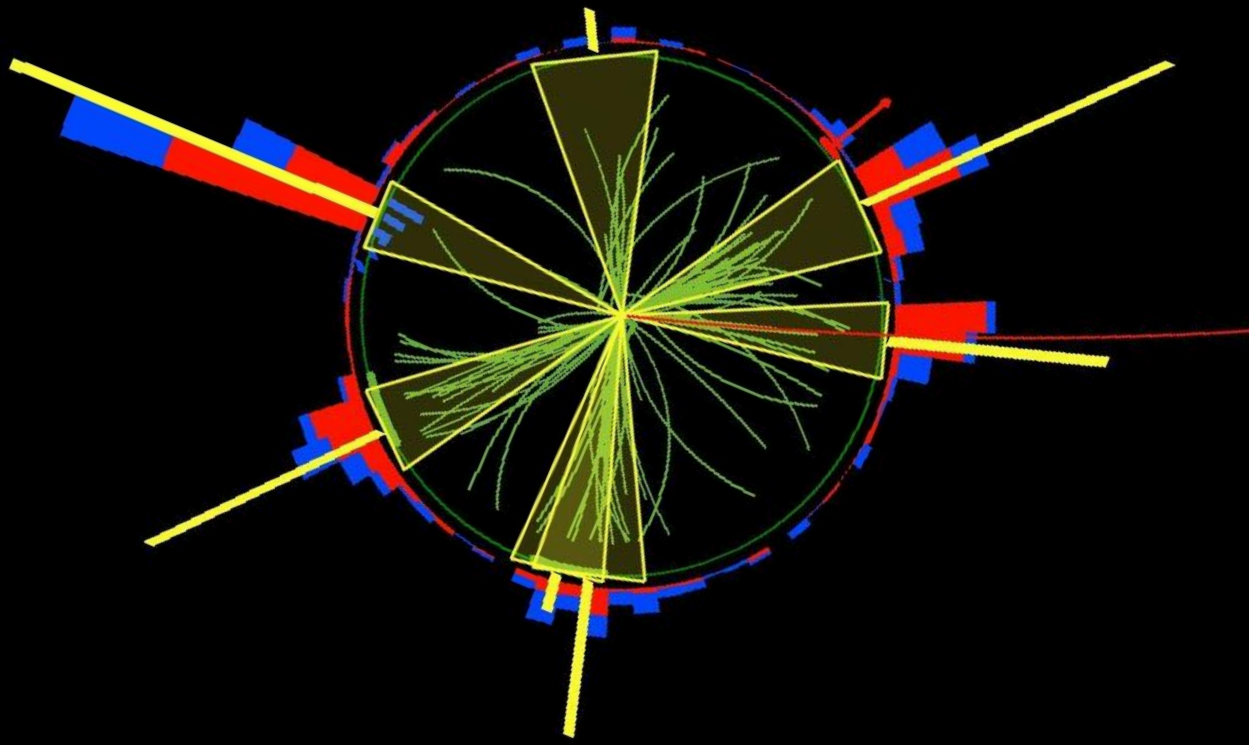
Supersymmetry searches with the α_T variable and trigger upgrade studies at CMS

