

# Non Susy BSM in 1st session

Samir FERRAG

University of Oslo

# Introduction

- Non Susy:
  - Bug eyed research: (analysis by topology)
    - E. Busato, D. Chodury, S. Ferrag, R. Godbole and (G. Polesello, J. Lykken, G. Azuelos)
  - Universal Extra-dimensions
    - D. Goudjami, H. Przysiezniak
  - Higgsless and  $Z \rightarrow \tau\tau$ 
    - G. Azuelos
  - BSM Tools
    - See Peter's talk

# Analysis by topologies

- Motivation:
  - Understand the SM predictions and establish their uncertainty band
  - Every prediction outside this band is a signature of new physics
- 1<sup>st</sup> year of LHC:
  - Simple topologies and robust analyses:
    - Di-leptons, di-photons, dijets...

# First topologies

- Dileptons:
  - SM:  $M_{\ell\ell}$ , boost,  $\Delta\eta$ ,  $\theta^*$ ,  $\Delta\phi$   
.PDF,  $\mu_{\text{fact}}$ ,  $\mu_{\text{ren}}$
  - .WW, tt, tt, ECal linearity, charge mis-id, W+jet
  - S-channel resonances  
 $Z'$ ,  $G^*$ ,  $Z_H$ ,  $Z_{KK}$
  - Leptoquarks  
and Leptogluons
  - Heavy scalars  
Graviscalar, radion, heavy higgs
- Diphotons:
  - SM: using DiPhox  
.PDF,  $\mu_{\text{fact}}$ ,  $\mu_{\text{ren}}$ ,  $\mu_{\text{frag}}$ , isolation  
.2-jets,  $\gamma$ +jet, ECal linearity,
  - S-channel resonances  
 $G^*$
  - Virtual Excited quarks
  - Heavy scalars
  - Non commutative geometry:  
.Triphoton coupling

# Dileptons: Standard Model at high energy

- Observables:

$M_{\ell\ell}$ ,  $P_t$ , boost,  $\Delta\eta$

- MC@NLO:

$\sigma$  computed by 100 GeV bin  
 $200 \text{ GeV} < \text{invMass} < 2500 \text{ GeV}$

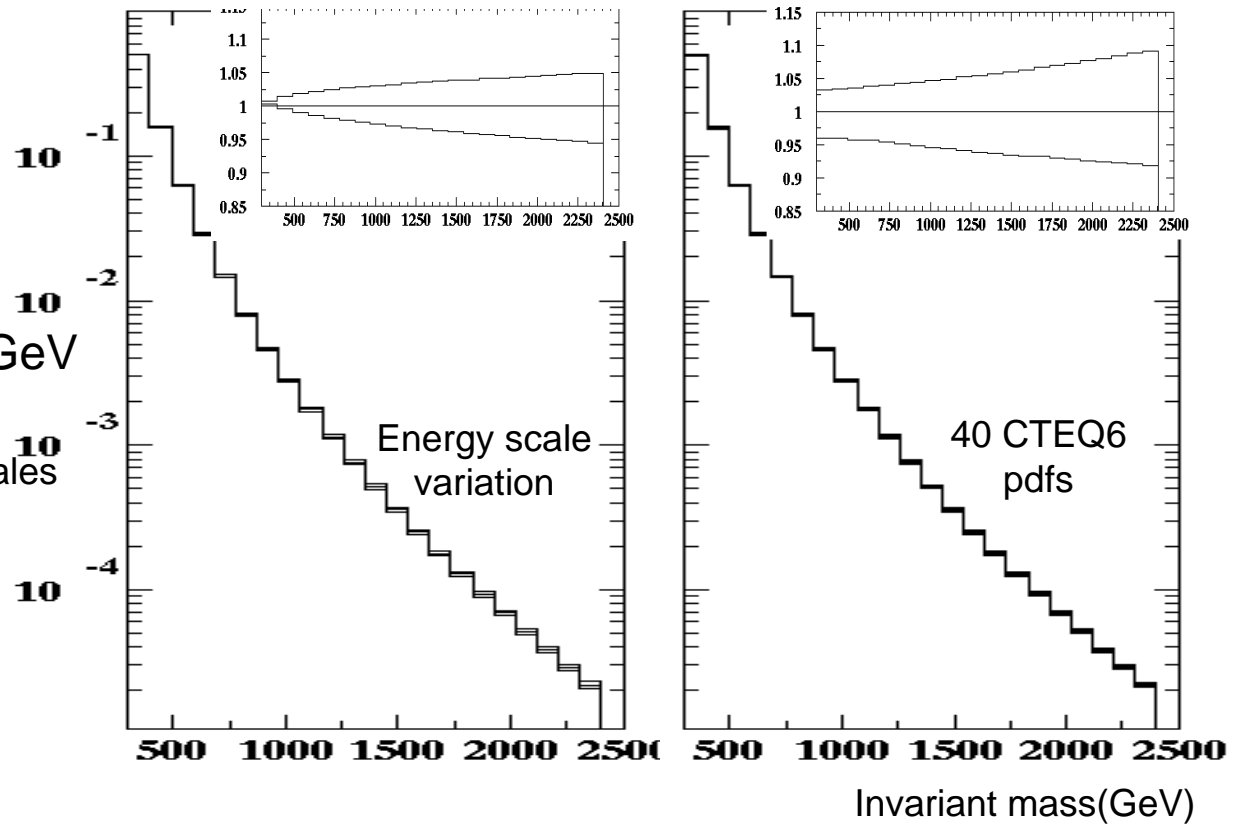
- Sources of uncertainties:

