Supersymmetric Dark Matter: Prospects for LHC Run 2

(WORK IN PROGRESS, NO RESULTS YET)

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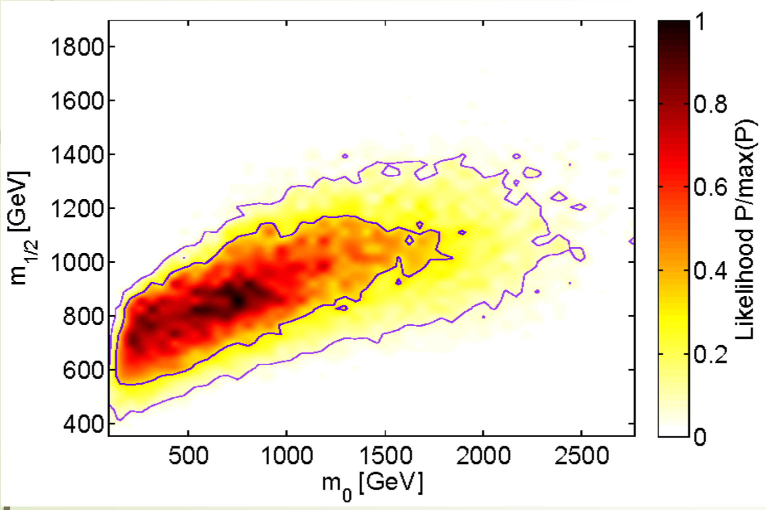
From Higgs to Dark Matter, Geilo 15.12.2014

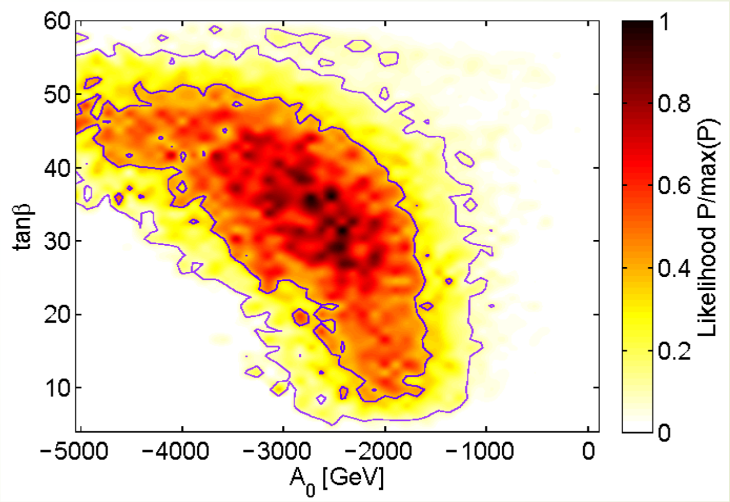
Introduction

- ATLAS effort to apply multiple existing analysis to DM compatible regions of pMSSM aiming for summary paper for Run 1 based on paper by Rizzo et. al (See talk by Lillian Smestad)
- We aim at implementing similar constraints to investigate pMSSM regions of interest for Run2
- Computationally hard problem:
  - High dimensionality (10x10 grid in 19D=1e19 models)
  - Event generation and NLO calculations are slow (hours single core)
- Proposed solution:
  - Efficient sampling technique: MCMC
  - Parallellize as much as possible and use supercomputer
  - Some sacrifise in accuracy

MCMC Based Scan: 4-parameter CMSSM

- Aim to apply an updated version of the MCMC scan developed for scanning cMSSM for experimentally viable τ-rich models to pMSSM19





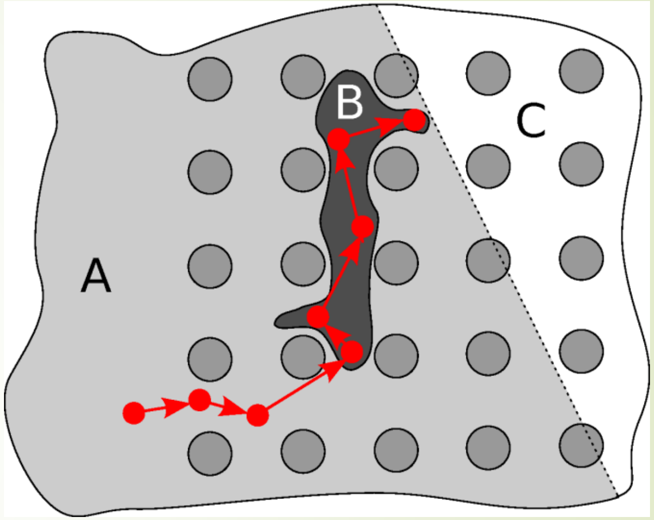
cMSSM likelihood maps from [ArXiv ePrint: 1210.7020]