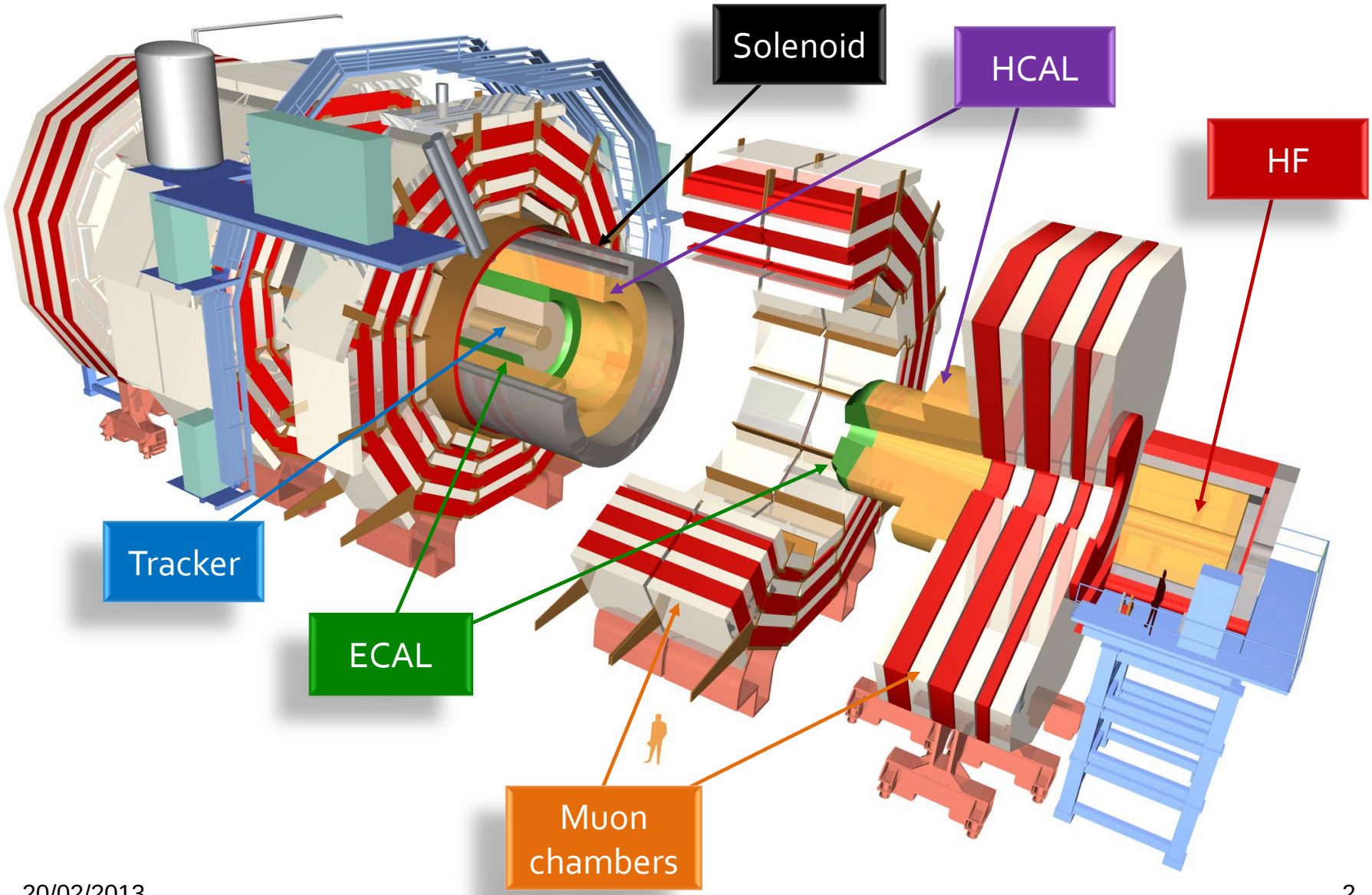


Mark Baber
Imperial College London

Outline

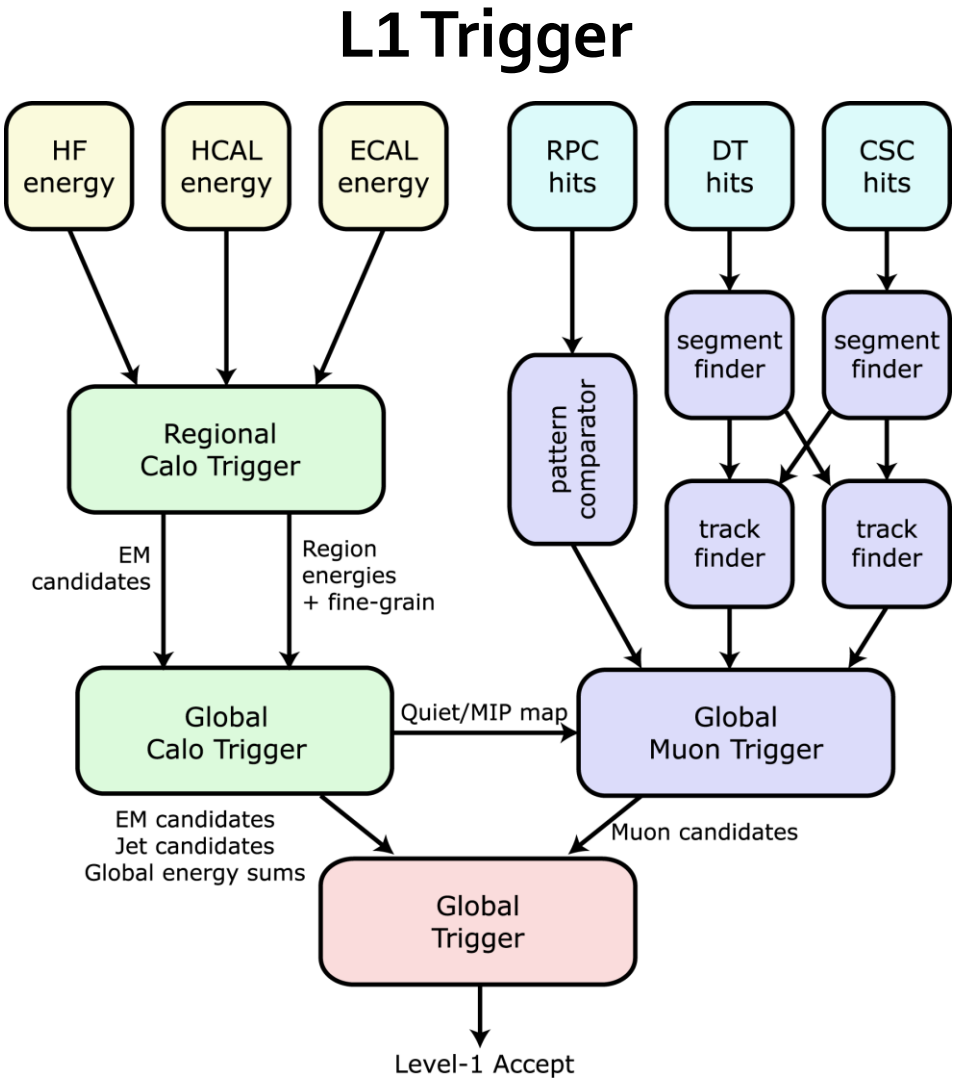
- CMS detector
- L1 Trigger
- LHC upgrade
- Supersymmetry searches at the LHC
- Supersymmetry α_T analysis
- Current exclusions
- Conclusion

