Neutrino Tridents at DUNE

Wolfgang Altmannshofer
altmanwg@ucmail.uc.edu

DUNE Beyond the Standard Model Group Meeting

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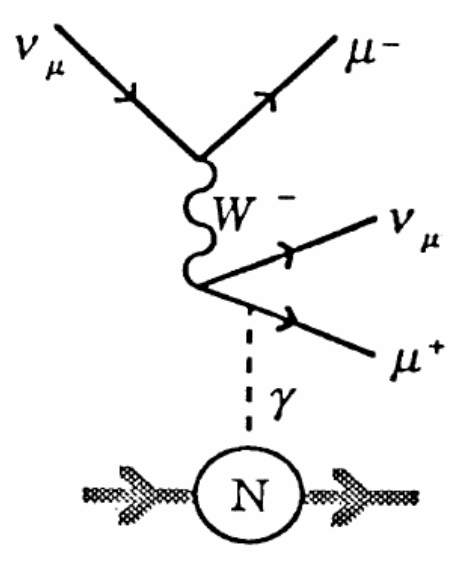
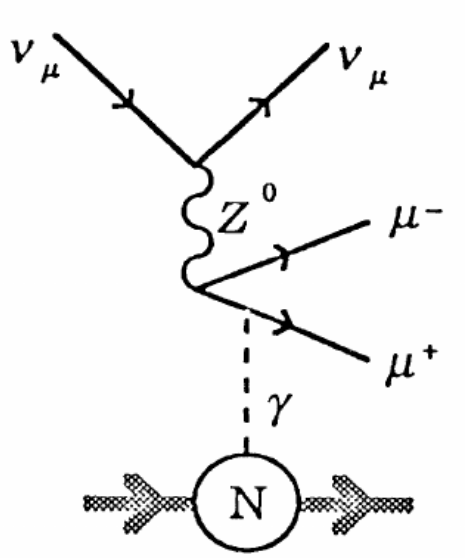
Reminder: Neutrino Trident Production

production of a muon anti-muon pair
in the scattering of a muon neutrino
in the Coulomb field of a heavy nucleus



probes the electro-weak interactions
of 2nd generation leptons

a rare process:
cross section is many orders of magnitude
smaller than the inclusive neutrino-nucleus
scattering cross section



see talk on Feb. 16, 2016
`https://indico.fnal.gov/conferenceDisplay.py?confId=11408`

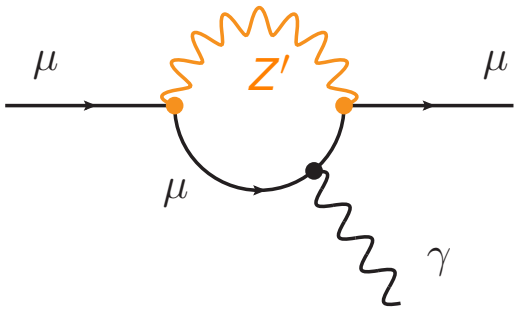
Motivation: New Muonic Forces

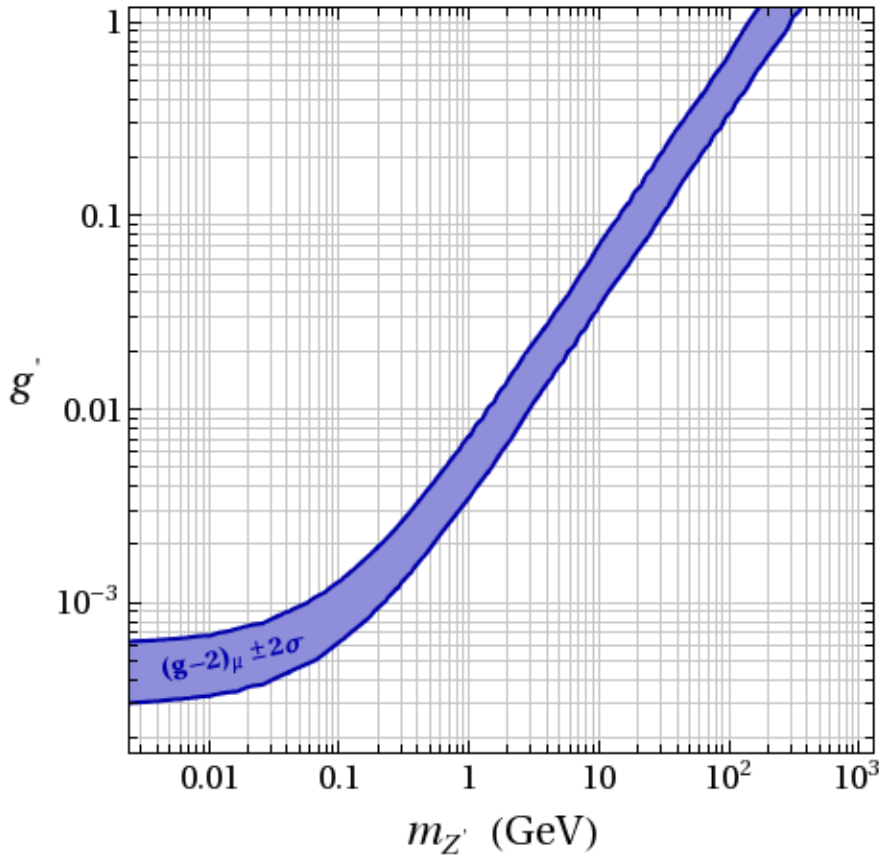
New forces with vector couplings to muons are motivated by the anomaly in the muon $g-2$

$$\Delta a_\mu \simeq (2.9 \pm 0.9) \times 10^{-9}$$

"benchmark" example:
Z' based on gauging $L_\mu - L_\tau$

(He, Joshi, Lew, Volkas '91)





$$\Delta a_\mu \simeq \frac{(g')^2}{12\pi^2}\frac{m_\mu^2}{m_{Z'}^2} + \mathcal{O}\left(\frac{m_\mu^4}{m_{Z'}^4}\right)$$

