Neutrino Backgrounds to Dark Matter Searches

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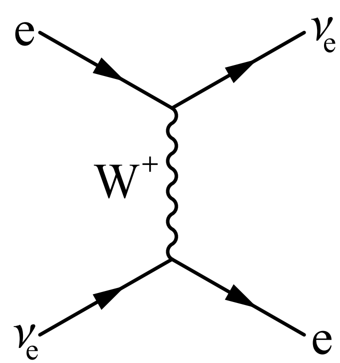
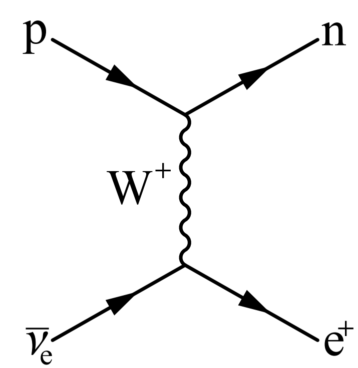
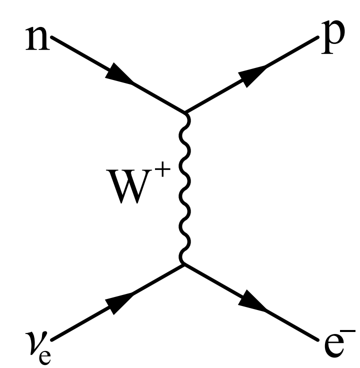
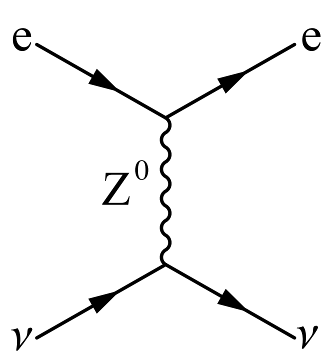
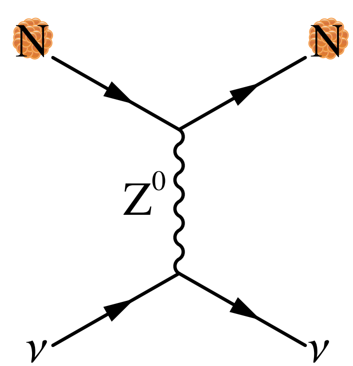
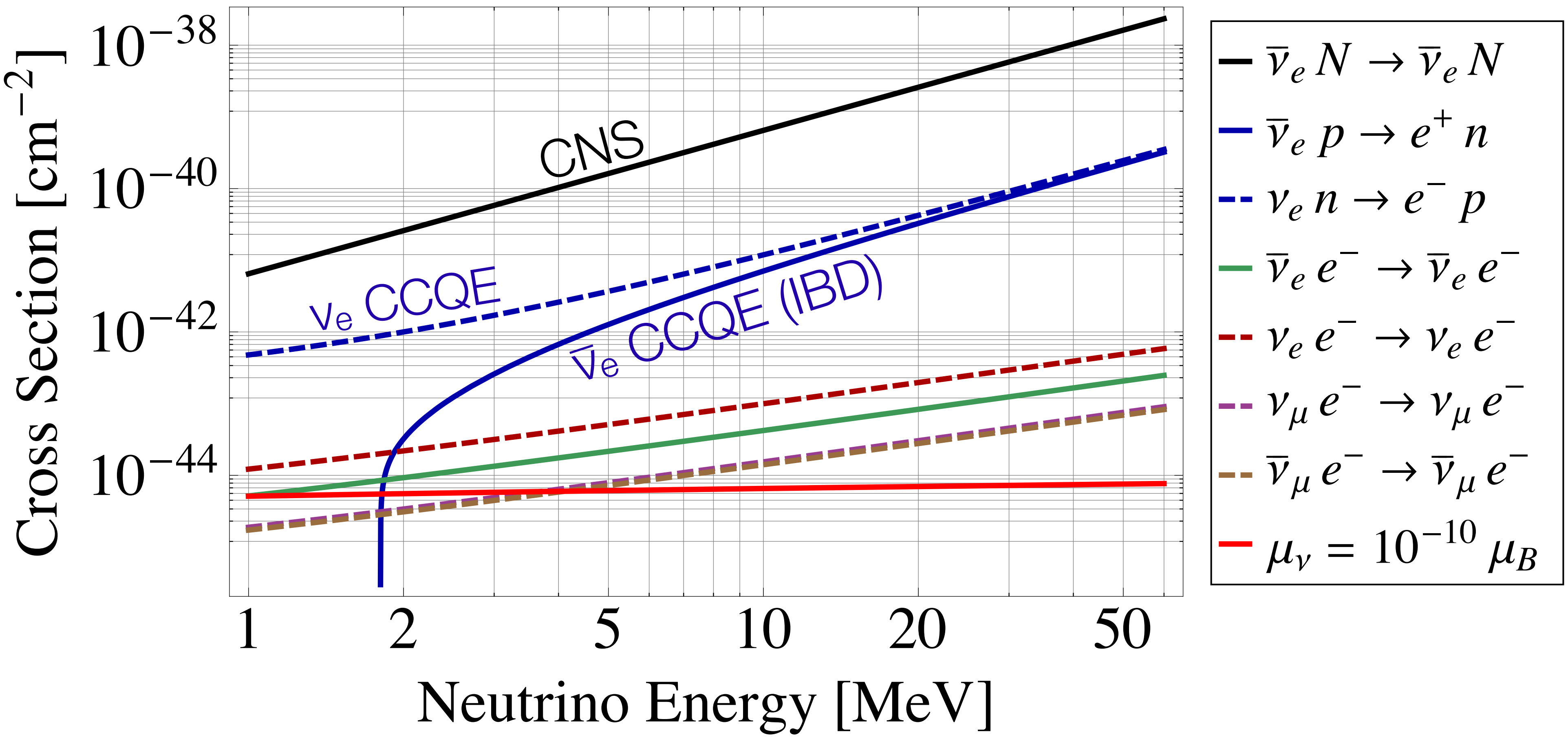
Outline

- Low-energy Neutrino Interactions and Cross Sections
- Neutrino Background Sources
- Nuclear Recoil Backgrounds (Coherent Scattering)
- Electron Recoil Backgrounds (Elastic and $2\nu\beta\beta$)
- Charged Current Quasi Elastic (CCQE)

Low-energy ν Interactions

	Elastic	Quasi-Elastic
Charged Current	 For ν_e and $\overline{\nu}_e$	 IBD  ν_μ, ν_τ not low-E
Neutral Current	  For all ν flavors	

