Simplified model approaches in the search for supersymmetry with tau leptons in the final state at ATLAS

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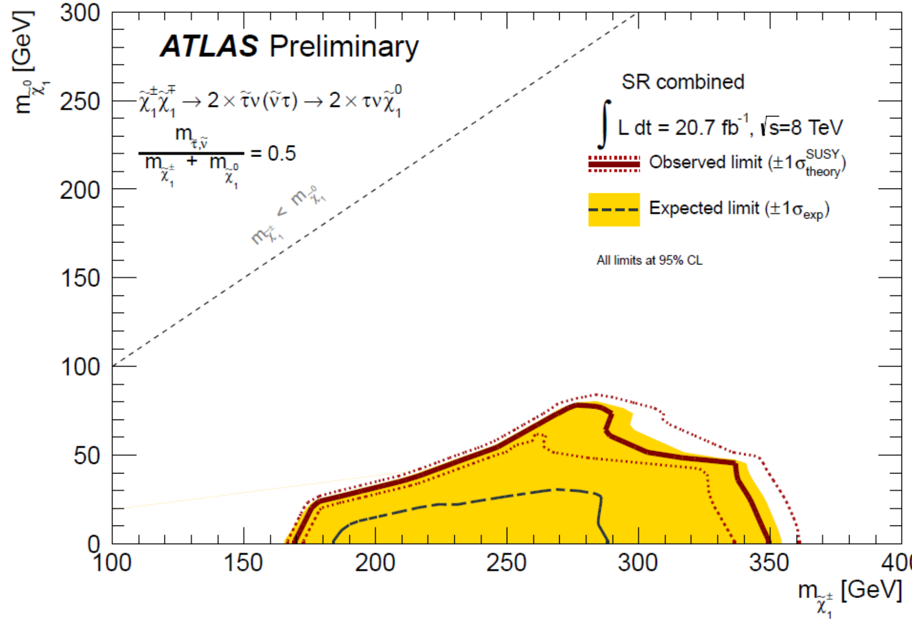
Simplified Models – Status at ATLAS

- Only few simplified models with taus so far:
  - First results presented at Moriond ’13
    - Legger et al.: elw. simplified model with stau nlsp

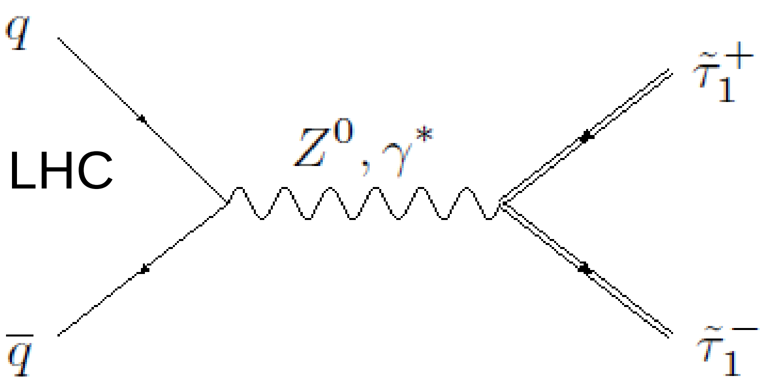


ATLAS-CONF-2013-028

- How we tackle this:
  - GMSB-inspired ($\tilde{G}$ as LSP)
  - $\tilde{\tau}_1^{\pm}$ as NLSP (stau promising NLSPs)
  - Expected signature: taus + MET
  - Pseudo-observables (masses) determine grid structure
  - „Hidden“ parameters, see if …
    - … Independent of → good, parameter stays hidden
    - … effects on analysis visible → try to parametrise

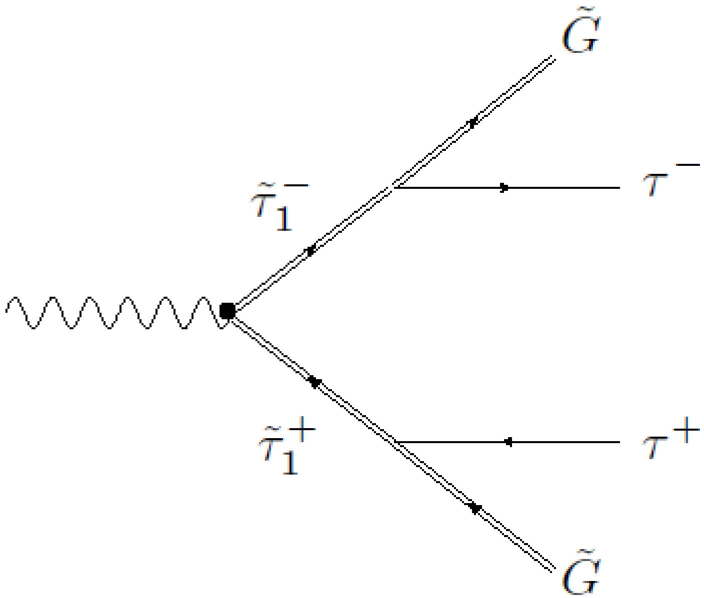
Studies in Bonn – Status & Plans

- Existing simplified model grids:
  - Electro-weak direct stau pair production
  - Electro-weak direct chargino pair production
  - Surpression of t-channel production ($m\left(\tilde{q}_{\mathrm{L,R}}\right) = 6\,\mathrm{TeV}$)
  - Easier to set up & control (less parameters)
  - Rather low production cross sections @ LHC
- Planned grid:
  - Strong gluino/squark production
  - More difficult (more parameters)
  - Larger production cross sections @ LHC
  - $\tilde{q}_{\mathrm{L,R}} \in \left\{\tilde{u}_{\mathrm{L,R}}, \tilde{d}_{\mathrm{L,R}}, \tilde{c}_{\mathrm{L,R}}, \tilde{s}_{\mathrm{L,R}}\right\}$



