Rockefeller University Activities at CMS

Anwar A Bhatti
The Rockefeller University
DOE Annual Site Visit
December 7, 2007

- SuperSymmetry Search
- Inclusive Jet Cross Section
- Jet Clustering Studies
- Jet Energy Calibration
- Missing Transverse Energy Calibration
- Summary

Personnel

- Luc Demortier is a chair of the CMS statistics committee.
- K. Goulianos is contributing to diffractive physics at CMS/FP420.
- Anwar Bhatti is a convener of the Fermilab LPC Jet+MET topology group.
- Anwar Bhatti is a member of the CMS Jet Energy Scale Task Force.
- Koji Terashi worked on missing Et corrections for muons.
- Gheorghe "Jim" Lungu and Ming Yan recently joined the effort.
  - Jim is working on Hadronic SUSY trigger and missing Et corrections.
  - Ming is working on jet energy scale determination using γ-jet data.
- Anwar Bhatti is supervising two students (Huseyin Topakli and Pelin Kurt) from Curkurova University, Adana, Turkey who are visiting LPC.
- We have a very successful collaboration with LPC postdocs/scientists.
- As a convener of the Jet+MET topology group, I expect to be supervising more students/postdocs at LPC.

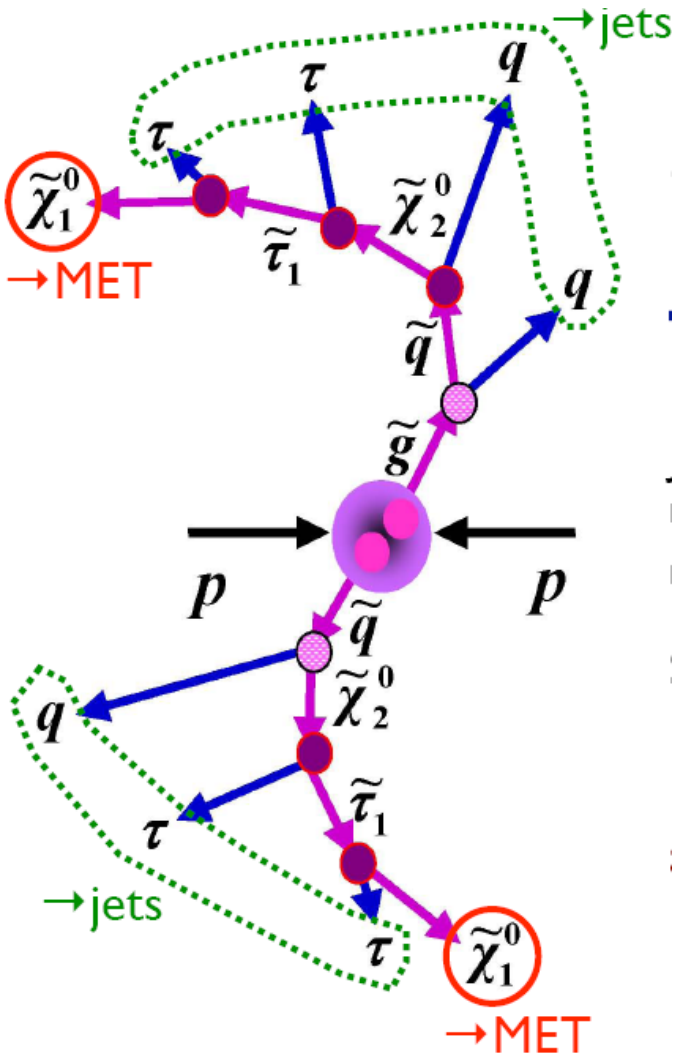
Search for SuperSymmetry

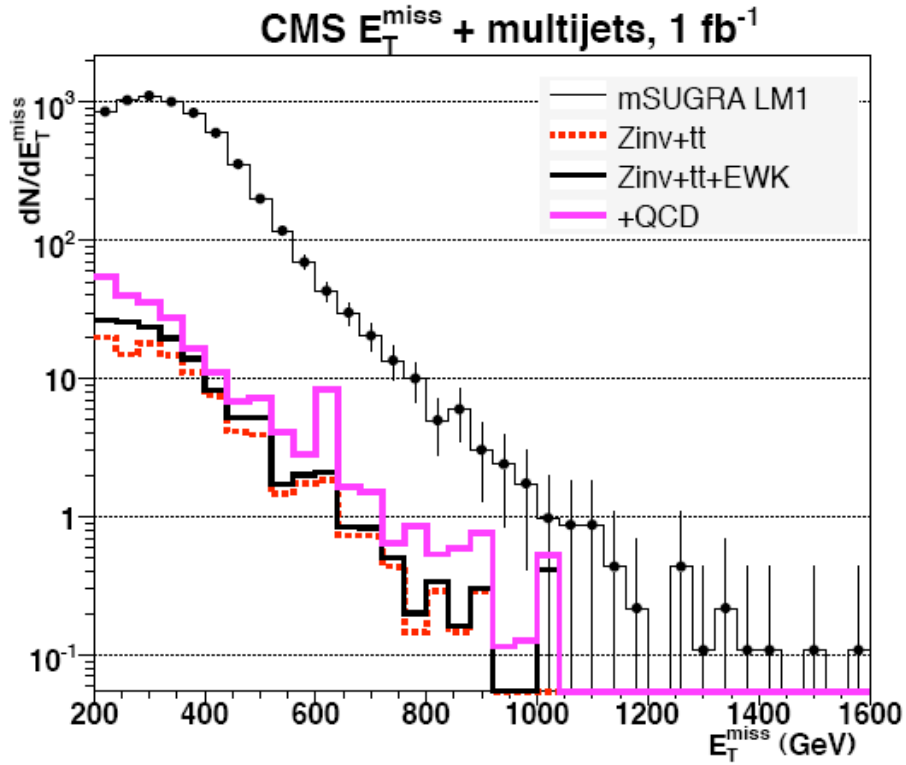
- SuperSymmetry (SUSY) is one of the most popular theories beyond the Standard Model.
- In the R-parity conserving scenario and $m_{\tilde{g}} > m_{\tilde{q}}$

$$pp \rightarrow \tilde{g}\tilde{g}, \tilde{g}\tilde{q}, \tilde{q}\tilde{q} \qquad \tilde{g} \rightarrow q\tilde{q} \qquad \tilde{q} \rightarrow q\tilde{\chi}_1^0$$

