The computation of cross sections in brane world models

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Introduction

- **CompHep** and **PYTHIA** are well known programs for simulation a processes of "New Physics".
- How do we simulate the collider processes $pp \to \text{jet} + \not{E}_T^{miss}$ in the brane world models with an extra spatial dimension of infinite size?
- Setup: modified Randall Sundrum model with one infinite and n compact extra dimension (RSII-n model).
- Motivation and cross-checking:
  1) **CTEQ**, **GLV**, **MRST** and **Alekhin's** LO PDFs coincide at large QCD-scale parameter Q^2.
  2) Simulations of $pp \to \text{jet} + Z^0$ collision on **CompHep** and **Mathematica7** in the framework of standard model.
- Simulations of $pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$ collision on **Mathematica7** were obtained in the framework of RSII-n with LO Gluck Reya Vogt PDFs.

Background metric of the RSII-n model

T. Gherghetta M. Shaposhnikov 2000.

Consider 3 - brane with n compact dimensions, embedded in a $(5+n)$ - spacetime AdS_{5+n} metric:

$$ds^2 = a(z)^2(\eta_{\mu\nu}dx^\mu dx^\nu - \delta_{ij}d\theta^i d\theta^j) - dz^2, \tag{1}$$

z -is the infinite extra-dimension

θ_i - are the compact extra-dimensions $\theta_i \in [0, 2\pi R_i]$, $i = \overline{1, n}$,

n - is a number of compact extra-dimensions,

$a(z) = e^{-k|z|}$ is a warp factor from Randall-Sundrum model,
k is a AdS curvature.

Symmetry breaking sector of the SM

$$S = \int d^4x\, dz \prod_{i=1}^{n} \frac{d\theta_i}{2\pi R_i} \sqrt{g} \Big[-\frac{1}{2} | W_{MN} |^2 + m_W^2 | W_M |^2 - \frac{1}{4} Z_{MN}^2 + \frac{1}{2} m_Z^2 Z_M^2 - \\ - \frac{1}{4} F_{MN}^2 + \frac{1}{2} (\partial_M \chi)^2 - \frac{1}{2} m_\chi^2 \chi^2 + \delta(z) \mathcal{L}_F \Big], \tag{2}$$

where $m_W^2 = \frac{1}{4}\widetilde{g}_2^2 v^2$, $m_Z^2 = \frac{1}{4}(\widetilde{g}_2^2 + \widetilde{g}_1^2) v^2$ and $m_\chi^2 = \lambda v^2$ are the bulk masses of the gauge fields and Higgs respectively.

At the energies of interest we have $\sqrt{s} \ll 1/R_i \sim M_{pl}$

The table of the constraints on n and k

n	1	2	3	4	5	6
k, GeV $\gtrsim$	$5.5 \cdot 10^6$	$2 \cdot 10^4$	$2.5 \cdot 10^3$	$9 \cdot 10^2$	$4 \cdot 10^2$	$3 \cdot 10^2$

Table I: The lower bounds on the parameter k for various numbers of compact extra dimensions n.

$$\Gamma_{RS}^{Z} = \frac{2\pi}{n\Gamma^2\left(\frac{n}{2}\right)} M_Z \left(\frac{M_Z}{2k}\right)^n, \qquad (3)$$

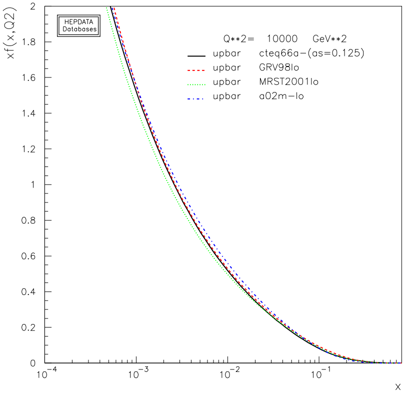
is the invisible decay rate of Z^0_{bulk} boson. Constraints on the parameters k and n are defined by the following condition:

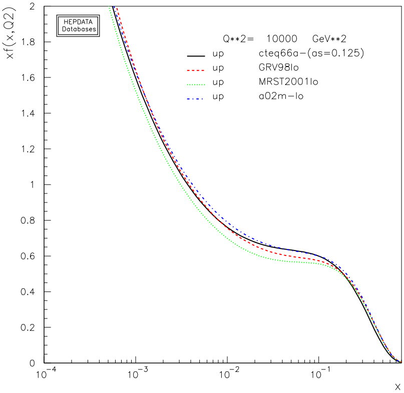
$$\Gamma_{RS}^{Z} \leq \Delta\Gamma_{invis}^{Z} \simeq 1.5 MeV \qquad \text{C.Amsler et al. PDG (2008)}$$

$$\Delta\Gamma_{invis}^{Z} - \text{is the experimental uncertanty.}$$

CTEQ, **GRV**, **MRST** and **Alekhin's** LO PDFs:

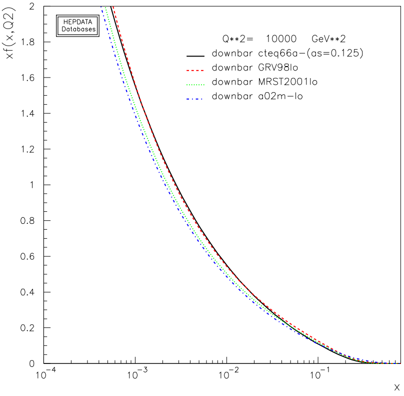
$x\bar{u}(x, Q^2)$ and $xu(x, Q^2)$ at $Q^2 = 10^4 GeV^2$

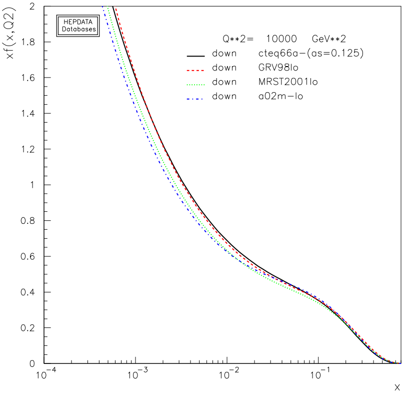




CTEQ, **GRV**, **MRST** and **Alekhin's** LO PDFs:

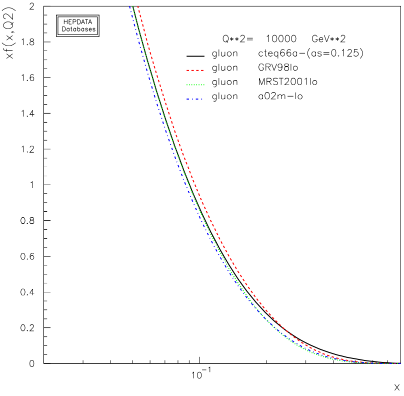
$x\bar{d}(x, Q^2)$ and $xd(x, Q^2)$ at $Q^2 = 10^4 GeV^2$

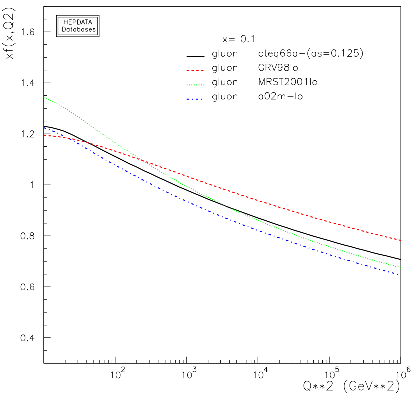




CTEQ, **GRV**, **MRST** and **Alekhin's** LO PDFs:

$xg(x, Q^2)$ vs x at $Q^2 = 10^4\,GeV^2$ and $xg(x, Q^2)$ vs Q^2 at $x = 0.1$

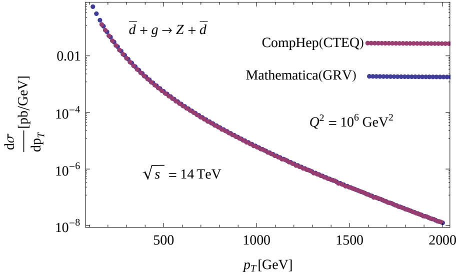


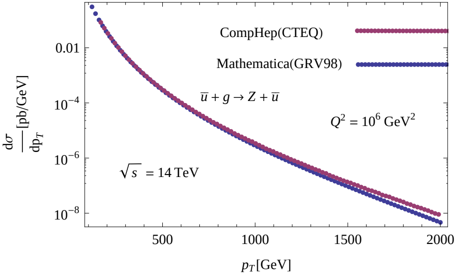


Cross-checking: **CompHEP** vs **Mathematica7**

Standard Model Test:

$\bar{d}g \to Z^0\bar{d}$ $\qquad\qquad$ $\bar{u}g \to Z^0\bar{u}$

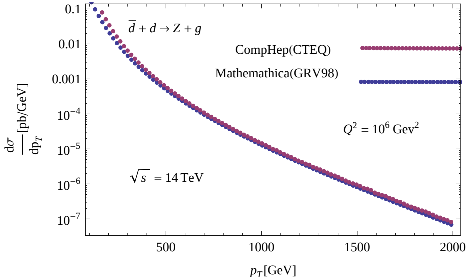


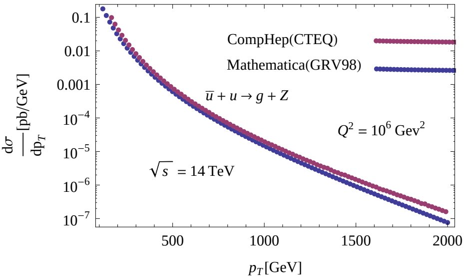


Cross-checking: **CompHEP** vs **Mathematica7**

Standard Model Test:

$\bar{d}d \to Z^0 g$ $\qquad$ $\bar{u}u \to Z^0 g$

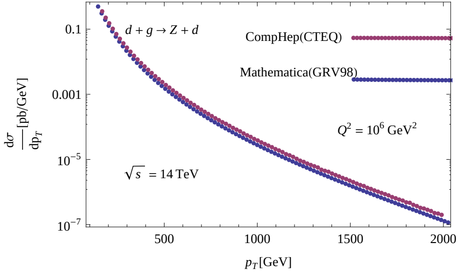


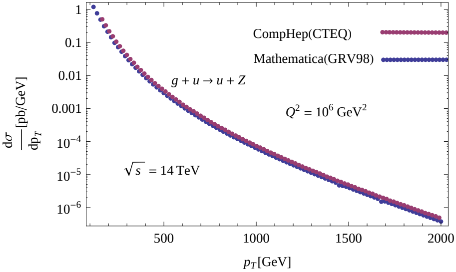


Cross-checking: **CompHEP** vs **Mathematica7**

Standard Model Test:

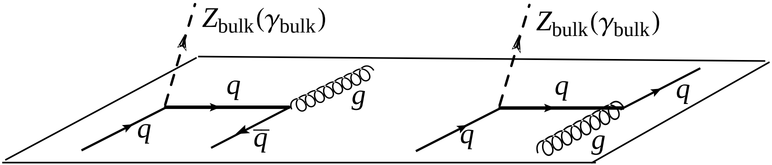
$dg \to Z^0 d$ $\qquad$ $ug \to Z^0 u$





$pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$

RSII-n setup:

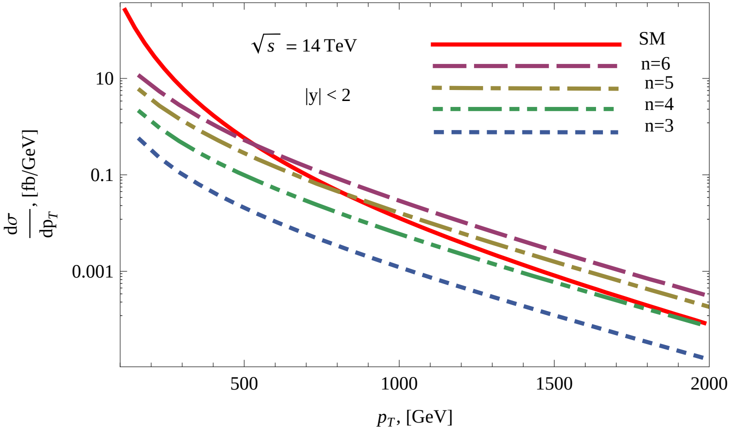


$$\frac{d^2\sigma}{dy\, p_T\, dp_T} = \int dx_1 dx_2 \sum_{i,j=q,\bar{q},g} \frac{f_i(x_1,Q^2)}{x_1}\frac{f_j(x_2,Q^2)}{x_2}\frac{1}{4\pi s\, m}\overline{\sum_k}|\mathcal{M}_{ij\to k(bulk)}|^2 \qquad (4)$$

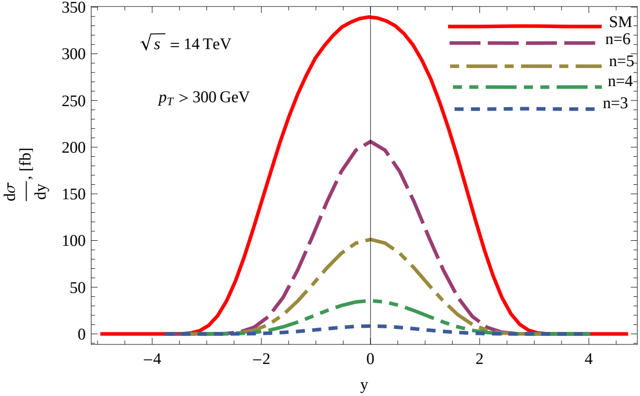
p_T - jet transversal momentum .

y - jet rapidity.

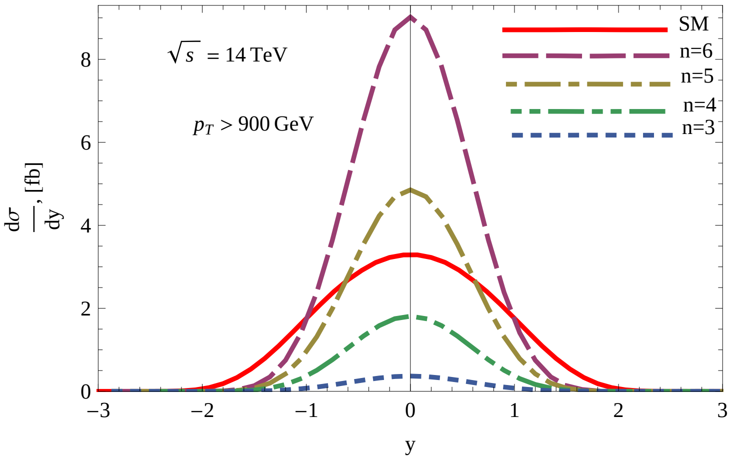
$m^2 = x_1 x_2 s\left(1 - \frac{p_T}{x_1\sqrt{s}}e^{-y} - \frac{p_T}{x_2\sqrt{s}}e^{y}\right) > 0$ is the invariant bulk mass of $Z^0_{bulk}(\gamma_{bulk})$. QCD-scale parameter Q^2 was fixed at $10^6\, GeV^2$



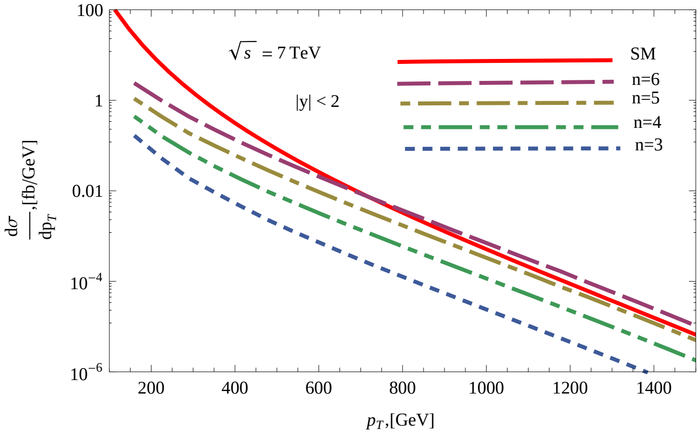
$pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$ (dashed lines). The jet rapidity cut is $|y| < 2$. SM background - $pp \to \text{jet} + \nu\bar{\nu}$ (solid line). At the LHC energy $\sqrt{s} = 14$ TeV. Signal dominates: $p_T > 500\,\text{GeV}$ for $n = 6$, $p_T > 800\,\text{GeV}$ for $n = 5$



