Supersymmetry analysis with bRPV

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Outline

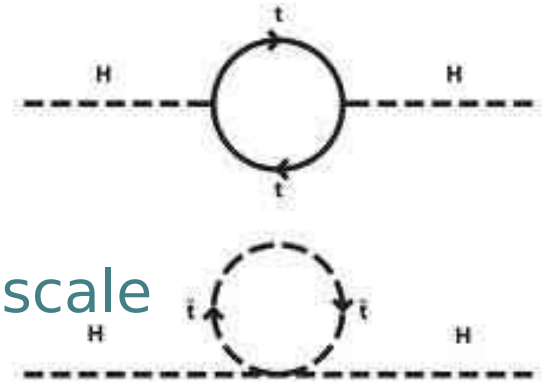
- Sneutrino LSP – resonant eμ production
- Displaced vertices
- Bilinear RPV (bRPV)

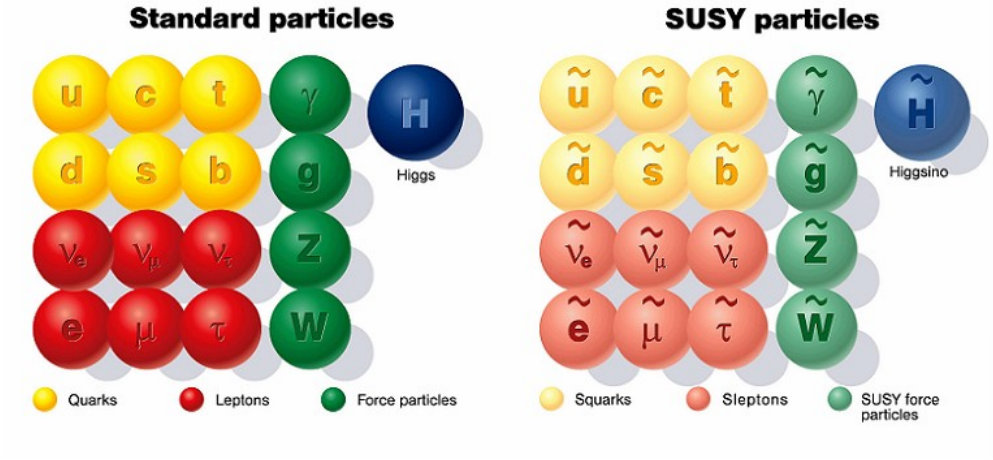
Supersymmetry

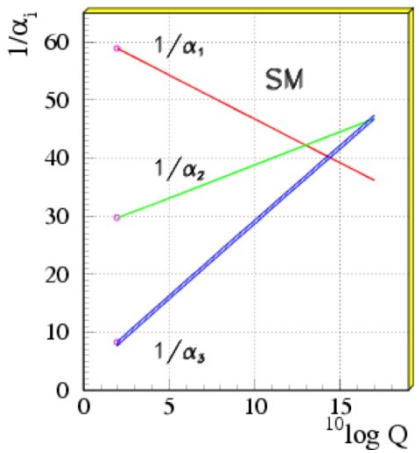
all SM particles have SUSY-partners with spin difference of ±1/2

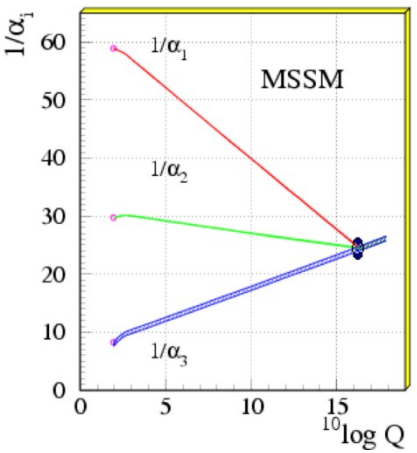
=>SUSY is an extension of the SM that try to solve it's problems

- Theoretical motivation
  - Higgs mass stabilisation against loop corrections (fine-tuning problem)
  - unification of gauge couplings at single scale
  - dark matter candidate: Lightest supersymmetric particle (LSP)









Theoretical models

- There is many SUSY models the Simplest is MinimalSupersymetricSM (MSSM) has > 100 new parameters

