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)

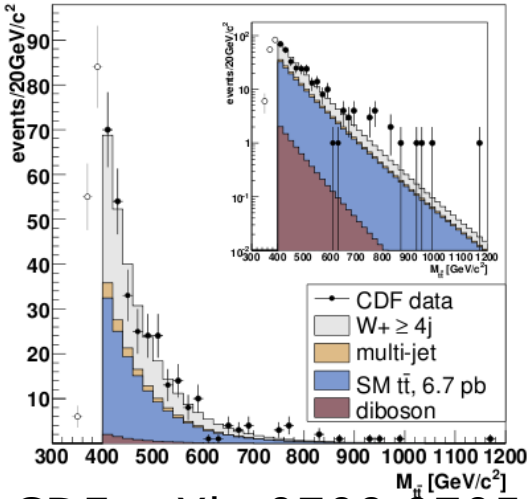
Resonances with large couplings to light quarks are produced abundantly, but by the same token they are no longer narrow wrt experimental resolution

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 %)

Tevatron searches

Important program at the Tevatron with ~ 20 papers since 2000 on searches for (narrow) tt resonance searchesand **$d\sigma/dM_{tt}$** measurement

D0, arXiv:0804.3664
CDF, arXiv:0710.5335v1, arXiv:0903.2850



CDF arXiv:0709.0705

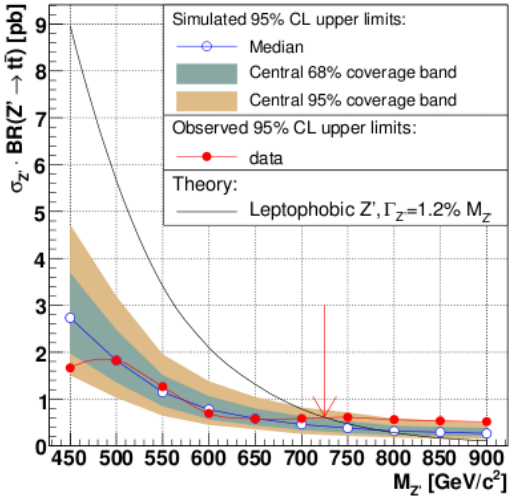
Few tt events at large invariant mass

Limits derived for narrow resonances with a sensitivity in mass range 0.7-1 TeV of:

σ x BR ~ 300 fb

leptophobic Z' in topcolor (hep-ph/9911288)

σ X BR= 700 fb @ 750 GeV
σ X BR= 80 fb @ 950 GeV



LHC early data:

200 pb^{-1} pp @ 10 TeV = 80.000 tt pairs

Tevatron

8 fb^{-1} ppbar @ 1.96 TeV = 64.000 tt pairs)

