KKDM

Seongchan Park
SKKU

PPC2012 @ KIAS
November 5-9, 2012

OUTLINE

OUTLINE

- Review Underlying math & physics for KK-DM

OUTLINE

- Review Underlying math & physics for KK-DM
- Report the current status of KK-DM after LHC7& LHC8

OUTLINE

- Review Underlying math & physics for KK-DM
- Report the current status of KK-DM after LHC7& LHC8
- Possible extensions of KK DM model Especially with bulk mass and BLKTs

SOME LATEST REFERENCES

1. UED an effective theory of RS

C, Csaki, J. Heinonen, J. Hubisz, SCP, J.Shu JHEP01(2011)089

2. updated experimental status after LHC7/LHC8

G.-Y. Huang, K. Kong, SCP, JHEP06(2012)099

3. effects of boundary terms

T. Flacke, K.C.Kong, SCP (coming soon)

see Tom's talk on Thursday

THE PROPERTIES OF DM TELLS US ABOUT SOME PROPERTIES OF NEW PHYSICS

DM IS HEAVY

... MOST PROBABLY

[Lee-Weinberg, PRL 1977]

DM IS STABLE

IF NOT, LONG LIVED >>13.7BYR

for unstable DM, see e.g. Jongchul's talk on Friday

DM $\Omega h^2 \simeq 0.11$

HEAVY

STABLE

DM $\Omega h^2 \simeq 0.11$

HEAVY

STABLE

↓

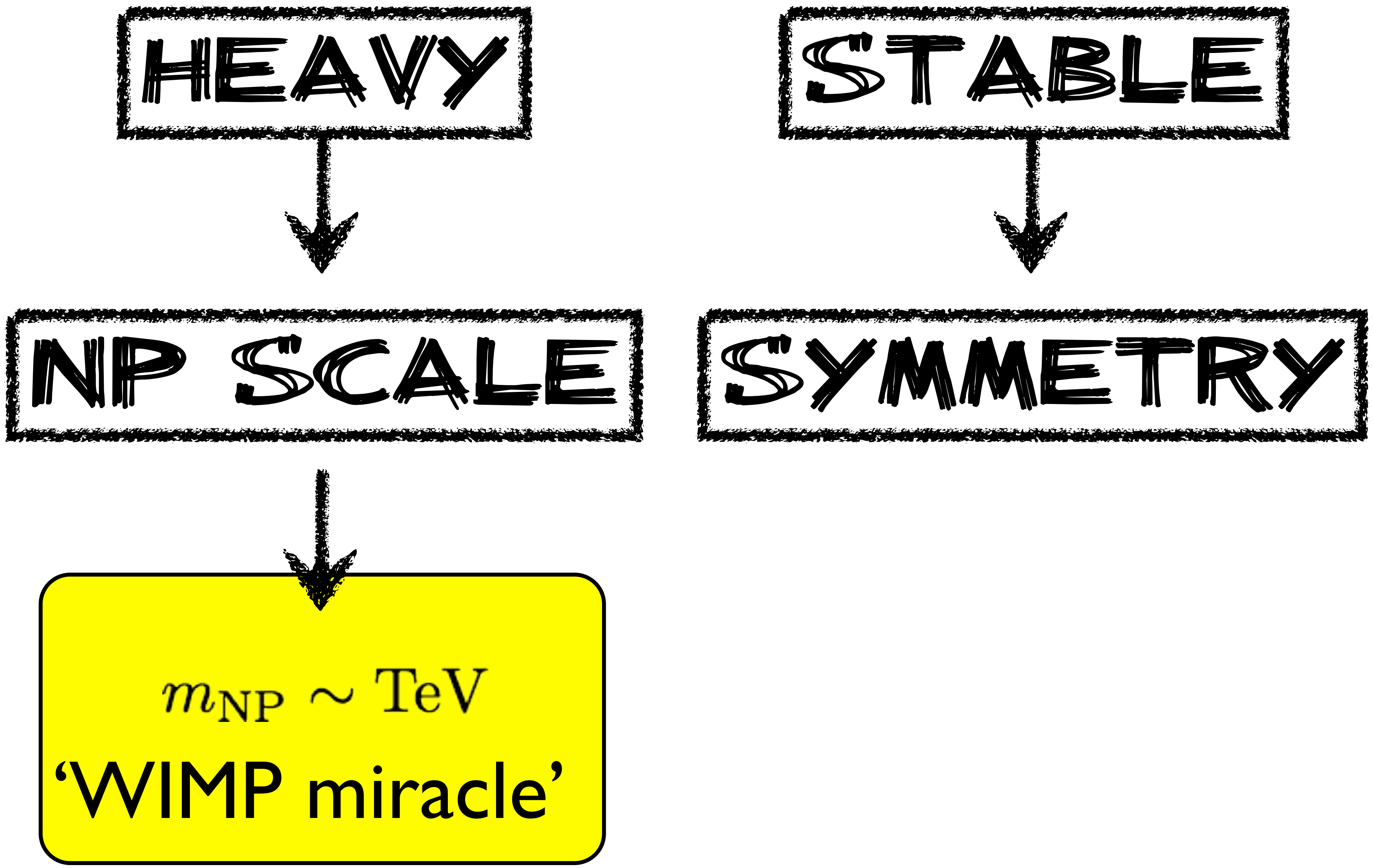
NP SCALE

DM $\Omega h^2 \simeq 0.11$

HEAVY → NP SCALE

STABLE → SYMMETRY

DM $\Omega h^2 \simeq 0.11$



DM $\Omega h^2 \simeq 0.11$

HEAVY → **NP SCALE** → $m_{\rm NP} \sim \rm TeV$ 'WIMP miracle'

STABLE → **SYMMETRY** → $\mathbb{Z}_2$ symmetric

$\mathbb{Z}_2$

$\mathbb{Z}_2$

- Z_2 symmetry can be useful for building a model of dark matter ..

$\mathbb{Z}_2$

- Z_2 symmetry can be useful for building a model of dark matter ..
- ..because the lightest Z_2 odd particle is automatically stable!

$\mathbb{Z}_2$

- Z_2 symmetry can be useful for building a model of dark matter ..
- ..because the lightest Z_2 odd particle is automatically stable!
- R-parity in MSSM, T-parity in Little Higgs and KK-parity in extra dimension models ...

UNDERLYING MATH

"no odd function can be decomposed into a finite number of even functions"

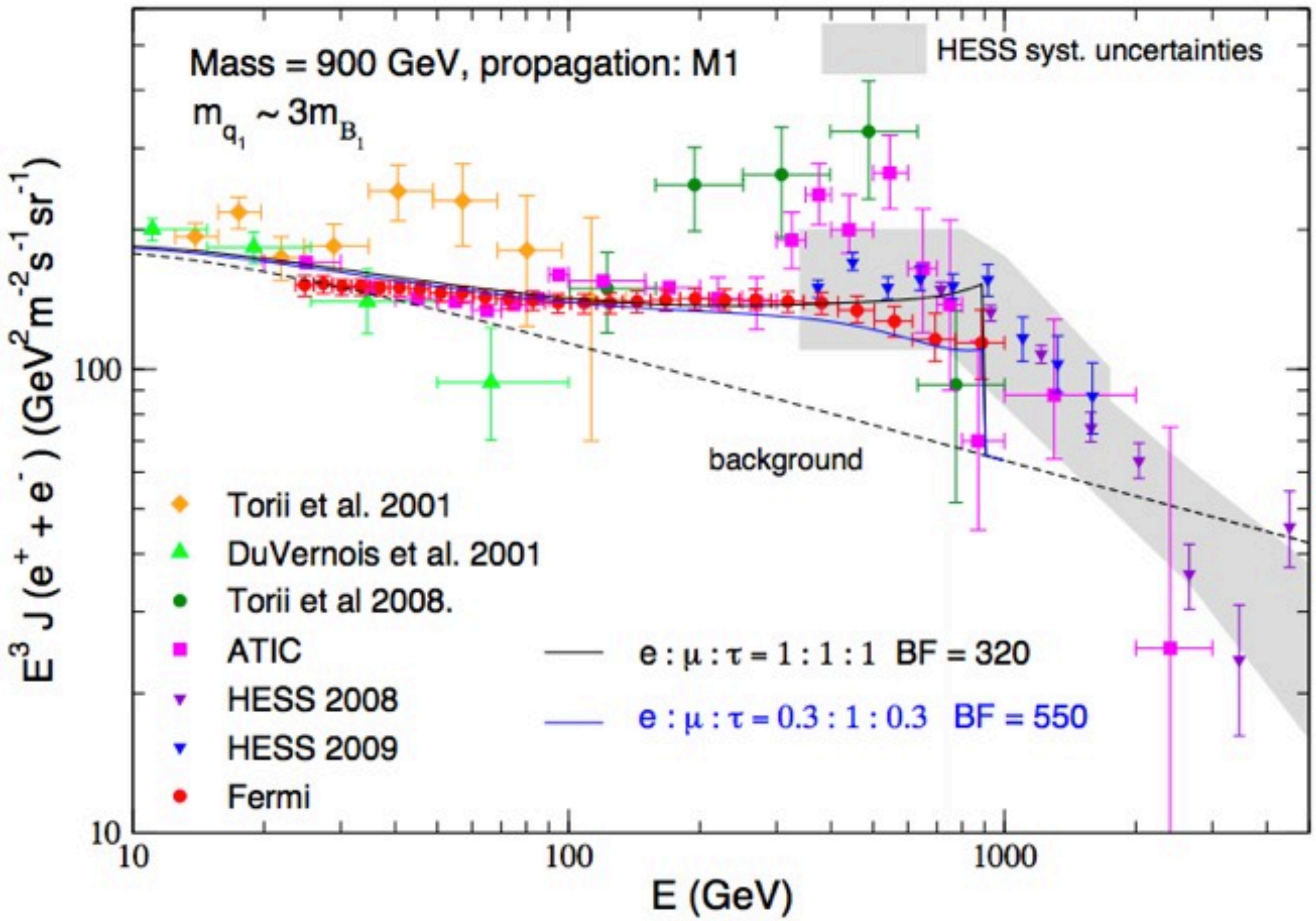
PHYSICAL CONSEQUENCE

"The lightest odd –particle cannot decay into even–particles thus is stable"

THE PROPERTIES OF DM TELLS US ABOUT SOME PROPERTIES OF EXTRA DIMENSIONS

Fermi, PAMELA fit by UED

[Chen, Nojiri, SCP, Shu 2009]



