Graviton Exchange in $b \to s \ell \ell$

"In the LHC era, the role of B-factories is to explore the details on New Physics - not to discover it."

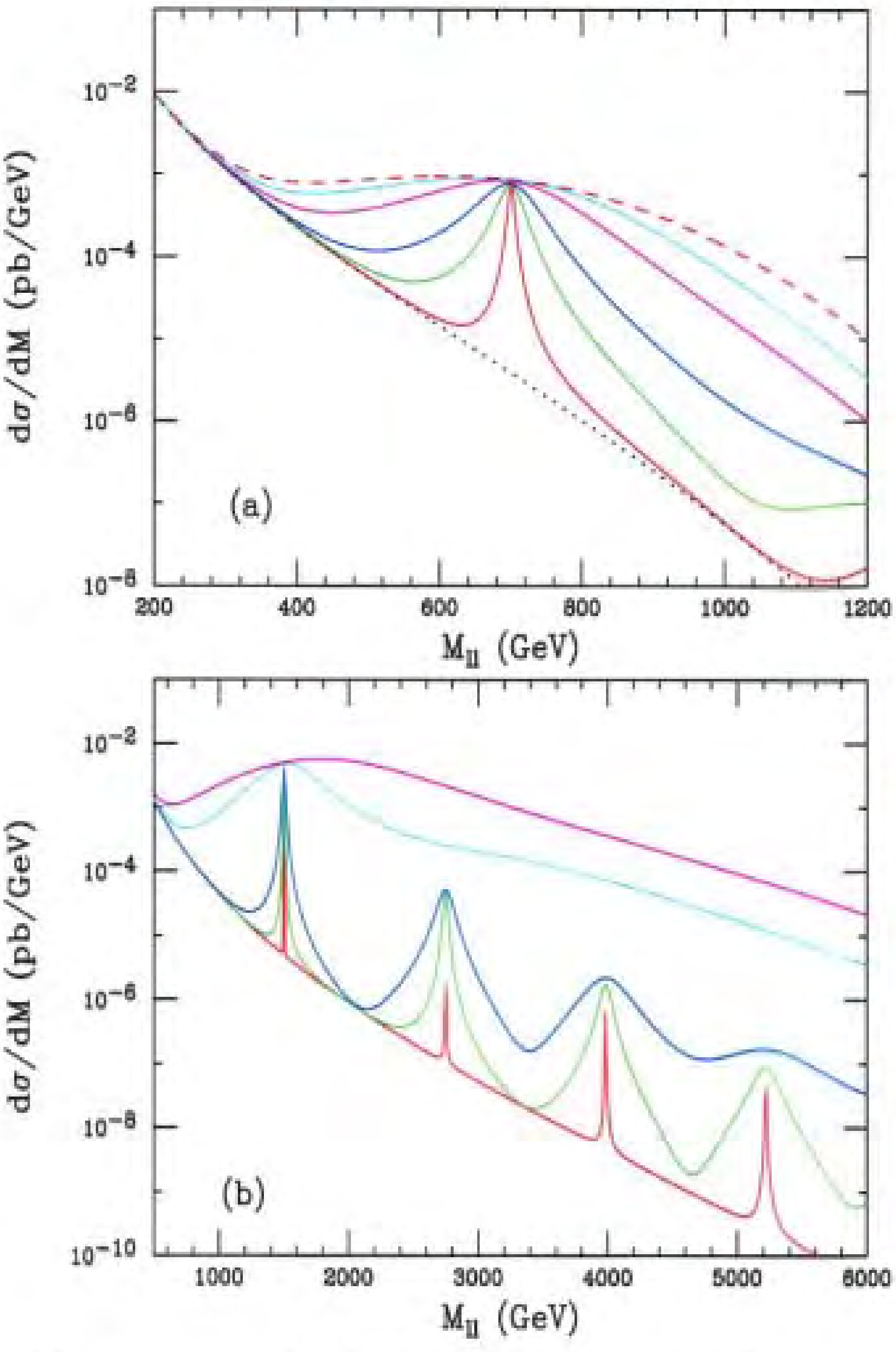
$\Rightarrow$ Proposed 'Solutions' to the hierarchy problem w/ TeV-scale Extra dimensions lead to unique physics signatures at the LHC:

ADD (arkani-hamed dimopoulos + dvali)
- $J + \not{E}$ events (graviton emission)
- contact interactions (grav. exchange)

RS (Randall-Sundrum)
- graviton tower resonances at ~TeV scale

$\rightarrow$ What can B-factories do??

