EWIMP dark matter detections

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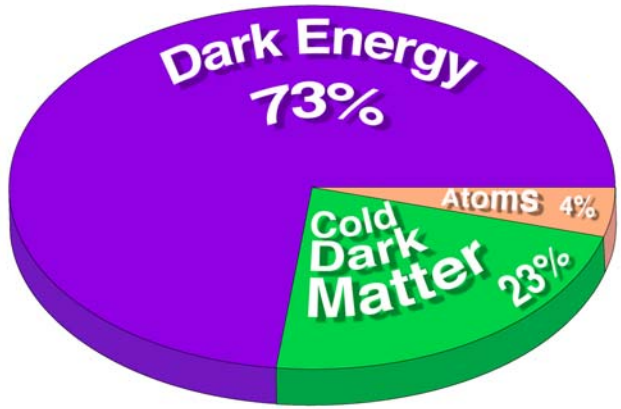
Dark Matter Abundance

Results from recent cosmological observation

Mean density of matter and baryon

$\rho_M \approx 2.9 \times 10^{-6}$ GeV/cc

$\rho_B \approx 4.6 \times 10^{-7}$ GeV/cc



Existence of non-baryonic (cold) dark matter

Constituent of dark matter = **Beyond SM Physics**

EWIMP Dark Matter

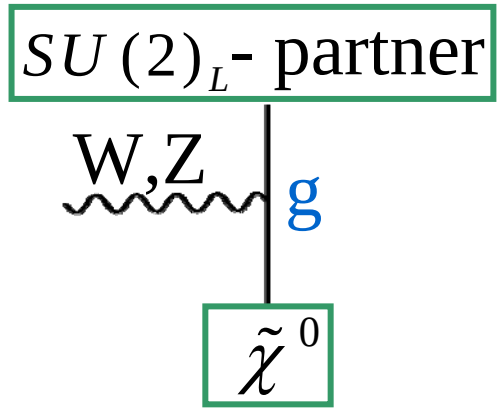
We consider $SU(2)_L$ non-singlet dark matter
(a neutral component of $SU(2)_L$ multiplet)
Electroweak charged WIMP = EWIMP

Concrete example

Neutralino in Minimal SUSY SM

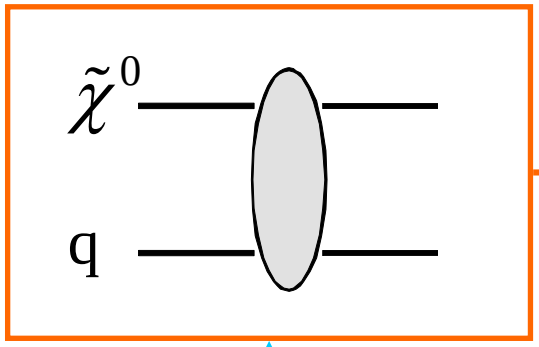
$$\tilde{\chi}^0 = Z_{01}\tilde{B} + Z_{02}\tilde{W} + Z_{03}\tilde{H}_d + Z_{04}\tilde{H}_u$$

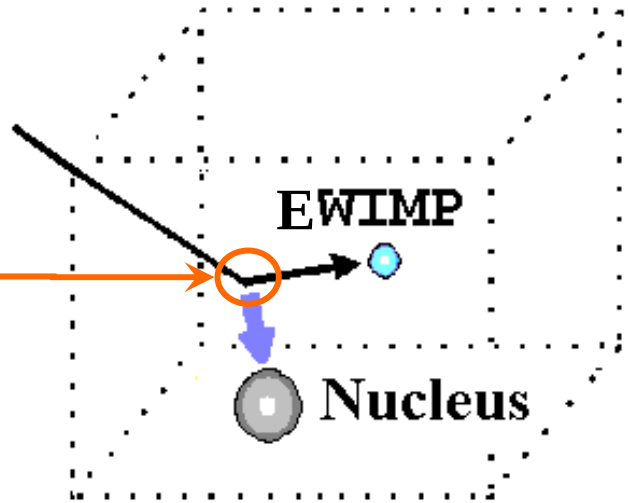
Triplet Doublet



We focus on signatures in EWIMP dark matter detections.
(**Direct detection**, **Indirect detection using** γ , e^+)
Interesting phenomena occur in these detections !!