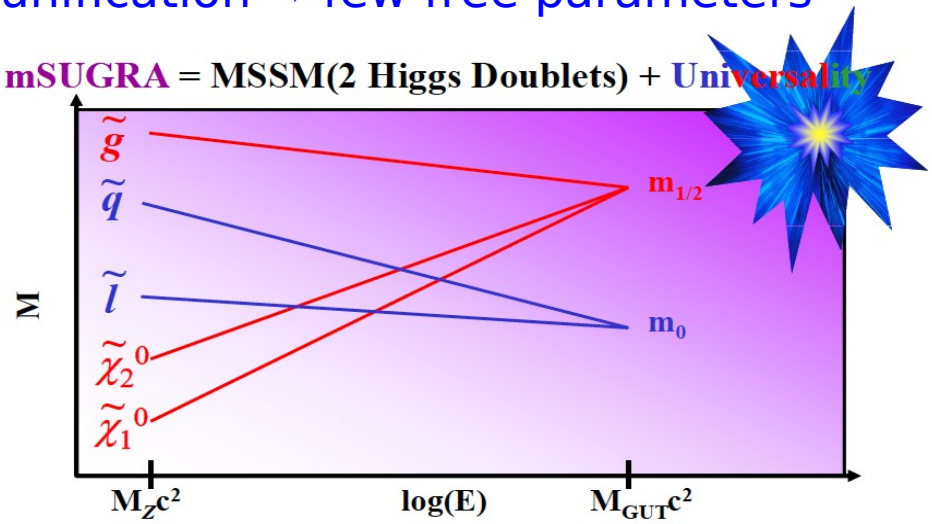
➞ different models

Gravity mediated (SUGRA)

Gauge mediated (GMSB)

…

GUT scale unification ➞ few free parameters



Searches for R-parity violating SUSY

R-parity violation (RPV)

- R-parity: $R = (-1)^{3(B-L)+2s} \rightarrow R = \begin{cases} +1, \text{ for SM particles} \\ -1, \text{ for superpartners} \end{cases}$

L-number violating terms

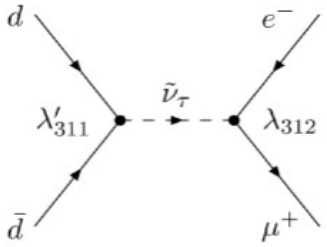
$$W_{\not R p} = \lambda_{ijk}\hat{L}_i\hat{L}_j\hat{E}^C_k + \lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k + \epsilon_i\hat{L}_i\hat{H}_u + \lambda''_{ijk}\hat{U}^C_i\hat{D}^C_j\hat{D}^C_k$$

