Supernova-Neutrinos in LENA

Channel Discrimination

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Motivation

- Supernova at 10 kpc would produce around 10^4 events
- Data can confirm, refute or extend the standard paradigm of stellar core collapse
- What are the conditions in collapsing cores of massive stars?
- Spectroscopy allows implications on the average neutrino energies
- Reveal detailed properties of the proto-neutron star

Overview

Charged-Current (CC) channels

- $\bar{\nu}_e + \mathrm{p} \rightarrow \mathrm{n} + e^+$
- $\bar{\nu}_e + {}^{12}\mathrm{C} \rightarrow e^+ + {}^{12}\mathrm{B}$
  - ${}^{12}\mathrm{B} \rightarrow {}^{12}\mathrm{C} + \mathrm{e}^- + \bar{\nu}_e$
- $\nu_e + {}^{12}\mathrm{C} \rightarrow e^- + {}^{12}\mathrm{N}$
  - ${}^{12}\mathrm{N} \rightarrow {}^{12}\mathrm{C} + \mathrm{e}^+ + \nu_e$

Overview

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  - ${}^{12}\mathrm{N} \rightarrow {}^{12}\mathrm{C} + \mathrm{e}^+ + \nu_e$

Neutral-Current (NC) channels

- $\nu + {}^{12}\mathrm{C} \rightarrow \nu + {}^{12}\mathrm{C}^*(\rightarrow {}^{12}\mathrm{C} + \gamma)$
- $\nu + \mathrm{e}^- \rightarrow \nu + \mathrm{e}^-$
- $\nu + \mathrm{p} \rightarrow \nu + \mathrm{p}$

Inverse Beta Decay (IBD)

$$\bar{\nu}_e + \mathrm{p} \rightarrow \mathrm{n} + e^+$$

- "Golden" detection channel
- Expected event number is around $1.1 - 1.5 \times 10^4$
- Threshold of 1.8 MeV
- Coincidence by the neutron capturing:
  - $\mathrm{n} + \mathrm{p} \rightarrow \mathrm{d} + \gamma\,(2.2\mathrm{MeV})$
  - Neutron is captured after average time of 0.25 ms
  - Neutron displacement is about 20 mm

CC-^{12}C channels

$$\bar{\nu}_e + {}^{12}\mathrm{C} \rightarrow e^+ + {}^{12}\mathrm{B}$$

- Expected event number is around $1.8 - 4.2 \times 10^2$
- Coincidence by decay of ^{12}B:
  - ${}^{12}\mathrm{B} \rightarrow {}^{12}\mathrm{C} + \mathrm{e}^- + \bar{\nu}_e$
  - Half-life of 20.20 ms
  - Q-Value of 13,3 MeV

CC-^{12}C channels

$$\bar{\nu}_e + {}^{12}\mathrm{C} \rightarrow e^+ + {}^{12}\mathrm{B}$$

- Expected event number is around $1.8 - 4.2 \times 10^2$
- Coincidence by decay of ^{12}B:
  - $^{12}\mathrm{B} \rightarrow {}^{12}\mathrm{C} + \mathrm{e}^- + \bar{\nu}_e$
  - Half-life of 20.20 ms
  - Q-Value of 13,3 MeV

$$\nu_e + {}^{12}C \rightarrow e^- + {}^{12}\mathrm{N}$$

- Expected event number is around $1.9 - 5.2 \times 10^2$
- Coincidence by decay of ^{12}N:
  - $^{12}\mathrm{N} \rightarrow {}^{12}\mathrm{C} + \mathrm{e}^+ + \nu_e$
  - Half-life of 11.00 ms
  - Q-Value of 17,3 MeV

NC Channels

$$\nu + {}^{12}\mathrm{C} \rightarrow \nu + {}^{12}\mathrm{C}^{*}(\rightarrow {}^{12}\mathrm{C} + \gamma)$$

