# Neutrino Signals from Unstable Dark Matter

## Ongoing Project in Collaboration with Laura Covi, Alejandro Ibarra and David Tran

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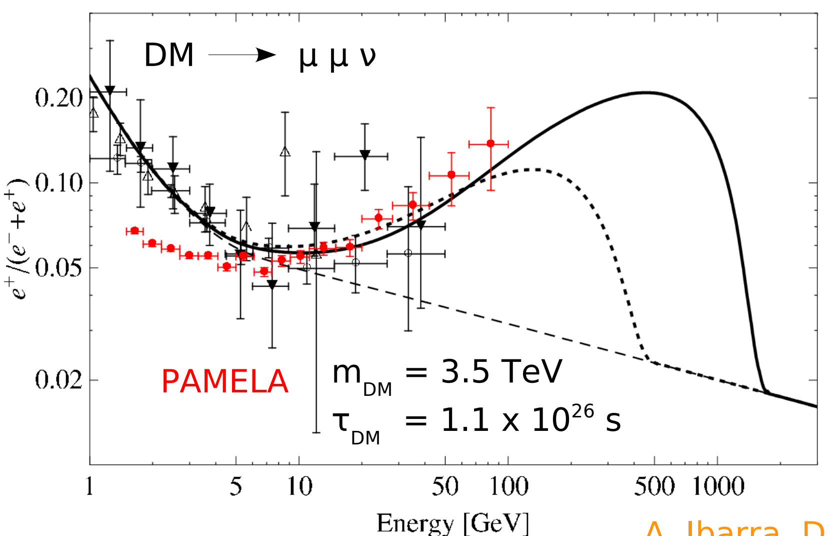
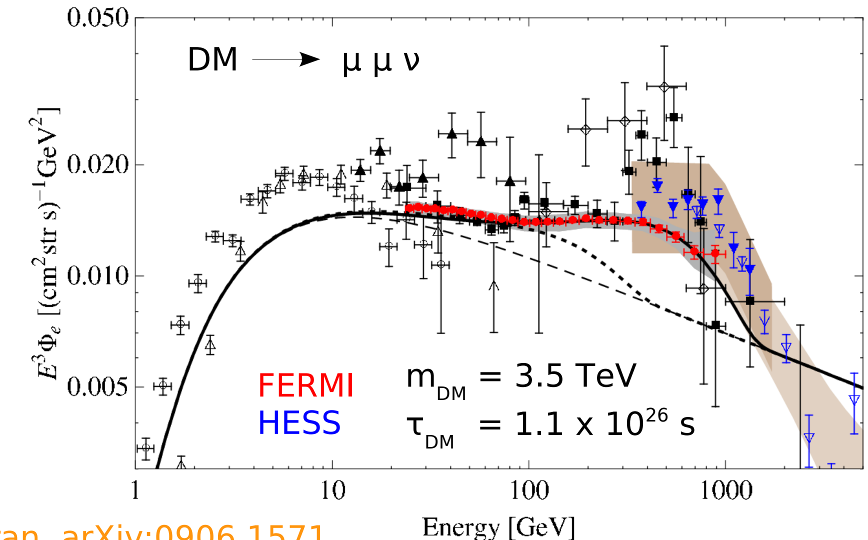
DESY Theory Group, Hamburg
Nijmegen09, 21st August 2009

# Motivation

- Recent cosmic ray experiments show anomalies in the 10 GeV up to TeV range (PAMELA, FERMI, HESS, …)
- Can be explained by astrophysical sources: pulsars
- But: could also be a signal of dark matter annihilation or decay!
- Need further observations to discriminate between scenarios



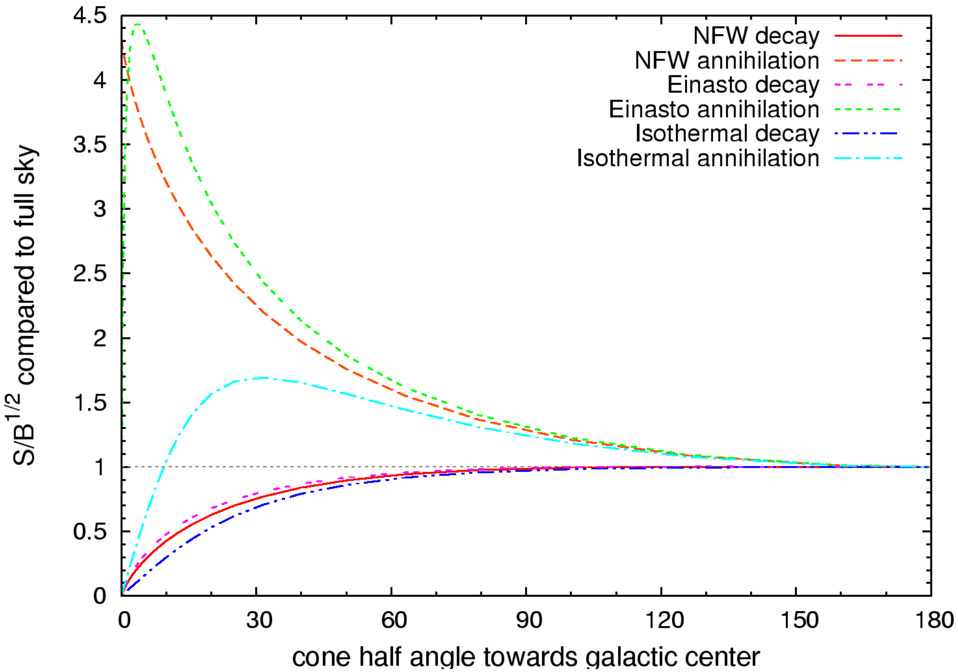

A. Ibarra, D. Tran, arXiv:0906.1571

# Annihilating vs Decaying Dark Matter

- Flux from galactic halo: $$\frac{dJ}{dE} = \frac{1}{4\pi} \underbrace{\frac{\langle \sigma v \rangle}{2 m_{DM}^2} \frac{dN}{dE}}_{\text{particle physics}} \underbrace{\int \varrho_{halo}^2(\vec{x})\, ds}_{\text{astrophysics}}$$

- Annihilation
  - $\propto \frac{\langle \sigma v \rangle}{2 m_{DM}^2} \varrho^2$
  - Look towards galactic center

- Decay
  - $\propto \frac{1}{m_{DM} \tau_{DM}} \varrho$
  - Look for diffuse signal




- Directionality discriminates annihilation and decay
- Gamma-rays and neutrinos are messengers that provide directional observations
- In addition isotropic (but subdominant) flux from cosmological dark matter density

