Searches for SUSY with the α_T variable

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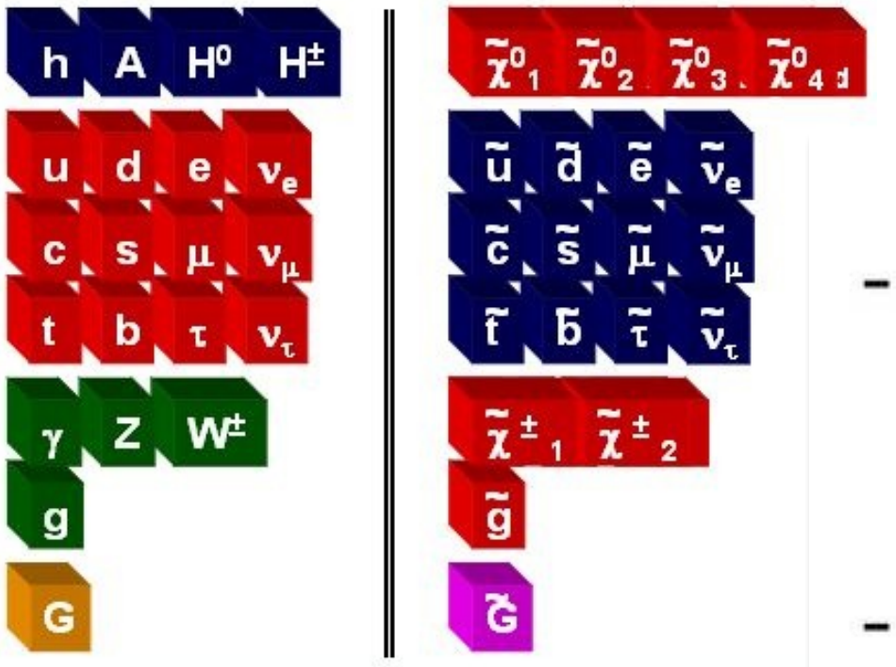
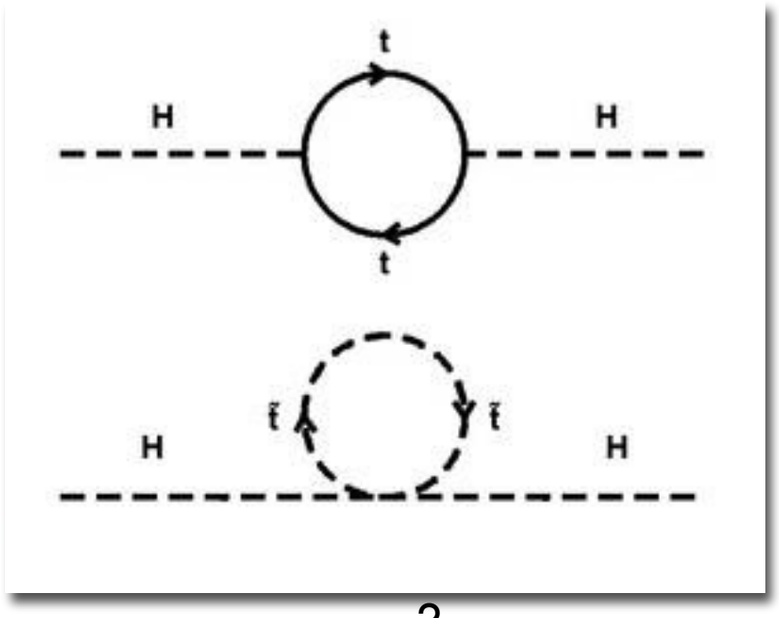
SUSY

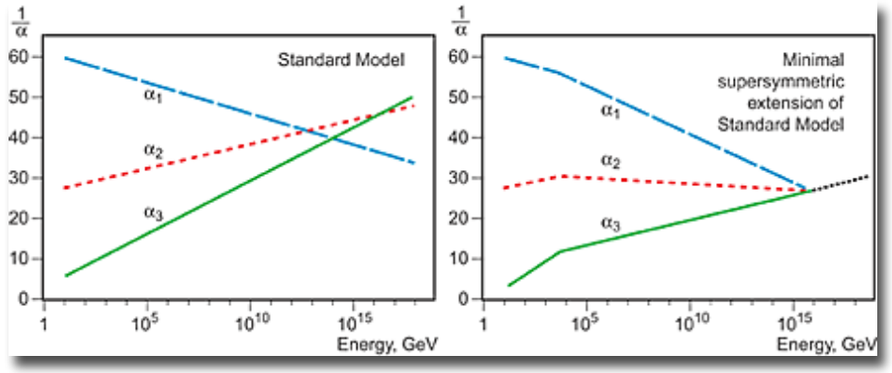
- SuperSymmetry has long since been a focus of both experimental and theoretical research towards a BSM theory
- Introduces super-partners to SM particles - differ by 1/2-spin
- R-parity conserving models provide a cold dark matter candidate
  - **Lightest SUSY particle (LSP) is stable**

$$R_p = (1)^{B+L+2s} = \begin{matrix}+1 \text{ for SM particles} \\ -1 \text{ for SUSY particles}\end{matrix}$$



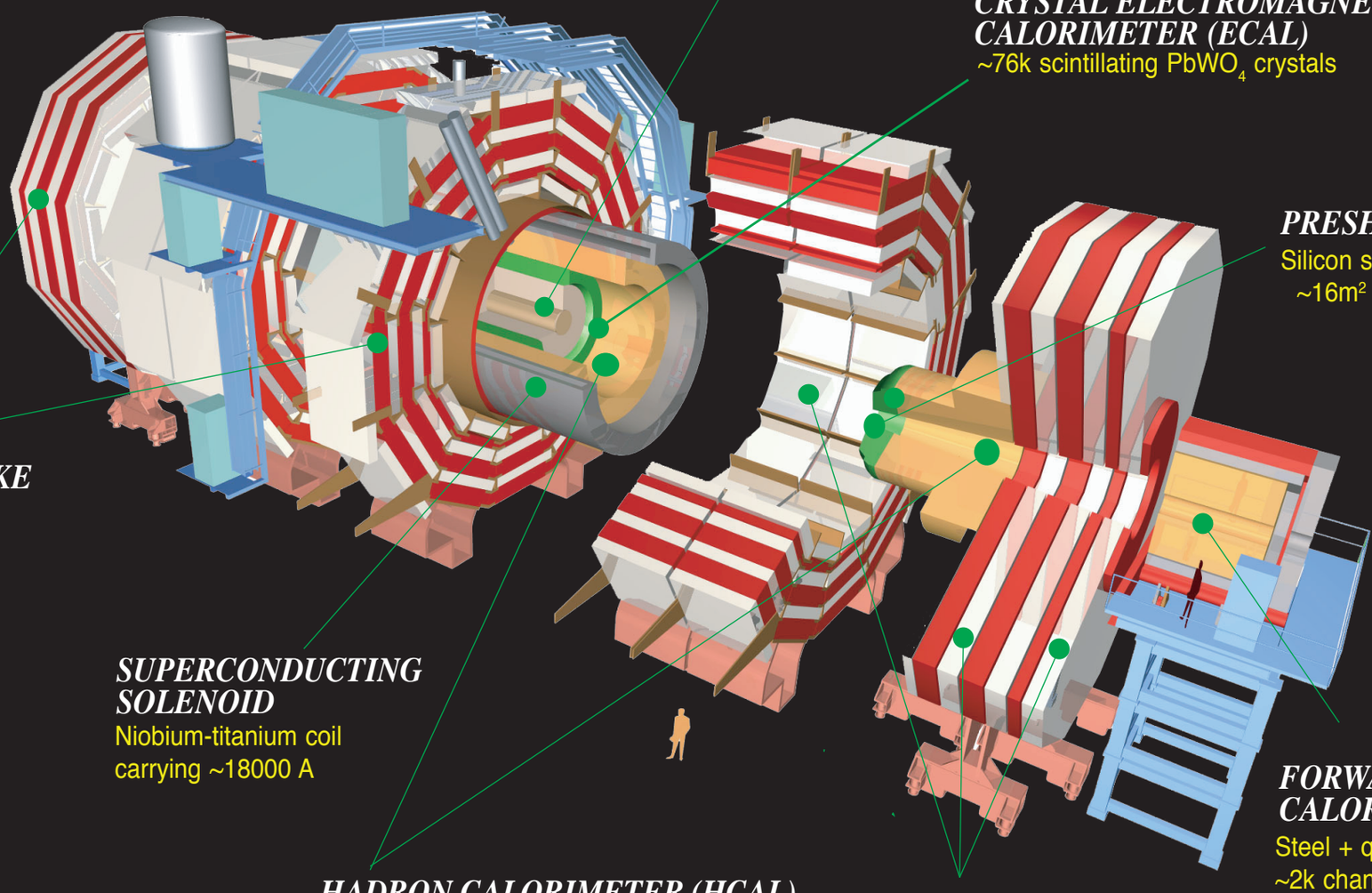
- Unification of gauge couplings
- Solution to the hierarchy problem
  - top is dominant wrt SM loop corrections, therefore stop becomes important in SUSY





