Effect of Pileup on EtMiss and suppression methods

Silvia Resconi
MILANO

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EtMiss activity in ATLAS

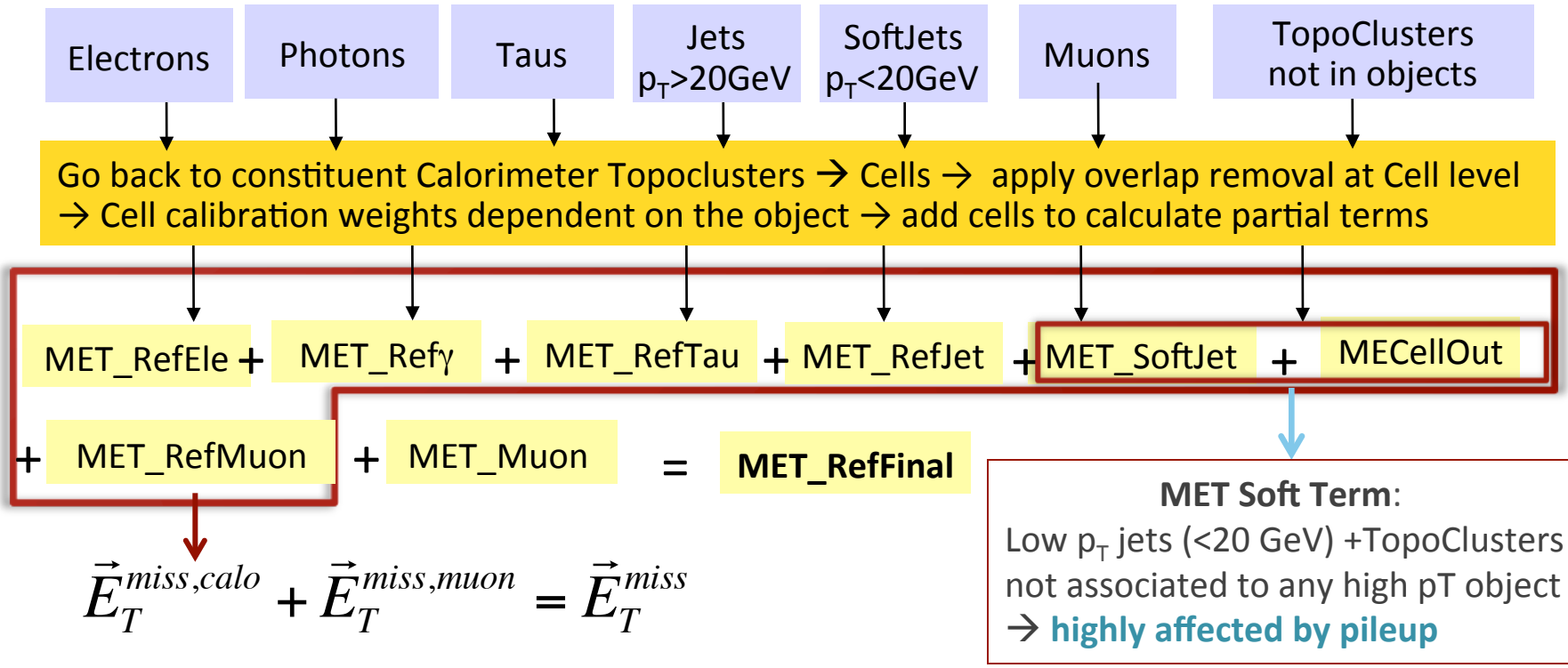
Strong involvement of Italians groups in EtMiss in ATLAS:

- Milano group:
  Donatella Cavalli, Silvia Resconi, Caterina Pizio, Rosa Simoniello
- Frascati group:
  Mario Antonelli, Marianna Testa, Roberto Di Nardo, Marco Dreucci

A CONF note is in preparation (editors: D. Cavalli, M. Testa) documenting the EtMiss performance in 2011 data/MC, including pileup studies.

- **Focus of this talk**: show effects of increasing pileup conditions on EtMiss and how to recover applying pileup suppression in soft terms.
  - Lot of activity in last weeks in the context of the EtMiss subgroup to develop and test methods for pileup suppression.
  - Main contribution by Milano and Frascati groups, Peter Loch (Arizona)

Etmiss reconstructed with *RefFinal* Algorithm

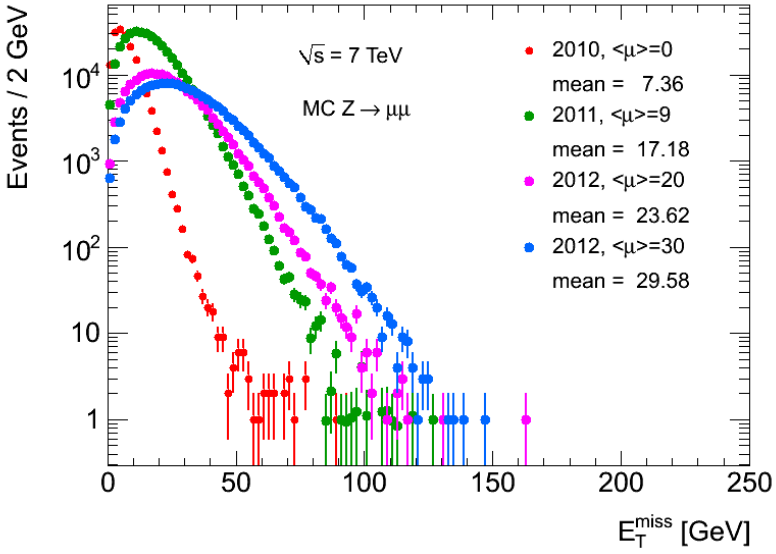


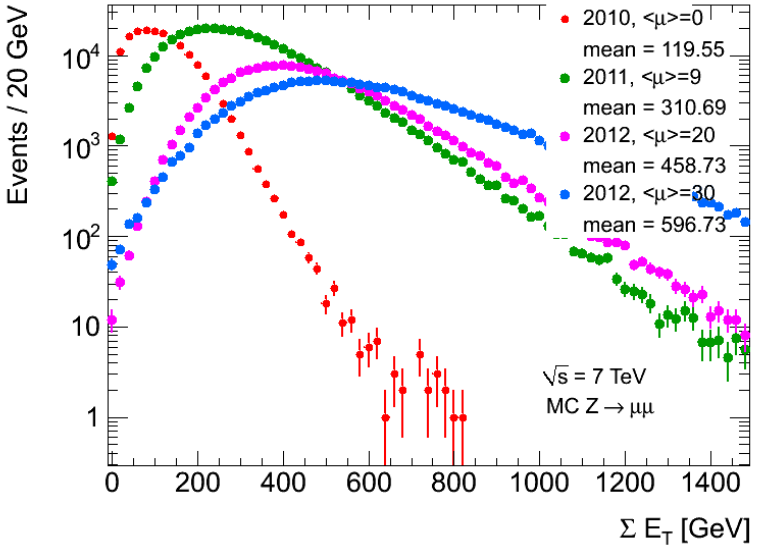
MET_RefFinal is the vectorial sum of MET Terms that correspond to the separated contributions from different objects plus the contribution of deposits not in objects.

- MET_RefFinal is the official recommendation from JetEtmiss group
  https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/JetEtmissDataAnalysisRecommendationSummer2010#Recommendation_for_MET_reconstru

Effect of pileup on ETmiss and SumET

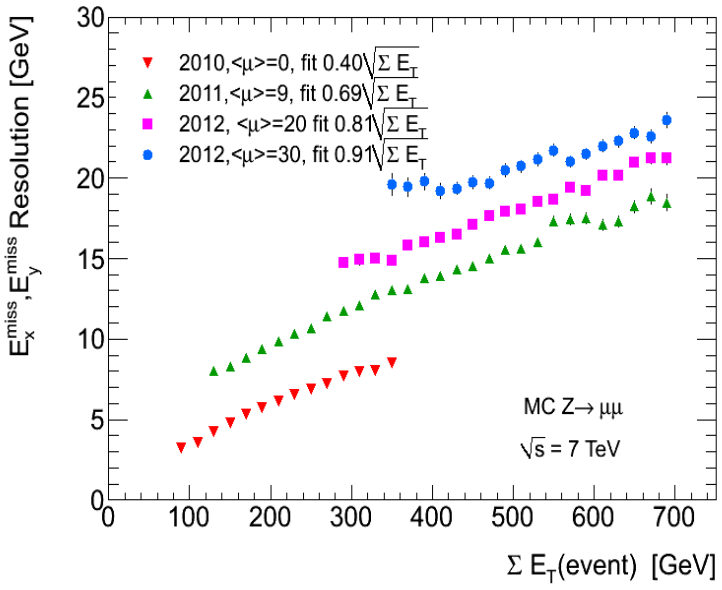
- **E_T^{miss} and SumET quantities highly affected by fluctuations from pileup,** largest acceptance (coverage area) of any given reconstructed quantity.
- In **Z→μμ events** in which no true E_T^{miss} is expected:
  - E_T^{miss} and SumET mean values increase of about a factor 2.5 going from 2010 data (no pile-up) to 2011 data (<μ> ~ 9).
  - **Expected further worsening with 2012 data :**
    - check on MC samples with <μ> = 20 and <μ> = 30

