MET Status and Commissioning

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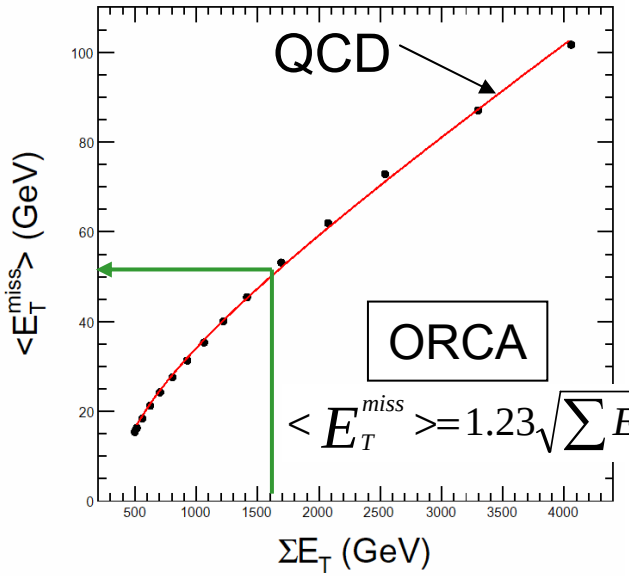
FIU Physics Workshop
07 February, 2007

Outline

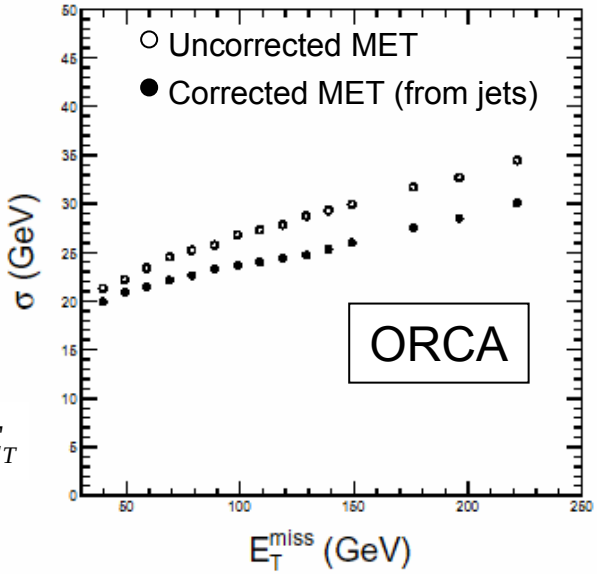
- MET in CMS
  - History
  - Basic Introduction
  - Recent Developments
- Commissioning
  - What should be done, and when?
  - Validation Efforts
  - Moving forward

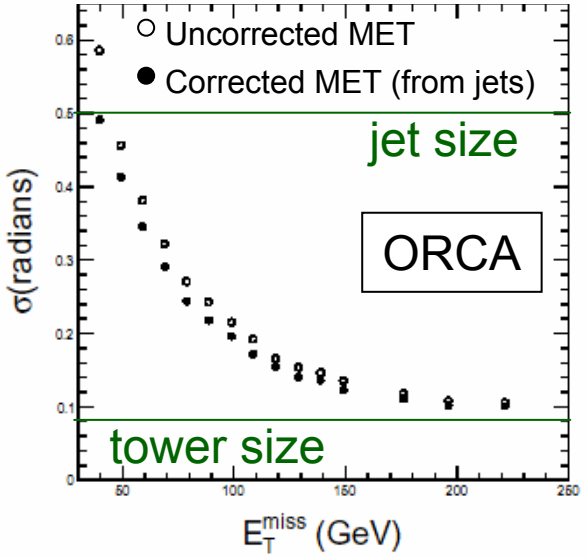
MET in PTDR Vol. I

$$\mathbf{E}_{\mathrm{T}}^{\mathrm{miss}} = \sum_{n\ towers}(E_n \sin\theta_n \cos\phi_n \hat{\mathbf{i}} + E_n \sin\theta_n \sin\phi_n \hat{\mathbf{j}}) = E_x^{\mathrm{miss}}\hat{\mathbf{i}} + E_y^{\mathrm{miss}}\hat{\mathbf{j}}$$



$$< E_T^{miss} >= 1.23\sqrt{\sum E_T} + 5.4 + 0.019\sum E_T$$





- Missing Transverse Energy
  - Low luminosity Pileup included
  - <MET> from QCD
    - Stochastic term ≈ 123%$\sqrt{\Sigma E_T}$
    - ≈1700 GeV ΣE_T → ≈700 GeV P_T dijets → ≈50 GeV observed MET
  - MET ϕ Resolution
    - Low MET : approaches Jet size
    - High MET : approaches calo cell size

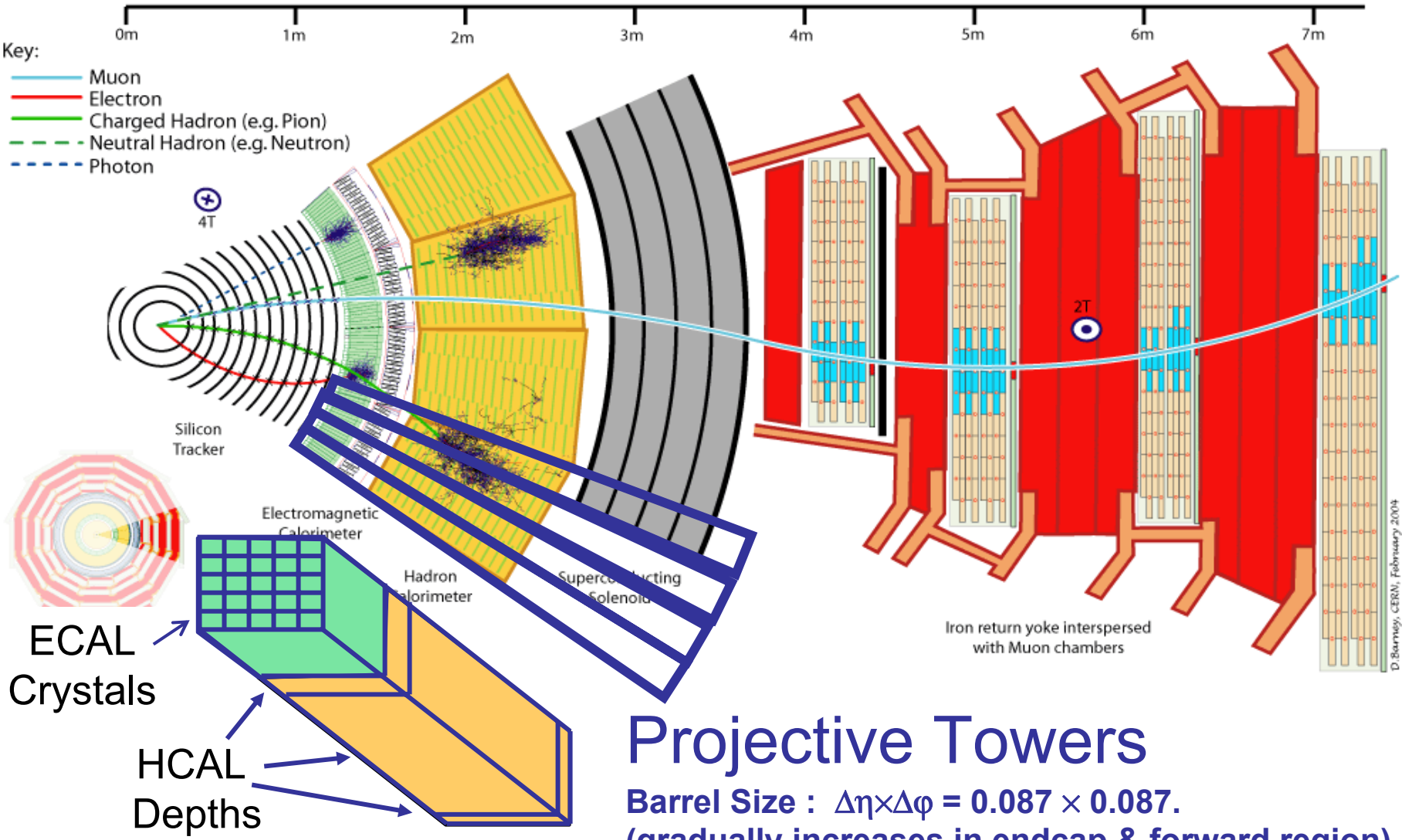
MET in PTDR Vol. II

Albert de Roeck

- Corrected/raw MET for offline studies
  - corrections type 1, muon corrections
- Corrected/raw MET in HLT
  - Quite some confusion till March 2005
  - Conclusions: do not use tower based energy corrections
- Issues during the approval process
  - Low MET values
    - Many in range 50-100,
    - 12 analyses with MET> 100 GeV,
    - few (5-6) with MET < 50 GeV,
    - some ~ 20 GeV means ~no cut
  - Systematics
    - Applying correct systematics as specified in note of Chris and Jim (or use 5% overall).
    - Other “proposals” ranged from very optimistic to very pessimistic
    - Many studies were sometimes too naive

- Need
  - good communication analysis ⇔ MET study group
- Need
  - to impose, perhaps to revisite the JetMet recommendations for MET, systematics etc. (partially done for the PTDR)
- Need
  - to study MET corrections schemes (not all used/tried so far)
- Need
  - to prepare for MET filter for real data, protect against detector and accelerator background.
- Need
  - to get rid of too low MET cut analyses (some sneaked into the PTDR)
- Need
  - a systematic comparison of FAMOS/ORCA/CMSSW
- Energy flow techniques should help to improve the MET resolution

