IFAE2007

Napoli, 11-13 Aprile 2007

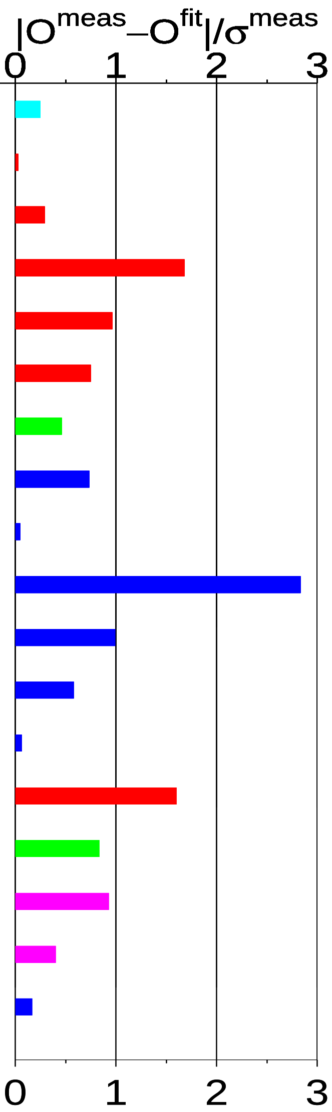
NUOVA FISICA

Stefania De Curtis

Tommaso Lari

Il Modello Standard descrive con notevole successo le interazioni delle particelle elementari....

	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4959
σ^0_{had} [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.743
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01643
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21581
R_c	0.1721 ± 0.0030	0.1722
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.404 ± 0.030	80.376
Γ_W [GeV]	2.115 ± 0.058	2.092
m_t [GeV]	172.5 ± 2.3	172.9



Tuttavia crediamo tutti che sia soltanto una teoria efficace di bassa energia

- Non incorpora la gravita'
- Naturalezza della scala elettrodebole
- Massa dei neutrini
- Materia Oscura
- Bariogenesi
- Masse dei fermioni
- ....

Nuova Fisica nel settore del top

- Nuova Fisica nel settore del top ad LHC (Benucci)

Supersimmetria

- Misure di Nuova Fisica al Tevatron (Rossi)
- *Produzione di stop-chargino ad LHC (Macorini)*
- Ricerche di SUSY con I primi dati di LHC (De Sanctis)
- Misura dello spin del neutralino ad LHC (Biglietti)

Bosoni di Higgs

- *Rilevazione dei bosoni di Higgs pesanti dell'MSSM (Moretti)*
- Ricerche di Higgs supersimmetrico ad LHC (Heldmann)
- *Fenomenologia dei modelli di Higgs composto (Contino)*
- *$pp \rightarrow WW$: un nuovo canale per testare scenari senza Higgs (Accomando)*

Dimensioni extra, nuove simmetrie, tecnicolore

- *Fenomenologia dei modelli di Higgs composto*
- *Rottura di simmetria elettrodebole e Materia Oscura da una quinta dimensione (Serone)*
- *Masse fermioniche e simmetrie discrete (Feruglio)*
- *Unificazione via nuove teorie di Tecnicolore (Sannino)*
- Nuovi bosoni di gauge ed extra dimensioni ad LHC (Palma)

Nuova Fisica nel settore del top ad LHC (Benucci)

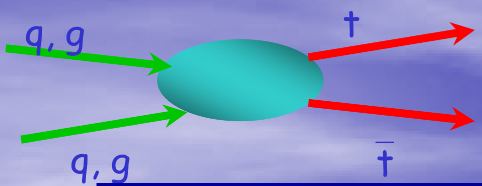
- t quark production and decays are evaluated within the Standard Model **with high accuracy** without any phenomenological parameters
- t quark decays ONLY through t→bW. Other decay channels have BR<10^{-3}
- $\tau(t) \sim 5\ 10^{-25}$ s, $\tau_{QCD} \sim 10^{-24}$ s: no formation of top-hadrons

Any observation of unusual process with top is an indication of a New Physics

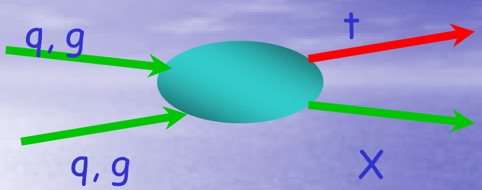
High statistics of tops at LHC: precision measurements possible, limited by systematics
10 $t\bar{t}$ pairs per day @ Tevatron ⇨ 1 $t\bar{t}$ pair per second @ LHC

- precise m_t measures will constrain the Higgs and enter the SUSY world
- cross-section and spin correlation in $t\bar{t}$ examine the QCD production
- the secrets of single-top: precise $|V_{tb}|$, hints of W', $H^{\pm}$, FCNC
- sensitivity to anomalous coupling is good and points directly to New Physics

The top quark large mass, close to the electroweak scale, makes it unique. Precise top measurements offers the possibility to test the Standard Model and open a window on New Physics effects.



t t̄ pair production



single-top production

Spin correlation in ttbar pairs

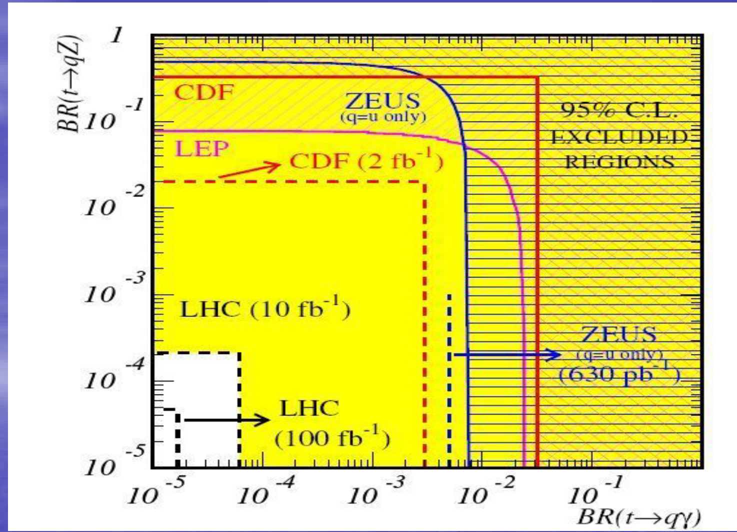
$$A = \frac{N(t_L\bar{t}_L + t_R\bar{t}_R) - N(t_L\bar{t}_R + t_R\bar{t}_L)}{N(t_L\bar{t}_L + t_R\bar{t}_R) + N(t_L\bar{t}_R + t_R\bar{t}_L)}$$

qq production: $3S^1$ state (⇑ ⇑)

gg production: $3S^0$ state (⇑⇓)

SM prediction at LHC:

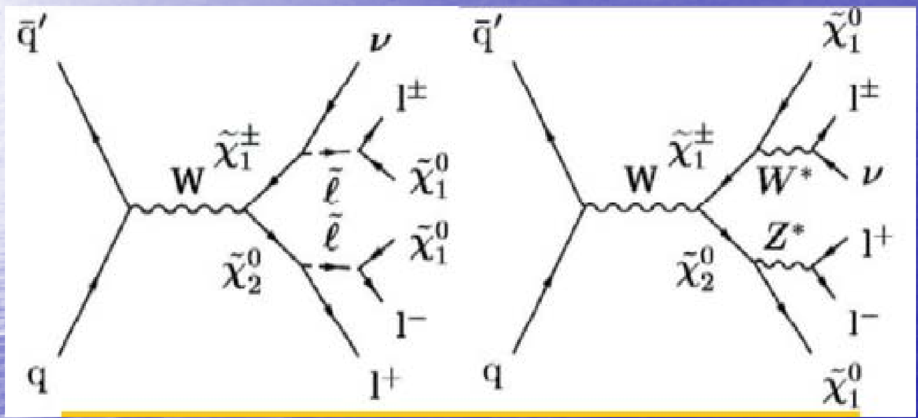
$$A = 0.311^{+0.034}_{-0.035}(stat) \pm 0.028(syst)$$

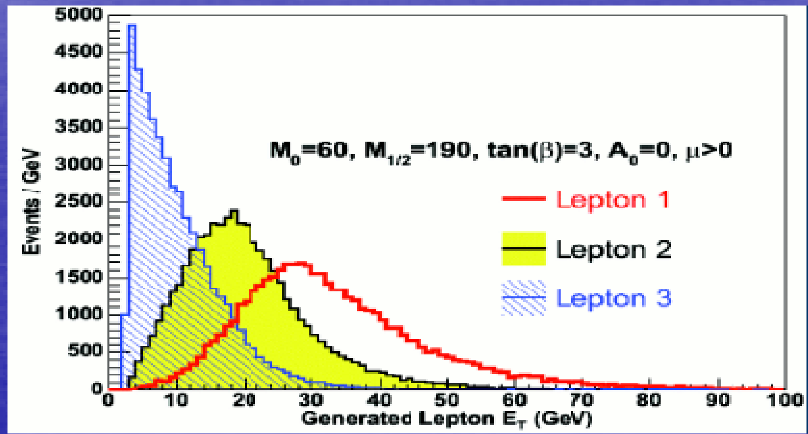


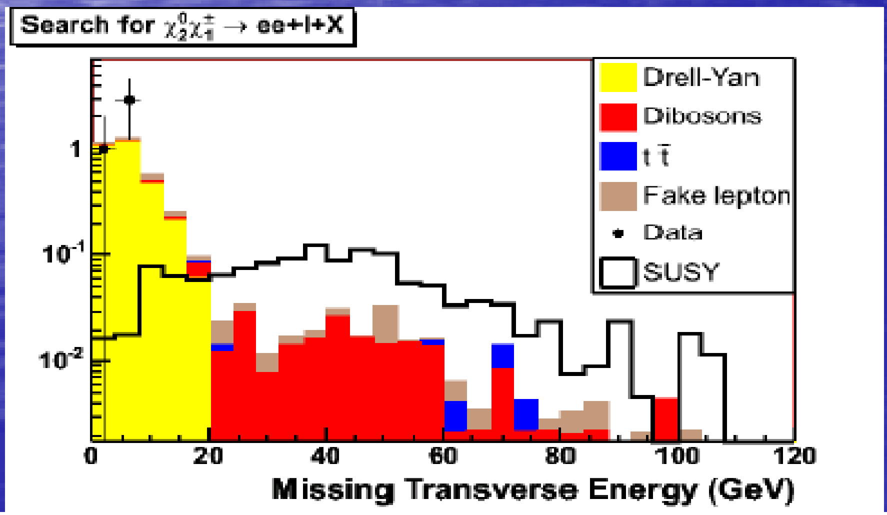
	Tevatron today	LHC	LHC > 100 fb^{-1}
$\delta\sigma(t\bar{t})$	12%	<7-8%	<7-8%
$\delta\sigma_{EW}(t)$	30%	< 9-10%	< 7-8%
Δm_t (GeV)	1.2	~ 1.0	< 1.0
$\Delta\mathcal{A}/\mathcal{A}$ (spin correlation)	≈50%	<7-8%	<5-6%
$\delta\lvert V_{tb}\rvert$ (direct meas.)	15%	<4-5%	<3-4%
BR(t→Zq)	10^{-1}	5 10^{-4}	1 10^{-4}
BR(t→Zγ)	10^{-2}	1 10^{-4}	4 10^{-5}