- Factorisation and Renormalisation scales

$$1/\pi * m_t < \mu < \pi * m_t$$

- PDFs

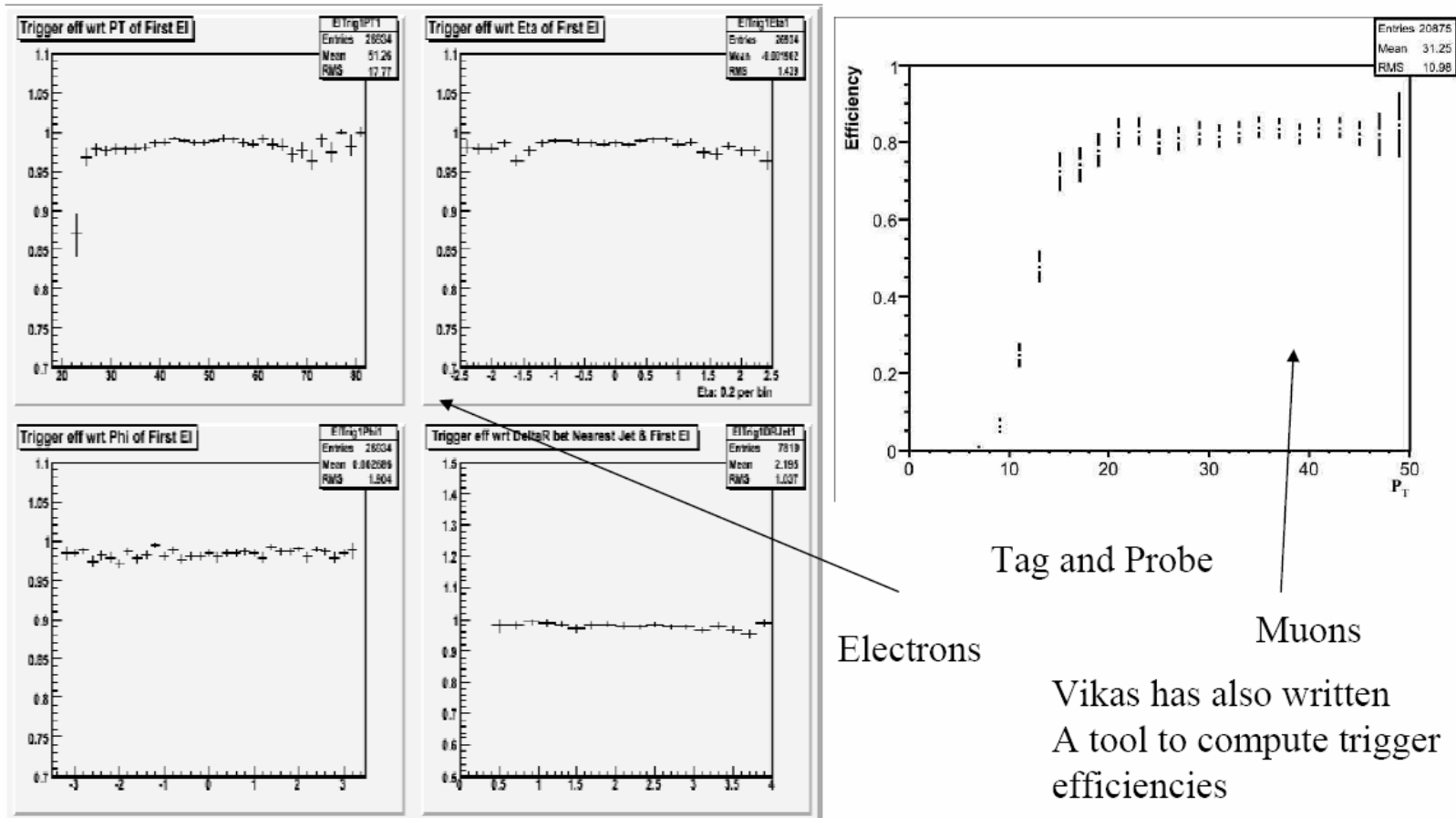
CTEQ6 40+1 pdf1



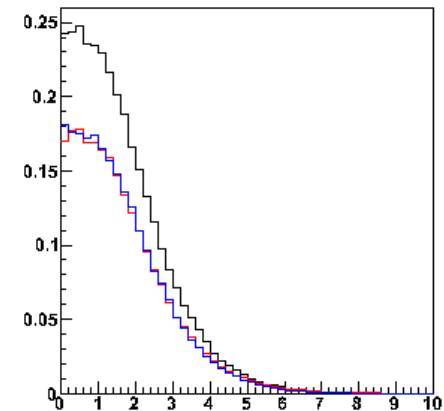
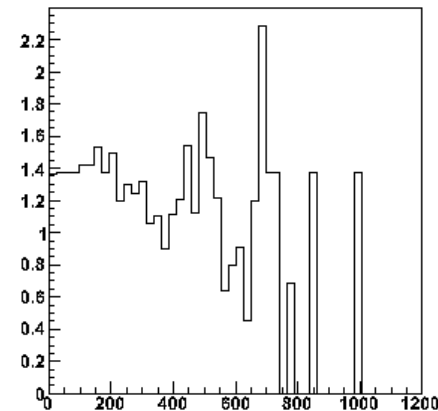
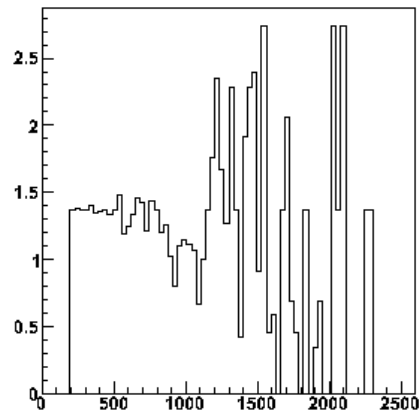
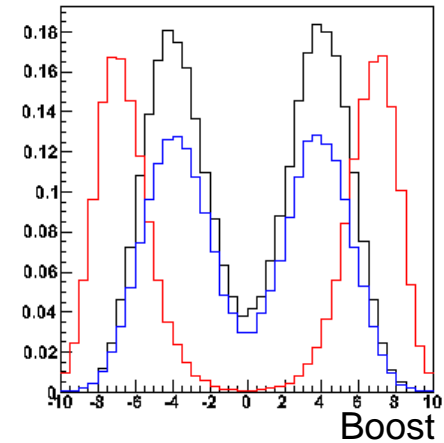
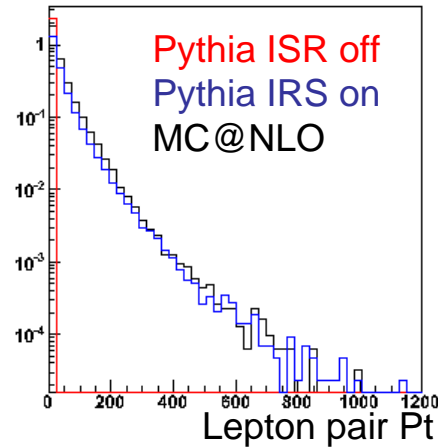
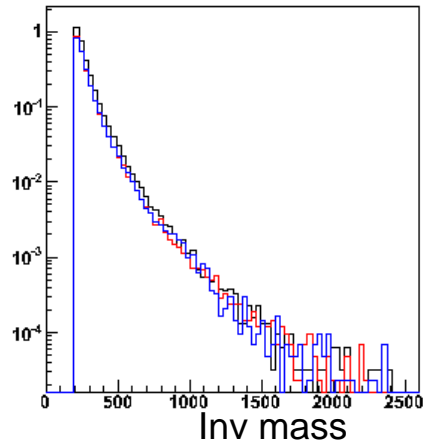
# Trigger studies

Electrons: V. Bansal

Muons: K. Black



# Dileptons: Standard Model



- energy scale pdf effects: in progress
- experimental study: WW,  $\tau\tau$ , tt, ECal linearity, charge mis-id, W+jet.  $\gamma$ -conversion
- Large x resummation and hard tails (Resbos, NNLO calculations)
- EW correction at high Pt spectrum