bilinear terms

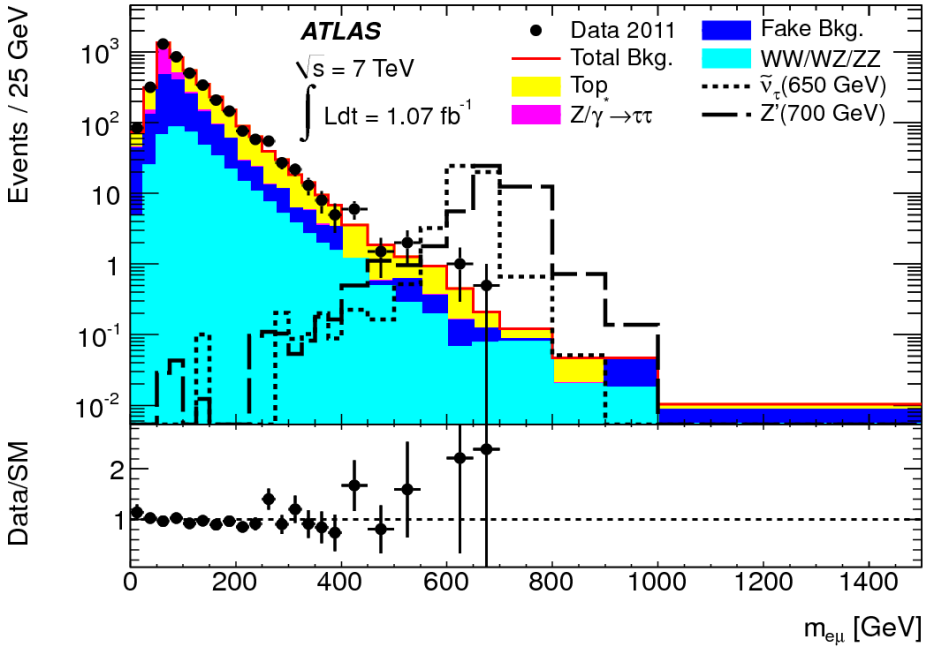
B-number violating terms

- R-parity conservation hinted but not required by proton stability

eμ resonance: analysis



- Search for an excess in high eμ invariant mass
- Clean signal: look for exactly one isolated **electron** and exactly one isolated **muon** with opposite charge and pT > 25 GeV
- Low SM background in the high meμ region



Process	Number of events
$t\bar{t}$	1580 ± 170
Jet fake	1180 ± 120
$Z/\gamma^* \rightarrow \tau\tau$	750 ± 60
WW	380 ± 31
Single top	154 ± 16
$W/Z + \gamma$	82 ± 13
WZ	22.4 ± 2.3
ZZ	2.48 ± 0.26
Total background	4150 ± 250
Data	4053

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eμ resonance: results

