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Book of Abstracts

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What can we learn from a sharply faling positron fraction?

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Recent results from the AMS-02 data have confirmed that the cosmic ray positron fraction increases with energy between 10 and 200GeV. This quantity should not exceed 50%, and it is hence expected that it will either converge towards 50% or fall. We study the possibility that future data may show the positron fraction dropping down abruptly to the level expected with only secondary production, and forecast the implications of such a feature in term of possible injection mechanisms that include both dark matter and pulsars.

Modeling: particle acceleration and propagation / 1

Anisotropic Cosmic Ray Diffusion and its Implications for Gamma-Ray Astronomy

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Analyses of TeV-PeV cosmic ray (CR) diffusion around their sources usually assume either isotropic diffusion, or anisotropic diffusion due to the regular Galactic magnetic field in the spiral arms of our Galaxy. We show that none of these descriptions is adequate on distances smaller than a few coherence lengths (˜ 10 pc) of the turbulent interstellar magnetic field.
As a result, we predict anisotropic gamma-ray emissions around CR proton and electron sources (even for uniform densities of target gas). The centers of extended emission regions may have non-negligible offsets from their sources, leading to risks of misidentifications. Gamma-rays from CR filaments have steeper energy spectra than those from surrounding regions.
We show that gamma-ray telescopes can notably be used in the future as a new way to probe the still poorly known interstellar magnetic fields.
Finally, we discuss the impact of CR-driven instabilities on the above results, and on the magnetic fields around CR sources.

The galaxy in gamma rays / 2

Comparison of the expected and observed supernova remnant counts with Fermi/LAT

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SNRs are commonly believed to be the accelerators of the galactic cosmic rays – mainly protons – and are expected to produce γ-rays through the inelastic proton-proton collisions. Fermi/LAT was expected to detect many of those, but only a dozen is listed in the most up to date Fermi/LAT 2nd Source catalogue. To test whether the observed number of SNRs is in agreement with the assumption that they are indeed the sources of the galactic cosmic rays, we use a simplified model of a SNR and calculate the predicted amount of the observable remnants taking into account their distribution in the Galaxy and the sensitivity of Fermi/LAT. We find that the observed number of SNRs agrees with the prediction of our model if we assume a low, $\ll 1\ \mathrm{cm}^{-3}$, number density of the SNR's ambient medium.

Summary:

The results, presented here, agree well with the assumption, that on average the supernova explosions happen in the under-dense regions, such as bubbles, creating by the winds of the progenitor stars. Under this natural assumption our results find an agreement with the assumption, that the observed population of supernovae remnants is indeed responsible for the production of the galactic cosmic rays.

Galactic cosmic rays: spectrum / composition / anisotropy / **3**

Latest results from the AMS-02 experiment

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The AMS-02 detector is a general purpose particle physics detector installed on the International Space Station to perform a unique long duration mission of fundamental physics research in space. The detector is operating at an altitude of 400 km, detecting cosmic rays in the GeV to TeV range, before they interact with the Earth atmosphere. The main goals of the experiment include the precise measurement of the cosmic rays fluxes, the search for primordial antimatter and indirect search for dark matter, as well as the study of the cosmic rays propagation.

Summary:

The AMS-02 detector is a general purpose particle physics detector installed on the International Space Station to perform a unique long duration mission of fundamental physics research in space. The detector is operating at an altitude of 400 km, detecting cosmic rays in the GeV to TeV range, before they interact with the Earth atmosphere. The main goals of the experiment include the precise measurement of the cosmic rays fluxes, the search for primordial antimatter and indirect search for dark matter, as well as the study of the cosmic rays propagation. We present the measurement of the positron fraction from 0.5 to 500 GeV, based on 10.9 million events. This measurement is currently exploring the highest energy ever achieved: it can be seen, for the first time, that above 200 GeV the positron fraction is no longer dependent on energy. Moreover, within the sensitivity of the detector, the positron fraction is isotropic. The electron and the positron flux are also shown as a function of energy. They are different in magnitude and their spectral indices are different. Moreover, they both cannot be described by a single power law. The combined electron plus positron flux, from 0.5 to 1 TeV, is also presented, being compatible with a single power law.

