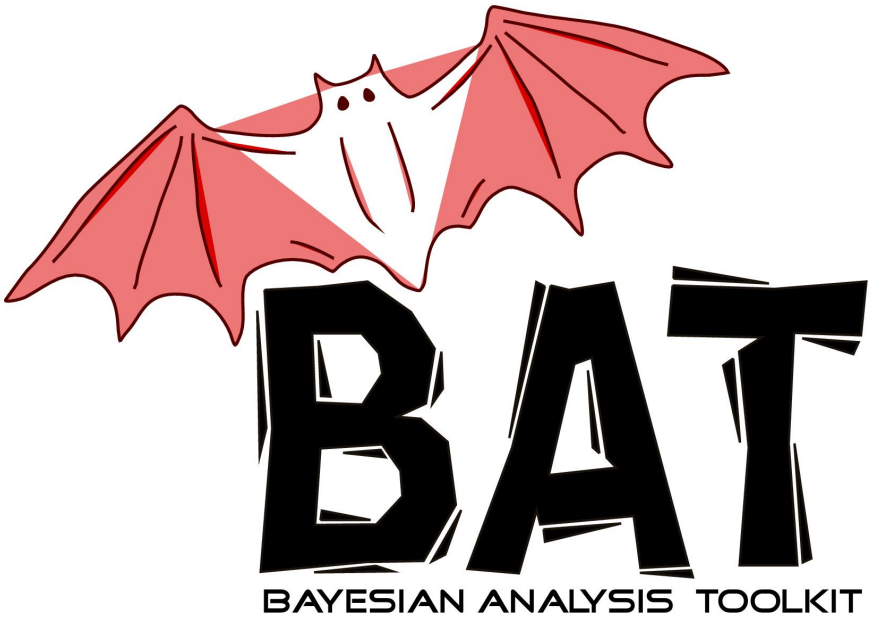

mpp.mpg.de/bat

Introduction to BAT

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Bayes theorem

Logical reasoning with uncertainties = probability theory

What is the probability that

- the SM is right? Or SUSY?
- the Higgs has a mass of 125 GeV?

$$P_1(\vec{\lambda}\,|\,\vec{D},M) = \frac{P(\vec{D}\,|\,\vec{\lambda},M)\,P_0(\vec{\lambda}\,|\,M)}{\int P(\vec{D}\,|\,\vec{\lambda},M)\,P_0(\vec{\lambda}\,|\,M)\,d\vec{\lambda}}$$

