Search for Kaluza-Klein excitations of the gluon

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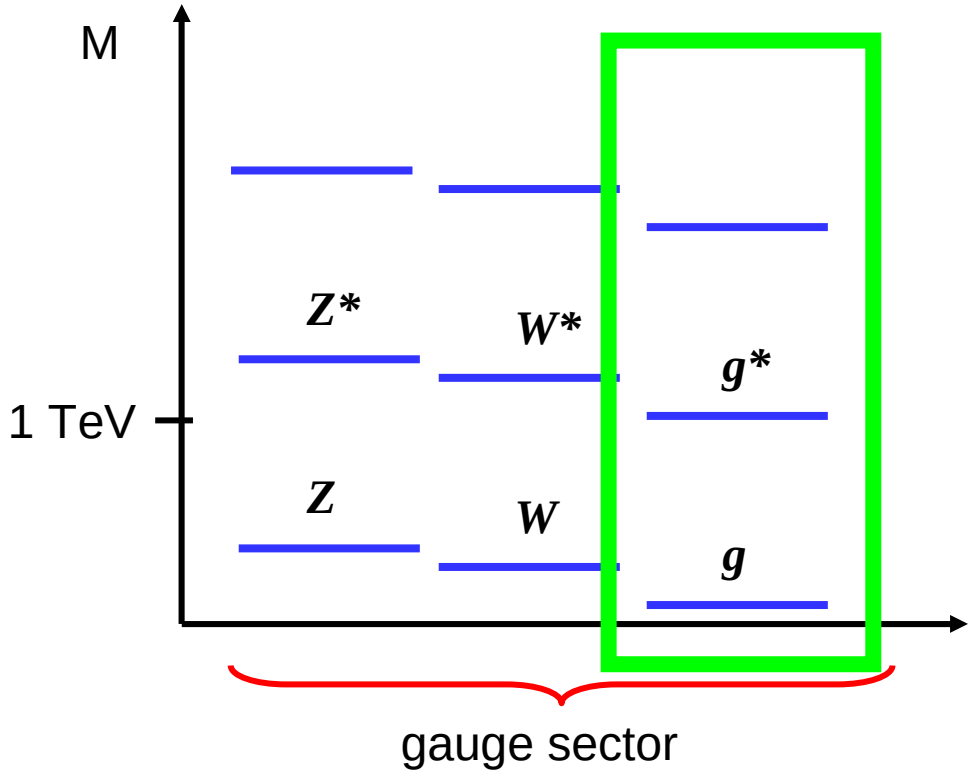
IFIC - Valencia

Presented by B. Salvachúa

ATLAS Overview Week – 23/02/2007

KK spectrum in extra dimensions



Theory

- Bosons propagate into one flat extra dimension of size TeV^{-1}
- Fermions confined to a D-brane

See for example:

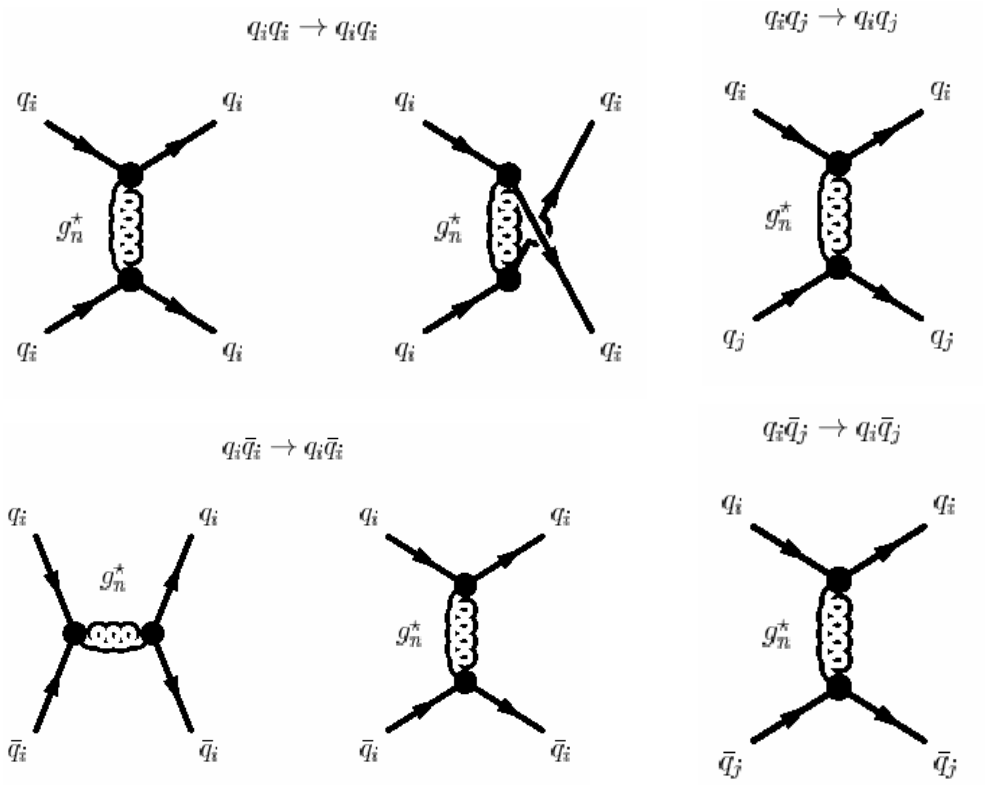
- T.G. Rizzo, Phys. Rev. D**61:** 055005 (2000)

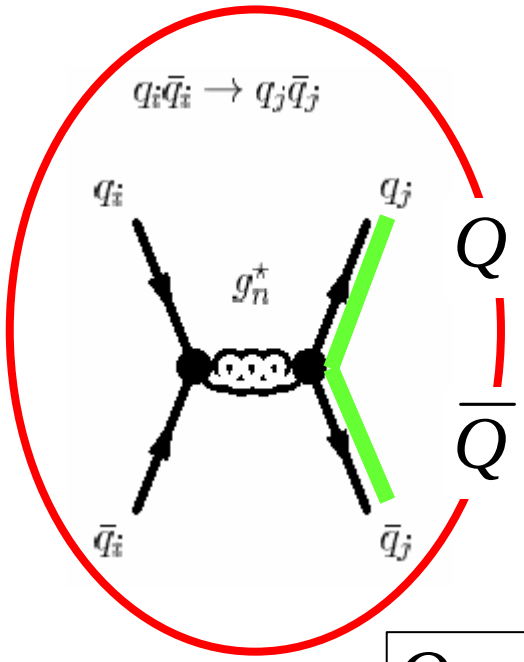
ATLAS searches

- SN-ATLAS-2003-023 (Z^*)
- SN-ATLAS-2003-036 (W^*)

