A bottom-up reconstruction of new physics at Large Hadron Collider

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at

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The Standard Model

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$\Rightarrow$ These particle must be build of something else.

The quark model

The matter particles were divide in two groups:

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Quarks carry color quantum number and fractional electric charges. (bottom-up)

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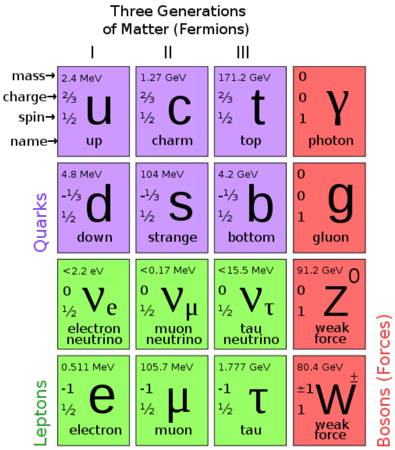

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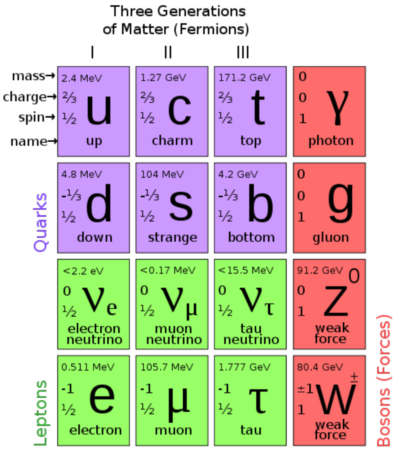

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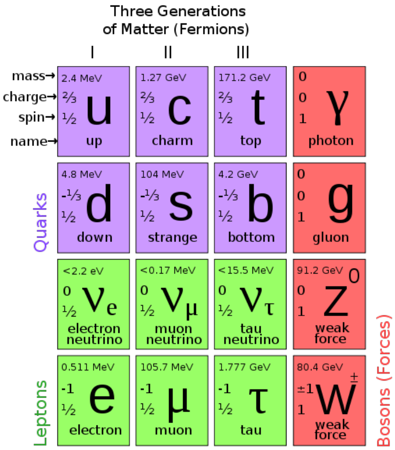

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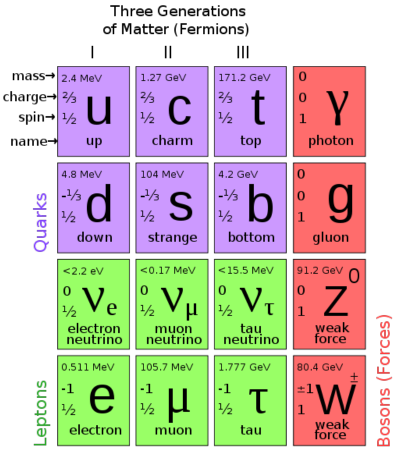

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Leads to masses of the particles via spontaneous symmetry breaking.

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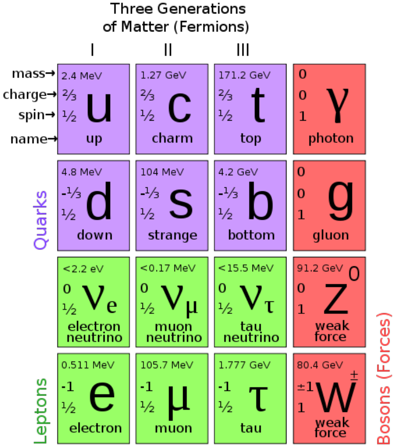

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Describes almost all observed phenomenon

Beyond the Standard Model

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Polarization observables and decay pattern are most important features to study new particles.

New physics with top quark

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We have a clean looking glass for new physics.

Anomalous top decay

JHEP **0612**, 021 (2006), [hep-ph/0605100]

Anomalous tbW vertex :

$$\Gamma^\mu = \frac{g}{\sqrt{2}} \left[\gamma^\mu (f_{1L} P_L + f_{1R} P_R) - \frac{i\sigma^{\mu\nu}}{m_W} (p_t - p_b)_\nu \, (f_{2L} P_L + f_{2R} P_R)\right]$$

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$$\frac{1}{\Gamma_t} \frac{d\Gamma_t}{d\cos\theta_f} = \frac{1}{2}\left(1 + \alpha_f \ P_t \ \cos\theta_f\right)$$

$$\alpha_l = 1 - \mathcal{O}(f_i^2)$$

$$\alpha_b = -\left[\frac{m_t^2 - 2m_W^2}{m_t^2 + 2m_W^2}\right] + \Re(f_{2R})\left[\frac{8m_t m_W (m_t^2 - m_W^2)}{(m_t^2 + 2m_W^2)^2}\right] + \mathcal{O}\left(\frac{m_b}{m_W}, f_i^2\right)$$

