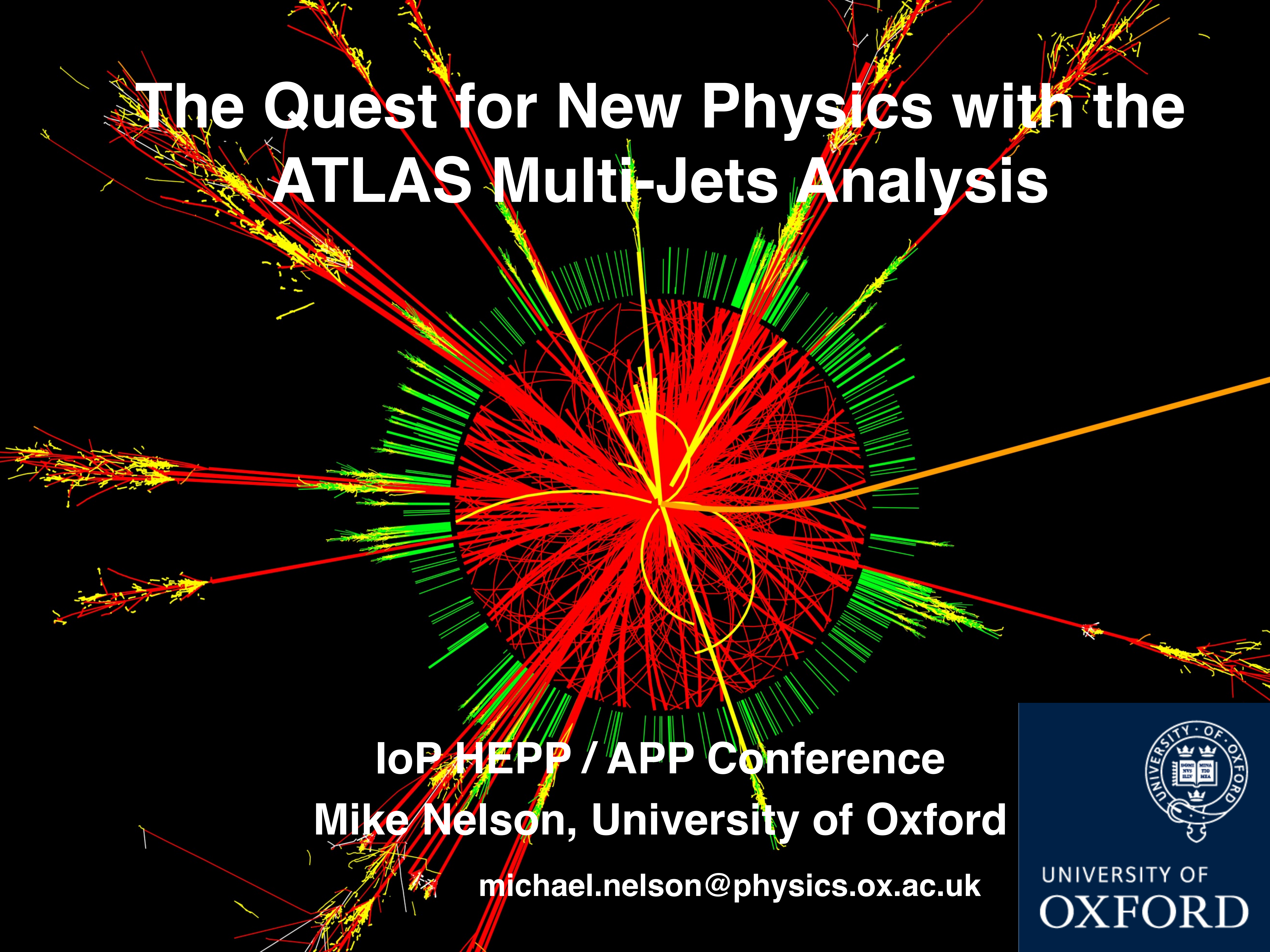

The Quest for New Physics with the ATLAS Multi-Jets Analysis

IoP HEPP / APP Conference

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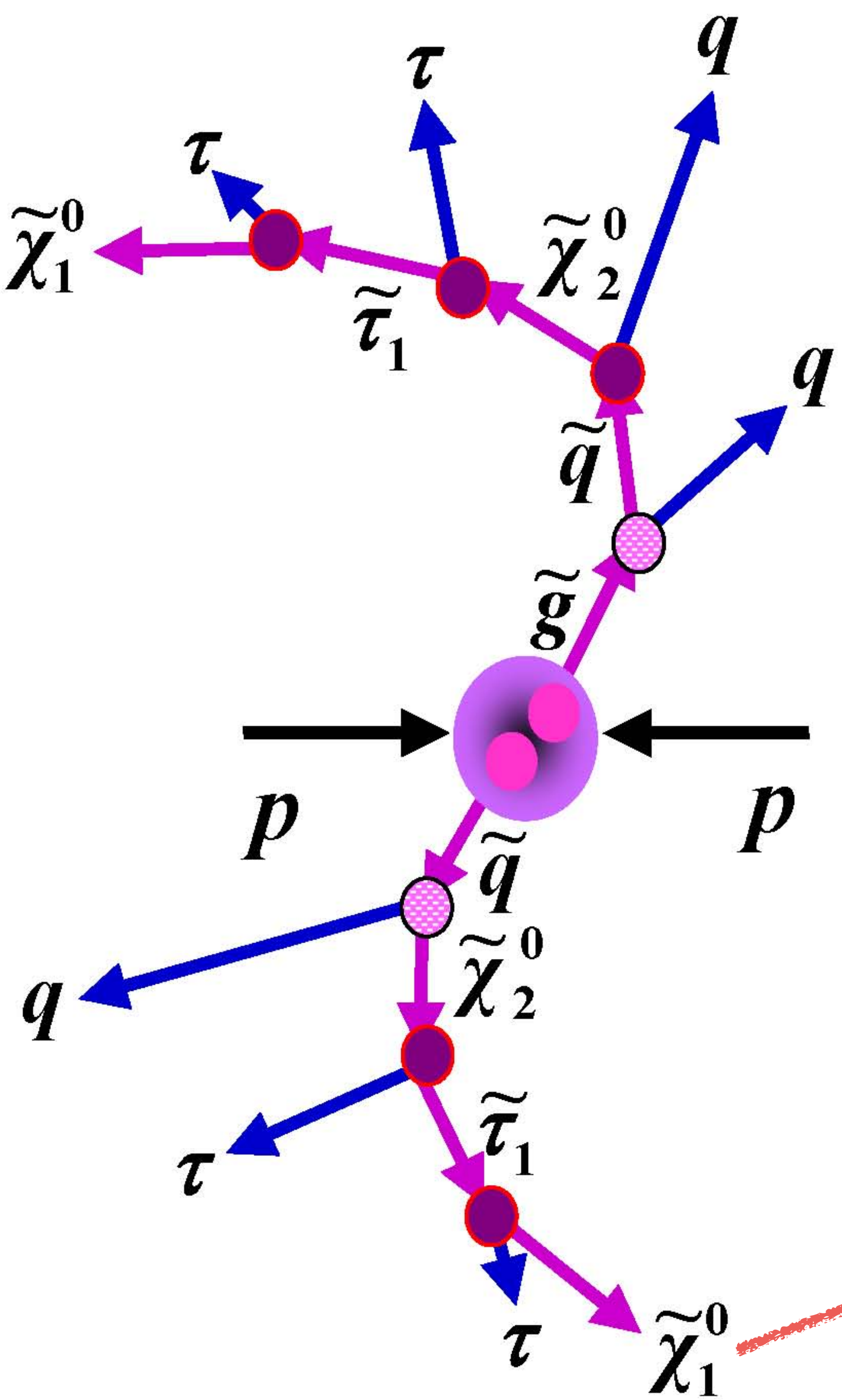
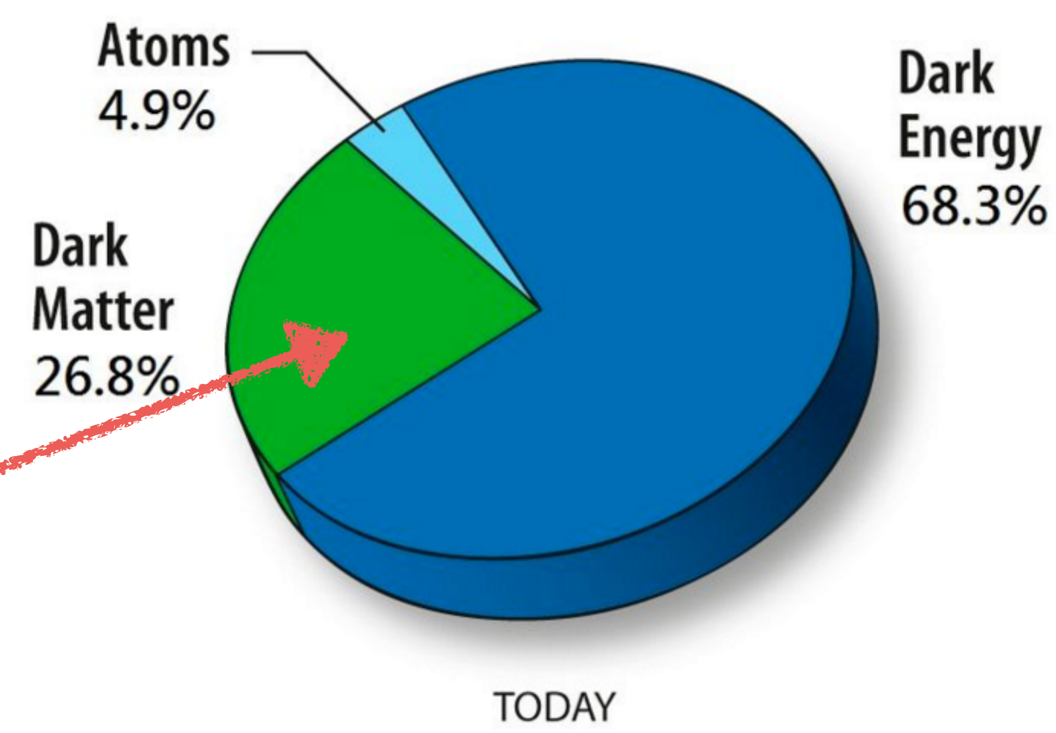
Supersymmetry at the LHC

