Indirect Dark Matter searches in the gamma-ray band and development of new analysis techniques for ground-based gamma-ray astronomy

tmiener@ucm.es

Tjark Miener[1]

Grupo de Altas Energías - UCM

[1]Instituto de Física de Partículas y del Cosmos and Departamento de EMFTEL, Universidad Complutense de Madrid, Madrid, Spain

Introduction

Branon Dark Matter

The nature of Dark Matter (DM) is still an open question for modern physics. In the particle DM paradigm, this elusive kind of matter cannot be made of any of the known particles of the Standard Model (SM). Many efforts have been made in order to model the nature of the DM. Among others, and beyond the SM of particle physics, we focus on one part of this contribution on brane world theory as a prospective framework for DM candidates. Branons are new degrees of freedom that appear in flexible brane-world models corresponding to brane fluctuations. They are a natural DM candidate, because branons behave as weakly interacting massive particles (WIMPs), that are one of the most favored candidates for DM.

Combined Dark Matter Search

Imaging atmospheric Cherenkov telescopes (IACTs) and other gamma-ray observatories could potentially detect DM indirectly, by observing secondary products of its annihilation into SM particles. In the past years, separate limits on the velocity-weighted cross section of DM self-annihilation have been produced by the Fermi-LAT, HAWC, H.E.S.S., MAGIC, and VERITAS collaborations. On the second part of this contribution, we will report on an initiative aiming at combining data from these five experiments in order to maximize the sensitivity of DM searches towards dwarf spheroidal galaxies (dSphs). We developed a python package, called LikelihoodCombiner, which produce combined limits.

Deep Learning for Gamma-Ray Astronomy

On the third part of this contribution, we present an alternative way of proceeding IACT data. IACTs capture images of the air showers, originated by the absorption of gamma rays and cosmic rays by the atmosphere, through the detection of Cherenkov photons emitted in the shower. One of the main factors determining the sensitivity of IACTs to gamma-ray sources in general is how well reconstructed the properties of the primary particle triggering the air shower are. We present how deep convolutional neural networks (DCNs) are being explored as a promising method for IACT event reconstruction, and illustrate it with some preliminary results obtained with CTLearn, a package for IACT event reconstruction through deep learning.

Constraining Branon Dark Matter with the MAGIC telescopes

from observations of the Segue 1 dSph

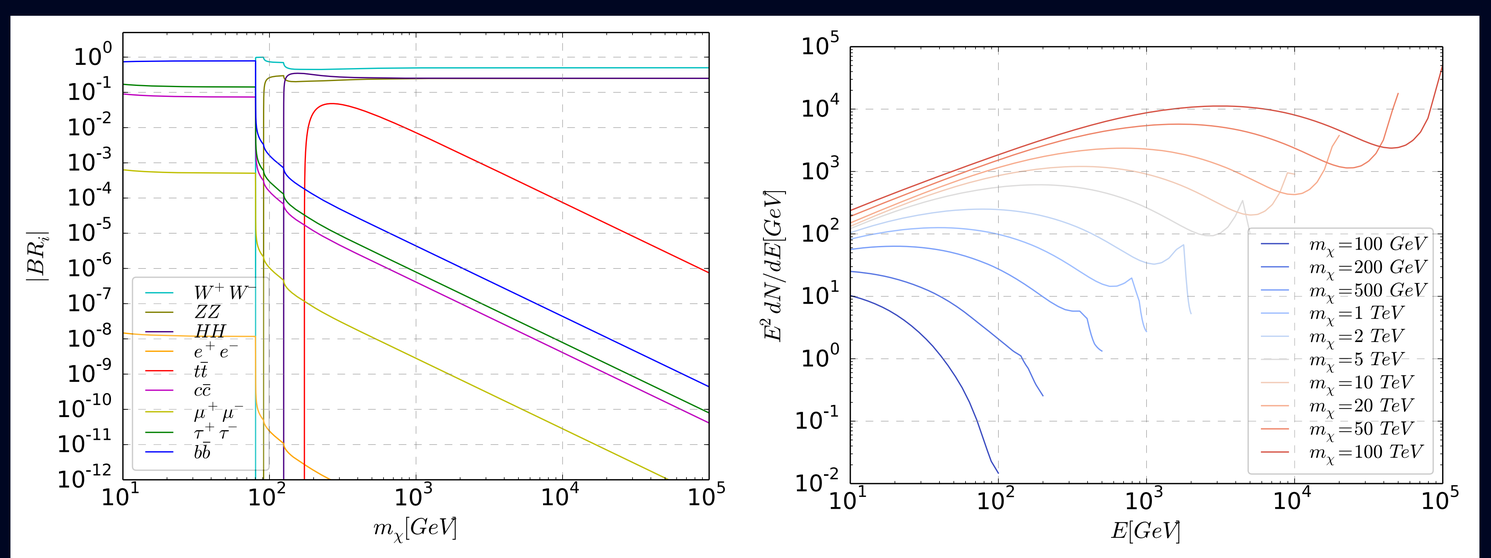


Fig. 1: Branon branching ratios as function of the DM mass (left) and the Branon annihilation photon yield for different DM mass (*right*).

