Dark Matter at the LHC

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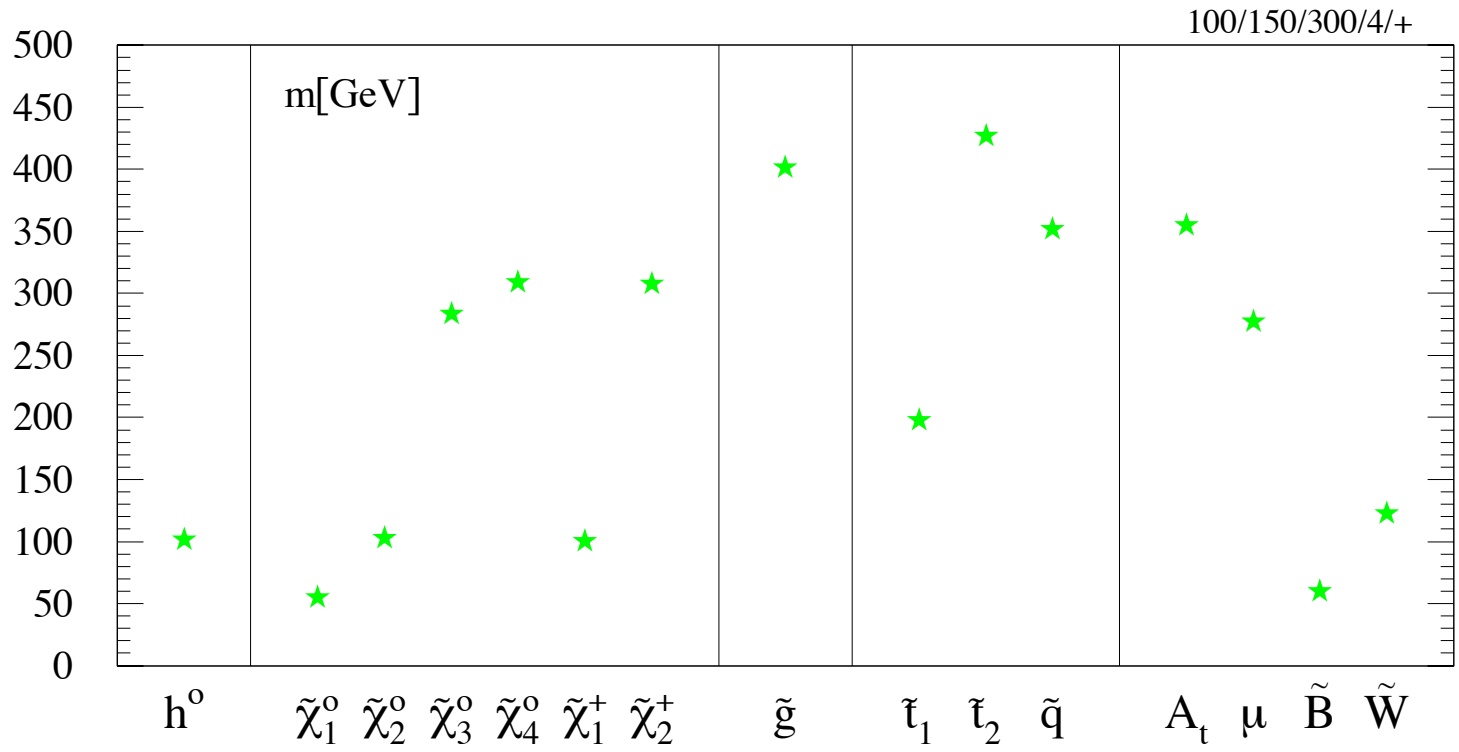
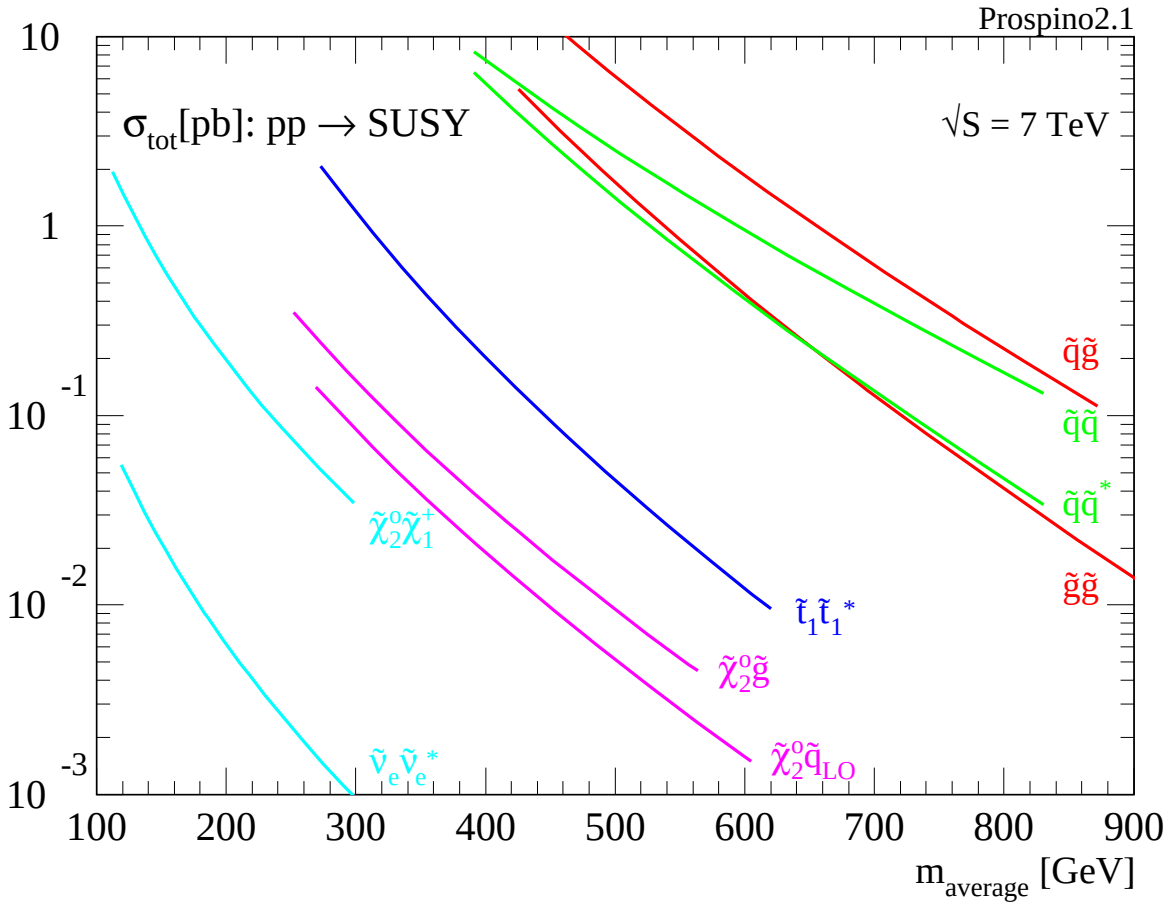
Weak-scale masses

- typical model with weakly and gravitationally interacting DM (WIMP)
- some kind of *R* parity
- light weakly interacting sector
- heavy strongly interacting sector
- simplified models



