- SUSY Searches - with First ATLAS data

CAT physics meeting, Apr. 18th 2007

Till Eifert (Geneva U.)

On behalf of the CAT SUSY group:

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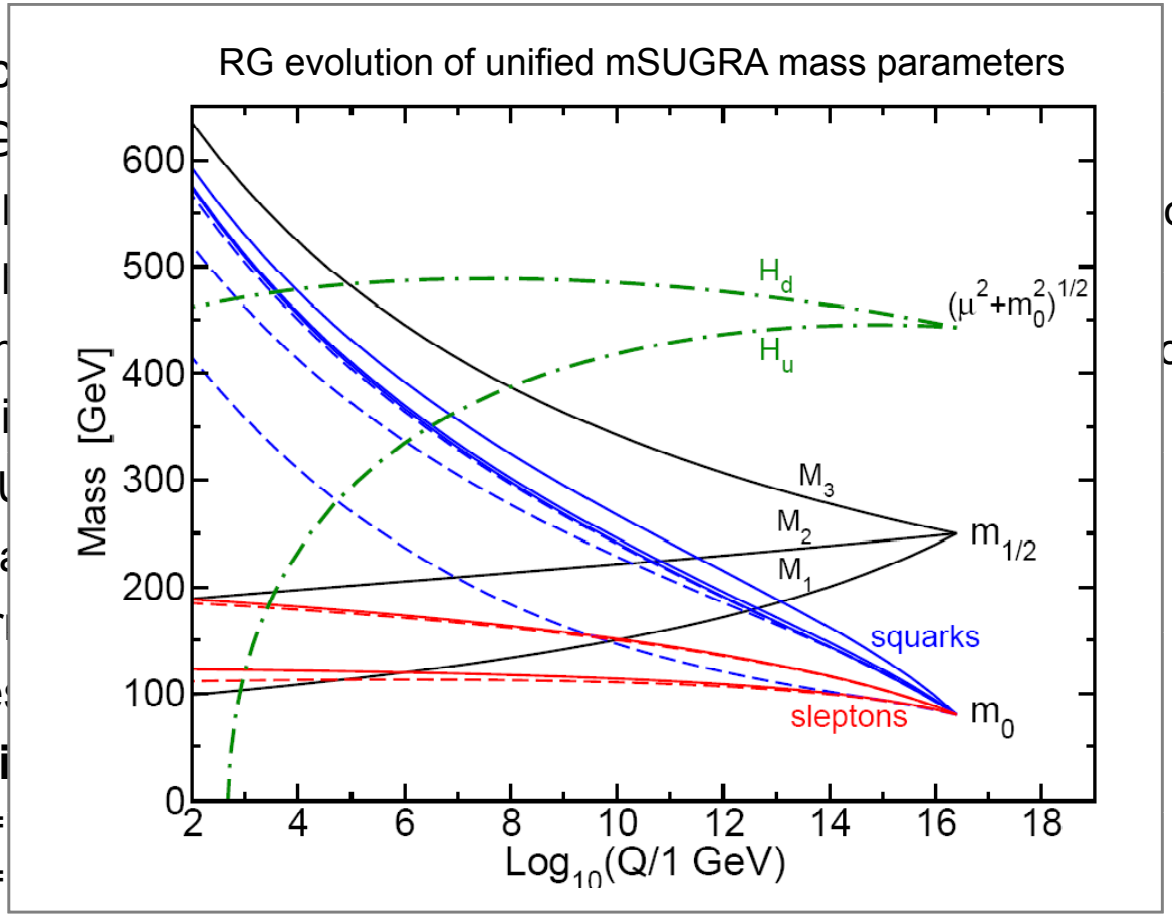
CAT SUSY group overview

- Activities
  - mSugra study (>=1 lepton), presented here (CSC-5)
  - Electron ID in specific SUSY (lots-of-jets) environment (CSC-5)
  - exclusive (>=2 lepton) analysis: Stefan Ask, Johannes Haller, & Christophe Clement (CSC-6)
  - Lots of common tool developments

Minimal SuperGravity (**mSUGRA**)

Quick reminder of mSugra …

- Reduc
- mSUG
  - all
  - all
  - ar
- Remai
  - SU
  - Ra
- Renor
- Lighte
- **R-pari**
  - R=
  - R=



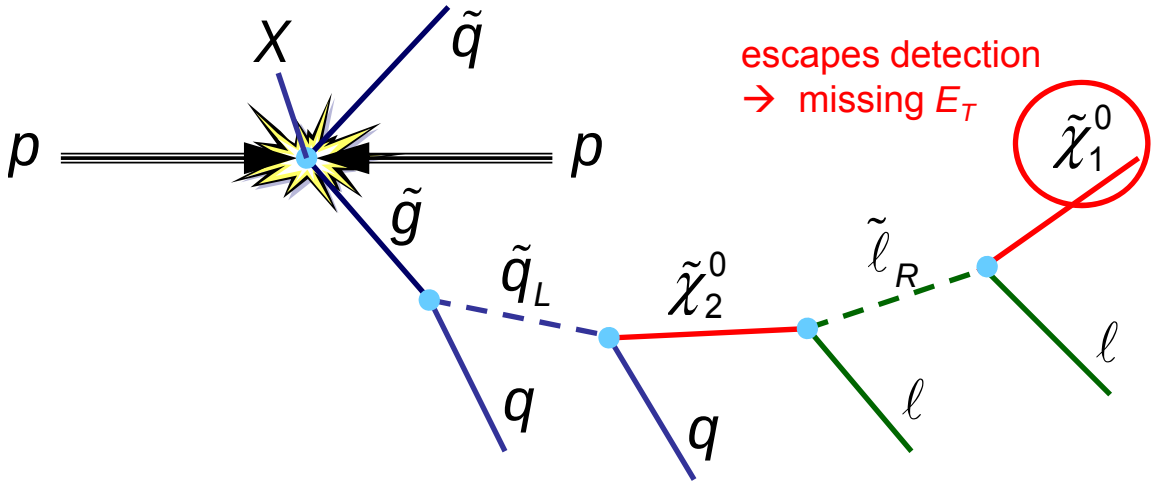
on mass $\mathbf{m_0}$,

ommon value $\mathbf{A_0}$

to the EW scale

Characteristic SUSY "Cascades" at the LHC

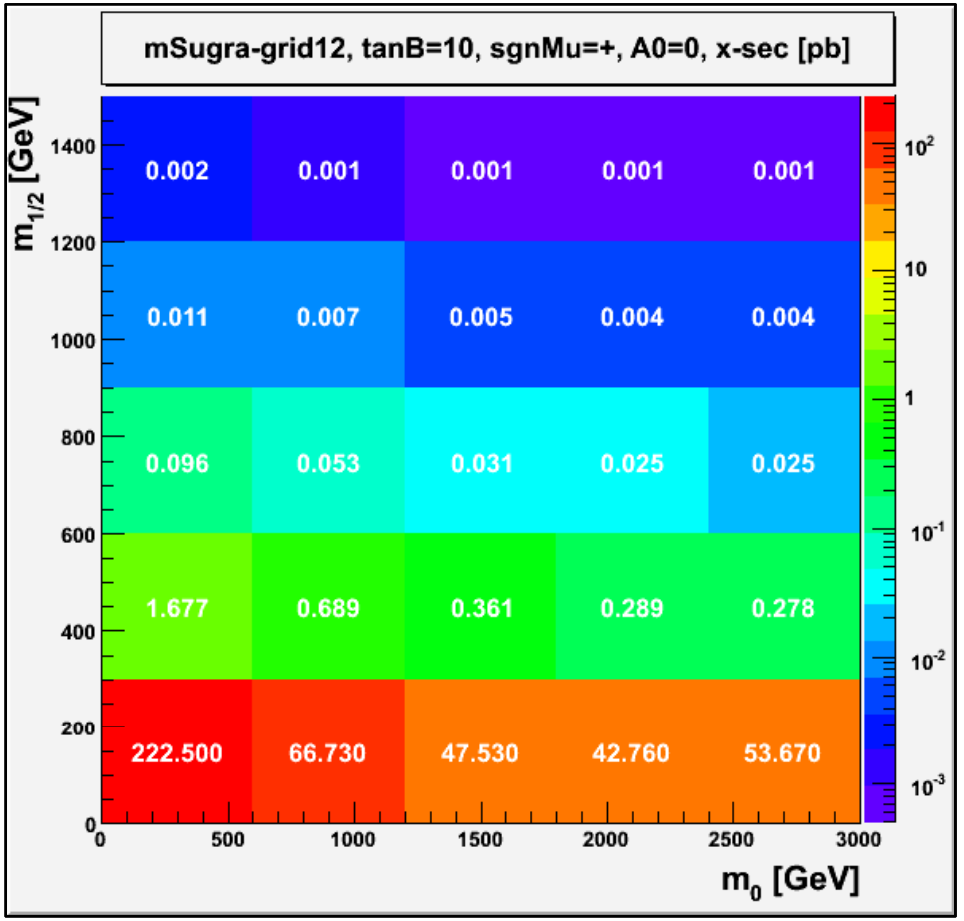
- Conserved ***R*-parity** requires existence of a **lightest stable SUSY particle** = "LSP". Since no exotic strong or EM bound states (isotopes) have been observed, the LSP should be neutral and colourless → **WIMP** !
- The experimental signature of the LSP would be just as the one of a heavy neutrino !
- The LSP is typically found to be a spin-½ "**neutralino**", a linear combination of gauginos (in much of the SUSY parameter space the neutralino is a mixture of photino and zino)



