



## The 3<sup>rd</sup> generation quarks in warped models : LHC predictions from LEP/Tevatron anomalies

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## **Outline**

*I) Introduction: a warped model* 

*II) A<sup>t</sup><sub>FB</sub> and tt cross section @ Tevatron III)*  $A^b_{FB}$  and EW precision tests @ LEP *IV) Constraints and predictions @ LHC V) Conclusions*   $\overline{1}$ 

## *I) Introduction: a warped model*

### **The Randall-Sundrum (RS) scenario with bulk fields:**



Planck-brane TeV-brane

• **RS addresses the gauge** *hierarchy* **:** 

$$
M_{grav} \approx TeV \approx Q_{EW}
$$

*Randall, Sundrum (1999)* 

• **RS generates the mass** *hierarchies* **:** 

 $m_e$  <<  $m_t$ 

*Gherghetta, Pomarol (2000)* 

*…*

## *I) Introduction: a warped model*

### **The Randall-Sundrum (RS) scenario with bulk fields:**



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<u>e</u> New Physics effects in the heavy fermion sector !

### *+ attractive features of the RS scenario with bulk fields (= dual via AdS/CFT to composite Higgs & top models) :*

- WIMP candidates for the dark matter of universe: a LKP stable due to a possible KK-parity *(like in UED)*
- Unification of gauge couplings *(as in ADD)* at high-energies
- Fermion mixing angles and flavor structure *(as in ADD) → in SUSY*
- *Extra-Dimensions* = necessary ingredients for higher-energy string theories

### **The EW precision constraints in warped models :**

Bulk gauge bosons/fermions mix with their KK excitations => tree-level contributions to EW observables

*Ways out* to respect the constraints from EW precision data for  $M_{KK}$ ~TeV :

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*~> Gauge custodial symmetry in the bulk* 

 $O(3)$   $SU(2)_V \times P_{LR}$  $O(4)$   $SU(2)_L \times SU(2)_R$ ⇓ ≈ ⇓

*Agashe, Delgado, May, Sundrum (2003)* 

*~> Brane-localized kinetic terms for fermions/gauge fields Carena et al. (2002) Aguila et al. (2003)* 

*~> Modification of the AdS metric in the vicinity of the IR brane Cabrer, Gersdorff, Quiros (2010)* « Minimal » representations under  $SU(2)_L$  x  $SU(2)_R$  x  $U(1)_X$ : H=(2,2)<sub>0</sub>

$$
\begin{pmatrix}\nt_{1L} & b'_{L} & q'_{-4/3L} \\
b_{1L} & q''_{-4/3L} & q'_{-7/3L}\n\end{pmatrix}_{-5/6} \n(b_R q'_{-4/3R})_{-5/6} \n\begin{pmatrix}\nq'_{5/3L} & t_{2L} \\
t'_L & b_{2L}\n\end{pmatrix}_{2/3} \n(t_R)_{2/3}
$$
\n
$$
SU(2)_R \longrightarrow U(1)_R
$$
\n
$$
U(1)_R \times U(1)_X \longrightarrow U(1)_Y
$$
\n
$$
W_R^3 \longrightarrow B_X \longrightarrow U(1)_Y
$$
\n
$$
(1)_Y \longrightarrow U(1)_Y
$$

« Minimal » representations under  $SU(2)_L$  x  $SU(2)_R$  x  $U(1)_X$ : H=(2,2)<sub>0</sub>

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t'_L & b_{2L}\n\end{pmatrix}_{2/3} \quad (t_R)_{2/3}
$$
\n
$$
SU(2)_R \longrightarrow U(1)_R
$$
\n
$$
U(1)_R \times U(1)_X \longrightarrow U(1)_Y
$$
\n
$$
W_R^3 \quad B_X \longrightarrow B_Y \quad (+Z' KK)
$$

 $Z'$  charges (I<sub>3R</sub> isospin) and coupling (g<sub>Z'</sub>~ 2) => Zbb couplings addressing  $A<sup>b</sup>_{FB}$ field belongs to a bidoublet (2*,* 2)<sup>0</sup> under the custodial symmetry, the group representations of

> $\mathbf{t}_\mathsf{R}$  singlet: no custodian top partners => possible large g<sup>KK</sup>tt̄ couplings favor  $\mathsf{A}^\mathsf{t}_{\mathsf{FB}}$  $\overline{1}$

#### *II)*  $A^{t}$ <sub>FB</sub> and tt cross section @ Tevatron *D* the propagator of the KK and the KK and the *KK and the KK and the KK and the KK* .<br>4

 $A<sup>t</sup><sub>FB</sub>$  at Tevatron  $\Delta y = -1$   $\Delta y = 1$ framework by, and the second by  $\mathcal{L}(\mathcal{L})$ 

« What is the Forward-Backward asymmetry for the top quark ? »

q origin, and the direction of the  $\alpha$  origin, in the *q* origin,  $\alpha$  $\begin{array}{ccc} t & B & F \end{array}$ *<sup>t</sup> >* 0 (and *p<sup>z</sup> >* 0) so that the asymmetry of Eq.(2) is equal to  $A_{\text{FB}}^t = \frac{\sigma^F - \sigma^B}{\sigma^F + \sigma^B} = \frac{\sigma[\cos\theta_t^*: 0 \to 1] - \sigma[\cos\theta_t^*: -1 \to 0]}{\sigma[\cos\theta_t^*: 0 \to 1] + \sigma[\cos\theta_t^*: -1 \to 0]}$  $\frac{\sigma[\cos \theta_t^* : 0 \to 1] - \sigma[\cos \theta_t^* : -1 \to 0]}{\sigma[\cos \theta_t^* : 0 \to 1] + \sigma[\cos \theta_t^* : -1 \to 0]} = \frac{\sigma[y_t > 0] - \sigma[y_t < 0]}{\sigma[y_t > 0] + \sigma[y_t < 0]}$ Now, *y<sup>t</sup>* = (*y<sup>t</sup>* − *y<sup>t</sup>*  $\mathsf{Periodit}(F)$ ¯ is a longitudinal motion invariant  $\bar{t}$  $\bar{t}$  B  $F$  $-\sigma[\cos\theta_t^*:-1\to 0]$   $\sigma[y_t>0]-\sigma[y_t<0]$  $\cos \theta_t^* : -1 \to 0$   $\sigma[y_t > 0] + \sigma[y_t < 0]$  $\frac{1}{\sqrt{2}}$ **0** with Parity-violating couplings  $\begin{bmatrix} 1 & 1 \end{bmatrix}$   $\begin{bmatrix} 1 & 1 \end{bmatrix}$   $\begin{bmatrix} 1 & 1 \end{bmatrix}$ of-mass frame for the *qq*¯ initial state, dˆσ*SM*−*LO*  $\frac{:-1 \rightarrow}{1}$ (ˆ*s*) 0  $\overline{\phantom{0}}$  $=$  $\frac{0}{1}$  $[u_t > 0] - \sigma[t]$  $\frac{]-\sigma[y_t<0]}{+}$ .<br>.