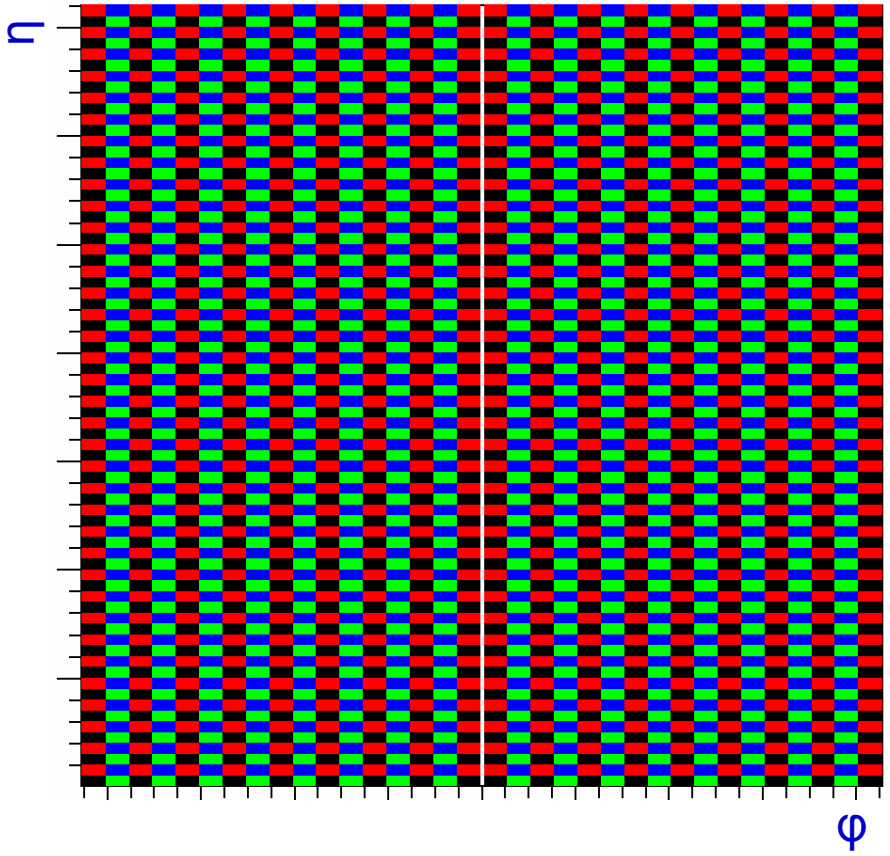
ECAL+HCAL Towers

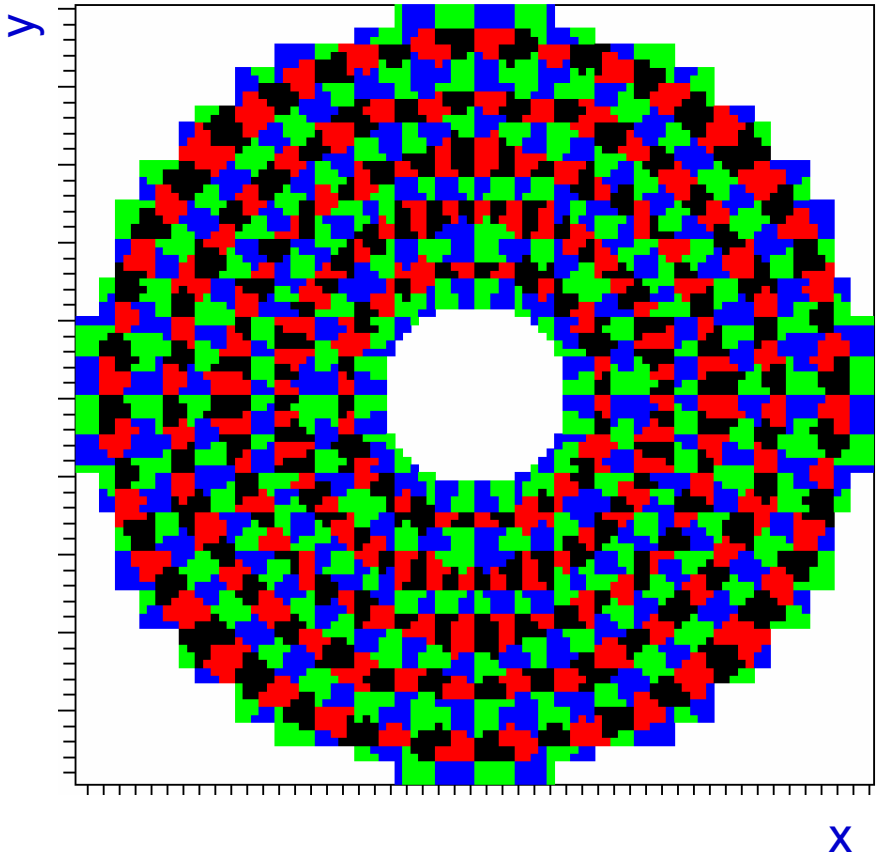


Projective Towers

Barrel Size : $\Delta\eta \times \Delta\varphi = 0.087 \times 0.087$.
(gradually increases in endcap & forward region)
Total 4176 towers

ECAL+HCAL Towers





- Barrel Towers (projective)
  - 5x5 ECAL (η,φ) Crystals to 1 HCAL (η,φ) Cell
- Endcap Towers
  - Significantly more complex ECAL (x,y) to HCAL (η,φ) association → "pixelization"

Calo Tower Energy Thresholds

Noise Suppression: Cells contribute to tower energy if they pass energy thresholds. Different schemes have been tried to evaulate noise level and jet energy losses (for cone size of 0.5)

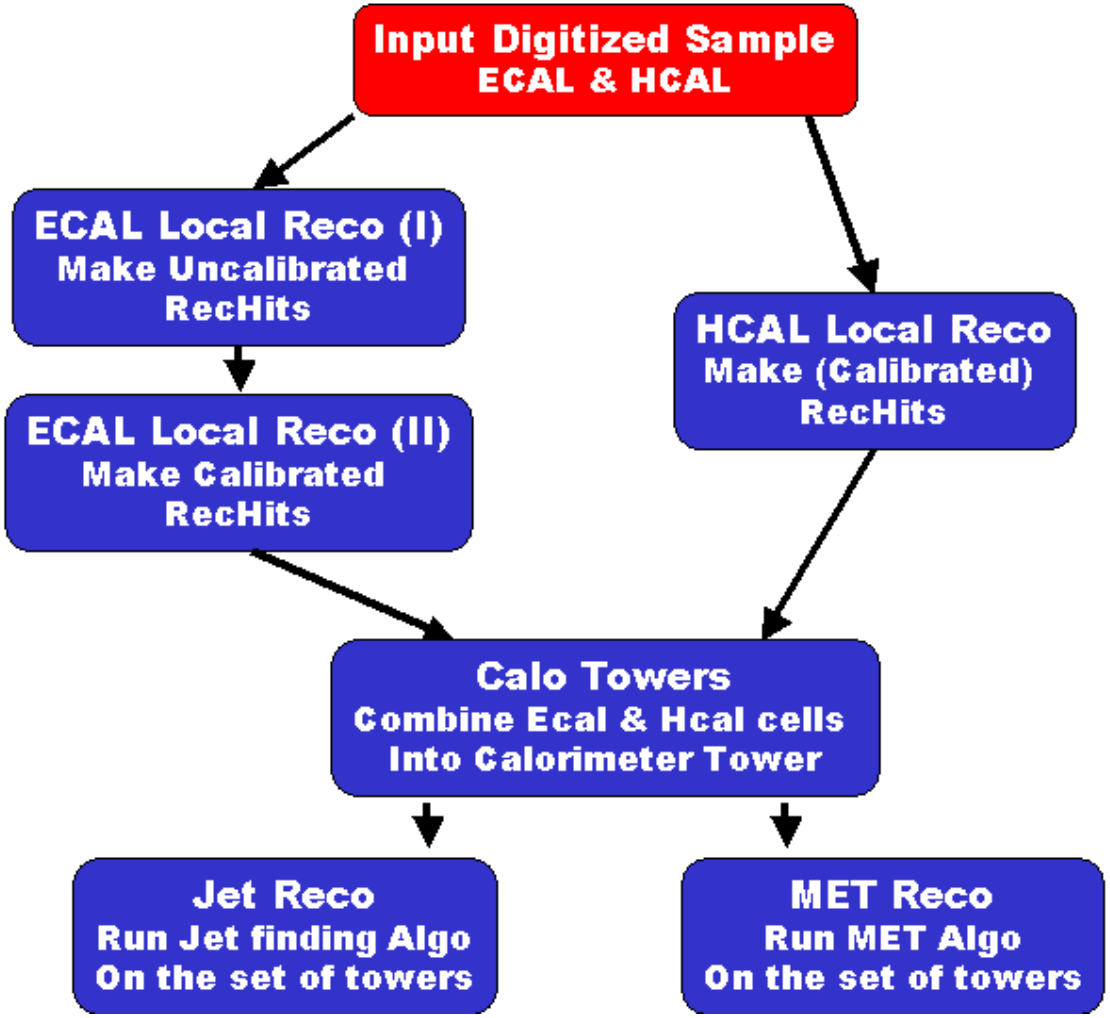
NIC = Noise In Cone (GeV)
JEL = Jet Energy Loss (GeV)

Scheme	Thresholds (GeV)					NIC	JEL	ΣE_T	ΣE_T
	HB	HO	HE	ΣEB	ΣEE	$\eta \simeq 0$	$\eta \simeq 0$	noise	QCD
A	0.7	0.85	0.9	0.2	0.45	1.4	–	28	168
B	0.9	1.1	1.4	0.2	0.45	0.3	1.0	6	162
C	1.2	1.3	1.8	0.2	0.45	0.2	1.9	4	158

Thresholds for different calorimeter sub-detectors

B scheme used by default in CMSSW JetMET Reco

CMSSW JetMET Reconstruction Chain



CMSSW JetMET Flavours

- Output of Jet algo is a 4-vector accompanied by list of jet constituents
- Depending on constituent type, produced Jets have different flavours:
  - CaloJets from CaloTowers
    - Contain separate information about ECAL and HCAL contributions from different calorimeters, EmFraction etc
  - GenJets from MC particles
    - Contain information about contribution from electromagnetic particles, hadrons, invisible neutrinos etc
  - BasicJets from arbitrary input collection
    - Contain no extra information on top of basic jet 4-vector

- Output of MET algorithm is a MET 2-vector (but stored in event as a 4-vector)
- Depending on input type, produced MET has different flavours:
  - CaloMET from CaloTowers
    - Contains separate information about ECAL and HCAL contributions from different calorimeters, EmFraction etc
  - GenMET from MC particles
    - Will Contain information about contribution from electromagnetic particles, hadrons, invisible neutrinos etc
  - MET from arbitrary input collection
    - Contains no extra information on top of basic MET 2-vector

RecoMET Class Structure

- Candidate

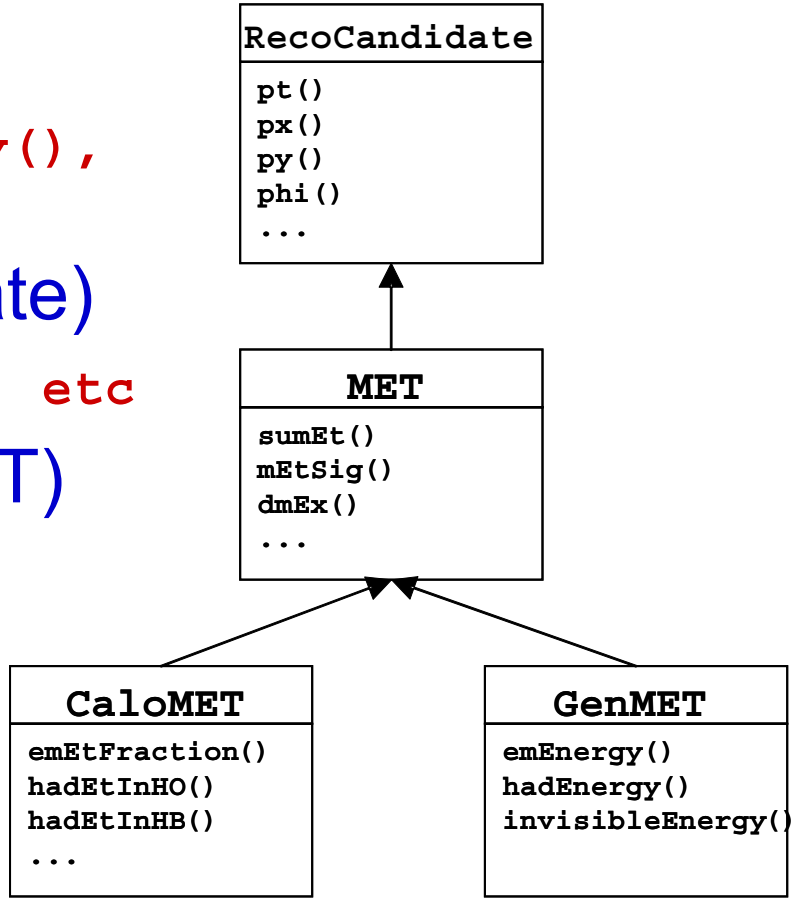
  `met.pt(), met.px(), met.py(), met.phi(), etc`

- MET (inherits from Candidate)

  `met.sumEt(), met.mEtSig(), etc`

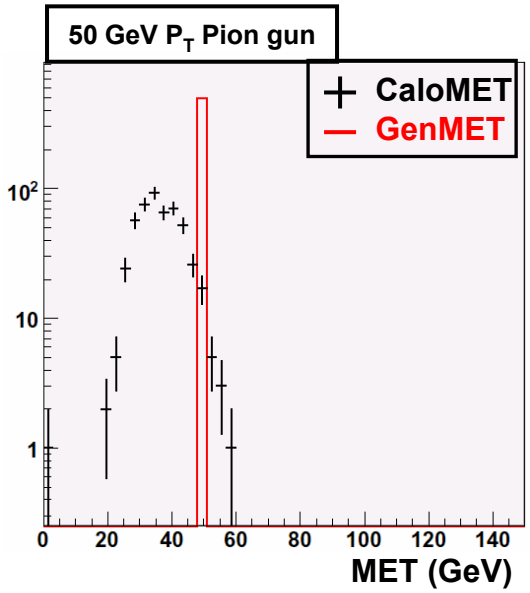
- CaloMET (inherits from MET)

