

Software Tools

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Outline

- General HEP software
- Requirements for the physics group
- GLoBES
 - Features
 - Structure
 - C-API
 - AEDL
- Summary

General HEP Software

- ROOT
- GEANT
- NUANCE –
neutrino event generator by Dave Casper

These tools are especially important for the detector and accelerator working groups.

General Requirements

Simulation

- fast pseudo-Monte-Carlo
- Efficiencies
- Backgrounds
- Energy response

Interface to the detector/accelerator working groups

General Requirements

Analysis

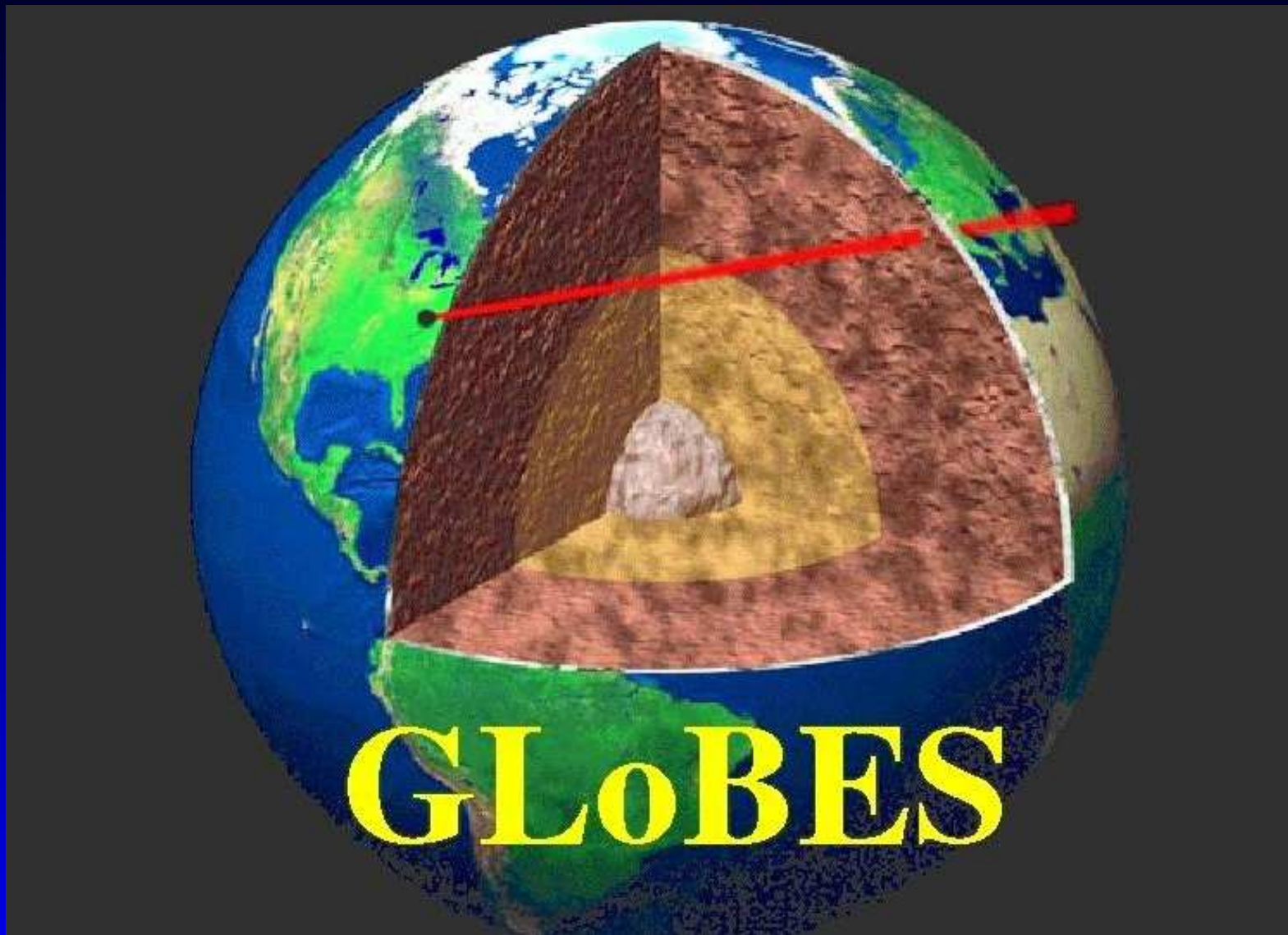
- Appearance channels
- Disappearance channels
- Energy information
- External information