# Dark Matter Decay Channels and Neutrino Flux

> Neutrino oscillations distribute the flux equally into all flavors

> Atmospheric neutrinos are the dominant background

> DM → $\nu\,\nu$

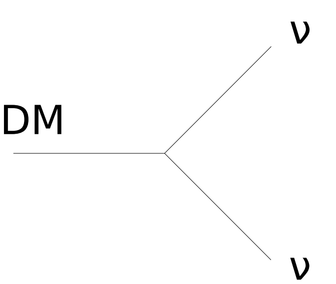
$l\ l$

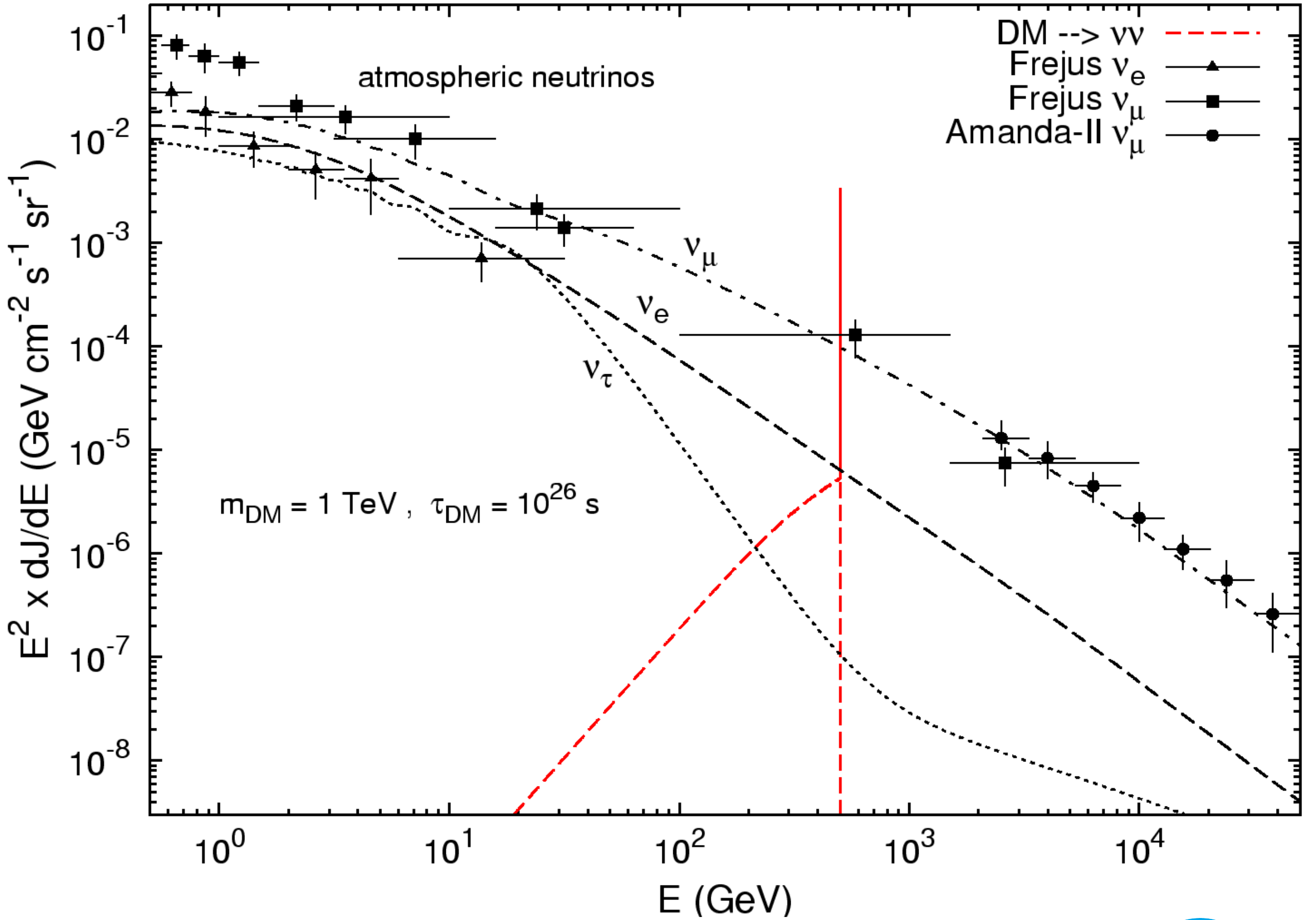
$l\ l\ \nu$

$Z\ \nu$

$W\ l$

$Z\ Z$



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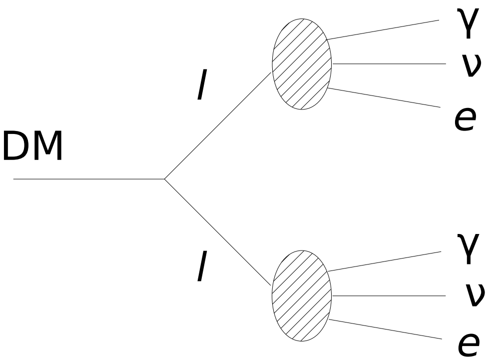