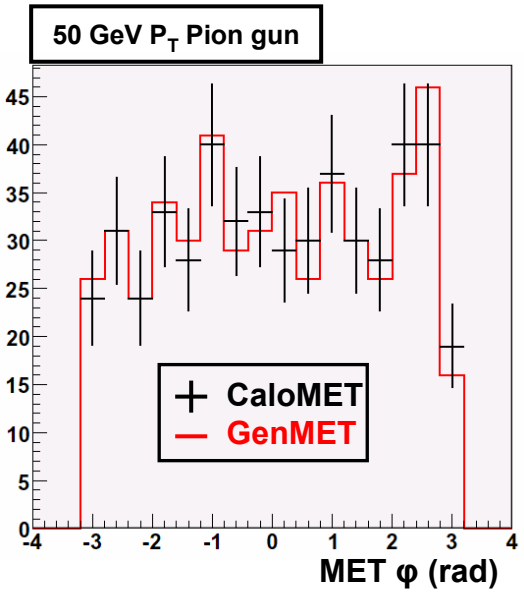
  `met.emEtFraction(), met.emEtInEE(), met.emEtInEB(), met.hadEtInHF(), met.hadEtInHE(), met.hadEtInHB(), met.hadEtInHO(), etc.`

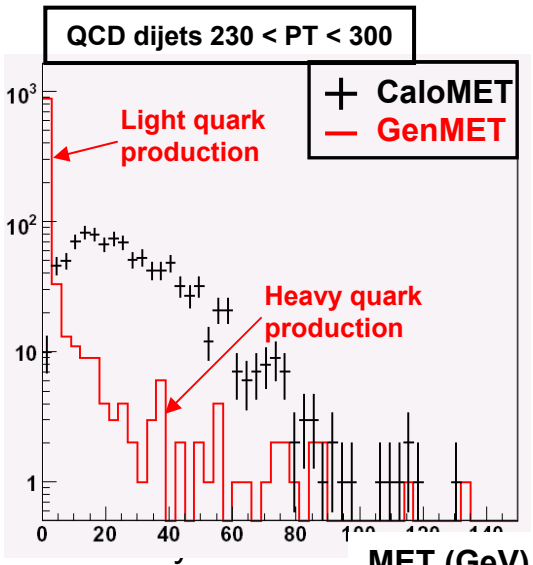


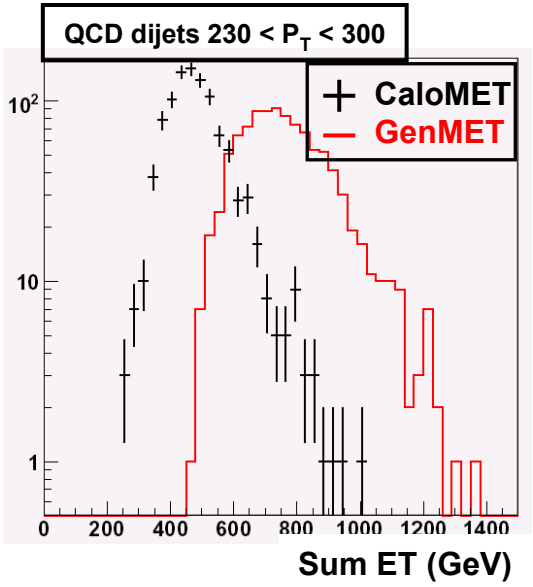
Some MET Distributions

- Pion Gun : Reconstructed MET-phi very similar to true MET-phi
- Reconstructed MET and Sum ET need corrections to reflect true MET and Sum ET





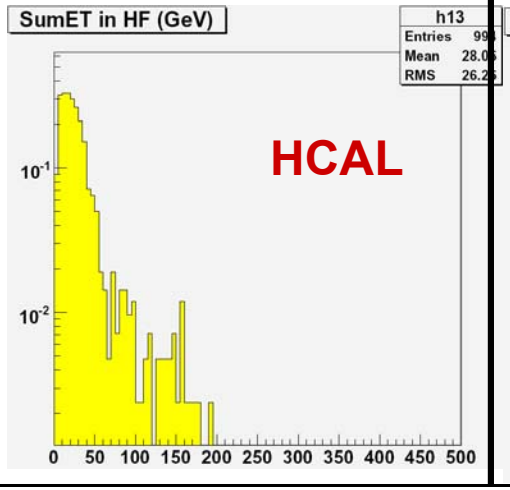




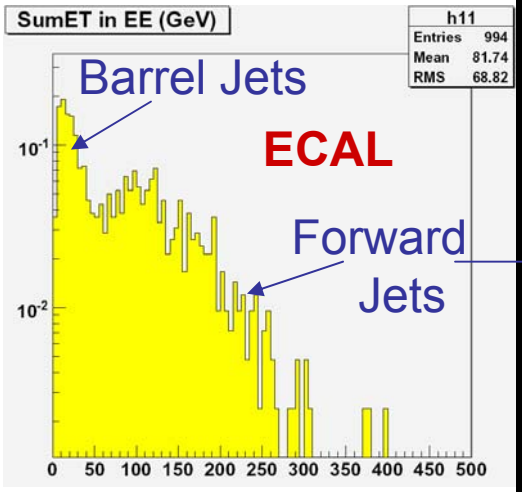
Scalar SumET Distributions

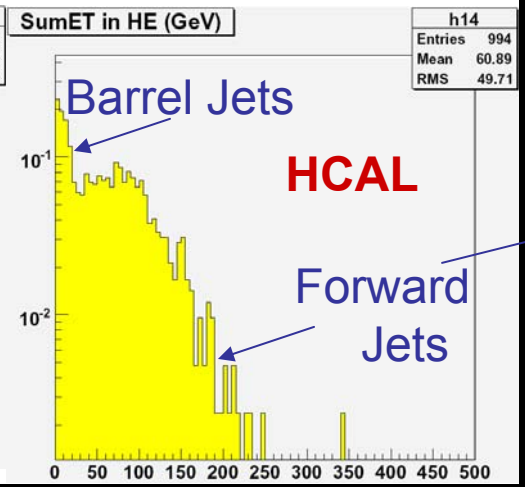
QCD Dijets $230 < \hat{P}_T < 300$ GeV

Forward

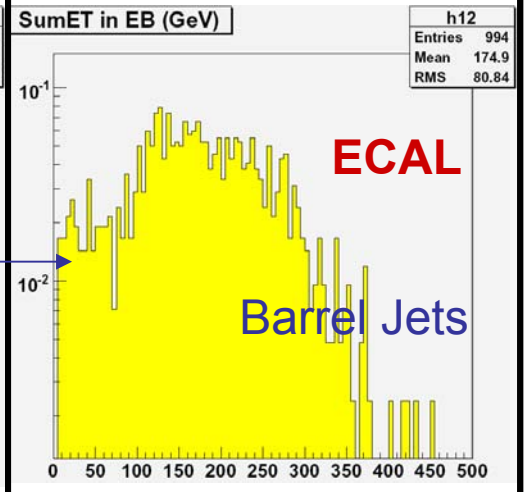


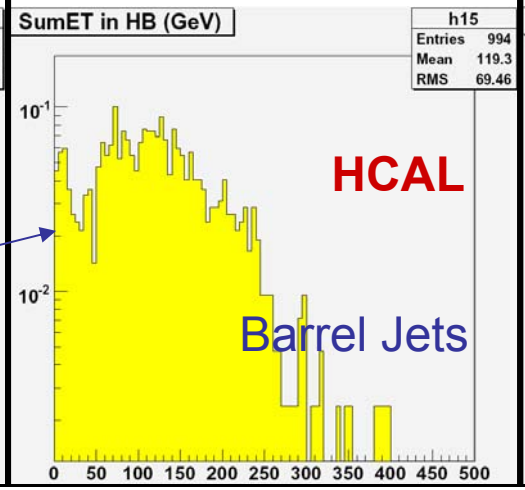
Endcaps



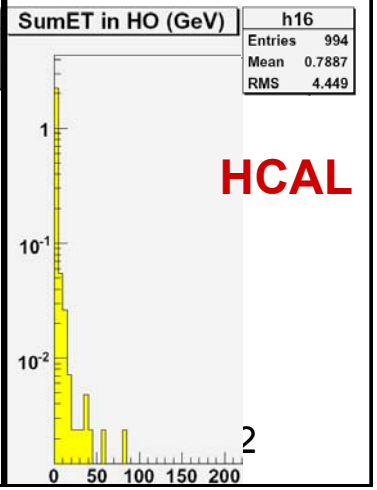


Barrel





Outer



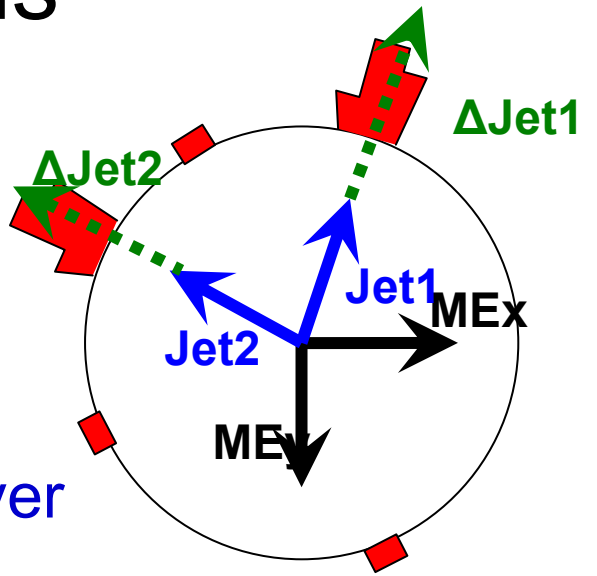
MET Corrections

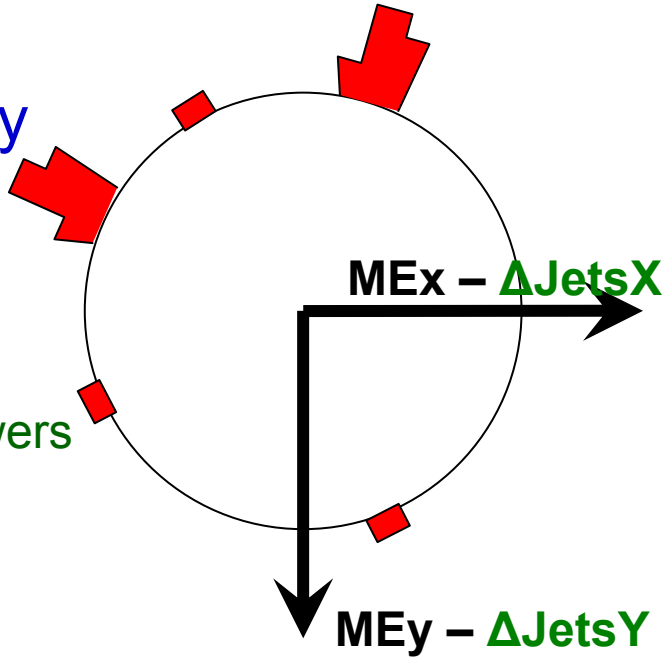
- Use Calibrated Jets:

$$\mathbf{E_T^{miss}} = -\sum_i \mathbf{E_{T,}^{tower}}_i - \sum_j \left(\mathbf{p_{T,}^{corr,}}_j^{jet} - \mathbf{p_{T,}^{raw,}}_j^{jet}\right)$$