The galaxy in gamma rays / **4**

Revealing Cosmic-Ray acceleration in the SNR W51C

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SNR are commonly assumed to accelerate the cosmic rays of E < 1 PeV observed at Earth. SNRs that interact with molecular clouds (MCs) are very promising targets to distinguish between leptonic and hadronic-induced gamma-ray emission. One of the brightest Fermi/LAT-detected SNRs interacting with a MC is W51C. Here we present a very detailed analysis of 5 years of Fermi/LAT data revealing a very significant low-energy break in the gamma-ray spectrum associated with the production threshold of neutral pions. This unmistakable feature of CR-acceleration in W51C is further investigated and we present a detailed modelling of the source with various gamma-ray production mechanisms. We finally compare the derived properties of W51C with those of the other known CR accelerators W44 and IC443.

The galaxy in gamma rays / 5

Lessons from the remote detection of Galactic cosmic rays

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The gamma radiation spawn by cosmic rays along their interstellar journey has received much attention over the years as an efficient means to trace the evolution of the cosmic-ray flux and spectrum on kiloparsec scales across the Milky Way.
The data are interpreted in the framework of an elementary scenario which involves cosmic-ray production by diffusive shock acceleration in supernova remnants, a nearly black box for their escape from the source, followed by diffusion at large with energy-dependent, but often spatially uniform diffusion properties. The abundance and quality of the Fermi LAT data allow us to test this scenario and we (happily) start to see a few cracks that I will review: detection or not of irradiated clouds near supernova remnants, cocoon of fresh cosmic rays in OB associations, cosmic-ray gradient problems in and out of the Galactic plane.

Modeling: particle acceleration and propagation / 6

Modeling cosmic ray propagation in the Galaxy

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At GeV-TeV energies the propagation of CRs is diffusive. Current models of galactic propagation are based on a simplified approach for which diffusion is constant and isotropic.
In fact, diffusion transport must be described as in-homogenous and anisotropic and experimental data have now reached an accuracy that allows to study such effects.
In my talk, I will present some of the consequences of adopting realistic diffusion models for the propagation of galactic CRs, and I will show how these models allow a better understanding of local observations and diffusion emissions within an unified framework.

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Variability of the γ-ray emission from the binary PSR B1259-63

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We examine temporal evolution of the observed γ-ray intensity from the direction of the binary PSR B1259-63 using only numbers of detected very high energetic photons.
Simple and straightforward method is applied to the published data obtained with the Imaging Atmospheric Cherenkov Technique during campaigns around three periastron passages of the binary system.
Changes attributable to the variations of the intrinsic source activity were recognized at high levels of significance.

The galaxy in gamma rays / **8**

The Gamma-Ray Sky as Seen with HAWC

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The High-Altitude Water Cherenkov (HAWC) TeV Gamma-Ray Observatory located at a site about two hours' drive east of Puebla, Mexico on the Sierra Negra plateau (4100 m a.s.l.) will be inaugurated in March 2015. The array of 250 water Cherenkov detectors can observe large portions of the sky simultaneously and, with an energy range of 100 GeV to 100 TeV, is currently one of the most sensitive instruments capable of probing particle acceleration near PeV energies. HAWC has already started science operation in Summer 2013 and preliminary sky maps have been produced from 260 days of data taken with a partial array. Multiple > 5 σ (pre-trials) hotspots are visible along the galactic plane and some appear to coincide with known TeV sources from the H.E.S.S. catalogue, SNRs and molecular cloud associations, and pulsars wind nebulae (PWNe). The data have also been searched for high-energy emission from GRBs detected at lower energies. I will discuss the latest maps of HAWC and the scientific potential of the instrument especially in the context of multi-wavelengths studies.

Multi-wavelength and Multi-messenger search for cosmic ray sources / **9**

Cosmic rays acceleration in stellar wind collisions

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Eta Carinae is the colliding wind binary with the largest mass loss rate in our Galaxy and the only one in which hard X-ray and gamma-ray emission has been detected. Eta Carinae is therefore a primary

candidate to search for particle acceleration. We present preliminary gamma-ray data covering two periastron passages. The source variability can be compared with the results of hydrodynamic simulations. The energy transferred to the accelerated hadrons (~ 5% of the collision mechanical energy) is comparable to that of the thermal X-ray emission. The colliding winds could accelerate as much cosmic rays as a supernova remnant. Extrapolation to OB association will be explored.