SUSY cross sections

- hadron collider processes
- parton densities
- pair production via strong coupling (Feynman diagrams)
- cascade decays (Feynman diagrams)



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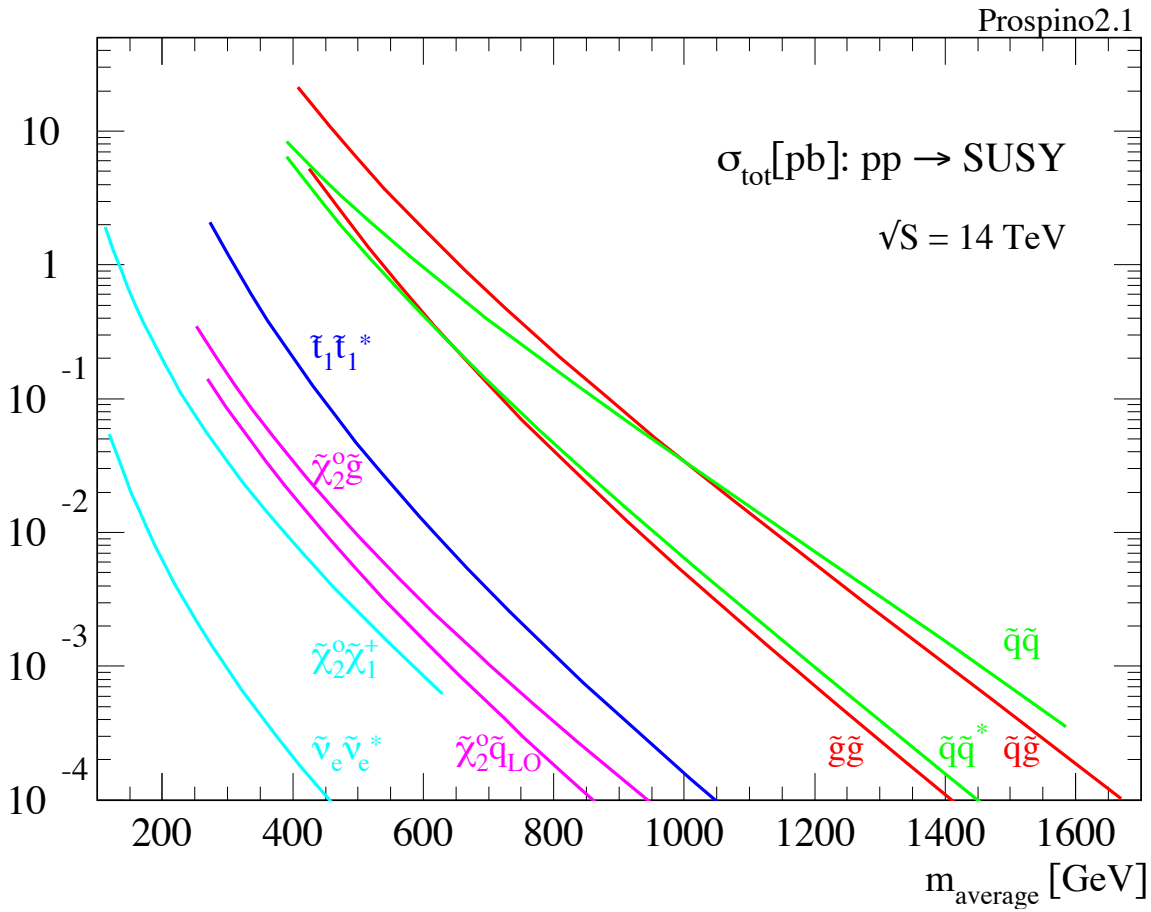
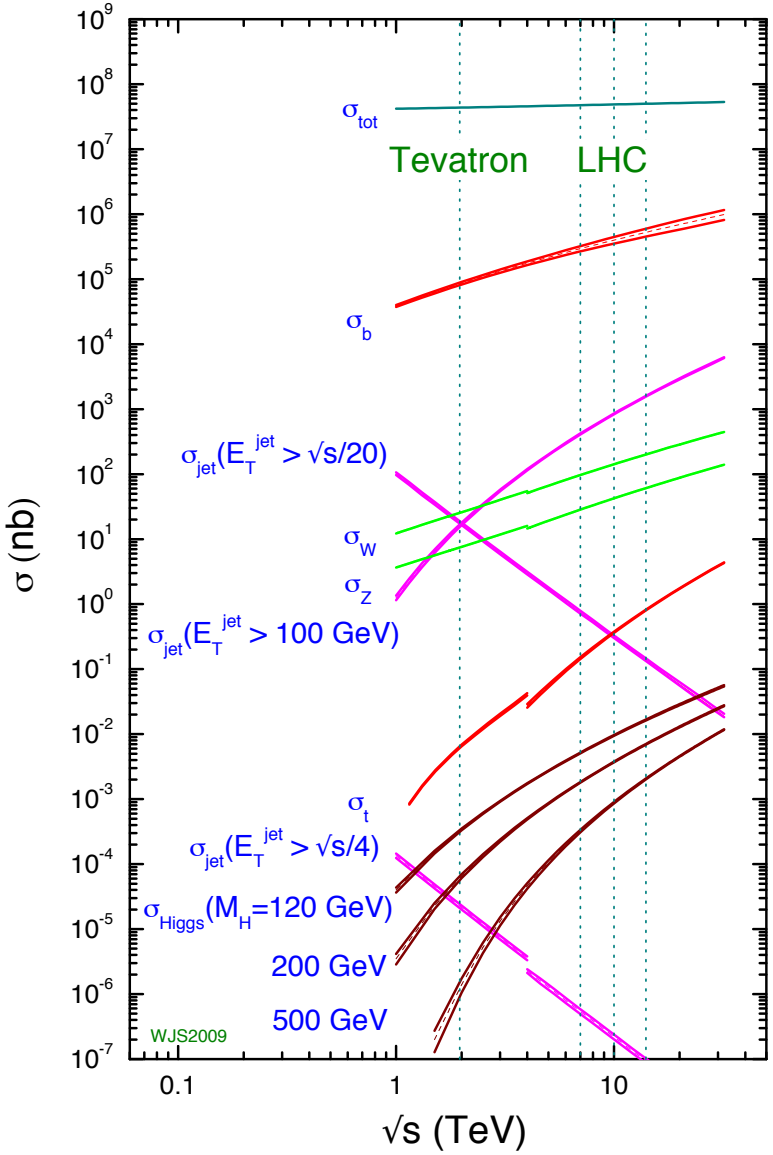


