# Absolute Array Calibration using Cosmic ray Electrons

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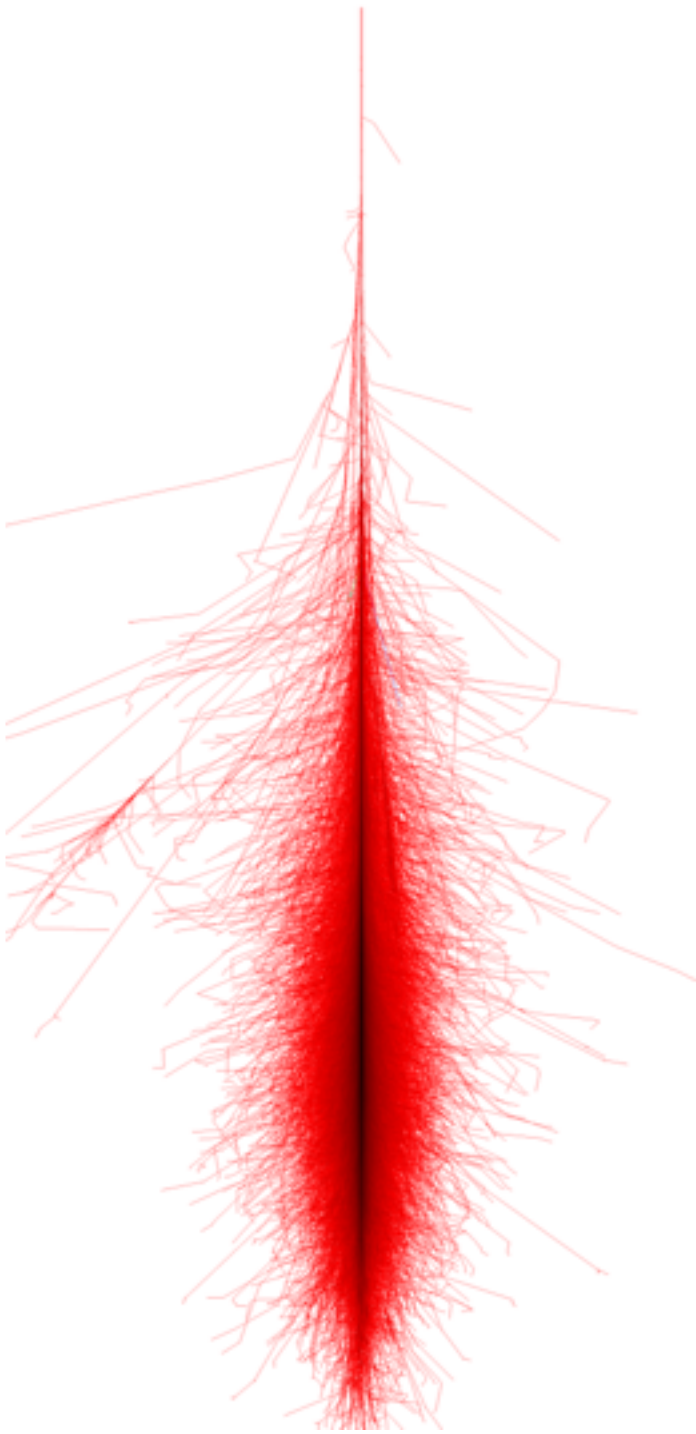
cta cherenkov telescope array

# Introduction



All techniques mentioned so far have sought to calibrate the light efficiency of the CTA telescopes

However in order to construct a spectrum the measured intensity must be used to estimate the energy of the event