# Dileptons: LeptoGluon virtual exchange

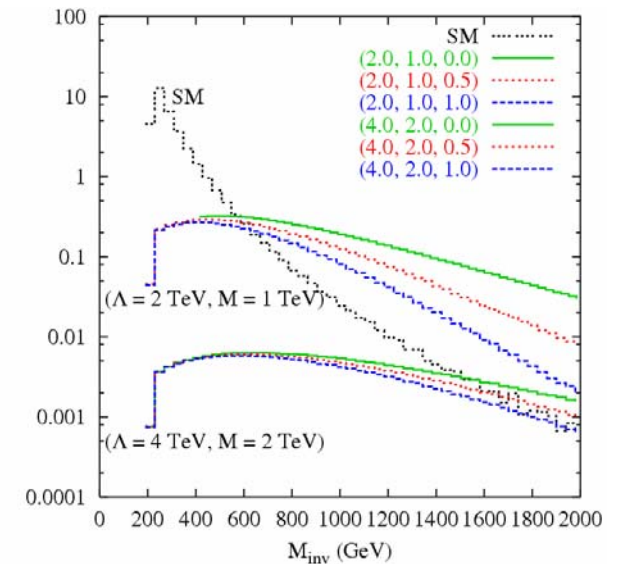
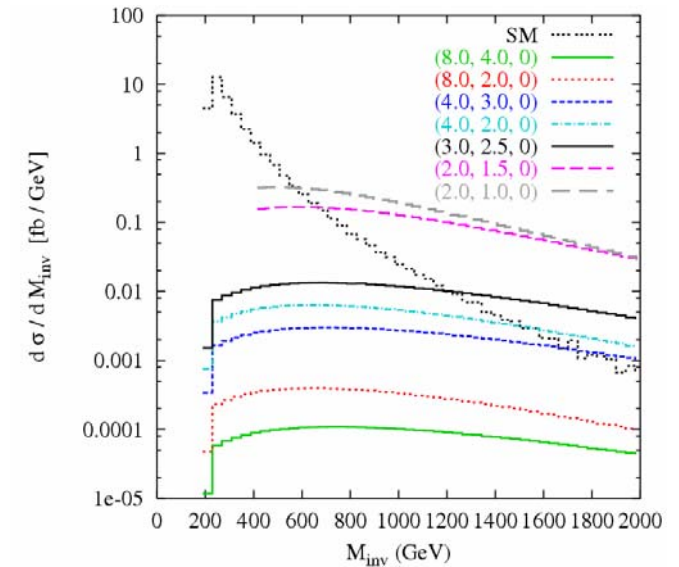
$$g + g \rightarrow \ell + \ell$$

- Spin 1/2 or 3/2 particles in composite models
- 2 scales (parameters) involved:  
 $\Lambda$  and  $M_{LG}$
- HERA limit: (resonance production)

$$\Lambda > 700 \text{ GeV for } M_{LG} \sim 150 \text{ GeV}$$

- Production cross section:

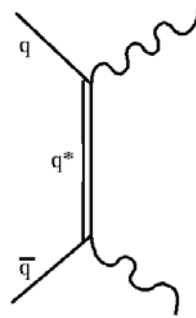
$$\frac{d\hat{\sigma}}{d\hat{t}}(gg \rightarrow \ell^+ \ell^-) = \frac{\pi \alpha^2}{4 \Lambda^4} \left\{ \frac{\hat{t} \hat{u}}{\hat{s}^2} \left[ \frac{\hat{t}^2}{(\hat{t} - M^2)^2} + \frac{\hat{u}^2}{(\hat{u} - M^2)^2} \right] + \frac{M^2}{\hat{s}} \left[ \frac{\hat{t}}{(\hat{t} - M^2)} + \frac{\hat{u}}{(\hat{u} - M^2)} \right]^2 \right\}$$





# DiPhotons: Virtual exchange of excited quark

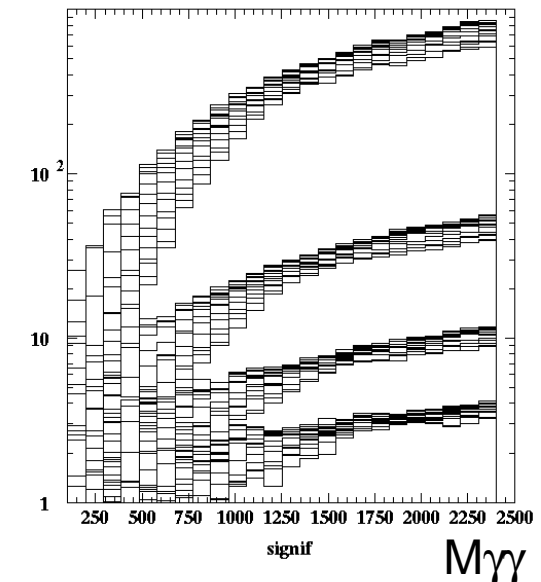
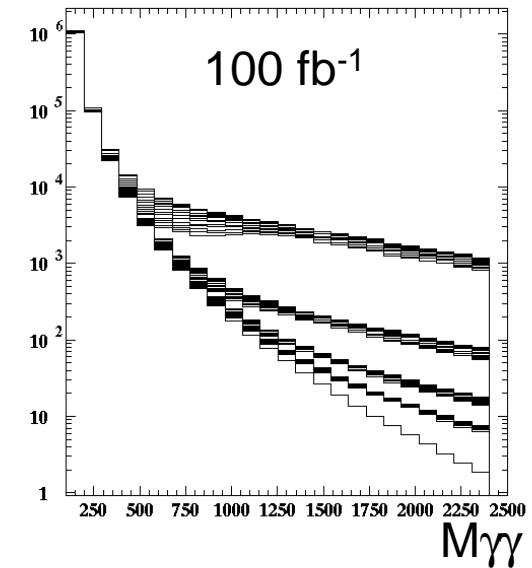
$$q + q \rightarrow \gamma + \gamma$$



