Status report on JME-10-005

CMS MET Performance in Events Containing Electroweak Bosons from pp Collisions at $\sqrt{s} = 7$ TeV

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JetMet meeting
CERN, 6 August 2010

Outline

Introduction

Goal

Demonstrate the performance of various $\not{E}_T$ algorithms using events containing a W, Z, or high p_T photon

- The focus of this PAS is NOT to study/measure EWK bosons as such but to study MET reconstruction in those events
- Study and compare the performance of various MET algorithms in events with real MET (W), measure MET scale and resolution in events with γ/Z
- CaloMET (raw, TypeI/II corrected), TcMET, PfMET

Links:

- CADI http://cms.cern.ch/iCMS/analysisadmin/cadi?ancode=JME-10-005
- HN: https://hypernews.cern.ch/HyperNews/CMS/get/JME-10-005.html
- Twiki: https://twiki.cern.ch/twiki/bin/view/CMS/EwkMetComm
- Previous Approval (indico)

History

- pre-approval (with $\sim 12\,\mathrm{nb}^{-1}$) on June 28
- approval on July 9^{th} with $\sim 56\,\mathrm{nb}^{-1}$ NOT approved
  - While one has to congratulate all people involved for the fast production of the plots with the newly arrived data, we also saw that many questions have come up and issues need to be understood in the plots, which were not visible before.
  - more work has to go into the understanding of the new results, in particular for the gamma+jet sample.
  - ... Concentrate on the data which have been taken up to now.
  - ... it is clear that we start to see PU effects, thus certain plots should be done as a function of Nvtx ...
- Decision to skip ICHEP and concentrate on analysis for $\gamma + jet$ and PU issues.

A Lighter PAS

Statistics

- Stay with "pre-ICHEP" integrated luminosity, as suggested. $\int \mathcal{L} dt \sim 200\,\text{nb}^{-1}$.

New PAS

- $\not{E}_T$ in Photon + Jet Events
- $\not{E}_T$ reconstruction in events with a W
- POSTPONED WAITING FOR MORE DATA Performance of $\not{E}_T$ reconstruction in events with a Z boson
- DROP FOR THE TIME BEING
  - Effects of muon reconstruction uncertainties on $\not{E}_T$
  - $\not{E}_T$ significance
  - Estimating the $\not{E}_T$ distribution in $W \to e\nu$ events

Title and abstract

CMS MET Performance in Events Containing Electroweak Bosons from pp Collisions at $\sqrt{s} = 7$ TeV
JME-10-005

During the spring of 2010, the LHC delivered proton-proton collisions with a centre-of-mass energy of 7 TeV. In this note, we present results of studies of missing transverse energy, as measured by the CMS detector, in events containing W bosons or isolated, high transverse momentum photons. The performance of several different MET reconstruction algorithms is compared.

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ARC: Fabio Cossutti (Trieste), Sharon Lee Hagopian (Florida-state), Paraskevas Sphicas [chair] (CERN)

Supporting Documents

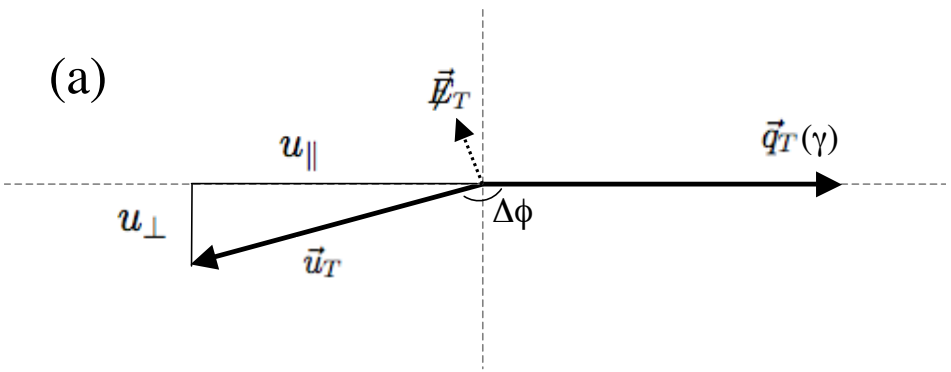
Seven supporting AN

- **AN-2010/118** CMS MET Performance in Events Containing Electroweak Bosons decaying into muons from pp Collisions at $\sqrt{s} = 7$ TeV
- **AN-2010/131** Type-I and Type-II CaloMET performances in 7TeV data
- **AN-2010/132** MET Scale Validation with Photon + Jet Events (TTU)
- **AN-2010/176** Commissioning of the missing transverse energy in $W \to \mu\nu$ events for 12 nb^{-1} with the pp center-of-mass energy of $\sqrt{s} = 7$ TeV
- **AN-2010/202** Missing transverse energy performances with electroweak bosons decaying into electrons in pp collisions at $\sqrt{s} = 7$ TeV

Basic Selection and Definition

Uniform Selection

- Vertex requirement, datasets, trigger selections (muon and electron)
- Electron and muon IDs following the VBTF recommendations (more on this later...)
- EGamma electrons are used in the studies of PFMET, in agreement with PF POG
- ECAL/HCAL noise is cleaned in re-reco used in the analysis