Theory of g^* production in pp collisions

D.Dicus, C. McMullen, S. Nandi, Phys. Rev. D**65**: 076007, 2002



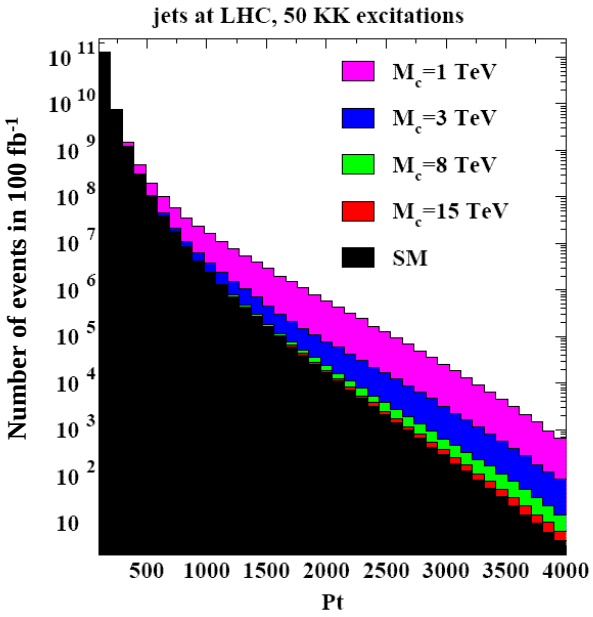


$Q = b, t$

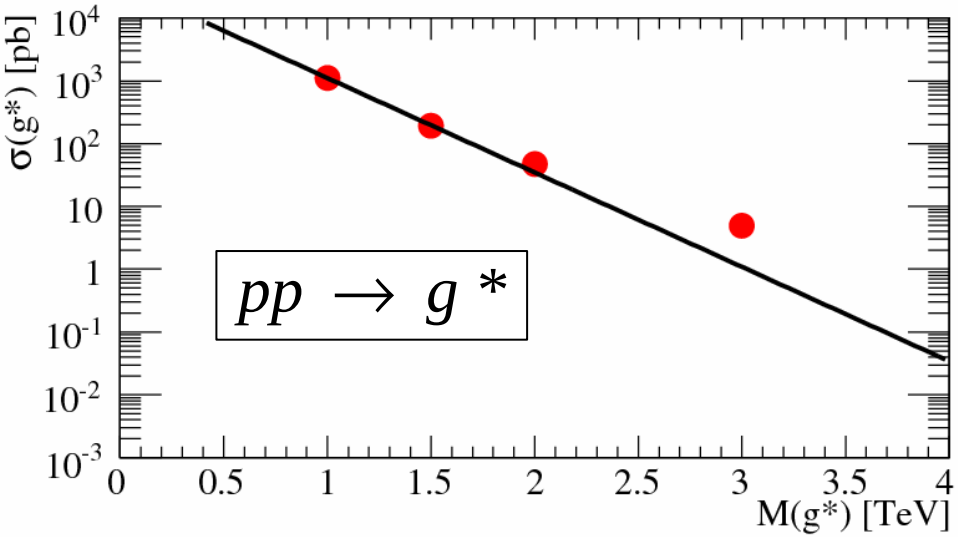
Strategies to search for g^* at LHC

Dijet cross-section

C.Balaz, M.Escalier, S.Ferrag, B.Laforge and G.Polesello, 3rd Les Houches Workshop, Physics at TeV Colliders, Les Houches, France, 26 May – 6 June 2003.