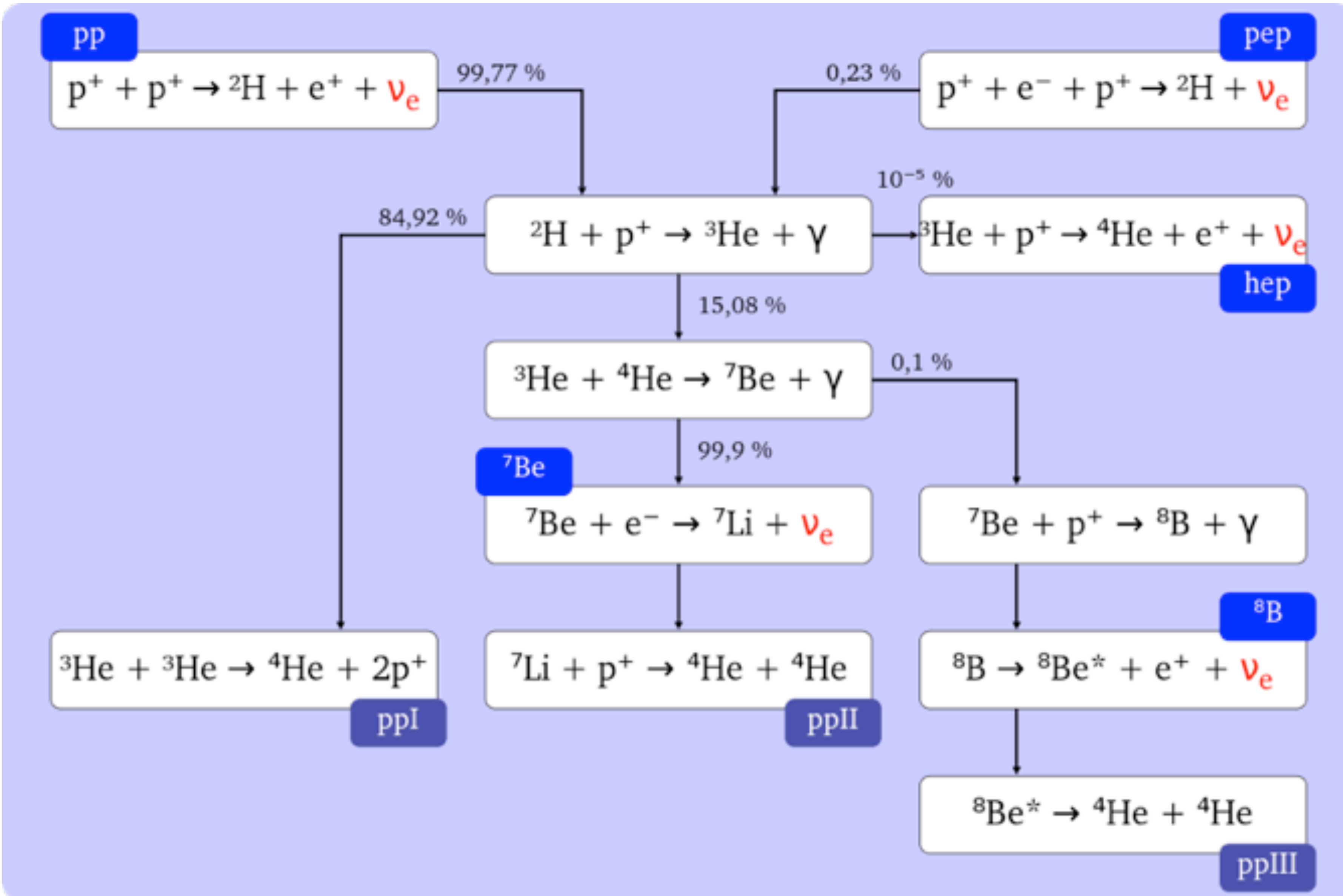
Low-Energy Neutrino Cross Sections



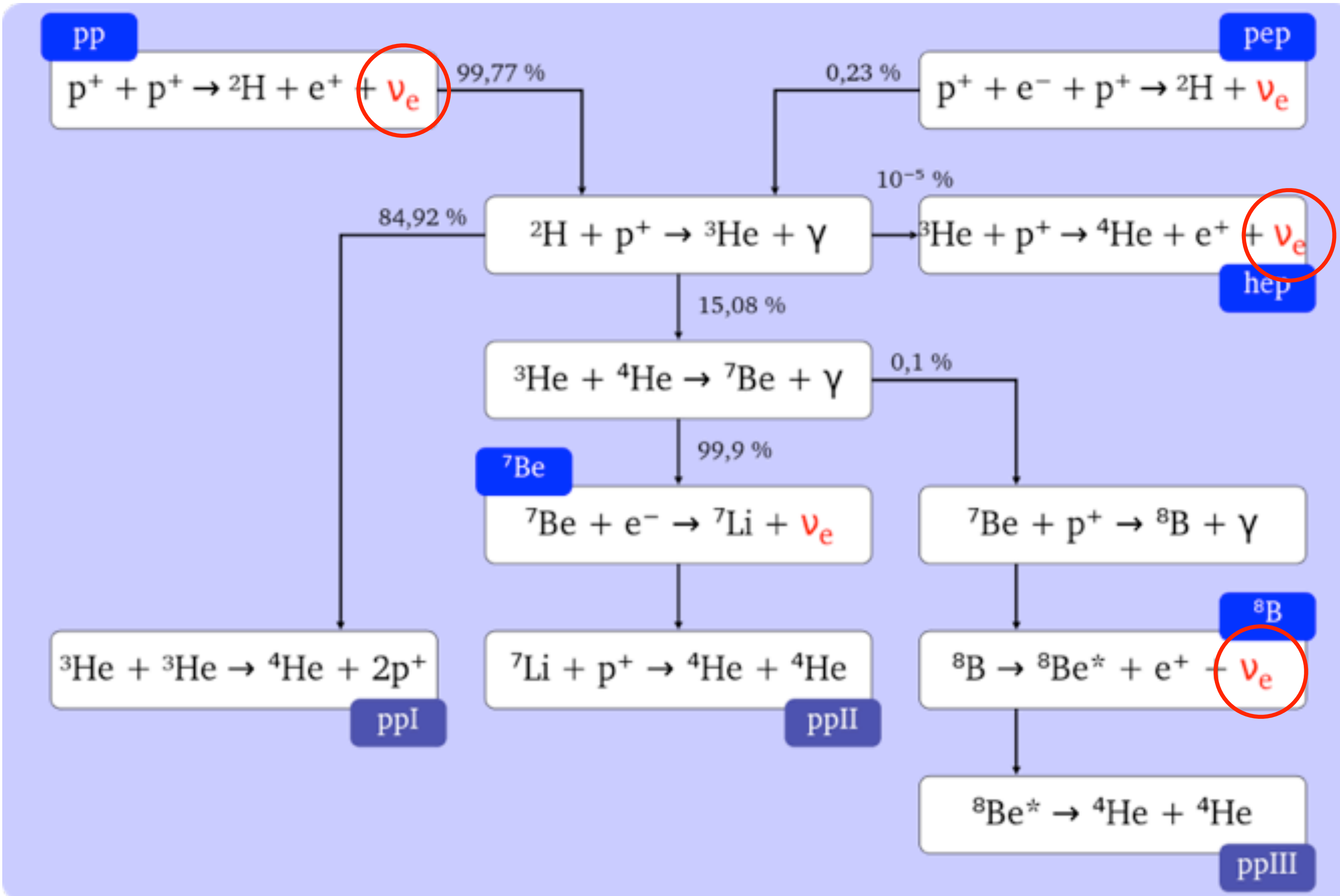
Neutrino Sources for Dark Matter Detectors

- Solar (ν_e)
- Diffuse Supernova Neutrino Background (all flavors)
- Atmospheric (all flavors)
- Geothermal ($\bar{\nu}_e$)
- Reactor ($\bar{\nu}_e$)
- Internal (ββ decays, $\bar{\nu}_e$)
- Supernova (burst, so not really a background, all flavors)

