Search for new Physics

...

in top quark topologies

Chabert Eric
24/11 – top meeting

Which title ?

Usually are assimilated:

Boosted top = Search for ttbar resonance = Mtt distribution = Search for new physics in ttbar

Connections between this subjects are obviously strong but they are not exactly the same !

- "Boosted top" can be used for different searches than pp->X->tt.

Ex: studying b-tagging at high Pt

- Search for ttbar resonances can be done at "low invariant mass", with top not so much boosted
- Study of Mtt distribution is useful for other things also:
  - understanding of production mechanism
  - can be used for a top mass estimation too
- But ttbar resonances can also be searched in other variables ...
- Search for new physics (in top sector) can appear in the decay products (charged Higgs), in the BR (FCNC) and in associated production tt+X (*but not discussed today*)

Actually the three first categories are covered by one "task force" in CMS called "boosted top"

Today we are discussing on ttbar resonances

Motivations: ttbar resonances

- New physics is expected to have strong couplings to the top sector because of the large top Yukawa coupling.
- Many models (BSM) attempt to solve an impressive array of problems, from explainig the large top mass to solving the hierarchy problem
- Some of them predict resonances decaying in top quark which are called:

ttbar resonances ! $pp \rightarrow X \rightarrow t\bar{t}$, m(X)>350 GeV

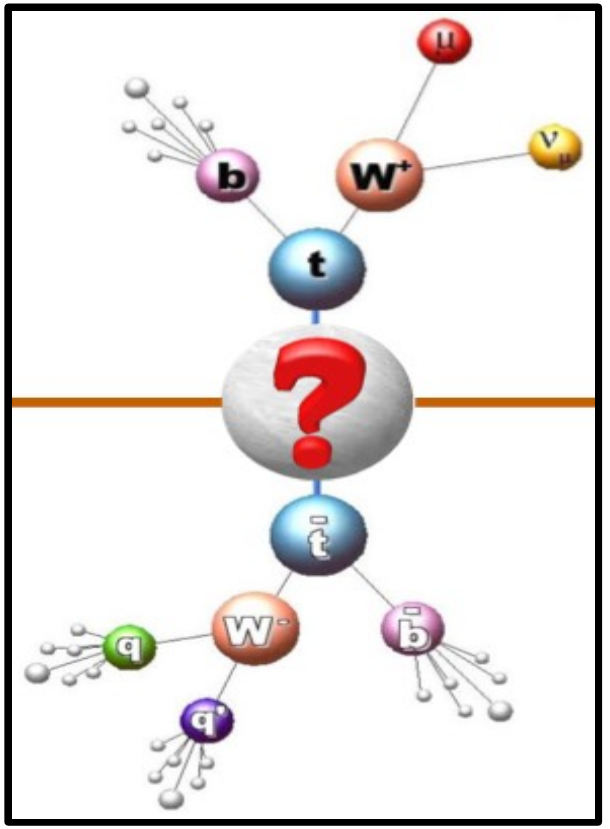
- No resonance production in ttbar system is expected in SM (heavy Higgs excluded)

Generic categories of models:

1-Weakly coupled models at the TeV scale
Introduce new particles to cancel SM "divergences"
symmetries->partners / top partners <2 TeV
Examples: SUSY, Little Higgs ...
Resonances: top parters, new scalars/vectors possibly strongly coupled with top

2-Strongly coupled models at the TeV scale:
New strong dynamics enters at ~1TeV – top often play a leading role
New Non-abelian group (as QCD) - Higgs is composite - new (techni-) particles
Examples: Technicolor, Topcolor, Top see-saw...
Resonances: ttbar bound states, colorons ...

3-New space-time structure:
Introduce extra space dimensions to lower the Planck scale cutoff to 1 TeV.
Examples: ADD,RS...
Resonances: KK-excitations including gravitons



ttbar resonances ?

Ttbar resonances is generic expression .... behind a

- Variety of models: previous slide
- Variety of particles: Higgs, Z', axi-gluons, gravitons …
- Variety of properties: Mass, width, spin , color, parity, coupling …

→ Huge number of models & and parameters to investigate ...

Zoology of new resonances

Spin	Color	(I,γ_5) [L,R]	SM-interf	Example
0	0	(1,0)	no	Scalar
	0	(0,1)	no	PseudoScalar
	0	(0,1)	yes	Boso-phobic
	8	(0,1),(1,0)	no	Techni-pi0[8]
1	0	[sm,sm]	yes/no	Z'
	0	(1,0),(0,1)(1,1),(1,-1)	yes	vector
	8	(1,0)	yes	coloron/kk-gluon
	8	(0,1)	"yes"	axigluon
2	0	--	yes	kk-graviton

For new physics associated, two approaches are possible:

- top-down:model parameter scanning
- bottom-up: inverse problem

→ search for deviation in a model independent way

ie: reconstruct top pairs and study deviations compare to predictions (depends on theory & MC) ...

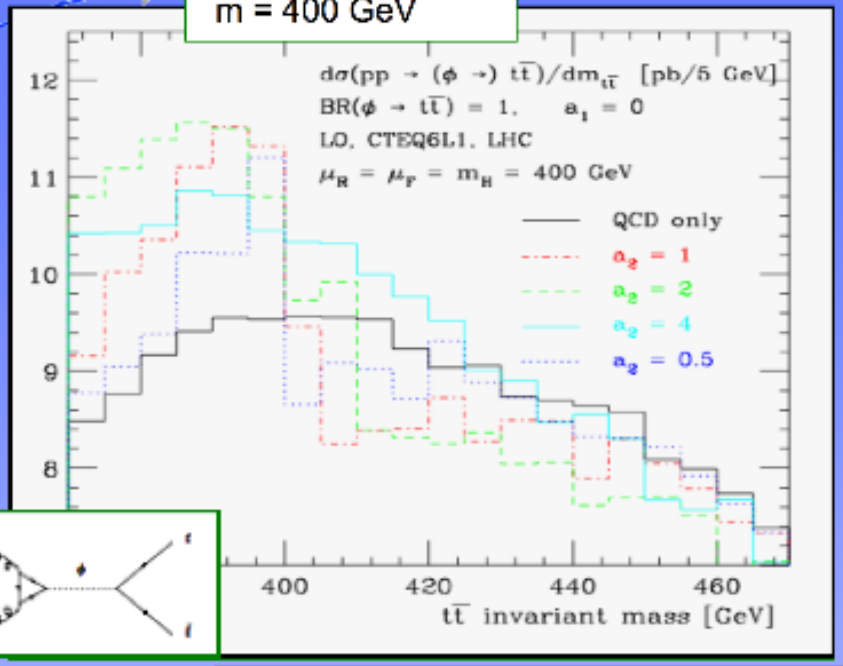
We are focusing on a bottom-up approach but " model independent approach" doesn't mean that "only one analysis is enough for searching everything" .... it's limited by the kind of effect on the distribution ! (spin & mass & width) ...

