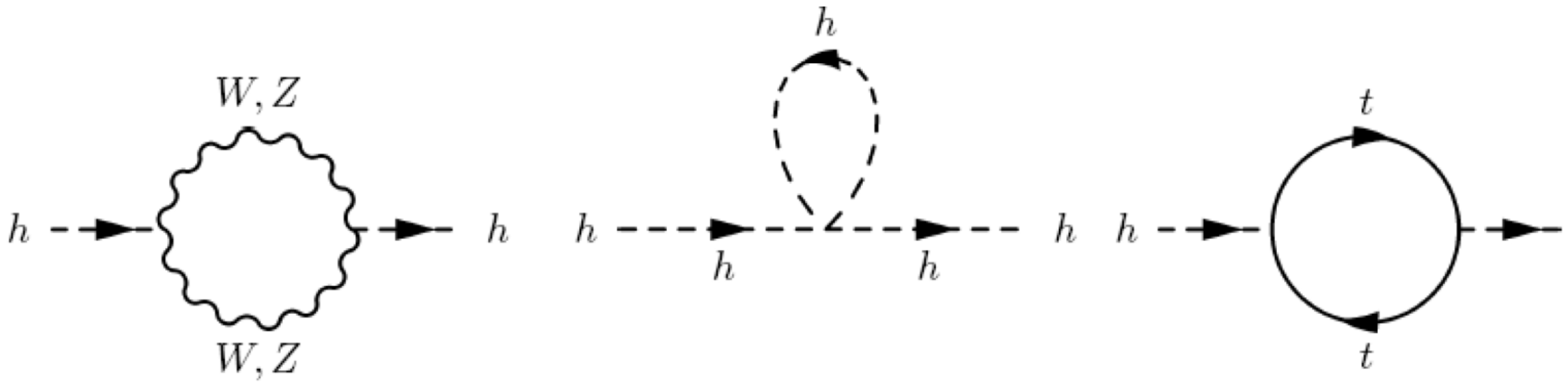
Physics
Beyond the Standard Model
(BSM)

However, the simplest Higgs mechanism SM is not stable with respect to quantum corrections (naturalness problem)

Loop corrections to the Higgs mass



$$\delta m_H^2 = \frac{3G_F}{4\sqrt{2}\pi^2}\left(2m_W^2 + m_Z^2 + m_H^2 - 4m_t^2\right)\Lambda^2 \approx -(0.2\,\Lambda)^2$$

$\delta m_H < m_H$ **$\Lambda < 1$ TeV**

In SM there is no symmetry which protects a strong dependence of Higgs mass on a possible new scale

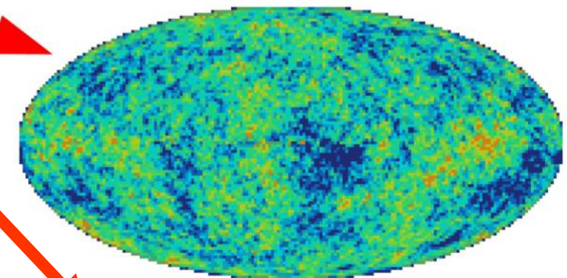
Something is needed in addition to SM…

There is a number of facts which needs to be explained

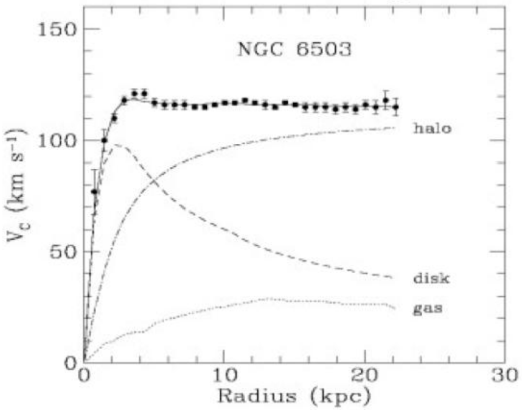
1. EW symmetry is broken – photon is massless, W and Z are massive prticles
Fermions have very much different masses
(Mtop ≈ 172 GeV, Me ≈ 0.5 MeV, $\Delta M\nu \approx 10^{-3}$ eV)

2. Dark Matter exists in the Universe

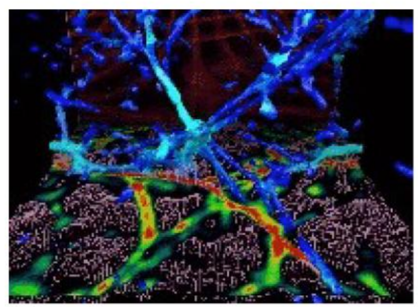
CMB



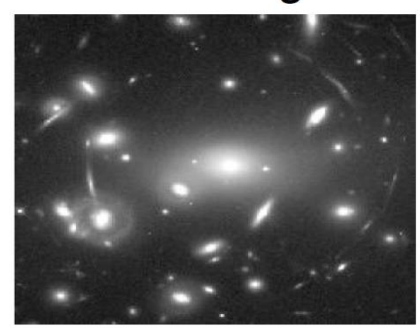
Rotation curves of galaxies

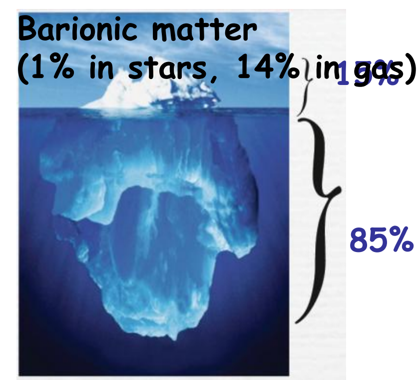


Large Scale Structure



Lensing





Dark unknown matter

3. (g-2)μ (about 3.5 σ)   4. Neutrino oscillations

4. Particle – antiparticle asymmetry in the Universe,
CP violation   baryon asymmetry: $\frac{n_B - n_{\bar{B}}}{n_B + n_{\bar{B}}} \sim 10^{-10}$

5. Gravity (no connection to EW?). Why gravity is so weak?

In addition to mentioned problems (naturalness/hierarchy, dark matter content, CP violation) SM does not give answers to many questions

What is a generation? Why there are only 3 generations?

How quarks and leptons related to each other, what is a nature of quark-lepton analogy?

What is responsible for gauge symmetries, why charges are quantize? Are there additional gauge symmetries?

What is responsible for a formation of the Higgs potential?

To which accuracy the CPT symmetry is exact?

Why gravity is so weak comparing to other interactions?

………

Why TeV energy range?

Unitarization of EW vector boson amplitudes → $\Lambda \leq 1.2$ TeV
(in case of light Higgs this argument is gone)

Stabilization of the Higgs mechanism → $\Lambda \leq 1$ TeV

Dark Matter density is estimated to be $\Omega_{DM} \approx 0.2\ \mathrm{pb}/\langle\sigma v\rangle$;
1pb is a typical EW cross section α^2/M^2 for M~100 GeV

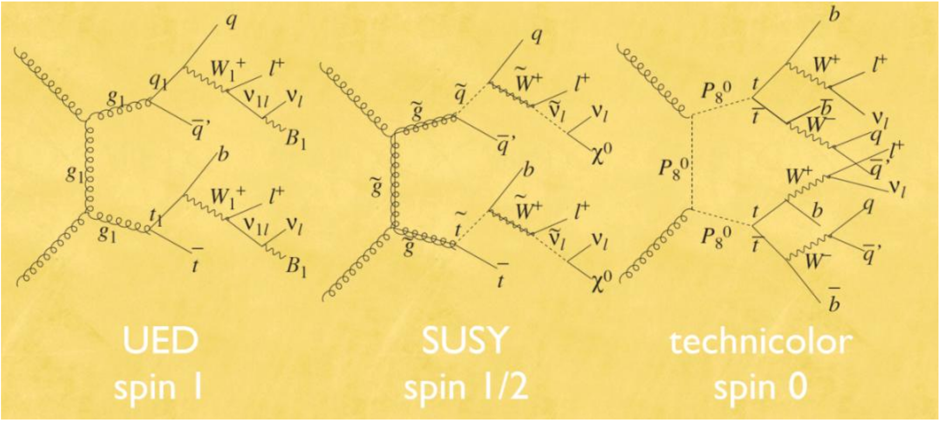
Mostly discussed BSM models pretend to provide
(at least partly)

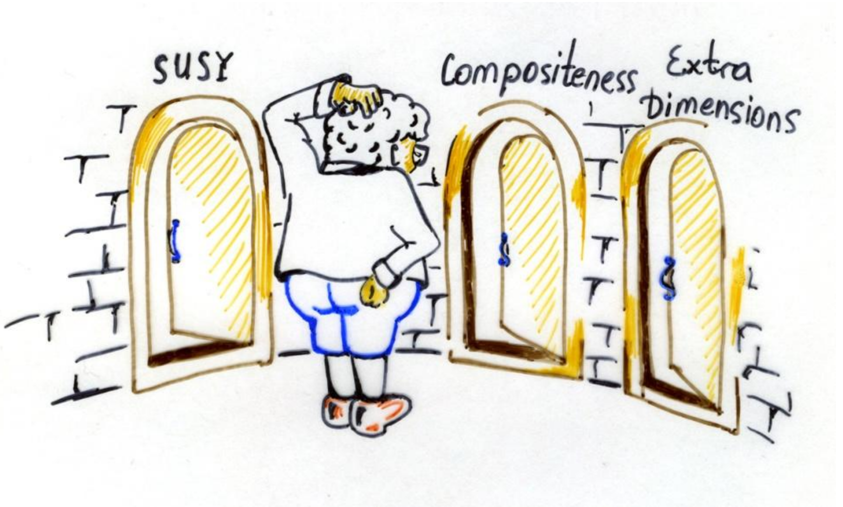
- a stable with respect to quantum corrections EWSB mechanism
- a candidate for Dark Matter
- a source for amount of CP violation to be enough for bariogenesis

and

- include gravity if possible

Supersymmetric models
(MSSM, NMSSM…)
Models with extra space dimensions
(ADD, RS, UED …)
Models with new strong dynamics
(latest technicolor variants, Little Higgs…)





New Physics manifestation

Характерная энергия столкновений > порога рождения

- Новые частицы
  - новые резонансы (KK states, W',Z', π_T, ρ_T ...)
  - партнеры топа
  - (stop, sbottom, heavy T or B decaying to top...)

Характерная энергия столкновений < порога рождения

- Новые/аномальные взаимодействия
  - Wtb anomalous couplings
  - FCNC
  - ...

Supersymmetry is one of the most favorite BSM ideas, relating spin $\frac{1}{2}$ fermions with spin 0,1 bosons

$$Q|\text{Boson}\rangle = |\text{Fermion}\rangle \qquad Q^\dagger|\text{Boson}\rangle = |\text{Fermion}\rangle$$

Fermion degrees of freedom ←→ boson degrees of freedom

Minimal particle content

❑ Gauge / Gaugino Sector

Standard Bosons	Supersymmetric Partners
$W^\pm$ $H^\pm$	Charginos $\chi_1^\pm$ $\chi_2^\pm$
g Z h H A	Neutralinos χ_1^0 χ_2^0 χ_3^0 χ_4^0
g_i	Gluinos $\tilde{g}_i$

[Two Higgs doublets] [All fermions]

And also ...

Graviton G	Gravitino $\tilde{G}$

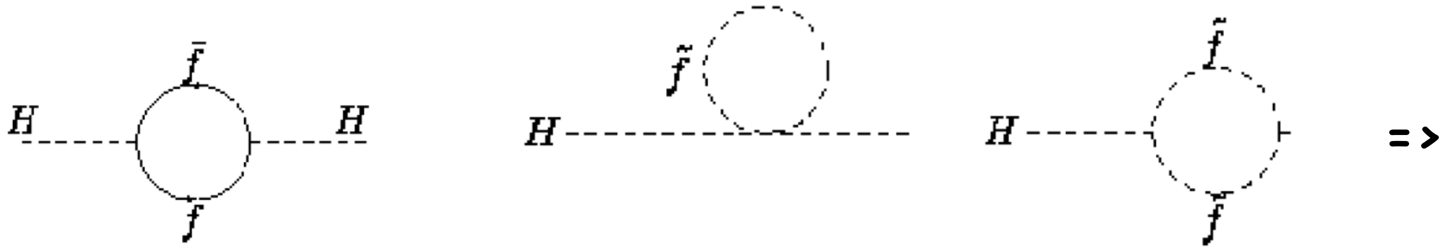
❑ Particle / Sparticle Sector

Standard Particles	Supersymmetric Partners
Leptons ℓ	Sleptons $\tilde{\ell}_{R,L}$
Neutrinos ν_ℓ	Sneutrinos $\tilde{\nu}_\ell$
Quarks q	Squarks $\tilde{q}_{R,L}$

[All scalars]

Why SUSY?

1. Cancellation of Λ^2 dependence

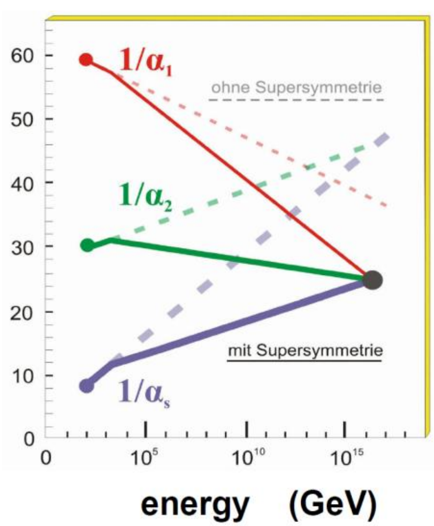


$$\Delta M_H^2|^{tot} = \frac{\lambda_f^2 N_f}{4\pi^2}[(m_f^2 - m_S^2)\log(\frac{\Lambda}{m_S}) + 3m_f^2\log(\frac{m_S}{m_f})]$$

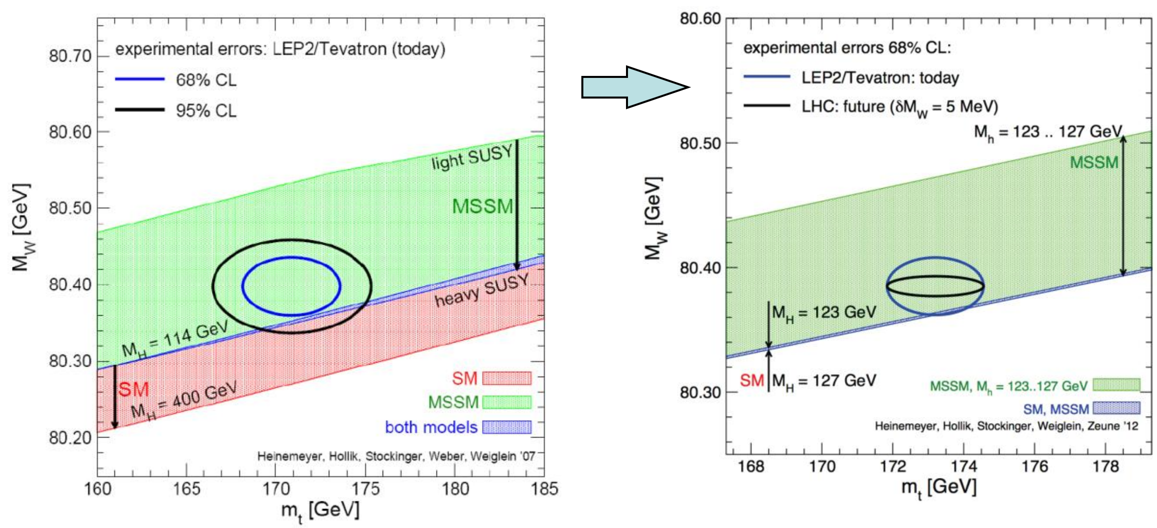
M_H is protected!