ATLAS prospects

Broad KK gluon, high-mass reconstruction scheme, exotics group

ATL-PHYS-PUB-2006-002

Narrow, standard top reco tools, top group

ATL-PHYS-PUB-2006-033. Updated, ATL-COM-PHYS-2008-082
CERN-OPEN-2008-020
ATL-COM-PHYS-2008-099

Results for different studies into the ATLAS potential for tt resonance searches

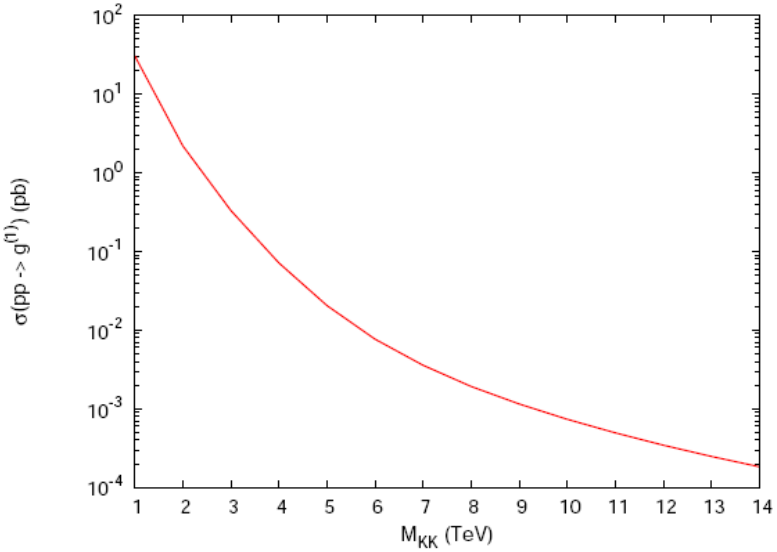
CERN-OPEN-2008-020	2%	6%	σxBR = 8 pb @ 1 TeV, 5 σ discovery
ATL-COM-PHYS-2008-184	?	5% (*)	σxBR =140 fb @ 2 TeV, 95 % C.L. Exclusion
ATL-PHYS-PUB-2006-002	10% x ε_b	15%	mass reach of 3 TeV

Comparison of methods generally not possible (mono-jet vs. classical resolved approach, ATLFAST vs. full, broad vs. narrow, b-tagging vs. none, mass ranges, limit vs. discovery, systematics)