- Expected event number is around $0.6 - 1.5 \times 10^3$
- Excited state of carbon has a energy of 15 MeV
  - Threshold: >15 MeV

$$\nu + \mathrm{e}^{-} \rightarrow \nu + \mathrm{e}^{-}$$

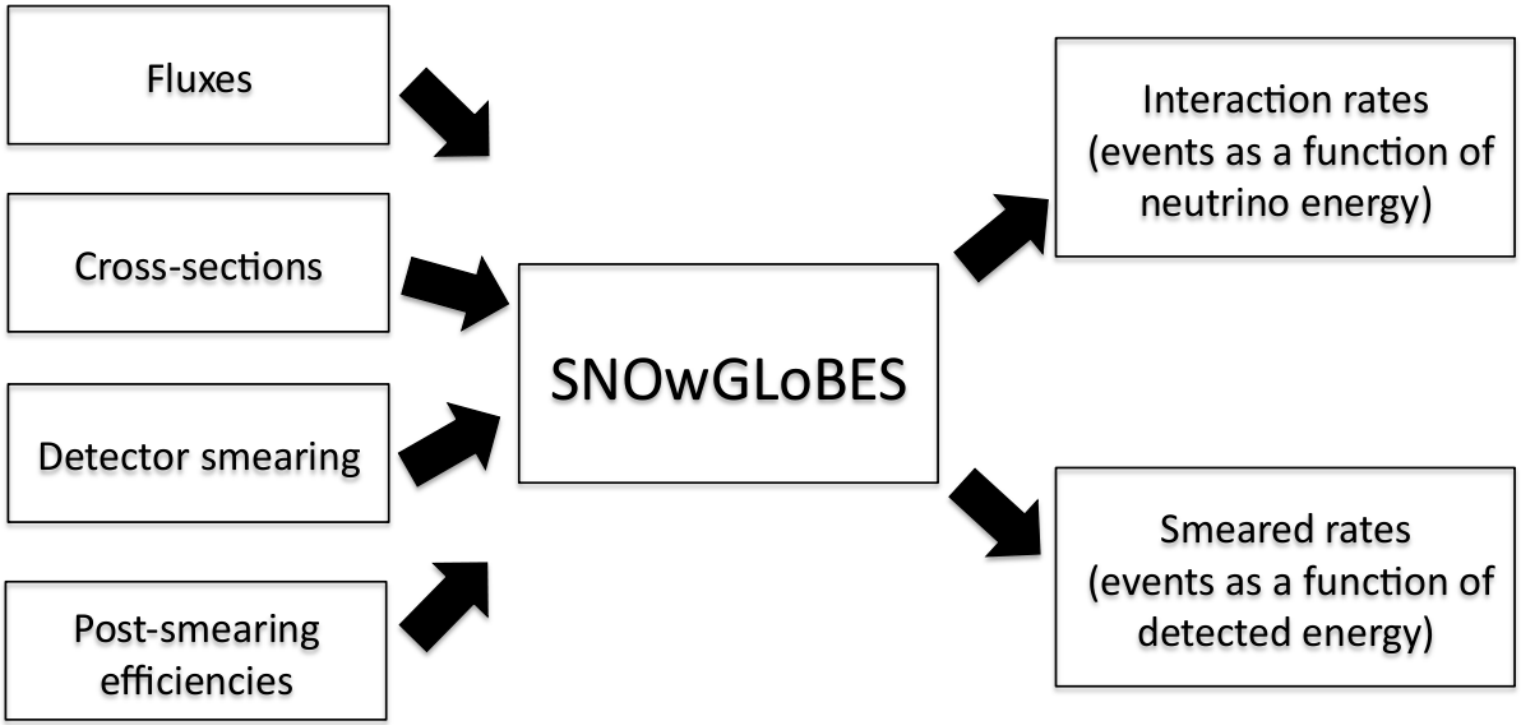
- Expected event number is around 0.6×10^3

$$\nu + \mathrm{p} \rightarrow \nu + \mathrm{p}$$

- Expected event number is around $1.3 - 4.4 \times 10^3$
- Low threshold: >0.2 MeV (^{14}C Background)

