Update on Calculations of Atmospheric Neutrinos Rates

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with support from

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The University Of Sheffield.

Shown at CM

Bodek-Ritchie Fermi gas

	cc	nc	total
mu	447	233	680
mu_bar	108	90	199
e	443	212	655
e_bar	105	83	188
tau	24	213	237
tau_bar	9	81	90
total	1136	912	2048

Local Fermi gas

	cc	nc	total
mu	453	228	681
mu_bar	107	88	195
e	448	207	655
e_bar	104	81	185
tau	24	209	233
tau_bar	9	79	88
total	1144	892	2036

Effective Spectral Function

	cc	nc	total
mu	420	233	653
mu_bar	105	90	195
e	415	212	627
e_bar	101	83	185
tau	23	213	237
tau_bar	9	81	90
total	1073	912	1985

- Calculated rates of atmospheric neutrinos interacting in the DNUE FD, 10 kton-year

- Used oscillated Honda flux for Homestake site, assuming solar maximum

- Oscillations done by Ivan

- Used cross-sections for 3 different nuclear models

Link to CM slides

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Compared to TDR Numbers

Bodek-Ritchie Fermi gas

	cc	nc	total
mu	447	233	680
mu_bar	108	90	199
e	443	212	655
e_bar	105	83	188
tau	24	213	237
tau_bar	9	81	90
total	**1136**	**912**	**2048**

In TDR: no oscillations considered

10 kt · year	CC	NC	Total
ν_μ	1038	398	1436
$\bar{\nu}_\mu$	280	169	449
ν_e	597	206	83
$\bar{\nu}_e$	126	72	198
Total	2014	845	2886

- 30% difference seen in total rate

- Total numbers in TDR given only for unoscillated flux

  - Late turn-on of nu_tau at high energy causes some of the difference

- Bartol flux used for the TDR numbers

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Compared Unoscillated Numbers

	cc	nc	total
mu	860	443	1303
mu_bar	220	180	401
e	485	227	712
e_bar	109	81	190
total	**1674**	**932**	**2606**

In TDR

10 kt · year	CC	NC	Total
ν_μ	1038	398	1436
$\bar{\nu}_\mu$	280	169	449
ν_e	597	206	83
$\bar{\nu}_e$	126	72	198
Total	2014	845	2886

- Used original un-oscillated Honda flux
- Used the same x-sections
- NC are higher, CC much lower
- Different by 10%
- -> Oscillation caused only part of the difference

Bug in My Code

- Found a small bug in my code today

- Only small effect on the final numbers

Before fix

Bodek-Ritchie Fermi gas

	cc	nc	total
mu	447	233	680
mu_bar	108	90	199
e	443	212	655
e_bar	105	83	188
tau	24	213	237
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Local Fermi gas

	cc	nc	total
mu	453	228	681
mu_bar	107	88	195
e	448	207	655
e_bar	104	81	185
tau	24	209	233
tau_bar	9	79	88
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Effective Spectral Function

	cc	nc	total
mu	420	233	653
mu_bar	105	90	195
e	415	212	627
e_bar	101	83	185
tau	23	213	237
tau_bar	9	81	90
total	1073	912	1985

After fix

Bodek-Ritchie Fermi gas

	cc	nc	total
mu	447	233	680
mu_bar	108	90	199
e	448	213	662
e_bar	107	84	191
tau	36	219	255
tau_bar	15	84	99
total	1162	922	2084

Local Fermi gas

	cc	nc	total
mu	453	228	681
mu_bar	107	88	195
e	452	209	661
e_bar	106	82	187
tau	37	214	251
tau_bar	15	82	96
total	1170	902	2072

Effective Spectral Function

	cc	nc	total
mu	420	233	653
mu_bar	105	90	195
e	420	213	633
e_bar	104	84	188
tau	36	219	255
tau_bar	15	84	98
total	1099	922	2021

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Looking at Bartol Flux

- In TDR: Bartol flux for Soudan, for solar minimum, based on AGLS1996 primary fluxes

  - There is also flux based on ICRC01 primary fluxes on the Bartol web page

- Calculated rates for the same unoscillated fluxes as used in TDR

	cc	nc	total
mu	892	438	1330
mu_bar	225	180	405
e	533	234	767
e_bar	104	75	179
total	1755	927	2682

In TDR

10 kt · year	CC	NC	Total
ν_μ	1038	398	1436
$\bar\nu_\mu$	280	169	449
ν_e	597	206	83
$\bar\nu_e$	126	72	198
Total	2014	845	2886

- Still see difference

- Now communicating with Aaron

- I think the difference comes from our understanding of the binning of the flux in energy and solid angle

- I am now more confident in my numbers which are 10% lower than in TDR

New Oscillation for Honda Flux

- Ivan found a bug in his oscillation code

- Josh provided recalculated oscillated Honda flux

- The numbers differ minimally, did not have much of an impact

- The oscillated flux is being checked, still may be updated, no major change is expected

Bodek-Ritchie Fermi gas

	cc	nc	total
mu	457	238	695
mu_bar	118	96	214
e	444	209	653
e_bar	100	77	177
tau	25	218	243
tau_bar	10	85	95
total	1155	922	2077

Local Fermi gas

	cc	nc	total
mu	463	233	697
mu_bar	117	94	211
e	448	204	653
e_bar	99	75	174
tau	25	213	238
tau_bar	10	83	93
total	1163	902	2065