2. Lightest SUSY particle is stable (if R-parity) – very good Dark Matter candidate

3. Unification of couplings in contrast to SM



4. Fit of EW precision data



In order to establish SUSY one needs:

-find superpartners
-measure spins which should differ by ½
-demonstrate their couplings are the same
-their quantum numbers are the same
…

$$M_h^{\max} = \sqrt{M_Z^2 + \epsilon} \qquad \epsilon = \frac{3 G_F \overline{m}_t^4}{\sqrt{2}\pi^2 \sin^2\beta}\left[f(t)\right] \qquad t = \log\left(\frac{M_S^2}{m_t^2}\right)$$

$$\mathbf{M_h^2 \leq M_Z^2 + \Delta m^2}$$

➥ susy breaking term (at one-loop)

$$\mathbf{(125\ GeV)^2} \qquad \mathbf{(91\ GeV)^2} \qquad \mathbf{(86\ GeV)^2}$$

SUSY is one of the most attractive idea for BSM physics

SUSY, if exists, is broken, and there are many possibilities:

Gravity mediation
Gauge madiation
Gaugino mediation
Anomaly mediation
Hidden sector mediation
…

In general the unconstrained MSSM has 105 parameters
(22 with reasonable assumptions)
(many parameter space points of mSUGRA scenario are rulled out already)

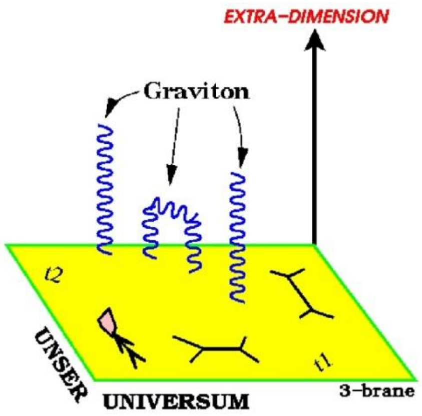
Concrete predictions depend strongly on MSSM breaking scenario.
There are no theory arguments to prefer some of them.

Many nice SUSY feaches are due to additional global symmetry-
R-parity. Tiny deviations of R-parity possible leading to processes
with FCNC, lepton/barion number violation, proton decay…
But what is an origin of R-parity?...

Models with extra space dimensions

we are confined on some 4-dim. brane imbedded into higher dim. bulk

ADD type models

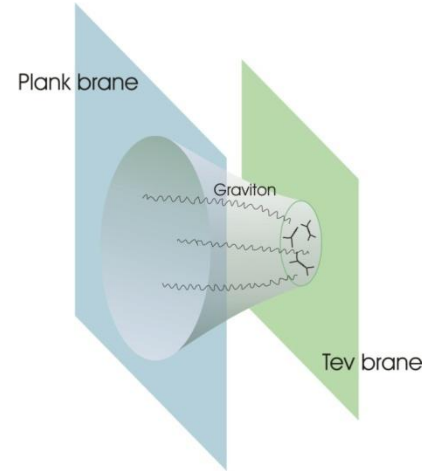


UED type scenarios

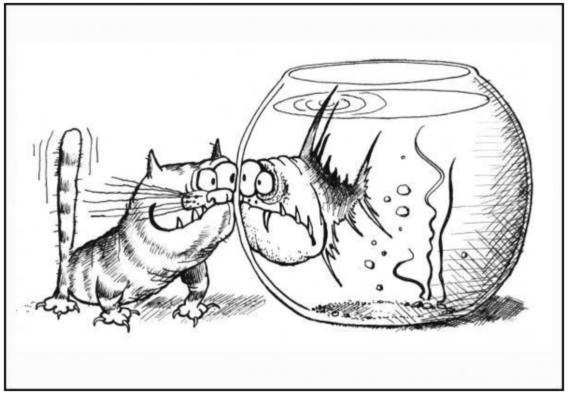
with SM fields in ADD or RS bulk

KK-parity ->
LKKP is a good DM candidate

RS type models

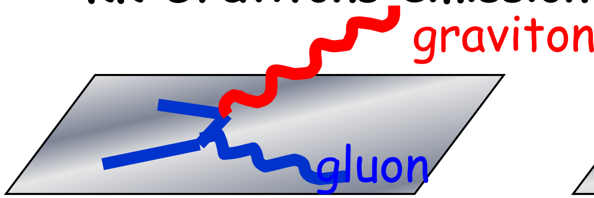


Can unify the forces
Can explain why gravity is weak (solve hierarchy problem)
Contain Dark Matter Candidates
Can generate neutrino masses

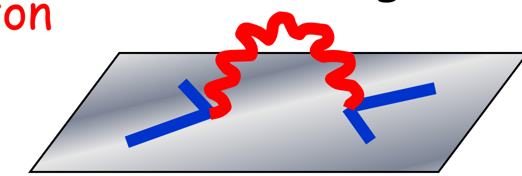


In ADD scenario typical processes:

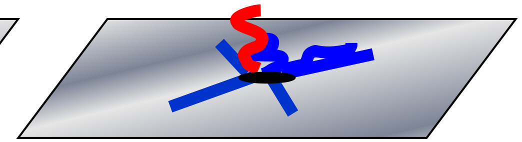
KK Gravitons emission

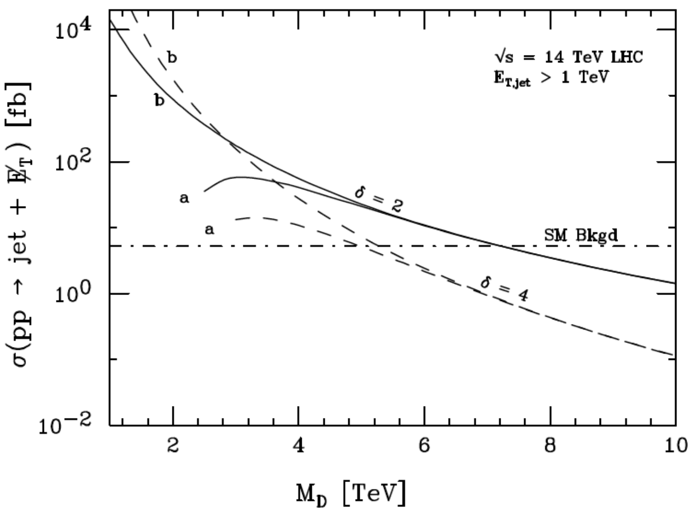


Virtual KK gravitons

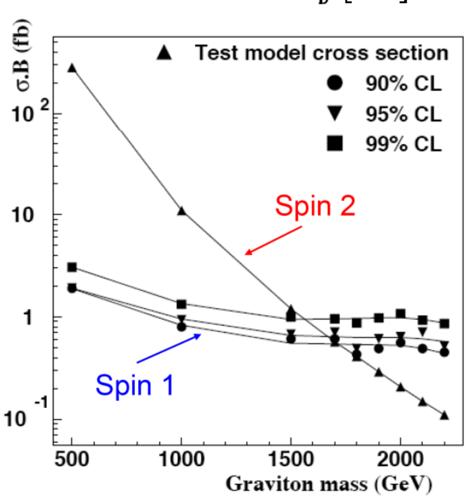


TeV black holes





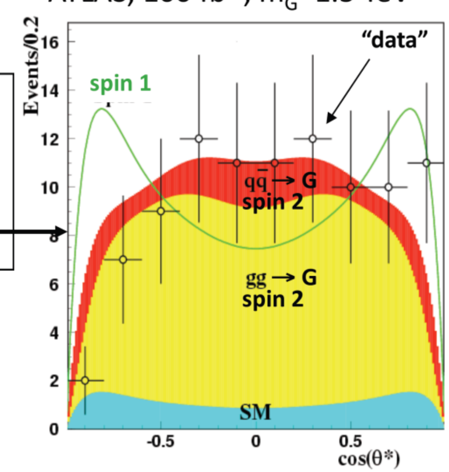
δ	Max M_D sensitivity $\mathcal{L} = 100$ fb^{-1}	Max M_D sensitivity $\mathcal{L} = 10$ fb^{-1}	Min M_D perturbativity
2	8.5 TeV	7.9 TeV	3.8 TeV
3	6.8	6.3	4.3
4	5.8	5.5	4.8
5	5.0	4.6	5.4



In RS scenario typical processes: Spin 2 resonances or virtual KK gravitons below thersholds

Graviton (s=2) or Z' (s=1) ?
→ look at $e^{\pm}$ angular distributions

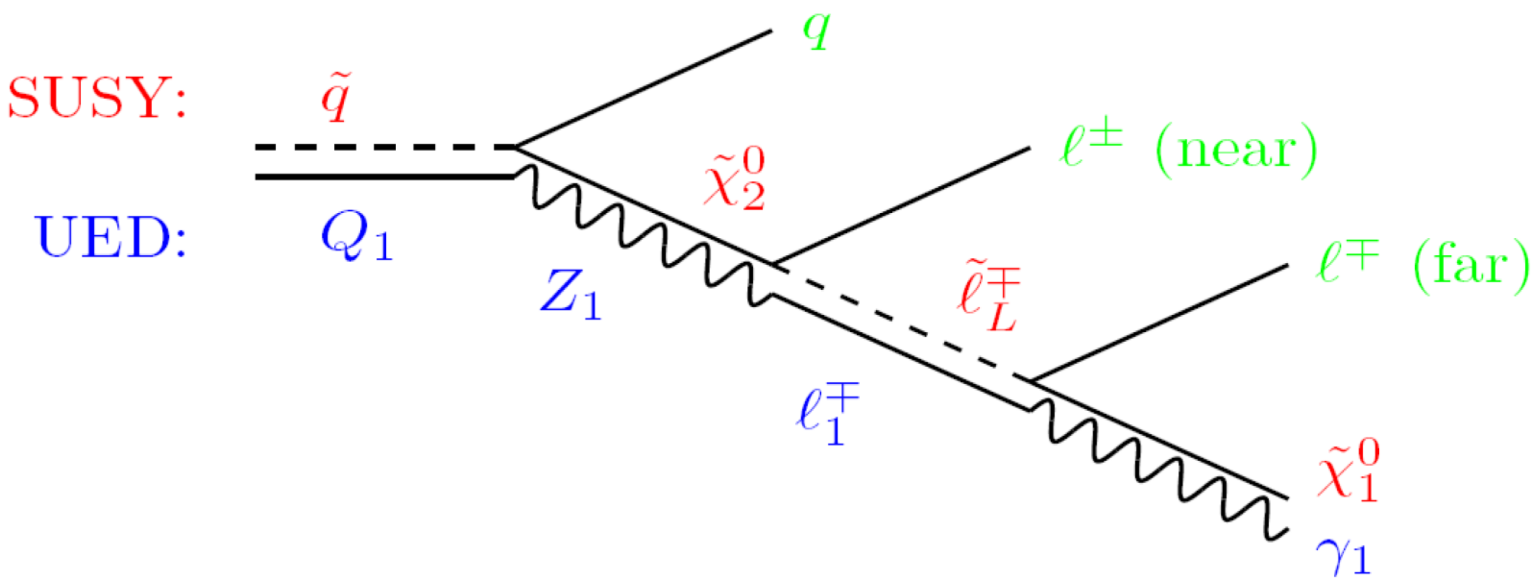
ATLAS, 100 fb^{-1}, m_G=1.5 TeV



Production of colorless sparticles in cascades usually dominate over direct production

$$\tilde{g} \to \bar{q}\tilde{q} \to \bar{q}q\tilde{\chi}_2^0 \to \bar{q}q\tilde{\tau}\tau \to \bar{q}q\tau\tau\tilde{\chi}_1^0$$

The problem is to distinguish SUSY cascades from cascades possible in other BSM scenarios like Universal extra dimensions



Models with new strong dynamics

Most of composite models are based on symmetry breaking by nontrivial Top condensate

For example (assisted technicolor with top-seesaw):

$$SU(3)_1 \times SU(3)_2 \times U(1)_1 \times U(1)_2 \stackrel{\langle \Phi \rangle}{\rightarrow} SU(3)_{\rm QCD} \times U(1)_Y$$

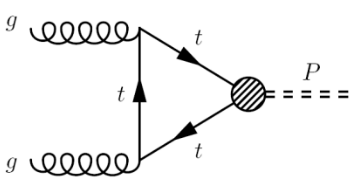
$$\langle \Phi \rangle \text{ is the condensation of } \langle t\bar{t} \rangle = f_\pi$$

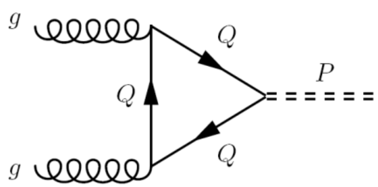
3d generation quarks and 1st,2d generation quarks are charged under two different SU(3)

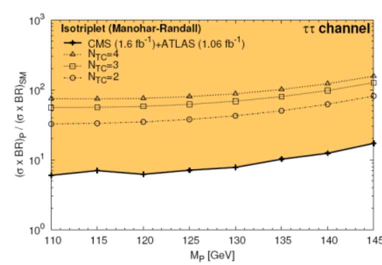
One should avoid FCNC, too large top mass, constrains from s,t,u parameters

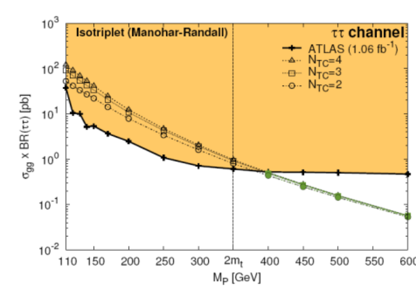
In general, there are: techni-pions, techin-rhos, composite Higgs(es), vector-like top-quark partners

R.Chivikula, P.Ittisamai, E.Simmons





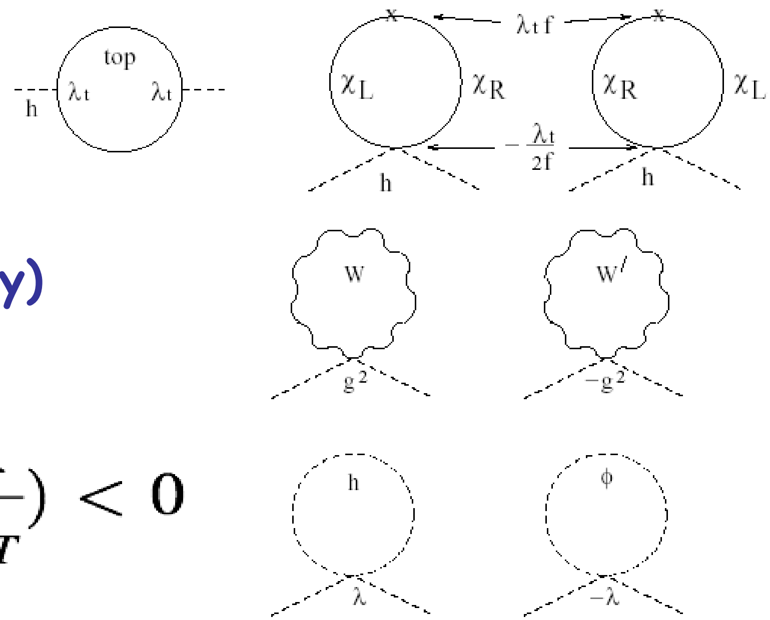




CMS and ATLAS searches for the Higgs in gamma-gamma and tau-tau modes exclude techni-(pseudo)scalars upto 2Mtop