difference  $\alpha$  and  $\alpha$  is the lepton charge  $y_t = \frac{1}{2} \ln[(E + p_z)/(E - p_z)] = \Delta y / 2$ **Rapidity**:  $y_t = \frac{1}{2} \ln[(E + p_z)/(E - p_z)] = \Delta y/2$ ( tt rest frame ) Rapidity :

 $\Delta y = -1$ 

 $\left(\begin{array}{c} \bullet \\ \bullet \end{array}\right)^{q}$   $\left(\begin{array}{c} \bullet \\ \bullet \end{array}\right)^{q}$ 

 $P$   $\bigvee$   $\bigwedge$   $\overline{P}$ 

t

*a<sup>q</sup>* = (*Q*(*cq<sup>R</sup>* ) − *Q*(*cq<sup>L</sup>* ))*/*2*, v<sup>q</sup>* = (*Q*(*cq<sup>R</sup>* ) + *Q*(*cq<sup>L</sup>* ))*/*2*,*

 $\theta$ 

 $q \rightarrow \frac{q}{\bar{q}}$ 

 $\mathcal{C}(\mathcal{M})$ 

*a*  $\frac{p}{2}$  /*c*  $\frac{p}{2}$  /*c*<sup>*x*</sup> *n d* 

the data we use cause: most recent, unfolded and the only ones on rapidity dependence

**01-2011** CDF in the lepton+jets channel with **5.3fb-1** *:* 

### $A_{FB}^{t} = 0.158 + 0.075$  (+1.3 sigma from SM prediction)





$$
A_{\text{FB}}^{|\Delta y| < 1} = \frac{N(1 > \Delta y > 0) - N(-1 < \Delta y < 0)}{N(1 > \Delta y > 0) + N(-1 < \Delta y < 0)}, \quad A_{\text{FB}}^{|\Delta y| > 1} = \frac{N(\Delta y > 1) - N(\Delta y < -1)}{N(\Delta y > 1) + N(\Delta y < -1)} \quad |\Delta y| < 3
$$

 $|\Delta y| \leq 3$ 

## **in the considered warped model**



 $\sim$  (negligible EW gauge contrib.)

\n $A_{FB}^t$ non-vanishing\n $\begin{bmatrix}\n g_s Q(c_t) \\  g_s Q(c_q) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n g_s Q(c_q) \\  \hline\n\end{bmatrix}\n \begin{bmatrix}\n g_s Q(c_t) \\  \hline\n\end{bmatrix}\n \$
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## **in the considered warped model**



**We will show that EW** c\_u/d<sub>1</sub>~0.44, c\_u/d<sub>R</sub>~0.8, c\_c/s<sub>1</sub>~0.6, c\_c<sub>R</sub>~0.6, **fits are OK for :**  $c_{B_R}$ ~0.49,  $c_{L}$ t/b<sub>l</sub> ~0.51,  $c_{D_R}$ ~0.53,  $c_{L_R}$  -1.3

EW tests

not so far

treated in

this setup

#### *Asymmetry at parton level (neglecting 2nd/3rd generation + gluon initial state)…* Asymmetry at parton level (neglecting 2nd/3rd generation + gluon initial state)...  $\mathcal{H} \mathcal{H} \mathcal{$  $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$  $cd/2rd$  consistent aliven initial atotal rangework by the series of arton lough incologing and index anoxation  $\mu$  alugn initial state) *arton lever (πeglecting z 70 generation • giuon initial state)...*

$$
\hat{A}_{\text{FB}}^{LO}(\hat{s}) = a_q a_t \frac{4\pi \alpha_s^2(\mu_r)}{9} \frac{\beta_t^2 |\mathcal{D}|^2 [(\hat{s} - M_{KK}^2) + 2v_q v_t \hat{s}]}{\hat{\sigma}_{SM-LO}^{total}(\hat{s}) + \hat{\sigma}_{RS+inter-LO}^{total}(\hat{s})} \begin{bmatrix} a_q = (Q(c_{q_R}) - Q(c_{q_L}))/2, \\ a_t = (Q(c_{l_R}) - Q(c_{l_L}))/2, \\ v_q = (Q(c_{q_R}) + Q(c_{q_L}))/2, \\ v_t = (Q(c_{l_R}) + Q(c_{l_L}))/2, \\ \frac{\hat{\sigma}_{\text{SM}}^{S} - NLO(\hat{s}) + \hat{\sigma}_{RS+inter-LO}^{BS}(\hat{s})}{\hat{\sigma}_{SM-NLO}^{S}(\hat{s}) + \hat{\sigma}_{RS+inter-LO}^{BS}(\hat{s})} \approx \hat{A}_{\text{FB}}^{LO}(\hat{s}) + \hat{A}_{\text{FB}}^{SM-NLO}(\hat{s}) \begin{bmatrix} q\bar{q} \rightarrow t\bar{t} \\ s\bar{t} \end{bmatrix}
$$

#### *Asymmetry at parton level (neglecting 2nd/3rd generation + gluon initial state)…* Asymmetry at parton level (neglecting 2nd/3rd generation + gluon initial state)...  $\mathcal{H} \mathcal{H} \mathcal{$  $\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}$  $cd/2rd$  consistent aliven initial atotal rangework by the series of arton lough incologing and index anoxation  $\mu$  alugn initial state) *arton lever (πeglecting z 70 generation • giuon initial state)...*

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$$
\nFor our parameters such that:  
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a_q a_t = -1.4 \quad v_q v_t = 0.7
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\n $$ 

Full asymmetry after convolution with MSTW-2008...