- MAGIC is a currently operating IACT sensitive to VHE gamma-rays (from ~50 GeV to ~50 TeV).
- Segue 1 data set is almost 160 hours of good-quality data and was taken under four different experimental conditions.
- Our work focuses on Brane World Theory as a prospective framework for DM candidates.
- We modified github.com/javierrico/glike to include the Branon DM model in our analysis.
- We would like to combine more observations from other DM targets from different instruments to improve our Branon limits (similar to the combined DM search).

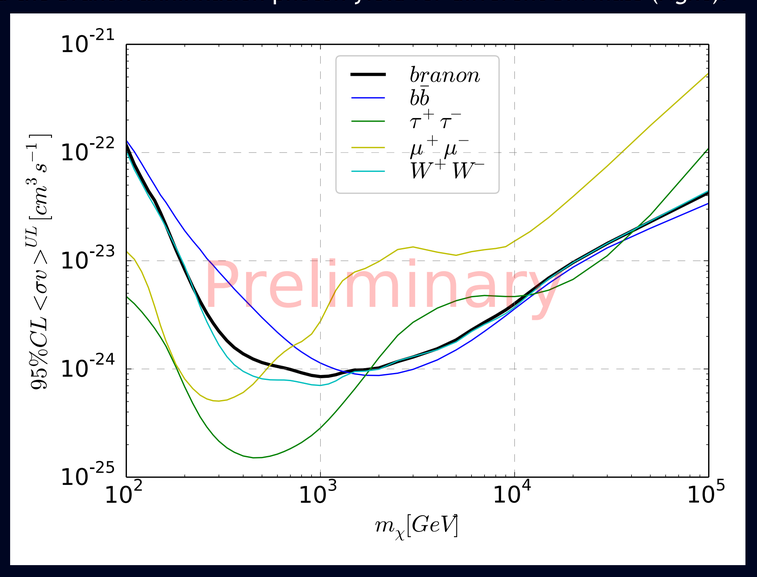


Fig. 2: *95% CL upper limits on the velocity weighted cross section ⟨σv⟩ vs DM mass for Branon DM particles from MAGIC observations of Segue 1.*

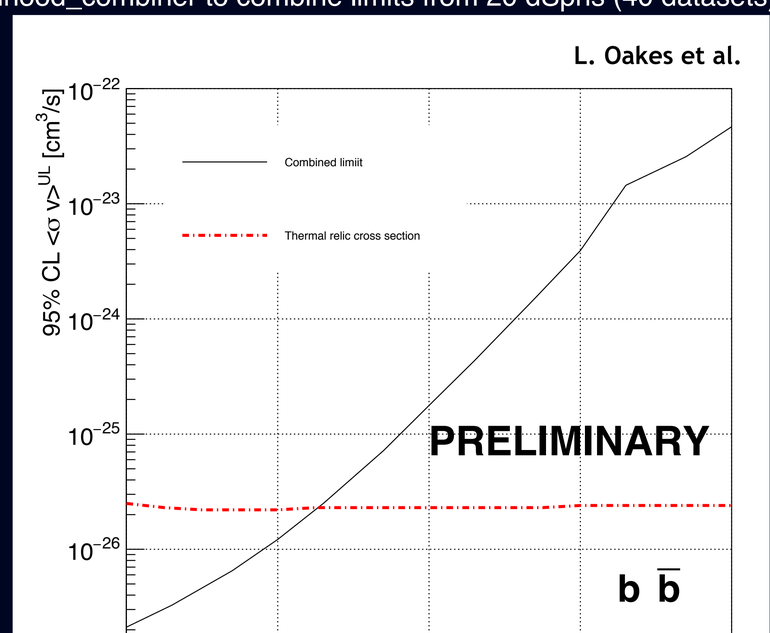
T. **Miener**, D. Nieto, V. Gammaldi, J. Rico

Combined Dark Matter search

by *Fermi*-LAT, HAWC, HESS, MAGIC and VERITAS

GloryDuck project (including **T. Miener**) PoS(ICRC2019)012

- We developed the python package github.com/tjarkmiener/likelihood_combiner to combine limits from 20 dSphs (40 datasets).