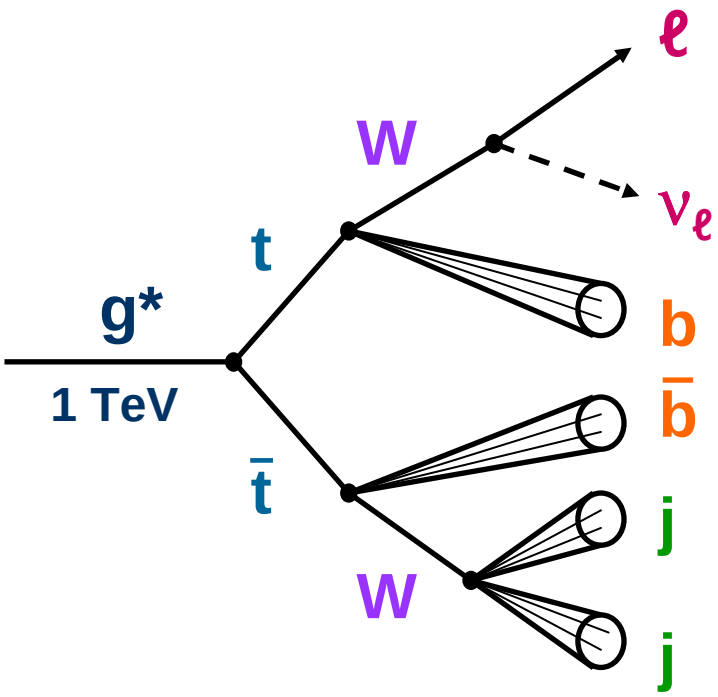
g* decay into top quarks



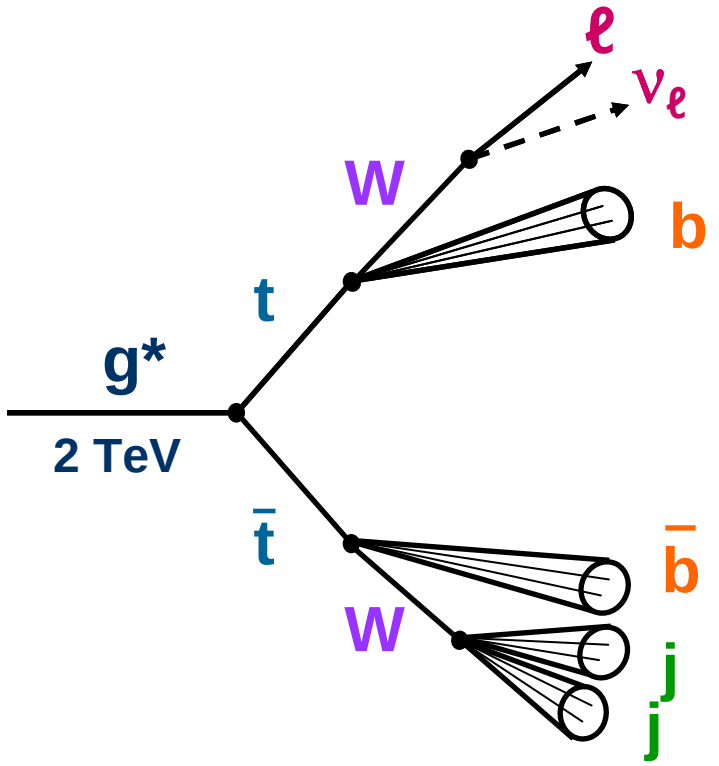
$$BR(g^* \to t\bar{t}) \approx 16.7\%$$

$$\Gamma/M = 2\alpha_s \approx 20\%$$

Kinematics of top decays



p_T (b-jets) ~ 250 GeV



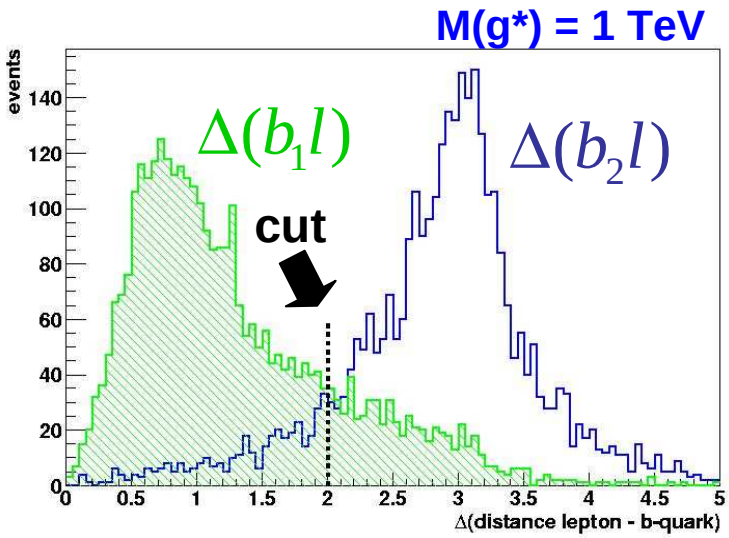
p_T (b-jets) ~ 500 GeV

Selection Cuts

- Lepton (e or μ) with p_T > 25 GeV and $|\eta|$ < 2.5
- $(E_T)_{miss}$ > 25 GeV
- 2 b-jets with p_T > 25 GeV and $|\eta|$ < 2.5
- Distance lepton b-quark:

$$\Delta(b_1 l) < 2 \qquad \Delta(b_2 l) > 2$$

where $\Delta = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$



- Neutrino parallel to lepton

  (discussion later)

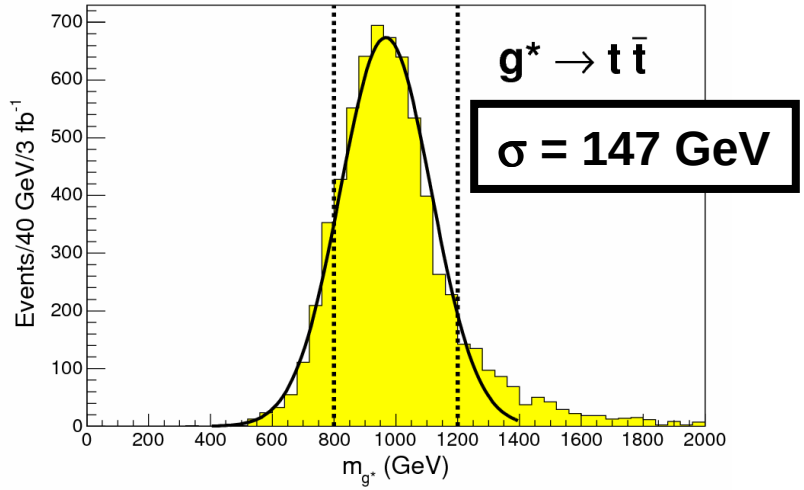
- Both tops can be fully reconstructed
- p_T(tops) > 350 GeV and 150 GeV for M(g*) = 1 TeV
  This cut is proportional to M(g*)

Observed Signal (ATLFAST)

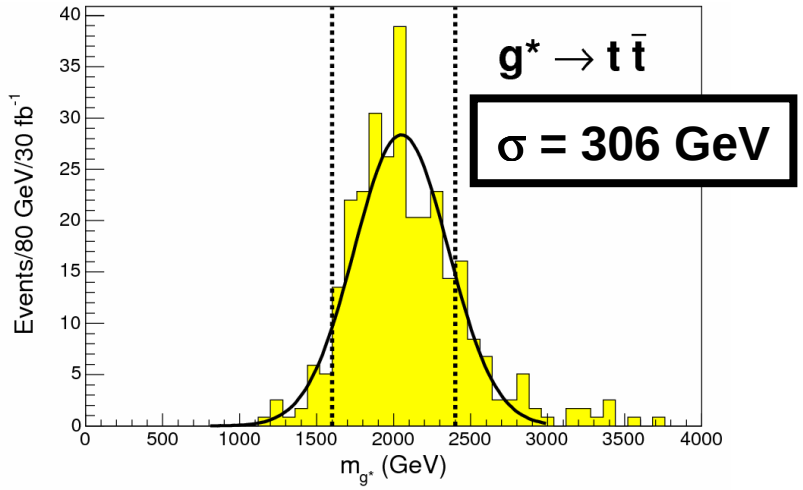
M (TeV)	ε_{kin}
1	14%
2	10%

Kinematic efficiency decreases with M due to lepton isolation

Signal for M(g*) = 1 TeV



Signal for M(g*) = 2 TeV



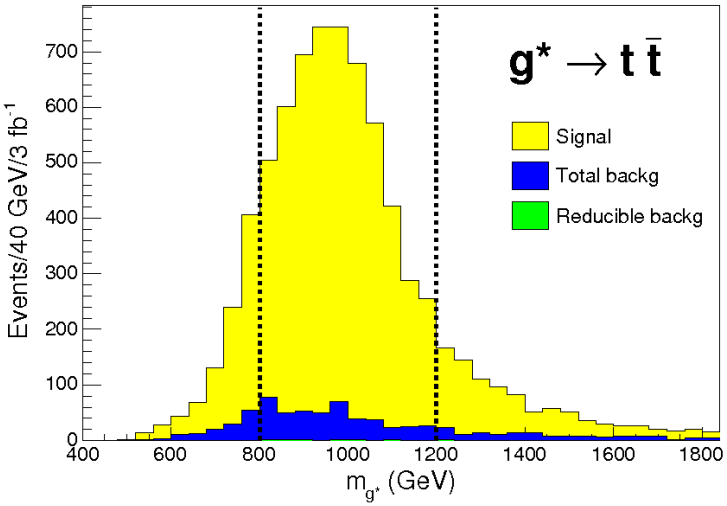
σ is dominated by fragmentation and detector effects