DM $\Omega h^2 \simeq 0.11$

HEAVY

STABLE

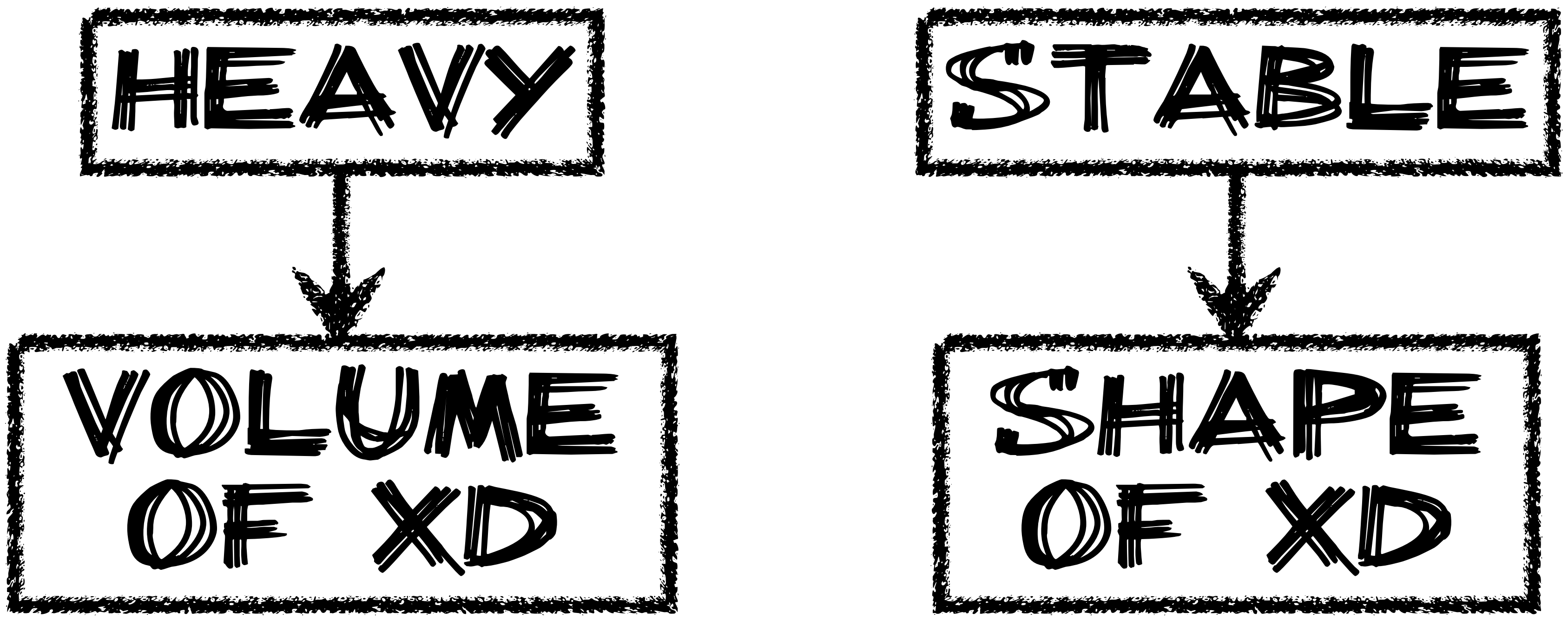
DM $\Omega h^2 \simeq 0.11$

HEAVY

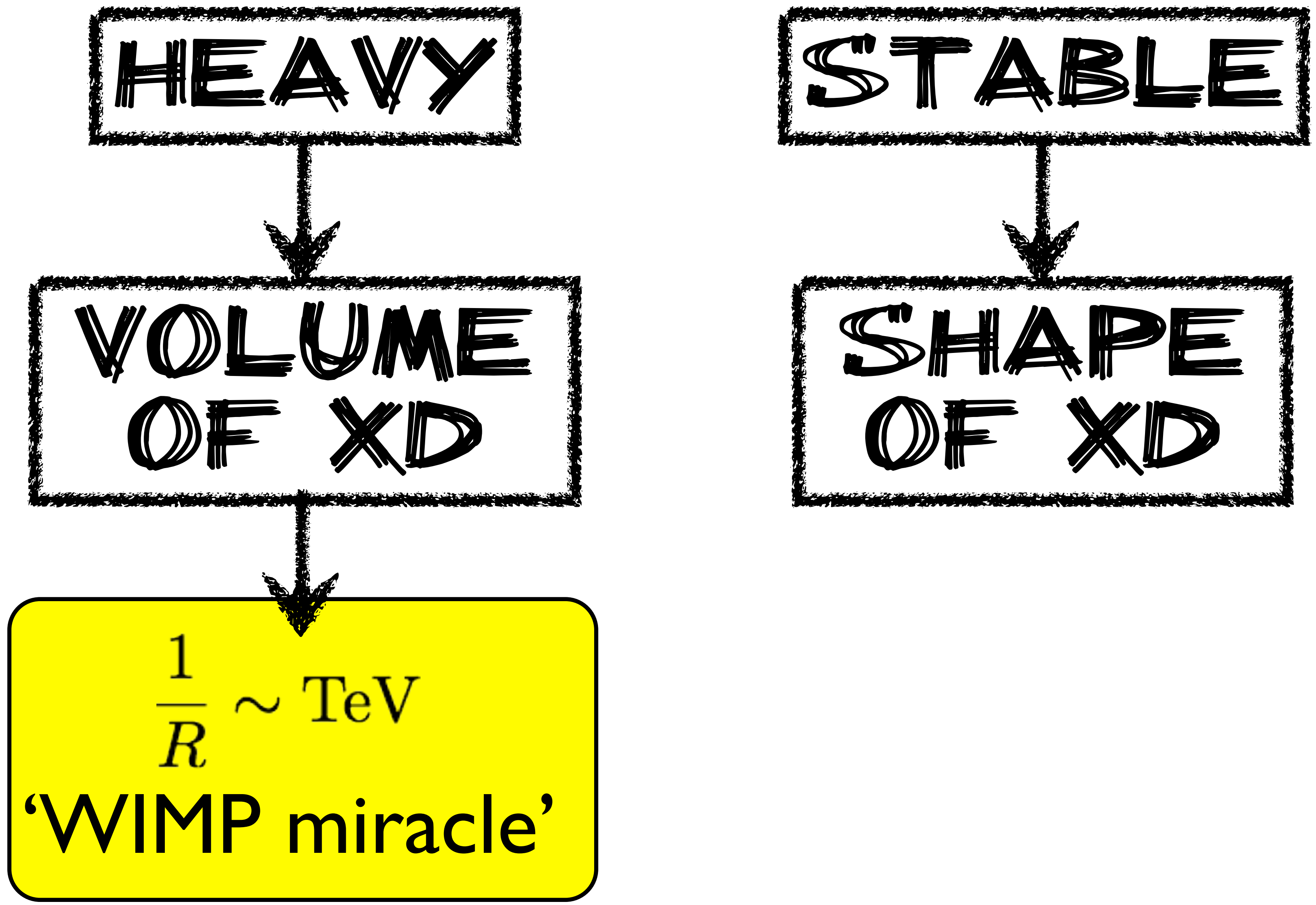
STABLE

VOLUME OF XD

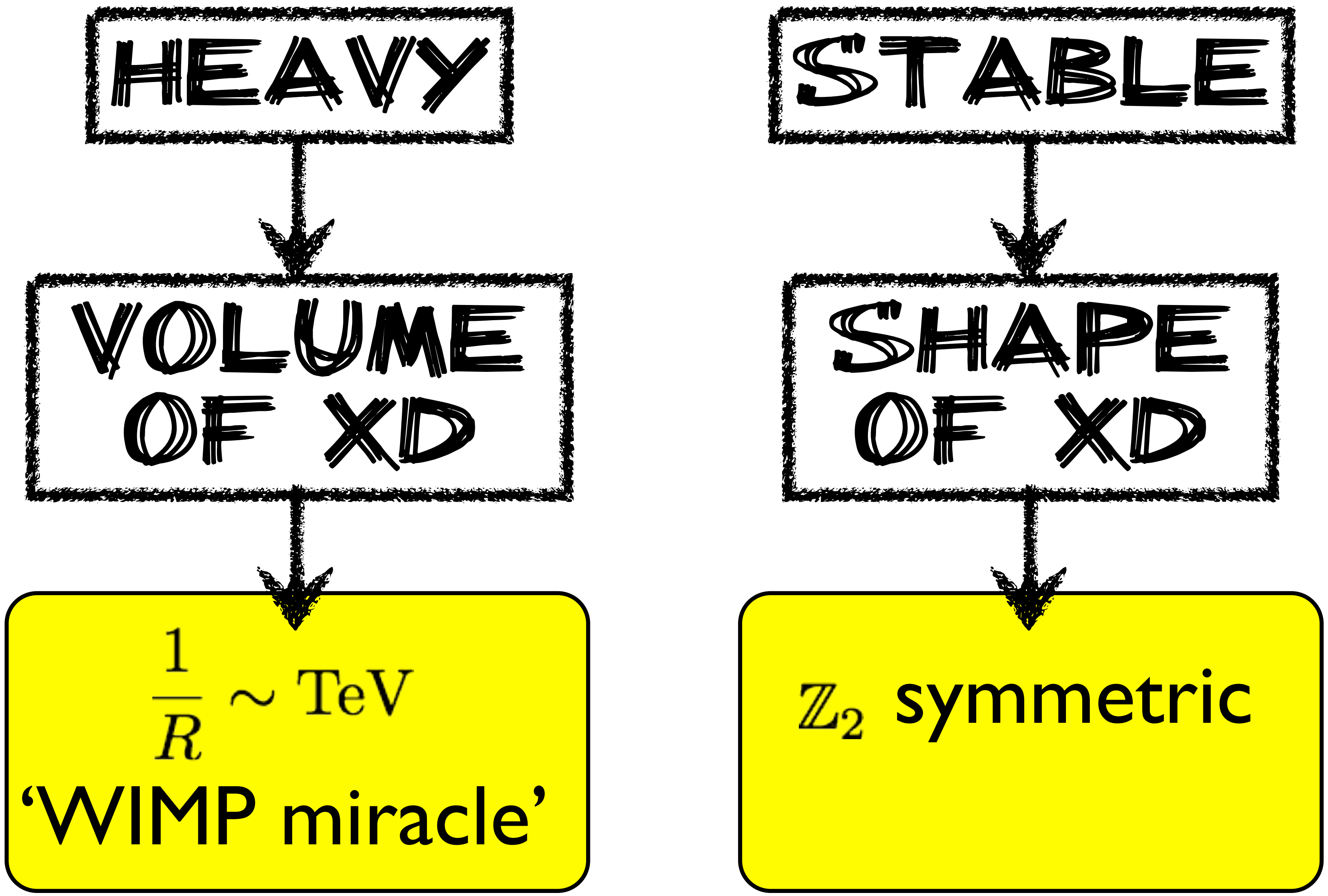
DM $\Omega h^2 \simeq 0.11$



DM $\Omega h^2 \simeq 0.11$



DM $\Omega h^2 \simeq 0.11$



A TOY MODEL

A TOY MODEL

- The spacetime is 5D

A TOY MODEL

- The spacetime is 5D
- The 5^{th} dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .

A Toy Model

- The spacetime is 5D
- The 5th dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .
- Z_2 symmetric about the middle point (x_5=0)

A TOY MODEL

- The spacetime is 5D
- The 5^{th} dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .
- Z_2 symmetric about the middle point (x_5=0)
- A 5D field is Fourier decomposed into cosine and sine functions.

A TOY MODEL

- The spacetime is 5D
- The 5^{th} dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .
- Z_2 symmetric about the middle point (x_5=0)
- A 5D field is Fourier decomposed into cosine and sine functions.
- L~1/TeV

A TOY MODEL

- The spacetime is 5D
- The 5^{th} dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .
- Z_2 symmetric about the middle point (x_5=0)
- A 5D field is Fourier decomposed into cosine and sine functions.
- L~1/TeV
- If the lightest sine mode is neutral, it can be a candidate of KKDM!

Minimal UED

- The spacetime is 5D
- The 5^{th} dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .
- Z_2 symmetric about the middle point (x_5=0)
- L~1/TeV

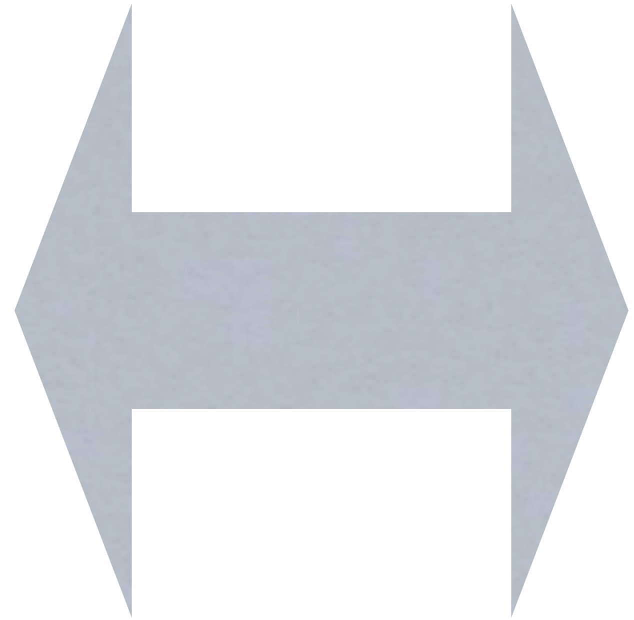
MINIMAL UED

- The spacetime is 5D
- The 5^{th} dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .
- Z_2 symmetric about the middle point (x_5=0)
- $L \sim 1/\text{TeV}$
- All the SM fields are in 5D (Universal) and they are Fourier decomposed by cosine and sine functions.

Minimal UED

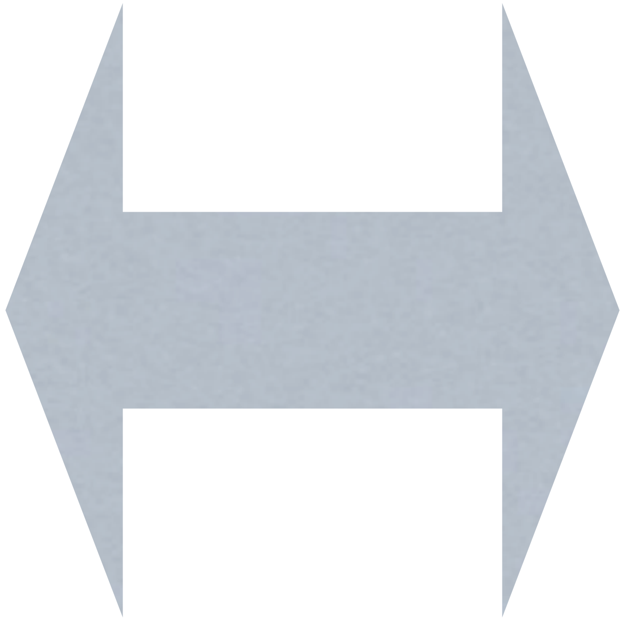
- The spacetime is 5D
- The 5^{th} dimension is a flat interval $[-L, L]$ or an orbifold S^1/Z_2 .
- Z_2 symmetric about the middle point (x_5=0)
- L~1/TeV
- All the SM fields are in 5D (Universal) and they are Fourier decomposed by cosine and sine functions.
- The lightest sine mode (LKP) is B_1, it is a candidate of KKDM!

In General...



In ‘symmetric’ extra dimension, we can immediately find a good geometric $\mathbb{Z}_2$ symmetry: the reflection about the middle point:

KK-PARITY



In symmetric space, the KK–basis functions are even or odd under the reflection about the middle point .

$$f(y)=(e_n(y),o_n(y))$$

if flat $\{\cos(n\pi x_5/L), \sin(n\pi x_5/L)\}$

There always exists the lightest odd state, which is automatically stable!