CMS detector



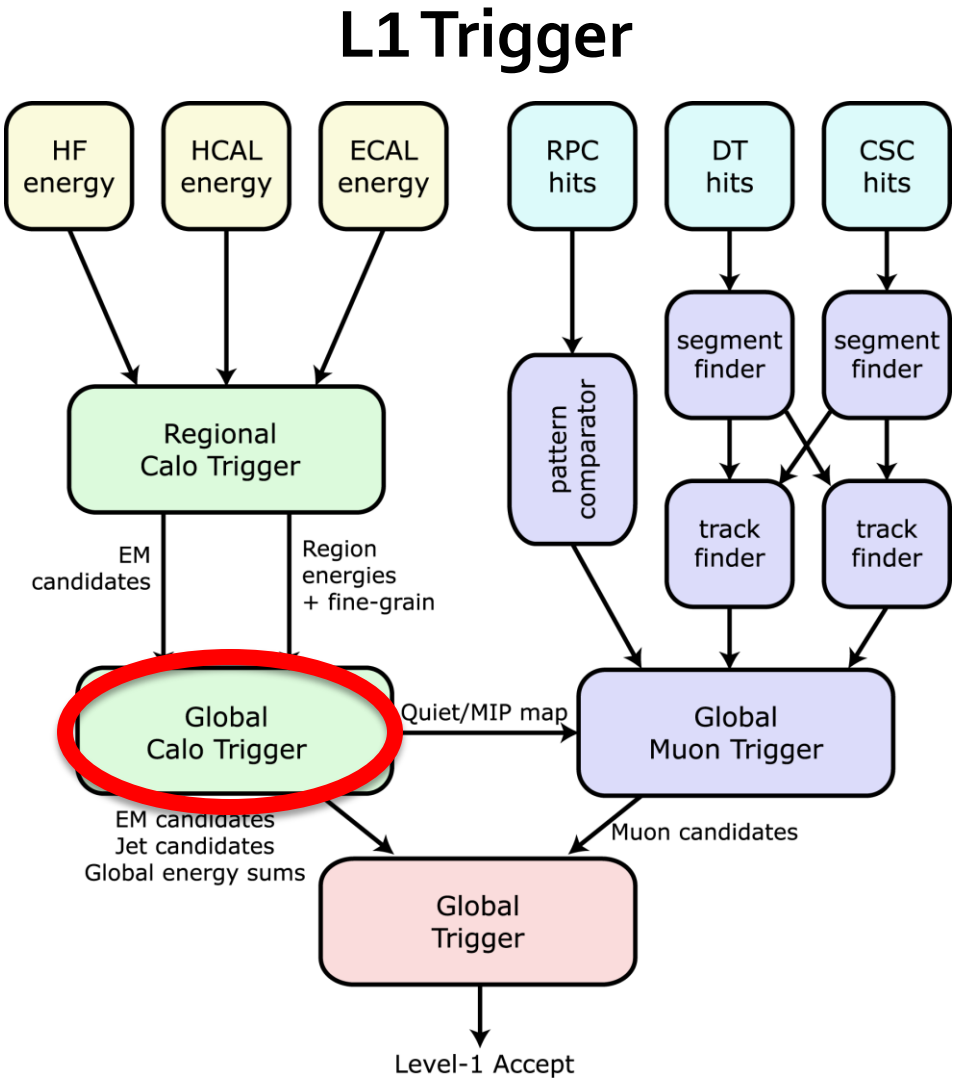
L1 Trigger

- 40 MHz bunch crossing rate
  - L1 $\rightarrow$ 100 kHz
  - HLT $\rightarrow$ 1 kHz
- Global Calorimeter Trigger
  - Builds calorimeter objects for Global Trigger: Jets, e/γ, ...
- Measurement of event quantities:
  - $\not{E}_{\mathrm{T}} \equiv \sum \vec{p}_{\mathrm{T}}$
  - $H_{\mathrm{T}} \equiv \sum E_{\mathrm{T}}^{j_i}$

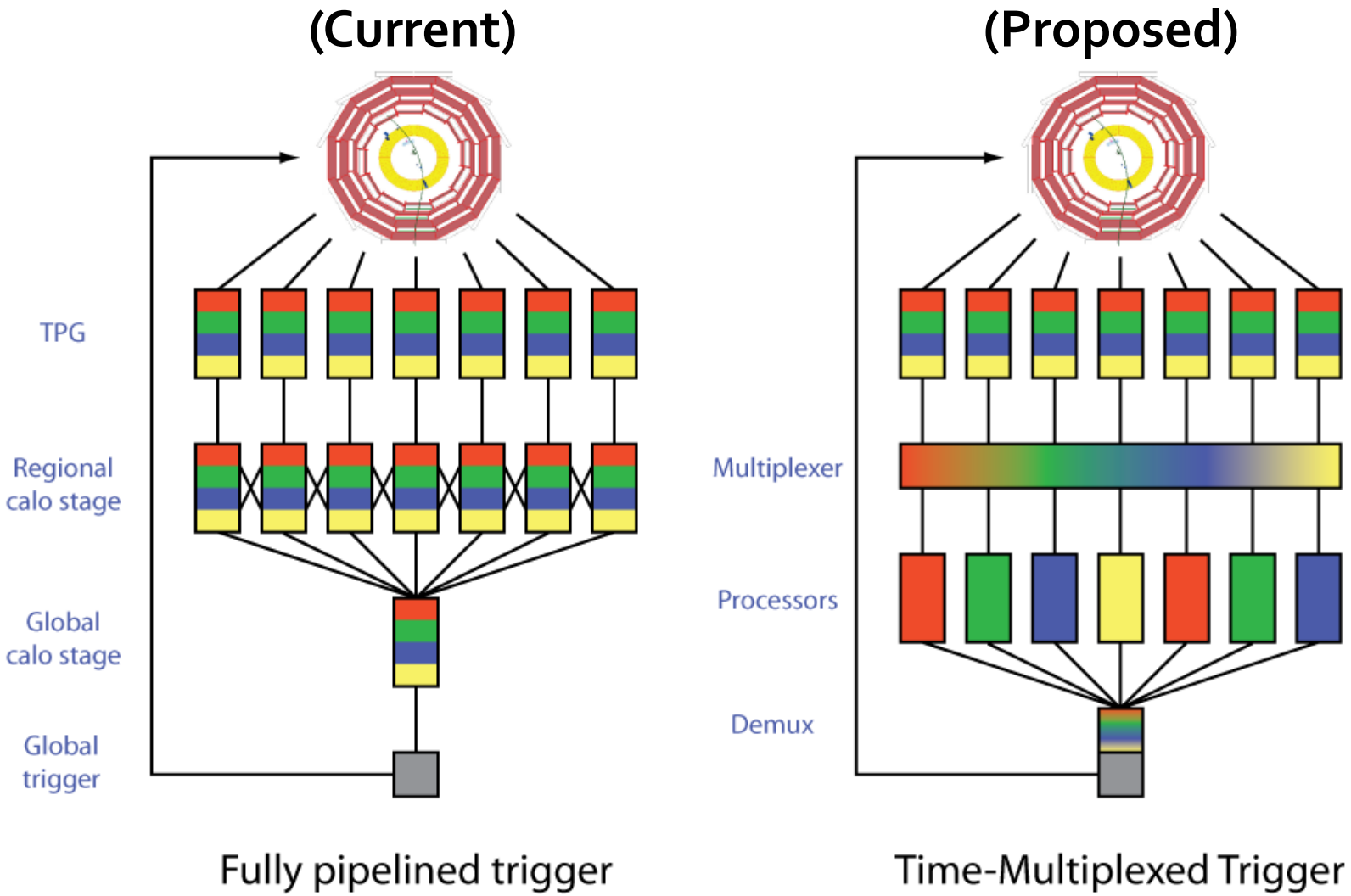


L1 Trigger

- 40 MHz bunch crossing rate
  - L1 $\rightarrow$ 100 kHz
  - HLT $\rightarrow$ 1 kHz
- Global Calorimeter Trigger
  - Builds calorimeter objects for Global Trigger: Jets, e/γ, ...
- Measurement of event quantities:
  - $\not{E}_{\mathrm{T}} \equiv \sum \vec{p}_{\mathrm{T}}$
  - $H_{\mathrm{T}} \equiv \sum E_{\mathrm{T}}^{j_i}$