Muonic Forces and Neutrino Tridents

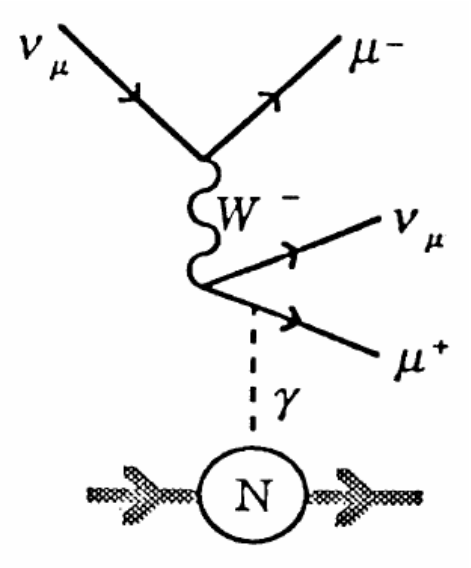
Z' bosons that couple vectorially to muons also couple to muon neutrinos

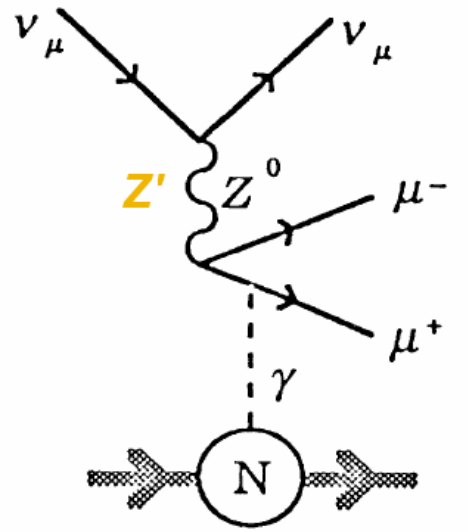
their contribution to neutrino trident production interferes constructively with the SM

for heavy enough Z':

$$\frac{\sigma}{\sigma_{\rm SM}} \simeq \frac{1 + (1 + 4s_W^2 + 2(g')^2 v^2 / m_{Z'}^2)^2}{1 + (1 + 4s_W^2)^2}$$

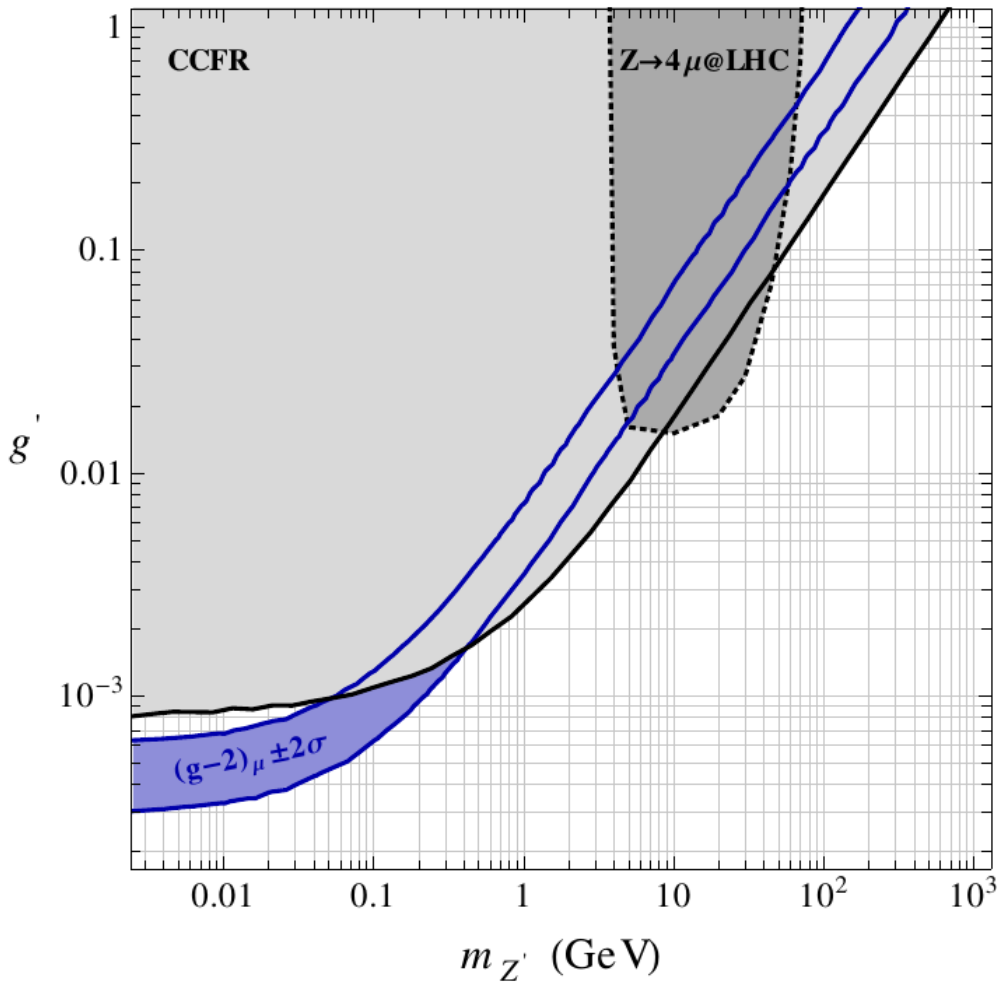
neutrino tridents can probe Z' bosons that explain $(g-2)_\mu$ anomaly





