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Boosted Objects from BSM

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outline

- New physics: the heavier & faster
- Boosted EW vector bosons
- Boosted Higgs boson(s)
- Conclusions

New physics: the heavier & faster

Benchmark NP and its landmarks

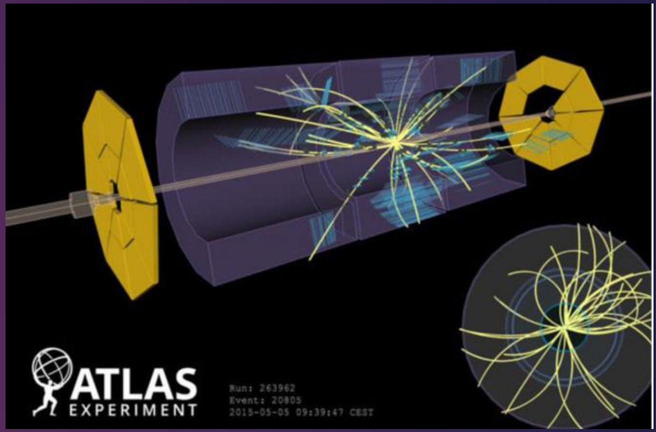
Supersymmetry (stop) & compositeness (t’)
⇒ address the hierarchy problem

Seesaw mechanism (right handed neutrino, RHN)
⇒ neutrino mass origin

Two Higgs doublets with/- singlet (extra Higgs bosons)
⇒ address the absence of antibaryon via baryogensis

New physics: the heavier & faster

Towards landmarks @ LHC



LHC is a QCD factory, a sea of background jets, which easily hides the colored drop, NP signals

To suppress those backgrounds, one usually requires unhadronic suppressons such as

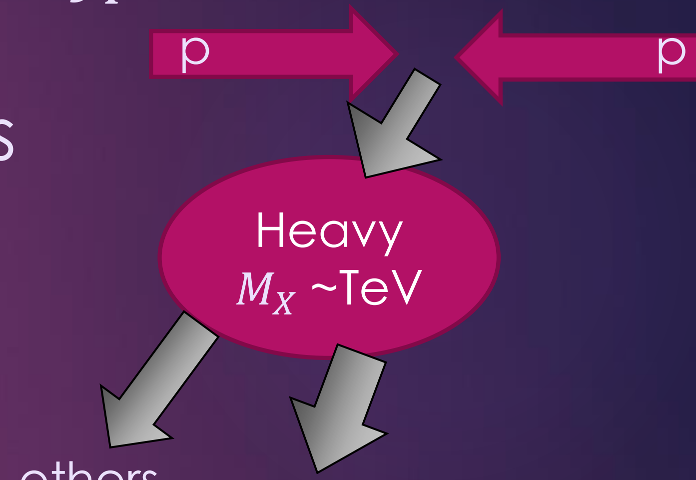
A large MET

Hard leptons

New physics: the heavier & faster

A hadronic suppresson : fat jets J_F

hadronic & "composite" objects could develop distinguishable substructures, in SM:



Boosted top quark t(→100%Wb)

Boosted electroweak (EW) vector bosons V=Z/W(→~70% jj')

Boosted Higgs boson h (→bb, 58%)

J_F from X decay is highly boosted, so J_F decay products are collimated

Boosted EW vector bosons

A new probe to quasi-natural compressed SUSY

Compressed SUSY: degeneracy between the lightest stop and LSP, why?

deplete the number density of bino-like dark matter via coannihilation, whose annihilation is small

Hide a lighter stop (thus natural SUSY) by removing large MET!

top carries away most momentum

However, detecting very compressed SUSY at LHC then becomes difficult….