$f(y)=(f_n(y))=(e_n(y),o_n(y)),$

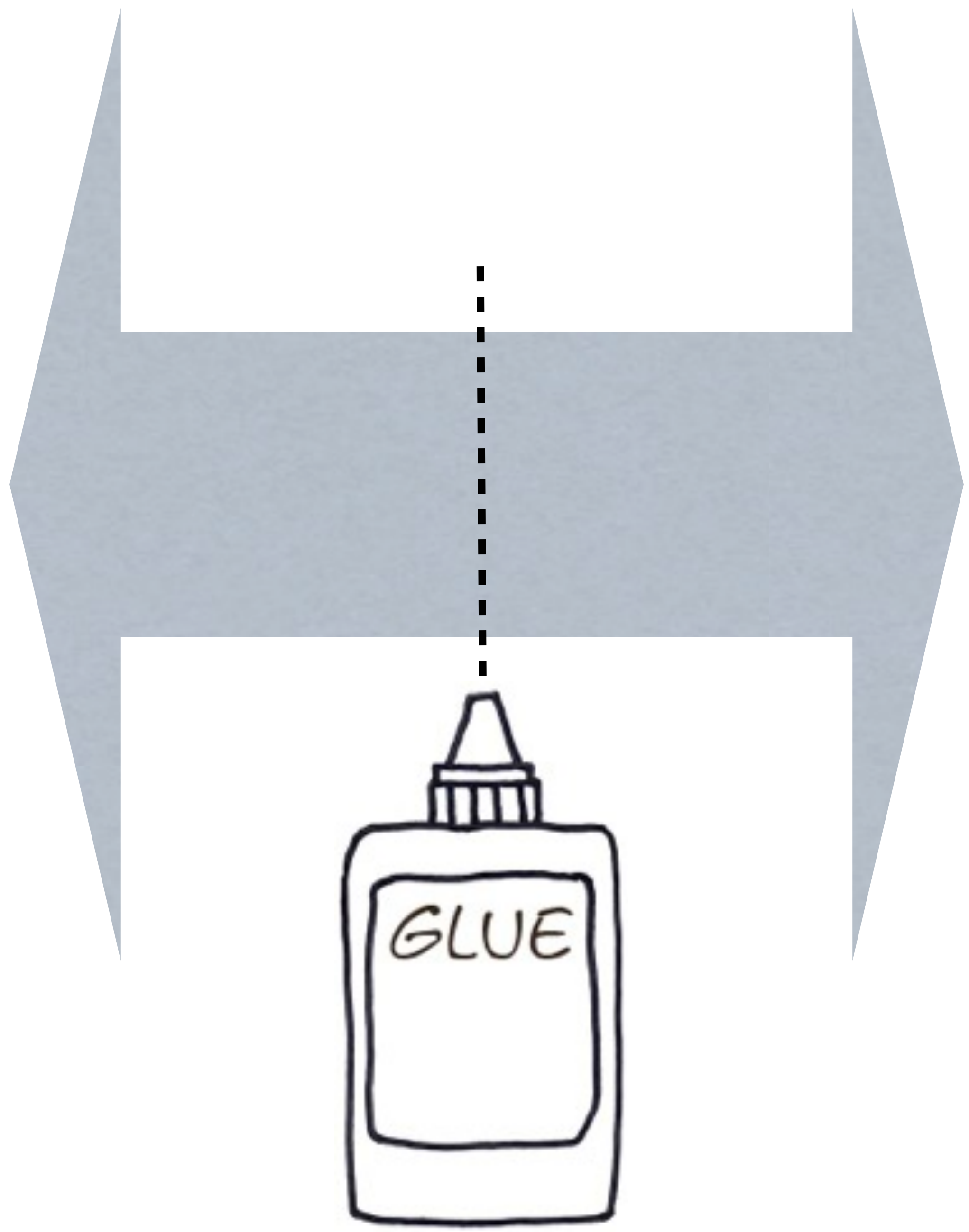
O_1 is stable!

LESSON:

O_1 (the LKP) in any symmetric extra dimension can be a good DM candidate, KKDM

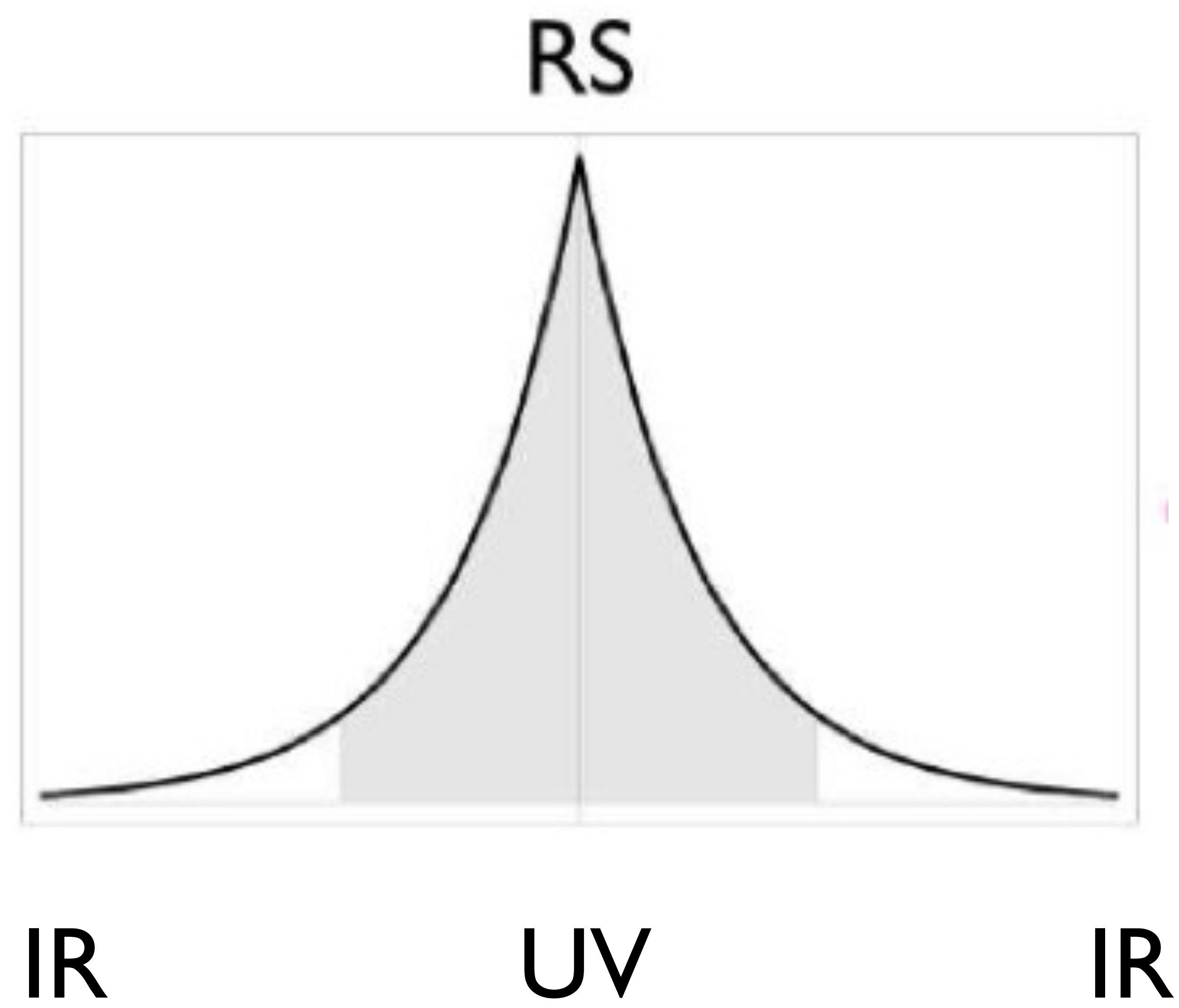
Q. How to construct a symmetric space?

DIY
:SYMMETRIC SPACE



(EX)TWO THROATS RS

[Agashe, Falkowski,Low, Servant 2008]



2T-RS

2T-RS

- provides a possible understanding of the big hierarchy in terms of geometry ~ warp factor

2T-RS

- provides a possible understanding of the big hierarchy in terms of geometry ~ warp factor
- also provides an interesting (best to date?) framework to understand the flavor structure of the SM ~the localization of wave function

2T-RS

- provides a possible understanding of the big hierarchy in terms of geometry ~ warp factor
- also provides an interesting (best to date?) framework to understand the flavor structure of the SM ~the localization of wave function
- LKP dark matter ~KK-parity

2T-RS

- provides a possible understanding of the big hierarchy in terms of geometry ~ warp factor
- also provides an interesting (best to date?) framework to understand the flavor structure of the SM ~the localization of wave function
- LKP dark matter ~KK–parity
- theoretically profound (AdS/CFT) and phenomenologically rich

- The LHC is limited so that the LHC may not be able to probe the full RS geometry but only the vicinity of the IR boundary.

- The LHC is limited so that the LHC may not be able to probe the full RS geometry but only the vicinity of the IR boundary.

- Thus, for the purpose of the LHC, we only need Low energy effective theory of RS for a few KK modes.

- The LHC is limited so that the LHC may not be able to probe the full RS geometry but only the vicinity of the IR boundary.

- Thus, for the purpose of the LHC, we only need Low energy effective theory of RS for a few KK modes.

- Near the IR boundary, the AdS curvature is highly red- shifted.

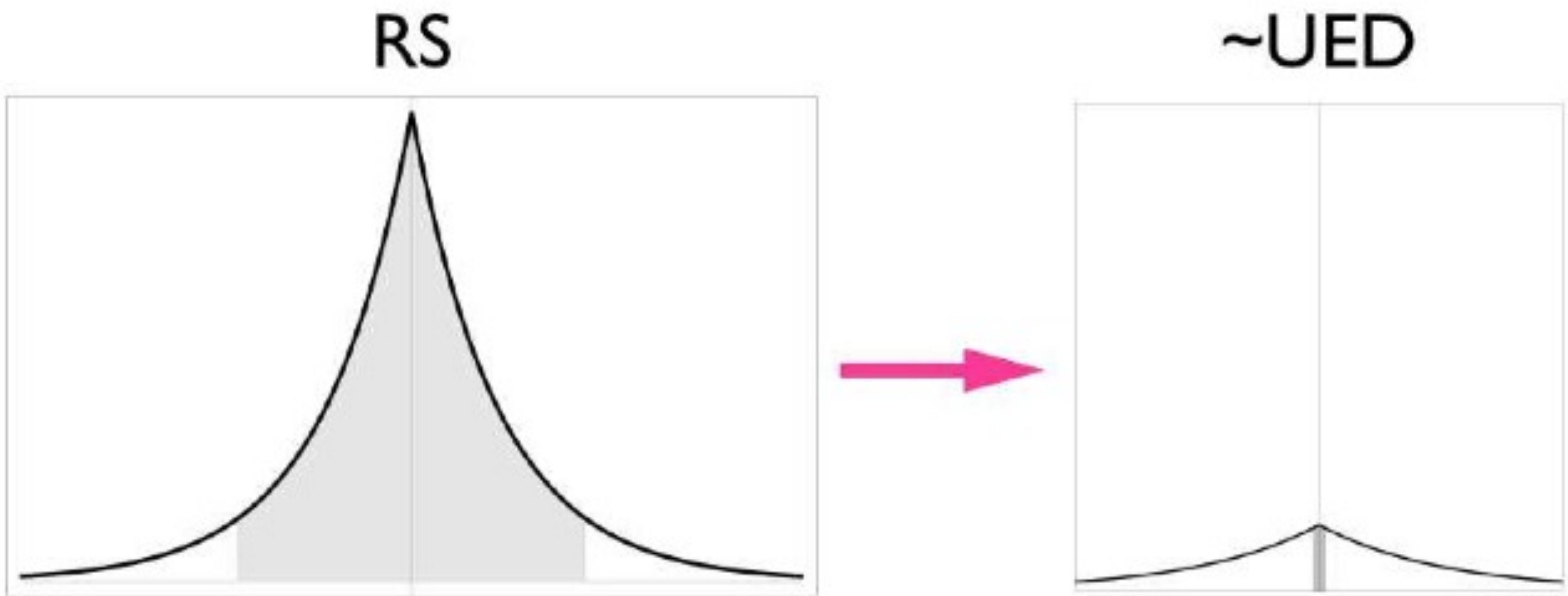
- The LHC is limited so that the LHC may not be able to probe the full RS geometry but only the vicinity of the IR boundary.

- Thus, for the purpose of the LHC, we only need Low energy effective theory of RS for a few KK modes.

- Near the IR boundary, the AdS curvature is highly red– shifted.

- Effectively, the LHC may only see 'flat' geometry rather than the curved 'AdS' geometry .

Effectively RS looks like UED!



Csaki, Heinonen, Hubisz, SCP, Shu, JHEP 1101 (2011) 089

Schematic form of the general UED Lagrangian

5D Lorentz invariant
Gauge covariant Kinetic terms + Mass terms

$$S = \int dy d^4x \, \mathcal{L}_5 + \delta(y - L)\mathcal{L}_L + \delta(y + L)\mathcal{L}_{-L}$$

4D Lorentz invariant
BLKT

Flat geometry assumed

Schematic form of the general UED Lagrangian

5D Lorentz invariant
Gauge covariant Kinetic terms + ~~Mass terms~~

'minimal UED'

$$S = \int dy d^4x \, \mathcal{L}_5 + \delta(y-L)\mathcal{L}_L + \delta(y+L)\mathcal{L}_{-L}$$

Flat geometry assumed

4D Lorentz invariant
BLKT

5D Lorentz invariant terms in the bulk

$$S_5 = \int d^4x \int_{-L}^{L} dy \, [\mathcal{L}_V + \mathcal{L}_\Psi + \mathcal{L}_H + \mathcal{L}_{Yuk}] \, ,$$

$$\mathcal{L}_V = \sum_{\mathcal{A}}^{G,W,B} -\frac{1}{4}\mathcal{A}^{MN} \cdot \mathcal{A}_{MN}$$

$$\mathcal{L}_\Psi = \sum_{\Psi}^{Q,U,D,L,E} i\overline{\Psi}\overleftrightarrow{D}_M \Gamma^M \Psi - M_\Psi \overline{\Psi}\Psi$$

$$\mathcal{L}_H = (D_M H)^\dagger D^M H - V(H),$$
$$V(H) = -\mu_5^2 |H|^2 + \lambda_5 |H|^4 \, ,$$
$$\mathcal{L}_{Yuk} = \lambda_5^E \overline{L} H E + \lambda_5^D \overline{Q} H D + \lambda_5^U \overline{Q} \tilde{H} D + \text{h.c.} \, ,$$

