Positrons from Dark Matter annihilation in the galactic halo: uncertainties

T. Delahaye[1], R. Lineros[2], F. Donato[2], N. Fornengo[2], P. Salati[1]

([1]) LAPTH/Annecy, CNRS-SPM and Universite' de Savoie 9, ([2]) University of Torino and INFN/Torino

Abstract.

Indirect detection signals from dark matter annihilation are studied in the positron channel. The positron propagation inside the galactic medium is calculated in a two-zone diffusion model and the astrophysical uncertainties on the positron DM signal are derived. We obtain dark matter scenarios and propagation models that nicely fit existing data on the positron fraction and show that running or planned space experiments have the potential to discriminate a possible signal from the background and, in some cases, to distinguish among different astrophysical propagation models.

Cosmic Ray Transport

The propagation of positrons in the galactic medium is governed by the transport equation:

(1) $$\frac{\partial \psi}{\partial t} - \nabla \cdot \{K(\mathbf{x}, E)\, \nabla \psi\} - \frac{\partial}{\partial E}\{b(E)\, \psi\} = q(\mathbf{x}, E)$$

where $\psi(\mathbf{x}, E)$ is the positron number density per unit of energy and $q(\mathbf{x}, E)$ is the positron source term.

Effects related with magnetic turbulences and energy losses are described by:

(2) $$K(\mathbf{x}, E) = K_0 \epsilon^{\delta}$$

(3) $$b(E) = \frac{E_0 \epsilon^2}{\tau_E}$$

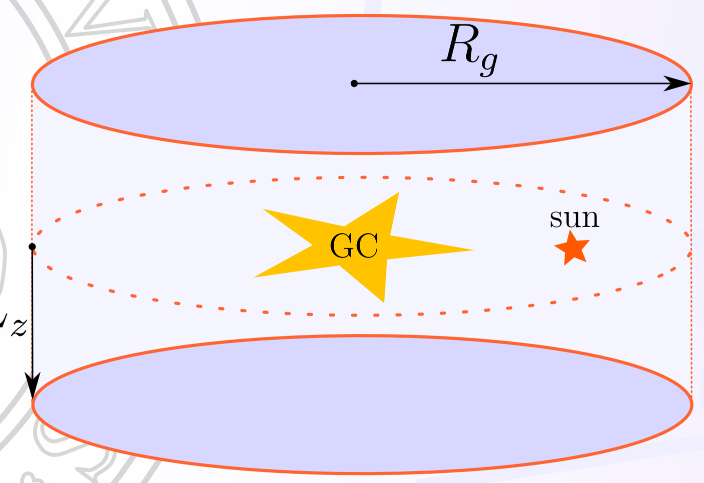
where $\epsilon = E/E_0$, $E_0 = 1\mathrm{GeV}$, $\tau_E = 10^{16}\mathrm{s}$.

Two-zone diffusion model

CR propagation takes place in a diffusion zone (**DZ**) [1], that is modeled as a cylinder with dimensions:

$$R_g = 20 \text{ kpc}$$

$$L_z : 1 \longleftrightarrow 15 \text{ kpc}$$



The interstellar medium (**ISM**) lies at *z=0*, where most of positrons are produced by interaction of other CR species with the ISM [2].

Close to DZ boundaries, ψ is expected to vanish, since positrons can move freely and escape from the DZ.

Dark Matter as a CR source

Non-baryonic DM present in galactic haloes can annihilate and produce Standard Model particles. The result of annihilations can be considered as an exotic CR source, for which:

(4) $$q(\mathbf{x}, E) = \eta \langle \sigma v \rangle \left\{ \frac{\rho(\mathbf{x})}{m_\chi} \right\}^2 f(\epsilon)$$

DM thermaly-averaged annihilation cross section

DM number density depends on DM distribution in the galaxy

Positron energy distribution related to how DM annihilates and annihilation subproducts decays

Transport uncertainties

Observations in other CR species, e. g. in the boron over carbon ratio (**B/C**), allow to constrain the CR transport parameters [1].

B/C best fit set

$$\delta = 0.7 \qquad L_z = 4 \text{ Kpc} \qquad K_0 = 0.0112 \text{ kpc}^2/\text{Myr}$$

The model is analyticaly solvable, giving advantages to calculate the positron flux [3]. The positron flux and the uncertainties related to propagation are shown in Fig. 1 and 2. Uncertainties are typically large and vary with the DM annihilation final state. In the low energy range uncertainties can be as large as a factor of 10 or more.

