Gravity Mediated

(Macesanu, McMullen, Nandi, hep-ph/0201300;
Rizzo, Phys.Rev. D64 095010, 2001;
DeRujula, Donini, Gavela, Rigolin, Phys.Lett.B482 195, 2000)

Universal Extra Dimensions

(Bounds on Universal Extra Dimensions, Appelquist, Cheng, Dobrescu, Phys.Rev. D64 035002, 2001)

:

striking two photon
+ jets,lepton + missing ET
final state

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Helenka Przysiezniak, LAPP, Annecy

(Minimal)UED scenario

Fermions and bosons live in a

$4+\delta$ ($R \sim TeV^{-1}$)

dimensional "thick" brane embedded in a larger

$4+N$ (size $\sim eV^{-1}$; e.g. N=2)

bulk where only gravitons propagate.
No a priori constraints on the number of UEDs.
We consider the case when $\delta = 1$.

At tree level,
KK excitations masses come from the 5D kinetic energy terms in the Lagrangian
with a small contribution from the Higgs interaction (which gives mass to the zero mode fields)

$$m_n^2 = n^2/R^2 + m_{SM}^2$$

where R is the compactification scale and n the KK excitation level.

The tree level masses of the first level KK excitations are hence almost degenerate,
though loop corrections can give important additional contributions.

In fact, due to these loop corrections,
the KK excitations of the SM quarks and gluons decay in a cascade down to the Lightest KK Particle :

the LKP γ^*

Gravity Mediated decays of the LKP

Some new mechanisms also provide for the decay of the KK excitations, through

KK number violating interactions mediated by gravity

When the decay widths of first level KK excitations due to mass splitting
>>
than gravity mediated decay widths,
the gluon and quark excitations will decay in a cascade down to the γ^* which in turn will decay as

$$\gamma^* \rightarrow \gamma G$$

Models which allow for gravity mediated decay of KK excitations :

hep-ph/0201300 Macesanu, 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.

The gravitons permeate the N extra space dimensions,
while the other particles are confined to the δ=1 brane.

Large density of states for the KK gravitons in the 5^{th} D

(the splitting between adjacent levels is of order eV)
makes up for the smallness of the gravitational coupling,
allowing the decay width of the matter KK excitations through this mechanism
to be phenomenologically relevant (they decay within the detector).

e.g. radiative corrections to KK Masses, hep-ph/0204342

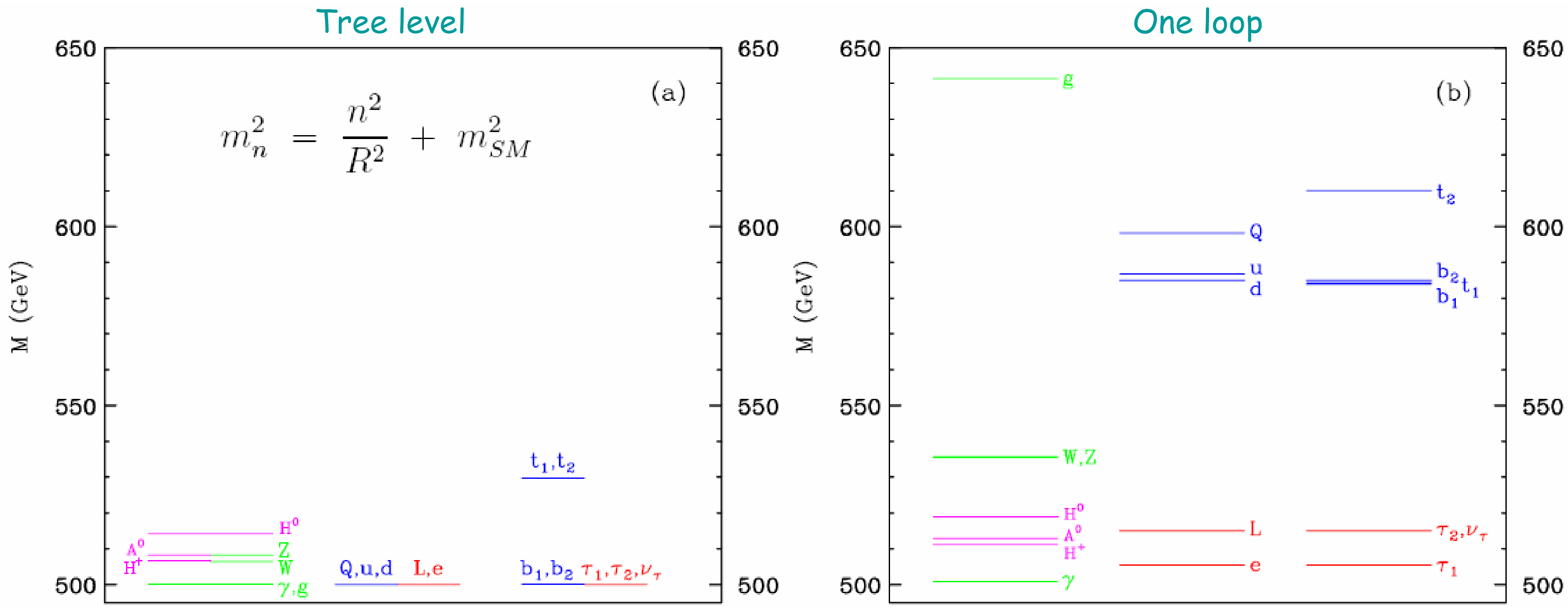


FIG. 6: The spectrum of the first KK level at (a) tree level and (b) one-loop, for $R^{-1} = 500$ GeV, $\Lambda R = 20$, $m_h = 120$ GeV, $\overline{m}_H^2 = 0$, and assuming vanishing boundary terms at the cut-off scale Λ.

Tools

1.CompHEP

for process generation.

For each SM Dirac fermion q,
two 5D fermionic fields denoted
$q^\bullet$ and q°
the first KK excitation of quark fields with respectively
left-handed and right-handed chiralities.
These two towers of states couple identically in the strong interaction.
Compactification on a S_1/Z_2 orbifold provide matching of the zero mode with the observed SM particle.

