

Prospects of ATLAS, high- p_T aspects



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*Exotics group convener at the previous workshop:
flavour at the era of the LHC (fLHC)*

- *Status of ATLAS experiment and expectations from LHC*
- *Previous studies mostly from fLHC workshop & ATLAS pub/SN work*
 - *top, Susy, Exotics, Higgs*
- *Ongoing work*

i n m e m o r i a m



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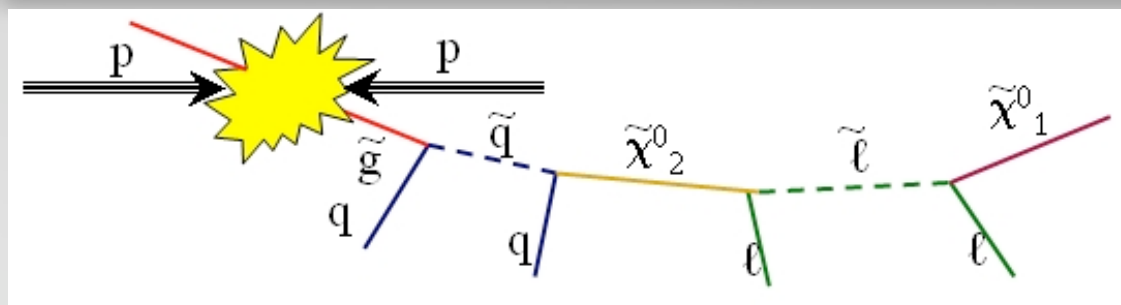


Prof. Engin Arik
14 Oct. 1948 - 30 Nov. 2007

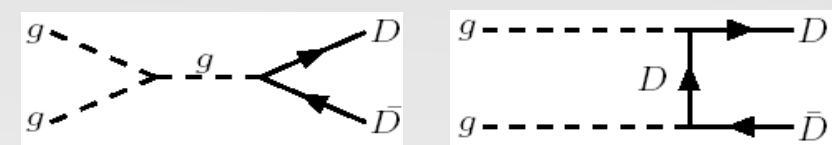
Participated CERN experiments: Charm-2, Chorus, SMC, CAST, ATLAS

introduction

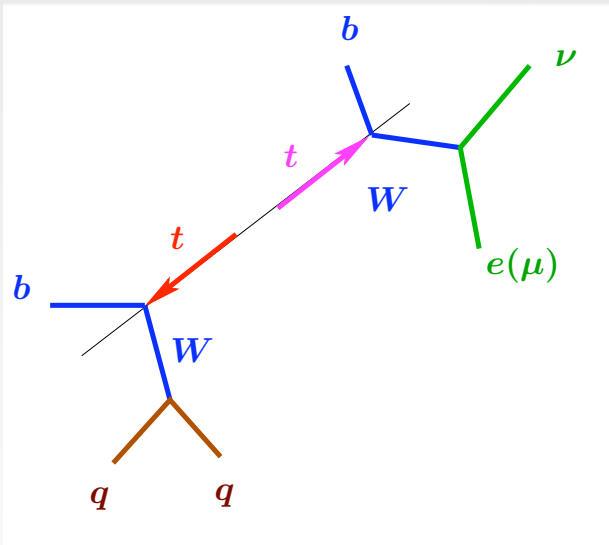
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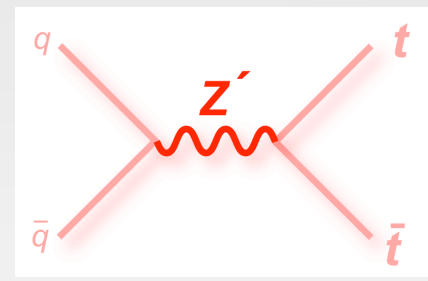
susy sparticle production



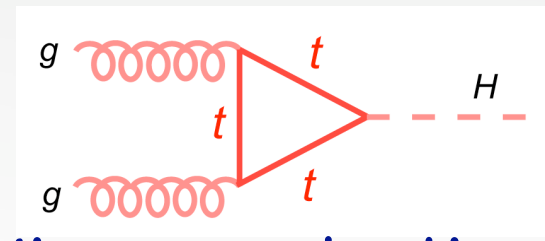
BSM quark production



SM tt production



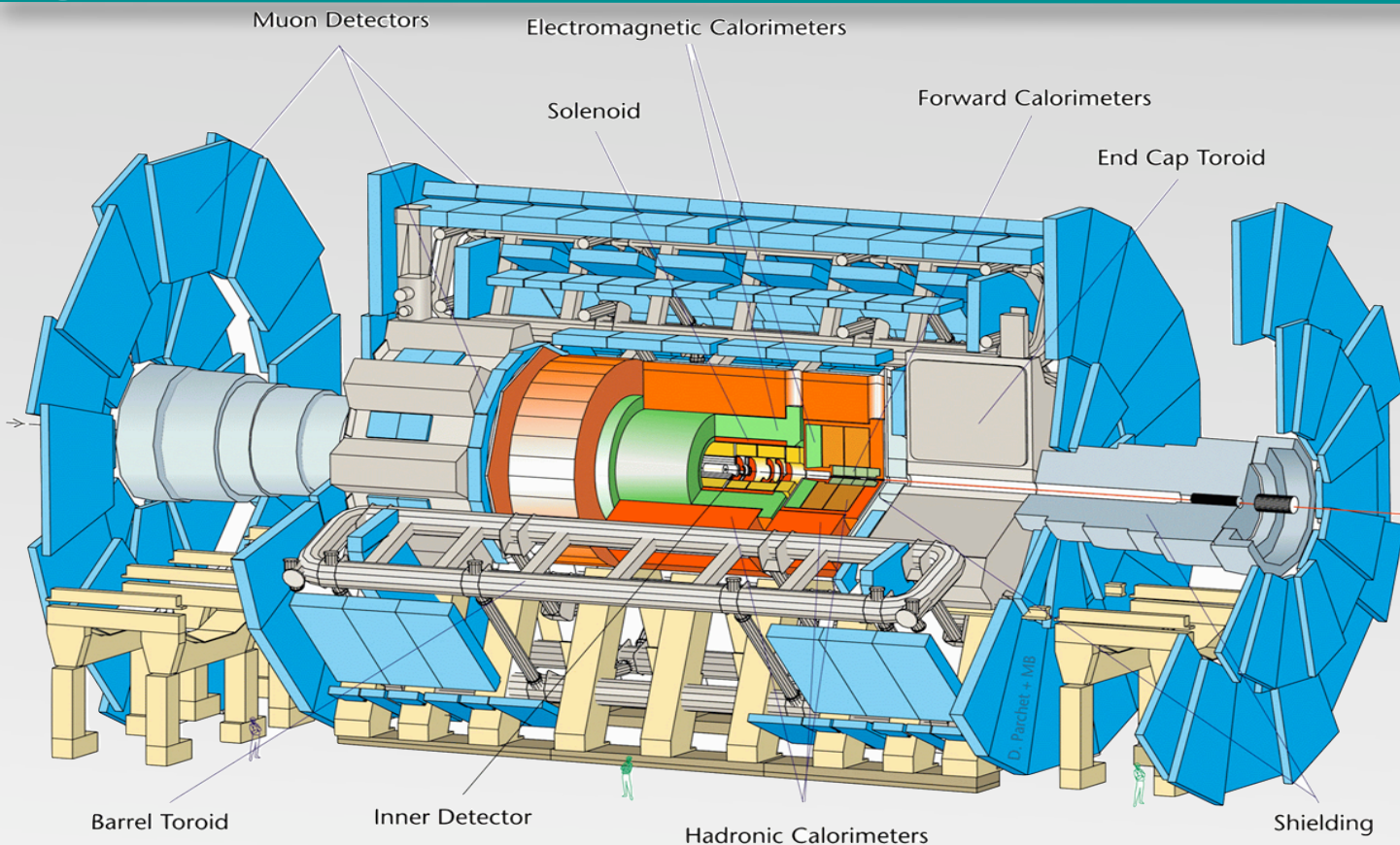
BSM V production



Higgs production



ATLAS detector



	ATLAS
weight	7 000 t
diameter	25 m
length	46 m
B Field	2 & 4 T

ID: $\sigma/p_T \approx 5 \times 10^{-4} p_T \oplus 0.001$

$\sigma(d_0)=15\mu\text{m}$ at 20GeV

ECAL: $\sigma/E \approx 10\%/\sqrt{E(\text{GeV})} \oplus 0.7\%$

HCAL: $\sigma/E \approx 50\% / \sqrt{E(\text{GeV})} \oplus 3\%$

Muon: $\sigma/p_T \approx 10\%$ at 1 TeV/c

▶ Inner tracker ($\eta < 2.5$, $B=2\text{T}$, solenoid)

- ▶ Pixel & Strip Silicon detectors
- ▶ Transition Radiation tracker (e/π distinguishing)

▶ Calorimeter ($\eta < 5$)

- ▶ EM: Pb-LAr, Accordion shaped
- ▶ HAD: Fe/scintillator (central), Cu/W-LAr (fwd)

▶ Muon system ($\eta < 2.7$, $B=4\text{T}$, toroid)

- ▶ Thin Gap Chs, Resistive Plate Chs, Cathode Strip Chs, Drift Tubes



ATLAS status **all in, except small muon wheels**

Technical Runs

- To test the infrastructure and the TDAQ by replaying the MC & cosmic data.
- Latest in Nov07, L31 menu fully tested

Commissioning Runs

- To test the sub-detectors by recording the cosmic events.
- Latest in Oct07, 2weeks of data taking