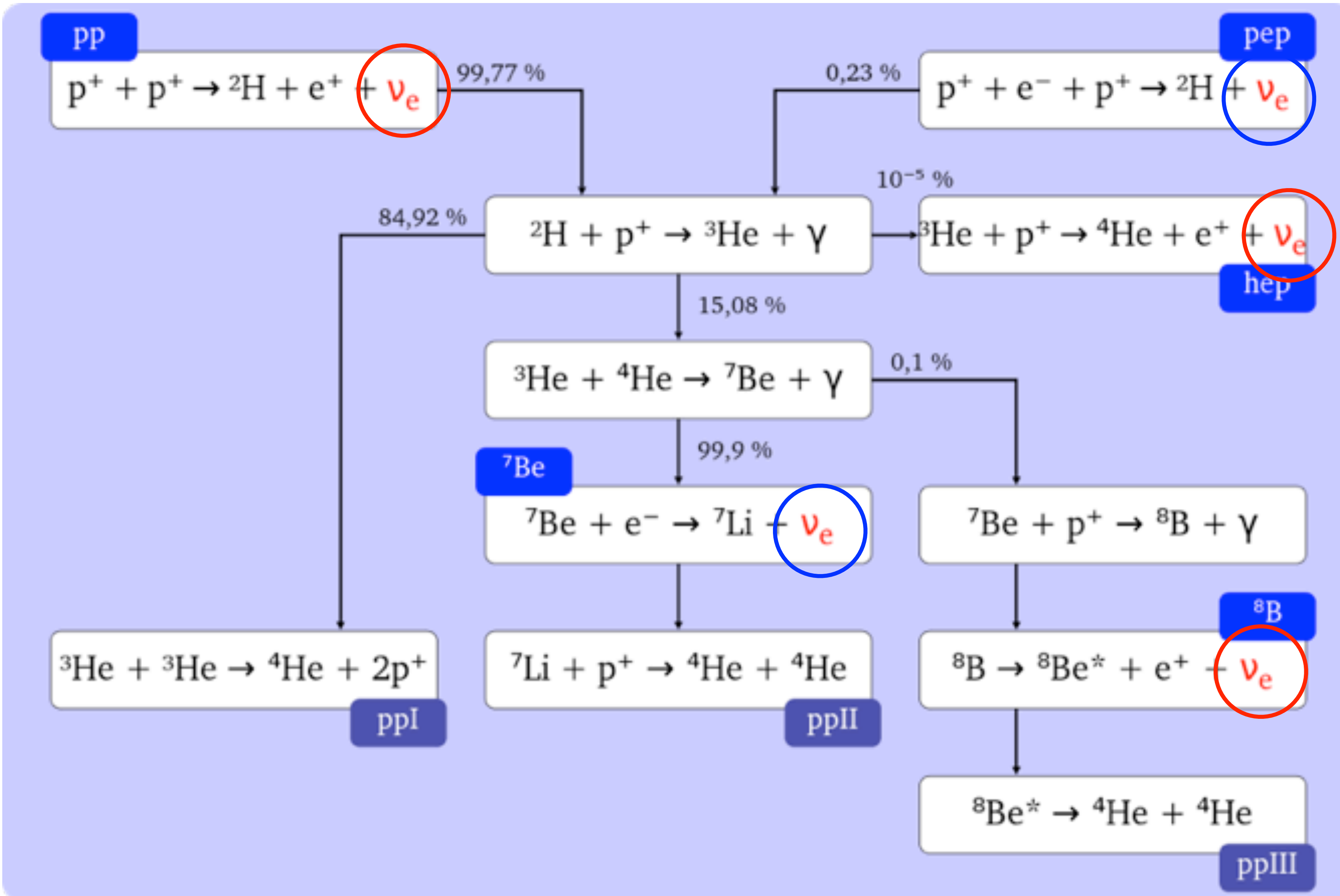
Solar Neutrino pp Chain



Solar Neutrino pp Chain

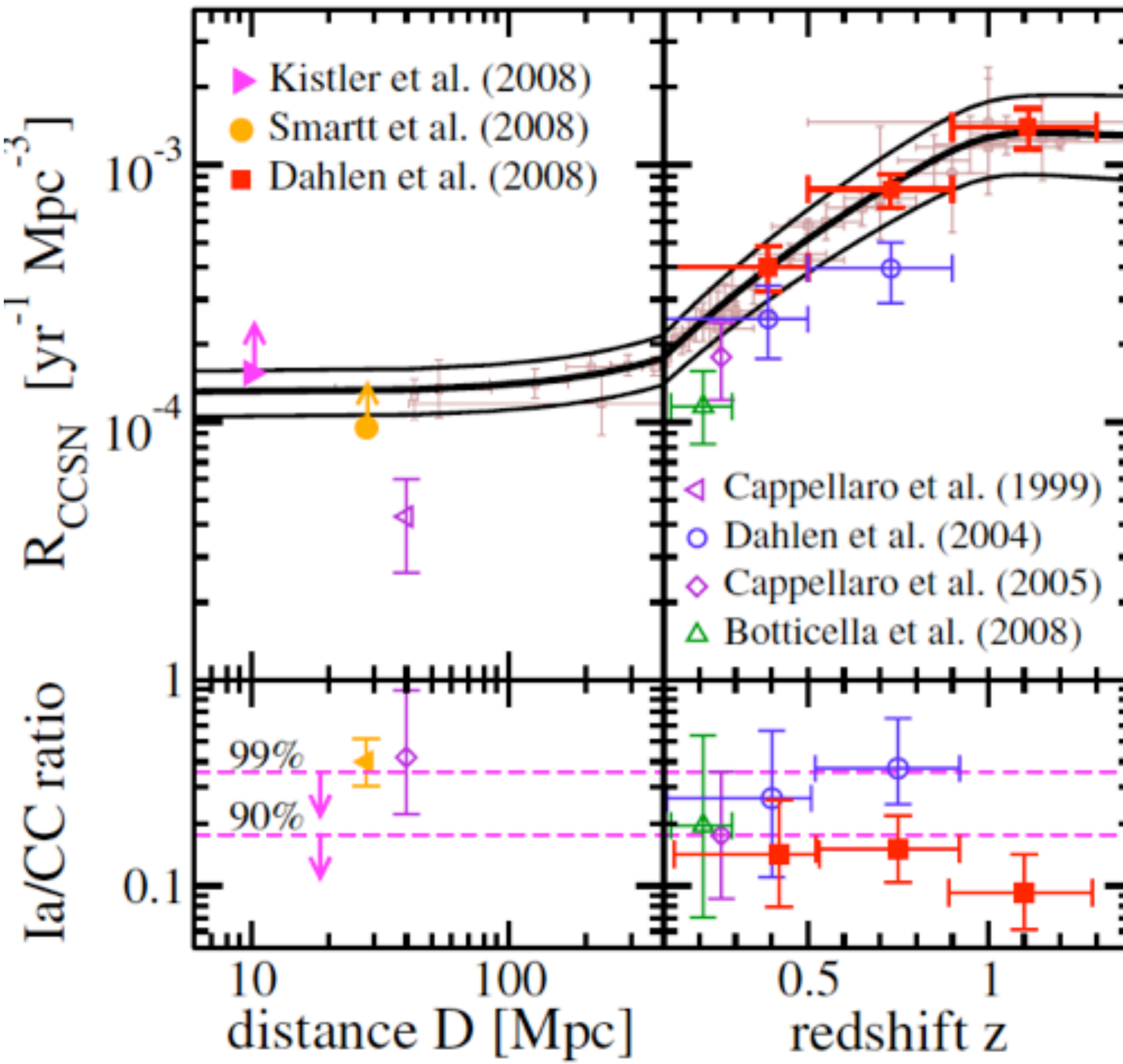


Solar Neutrino pp Chain



Diffuse Supernova Background

- Mostly from Core Collapse and Type Ia Supernovae in our galaxy



Horiuchi 2009

Atmospheric Neutrinos

- From Cosmic Ray interaction in atmosphere. All flavors are made.

Table 1
Fraction of each neutrino flavor with energy below 100 MeV

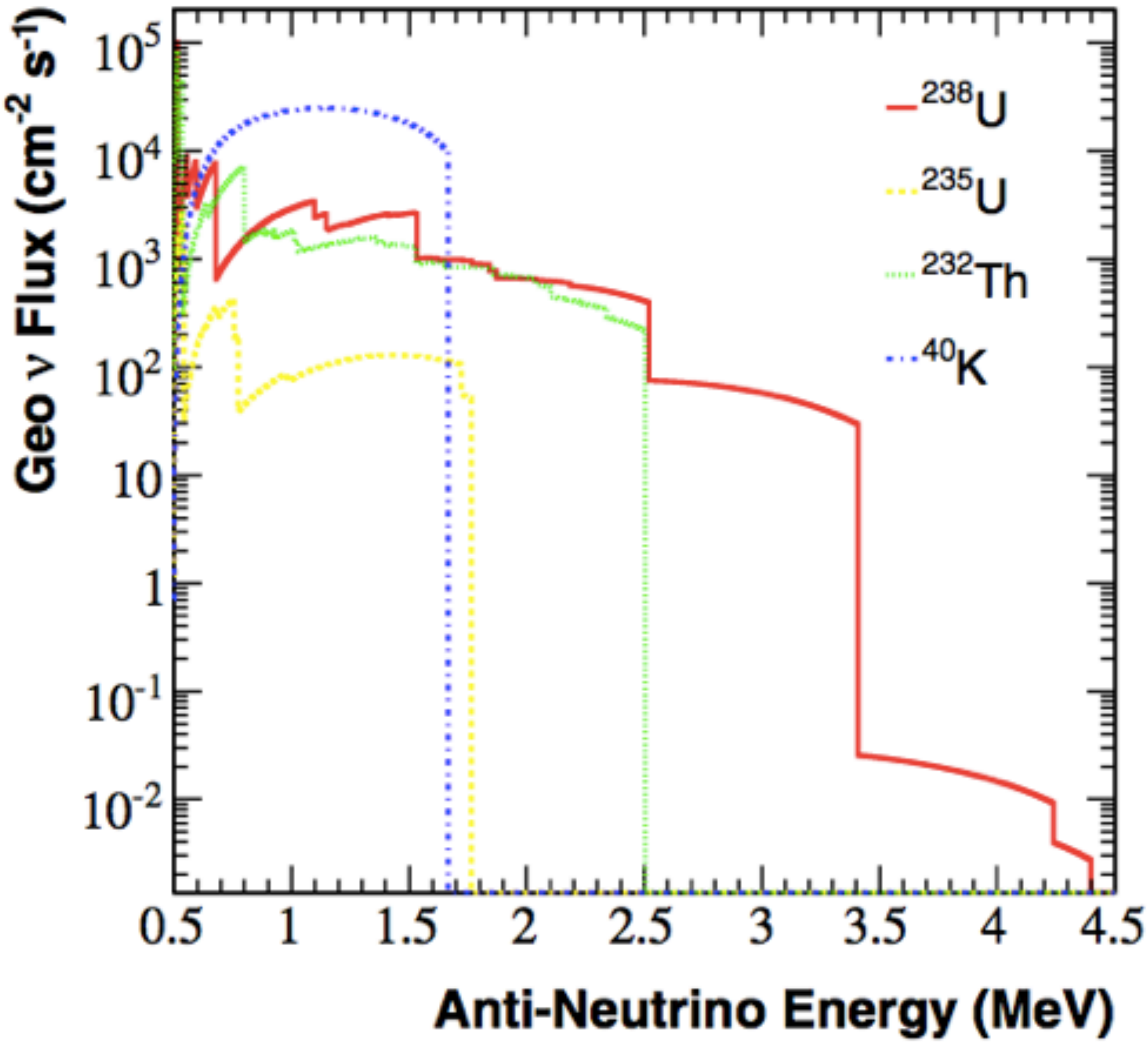
	ν_μ	$\bar{\nu}_\mu$	ν_e	$\bar{\nu}_e$
Stopping μ decay	0.078	0.070	0.124	0.148
μ decay in flight	0.378	0.470	0.876	0.852
Stopping π decay	0.003	0.007	0.00002	~0
π decay in flight	0.541	0.453	0.00003	0.00005
K decay in flight	0.0005	0.0003	0.0007	0.0006
Total fraction of each flavor	0.329	0.338	0.183	0.150

Total fraction and contribution by the different production channels are given.