CMS Apparatus

Pixels
Tracker
ECAL
HCAL
Solenoid
Steel Yoke
Muons



SILICON TRACKER
Pixels (100 x 150 μm²)
~1m² ~66M channels
Microstrips (80-180μm)
~200m² ~9.6M channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76k scintillating $PbWO_4$ crystals

PRESHOWER
Silicon strips
~16m² ~137k channels

STEEL RETURN YOKE
~13000 tonnes

SUPERCONDUCTING SOLENOID
Niobium-titanium coil
carrying ~18000 A

HADRON CALORIMETER (HCAL)
Brass + plastic scintillator
~7k channels

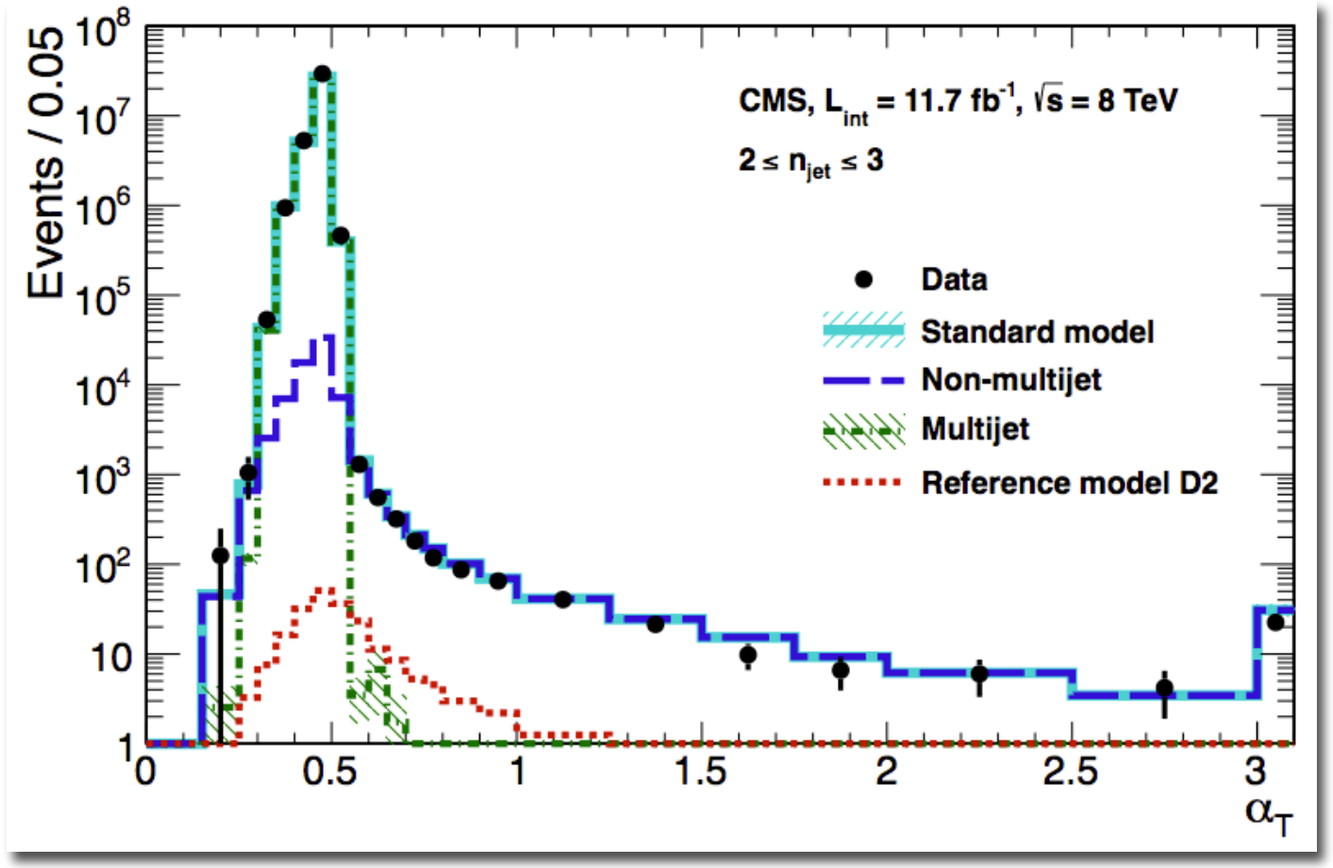
FORWARD CALORIMETER
Steel + quartz fibres
~2k channels

MUON CHAMBERS
Barrel: 250 Drift Tube & 480 Resistive Plate Chambers
Endcaps: 473 Cathode Strip & 432 Resistive Plate Chambers

Total weight : 14000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

α_T

- Target a **Jets+MET** final state
  - interested in direct production of squarks and gluinos
  - veto leptonic activity
  - *QCD is main background!*
- Dimensionless variable based on jet kinematics
- Multijet background made *negligible* by α_T requirement
  - Perfectly measured back-to-back dijet system: $\alpha_T = 0.5$
  - Mis-measured jet system - fake missing energy: $\alpha_T < 0.5$
  - Genuine missing energy: $\alpha_T > 0.5$
- Require $\alpha_T > 0.55$