In order to perform this reconstruction comparisons must be made to simulations

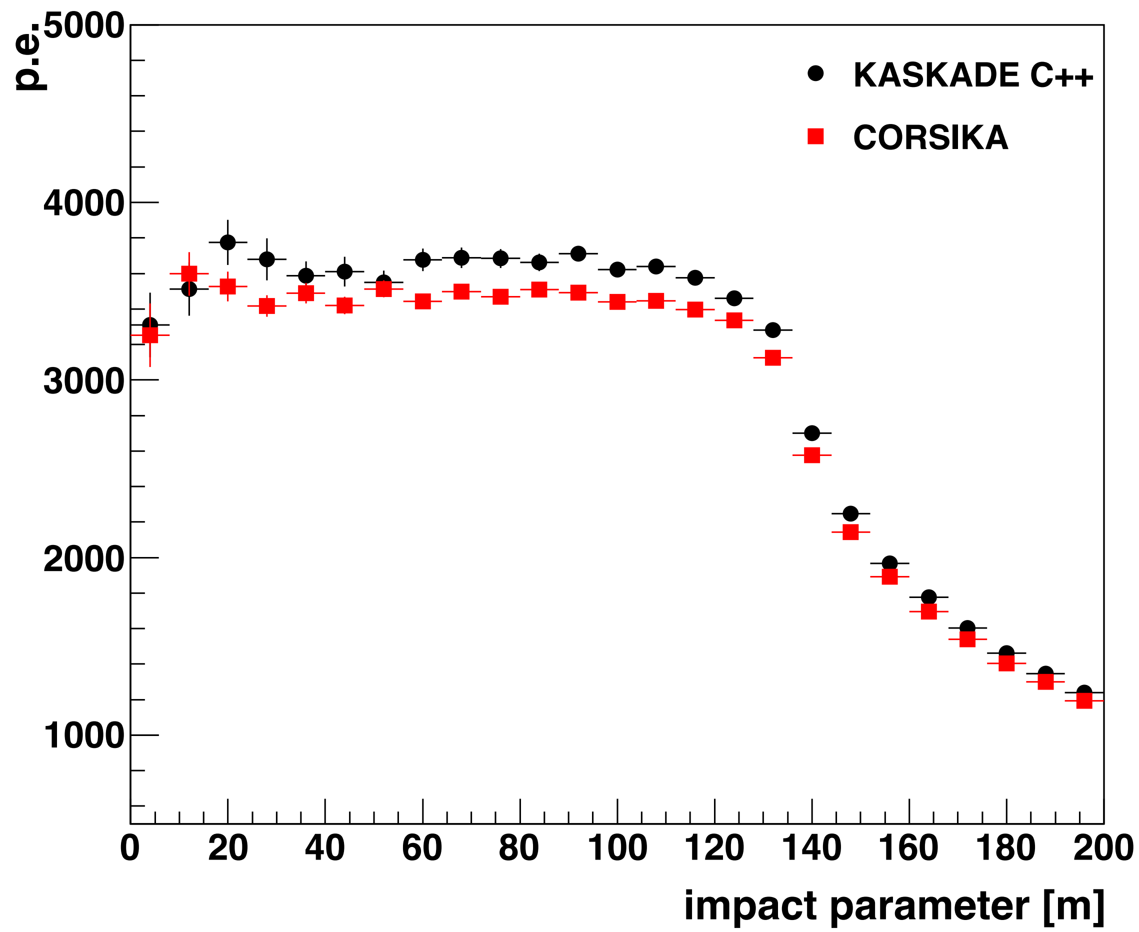
Monte Carlo air shower simulation

Telescope and Electronics simulation

In both these steps systematic differences from observations can creep in

Can manifest in shift in both the reconstructed energy and effective collection area