$R^{-1}=M_{KK}=1.3$ TeV

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

2.Pythia

for cascade decay of KK quarks using existing excited quark and boson channels.
(singlet KK quarks decay directly to the LKP: $q^\circ \to q\gamma^*$)

$$q_1^\bullet \to q\, Z_1^* \to q\, l\, l_1^\bullet \to q\, l\, l\, \gamma_1^*, \qquad \text{Br.} \sim 33\%$$
$$q_1^\bullet \to q\, W_1^* \to q\, l'\, l_1^\bullet \to q\, l'\, l\, \gamma_1^*, \qquad \text{Br.} \sim 65\%$$

Tools

3. Outside of Pythia
code from P.-H. Beauchemin and G.Azuelos, ATL-PUB-PHYS-2005-003

for gravity mediated decay of KK photon
$\gamma^* \to \gamma G$
using proper integration over all graviton KK states

For the LKP decay, sum up the graviton towers by following the analyses in
G.F.Giudice, R.Rattazzi, J.D.Wells, Nucl. Phys. B544, 3 (1999);
T.Han, J.D.Lykken, R-.J. Zhang, Phys. Rev. D59, 105006 (1999).
Result should be relatively independent of the spin of the original KK state.
The total width is given by

$$\Gamma = \frac{(2\pi)^{\delta/2}\ \overline{M}_{Pl}^2}{\Gamma(\delta/2)\ M_D^{2+\delta}} \int_{R_G^{-1}}^{M_{KK}} dm_g\ m_g^{\delta-1}\ \Gamma(m_g)\ [\mathcal{F}(m_g R_c)]^2 (n=1)$$

where $\Gamma(m_g)$ is the width for the decay into a graviton of mass m_g
M_D is the 4+δ Planck scale,
M_{Pl} is the conventional 4-d reduced Planck scale,
and M_{KK} is the mass of the relevant decaying KK state.

No results yet for this part.
Code implementation stage.

Production Cross Sections

From P.-H.Beauchemin and G.Azuelos, atl-pub-phys-2005-003

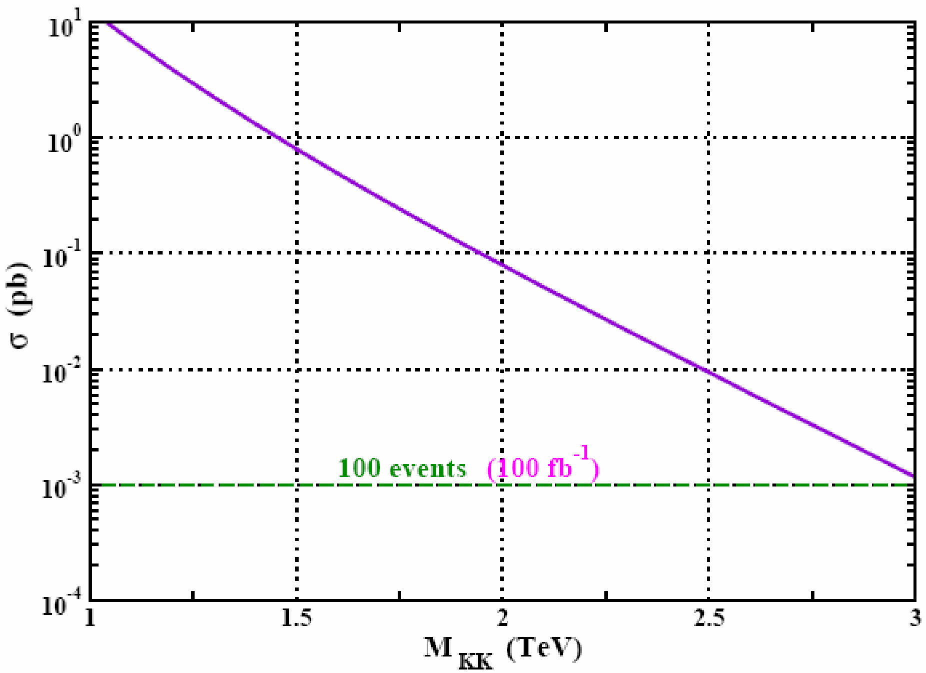


Figure 1: The total cross section for the production of two KK final states at the LHC is shown in function of the KK mass of these states with $E_{T,jet}^{\min} > 250$ GeV. The dashed line mark 100 events at an integrated luminosity of 100 fb^{-1}.

Production Cross Sections

From Macesanu, McMullen and Nandi, hep-ph/0201300.

