SUSY @ ATLAS

JJC-2010

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LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

ATLAS EXPERIMENT
http://atlas.ch

Overview

- Susy at TeV scale (MSSM and mSUGRA).
- What can we say about Susy scale given current measurements.
- How do we discover susy at ATLAS ?
- How do we measure susy ?
- How do we reconstruct susy Lagrangian ?
- Beyond MSSM as multijet resonances.

What is susy ?

Well, relation boson fermion.

$$Q\,|boson\rangle = |fermion\rangle$$
$$Q\,|fermion\rangle = |boson\rangle$$

Could provide a DM candidate.
Could help force unification at GUT scale.
$R_P = (-1)^{3(B-L)+2s}$
LSP=χ_1^0

And the MSSM ?

$[u,d,c,s,t,b]_{L,R}$		$[e,\mu,\tau]_{L,R}$	$[\nu_{e,\mu,\tau}]_L$	Spin 1/2
$[\tilde{u},\tilde{d},\tilde{c},\tilde{s},\tilde{t},\tilde{b}]_{L,R}$		$[\tilde{e},\tilde{\mu},\tilde{\tau}]_{L,R}$	$[\tilde{\nu}_{e,\mu,\tau}]_L$	Spin 0
$g,$	$\underbrace{W^\pm, H^\pm}$,	$\underbrace{\gamma, Z, H_1^0, H_2^0}$		Spin 0 and 1
$\tilde{g},$	$\tilde{\chi}^\pm_{1,2},$	$\tilde{N}^\pm_{1,2,3,4}$		Spin 1/2

But $m_e \neq m_{\tilde{e}}$ so susy has to be broken.
Do it via soft Susy breaking terms and give a mass to susy Particles $M_{susy} = 1 TeV$.

SM or MSSM ?

Two possible ways :

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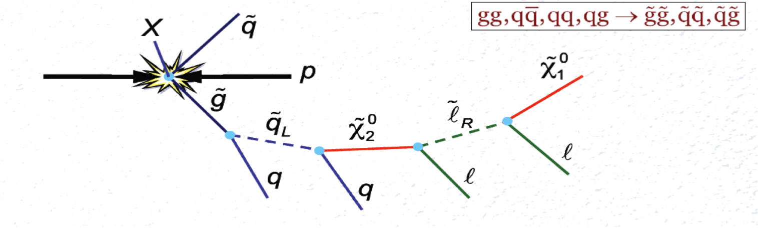
- Search for new SUSY particles ::: SM must be extended. ATLAS.



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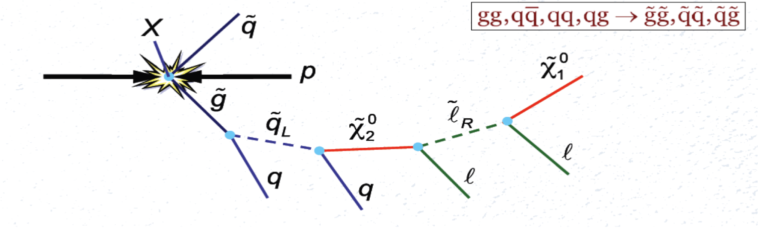
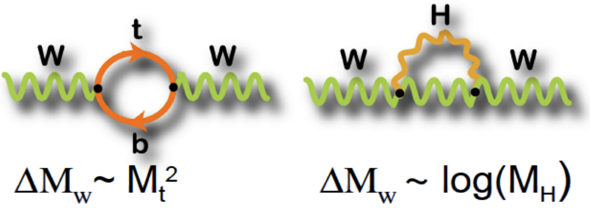


- Search for indirect effects of SUSY via precision observables. SFITTER.



What susy are we gonna have ?

- Search for indirect effects of SUSY via precision observables. SFITTER.

We can use precision observables, like M_W to perform a global fit of our susy model and determine the mass of the sparticles but ... More than 100 parameters in MSSM.

Assume :

- no new source of CP-violation
- no FCNC

Assume unification at GUT scale of :

- gauge coupling
- scalar masses
- gaugino masses
- trilinear couplings

20 parameters in pMSSM.