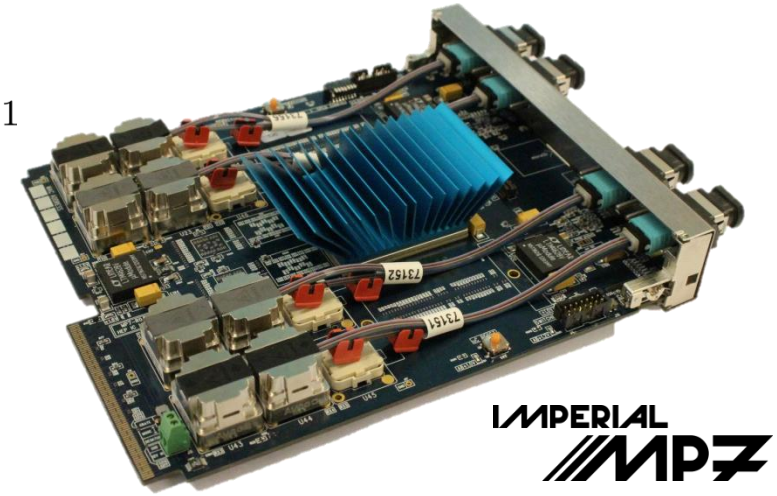


Trigger architectures



LHC upgrade

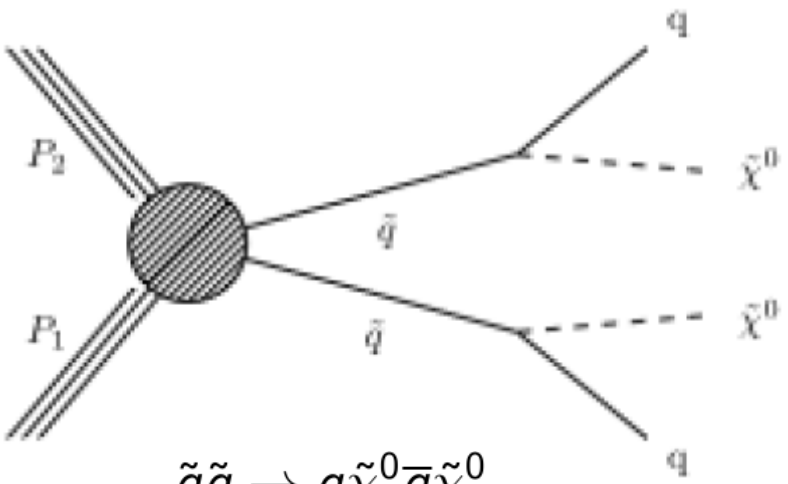
- Upgrade in energy and luminosity
  - $\sqrt{s} = 13/14\ \mathrm{TeV},\ \mathcal{L} = 2 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
  - Expect : ~50 pileup
  - Trigger design : ~20 pileup



- Calorimeter trigger upgrade
  - Time-multiplexed trigger architecture
  - MP7 – Fast, high bandwidth, redundancy
  - Enables lowering of thresholds → Measurement of Higgs properties
  - Increased sensitivity of new physics searches

- Jet reconstruction studies
  - Higher granularity – Trigger tower-level $(\Delta\eta \times \Delta\phi = 0.087 \times 0.087)$
  - New jet shapes – Circular
  - Different jet size – Fat/thin
  - Event-by-event pileup subtraction

SUSY - Searches at the LHC



$\tilde{q}\tilde{q} \rightarrow q\tilde{\chi}^0\overline{q}\tilde{\chi}^0$

- Decay is model dependent
  - ⇒ Search for common signatures

Hadronic signature

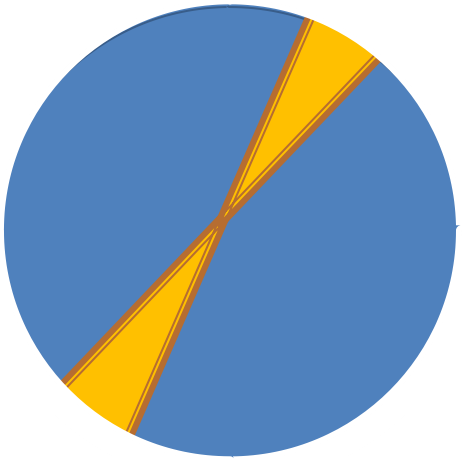
- Strong pair production of sparticles
- Decay cascade to the Lightest Supersymmetric Particle (LSP)
- ⟶ Hadronic final states
- ⟶ Large $\not{E}_{\mathrm{T}}$ (LSP)

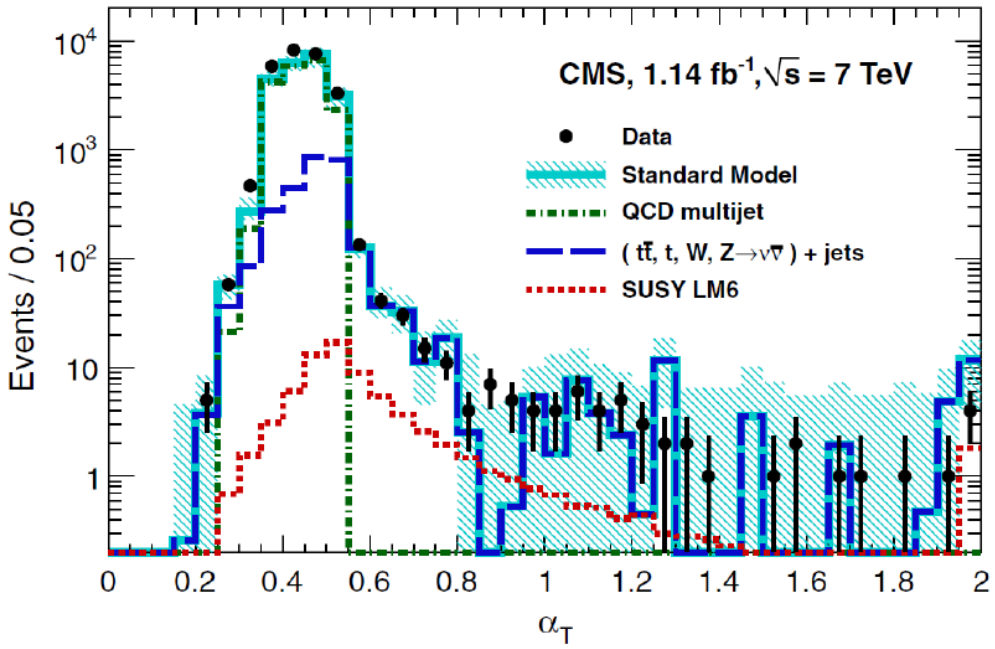
SM backgrounds

- $\boldsymbol{W}$ **+ jets** : $W \rightarrow l\nu$, where e/μ not reconstruction/ fail isolation
  τ misidentified as jet
- $\boldsymbol{Z}$ **+ jets** : $Z \rightarrow \nu\overline{\nu}$, irreducible background
- $\boldsymbol{t}, \boldsymbol{t\bar{t}}$ **production** : $\not{E}_{\mathrm{T}}$ from semi-leptonic decay of t and b quarks
- **QCD multijets** : Fake and real $\not{E}_{\mathrm{T}}$, dominant background