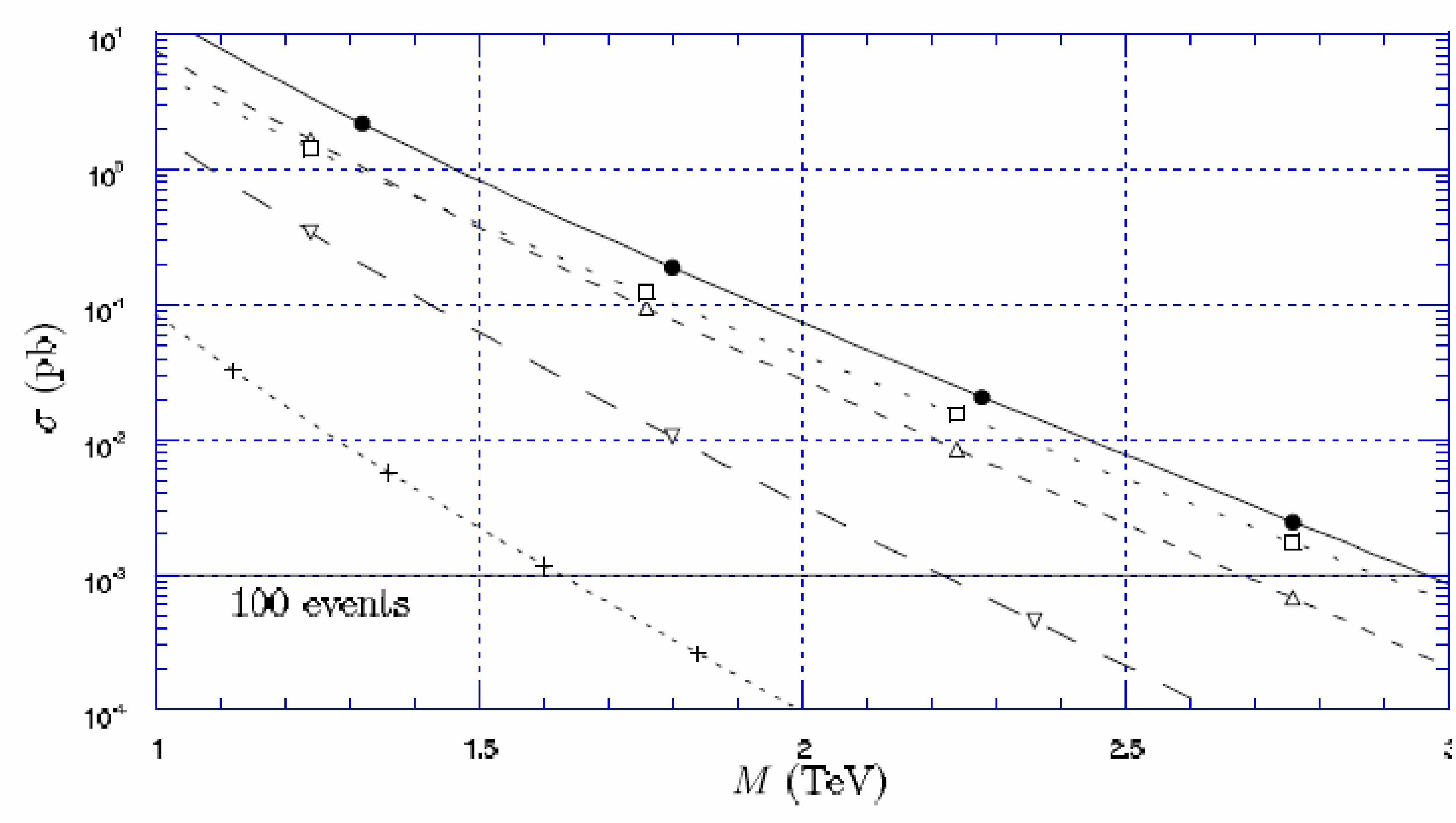
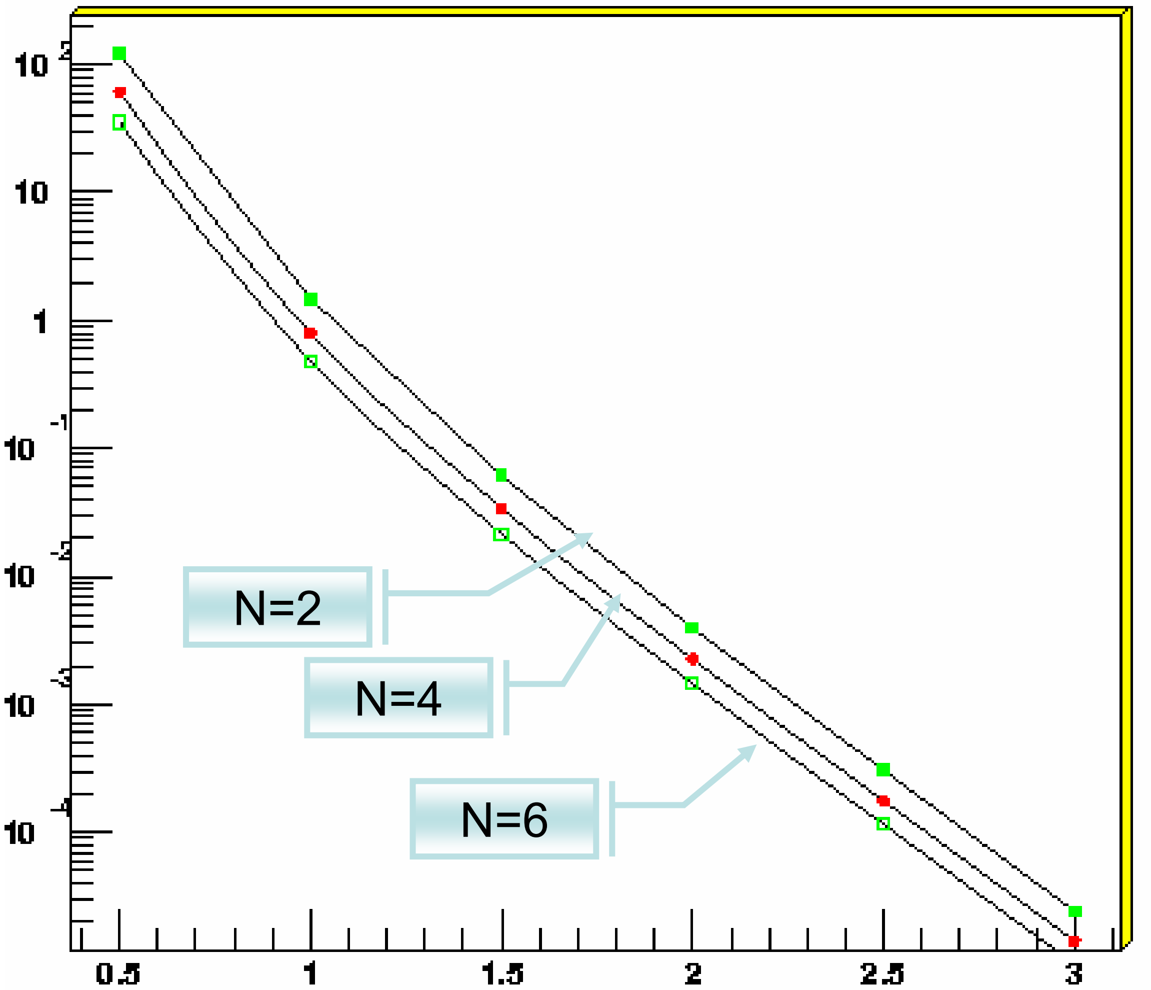


Figure 2: The cross section for the production of two stable KK final states is shown as a function of the KK mass for Tevatron Run I (top) and II (bottom). The solid curve corresponds to the total contribution, while the dashed lines represent the partial contributions of KK quark pair (□), KK quark-gluon (△), and KK gluon pair (▽) production. Also shown is top production (+), which features a different collider signature (namely, the top will subsequently decay into additional states). Solid horizontal lines mark 100 events at the initial and final projected luminosities for Run II.