5 parameters in mSUGRA
m_0 : universal scalar mass parameter
$m_{1/2}$: universal gaugino mass parameter
A_0 universal trilinear coupling
$\tan\beta$: ratio of Higgs vacuum expectation values
sign(μ) : sign of supersymmetric Higgs parameter

What susy are we gonna have ?

- Search for indirect effects of SUSY via precision observables. SFITTER.

B physics

- $B_r(B \to \tau\nu) = (1.41 \pm 0.43)10^{-5}$
  Babar 2008 (superIso)
- $B_r(B \to X_s\gamma) = (3.55 \pm 0.24)10^{-4}$
  HFAG 2006 (suspect)
- $\Delta_{0\_} = 0.0375 \pm 0.0289$
  PDG 2008 (SuperIso)

EWPrecisionObservables

- $\delta a_\mu = (3.02 \pm 0.88)10^{-9}$
  TEWG (Suspect)
- $M_w = 80.399 \pm 0.025$ GeV.
  TEWG (Suspect)

DM relic density

- $\Omega_{DM} h^2 = 0.104 \pm 0.009$
  WMAP (Micromegas)

What susy are we gonna have ?

With only 5 parameters mSUGRA can be done with MINUIT :

Param	**value**	**error**
m_0	110	35.8
$m_{1/2}$	341	1
$\tan\beta$	15.4	0.6
A_0	757	132

$$M_{\tilde{g}} = 770\ GeV$$
$$M_{\tilde{q}} = 570\ GeV$$
$$M_{\tilde{\chi}_1^0} = 130\ GeV$$

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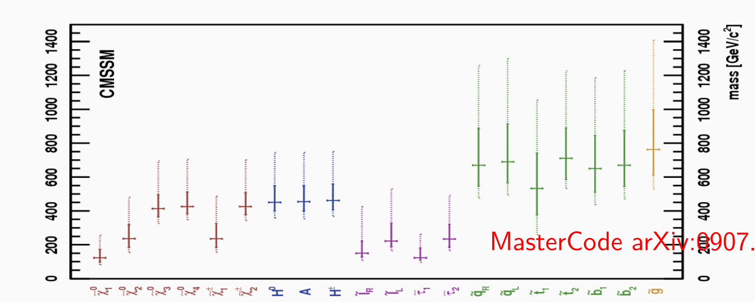
Putting additional constraints and with proper error treatment :



MasterCode arXiv:0907.5568v1

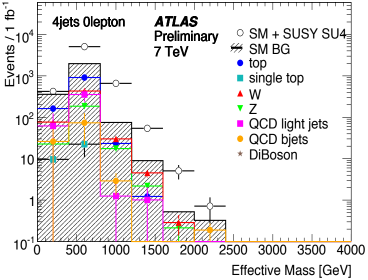
How do we discover susy at ATLAS?

Discover squark, gluino production as an excess of events in jet(s) + E_T^{miss} + lepton(s) final states.

Example of 4 jet + E_T^{miss}. Expect events in the tails of distributions. Background is QCD, W+jets, Z+jets, $t\bar{t}$.

- Leading jet $P_T > 100$ GeV
- 2nd, 3th, 4th jet $P_T > 40$ GeV
- $E_T^{miss} > 80$ GeV
- $E_T^{miss} > 0.2 M_{eff}$
- $\Delta\phi(jet, E_T^{miss}) > 0.2$
- Transverse Sphericity $S_T > 0.2$

$$M_eff = E_T^{miss} + \sum_{jet} |P_T|$$



Not so simple !!!!
(can we trust our MC?)

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$\Longrightarrow$ Just plot E_T^{miss}.

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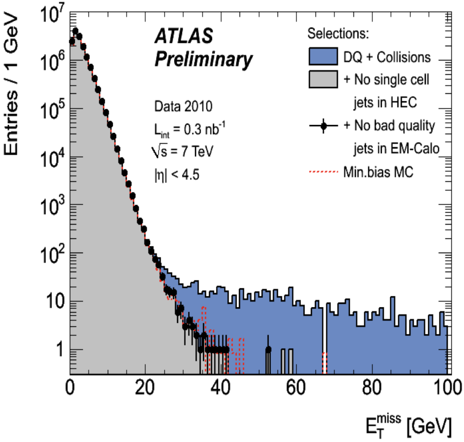

Susy discovered. Thanks.