New strong dynamics (Little Higgs, Technicolor like models …)

In Little Higgs models
new particle loops cancel
same spin SM particle loops
(cancellation at 1-loop level only)

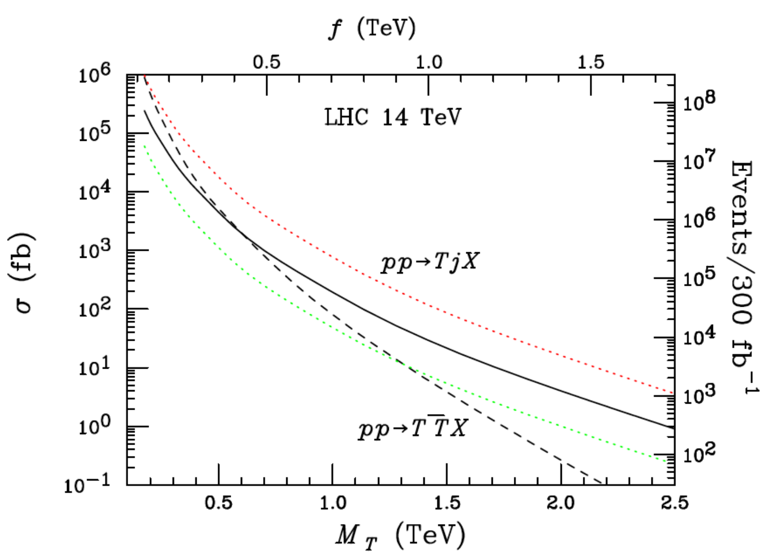


$$\delta m_H^2 = -\frac{3}{8\pi^2}\lambda_t^2 m_T^2 \ln\left(\frac{\Lambda}{m_T}\right) < 0$$

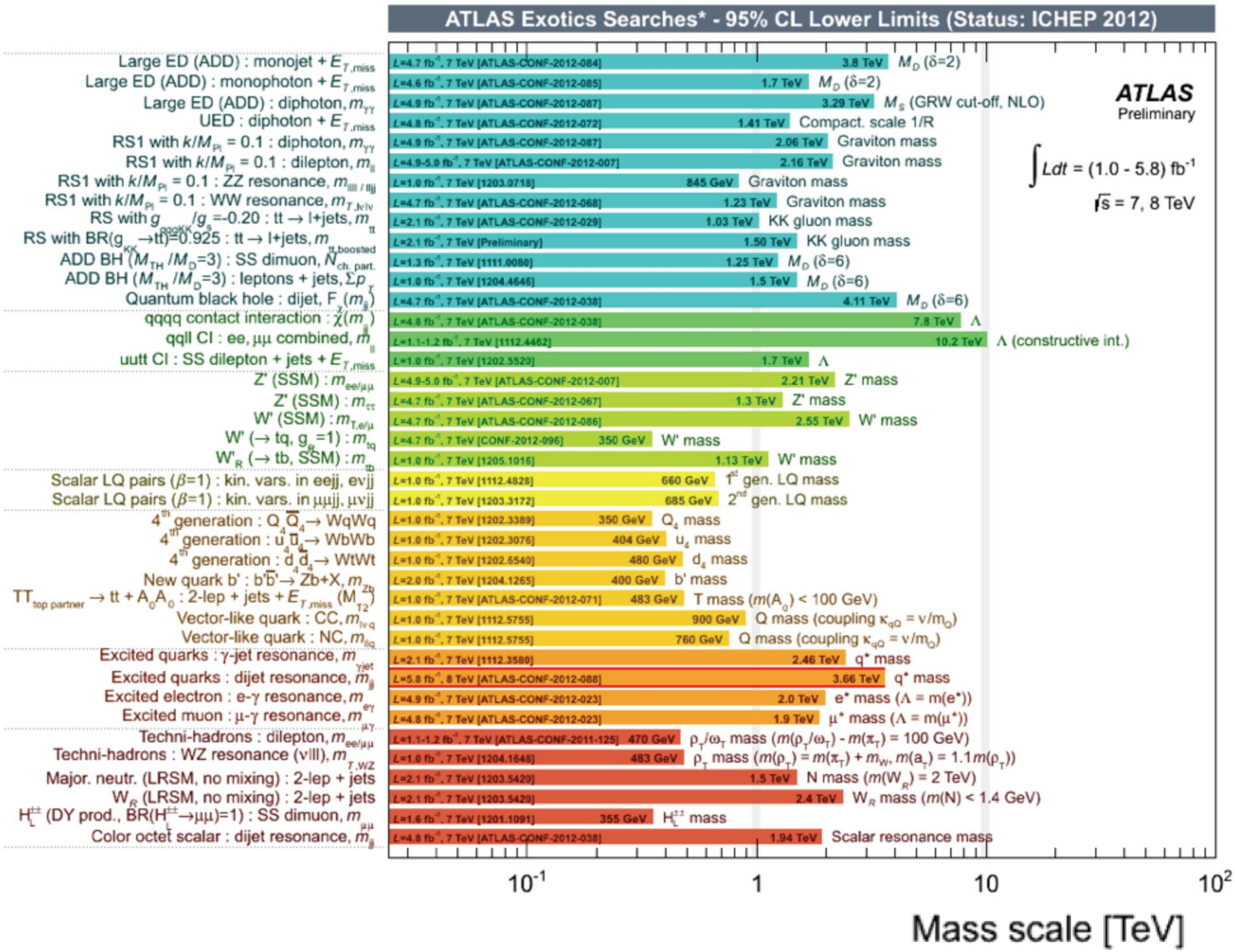
(similar to SUSY)

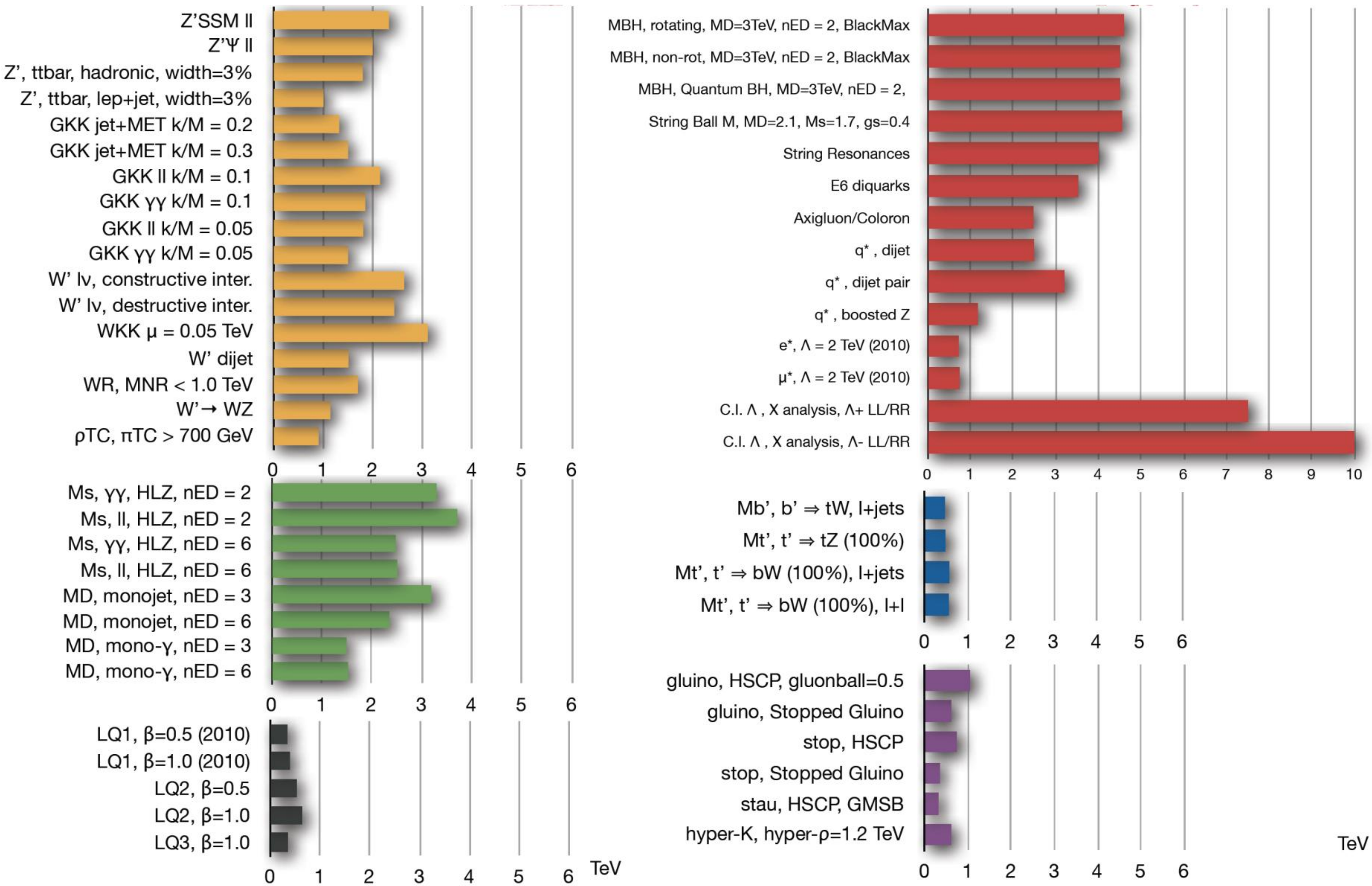
If T-parity is assumed there is a DM candidate

top-qaurk partner T can be found
at the LHC in few TeV mass range



Many direct searches by CMS and ATLAS

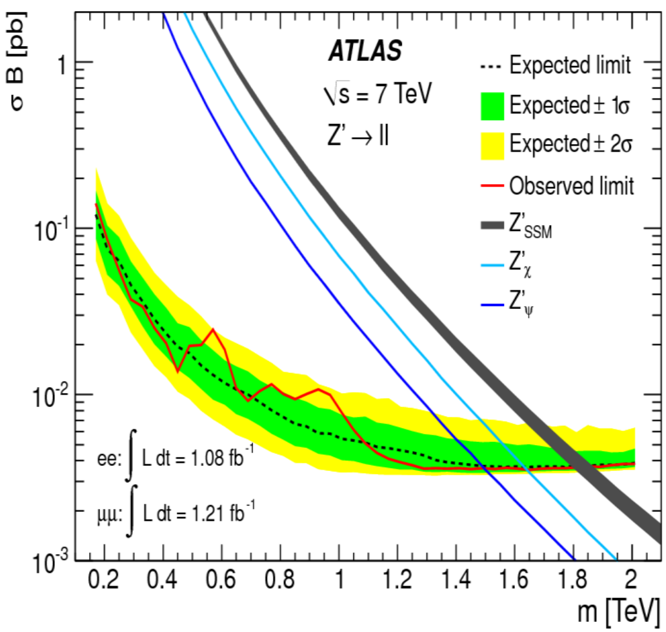


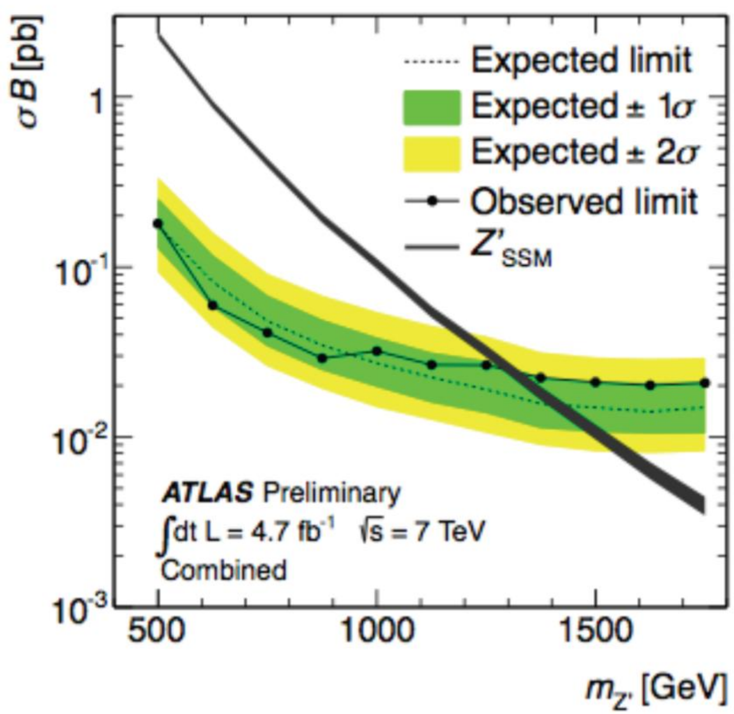


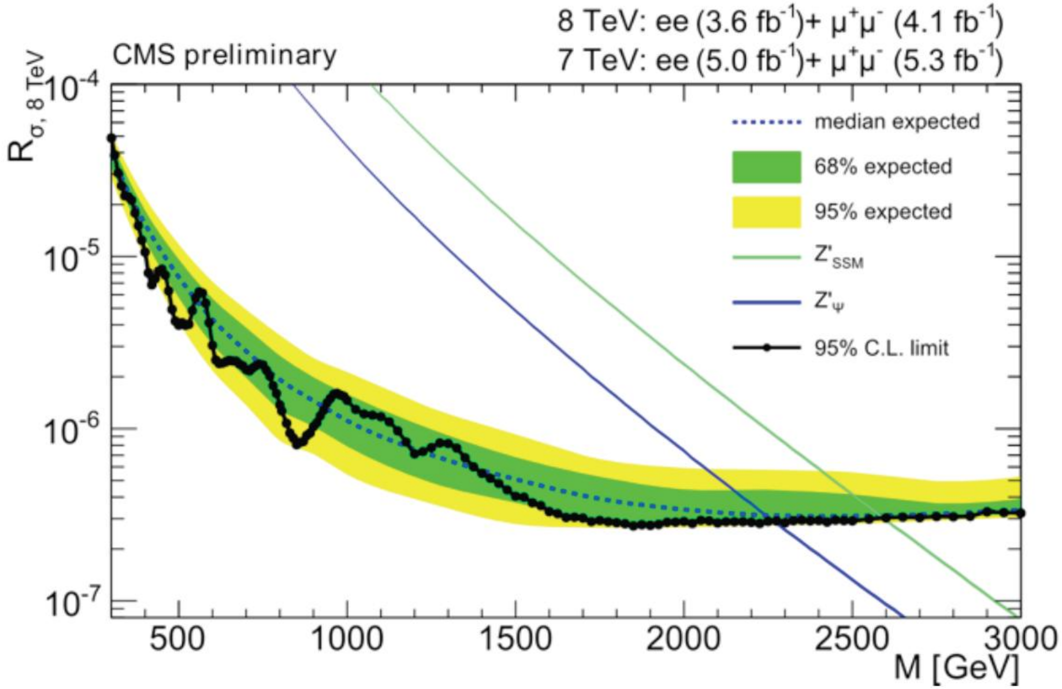
"There are more things in heaven and earth, Horatio, than are dreamt of in your philosophy." -- Hamlet

Limits on Z′

Latest limits exclude on m(Z′) in the Sequential Standard Model.