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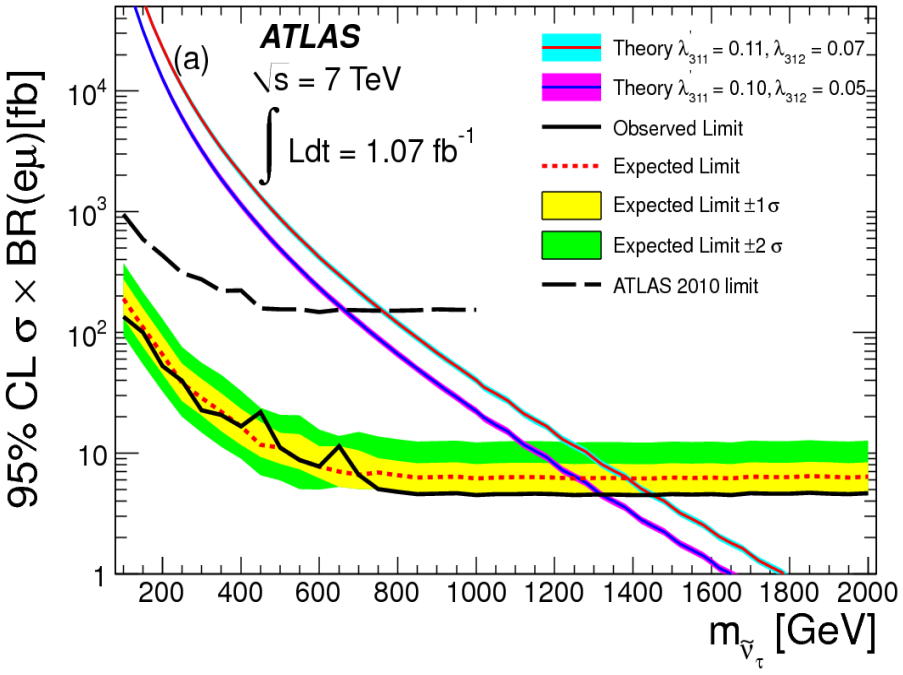
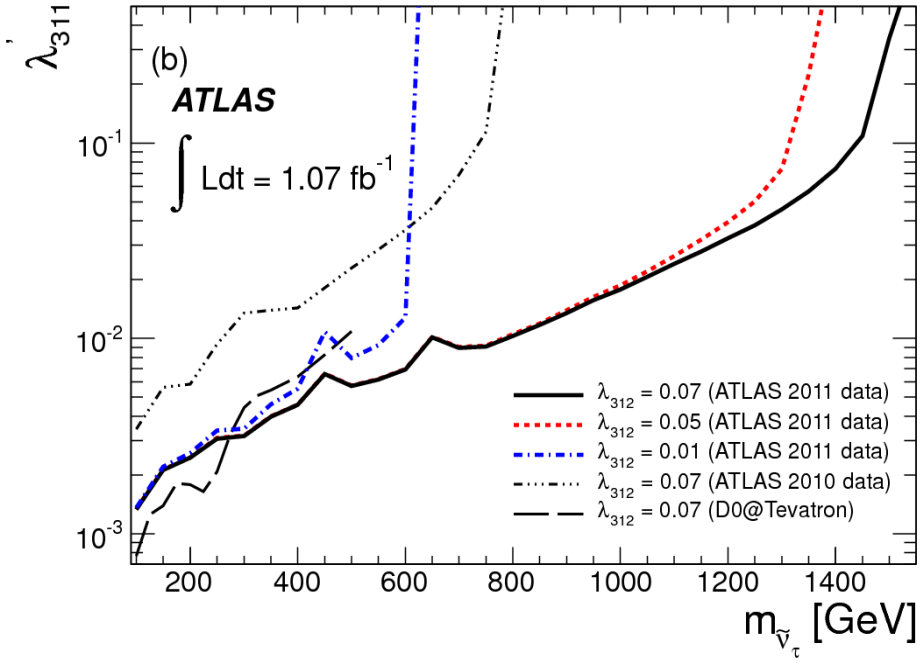
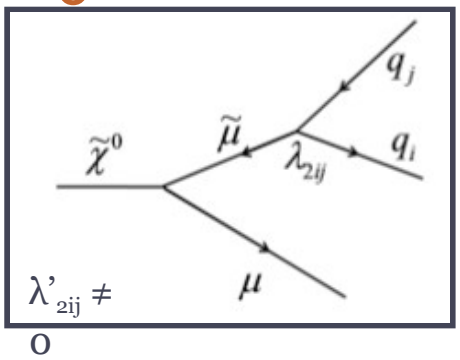
- 95% Confidence Level (CL) upper limits on $\sigma(pp \rightarrow \tilde{\nu}_\tau) \times BR(\tilde{\nu}_\tau \rightarrow e\mu)$ as a function of $m_{\tilde{\nu}}$
- Tau sneutrinos with a mass below 1.32 (1.45) TeV are excluded, assuming coupling values $\lambda'_{311} = 0.10$ & $\lambda_{312} = 0.05$ ($\lambda'_{311} = 0.11$ & $\lambda_{312} = 0.07$)
- 95% CL upper limits on the λ'_{311} couplings as a function of $m_{\tilde{\nu}}$ for three values of λ_{312}
- Limits on λ'_{311} are better than D0 results for sneutrino mass > 270 GeV assuming λ_{312}=0.07