Dijet system

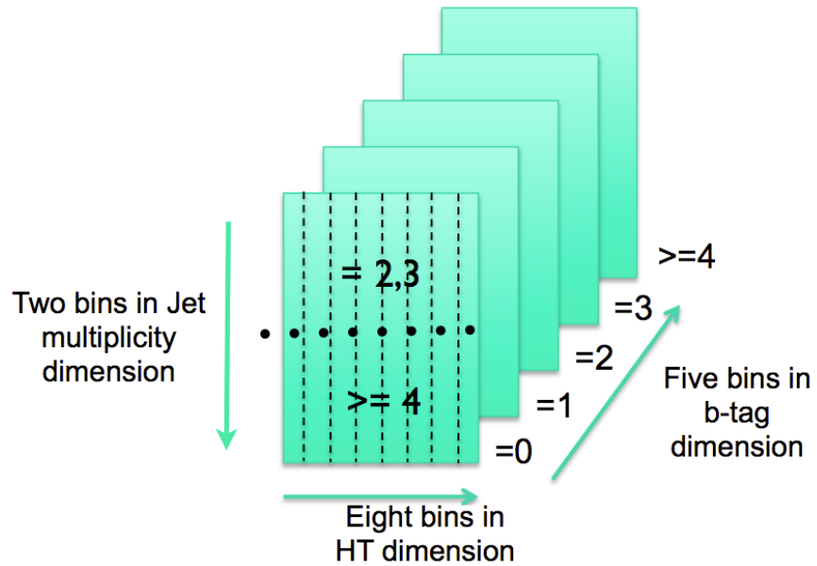
$$\alpha_T = \frac{E_T^{j2}}{M_T}$$

N-jet system

$$\alpha_T = \frac{1}{2}\frac{H_T - \Delta H_T}{\sqrt{H_T - \not{H}_T}}$$

8TeV 2012 Analysis

- Preliminary result for HCP '12 - **11.7 fb^{-1} @ 8TeV**
  - Paper in '13
- Dedicated suite of signal triggers - HT ✖ α_T
- Analysis binned in HT, jet and b-tag multiplicity
  - allows for *targeted interpretations* of specific signatures
- **Focus is on direct production of squarks and gluinos**
- Interpret within the *Simplified Model Spectra* framework
  - Assumption of **100% BR** to a given final state
  - Moves away from model-specific to signature-specific interpretations



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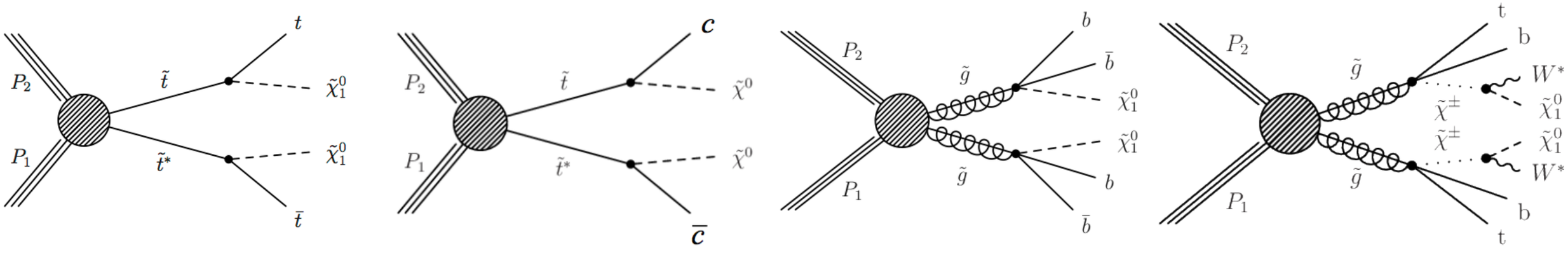


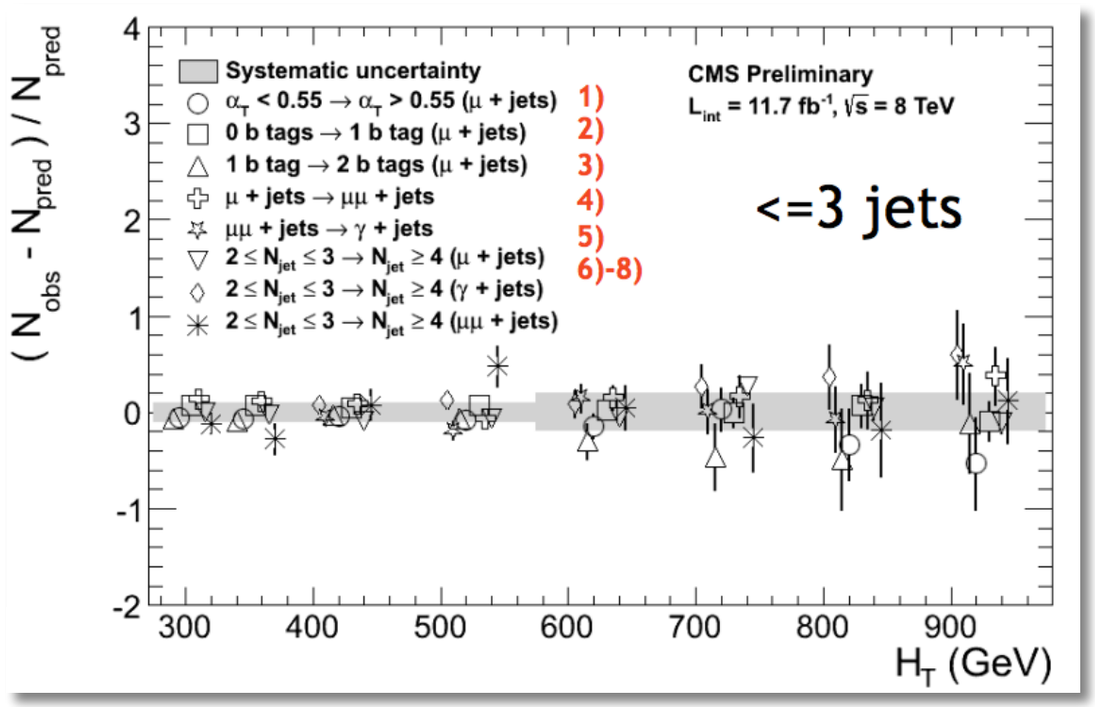
Backgrounds

- Dominant backgrounds from electroweak sources of genuine missing energy.
- Define kinematically similar, independent process enriched control samples:
  - Single Photon: Z→νν+jets
  - Single Muon: W→lν + jets, tt + jets
  - Double Muon: Z→νν+jets
- Estimate contribution in signal region by extrapolation via transfer factors
  - Potential biases (e.g. PU effects, MC mis-modelling etc) cancel in ratio, minimising dependence on MC samples

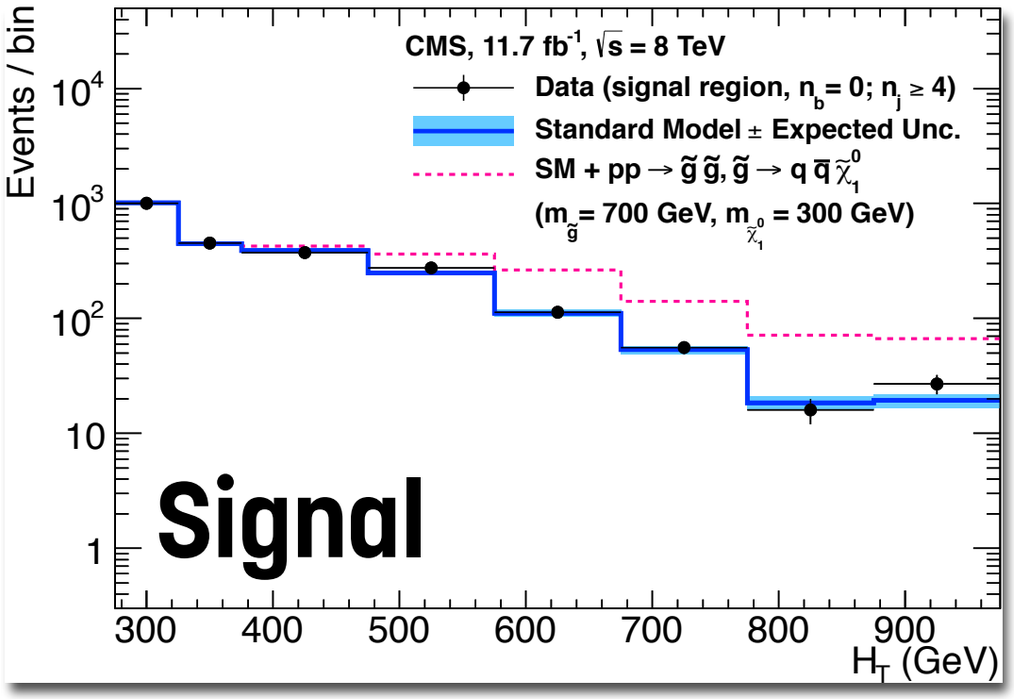
$$N_{pred}^{signal} = N_{data}^{control} \times \frac{N_{MC}^{signal}}{N_{MC}^{control}}$$