Direct detection for EWIMP dark matter

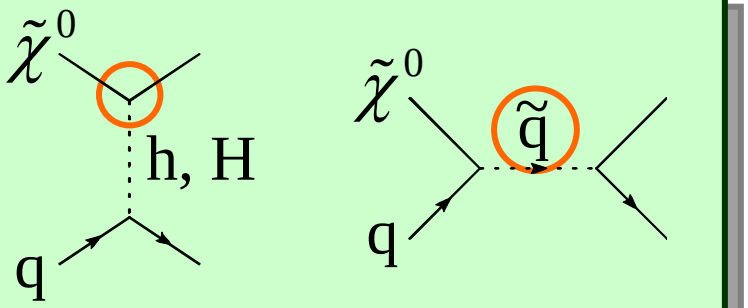




Nuclear recoil after
EWIMP-nucleus scattering

If the EWIMP mass is large enough,
the cross section at tree level is suppressed by new physics scale

Diagrams for Spin-independent Int.



gaugino-higgsino mixing

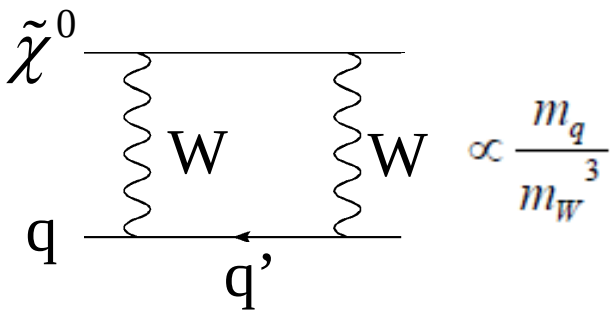
squark mass

Triplet EWIM (Wino-like dark matter)

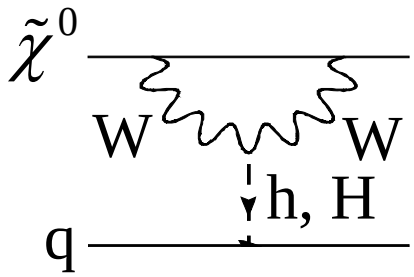
$$\sigma_{SI} \sim 3\times10^{-43} cm^2 \times \left(\frac{\mu^2}{100GeV \times M_2} \right)^{-2}$$

Non-decoupling interaction at 1-loop level

At 1-loop level, there are some diagrams not suppressed by new physics scale.