Battistoni 2009

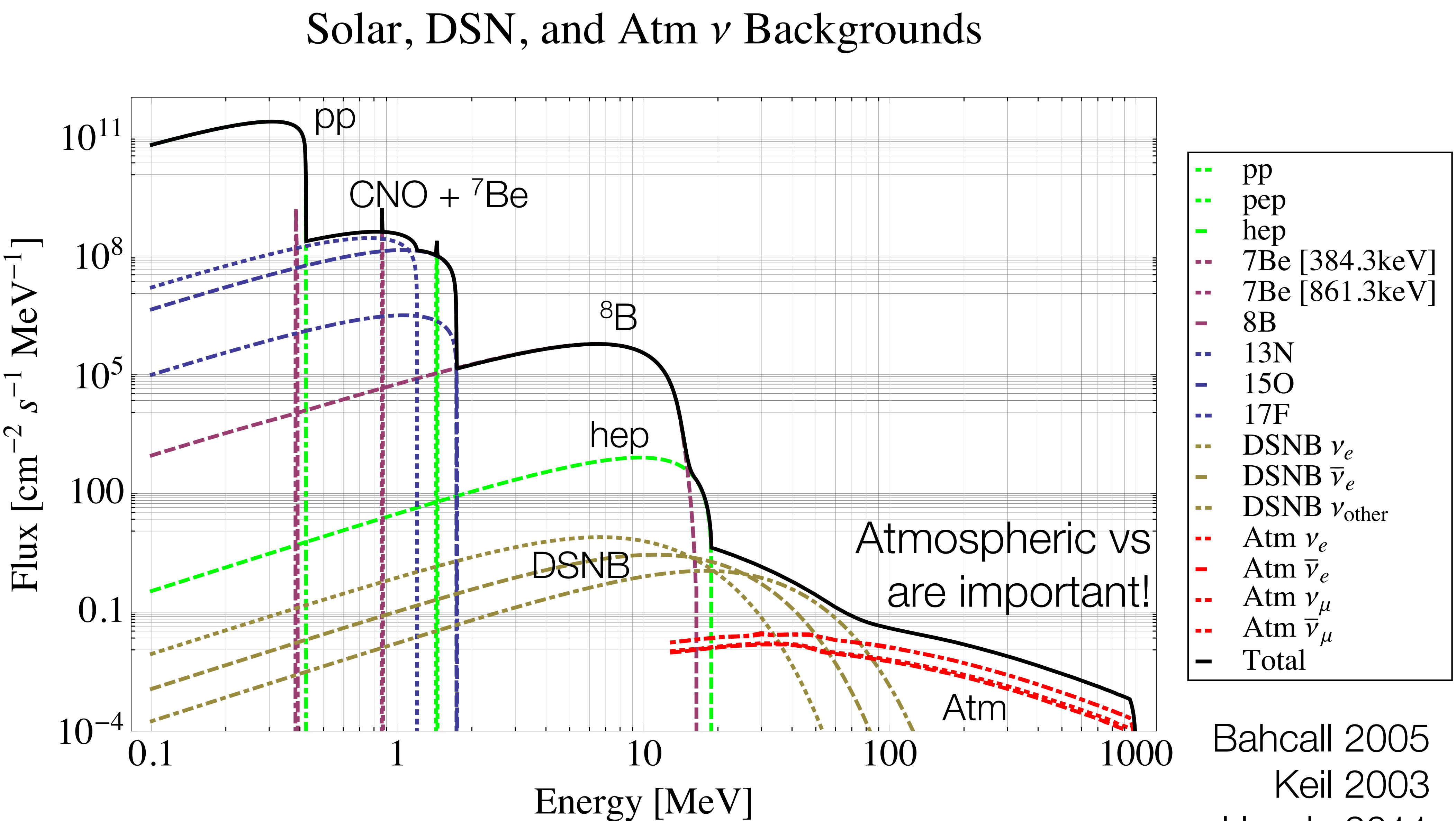
Geoneutrinos and Reactor Neutrinos

- Geoneutrinos are plentiful, but too low energy and are thus subdominant to the Solar ν flux.
- Reactors vs can are only important if physically close to a reactor, so we can safely ignore them.



Enomoto 2005
Monroe 2007

Dominant Neutrino Background Spectrum



Bahcall 2005
Keil 2003
Honda 2011

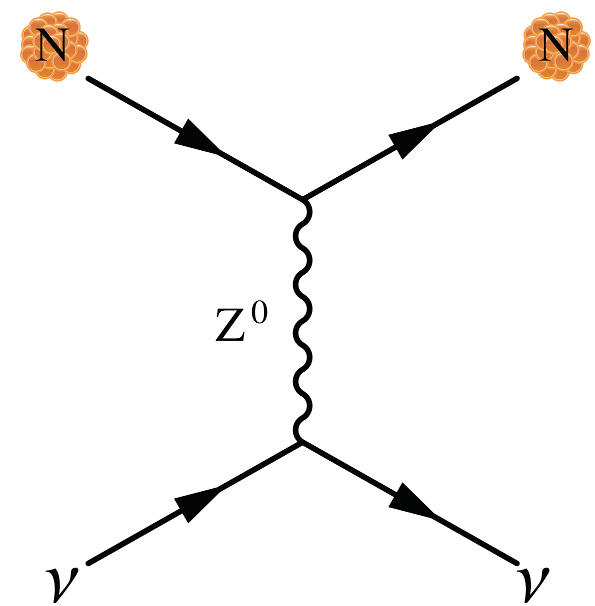
Neutrino Nucleus Coherrent Scattering

Baudis 2012, Biassoni 2012, Gütlein 2010, Strigari 2009, Monroe 2008

Coherent ν Scattering

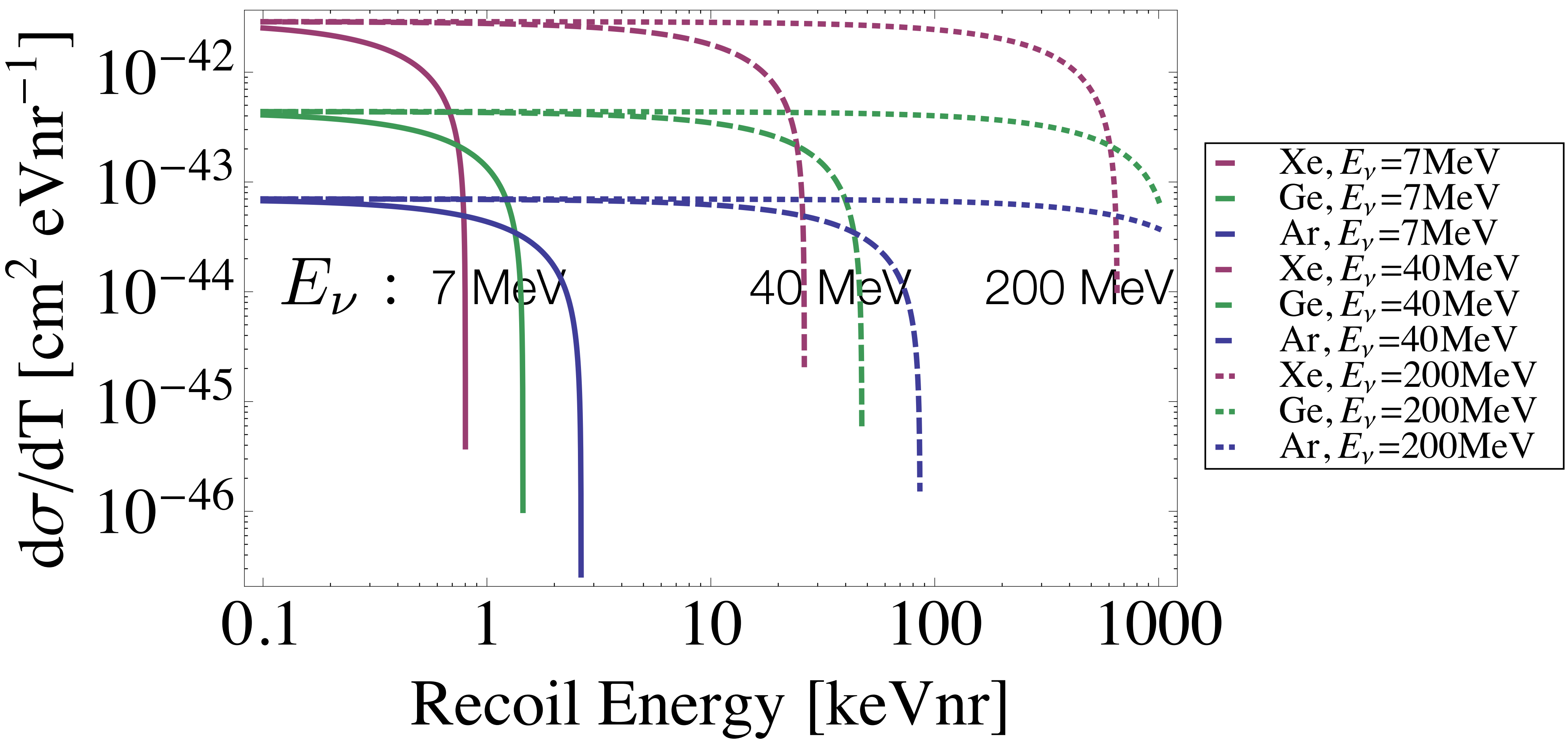
$$\frac{d\sigma}{dT} = \frac{G_F^2}{4\pi} Q_W^2 M_A \left(1 - \frac{M_A T}{2E_\nu^2}\right) F(q^2)^2$$

- σ: Cross Section
- T: Recoil Energy
- E_ν: Neutrino Energy
- G_F: Fermi Constant
- Q_W: Weak Charge
- M_A: Atomic Mass
- F: Form Factor