"Typical" SUSY decay chain at the LHC

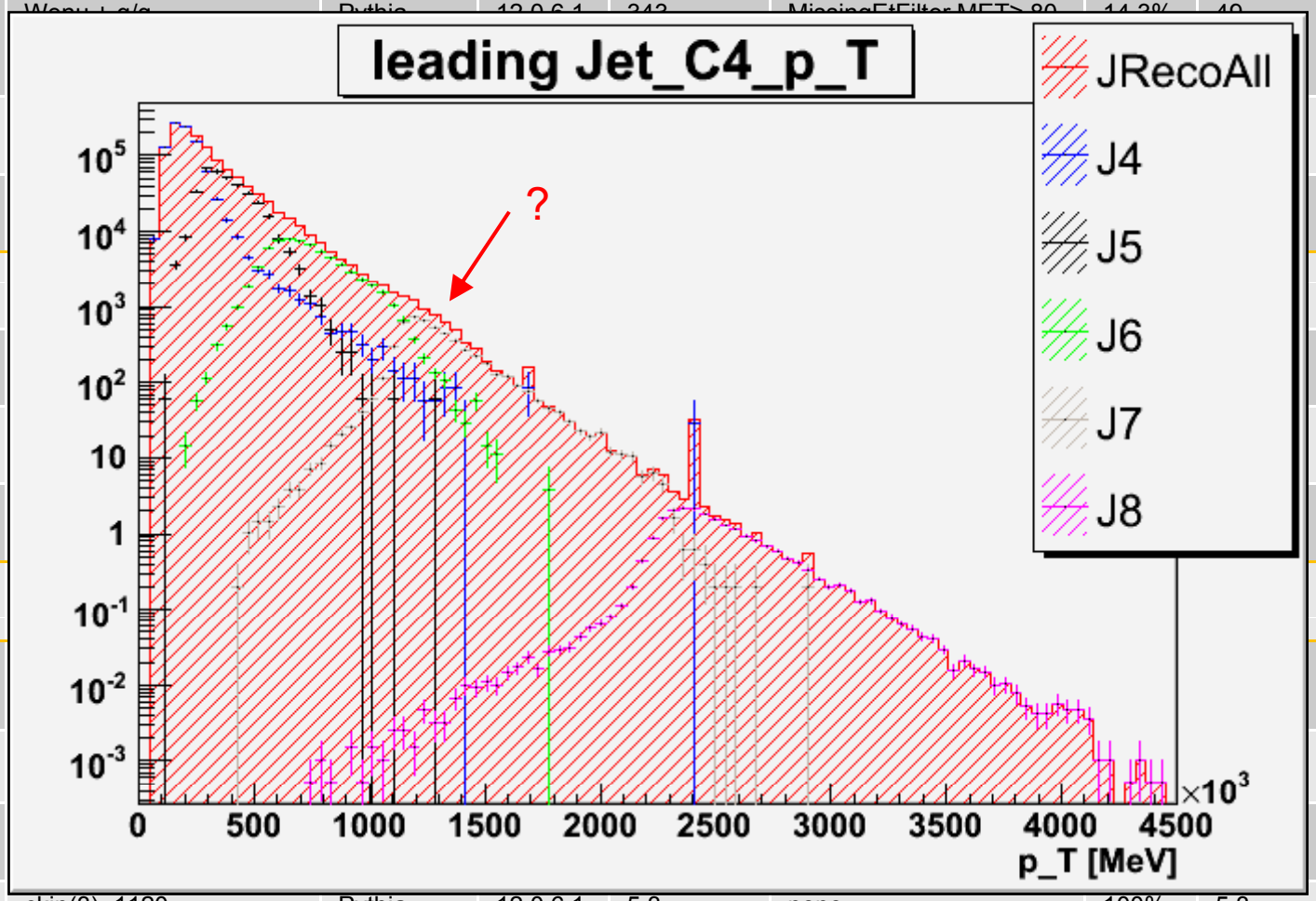
Data samples

- mSugra signal
  - Grid in parameter space
    - $A_0 = 0$
    - $\tan \beta = 10$
    - sign $\mu = +$
    - scalar mass $m_0 = 0 .. 3TeV$
    - Gauginos mass $m_{1/2} = 0 .. 1.5$ TeV
  - 5k events on each par. Point
  - All AtlFast 12.0.6
- SM Backgrounds
  - Consider various SM bkg samples, see next slide
  - All AtlFast 12.0.6+
- Software
  - Isajet 7.75 (for the mSugra spectra) + HERWIG/Jimmy
  - AtlFast (Athena) 12.0.6
  - HighPtView
- Production
  - LCG grid (usgin ganga)
  - Private production



SM Background Samples

process		description	gen.	Vers.	σ_{gen} (pb)	EventFiler	ε_{EF}	σ_{EF} (pb)	# evts$_{disk}$
Wenu	8270								48k
Wmunu	8271								54k
Wtaunu	8272								54k
Znunu	8190								26k
Zee	8194								20k
Zmumu	8195								61k
Ztautau	8191								47k
T1	5200								720k
J4	8090								32k
J5	8091								8k
J6	8092								18k
J7	8093	ckin(3)=1120, ckin(4)=2240	Pythia	12.0.6.1	5.3	none	100%	5.3	26k
J8	8094	ckin(3)=2240	Pythia	12.0.6.1	2.21×10^{-2}	none	100%	0.02	42k



PreSelection

- Put samples on an equal basis & reduce #evts
  - Lepton cut
    - ≥ 1 lepton (El / Mu)
    - pT ≥ 20GeV
  - Jet cut
    - ≥ 2 Jets
    - pT ≥ 80, 40 GeV
  - MET ≥ 100 GeV
- Add some variables
  - AllMeff = MET+ΣJet_pT
  - TransverseMass of hardest lepton + MET

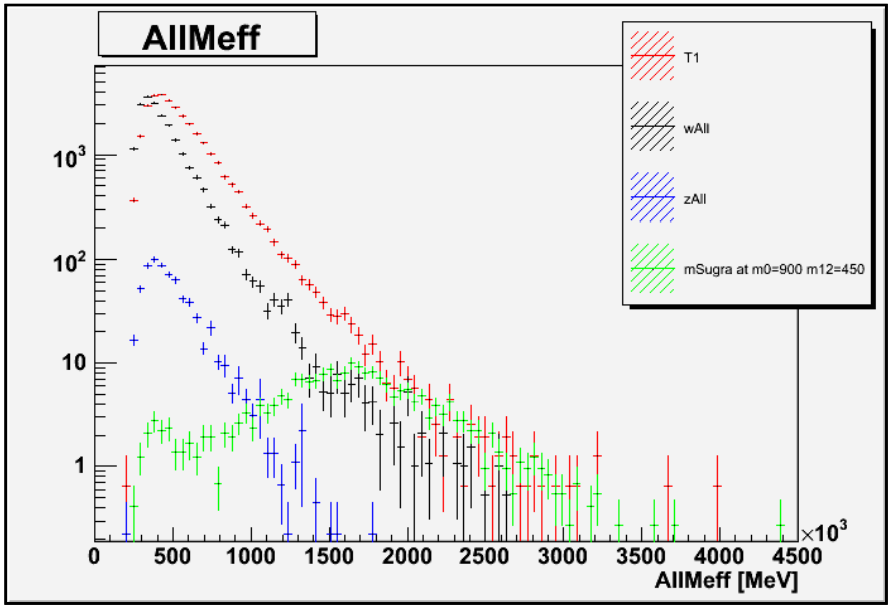
Background efficiencies

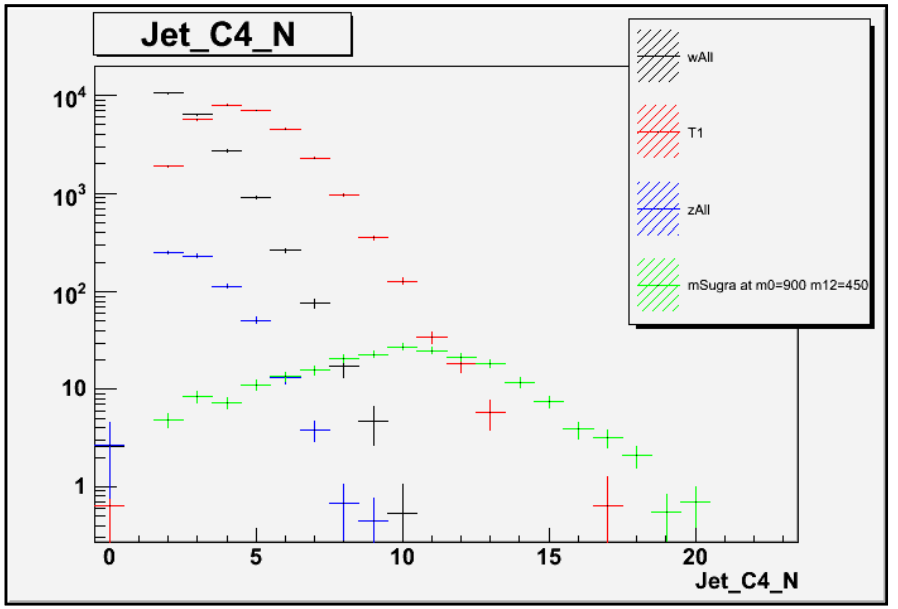
proc.	Lep ε	Jet ε	MET ε	Tot ε	$\sigma_{PS(pb)}$	# $evts_{PS}$	$\#evts_{100pb^{-1}}$
Wenu	62.8%	41.5%	68.5%	17.8%	8.7	8k	874
Wmunu	50.8%	88.0%	68.9%	30.8%	8.8	16k	881
Wtaunu	12.6%	62.6%	75.2%	5.9%	3.3	3k	330
Znunu	0.005 %	33%	100%	0.002%	$7x10^{-4}$	1	0.1
Zee	83.0%	28.7%	0.2%	0.05%	0.02	12	2
Ztautau	30.5%	70.9%	66.8%	14.4%	0.65	3k	65
Zmumu	83.7%	84.0%	2.4%	1.7%	0.16	1k	16
T1	54.5%	60.7%	20.3%	6.7%	30.9	48k	3092
J4	0.1%	90.0%	3.8%	~0.003%	0.03	1	3
J5	0.05%	100 %	67 %	~ 0.12	0.12	2	12
J6	0.02%	100 %	0 %			0	
J7	0.01 %	100 %	0 %			0	
J8	0.02 %	100 %	40 %	~0.009%	2^{-6}	4	0