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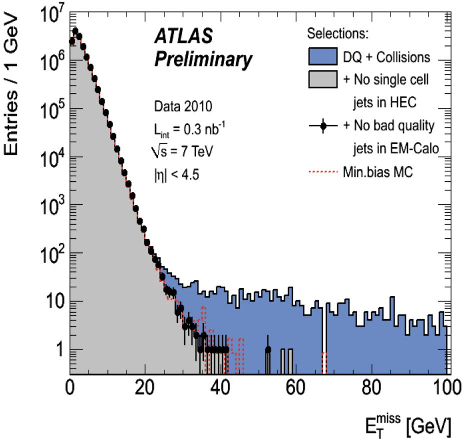
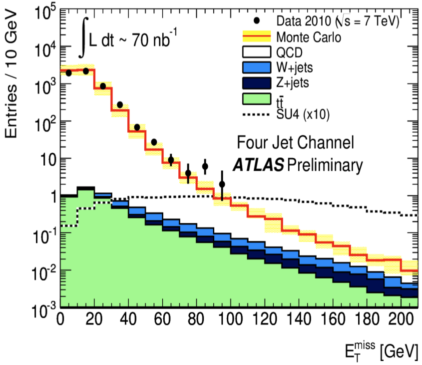
We do not need all those cuts

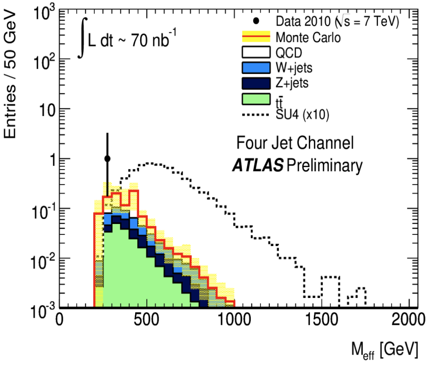
$\Longrightarrow$ Just plot E_T^{miss}.



Susy discovered. Thanks.

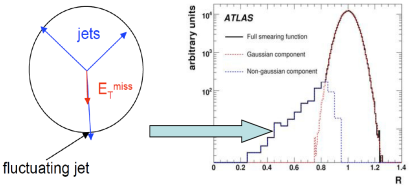
No :: clean your events from not physical jets and come back.





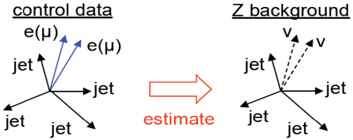
Before Susy cuts :

- jet $P_T > [70, 30, 30, 30]$ GeV



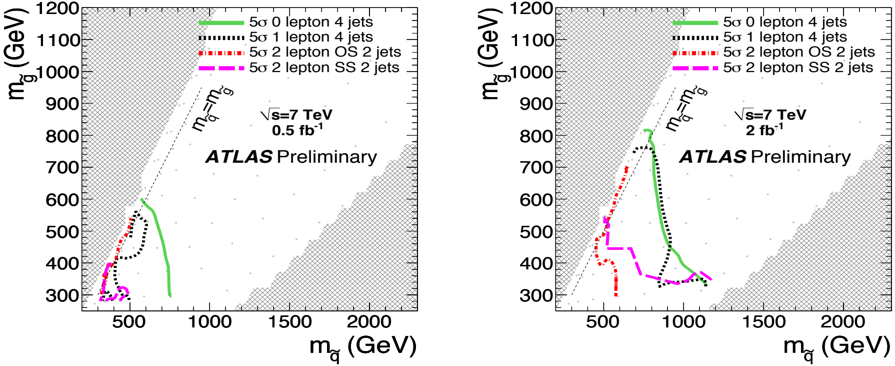
After Susy cuts :

- jet $P_T > [70, 30, 30, 30]$ GeV
- $E_T^{miss} > 40$GeV
- $\Delta\phi(jet, E_T^{miss}) > [0.2, 0.2, 0.2]$



How do we discover susy at ATLAS?