# Source of Systematics

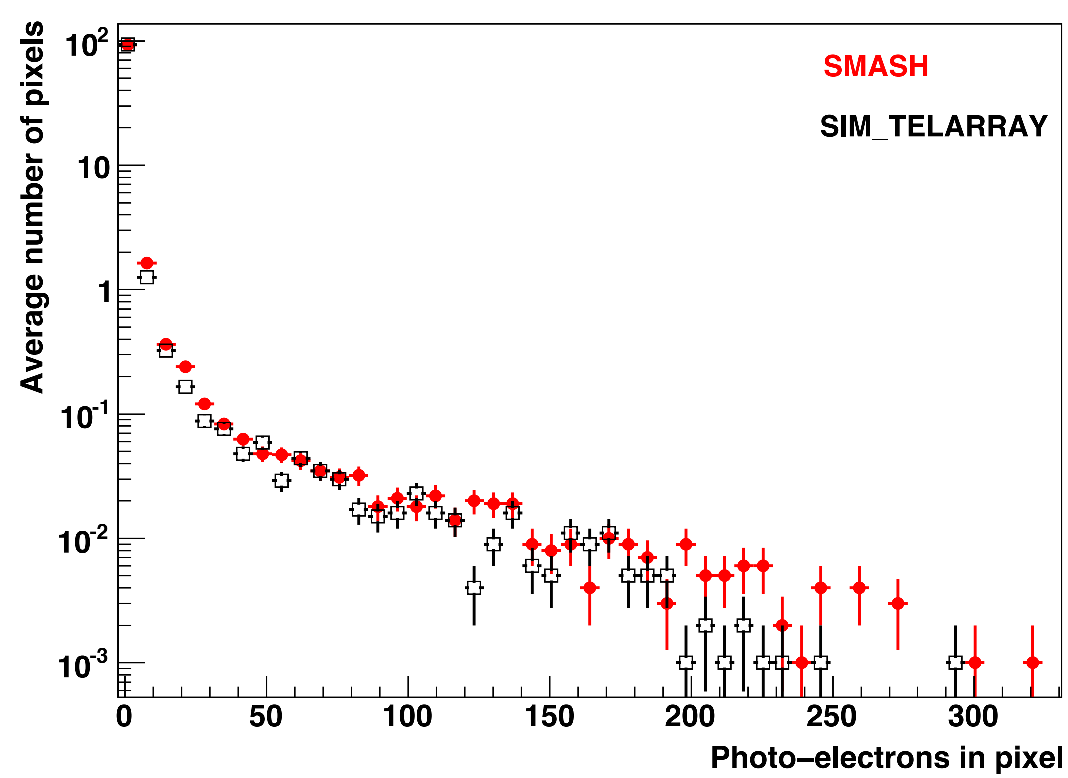



Systematic uncertainties are present at several levels in the simulation chains

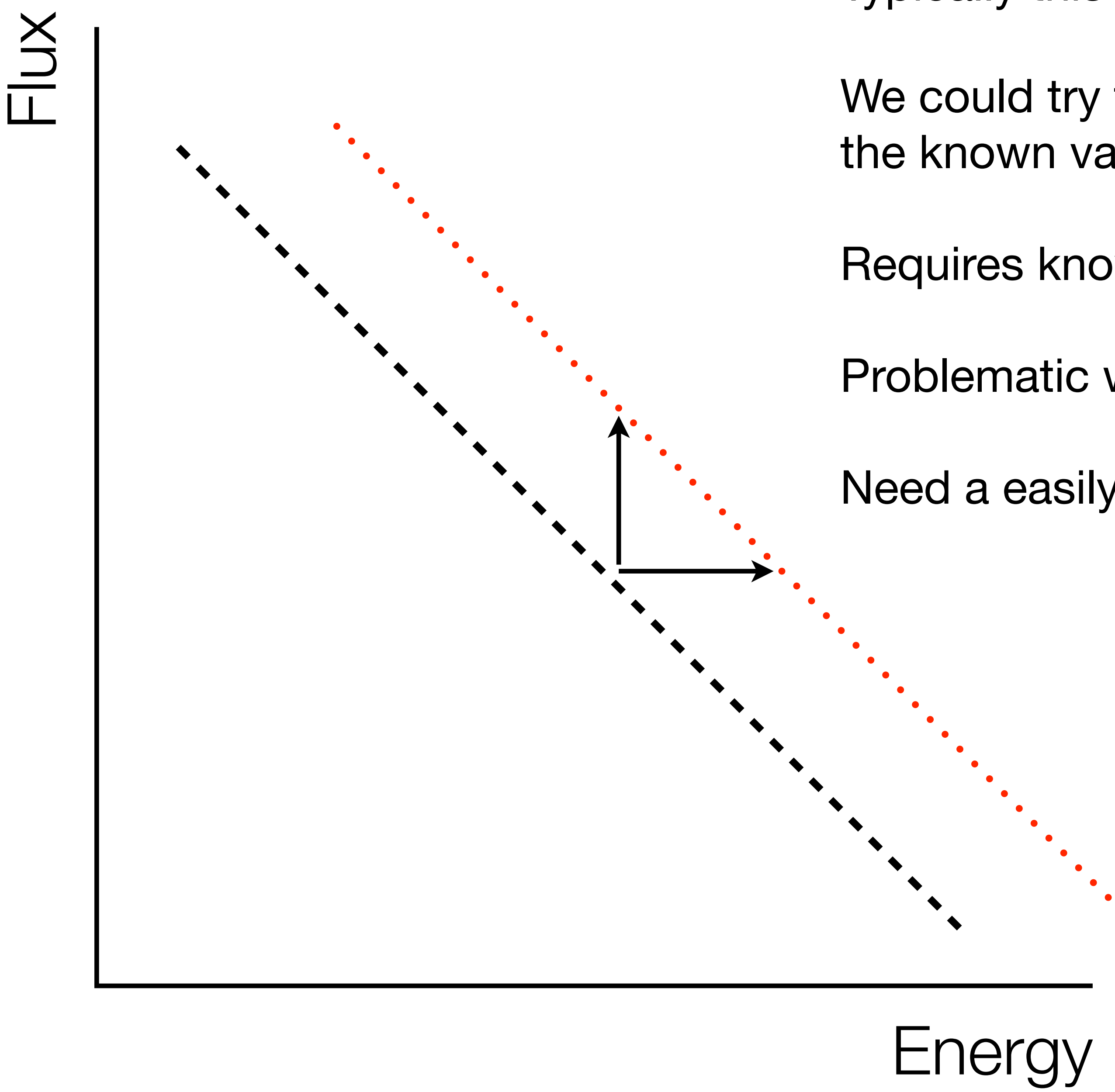
Studies were performed in CTA-MC work package comparing different simulation chains

MC shower simulations show a difference of 5% in Cherenkov light yield

Telescope simulations seem more consistent



# Reconstruct spectrum




In order to quantify the effect of scaling we need to compare results to another instrument (that does not suffer from the same systematics)

Typically this is a satellite measurement (such as Fermi)

We could try to reconstruct the spectrum of a source and compare this to the known value

Requires knowing the source spectrum very well

Problematic with power law sources

Need a easily observable source, with a strong spectral feature...

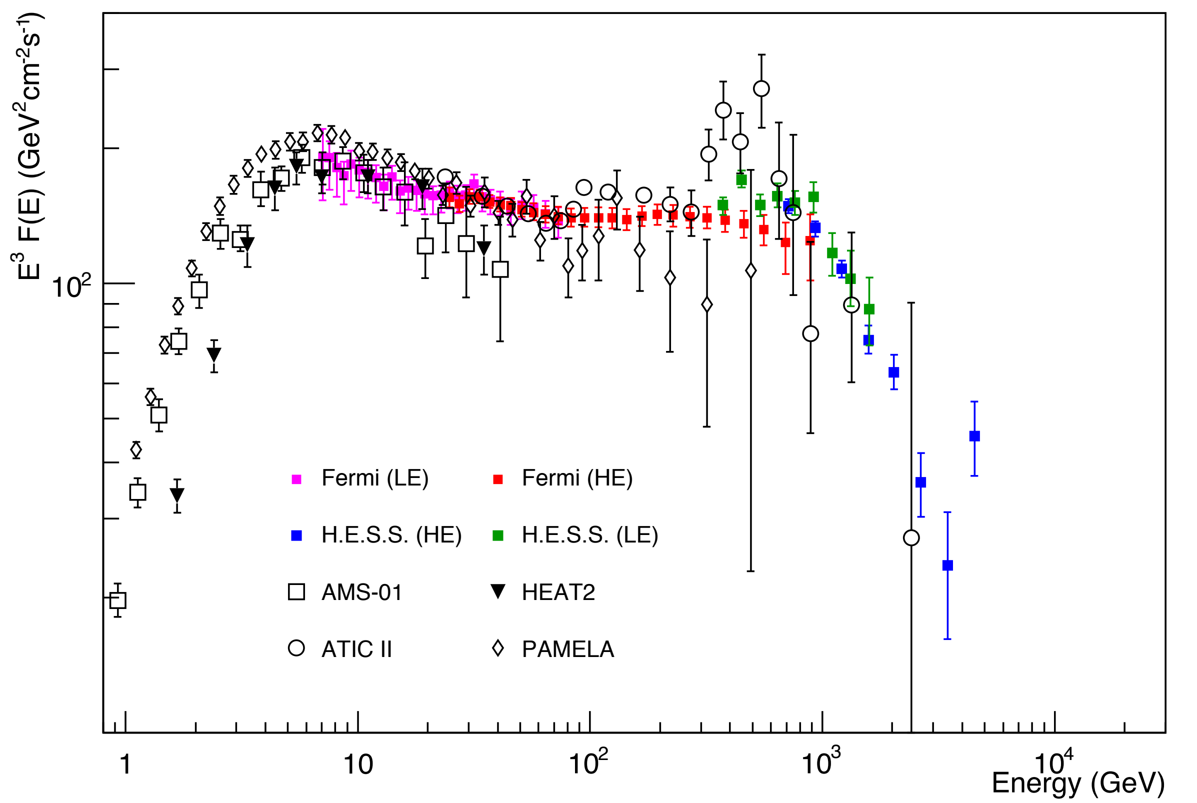
Effective area or energy scale???