- Systematics
- Correlations
- Matter density uncertainties
- Degeneracies

General Requirements

Comparison

- Parameters of interest
- Figure(s) of merit
- Risk function



General Long Baseline Experiment Simulator

GLOBES is a software package designed for

- Simulation
- Analysis
- Comparison

of neutrino oscillation experiments

Why use GLoBES?

- Avoids re-inventing the wheel
- Well defined interface between beam, detector and neutrino physics
- Facilitates data exchange
- Encourages collaboration
- Easy comparison of different setups

GLOBES – features

- Accurate treatment of systematical errors
- Arbitrary matter profile & uncertainties
- Arbitrary energy resolution function
- Single and multiple experiment simulation
- Simple χ^2 calculation
- Inclusion of external input
- Projection of χ^2 (minimization)
- ...

GLOBES – features

Example – χ^2 projections

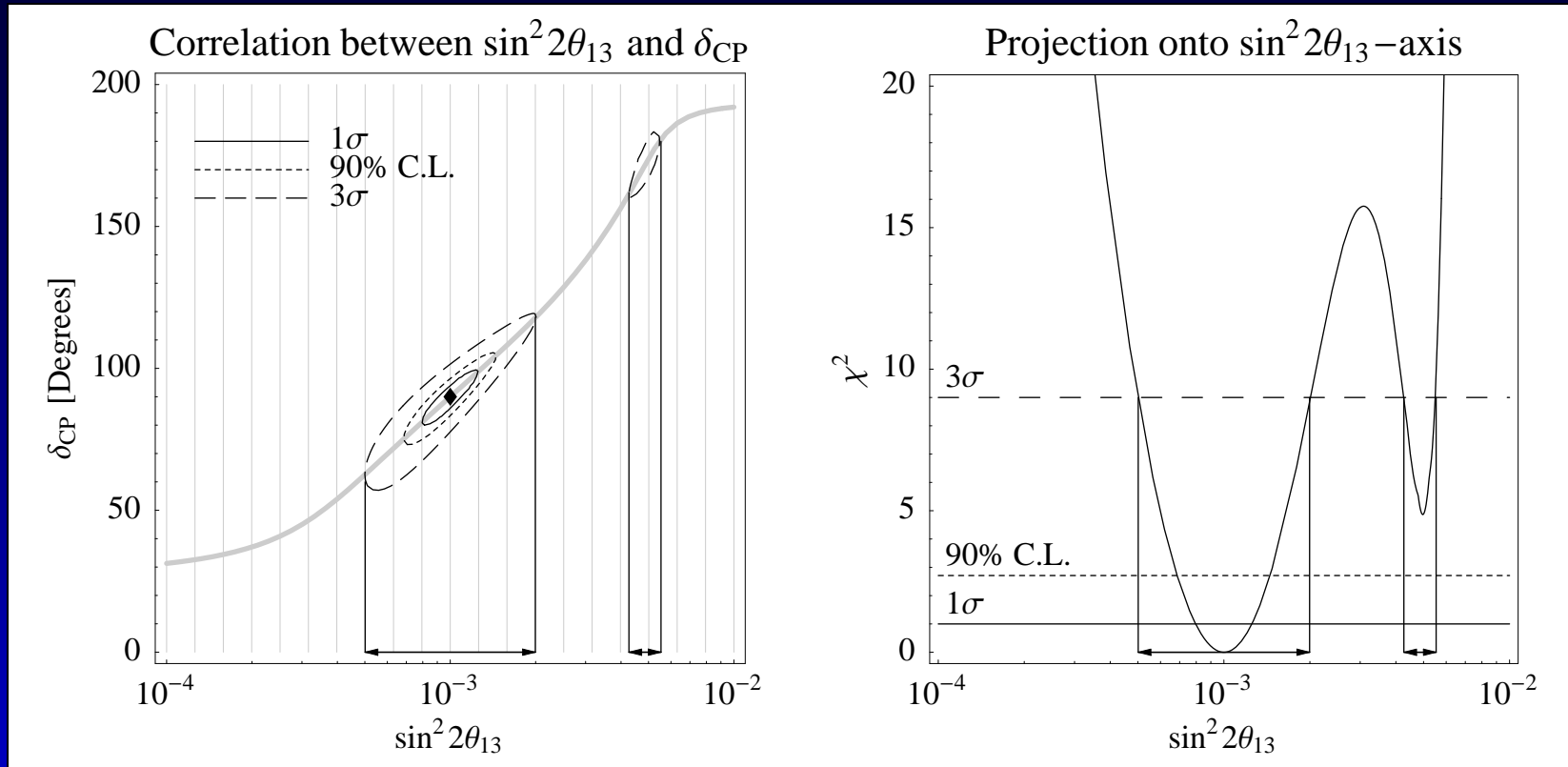


figure taken from PH, M. Lindner, W. Winter, Comput. Phys. Commun. **167** (2005) 195

GLOBES – features

GLOBES has been used for simulating

- MINOS, CNGS
- Reactor experiments, Double-CHOOZ
- T2K
- $\text{NO}\nu\text{A}$
- JHF-HK (T2K upgrade)
- Neutrino factory
- β -beam
- BNL neutrino beam

The GLoBES-Team

GLoBES is developed, documented, maintained and supported by

- Patrick Huber (UW)
- Joachim Kopp (TUM)
- Manfred Lindner (TUM)
- Mark Rolinec (TUM)
- Walter Winter (IAS)

The GLoBES tar-ball as well as an extensive manual are available since August 2004 at

