Kaluza-Klein / Z′ Differentiation at the LHC and LC**

- Intro
- Scenario + Problem
- Analysis

→ LHC
→ LC
} → ID reaches (+ Comparisons)

- Conclusions

** KK gauge bosons NOT gravitons ....

T. Rizzo
7/03
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- KK excitations of the SM GB occur in many models w/ extra dimensions

e.g.,

- TeV^{-1}
- RS

} Universal, non-universal, brane terms, localized fermions, etc

Many possibilities.....

Simplest Case : GB in bulk w/ fermions localised at S^1/Z_2 fixed points, i.e., 5D

(no brane terms, no .....)

(i) "D=0" all fermions at y=0 FP

(ii) "D=πR" q's at one FP, ℓ's the other sep. is πR

- Very well studied case w/ Higgs on + off y=0 'brane'

$M_{KK}^{(1)} \gtrsim 4$ TeV (Rizzo+ wells)

from precision measurements

at the LHC ... $M_Z^{(1)} - M_\gamma^{(1)} \leq 1\,\text{GeV}$ so they appear as a single resonance ...

- If a $M \gtrsim 4$ TeV resonance were observed in Drell-Yan $[\ell^+\ell^- / \ell^\pm \not{E}_T]$ ... is it a $[Z'/W']$ or a KK state ??

- Recall, if $M^{(1)} \gtrsim 4$ TeV then $M^{(2)} \gtrsim 8$ TeV for S^1/Z_2 (w/ brane terms) ... this is beyond the LHC range (maybe even w/ the upgrade!)

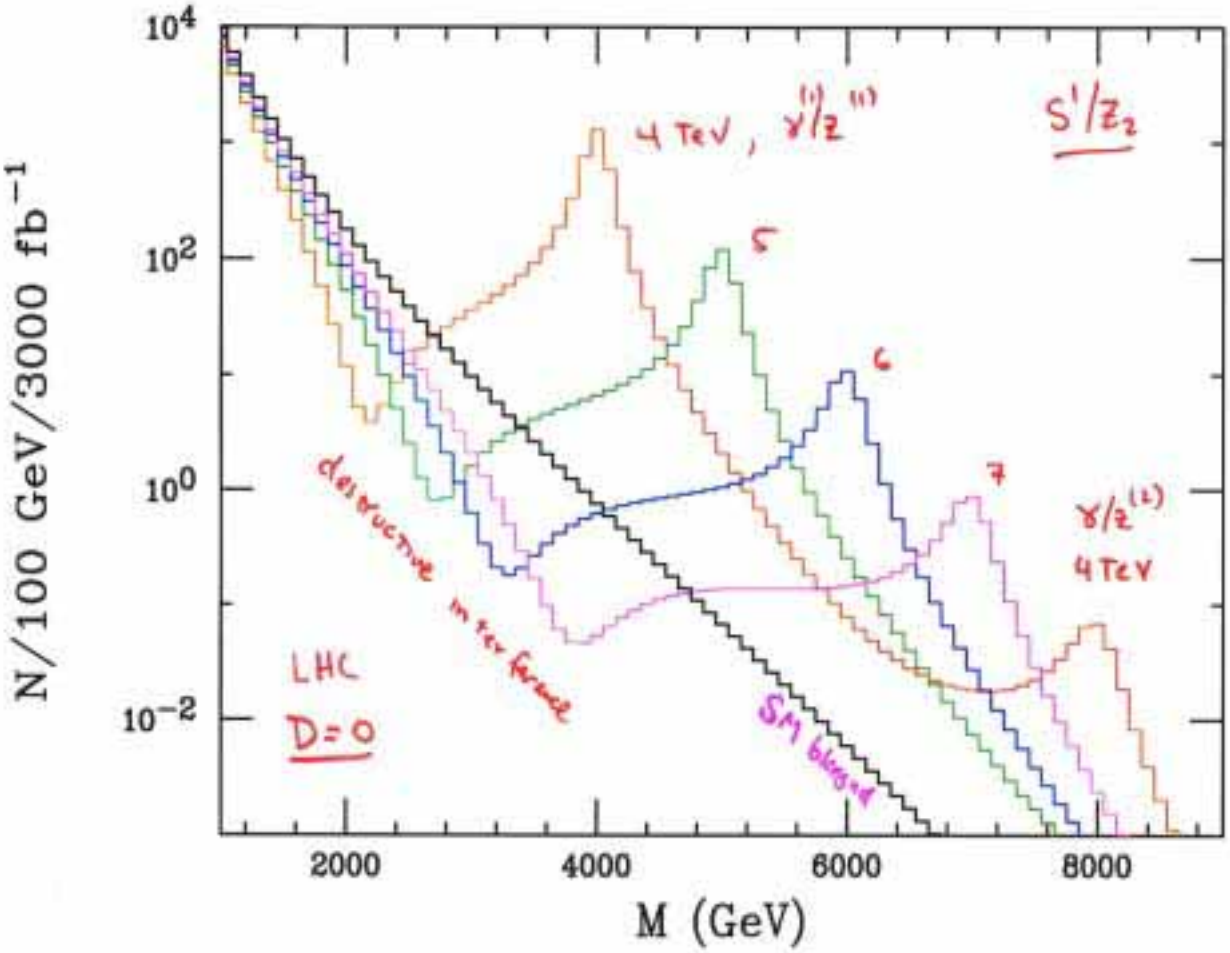
$\Rightarrow$ Only the first KK peak is visible ... no nice set of peaks to tell you ED's are there ....

{ recall: degenerate W'/Z' models exist since
  also: early 80's }

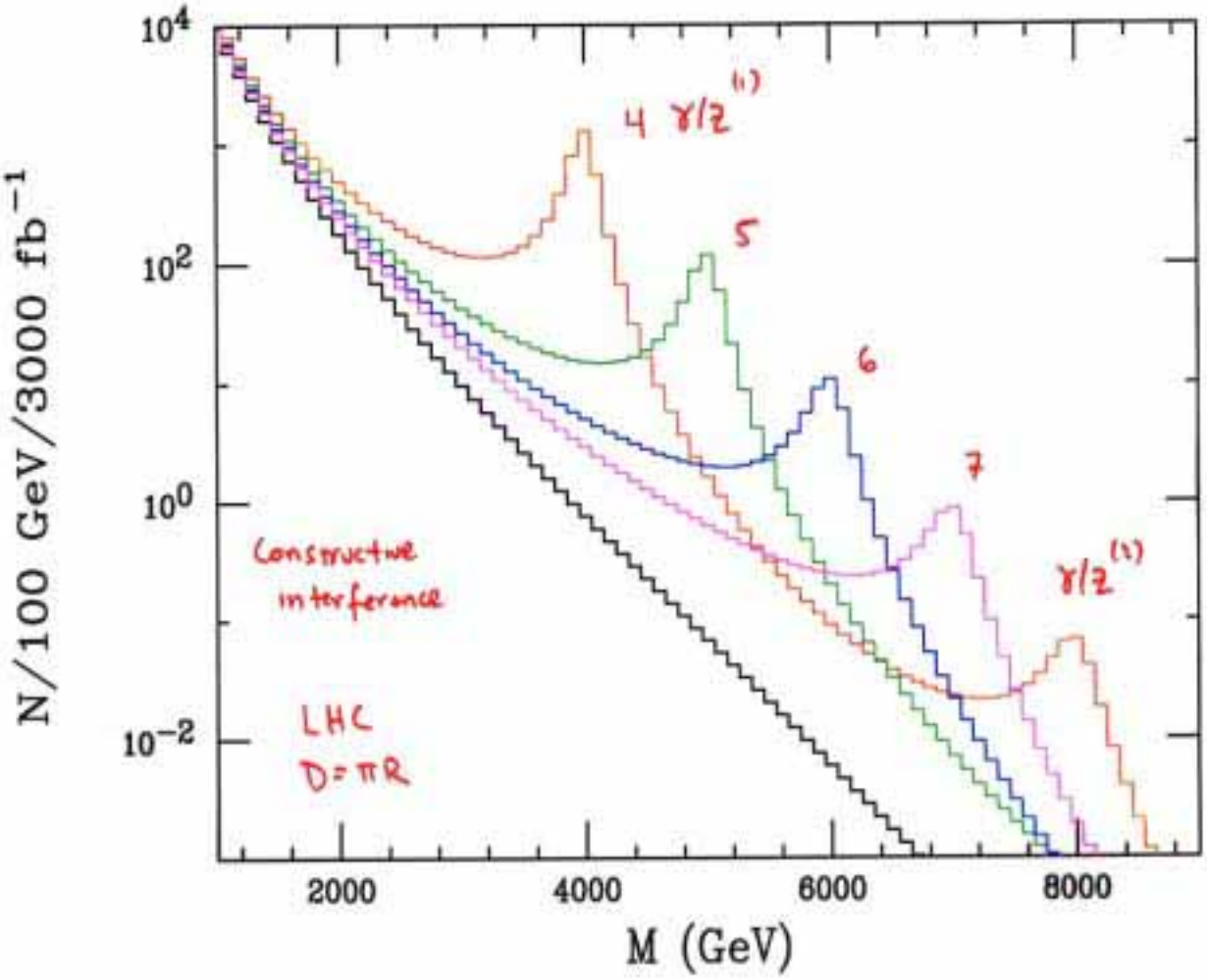
Is it a Z' or a KK ? $\rightarrow$ Take a look at the excitation structure .....

