Cosmic-ray $e^{-}+e^{+}$ spectrum from 7 GeV to 2 TeV with Fermi-LAT

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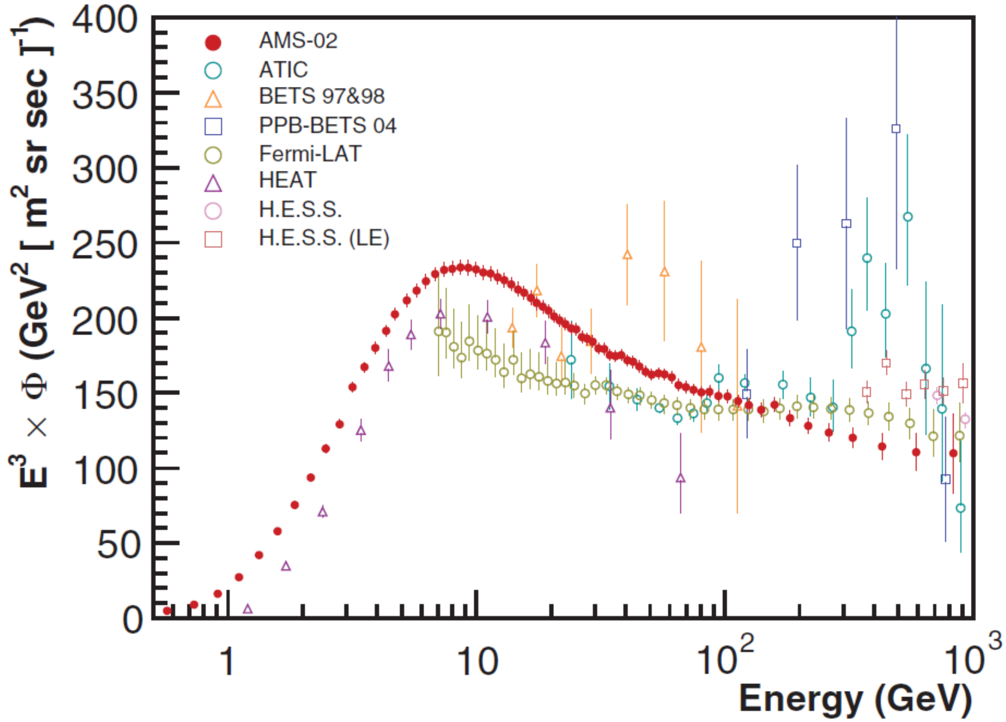
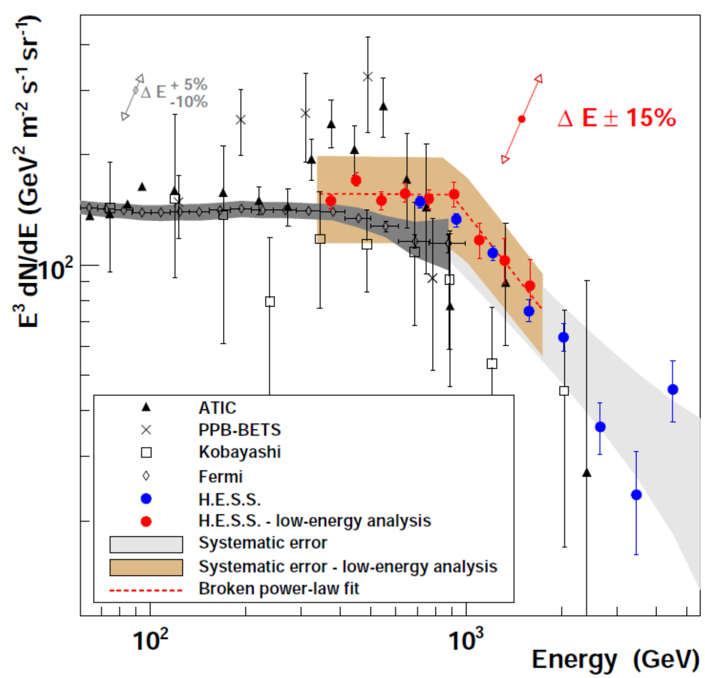
Introduction

- Measurements of the Cosmic-Ray electron+positron (CRE) spectrum:
  - AMS-02 up to 1 TeV (2014): single power law above 30.2 GeV
  - H.E.S.S. from 300 GeV to 5 TeV (2008/2009): cutoff around 2 TeV
  - Fermi-LAT up to 1 TeV (2009 – 1yr of data): single power law
- The features of the spectrum can sign the presence of local sources of CRE
- We have updated the LAT measurement:
  - 1 yr of Pass 6/7 data → 7 yr of Pass 8 data
  - up to 2 TeV

