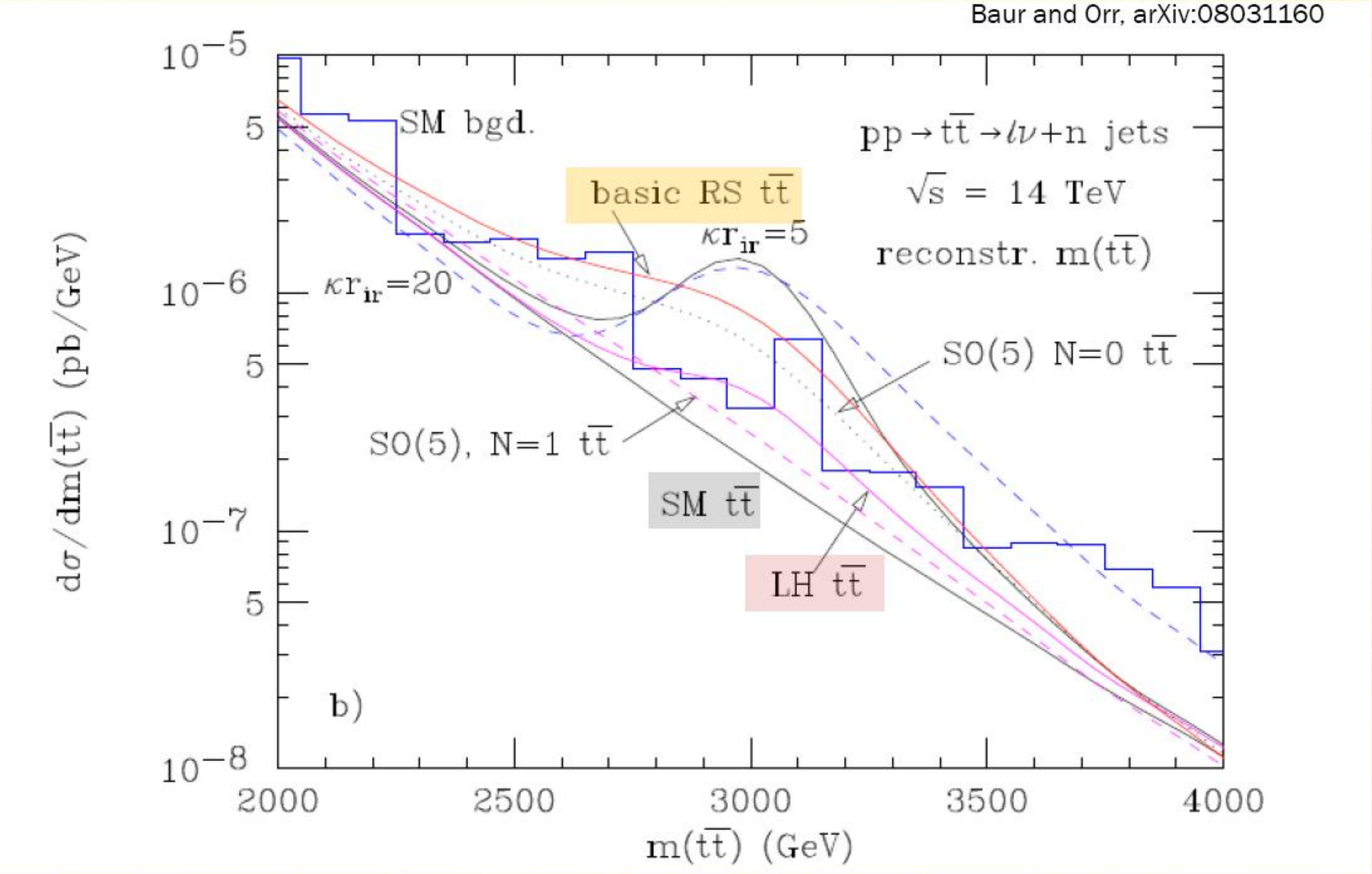
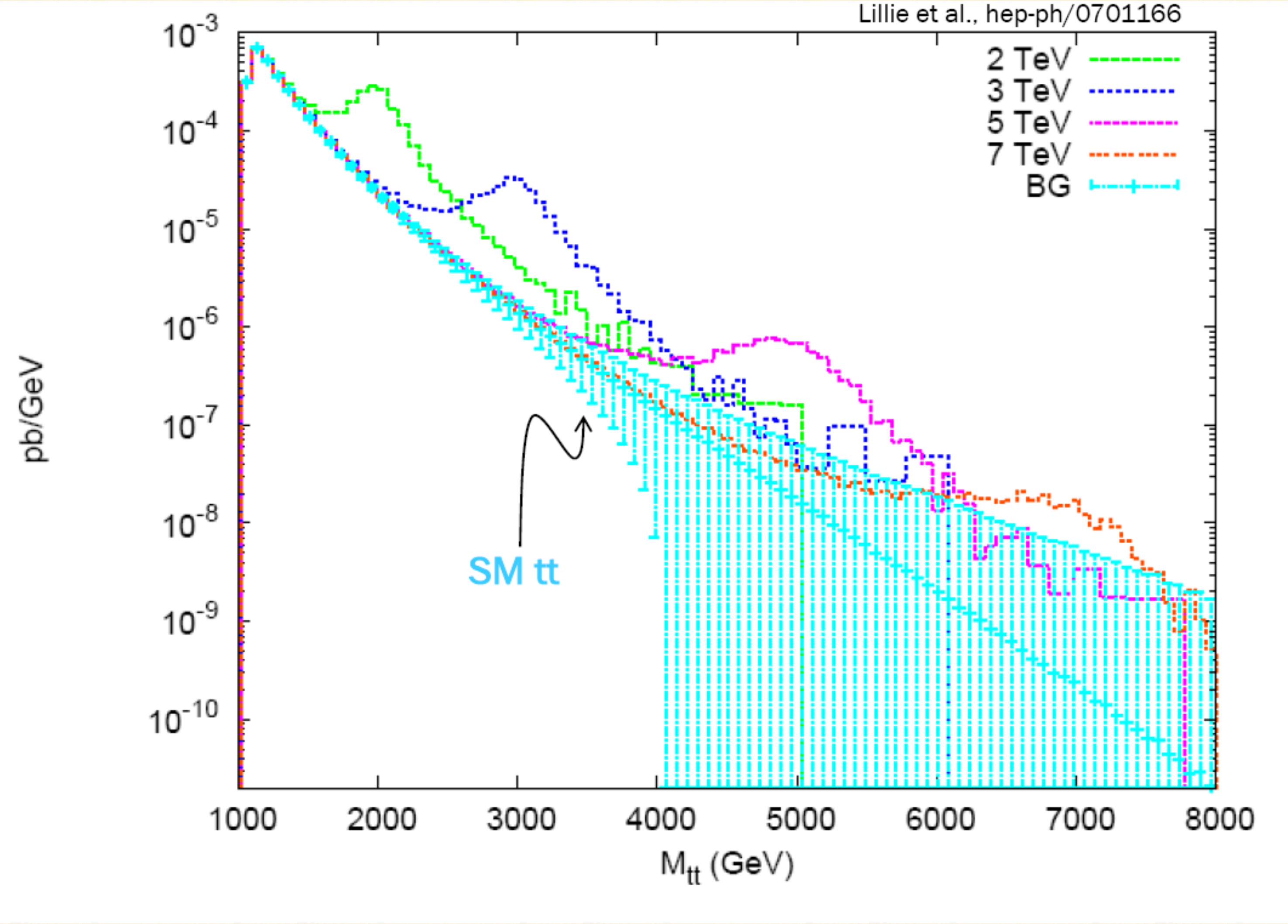
TOP TAGGING

Matthew Schwartz
Harvard University

TT RESONANCES

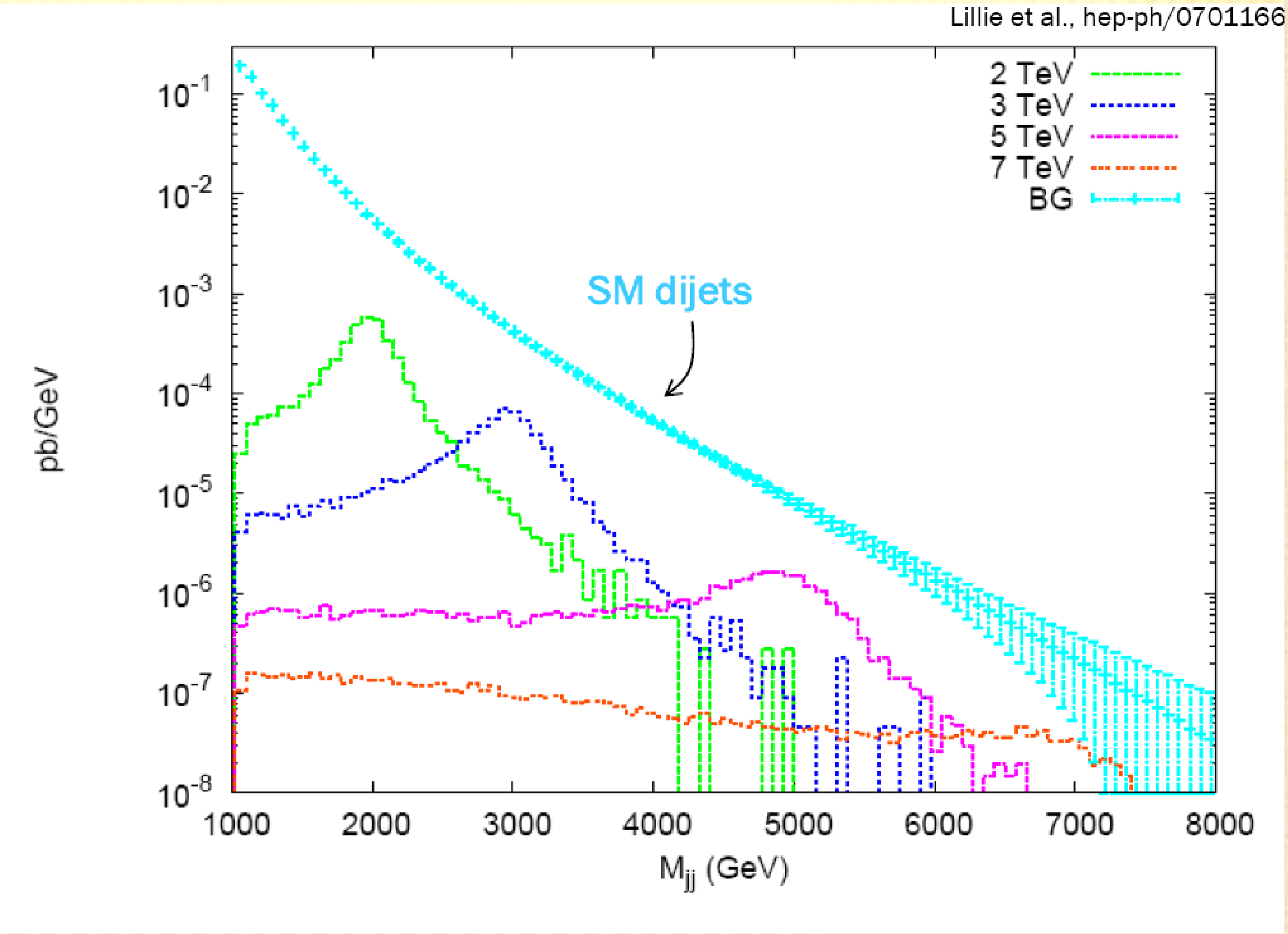


KK GLUONS

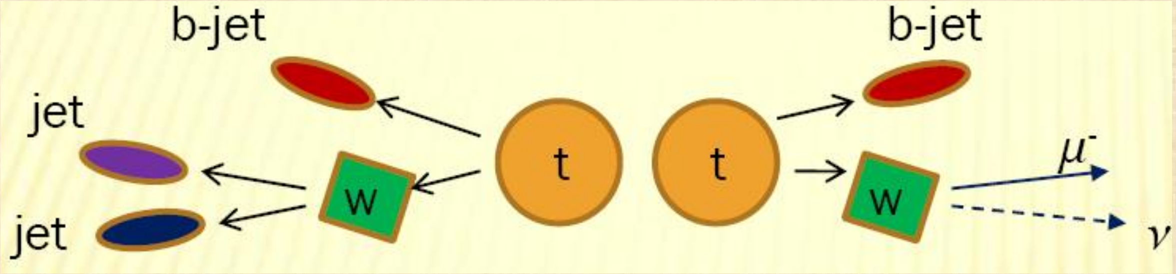


Lillie et al., hep-ph/0701166
2 TeV
3 TeV
5 TeV
7 TeV
BG
SM tt
pb/GeV
M_tt (GeV)
10^-3
10^-4
10^-5
10^-6
10^-7
10^-8
10^-9
10^-10
1000
2000
3000
4000
5000
6000
7000
8000

BACKGROUND IS HUGE



FINDING TOPS



= 2 b-jets+2 jets + μ + E_T

- Difficult to use electrons – at high p_T not isolated
- Branching ratio with one muon is 10% -- lose a lot of signal
- Branching ratio to two muons is 1% -- lose most of signal

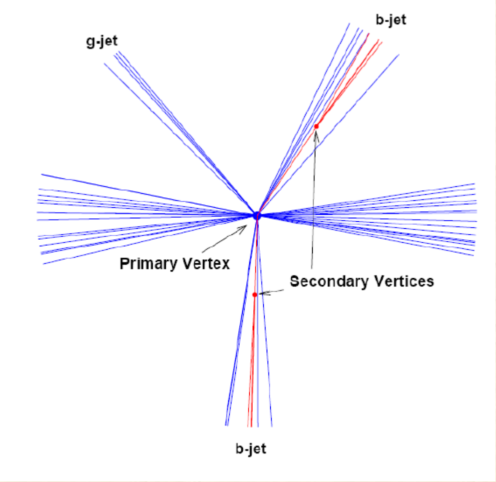
- At high p_T, jets from hadronic decays are not isolated

