Computational Modeling
β Decay Spectroscopy

JASON BARKELOO

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Outline

- Motivation and Previous Talks
  - Basics of Particles and Beta Decay
  - The Spectrometer and Model
- Looking at Past Data
  - Allowed Curve Vs. Fermi Fit
    - Splitting up the data

Motivation – Beta Decay

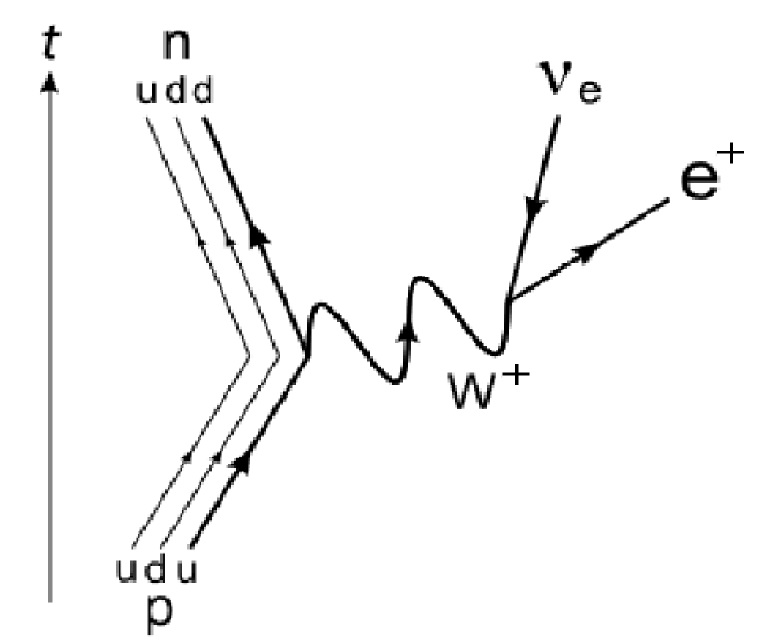
- Beta (plus) Decay:

$$p \rightarrow n + e^{+} + \nu_e$$

- Decay of interest:

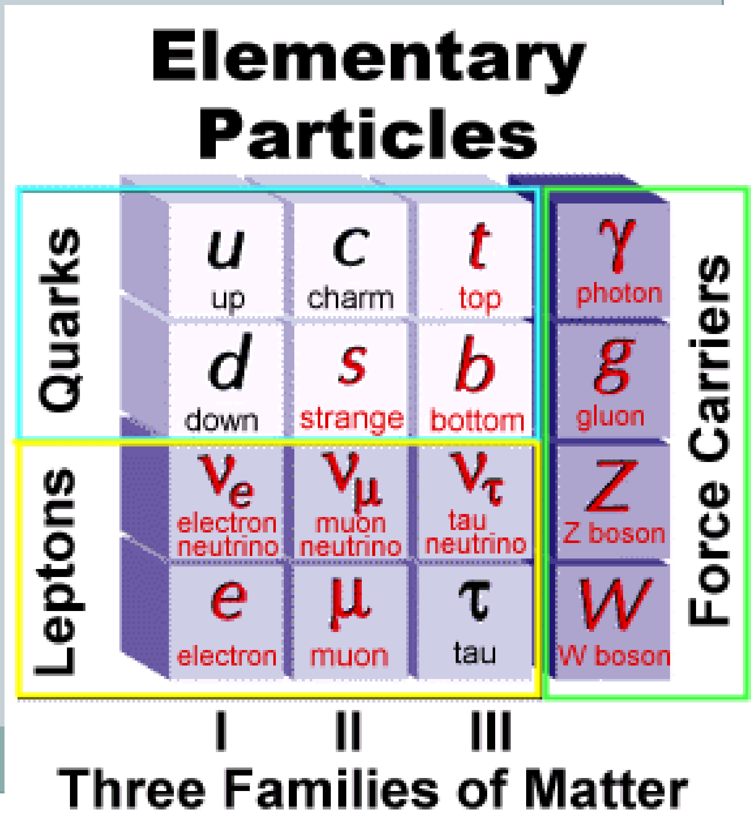
$$^{8}B \rightarrow {}^{8}Be + e^{+} + \nu_e$$