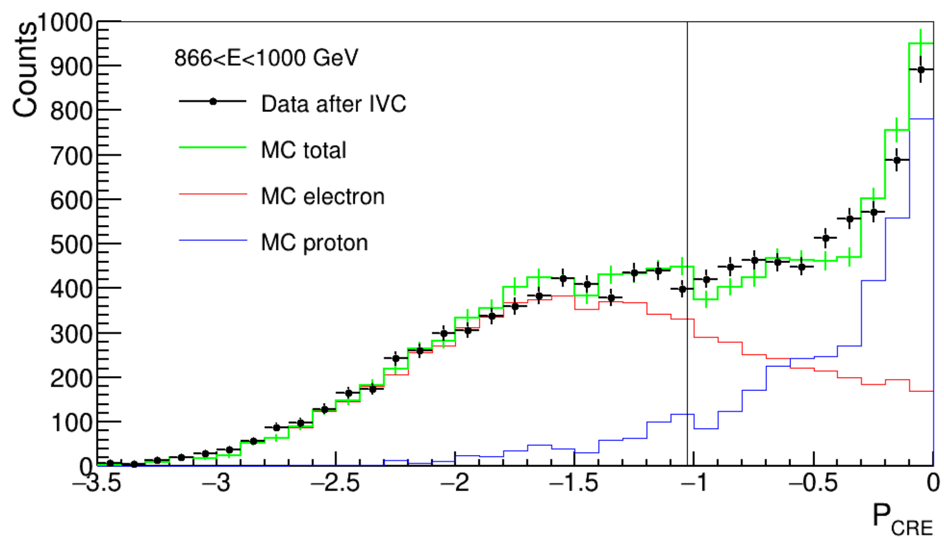




Analysis chain

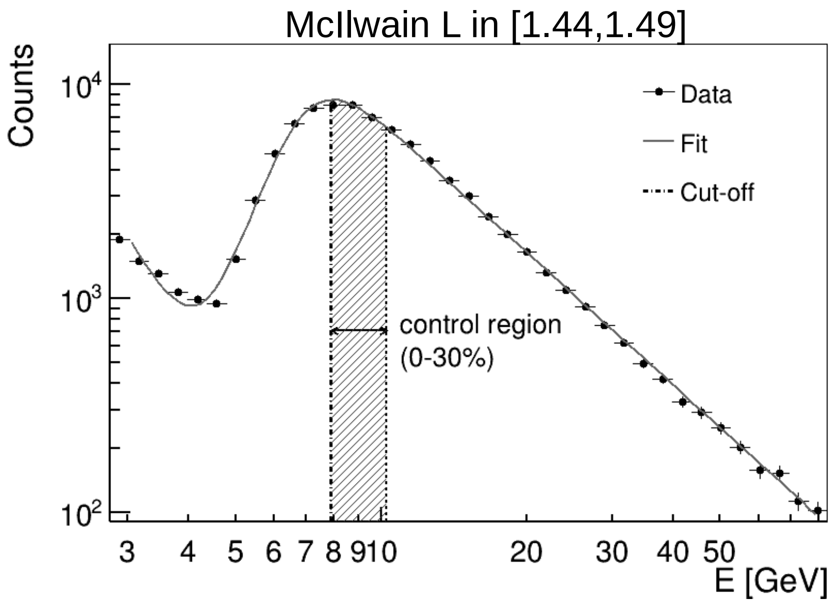
	Event selection			Corrections and systematic uncertainties
	On-board filter	Simple cuts	Multivariate analysis with Boosted Decision Trees	
Low Energy 7 GeV → 70 GeV	minimum bias	• θ<60deg • Z=1 • quality cuts	1 BDT	Geomagnetic field corrections
High Energy 42 GeV → 2 TeV	gamma		8 BDTs	• Data/MC agreement • Energy reconstruction

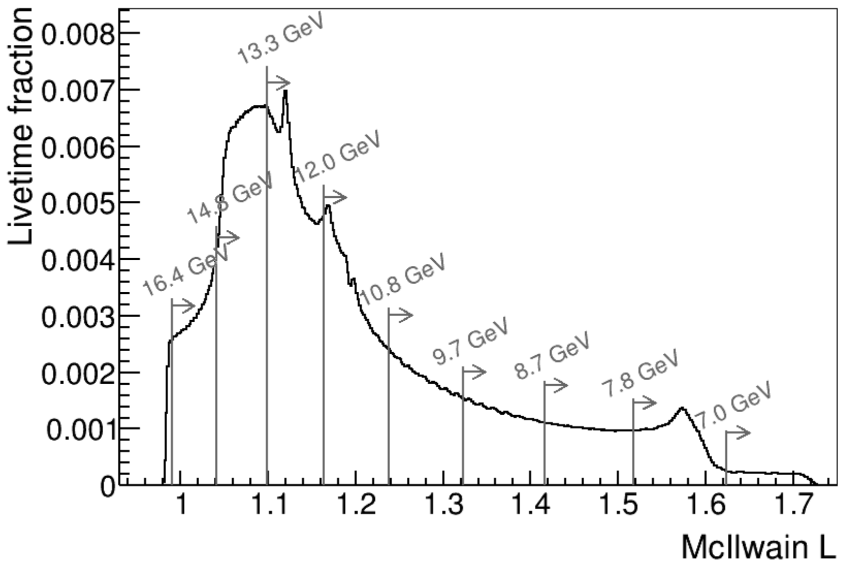
- The BDT analyses use input variables that capture the shower trajectory and topology in order to discriminate between electrons and background (mainly protons)
- The BDT output variable is fit with MC templates to estimate the residual background