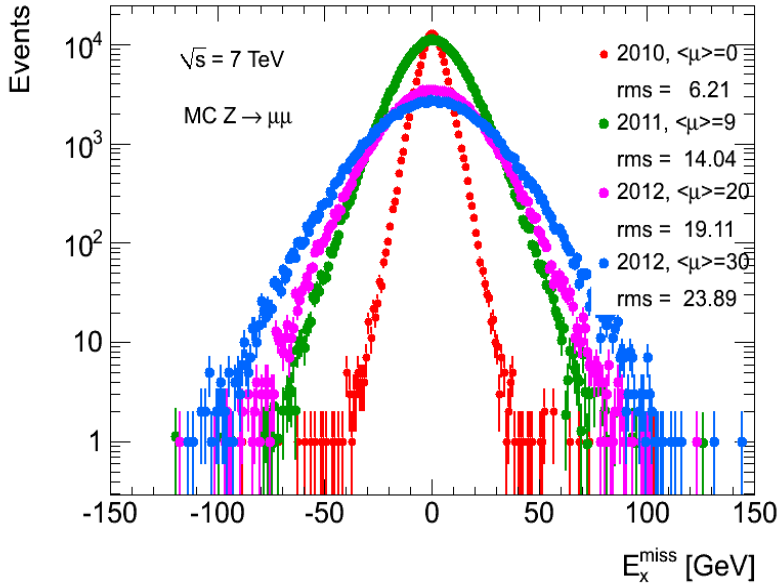




Effect of pileup on MET Resolution

- Dramatic effect on $E_{x,y}^{miss}$ resolution with increasing pile-up conditions:





- Large impact on analyses with E_T^{miss} in the final state.
- Pileup correction is needed for E_T^{miss} → for each MET_Ref term
  - CP groups have provided pileup suppression for different objects (i.e. jets,taus)
  - In the context of EtMiss subgroup lot of work to develop and tests methods for pileup suppression in MET Soft Term = CellOut + SoftJet terms

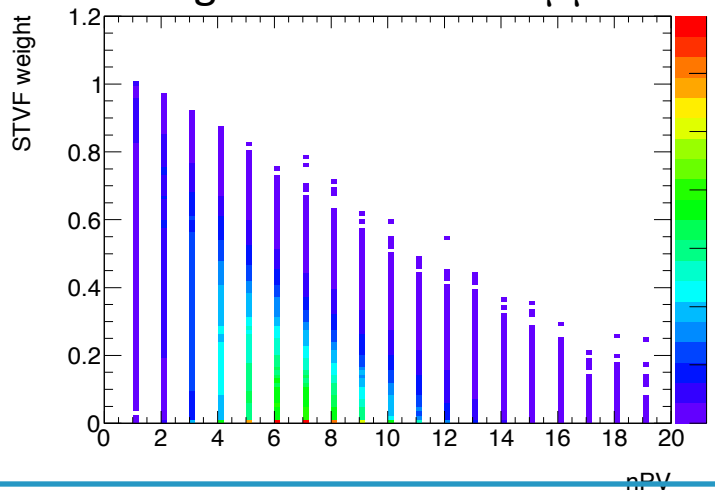
STVF pileup suppression in MET SoftTerm

Soft Term Vertex Fraction (STVF) method:

scale the SoftTerm with a weight calculated from the ratio of tracks from PV over all tracks unmatched to physics objects.

➔ $SoftTerm\_corr_{xy} = SoftTerm_{xy} * (\Sigma pt\ PV / \Sigma pt)$

STVF weights vs nPV in Z→μμ MC evts

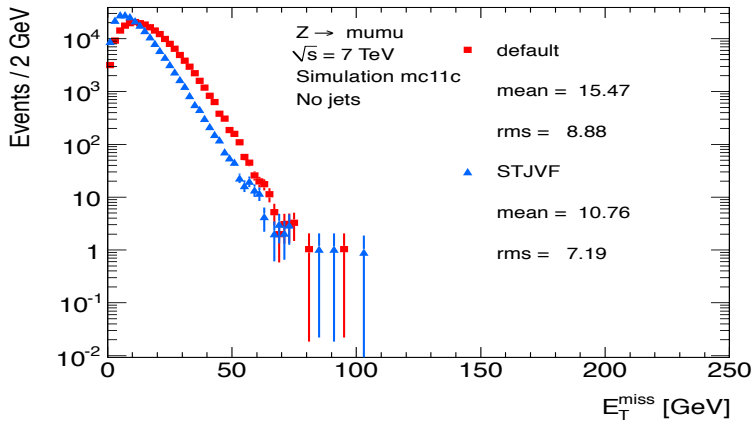


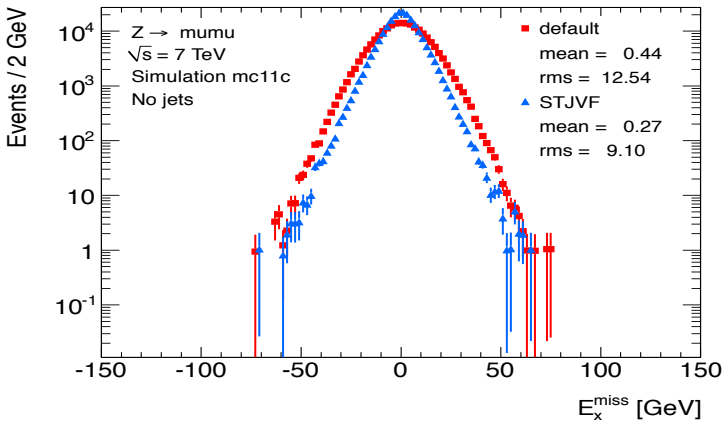
Technical remark:

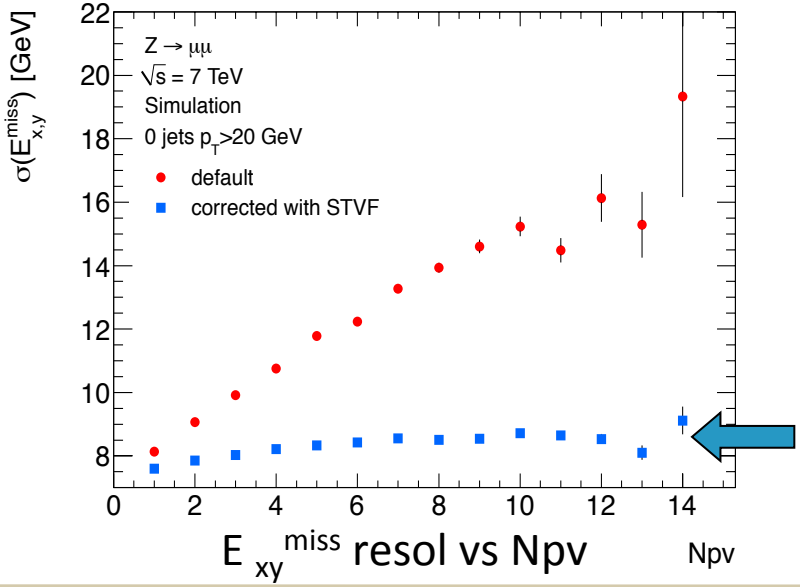
Used composition map in D3PDs to identify all tracks unmatched to physics objects. Same selection of tracks as the one used for CellOut_Eflow

Using the assignement of tracks to primary vertex provides a reliable estimate of the pileup coditions BUT in limited coverage and no neutral contributions are taken into account

Effect of STVF correction in evts without jets





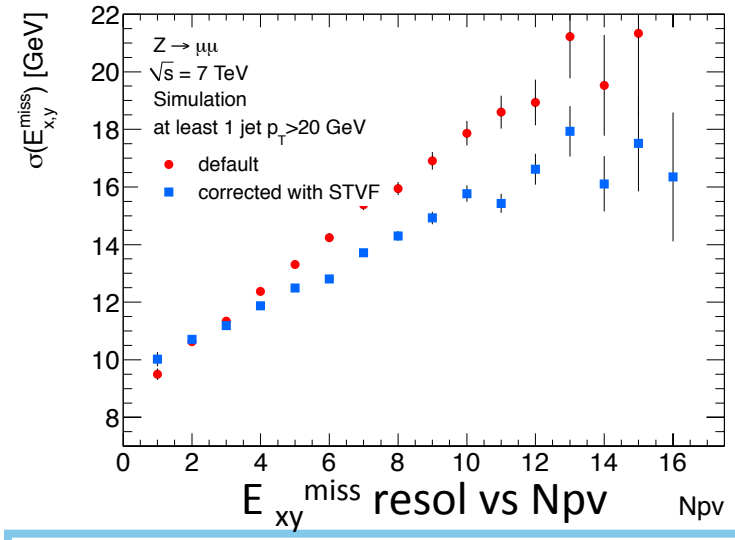


Check effect of STVF correction on SoftTerm selecting evts without jets with pT> 20 GeV in MC $Z \rightarrow \mu\mu$ sample.

No tails in EtMiss and ExMiss distributions seem to be created applying STVF correction

Thanks to the STVF correction the EtMiss resolution is no more dependent on Npv (blue points)

Effect of STVF correction in evts with jets



In events with jets worsening of the EtMiss resolution and increased Npv dependence.

Evts with at least 1 jets with pT> 20 GeV

The offset correction applied to jets in RefJet is not enough to suppress pile-up.