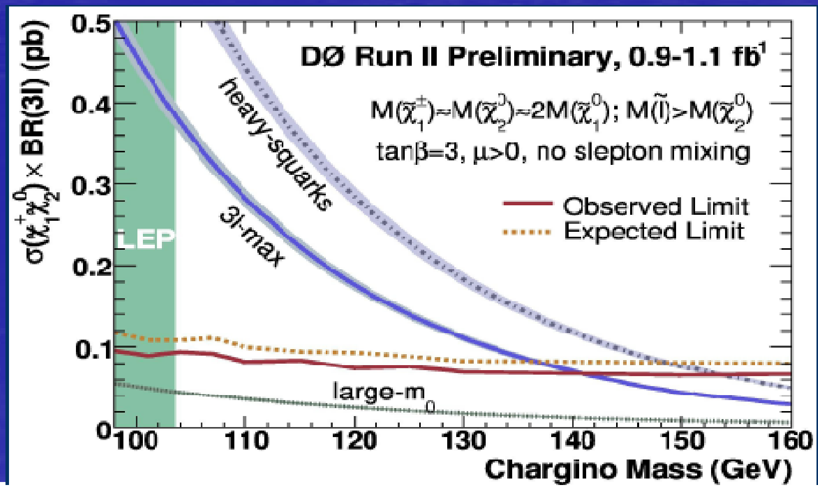
Ricerche di supersimmetria al Tevatron (Rossi)

- **Chargino+neutralino production: three leptons plus missing energy**
- Striking signature, but also challenging low-pt lepton reconstruction



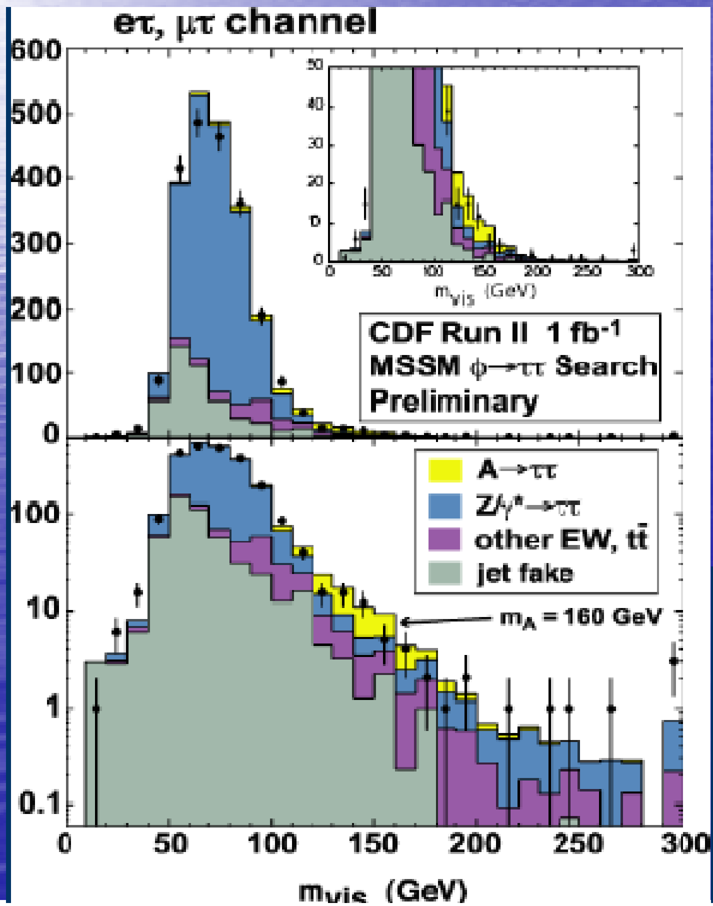


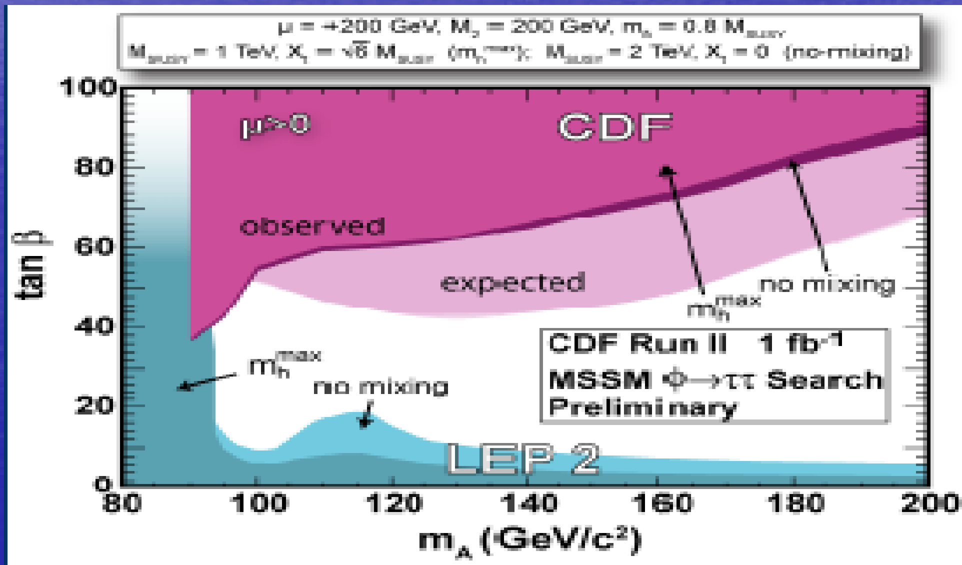




Search for neutral Higgs decaying into tau pairs

- In the MSSM there are two Higgs doublets
  - 5 Higgs particles after the EWSB: **h,H,A,H$^{\pm}$**
  - MSSM Higgs masses are governed by **m_A** and **$\tan\beta = v_u/v_d$**
- At large **tanβ** the MSSM Higgs couplings to down-type fermions, e.g. b-quark, are enhanced w.r.t. the SM





- CDF observed limit weaker than expectation
  - due to some excess of events in the data sample
- Both experiments have similar results:
  - in the region $90 < m_A < 200$ GeV,

    tanβ values in the 40-60 range are excluded for the no-mixing and the m_h^{max} scenarios

Produzione di stop-chargino a LHC (Macorini)

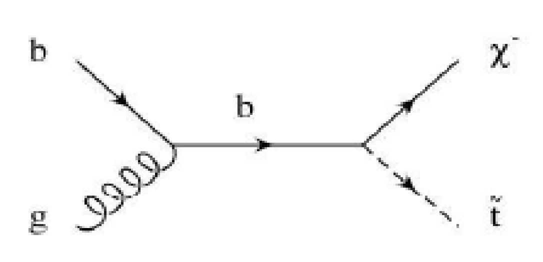
Perché $\tilde{t}_a \chi_i$?

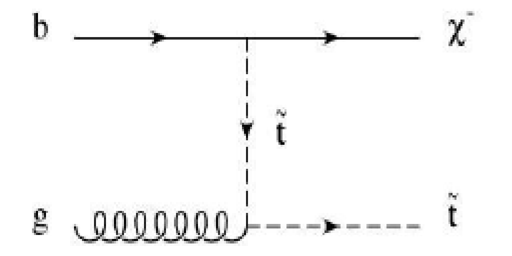
- Leggeri ...
- Complementare a $\tilde{t}_a \tilde{t}_a^*$: accesso ai parametri elettrodeboli e accoppiamenti Yukawa del MSSM:

$$\tan\beta,\ A_i^{L,R}(\tilde{t}_a)$$

- Analogo supersimmertico del "Single Top"

CKM-SUSY [B. Fuks]





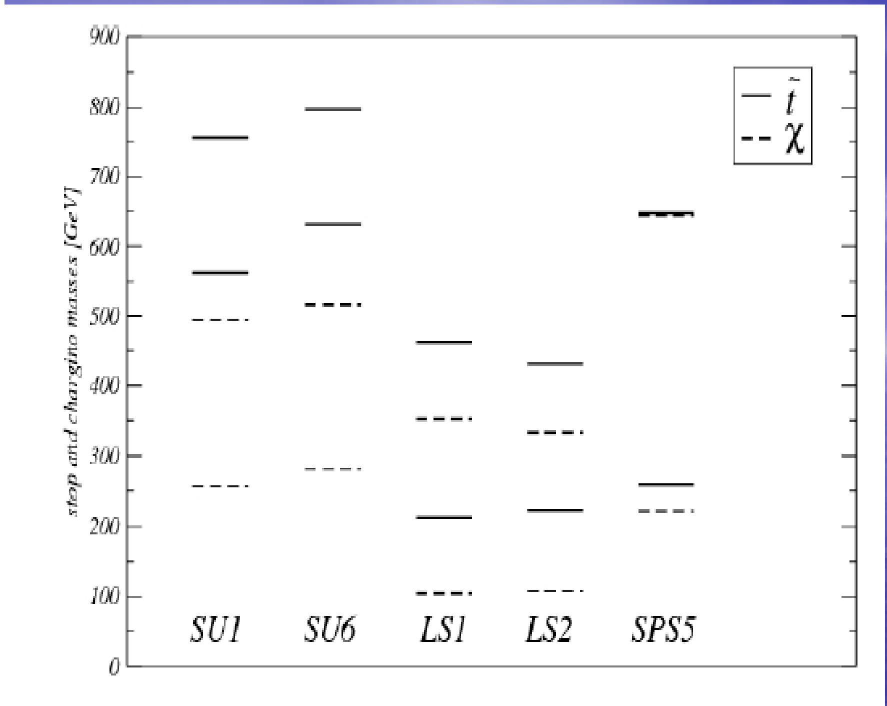
Gli accoppiamenti al Born Level

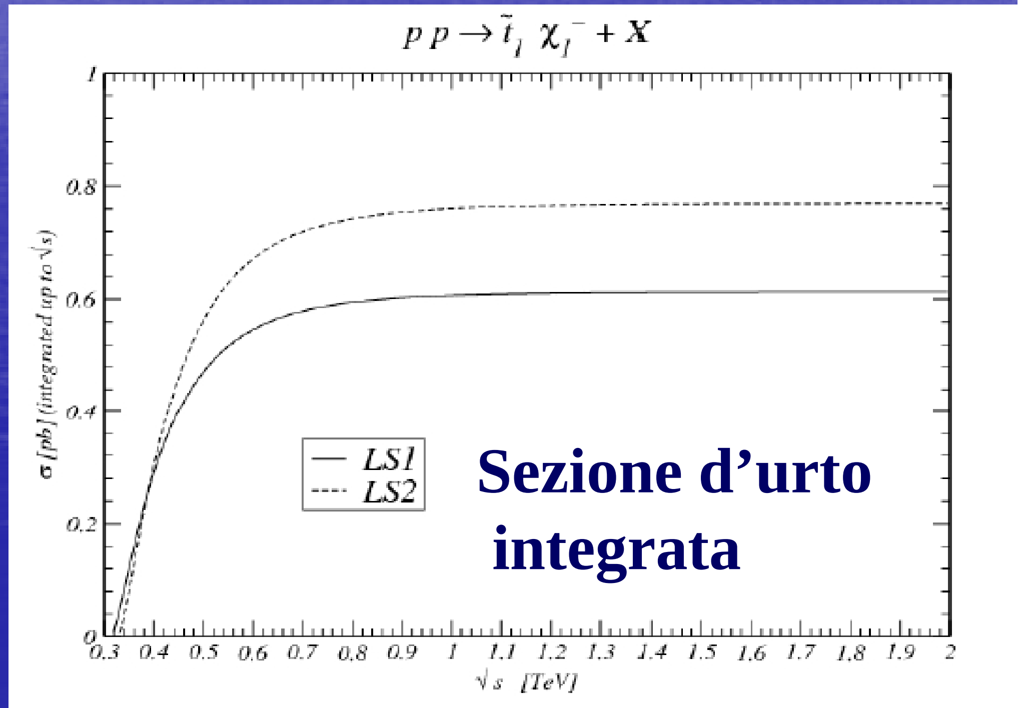
$$A_i^L(\tilde{t}_L) = -\frac{e}{s_W} Z_{1i}^+ \quad A_i^L(\tilde{t}_R) = \frac{e\, m_t}{\sqrt{2} M_W\, s_W \sin\beta} Z_{2i}^+$$

$$A_i^R(\tilde{t}_L) = \frac{e\, m_b}{\sqrt{2}\, M_W\, s_W \cos\beta} Z_{2i}^{-*}$$

coinvolgono le matrici di mixing dei chargini $Z_{ki}^{\pm}$ che ne controllano la composizione "Higgsino" "gaugino":