SNOwGLobES: SuperNova Observatories with GLoBES

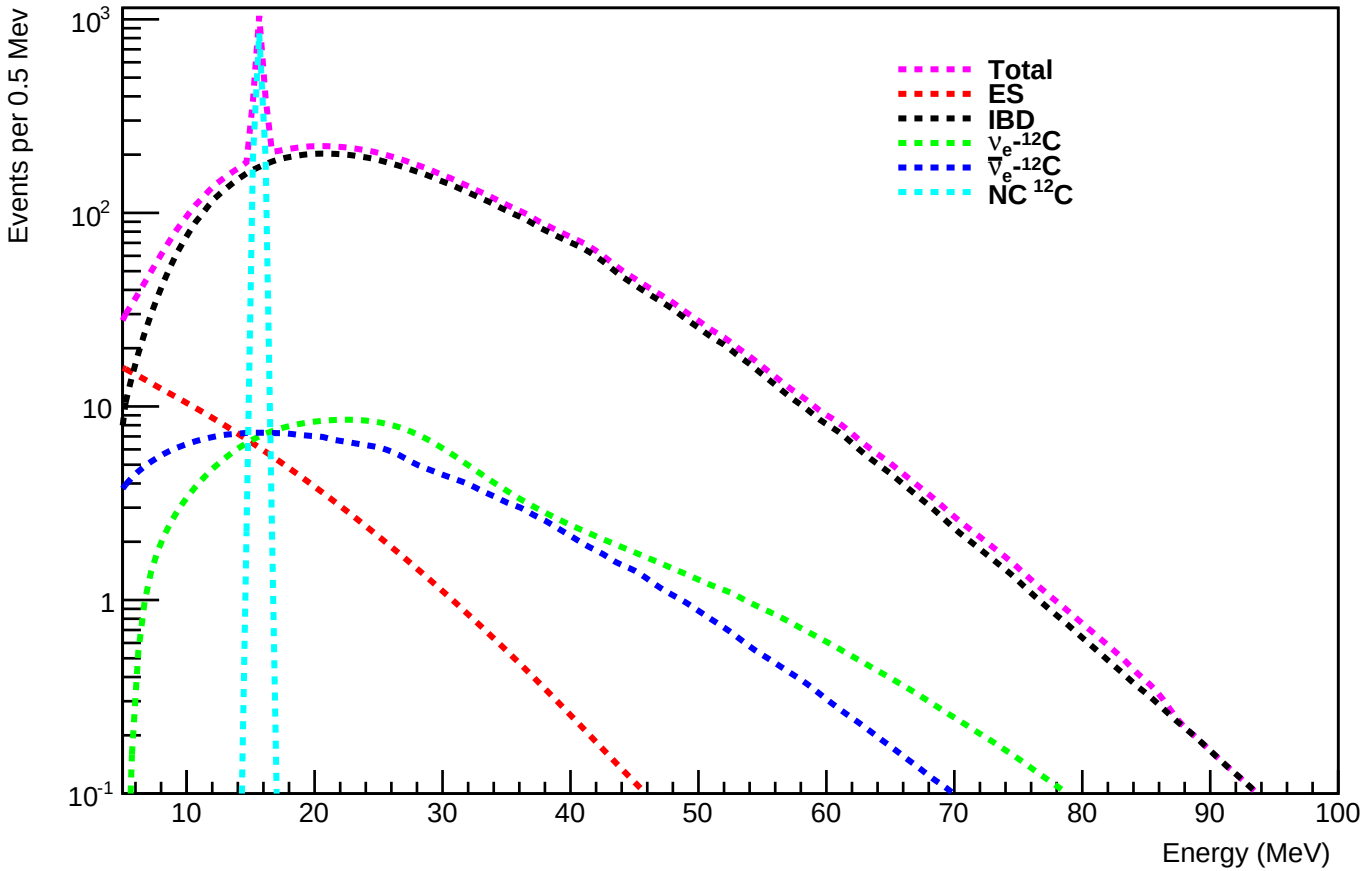
Dataflow in SNOwGLobES



Source: SNOwGLobES Manual

Ereignisraten

Event rates as function of detected energy



Approach

1. Tag the IBD events
2. Tag the CC-^{12}C events
3. Distungish the CC-^{12}C channels by fitting the beta spectra
4. Distungish the NC specta with energy cuts

Finding the coincedence events

IBD coincedence cut values

- Position cut: 600 mm
- Time cut: 3 ms
- Energy: 1,7 - 2,7 MeV

CC-^{12}C coincedence cut values

- Position cut: 450 mm
- Time cut: 150 ms
- Energy: $<$20 MeV

Finding the coincedence events

IBD coincedence cut values

- Position cut: 600 mm
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- Energy: 1,7 - 2,7 MeV