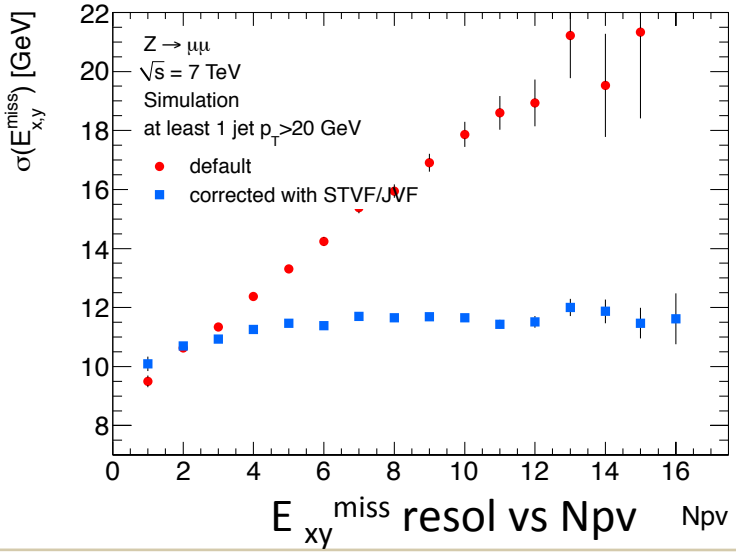
Applying a correction based on JVF (Jet Vertex Fraction) to the jets entering the RefJet term improves the EtMiss resolution vs Npv.

JVF = ptsum of matched tracks from PV over the ptsum of all matched tracks.

Correction applied:

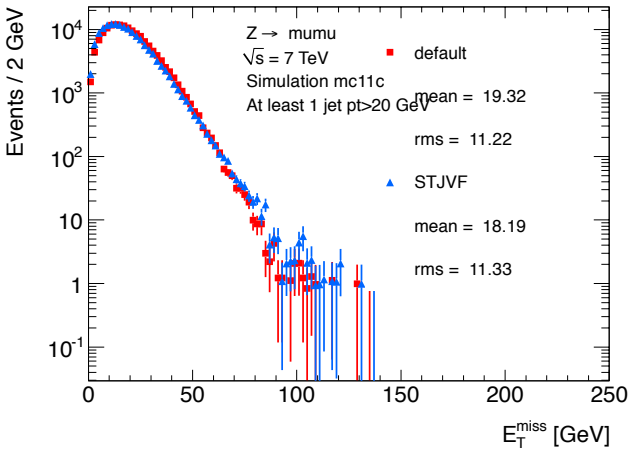
p_T jet corr = p_T jet * |JVF|

p_T jet corr = 0 if JVF==-1 && |η|<2.5

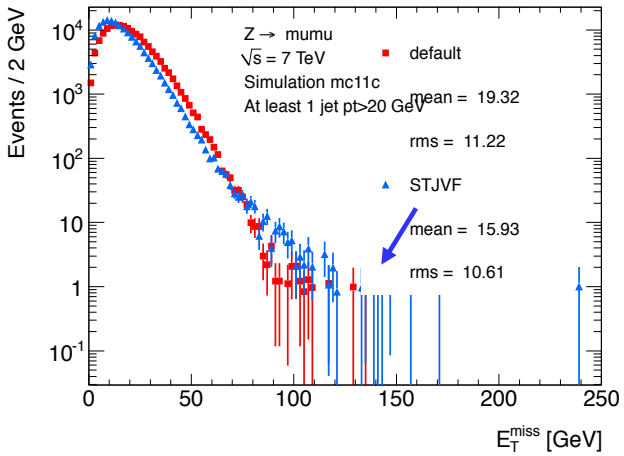


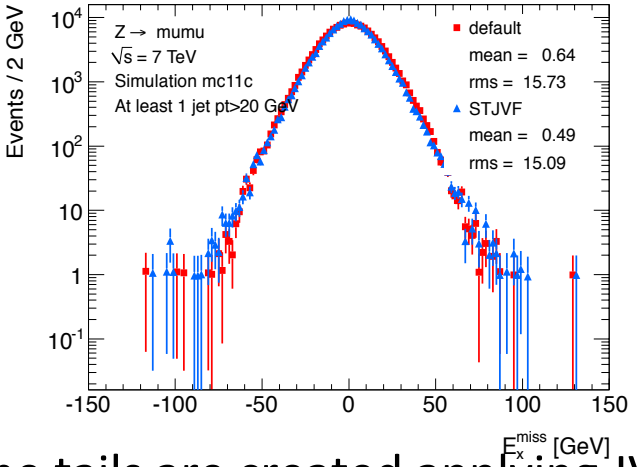
MET and METx in events with jets

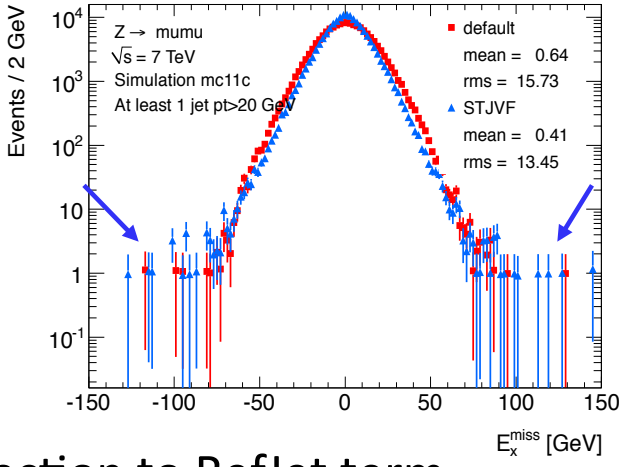
No JVF corr to RefJet term



JVF corr to RefJet term

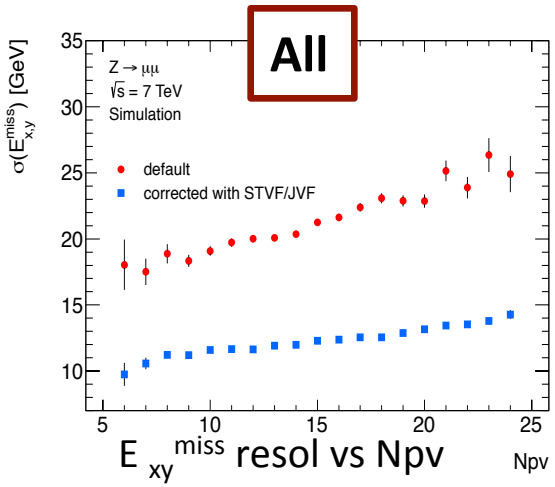


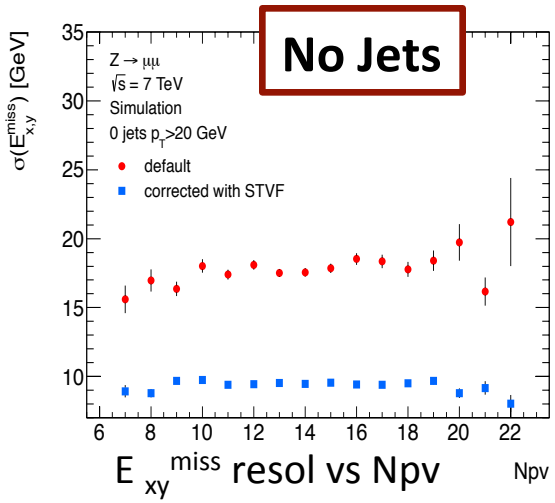


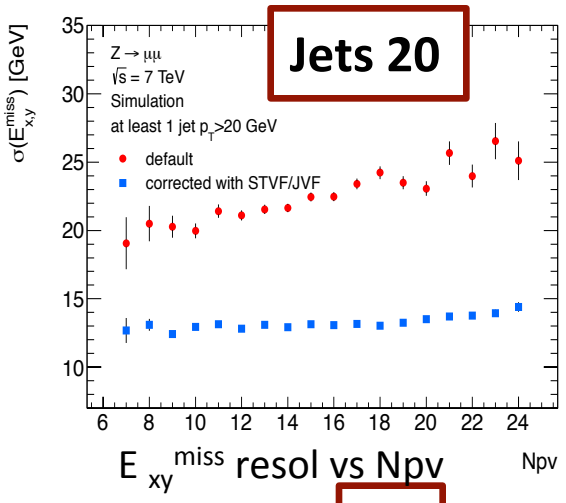


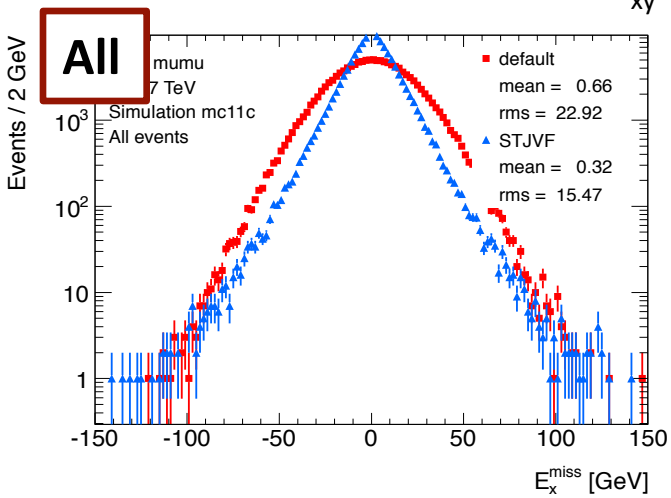
Some tails are created applying JVF correction to RefJet term, to be studied in more details