Stau grid - setup

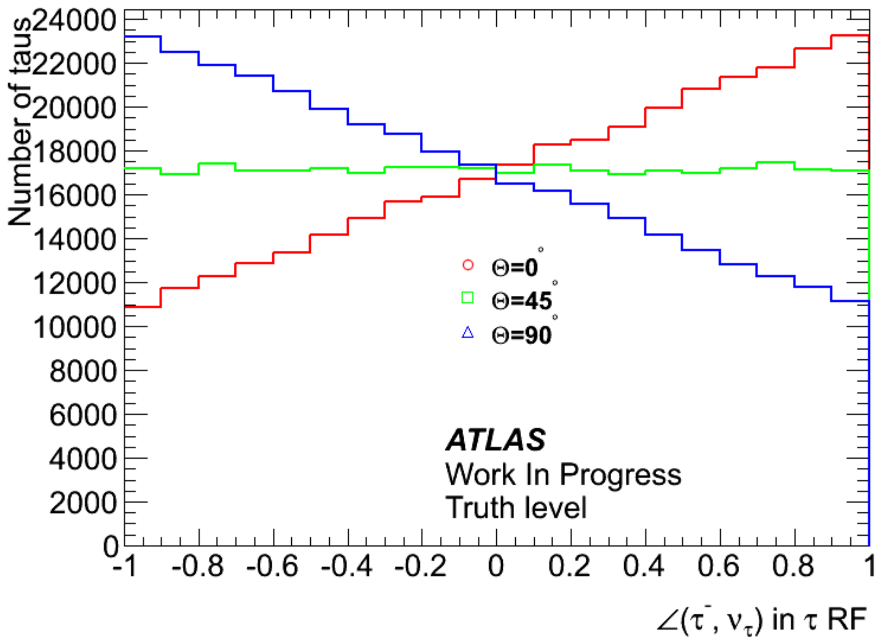
- Stau pair production (elw.) (just warm-up studies)
  - Parameter: $m\left(\tilde{\tau}_1\right)$
  - Hidden parameter: stau mixing angle $\Theta_{\tilde{\tau}}$
  - Studies of FS tau polarisation (wrt. stau mixing)

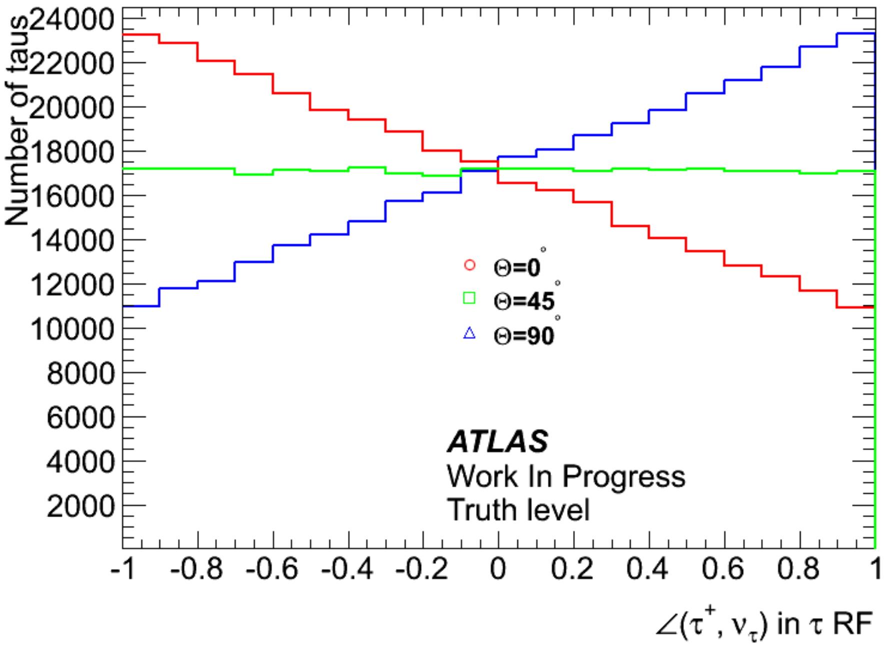


$$\begin{pmatrix} \tilde{\tau}_1 \\ \tilde{\tau}_2 \end{pmatrix} = \begin{pmatrix} \cos\Theta_{\tilde{\tau}} & \sin\Theta_{\tilde{\tau}} \\ -\sin\Theta_{\tilde{\tau}} & \cos\Theta_{\tilde{\tau}} \end{pmatrix} \begin{pmatrix} \tilde{\tau}_{\mathrm{L}} \\ \tilde{\tau}_{\mathrm{R}} \end{pmatrix}$$

Stau grid – polarisation studies

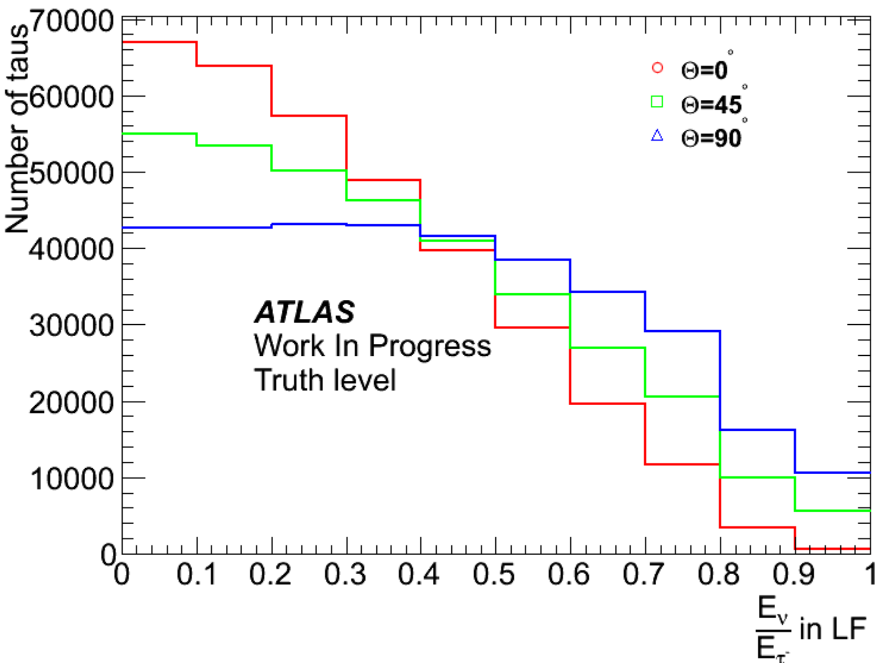
- FS tau polarisation studies: $\tau \rightarrow \nu_\tau + X_{\text{had.}}$
  - $\angle(\nu_\tau, \tau)$ in tau RF
  - Charge dependent effects due to stau mixing
  - Hard to probe in the experiment