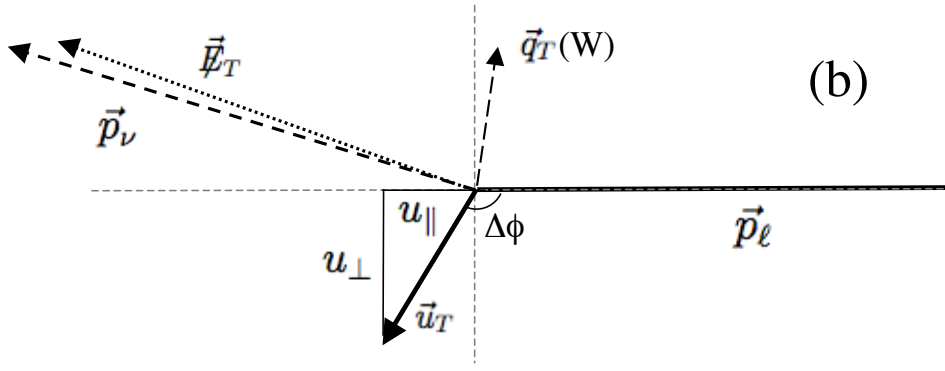
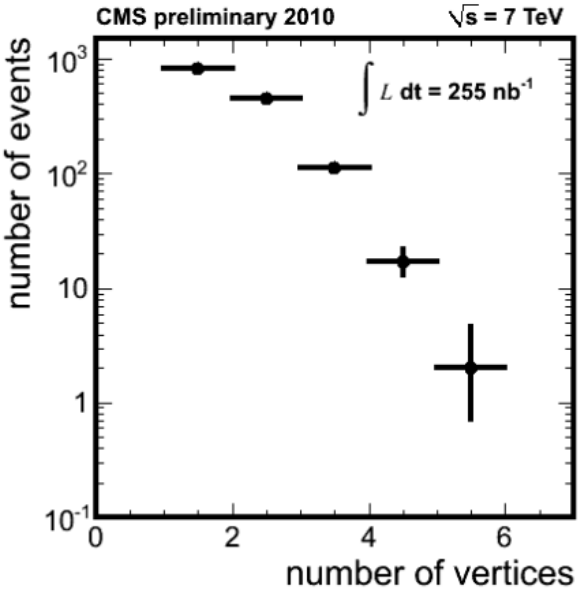


Figure: Kinematics: (a) Photon-Jet events; (b) W events. (Note that the lepton direction need not be as strongly correlated with the W direction as indicated

PU Estimation and Treatments

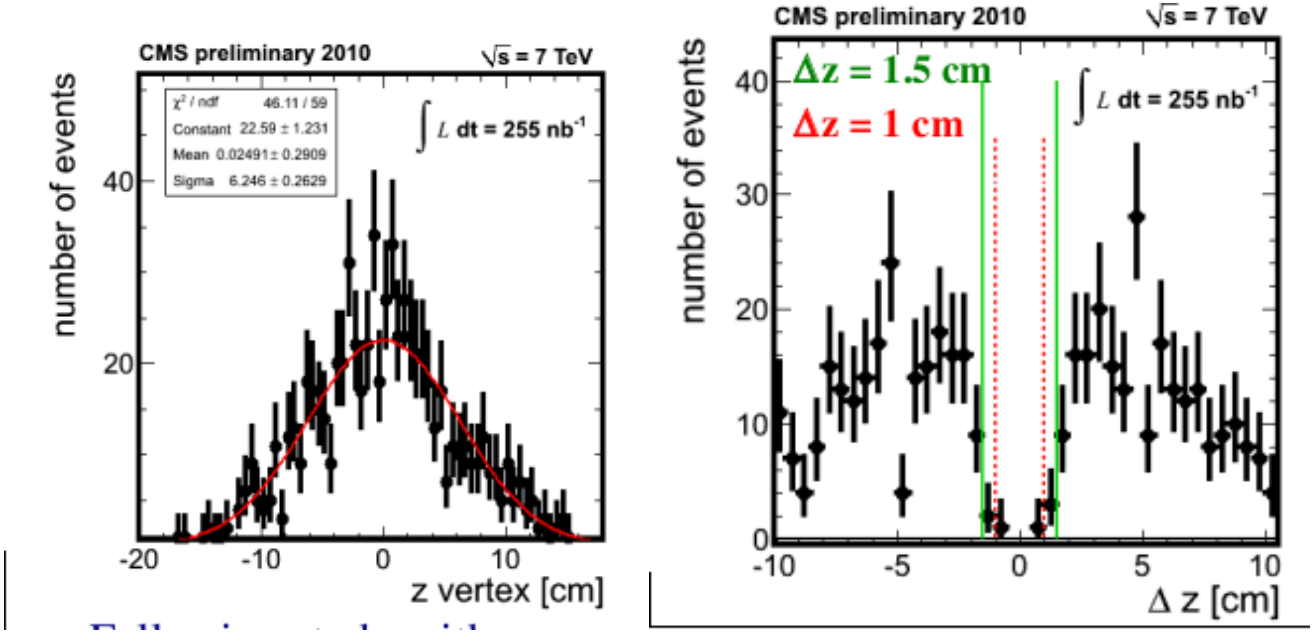
- MET related variables are sensitive to PU.
- Require just one Primary Vertex.
- MOTIVATION: start with simple (no PU) events and then eventually move to events with PU (not for this PAS)
- Estimate PU distribution by PV multiplicity: 58% 1 PV



- Contamination from 2 not resolved PV estimated with toy MC to be $\sim 7 \pm 2\%$ (next slide)

Contamination from multiple PV

- Get z_{pv} distribution from data: $\sigma = 6.25 \pm 0.26$ cm



- Get minimal Δz for two PV to be resolved from data: $\Delta z = 1.5 \pm 0.5\,\text{cm}$
- Use Toy MC to estimate the $PV = 2$ contamination in $PV = 1$ sample: $5 - 7 \pm 2\%$. Negligible for $PV > 2$.
- scale the multi-PV distribution and subtract from the 1-vertex distribution

Outline

$\not{E}_T$ in Photon + Jet Events

Goal

- Events with no intrinsic $\not{E}_T$
- cross-section larger than that of Z
- *induce* $\not{E}_T$ by removing γ deposit in calo
- magnitude of *induced* $\not{E}_T$ well known.

