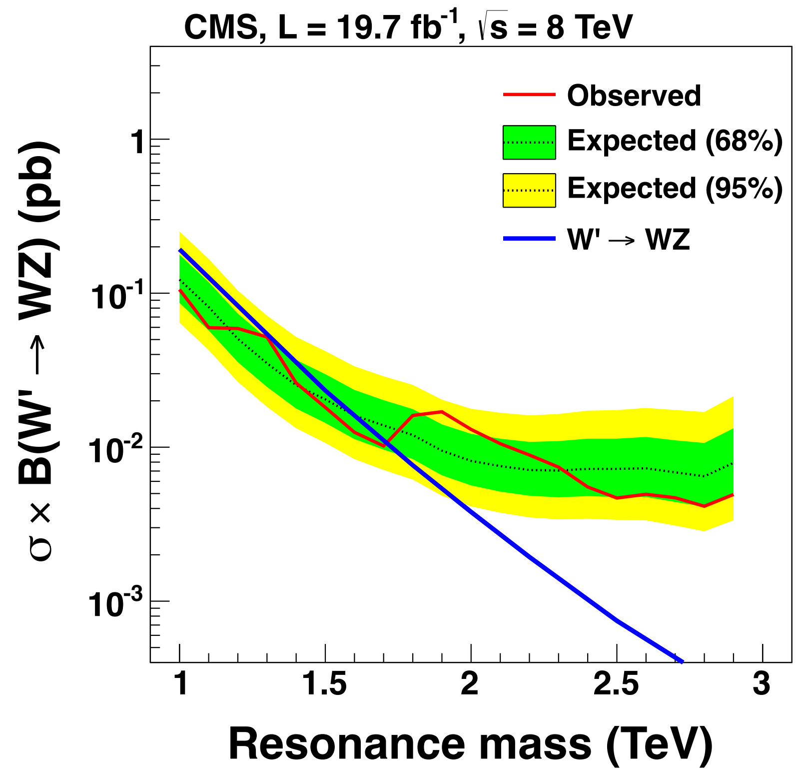
BOOST 2015 Theory Summary

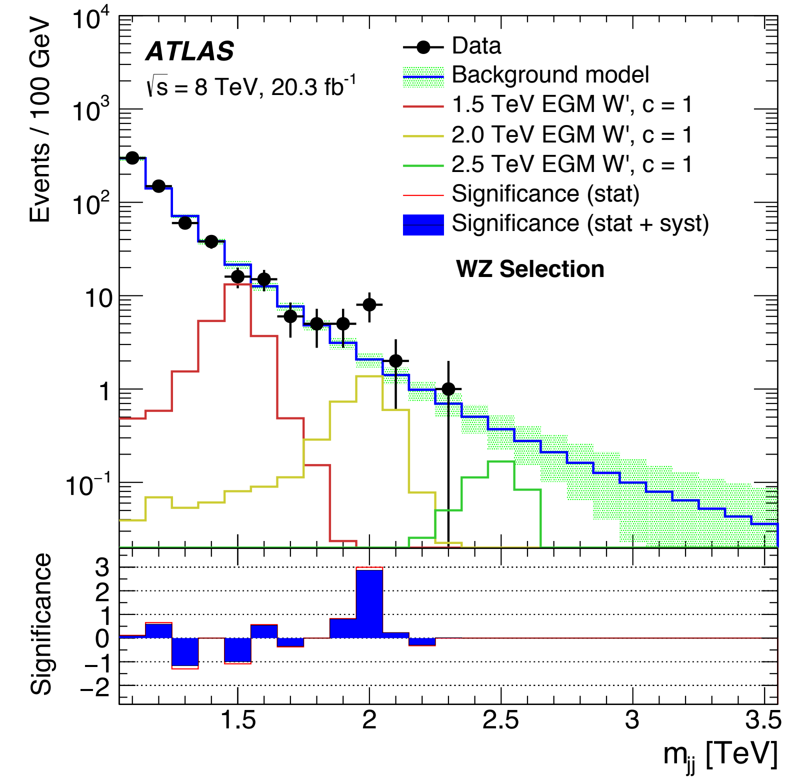
Andrew Larkoski
MIT

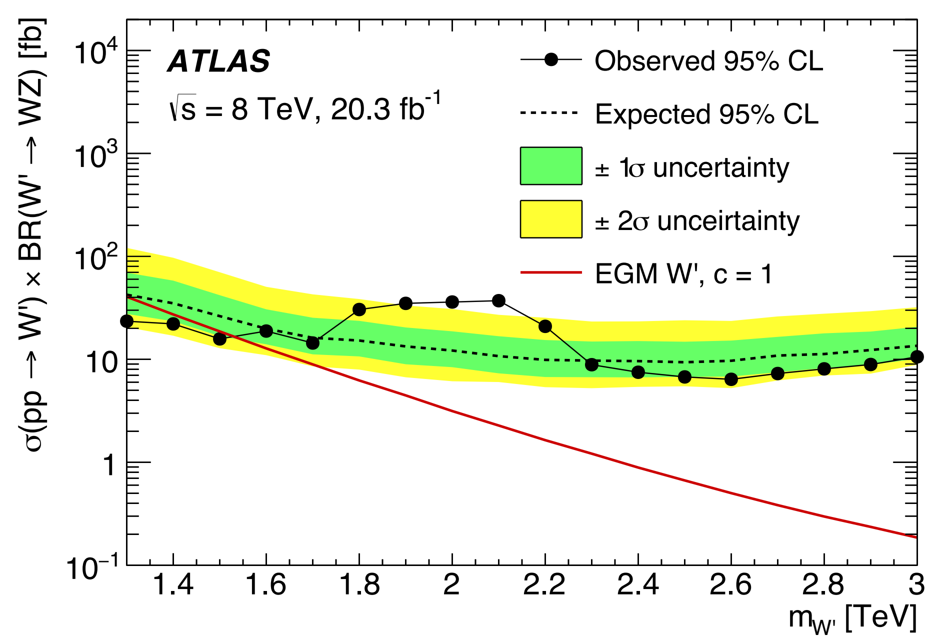
$W' \to WZ \to JJ$

CMS (1405.1994):



ATLAS (1506.00962):



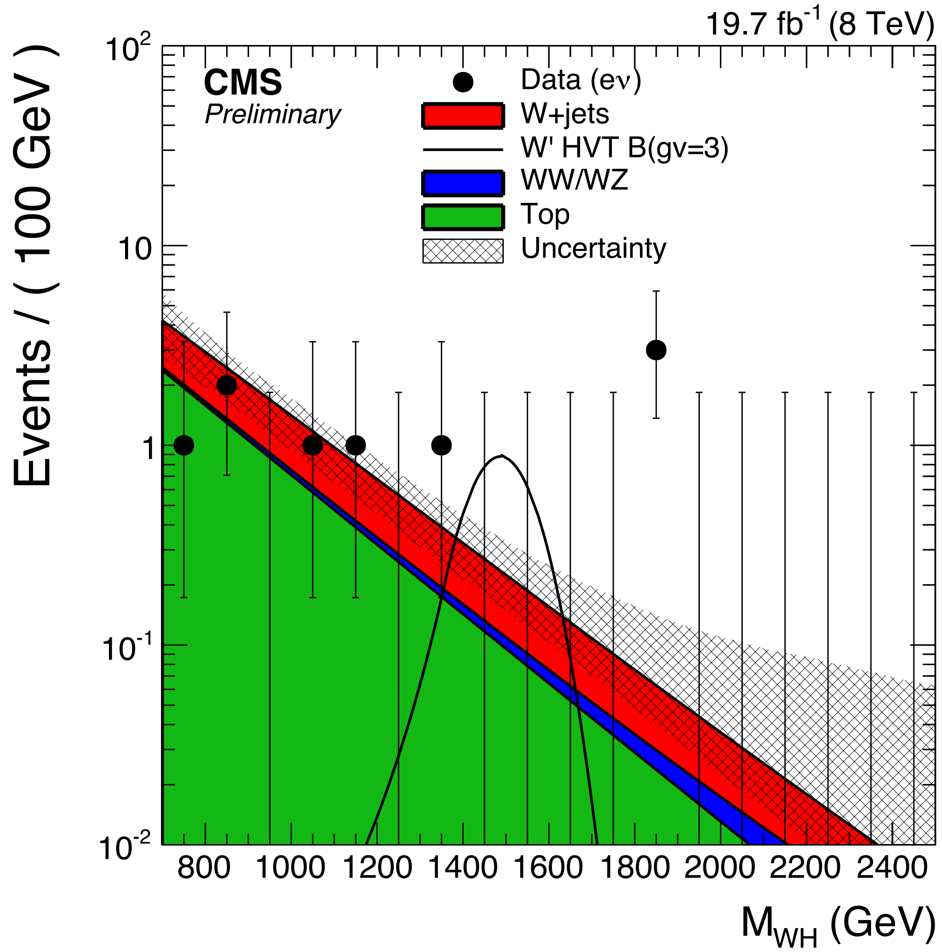


$$\sigma(pp \to W' \to WZ) = O(5) \text{ fb} \longleftarrow$$

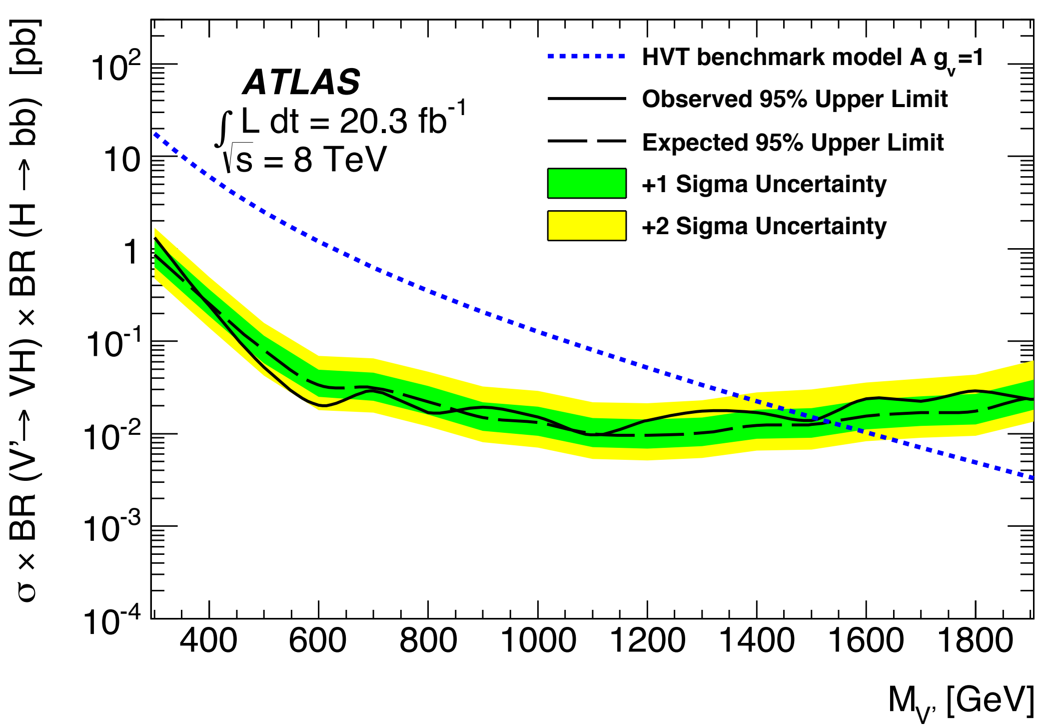
Bogdan Dobrescu

$W' \to Wh \to (\ell\nu)(b\bar{b})$

CMS (EXO-14-010):



ATLAS (EXOT-2013-23, *1503.08089*):



5 excesses of $\sim 2\sigma$ $\ll$ 2 excesses of 5σ $\longrightarrow$ need Run 2

Immediate Questions

How do we convince ourselves that the excess is real?

Is there some implicit cut or constraint that sculpts the mass distribution?

Do we see the excess using a broad range of substructure techniques?

How do we convince others?

Is there any signal in "clean" channels?

Immediate Questions

How does the boosted community fit into the broader QCD community?

What precision measurements and calculations can we do?

How can what we have learned inform more general QCD issues?

What do we need to do to exhibit the power of boosted techniques?

What is a QCD killer app(s)?

What is our "wish list"?

NNLO QCD and NLO EW Les Houches Wishlist

Wishlist part 1 - Higgs (V=W,Z)

Process	known	desired Now known!	motivation
H	d\sigma @ NNLO QCD d\sigma @ NLO EW finite quark mass effects @ NLO	d\sigma @ NNNLO QCD + NLO EW MC@NNLO finite quark mass effects @ NNLO	H branching ratios and couplings
H+j	d\sigma @ NNLO QCD (g only) d\sigma @ NLO EW	d\sigma @ NNLO QCD + NLO EW finite quark mass effects @ NLO	H p_T
H+2j	\sigma_tot(VBF) @ NNLO(DIS) QCD d\sigma(gg) @ NLO QCD d\sigma(VBF) @ NLO EW	d\sigma @ NNLO QCD + NLO EW	H couplings
H+V	d\sigma(V decays) @ NNLO QCD d\sigma @ NLO EW	with H→bb @ same accuracy	H couplings
t\bar tH	d\sigma(stable tops) @ NLO QCD	d\sigma(NWA top decays) @ NLO QCD + NLO EW	top Yukawa coupling
HH	d\sigma @ LO QCD finite quark mass effects d\sigma @ NLO QCD large m_t limit	d\sigma @ NLO QCD finite quark mass effects d\sigma @ NNLO QCD	Higgs self coupling

Wishlist part 2 - jets and heavy quarks

Outline

Theory review of BOOST 2015

New Physics Boosted Analyses

New Methods and Algorithms

New Jet Definitions

New Calculations

New Horizons

5 talks by students!

A first boosted "wish list"

New Physics Boosted Analyses

American Gothic, Grant Wood

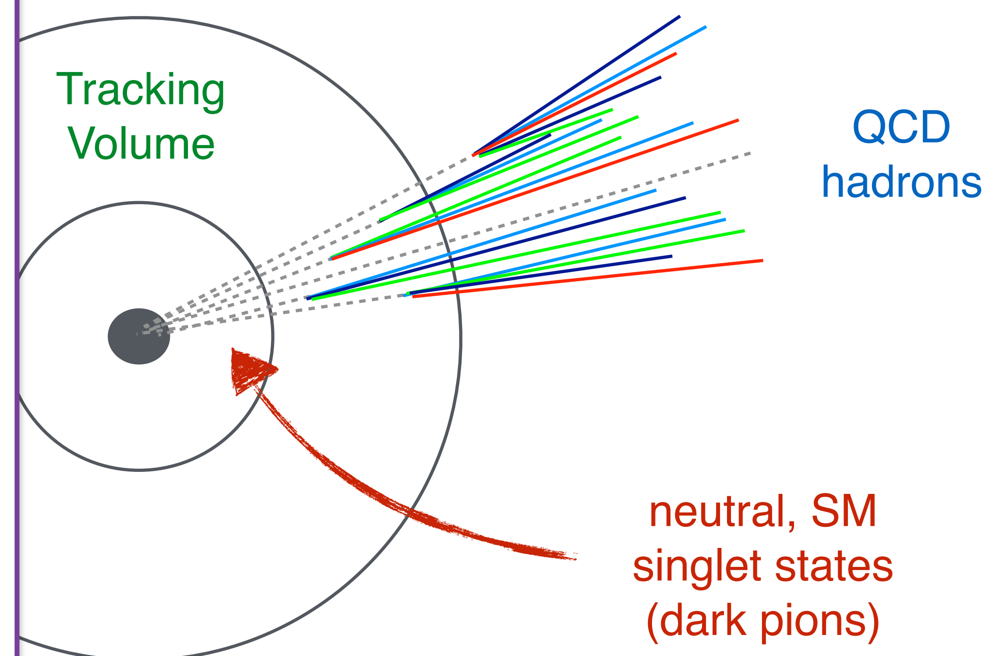
What is an Emerging Jet?

