Modeling Smooth Backgrounds at Collider Experiments With Log Gaussian Cox Processes

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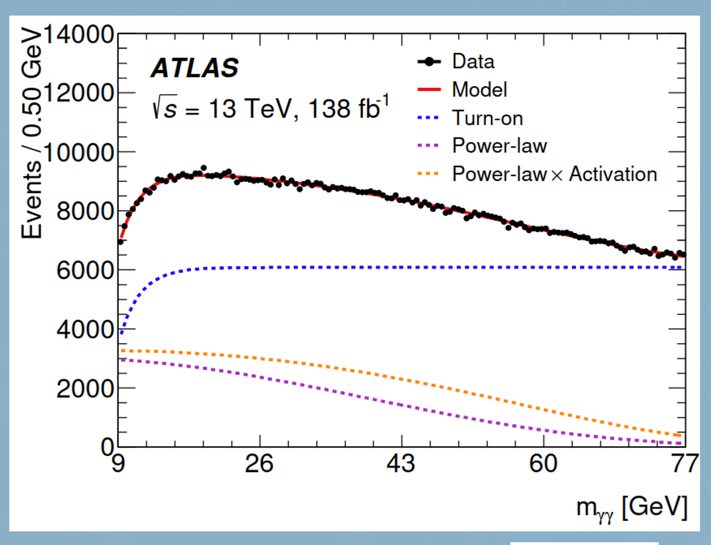
Motivation

- BKG modeling is a key element in New Physics searches
- Typical method: analytic function fitting – possibly inefficient and complicated
- LGCP is fast, automated, with 1D count data input



Very Low Mass Diphoton Search in ATLAS, requiring a complicated combination of functional forms

Log Gaussian Cox Process

- Assuming data drawn from non-homogeneous Poisson process, with log likelihood

$$\log p(X|\lambda) = \sum_{i=1}^{n} \log \lambda(x_i) - \int_{X_a}^{X_b} \lambda(x')dx'$$

- Assuming λ is a log gaussian process
- Bayes' law yields

$$p(\lambda|X, \Theta_{\mu,\Sigma}) = \frac{p(X|\lambda) \cdot p(\lambda|\Theta_{\mu,\Sigma})}{p(X|\Theta_{\mu,\Sigma})}$$

- GP set with mean 0 vector and RBF kernel - two hyper parameters

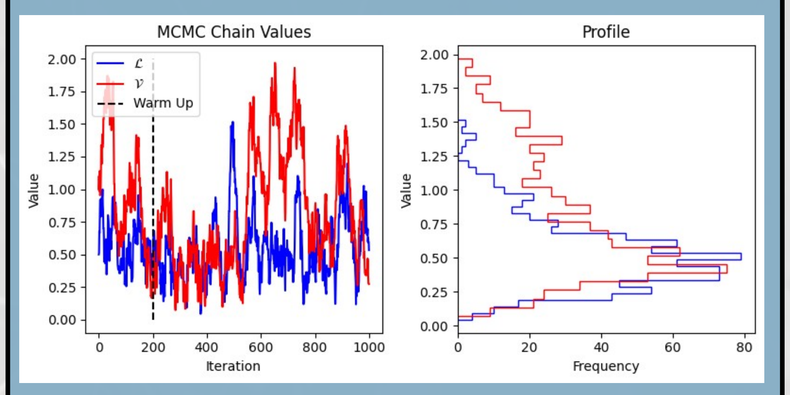
$$\mathcal{K}(x - x') = \mathcal{V} \cdot \exp^{-\frac{(x-x')^2}{2\mathcal{L}^2}}$$

- Marginal likelihood estimated with Monte Carlo integration
- Comparison to Maximum Log Likelihood Estimation (MLE) method
- Samples generation and MLE fit using

