Cosmic Ray Electron Spectrum with the Fermi-LAT

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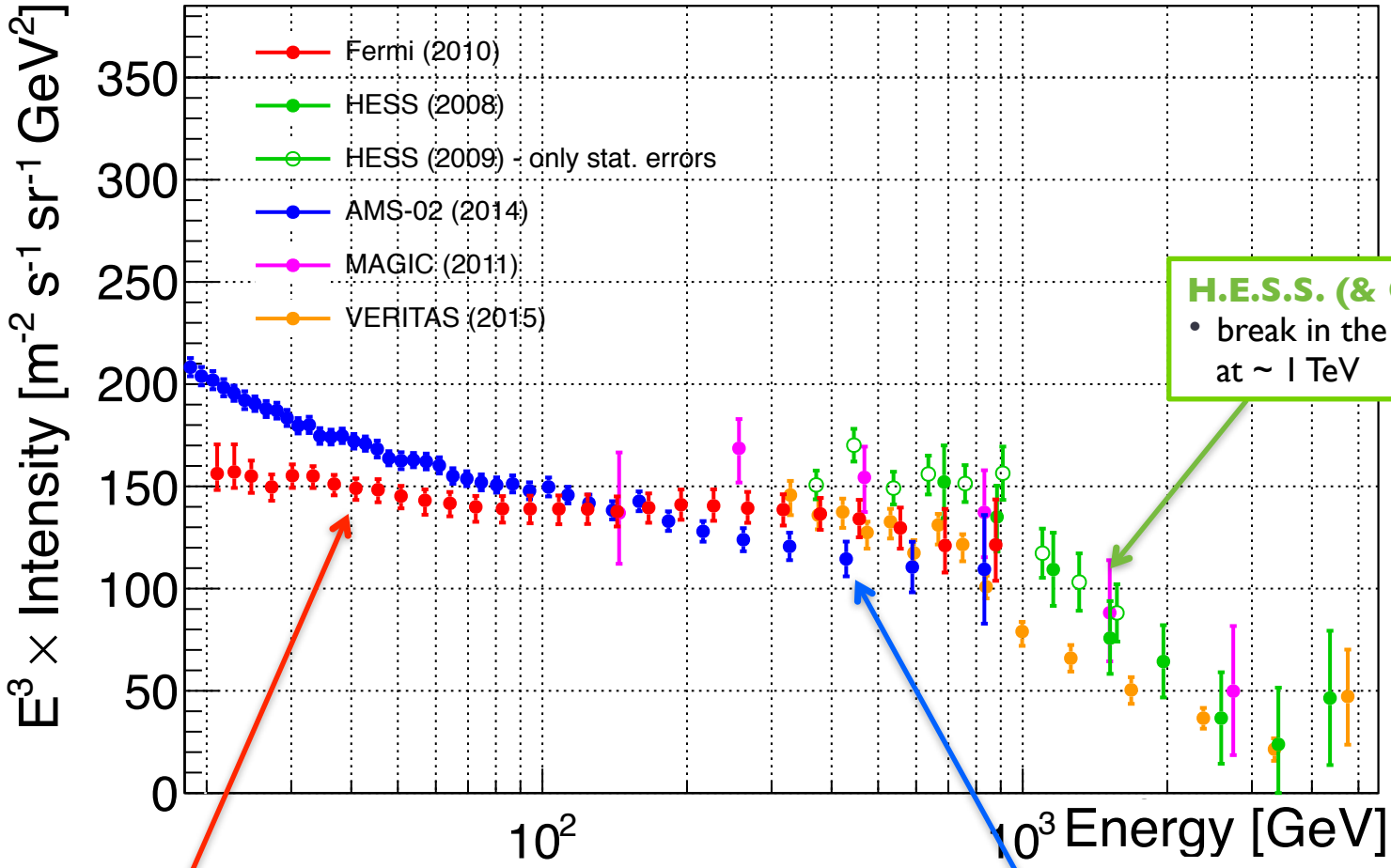
on behalf of the ***Fermi-LAT Collaboration***

CRE(e^+e^-) experiments

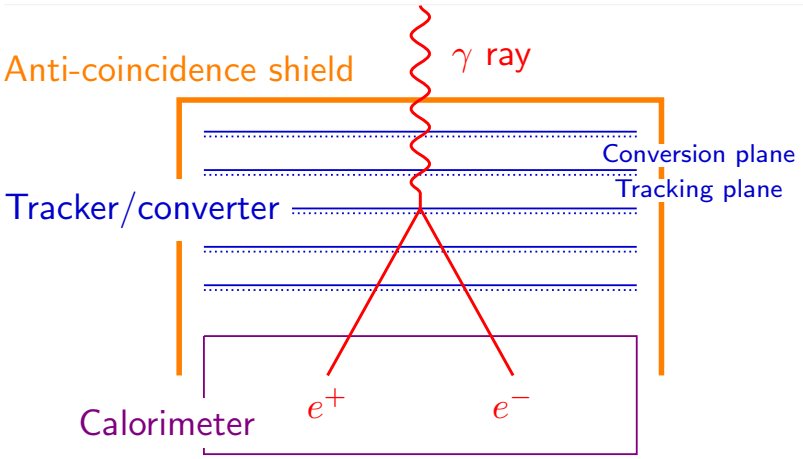


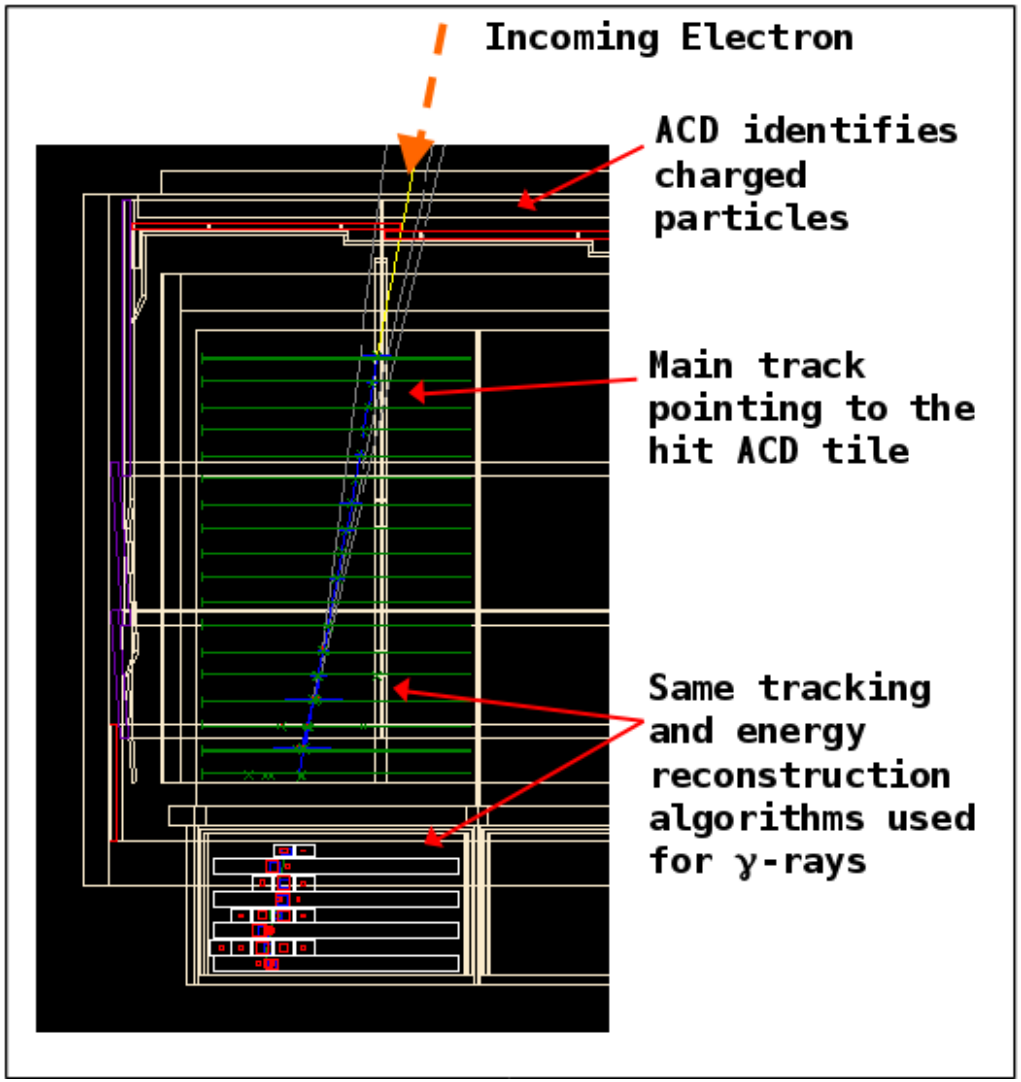
H.E.S.S. (& Cherenkov)
- break in the spectrum at ~ 1 TeV