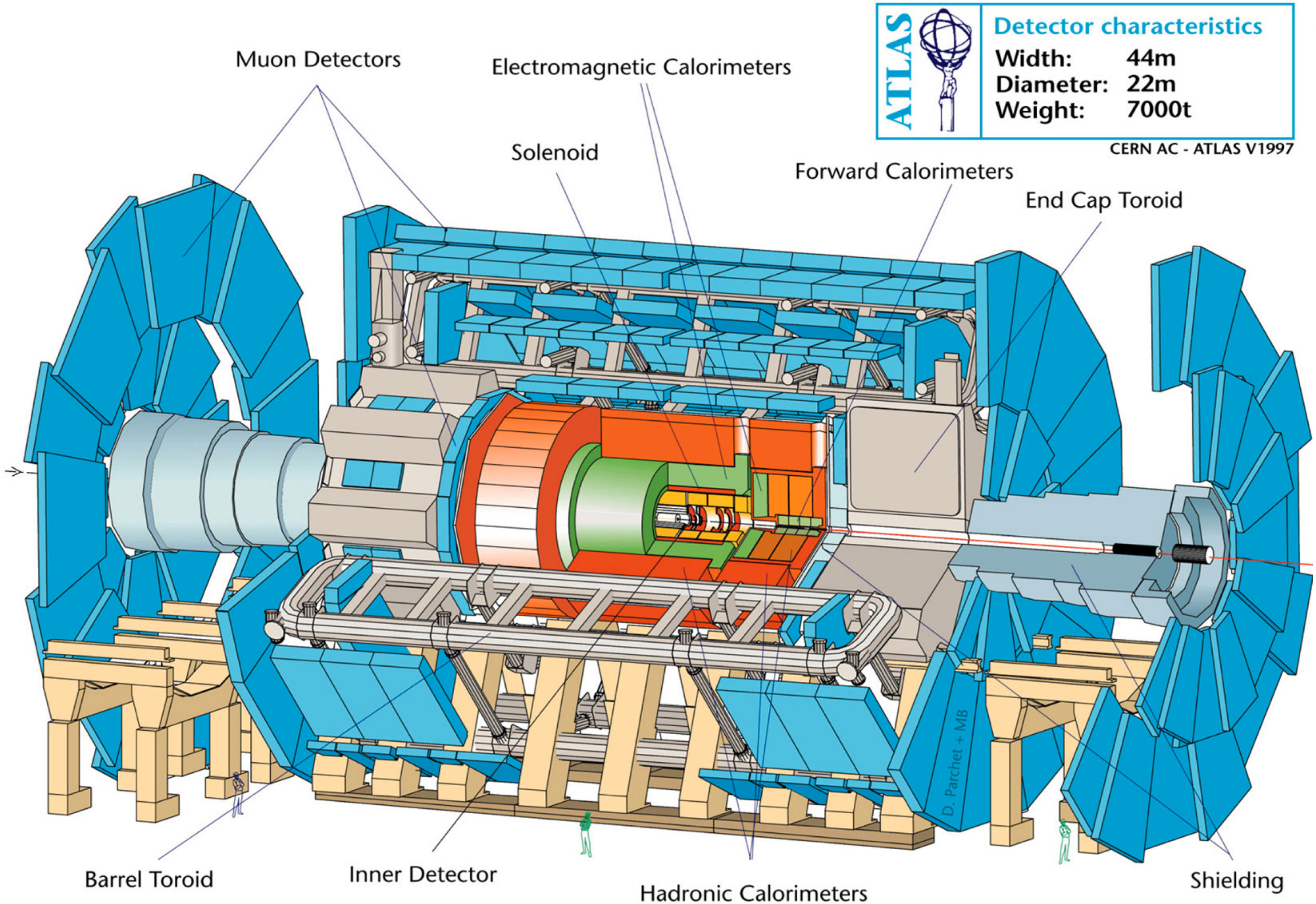


SUSY decay cascades —> final-state quarks **hadronise into jets**

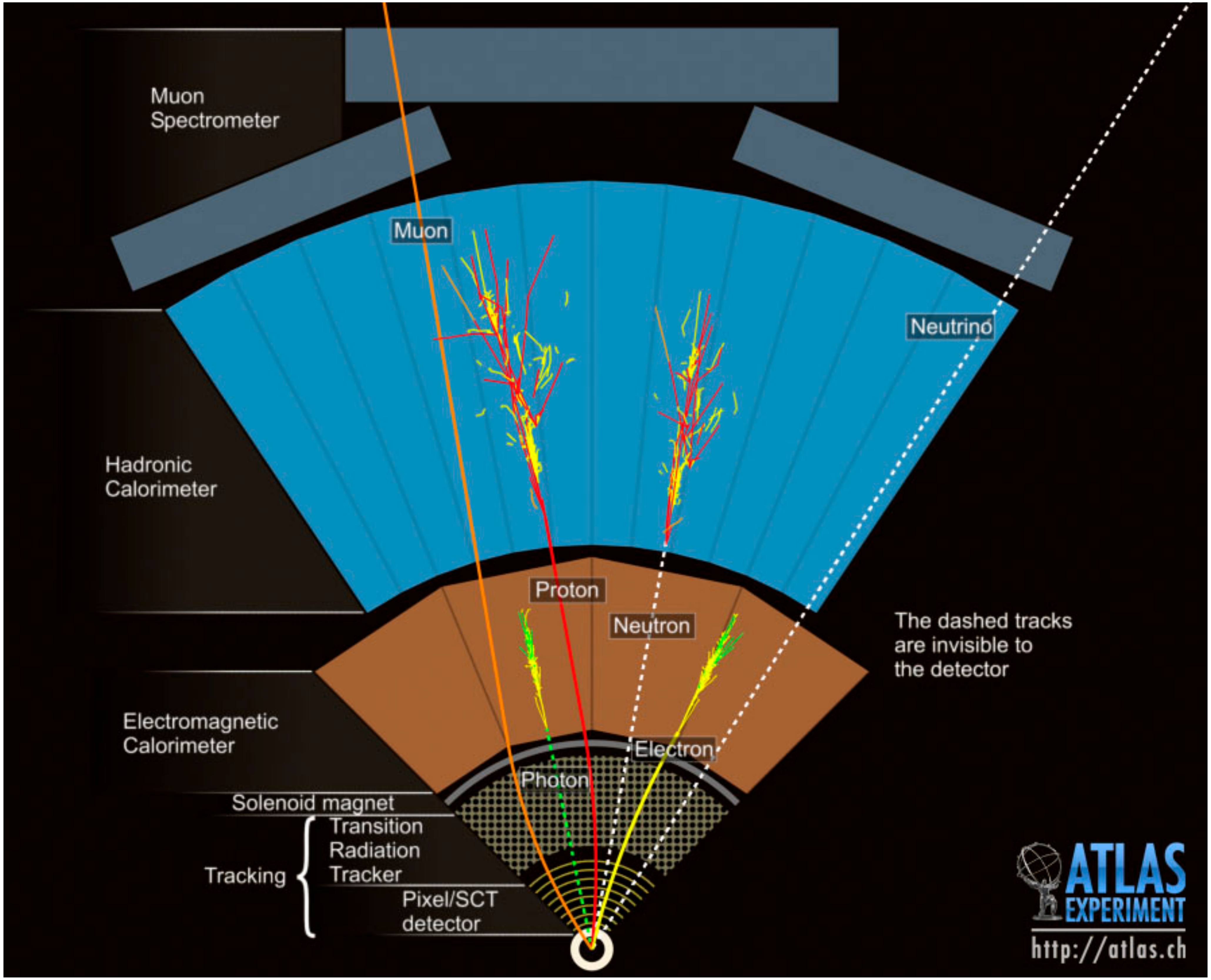
Lightest Sparticle in decay chain is electromagnetically neutral and stable —> **the LSP**



The ATLAS Detector



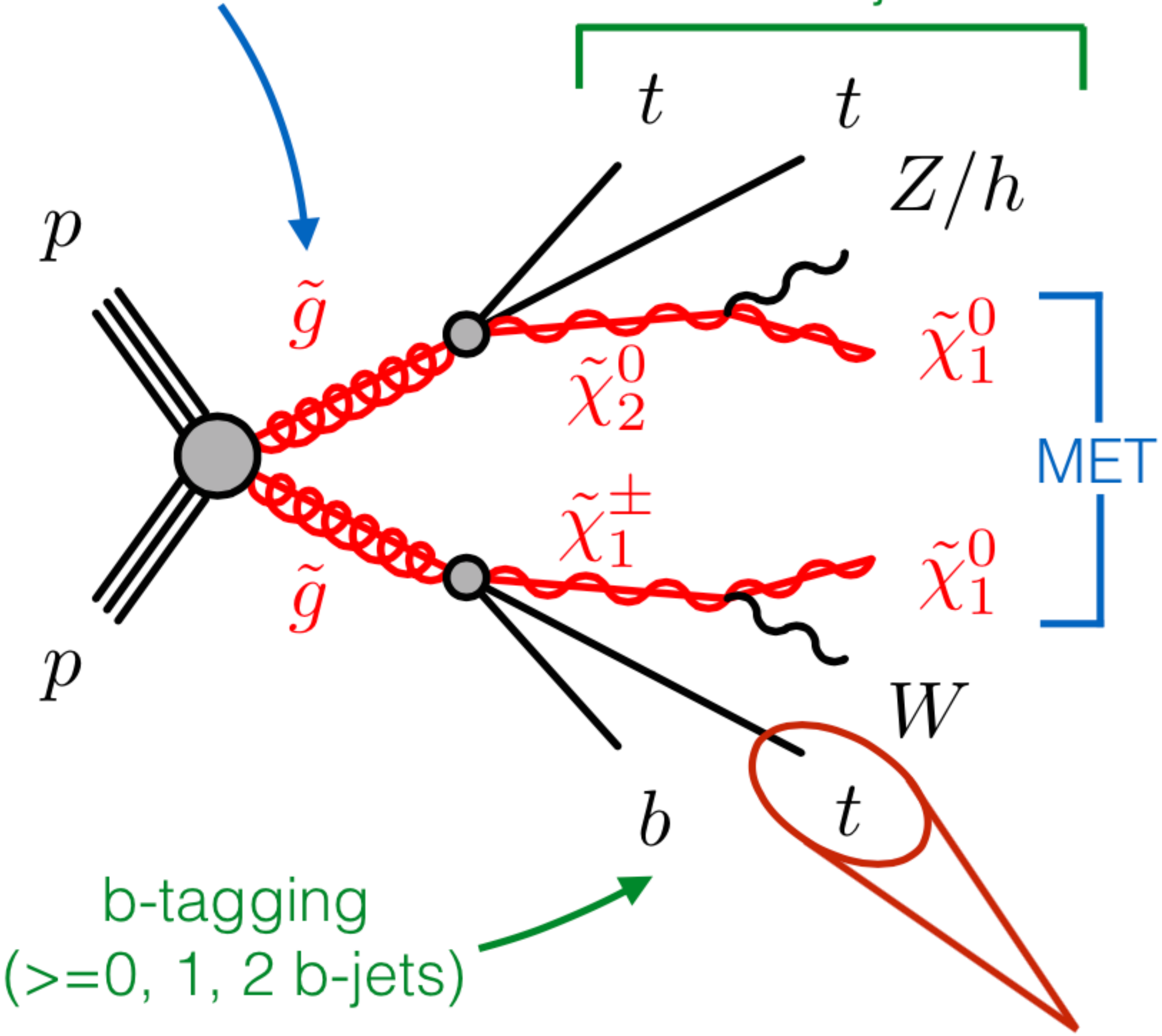
A ‘Slice’ of ATLAS



What are we looking for ?