  - Halflife: 0.77s
  - Endpoint Energy: 14.06 MeV

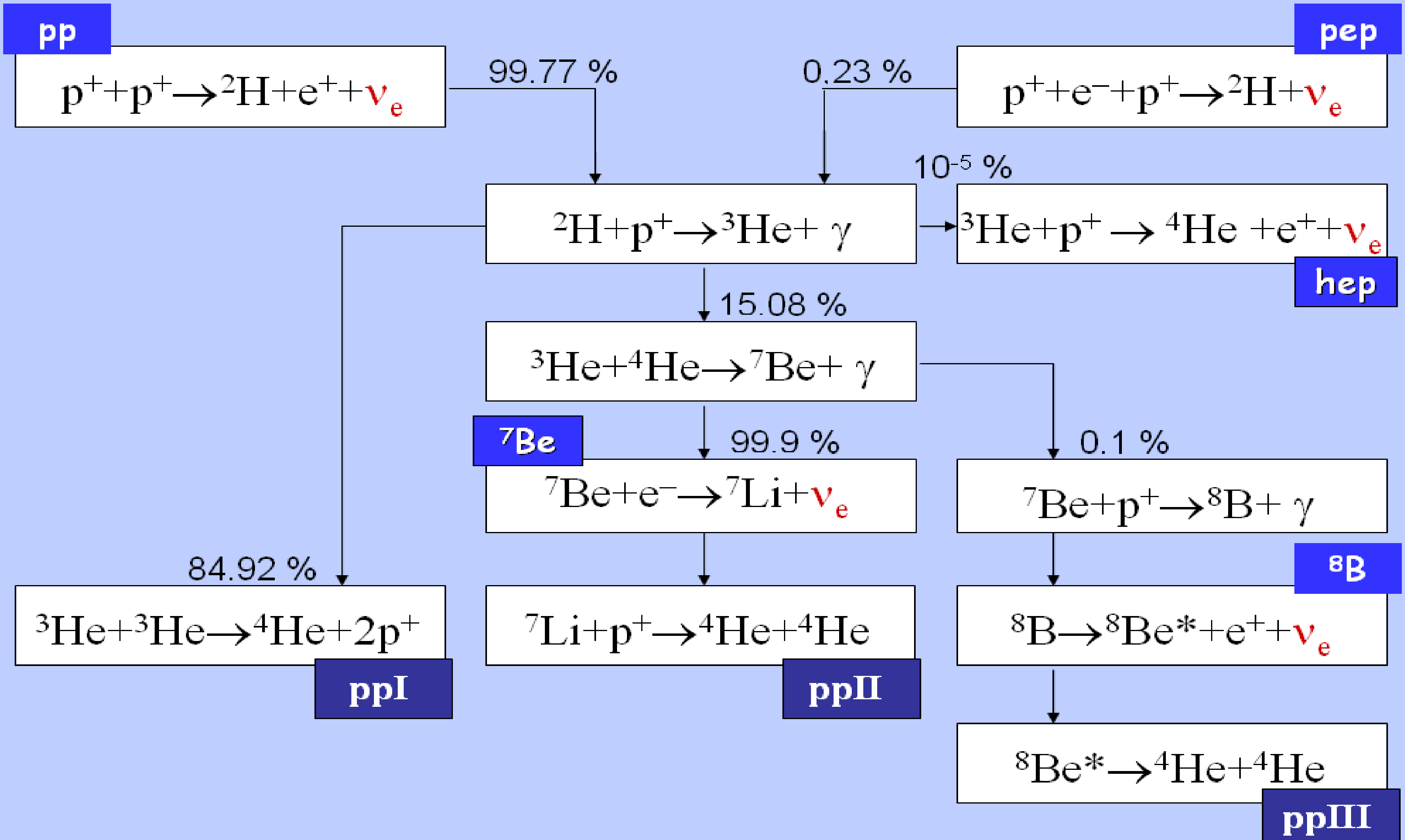


Motivation - Neutrinos

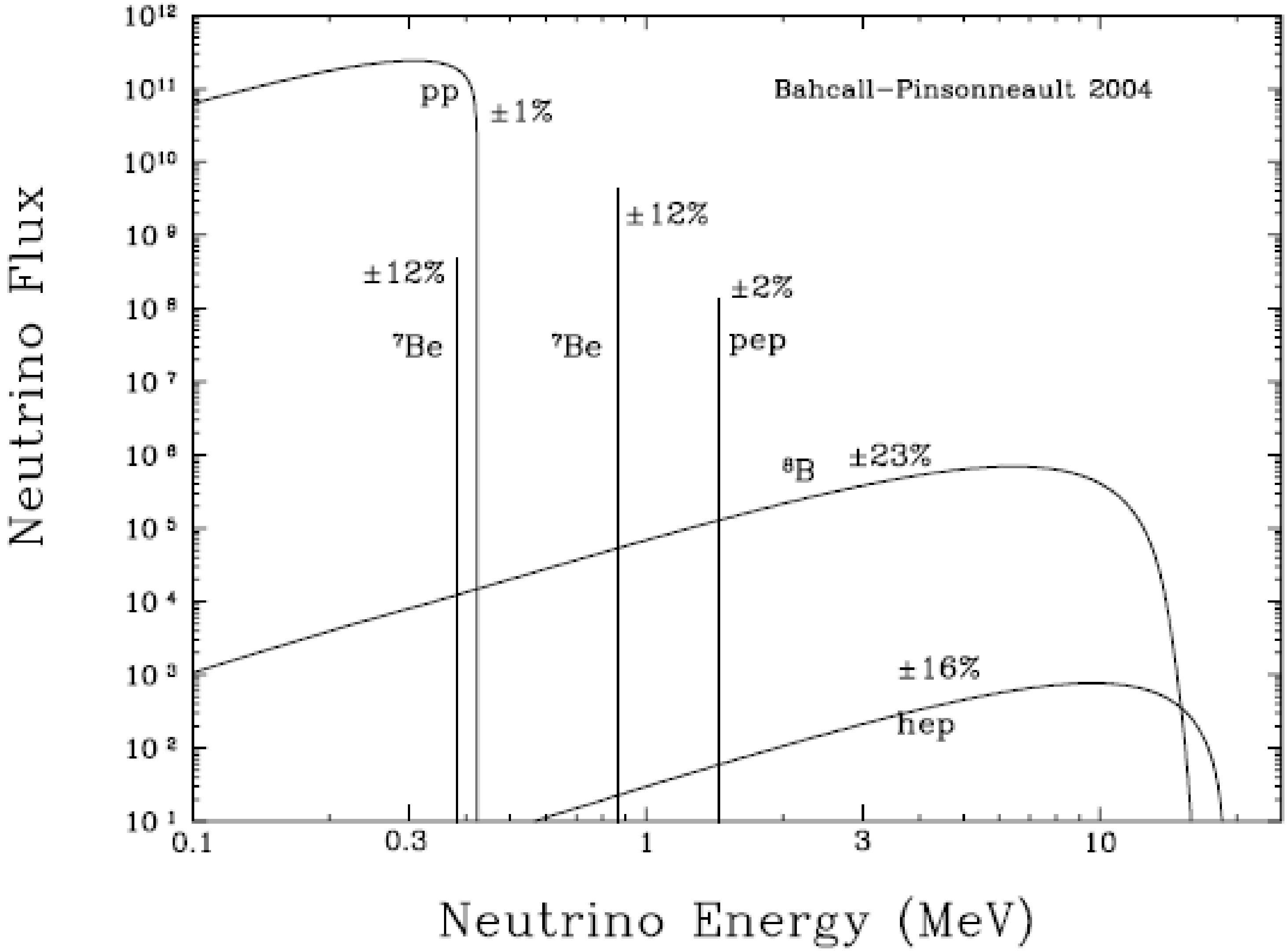
- No electric charge
- Nearly Massless
- Interact weakly with matter
- Carry information from solar reactions
- Hard to measure directly