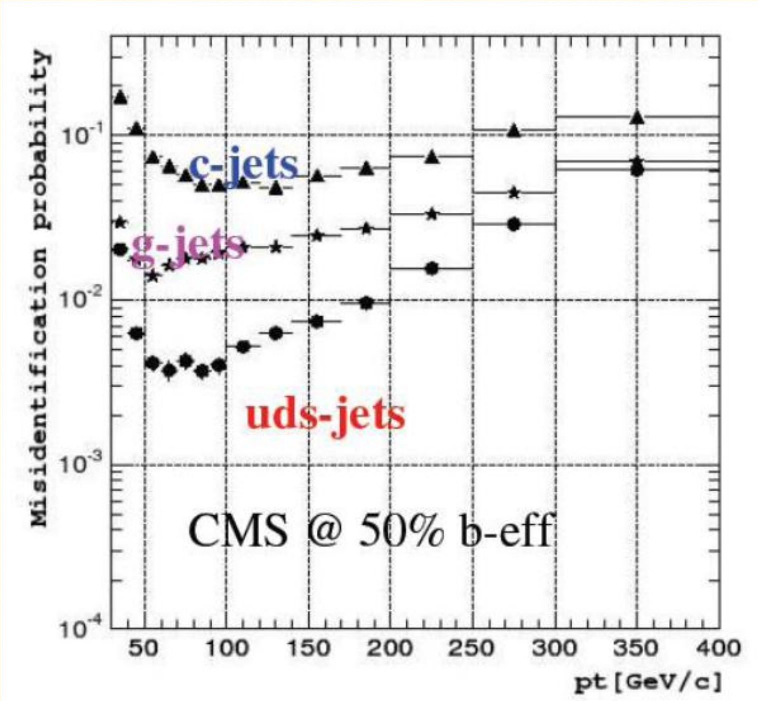
- Require 1 or 2 b-tags
  - b-tagging efficiency degrades at high p_T

B-TAGGING

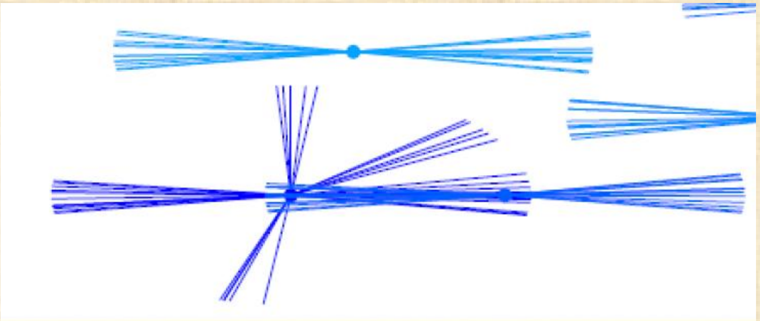
Taken from A. Rizzi

B-tagging efficiency degrades at high p_T





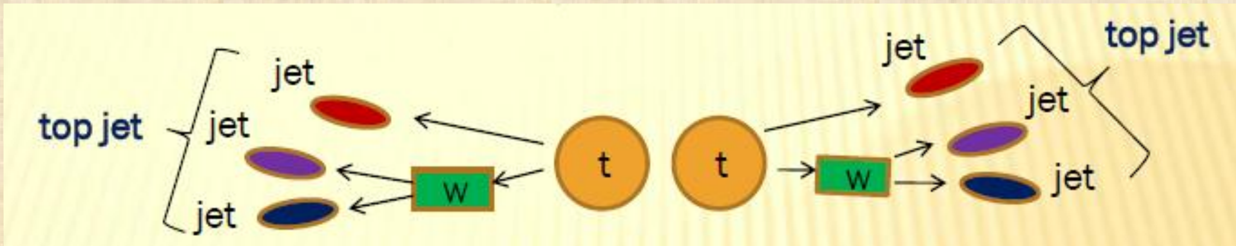
And high luminosity (pileup)



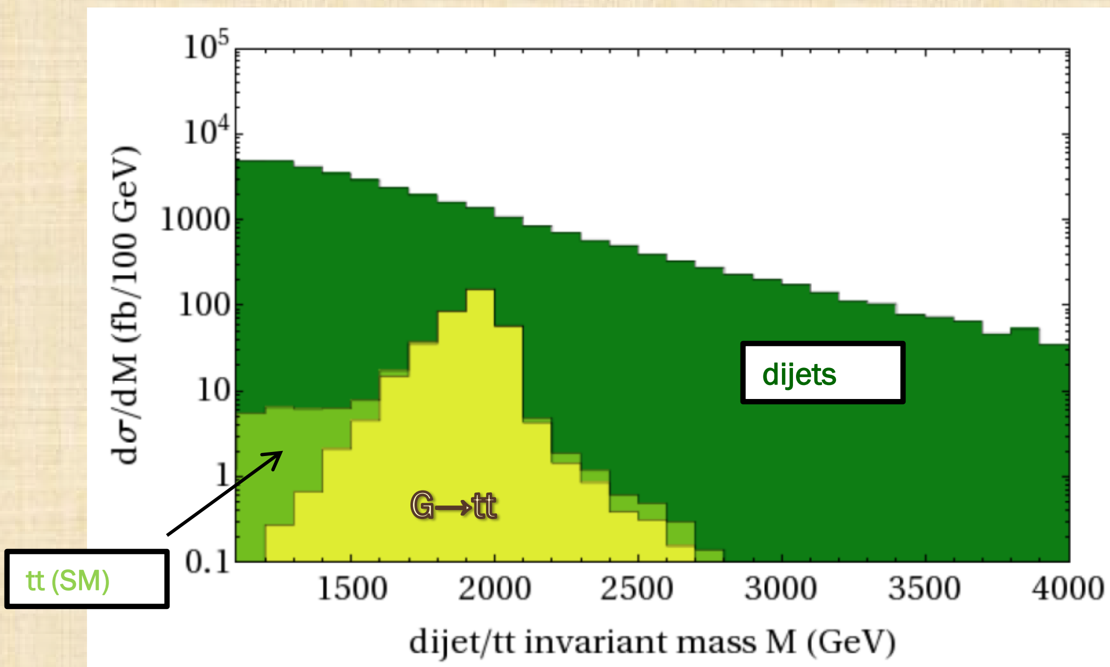
However…

- ATLAS can get 70% b-tagging efficiency at high p_T
- B-tagging will improve with time

ALL-HADRONIC BOOSTED TT



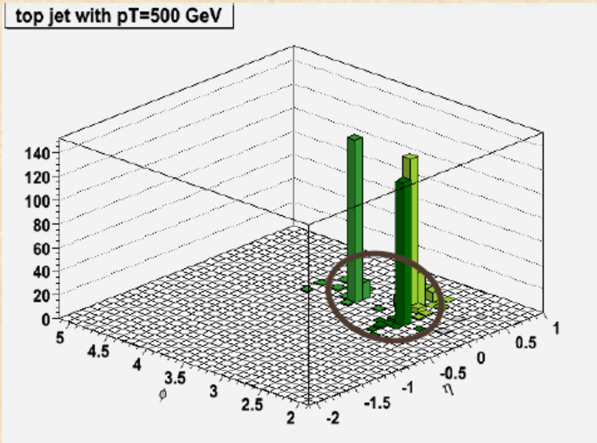
All-hadronic tt events at high p_T look just like dijets!

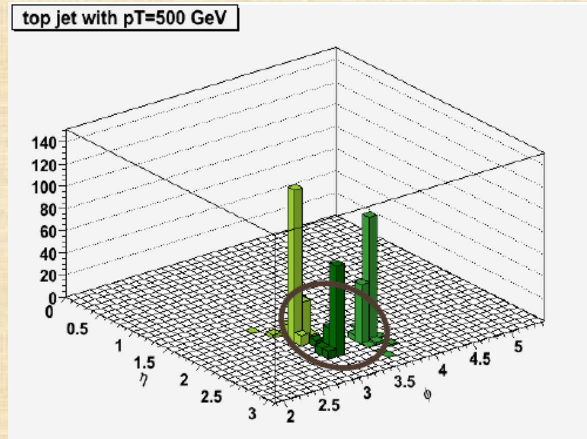


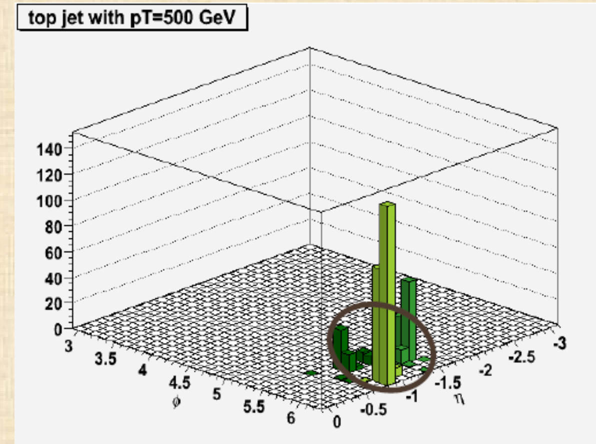
Or do they…?