- trigger HLT_Photon10_L1R
- Photon ID based on *loose* selections
  (see ‘‘Photon reconstruction and identification at $\sqrt{s} = 7\,\text{TeV}$’’, EGM-10-005.)

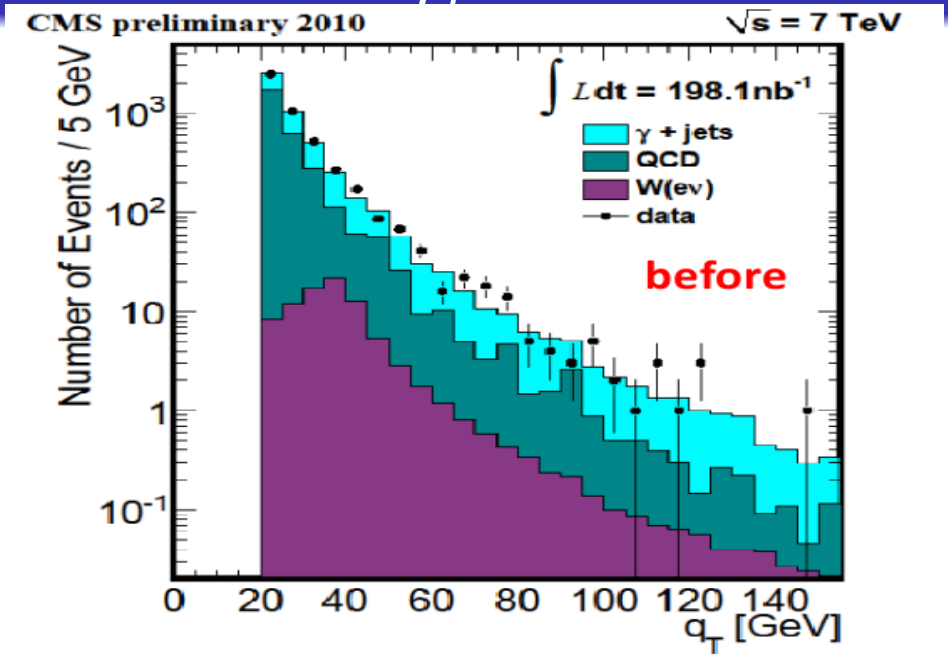
Analyzed Data Sample:

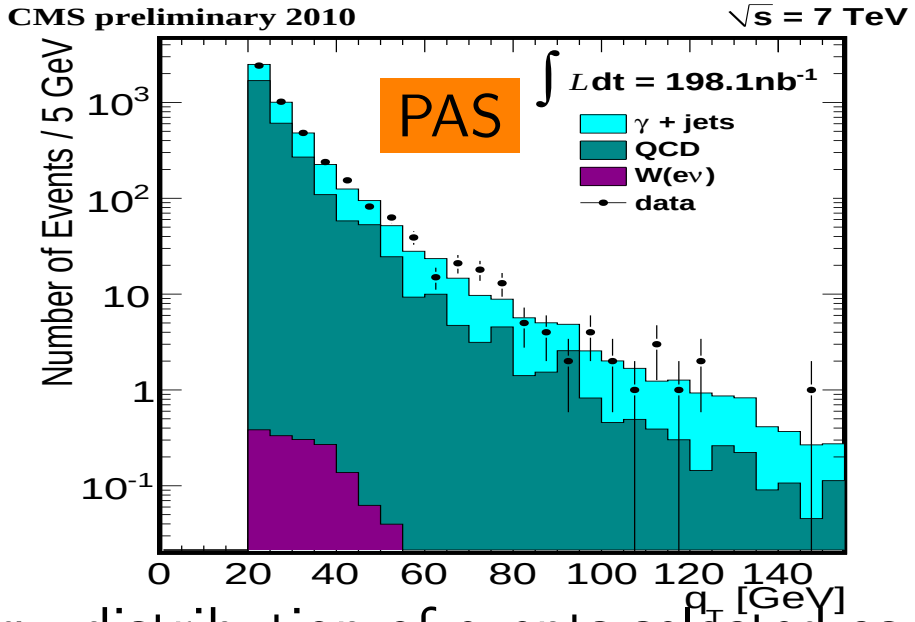
$\int \mathcal{L} dt = 198.1\,\text{nb}^{-1}$

Event selection:

- ECAL energy deposit ($\Delta R < 0.4$) $E < 4.2 + 0.004 \times q_T$.
- HCAL energy deposit ($\Delta R < 0.4$) $E < 2.2 + 0.001 \times q_T$.
- Ratio HCAL/ECAL ($\Delta R < 0.15$) $R < 0.05$.
- N. tracks ($\Delta R < 0.4$) $N_{trk} < 3$.
- $\Sigma_{(0.04<\Delta R<0.4)} p_{\mathrm{T}} < 2.0\,\mathrm{GeV} + 0.001 \times q_T$
- $R9 > 0.9 \times E^{\gamma}$
- γ cluster major and minor 2^{nd} moments in $0.20 - 0.35$, $0.15 - 0.3$.
- $\eta_{width} < 0.03$
- $q_T > 20$ and $|\eta| < 1.479$ (Barrel)
- Only 1 Primary Vertex (No PU)
- γ supercluster not match pixel hits consistent with a track from the interaction region ($W \to e\nu$ suppression)

