

SI2013 19th Aug 2013, @ Jirisan KOREA

Constraints on Universal Extra Dimensions(UEDs) from Higgs boson search

PRD.88 (2013) 035007



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R.Watanabe (KEK , Japan)

Our interest

Q, Are 1TeV UEDs gone ?

Our interest

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A, Yes!
LHC killed them.

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A, Yes!
LHC killed them.

I'll show this
by inexpensive way.



Contents

1. Virtue of the UEDs.

2. “Kaluza-Klein(KK) scale analysis”.

3. Bounds from...

S,T parametes → loose...

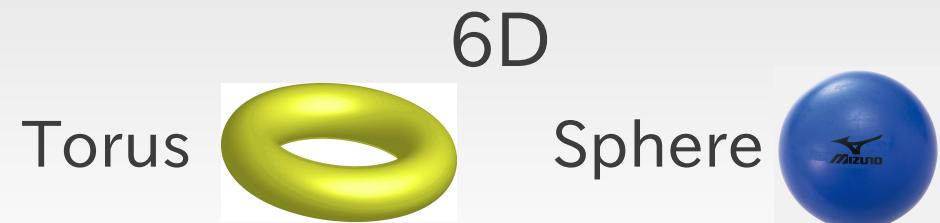
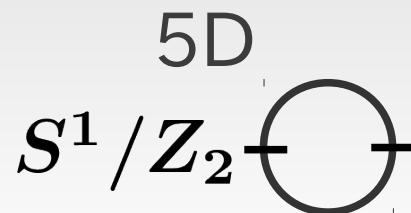
Higgs decay @ LHC → dying...?

RGE → danger

1. Virtue of the UEDs

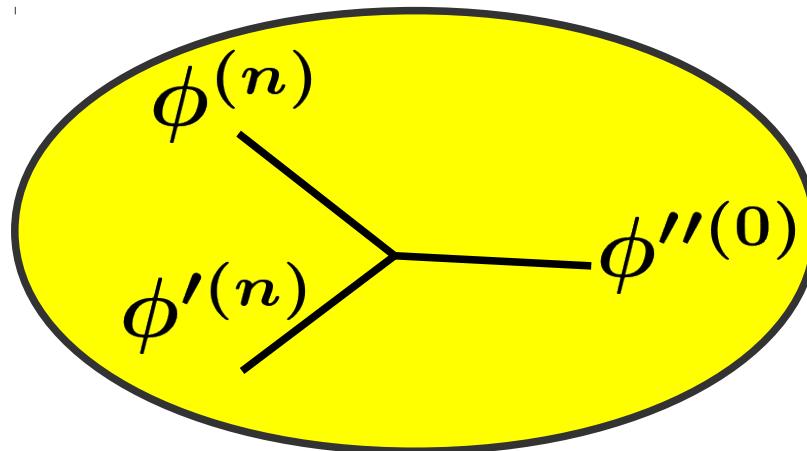
- Property of UEDs (5D&6D)

Introduce compactified extra spacial dimension(s)
No other assumptions



- In 4D effective lagrangian

SM with KK tower $\mathcal{L} = \frac{\mathcal{L}^{(0)}_{\text{SM}}}{\text{SM}} + \sum_{n=1}^{\infty} \mathcal{L}^{(n)} (n^2 M_{KK}^2)$



n is conserved = KK parity
→ Lightest KK Particle(LKP)
is stable

Dark Matter candidate

2.The “KK scale” analysis

How can we catch the vestige of KKs?

Direct search

DM abundance

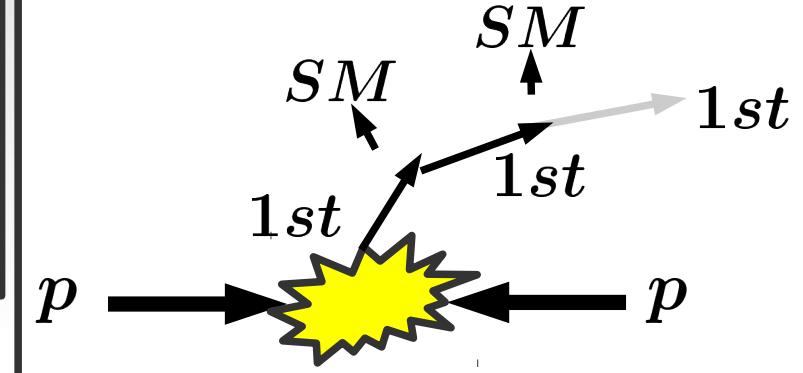
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Direct search

LHC Ex-dim search

- Z' , W' search
- $g_3^{(1)}$ search



DM abundance

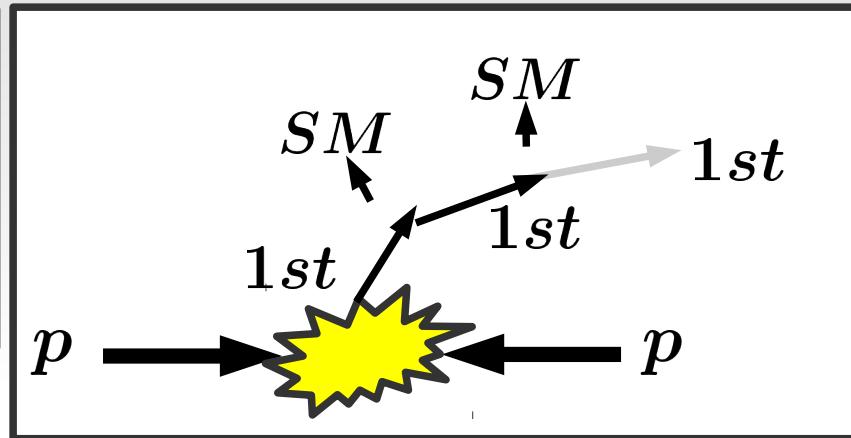
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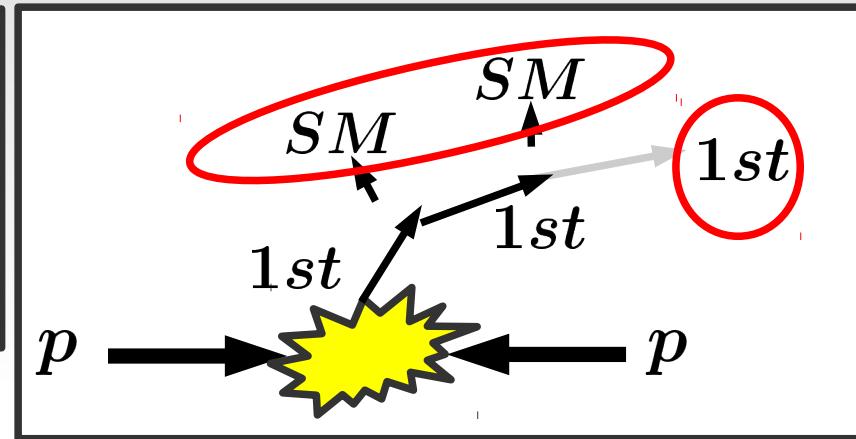
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Direct search

- LHC Ex-dim search
 - Z' , W' search
 - $g_3^{(1)}$ search

KK parity

DM abundance



Difficult...