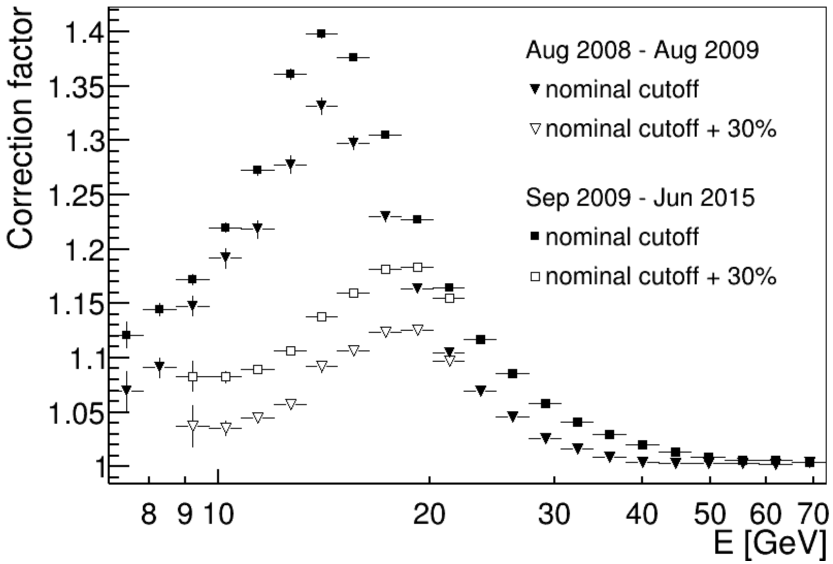


LE analysis

- Below ~20 GeV the observed CRE flux is strongly influenced by the Earth magnetic field
- At a given geomagnetic position, only CREs above a certain rigidity can reach the LAT
- We map the relation McIlwain L ↔ Energy cutoff
- For each energy bin the selection includes a cut on McIlwain L
- The remaining loss due to the geomagnetic effect is estimated thanks to particle trajectory tracing code (Smart and Shea): between 5% and 40%