Signal and Background

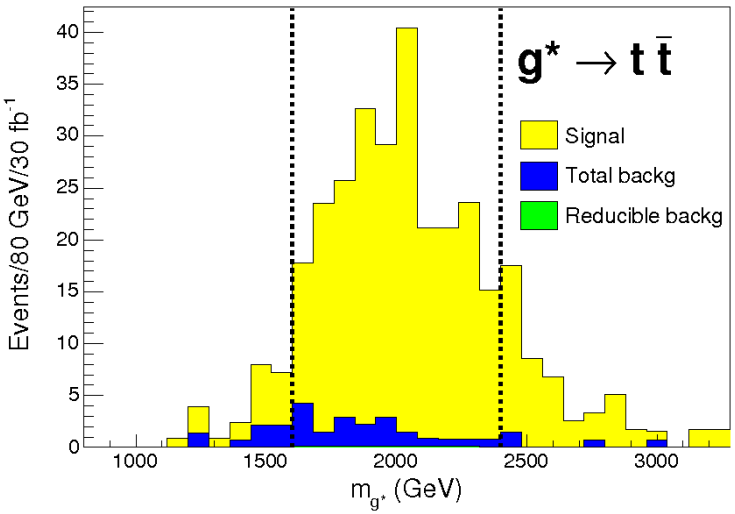
Events in a window around signal central value ± 200(400) GeV for M=1(2) TeV

M (TeV)	Luminosity (fb^{-1})	Signal (PYTHIA)	Irreducible bkg $t\bar{t}$ (PYTHIA)	Reducible bkg W+jets (ALPGEN)	Significance
1	3	5054	446	5	238
2	30	232	17	1.2	54

M(g*) = 1 TeV **L = 3 fb^{-1}**



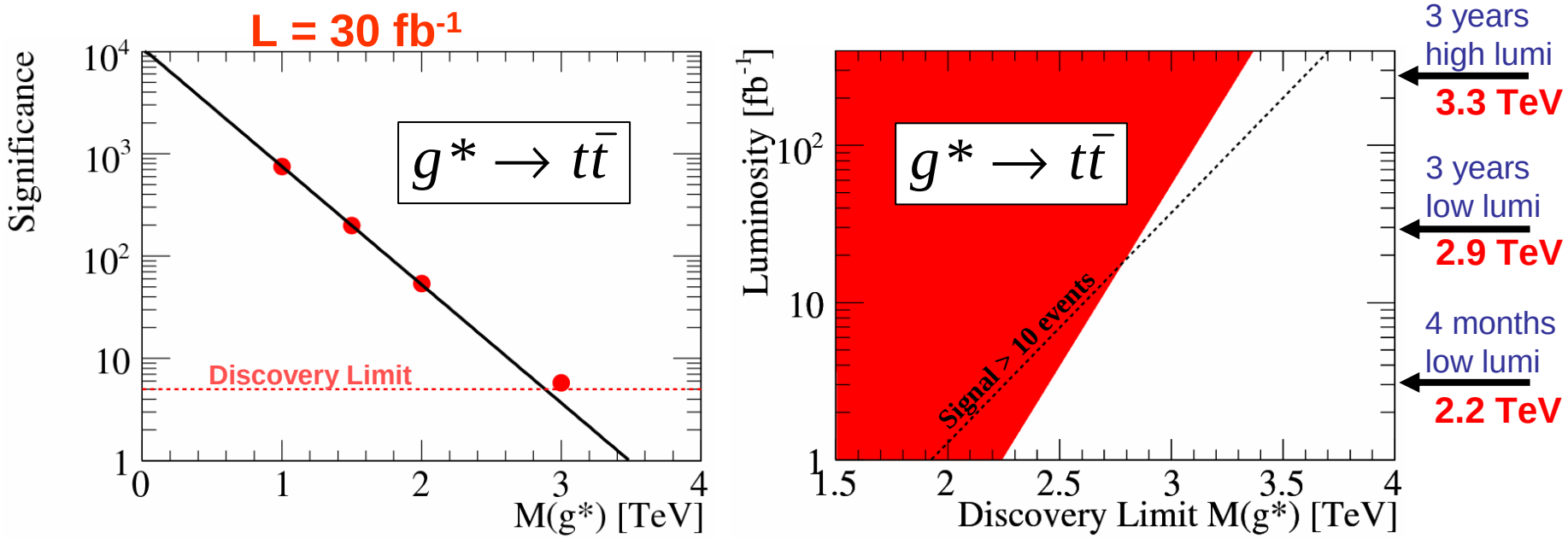
M(g*) = 2 TeV **L = 30 fb^{-1}**



Negligible due to b-tagging

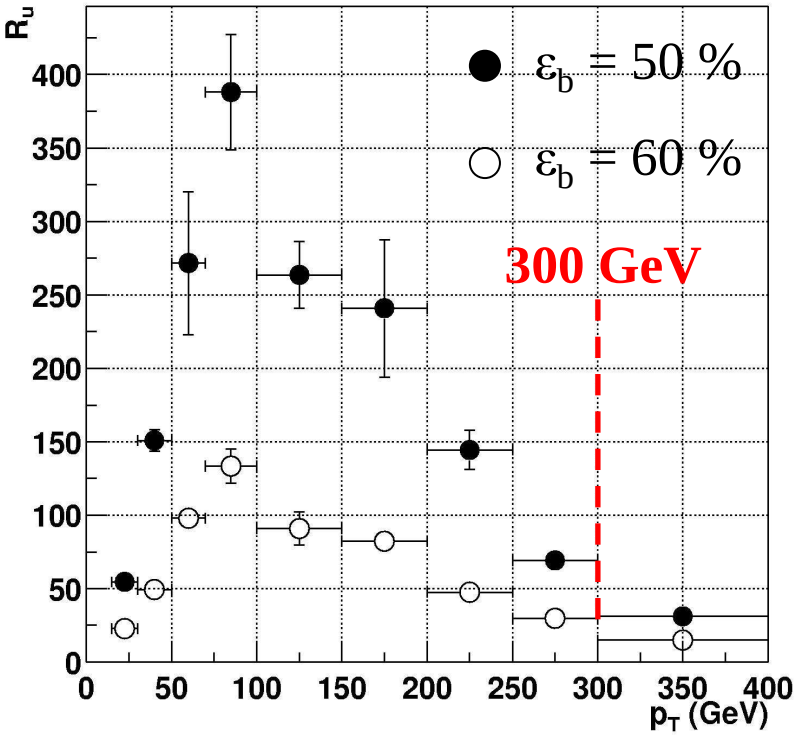
Discovery Limits

$$\text{Discovery} \begin{cases} \text{Significance} = \dfrac{\text{Signal}}{\sqrt{\text{Bkg}}} > 5 \\ \text{Signal} > 10 \text{ events} \end{cases}$$



p_T dependence of b-tagging

ATL-COM-INDET-2003-017



2D algorithm – DC1 data

pp → W H (120 + 400 GeV)