4D Lorentz invariant terms on bdys

$$S_{bdy} = \int d^4x \int_{-L}^{L} dy \, (\mathcal{L}_{\partial V} + \mathcal{L}_{\partial \Psi} + \mathcal{L}_{\partial H} + \mathcal{L}_{\partial Yuk}) \left[\delta(y-L) + \delta(y+L)\right],$$

$$\mathcal{L}_{\partial V} = \sum_{\mathcal{A}}^{G,W,B} -\frac{r_{\mathcal{A}}}{4} \mathcal{A}_{\mu\nu} \cdot \mathcal{A}^{\mu\nu},$$

$$\mathcal{L}_{\partial \Psi} = \sum_{\Psi_L}^{Q,L} i r_{\Psi_L} \overline{\Psi}_L D_\mu \gamma^\mu \Psi_L + \sum_{\Psi_R}^{U,D,E} i r_{\Psi_R} \overline{\Psi}_R D_\mu \gamma^\mu \Psi_R,$$

$$\mathcal{L}_{\partial H} = r_H \left(D_\mu H\right)^\dagger D^\mu H + r_\mu \mu_5^2 |H|^2 - r_\lambda \lambda_5 |H|^4,$$

$$\mathcal{L}_{\partial Yuk} = r_{\lambda^E} \lambda_5^E \overline{L} H E + r_{\lambda^D} \lambda_5^D \overline{Q} H D + r_{\lambda^U} \lambda_5^U \overline{Q} \tilde{H} D + \text{h.c.}\,.$$

MODEL PARAMETERS

- 1/R ~geometrical data
- M's: 5D Dirac masses for fermions : 0 in mUED
- r's~the strength of BLTs relative to the SM ones : 0 in mUED

LOWER BOUNDS ON 1/R (SET IN MUED)

Lower Bounds on 1/R (set in MUED)

- 1/R > 600 GeV (flavor physics .. loose bound due to MFV type + KK-parity)

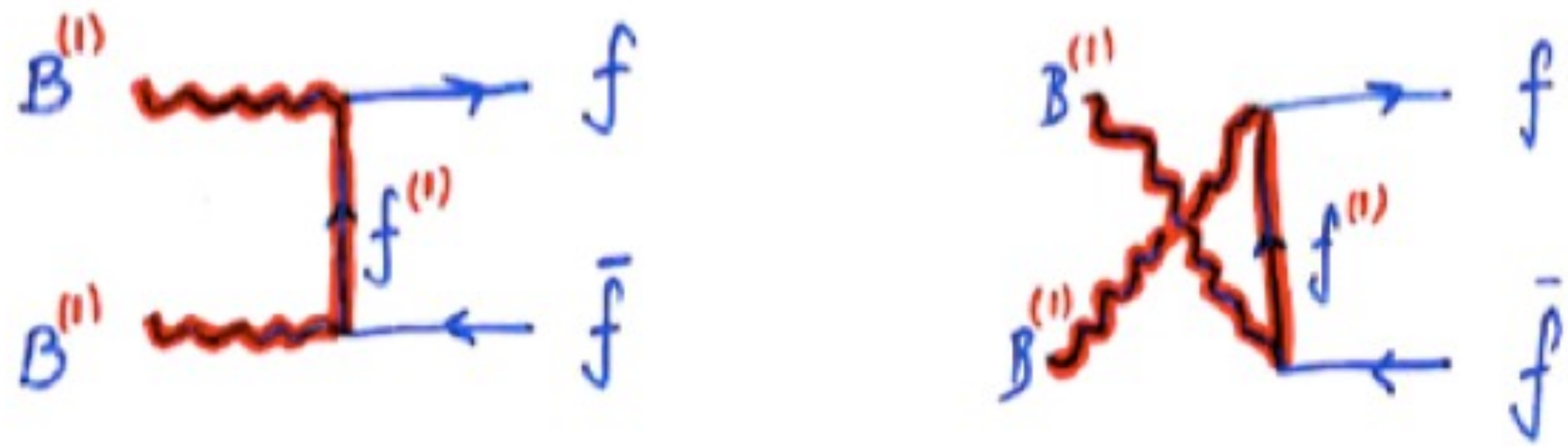
Lower Bounds on 1/R (set in MUED)

- 1/R > 600 GeV (flavor physics .. loose bound due to MFV type + KK-parity)
- 1/R > 700 GeV (LHC7+LHC8)

LOWER BOUNDS ON 1/R (SET IN MUED)

- 1/R > 600 GeV (flavor physics .. loose bound due to MFV type + KK-parity)
- 1/R > 700 GeV (LHC7+LHC8)
- 1/R > 750 (300) GeV (EWPT for m_{Higgs}=115 (750)GeV)

Upper bound on 1/R (allowing mass deform)

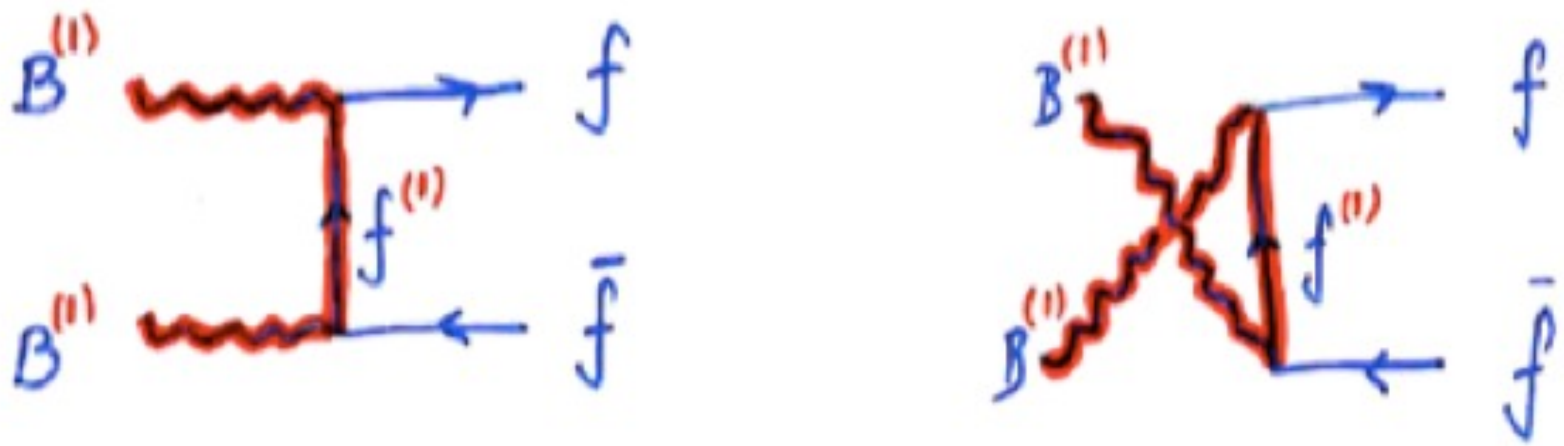


$$\sigma_{tree} v = a + b\,v^2 + \mathcal{O}\left(v^4\right)$$

$$a = \sum_f \frac{32\pi\alpha_1^2 N_c m_{\gamma_1}^2}{9}\left(\frac{Y_{f_L}^4}{(m_{\gamma_1}^2 + m_{f_{L1}}^2)^2} + \frac{Y_{f_R}^4}{(m_{\gamma_1}^2 + m_{f_{R1}}^2)^2}\right),$$

$$b = -\sum_f \frac{4\pi\alpha_1^2 N_c m_{\gamma_1}^2}{27}\left(Y_{f_L}^4 \frac{11 m_{\gamma_1}^4 + 14 m^2 m_{f_{L1}}^2 - 13 m_{f_{L1}}^4}{(m_{\gamma_1}^2 + m_{f_{R1}}^2)^4} + Y_{f_R}^4 \frac{11 m_{\gamma_1}^4 + 14 m_{\gamma_1}^2 m_{f_{L1}}^2 - 13 m_{f_{L1}}^4}{(m_{\gamma_1}^2 + m_{f_{R1}}^2)^4}\right),$$

Upper bound on 1/R (allowing mass deform)



$$\sigma_{tree} v = a + b\, v^2 + \mathcal{O}\left(v^4\right)$$

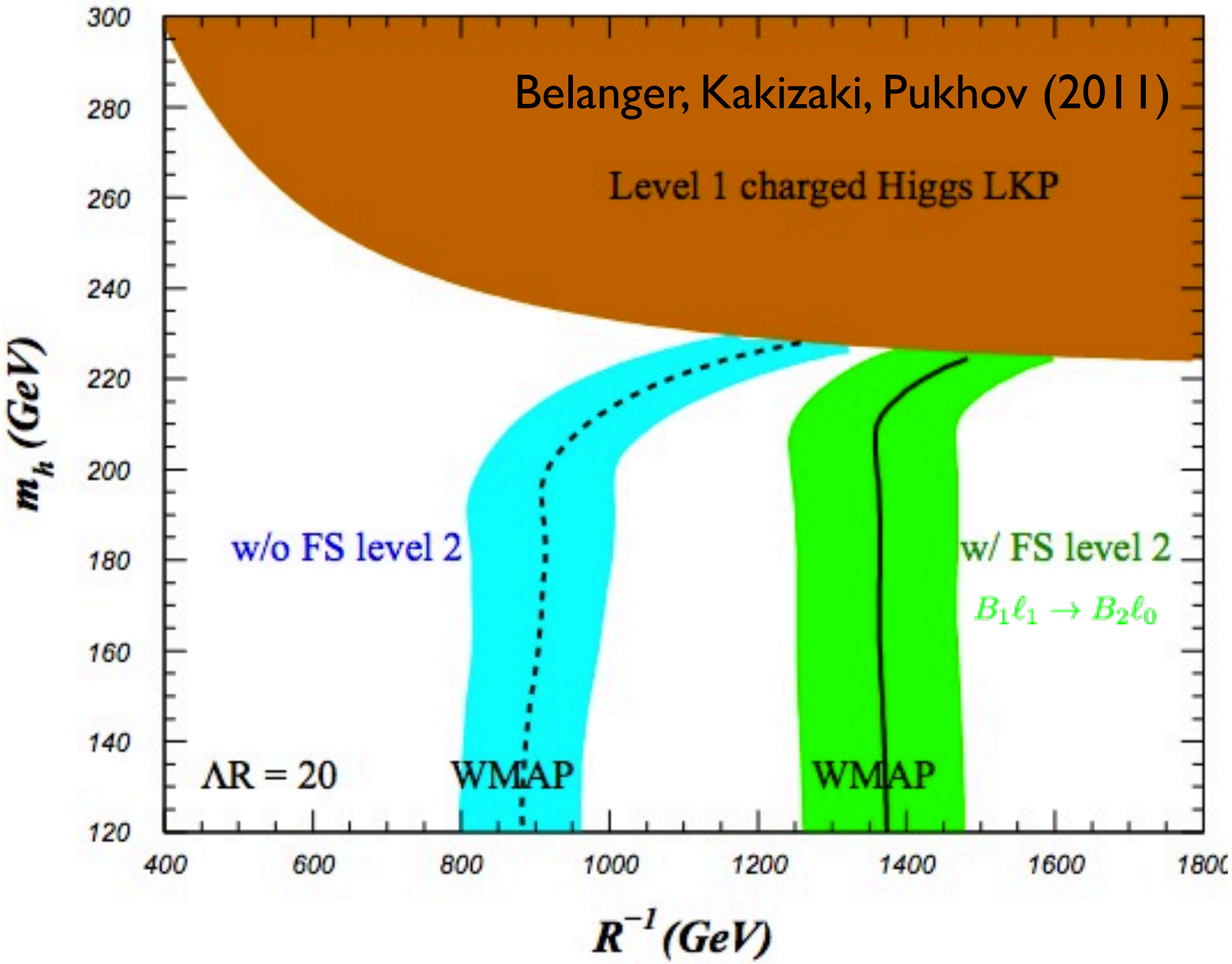
$$a = \sum_f \frac{32\pi\alpha_1^2 N_c m_{\gamma_1}^2}{9}\left(\frac{Y_{f_L}^4}{(m_{\gamma_1}^2+m_{f_{L1}}^2)^2}+\frac{Y_{f_R}^4}{(m_{\gamma_1}^2+m_{f_{R1}}^2)^2}\right),$$

$$b = -\sum_f \frac{4\pi\alpha_1^2 N_c m_{\gamma_1}^2}{27}\left(Y_{f_L}^4\frac{11m_{\gamma_1}^4+14m^2 m_{f_{L1}}^2-13m_{f_{L1}}^4}{(m_{\gamma_1}^2+m_{f_{R1}}^2)^4} + Y_{f_R}^4\frac{11m_{\gamma_1}^4+14m_{\gamma_1}^2 m_{f_{L1}}^2-13m_{f_{L1}}^4}{(m_{\gamma_1}^2+m_{f_{R1}}^2)^4}\right),$$

larger M_{f1}
⇒smaller cross section
⇒larger Relic abundance
⇒ set "upper bound" on KK-scale