Motivation – Solar Reactions

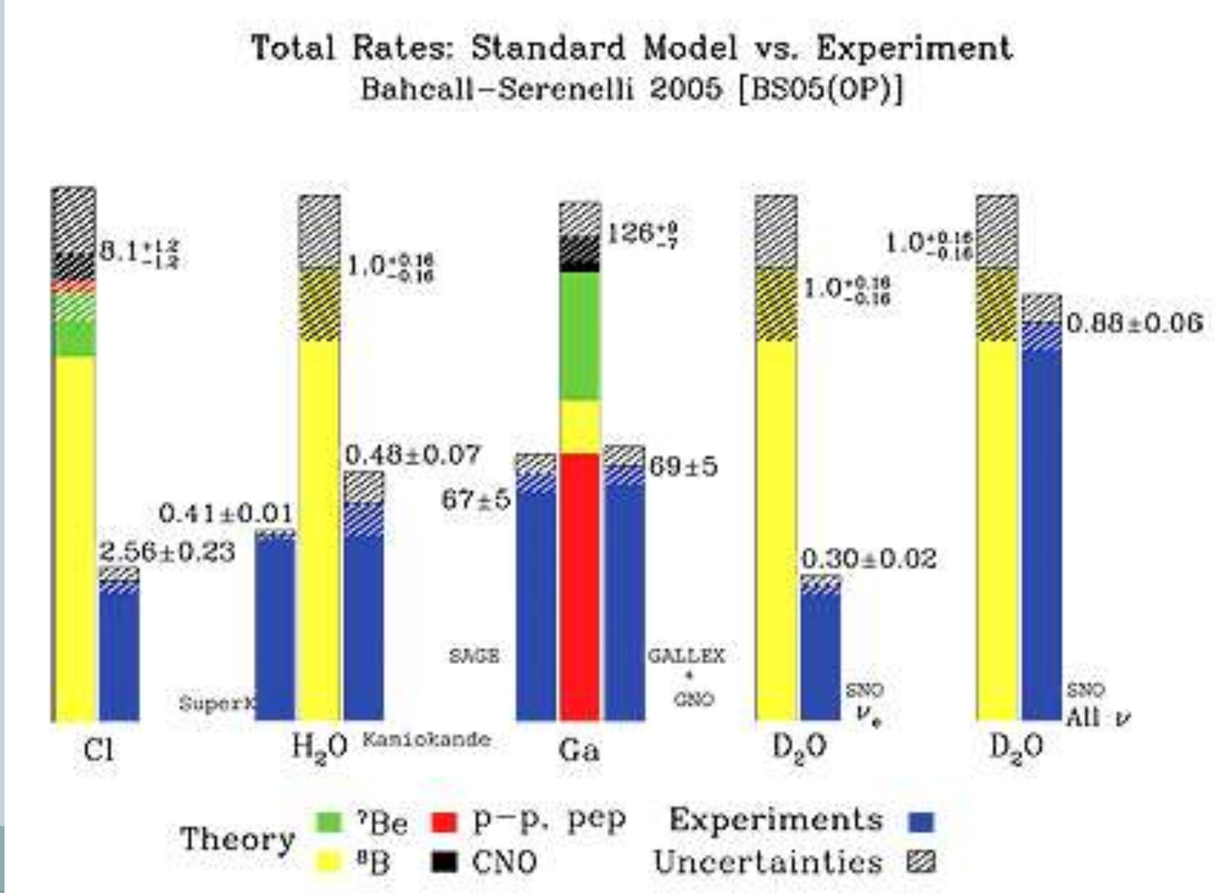


Motivation – Solar Neutrino Spectra



Motivation - Solar Neutrino Experiments

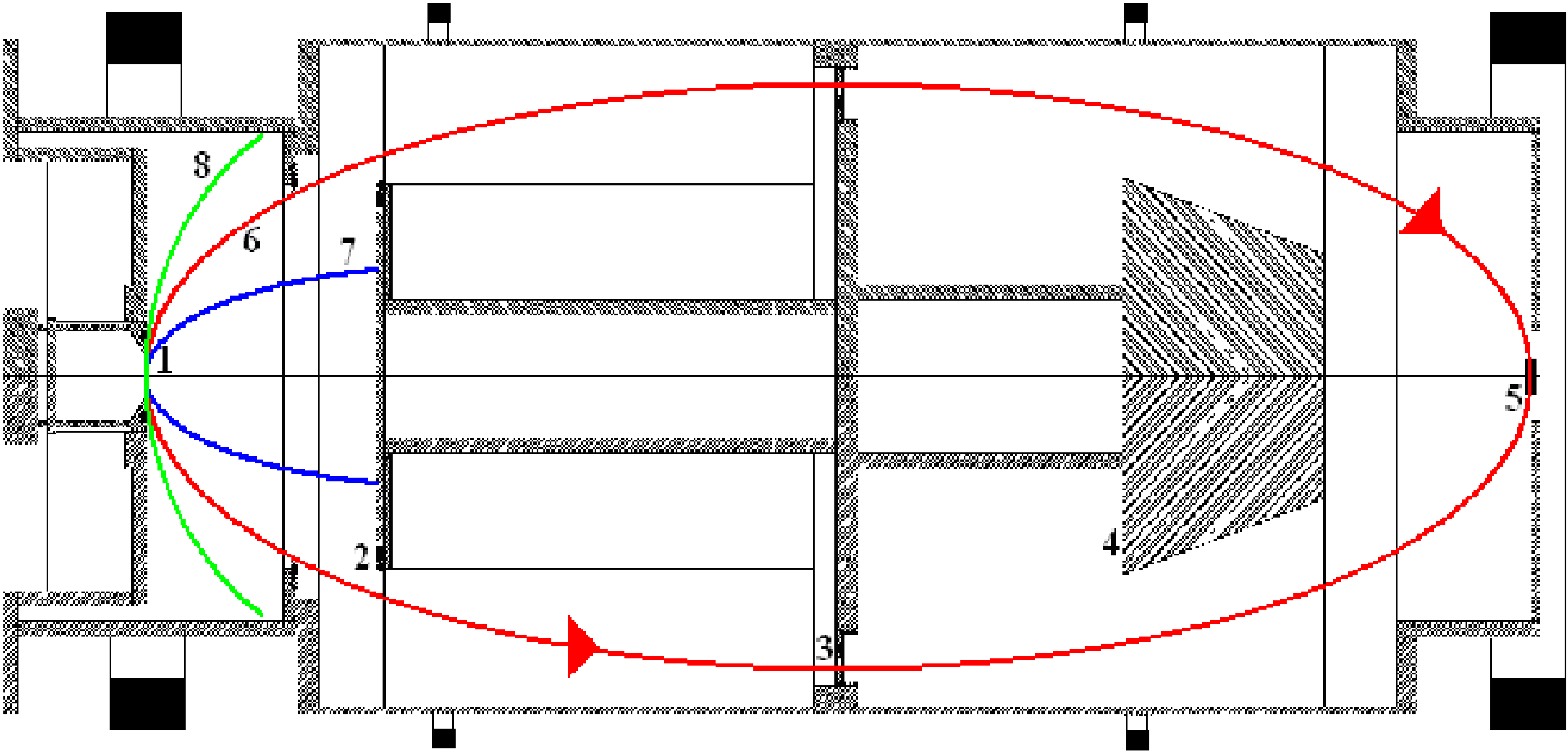
- Fewer higher energy neutrinos
  - Larger Cross Section



