EFT: the analysis approach and implementation in generators

Cen Zhang

- SM Lagrangian supplemented with DIM-6 operators (hence SMEFT)

$$\mathcal{L}_{\mathrm{EFT}} = \mathcal{L}_{\mathrm{SM}} + \sum_i \frac{C_i O_i}{\Lambda^2}$$

- The physics goal is to **determine the SM Lagrangian at Dim-6.**

IMPLEMENTATIONS

UFO

EFT with MG5

all you can do with the SM can be done with higher- dim operators.

EFTs with Sherpa

- First EFT applications with tree-level merging
- First steps towards fixed-order NLO with OpenLoops

EFT with Whizard

SM EFT at Dim-6, Some Dim-8 operators available

EXAMPLES

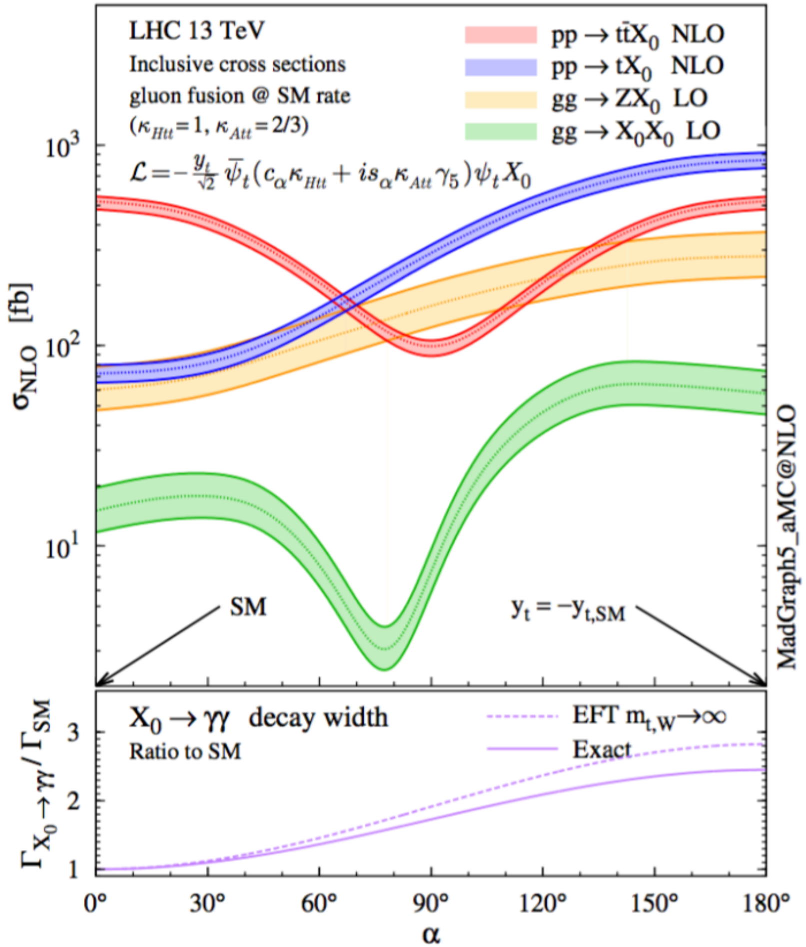
Top EFT

Multi-vector boson

Higgs Eff. Lagrangian

...and many more

Going to NLO in QCD with EFT



On going developments:
HEL at NLO
(Degrande, Fuks, Mawatari, Mimasu, Sanz)

Top FFT

Flavor-conserving / Flavor-changing

Process	O_{tG}	O_{tB}	O_{tW}	$O^{(3)}_{\varphi Q}$	$O^{(1)}_{\varphi Q}$	$O_{\varphi t}$	$O_{t\varphi}$	O_{4f}	O_G	$O_{\varphi G}$
$t \to bW \to bl^+\nu$	X		X	X				X		
$pp \to t\tilde{q}$	X		X	X				X		
$pp \to tW$	X		X	X				X	X	X
$pp \to t\bar{t}$	X						X	X	X	X
$pp \to t\bar{t}\gamma$	X	X	X				X	X	X	X
$pp \to t\gamma j$	X	X	X					X		
$pp \to t\bar{t}Z$	X	X	X	X	X	X	X	X	X	X
$pp \to tZj$	X	X	X	X	X	X		X		
$pp \to t\bar{t}h$	X						X	X	X	X
$pp \to t\bar{j}h$	X						X	X		X
$gg \to H, HZ$	X			X	X	X	X			X

Process	$O^{(3)}_{\phi q}$	$O^{(1)}_{\phi q}$	$O^{(1)}_{\phi u}$	O_{uW}	O_{uB}	O_{uG}	$O_{u\phi}$	O_{4f}
$t \to qZ^*, \gamma^* \to ql^+l^-$	X	X	X	X	X	X		X
$t \to q\gamma$				X	X	X		
$t \to qH$						X	X	
$pp \to t$						X		X
$pp \to tZ$	X	X	X	X	X	X		X
$pp \to t\gamma$				X	X	X		X
$pp \to tH$						X	X	X

eventually full SMEFT@NLO can be expected.