TYPICAL TOP JETS

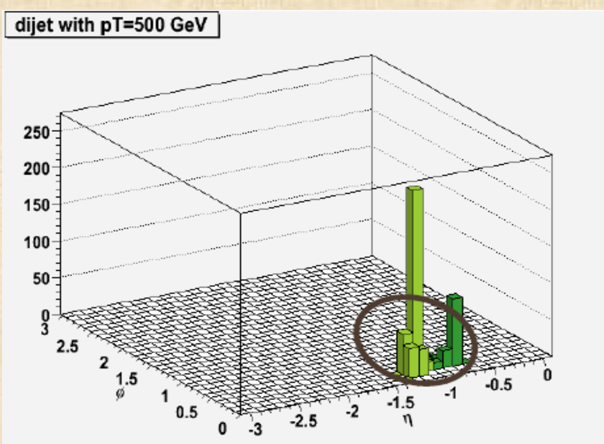
$P_T > 500$ GeV

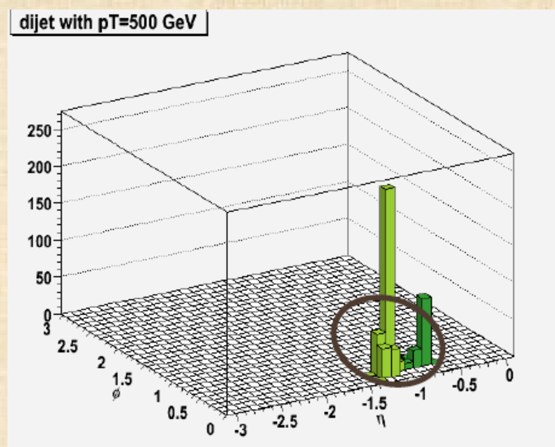


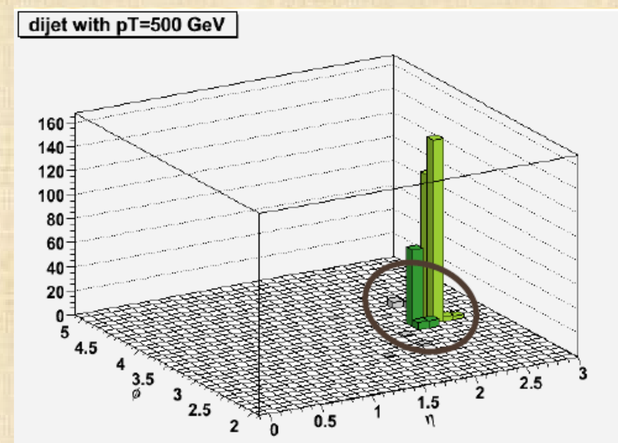




TYPICAL BACKGROUND JETS

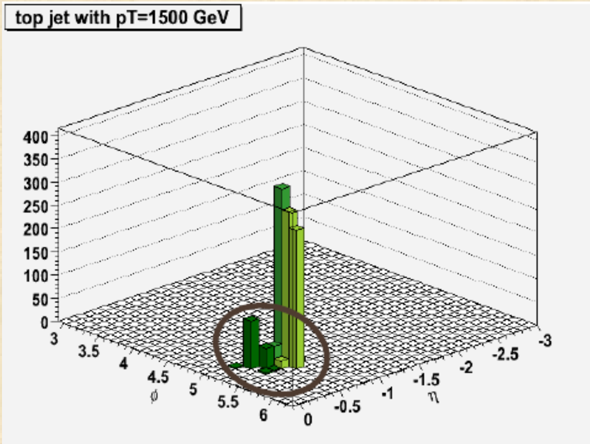


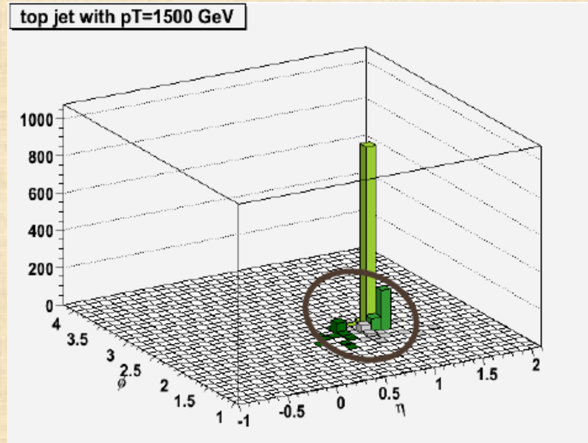


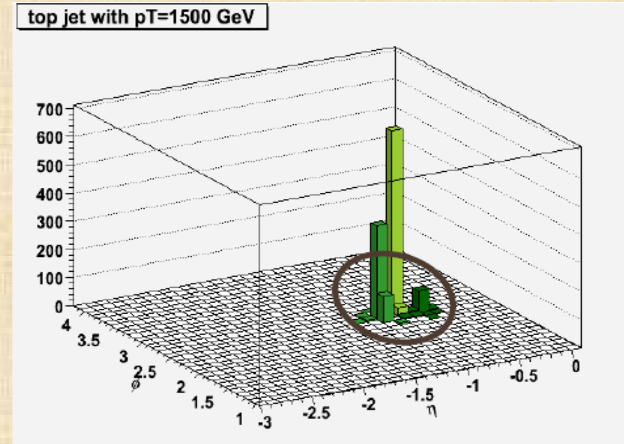


TYPICAL TOP JETS

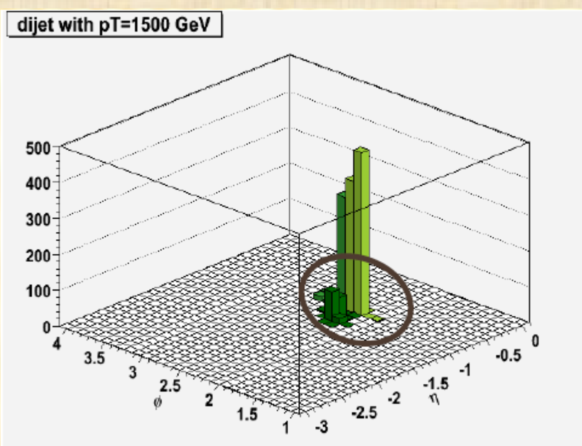
P_T > 1500 GeV

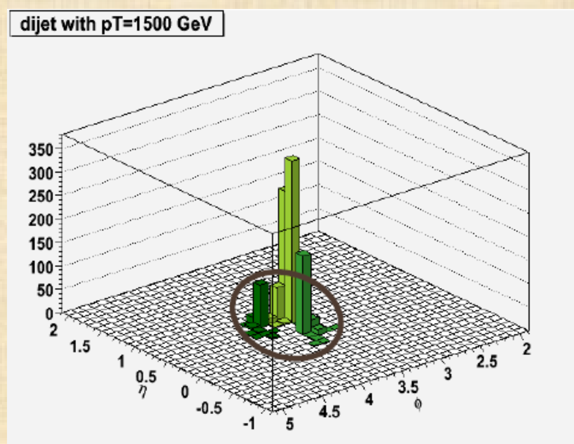


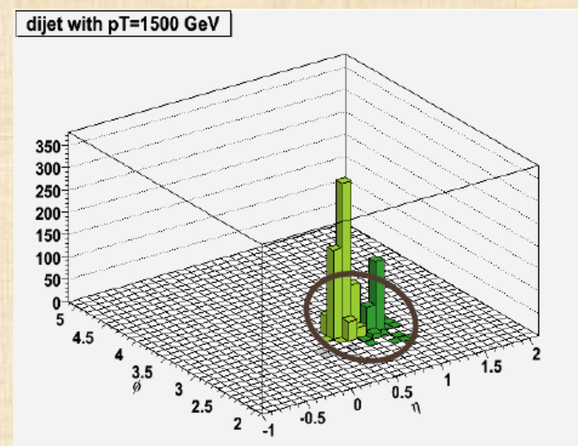




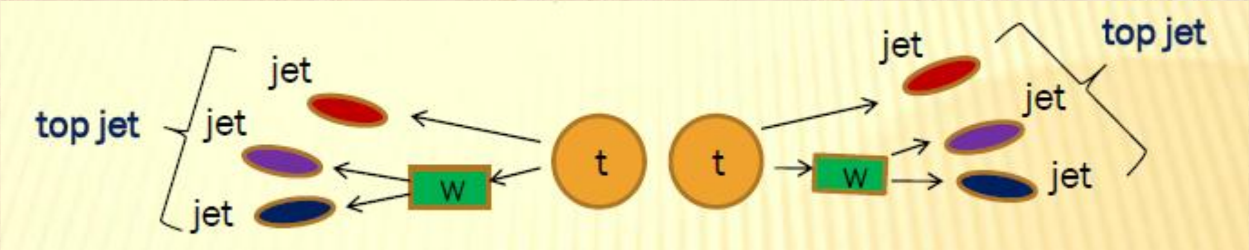
TYPICAL BACKGROUND JETS







ALL-HADRONIC BOOSTED TT



How can we tag the all-hadronic tt events at high p_T?

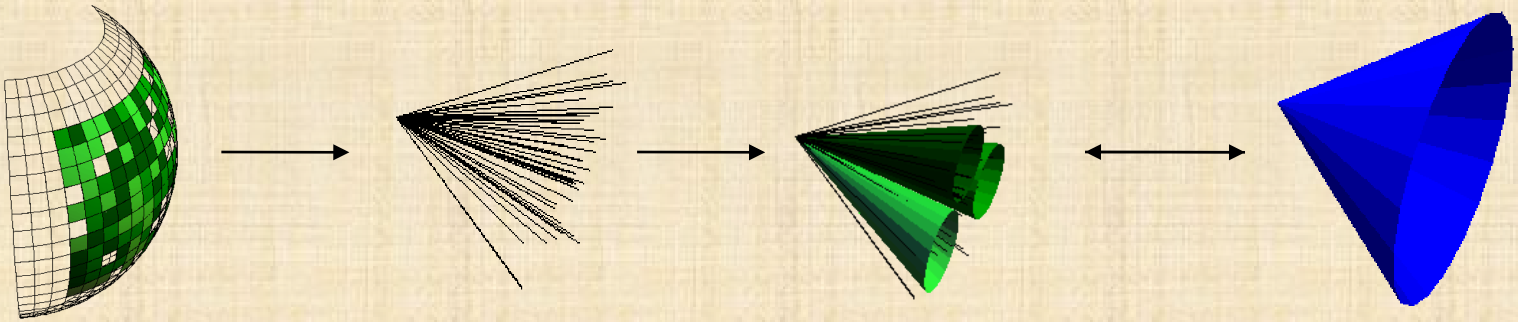
1. Look for subjets
2. Cut on top mass
3. Cut on W mass
4. Cut on helicity angle

D. Kaplan, K. Rehermann, MDS, and B.Tweedie
PRL 101:142001 (2008)

SUBJET DECOMPOSITION

1. Find fat jets first
   - We use geometric Cambridge-Aachen algorithm
   - Fat jet size R= 0.4-0.8

Fat jet size R=0.4-0.8
Varies with jet p_T



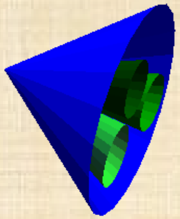
2. Reverse clustering steps
   - Clean out soft radiation

$$\frac{p_T^{(\text{particle})}}{p_T^{(\text{jet})}} > \delta_p \sim 0.05 - 0.1$$

   - Clean out collinear radiation

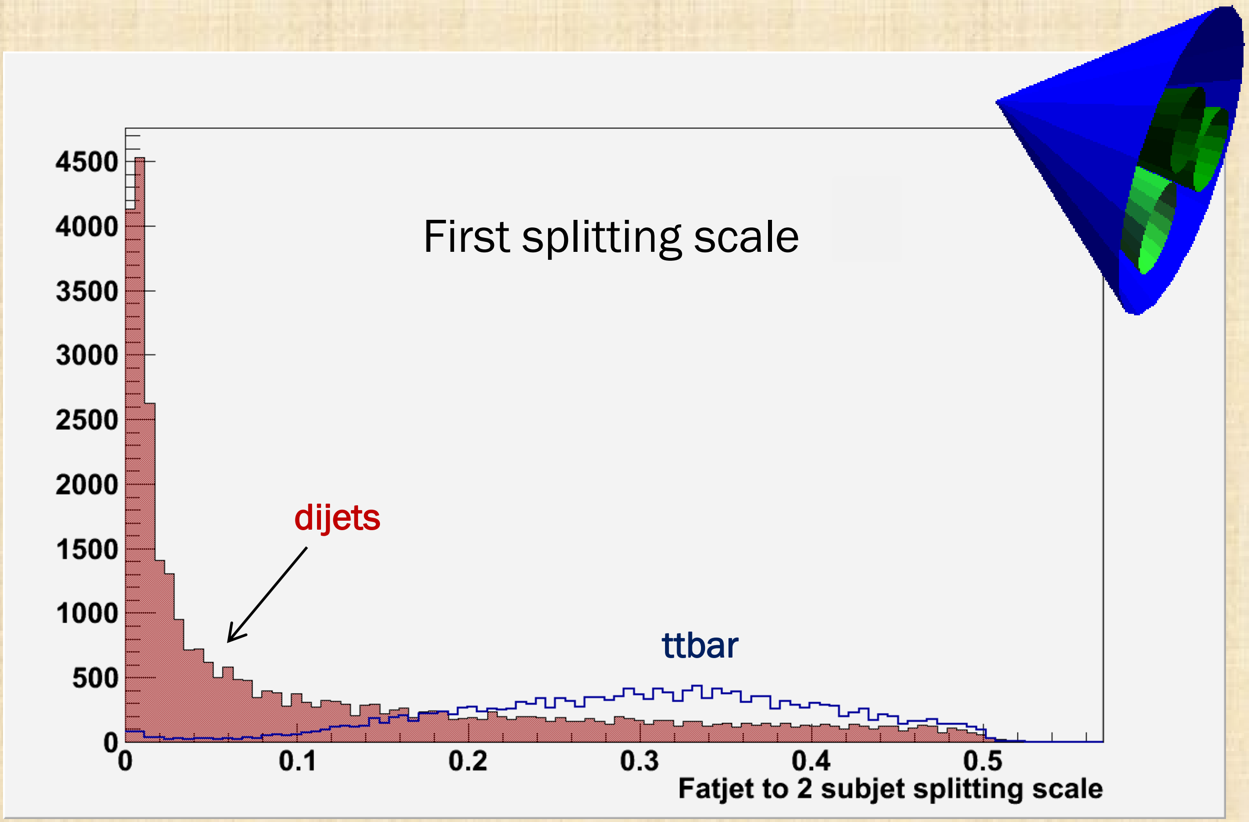
$$|\Delta\eta| + |\Delta\phi| > \delta_r \sim 0.2$$

   - Tops should have a 3 (or 4) subjets



DEMANDING 3 SUBJETS

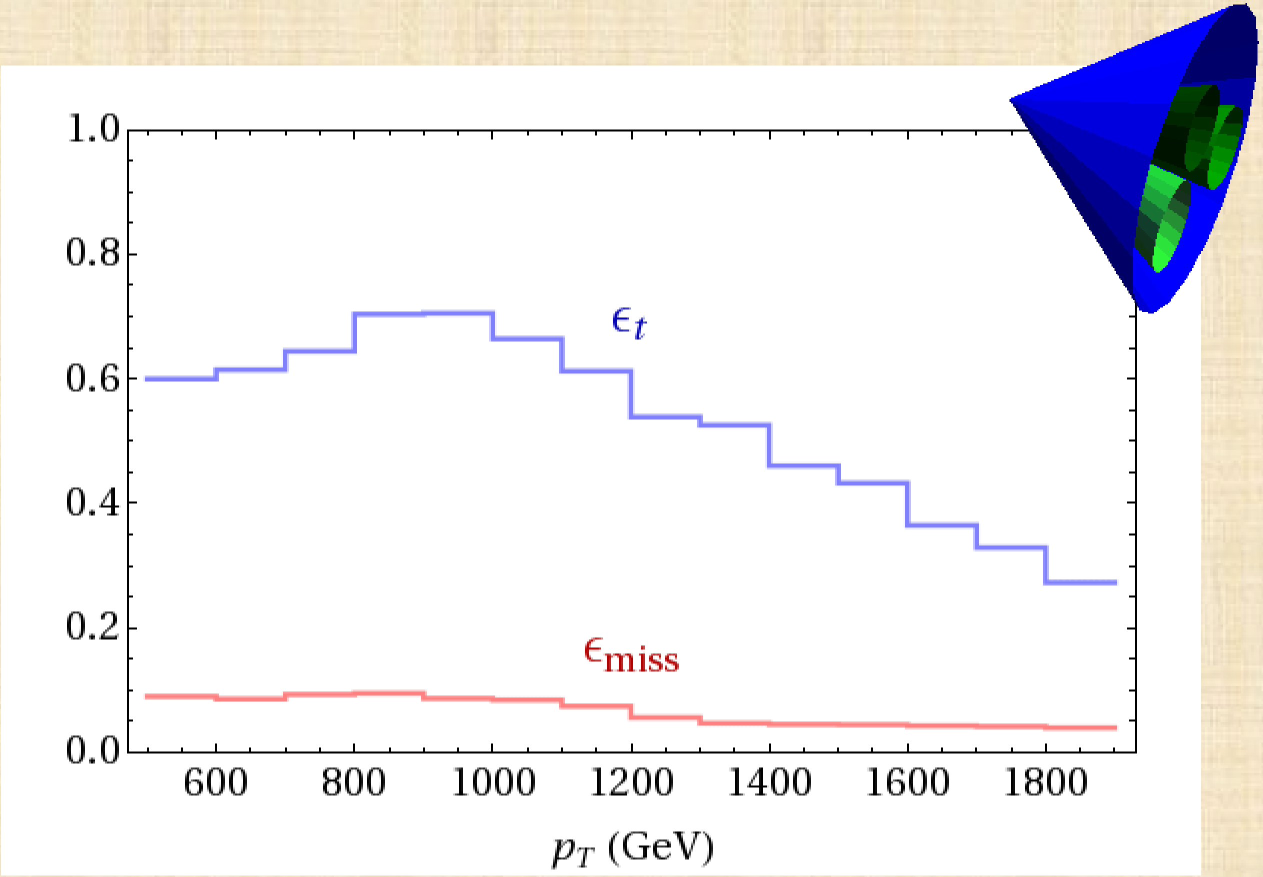
- **Fat jet** has 3 or 4 **hard** (δ_p) **separated** (δ_r) **subjets**