↳ b $\bar{b}$, u $\bar{u}$

ε_b = b - tagging efficiency

$R_u = 1/\varepsilon_u$ = light jet rejection

Typical values :

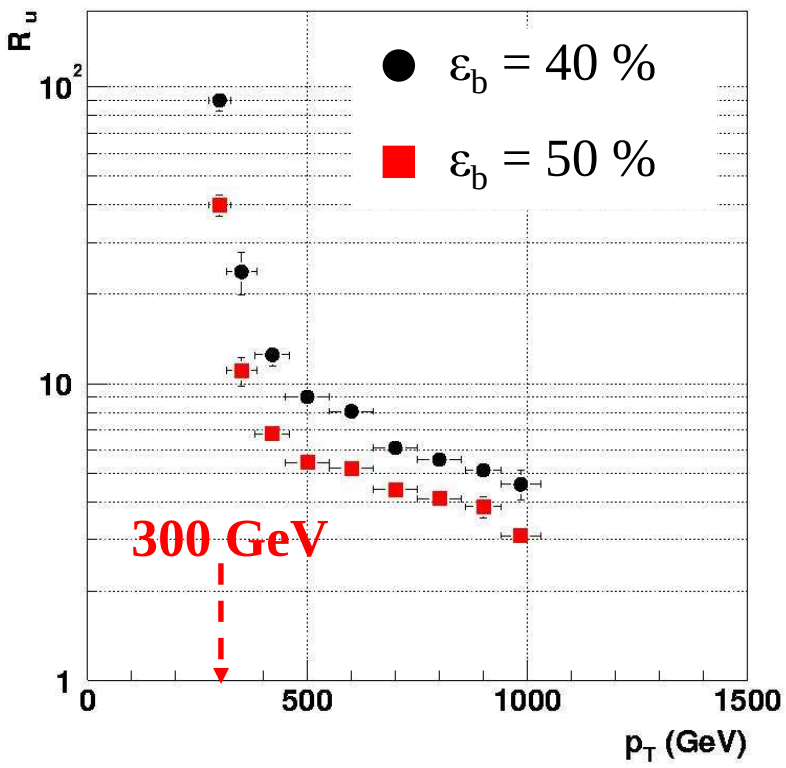
$\varepsilon_b = 60\%$

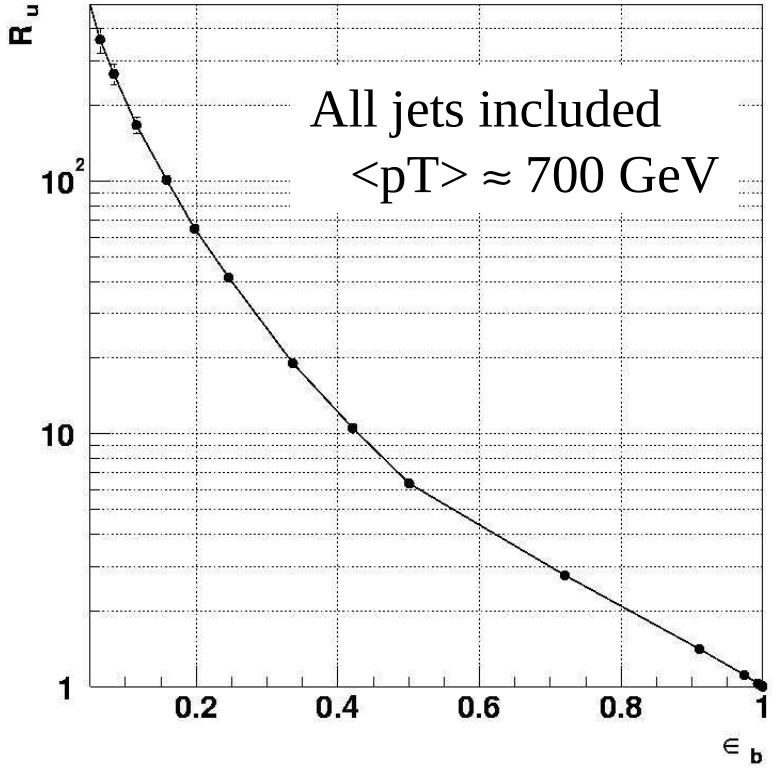
$R_u = 100$

$p_T \sim 100$ GeV (b - jet)

b-tagging of very high p_T jets

2D algorithm - DC1 data $\left[pp \to Z_H(2\,\mathrm{TeV}) \to b\bar{b}, u\bar{u}\right]$