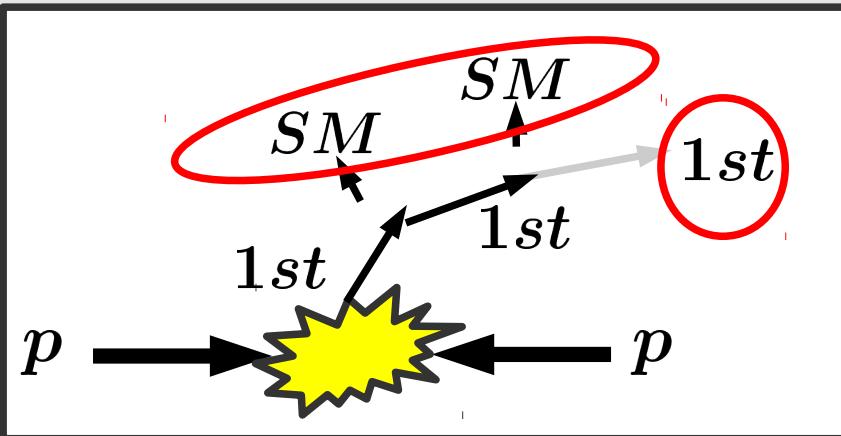
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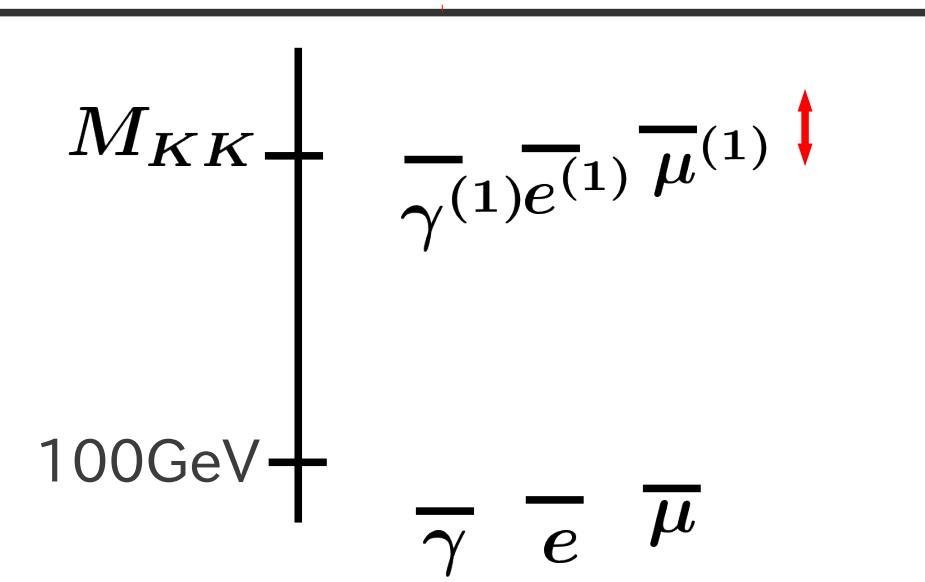
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DM abundance

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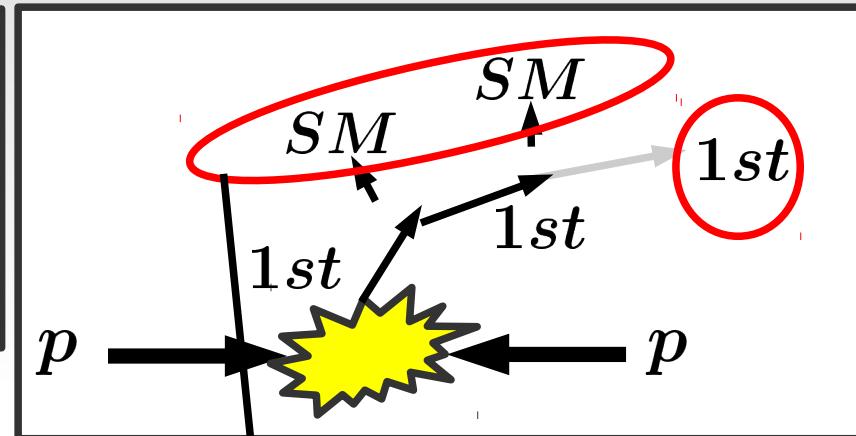
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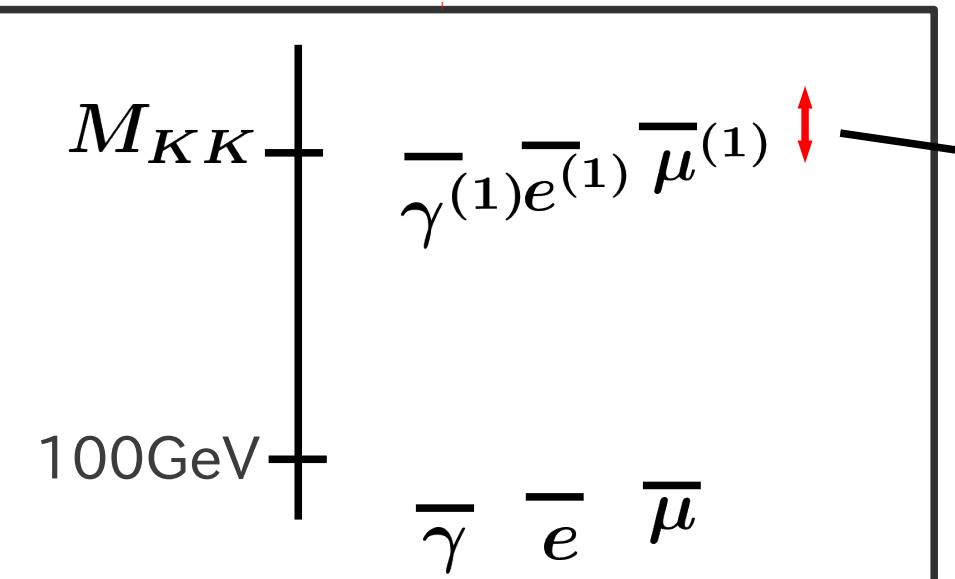
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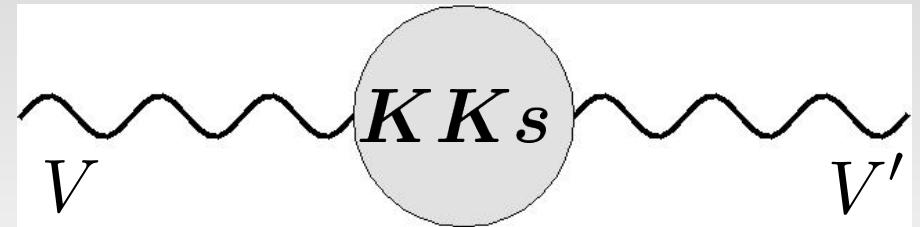


Depend on small mass splitting
=Strongly depend on the details of the models...