Galactic cosmic rays: spectrum/ composition / anisotropy / **13**

The Astrophysics of Cosmic Ray Anisotropy

Author: Paolo Desiati[1]

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This is a review of the observations of cosmic ray anisotropy in a wide energy range, spanning from sub-TeV to EeV energy range. The observations will be described, addressing the different experimental techniques used at the various energy ranges, and stressing the potential physical mechanism they are able to probe. Proposed scenarios that address the origin of the cosmic ray anisotropy will be reviewed as well. The interpretations of experimental results will have to rely on a multi-displininary approach in order to disentangle different physics processes that simultaneously affect the transport of cosmic rays in magnetized plasmas. Using cosmic rays to probe the properties of magnetic fields at different scales and to pinpoint to the origin of cosmic rays are among the main drivers.

Galactic cosmic rays: spectrum / composition / anisotropy / **14**

One Century of Cosmic Rays

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Galactic cosmic rays: spectrum / composition / anisotropy / **15**

Results from the PAMELA space experiment

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The Pamela spectrometer was launched in 2006 from the cosmodrome of Baikonur, Kazakistan, on board the Russian satellite Resurs-DK1. Since then, it has been collecting cosmic rays from its 70 degrees inclination, 600 km altitude polar orbit. This orbit allows to sample particles of trapped, semi-trapped nature in the Earth geomagnetosphere, of solar origin (emitted in solar particle events), of galactic origin (modulated by solar activity). Antiparticles of galactic origin can constrain and provide information on the dark matter component in the galaxy. Furthermore the Proton and Helium spectra provide detail information on the acceleration and propagation processes in the galaxy. At lower enegy, particles of solar and trapped nature provide crucial clues on the acceleration and propagation processes in the Heliopshere. In this talk we will discuss some of these recent results of Pamela and the implication for various fields of research

Galactic cosmic rays: spectrum / composition / anisotropy / **16**

All-particle cosmic ray spectrum measured with IceTop

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Origin of Galactic Cosmic Rays

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Multi-wavelength and Multi-messenger search for cosmic ray sources / 20

Search for galactic cosmic ray sources: a multi-wavelength approach

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Modeling: particle acceleration and propagation / 22

Acceleration of cosmic rays and gamma-ray emission from supernova remnants and molecular clouds

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Parametrization of gamma-ray production cross-sections for pp interactions in a broad proton energy range from the kinematic threshold to PeV energies

Author: Andrew Taylor[1]

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Using different Monte Carlo codes such as Geant 4.10, Pythia 8.18, SIBYLL and QGSJET, as well as compiling published data on *pp* interactions close to the kinematic threshold, we parametrize the energy spectra and production rates of gamma-rays by simple but quite accurate ($\leq 20\%$) analytical expressions in a broad range from the kinematic threshold to PeV energies.

The galaxy in gamma rays / 25

The Cygnus region of the Galaxy: A VERITAS perspective

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The Cygnus-X star-forming region ("Cygnus") is the richest star-forming region within 2 kpc of Earth and is home to a wealth of potential cosmic ray accelerators, including supernova remnants, massive star clusters, and pulsar wind nebulae. Over the past five years, discoveries by several gamma-ray observatories sensitive in different energy bands, including the identification by Fermi-LAT of a potential cocoon of freshly accelerated cosmic rays, have pinpointed this region as a unique laboratory for studying the early phases of the cosmic ray life cycle. From 2007 to 2009 VERITAS, a very high energy (VHE; E > 100 GeV) observatory in southern Arizona, undertook an extensive survey of the Cygnus region from 67 to 82 degrees Galactic longitude and from -1 to 4 degrees in Galactic latitude. In the years since, VERITAS has continued to accumulate data at specific locations within the survey region. We will review the discoveries and insights that this rich dataset has already provided. We will also consider the key role that we expect these data to play in interpreting the complex ultiwavelength picture we have of the Cygnus region, particularly in the vicinity of the Cygnus cocoon. As part of this discussion we will summarize ongoing studies of VERITAS data in the Cygnus region, including the development of new data analysis techniques that dramatically increase VERITAS' sensitivity to sources on scales larger than a square degree.