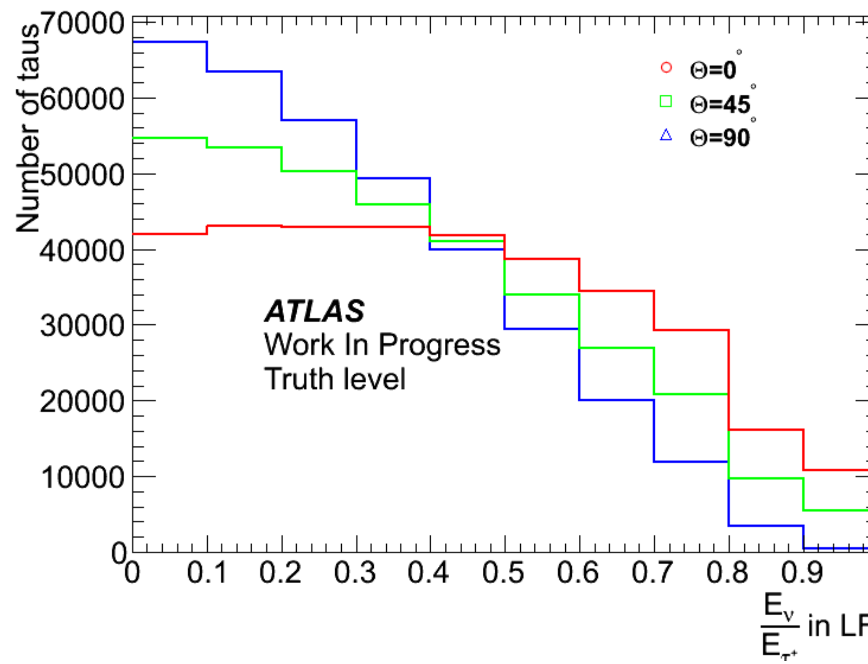




Stau grid – polarisation studies

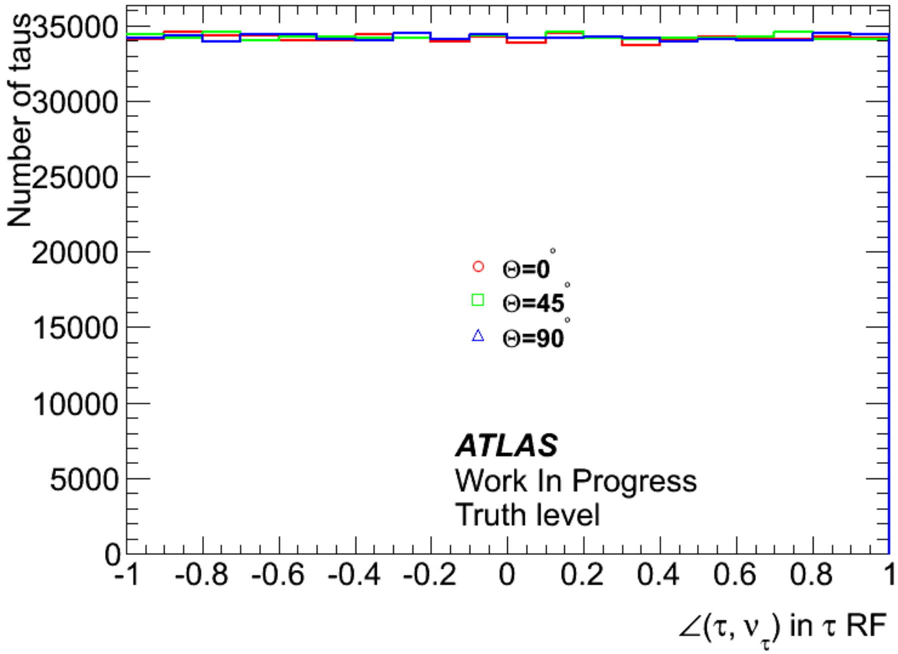
- FS tau polarisation studies $\tau \rightarrow \nu_\tau + X_{\mathrm{had.}}$
  - $\frac{E(\nu_\tau)}{E(\tau)}$ in LF
  - Charge dependent effects due to stau mixing
  - Hard to probe in the experiment but visible in p_t

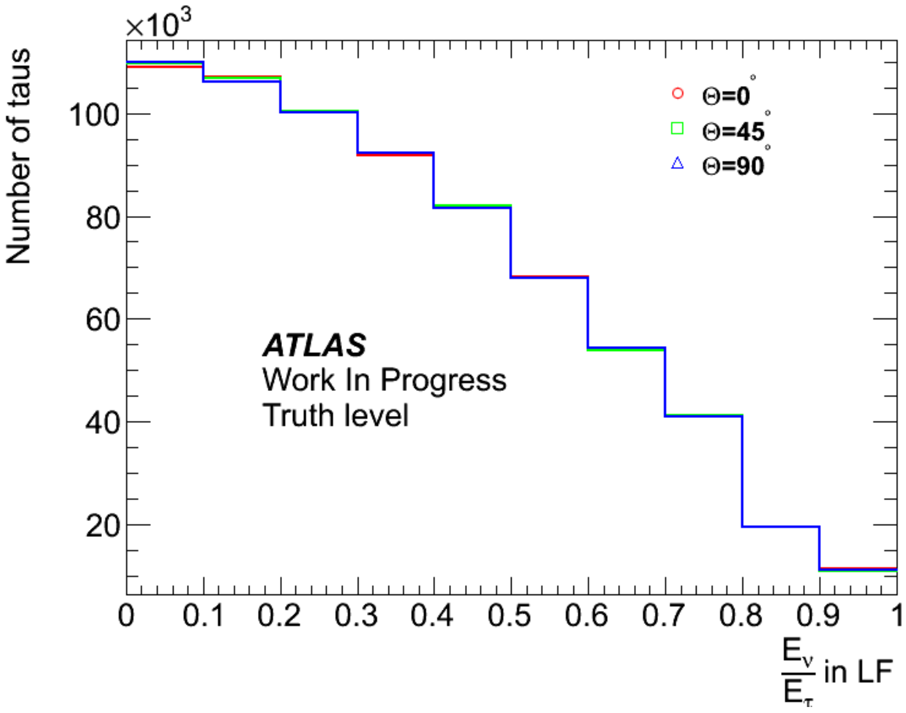




Stau grid – polarisation studies

- FS tau polarisation studies $\tau \rightarrow \nu_\tau + X_{\text{had.}}$
  - Both effects vanish when insensitive to tau charge