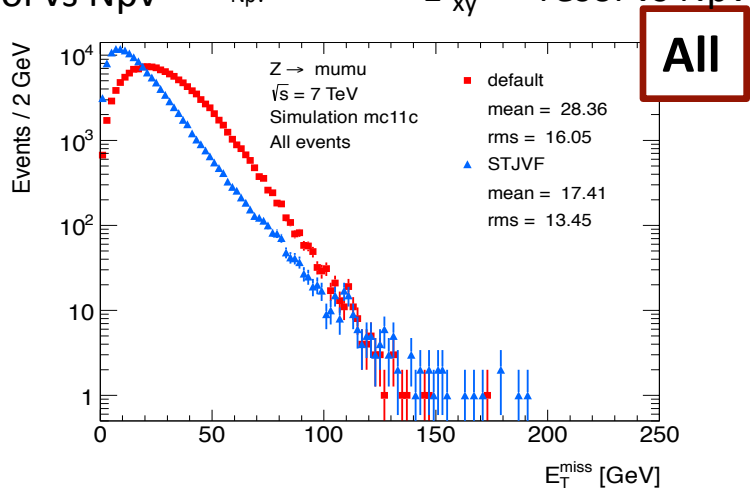
high pileup Z→μμ sample (<μ> =30)











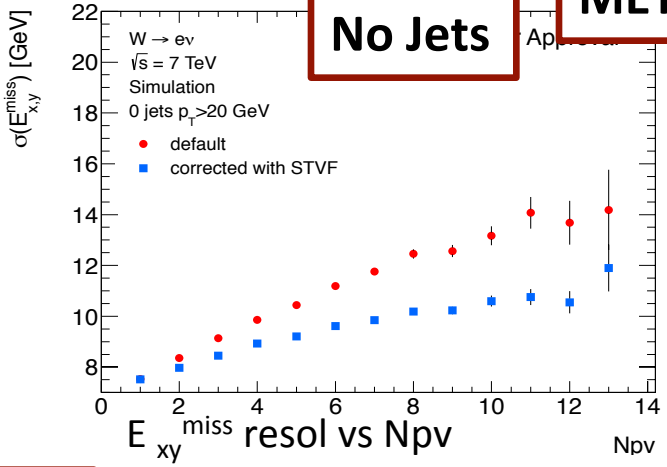
Check high pile-up sample in: all evts, evts with and w/o jets with p_T>20 GeV

STVF (on Soft Term) +JVF (on RefJet) improve E_{xy}^{miss} resol vs Npv, few tails to be studied.

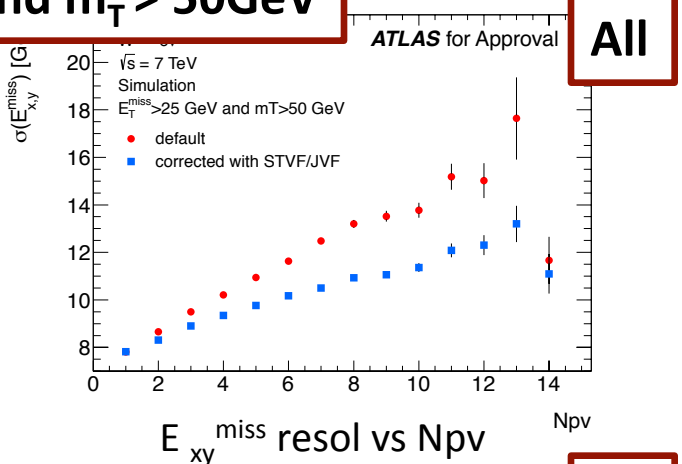
STVF correction in evts with true EtMiss (W→eν)

MET >25 GeV and m_T > 50GeV

No Jets



All



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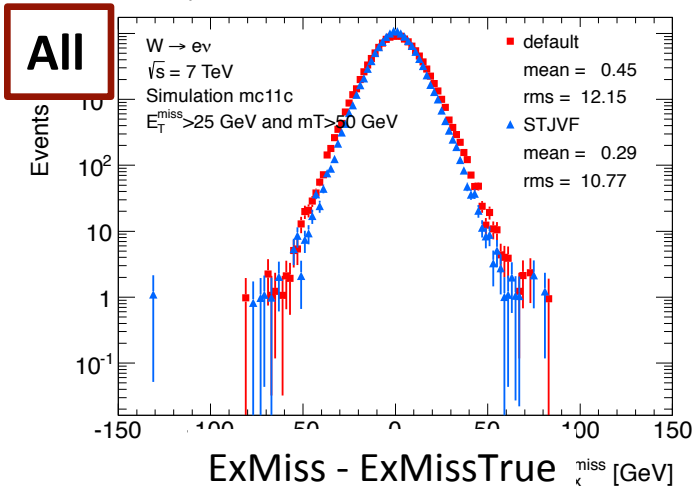

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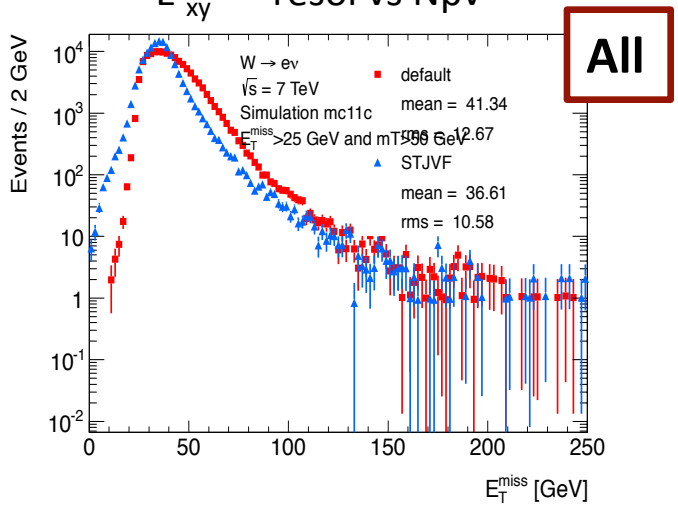
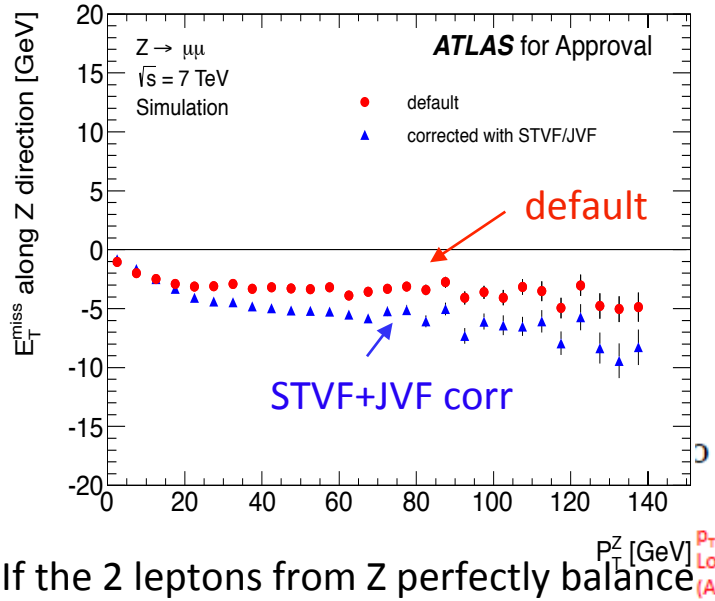


Also in evts with real EtMiss the pileup correction with STVF (on Soft Term) + JVF (on RefJet) improve E_{xy}^{miss} resol vs Npv

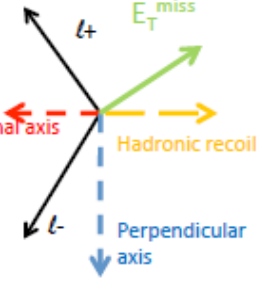
Check of the EtMiss scale after STVF to SoftTerm and JVF to RefJet

Zμμ: diagnostic plot

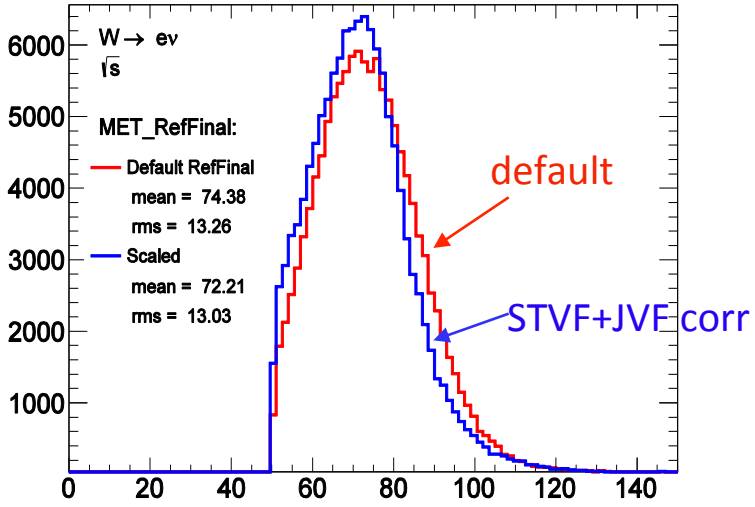


If the 2 leptons from Z perfectly balance the hadronic recoil the projection of ME along Z direction should be zero.

Preserving the direction of the original MET_RefFinal the diagnostic plot after STVF+JVF seems not so spoiled.



Weν: m_T(lept, E_T^{Miss})



MET>25 GeV and m_T>50 GeV

Wenu transverse mass after pileup correction is not spoiled

$$m_T = \sqrt{2(p_{Tlept} * EtMiss)(1 - \cos|\Delta\phi_{lept,EtMiss}|)}$$

Alternative methods for MET Soft Term correction based on tracks

(1) Replace Soft Term with Tracks:

Use only the tracks from primary vertex (PV) and unmatched to physics objects to calculate the Soft Term.

➔ $\text{RefFinal\_corr}_{xy} = \text{RefFinal}_{xy} - \text{SoftTerm}_{xy} + \Sigma\, p_{xy}$ tracks from PV

(2) Replace Soft Term with Tracks plus clusters in a cone:

Use tracks from primary vertex unmatched to physics objects plus clusters in a cone of $\Delta R=0.3$ around them to recover neutral contributions.