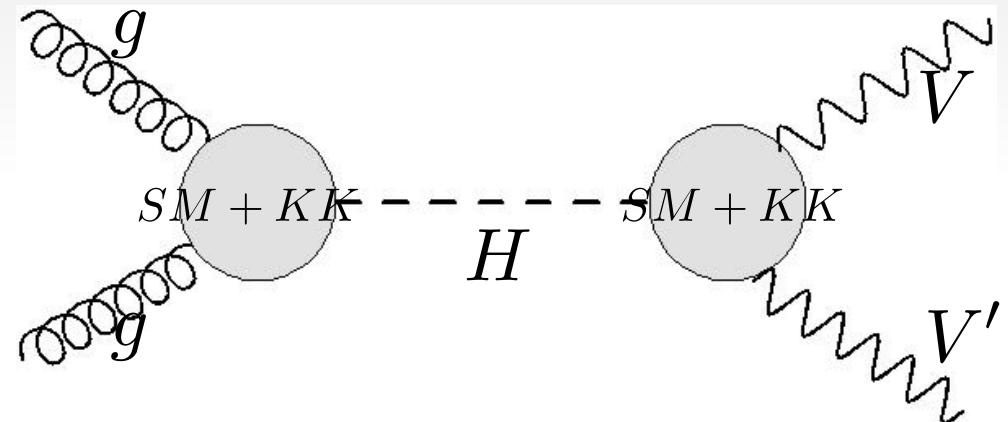
2.The “KK scale” analysis

We focus on **KK loops**

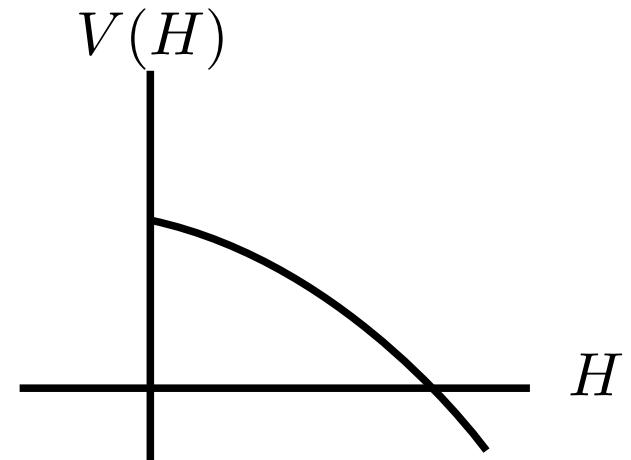
- Peskin-Takeuchi
S,T parameters



- Higgs signals
@ the LHC

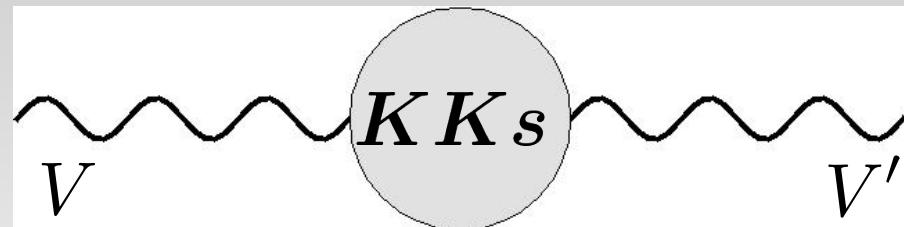


- 1-loop RGE
& vacuum stability



3. Bounds on M_{KK}

- Peskin Takeuchi S,T parameters



KK top

S&T : large enhancement

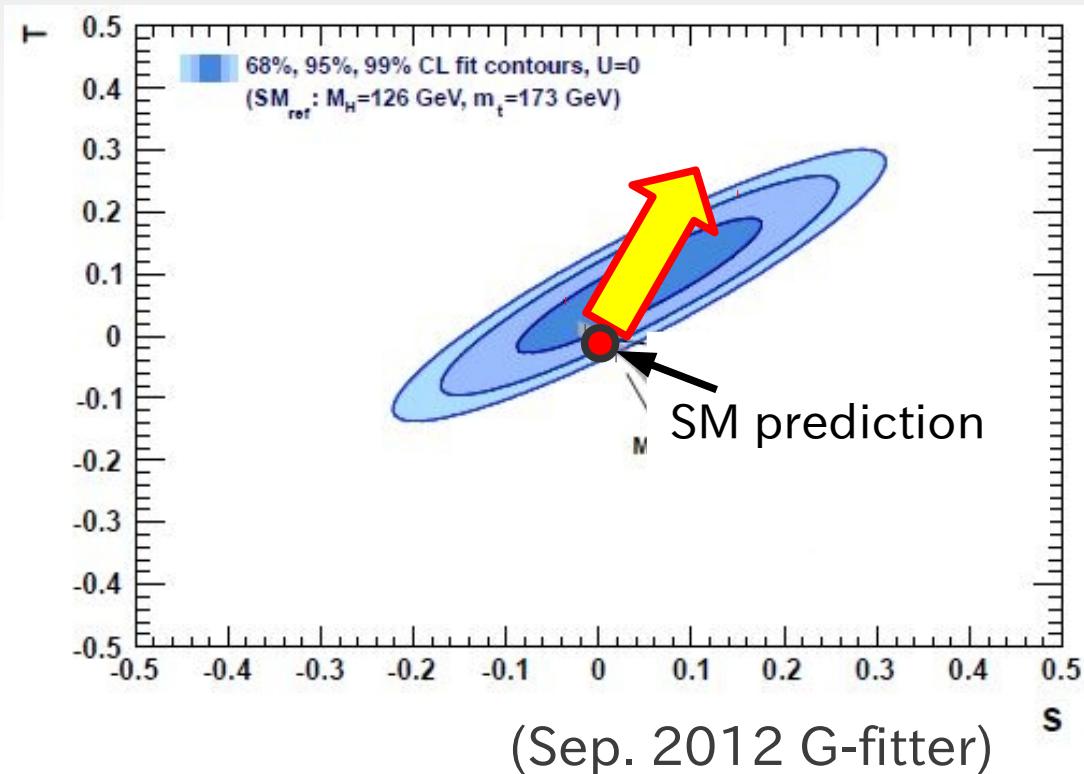
KK bosons

S&T : small suppression

Light generation

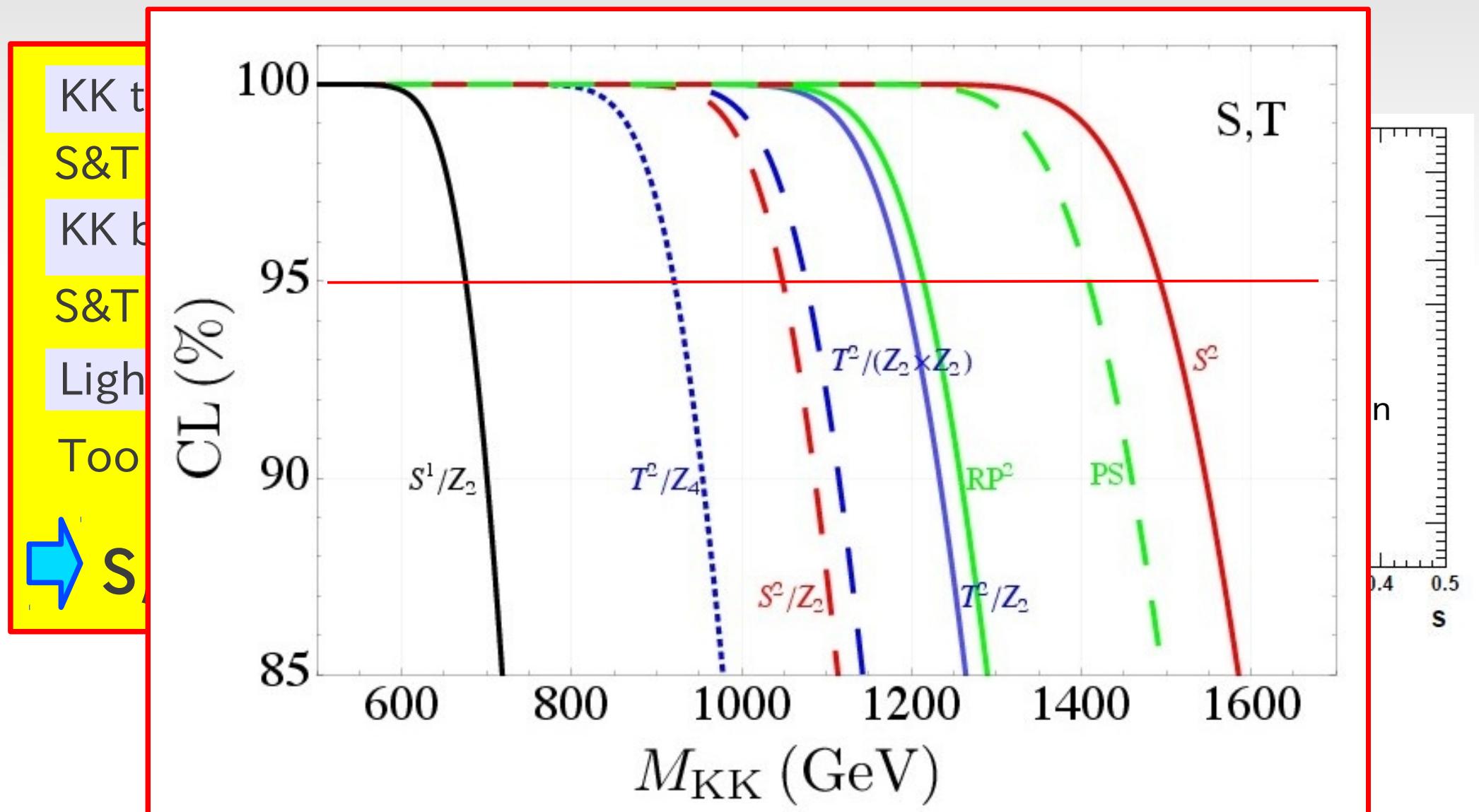
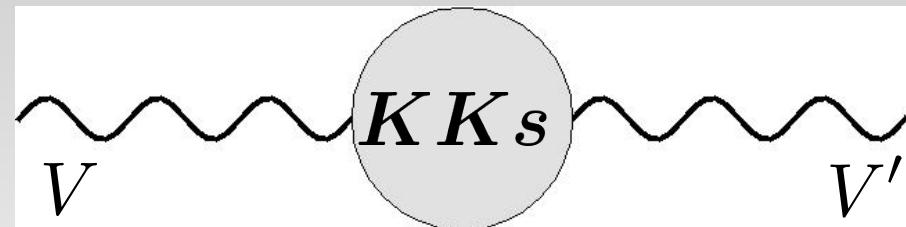
Too small yukawa
→ neglected

