Lecture6: GLoBES

“General Long Baseline Experiment Simulator”

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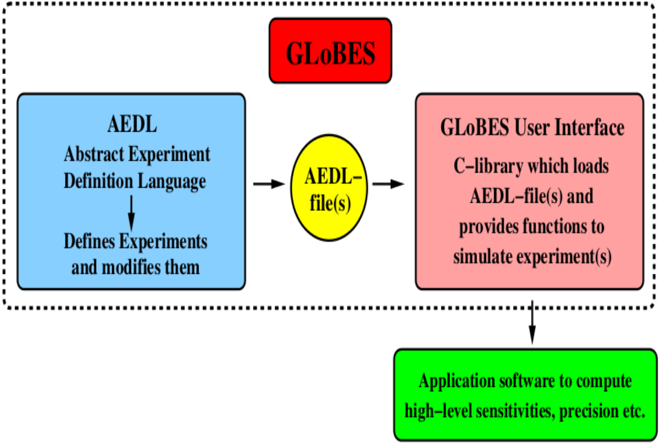
AEDL:

∗ AEDL is a language to define experiments in the form of ordinary text files.



Credits: GLoBES manual 3.1.8

Event Rates:

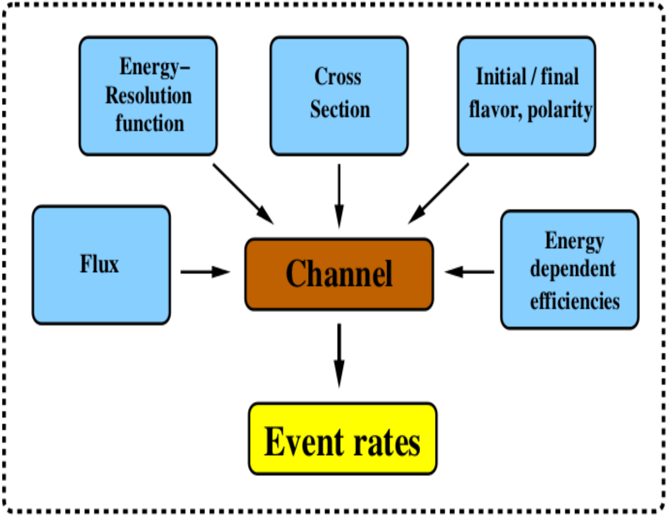
- The schematic form of the electron-neutrino events:

$$N \simeq \Phi_\mu P_{\mu e} \left\{ E, L, \rho, \Delta m^2_{21}, \Delta m^2_{31}, \theta_{12}, \theta_{13}, \theta_{23}, \delta_{CP} \right\} \sigma_e \ ,$$

  where σ_e denotes the cross section of the ν_e

- Also, E the energy of the initial neutrino
- L is the source to detector distance, and ρ is the matter density

Cont...



Energy–
Resolution
function
Cross
Section
Initial / final
flavor, polarity
Flux
Channel
Energy
dependent
efficiencies
Event rates

Cont...

- The differential event rate for each channel:

$$\frac{dn_{\beta}^{\mathrm{IT}}}{dE'} = N \int_0^{\infty}\int_0^{\infty} dE\, d\hat{E} \quad \underbrace{\Phi_{\alpha}(E)}_{\text{Production}} \times$$
$$\underbrace{\frac{1}{L^2} P_{(\alpha\to\beta)}(E, L, \rho; \theta_{12}, \theta_{13}, \theta_{23}, \Delta m_{31}^2, \Delta m_{21}^2, \delta_{\mathrm{CP}})}_{\text{Propagation}} \times$$
$$\underbrace{\sigma_f^{\mathrm{IT}}(E) k_f^{\mathrm{IT}}(E-\hat{E})}_{\text{Interaction}} \times$$
$$\underbrace{T_f(\hat{E}) V_f(\hat{E}-E')}_{\text{Detection}},$$

- α (β) is the intial (final) neutrino flavor
- Φ_{α}, L, N, ρ are the flux of initial flavor, baseline, normalization factor, and matter density, respectively
- E, $\hat{E}$, E' are the energies for the initial neutrino, secondary particle, and reconstructed neutrino, respectively
- Interaction term: σ is the total cross section for flavor f and $k(E-\hat{E})$ is the energy distribution of the secondary particle
- Detection term: T_f is the threshold function, and $V(\hat{E}-E')$ is the energy resolution function of the secondary particle

Cont...