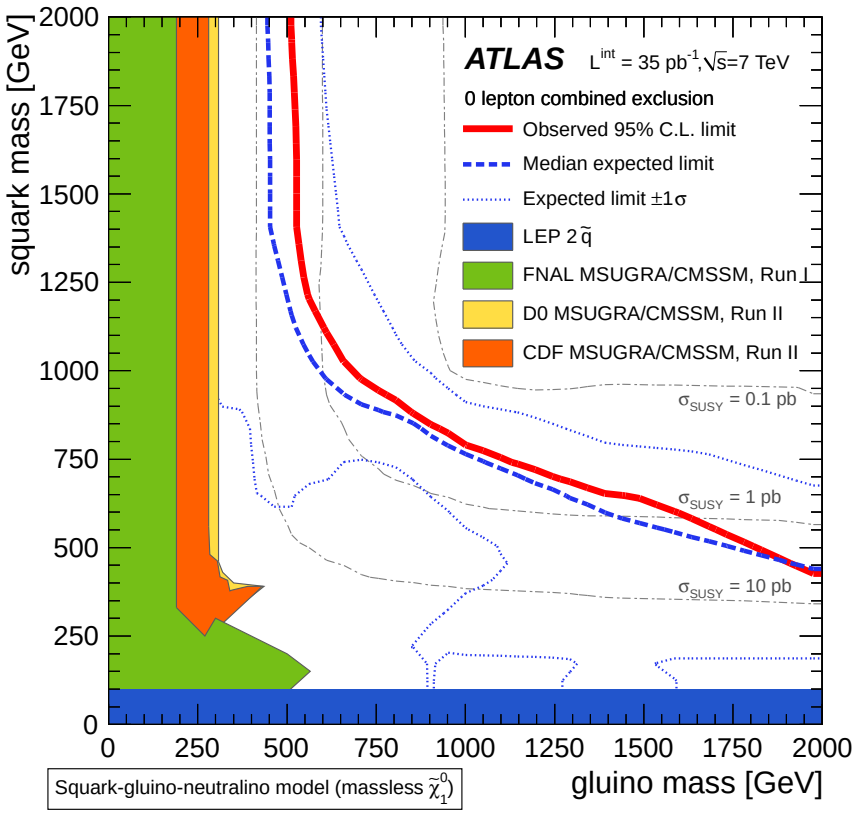
SM cross sections

- compared to $\mathcal{O}(10 - 100)$ pb for SUSY
- triggers
- background rejection: DM particle, leptons



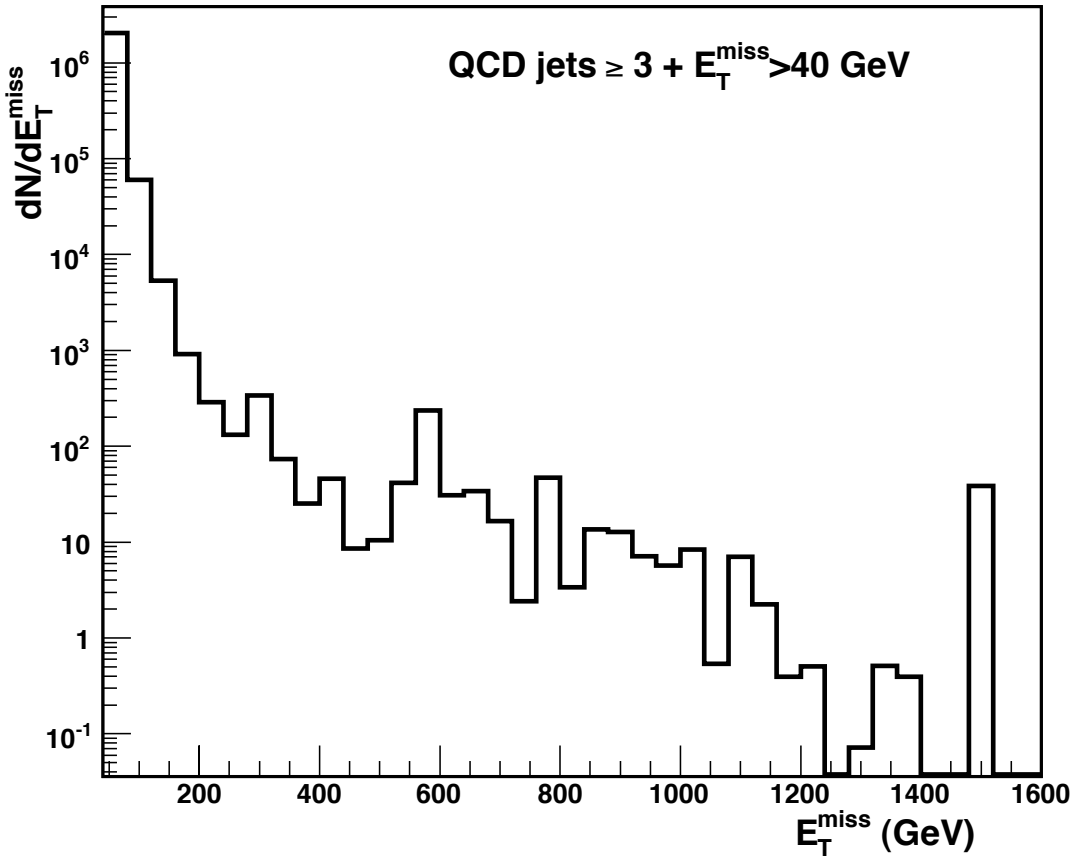
Jets plus missing energy

- missing transverse energy (kinematics)
- SUSY as role model, but analysis inclusive
- typical short/long cascades (Feynman diagrams)
- constraints in squark-gluino mass plane (mSUGRA?)
- known from Tevatron



