T-CHANNEL SINGLE TOP PRODUCTION AT LHC:

A REALISTIC TEST OF ELECTROWEAK MODELS.

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THIS PRESENTATION IS A SUMMARY OF THE VERY RECENT PAPER:

"Single top production in the t-channel: a realistic test of electroweak models"

hep-ph/

M.Beccaria,G.Macorini, F.M.Renard, C.V.

All the (several) technical details can be found in the paper, and will not be given here.

Only the main results will be quickly shown .

Some of them allow a related conclusion; other ones are only indicative.

The relevance of single top production at LHC is well known

1)both for physics within the SM

2)and for physics beyond the SM.

In case (1), single top production offers a priviledged possibility of measuring the Wtb coupling, that appears in the expression of the cross section

ALREADY AT TREE LEVEL.

In case (2), it can be sensitive to a variety of effects due to exchanges of new particles.

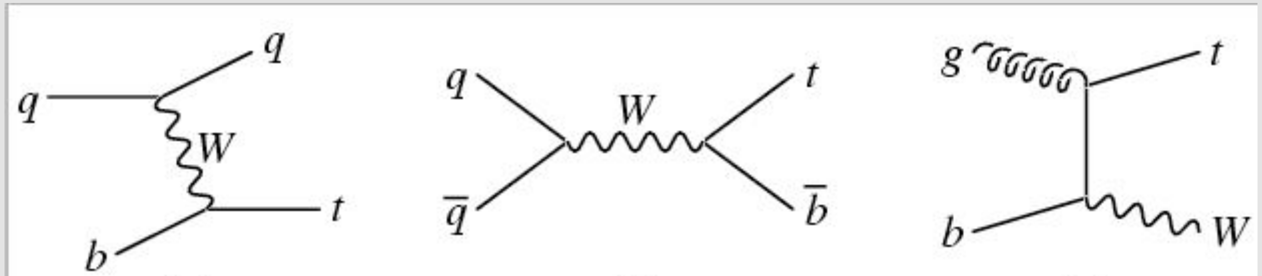
In this situation, a lucky possibility is provided by the existence of three different single-top production processes, normally labelled as

a)t-channel single top production

b)s-channel single top production

c)associated tW production

(see Figure)



(a) (b) (c)

At LHC, one expects for the three processes a cross section of the following size (approximately):

1) t-channel: 250 (pb)
2) associated production: 60 (pb)
3) s-channel: 10 (pb)

If no new physics is around, one expects to find Vtb=1(roughly) with an accuracy fixed by the overall uncertainty in the measured cross sections.

For this accuracy, one aims to reach a final overall value of the

1)5 percent(ambitious)
2)10 percent (prudent)

size (“top quarkphysics” component of the CERN Y.B. 2000-004, G.Altarelli, M.Mangano eds.).

At these levels of accuracy, the possibility of performing precision tests AT LHC becomes realistic.

What needs to be done by theoreticians to use the process to perform precision tests?

A precise calculation!

At the partonic level, this means nowadays a complete one-loop calculation.

Within the SM, this is nowadays available for the QCD component(refs. given in hep-ph/0512250,S.Frixione, E.Laenen,P.Motylinski,B. Webber).

Modulo scale uncertainty, the overall NLO QCD effect on the rate appears to of the relative few percent (small).

If the NLO electroweak effect were of smaller size,as a priori expected, it would not affect the observable rate.

For reasons of fairness, it should be anyway computed..

In this spirit, we did compute the complete one-loop electroweak effect on the t-channel process in the MSSM,with mSUGRA symmetry breaking scheme.

Details of the calculation are given in hep-ph

M.Beccaria,G,Macorini,F.
.Renard,C.V.

3 important checks of the calculation have been verified:

1)Cancellation of the ultraviolet divergences.

2)Cancellation of the infrared divergences.

3)Asymptotic agreement with Sudakov expansion.

Our C++ program LEONE passed all tests-->results.