*Full asymmetry as a function of rapidity...* 





## *III) A<sup>b</sup><sub>FB</sub>* and EW precision tests @ LEP



### *Interpretation in a generic extra-dimensional model…* **(difficult in SUSY)**



### *Interpretation in a generic extra-dimensional model…* **(difficult in SUSY)**



$$
\left| \delta Q_Z^f \right| \approx 1\% \quad \ll \quad \left| \delta Q_Z^L / R \right| \approx \left| -1.5/30\% \right| \quad m_b(c_{t_R}) \ll m_f(c_{\text{light}})
$$
\nCoupling  $Z_{KK} f_l \overline{f_l} \ll$  Coupling  $Z_{KK} b \overline{b} \qquad m_t(c_{t_R}) \uparrow \Rightarrow m_b(c_{t_R}) \downarrow$ 

'natural' conditions within the RS model  $\overline{\phantom{0}}$ 

### *Summary of the EW observables…*



#### *IV)* Constraints and predictions @ LHC CMS 158 *±* 19 pb 163 pb [21] +0*.*26σ +0*.*24σ right-hand side of Fig. 2, in which are given these unfolded results, illustrates that the  $\bm{I}(\bm{V})$  Constraints and predictions  $\bm{\omega}$  LHC  $\bm{\omega}$  ${\bf f}$  graphic series and productions at  ${\bf H}$ *along the flat preductions @ LHC* profile of the gluon. The *g*(1)*gg* coupling is zero at tree level due to the orthonormalization condition on the ¯ production cross section : **Constraints and predictions @ LHC** The *g*(1)*gg* coupling is zero at tree level due to the orthonormalization condition on the  ${\bf n}$ straints and predictions (0) LHC with the flat profile of the flat profile of the flat profile of the gluon.

**Comparison of the tt cross section**  $\sigma_{t\bar{t}}$  $\bar{t}$  and the point of  $\bar{t}$ The local communications of the  $t$  in the small contribution at the  $t$  is contribution function. at the LHC  $\alpha$  superiorition of the KK gluon exchange of the KK  $\alpha$ being the scattering angle, so that the asymmetry generated by the asymmetry generated by the K gluon exchange As a consequence, the RS contribution to the *tt*  $\frac{d}{dt}$  rate is ordered and  $\frac{d}{dt}$  $\begin{array}{|c|c|c|}\hline \textbf{Comparison of the t\bar{t}}\textbf{ cross section} & \sigma_{t\bar{t}}\hline \end{array}$ <u>de la production cross section de la production de la production de la production de la production de la produc</u> wave functions along the extra dimension  $\blacksquare$  $G$  comparison of the  $\frac{1}{2}$  cross soction  $\sigma =$ wave functions along the extra dimension  $\mathcal{S}$  combined with the gluon. The flat profile of the gluon. The *g*(1)*gg* coupling is zero at tree level due to the orthonormalization condition on the **Example 19 Separate School Section Section 19** wave functions along the extra dimension  $\mathbb{R}$  combined with the flat profile of the gluon. The gluon. The loop induced coupling leads to small contributions to the *tt* at the LHC [37]. The contribution of the KK gluon exchange originates mainly from the **q** internal state so that the rate of *the rate of pp* → *t*  $\frac{1}{\sqrt{t}}$  in RS+SM is not significantly different from  $\frac{1}{\sqrt{t}}$ 

in RS+SM NNLO  $\mu_F = \mu_R = m_t = 173 \text{ GeV}$   $\sqrt{s} = 7 \text{ TeV}$  $\mathcal{L} = 35$  m  $\mathcal{L} = 35$  m As a consequence, the RS contribution to the *tt* ¯)=6*.*62*±*1 pb for *<sup>µ</sup>*<sup>R</sup> <sup>=</sup> *<sup>µ</sup>*<sup>F</sup> <sup>=</sup> (HATHOR)  $\mathcal{L} = 35 \text{ pb}^{-1}$  $\sin$  RS+SM is not significantly different from  $\mu$ <sub>F</sub> that in the SM, whose major contribution at the LHC is computed from gluon-gluon-gluon-gluon-gluon-gluon-gluon $t_{\text{N}} = \mu = \mu = \mu_0 - 179 \text{ GeV}$  is  $\sqrt{s} = 7 \text{ TeV}$ As a consequence, the RS contribution to the *tt*  $r = i$  $\mathcal{L}_{\mathcal{A}}$  , the theoretical NNLO prediction in our RS model for the central NNLO prediction in our RS model for the central NNLO prediction in our RS model for the central NNLO prediction in our RS model for the cent  $\frac{1}{2}$  in RS $\pm$ SM NNLO  $\frac{1}{2}$  $H = \frac{1}{2}$  in  $T = \frac{1}{2}$  in  $T = \frac{1}{2}$  $\mu_{\rm F} = \mu_{\rm R} = m_t = 173\,\,{\rm GeV} \hspace{1cm} \sqrt{s} = 7\,\,{\rm TeV} \, \, .$ *q* intervals the rate so that the rate  $\alpha$  in the rate  $\alpha$  ${\cal L}=35\;{\rm pb}^{-1}$  in RS-SM is not significantly different from  ${\cal L}=35\;{\rm pb}^{-1}$ ¯) in RS+SM is not significantly different from  $m_{\rm EHE}$ at the  $\mu_{\text{z}} = \mu_{\text{z}} = m_s = 173 \text{ CoV}$   $\sqrt{s} = 7 \text{ TeV}$  $q^{\mu}$  is a transferred that the rate  $r^{\mu}$  is  $r^{\mu}$  in  $r^{\mu}$  is not significantly different from  $r^{\mu}$  is not significantly different from  $r^{\mu}$  is not significantly different from  $r^{\mu}$  is not significantly that in the SM, whose major contribution at the LHC is computed from gluon-gluon-gluon-gluon-gluon-gluon-gluon-g The loop induced coupling leads to small contributions to the *tt*  $\overline{a}$  $\mu_F - \mu_R - m_t - m_3$  gev  $V^b - r$  is  $r$  $(nA1HOK)$ at the LHC [37]. The contribution of the KK gluon exchange originates mainly from the  $=$   $\sqrt{\text{rev}}$  $\mathcal{L} = 30$  po in RS+SM **in RS+SM** is not significantly  $\mu_F = \mu_R = m_t = 173 \text{ GeV}$   $\sqrt{s} =$  $\sqrt{s} = 7 \text{ TeV}$ (HATHOR)  $\mathcal{L} = 35 \text{ pb}^{-1}$ that in the SM, whose major contribution at the SM, whose major contribution at the LHC is computed for  $\mathcal{L}$  $\sqrt{s} = 7$  TeV  $\mathcal{L} = 35 \; \mathrm{pb}^{-1}$  $GeV \qquad \qquad \sqrt{s} = 7 \text{ TeV}.$  $\mathcal{L} = 35 \; \mathrm{pb}^{-1}$ at the LHC [37]. The contribution of the KK gluon exchange originates mainly from the

