

Marco Taoso

IFIC (CSIC-Universitat de Valencia)

DM gamma-ray lines: Higgs in space

with C.Jackson, G.Servant, G.Shaughnessy & T.Tait

MULTI-3 WORKSHOP

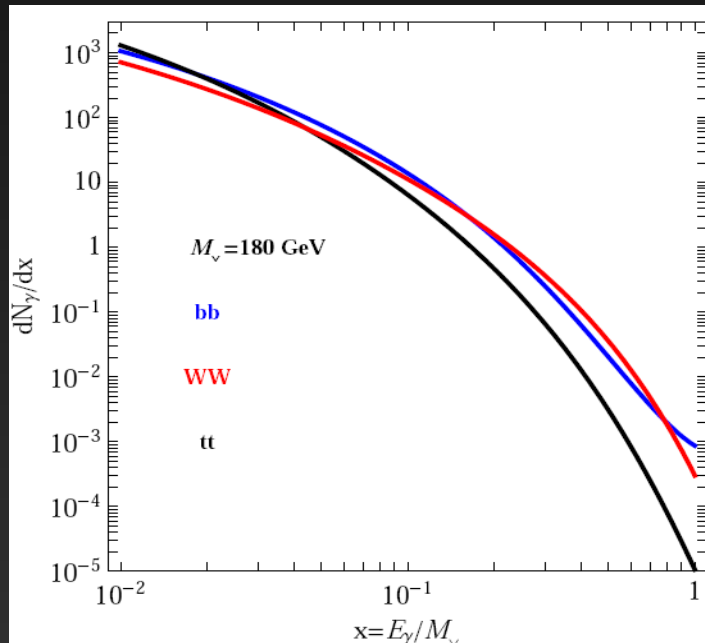
Padova March 1-4, 2010

γ -RAY LINES: A SMOKING GUN FOR DM ANNIHILATIONS

CONTINUUM

From hadronization and decays of SM particle, final state radiation from charged particles

Almost featureless but with cut-off at DM mass



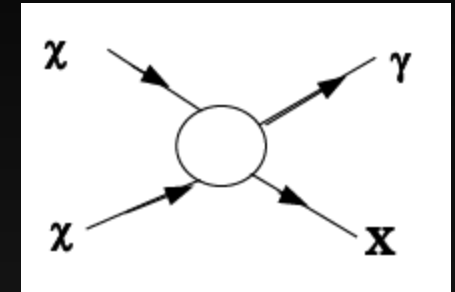
γ LINES

From loop level:

mono energetic emission

@ energy:

$$E_\gamma = M \left(1 - \frac{M_X^2}{4M^2} \right)$$

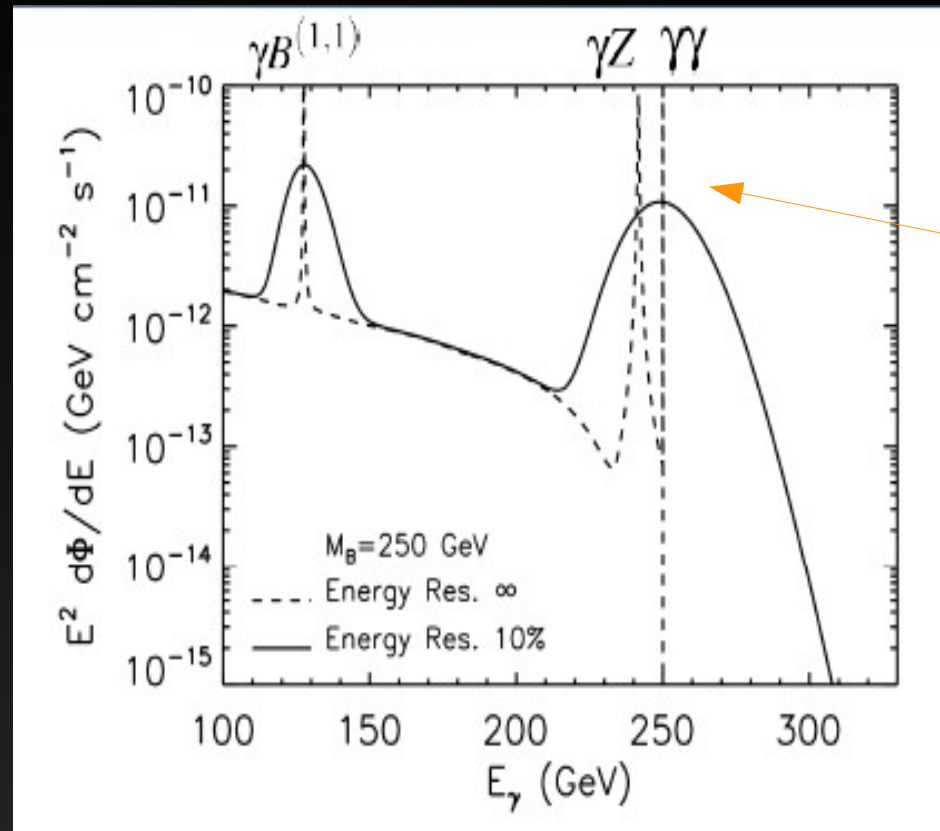


**Striking spectral feature:
smoking gun for Dark Matter emission.**

Cross sections are usually small
(loop suppressed)

WIMP FORESTS

6D UED MODEL: “CHIRAL SQUARE”



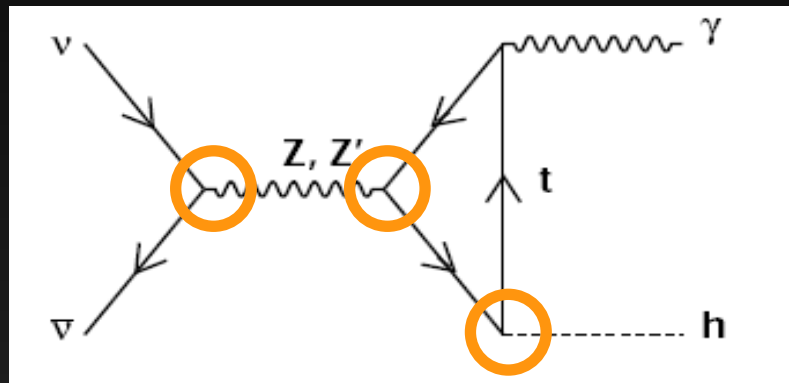
DETECTOR
ENERGY RESOLUTION
MATTERS

“WIMP FOREST”: SERIES OF LINES! → MEASURE THE MASS OF THE PARTICLES FROM
THE ENERGY POSITION OF THE LINES

SEE ALSO Gustafsson et al. '07, Y.Mambrini 09, Ibarra et al 07, Bazzocchi et al. 09 ...

ANNIHILATIONS INTO $H\gamma$?

