Boosted Final States:
Beyond the Standard Model
Motivation
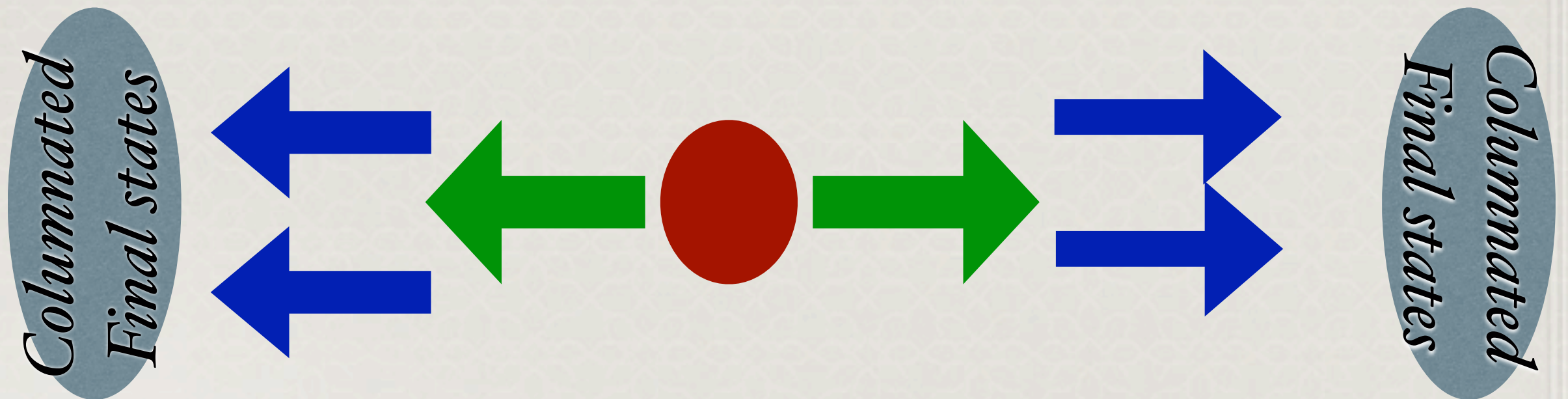
Jay Wacker

SLAC

Boosted Final States

The Top is the heaviest mass particle in the SM

The LHC has access to much higher energy scales

Cascade decays become columnated final states

Columnated Final states

Columnated Final states

Boosted Final States

Has become a way of classifying otherwise complicated signatures
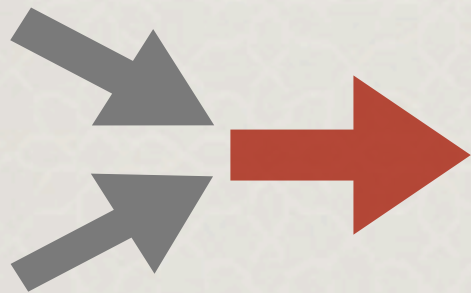
Reduces combinatoric backgrounds

Requires rethinking cuts (eg isolation)

Becomes a unifying framework for peculiar signatures that were falling between cracks
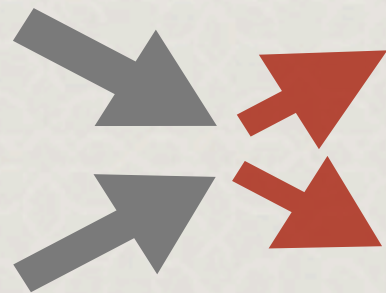
Overview

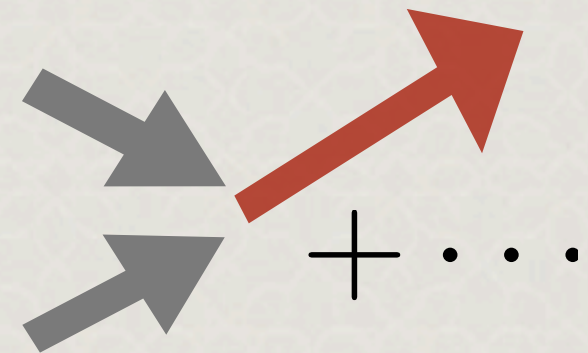## Production modes to get a boost

Resonant Production   *Heavy Pair Production*   *Boosted Light Particle Production*

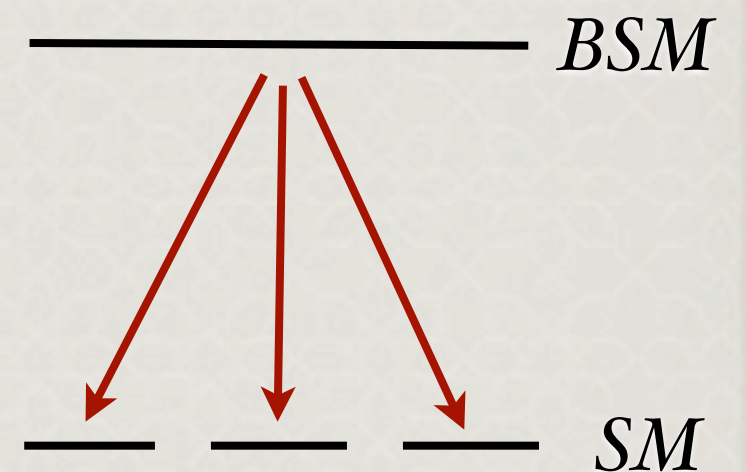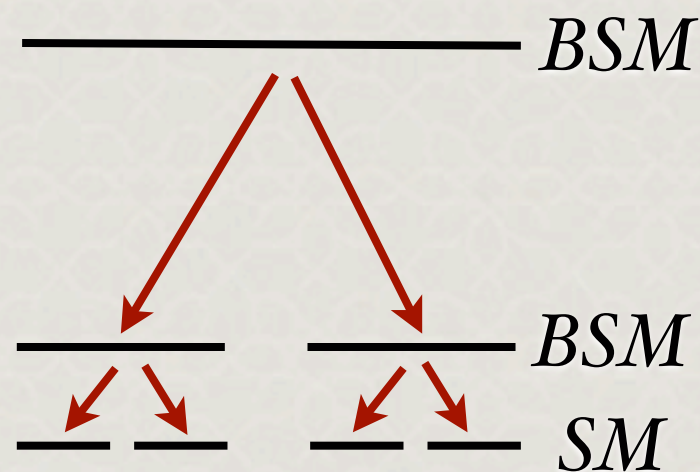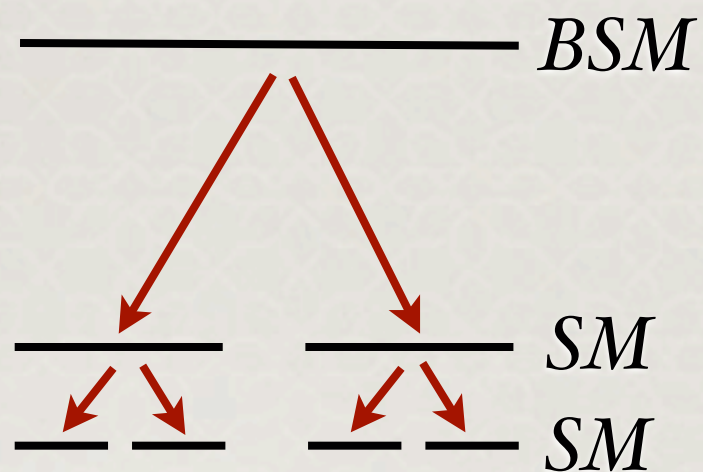*Momentum comes from produced particle's rest mass*   *Momentum comes produced particle's momentum*
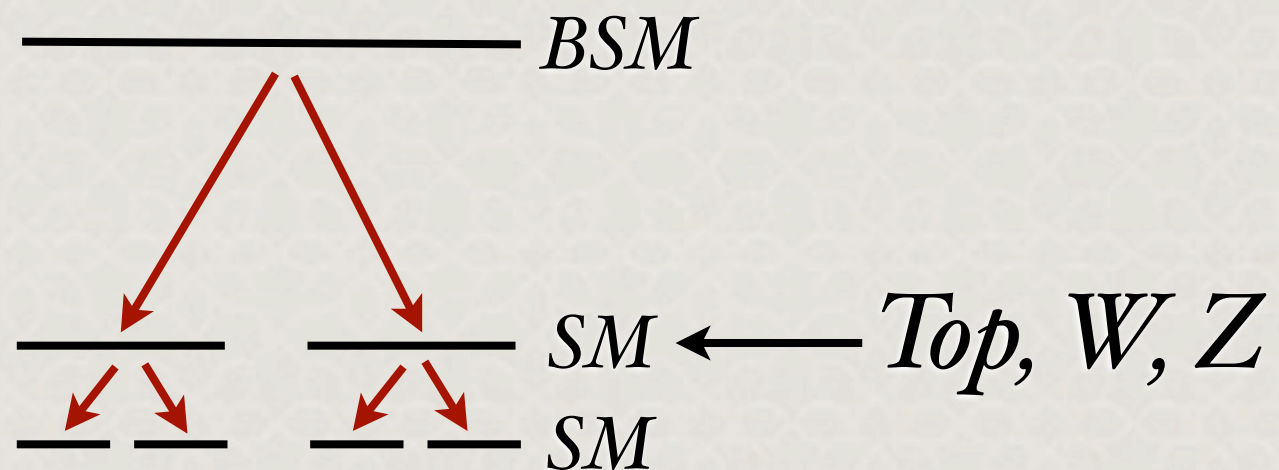
Overview