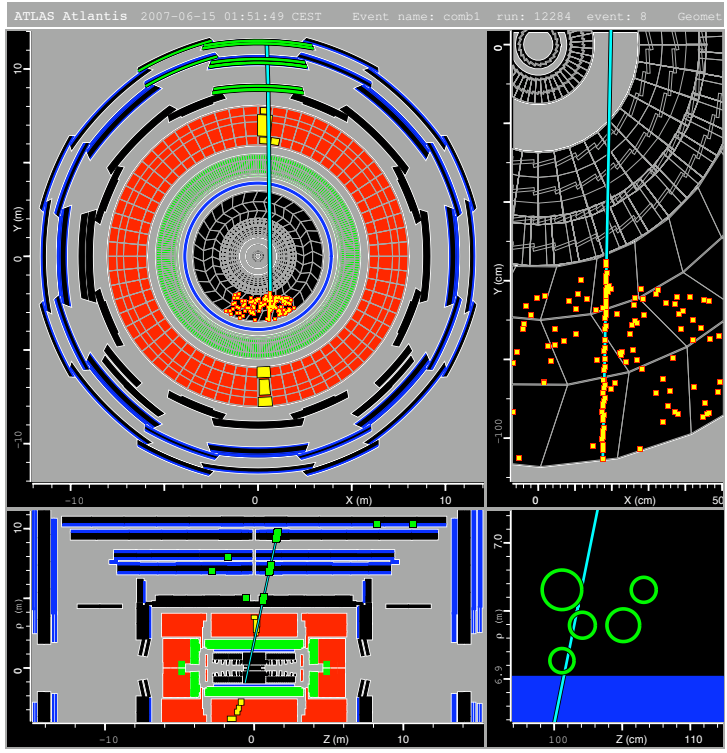
- All detectors, except CSC, integrated
 - In DCS, DAQ, control room, timing and trigger
 - Pixel and SCT, no detector (some F/E modules)

Triggers

Trigger	rate	
Tile	< 1 Hz	
RPC	~ 60 Hz	Pointing in phi
TGC	~ 20-40 Hz	Both sides
L1-calo	Sub-hertz	Last M5 week end
MB scintillators	Sub-hertz	test

- HLT integrated with and without algorithms
- DQ, monitoring: online and offline
- Data bases, more consistent use of Cool
- TO operational, offline

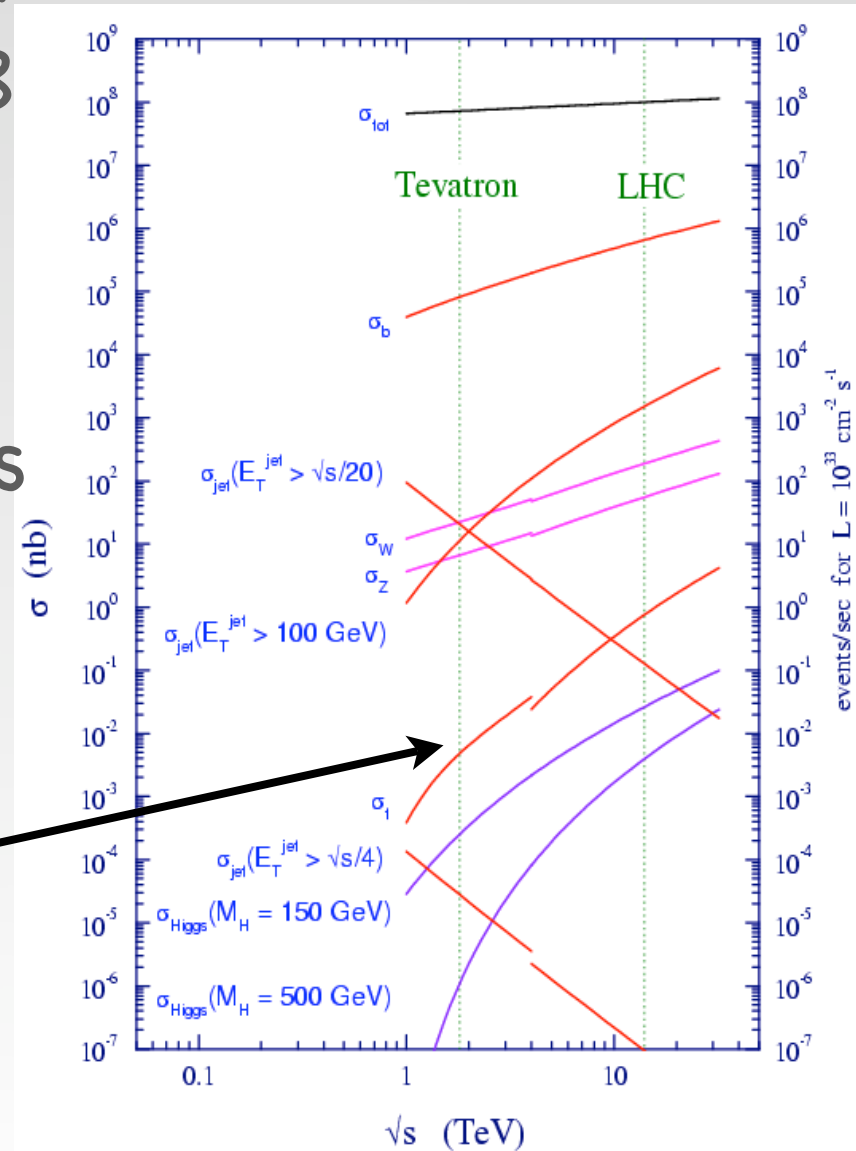
System	Size	
Pixel	~ 100% R/O	No detector
SCT	~ 1%	Test module
Lar	~ 90%	Ba + EC
Tile	~ 55%	H/W work
MDT-Ba	25%	More sectors were available
MDT-EC	100% big wheels + EIL4	Side A not fully powered
RPC	1/8	Trigger & R/O
TGC	6 sectors per side	Trigger & R/O



LHC expectations

- Machine closed April, 2008
- Beam commissioning starts May 2008
- First collisions in summer 2008
 - 2008: $\sim 100 \text{ pb}^{-1}$ of data,
 - 2009: a few fb^{-1} .
- With the first data, the plan is
 - commission & calibrate the detector,
 - "rediscover" the SM.

From Tevatron to LHC:
 top σ increases by 2 orders of magnitude
 yesterdays signal is tomorrows background



● Aim to “rediscover” the SM physics and especially $t\text{-}t\text{-bar}$ events with the first data ($\sim 100\text{pb}^{-1}$)

● initially without $b\text{-tagging}$ at 5σ level (see plot)

● to use the previous sample for calibrating $b\text{-tagging}$, jet scale..

● With more data ($\sim 1\text{fb}^{-1}$) SM top properties

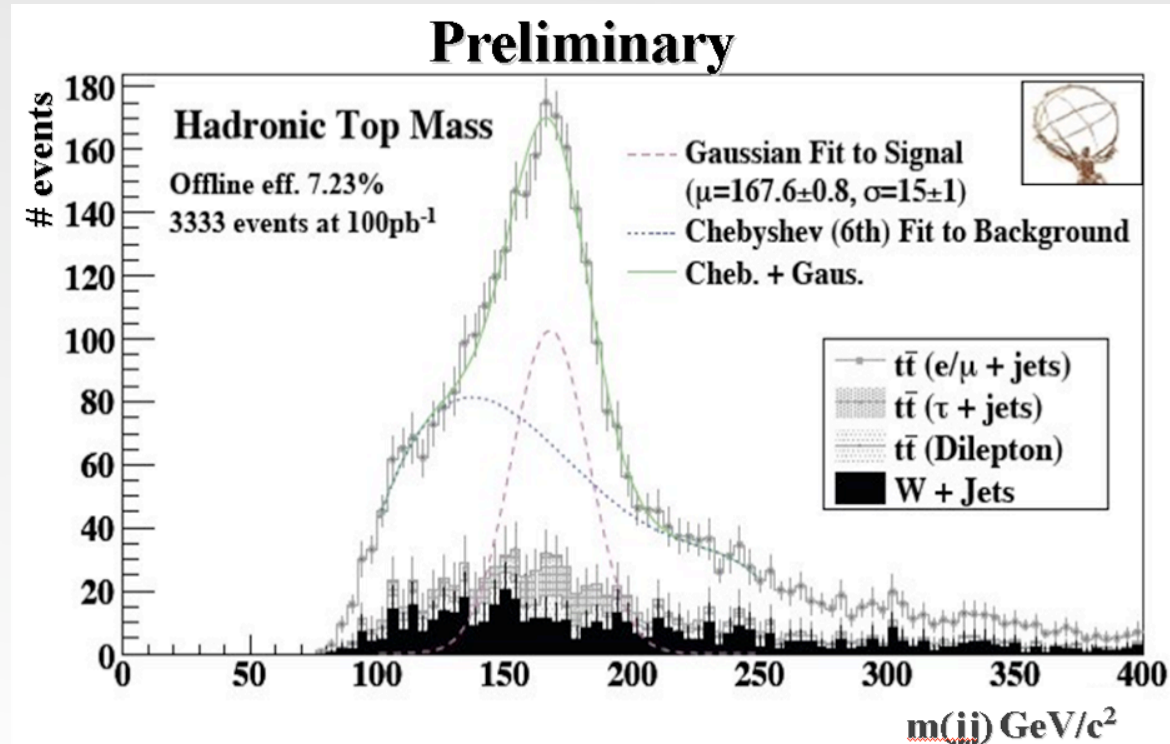
● decay modes, BRs..