 $\sigma(pp \to t\bar{t})$  at  $-0.86\sigma$  from the ATLAS measurement, 180 + 18.  $SM \text{ at } -0.81\sigma$  $\bar{t}$ ) at  $-0.86\sigma$  from the ATLAS measurement,  $180 + 18.5$  pb SM at  $-0.81\sigma$  $\text{SM}$  at  $\sigma(pp \to t\bar{t})$  at  $-0.86\sigma$  from the ATLAS measurement,  $180 \pm 18.5$  pb  $\frac{1}{86\sigma}$  **a**  $\frac{1}{86\sigma}$  with  $\frac{1}{86\sigma}$   $\frac$  $\text{SUSO}$  from the ATLAS measurement,  $180 \pm 18.5$  pb [M], at  $-0.81\sigma$ at the CMS value, 158  $\frac{1}{2}$  19 pp  $\frac{1}{2}$ ; even with the contract taking into a count taking into a count the contract taking into a count taking into a count taking into a count taking into a count taking into a cou  $S_{\rm M}$  at  $-0.81\sigma$  in ¯) value, based on Ref. [25] with *<sup>µ</sup>*<sup>F</sup> <sup>=</sup> *<sup>µ</sup>*<sup>R</sup> <sup>=</sup> *<sup>m</sup><sup>t</sup>* = 173 GeV, is at <sup>−</sup>0*.*81<sup>σ</sup> (the  $\frac{100 + 105}{\pi}$ SM is at −0*.*86σ) from the ATLAS measurement, 180*±* 18*.*5 pb [40], and at +0*.*36σ (SM As a consequence, the RS contribution to the *tt*  $\rightarrow tt$ ) at  $-0.86\sigma$  from the ATLAS measurement,  $180 \pm 18.5$  pb  $\text{SM} \quad \text{at} \; -0.81\sigma$ σ(*pp* → *tt* ¯) value, based on Ref. [25] with *<sup>µ</sup>*<sup>F</sup> <sup>=</sup> *<sup>µ</sup>*<sup>R</sup> <sup>=</sup> *<sup>m</sup><sup>t</sup>* = 173 GeV, is at <sup>−</sup>0*.*81<sup>σ</sup> (the  $S_{\rm M}$  at  $-0.81\sigma$  at  $\sigma$ easurement,  $180 \pm 18.5$  pb  $\sigma(pp \to tt)$  at  $-0.86\sigma$  from the ATL  $SM \text{ at } -0.81\sigma$  $\Rightarrow t\bar{t}$ ) at  $-0.86\sigma$  from the ATLAS measurement,  $180 + 18.5$  pb SM at  $-0.81\sigma$   $\cdots$  the CMS contracts of extreme, 158  $\pm$  1916  $\mu$  pb  $180 + 185$  ph  $r_{\rm SM}$ 

 $\sigma(pp \to tt)$  at  $+0.36\sigma$  from the CMS measurement,  $158 \pm 19$  pb  $d\mu + 0.510$  $\overline{16}$  from the CMS  $\overline{26}$   $\overline{4}$  $\sigma(pp \to t\bar{t})$  at  $+0.36\sigma$  from the CMS measurement  $158 \pm 10$  pb  $\text{SM} \quad \text{at } +0.31\sigma$  moin the OMD incasurement, 190  $\pm$  19 pb SM is at −0*.*86σ) from the ATLAS measurement, 180 *±* 18*.*5 pb [40], and at +0*.*36σ (SM  $\sigma(pp \to tt)$  at  $\to 0.300$  from the CMS into account the contract term in the contract of the co  $\sigma(pp \to t\bar{t})$  at  $+0.36\sigma$  from the CMS measurement, 158 + 1 <sup>7</sup>Note that recently, a similar framework has been suggested [36] where a modifications of the *AdS*  $SM$  at  $+0.31\sigma$  $\alpha t + 0.31\sigma$ at +0*.*31σ) from the CMS value, 158 *±* 19 pb [41]; even without taking into account the  $\pm 0.36\sigma$  $\frac{1}{2}$  at 19.500 from the CMS measurement,  $158 \pm 19$  pb  $\pm 0.510$  $\sqrt{t}$  +*t*) at  $±$ 0.36σ  $\frac{1}{20M}$  at  $\pm 0.310$ SM is at −0*.*86σ) from the ATLAS measurement, 180 *±* 18*.*5 pb [40], and at +0*.*36σ (SM QCD uncertainties, the agreement is thus satisfactory.  $\sigma(pp\to t\bar t$  $\bar{t}$ ) at  $+0.36\sigma$  from the CMS measurement,  $158 \pm 19$  pb  $\text{SM} \quad \text{at } +0.31\sigma$  $\sigma(pp \to t\bar{t})$  at  $+0.36\sigma$  $\frac{1}{2}$   $\frac{1}{2}$   $\frac{1}{8M}$  at  $+0.31\sigma$  from the CMS into account the set of account transitional to account the CMS in  $\sigma(pp \to t\bar t)$  $S<sub>δ</sub>$  is at +0*.*86  $+$  187*m*  $S<sub>δ</sub>$ , and at +10*.*5 pm  $S<sub>δ</sub>$ 

metric near the infrared brane allows a KK scale at 1 TeV without conflicting with EW precision tests.

