Bayesian sensitivity studies for CYGNO

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JAGS and PyJags

- For our study we used the general analysis framework python and the MCMC algorithm called *Gibbs Sampler* as implemented in JAGS and interfaced with python in the package pyjags.
- The Monte Carlo simulation gives the unnormalised posterior p.d.f. of the parameters of interest sampled using the *Gibbs* algorithm.

- JAGS 4.3 http://mcmc-jags.sourceforge.net
- PyJags https://pypi.org/project/pyjags/

Likelihood

$$\mathcal{L} = \mathcal{L}_C \times \mathcal{L}_B$$

$$\mathcal{L}_C = \prod_{i=1}^{N_{bin}} \frac{\lambda_i^{x_i}}{x_i!} e^{-\lambda_i}$$

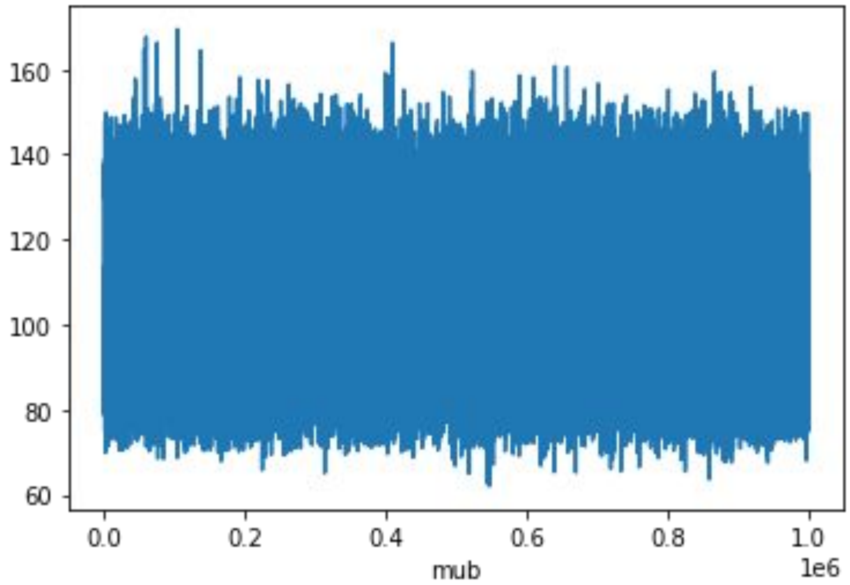
$$\lambda_i = E\left[\mu_S \sum_{j=\mathrm{He}}^{El} P_{S,j,i} P_j + \mu_B P_{B,i}\right]$$

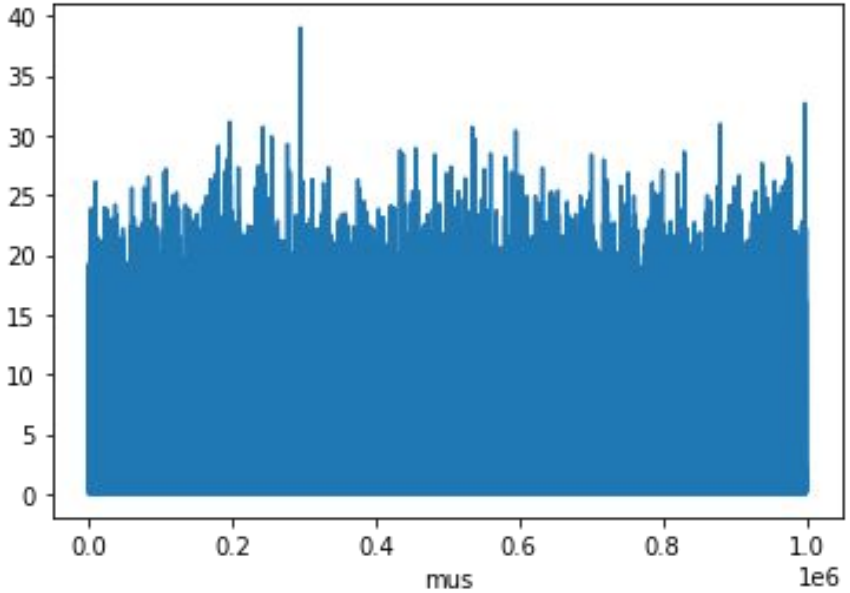
$$\mathcal{L}_B = \prod_{i=1}^{N_{bin}} \mathcal{N}\left(\mu_i = B_i, \sigma_i = \sigma_{B_i}\right)$$