Production Cross Sections from CompHEP

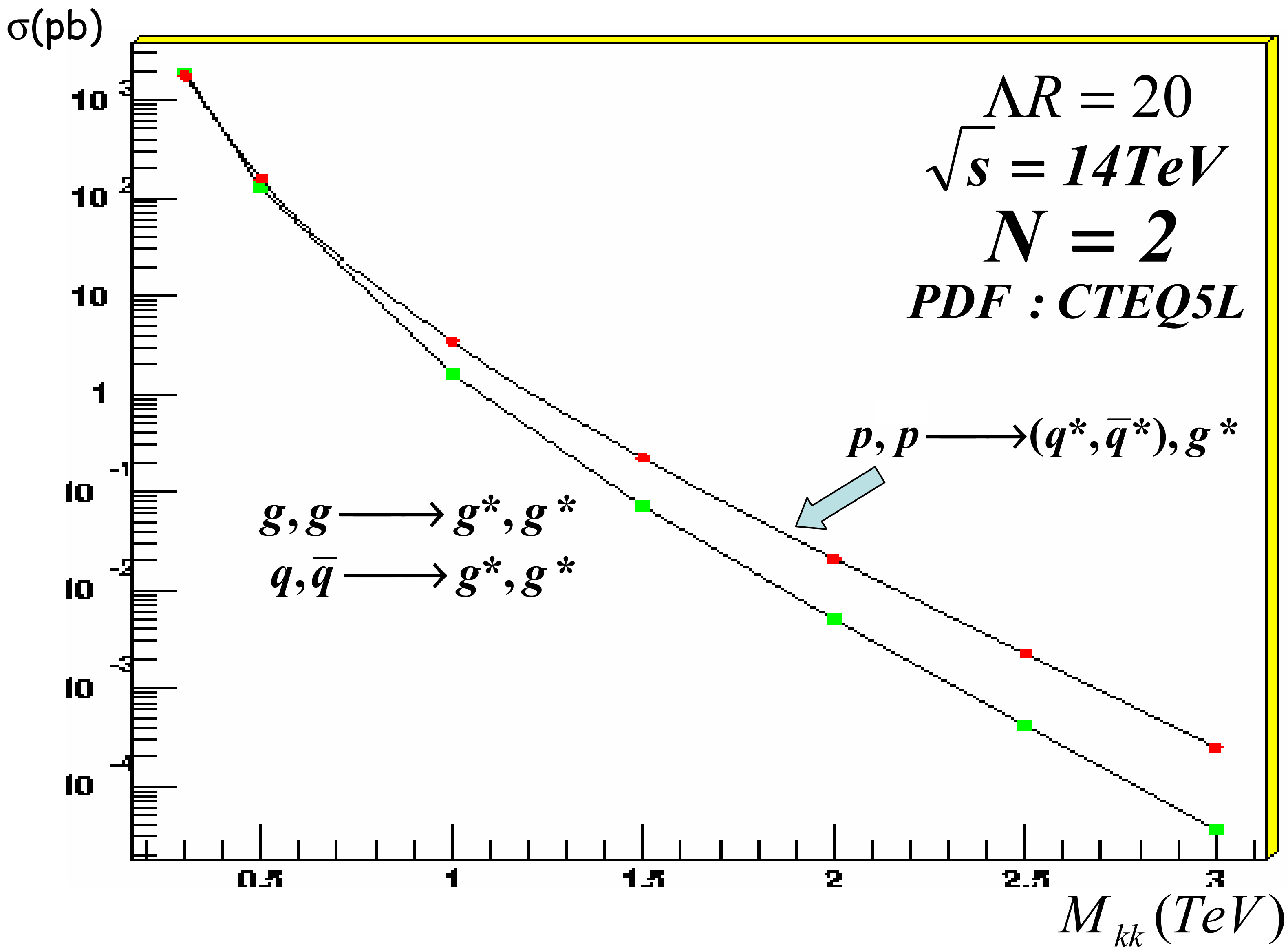
our result pdf CTEQ5L

$$g, g \longrightarrow g^*, g^*$$



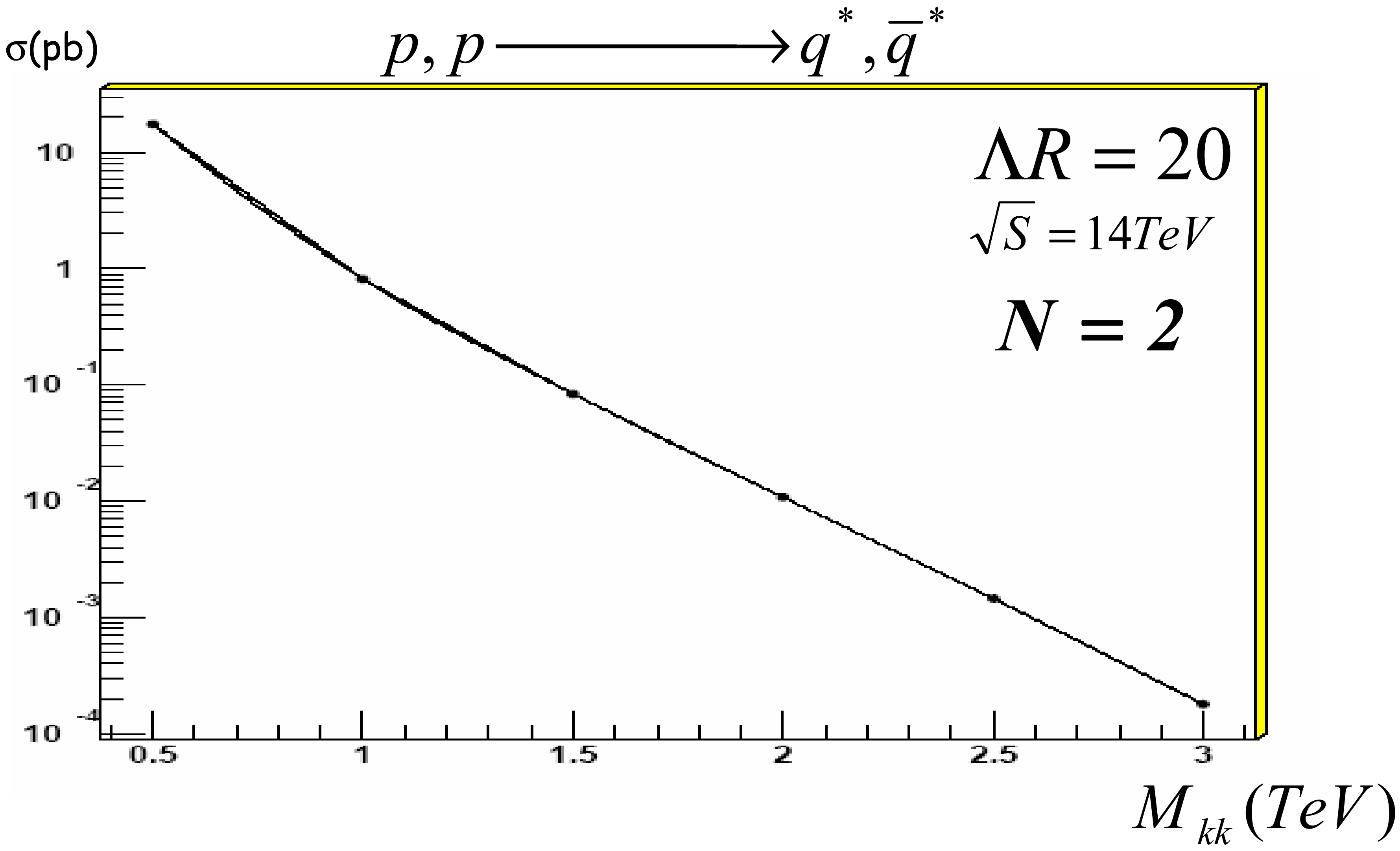
Production Cross Sections from CompHEP