Possible origin:

Hidden sector with confining SU(N) gauge interactions **"dark QCD"**

Bai, PS, PRD 2014
PS, Stolarksi, Weiler, JHEP 2015

Also in "Hidden Valleys"
Strassler, Zurek, 2006,2007
Han, Strassler, Zurek, 2007

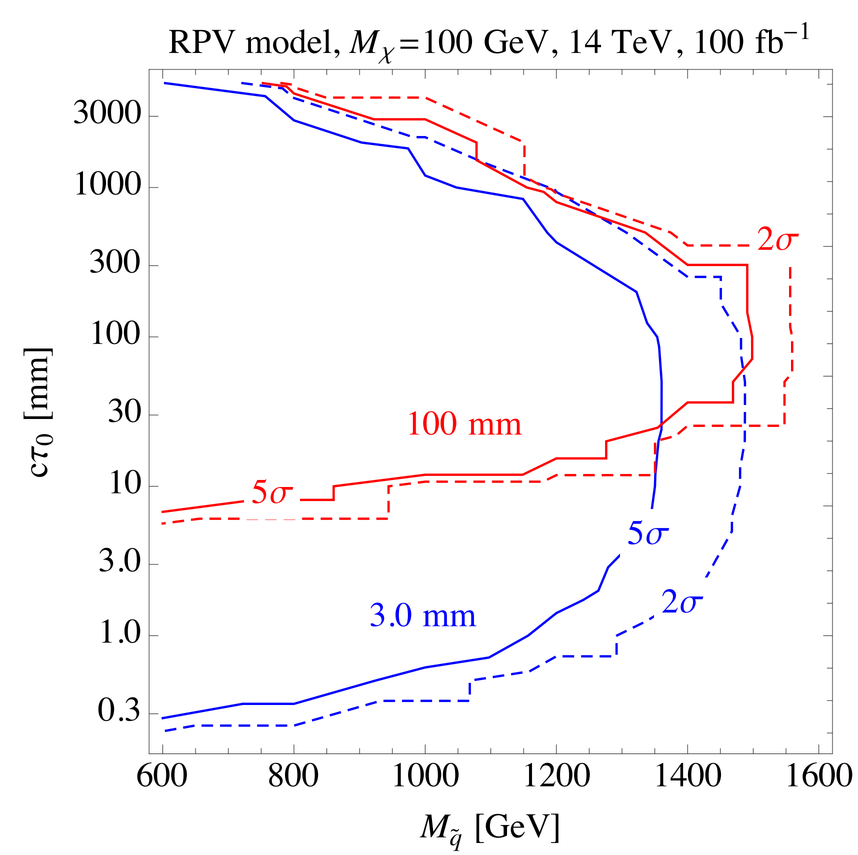


Jets from hidden sector decays to SM

Vetoing tracks results in powerful bounds!

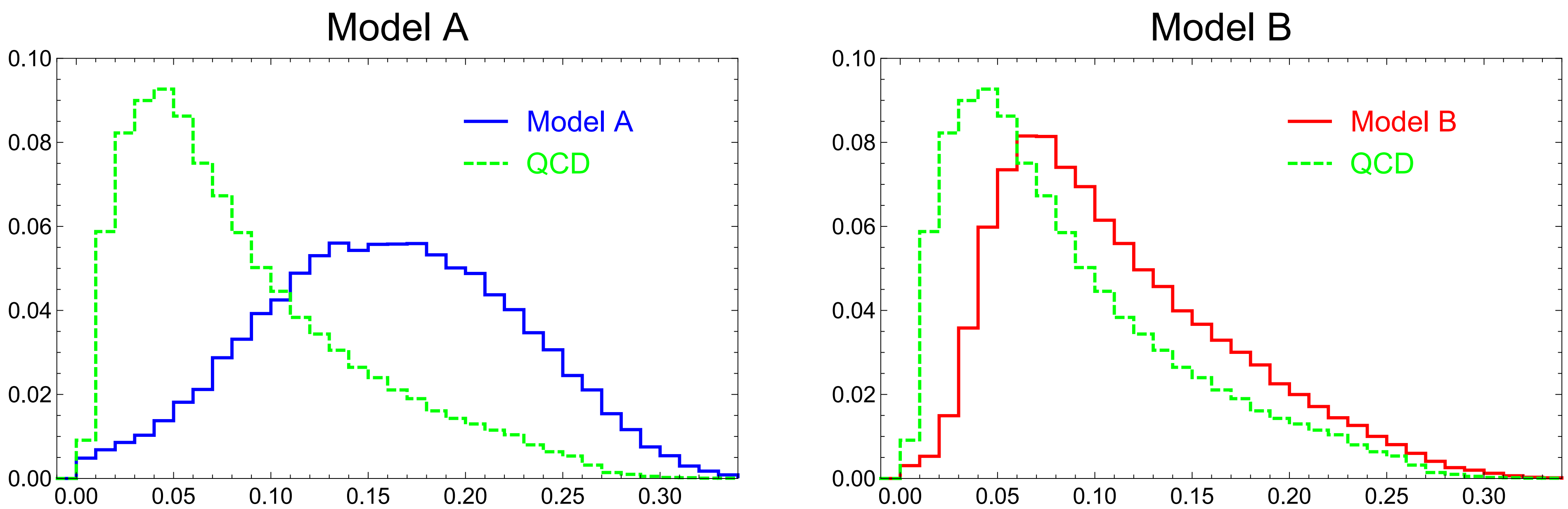
- Less model dependent
- "Natural SUSY" scenario with top jets to be done

SY sensitivity



Jet Shape(s)

- Girth $\frac{1}{p_T^{\rm jet}} \sum_i p_T^i \, \Delta R_i$

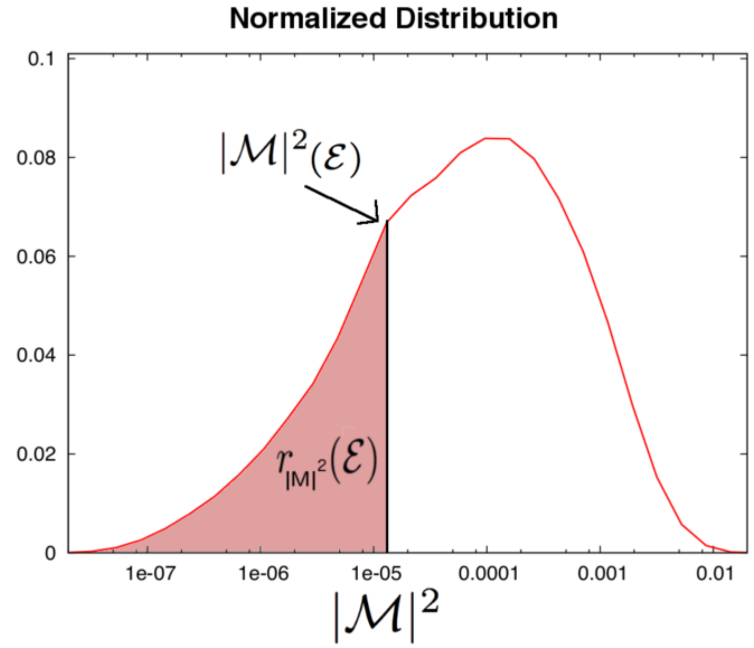


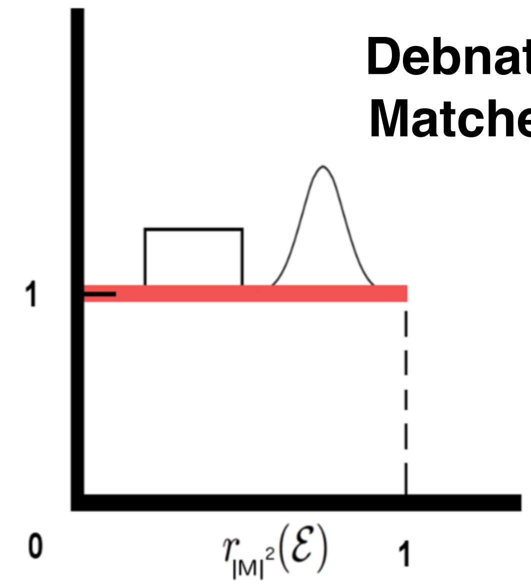
- Model discrimination (?)
- Subtleties: Might loose hardest dark meson, etc…

Robust prediction: singularity structure of emerging jets is different from QCD!

Pedro Schwaller

Model-Independent Searches





Debnath, JSG, Matchev, 2014

- Potential approach to finding new physics in a model-independent way
  and displaying the results:

  "**Flatten**" (take the cdf) of a powerful variable, then look for deviations from flatness in the data.

- New physics shows up as excesses or deficits.

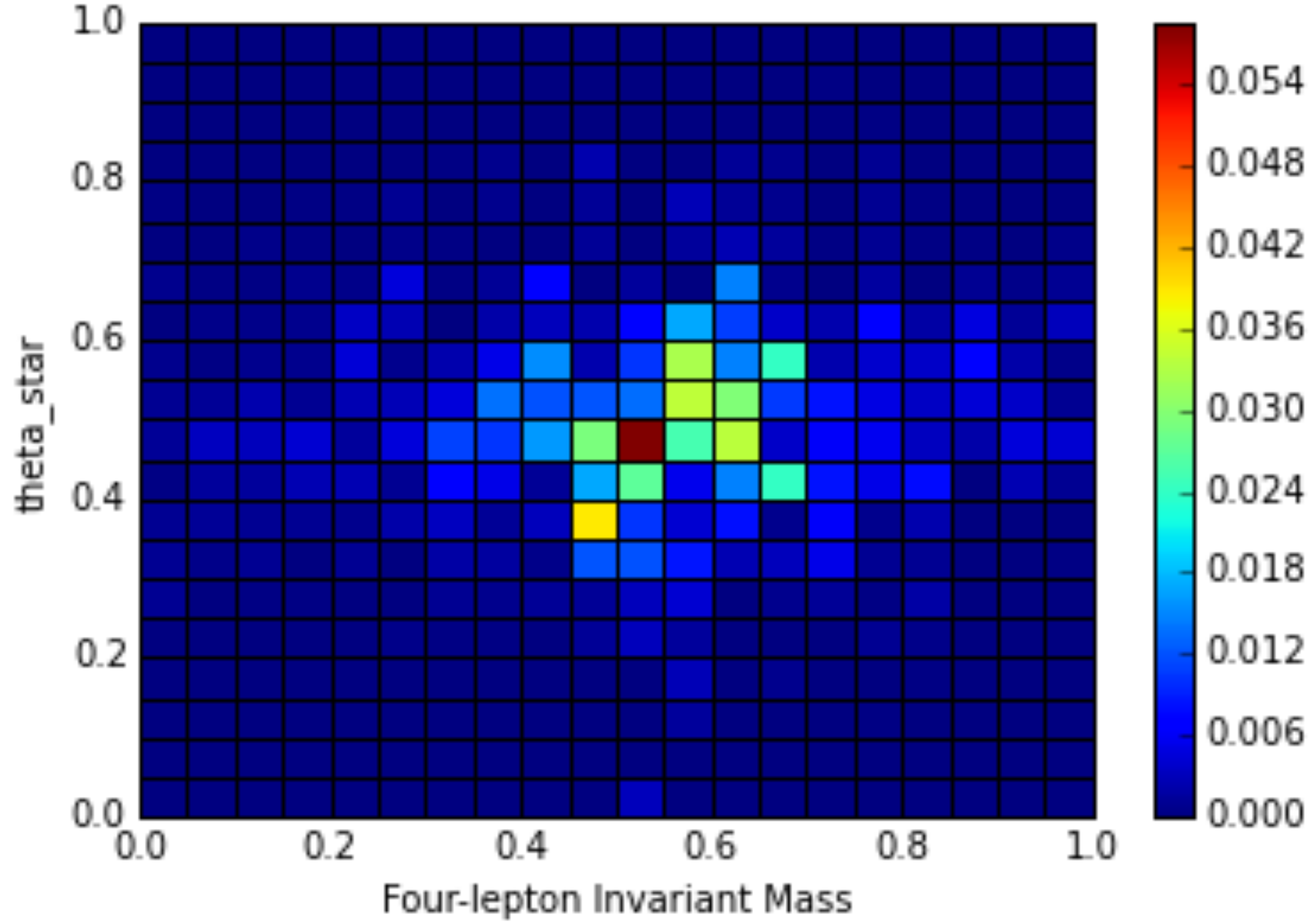
"Ranking and Flattening for Model-Independent Discoveries" J. Gainer BOOST 2015 Tuesday August 11, 2015

"Increasing RS Graviton Discovery Sensitivity with the MEM in 4l Final States" J. Gainer BOOST 2015 Tuesday August 11, 2015

"Discovery and Study of Resonances Decaying to Boosted Vector Bosons" J. Gainer BOOST 2015 Tuesday August 11, 2015

Extension of MEM to isolate deviations from background

Preliminary Results



Signal is narrow 2 TeV RS Graviton

Identification of dominant signal/background discriminants!

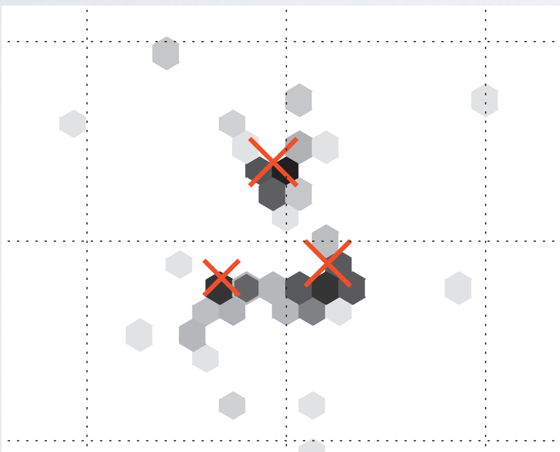
New Methods and Algorithms

The Old Guitarist, Pablo Picasso

(Crazy) New idea…

Treat a jet as a **"splash pattern"** or image.

Use **image/pattern recognition** technology to classify "splash patterns".



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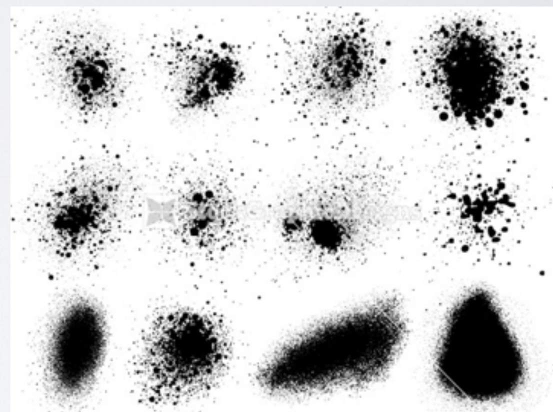
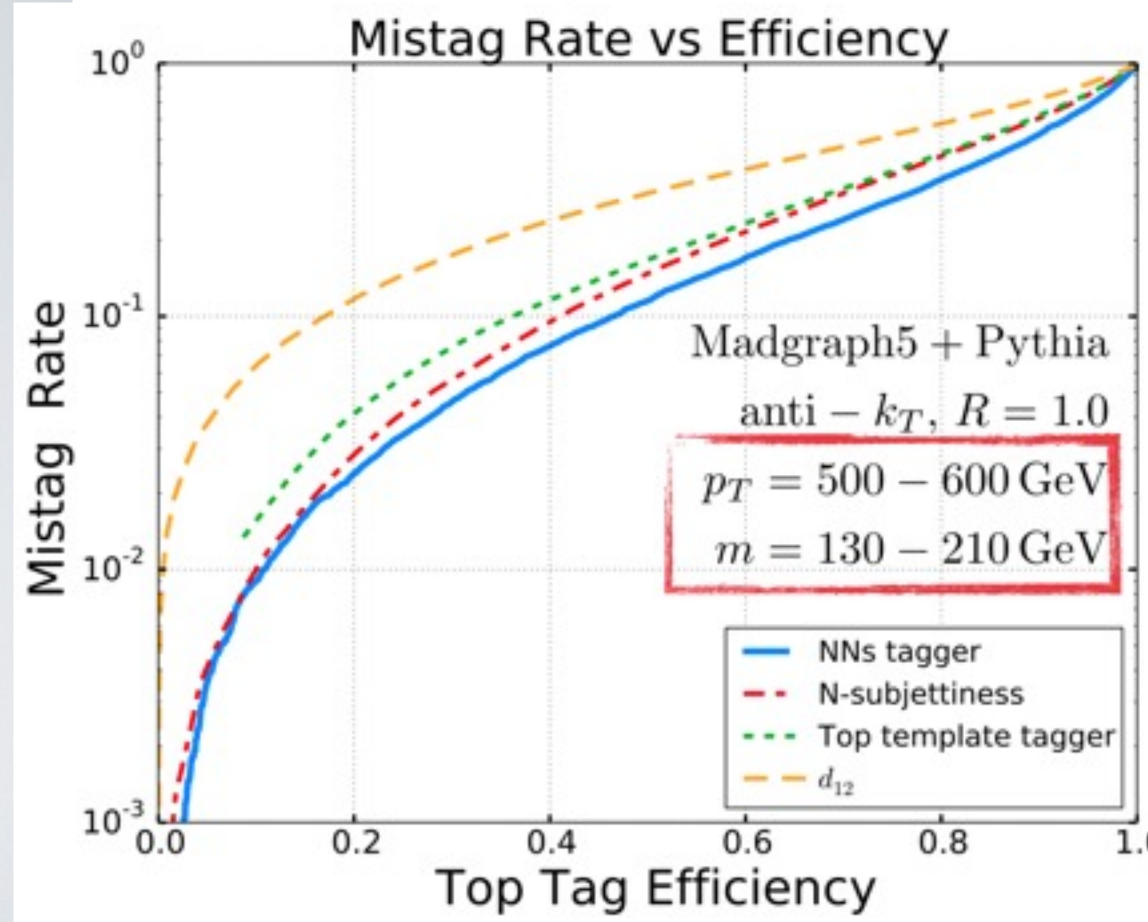


jet "splash patterns" contain all of calo. information.