<http://www.ph.tum.de/~globes/>

GLOBES – basic structure

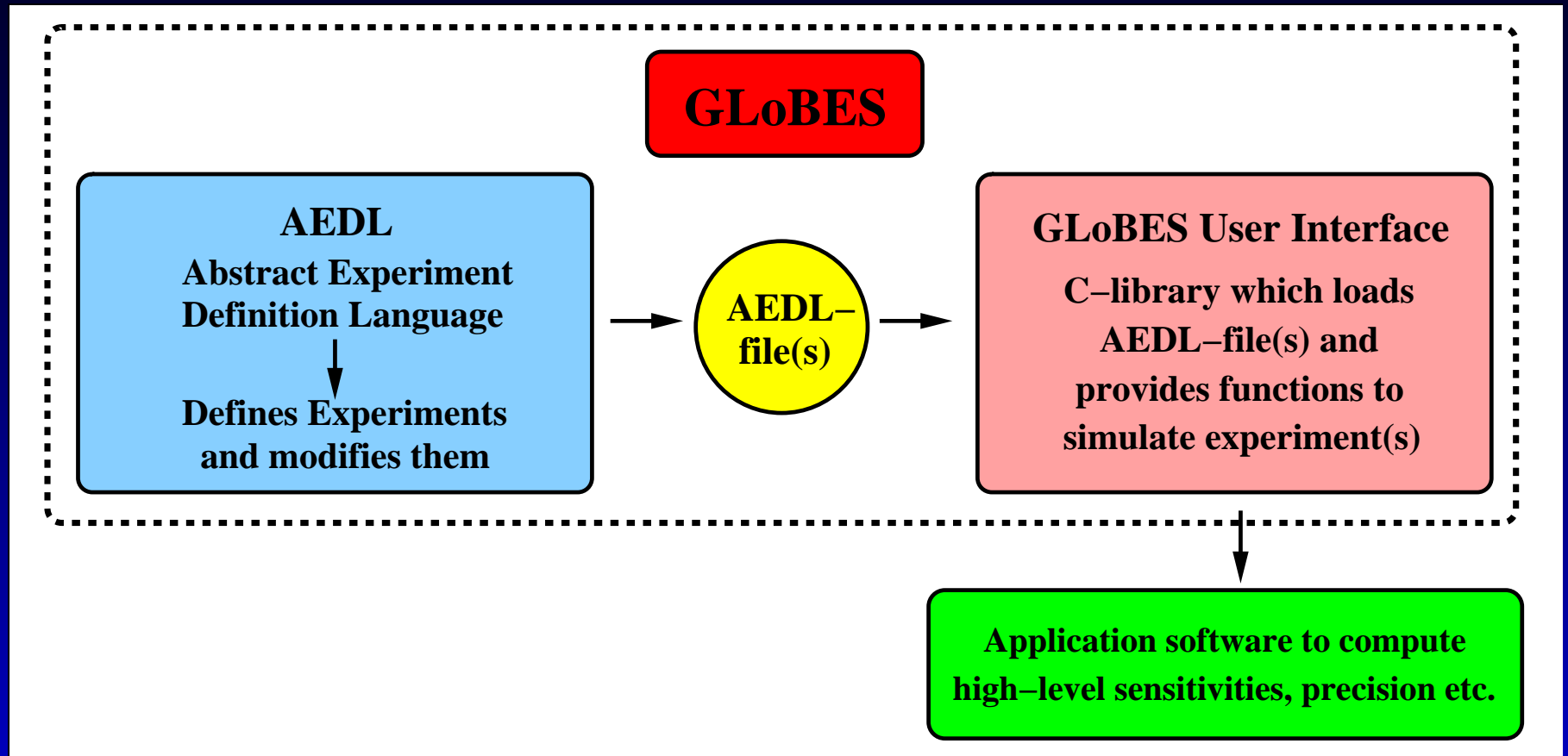
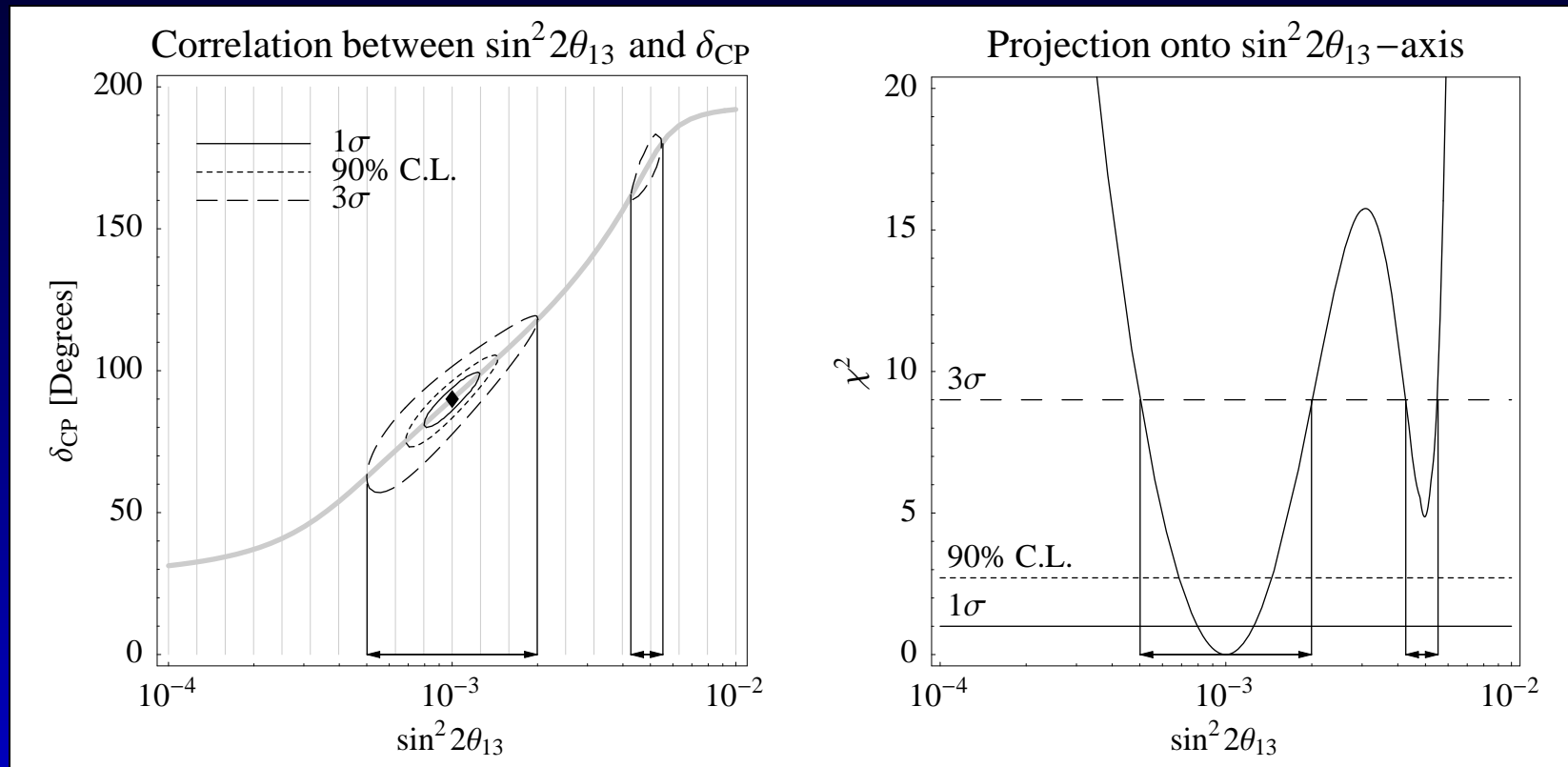