our result



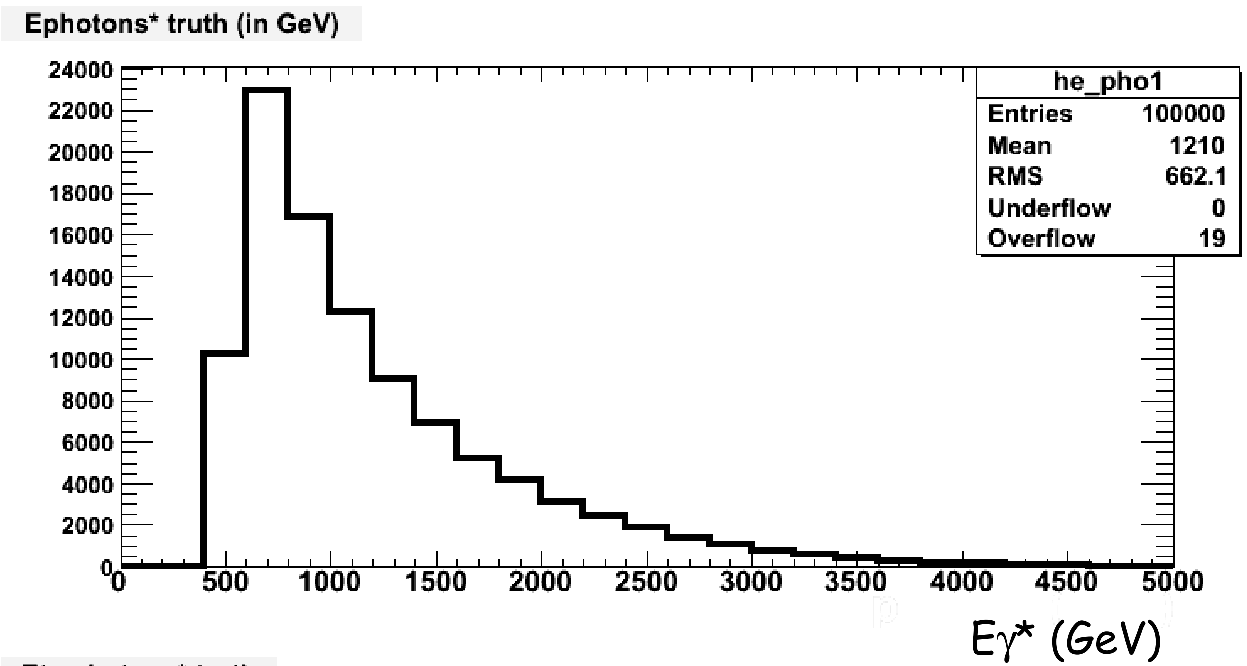
Production Cross Sections from CompHEP

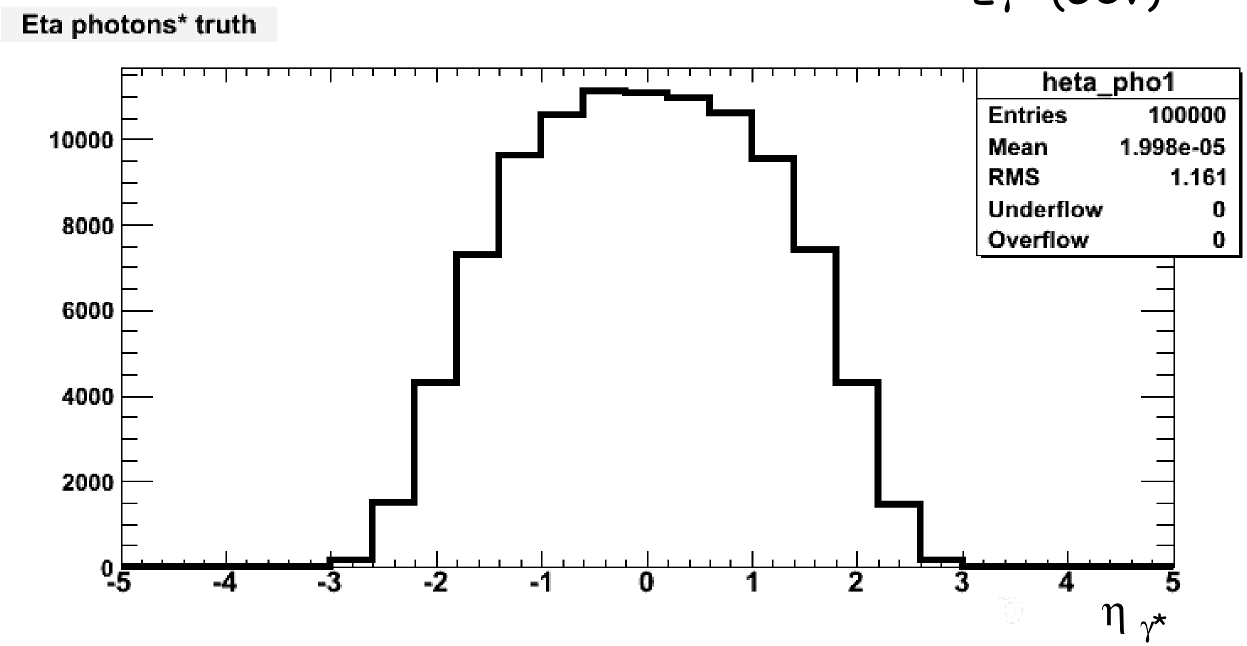
our result



Cascade decay from Pythia

R^{-1}=500GeV, ΛR=10, N=2