Pseudo-scalaire

boson-phobique

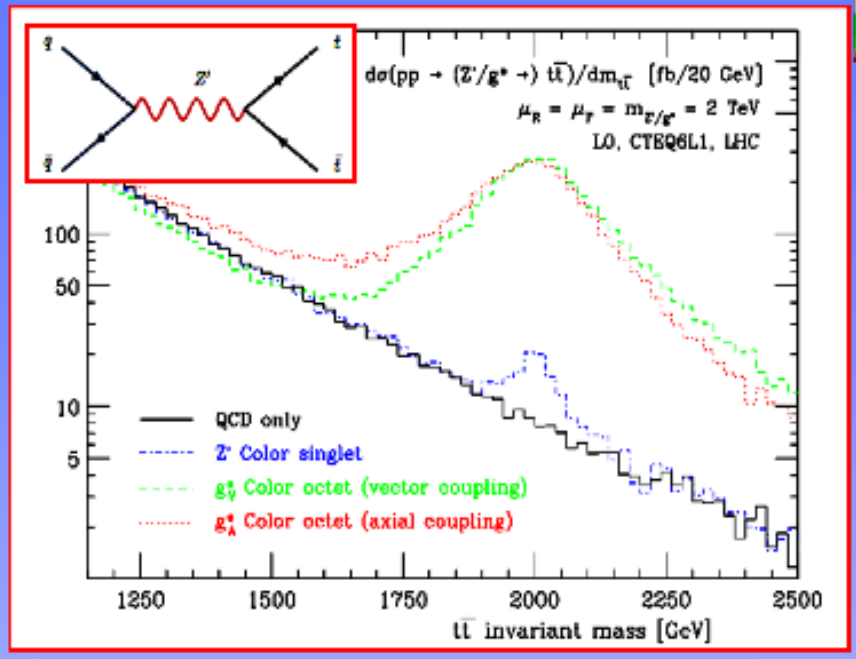
m = 400 GeV

Spin 0



Z' and axi-gluons

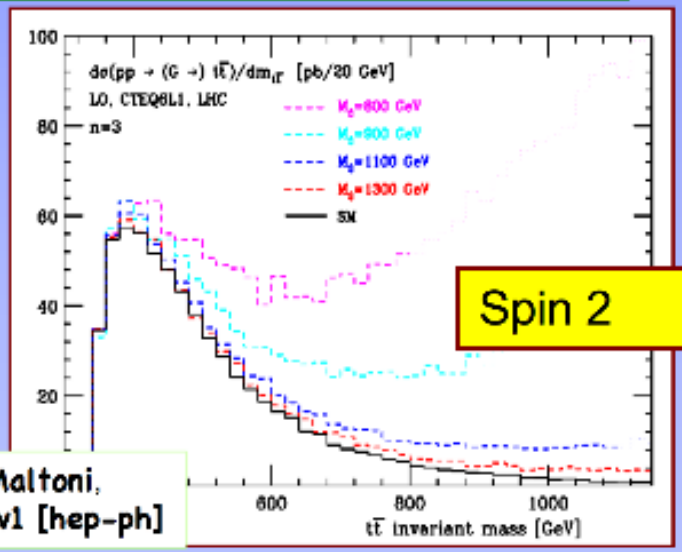
Spin 1



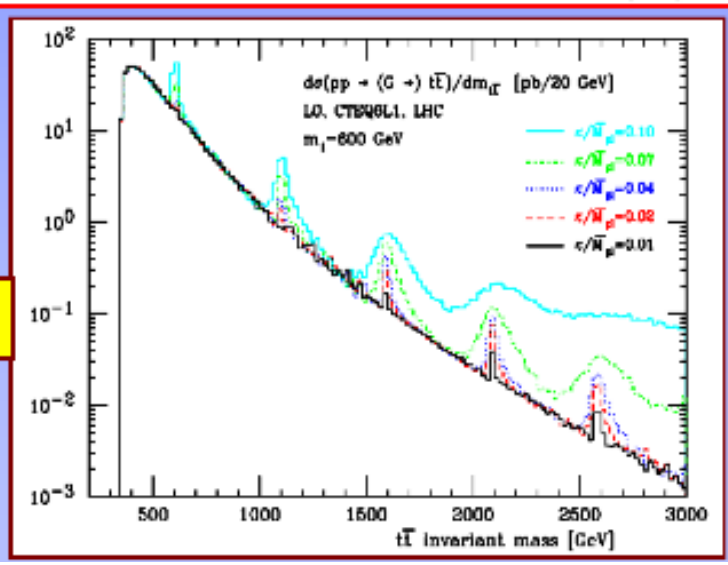
Modèle ADD

KK graviton

n=3D



Spin 2



Modèle RS

KK graviton

R. Frederix, F. Maltoni,
arXiv:0712.2355v1 [hep-ph]

- Still now analysis considered only spin 1 particles and more generally: “ narrow width resonances” (mean: width<resolution - easiest & more promising)
- How to deal with large width resonances ? Are we prepared to observe more than a peak and to conclude?

Strategy for discovery

★ 3 phases:

1- Discovery

2- ttbar angular distribution (identify spin)

3- spin correlations (identify more properties ...)

★ Discovery: the bottom-up approach:

- Choose a channel (→3)
- Choose a Mttbar region (~ topology) (→2-3)
- Define/choose a variable (→only one used)

it should be a SM observable that is

a. naturally sensitive to BSM

b. is well-predicted & possibly "background free" (Maltoni)

- Define a strategy (selection & reconstruction)

→many variables/ tools/ approaches ... from simplest one to more complex ...

And after a lot of work ...

- Determinate the sensitivity on new physics in term of σ•Br as a function of Mttbar (depend on luminosity) taking into account experimental (→a lot ...) & theoretical uncertainties (→depend on mtt ... more complex)

➨ true for 'narrow width resonances' but more complicated for other kind of signal

---

★ From discovery to identification: a ambitious plan (Maltoni)

1-Find excess(es) over SM backgrounds

2-Identify a finite set of coarse models compatible with the excess(es).

3-Look for "predicted excesses" in other channels

4-Refine cross-section & couplings calculations ...

5-Perform more detailed studies to measure mass spectrum, quantum numbers, couplings

6-Refine MC ...