Heavy initial particles
-> Central jets

Long decay chain
≥7-11 jets



b-tagging
(>=0, 1, 2 b-jets)

Jet Reclustering
M_J^{Σ}

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Common Selection
Lepton veto

Many central jets: $|\eta|<2.0$

Key variable: MET-significance:

$$E_T^{\mathrm{miss}}/\sqrt{H_T}$$

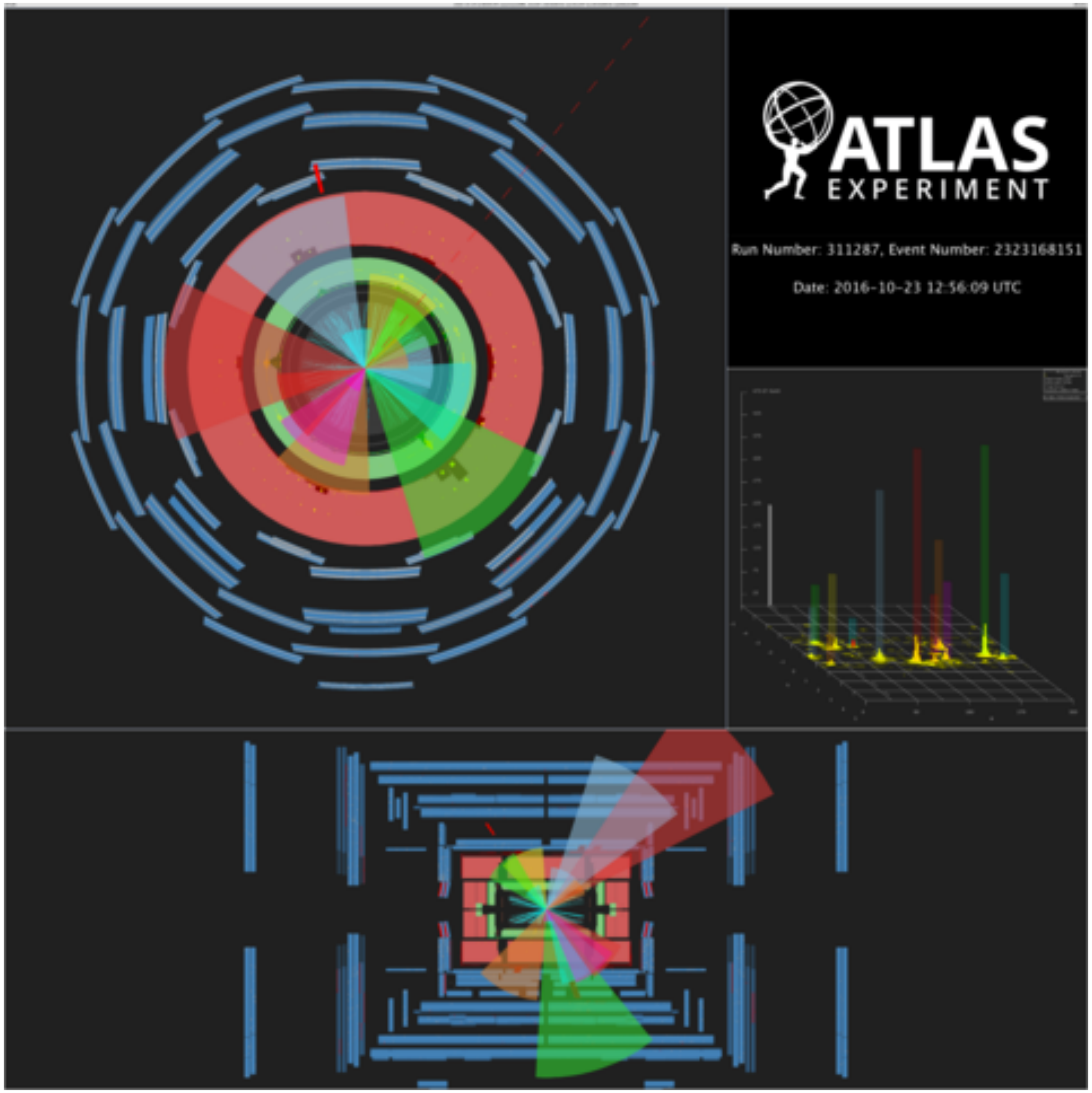
$$H_T = \sum p_{T,\mathrm{jet}}$$

Two analysis streams
Flavour: select b-jets

MJSigma: makes use of jet reclustering

$$M_J^{\Sigma} = \sum_j m_j^{R=1.0}$$

In reality …



13-jet event reconstructed in the ATLAS calorimeter !

What obscures our signal ?

Split background into two categories:

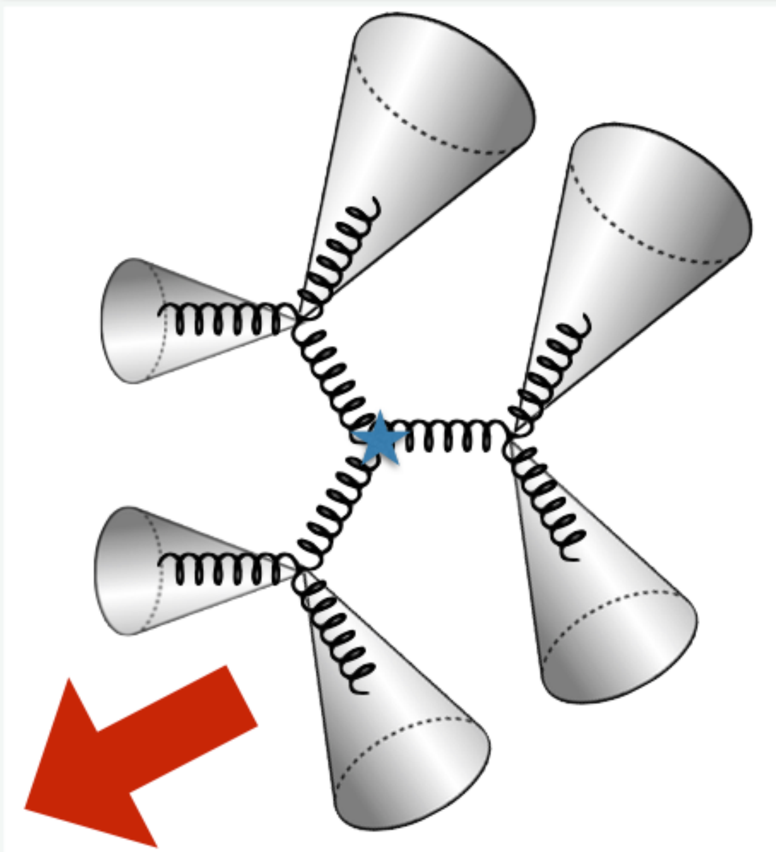
Multi-jet

Fully hadronic *tt*
—> Cannot be estimated with MC

“Leptonic”

Backgrounds producing a lepton (which escapes the veto we apply)
—> Can be estimated with MC
Semi-leptonic *tt*
W + jets
Smaller backgrounds

QCD multijet event



Gain **artificial MET** from mismeasured jets
-> low MET significance

Signal regions: select high MET significance

High Jet Multiplicity Signal Regions

Criterion	Heavy-flavour channel		Jet mass channel
Jet $\|\eta\|$	< 2.0		
Jet p_{T}	$>$50 GeV	$>$80 GeV	$>$50 GeV
N_{jet}	$\geq 8, 9, 10, 11$	$\geq 7, 8, 9$	$\geq 8, 9, 10$
Lepton veto	No preselected e or μ after overlap removal		
b-jet selection	p_{T} $>$50 GeV and $\|\eta\| < 2.0$		
Large-R-jet selection	p_{T} $>$100 GeV and $\|\eta\| < 1.5$		
$N_{b\text{-tag}}$	$\geq 0, 1, 2$		≥ 0
M_{J}^{Σ}	≥ 0		$\geq 340, 500\,\mathrm{GeV}$
$E_{\mathrm{T}}^{\mathrm{miss}}/\sqrt{H_{\mathrm{T}}}$	$> 5\,\mathrm{GeV}^{1/2}$		

Signal regions (SRs) are constructed from 7, 8, 9, 10, and 11 inclusive jets (leptons vetoed). Two channels:

•"**Heavy-flavour channel**": 0, 1, and 2 inclusive *b*-jets are required.

High Jet Multiplicity Signal Regions

Criterion	Heavy-flavour channel		Jet mass channel
Jet $\|\eta\|$	< 2.0		
Jet p_{T}	>50 GeV	>80 GeV	>50 GeV
N_{jet}	$\geq 8, 9, 10, 11$	$\geq 7, 8, 9$	$\geq 8, 9, 10$
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Signal regions (SRs) are constructed from 7, 8, 9, 10, and 11 inclusive jets (leptons vetoed). Two channels:

•"**Jet mass channel**": Jets are **reclustered** into larger fat-jets, uses the total fat-jet mass per event (M_{J}^{Σ}).