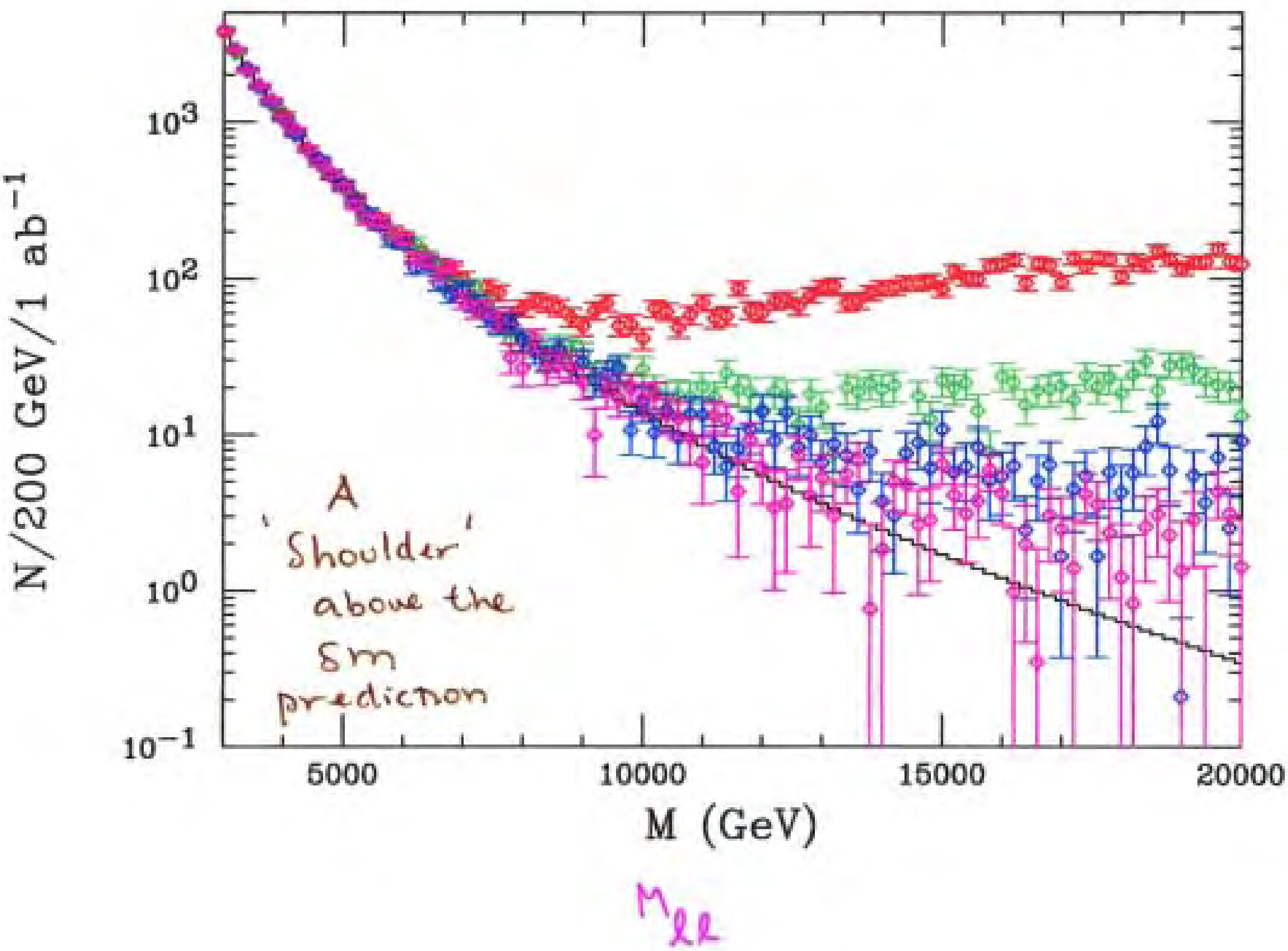
RS Signatures : Dijet/dilepton graviton resonances



multiple KK excitations

Figure 17: Drell-Yan production of a (a) 700 GeV KK graviton at the Tevatron with $k/\overline{M}_{Pl} =$ 1, 0.7, 0.5, 0.3, 0.2, and 0.1, respectively, from top to bottom; (b) 1500 GeV KK graviton and its subsequent tower states at the LHC. From top to bottom, the curves are for $k/\overline{M}_{Pl} =$ 1, 0.5, 0.1, 0.05, and 0.01, respectively.