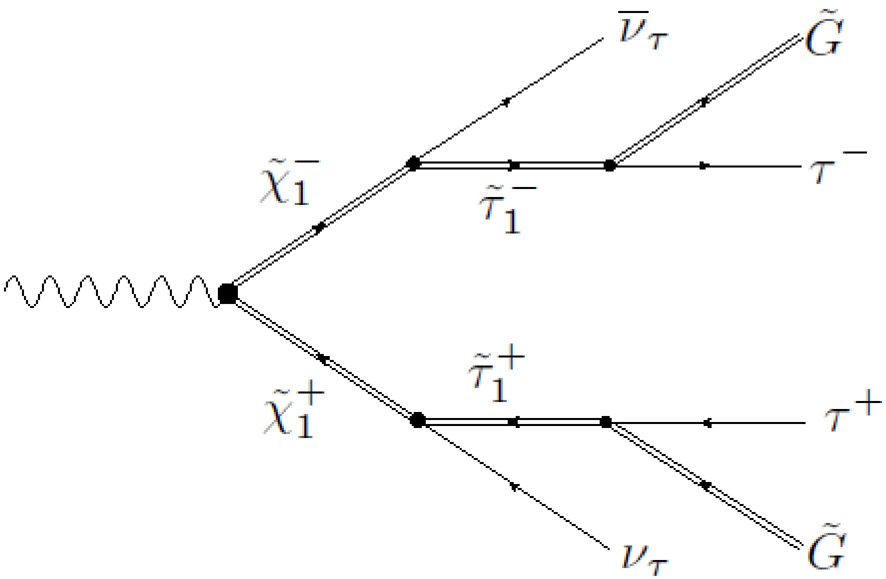




Chargino/stau grid - setup

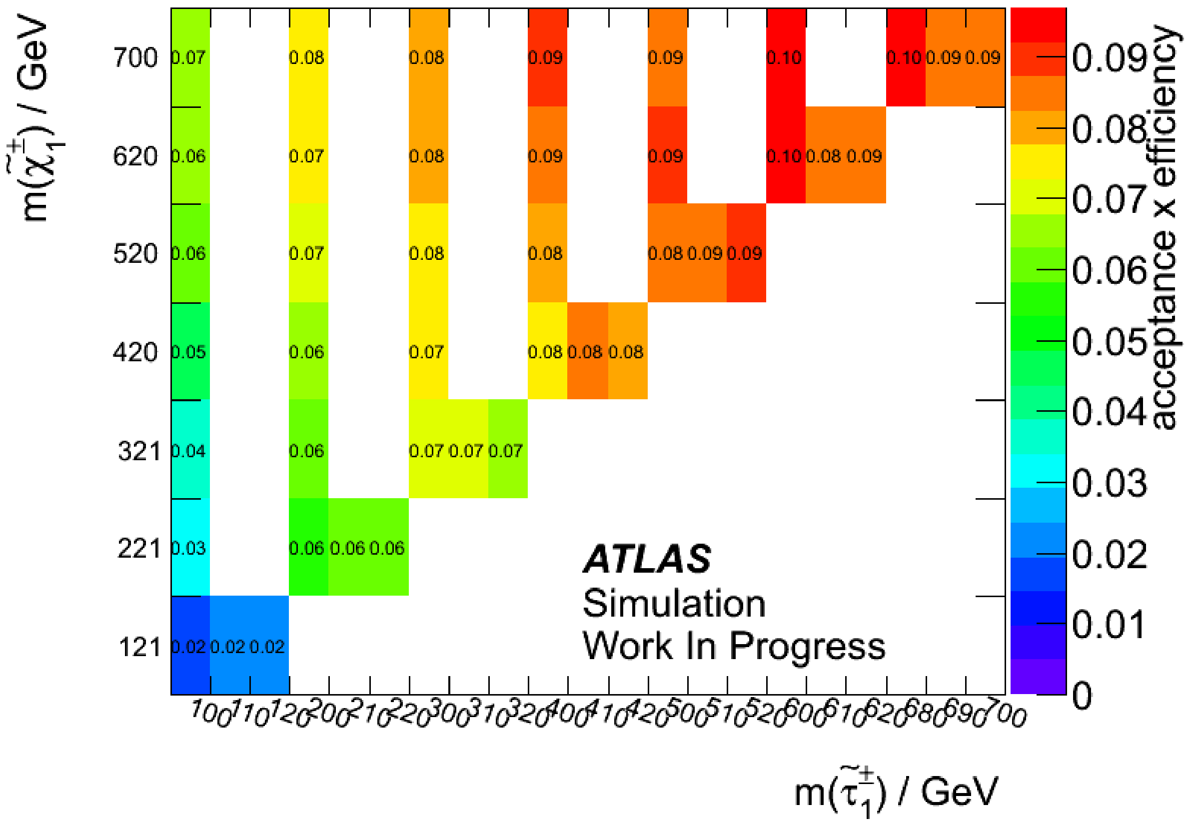
- Chargino pair production (elw.)
  - Parameters: $m\left(\tilde{\chi}_1^{\pm}\right)$, $m\left(\tilde{\tau}_1\right)$
  - Hidden parameters: chargino mixing angle $\Phi_{\mathbf{v},\mathbf{u}}$, LSP mass $m\left(\tilde{G}\right)$

$\tilde{\chi}_1$-$\tilde{\tau}_1$ grid point selection, masses in GeV							
$m_{\tilde{\chi}_1}$	121	221	321	420	520	620	700
$m_{\tilde{\tau}_1}$	100	100	100	100	100	100	100
$m_{\tilde{\tau}_1}$	110	200	200	200	200	200	200
$m_{\tilde{\tau}_1}$	120	210	300	300	300	300	300
$m_{\tilde{\tau}_1}$		220	310	400	400	400	400
$m_{\tilde{\tau}_1}$			320	410	500	500	500
$m_{\tilde{\tau}_1}$				420	510	600	600
$m_{\tilde{\tau}_1}$					520	610	680
$m_{\tilde{\tau}_1}$						620	690
$m_{\tilde{\tau}_1}$							700