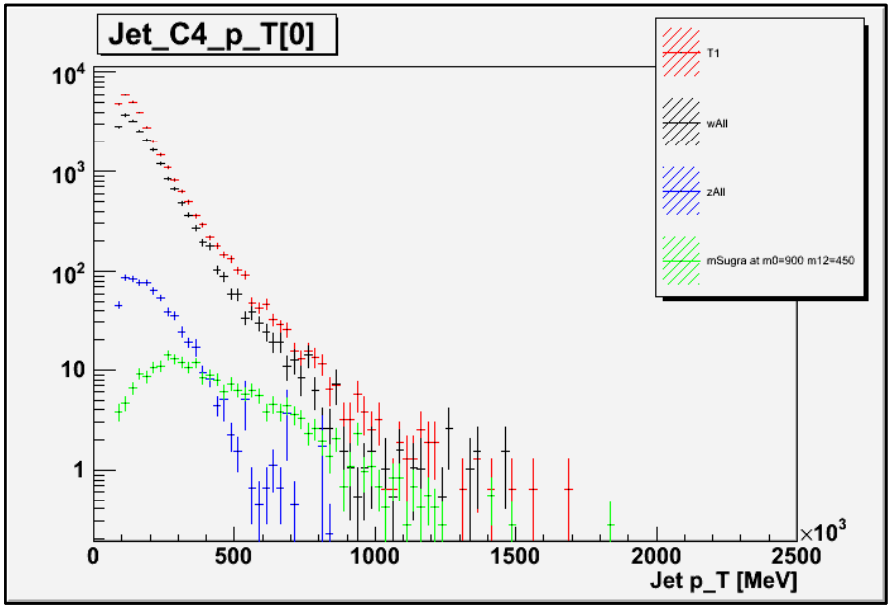
out of statistics

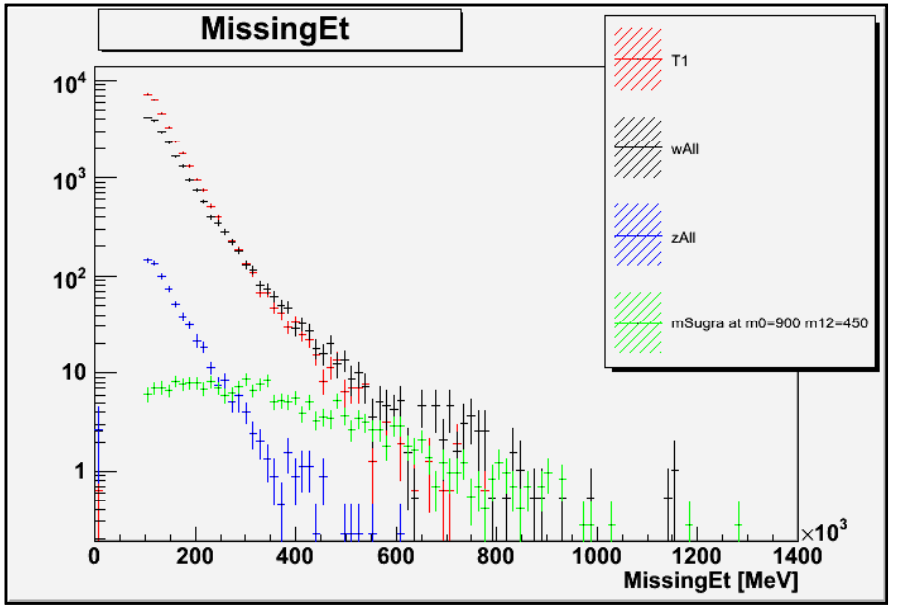
out of statistics

PreSelection bkg distributions

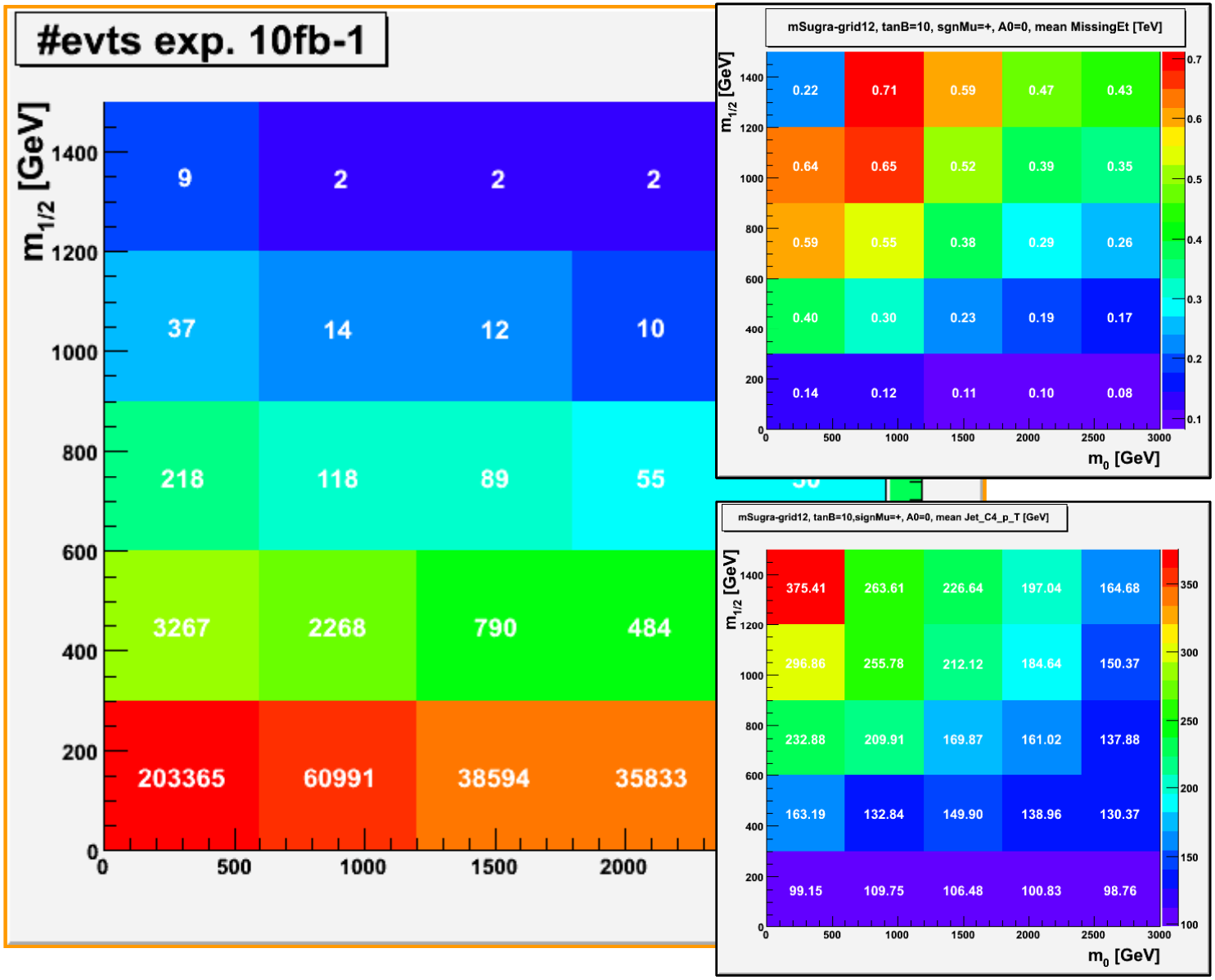






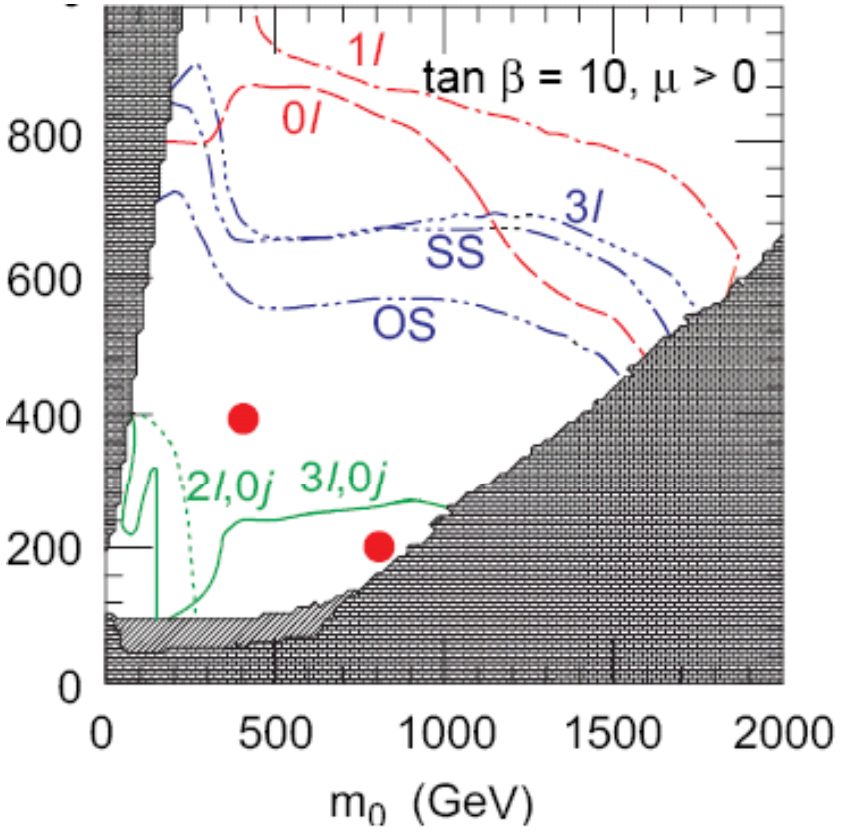


PreSelection .. signal



TDR SUSY analysis

- ATLAS TDR vol. II, page 820
- Reach for S/sqrt(S+B) > 5 for various SUSY signatures in the mSugra parameter space
- TDR Selection
  - Transverse mass (l, MET)
    - ≥ 100 GeV
    - "..reduce W+jet bkg.."
  - Jet cut
    - ≥ 2 Jets
    - pT ≥ 100 GeV optimize pT cut for each point
  - MET
    - ≥ 100 GeV optimize cut for each point
  - transverse sphericity
    - > 0.2
    - " .. To reduce dijet background .. "
  - Lepton
    - pT > 20 GeV
    - Eta < 2.5
- Integrated lumi = 10 fb^{-1}



TDR one lepton analysis

- Selection
  - Transverse mass (l, MET)
    - ≥ 100 GeV
    - "..reduce W+jet bkg.."
  - Jet cut
    - ≥ 2 Jets
    - optimize pT cut for each point
  - MET
    - Optimize cut for each point
  - transverse sphericity not used
    - variable missing in some ntuples ☹
- Optimization with TMVA
  - Simple box cuts
  - Optimize for min p-value (max sigma)
    - W bkgs
    - T1 bkg
  - Resulting reach
    - ≥ 10 signal evts
    - Significance ≥ 5 sigma
  - For integrated luminosities:
    - 100 pb^{-1}
    - 10 fb^{-1}

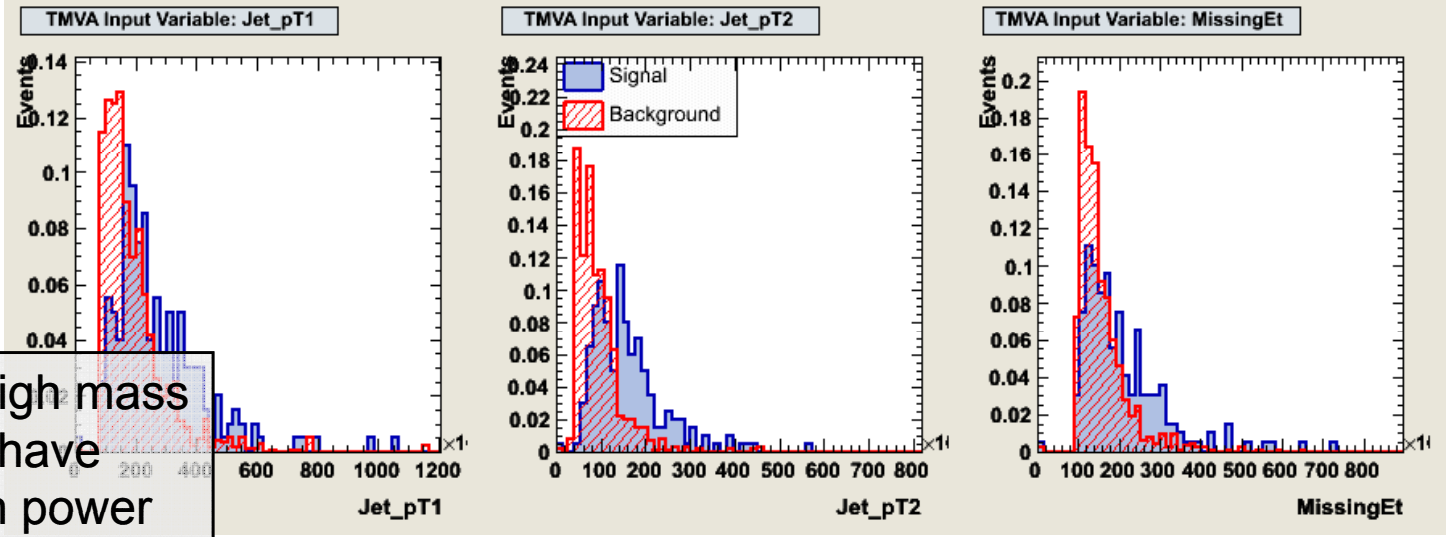
Background efficiencies

proc.	transMass ε	$\sigma_{PS(pb)}$	# $evts_{TDR}$	#$evts_{100pb^{-1}}$
Wenu	43.5%	3.8	4k	380
Wmunu	43.4%	3,8	7k	382
Wtaunu	47.5%	1.6	2k	157
Znunu	~100 %		1	~0
Zee	~33%		4	~1
Ztautau	44.9%	0.3	1k	29
Zmumu	40.8%	0.06	0.3k	6
T1	47.3%	14.6	22k	1462
J4	~100%		1	~3
J5	~100%		2	~12
J6	?		0	
J7	?		0	
J8	~75%	$2x10^{-6}$	3	~0