“WIMP MIRACLE”: EW-SIZE SCALES AND COUPLINGS ACCOUNT FOR MEASURED THERMAL ABUNDANCE



$H\gamma$ CALLS FOR A DIRAC FERMION OR VECTOR WIMP PARTICLE

A SIMPLE EFFECTIVE THEORY

$$\mathcal{L} = \mathcal{L}_{SM} - \frac{1}{4} \hat{F}'_{\mu\nu} \hat{F}'^{\mu\nu} + M_{\hat{Z}'}^2 \hat{Z}'_\mu \hat{Z}'^\mu + \frac{\chi}{2} \hat{F}'_{\mu\nu} \hat{F}_Y^{\mu\nu} + \hat{g}_t^{Z'} \hat{t} \gamma^\mu P_R \hat{Z}'_\mu t + i\bar{\nu} \gamma^\mu \left(\partial_\mu - i\hat{g}_\nu^{Z'} P_R \hat{Z}'^\mu \right) \nu + M_\nu \hat{\nu} \nu$$

THE WIMP IS A DIRAC FERMION, ν , SINGLET UNDER SM AND CHARGED UNDER A SPONTANEOUSLY BROKEN U(1)'

Z' IS THE PORTAL TO THE SM COUPLING TO THE RH TOP

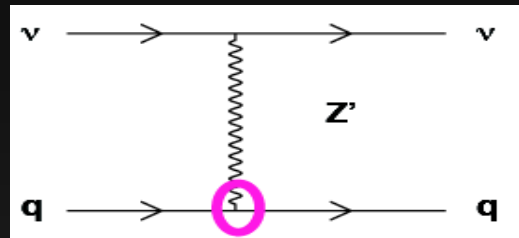
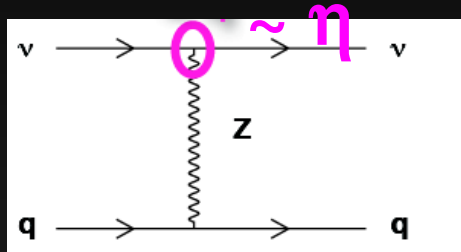
THIS MODEL IS INSPIRED TO A SO(10) RANDALL-SUNDRUM MODEL AGASHE, SERVANT, 04

A Z3 SYMMETRY INTRODUCED TO AVOID RAPID PROTON DECAYS STABILIZES THE LIGHTTEST KK PARTICLE

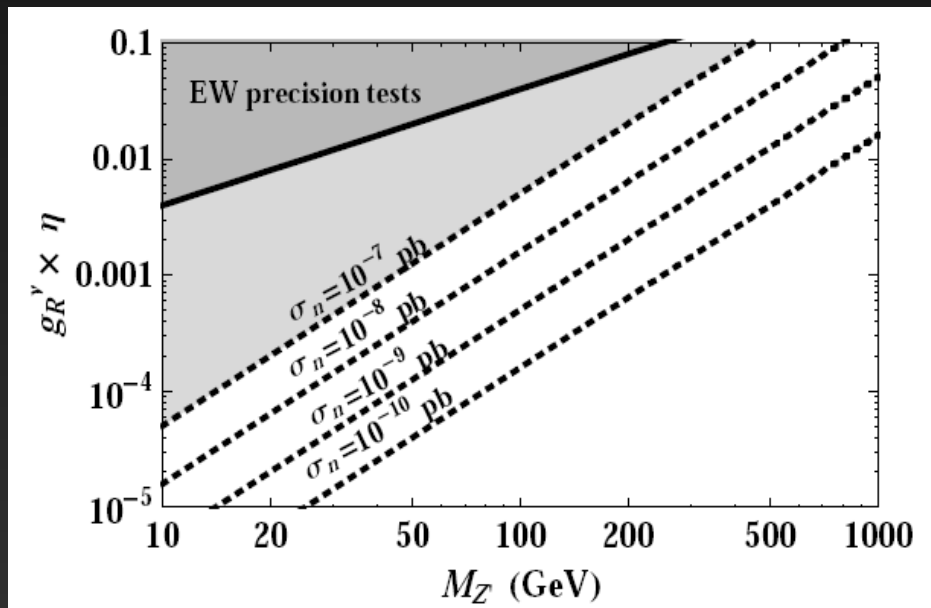
HYPERCHARGE-Z' MIXING IS INDUCED BY TOP QUARK LOOPS

KINETIK MIXING INDUCE AN EFFECTIVE COUPLING η OF SM STATES TO Z' AND ν TO SM Z BOSON

ADDITIONAL MASSIVE FERMIONS COULD CONTRIBUTE TO η (and cancel gauge anomalies)



DIRECT DETECTION CONSTRAINTS

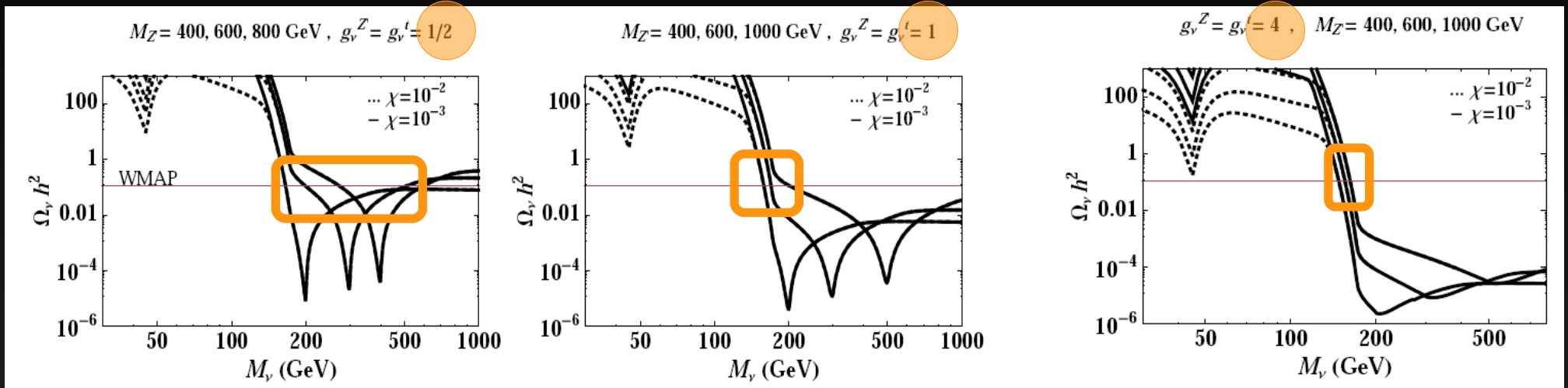
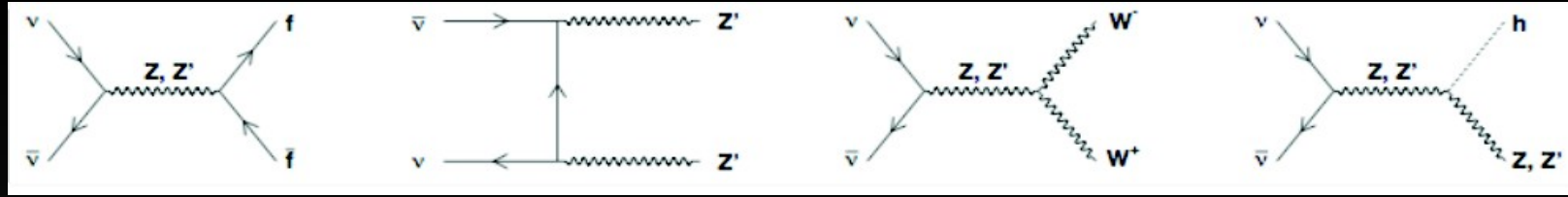