 **S,T are enhanced**



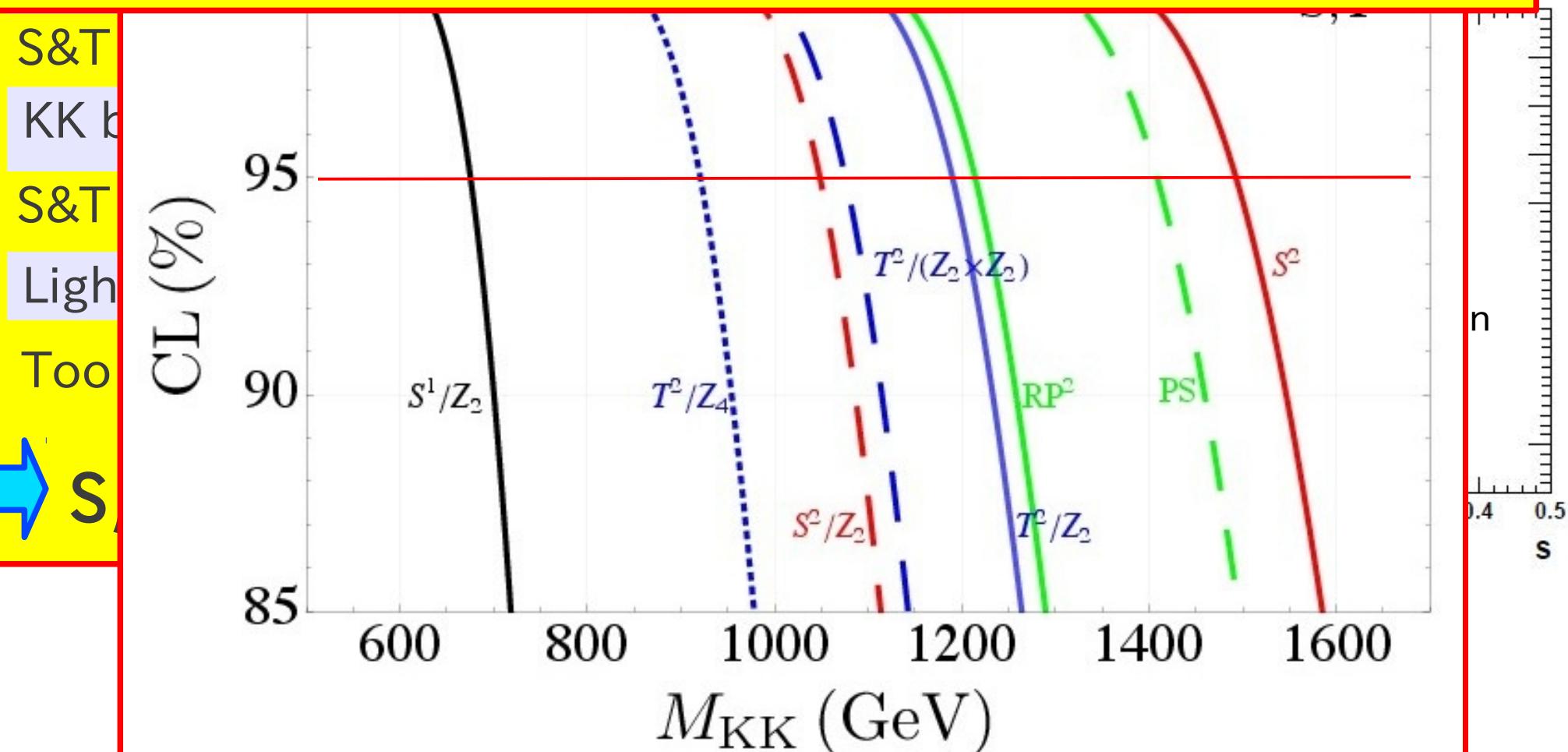
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- Peskin Takeuchi S,T parameters