● single top in t channel

● with $>10\text{fb}^{-1}$

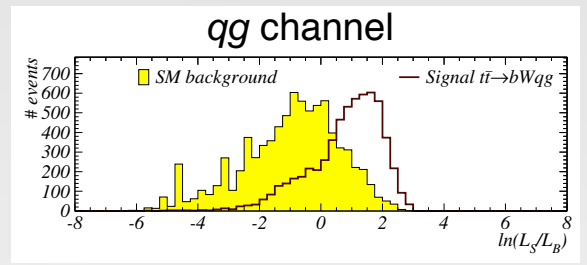
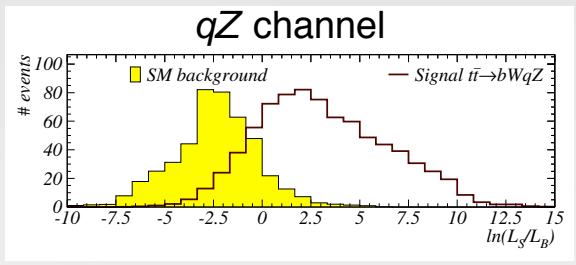
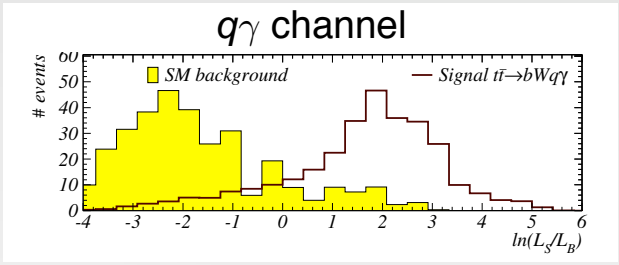
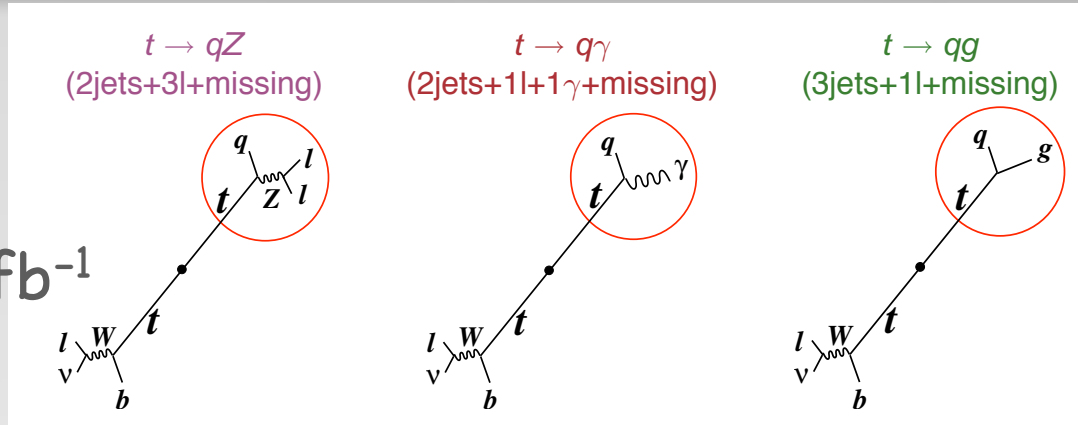
● anomalous couplings, BSM
– FCNC decays

● single top in s channel



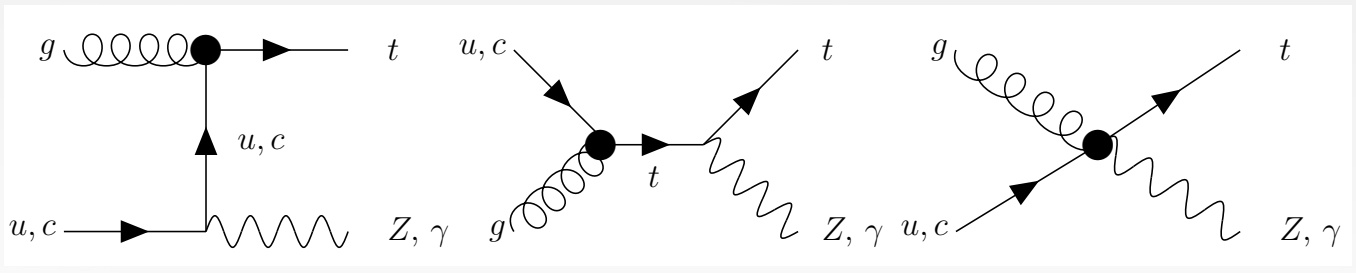
ttbar FCNC decays

- 3 studied topologies →
- if $BR \sim 10^{-4}$, 5σ signal with $10fb^{-1}$



SN-ATLAS-2007-059

Anomalous (FCNC) single top production



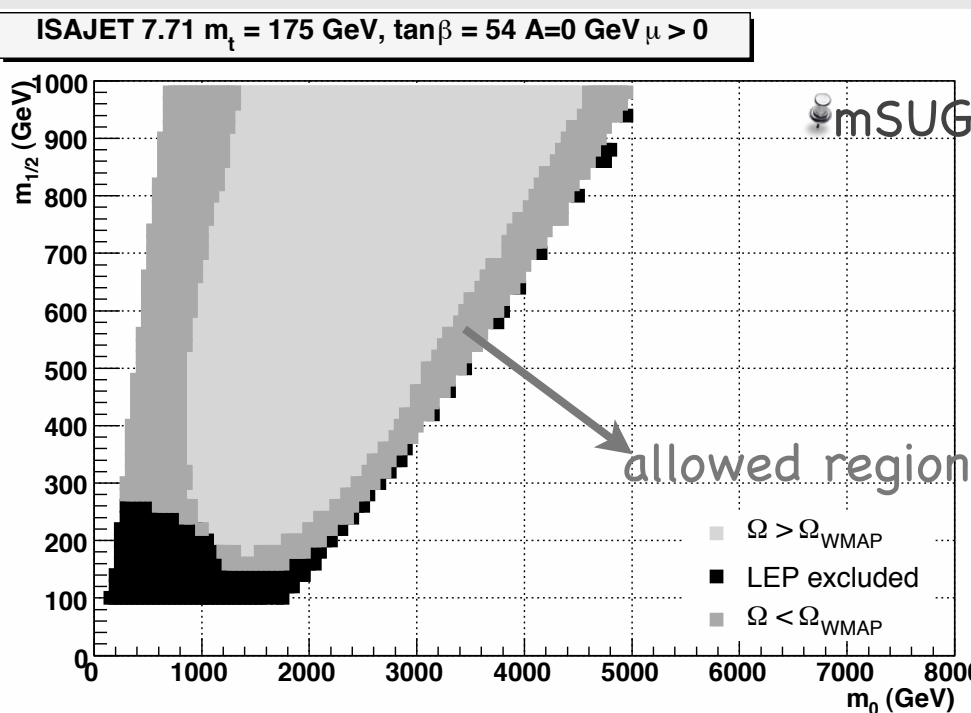
- if $\sigma_{FCNC} > 15pb$, 5σ signal with $10fb^{-1}$

Susy I (mSUGRA)

initially inclusive searches in final states with energetic jets, leptons & significant $E_{T\text{miss}}$.

Sensitivity for 100 pb^{-1} , and only gets better.

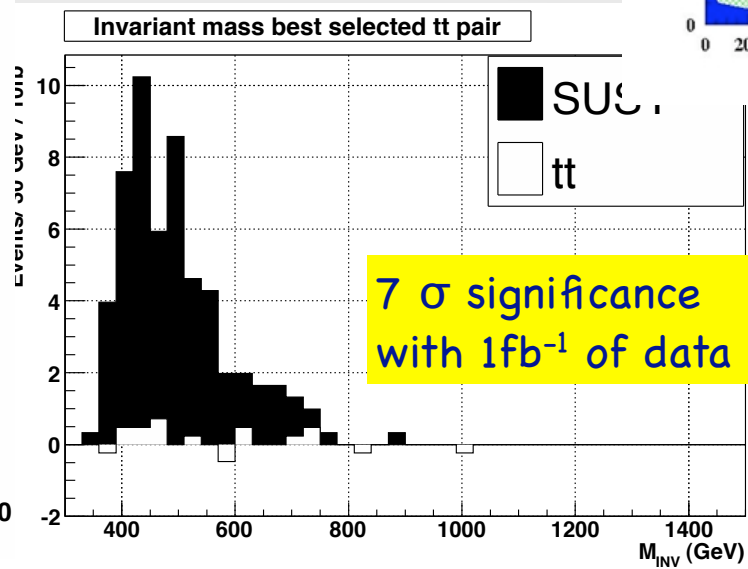
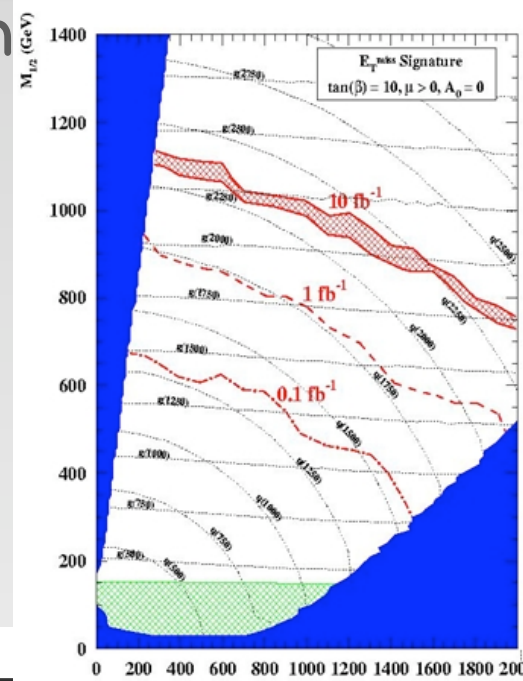
SN-ATLAS-2007-049



$$pp \rightarrow \tilde{g}\tilde{g}$$

$$\tilde{g} \rightarrow \tilde{\chi}^0 t\bar{t}$$

mSUGRA's LSP is DM candidate



non-mSUGRA models also studied: GMSB with γ s, R-hadrons in split SUSY, long living stau ..