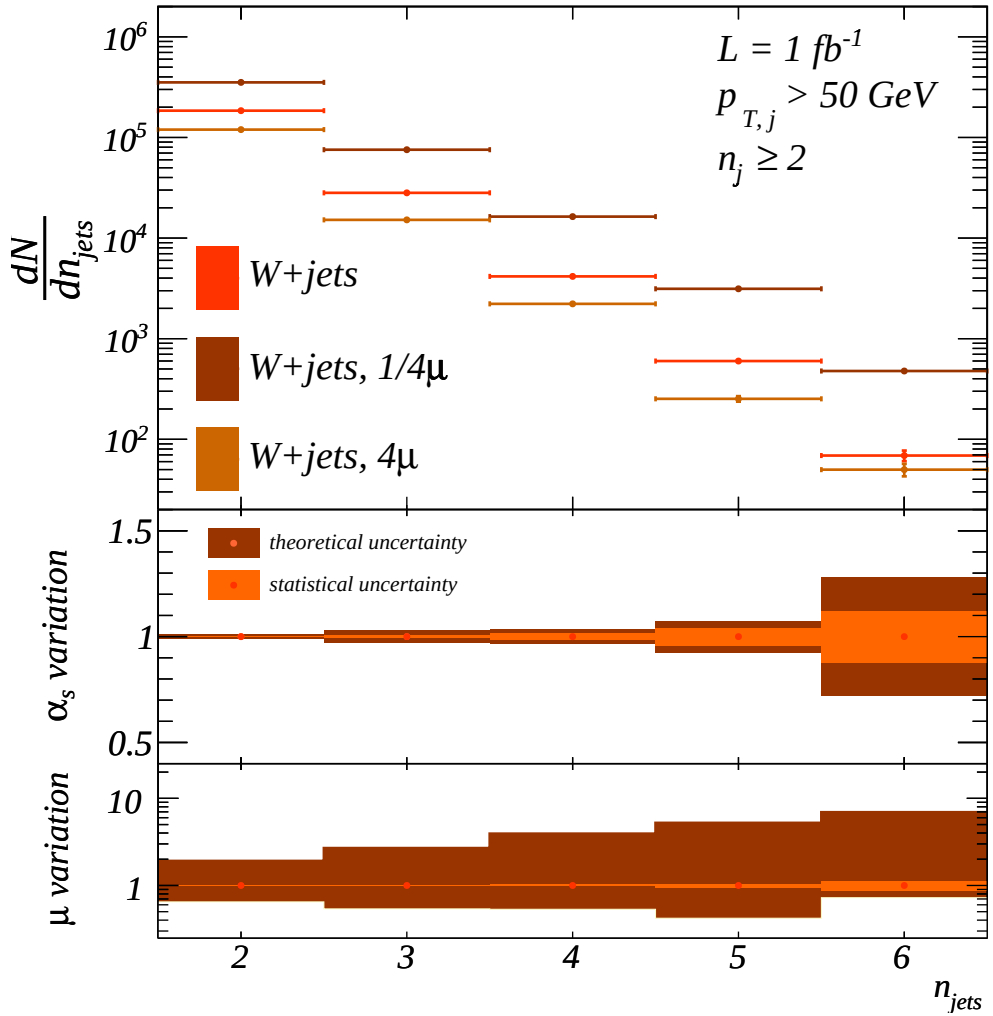
Fake missing energy

- sources of physical missing energy (W, Z, and $t\bar{t}$)
- sources of fake missing energy (list)
- 0.4% of the ATLAS calorimeter missing?



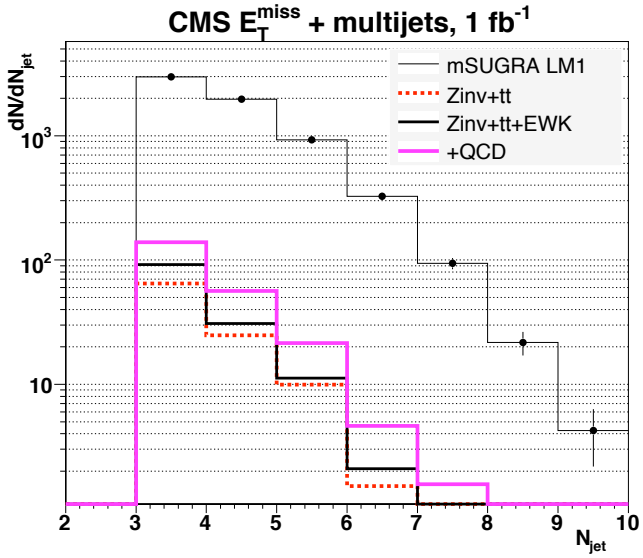
Backgrounds

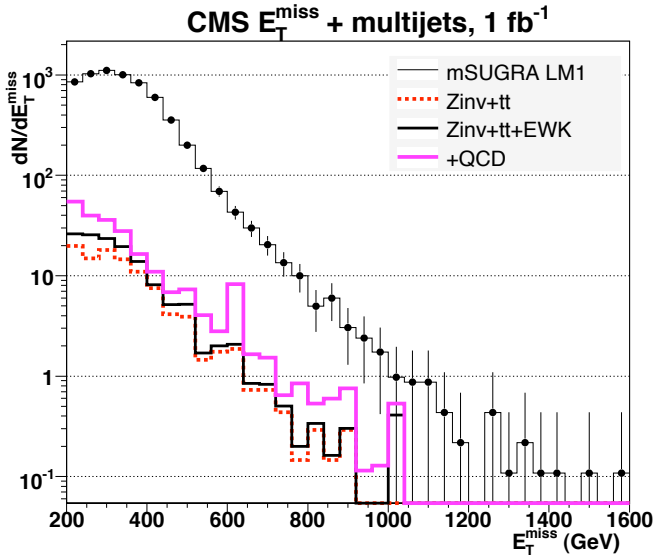
- W with jets from QCD (transverse mass)
- QED: Poisson scaling
- QCD: staircase scaling
- lepton veto against W+jets
- jet veto and lepton subtraction against top pairs
- mergers: Sherpa, Alpgen, Madevent

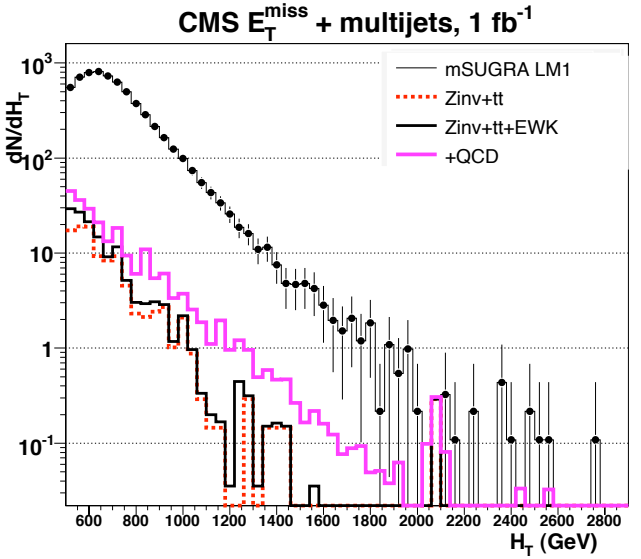


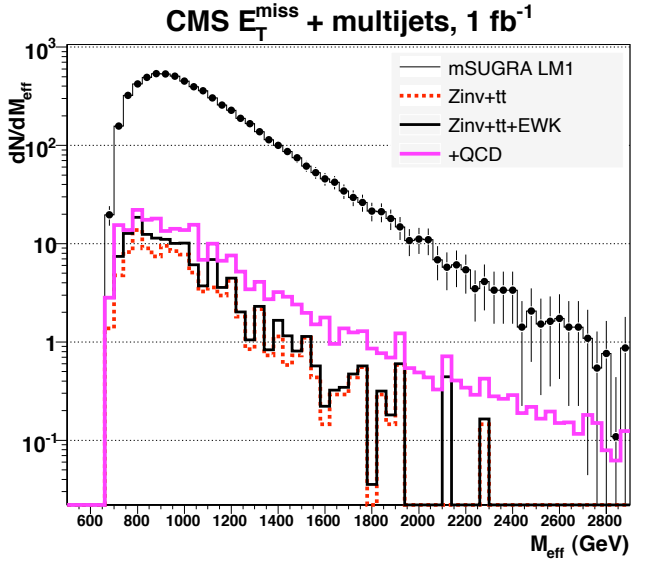
Inclusive observables

- targeted at heavy stuff in general
- scalar momentum sums (define)
- background uncertainties huge