Two possible conclusions:

Using neural networks to extract "all information" from calorimeter hits in jet

1) Using a NN leads to better discrimination power

Very IRC unsafe; what do we learn from an NN? Possible to calibrate/validate?

2) N-subjettiness contains almost all of the useful discrimination information!

HEPTopTagger – Algorithm

0. **fat jet**: C/A $R = 1.5$, $p_T > 200$ GeV

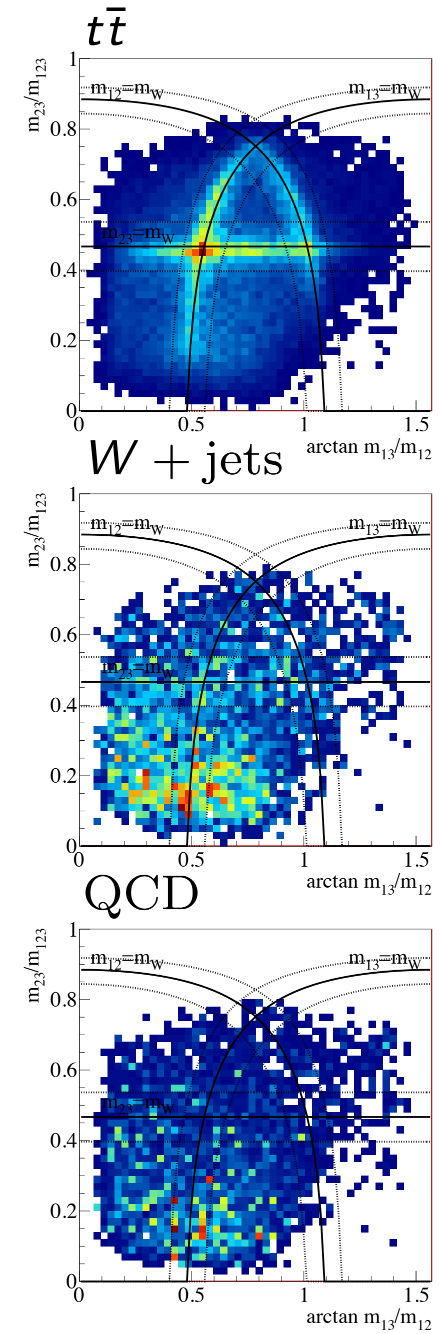
1. **hard substructures**:
   mass drop $f_{\text{drop}} = 0.8$, $m_i < m_{sub} = 30$ GeV

2. **filtering**:
   filter triplets of hard substructures $\rightarrow$ 3 jets (j_1, j_2, j_3)
   150 GeV $< m_{123} <$ 200 GeV

3. **mass plane cuts**:
   $0.85\,\frac{m_W}{m_t} < \frac{m_{ij}}{m_{123}} < 1.15\,\frac{m_W}{m_t}$
   $m_{23} \approx m_W$: $0.2 < \arctan\frac{m_{13}}{m_{12}} < 1.3$; else $\frac{m_{23}}{m_{123}} > 0.35$

4. **triplet selection**: choose triplet closest to m_t

5. **consistency:** $p_T^{(\text{tag})} > 200\ \text{GeV}$



Old HEPTopTagger Algorithm

Torben Schell

QJETS

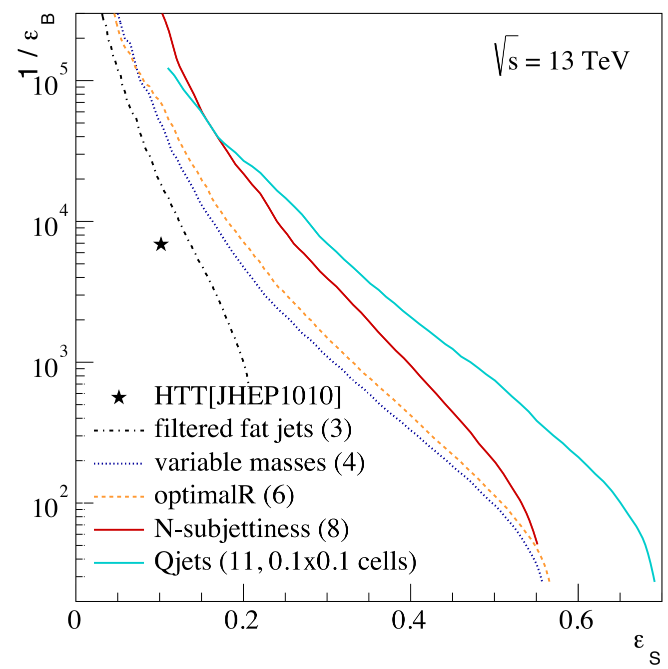
[Ellis, Hornig, Roy, Krohn, Schwartz]

- deterministic clustering $\rightarrow$ set of weighted histories
- each possible merging (ij) gets a weight

$$\omega_{ij}^{(\alpha)} = \exp\left(-\alpha\,\frac{d_{ij} - d_{ij}^{\text{min}}}{d_{ij}^{\text{min}}}\right)$$

- clustering history weight

$$\Omega^{(\alpha)} = \prod_{\text{mergings}} \omega_{ij}^{(\alpha)} = \left[\prod_{\text{mergings}} \exp\left(-\frac{d_{ij} - d_{ij}^{\text{min}}}{d_{ij}^{\text{min}}}\right)\right]^{\alpha}$$



- use leading tagged QJETS history + statistical information from tagged histories

$$\{\ m_{tt},\, m_{\text{ff}},\, p_{T,t_1},\, p_{T,t_2},\, p_{T,\text{f}_1},\, p_{T,\text{f}_2},\, m_{\text{rec}}^{\text{min}},\, m_{\text{rec}}^{\text{max}},\, f_{\text{rec}}^{\text{max}},\, R_{\text{opt}} - R_{\text{opt}}^{(\text{calc})},\, \{\tau_N\},\, \varepsilon_{\text{Qjets}}^{\text{min}},\, \{m_{\text{rec}}^{\text{Qjets}}\}\ \}$$

Need to add Seattle and Boston to H, E, P?

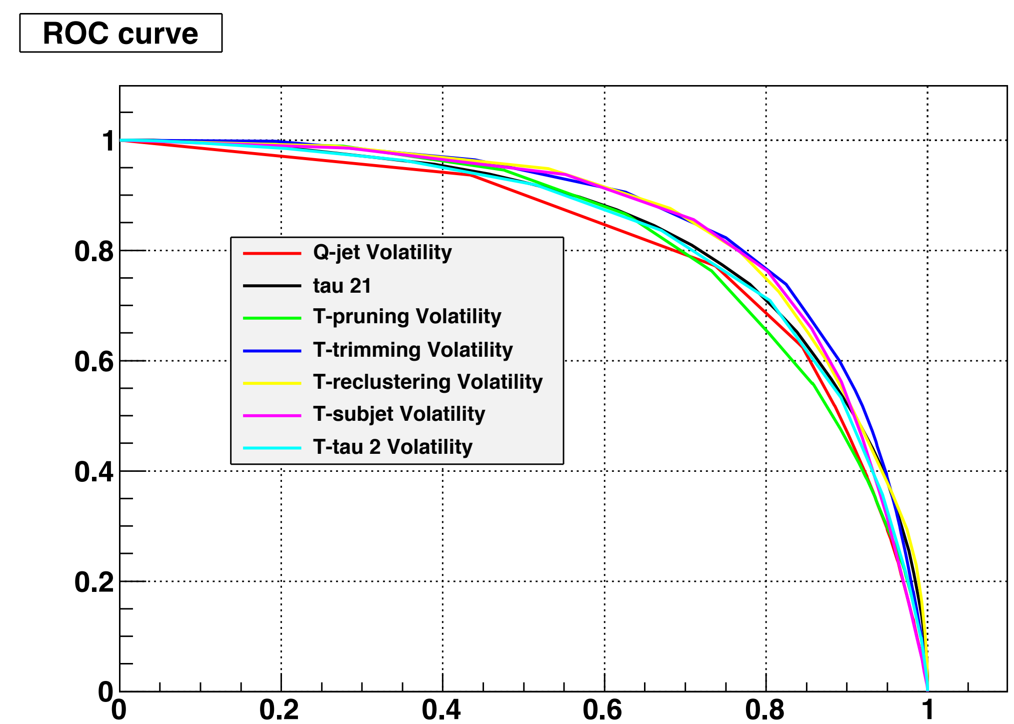
New HEPTopTagger Algorithm

Still HEPTT? Or just ~20 parameter MVA?
Dangerously overtrained?

Telescoping X setup

- Samples
  - W: 1 and 2 TeV $W' \to WZ$, anti-k_T $R_0 = 1.0$
  - t: 1 and 2 TeV $Z' \to t\,\bar{t}$, anti-k_T $R_0 = 1.0$
  - $300\text{ GeV} < p_T < 500\text{ GeV}$ and $800\text{ GeV} < p_T < 1000\text{ GeV}$, $|\eta| < 1.2$
  - For W, $70\text{ GeV} < m_{trim} < 90\text{ GeV}$ with `Rfilt = 0.3` and `fcut = 0.05`
- T- specifics
  - 20 values in the parameter ranges below
  - T-pruning
    - `zcut = 0.1, 0.1 < Rcut factor < 2.0 (2m/pt)`
  - T-trimming
    - `Rfilt = 0.1 or 0.2, 0.0 < fcut < 0.1`
  - T-reclustering
    - `anti-kt, 0.05 or 0.1 < Rsub < 0.6`
  - T-subjet
    - `tau2 axes, 0.05 or 0.1 < Rsub < 0.6`
  - T-subjettiness
    - `onepass kt axes, 1.0 < beta < 3.0`

$300\text{ GeV} < p_T < 500\text{ GeV}$, truth particles, ROC curves



An MVA for observable parameters

Relatively small improvement;
how much information is gained?

Is it constructive? Can better observables be found?

Yang-Ting Chien

New Jet Definitions

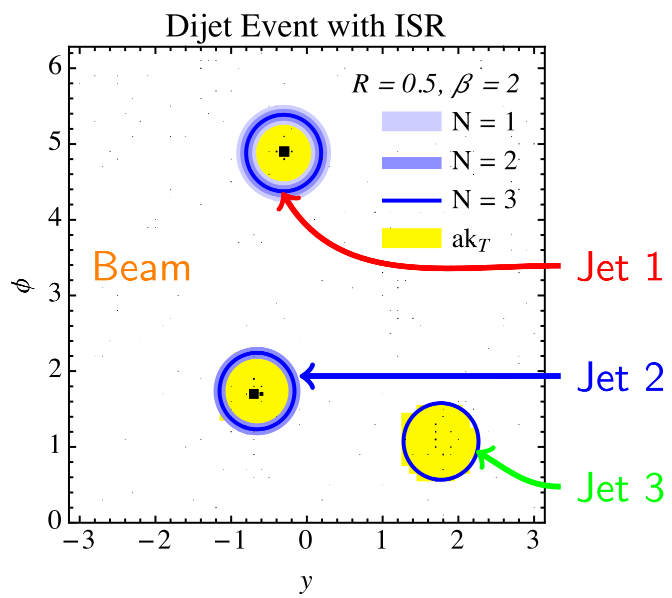
 Un dimanche après-midi à l'Île de la Grande Jatte, Georges Seurat

Basics of N-jettiness

General definition of N-jettiness:
[Stewart, Tackmann, Waalewijn, 1004.2489]; see also [Brandt, Dahmen, 1979]

$$\widetilde{\mathcal{T}}_N = \sum_i \min\left\{\rho_{\text{jet}}(p_i, n_1), \ldots, \rho_{\text{jet}}(p_i, n_N), \rho_{\text{beam}}(p_i)\right\}$$

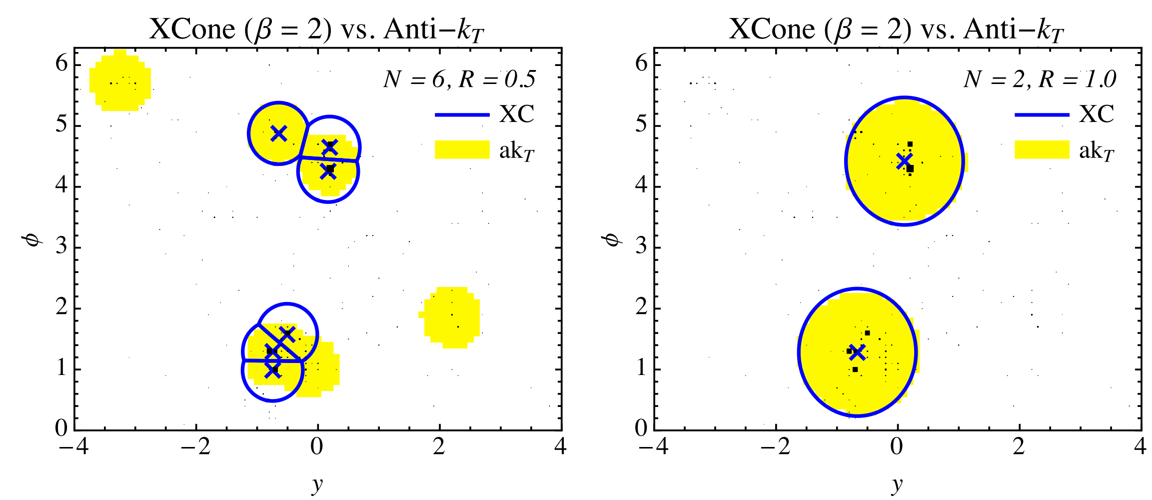
$$\mathcal{T}_N = \min_{n_1, n_2, \ldots, n_N} \widetilde{\mathcal{T}}_N$$



- $\mathcal{T}_N$ partitioning: N jets + beam (unclustered) region
- Quality measure of particle alignment along N axes
- Minimization of $\mathcal{T}_N$ defines exclusive jet algorithm

New, exclusive* cone jet algorithm

Comparison to Anti-k_T: General Considerations



Anti-k_T:

- Conical, subject to "nibbling"
- Variable # of jets (inclusive)
- Merges adjacent jets

XCone:

- Conical, except for overlapping
- Fixed # of jets (exclusive)
- Splits adjacent jets

For well-separated jets, 2 hardest anti-k_T $\approx$ XCone $N = 2$

Similar behavior to anti-kT in resolved regime

Can resolve very small angle structure with fixed jet radius

*Exclusive = N jets + anything

TJ Wilkason

Boosted Top Reconstruction

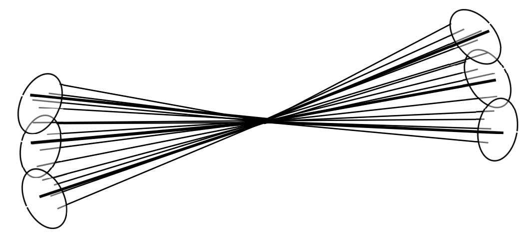
Classic example of jet substructure

$pp \to \bar{t}\, t$

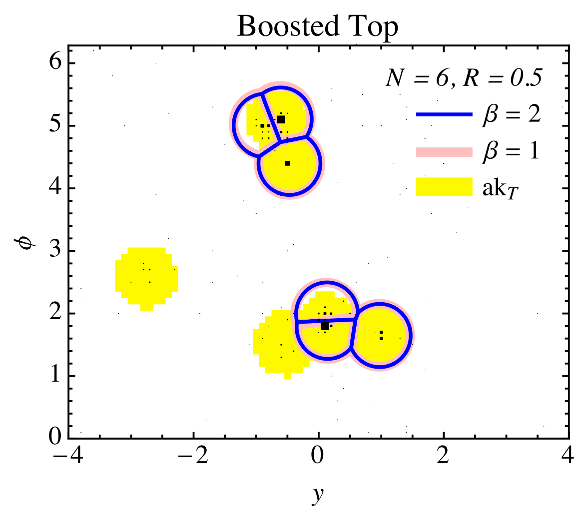
$t \to bW$

$W \to q\bar{q}'$

$\Longrightarrow$

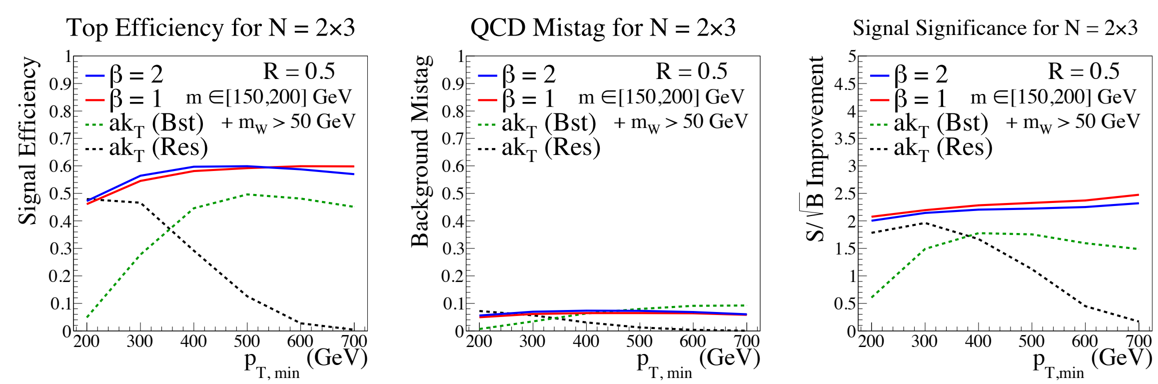


Most Obvious: $N = 6 +$ kinematic grouping



Boosted Top Reconstruction Efficiency

Cutting tight on mass gives strong signal efficiency and significance



- Higher significance than traditional strategies across all p_T!
- Further gains possible with additional discrimination methods

How does this compare to standard fat jet substructure analyses?