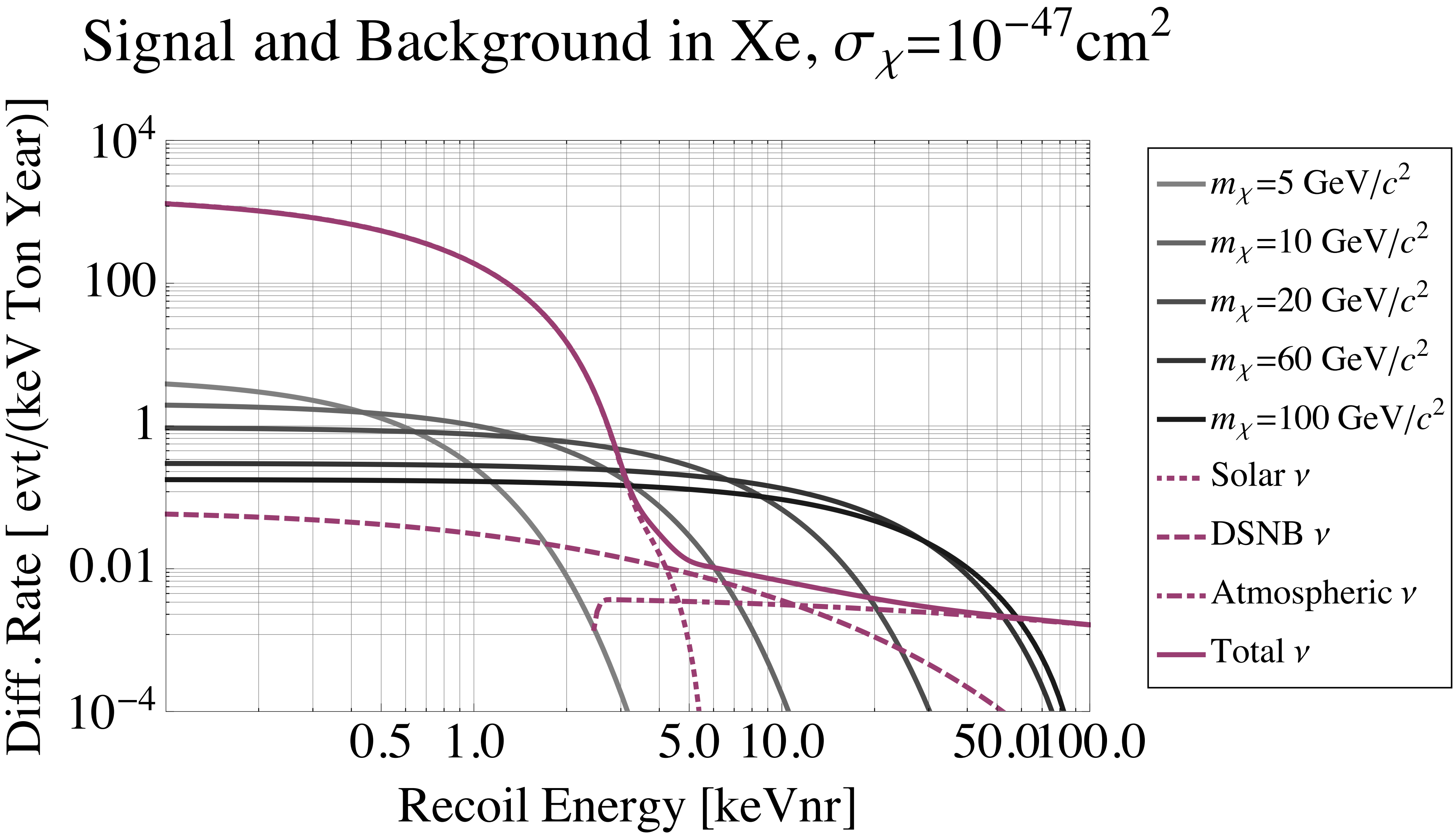


No flavor-specific terms!!!
Same rate for ν_e, ν_μ, and ν_τ

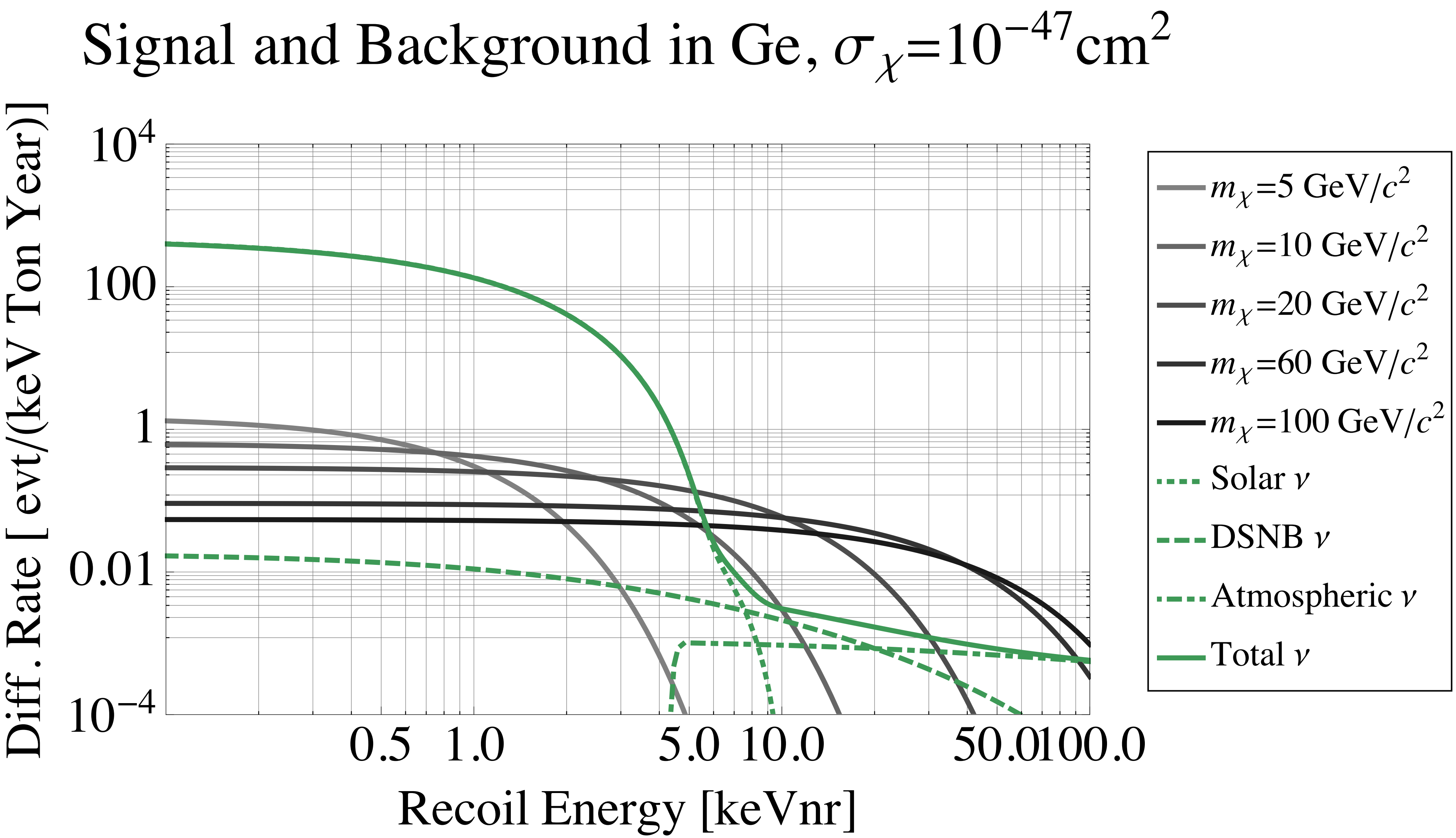
CNS Cross Sections



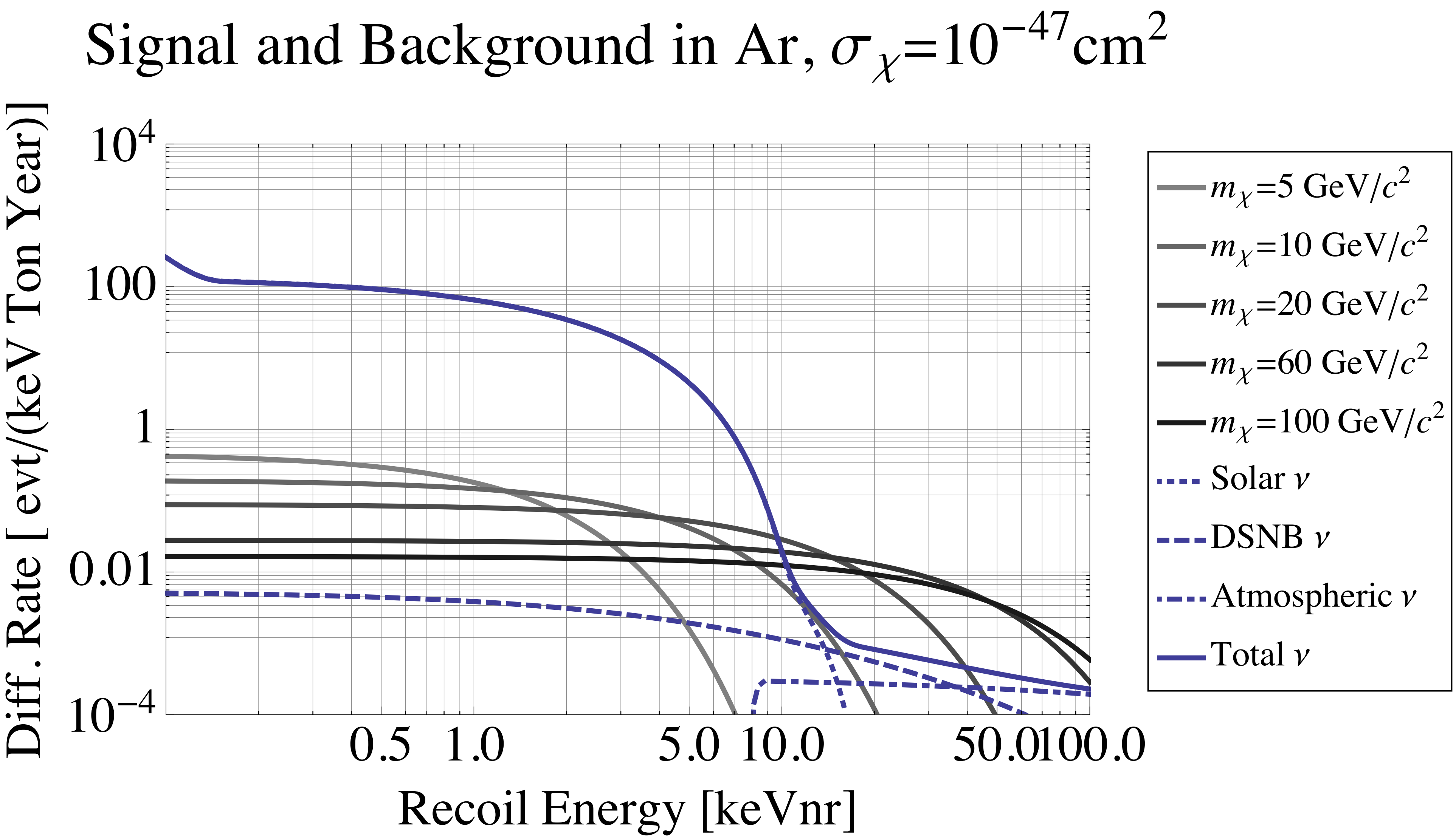
Neutrino Coherent Scattering Background



Neutrino Coherent Scattering Background



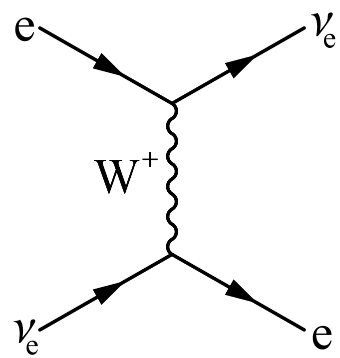
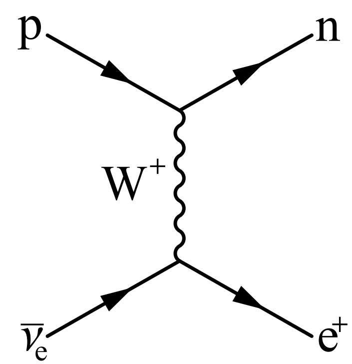
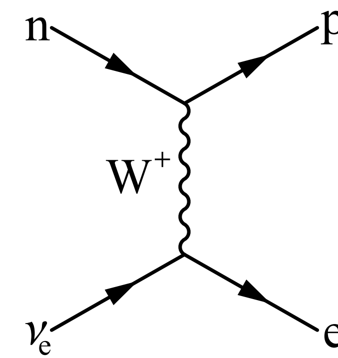
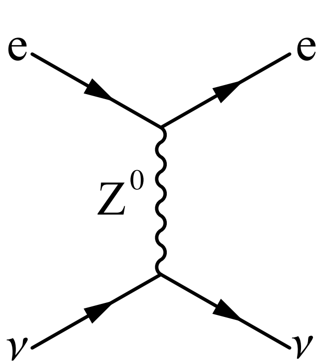
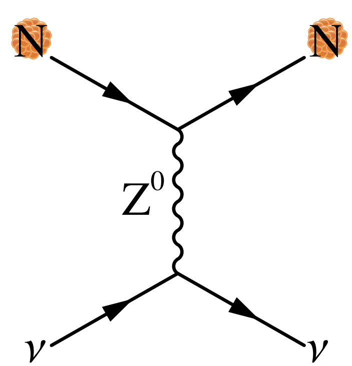