EFFICIENCY FOR SUBJET CUT

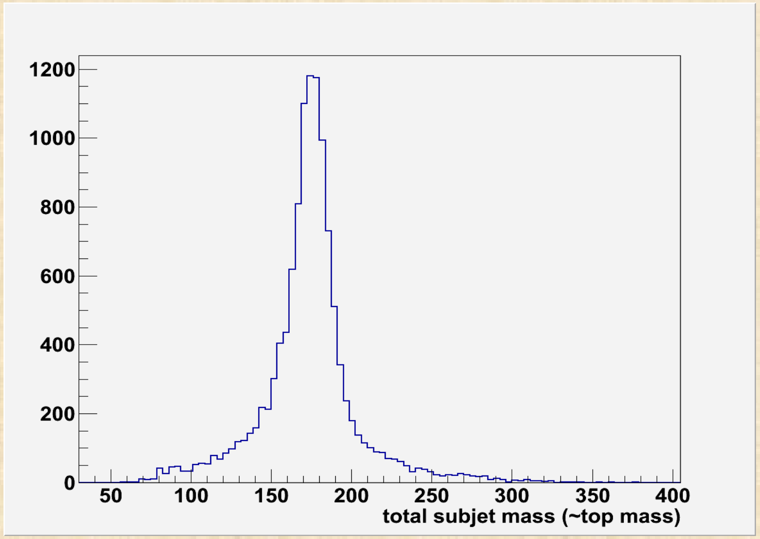
Keeps 60% tops

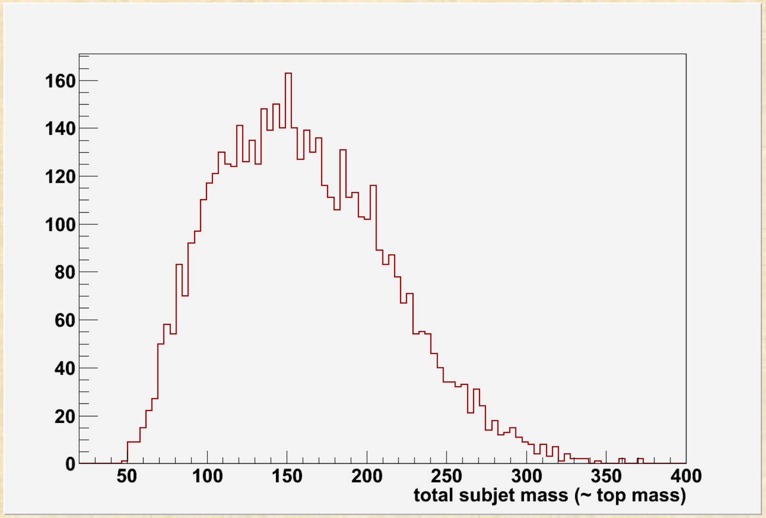
Rejets 90% of jets



TOP MASS

- After **subjet** requirement
- Cut on **fat jet** mass

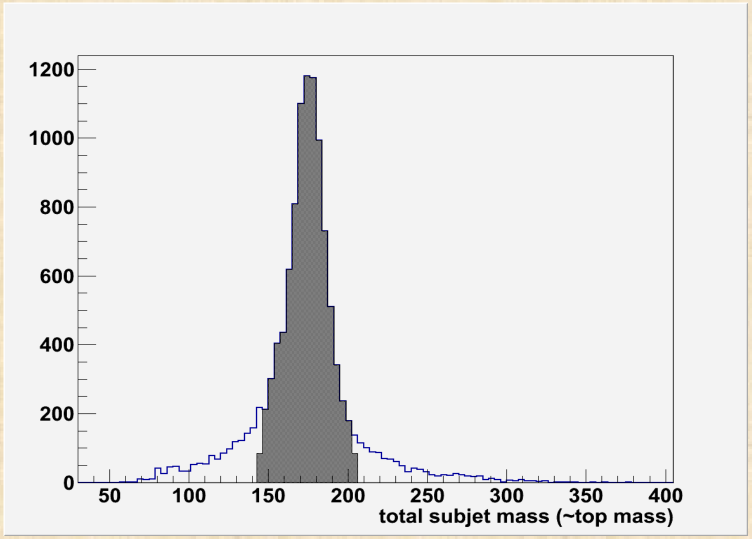


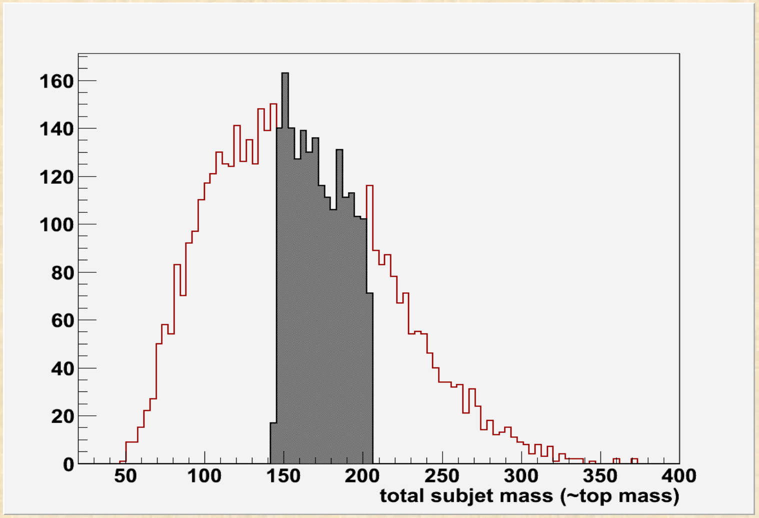


CUT ON TOP MASS

- After subjet requirement
- Cut on fat jet mass

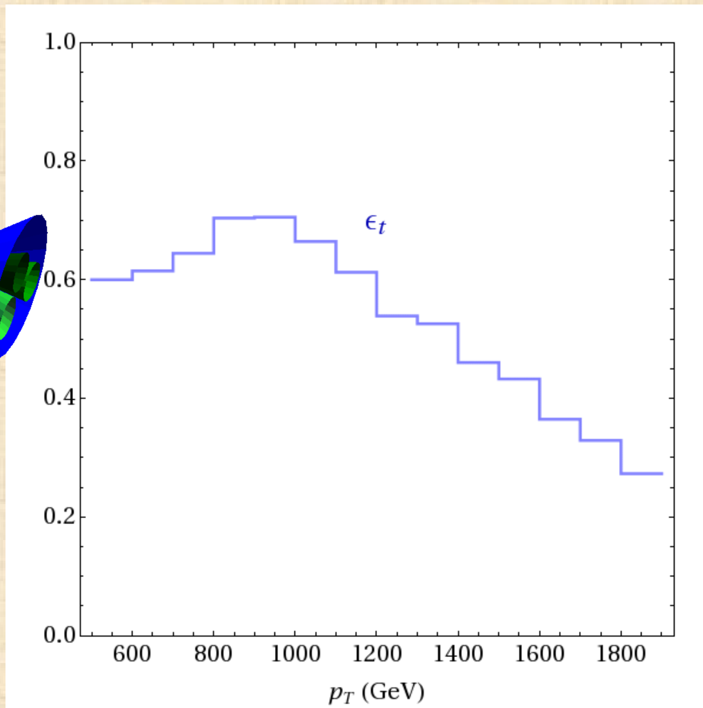
145 GeV < M_t < 205 GeV

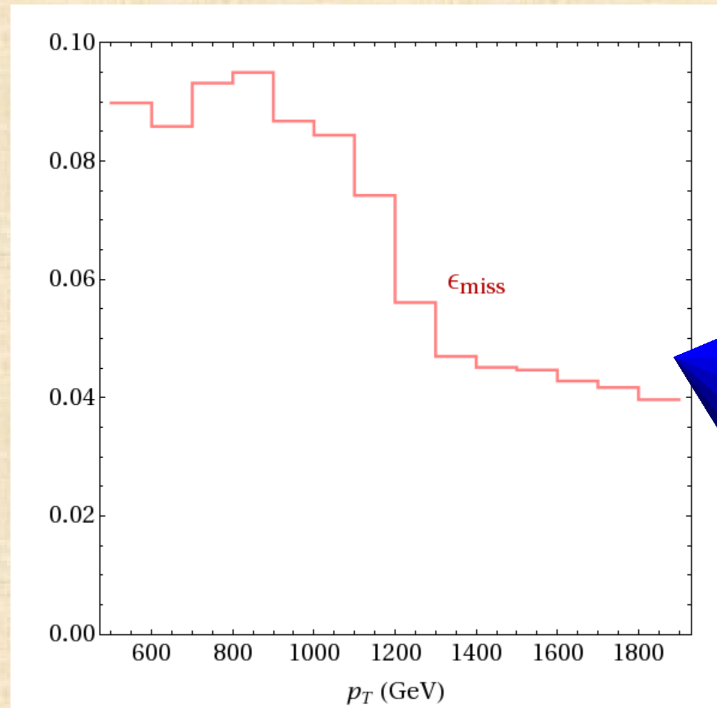




EFFICIENCIES

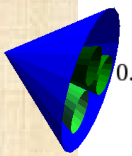
subjet cut only



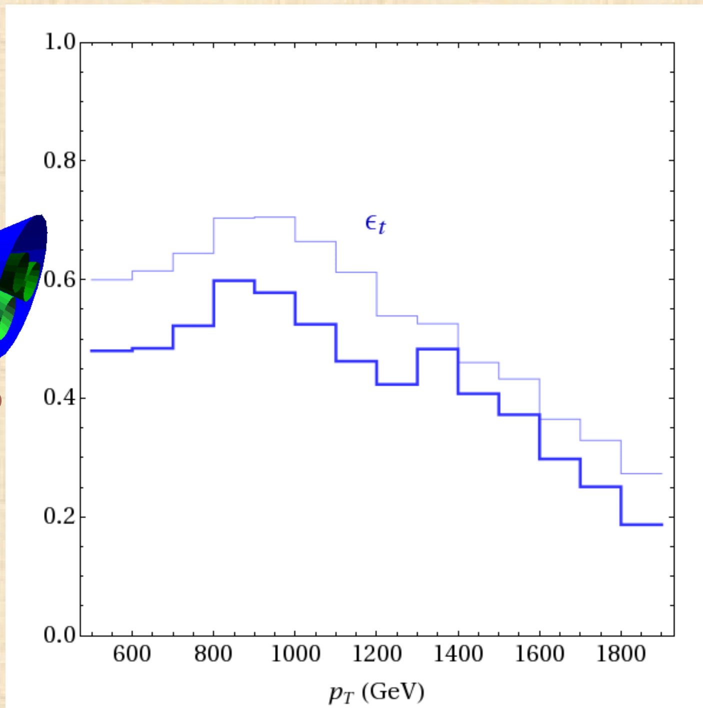


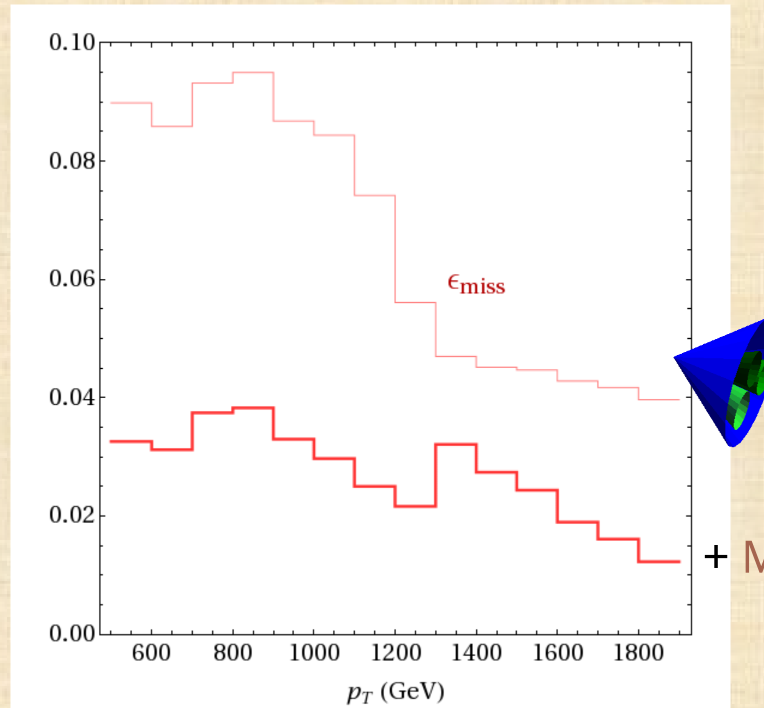
EFFICIENCIES

subjet + M_{top} cut



+ M_{top}

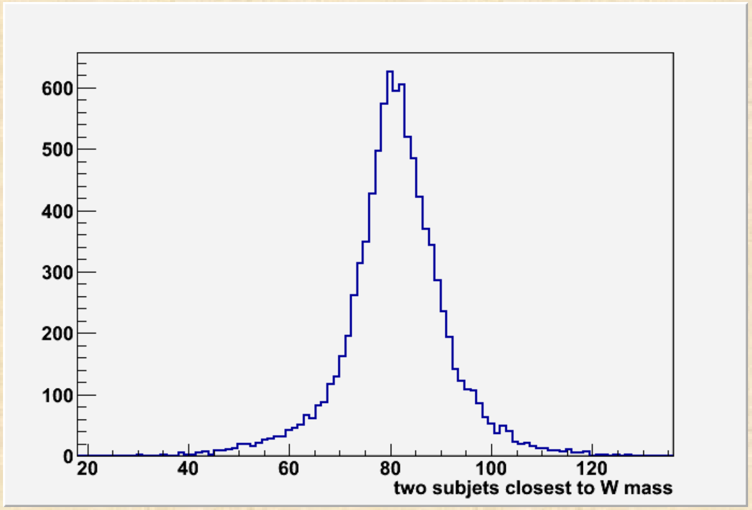




+ M_{top}

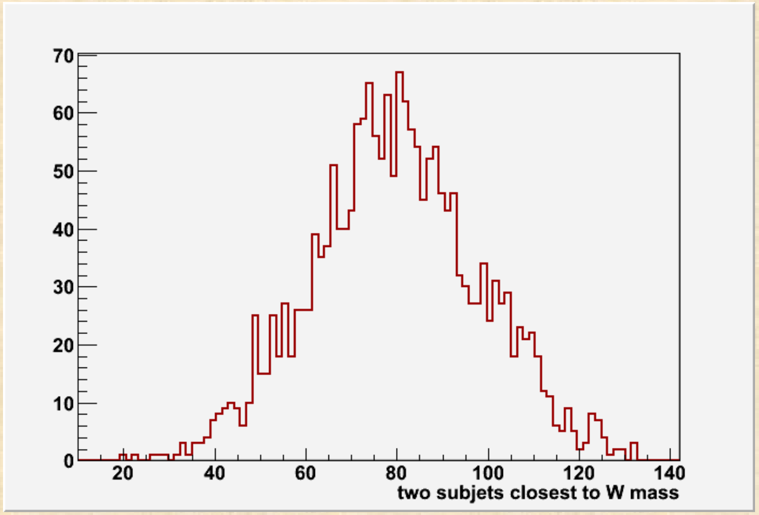
W MASS

- After subjet requirement
- After top mass requirement
- Cut on 2 subjets closest to W mass