Backgrounds and How to Control Them

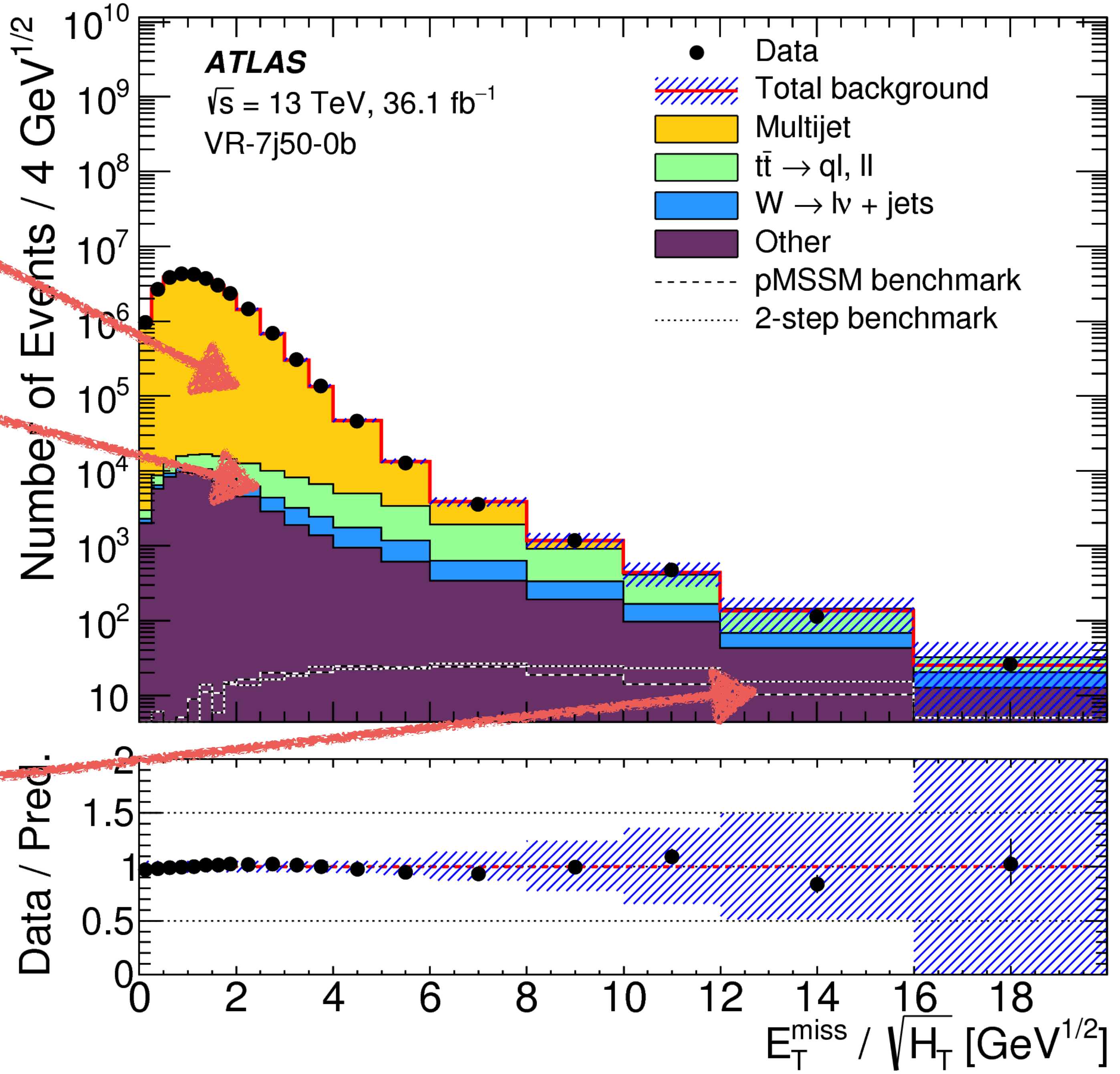
Major backgrounds:

- **Multi-jet background**: QCD multi-jets and fully-hadronic top production.
- **Leptonic backgrounds**.

Large multi-jet background at moderate E_T^{miss} significance.

Sufficiently large E_T^{miss} significance is our hunting ground for new physics.

The multi-jets background must be estimated using a fully data-driven approach … **the template method**.



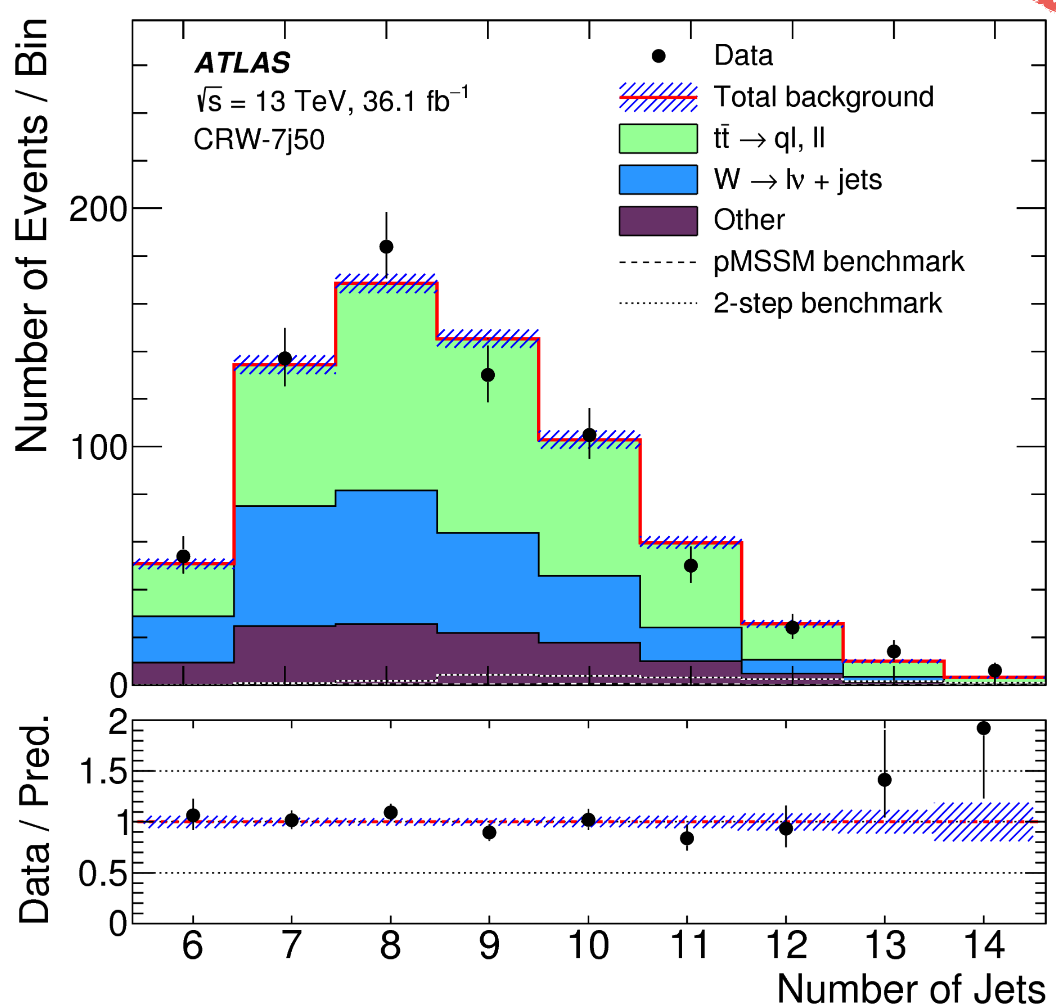
Backgrounds and How to Control Them

CRs for two largest Monte Carlo backgrounds: ***W* +jets and top production + jets,** constructed by **requiring zero and one inclusive *b*-jet respectively**.

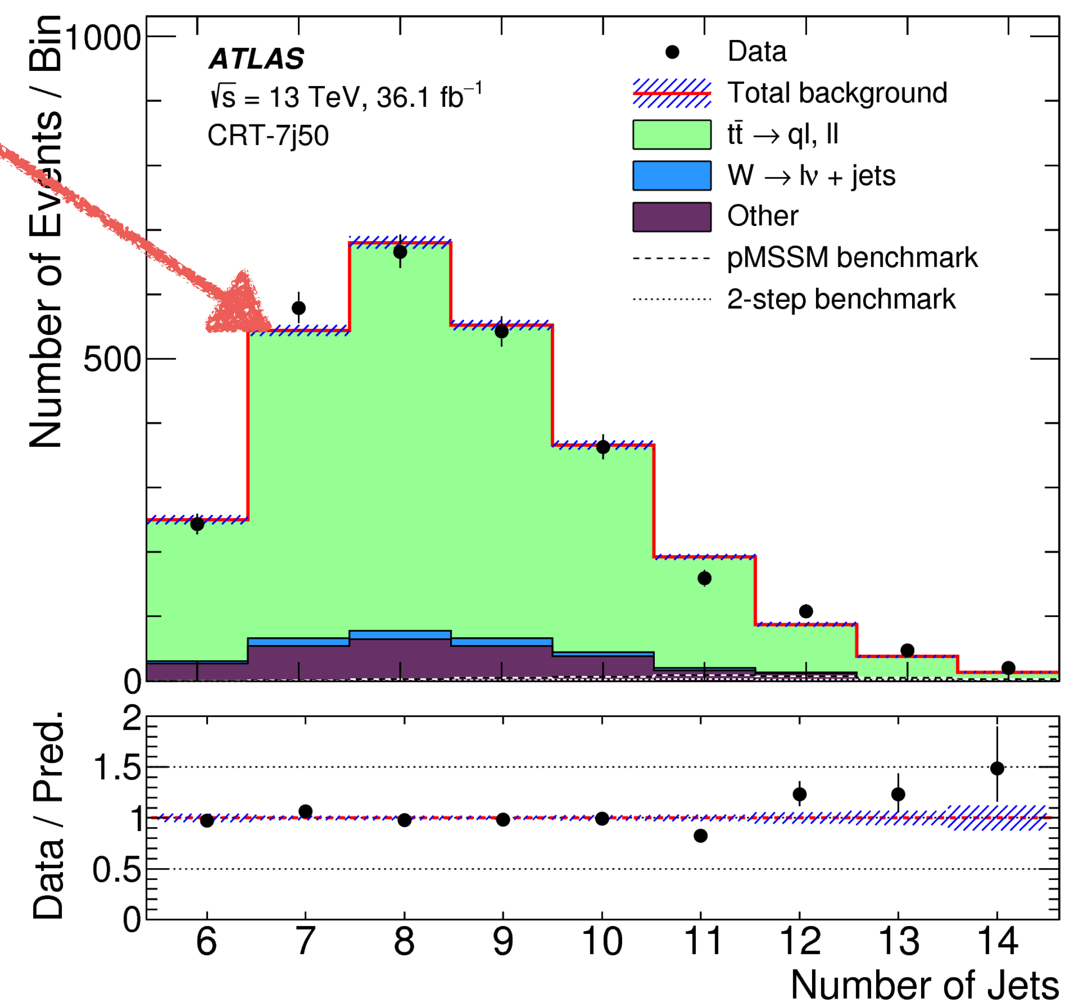
For each N_{jet} SR of jet multiplicity N_{jet}, an **N_{jet}-1 CR** is calculated for the *W*+jets and hadronic top backgrounds.

These CRs provide normalisations to the yields from the **largest MC backgrounds**.