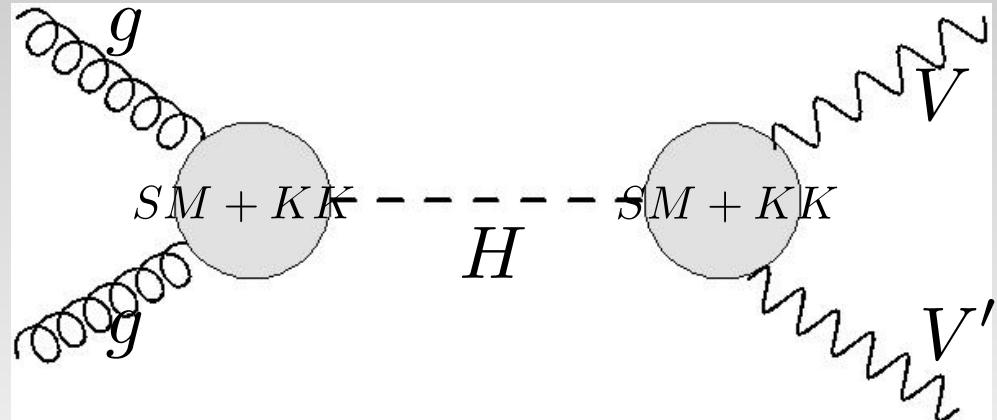
3. Bounds on M_{KK}

mUED : $M_{KK} > 670$ GeV
6D UED : $M_{KK} > 950-1500$ GeV

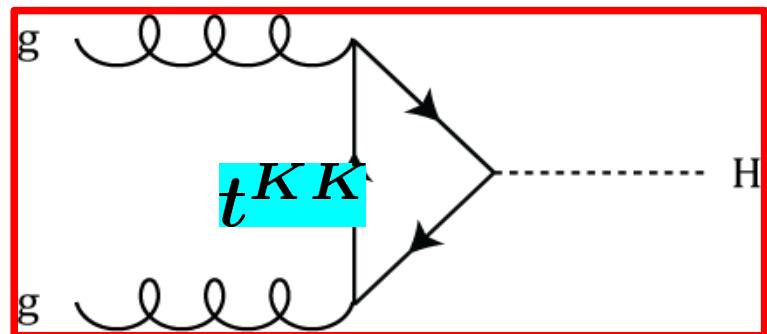


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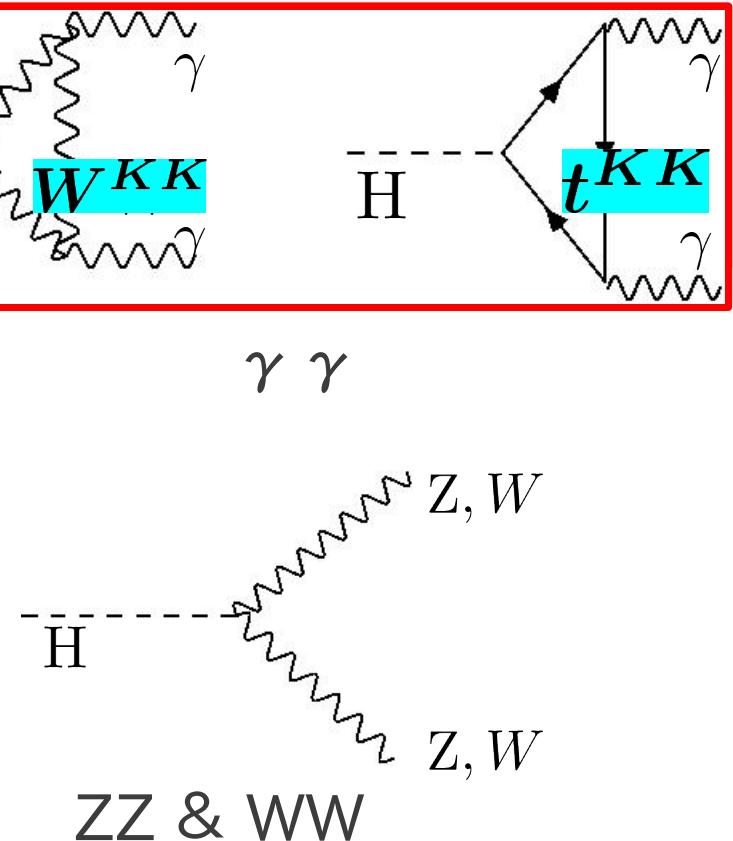
- Higgs signals @ the LHC



Higgs production is enhanced by KK top loops

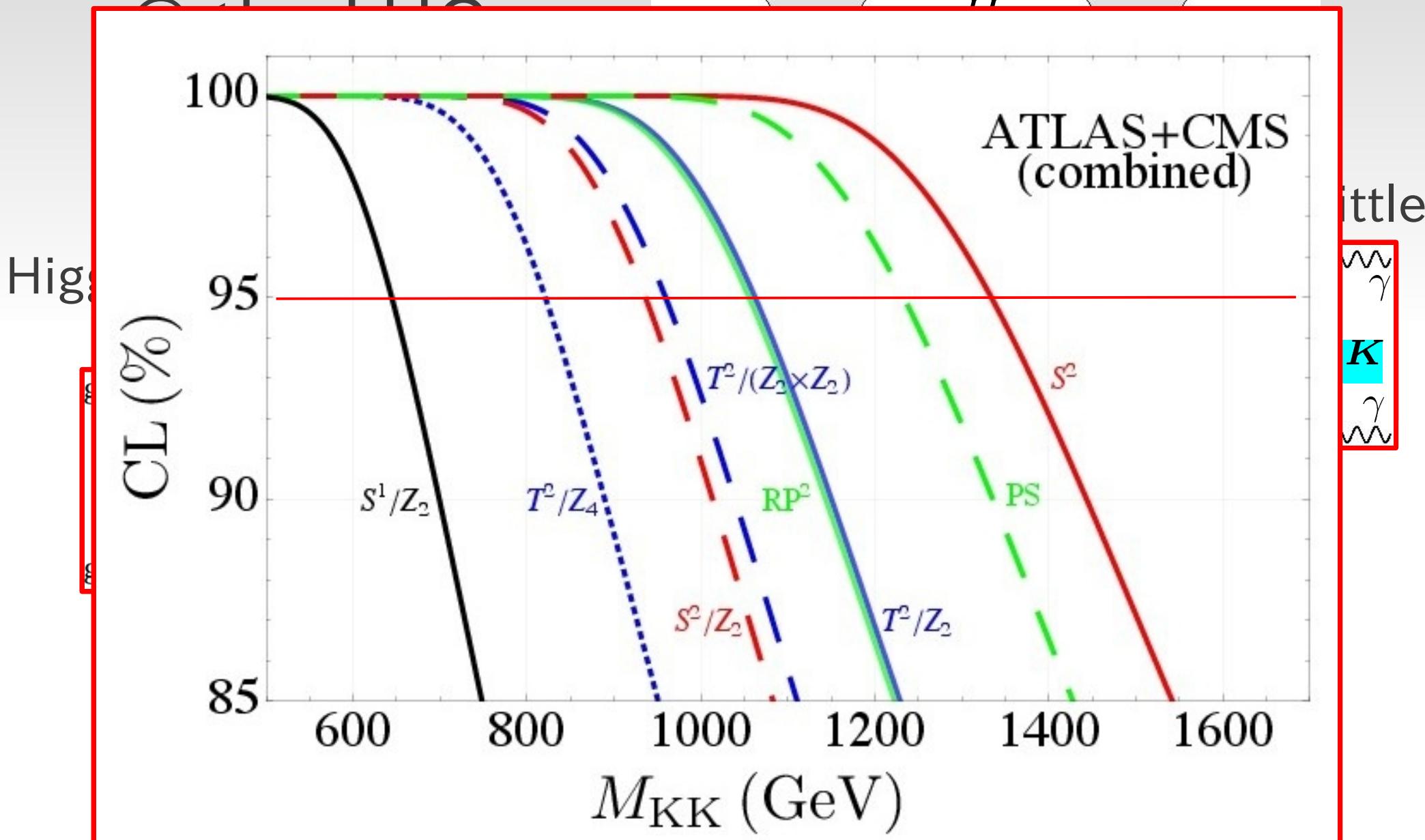
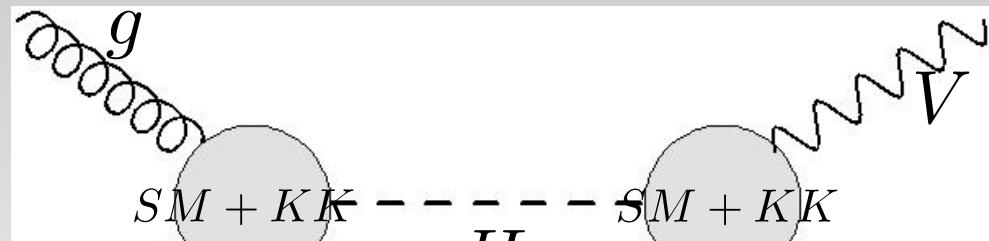