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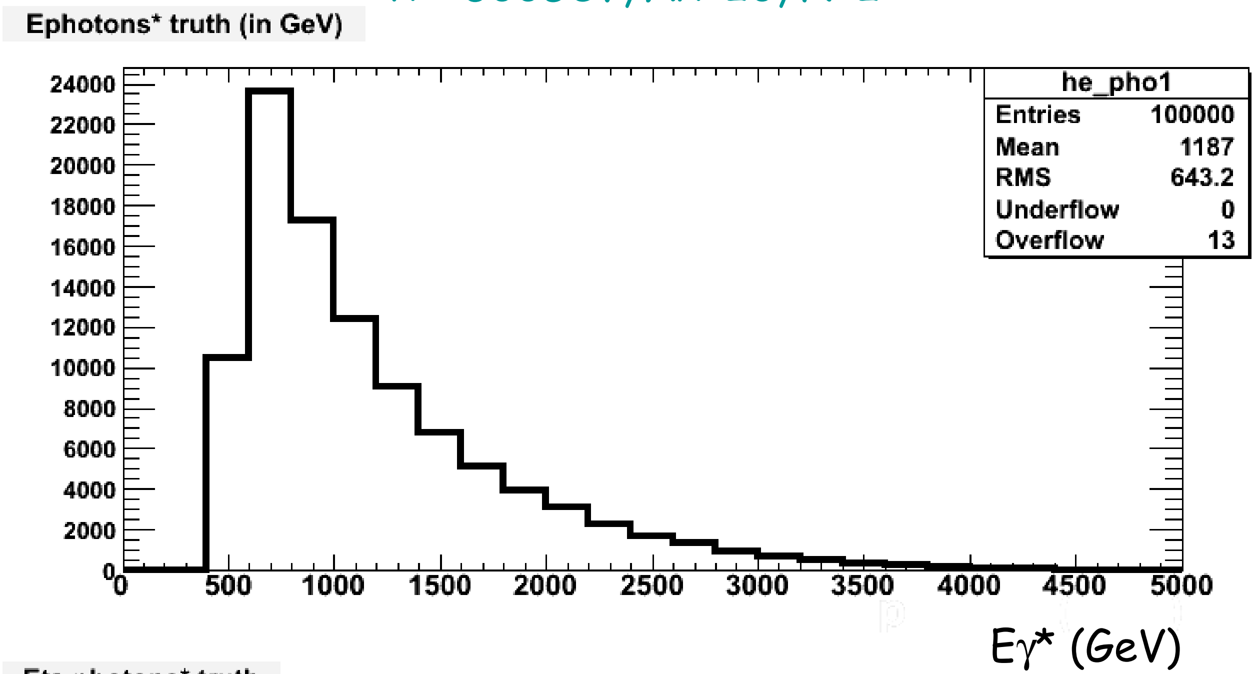
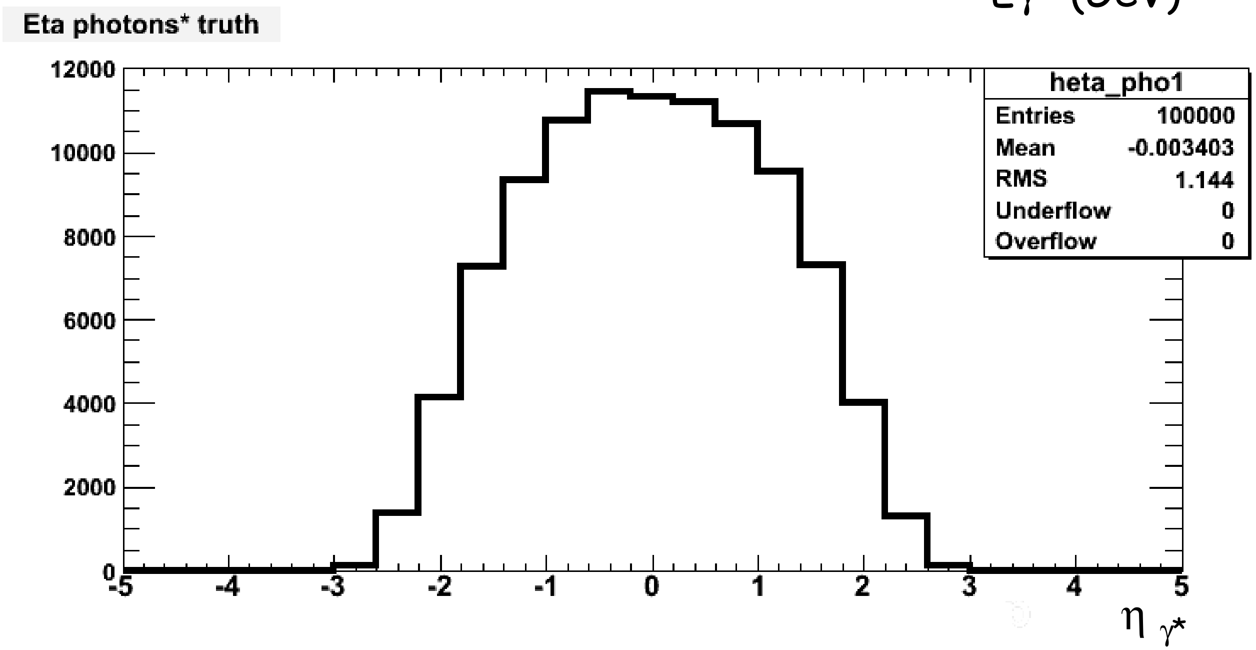
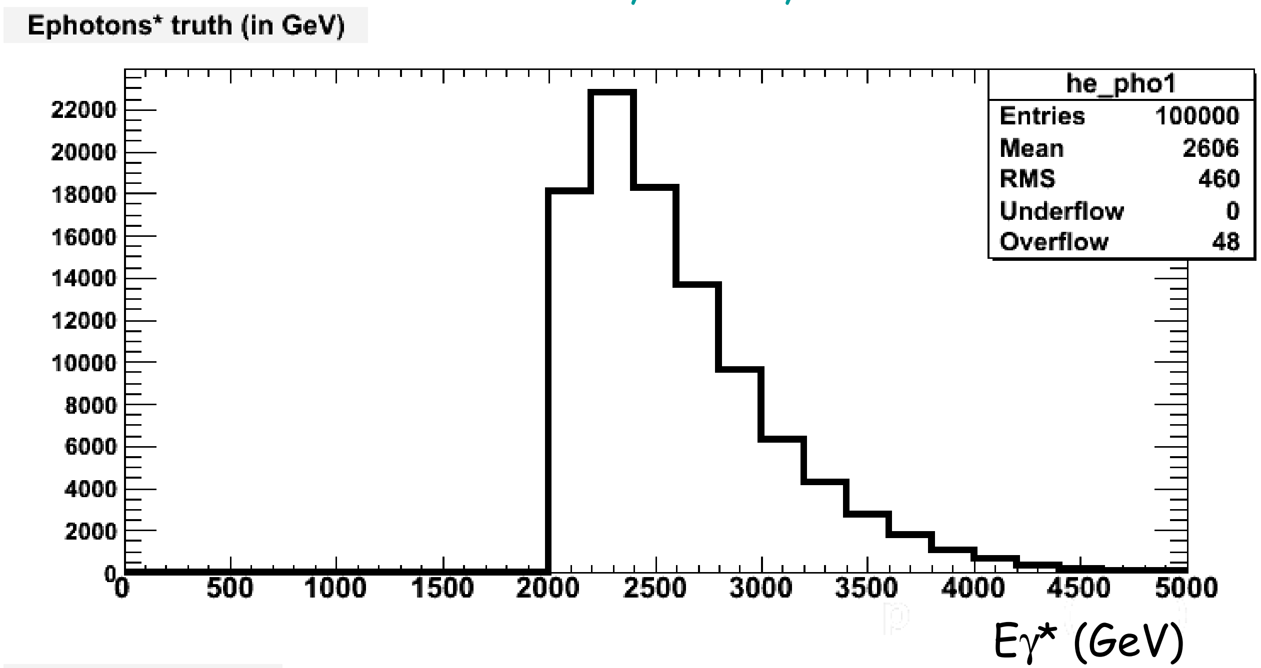
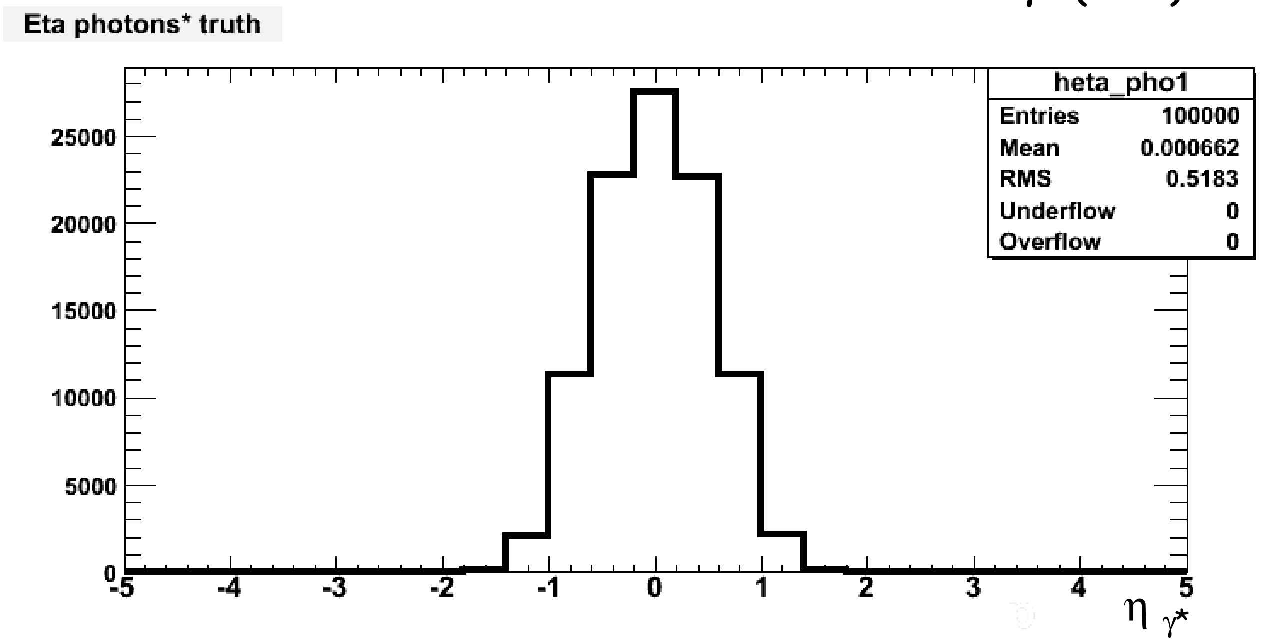