Produces irregular sized/shaped jets. Easy* to calibrate/validate?

*Easy = just like anti-kT

TJ Wilkason

What is a quark jet?

What is a Quark Jet?

From lunch/dinner discussions

Ill-Defined ↓ Well-Defined	What people sometimes think we mean ↑ What we mean	
Quark as noun		A quark parton
		A Born-level quark parton
		The initiating quark parton in a final state shower
		An eikonal line with baryon number 1/3 and carrying triplet color charge
		A quark operator appearing in a hard matrix element in the context of a factorization theorem
		A parton-level jet object that has been quark-tagged using a soft-safe flavored jet algorithm (automatically collinear safe if you sum constituent flavors)
Quark as adjective		A phase space region (as defined by an unambiguous hadronic fiducial cross section measurement) that yields an enriched sample of quarks (as interpreted by some suitable, though fundamentally ambiguous, criterion)

J Thaler & co., Les Houches 2015

The QCD-aware algorithm

Here's what we came up with and tried...

1. Cluster the event *final* partons into jets ("parton jets") with two additions to the usual algorithms:
   - only allow clustering steps that follow $1 \to 2$ QCD or QED Feynman rules;
   - track the flavor of each pseudo-jet based on the Feynman rule used to create it.
2. For each particle jet in the event, label it with the flavor of the corresponding parton jet.

The parton clustering is fairly simple to realize for the k_t family of clustering algorithms: set $d_{ij} \to \infty$ for disallowed recombinations.

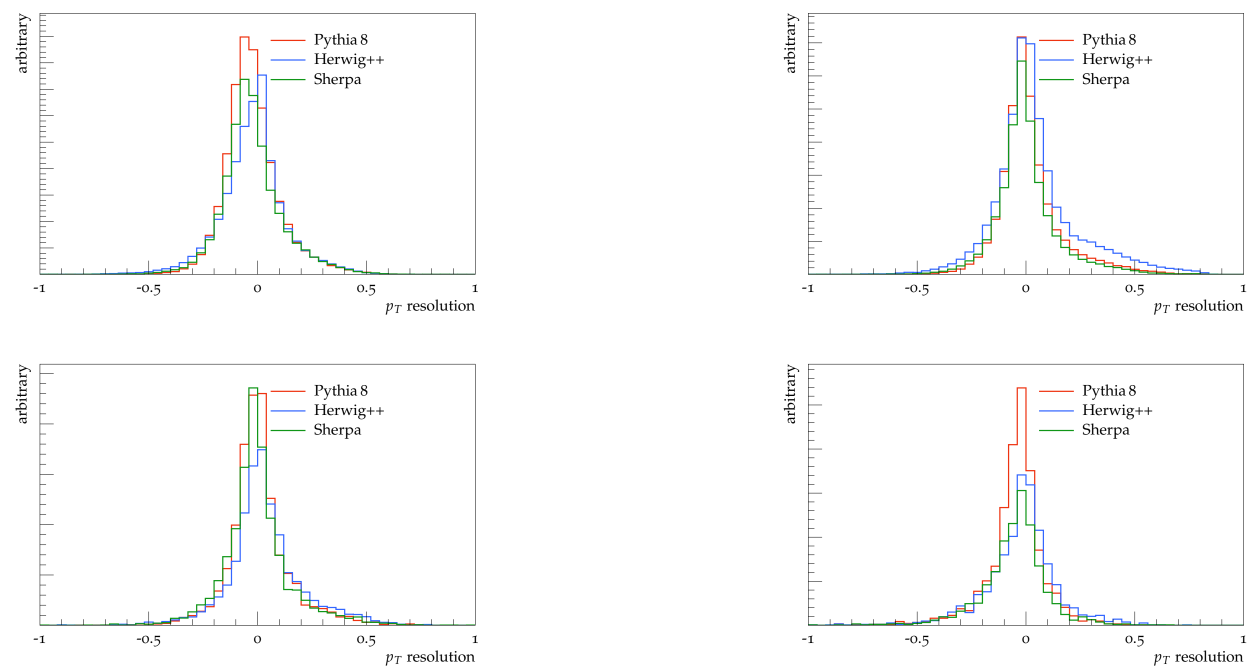
It's also similar to the "bland" flavor algorithm outlined in hep-ph/0601139 (Banfi, Salam, Zanderighi).

New flavor jet algorithm

Can "quark"-ness and "gluon"-ness be made well-defined at the jet clustering level?

enerator dependence: inclusive jets

gluon labeled jets — light-quark labeled jets



charm-quark labeled jets — bottom-quark labeled jets

rison across generators and jet definitions

Scheme	Generator	Jets q/g	$\gamma+$jet γ/g	$\gamma+$jet q/g
Max-p_T	Pythia 8	0.38	17.2	10.5
	Herwig++	0.33	7.7	4.8
	Sherpa	0.55	21.0	9.6
k_T	Pythia 8	0.80	10.4	8.2
	Herwig++	1.17	3.6	4.6
	Sherpa	0.85	10.5	7.5
anti-k_T	Pythia 8	0.79	10.2	8.3
	Herwig++	1.74	3.2	4.5
	Sherpa	0.86	10.2	7.5
Reclustered	Pythia 8	0.77	10.1	8.0
	Herwig++	1.36	3.5	4.8
	Sherpa	0.83	10.1	7.3

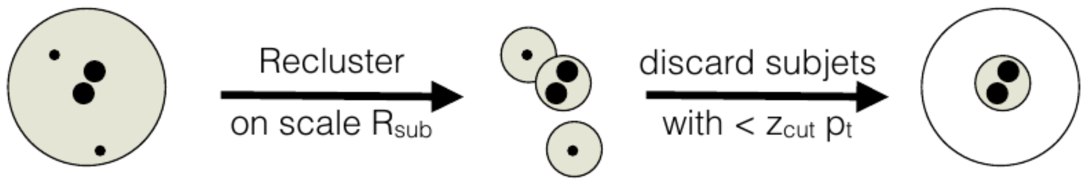
See some differences in Monte Carlo. From parton shower? From hadronization? From MPI? No clear picture.

Fixed-order calculations in e+e- collisions might help understand source of differences and provide "truth"

New Calculations

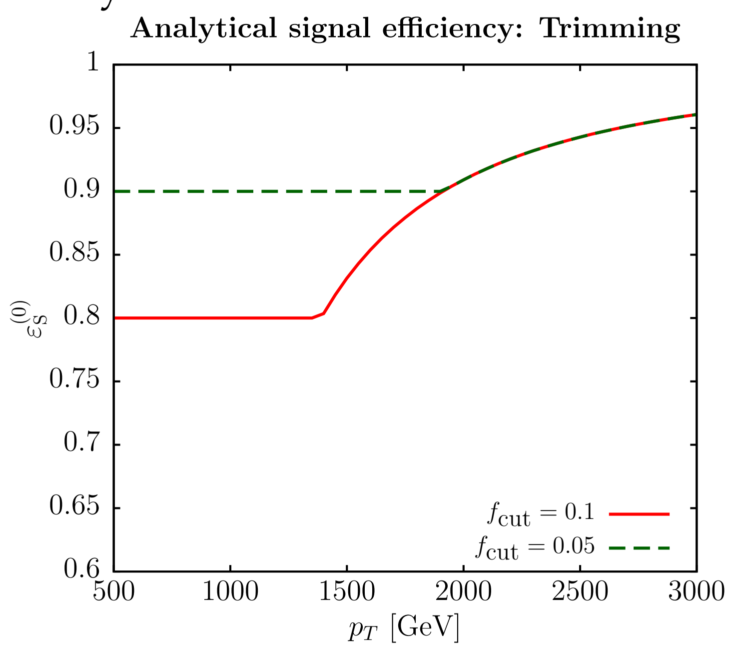
Self Portrait, Vincent van Gogh

Trimming

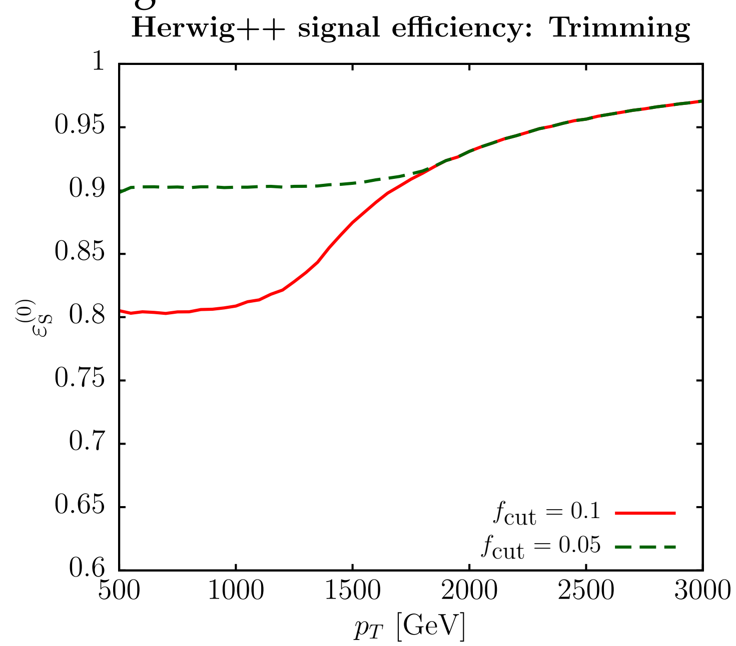


LO results:

Analytical



Herwig++ 2.7.1



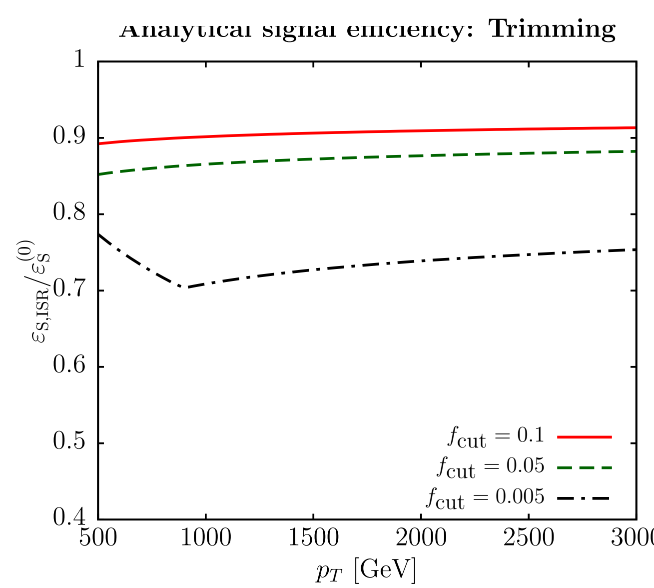
Applying "Back to basics" to signal jets

Trimming - Initial State Radiation

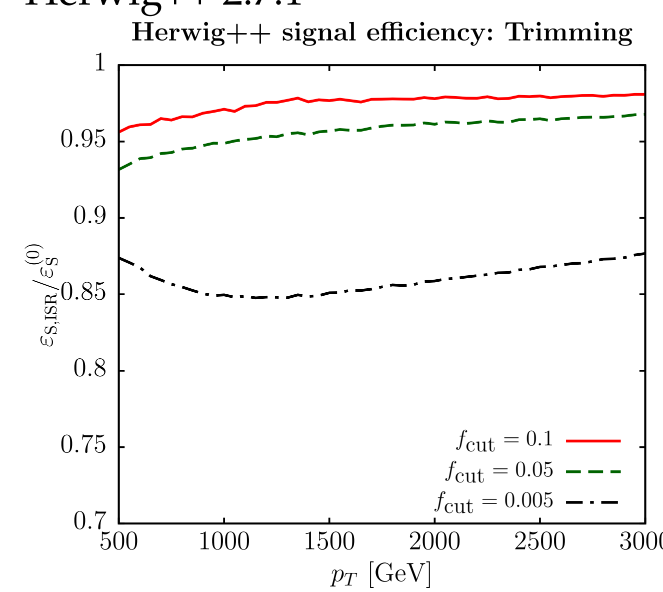
has two distinct regimes. For $f_{\rm cut} > \frac{2M_H\delta M}{R^2 p_T^2}$:

$$R^2 \ln \frac{1}{f_{\rm cut}} + R^2_{\rm trim} \ln \left(\frac{f_{\rm cut} p_T^2 R^2_{\rm trim}}{2M_H \delta M} \right) \Theta \left(f_{\rm cut} - \frac{2M_H \delta M}{p_T^2 R^2_{\rm trim}} \right) \Bigg) ,$$

$$\frac{\delta M}{p_T^2}: \frac{\varepsilon_{\rm S,ISR}}{\varepsilon_{\rm S}^{(0)}} \approx 1 - C_F \frac{\alpha_s}{\pi} R^2 \ln \frac{R^2 p_T^2}{2M_H \delta M} .$$

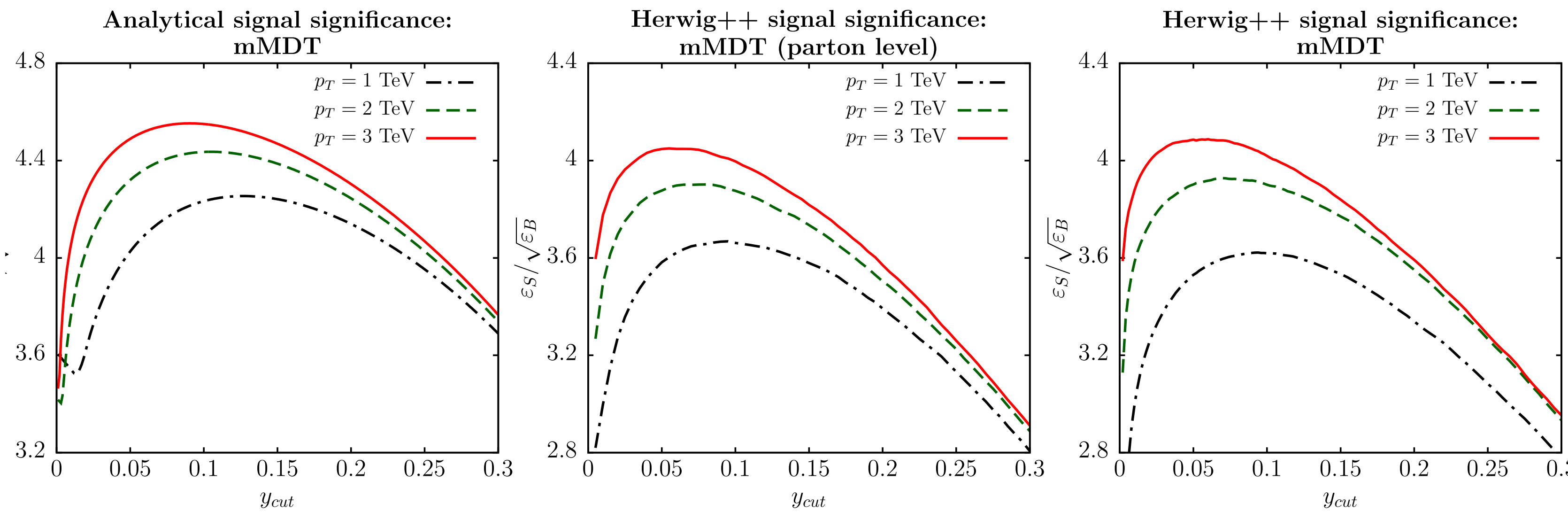


Herwig++ 2.7.1

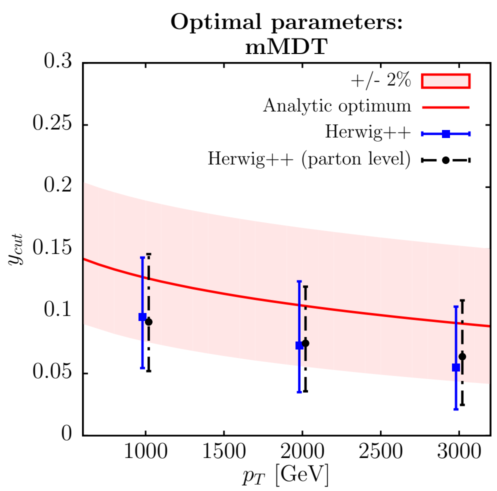


Predicts shape of efficiency curves (if not normalization)

Optimal values - mMDT



Impressive agreement with Monte Carlo!