Z' HEAVIER THAN 10's GeV

CONSISTENT WITH

- ORDER ONE Z'- ν COUPLINGS
- LOOP SUPPRESSED η

RELIC DENSITY

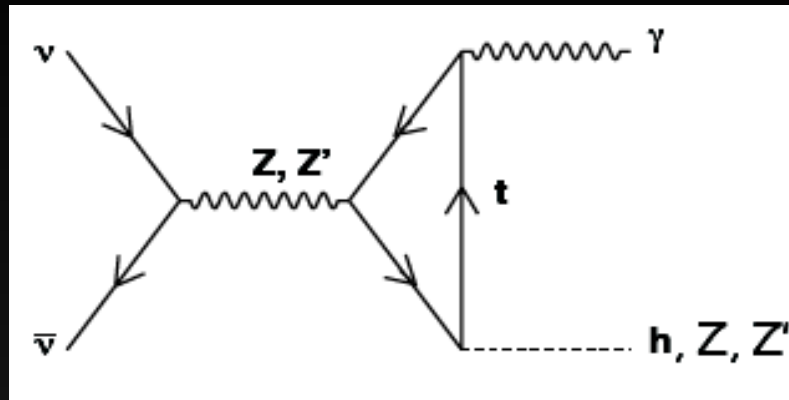


$M_\nu \ll M_t$ and $M_{Z'}/2$: ANNIHILATIONS INTO $f\bar{f}$. TYPICALLY TOO MUCH HIGH RELIC DENSITY

$M_\nu > M_t$ and $M_{Z'}/2$: ANNIHILATIONS INTO $t\bar{t}$. CONTINUUM OF ALLOWED VALUES FOR M_ν

INCREASING THE COUPLINGS THE PREDICTION FOR M_ν GETS NARROWER

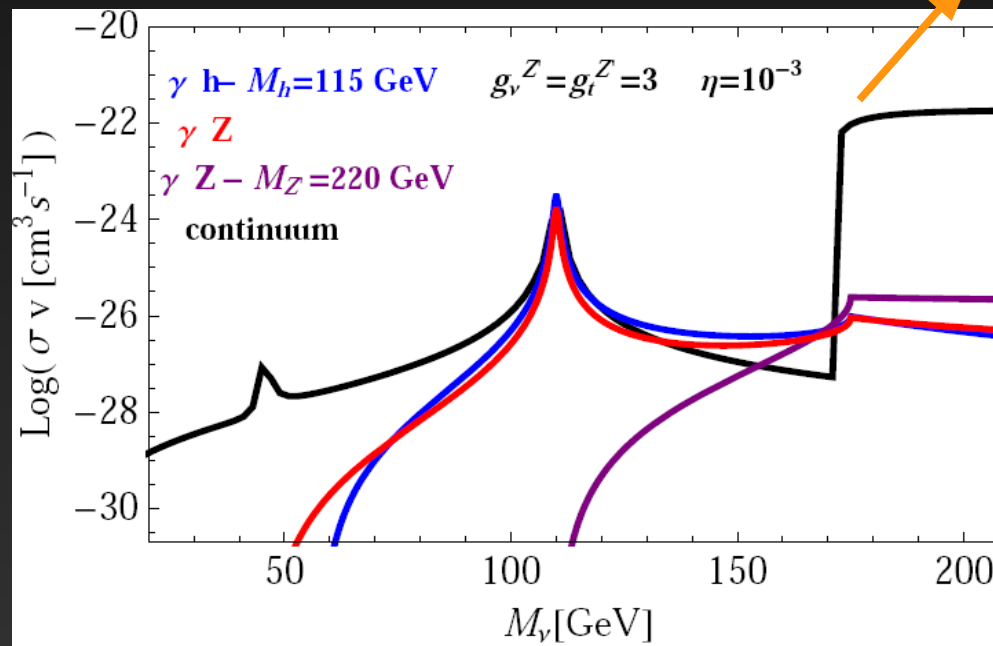
GAMMA-RAY LINES FROM ν ANNIHILATIONS



NO $\gamma\gamma$ LINE BECAUSE
OF THE LANDAU-YANG THEOREM

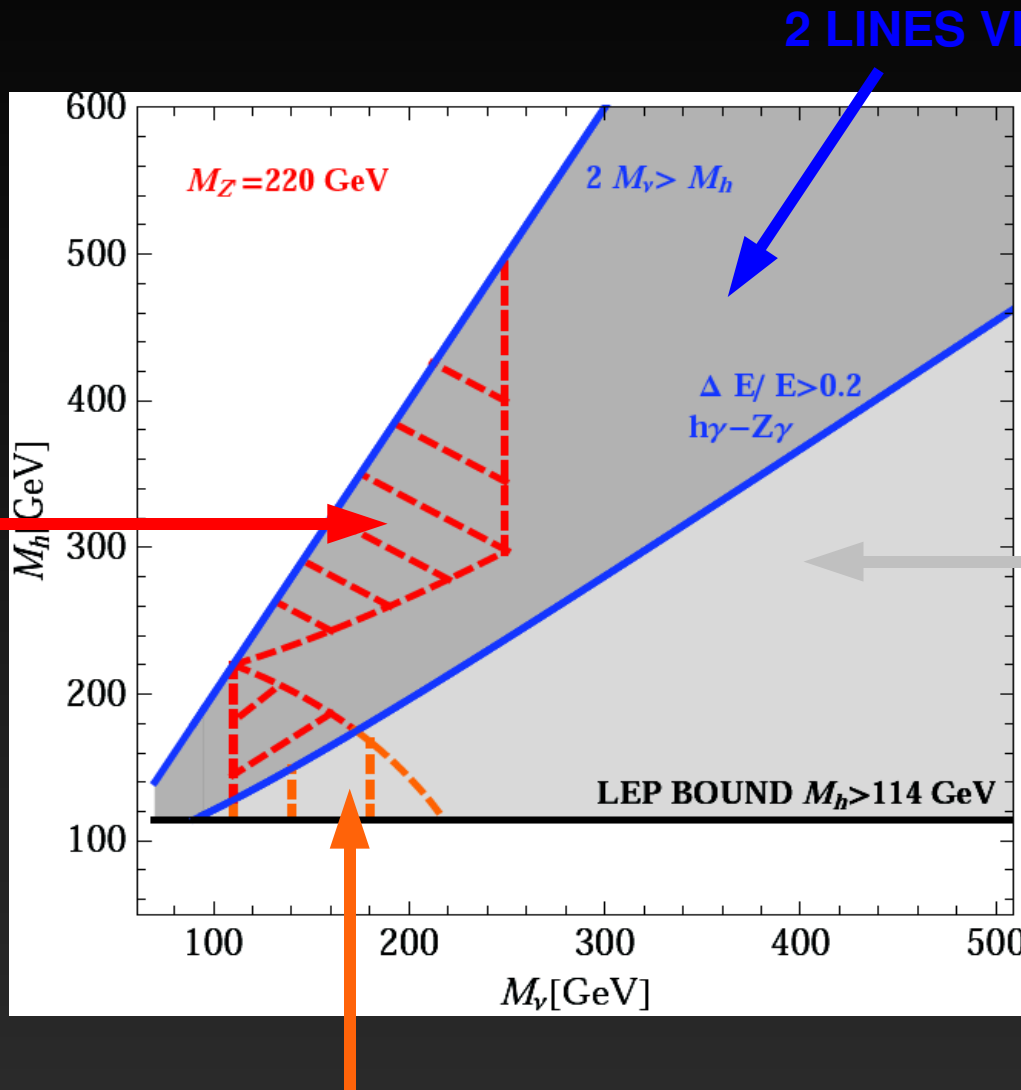
LINES NOT SUPPRESSED COMPARED TO THE CONTINUUM