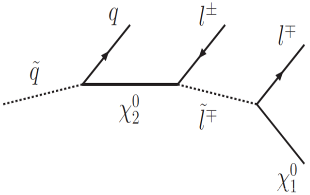
Discovery potential for next year :



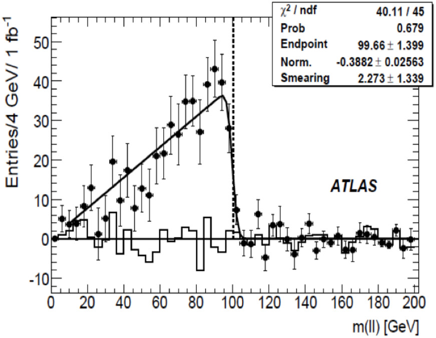
ATLAS not working in the "Christophe Lambert" plane anymore !!!!!!!!

How do we measure susy ?

The observables are endpoints or thresholds of invariant mass combinations among the leptons and jets in cascade decay.
Kinematic edges depend only on the intervening masses, not on the underlying SUSY model.



$$(m_{ll}^2)^{edge} = \frac{(m^2_{\tilde{\chi}_2^0} - m^2_{\tilde{l}_R})(m^2_{\tilde{l}_R} - m^2_{\tilde{\chi}_1^0})}{m^2_{\tilde{l}_R}}$$



How do we measure susy ?

The observables are endpoints or thresholds of invariant mass combinations among the leptons and jets in cascade decay.

sPS1a :
$m_0 = 100$
$m_{1/2} = 250$
$\tan\beta = 10$
$A_0 = -100$
$sign(\mu) = +1$
Still close to DM-EW best fit point :)

measurements for $100 fb^{-1}$

	type of measurement	nominal value	stat.	LES error	JES error	theo.
m_h		108.7	0.01	0.25		2.0
m_t		171.20	0.01		1.0	
$m_{\tilde{l}_L} - m_{\chi_1^0}$		102.38	2.3	0.1		1.1
$m_{\tilde{g}} - m_{\chi_1^0}$		511.38	2.3		6.0	6.1
$m_{\tilde{q}_R} - m_{\chi_1^0}$		446.39	10.0		4.3	5.5
$m_{\tilde{g}} - m_{\tilde{b}_1}$		89.01	1.5		1.0	8.0
$m_{\tilde{g}} - m_{\tilde{b}_2}$		62.93	2.5		0.7	8.2
m_{ll}^{max}:	three-particle edge($\chi_2^0,\tilde{l}_R,\chi_1^0$)	80.852	0.042	0.08		1.2
m_{llq}^{max}:	three-particle edge($\tilde{q}_L,\chi_2^0,\chi_1^0$)	449.08	1.4		4.3	5.1
m_{lq}^{low}:	three-particle edge($\tilde{q}_L,\chi_2^0,\tilde{l}_R$)	326.32	1.3		3.0	5.2
$m_{ll}^{\text{max}}(\chi_4^0)$:	three-particle edge($\chi_4^0,\tilde{l}_L,\chi_1^0$)	277.36	3.3	0.3		2.0
$m_{\tau\tau}^{\text{max}}$:	three-particle edge($\chi_2^0,\tilde{\tau}_1,\chi_1^0$)	83.21	5.0		0.8	1.0
m_{lq}^{high}:	four-particle edge($\tilde{q}_L,\chi_2^0,\tilde{l}_R,\chi_1^0$)	390.18	1.4		3.8	5.0
m_{llq}^{thres}:	threshold($\tilde{q}_L,\chi_2^0,\tilde{l}_R,\chi_1^0$)	216.00	2.3		2.0	3.3
m_{llb}^{thres}:	threshold($\tilde{b}_1,\chi_2^0,\tilde{l}_R,\chi_1^0$)	198.41	5.1		1.8	3.1

SFitter arXiv:1007.2190v1

How do we reconstruct susy L ?

R. Lafaye, T. Plehn, M. Rauch, D. Zerwas + C. Adam Bourdarios and J.L. Kneur.

Perform a global fit using SFitter.

Test MSSM and not mSUGRA.
Because mSUGRA make assumptions at high scale $\longrightarrow$ Analysis bias.

