AEDL 101
or how to put your experiment into GLoBES

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on behalf of
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Outline

- Basic concept behind GLoBES
- Step by step example
- The Manual is your friend!
- Friends sometimes let you down
- In that case: globes@ph.tum.de
Basic Concept

AEDL
Abstract Experiment Definition Language
Defines Experiments and modifies them

GLoBES User Interface
C-library which loads AEDL-file(s) and provides functions to simulate experiment(s)

Application software to compute high-level sensitivities, precision etc.
What does a detector do?

- It maps some incident, true particle flux $X$ into a detected, reconstructed flux $Y$
- The particles in $X$ and $Y$ may be different
- There may be many different $Y$'s for one $X$

\[
p(x') = \int dx f(x) K(x, x')
\]
Intermediate states?

- This mapping usually involves intermediate states, eg. hadron showers, muons asf.
- They are only important in as far as they determine the properties of the mapping function.
- Goal: Fast detector “simulation”
Detectors in GLoBES

\[
\frac{d n^\text{IT}_\beta}{d E'} = N \int_0^\infty \int_0^\infty dE \, d\hat{E} \Phi_\alpha(E) \times \\
\frac{1}{L^2} P_{\alpha \rightarrow \beta}(E, L, \rho; \theta_{23}, \theta_{12}, \theta_{13}, \Delta m^2_{31}, \Delta m^2_{21}, \delta_{\text{CP}}) \times \\
\sigma^\text{IT}_f(E) k^\text{IT}_f(E - \hat{E}) \times \\
T_f(\hat{E}) V_f(\hat{E} - E') ,
\]
AEDL / Channels

- Energy-Resolution function
- Cross Section
- Initial / final flavor, polarity
- Flux
- Energy dependent efficiencies

Event rates
AEDL Channels cont.

- Different intermediate states may yield a different mapping
- There may be some events cleaner than others, eg. QE
- Different sources for signal and backgrounds
- Different event types, eg. QE vs NC
- Currently up to 32 channels per experiment
Example

- From here on I will present a toy example
- The detector Monte Carlo is a black box
  - I made up a resolution function etc
  - I then “generated” events
  - and arbitrarily tagged them as 'signal' or 'garbage'
- How to put each of the parts into AEDL syntax, is better explained in the Manual
Flux

- Flux either given by formula (NF, Beta-Beam)
- or MonteCarlo (superbeams)

Warning!
The normalization constant is not documented. There is a factor of 5.20... which has to be properly accounted for!
Cross section

- From calculation (rarely)
- From fit to data
- Event generator, eg. NUANCE
Mapping function

- Has to be derived from MC
- either parametrically, eg. Gaussian resolution
- or in form of migration or smearing matrices

Typical output from MC

- Draw true energies from flux times x-section
- Follow events through detector
- Assign to each event the reconstructed energy and event type

blue – tagged as signal
green – tagged as garbage
Migration matrix for the signal

- Take the blue points
- Bin them in 2D bins
- Raw matrix

\[
E_{\text{REC}} \begin{pmatrix} 2 & 1 & 0 & 0 & 0 \\ 0 & 7 & 9 & 4 & 1 \\ 0 & 0 & 2 & 9 & 7 \end{pmatrix} E_{\text{TRUE}}
\]

bins in true energy: sampling points
bins in rec. energy: bins
Reweighting

- Raw matrix has to be reweighted
  - flux used for MC will be modulated by oscillations
  - number of events in MC does not correspond to actual number, eg. I generated 20000 events, but the real experiment may have only 500
  - number of generated events usually is not the same than the number of events which are reconstructed as signal (efficiency)
Reweighting cont.

Sum each column

\[ n_i = \sum_{j=1}^{N_{\text{bins}}} m_{ij} \]

Divide each column by that sum

\[ m_{ij} \rightarrow m_{ij} / n_i \]

Account for 'lost' events, efficiency

\[ \epsilon = \frac{\sum_{i=1}^{N_{\text{sampling}}} n_i}{\text{number of generated events}} \]
Computing events

- Event computation reduced to matrix multiplication

\[ \Phi(E) = P(E) \times \sigma(E) \times \phi(E) \]

Can be regarded as vector and thus we can compute the events \( N \)

\[ N_j = \sum_{i=1}^{N_{\text{sampling}}} m_{ij} \cdot \Phi_i \]
Computing events

Toy oscillation probability

$$P(E) = \sin^2 \left( \frac{30.0}{E} \right)$$

That was only 1 channel – next you would do the same for all the backgrounds
AEDL / Rules

Signal → Channel 1 ... 
Background → Channel 2 ... 

Rule
Signal + Backgrounds with systematics

$\Delta \chi^2$
AEDL / Experiment

Rule 1 ➔ Experiment ➔ \[ \Sigma \Delta \chi^2 \]

Rule 2

Rule 3

...
Debugging AEDL

Interactive call of globes

=> event rates

globes has many command line options

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Total: 135.989
Summary

- GLoBES tries to implement a fast simulation
- Generating migration matrices from MC output is straightforward, but requires care
- Channels offer quite some flexibility
- If all else fails, look into the manual
- There is an AEDL debugging tool, globes
- globes@ph.tum.de