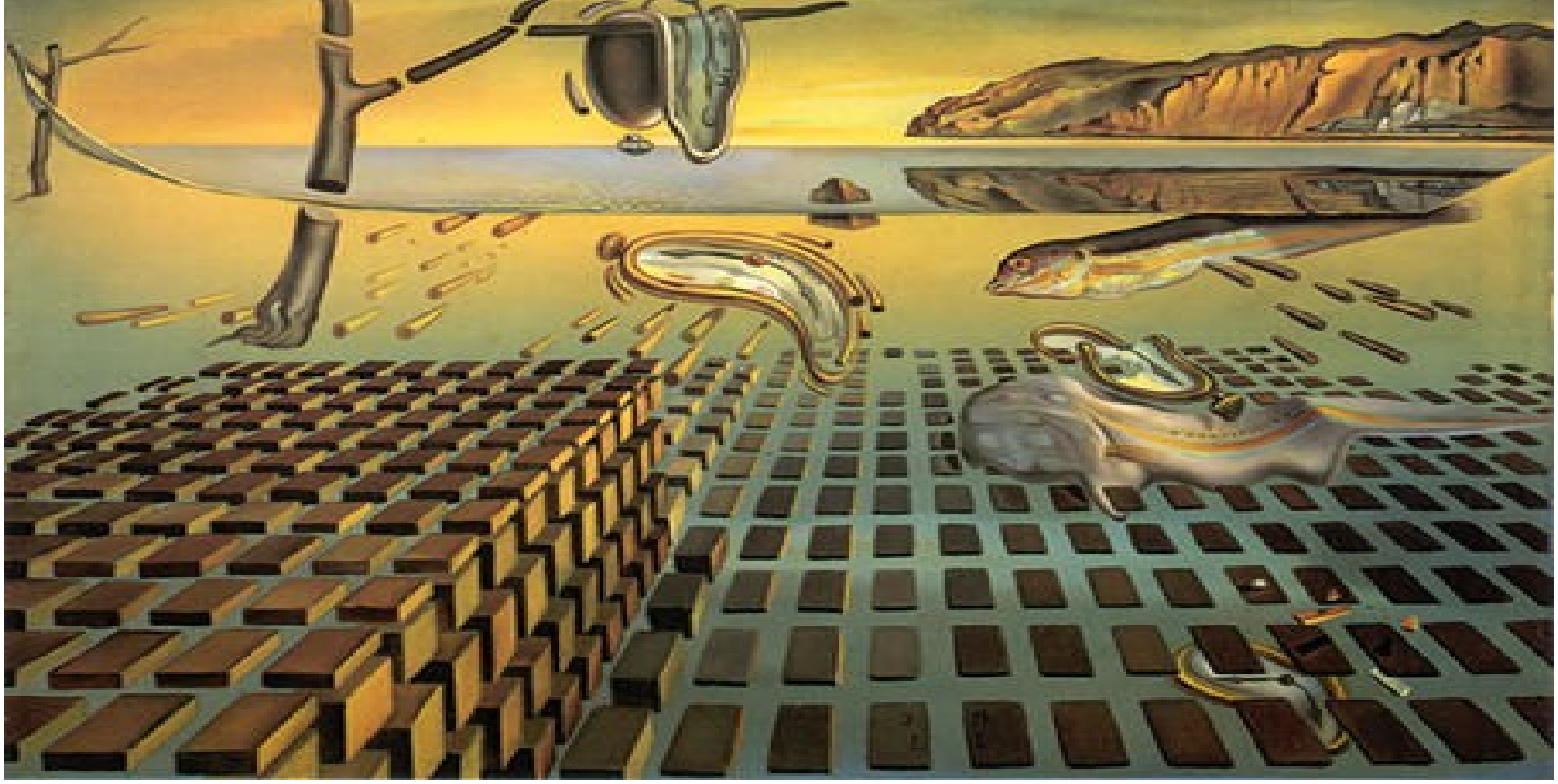
Beyond the Standard Model with top quarks



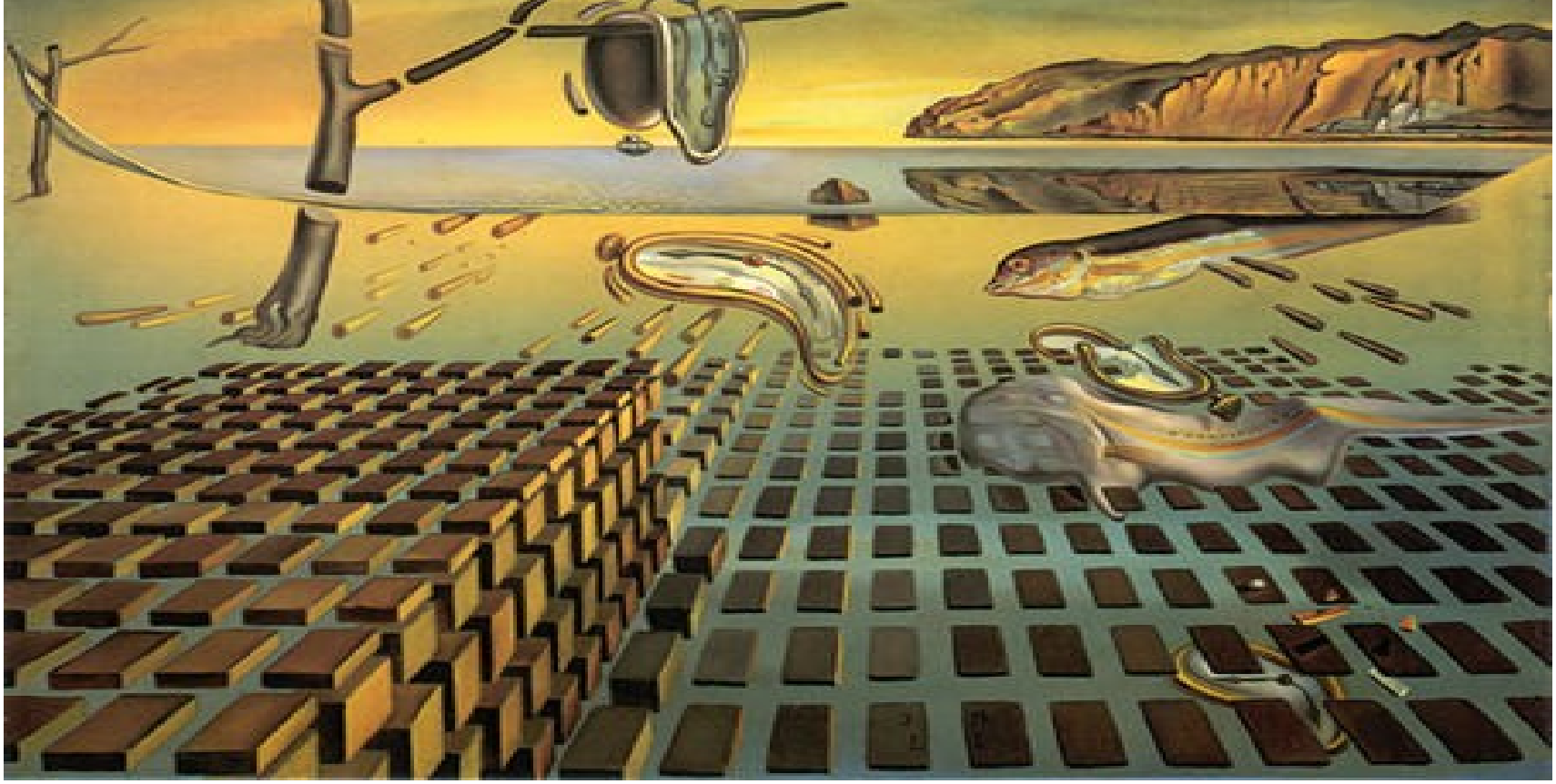
Dali's view of BSM !!