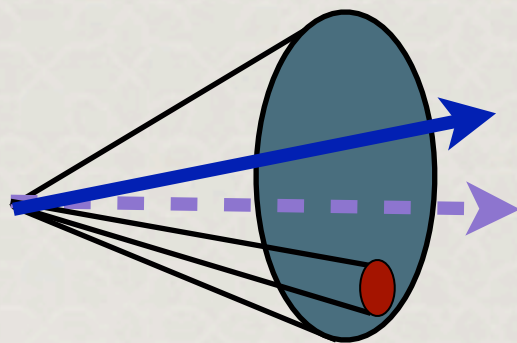## Common Decay Chains

1-step Cascade Decays
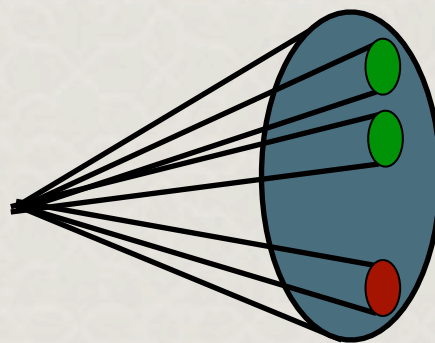
Direct Decays
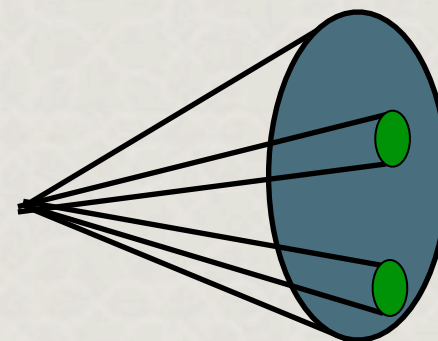
The Classic Boosted Final State

BSM

SM ⟵ *Top, W, Z*

SM

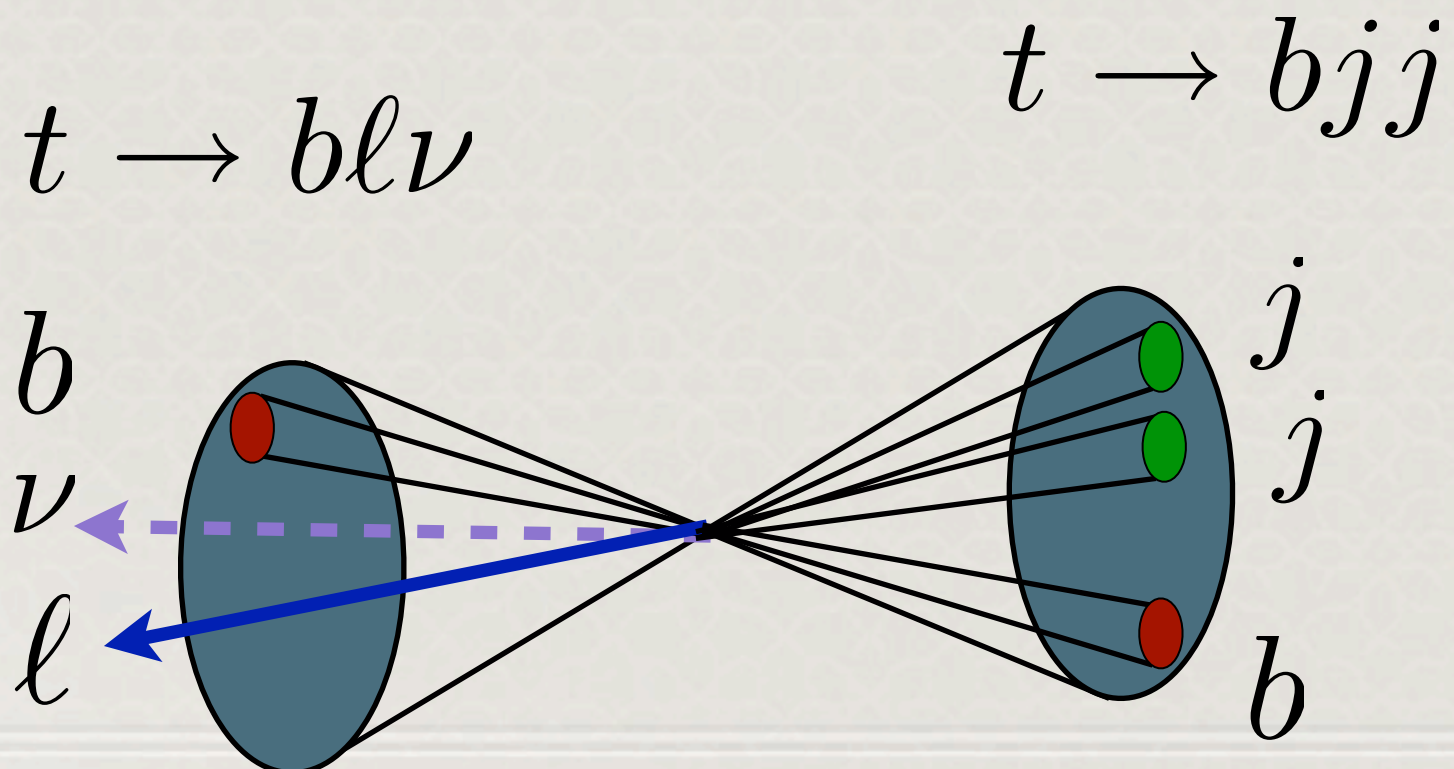$t \rightarrow b\ell\nu$ $t \rightarrow bjj$ $W^{\pm}, Z^{0} \rightarrow jj$