M_W = pair whose mass is closest to M_W

(keeps the most signal)



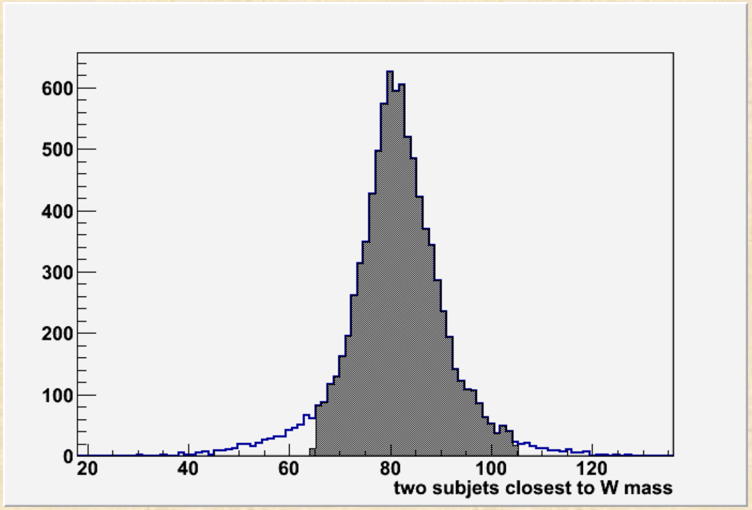
CUT ON W MASS

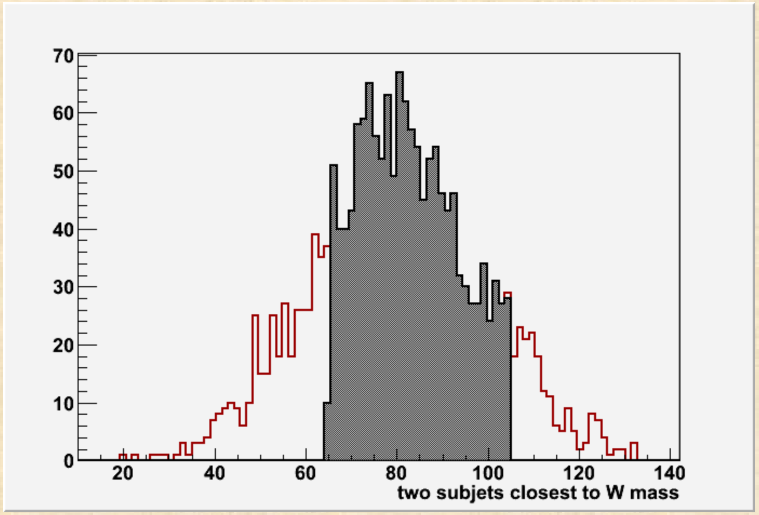
- After subjet requirement
- After top mass requirement
- Cut on 2 subjets closest to W mass

65 GeV < M_W < 105 GeV

M_W = pair whose mass is closest to M_W

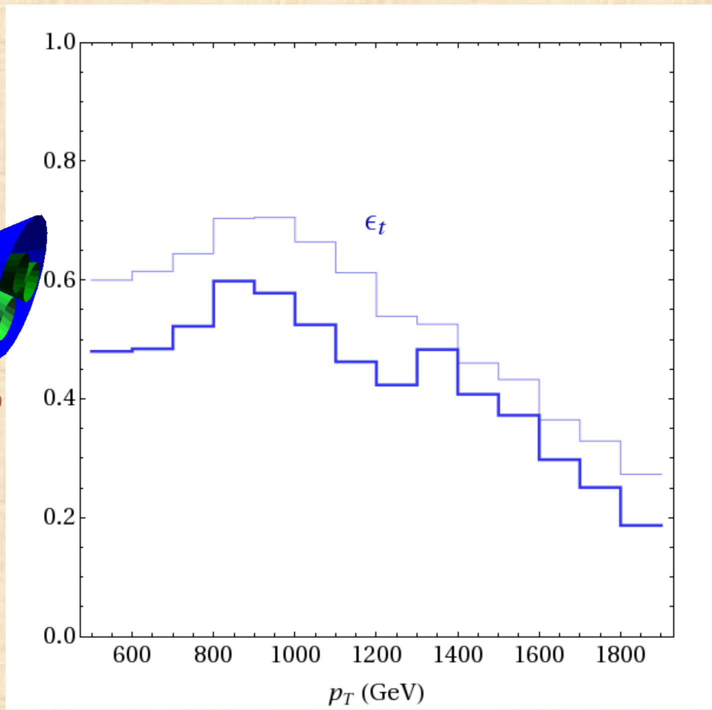
(keeps the most signal)