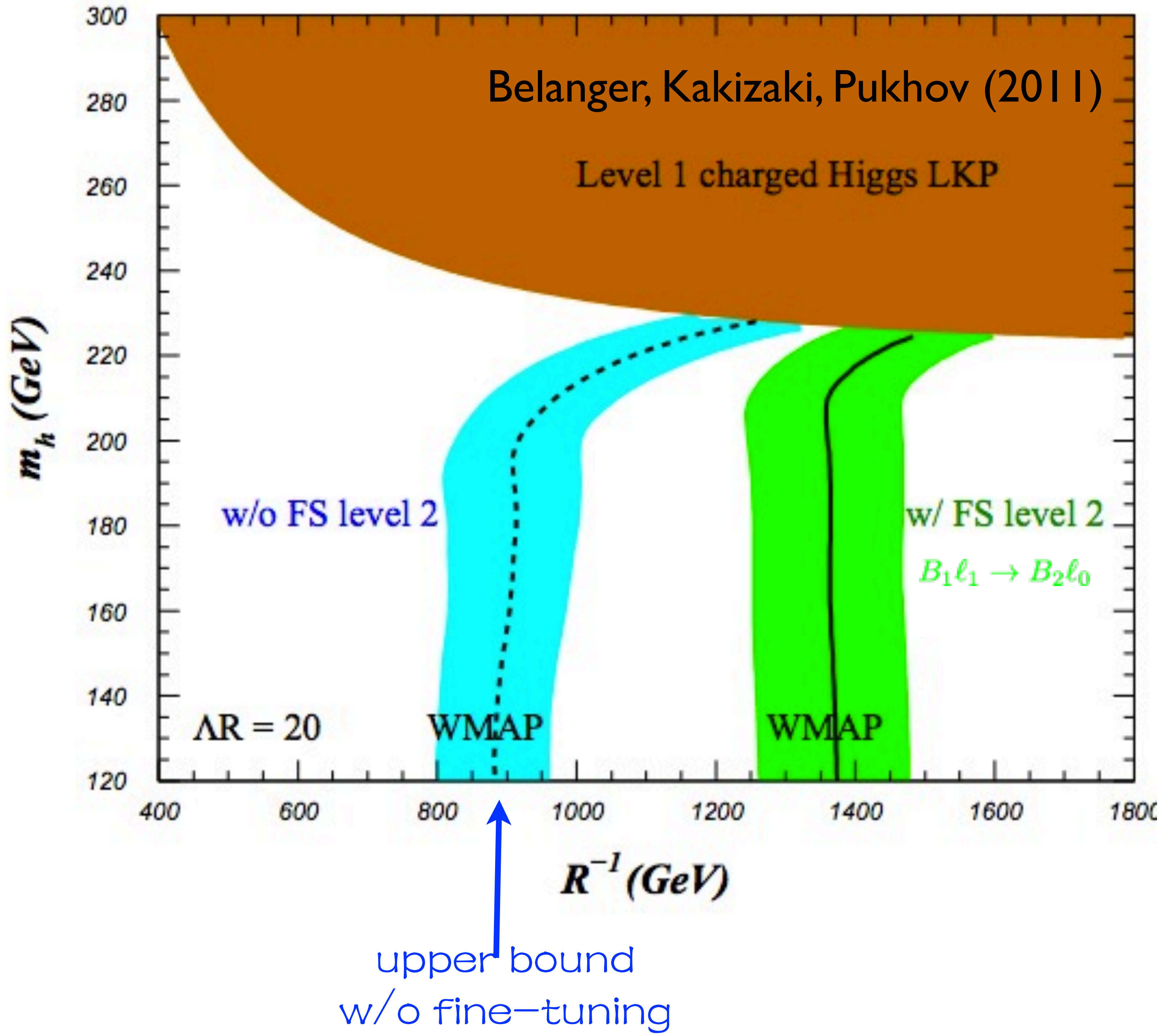
Upper bound on 1/R set by DM relic abundance

(set in MUED +allowing tuning in KK-mass)



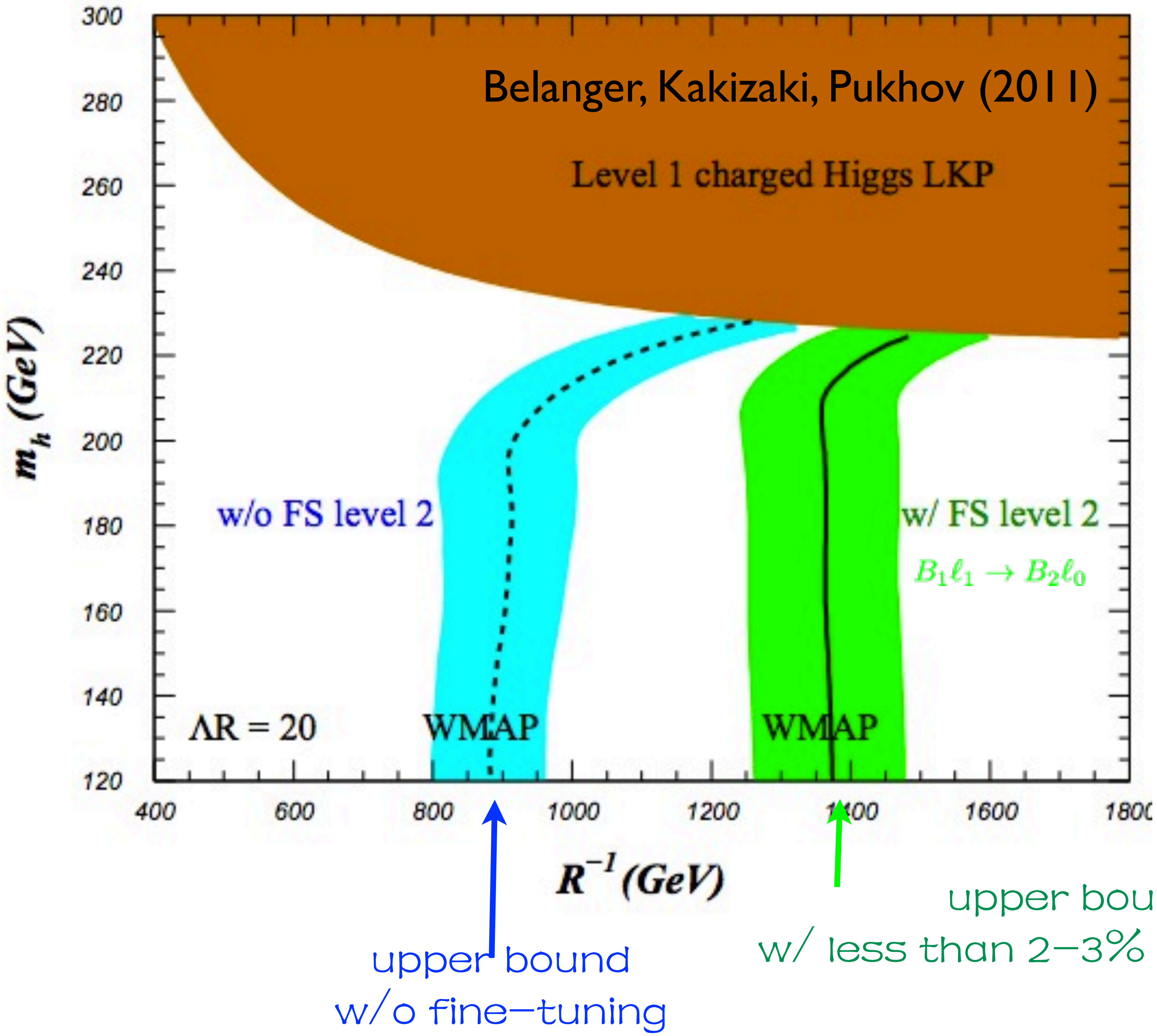
Upper bound on 1/R set by DM relic abundance

(set in MUED +allowing tuning in KK-mass)



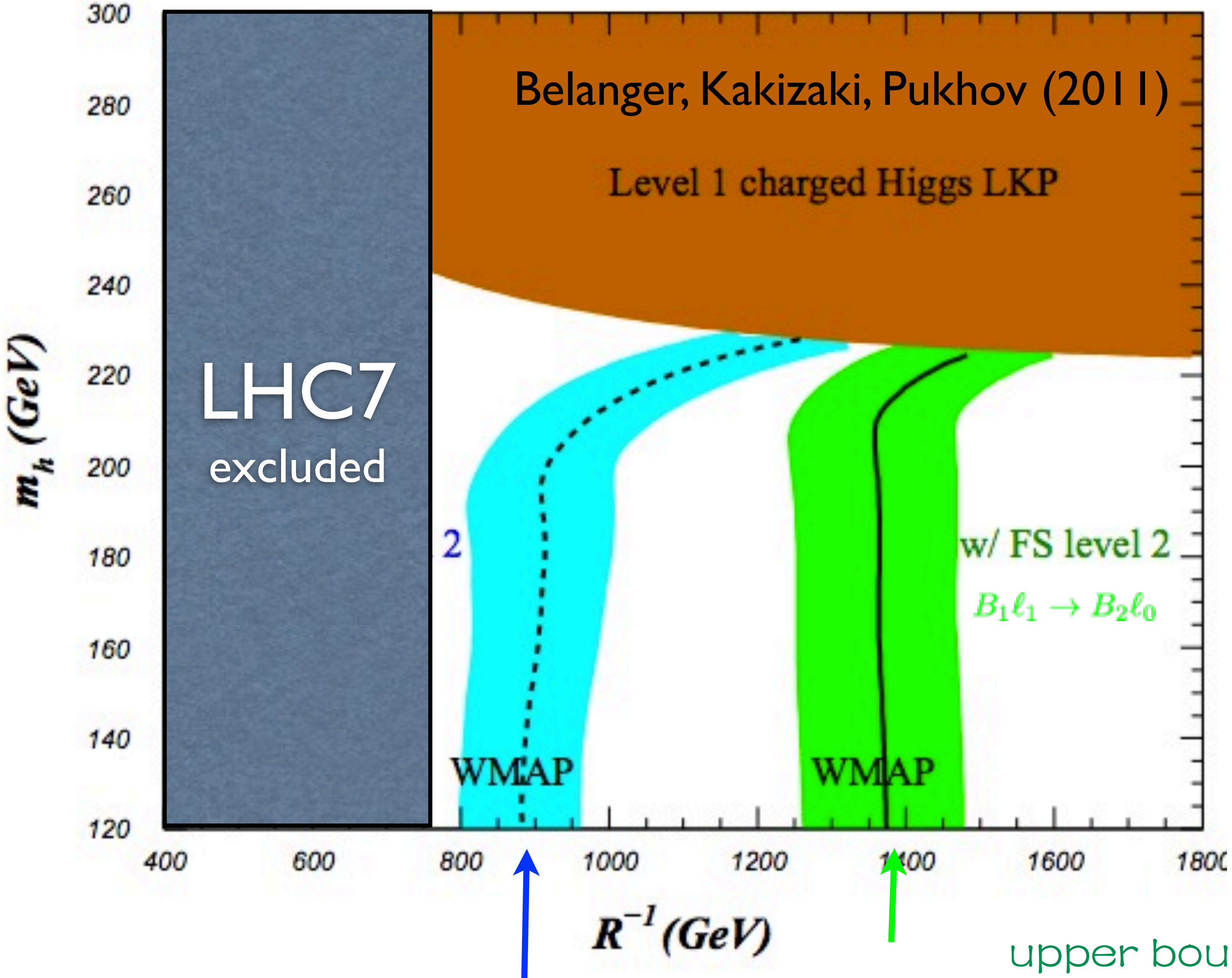
Upper bound on 1/R set by DM relic abundance

(set in MUED +allowing tuning in KK-mass)



Upper bound on 1/R set by DM relic abundance

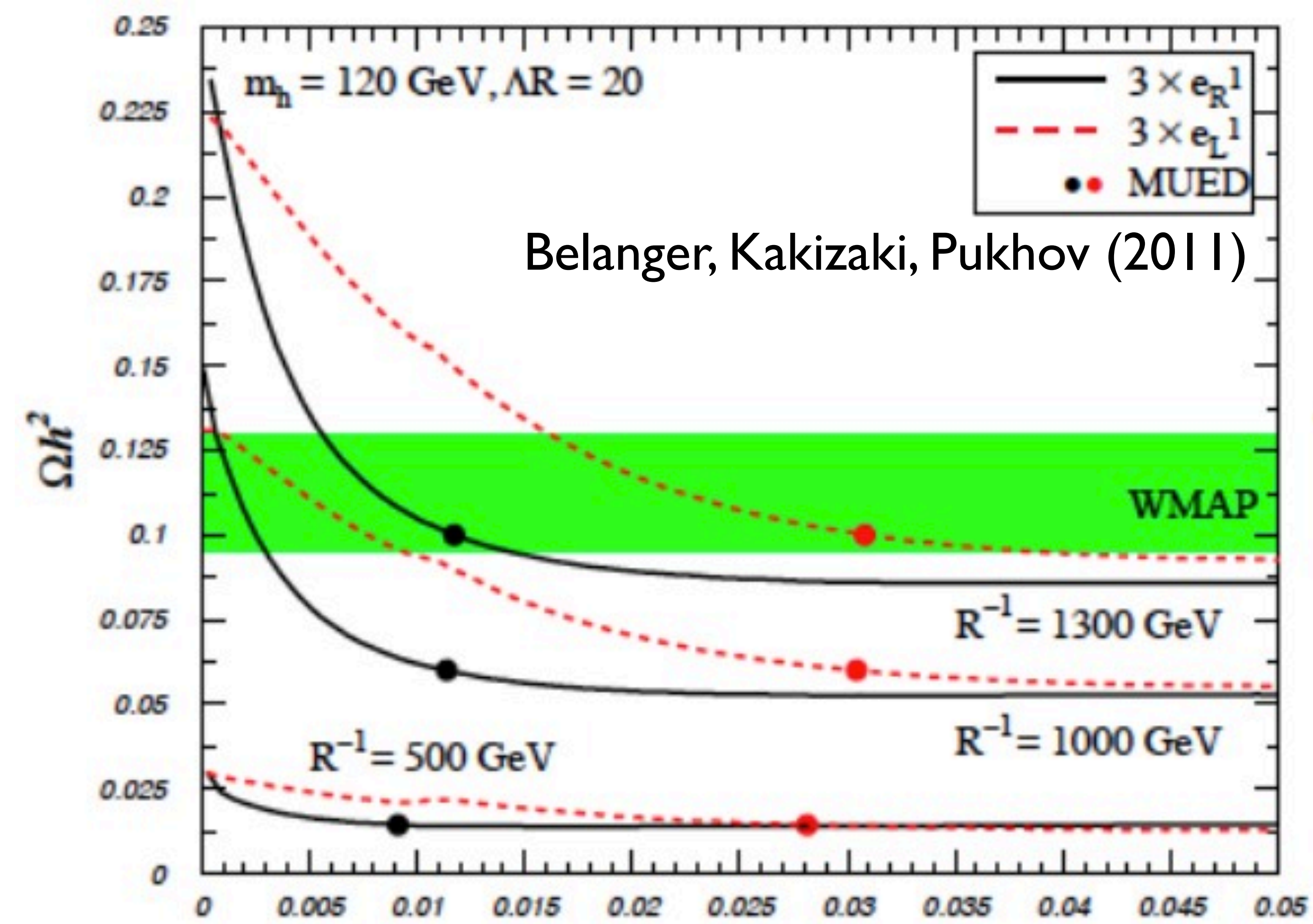
(set in MUED +allowing tuning in KK-mass)



upper bound
w/o fine-tuning

upper bound
w/ less than 2-3% fine-tuning

Required level of fine-tuning for coannihilation



Fine tuned ← Mass splitting → less tuned

$$\Delta_e = \left(m_{e_R^1} - m_{B_1}\right)/m_{B_1}$$

THERE ARE TWO MORE SETS OF PARAMETERS IN GENERAL UED

There are two more sets of parameters in general UED

- Bulk masses for fermions : Dim-4 operators

There are two more sets of parameters in general UED

- Bulk masses for fermions : Dim−4 operators
- Boundary localized mass & kinetic terms : Dim−5 operators