- The final state has multiple jets and large Missing Et from LSPs.
- Major backgrounds are
  - QCD multi-jets, removed by MET, Δφ(jet,MET) cuts.
  - Top quarks, W+jets, Z(→μμ,*ee*)+jets, removed by lepton veto.
  - Z(→νν)+jets, W→τν+jets, irreducible, same signatures as the signal.
- Rockefeller U. is working to estimate the Z(→νν) rate by scaling the Z→μμ and Z→*ee* rates measured from the data.
- Rockefeller U. will also work on the QCD multi-jet background determination.
- SUSY point LM1 ($m_{gluino} \sim 600$, $m_{squark} \sim 520$) has large cross section and can be discovered with $< 10\ pb^{-1}$ of data.
- Current limit from CDF is $m > 370$ GeV for $m = m_{squark} \sim m_{gluino}$.

SUSY



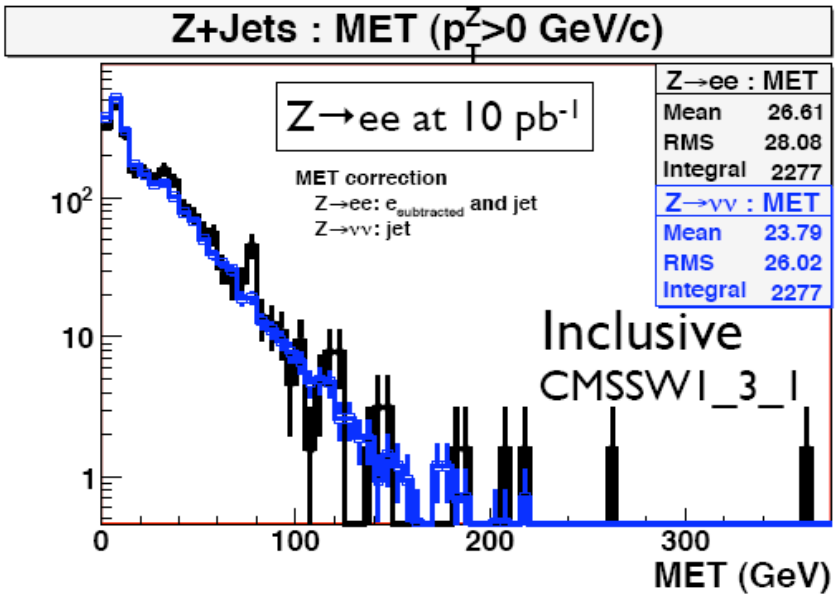


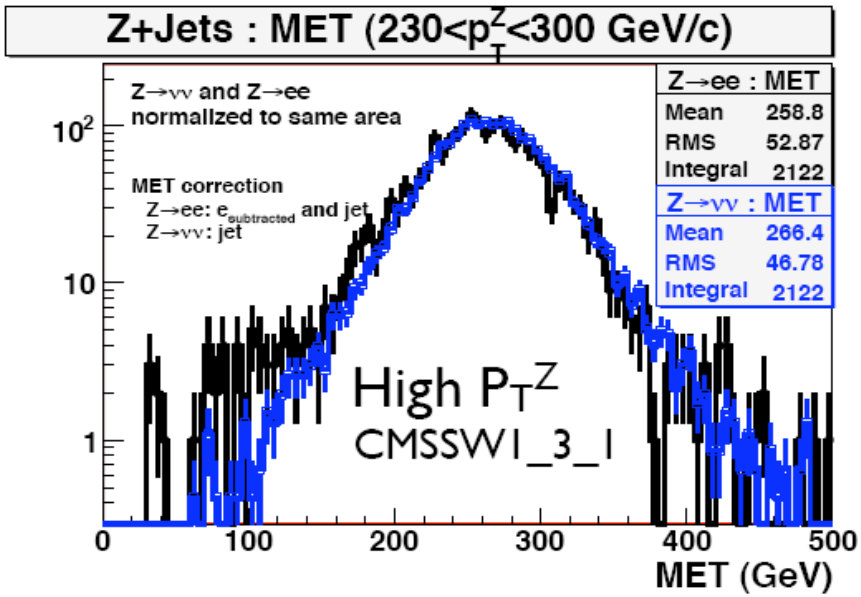
SUSY LM1 (m_{gluino}=600, m_{squark}= 520 GeV
Discovery possible with < 10 pb^{-1} of data.