Cascade decay from Pythia

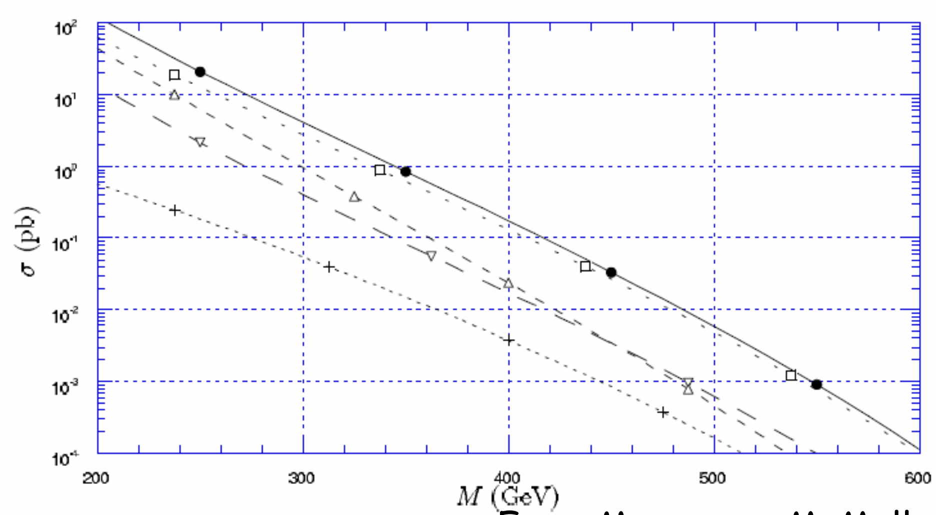
R^{-1}=2000GeV, ΛR=20, N=2

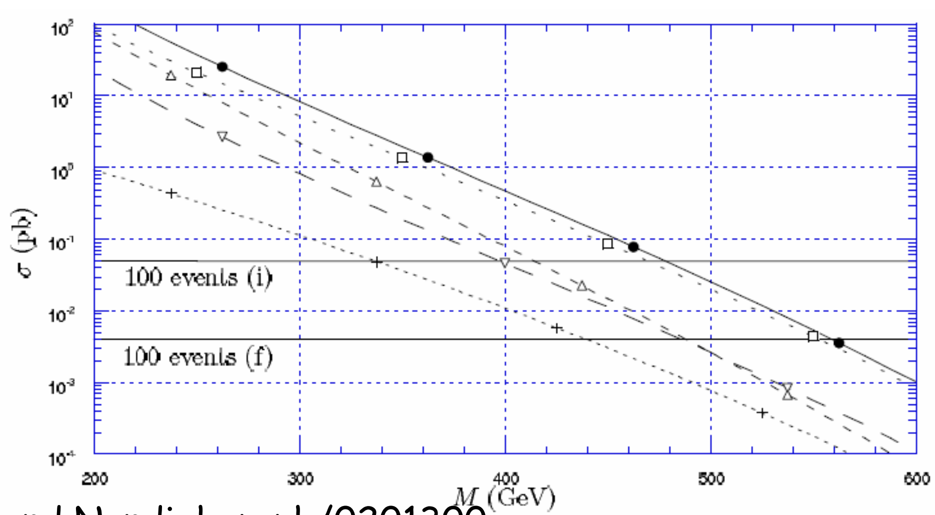




End of presentation

Production Cross Sections





From Macesanu, McMullen and Nandi, hep-ph/0201300.