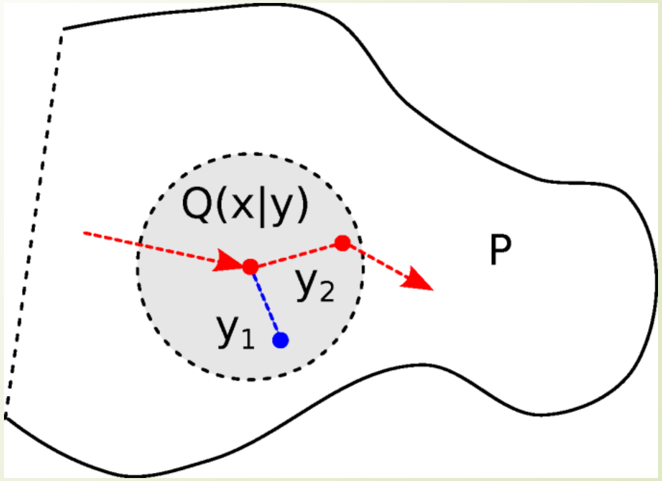
Basic idea

- Construct a distribution function (likelihood) P based on interest: Higher P -> more interesting
- Use Markov Chain Monte Carlo (MCMC) to efficiently map out the interesting regions
- For pMSSM scan we are interested:
  1. Fitting experimental constraints: DM, Higgs, LHC
  2. Possibility of discovery using ATLAS data

$$P = P_{exp} \cdot P_{obs}$$

- P should be as smooth as possible for efficient MCMC





Implementation: P_{exp}

- Construct experimental likelihood based on various experimental constraints

Constraints		**Distribution P_i (Undecided)**
Theory constraints (No tachyons, Correct EWSB)		Discrete
LEP mass limits, $\Delta\rho$, Invisible Z-width		Discrete, Gaussians
Branching fractions	$[Br(B_s \to \mu\mu), Br(b \to s + \gamma)]$	Gaussians
Higgs sector	$[m_{h0}, Br(H \to XX)]$	Gaussians
Dark Matter	$[\Omega h^2, \sigma_{\chi N}]$	Gaussian (one sided)
ATLAS 8 TeV	$[N_{obs}]$ (0l, 1τ,...)	Discrete/Poisson

Some important constraints

Implementation: P_{obs}

- P_{obs} based on probability of producing one or more observable SUSY events (sum over Poissonians)

$$P_{obs}(\mu_N) = \sum_{n=1}^{\infty} Poiss(n|\mu_N) \quad , \quad \mu_N = \epsilon_{obs}\sigma_{SUSY} \int \mathcal{L}dt$$

- Events are stored for analysis specific reweighing of likelihoods
- Same sample used for 14 TeV discovery and 8 TeV exclusion, by PDF reweighing

$$w_{14} = 1 \;\rightarrow w_{13/8} = \frac{PDF(Q^2, x_{13/8})}{PDF(Q^2, x_{14})}$$

Implementation: Tool chain

- For the likelihood calculation several publicly available packages are used, tools communicate through slha interface

Tool	**Output (Undecided)**
Softsusy 3.5.1	SUSY spectrum
Susyhit 1.4 (modified)	SUSY and Higgs decays
FeynHiggs 2.10/ Higgsbounds	Higgs sector
microMEGAS 3.5.5 (modified)	$\sigma_{\chi N}, \Omega h^2, Br(B_s \to \mu\mu), Br(b \to s + \gamma)$
Pythia 8 w. MG procs	σ_{LO}^{Susy}, Showered Events (jet clustering?)
Delphes/Prospino 2.1	Detector simulation and/or k-factors