$\gamma\gamma$ decay suppressed a little



3. Bounds on M_{KK}

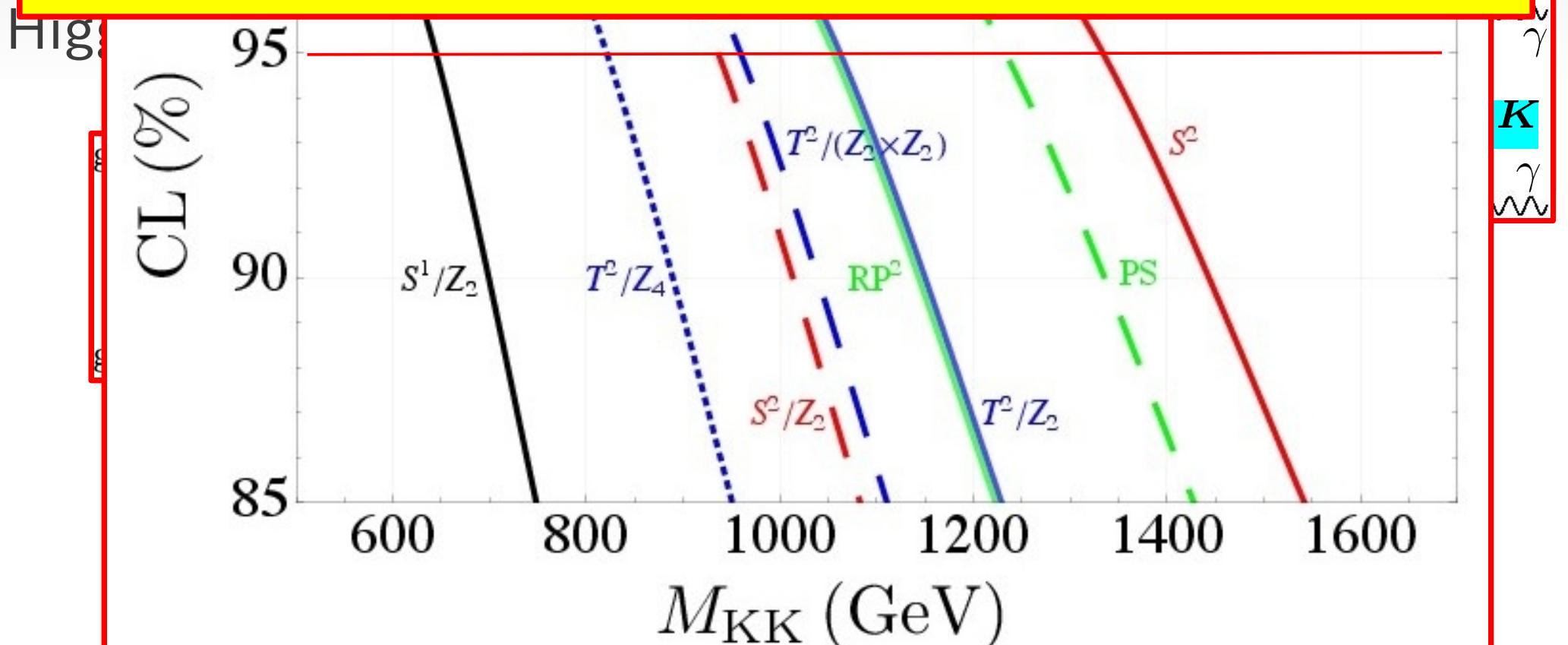
- Higgs signals



3. Bounds on M_{KK}

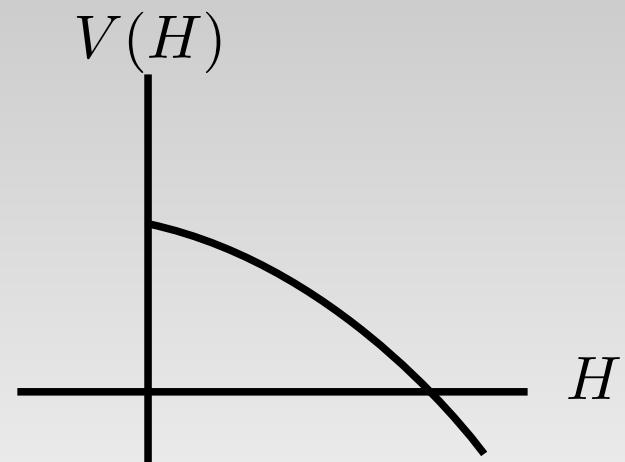
mUED : $M_{KK} > 650$ GeV
6D UED : $M_{KK} > 850-1390$ GeV

But the Higgs signals are closing to the SM prediction...



3.Bounds on M_{KK}

- 1-loop RGE
& vacuum stability



The scale that
Higgs quartic interaction $\lambda = 0$
 \rightarrow vacuum stability bound as
the upper bound on UV cutoff Λ

1-loop RGE in UEDs
 \rightarrow Rapidly grow by KK loops

3. Bounds on M_{KK}

	model	Vacuum stability bound
Sphere based 6D models	PS	$1.9 M_{KK}$
	S^2/Z_2	$2.3 M_{KK}$
	S^2	$3.2 M_{KK}$
Torus based 6D models	RP^2	$2.3 M_{KK}$
	T^2/Z_2	$2.5 M_{KK}$
	T^2/Z_4	$3.4 M_{KK}$
5D model	$T^2/Z_2 \times Z'_2$	$3.2 M_{KK}$
	mUED	$5.0 M_{KK}$

3. Bounds on M_{KK}

Spherical
6D



Torus based
6D models

5D model



model	Vacuum stability bound
PS	$1.9 M_{KK}$
ζ^2/z	$2.2 M_{KK}$

If we assume UV cutoff $\Lambda \geq 10\text{TeV}$
 $M_{KK} > 2\text{-}5\text{TeV}(!)$

T^2		$2.5 M_{KK}$
		$3.4 M_{KK}$
		$3.2 M_{KK}$
		$5.0 M_{KK}$

Summary

- UEDs are good
very simple extension of the SM
LKP as DM candidate
- We focus on “KK loop contribution”
Direct detection of KKs is difficult @ LHC
DM abundance depend on the details
- 1TeV UEDs are gone
S,T parameters → mUED : $M_{KK} > 670$ GeV
6D UED : $M_{KK} > 950-1500$ GeV
Higgs signals @ LHC → mUED : $M_{KK} > 650$ GeV
6D UED : $M_{KK} > 850-1390$ GeV
it will be more tight...
- RGE & vacuum stability → $M_{KK} > 2-5$ TeV
for $\Lambda \sim 10$ TeV

Thank you for pay your attention!

If you want to know the details of analysis · ·
see PRD.88 (2013) 035007
“Universal Extra Dimensions after Higgs discovery”

If you want to know the details of the models · ·
see PRD.85 (2012) 035026
“Heavy Higgs boson at the Tevatron
and the LHC in universal extra dimension models”