- Raw MET Calculation based on sum over towers

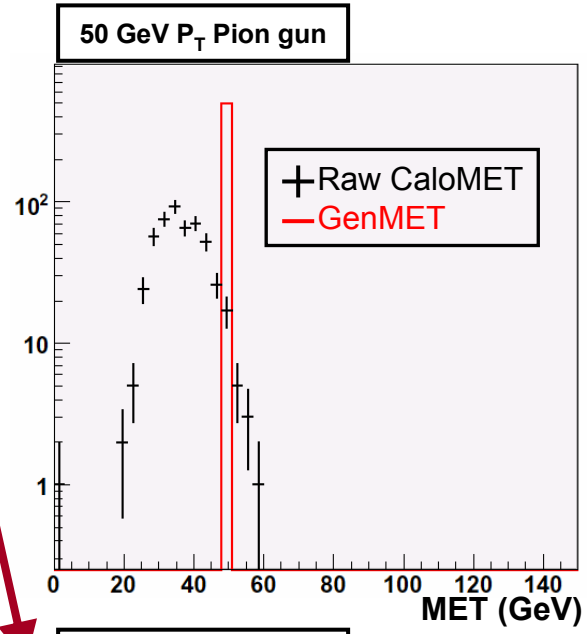
- Clustered (Jets) and Unclustered Energy Calibrations
  - Type-1 (most commonly used)
    - Calibrated Jets + Unclustered Towers
  - Type-2
    - Calibrated Jets + Calibrated Unclustered Towers

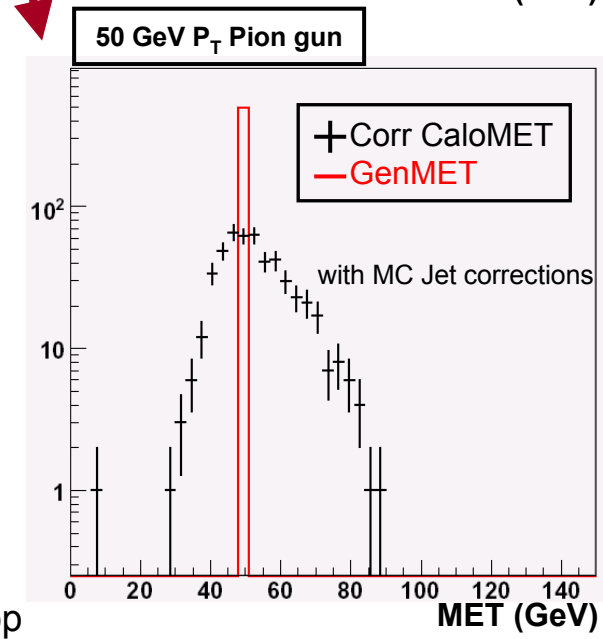




MET Corrections

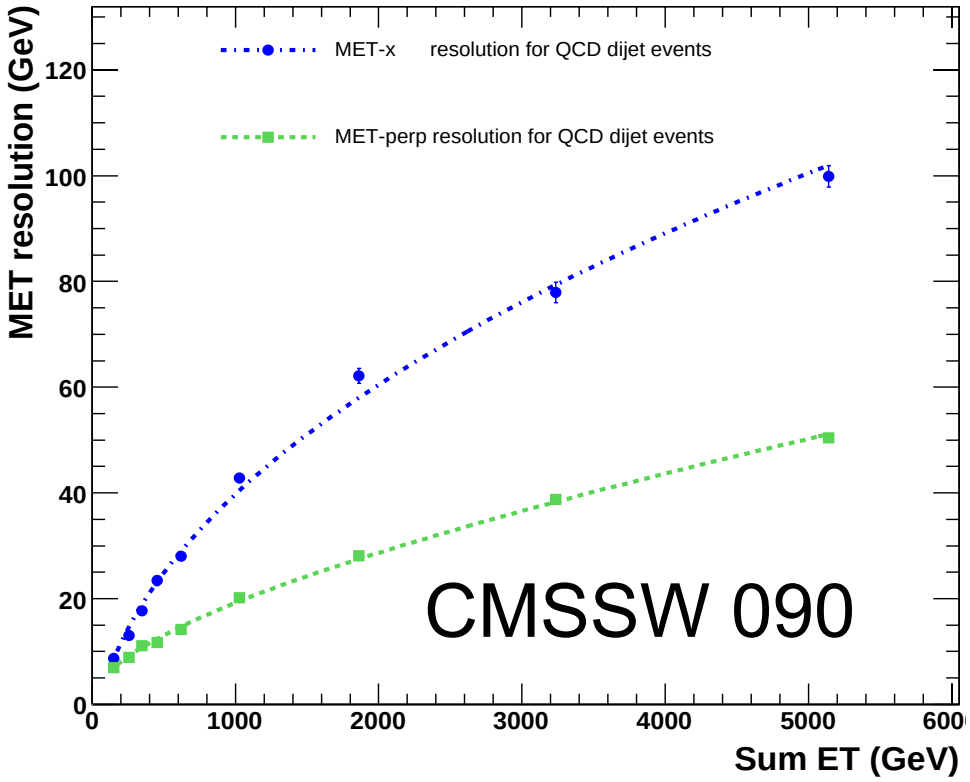
- Type-1 Corrected MET
  - MC Jet Correction example
    - Available since CMSSW_1_0_0
  - Configurable Jet P_T threshold
    - Available in CMSSW_1_2_0_pre3
    - Default : 20 GeV
  - Currently being studied and optimised
- Additional Planned Packages
  - Muon Corrections
  - Type-2 (PU, UE, E/H, etc)

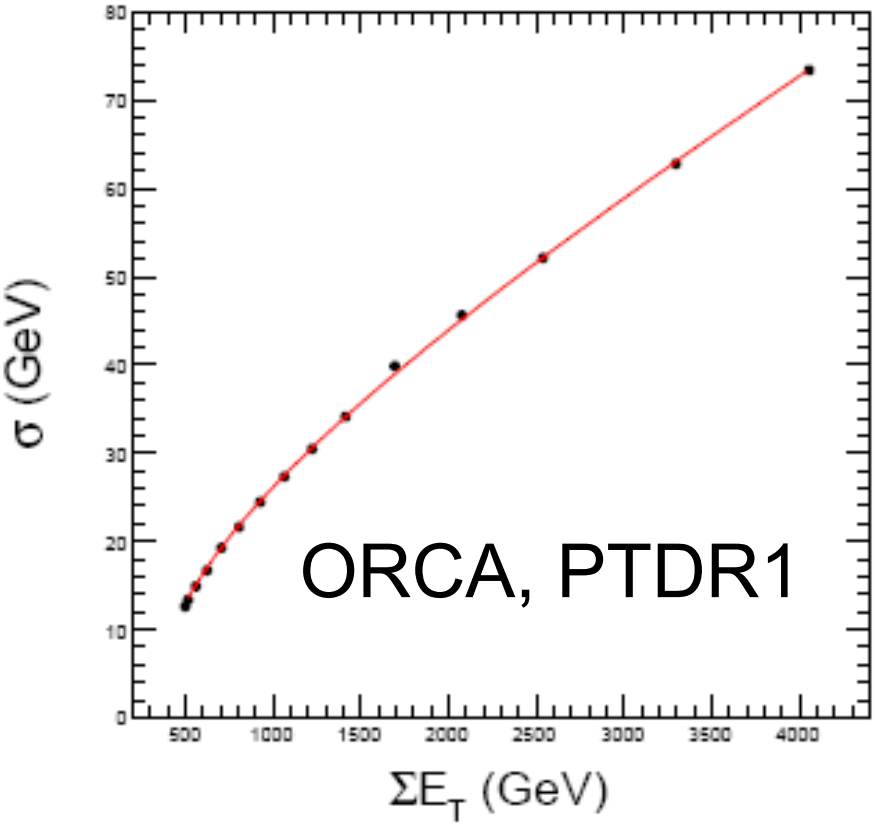




MET Performance in CMSSW

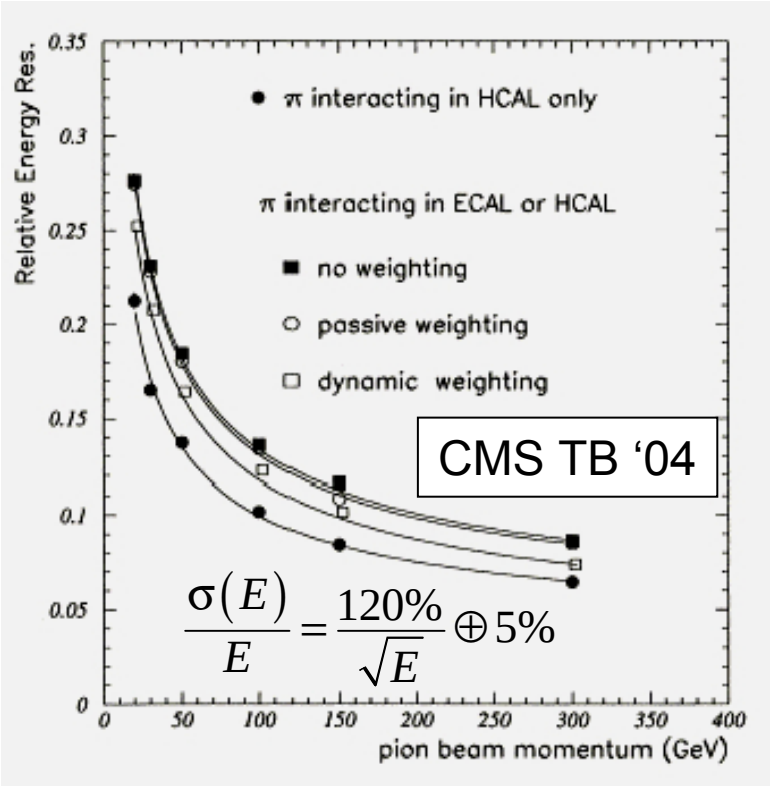
Marek Zielenski



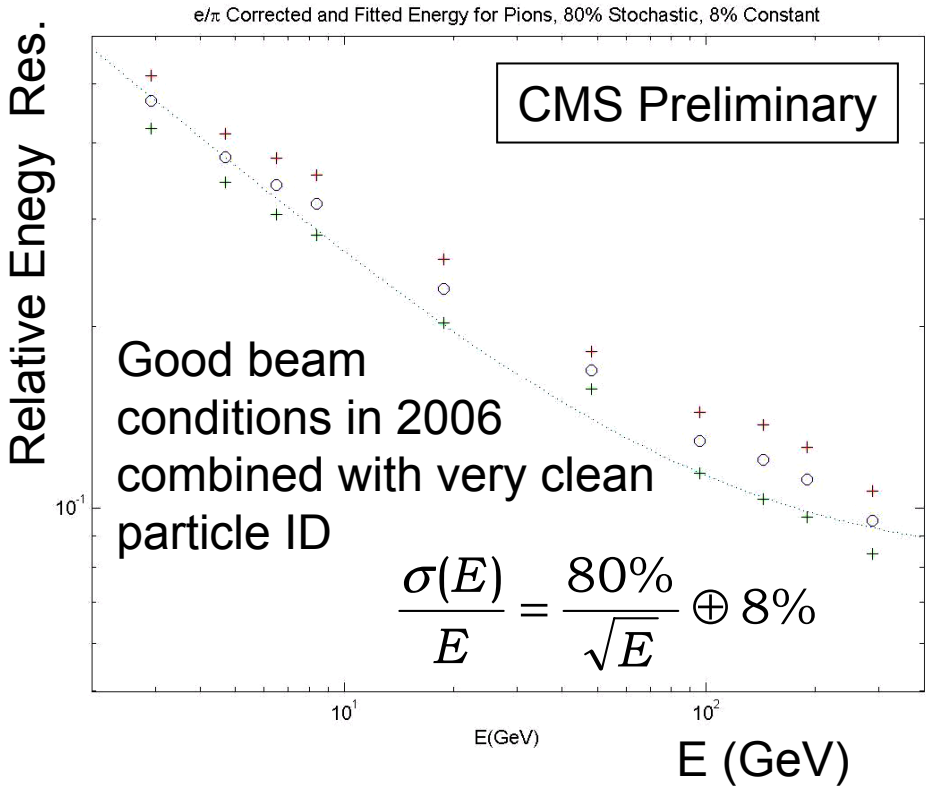


- MET-perp resolutions similar between CMSSW and ORCA
- MET-x resolution higher in CMSSW
  - Many known issues (some resolved) in lower-level calorimetery reconstruction & calibration