Resonant Production

Best Opportunity for 7TeV LHC
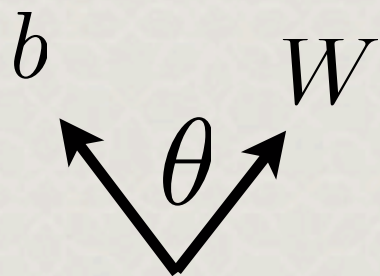
"KK" Gluon in Technicolor & Randall Sundrum Models

Dominantly Decays into tops

$$g' \to t\bar{t}$$

$$t \to bjj$$

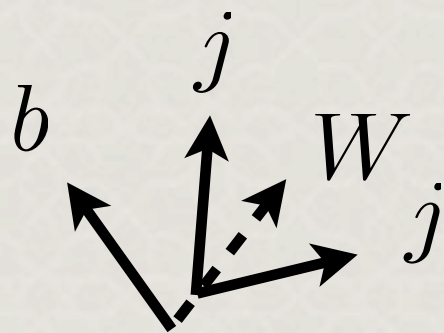$$t \to b\ell\nu$$

b

ν

ℓ

j

j

b

Back of the Envelope Estimate

$$m_{g'} = 1 \text{ TeV} \Rightarrow \frac{p_t}{m_t} \simeq 2.7 \equiv B$$
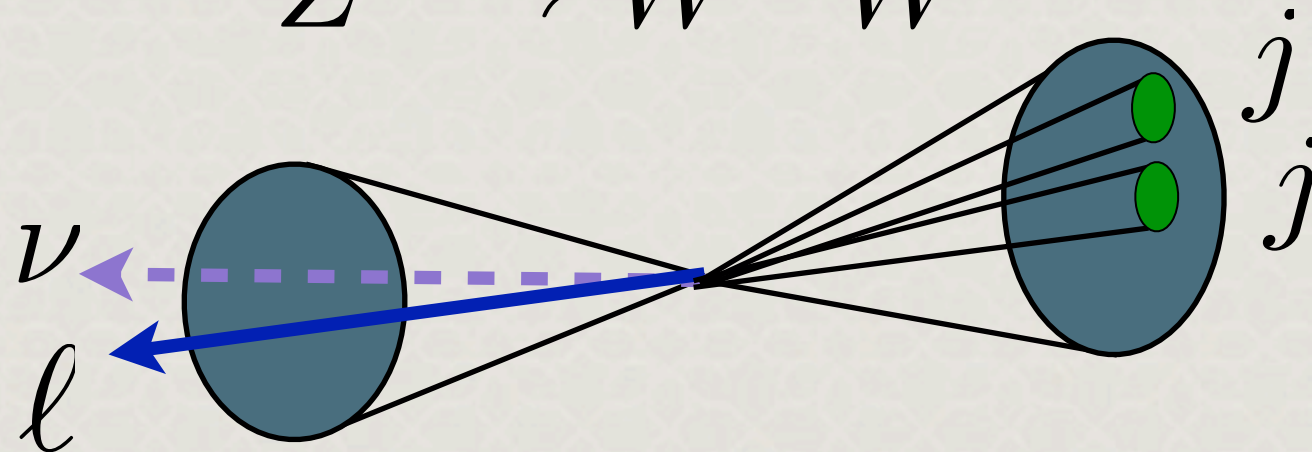
$$\cos\theta \simeq \frac{B^2 - 1}{B^2 + 1}$$
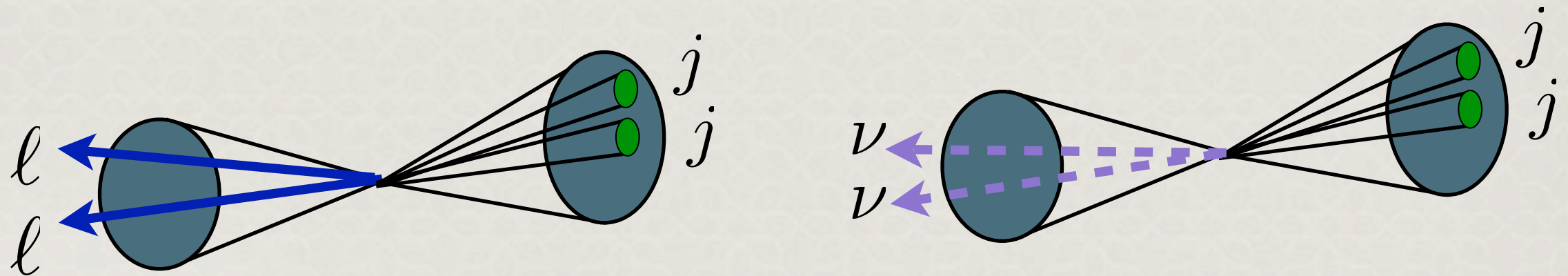
$$\Delta R_t \sim 0.7$$

We will enter the Boosted Era this year

New Vector Bosons also Promising

$$Z' \rightarrow W^+ W^-$$

$$W'^{\pm} \rightarrow Z^0 W^{\pm}$$

Small Branching ratios, but easy to get larger boost

Heavy Particle Pair Production
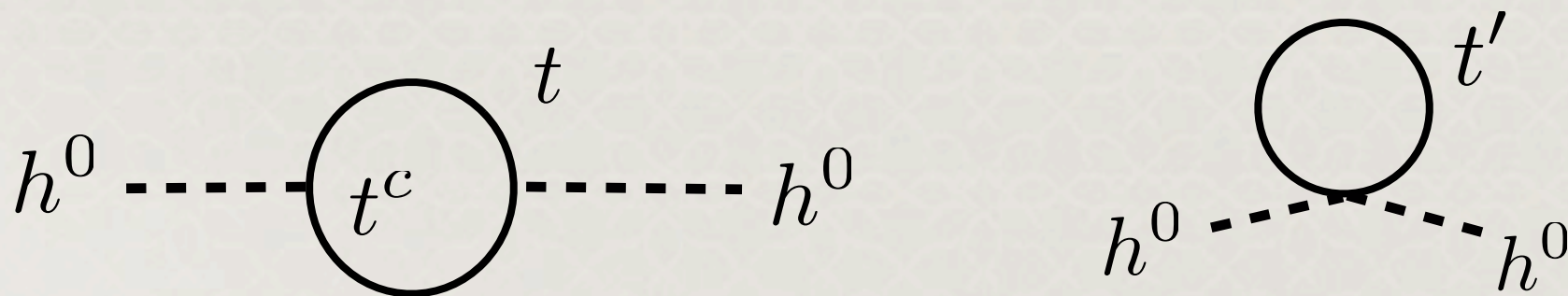
Top Partners are common example