The galaxy in gamma rays / **26**

The H.E.S.S. Survey in the context of Galactic cosmic ray searches

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The H.E.S.S. Galactic Plane Survey was an ambitious observational program which spanned a period of over 10 years, finishing just recently in 2013. The rich data set accumulated covers nearly the entire Galactic plane visible from Namibia; has an unprecedented, deep sensitivity; and features an energy coverage and angular resolution which is well suited for the search for sources of Galactic cosmic rays. This talk will present the H.E.S.S. Survey from a perspective of that complex, elusive, and on-going search, highlighting some very recent discoveries which are helping to guide the way in the near future. A summary of the latest results from the upgraded H.E.S.S.-II array will also be given.

The future of gamma ray astronomy / **28**

The Cherenkov telescope Array

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The Cherenkov Telescope Array will be the first open access gamma-ray ground-based observatory. I will describe the project, its physics goals, its potential compared to existing experiments, its current status and the schedule.

Concluding remarks and discussion / **29**

Summary of the workshop

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Galactic cosmic rays: spectrum / composition / anisotropy / 30

The NUCLEON Space Experiment

Authors: Aleksey Pakhomov[1]; Alexandr Voronin[1]; Andrey Turundaevskiy[1]; Artur Tkachenko[2]; Danil Polkov[3]; Dmitriy Karmanov[1]; Dmitry Podorozhny[1]; Eduard Atkin[4]; Igor Kovalev[1]; Ilya Kudryashov[1]; Leonid Tkachev[2]; Lubov Sveshnikova[1]; Mikhail Merkin[1]; Mikhail Torochkov[1]; Nikolai Gorbunov[2]; Oleg Vasiliev[1]; Sergei Filippov[3]; Sergey Porokhovoy[2]; Vadim Bulatov[3]; Victor Grebenyuk[2]; Vitaly Shumikhin[4]; Vyacheslav Dorokhov[3]

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The NUCLEON satellite experiment is designed to investigate directly, above the atmosphere, the energy spectra of cosmic-ray nuclei and the chemical composition (Z=1-30) at energy range 100 GeV - 1000 TeV. The effective geometric factor is more than 0.2 m2sr for nuclei and 0.06 m2sr for electrons. The planned exposition time is more than 5 years.

Galactic cosmic rays: spectrum/ composition / anisotropy / 31

Measuring TeV Cosmic Rays at the HAWC Observatory

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The High-Altitude Water Cherenkov Observatory, or HAWC, is an air shower array in central Mexico designed to observe cosmic rays and gamma rays between 100 GeV and 100 TeV. HAWC will be completed in early 2015, but has been collecting data in a partial configuration since mid-2013. With only part of the final array in data acquisition, HAWC has already accumulated a data set of nearly 100 billion air showers. These events are used to calibrate the detector using the shadow of the Moon, and to measure the anisotropy in the arrival directions of the cosmic rays above 1 TeV. Using data recorded between June 2013 and July 2014, we have observed a significant 10^{-4} anisotropy consisting of three statistically significant "hotspots" in the cosmic ray flux. We will discuss these first results from HAWC and compare them to previous measurements of the northern and southern sky.

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Particle acceleration and radiation friction effects in the filamentation instability of pair plasmas

Author: Marta D'Angelo[1]

Co-authors: Andrea Macchi [2]; Andrea Sgattoni [3]; Francesco Pegoraro [4]; Luca Fedeli [4]

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Electron-positron pair plasmas are believed to play a role in a wide range of cosmic ray sources, including for example relativistic jets from Active Galactic Nuclei or wind outflows in Pulsar Wind Nebulae. One of the key points to understand cosmic ray acceleration is the generation of turbulent magnetic field near the shock front via plasma instabilities. In this work we investigate the development of the filamentation instability in counter-streaming pair plasmas, using particle-in-cell simulations (PIC) in both one and two spatial dimensions. Radiation friction effects on particles are taken into account. After an exponential growth of both the magnetic field and the current density, a nonlinear quasi-stationary phase sets up. This phase is characterized by filaments of opposite currents. During the nonlinear stage, a strong broadening of the energy spectrum occurs accompanied by the formation of a peak at twice the initial energy of the particles. A simple theory of peak formation is presented.