Outlook and Recent Developments



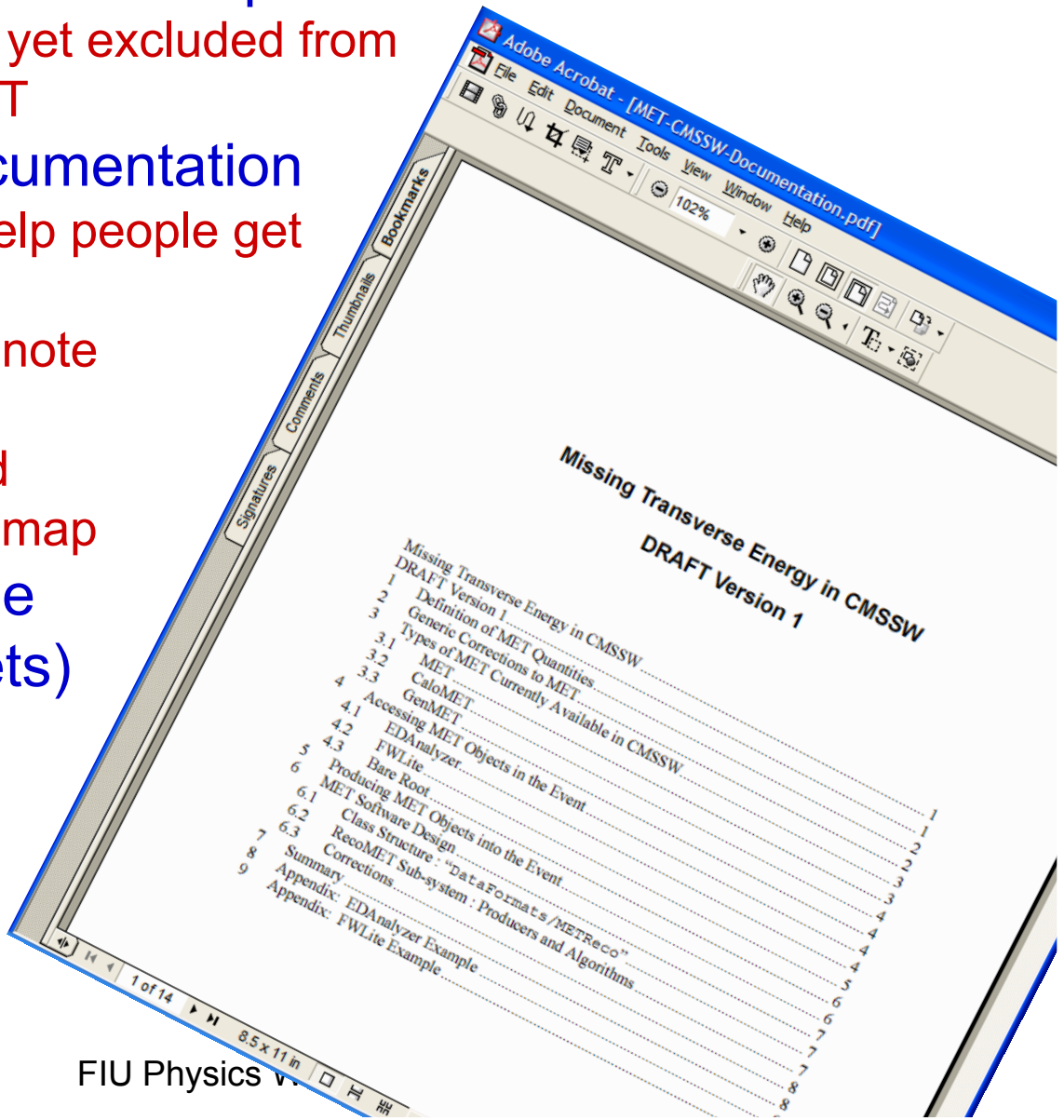
Breaking News: TB '06



- Calorimeter tower reconstruction
  - Does not currently use different EM & Hadronic weights depending on particle type
  - Correct for E/H for non-compensation
    - Potential significant improvement in resolution possible!

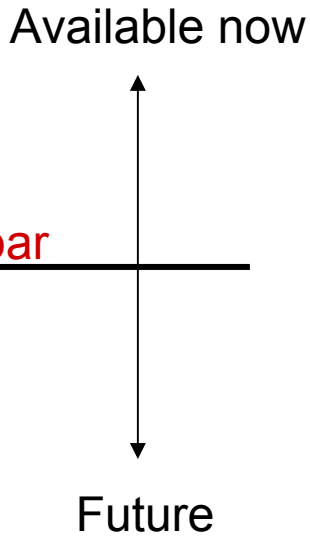
MET Documentation & Issues

- Working with Physics Tools Group
  - Exotic stable WIMPS not yet excluded from "true" generator-level MET
- RecoMET Software Documentation
  - Currently just a draft to help people get started with using MET
  - Aim to evolve as internal note documenting RecoMET performance, design, and future development road-map
- Slowly working to include better examples (*a la* Jets) directly in CMSSW
  - Analyzer package,
  - FWLite example



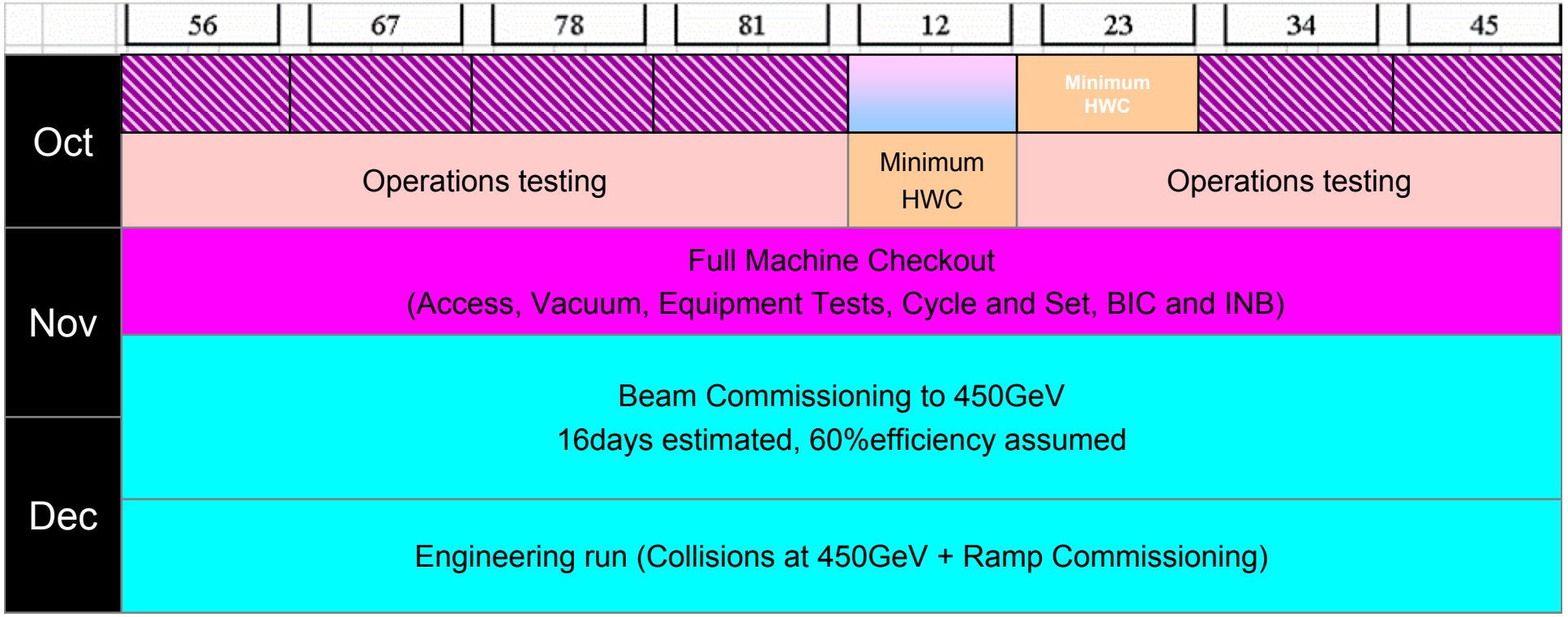
Current & Upcoming Opportunities for Commissioning

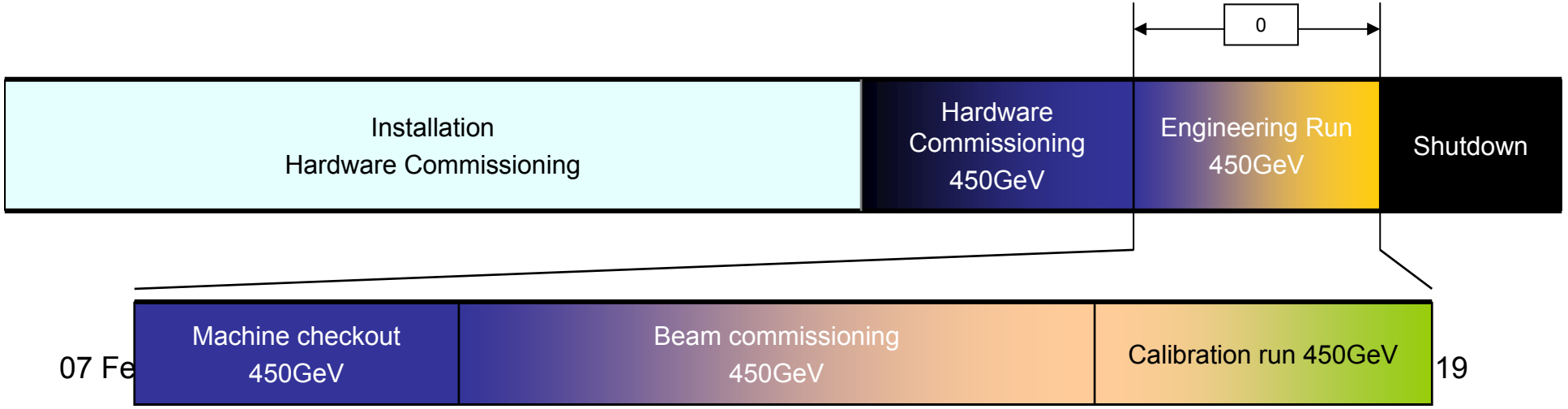
- LPC Monte Carlo Samples
  - QCD, Z'
- MTCC 2006
  - First opportunity to analyze at Global DAQ Data
- ECAL+HCAL TB 2006
- CSA06
  - minbias, QCD dijet, Z' → dijet samples, Z+jets, W+jets, ttbar
- MTCC "Phase-3" : Cosmics underground
- Pilot Run 2007
  - Single beam at injection energy
    - Measure BH backgrounds, test cleaning algos
  - Collisions at injection energy
    - minbias: MET resolution (MEx), refine cleaning algos
- Physics Run 2008
  - QCD dijets: MET resolution
  - Z(→dimuons)+jets: MET perp, MET parallel, MET response