A VECTOR LIKE MASS

$$S = -\int d^5x\, M_\Psi \overline{\Psi}\Psi$$

the Dirac mass term is generically allowed

$$M_\Psi \propto \mu\theta(y)$$

15 (18) BULK MASSES

15 (18) BULK MASSES

$M_{Q_3}, M_{Q_2}, M_{Q_1}$

$M_{u_3}, M_{u_2}, M_{u_1}$

$M_{d_3}, M_{d_2}, M_{d_1}$

$M_{L_3}, M_{L_2}, M_{L_1}$

$M_{e_3}, M_{e_2}, M_{e_1}$

$M_{N_3}, M_{N_2}, M_{N_1}$

15 (18) BULK MASSES

$M_{Q_3}, M_{Q_2}, M_{Q_1}$

$M_{u_3}, M_{u_2}, M_{u_1}$

$M_{d_3}, M_{d_2}, M_{d_1}$

M_Q

(MFV)

$M_{L_3}, M_{L_2}, M_{L_1}$

$M_{e_3}, M_{e_2}, M_{e_1}$

$M_{N_3}, M_{N_2}, M_{N_1}$

M_L

15 (18) BULK MASSES

$M_{Q_3}, M_{Q_2}, M_{Q_1}$

$M_{u_3}, M_{u_2}, M_{u_1}$

$M_{d_3}, M_{d_2}, M_{d_1}$

M_Q

(MFV)

$M_{L_3}, M_{L_2}, M_{L_1}$

$M_{e_3}, M_{e_2}, M_{e_1}$

$M_{N_3}, M_{N_2}, M_{N_1}$

M_L

$M_\Psi = M$

(simpler)

15 (18) BULK MASSES

$M_{Q_3}, M_{Q_2}, M_{Q_1}$

$M_{u_3}, M_{u_2}, M_{u_1}$

$M_{d_3}, M_{d_2}, M_{d_1}$

M_Q

(MFV)

$$M_\Psi = M$$

$M_{L_3}, M_{L_2}, M_{L_1}$

$M_{e_3}, M_{e_2}, M_{e_1}$

$M_{N_3}, M_{N_2}, M_{N_1}$

M_L

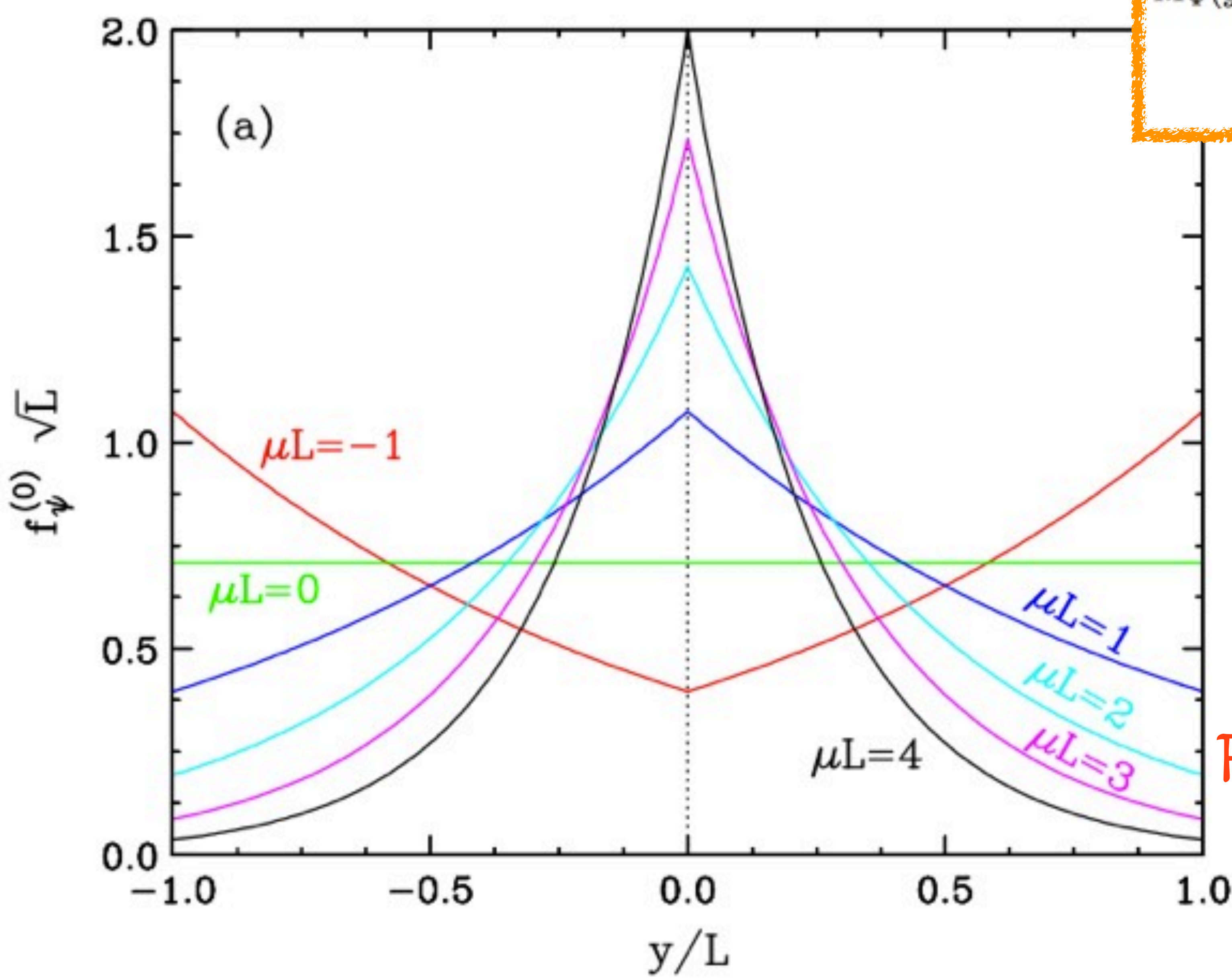
(simpler)

$\to 0(\mathrm{mUED})$

WAVE FUNCTIONS FOR FERMION

$$f^0_{R/L}(y) \sim e^{\mp \int_{-L}^{y} m_5(y')dy'} \rightarrow f^0_{R/L}(y) = N_{R/L} e^{\mp\mu|y|}$$

$$M_\Psi(y) = \mu_\Psi \tanh my \xrightarrow{m\to\infty} \mu_\Psi \mathrm{sgn}(y) = \begin{cases} -\mu_\Psi & \text{if } y < 0 \\ +\mu_\Psi & \text{if } y > 0 \end{cases}$$



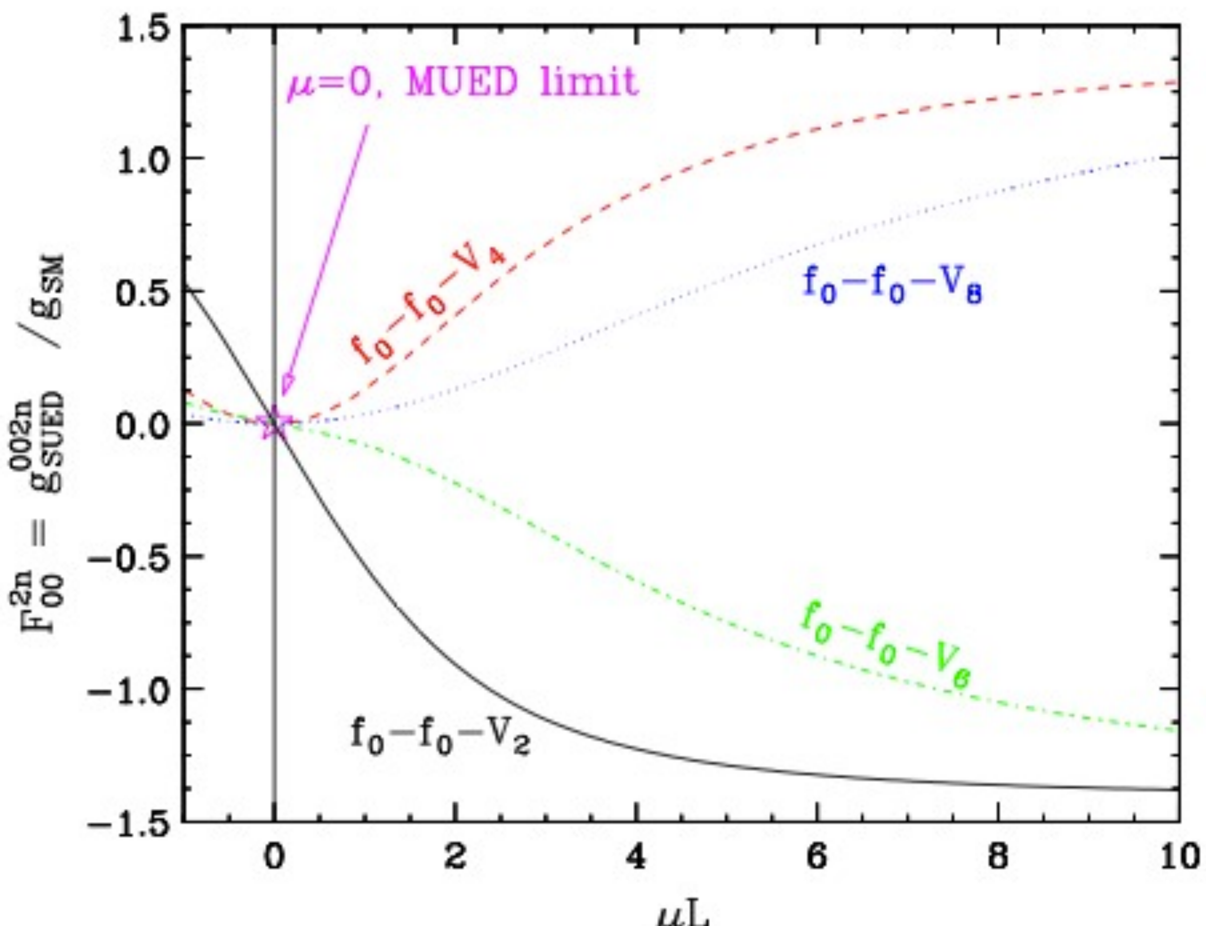
KK-parity conserved!

(bonus)
Room for Flavor physics

"split-UED"
SCP, Shu Phys.Rev. D79 (2009) 091702

"Running" Coupling Constant

$$g_{m\ell n} = \frac{g_5}{\sqrt{L}} \int_{-L}^{L} dy \psi_m(y) \psi_\ell^*(y) f_V^n(y)$$
$$= g_{\rm SM} \mathcal{F}_{m\ell}^n (m_\Psi L)$$