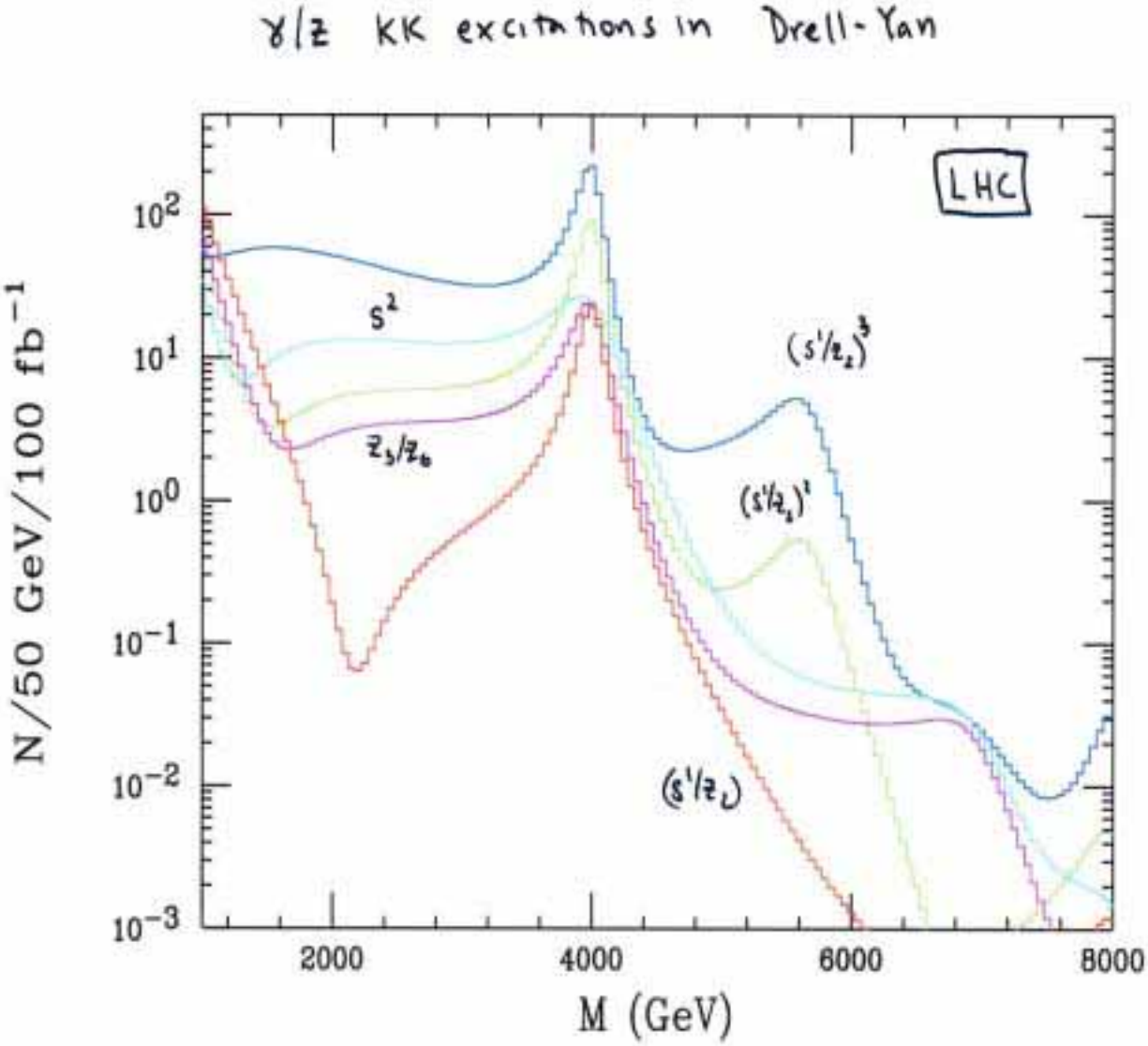
$pp \to \ell^+\ell^- + X$

flat, TeV^{-1}, no brane terms



$pp \to \ell^+\ell^- + X$ S^1/Z_2, flat, TeV^{-1}, no brane terms

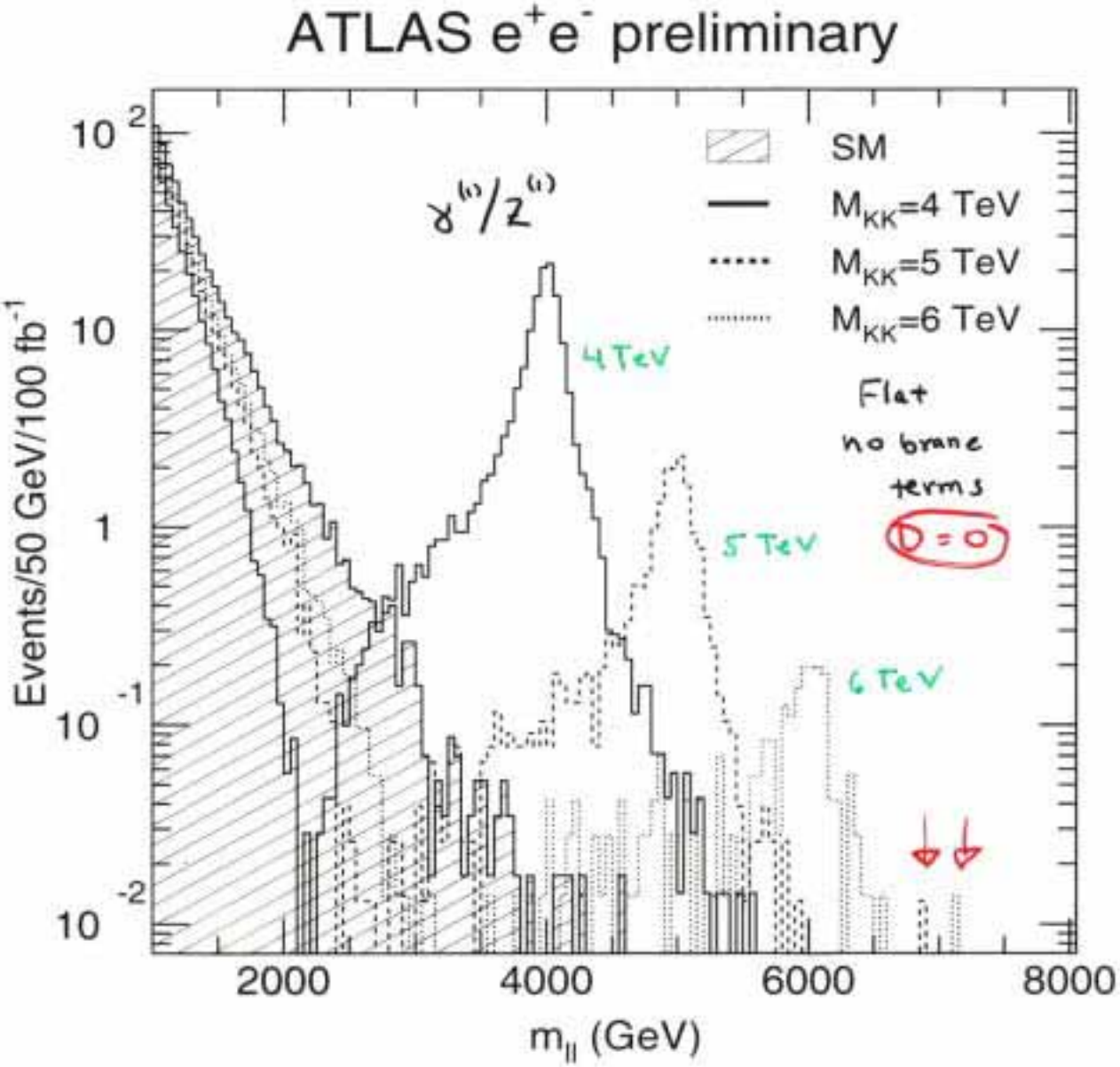



γ/Z KK excitations in Drell-Yan
LHC
N/50 GeV/100 fb^{-1}
M (GeV)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
2000
4000
6000
8000
S^2
Z_3/Z_6
$(S^1/Z_2)^3$
$(S^1/Z_2)^2$
(S^1/Z_2)

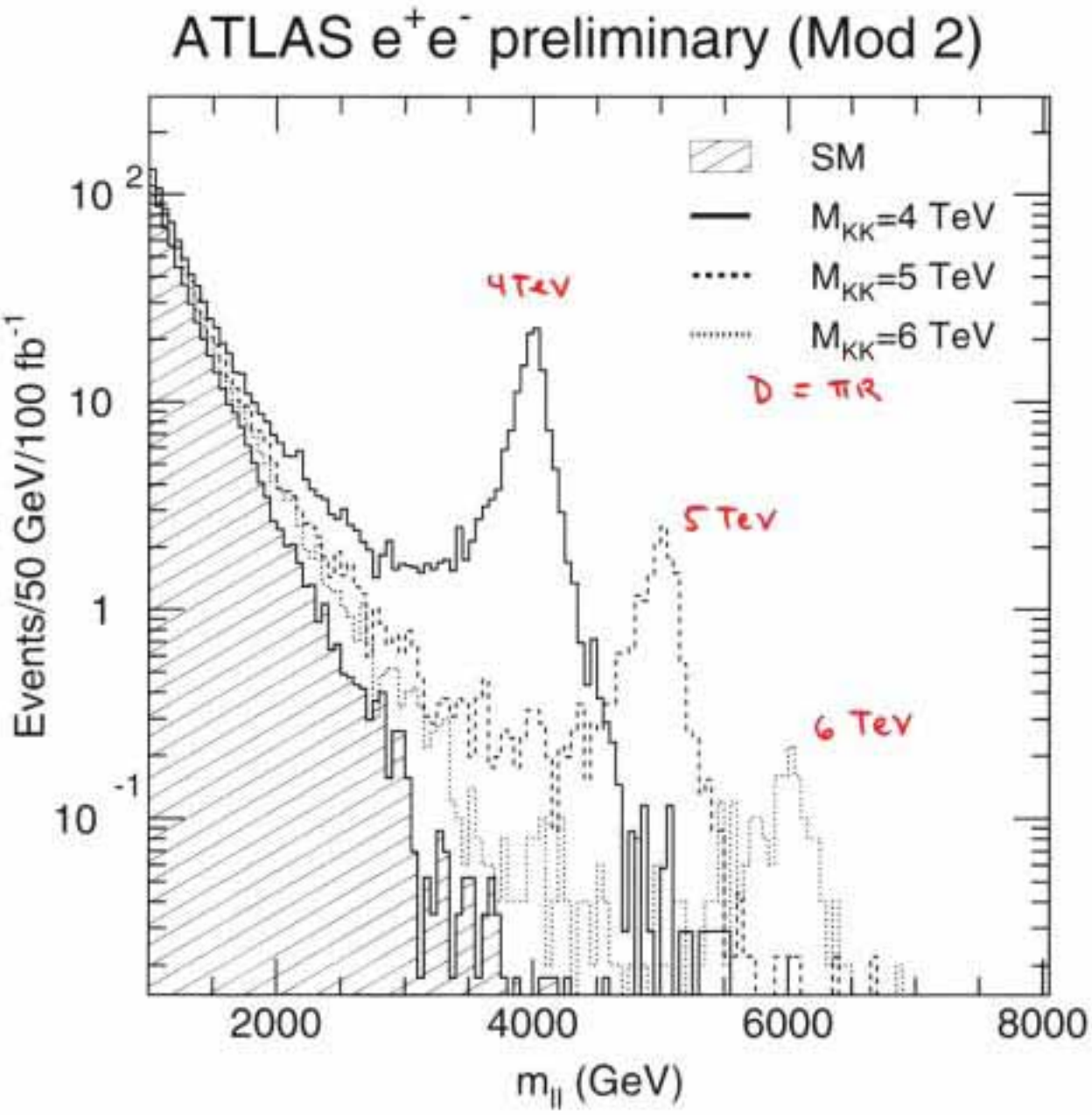
naive TeV^{-1}

Direct
Reach $\simeq$ 7 TeV

G. Azuelos +
G. Polesello
(Les Houches '01)
(ATLFAST)



Arduini + Polesello



Observables : Useful ones are limited due to resonance width sensitivity...