All is there:

space-time deformation,

symmetry broken

super-partners ....



Introduction

Top can be use as a probe for new physics searches ... because

- Top quark is the heaviest particle of the SM
- heavily coupled to higgs boson (Yukawa coupling)
- play a leading role in many BSM models

New physics can be search in

- production mode
- decay mode
- associated production

Topics:

- **Ttbar resonances (Z')** $Z' \rightarrow t\,\bar{t}$
- **SUSY with top** stop decay ...
- **Fourth family: t' (or b')** $pp \rightarrow b'\bar{b}' \rightarrow W^+W^-\,t\,\bar{t}$
- **4 tops (compositeness)**: $pp \rightarrow t\,\bar{t}\,t\,\bar{t}$
- **Charged Higgs**
- ...

PAG involved: Top – SUSY – New Phenomena – Boosted top task force

Actually we are focused on Z' and SUSY searches

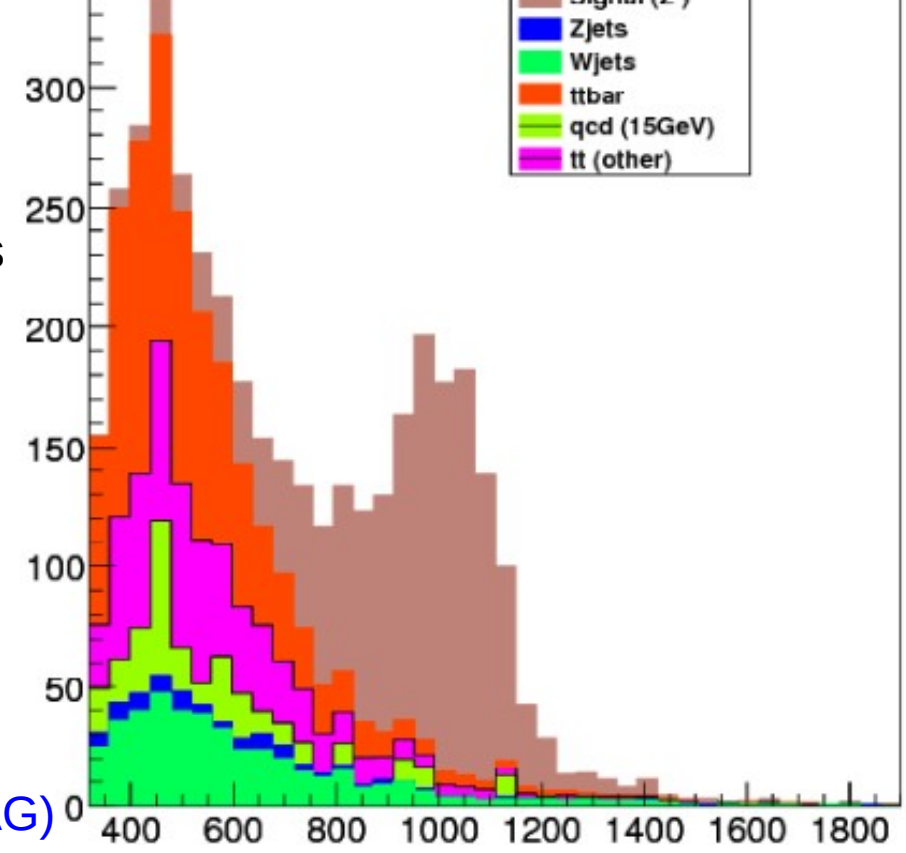
Search for resonances: Z'

Actuality:

Several (4-5) notes in preparation in the
We are Involved in the semi-muonic channel @ low masses (<1-2 TeV) with Lyon's group

Update:

- 100 pb^{-1} @ 10 TeV instead of 1 fb^{-1} @ 14 TeV
- Muon quality cut (χ^2, nof hits, d0)
- Muon isolation ($\Delta R(\mu,j), P_t^{rel}$)
- Jet combination (usage of a χ^2 involved until 8 jets
- Reconstruction with a external KinFit
- Samples: 500-750-1000-1250-1500 GeV
- Estimation of QCD background



Improvements:

- selection efficiency (muon isolation)
- purity X^2 ranking
- linearity of Mtt reco vs gen and resolution (KinFit)

A first draft should circulate soon (boosted top – top PAG)

A combination of the analysis/channels should be prepared next weeks

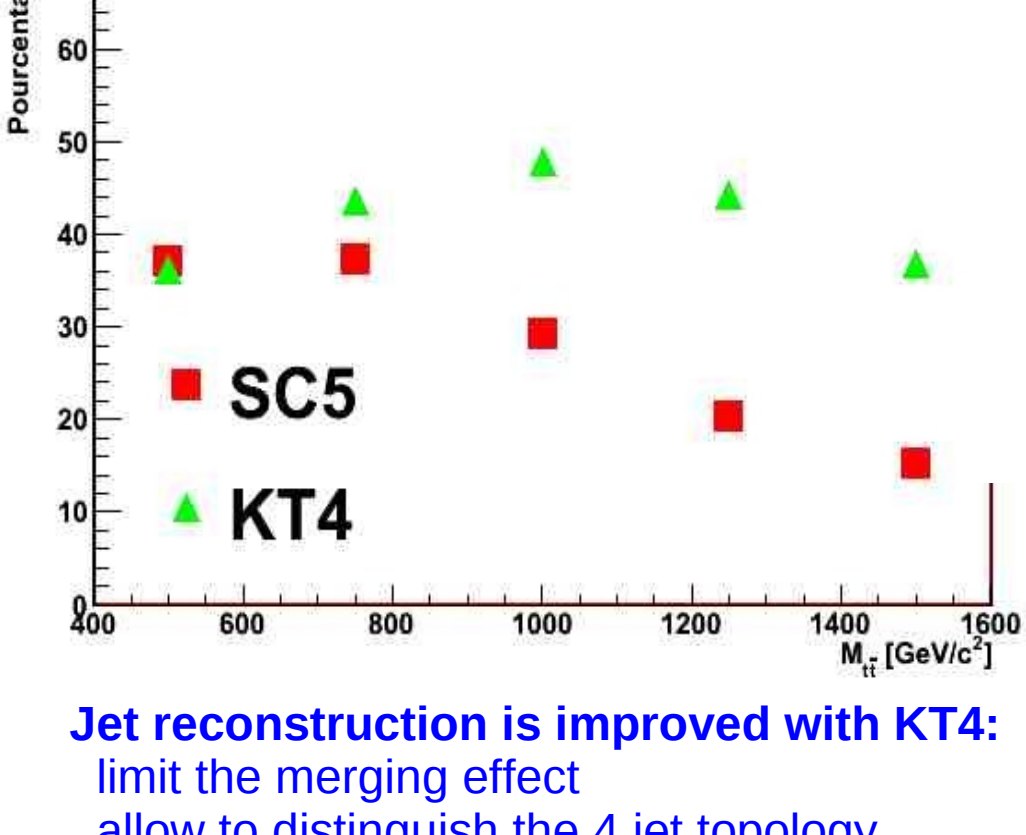
Search for resonances: Z'

