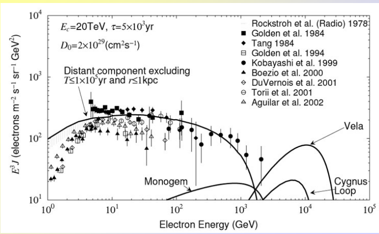
LAT perspectives in detection of high energy cosmic ray electrons

Alexander Moiseev (CRESST/USRA/GSFC), J.F. Ormes (University of Denver) and Stefan Funk (SLAC)

Abstract. **The LAT science objectives and capabilities in the detection of high energy electrons in the energy range from 20 GeV to ~1.5 TeV are presented. LAT simulations are used to establish the event selections. It is found that maintaining the efficiency of electron detection at the level of 30%, the residual hadron contamination does not exceed 2-3% of the electron flux. It is expected to collect ~ ten million of electrons with the energy above 20 GeV for one year of observation. Precise spectrum reconstruction with collected electron statistics opens the unique opportunity to investigate several important problems such as models of IC radiation, revealing the signatures of nearby sources such as high energy cutoff in the electron spectrum, testing the propagation model, and search for KKDM particles decay through their contribution to the electron spectrum.**

What can be learned from HE electrons (> 10 GeV) ?



Data points represent All available experimental data on HE electron flux. Not too much?

Data scattering allows for different speculations. Much better precision is needed!

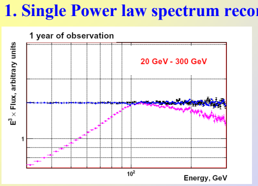
Precise measurement of electron spectrum above 10 GeV addresses the topics (see accompanying poster by Ormes and Moiseev for more details):

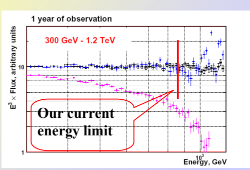
- **CR propagation model – observed electron spectrum is very sensitive to the cosmic ray propagation parameters (see e.g. Aharonian & Atoyan, Nishimura et al.)**
- **IC gamma ray flux model calibration, (GALPROP, Moskalenko & Strong)**
- **HE electrons origin: Search for the signature of nearby HE electrons sources (believed to be SNR) in the electron spectrum above ~ TeV**
- **Search for Dark Matter Signatures (KKDM) – above ~100 GeV (see e.g. Baltz & Hooper, 2004)**
- **Search for anisotropy in HE electron flux : nearby sources, streaming of local magnetic fields? (see e.g. Ptuskin & Ormes, 1995)**

Our task is to prepare the tools to be ready for selecting HE electrons from the flight data and analyze them. All listed topics require the accurate measurement of the electron spectrum

Two examples of How the data might look like after selecting electrons:

1. Single Power law spectrum reconstruction





We applied obtained energy reconstruction and collecting power for electrons to the single power law electron spectrum (α=-3) to demonstrate LAT ability to reconstruct the electron spectrum for 1 year of observation (1.4×10^7 generated events above 20 GeV)

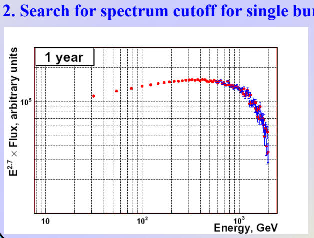
Black points represent incident electron flux as it would be detected by LAT with unbiased energy reconstruction and energy independent collecting power

Magenta points represent the data would be obtained with our analysis (cuts)

Blue points – after our energy and flux reconstruction

Need to improve our cuts to increase collecting power for E>500-700GeV

2. Search for spectrum cutoff for single burst-like galactic source (SNR)



This example is for the "old" source (~10^5 years old) with energy cutoff at ~ 2 TeV. If this is the only "contributing" nearby source, it would be clearly and reliably identified for 1 year of LAT observation (data points are in red, and error bars according to anticipated statistics – in blue), assuming <20% energy resolution and good energy calibration at high energy

Expected number of detected electrons for 1 year of observation (with our current cuts):

> 20 GeV	~ 10^7
> 100 GeV	~ 4 ×10^5
> 500 GeV	~ 2,500

Summary

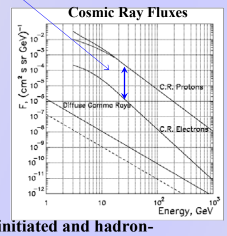
- **Electron spectrum can be well reconstructed up to ~1 TeV with 1 year data**
- **Remaining proton contamination is ~ 3% of the detected electron flux**

Nearest future work:

- **Start using Classification tree technique to improve electron cuts and G(E)**
- **Develop the energy reconstruction technique for high energy events (> ~ 700 GeV)**

Exploring LAT Capability to detect HE electrons

- **Being a gamma-ray telescope, LAT is already an excellent detector of electrons**
- **The main problem is to separate electrons from all other species; Proton-electron separation power above 10 GeV is needed to be 10^3 – 10^4 to have not more than 10% proton contamination in measured electron flux. Gammas can be removed by the ACD**

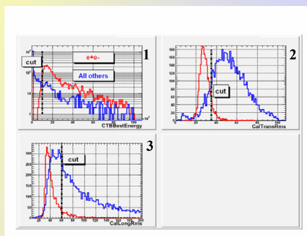


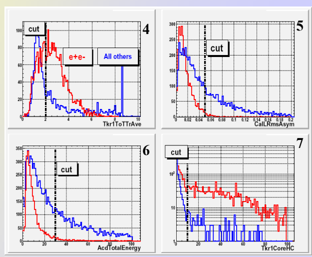
- **We explored LAT's capability to detect electrons in the energy range from 10 GeV to ~1500 GeV. We developed the cuts with which we observe reasonable flux reconstruction for electrons up to ~700 GeV; above this energy the resolution quickly degrades**
- **residual proton contamination is ~ 3% of the electron flux after applying our cuts (see Table below)**

Our high energy electrons selections:

Approach: Utilization of the difference between electron-initiated and hadron-initiated event patterns in LAT:

- **LAT includes configurable trigger mode that sends all events with energy > 10-20 GeV in calorimeter to the ground for further analysis. Our data will be in the set with this trigger.**
- **no problem with albedo, geomagnetic variation or with SAA**





Selection Group 1 (panel 1). Remove events which passed the LAT without interaction or interacted too deep in the calorimeter (CTBBestEnergy > 10 GeV). Removes ~75% of all hadrons

Selection Group 2 (panels 2 and 3). Electron-initiated shower in calorimeter is much more compact (dense) than most of hadron-initiated events. Remove events which have scattered hit crystals at some distance from shower axis (CalTransRms, CalLongRms, CalXtalRatio)

Selection Group 3 (panel 6). Hadron-initiated events have larger number of backward moving charged particles which create excessive hits in the ACD – remove events with large energy deposition in ACD tiles (AcdTotalEnergy)

Selection Group 4 (panel 5). Use asymmetry of the shower shape in calorimeter – most hadron-initiated events have larger asymmetry (CalLRmsAsym)

Selection Group 5 (panels 4 and 7). Select events which interact in the tracker – very powerful cut to separate electrons from hadrons, but of course it also removes many electrons (Tkr1ToTTrAve, Tkr1CoreHC)

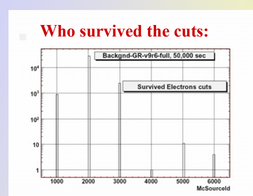
Selection Group 6. Select events with the path in the calorimeter to be longer than 8 X_0 – to improve energy resolution

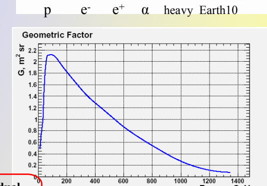
Efficiency of electron cuts

Selection	e^- and e^+ passed selections	All other species passed selections	Residual contamination in (e^- and e^+) flux
10 GeV < McEnergy < 500 GeV	1.0	1.0	0.971
10 GeV < CTBBestEnergy < 500 GeV	0.74	0.25	0.918
CalTransRms*CalLongRms< 1300+0.00142*CTBBestEnergy	0.60	0.021	0.542
AcdTotalEnergy < 30	0.55	0.011	0.409
CalXtalRatio < 0.25	0.53	0.009	0.355
CalLRmsAsym < 0.05	0.52	0.0074	0.321
Tkr1ToTTrAve > 2	0.36	0.0011	0.090
Tkr1CoreHC > 10	0.30	0.0003	0.028
CalTotRLn > 8	0.29	0.00025	0.028

Residual proton contamination

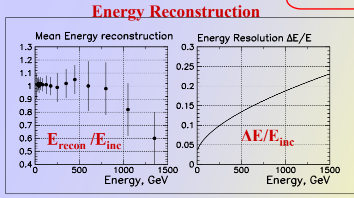
Who survived the cuts:





Simulated results for collecting power: it is tuned well for 100-200 GeV; need work on electron cuts to improve for high energy

Energy Reconstruction



Authors are grateful to C&A working group and all LAT collaborators for support and excellent analysis tools!