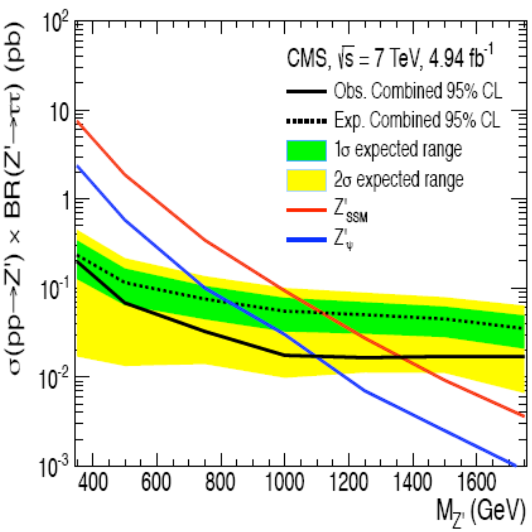


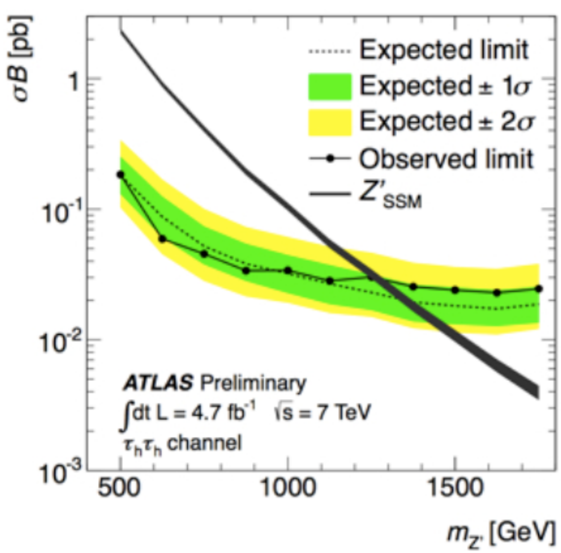
$$R_\sigma = \frac{\sigma(pp \to Z' + X \to \ell\ell + X)}{\sigma(pp \to Z + X \to \ell\ell + X)}$$

$M(Z'_{SSM}) > 2590$ GeV at 95% C.L.

$M(Z'_{\psi}) > 2260$ GeV at 95% C.L.

Limits in tau-tau decay mode

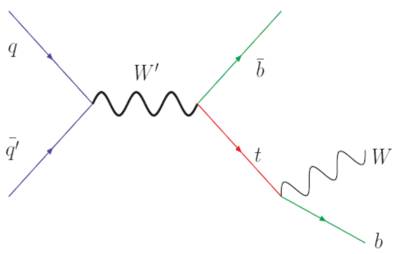


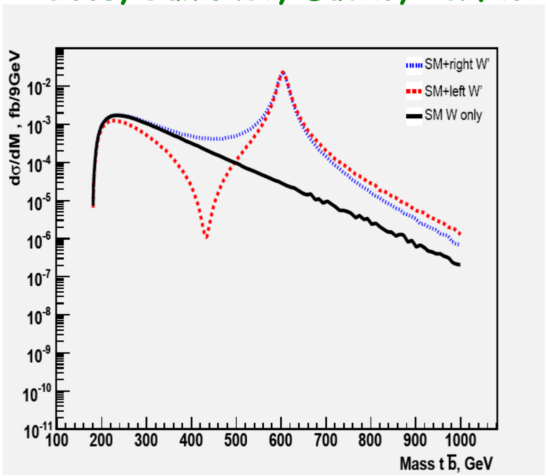


$M(Z'_{SSM})$	expected	observed
CMS	> 1.1 TeV	> 1.4 TeV
ATLAS	> 1.4 TeV	> 1.3 TeV

Поиски нового резонанса W'

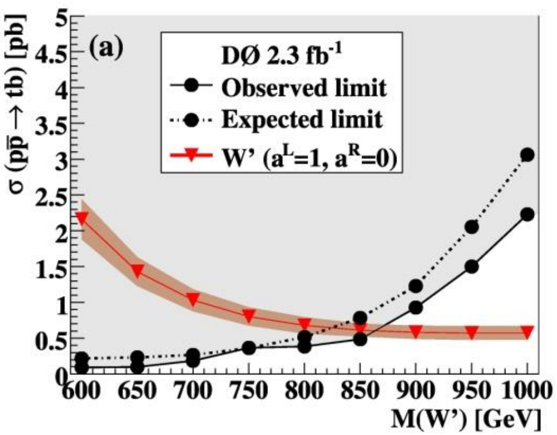
Boos, Bunichev, Dudko, Perfilov

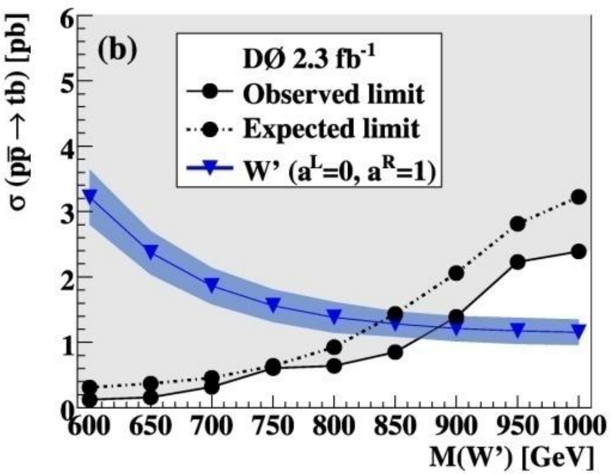




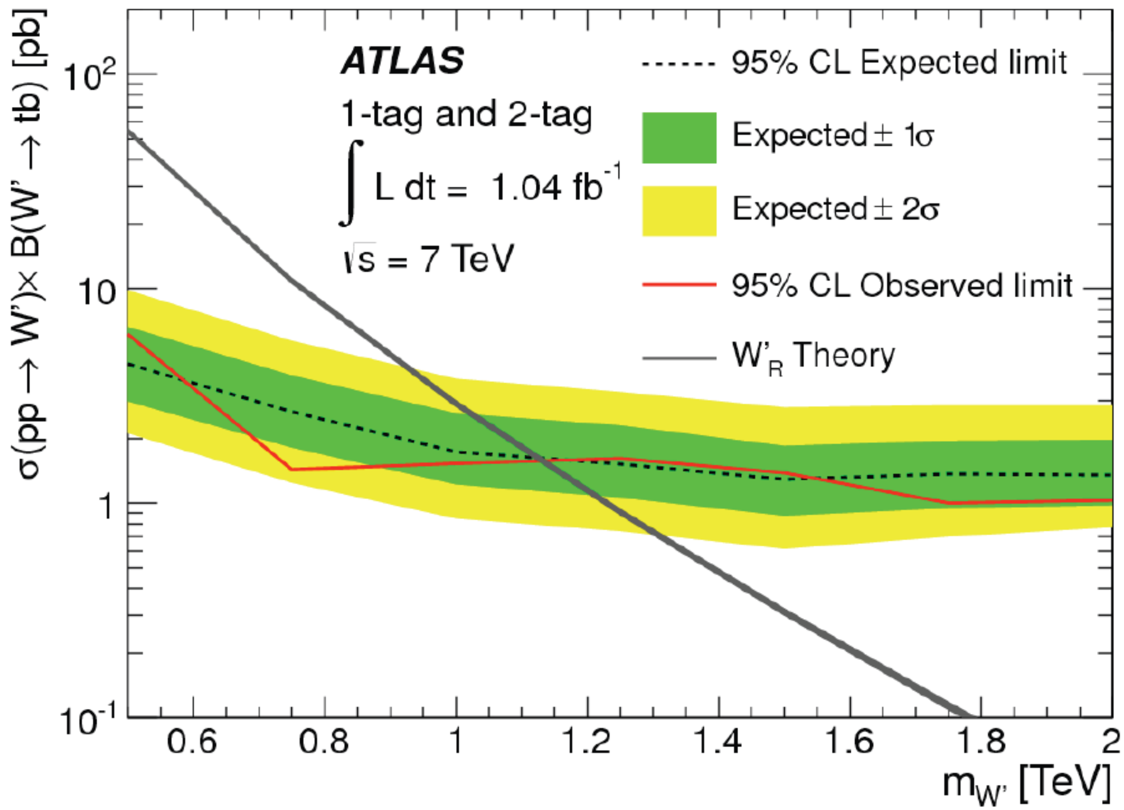
Отрицательная интерференция

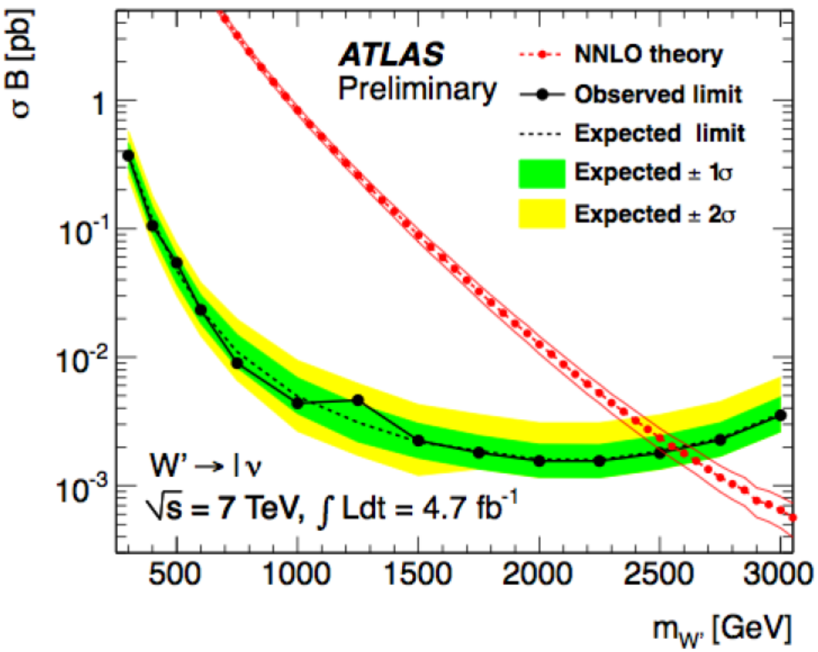
Пределы на массу W'-бозона (D0, 2.3 fb^{-1}): $M_{W'}$ > 830 (860) GeV L(R)