Optimal b-tagging efficiency versus mass

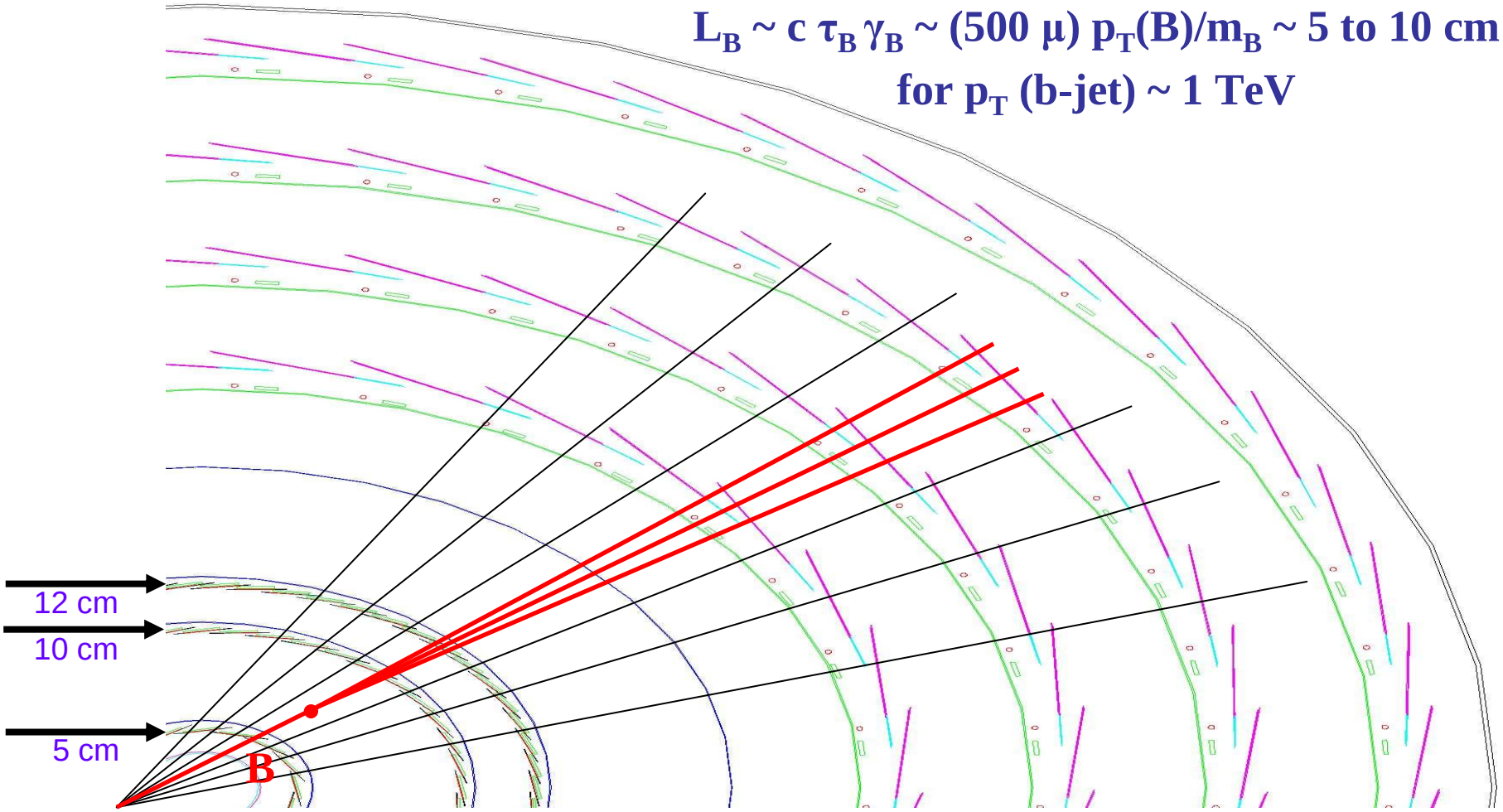
Strategy: eliminate reducible bkg (W + jets) as much as possible

2D algorithm - DC1 data

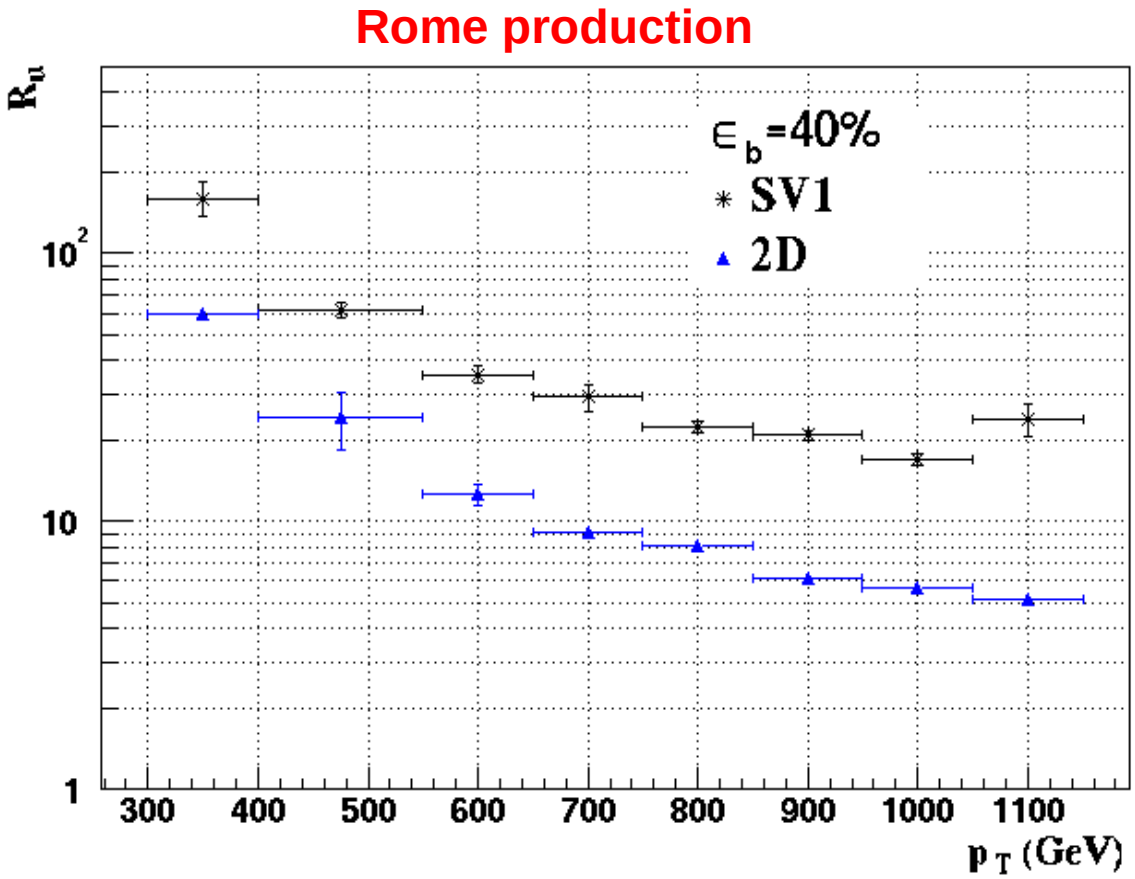
M(g*) (TeV)	$\langle p_T \rangle$ b-jets (GeV)	ε_b	R_u
1.0	200	50%	100
1.5	300	30%	200
2.0	400	20%	130
3.0	600	20%	30

A typical very high p_T b-jet

$L_B \sim c\,\tau_B\,\gamma_B \sim (500\ \mu)\ p_T(B)/m_B \sim 5$ to 10 cm
for p_T (b-jet) ~ 1 TeV



b-tagging performance (SV1 versus 2D)



b-tagging algorithms
2D: impact parameter
SV1: secondary vertex tag

- 2D used in $g^* \to t\bar{t}$ analysis
- SV1 should improve results but …
- Performance is possibly degraded in new CSC samples (now under study)