Take the measurements : $m_{ll^{edge}}$...
Compute the predictions of your model for this observable with respect to the model parameters $M_{1,2,3}$, $M_{\tilde{q}_{L,R}}$, $\tan\beta$.
Then minimize with respect to model parameters :

$$-2\log L \equiv \chi^2 = \sum_{\text{measurements}} \begin{cases} 0 & \text{for } |x_{\text{data}} - x_{\text{pred}}| < \sigma_{\text{theo}} \\ \left(\frac{\left||x_{\text{data}} - x_{\text{pred}}| - \sigma_{\text{theo}}\right|}{\sigma_{\text{exp}}}\right)^2 & \text{for } |x_{\text{data}} - x_{\text{pred}}| \geq \sigma_{\text{theo}} \end{cases}$$

How do we reconstruct susy L ?

Best Fit point result : True sps1a recover.

	LHC	LHC+ILC	SPS1a
$\tan\beta$	13.8± 7.4	10.7± 3.1	10.0
M_1	105.0± 6.9	103.1± 0.7	103.1
M_2	194.7± 7.3	193.0± 1.6	192.9
M_3	568.3± 11.6	568.5± 7.8	567.7
$M_{\tilde{\tau}_L}$	321.4± 248	192.4± 4.7	193.5
$M_{\tilde{\tau}_R}$	164.3± 120	134.9± 5.7	133.4
$M_{\tilde{\mu}_L}$	196.3± 7.6	194.4± 1.2	194.3
$M_{\tilde{\mu}_R}$	138.0± 7.0	135.8± 0.6	135.8
$M_{\tilde{e}_L}$	196.4± 7.5	194.3± 0.8	194.3
$M_{\tilde{e}_R}$	137.9± 7.1	135.8± 0.6	135.8
$M_{\tilde{q}3_L}$	491.4± 16.2	486.2± 11.1	481.1
$M_{\tilde{t}_R}$	483.4± 232	409.6± 17.1	409.4
$M_{\tilde{b}_R}$	502.6± 15.3	499.1± 13.1	502.7
$M_{\tilde{q}_L}$	529.6± 12.1	526.4± 5.3	526.4
$M_{\tilde{q}_R}$	508.9± 16.4	507.8± 14.4	506.8
A_τ	fixed 0	-102.9± 681	-249.3
A_t	-394.4± 353	-497.3± 74	-496.8
A_b	fixed 0	-274.2±1830	-764.0
m_A	558.2±271.2	394.9± 1.5	394.9
μ	353.1± 7.7	350.8± 2.5	351.0

SFitter arXiv:1007.2190v1

How do we reconstruct susy L ?

Test unification of masses using the RGE's :: Bottom-up approach.

Best Fit point result : True sps1a recover.

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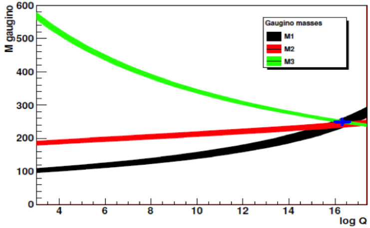
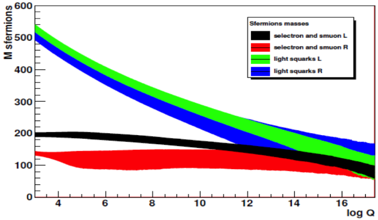
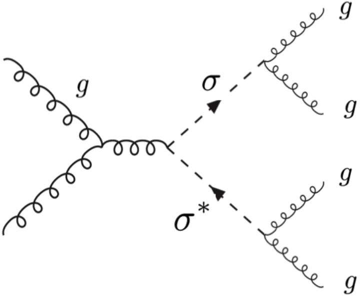




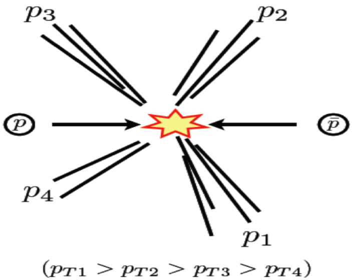
BMSSM as Multijet-Resonances

Or, how we could miss new-physics.