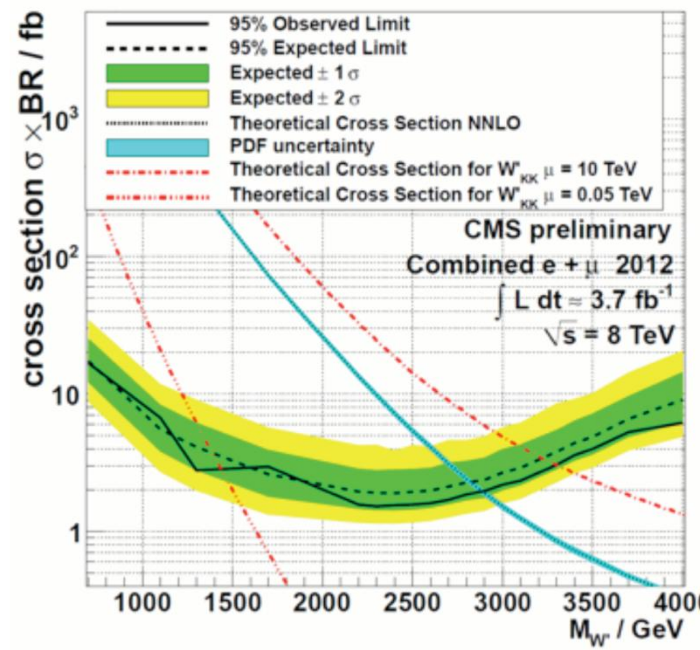




95% CL limit:
m(W'$_R$) > 1.13 TeV



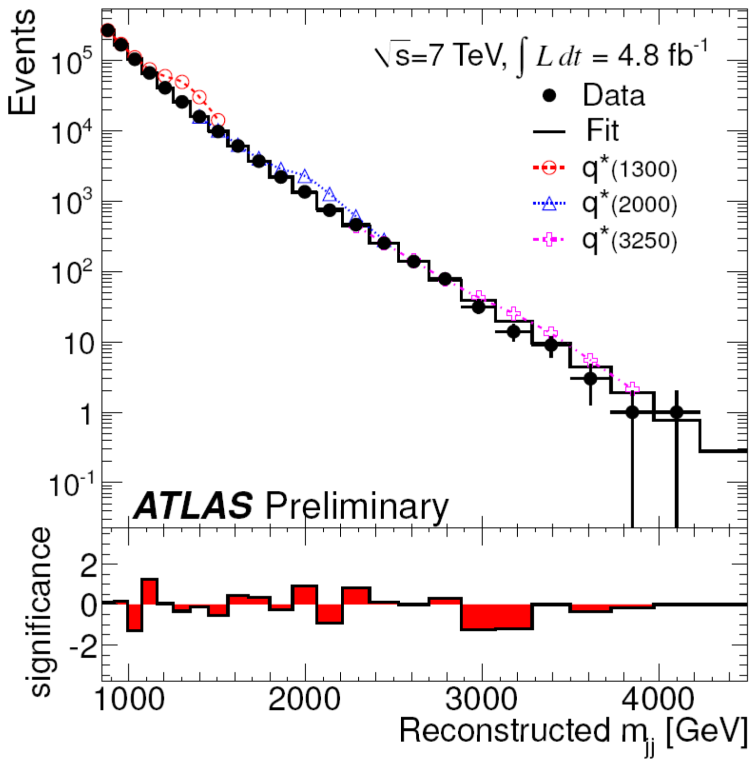


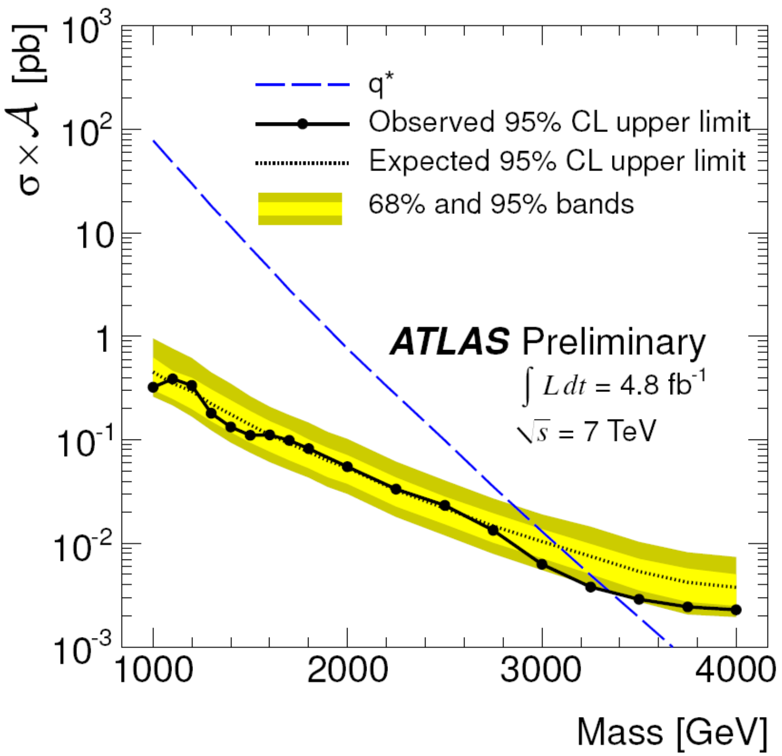


M(W'SSM) > 2.85 TeV

Dijets

Limits on excited quarks

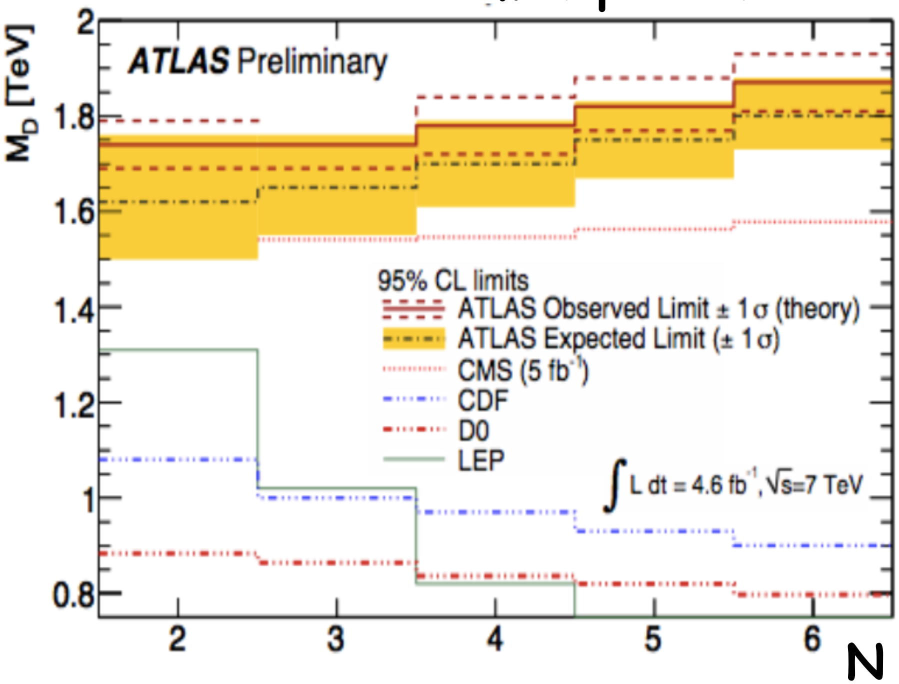




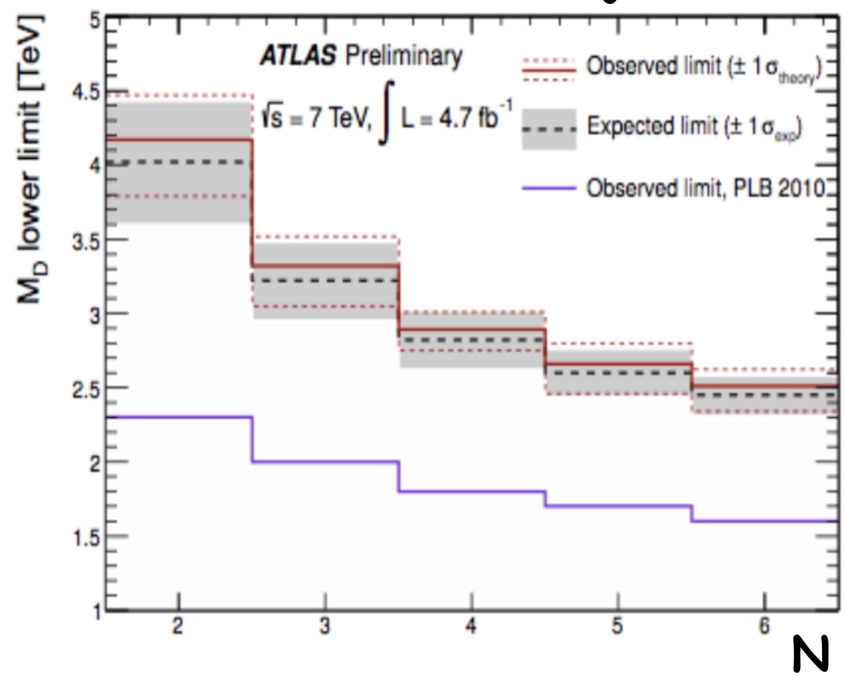
M(q*) 95% CL	Luminosity	Expected	Observed
ATLAS 2011	4.8	> 3.09 TeV	> 3.55 TeV
CMS 2011	5.0	> 3.27 TeV	> 3.05 TeV
CMS 2012	4.0	> 3.43 TeV	> 3.19 TeV
ATLAS 2012	5.8	> 3.53 TeV	> 3.66 TeV

Limints on number of extra dimensions N in ADD

monophoton

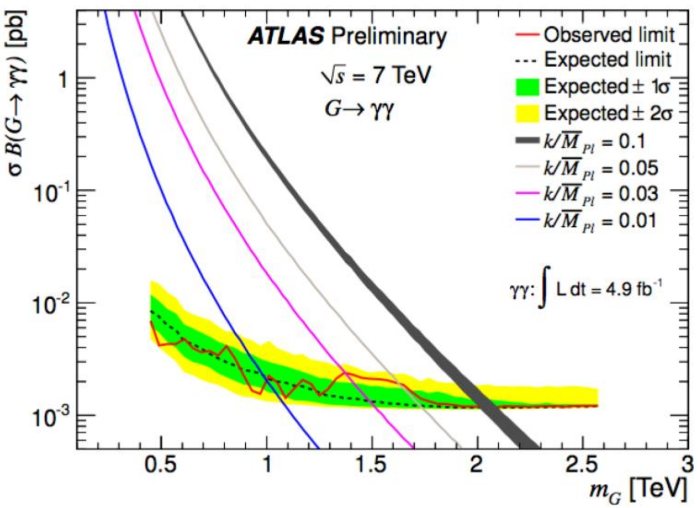


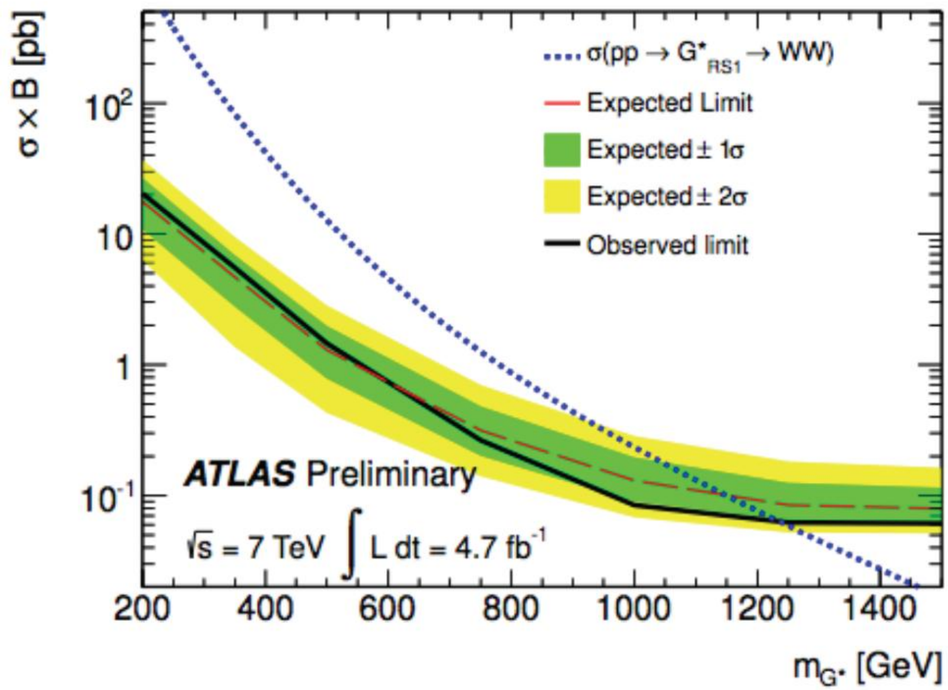
monojet

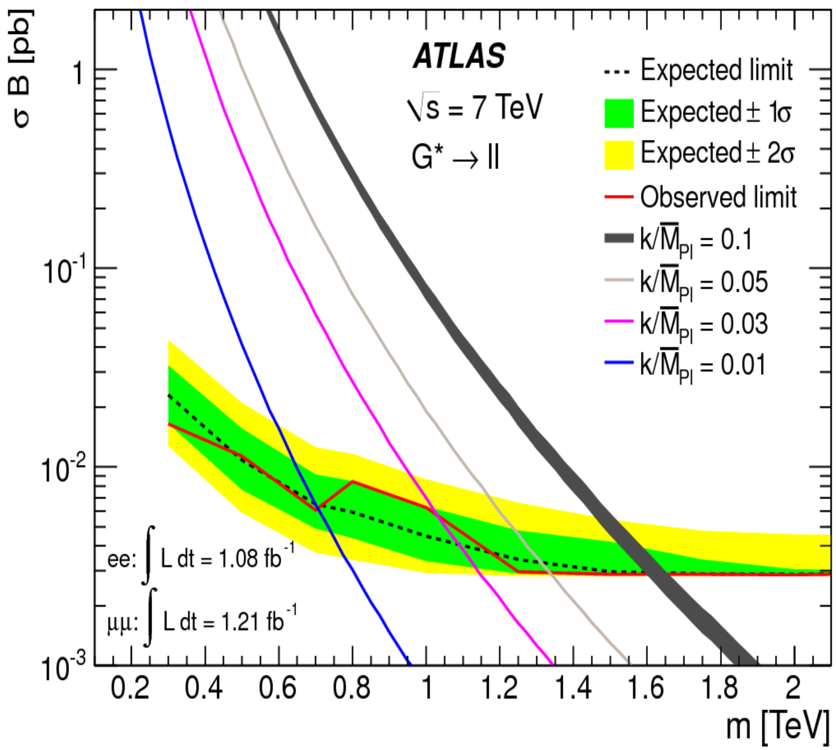


M_D (ADD) at LO 95% CL limits	Lumi [fb^{-1}]	δ=3 Exp.	δ=3 Obs.	δ=6 Exp.	δ=6 Obs.
CMS Monophoton	5.0	1.5	1.6	1.6	1.6
ATLAS Monophoton	4.6	1.7	1.7	1.8	1.9
CMS Monojet	5.0	3.1	3.2	2.3	2.4
ATLAS Monojet	4.7	3.2	3.3	2.4	2.5

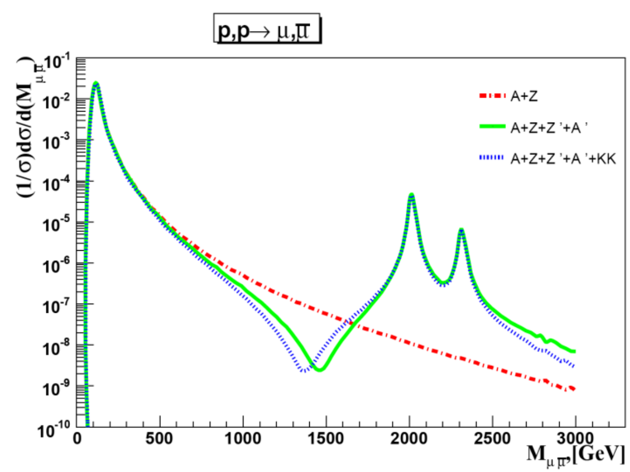
Searches for RS gravitons







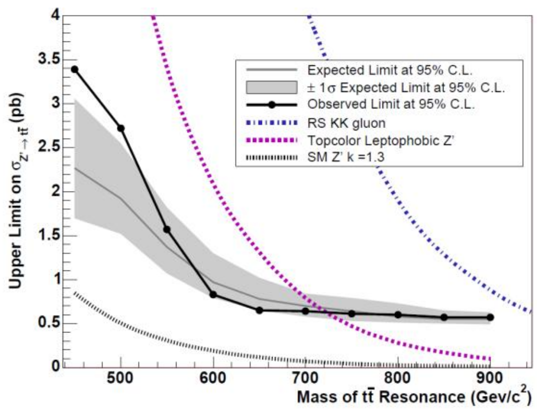
Boos, Bunichev, Smolyakov, Volobuev

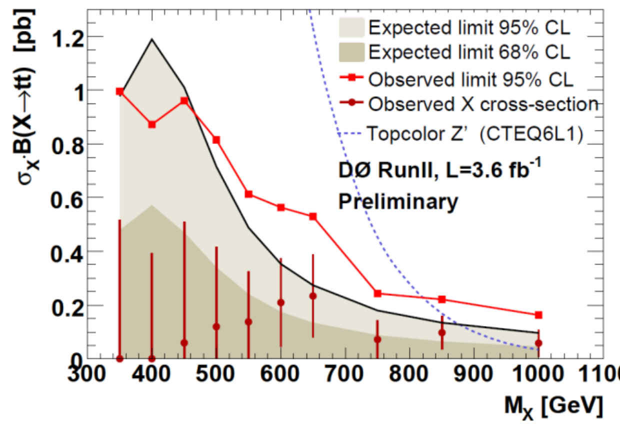


No interferences yet
The interferences should be included

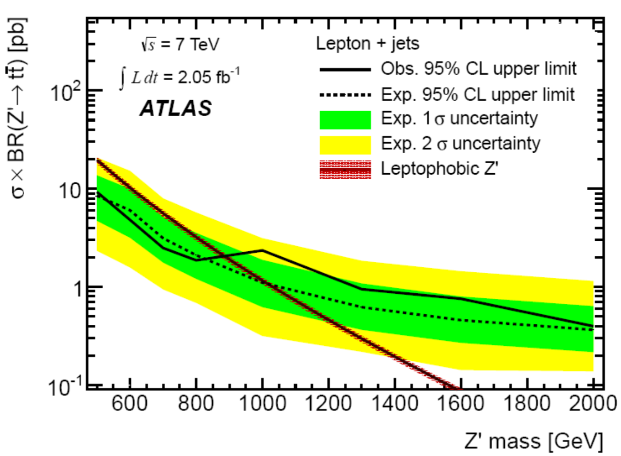
s-channel resonances decaying to tops

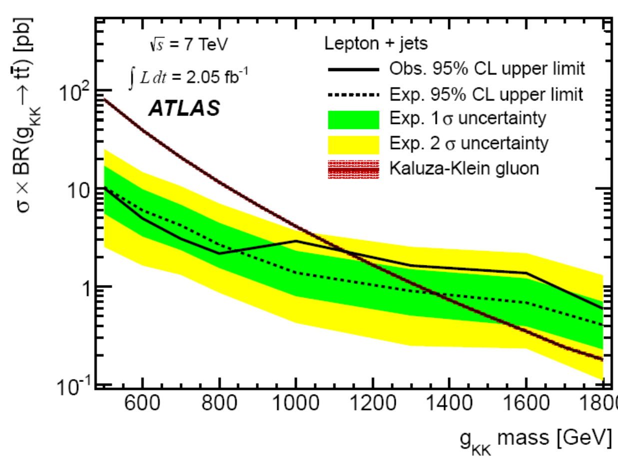
Higgses in SUSY models, 2HDM…
KK gluons, KK gravitons , KK Z, KK W … in models with extra dimensions
π_T, ρ_T, topgluons, topcolor Z',W' … in with new strong dynamics