- Herwig parton level agrees with analytics (both the peak positions and the evolution of opt. y_{cut} with p_T).
- hadronisation and UE do not change the picture significantly
- peaks are broad $\Rightarrow$ slightly non-optimal y_{cut} is still ok.
- good degree of overlap within tolerance band between full MC and analytical estimates.

First principles predictions for optimal grooming parameters

How far can this be extended?
Foundation of precision boosted calculations?
Or, only for understanding Monte Carlo?

How relevant are small-R effects?

Energy loss has big effect on jet spectrum.

R	correction to jet spectrum
0.4	$\mathcal{O}(-25\%)$
0.2	$\mathcal{O}(-50\%)$

"In the small R limit, new clustering logarithms [of R ...] arise at each order and cannot currently be resummed."

— Tackmann, Walsh & Zuberi (arXiv:1206.4

We aim to resum all leading logarithmic $(\alpha_s \ln R)^n$ terms in the limi
of small R for a wide variety of observables.

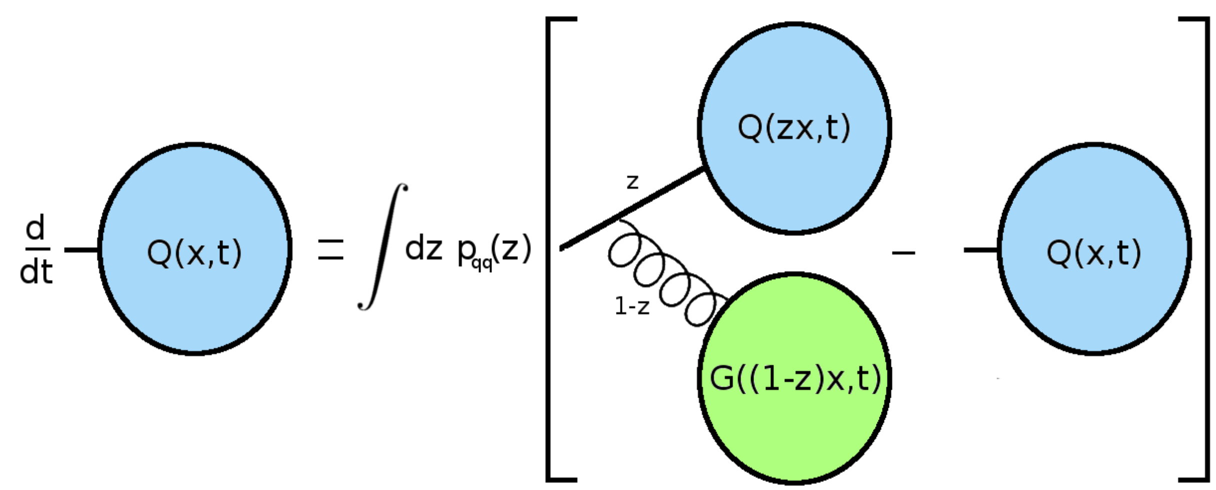
Frédéric Dreyer

Jet radius effects can be large; require resummation for perturbative control

Developed generating functional formalism for LL resummation

Quark evolution equation

Evolution equation for the quark generating functional can be rewri
differential equation.



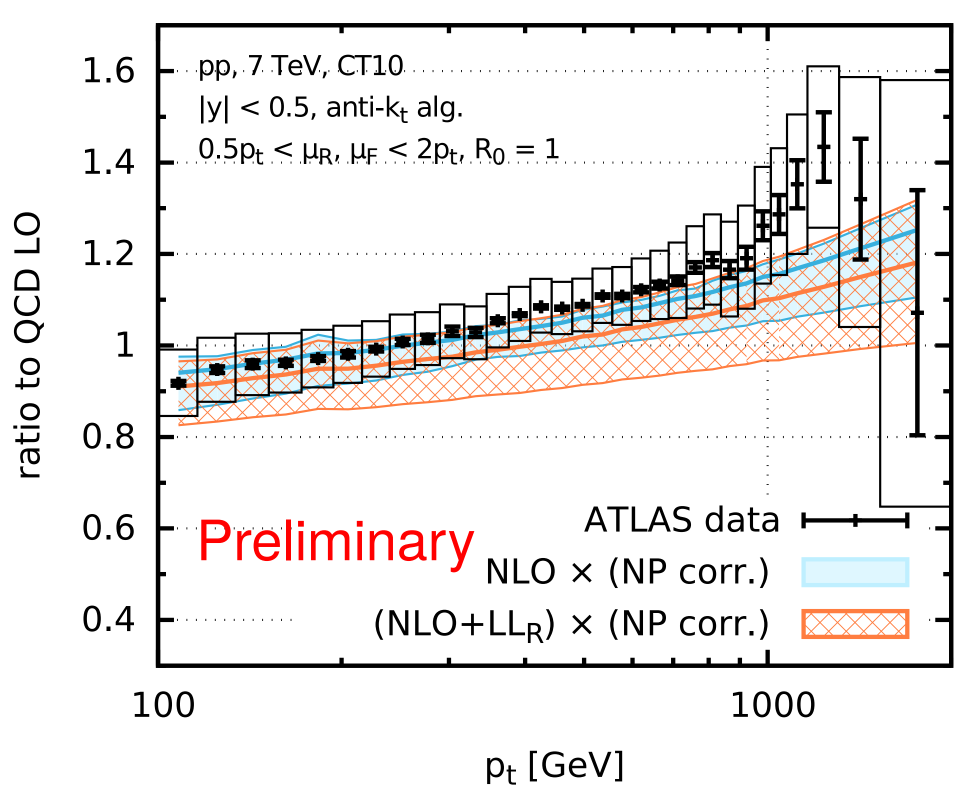
A similar equation can be obtained for the gluon evolution.

These equations allow us to resum observables to all orders nume
They effectively exploit angular ordering.

Frédéric Dreyer

Comparison to data: ATLAS with $R = 0.4$

Small-R resummation shifts the spectrum by $5 - 10\%$, and changes the scale dependence of the NLO prediction.

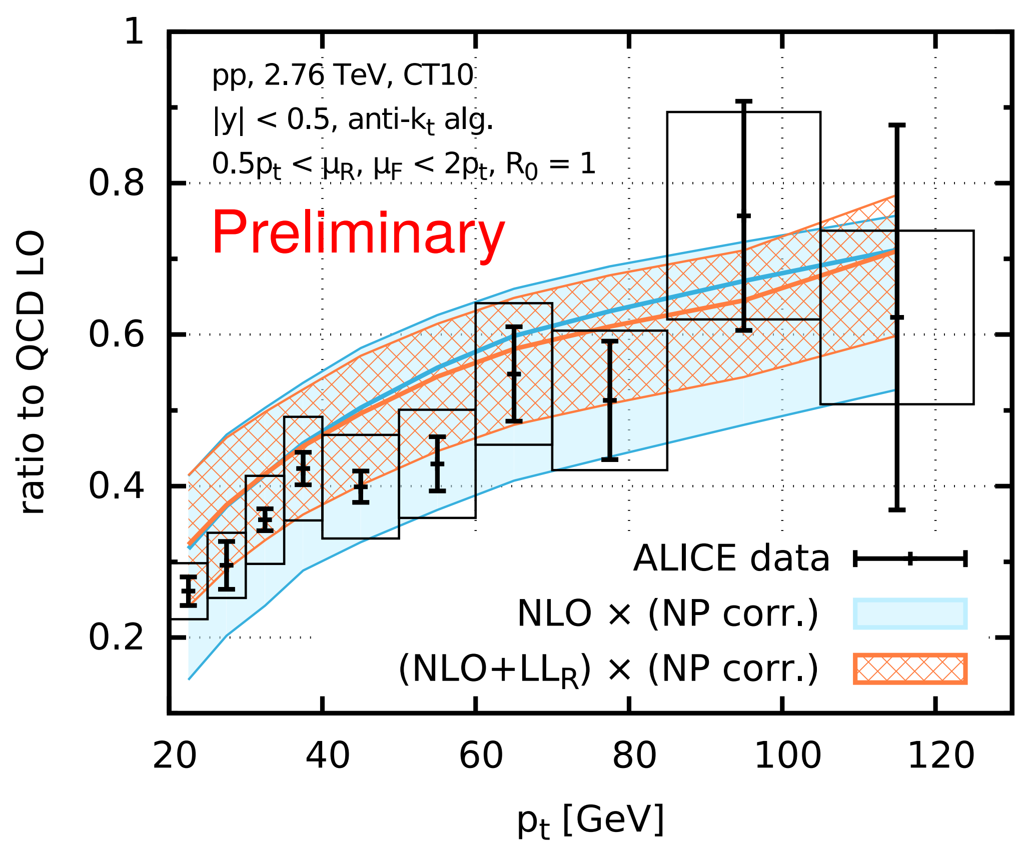


Frédéric Dreyer

Some confusion; resummation appears to increase scale dependence in some cases

Comparison to data: ALICE with $R = 0.2$

Small-R resummation somewhat improves agreement with Alice $R = 0.2$ data, and reduces the scale dependence of the NLO prediction.



Resummation appears to reduce scale dependence in other cases

Understanding? Are perturbative uncertainties accurately represented? Higher-order resummation required?

Frédéric Dreyer

Frédéric Dreyer

Leading-logarithmic calculations of 2-prong jet discriminants

Before we start...

N-subjettiness

- For τ_2: three possible partitions of p_0 and emissions p_1,p_2.
- Depends on choice of axis:

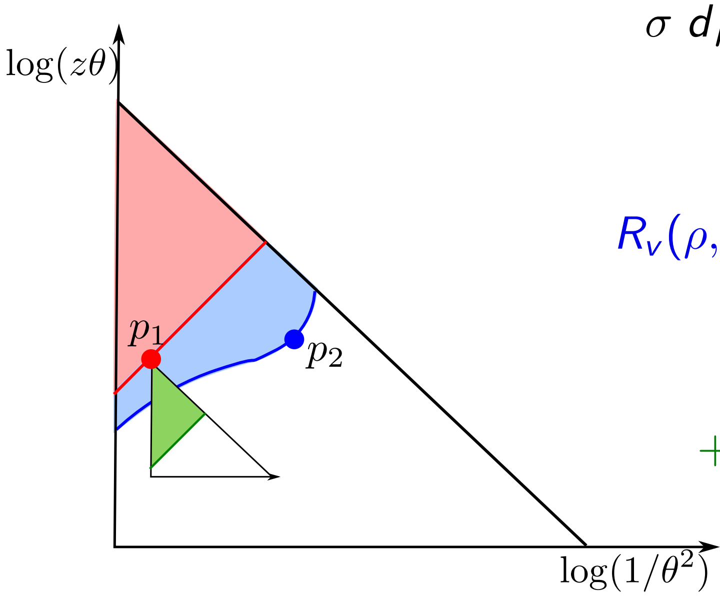
optimal	$\tau_2 \approx z_2\theta_2^2$	up to our accuracy
excl. gen-$k_t^{p=1/2}$	$\tau_2 \approx z_2\theta_2^2$	simpler than optimal
excl. k_t	$\tau_2 \approx z_2\theta_2^2$ if $z_2\theta_2 < z_1\theta_1$ $\approx z_1\theta_1^2$ if $z_2\theta_2 > z_1\theta_1$	not in this talk

Sub-jet axes for N-subjettiness are subtle

Structure of the results

- The second most massive emission p_2 sets the value of v.
- For a jet of a given mass + a cut in the shape v_{cut}:

$$\frac{\rho}{\sigma}\frac{d\sigma}{d\rho}\bigg|_{<v} = \int_\rho^1 dz_1 P(z_1)\frac{\alpha_s(z_1\rho p_t^2 R^2)}{2\pi} \times e^{-R_{plain}(\rho)-R_v(\rho,z_1)}$$



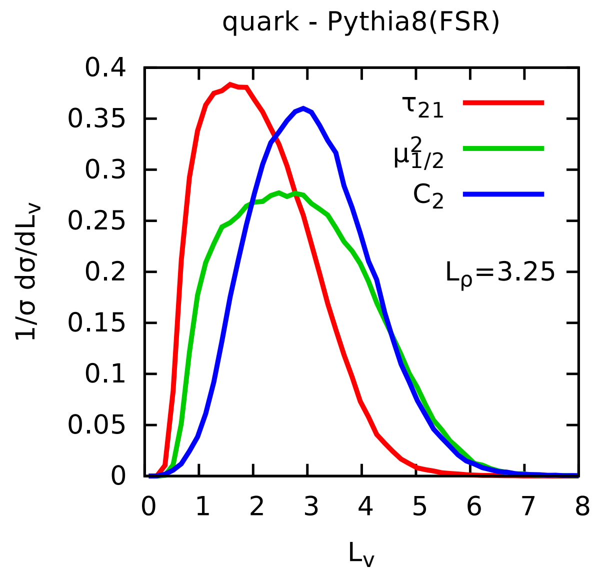
$$R_v(\rho,z_1) = \int_0^1 \frac{d\theta_2^2}{\theta_2^2}\int_0^1 dz_2 P_i(z_2)\frac{\alpha_s(z_2^2\theta_2^2 p_t^2 R^2)}{2\pi} \times\Theta(v(\rho,z_1,z_2,\theta_2) > v_{cut})\Theta(z_2\theta_2^2 < \rho)$$

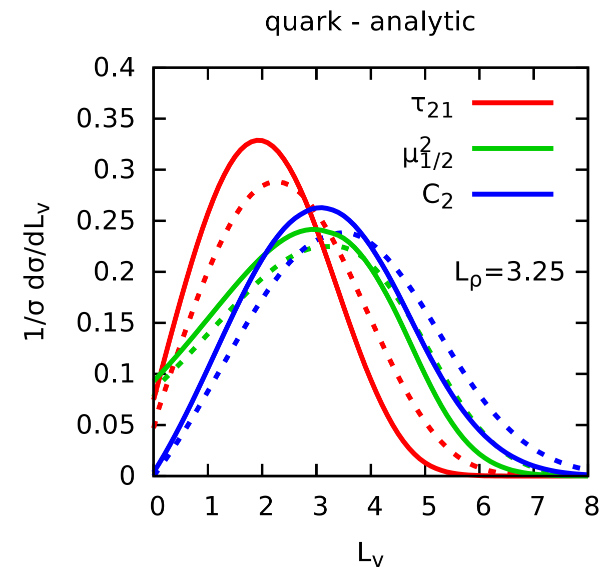
$$+\int_0^1 \frac{d\theta_{12}^2}{\theta_{12}^2}\int_0^1 dz_2 P_g(z_2)\frac{\alpha_s(z_1\rho z_2^2\theta_{12}^2 p_t^2 R^2)}{2\pi} \times\Theta(v^{sec}(\rho,z_1,z_2,\theta_{12}) > v_{cut})$$

Now all we need is to find $v(\rho, z_1, z_2, \theta_2)$.