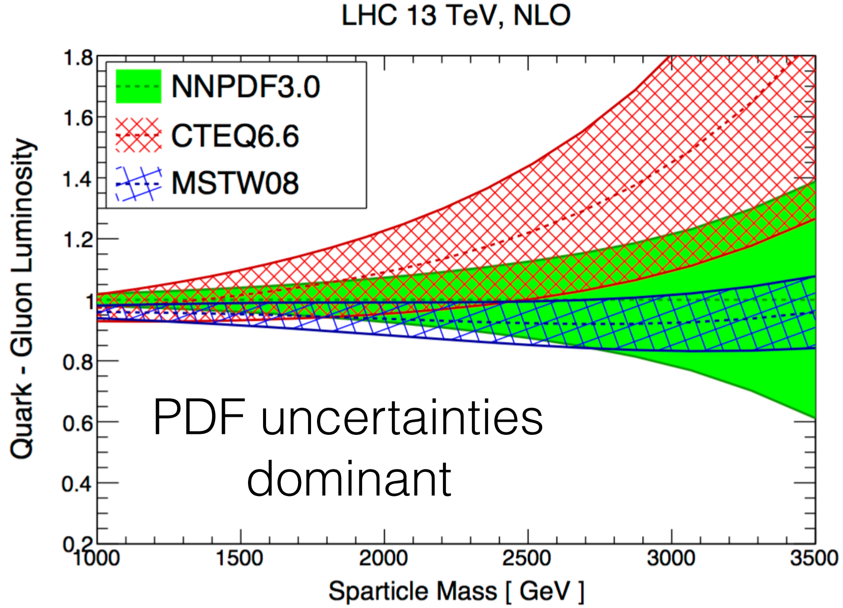
QCD corrections to SUSY particle production at the LHC

Michael Krämer

Squark and gluino production

- large cross sections
- largely model-independent
- large higher-order QCD effects

The cross sections only depend on the SUSY masses



NLO-QCD corrections for generic MSSM spectra

→ Effect of O(10%) on σ x BR for generic MSSM benchmark scenarios

Hollik, Lindert, Pagani; Goncalves-Netto, Lopez-Val, Mawatari, Plehn, Wigmore, Gavin, Hangst, MK, Mühlleitner, Pellen, Popenda, Spira

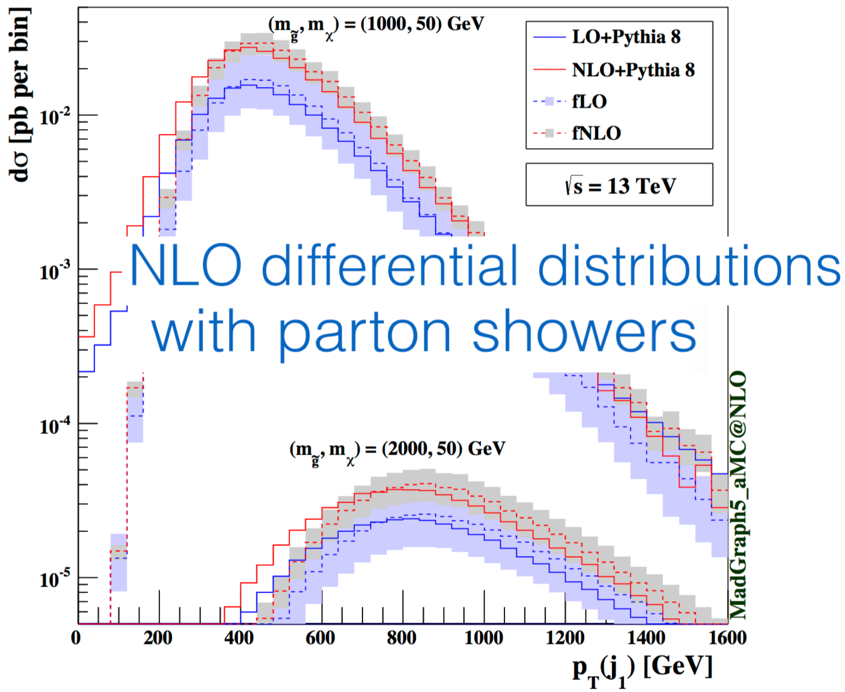
EWK corrections (EWK loops, EWK x QCD, γ-induced processes)

→ model dependent

→ O(few %) for inclusive cross sections

→ more significant for specific processes and large Q^2

see e.g. Hollik, Lindert, Mirabella, Pagani (1506.01052 [hep-ph]) and references therein



Squark and gluino production: tools

Prospino, NLL-fast, MadGolem, sPOWHEG, MadGraph5_aMC@NLO, …

The LHC SUSY cross section working group

will

- provide an update of the SUSY cross section recommendation at NNLL, and including recent pdfs;
- quantify the difference between Mellin space ↔ SCET resummation;
- collect benchmark results for EWK corrections;
- provide links to NLO SUSY tools, together with benchmark results for validation.