JUMPS DUE TO THE OPENING OF



$t\bar{t}$ CHANNEL

LINE OBSERVABILITY IN THE $(M_v - M_h)$ PLANE



3 LINES VISIBLE

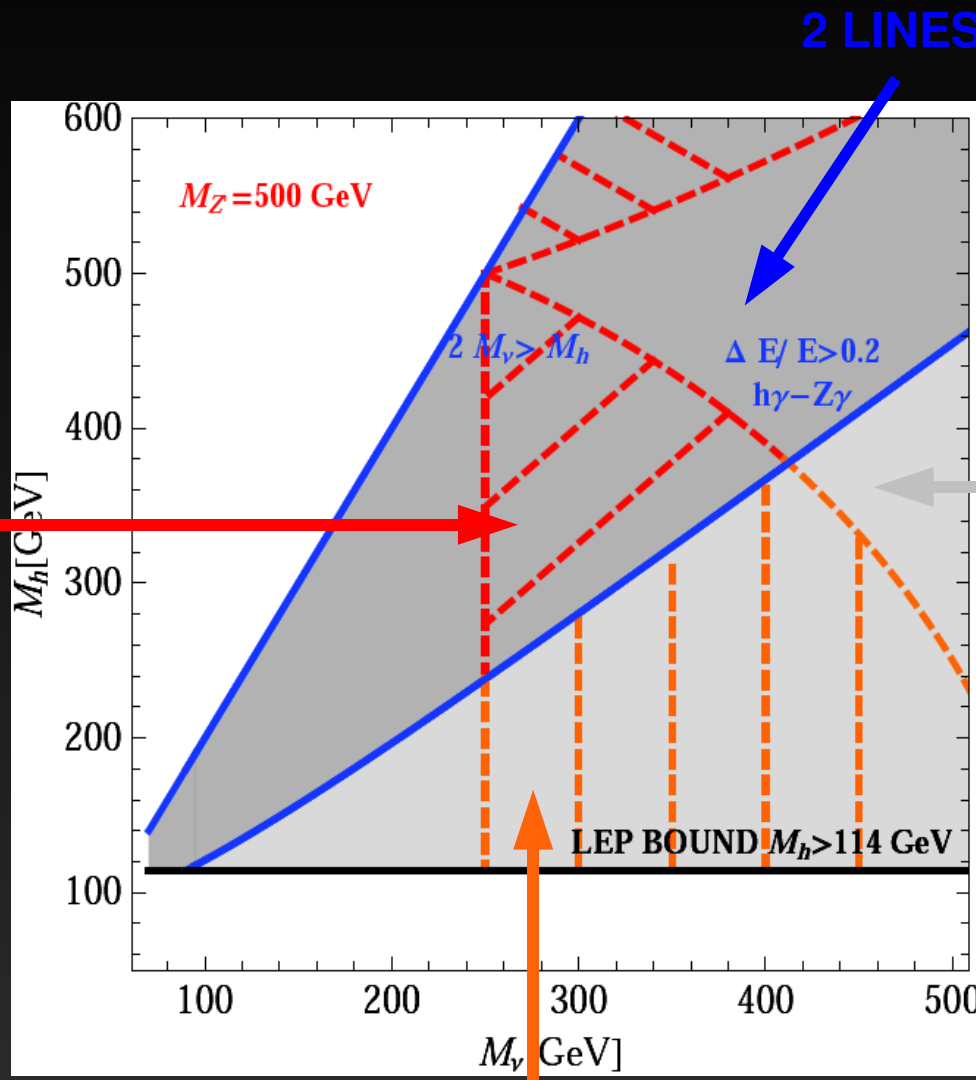
$(H\gamma, Z\gamma, Z'\gamma)$

2 LINES VISIBLE ($H\gamma, Z\gamma$)

2 LINES VISIBLE $H\gamma, Z\gamma$
 ($H\gamma, Z\gamma$ merged)

2 LINES VISIBLE $H\gamma, Z'\gamma$

LINE OBSERVABILITY IN THE (M_v - M_h) PLANE



3 LINES VISIBLE
($H\gamma$, $Z\gamma$, $Z'\gamma$)

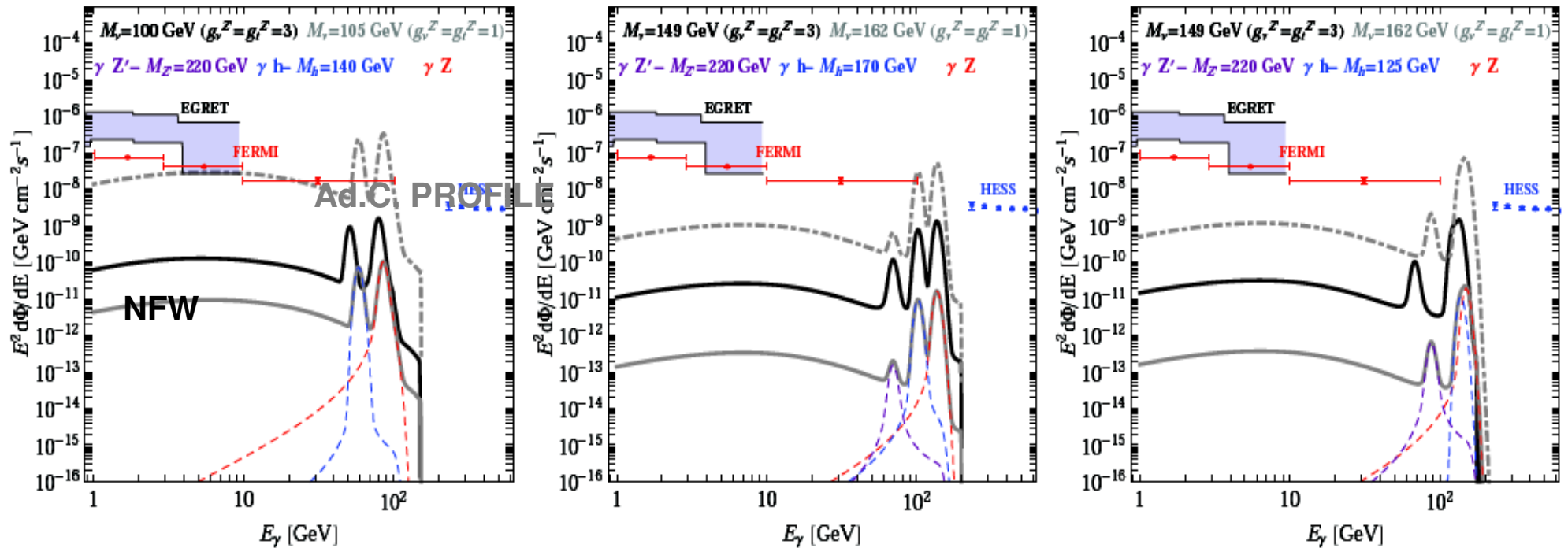