III. PHYSICAL PREDICTIONS

We shall concentrate our analysis on the investigation of the electroweak one-loop MSSM effect on the unpolarized cross section, for which a preliminary discussion of the expected experimental error already exists [4]. In principle, the final top polarization could also be measured, but a similar experimental analysis has not yet been completed, to our knowledge. The starting quantity will be therefore the inclusive differential cross section of the process, defined as usual as:

$$\frac{d\sigma(PP \to td + X)}{ds} = \frac{1}{S} \int_{\cos\theta_{min}}^{\cos\theta_{max}} d\cos\theta \; [L_{ub}(\tau, \cos\theta) \frac{d\sigma_{ub\to td}}{d\cos\theta}(s) \;] \tag{15}$$

where $\tau = \frac{s}{S}$, and L_{ub} is the parton process luminosity.

$$L_{ub}(\tau, \cos\theta) = \int_{\bar{y}_{min}}^{\bar{y}_{max}} d\bar{y} \;\; \left[\, b(x)u(\frac{\tau}{x}) + u(x)b(\frac{\tau}{x}) \, \right] \tag{16}$$

where S is the total pp c.m. energy, and $i(x)$ the distributions of the parton i inside the proton with a momentum fraction, $x = \sqrt{\frac{s}{S}} \, e^{\bar{y}}$, related to the rapidity $\bar{y}$ of the td system [15]. The parton distribution functions are the latest LO MRST (Martin, Roberts, Stirling, Thorne) set available on [16]. The limits of integrations for $\bar{y}$ depends on the cuts. We have chosen a maximal rapidity $Y = 2$ and a minimum p_T which we shall specify later.

Note that we are at this stage considering as kinematical observable the initial partons c.m. energy $\sqrt{s}$, and not the realistic final state invariant mass M_{td}.

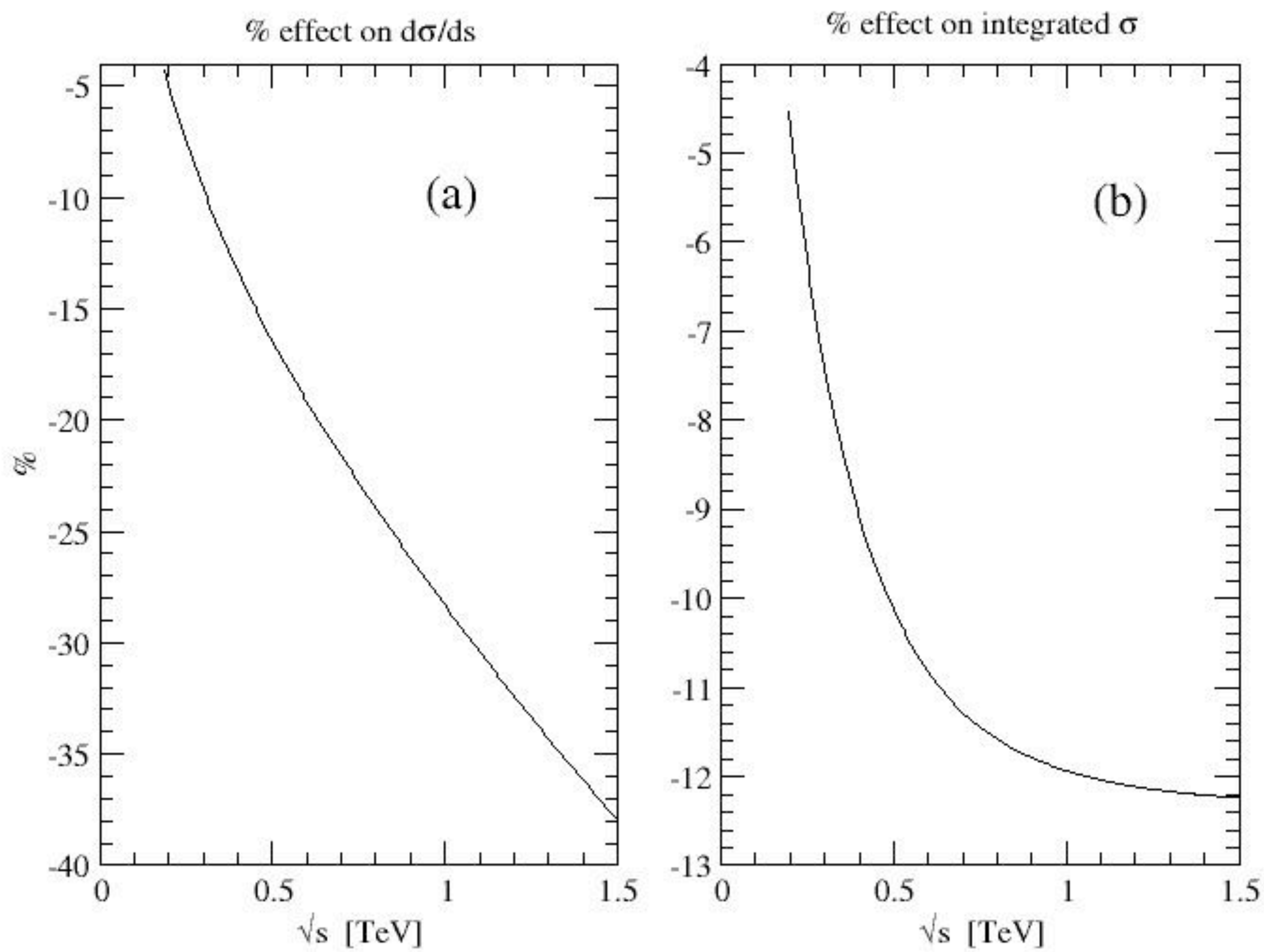
In a next step,the more meaningful final invariant mass will be used (from previous experience-