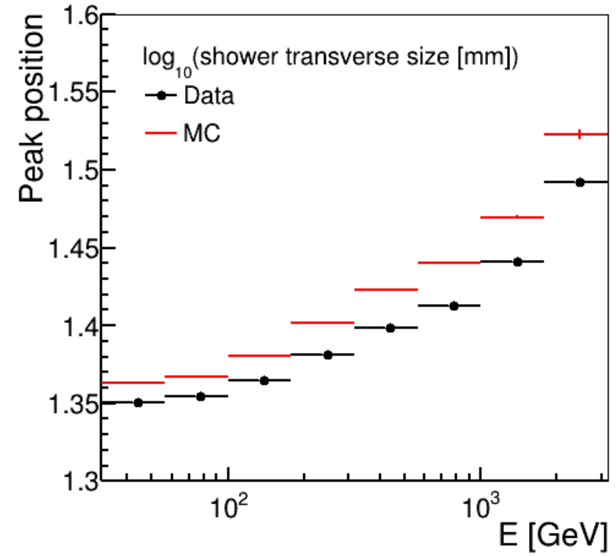


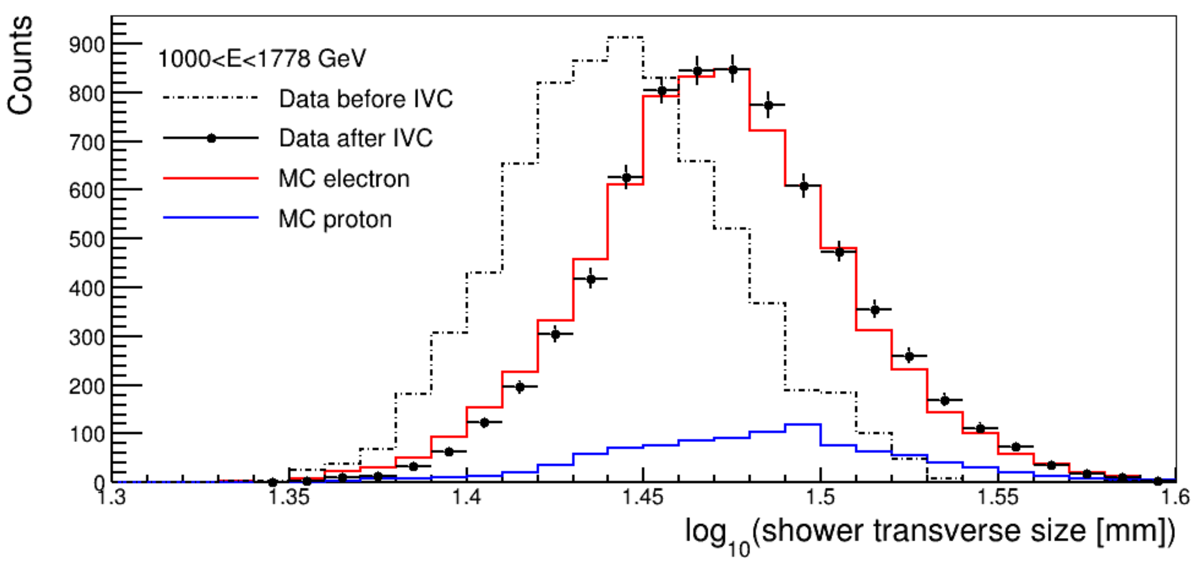


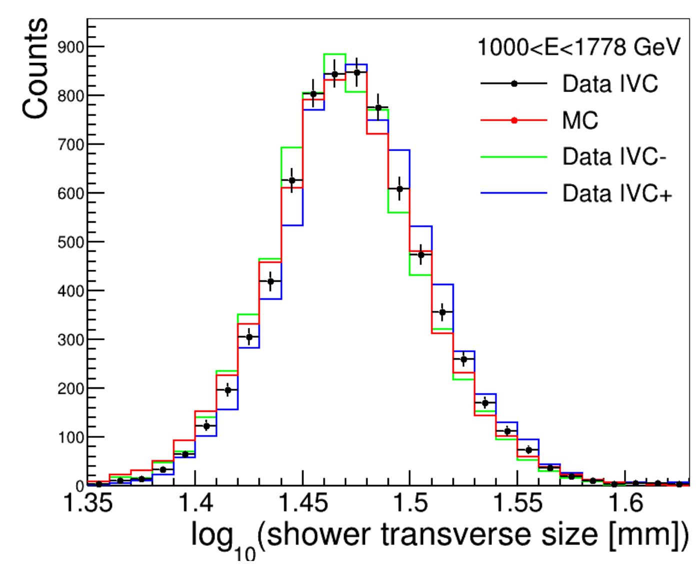


Data/MC agreement

- Multivariate analysis precision depends on the data/MC agreement
- Some variables suffer from significant data/MC disagreement
- We perform an Individual Variable Calibration: the distributions are shifted by corrections derived from data/MC comparison in E and θ bins
- Two bracketing sets of IVC correction are used to estimate the systematic uncertainty due to this correction