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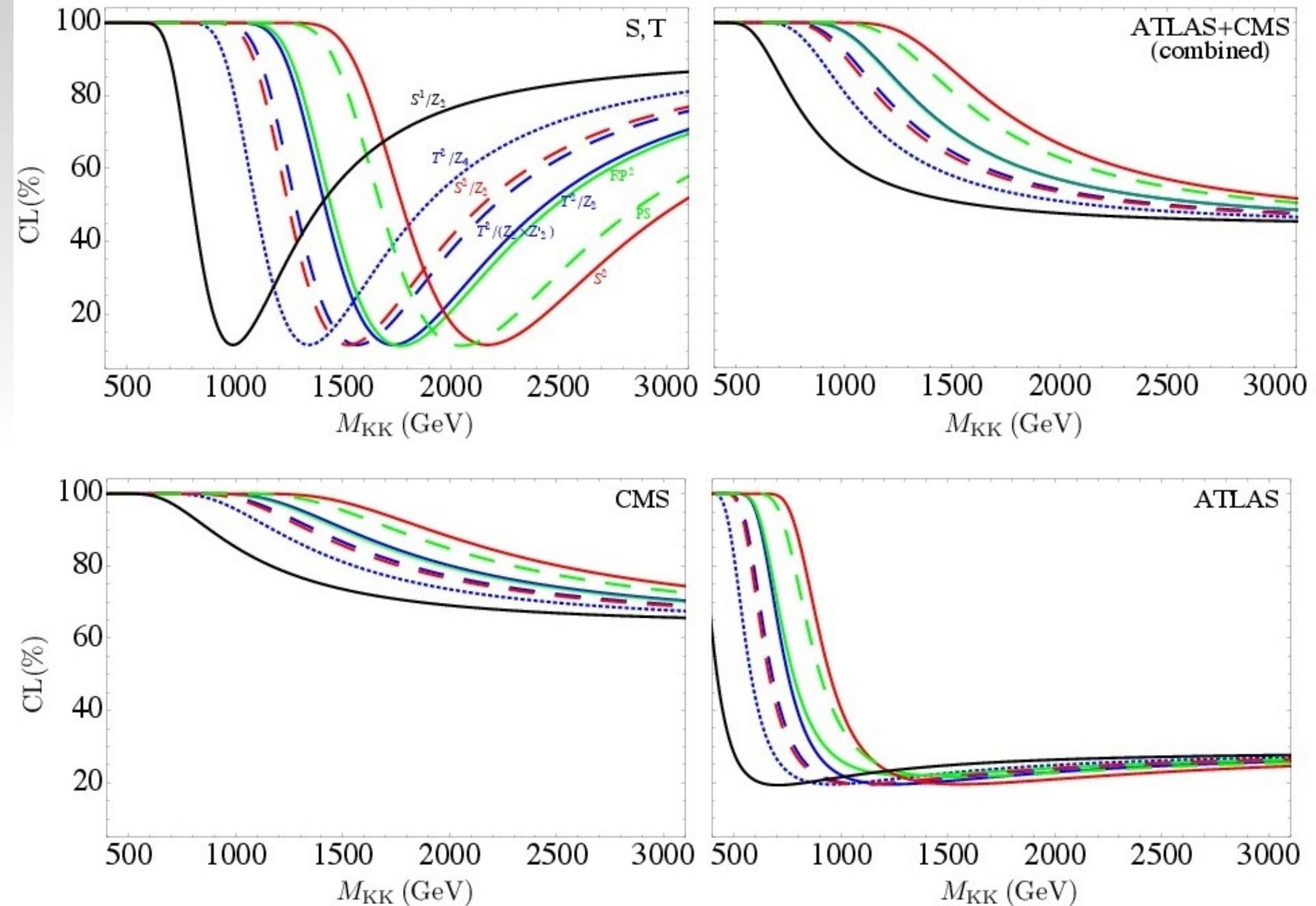
1. Virtue of UEDs

Mass eigenvalue

$$\left(m_{KK}^{(n)}\right)^2 \sim m_{SM}^2 + n^2 M_{KK}^2 + \delta(m^{(n)})^2$$

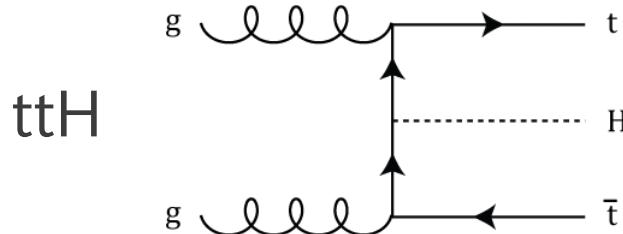
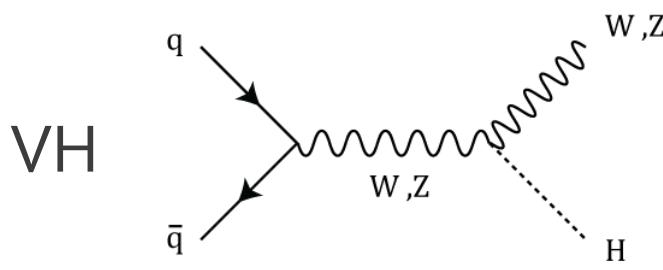
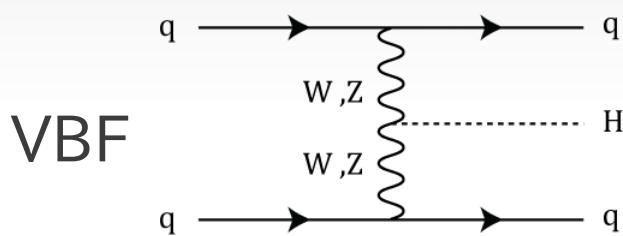
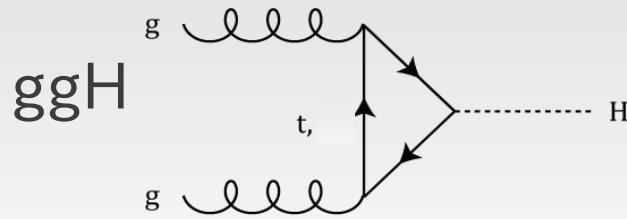
This correction depend on the philosophy

- Low energy boundary condition in RGE?
- UV boundary condition in RGE?
-
-
-

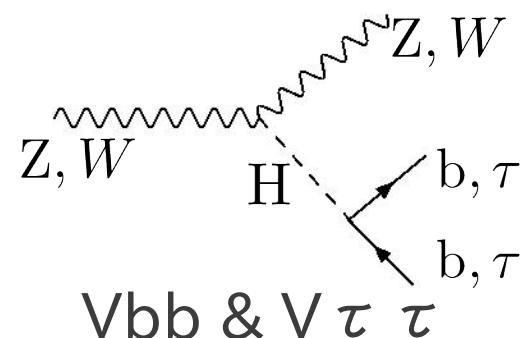
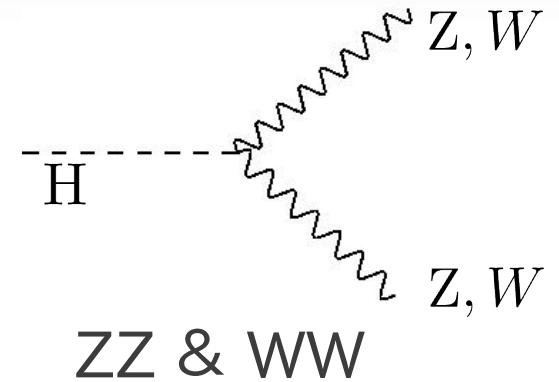
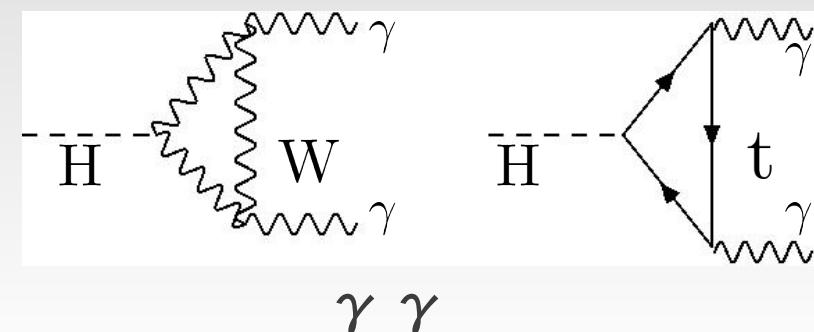