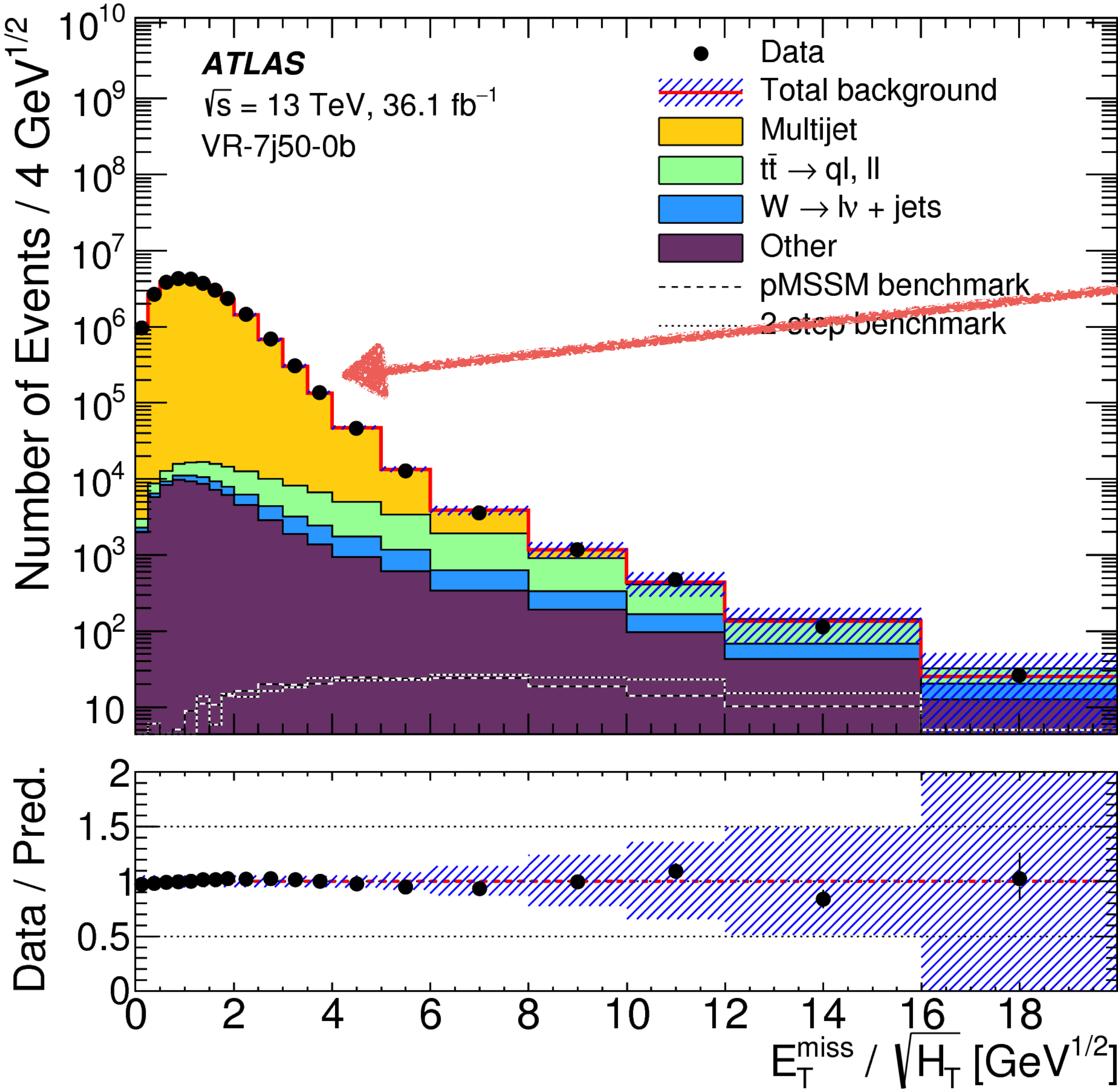
W+jets CR



Top CR



The Template Method



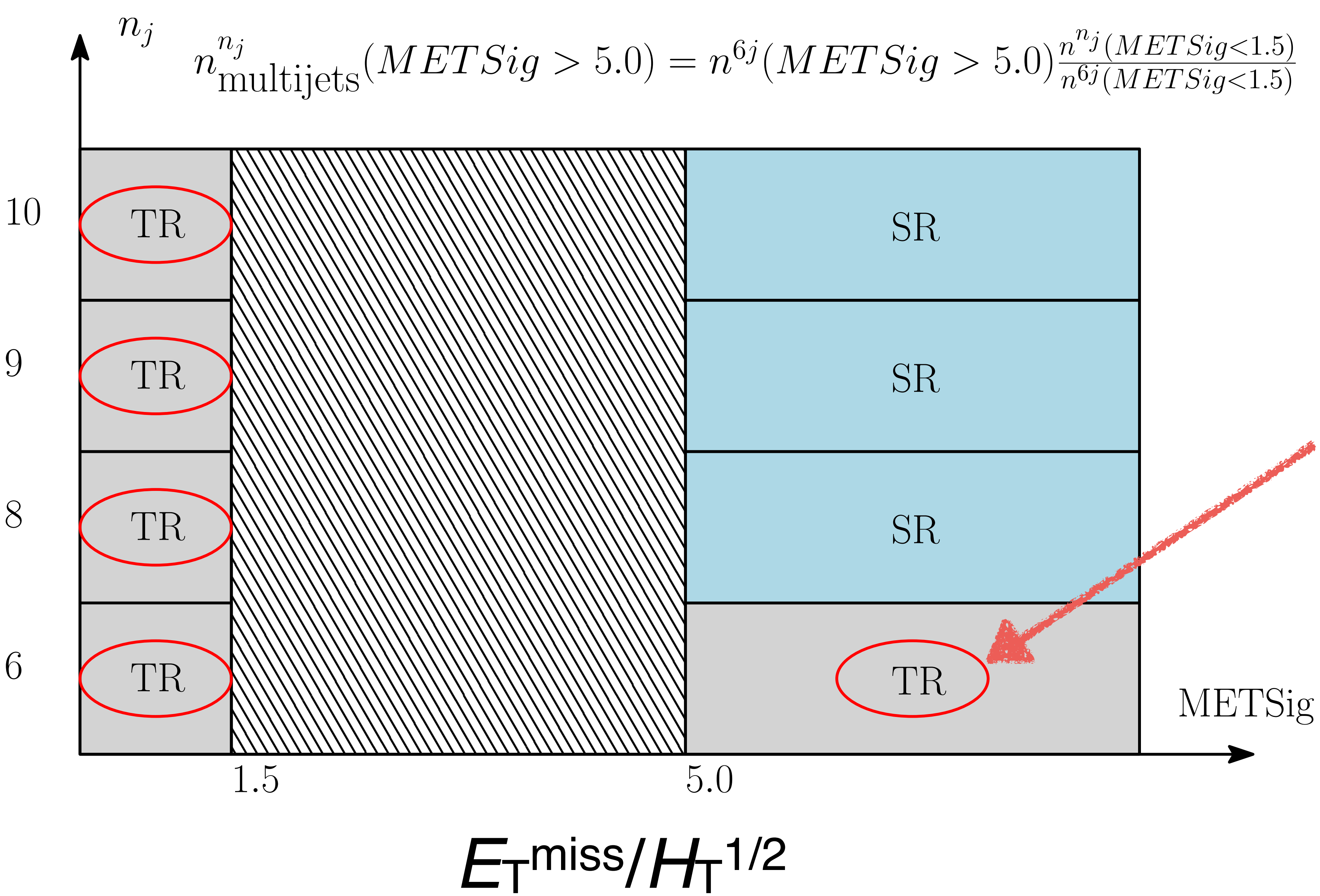
Fully data-driven multi-jet background estimation.

E_T^{miss} significance shape is **approximately invariant** under different (high) jet multiplicities.

Calculate the multi-jet contribution in the 6-jet, E_T^{miss} significance > 5 GeV$^{1/2}$ **template region**.

Rescale the shape in each of the signal regions by considering the relative change in size of the multi-jet dominated peak at ***E_T^{miss}* significance < 1.5 GeV$^{1/2}$**.

The Template Method



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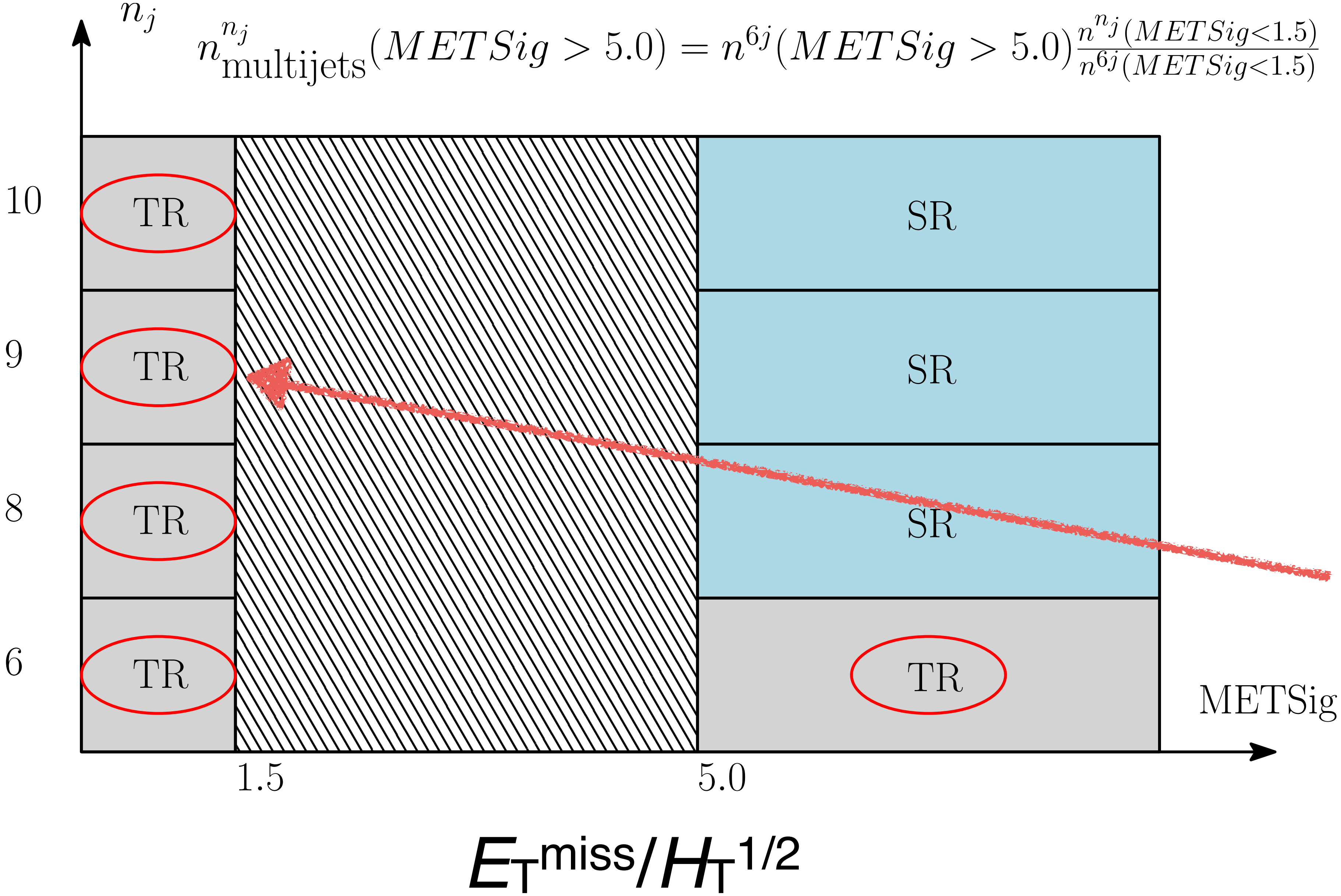
The Template Method

$$n^{n_j}_{\text{multijets}}(METSig > 5.0) = n^{6j}(METSig > 5.0)\frac{n^{n_j}(METSig<1.5)}{n^{6j}(METSig<1.5)}$$