Boosted EW vector bosons

ZK, Jinmian Li & Mengchao Zhang, EPJC 2017

A new probe to quasi-natural compressed SUSY

But, (quasi-)natural SUSY has other members

$$-\mathcal{L}_{QNS} = m^2_{\tilde{Q}_3}|\tilde{Q}_3|^2 + \frac{m_{\tilde{B}}}{2}\tilde{B}\tilde{B} + m^2_{\tilde{t}_R}|\tilde{t}_R|^2 + \left(h_t A_t \tilde{Q}_3 H_u \tilde{t}^\dagger_R + |D_\mu \tilde{Q}_3|^2\right)$$
$$+ i\sqrt{2}\left(\frac{g_Y}{6}\tilde{Q}^\dagger_3 \tilde{B} t_L - \frac{2g_Y}{3}\tilde{t}^\dagger_R \tilde{B} t_R\right) + \left(\mu \tilde{H}_u \tilde{H}_d + h_t \tilde{Q}_3 \tilde{H}_u t^\dagger_R + h_b \tilde{Q}_3 \tilde{H}_d b^\dagger_R\right)$$

$\tilde{t}_1 \approx \tilde{t}_R$ degenerate with LSP

$\tilde{t}_1 \approx \tilde{t}_L$ would make $\tilde{b}_L$ excluded

A large A_t is favored: enhance m_h & bosonic decay branching raito

Boosted EW vector bosons

ZK, Jinmian Li & Mengchao Zhang, EPJC 2017

Decays of $\tilde{Q}_3$: bosonic modes

$$\Gamma(\tilde{b}_1 \to \tilde{t}_1 W) \approx \frac{g_2^2 \cos^2\theta_{\tilde{t}}}{32\pi} \frac{m_{\tilde{b}_1}^3}{m_W^2}$$

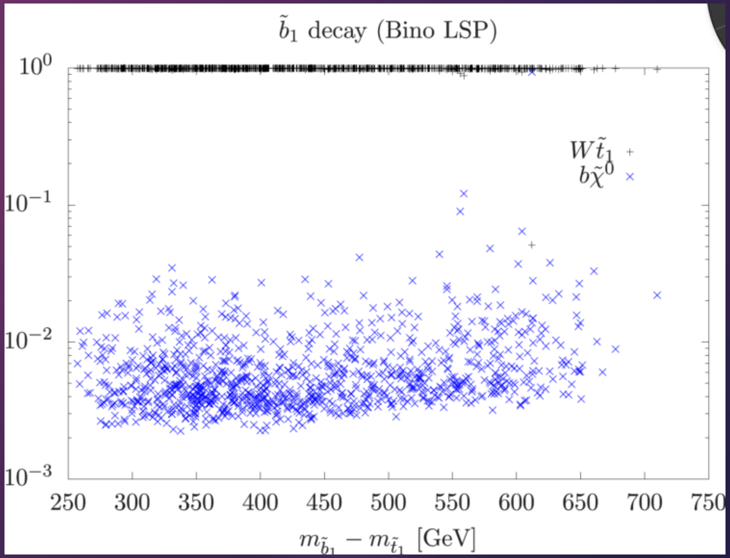
$$\Gamma(\tilde{t}_2 \to \tilde{t}_1 Z) \approx \frac{g_2^2}{\cos^2\theta_W} \frac{\sin^2 2\theta_{\tilde{t}}}{256\pi} \frac{m_{\tilde{t}_2}^3}{m_Z^2}$$

$$\Gamma(\tilde{t}_2 \to \tilde{t}_1 h) \approx \frac{g_2^2 \cos^2 2\theta_{\tilde{t}}}{64\pi} \frac{m_t^2}{m_W^2} \frac{A_t^2}{m_{\tilde{t}_2}}$$

maximal LR stop mixing $\Leftrightarrow$ large A_t

The heavier mother particles

The bosonic modes can easily beat the fermionic modes like $\tilde{b}_1 \to b\tilde{\chi}^0$