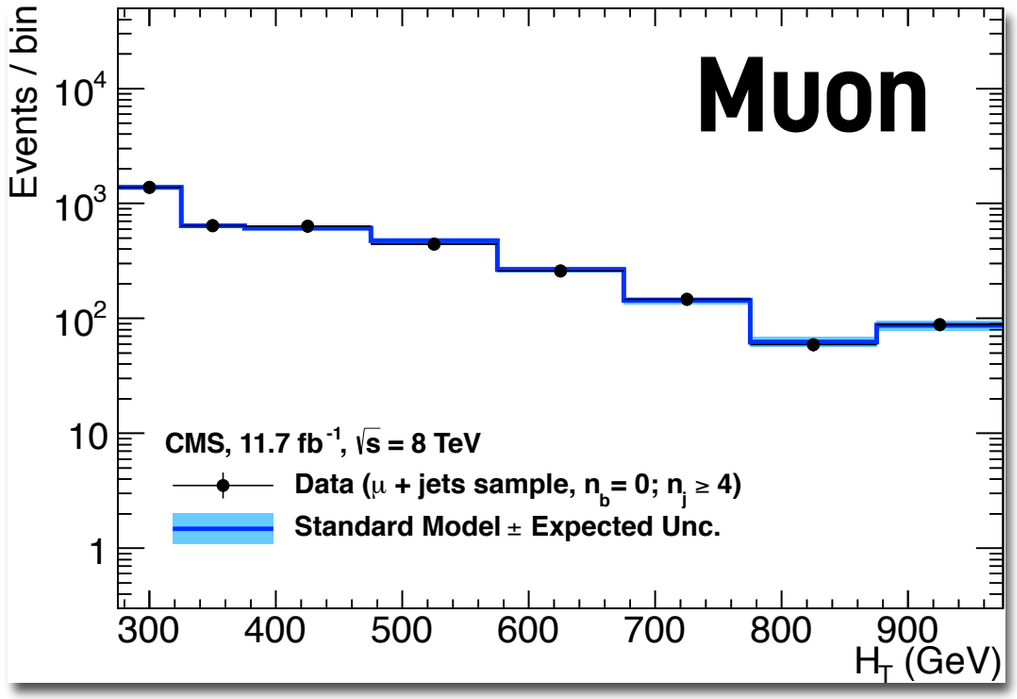
- Use a set of statistically powerful closure tests to assess control sample modelling
  - Predict between different areas of the various control samples - gives confidence in both techniques used and the control samples
  - Use to determine HT-dependent systematics

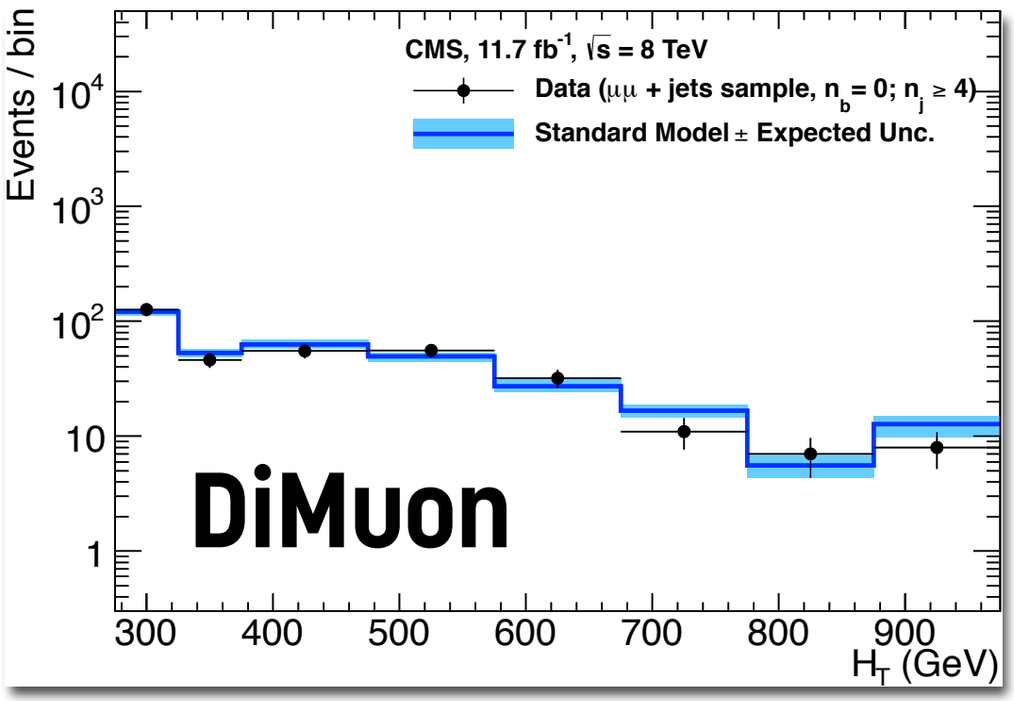
1. α_T Distribution in generic MET events
2. relative composition of ttbar and W+Jets
3. b-jet reconstruction
4. relative contribution of Z+Jets and W/ttbar
5. consistency between mumu+jets and g+jets
6. jet multiplicity closure between control samples
7. jet multiplicity closure between control samples
8. jet multiplicity closure between control samples

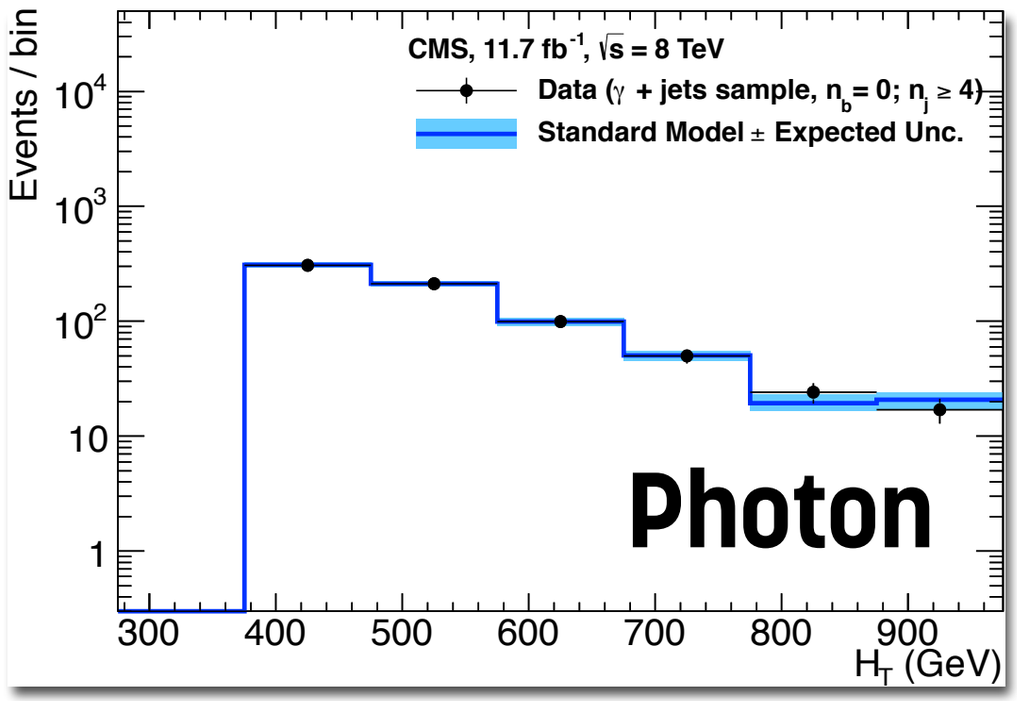


Results


CMS, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (signal region, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
SM + pp → $\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}\tilde{\chi}_1^0$
($m_{\tilde{g}}$ = 700 GeV, $m_{\tilde{\chi}_1^0}$ = 300 GeV)
Signal
Events / bin
H_T (GeV)