posterior ~ likelihood x prior

Key idea: draw random numbers from posterior

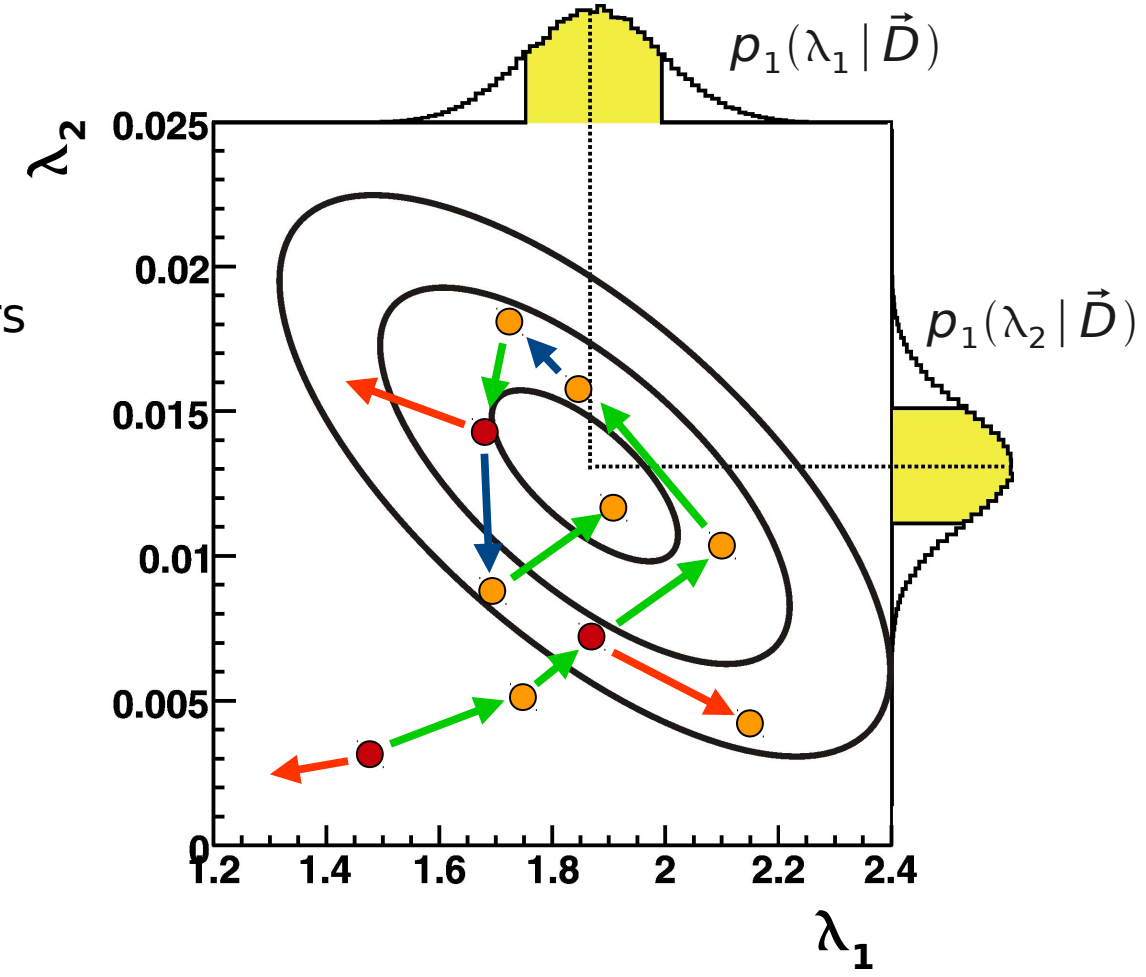
- In BAT use **Markov Chain Monte Carlo (MCMC)**

$$\vec{\lambda} \sim p_1(\vec{\lambda} \mid \vec{D}) = \frac{p(\vec{D} \mid \vec{\lambda})\, p_0(\vec{\lambda})}{\int p(\vec{D} \mid \vec{\lambda})\, p_0(\vec{\lambda})\, d\vec{\lambda}}$$

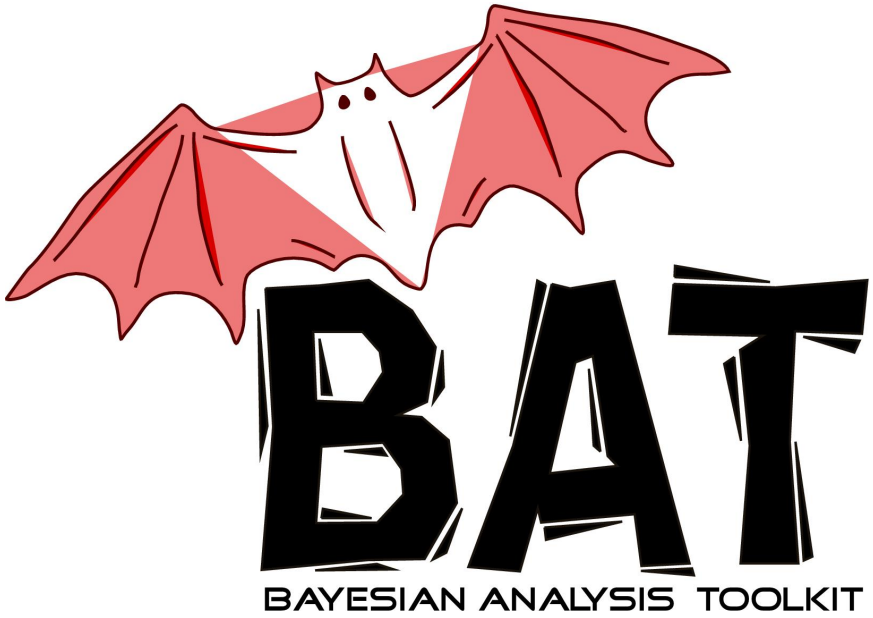
- Marginalize wrt. individual parameters while walking → obtain

$$p_1(\lambda_i \mid \vec{D}) = \int p(\vec{D} \mid \vec{\lambda})\, p_0(\vec{\lambda})\, d\vec{\lambda}_{j \neq i}$$