(Can't use anything which depends on what else the Z′ or KK decays into, e.g, susy) **

⇒⇒ $d\sigma/dM$ away from peak region

→ A_{FB}^{e} (low stat's except near peak + at quite low M_{ee})

* Here : use shape of $d\sigma/dM$ below + away from peak... { A_{FB}^{e} not used - in this analysis } ONLY

• Try to fit KK w/ Z′ hypothesis ....

(i) assume flavor indep. (as is KK)

(ii) assume $[G_{Z'}, SM] = 0$

∴ 5 parameter fit (not 6)

(L_L, Q_L, u_R, d_R, e_R)

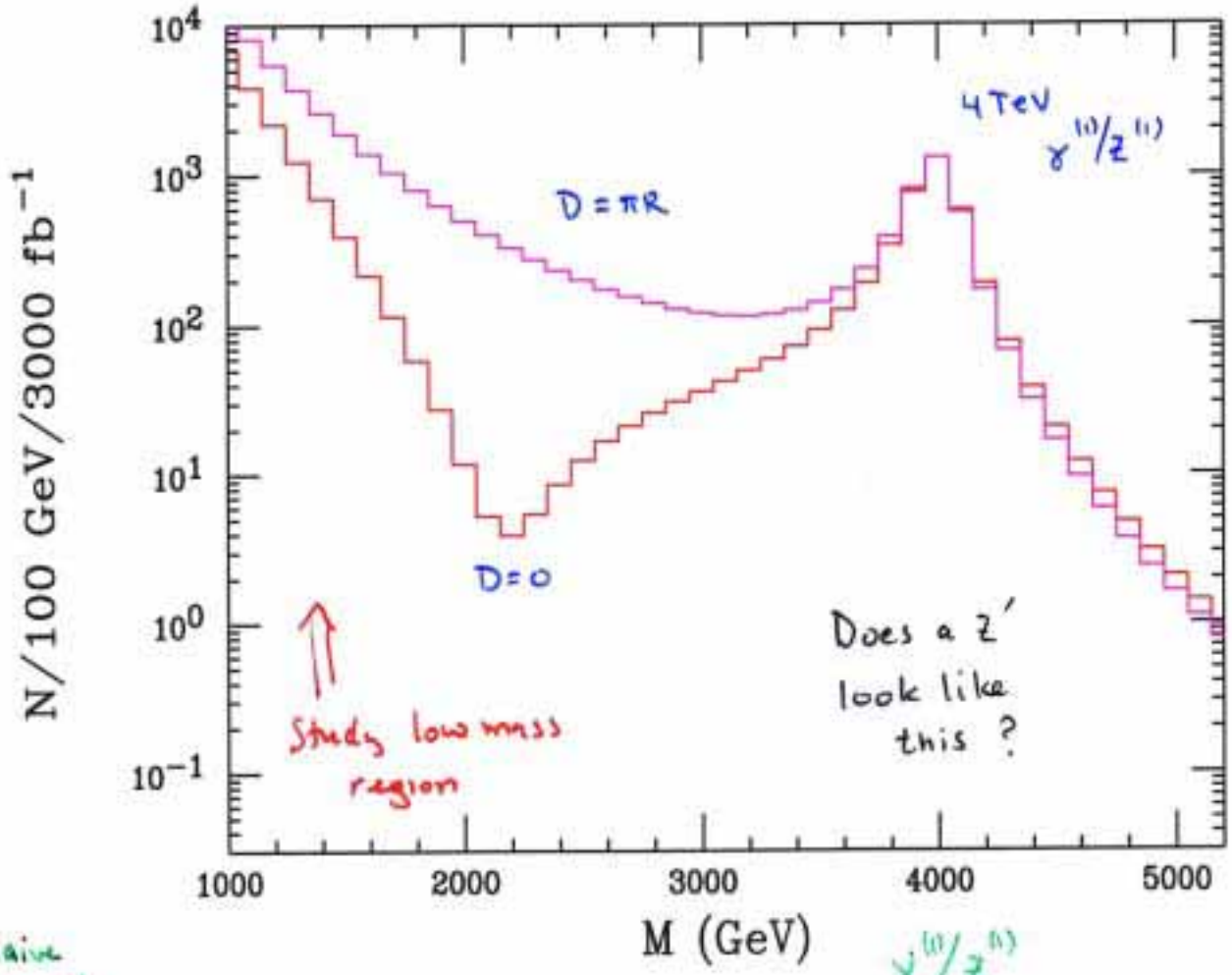
$\geq 10^{10}$ combinations scanned

** Dittmar, Nicollerat + Djouadi (hep-ph/0307020)

$pp \to \ell^+\ell^- + X$

S^1/Z_2

close up



naive

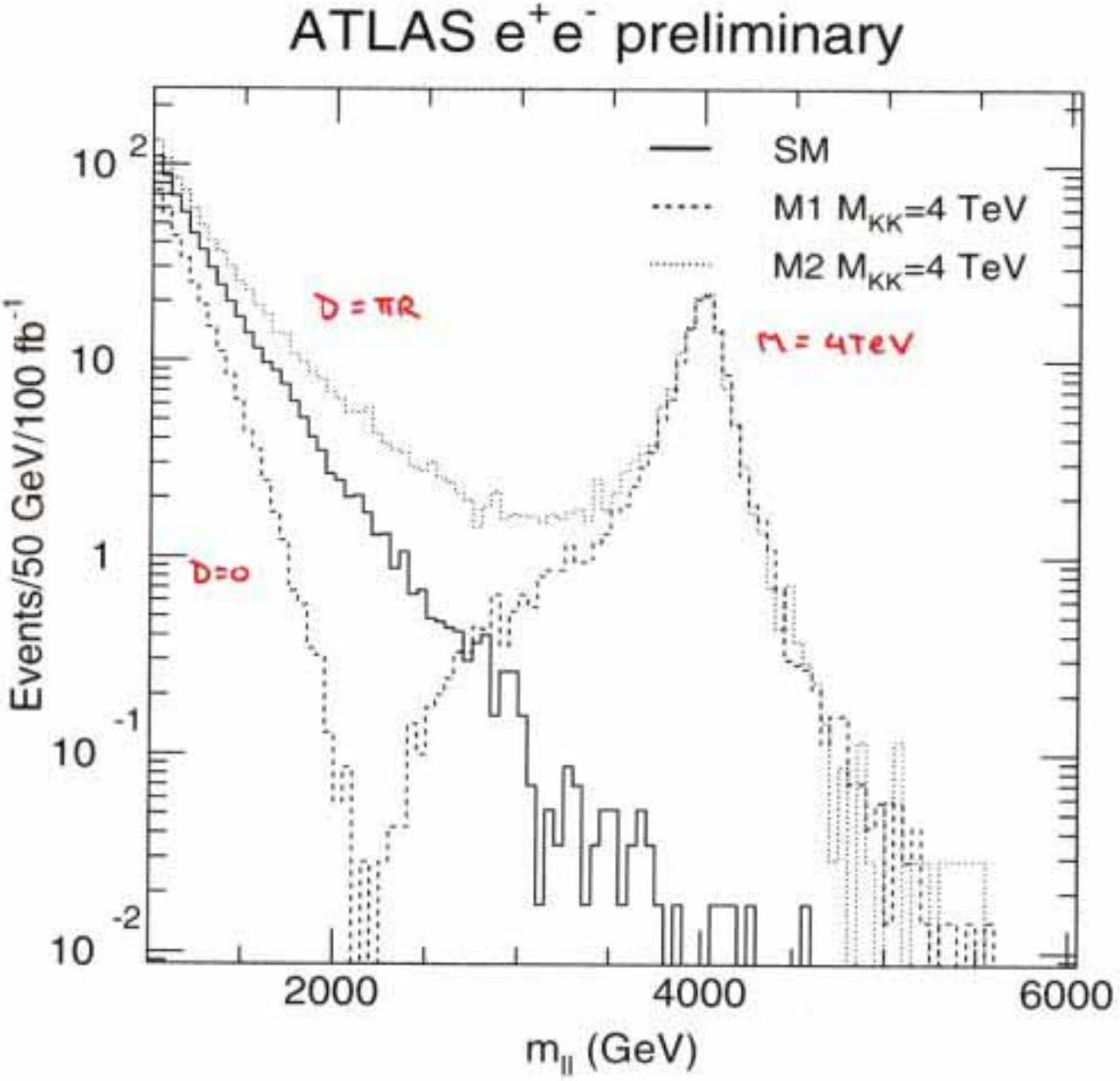
TeV^{-1}

no brane terms