CC-^{12}C coincedence cut values

- Position cut: 450 mm
- Time cut: 150 ms
- Energy: $<$20 MeV

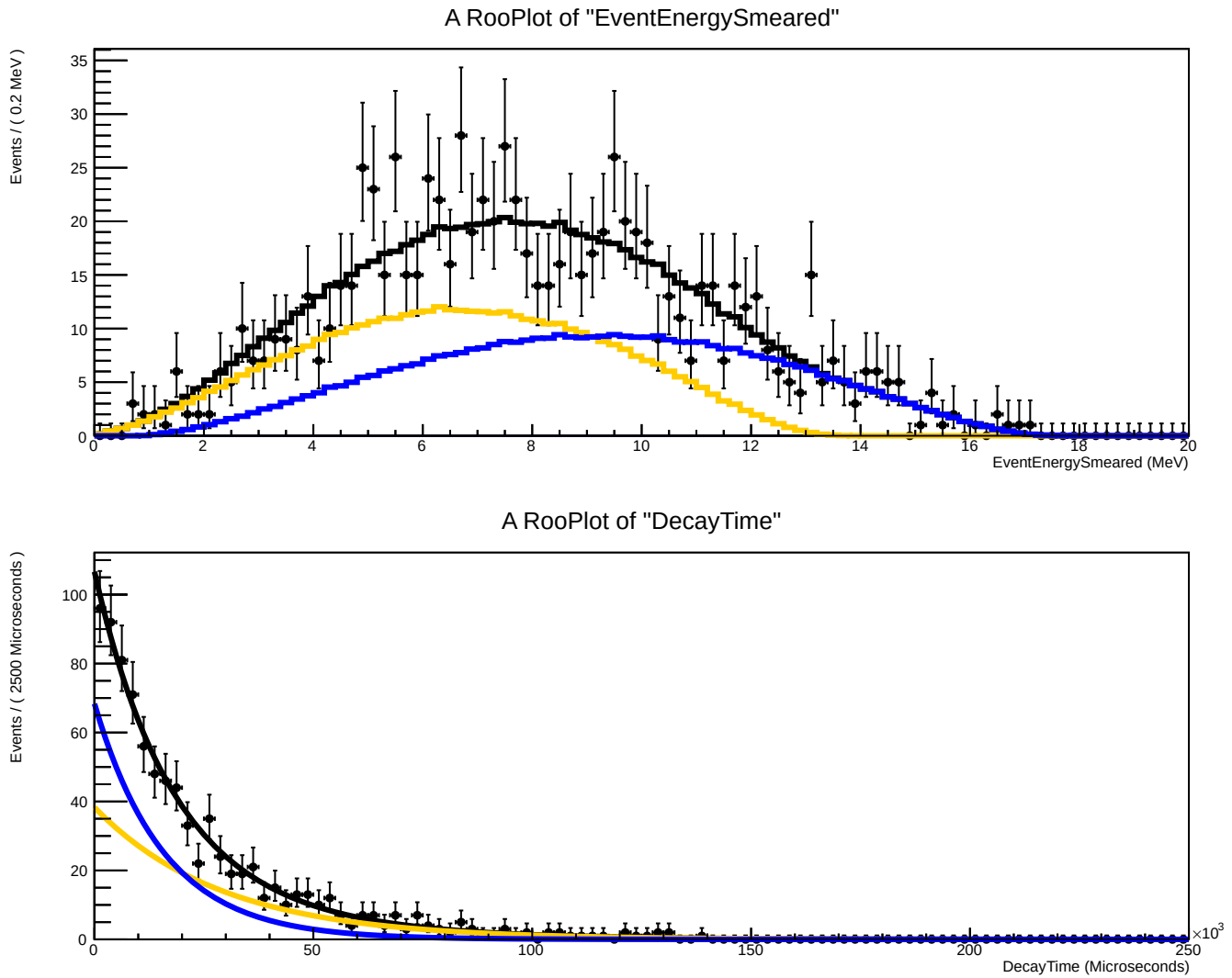
NC energy cut values

- ν – ^{12}C scattering: 14.0 - 16.0 MeV
- ν – e^- scattering: 3.5 - 14.0 MeV and $>$16 MeV
- ν – p scattering: 0 - 3.5 MeV

Distinguish of the CC-^{12}C channels

- Figure out how many events are associated with each spectra
- Challenge: Distinguish two beta spectra with similar decay properties (Q-Value, decaytime)
- Approach: Simultaneous fit of energy and decaytime spectra (RooFit)
- Input: Shape of the beta spectra and half-life