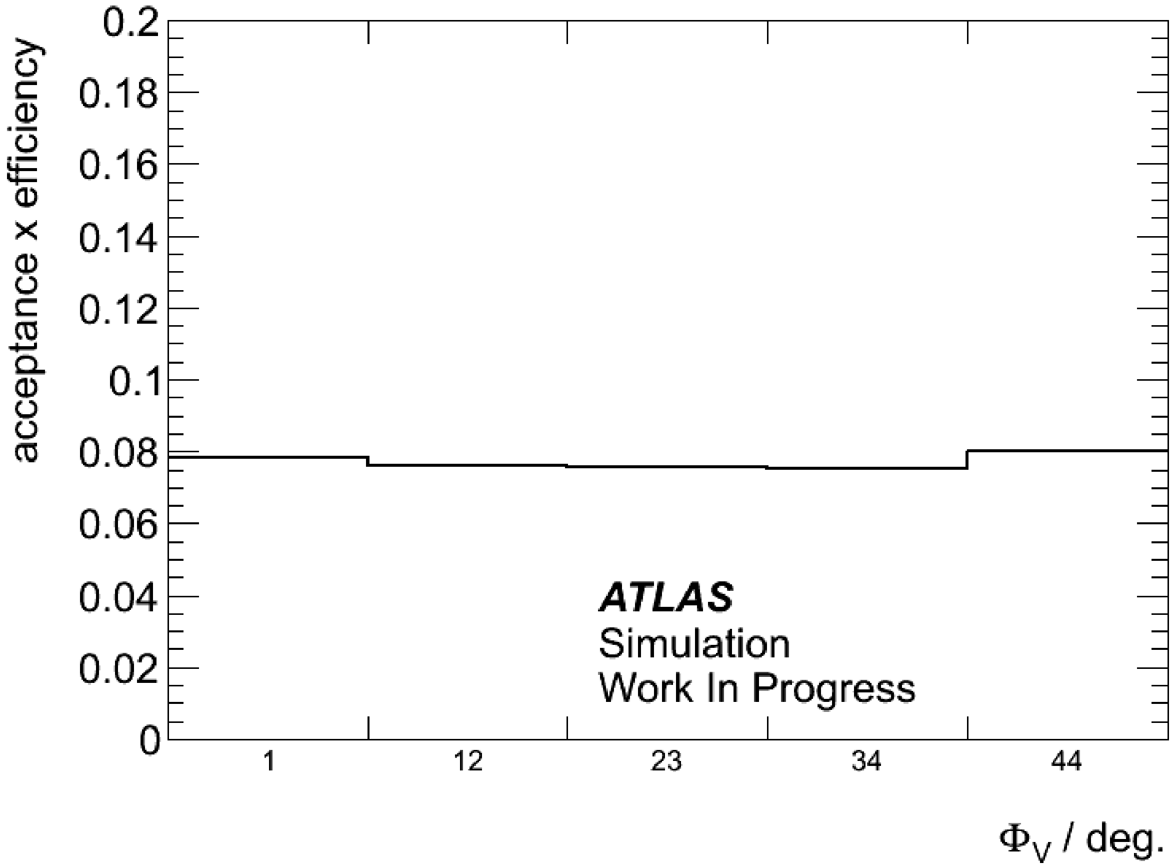
Chargino/stau grid – teaser plots

- Acceptance x efficiency for the full grid
  - Analysis of the elw. chargino pair production applied (ATLAS-CONF-2013-028)



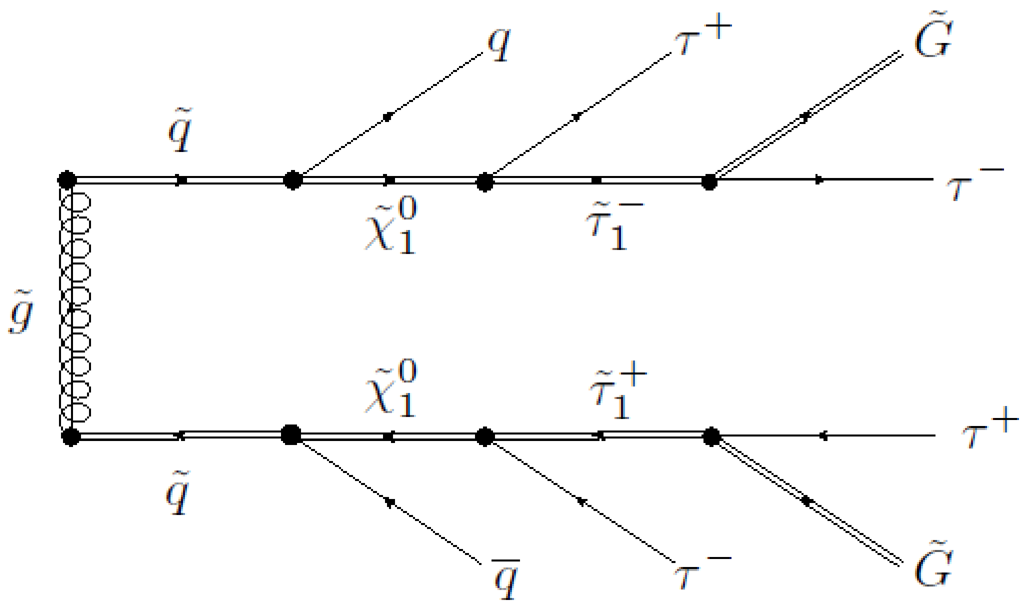
Chargino/stau grid – teaser plots

- Acceptance x efficiency for
  - $m\left(\tilde{\chi}_1^{\pm}\right) = 520\,\mathrm{GeV}$, $m\left(\tilde{\tau}_1^{\pm}\right) = 300\,\mathrm{GeV}$



Gluino/squark grid - setup

- Gluino/squark grid (strong production)
  - Still working on proper parametrisation
  - Hidden parameters: yet to be determined
  - exemplary process: $\tilde{q}_{\mathrm{L,R}} \to \tilde{\chi}_1^0 + q \to \tilde{\tau}_1^{\pm} + \tau^{\mp} + q \to \tilde{G} + \tau^{\pm} + \tau^{\mp} + q$



Open questions

- Looking for further hidden parameters for all grids that possibly affect the efficiency
  - E.g. stau mixing:
    - Effect on p_t → effect on efficiency & tauID (efficiency/fake rate)
- Looking for possible parametrisation of strong production grid
  - Which sparticle masses are needed?
  - Which hidden parameters are intereseting?