- Find maximum: “best” parameters
- Uncertainty propagation: distribution of $f(\vec{\lambda})$



Bayesian Analysis Toolkit



http://mpp.mpg.de/bat
Fork me on https://github.com/bat/bat
Comp. Phys. Comm. 180 (2009) 2197-2209
70 citations, ~100 downloads/month

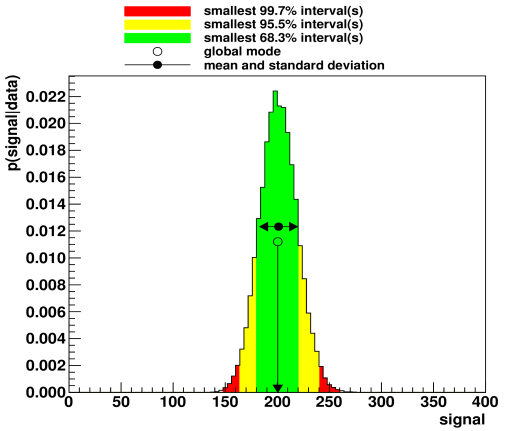
Motivation:

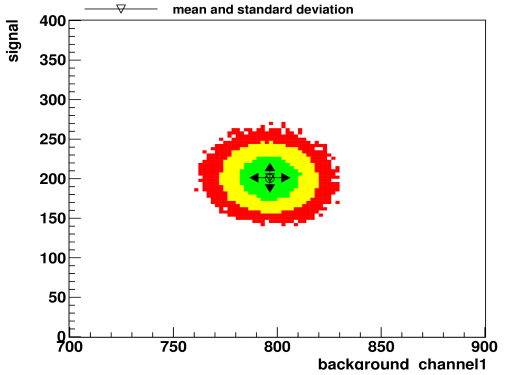
- Bayes' theorem simple on paper, but numerics hard
- Implementing standard algorithms by yourself a time waster, error prone
- toolkit (C++ library) helps user focus on problem
- uses ROOT, optional: used by roostats, interface to CUBA, Minuit
- Doc, tutorials, examples... on web page

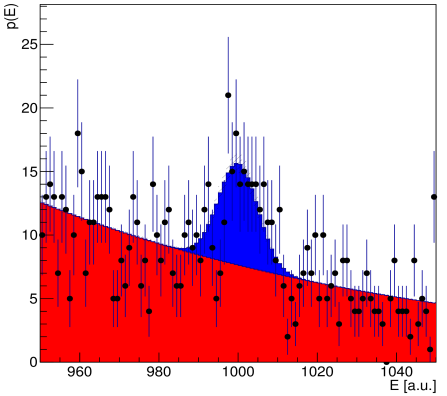
Example: template fit

- Code up P(D|λ), P0(λ) or...
- Use MultiTemplateFitter
- Signal/bkg. shape as histogram, events binned

```
// create new fitter object
BCMTF m("SingleChannelMTF");

m.AddChannel("channel1");

m.AddProcess("background", 200., 400.);
m.AddProcess("signal",       0., 200.);

m.SetData("channel1", hist_data);

// set template and histograms
m.SetTemplate("channel1", "signal",     hist_signal,     1.0);
m.SetTemplate("channel1", "background", hist_background, 1.0);

// set priors
m.SetPriorGauss("background", 300., 10.);
m.SetPriorConstant("signal");

// run MCMC, fills histograms
m.MarginalizeAll();

// use minuit or simulated annealing
m.FindMode( m.GetBestFitParameters() );

// graphical output
m.PrintAllMarginalized("marginalized.pdf");
m.PrintStack(0, m.GetBestFitParameters(), "stack.pdf")
```