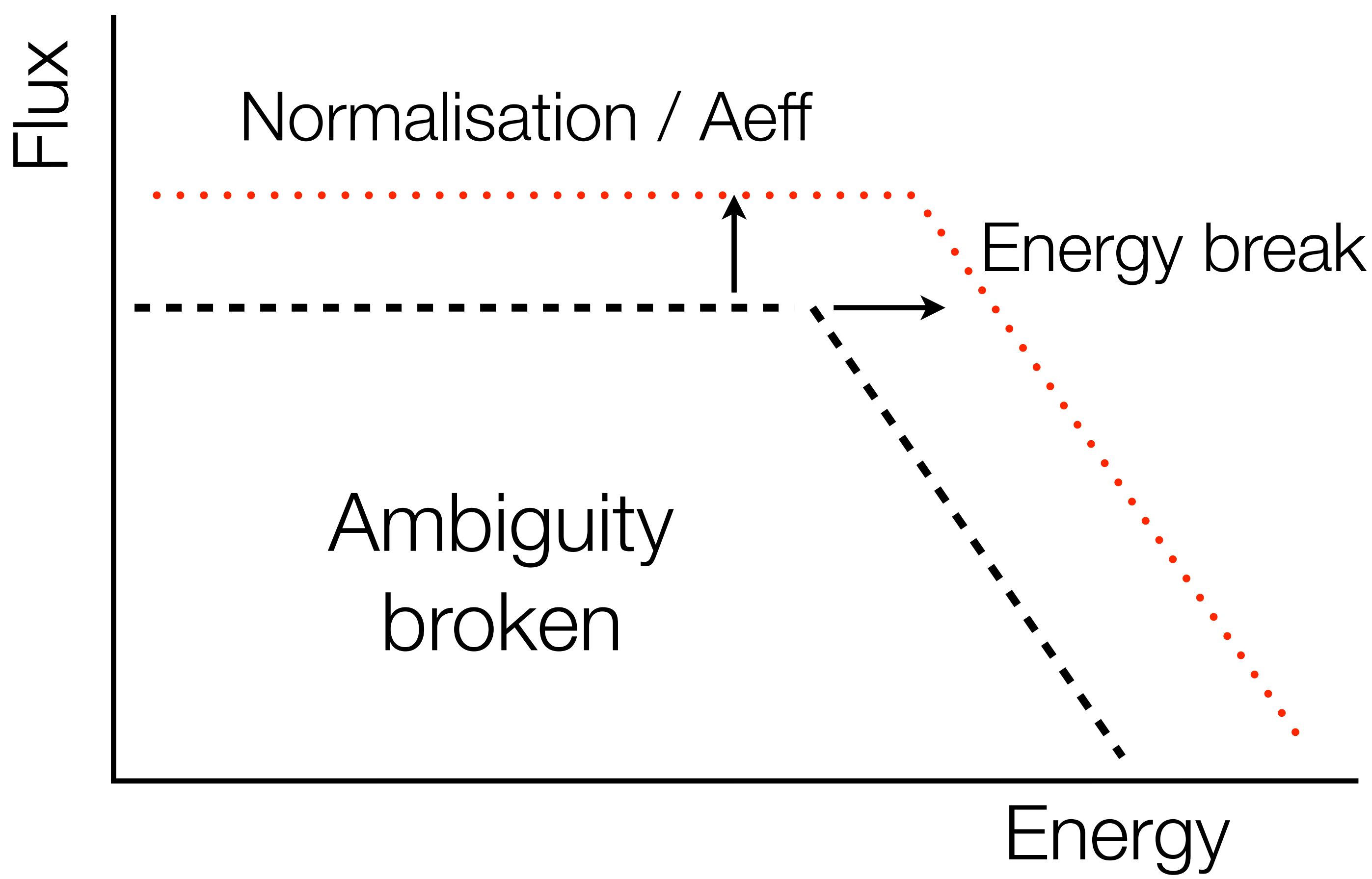
# Cosmic Ray Electrons

Cosmic ray electrons are seen in all IACT observations (we can use already available observations)

They have a strong spectral break (-3 to -4.1) at 900 GeV

HESS, MAGIC & VERITAS have already been able to measure this spectrum




Current generation observatory measurements took around 100 hours of data

Likely not sensitive enough to allow short timescale checks (daily, weekly etc)

But CTA has >10 times the effective area and 3 times the rejection power...