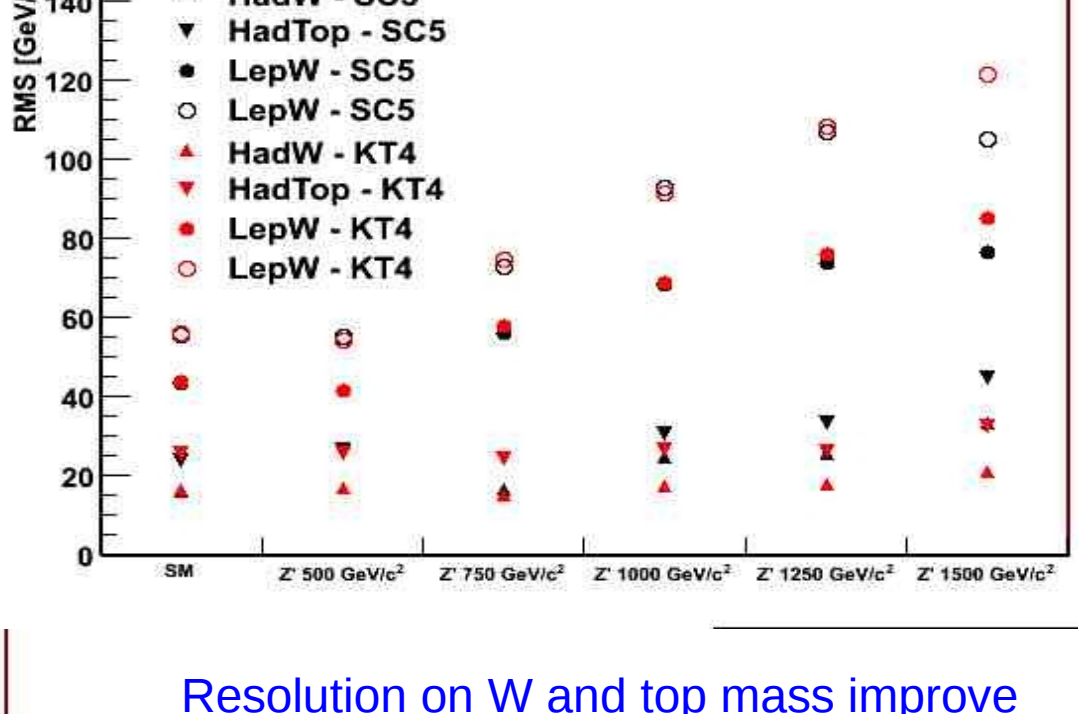
Study of the jet algorithms

Boosted Top task force

Compare SC5 vs KT4

Events where 4 jets are matched to partons





Resolution on W and top mass improve using KT4 above 1 TeV: ~ 12-13 %

Jet reconstruction is improved with KT4:

limit the merging effect

allow to distinguish the 4 jet topology

should improve the sensitivity to Z'

Search for resonances: Z'