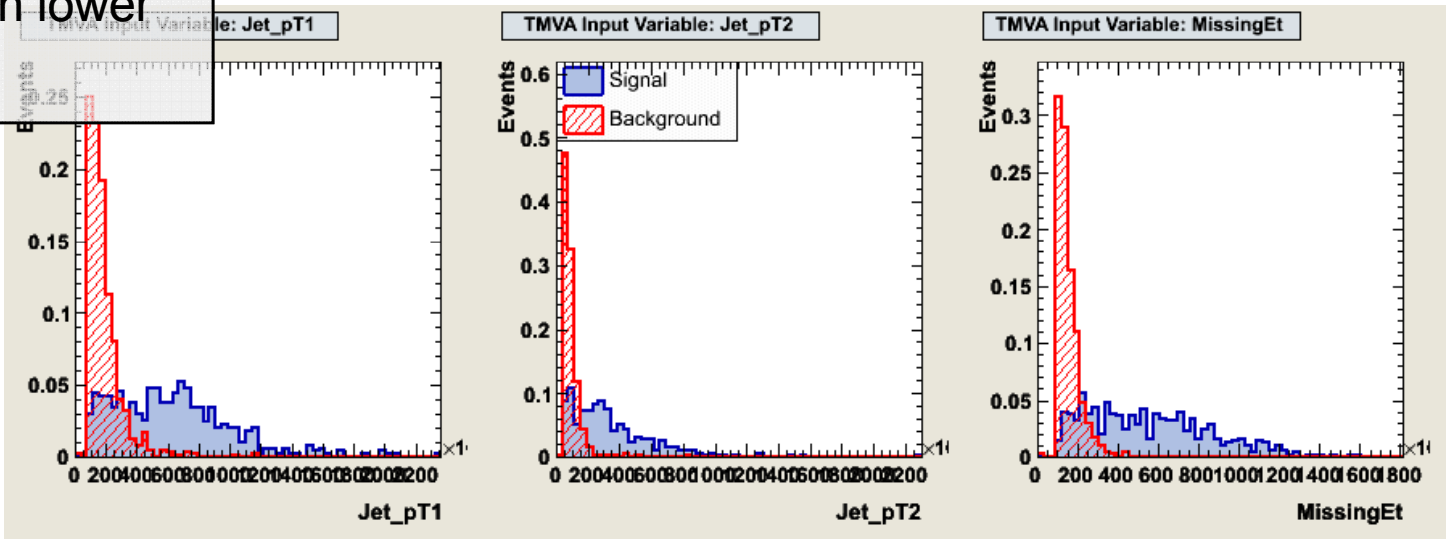
TMVA cut optimization

- Good news ☺, high mass points generally have better separation power
- Bad news ☹, high mass points have much lower cross sections

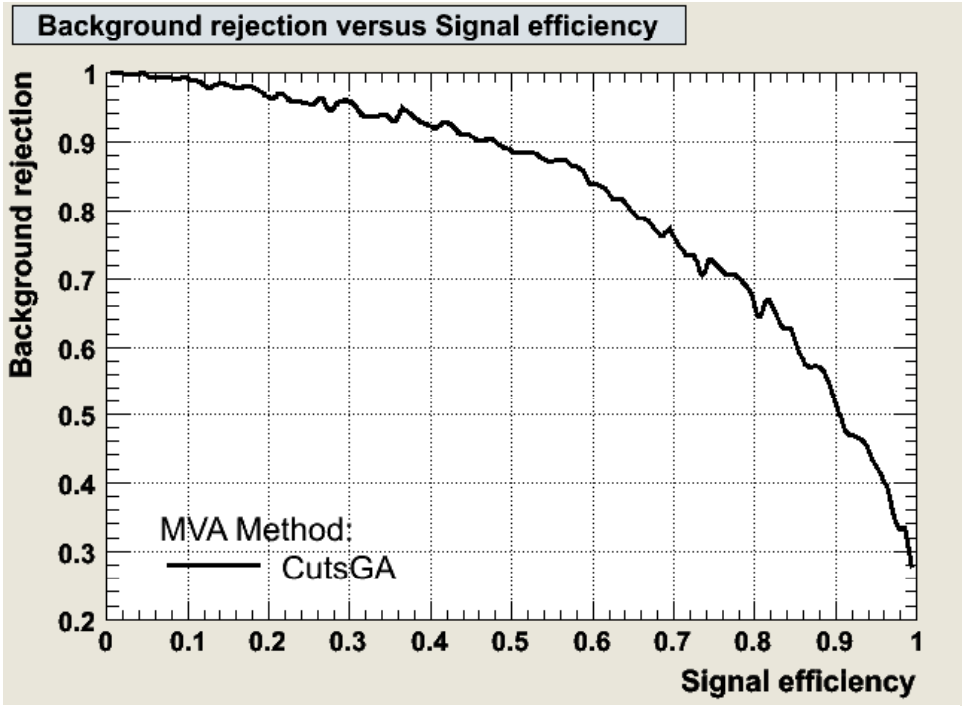
Signal: mSugra point @ m_0=900, $m_{1/2}$=150



Signal: mSugra point @ m_0=900, $m_{1/2}$=750



TMVA cut optimization .. II



Signal: mSugra point @ m_0=900, $m_{1/2}$=150

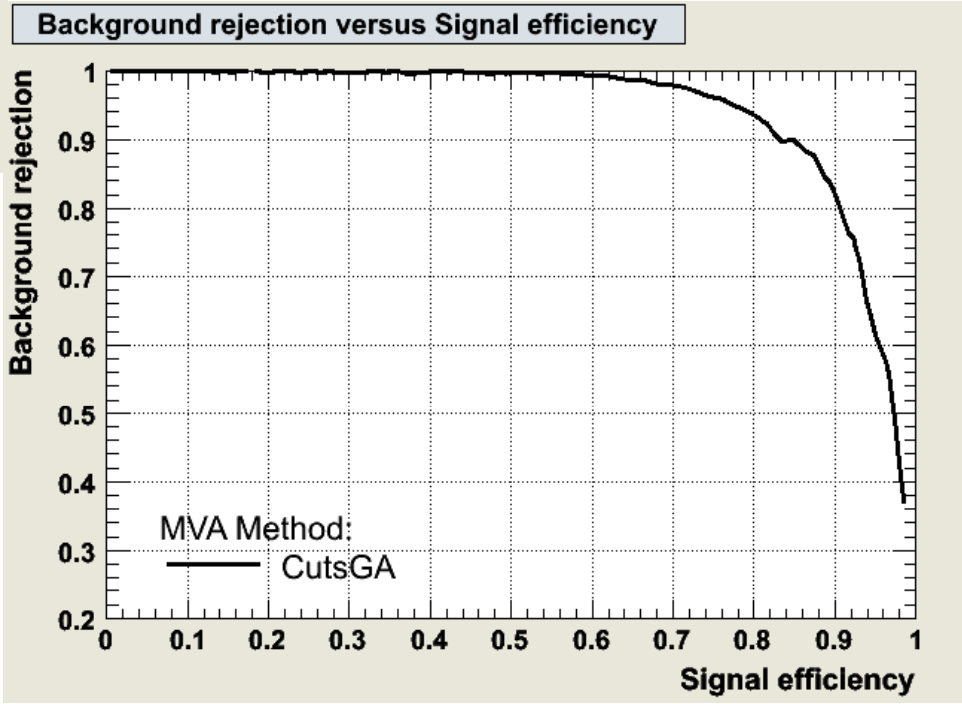
ε_{signal} = 0.575 ε_{bkg} = 0.13

Var	Min	Max
Jet_pT1	82 GeV	1.8 TeV
Jet_pT2	135 GeV	704 GeV
MissingEt	101 GeV	965 GeV

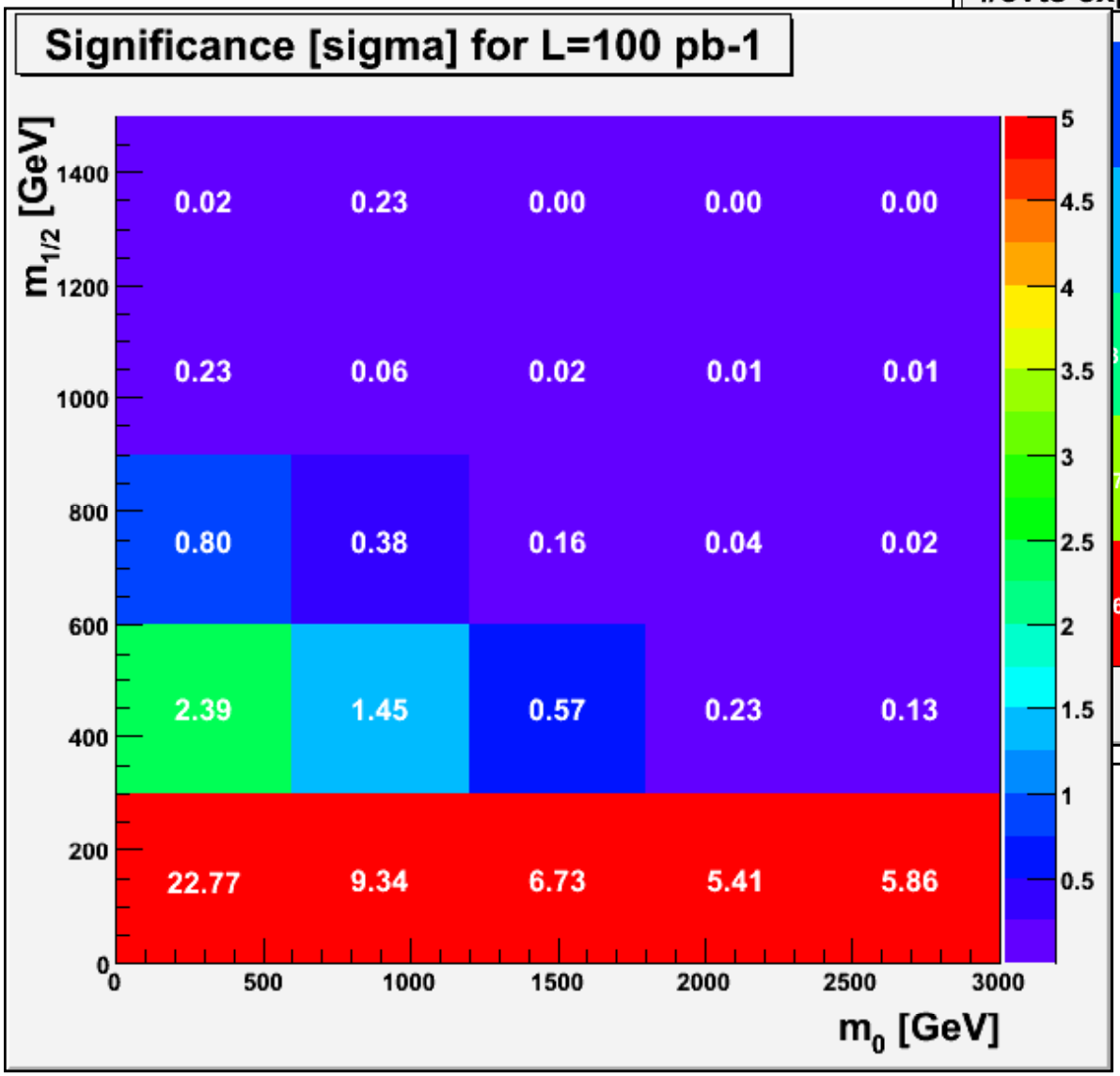
Signal: mSugra point @ m_0=900, $m_{1/2}$=750