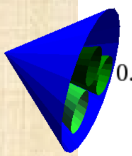




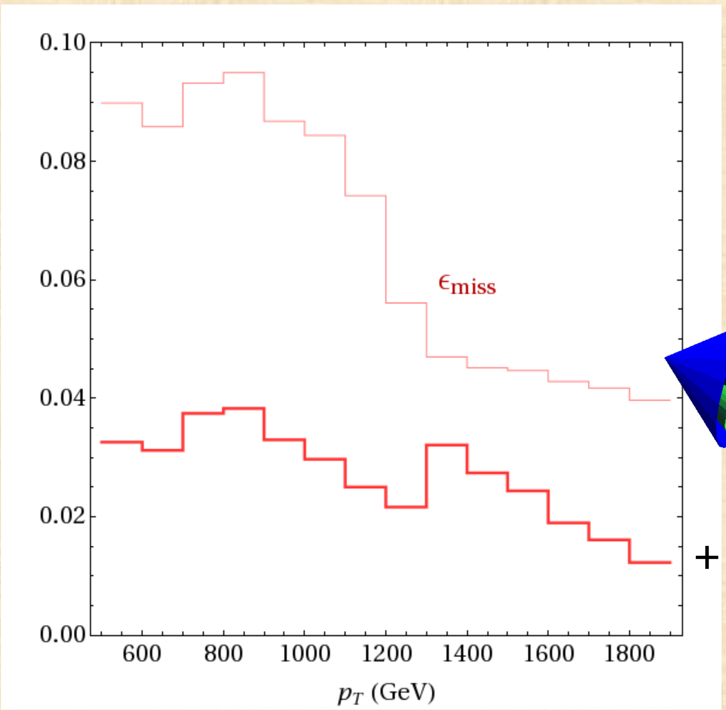
EFFICIENCIES

subjet + M_{top} cut





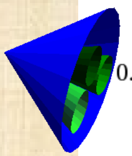
+ M_{top}



+ M_{top}

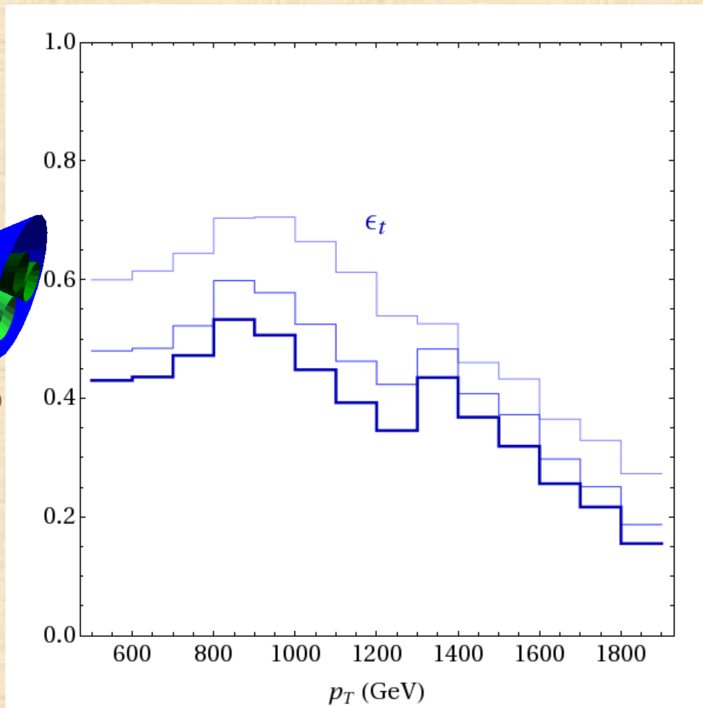
EFFICIENCIES

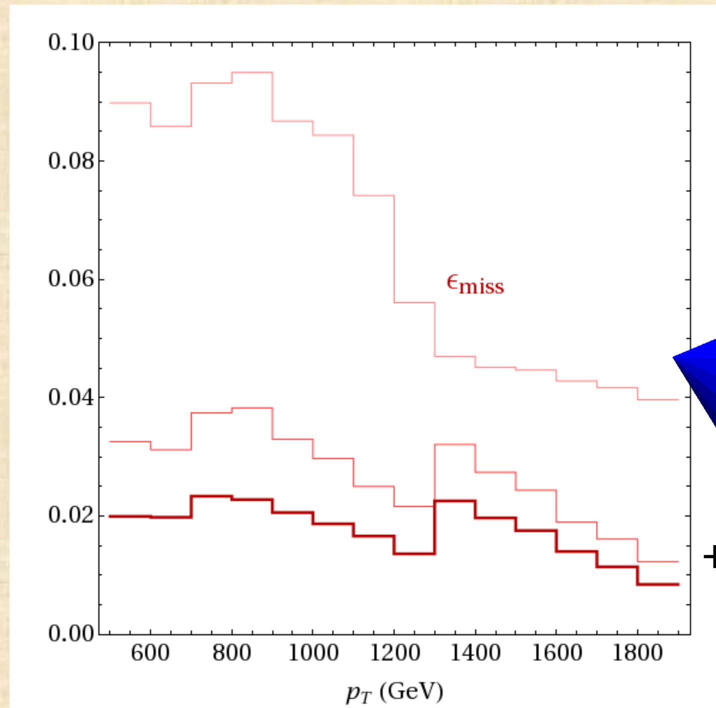
subjet + M_{top} + M_W cut

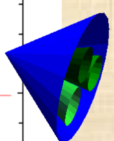


+ M_{top}

+ M_W



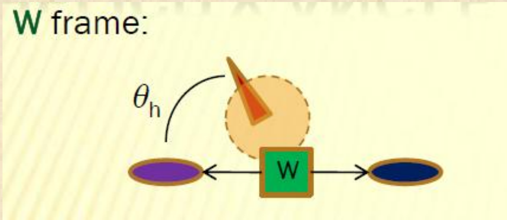


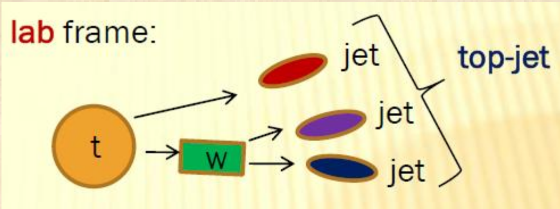


+ M_{top}

+ M_W

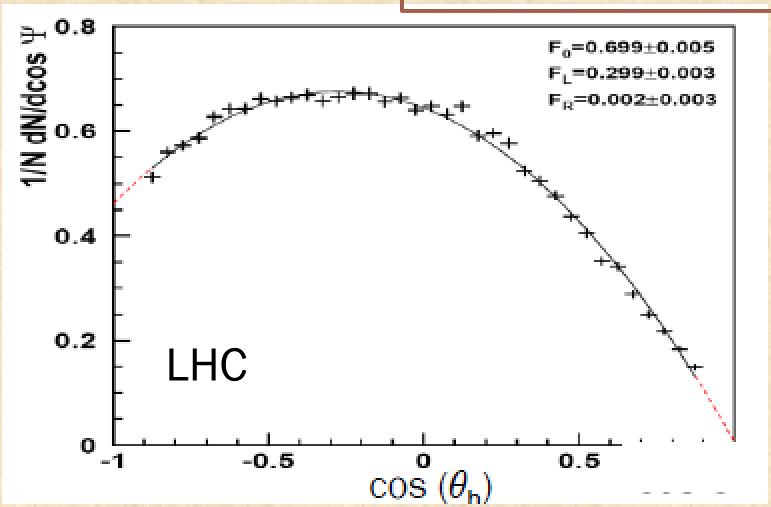
HELICITY ANGLE

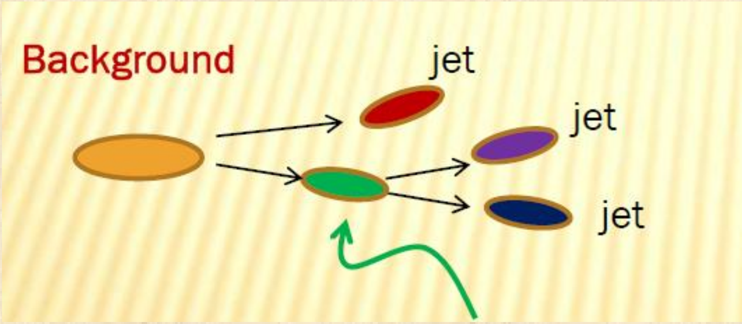




Hubaut hep-ph/06005029

- **W** decays basically isotropically
- Can be used to measure **W** helicity



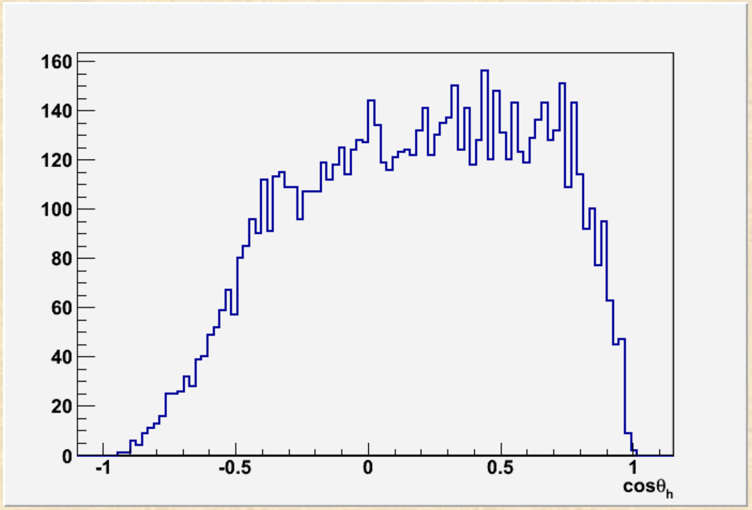


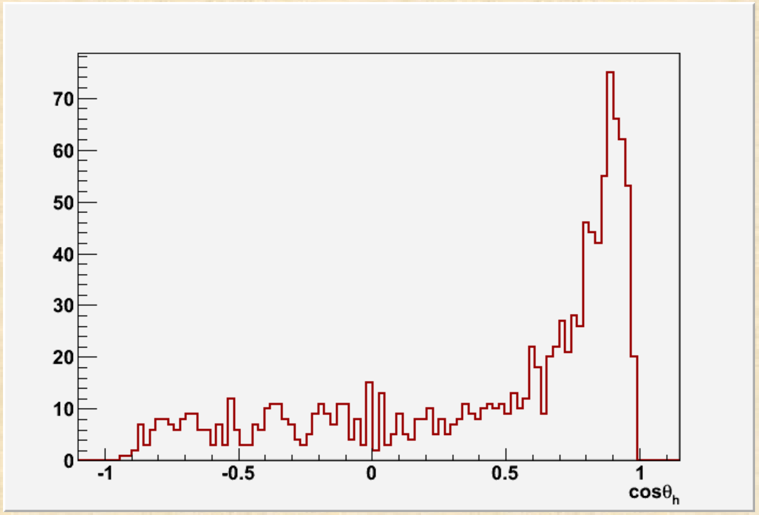
- Intermediate **off-shell massless** parton
- Helicity angle **strongly peaked**
- **Divergent** in perturbation theory (soft divergence)

$$\frac{d\sigma}{dM_{12}\,d\cos\theta_h} = \frac{2 - \frac{M_{12}^2}{M_{123}^2} - \frac{2M_{123}^2}{M_{12}^2}}{1-\cos(\theta_h)} + \cdots$$

HELICITY ANGLE

- After subjet requirement
- After top mass requirement
- After W mass requirement
- Exclude small $\cos(\theta_h)$

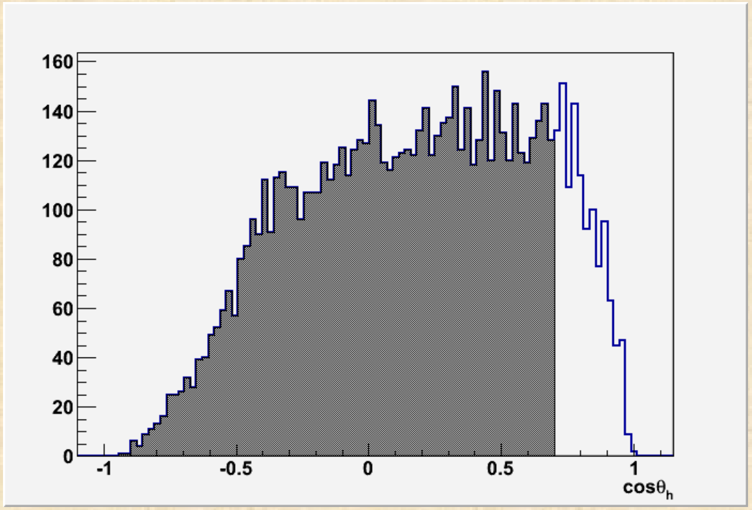


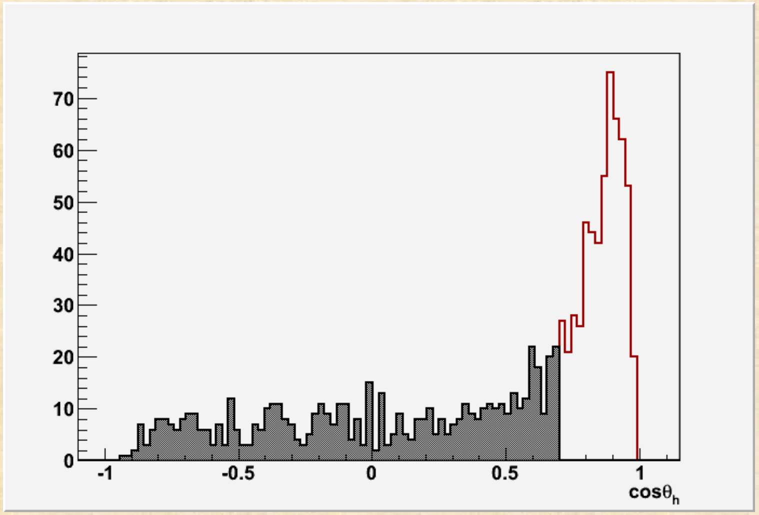


CUT ON HELICITY ANGLE

- After subjet requirement
- After top mass requirement
- After W mass requirement
- Exclude small $\cos(\theta_h)$

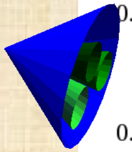
$\cos(\theta_h)$ < 105 GeV





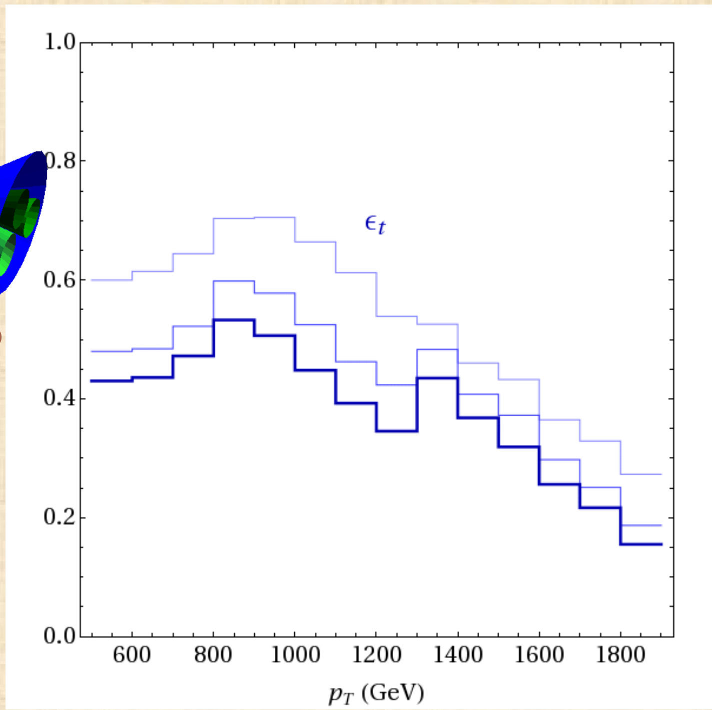
EFFICIENCIES

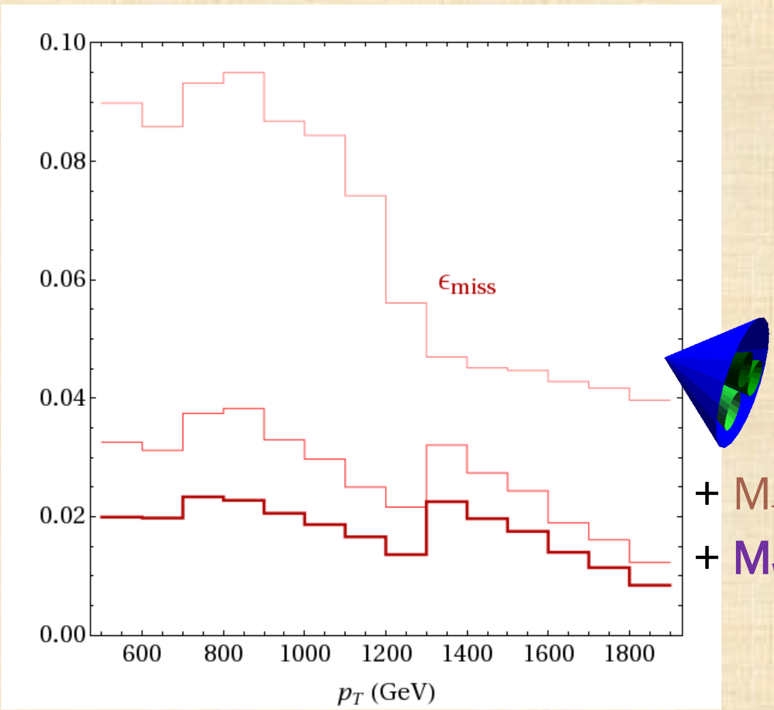
subjet + M_{top} + M_W cut



+ M_{top}

+ M_W



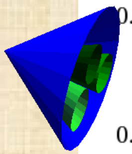


+ M_{top}

+ M_W

EFFICIENCIES

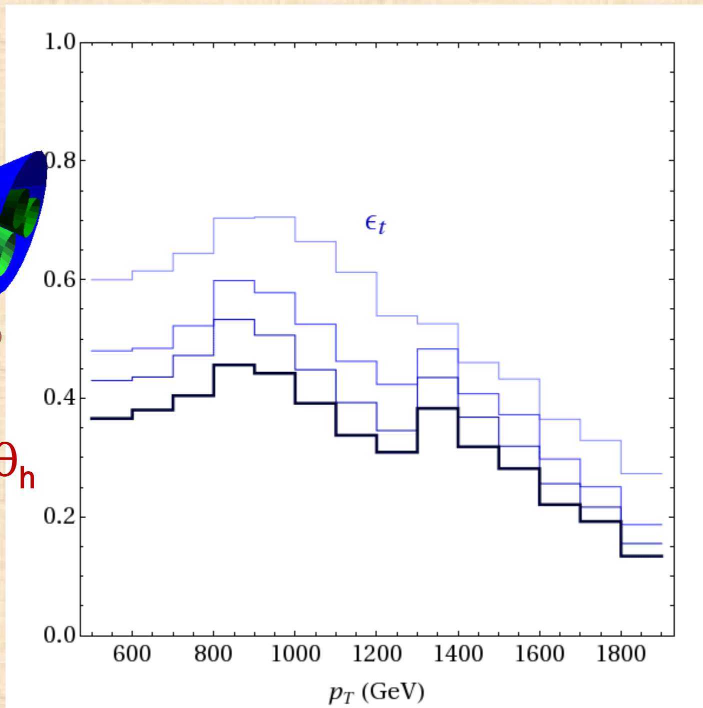
subjet + M_{top} + M_W + $\cos\theta_h$ cut