Codes used, some of the tools have been modified with the help of Rizzo et. al

Implementation: MCMC algorithm Hybrid MPI-Multithread

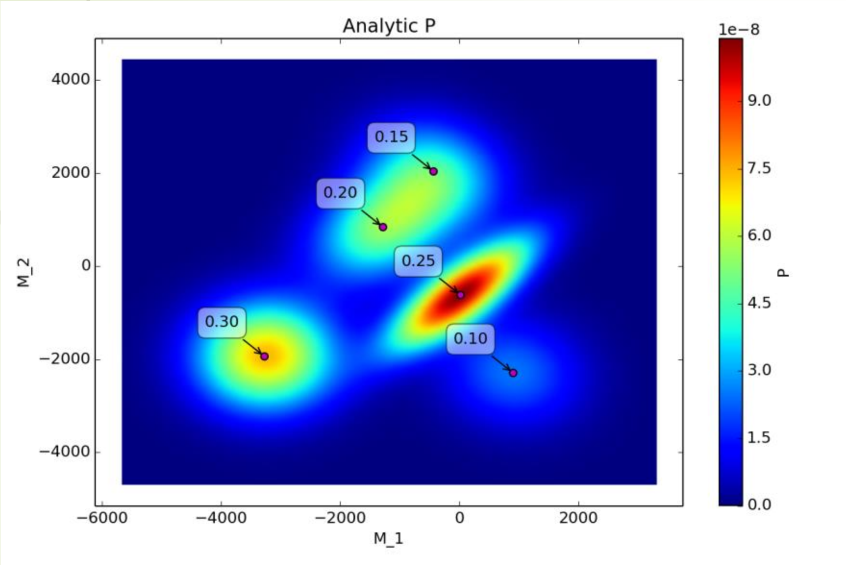
- Multichain MCMC algorithm with multimodal sampling distribution and adaptive stepsize

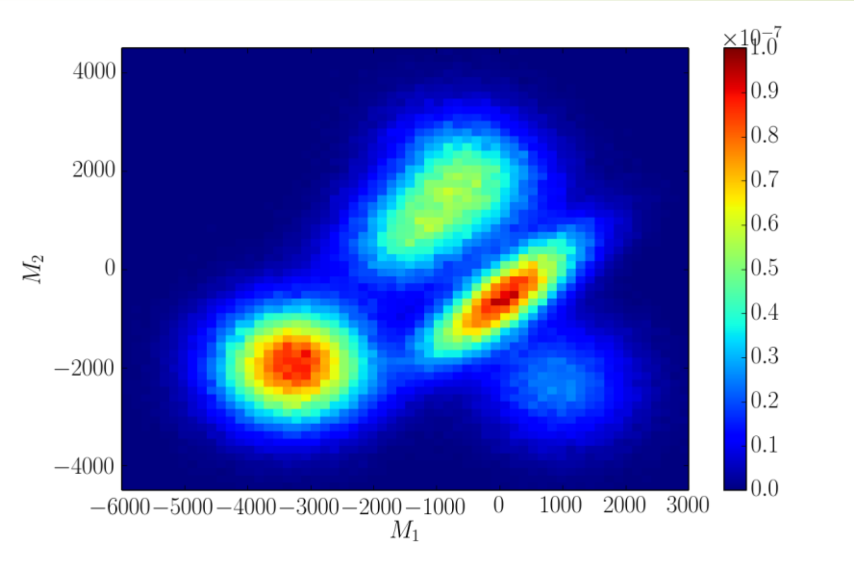
  → Convergance speed up for multimodal distributions
- Sampling distribution is constructed by clustering an initial sample of models.
- Each chain with multithreaded event generation and hierarchical likelihood evaluation

  → Model calculation speed up
- Implementation on supercomputer Hexagon (Ongoing):
  - Cray XE6, 205 Tflops peak performance
  - 696 nodes, 22272 2.3GHz cores in total

Current Status

- Validation of algorithm using test distributions and benchmarking





Test using 19D gaussian mixture model (without reclustering)

Current Status

- Validation of physics calculations against ATLAS pMSSM sample
- MCMC code has been rewritten for MPI and multithreading
- Optimization ongoing, currently ~ 4 min per point (12 cores per chain, LO Pythia+Delphes, wo. ATLAS analysis)
- 10^6 points with 100 chains (1200 cpus) with optimal scaling:

  t~1 month , cpuhours $\sim 10^6$
- Considering swapping Delphes for multithreaded NLO calculations
- Hopes to have Hexagon run started early 2015

Back Up

pMSSM Scan: Proposal Distribution

- Start with crude random scan to locate high likelihood regions with $P > P_{min}$
- Construct an approximation $Q_G(y)$ to the underlying distribution $P(y)$ using a weighted Gaussian mixture

$$Q_G(y) = \sum_i \omega_i \mathcal{N}_i$$

- Let the full proposal $\mathrm{Q}(y|x)$ be a combination of a local Gaussian term with mean x, $Q_L(y|x)$, and the Gaussian mixture $Q_G(y)$ given by the

$$\mathrm{Q}(y|x) = \beta Q_L(y|x) + Q_G(y)$$

- $Q_L(y|x)$ is taken to have covariance proportional to that of the closest gaussian in the mixture and is addapted to give a local acceptance rate $r_{acc} \sim 0.1$