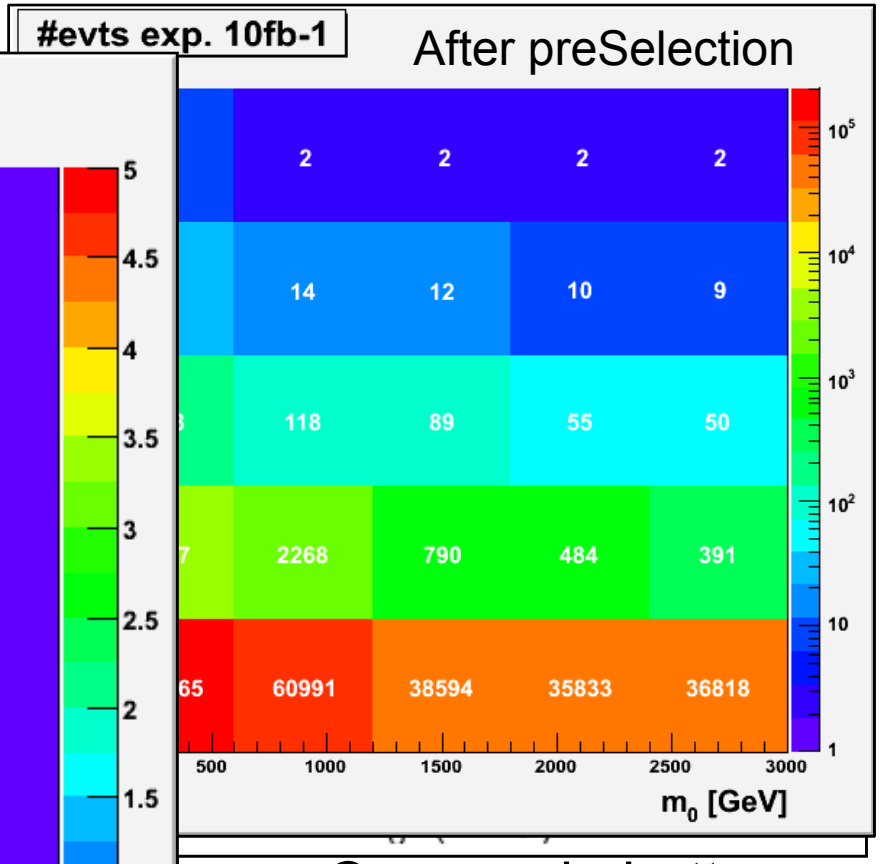
ε_{signal} = 0.505 ε_{bkg} = 0.00092

Var	Min	Max
Jet_pT1	132 GeV	2 TeV
Jet_pT2	47.8 GeV	1.4 TeV
MissingEt	559 GeV	2.4 TeV



All opt result





- Can we do better
  - Other/more variables ?
  - Other methods ?

Detailed numbers ... @10fb^{-1}

- Tables: Events and efficiencies after final selection (TMVA)
- Signal @ m_0=300, $m_{1/2}$=150
  - S/sqrt(S+B) = 194
  - StatTools::Poisson .. p-value too small
  - Though, would make a huge difference since tails of gaus and poisson are very different
- Signal @ m_0=300, $m_{1/2}$=450
  - S/sqrt(S+B) = 20.0
  - StatTools::Poisson = 23.9

Sample	TMVA eff	Events
Signal @ m0=300, m12=150	0.869	**91225**
Wenu	0.506	19238
Wmunu	0.504	19288
Wtaunu	0.505	7916
Zee	0.75	53
Zmumu	0.39	255
Ztautau	0.604	1762
Znunu	0.0	0
J5	0.5	620
Other Js	0.0	0
T1	0.556	81283
Bkg sum		**130416**

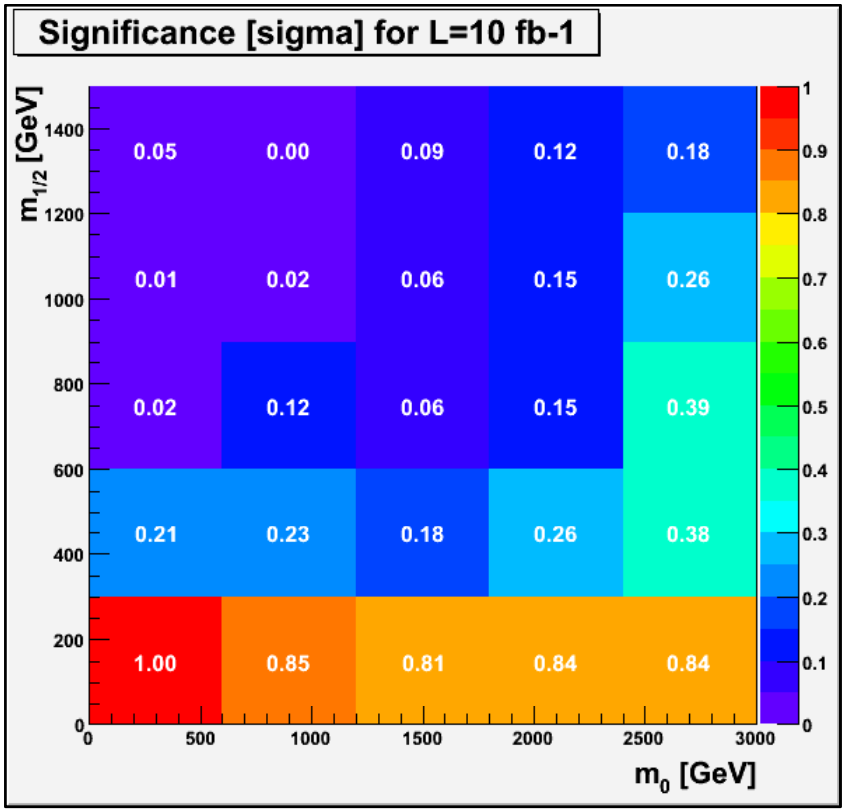
Sample	TMVA eff	Events
Signal @ m0=300, m12=450	0.368	**932**
Wenu	0.005	195
Wmunu	0.006	245
Wtaunu	0.008	133
Zee	0.0	0
Zmumu	0.0	0
Ztautau	0.004	11
Znunu	0.0	0
J4..J8	0.0	0
T1	0.004	653
Bkg sum		**1238**

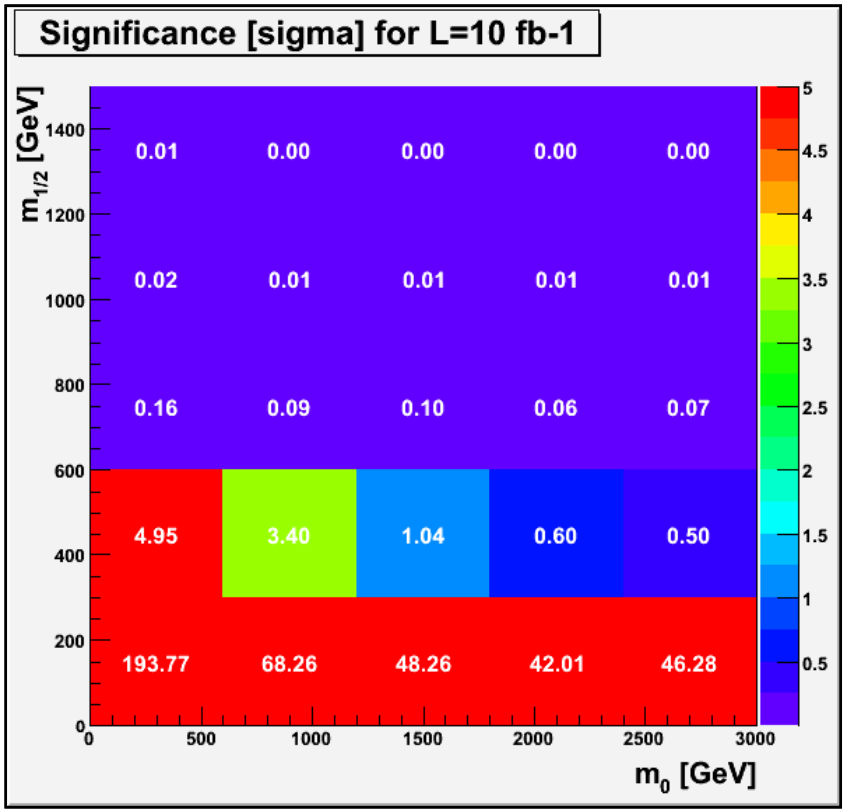
Optimizing each point ?

- Optimizing each point separately effectively means having one analysis per point…
  - decreases rate of the statistical **type-II** error (missing a true signal) ☺
  - increases the rate of the statistical **type-I** error (finding a wrong signal) ☹
- One needs to find a balance
  - Divide parameter region into regions with different signatures => optimize on as few points as possible… ?

A single optimization point

- Apply set of optimized cuts of signal @
  - m_0=300, $m_{1/2}$=150
- 5-sigma region smaller, see sigma plot
- High-sigma points stay
- Low-sigma points gone