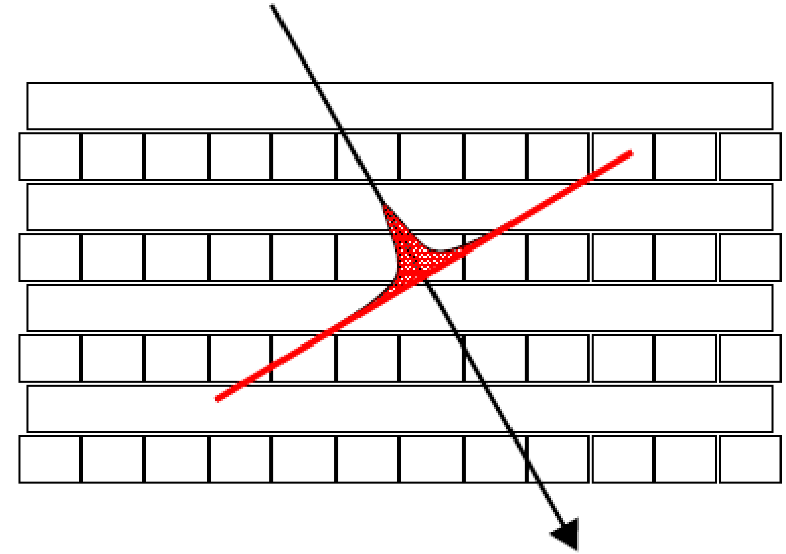


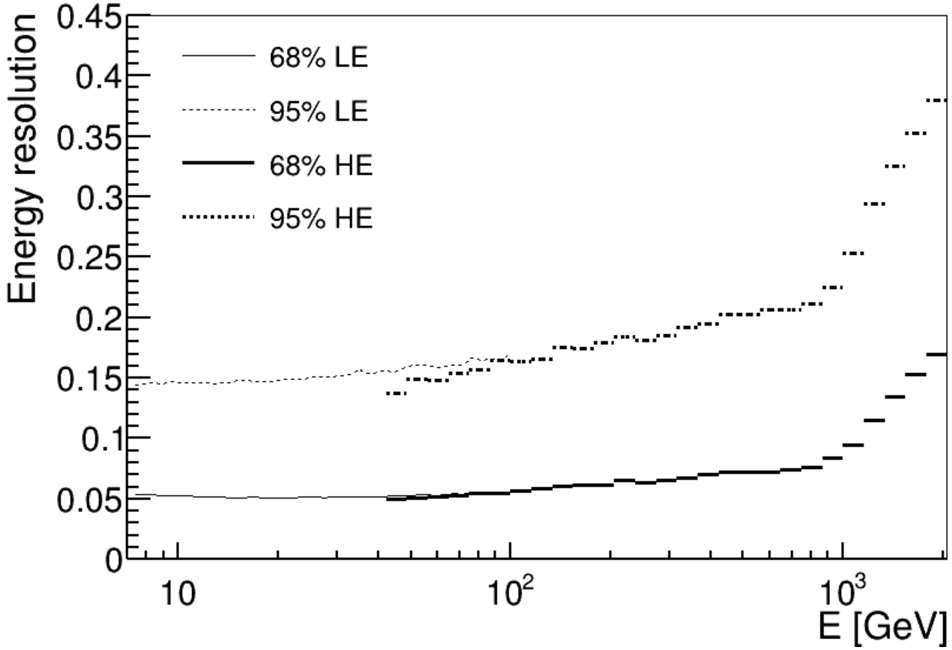




Energy reconstruction

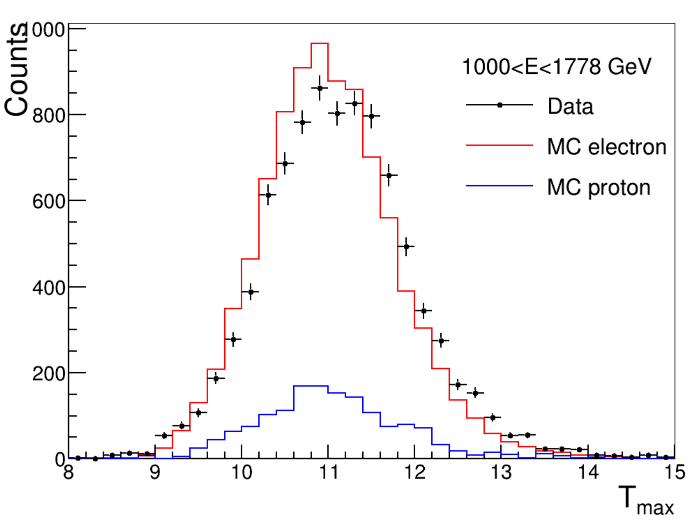
- The energy is estimated by fitting the shower profile, using the longitudinal segmentation of the calorimeter in 8 layers (~1.1 X_0 each when on axis)
- We use a parameterization of the shower parameters (both average and RMS of α and T_{max}) as a function of energy
- Event by event, using the event trajectory given by the tracker, we compute the fraction of energy deposited in the each layer as a function of radiation length, taking into account the shower longitudinal and radial profiles, as well as the calorimeter geometry
- Crystal saturation (>70 GeV in one crystal) starts to occur for >600 GeV CREs but impacts energy reconstruction only above ~1 TeV

