Tt resonance searches

Marcel Vos, IFIC Valencia

Early resonance search?

Resonances may occur in many models.

To be relevant for early physics the cross-section must be large

resonance X	Γ/M	B.R. (X->tt)	σ (1 TeV)	σ x BR (1 TeV)
sequential Z'	3.0%	11%	12.7 pb	1.39 pb
Little Higgs Z_H (cot θ = 1)	3.4%	13%	16.8 pb	2.10 pb
LR Twin Higgs Z_H	2.7%	8%	13.3 pb	1.0 pb
KK g* (universal couplings)	20%	17%	1109 pb	190 pb
Basic RS g*	15%	92%	30 pb	28 pb

Quite generally, narrow resonances require a sensitivity on σxBR that is out of reach for another year or two (expect 100 events over winter)

Resonances with large couplings to light quarks are produced abundantly, but by the same token they are no longer narrow wrt experimental resolution

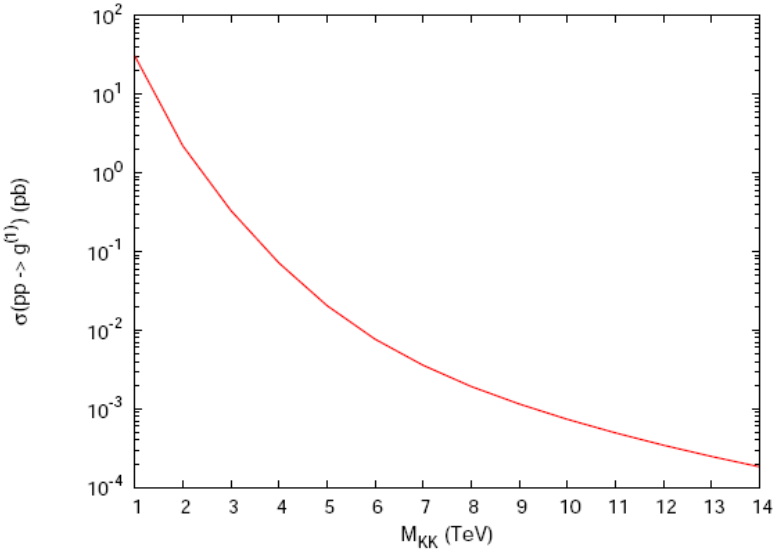
Example: Little Higgs resonance, for cot θ = 3 the cross-section increases by a factor 9 (reaching 20 pb @ 1 TeV), but so does the width (Γ/M = 30 %)

analysis	mass resolution	sensitivity
traditional (CERN-OPEN-2008-020)	1%	σxBR = 8 pb @ 1 TeV yields 5 σ discovery
Mono-jet (ATL-COM-PHYS-2008-18	0%	σxBR =140 fb @ 2 TeV, 95 % C.L. Exclusion

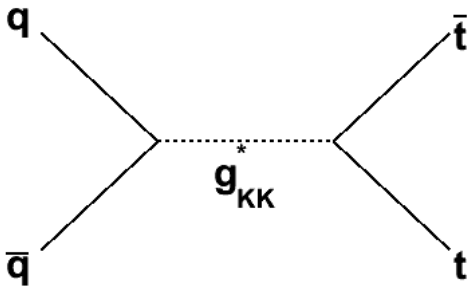
An example of a signal

RS warped (universal) extra dimensions

Randall, Lillie and Wang,
The Bulk RS KK-gluon at the LHC,
JHEP 0709:074 (2007)



When SM gauge penetrate the bulk, Kaluza Klein towers of excited states appear. The KK gluon has some quite attractive features for experimentalists



couples strongly to quarks:

large cross-section: 15 pb for $m(g^*_{KK}) = 1$ TeV @ 10 TeV

but, by the same token:

not a narrow resonance! Basic RS model: $\Gamma = 0.17\ M$

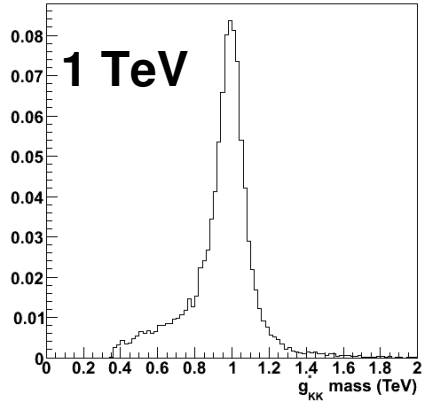
Large branching fraction into tt

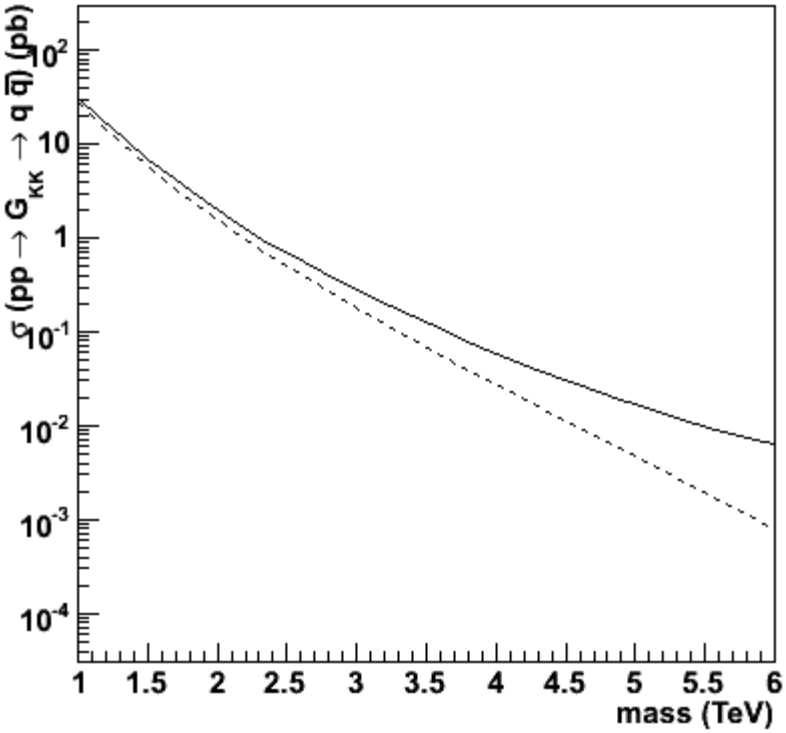
Basic RS scenario: 92.6 %

Fast simulation study into ATLAS potential of heavy gluon searches, March, Ros, Salvachua, PHYS-PUB-2006-002

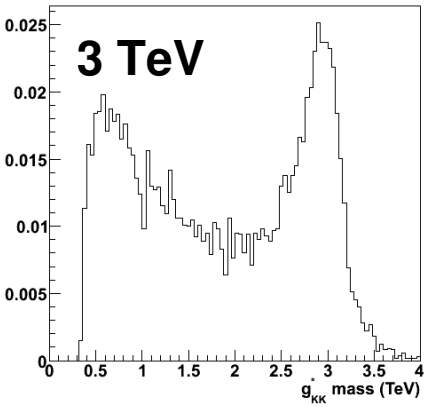
Generate some events

MadGraph/MadEvent (Maltoni/Stelzer, hep-ph/0208156)
TopBSM model (R. Frederix and F. Maltoni, 0712.2355)
with some modifications (thanks to R. Frederix)
Full Matrix Element calculation of pp → g* → tt → bb lν
g* is represented by a generic colour octet labelled o1





Mass distribution:
Convolution of broad Breit-Wigner and luminosity function



MadGraph:
cross-section @ 14 TeV
within nominal mass ± 30 %

Early tt resonance search paper

tt-resonance search among the “early ATLAS physics papers”.
Need to work out the complete experimental strategy for early data. Be prepared for discovery, or to significantly sharpen Tevatron limits with 100 pb^{-1}.

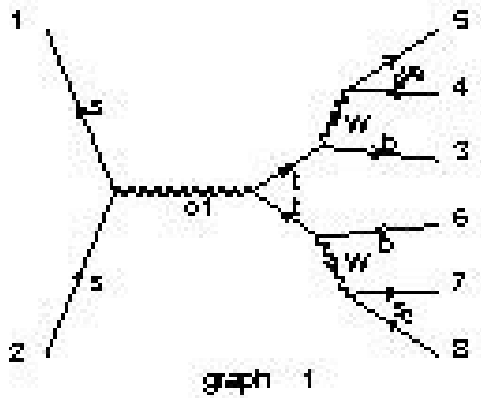
Monte Carlo requests:

The signal: basic Randall-Sundrum KK gluon, m = 1 TeV
Z' narrow resonance, m = 1 TeV

The backgrounds: Standard Model tt (105200, common, 2008)
W+jets (107680/107690/107700, common, 2008)
Di-jet J0-J8 (105009,common,2008)
High p_T tops (105208, top group, 2009)