figure taken from PH, M. Lindner, W. Winter, Comput. Phys. Commun. **167** (2005) 195

GLoBES – C API

How do you this ?



GLoBES – C API

```
/* Set starting values and input errors for all projections */
glbDefineParams(input_errors, theta12*0.1, 0, 0, 0, sdm*0.1, 0);
glbSetDensityParams(input_errors, 0.05, GLB_ALL);
glbSetStartingValues(true_values);
glbSetInputErrors(input_errors);

/* Define my own two-parameter projection for glbChiNP: Only deltacp is
free! */
glbDefineProjection(th13_projection, GLB_FIXED, GLB_FIXED, GLB_FIXED,
                   GLB_FREE, GLB_FIXED, GLB_FIXED);
glbSetProjection(th13_projection);
```

GLoBES – C API

```
/* Iteration over all values to be computed */
double x,res1,res2;
for(x=-4;x<-2.0+0.001;x=x+2.0/50)
{
/* Set fit value of stheta */
glbSetOscParams(test_values,asin(sqrt(pow(10,x)))/2,1);

/* Guess fit value for deltacp in order to safely find minimum */
glbSetOscParams(test_values,200.0/2*(x+4)*M_PI/180,3);

/* Compute Chi2 for user-defined two-parameter correlation */
res1=glbChiNP(test_values,NULL,GLB_ALL);

/* Compute Chi2 for full correlation: minimize over all but theta13 */
res2=glbChiTheta(test_values,NULL,GLB_ALL);

AddToOutput(x,res1,res2);
}
```