Neutrino Coherent Scattering Background



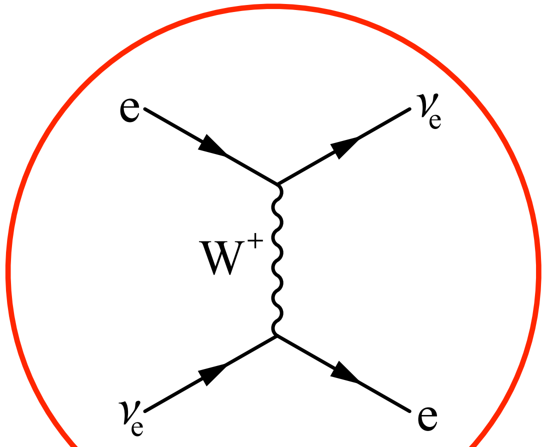
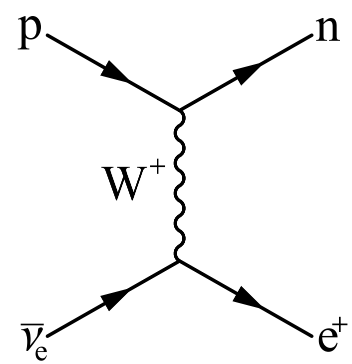
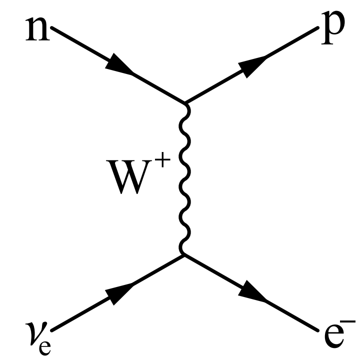
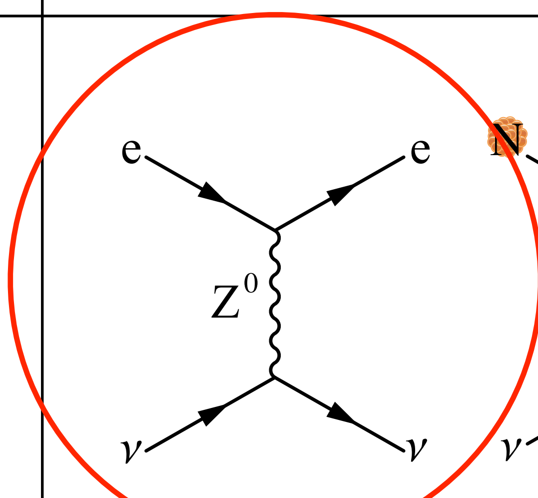
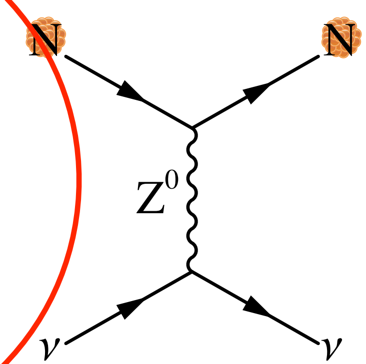
Electron Recoil Backgrounds from Neutrinos

Baudis 2012, Arisaka 2012

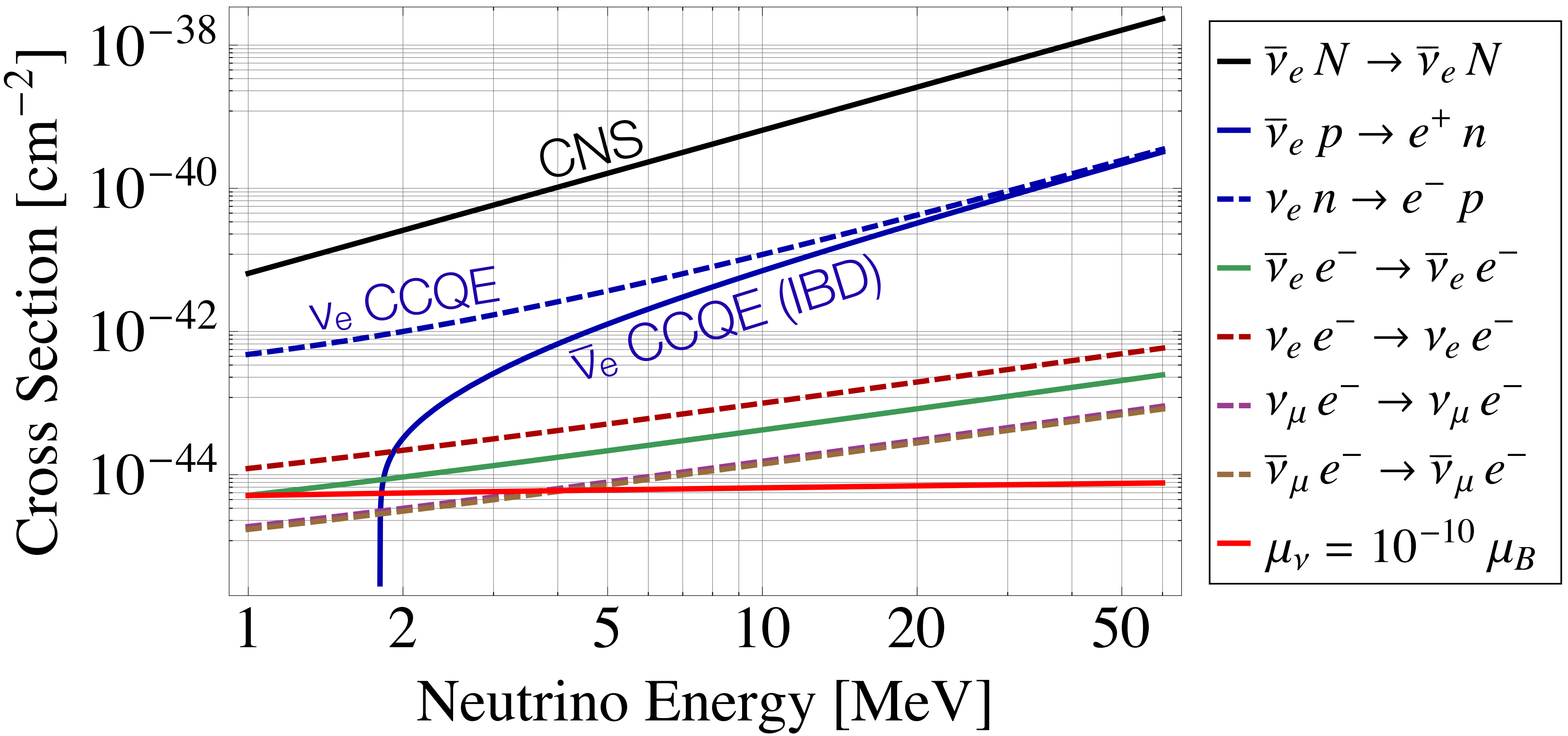
Low-energy ν Interactions

	Elastic	Quasi-Elastic
Charged Current	 For ν_e and $\bar{\nu}_e$	 IBD  ν_μ, ν_τ not low-E
Neutral Current	  For all ν flavors	