➔ $\text{RefFinal\_corr}_{xy} = \text{RefFinal}_{xy} - \text{SoftTerm}_{xy} + (\Sigma\, p_{xy}$ tracks PV + $\Sigma\, E_{xy}$clust in $\Delta R=0.3)$

Effect of alternative methods in Z→μμ events without jets

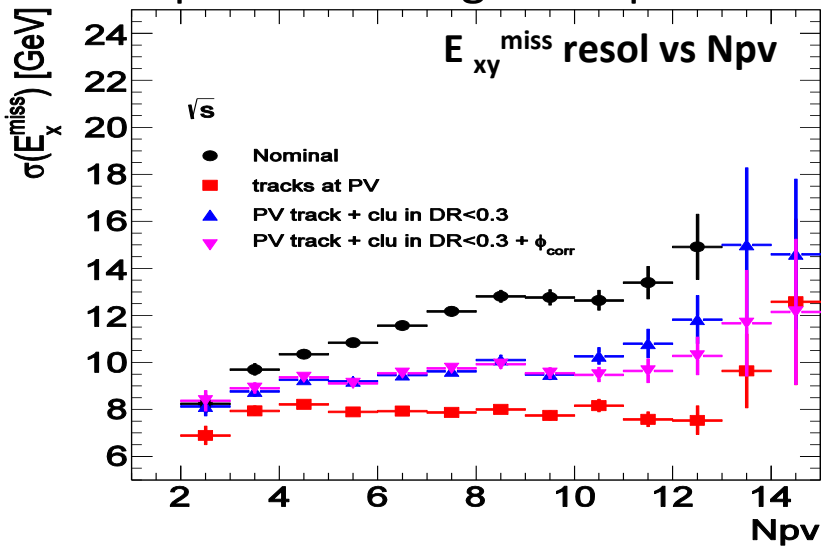
(1) Replace Soft Term with Tracks:

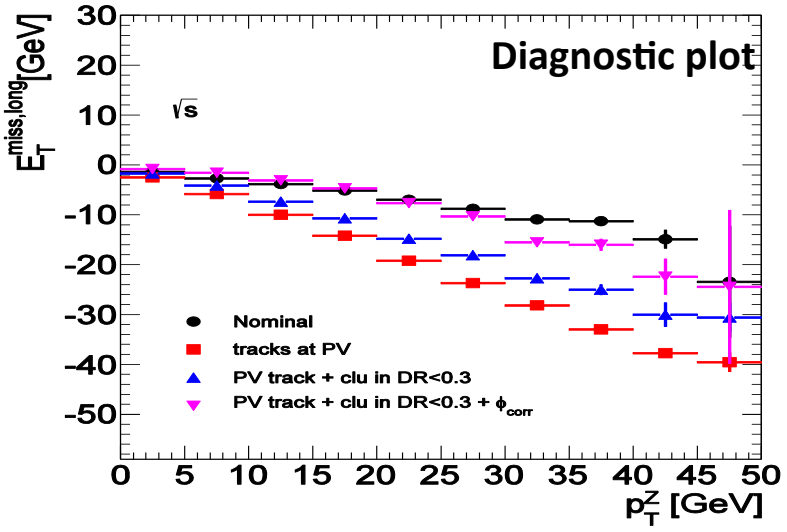
Provides best resolution and flat behavior vs Npv but worse performance of the diagnostic plot

(2) Replace Soft Term with Tracks plus clusters in a cone:

Provides slight worse resolution but better diagnostic plot

(3) Preserving the original phi direction of MET_RefFinal for case (2) helps to improve the diagnostic plot





In evts with jets plan to apply JVF corr similar to STVF case

Pileup suppression of SoftTerm based on the Cacciari "jet area method"

- Based on the idea that **noise (pileup) has a lower density (ρ) than signal**
- **Data driven method**: event-by-event, and jet-by-jet pileup subtraction
- **Advantage to take into account also neutral and forward particles** for which the track info is not available.

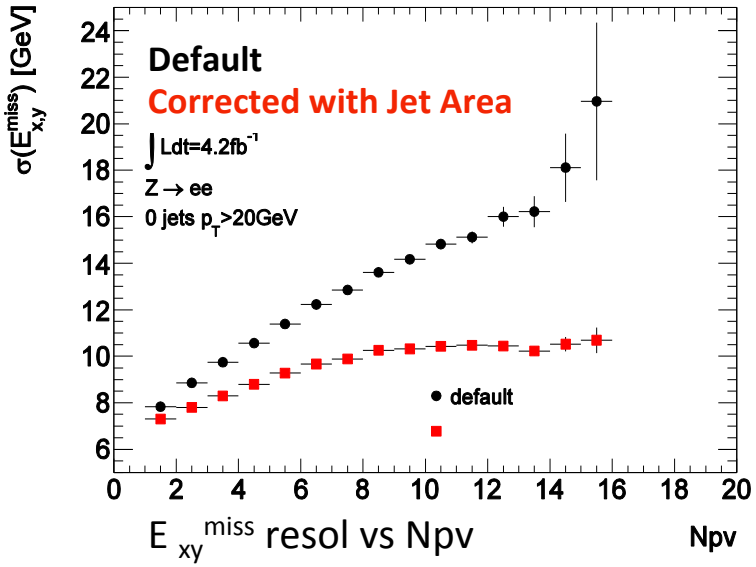
- Procedure:
  - *Reconstruct Kt jets (DR=0.4) down to pT=0 from topoclusters and tracks used to calculate the SoftTerm*
  - *Get the reference ρ shape to determine pileup contribution (from minbias data)*
  - *Use the shape to remove pileup contribution:* different methods available
    → *at the moment the "preferred" method is:*

$$E_{T,jet}^{corr} = \begin{cases} 0 & E_{T,jet} \leq \rho_{ref} A_{jet} \\ E_{T,jet} - \rho_{ref} A_{jet} & E_{T,jet} > \rho_{ref} A_{jet} \end{cases}$$

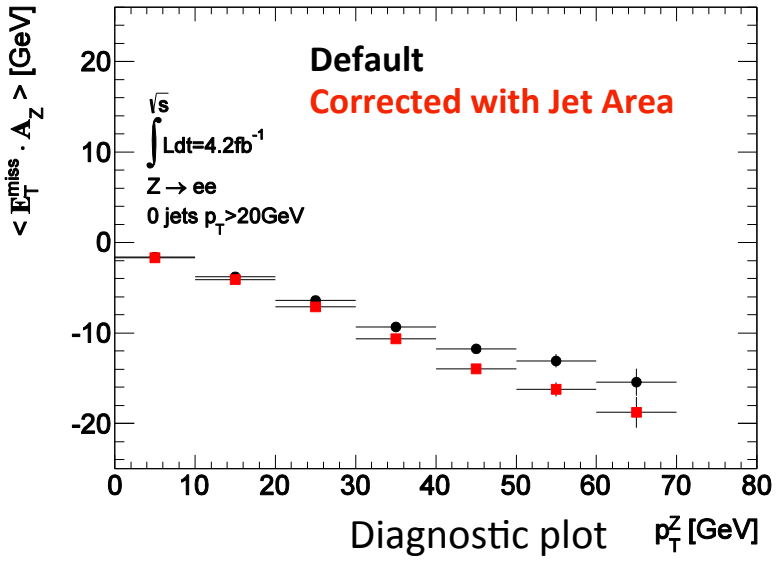
  - *Recalculate MET (RefFinal) from corrected Kt jets:*

RefFinal_corr $_{xy}$= RefFinal$_{xy}$ – SoftTerm$_{xy}$ + Σ E$_{xy}$ Kt jets PU corr

Effect of "jet area method" in Zee evts without jets



E xy miss resol vs Npv



Diagnostic plot

→ After pileup suppression the resolution has very little dependence on Npv

→ Preserving the direction of orginal RefFinal the diagnostic plot is not spoiled.

→ In evts with jets plan to use jet area method also for jets entering RefJet Term to be more coherent with this method.

Those results confirm the results obtained with the STVF and the other track-based methods.

Conclusions

EtMiss highly affected by fluctuations from pileup spoiling performances

Shown results of promising methods to suppress pileup in SoftTerm:

Track-based

(1) STVF (Soft Term Vertex Fraction) applied to SoftTerm plus JVF correction applied to jets in RefJet term

- The resolution is improved and has smaller dependence on Npv both in evts with and w/o jets and with and w/o real EtMiss (Zμμ ,Wenu)
- The diagnostic plot in Zμμ and the m_T in Wenu are not spoiled

(2) Replace SoftTerm with tracks from PV unmatched to physics objects

(3) Like (2) but adding also matched clusters

(4) Cacciari "Jet area method":

- The resolution is improved and has smaller dependence on Npv and diagnostic plot in Zμμ is not spoiled. To be checked in Wenu.

