How Can a Heavy Higgs Boson be Consistent with Precision Electroweak Measurements?

Preliminary

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w.
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cf. Kane + Wells
hep-ph/0003249

precision electroweak limits on the Higgs boson mass.

Moriond '00

$m_H <$ 188 (95% CL) 300 (99% CL)

Osaka '00

< 170

w. new BES R (preliminary)

< 230

But this is only within the Standard Model, right ?

Could we have a 500 GeV Higgs boson in more general models ?

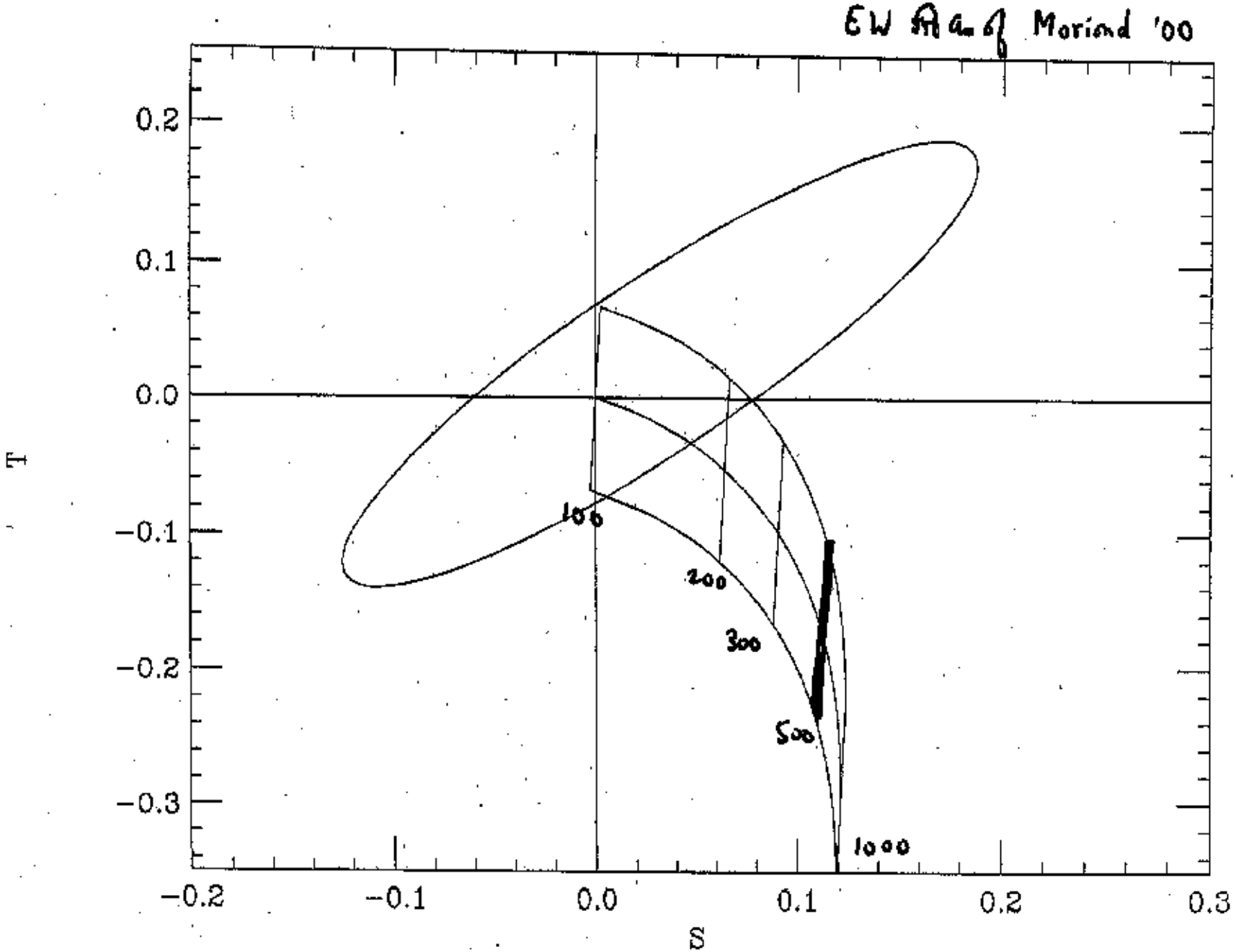
S, T analysis

S, T ← vacuum polarization amplitudes

$$\alpha T = \frac{e^2}{s^2 c^2 m_Z^2} \left[\Pi_{11}(0) - \Pi_{33}(0)\right]$$ weak isospin violating