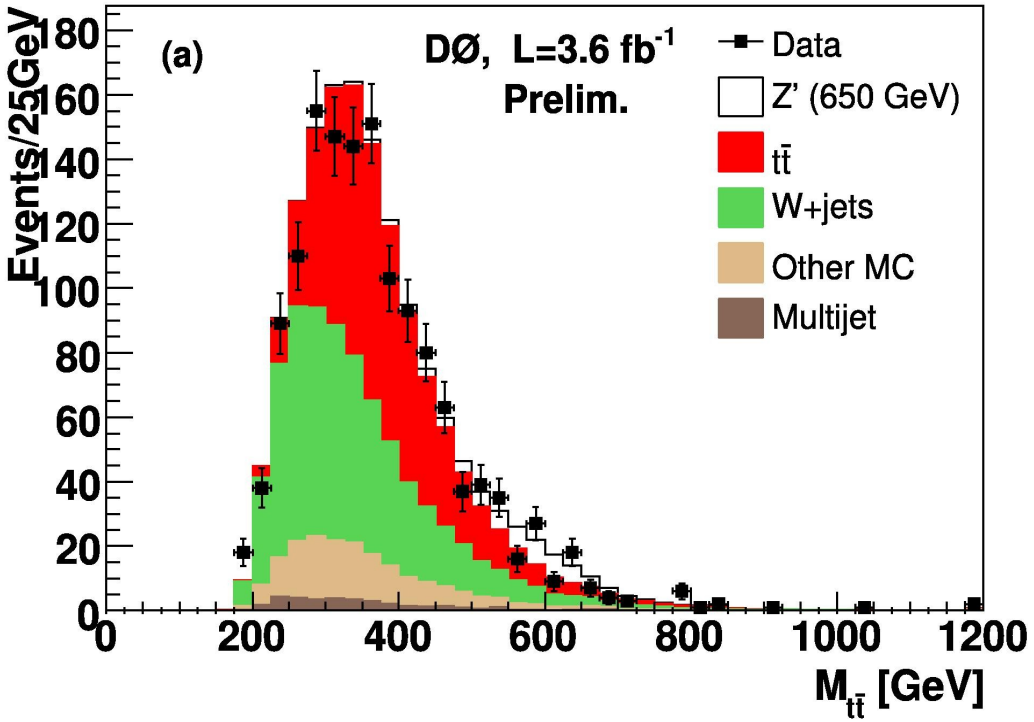
Actual status from TeVatron

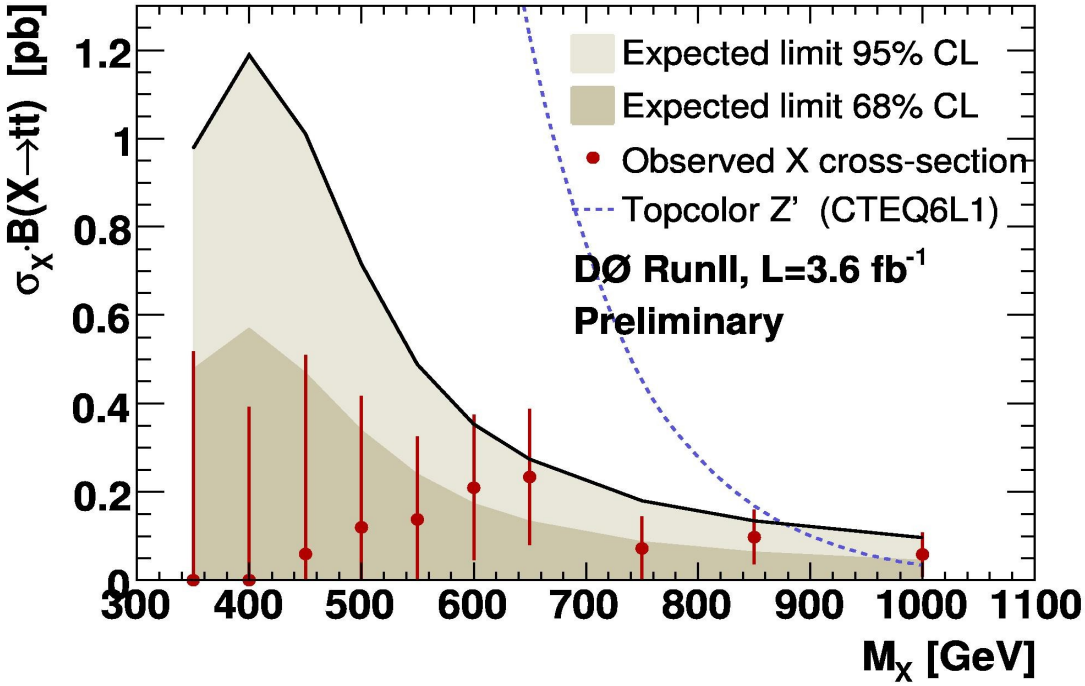
Last meeting (nov 08)

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





Winter 09: analysis updated:

- DO: $m_{Z'} > 820$ GeV @ 3.6 fb-1
- CDF: no excess @ 2.7 fb-1

Limitation: E(CM)
Luminosity

Waiting for LHC startup ...

Search for SUSY with tops: topology considerations ...

Aim:

Inclusive analysis with top:

looking for SUSY events where an hadronic top (probe) is produced (ex: stop decay)

analysis performed in leptonic channel (muon)

selection: 4 jets (3 coming from top)

1 isolated muon (coming from SUSY decay chain)

Main background:

- obviously ttbar (as to be estimated)
- W+jets
- QCD
- ...

How to distinguish SUSY from top:

- excess of MET due to neutralinos
- higher jet multiplicity (#,HT ...)
- difference in the (μ,"4th jet") system: doesn't come from top decay (m_T(W) ...)
- different event shape (centrality, sphericity ...)

Build variable using that differences and search SUSY in the tails of these variables ... after ttbar estimation !!

Search for SUSY with tops: event reconstruction ...

Aim

To identify these event we will use an hadronic top as a probe which suppose an event reconstruction

SUSY production:

- **high jet multiplicity** environment
  - 3 jets coming from top decay are not the 3 leading jets ....
  - importance of jet algorithms
- top more **boosted** (higher Pt, decay products more collimated, lowest angle)
  - cannot play too much with jets Pt constraint
  - importance of jet algorithms
- top mainly **centrally produced**
  - cannot play too much with jets Eta constraint

Event reconstruction:

- **NN/LR**: too much hypothesis dependent (to be avoid for BSM searches)
- **KinFit**: resolution between ttbar & SUSY – no real gain (no resonances)
- **χ^2 sorting** more adapted

Search for SUSY with tops: background estimation ...

Ttbar estimation in the tail of variable used for search (ex: MET) is required

Different methods exists

No one is perfect ...

We have to find one adapted to our signal

Possibilities:

- estimation from MC/Data (shape and/or normalisation)
- estimation of only tt or all bkg in one/several steps

Data driven techniques:

- ABCD method
- fit 1D (extrapolation)
- Template fit
- Matrix Element method

W+jets
- Forward jets
- Charge asymetry

- extrapolation of the shape & normalization

QCD
- top redecay (mixt between data&MC)
- smearing function (fake MET estimation)

Search for SUSY with tops: study @ MadGraph level

Activity started by Alexis Kalogeropoulos
Actually a set of SUSY & ttbar samples are available using
MadGraph + Pythia (PS) + PGS (detector simulation)

Aim:

- Benefit of MadGraph flexibility to implement new physics (not only SUSY)
- Analysis easily realized (~ not too much CPU limited ..)
- Scan of parameters can be performed
- Test different variable to distinguish between SUSY & top
- Test ideas @ generator level before full RECO level !

Next step:

- Develop an interface to produce TopTree using MadGraph samples !
  → Analysis' tools will be the same @ MadGraph & CMSSW level !!
- Compare variables for SUSY searches

Worflow

Greg/Ilaria/Joris/Petra & I developed tools the last months to have a full analysis strategy in place. It's almost done !! ouff....

- Root-trees can fit on a laptop !
- Standalone c++ code compiled (root)
- Code can run interactively or via grid (script using glite command)

- Produce log file & plots
- Should be centralized in the future ...

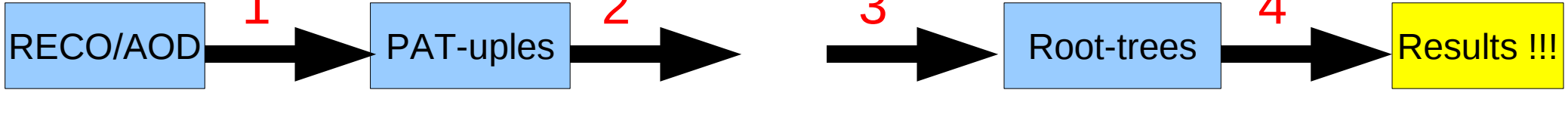
- Already 3 “rounds” !
- Publication
- wiki

- ~ 4.5 Go of Root-trees
- wiki

(1) “PATification”
(2) SanityChecker
(3) TopTreeProducer
(4) Analysis

Compare to Fwlite:
time compression factor: ~150
data compression factor: ~40

Worflow



SanityChecker

- KinematicsChecker
- ResolutionChecker
- MuonChecker
- JetMETChecker
- VertexChecker
- TtGenEventChecker
- TruthRecoChecker

general

objects

Ttbar oriented

TopTreeProducer

- TRootEvent
- TRootRun
- TRootMuon
- TrootElectron
- TrootJet
- TRootMET
- TRootGenEvent
- ...
- TRootSpinCorrelation
- TRootNPGenEvent

general

objects

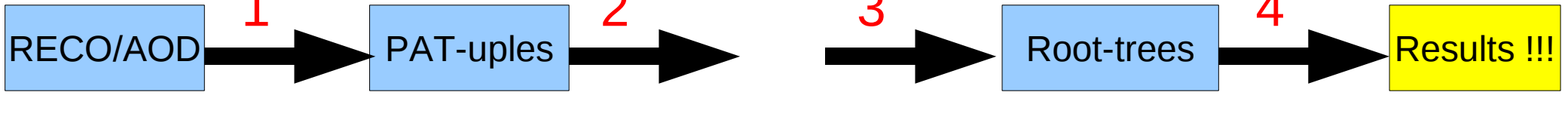
Ttbar oriented

Analysis specific

(1) "PATification"
(2) SanityChecker
(3) TopTreeProducer
(4) Analysis

The "Layer 2" is still missing ...
I implemented it but it's not finished ...