Boosted EW vector bosons

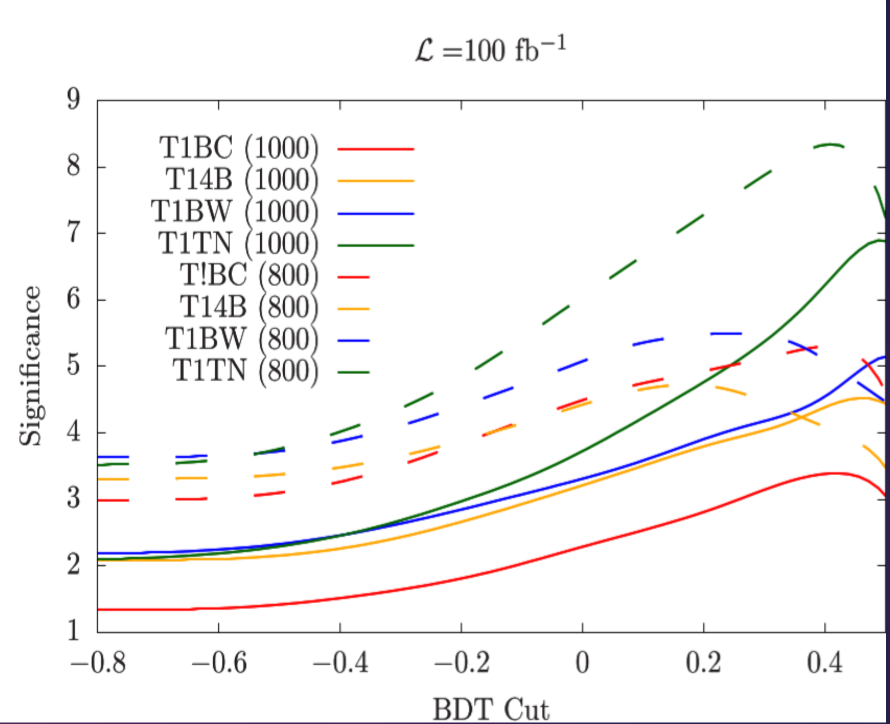
ZK, Jinmian Li & Mengchao Zhang, EPJC 2017

A new probe to quasi-natural compressed SUSY

benchmark points

@14TeV & 100/fb LHC

	$m_{\tilde{t}_2/\tilde{b}_1} \sim 800$ GeV				$m_{\tilde{t}_2/\tilde{b}_1} \sim 1000$ GeV			
	T1BC	T14B	T1BW	T1TN	T1BC	T14B	T1BW	T1TN
$m_{\tilde{t}_1}$/GeV	518	533	533	533	574	517	517	517
$m_{\tilde{t}_2}$/GeV	810	826	826	826	993	984	984	984
$m_{\tilde{b}_1}$/GeV	774	821	821	821	977	968	968	968
$m_{\tilde{\chi}_1^0}$/GeV	470	454	383	343	471	434	374	334
$m_{\tilde{\chi}_2^0}$/GeV	475	2000	2000	2000	476	2000	2000	2000
$m_{\tilde{\chi}_1^\pm}$/GeV	472	2000	2000	2000	472	2000	2000	2000
$\mathrm{Br}(\tilde{t}_2 \to h\tilde{t}_1)$	0.163	0.399	0.393	0.389	0.204	0.502	0.501	0.500
$\mathrm{Br}(\tilde{t}_2 \to Z\tilde{t}_1)$	0.330	0.526	0.518	0.514	0.219	0.486	0.485	0.484
$\mathrm{Br}(\tilde{b}_1 \to W\tilde{t}_1)$	0.621	0.963	0.954	0.949	0.431	0.988	0.987	0.986
$\mathrm{Br}(\tilde{t}_1 \to b\tilde{\chi}_1^\pm)$	1.0	0	0	0	1.0	0	0	0
$\mathrm{Br}(\tilde{t}_1 \to bW^{(*)}\tilde{\chi}_1^0)$	0	1.0	1.0	0	0	0.882	1.0	0
$\mathrm{Br}(\tilde{t}_1 \to t\tilde{\chi}_1^0)$	0	0	0	1.0	0	0	0	1.0



Boosted Higgs boson(s)

Why boosted Higgs bosons?