$Z \rightarrow \nu\nu$ MET Calibration using $Z \rightarrow ee$

$Z \rightarrow ee$: subtract electron $\vec{P}_{SC}$ from $-\vec{MET}$, and correct for JES

$Z \rightarrow \nu\nu$: correct for JES





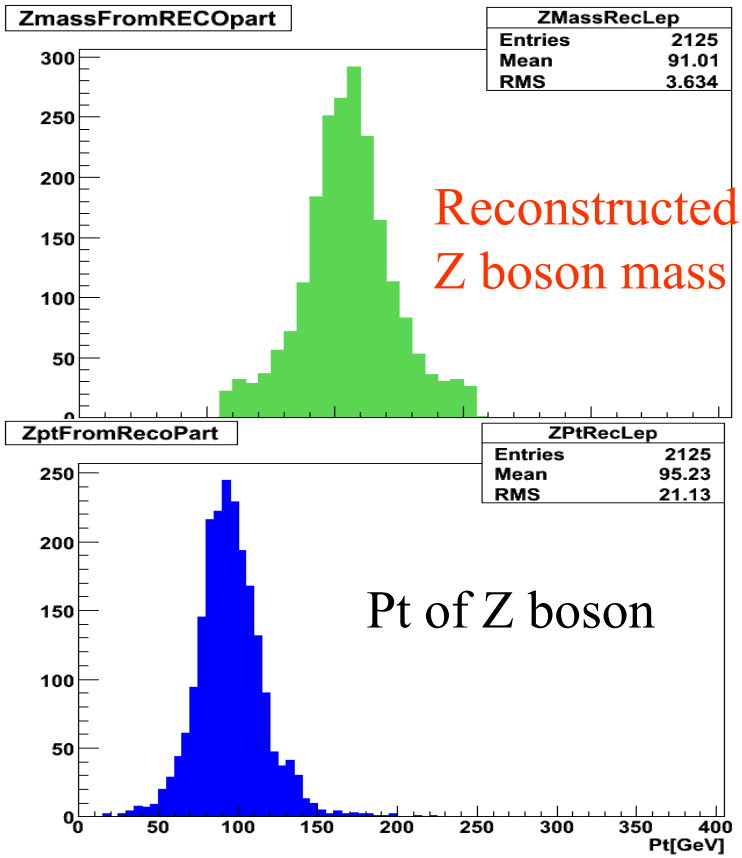
NOTE: $Z \rightarrow \nu\nu$ normalized to $Z \rightarrow ee$ and $Z \rightarrow \mu\mu$ for shape comparison

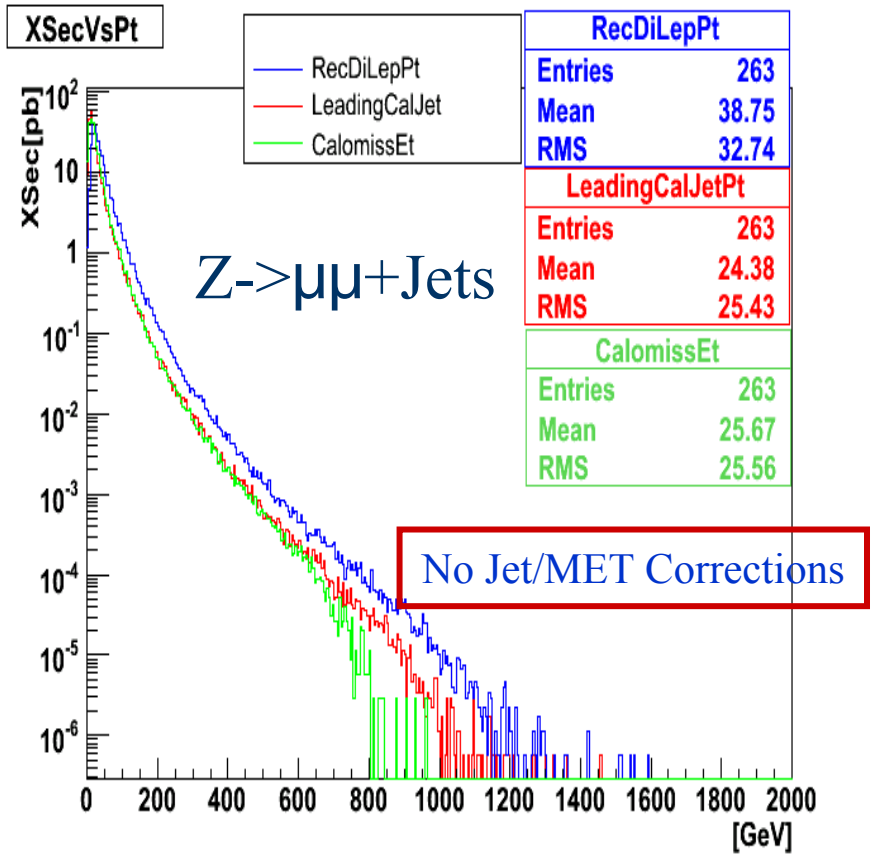
Good agreement in shape after subtracting electron momenta