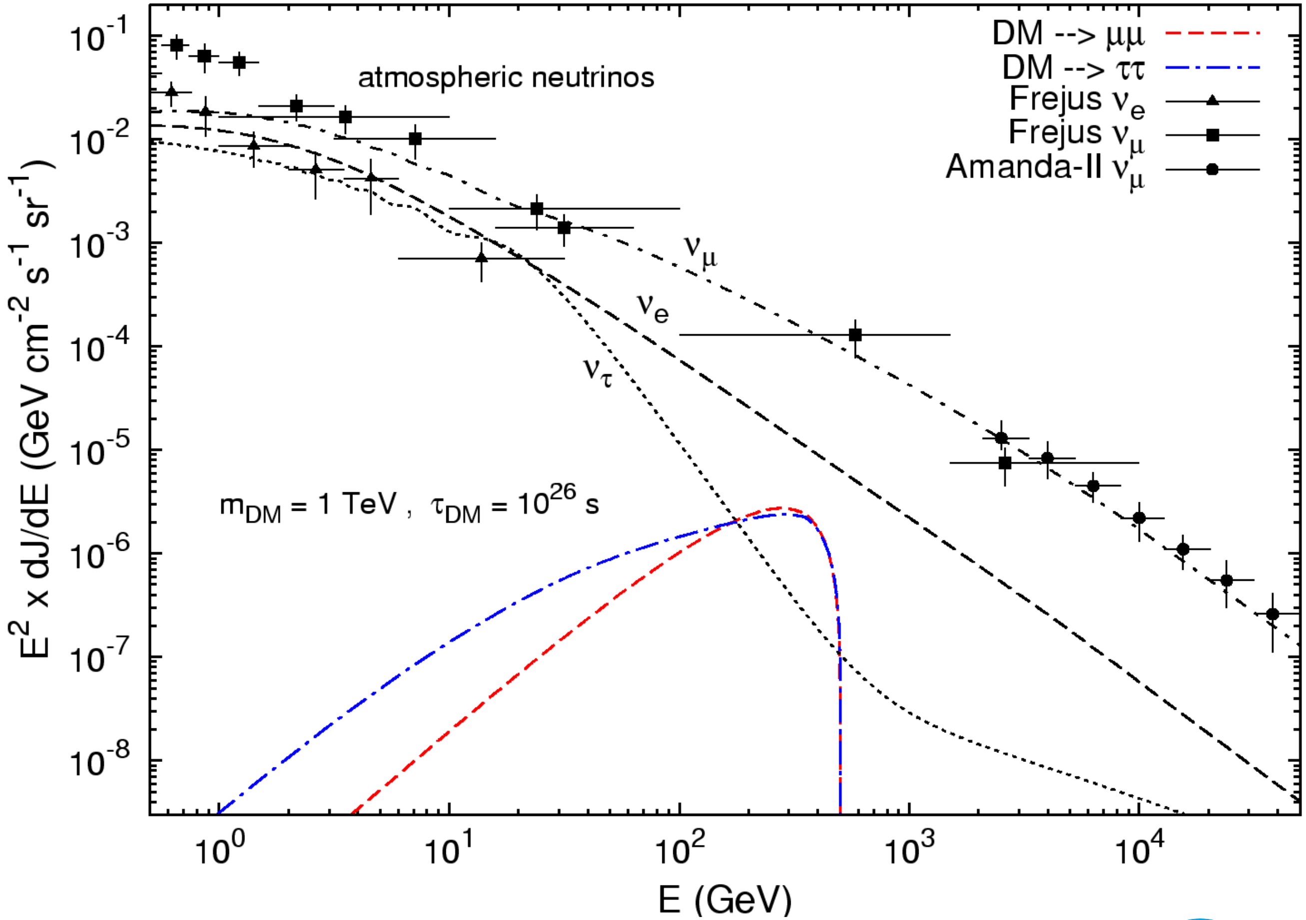

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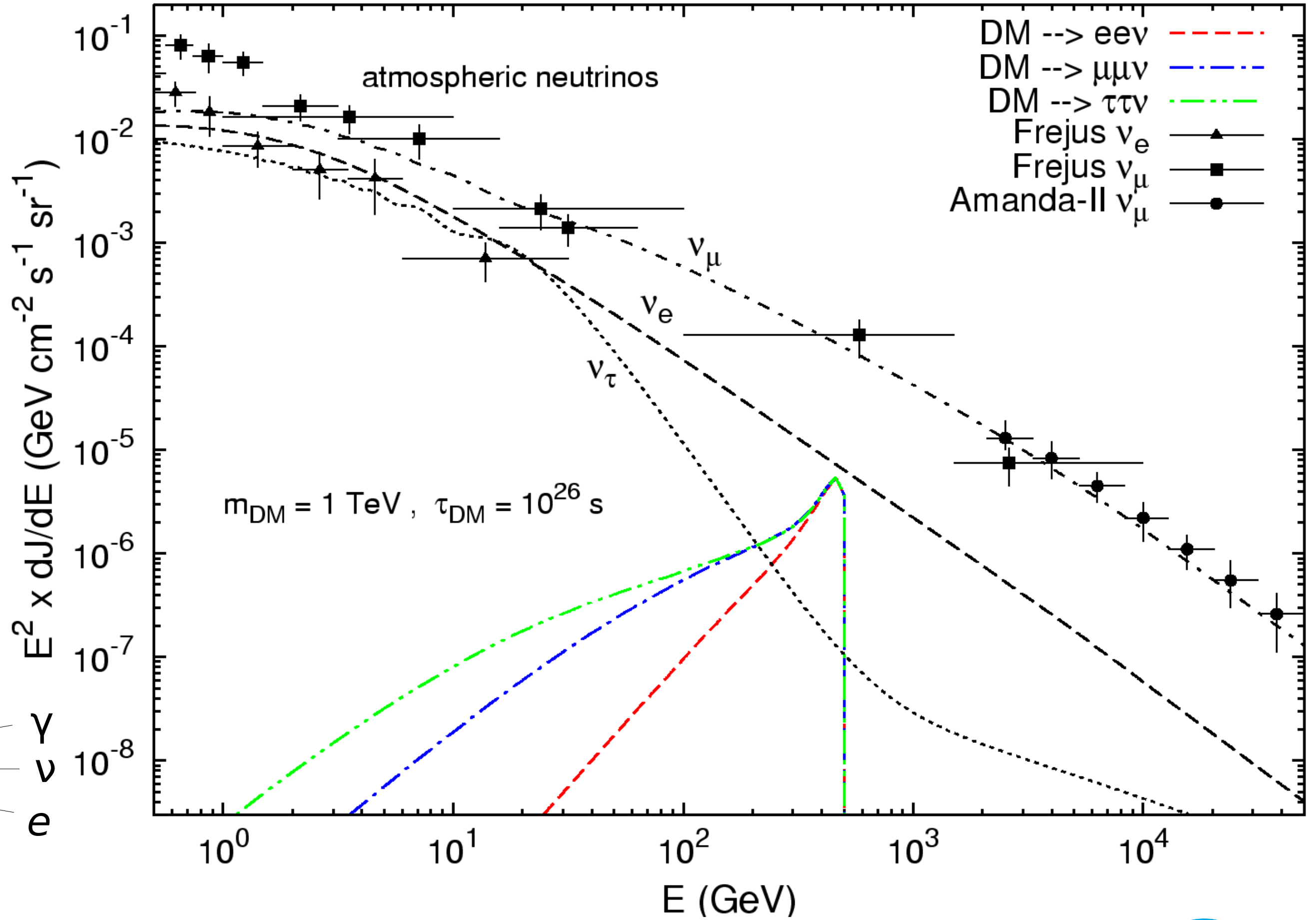


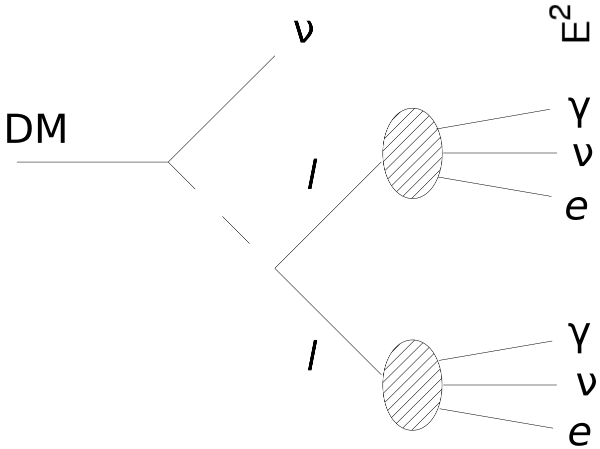

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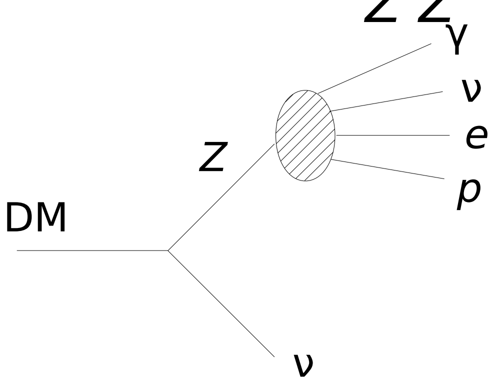