ADD Signature / Contact Int. in Drell-Yan



ADD : gravity prop. in 4+n dims
SM on a 3-brane

$$M_{Pl}^2 = V_n M_*^{n+2}$$

M_* ← true gravity scale ~ few TeV

M_{Pl} ↑ $\sim 10^{19}$ GeV

V_n ↑ vol. of compact space

eg, $(2\pi R)^n$ or $(2\pi R)^{n_1} (2\pi R')^{n_2} \ldots$

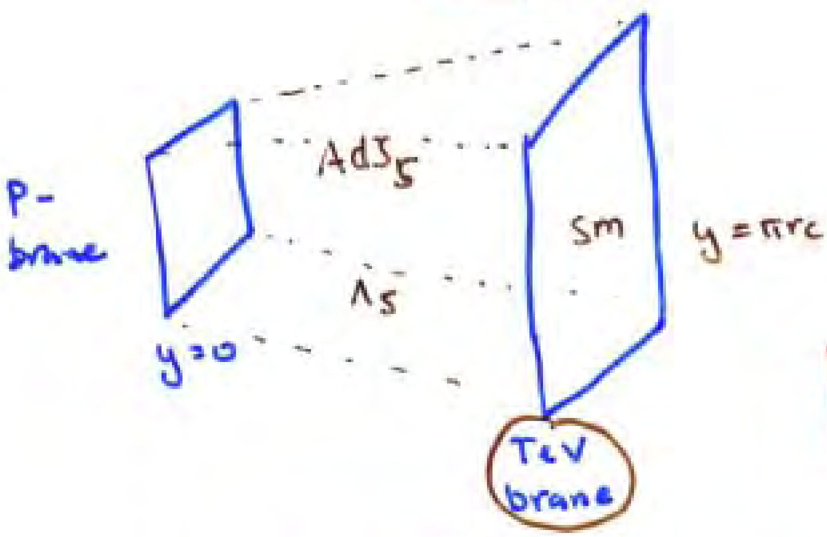
likely $n > 2$

KK $\quad m_n^2 = \frac{\vec{n}\cdot\vec{n}}{R^2}$,
$$-\frac{1}{\bar{M}_{Pl}} T_{\mu\nu} h^{\mu\nu}_{(n)} = \mathcal{L}$$

(RS) $\quad ds^2 = e^{-2\sigma(y)} \eta_{\mu\nu} dx^\mu dx^\nu - dy^2 \qquad (S^1/Z_2)$

$e^{-2\sigma(y)}$ ↑ warp factor

(S^1/Z_2): orbifold compactified



$$m_{TeV} = m_{Pl}\, e^{-kr_c\pi}$$

$kr_c \simeq 11$

$$\mathcal{L} = -\frac{1}{\Lambda_\pi} T_{\mu\nu} h^{\mu\nu}_{(n)}$$

$\Lambda_\pi = \bar{M}_{Pl}\, e^{-kr_c\pi}$, $J_1(x_n) = 0$, $\quad m_n = x_n \frac{k}{\bar{M}_{Pl}} \Lambda_\pi$

x_n ↑ few; $\frac{k}{\bar{M}_{Pl}} \sim 0.1$; Λ_π ← few TeV

Many variations on basic models in literature

But graviton exchange is a common feature ...

$$\mathcal{M} = \left(\frac{1}{\Lambda_\pi^4}, \frac{1}{M_{pl}^2}\right) \sum_n \frac{1}{s - m_n^2} T_{\mu\nu} T^{\mu\nu}$$

In Either model, at low energies, graviton exchange is just a contact interaction

- Our philosophy here is a model-indep. approach — can we see dim-8 gravity-induced operator

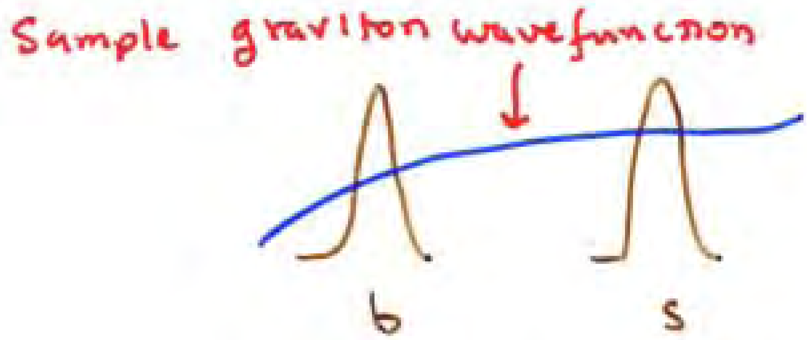
$$\mathcal{O}_{grav} \sim \frac{1}{M^4} T_{\mu\nu} T^{\mu\nu}$$

⇒ Can we see flavor sensitivity in gravity??

- Does gravity have FC couplings ??
- How would we know ??