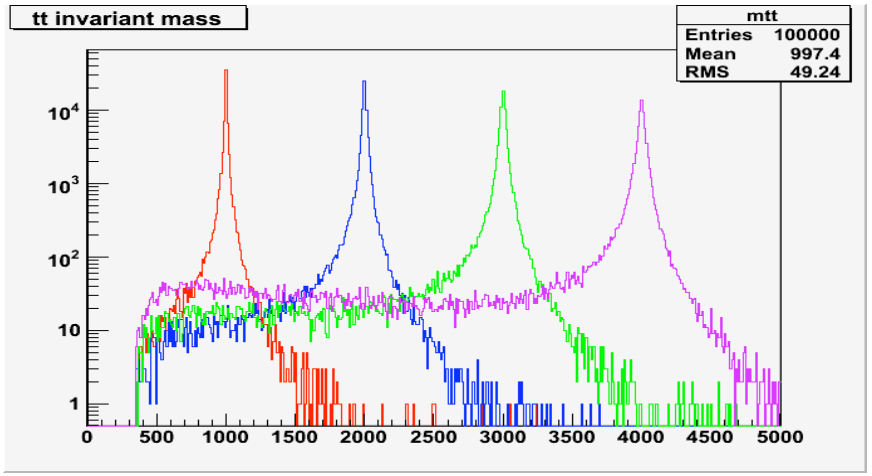
Few comments ...

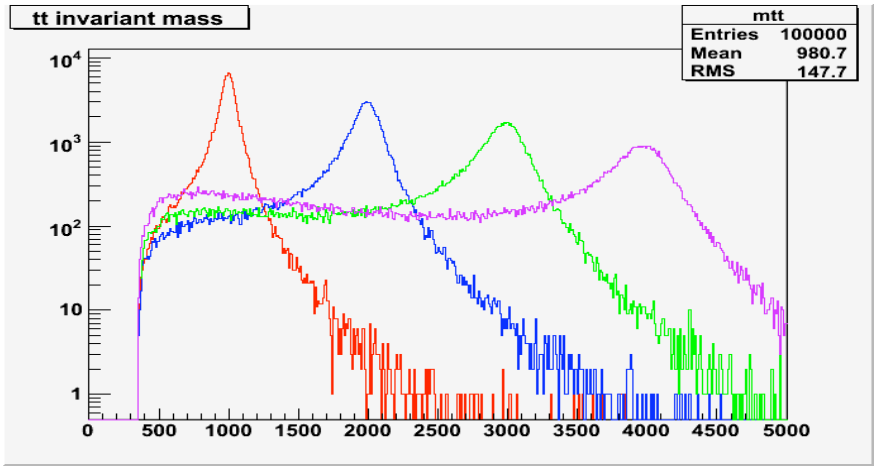
This studies can be also useful for other searches ...

- new flavor extension: fourth family
  - pp → t't'→ W+W−bb (adapted mass criteria on top ...)
  - pp → b'b'→ W+W−tt (can appear as an excess in tt+nj at high multiplicity)
- SUSY models:
  - tt+phi (associated production with an excess of MET)
  - some channels with stop decays (t'→ t+X)

Excess in ttbar variables can be assigned to other new physics than ttbar resonances ...

Few words about width .... here Z' @ 1,2,3,4 TeV width width = 1% (left) – 10% (right) x mass





Competition between the Breit-Wigner of the resonance and the decreasing pdf of the partons creating the resonance:
→ sizable low mass tail for the large width
→ can potentially appear experimentally as a double peak (or just a excess at low mass) depending on the reconstruction efficiency shape

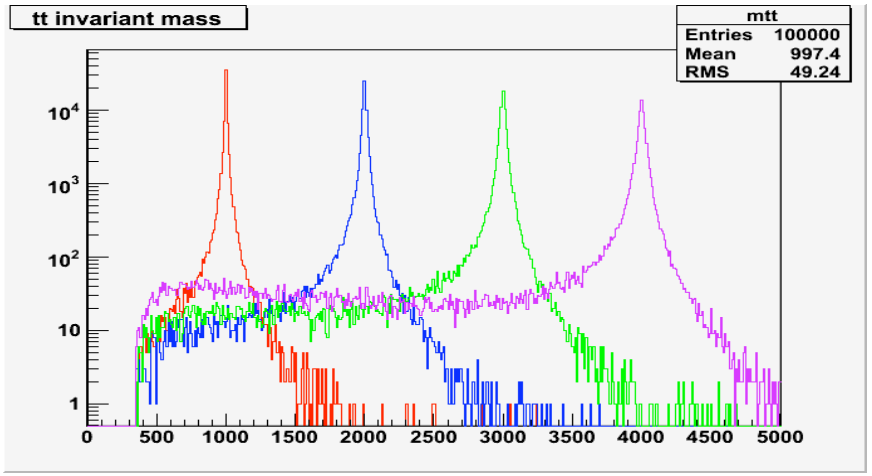
Few comments ...

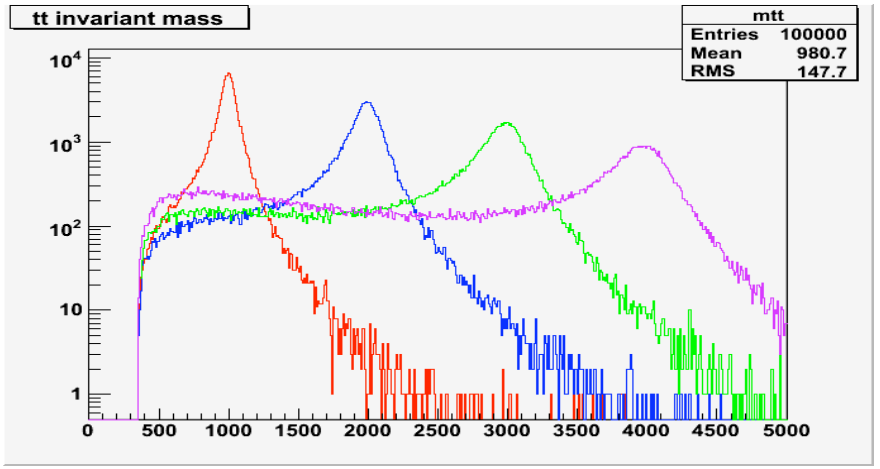
This studies can be also useful for other searches ...