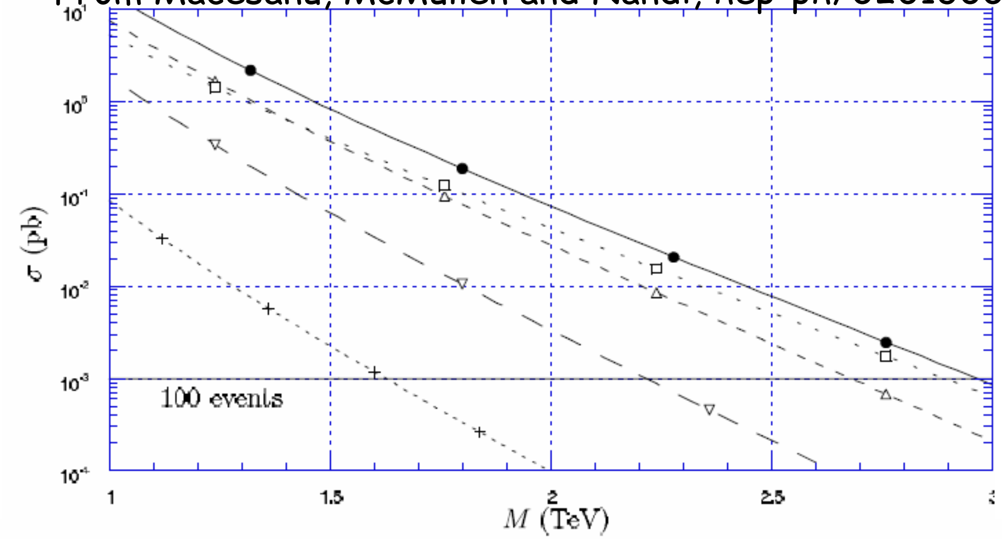


Figure 2: The cross section for the production of two stable KK final states is shown as a function of the KK mass for Tevatron Run I (top) and II (bottom). The solid curve corresponds to the total contribution, while the dashed lines represent the partial contributions of KK quark pair (□), KK quark-gluon (△), and KK gluon pair (▽) production. Also shown is top production (+), which features a different collider signature (namely, the top will subsequently decay into additional states). Solid horizontal lines mark 100 events at the initial and final projected luminosities for Run II.

UED scenario

All particles, fermions as well as bosons,, live in a 4+δ dimensional brane
which is potentially embedded in a larger space where only gravitons propagate.

Momentum conservation along the Xtra dimensions dictates that KK particles can be produced only in pairs.
The limits on the compactification scale of these extra dimensions are so far as low as a few hundred GeV.

There are no a priori constraints on the number of UEDs.
But we shall consider only the simpler case when δ =1.
For δ=1 obtaining the SM chiral fermions out of the zero modes of the 5^{th} dimensional KK fields requires that the 5^{th} dimension have an orbifold structure???. For simplicity this is usually taken to be S_1/Z_2.
In this model, for each SM Dirac fermion q there are two 5D fermionic fields "qdot" and "qspot".
Qdot is a doublet under SU(2) while qspot is a singlet.
qdot_L and qspot_R are taken to be even under the Z2 orbifold symmetry,
while qdot_R and qspot_L are taken to be odd,
therefore projecting out half the zero modes of each KK field???
The remaining halves stand for the left and right-handed parts of the SM chiral fermions:
q_L=qdot_0, q_R=qspot_0.

4D interactions of the nth KK excitation of qdot and qspot fields with the SM gauge bosons are given by

$$\mathcal{L}_{q_n - A} = -\bar{Q}_n^{\bullet} \left\{ Qe \not{A} + \frac{g_2}{\cos\theta_W} \left(\frac{\tau_3}{2} - Q\sin^2\theta_W \right) \not{Z} + \frac{g_2}{\sqrt{2}} \begin{bmatrix} 0 & \not{W}^+ \\ \not{W}^- & 0 \end{bmatrix} \right\} Q_n^{\bullet}$$

$$- \bar{q}_n^{\circ} Q \left(e \not{A} - g_2 \frac{\sin^2\theta_W}{\cos\theta_W} \not{Z} \right) q_n^{\circ}$$

At tree level, the KK excitations masses come from the 5D kinetic energy terms
with a small contribution from the Higgs interaction (which gives mass to the zero mode fields)
$m_n^2 = n^2/R^2 + m_{SM}^2$

Gravity Mediated decays of the LKP

The UED fields propagate a short way in the 5th D (the width of the brane π*R)
while gravity propagates all the way up to 2π*R_b.

The extra momentum along the y direction resulting from KK number violation is absorbed in the brane.

Large density of states for the KK gravitons in the 5th D
(the splitting between adjacent levels is of order eV)
makes up for the smallness of the gravitational coupling,
allowing the decay width of the matter KK excitations through this mechanism
to be phenomenologically relevant (they decay within the detector).

Cascade decay
Radiative Corrections to KK Masses, hep-ph/0204342

$$\delta\,(m^2_{B_n}) = -\frac{39}{2}\,\frac{g'^2\,\zeta(3)}{16\pi^4}\boxed{\left(\frac{1}{R}\right)^2},$$

$$\delta\,(m^2_{W_n}) = -\frac{5}{2}\,\frac{g_2^2\,\zeta(3)}{16\pi^4}\left(\frac{1}{R}\right)^2,$$

$$\delta\,(m^2_{g_n}) = -\frac{3}{2}\,\frac{g_3^2\,\zeta(3)}{16\pi^4}\left(\frac{1}{R}\right)^2,$$

$$\delta(m_{f_n}) = 0,$$

$$\delta(m^2_{H_n}) = 0,$$

$$\bar\delta\,m_{Q_n} = m_n\left(3\,\frac{g_3^2}{16\pi^2} + \frac{27}{16}\,\frac{g_2^2}{16\pi^2} + \frac{1}{16}\,\frac{g'^2}{16\pi^2}\right)\ln\frac{\Lambda^2}{\mu^2},$$

$$\bar\delta\,m_{u_n} = m_n\left(3\,\frac{g_3^2}{16\pi^2} + \frac{g'^2}{16\pi^2}\right)\ln\frac{\Lambda^2}{\mu^2},$$

$$\bar\delta\,m_{d_n} = m_n\left(3\,\frac{g_3^2}{16\pi^2} + \frac{1}{4}\,\frac{g'^2}{16\pi^2}\right)\ln\frac{\Lambda^2}{\mu^2},$$

$$\bar\delta\,m_{L_n} = m_n\left(\frac{27}{16}\,\frac{g_2^2}{16\pi^2} + \frac{9}{16}\,\frac{g'^2}{16\pi^2}\right)\ln\frac{\Lambda^2}{\mu^2},$$

$$\bar\delta\,m_{e_n} = m_n\,\frac{9}{4}\,\frac{g'^2}{16\pi^2}\boxed{\ln\frac{\Lambda^2}{\mu^2}},$$

$$\bar\delta\,(m^2_{B_n}) = m_n^2\left(-\frac{1}{6}\right)\frac{g'^2}{16\pi^2}\ln\frac{\Lambda^2}{\mu^2},$$

$$\bar\delta\,(m^2_{W_n}) = m_n^2\,\frac{15}{2}\,\frac{g_2^2}{16\pi^2}\ln\frac{\Lambda^2}{\mu^2},$$

$$\bar\delta\,(m^2_{g_n}) = m_n^2\,\frac{23}{2}\,\frac{g_3^2}{16\pi^2}\ln\frac{\Lambda^2}{\mu^2},$$

$$\bar\delta\,(m^2_{H_n}) = m_n^2\left(\frac{3}{2}\,g_2^2 + \frac{3}{4}\,g'^2 - \lambda_H\right)\frac{1}{16\pi^2}\ln\frac{\Lambda^2}{\mu^2} + \overline{m}_H^2\ .$$