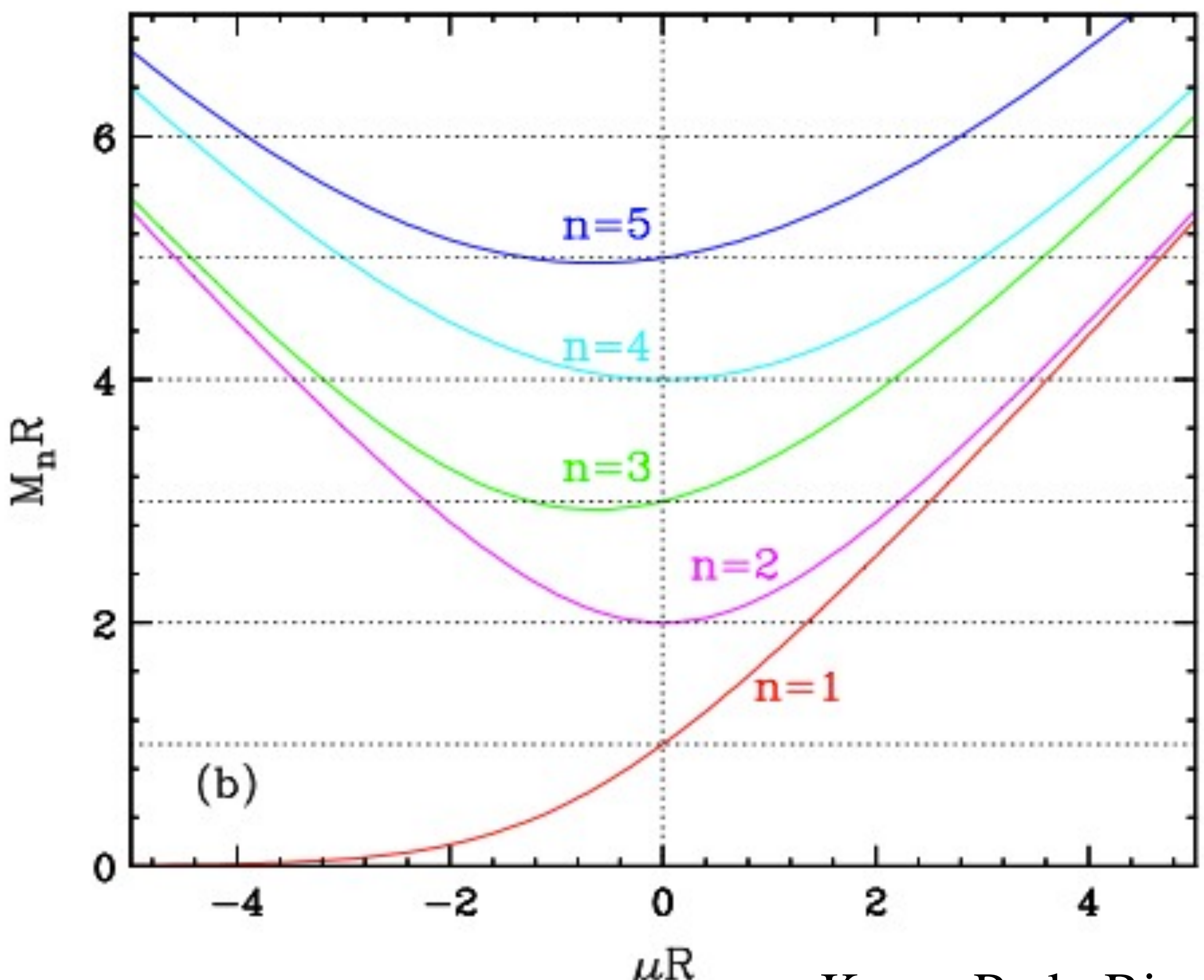


Kong, Park, Rizzo JHEP 1004 (2010) 081

$$(-1)^n \sqrt{2}$$
for $0-0-2n$

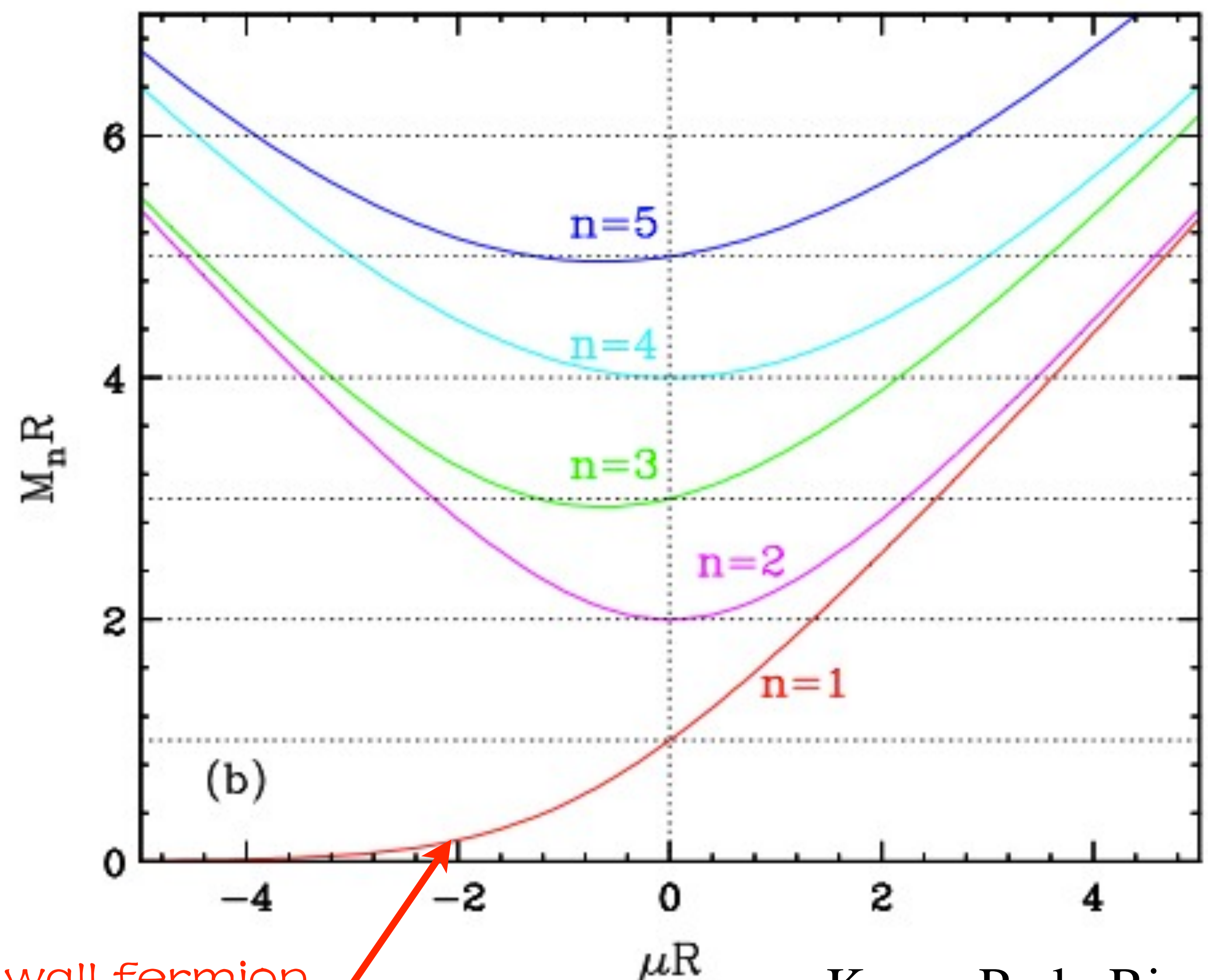
0–0–(2n) couplings can be sizable!

"Running" KK-mass



Kong, Park, Rizzo JHEP 1004 (2010) 081

"RUNNING" KK-MASS



the domain wall fermion
(an origin of 4th generation)

Kong, Park, Rizzo JHEP 1004 (2010) 081

Kong, Park, Rizzo JHEP 1007 (2010) 059

Q. What is the most preferred parameter space for (1/R, M)?

THEORETICALLY

Theoretically

- “Natural” choice is M~1/R (the only scale in the theory)

Theoretically

- "Natural" choice is $M \sim 1/R$ (the only scale in the theory)
- Any value of M below cutoff scale is allowed, $M < \Lambda$.

EXPERIMENTALLY

EXPERIMENTALLY

- If $1/R \gg$ TeV, theory decouples (hard to get tested ..)

Experimentally

- If $1/R \gg$ TeV, theory decouples (hard to get tested ..)
- If $1/R \sim$ TeV, theory can get constrained by EWPD(S,T,U), 4Fermi, g−2 , LHC, Dark matter..

S,T,U

MUED Appelquist-Yee (2001)

KK top

$$S_{UED} = \frac{4\sin^2\theta_W}{\alpha}\left[\frac{3g^2}{4(4\pi)^2}\left(\frac{2}{9}\sum_n \frac{m_t^2}{(n/R)^2}\right) + \frac{g^2}{4(4\pi)^2}\left(\frac{1}{6}\frac{m_h^2}{1/R}\right)\zeta(2)\right],$$

$$T_{UED} = \frac{1}{\alpha}\left[\frac{3g^2}{2(4\pi)^2}\frac{m_t^2}{m_W^2}\left(\frac{2}{3}\sum_n \frac{m_t^2}{(n/R)^2}\right) + \frac{g^2\sin^2\theta_W}{(4\pi)^2\cos^2\theta_W}\left(-\frac{5}{12}\frac{m_h^2}{1/R}\right)\zeta(2)\right]$$

$$U_{UED} = -\frac{4\sin^2\theta_W}{\alpha}\left[\frac{g^2\sin^2\theta_W}{(4\pi)^2}\frac{m_W^2}{(1/R)^2}\left(\frac{1}{6}\zeta(2) - \frac{1}{15}\frac{m_h^2}{(1/R)^2}\zeta(4)\right)\right],$$

KK Higgs, W,Z

Note

1. other loops with KK fermions are negligible (fermion mass suppression)
2. the Riemann zeta functions are from infinite sum over KK-tower.
3. For Mh=120 GeV, 1/R>700 GeV at 95% CL.

KK-number violating contribution

$$\delta G_F = \frac{1}{\sqrt{32}} \sum_n \frac{g_{002n}^2}{m_W^2 + (2n/R)^2}$$

for fermion KK–tower

$$\sum_n \frac{m_f^2}{(n/R)^2} \rightarrow \sum_n \frac{m_f^2}{\mu^2 + k_n^2 + m_f^2}$$

$$S_{SUED} = S_{UED},$$

$$T_{SUED} = T_{UED} - \frac{1}{\alpha}\frac{\delta G_F}{G_F},$$

$$U_{SUED} = U_{UED} + \frac{4\sin^2\theta_W}{\alpha}\frac{\delta G_F}{G_F}$$

Carena et.al. (2003), Flacke,Pasold (2012), Huang, Kong, Park (2012)

COLLIDER BOUNDS

Collider Bounds

- remember (0-0-2n) is allowed and can be sizable at tree-level in general

Collider Bounds

- remember (0–0–2n) is allowed and can be sizable at tree-level in general
- not degenerate mass spectrum..depends on the details..

Collider Bounds

- remember (0-0-2n) is allowed and can be sizable at tree-level in general
- not degenerate mass spectrum..depends on the details..
- The existence of the 2^{nd} Gauge boson Resonances is characteristic feature!

COLLIDER BOUNDS

- remember (0–0–2n) is allowed and can be sizable at tree-level in general
- not degenerate mass spectrum..depends on the details..
- The existence of the 2nd Gauge boson Resonances is characteristic feature!

★ $pp \to W_2 \to l$ MET

Collider Bounds

- remember (0−0−2n) is allowed and can be sizable at tree−level in general
- not degenerate mass spectrum..depends on the details..
- The existence of the 2^{nd} Gauge boson Resonances is characteristic feature!

★ $pp \rightarrow W_2 \rightarrow$ l MET

★ $pp \rightarrow Z_2 \rightarrow$ ll, jj

Huang, Kong, Park (2012)