Squark and gluino production

A lot of effort (> 20 years) went into calculating higher-order QCD corrections for squark and gluino production

The theoretical uncertainty for inclusive cross sections is $\lessapprox$ 15%, and is now dominated by the pdf error

In the future, we need to work towards automated NLO calculations for more generic models, including NLL resummation

Exotica Monte Carlo and formats for reporting results

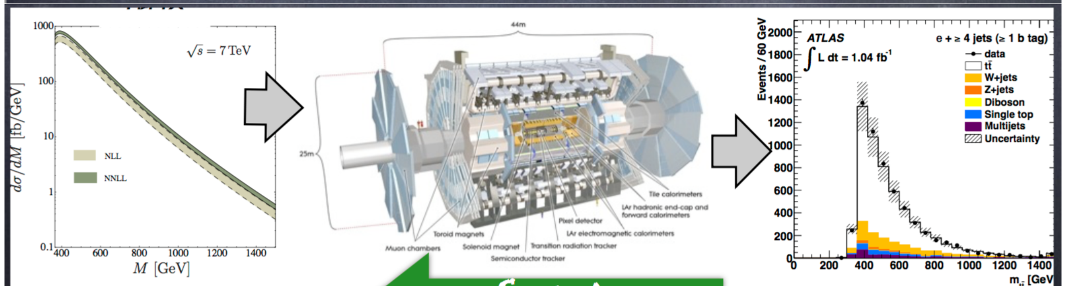
Maurizio Pierini

- Three messages to convey
  - Common repository for MC samples (a new MCDB)
  - Official detector simulation to fold detector effects
  - (Even better) supporting RECAST to use official MC/analysis tool (also good for long-term preservation)

Parton Shower

LHE files → particle 4mom → GEN +SIM → gen-particle hits in detector → DIGI +RECO → reco-hits in detector → Analysis

Experiment Framework



Unfolding

7

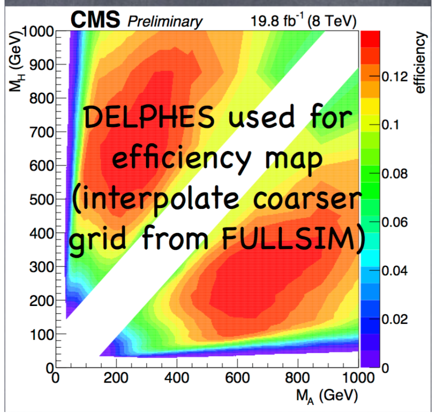
~~Un~~folding

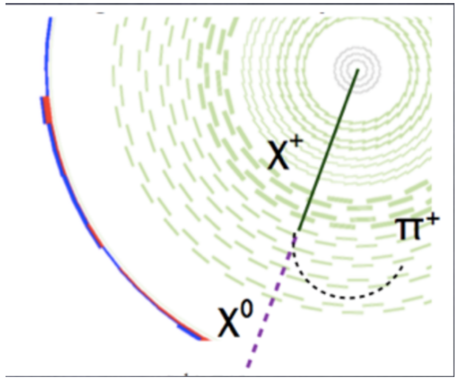
9

An Official Detector Parameterisation?

- Often, inaccuracy on detector resolution is the perturbation
- Sometimes the signature is more detector specific

CMS-PAS-HIG-15-001





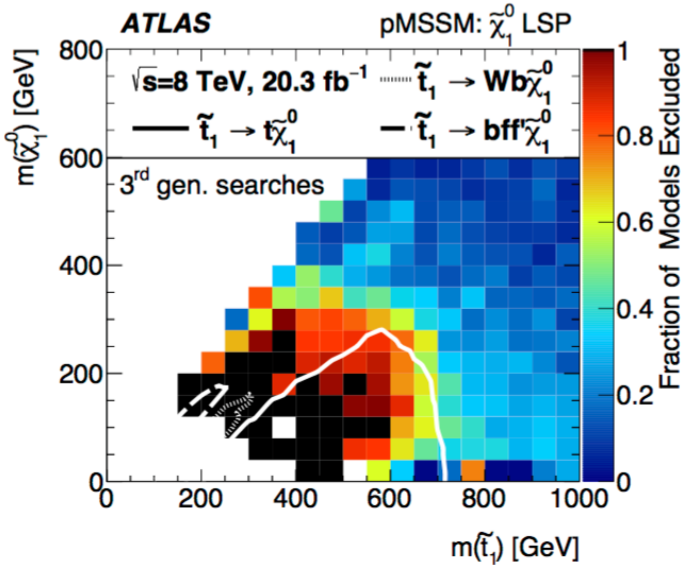
Having the likelihood, would be IMPORTANT