2 LINES VISIBLE ($H\gamma$, $Z\gamma$)

2 LINES VISIBLE $H\gamma$, $Z\gamma$
($H\gamma$, $Z\gamma$ merged)

2 LINES VISIBLE $H\gamma$, $Z'\gamma$

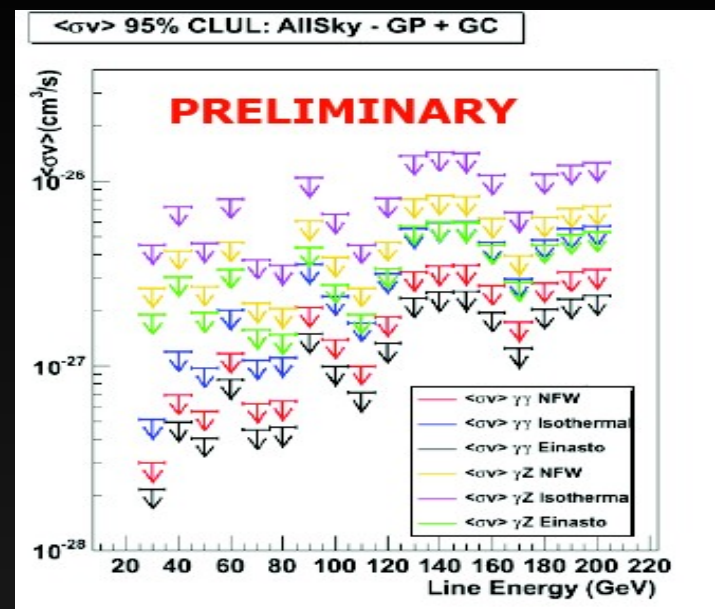
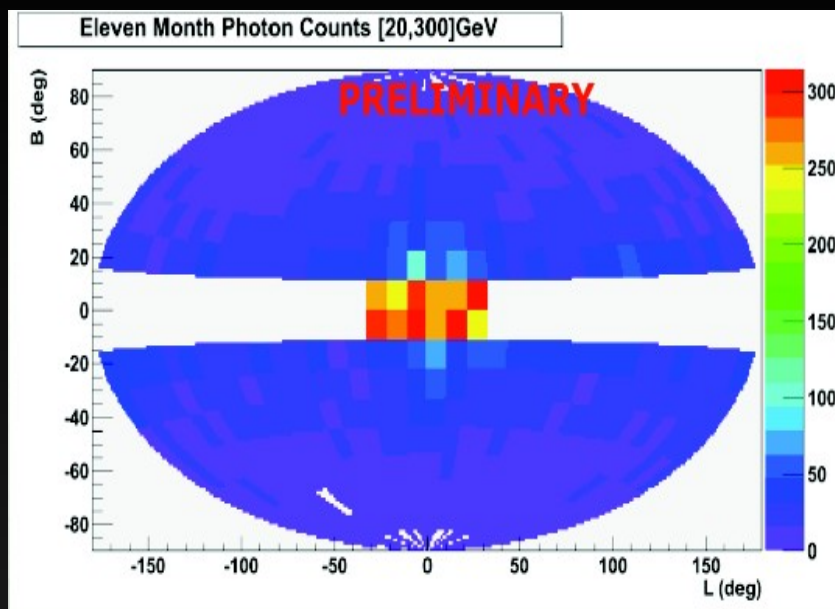
THE GALACTIC CENTER TO LOOK FOR WIMPS ANNIHILATIONS

FERMI SYMPOSIUM 2009

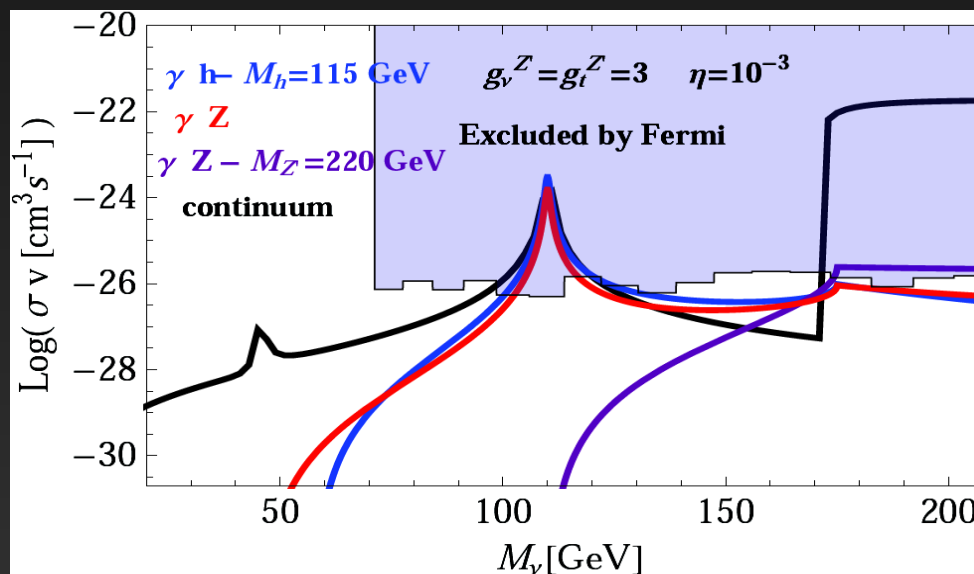


MW halo model	r_s in kpc	ρ_s in GeV/cm ³	\bar{J} (10 ⁻⁵)
NFW [27]	20	0.26	$15 \cdot 10^3$
Einasto [28]	20	0.06	$7.6 \cdot 10^3$
Adiabatic [29]			$4.7 \cdot 10^7$