Finding the Neutrino Spectrum

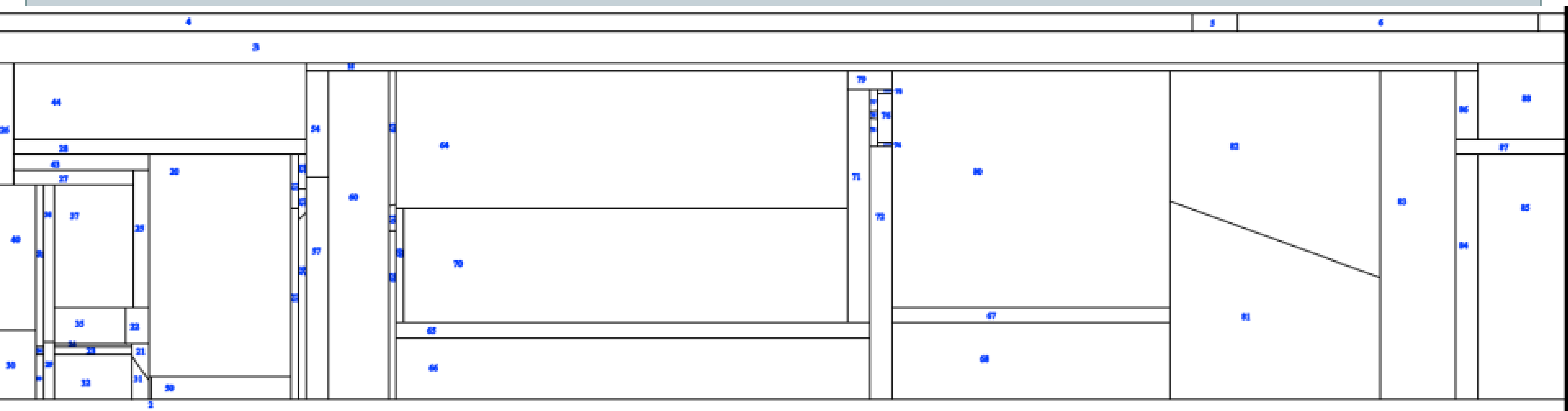
- Cannot Measure Directly
  - Find beta spectrum – Conservation of energy/momentum to determine neutrino spectrum
- Will use superconducting magnetic spectrometer
  - Can model this spectrometer

The Spectrometer



Modeling Techniques

- Monte Carlo Techniques
  - Based on probabilistic nature of physics
  - To understand the real world physics we need a detailed model of the spectrometer



Physics Package Used

- Electron Gamma Shower national research council (Canada) (EGSnrc)
  - Deals with coupled electron (or positron) plus gamma ray transport
  - Energies from 1 keV-10 GeV

Monte Carlo Techniques (1)

- Physics is probabilistic
  - Different processes can happen
  - Can calculate the probability of those processes
- We know the geometry and materials of the spectrometer
- We “Send in” particles with known energy/properties and follow them through

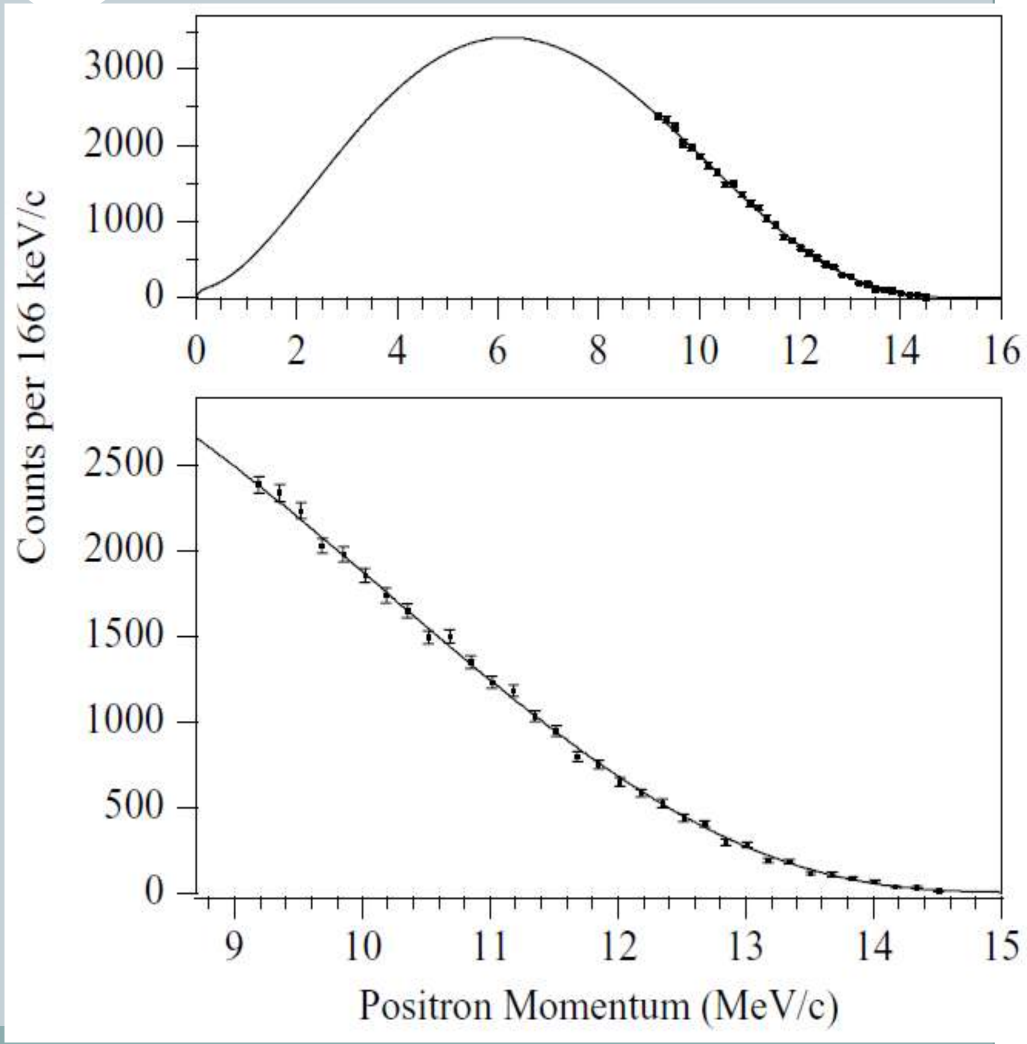
Monte Carlo Techniques (2)

- Each particle has a chance of undergoing various interactions
  - Pair production, Compton scattering, etc.
- A random number is generated and corresponds to an outcome
  - Any extra particles created are also followed to the cut off energy
- To get high accuracy we run lots of particles
  - As in the real world, most of them don’t do anything
  - Our simulations require 10^7 to 10^8 source particles