Muon
CMS, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (μ + jets sample, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
Events / bin
H_T (GeV)

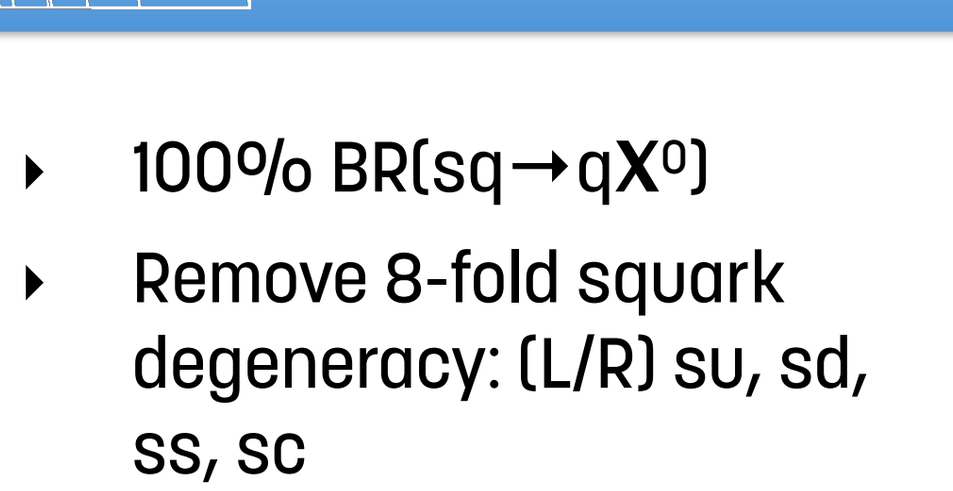

CMS, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (μμ + jets sample, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
DiMuon
Events / bin
H_T (GeV)


CMS, 11.7 fb^{-1}, $\sqrt{s}$ = 8 TeV
Data (γ + jets sample, $n_b = 0$; $n_j \geq 4$)
Standard Model ± Expected Unc.
Photon
Events / bin
H_T (GeV)

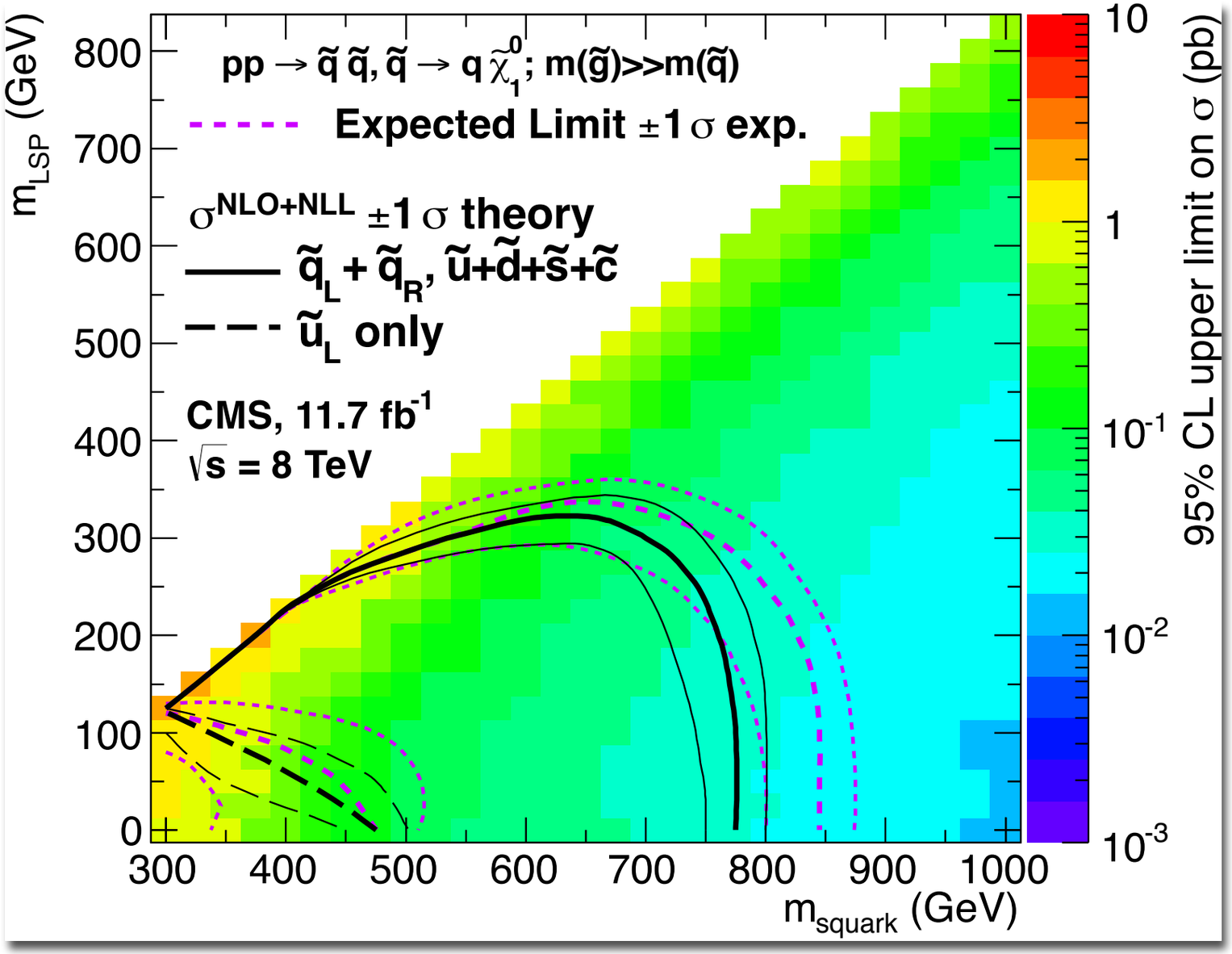
Interpretations
Direct Squark production

- 100% BR(sq→qX⁰)
- Remove 8-fold squark degeneracy: (L/R) su, sd, ss, sc
  - Single squark/chirality limit shows we still haven't touched a significant region of phase space