$$\propto \frac{m_q}{m_W^3}$$

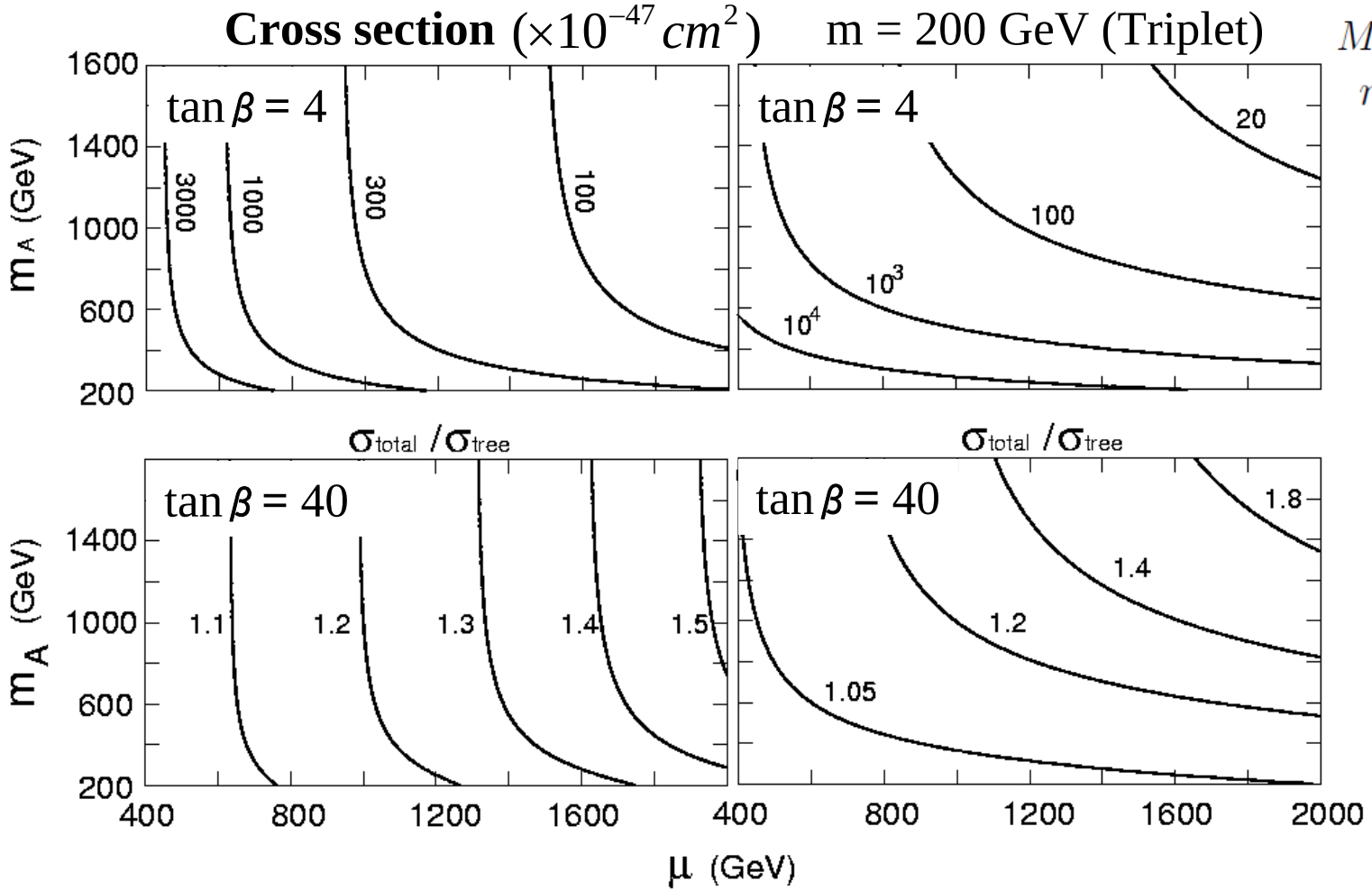


$$\propto \frac{m_q}{m_W m_h^2}$$

Intermediate chargino particle in these diagrams are almost On-shell.
There are no suppression at each vertex in these diagrams.

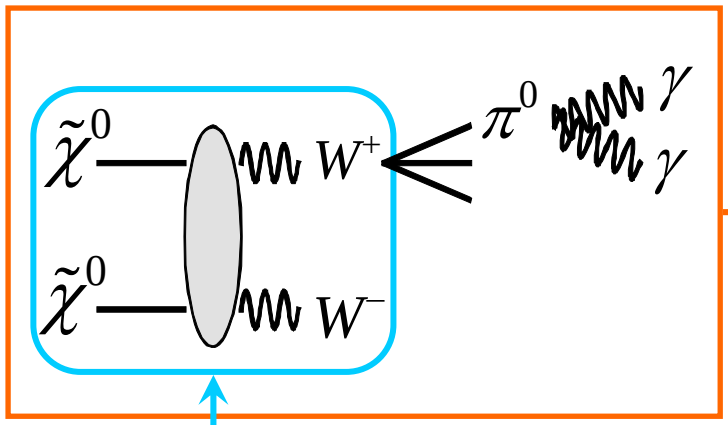
In the extremely heavy EWIMP case, the 1-loop diagrams
are larger than diagrams at tree level !!
The 1-loop diagrams give the lower limit of the collision cross section.