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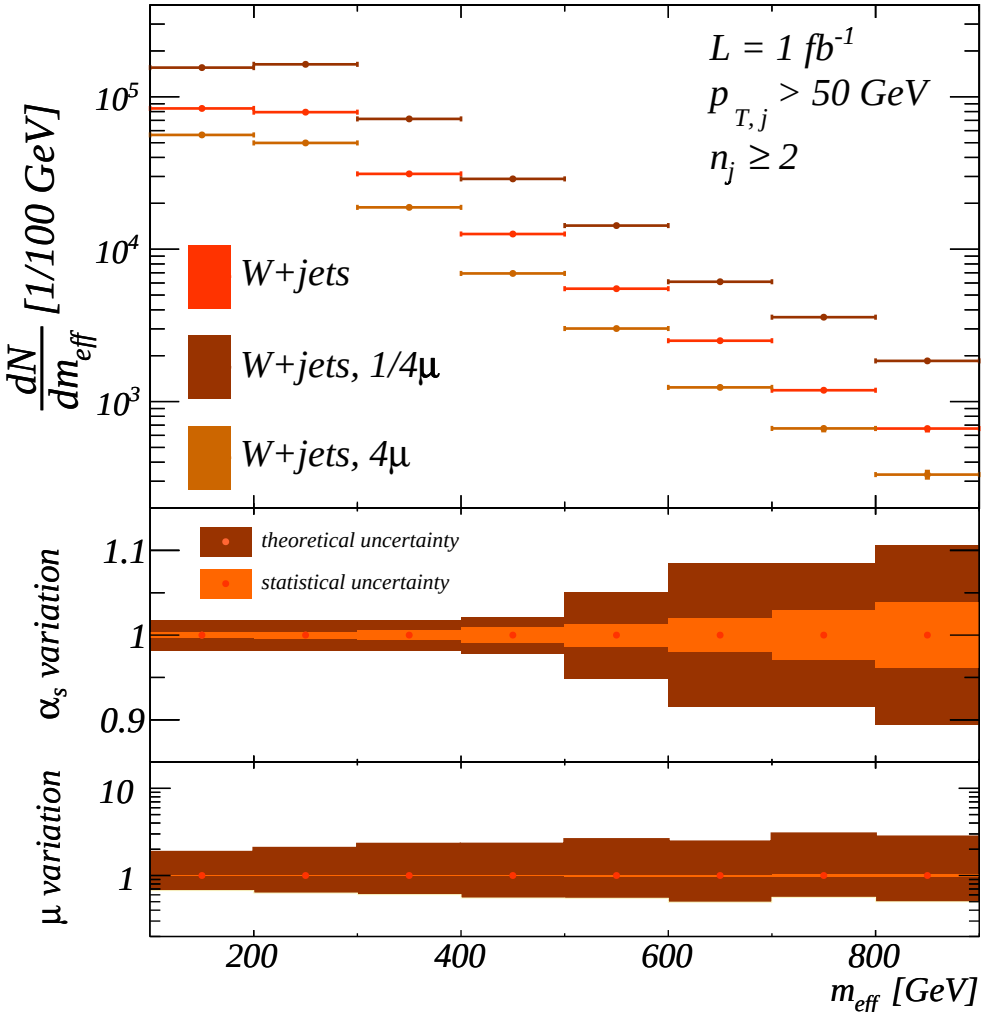
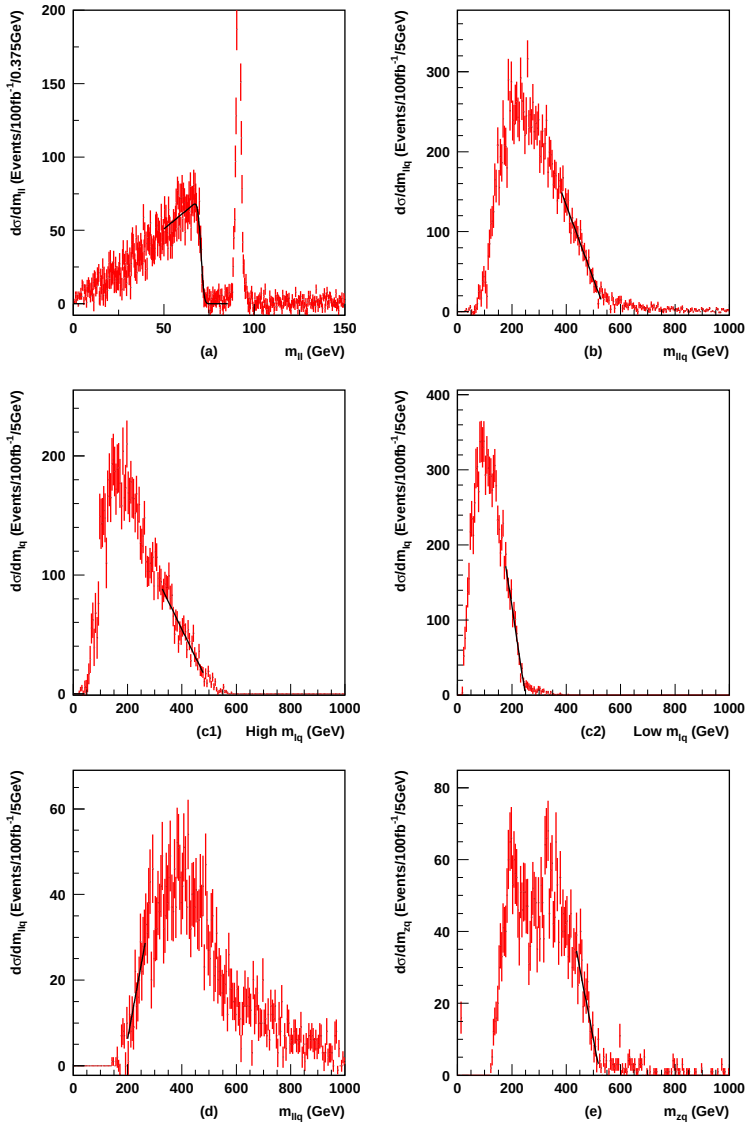


Kinematic endpoints

- no invariant mass reconstruction
- no transverse mass
- thresholds and edges in cascade decays
- lepton-lepton edge and mass-squared differences (edge)



SPS1a measurements

- systematic errors
- theory errors and higher orders
- combinatorics
- mass differences vs masses

type of measurement		nominal value	stat.	LES error	JES error	theo.
m_h		108.99	0.01	0.25		2.0
m_t		171.40	0.01		1.0	
$m_{\tilde{l}_L} - m_{\chi_1^0}$		102.45	2.3	0.1		2.2
$m_{\tilde{g}} - m_{\chi_1^0}$		511.57	2.3		6.0	18.3
$m_{\tilde{q}_R} - m_{\chi_1^0}$		446.62	10.0		4.3	16.3
$m_{\tilde{g}} - m_{\tilde{b}_1}$		88.94	1.5		1.0	24.0
$m_{\tilde{g}} - m_{\tilde{b}_2}$		62.96	2.5		0.7	24.5
$m_{ll}^{\max}$:	three-particle edge(χ_2^0,$\tilde{l}_R$,χ_1^0)	80.94	0.042	0.08		2.4
$m_{llq}^{\max}$:	three-particle edge($\tilde{q}_L$,χ_2^0,χ_1^0)	449.32	1.4		4.3	15.2
m_{lq}^{low}:	three-particle edge($\tilde{q}_L$,χ_2^0,$\tilde{l}_R$)	326.72	1.3		3.0	13.2
$m_{ll}^{\max}(\chi_4^0)$:	three-particle edge(χ_4^0,$\tilde{l}_R$,χ_1^0)	254.29	3.3	0.3		4.1
$m_{\tau\tau}^{\max}$:	three-particle edge(χ_2^0,$\tilde{\tau}_1$,χ_1^0)	83.27	5.0		0.8	2.1
m_{lq}^{high}:	four-particle edge($\tilde{q}_L$,χ_2^0,$\tilde{l}_R$,χ_1^0)	390.28	1.4		3.8	13.9
m_{llq}^{thres}:	threshold($\tilde{q}_L$,χ_2^0,$\tilde{l}_R$,χ_1^0)	216.22	2.3		2.0	8.7
m_{llb}^{thres}:	threshold($\tilde{b}_1$,χ_2^0,$\tilde{l}_R$,χ_1^0)	198.63	5.1		1.8	8.0