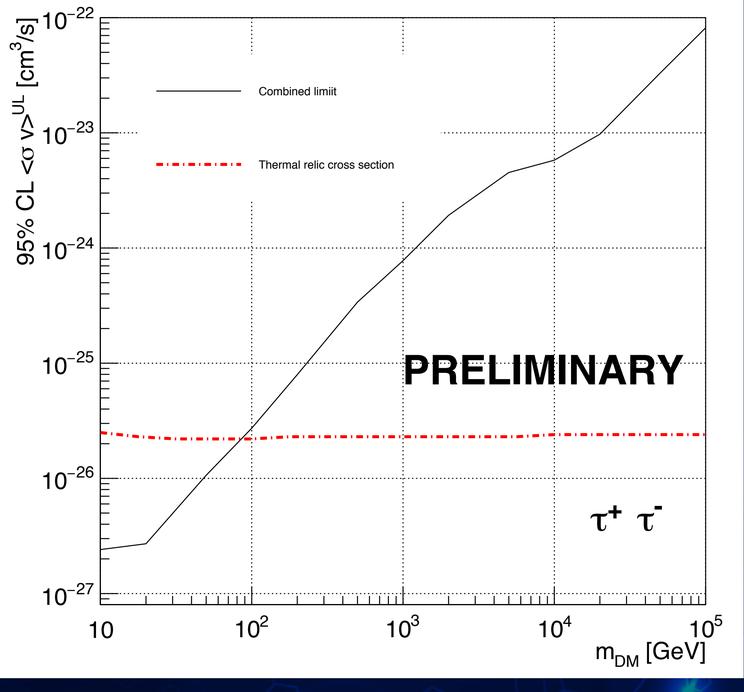


Fig. 3: Combined *95% CL upper limits on the velocity weighted cross section ⟨σv⟩ vs DM mass for DM particles annihilating into $b\bar{b}$ (left) and $\tau^+\tau^-$(right).*

CTLearn

Deep Learning for IACT Event Reconstruction

A. Brill, Q. Feng, B. Kim, **T. Miener**, D. Nieto

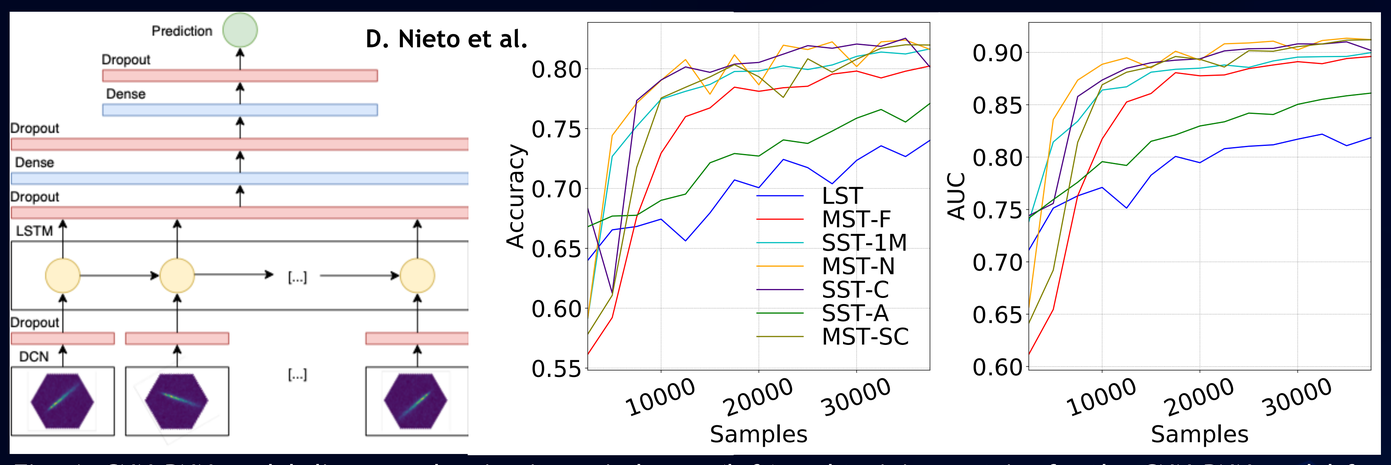


Fig. 4: *CNN-RNN* model diagram, showing its main layers (left) and training metrics for the *CNN-RNN* model for seven telescope designs proposed for the Cherenkov Telescope Array (CTA) (middle and right).

- CTLearn is a high-level, open-source, Python package providing a backend for training deep learning models (like the *CNN-RNN*) for IACT event reconstruction using TensorFlow.
- We want to add a full event reconstruction, which include energy and arrival direction estimation of the primary particle. This will be implemented with the Multitask Learning approach, where the network is learning multiple task at once.

PoS(ICRC2019) 752 & PoS(ICRC2019) 753

Conclusions & Outlook

We presented three independent projects, which have a huge potential to be merged into one big project during the PhD study. Current and future IACTs could be solving the riddle of the nature of DM and hence combined/global DM searches are gaining more and more importance in today's DM research. Besides that, we develop new alternative analysis techniques (like Deep Learning) to enhance the performance of the IACTs. Any improvement in the sensitivity of IACTs can be directly applied to indirect DM searches.

This work was conducted in the context of the CTA Analysis and Simulations Working Group, the MAGIC Astroparticles & Fundamental physics Working Group and the GloryDuck project. TM and DM acknowledge support from the former *Spanish Ministry of Economy, Industry, and Competitiveness / European Regional Development Fund* grant FPA2015-73913-JIN. TM and DN also acknowledges the support of NVIDIA Corporation with the donation of a Titan X Pascal GPU used for this research.

Supported by:

github.com/ctlearn-project/ctlearn
github.com/cta-observatory/dl1-data-handler
github.com/javierrico/glike
github.com/tjarkmiener/likelihood_combiner