GLoBES – AEDL

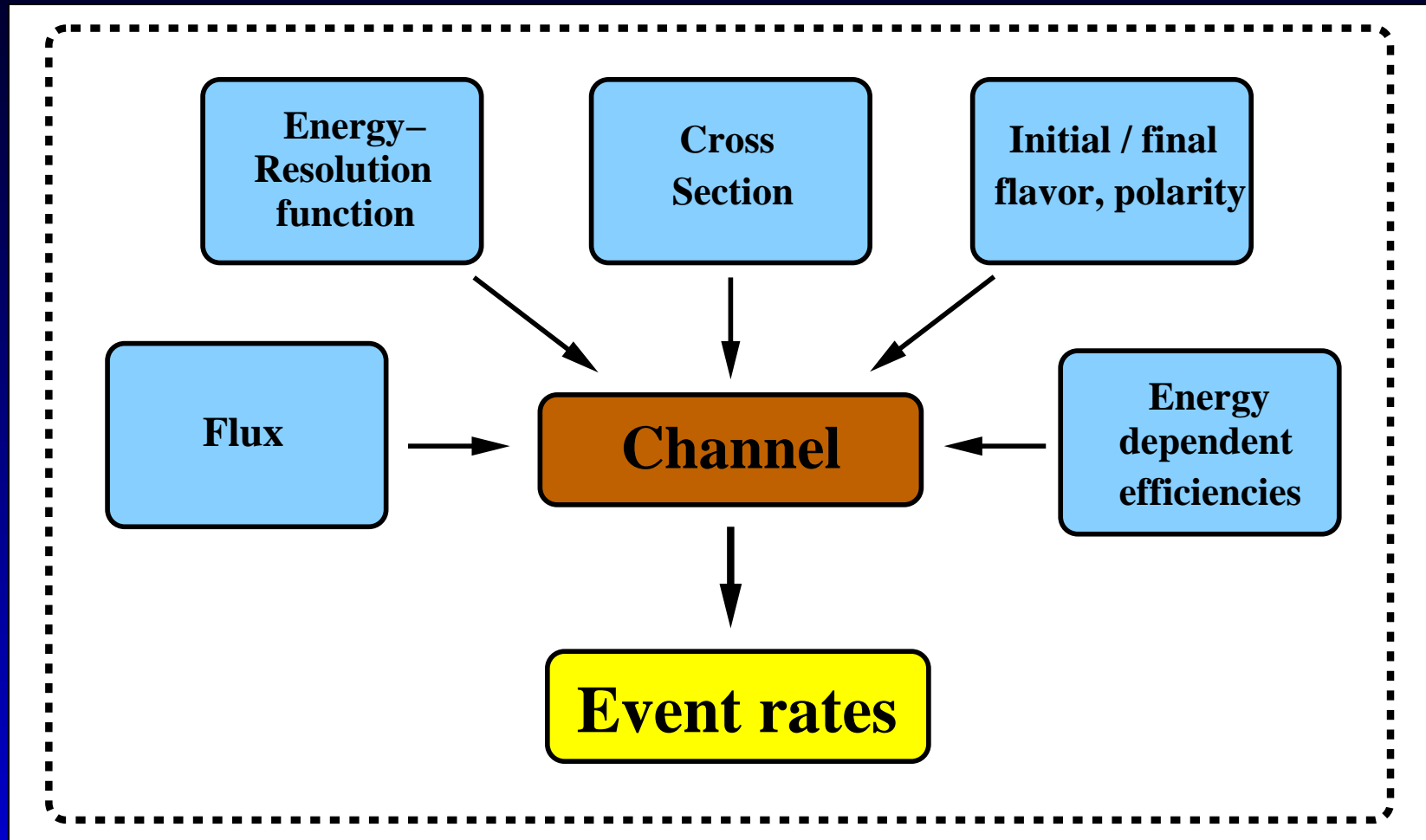


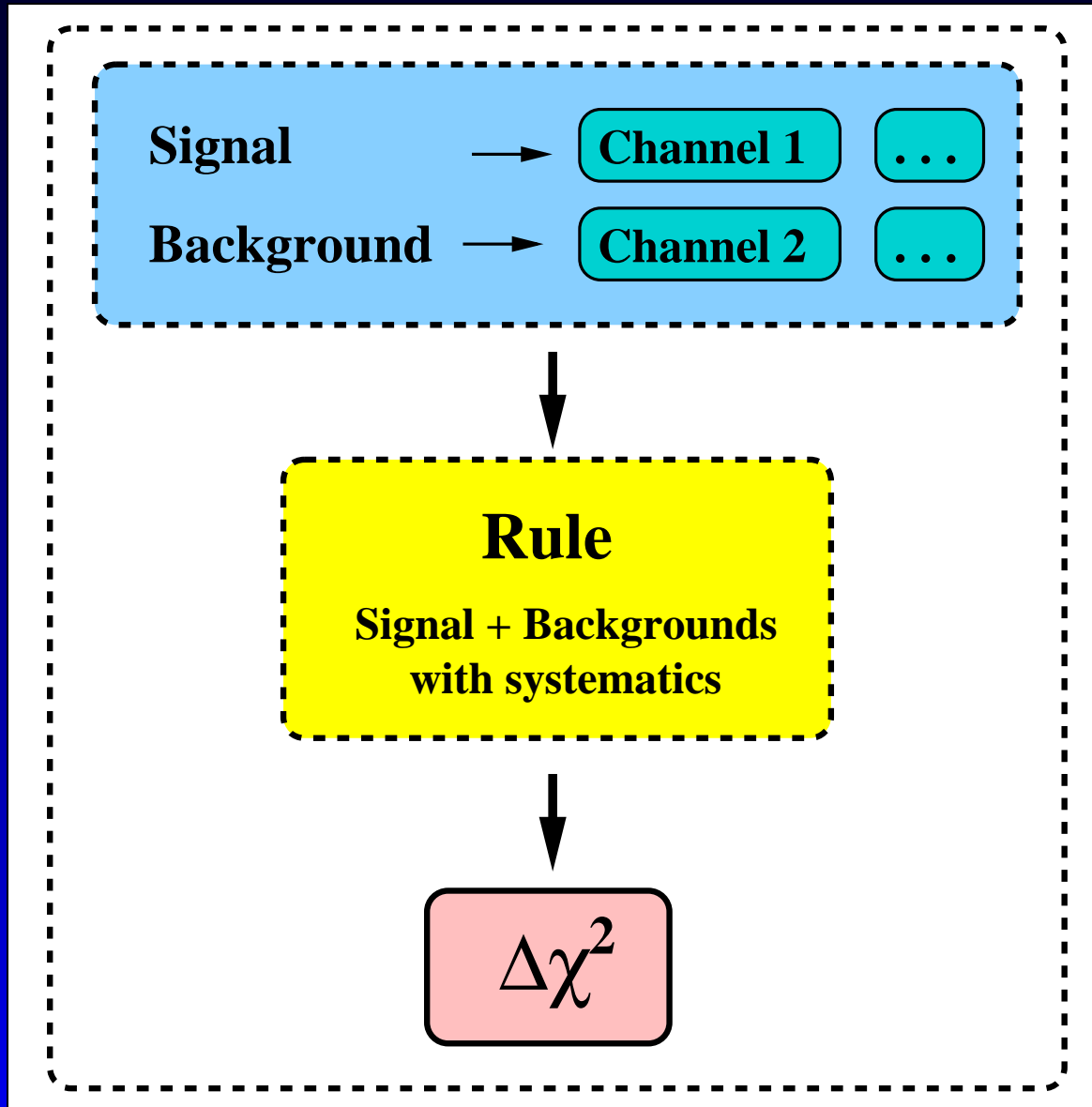
figure taken from PH, M. Lindner, W. Winter, Comput. Phys. Commun. **167** (2005) 195

GLoBES – AEDL

Neutrino factory example

```
channel(#mu_minus_appearance)<  
  @channel = #mu_plus: +: e: m: #CC: #sm0  
  @post_smearing_efficiencies = {0.07, 0.21, 0.35, 0.50, 0.65, 0.80,  
    0.93, 1, 1,1, 1, 1, 1, 1,1, 1, 1, 1, 1, 1}  
>
```

GLoBES – AEDL



GLOBES – AEDL

Neutrino factory example

```
rule(#wrong_sign_muons_1)<

    @signal = 0.45@#mu_minus_appearance
    @signalerror = 0.001 : 0.0001

    @background = 1@#mu_plus_disappearance
    @backgrounderror = 2e-06 : 0.0001
    @backgroundcenter = 1e-05 : 0

    @errordim_sys_on = 0
    @errordim_sys_off = 2
    @energy_window = 4 : 50
```