$N_{jet} \leq 3$ $N_b = 0$

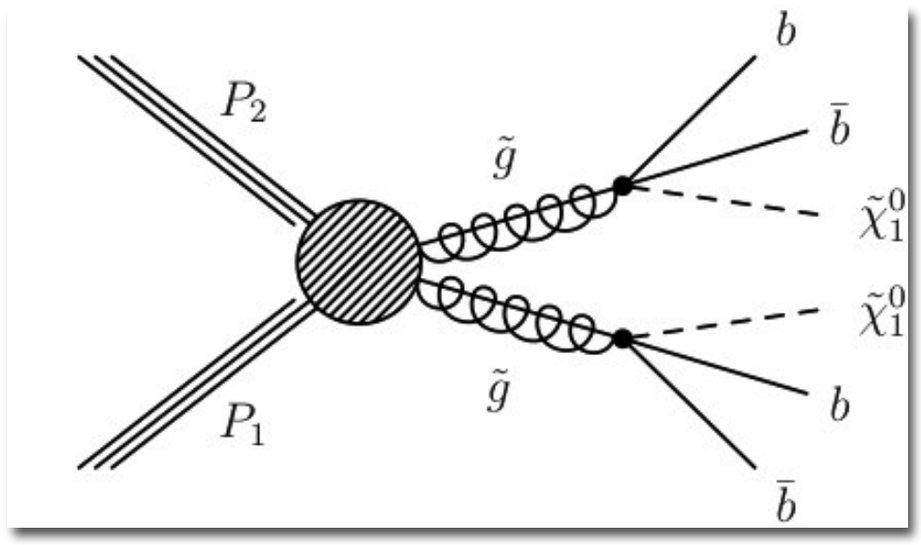


Motivated by:
http://arxiv.org/abs/1212.3328



Interpretations

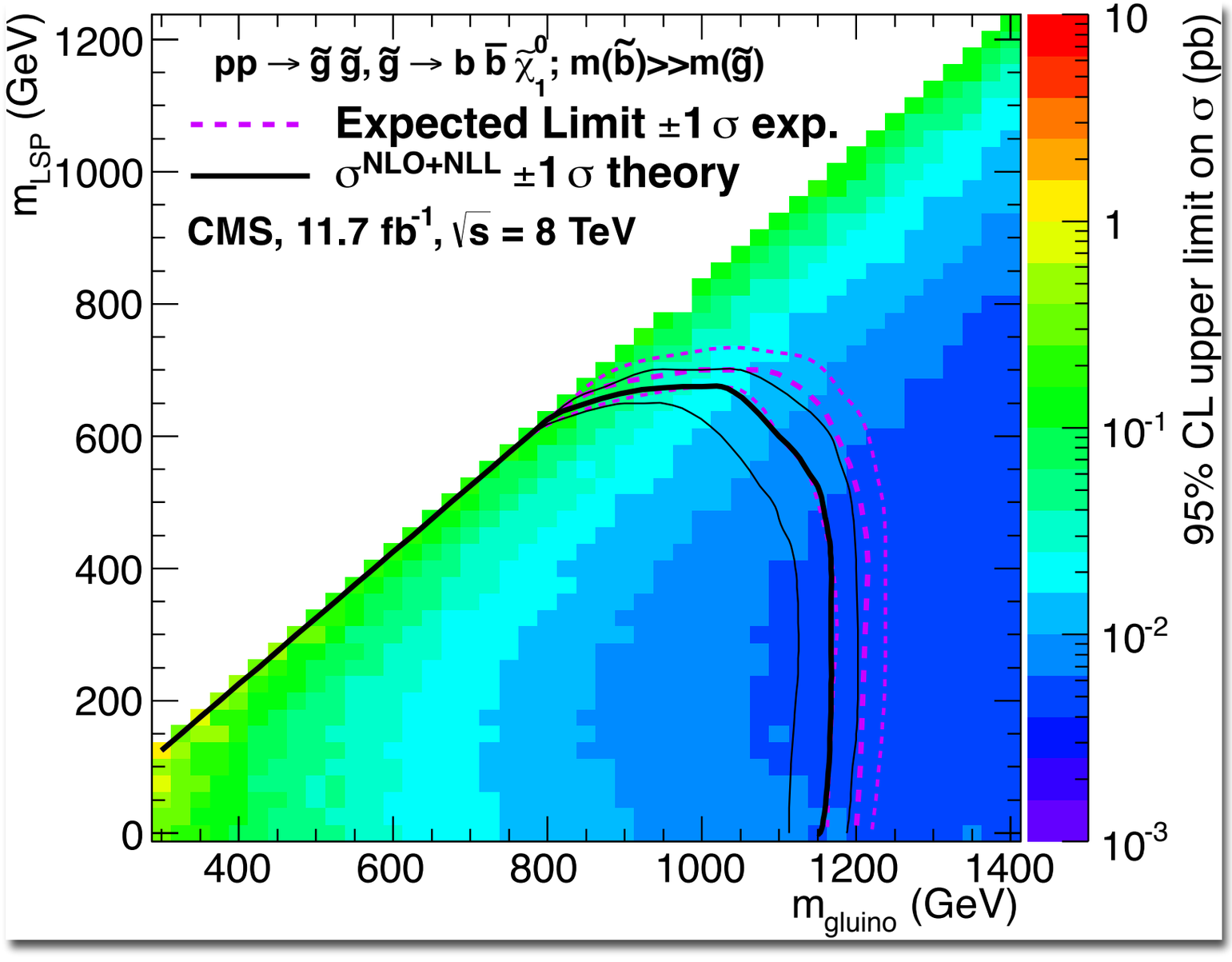
Direct Gluino production



- 100% BR(glu ->bbchi0)
- Very competitive limit due to choice of high bjet multiplicity bins
  - Massively reduce SM backgrounds!