σ(*pp* → *tt*

**EXECTION CRASS SECTION CONTRARY SECTION CONFLICT SIGNATURE ASSESSED SIGNATURE AT 1 TEV WITHOUT CONFIDENTIAL STRONGER SIGNATURE ARE THE INFORMATION CONFIDENTIAL STRONGER STRONGER STRONGER STRONGER STRONGER STRONGER STRONGE** –8– OK as major contribution from the gg initial state metric near the infrared brane allows a KK scale at 1 TeV without conflicting with EW precision tests. <sup>7</sup>Note that recently, a similar framework has been suggested [36] where a modifications of the *AdS* <sup>7</sup>Note that recently, a similar framework has been suggested [36] where a modifications of the *AdS*  $7 \times 7 \times 7$  where  $3 \times 7$  where  $3 \times 7$  where a modifications of the  $36$ due to the smaller *cqL* values for first generation compared to the usual case *cqL >* 0*.*5 (i.e. the light quarks are now slighlty shifted towards the TeV-brane). The consequence is an important increase due to the smaller *cqL* values for first generation compared to the usual case *cqL >* 0*.*5 (i.e. the light  $q$ g muar stats shifted towards the consequence is an important increase. OK as major contribution from the gg initial state

### **Constraints from dijets**



 $\frac{1}{2}$  kK aluan exchange @ 0.023 ph => KK gluon exchange @ 0.023 pb

### **Constraints from dijets**





What does the RS model predicts at the expected luminosity of 1 fb-1?



**A** assuming 100 GeV bin resolutions FIG. 9: Same as in Fig. (7) but with expected 100 GeV bins of resolution and an integrated luminosity of  $\alpha$ 

integration of the cross section e.g. over  $[1050, 1750]~{\rm GeV}$ 

800 1000 1200 1400 1600 1800 2000 2200  $\rightarrow$  *Signal* /  $\sqrt{Background} \approx 13.9$  $Signal / \sqrt{Background} \approx 13.9$ 

ariy vis **An excess should be clearly visible.** 



## *V) Conclusions*

- The 'warped paradigm', with theoretical motivations, predicts deviations from SM in the 3<sup>rd</sup> generation sector =>  $A^b_{FB}$  ,  $A^t_{FB}$  = early indications ?
	- We suggest a geometrical RS realization addressing both  $A_{FB}^b$  and  $A_{FB}^t$ .
- The several constraints on the parameter space render this RS scenario quite predictive on the effects in the  $t\bar{t}$  invariant mass ditribution  $@$  LHC.
- One must wait for more data (Tevatron,LHC) in order to discriminate between the main A<sup>t</sup><sub>FB</sub> interpretations: Z/W<sup>'</sup>, KK gluon, Axigluon, stop...
- This RS model addressing A<sup>b</sup><sub>FB</sub>, At<sub>FB</sub> predicts a **KK gluon resonance** Other RS models usually with light **custodians copiously producable** ( '**no-lose** signal' theorem in warped pheno. @ LHC ) با <sub>E:B</sub><br>ا

# Back up

 $\alpha$ **integration over cost over a**<br> *y*<sup>*y*</sup> **this is done by changing the variable using the va** *x* + (*a*) Some useful formula's… 8*vqvtaqat*β*<sup>t</sup>* cos θ<sup>∗</sup> + (*a*<sup>2</sup> *<sup>q</sup>* + *v*<sup>2</sup> *q* ) \*

$$
\cos \theta_t^* = \sqrt{1 + \frac{4m_t^2}{\hat{s} - 4m_t^2}} \ \tanh y_t
$$

$$
\frac{1}{\mathcal{D}} = \hat{s} - M_{KK}^2 + i \frac{\hat{s}}{M_{KK}^2} \sum_q \; \Gamma_{KK}^{g^{(1)} \rightarrow q \bar{q}} M_{KK} \frac{\beta_q [v_q^2 (3-\beta_q^2)]/2 + a_q^2 \beta_q^2}{v_q^2 + a_q^2}
$$

 $\beta_t=\sqrt{1-4m_t^2/\hat{s}}$  $\beta_t = \sqrt{1-4m_t^2/\hat s}$ of the imaginary part of the propagator leads to a shift in the resonance pole position: of the imaginary part of the propagator leads to a shift in the resonance pole position:  $\frac{2}{t}/\hat{s}$ 

$$
\sqrt{\hat{s}_0} \simeq \frac{M_{KK}}{(1 + \Gamma_{KK}^2 / M_{KK}^2)^{1/4}}
$$

$$
\frac{d\hat{\sigma}_{RS-LO}}{d\cos\theta_t^*}(\hat{s}) = \frac{\pi \alpha_s^2(\mu_r)\beta_t}{9\hat{s}} \times \hat{s}^2 |\mathcal{D}|^2 \Big[ 8v_q v_t a_q a_t \beta_t \cos\theta^* + (a_q^2 + v_q^2) \left( v_t^2 (2 - \beta_t^2 \sin^2\theta^*) + a_t^2 \beta_t^2 (1 + \cos^2\theta^*) \right) \Big]
$$

$$
\frac{\mathrm{d}\hat{\sigma}_{inter.-LO}}{\mathrm{d}\cos\theta_t^*}(\hat{s}) = \frac{\pi \alpha_s^2(\mu_r)\beta_t}{9\hat{s}} 4\hat{s} \text{Re}(\mathcal{D}) \big[ v_q v_t \left(1 - \frac{1}{2}\beta_t^2 \sin^2\theta^* \right) + a_q a_t \beta_t \cos\theta^* \big]
$$

$$
\begin{pmatrix} \left. \frac{\mathrm{d}\hat{\sigma}_{SM-LO}}{\mathrm{d}\cos\theta_t^*}(\hat{s}) \right|_{q\bar{q}} = \frac{\pi \alpha_s^2(\mu_r) \beta_t}{9\hat{s}} \left\{ 2 - \beta_t^2 \sin^2 \theta^* \right\} \end{pmatrix}
$$