Extra-dim theories CAN have a non-trivial flavor structure !!

e.g, localized fermions in thick brane or in RS bulk :



graviton KK excitations couple diff. to various flavors

→ FCNC's by graviton exchange

In the ADD case } $\mathcal{L} \sim \frac{\lambda}{M_H^4} X_{ij} T^{ij}_{\mu\nu} T^{\mu\nu}_{\ell\ell}$

mediates, e.g, $\boxed{i \to j \ell^+ \ell^-}$ processes

X_{ij} - model-dependent parameters

$T_{\mu\nu}$ - stress-energy tensor ; $\lambda = \pm 1$

M_H - 'Hewett'-scale

RS $\quad \lambda / M_H^4 : \to \frac{1}{8\Lambda_\pi^2} \sum_n \frac{1}{m_n^2}$

$\boxed{m_n = x_n c \Lambda_\pi}$, x_n = root of $J_1(x_n)$ $\quad \boxed{c \sim 0.1}$

$$\frac{d^2\Gamma}{ds\,dz} \sim (1-s)^2 \Big\{ \left[(C_9 + 2C_7/s)^2 + C_{10}^2 \right]$$

$$\cdot \left[(1+s) - (1-s)z^2 \right] - 2C_{10}(C_9 + 2C_7/s)\, s z$$

$$+ \frac{4}{s^2} C_7^2 (1-s)^2 (1-z^2) - \frac{4}{s} C_7 (C_9 + 2C_7/s)(1-s)(1-z^2)$$

$$+ D C_9 (1-s) \underline{\underline{z}} \left[2s + (1-s) \underline{\underline{z^2}} \right.$$

$$\left. + D C_{10}\, s(1-s)(1-z^2) \right] \Big\}$$

ADD parameterization

$$D \equiv \frac{2m_b^2}{G_F \alpha} \sqrt{2}\pi \frac{1}{V_{tb}V_{ts}} \frac{\lambda x}{M_H^4} \to 0.062 \frac{\lambda x}{M_H^4 (\text{in TeV})}$$