Photon q_T and $W \to e\nu$ suppression





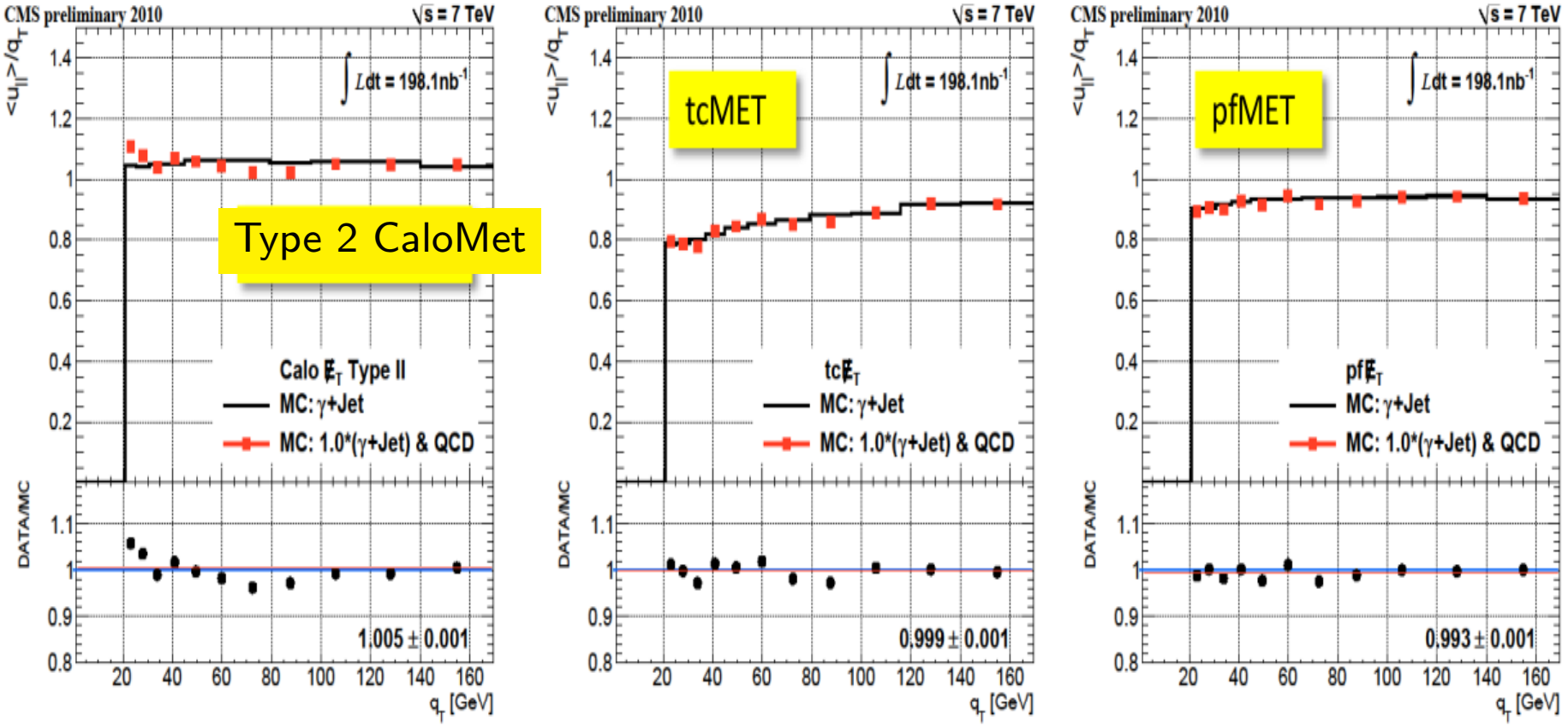
- significative amount of $W \to e\nu$ events pass standard γ loose ID
- not considered as background in previous approval
- strongly suppressed ($\sim 98\%$) by pixel seeds veto

q_T distribution of events selected as photon-jet candidates. Monte Carlo predicted rates for signal and backgrounds are as shown.

QCD di-jet contamination is dominated by $\pi^0 \to \gamma\gamma$ enriched jets. Still good for energy scale studies

Effect of di-jet contamination (NOT FOR PAS)

Shown response ($u_{||}/q_T$) for MC pure $\gamma + jet$ and $\gamma + jet$ & QCD di-jet