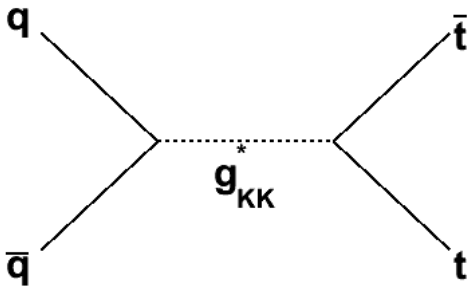
An example of a signal

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: $\Gamma = 0.17\ M$

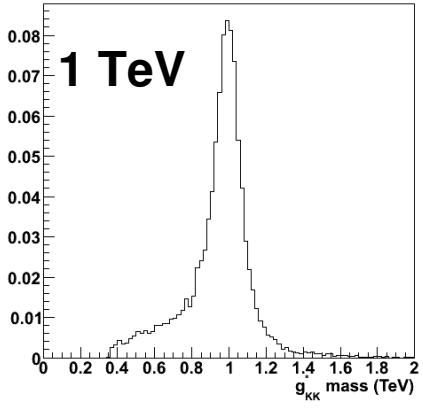
Large branching fraction into tt

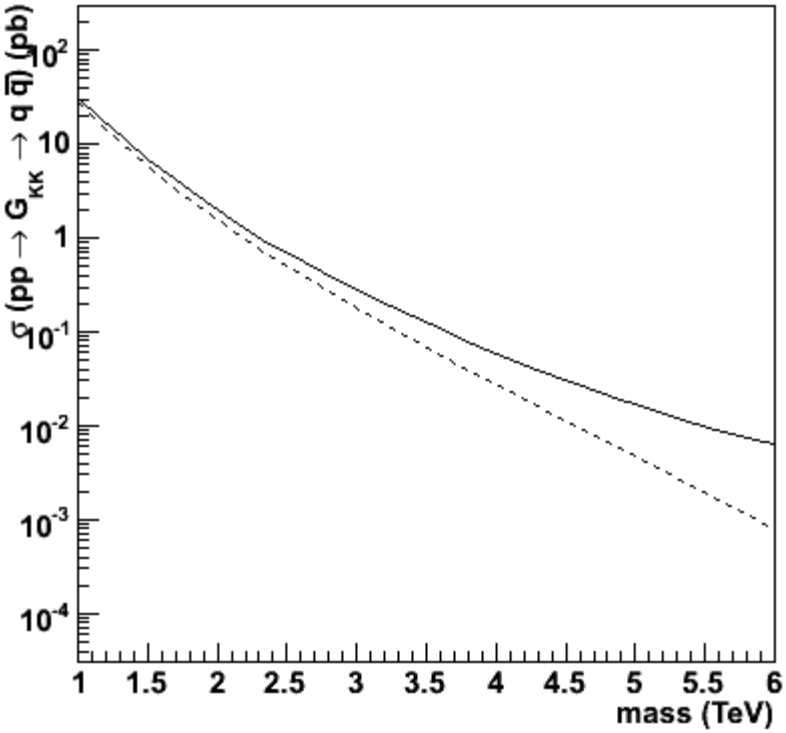
Basic RS scenario: 92.6 %

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

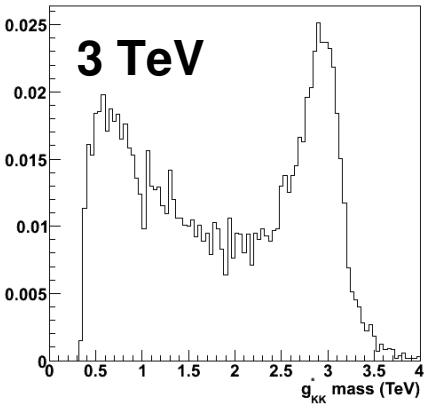
Generate some events

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



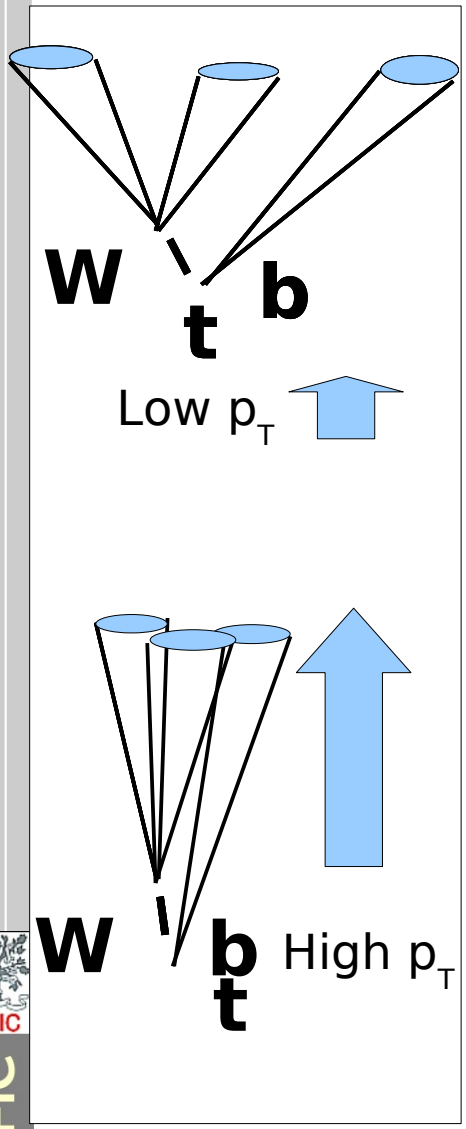


Mass distribution:
Convolution of broad Breit-Wigner and luminosity function



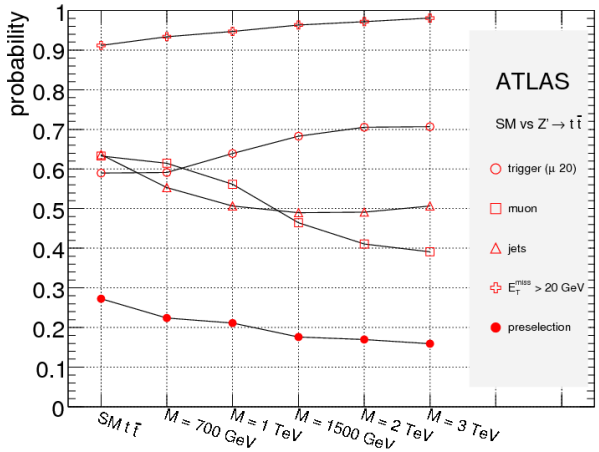
MadGraph:
——— cross-section @ 14 TeV
– – . within nominal mass ± 30 %