SUSY - The α_T variable

- Dimensionless variable to discriminate events with small/fake $\not{E}_T$
- QCD dijet event $: \alpha_T = 0.5$





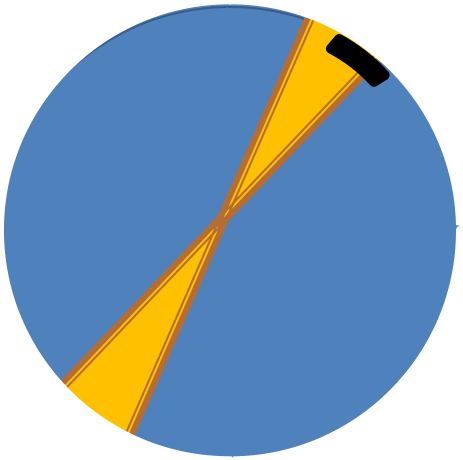
Definitions

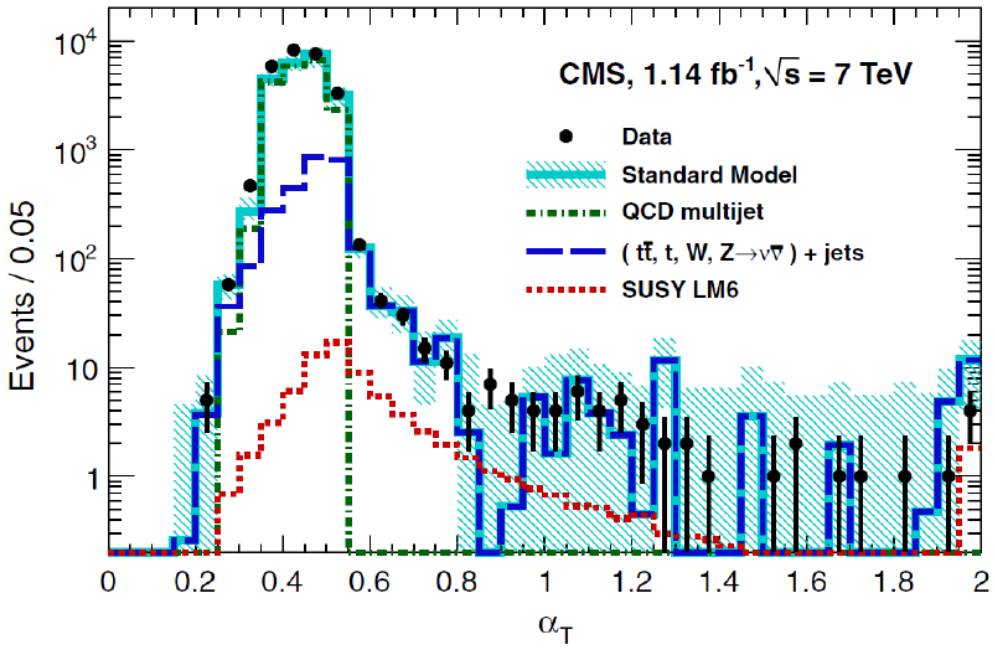
- $\alpha_T \equiv E_T^{j_2} / M_T$
- $M_T \equiv \sqrt{H_T^2 - \not{H}_T{}^2}$
- $H_T \equiv \sum E_T^{j_i}$, $\not{H}_T \equiv |\sum \vec{p}_T^{\,j_i}|$

SUSY - The α_T variable

- Dimensionless variable to discriminate events with small/fake $\not{E}_T$
- QCD dijet event
  - Event mismeasurement