« How is  $A_{FB}^t$  measured at Tevatron in lepton+jet channels ? » *<sup>t</sup>* : 0 → 1] + σ[cos θ<sup>∗</sup>  $\frac{1}{2}$ *the interpretion in lenton+iet channels*  $2 \mu$ FB <sup>=</sup> *<sup>N</sup>*(∆*y >* 0) <sup>−</sup> *<sup>N</sup>*(∆*y <* 0) *<sup>N</sup>*(∆*y >* 0) + *<sup>N</sup>*(∆*y <* 0)<sup>=</sup> *<sup>N</sup>*(*q*∆*ylh <sup>&</sup>gt;* 0) <sup>−</sup> *<sup>N</sup>*(*q*∆*ylh <sup>&</sup>lt;* 0) *<sup>N</sup>*(*q*∆*ylh <sup>&</sup>gt;* 0) + *<sup>N</sup>*(*q*∆*ylh <sup>&</sup>lt;* 0)*.* (11)  $\mathbf{r}$  which can be measured at  $\mathbf{r}$  reconstruction from missing energy degrades  $\mathbf{r}$ the precision of the asymmetry measurement of experimental cuts apply on  $\frac{1}{\sqrt{2}}$   $\frac{1}{\sqrt{2}}$   $\frac{1}{\sqrt{2}}$ 

$$
\Delta y = y_t - y_{\bar{t}} \qquad y_t = (y_t - y_{\bar{t}})/2
$$

$$
\Delta y = q(y_l - y_h) = q \Delta y_{lh} \qquad t \to W^+ b \qquad t \to W^+ b
$$

in the laboratory frame *N*(*q*) + in the laboratory frame are measured, for compute the three computers  $\frac{1}{2}$  as  $\frac{1}{2$ 

> 4*m*<sup>2</sup> *t*

$$
A_{\text{FB}}^{t} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)} = \frac{N(q\Delta y_{lh} > 0) - N(q\Delta y_{lh} < 0)}{N(q\Delta y_{lh} > 0) + N(q\Delta y_{lh} < 0)}
$$

asymmetries

the precision of the asymmetries... Since the experimental cuts apply on  $\sim$  3 and 3  $\sim$  3  $\$ the precision on the asymmetry measurement). Since the experimental cuts apply on *|*∆*y| <* 3 and texte de la costa de la co<br>2 + texta de la costa de l Other asymmetries... tanh *yt.*

After solving a significant distribution.

\n
$$
A_{\text{FB}}^{p\bar{p}} = \frac{\sigma[y_t^{p\bar{p}} > 0] - \sigma[y_t^{p\bar{p}} < 0]}{\sigma[y_t^{p\bar{p}} > 0] + \sigma[y_t^{p\bar{p}} < 0]} \qquad A_{\text{C}}^t = \frac{\sigma_t[y_t > 0] - \sigma_{\bar{t}}[y_t > 0]}{\sigma_t[y_t > 0] + \sigma_{\bar{t}}[y_t > 0]} \quad A_{\text{C}}^t = A_{\text{FB}}^t = > CP
$$

which can be measured experimental the reconstruction of neutrino from missing energy degrades to the reconstruction of neutrino from missing energy degrades to the reconstruction of neutrino from missing energy degrades t

*App*¯

FB <sup>=</sup> <sup>σ</sup>[*ypp*¯

*t* − *o d* − *d* − *d* − *d* − *d* − *d* − *d* 

*<sup>t</sup> <* 0]

*<sup>t</sup> <sup>&</sup>lt;* 0] (13)

### $\boldsymbol{\mathsf{Standard}}$  Model (QCD) contribution to A $\boldsymbol{\mathsf{t}}_\mathsf{FB}$ **and one of the interference part of the interference part of the cross section. Eq.(2)** can be directed as  $A^*$



MCFM for SM *(m<sub>t</sub>=172.5GeV, PDF=CTEQ)* @ NLO :  $A^{t}{}_{FB} = 0.058 +1$  0.009 B. NLO QCD Simulation with MC@NLO

Ahrens et al. (2010) obtain  $(m_t=173.1{\rm GeV},$  PDF=MSTW) : @ NLO:  $A^{t}{}_{FB} = 0.067 \cdot 0.006$ <sub>-0.004</sub> @ NNLO-approx:  $A^{t}{}_{FB} = 0.064 \cdot 0.009$ <sub>-0.007</sub>  $\sim$   $\sim$   $\sim$   $\sim$   $\sim$   $\sim$  $\alpha$  NLO :  $A_{\text{eq}} = 0$  $W = \bigcup_{\alpha \in \mathcal{A}} \mathcal{A}$  $U$ וטומור $U_{t}$ דט א ז סטו $\sigma$  v  $\overline{a7}$  +0.006  $\overline{a}$  NINII  $\overline{0}$  approv to  $\mathsf{u}_1$  increases the association processes the  $\omega$  processes the property  $\mathsf{u}_2$ erly estimates the amount of *gg*, and thus the dilution of  $0.2 < \mu_f$  /  $TeV < 0.8$ 

=>  $A_{FB}^{t}$  [M<sub>tt</sub>>450GeV] anomaly probably not fully explained by QCD errors ~0.01  $t \geq A_{\text{in}}^t$  [M<sub>tre</sub> IM<sub>tr</sub>>450GeV] anomaly probably not fully explain ariomary probably not fully explain

```
now 5.1fb-1: see F.Badaud's talk
```
**07-2010** D0 in the lepton+jets channel with **(0.9fb-1 then)** 4.3fb-1 <del>←</del> *(ttbar frame, not unfolded = no subtracting bckgrd & effic. + no ttbar level*) :  $A_{FB}^t = 0.08 + -0.04 + -0.01$ FB = 0.08 +/- 0.04 +/- 0.01 (**+1.7 sigma** from SM prediction)

**03-2009** CDF in the lepton+jets channel with **(1.9fb-1 then) 3.1fb-1**  *(lab frame, unfolded)* :  $A_{FB}^t = 0.193 + (-0.065 + (-0.024$ FB = 0.193 +/- 0.065 +/- 0.024 (**+2.1 sigma** from SM prediction)