Current Trident Limit

(WA, Gori, Pospelov, Yavin, Phys.Rev.Lett. 113 (2014) 091801)



Z' that does not couple to electrons and quarks is very weakly constrained otherwise

existing measurements of neutrino tridents leave parameter space to explain $(g-2)_\mu$ with new muonic forces

$\rightarrow$ natural target

What is the Sensitivity of DUNE ?

Wolfgang Altmannshofer, Stefania Gori

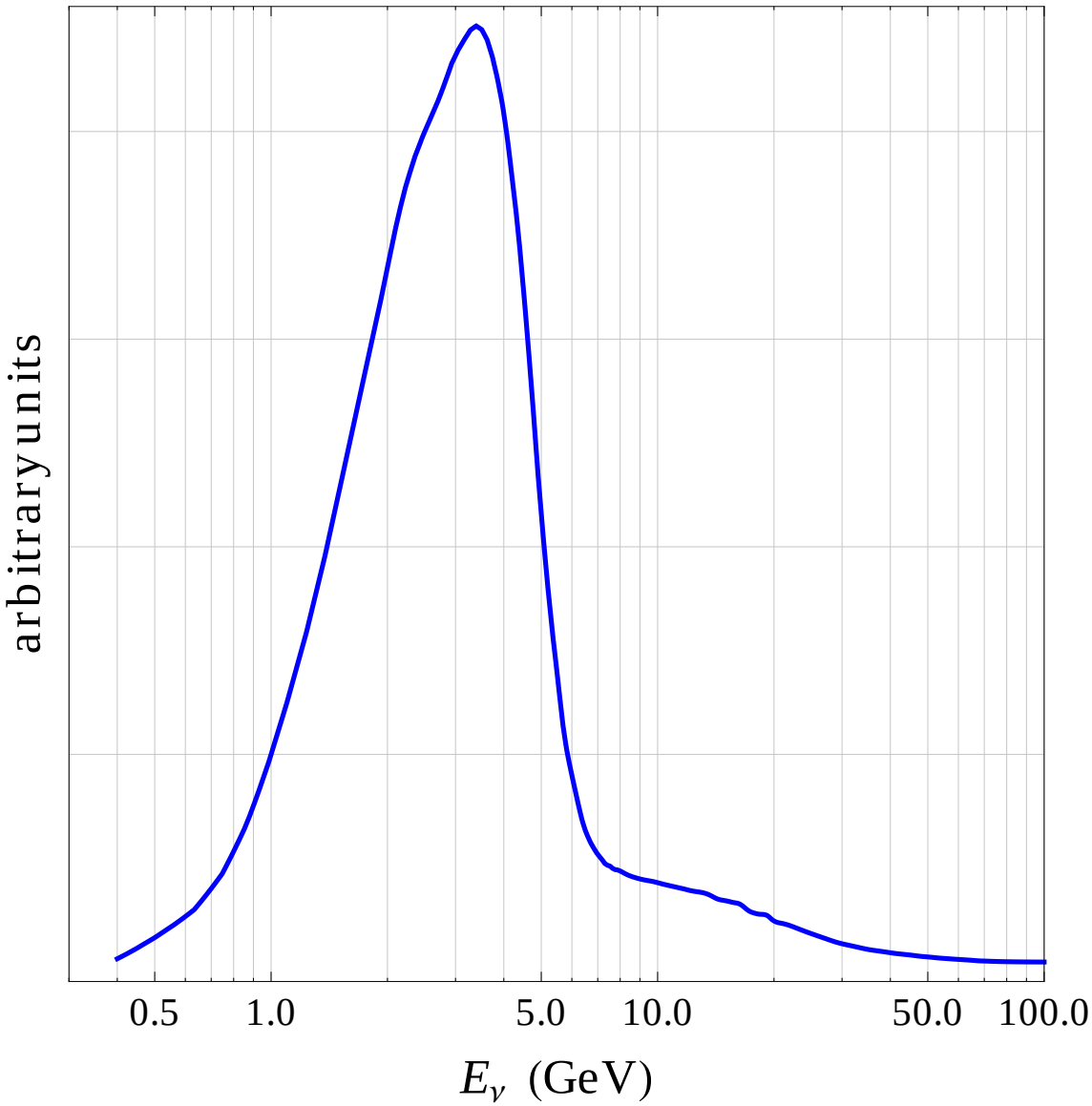
work in progress

Disclaimer

all results preliminary

Neutrino Energy Spectrum at Near Detector

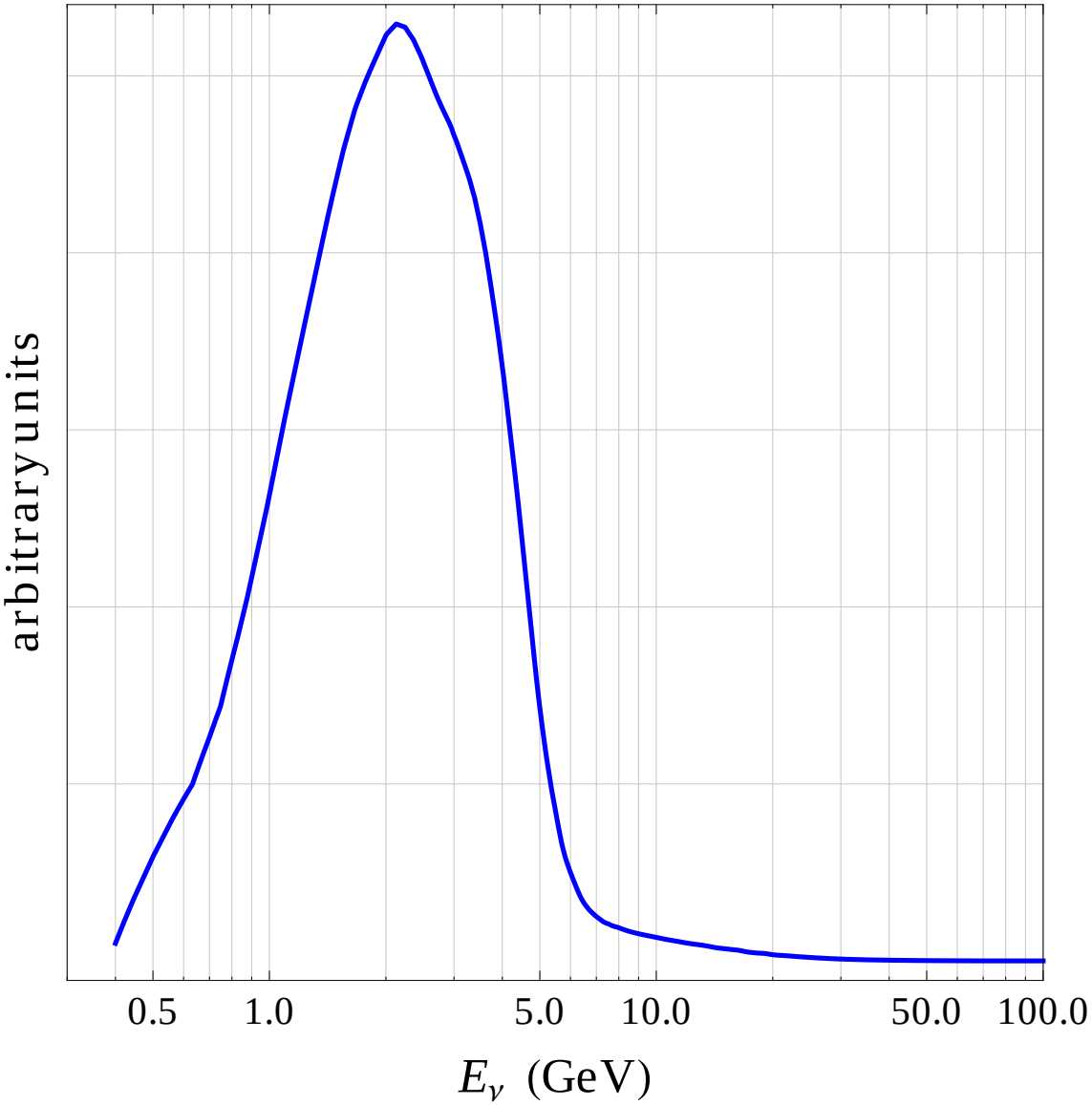
Thanks to Alex for providing the spectrum!