Plot of simultaneous Fit with RooFit



Motivation

Detection channels in LENA

Channel Discrimination

Results and Outlook

Results

Error rate: false identified events / correct identified events
Hit rate: correct identified events / true number of events

Channel	Error rate	Hit rate
IBD	0.1%<	99,9%>
CC-^{12}C	1%	99%
NC total	1%	99%
NC-^{12}C	2%	99%>
NC e-scattering	25%	67%
NC p-scattering	3%	98%

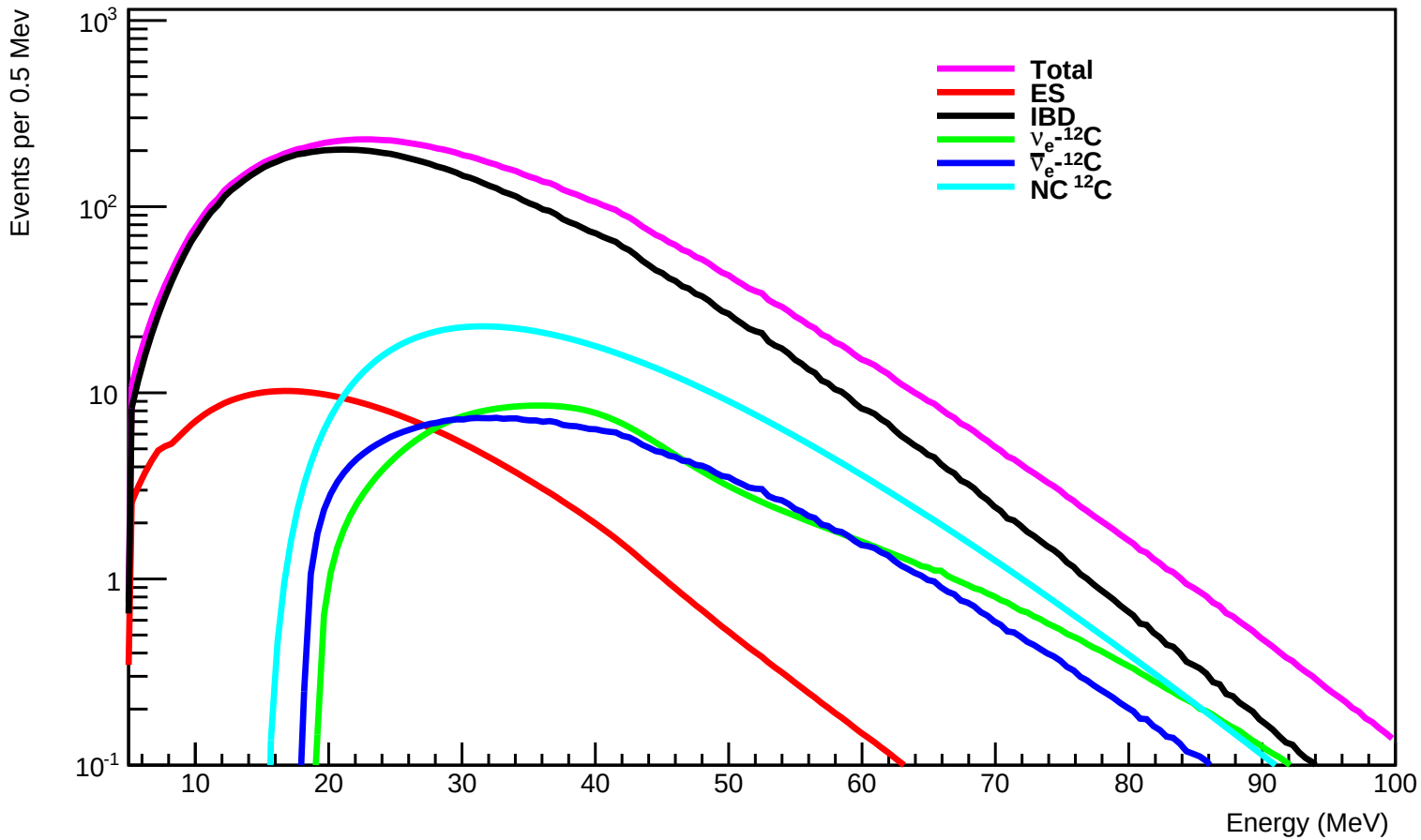
- Distinction between CC-^{12}C channels: Error of about 7%