MC studies shows that QCD (di-jet) contamination give no bias in MET response

Recoil projections along the γ axis

Parallel component used to study $\not{E}_T$ scale and resolution PAS

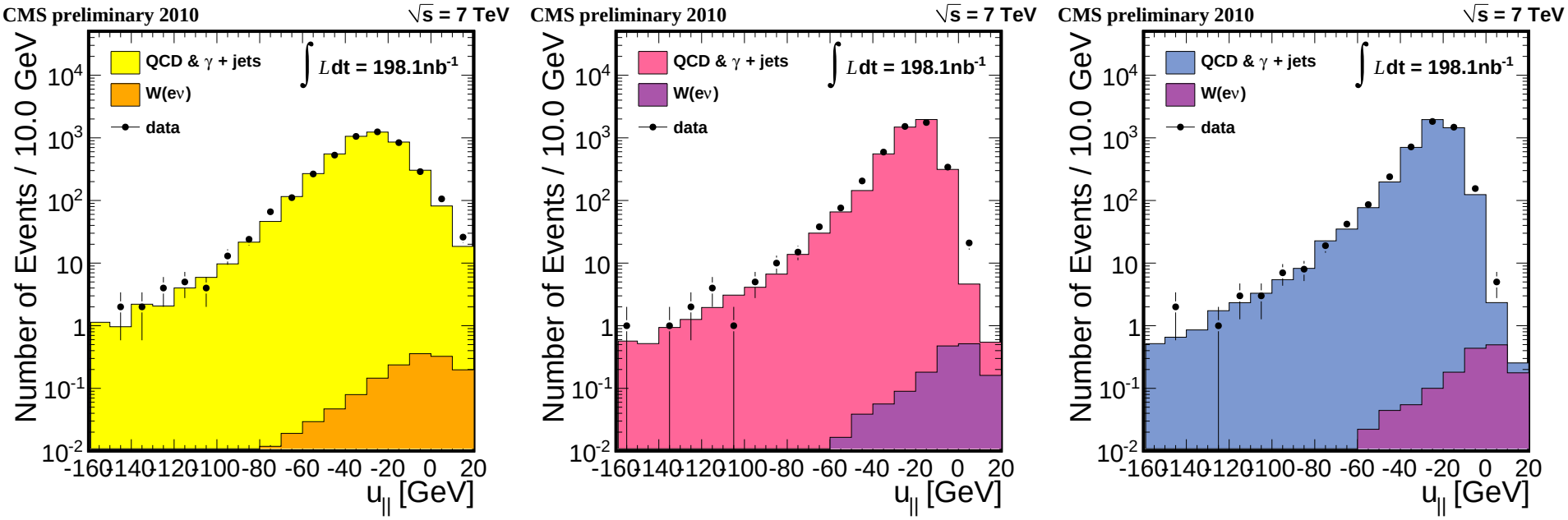
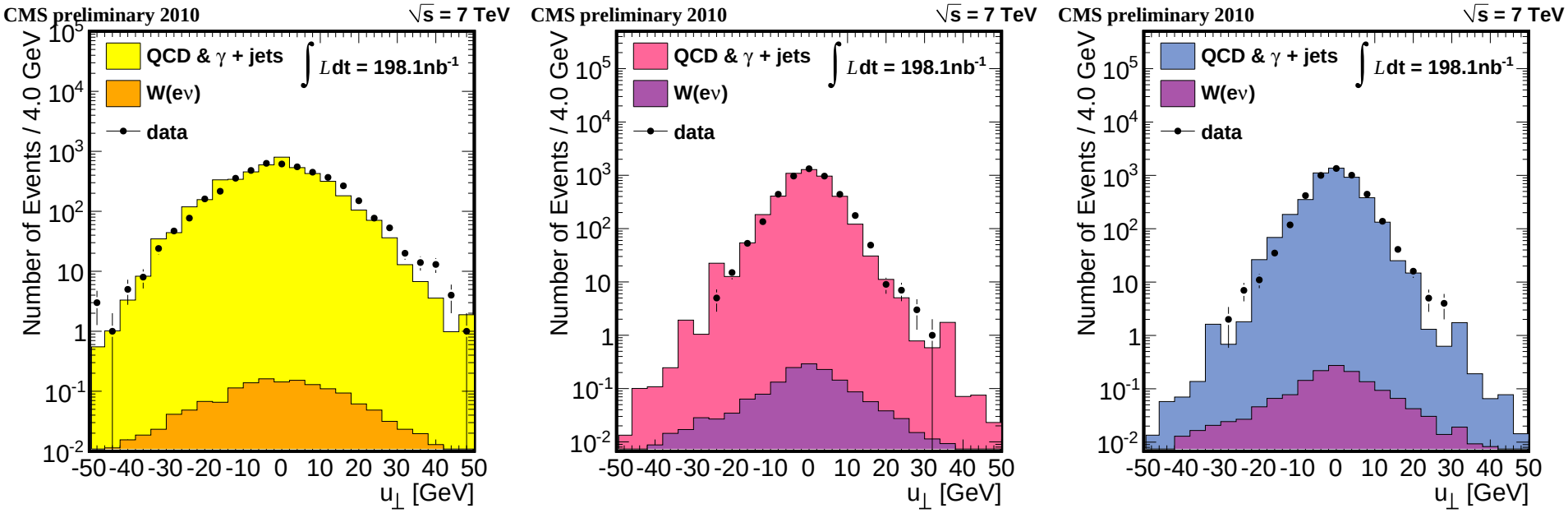


Figure: Decomposition of hadronic recoil into components parallel and perpendicular to photon probe. Upper row: $u_{||}$ distributions for (left to right) calo$\not{E}_T$, tc$\not{E}_T$, and pf$\not{E}_T$;

$W \to e\nu$ contamination strongly suppressed by pixel seed veto

Recoil projections perpendicular to the γ axis

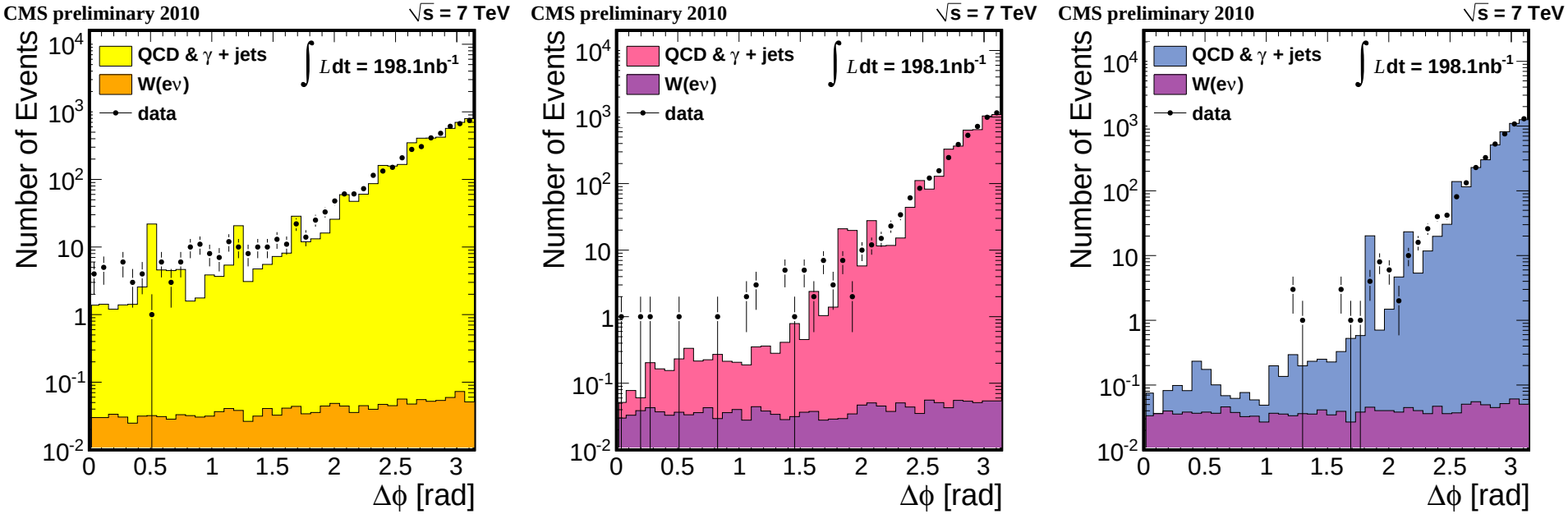
Perpendicular component used to study $\not{E}_T$ resolution due to calo nois, UE and PU PAS