$$\alpha S = 4e^2 \left[\Pi'_{33}(0) - \Pi'_{3Q}(0)\right]$$ weak isospin conserving

~ 5σ accuracy of a 500 GeV machine
both ΔS, ΔT from the SM value


EW Stand Moriond '00
0.2
0.1
0.0
−0.1
−0.2
−0.3
T
−0.2
−0.1
0.0
0.1
0.2
0.3
S
100
200
300
500
1000

In general, physics from beyond the SM can provide additional large corrections

Minimal technicolor: large positive S → excluded!

Supersymmetry: "decoupling"; effects are

$$\sim \frac{\alpha}{4\pi}\frac{m_Z^2}{M^2} \quad (\sim \text{negligible})$$

other models can span this range of effects.

"Model-independent analysis"

Barbieri + Strumia, Bagger, Falk Swartz
Kolda + Murayama Chivukula, Holdom + Evans

add general non-renormalizable operators to SM; vary their coefficients + m_H

→ very weak constraints on m_H ($m_H < 1\text{-}3$ TeV)

no surprise! non-renorm. ops. contribute to S, T

We believe that a model-dependent approach is necessary.

The new physics that allows m_H to be large may be observable directly at a 500 GeV LC.

We have done a literature search (1990–2000)

$\rightsquigarrow$ 3 general mechanisms for relaxing the constraint on m_H

Method A:

add new species which contribute negatively to S

Georgi, Randall-Dugan

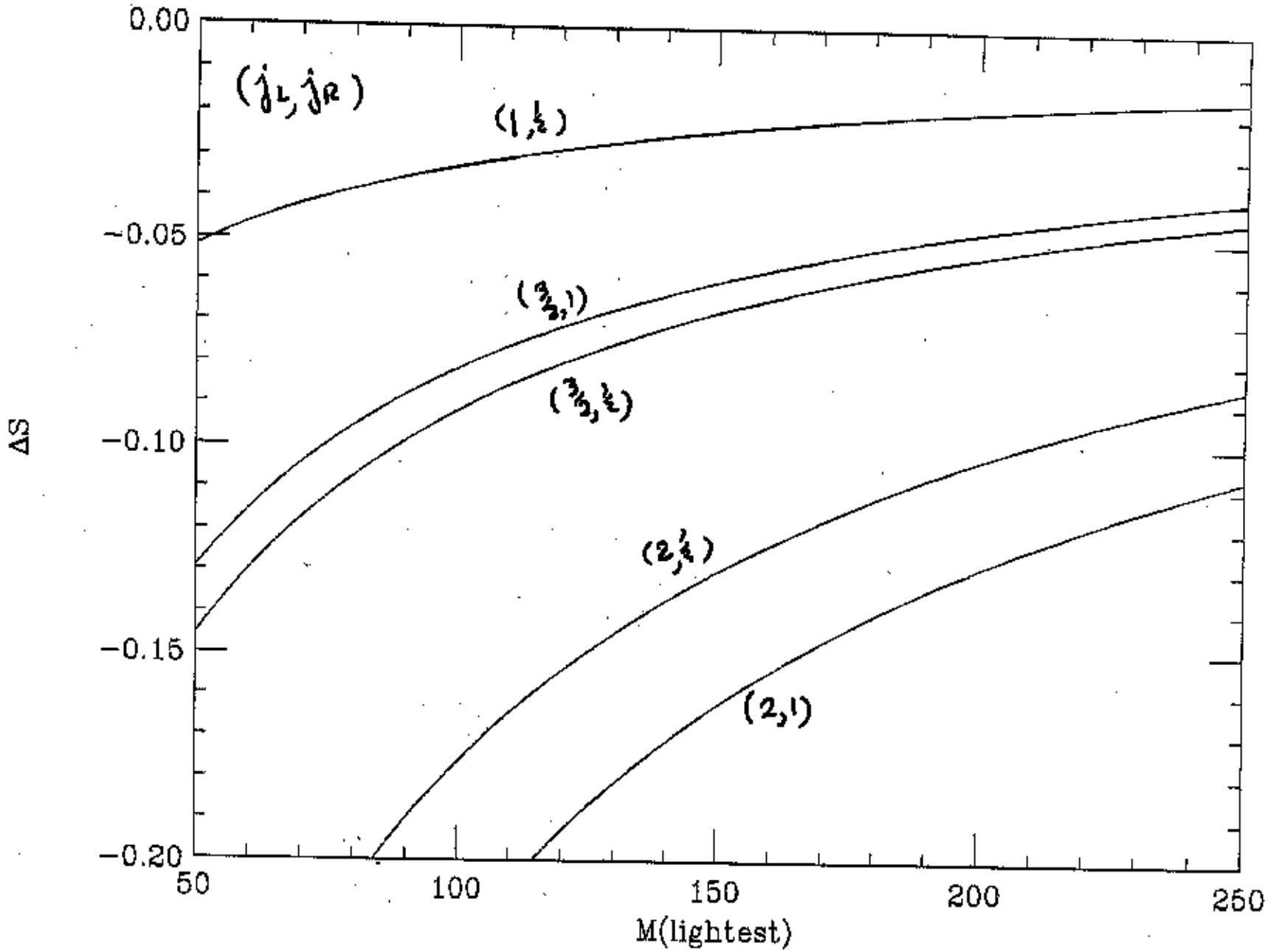
bosons w. $(j_L, j_R) \to (J_1, \cdots, J_N)$

$$\Delta S \cong \frac{1}{3\pi} \sum_{JJ} \ln \frac{M^2}{m_J^2}$$

Gates Terning

fermions w. Majorana + Dirac masses

$$\Delta S \sim -\frac{1}{6\pi} \ln \frac{M_1^2}{M_2^2} \quad \text{in some region}$$


0.00
−0.05
−0.10
−0.15
−0.20
ΔS
50
100
150
200
250
M(lightest)
(j_L, j_R)
$(1, \frac{1}{2})$
$(\frac{3}{2}, 1)$
$(\frac{3}{2}, \frac{1}{2})$
$(2, \frac{1}{2})$
(2,1)