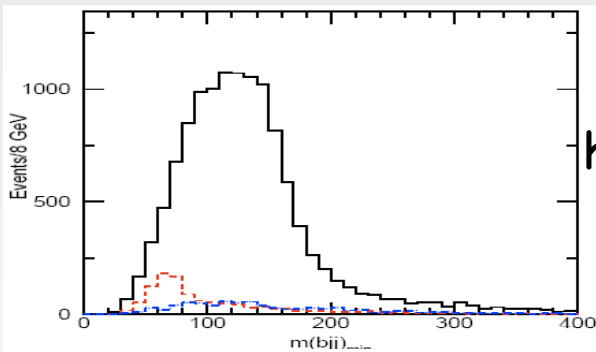
light stop search: $m_{\text{stop}} < m_{\text{top}}$

HERWIG($t\bar{t}$)/PYTHIA($t\bar{t}$)/ALPGEN(Wbb)/ATLFAST

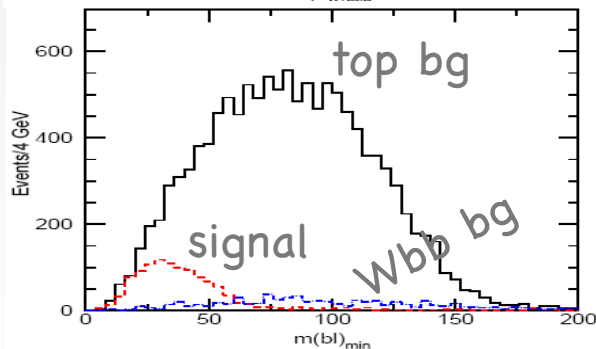
- $t_1 \rightarrow b\chi_1^\pm \rightarrow bW^\pm\chi_1^0$
- semi-leptonic W decays

$$m(\tilde{t}_1) = 137 \text{ GeV}, m(\tilde{\chi}_1^\pm) = 111 \text{ GeV}, m(\tilde{\chi}_1^0) = 58 \text{ GeV}.$$

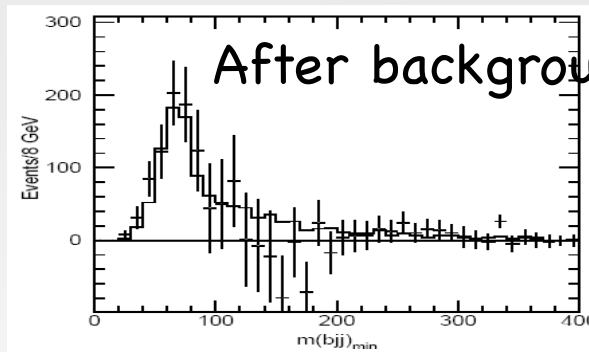
- One and only one isolated lepton (e, μ), $p_T^l > 20 \text{ GeV}$.
 - $E_T^{\text{miss}} > 20 \text{ GeV}$.
 - At least four jets $P_T(J_1, J_2) > 35 \text{ GeV}, P_T(J_3, J_4) > 25 \text{ GeV}$.
 - Exactly two jets in the events must be tagged as b -jets, and they both must have $p_T > 20 \text{ GeV}$.
- b-tagging efficiency of 60%



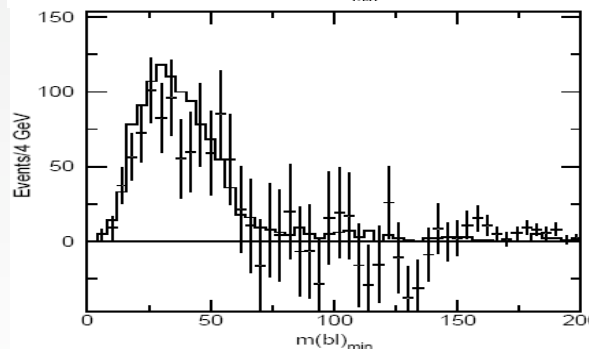
hadronic W



leptonic W



After background subtraction



clear signal with 1fb^{-1}

• Susy breaking scale close to weak scale

- LSP is gravitino, FCNC is suppressed

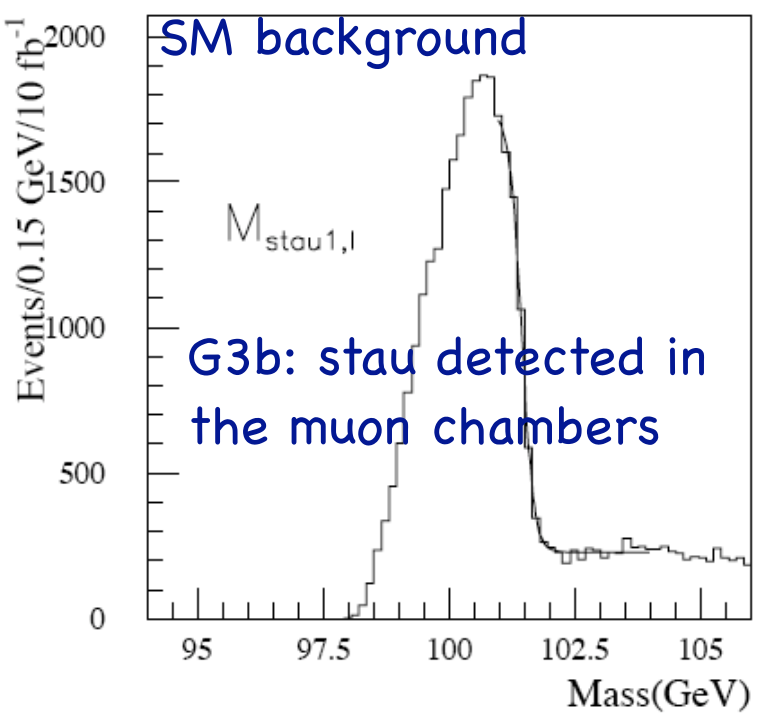
• Reference points with different model parameters & NLSP

- Fast MC based study @ G3 (NLSP is stau)
- G3b: NLSP is quasi-stable
- G3a: NLSP immediately decays

$$\tilde{q} \rightarrow \tilde{\chi}_{1,2}^0 q \rightarrow \tilde{\ell} \ell q \rightarrow \tilde{\tau}(\tau) \ell \ell q \rightarrow \tilde{G} \tau(\tau) \ell \ell q$$

leptons + jets + E_T^{miss}

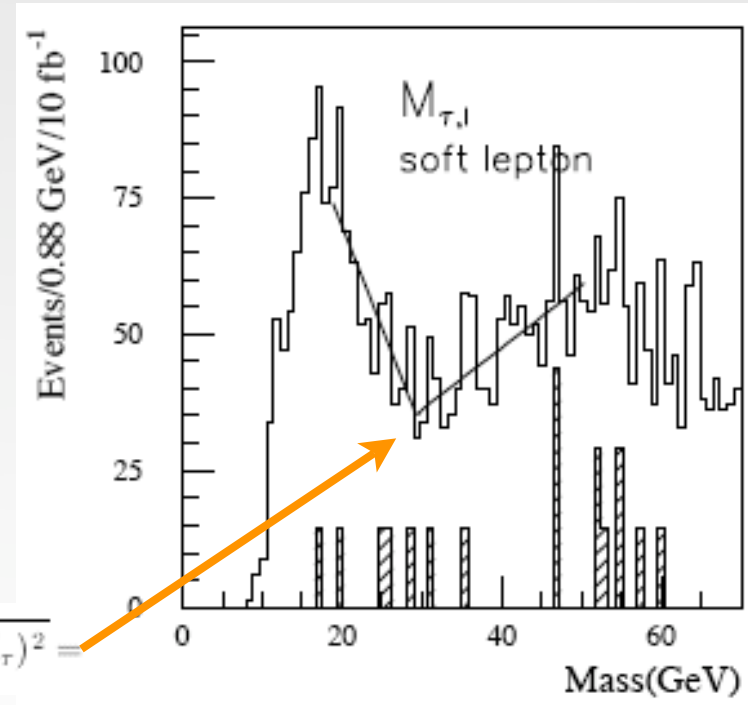
Negligibly small



Excellent signal with few fb⁻¹ in both cases

G3a: stau decays before detection but dips can be calculated & fit:

$$M_{\tau l}^{\text{max}} = \sqrt{M_{lR}^2 - (M_{\tilde{\tau}_1} + M_{\tau})^2}$$