Displaced vertices: description

- Targeting LSP decays 4 – 180 mm from the interaction point for couplings $\lambda'_{2ij} \neq 0$



- Results obtained independent of the value used for λ'_{2ij}

- Main source of background: interaction with detector material

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Displaced vertices: event selection

- At least one PV with more than 4 tracks and a z position < 200 mm
- m_{DV} > 10 GeV: removes bkg from interaction with material
- Veto to vertices reconstructed within regions of high-density material
  → removes bkg from interaction with material + high-p_T track
- At least 1 DV per event and a muon candidate with p_T > 45 GeV

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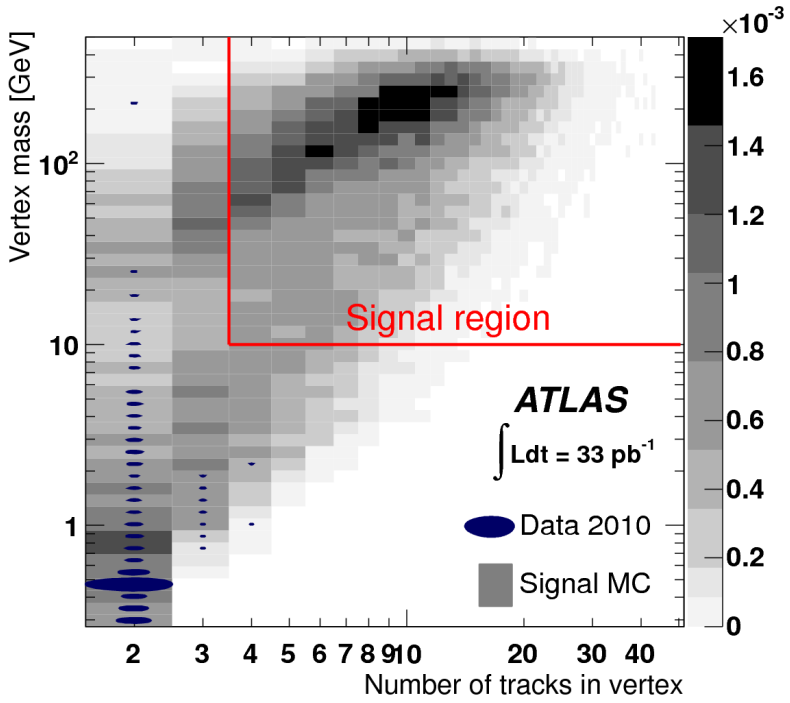
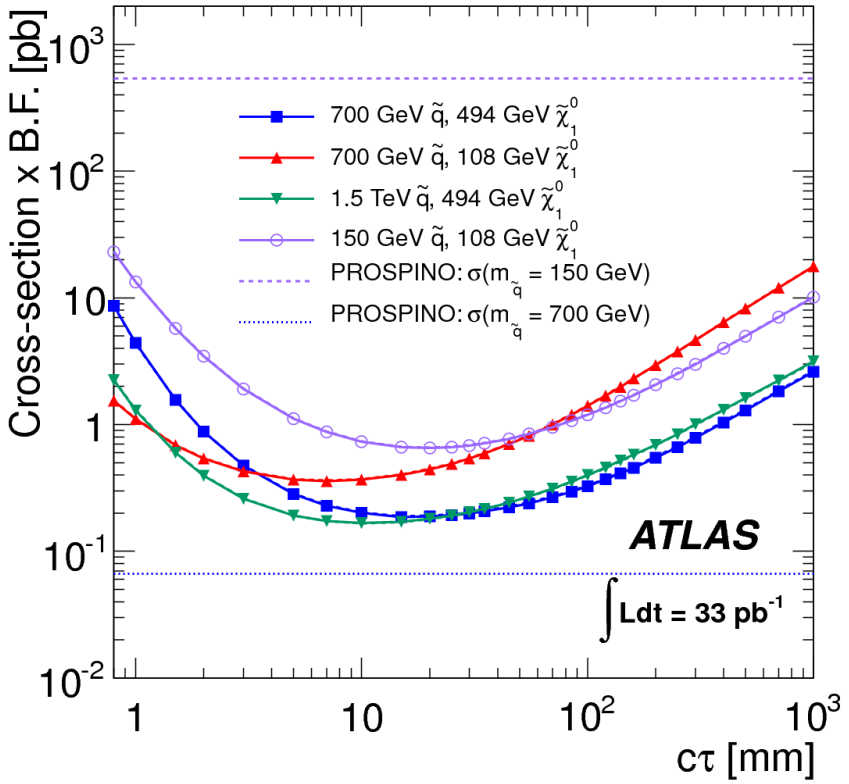
Displaced vertices: results

- Number of events passing the selected requirements except for the m_{DV} and $N_{DVtracks}$
- No data events observed in the signal region



- Upper exclusion limits at 95% CL for different squark and neutralino masses



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Bilinear RPV: theoretical motivation

$$W_{\rm bRPV} = W^{\rm MSSM} + \epsilon_i \hat{L}_i \hat{H}_u$$
$$V_{\rm soft} = V^{\rm MSSM}_{\rm soft} - B_i \epsilon_i \tilde{L}_i H_u$$

- RPV through bilinear terms
  - six bRPV parameters:
    ϵi, Bi ⇔ ϵi, Λi (Λi = ϵivd + μvi)

- Bilinear RPV introduces new aspects
  - EW symmetry is broken by Higgs and sneutrino vev's
  - neutrinos mix with neutralinos → 7 × 7 mixing matrix
  - a "low-scale" seesaw mechanism renders neutrinos massive
  - tree level → atmospheric scale
  - 1-loop → solar scale