Method B

add a $Z^{0\prime}$ which perturbs all electroweak quantities

Altarelli
Barbieri
Jadach

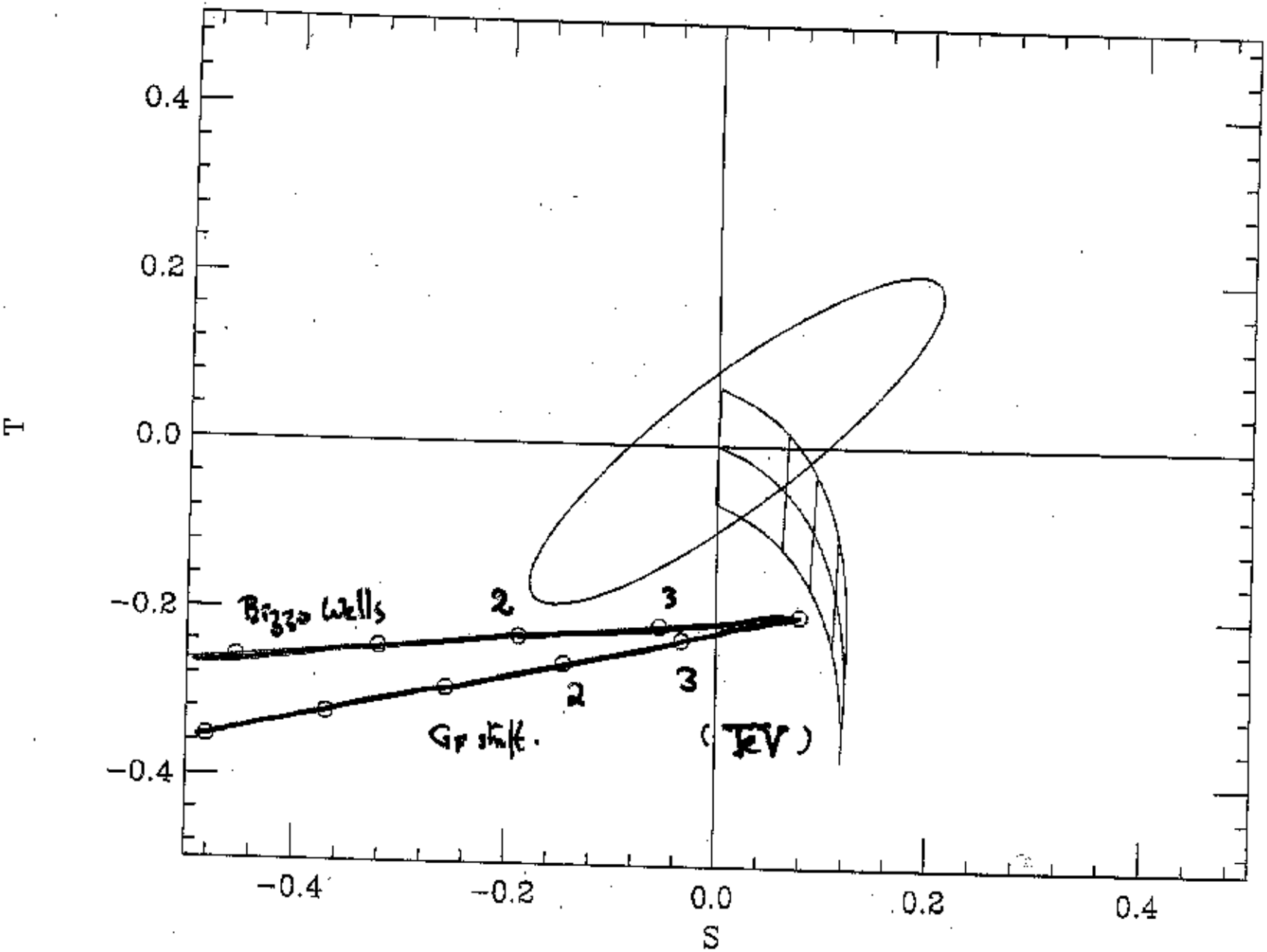
Riazo

typically $m_{Z'} < 3$ TeV for large enough effect