$$: \alpha_T = 0.5$$
$$: \alpha_T < 0.5$$





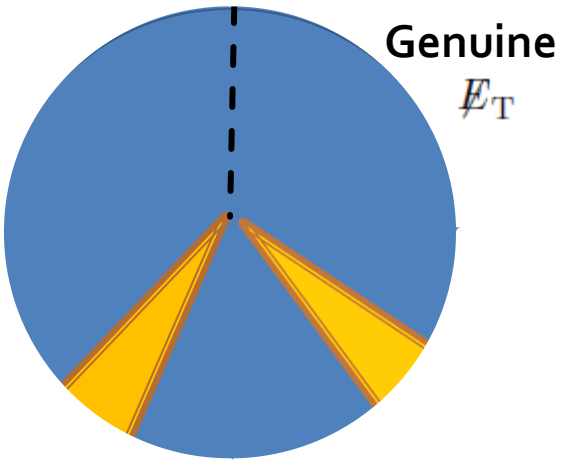
Definitions

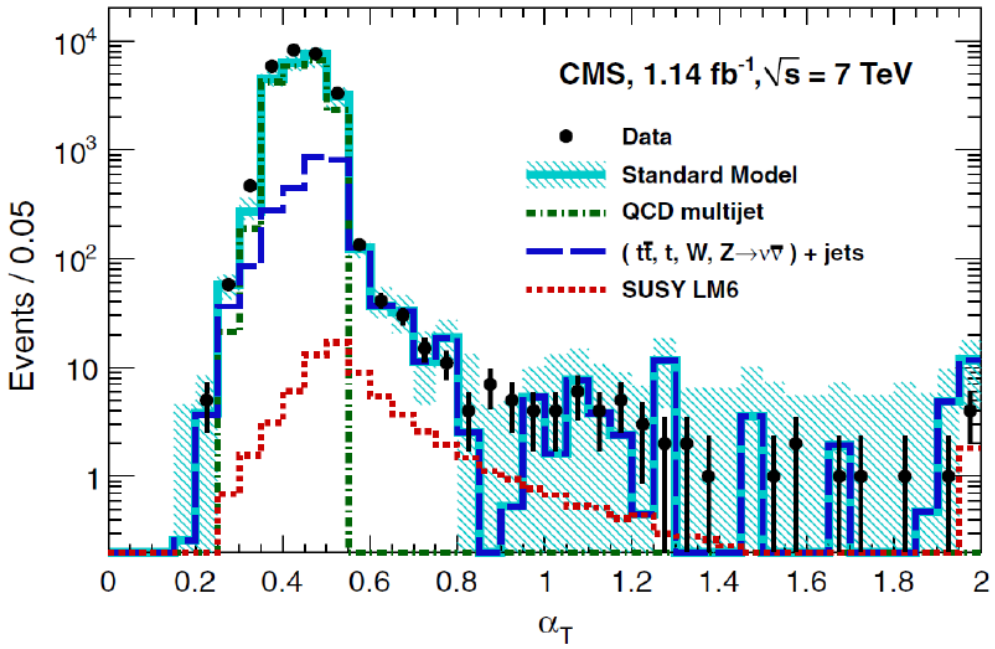
- $\alpha_T \equiv E_T^{j_2} / M_T$
- $M_T \equiv \sqrt{H_T^2 - \not{H}_T{}^2}$
- $H_T \equiv \sum E_T^{j_i}$, $\not{H}_T \equiv |\sum \vec{p}_T^{\,j_i}|$

SUSY - The α_T variable

- Dimensionless variable to discriminate events with small/fake $\not{E}_T$
- QCD dijet event
  - Event mismeasurement
- Jets recoiling against genuine $\not{E}_T$

$$: \alpha_T = 0.5$$
$$: \alpha_T < 0.5$$
$$: \alpha_T > 0.5$$



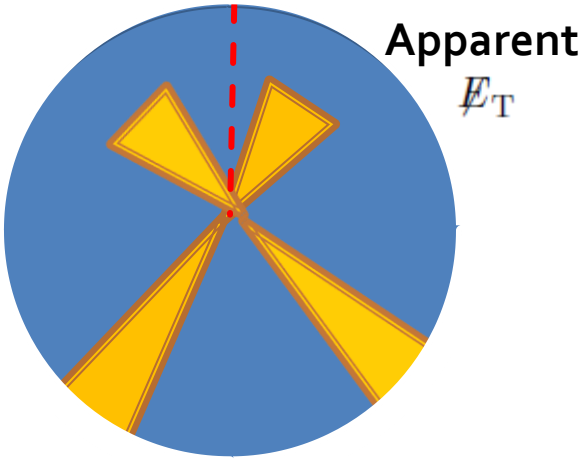


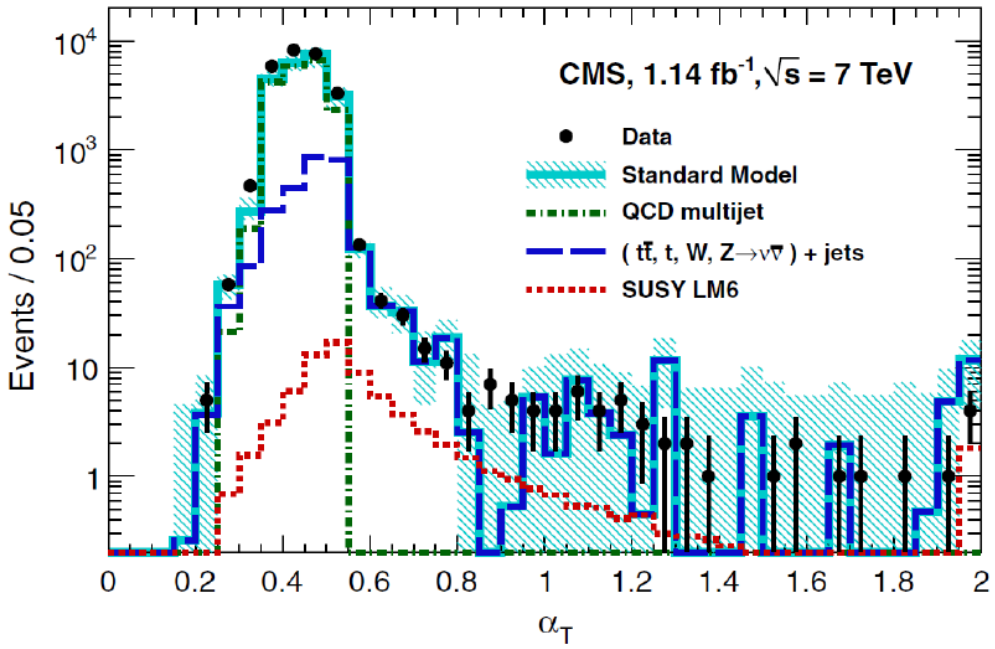
Definitions

- $\alpha_T \equiv E_T^{j_2} / M_T$
- $M_T \equiv \sqrt{H_T^2 - \not{H}_T{}^2}$
- $H_T \equiv \sum E_T^{j_i}$, $\not{H}_T \equiv |\sum \vec{p}_T^{\,j_i}|$

SUSY - The α_T variable

- Dimensionless variable to discriminate events with small/fake $\not{E}_T$
- QCD dijet event : $\alpha_T = 0.5$
  - Event mismeasurement : $\alpha_T < 0.5$
- Jets recoiling against genuine $\not{E}_T$: $\alpha_T > 0.5$
- Severe mismeasurement : $\alpha_T > 0.5$