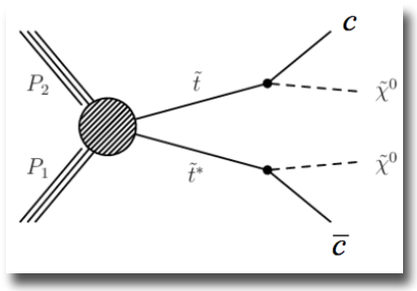
Full results twiki

$N_{jet} \geq 4$ $N_b \geq 2$

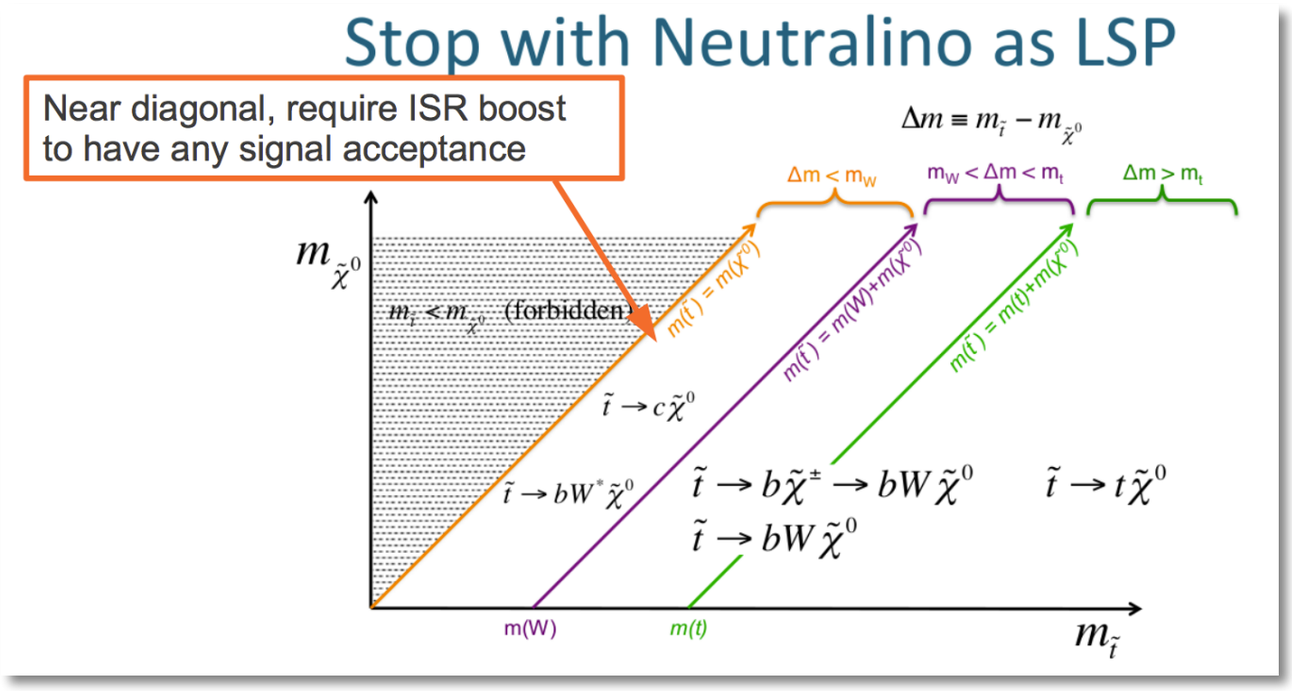


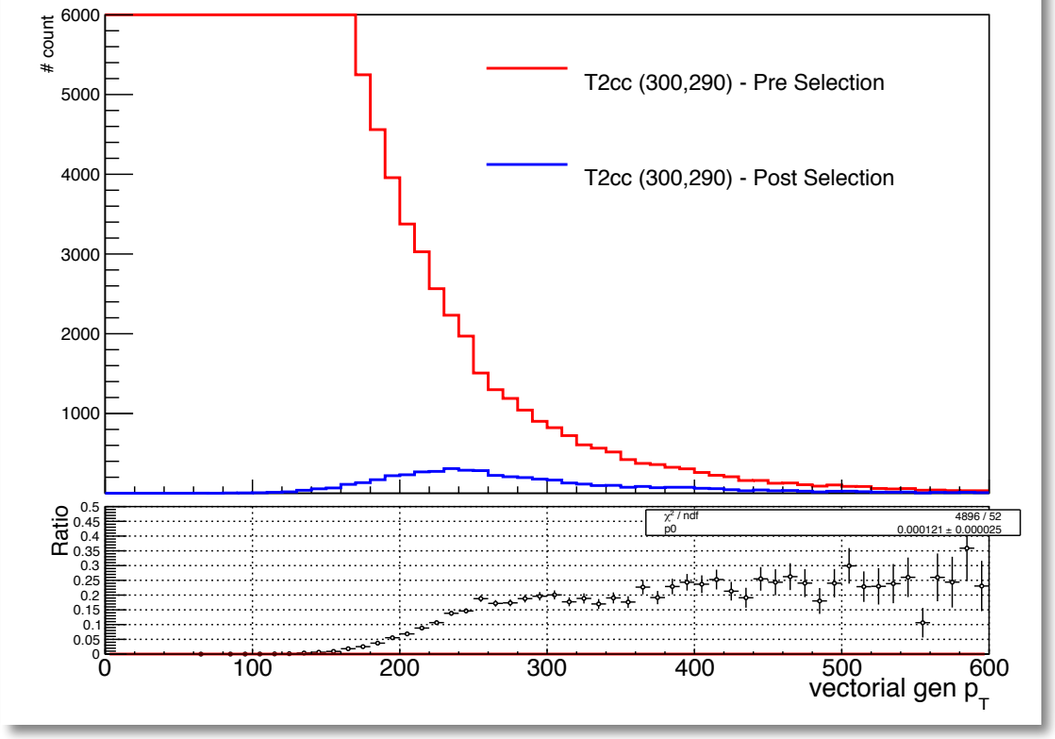
Mass-degenerate SUSY

- Highly compressed regions of phase space still largely un-probed - fertile ground for future investigations!
- Implies $m_{stop/gluino} - m_{LSP} = \Delta m \lesssim 80$ GeV
  - Below this limit, co-annihilation of stop+neutrilino can occur
  - Required for LSP dark matter to agree with cosmological relic density constraints
- One example model is stop->charm+LSP



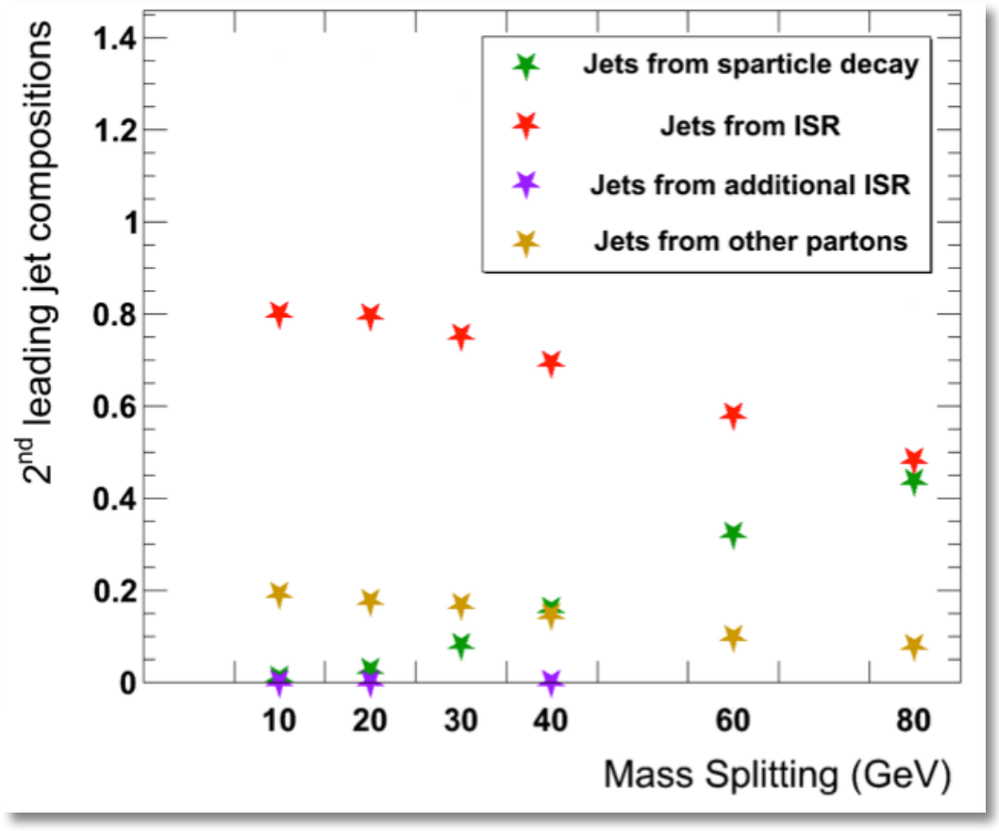
- In compressed region, SUSY decay products become very soft - fall below analysis threshold - analyses become dependent in ***initial state boost***