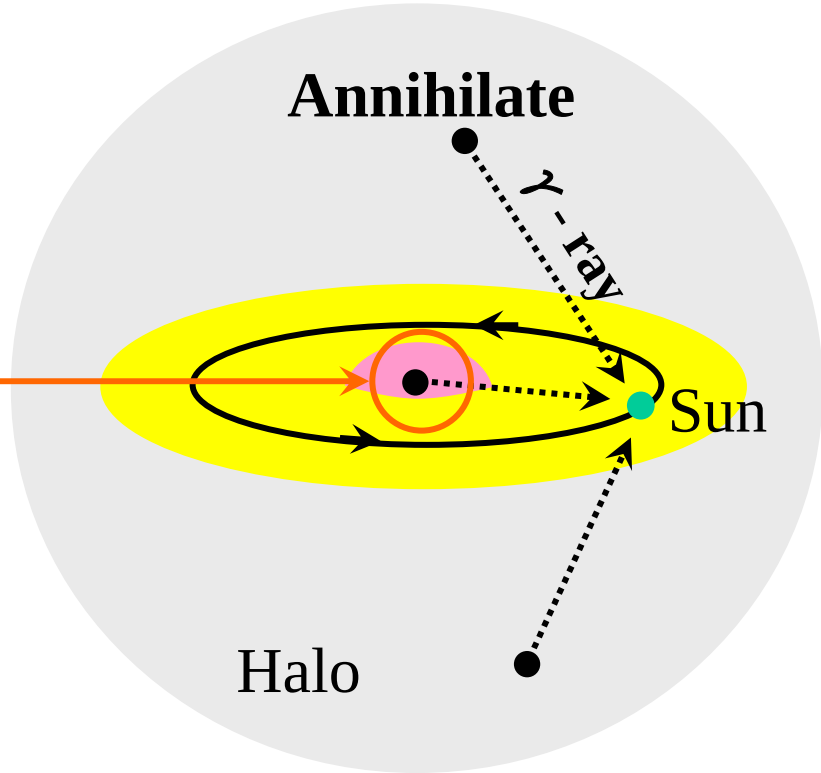
EWIMP-Nucleon cross section including 1-loop diag.



The cross section for the EWIMP receives the sizable 1-loop correction, when the cross section is smaller than about 10^{-45}cm^2.

Indirect detection of EWIMP dark matter using γ-rays

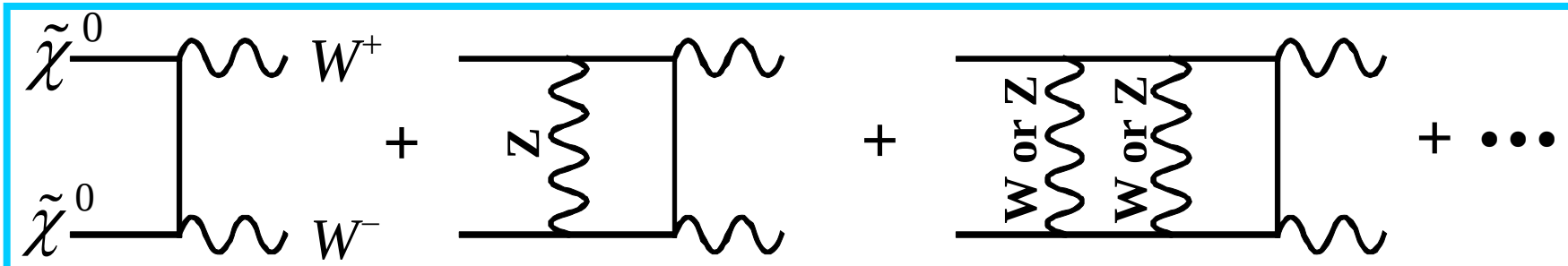




Calculation of annihilation cross sections is important!!

When $m > m_W$, usual perturbation can not be applied due to the threshold singularity !!

Breakdown of perturbation in cal. of cross section



$A_0 \sim \alpha_2$

$\sim A_0 \dfrac{\alpha_2 m}{m_W}$

$\sim A_0 \dfrac{\alpha_2^2 m^2}{m_W^2}$

Ladder diagram

Diagrams have an additional factor $\alpha_2 m / m_W$ for each weak gauge boson exchange.