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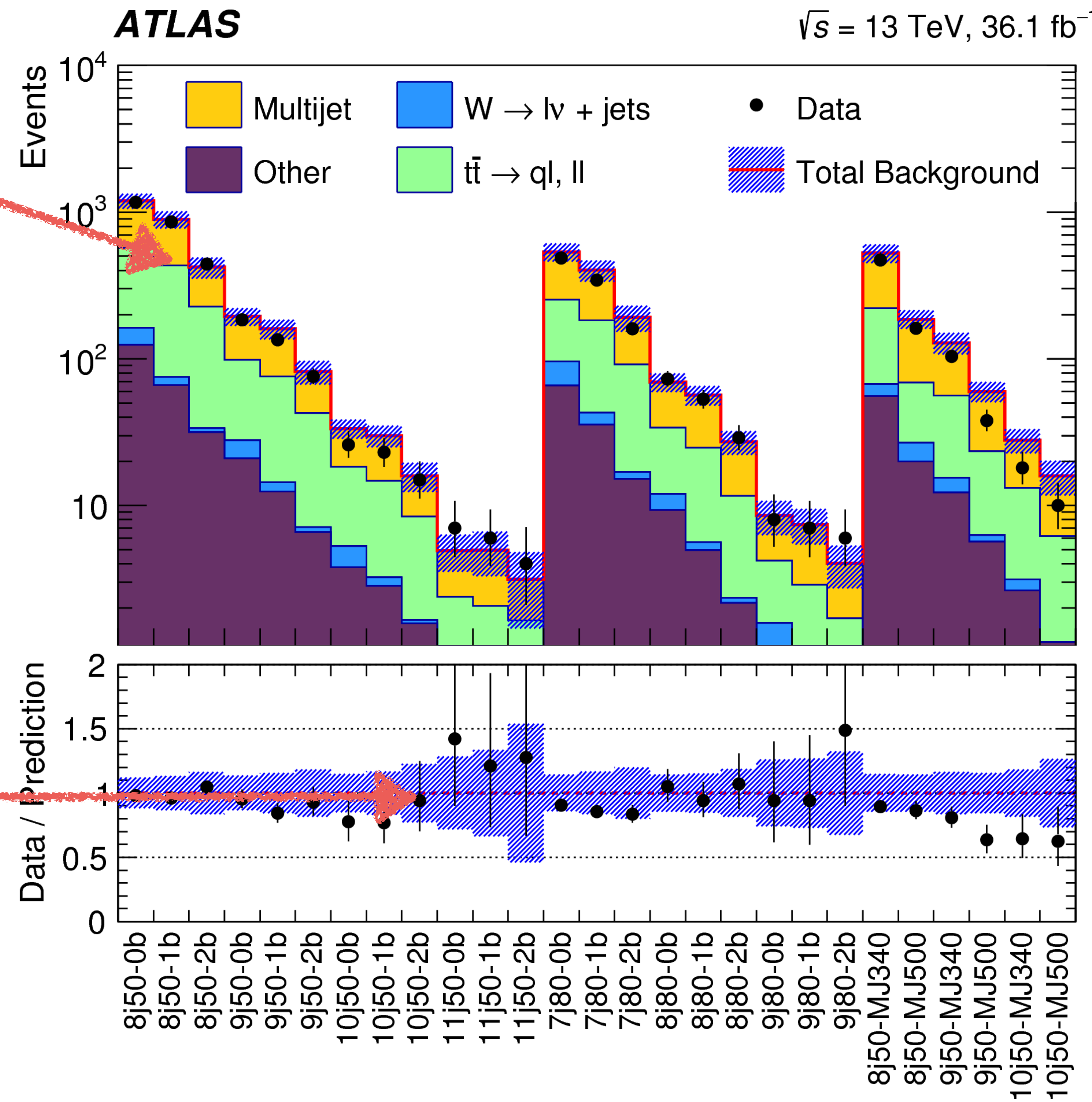
Results with 36.1 fb^{-1} (2015 + 2016)

Yields in each of the 27 signal regions — excellent data/(MC + template) prediction.

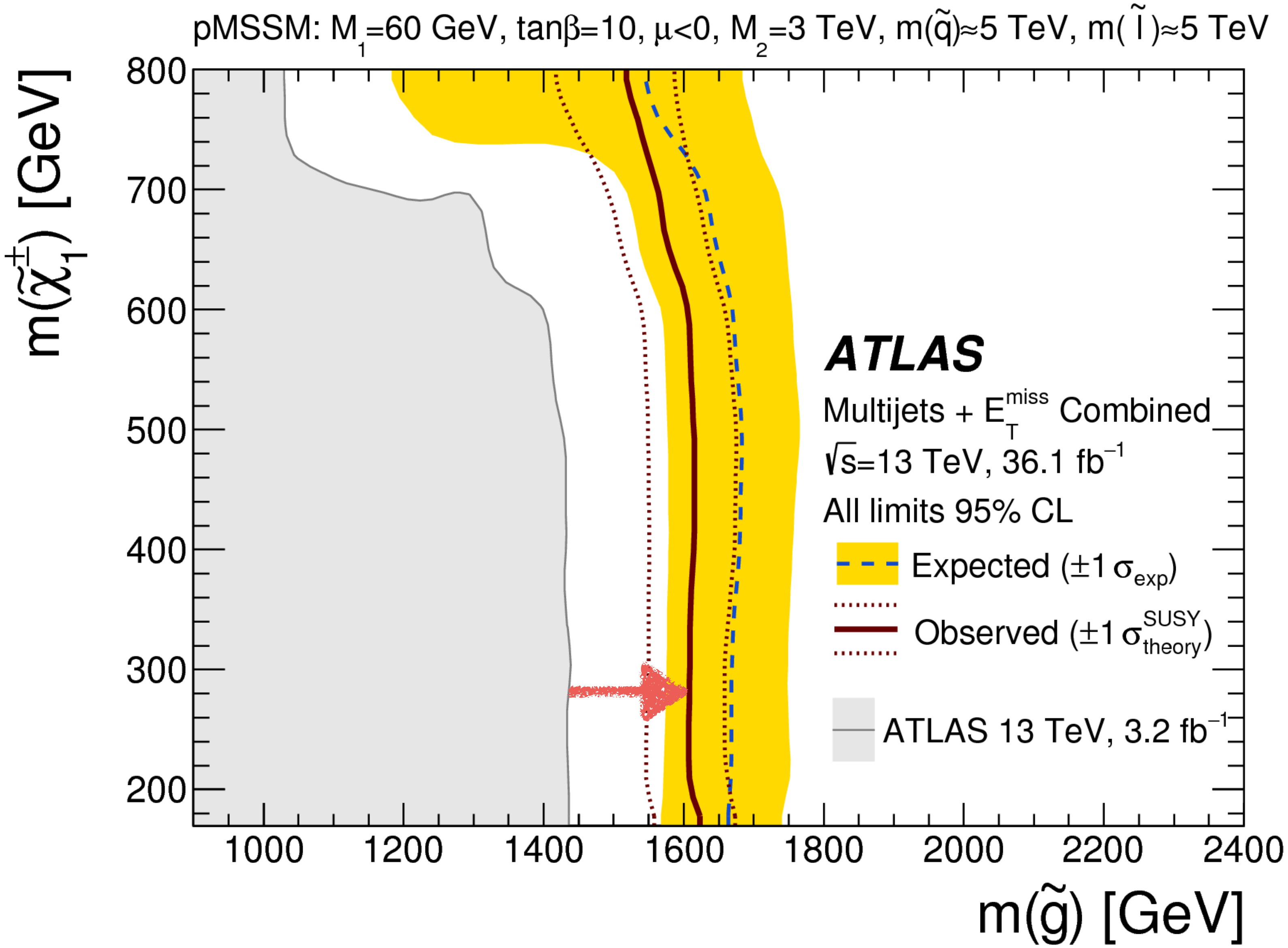
The signal yields in each SR using **2015 + 2016 LHC data**.

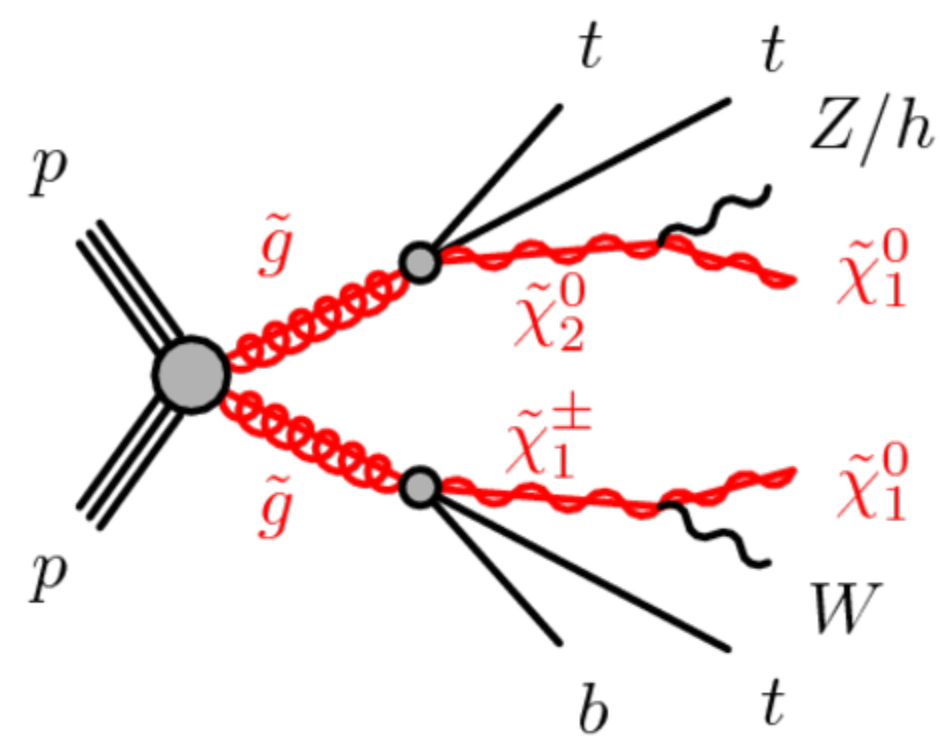
Smoking gun for this new physics search: large SR excesses at moderate E_T^{miss} significance coming from SUSY particle production.

No statistically significant excesses are observed — use this to understand sensitivity to existing SUSY models.