$$t' \to bW^+ \qquad t' \to tZ^0 \qquad t' \to tg \qquad b' \to tW^-$$

Holdom et al 1004.3031

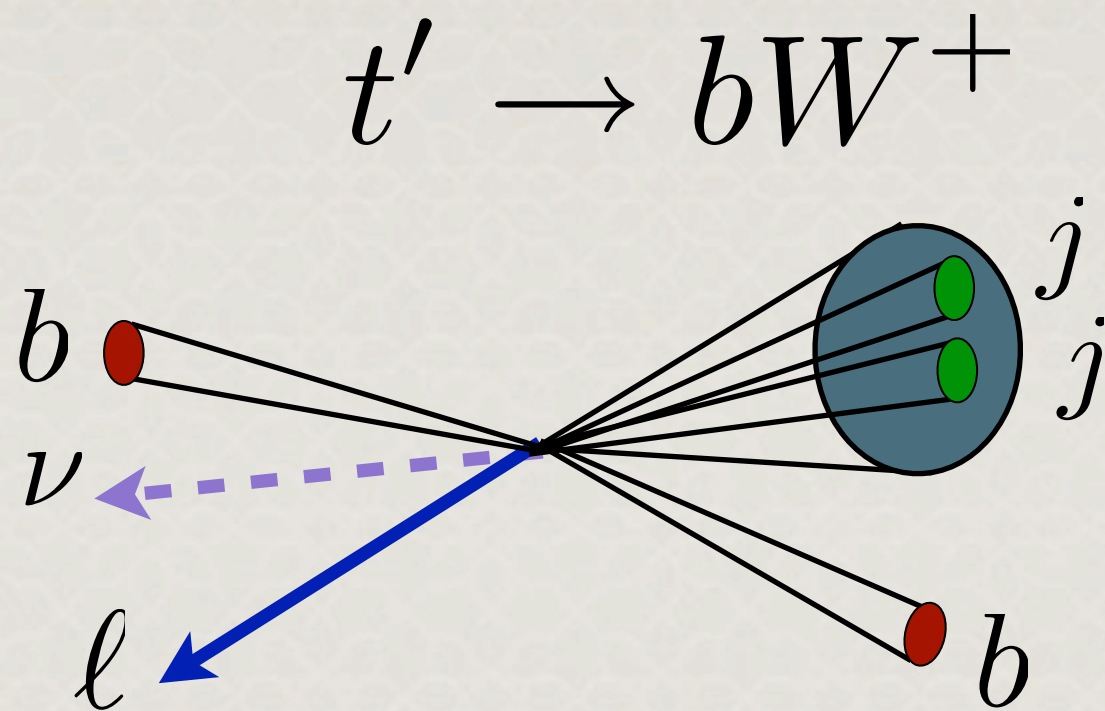## Frequently appear in Little Higgs or Extra Dim Models

Top partners are heavy $\quad m_{t'} \gtrsim 500 \text{ GeV}$
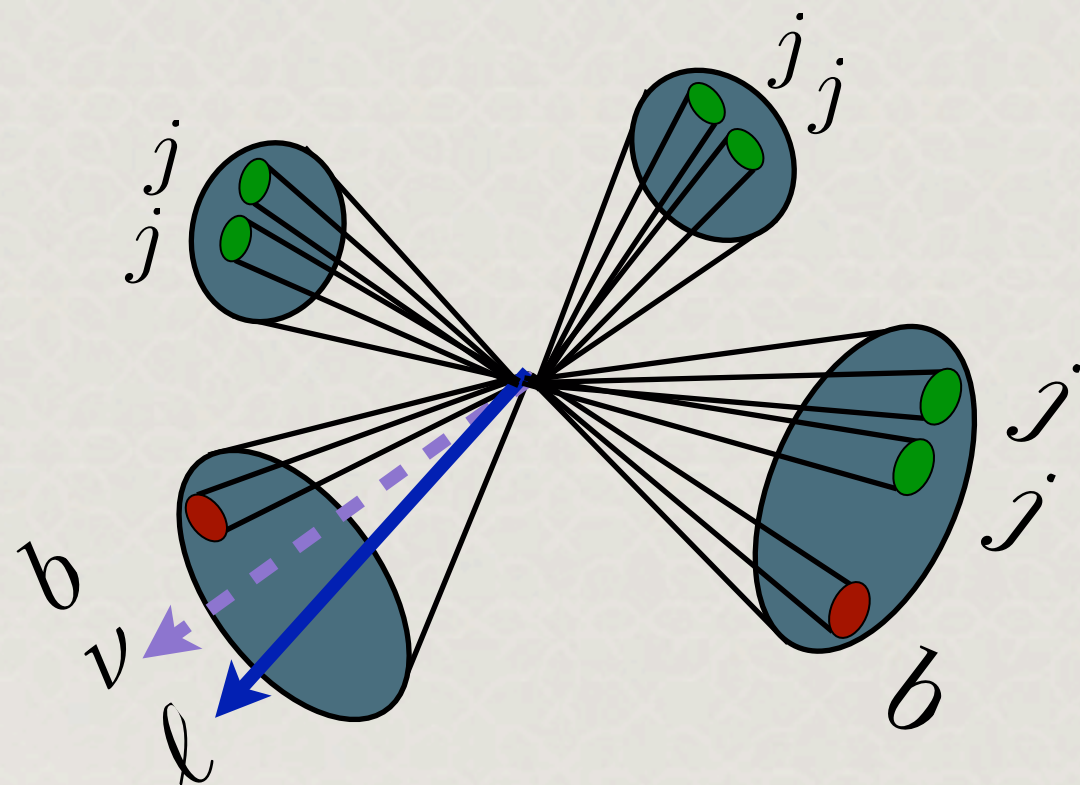
Cut off Top Quadratic Divergences to Higgs Mass

$$t' \to bW^+$$

*Not much
substructure*

b

j

j

ν

ℓ

b

$$b' \to tW^-$$

*Too much mass
for a big
boost at 7 TeV*

$$m_{b'} = 700 \text{ GeV}$$

$$B_t = 1.8 \quad B_W = 4.0$$

j

j

j

j

j

j

b

ν

ℓ
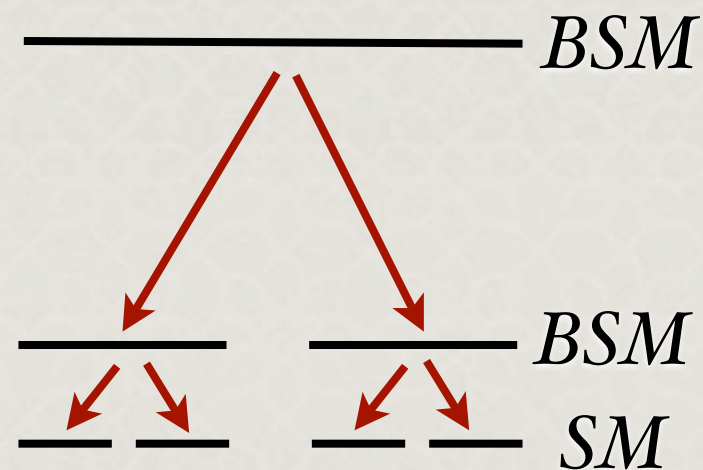
b

Energies/Luminosities Challenging

Best case for a boosted final state:

$$t' \to tg$$
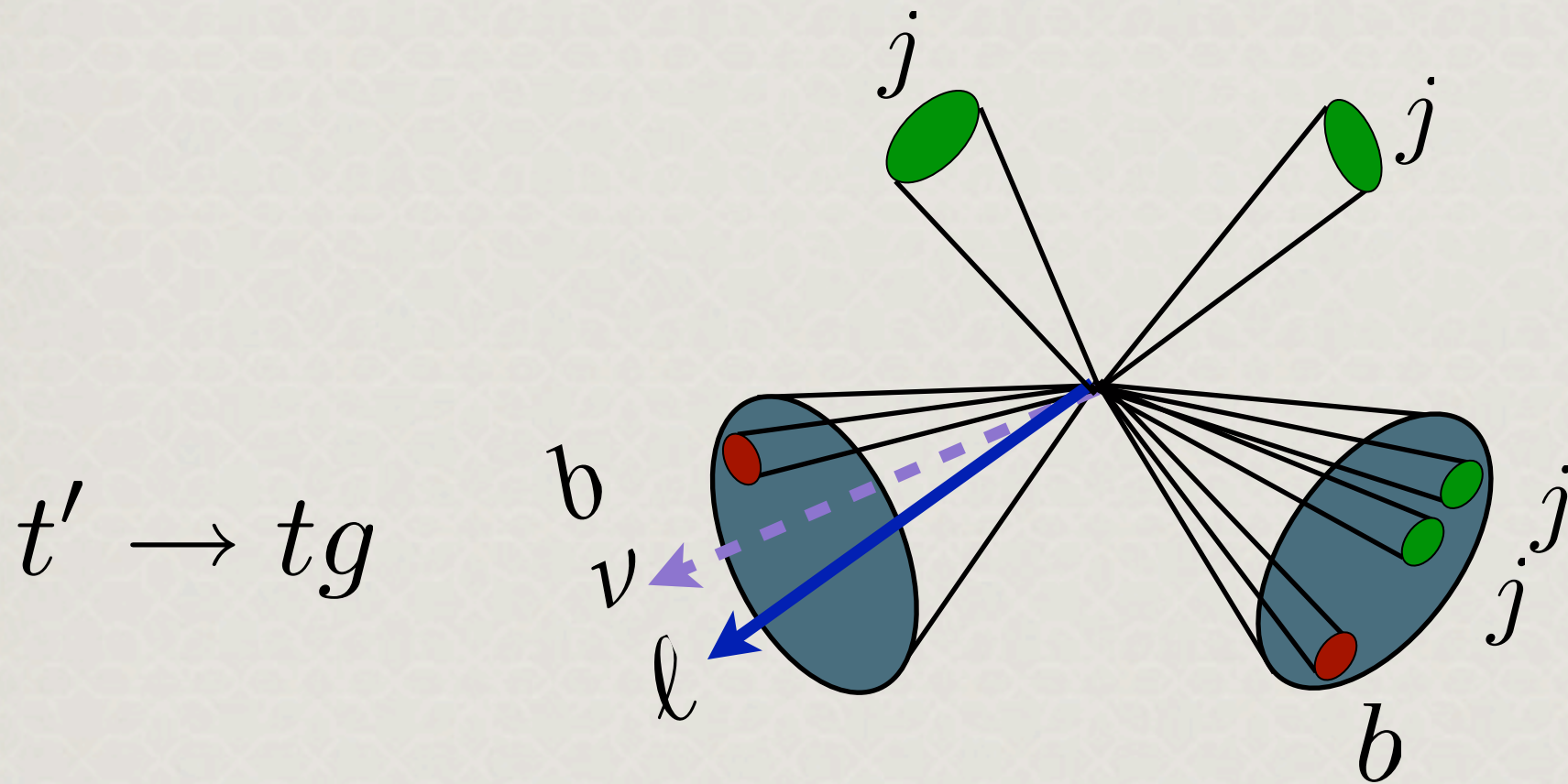
$$m_{t'} = 500 \text{ GeV} \Rightarrow \frac{p_t}{m_t} = 1.25$$

$$m_{t'} = 700 \text{ GeV} \Rightarrow \frac{p_t}{m_t} = 1.9$$

The BSM Boosted Cascades

Resonant Production $\quad h^0 \to a^0 a^0$

$$a^0 \to 2\mu, 2\gamma, 2\tau, 2b, 2c, 2g$$
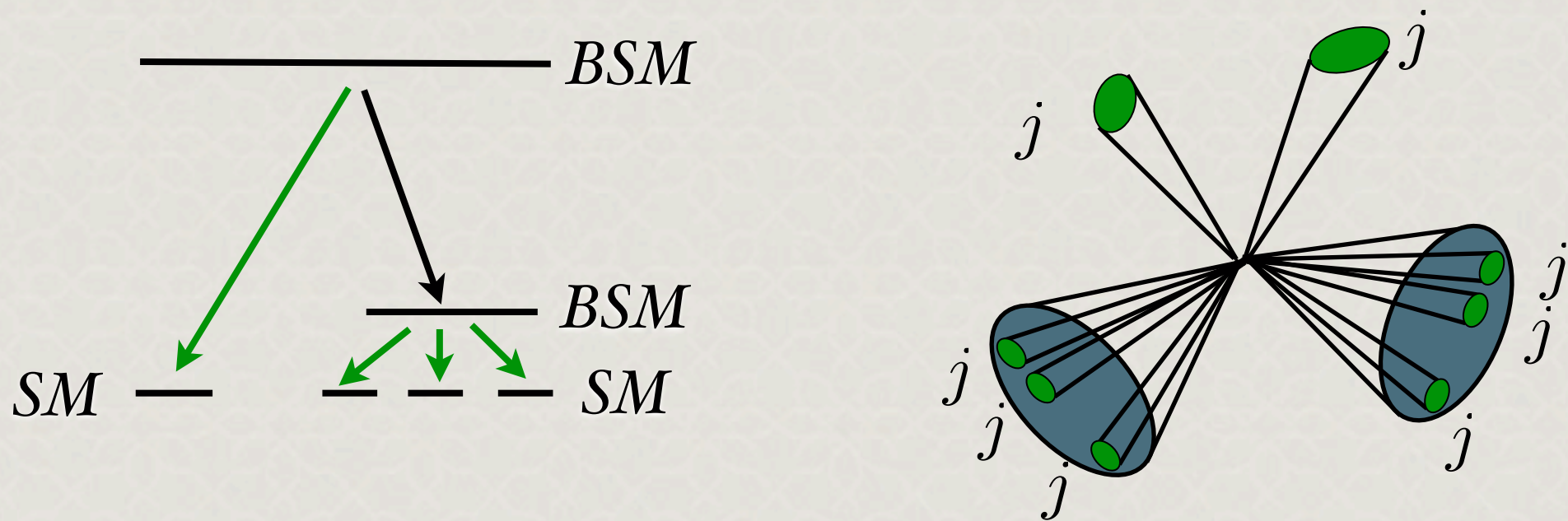
Lisanti et al 0903.1377 $\longrightarrow h^0 \to 2\mu 2\tau$

DZero 0905.3381 $\longrightarrow h^0 \to 4\mu$

Bellazzini et al 0906.3026
Falkowski et al 1006.1650 $\longrightarrow h^0 \to 4c, 4g$
Chen et al 1006.1151