Exotics I

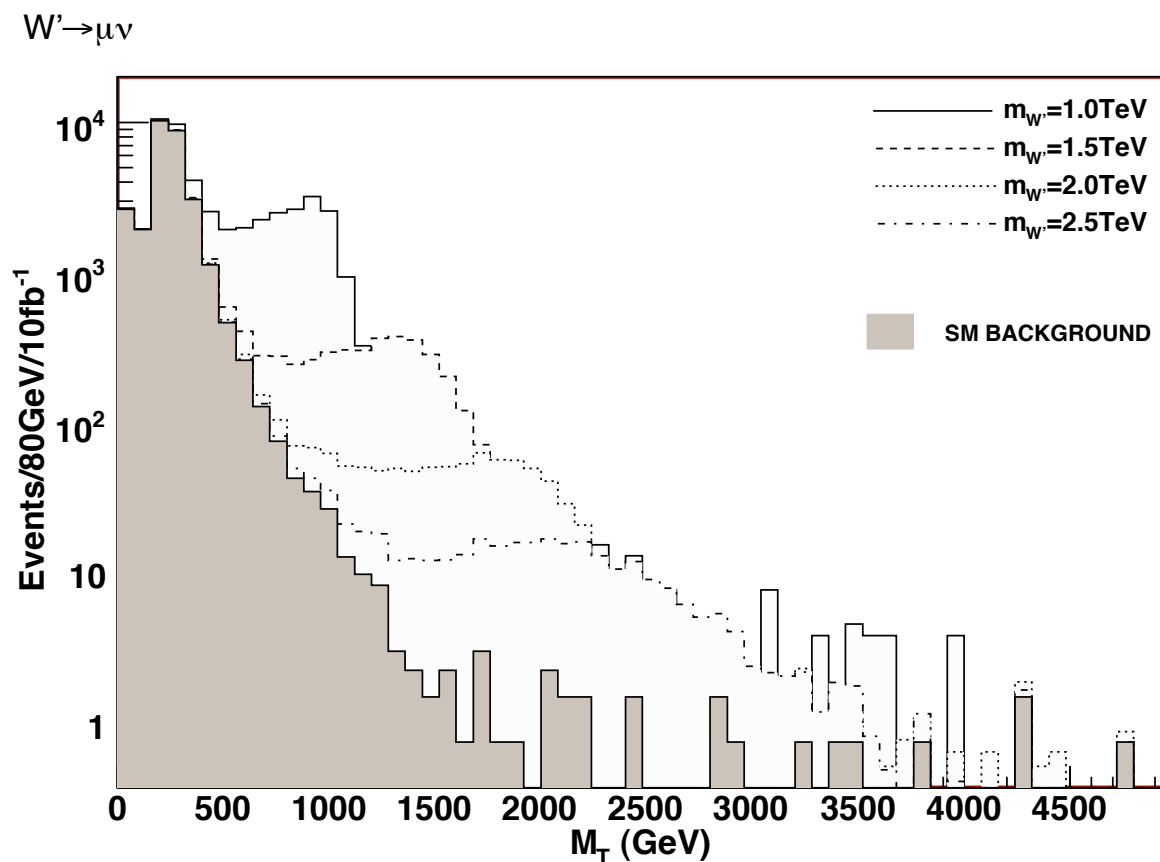
W' expected in models with additional SU(2): E₆, LH..

- ▶ Couplings model dependent
- ▶ SM-like W' considered in ATLAS full simulation

signal: $l + E_{\text{miss}}^T + X$

W' from leptonic decays
 $M_{W'} = 1.. 2.5 \text{ TeV}$ studied

5 σ discovery
with 10 signal events possible
for $M_{W'} = 1 \text{ TeV}$
after $0.5 \text{ fb}^{-1} \int \text{Lumi}$





Exotics 2

heavy neutrinos (N) as singlets

▶ Constrained from the extended MNS matrix elements

- Neutrinos interact only from SM neutrino mixing (see-saw); small production cross section?
- $\sigma \sim (V_{IN})^2 \quad 0.01 > (V_{IN})^2 \sim O(m_I/m_N)$

▶ Majorana N: LFV is allowed

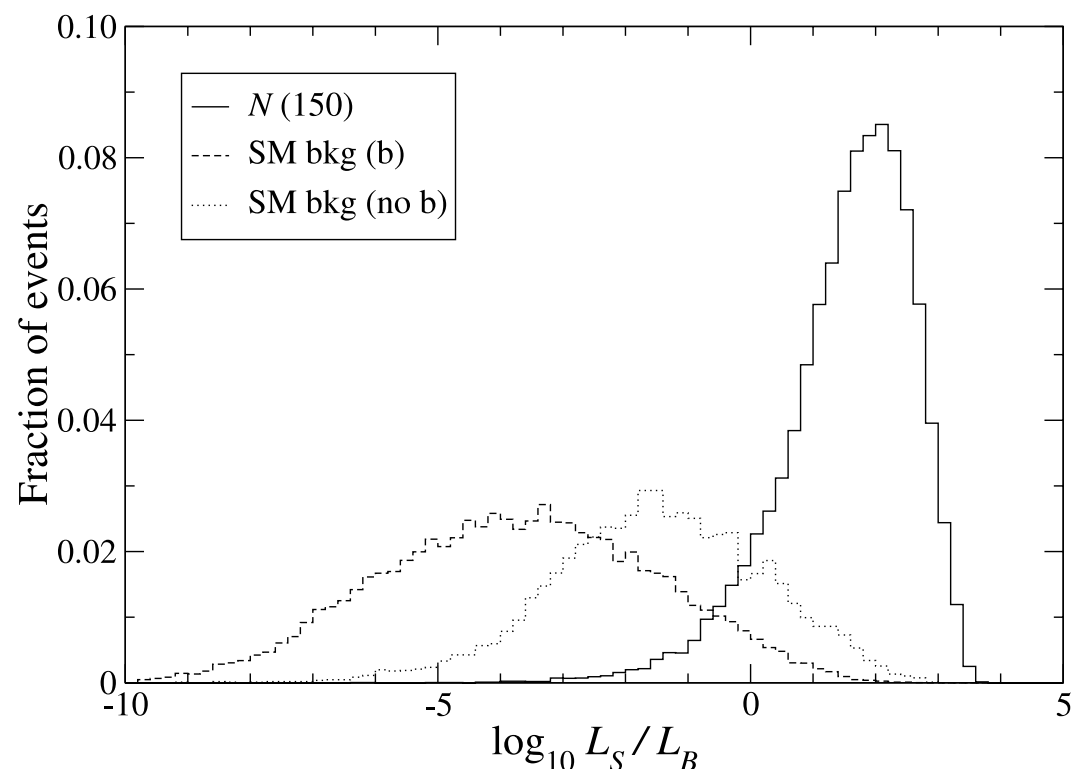
▶ $pp \rightarrow \mu^\pm N \rightarrow \mu^\pm \mu^\pm W \rightarrow \mu^\pm \mu^\pm jj$:

- SM main BG naively is $W^\pm W^\pm nj$
- BUT: $WZnj$, $ttnj$ also!
semi-leptonic decays of b

▶ ATLAS FastMC study

with max mixing
 $m_N = 175 \text{ GeV}$
 $\int L = 30 \text{ fb}^{-1}$
 $s/\sqrt{b} \sim 5$

signal: $2\mu_{\text{same sign}} + 2j$

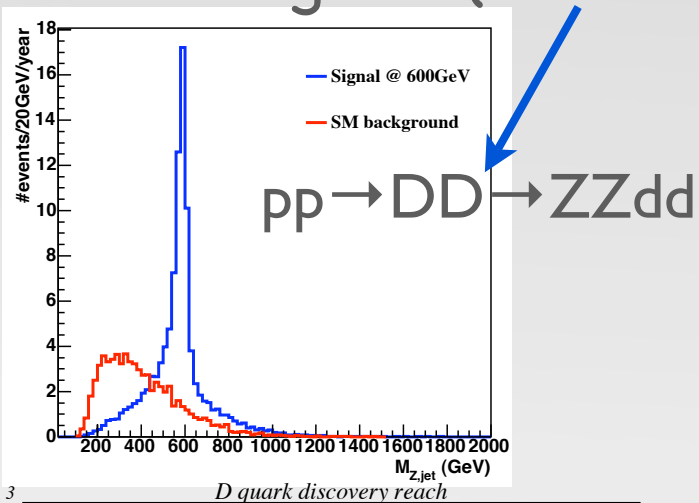




Exotics 3

heavy quark searches

- iso-singlets (down & up type), fourth SM family considered.