Fermi
- First high-statistics measurement of inclusive spectrum between 7GeV and 1TeV
- Measurements compatible with single power-law over the entire energy range $\propto E^{-3.08\pm0.05}$

AMS-02
- Range: 0.5 GeV to 1 TeV.
- No structures observed.
- From 30 GeV to 1 TeV described by a single power law with γ=-3.170±0.008(stat+syst)±0.008(E scale)

LAT as electron detector



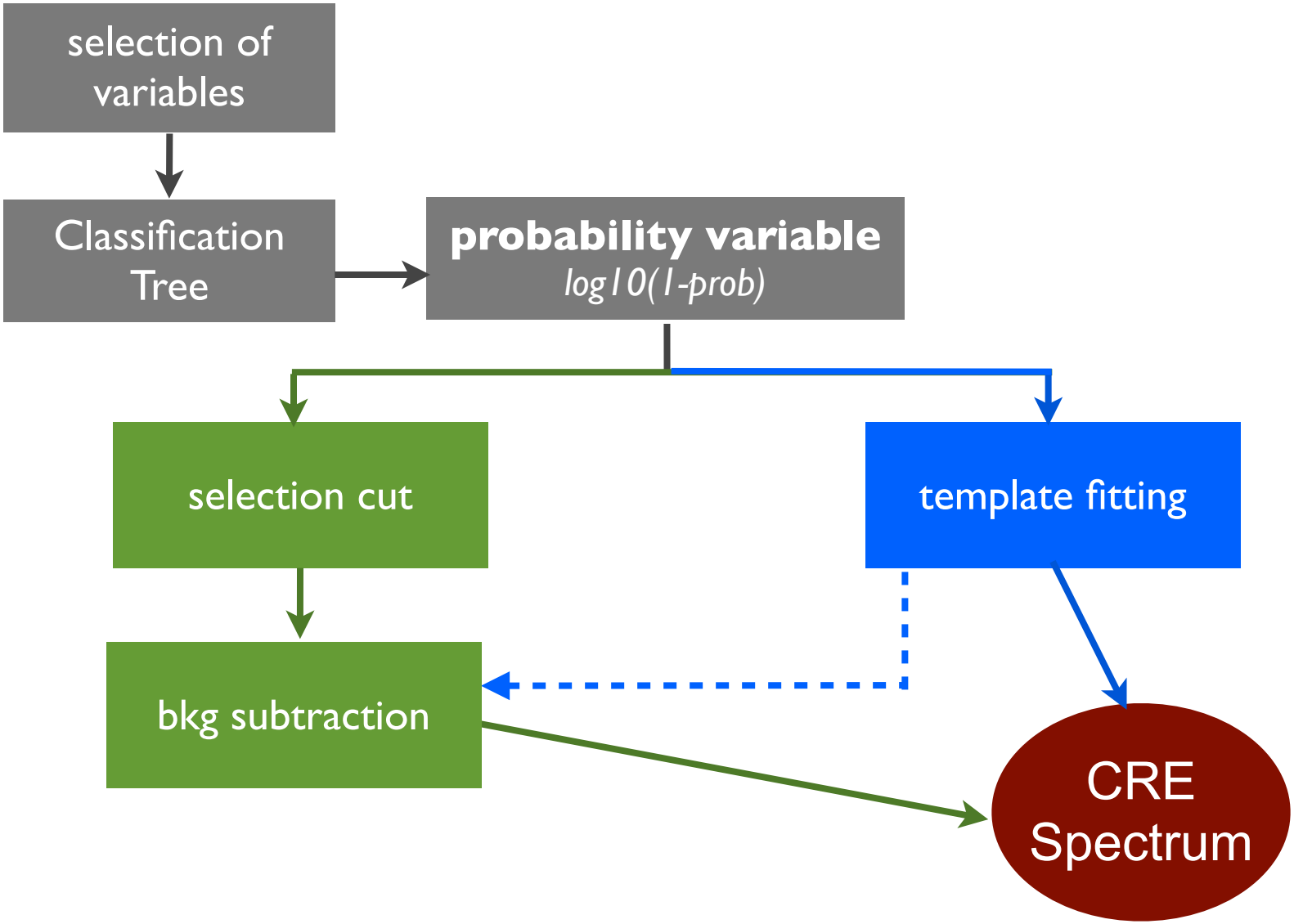


- Detector is designed for E. M. showers:
  - ➡ naturally including electrons
  - ➡ event reconstruction works also for electrons
- Electron identification requires dedicated **event selection**

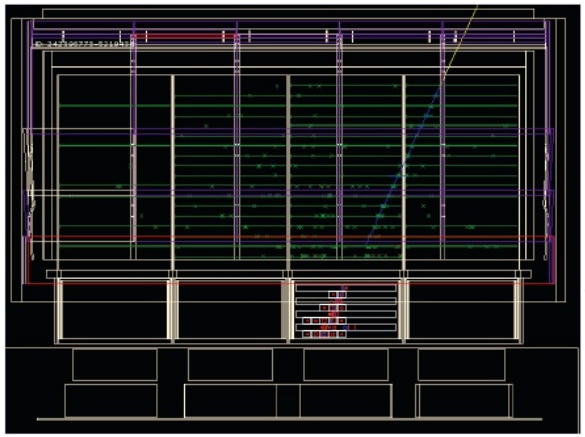
Analysis features

- **Objective:** discriminate signal (e^+/e^-) from background (mainly p) and compute the CRE energy spectrum
- **Data set:** ~ 7 years
- **Energy range:** 50 GeV - 2.5 TeV
- **Event reconstruction:** Pass 8
- **Event selection:**
  - **PRECUTS**
  - **Classification Tree:** TMVA with the Boosted Decision Tree method
    - trained on MC data samples (signal=MC electron, bkg=MC proton)
    - in 0.25 wide log energy bins → training optimized for the whole energy range
- **CRE spectrum**