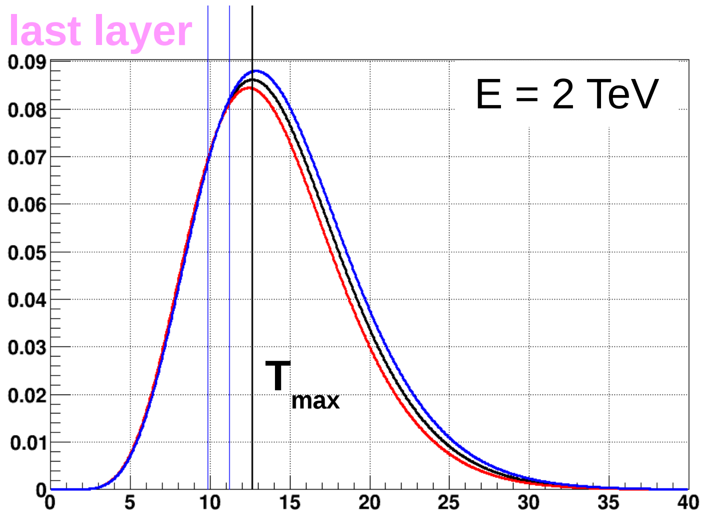


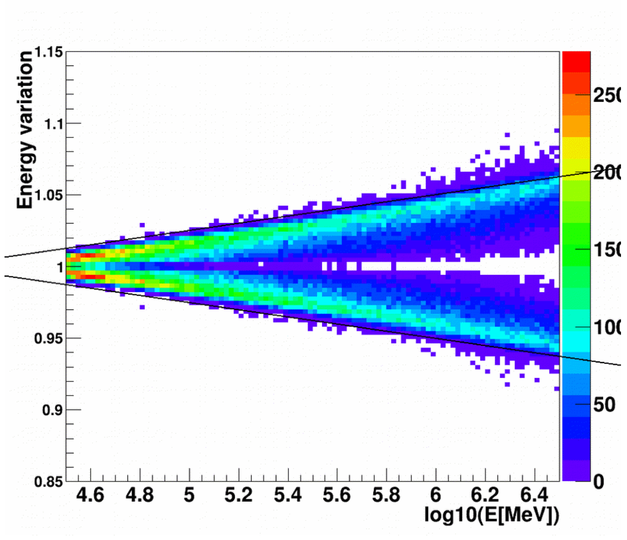


Energy related systematics

- The systematic uncertainty on the energy measurement comes from:
  - absolute energy scale uncertainty
  - energy reconstruction uncertainty due to leakage from the calorimeter
- Absolute energy scale systematic uncertainty:
  - we used the geomagnetic cutoff around 10 GeV to check the calibration of the absolute energy scale
  - we found a mean data/model ratio of 3% +- 2% → the energy is corrected by -3% and the systematic uncertainty is 2%
- Energy reconstruction systematic uncertainty:
  - Leakage increases linearly with logE from 20% at 10 GeV to 65% at 1 TeV
  - We vary α and T_{max} within data/MC differences and compute the relative energy change: δE = 2.5% x (logE/GeV-1) → 5% at 1 TeV