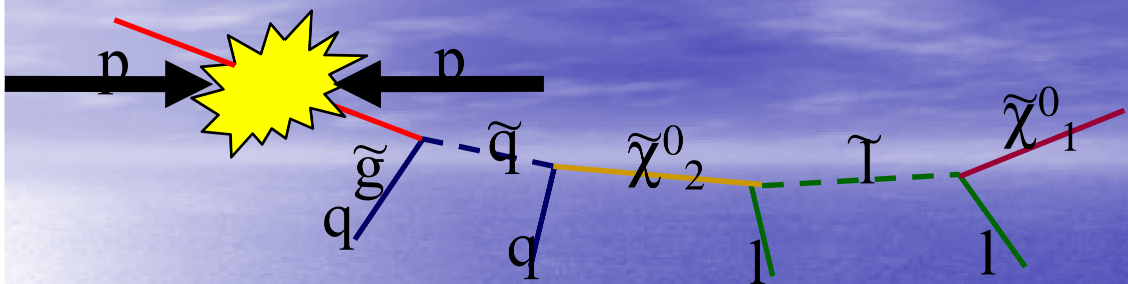
- la componente "Higgsinica" é direttamente sensibile a $\tan\beta$



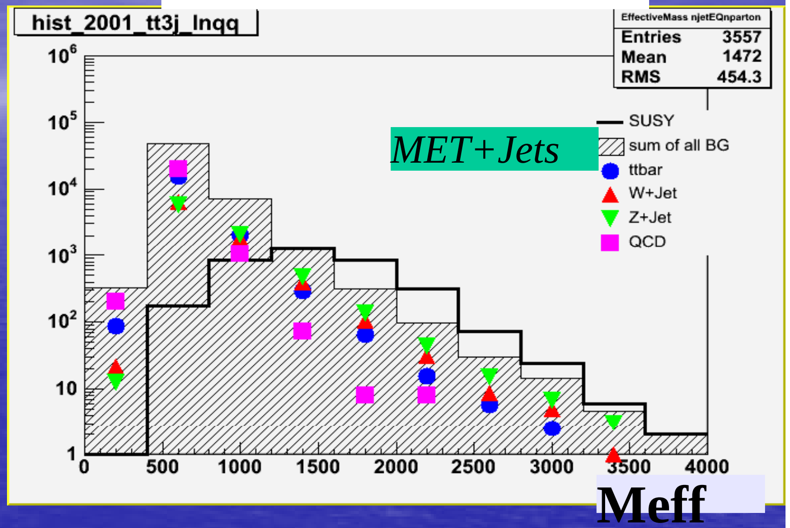


- 4 parametri: θ_t, $\phi_{L,R}$ (Matrici di mixing dei chargini), e $\tan\beta$.
- Misura dei singoli parametri $\Rightarrow$ possibile con misure della polarizzazione del chargino.

Ricerca di SUSY con i primi dati di LHC (De Sanctis)



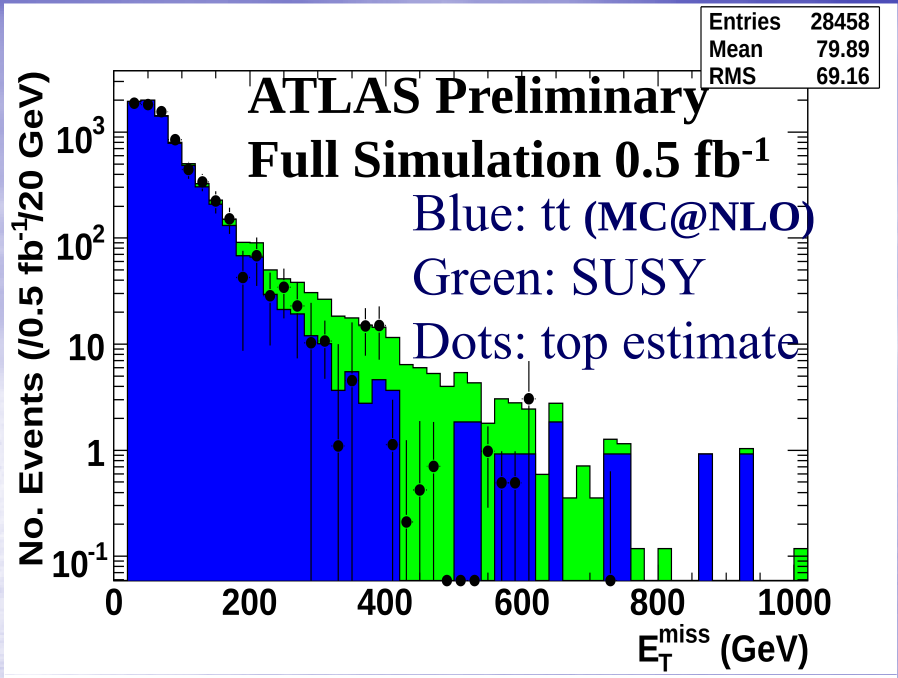
M_{eff}=MET+ΣP_T^j

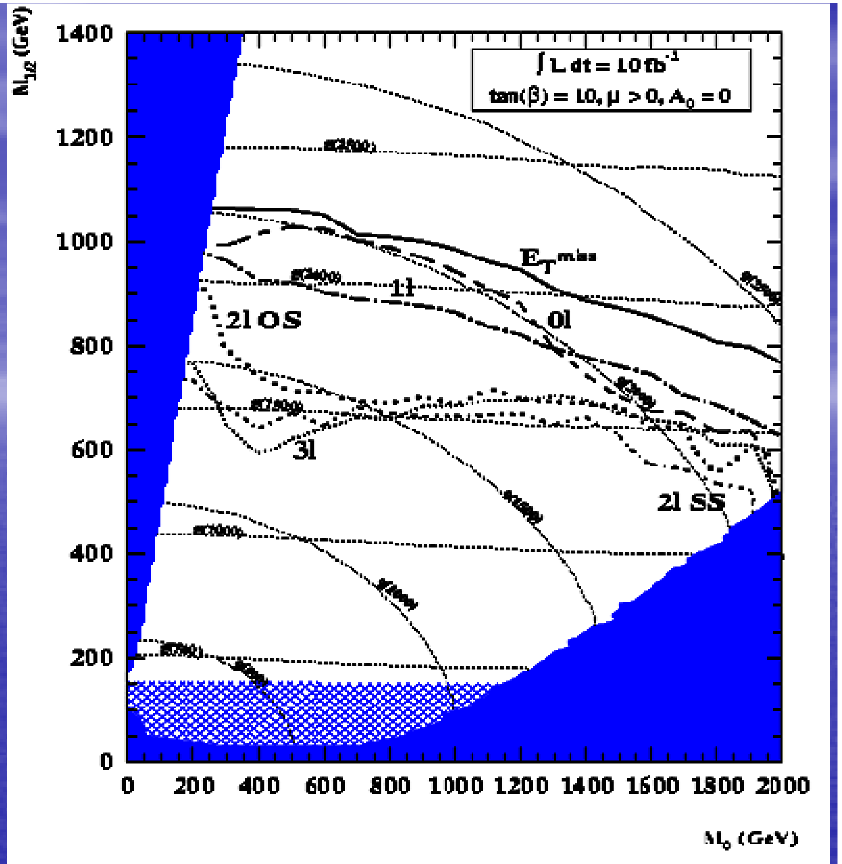


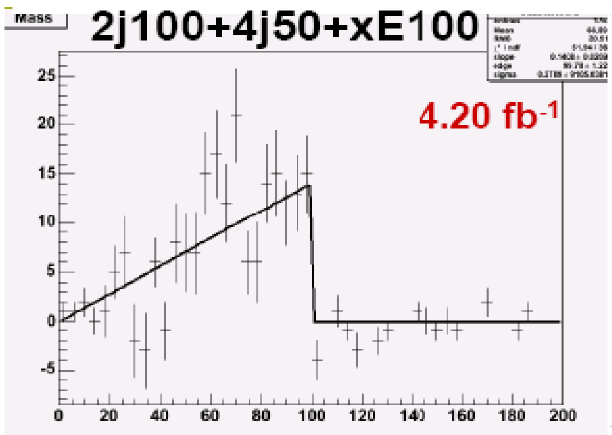
Most general strategy:

Jet + EtMiss + n leptons

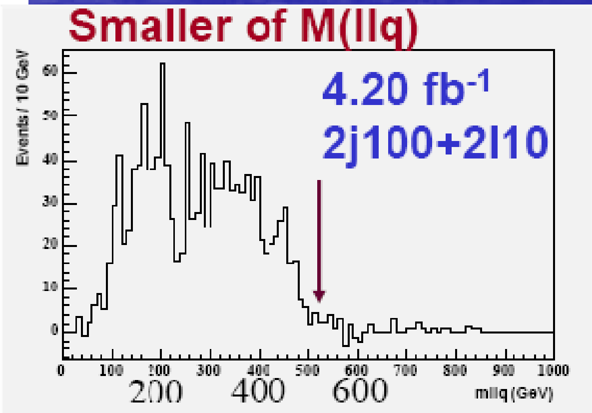
- **Use a set of kinematical cuts to reduce SM backgrounds and plot some kinematical variable that shows a deviation from SM previsions;**
- **Backgrounds:**
- **Real missing energy from SM processes with hard neutrino (tt, W+jets, Z+jets events);**
- **Fake missing energy or lepton from the detector;**
- **A good understanding of both SM physics and detector (missing energy expecially) critical to claim excess over SM predictions.**