Past Work

- Past Measurement –

W.T. Winter

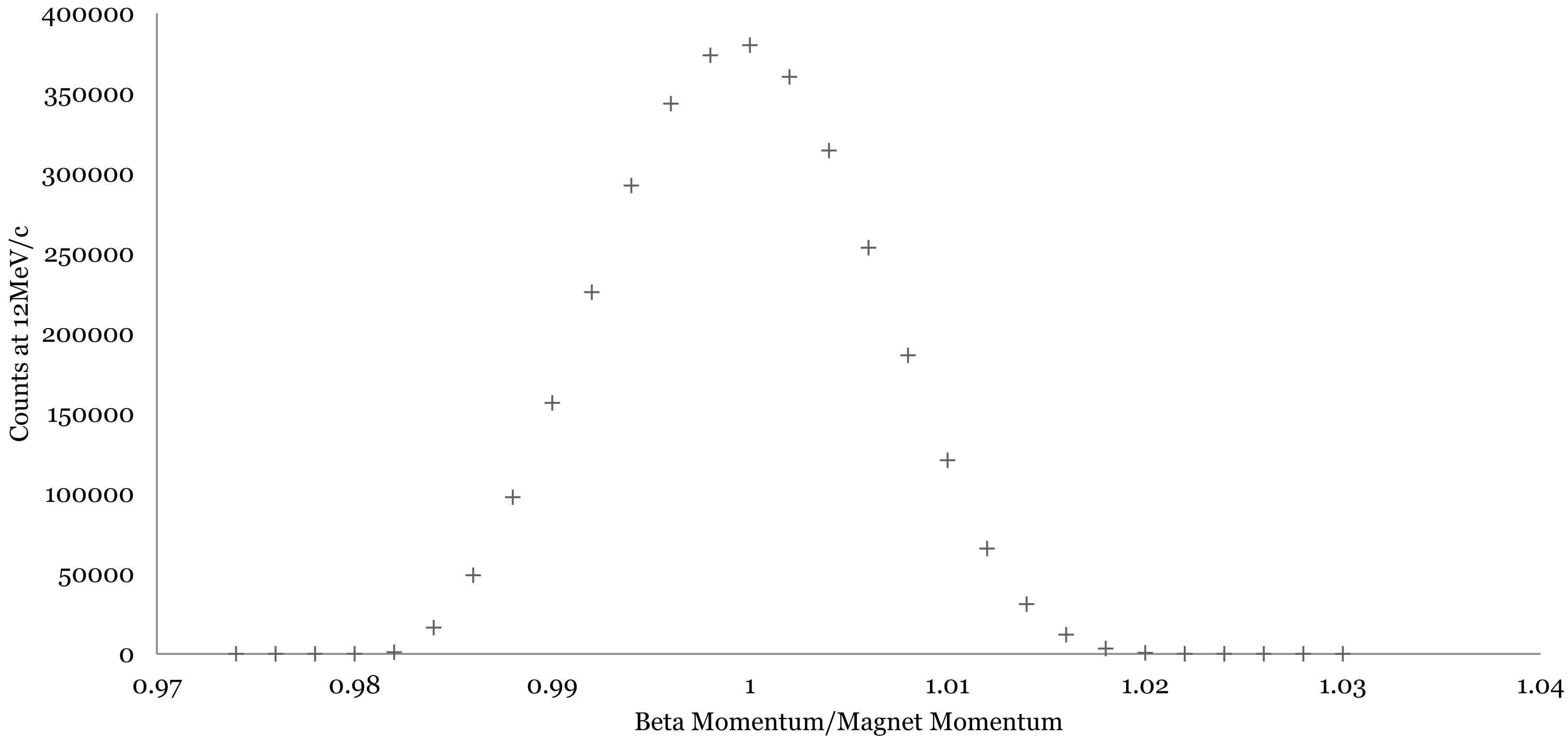


What We Observe

- Theoretical beta spectrum
- Magnetic field and geometry effects
- Scattering inside the spectrometer

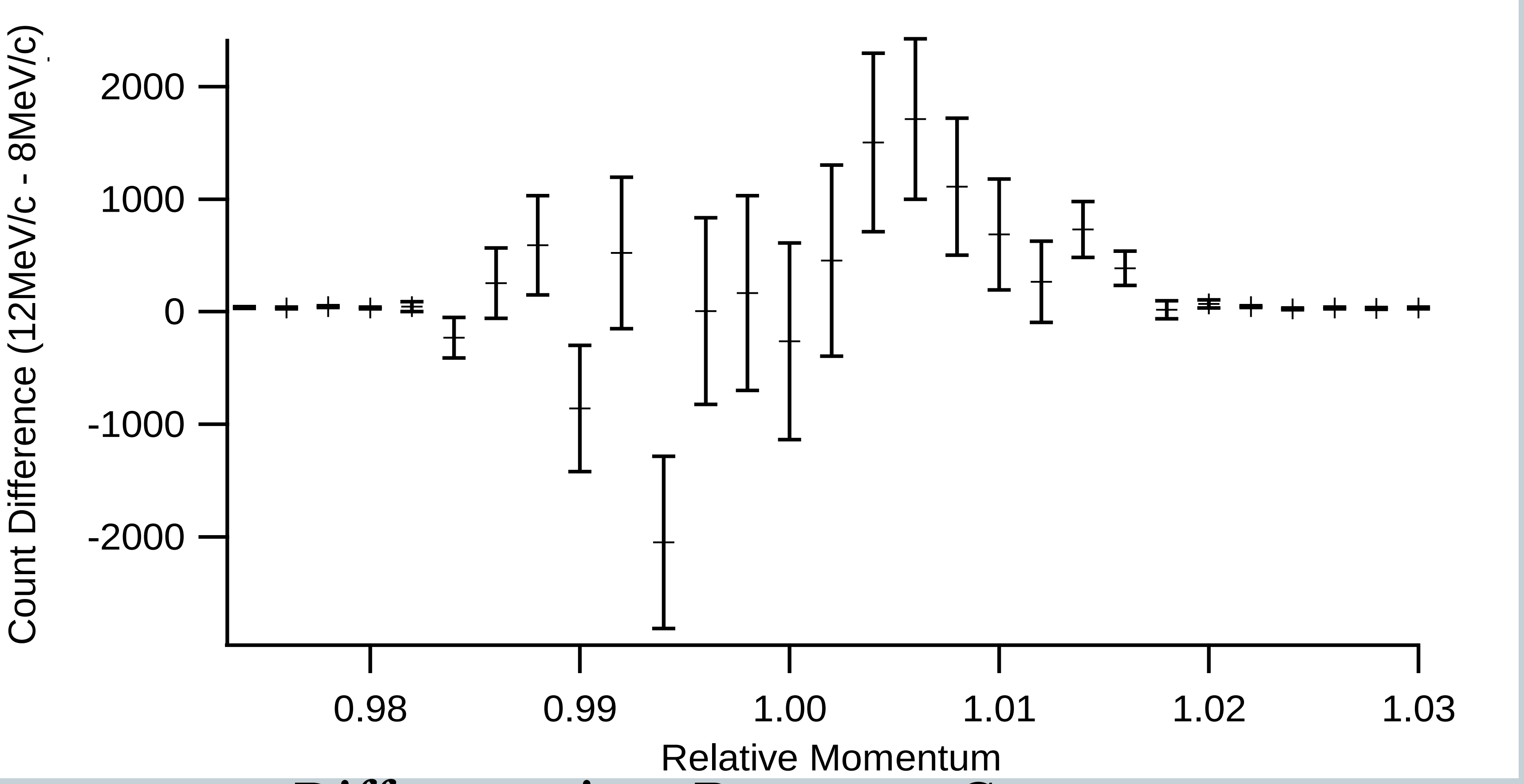
- Last two can be modeled using Monte Carlo techniques
  - Spectrometer response