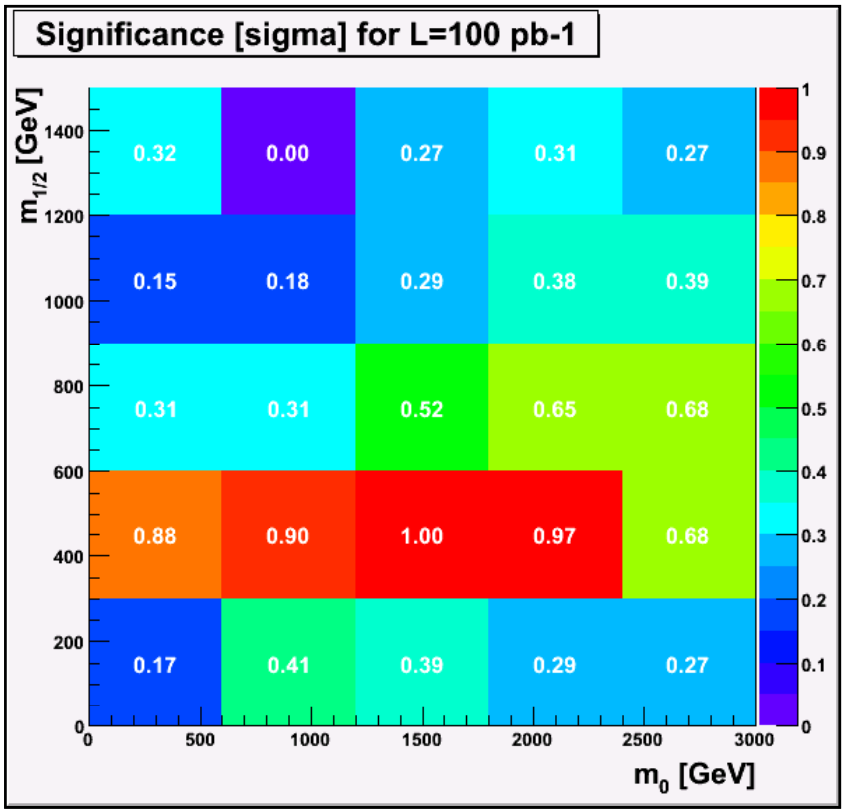


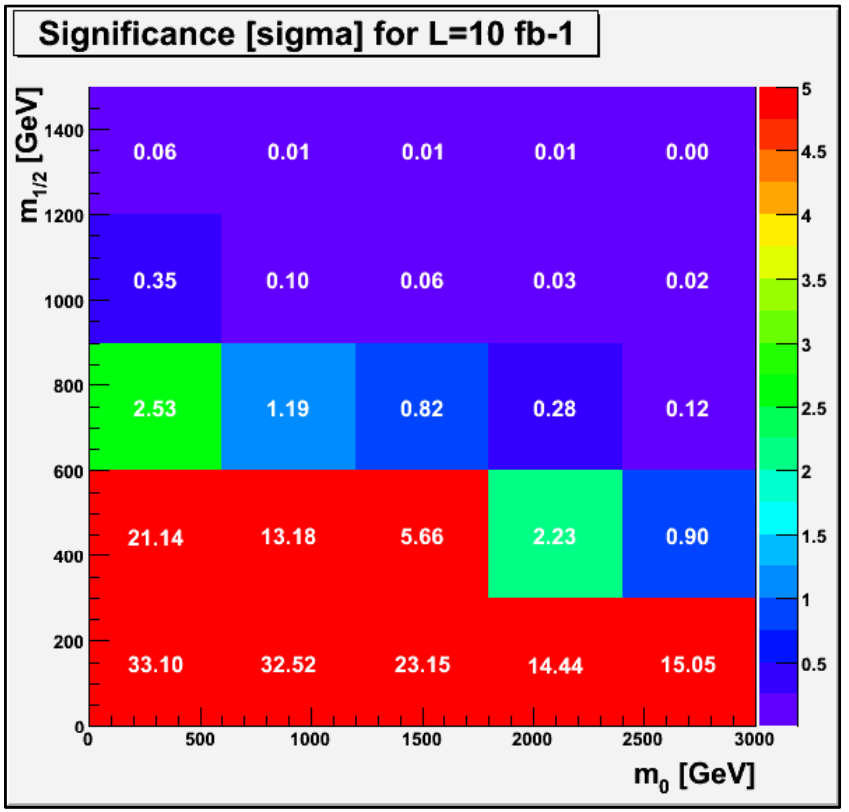


Ratio of significance w.r.t.
"all optimized points" plots

One set of optimized cuts .. II

- Try lower-sigma point:
- Apply set of optimized cuts of signal@
  - m_0=1500 $m_{1/2}$=450
- High-sigma points go down, but …
- Keep some more low-sigma points

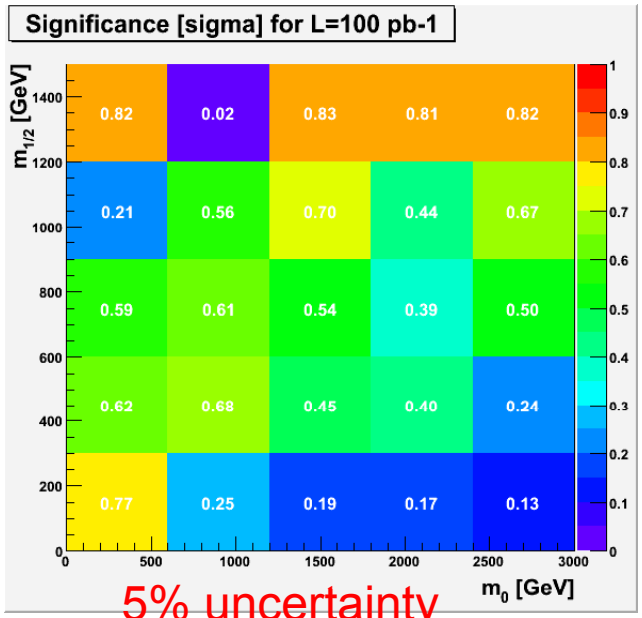




Ratio of significance w.r.t.
“all optimized points” plots

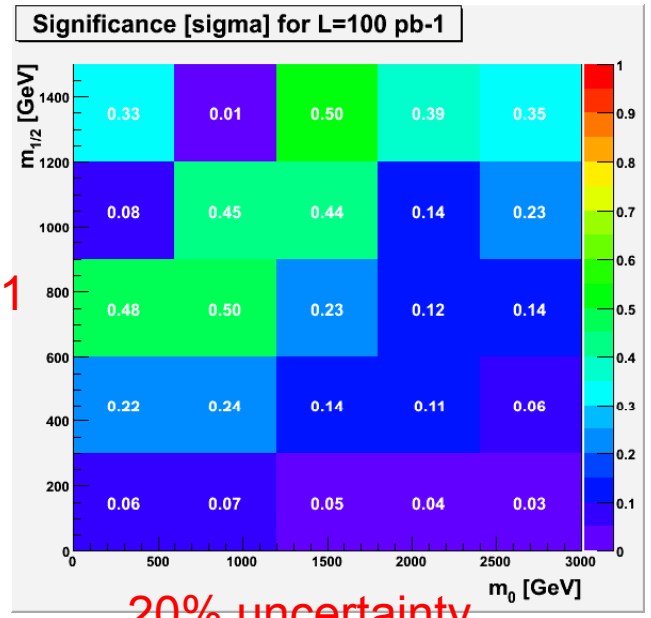
Systematics

- Study the effect of background uncertainties on the significance
  - Add uncertainty to T1 sample
  - Add uncertainty to W samples
- Look at the ratio w.r.t. to plot w/o errors
- Theory estimate: **T1**: x-section 830 **± 100 pb** .. due to choice of factorisation/renormalisatoi n scale and predicted uncertainties in the PDF-s (hep-ph/0204244)

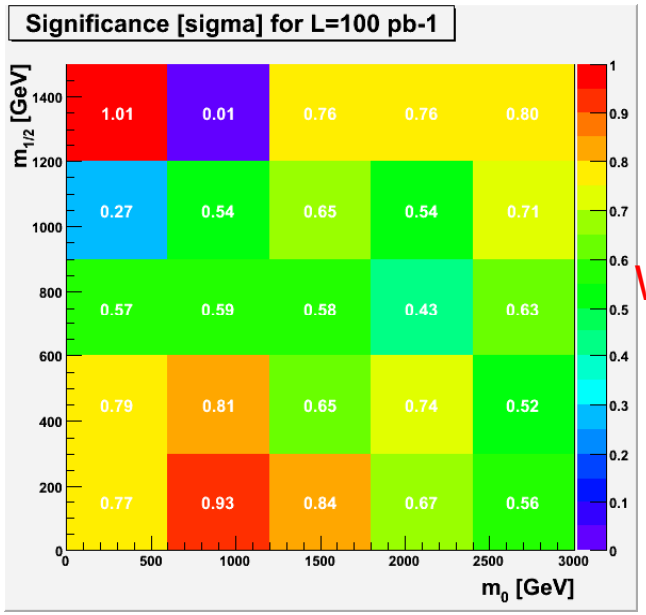


5% uncertainty

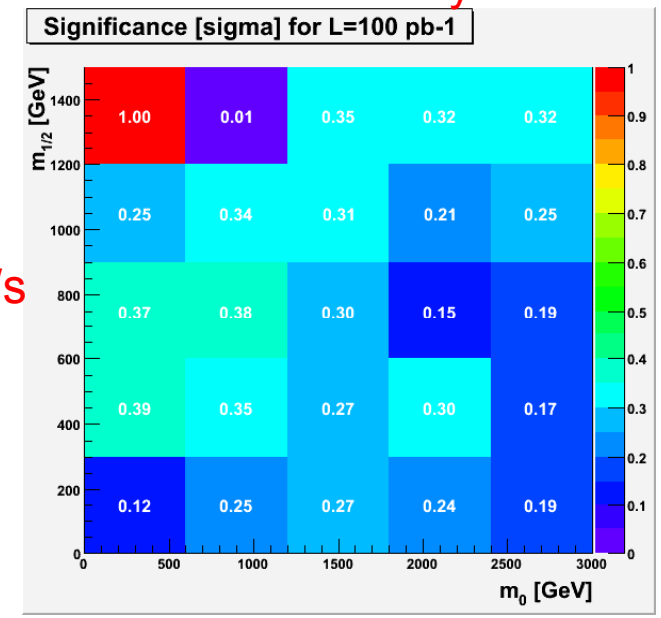
T1



20% uncertainty



Ws



Technicalities .. tools

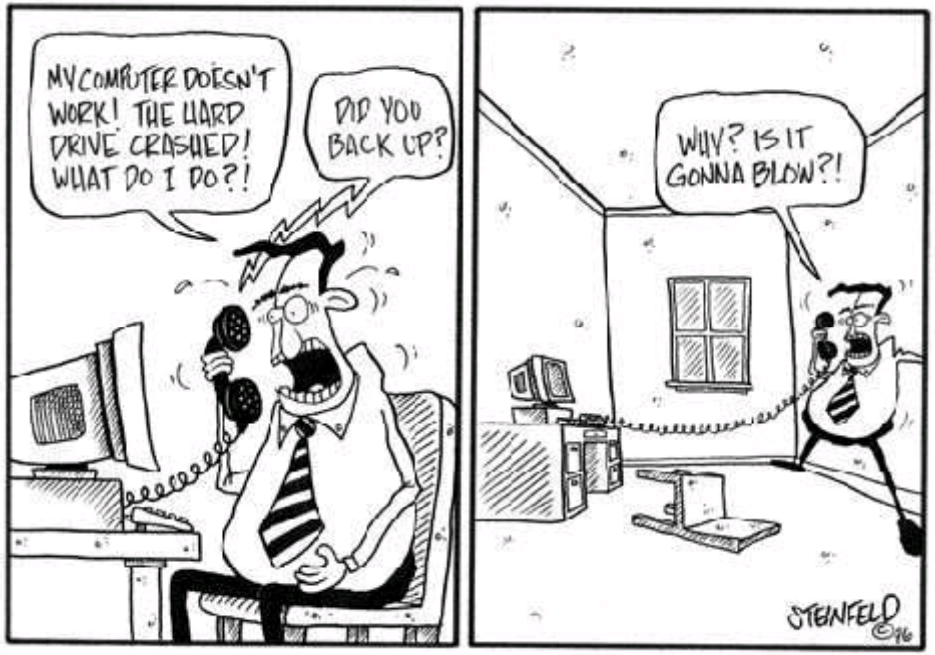
Development of various tools within our group (all in CVS!)