Riazo + Wells : extra dimension relax $m_{Z'}$ limit by same effect

reach of 500 GeV LC

→ above 4 TeV in $m_{Z'}$

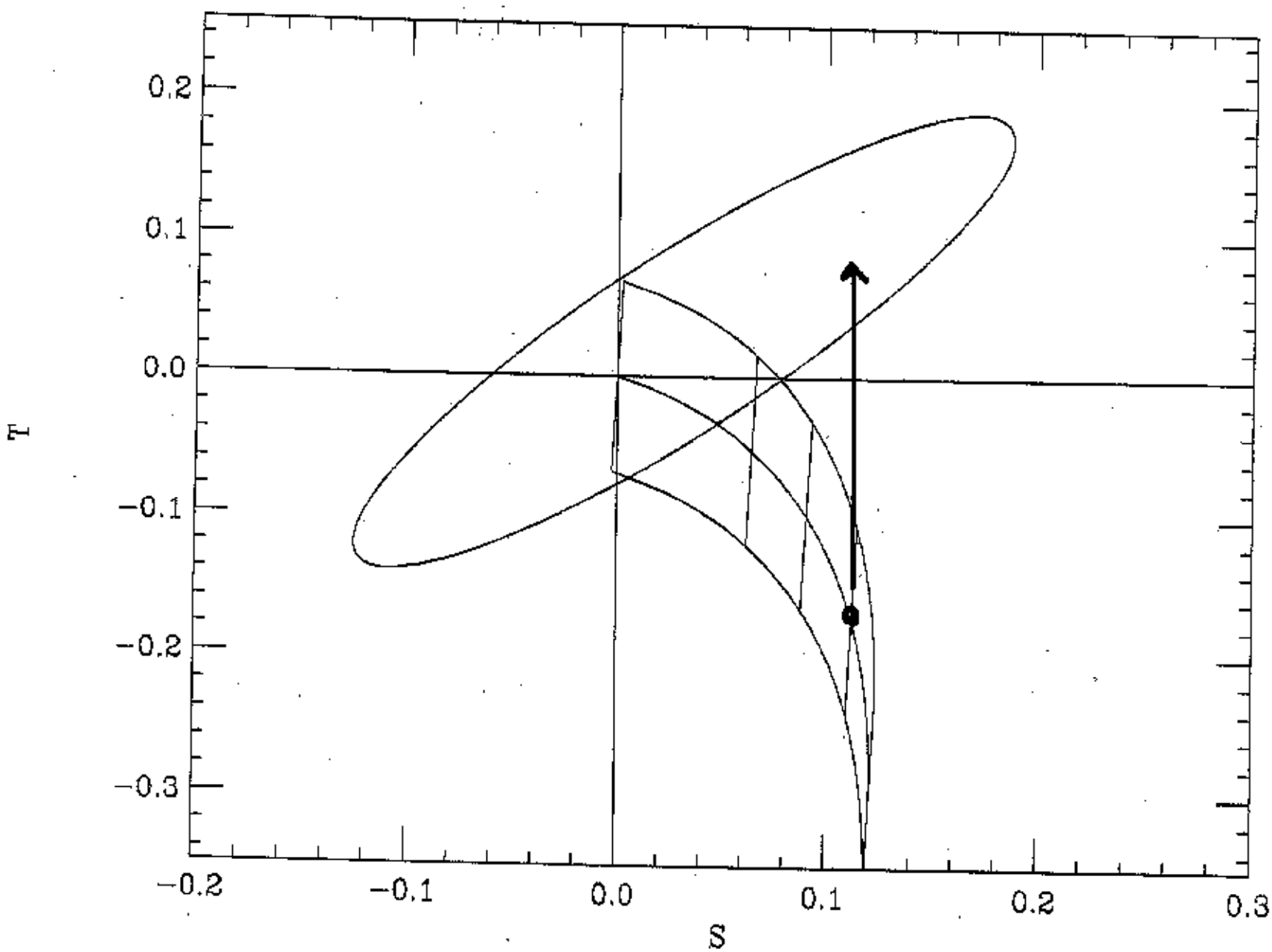

0.4
0.2
0.0
−0.2
−0.4
T
−0.4
−0.2
0.0
0.2
0.4
S
Bigga wells
2
3
2
3
Gr shift.
(TeV)