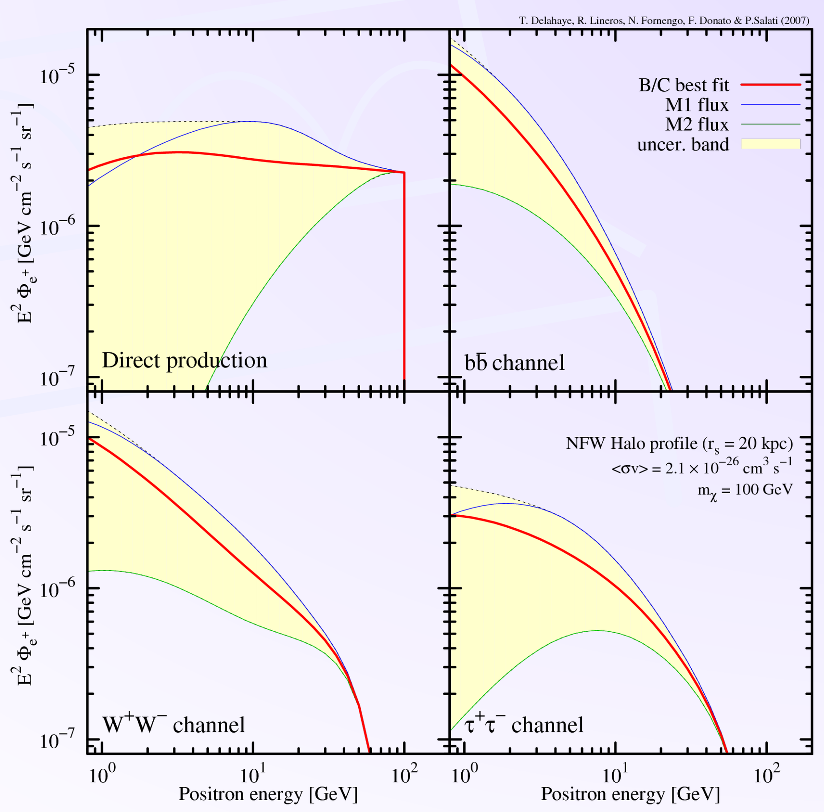


Fig.1: Positron flux $E^2\Phi_{e^+}$ vs. positron energy for selected annihilation channels.

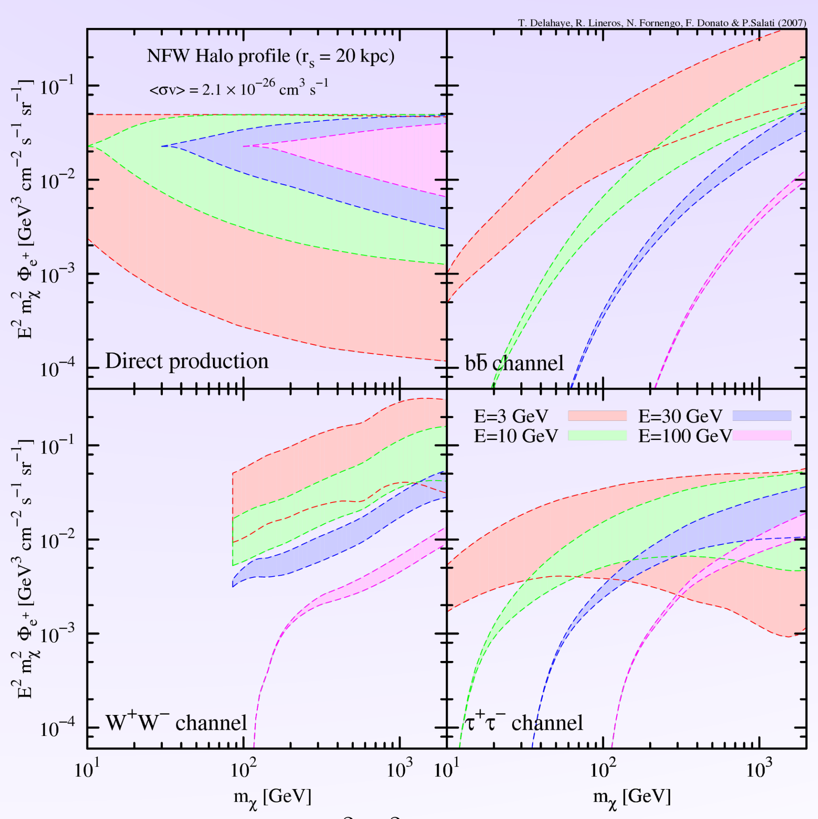


Fig.2: Positron flux $E^2 m_\chi^2 \Phi_{e^+}$ vs. DM particle mass for selected annihilation channels and values of energy.

Positron fraction

Defined as the ratio of positron flux over the sum of electron and positron fluxes.

The positron fraction (**PF**) is shown for four specific annihilation channles in Fig. 3, and compared with available experimental results. The data, including the possible excess identified by HEAT, are nicely reproduced, even when uncertainties on CR transport are considered.

Predictions for PAMELA (Fig. 4) [3] and AMS [3] show that good prospects of desentagling a signal from the background are present, especially for annihilations into gauge bosons, tau leptons or directly into positrons. Astrophysical uncertainties, although sizeable, do not strongly limit detection capabilities for DM lighter than a few hundreds of GeV.

