





- Two classes of searches
 - Model dependent: dependent on other new particles
 - Higgs to invisible
 - Supersymmetry
 - "Model independent"
 - Production of DM with SM particles
 - Jets
 - Photons
 - -W
 - Тор
- I will discuss
 - Higgs
 - Model independent examples
 - SUSY examples

Superb LHC and ATLAS performance

- I will show ATLAS results
 - Some comments on cms
 - Reference list at end
- I will show results from pp at 7 TeV and 8 TeV
 - Some 8 TeV data analysis is still incomplete





Dark matter

- We know that it exists
 - Astrophysical observations
 - Galactic rotation curves
 - CMB fluctuations
- We do not know what it is
 - Axions



- Jupiters (strongly disfavoured, not seen enough)
- Neutral Heavy particles: WIMPS







- Neutral Heavy particles: WIMPS
 - Stable
 - (cannot have electric charge)
 - 1-1000 GeV
 - Interact "weakly"
 - Non relativistic at freeze out
 - Need not be only one type of particle
 - Could be several
 - Often used as an escape by SUSY beleivers

Dark matter models: comparing experiments

- Need a well defined theory (model)
 - Can then compare, direct observation (e.g. Lux, CDMS), astrophysics and direct production (LHC)

- No reason why theory should be simple (pace Occam)
- Some BSM (Beyond Standard Model) theories have candidates
 - SUSY, Lightest SUSY particle (LSP)
 - Often stable (model dependent)
 - Cross section and mass in right range
 - Huge number of parameters
 - No evidence that it exists!



- Might produce DM particle
 - Either directly (small cross section)
 - Or in decay of other new particles (larger cross section?)
 - Stability of particle protected by quantum number
 - Particles produced in pairs
- All limits will be model dependent
- If a candidate is observed
 - Cannot prove it is stable
 - Can constrain couplings and mass
- If a candidate is not observed
 - Can exclude a particular model

Can only make some general statements

Dark matter "detection" at LHC



- DM particle (wimp) produced in proton-proton collision
 - Neutral
 - Has "weak" interactions
 - Deposits no energy in detector
 - Similar to neutrino
- Events will have
 - Missing (transverse) energy (E^{Miss}_t)
 - Other objects produced
- Events must be triggered
 - Missing transverse energy
 - Other objects, e.g jets or leptons (muon or electron)



- A very simple well defined model
 - Higgs decays to pairs of DM particles
 - DM particles only couple to matter via Higgs ("Higgs Portal")
- Measurements of Higgs properties can constrain this
 - DM contributes to "Invisible Higgs decays"
 - Invisible width limited by experiment
 - $M_{DM} < M_{H} / 2$ has bound on coupling to Higgs
 - Bound depends on spin of DM
 - Can compare to direct searches (three spins are shown
- Powerful at low values of M

"Higgs portal" model



Higgs to "invisible"

- Uses production of Z+Higgs
- Detect Z to leptons

(Can also use Z to bbar)



- Event selection
 - Cut A: 2 e or 2 μ , pt>20 GeV, mass consistent with Z
 - Cut B:EtMiss> 90 GeV
 - Cut C: $\Delta \Phi(Z, Etmiss) > 2.6$ rad
 - Cut D: |Etmiss p_{TZ} |/ p_{TZ} <0.3
 - Cut E:No jet with p₇>20 GeV, η <2.4

Z+Missing ET event





Z+Missing ET event





Higgs to "invisible": Backgrounds



- ZZ, WZ from MC.:Validated from data
- WW, ttbar, Wt from MC and data:
 - These make $e\mu$ final states: signal does not
- Z+jets with jet mismeasured or lost
 - Data driven using $\Delta \Phi(Z, Etmiss)$ and $|Etmiss p_{TZ}|/p_{TZ}$
 - Use regions outside of selections
 - Agrees within 10% with pure MC estimate
- Final background dominated by ZZ
 - Note that Higgs discovery itself validates this background.