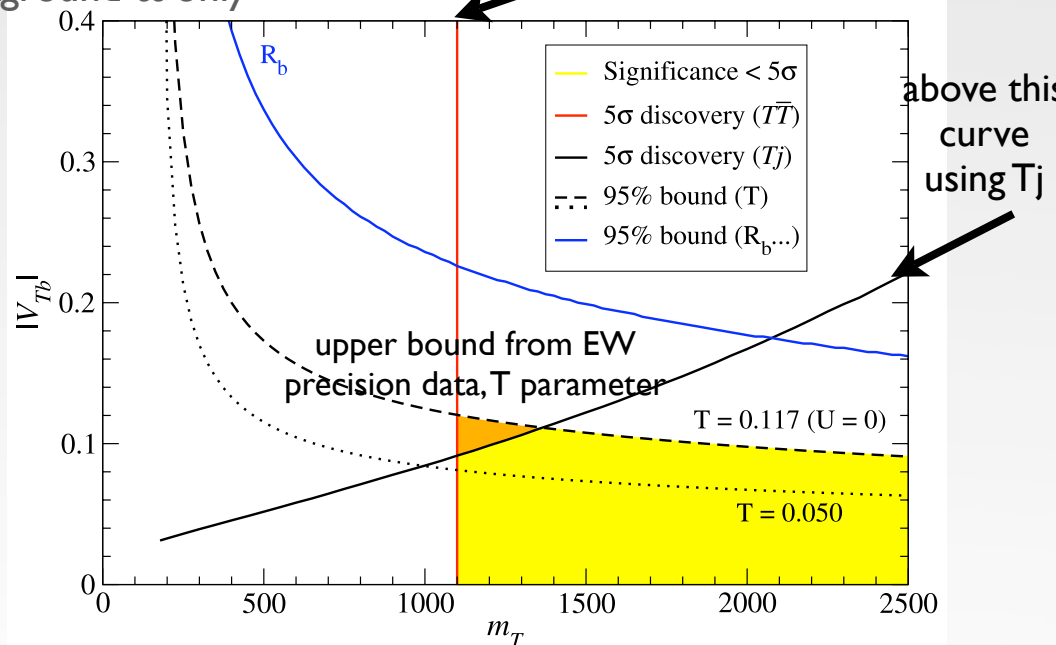
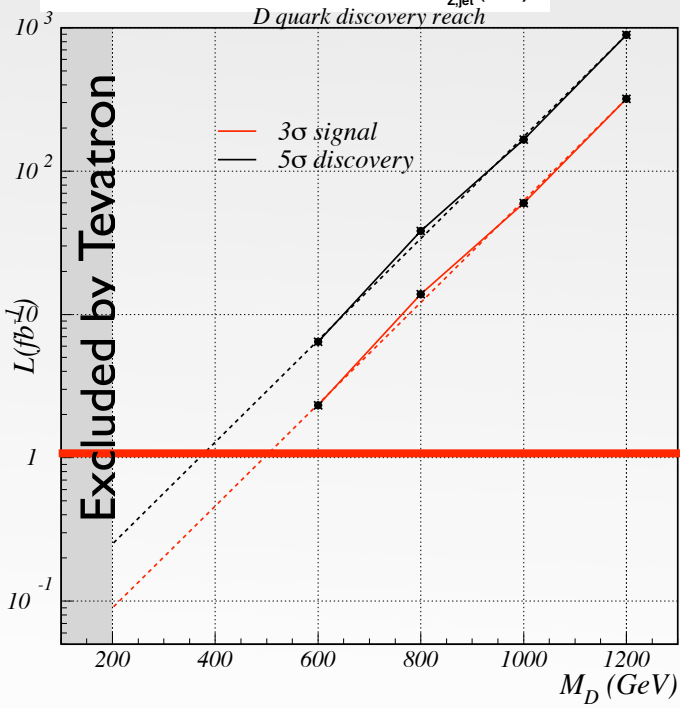
TT decay	signature
WbWb	$l\nu$ bb jj
WbHt	$l\nu$ bbbb jj
WbZt	$l\nu$ bb jjjj

- ▶ TT & Tj used for $\int L=300 \text{ fb}^{-1}$ data for only $T \rightarrow Wb$

- $\sigma_{Tj} \sim |V_{Tb}|^2$ where $V_{Tb} \sim O(m_t/m_T)$

- background tt only

up to 1.1 TeV using TT





Exotics 4

• KK excitations of Z in RS, ADD models

• produced from q-q annihilation

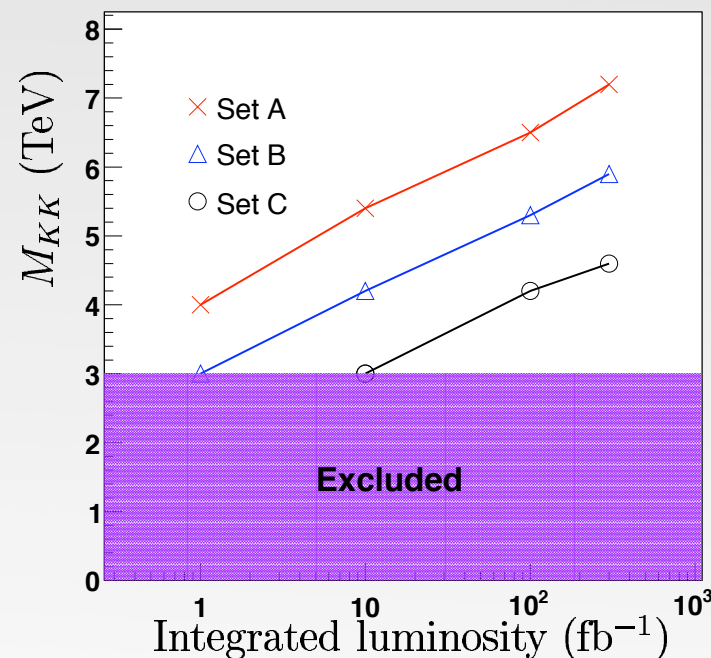
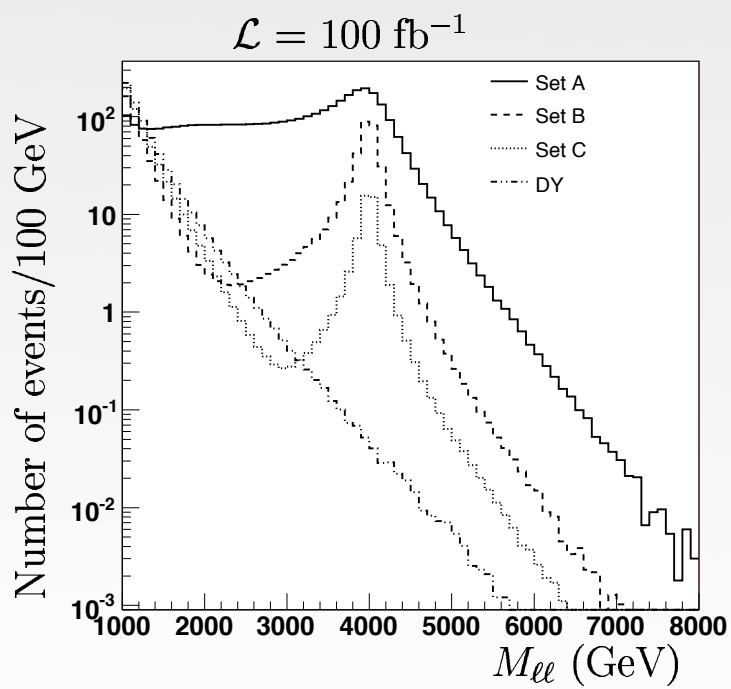
$$pp \rightarrow \gamma^n / Z^n \rightarrow \ell^+ \ell^-$$

• decay via lepton pairs

▶ all SM fields (except H) are bulk fields

- FULL simulation based study
- 3 Parameter sets to reproduce the fermion masses & mixings (A, B, C)
- only electrons were reconstructed

▶ Fermions acquire *localisations* along the ED, related to their mass

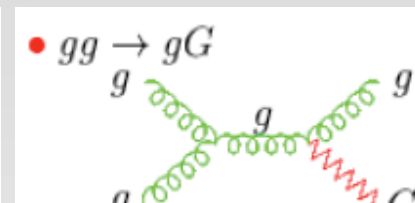
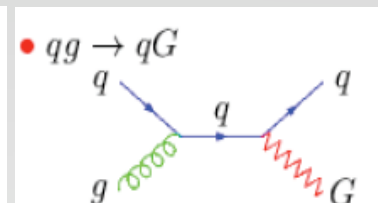
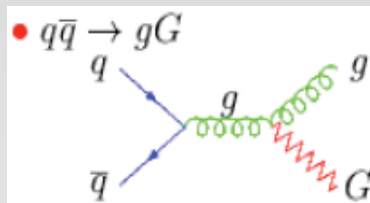
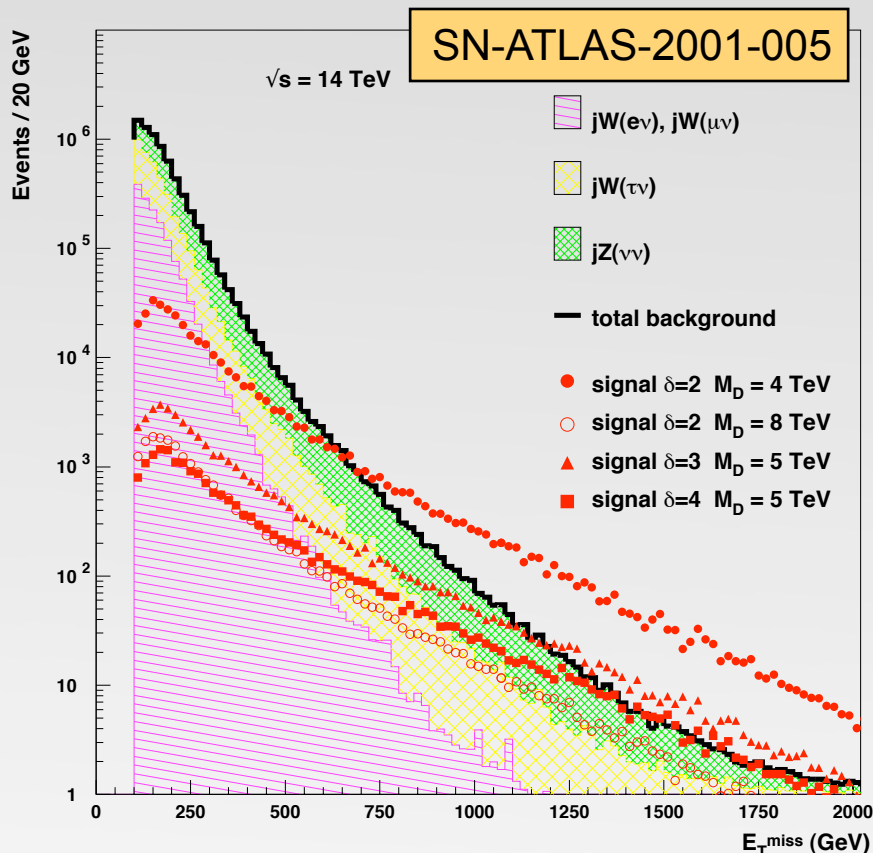


Discovery reach is about 5 TeV depending on the model for 10 fb^{-1} data.