Provides powerful, quantitative insight into jet observables and Monte Carlos

Laís Sarem Schunk





Log plots for comparison to fixed-order divergences

- Difference between shapes qualitatively reproduced (but Pythia has a more "peaked" distribution).
- Including global NLL corrections improves the agreement.

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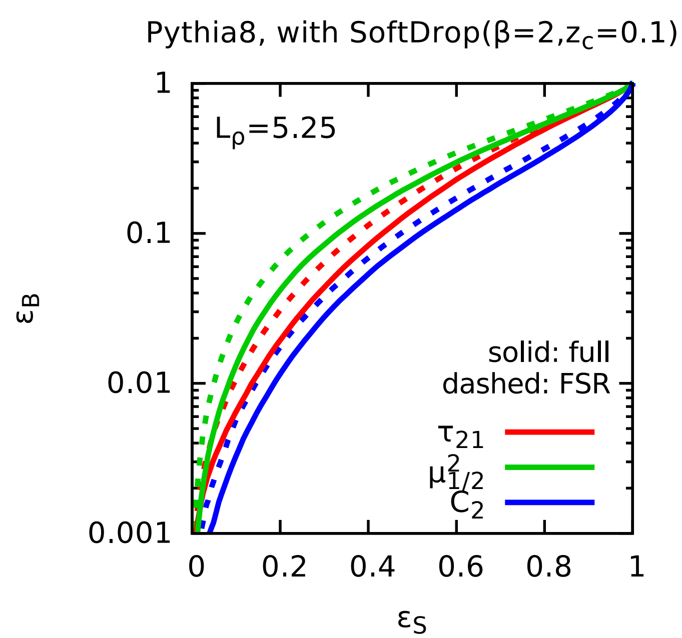
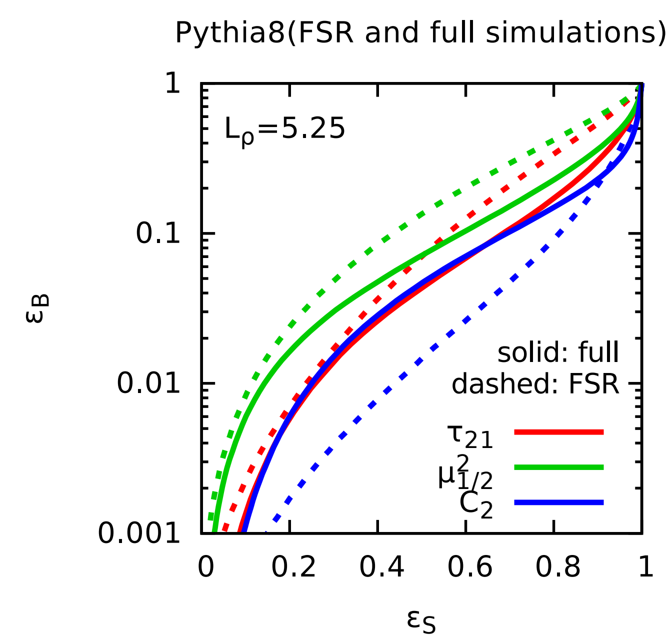
und ε_B vs. signal ε_S.
large-angle constraints, and τ_{21}
elicate call).

Can be misleading; small L region is poorly described

Observables are still in resummation regime there





- Soft drop reduces NP effects but decreases efficiency.

Hadronization corrections should be able to be included from first principles

Approach to Calculation

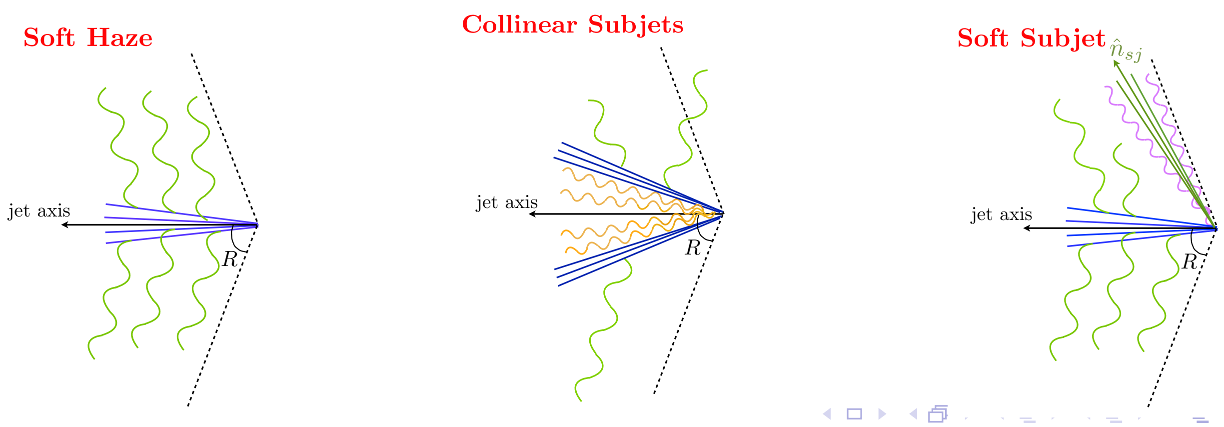
Experiment

- Measure collection of IRC safe observables: $\tau_1^{(\beta)}, e_2^{(\beta)}, \cdots$
- Impose cuts on observables to classify different jet structures.
- Events in each classification separately treated.

Calculation

- Calculate collection of IRC safe observables: $\tau_1^{(\beta)}, e_2^{(\beta)}, \cdots$
- Parametric relations between observables define classification.
- Effective field theory description of jets in each classification used for calculation.

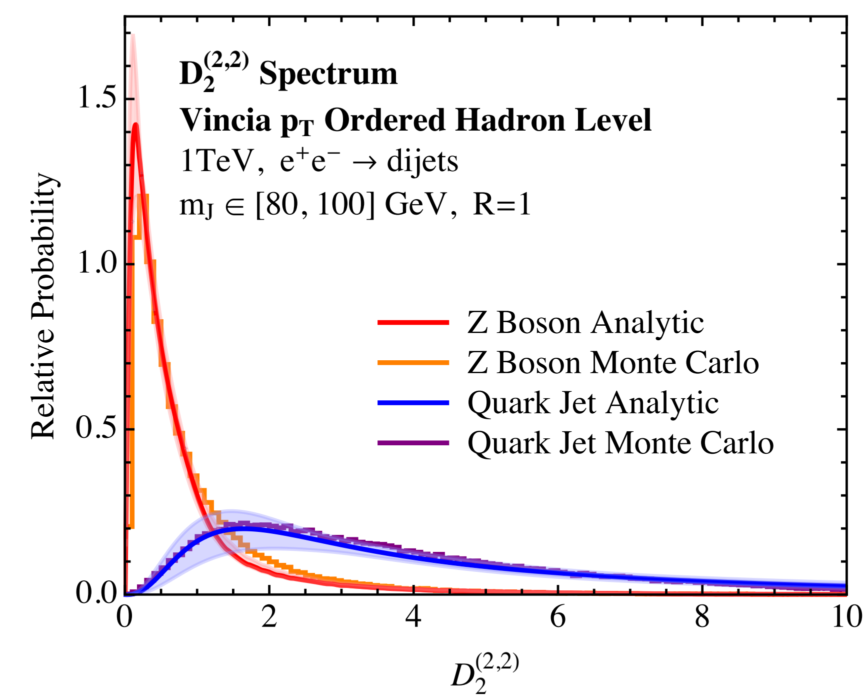
EFTs for 2-prong Substructure:



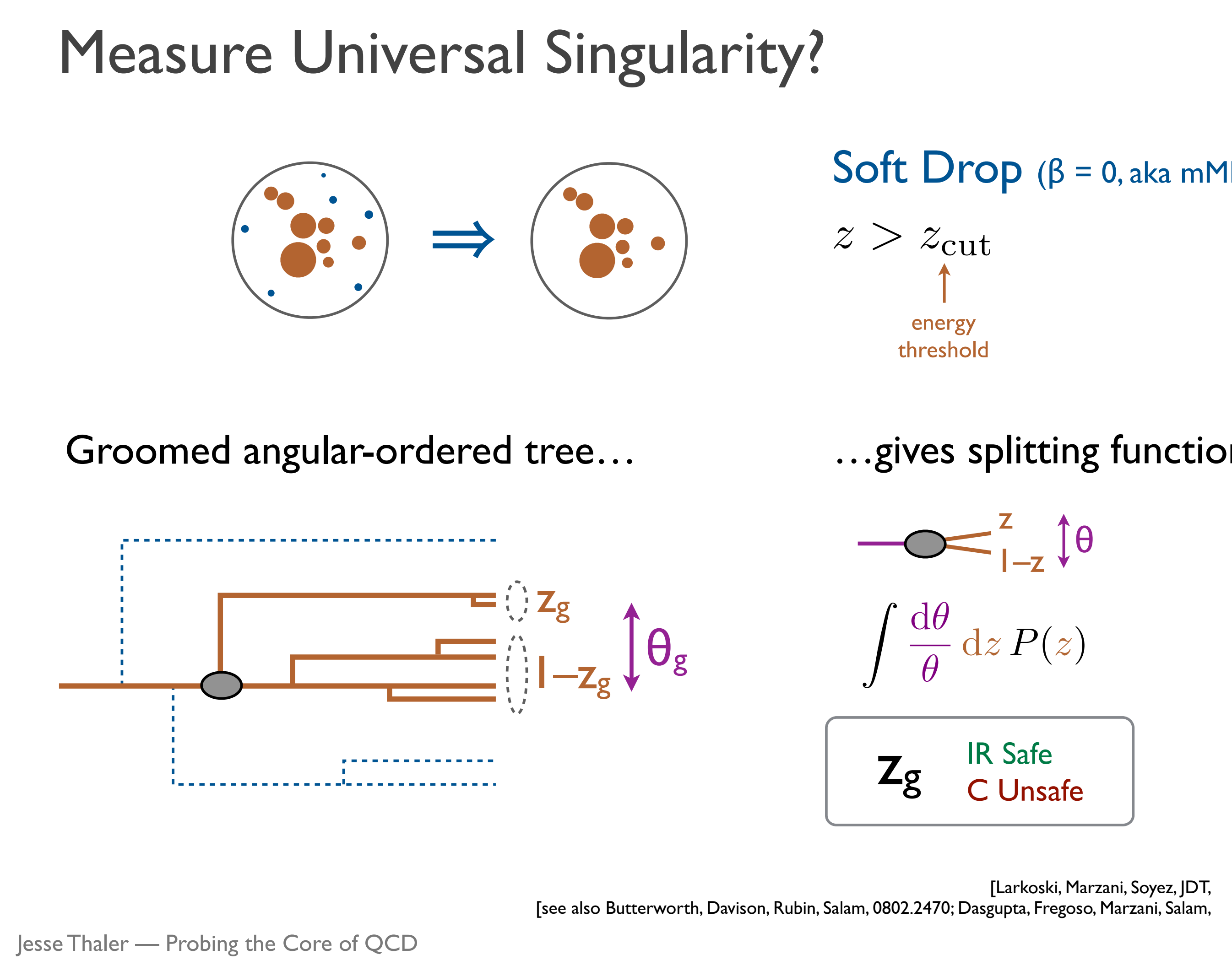
Presented factorization theorem for 2-prong discriminants

alytic Boosted Boson Discrimination

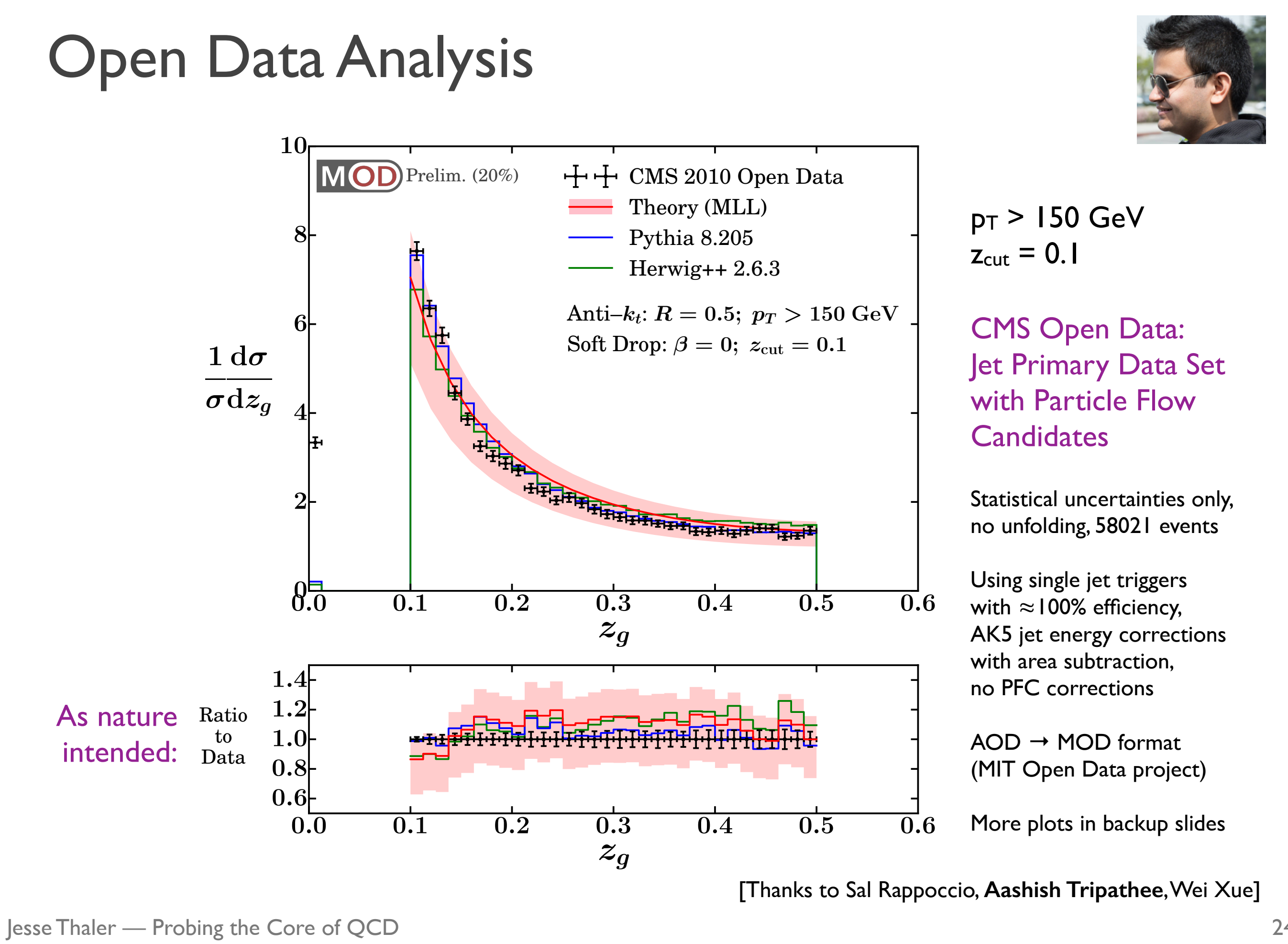
- Analytic predictions for both signal and background allows for analytic boosted boson discrimination.



Any insight into groomed observables?