**01-2011** CDF in the dilepton channel with **5.1fb-1** *(lab frame, unfolded)* :  $A<sup>t</sup><sub>FR</sub> = 0.42 + (-0.15 + (-0.05$  $(+2.3 \text{ sigma from SM prediction})$  (large error => +1.7 sigma from lept.+jets channel) *(lab frame, not unfolded)* :  $A_{FB}^{t}$  (M<sub>tt</sub><450GeV)= 0.104 +/- 0.066 (+1.6 sigma from SM prediction) A<sup>t</sup><sub>FB</sub> (M<sub>tt</sub>>450GeV)= 0.212 +/- 0.096 (**+2.6 sigma** from SM prediction)

 $\tau_{he,mean}$  to compute it  $T_{\text{ref}}$  is the way be compared as: *The way to compute it... mpute it…* 

$$
A_{\text{FB}}^t = \frac{(\sigma_{SM}^F + \sigma_{RS}^F + \sigma_{inter.}^F) - (\sigma_{SM}^B + \sigma_{RS}^B + \sigma_{inter.}^B)}{(\sigma_{SM}^F + \sigma_{RS}^F + \sigma_{inter.}^F) + (\sigma_{SM}^B + \sigma_{RS}^B + \sigma_{inter.}^B)}
$$

$$
\Leftrightarrow \quad A_{\text{FB}}^t = A_{\text{FB}}^{RS} \times R + A_{\text{FB}}^{SM} \times (1 - R)
$$

**Cao et al.** (2010)

\n
$$
\text{With } A_{\text{FB}}^{RS} = \frac{(\sigma_{RS-LO}^F + \sigma_{inter.-LO}^F) - (\sigma_{RS-LO}^B + \sigma_{inter.-LO}^B)}{(\sigma_{RS-LO}^F + \sigma_{inter.-LO}^F) + (\sigma_{RS-LO}^B + \sigma_{inter.-LO}^B)}
$$
\n
$$
R = \frac{\sigma_{RS-LO}^{\text{total}} + \sigma_{inter.-LO}^{\text{total}}}{\sigma_{SM-LO}^{\text{total}} + \sigma_{RS-LO}^{\text{total}} + \sigma_{inter.-LO}^{\text{total}}}
$$

ex: 
$$
\sigma_{RS-LO}^F = \sigma_{RS-LO}[\cos \theta_t^* : 0 \to 1]
$$
  
\n
$$
\sum_{ij} \int_{\tau_{min}}^{\tau_{max}} d\tau \left[ \int_0^1 d\cos \theta_t^* \left( \frac{d\hat{\sigma}_{RS-LO}}{d\cos \theta_t^*} (\tau s) \right)_{ij} \right] \left\{ \int_{\tau}^1 \frac{dx}{x} f_i(x, \mu_f) f_j(\frac{\tau}{x}, \mu_f) \right\}
$$
\n
$$
\tau_{min/max} = \hat{s}_{min/max/s}
$$
 MSTW-2008-NLO

*s*ˆ and *m<sup>t</sup>* = 173*.*1 GeV.

Looking at the effect of MSTW uncertainties [@ 90%C.L.]...

external  $\begin{bmatrix} 0.6 \end{bmatrix}$  CDF data unfolded bins  $\begin{bmatrix} 350 \\ 450 \end{bmatrix}$ ¯ (in *GeV /c*<sup>2</sup>) computed within the RS extension of the SM (*A<sup>t</sup>*  $-1.7\sigma$ *H*  $\frac{1}{2}$   $\frac{1}{$ as well as to the unfolded CDF data (for *m<sup>t</sup>* = 172*.*5 GeV) [18] [black crosses exhibiting the experimental  $\epsilon_{\text{M/NI}}$  and  $\epsilon_{\text{M/NI}}$  and  $\epsilon_{\text{M/NI}}$ FB is acceptaby at 1*.*6σ. In the second energy bin, *ASM*  $-3.4\sigma$  $\begin{bmatrix} -0.2 \end{bmatrix}$ external to Eq. (1tbar frame)  $\mu_f = \mu_r = m_t = 172.5 \text{ GeV}$ as well as to the unfolded CDF data (for *m<sup>t</sup>* = 172*.*5 GeV) [18] [black crosses exhibiting the experimental errors are MSTM-2008 at NLO  $\left[\begin{array}{c} 1 \end{array}\right]$ data whereas *A<sup>t</sup>*  $\frac{1}{R}$   $\frac{1}{R}$  is only and away by −1.950 particles away by −1.950 particles away by −1.9*0.*900 particles are the set of the s SM(NLO)  $RS + SM$ 400 500 600 700 800  $-0.2$ 0.0 0.2 0.4 0.6  $M_{tt}$ (GeV) *At*FB on the RS part of RS part only. Considering the central values with respect to the first energy  $\sim$ FB is at 1*.*0σ from data whereas *A<sup>t</sup>* from data whereas *A<sup>t</sup>*  $-1.7\sigma$  $\overline{\mathcal{O}}$  and  $\overline{\mathcal{O}}$  and  $\overline{\mathcal{O}}$  and  $\overline{\mathcal{O}}$  and  $\overline{\mathcal{O}}$  and  $\overline{\mathcal{O}}$  w.r.t.  $\overline{\mathcal{O}}$  and  $\overline{\mathcal{O}}$ **F** B  $\bullet$  0*.*  $\bullet$ ¯ 7*.*50 *±* 0*.*48 pb 7*.*46 pb [43] −0*.*08σ 6*.*80 pb −1*.*44σ −8*.*7%  $\frac{1}{2}$ ¯ 7*.*50 *±* 0*.*48 pb 7*.*29 pb [44] −0*.*43σ 6*.*65 pb −1*.*76σ −8*.*7% ¯ 7*.*50 *±* 0*.*48 pb 7*.*26 pb [45] −0*.*5σ 6*.*62 pb −1*.*82σ −8*.*7%

 $M_{\text{H}}$  = 450GeV no significant dependence as well on  $\mu_f$ ,  $\mu_r$  and  $m_t$ 