Outlook

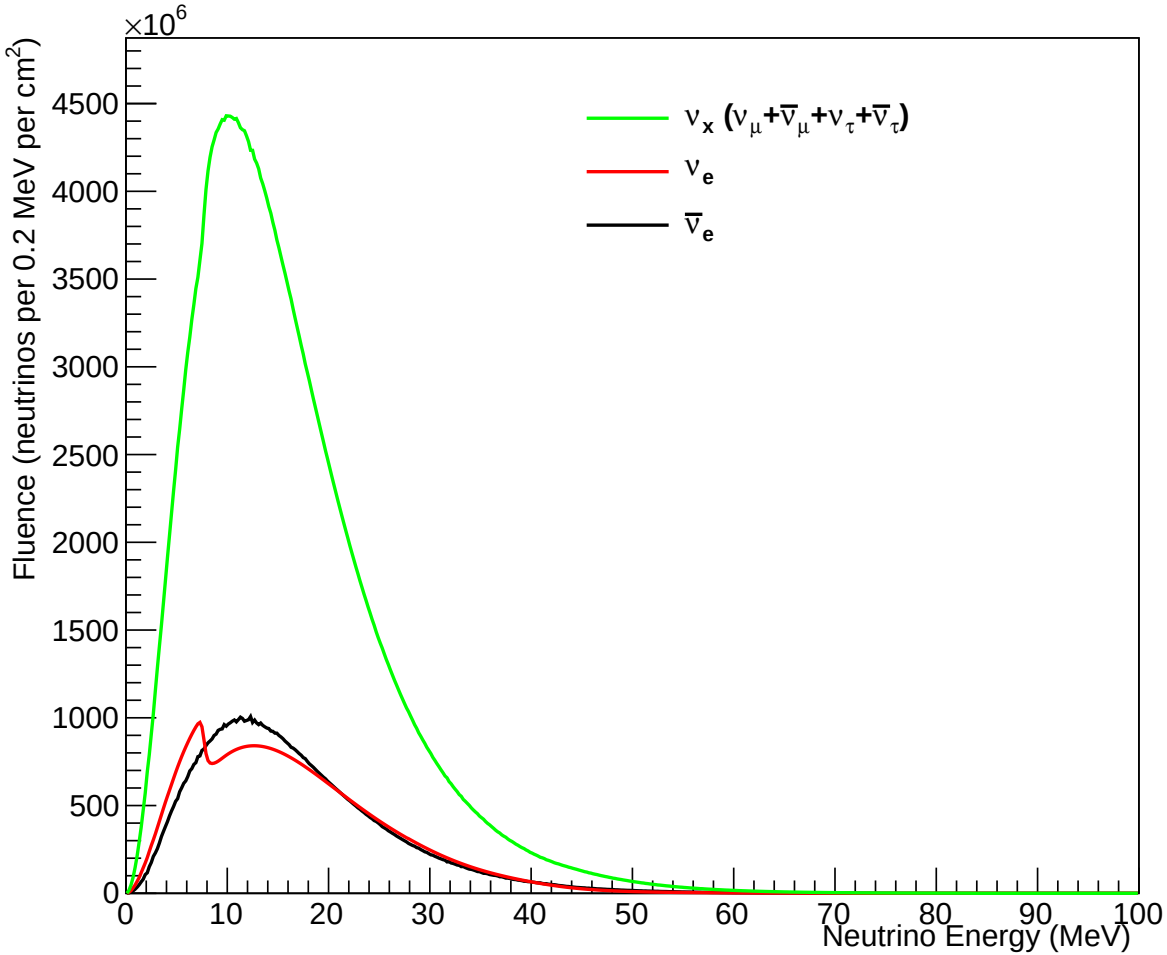
- Use LENA Software to produce the Monte-Carlo data
- Use PMT pulse shape information to distingiush NC channels
- Repeat the analysis for time dependent spectra
- Background studies
- Analyse what can be learned from the distingiushed spectra

Thank you for your attention

Ereignisraten abhängig von der Neutrino-Energie



GVKM Fluss


×10^6
Fluence (neutrinos per 0.2 MeV per cm^2)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
10
20
30
40
50
60
70
80
90
100
Neutrino Energy (MeV)
ν_x (ν_μ+ν̄_μ+ν_τ+ν̄_τ)
ν_e
ν̄_e

Wirkungsquerschnitte