End 2007

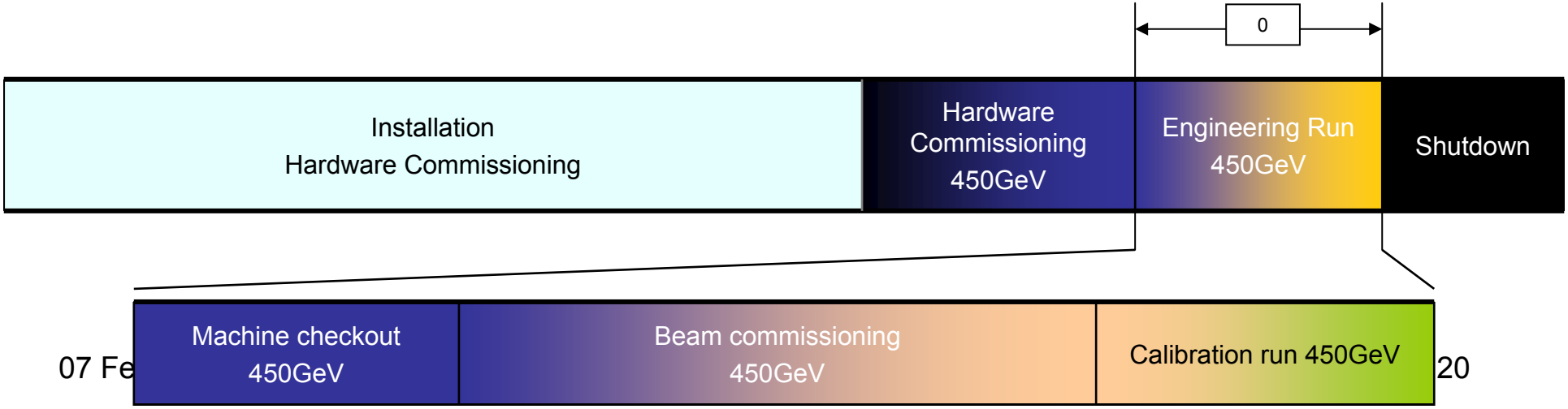
Mike Lamont





End 2007

	56	67	78	81	12	23	34	45
Oct	Cosmics : Low-level Calorimeter validation Test MET Cleaning Tools							
Nov	Beam Commissioning to 450GeV 16days estimated, 60%efficiency assumed							
Dec	Engineering run (Collisions at 450GeV + Ramp Commissioning)							



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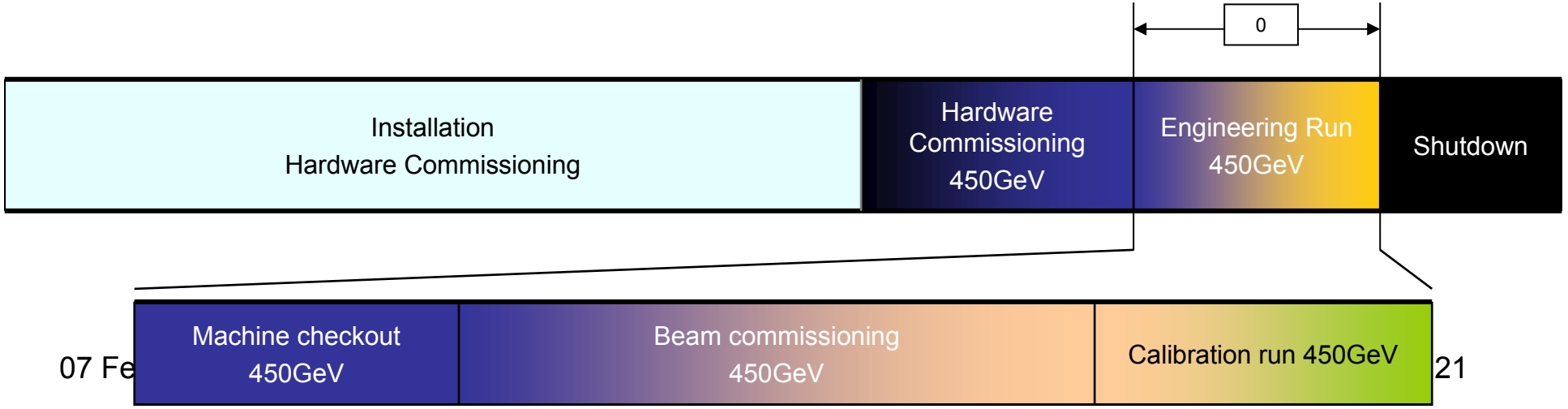
Nov	Structured Beam + Halo Backgrounds : Low-level Calorimeter validation (timing, etc) Refine MET Cleaning Tools							
Dec	Engineering run (Collisions at 450GeV + Ramp Commissioning)							



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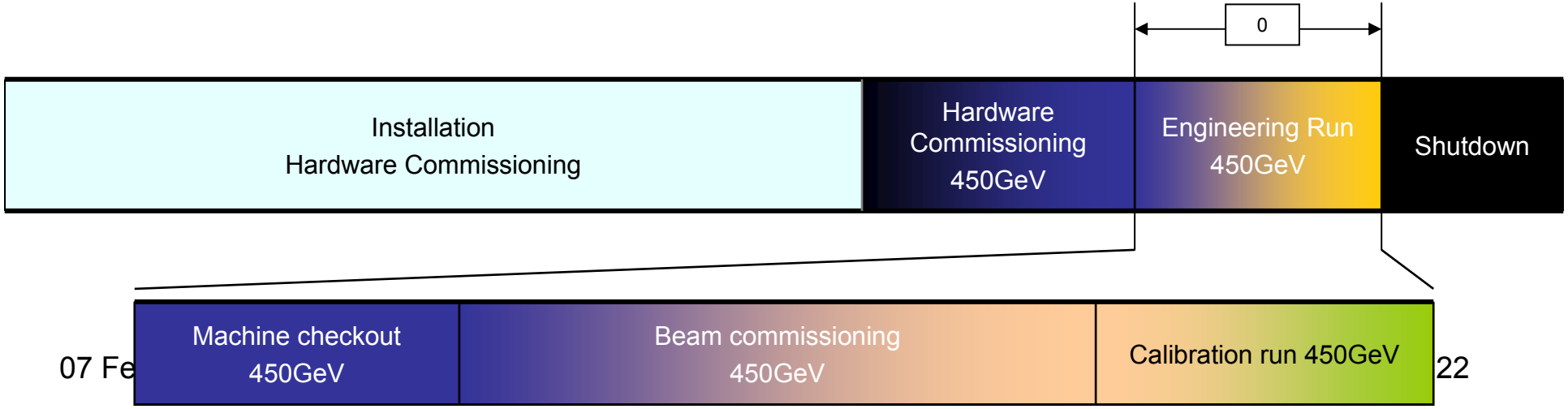
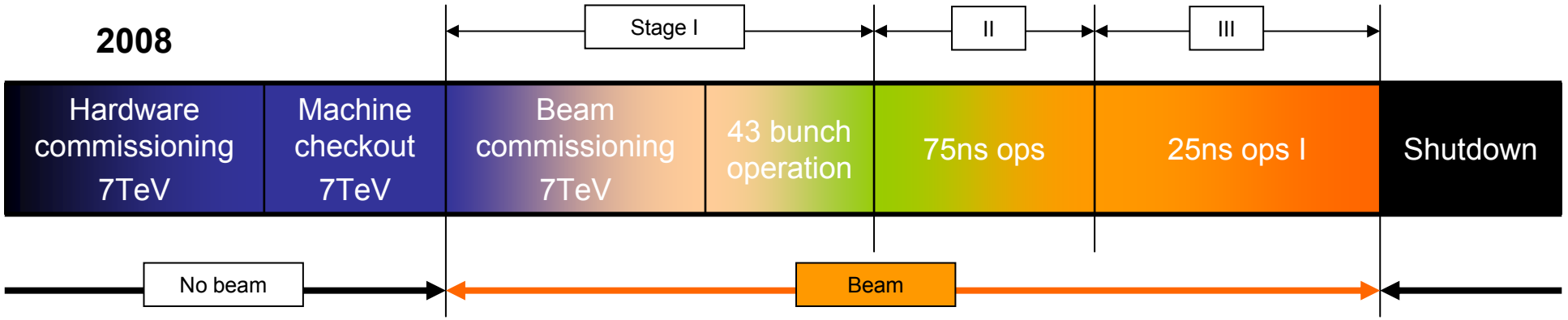
Oct	Cosmics : Low-level Calorimeter validation Test MET Cleaning Tools							
Nov	Structured Beam + Halo Backgrounds : Low-level Calorimeter validation (timing, etc) Refine MET Cleaning Tools							
Dec	Minbias : MET-phi symmetry, MET resolution, etc.							

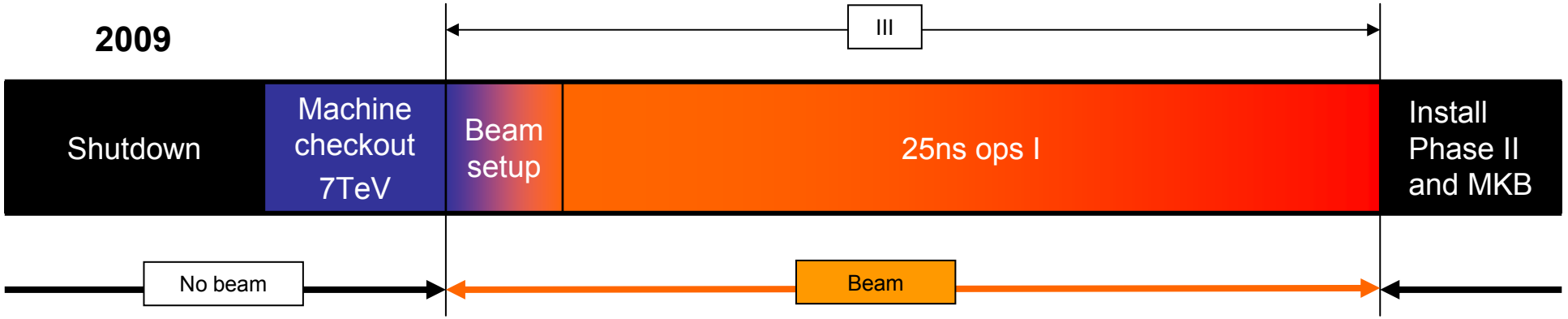


Mike Lamont

Staged commissioning plan for protons@7TeV



14 TeV Physics…but lots of varying beam conditions in 2008!!
→ Expect difficulties in understanding MET!



2009 : First year of stable running!