Sensitivity to RPC SUSY

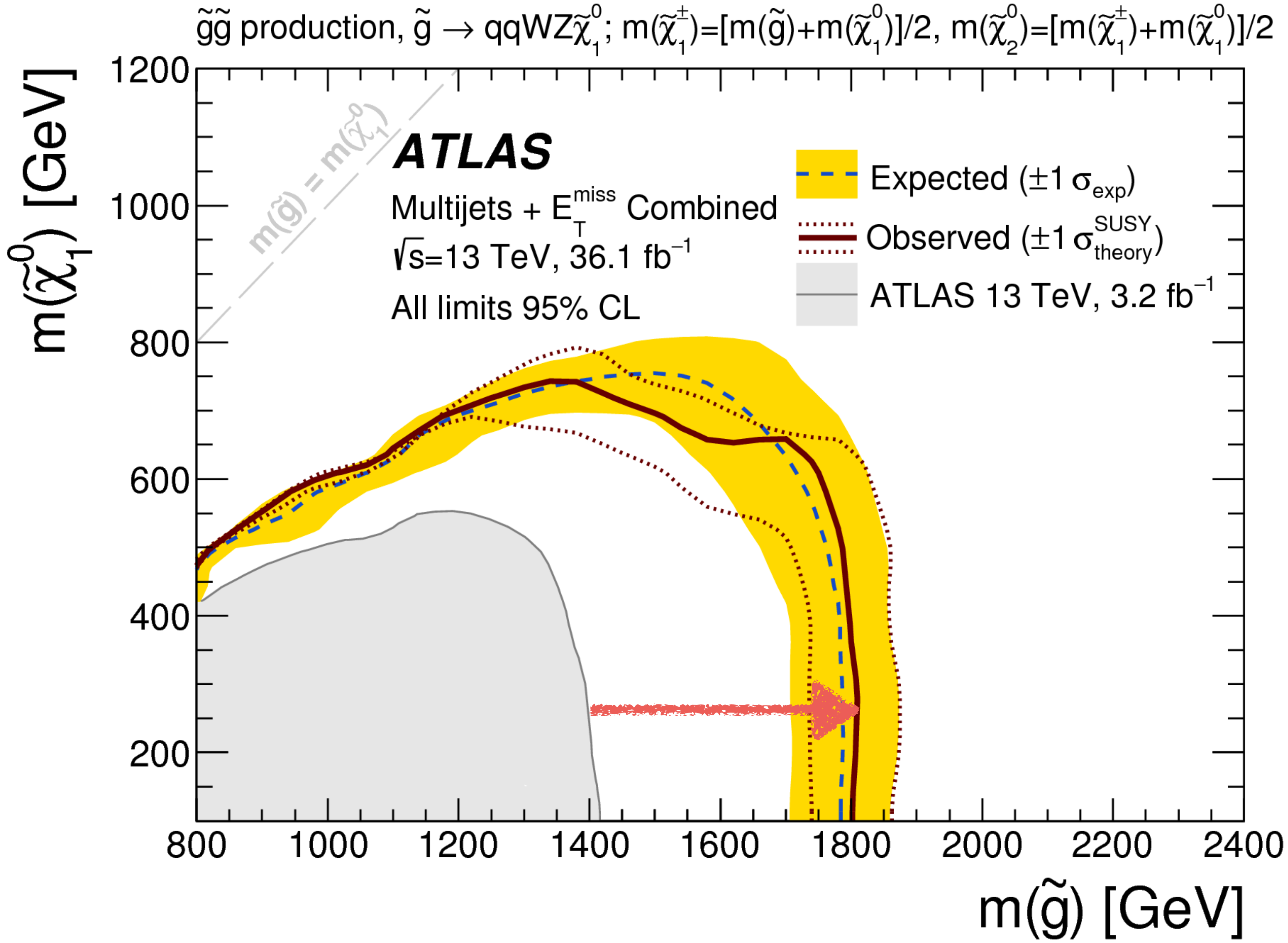


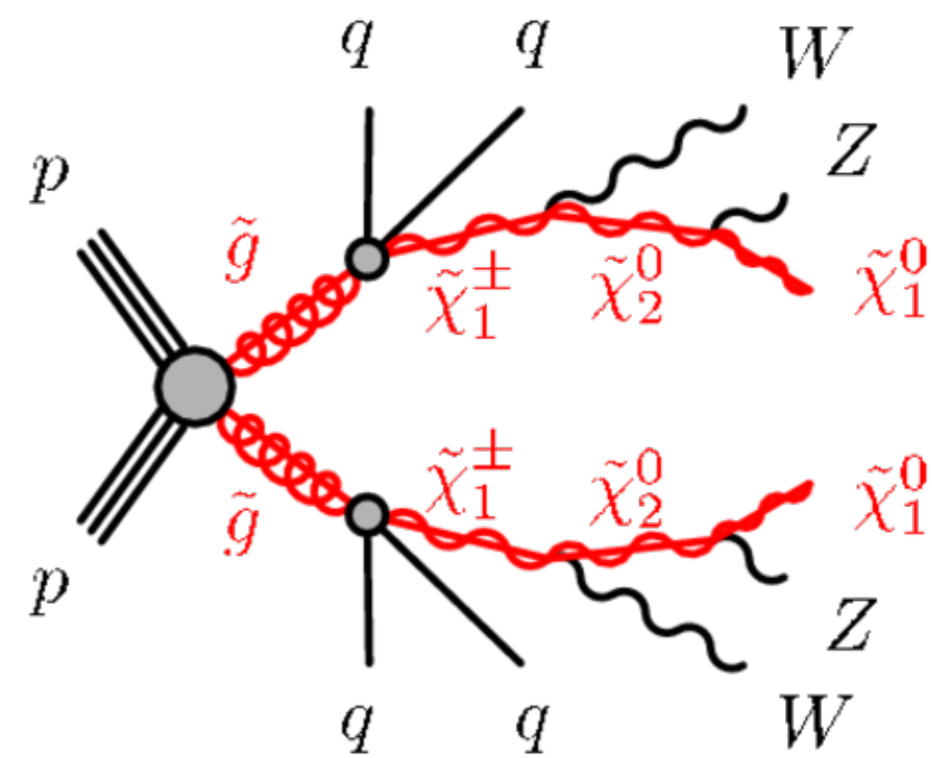


95 % confidence level (CL) exclusion limits are set on different strongly-produced SUSY models: three *R*-parity conserving (pMSSM above), and a fourth model which is *R*-parity violating (RPV) .

Sensitivity to gluino masses extended up to 1.8 TeV.