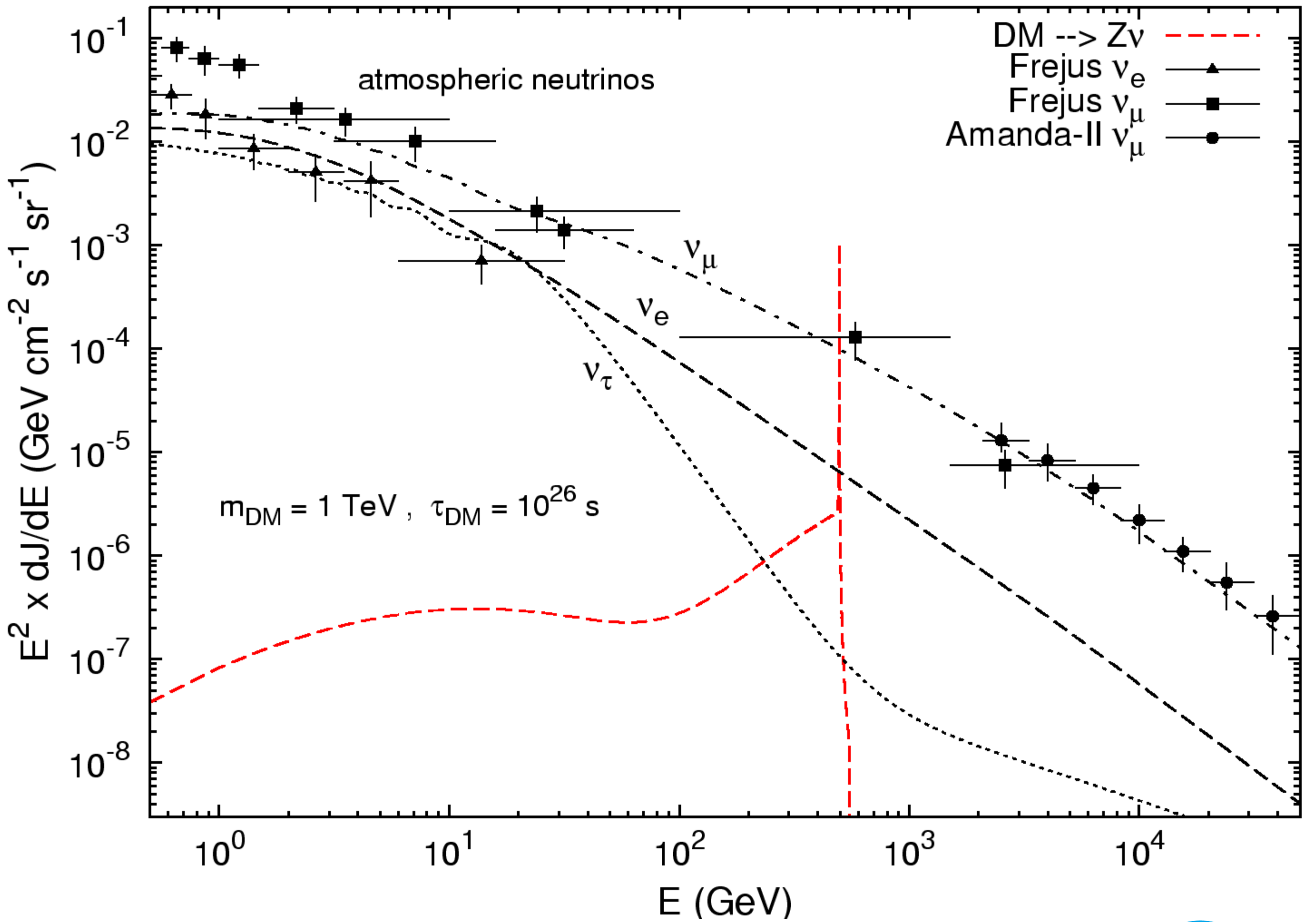

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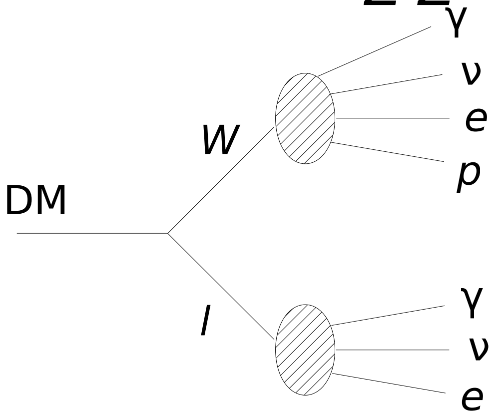