From 10^{23} to 10^{27} /(cm^2sec) – 14 TeV

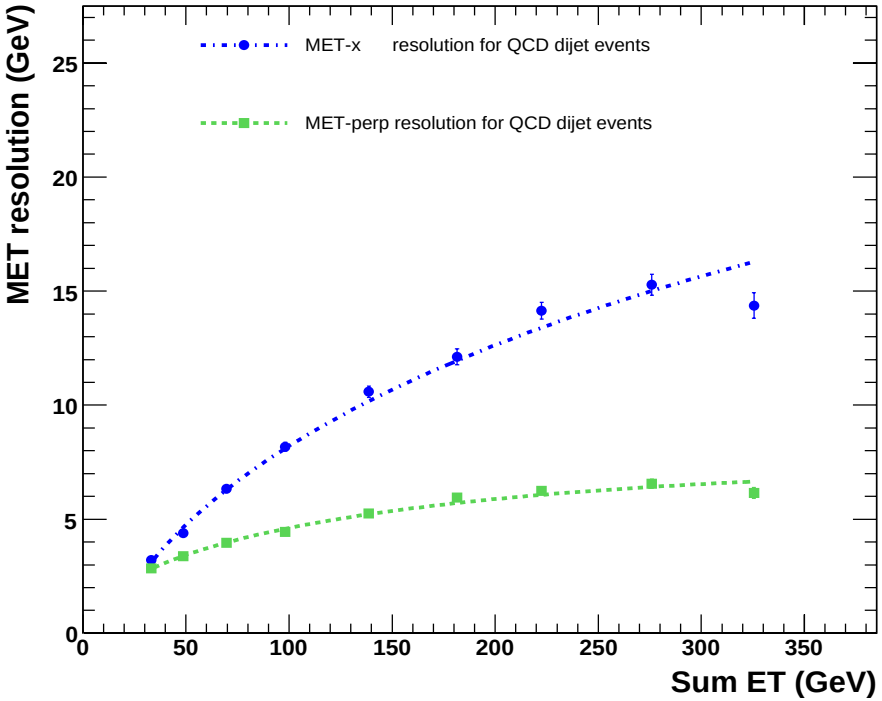
Dan Green

L for 1 month run (10^6 sec)	Integrated L	Trigger	Process	Comments
10^{23}	100 mb^{-1}	None σ_I~ 50 mb	Inelastic non-diff	Input to tweak Pythia
10^{24}	1 μb^{-1}	Setup Jet	Inelastic non-diff	Calib in azimuth
10^{25}	10 μb^{-1}	Jet $\sigma(gg)$ ~ 90 μb $\sigma(ggg)$ ~ 6 μb	g+g -> g+g g+g -> g+g+g	Establish JJ cross section
10^{26}	100 μb^{-1}	Jet	g+g -> g+g g+g -> g+g+g	Dijet balance for polar angle – Establish MET
10^{27}	1 nb^{-1}	Jet Setup Photon $\sigma(q\gamma)$ ~ 20 nb	g+g -> g+g g+g -> g+g+g q+g -> q+γ	Dijet masses – start jet balance J+γ calib

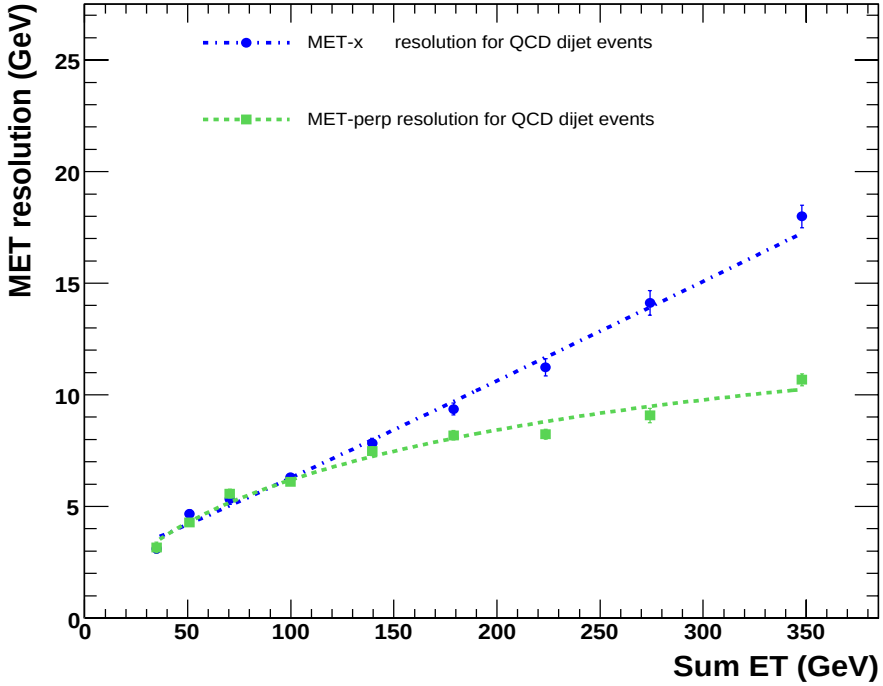
CMSSW 090: 900 GeV and 14 TeV

Marek Zielenski

900 GeV LHC Energy



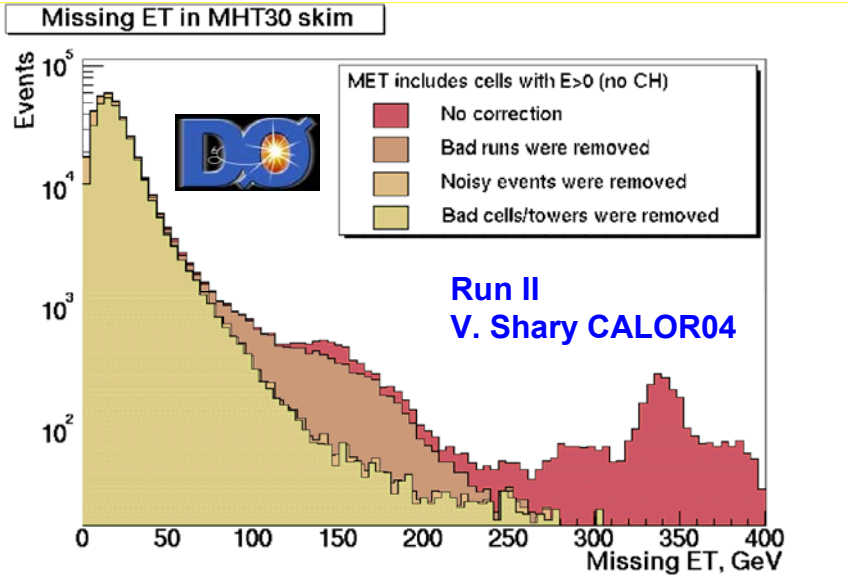
14 TeV LHC Energy

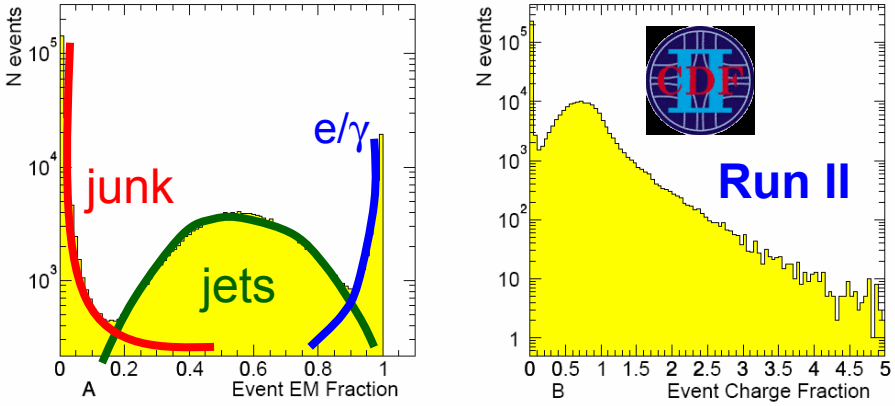


- Resolutions of METx roughly similar at 900 GeV and 14 TeV
  - Dominated by jet response
- Resolution of MET-perp worse at 14 TeV
  - Due to higher activity in UE?
  - Another illustration of different sensitivities of these components

MET Cleaning from Tevatron

- MET is very powerful SUSY discriminator
  - Difficult part is to convince yourself that there is a real excess!
- Tevatron teaches us
  - MET is not easily understood!
- Non-collisional backgrounds
  - Beam halo
  - Cosmic muons
- Detector Effects
  - Instrumental Noise
  - Hot/dead channels (DQM)





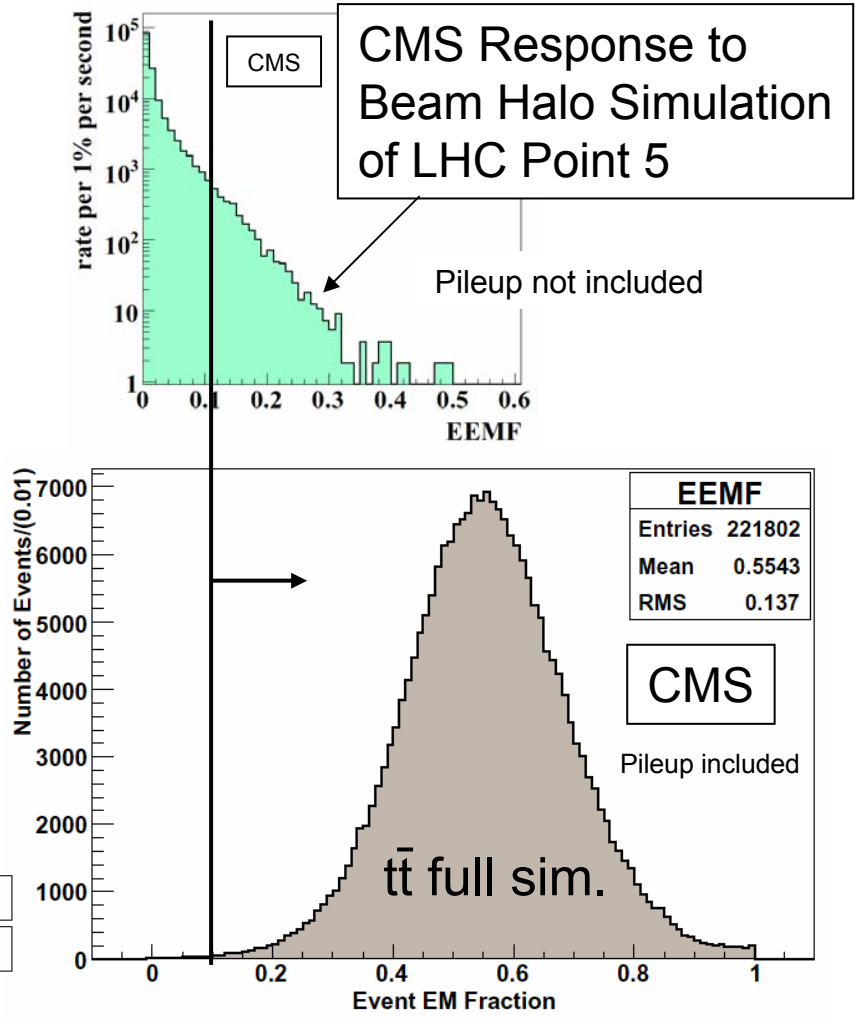
D. Tsybychev, Fermilab-thesis-2004-58

Early Study of MET Cleaning using ORCA

(of course, Real Data will be different!)

- Apply clean up cuts to remove fake high MET events (inspired by CDF & D0)
  - ≥ 1 central jet (|η|<1.7) with ≥ 4 tracks
  - ≥ 1 vertex
  - F_{em} > 0.1 (Event Electromagnetic Frac.)
  - F_{ch} > 0.175 (Event Charged Fraction)
- Affect on SUSY Signal

Sample/Requirement	$F_{em} > 0.1$	$F_{ch} > 0.175$	Both(%)
LM1	99.88%	91.32%	91.24%