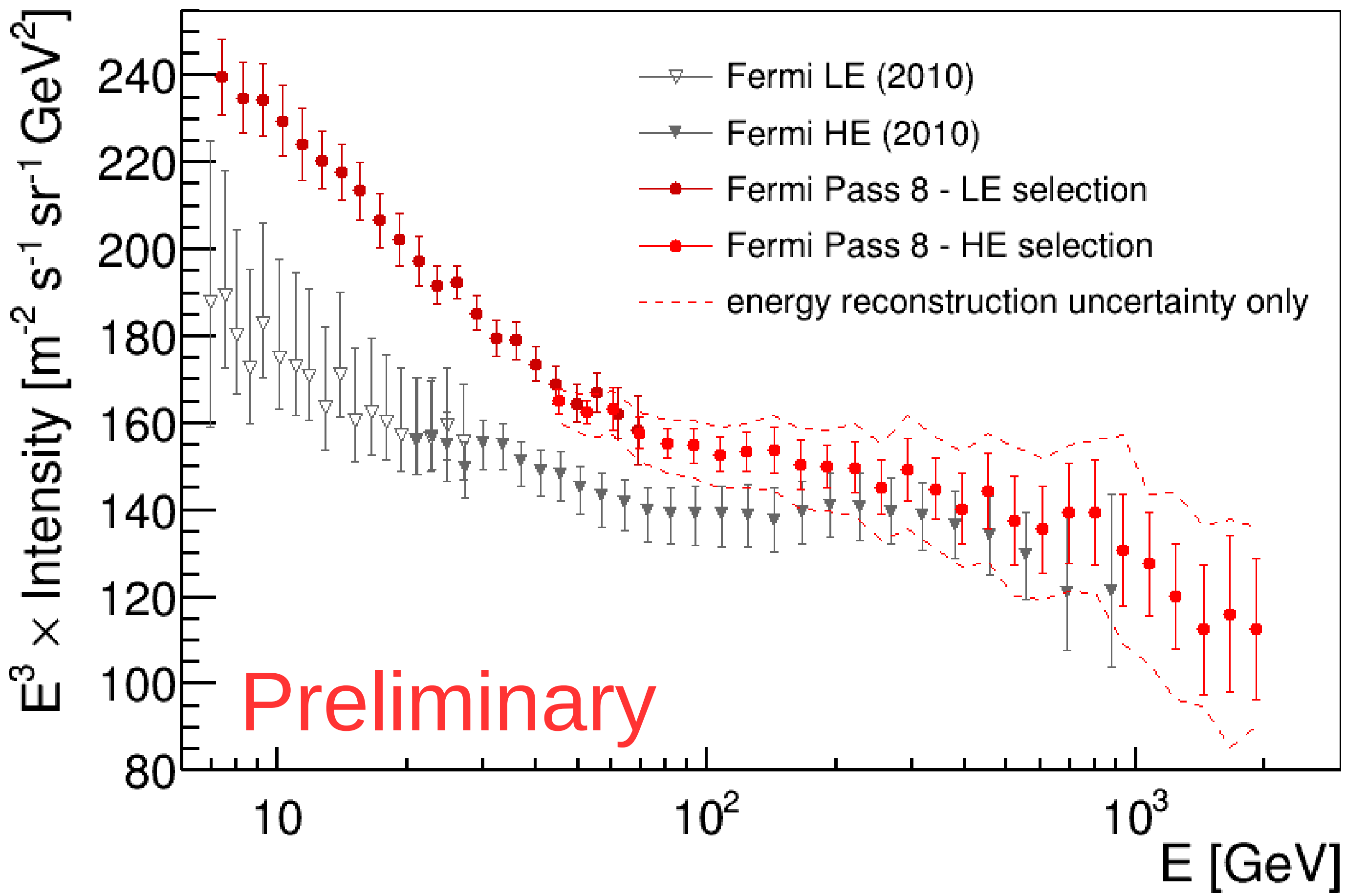






CRE spectrum

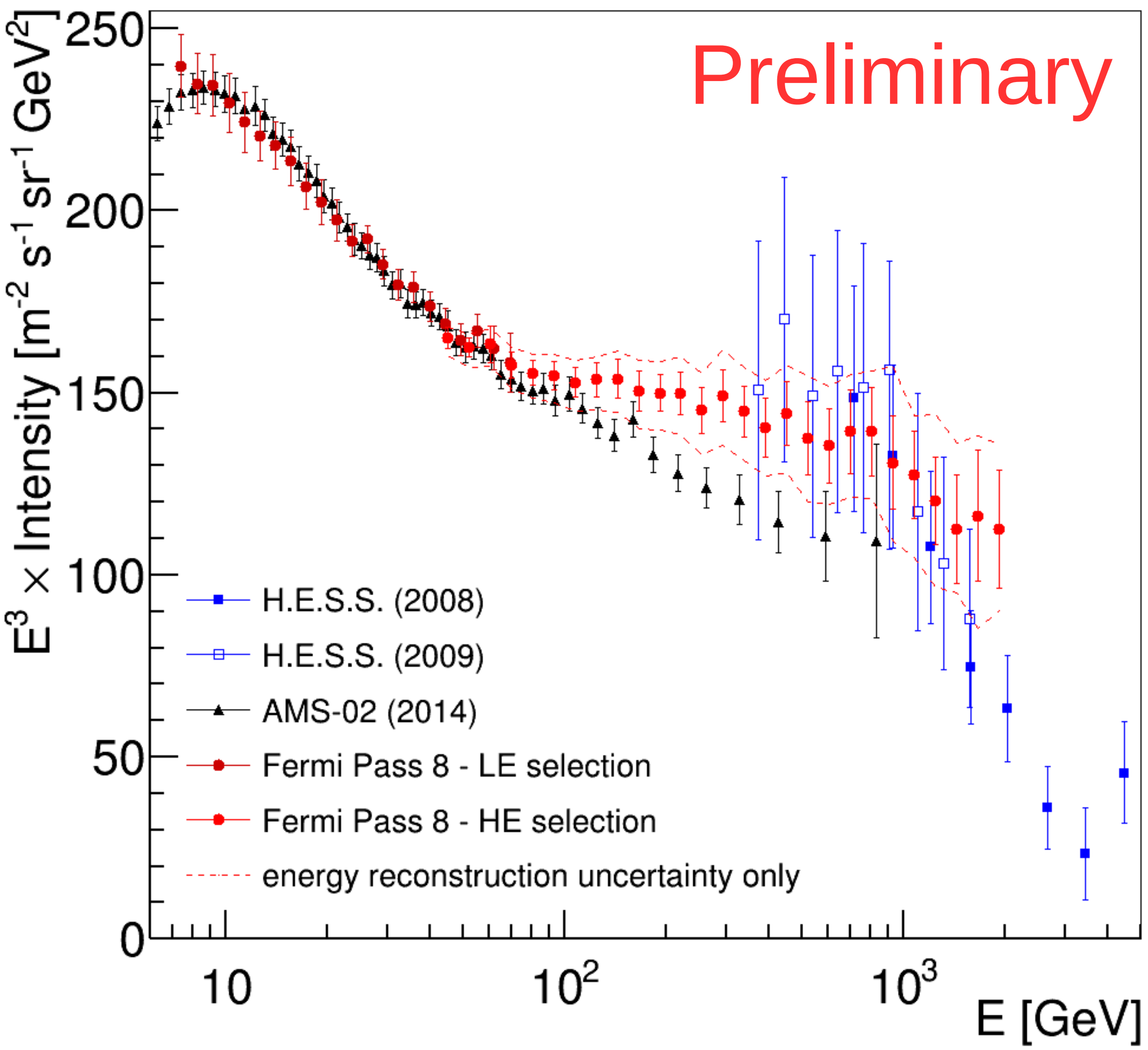
- LE and HE spectra agree in the overlapping energy range
- The difference with the previous LAT spectrum is due to some imperfections of the previous analysis:
  - the remaining loss due to geomagnetic effect was not taken into account
  - the MC did not simulate the out-of-time particles crossing the LAT



CRE spectrum

- Fermi above 7 GeV:
  - broken power law is preferred with break energy at 50 GeV, even when energy systematic uncertainty is taken into account (4σ)
  - above 50 GeV, the spectrum is compatible with a simple power law. Cutoff is >1.8 TeV at 95%CL