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On the CR spectrum released by a type II Supernova Remnant expanding in the presupernova wind.

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One of the main open issues about the origin of Galactic CRs is the maximum energy that can be achieved by acceleration in Supernova Remnants.
In a rigidity dependent acceleration mechanism, protons are expected to reach a few PeV and heavier ions correspondingly higher energies.
A recent theory suggests that, in a core-collapse SNR expanding in its pre-supernova wind, magnetic field amplification through the so called Non-Resonant Hybrid Instability (NRH) could explain energies of the PeV order. If this instability is the main responsible for particle scattering, then the maximum achievable energy in a SNR is reached very early during its evolution and then decreases at later stages.
In this work, assuming that the maximum energy is set by the NHR instability at every time during the evolution of a type II Supernova Remnant, we computed the particle spectrum injected in the ISM by this kind of source. We showed that the released particle spectrum is a power-law both during the Ejecta dominated and the Sedov-Taylor expansion phase, but with a steeper index during the first. We address the question of whether this mechanism can naturally reproduce the observed overallCR spectrum up to energies of order 100 PeV.

Multi-wavelength and Multi-messenger search for cosmic ray sources / **34**

High-energy Astrophysical Neutrinos in IceCube.

Author: Juan Antonio Aguilar Sanchez[1]

[1] *Unknown*

The IceCube Neutrino Observatory is a kilometer-scale neutrino telescope located at the South Pole underneath the Antarctic ice. In the last years IceCube has provided evidence of a diffuse flux component of high-energy astrophysical neutrinos at the level of 10-8 GeV cm-2 s-1 sr-1 per flavor. The origin of these neutrinos remains, however, unknown. Ongoing analyses are trying to solve this mystery by searching for spatial and timing correlations. I will discuss the latest results of the IceCube experiment and the possible interpretations about the origin of this high energy component. I will conclude with prospects of future upgrades of the IceCube experiment.

The galaxy in gamma rays / 35

High energy emission from the Galactic Center: theory and observations

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Co-authors: Andrii Neronov [2]; Denys Malyshev [3]; Roland Walter [2]

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Galactic Centre is a bright γ-ray source with the GeV-TeV band spectrum composed of two distinct components in the 1-10 GeV and 1-10 TeV energy ranges. The nature of the two components is not clearly understood. We report the analysis of the data of 74 months of observations of the Galactic Center by Fermi/LAT γ-ray telescope with the goal to constrain the morphology of the source and the nature of the two components. Spatially the Galactic Center is consistent with point source with 0.13° 3σ upper limit on its radius. We use the Fermi/LAT data in the energy band below 100 MeV to show that the γ-ray emission from the Galactic Centre source can't be explained within the pure hadronic model and discuss the necessary modifications to make the model to be consistent with the observational data. We also discuss an alternative self-consistent interpretation of the 60 MeV – 30 TeV spectrum of the source by a model in which the signal is produced via inverse Compton scattering of the ambient infrared radiation field.

The galaxy in gamma rays / 36

Gamma-ray emission from star-forming complexes observed by MAGIC: the cases of W51 and HESS J1857+026

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Massive star-forming regions assemble a large number of young stars with remnants of stellar evolution and a very dense environment. Therefore, particles accelerated in supernova remnants and pulsar wind nebulae encounter optimal conditions for interacting with target material and photon fields, and thus produce gamma-ray emission. However, observations are challenging because multiple phenomena may appear entangled within the resolution of current gamma-ray telescopes. We report on MAGIC observations aimed to understand the nature of the emission from the star-forming region W51 and the unidentified source HESS J1857+026. While gamma-ray emission from W51 is dominated by the interaction of the supernova remnant W51C with compact molecular clumps, HESS J1857+026 seems to be mainly associated to the pulsar wind nebula from PSR J1856+0245. However, a second source, MAGIC J1857.6+0297 is resolved, with sufficient separation to determine that it cannot be powered by the pulsar. We search for multi-wavelength data to determine the origin of the new source, and we suggest that the interaction of compact HII regions with the environment may produce the observed gamma-ray emission.