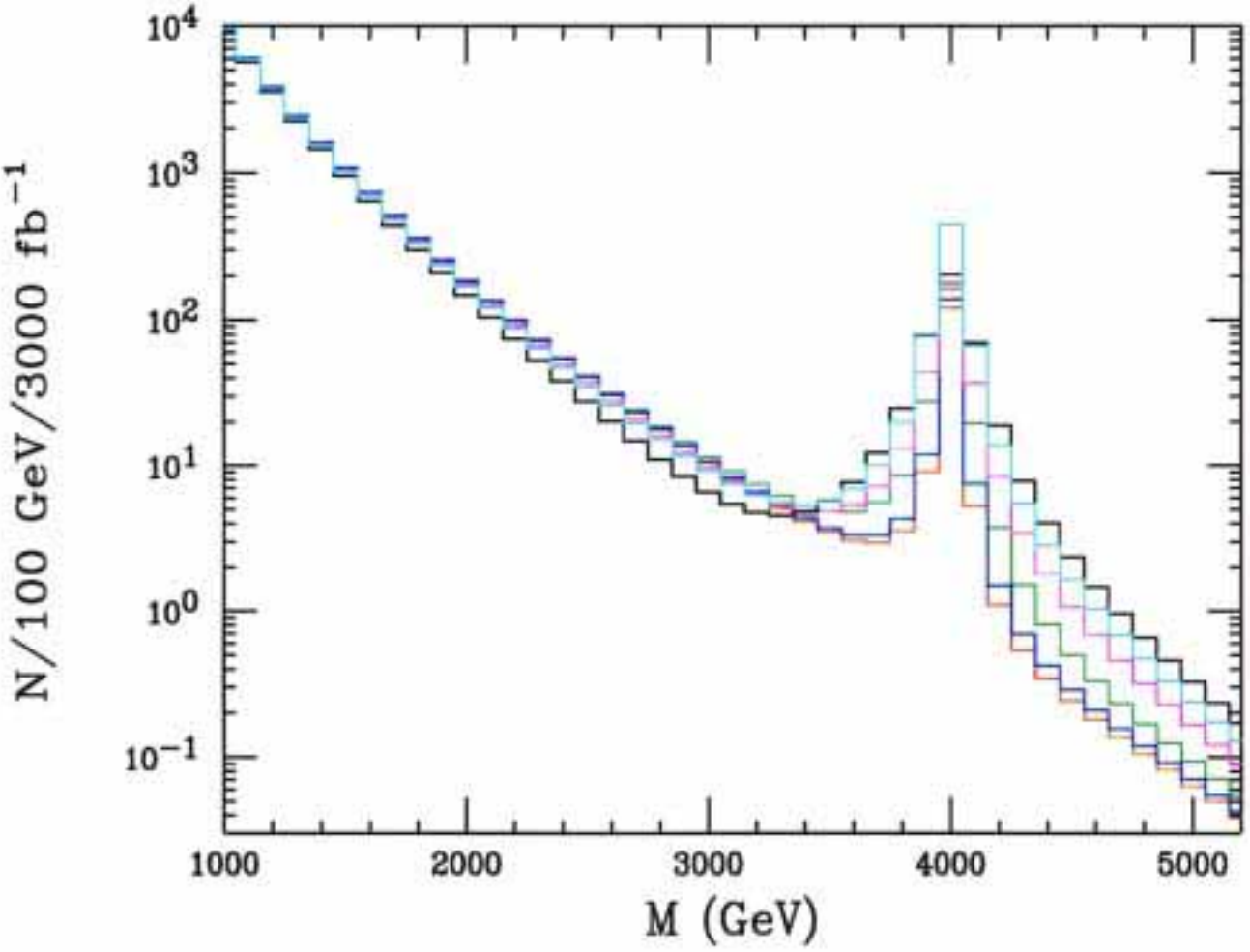
$\gamma^{(1)}/Z^{(1)}$

KK resonance

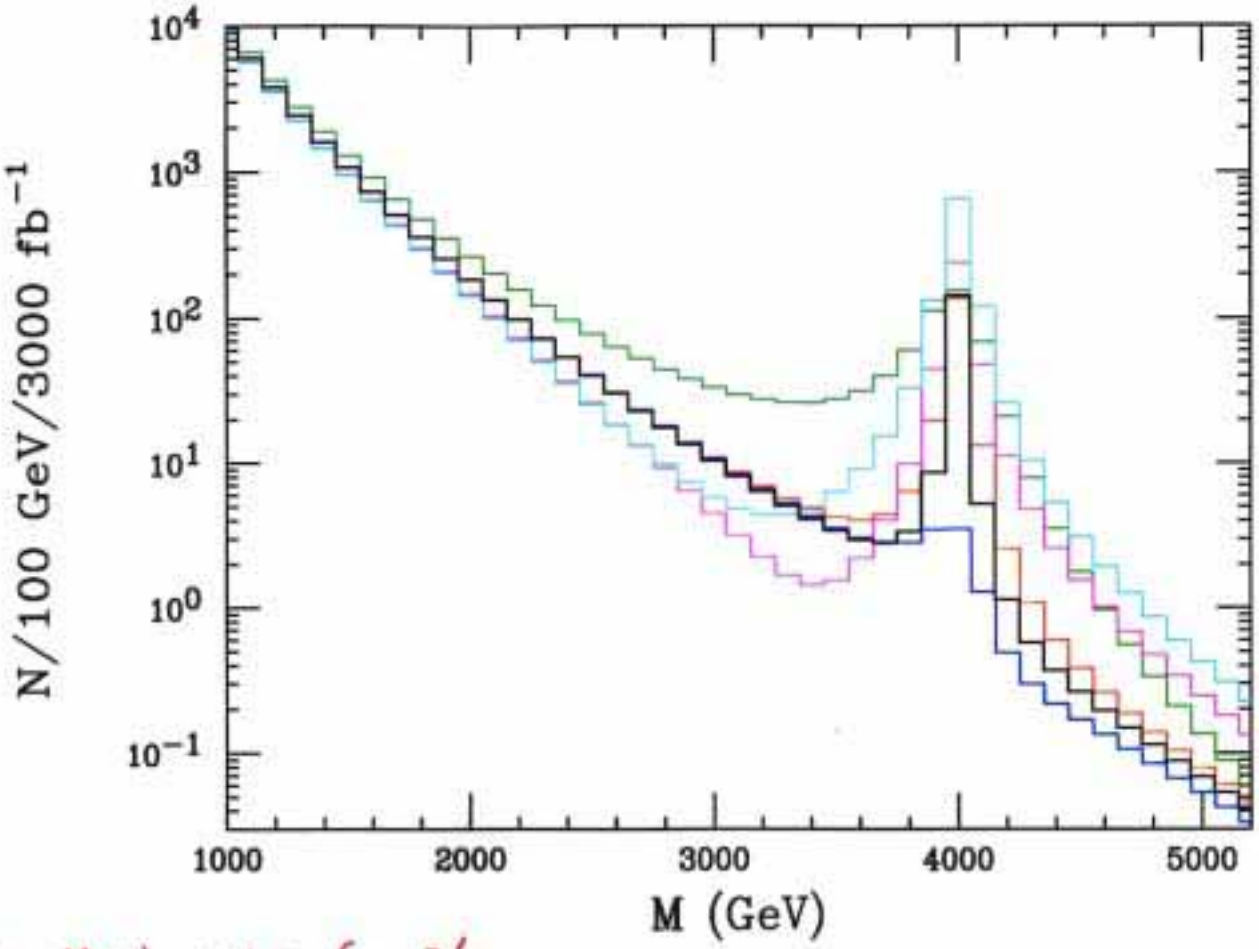
Azuelos + Polesello



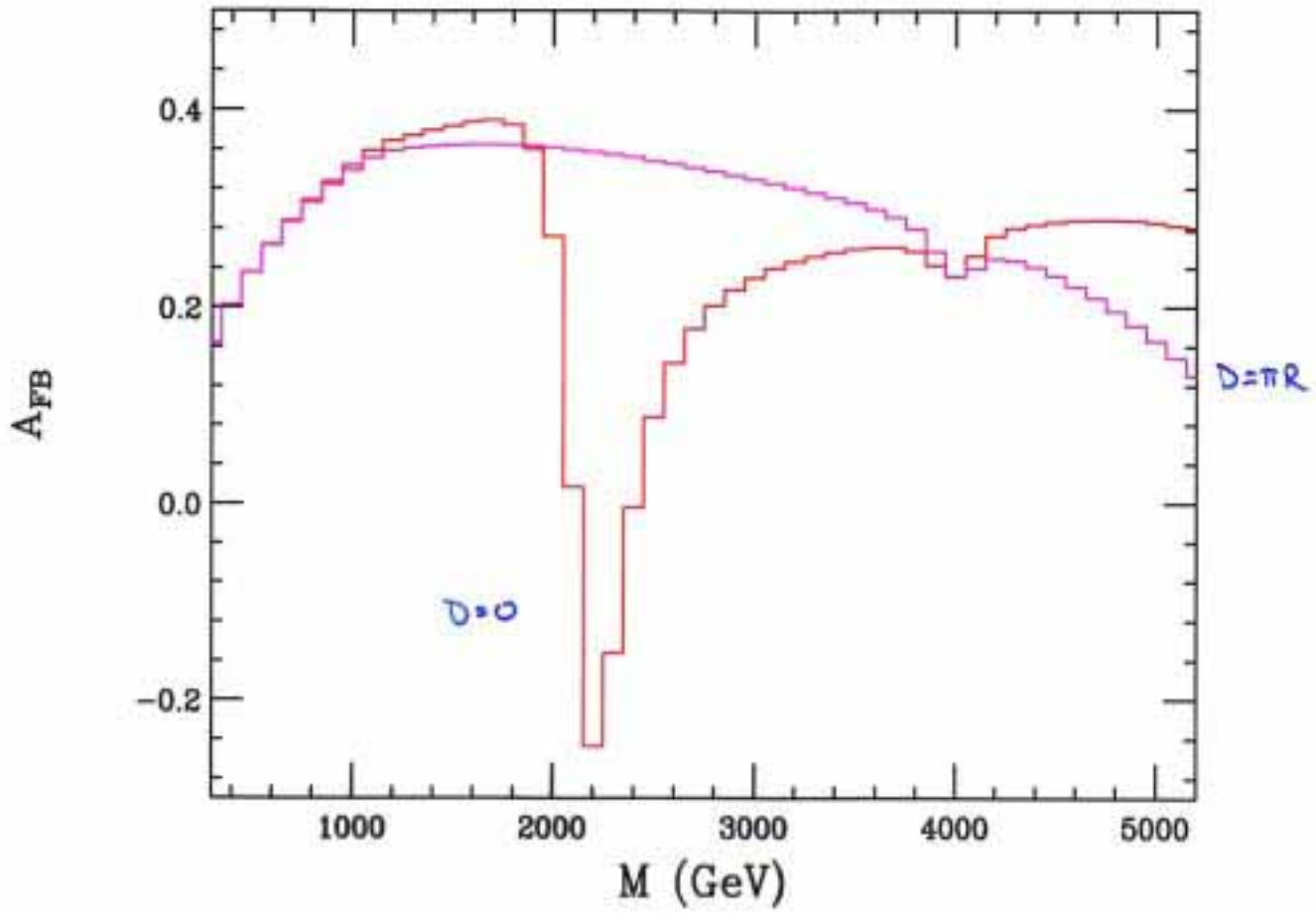
6 Favorite
Z′ models

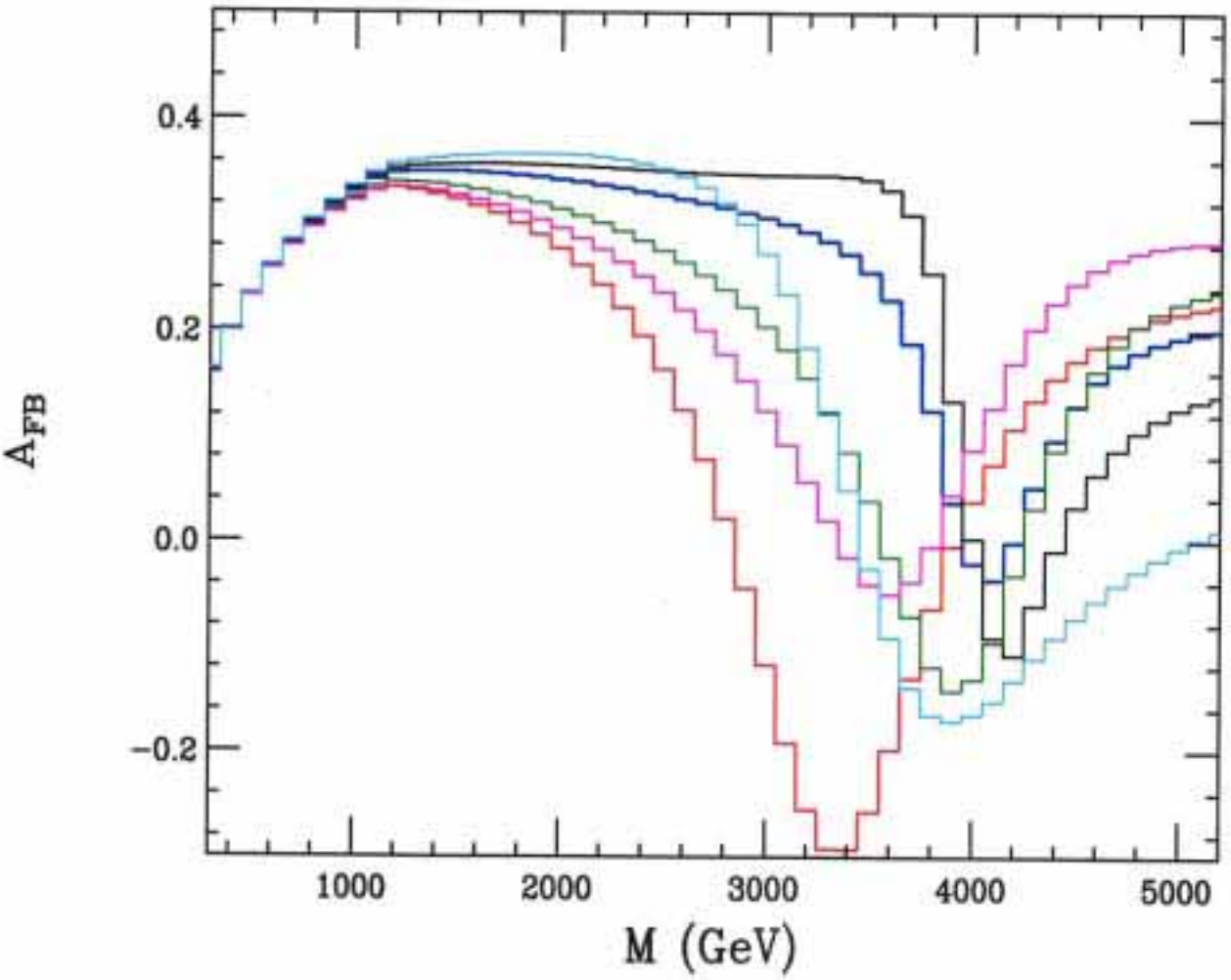


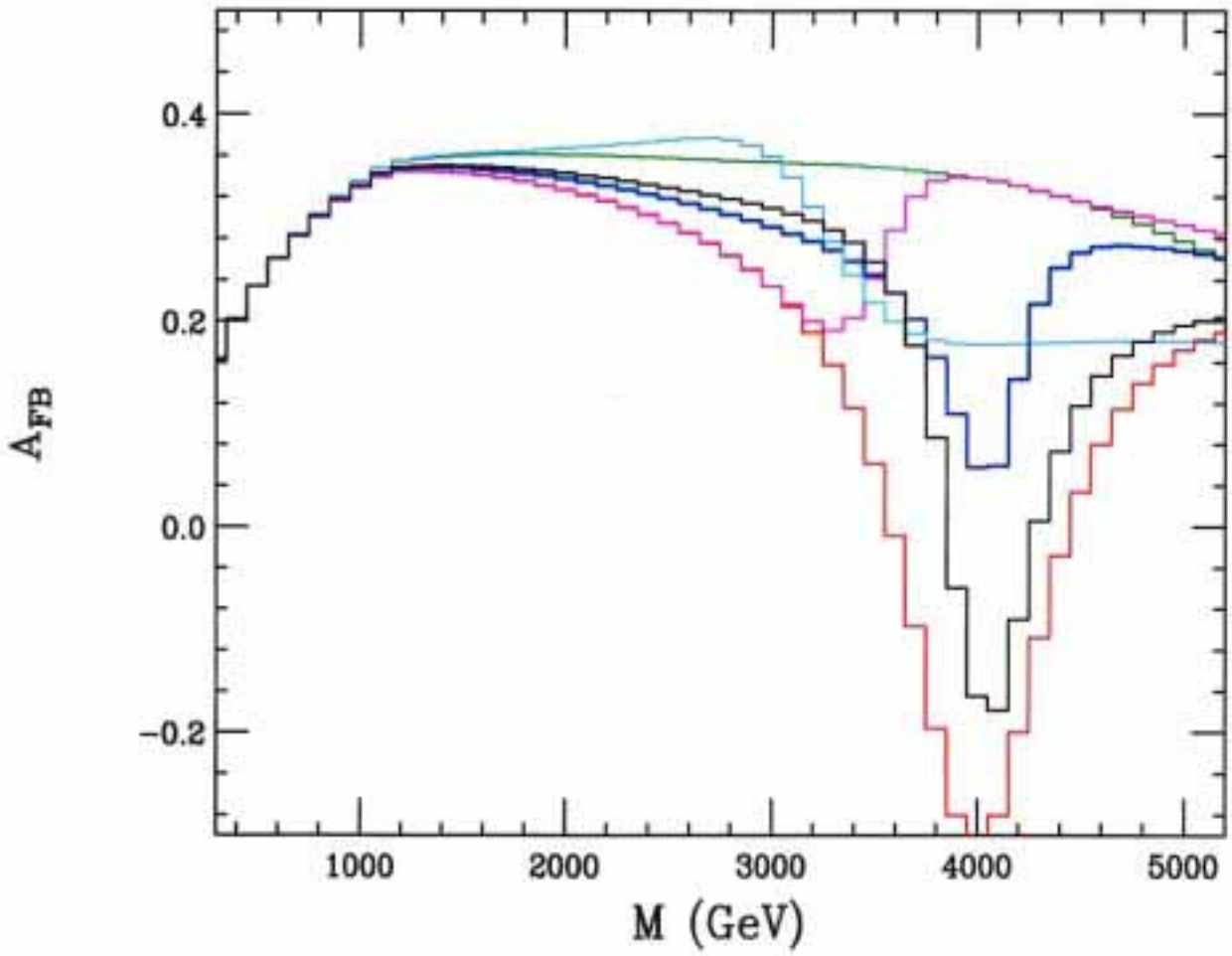
6 more Favorite
Z' models



↓ Much easier for Z'
to fake KK when $D = \pi R$!