- new flavor extension: fourth family
- pp → t't'→ W+W−bb (adapted mass criteria on top ...)
- pp → b'b'→ W+W−tt (can appear as an excess in tt+nj at high multiplicity)
- SUSY models:
- tt+phi (associated production with an excess of MET)
- some channels with stop decays (t'→ t+X)

Excess in ttbar variables can be assigned to other new physics than ttbar resonances ...

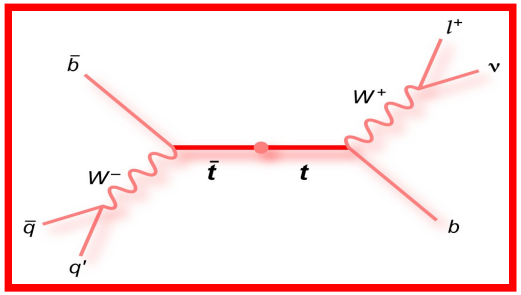
Few words about width .... here Z' @ 1,2,3,4 TeV width width = 1% (left) – 10% (right) x mass

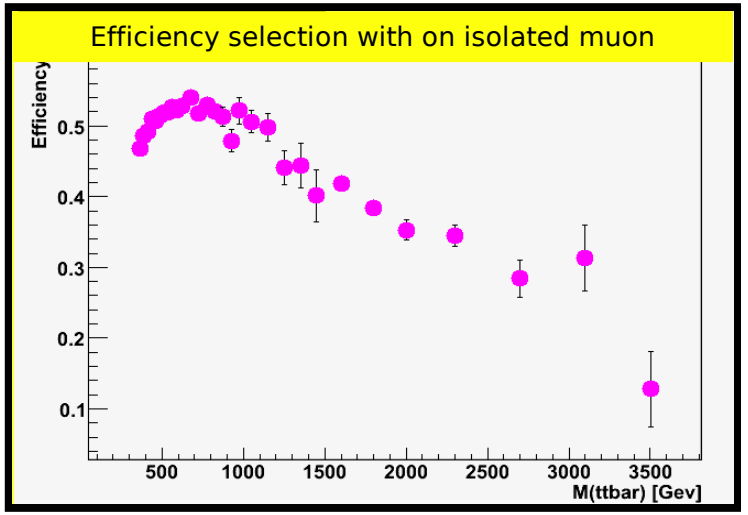


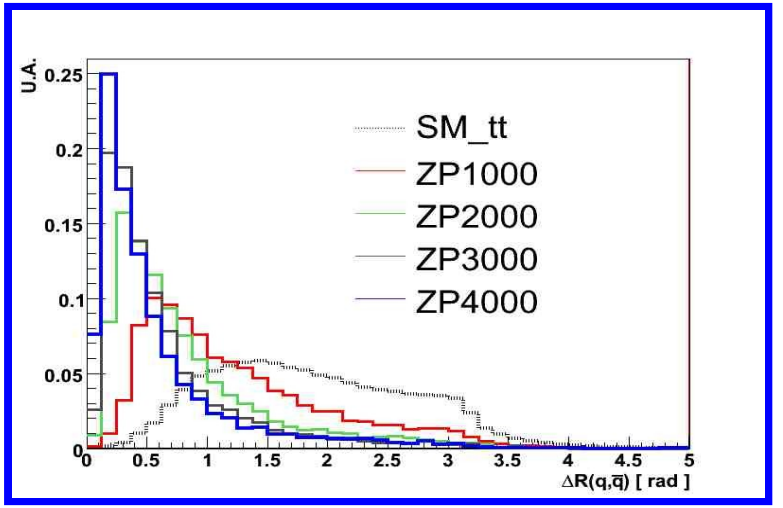


Competition between the Breit-Wigner of the resonance and the decreasing pdf of the partons creating the resonance:
→ sizable low mass tail for the large width
→ can potentially appear experimentally as a double peak (or just a excess at low mass) depending on the reconstruction efficiency shape

Topology considerations







Mode de production	Pourcentage d'évènements où	
	$\Delta R_{q,\bar{q}}<0.5$	$\Delta R_{q,\bar{q}}<1.0$
$t\bar{t}$ Modèle Standard	1.6 ± 0.4	14.8 ± 0.1
Z' 1 TeV/c^2	12.5 ± 0.3	48.5 ± 0.5
Z' 2 TeV/c^2	38.9 ± 0.6	73.2 ± 0.5
Z' 3 TeV/c^2	54.9 ± 0.6	82.0 ± 0.5
Z' 4 TeV/c^2	62.7 ± 0.6	85.1 ± 0.5

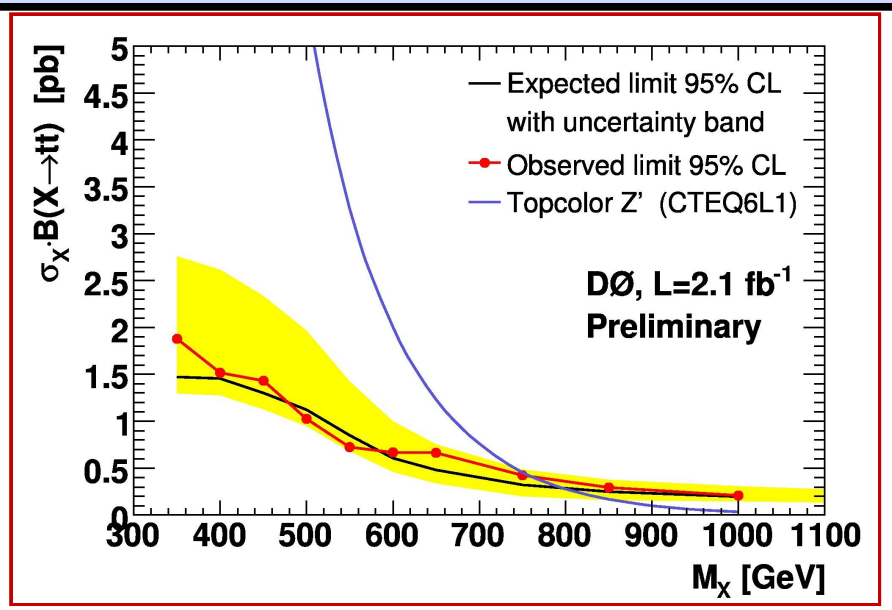
Mode de production	Pourcentage d'évènements où		
	$\Delta R_{\mu,b}<0.1$	$\Delta R_{\mu,b}<0.2$	$\Delta R_{\mu,b}<0.3$
Z' 1 TeV/c^2	0.97 ± 0.03	0.7 ± 0.1	1.9 ± 0.1
Z' 2 TeV/c^2	0.44 ± 0.09	4.1 ± 0.2	15.5 ± 0.5
Z' 3 TeV/c^2	1.0 ± 0.1	13.5 ± 0.4	30.5 ± 0.5
Z' 4 TeV/c^2	3.1 ± 0.2	23.1 ± 0.5	40.6 ± 0.6
$t\bar{t}$ Modèle Standard	0.016 ± 0.003	0.11 ± 0.01	3.0 ± 0.1