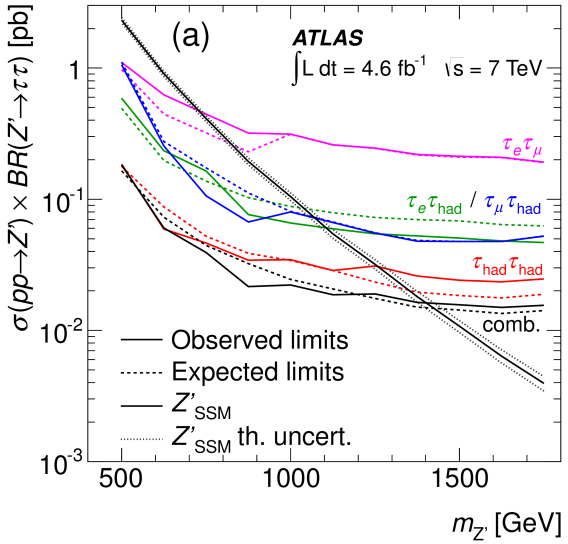






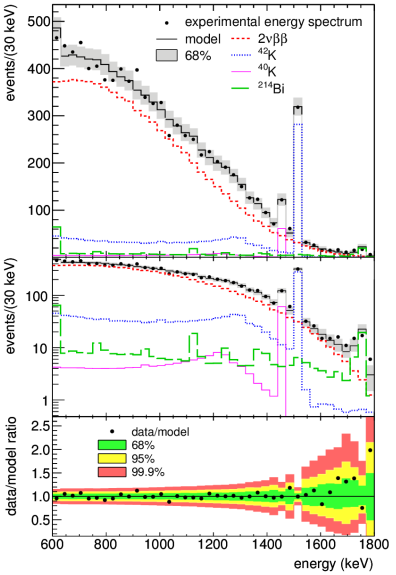
ATLAS: Z' search

Phys. Lett. B 719 (2013)



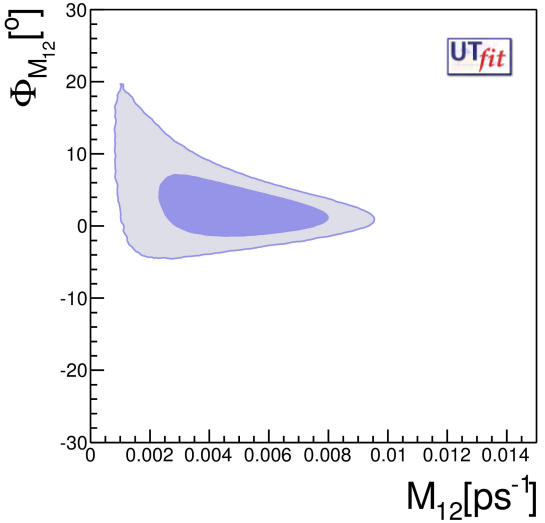
GERDA: double beta decay

J. Phys. G 40 (2013) 035110



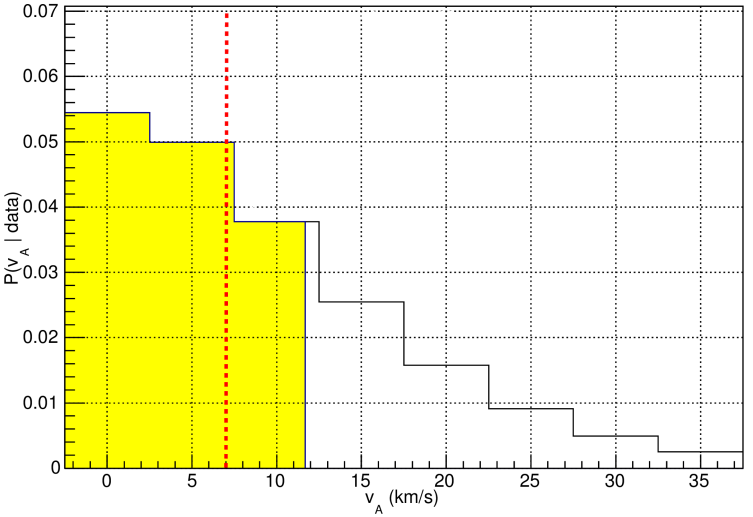
UTFIT: D meson mixing

arXiv:1402.1664



PAMELA: cosmic-ray proton spectrum

arXiv:1306.1354



Status and outlook

- Broader user base: contributions welcome https://github.com/bat/bat
- v0.9.3 released in Oct 2013: cleanup, multithreading, plots...
- v1.0 soon(?)
- V2.0: more sampling algorithms, run on clusters...

Developers welcome!