MadGraph output

```
#*********************************************************************
#                    MadGraph/MadEvent                              *
#                  http://madgraph.hep.uiuc.edu                     *
#                     proc_card.dat                                 *
#*********************************************************************
# Begin PROCESS # This is TAG. Do not modify this line
qq~>(t>b(w+>levle))(t~>b~(w->qq~))/s1azg
QCD=0              # Max QCD coupling
QED=4              # Max QED coupling
QS0=0
QS1=2              # QS1 used also for O1
QS2=0
end_coup           # no more couplings for this proc
done               # no more procs
# End PROCESS  # This is TAG. Do not modify this line
#---------------------------------------------------------------------
# Begin MODEL  # This is TAG. Do not modify this line
topBSM2
# End   MODEL  # This is TAG. Do not modify this line
#---------------------------------------------------------------------
# Begin MULTIPARTICLES # This is TAG. Do not modify this line
q udscb
q~ u~d~s~c~b~
le e+e-mu+mu
vle veve~vmvm~
# End  MULTIPARTICLES # This is TAG. Do not modify this line
```



TopBSM: standard MadGraph model that provides generic tt resonances (spin, colour), Rikkert Frederix

TopBSM2:improved version that allows to set quark couplings individually. This yields the correct cross-section and width for a basic RS KK gluon. Now standard on Louvain cluster

The “o1” particle with PDG code 47 must be converted to “g*” with 5100021

Status of KK gluon sample

- a small sample LHA file is available under
  http://ific.uv.es/~vos/semi_leptonic2.events
- Large event files under:
  `srm://srmv2.ific.uv.es//lustre/ific.uv.es/grid/atlas/scratch/users/vos/kkgluon`

- Pythia 6.148 (in ATHENA 14.2.X) fails to process the LHA event files due to very frequent colour connection errors:

  Error type 2 has occured after 46 PYEXEC calls
  (PYPREP:) no matching colour tag: 5

  see log files (thanks to TadaAki Isobe) in:
  user09.TadaakiIsobe.valid.090422.isobe.kkgluon1tev_tadaakiFile.EVGEN.v14022509

- Pythia8 works fine (but lacks an interface in ATHENA 14.2.x)
- Herwig does not recognize PDG code 5100021
- Pythia 6.149 (in ATHENA 15.0.0.x) works much better (thanks to Bertrand Brelier for pointing this out).

Early tt resonance paper

Reconstruction algorithms (top reco group):

- **adapted version of resolved approach**
- **dedicated high p_T top reconstruction/identification**

Understand implications in resonance searches:

- **efficiency**
- **mass resolution**
- **intermediate mass region**

Establish ATLAS reach

- **very early (few 100 pb^{-1} – 1 fb^{-1}, 700 GeV – 1.5 TeV, broad?)**
- **longer term (2-3 TeV)**

One, two, three,... papers

Proposal: ATLAS should write a *single* ATLAS note, available to non-ATLAS public, where all the relevant aspects of tt resonance searches are discussed

Under discussion!

- strong overlap with Jet+X tt skeleton paper (i.e. paper contains key results)
- strong overlap with top reconstruction (to be coordinated)

Time scale: before the start of data taking

Inventory of Jet+X effort required. Please, feel free to sign up by sending me an e-mail. Contributions to be added to:

https://twiki.cern.ch/twiki/bin/view/AtlasProtected/ExoticTtResonances

MadGraph output: Les Houches event file

```
<event>
 13   0  0.7803800E-04  0.1743000E+03  0.7818608E-02  0.1178854E+00
     -2  -1   0   0   0 503  0.00000000000E+00  0.00000000000E+00  0.16290713358E+03  0.162907133
      2  -1   0   0 502   0  0.00000000000E+00  0.00000000000E+00 -0.10541830031E+04  0.105418300
     47   2   1   2 502 503 -0.34106051316E-12  0.45474735089E-12 -0.89127586948E+03
     -6   2   3   3   0 503 -0.15364958232E+03  0.19221295670E+03 -0.28271256955E+02  0.302931889
      6   2   3   3 502   0  0.15364958232E+03 -0.19221295670E+03 -0.86300461252E+03  0.914158246
    -24   2   4   4   0   0 -0.14139956292E+03  0.19253721053E+03  0.19790393643E+02  0.253155084
     24   2   5   5   0   0  0.38379054970E+02 -0.52978390997E+02 -0.47687670354E+03  0.487794598
      5   1   5   5 502   0  0.11527052735E+03 -0.13923456571E+03 -0.38612790899E+03  0.426363648
    -13   1   7   7   0   0  0.48427617078E+02 -0.66683787494E+02 -0.33896919137E+03  0.348843911
     14   1   7   7   0   0 -0.10048562108E+02  0.13705396497E+02 -0.13790751216E+03  0.138950686
     -5   1   4   4   0 503 -0.12250019396E+02 -0.32425382905E+00 -0.48061650598E+02  0.497768055
      1   1   6   6 501   0 -0.28217227696E+02  0.52204272629E+02 -0.29472887201E+02  0.662582002
     -2   1   6   6   0 501 -0.11318233522E+03  0.14033293790E+03  0.49263280843E+02  0.186896884
</event>
```

Process Les Houches files using Pythia.