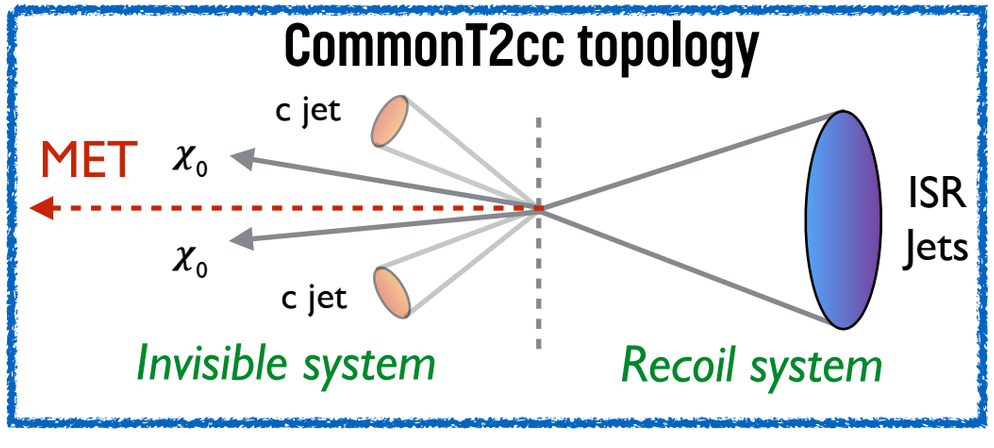


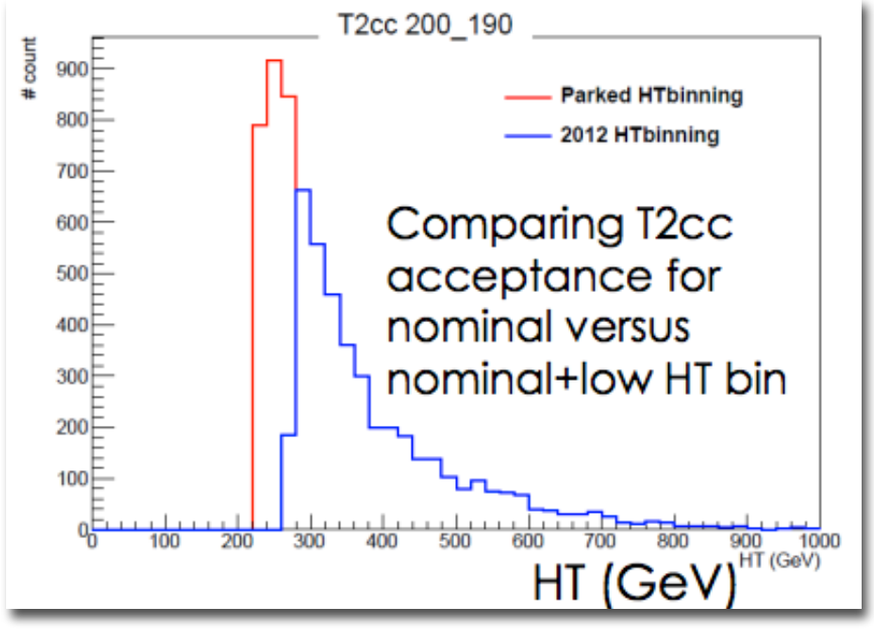


T2cc

- Sensitivity in the compressed region depends on decay system being boosted by Initial State Radiation (ISR) jets
- Nearest the diagonal, only these ISR are visible, balancing a now invisible SUSY decay system - perfect α_T signature!
  - *high alphaT values!*
- Intend to probe such models with our full 2012 parked dataset
  - Lower online trigger thresholds allows lower analysis HT thresholds - expect good improvement!

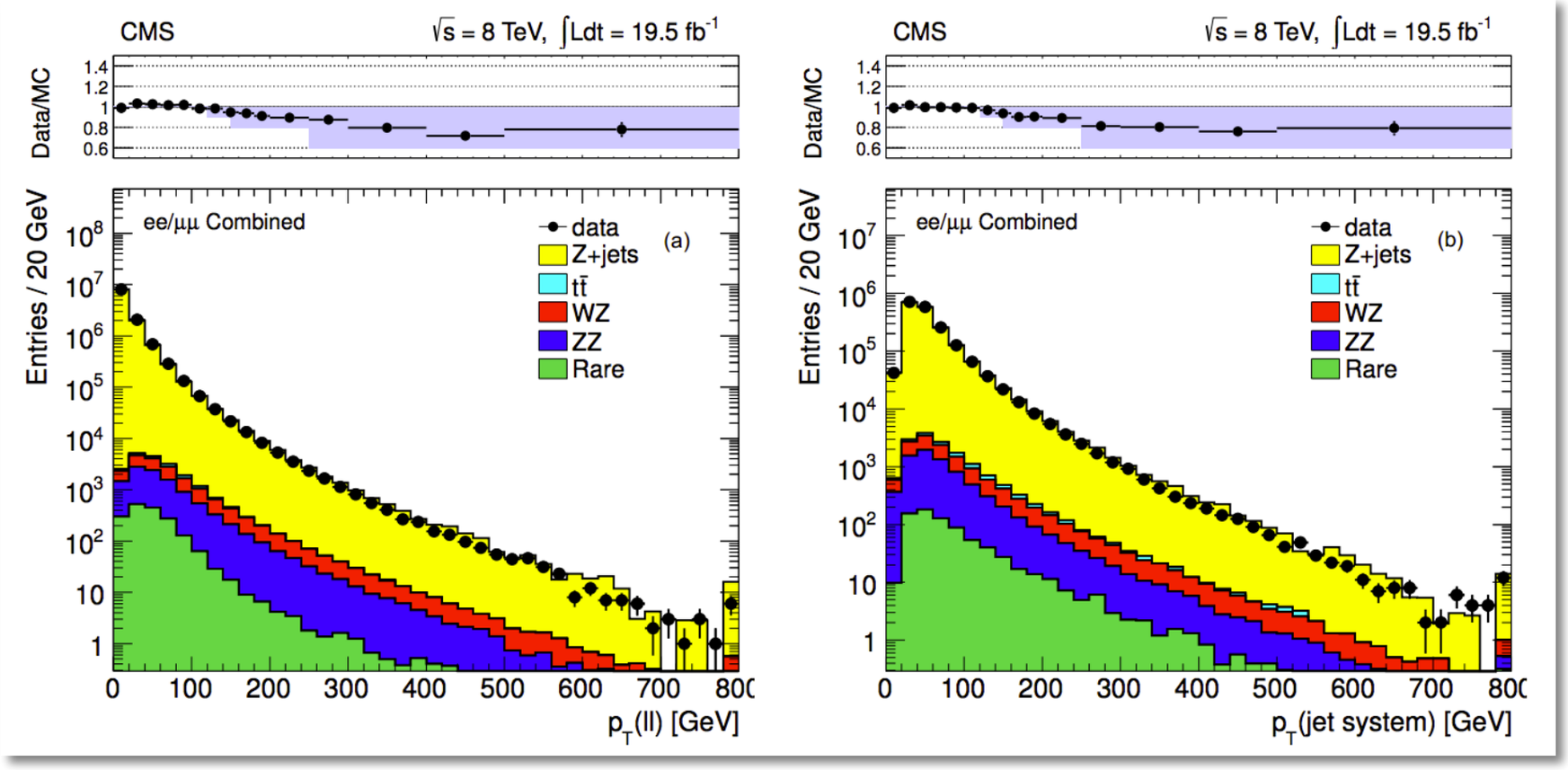






ISR Considerations

- Such heavy reliance on ISR in final state requires accurate modelling in MC
- Studies have been undertaken to assess and account for MC ISR modelling
- Define an ISR selection [for all production mechanisms] and compare Data to MC
- Derive boost-pT dependent correction factors to bring MC back in line with data to be applied to all signal MC



arXiv:1308.1586

Summary

- CMS has carried out a search for SUSY in the all-hadronic channel on 12fb^{-1} of 2012 8TeV data
- The dimensionless α_T kinematic variable has been used to reduce QCD background to a negligible level
- Unfortunately no excess was observed, and so very competitive limits were set on both direct squark and gluino production
- MC truth investigations of compressed-spectra models indicate good sensitivity using parked dataset due to lower trigger thresholds
- Parked analysis in the pipeline - aiming for a result in the near future...