Higgs to "invisible": selection





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Invisible Higgs decay: Result





"Signal" assumes H> invisible dominates decays Sensitive to large BR

Combined with 7 TeV data: BR(H> invisible)<75%

Invisible Higgs decay: CMS



- Analysis similar: uses transverse mass of Z+etmiss as discriminant
- Similar cuts on Etmiss, jet veto etc.



Higgs and Dark Matter



- Translate limit to coupling of Higgs to DM
 - Three options: Scalar, Majorana Fermion, Vector
 - Compare to direct detection: Very powerful at low mass



Invisible Higgs: Global fit



 Previous limit improves slightly if all Higgs data is used in a combined fit.





Generic production



 Parameterize interactions of DM and quarks/gluons by effective operators

Name	Initial state	Type	Operator
D1	qq	scalar	$\frac{m_q}{M_\star^3} \bar{\chi} \chi \bar{q} q$
D5	qq	vector	$\frac{1}{M_{\star}^2} \bar{\chi} \gamma^{\mu} \chi \bar{q} \gamma_{\mu} q$
D8	qq	axial-vector	$\frac{1}{M_{\star}^2} \bar{\chi} \gamma^{\mu} \gamma^5 \chi \bar{q} \gamma_{\mu} \gamma^5 q$
D9	qq	tensor	$\frac{1}{M_\star^2} \bar{\chi} \sigma^{\mu\nu} \chi \bar{q} \sigma_{\mu\nu} q$
D11	gg	scalar	$\frac{1}{4M_{\star}^3}\bar{\chi}\chi\alpha_s(G^a_{\mu\nu})^2$

Generic production

- Parameterized by
 - DM mass
 - Interaction strength (M*)
- Assumptions
 - Only SM and DM produced
 - No other new particles Energy of collision
 - Interaction is treated as point
 - M*> kinematics of production
- Need something else in the event to observe
 - Get this by QCD or QED radiation.
 - Only small fraction of total production observable



M*

m(wimp)

Associated production





Event display of "monoiet"







Run Number: 189090, Event Number: 2069

Date: 2011-09-10 17:17:48 CEST

Search 1: Event selection: jet+E^{miss}



Uses 2011 ATLAS pp data (4.7 fb-1)

- E^{miss} trigger (plateau above 150 GeV, 98% efficient at 120 GeV)
- Primary vertex with at least 2 associated tracks
- Biggest jet $p_{\tau} > 120$ GeV, $|\eta| < 2$ (central part of detector)
- $|\Delta \phi(\text{jet2, E}^t_{\text{miss}})| > 0.5$ in order to suppress back-to-back dijet events
- No more than two jets with pT > 30 GeV, $|\eta| < 4.5$ (full detector range)
- no electrons with $p_{\tau} > 20$ GeV, $|\eta| < 2.47$
- no muons with $p_{\tau} > 7$ GeV, $|\eta| < 2.5$
- Four signal regions with symmetric cuts on the leading jet p_T and Etmiss p_T , $E_t^{miss} > 120, 220, 350, 500 \text{ GeV}$

Look for event excess above known physics expectation
 Each of these has different sensitivity to wimp

Sources of background



- Must mimic final state
 - Instrumental backgrounds
 - Non collision background, cosmics etc
 - Jet events with badly mis-measured or lost jet

 Use data
 - Real physics backgrounds giving rise to same final state
 - Z(vv)+jets
 - W(μv)+jets (μ outside acceptance)
 - Top (small from MC)
 - Gauge boson pairs (WZ etc) (small from MC)
 - W/Z +jets dominates:
 - Estimate rest first then
 - Normalize from these data



W/Z backgrounds

- Basic idea
 - Use related process to measure
 - Eg Z-> ee
 - Limited by statistics
 - Muon leaves little energy in calorimeter
 - Use W(μν)
 - W and Z production dynamics similar
- Define control regions
 - "replace E^{miss} by leptons"
 - Selection contains leptons
 - Same jet selections as signal candidates
- Details in backup

Control regions

Quite well modeled Therefore corrections applied to MC are small





New physics examples show excess at large values



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Jet Results: events observed