- Spin  $\frac{1}{2}$  particles in composite models
- 2 scales (parameters) involved:  
 $\Lambda$  and  $M_{EQ}$
- Production cross section:

$$\begin{aligned} \frac{3\hat{s}^2}{2\pi\alpha^2} \frac{d\hat{\sigma}}{d\hat{t}} &= e_q^4 \left[ \frac{\hat{u}}{\hat{t}} + \frac{\hat{t}}{\hat{u}} \right] \\ &- \frac{e_q^2}{\Lambda^2} \left[ \frac{\hat{t}^2}{\hat{t} - M^2} + \frac{\hat{u}^2}{\hat{u} - M^2} \right] \\ &+ \frac{1}{\Lambda^4} \left\{ \hat{t}\hat{u} \left[ \frac{\hat{t}^2}{(\hat{t} - M^2)^2} + \frac{\hat{u}^2}{(\hat{u} - M^2)^2} \right] + M^2 \hat{s} \left[ \frac{\hat{t}}{(\hat{t} - M^2)} + \frac{\hat{u}}{(\hat{u} - M^2)} \right]^2 \right\} \end{aligned}$$

- Implemented in Pythia



# UED scenario and Gravity Mediated decays of the LKP

Driss Goujdami, Université Cadi Ayyad Marrakech  
Helenka Przysiezniak, LAPP, Annecy

- 1  $\text{TeV}^{-1}$  Extra-dimension + N large extra-dimensions  $eV^{-1}$
- SM particles allowed only in  $\text{TeV}^{-1}$  and gravitation propagates everywhere
- KK number is conserved (Momentum conservation along XD)  
→ Pair production only and stable Lightest KK Particle (LKP= $\gamma^*$ )
- At tree level, the KK masses:  
 $m_n^2 = n^2/R^2 + m_{SM}^2$  ( $\sim \text{TeV}^{-1}$ )
- Heavier KK decay cascade → LKP + soft SM particles.
- LKP: missing energy or gravity mediated decay (KK number violation)  
([hep-ph/0201300](#) Maccesanu, McMullen, Nandi;  
[Phys.Rev.D64, 095010 \(2001\)](#), T.G.Rizzo;  
[Phys.Lett.B482 195\(2000\)](#), A.DeRujula, A.Donini, M.B.Gavela and S.Rigolin).
- Studied exemple:  $\gamma^* \rightarrow \gamma + \text{massive Graviton}$  (which is massive).

## TOOLS

### Generation: CompHEP

Two 5D fermionic fields denoted  $q^\bullet$  and  $q^\circ$  are associated to each SM fermion

| Processes  | $\sigma$ fb | Processes  | $\sigma$ fb | Processes  | $\sigma$ fb |
|--|-------------|--|-------------|--|-------------|
| $gg \rightarrow g^* g^*$                           | 212         | $q\bar{q} \rightarrow g^* g^*$                   | 14          | $qg \rightarrow q^\bullet g^*$                     | 605         |
| $qq \rightarrow q^\bullet q^\bullet$               | 175         | $q\bar{q} \rightarrow q^\bullet \bar{q}^\bullet$ | 25          | $gg \rightarrow q^\bullet \bar{q}^\bullet$         | 11          |
| $q\bar{q} \rightarrow q'^\bullet \bar{q}'^\bullet$ | 22          | $qq' \rightarrow q^\bullet q'^\bullet$           | 121         | $q\bar{q}' \rightarrow q^\bullet \bar{q}'^\bullet$ | 26          |
| $qq \rightarrow q^\bullet q^\circ$                 | 222         | $q\bar{q} \rightarrow q^\bullet \bar{q}^\circ$   | 16          | $qq' \rightarrow q^\bullet q'^\circ$               | 84          |
| $q\bar{q}' \rightarrow q^\bullet \bar{q}'^\circ$   | 38          |  |             |  |             |