EGS Modeling



Response Curve at 12 MeV/c

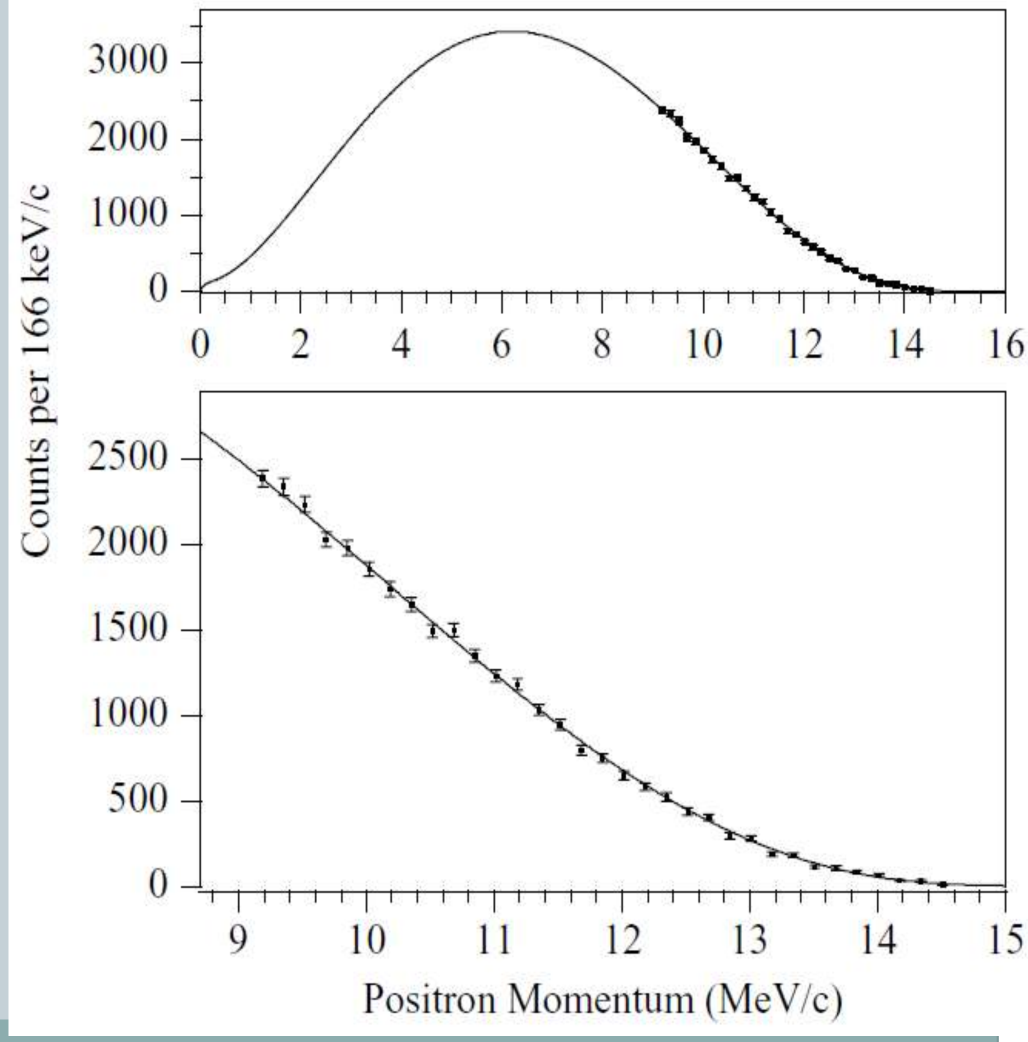
EGS Modeling



Difference in 2 Response Curves

Current Work

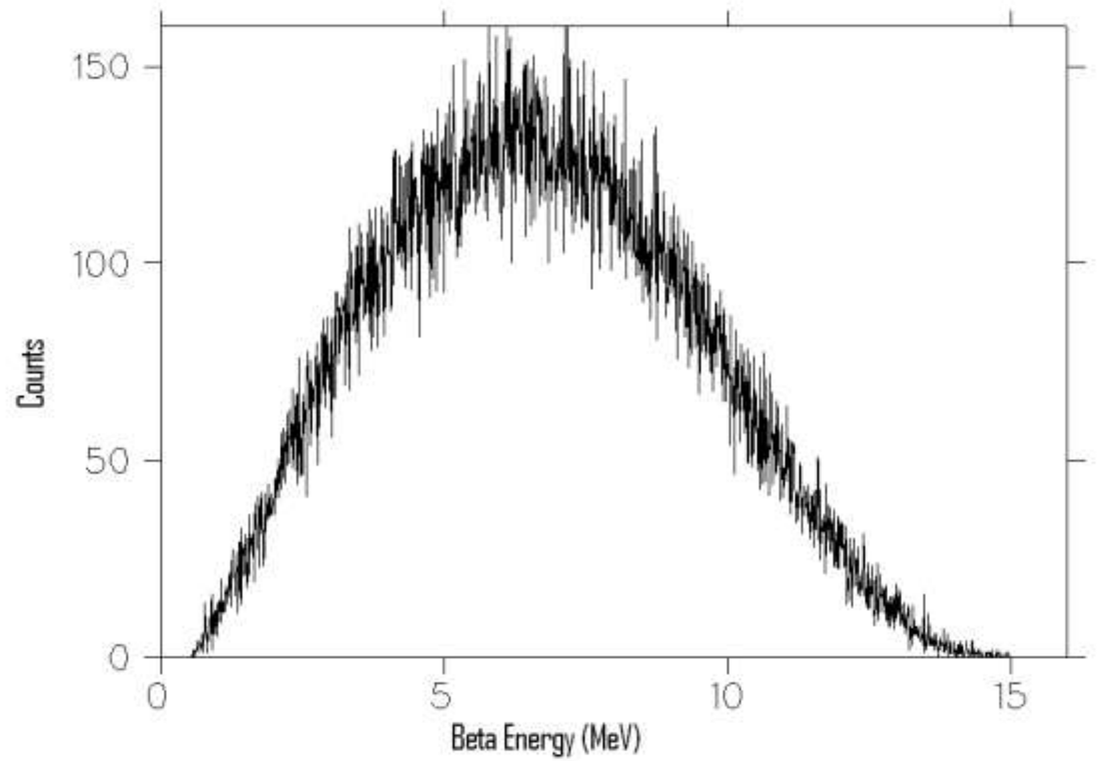
- Winter's spectrum
  - Interpolated
  - Convolved
  - Smeared