Neutrino Energy Spectrum Unfolded

We "unfold" the spectrum using inclusive CC neutrino cross sections from PDG

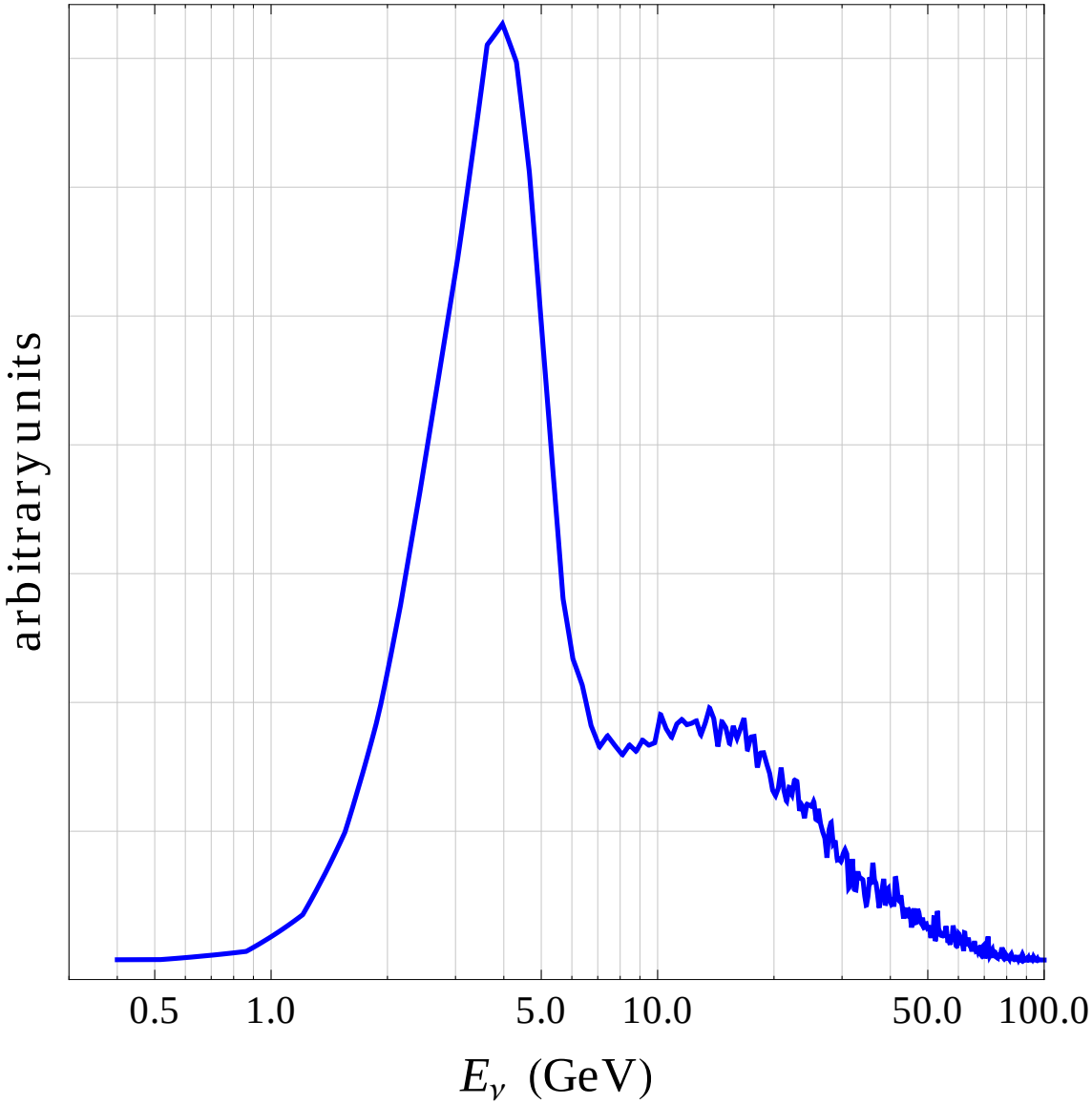
$\rightarrow$ proxy for the actual neutrino flux



Neutrino Energy Spectrum of Trident Events

We use the derived neutrino flux to predict the spectrum of trident neutrinos

(the noise is an artifact of the monte-carlo integration)