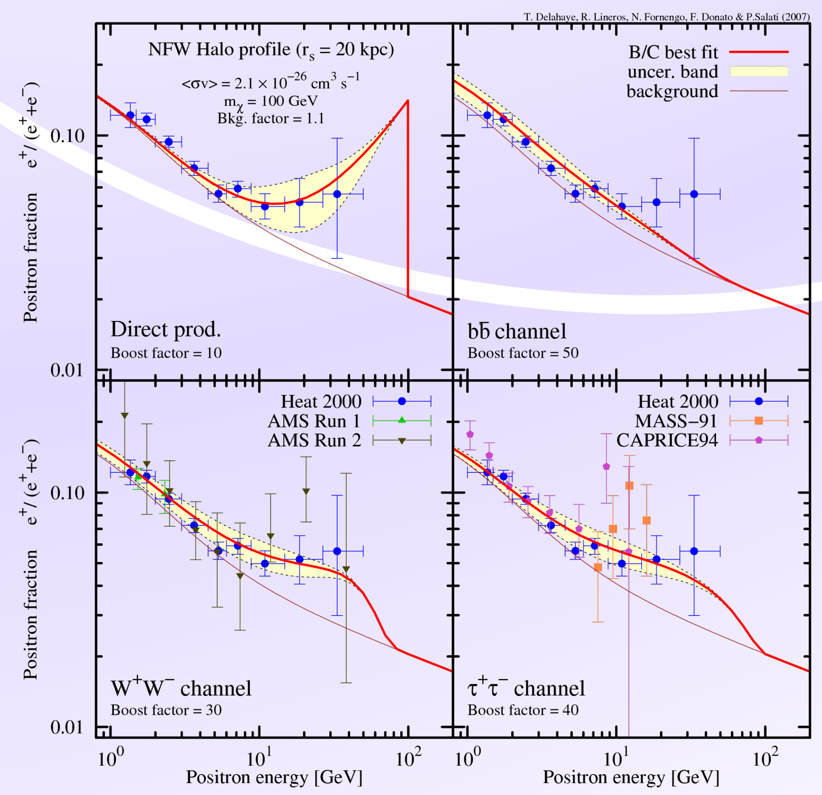


Fig.3: Positron fraction vs positron energy. Each panel corresponds to different DM annihilation channels. Experimental data from HEAT, AMS01, CAPRICE and MASS are also plotted

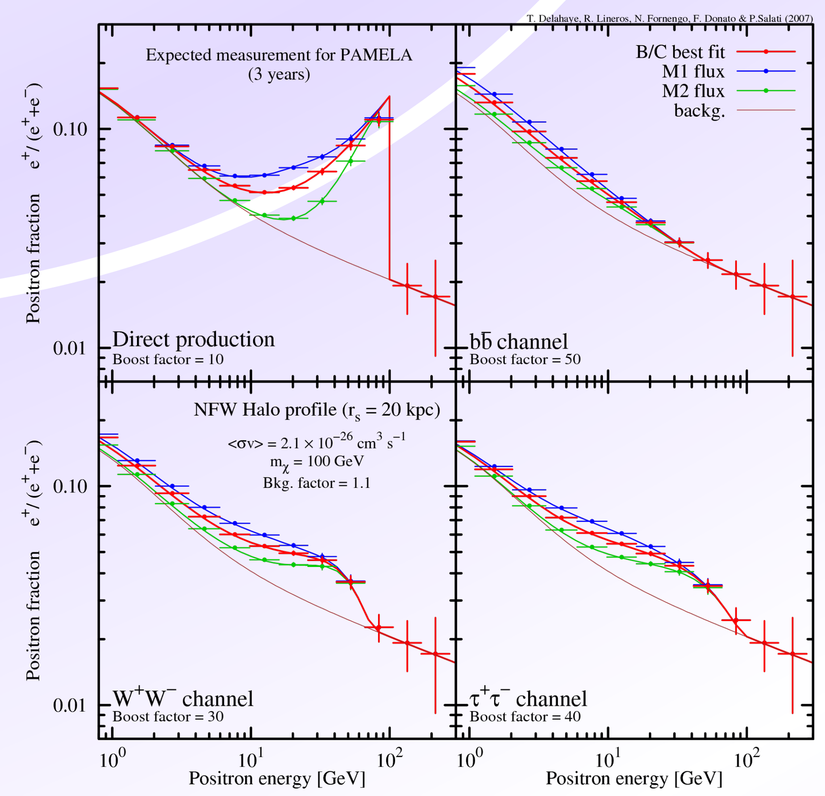


Fig.4: Expected PAMELA positron fraction vs. positron energy for different DM annihilation channels. B/C best fit positron flux and extreme parameters set are also plotted.

REFERENCES:

[1] D. Maurin, F. Donato, R. Taillet and P. Salati. **Astrophys. J. 555, 585 (2001)**

[2] I. V. Moskalenko and A. W. Strong. **Astrophys. J. 493, 694 (1998)**

[3] T. Delahaye, R. Lineros, F. Donato, N. Fornengo and P. Salati. **arXiv:0712.2312** (PRD in press)