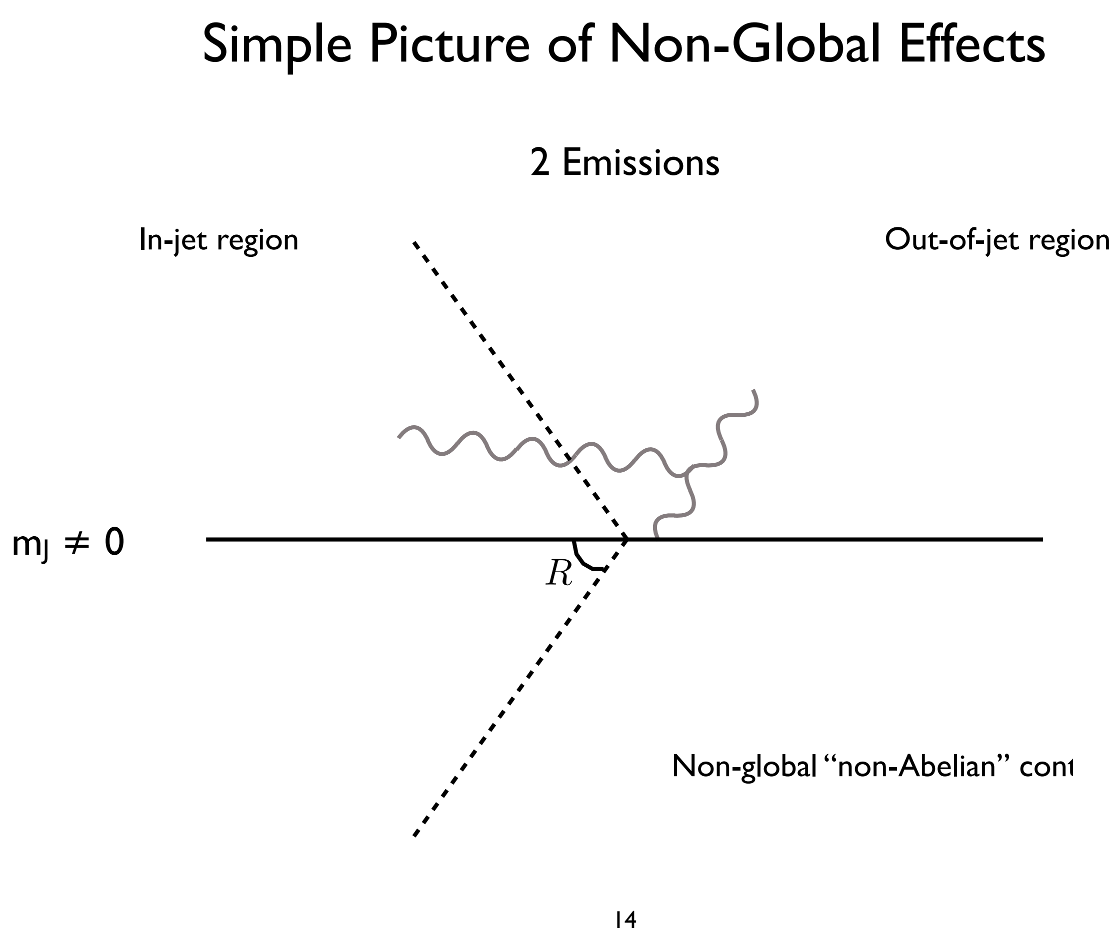


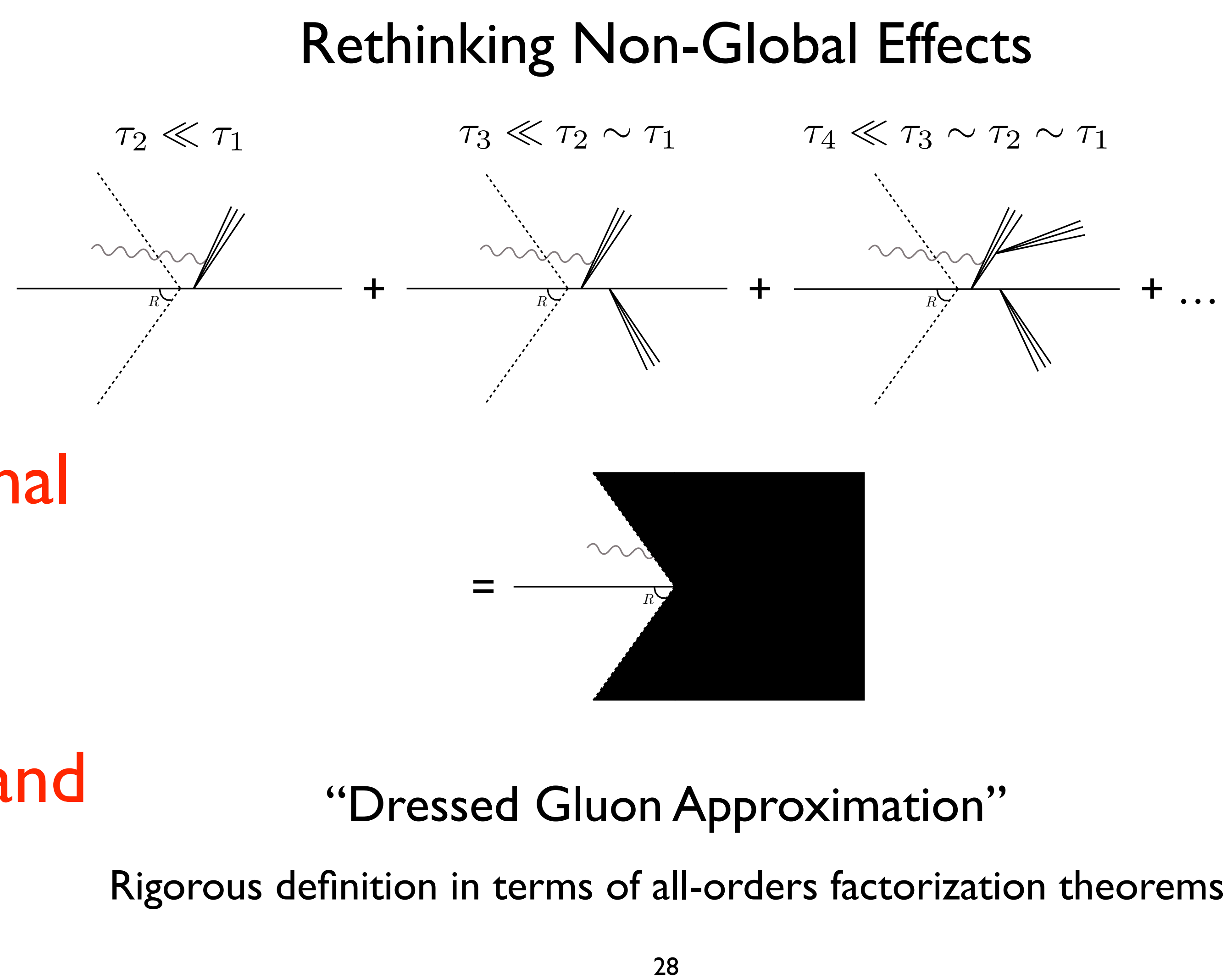
Measurement of the QCD splitting function from CMS Open Data



Other than novelty, is there a "killer app" for this?

Jet substructure-based insights into non-global logarithms

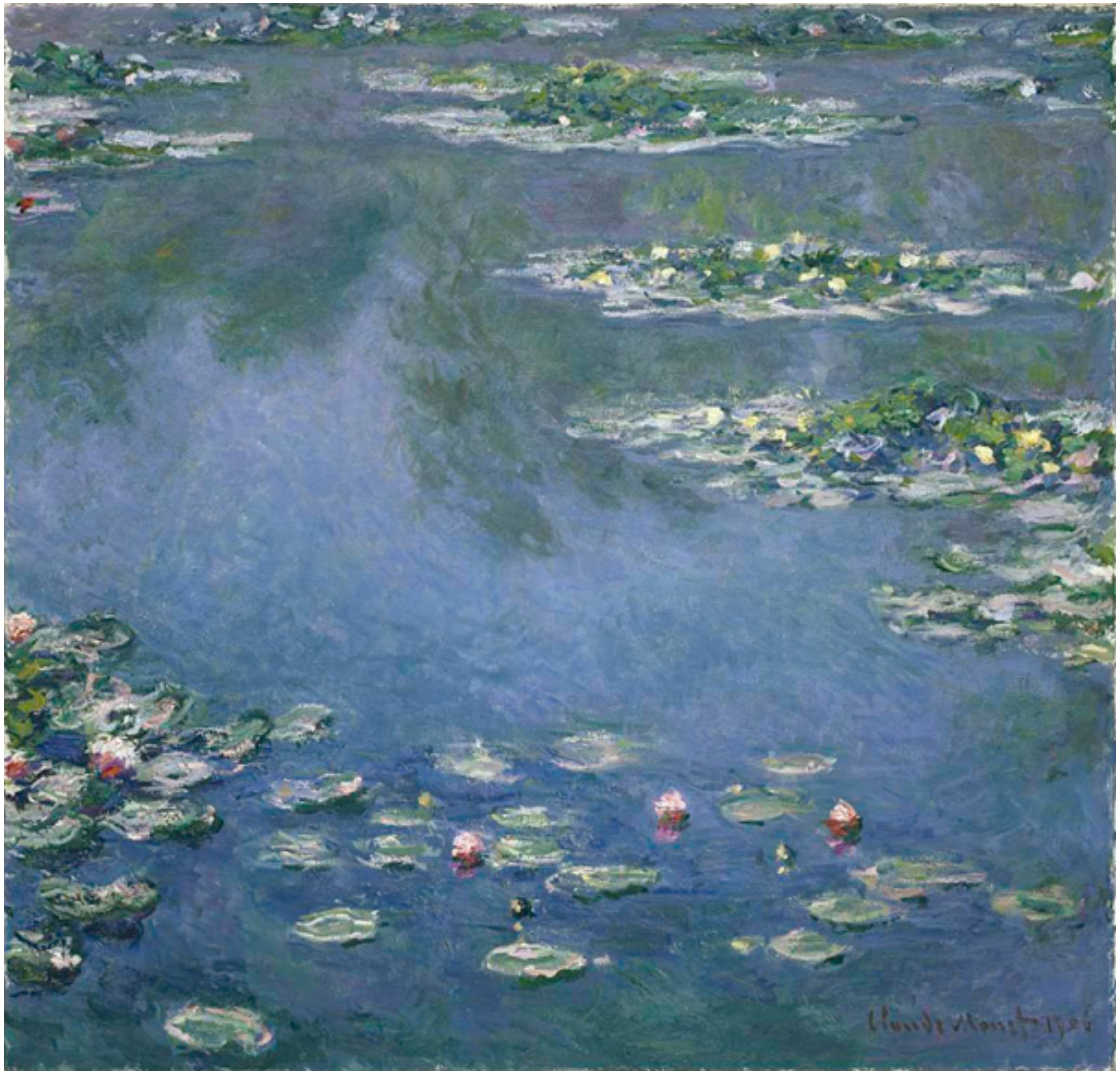




How is this related to the traditional logarithmic counting?

What is the expansion parameter and how does it formally scale?

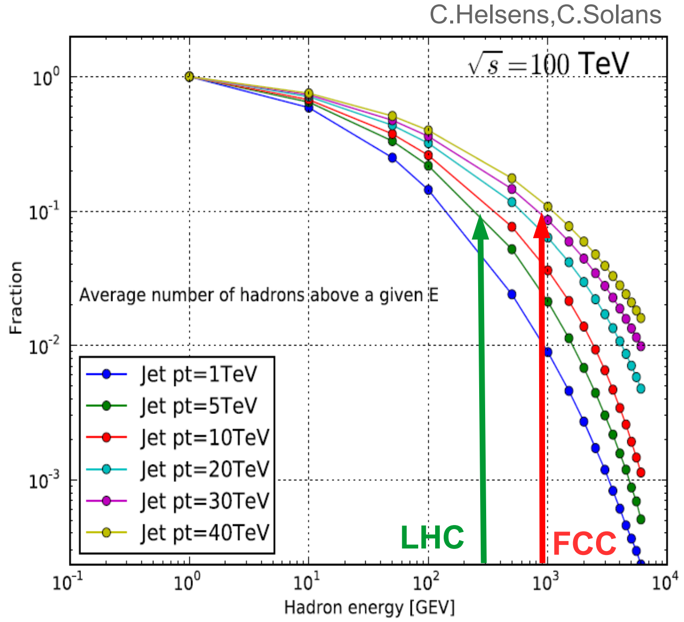
New Horizons



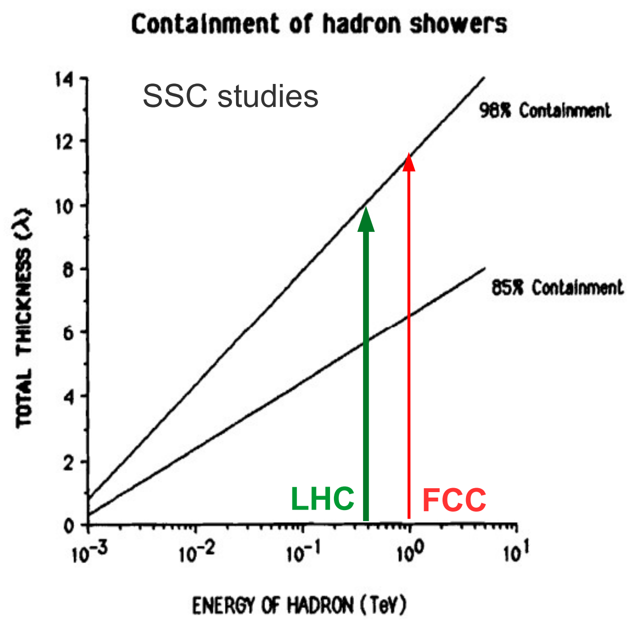
Nymphéas, Claude Monet

Estimating HCAL depth

Leading particles in high-pT jets
C.Helsens,C.Solans



http://lss.fnal.gov/conf/C860623/p355.pdf

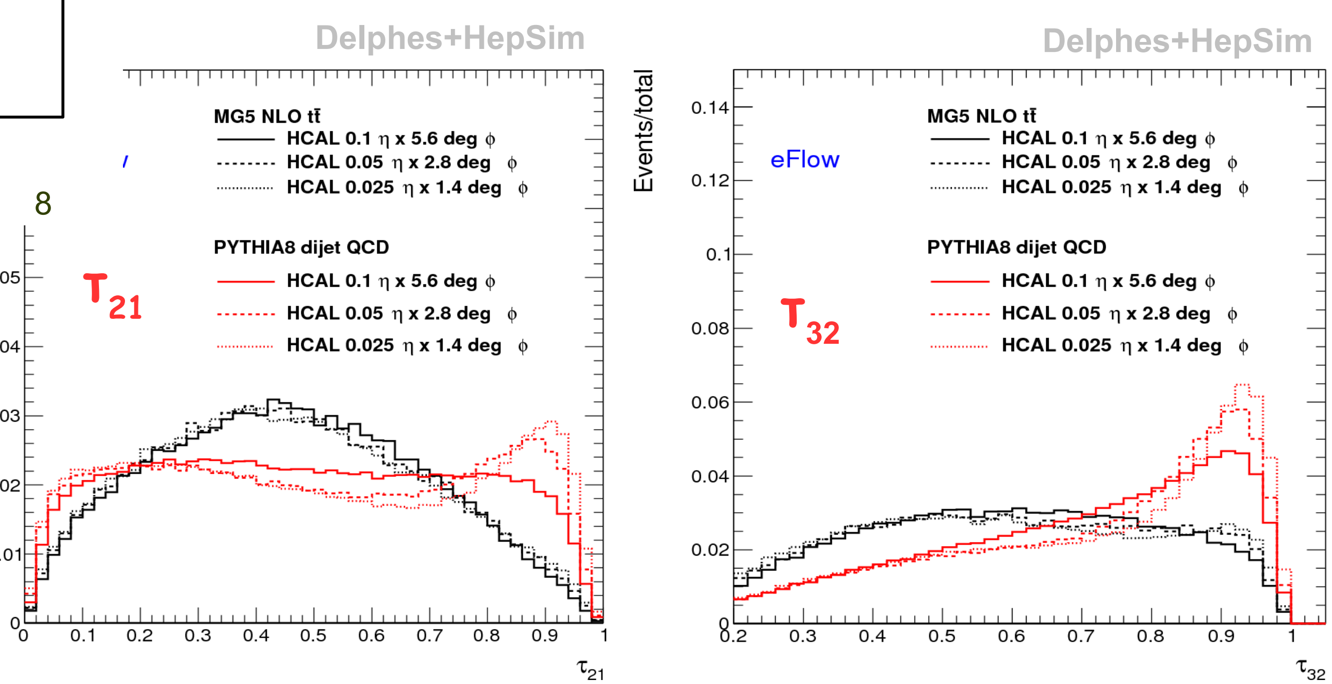


pT(jet)>30 TeV: ~10% will be carried by 1 TeV hadrons (~9 hadrons/jet)
12 λ is needed to contain 98% of energy of a 1 TeV hadron
Agrees with SSC estimates

Need deep calorimeter to capture hadronic radiation at a future collider

Old lessons from SSC?

HCAL cells. Boosted top quarks vs QCD dijets



- 0.1 → 0.05 cell size reduction improves QCD background rejection
- 0.05 → 0.025 cell size reduction shows smaller improvement
- Same conclusion for smaller cell size

Improved angular resolution, improved discrimination

What happens with the mass resolution?