Exotics 5

graviton is predicted by all ED models: $j + E_{T\text{miss}}$



σ depends on #EDs and ED scale

$M_{\text{Pl}(4+d)}^{\text{MAX}}(\text{TeV})$	$\delta=2$	$\delta=3$	$\delta=4$
30fb^{-1}	7.7	6.2	5.2
100fb^{-1}	9.1	7.0	6.0

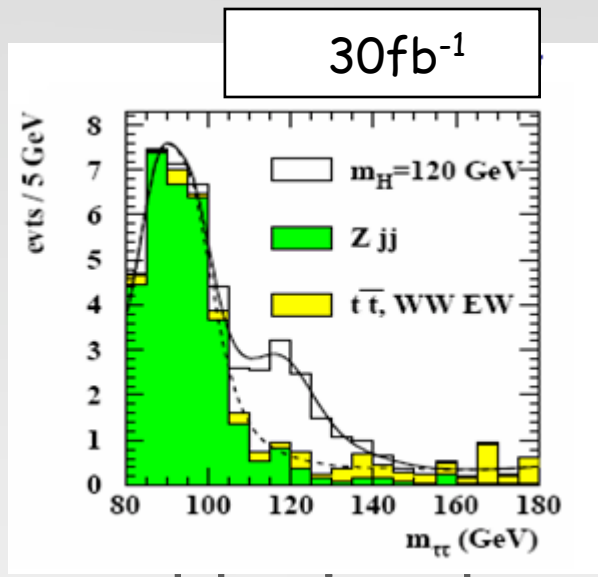
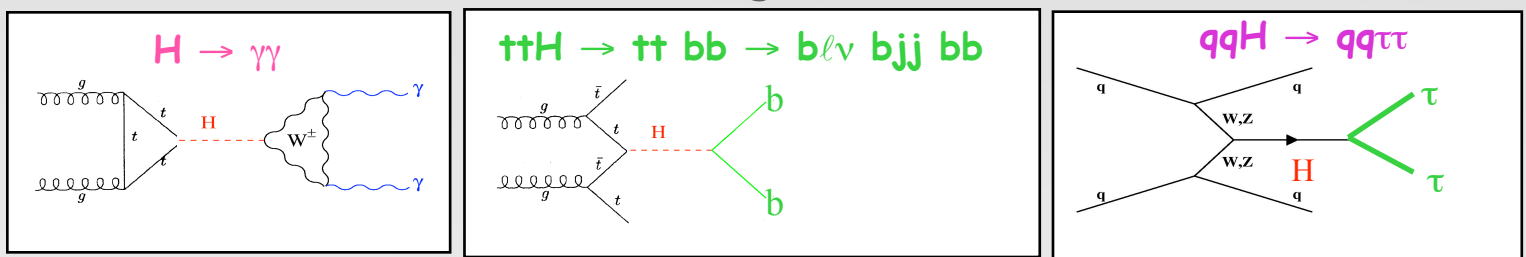
► With 10fb^{-1} we can discover:

- Quarks: up to (1) 750 GeV (in)dependent of mixing angle
- Heavy neutrinos: up to ~ 0.2 or 2 TeV depending on Model
- Bosons: 2-3 TeV

Higgs I

SM Higgs needs luminosity

- 1fb^{-1} : sensitive around 160 GeV, ($h \rightarrow WW$ BR $\sim 95\%$)
- $5\text{--}10\text{fb}^{-1}$: everything else.



Also holds for SM-like SUSY Higgs.

- Specific SUSY Higgs searches in $\tau\tau$ channel: need lumi and good tau identification. ATLAS analyses:
 $-H/A \rightarrow \tau\tau, H^\pm \rightarrow \tau\nu, H^\pm \rightarrow tb.$

Contributions to SM h from BSM physics

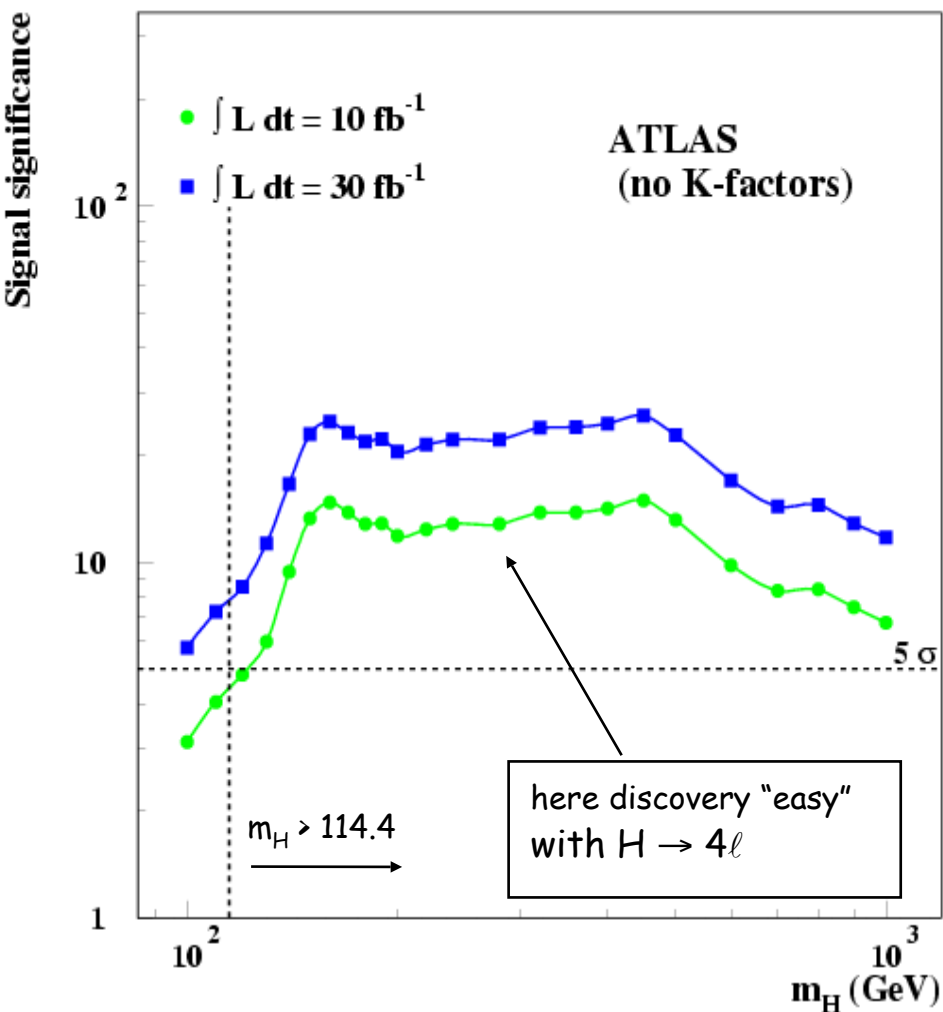
- additional quarks in the gluon fusion loop
- Heavy quarks decaying to $h + \text{jet}$



Higgs 2

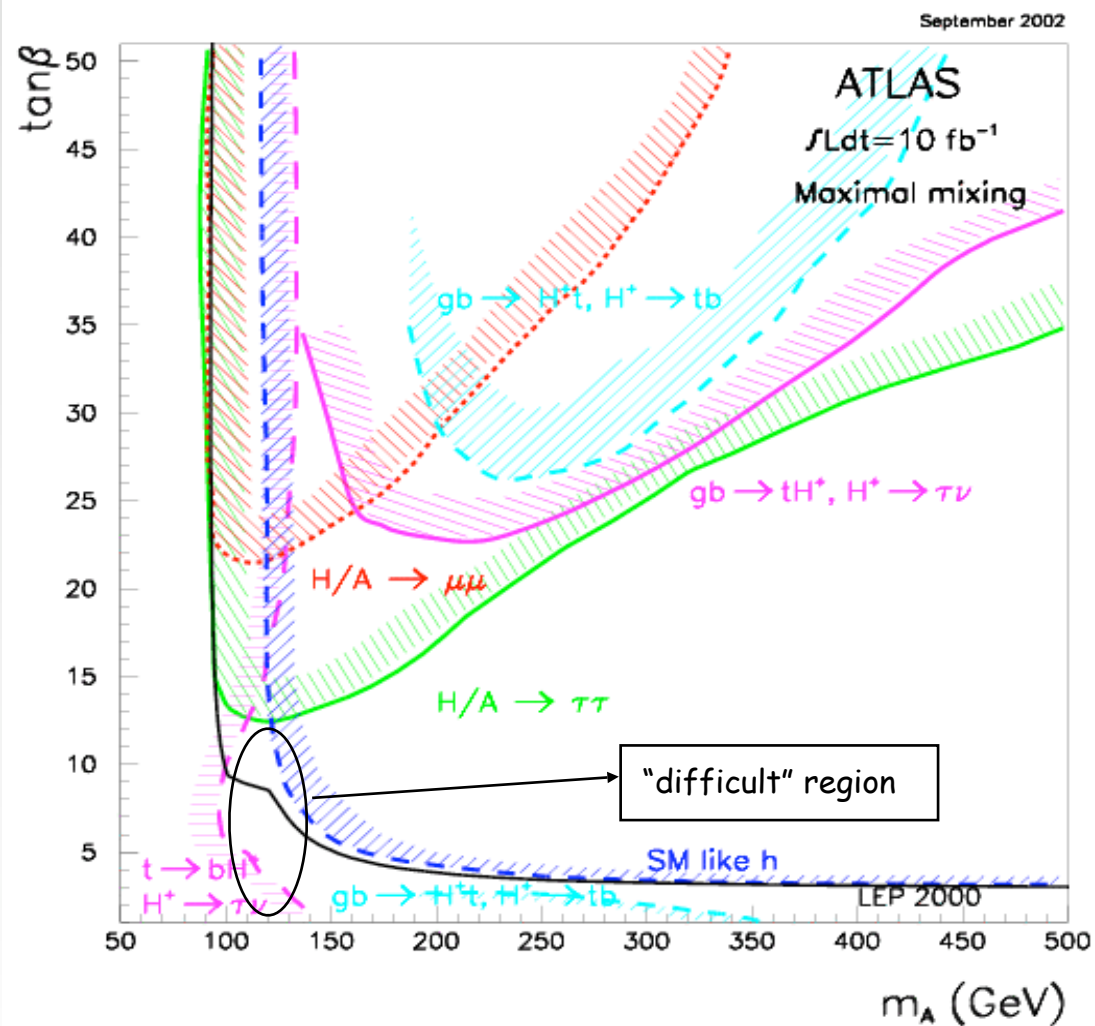
SM Higgs: h

complete coverage with 10fb



MSSM Higgs: h, H, A, H^+, H^- ;
2 parameters: m_A & $\tan\beta$

5σ curves shown, large #channels,





Higgs 3

- ▶ T quarks pair production study with pythia with at least 1 Higgs
 - ▶ the main background tt & tt nj where n=1,2,3,4,5.
- ▶ D quark pair production & decay study with ATLFast