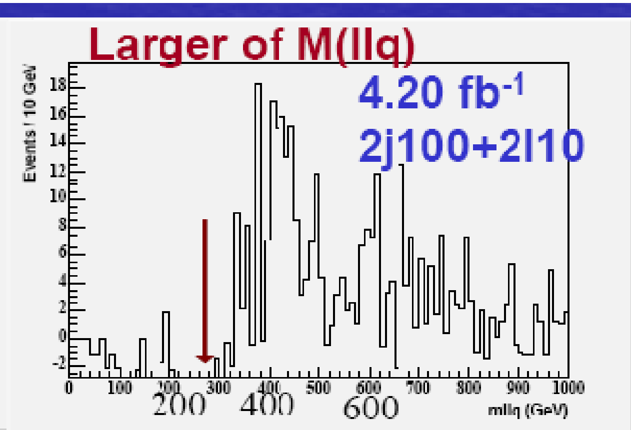




Edge after cuts: 99.8 ± 1.2 GeV



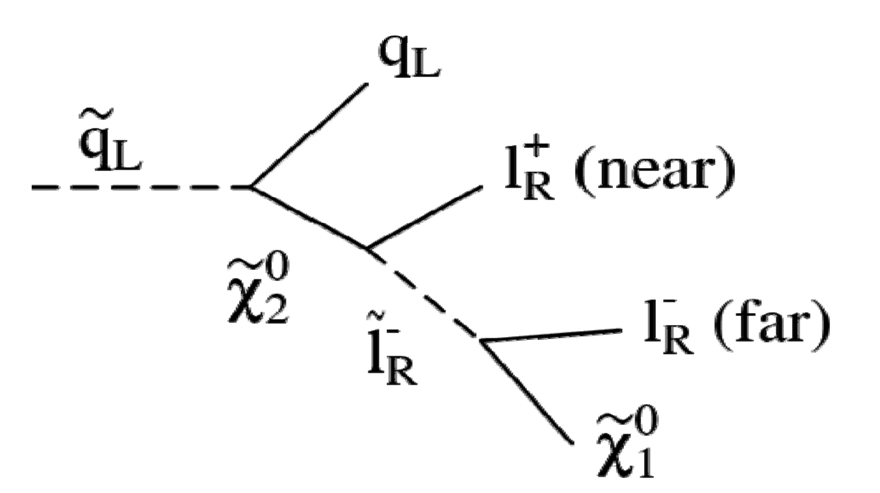
M_{llq}^{max} =501 GeV

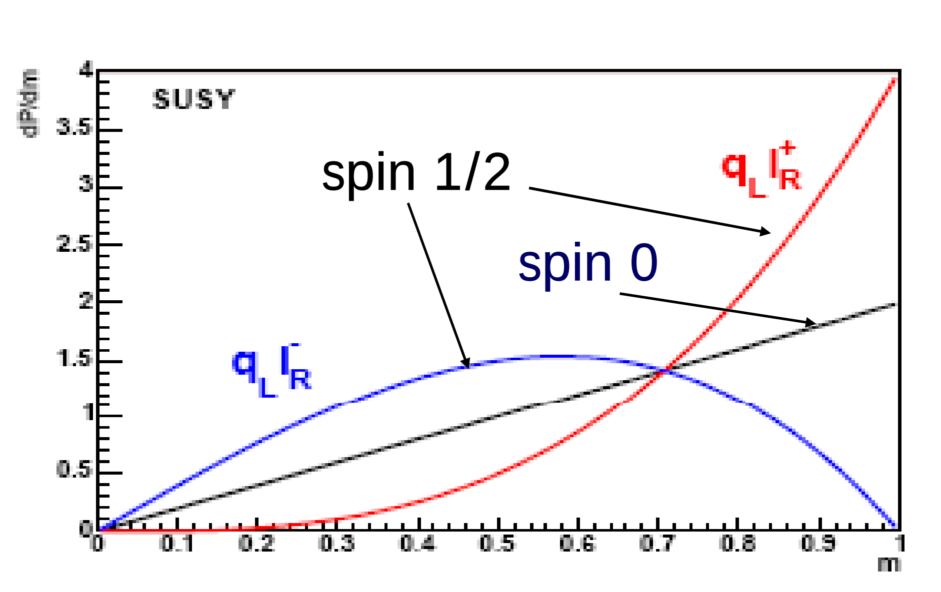


M_{llq}^{min} =271 GeV

Misura dello spin del neutralino ad LHC (Biglietti)

2010: ATLAS e CMS hanno osservato la produzione di particelle colorate che decadono in una particella invisibile (getti+missEt), e misurato un po' di masse.
Si tratta davvero di supersimmetria?
E' importante misurare lo spin delle nuove particelle.





L'asimmetria di carica è diluita poichè

1. In generale non è possibile distinguere sperimentalmente tra il leptone *near* e *far:* si sommano le masse invarianti $m(ql^{far})$ e $m(ql^{near})$
2. La cascata di decadimento C-coniugata (dall'antisquark left-handed) porta ad un'asimmetria di carica uguale ed opposta. Ad LHC viene prodotto un numero maggiore di squarks che anti-squarks per cui l'asimmetria non si cancella esattamente

SU1 point: 7.8 pb x 1.6%
Rapporto squarks/anti-squarks ~3.5

$$\tilde{q}_L \to q\,\tilde{\chi}_2^0 \to q\,\tilde{l}_L\,l \to q l^{\pm} l^{\mp} + \tilde{\chi}_1^0$$

264 255 soft hard 137

$$\tilde{q}_L \to q\,\tilde{\chi}_2^0 \to q\,\tilde{l}_R\,l \to q l^{\pm} l^{\mp} + \tilde{\chi}_1^0$$

264 154 hard soft 137

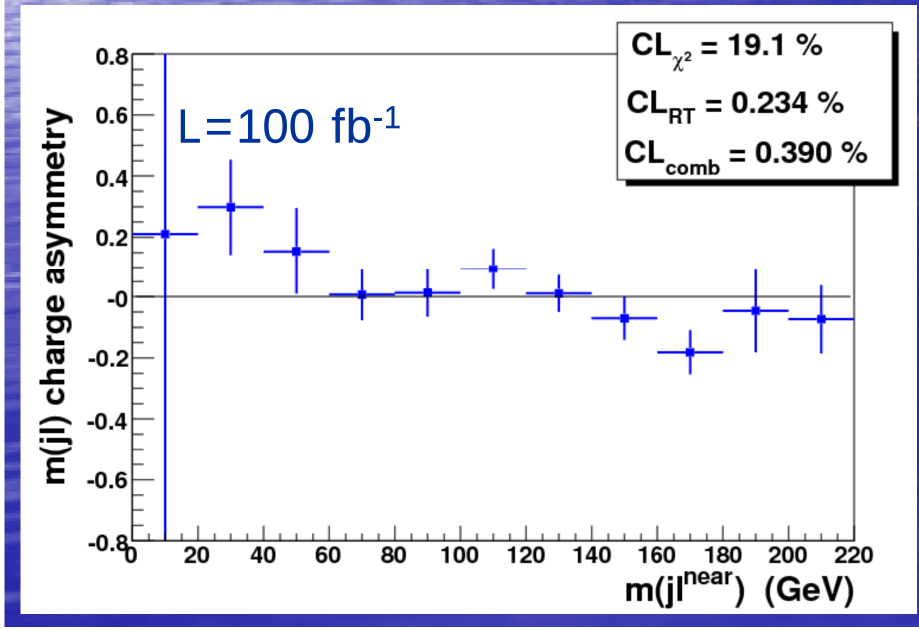
SU3 point: 19.3 pb x 3.8%
Rapporto squarks/anti-squarks ~3

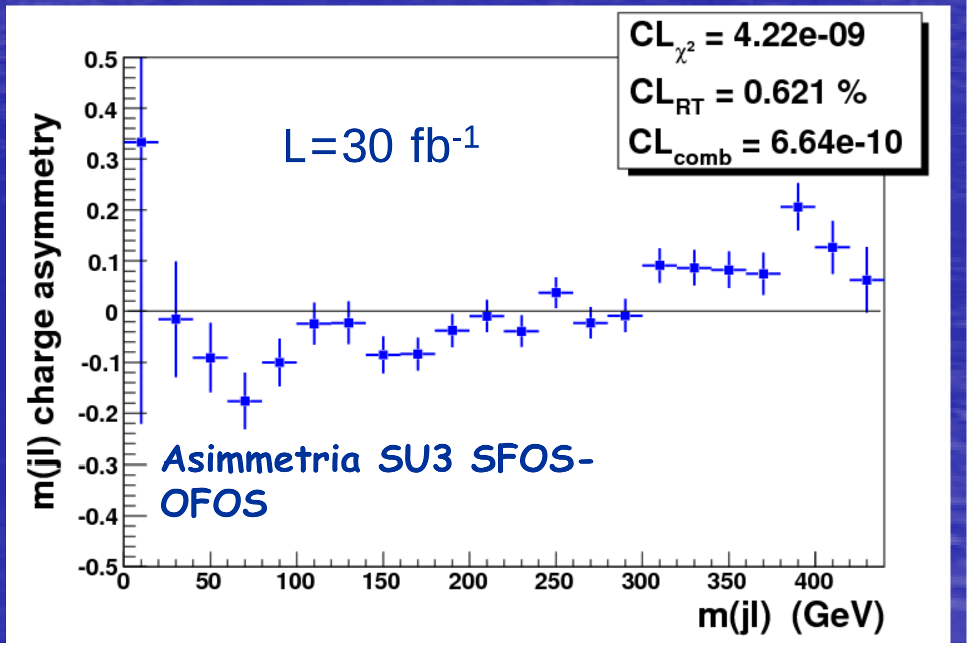
$$\tilde{q}_L \to q\,\tilde{\chi}_2^0 \to q\,\tilde{l}_R\,l^{\pm} \to q l^{\pm} l^{\mp} + \tilde{\chi}_1^0$$

219 155 118

- Cuts on missing energy and jet pt to reject SM background
- 2 Opposite Sign, Same Flavour (OSSF) electrons or muons. Subtract background from independent decay chains with the combination

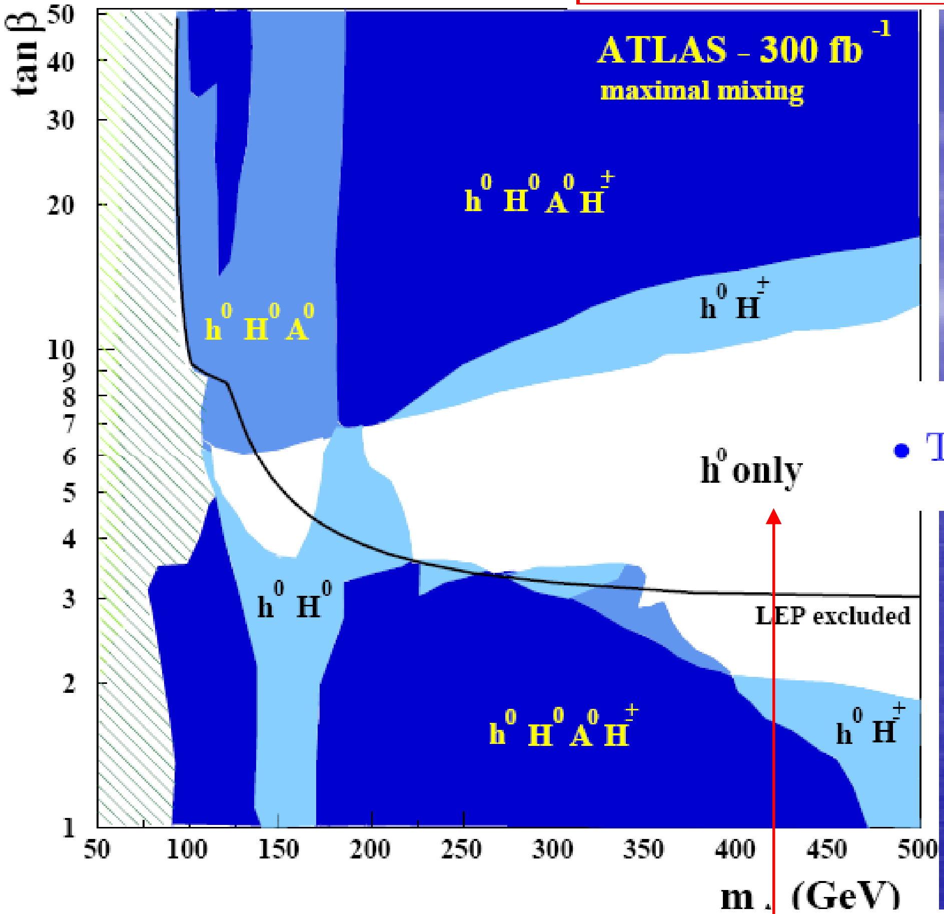
$$\mu^+\mu^- + e^+e^- - \mu^{\pm}e^{\mp}$$