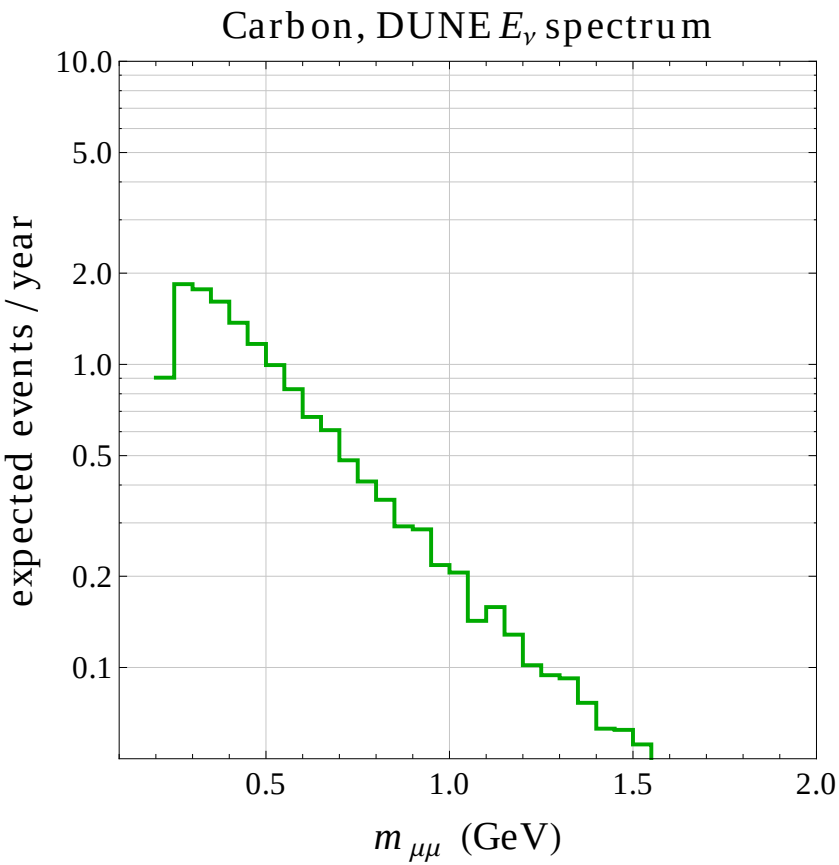
Trident Rate

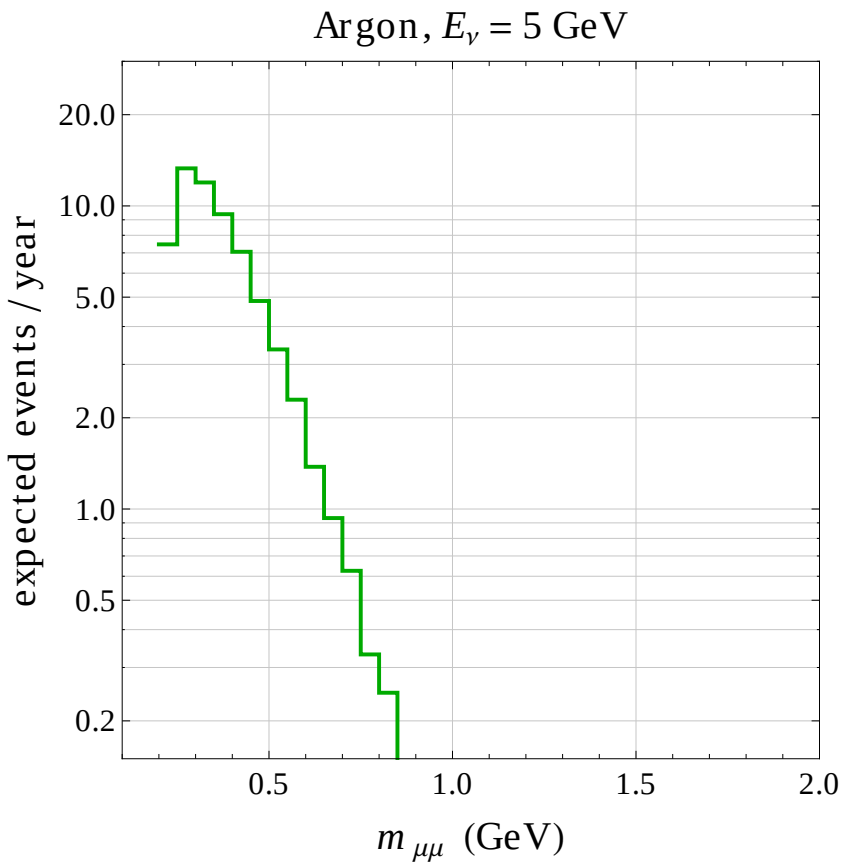
to predict the trident rate we use our calculated integrated trident cross section and compare it to the inclusive CC cross section and the expected rate of CC events at the near detector
(170,000 per ton of Carbon and per 10^{20} POT from the CDR)

$$\sim 15 \text{ trident events / year} \times \left(\frac{\text{detector mass}}{8 \text{ tons}} \right) \times \left(\frac{\text{POT / year}}{1.1 \times 10^{21} / \text{year}} \right)$$

(does not yet include anti-neutrino tridents: $\sigma_{\nu}^{\text{trident}} = \sigma_{\bar{\nu}}^{\text{trident}}$)