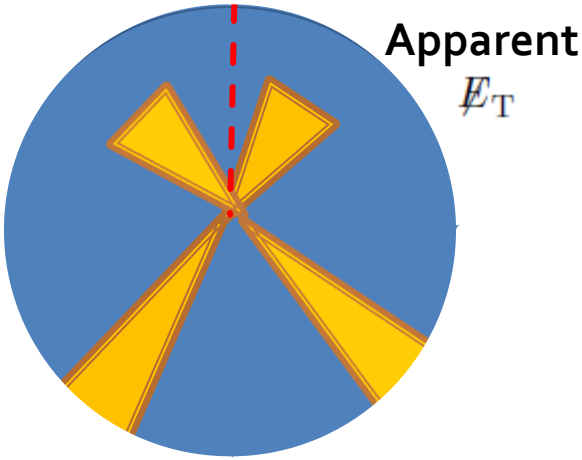


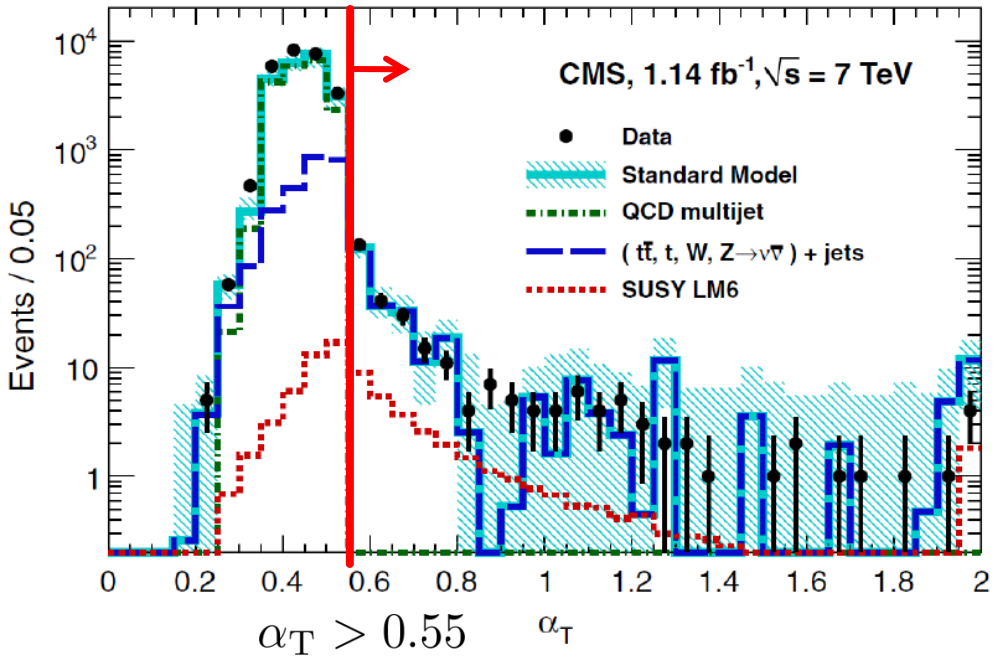
Definitions

- $\alpha_T \equiv E_T^{j_2} / M_T$
- $M_T \equiv \sqrt{H_T^2 - \not{H}_T{}^2}$
- $H_T \equiv \sum E_T^{j_i}$, $\not{H}_T \equiv |\sum \vec{p}_T^{\,j_i}|$

SUSY - The α_T variable

- Dimensionless variable to discriminate events with small/fake $\not{E}_T$
- QCD dijet event : $\alpha_T = 0.5$
  - Event mismeasurement : $\alpha_T < 0.5$
- Jets recoiling against genuine $\not{E}_T$: $\alpha_T > 0.5$
- Severe mismeasurement : $\alpha_T > 0.5$



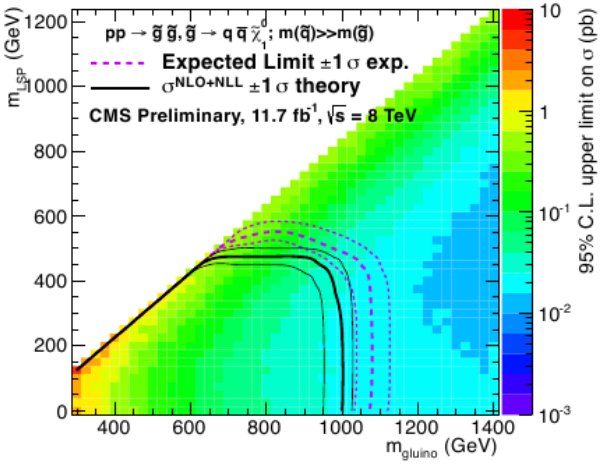


Definitions

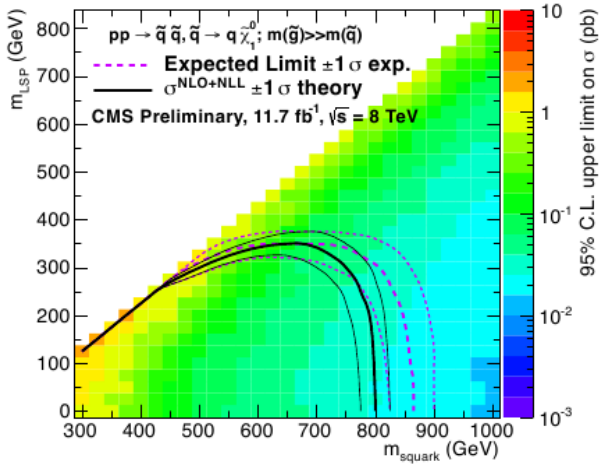
- $\alpha_T \equiv E_T^{j_2} / M_T$
- $M_T \equiv \sqrt{H_T^2 - \not{H}_T{}^2}$
- $H_T \equiv \sum E_T^{j_i}$, $\not{H}_T \equiv |\sum \vec{p}_T^{\,j_i}|$

SUSY - Simplified model exclusion

- Analysis method
  - Bin events in H_{T}
  - Fit background and signal expectations
  - → Set limits
- Current limits set with 8 TeV, 11.7 fb^{-1} data
- Future of the analysis
  - Parked data → Compressed spectra
  - 13/14 TeV data → Increase in sensitivity