R-Parity Violation

$$\tilde{q} \rightarrow \tilde{\chi}^0 q$$

Butterworth et al 0906.0728

$$W_{\mathrm{RPV}} = U^c D^c D^c \qquad \Rightarrow \tilde{\chi}^0 \rightarrow 3q$$
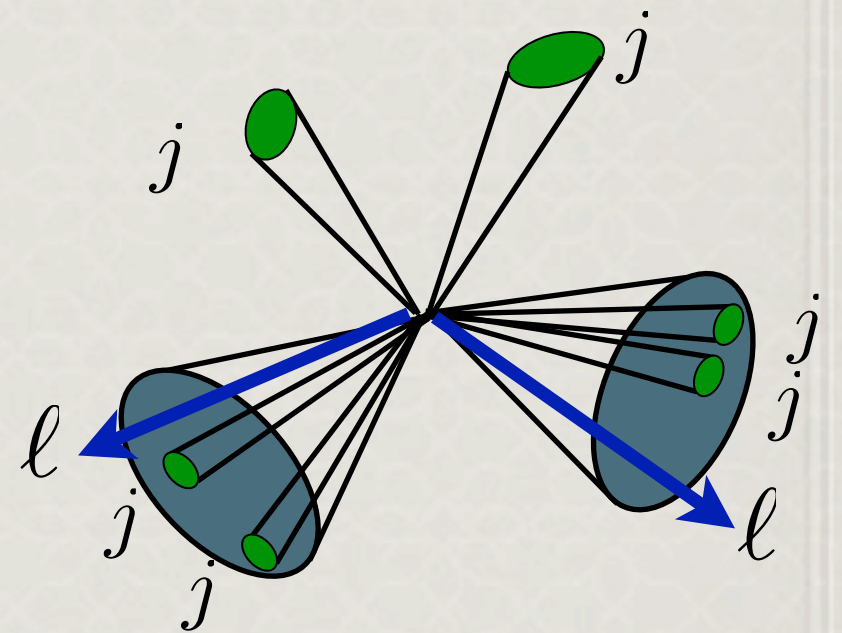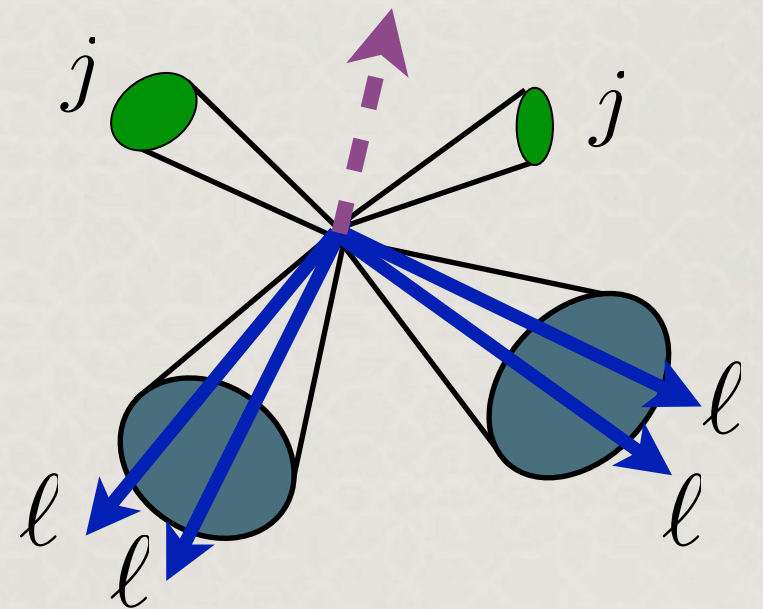

No significant MET, can reconstruct everything

R-Parity Violation

$$\tilde{q} \rightarrow \tilde{\chi}^0 q$$

$$W_{\mathrm{RPV}} = QD^c L \implies \tilde{\chi}^0 \rightarrow lqq$$
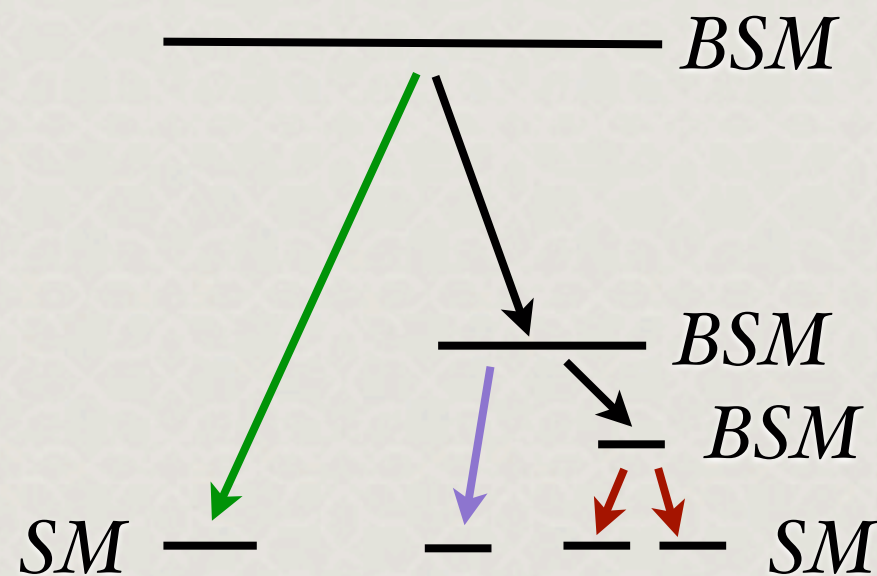
$$W_{\mathrm{RPV}} = LE^c L \implies \tilde{\chi}^0 \rightarrow \ell\ell\nu$$
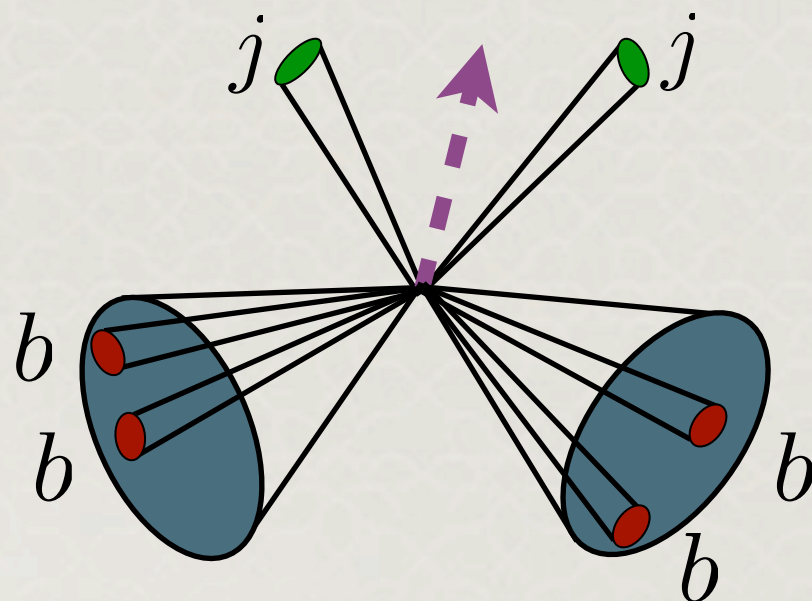
Susy Higgs Discovery