Lepton distribution

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$$AB \longrightarrow t \; P_1 \; \dots \; P_{n-1}$$

$$t \longrightarrow b \; W^+$$

$$W^+ \longrightarrow l^+ \, \nu$$

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Lepton distribution is independent of anomalous tbW coupling if

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JHEP **0612**, 021 (2006), [hep-ph/0605100]

$$AB \longrightarrow t \;\; P_1 \; \ldots \; P_{n-1}$$
$$t \longrightarrow b \;\; W^+$$
$$W^+ \longrightarrow l^+ \, \nu$$

Lepton distribution is independent of anomalous tbW coupling if

- t-quark is on-shell; narrow-width approximation for t-quark,

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- $t \to bW(\ell\nu_\ell)$ is the only decay channel for t-quark.

$\Rightarrow$ **Lepton distribution from top decay is pure probe of possible new physics in the top production process.**

Polarization or t-quark: top-down

JHEP **0612**, 021 (2006), [hep-ph/0605100]

Polarized cross-sections

$$\sigma(\lambda,\lambda') = \int \frac{d^3p_t}{2E_t(2\pi)^3}\left(\prod_{i=1}^{n-1}\frac{d^3p_i}{2E_i(2\pi)^3}\right)\frac{(2\pi)^4}{2I}\delta^4\left(k_A+k_B-p_t-\left(\sum_{i=1}^{n-1}p_i\right)\right)\rho(\lambda,\lambda')$$

where $\rho(\lambda,\lambda') = \mathcal{M}(\lambda,\ldots)\,\mathcal{M}^*(\lambda',\ldots)$

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Total cross-section: $\sigma_{tot} = \sigma(+,+) + \sigma(-,-)$

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Polarization density matrix :

$$P_t = \frac{1}{2}\begin{pmatrix} 1+\eta_3 & \eta_1 - i\eta_2 \\ \eta_1 + i\eta_2 & 1-\eta_3 \end{pmatrix},$$

$$\eta_3 = (\sigma(+,+) - \sigma(-,-))\,/\sigma_{tot}$$
$$\eta_1 = (\sigma(+,-) + \sigma(-,+))\,/\sigma_{tot}$$
$$i\ \eta_2 = (\sigma(+,-) - \sigma(-,+))\,/\sigma_{tot}$$

Polarization or t-quark: bottom-up

JHEP **0612**, 021 (2006), [hep-ph/0605100]

Polarization of t-quark through decay asymmetries:

$$\alpha_b = -0.4$$

$$\alpha_l = +1.0$$

$$\alpha_f \, \frac{\eta_3}{2} = \frac{\sigma(p_f.s_3 < 0) - \sigma(p_f.s_3 > 0)}{\sigma(p_f.s_3 < 0) + \sigma(p_f.s_3 > 0)}$$

$$\alpha_f \, \frac{\eta_2}{2} = \frac{\sigma(p_f.s_2 < 0) - \sigma(p_f.s_2 > 0)}{\sigma(p_f.s_2 < 0) + \sigma(p_f.s_2 > 0)}$$

$$\alpha_f \, \frac{\eta_1}{2} = \frac{\sigma(p_f.s_1 < 0) - \sigma(p_f.s_1 > 0)}{\sigma(p_f.s_1 < 0) + \sigma(p_f.s_1 > 0)}$$

$$s_i.s_j = -\delta_{ij} \qquad p_t.s_i = 0$$

For $p_t^\mu = E_t(1, \beta_t \sin\theta_t, 0, \beta_t \cos\theta_t)$, we have

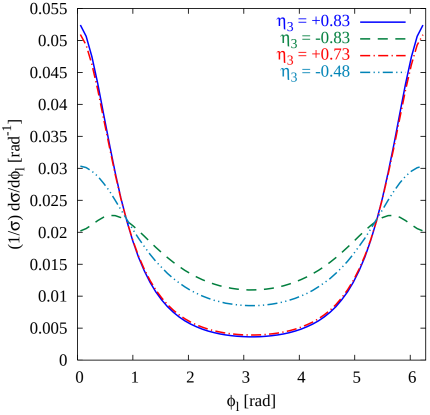
$$s_1^\mu = (0, -\cos\theta_t, 0, \sin\theta_t), \;\; s_2^\mu = (0, 0, 1, 0), \;\; s_3^\mu = E_t(\beta_t, \sin\theta_t, 0, \cos\theta_t)/m_t.$$

`Ptlong` is implemented in `SHERPA`.