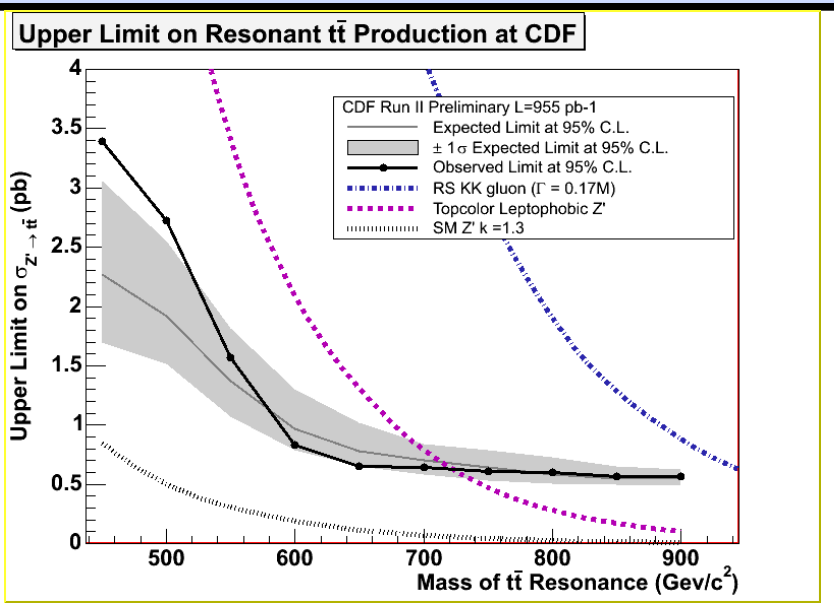
Production processes:

- SM: «boost» mainly along z-axis ($P_{partons}$ asymetry)
- Resonance: P/E↗M_X ⇒ «boost» more isotropic (jets more central)
  - "boost" of top ↘ with $M_{t\,\bar{t}}$
  - Decay products angles ↗ with $M_{t\,\bar{t}}$
  - ⇒difficulties to reconstruct jets
  - ⇒isolation criteria fails at high mass

- Topology evolute with Mttbar
- For a given mass, difference between SM & ttbar production

Actual status from Tevatron





- No excess found
- Limits on a Z' leptophobic width $\sigma_{Z'} = 0.012\ M_{Z'}$ in a specific model: topcolor assisted technicolor:
- DO: $m_{Z'} > 760$ GeV @ 2.1 fb^{-1}
- CDF: $m_{Z'} > 720$ GeV @ 1 fb^{-1}

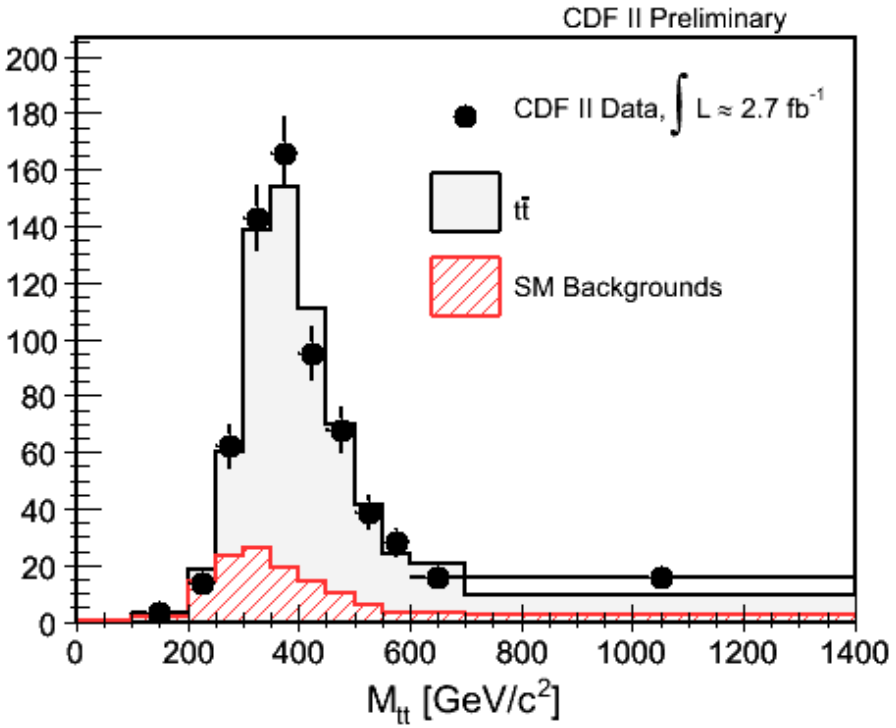
Doesn't not mean that there is no resonances below 700 GeV ... !!!

Limitation:

- $E_{CM} \Rightarrow$ actually no events with $M_{ttbar} \geq 1$ TeV
- Statistic ≈ 10^3 evts

@ LHC we can search at higher masses (≈ 5 Tev) and with a better statistic (≈ 10^4 events/fb^{-1})

...



With this statistic, interference effect
for few hundred GeV resonances
are not observable ....
that's mean also not excluded !

Below 1 TeV there is still interesting searches to do.
In that region, top are not yet so boosted and standard tools can be used.
The new physics cross section production is also higher on that region ...
Extend the limit of tevatron, do precision mesurement on ttbar production
At 10 TeV (startup) the sensitivity will be better at low masses...