FERMI LINE SEARCHES



FROM FERMI SYMPOSIUM 2009

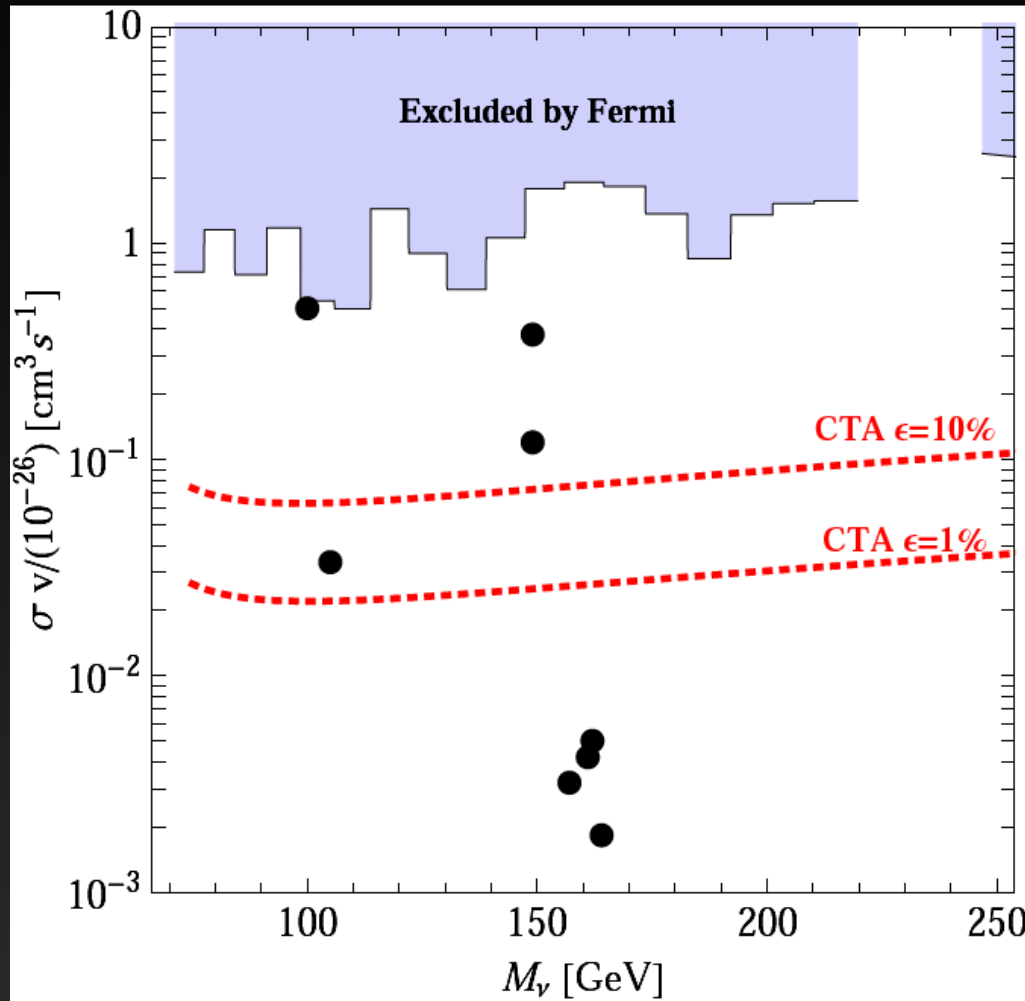


2 DEGREES REGION AROND THE GALACTIC CENTER

NFW PROFILE IS ASSUMED

γ - HIGGS LINE

$$\sigma_{\nu\nu\rightarrow\gamma h}$$



3σ SENSITIVITY CURVE

200 HOURS OF

CTA OBSERVATIONS

TO RECAP

WE PROPOSE A **DM DIRAC FERMION** WITH ENHANCED COUPLINGS TO A Z' WHICH IN TURN COUPLES TO THE TOP QUARK

THE RELIC DENSITY BOUND IS SATISFIED FOR ν MASSES OF THE ORDER OF THE TOP MASS

TOP LOOPS INDUCE ANNIHILATIONS INTO $H\gamma, Z\gamma, Z'\gamma$ -----> **PROMINENT GAMMA LINES**

FERMI-LAT CAN POTENTIALLY OBSERVE THESE LINES

FOR THE MOMENT NO SPECTRAL FEATURE OBSERVED ----> UPPER BOUNDS

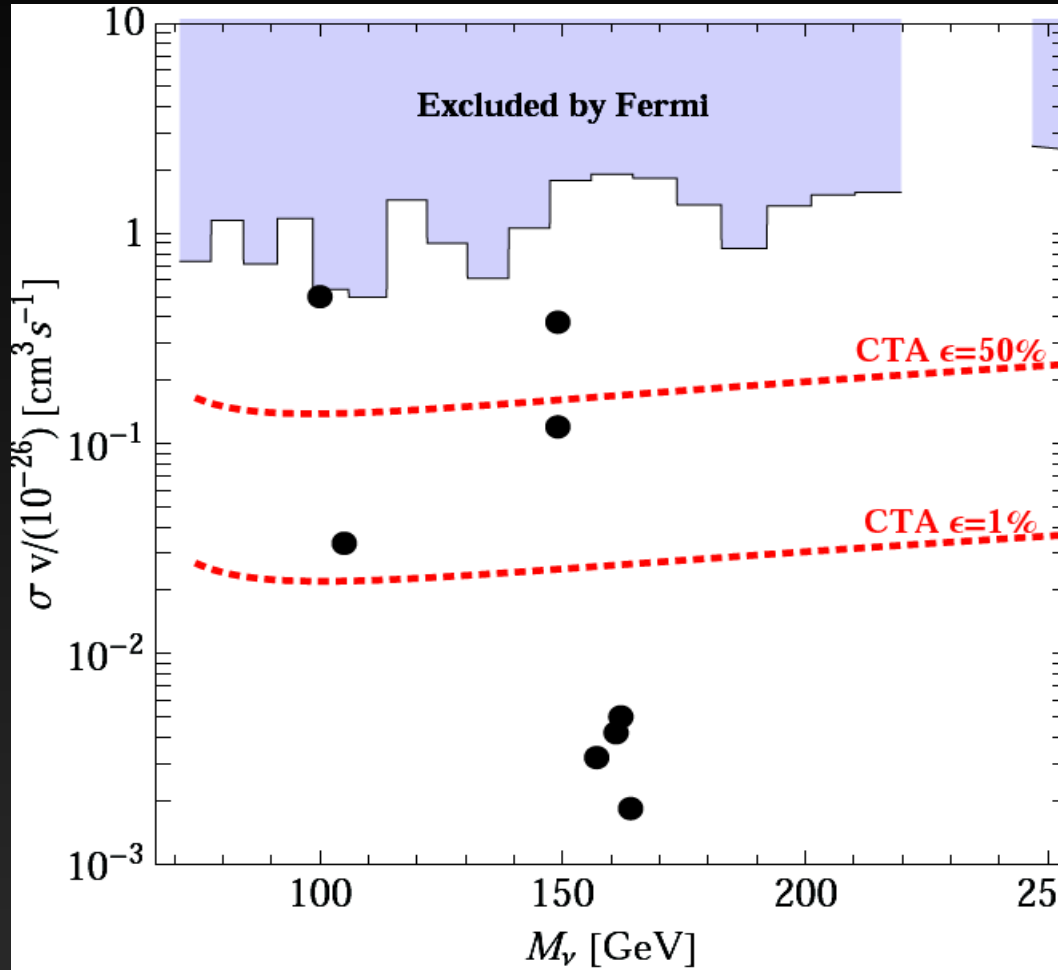
STUDY OF THE GALACTIC CENTER REGION IN PROGRESS