Low-energy ν Interactions

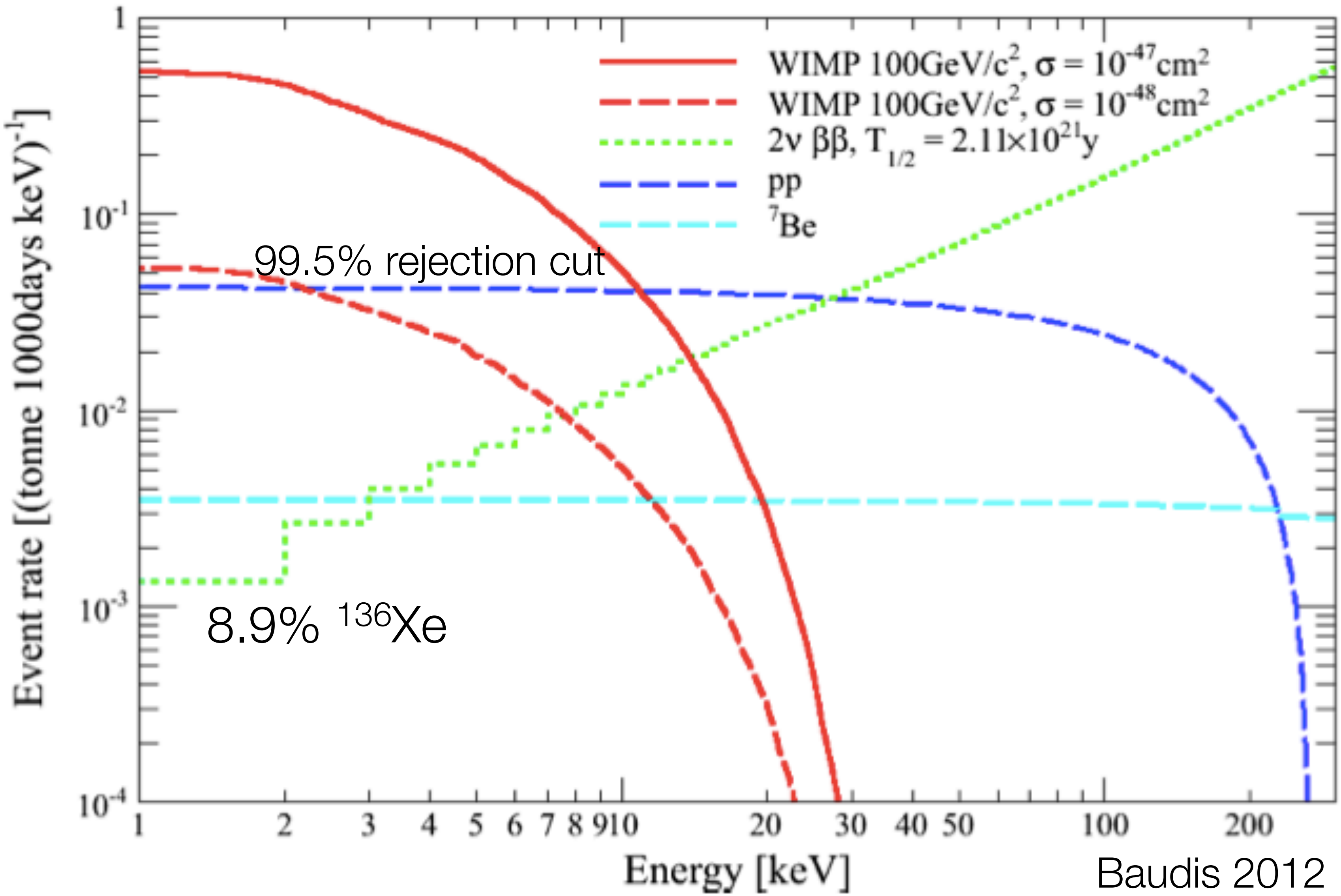
	Elastic	Quasi-Elastic
Charged Current	 For ν_e and $\bar{\nu}_e$	 IBD  ν_μ, ν_τ not low-E
Neutral Current	  For all ν flavors	

Low-Energy Neutrino Cross Sections



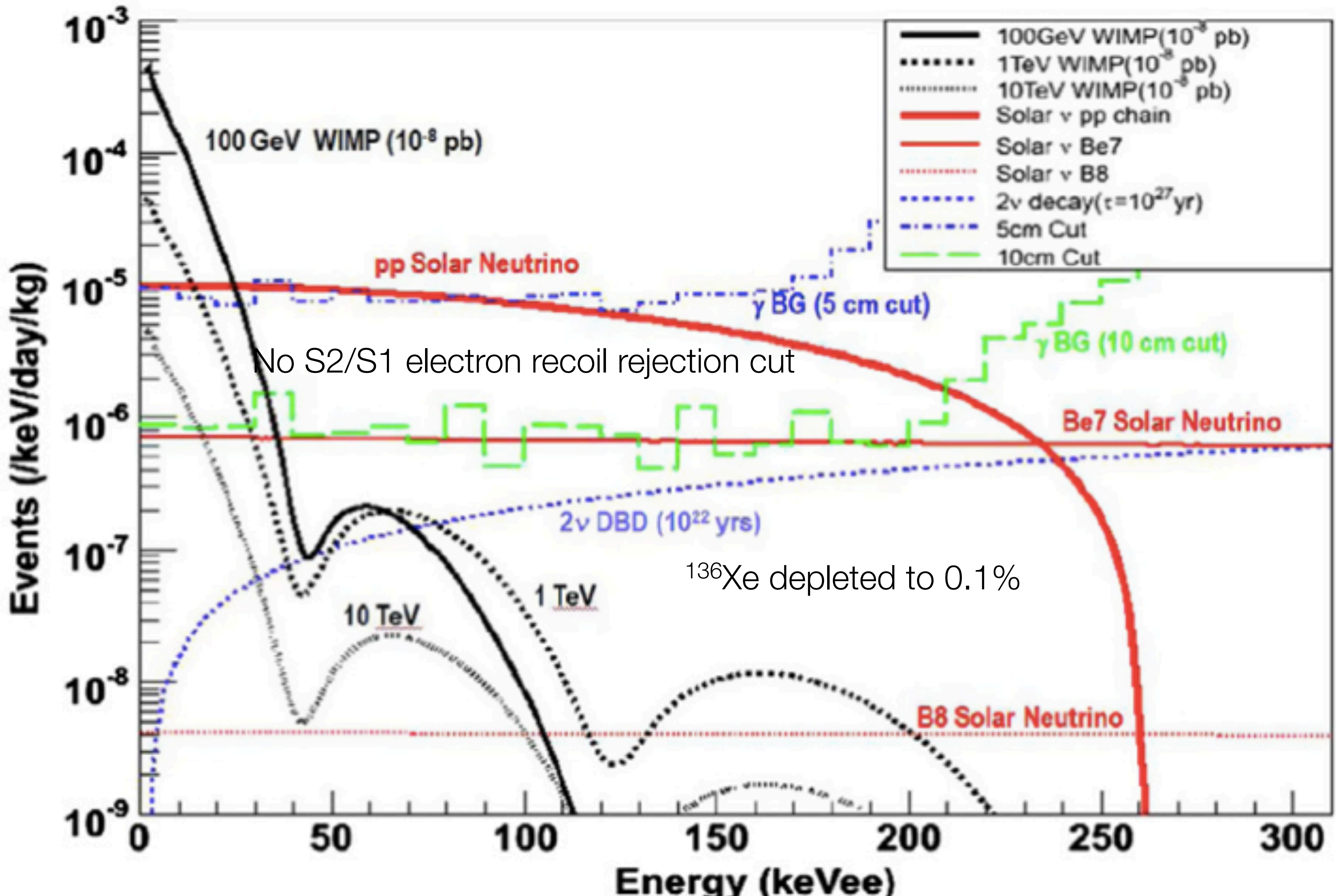
- Cross Section is 10,000 times smaller than CNS…
- But you get a much higher recoil due to the small mass of the electron.
- Thus pp and ^{7}Be (and CNO?) will dominate at 10 keVee recoil