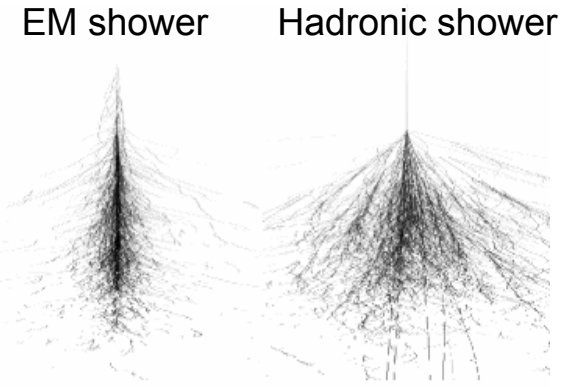
Analysis steps

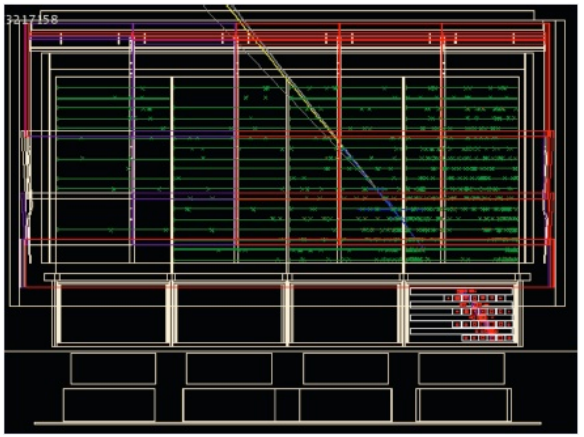


Selection of variables

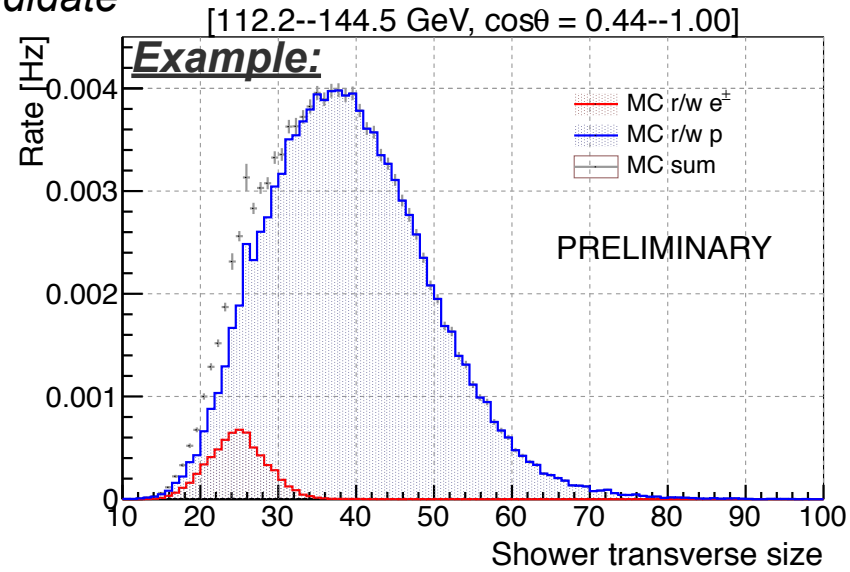


1 TeV electron candidate





1 TeV proton candidate

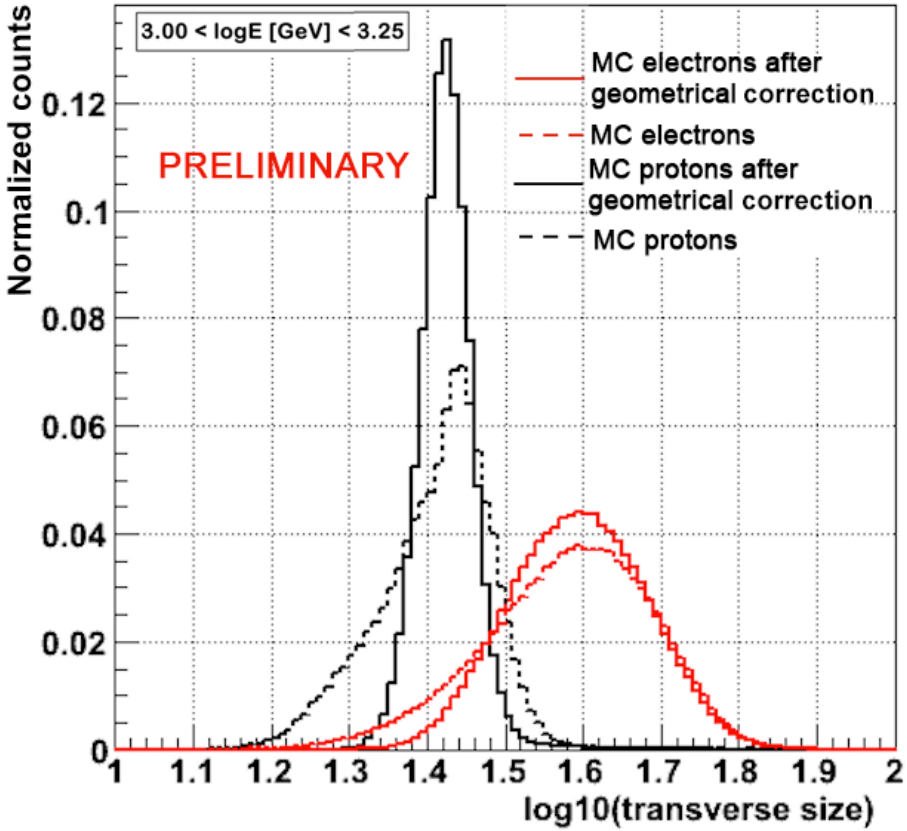


- The LAT uses shower topology information to separate the electron signal from the hadronic background

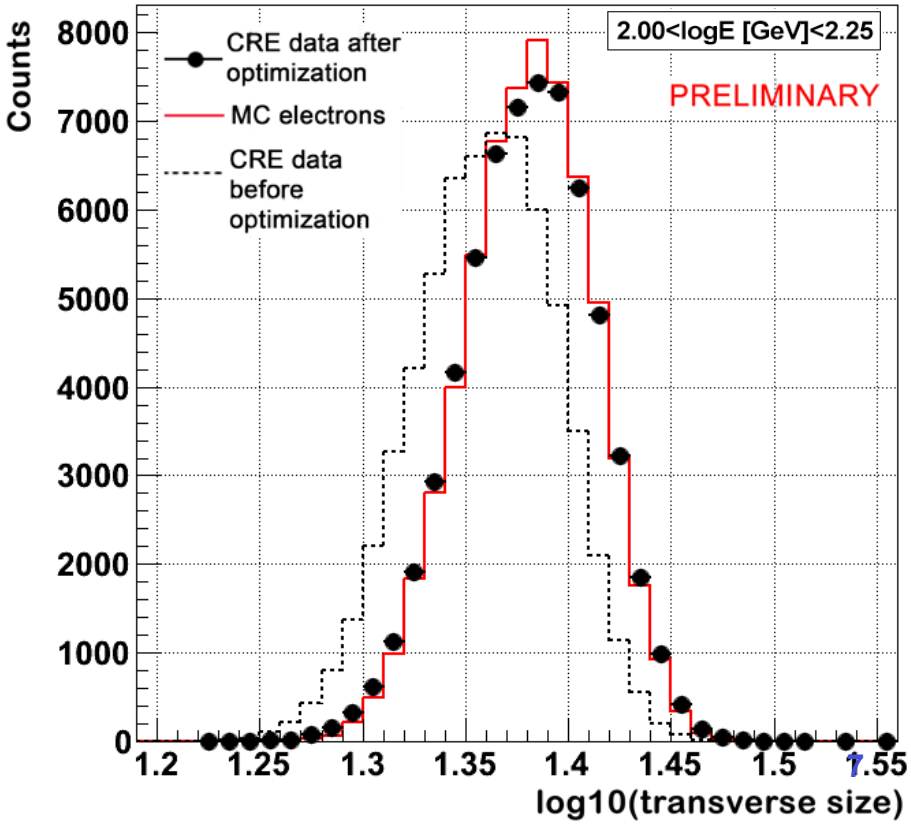
Selection of variables

- Variables chosen according to: good MC-data agreement and high separation efficiency