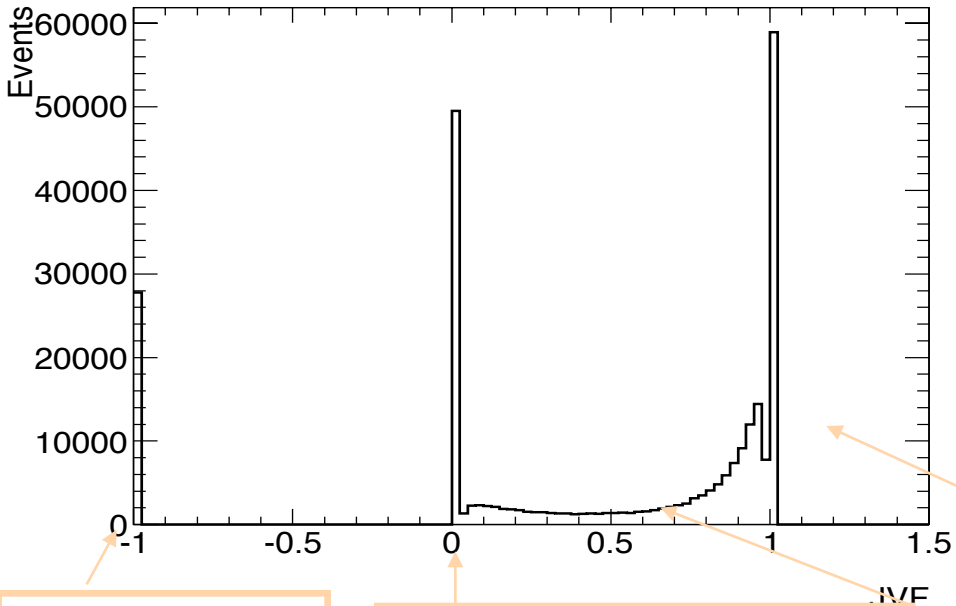
All these methods are ready to be implemented in Athena for D3PD production:

- implementation of 1,2,3 is ongoing and soon provided a MET tag for D3PD prod,

  4 requires much complex implementation, will be provided in a second step.

Backup

JVF of jets in MC11c Z→μμ events



JVF = $p_T$sum of matched tracks from PV over the $p_T$sum of all matched tracks.

Correction applied to jets entering the RefJet term :

$P_T$corr = pT jet * |JVF|

$P_T$corr = 0 if JVF==-1 && |η|<2.5

Jets without matched tracks

Jets with all matched tracks from pileup vertices

Jets with all matched tracks from PV

Jets with some contribution from pileup

	JVF = -1	JVF = 0	JVF>0
|η|<2.5	1%	17%	69%
|η|>2.5	13%	<1%	<1%

Ongoing studies in jet/etmiss + tracking WG to optimize cuts, corrections based on JVF with increasing pileup conditions

PV and Eflow track selection

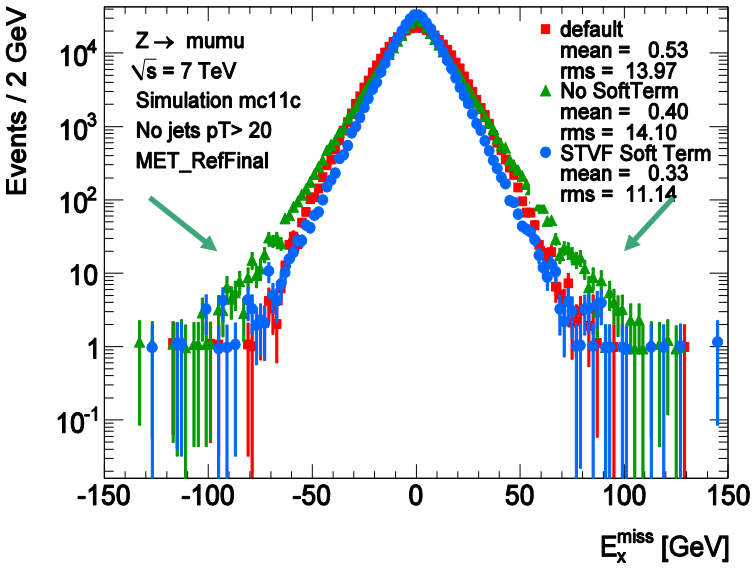
Primary Vertex selection:

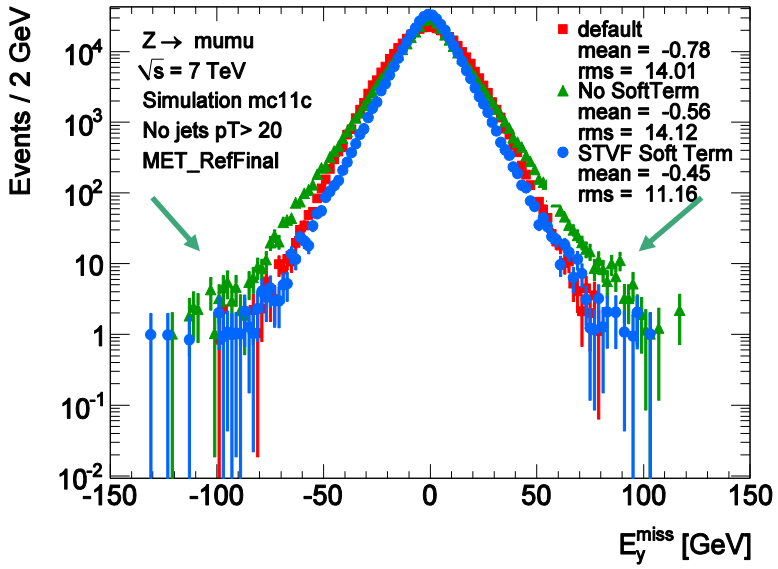
- $|d0| < 2$ mm
- $|z0 * \sin(\theta)| < 2$ mm

Track selection (for Eflow algorithm):

- for tracks with $p_T > 500$ MeV:
  - $N_{hit}^{PIXEL} + N_{hit}^{SCT} > 6$
  - $N_{hit}^{PIXEL} + N_{hit}^{SCT} + N_{hit}^{TRT} > 10$
- for tracks with $p_T < 500$ MeV:
  - $N_{hit}^{PIXEL} + N_{hit}^{SCT} > 8$
- χ^2 by track fit > 0.01 with $p_T > 10$ GeV

Removing Soft Term entirely





Remove entirely soft terms (CellOut and SoftJets) from MET_RefFinal,
similar to HT approach

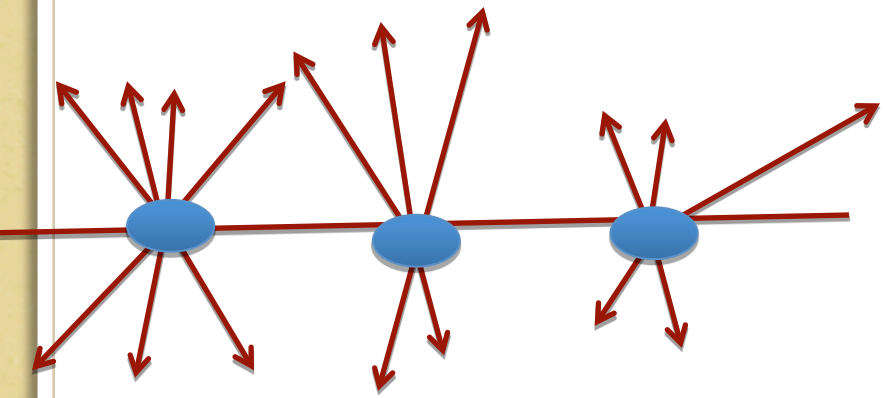
➔ $RefFinal_{corr}$ xy = RefFinal xy – SoftTerm xy

Check in all Z→μμ evts (with and w/o jets):

Exmiss, Eymiss distributions are wider and with more tails.

p_T^{miss} definition

Event based p_T^{miss}



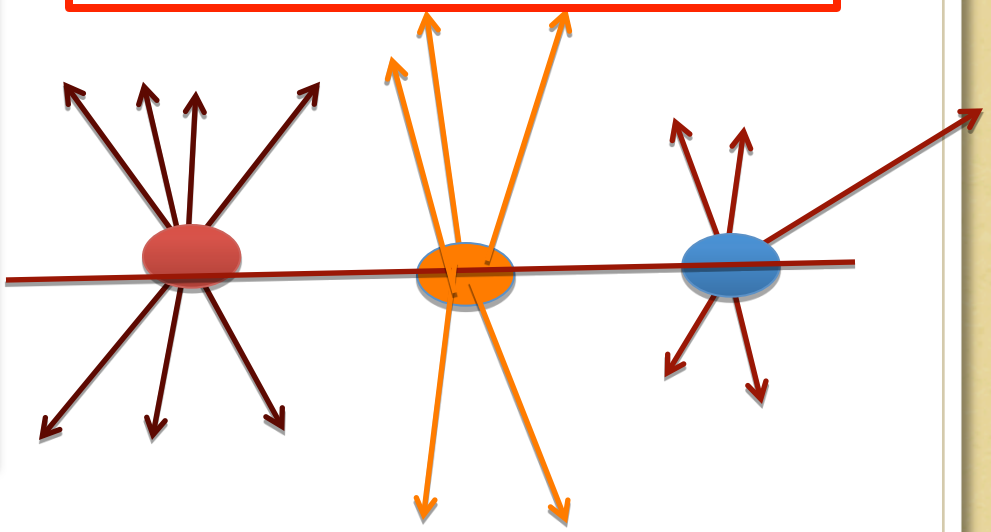
- Calculate one p_T^{miss} per event
- Sum up contributions from all primary vertexes

$$P_x^{miss} = \Sigma_{v=0}^{v=Nvertex} \Sigma_{i=0}^{(v)i=NTrack} (p_{xi}^{v})$$

$$P_y^{miss} = \Sigma_{v=0}^{v=Nvertex} \Sigma_{i=0}^{(v)i=NTrack} (p_{yi}^{v})$$

$$P_T^{miss} = \sqrt{P_x^{miss2} + P_y^{miss2}}$$

Vertex based p_T^{miss}



- Calculate one p_T^{miss} per primary vertex
- For a given vertex with vertex index v :