$$s \equiv q^2/m_b^2 \qquad z \equiv \cos\theta$$

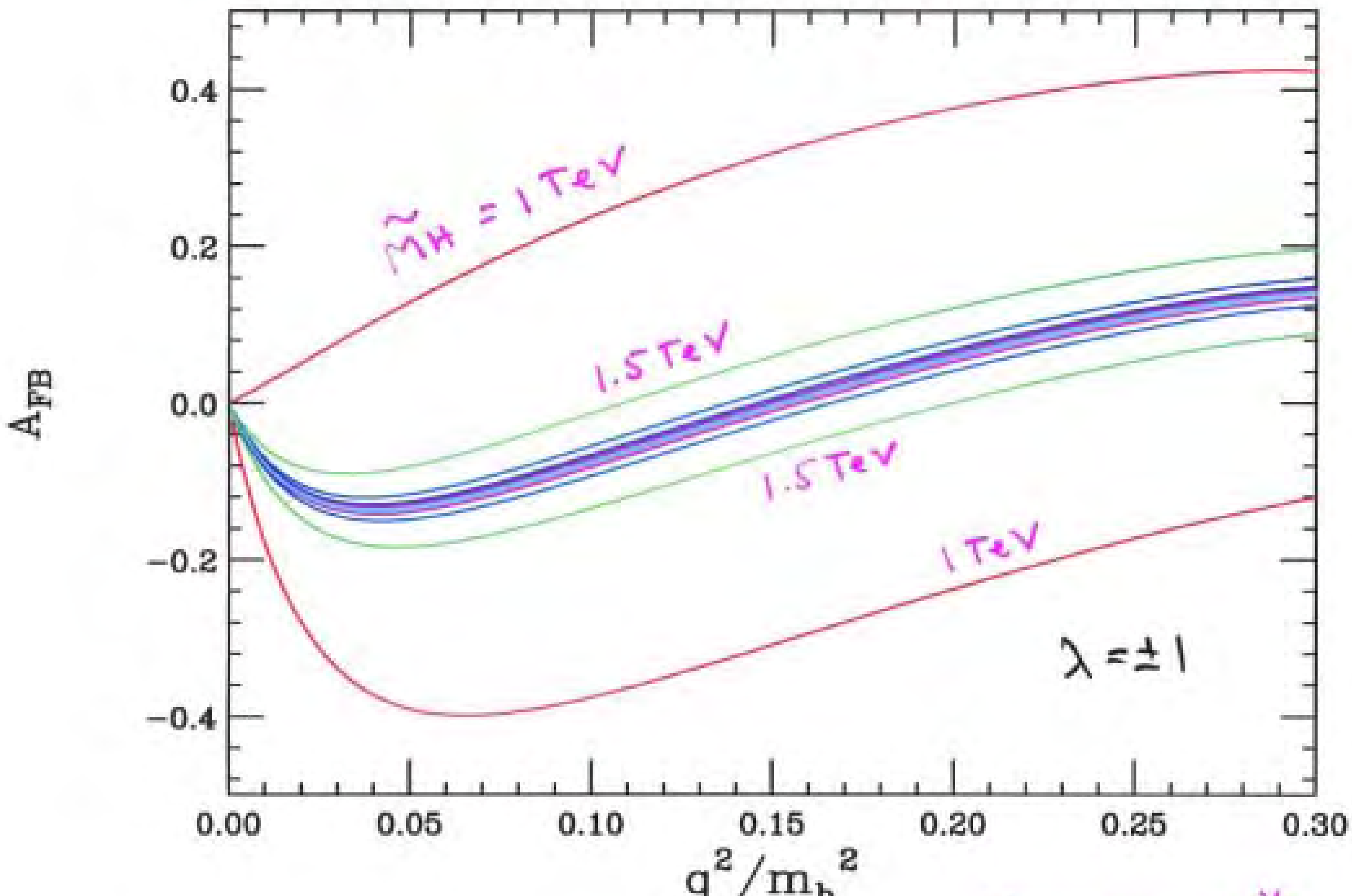
<u>Note</u> DC_9 term has a z^3 in it

— <u>spin-2 signal</u>

How is, e.g, A_{FB} modified ??

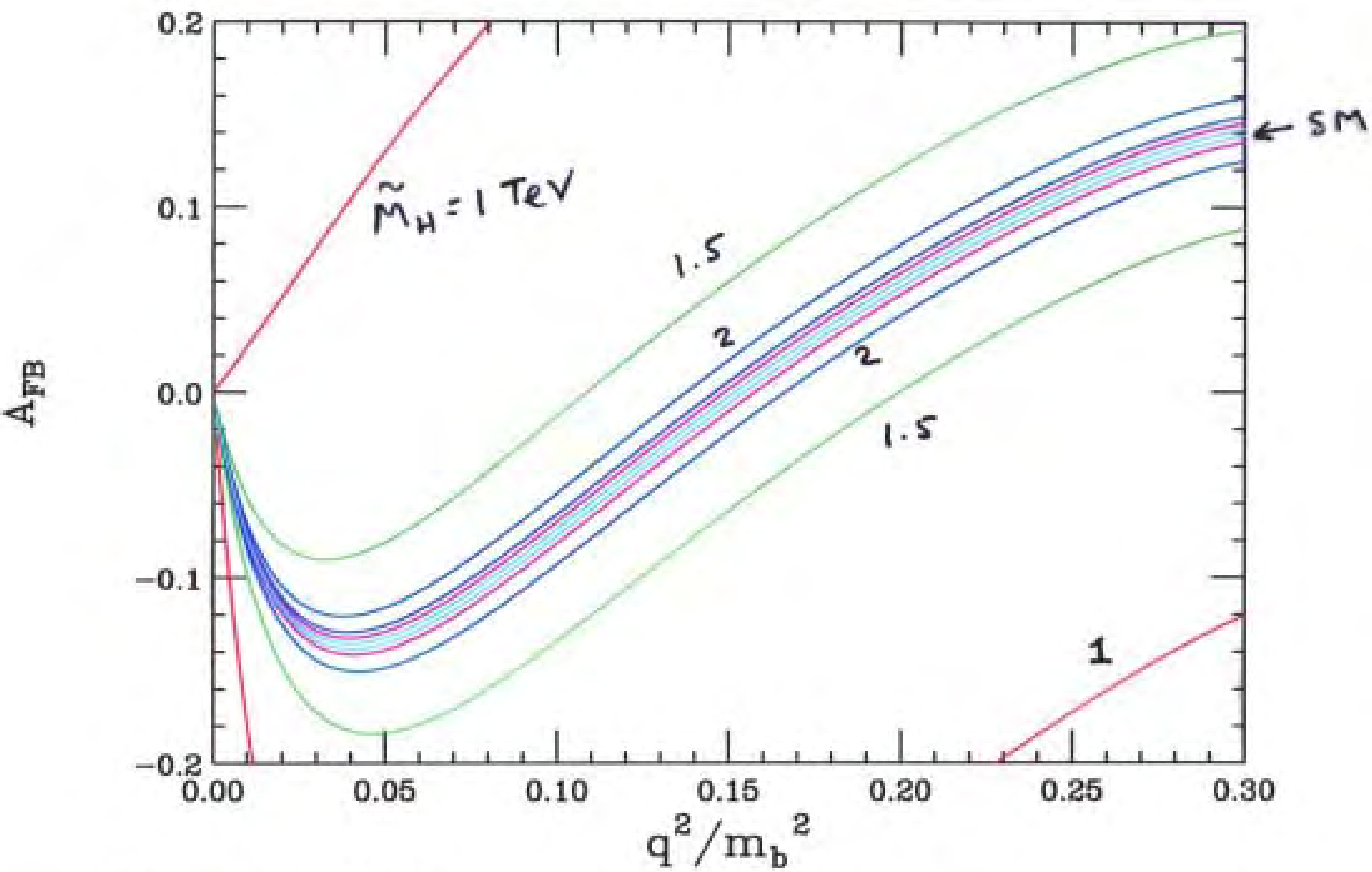
(The usual observable to look at...)