Problem: Pythia doesn't know what this particle 47 is. In particular, the colour reconnection algorithms get confused.

Pythia version ≥ 6.4.18 do know g(1) = 5100021

PDG particle naming scheme

$R^{+}_{\tilde{t}_1 u d_1}$	1006213
$R^{++}_{\tilde{t}_1 u u_1}$	1006223
$R^{0}_{\tilde{t}_1 s d_0}$	1006311
$R^{0}_{\tilde{t}_1 s d_1}$	1006313
$R^{+}_{\tilde{t}_1 s u_0}$	1006321
$R^{+}_{\tilde{t}_1 s u_1}$	1006323
$R^{0}_{\tilde{t}_1 s s_1}$	1006333

SPECIAL PARTICLES

G (graviton)	39
R^0	41
LQ^c	42

KALUZA-KLEIN EXCITATIONS

$d_L^{(1)}$	5100001*
$u_L^{(1)}$	5100002*
$e_L^{(1)-}$	5100011*
$\nu_{eL}^{(1)}$	5100012*
$d_R^{(1)}$	6100001*
$u_R^{(1)}$	6100002*
$e_R^{(1)-}$	6100011*
$\nu_{eR}^{(1)}$	6100012*
$g^{(1)}$	5100021*
$\gamma^{(1)}$	5100022*
$Z^{(1)0}$	5100023*

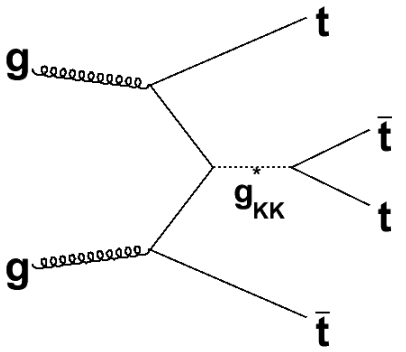
An example of a signal

Remember: it's just one example of a signal...

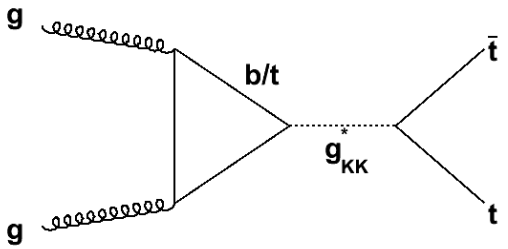
The other gauge bosons are not considered

Higher-order process are less dependent on couplings to light quarks

Many possible choices for parameters



Scenario	g^q	$g_L^b = g_L^t$	g_R^b	g_R^t	$\Sigma(g^*_{KK} \to qq)$	$\Sigma(g^*_{KK} \to bb)$	$\Sigma(g^*_{KK} \to tt)$	$\Gamma g^*/Mg^*$
Basic RS	-0.2	1	-0.2	4	1.7%	5.7%	92.6%	0.153
$kr_{IR} = 5$	-0.4	-0.2	-0.4	0.6	68.1%	10.6%	21.3%	0.016
$Kr_{IR} = 20$	-0.8	-0.6	-0.8	-0.2	78.5%	15.3%	6.1%	0.054
SO(5), N=0	-0.2	2.76	-0.2	0.07	2.0%	49.1%	48.9%	0.130
SO(5), N=1	-0.2	2.76	-0.2	0.07	0.7%	16.0%	15.9%	0.400
E_1	-0.2	1.34	0.55	4.9	1.1%	7.4%	91.4%	0.235
E_2	-0.2	1.34	3.04	4.9	0.9%	29.7%	69.4%	0.310
E_3	-0.2	1.34	0.55	3.25	2.2%	14.2%	83.6%	0.123
E_4	-0.2	1.34	3.04	3.25	1.3%	46.6%	52.1%	0.198



From: Baur and Orr, arXiv:0803.1160

Basic RS: Randall, Lillie and Wang, JHEP 0709:074 (2007)

Large brane kinetic terms:H. Davoudias, J.L. Hewett, T.G. Rizzo,Phys. Rev. D 68, 045002 (2003), M. S. Carena, E. Ponton, T. M. P. Tait and C. E. M. Wagner, Phys. RevD 67 (2003), Phys. Rev. D 71 (2005)

Custodial symmetry (SO(5) x U(1)$_x$):M. S. Carena, E. Ponton, J. Santiago and C. E. M. Wagner, Phys. Rev. D 76, 035006 (2007)

A^b_{FB} inspired: A. Djouadi, G. Moreau, and R.K. Singh, Nucl. Phys. B 797 (2008)