$$P_x^{miss}(v) = \Sigma_{i=0}^{(v)i=NTrack} (p_{xi}^{v})$$

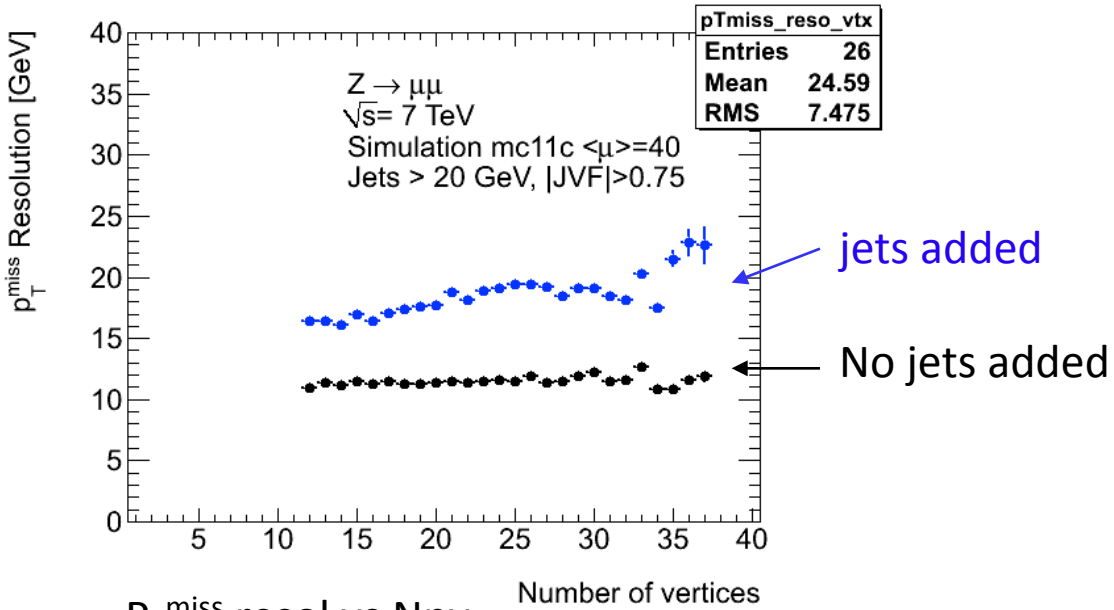
$$P_y^{miss}(v) = \Sigma_{i=0}^{(v)ii=NTrack} (p_{yi}^{v})$$

$$P_T^{miss}(v) = \sqrt{P_x^{miss2}(v) + P_y^{miss2}(v)}$$

Track MET

Information only from ID → Contributions only from charged particles within $|\eta| < 2.5$

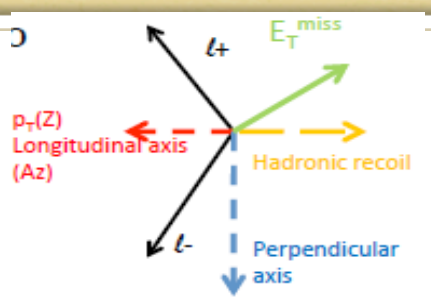
- Degraded in events with jets due to the limited coverage of the ID
- A possible solution is to include jets that lie outside $|\eta| > 2.5$ in $p_T$miss
- Adding the jet p_T in the $p_T$miss calculation introduce a dependence of $p_T$miss resolution on Npv

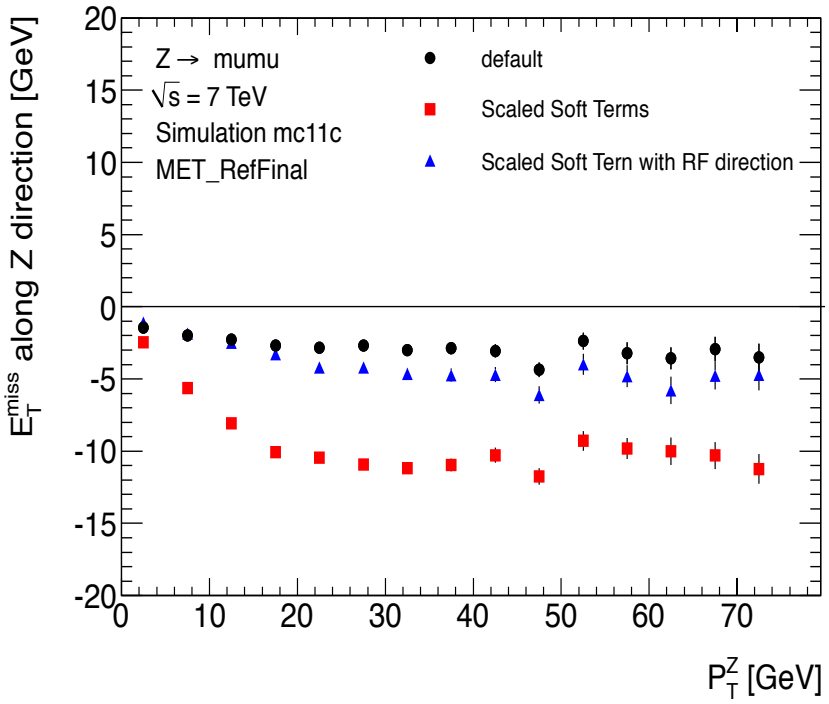


P_T^{miss} resol vs Npv

Check done only on Zμμ events, few forward jets → more tests needed, e.g. in VBF H →ττHevents, ttbar events

Zmumu, all events after Zmumu selection





Diagnostic plot in Zll events:

The longitudinal axis is defined by the vectorial sum of the 2 leptons momenta and it is sensitive to the balance between the electrons and the hadronic recoil.

If the leptons perfectly balance the hadronic recoil the projection of EtMiss along the the longitudinal axis should be zero.

Correcting the soft terms to suppress pile-up and improve the EtMiss resolution spoils the EtMiss scale (red points)

It's possible to restore the EtMiss scale preserving the phi direction of MET_RefFinal (blu points).

MET_RefFinal provides the best phi direction of EtMiss (black points)

RefFinal Etmiss Configuration

Object	Selection/Algo	p_T threshold	Calibration	Symbol
Electrons	"MediumWithTrackMatch"	> 10 GeV	default electron calibration	$E_T^{\text{miss},e}$
Photons	"Tight"	> 10 GeV	EM scale	$E_T^{\text{miss},\gamma}$
Taus	"BDTMedium EleBDTMedium-MuonVeto"	> 20 GeV	LCW +TES	$E_T^{\text{miss},\tau}$
Soft jets	anti-k_t R=0.4	10-20 GeV	LCW	$E_T^{\text{miss,softjets}}$
Jets	anti-k_t R=0.4	> 20 GeV	LCW+JES	$E_T^{\text{miss,jets}}$
Muons	"Staco combined and Mutag"			$E_T^{\text{miss,calo},\mu} + E_T^{\text{miss},\mu}$
Topoclusters outside objects			LCW+eflow	$E_T^{\text{miss,CellOut}}$

- It is based on LCW (Local Hadron) calibration
- This configuration gives the best performance (see Etmiss paper: EPJC 72 (2012) 1844)
- Calibration of topoclusters outside reconstructed objects improved adding tracks information (eflow)

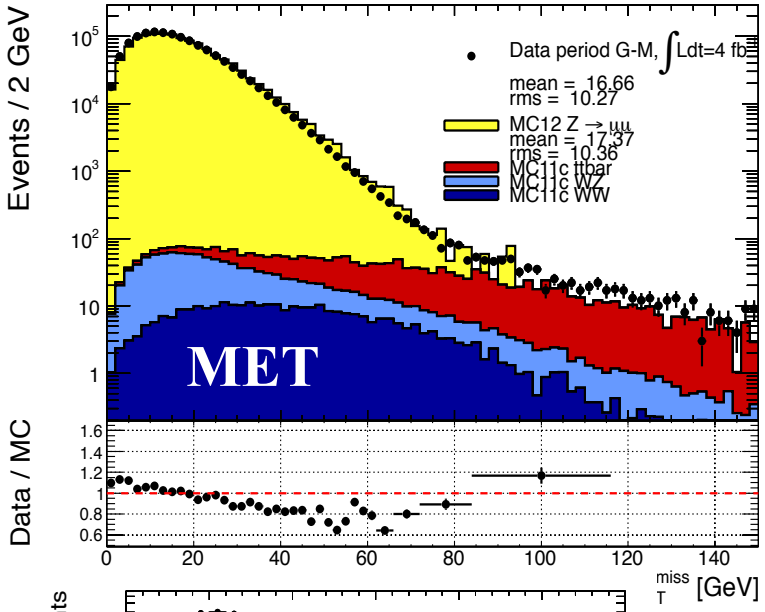
MET changes for rel 17.2

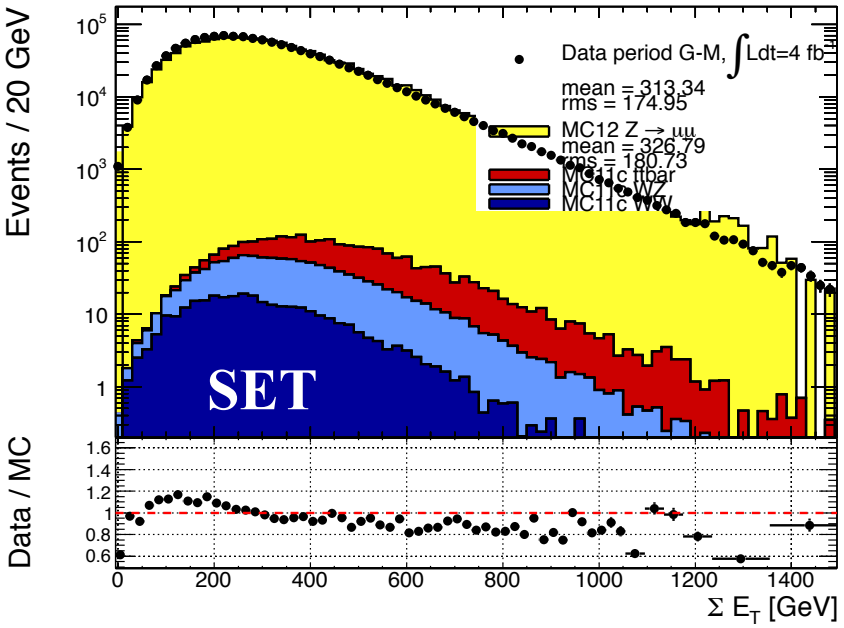
- Some changes in RefTau term
  - New default Tau id "BDTMedium_EleBDTMedium_MuonVeto"
    Other possibile Tau id criteria provided in case of tau D3PD prod.
  - RefTau calculation uses the entire object with TES and offset subtraction (pt>20GeV)
- Added a new RefFinal based on the third Muon chain
- Update of METTrackTool to provide a MET_Track based on the primary vertex