Koji Terashi LPC Physics Meeting June 28, 2007

Z+jet Studies

Huseyin Topakli (Cukurova) Ph. D. Thesis

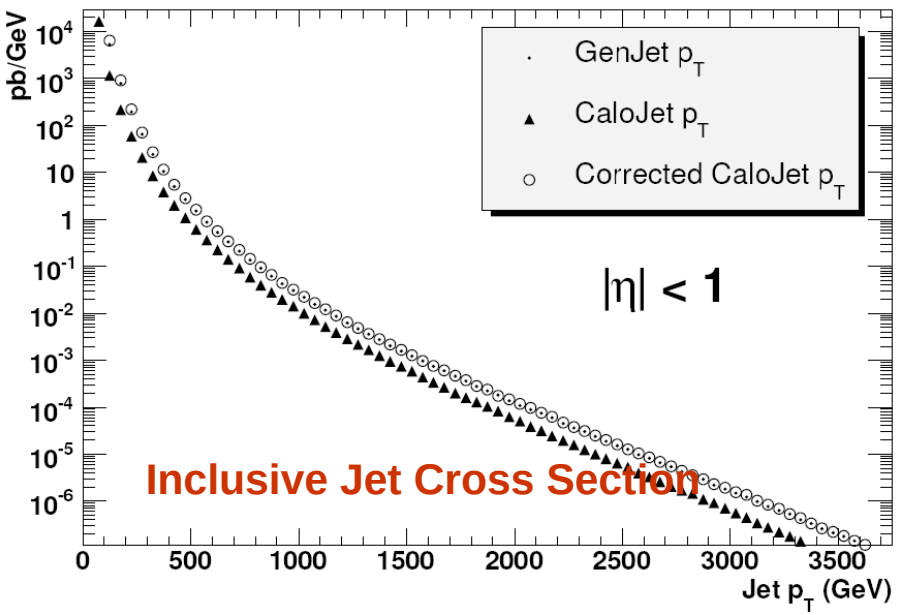


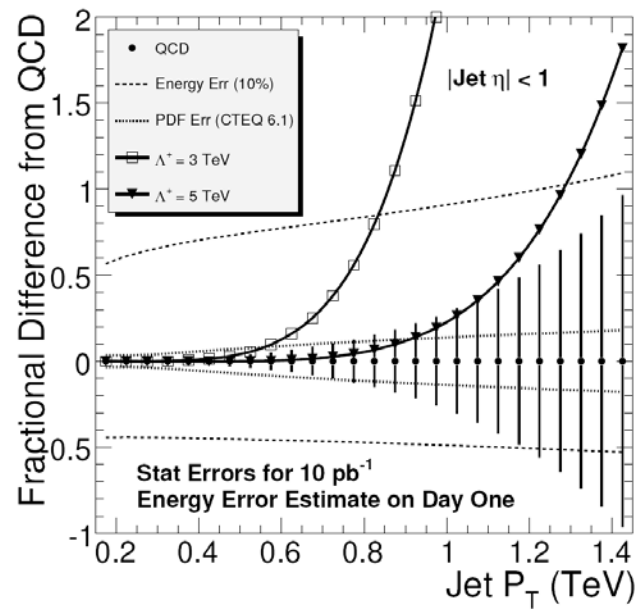


We plan to study Z+jet events and compare with SM predictions. It is important that the P_T spectrum of the jets matches the MC predictions so that the MC can be used to scale the MET in Z→μμ events to predict background from Z→νν events.

Inclusive Jet Cross Section with Dave Mason (Fermilab)

- Inclusive jet p_T is a QCD measurement that is sensitive to new physics.
  - Count all jets inside a p_T bin and η interval, divide by luminosity.
  - Only real challenge is the determination of jet energy corrections.
- With $L^{int}=10\ pb^{-1}$, contact interactions corresponding to $\Lambda=3$ TeV can be detected, assuming <10% jet energy scale uncertainty.
- Current published limit from Tevatron is 2.7 TeV.
- Dijet mass group is also working on search for new physics using dijet mass resonance search and ratio of dijet Njj($|\eta|<0.7$)/Njj($0.7<|\eta|<1.3$).



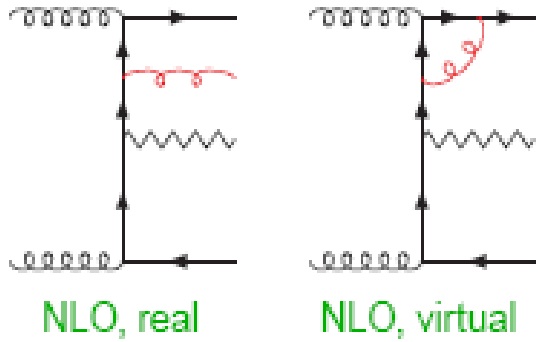


SISCone Jet Clustering Algorithm

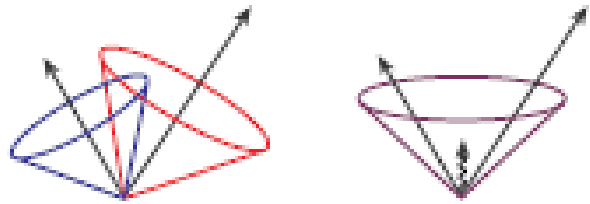
Stability upon emission of soft particles is required for perturbative predictions to make sense.

- Current iterative cone clustering algorithms including *MidPoint* are not IR safe as they finds stable cones around the seeds only.
- Seedless Infrared Stable Cone (SISCone) algorithm finds all stable cones and is still fast enough.
- JHEP 05 (2007) 086 [arXiv:0704.0292 [hep-ph]].

- SISCone finds all stable cones by checking the circles determined by a pair of particles on their circumference.
- We compared the *SISCone* and *MidPoint* algorithms performance in dijet, Z' and top quark samples.
- Two algorithms have similar performance.
- CMS Jet Algorithm Group has accepted the proposal to replace the *MidPoint* algorithm by *SISCone*.



Cancellation of contributions from real and virtual partons is not ensured if the algorithm is not IR safe.

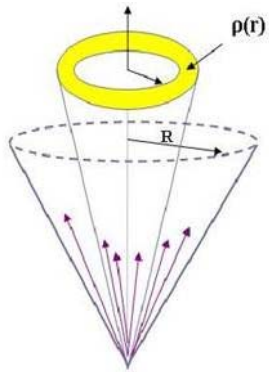


Addition of extra seed results in merging of two distinct jets.