1. Velocity of EWIMP: $v \simeq 10^{-3} c$
2. Degeneracy between EWIMP & partner

→ Intermediate states (EWIMP& partner) are almost on-shell.
Threshold Singularity

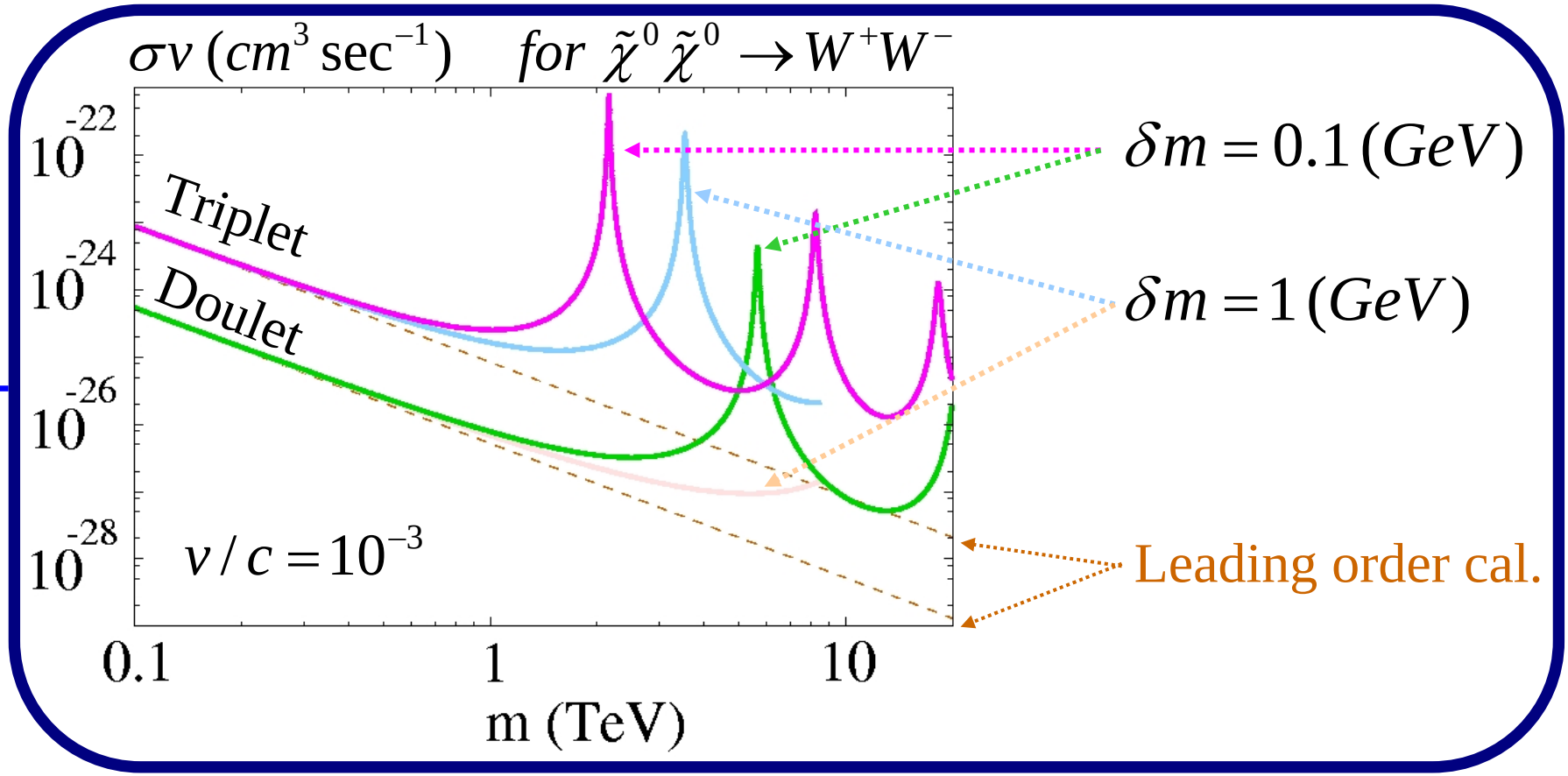
→ We have to resum ladder diagrams!!
Non-pertuvative effect

We performed the resummation using NR-Lagrangian.