What happens with realistic pile-up (and grooming)?

Finite resolution

(typical lengths, in ATLAS , CMS & future cal [CALICE] being 20–30 cm)

- Smaller scales cannot be resolved in the hadronic cal. (HCAL)!

- For any given detector exists minimal angular scale:

$$\theta_{\rm had} \approx \frac{d_{\rm had}}{r_{\rm HCAL}} \approx 0.1 \times \frac{\lambda_{\rm HCAL}}{20\,{\rm cm}} \times \frac{2\,{\rm m}}{r_{\rm HCAL}}$$

(muon-cal+magnets => hard to imagine $r_{\rm HCAL}$ > 1-2 m

Irreducible angular resolution with traditional calorimetry?

No resolution improvement with 3D shower information?

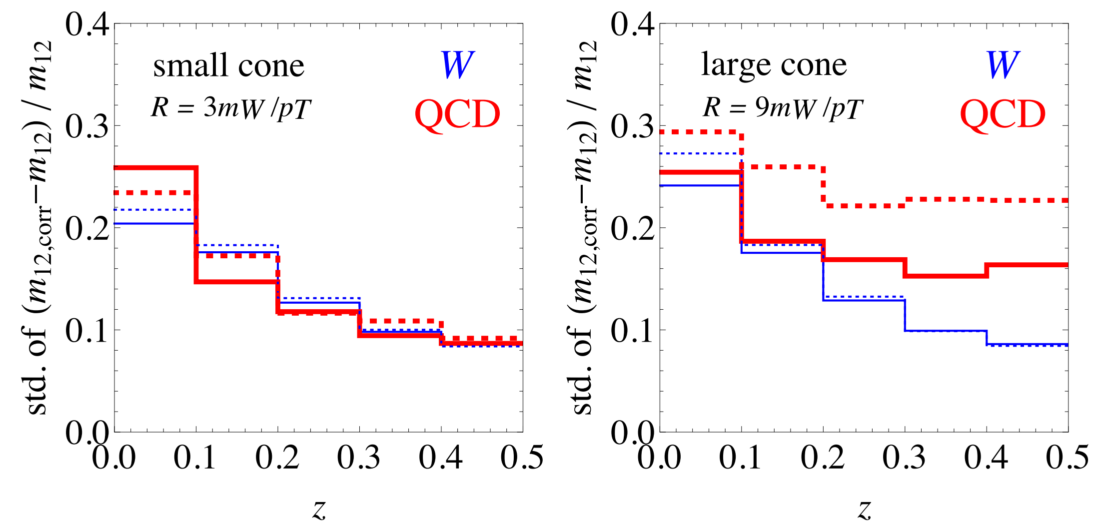
Neutral-less jet substructure

Lose 15% of jet energy ±15%

Jet mass error due to subjet fluctuations

- Understand analytically, first focus on blue curves for signal:

Bressler, Flacke, Kats, Lee & GP (15)



jet mass (truth mass = 75 ± 5 GeV), jet p_T = 3 TeV (solid) , 10 TeV (dotted).

$$\left(\delta\left(\frac{m_{12,\rm corr} - m_{12}}{m_{12}}\right)\right)^2 \simeq 2\left(\frac{1}{2} - z\right)^2 (\delta f_N^{1,2})^2 + \langle y\rangle^2\,(\delta f_N^{3+})^2 + \ldots$$

$$y \equiv \left(\sum_i E_i - E_1 - E_2\right)/\sum_i E_i, \quad f_N^{3+} \equiv \sum f_N^i E_i/\sum E_i,$$

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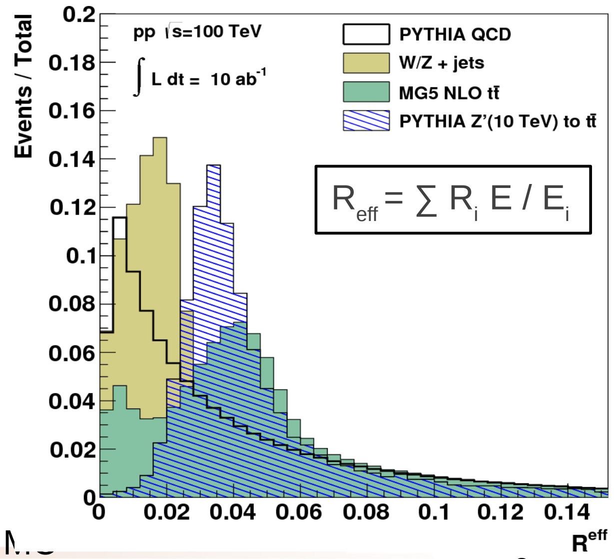
Gilad Perez

Jet Substructure Variables

- Used jet substructure variables to test if substructure can provide needed background rejection
  - Jet Mass
  - Splitting scale d_{12} Phys. Rev. D65 (2002) 96014
  - N-subjettiness variables τ_{32} τ_{21} JHEP 1103:015, 2011
  - Jet Eccentricity Phys. Rev. D81 (2010) 114038
  - R_{Eff} – Energy Averaged Distance from Radius
  - And combinations thereof
- Anti-k_T jets with radius 0.5
  - Built from truth record particles minus neutrinos
  - An infinite and perfect detector



Ideal, particle-level top tagging at 100 TeV

Physics Reach

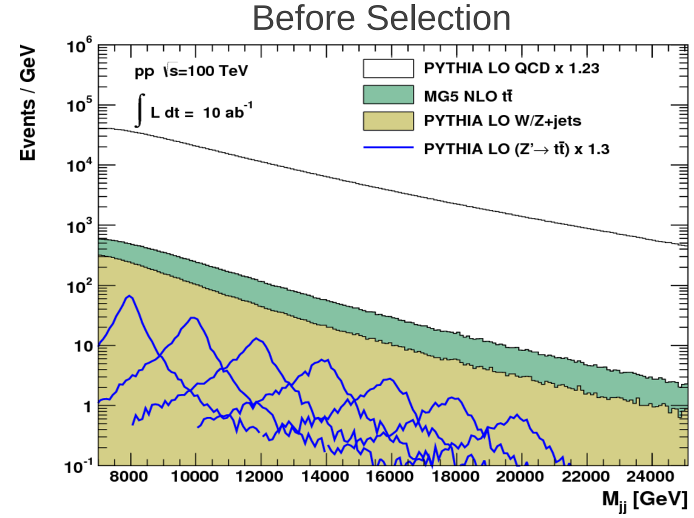
After jet substructure and b-tagging requirements sensitivity to new resonances decaying to ttbar are calculated

- With 10 ab^{-1} can discover 12 TeV signal
- With 150 ab^{-1} can discover 20 TeV signal

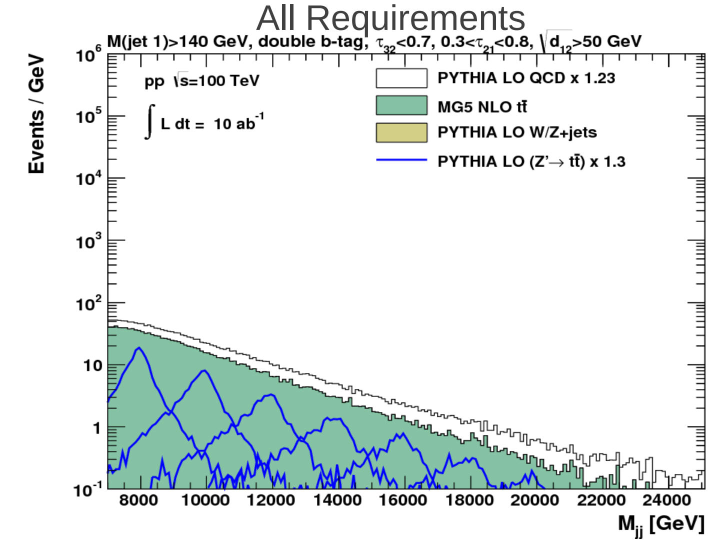
Cross Section X BR 95 %CL Limit

mass (TeV)	$\sigma \times$Br (fb) $Z^{0\prime}$ (th.)	$Z^{0\prime}$ (exp.)	g_{KK} (th.)	g_{KK} (exp.)
8	18.46	7.00	262.3	20.2
10	7.03	3.97		
12	3.02	2.54	45.4	7.7
14	1.44	1.75		
16	0.73	1.27	12.2	4.7
18	0.39	1.10		
20	0.21	0.98	4.2	4.1

Before Selection



All Requirements



Is this a pipe dream?

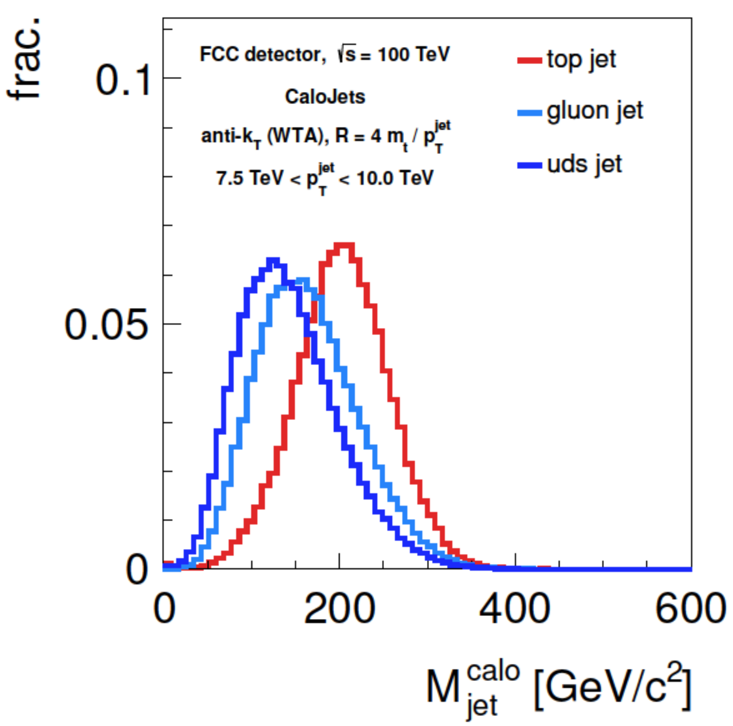
Is there hope for super-TeV b-tagging in a busy tracker?

Charged Jet Mass

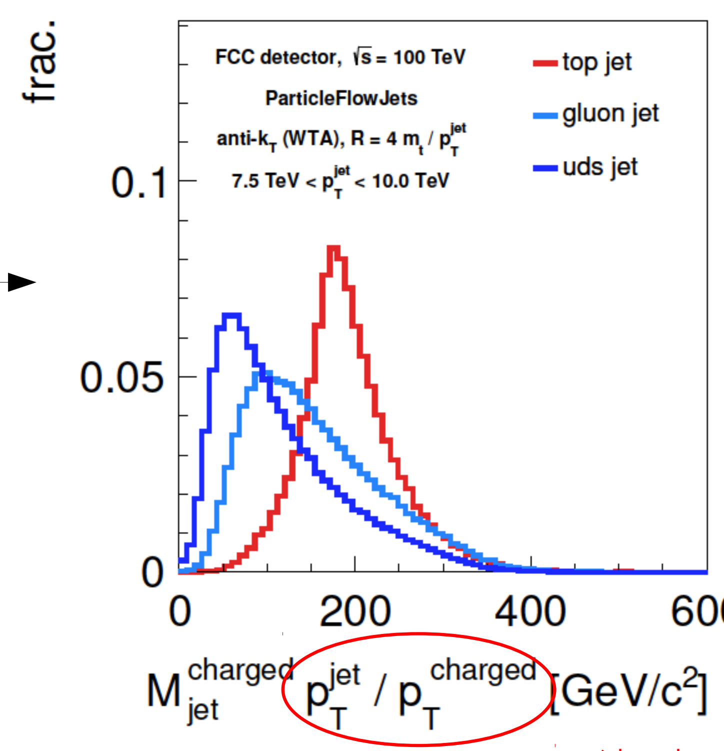
to recover correct value of top mass, rescale charged jet mass by:

$p_T / p_T^{charged}$

Calorimeter based jet Mass



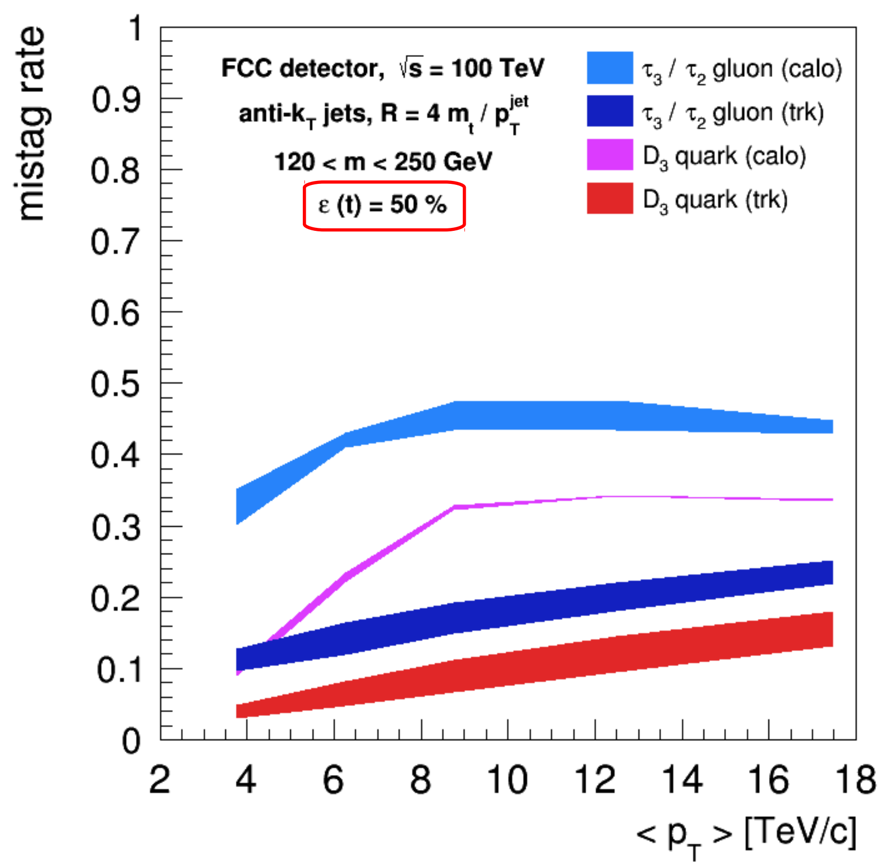
Track- based jet Mass



(thanks Gavin)

Presented procedure for identifying hyper-boosted top quarks

Performance



Is this "good" discrimination?
Is this representative of a future detector?

A First Boosted "Wish List"

Nighthawks, Edward Hopper

Boosted Wish List*

Precision α_s with substructure

Substructure inputs and constraints to PDFs

"Standard Candle" validated, unfolded measurements

*My restricted, biased wish list

Precision α_s with substructure

Current LHC α_s measurements:

CMS 1304.7498:
Ratio of 3-to-2 jet cross sections. Only need fixed-order results.

CMS 1307.1907:
Top production cross section. Only need fixed-order results + soft resummation.

CMS 1412.1633:
Three-jet inclusive cross section, pT > 100 GeV. Only need fixed-order.

CMS 1410.6765:
Inclusive jet cross section and PDFs. Matched parton showers.

ATLAS 1508.01579:
Energy-energy correlators. Fixed-order (NNLO) + Monte Carlo (LL).

Precision α_s with substructure

Current LHC α_s measurements:

No measurements use high precision resummed observables.

Rely on Monte Carlo to model UE/ISR or other contamination.

Goal: Precision α_s from groomed jet observables

No UE/ISR/PU/NGL contamination

Minimum accuracy: resummation to NNLL, match to NLO

%-level precision jet measurements

Substructure inputs and constraints to PDFs

Improvements to quark/gluon jet definitions and discrimination

Are improvements to gluon PDF fits possible?

Jet charge measurements and calculations

Are improvements to quark PDF fits possible?

Grooming for robust jet pT definition

PDF fits in high pile-up environment

“Standard Candle” validated, unfolded measurements

Feasible calculation:
Jet observables measured on $pp \rightarrow Z/\gamma + j$

Measure large class of groomed and ungroomed observables

Goal: Precision calculations to compare to precision measurements

Inputs to Monte Carlo tuning

Fits for universal non-perturbative parameters

As a community, we need clear goals, both theoretically and experimentally

Thank you for a wonderful Chicago-style BOOST!