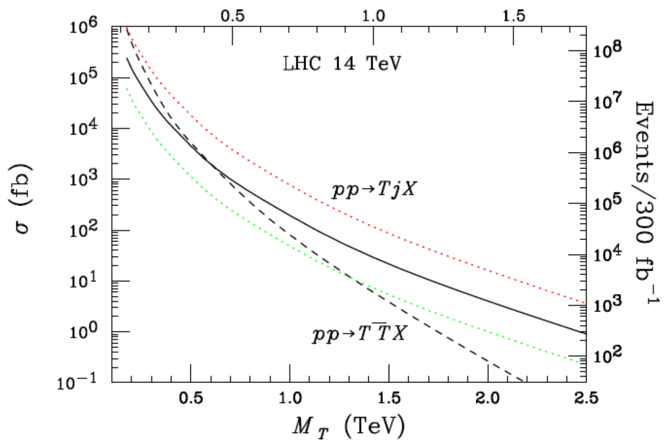


D0 limits based on 3.6 fb^{-1}: (topcolor Z') $M_{Z'}$ > 860 GeV at 95 % CL



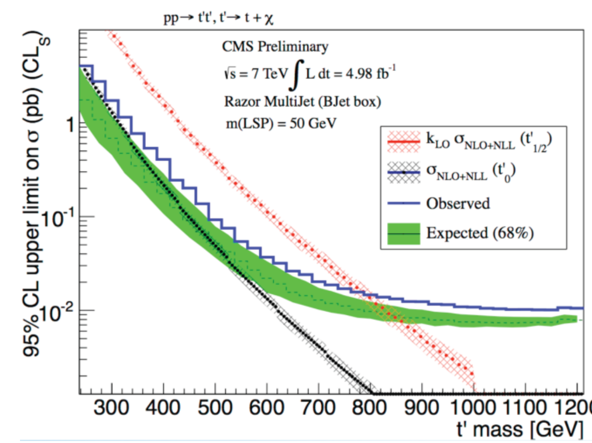


Production of top quark partner T predicted in many BSM in accord with "naturalness" argument to cancel quadratic scale dependence in loops (stop, Little Higgs Top, KK top mode…)

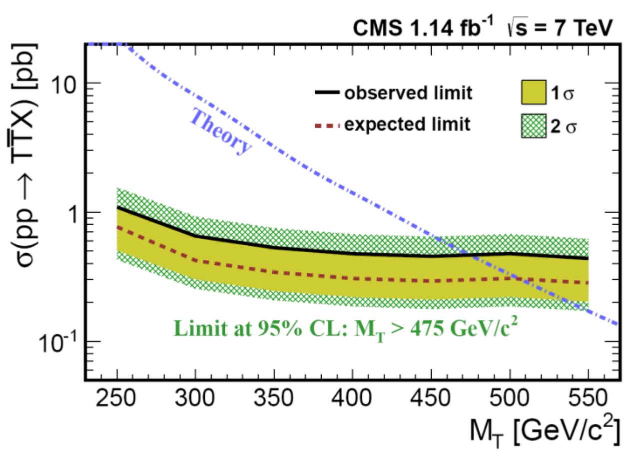


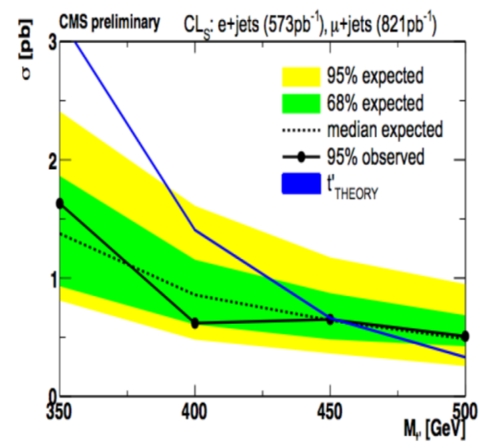
Single fermion T for various couplings (dominates for heavy T) and TT pair

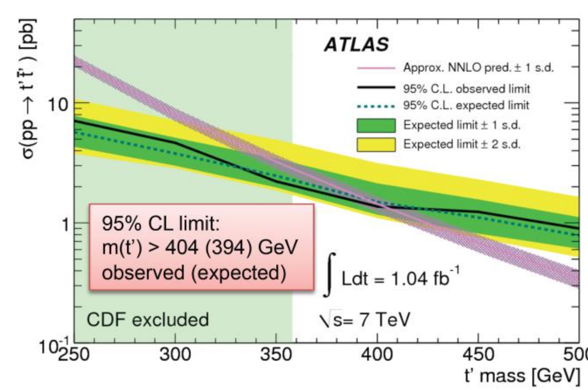
Limits on t' $t'\bar{t}' \rightarrow WbW\bar{b}$



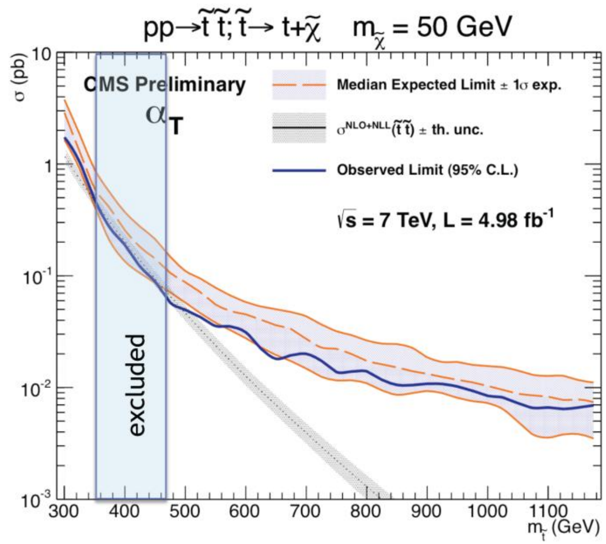
Limits on vector-like top partner in T->tZ decay mode





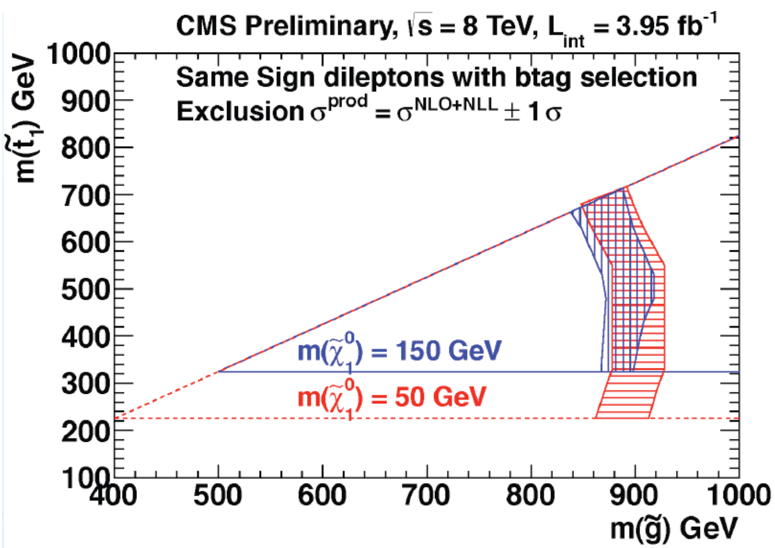


Limits on sbottoms and stops from direct production

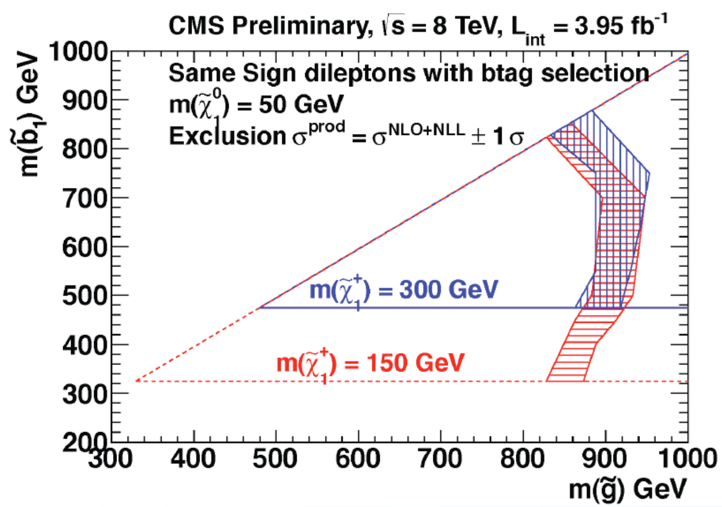


Limits on stop and sbottom from gluino mediated processes

$$\tilde{g} \to t\tilde{t}, \tilde{t} \to t\chi^0$$



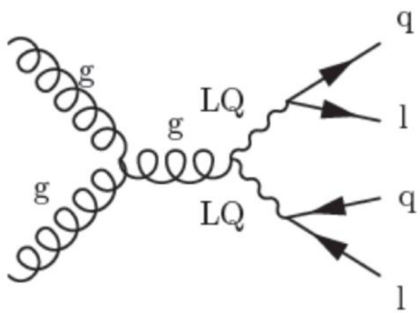
$$\tilde{g} \to b\tilde{b}, \tilde{b} \to t\chi^-, \chi^- \to W^-\chi^0$$

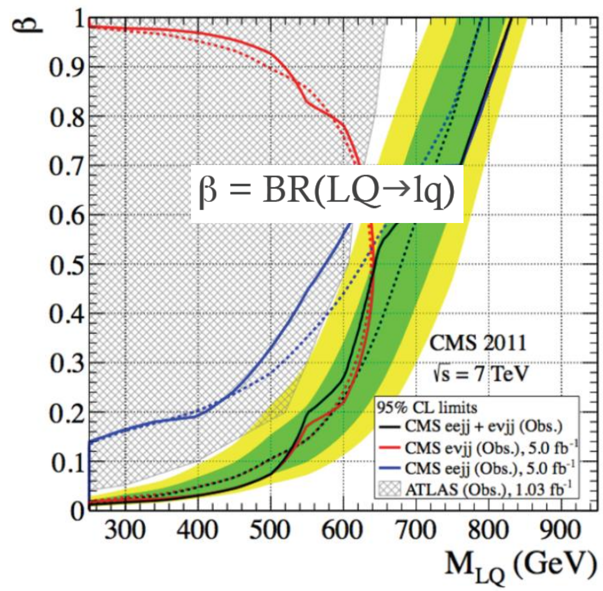


Leptoquark searches

LQs are predicted by composite models, GUT …

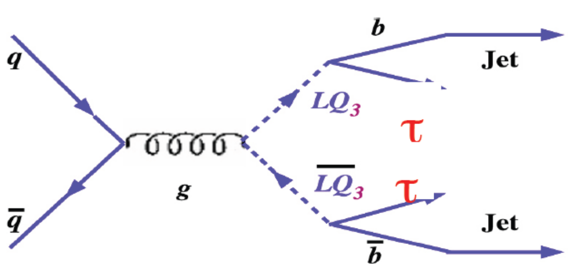
1st and 2d generation LQs

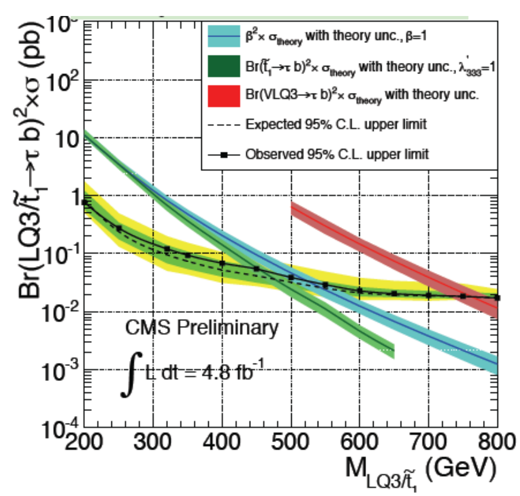




M_{LQ1}> 830 (640) GeV for β=1 (0.5)
M_{LQ2}> 840 (650) GeV for β=1 (0.5)

3d generation LQs





M_{SLQ3}> 525 GeV for β=1
M_{VLQ3}> 763 GeV for β=1

Anomalous Wtb Couplings

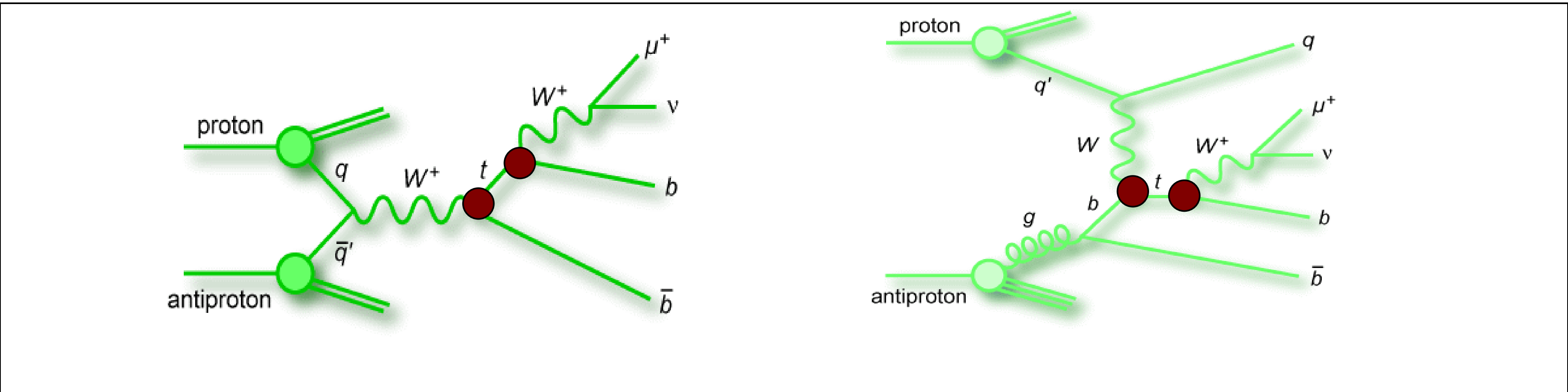
- Lagrangian

$$\mathcal{L} = \frac{g}{\sqrt{2}} V_{tb} \left[W_\nu^- \bar{b} \gamma_\mu P_- t - \frac{1}{2M_W} W_{\mu\nu}^- \bar{b} \sigma^{\mu\nu} (F_2^L P_- + F_2^R P_+) t \right] + h.c.$$

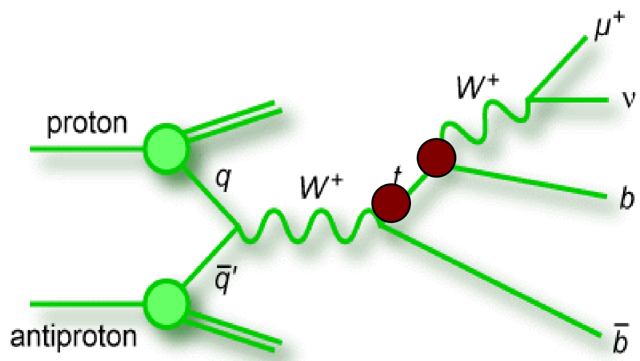
with $W^\pm_{\mu\nu} = D_\mu W^\pm_\nu - D_\nu W^\pm_\mu$, $D_\mu = \partial_\mu - ieA_\mu$, $\sigma^{\mu\nu} = i/2[\gamma_\mu, \gamma_\nu]$ and $P_\pm = (1 \pm \gamma_5)/2$. The couplings F_2^L and F_2^R are proportional to the coefficients of the effective Lagrangian

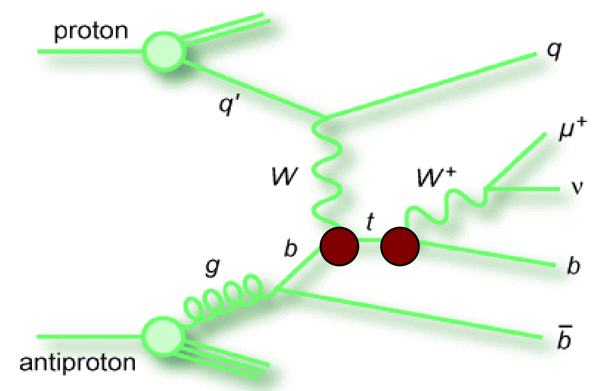
$F_{L2} = \frac{2M_W}{\Lambda} \kappa^W_{tb} (-f^W_{tb} - i h^W_{tb})$,