$1/R = MKK = 1.3 \text{ TeV}$

### Cascade decay: Pythia

Existing excited quark and boson decay channels are used

$$q_1^\bullet \rightarrow q Z_1^* \rightarrow q l l_1^\bullet \rightarrow q l l \gamma_1^*, \quad \text{Br.} \sim 33\%$$

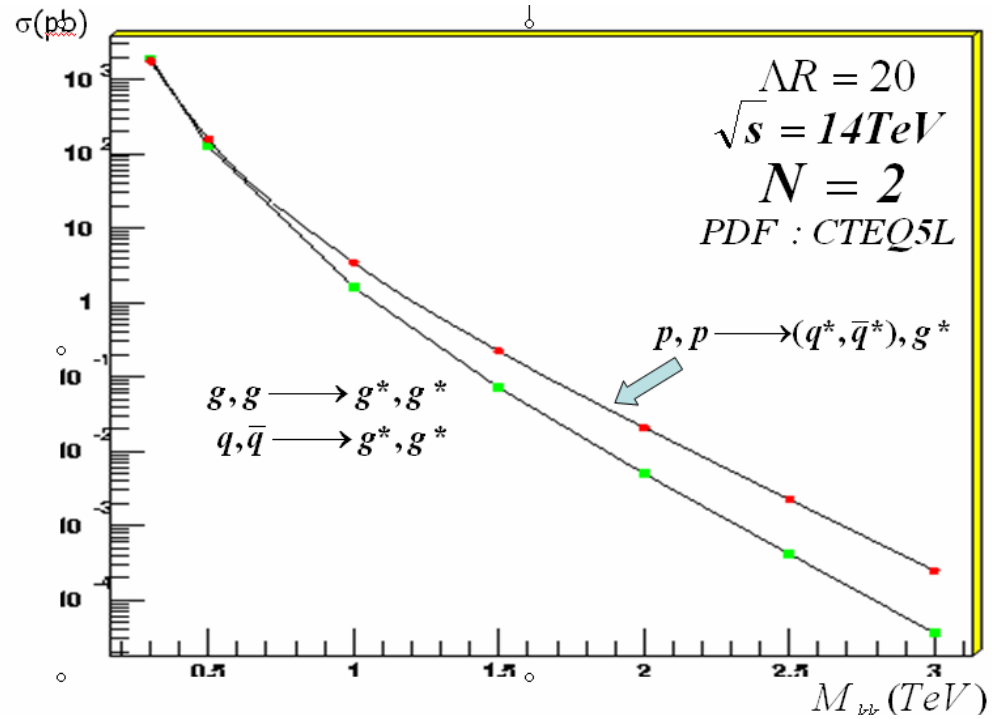
$$q_1^\bullet \rightarrow q W_1^* \rightarrow q l' l_1^\bullet \rightarrow q l' l \gamma_1^*, \quad \text{Br.} \sim 65\%$$

LKP decay  $\gamma^* \rightarrow \gamma + G$ : *GMSB* decay of LSP  $\rightarrow$  gravitino+photon is used.

**Our ultimate plans are to decay the KK photon outside of Pythia using proper integration over all graviton KK states and taking into account spin effects.**

# UED: some results

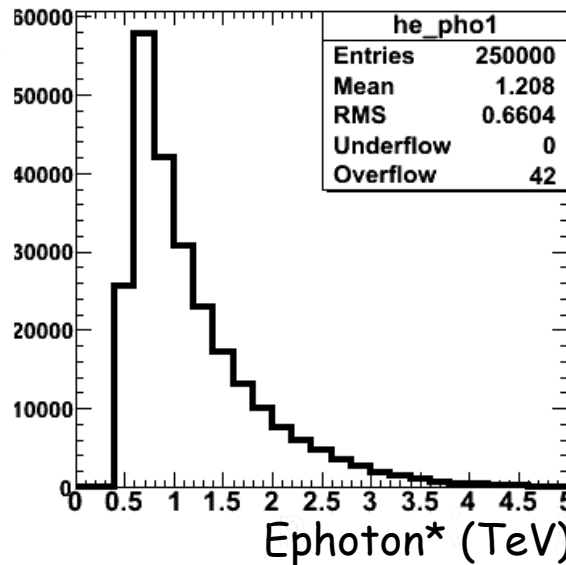
Production Cross Sections  
from CompHEP



