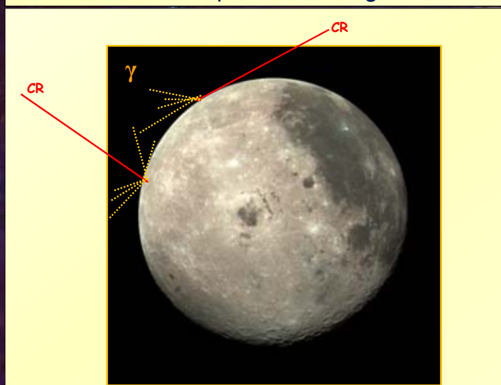
Gamma-ray Emission from the Moon as observed by FERMI

M. Brigida (Dipartimento Interateneo di Fisica "M.Merlin", Università di Bari)
on behalf of the *Fermi*-LAT Collaboration

Abstract: The large Area Telescope (LAT) on board the Fermi satellite is exploring the gamma-ray sky in the enrgy range from 20 MeV to > 300 GeV. Since the start of the science phase of the mission the LAT has detected high-energy gamma ray from the Moon. This mission is produced by interaction of cosmic-ray nuclei with the lunar surface and depends on the level of the solar activity.
Moon was detected by EGRET on CGRO with low statistics, but Fermi is the only gamma-ray mission capable of detecting the Moon over the full 24^{th} cycle. Here we report the detection of gamma-ray emission from the Moon during the first monthe of observation showing the status of the analysis and interpretation.

The gamma-ray emission produced by solid solar system bodies is due to the interactions of Galactic cosmic ray nuclei (mainly protons) with their surface layers.The main processes involved are the production and decay of neutral pions and kaons by ions, bremsstrahlung by electrons and Compton scattering of the secondary photons.



The Gamma-ray telescope EGRET on the Compton Gamma-Ray Observatory detected the gamma-ray emission from the Earth [1], the Moon [2, 3], and the Sun [2]. The Moon is so far the only observed gamma-ray emitting body with the solid surface. For the Sun the gamma-ray emission from the disk, due to the interactions of cosmic ray nuclei with the solar atmosphere [2, 5], is accompanied by extended and brighter gamma-ray emission due to the inverse Compton scattering of Galactic cosmic ray electrons of solar photons [2, 6, 7].
Recent reanalysis of EGRET observation of the Moon confirmed the detection and yielded a flux F(E > 100 MeV) = (5.55 ± 0.65) × 10−7 cm−2 s−1 averaged over the entire mission duration [2].

Large AreaTelescope (LAT)
20 MeV - >300 GeV

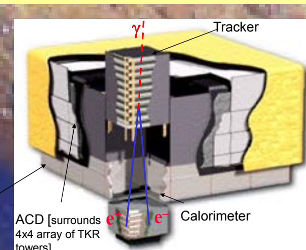
Gamma-ray Burst Monitor (GBM)
NaI and BGO Detectors
8 keV - 40 MeV

•*Launch 11 June 2008 at 12:05PM EDT*

•*Circular orbit, 565 km altitude (96 min period), 25.6 deg inclination.*

Quantity	Requirement	Minimum	EGRET
Mission Lifetime	>5 years	>2 years	
LAT High-latitude Point Source Sensitivity (E>100 MeV)	$<6\times10^{-9}$ cm^{-2}s^{-1}	$<6\times10^{-9}$ cm^{-2}s^{-1}	$\sim1\times10^{-7}$ cm^{-2}s^{-1}
LAT High-latitude Source Location Benchmark	<0.5 arcmin	<1 arcmin	5 arcmin
LAT Peak Effective Area	>8000 cm^2	>8000 cm^2	1500 cm^2
LAT Energy Range	<20 MeV - > 300 GeV	<30 MeV - >100 GeV	20 MeV-30GeV
LAT Background Rejection	<10% high-latitude diffuse	<20% high-latitude diffuse	<1%
LAT Energy Resolution (on-axis, 100 MeV – 10 GeV)	<10%	<20%	10%
LAT Field of View	>2 sr	>1.5 sr	0.5 sr

Large Area Telescope (LAT)



References
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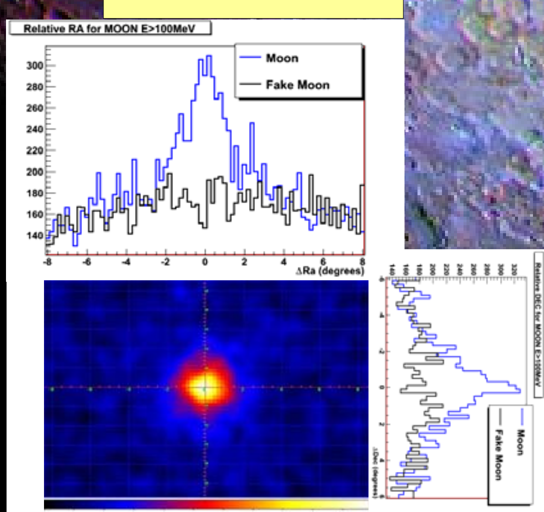
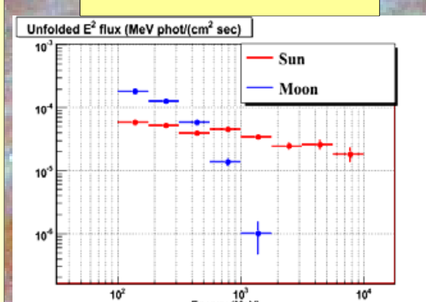
Moon counts map



The spectrum of gamma-rays from the Moon is steep with an effective cutoff around 3–4 GeV (600 MeV for the inner part of the lunar disk). Due to the kinematics of the collision, the secondary particle cascade from cosmic ray particles hitting the lunar surface at small zenith angles develops deep into the rock making it difficult for gamma-rays to get out. Therefore the lunar gamma-ray emission is produced by a small fraction of splash albedo particles in the surface layer of the Moon rock. High energy gamma-rays can be produced by cosmic ray particles hitting the Moon surface with a more tangential trajectory; thus only a very thin limb contributes to the high energy emission.

Moon and Sun Spectra



The average integral flux mesured with the LAT from the beginning of the mission to May 2010 for E>100MeV is:
F = (1.21 ± 0.02 ± 0.2) × 10^{-6} cm^{-2}s^{-1}
Paper in pubblication.