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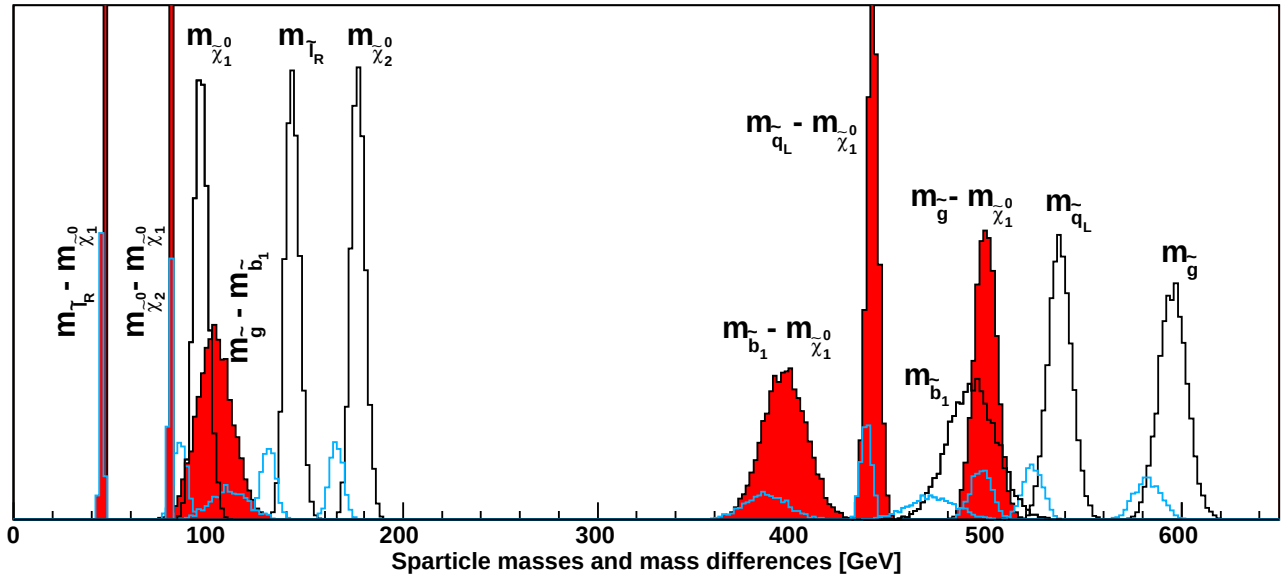
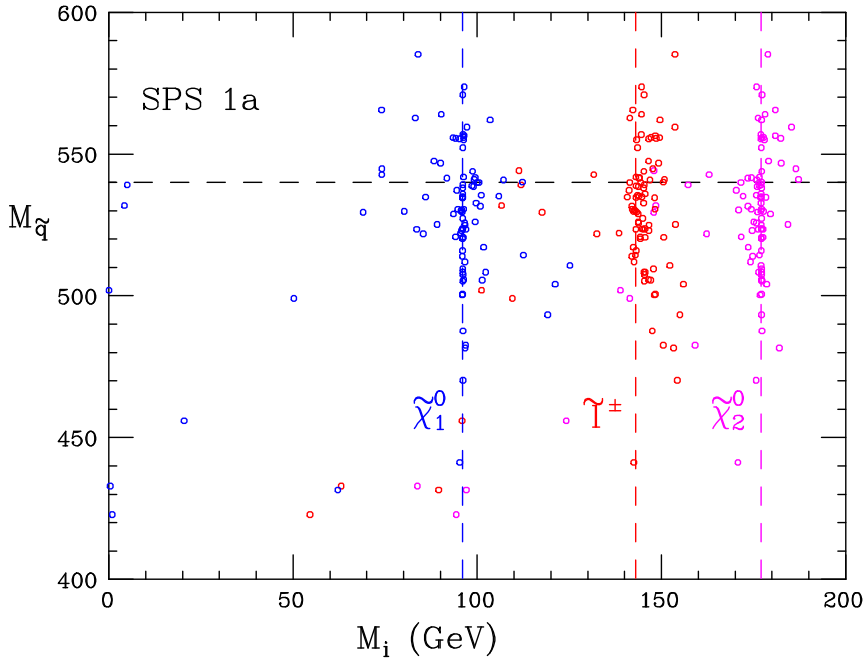


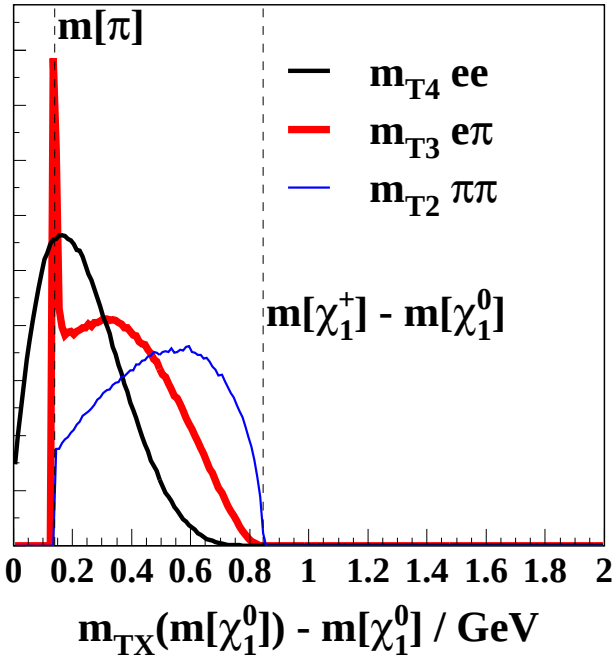
Mass relations

- endpoints only using fraction of events
- mass relation methods (set of eqs)
- backgrounds and mismeasurements