Topologies & strategy

Actual limits (Tevatron)

0.35 TeV

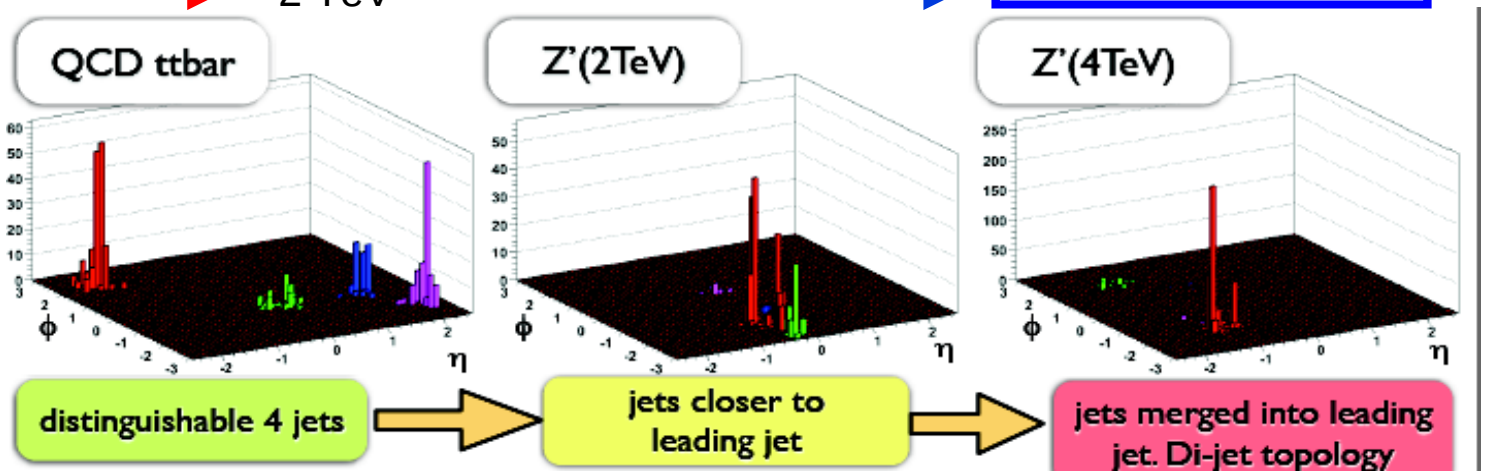
Intermediates topologies

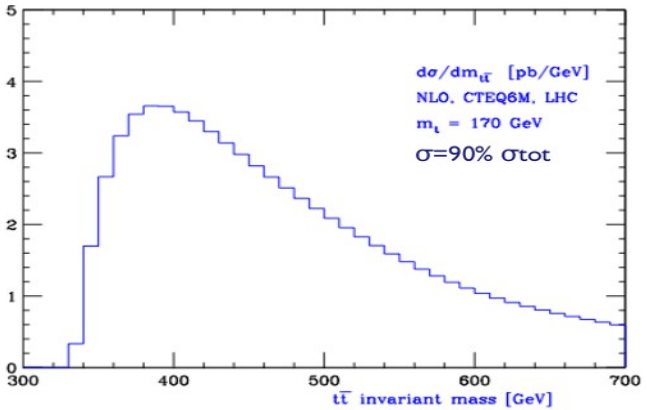
5 TeV

Topology:
4jets+lepton + MET

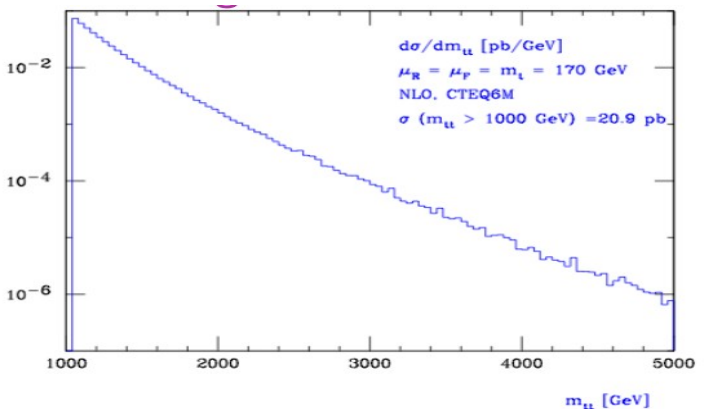
2 TeV

Topology: 2 top-jets





90% of ttbar sample – Mttbar<700 GeV



2% of ttbar sample – Mttbar> 1 TeV

Different analysis:

topology & background & tools & candidates models evolute

My thesis

- channel: semi-leptonic
- region: low mass – ie topology: 4 jets+ lepton+MET
- variable: Mttbar
- selection:
  - isolation on lepton (QCD rejection)
  - jets IC 0.5
  - b-tagging
- tools: use a kinematic fit (4 constraints)

optimization done for selection & reconstruction

- Topology & Trigger & systematics studies done

✓ First searches & extend Tevatron limits

✓ Already cover many models (low mass resonances)

✓ Important backgrounds ⇒selection

✓ Difficultés: combinatorial bdf / radiations / jet-merging

Main problematics:

- selection of jet combination

- [5-35] jets in ttbar events
- Association 4 jets / 4 quarks

- all jets: Only 50% events (due to acceptance (~ 15 %) & jet-merging (15-30 %) & jet-definition & association definition)

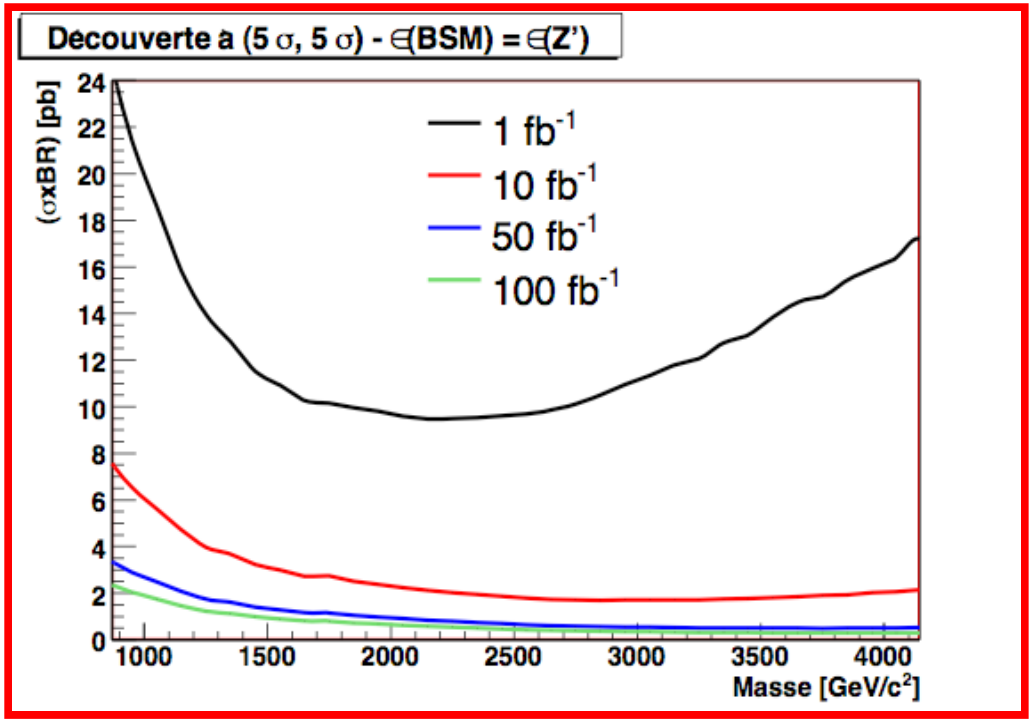
4^{th} highest Pt jets: Only 15-20%

.... we could gain a lot changing jet algorithm !