Etmiss, Pt (jet	120 GeV	220 GeV	350 GeV	500 GeV
	SR1	SR2	SR3	SR4
$Z \rightarrow \nu \bar{\nu} + jets$	63000 ± 210	5300 ± 200	$280 500 \pm 40$	58 ± 9
$W \rightarrow \tau \nu + \text{jets}$	31400 ± 100	$1853 \pm$	81 133 \pm 13	13 ± 3
$W \rightarrow ev + jets$	14600 ± 50	679 ± 4	$43 \qquad 40 \pm 8$	5 ± 2
$W \rightarrow \mu \nu + jets$	11100 ± 60	$0 704 \pm 6$	$50 \qquad 55 \pm 6$	6 ± 1
$t\bar{t} + \text{single } t$	1240 ± 250	57 ± 12	$2 4 \pm 1$	-
Multijets	1100 ± 900	64 ± 6	$4 \qquad 8 \pm 9$	-
Non-coll. Background	575 ± 83	25 ± 1	3 -	-
$Z/\gamma^* \rightarrow \tau \tau + \text{jets}$	421 ± 25	15 ± 2	$2 = 2 \pm 1$	-
Di-bosons	302 ± 61	29 ± 5	$5 5 \pm 1$	1 ± 1
$Z/\gamma^* \rightarrow \mu\mu + \text{jets}$	204 ± 19	8 ± 4	-	-
Total Background	124000 ± 40	8800 ± 4	$100 748 \pm 60$	83 ± 14
Events in Data (4.7fb ⁻¹) 124703	8631	785	77

No excess



Background uncertainties

Source	SR1	SR2	SR3	SR4
$\rm JES/JER/E_T^{miss}$	1.0	2.6	4.9	5.8
MC Z/W modelling	2.9	2.9	2.9	3.0
MC statistical uncertainty	0.5	1.4	3.4	8.9
$1 - f_{\rm EW}$	1.0	1.0	0.7	0.7
Muon scale and resolution	0.03	0.02	0.08	0.61
Lepton scale factors	0.4	0.5	0.6	0.7
Multijet BG in electron CR	0.1	0.1	0.3	0.6
Di-boson, top, multijet, non-collisions	0.8	0.7	1.1	0.3
Total systematic uncertainty	3.4	4.4	6.8	11.1
Total data statistical uncertainty	0.5	1.7	4.3	11.8

Percentage uncertainties from various sources Systematics dominate: usually Jet energy scale (JES)





8 TeV data





Comparisons

BERKELEY LAB

Excluded regions above lines

Spin independent operators



Comparisons

BERKELEY LAB

Excluded regions above lines

Spin dependent operators



Comments



- Limits insensitive to mass at small values
 - Production rates controlled by event selection, (p, Jet, E, ^{miss}) not mass
- Rates fall off at large masses
- Now compare to other searches
 - Recall caveat about other states and mass spectrum in full model
 - Comparison may not be valid





- Supersymmetry models can provide dark matter candidates
 - R parity conservation --> Lightest SUSY particle (LSP) stable
 - Must be Neutral and probably weakly interacting
- Models have strongly interacting SUSY particles
 - Heavier than LSP
 - But production rates might be larger at LHC
- Generic searches for SUSY particles cannot be easily interpreted as Dark Matter constraints
 - Direct production of LSP small (but not negligible)
- Searches within fully defined model can provide constraints
- General statements impossible

SUSY and Dark Matter



• Typically complicated decay at LHC

- Electrons, muons, jets....



Many searches in many models: nothing seen

Events of this type







SUSY at LHC:example

CMSSM/MSugra

- Very constrained complete model
 - relates DM to other new particles
- Very few parameters: falsifiable
- Severely constrained now (dead?) by LHC searches
 - Example next