Fit Inputs

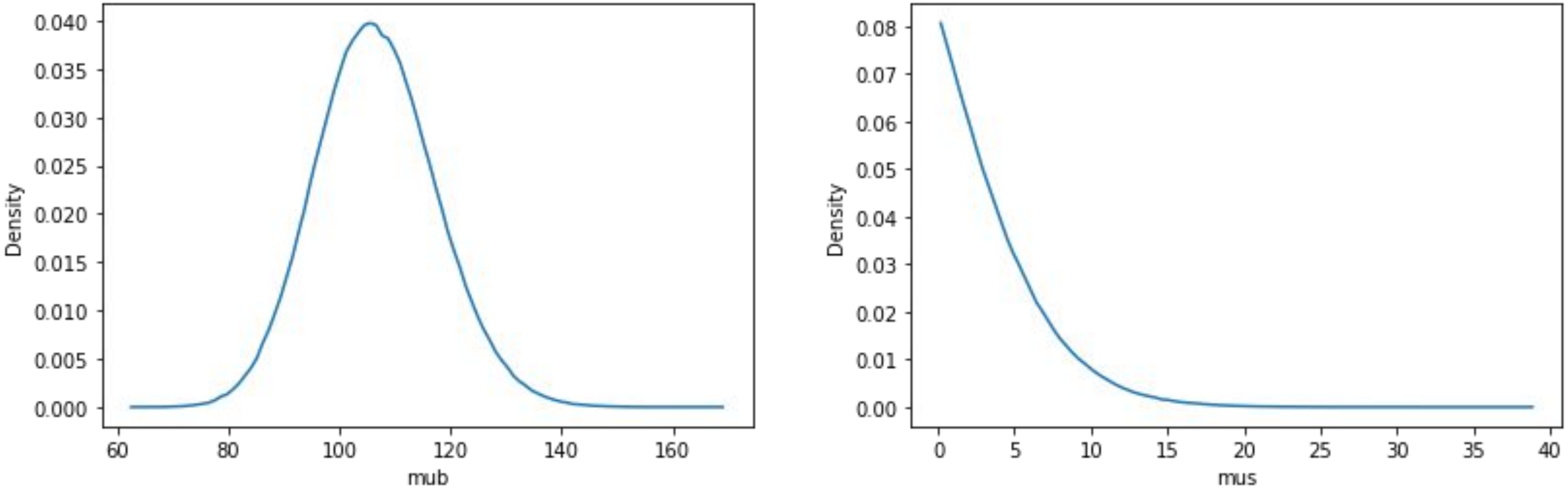
- Background templates.
  - Normalized to 1 event on the whole 2D spectrum
  - Assumptions:
    - 5% uncertainty on each bin [arbitrary]
- Pseudo dataset
  - Generated from the background templates assuming N_{evt}= 100
- Signal templates
  - Normalized to 1 event on the whole 2D spectrum
  - Computed for m_{χ}= {1, 10} GeV
- Prior choices
  - μ_B flat prior in the range [0,200] [arbitrary]
  - μ_S flat prior in the range [0,200] [arbitrary]

Fit results in terms of MCMC chain - m_χ = 1 GeV



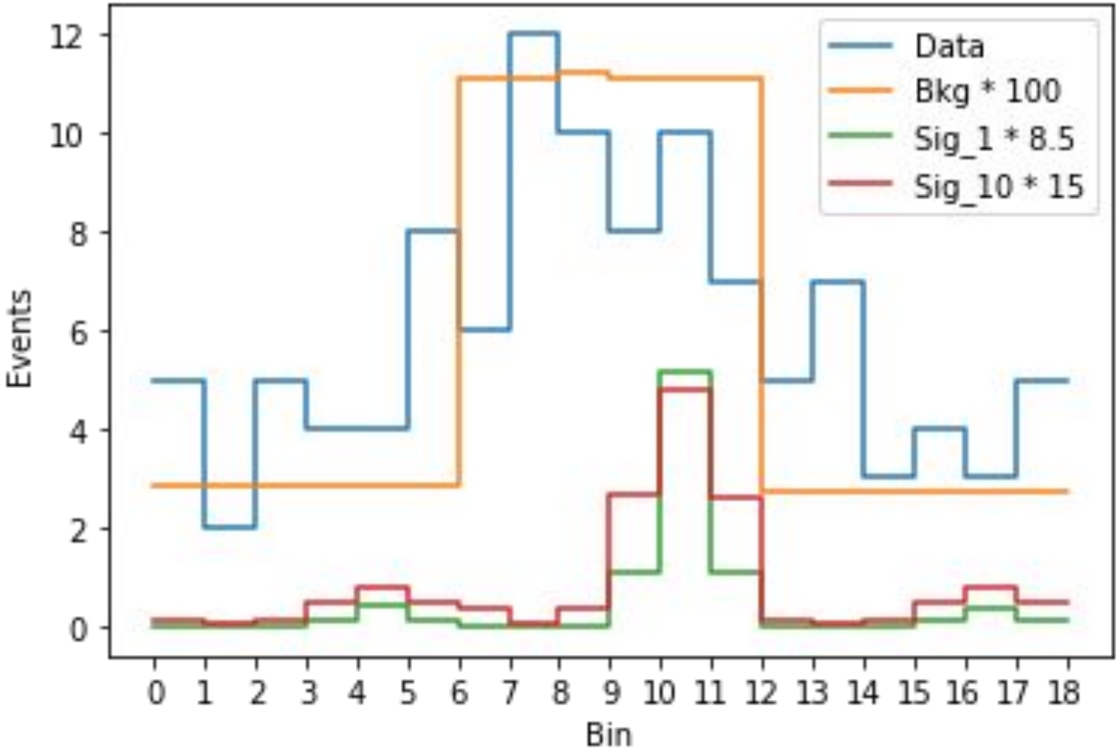


Fit results in terms of posterior pdf - $m_\chi = 1$ GeV



Fit results

- m_χ = 1 GeV
  - μ_S [90 % C.I.] = 8.5
  - μ_B = 107 ± 11
- m_χ = 10 GeV
  - μ_S [90 % C.I.] = 15
  - μ_B = 103 ± 12



Conclusions

- The bayesian analysis framework is being set up
- The computation tools used for the analysis are:
  - JAGS 4.3 http://mcmc-jags.sourceforge.net
  - pyjags https://pypi.org/project/pyjags/
- We developed a first simplified version of the likelihood
- We performed a preliminary fit on a pseudo dataset, obtaining, for an exposure corresponding to 100 events, an expected sensitivity of 8.5 events for a NR signal with m_χ = 1 GeV and 15 events for a NR signal with m_χ = 10 GeV. These results are reasonable because they are of the order of $\sqrt{N_{evt}} = 10$, and the remaining differences can be attributed to the different shapes of the two signal templates used in the analysis.