# Electrons with HESS

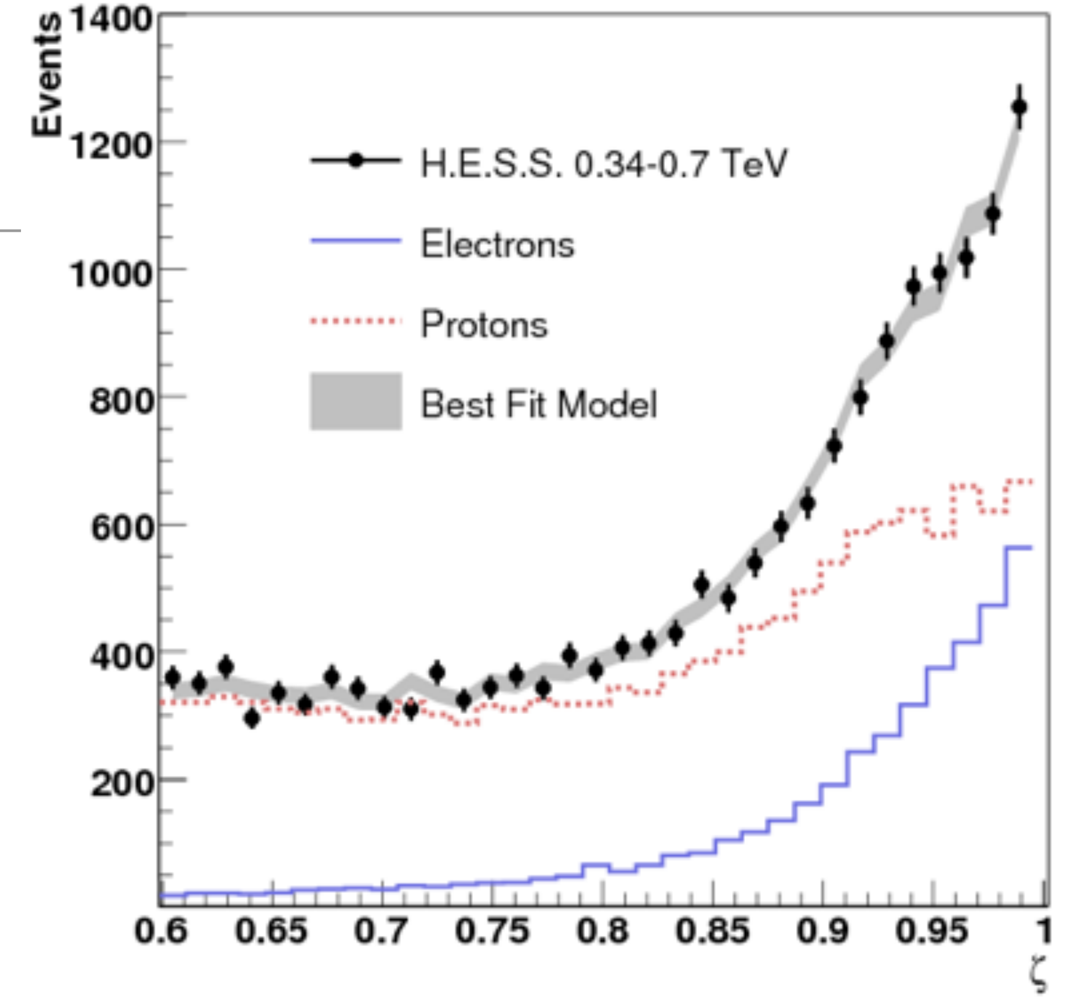
In order to test how well this measurement can be made we must first reconstruct the electron spectrum with CTA

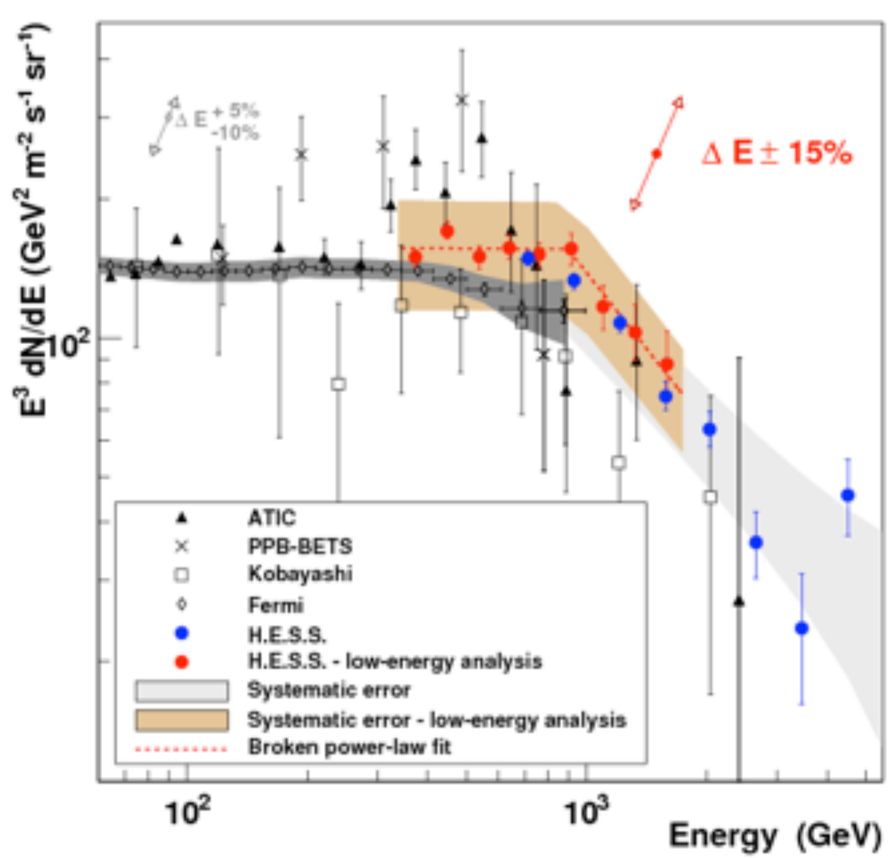
Use the same method as HESS

Create a neural network to distinguish protons and electrons

Fit the “data” distribution with proton and electron distribution to determine relative contributions

Measurement will have large systematics due to lack of knowledge of the “true” proton distribution