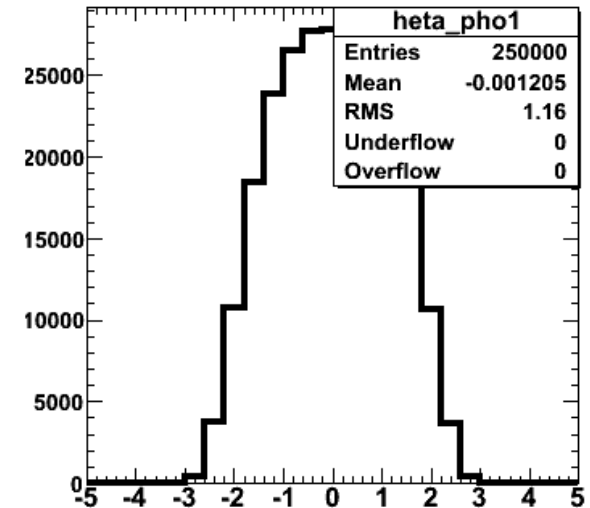
Cascade decay from Pythia  
 $1/R=500 \text{ GeV}, \Lambda R=10$

$$\begin{aligned}
 q_1^\bullet &\rightarrow q Z_1^* \rightarrow q l l_1^\bullet \rightarrow q l l \gamma_1^*, \\
 q_1^\bullet &\rightarrow q W_1^* \rightarrow q l' l_1^\bullet \rightarrow q l' l \gamma_1^*,
 \end{aligned}$$

Ephotons\* truth (in TeV)



Eta photons\* truth



# Higgsless models

G. Azuelos

Warped space, with boundary conditions that break the symmetry on the TeV brane and on the Planck brane:

C. Csáki et al., hep-ph/0310355,  
C. Csáki, hep-ph/0412339

The model explains:

- $\gamma$  : massless photon (flat wavefunction in bulk)
- $W, Z$  : lowest KK states of massive gauge bosons
- correct ratio of  $W/Z$  mass

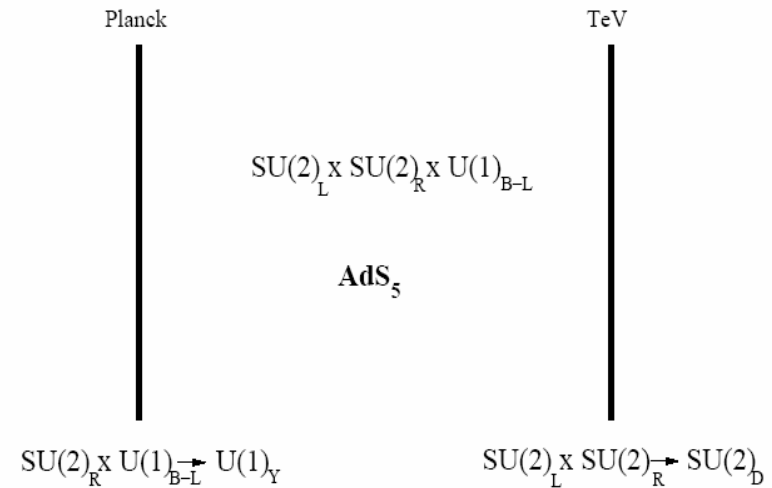
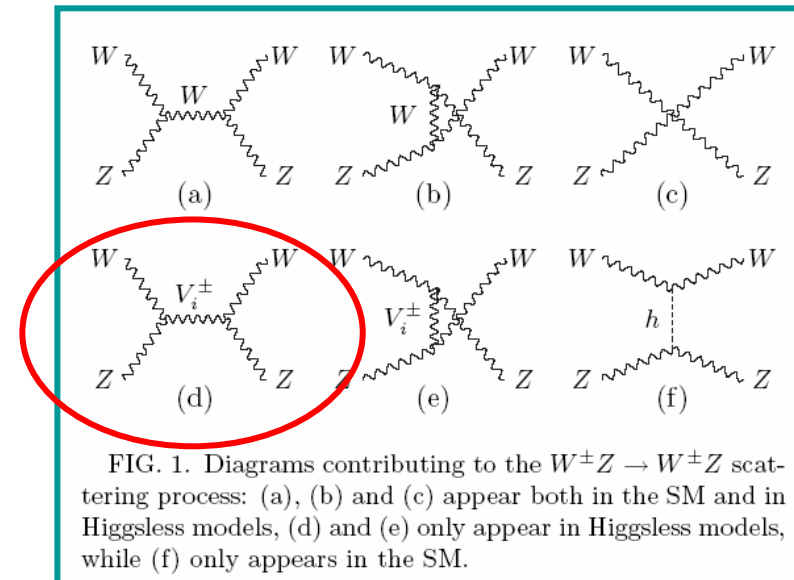


Figure 3: The symmetry breaking structure of the warped higgsless model.