Valle, Hirsch, Porod, Diaz *et al.*

Bilinear RPV & 1-lepton analysis

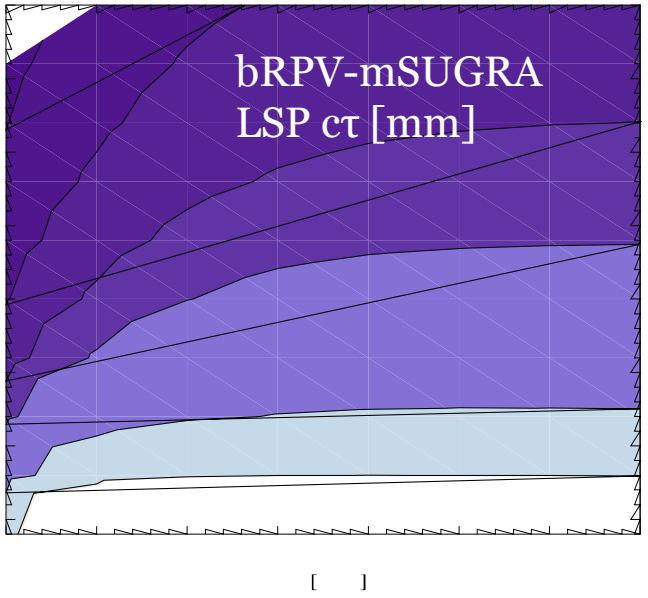
- Common event selection:
  - exactly one isolated muon with p_T > 20 GeV
  - veto for events with at least one electron with p_T > 20 GeV, aimed at avoiding overlap with other analyses
- Four signal regions requiring 3 or 4 jets with loose or tight cuts

$$m_{\text{eff}} = p_{\text{T}}^{\ell} + \sum_{i=1}^{3(4)} p_{\text{T}}^{\text{jet}_i} + E_{\text{T}}^{\text{miss}}$$

$$m_{\text{T}} = \sqrt{2 \cdot p_{\text{T}}^{\ell} \cdot E_{\text{T}}^{\text{miss}} \cdot (1 - \cos(\Delta\phi(\vec{\ell}, \vec{E}_{\text{T}}^{\text{miss}})))}$$

Bilinear RPV: signatures in colliders

- bRPV couplings can be embedded in any supersymmetric scenario:
  - MSSM, SUGRA, AMSB, …
- Almost same event as in RPC SUSY except that (N)LSP decays at end of SUSY cascade
- Common features among SUSY scenarios
  - LSP lifetime may be long ($c\tau \sim 1 - 100$ mm)
    → search for displaced vertices
  - many leptons and taus in final state
    → 1-, 2- or multilepton analyses relevant
  - large MET due to copious neutrino production
    → conventional MET-based searches applicable to bRPV SUSY



References on Theoretical bRPV and dark matter

- D.~Restrepo, M.~Taoso, J.~W.~F.~Valle and O.~Zapata, ``Gravitino dark matter and neutrino masses with bilinear R-parity violation,'' Phys.\ Rev.\ D {\bf 85} (2012) 023523 [arXiv:1109.0512 [hep-ph]]
- J.~C. Romao {\em et~al.}, Phys. Rev. {\bf D61}, 071703 (2000), [hep-ph/9907499]
- M.~Hirsch {\em et~al.}, Phys. Rev. {\bf D62}, 113008 (2000), [hep-ph/0004115], Err-ibid. {\bf D65}:119901,2002.
- M.~A. Diaz {\em et~al.}, Phys. Rev. {\bf D68}, 013009 (2003), [hep-ph/0302021].
- W.~Porod {\em et~al.}, Phys. Rev. {\bf D63}, 115004 (2001).
- F.~de Campos et al, “Probing bilinear R-parity violating supergravity at the LHC,'' JHEP {\bf 0805}, 048 (2008) [arXiv:0712.2156 [hep-ph]].
- F.~De Campos et al, ”Probing Neutrino Oscillations in Supersymmetric Models at the Large Hadron Collider,'' Phys.\ Rev.\ D {\bf 82}, 075002 (2010) [arXiv:1006.5075 [hep-ph]].
- M.~Hirsch, J.~W.~F.~Valle, “Supersymmetric origin of neutrino mass,'' New J.\ Phys.\ {\bf 6 } (2004) 76 [hep-ph/0405015].