New model with Randall-Sundrum KK-gluon

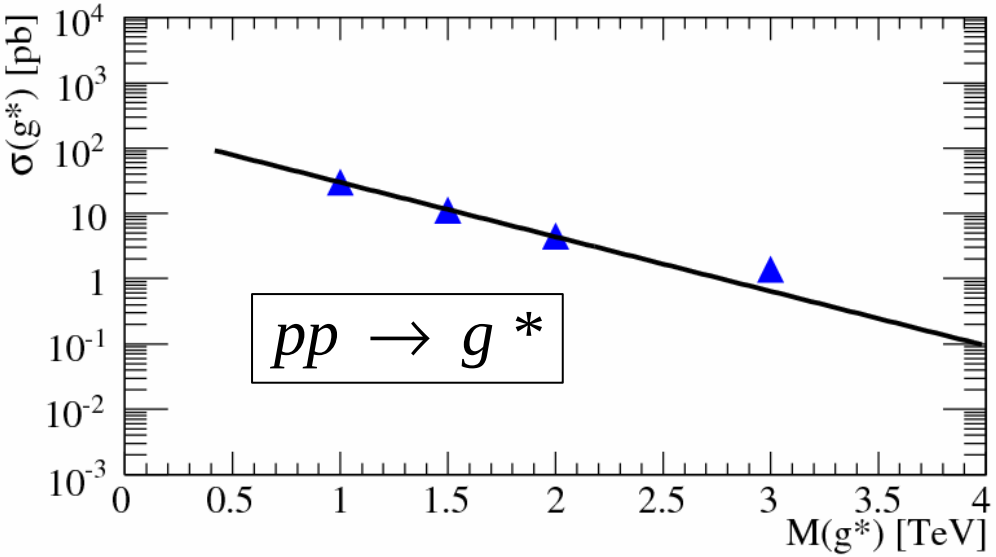
B. Lillie, L. Randall, L.T. Wang
hep-ph/0701166 (19 Jan 2007)

- Single warped ED
- All particles in the bulk
- $Z^*, W^*, g^* \rightarrow t\bar{t}$ decays are dominant

Good features:

- Explanation of fermions mass hierarchy
- Unification of coupling constants
- Dark matter candidate

g* decay into top quarks

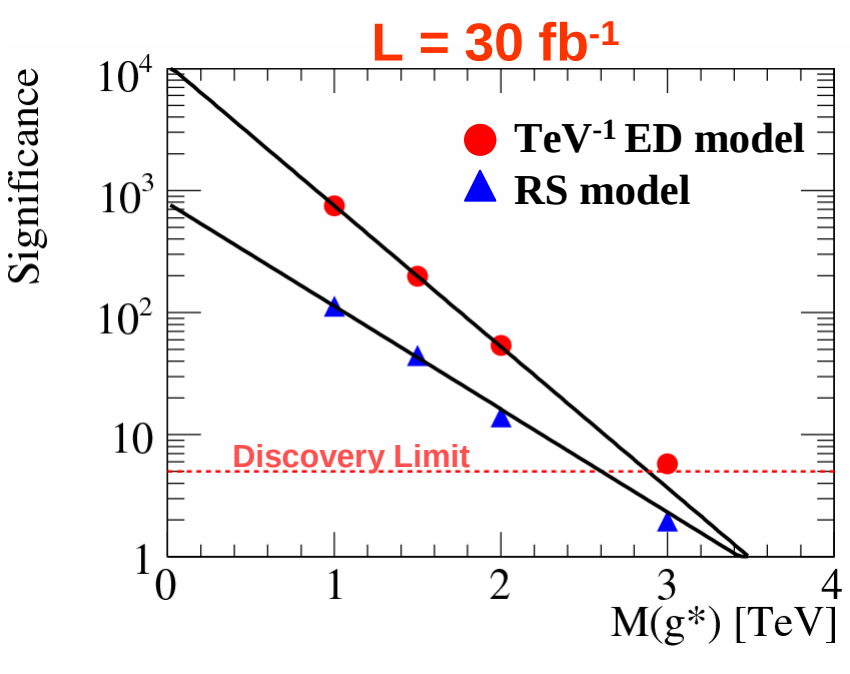


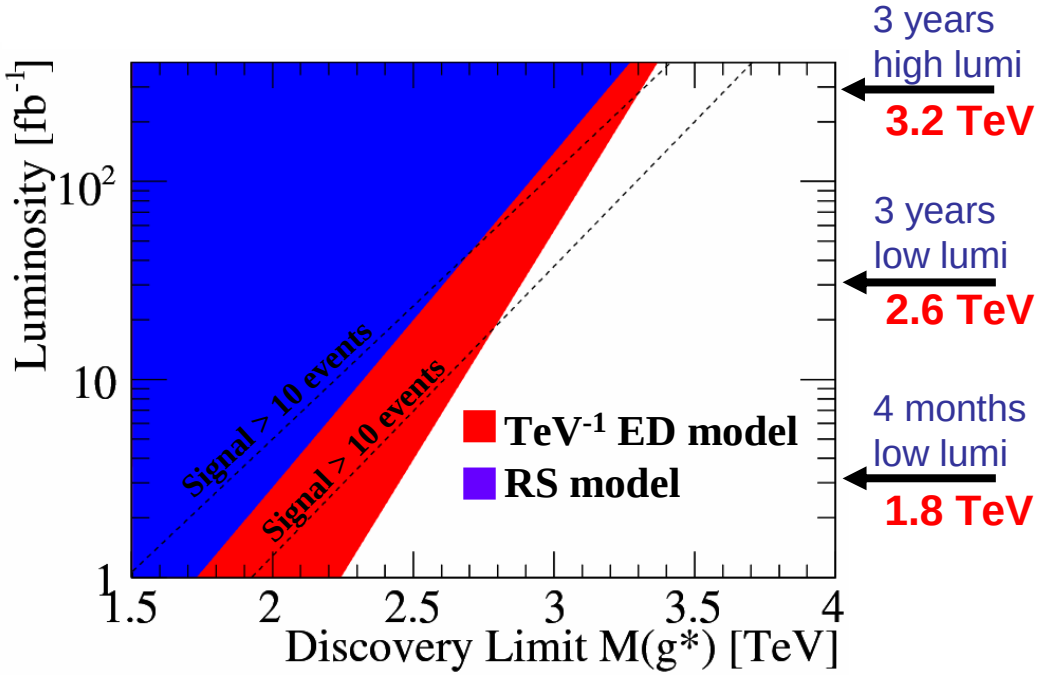
$$BR(g^* \rightarrow t\bar{t}) \approx 92.5\%$$