## Important constraints:

- **S parameter from LEP:**  
→ weak coupling of  $Z'$  to fermions (and possibly light  $Z'$ )
- **unitarity in VB scattering**  
→ resonances in  $WZ$  scattering distinguishable from QCD-like chiral Lagrangian model resonances.
- **problems with the top**



A. Birkedal et al., hep-ph/0412278

# resonance in WZ scattering

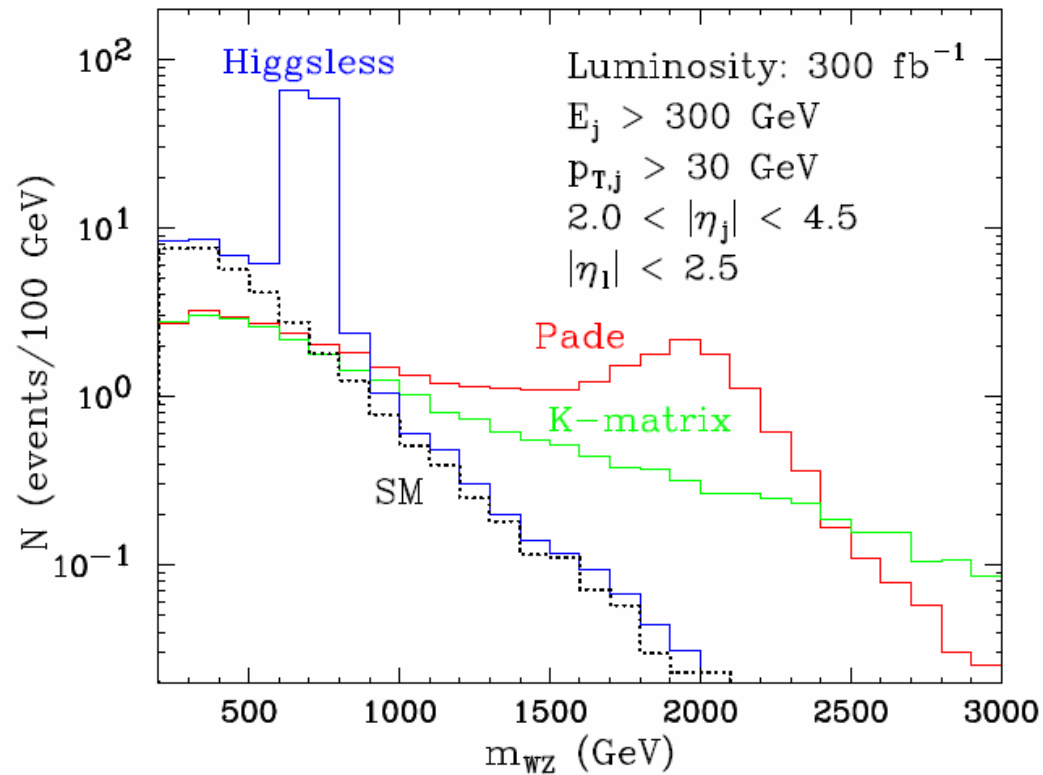


FIG. 4. The number of events per 100 GeV bin in the  $2j + 3\ell + \nu$  channel at the LHC with an integrated luminosity of  $300 \text{ fb}^{-1}$  and cuts as indicated in the figure. The model assumptions and parameter choices are the same as in Fig. 2.

# BSM Tools – Session 1

Contact: Peter Skands  
(skands@fnal.gov)

Discussions so far concentrated on:

- Extending the SUSY Les Houches Accord
- Tools for Extra Dimensions
- Tools for NMSSM and CPV-SUSY
- + some bug-eyed BSM ...

# Projects - 1

- **Extending the SLHA** [Allanach, Porod, Moortgat, Penaranda, Desch, Wienemann, Skands, Schumacher, Lykken, Godbole, Kraml, Choudhury, Guchait, Boudjema, ...]
  - CPV, RPV, Flavour Violation, NMSSM
  - Framework for Theory Errors, Cross sections
  - Validating Tools
- **Tools for Extra Dimensions** [Ferrag, Kraml, de Roeck, Azuelos, Skands, Miakov?]
  - Collecting a repository, review available tools
  - Validating, esp private and semi-public tools
  - Towards standardization & benchmarks?



# Projects - 2

- **K-factors / Universality**

Huston, Mrenna, more?

- To what extent are higher-order corrections universal?

- **Event Generators for NMSSM**

Hugonie, Skands, Moretti, Kraml, Zerwas

- Very important to investigate more & soon, need tools. NMHDecay + event generators ...

- **Event Generators for CPV-SUSY**

Mrenna, Kraml, Schumacher, Richardson?