Summary & Outlook

- Simplified models with FS taus
  - Promising (stau NLSP) but challenging (taus hard to detect)
  - So far only few approaches
- Studies in Bonn
  - Elw. stau production → tau polarization effects visible!
  - Elw. chargino production → studies ongoing
  - Strong squark/gluino production → planned

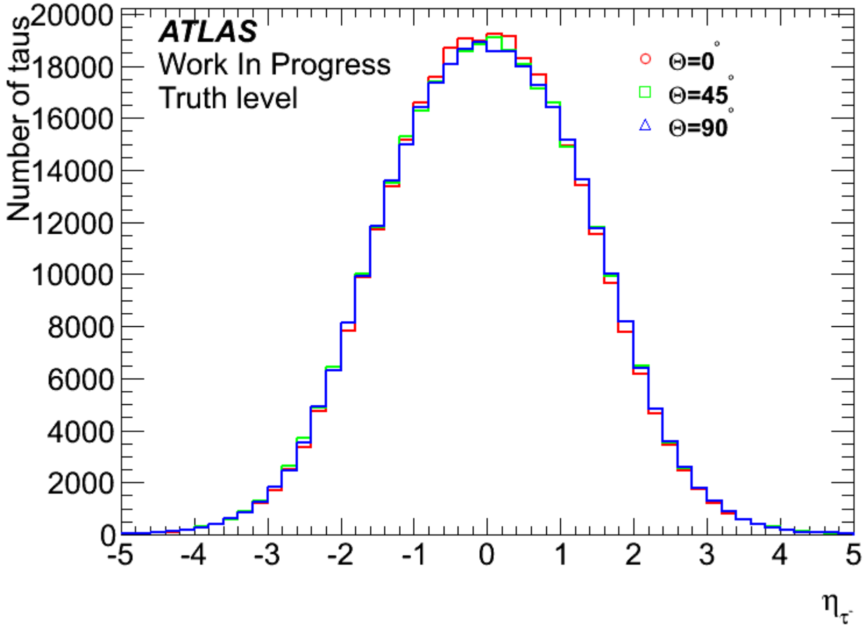
Backup – Chargino/stau selection

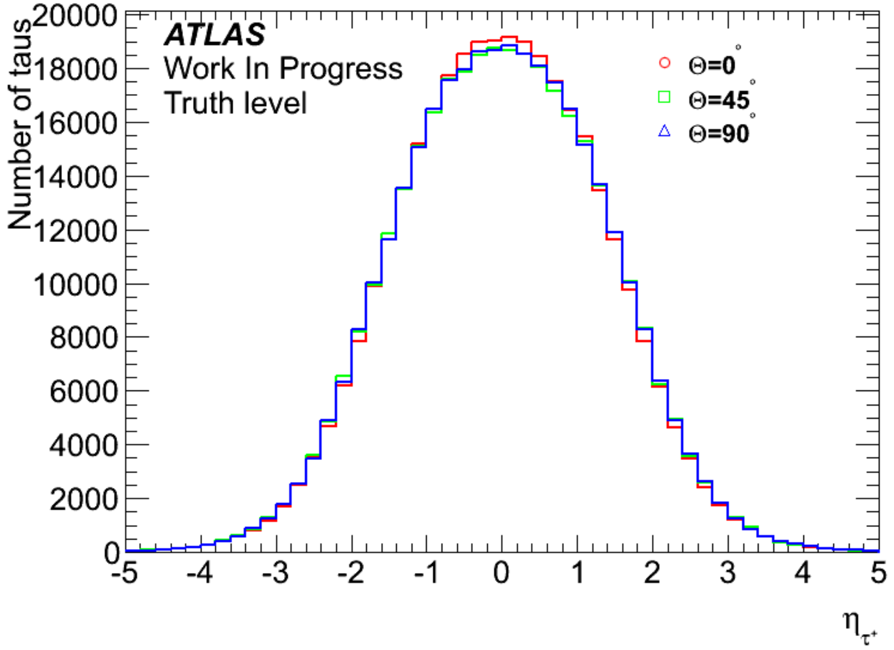
- Tau baseline selection
  - $p_t \geq 20\,\mathrm{GeV}, |\eta| < 2.5, |\mathrm{q}| = 1, 1\,\mathrm{or}\,3\,\mathrm{prong}$
  - MV technique (BDT) to distinguish from e/jet
- Overlap removal in applied order:
  - $\Delta R(e_1, e_2) \geq 0.1$, electron w/ lower energy is rejected
  - $\Delta R(e, j) \geq 0.2$, jet is rejected
  - $\Delta R(j, e) \geq 0.4$, electron is rejected
  - $\Delta R(j, \mu) \geq 0.4$, muon is rejected
  - $\Delta R(e, \mu) \geq 0.1$, muon is rejected
  - $\Delta R(\mu_1, \mu_2) \geq 0.05$, both muons are rejected
  - $m(e_1^\pm, e_2^\mp) \geq 12\,\mathrm{GeV}$, $m(\mu_1^\pm, \mu_2^\mp) \geq 12\,\mathrm{GeV}$, both particles are rejected
  - $\Delta R(e, \tau) \geq 0.2$, $\Delta R(\mu, \tau) \geq 0.2$, tau is rejected
  - $\Delta R(\tau, j) \geq 0.2$, jet is rejected
  - $m(\tau_1^\pm, \tau_2^\mp) \geq 12\,\mathrm{GeV}$, both taus are rejected