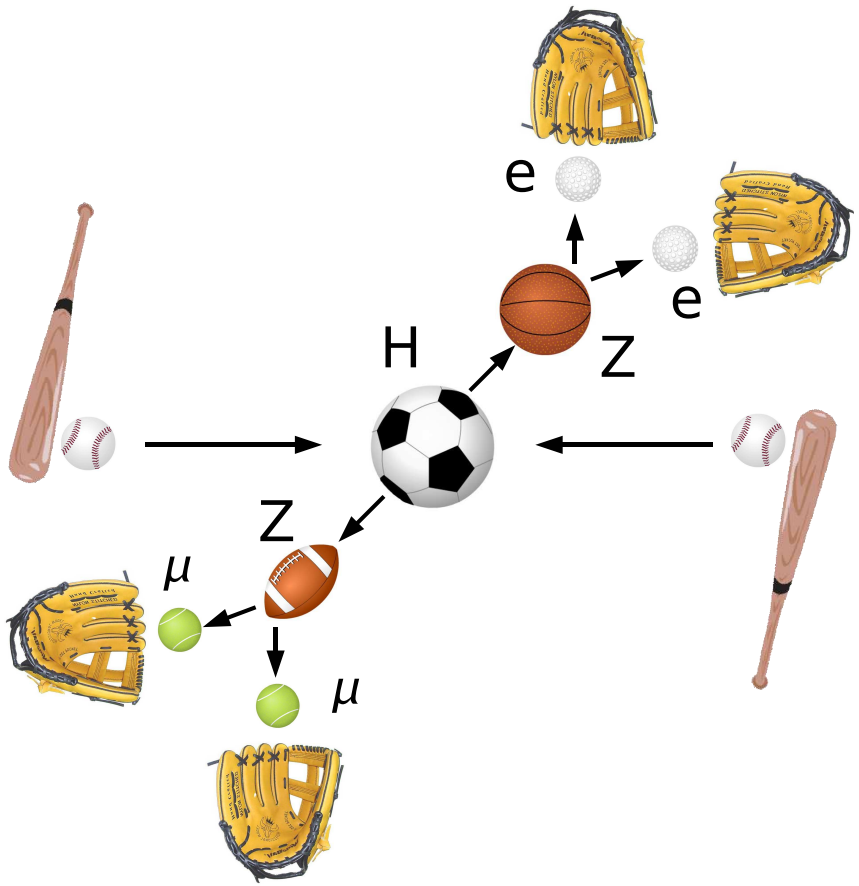


MT2 magic

- construct stransverse mass with endpoint
- pair production and direct decay (Feynman diagrams)
- m_{T2} algorithm (formula)
- Lorentz invariance

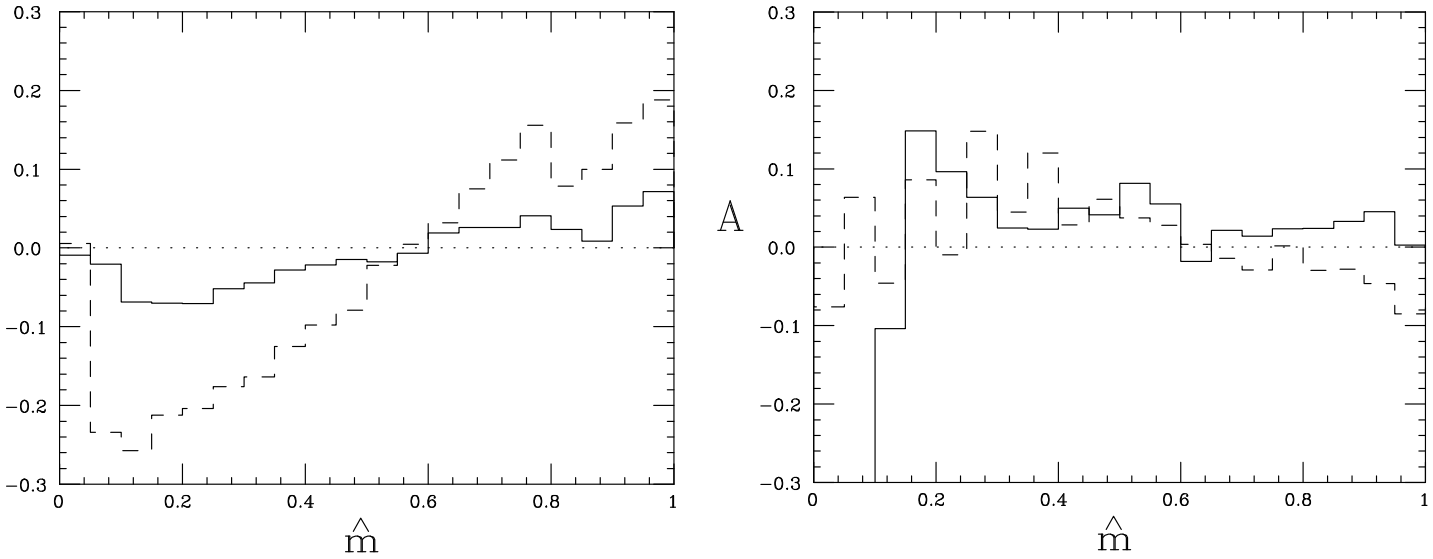


Squarks or KK quarks?



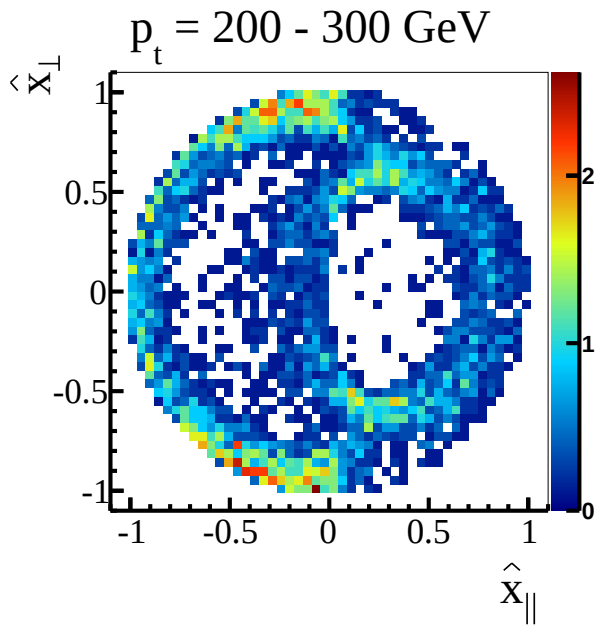
Squarks or KK quarks?

- general approach impossible
- hypothesis test: SUSY (dashed) vs UED (solid) (cascades)
- hierarchical spectrum: SPS1a



Boosted tops

- hadronic case: top tagging
- leptonic case: missing energy (neutrino) direction (Feynman diagram)
- testable in semileptonic tops



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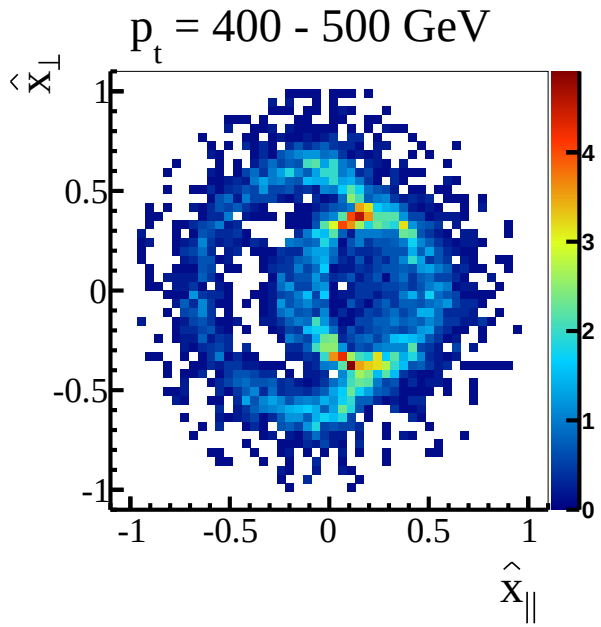

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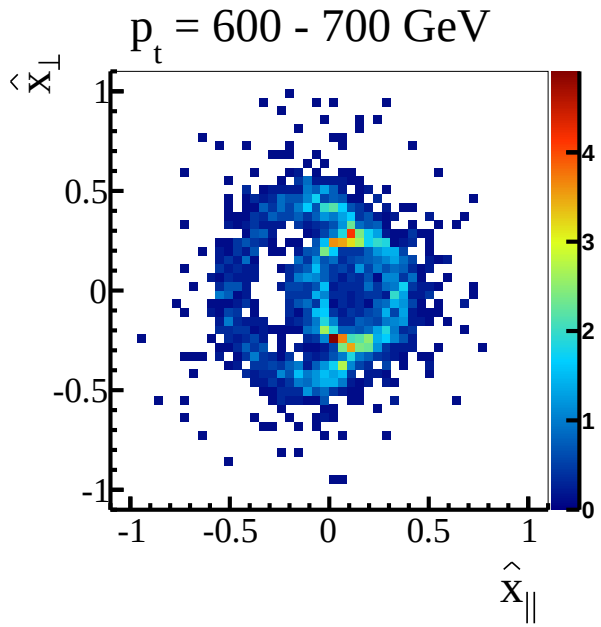