$$\tilde{q} \rightarrow q\chi_2 \rightarrow q(\chi_1 h)$$

Kribs et al 0912.4731

Higgs is the boosted final state
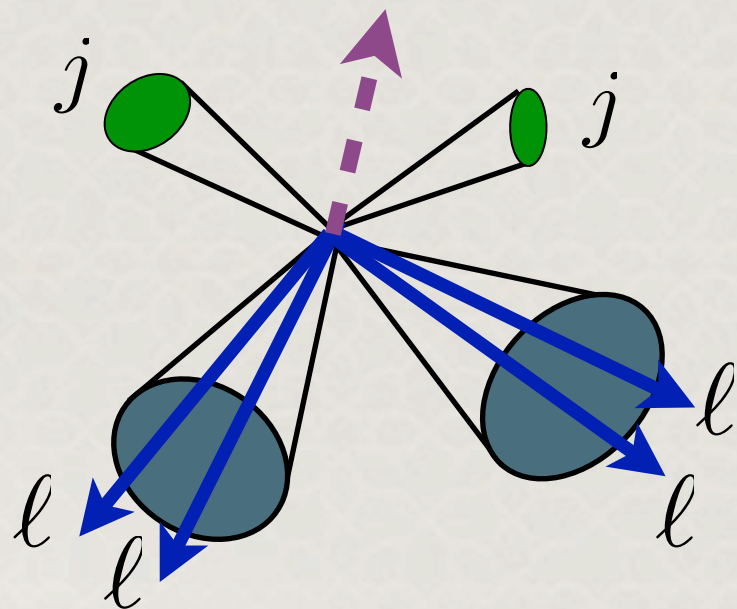
Supersymmetric New Light Mediators

$$\mathcal{L}_{\text{int}} \simeq \epsilon F^{\mu\nu} F'_{\mu\nu} \implies \mathcal{L}_{\text{int}} \simeq e\epsilon\, A'_\mu J^\mu_{\text{EM}}$$

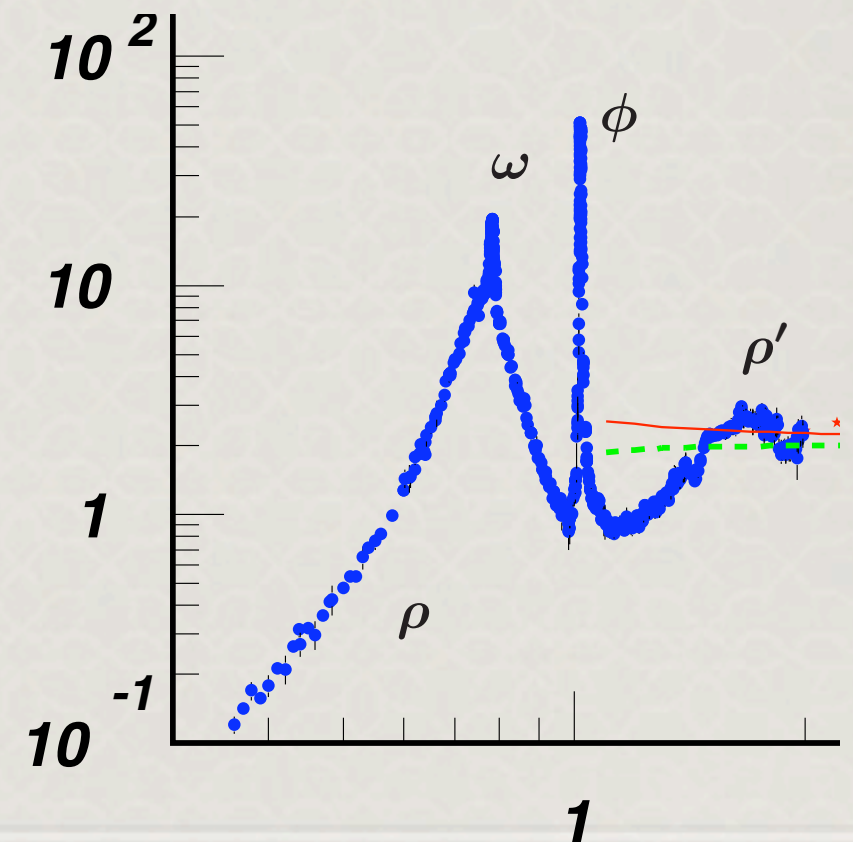$$\tilde{q} \to \tilde{A}' q \quad \tilde{A}' \to A'\, \tilde{G}$$

$$A' \to 2\mu, 2e$$

Arkani-Hamed et al 0810.0714
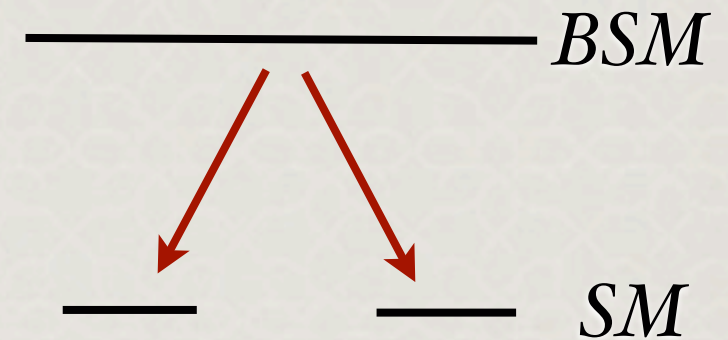*Cheung et al 0909.0290*
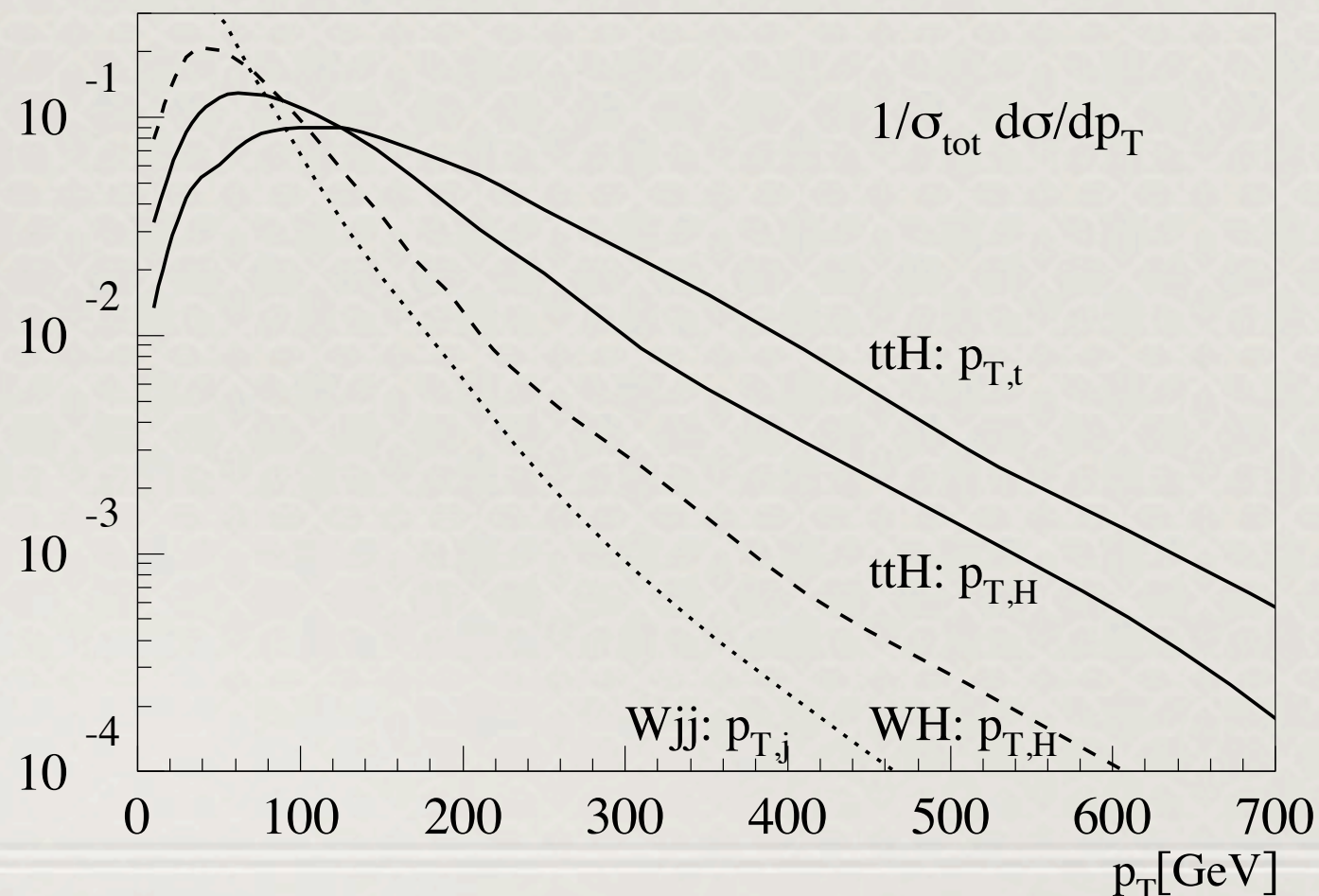
Boosted Light Particle Production