→ Bound states composed by EWIMP & Partner's pair appear if $m > m_W$!!

→ Annihilation cross section is enhanced compared to leadings.

Annihilation cross section including effects of T.S.



Gamma ray flux is increased

Models of particle physics can be constrained by the observation !!

For example

Constraint on MSSM parameters by gamma rays (1-10GeV) from the galactic center using EGRET observation .

Gamma ray signal from EWIMP annihilation in galactic cneter

$$\frac{d\Psi_\gamma(E)}{dE} = 9.3\times10^{-14}(cm^{-2}s^{-1})\sum_i \frac{dN_\gamma^i}{dE}\left(\frac{<\sigma_i v>}{10^{-27}\ cm^3 s^{-1}}\right)\left(\frac{1\,TeV}{m}\right)^2 \bar{J}\,\Delta\Omega$$

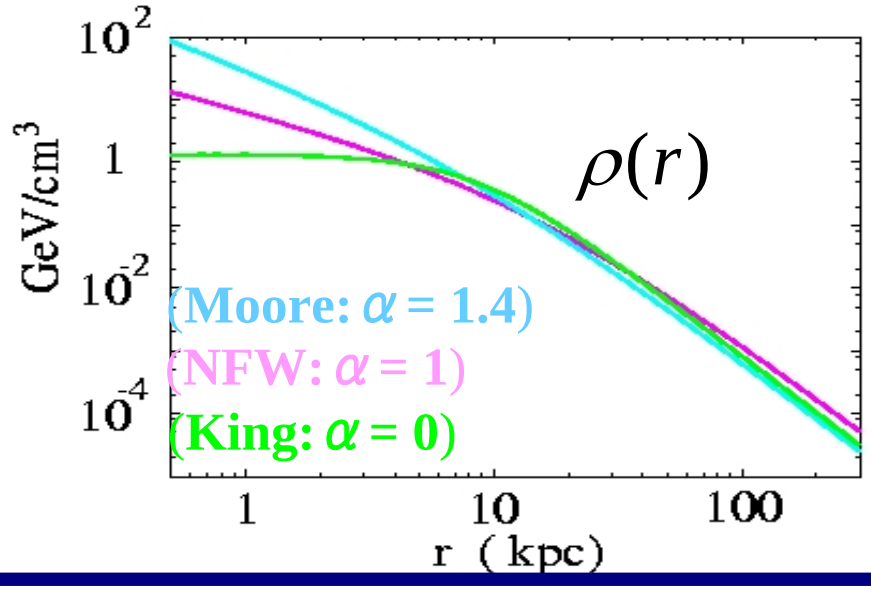
$$\bar{J} = \frac{1}{8.5\,(kpc)\,\Delta\Omega}\int_{\Delta\Omega} d\Omega \int_{l.o.s} dl(\theta)\left(\frac{\rho}{0.3\,GeV\ cm^{-3}}\right)^2$$

Flux strongly depends on dark matter profile, so evaluation of the profile is important !!