Worflow



Store all this information in a DB
→ will be done by Olivier: thanks :-)

Ideas:

Webpage: forms
status of the PAT-uples production ...
DB: all the information & links stored (diff DB & links)
Storage: SE for PAT-uples & TopTree
msa3 for logfiles & rootfiles from SanityChecker

Aim: go on the web and in one click find the location of TopTrees to use (previously checked ..) and the "kfactor" for the plot normalisation ...

(1) "PATification"
(2) SanityChecker
(3) TopTreeProducer
(4) Analysis

Com:
wiki (used) :https://mon.iihe.ac.be/trac/t2b/wiki/TopQuarkGroup
"webpage" (empty):
http://w3.iihe.ac.be/~echabert/TopGroupPage/

Code: cvs directory UserCode/TopBrussels

Plan

After weeks of development ... you have more or less all the tools in hand for the analysis ...
Now benefits/results should arrive soon ....

New physics

- **Z'**: final note should arrive soon for approval
- **SUSY with top**: reconstruction
  ttbar estimation
  limit on SUSY parameters
  scan of the parameters
- **More generally:**
  comparison of variables for BSM search
  compare performances
  background estimation
- **LHC09 TH Institute (may)**:

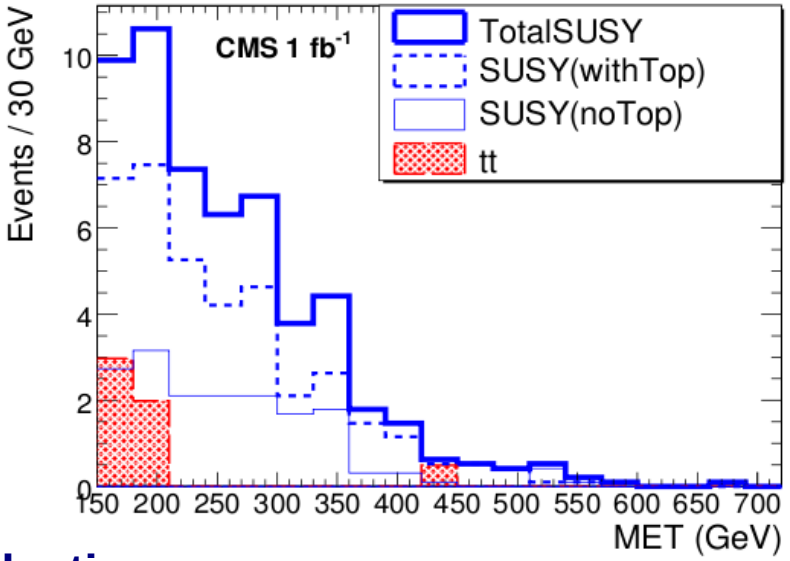
"Top quark physics:from the Tevatron to the LHC"
strategies for BSM study should be discussed

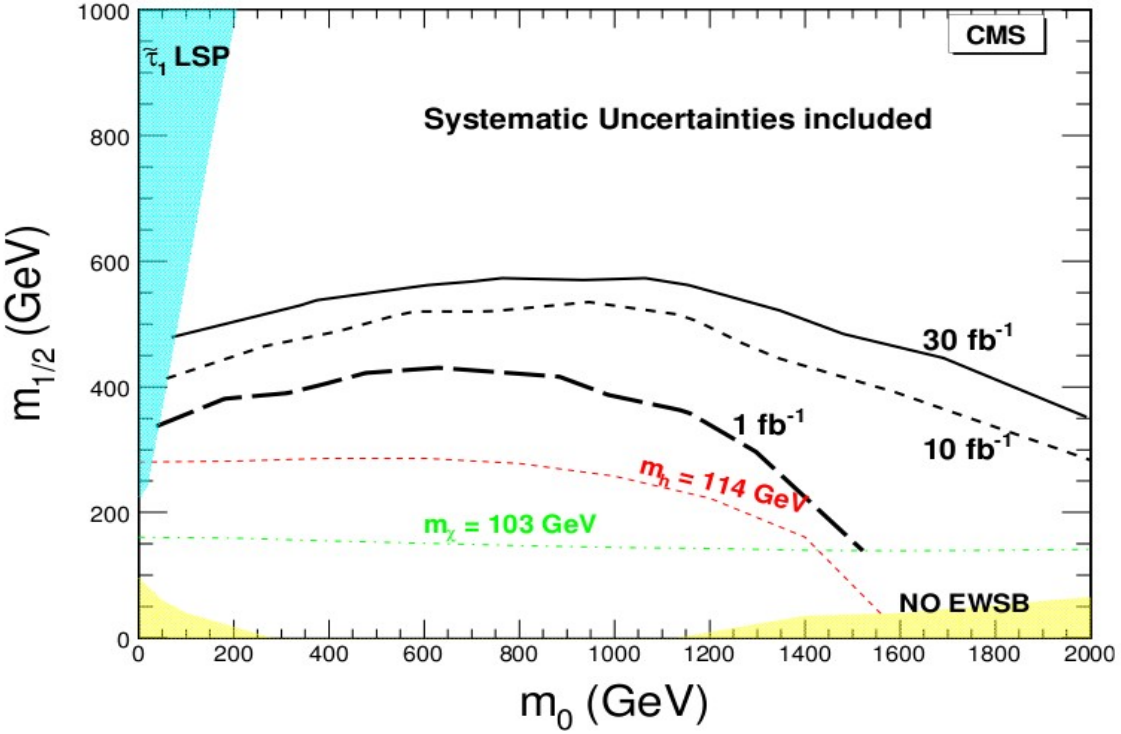
- New physics activity in the group started !
- After a development phase results start to be produced ...
- This activity could grow up with new comers (PhD/students ...)
  ... enough possibilities ...

Backup

Search for SUSY with tops: topology considerations ...