Phys.Rev.D71,073003, 2005)

with S.Bentvelsen and M.Cobal- we expect a small difference).

As a more realistic observable to be measured in the initial LHC period, we c onsidered then the total rate, and computed it from threshold to a final energy (say, no more than 1 Tev).

Next Figure shows the Standard Model results.



% effect on dσ/ds
(a)
%
√s [TeV]
% effect on integrated σ
(b)
√s [TeV]

As one sees, the SM electroweak NLO effect is

a) large (of the ten percent size)

b)larger (than the NLO QCD effect).

A similar statement was made time ago for e+e- annihilation into hadrons at very high energies

(P.Ciafaloni,D.Comelli, Phys.Lett.B446,278(1999).

In the e+e- situation, this was due to the assumed validity of an approximate asymptotic Sudakov expansion.

In the t-channel case, it arises from a COMPLETE one-loop calculation,that includes both low and (relatively) high energies.

Therefore, in any future computational program that requires the SM NLO partonic amplitude as input (see Frixione, last April CERN seminar...)

for the t-channel process the inclusion of the electroweak component appears mandatory.

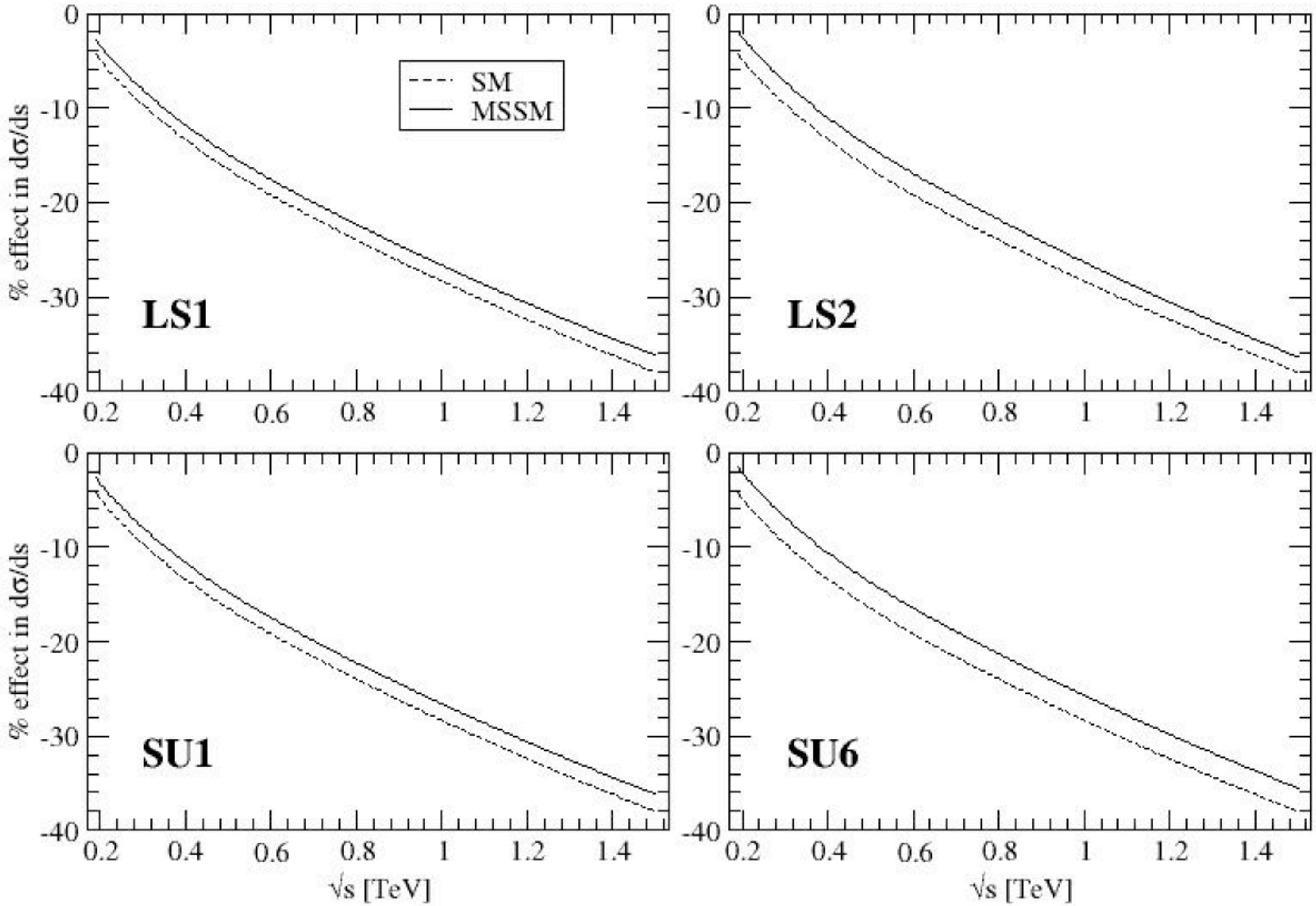
Next step: calculation of the complete MSSM electroweak one loop effect,i n the mSUGRA symmetry breaking scheme.