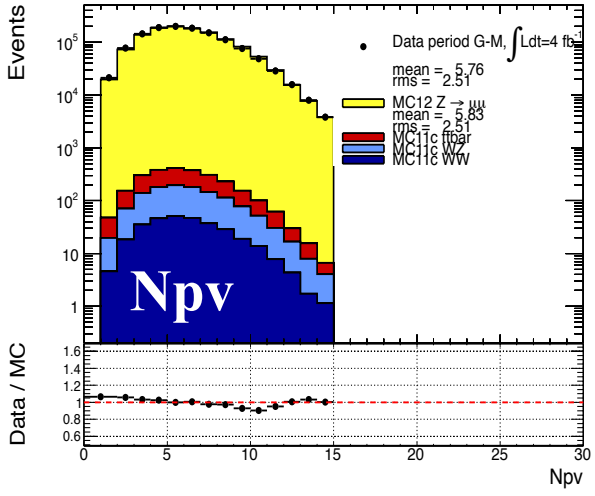
RefFinal configurations available in official reconstruction

- MET_RefFinal: based on LCW + JES (RefJet)+ Eflow (CellOut) + Staco
- MET_RefFinal_em: EM scale + JES (RefJet) + EM scale (CellOut) + Muid
- MET_RefFinal_Muid: based on LCW + JES (RefJet)+ Eflow (CellOut) + Muid
- MET_RefFinal_Muons: based on LCW + JES (RefJet)+ Eflow (CellOut) + Muons

First look at MonteCarlo mc12

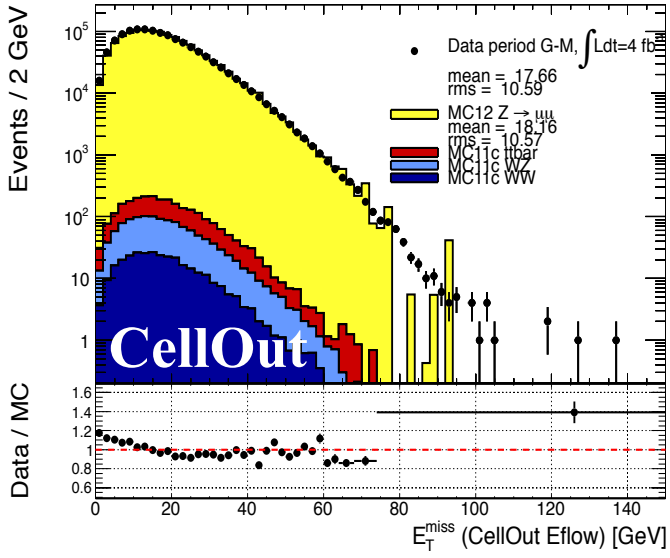


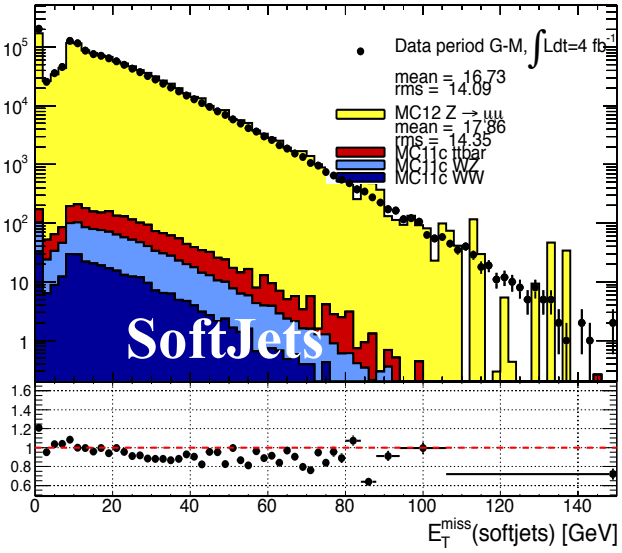




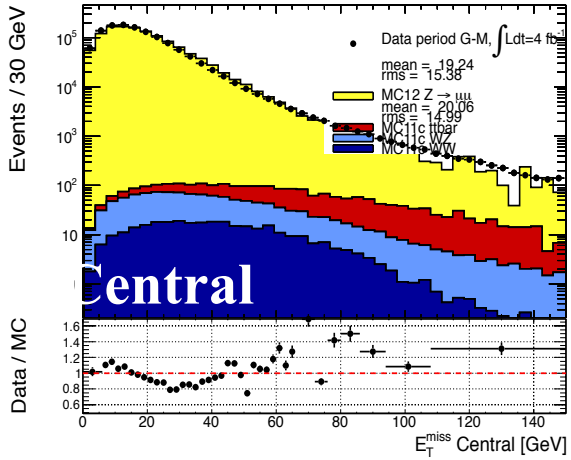
- Z→mumu data (G-M) vs Pythia8 mc12
- **Used 0.88 <mu> scaling provided by tracking WG**
- **A2M Pythia8 tuning (MSTW08 LO)** → it has been chosen as default tuning
- Good data-MC agreement

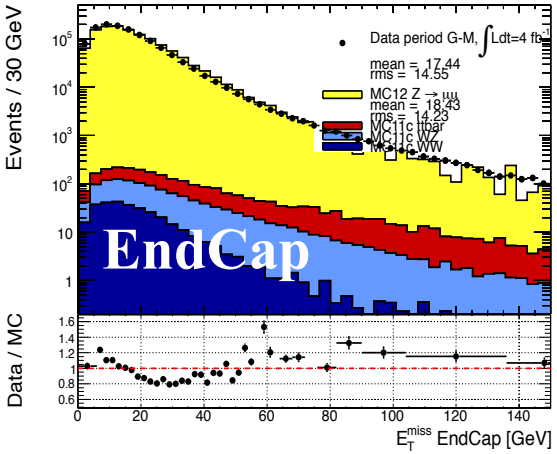
mc12: Etmiss in Soft terms and regions

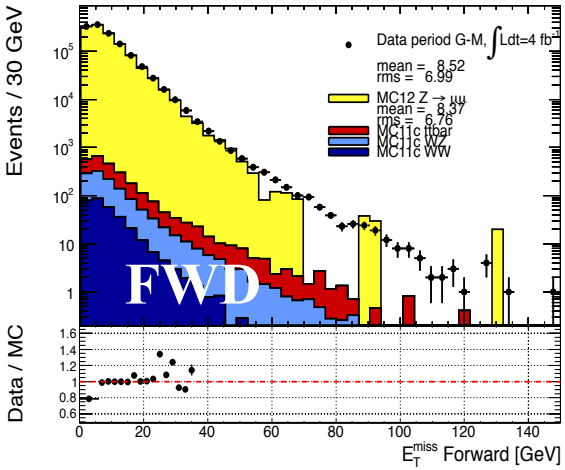




- Z→μμ data (G-M) vs Pythia8 A2M mc12
- 0.88 <mu> scaling
- Good data-MC agreement also in Soft Term and Forward







MET systematic uncertainty

The MET_RefFinal is the sum of contributions of different terms, so its systematic uncertainty is calculated from:

1. the scale and resolution uncertainties of all objects (electrons, photons, muons, taus, jets) → provided by CP groups

2. the CellOut and SoftJets uncertainties → originating from:
   A. topoclusters energy scale and threshold uncertainties, from E/p
   B. pile-up → **recent new estimation is 2.3%**

Source	CellOut	SoftJets	Obtained
A	13%	10%	E/p analysis of 2010
B	6.6%	6.6%	Data to MC11c comp: SumET vs nvtx

3. All uncertainties are propagated to the RF using the METUtility tool

New approach for soft terms systematics

- Two methods to determine the systematic uncertainty on the scale and the resolution of soft MET term (CellOut+SoftJets)
- Both methods are based on the data-MC agreement parametrized as a function of different quantities (SumET or pt hard of the event)
- Both methods take into account the dependence on Npv and <μ>

→The systematic uncertainty includes both modeling and pileup and replace the old estimation from A+B

	scale	resolution
In-situ determination in Z->ll events with no jets	4% - 5%	3%
Balance between soft terms and hard objects	3%	3% +Npv correction

- The two methods give very similar estimations
  impact on the total MET_RefFinal about 3% in Wenu events
- These new systematics will be implemented in METUtility soon