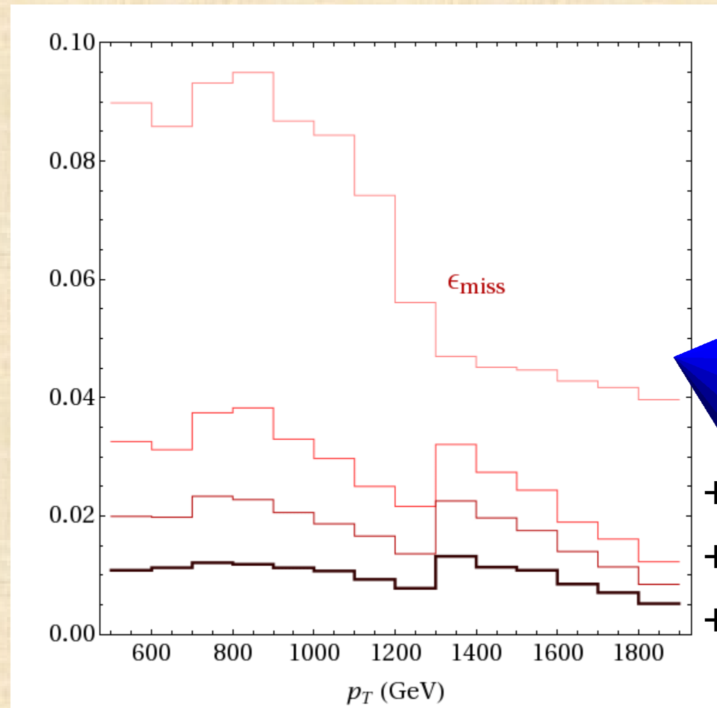


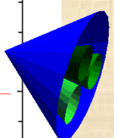
+ M_{top}

+ M_W

+ $\cos\theta_h$







+ M_{top}

+ M_W

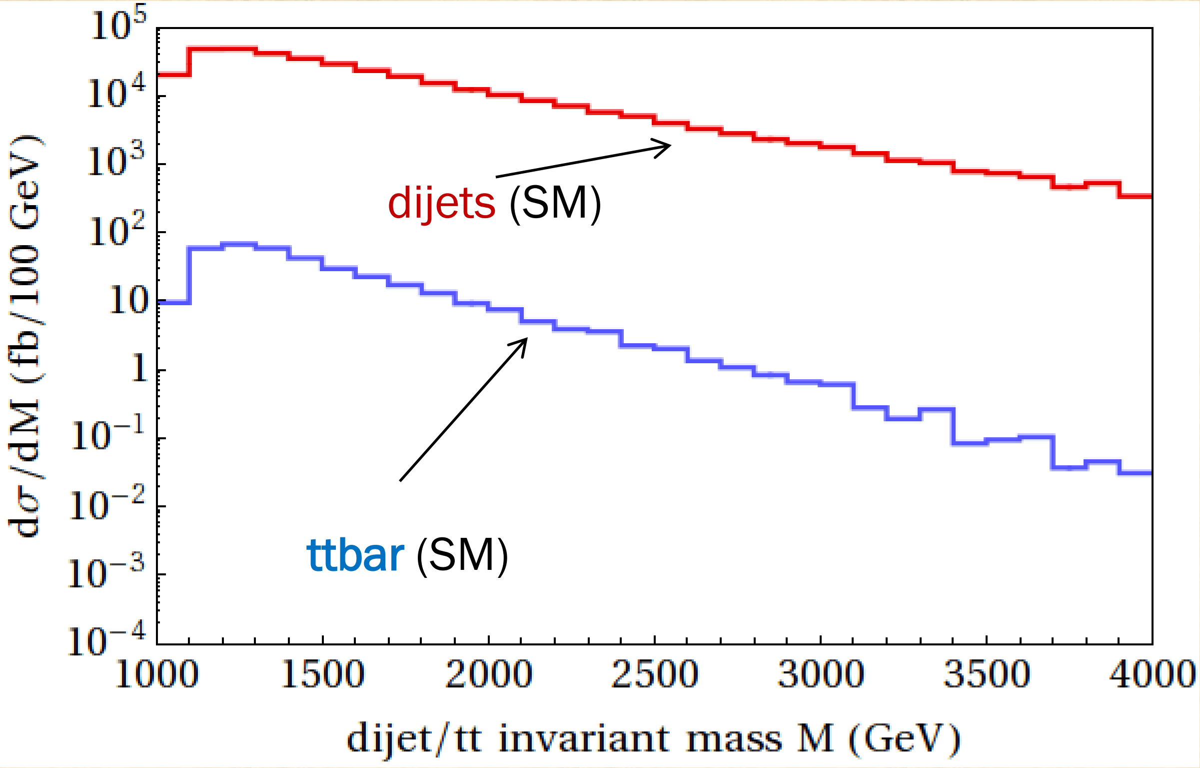
+ $\cos\theta_h$

For pT > 1000 GeV

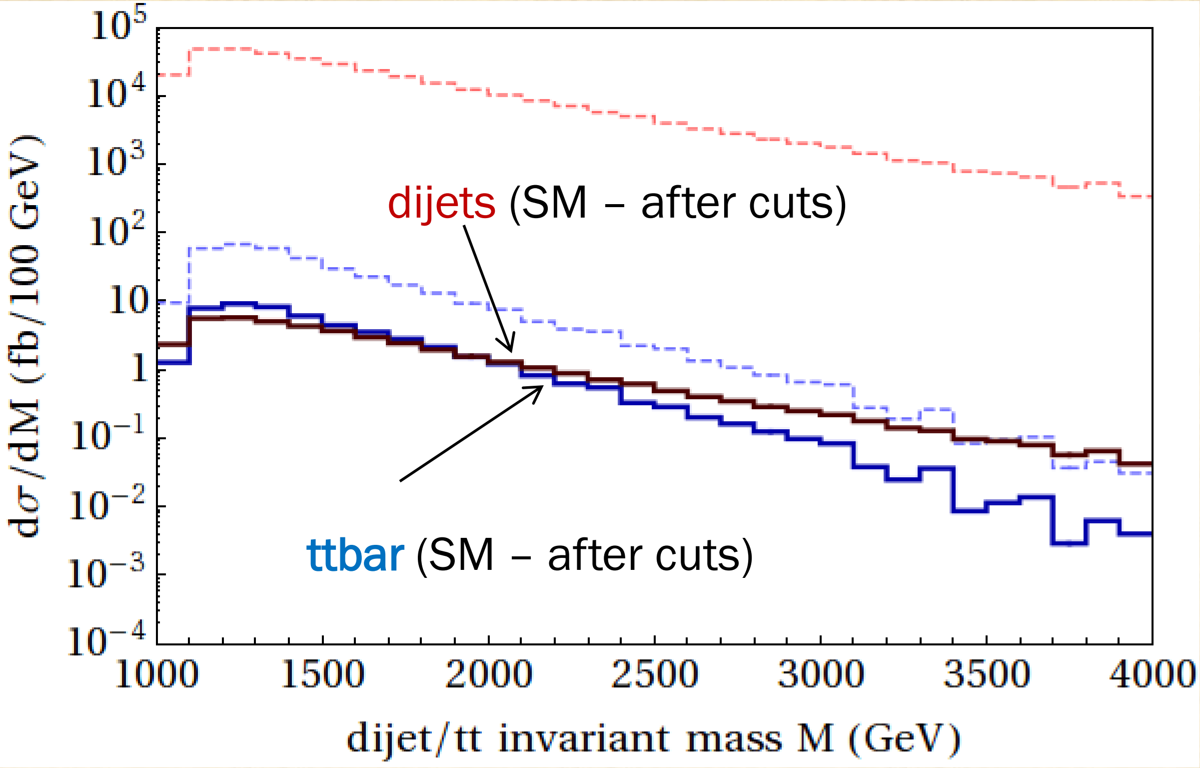
- Keep **40% tops**
- Reject **99% of light jets**

Numbers get **squared** for **di**jet events

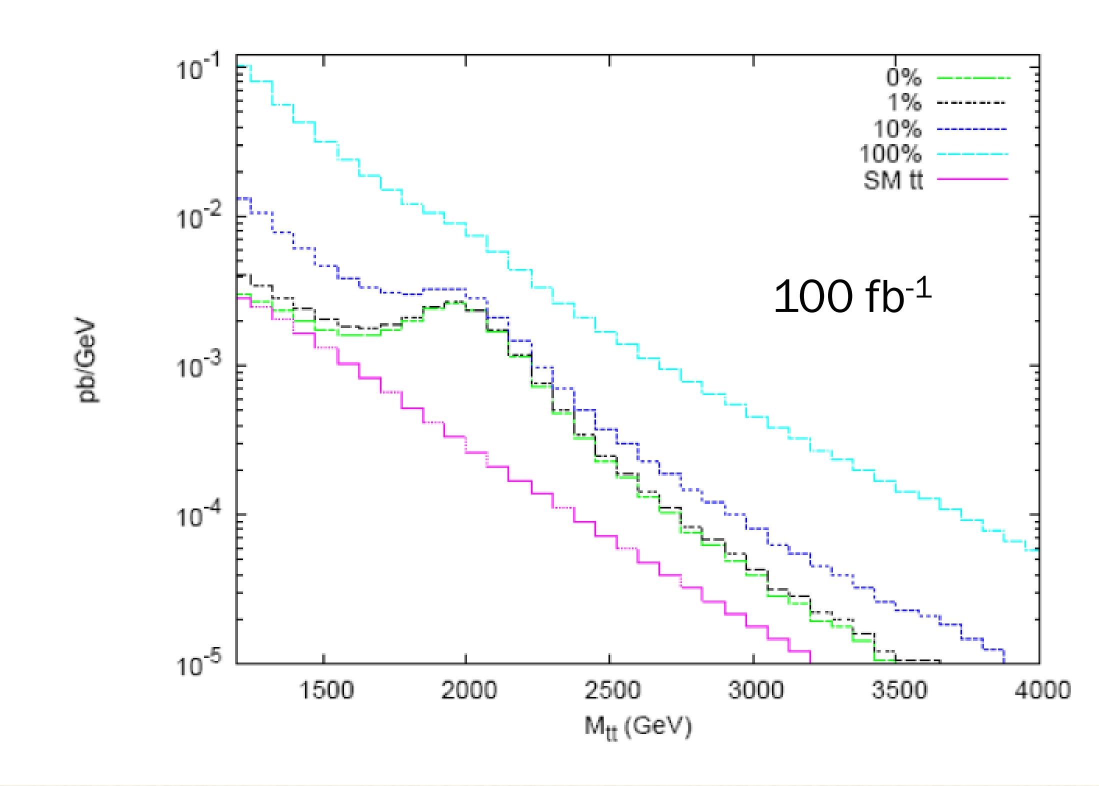
DIJET CROSS SECTION



DIJET CROSS SECTION



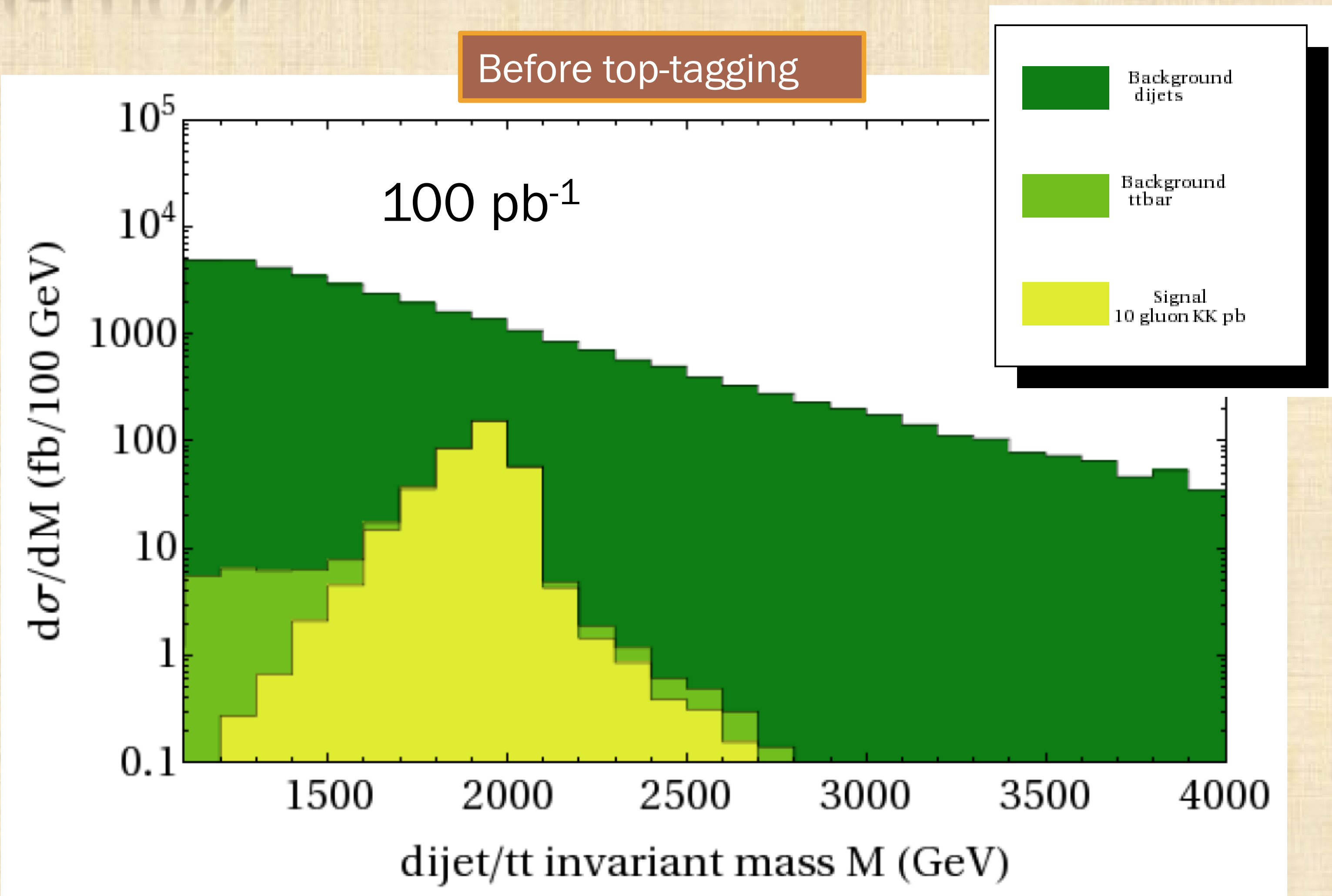
NEW PHYSICS



- Lillie et al, hep-ph/0701166, p.10
  "extraction of signal will require a background **rejection** of about a factor of **10**"

- We have a **rejection** factor of **10,000**!