Sensitivity to RPC SUSY

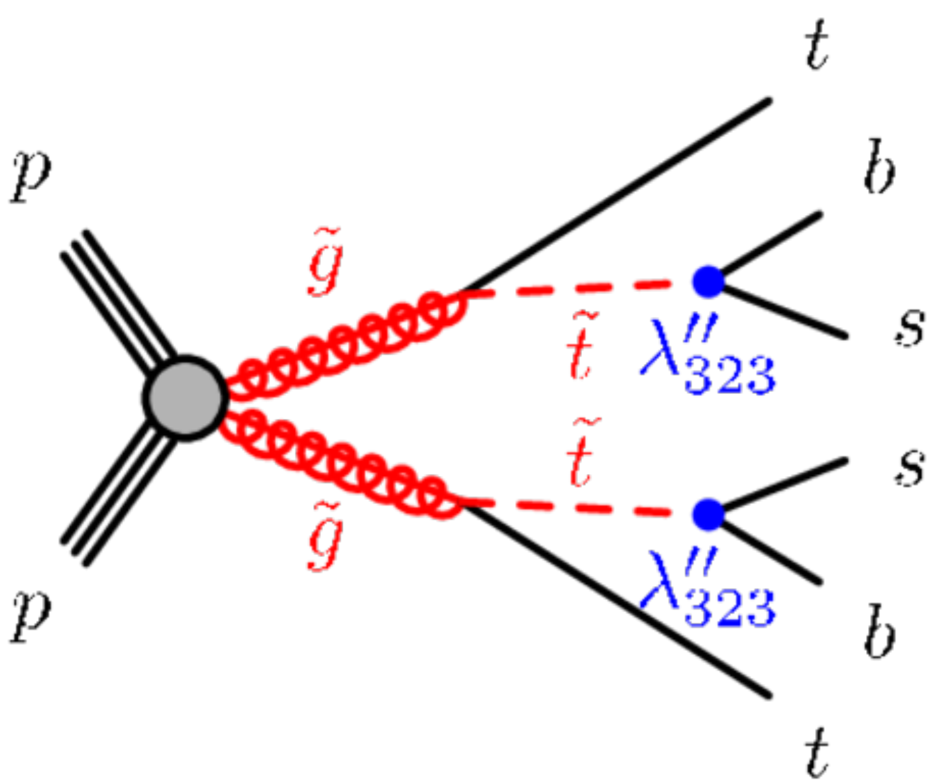


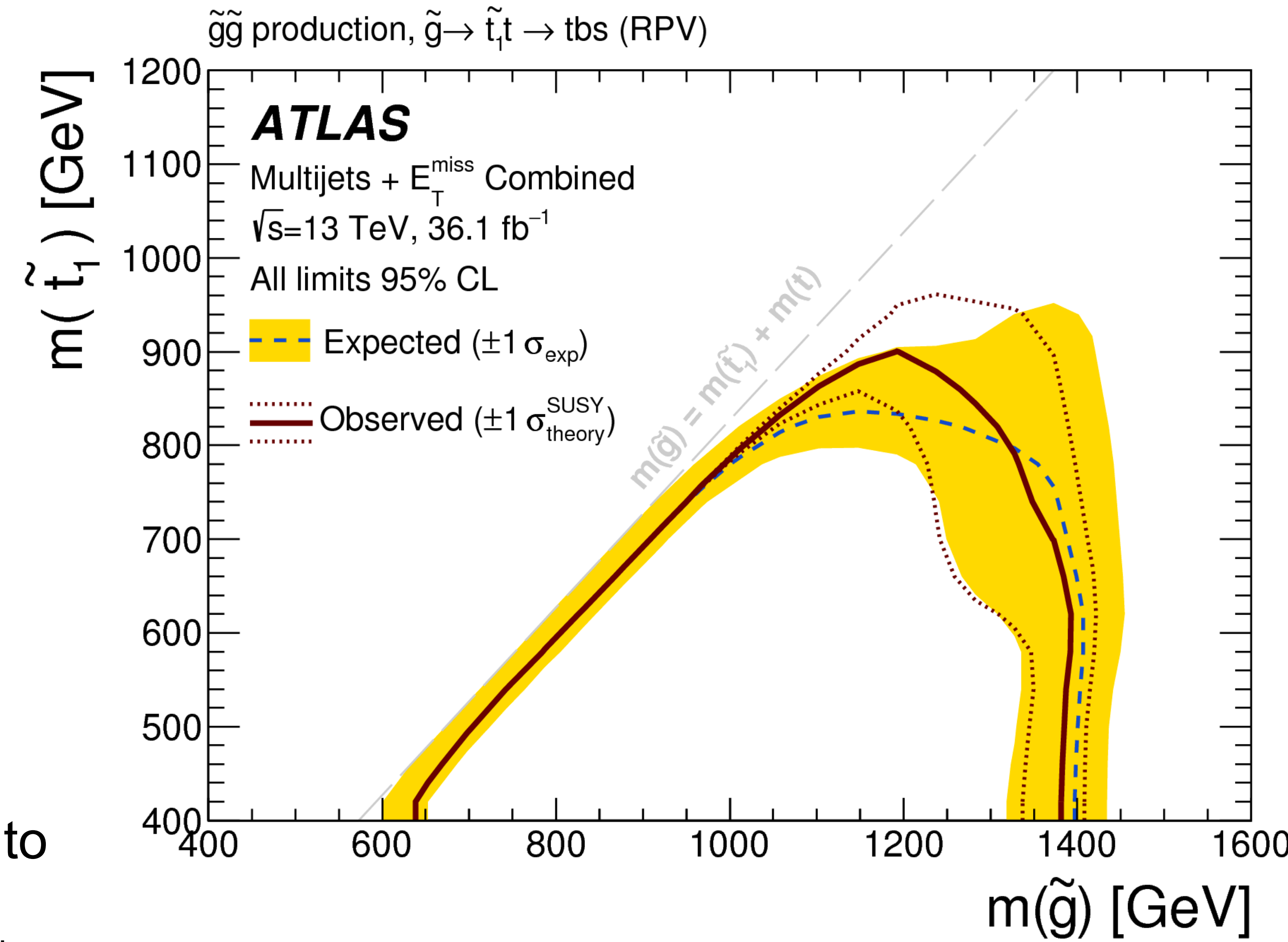


95 % confidence level (CL) exclusion limits are set on different strongly-produced SUSY models: three *R*-parity conserving (2-step above), and a fourth model which is *R*-parity violating (RPV) .

Sensitivity to gluino masses extended up to 1.8 TeV.

Sensitivity to RPV SUSY





RPV: no LSP, **stop undergoes a direct decay into heavy-favour quarks**.

The multi-jets analysis is sensitive to such a model because its SRs contain a small amount of real E_T^{miss}

Other strong-SUSY-motivated analyses, which have an explicit E_T^{miss} cut, are not as sensitive to such RPV scenarios.

Summary JHEP12 (2017) 034

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The **multi-jets analysis is a search for new physics**, motivated by the models of strongly-produced SUSY, where the final states could consist of many hadronic jets.

The search exploits techniques of ***b*-tagging and jet reclustering** in order to enhance the sensitivity to RPC SUSY.

The **non-zero real E_T^{miss}** provides sensitivity to RPV SUSY scenarios.

No statistically significant excesses (consistent by SUSY) have been observed in 36 fb^{-1} of ATLAS data — the sensitivity to gluino mass has been **extended to 1.8 TeV**.

Backup

All Regions

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27 SR in total!

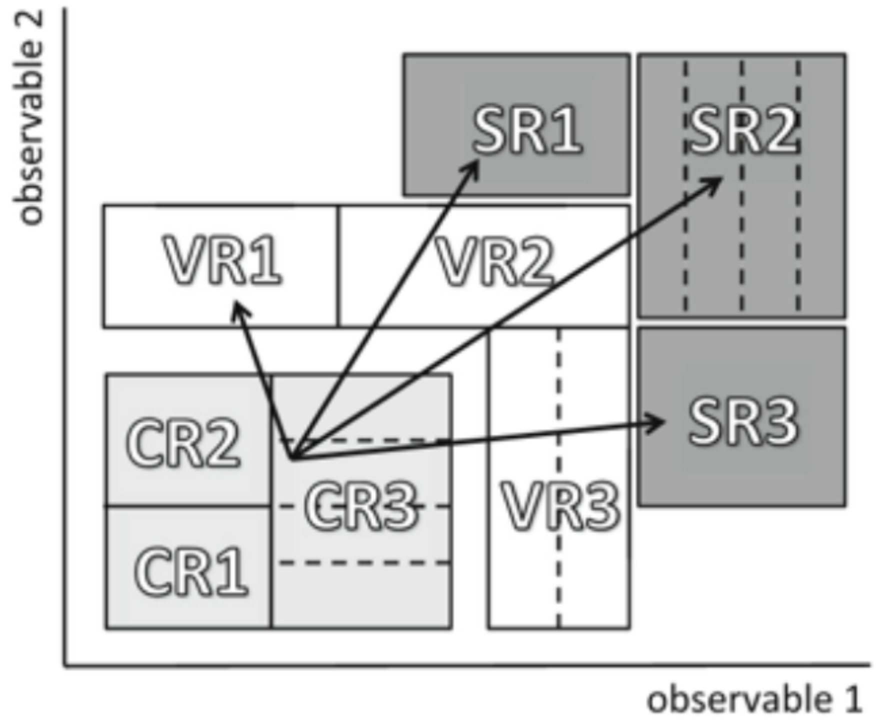
Jet Multiplicity	Jet pT	b-jets / MJSigma	METSig		
==6	50 GeV	0+, 1+, 2+ / > 340, >500	< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
==7			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
>=8			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
>=9			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
>=10			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
>=11		0+, 1+, 2+	< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
==5	80 GeV	0+, 1+, 2+	< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
==6			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
>=7			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
>=8			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$
>=9			< 1.5 $GeV^{1/2}$	1.5—4.0 $GeV^{1/2}$	> 5 $GeV^{1/2}$

Key: control regions, validation regions, signal regions

Control Region Strategy

- ttbar and W+jets background are estimated in the SR with MC
- The prediction is then improved via a fit to dedicated control regions (CR)
- The CR select exactly 1 lepton, and have Njet 1 fewer than the corresponding Signal Region
- Extract scale factors to modify the background prediction in the SR
- mT cut to reduce signal contamination
- Other cuts the same or as close as possible to SR

Control regions	
Trigger (50 GeVregions)	HLT_6j45_0eta240
Trigger (80 GeVregions)	HLT_5j70 || HLT_5j65_0eta240
Lepton p_T	> 20 GeV
Lepton multiplicity	Exactly one, $\ell \in e, \mu$
m_T	< 120 GeV
Jet p_T	Same as SR
Jet $\|\eta\|$	< 2.0
Number of jets including lepton	$N_{SR} - 1$
b-jet multiplicity	$= 0$ (W) or ≥ 1 ($t\bar{t}$)
M_J^{Σ}	Same as SR
$E_T^{miss}/\sqrt{H_T}$	$> 3, 4, 5$ GeV$^{1/2}$



Systematics

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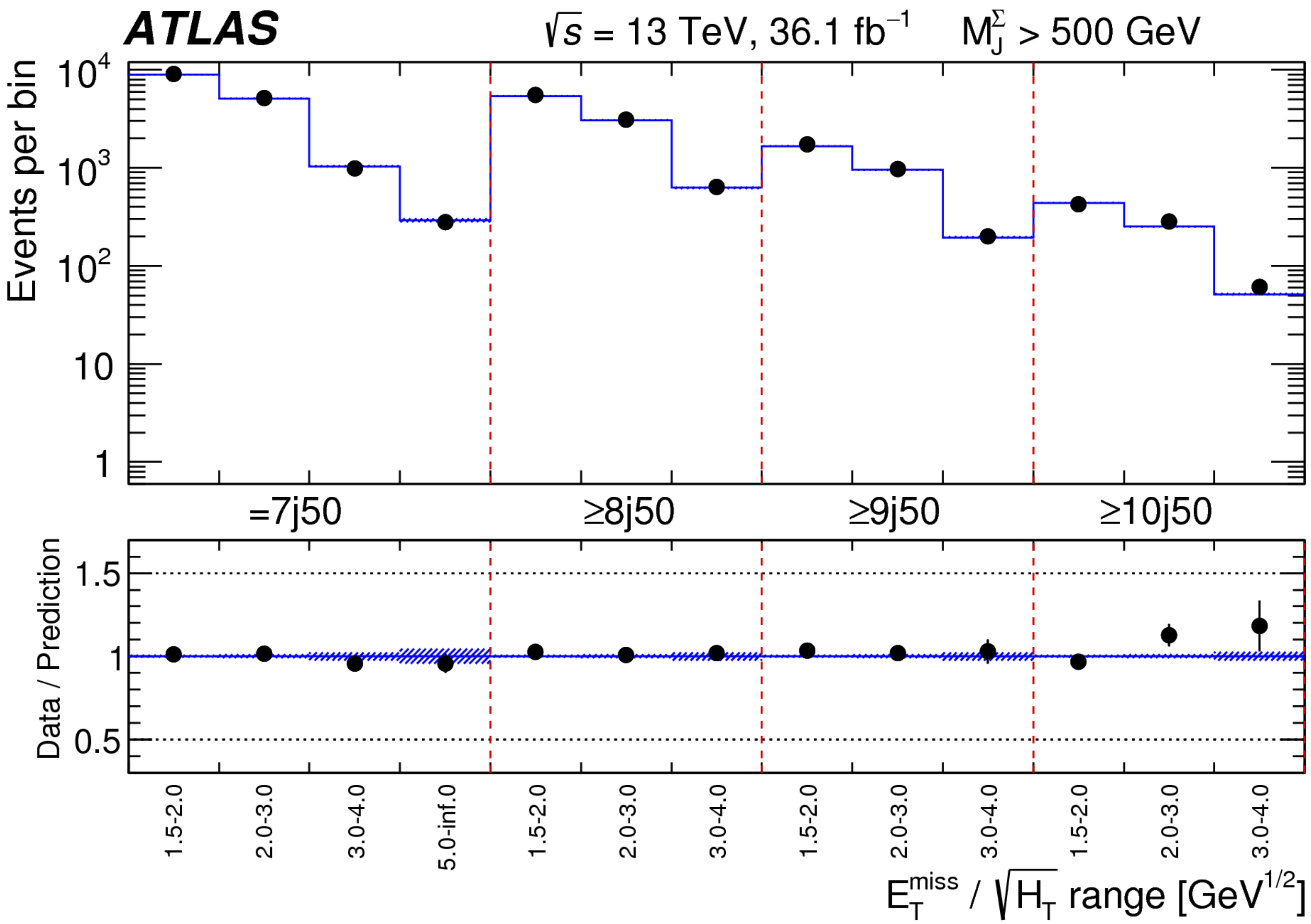
- Normal detector and theory systematics are taken into account for the MC backgrounds
- For the multijet background estimate, three systematic uncertainties are calculated:
  - HT binning: A variation in the binning scheme
  - Closure systematic
  - Flavour systematic

Systematics

- Use the difference between the template prediction and the data in several validation regions:
  - bins of low METSig [1.5—2.0—3.0—4.0]
  - METSig > 5 at jet multiplicities 1 lower than the signal region
- For SR with njet=N, the systematic is the largest deviation in any of these VRs with njet≤N



Systematics