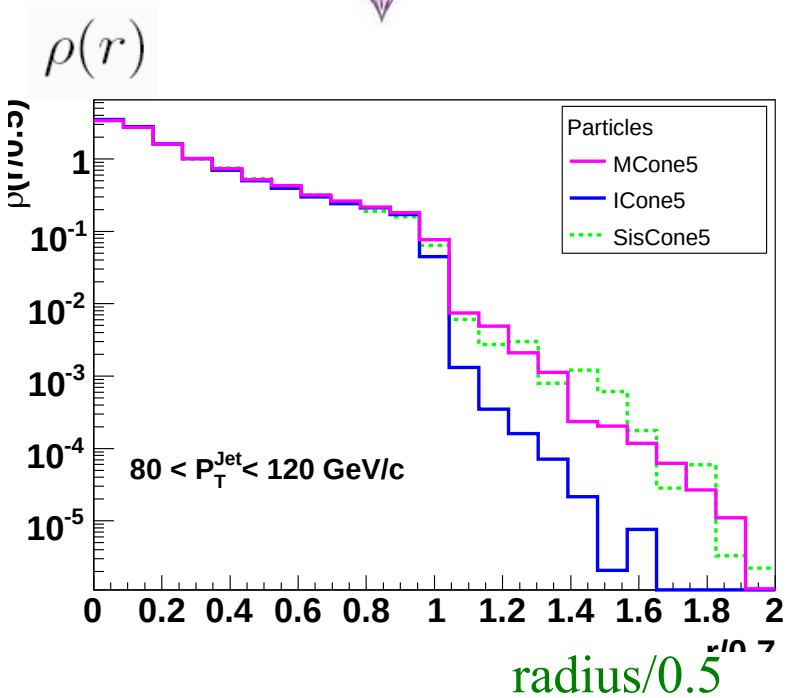
Jet Shape Studies

Pelin Kurt (Cukurova U.)

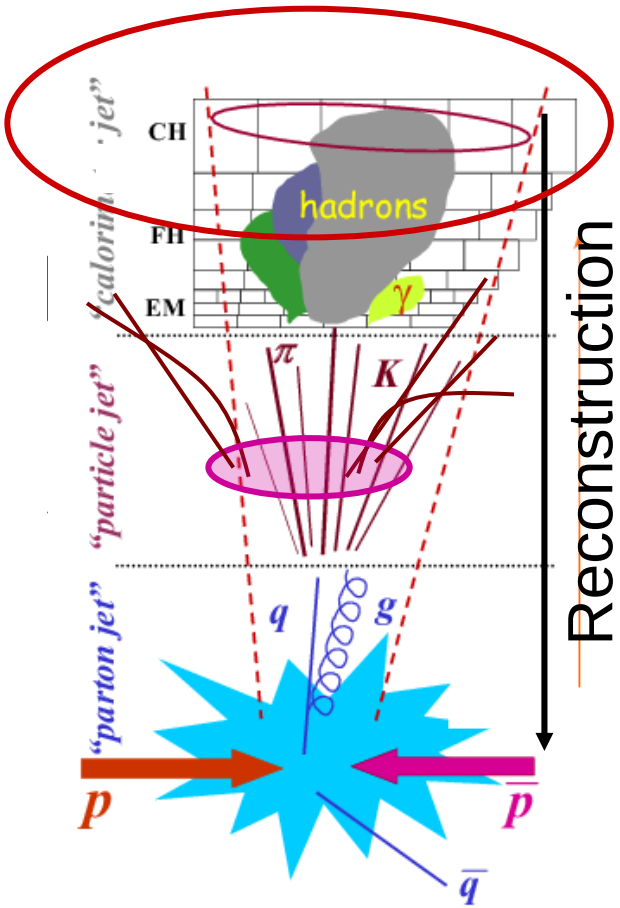
$$\rho(r) = \frac{\sum P_T(r - \Delta r/2, r + \Delta r/2}{\Delta r \sum P_T^{Jet}}$$



- Jet shapes measure the energy flow distribution within a jet and hence provide insight into the performance of jet clustering algorithms.
- Test the NLO QCD calculations and Monte Carlo generators.
- S. Ellis *et al*, Phys. Rev. Lett. 69, 3615(1992) .
- Measurements: CDF, D0, H1, ZEUS, OPAL
- Calorimeter response to a jet depends on the jet fragmentation functions, and it is important to compare the jet fragmentation measured in the data with the MC generator used to determine the jet energy scale.
- Jet shapes can be used to discriminate between different models of underlying event.



Jet Energy Scale Calibration



After absolute correction, the jet is equivalent to a particle jet and independent of any detector effect and pile-up/noise contributions.