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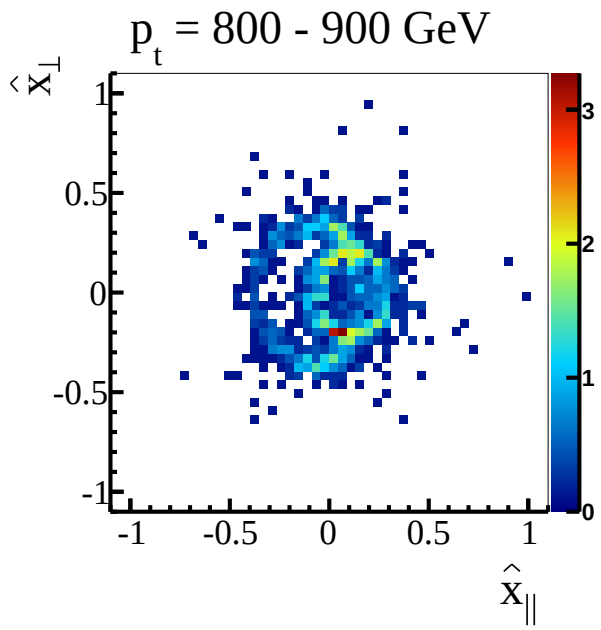

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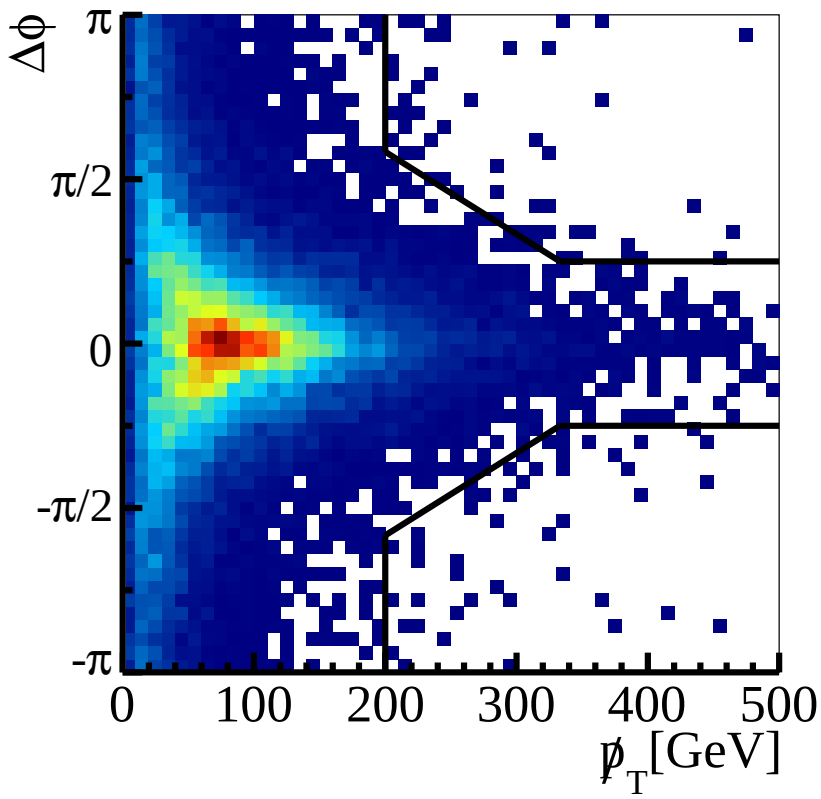
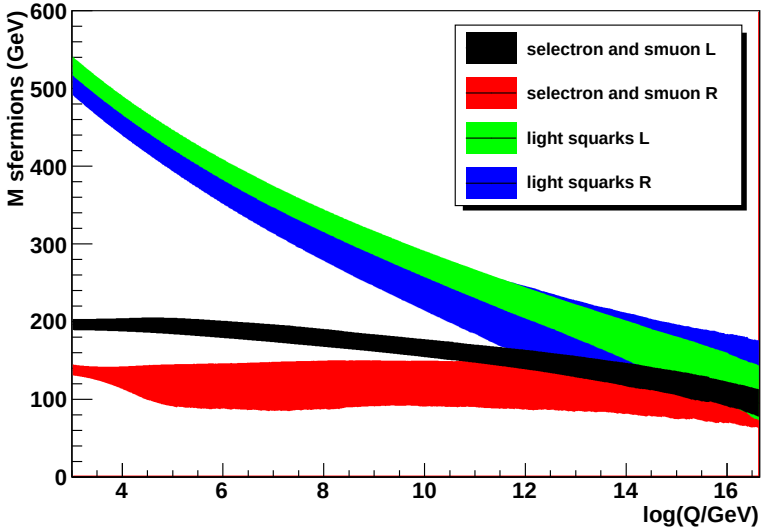
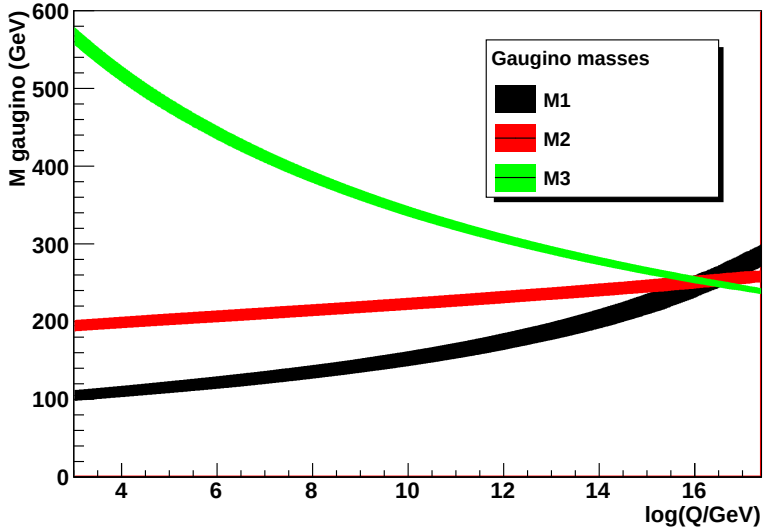


Measuring unification





tools for parameter extraction: SFitter/Suspect, Fittino/Spheno

Literature

- basic: Ian Aitchison's SUSY introduction (hep-ph/0505105)
- more advanced: Steve Martin's SUSY primer (hep-ph/9709356)
- review with David Morrissey and Tim Tait
  New Physics at the LHC (arXiv:0912.3259) [new version on my website]
- lecture notes on QCD and Higgs physics
  An LHC Lecture (arXiv:0910.4182) [new version on my website]
- many great TASI lectures...
- you'd be surprized how much of this talk happened in the last five years!