Lepton's azimuthal distribution

JHEP **0612**, 021 (2006), [hep-ph/0605100]

Lab frame azimuthal distribution of leptons:



$$A_\ell = \frac{\sigma(\cos\phi_l > 0) - \sigma(\cos\phi_l < 0)}{\sigma(\cos\phi_l > 0) + \sigma(\cos\phi_l < 0)}$$

Used for:

- Z' at LHC (Les Houches 05)
- $g^{(1)}$ in RS model at LHC (Nucl. Phys. **B797**, 1, (2008))

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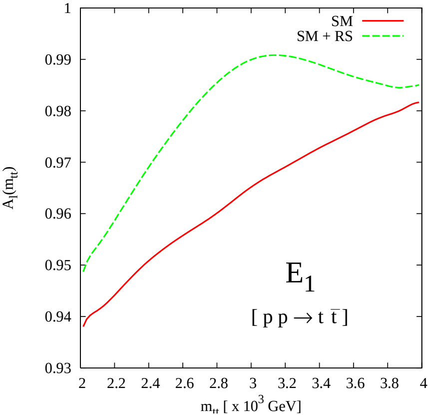

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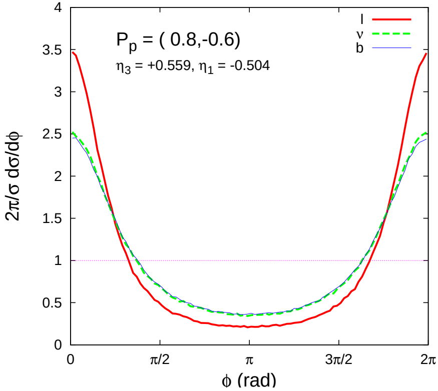
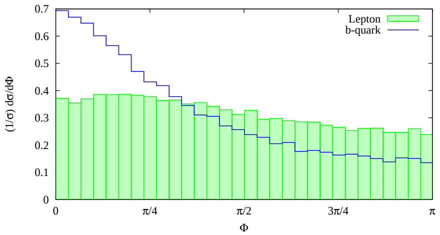


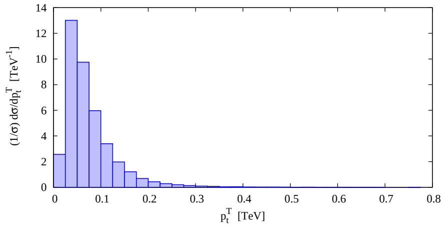
Distribution of all the decay particles.

Top polarization at LHC

Boudjema, Porod and RS: **Under progress**

$$pp \to tj \to bl^+\nu_l j$$





$$\Delta_{lb} = \frac{1}{\sigma}\left|\frac{d\sigma}{d\phi_l} - \frac{d\sigma}{d\phi_b}\right|$$

Depends upon:

- Top polarization
- p_t^T distribution

$\sigma = 131$ pb $\quad \eta_3 = -0.196$

$\Delta_{lb} = 0.35$

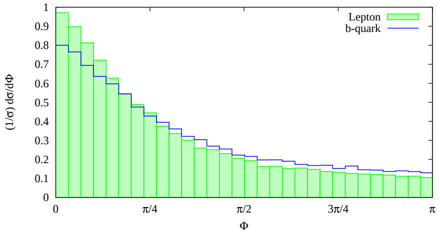
Cuts: No cuts

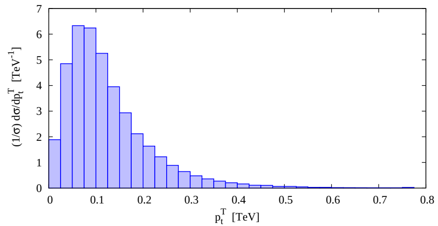
Model: SM

Top polarization at LHC

Boudjema, Porod and RS: **Under progress**

$$pp \to \tilde{t}_1 \bar{\tilde{t}}_1 \to t\chi_1^0 \bar{t}\chi_1^0$$





$$\Delta_{lb} = \frac{1}{\sigma} \left| \frac{d\sigma}{d\phi_l} - \frac{d\sigma}{d\phi_b} \right|$$

Depends upon:

- Top polarization
- p_t^T distribution

$\sigma = 1.44$ fb $\quad \eta_3 = +0.184$
$\Delta_{lb} = 0.12$

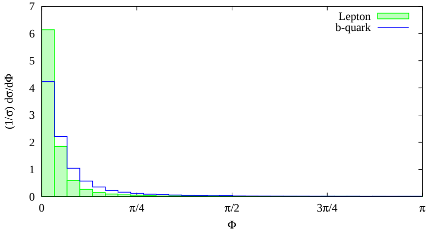
Cuts: No cuts

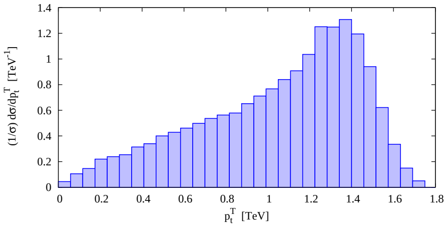
Model: MSSM
$M_{\tilde{t}_1} = 355$ GeV, $m_\chi = 164$ GeV $Br(\tilde{t}_1 \to t\tilde{\chi}_1^0) = 0.76$

Top polarization at LHC

Boudjema, Porod and RS: **Under progress**

$$pp \to t\bar{t} \to bl^+\nu_l \; \bar{b}l^-\bar{\nu}_l$$





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Depends upon:

- Top polarization
- p_t^T distribution

$\sigma = 3.36$ pb $\quad \eta_3 = +0.819$

$\Delta_{lb} = 0.40$

Cuts: $\quad m_{tt} \in [2.5, 3.5]$ TeV

Model: SM$+g^{(1)}$

$M_g = 3$TeV, $\Gamma_g = 500$ GeV

Search for Extra-dimensions

World with extra-dimesions

In models with extra space dimensions, the additional dimensions are compact.

Particle in a box

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0, (R^{-1}) GeV, $2(R^{-1})$ Gev, ...

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Several particles with same QN as in SM and large (R^{-1}) but near-degenerate mass.

Flat extra-dimensions and top quarks

Under progress

In the models of flat extra-dimensions, there is a KK-tower of excitations corresponding to each SM gauge bosons and fermions.

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All KK-excitations contribute to a resonance in $m_{t\bar{t}}$ distribution. The presence of Z and $Z^{(1)}$ is responsible for finite polarization of top quark.

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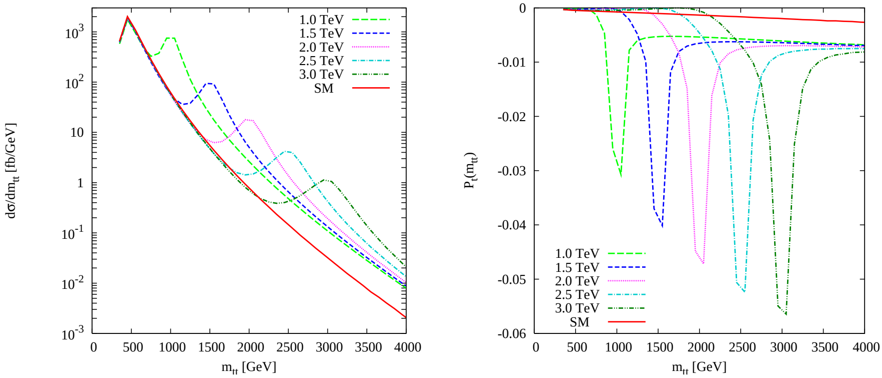


Flat extra-dimensions and top quarks

Under progress

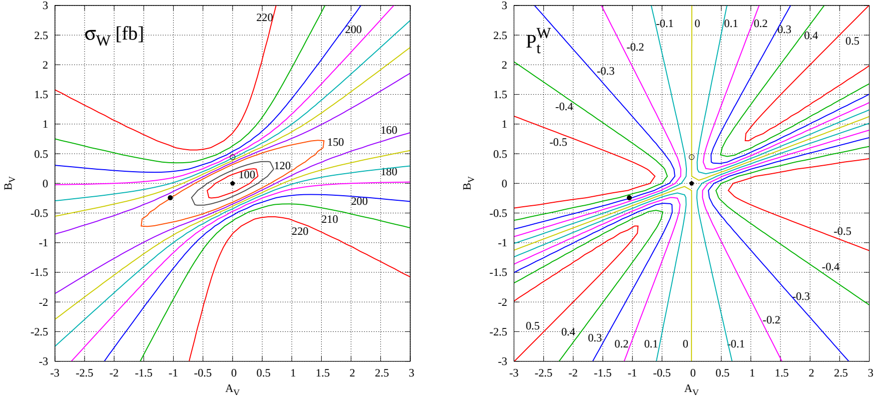
For $M_{KK} = 2$ TeV, and $|m_{t\bar{t}} - M_{KK}| < 50$ GeV,