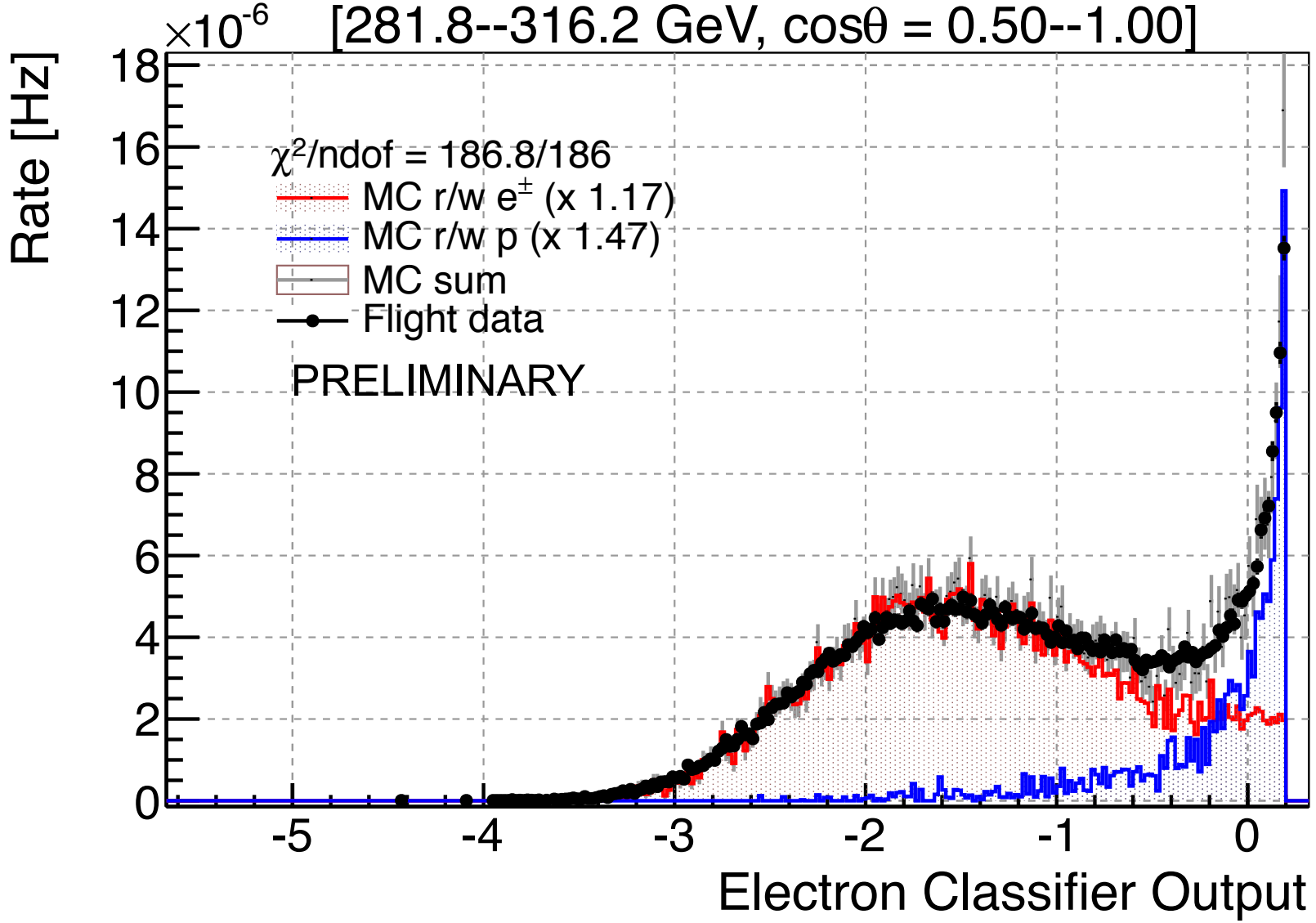
- Separation efficiency improved after correcting some observables for **geometry** dependence



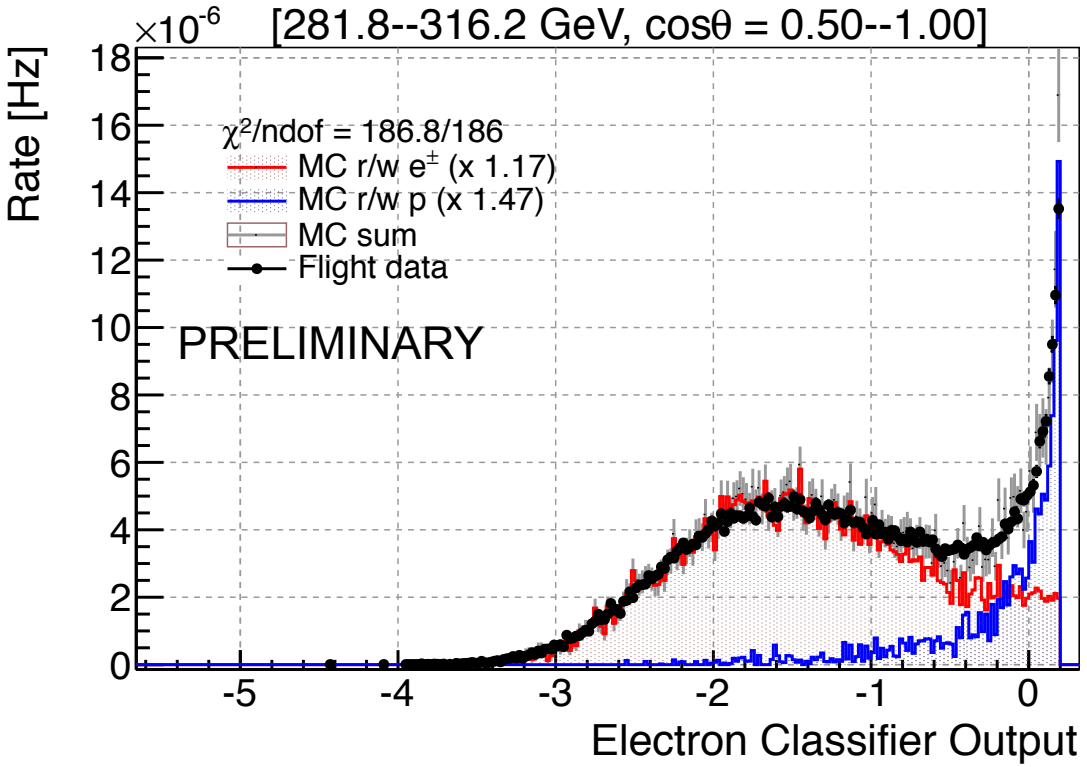
- MC-data agreement optimized after correcting for **energy** and **incidence angle** dependences