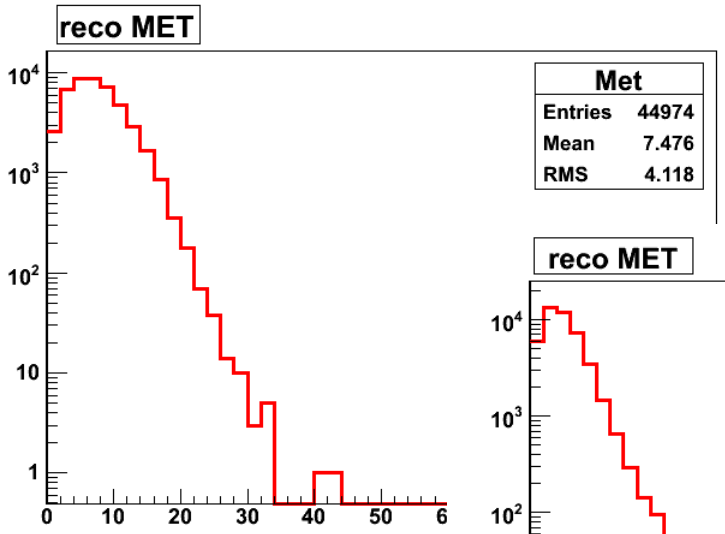


Effect of HCAL Zero Suppression

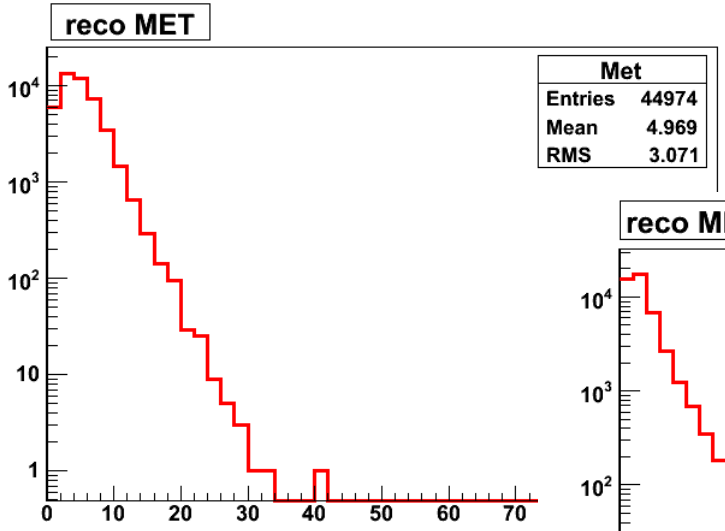
Sinjini Sengupta

MinBias w/o Scheme-B

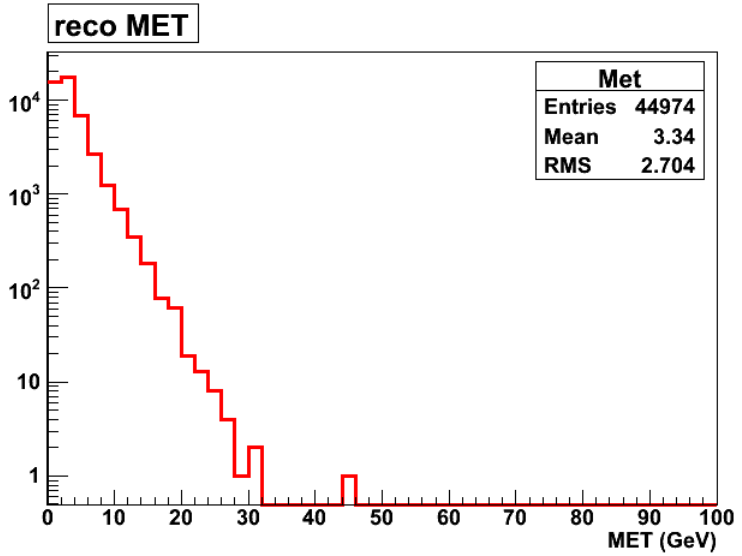
RecoMET distribution



1 ADC count



3 ADC count



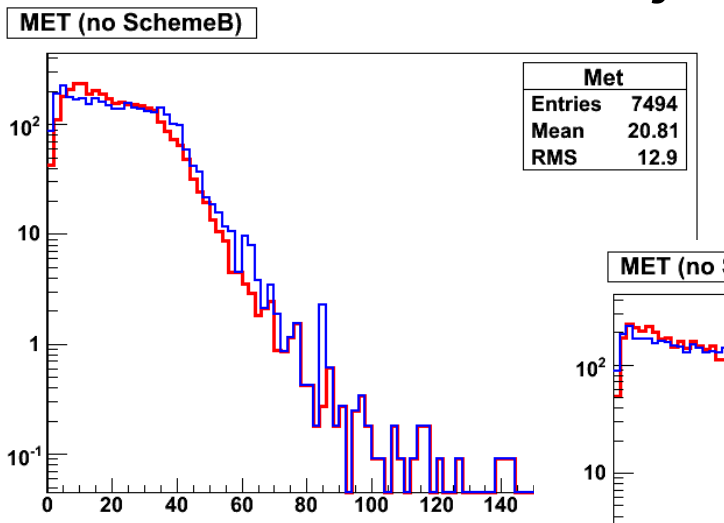
4 ADC count

Effect of HCAL Zero Suppression

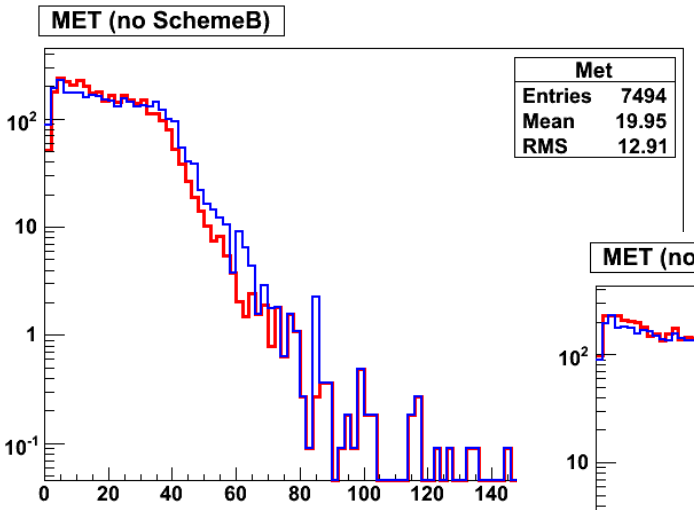
W+jets w/o Scheme-B

Sinjini Sengupta

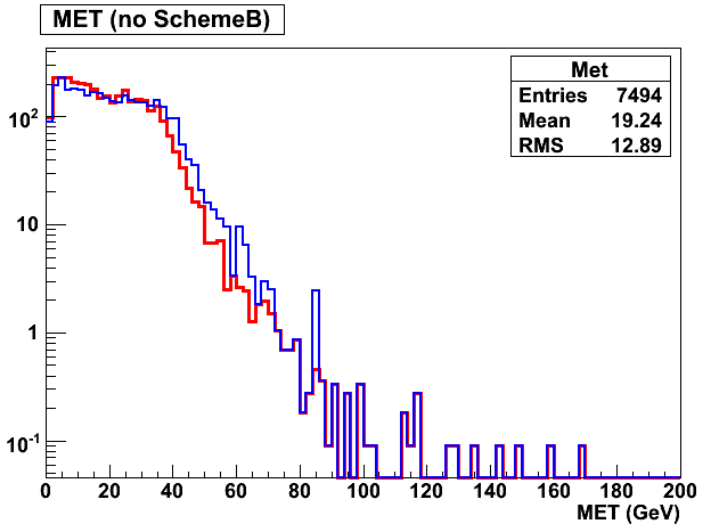
MET distribution



1 ADC count



3 ADC count



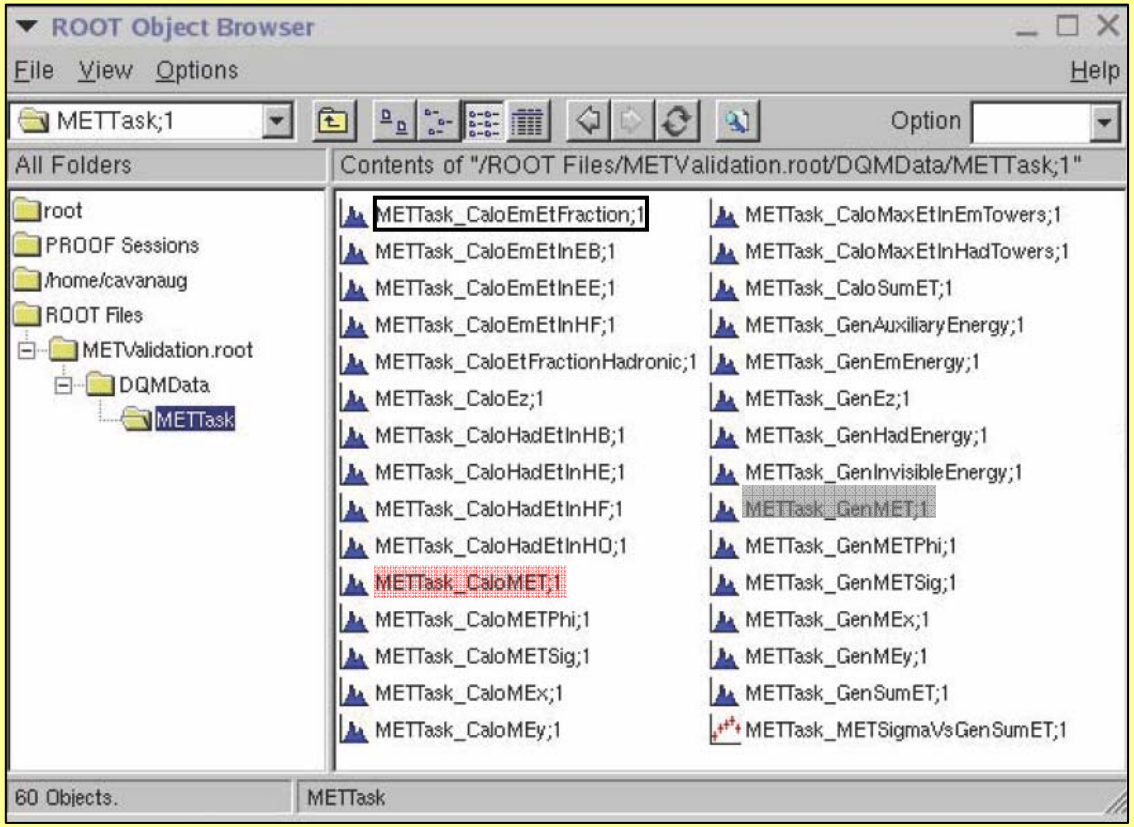
5 ADC count

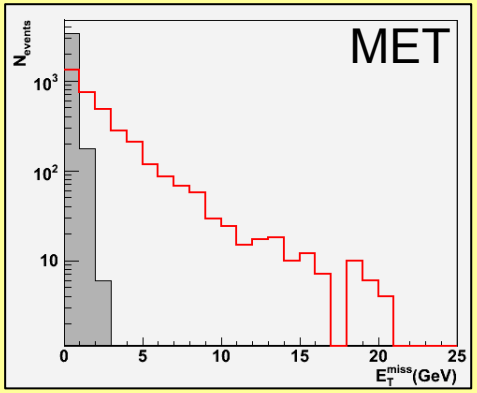
Generated
Reconstructed

Validation/RecoMET

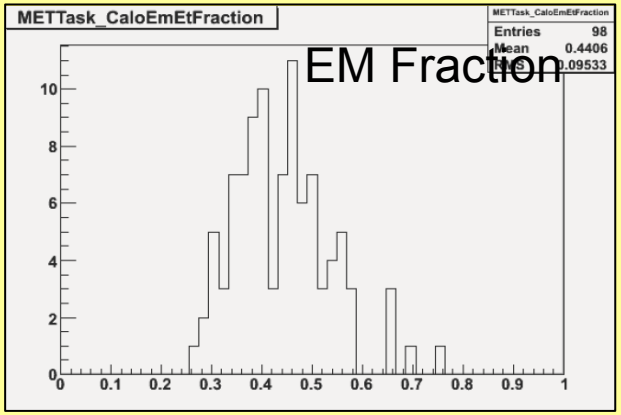
Bobby Scurlock
Mike Schmitt

- Simple EDAnalyzer : METTester
- Two types of MET currently defined
  - GenMET
  - CaloMET
  - Every method is monitored via a histogram





minbias



Begin to Extend Beyond Software Validation

- Immediate Plans
  - Also monitor “Corrected MET”
- Include MET ||, and MET ⊥
  - Demonstrated by Zielinski to be a good problem discriminator in QCD dijets, Z→μμ
- Build up a library of EDAnalyzers relevant to MET:
  - CaloTowerMETAnalyzer, RecoHitMETAnalyzer
  - MuonMETAnalyzer, etc
- Monitor MET-specific lower-level views (towers, RHs)
  - iphi-distributions for different ieta (search for asym’s)
  - iphi-distributions for different sub-detectors
  - Applied masks, calibrations, thresholds (per sub-detector)
  - Relevant quantities for muon system, etc
- Goal: attempt to target & correlate problems across different lower-level sub-systems
  - Strictly from a MET point of view