>

GLoBES – AEDL

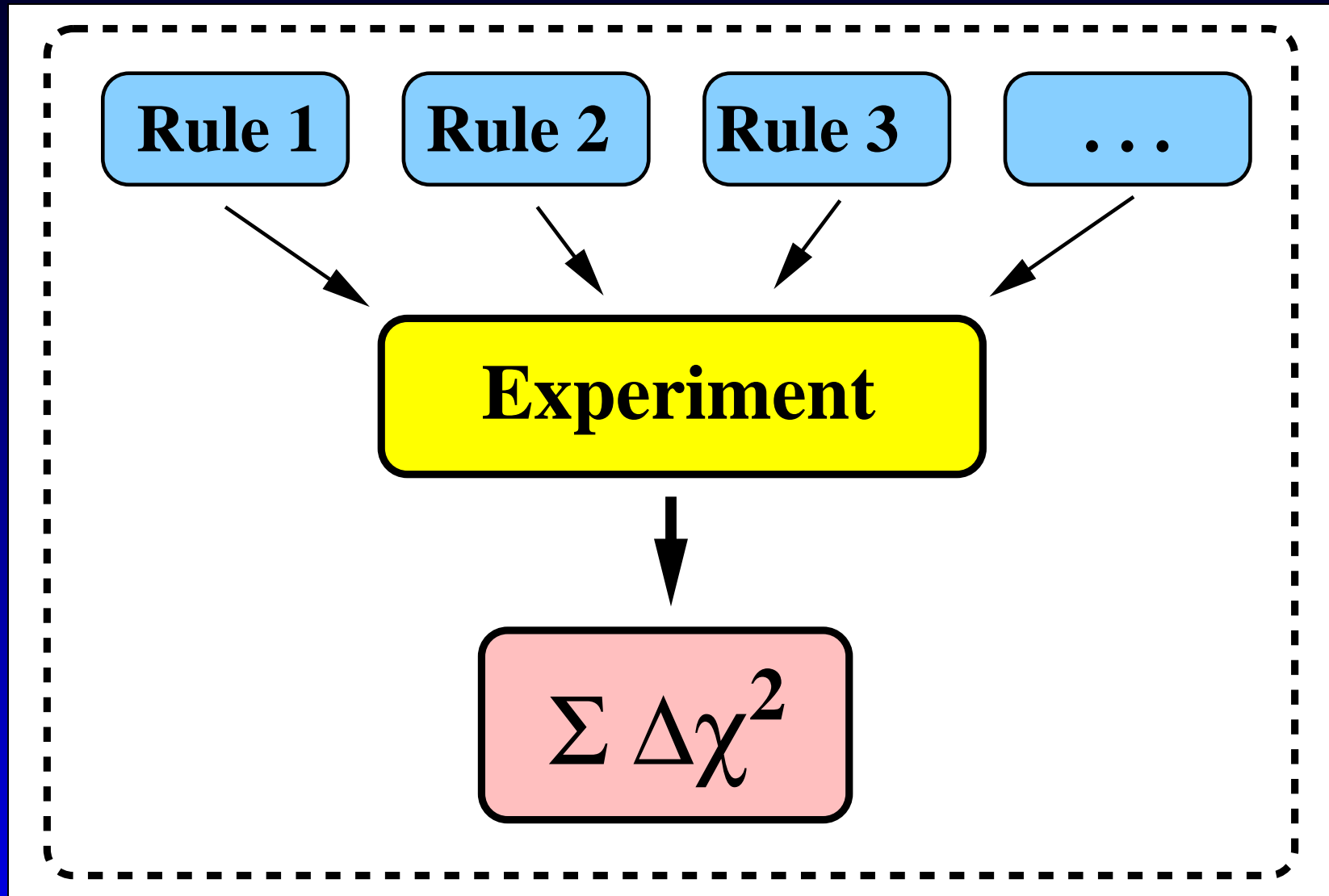


figure taken from PH, M. Lindner, W. Winter, Comput. Phys. Commun. **167** (2005) 195

Summary

GLOBES is a

- a well tested
- powerful
- flexible

software package for the

- Simulation
- Analysis
- Comparison

of neutrino oscillation experiments