Boost comes from the pT of the process, not from a decay

Higgs Searches in Vh, or t t h
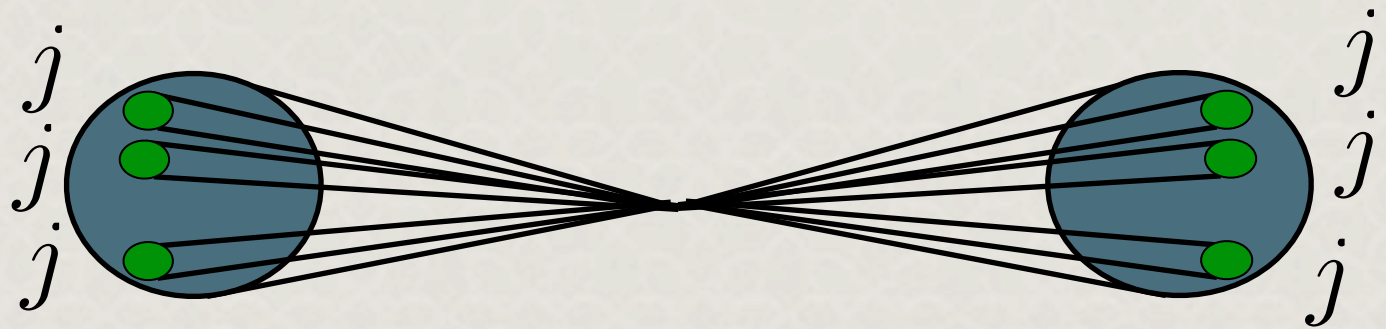
BSM

SM

Butterworth et al 0802.2470
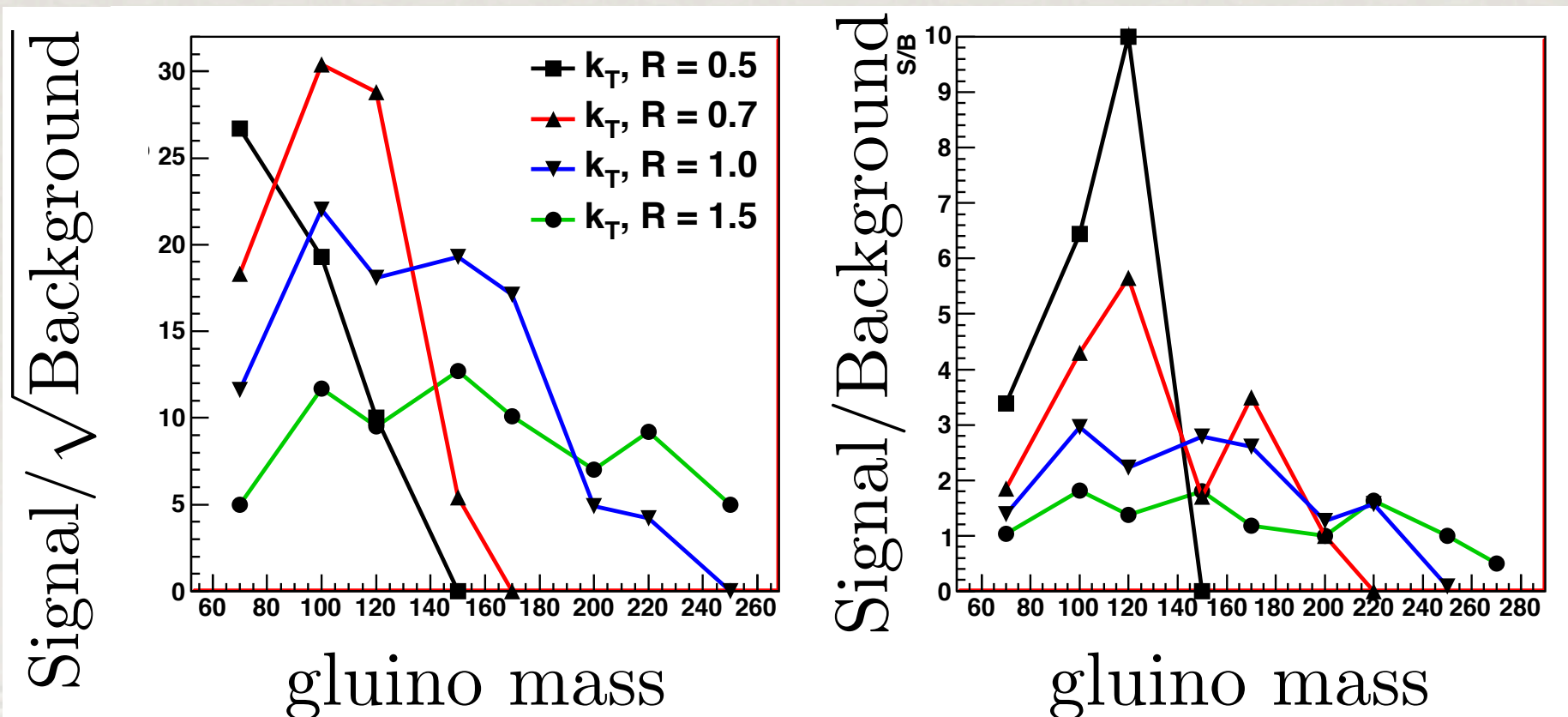
Plehn et al 0910.5472

Direct production of susy w/ RPV

Limits on gluinos are very weak $m_{\tilde{g}} \gtrsim 50$ GeV

gluino could be LSP... Produce high pT gluinos

Raklev et al in 1005.1229

Summary

Boosted final states unify a class of otherwise disparate signatures

Broadly grouped into leptonic and hadronic final states

Signatures & Searches are rapidly advancing!