Probability variable

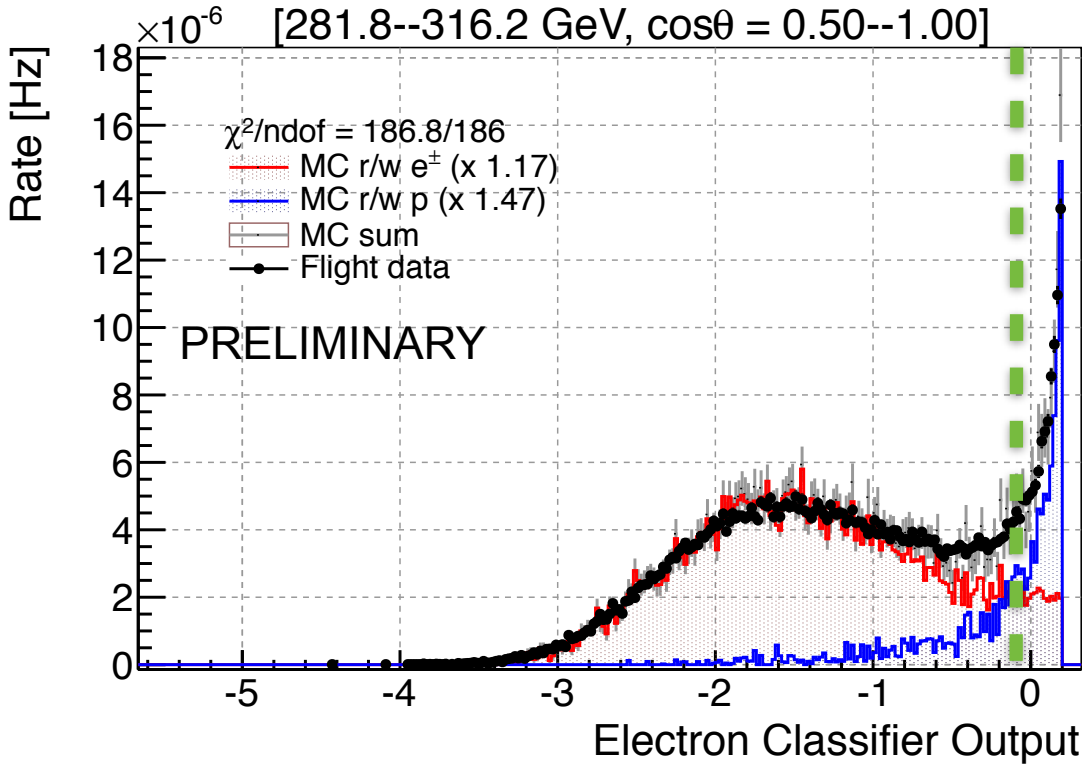


a. Template fitting

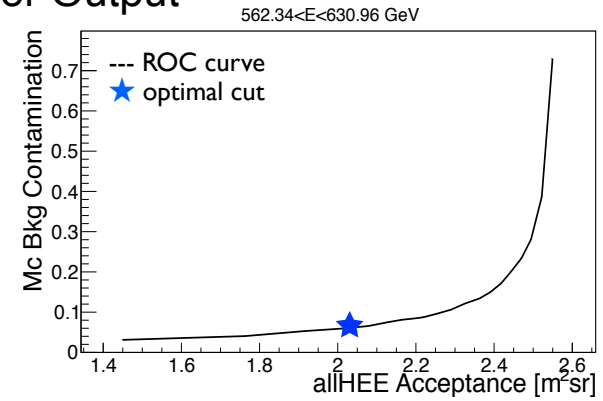


- **Fit the data with the MC electron and proton template**
  - signal rate = (rate from flight data) x (fraction of electrons from MC)
  - use that rate for the spectrum directly!
- **MC proton template** (i.e. parameterization of AMS-01) is renormalized and fit to the data in each energy bin

b. Bkg subtraction

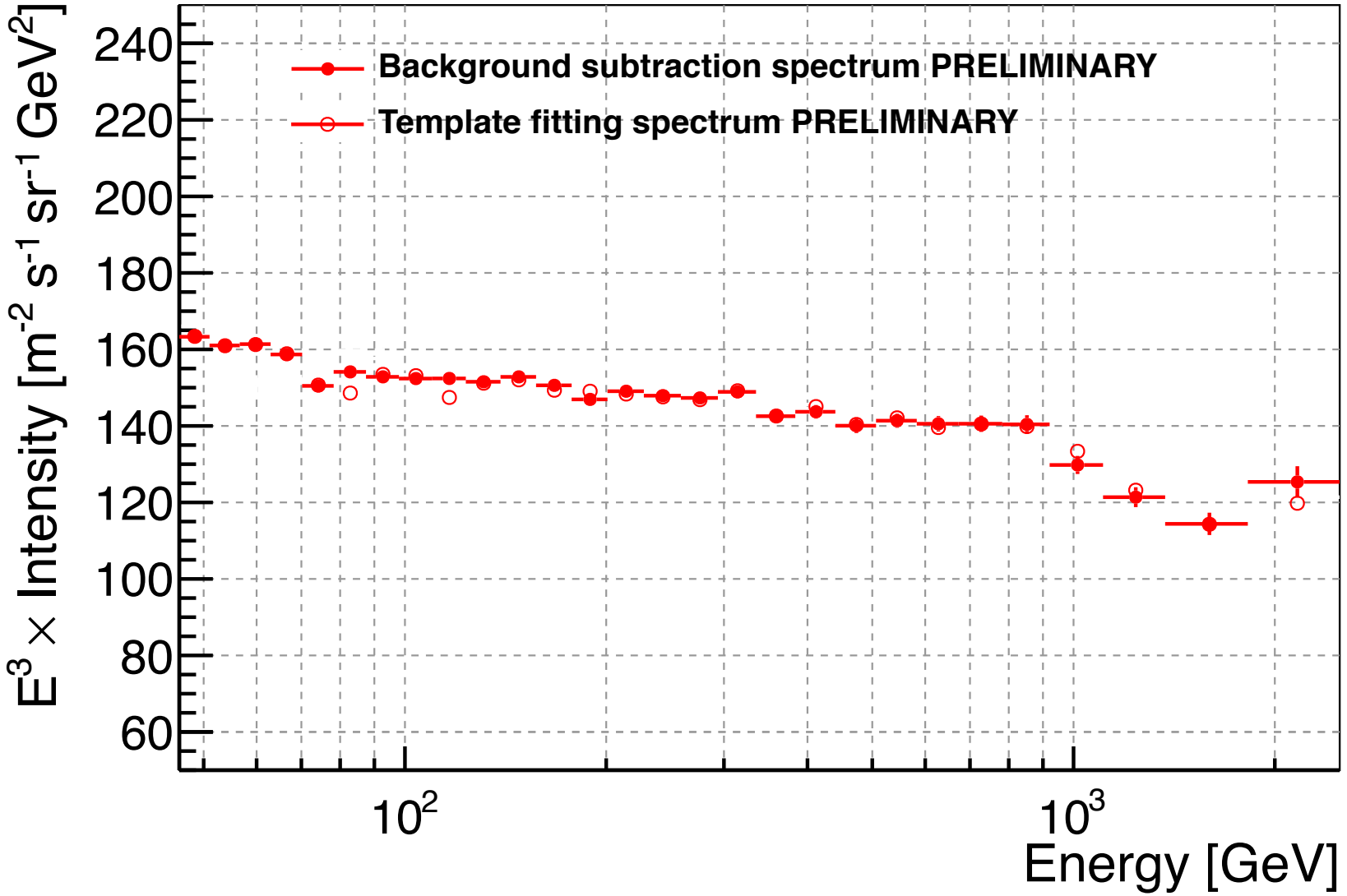


- **Cutting on the CT probability variable**:
  - **"optimal cut"** = point on the performance curve (ROC) in which the slope becomes greater than a defined threshold
  - fit the cut values as a function of energy
    → **analytical function of *Prob(E)***