Higgs production and decay channels @LHC

Higgs production channel @ HLC



Higgs decay channel

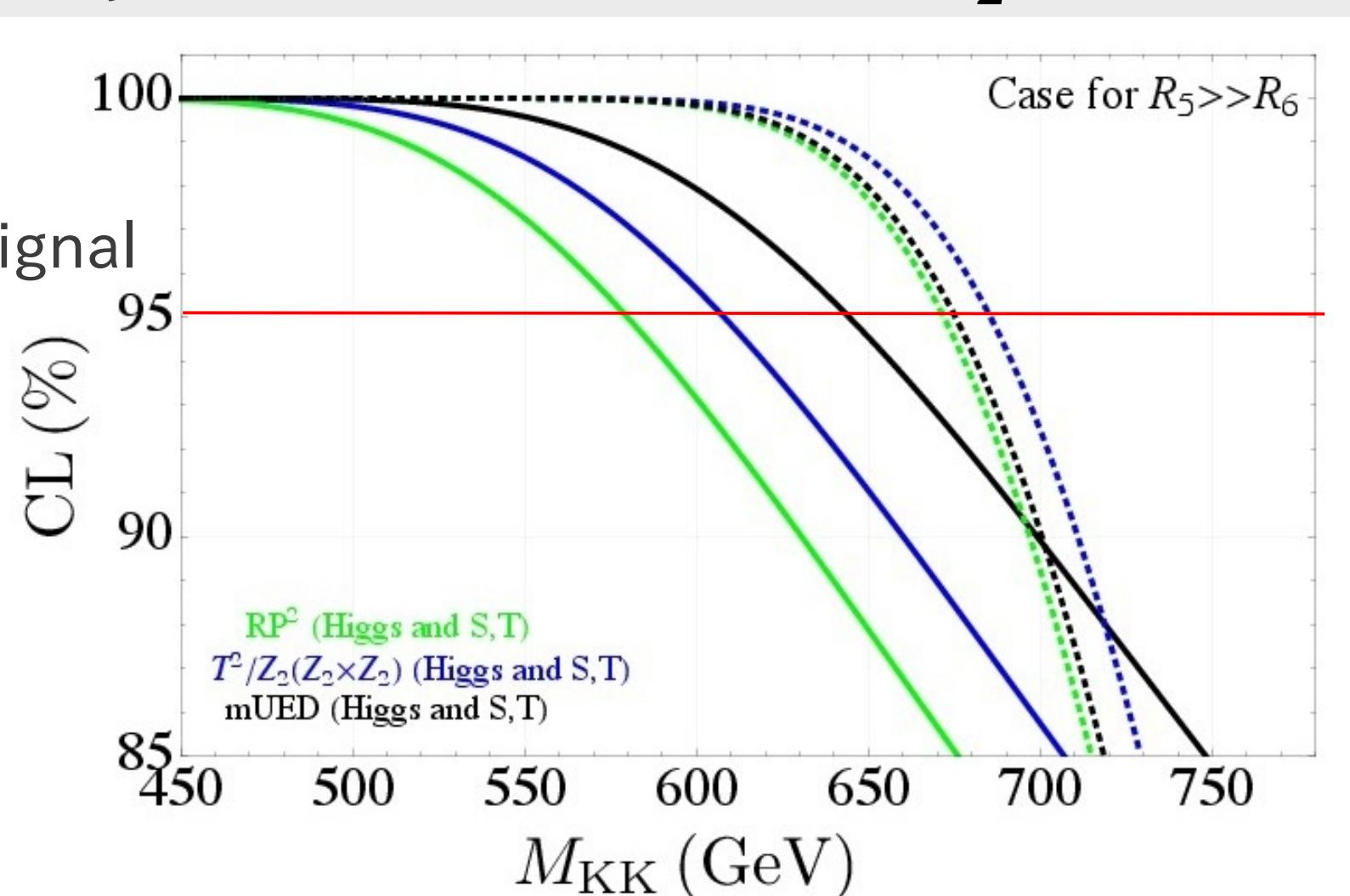


We assume $R_5 = R_6$ above

The case $R_5 \gg R_6$?

We can analyze T^2/Z_2 $T^2/Z_2 \times Z'_2$ $RP^{2'}$

Dashed :S,T
Solid :Higgs signal

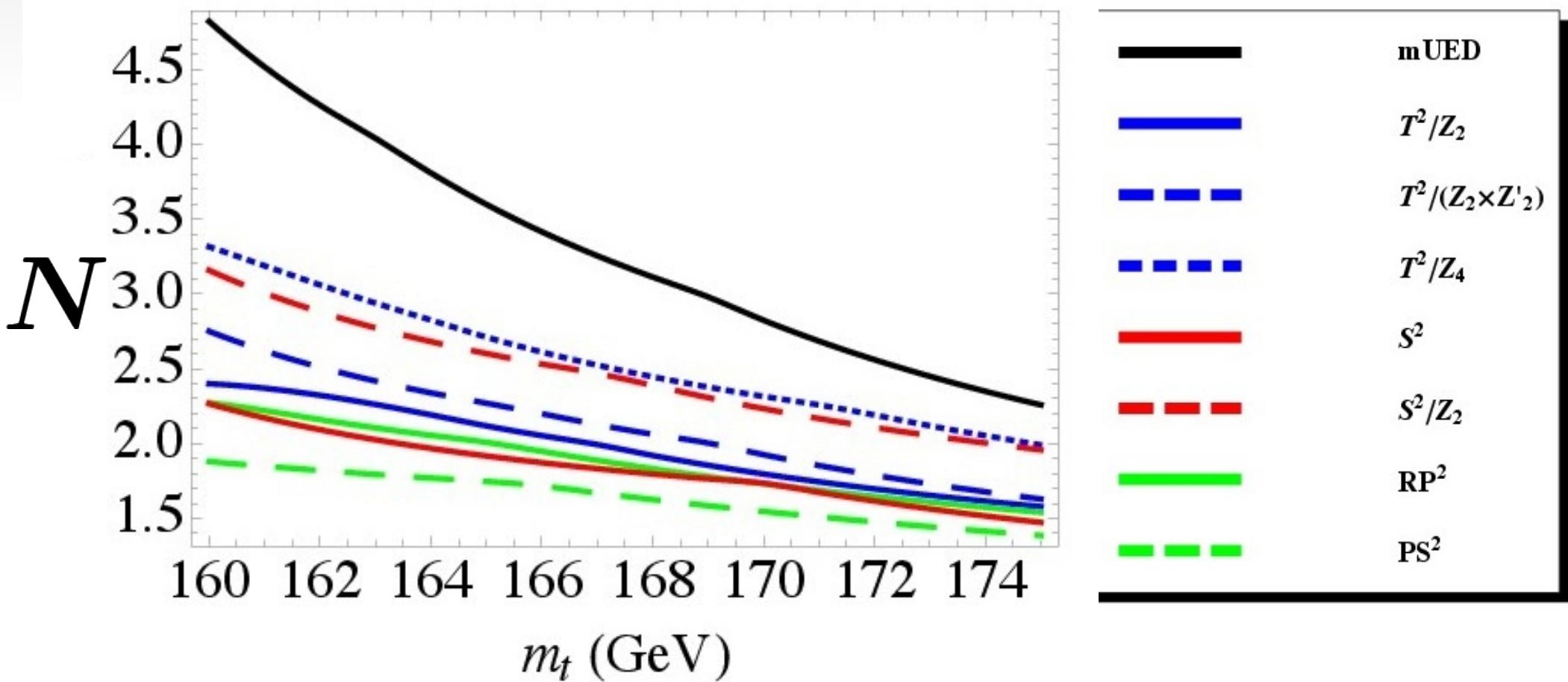


Top mass dependence of RGE

We choice $m_t^{\overline{MS}} = 160 \text{ GeV}$

RGE strongly depend on \overline{MS} top mass.

Top mass dependence of $N = \Lambda_{max}/M_{KK}$
($R_5 = R_6 = 1\text{TeV}$ case)



ここまで製作したお