# Electrons with CTA

Tests were made using CTA production simulations with array I

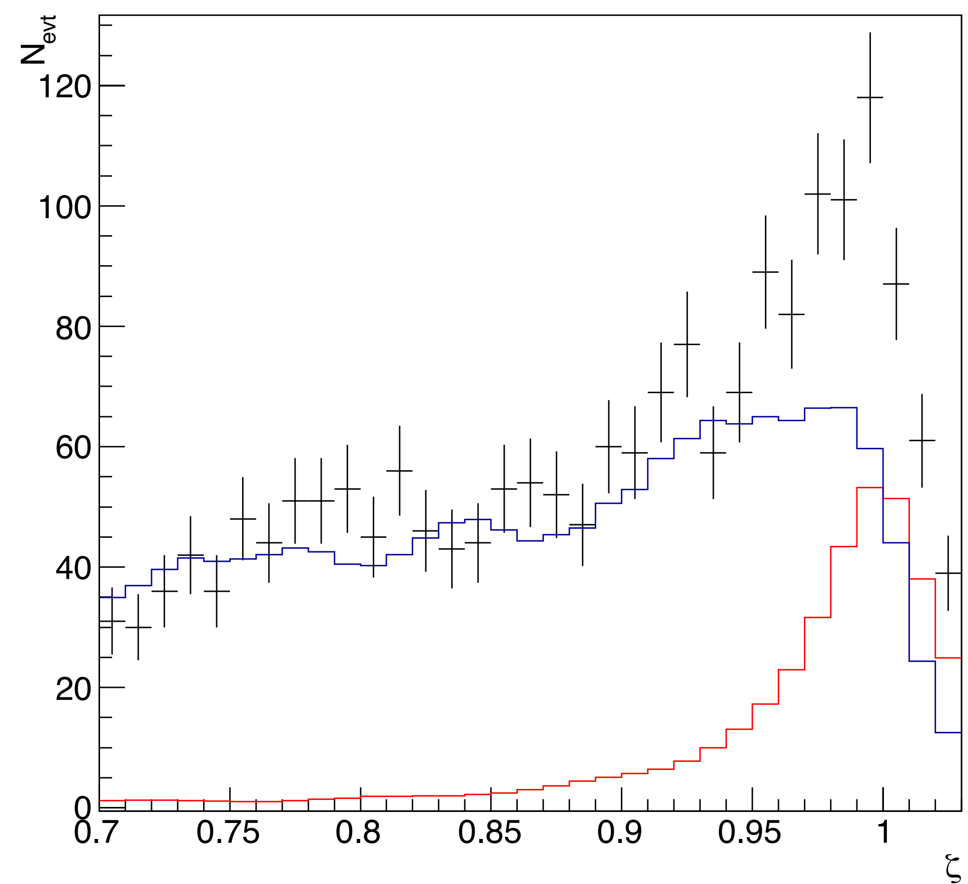
Systematics difficult to evaluate as we have no real data and only small numbers of simulations with different interaction models

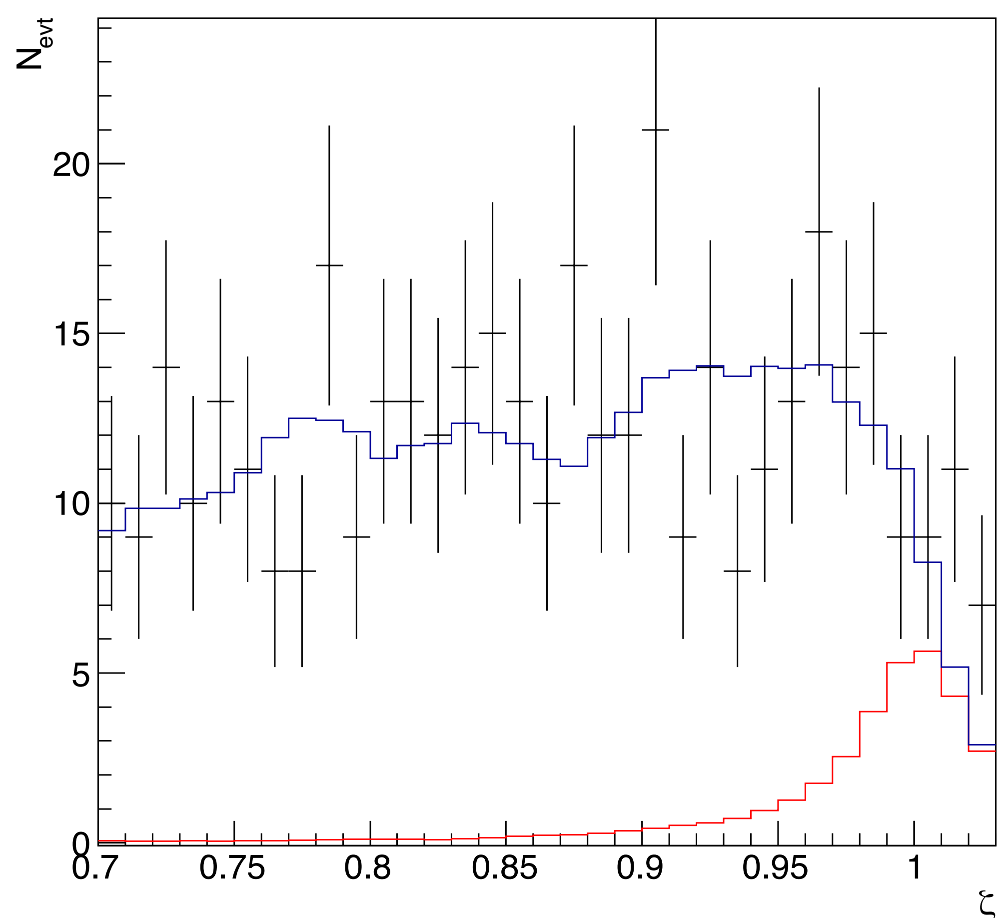
MVA trained and model distributions constructed for electrons and protons

“Data” distribution constructed by taking expected addition of the 2 components with Poissonian noise