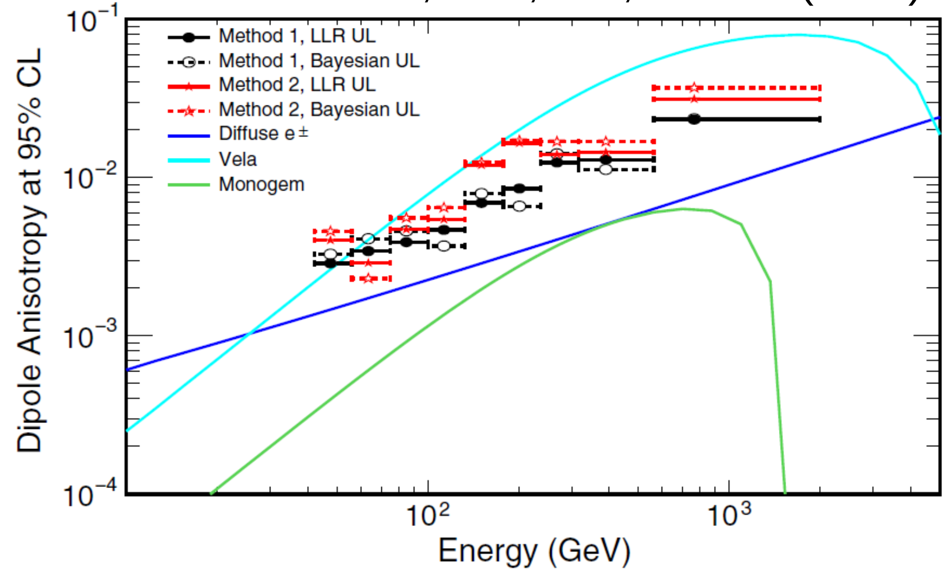
- AMS-02 and Fermi well agree up to ~50 GeV but Fermi spectrum is harder above 50 GeV
- Fit above 30.2 GeV: the spectral index difference between Fermi and AMS-02 is 1.7σ
- Fermi lower energy scenario connects with H.E.S.S. at 1 TeV



Related CRE results

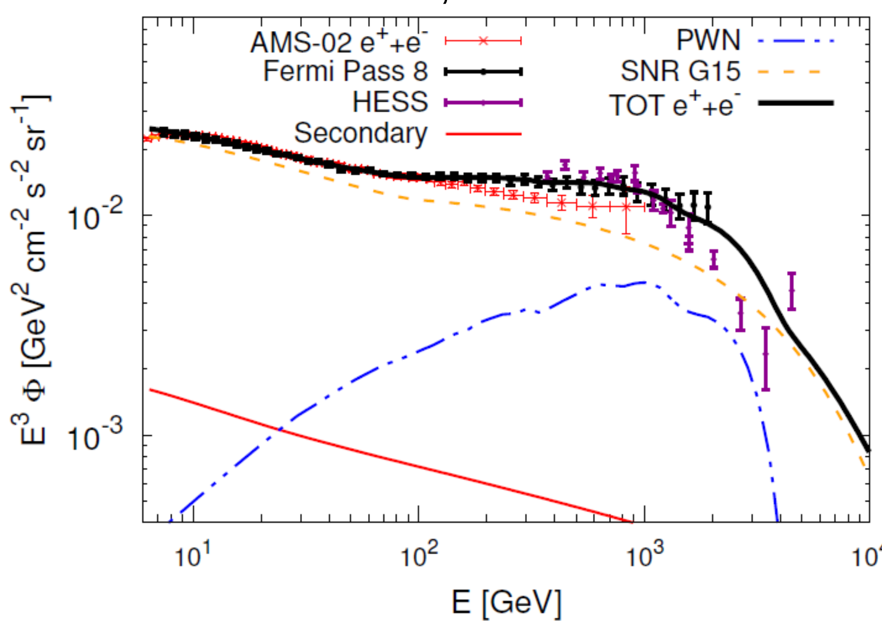
- A search for anisotropy using the CRE selection has been performed:
  - No anisotropy has ben detected
  - The current limits on the dipole anisotropy are probing nearby young and middle-aged sources

Abdollahi et al., PRL, 118, 091103 (2017)



- Interpretation of the LAT CRE spectrum:
  - testing various models with secondaries and CRE sources (SNR, PWN)
    - split SNRs into near and far SNRs
    - break in SNR injection spectrum

Di Mauro et al., arXiv:1703.00460



Conclusions

- The new LAT CRE measurement extends the energy range up to 2 TeV
- The analysis is systematics limited, especially because of the systematic uncertainty on the energy reconstruction due to the large shower leakage at very high energy

- The LAT CRE spectrum is well fit by a broken power law with a break energy at about 50 GeV
- An exponential cutoff lower than 1.8 TeV is excluded at 95% CL

- Above 50 GeV, the LAT spectrum is slightly harder than the AMS-02 one

- In order to reduce the systematic uncertainty on the energy reconstruction, we have started to investigate the possibility of using very off-axis events (>60deg) with better contained showers. The drawback of this approach is that the track information is scarce or inaccurate.