- For the Experiments:
  - use of LHE files makes easier to integrate generators in experimental frameworks
  - **A common repository** (of LHE files? Gridpacks? UFOs?) would be very beneficial (for analyses and phone studies). A new life for MCDB?
- For Pheno studies:
  - for plain signatures, fastsim MC codes exist
  - integrated with **official detector tuning** by ATLAS & CMS
  - BUT sometimes a "good-enough" fastsim is not enough (e.g. exotic signatures)
- The ultimate solution:
  - a system like **RECAST** would solve the problem of re-producing and re-interpreting results.
  - With a complete RECAST library and enough CPU resources all phone needs would be covered
- Our community should (in my opinion) push **in these directions** more

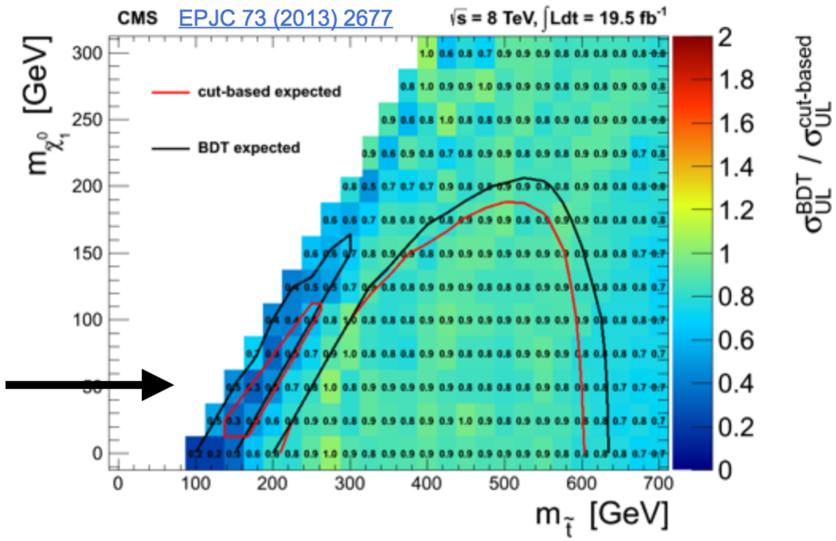
SUSY MC and formats for reporting results

Benjamin Nachman

Complete models



Simplified models



- **Theory Systematic Uncertainties**

  ATLAS: use uncertainties from LHC XS WG (1407.5066)

  CMS: 10% for PDF (based on 100 NNPDF variations), independent fact. and ren. scales, ISR modeling (next slide)

- **(Extra) Radiation**

  ATLAS: Vary ISR/FSR in Pythia for sensitive models/selections only

  CMS: (Re-weight*) and take the uncertainty from Z+recoil and ttbar+recoil measurements

- Both **ATLAS** and **CMS** use unpolarized decay and then re-weight after-the-fact (not the case for ATLAS in Run I)

- **Saving Generation Time: Matrix Element Calculations**
  Detector Sim *Generator Filters*
- **Truth Definitions** The definitions are very similar between **ATLAS** and **CMS**, and likely for SUSY searches the subtle differences are not important.
- **Presentation of results**

Repo for plots and tables: HepData

Repo for plots and tables: CMS public twiki (ROOT files)

ATLAS and CMS (mostly) agree on simulation

As we push further into the new energy frontier, we will have key questions to answer:

When/where do we need more precise simulation?

Compressed spectra? 3- and 4-body decays? When ISR jets are involved? When background looks just like signal?

How can we save disk space and CPU time?

Recycling events, filters, etc.

2015 was a great kickoff to hopefully an exciting investigation of the unexplored at the 13 TeV!