Method C

add new species which contribute positively to T

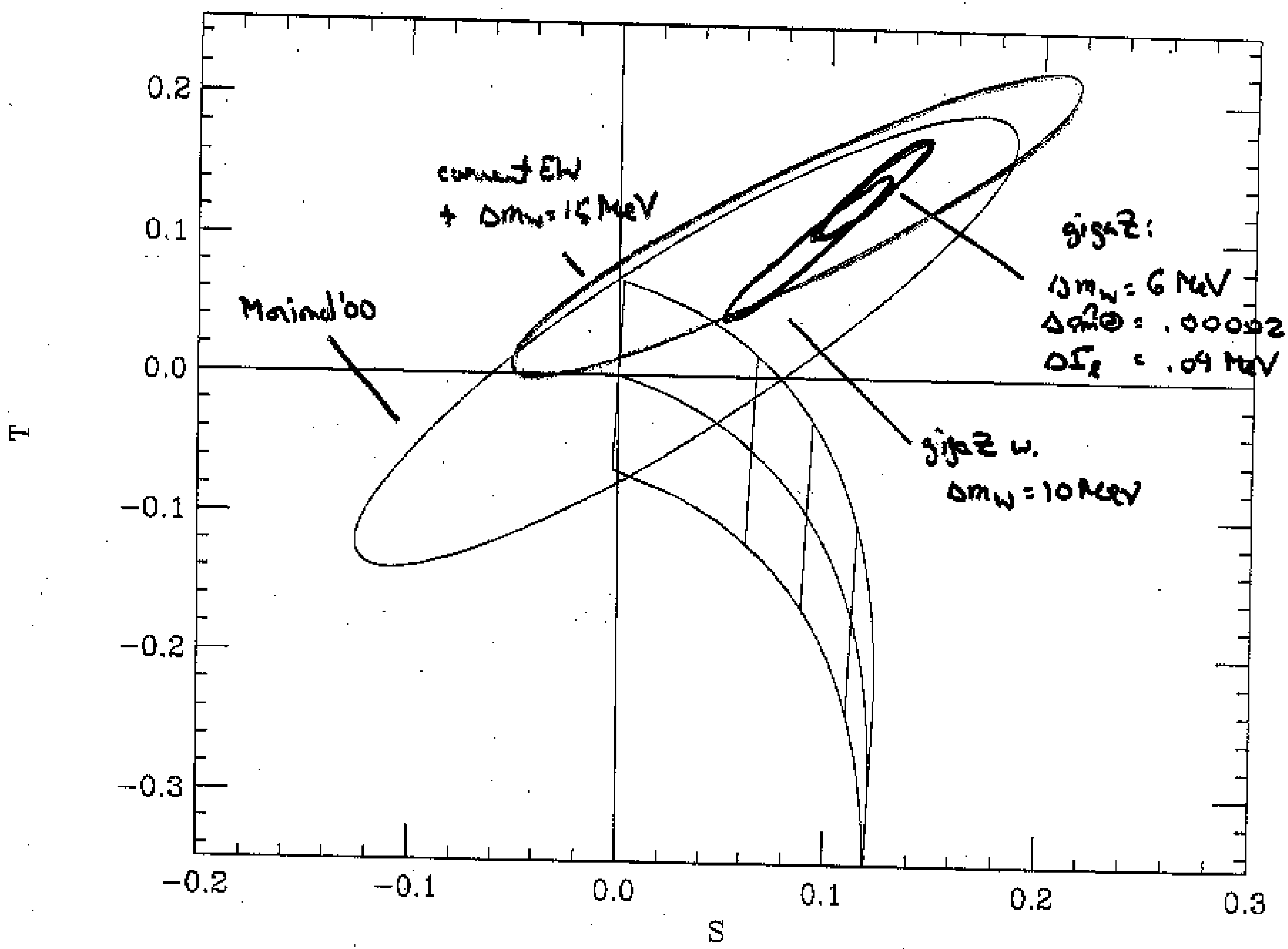
Dobrescu - Hill : topcolor seesaw ($m_\chi \cong 5$ TeV)

Grzadkowski - Gunion : region of 2-Higgs-doublet model


0.2
0.1
0.0
−0.1
−0.2
−0.3
T
−0.2
−0.1
0.0
0.1
0.2
0.3
S

this mechanism cannot necessarily be probed directly at a 500 GeV LC

but, it is tested at g-2.


Maiani'00
current EW
+ Δmw=15 MeV
gigaZ:
Δmw = 6 MeV
gigaZ w.
Δmw = 10 MeV
0.2
0.1
0.0
−0.1
−0.2
−0.3
T
−0.2
−0.1
0.0
0.1
0.2
0.3
S

Conclusion:

Physics beyond the SM can make

$m_H \geq 500$ GeV possible,

but the window is very narrow

- Stay-comply, not SUSY, EWSB
- New signatures for 500 GeV LC

  or

  non-standard result from sfs-Z