- Radiations
- bias on Mtt reconstructed (mainly come from top's radiations)

...

- Selection/reconstruction efficencies decrease with M_{tt}
- b-tagging increase purity of the sample échantillons
- Kinematic fit: improve Mttbar resolution & sensibility & less sensitive to JES



Extensions:

- change jet algorithm
- check all the systematic effects ...

including radiation & lepton isolation & knowledge of the momentum uncertainties

- define a strategy to estimate background from data
- define to tune the MC with data

Boosted Top : task force

- Joint group: Exotica & Top
- Convenors: R.Chierici & F.Yumiceva
- hypernews: hn-cms-toppairbsm@cern.ch
- twiki page: https://twiki.cern.ch/twiki/bin/view/CMS/BoostedTop

People involved or interested in this effort

- Lyon group: Roberto Chierici, Stephane Perries, Eric Chabert, Farida Fassi, Thomas Le Grand
- Fermilab group: Dan Green, Francisco Yumiceva
- Karlsruhe group: Thomas Peiffer, Jeannine Wagner, Jochen Ott
- Maryland group: Malina Kirn, Jeff Temple, Nick Hadley
- Brussels group: Jorgen D'Hondt, Gregory Hammad, Catherine Vander Velde, Petra Van Mulders
- Aachen group: M. Erdmann, A. Hinzman, J. Steggemann
- UC Davis group: John Conway, Jim Dolen, Matt Searle, Mike Squires, Ricardo Vasquez
- Johns Hopkins group: Petar Maksimovic, Morris Swartz, Gavril Giurgiu, Sal Rappoccio, Dave Fehling
- UC Riverside group

- Update list:
 Aachen/Karlsruhe/Lyon/UC Riverside/UC Davis/Mariland/Fermilab: ~ 30 contributors
- What's about Brussels ??

Status

Analysis Matrix

Mttbar regions and decay channels that can be explored

Analysis\Decay	Muon Semileptonic	Electron Semileptonic	Dilepton	All Hadronic
Low-Mttbar Standard Analysis. Selection criteria suggested by Top Group	Explored with 1.3.X and partially in 1.6.X	Explored before with 1.3.X	Explored before with 1.3.X	-
High-Mttbar *Simple Analysis*. Use as much as possible standard tools	Explored with 1.3.X and partially in 1.6.X	-	-	Explored in 1.6.X
High-Mttbar *Optimized Analysis*. Use new tools, new variables.	-	-	-	-

Lyon: My thesis ...

FNAL: Yumiceva & Green

German team

UCDavis

- Many subjects not yet covered ...
- "Explored" doesn't mean "finished" ...
- Only Mtt variable used for search
- There is still work to do with simulation before data taking ...
- Do we want to be involved in that effort ? Which subject(s) ?

News & Plans

- MC production ongoing:
  - will be upload in DBS and propagated to Tier-2 -> accessibility
  - scan differentes masses & width (1-10% of mass) and spin 0-1-2 with madgraph

... but still now only spin 1 → *possibility to help on MC production*

- Aim: have approved few analyses
  - Deadline: First draft of internal analysis notes by Jan/Feb
  - Focus on 2/3 analyses. Candidates:
    - Muonic channel at low Mttbar region: 1 FTE (Lyon) ...
    - Muonic channel at high Mttbar region: 1 FTE (FNAL) ...
    - All hadronic channel at high Mttbar region 1FTE (UCDavis) ...
  - "Please let us know if you are interested in helping one of these analyses"

→ *do we want to be involved in these analyses ? Is it a good schedule ?*

- Question: "We do not have enough manpower to cover all the regions and channels for next year ? "

"Strategy analysis has not yet been write down" ...

→ *it's still possible to contribute and make propositions !*

- Next meeting: 5/12 → *good time to express our wishes/position*

Activities

Why are these studies important at this time?

We need to be ready for discovery, (good) surprises may appear any time.
e.g. observation of first high-pT jets, those could be boosted top jets!

Strain our current tools in special scenarios.
e.g. know beforehand the limits of our current techniques and algorithms.

Implementation of new algorithms that could be useful for other analysis
e.g. new discriminant variables, new jet algorithms.

Complementary studies for standard analyses:
e.g. study of non-isolated muons, reconstruction and ID of muons in jets.

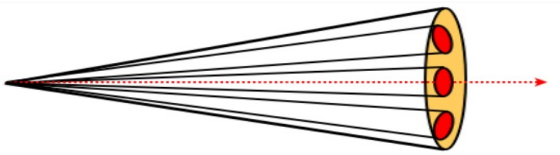
Bread & butter analyses (which can be done with first data samples)
e.g. mttbar distribution, top mass using mttbar distribution.

Summary

- We are straining our current tools and exploring new ideas.
- Current efforts are ongoing to improve understanding of:
  - Fast vs full Monte Carlo simulation of high-pT objects,
  - trigger efficiencies at low and high Mttbar regions,
  - muon isolation and identification in jetty environment,
  - new jet algorithms,
  - tracking and b-tagging at high-pT jets.
- These analyses are very rich and touch every part of the detector and software tools.
- Plans:
  - Porting analyses to CMSSW 2.1.X (ongoing)
  - Private production of 2.1.X MC samples: Madgraph Z' signal samples, and high-pt QCD di-jet and ttbar events. (ongoing)
  - Repeat and refine analysis with new samples. Plan to have analyses at low and high mttbar regions.