Already done for the tW process(M.Beccaria,F.M. Renard,G.Macorini,C.V., Phys.Rev.D73,093001/06)

LEONE tells us that:

for a large choice of benchmark points, the genuine SUSY effect appears to be generally MODEST (few percent at most).

Results for 4 typical selected points:


SM
MSSM
LS1
LS2
SU1
SU6
% effect in dσ/ds
√s [TeV]
0
-10
-20
-30
-40
0.2
0.4
0.6
0.8
1
1.2
1.4

A simple explanation of the smallness of the SUSY effect:

SUSY masses in mSUGRA benchmark points are not "sufficiently" small with respect to the final energy (in fact, they are often larger).

	SU1	SU6	LS1	LS2
m_0	70	320	300	300
$m_{1/2}$	350	375	150	150
A_0	0	0	-500	-500
$\tan\beta$	10	50	10	50
$\mu/\lvert\mu\rvert$	1	1	1	1
α	-0.110	-0.0212	-0.109	-0.015
M_1	144.2	155.8	60.1	60.6
M_2	270.1	291.3	114.8	115.9
μ	474.4	496.6	329.7	309.3
$H^{\pm}$	534.3	401.7	450.4	228.9
H^0	528.3	392.5	442.5	211.1
h^0	114.6	115.7	111.4	110.8
A^0	527.9	392.5	443.4	212.0
$\chi_1^{\pm}$	262.8	289.3	108.0	111.1
$\chi_2^{\pm}$	495.3	514.8	350.1	329.4
χ_1^0	140.1	153.0	57.38	58.92
χ_2^0	263.1	289.4	108.5	111.3
χ_3^0	479.2	501.0	335.3	315.8
χ_4^0	495.4	514.0	348.7	326.5

	SU1	SU6	LS1	LS2
$\tilde{l}_L$	253.3	412.3	321.0	321.2
$\tilde{l}_R$	157.6	353.4	308.7	308.7
$\tilde{\nu}_e$	241.0	404.8	311.3	311.3
$\tilde{\tau}_L$	149.6	195.8	297.1	078.1
$\tilde{\tau}_R$	256.1	399.2	323.8	282.5
$\tilde{\nu}_\tau$	240.3	362.5	308.4	243.6
$\tilde{u}_L$	762.9	870.5	459.8	460.2
$\tilde{u}_R$	732.9	840.7	451.9	452.3
$\tilde{d}_L$	766.9	874.0	466.4	467.0
$\tilde{d}_R$	730.2	837.8	452.8	453.2
$\tilde{t}_L$	562.5	631.5	213.3	223.6
$\tilde{t}_R$	755.8	796.9	462.9	431.3
$\tilde{b}_L$	701.0	713.7	380.6	304.0
$\tilde{b}_R$	730.2	787.6	449.1	401.7
θ_τ	1.366	1.133	1.091	1.117
θ_b	0.3619	0.7837	0.184	0.653
θ_t	1.070	1.050	1.016	0.9313

TABLE I: Table of spectra for the various benchmark points. All entries with the dimension of a mass are expressed in GeV. The spectra have been computed with the code SUSPECT [21].