Calorimeter jets

↓

Offset corrections

↓

Eta-dependent corrections

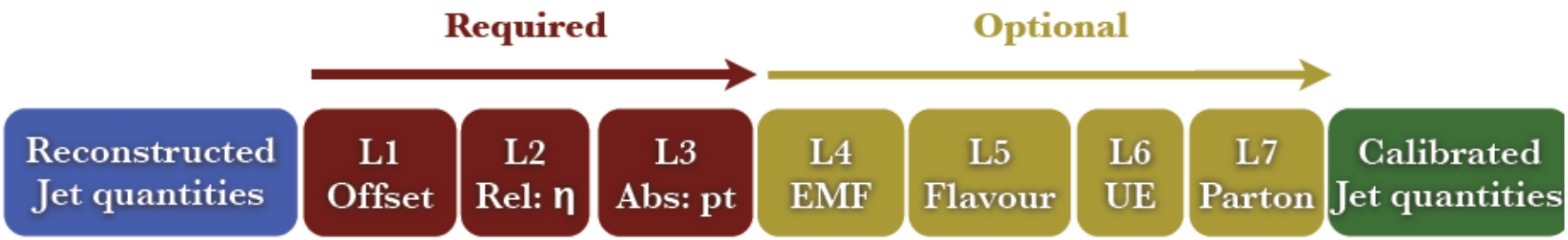
↓

Particle-level jets

↓

Parent Parton

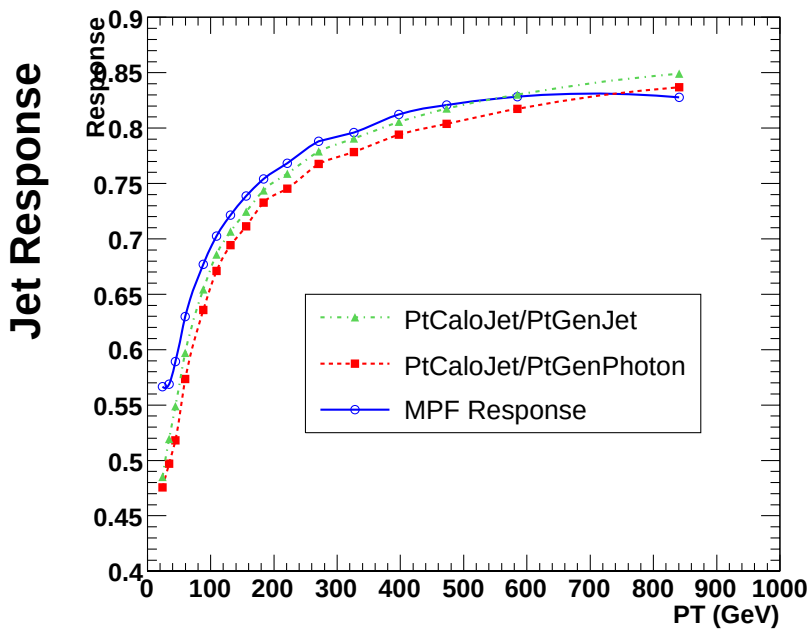
Jet Energy Scale Calibration

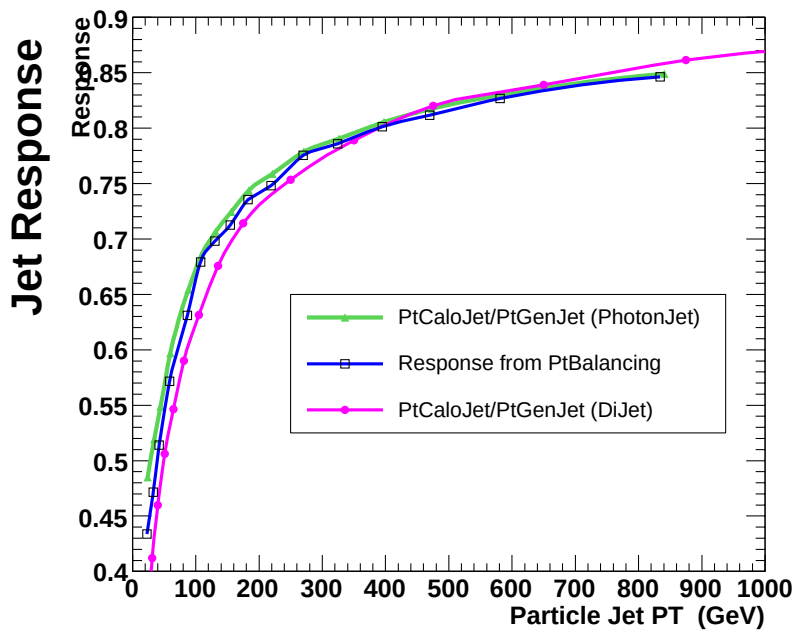


- CMS adopted the same modular scheme to determine jet energy scale as CDF.
- We are working on dijet balancing (L2) to make the calorimeter response uniform in rapidity.
    - We wrote the software and did initial studies. Mehmet Vergili (Cukurova U.) wrote his MS thesis.
    - Kostas Kousouris has taken over this project, collaborating with us.
- We are working on determining the absolute corrections (L3) using
    - Monte Carlo based corrections following the CDF technique.
    - Data driven technique using photon-jet balancing.
- We are also working on closure tests of the jet energy scale.

Absolute Corrections from Photon Jet Data

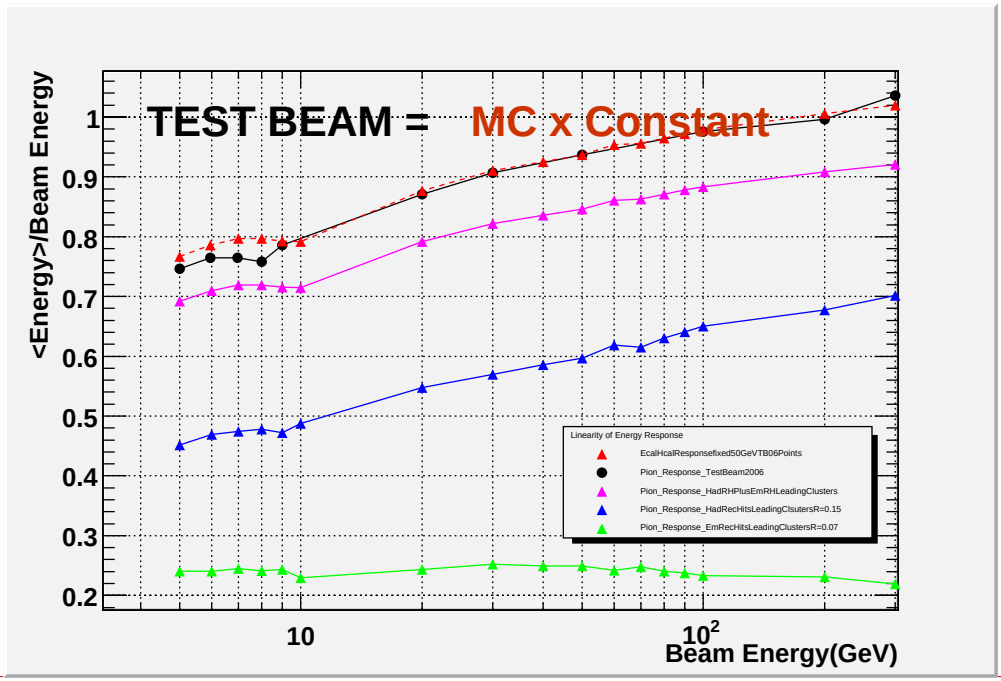
- Both P_T balance and Missing Et Projection Fraction techniques are used to determine jet response vs. P_T from γ-jet event.
- High rate calibration process, but lots of subtle issues need further studies.
- MPF response a little higher than P_T bal. at most P_T (radiation?).
- Response to ParticleJet a little larger than P_T bal. (particle vs. parton ?).
- P_T bal. response in γ-jet data a little higher than in dijet data response (q vs. g?).