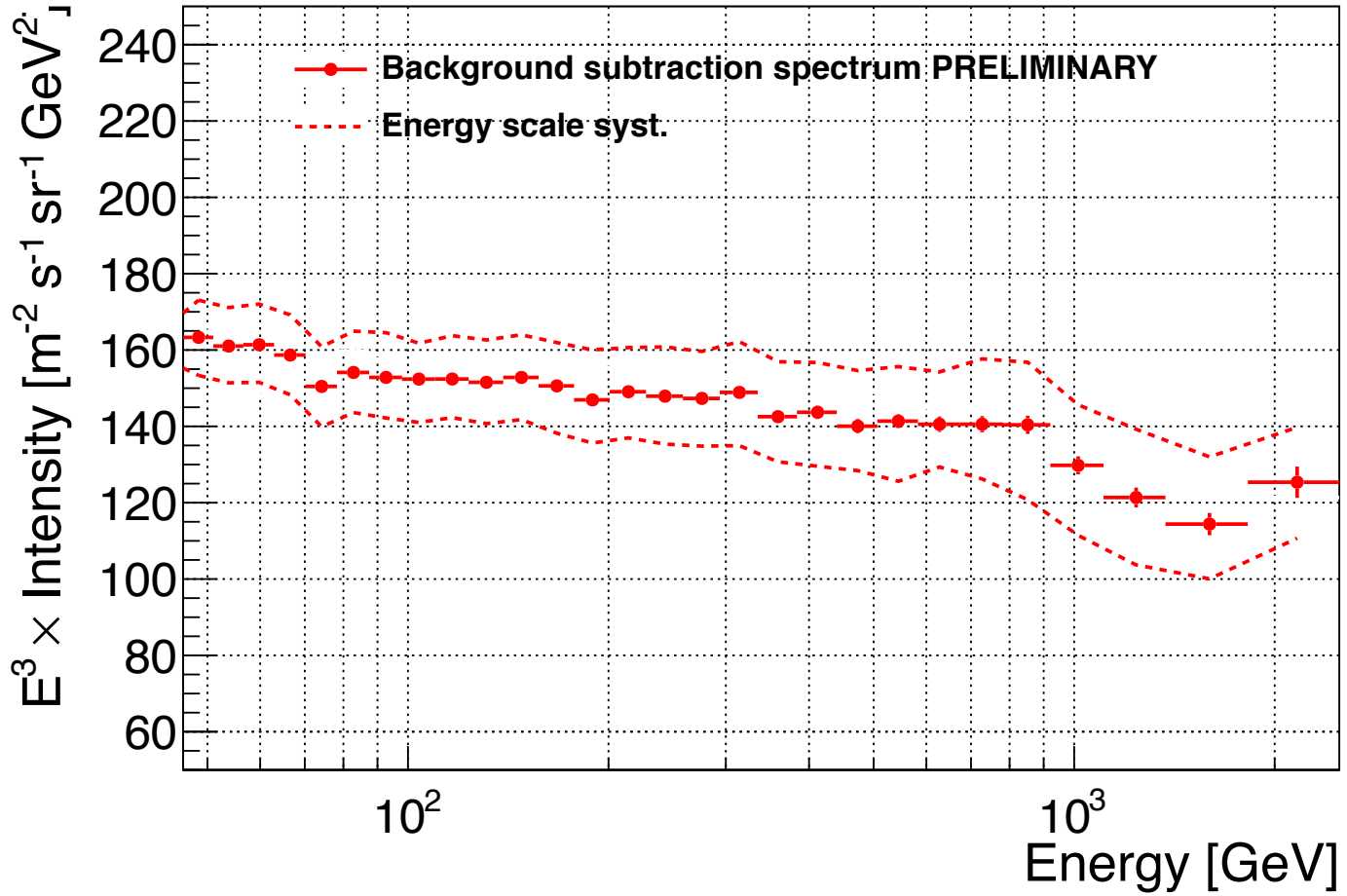


- Bkg contamination estimated after applying "correction" from template fitting

Resulting CRE spectra

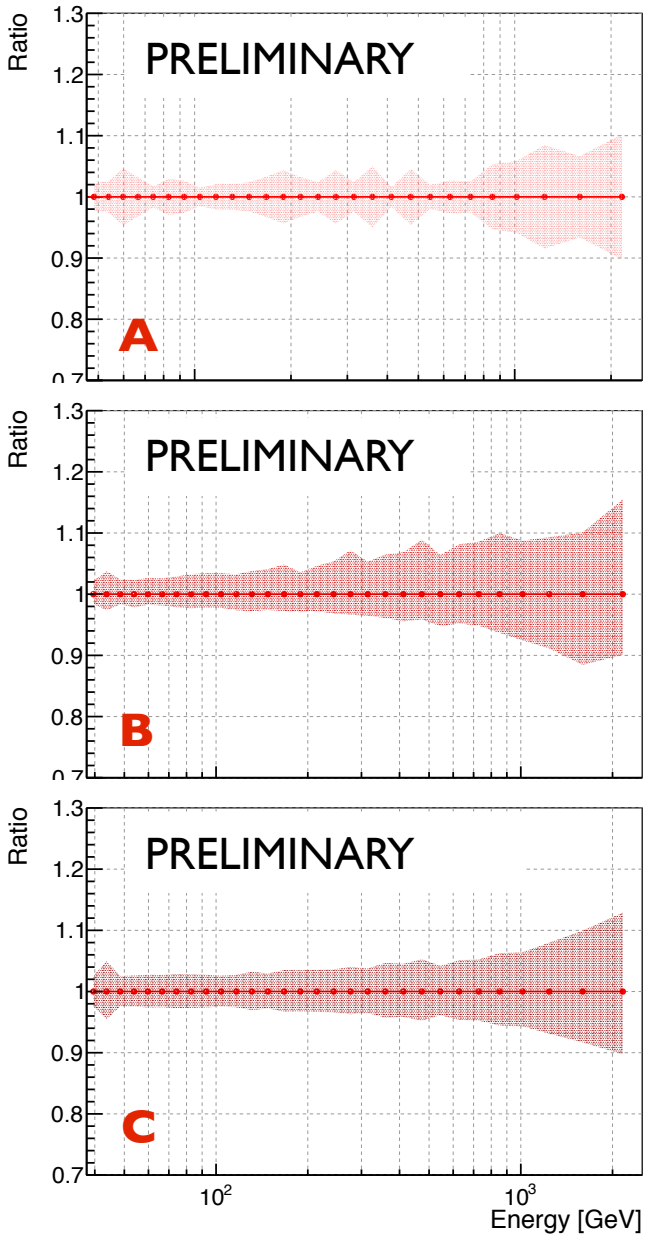


Energy scale systematics



- The uncertainty on the absolute energy scale is the **largest source of systematics**
- Pass 8 in-flight measurement of the absolute energy scale via geomagnetic cutoff study → **3.7% offset** around 10 GeV
- We have rescaled the whole spectrum by 3.7% and we have estimated the error on this scaling factor to be **2% at 10 GeV** and increasing up to **5% at ~ 1 TeV**

Other systematics



A) Event selection:

- main uncertainty at this level is due to the estimation of the effective area → we take it into account by varying the signal efficiency between 30% and 90%

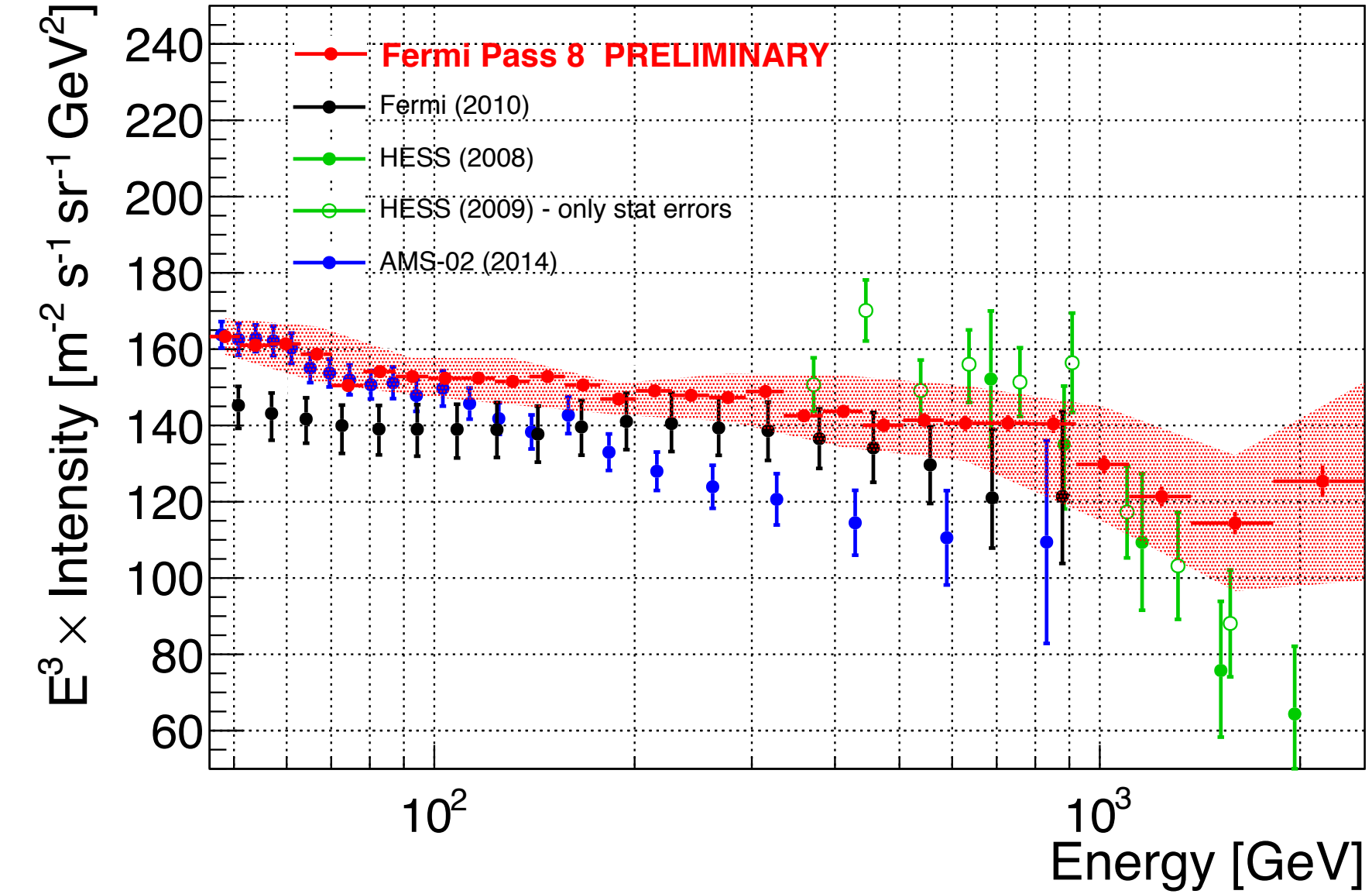
B) Correction factor:

- the band is calculated by moving the correction magnitude by one sigma

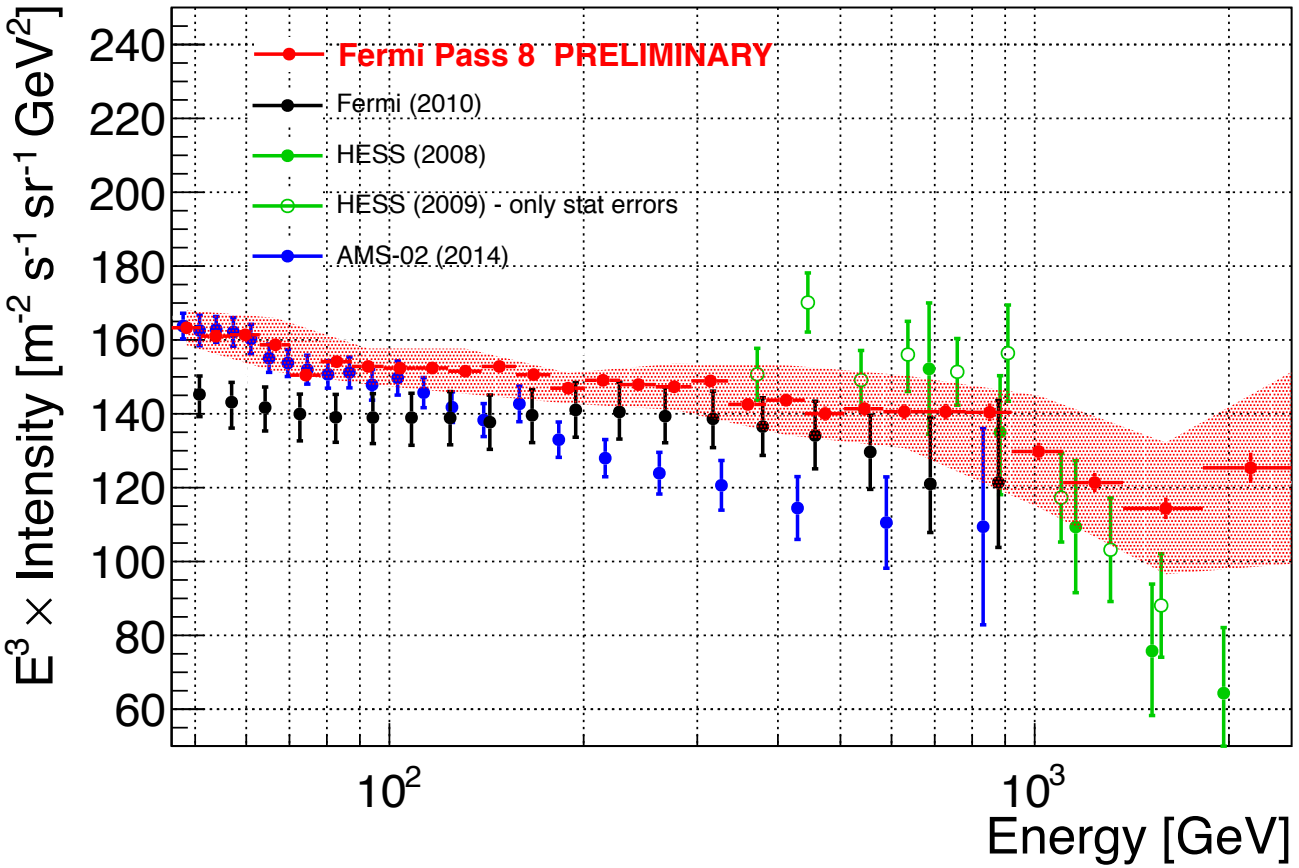
C) Bkg simulation reliability:

- the uncertainties related to the MC simulation of hadronic interactions could produce a 30% uncertainty on the residual contamination