$$\Gamma/M \approx 17\%$$

Discovery Limits

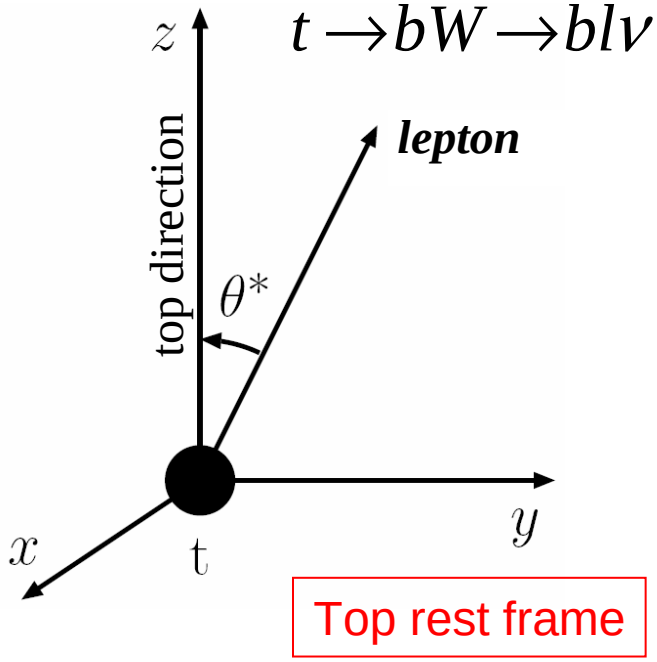
Using the results of the TeV^{-1} ED model, the following discovery limits are obtained for the new RS model:





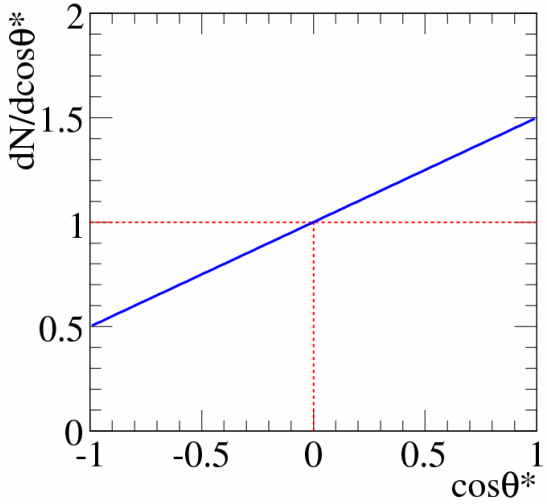
Study of top polarization

TeV^{-1} ED model:	$g^* \to t\bar{t}$	top is NOT polarized
RS model:	$g^* \to t_R\bar{t}_R$	top is HIGHLY polarized



Top rest frame

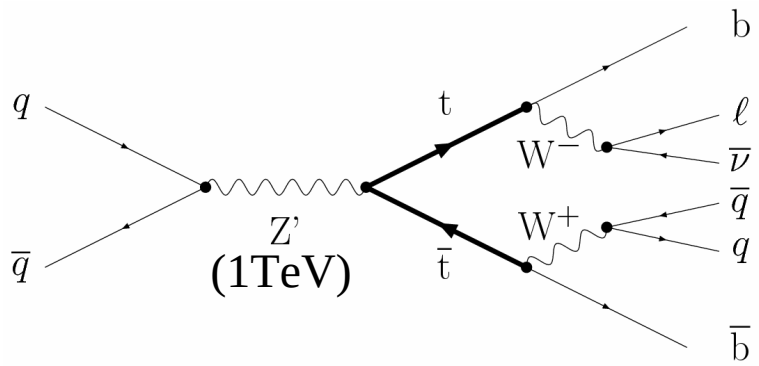
$$\frac{1}{N_0}\frac{\mathrm{d}N}{\mathrm{d}\cos\theta^*} = \frac{1}{2}\left[1 + S\cos\theta^*\right]$$

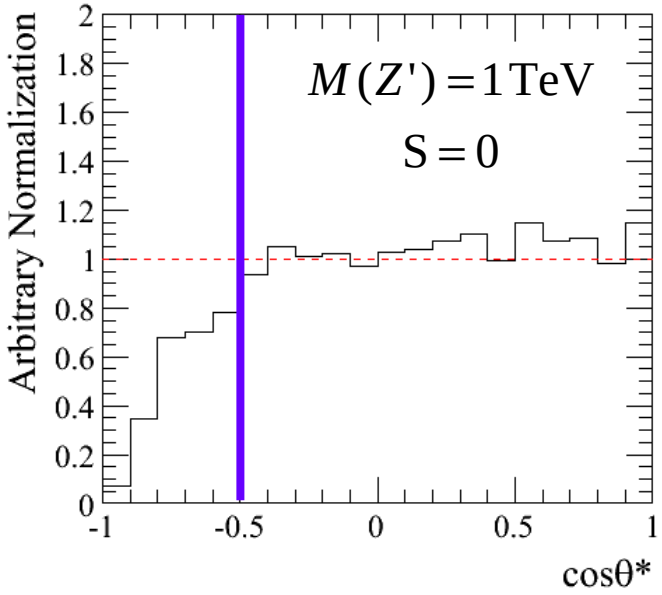


$$-1 < S < +1$$

$$S = \begin{cases} +1 & \to t_R \\ 0 & \to t \text{ unpol.} \\ -1 & \to t_L \end{cases}$$

Top polarization with ATLFAST





- Full $2 \rightarrow 6$ matrix element needed to have correct top polarization
- Top polarization available in ACER MC for $Z' \rightarrow t\bar{t}$ but not in PYTHIA
- $\cos\theta^*$ reconstruction for $S=0$ (unpolarized top)
- Measurement of top polarization possible for:

  $\cos\theta^* > -0.5$
- Good reconstruction of $\vec{p}_\nu$ important

Reconstruction of $\vec{p}_\nu$ in $t \to bl\nu$ decay

- $\vec{p}_\nu \,//\, \vec{p}_l$ is a good assumption for high p_T top decays but needs improvement for top polarization analysis
- $m_W^2 = (p_l + p_\nu)^2 \to$ quadratic equation in p_z^ν with

$$p_z^\nu = \frac{A p_z^l}{\left(p_T^l\right)^2} \pm \frac{E_l}{\left(p_T^l\right)^2}\sqrt{A^2 - \left(p_T^l \cdot p_T^\nu\right)^2} \qquad A = \frac{m_W}{2} + \vec{p}_T^{\,l} \cdot \vec{p}_T^{\,\nu}$$

Problem because:
- $A^2 - \left(p_T^l \cdot p_T^\nu\right)^2$ may be < 0
- Solution is not unique

- A good assumption for top polarization analysis is:

$$p_z^\nu \approx \frac{A p_z^l}{\left(p_T^l\right)^2}$$

Summary and Conclusions

- The ATLAS experiment has the potential to discover KK excitations of the gluon using the decay:

$$g^* \rightarrow t\bar{t}$$

even with low luminosity, up to masses M(g*) ≈ 3 TeV

- The measurement of top polarization is useful for model discrimination and must be investigated

Many thanks to:

Georges Azuelos for useful comments
Borut Kersevan for providing MC with top polarization