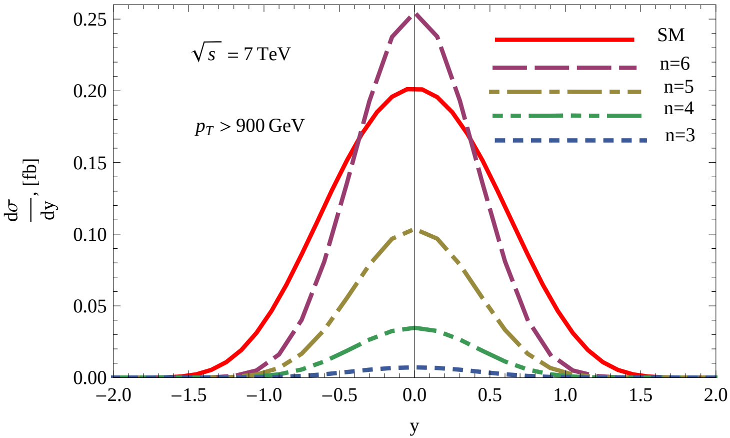
$pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$ (dashed lines) The jet transverse momentum cut is $p_T > 300$ GeV. SM background is $pp \to \text{jet} + \nu\bar{\nu}$ (solid line). At the LHC energy $\sqrt{s} = 14$ TeV. The main background contribution comes from 300 Gev $< p_T <$ 800 GeV



Diff. cross section of $pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$ (dashed lines) The jet transverse momentum cut is $p_T > 900$ GeV. SM background is $pp \to \text{jet} + \nu\bar{\nu}$ (solid line). The center-of-mass energy of incoming protons is $\sqrt{s} = 14$ TeV.



Diff. cross section of $pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$ (dashed lines). The jet rapidity cut is $|y| < 2$. SM background is $pp \to \text{jet} + \nu\bar{\nu}$ (solid line). The center-of-mass energy of incoming protons is $\sqrt{s} = 7$ TeV.



Diff. cross section of $pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$ (dashed lines). The jet rapidity cut is $p_T > 900$ GeV. SM background is $pp \to \text{jet} + \nu\bar{\nu}$ (solid line). The center-of-mass energy of incoming protons is $\sqrt{s} = 7$ TeV.

n	3	4	5	6
k, GeV	$2.5 \cdot 10^3$	$9 \cdot 10^2$	$4 \cdot 10^2$	$3 \cdot 10^2$
$\mathcal{L}$, fb^{-1}	$7.1 \cdot 10^2$	$3.7 \cdot 10^1$	7.5	3.1
N_S	$3.6 \cdot 10^2$	10^2	$5 \cdot 10^1$	$3.8 \cdot 10^1$

Integrated luminosity $\mathcal{L}$ and numbers of signal events N_S for various numbers of compact extra dimensions n, reqired for 5σ discovery at the LHC center-of-mass energy $\sqrt{s} = 14$ TeV. Jet cuts are $|y| < 2$, $p_T > 900$ GeV.
At 7 TeV the integrated luminosity is $\mathcal{L} = 200$ fb^{-1} for numbers of compact dimension $n = 6$.

Summary

- In the framework of RSII-n model the distributions of $pp \to \text{jet} + Z^0_{bulk}(\gamma_{bulk})$ collision were simulated on **Mathematica7** with GRV LO PDFs implemented.
- The detection of the extra spatial dimension at 7 TeV appears to be hopeless: $\mathcal{L} \gtrsim (200 - 1000)\,\text{fb}^{-1}$ for $n = 3, 4, 5, 6$;
- At the LHC energy equal 14 TeV luminosity: $\mathcal{L} \gtrsim (10 - 100)\text{fb}^{-1}$ for $n = 3, 4, 5, 6$.