This prevents any kind of sizeable ("of Sudakov kind") effect to show up (a veto not existing for the SM component...)

(see for an illustrative comparison the following Figure):

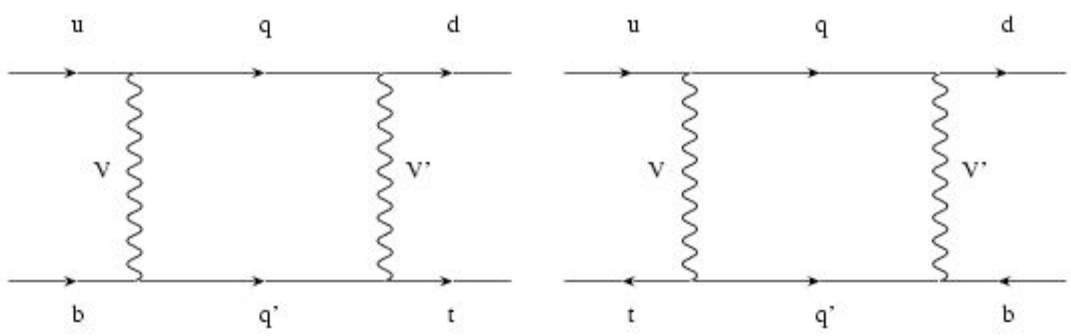


FIG. 1: Standard Model direct and twisted box diagrams. The virtual q and q' are quarks. The gauge bosons (V, V') can be (γ, W), (Z, W), (W, γ) or (W, Z)

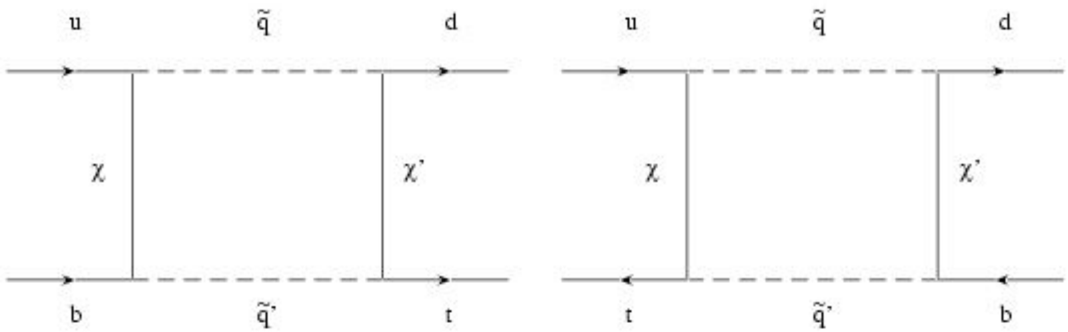


FIG. 2: SUSY direct and twisted box diagrams. The virtual $\tilde{q}$ and $\tilde{q}'$ are squarks. The fermion lines (χ, χ') can be charginos or neutralinos, (χ^0, χ^+) or (χ^+, χ^0).

A curiosity that might arise is that of investigating whether ,in a different scheme with "suitably light"sparticles, there might be more interesting effects.

Our "curious" analysis was devoted to a scheme with a very light stop.