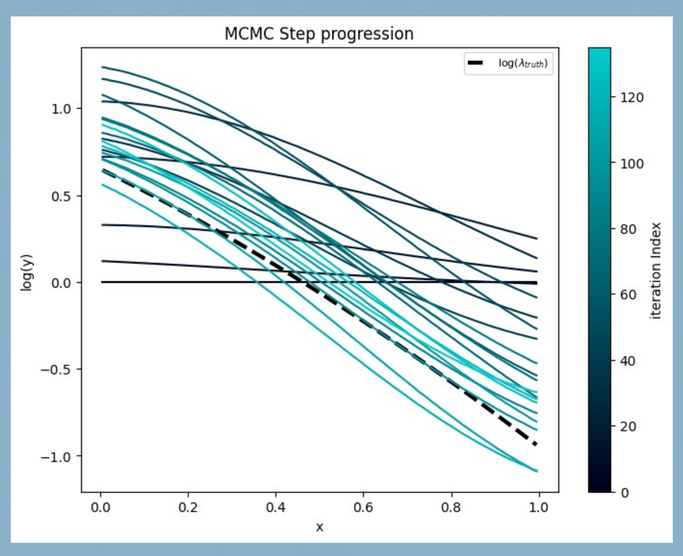
$$F(x|a, b) = \exp^{-\frac{(1+x)^a}{x+b}}$$

Markov Chain Monte Carlo Fits

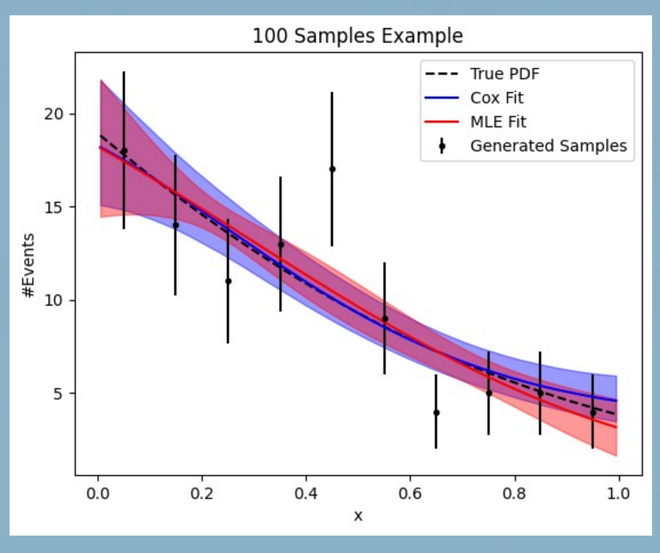
- Markov Chain Monte Carlo estimates non-normalized probability distributions
- A 2D MCMC for the marginal likelihood estimates the hyper-parameters

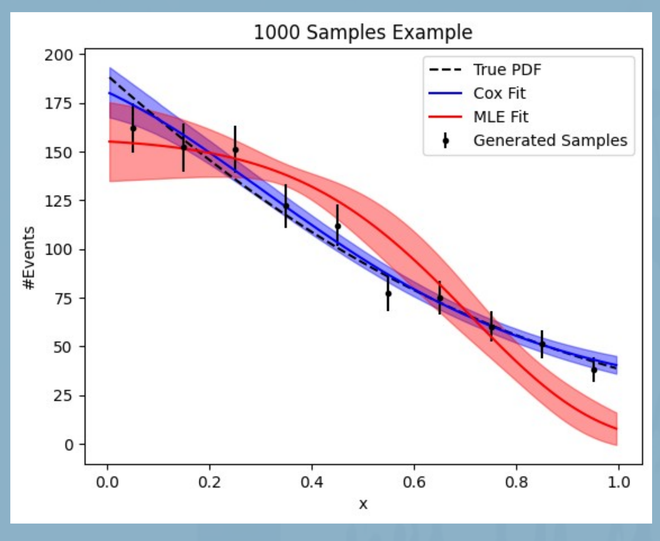


- the optimized hyper-parameters are defining the multivariate normal used for the posterior MCMC