Higgs may be the new physics messenger

The faster Higgs may signal the higher new physics

Equilibrium theorem

h = Z = W

can be violated beyond SM

Pure hadronic but larger branching ratio & 2b-tagging

Hard leptons but with suppressed branching ratios

Boosted Higgs boson(s)

ZK, Jinmian Li & Ko.P, PRL,PRD 2016

Boosted di-Higgs+MET from seesaw

seesaw with nonsterile RHNs: well motivated in the extensions with B-L and LR gauge symmetries

$$
\begin{aligned}
-\mathcal{L}_X &= \frac{1}{2} M_X^2 X_\mu X^\mu + g_N \overline{N_R} \gamma_\mu N_R X^\mu + g_q \bar{q} \gamma_\mu q X^\mu, \\
-\mathcal{L}_\phi &= \frac{1}{2} m_\phi^2 \phi^2 + \frac{\lambda_N}{\sqrt{2}} \phi \overline{(N_R)^c} N_R + \sin\theta \frac{\alpha_s}{m_t} \phi G G.
\end{aligned}
$$

Larger production rate via resonant enhancement

Open TeV seesaw region at colliders

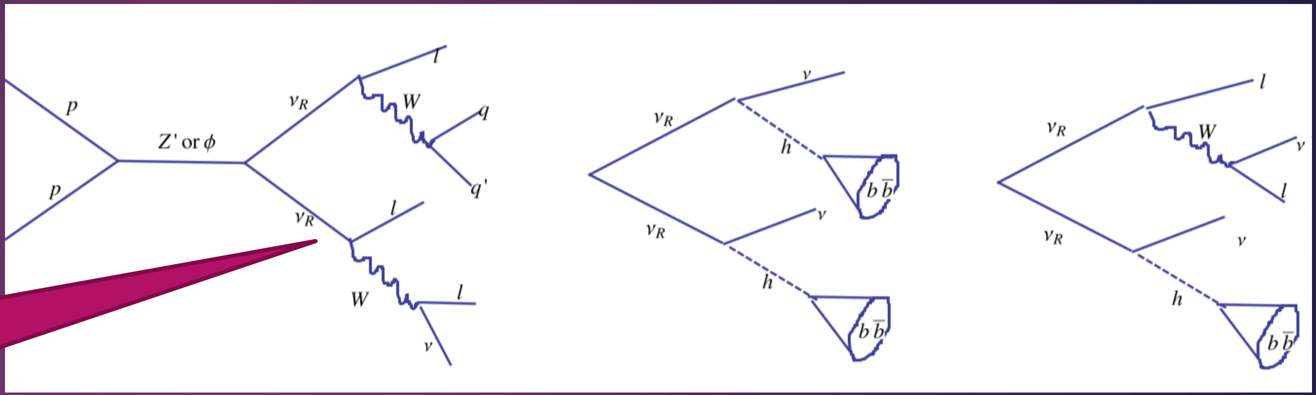
without invoking large left-right neutrino mixing which is supposed to be very small

Boosted Higgs boson(s)