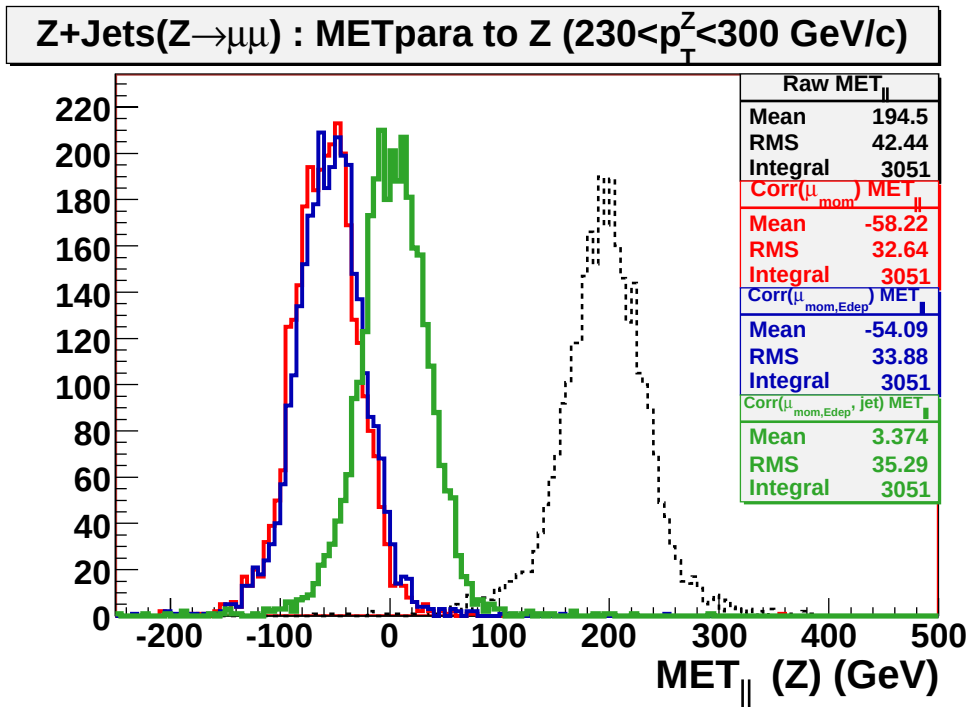
Level 3: MC based absolute corrections (H. Topakli)

- Use MC dijet events to determine correction by matching calorimeter jets with particle jets.
- On day one, we will have only the MC and Test Beam data.
- Working hard to tune GEANT to reproduce the Test Beam response.
- Initial studies are encouraging, indicating that we should be able to tune to ~2-3%.



Missing Transverse Energy Calibration

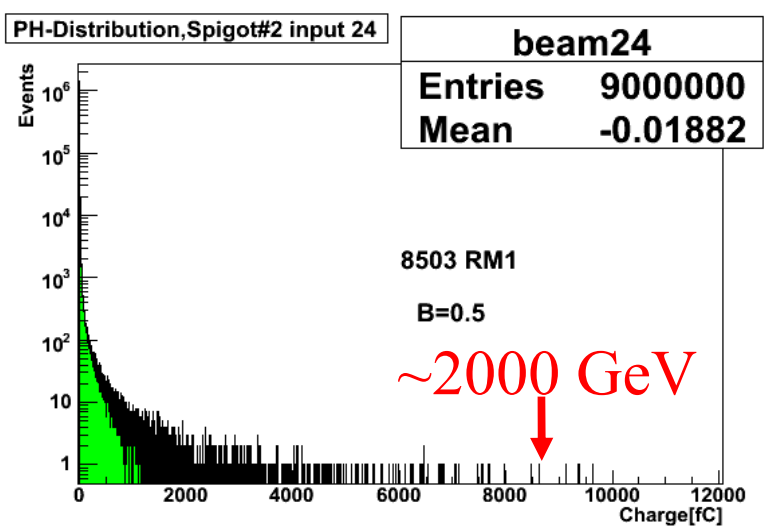
$$E_T^{miss} = -\sum_{i=1}^{\text{towers}} E_T^i - \sum^{\text{muons}} p_T^\mu + \sum_{i=1}^{\text{deposit towers}} E_T^i$$