Jets +E^{miss}: search example



- Final states can be complex
 - Quarks, gluons (jets): momenta measured
 - Leptons (electrons, muons, tau), momenta measured
 - Neutrinos, LSP: sum or transverse momenta (energy) measured: two component vector.
- Example search
 - Missing transverse energy and at least 2 jets.
 - $E_t^{miss} > 160 \text{ GeV}, \text{pt}_{J1} > 130 \text{ GeV}, \text{pt}_{J-other} > 60 \text{ GeV}$
- Basic variable: $M_{eff} = \Sigma pt_{Jet} + E_t^{miss}$
- Look for excess at large M_{eff}
- Separate into final states by numbers of jets
- Backgrounds dominated by top,W/Z+jets
 - Composition varies with jet multiplicity
 - Differently than for a signal

Jets +E^{miss} example: 3 jets



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Jets +E^{miss} example: 6 jets



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ATLAS Preliminary

SUSY limits (nothing observed)

ATLAS SUSY Searches* - 95% CL Lower Limits

Sta	atus: ICHEP 2014						$\sqrt{s} = 7, 8 \text{ leV}$
	Model	e, μ, τ, γ	Jets	$E_{\rm T}^{\rm miss}$	∫ <i>L dt</i> [fb	¹] Mass limit	Reference
Inclusive Searches	$ \begin{array}{l} \text{MSUGRA/CMSSM} \\ \text{MSUGRA/CMSSM} \\ \text{MSUGRA/CMSSM} \\ \tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{s}, \tilde{s} \rightarrow q \tilde{q} \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{s}, \tilde{s} \rightarrow q q \tilde{\chi}_{1}^{0} \\ \tilde{g}\tilde{s}, \tilde{s} \rightarrow q q \tilde{\chi}_{1}^{0} \\ \text{GMSB} (\tilde{\ell} \text{NLSP}) \\ \text{GMSB} (\tilde{\ell} \text{NLSP}) \\ \text{GGM} (bino \text{NLSP}) \\ \text{GGM} (bino \text{NLSP}) \\ \text{GGM} (higosino \text{NLSP}) \\ \text{Gravitino LSP} \\ \end{array} $	$\begin{matrix} 0 \\ 1 \ e, \mu \\ 0 \\ 0 \\ 1 \ e, \mu \\ 2 \ e, \mu \\ 1 \ 2 \ e, \mu \\ 1 \ 2 \ r + 0 - 1 \ \ell \\ 2 \ \gamma \\ 1 \ e, \mu + \gamma \\ \gamma \\ 2 \ e, \mu \ (Z) \\ 0 \end{matrix}$	2-6 jets 3-6 jets 2-6 jets 2-6 jets 3-6 jets 0-3 jets 0-2 jets - 1 <i>b</i> 0-3 jets mono-jet	Yes Yes Yes Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 4.7 20.3 20.3 20.3 4.7 20.3 20.3 4.8 5.8 10.5	\tilde{q} , \tilde{g} 1.7 TeV $m(\tilde{q})=m(\tilde{g})$ \tilde{g} 1.2 TeV ary $m(\tilde{q})$ \tilde{g} 1.1 TeV $m(\tilde{\chi}_1^0)=0$ GeV, $m(1^{st}$ gen. $\tilde{q})=m(2^{sd}$ gen. $\tilde{q})$ \tilde{g} 1.18 TeV $m(\tilde{\chi}_1^0)=0$ GeV \tilde{g} 1.12 TeV $m(\tilde{\chi}_1^0)=0$ GeV \tilde{g} 1.24 TeV tan $\beta > 10$ GeV \tilde{g} 1.28 TeV $m(\tilde{\chi}_1^0)>50$ GeV \tilde{g} 619 GeV $m(\tilde{\chi}_1^0)>50$ GeV \tilde{g} 690 GeV $m(\tilde{\chi}_1^0)>200$ GeV \tilde{g} 690 GeV $m(\tilde{\chi}_1^0)>20$ GeV	1405.7875 ATLAS-CONF-2013-062 1308.1841 1405.7875 1405.7875 ATLAS-CONF-2013-062 ATLAS-CONF-2013-089 1208.4688 1407.0603 ATLAS-CONF-2012-144 1211.1167 ATLAS-CONF-2012-147 ATLAS-CONF-2012-152 ATLAS-CONF-2012-152