Dimuon Invariant Mass Spectrum

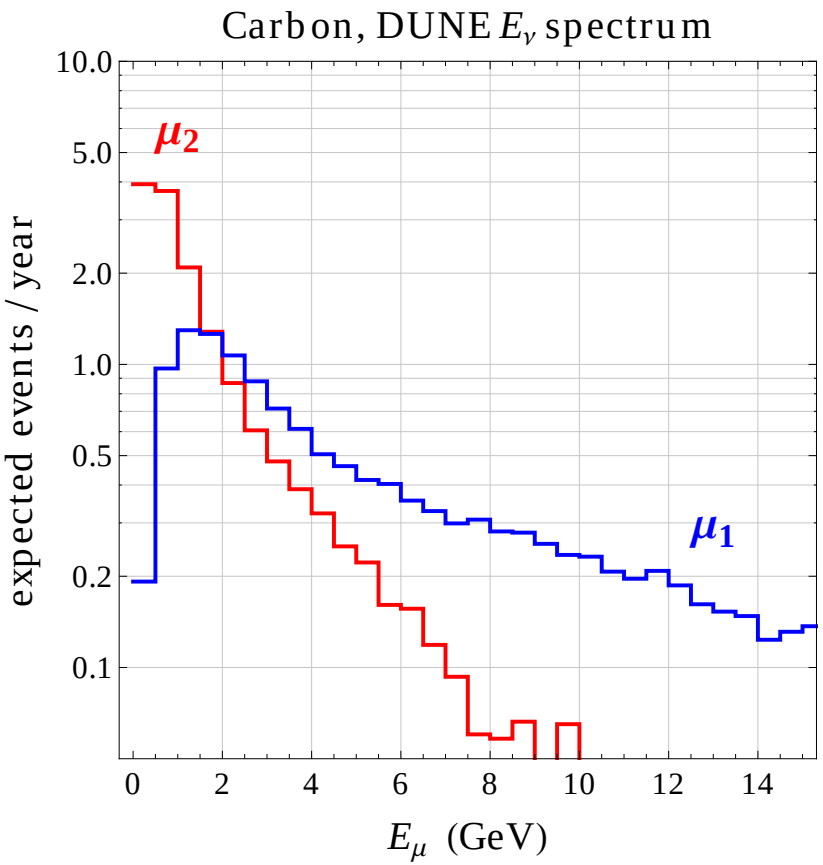


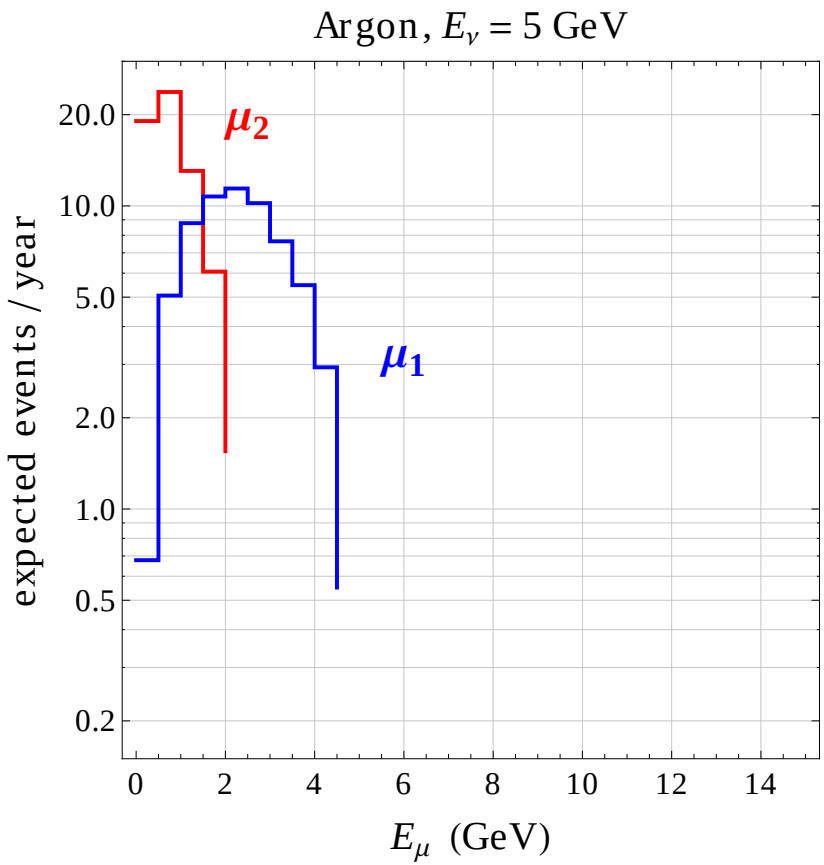


The shapes are different due to the different energy spectrum

The difference in the overall rate is mainly due to the material (Carbon instead of Argon)