How to Detect Heavy Higgs Bosons of the MSSM

Stefano Moretti



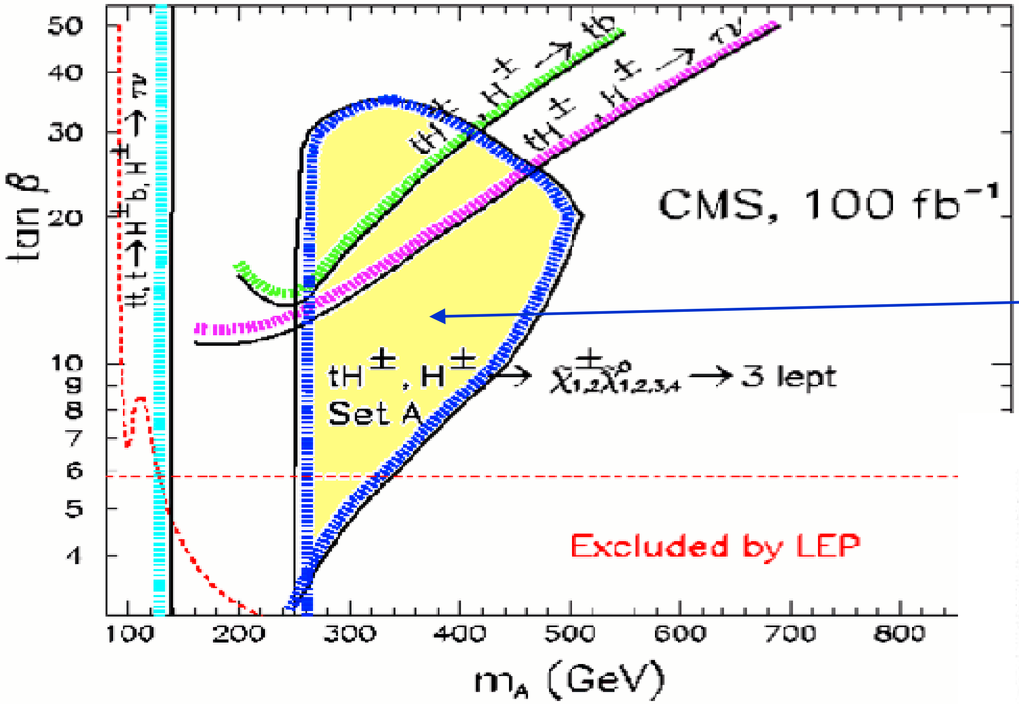
- They only include SM-particle to Higgs interactions

Imagine now unreachable coloured sparticles and light gauginos and sleptons (not from DY)

- LHC prospects from ATLAS and CMS for the MSSM

→ no-lose theorem but large decoupling SM-like area !

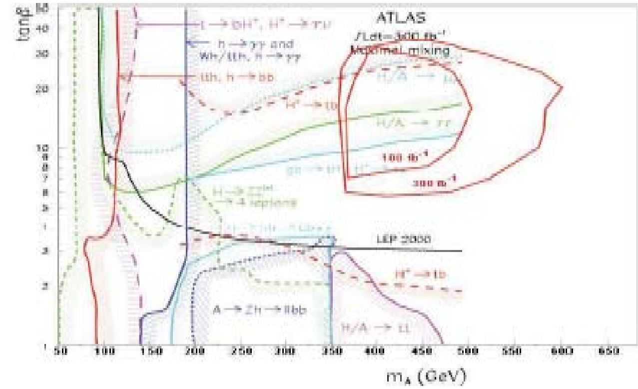
- Ought to observe second Higgs state or make precision measurements of BRs, Γs, etc.
- Why do not reduce the SUSY mass spectrum ? To sub-TeV scales.
- (Preferred scenario for SUSY couplings unification)



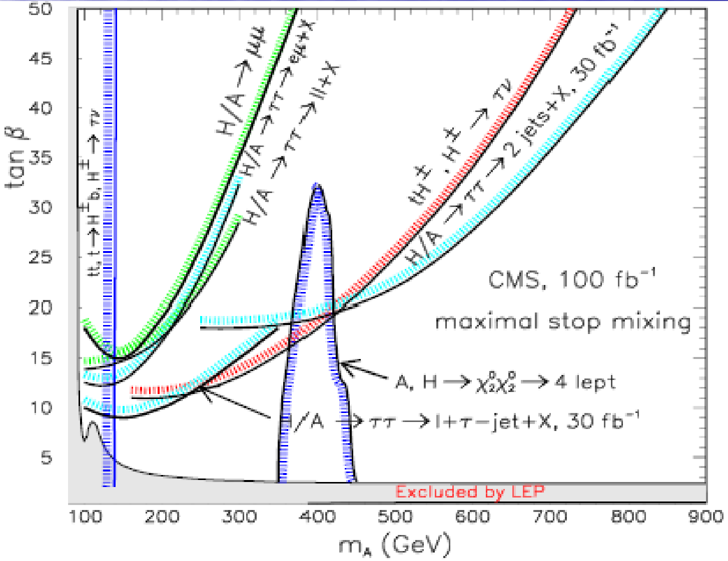
MSSM parameters:

$M_2 = 210$ GeV,
$\mu = 135$ GeV,
$M_{sleptons} = 110$ GeV,
$M_{squark,\ gluino} = 1$TeV

PRELIMINARY !!!

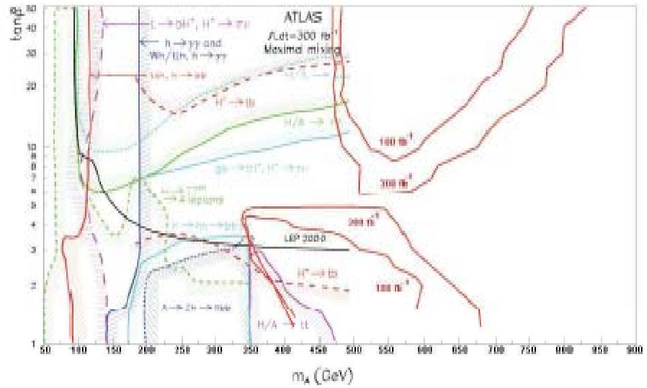


$\tilde{\chi}_2^0\tilde{\chi}_2^0$ dominated: $M_2 = 180$ GeV, $M_1 = 90$ GeV, $\mu = -500$ GeV, $m_{\tilde{\ell}_{soft}} = m_{\tilde{\tau}_{soft}} = 250$ GeV



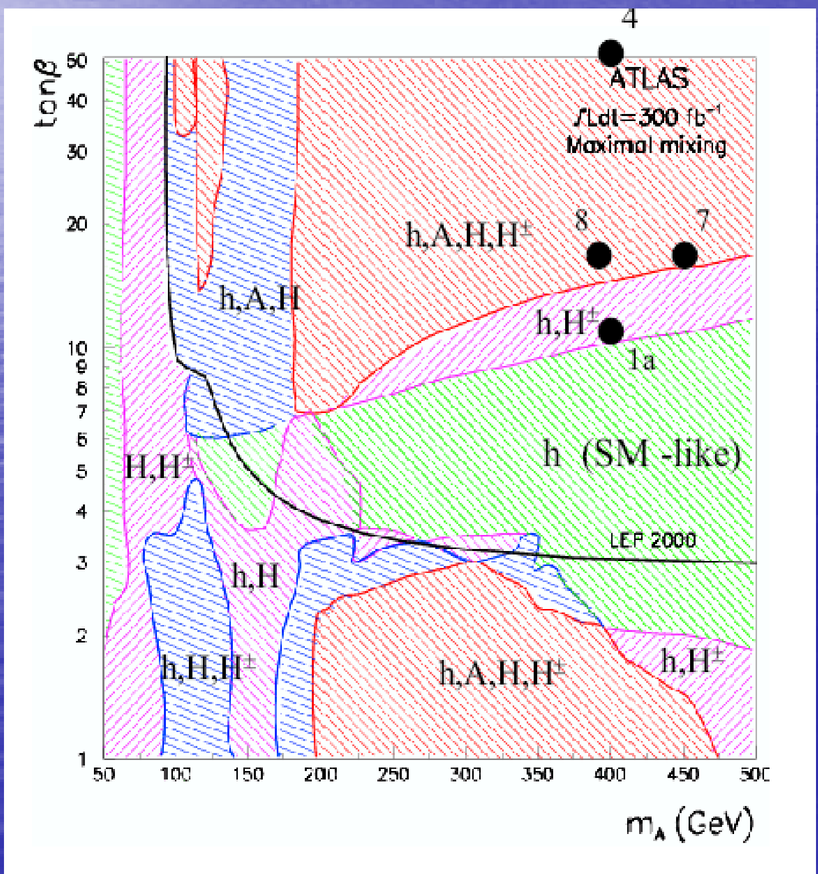
CMS after 100 fb^{-1} assuming $M_1 = 90$ GeV, $M_2 = 180$ GeV, $\mu = 500$ GeV, $M_{\tilde{\ell}} = 250$ GeV, $M_{\tilde{q},\tilde{g}} = 1000$ GeV.

AND NOT ATLAS !!!



Heavier -inos dominated: $M_2 - 200$ GeV, $M_1 - 100$ GeV, $\mu - -200$ GeV, $m_{\tilde{\ell}_{soft}} - 150$ GeV, $m_{\tilde{\tau}_{soft}} - 25$

- If Higgs-sparticle interactions are allowed, a rich phenomenology emerges
- Under these conditions all MSSM Higgs bosons can *potentially* be observed (some rescaling of SM-like channels may be needed)
- Approach so far: optmise yield of clean signatures implies discovery contours not overlayable (i.e., different MSSMs) on usual plane ($M_A, \tan\beta$)
- Need to define SUSY Higgs benchmarks
  (K Jacobs, S Moretti, P Osland et al., in progress)



Snowmass points and slopes: SPS
hep-ph/0202233

Chosen with SUSY space rather than Higgs space in mind.

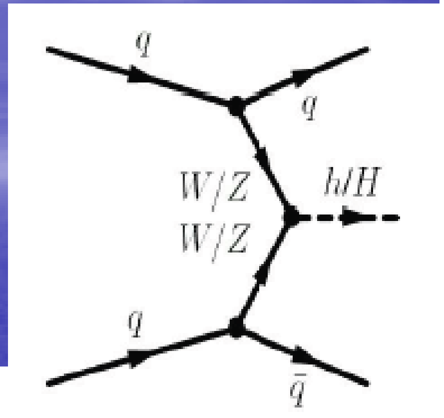
9 points: 5+1 mSugra, 2 GSMB, 1 AMSB

Only 4 points feature in usual Higgs plane. 1a, 4 (mSUGRA) 7,8 GMSB.

Benchmarks from Carena et al. Eur. Phys. J. C 26 601 (2003) not designed to take light SUSY particle effects into account, except in stop loops (gluo-phobic Higgs scenario)

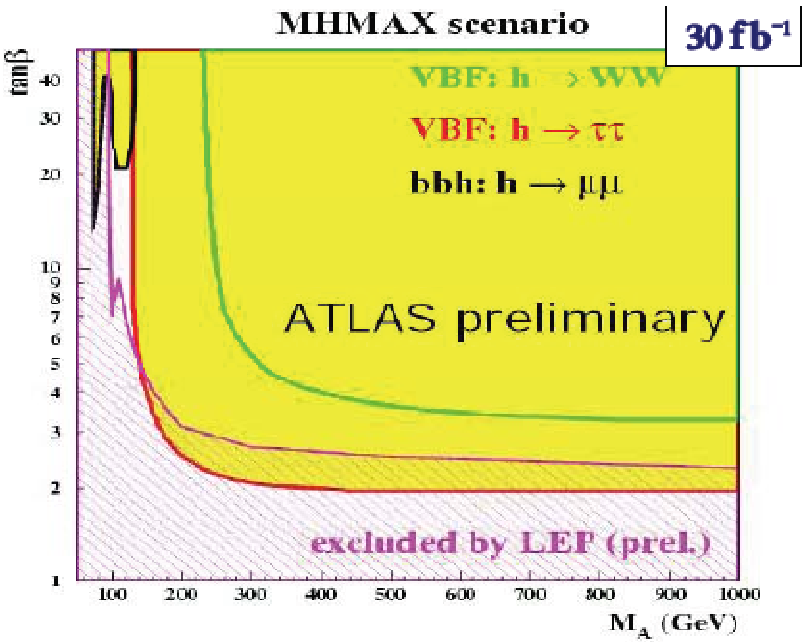
Ricerche di Higgs supersimmetrici ad LHC (Heldmann)