Backup – Chargino/stau selection

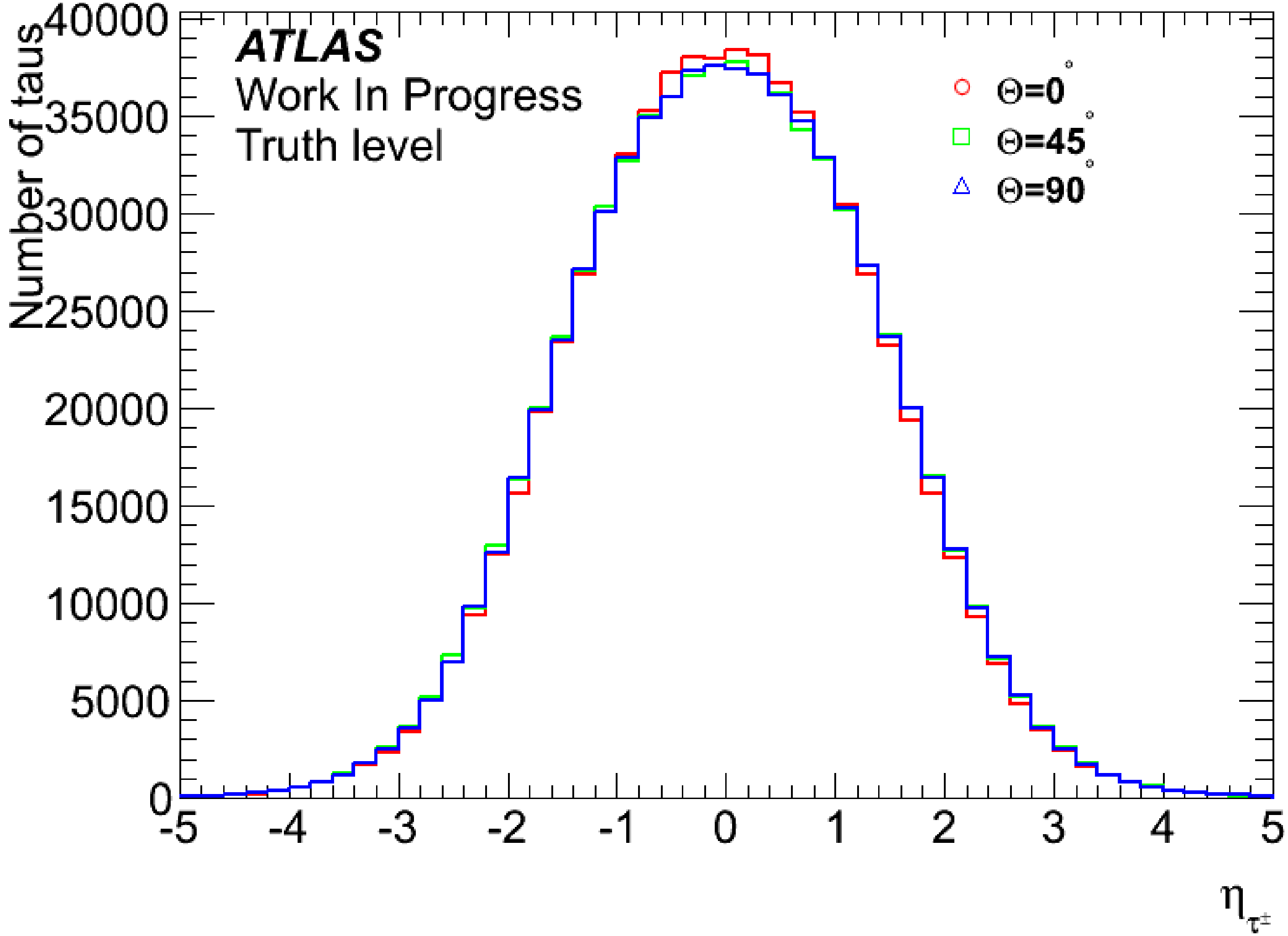
- Pile-up reweighting
- Event selection steps:
  - Event quality
  - Triggers: DiTau OR MET
  - Trigger plateau: 40 GeV + 25 GeV taus, 150 GeV MET
  - Exactely 2 OS signal taus, lepton veto