Muon Energy Spectrum





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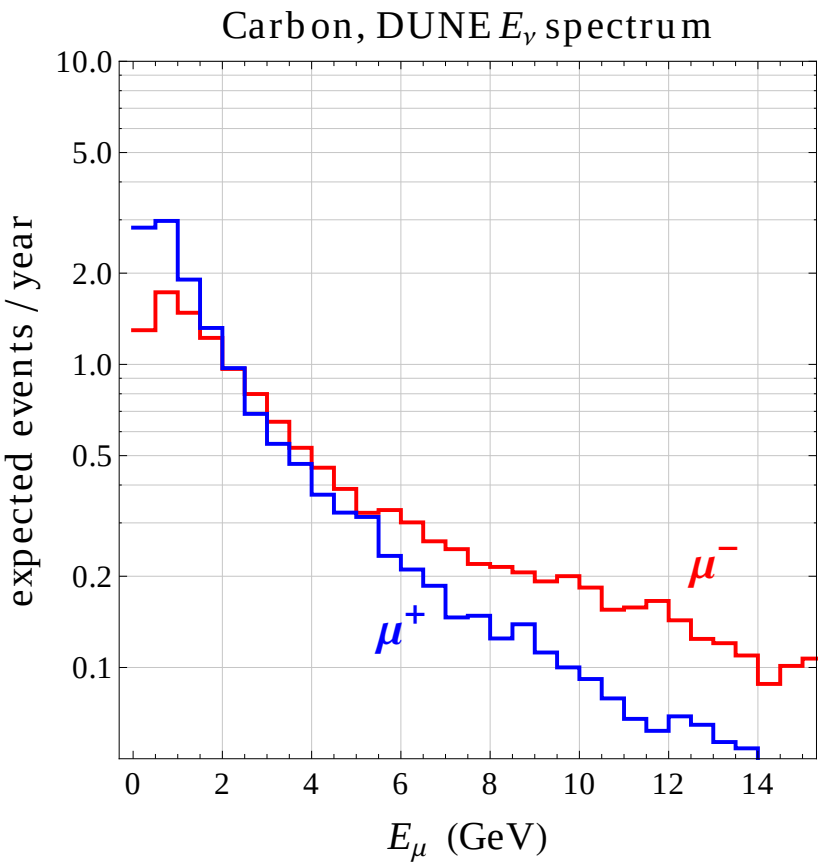
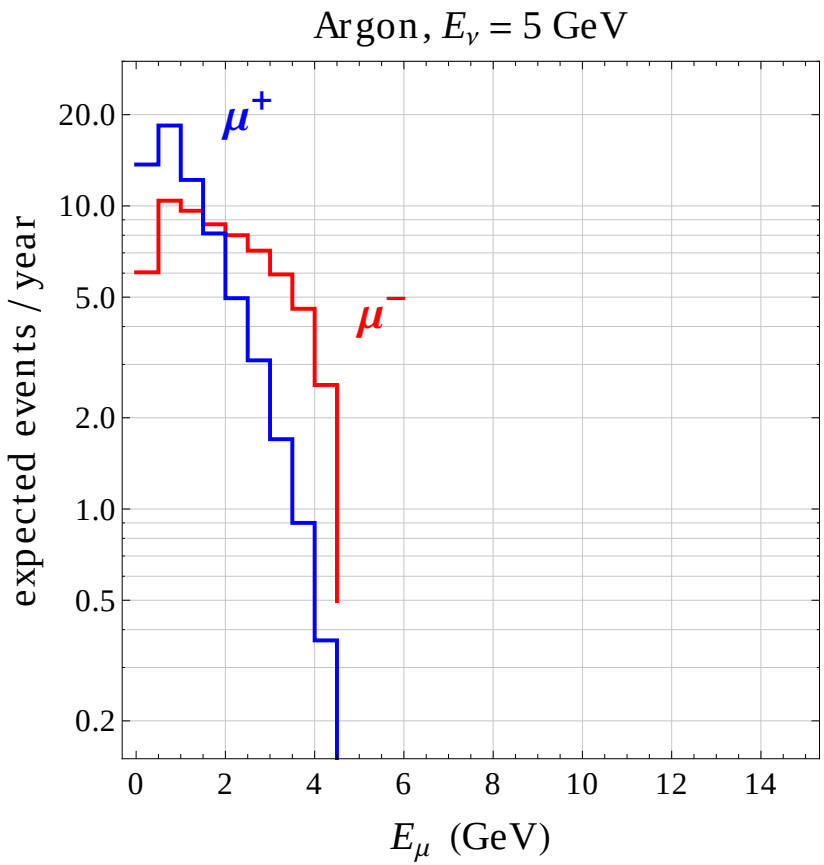
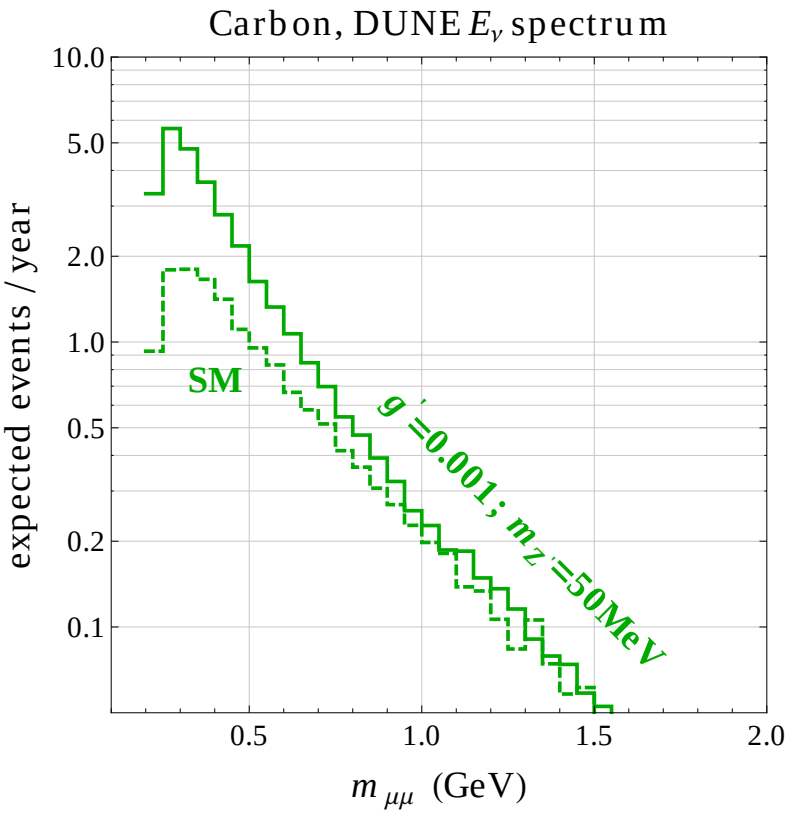