Imagine that processus



witch will look like :

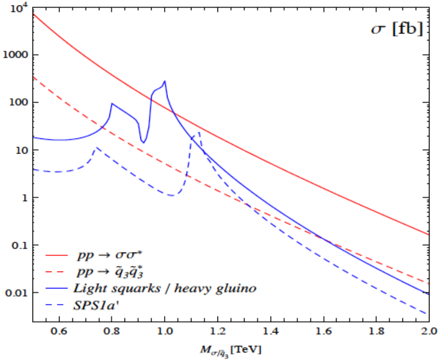


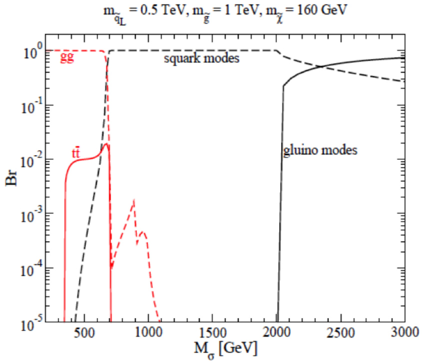
It's a pure multijet final state without leptons or missing transverse energy.
Huge QCD background.

Scalar-gluons in hybrid N=1/N=2 susy

Scalar-gluon is spin0, color octet, $R_P = +1$.

Model	MSSM	+	= N=1/N=2
Multiplet	$\tilde{g}, g$	$+\tilde{g}, \sigma$	$= \tilde{g}, \sigma$
Spin	$1/2, 1$	$1/2, 0$	$1/2, 0$





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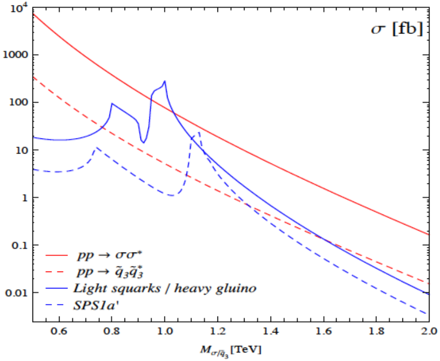
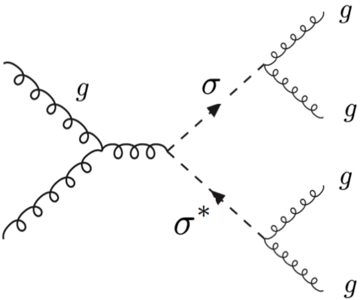
Model	**MSSM**	$+$	$=$ **N=1/N=2**
Multiplet	$\tilde{g}, g$	$+\tilde{g}, \sigma$	$= \tilde{g}, \sigma$
Spin	$1/2, 1$	$1/2, 0$	$1/2, 0$





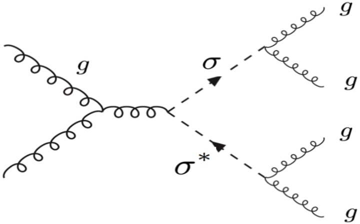
Scalar-gluons in hybrid N=1/N=2 susy

Can we extract the scalar-gluon signal from QCD background.

MC study

- Signal : home made implementation of scalar-gluon pair production in PYTHIA.
- Background : Alpgen Njets (full LO ME up to 6 partons in final state).

Main feature is two jet pairs with equal invariant masses.
3 different combinations.
Keep only the one that give the closest two invariant masses.



Scalar-gluons M=225GeV

Ask for 4 jets with $P_T > 50$ GeV.

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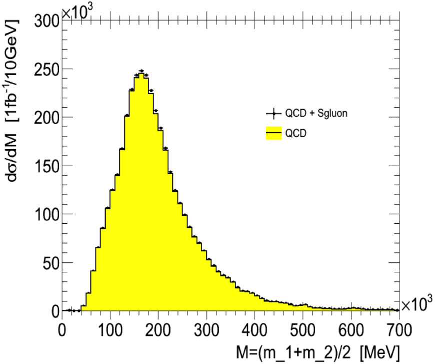

NO

Scalar-gluons M=225GeV

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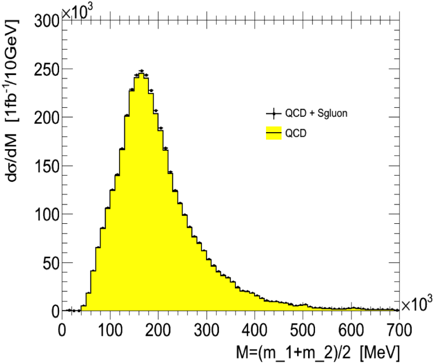
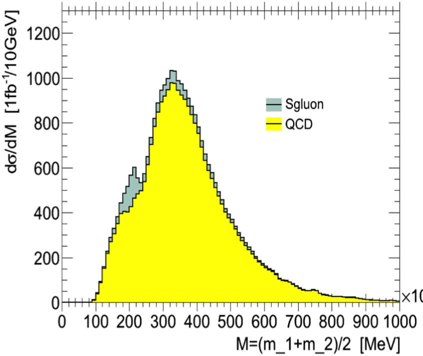
Is it enough to suppress QCD background ?