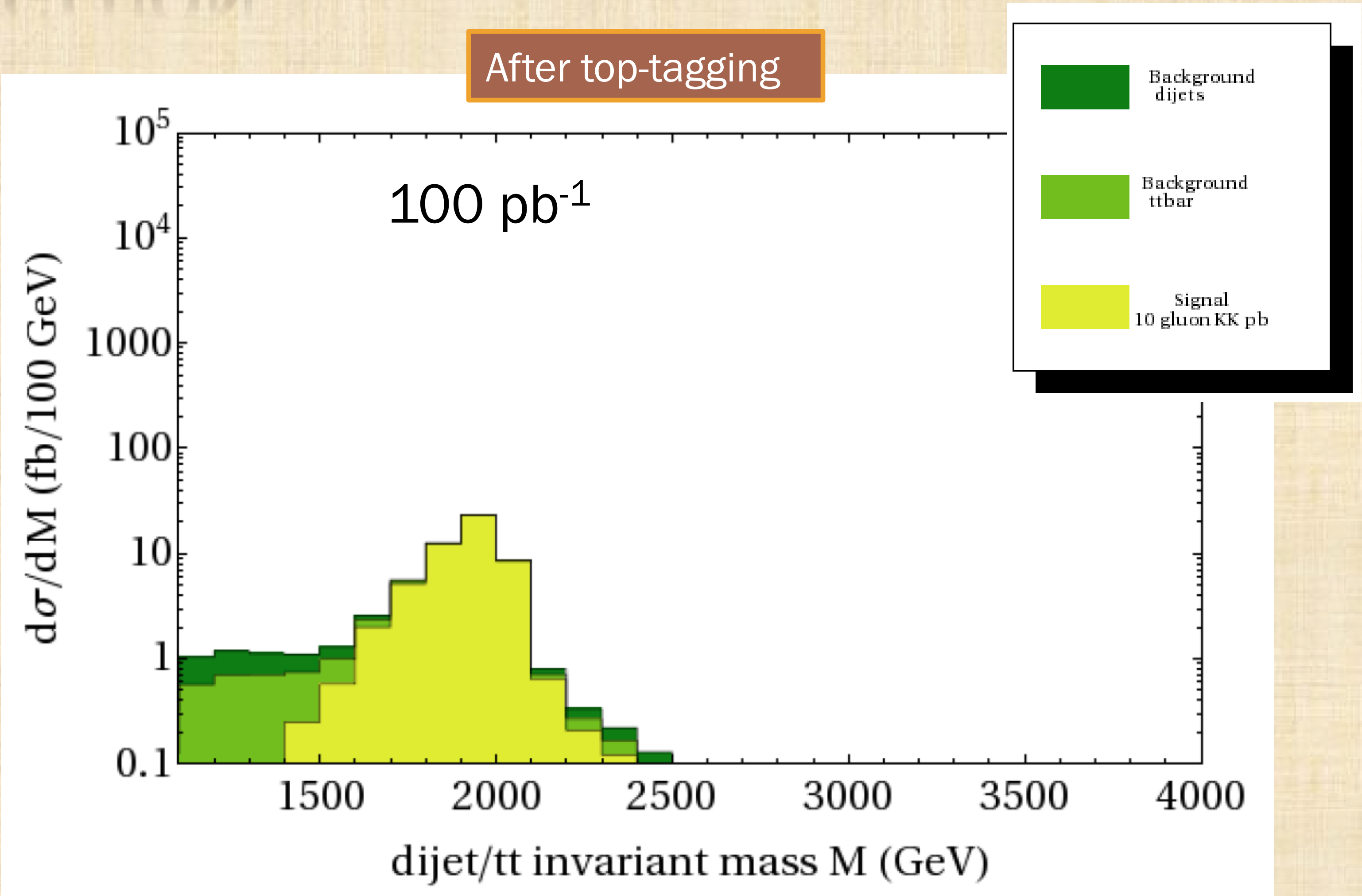
KK GLUON



σ x BR=**10 pb**

KK GLUON

After top-tagging

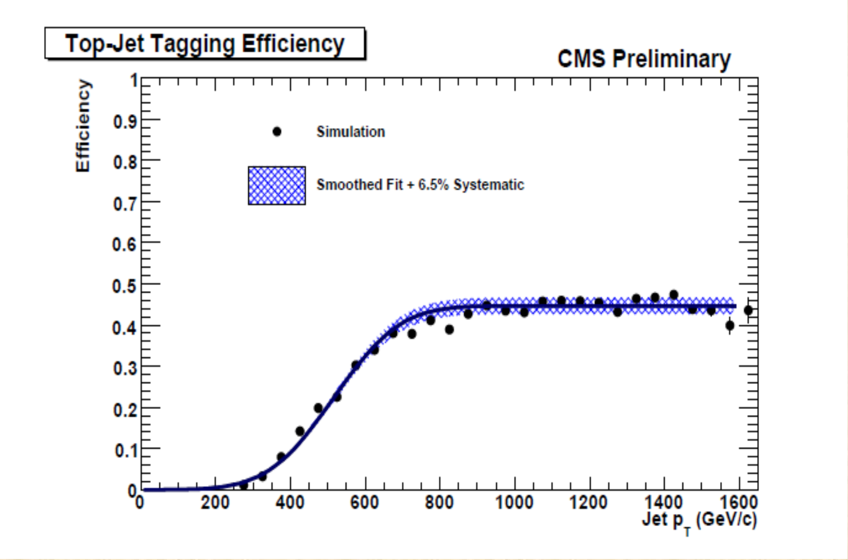


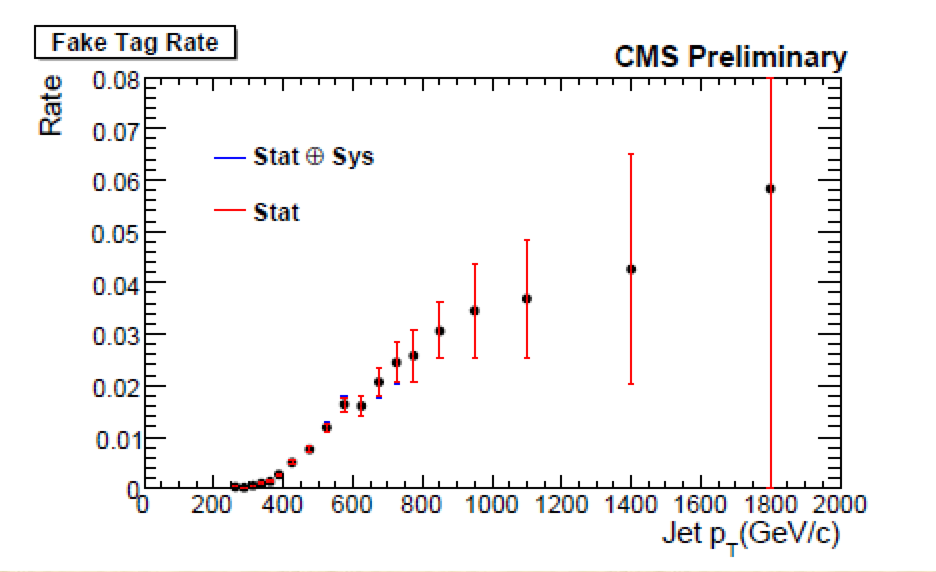
σ =10 pb

CMS PAS JME-09-001

New CMS study (Rappoccio & Maksimovic)

Top p_T = 600 GeV:
- 46% top-tagging efficiency
- 98.5% background rejection

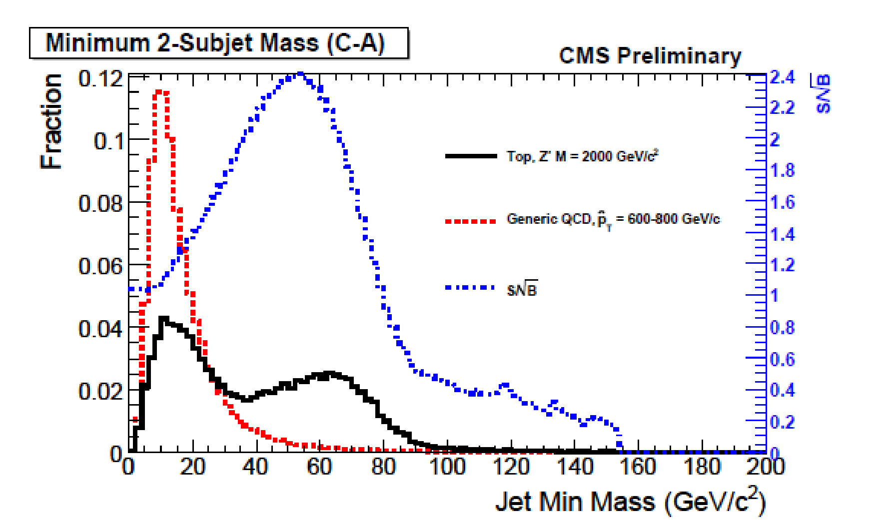


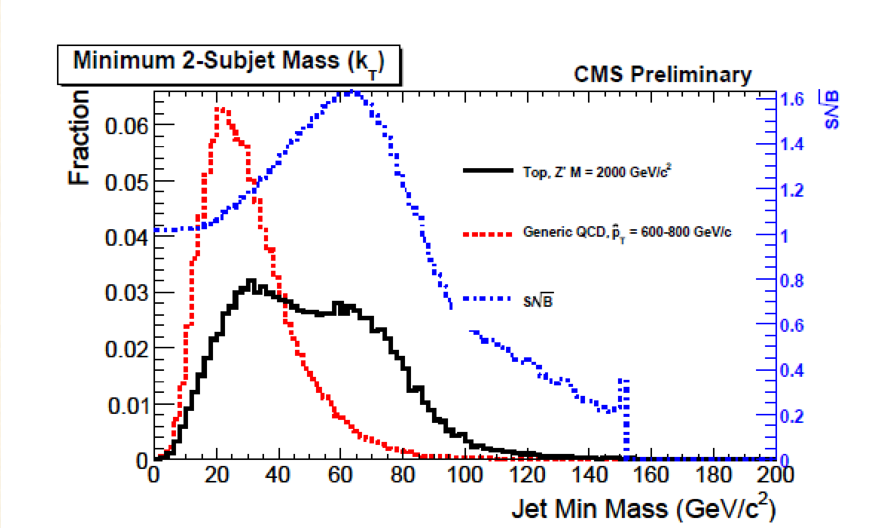


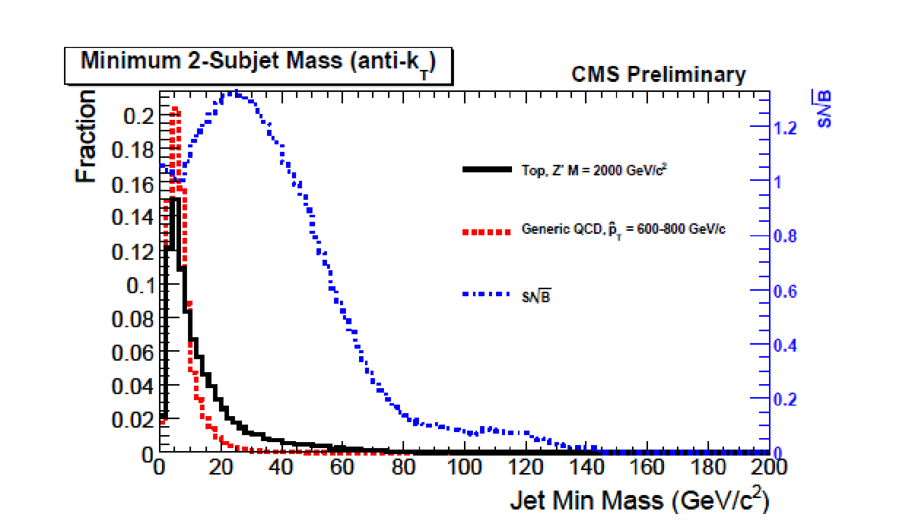
- With full simulation, similar efficiencties
- With 100 pb^{-1} at 10 TeV, can rule out 2 TeV KK gluons (95% c.l.)

CMS PAS JME-09-001

Explored jet algorithm dependence

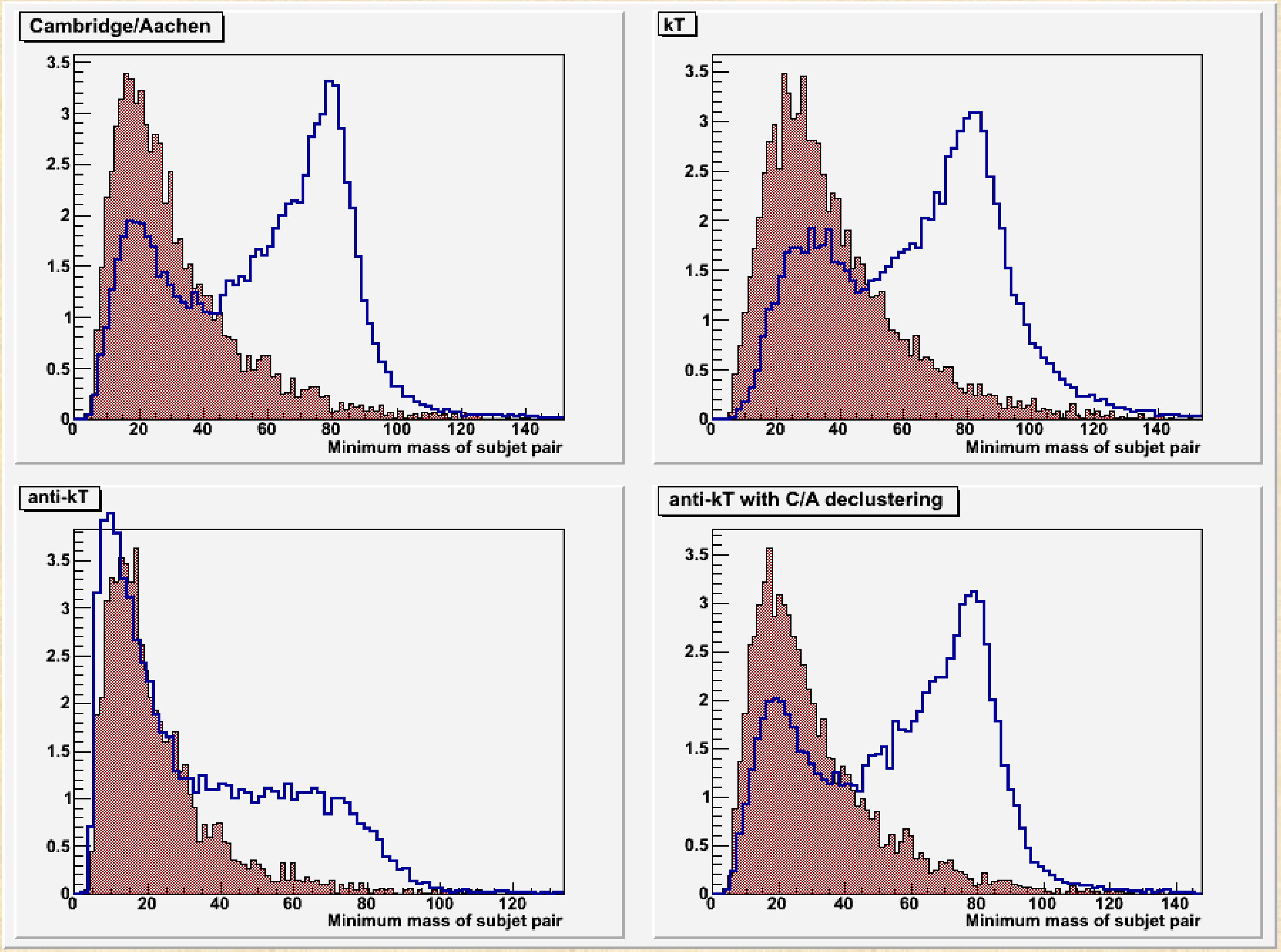






RECLUSTERING

But using anti kT and reclustering with C-A works great



CONCLUSIONS

Top tagging turns 100 fb^{-1} physics into 100 pb^{-1} physics

Top-tagging works:

1. Look for **subjets**
   - Clean up soft and collinear radiation
2. Cut on **top mass**
3. Cut on **W mass**
4. Cut on **helicity angle**

- Reject **99.99%** dijets
- Keep **10%** ttbar

- **No** b-tagging required
- Can use **all-hadronic** channel
- Works great after **full simulation (CMS)**
- Can use **any** jet **algorithm**
- **Top**-tagging **better** than **b-**tagging at high p_T