- In the MSSM there are two Higgs doublets
  - 5 Higgs particles after the EWSB: h,H,A,$H^{\pm}$
  - MSSM Higgs masses are governed by m_A and $\tan\beta = v_u/v_d$
- At large $\tan\beta$ the MSSM Higgs couplings to down-type fermions, e.g. b-quark, are enhanced w.r.t. the SM

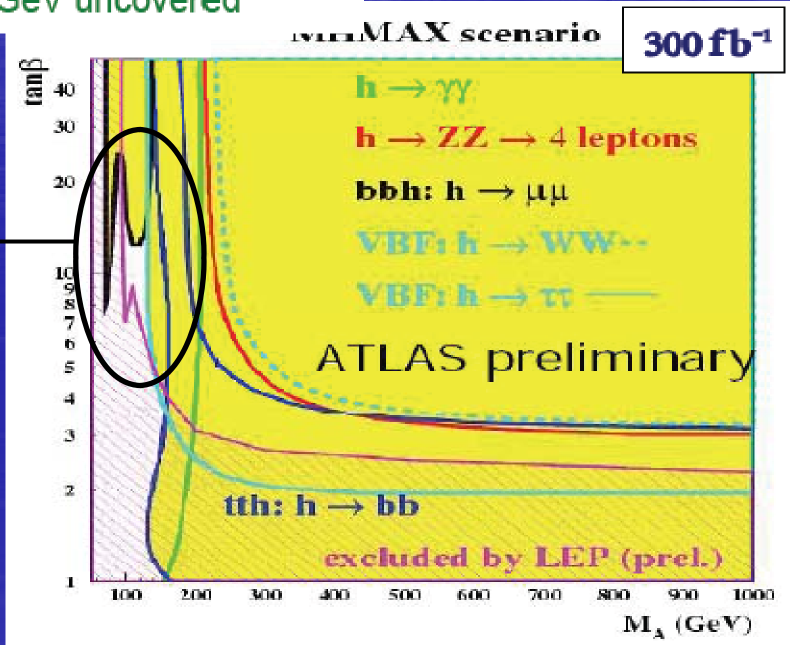


Lightest Higgs discovery potential (n.b. in MSSM m_h < 135 GeV)

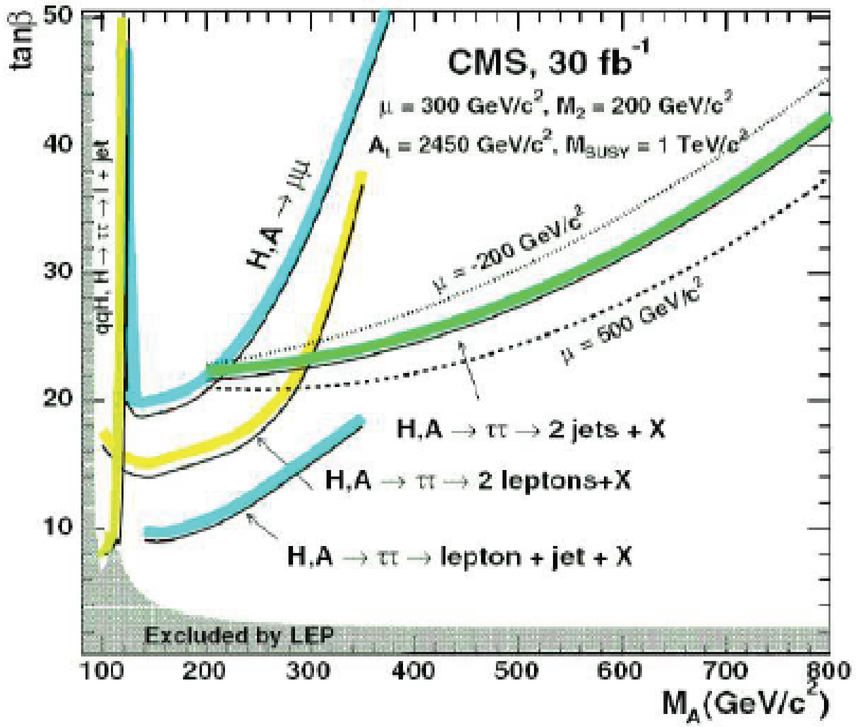
- VBF dominates for low luminosity
- small area from bbh→μμ
- large space covered by several channels
- determination of parameters possible
- small are m_h ~ 95 GeV uncovered



Covered by heavy Higgs



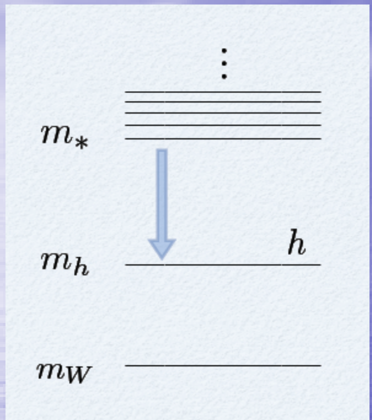
Heavier Higgs discovery potential

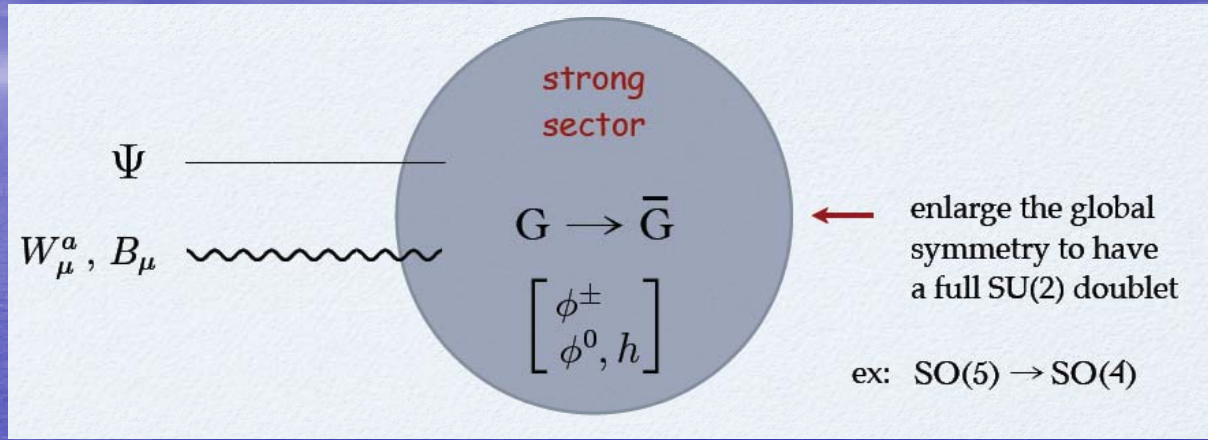


- H/A → μμ visibile solo per una regione ridotta di parametri (ma consente una misura molto precisa della massa)
- H/A → ττ ricostruito assumendo che I neutrini del tau siano collineari con I prodotti visibili (perche' boostati). Visibile a tan β elevati.
- H^+ → tb, τν visibili a largo tan β
- A tan β moderato solo l'Higgs piu' leggero, simile a quello dello SM, e' visibile… a meno che decadimenti in particelle SUSY non aiutino

R. Contino: fenomenologia dei MCHMs

EWSB guidata da un Higgs leggero composto derivante da un settore fortemente interagente come pseudo-Goldstone boson





F_π = scale at which $G \to \bar{G}$

new parameter: $\epsilon = \dfrac{v}{F_\pi}$ $\quad 0 \leq \epsilon \leq 1$

Come si fa a sapere che si tratta di un Higgs composto?
Misura degli accoppiamenti + int. forte in WW scattering

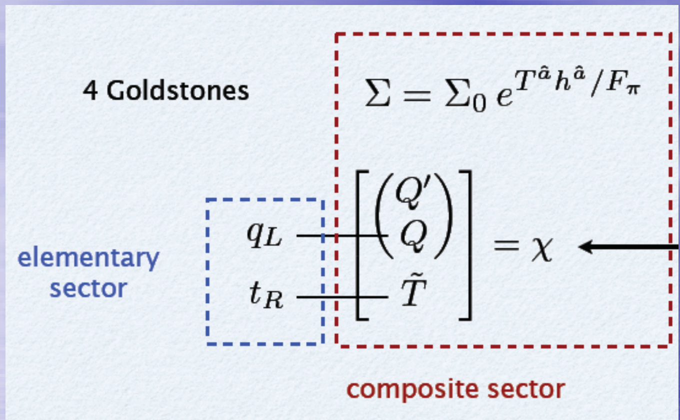
Evidenza indiretta da produzione di nuove risonanze del settore fortemente interagente: vettori e fermioni

necessaria una descrizione effettiva di bassa energia per lo studio della fenomenologia delle nuove risonanze:

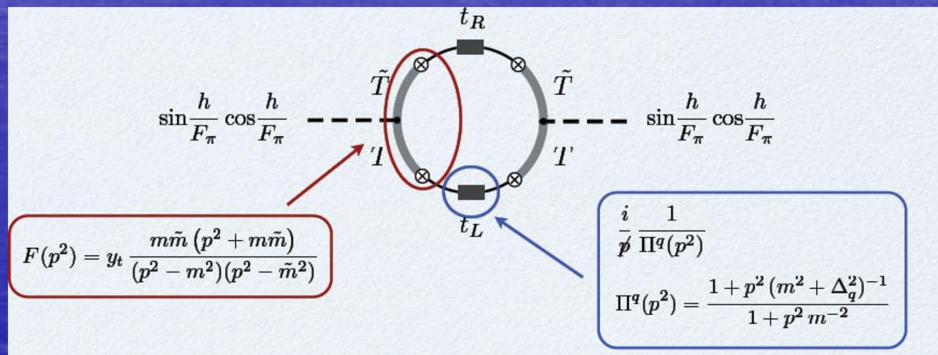
two-site model con accoppiamenti lineari tra il settore composto ed elementare

•Elementary sector:	{SM - Higgs} inter-elementary coupling: $g_{el} \sim 1$
•Composite sector:	{ρ, χ + Higgs} [$\supset$ excited massive copy of the SM] inter-composite coupling: $4\pi \gg g_* \gg 1$
•Mixing:	only mass mixings allowed
•Higgs:	H couples only to ρ and χ

A simple Two-Site SO(5)/SO(4) model



Potenziale di Higgs generato da loop di nuovi fermioni = no little hierarchy problem



Produzione di coppie di nuovi fermioni colorati e studio dei loro decadimenti

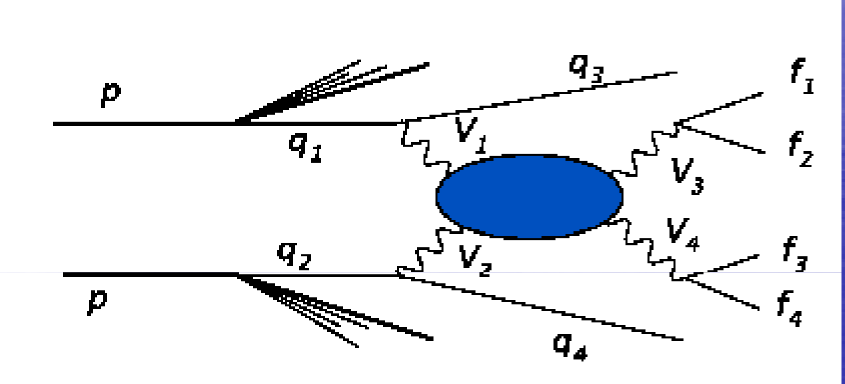
☆ Discriminating between an elementary and a composite Higgs must be a goal of the LHC

E. Accomando: VBS and gluon fusion to test EWSB at the LHC

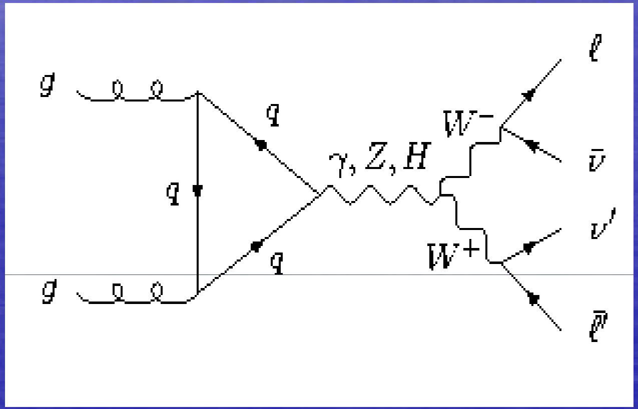
Higgsless scenario ⟶ **SM is lost, SUSY as well**

Where do we get clues on EWSB?