Theoretical status and progress of jet substructure

Gavin Salam

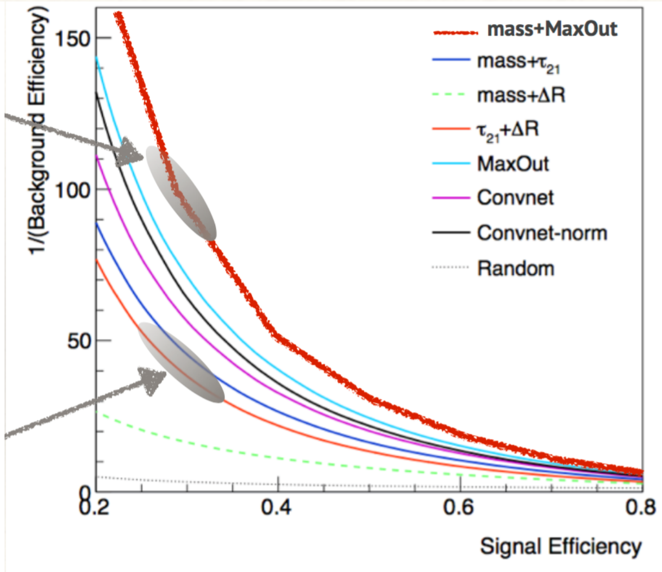
Principles

#1: the jet mass, a fragile observable.

#2: QCD gluon emission is soft; V/H→qq is not

#3: Radiation patterns differ in V/H/top v. QCD

Computer-vision

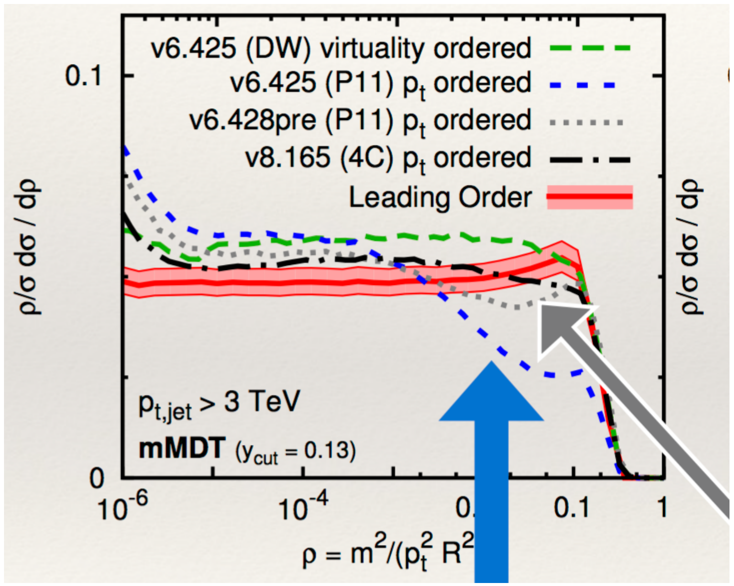


What theory aims?

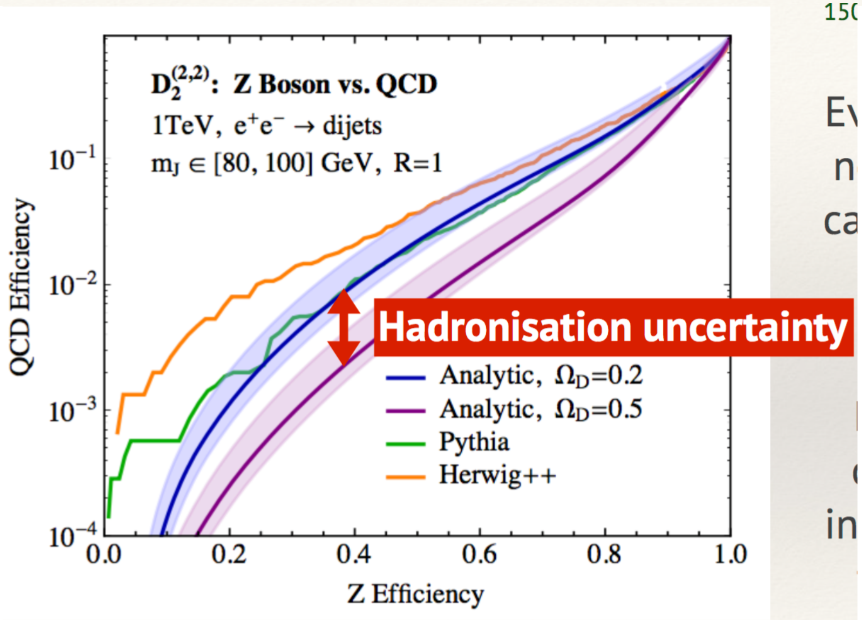
- Develop more powerful methods for discriminating signal/ background
- Understand what physics various "taggers" are actually tagging on:
  - to know whether it's reliably modeled by MCs
  - to know what "features" tagging might induce in data
  - as a guide to developing better tools & for predicting signals & backgrounds