- PU affect the width of distribution See later
- 1 Primary vertex to select event with no PU
- NO PileUp in MC simulation

Angular correlation

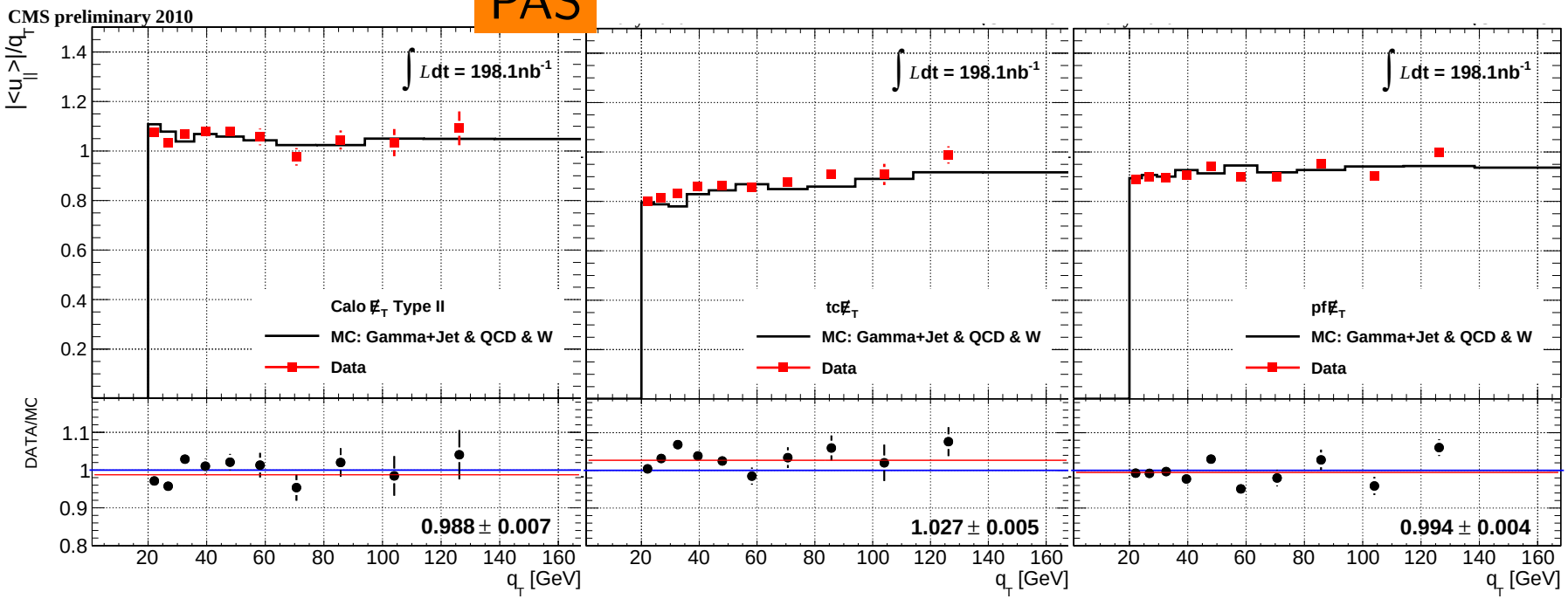
Angular correlation between hadronic system and photon, $\Delta\phi = \cos^{-1}(\hat{u}_T \cdot \hat{q}_T)$, for (left to right) calo$\not{E}_T$, tc$\not{E}_T$, and pf$\not{E}_T$. PAS



- $W \to e\nu$ is flat in $\Delta\phi$
- If not suppressed give large contribution at low $\Delta\phi$ (see previous approval talk)
- List of Tc$\not{E}_T$ events with $\Delta\phi < 2$ given to expert for inspection.