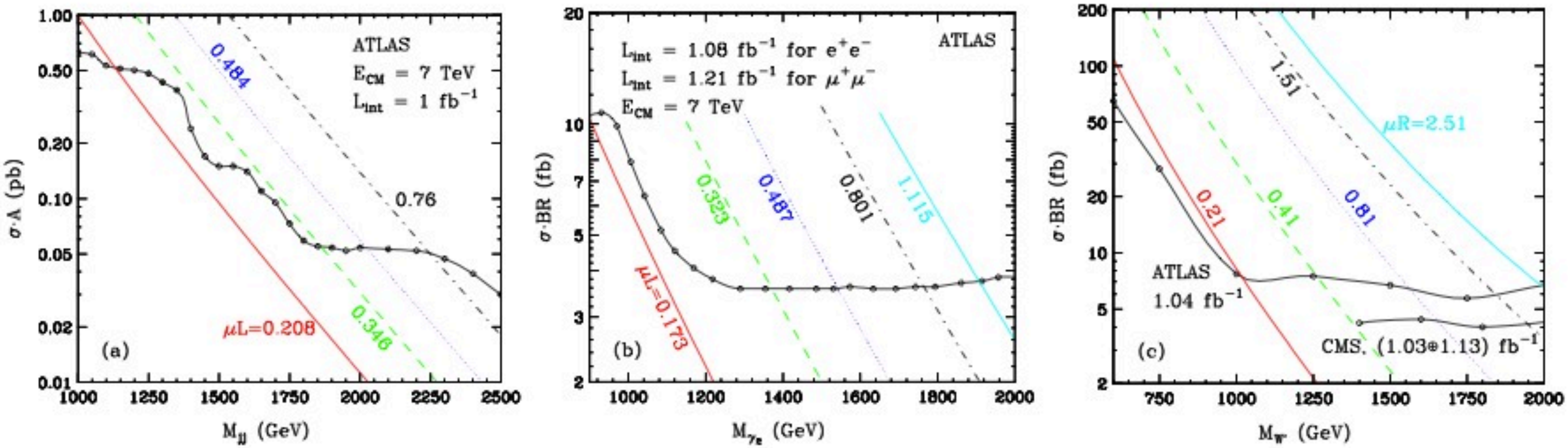
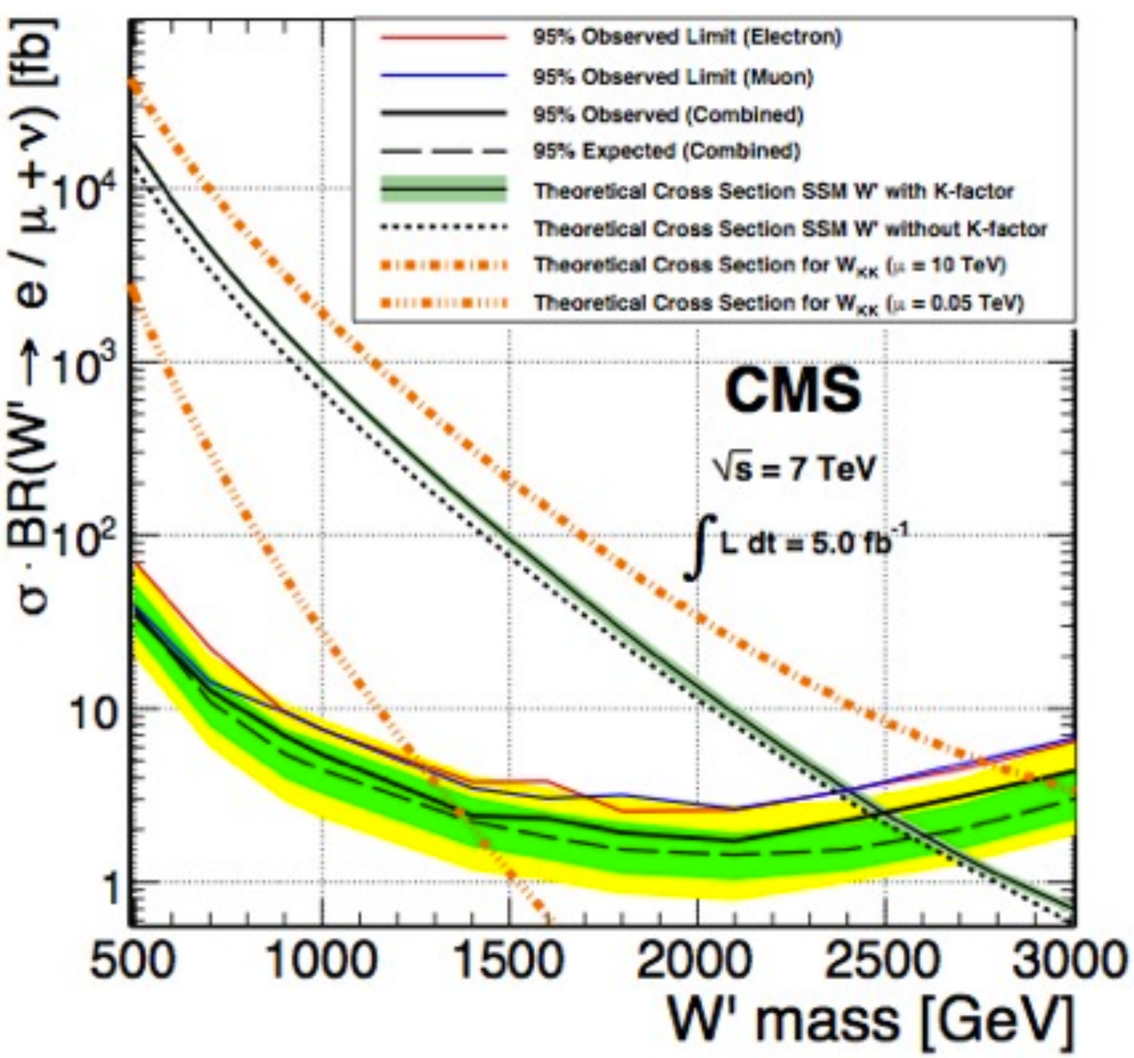
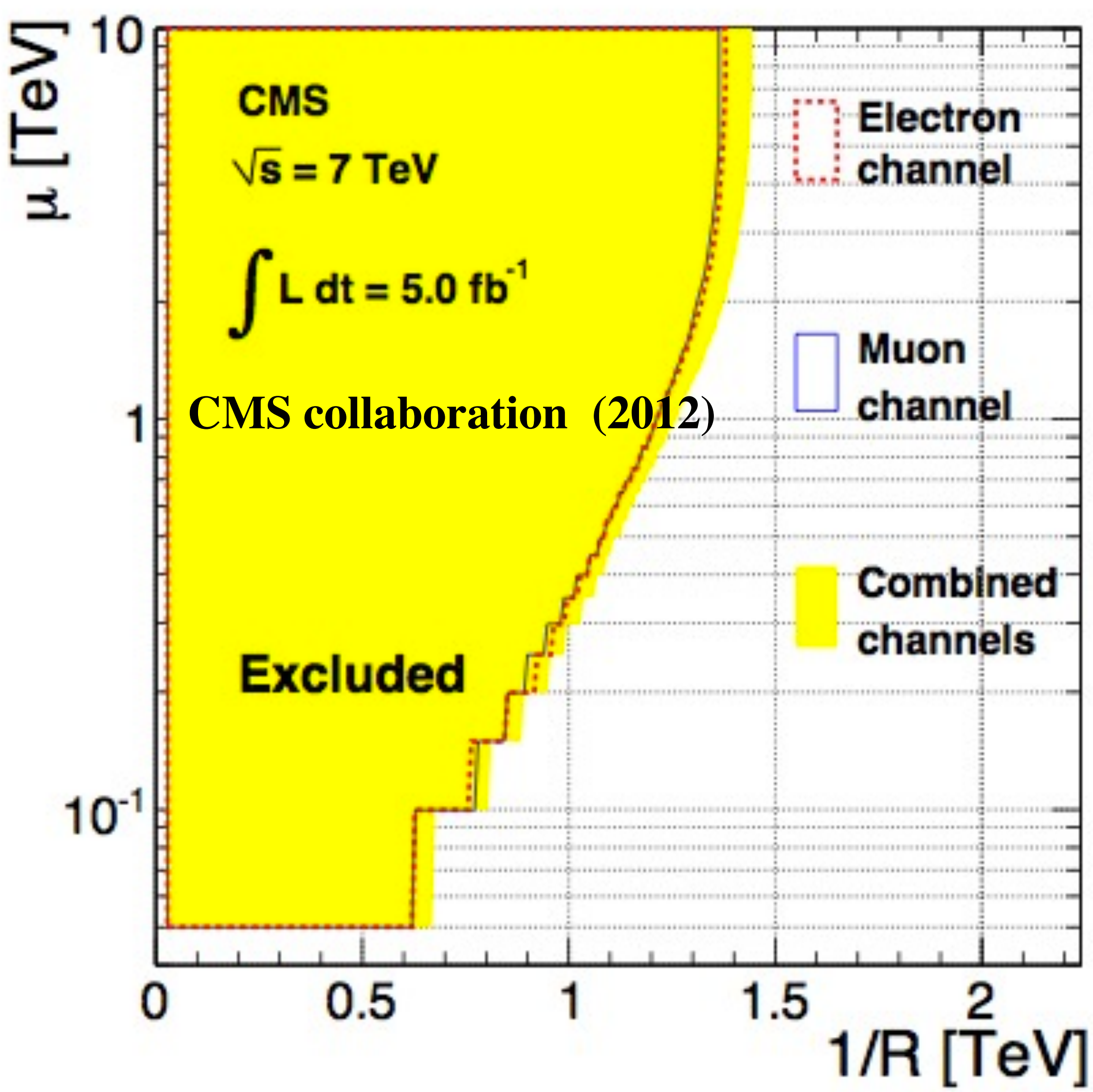


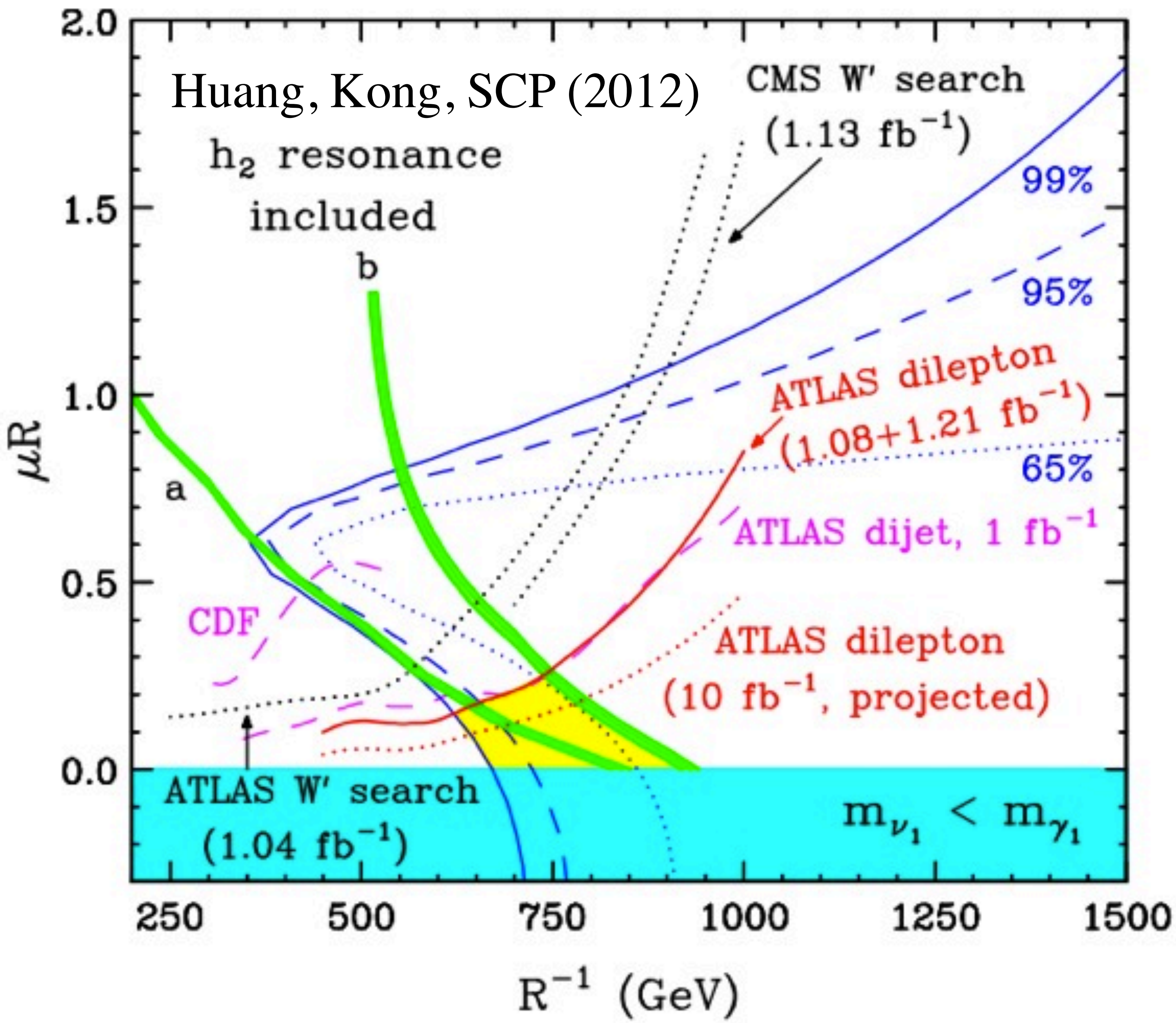
Figure 5. *Bounds on KK resonances in dijet (jj in (a)), dilepton ($\ell\ell$ in (b)), and lepton plus missing momentum ($\ell\nu$ in (c)) channels. Curves with dots represent the 95% C.L. upper limit on signal cross sections.*

The 1st Official LHC Bound on Split-UED by CMS

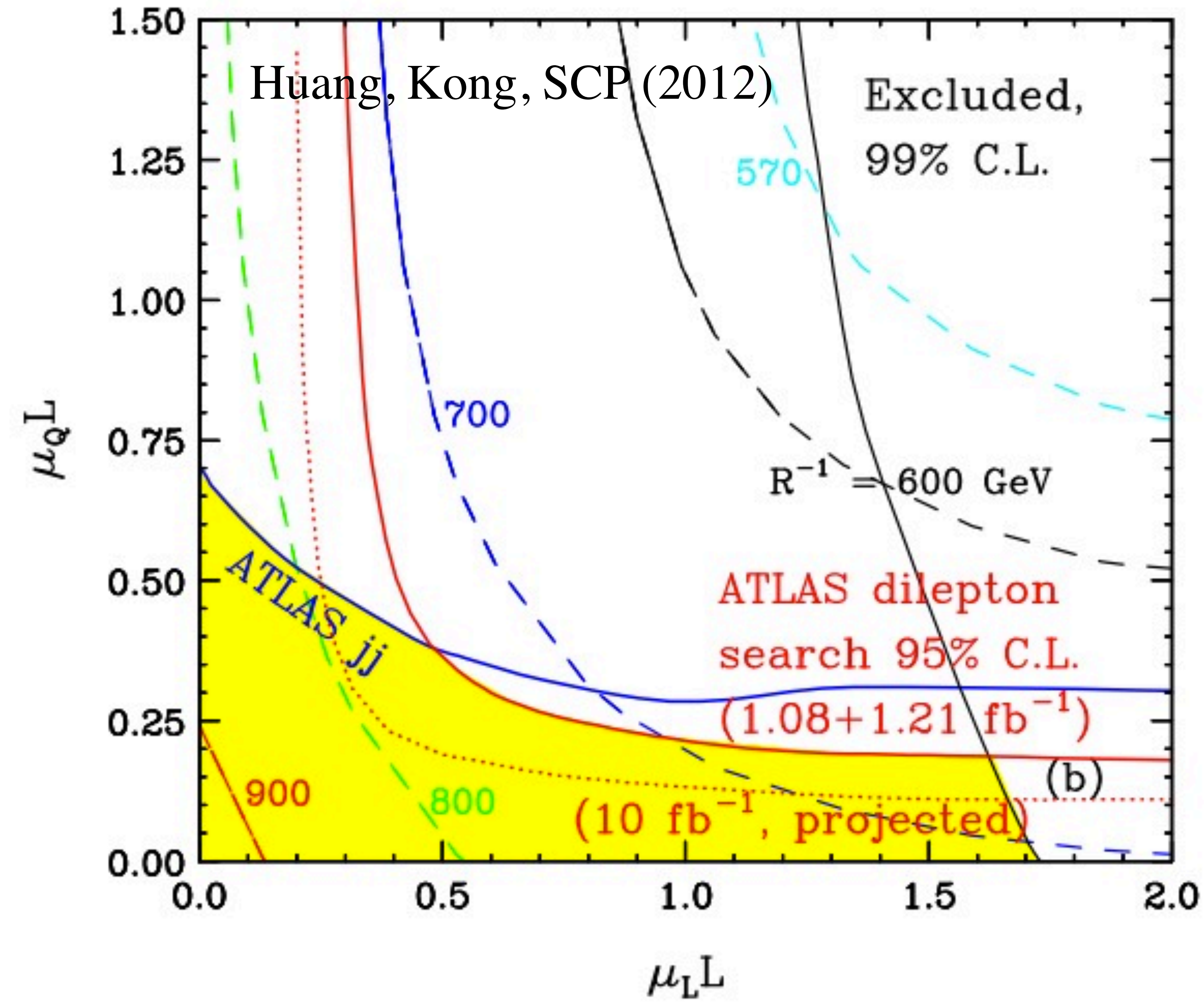




FOR UNIVERSAL MASS



FOR NON-UNIVERSAL MASSES



** Contours for $\Omega h^2 = 0.1123$

INCLUDING BLKTS?

See T. Flacke's talk on Friday!

SUMMARY

- In symmetric extra dimension, the LKP is a good DM candidate thanks to KK-parity.
- UED, an effective description of more generic geometry, e.g. RS, provides a useful framework to study KKDM.
- 1/R~TeV, M's (and r's) provide rich phenomenology
- DM+LHC7&LHC8+EWPT already started to probe a part of parameter space in mUED and its generalization.
- LHC 14 and future DM searches(Direct/Indirect) will give us more definite answers for KKDM.