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

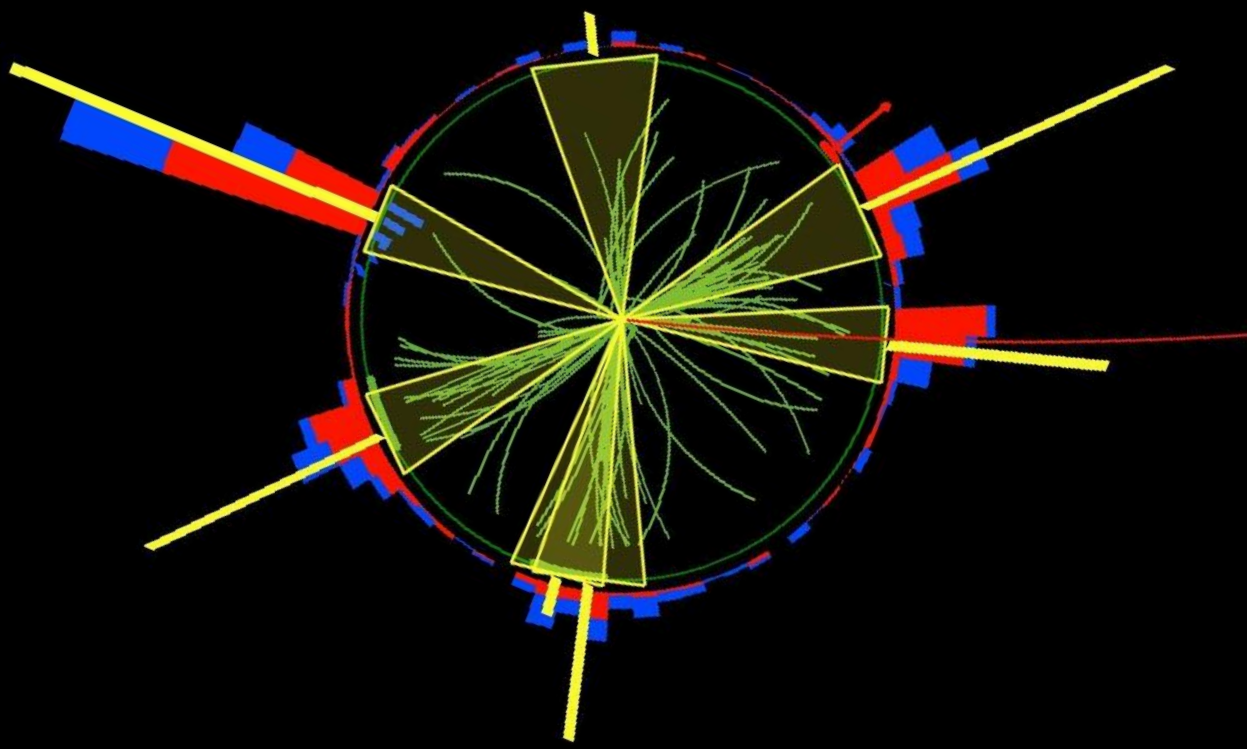


$$\tilde{q}\tilde{q} \rightarrow q\tilde{\chi}^0\bar{q}\tilde{\chi}^0$$

Conclusion

- Research centred around SUSY searches and LHC upgrade
- Work on developing jet reconstruction algorithms for the upgrade
- Develop the α_T analysis of 8 TeV parked data
  - $\rightarrow$ Compressed spectra
- First analysis of 13/14 TeV data in 2015
  - Discovery! (*or improve current limits*)

Backup



Analysis cuts

- Jet $E_{\mathrm{T}} > 50$ GeV and $|\eta| > 3$ $(\eta \equiv -\ln[\tan(\theta/2)])$
- Lead and second jet $E_{\mathrm{T}} > 100$ GeV
- Lead jet $|\eta| < 2.5$
- $\alpha_{\mathrm{T}} > 0.55$
- $H_{\mathrm{T}} > 275$ GeV

- Event vetoes
  - Jet $E_{\mathrm{T}} > 50$ GeV and $|\eta| > 3$ / abnormal calorimeter signals
  - Isolated e/μ $p_{\mathrm{T}} > 10$ GeV
  - Isolated γ $p_{\mathrm{T}} > 25$ GeV

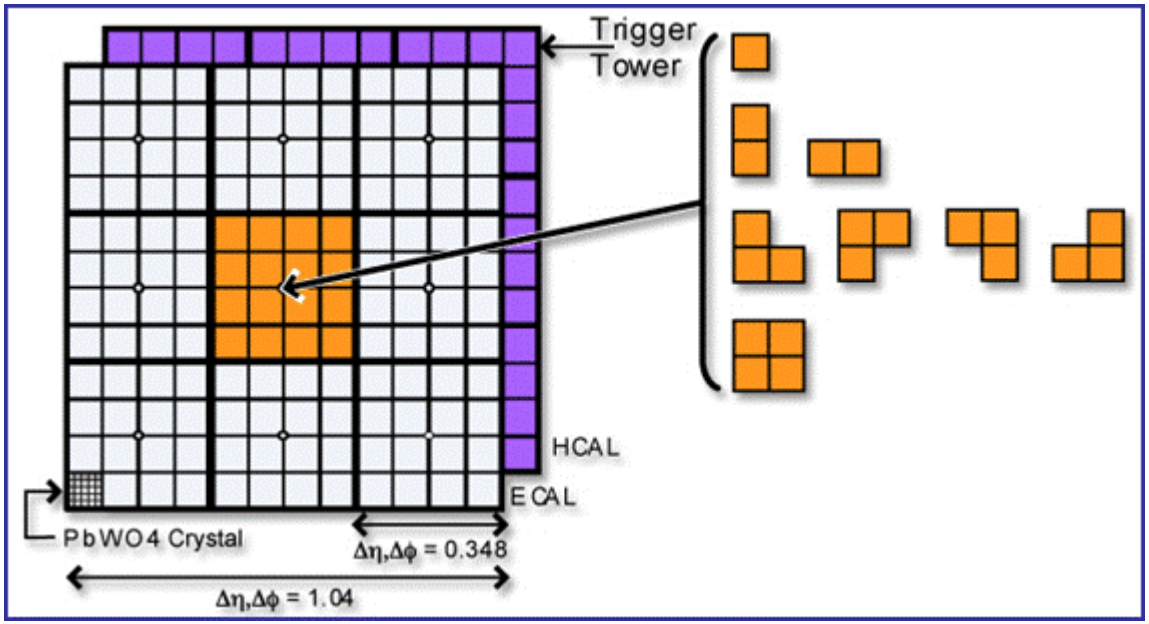
- Data control samples
  - $W + \mathrm{jets} \to l\nu$, $Z + \mathrm{jets} \to \mu\overline{\mu}$, $\gamma + \mathrm{jets}$

Problems with the SM

- Unification of the force coupling constants
  - Unified at GUT scale in SUSY
- Dark matter
  - No candidate for DM in SM
  - SUSY has several candidates: neutralino, sneutrino, …
- Heirarchy problem
  - Mass of Higgs dependent on energy cut off
  - Require a high precision of fine tuning (10^{32})
  - Quadratic divergences of Higgs mass cancelled by sparticles
  - Resulting in logarithmic divergence
  - Require that the stop mass < 400 GeV

Jet algorithms

- Current algorithm



- (One of) Proposed algorithms
  - Create jet candidates
  - Select top 12 (or all) jets
  - Determine median jet $\not{E}_{\mathrm{T}}$
  - Use for PU subtraction