VBS at LHC



GGF: ex.



piu' altri diagrammi

If no Higgs VBS violates unitarity. W and Z strongly interacting at the TeV scale. Common signal: increased production of WL and ZL

VBS from six-fermion final states

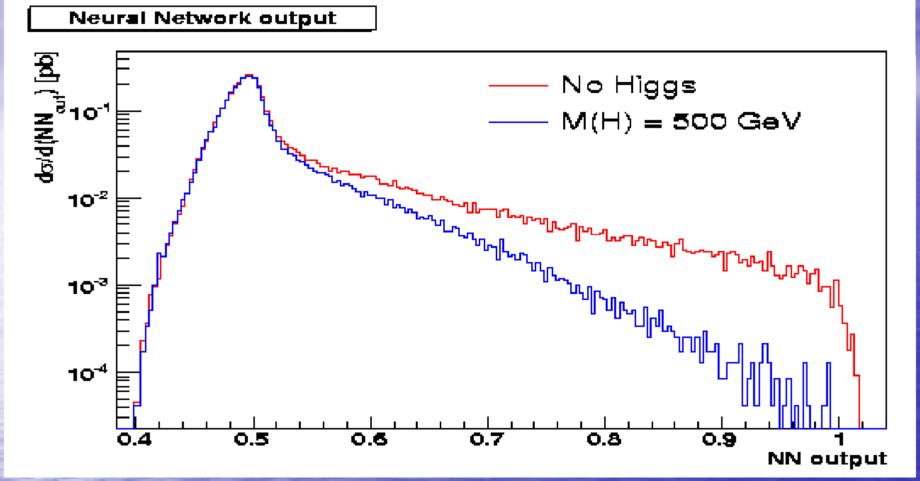
How to extract the VBS signal?

σ(VBS)=σ(no Higgs)-σ(light Higgs) *Barger(94)*

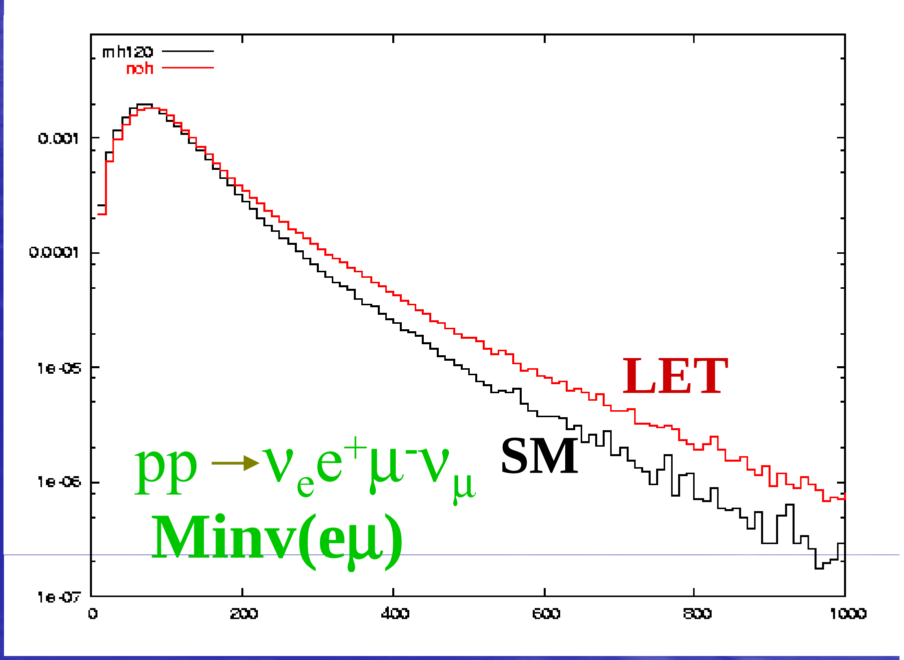
needs a complete Event Generator

LET Model vs SM with PHASE, with CMS Torino Mariotti e Bolognesi

VBS: the gold-plated channel



GGF: a new silver-plated channel



Great improvement from simultaneous analyses

M.Serone: EWSB e DM da extra dimensioni

$$G = SU(3)_w \times U(1)'$$

•Higgs is an internal component of a 5D gauge field, gauge-Higgs unification
•Higgs potential V(H) is generated radiatively and non-local in the extra dim

• Massive bulk and massless chiral boundary fermions mix with each other. zero modes are the SM fermions. The Yukawa couplings are effective non-local couplings, exponentially sensitive to the microscopic parameters of the model

$$m_q \simeq M_W \frac{\lambda}{\sinh \lambda} \qquad \lambda = \pi R M$$

•Problems: Top and Higgs too light.
•Solution: break 5D Lorentz symmetry

- Fermions: $\overline{\Psi}\left[i\,\not{D}_4 - k D_5 \gamma^5\right]\Psi$
- Gauge fields: $-\frac{1}{2}\mathrm{Tr}\,F_{\mu\nu}F^{\mu\nu} - \rho^2 \mathrm{Tr}\,F_{\mu 5}F^{\mu 5}$

Address the compactification scale problem

- Double part of the bulk fields: $\phi \longrightarrow \phi_1,\ \phi_2$

  and impose twisted boundary conditions

$$\phi_1(y \pm 2\pi R) = \phi_2(y), \quad \phi_1(-y) = \pm\phi_2(y)$$

- Require interchange symmetry: $\phi_1 \leftrightarrow \phi_2$

- An order of magnitude hierarchy between the EW scale and $1/R$ is completely natural

All SM fields are $\mathbf{Z}_2$ even $\longrightarrow$ lightest $\mathbf{Z}_2$ particle absolutely stable (DM candidate)

DM candidate is identified as the $n = 1/2$ KK mode of the $U(1)_-$ bulk gauge field A_-

Its annihilation rate too small for correct relic density (too massive: $M_A \gtrsim 2.3$ TeV), **BUT** coannihilations (resonance) effects present, because typically several $\mathbf{Z}_2$ odd states are close in mass. They are **colored** particles and greatly enhance annihilation rate, giving realistic relic densities

Fine-tuning needed for coannihilations and resonance effects is $O(5\%)$ in both cases.

F. Feruglio: Masse fermioniche e simmetrie discrete

La matrice di mixing dei neutrini e` sperimentalmente compatibile con la forma Tri-Bimassimale:

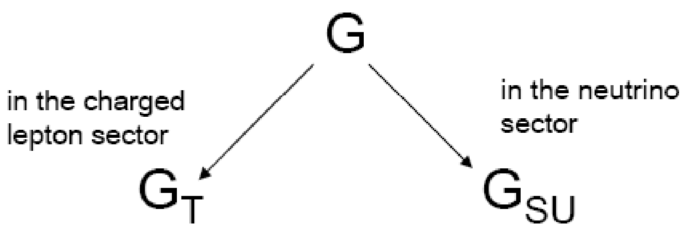
$$\sin^2\theta_{23} = \frac{1}{2}, \quad \sin^2\theta_{13} = 0, \quad \sin^2\theta_{12} = \frac{1}{3}$$

come derivare TB mixing da un modello teorico?

1. start from a flavour symmetry group $G \supset G_T, G_{SU}$

[In practice, G_S is already sufficient]

2. arrange symmetry breaking of G:



spontaneous symmetry breaking

vacuum alignment problem $\langle \varphi_T \rangle, \quad \langle \varphi_{SU} \rangle, \ldots$

should have specific magnitudes and relative directions in flavour space.

Modello minimale: $G = A_4$ Gruppo delle permutazioni pari di 4 oggetti

	l	e^c	μ^c	τ^c	h_u	h_d	φ_T	φ_S	ξ_i
A_4	3	1	1''	1'	1	1	3	3	1

matter fields (l, e^c, μ^c, τ^c) — Higgses (h_u, h_d) — A_4 breaking sector (φ_T, φ_S, ξ_i)

Lagrangiana invariante sotto
$SU(2) \otimes U(1) \otimes A_4$

angoli di mixing solo nel settore dei neutrini
spettro con "normal hierarchy"

Estensione ai quark e` non-banale: $A_4 \to T'$ = doppio ricoprimento di A_4

	$\begin{pmatrix} u & d \\ c & s \end{pmatrix}$	$\begin{pmatrix} u^c \\ c^c \end{pmatrix}$	$\begin{pmatrix} d^c \\ s^c \end{pmatrix}$	$(t \quad b)$	t^c	b^c	η	ξ''
T'	2''	2''	2''	1	1	1	2'	1''

- lepton sector as in the A_4 model

- t and b masses at the renormalizable level

- masses and mixing angles of 1st generation from higher-order effects
- despite the large number of parameters two relations are predicted

$$\sqrt{\frac{m_d}{m_s}} = |V_{us}| + O(\lambda^2) \qquad \sqrt{\frac{m_d}{m_s}} = \left|\frac{V_{td}}{V_{ts}}\right| + O(\lambda^2)$$

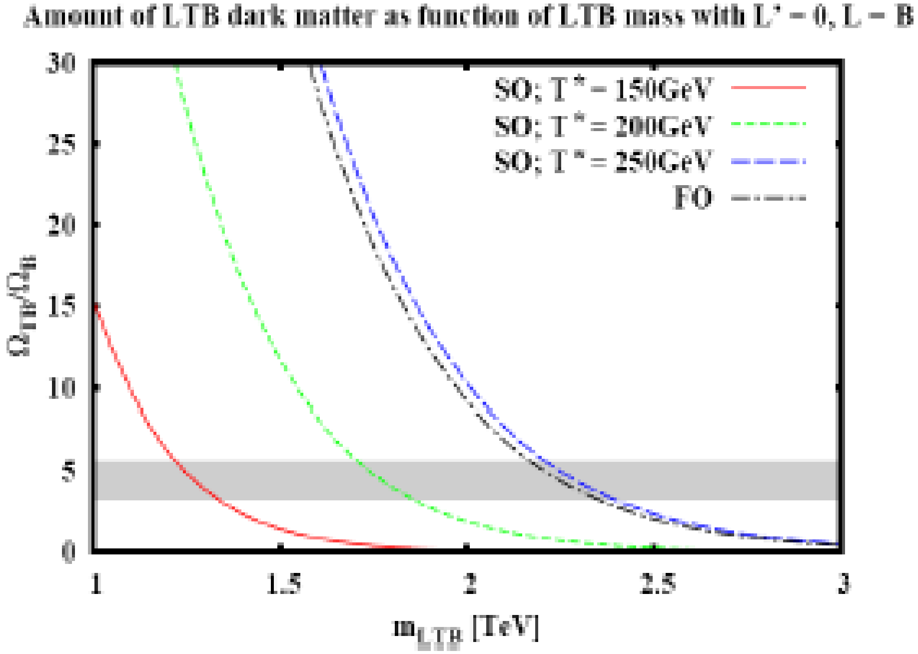
$0.213 \div 0.243 \qquad 0.2257 \pm 0.0021 \qquad 0.208^{+0.008}_{-0.006}$

- vacuum alignment explicitly solved
- lepton sector not spoiled by the corrections coming from the quark sector