NO

Increase the P_T cut, 4 jets $P_T > 100$ GeV.



Signal visible but nightmare to fit and the 'first bump' could be reproduce by QCD only.

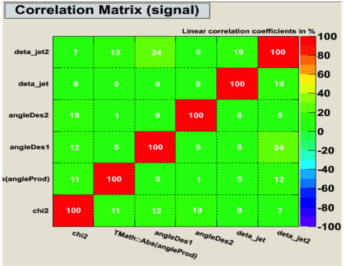
Scalar-gluons M=225GeV

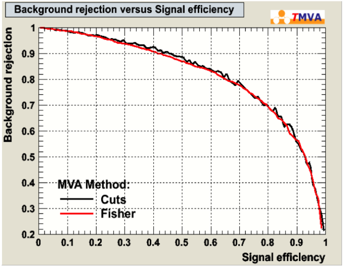
Since their is no E_T^{miss} we can reconstruct the all kinematic of the event and find some discriminant variables.

Scalar production is central $\neq$ QCD background rather forward :

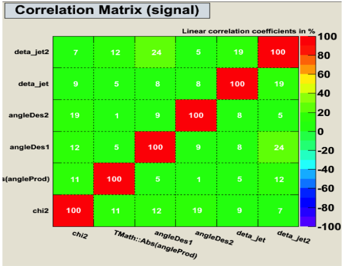
$+ \Delta R(jet, jet)$

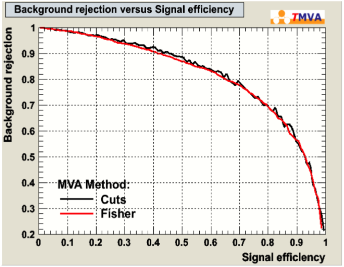
Scalar-gluons M=225GeV



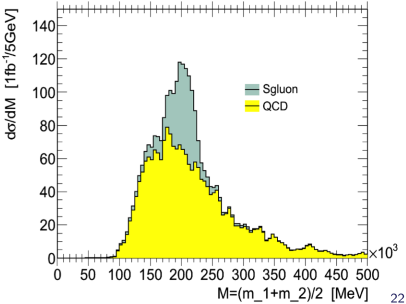


Scalar-gluons M=225GeV





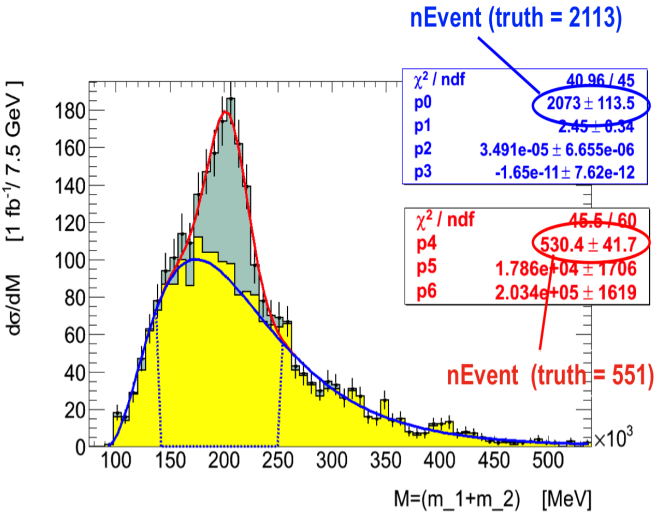
Use multivariate analysis to optimize.



Scalar-gluons M=225GeV

In real data you need to fit the curve to extract the number of background and signal events.

$$\sigma = S/\sqrt{B} \simeq 11$$



Conclusion

- Susy discovery, next two years or in a 'far' future ?
- BMSSM multijet resonances scenarios are very promising for next two years.
  - Sgluon analysis could be applied to coloron/technipion search.
  - Develop analysis for higher jet multiplicities (RPV gluinos).