High mass search

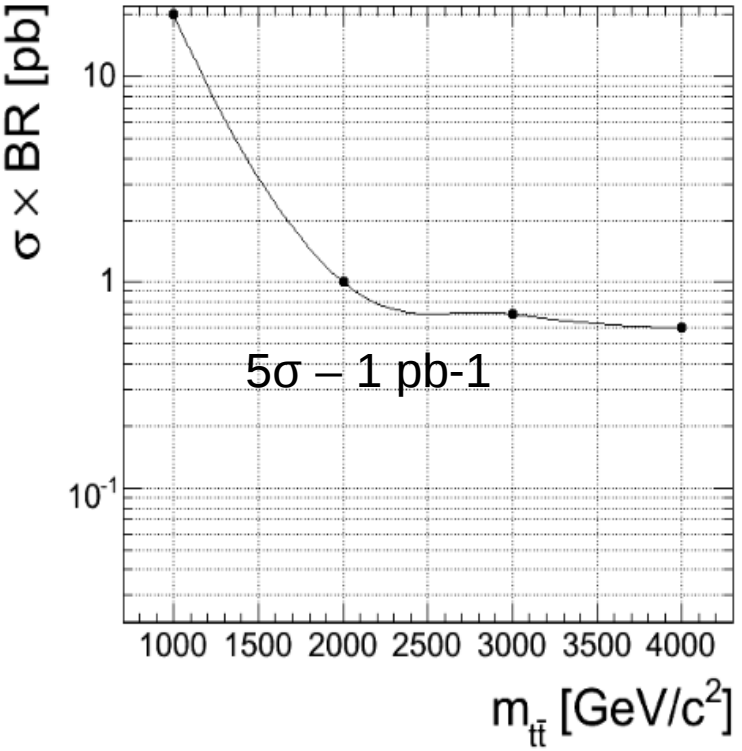
CMS AN-2008/011



Search for narrow resonances at masses above 1 TeV decaying into $t\bar{t} \rightarrow b\mu\nu\ bqq$

Ideas: reconstruct merged jets
Procedure:
Search for a muon (no isolation criterium)
On the other hemisphere ($\Delta R>2.5$) take the leading jet and construct a Mjet
Mjet $\Delta R<1.6$
b-jet associated to muon if $\Delta R<0.75$
MET: $\Delta Phi(MET,mu)<0.75$
Pz(nu): W mass constraint

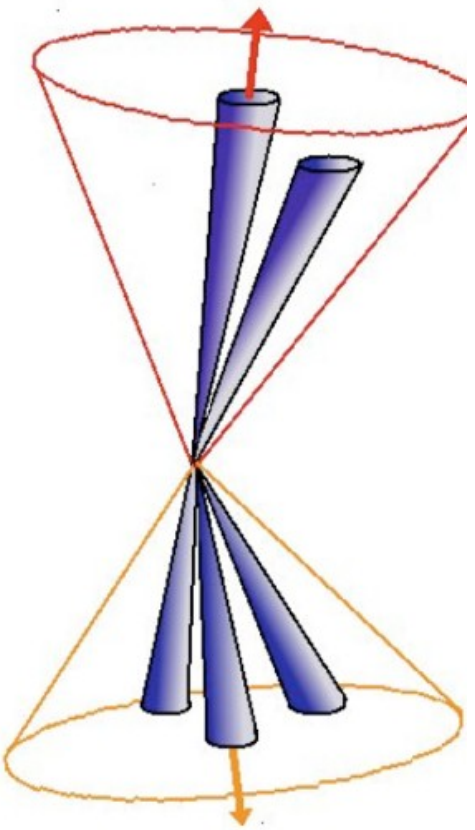
Limits:
Only tt bg considered (not QCD)
No systematics studies



All hadronic decay

J. Dolen UCDavis Group

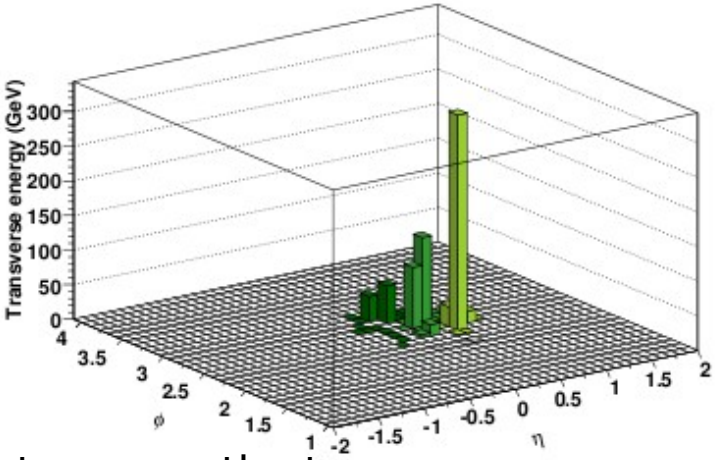
1. Find the leading jet (the highest E_T jet)
   - Only consider events in which the leading jet is central and very energetic ($|\eta|<1.3$ & $E_T>500$)
2. Draw a cone around the leading jet.
   - Group together all jets within 30 degrees of the leading jet
   - Jets in cone should reconstruct the top mass
   - "Group A"
3. Find the highest E_T jet outside of Group A (second leading jet)
4. Draw a 30° cone around the second leading jet
   - Jets in cone should reconstruct the top mass
   - "Group B"
5. Only consider events in which Group A and Group B are separated by at least 120° in phi.



Tagging is very important in this channel to reduce backgrounds.
Either b-tagging or top-tagging is required for this analysis

A Boosted Top-Jet Tagging Algorithm

CMS AN-2008/069



Average jet mass increases as ~ 10% x pT
So once QCD jets pT~1TeV, the average jet invariant mass ~ the top mass.
We need tools to have a good rejection of QCD jets

Idea coming from theorists: arxiv:hep-ph/0806.0848v1
adapted to CMS by Johns Hopkins University's group: CMS AN-2008/069

- Use Cambridgre-Aachen jet finding algorithm to decompose highly boosted jets into subjet components
- Parameters are adapted $\Sigma|Pt|$ of the jets: Cone size & min subjet Pt fraction
- Cuts on jet mass (top) & minimum 2-subjets mass combination
- For top-jets with a pt>500 GeV ε=33% & QCD-jets rejections 98-99%
- This jet algorithm could be used for different analysis
- Could be produced as a standard collection

Conclusions & perspectives

X found Y in 20xx

- Search for new physics in top topologies is an existing & important topic
In CMS, we are not yet enough prepared (with simulation) to observe new signals in top pairs events

- If we want to join the effort, it's time to declare our intentions
Decisions/positions could be reported 5/12 at BoostedTop meeting

- Why should we join that effort ?
  - Brussels is a big top group
  - I already have some expertise in this thematic & I can continue
  - Can be part of Gregory's thesis
  - Studies of M2 students on pflow vs CaloJet ... be useful for ttbar resonance searches
  - We could have privileged links this Maltoni & al:
    - strategy to tune of MC with data taking
    - discussion on theory uncertainties
    - production of BSM with madgraph

Questions:

- Should we participate to the publications scheduled ? (Jan/Feb)
- How to participate:
  - Development of tools
  - Choose an analysis: which channel & region & variable ?