The galaxy in gamma rays / **37**

Tracing Cosmic Ray Origins: From the First Fermi-LAT SNR Catalog to SuperTIGER

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Despite tantalizing evidence that supernova remnants (SNRs) are the source of Galactic cosmic rays (CRs), including the detection of a spectral signature of hadronic gamma-ray emission from two SNRs, their origin in aggregate remains elusive. Interactions between CRs and ambient gas emit photons via pion decay at GeV energies, providing an in situ tracer for CRs otherwise measured directly with balloon-borne and satellite experiments near the Earth. We address the long-standing question of Galactic CR nuclei origins using a statistically significant GeV SNR sample derived from Fermi-LAT data to estimate the contribution of SNRs to directly observed CRs. To do so, we have performed the first systematic survey of SNRs at energies from 1 to 100 GeV, including developing a method for estimating systematic errors arising from the diffuse, interstellar emission model, a key ingredient of all Galactic Fermi-LAT analyses. From the 279 known radio SNRs, we found more than 100 GeV candidates, 31 of which show significant overlap with the radio, making them likely counterparts, and 14 of which are marginally associated. These candidates span a wide range of multiwavelength properties, providing a critical context for complementary, in depth individual studies. Modeling this multiwavelength data demonstrates the need for improvements to previously sufficient, simple models describing the GeV and radio emission from hadronic and leptonic particle populations in these objects. Together with the >240 upper limits on GeV emission at the radio position and extension, our results enable us to indirectly constrain SNRs' aggregate ability to accelerate cosmic rays.

Additional evidence for revisions to current CR origin models comes from the balloon-borne TIGER and the recent, record-breaking SuperTIGER missions, which directly measure ultraheavy CRs, beyond iron. These results include a distinctive separation when including a mix of massive star material (˜20%) with nominal interstellar material, of refractory nuclei from volatile nuclei, suggesting a CR origin paradigm more closely tied to massive stars in OB associations. Further, the apparent preferential acceleration of refractory, dust-bound elements relative to volatiles has important implications for understanding the acceleration mechanism, including likely sputtering from dust grains formed in the winds of massive stars and SNRs, of highly energetic CR nuclei. Bringing together these direct and indirect results will lead us to a significantly deeper understanding of CRs' origins and acceleration mechanisms.

Multi-wavelength and Multi-messenger search for cosmic ray sources / **38**

Gamma-ray, Cosmic-ray, and Neutrino Connections from the Acceleration of Cosmic Rays at SNR Shocks in the Milky Way and other Star-Forming Galaxies

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Results relevant to the question of Galactic cosmic-ray origin are presented. These include updates on hadronic strong-interaction cross sections for the production of secondary gamma rays, leptons

and neutrinos, and the use of these cross sections to reveal cosmic-ray interactions and the cosmic-ray spectra in analyses of Fermi-LAT data on supernova remnants and the diffuse Galactic gamma-ray glow. The superposition of these galactic gamma-ray emissions contributes to the extragalactic gamma-ray background light, and constrains models for production of the excess extragalactic neutrino flux measured reported by the IceCube Collaboration.

Multi-wavelength and Multi-messenger search for cosmic ray sources / 39

On the possible correlation of Galactic very-high energy source locations and enhancements of the surface density in the Galactic plane

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The association of very-high energy sources with regions of the sky rich in dust and gas has been noticed in the study of individual very-high energy (VHE; E > 100 GeV) sources. However, the statistical significance of this correlation for the whole population of TeV detections has not been assessed yet. To trace the material content, we make use of the recently released all-sky maps of astrophysical foregrounds of the Planck Collaboration, and of an extensive existing CO mapping of the Galactic sky. To test the correlation, we construct randomized samples of VHE source positions starting from the inner Galactic plane survey. We present here our findings.