$\sqrt{N}$

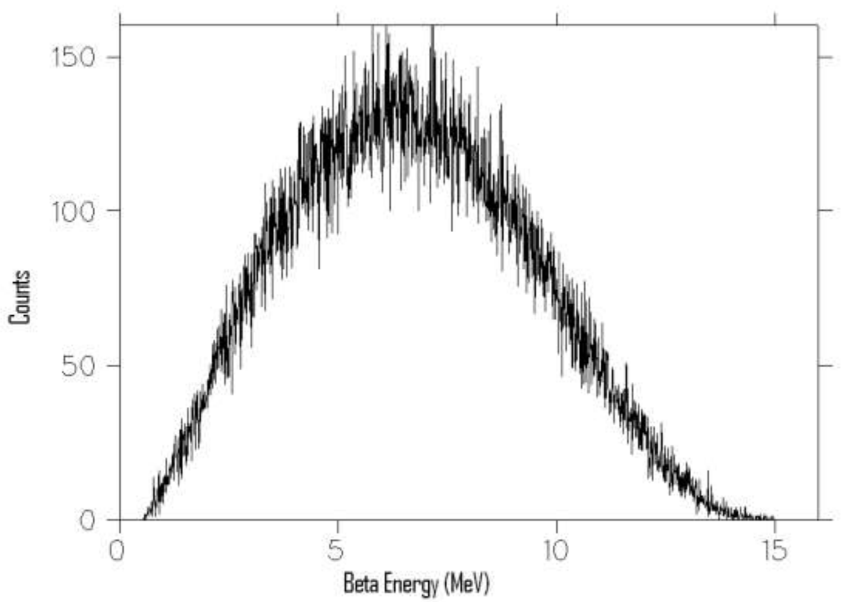
Smeared Curve

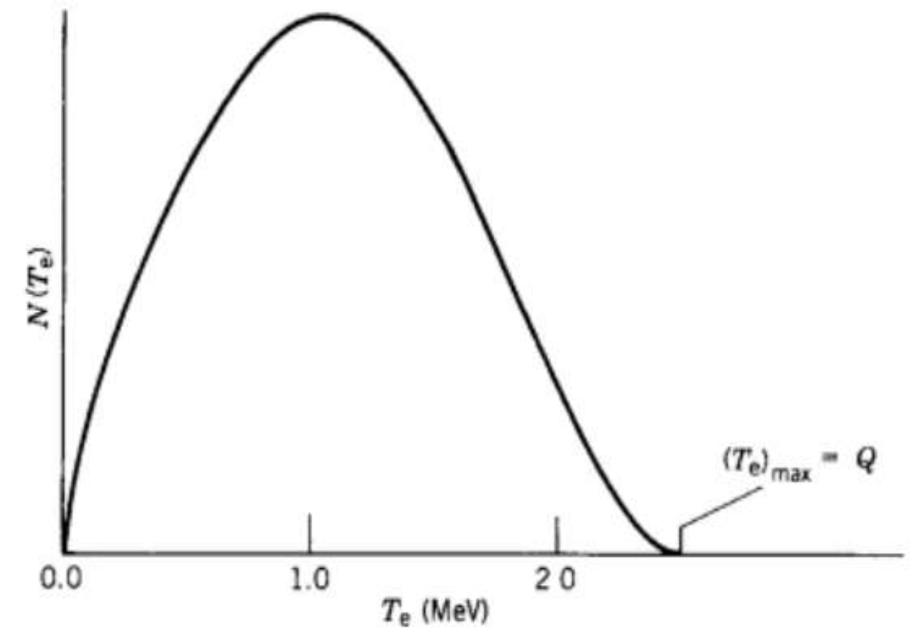
- Random statistical noise added
  - Based on counting statistics ($\sqrt{N}$)
  - Will fit this



Allowed Curve

$$N(T_e) = \frac{C}{c^5}\sqrt{T_e{}^2 + 2\,T_e\,m_e c^2}\,(Q - T_e)^2(T_e + m_e c^2)$$