$\not{E}_T$ Scale: $|u_{||}|/q_T$

PAS

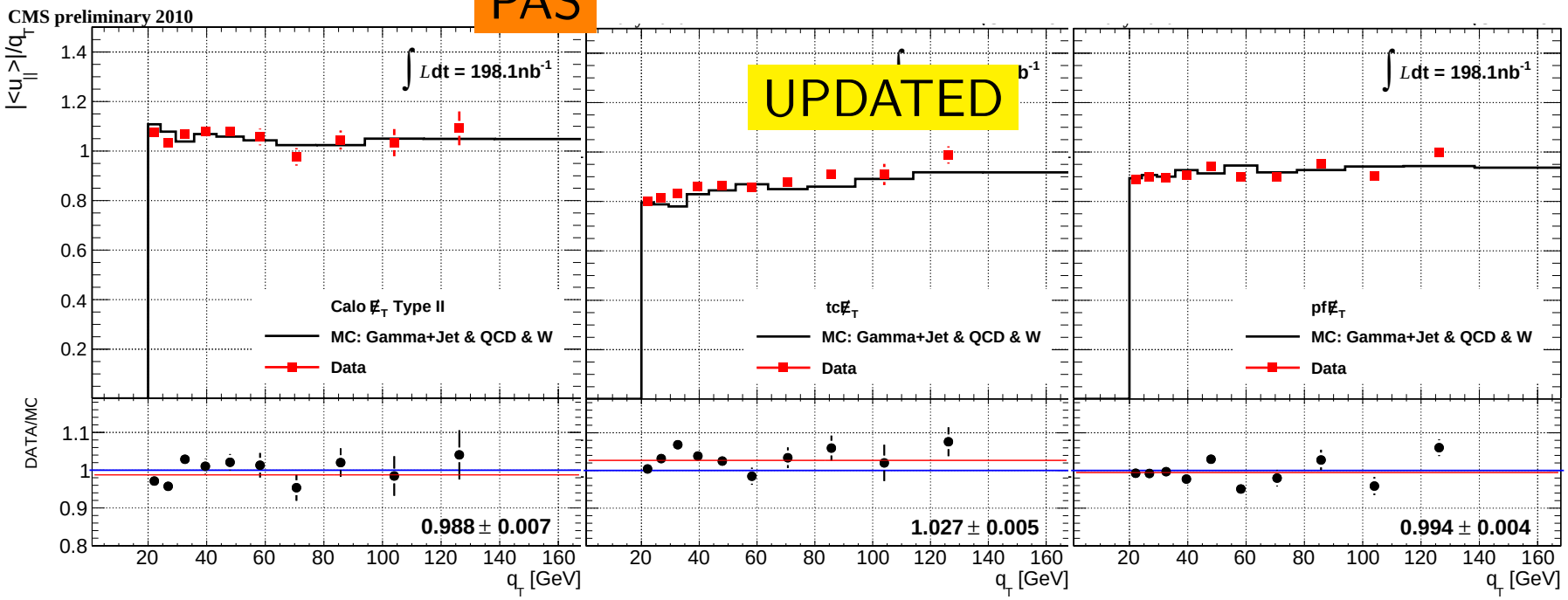


JES correction are based on quark and gluon jets. Response to quark jets is $\sim 10\%$ higher that gluon one. Direct γ have mostly quark jet, so overcorrection is expected.