Backup – tau polarisation plots

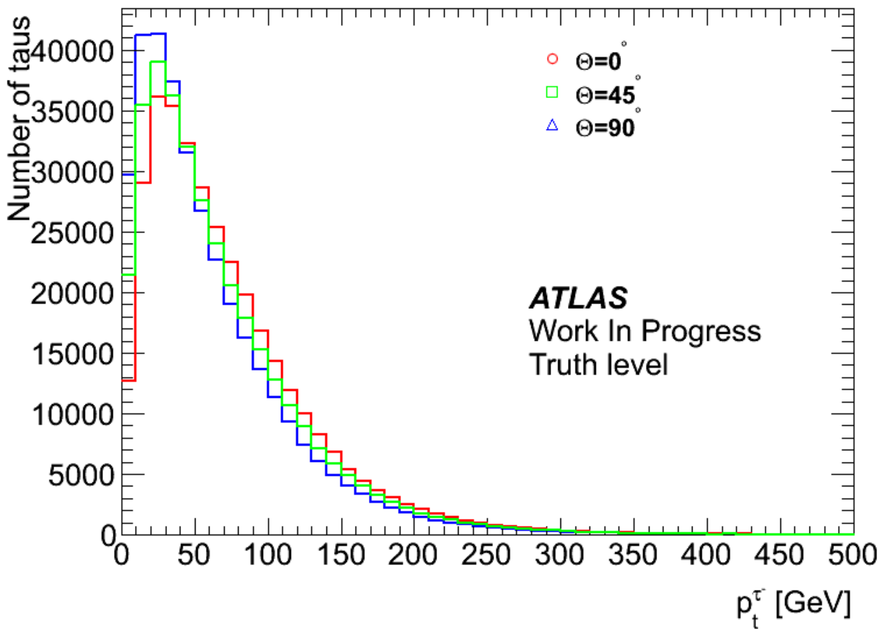


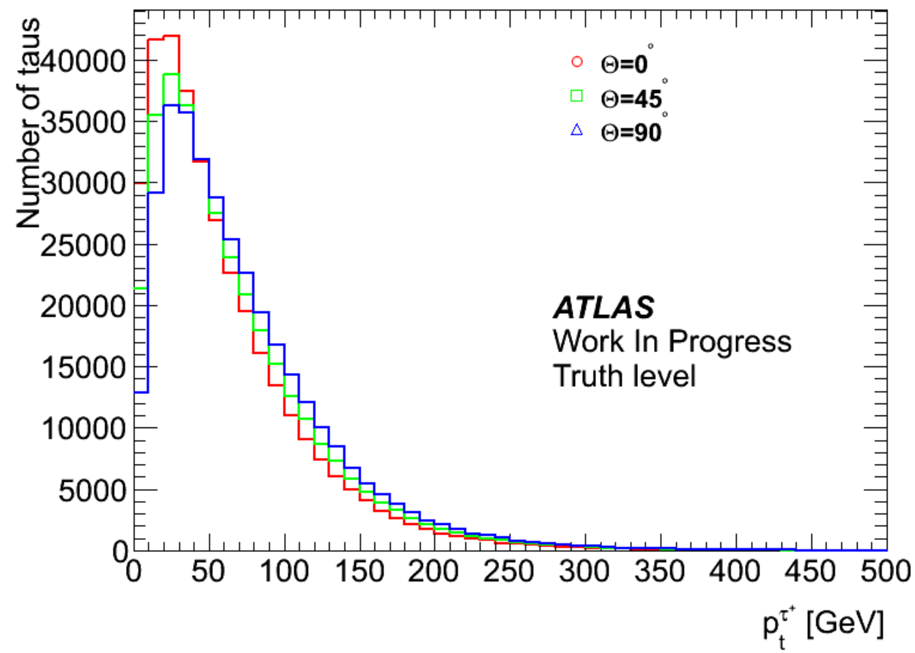


Backup – tau polarisation plots

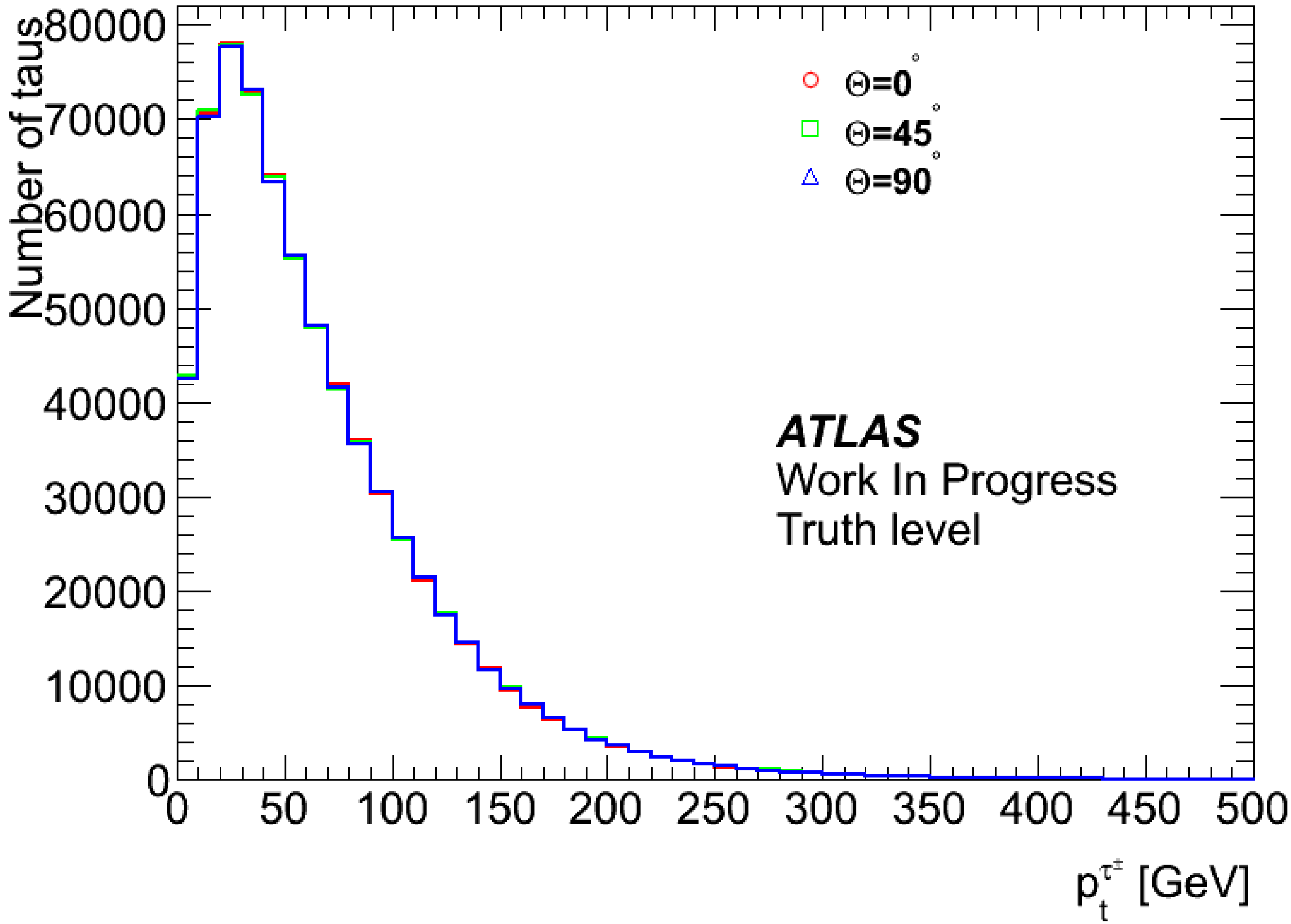


Backup – tau polarisation plots





Backup – tau polarisation plots



Backup – Susy decay chains in GMSB

Λ / TeV	$\tan(\beta)$	most abundant elw. chain	abundance	most abundant strong chain	abundance	ratio stau/slepton to $\tilde{G}$
60	2	$\tilde{l}_R \to \tilde{G}$	4824	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{G}$	719	5946/14054
60	5	$\tilde{l}_R \to \tilde{G}$	3570	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{G}$	622	6231/13569
60	10	$\tilde{l}_R \to \tilde{G}$	3416	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{G}$	54	7317/12683
60	15	$\tilde{l}_R \to \tilde{G}$	3325	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{G}$	490	8586/11414
60	20	$\tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	2863	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	397	18344/1656
60	30	$\tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	3282	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	384	19995/3
60	40	$\tilde{\tau}_1 \to \tilde{G}$	4018	$\tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	392	20000/0
60	50	$\tilde{\tau}_1 \to \tilde{G}$	8040	$\tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	367	20000/0
60	55	$\tilde{\tau}_1 \to \tilde{G}$	12137	$\tilde{g} \to \tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	217	20000/0
60	61	$\tilde{\tau}_1 \to \tilde{G}$	19414	$\tilde{g} \to \tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	21	20034/0
30	30	$\chi^+ \to \tilde{\tau}_1 \to \tilde{G}$	2130	$\tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	2246	20000/0
35	30	$\chi^+ \to \tilde{\tau}_1 \to \tilde{G}$	2198	$\tilde{g} \to \tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	1648	20000/0
40	30	$\chi^+ \to \tilde{\tau}_1 \to \tilde{G}$	2195	$\tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	1236	20000/0
45	30	$\chi^+ \to \tilde{\tau}_1 \to \tilde{G}$	2152	$\tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	932	20000/0
50	30	$\tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	2193	$\tilde{q}_R \to \chi^0 \to \tilde{\tau}_1 \to \tilde{G}$	688	20000/0
70	30	$\tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	3956	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	212	19991/9
80	30	$\tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	4664	$\tilde{q}_R \to \chi^0 \to \tilde{l}_R \to \tilde{\tau}_1 \to \tilde{G}$	94	19955/45

Simplified Models - Motivation

- Goals:
  - Make model-independent predictions
  - Set limits on visible cross section of particular susy processes
    - Acceptance x efficiency x cross section
- Determine parametrisation
  - Set of pseudo-observables (e. g. sparticle masses)
  - Keep parameter space as small as possible
- Manual for theorists:
  - Plug in parameters & determine limit
  - Multiply with branching ratio & lumi.
  - See if result is excluded