- It is computationally very expensive to solve this double integral numerically, GLoBES splits the integration in two parts
- It computes $\hat{E}$ integration first using the internal Gaussian 'energy resolution function':

$$\mathcal{R}(E,E') = \frac{1}{\sqrt{2\pi}\sigma(E)}\, e^{-\left[\frac{(E-E')^2}{2\sigma^2(E)}\right]} ,$$

where, $\sigma(E) = \alpha E + \beta\sqrt{E} + \gamma$ with the coefficients α, β and γ depend on the detector specifications.

Cont...

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Eventually, we can write down the number of events per bin i and channel c as

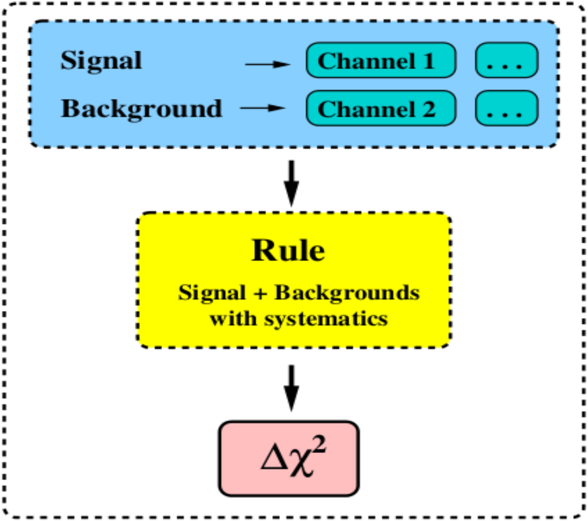
$$n_i^c = \int_{E_i-\Delta E_i/2}^{E_i+\Delta E_i/2} dE' \quad \frac{dn_\beta^{\mathrm{IT}}}{dE'}(E') \tag{11.5}$$

where ΔE_i is the bin size of the ith energy bin. This means that one has to solve the integral

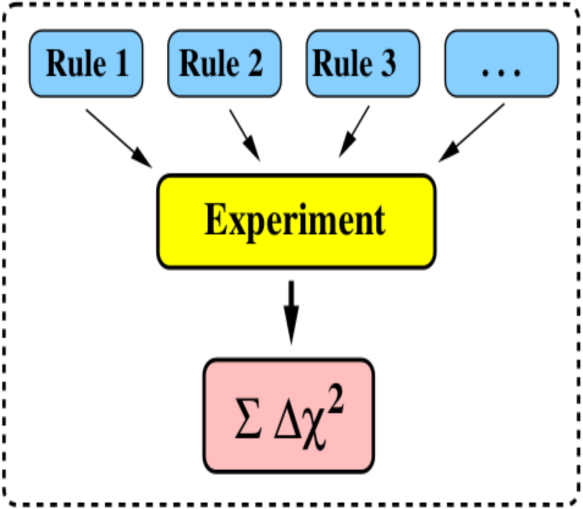
$$n_i^c = N/L^2 \int_{E_i-\Delta E_i/2}^{E_i+\Delta E_i/2} dE' \quad \int_0^\infty dE \; \Phi^c(E)\, P^c(E)\, \sigma^c(E)\, R^c(E, E')\, \epsilon^c(E') \, . \tag{11.6}$$

Note that the events are binned according to their *reconstructed* energy.

Cont...


Signal
Background
Channel 1
...
Channel 2
...
Rule
Signal + Backgrounds
with systematics
$\Delta\chi^2$

Cont...



χ^2 definition:

- **The mass hierarchy sensitivity,**

$$\chi^2_{\rm stat} = \textbf{Min} \frac{[N_{\rm ex}^{true}(NH) - N_{\rm th}^{test}(IH)]^2}{\sigma(N_{\rm ex}^{true}(NH))^2}$$

- **The octant sensitivity,**

$$\chi^2_{\rm stat} = \textbf{Min} \frac{[N_{\rm ex}^{true}(LO) - N_{\rm th}^{test}(HO)]^2}{\sigma(N_{\rm ex}^{true}(LO))^2}$$

- **The CP violation discovery χ^2,**

$$\chi^2_{\rm stat} = \textbf{Min} \frac{[N_{\rm ex}(\delta^{\rm true}) - N_{\rm th}(\delta^{\rm test} = 0, \pm 180^\circ)]^2}{\sigma(N_{\rm ex}(\delta^{\rm true}))^2}$$