Effective Spectral Function

	cc	nc	total
mu	431	238	669
mu_bar	114	96	211
e	417	209	625
e_bar	97	77	174
tau	25	218	242
tau_bar	10	85	95
total	1093	922	2015

Difference Between Bartol and Honda Fluxes

- Compared spectrum of interacting neutrinos

- Used unoscillated fluxes for solar maximum, Bartol flux based on ICRC01 primary fluxes

- They don't differ by much, Bartol flux lower at lower energies
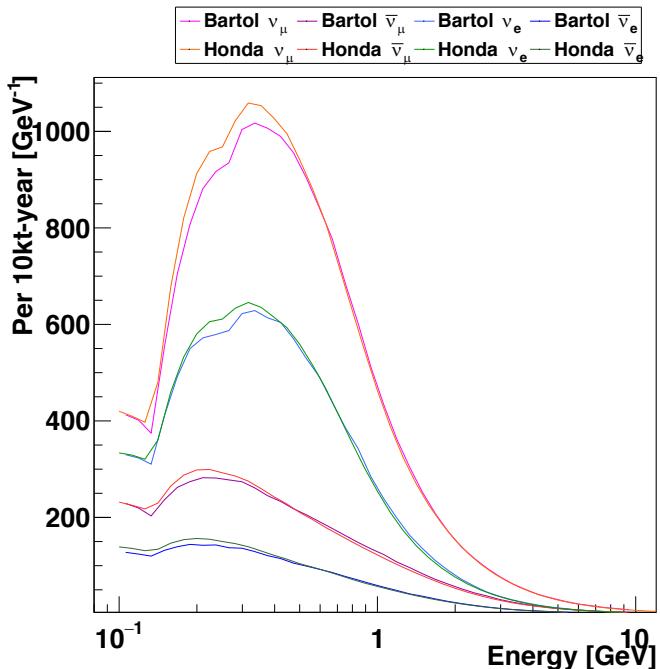
# Difference Between Bartol and Honda Fluxes – binning

Bartol

- Normalized as dN/dlogE/dΩ [s^{-1} sr^{-1}]

- Binned in log E and cosθ

- cosθ:
  - 20 bins, from -1 to 1

- energy:
  - 10/20 bins per decade, from 0.1 GeV to 10 GeV
 - Mean energy for each bin is also given

Honda

- Normalized as dN/dE/dΩ [GeV^{-1} s^{-1} sr^{-1}]

- Binned in log E, cosθ, and azimuth φ

- cosθ:
  - 20 bins, from -1 to 1

- φ :
  - 12 bins, from 0° to 360°

- Energy:
  - 20 values per decade, from 0.1 GeV to 10 TeV
  - Values given for energies $10^{-1+i/20}$ GeV
  - -> 101 values per solid angle bin

Difference Between Bartol and Honda Fluxes – binning

Bartol

0.1 GeV   1 GeV

Honda

0.1 GeV   1 GeV
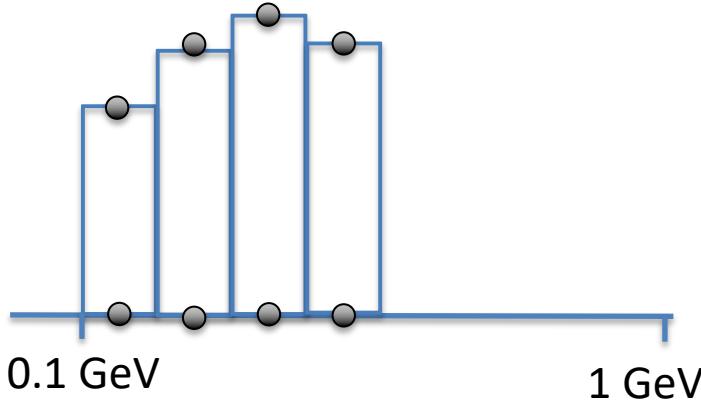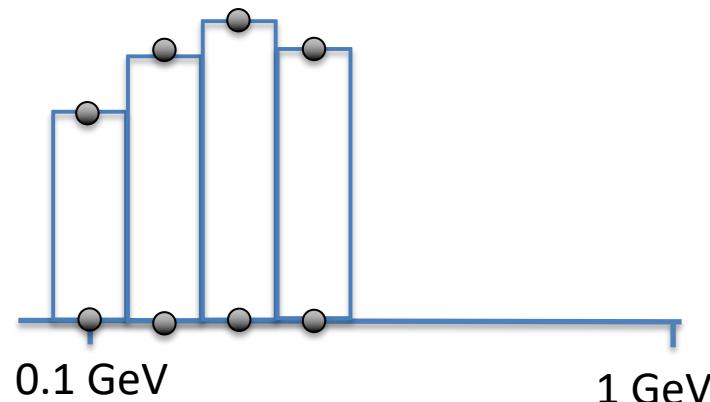
Not sure how to understand the binning in Honda files. The picture above illustrates how I did it

Conclusion

- Tested differences between Honda and Bartol fluxes

- Understand why I get different numbers from what is in TDR

- Lesson learned: it is important how binning of the fluxes is interpreted

- Oscillated Honda flux gives about 30% lower rates (more so if one does not count nu_tau)

- Rates do not vary much with nuclear model assumption

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