 $4000$   $100$ 

¯ (in *GeV /c*<sup>2</sup>) computed within the RS extension of the SM (*A<sup>t</sup>*

$$
1/(t - M_{KK}^2) \t -t \leq M_{KK}^2 \t t = -M_{jj}^2/2 \t M_{jj} = \sqrt{2}M_{KK} \sim 2 \text{ TeV}
$$
  

$$
\oint_{\mathbf{S}} \underbrace{\mathbf{a} \cdot \mathbf{r}}_{\text{QCD prediction}} = \underbrace{\mathbf{c} \cdot \mathbf{M}_{\text{S}}}_{\text{S=7 TeV}} \t \cos \theta^{\star} = 0
$$



incompatible with the LHC data. *3. Pigure 1:* Normalized dijet angular distributions in several  $M_{ij}$  ranges, shifted vertically by the additive amounts given in parentheses in the figure for clarity. The data points include statistical and systematic



## *Global A<sup>b</sup><sub>FB</sub> fit @ and off the Z pôle :*



are indicated on the figure. An important final comment is on the *tt* What about the whole integrated top quark asymmetry and cross section? The FB asymmetries at low (*|*∆*y| <* 1) and high (*|*∆*y| >* 1) top rapidities, *y<sup>t</sup>* = ∆*y/*2, have been measured by the CDF collaboration [5] with a rapidity cut *|*∆*y| <* 3. The **Collaboration (T. A. A. Aast al., 2018)** integrated top quark as virtum and cross section **a** asymmetry and **cross secuon** ? **E** whole integrated top quark asymmetry and cross section ? what about the whole integrated top quark asymmetry and cross section

①	Tevatron data [5]:	0.158 ± 0.075	[5]	CDF Collaboration
SM [NLO] [5]:	0.058 ± 0.009 (-1.33 $\sigma$ )	arXiv:1101.0034		
RS+SM:	0.189 ± 0.010 (+0.42 $\sigma$ )	improves		

**C** Theoretical (HATHOR):  $\sigma(p\bar{p} \rightarrow t\bar{t}) = 6.62 \pm 1 \text{ pb}$  $m_{\rm R} = \mu_{\rm F} = m_t = 1$  $T_{\text{NLO}}$  and  $T_{\text{NLO}}$  and the top quark mass which have been estimated according according according according according according to  $T_{\text{NLO}}$  $\mu_{\rm R} = \mu_{\rm F} = m_t = 172.5 \,\, \mathrm{GeV}$  $MSTW$  PDF set is a  $MSTW$  property is set in the combined uncertainty is from the combined the scale variation, PDF and the top quark mass which have been estimated according to the top  $\mathbb{R}^n$  $MSTW$  PDF 0601 MSTW PDF  $\mu_{\rm R}$  $t_{\text{MSE}}$  $\bigcap$  Theoretical (111. T1.00):  $\pi(x\overline{x} + t\overline{t})$  (3.800) 141.  $\mu_{\rm R} = \mu_{\rm F} = m_t = 172.5 \text{ GeV}$  $\bm{V}$  PDF and NNLO  $\overline{261}$  J. L. Hewett, J. Hewett, J. Kaplan and T. G. Rizzo, J. Kaplan and T. G. Rizzo, J. Rizzo, J  $M51W$  PDF NNLO **C.** Theoretical (HATHOR):  $\sigma(p\bar{p} \rightarrow tt) = 6.62 \pm 1 \text{ pb}$  $\operatorname{MSTM}$  PDF  $\quad$  NNLO

**Experimental (levatron):**  $7.50 \pm 0.48$  pb CDF Collaboration, Note 9 a green with the value measured at the value of  $\frac{1}{2009}$ ,  $\tau$  scale variation, PDF and the top quark mass which have been estimated according  $P$  F  $\alpha$  ,  $\alpha$  ,  $\alpha$  ,  $\alpha$  ,  $\alpha$ Experimental (Tevatron):  $7.50 \pm 0.48$  pb CDF Collaboration a green with the value of  $\mathbb{Z}$  $t_{\rm max}$  and uncertainties, the uncertainties, the cross section value is in Ref. . a greed at the value of  $\frac{1}{2}$ <br>09. obtained for *m<sup>t</sup>* = 172*.*5 GeV. This agreement is essentially due to the large mass and  $t \hbar \Omega$  , PDF and the top quark mass which have been estimated according to the top quark mass  $\Omega$  $\text{for } \pm 0.40 \text{ pV}$  CDF Conaporation, note 9915, a green with the value of  $\frac{1}{2003}$ . obtained for *m*<sub>t</sub> and *m*<sub>t</sub> due to the large mass and b CDF Collaboration, Note 9913,  $DctO$  Det $T2009$ . Run II, October 2009.  $\frac{28}{28}$  Collaboration, and  $\frac{28}{28}$ .  $Covariantity of a function of  $750 \pm 0.48$  nb$  $\overline{P}$ **DEC**<sup>H</sup><sub>1</sub> *µ* + *N* + **0015 Experimental** *dividitory*. The  $\sigma$ -to-the MSTM CDF Combination, note 9913

obtained for *m<sup>t</sup>* = 172*.*5 GeV. This agreement is essentially due to the large mass and total width of the KK gluon with proad resonance in the significant  $\overline{R}$  coupling, which will be significant  $\overline{R}$ OK as heavy KK gluon with broad resonance lead to only a small departure from the SM prediction. The SM prediction of  $\mathcal{O}(K)$  and  $\mathcal{O}(K)$ [12] A. Djouadi, G. Moreau, F. Richard and R. K. Singh, Phys. Rev. D82 (2010) 071702. [29] V. Ahrens *et al.*, JHEP 1009 (2010) 097; arXiv:1103.0550 [hep-ph]. UN AS HEAVY NN GIUOH WILL DI OAU TESUHAHUE a good agreement with the value measured at the value measured at the Tevatron, 7*.*50 **b**  $\rightarrow$  0*.*48 pb  $\rightarrow$  0*.*48 pb  $\rightarrow$  0*.*50  $\rightarrow$  0.48 pb  $\rightarrow$  0.48 p