$F_{R2} = \frac{2M_W}{\Lambda} \kappa^W_{tb} (-f^W_{tb} + i h^W_{tb})$, $|F_{L2,R2}| < 0.6$ from unitary bounds



Структура вершины взаимодействия Wtb





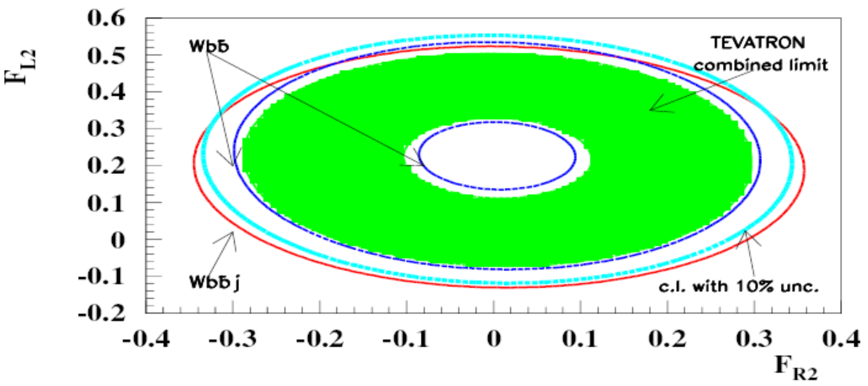
$$\Gamma^{\mu}_{Wtb} = -\frac{g}{\sqrt{2}} V_{tb} \left\{ \gamma^{\mu} \left[f_1^L P_L + f_1^R P_R \right] - \frac{i\sigma^{\mu\nu}}{M_W} (p_t - p_b)_{\nu} \left[f_2^L P_L + f_2^R P_R \right] \right\}$$

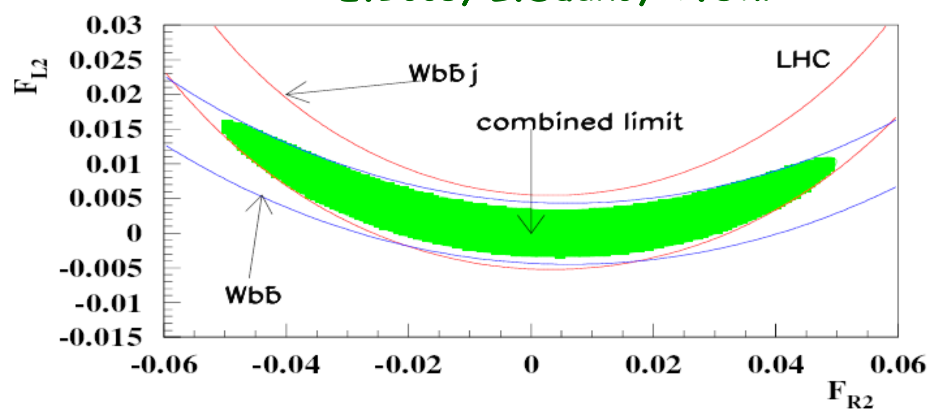
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

В СМ: $f_1^L = 1$, $f_1^R = 0$, $f_2^{L,R} = 0$

Ожидаемые точности измерения аномальной Wtb вершины на Tevatron и LHC

E.Boos, L.Dudko, T.Ohl





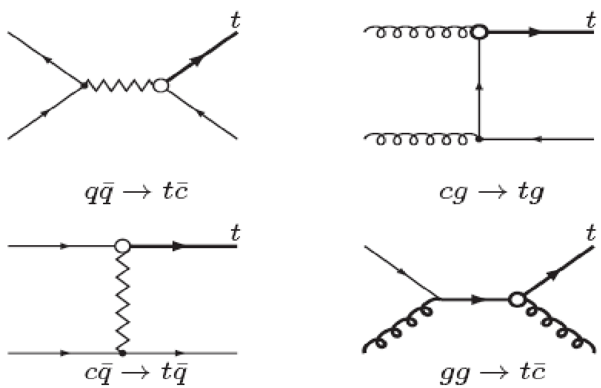
Пределы D0 на статистике 900 pb^{-1} (генератор событий SingleTop)

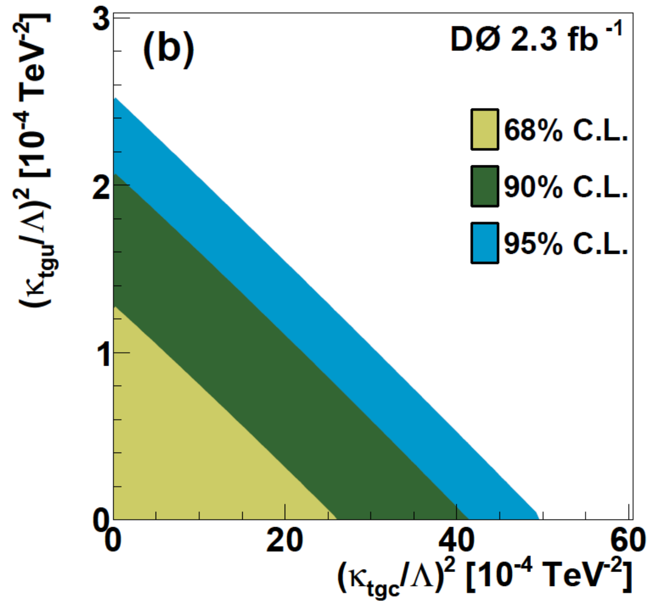
Scenario	Cross Section	Coupling
(L_1, L_2)	$4.4^{+2.3}_{-2.5}$ pb	$\|V_{tb} f_1^L\|^2 = 1.4^{+0.6}_{-0.5}$
		$\|V_{tb} f_2^L\|^2 < 0.5$ at 95% C.L.
(L_1, R_1)	$5.2^{+2.6}_{-3.5}$ pb	$\|V_{tb} f_1^L\|^2 = 1.8^{+1.0}_{-1.3}$
		$\|V_{tb} f_1^R\|^2 < 2.5$ at 95% C.L.
(L_1, R_2)	$4.5^{+2.2}_{-2.2}$ pb	$\|V_{tb} f_1^L\|^2 = 1.4^{+0.9}_{-0.8}$
		$\|V_{tb} f_2^R\|^2 < 0.3$ at 95% C.L.

FCNC couplings

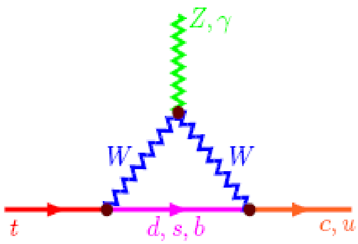
- Couplings: tqg, $tq\gamma$, tqZ, where $q = u, c$

$$\Delta\mathcal{L}^{eff} = \frac{1}{\Lambda}[\kappa_{tq}^{\gamma,Z} e\bar{t}\sigma_{\mu\nu}qF_{\gamma,Z}^{\mu\nu} + \kappa_{tq}^{g} g_s\bar{t}\sigma_{\mu\nu}\frac{\lambda^i}{2}qG^{i\mu\nu}] + h.c.$$





W' boson and FCNC MC event samples from SingleTop (CompHEP) generator



	SM	two-Higgs	SUSY
$BR(t \to cg)$	$5 \cdot 10^{-11}$	10^{-6}	10^{-3}
$BR(t \to c\gamma)$	$5 \cdot 10^{-13}$	10^{-6}	10^{-5}
$BR(t \to cZ)$	$\sim 10^{-13}$	10^{-9}	10^{-4}

FCNC decays are highly suppressed in SM $t \to qg$, $t \to q\gamma$, $t \to qZ$

To compare FCNC limits from top decays and top production one can express limits on FCNC couplings in term of Br fractions

$$\Gamma(t \to qg) = \left(\frac{\kappa_{tq}^g}{\Lambda}\right)^2 \frac{8}{3}\alpha_s m_t^3 \quad , \quad \Gamma(t \to q\gamma) = \left(\frac{\kappa_{tq}^\gamma}{\Lambda}\right)^2 2\alpha m_t^3 ,$$

$$\Gamma(t \to qZ)_\gamma = \left(|v_{tq}^Z|^2 + |a_{tq}^Z|^2\right) \alpha\, m_t^3 \frac{1}{4M_Z^2 \sin^2 2\theta_W}\left(1 - \frac{M_Z^2}{m_t^2}\right)^2 \left(1 + 2\frac{M_Z^2}{m_t^2}\right),$$

$$\Gamma(t \to qZ)_\sigma = \left(\frac{\kappa_{tq}^Z}{\Lambda}\right)^2 \alpha\, m_t^3 \frac{1}{\sin^2 2\theta_W}\left(1 - \frac{M_Z^2}{m_t^2}\right)^2 \left(2 + \frac{M_Z^2}{m_t^2}\right)$$

$t \to$	Tevatron Run II	LHC decay	LHC production	ILC
$g\,q$	0.06%	1.6×10^{-3}	1×10^{-5}	–
$\gamma\,q$	0.28%	2.5×10^{-5}	3×10^{-6}	4×10^{-6}
$Z\,q$	1.3%	1.6×10^{-4}	1×10^{-4}	2×10^{-4}

D0:

	tgu	tgc
Cross section	0.20 pb	0.27 pb
κ_{tgf}/Λ	0.013 TeV^{-1}	0.057 TeV^{-1}
$\mathcal{B}(t \to qg)$	2.0×10^{-4}	3.9×10^{-3}

CDF:

$$\mathcal{B}(t \to u + g) < 3.9 \cdot 10^{-4}$$

$$\mathcal{B}(t \to c + g) < 5.7 \cdot 10^{-3}$$

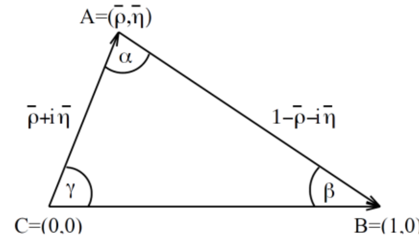
B physics

Indirect search for BSM physics – the main goal of the LHCb experiment.

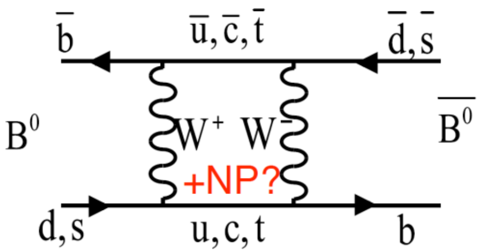
Flavor & CP in CKM matrix

$$V=\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \sim \begin{pmatrix} 1 & +\lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1 & +A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

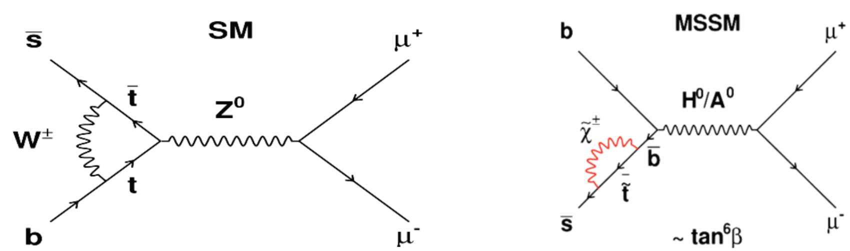
One of unitarity triangles $V_{ub}V_{ud}^* + V_{cb}V_{cd}^* + V_{tb}V_{td}^* = 0$



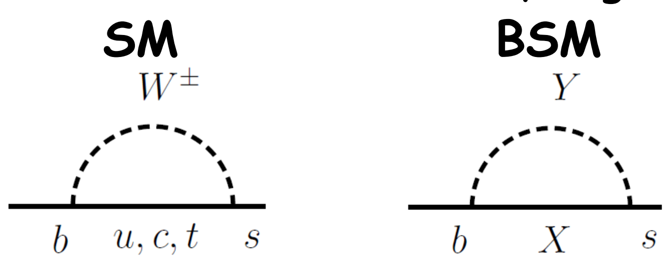
Two body B-meson hadronic decays ($B_d \to J/\Psi\ K^0_S$...) and phase of B0 oscillations for CP violation studies



Deviations in Br fractions in rare b-decays



A-penguin, where A isadded in all places radiative boson, $A=\gamma, Z, g, h^0$

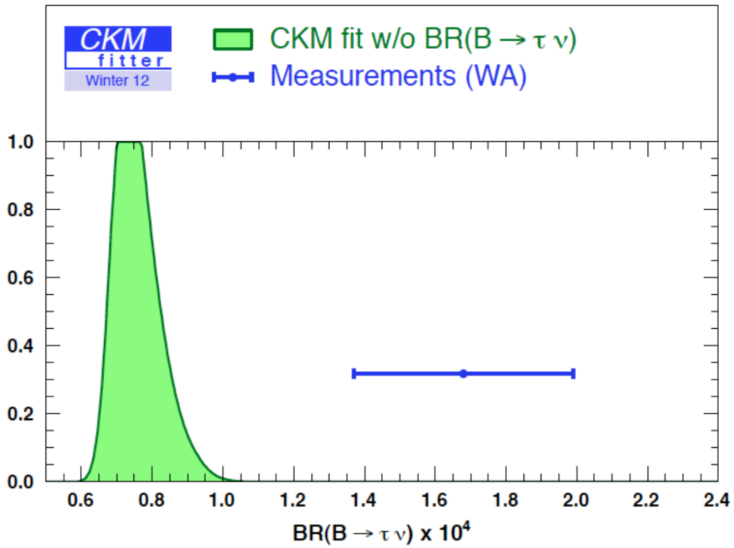


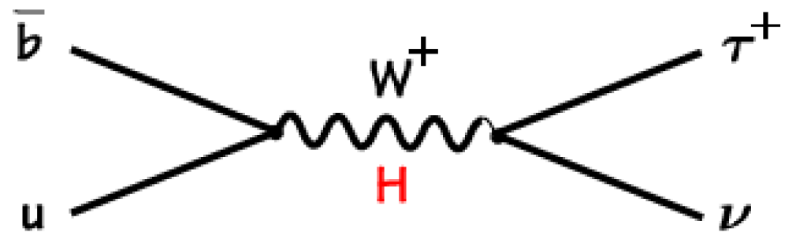
Key measurements: rare B-meson decays ($B_S \to \mu\mu$, $B_S \to K^*\mu\mu$, $B_d \to K^*ee$, $B_S \to \varphi\gamma$)

LHCb with 0.3 fb^{-1} improved Tevatron limits with $9fb^{-1}$

Many interesting new results

2.8σ tension between direct measurements and inderct SM fit for B-meson decay to tau and neutrino





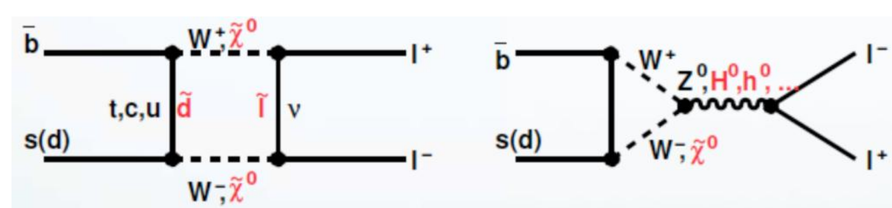
Rare B_S->μμ decays – close to the SM prediction

$$\mathrm{Br}(B_s \to \mu\mu) = (3.53 \pm 0.38) \times 10^{-9}$$

ATLAS: $Br(B_s \to \mu^+\mu^-) < 2.2 \times 10^{-8}$ (2.4 fb^{-1})

CMS: $Br(B_s \to \mu^+\mu^-) < 7.7 \times 10^{-9}$ (4.9 fb^{-1})