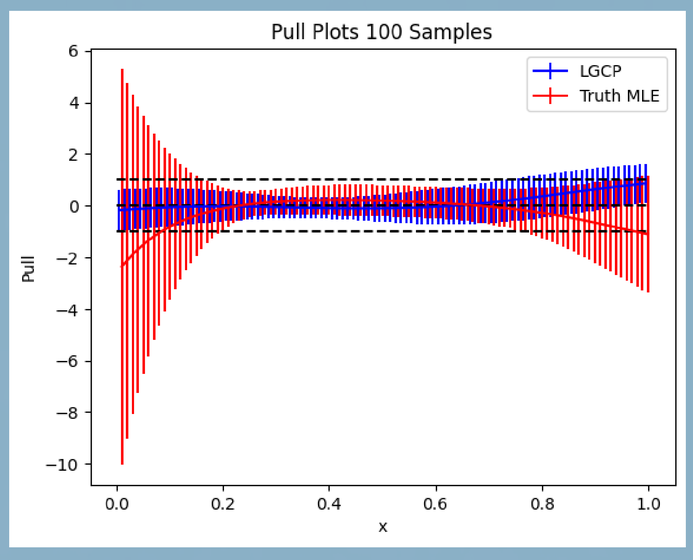
- The 16,50 and 84 percentiles of the chain defines the fit and 1 σ uncertainty band

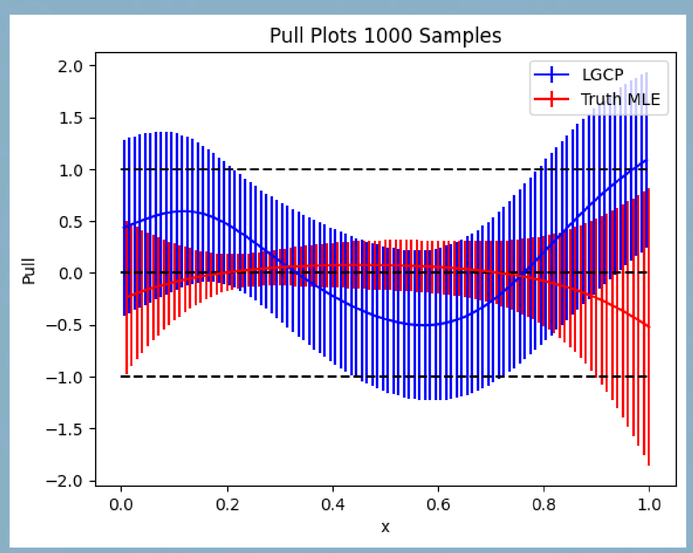


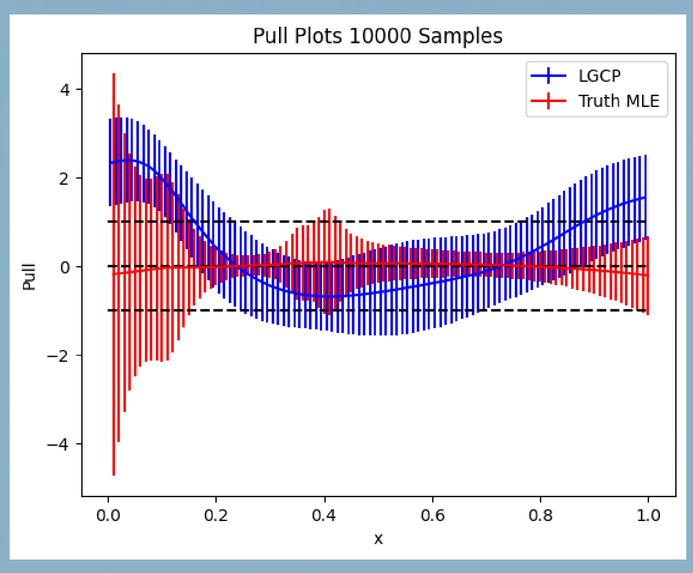


Results

- Pull plots with 1000 seeds comparison for LGCP and MLE reference
- Ideally mean at 0, uncertainty [-1,1]







Future Steps

- Further uncertainty estimations
- Spurious Signal and Injection Test studies
- Test feasibility for smoothing
- Implementing in very low statistics analyses, like the ditau diphoton

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