Relative normalisation of the 2 components then fit to the data distribution

Used to construct histogram of $N_{elec}$ vs energy and hence spectrum



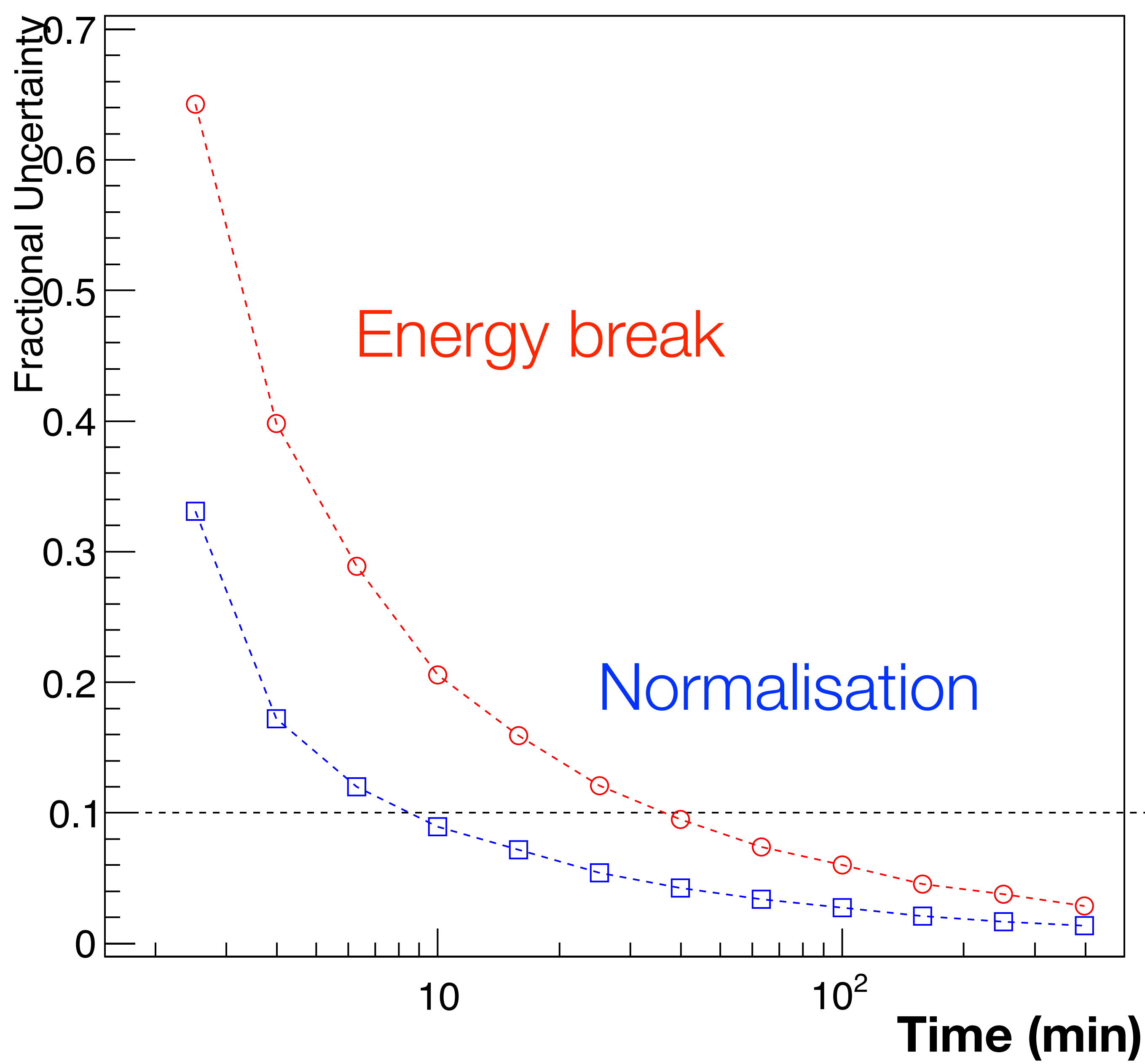



# Electron Calibration

200 realisations of the spectrum (with different noise) produced

Forward folding fit of electron spectrum, leaving normalisation and Ebreak free performed

Evolution of the RMS of fit parameters with observation time calculated



# Current Work

All previous studies were performed using Prod 1 simulations

Now this work is being updated to use Prod 2 simulations

Paper writing has also begun

Will be submitted to Astroparticle physics

Should be ready for WP review in the next few months (depending on paper classification)

## Calibration of Cherenkov Telescope Arrays using Cosmic Ray Electrons

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**Abstract**

Cosmic ray electrons represent a background for gamma-ray observations with Cherenkov telescopes, initiating air-showers which are difficult to distinguish from photon-iniated showers. This similarity, however, and the presence of cosmic ray electrons in every field observed, makes them potentially very useful for calibration purposes. Here we study the precison with which the absolute energy scale and collection area/efficiency for photons can be established using electrons for a major next generation instruments such as CTA. We find that variations in collection efficiency on hour timescales can be corrected to better than 5%. Furthermore, the break in the electron spectrum at ~1 TeV can be used to calibrate the energy scale at the 10% level on the same timescale and with negligable statistical error for timescales of 10s of hours, allowing an absolute energy scale cross-check with instruments such as CALET and AMS Cosmic ray electrons therefore provide a powerful calibration tool, either as an alternative to intensive monitoring and modelling of the atmosphere, or for independent verification of such proceedures.