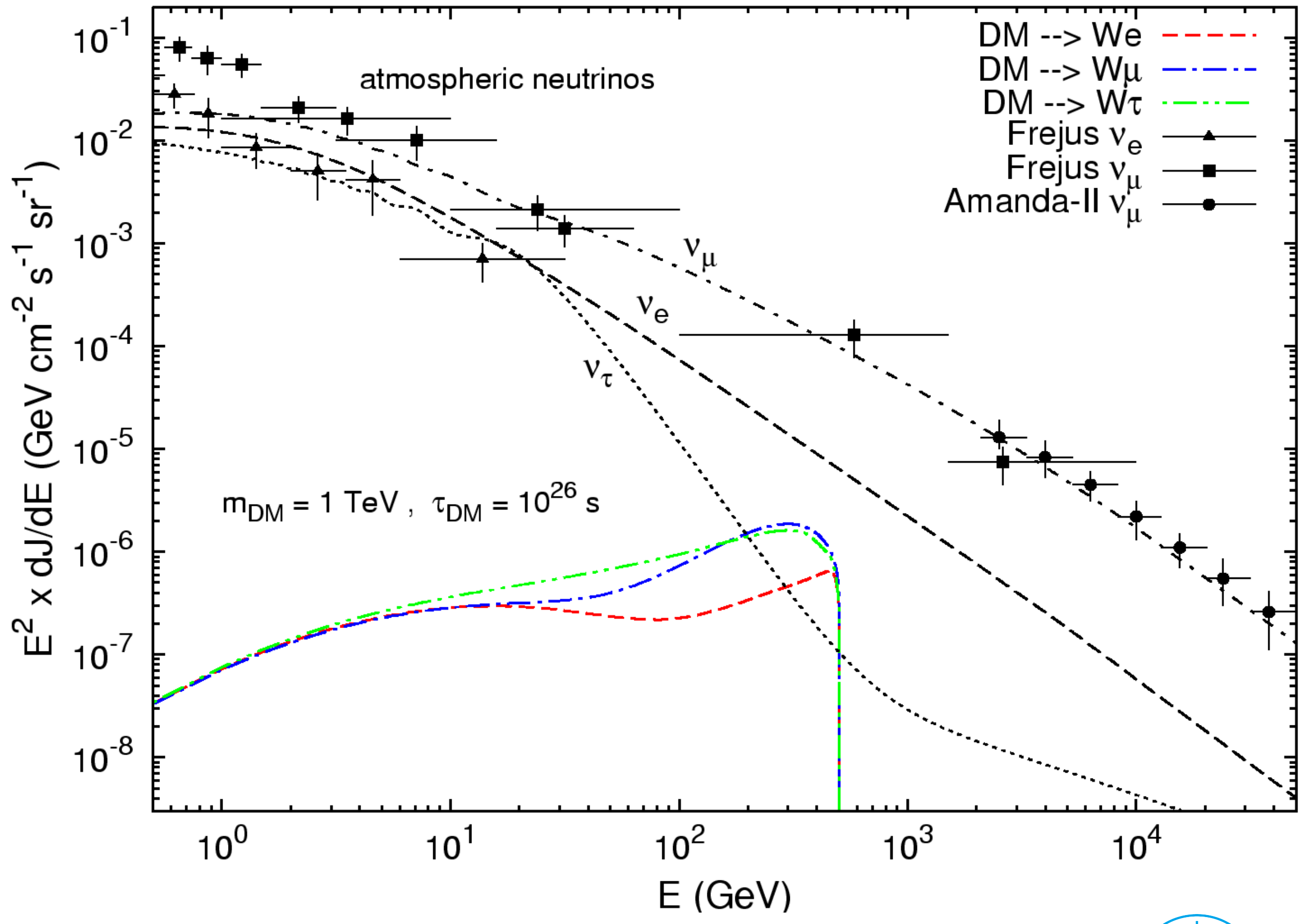

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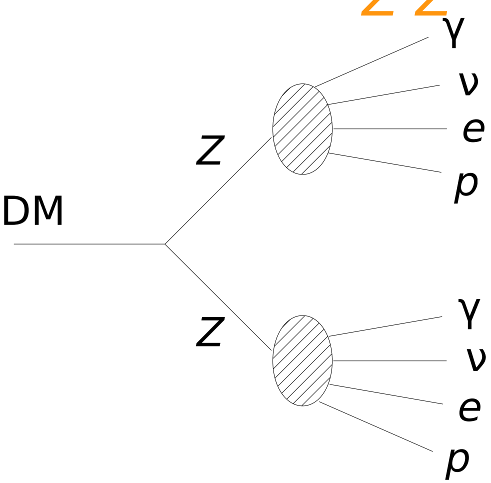
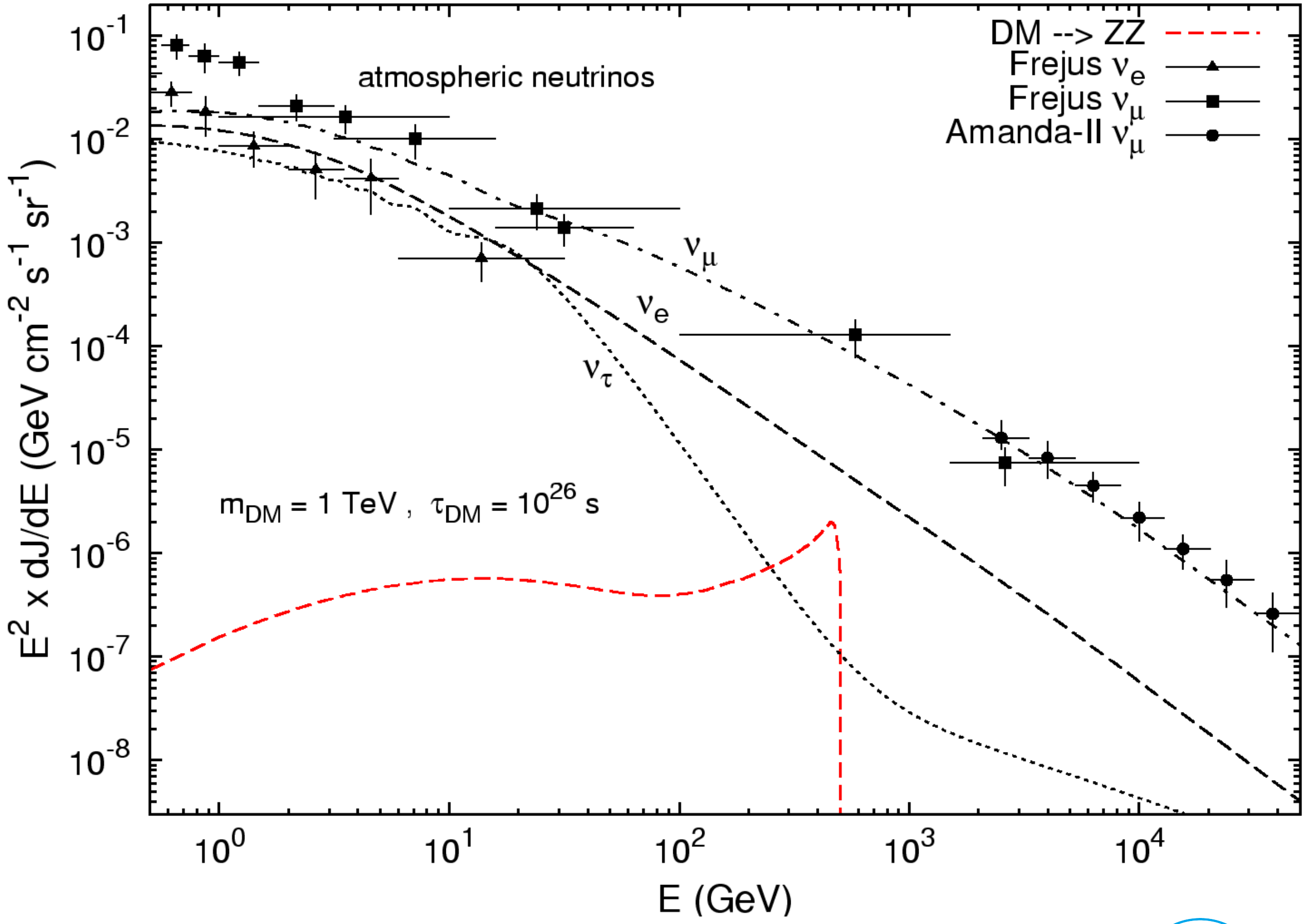
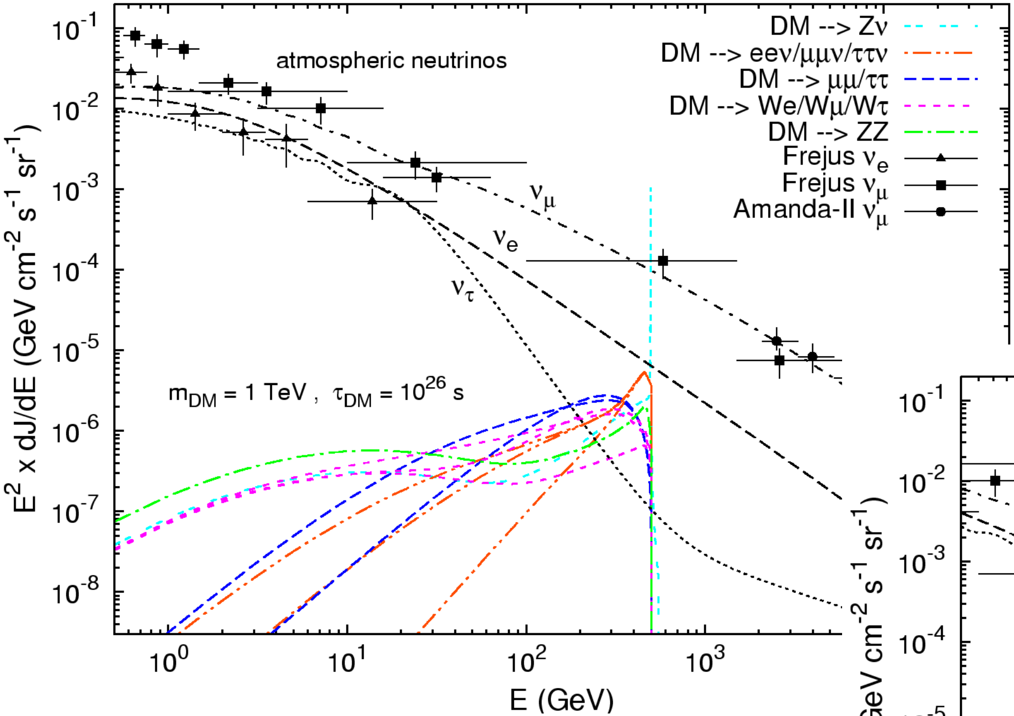
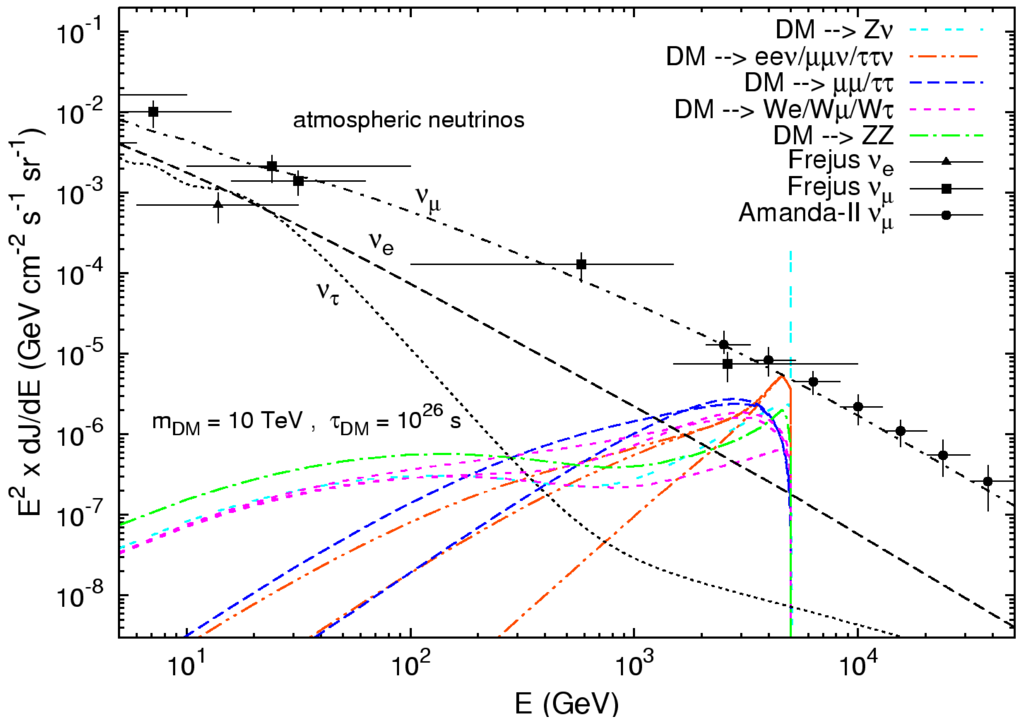