ADD contribution to A_{FB} in b→sll



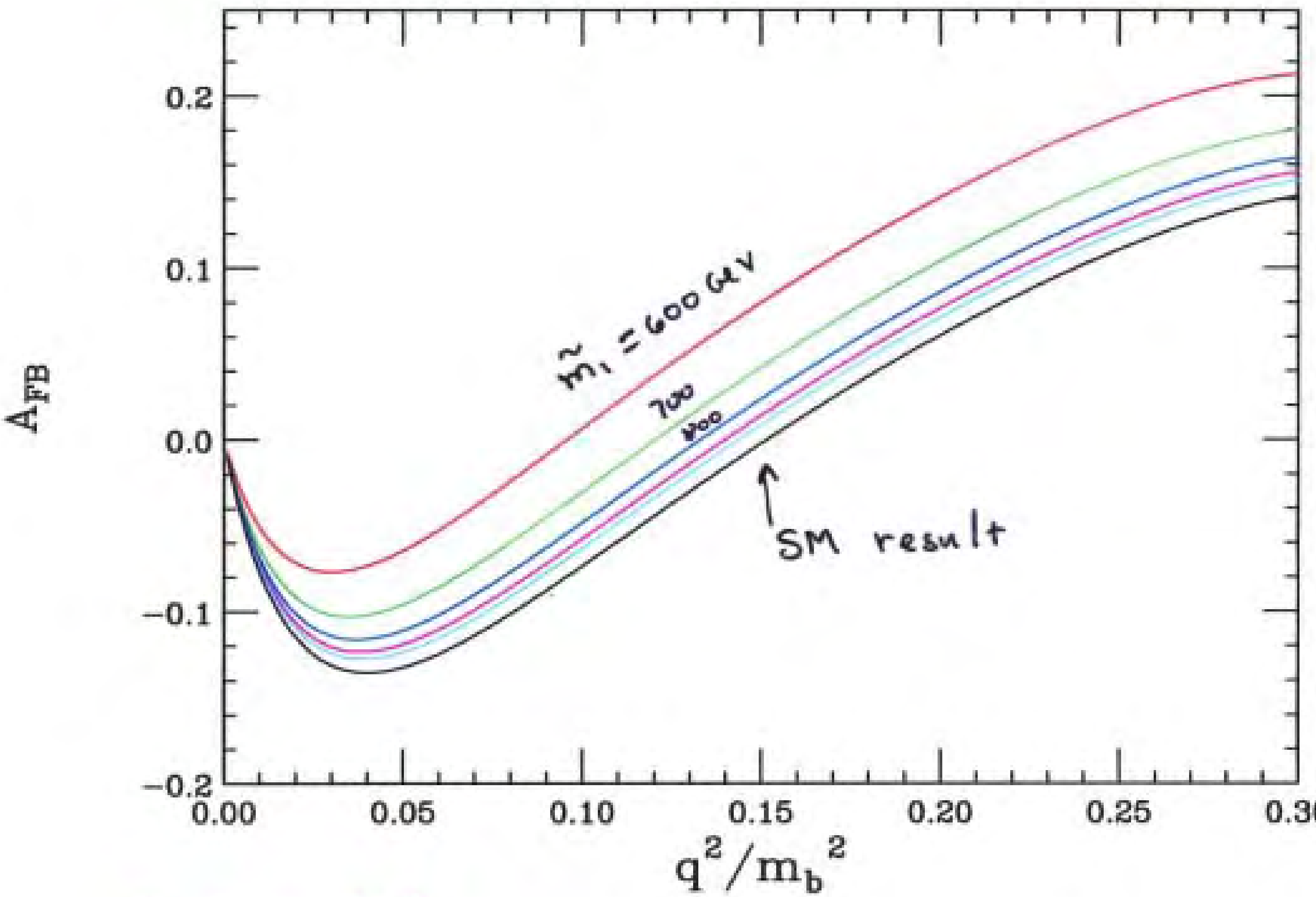
$\tilde{M}_H = M_H / x^{1/4}$

ADD contribution to AFB in $b \to s \ell \ell$ $\lambda = \pm 1$



$\tilde{M}_H \equiv M_H / X^{1/4}$

RS contribution to A_{FB} in $b \to s \ell \ell$



$\tilde{m}_1 \equiv m_1 / X^{1/4}$

This is all very nice, but

MANY sources of new physics shift

A_{FB} ...