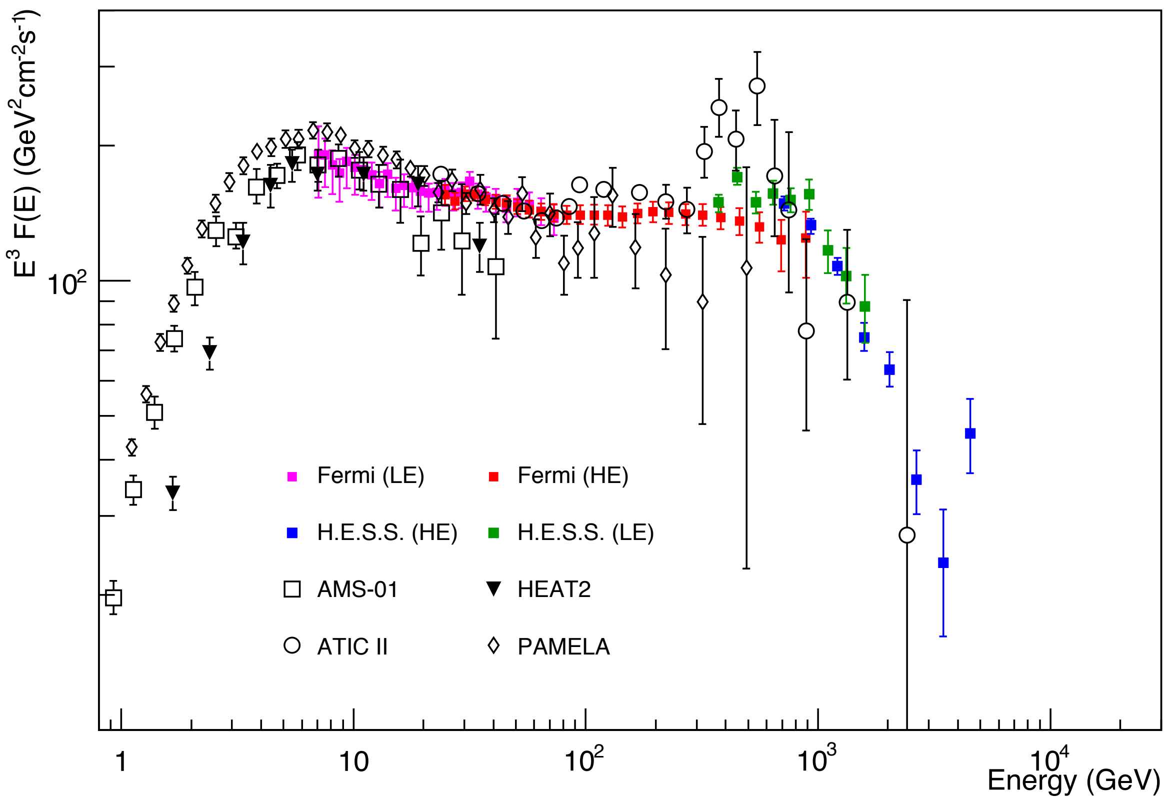
*Keywords:*

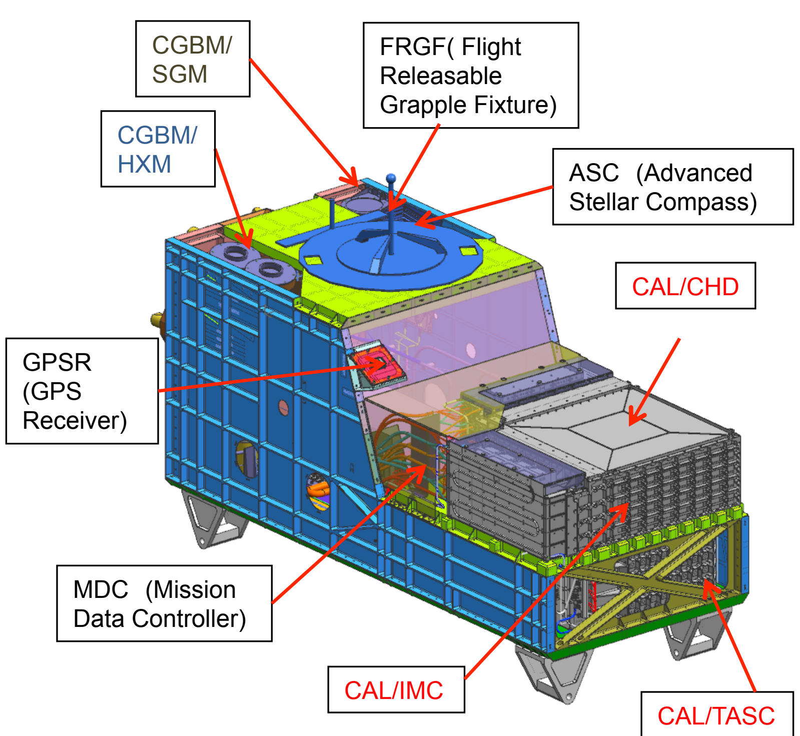
### 1. Introduction

Electrons (and positrons) represent ~1% of the cosmic ray flux at XXX GeV energies. After the hadron-rejection cuts typically made for Cherenkov telescope arrays, however, they represent a dominant background over a wide energy range, with improving hadron rejection compensating for the steeper electron spectrum ($simE^{-3.3}$ versus $\sim E^{-2.7}$) up to the sharp break in the electron spectrum at around around 1 TeV Aharonian et al. (2008). The electron background is uniform on the sky at the <X% level **?** at X GeV, and expectations for anisotropy are significantly

and instrumental corrections have been successfully applied. The advantages over cosmic ray protons and nuclei for this purpose (see for example **?**) is the close similarity of gamma and electron showers in terms of morphology and depth of maximum (albeit with a half radiation length shift) and the presence of a distinct feature in the CR electron spectrum: the 1 TeV break. This feature raises the prospect of independently establishing collection area and energy scale changes, something which is impossible using power-law spectra. The spectral break position in electrons will be established independently by future ground-based Cherenkov telescope arrays and by space-based instruments such as CALET **?** and perhaps

# What Experiment to Compare to?




This method however relies on having a well measured electron spectrum beyond the spectral break

Could compare to strongly selected CTA data (relative calibration)

High statistics satellite data should be available in the near future

AMS-02 is currently taking data, but unclear if it can measure electrons > 1 TeV

CALET experiment should be able to measure multi-TeV electrons

Launched this year, should have a spectrum available in a few years

# Conclusions

In order to calibrate the absolute energy scale CTA results must be compared to other instruments

Strong, well measured source required to make comparison

Cosmic ray electron spectrum may be a useful tool in the high level calibration of effective area and energy scale for CTA

Can only check the gross behaviour of the array (not individual telescopes)

This shape can then be fit to short timescale observations and the changes in flux normalisation and break energy observed

In order to reach a 10% fit accuracy only 10 mins of data needed for effective area and 40 mins needed for break energy

Low enough to be taken from extragalactic runs in a single night

Could be used to scale effective area and energy scale