$$T\bar{T} \rightarrow WbHt$$

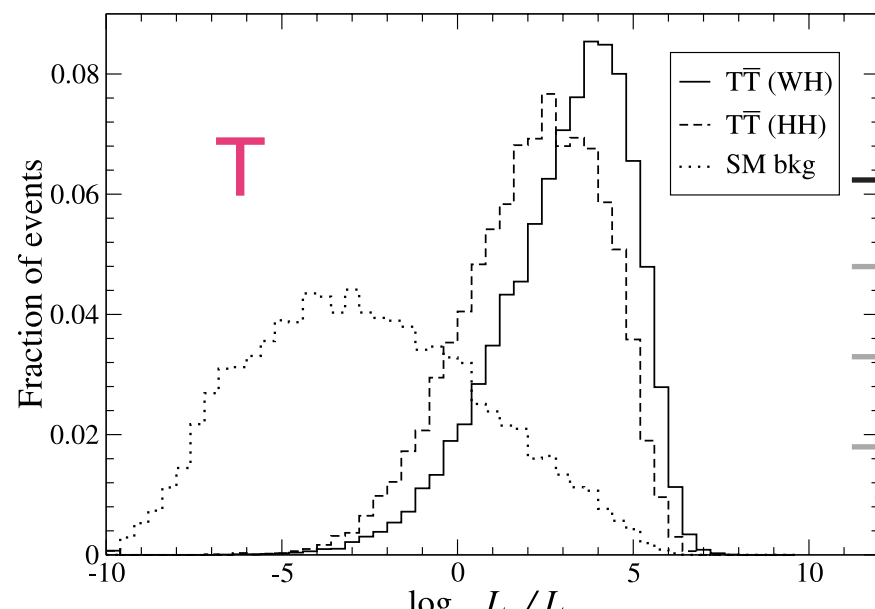
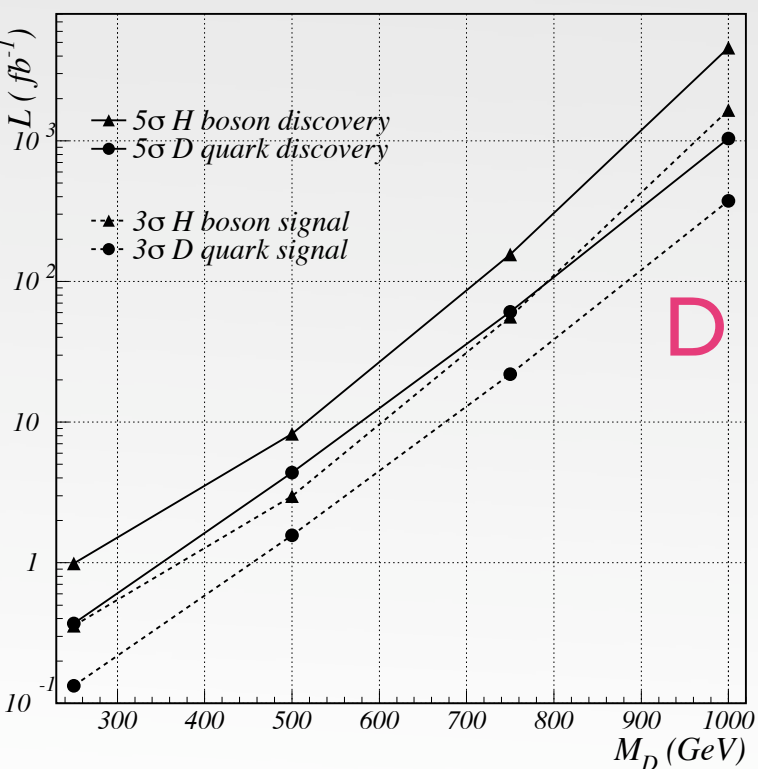
$$T\bar{T} \rightarrow HtHt$$

$$T\bar{T} \rightarrow HtZt$$

signal: 1 ℓ + 2j + 4,5,6b_j + E^T_{miss}

example at m_T=500 GeV,
M_H=115 GeV, ∫L=30 fb⁻¹

D ₁	D ₂	BR	expected final state
D → h j	D → h j	0.029 (0.053)	2j 4j _b
D → h j	D → Z j	0.092 (0.120)	2j 2j _b 2l
D → h j	D → W j	0.190 (0.235)	2j 2j _b l E _{T,miss}



#b _j	h signal significanc
4	6.43
5	6.02
6	5.63
combined	10.45

The others..

Preonic models, contact interactions SN-ATLAS-2004-047

BSM Leptons ATLAS-PHYS-2003-014

Leptoquarks SN-ATLAS-2005-051

Z' searches ATLAS-PHYS-PUB-2006-024

W_H searches SN-ATLAS-2004-038 ATLAS-PHYS-PUB-2006-003

Scalar particle searches SN-ATLAS-2005-049

ED searches (from excited gluons) SN-ATLAS-2006-002

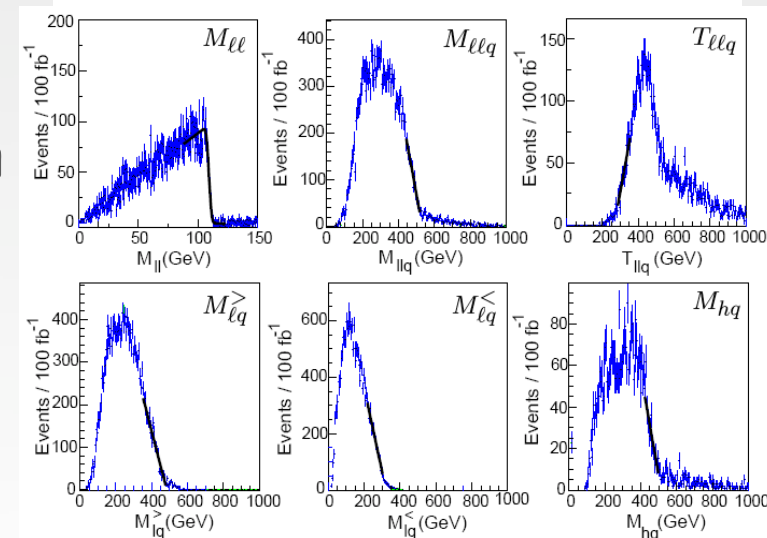
More Susy in fLHC:

- dilepton, and lepton+jet mass distributions with kinematic edges giving information on susy particles masses with 1fb⁻¹.

- LFV in Neutralino and Slepton Decays

- RPV models

$$\tilde{q}_L \rightarrow \tilde{\chi}_2^0 q \rightarrow \tilde{\ell}_R^\pm \ell^\mp q \rightarrow \tilde{\chi}_1^0 \ell^+ \ell^- q$$





Ongoing work

- ATLAS TDR from 1999, almost 10 years ago
- ATLAS "CSC" results early next year:
 - Based on studies with more realistic detector, full detector simulation,
 - Contains repetitions and new analyses:
 - Most of what was presented here
 - BHs, EDs, $h \rightarrow b\bar{b}$ in SUSY events ($\chi_2^0 \rightarrow \chi_1^0 h$)
 - almost like a second TDR: 8 SM, 8 top, 10 Higgs, 6 susy, 5 exotics, 10 b-physics + 10s of performance studies
- CSCs should indicate what ATLAS can realistically do with the data of 2008 and 2009.
- Also there are other studies which did not make to CSC for (mostly) technical reasons



Summary

- ATLAS has very rich potential for high p_T physics.
 - mostly work preformed in the context of fLHC shown,
 - otherwise scientific or pub note results given.
- Concentrated on a selection* of discovery possibilities;
 - some popular models (e.g. micro BHs) not shown,
 - differentiation between models not shown,
- Some results with Fast MC were shown,
 - New analyses with full simulation ongoing for first 1fb^{-1} , CSCs
 - Trigger aware studies immediately applicable to LHC data
- Next few years will be very exciting, stay tuned..

*Apologies to all the analyses not mentioned here...



Thank you



Disclaimer

- Apologies for bias on exotics
- Many thanks to Paul de Jong for non-exotic material



Further details can be found at:

- Flavour at the era of the LHC, WG1 report; to be printed as a yellow report early next year.
- <https://twiki.cern.ch/twiki/bin/view/Atlas/AtlasPhysicsPublicResults>