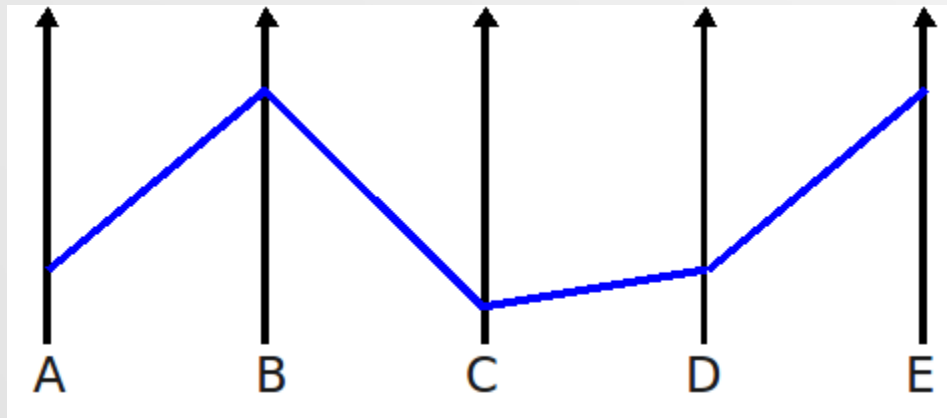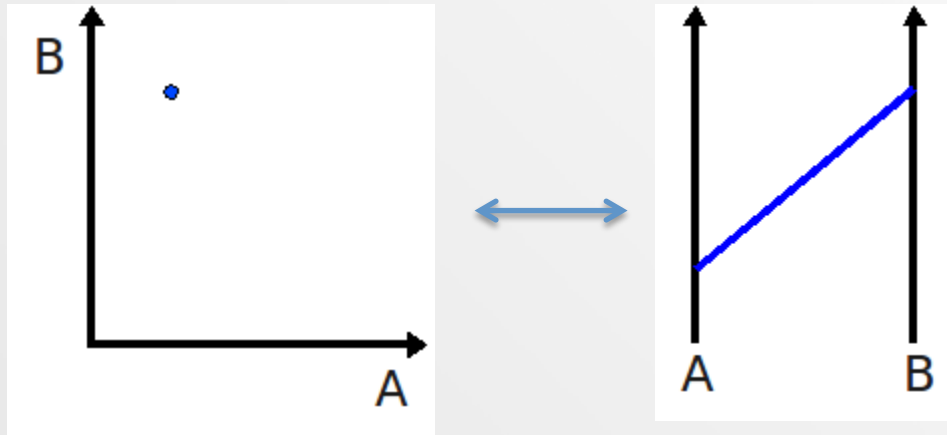
1 Instance in 5D

Bonus Level

- Multivariate Visualisation: Parallel Coordinates

5 Instances in 5D

20k Instances in 5D

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