Recherche de SUSY inclusive avec des quarks top.
(Modèle mSugra)

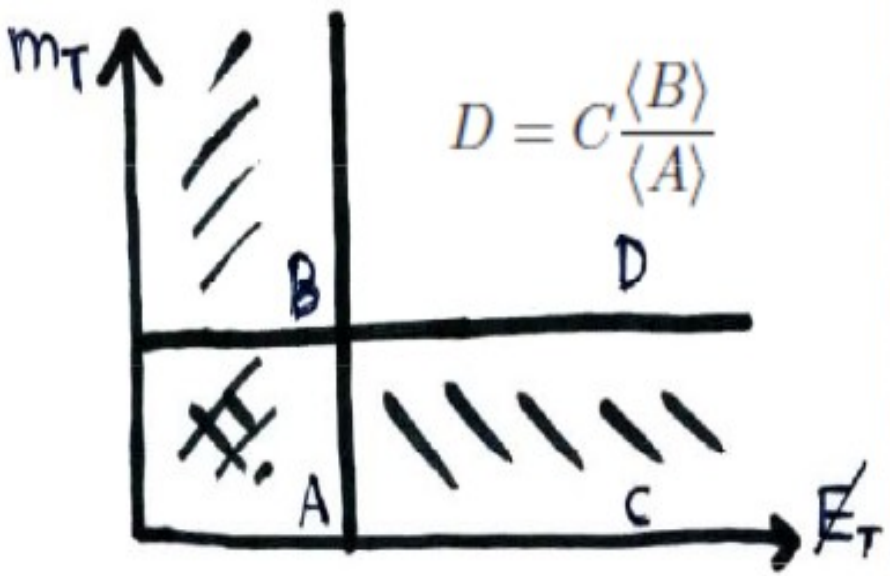




Sélection:
- HLT: 1jet+MET
- au moins 4 jets Et>30 GeV & |η|<2.5
- au moins 1 b-jet
- 1 muon isolé Pt>5GeV & |η|<2.5
- MET>150 GeV

Reconstruction:
- ajustement cinématique (W,top hadronique)
- P(χ2)>0.1
- ΔΦ(top,MET)<2.6

ABCD



$$D = C\frac{\langle B\rangle}{\langle A\rangle}$$

assumptions:

Bkg. dominates in A, B and C

possible problems:

signal contamination in C

- affects the measured MET shape

signal contamination in B

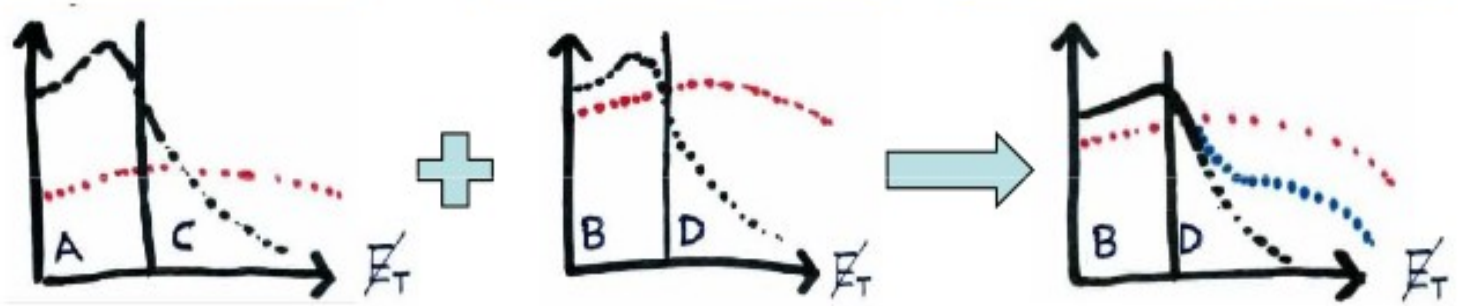
- affects normalization

m_T-control-region A, C

m_T-signal-region B, D

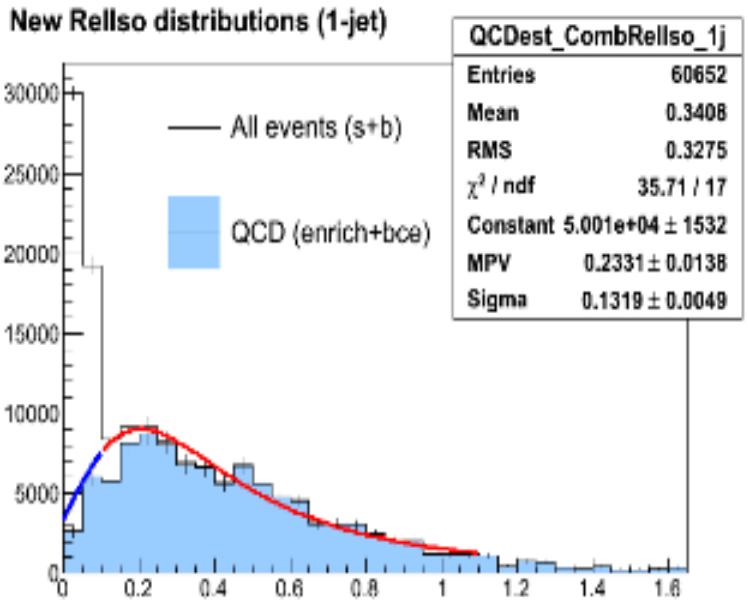
blue: predicted Bkg. in D

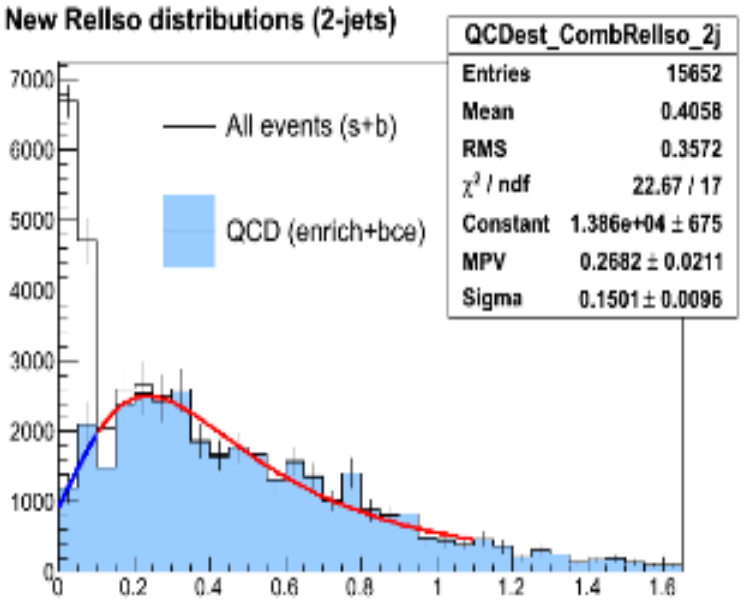
black: true Bkg.