3'" gen. § med.	$\begin{array}{c} \tilde{g} \rightarrow b \tilde{b} \tilde{\chi}_1^0 \\ \tilde{g} \rightarrow t \tilde{\lambda}_1^0 \\ \tilde{g} \rightarrow t \tilde{\lambda}_1^0 \\ \tilde{g} \rightarrow b \tilde{\lambda}_1^{-1} \end{array}$	0 0 0-1 <i>e</i> , <i>µ</i> 0-1 <i>e</i> , <i>µ</i>	3 <i>b</i> 7-10 jets 3 <i>b</i> 3 <i>b</i>	Yes Yes Yes Yes	20.1 20.3 20.1 20.1	ĝ 1.25 TeV m(ℓ ⁰ ₁)<400 GeV ĝ 1.1 TeV m(ℓ ⁰ ₁)<450 GeV	1407.0600 1308.1841 1407.0600 1407.0600
3 rd gen. squarks direct production	$ \begin{array}{c} b_1b_1, b_1 \rightarrow b\tilde{\chi}_1^0 \\ b_1b_1, b_1 \rightarrow d\tilde{\chi}_1^1 \\ \bar{\chi}_1\tilde{\chi}_1([[ght]), \tilde{\chi}_1 \rightarrow b\tilde{\chi}_1^1 \\ \bar{\chi}_1\tilde{\chi}_1([[ght]), \tilde{\chi}_1 \rightarrow Wb\tilde{\chi}_1^0 \\ \bar{\chi}_1\tilde{\chi}_1([[ght]), \tilde{\chi}_1 \rightarrow Wb\tilde{\chi}_1^0 \\ \bar{\chi}_1\tilde{\chi}_1([[ght]]), \tilde{\chi}_1 \rightarrow \tilde{W}\tilde{\chi}_1^0 \\ \bar{\chi}_1\tilde{\chi}_1([[ght]]), \tilde{\chi}_1 \rightarrow \tilde{W}\tilde{\chi}_1^0 \\ \bar{\chi}_1\tilde{\chi}_1([[ght]]), \tilde{\chi}_1 \rightarrow \tilde{\chi}_1^0 \\ \bar{\chi}_1\tilde{\chi}_1 = \tilde{\chi}_1\tilde{\chi}_1 = \tilde{\chi}_1^0 \\ \bar{\chi}_1\tilde{\chi}_1 = \tilde{\chi}_1\tilde{\chi}_1 = \tilde{\chi}_1^0 \\ \bar{\chi}_1\tilde{\chi}_1 = \tilde{\chi}_1\tilde{\chi}_1 = \tilde{\chi}_1\tilde{\chi}_1$	$\begin{matrix} 0 \\ 2 \ e, \mu \ (\text{SS}) \\ 1-2 \ e, \mu \\ 2 \ e, \mu \\ 2 \ e, \mu \\ 0 \\ 1 \ e, \mu \\ 0 \\ 1 \ e, \mu \\ 0 \\ 3 \ e, \mu \ (Z) \end{matrix}$	2 b 0-3 b 1-2 b 0-2 jets 2 jets 2 b 1 b 2 b ono-jet/c-ta 1 b 1 b	Yes Yes Yes Yes Yes Yes Yes ag Yes Yes Yes	20.1 20.3 4.7 20.3 20.3 20.1 20 20.1 20.3 20.3 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1308.2631 1404.2500 1208.4305, 1209.2102 1403.4853 1403.4853 1308.2631 1407.0583 1406.1122 1407.0608 1403.5222 1403.5222
EW direct	$ \begin{array}{c} \tilde{\ell}_{LR}\tilde{\ell}_{LR}, \tilde{\ell} \rightarrow \ell \tilde{k}_{1}^{0} \\ \tilde{k}_{1}^{*}\tilde{k}_{1}^{*}, \tilde{k}_{1}^{*} \rightarrow \tilde{\ell} \nu(\ell \tilde{\nu}) \\ \tilde{k}_{1}^{*}\tilde{k}_{1}^{*}, \tilde{k}_{1}^{*} \rightarrow \tilde{\ell} \nu(\ell \tilde{\nu}) \\ \tilde{k}_{1}^{*}\tilde{k}_{2}^{*}, \tilde{k}_{2}^{*} \rightarrow \tilde{\ell} \nu(\ell (\tilde{\nu}) \nu), \ell \tilde{\ell}_{L} \ell(\tilde{\nu} \nu) \\ \tilde{k}_{1}^{*}\tilde{k}_{2}^{0} \rightarrow W \tilde{k}_{2}^{*} \tilde{k}_{1}^{0} \\ \tilde{k}_{1}^{*}\tilde{k}_{2}^{0} \rightarrow W \tilde{k}_{1}^{*} \tilde{k}_{1}^{0} \\ \tilde{k}_{2}^{*}\tilde{k}_{2}^{*} \rightarrow W \tilde{k}_{1}^{*} \tilde{k}_{1}^{*} \\ \tilde{k}_{2}^{*}\tilde{k}_{2}^{*} \rightarrow \tilde{k}_{L} \ell \end{array} $	2 e, µ 2 e, µ 2 τ 3 e, µ 2-3 e, µ 1 e, µ 4 e, µ	0 0 - 0 2 <i>b</i> 0	Yes Yes Yes Yes Yes Yes Yes	20.3 20.3 20.3 20.3 20.3 20.3 20.3 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	1403.5294 1403.5294 1407.0350 1402.7029 1403.5294, 1402.7029 ATLAS-CONF-2013-093 1405.5086
Long-Ilved particles	Direct $\tilde{\chi}_{1}^{+}\tilde{\chi}_{1}^{-}$ prod., long-lived $\tilde{\chi}_{1}^{\pm}$ Stable, stopped \tilde{g} R-hadron GMSB, stable $\tilde{\tau}, \tilde{\chi}_{1}^{0} \rightarrow \tilde{\tau}(\tilde{e}, \tilde{\mu}) + \tau(e, g)$ GMSB, $\tilde{\chi}_{1}^{0} \rightarrow \gamma \tilde{G}$, long-lived $\tilde{\chi}_{1}^{0}$ $\tilde{q}\tilde{q}, \tilde{\chi}_{1}^{0} \rightarrow qq\mu$ (RPV)	Disapp. trk 0 μ) 1-2 μ 2 γ 1 μ, displ. vtx	1 jet 1-5 jets - -	Yes Yes - Yes -	20.3 27.9 15.9 4.7 20.3	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	ATLAS-CONF-2013-069 1310.6584 ATLAS-CONF-2013-058 1304.6310 ATLAS-CONF-2013-092
RPV	$ \begin{array}{l} LFV \ pp \rightarrow \tilde{\mathbf{v}}_{\tau} + X, \tilde{\mathbf{v}}_{\tau} \rightarrow e + \mu \\ LFV \ pp \rightarrow \tilde{\mathbf{v}}_{\tau} + X, \tilde{\mathbf{v}}_{\tau} \rightarrow (\mu) + \tau \\ Biinear \ RPV \ CMSSM \\ \tilde{\mathbf{t}}_{\tau}^{(1)}, \tilde{\mathbf{t}}_{\tau}^{(1)} \rightarrow W \tilde{\mathbf{v}}_{1}^{(1)} \wedge e e \tilde{v}_{\mu}, e \mu \tilde{v}_{e} \\ \tilde{\mathbf{t}}_{\tau}^{(1)}, \tilde{\mathbf{t}}_{\tau}^{(1)} \rightarrow W \tilde{\mathbf{v}}_{1}^{(1)}, \tilde{\mathbf{t}}_{\tau}^{(1)} \rightarrow \tau \tau \tilde{v}_{e}, e \tau \tilde{v}_{\tau} \\ \tilde{g} \rightarrow q q \\ \tilde{g} \rightarrow \tilde{t}_{\tau} (\tau, 1) \rightarrow b s \end{array} $	$\begin{array}{c} 2 \ e, \mu \\ 1 \ e, \mu + \tau \\ 2 \ e, \mu \ (SS) \\ 4 \ e, \mu \\ 3 \ e, \mu + \tau \\ 0 \\ 2 \ e, \mu \ (SS) \end{array}$	- 	- Yes Yes Yes - Yes	4.6 4.6 20.3 20.3 20.3 20.3 20.3 20.3	$\begin{array}{c c c c c c c c c c c c c c c c c c c $	1212.1272 1212.1272 1404.2500 1405.5086 1405.5086 ATLAS-CONF-2013-091 1404.250
Other	Scalar gluon pair, sgluon $\rightarrow q\bar{q}$ Scalar gluon pair, sgluon $\rightarrow t\bar{t}$ WIMP interaction (D5, Dirac χ)	0 2 <i>e</i> , µ (SS) 0	4 jets 2 b mono-jet	- Yes Yes	4.6 14.3 10.5	sgluon 100-287 GeV incl. limit from 1110.2693 gluon 350-800 GeV m(χ)<80 GeV, limit of <687 GeV for D8	1210.4826 ATLAS-CONF-2013-051 ATLAS-CONF-2012-147
$\sqrt{s} = 7$ TeV full data $\sqrt{s} = 8$ TeV full data 10^{-1} 1 Mass scale [TeV] *Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1 σ theoretical signal cross section uncertainty.							