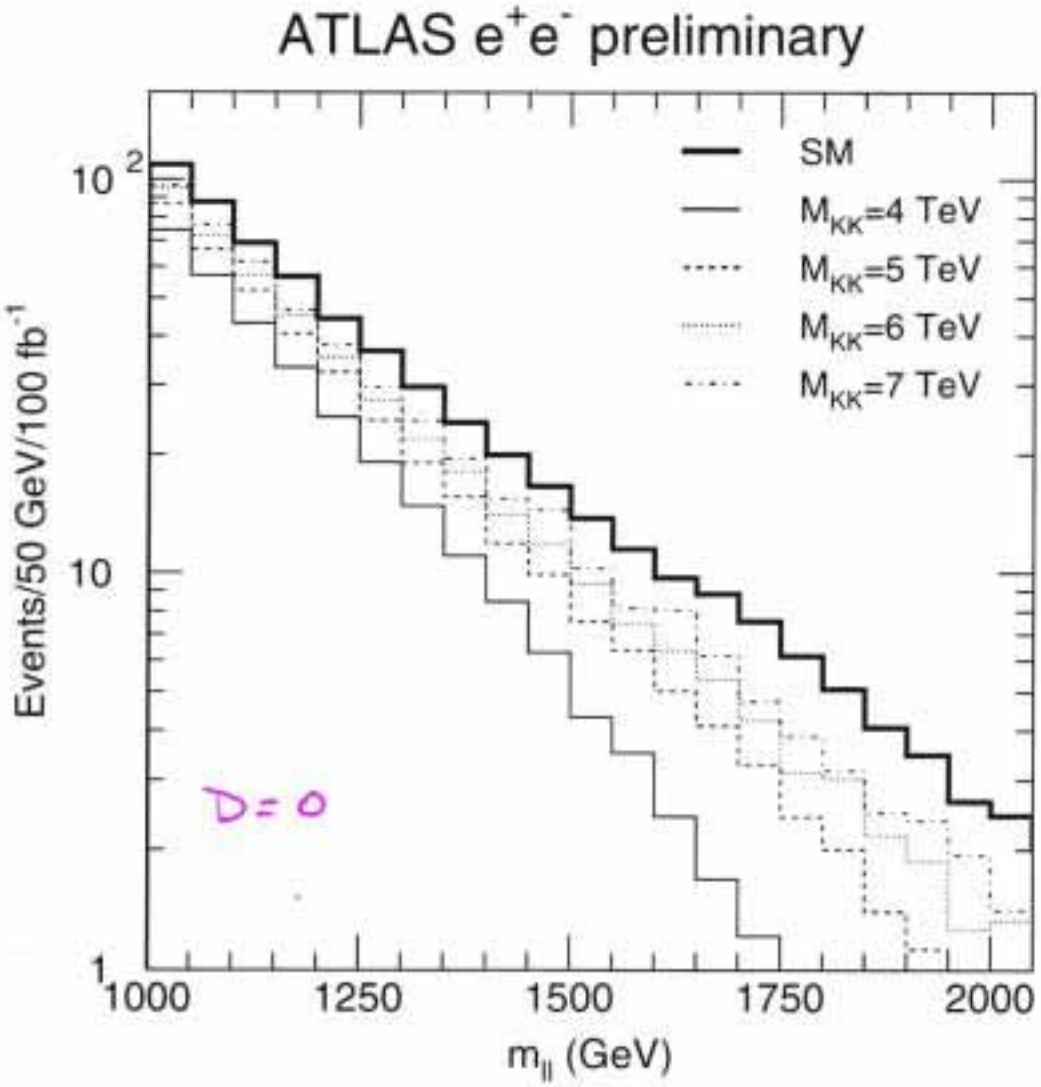

0.4
0.2
0.0
−0.2
A_FB
1000
2000
3000
4000
5000
M (GeV)
D=0
D=πR


0.4
0.2
0.0
−0.2
A_{FB}
1000
2000
3000
4000
5000
M (GeV)


0.4
0.2
0.0
−0.2
A_{FB}
1000
2000
3000
4000
5000
M (GeV)

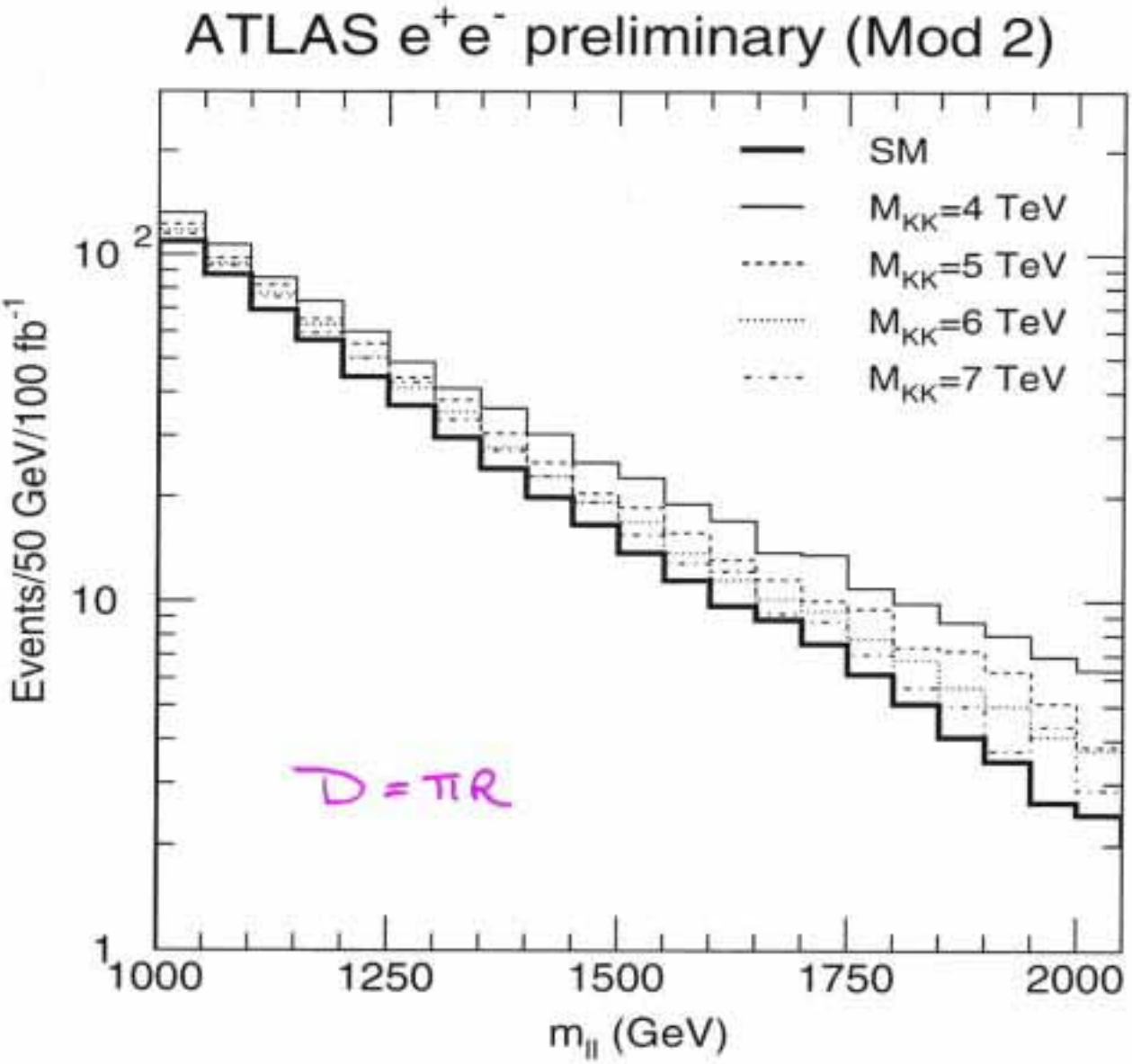
KK (or Z′) distorts dσ/dm below resonance region

Anzelos+ Polesello



Can these distortions be mimicked by a Z', albeit, with large couplings ???

Anzuelos + Polesello



LC analysis

LC very sensitive to high-mass γ/Z KK states $\Rightarrow$ $M_C \sim 30\sqrt{s}$!

- Consider deviations in σ, $\frac{d\sigma}{dz}$, $A_{LR}(y)$, $P_\tau(y)$ $(y = \cos\theta)$

  for leptonic final states AND LHC supplies the resonance mass to LC ... $D = 0, \pi R$ (same here)

- Z' hypothesis : fit to 2 unknown couplings v_e', a_e' (universality assumed !)

→ well-known that LC can extract Z' coupling info for $\sqrt{s} < M_{Z'}$ from deviations in observables esp. when $M_{Z'}$ known

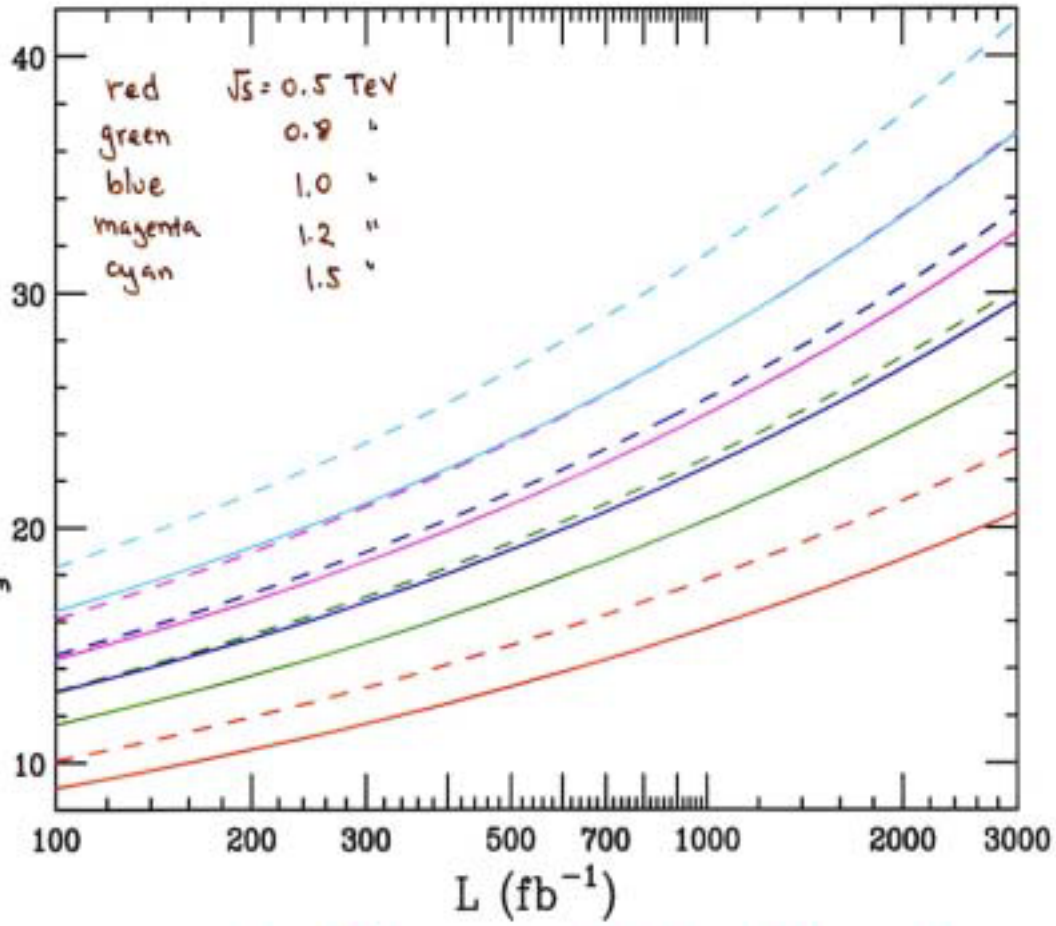
* The fit in the KK is very bad - can't fit KK with only 2 couplings [2 resonances !]