# Neutrino Flux from Dark Matter Decays



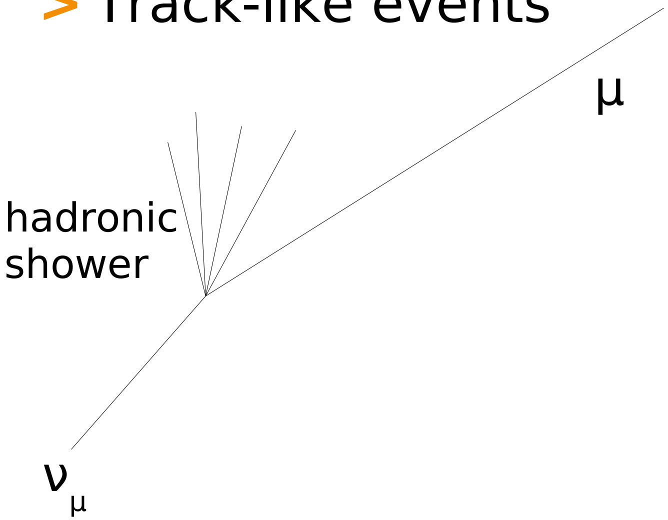




> Larger dark matter mass:

- Spectrum shifts to higher energies
- Signal-to-background ratio increases

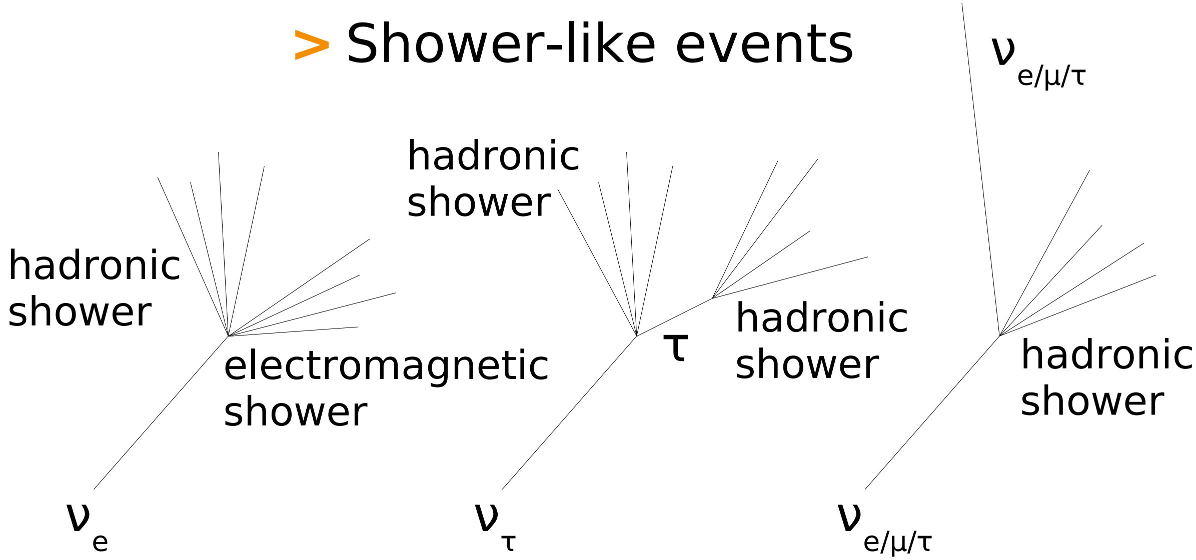
# Neutrino-induced Events

## > Track-like events




- Charged current $\nu_\mu N$ interactions produce muon track
- Muon can penetrate rock around the detector
- Larger effective detector volume
- Good angular resolution