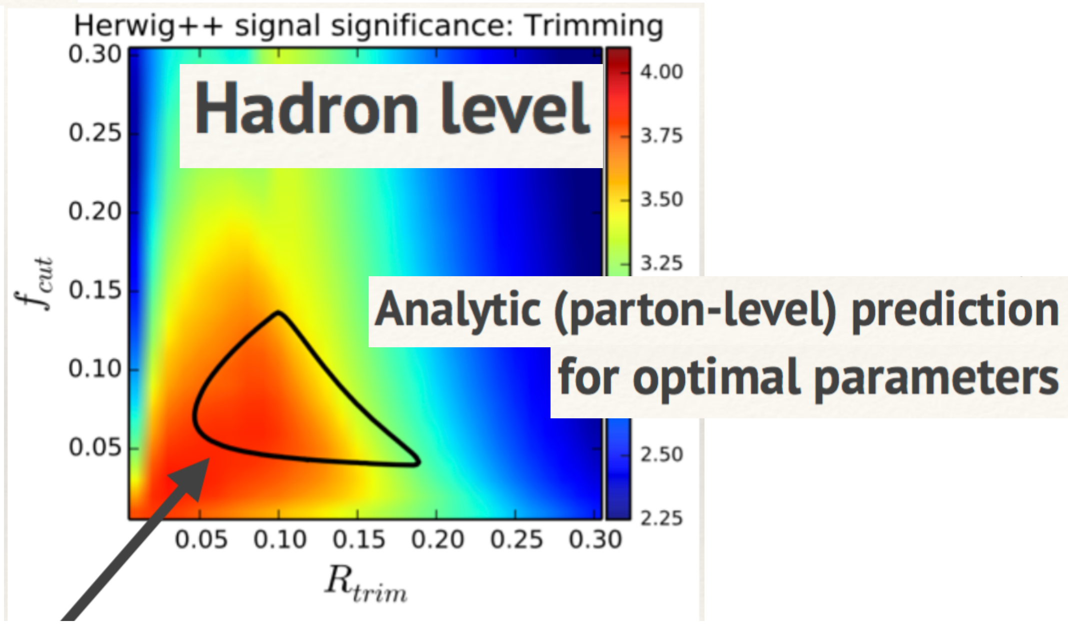
Event generators play key role in testing methods

& theory calculations may teach us things about event generato

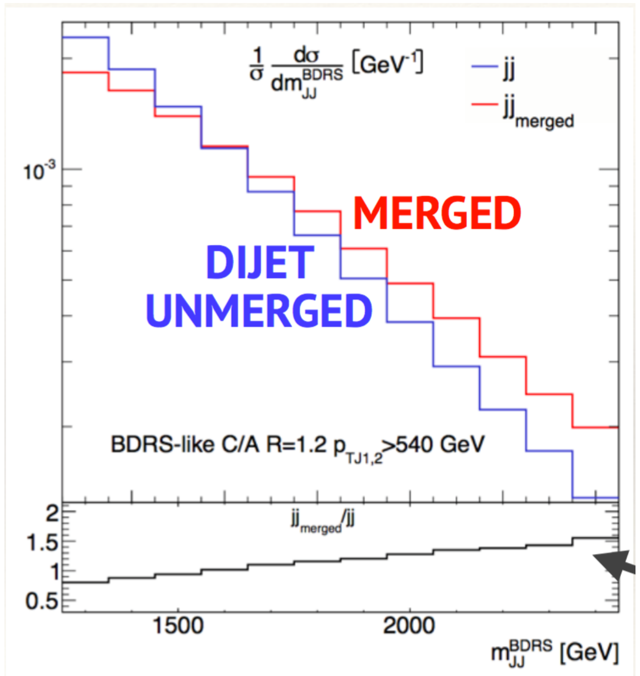


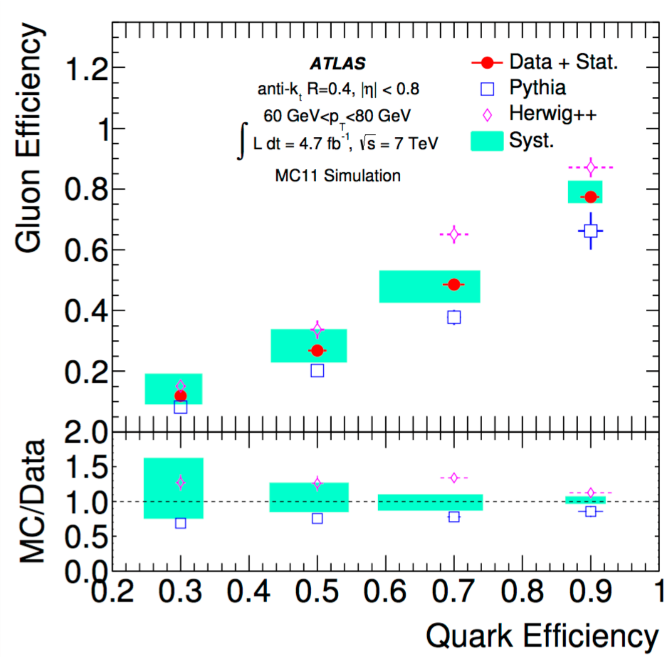
Better discrimination?