These models lead to something

special due to the z^3 term

How to probe it ? - as done in e^+e^-

$$\langle P_3 \rangle \equiv \frac{\int_{-1}^{1} \frac{d^2\Gamma}{dz\,ds} \cdot P_3(z)\, dz}{d\Gamma/ds}$$

... The moment of the $\measuredangle$ distribution wrt

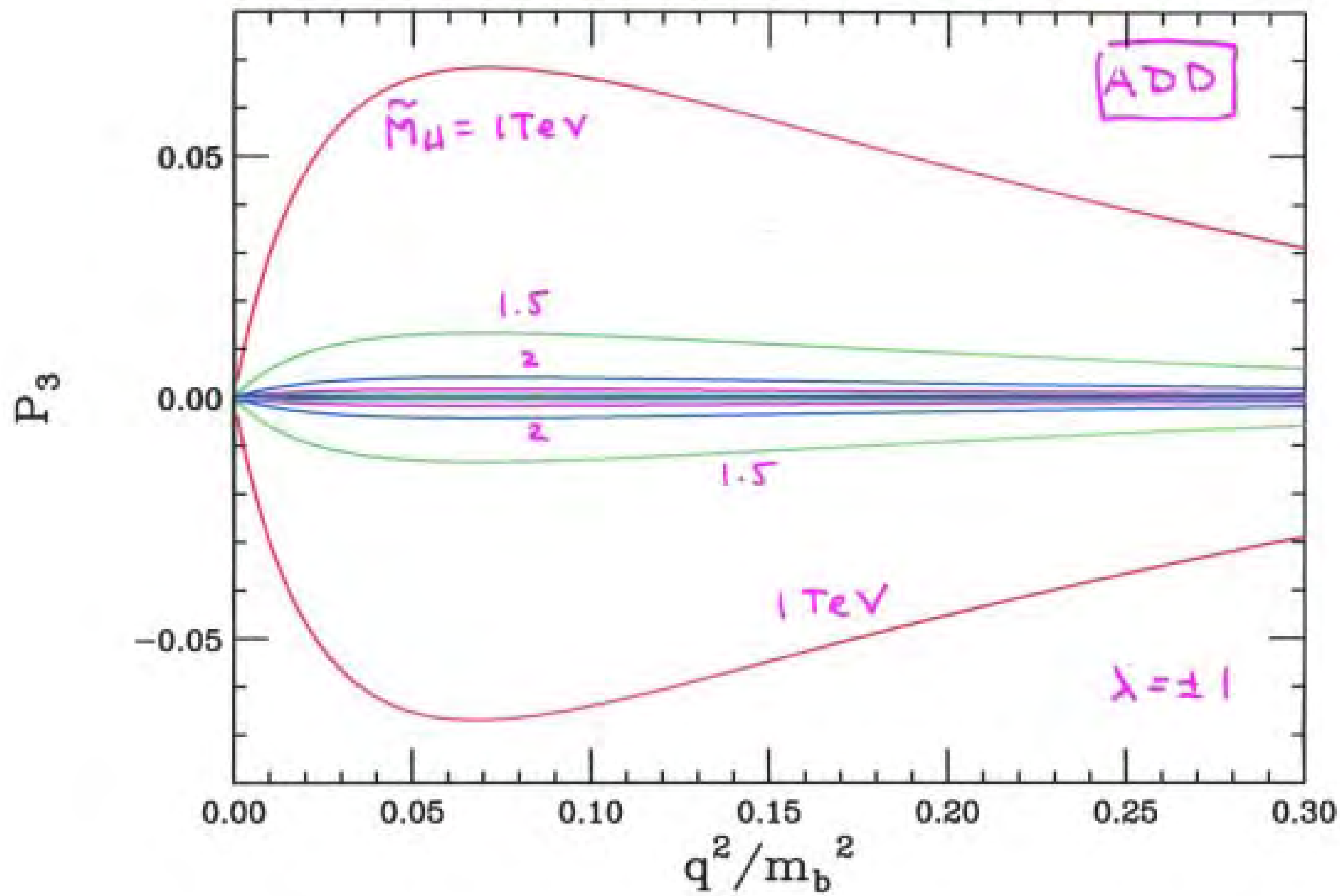
the 3rd Legendre polynomial ....