2 DEGREES REGION AROND THE GALACTIC CENTER

NFW PROFILE IS ASSUMED

γ - HIGGS LINE

$\sigma_{\nu\nu\rightarrow\gamma h}$

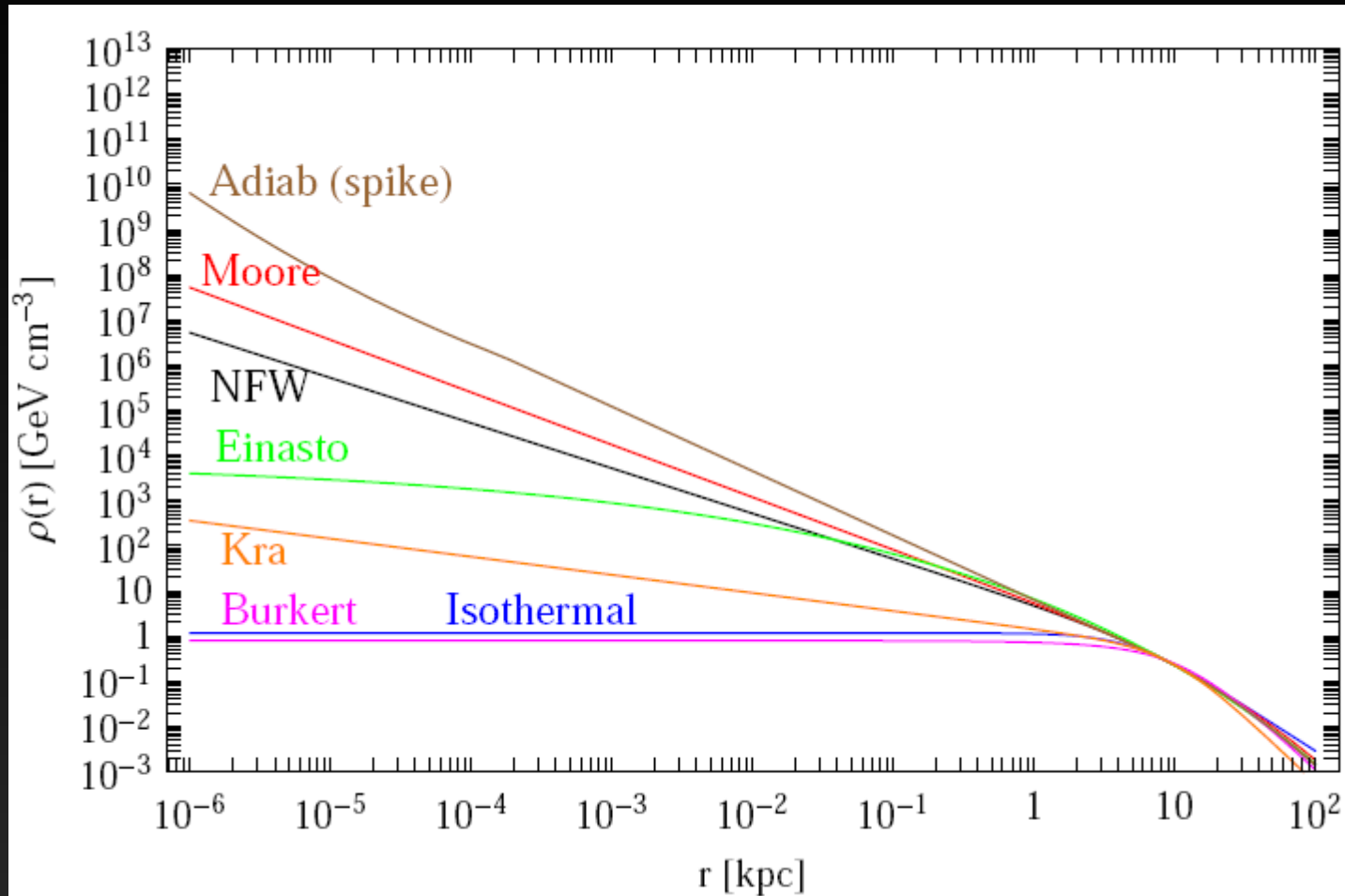


3σ SENSITIVITY CURVE

200 HOURS OF

CTA OBSERVATIONS

DM DENSITY PROFILES

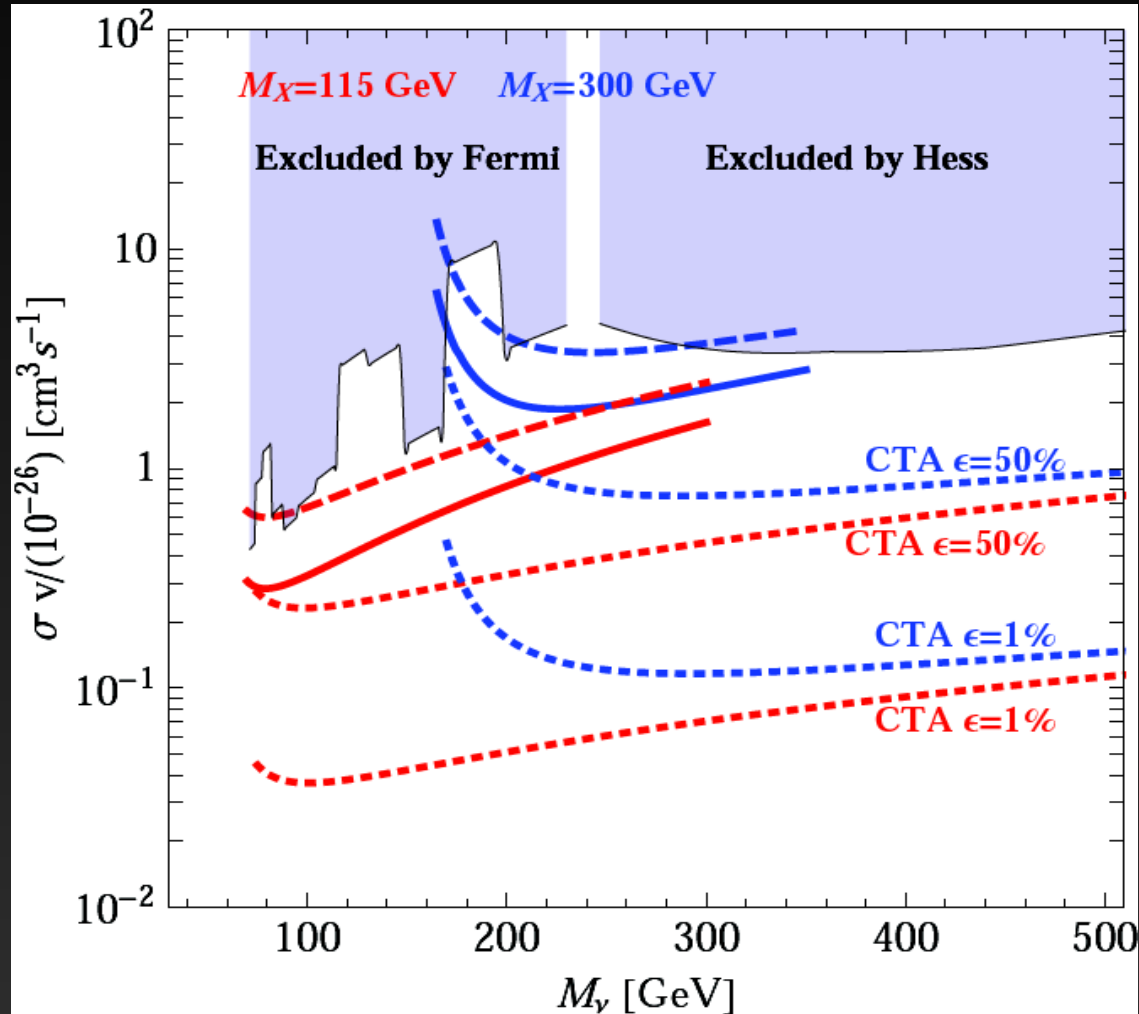


$$\frac{d\Phi}{d\Omega dE} = \frac{1}{8\pi} \frac{(\sigma v)}{M_{DM}^2} \frac{dN_\gamma}{dE} \int_{\text{line-of-sight}} \rho(l)^2 dl$$

EXPERIMENTAL SENSITIVITY FOR AN “OPTIMIZE” REGION OF OBSERVATION

5- σ EXCLUSION PLOT. NFW PROFILE. 10 yrs OF FERMI OBSERVATIONS

$\sigma_{\nu\nu\rightarrow\gamma X}$



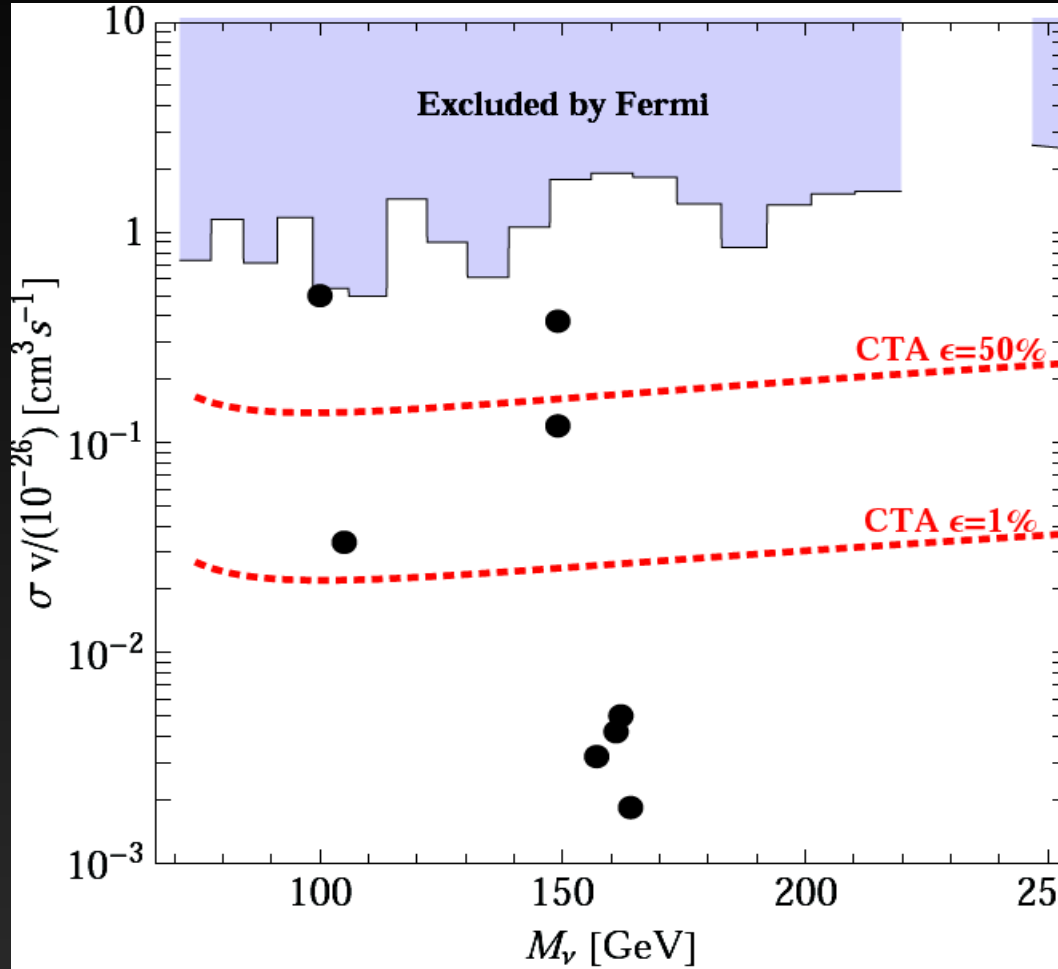
200 HOURS OF
CTA OBSERVATIONS

2 DEGREES REGION AROND THE GALACTIC CENTER

NFW PROFILE IS ASSUMED

γ - HIGGS LINE

$\sigma_{\nu\nu\rightarrow\gamma h}$



3σ SENSITIVITY CURVE

200 HOURS OF

CTA OBSERVATIONS

UV

SO(10)

IR

**LIGHT
SM FERMIONS**

WARPING

**R TOP, HIGGS
KK STATES**

DM IS A RH NEUTRINO FROM A 16 OF SO(10)

$$\begin{pmatrix} u'_L, d'_L \\ u_R^c \\ d_R^c \\ \nu'_L, e'_L \\ e_R^{/c} \\ \nu_R^{/c} \end{pmatrix}_{-1/3}$$

BULK FERMION WITH BC (-,+) ----> LIGHT!

Z3 SYMMETRY

$$\Phi \rightarrow e^{2\pi i \left(B - \frac{n_c - \bar{n}_c}{3} \right)} \Phi$$

STABILIZES THE LIGHTEST KK MODE

SUPPRESS PROTON DECAYS OPERATORS