ZK, Jinmian Li & Ko.P, PRL,PRD 2016

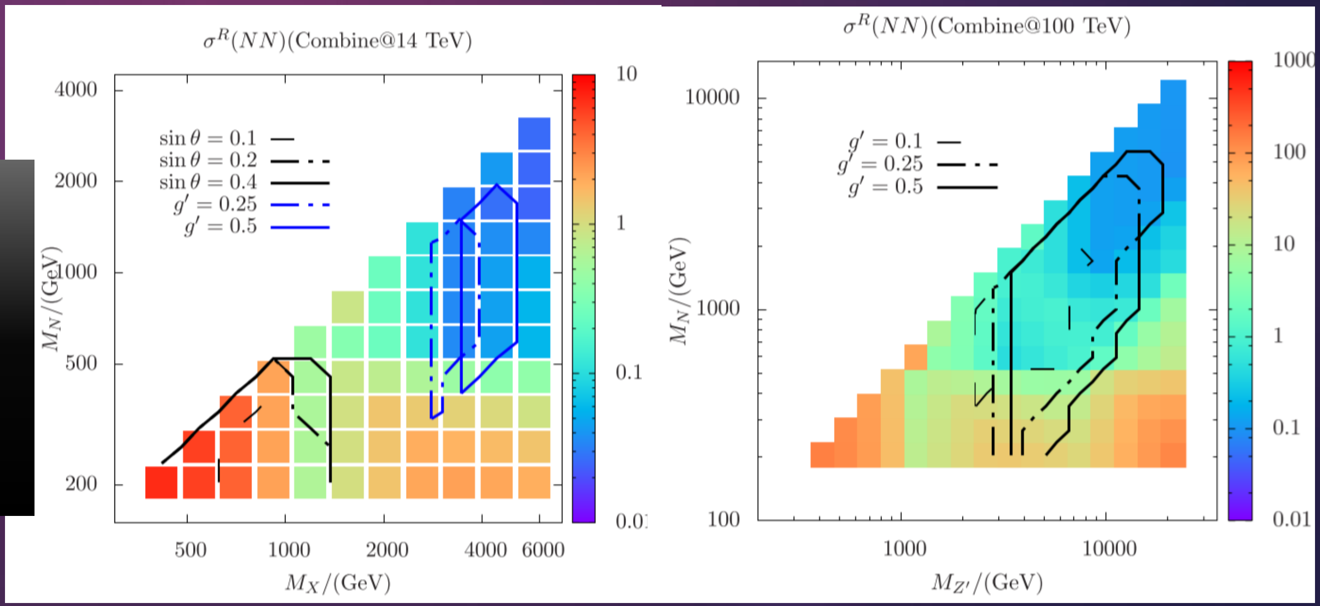
Boosted di-Higgs+MET from seesaw

with $W_l + W_h$ & boosted h+ W_l



Same sign dilepton becomes inefficient for superboosted RHN

To few TeV @ the end of LHC & to 10TeV @ 100 TeV pp collider



Boosted Higgs boson(s)

ZK, Jinmian Li etc., PRD, 2013

Boosted X from the natural NMSSM

A model to address the unique mass parameter in the superpotential of MSSM

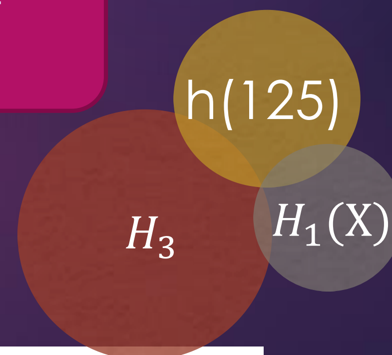
A smaller μ= λv_s~O(100)GeV

a smaller tanβ=$\frac{v_u}{v_d}$~1

a larger λ~1

extra H_1 lighter than h(125), to push up h(125) via mixing

To enhance the SM-like Higgs boson mass at tree level



$$m_{H_3}^2 \approx M_A^2 \simeq \left(\frac{2\mu}{\sin 2\beta}\right)^2 \left(1 - \frac{\kappa}{\lambda}\frac{\sin 2\beta}{2}\right)$$

Not very heavy!!

Boosted Higgs boson(s)

ZK, Jinmian Li etc., PRD, 2013

Boosting test of the 3 CP-even Higgs bosons

Higgs to Higgs: decay chain $H_3 \to H_2(125) H_1$(boosted)

$$\sigma_{H_3} = 0.2 \left(\frac{C_{3,g}}{0.4}\right)^2 \frac{\mathrm{Br}(H_3 \to H_1 H_2)}{20\%} \frac{\mathrm{Br}(H_1 \to b\bar{b})}{90\%} \frac{\mathrm{Br}(H_2 \to W_\ell W_h)}{28\%} \frac{\sigma_{\mathrm{GF}}(h_{\mathrm{SM}})}{10\,\mathrm{pb}}\,\mathrm{pb},$$

@ 14TeV 500/fb LHC

	m_{H_1}(GeV)	m_{H_3}(GeV)	σ (fb)	$\frac{S}{\sqrt{S+B}}$
B1	100	300	70	0.81
B2	65	300	50	3.84
B3	98	400	25	4.73
B4	65	400	20	7.68
B5	100	600	2	2.79
B6	65	600	2	4.99

Sub TeV H_3 & sub 0.1 TeV H_1 may have good prospect

The new di-photon excess???

Conclusions

New physics may have been pushed into the TeV region by the null LHC new physics searches

Then, boosted t/W/Z/h or h(X) may provide signs to those new heavy resonances

Good examples: heavier stops/right-handed neutrino/heavy Higgs

Thank you