4 are required

KK gauge bosons SD SM 95%CL

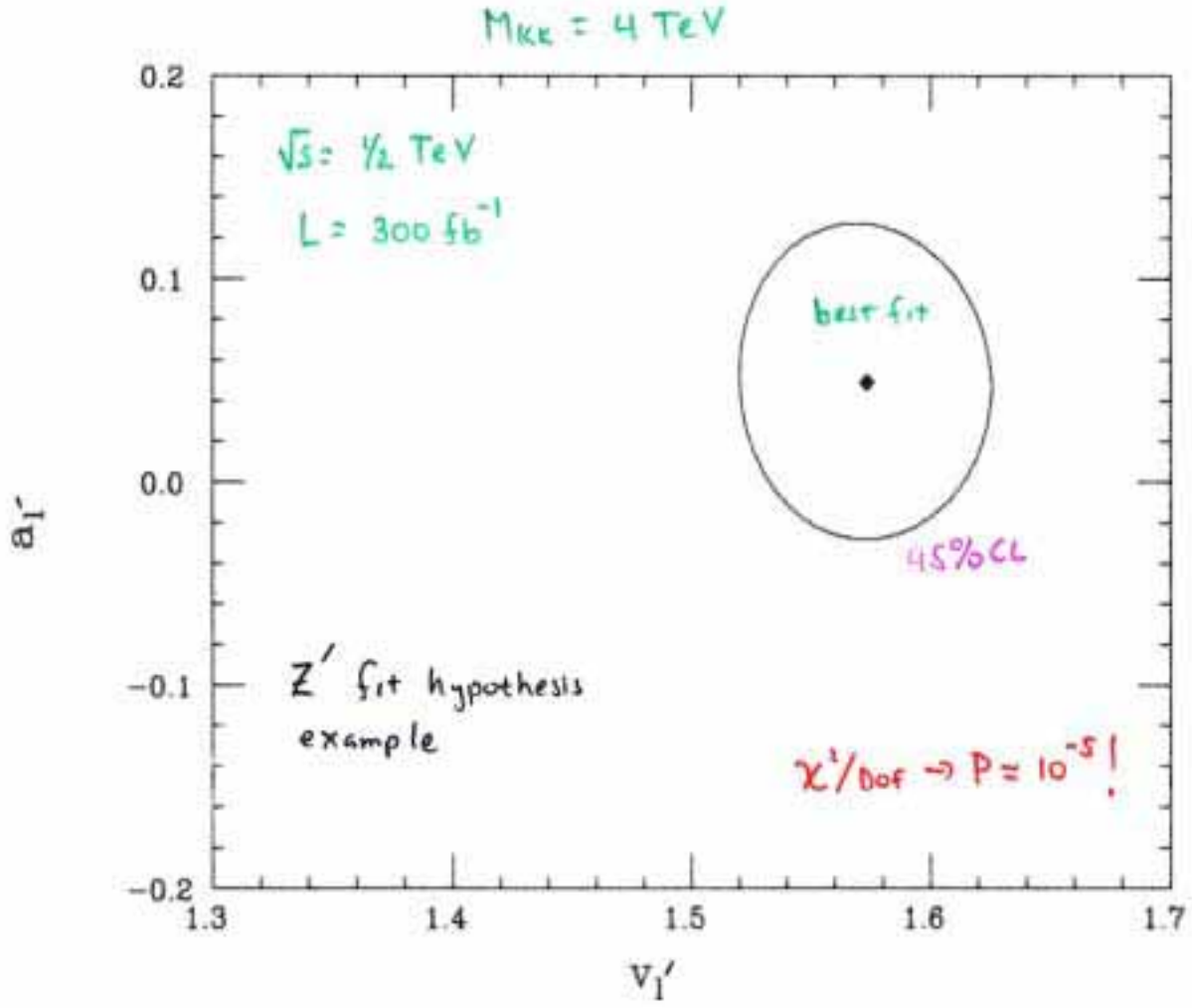
Solid: 80%
dash: 80+60%

≈12% gain

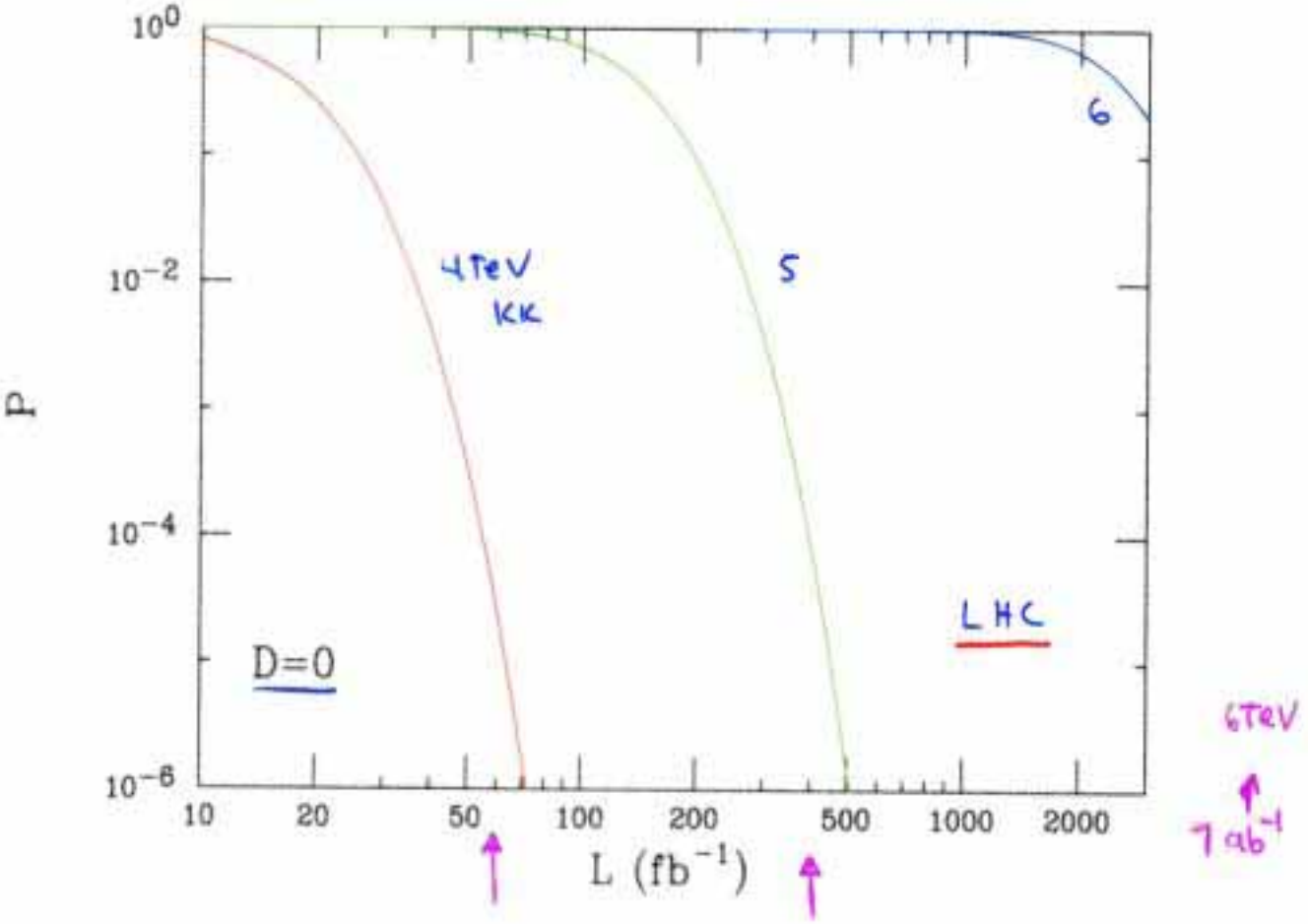


Again, reach ≈ $(sL)^{1/4}$....

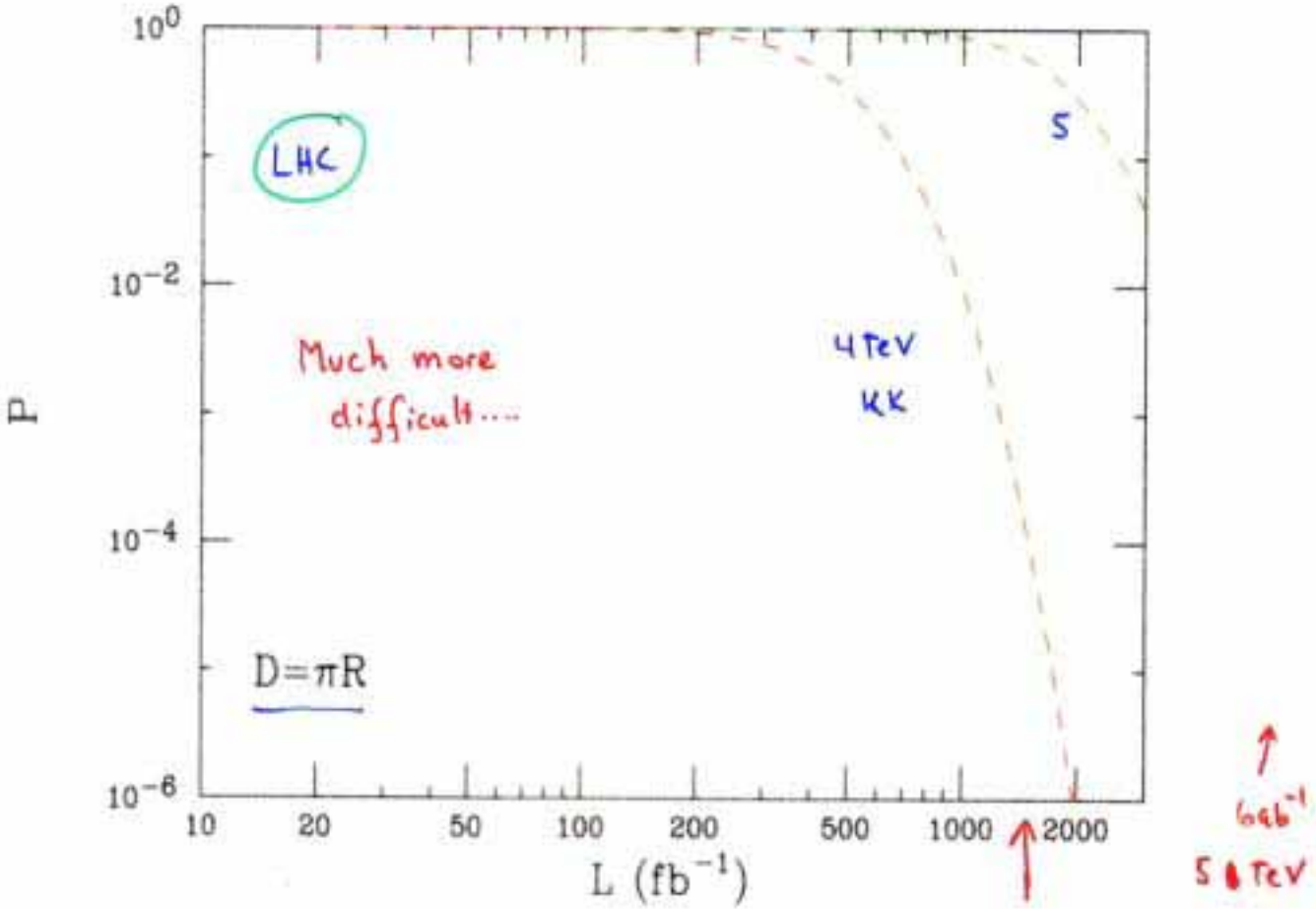
slightly different slopes seen.