$\langle P_3 \rangle = 0$ w/o spin-2 exchange

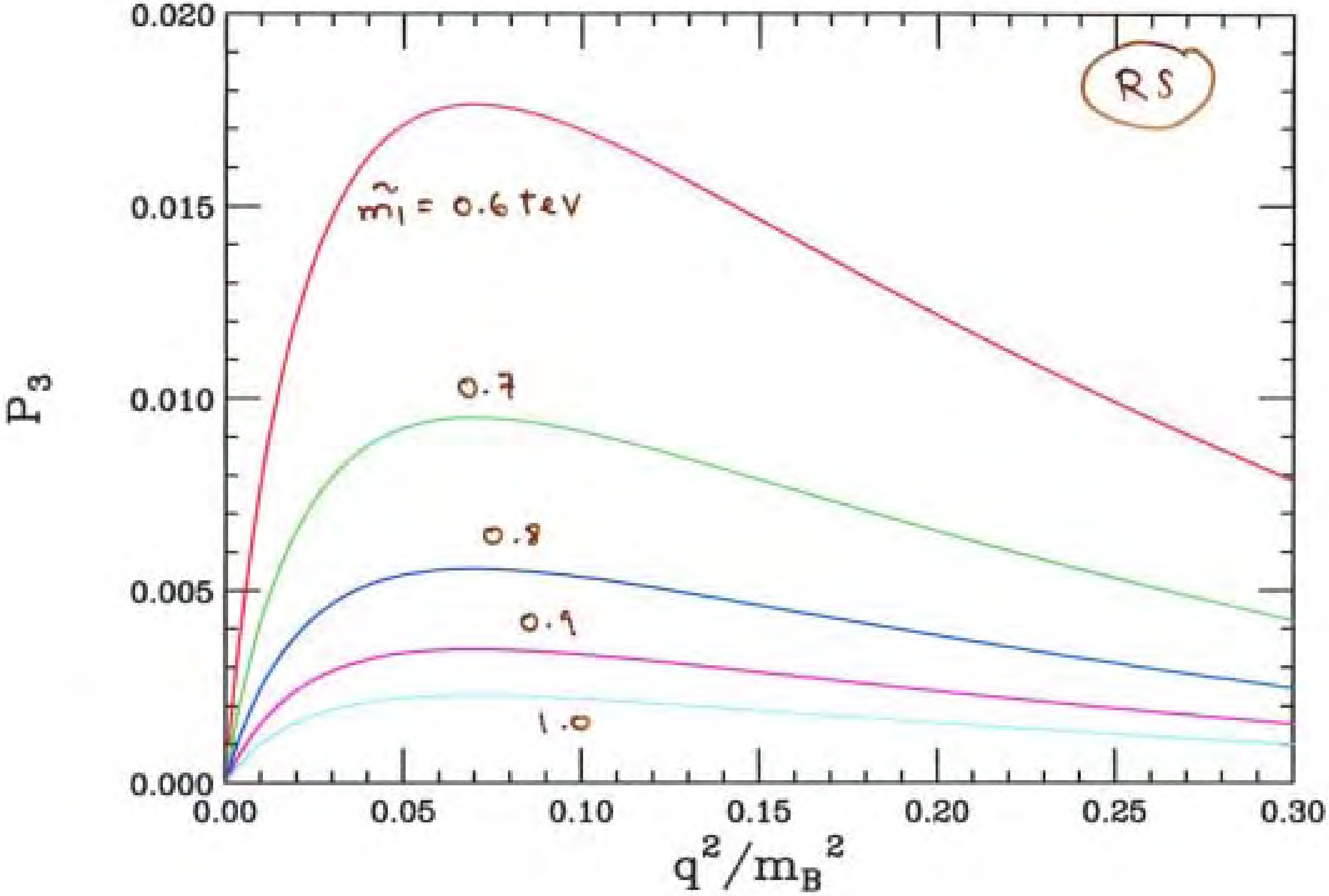
$\langle P_3 \rangle$'s will be relatively small with

this normalization.

3rd Legendre moment in $b \to s \ell^+ \ell^-$



3rd Legendre moment in $b \to s \ell^+ \ell^-$



- $\langle P_3 \rangle$ (and $\langle P_4 \rangle$) $\neq 0$ are the most sensitive probes of spin-2 exchange at LC's

What about here? $\langle P_4 \rangle \neq 0$

only if |gravity|^2 terms are large ...

neglected here

$\langle P_3 \rangle$

Need the whole $\cos\theta^*$ distribution ...

→ Measurement of $\langle P_6 \rangle$ explores FC gravity couplings of generalized ED scenarios

→ important model info when combined w/ hi-p_T LHC data

- How well can a $\langle P_6 \rangle \neq 0$ be measured at 10^{36} ??

Summary + Conclusions

- Graviton Exchange in either the ADD or RS models may have FC couplings not easily probed at the LHC
- B-factories may be sensitive to such FC interactions in, eg, $b \to s\ell\ell$
- graviton contributions modify A_{FB} + produce $\langle P_3 \rangle \neq 0$ unique signature

$\Rightarrow$ $\langle P_3 \rangle$ probes FC graviton coupling

$\Rightarrow$ LHC ⊕ Flavor factories can reveal detailed structure of ED models