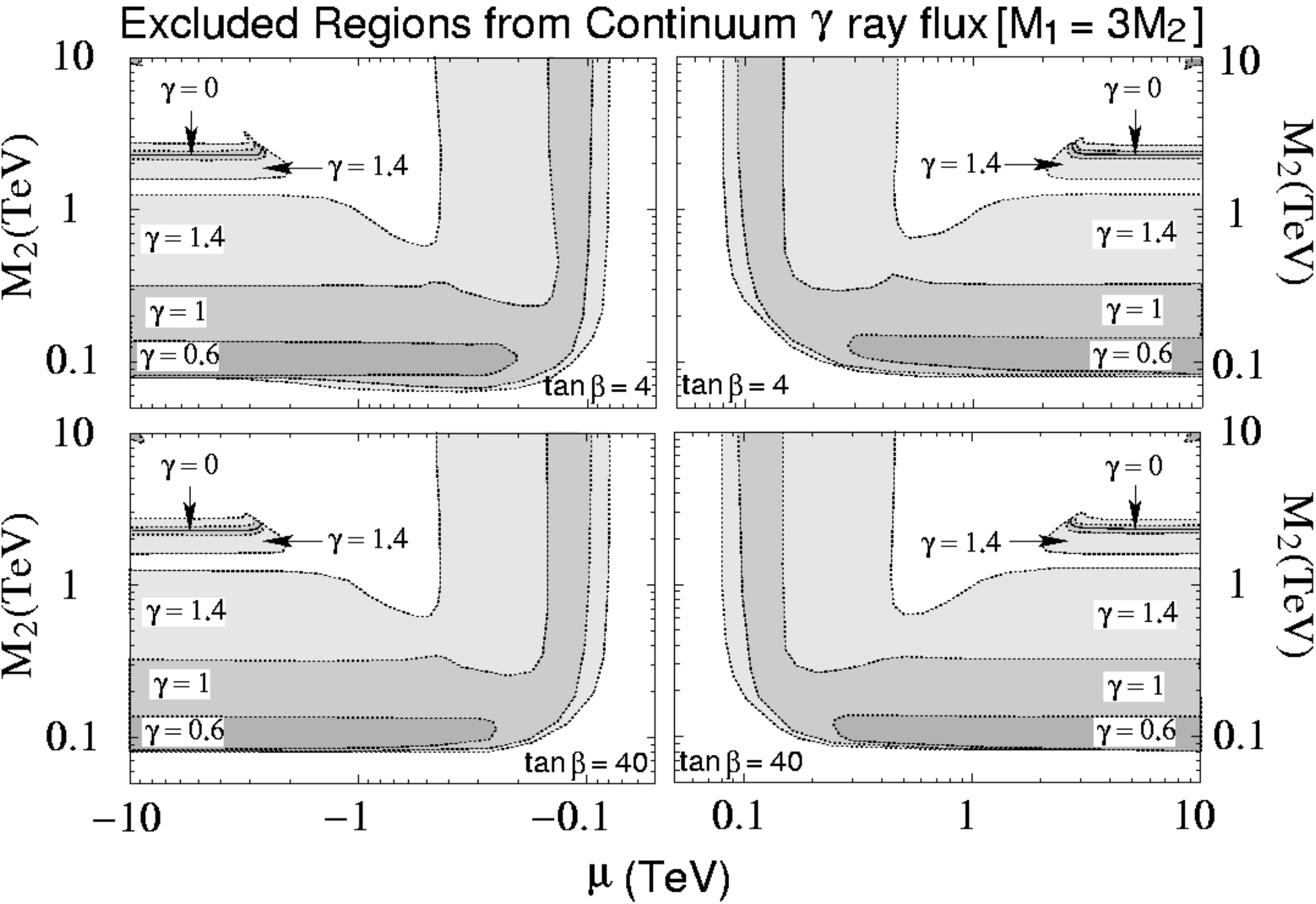
Cuspy structure

$\rho(r) \simeq r^{-\alpha}\ (r \sim 0)$

Recent N-body Simulations suggest

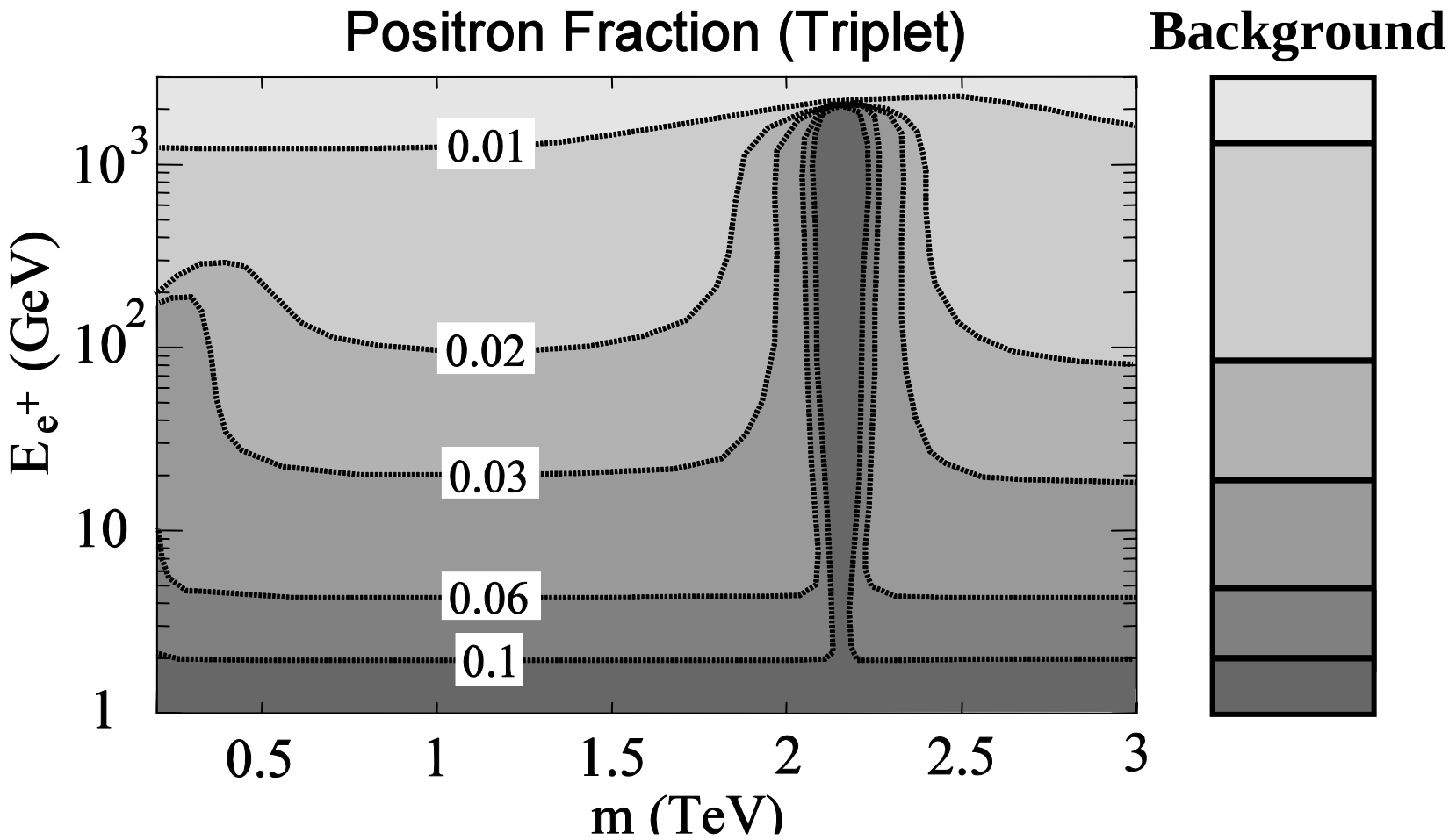


Excluded region by EGRET from G.C. for different profiles



Indirect detection of EWIMP dark matter using positrons

Positron Fraction = (Positron Flux) / (Positron + Electron Flux)



Large excess of the positron fraction !!

Summary

We computed the cross sections of dark matter relevant to direct and indirect detections when the DM is $SU(2)_L$ non-singlet (EWIMP).
We calculated the collision cross section between EWIMP and nucleus, gamma ray flux from the galactic center, positron excess in C.R..

When the mass of EWIMP is large $(m > m_W)$, some 1-loop diagrams significantly contribute to the collision cross section (Non-decoupling).
In cal. of the annihilation cross section, non-perturbative effects become important, and the cross section is enhanced (Threshold Singularity).

If EWIMP is realized as the dark matter, strong signals are expected in both direct and indirect detections.
In direct detections, EWIMP has the collision cross section larger than $10^{-46}\mathrm{cm}^2$ for the triplet, and $10^{-47}\mathrm{cm}^2$ for the doublet case.
In indirect detections, strong signals such as excesses of gamma rays and positrons in C.R. are expected. Some regions in MSSM parameter space are already constrained by the EGRET observation.