LHCb: $Br(B_s \to \mu^+\mu^-) < 4.5 \times 10^{-9}$ (1 fb^{-1})



Heavy Ion physics

Study of quark-gluon color medium at high temperature and high density

A dedicate experiment ALICE, heavy ion physics programs of ATLAS and CMS

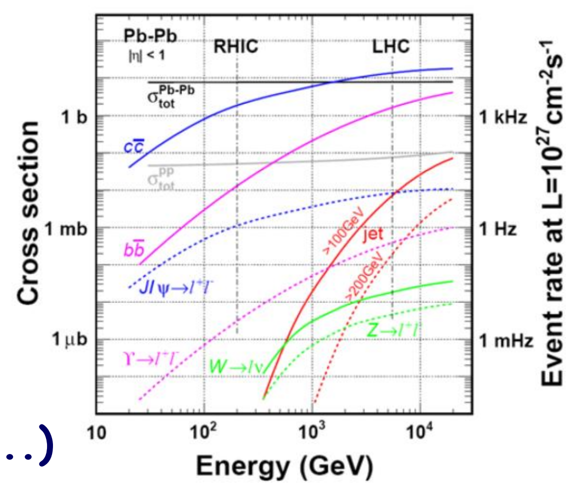
Ideally collision energy per nucleon:

$$\sqrt{s_{NN}} = \frac{2E_{Pb}}{A} = \frac{Z}{A}\sqrt{s_{pp}} = 0.39\sqrt{s_{pp}} = 5.5\ \text{TeV}$$

2010-2011: PbPb ($\sqrt{s_{NN}}$ = 2.76 ТэВ);

Study of deconfinement QCD region, study properties of medium (energy density, temperature, pressure, entropy, viscosity, sound velocity…)
in order to understand better nonperturbative QCD itself
(sum of masses of uud quarks due to Higgs mechanism is about 12 MeV
but proton mass is 938 MeV => QCD is responsible for 99% of barion mass)
and our Universe much closer to the Big Bang

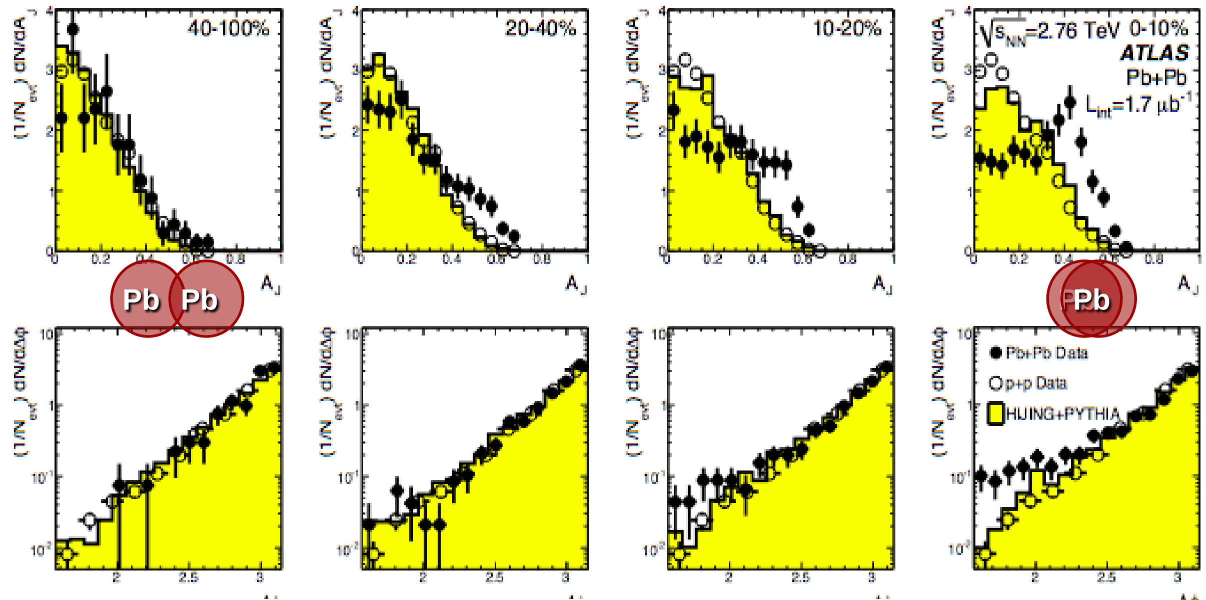
Key measurements: event multiplicity, rapidity density, elliptic flow, interferometry, jet quenching, heavy-flavor energy losses, resonances production and decays

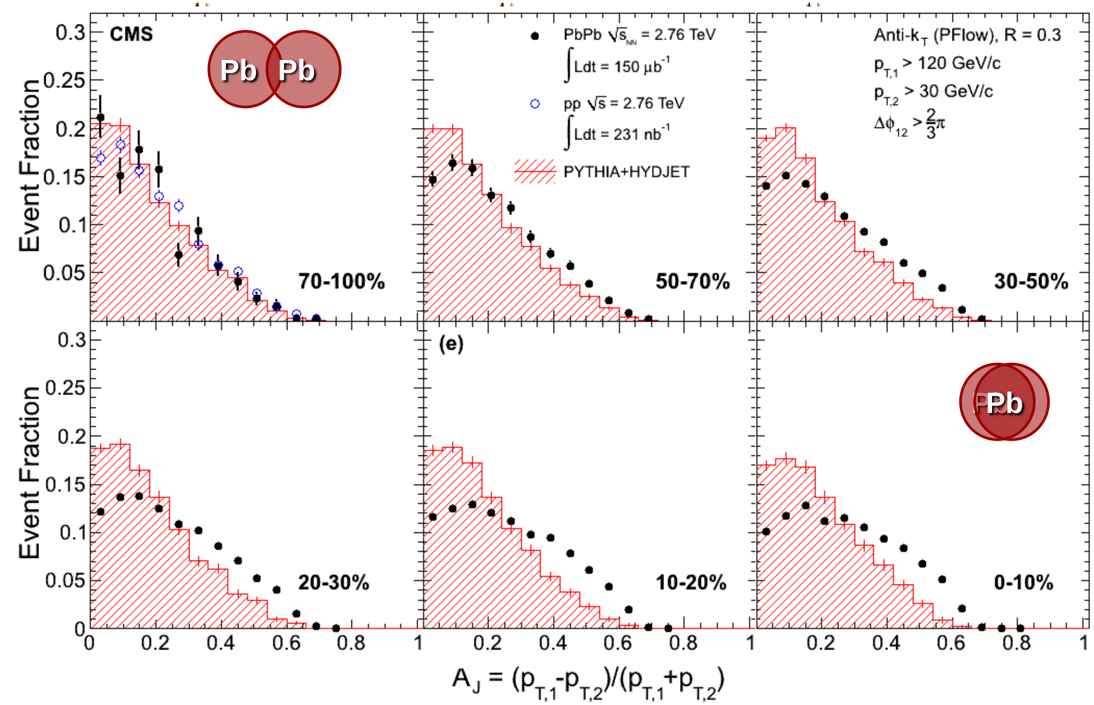


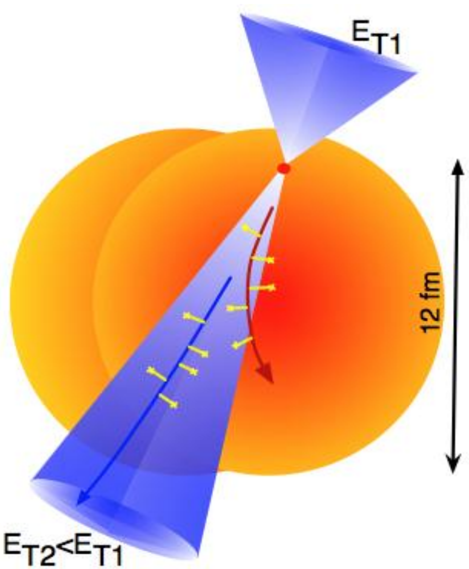
Much higher energy than before allows one to use "hard probes" (EW bosons, heavy quarks...)

Direct observation of jet quenching with dijets

A strong increase in the fraction of highly unbalanced jets is seen by ATLAS & CMS in central PbPb collisions as compared with pp and peripheral PbPb collisions, and the dijet embedded MC simulations, that consistent with jet quenching in hot quark-gluon medium .

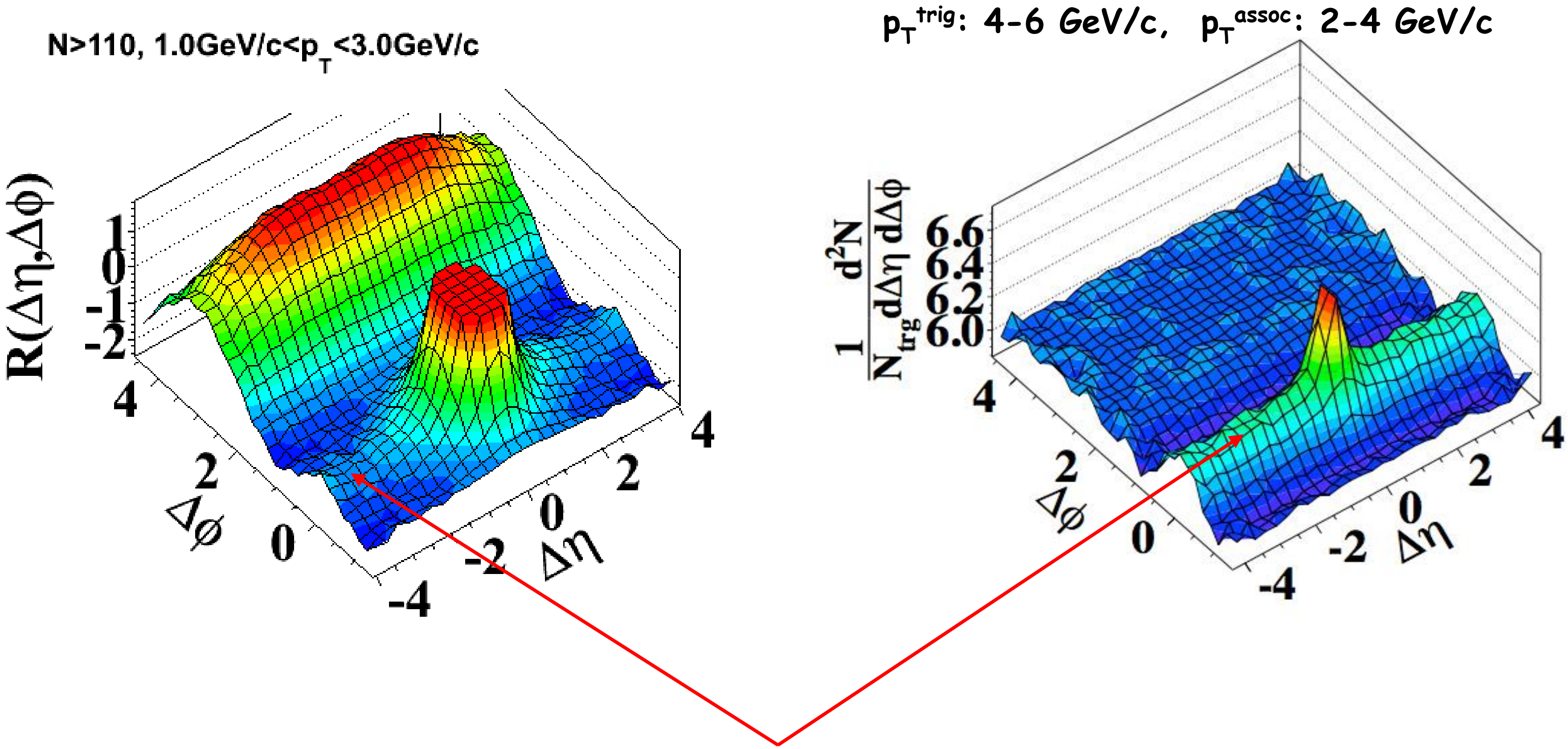




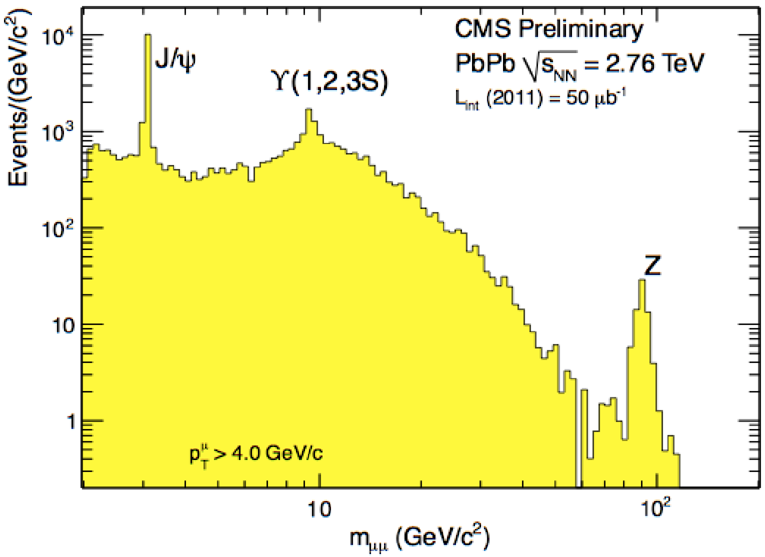


Two-particle correlations

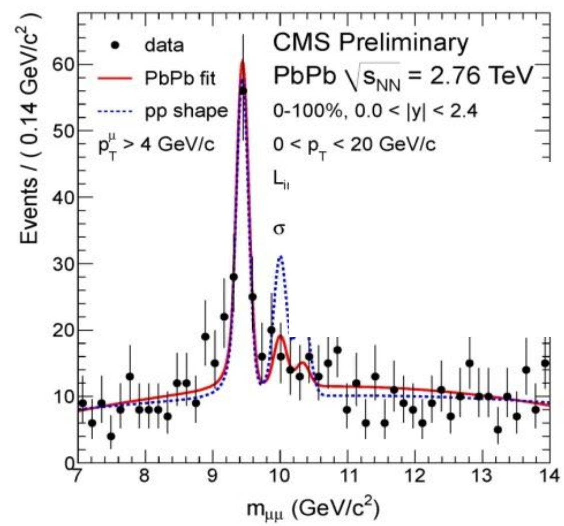
pp, 7 TeV **PbPb (0-5%), 2.76 A TeV**



"Ridge" (long-range azimuthal correlations) is observed by CMS in high multiplicity pp as well as in central PbPb collisions



CMS observes for the first time an additional suppression of exited Y-states (2S+3S) relatively to Y(1S) by a factor ~3 in PbPb vs. pp collisions, that consistent with the Debye screening of colour charge in hot quark-gluon medium



Concluding remarks

1. LHC physics program has started. MH range 127-600 GeV is excluded.

Higgs-like state is found - more studies will be needed to clarify

Which Higgs?-

Fundamental or composite? SM Higgs, or SUSY Higgses, or Pseudo-Goldstone boson of an enlarged symmetry, or fifth component of a gauge boson on a brane in models with extra dimensions, or …? One doublet, two doublets, many doublets?

2. Top quark physics is started to be a precision physics allowing to search for delicate deviations from the SM

3. Many new BSM limits in the range 1-4 TeV from direct and indirect searches . Many more are expected (for example, on top quark partners) for various SUSY and non-SUSY scenarios

4. Many very interesting results on QCD in various regions and regimes in pp and PbPb (hard, soft, high density, high temperature…)

We are in a very beginning of exploration of the Terascale at LHC !