SUSY limits (nothing observed)



Summary of CMS SUSY Results* in SMS framework





SUSY Limits

- BERKELEY LAB
- Translating this limit to compare with Direct DM search needs a model
- Simplest CMSSM model with 5 parameters is almost dead
 - Once this is relaxed, huge number of parameters
- **PMSSM** is next simplest version: 19 parameters
 - Not easy to show on 2d plot
- The Baysian who knows SUSY is right can examine parameter space
 - Favoured space tends to have large DM mass.



- Higgs portal model constrained by Higgs measurements
 - Small mass region challenged

Summary

- No SUSY observed
 - Can only be converted into DM limit in a model
 - Specific models have been ruled out
 - CMSSM on life support (vegetative state?)
- Generic search for DM production
 - No signal
 - Limits very competitive
 - Particularly at small wimp mass
 - Beware caveat about mass gaps



- (Z(to leptons) +ETmiss)http://arxiv.org/abs/1404.0051
- (Z/W(to hadrons)+Etmiss) http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.112.041802 http://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2013-073/
- (Jets + Etmiss) http://link.springer.com/article/10.1007/JHEP04%282013%29075 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-147/
- (Photon+Etmiss)http://journals.aps.org/prl/pdf/10.1103/PhysRevLett.110.011802 https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-085/
- (Higgs to dark matter) https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2014-010/ (Higgs to invisible) http://arxiv.org/abs/1402.3244

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults



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https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSUS

References: other (incomplete)



- Operator formalism: Goodman et al Phys.Rev. D82 (2010) 116010 and papers that cite this.
- Higgs portal: Brian Patt, Frank Wilczek (MIT, LNS). May 2006. 3 pp. MIT-CTP-374, e-Print: hep-ph/0605188.
- SUSY parameter space: Cahill-Rowley et al, arXiv:1308.0297, arXiv:1305.6921 etc: Jellis et al arXiv:1305.6921 etc; Arby et al Eur.Phys.J. C72 (2012) 1906

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- (Photon+Etmiss) http://journals.aps.org/prl/abstract/10.1103/PhysRevLett.108.261803
- (jet+etmiss) http://link.springer.com/article/10.1007%2FJHEP09%282012%29094
- (ttbar+ LSP) http://cds.cern.ch/record/1697173?In=en
- (higgs to invisible) http://cds.cern.ch/record/1561758?In=en

https://**(WIEteniss)**/twiki/bin/view/AtlasPublic/ExoticsPublicResults

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsEXO https://twjggggrn.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

Atlas results pages



Backup

Comparison of jet vs photon





Jets +E^{miss} example: 5 jets



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photon





W/Z backgrounds





- fraction of electroweak processes of a given kind in the control region
- lepton acceptance and reconstruction efficiency
- efficiency of the Z and W selection
- trigger efficiency and the luminosity correction (only for the electron CR)

Comparisons





photon