Models	$\sigma(pp \to t\bar{t})$ (fb)	P_t
SM	77.9	-1.33×10^{-3}
$SM + \gamma^{(1)}$	185	-2.55×10^{-4}
$SM + Z^{(1)}$	150	-3.26×10^{-1}
$SM + g^{(1)}$	1700	-6.13×10^{-5}
$SM + V_{KK}$	1900	-5.78×10^{-2}

Flat extra-dimensions and top quarks

Under progress

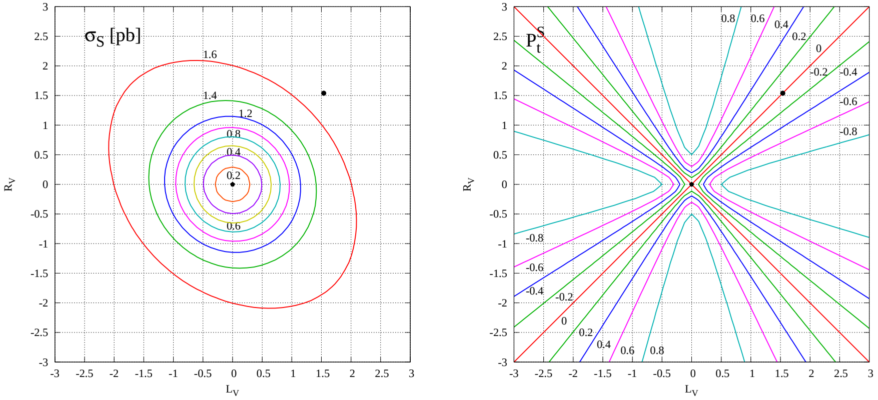
Weak resonance model, $f_i \bar{f}_i V := A_V \; T_3^{f_i} + B_V \; Q^{f_i} \; ; i = L, R$



Flat extra-dimensions and top quarks

Under progress

Strong resonance model, $f\bar{f}V := R_V\ P_L + L_V\ P_L$



Warped extra-dimension and top quark

Under progress

In universal wrapped extra dimension model, with fermion localization in the fifth dimensions, one has differing couplings of V_{KK}.

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For electro weak boson:

$$f_i \bar{f}_i V := \left(A_V \ T_3^{f_i} + B_V \ Q^{f_i} \right) Q_V(f_i) \ ; i = L, R$$

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- can be probed at LHC upto $M_{KK} = 3$ TeV through polarization.

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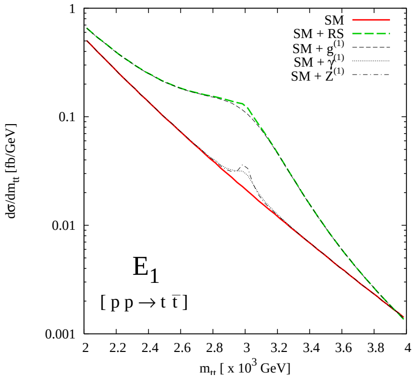

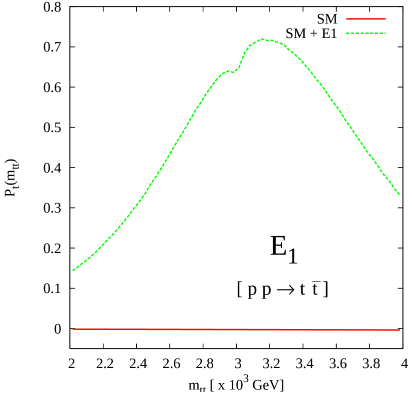

$$\Gamma_{g^{(1)}} = 627 \text{ GeV}, \ \Gamma_{Z^{(1)}} = 75 \text{ GeV}, \ \Gamma_{\gamma^{(1)}} = 137 \text{ GeV}$$

(Nucl. Phys. **B797**, 1, (2008))

Warped extra-dimension and top quark

Under progress

In the case of warped extra-dimension:

- there are too many free parameters for the fit.
- the "Weak resonance model" fails
- the "Strong resonance model" fits well with "wrong" values of the couplings.
- more observables are needed to establish the presence of extra-dimensions.

to conclude ....

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- Many of the models will have similar collider signature.
- We need a model-independent i.e. a bottom-up approach to the signatures to establish or rule out some models.

Beyond the conclusions....

- Spin measurement using azimuthal distribution (arXiv:0903.4705)
- Spin assesment in off-shell decays: A case of gluino (Under progress)
- Markov-Chain-Monte-Carlo analysis of MSSM-UG models (arXiv:0906.5048)
- MCMC analysis of CPV-MSSM and GHU-MSSM (Under progress)