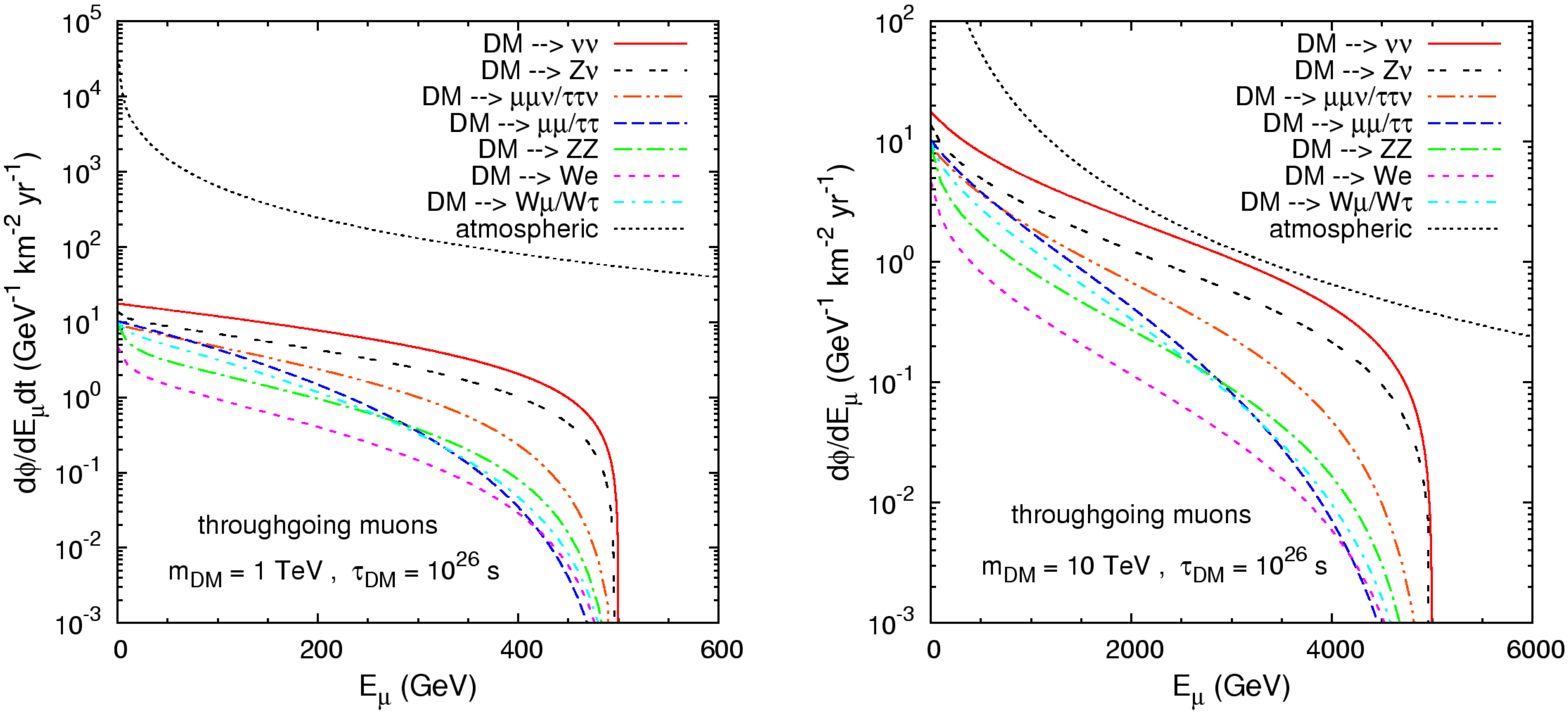
## > Shower-like events




- Charged current $\nu_{e/\tau} N$ and neutral current interactions of all flavors generate hadronic and/or electromagnetic showers
- Only interactions inside the detector are observed
- Good energy resolution