CRE inclusive spectrum

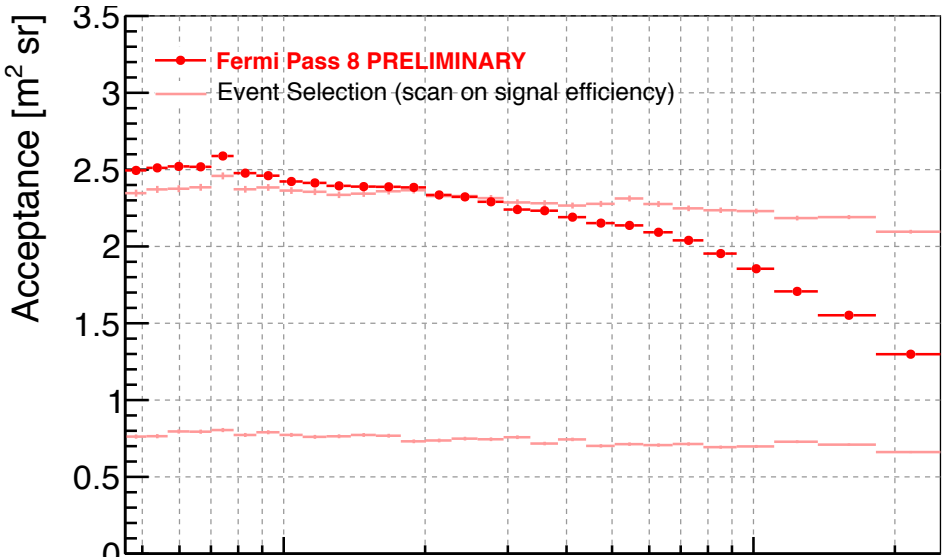


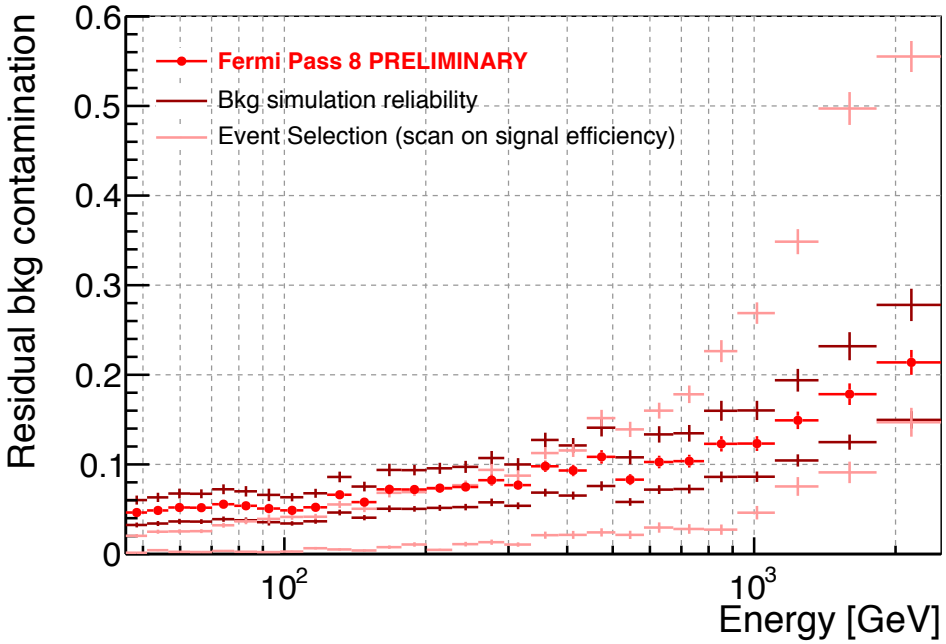
CRE inclusive spectrum



- Central points from the "optimal cut", the shaded band has been obtained by summing in quadrature all the studied systematics (except for the energy scale)
- Compatible with **AMS** up to ~ 100 GeV but different spectral index
- Disagreement wrt published spectrum (**Fermi 2010**):
  - likely due to "ghost" signal not taken into account in the acceptance in our first analysis

Instrument response





- **Acceptance** resulting after applying the "optimal cut"

  +

  - acceptances resulting by varying the signal efficiency between 30% and 90% also shown

- **Contamination** below 20% when applying the "optimal cut"

  +

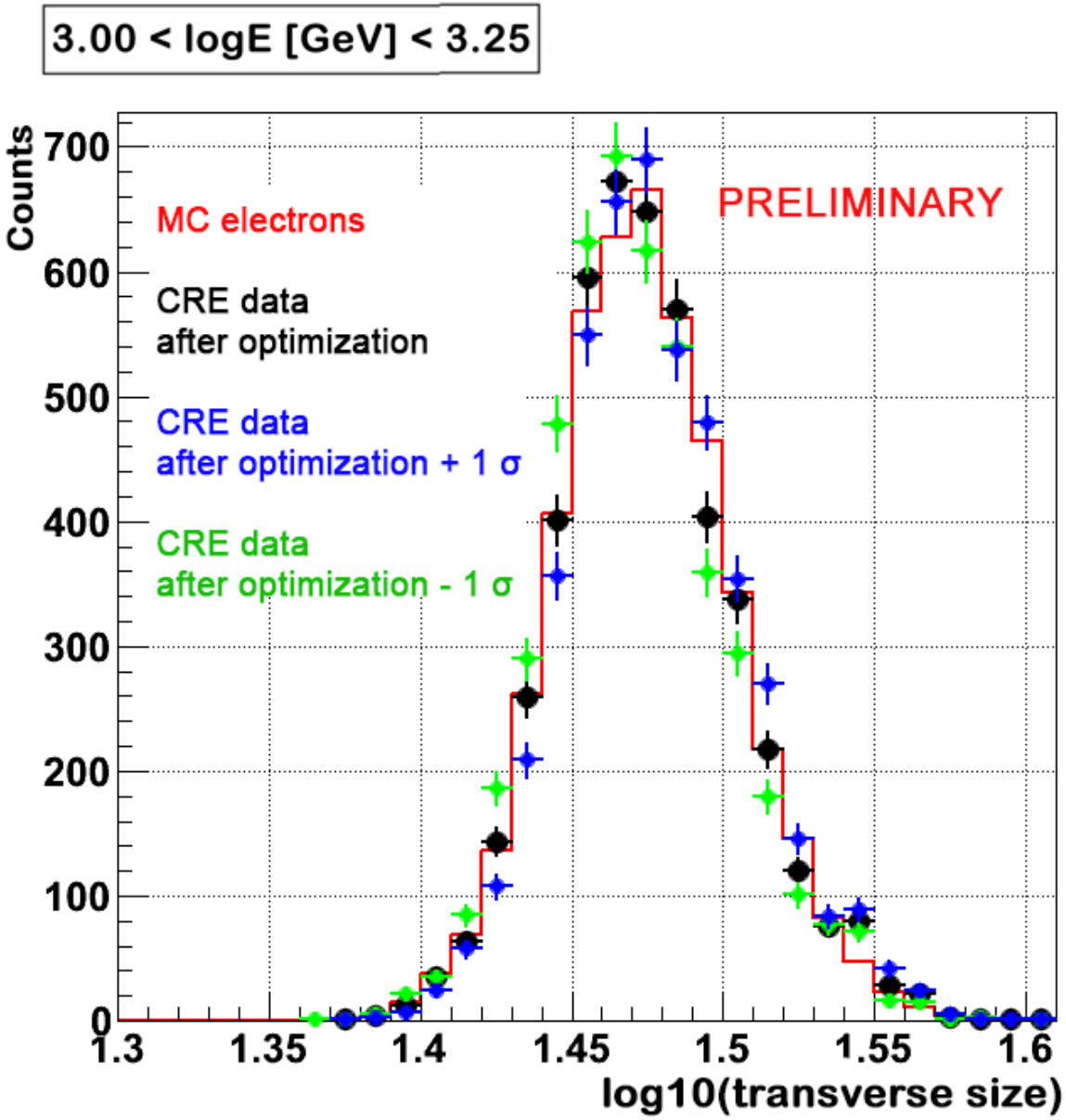
  - contamination resulting by varying the signal efficiency between 30% and 90%
  - contamination resulting by taking into account the bkg simulation reliability

Conclusions

- **We performed a new measurement of CRE spectrum with Pass 8**
- **Improvements in the new analysis:**
  - almost 7 times the PRD data set
  - new event reconstruction & selection (Pass 8)
  - new multi-variate analysis tool
  - new selection of variables → variables are now "calibrated"
  - new CTs trained in energy bins → training optimized for the whole energy range
  - ➡ **new CRE spectrum** and associated systematics
- See also the posters:
  - More **technical details** on the event selection and systematics (*M.Negro et al - Diff.6*)
  - Analysis extended down to **7 GeV** by including the DGN filter effect (*A. Manfreda et al - In/An.10*) → in the overlapping energy region it's in agreement with this one
  - Cross-check the **energy scale** at TeV energies by measuring the Earth Limb spectrum (*F. Spada et al - In/An.7*)
  - Study CRE **anisotropies** to validate possible astrophys. interpretations (*N. Mazziotta et al - Diff.5*)
  - Viable **interpretations** of our CRE spectrum (*F. Donato et al - Diff.3*)

BACKUP SLIDES

Systematics: corr. factor



Pre-cuts

- **PRECUTS** = TRIGGER FILTER + QUALITY CUT + ALPHA CUT
  - **TRIGGER FILTER:** the event triggers the LAT and passes the on-board gamma filter *'(GltGemSummary&0x20)==0 && (GltGemSummary&0x40)==0 && FswGamState == 0'*
  - **QUALITY CUT:** the event has at least a reconstructed track, a minimal PSF quality and the path length in the Cal is larger than the Cal on-axis thickness *'EvtCalCsIRLn>8 && CalLRawEnergySum>5000 && TkrNumTracks>0 && WP8CTPSFTail>0.05'*
  - **ALPHA CUT:** MC doesn't reproduce accurately interactions of α and heavy ions in the LAT → cut removing the majority of α and heavies