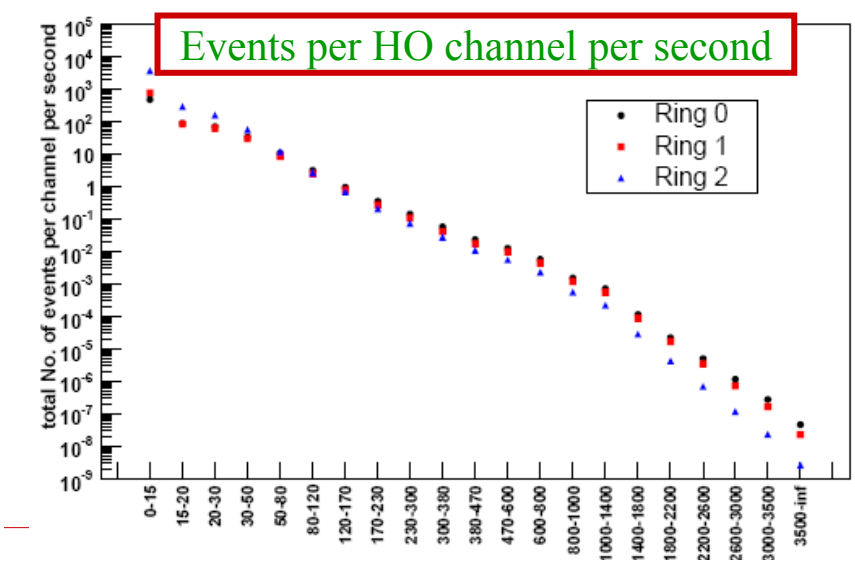


- Koji Terashi developed the software to do the muon corrections.
- The software was released to the collaboration in October 2007.

HPD Noise Studies (Seam Sharma, Tata Institute, India)

- The Hadron Outer calorimeter is read out by Hybrid Photodiodes.
- In MTCC06 test, it was found that HPD have a very large noise component.
- CMS is considering replacing these HPDs with Silicon Photo Multipliers. SiPM is a solid state device, operated in Geiger mode, has ~100 μs recovery time. Each SiPM channel has ~2000 pixels.
- We studies the HO occupancy rate using dijet events.
- At $L^{inst} = 10^{34}$ cm^{-2} s^{-1}, 0.25% of pixels of a channel will be dead leading to a small loss in signal.





Summary

- We started working on a hadronic SUSY search in 2007 and will play a leading role in this analysis. We plan to contribute to
  - specification of the hadronic SUSY trigger
  - measurement of the $Z \rightarrow \nu\nu$ background from data
  - optimization of the signal selection cuts
  - missing Et corrections and clean-up
- We will continue to work on the determination of the jet energy scale using both data driven and Monte Carlo based techniques, and to improve calorimeter simulations.
- We made significant contribution to jet clustering algorithm studies.
- We have a very fruitful collaboration with people at LPC.

We hope to show 14 TeV pp collision data at 2008 DOE meeting.

Search for SuperSymmetry

- PTDRII mSUGRA LM1 study by M. Spiropulu, T. Yetkin, AN 2006/089
- $m_{gluino} \sim 600$ GeV/c^2, $m_{squark} \sim 520$ GeV/c^2, $\tan\beta = 10$

- Dominated by gluino and squark productions

  $pp \rightarrow \tilde{g}\tilde{q}$ (47%), $\tilde{q}\tilde{q}$ (27%), $\tilde{g}\tilde{g}$ (9%), $\tilde{q}\tilde{\chi}^{0(\pm)}$, $\tilde{t}\tilde{t}$, $\tilde{b}\tilde{b}$, etc. (16%)

  - $\tilde{g}\tilde{q}_L$ (22%)
  - $\tilde{g}\tilde{q}_R$ (25%)
  - $\tilde{q}_L\tilde{q}_L$ (8%)
  - $\tilde{q}_L\tilde{q}_R$ (11%)
  - $\tilde{q}_R\tilde{q}_R$ (8%)

  $\Rightarrow \sigma_{LO} = 47$ pb

- Cascade decays lead to complex final states

  $\tilde{g} \rightarrow \tilde{q}_L q$ (27%) $\quad \tilde{q}_L \rightarrow \tilde{\chi}_1^0 q + \nu l$(34%), $\tau\nu$(29%), $\tau\tau$(15%), $\nu\nu$(13%)

  $\rightarrow \tilde{q}_R q$ (42%) $\quad \tilde{q}_R \rightarrow \tilde{\chi}_1^0 q$ (98%)

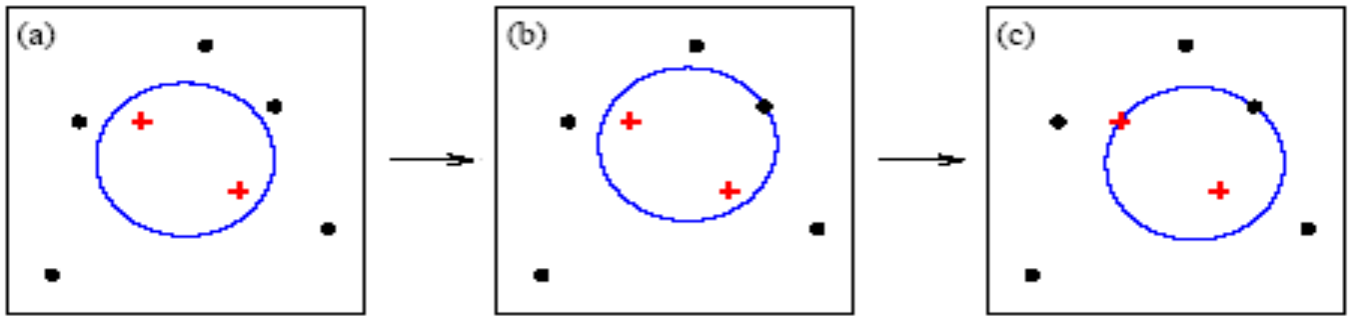
Final state contains ≥2 jets and 2 stable LSPs (⇒MET)

Transform into a geometrical problem

Cones are just *circles* in the $y - \phi$ plane. To find all stable cones:

1. Find all distinct ways of enclosing a subset of particles in a $y - \phi$ circle
2. Check, for each enclosure, if it corresponds to a stable cone

Finding all distinct circular enclosures of a set of points is *geometry:*



Any enclosure can be moved until a pair of points lies on its edge.

Polynomial time recipe for finding all distinct enclosures:

- For each *pair* of points in the plane, draw the two circles that have those two points on their edge.