Electron Recoil Backgrounds

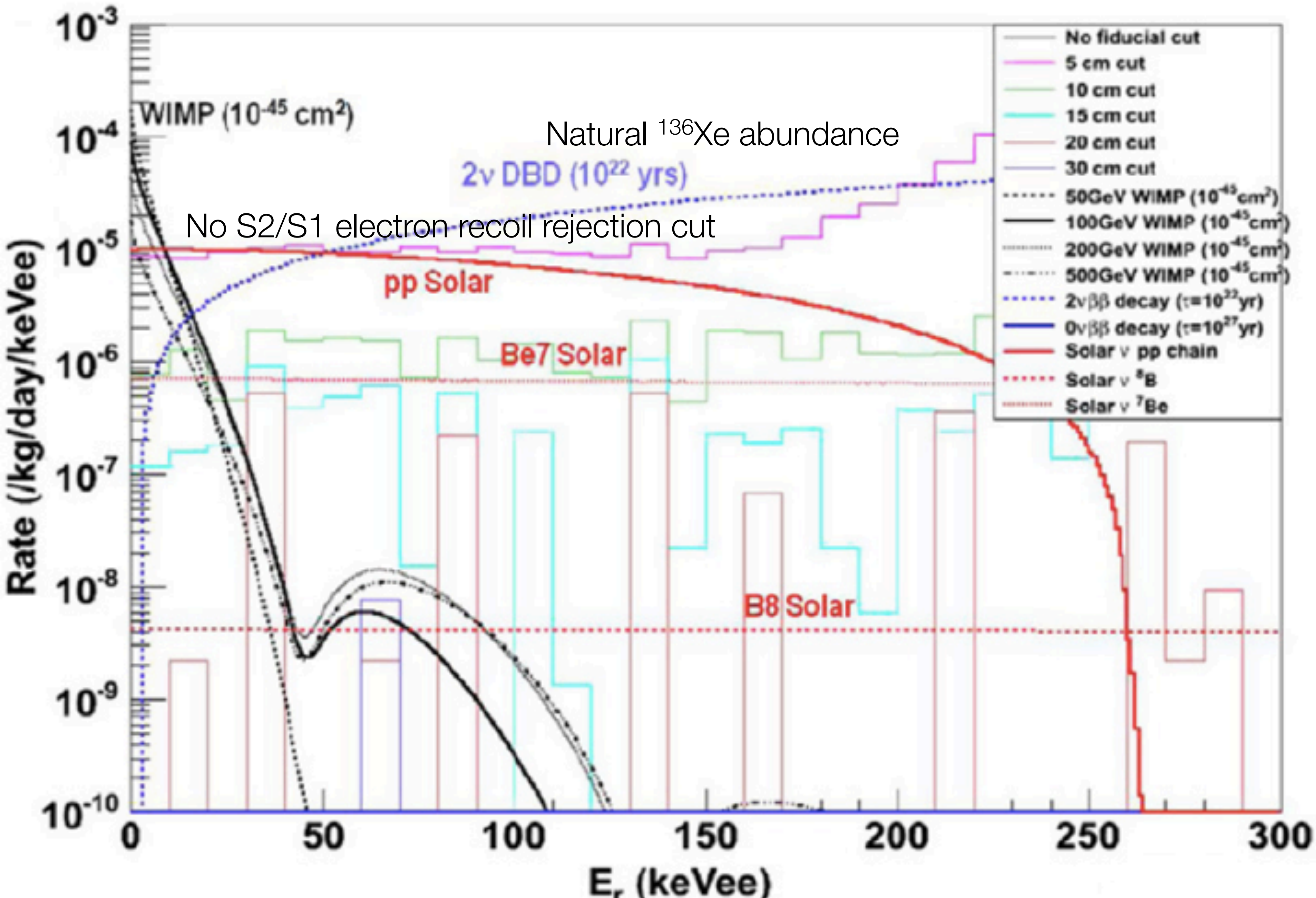


Note that CNO neutrinos don't seem to have been included...

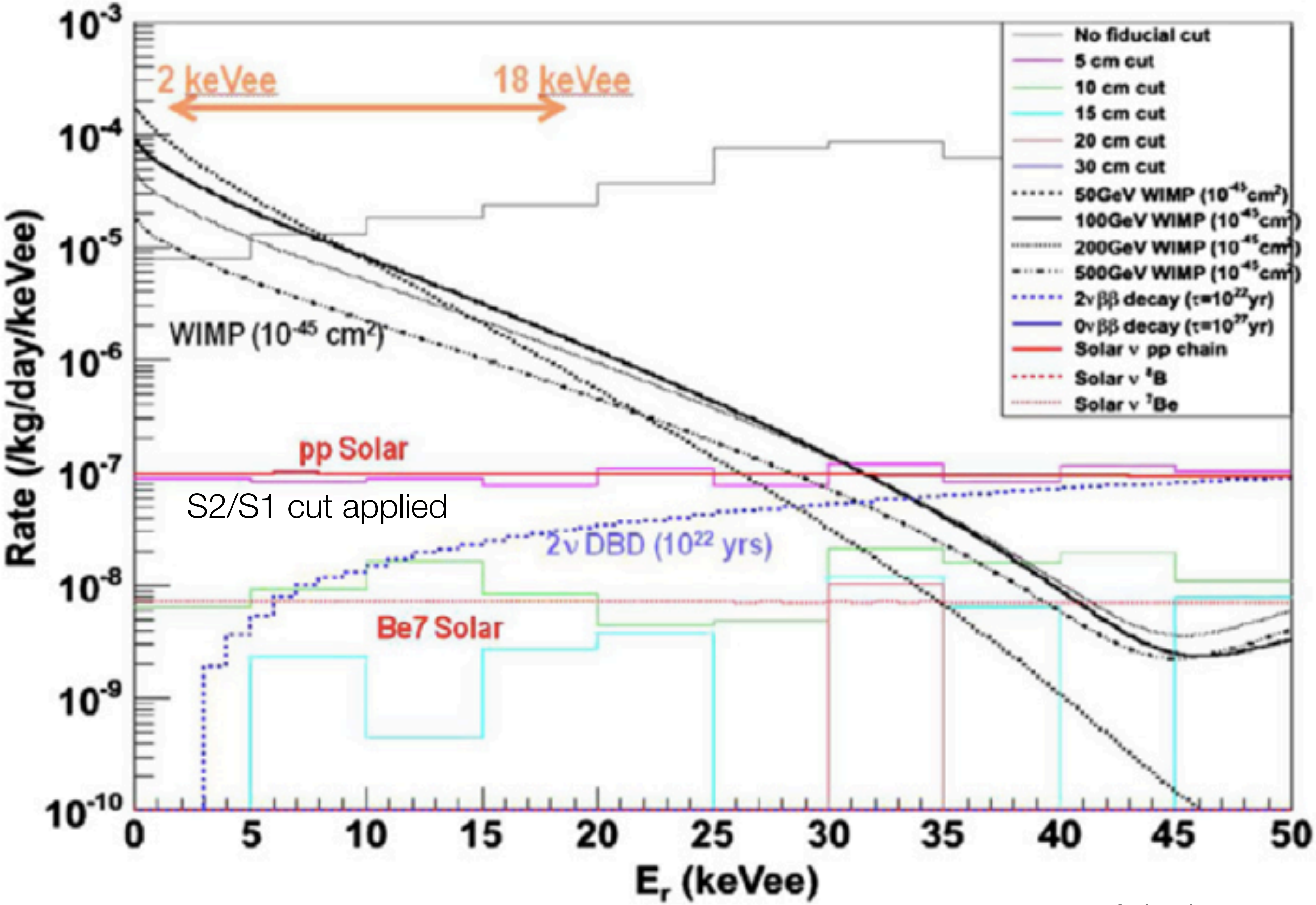
Electron Recoil Backgrounds - 2



Arisaka 2012



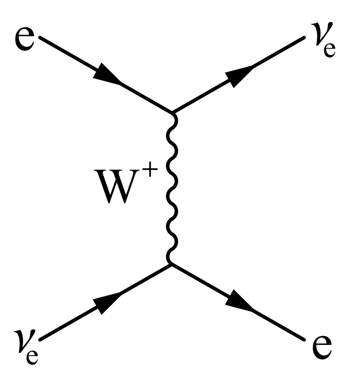
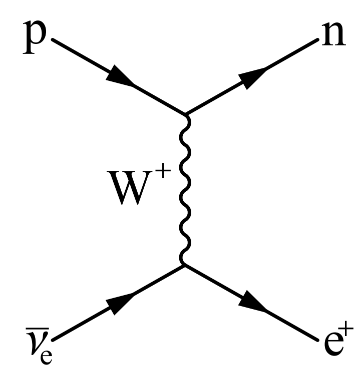
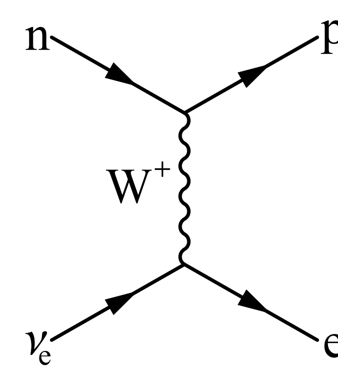
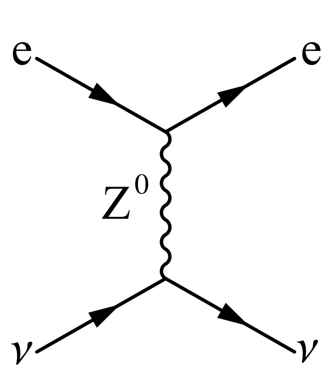
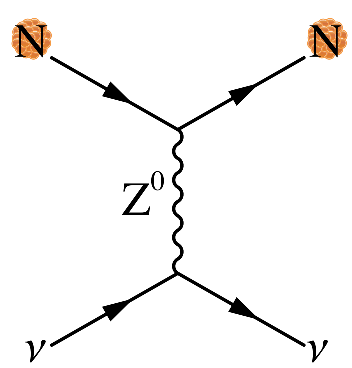
Arisaka 2012



Arisaka 2012

Remember Quasi Elastic!

Low-energy ν Interactions

	Elastic	Quasi-Elastic
Charged Current	 For ν_e and $\overline{\nu}_e$	 IBD  ν_μ, ν_τ not low-E
Neutral Current	  For all ν flavors	Will make some interesting decays… Might make a very nice calibration source!

Conclusions

- Neutrinos will be a dominant background as we approach sensitivities around 10^{-48} cm^2.
- Coherent scattering will become important for dark matter masses below 10 GeV/c^2 for 10^{-47} cm^2 cross sections, and for higher masses for smaller cross sections.
- Electron recoils from elastic neutrino interactions will likely be a dominant background for Xe multi-ton detectors.
  - For Ar and Ge, higher electron recoil discrimination may ameliorate this background, if the high discrimination can be maintained at low recoil energies.
- We could do very interesting neutrino physics if we could measure the coherent signal, especially if we subtract the pesky dark matter signal...