- HighPtView
  - Production of common root ntuple
  - See: https://twiki.cern.ch/twiki/bin/view/Atlas/HighPtView
- SUSYView
  - Specialisation of HighPtView for additional variables: AllMeff, sphericity, ..
  - See: https://twiki.cern.ch/twiki/bin/view/Atlas/SusyView
- SPyRoot
  - An interactive PyRoot analysis framework, useful for e.g.
    - Preselection (write out new ntuples)
    - train & apply TMVA
    - Nice plotting
  - See: http://atlas-sw.cern.ch/cgi-bin/viewcvs-atlas.cgi/groups/catsusy/SPyRoot/
- SFrame
  - As SPyRoot, but based only on ROOT and runs as stand-alone program
  - See: https://twiki.cern.ch/twiki/bin/view/Main/SFramePage
- StatTools
  - Calculate significance in a “count” analysis in the presence of multiple backgrounds with uncertainties. Implemented methods:
    - Gauss approximation
    - Poisson approximation & Poisson analytical
    - toy MC
  - See note: http://hoecker.home.cern.ch/hoecker/significance.pdf

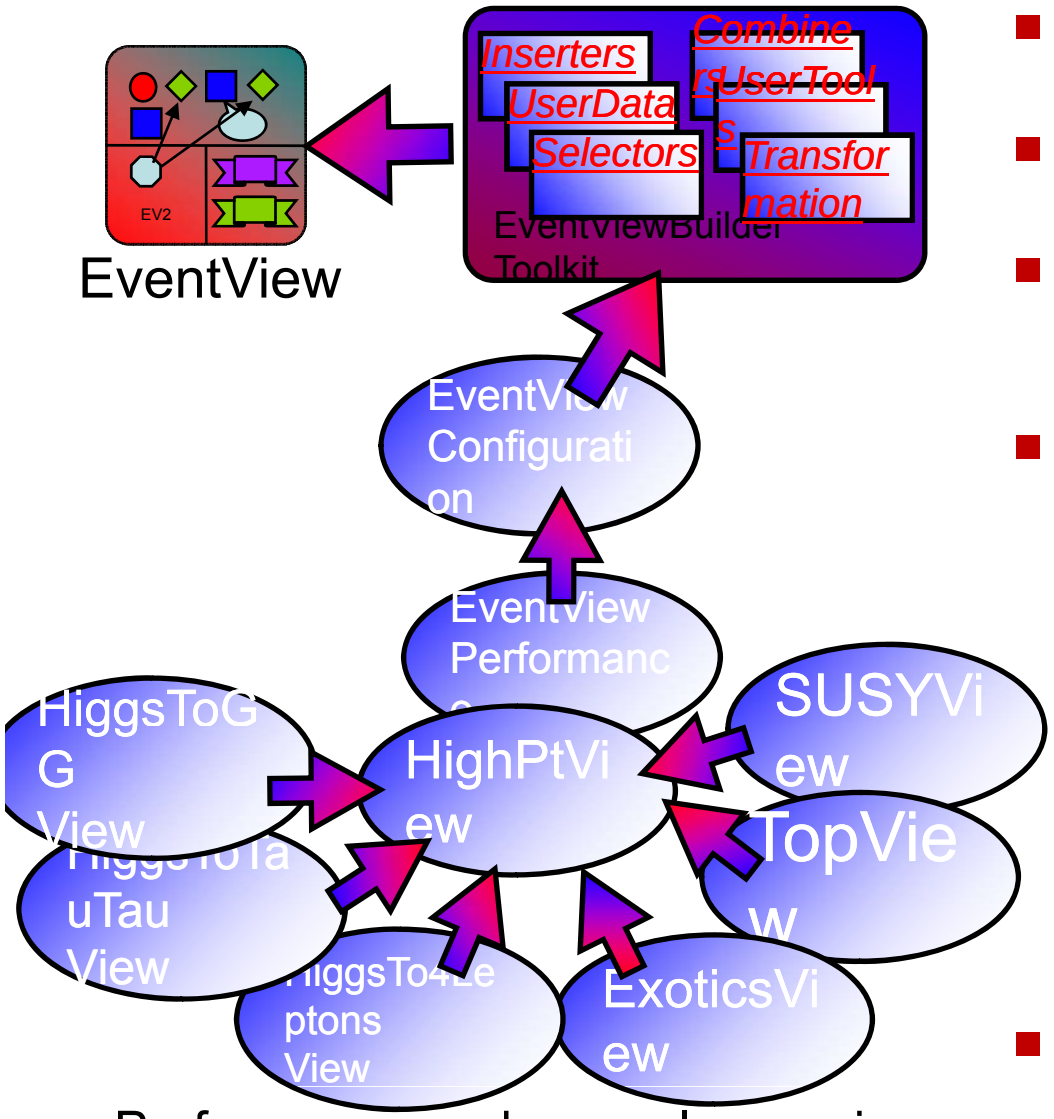
Conclusions / Outlook

- Contribution to CSC 5 note
  - Lep (electron) ID in SUSY environment
  - mSugra study (presented here)
  - SM background validation with first data
  - common tools developments
- need to find out best (most sensitive) cut approach (single cut, cut as function of integrated lumi, multiple cut regions) *including* systematics

Backup slides



HighPtView



Performance packages also coming:
egammaView, JetView, MuonView

- EventView: Generic Analysis Data object
- EV Builder Toolkit: General analysis tools.
- EV Configuration: Modules (grouping + configuration) of tools for doing common tasks.
- HighPtView: Generic Analysis package running in production ⇒ Standard:
  - Particle selections
  - Truth/Trigger Match
  - Output
  - ➡ Goal: serve as benchmark/starting point for analyses
- Physics groups customize HighPtView for specific analyses ⇒ SUSYView, TopView, ...

HighPtView/SUSYView...