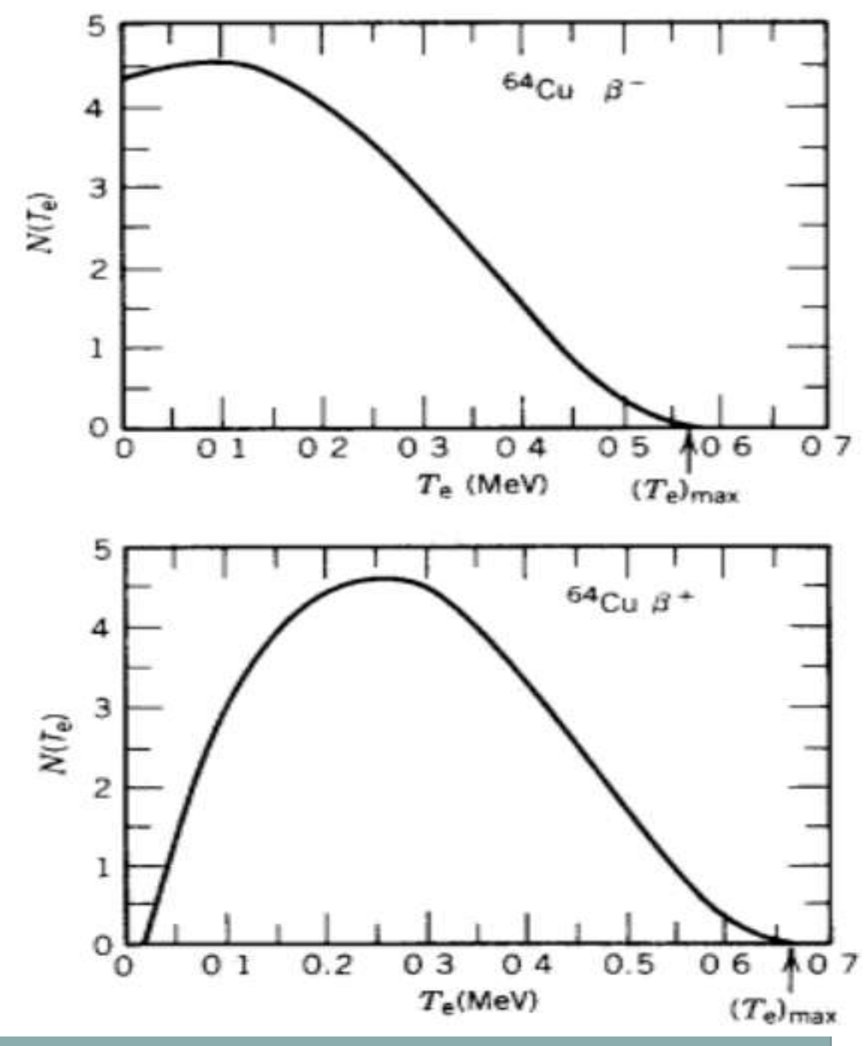


The Fermi Function

- Based on Coulomb interaction between emitted particle and positive nucleus

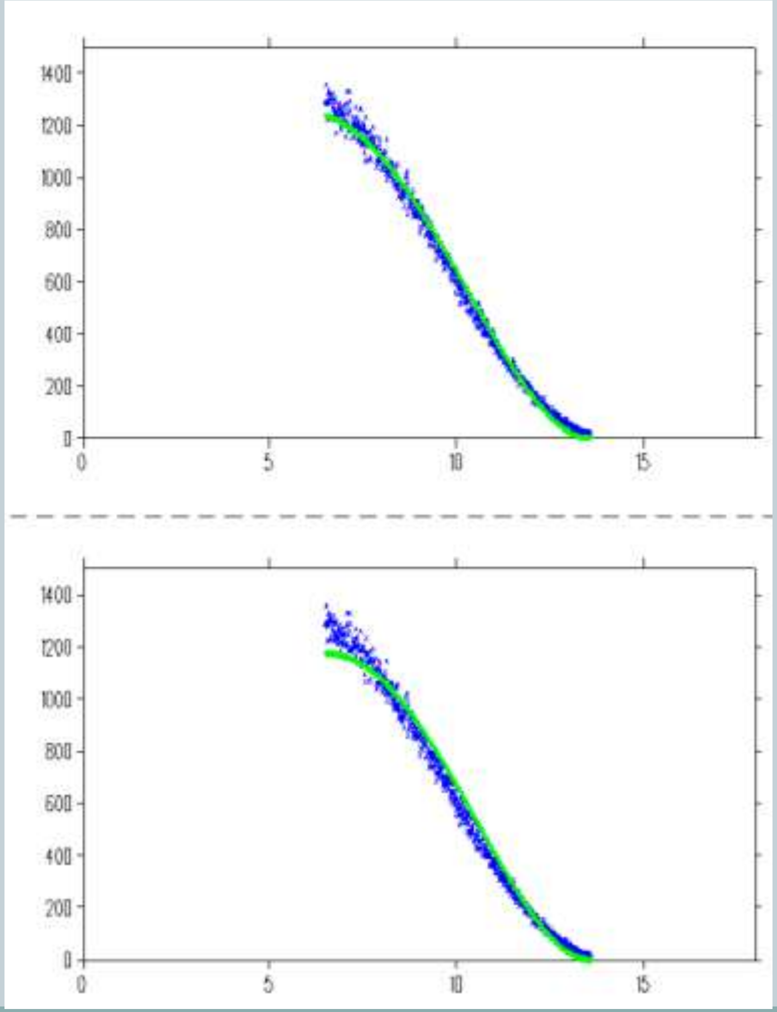
$$F(Z, T_e) = \sqrt{A + \frac{B}{T_e - 1}}$$

$$A = mZ + K$$
$$B = aZ\, e^{bZ}$$



Comparison of Fits

- With Fermi:
- Allowed :

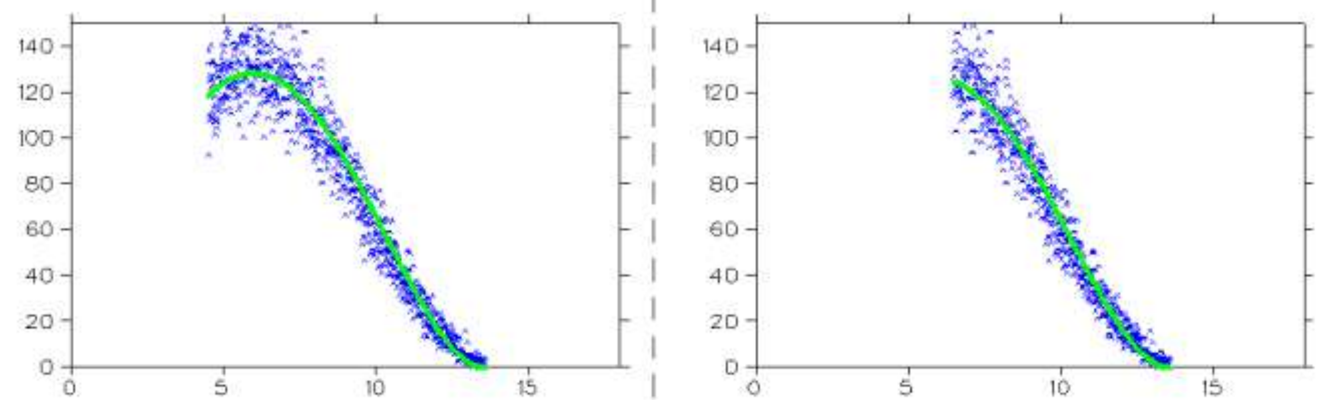


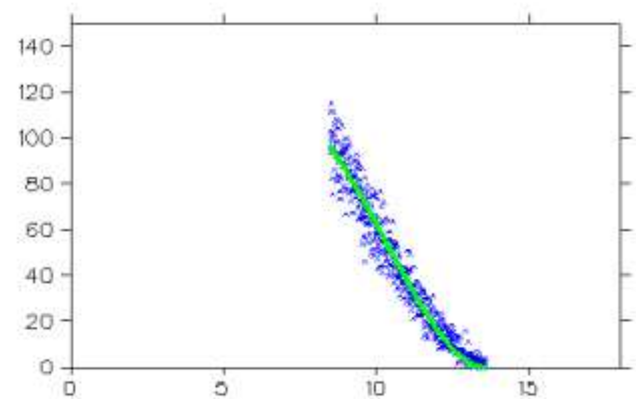
Y-Axis: Counts

X-Axis: MeV

Energy Dependence on Fit

- Looking at experimentally possible proportions and how the fit works





Y-Axis: Counts

X-Axis: MeV

Further Steps

- Use data that is more spread out
  - Interpolate data with smaller number of new points
  - Choose fewer points to do a fit with
    - Use initial energy data points and new counts to fit to

Conclusion

- Working to measure Boron-8 Beta Spectrum
- Have some preliminary results with Monte Carlo Simulations
  - Help us decide where taking data is most efficient
    - Upper portion of energy fits easier with Fermi function (lower X^2/degree s of freedom)
      - Possible explanation of why others only took data here

Acknowledgements

- Drs. George and Voytas
- Bahcall, John, et al."Standard neutrino spectrum from 8B decay." *Physical Review C*. 54.1 (1996): 411-22.
- K. Krane. *Introductory Nuclear Physics*. (John Wiley & Sons, New York, 1987), p. 280-1.

Questions

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