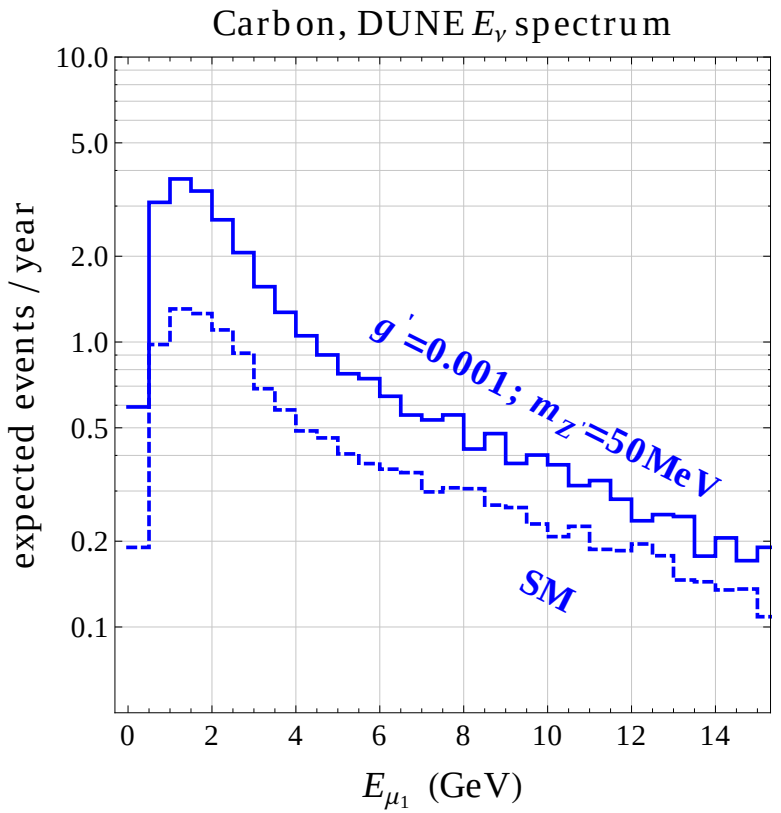


muon and anti-muon energy spectra for neutrino tridents

for anti-neutrino tridents, the muon and anti-muon spectra will be exchanged

Impact of New Physics (*super-preliminary*)





A light Z' can increase the rate by a factor of few

To Do List

- use measured nuclear form factors
  (instead of simple exponential parametrization)
- incorporate inelastic processes
  (shown results correspond to “elastic tridents”)
- code up a monte-carlo that
  generates unweighted trident events

Wish List

- energy spectrum of the neutrino flux
- energy spectrum of the anti-neutrino flux
- any insights to which extent "inelastic tridents" can be measured or distinguished from "elastic tridents"