1D fit

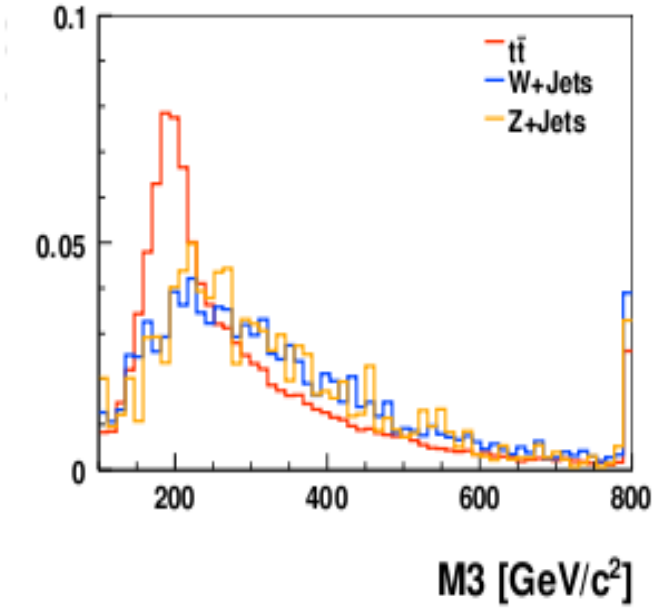
- I repeated the studies using new RelIso.
- I found Landau function give the most optimal results.
- If we restrict ourselves to a fixed range for different njet bins, then the optimal range is 0.1 to 1.1.

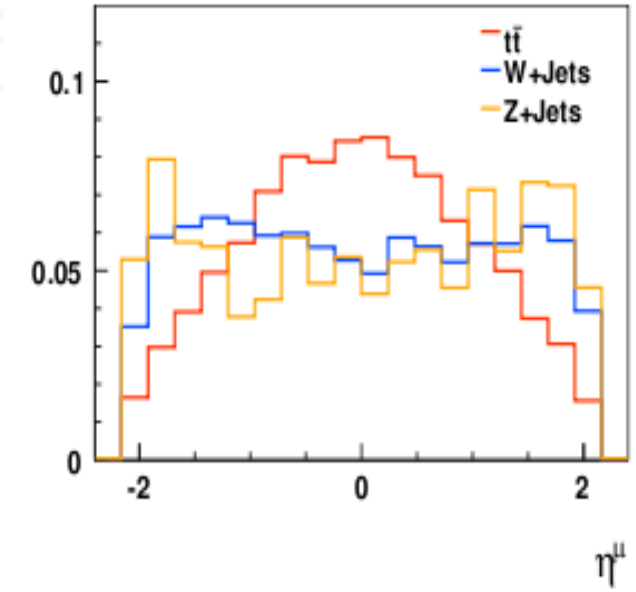




Template fit

- Variables for the fit need to have different shapes for Signal and Background
- Used variables: $\eta(\mu)$ and M3, where M3 is the inv. Mass of those three (out of all) jets with the highest vectorial summed E_T
- Similar shape for W/Z+Jets, use only W+Jets template





Matrix element

- Define 3 set of cuts : *loose*, *medium* and *tight* (*loose* = no isolation, *medium* = isolation on at least one selected leptons, *tight* isolation on 2 leptons).

$$N^t = N_S^t + N_{W+jets}^t + N_{QCD}^t$$

$$N^m = N_S^m + N_{W+jets}^m + N_{QCD}^m$$

$$N^l = N_S^l + N_{W+jets}^l + N_{QCD}^l$$

- N_s = signal +physical background (Z+jets, dibosons)
- N_{W+jets} = W+jets events + tt semi-leptonic (1 fake lepton)
- N_{QCD} (2 fake leptons)
- We can introduce the efficiencies to pass from loose to medium and loose to tight cuts: $\varepsilon^{l->t}$ and $\varepsilon^{l->m}$.

Charge asymmetry

- W+ and W- cross sections are different at LHC .
- For the single lepton channels, the number of selected events which have a selected lepton (negative charge) is different than the number of selected events which have a selected anti-lepton (positive charge) .
- W+jets background can then be estimated.

$$\frac{N_+ - N_-}{N_+ + N_-} = \frac{\epsilon_+ L\sigma_+ - \epsilon_- L\sigma_-}{\epsilon_+ L\sigma_+ + \epsilon_- L\sigma_-} = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

Assuming that $\varepsilon^+ = \varepsilon^-$

- Where $N^+(N^-)$ is the number of selected W events with a positive (negative) charge, ε^+ (ε^-) are the global selection efficiencies, L *is* the integrated luminosity and $\sigma^+(\sigma^-)$ the $W^+(W^-)$ cross sections.

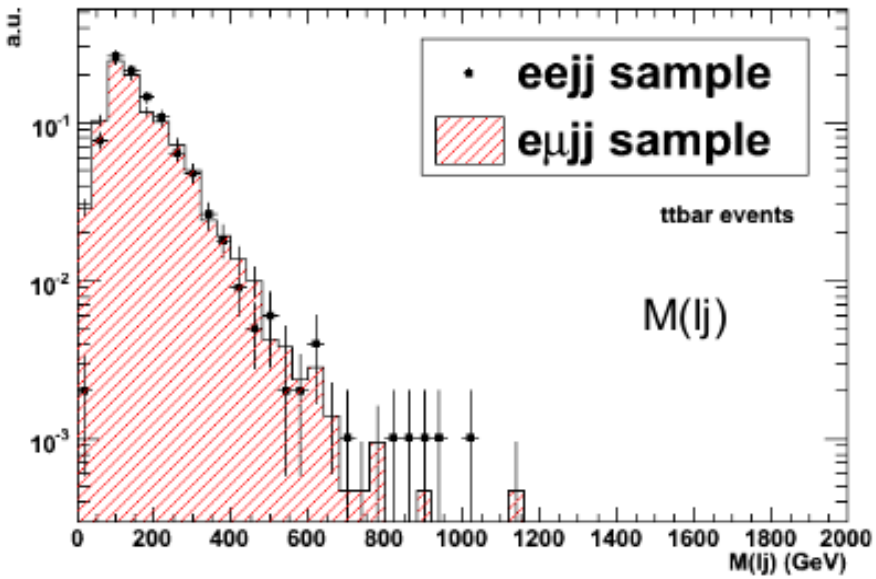
$$N_+ + N_- = \frac{\sigma_+ + \sigma_-}{\sigma_+ - \sigma_-}(N_+ - N_-)$$

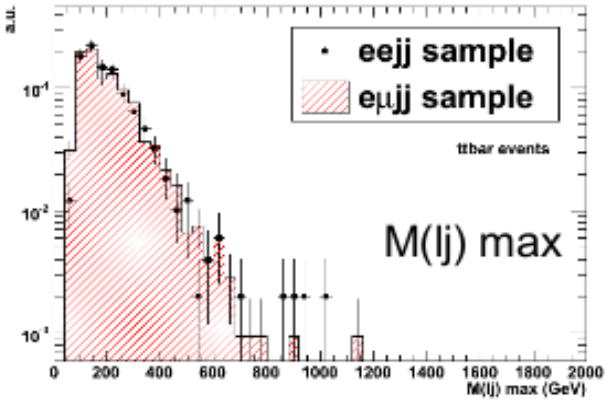
Where (N^+-N^-) is estimated from data!