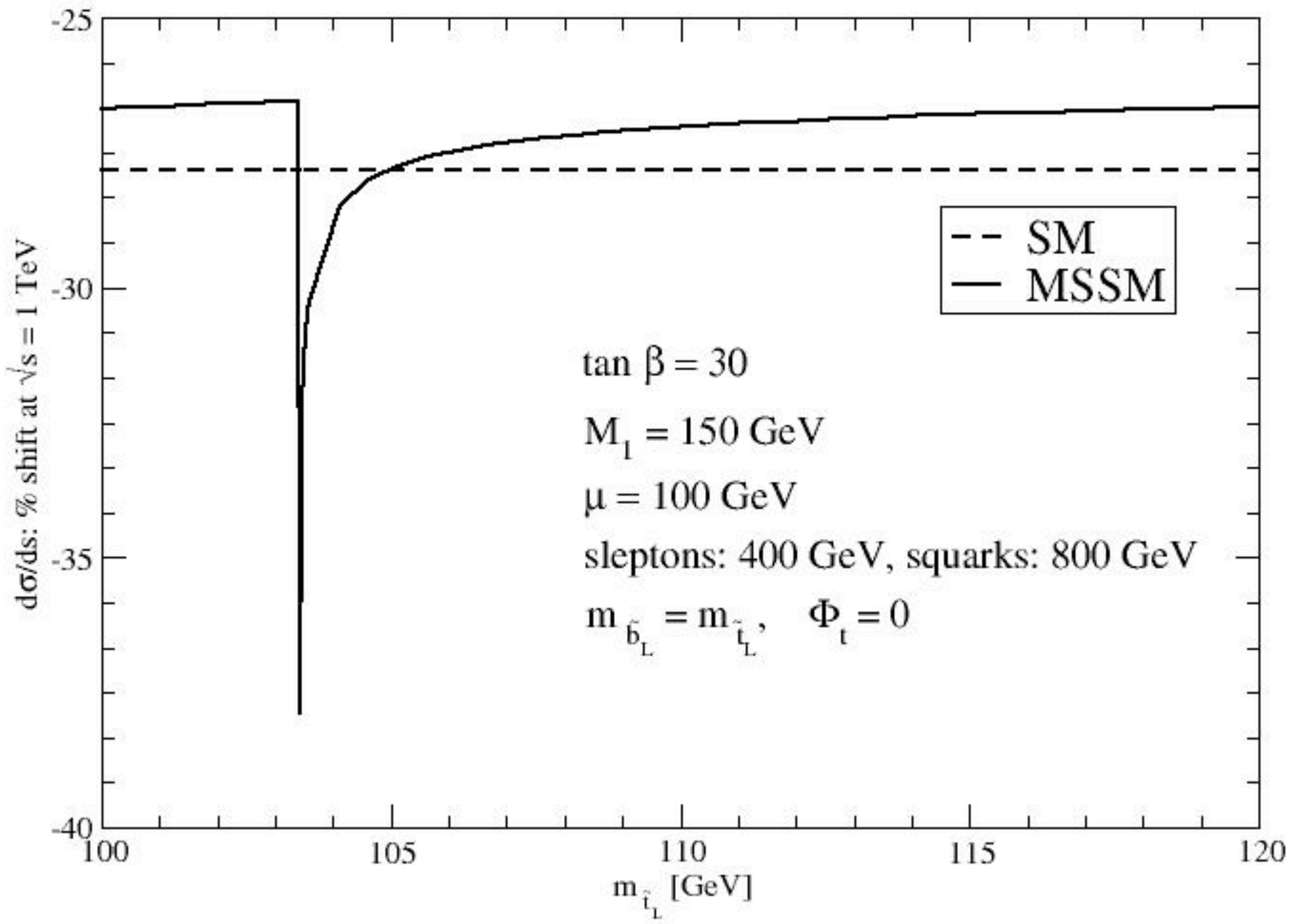
We considered a model that was proposed in the last CERN Flavor meeting (seminar by T.Lari, see e.g.Balazs, Carena,Menon,Morissey, Wagner, Phys.Rev.D70-2005)

and an old point of Hollik,Mosle,Wackeroth (Nucl.Phys.B516,98).

Our first results: no special effect found in correspondence with the chosen bench. points.

For the “Hollik” point, there is an effect, but only of “threshold” kind.

A more rigorous analysis (with widths) requested!



-25
-30
-35
-40
100
105
110
115
120
dσ/ds: % shift at √s = 1 TeV
SM
MSSM
tan β = 30
M1 = 150 GeV
μ = 100 GeV
sleptons: 400 GeV, squarks: 800 GeV
m b̃L = m t̃L, Φt = 0
m t̃L [GeV]

CONCLUSIONS.

IN THE PROCESS OF T-CHANNEL SINGLE TOP PRODUCTION AT LHC, THE SM ELECTROWEAK ONE LOOP EFFECT ON THE RATE IS SIZEABLE AND CANNOT BE FORGOTTEN.

THE GENUINE SUSY EFFECT IN THE MSSM WITH mSUGRA SYMMETRY BREAKING APPEARS MODEST.

(modulo possible threshold effects e.g. for special light stop scenarios...?).

IN ANY CASE: EVEN IF THE "GENUINE" SUSY EFFECT IS SMALL, THE OVERALL MSSM ONE-LOOP ELECTROWEAK EFFECT ON THE RATE REMAINS "LARGE" AND,IN PRINCIPLE, VISIBLE.

IN THIS SENSE, WE AGREE WITH THE ORIGINAL STATEMENT OF TAIT AND YUAN ,THAT DEFINED THE SINGLE TOP PRODUCTION PROCESS AS A

WINDOW TO NEW PHYSICS.