- HPTV ntuples will be made by central production, and will be accessible through dq2.
- But HPTV is meant to be generic... SUSYView is meant to be for SUSY WG.
- Lots of people run HPTV themselves with customization for their specific needs.
- SUSYView today: Just HPTV + one extra “module”:
  - Multiplicities of various objects
  - Sphericity + FW moments
  - M_{eff}
  - Higher detail level than default HPTV

```
FullRec0->Draw("four_C4_Meff","Jet_C4_N>3 && MissingEt>100000 &&
AllFS2D_C4_Sphericity > 0.2 && Jet_C4_p_T[0]>100000 &&
Jet_C4_p_T[1]>50000 && Jet_C4_p_T[2]>50000 && Jet_C4_p_T[3]>50000”)
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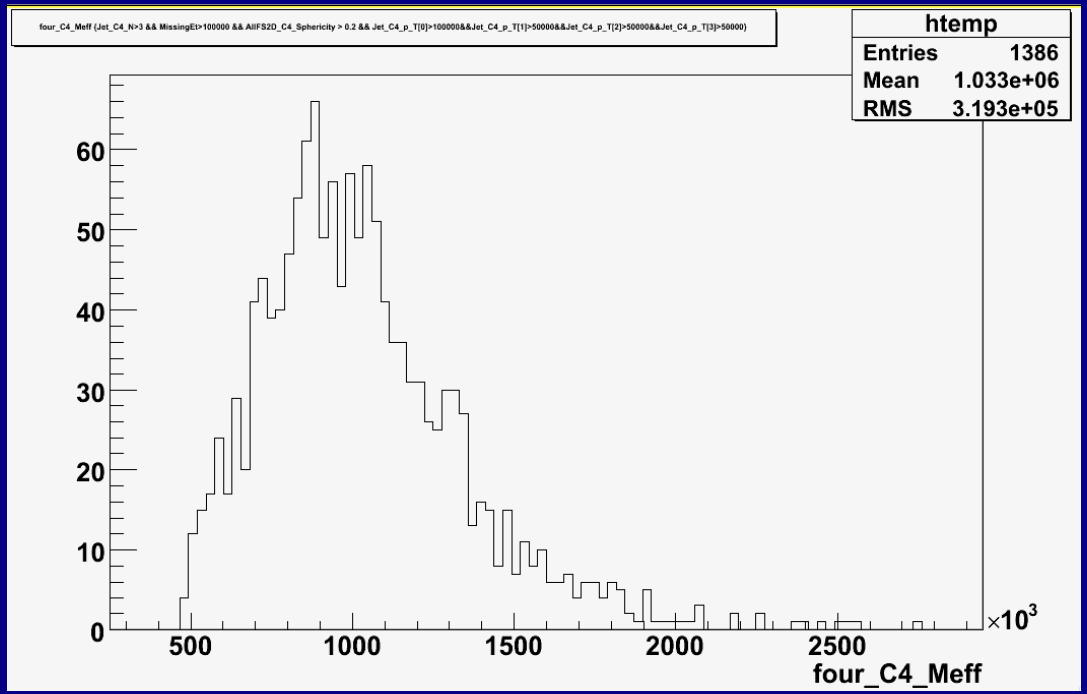
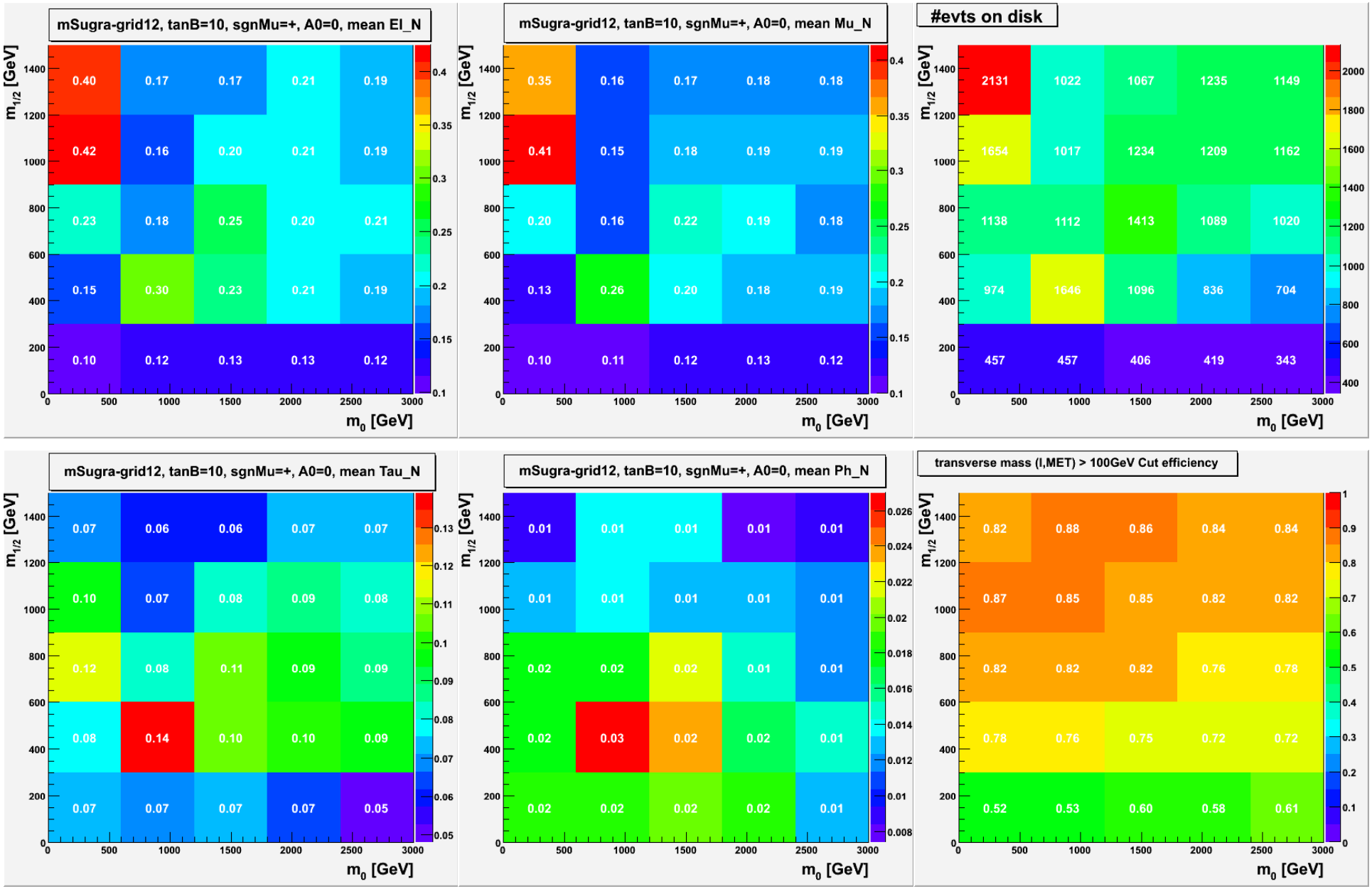


- SV used by many groups within SUSY WG.
- Central production of SV ntuples coordinated between various groups (CERN, UTA, Freiburg, LBL, ...)

Background Samples .. II

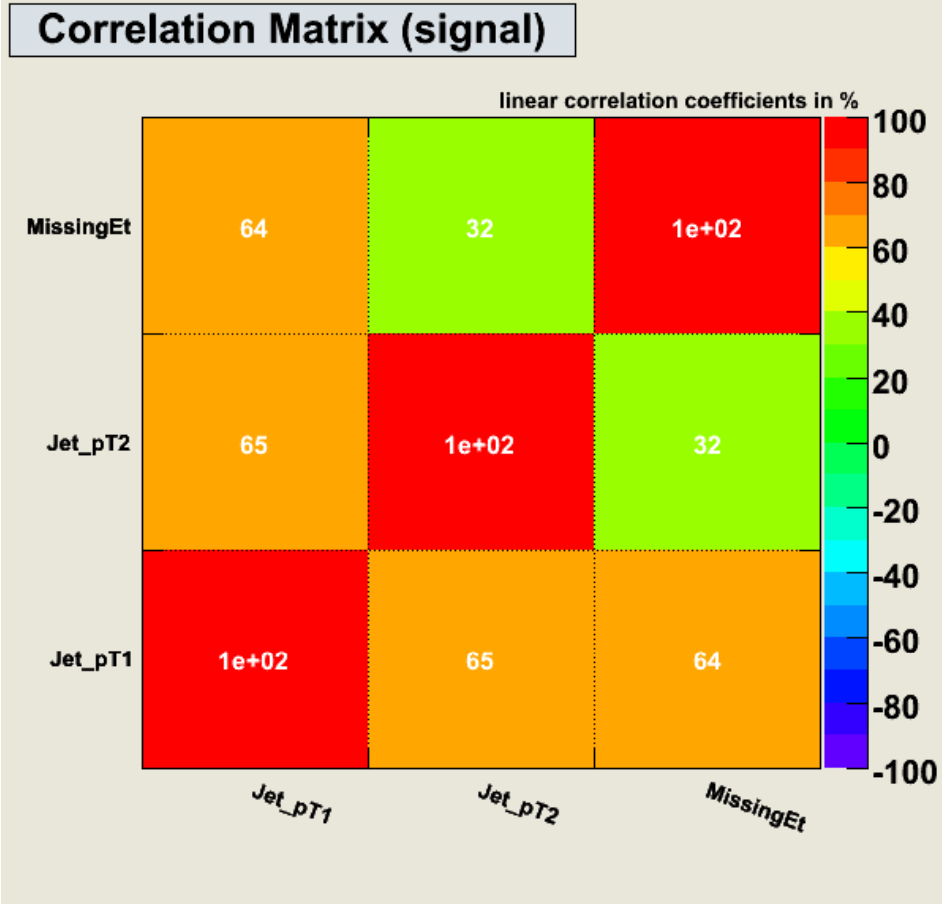
process		description	generator	σ_{gen} (pb)	EventFiler	ε_{EF}	# evts$_{disk}$	σ_{EF} (pb)
ttbar	5201	ttbar "l+jets" , high top pt	MC@NLO/Jimmy	854	TTbarLepton : 1 charged lepton from W decay & top pt > 200GeV	12%	---	100
ttbar	5204	ttbar all hadronic	MC@NLO/Jimmy				---	369
WW	5985	Produced by central team	HERWIG	24.5	LeptonFilter, Pt≥10, eta≤2.8		---	
ZZ	5986	Produced by central team	HERWIG	2.1	as above		---	
WZ	5987	Produced by central team	HERWIG	7.8	as above		---	
Z + bjets	5178		AcerMC/Pythia	205	as above	14.8%	---	30.3

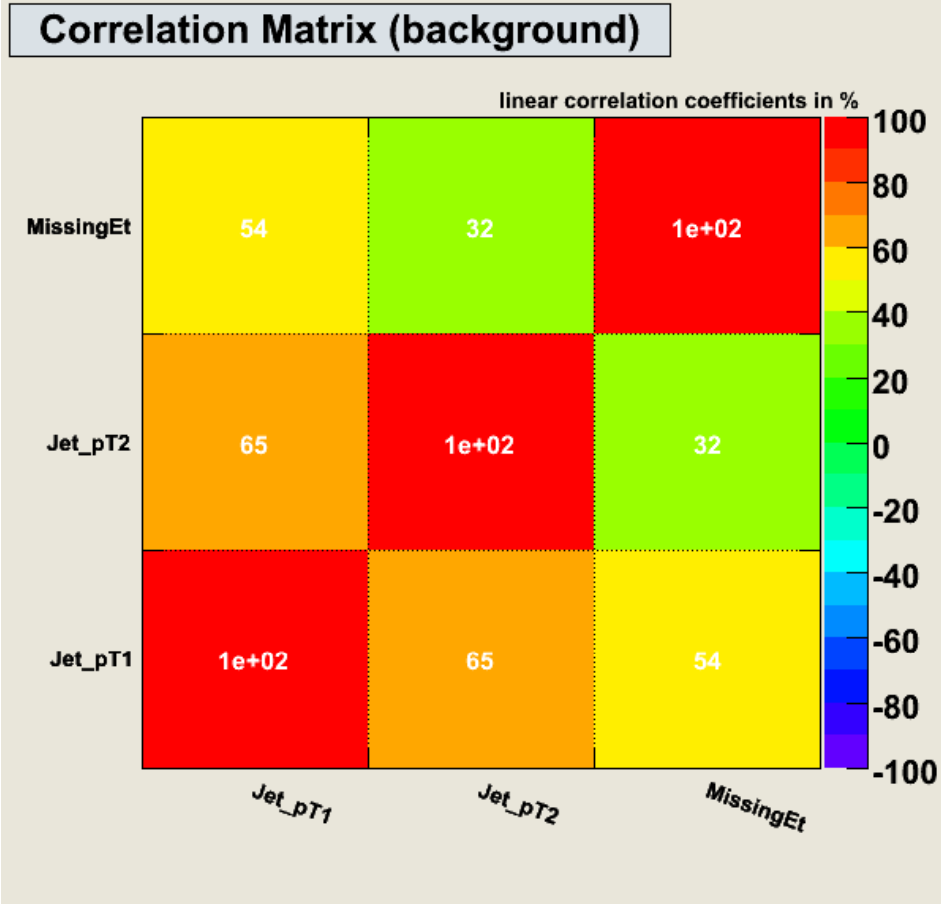
Signal distributions



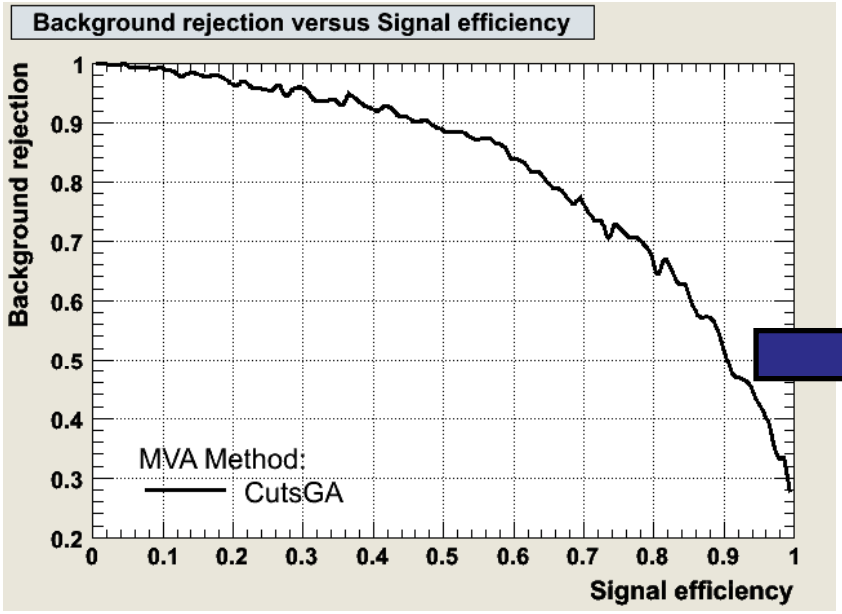
TMVA variable correlations

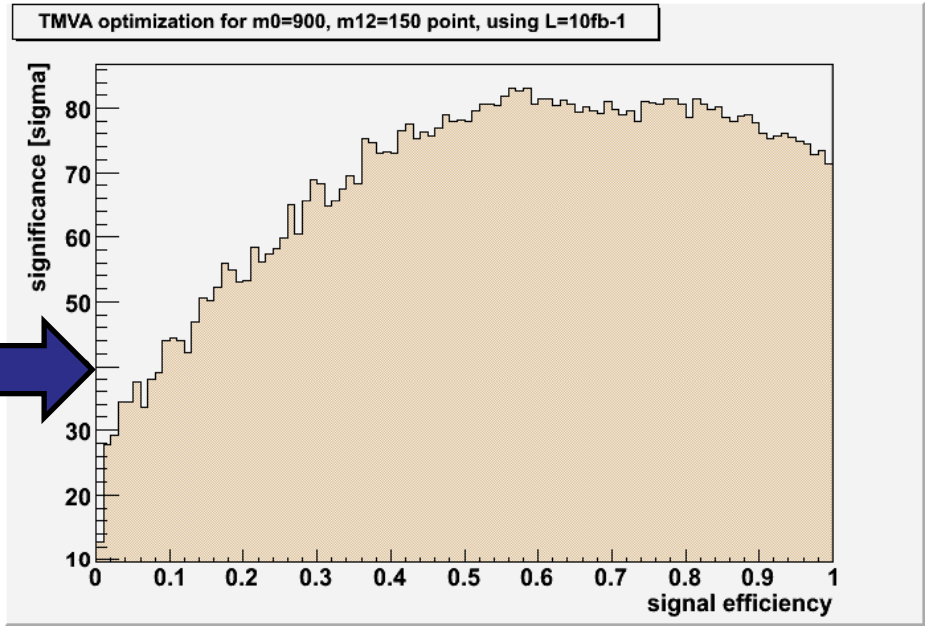
Signal: mSugra point @ m_0=900, $m_{1/2}$=150





Choosing opt ε_{signal} point





- Calculate Siginificance for each bin (ε_{signal})
  - All bkg samples
  - Signal sample
  - Poisson distribution (StatTools, see CVS: groups/catsusy/StatTools)
- Find maximum significance yields best ε_{signal} point