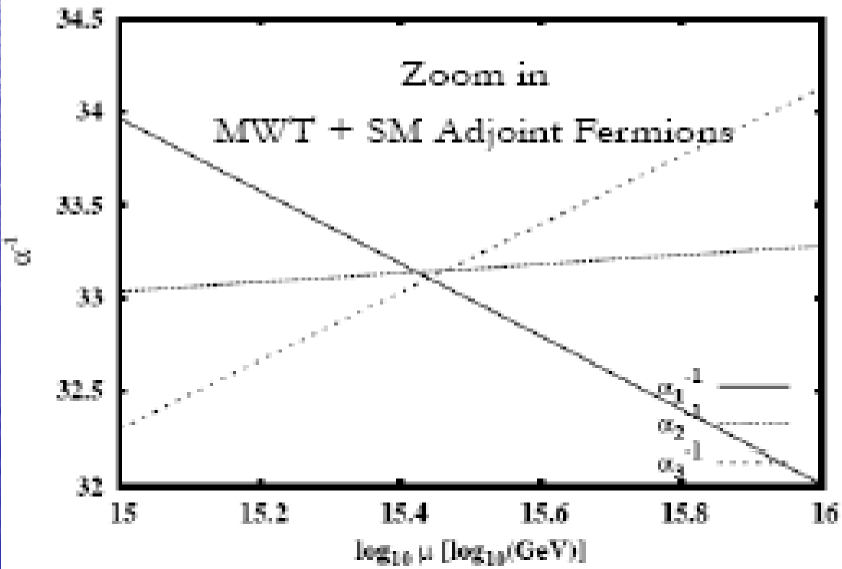
Nuove teorie di technicolor (Sannino)

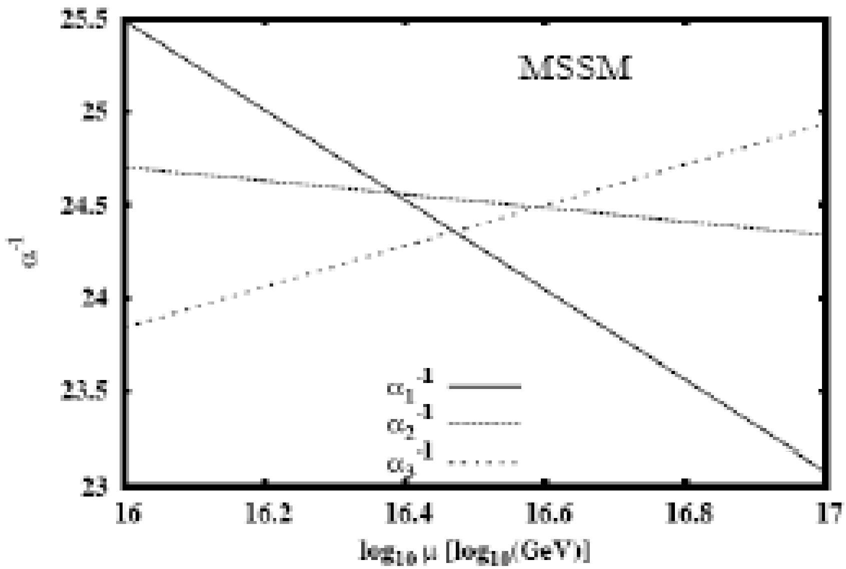
- **Introduce diversi tipi di modelli di technicolor**
- **Difficolta' con le variabili S e T elettrodeboli risolte con una costante d'accoppiamento quasi costante ("walking")**
- **Diagramma di fase per le rappresentazioni a dimensioni elevate**
- **Candidato di Materia Oscura (tecnibarione)**
- **Unificazione e una ricca fenomenologia**

DARK Technibaryon



TC Assisted Unification





Nuovi bosoni di gauge ed extra dimensioni ad LHC (Palma)

Nuovi bosoni di gauge (neutri o carichi) previsti da molte teorie…

- Sequential Standard Model (SSM): Z'_{SSM} ("benchmark model")
- GUT basate sul gruppo di gauge E6: $Z'\eta$, $Z'\psi$, Z'_I, $Z'\chi$
- Left-Right symmetric models: Z'_{LRM} , Z'_{ALRM}

Ma anche Little Higgs, extra dimensions, …

Limiti attuali dal Tevatron:

$M_{Z'} > 730 \div 920$ GeV (dip. dal modello)

M>790 GeV @95%CL (W)

Z'→ee (μμ)

segnatura molto evidente

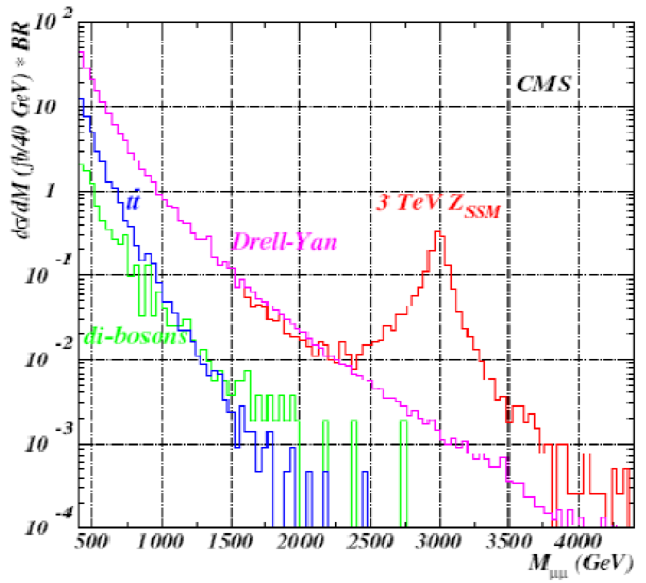
. 2 leptoni isolati di alto p_T =O(1 TeV)

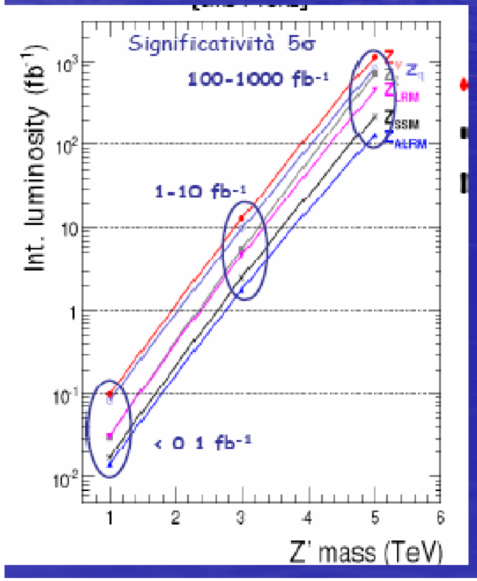
fondo molto piccolo

W'→eν (μν)

1 leptone isolato di alto p_T = O(1 TeV)

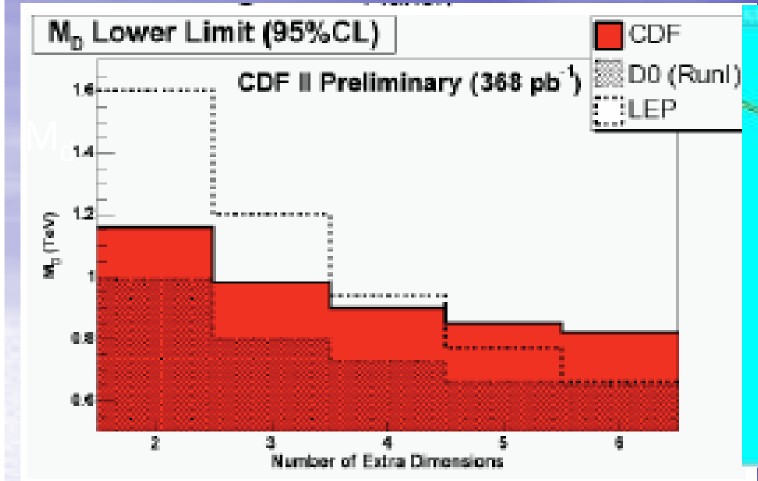
$\not{E}_T$ = O(1 TeV)





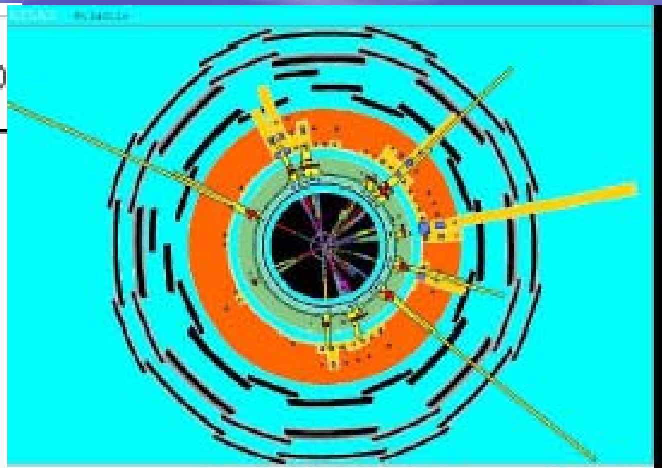
- Risoluzione non importante per la scoperta: incertezze teoriche e sperimentali (miscalibrazioni, misallineamenti) hanno un impatto molto basso
- 100 pb^{-1} sufficienti per una Scoperta di Z per masse ~ 1 TeV

New flat extra dimensions at scale M_D



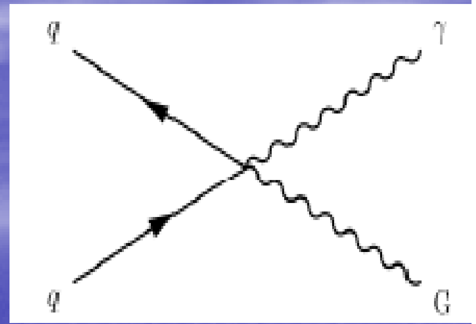
Numero di dimensioni extra

Limiti esistenti su M_D ~ TeV

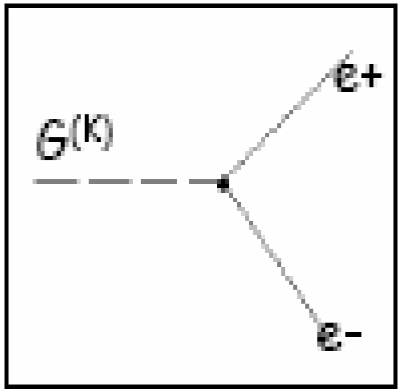


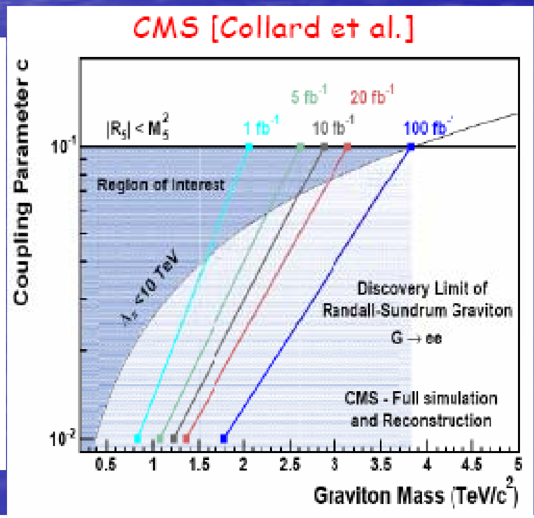
Black hole production ($\sqrt{s} >> M_D$)
Striking signature, detection possible for very low luminosity **(~1 pb^{-1})**

- Media di 6 particelle nello stato finale, emesse sfericamente
- Decadimento "democratico": equiprobabili ~120 canali particella-antiparticella -> probabilità di neutrini ($\not{E}_T$) bassa



Graviton production:
Missing Et+photon





Warped extra dimensions

Graviton resonances observables for all natural parameter space in original Randall-Sundrum model

Conclusions

We need the LHC data!