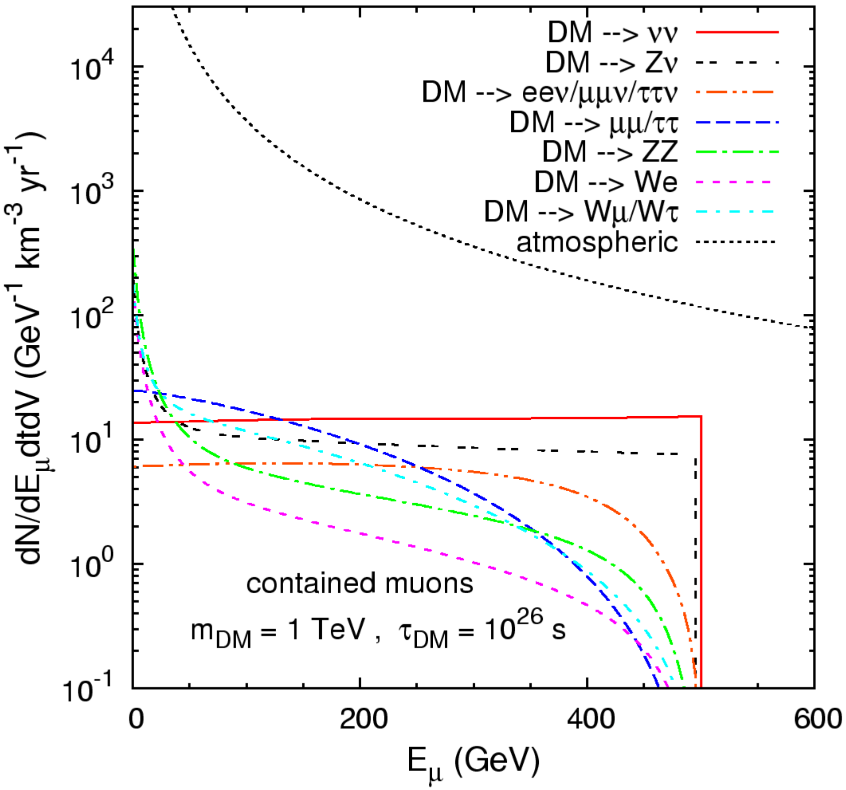
# Upgoing-Throughgoing Muon Events

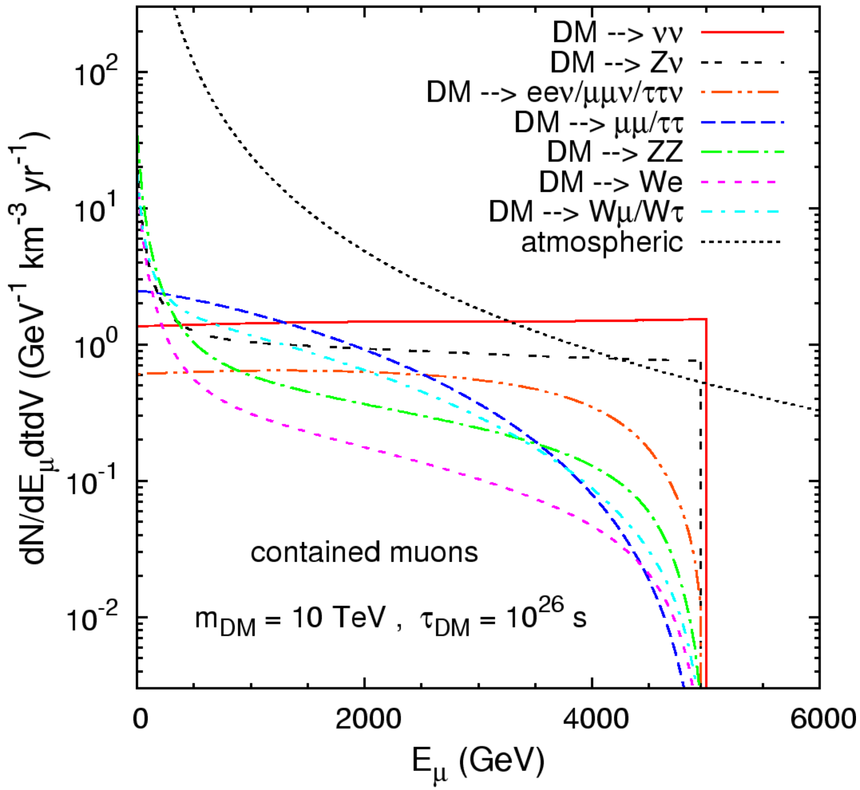
> Downgoing muons overwhelmed by atmospheric muons
> Muon propagation shifts spectrum to lower energies
> Original signal shape obscured



# (Partially) Contained Muon Events

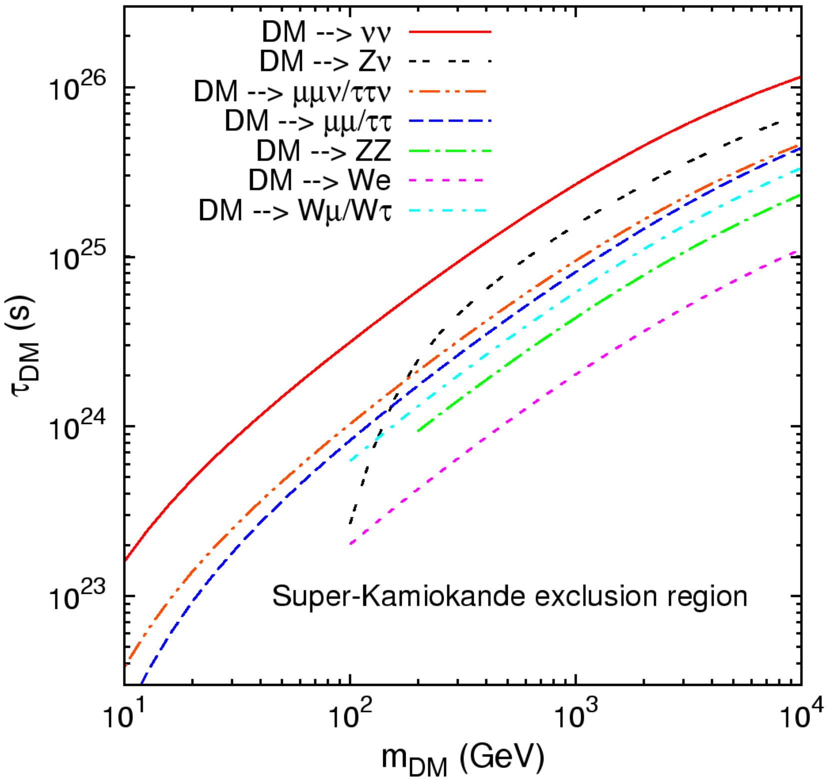
- Muon veto allows to discriminate from throughgoing muons
- 4π sensitivity (Super-Kamiokande, IceCube+DeepCore)
- Use collinear muon to reduce atmospheric background

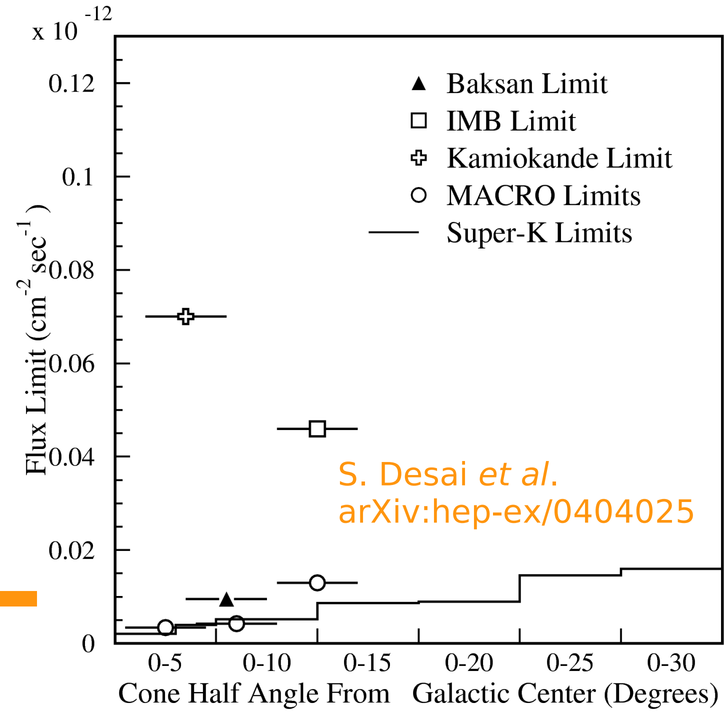


# Limits on the Dark Matter Parameter Space

- Super-Kamiokande:
  - Upgoing-throughgoing muons
  - Strongest limit from 30° cone around galactic center




- Ongoing work:
  - Neutrino telescopes will provide stronger limits
  - Volume $10^4$ times larger than Super-Kamiokande

# Conclusion

- Indirect dark matter searches might help to unveil the nature of the dark matter in the near future
- Decaying dark matter will need different search strategies than annihilating WIMPs
- Neutrinos are a complementary tool to charged cosmic rays and gamma rays that can help to decide between annihilating and decaying dark matter
- Forthcoming neutrino telescopes will be able to set constraints on dark matter parameters that are competitive with those from other cosmic ray species

- Thank you for your attention!