Questions



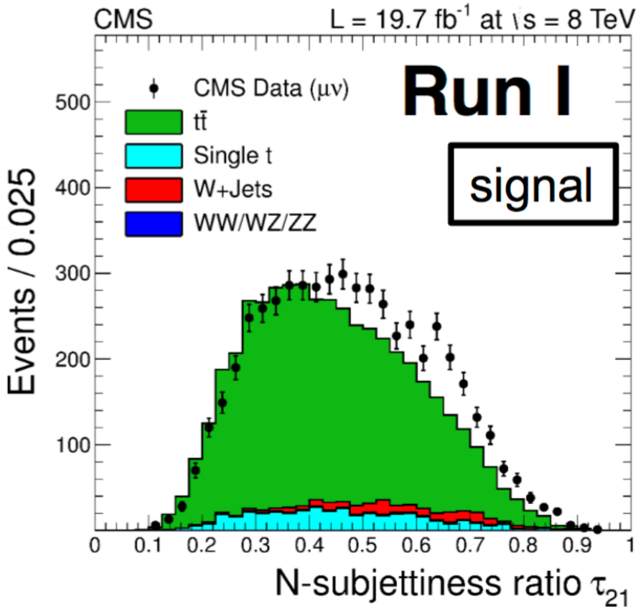


proper evaluation of theoretical uncertainties

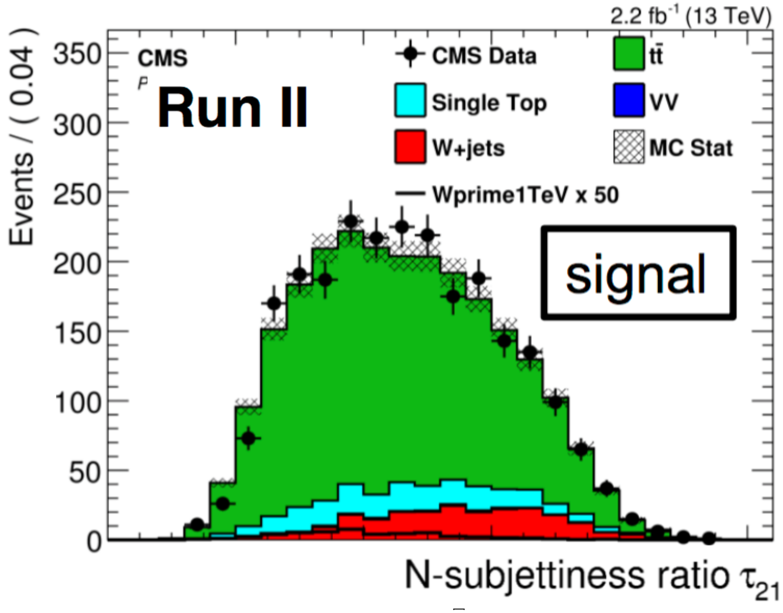
Jet Substructure Tools in CMS

W/Z/H/t

Matthias Mozer

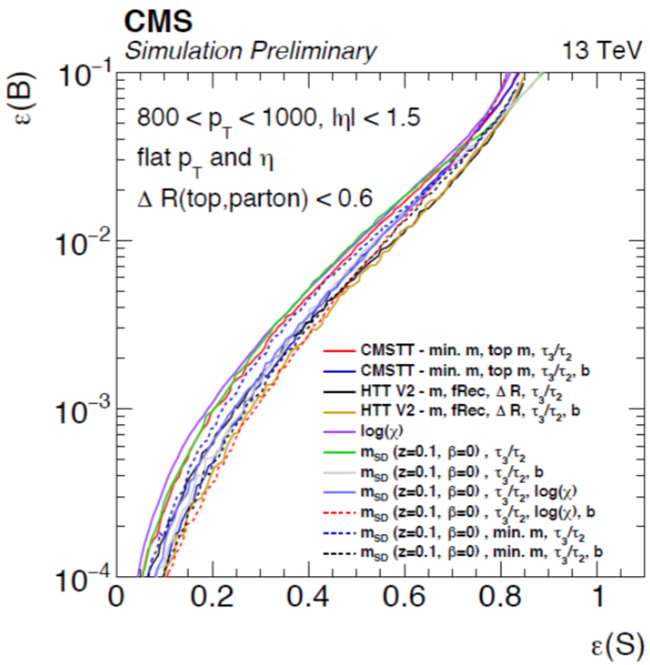


updated:
- reco
- simulation
- Pythia version



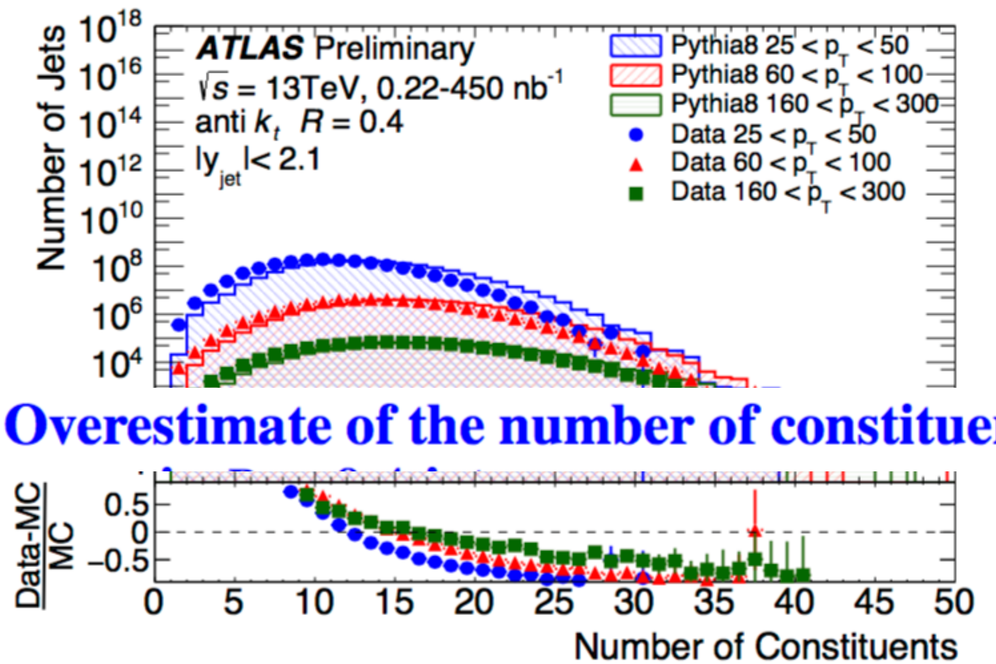
Run II plans

- Significant gains from MVA
  => will need more commissioning work
- Complete revamp **for subjet b-tag**
- CMS-Top-tagger (updated)
- softdrop + PUPPI jet masses



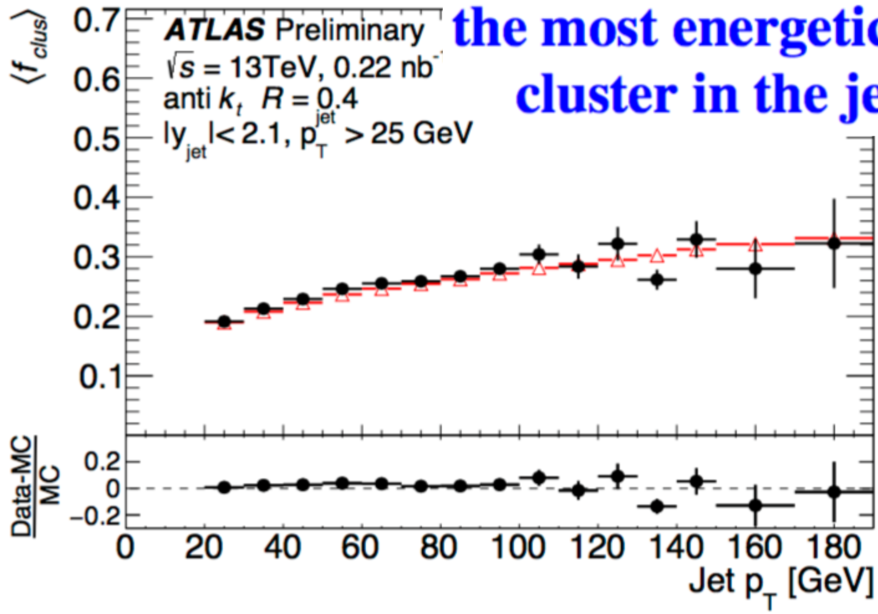
Boosted searches and merged-jet techniques in ATLAS

David W. Miller,



Overestimate of the number of constituents

Accurate description of the fraction of the most energetic cluster in the jet,



- **Accurate description at detector-level of the calorimeter jet width across a substantial range in p_T using the A14 tune**
- **Accurate description of the jet p_T and D_2 in a W/Z+jets dominated final state**
- **Excellent modeling of both the jet mass and τ_{32} for trimmed jets with $p_T > 300$ GeV**
- **Excellent modeling of both the jet mass and D_2 for trimmed jets with $p_T > 200$ GeV**