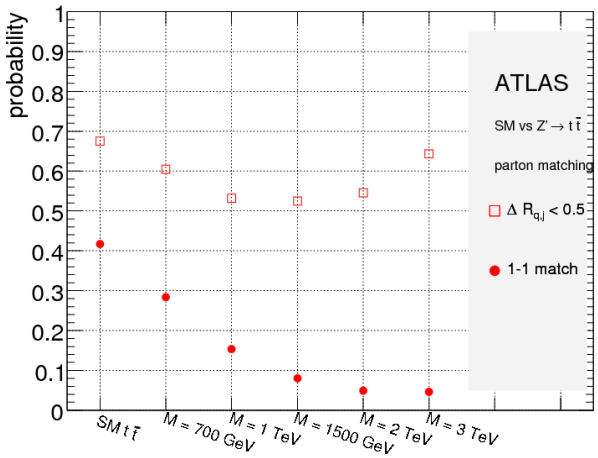
Selection and reconstruction



High pT top quarks are a challenge to the standard tt **selection and reconstruction** scheme:

- Lepton isolation
- Jet multiplicity
- B-tagging





Several reconstruction methods are being explored, using features of the mono-jet to reduce the QCD/W+jets background

Jet substructure ATL-PHYS-CONF-2008-008, COM-PHYS-2008-184

Life-time ATL-PHYS-CONF-2008-016

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.

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)

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)

One, two, three,... papers

Agreement between top and exotics groups: ATLAS should write a *single* ATLAS note, available to non-ATLAS public, where all relevant aspects of early tt resonance searches are discussed

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

Two editors, from top (TBA) and exotics group (M.V.)
Time scale: 5 months, before the start of data taking

Inventory of Jet+X effort underway;

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

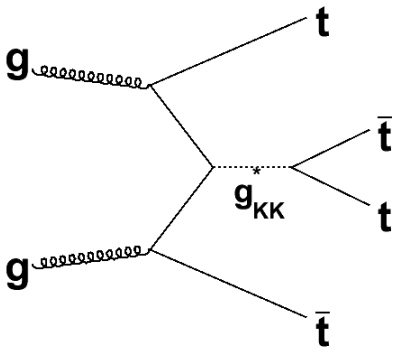
An example of a signal

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

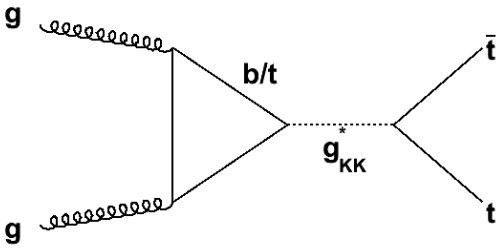
The other gauge bosons are not considered

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)

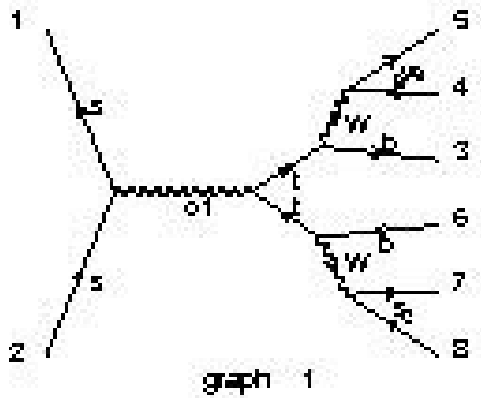
Large brane kinetic terms:H. Davoudias, J.L. Hewett, T.G. Rizzo,Phys. Rev. D 68, 045002 (2003), M. S. Carena, E. Ponton, T. M. P. Tait and C. E. M. Wagner, Phys. RevD 67 (2003), Phys. Rev. D 71 (2005)

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)

MadGraph output

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).