M_{KK} = 4 TeV
$\sqrt{s}$ = ½ TeV
L = 300 fb^{-1}
best fit
45% CL
Z′ fit hypothesis example
χ^2/DOF → P ≈ 10^{-5} !
0.2
0.1
0.0
−0.1
−0.2
1.3
1.4
1.5
1.6
1.7
a_l'
v_l'

LHC : Best fit probability for Z′ hypothesis



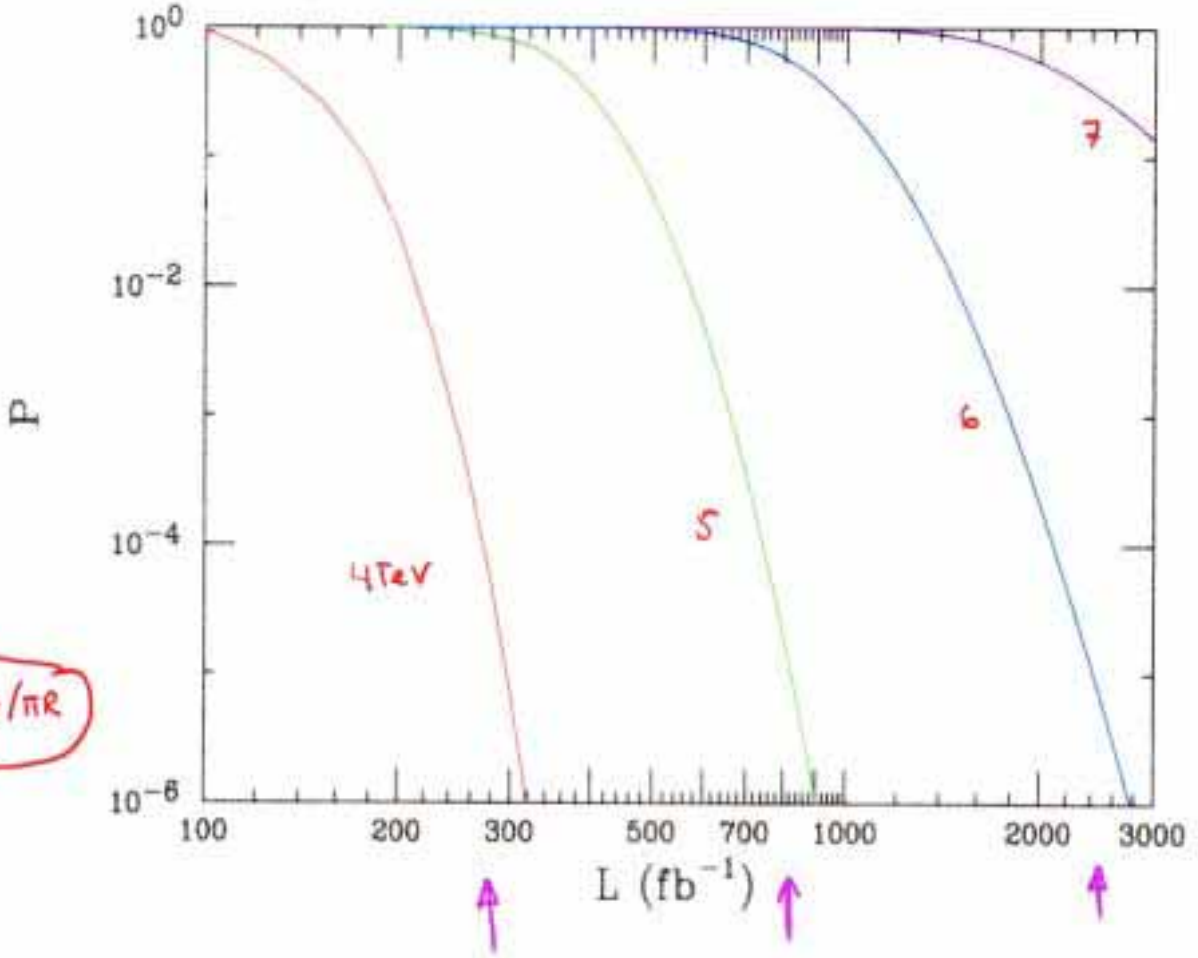
Best fit probability for Z' hypothesis



Best fit probability for Z' hypothesis

LC $\sqrt{s} = 500$ GeV

"$M_{Z'}$" from LHC

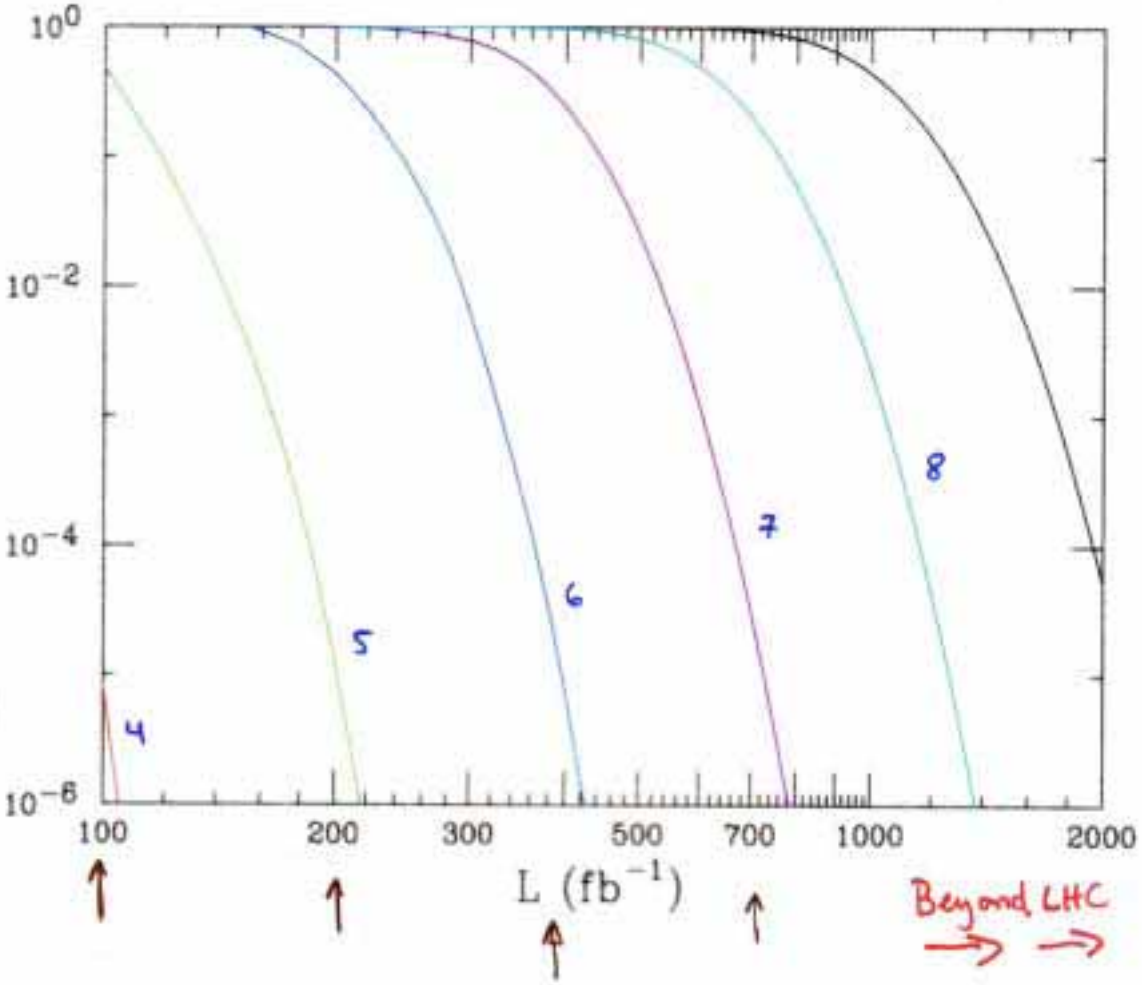


D=0/πR

Best fit probabilities for Z' hypothesis

LC, "$M_{Z'}$" from LHC

$\sqrt{s}$ = 1 TeV



D = 0 or πR

M_c (TeV)	LHC		LC*	
	D=0	D=πR	500 GeV	1 TeV
4	60	1500	300	80
5	400	6000	800	200
6	7500	—	2400	380
7	—	—	—	700
8	—	—	—	1300

$\Rightarrow$ Lumi required to get $P \sim f_{sw} \cdot 10^{-5}$ (5σ) in fb^{-1}

* Assumes KK mass is well known from LHC

Conclusions :

→ Simplest analysis of simplest model ...

→ LHC and LC have Z'/KK differentiation capabilities ...

→ Future → explore A_{FB}^{R} use + rapidity ratio possibilities

↓

Consider other models, e.g.,

RS w/ brane terms

(lighter KK w/ weaker couplings)

Plenty to do ....