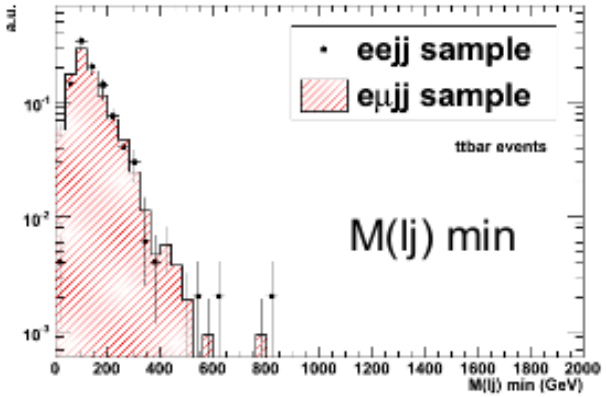
Can also be estimated from data (with some assumptions)

Shape - Normalisation

The eμjj control sample







- Get the M(lj) shape from the eμjj sample
- Get the normalization from:

$\sigma_{tt\to ee} = ½ * \sigma_{tt\to e\mu}$

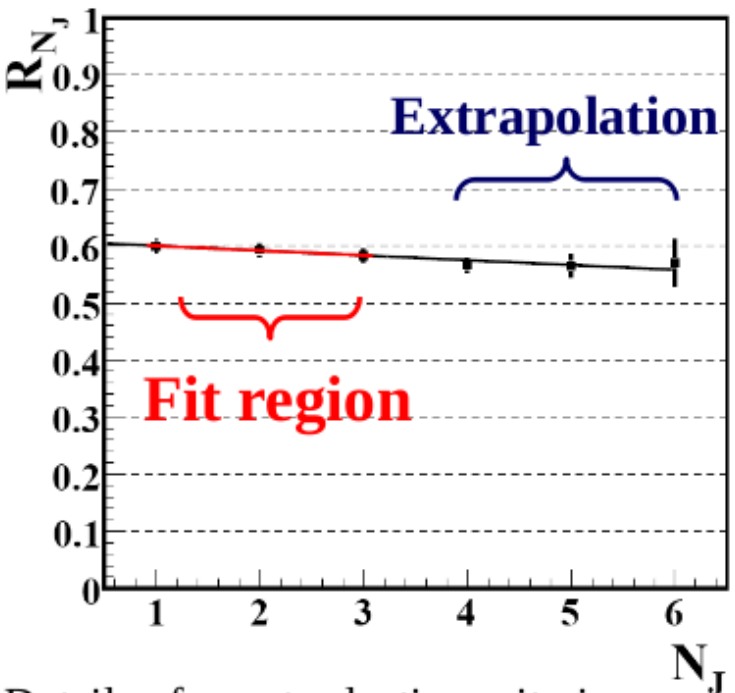
$N_{ee}/\varepsilon_{ee} = ½ * N_{e\mu}/\varepsilon_{e\mu}$

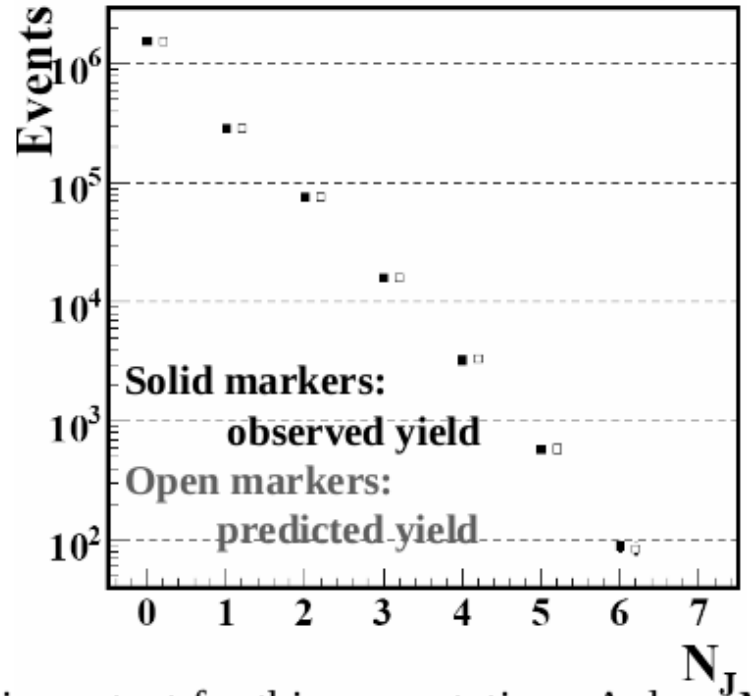
$N_{ee} \sim= ½ * N_{e\mu} * \varepsilon_e/\varepsilon_\mu$ (assuming the only difference is μ instead of e)

$N_{ee} = ½ * \Sigma_{pT\mu} [N_{e\mu}(pT_\mu) * R(pT_\mu)] \ldots \rightarrow$

Forward

Extrapolate ratios $R_{N_J} \equiv \frac{N_J^{Central}}{N_J^{Forward} + N_J^{Central}}$ from small to high N_J bins; combine them with forward yields to predict central yields at high N_J:



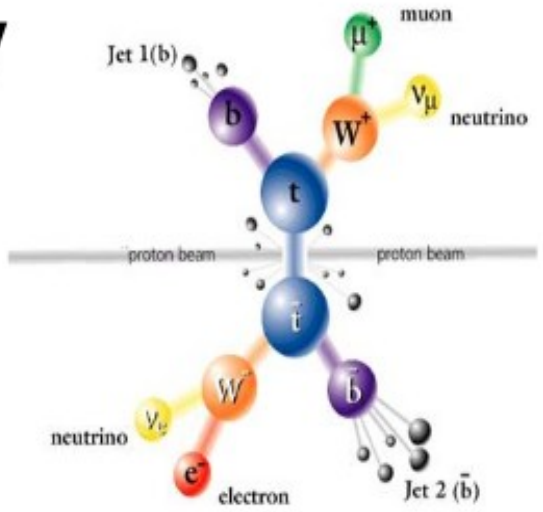


Details of event selection criteria are not important for this presentation; Aplgen MC with 0-5 partons is used everywhere; MET is not used unless otherwise indicated.

NB: the definition of R_{N_J} here is different from that in our earlier talks

Top redecay

Dileptonic tt: top redecay



- Tag *seed* events (with low $E_{T,miss}$) containing 2 tops
- Reconstruct 4-momentum of tops
- Redecay/hadronize with Pythia
- Simulate decay products with fast simulation (ATLFAST)
- Remove from seed event original decay products and merge new ones
- Apply standard SUSY selection cuts on merged events
- Normalization to *data* in low $E_{T,miss}$ region

Statistic uncertainties ~30%
Systematic uncertainties ~30%
SUSY contamination ~60%