$\not{E}_T$ Scale: $|u_{||}|/q_T$ Updated

PAS

UPDATED

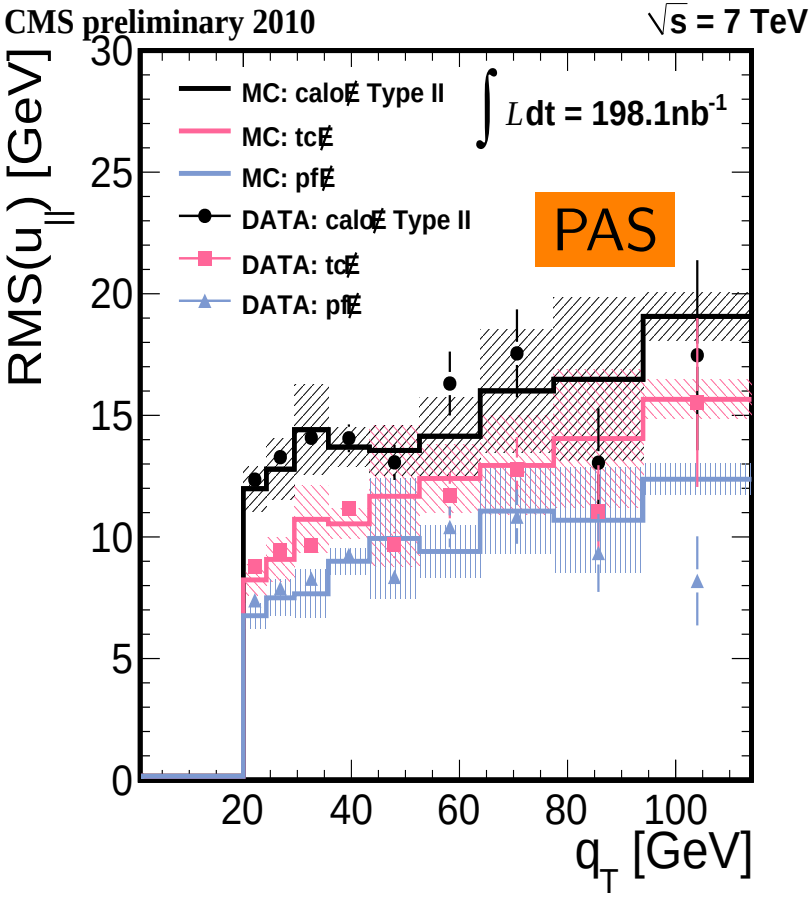


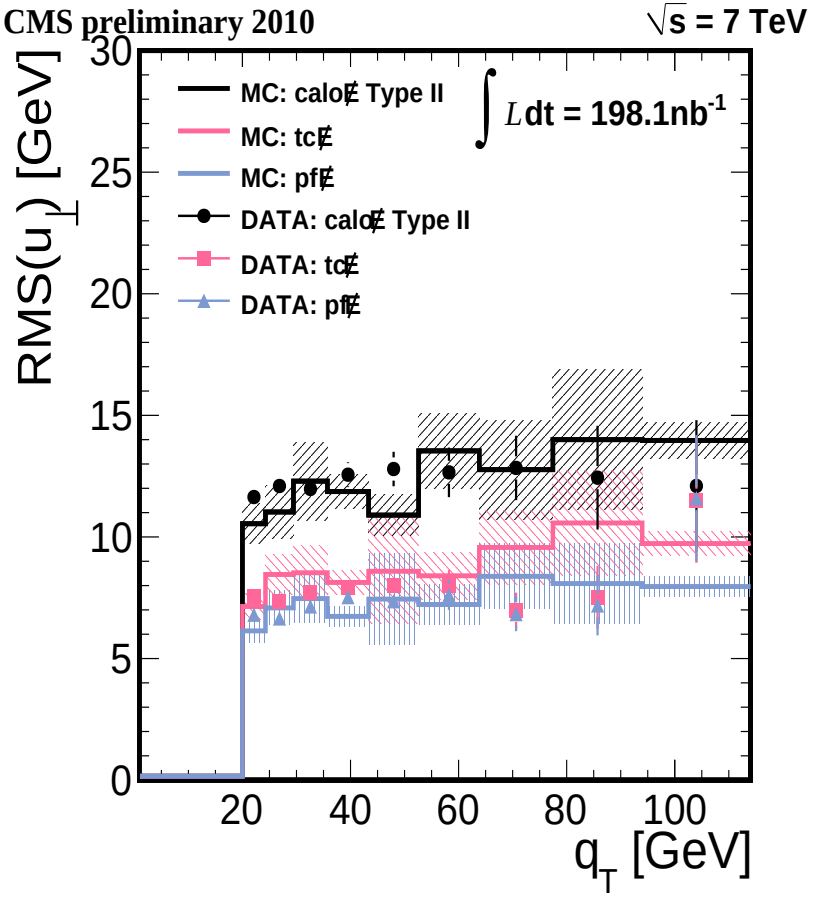
WARNING!

For TC$\not{E}_T$ a re-reco for MC was produced, using the same 36x based TcMet algo as in the data. It changes the MC response by $\sim 4\%$, yielding a better agreement with Data

We henceforth ask to be allowed to update the TcMET plots: only the MC curves chances, DATA do not!

Resolution for u_T vs q_T

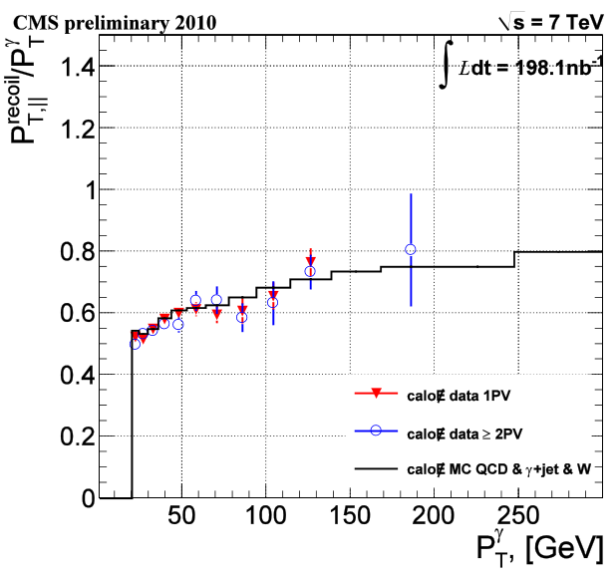


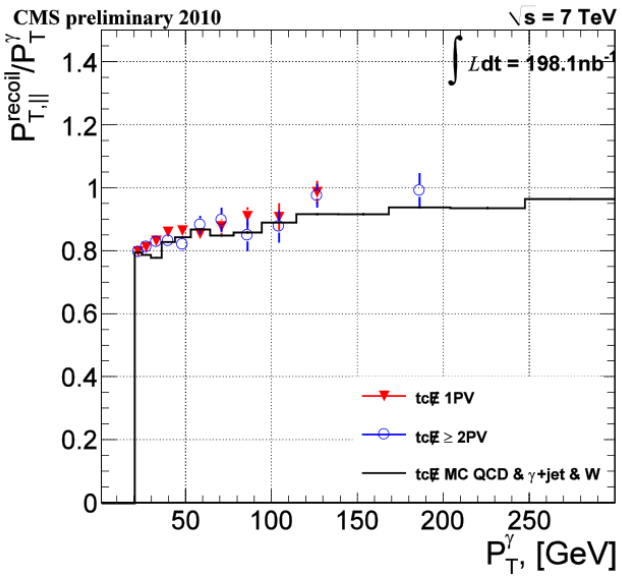


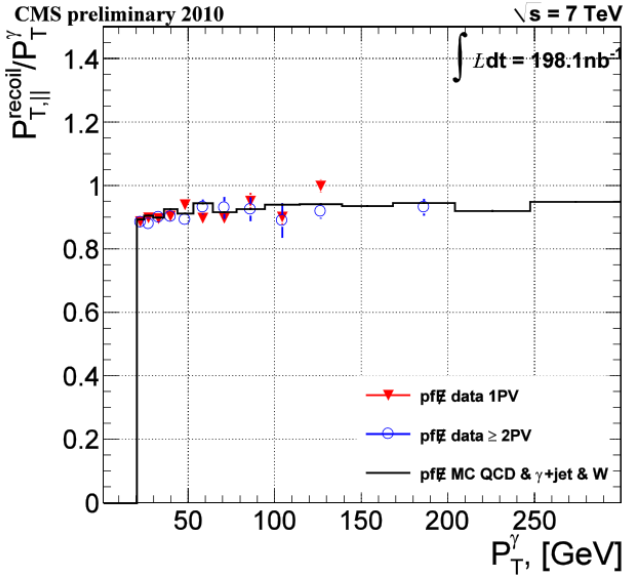
- Resolution (RMS) $u_{\parallel}$ and $u_{\perp}$, vs q_T
- including uncertainties from MC
- Resolution corrected for response curve
- Use of tracking information improves significantly the MET resolution

Effect of PU on scale

Response for events with $PV = 1$ and $PV \geq 2$ Not for PAS



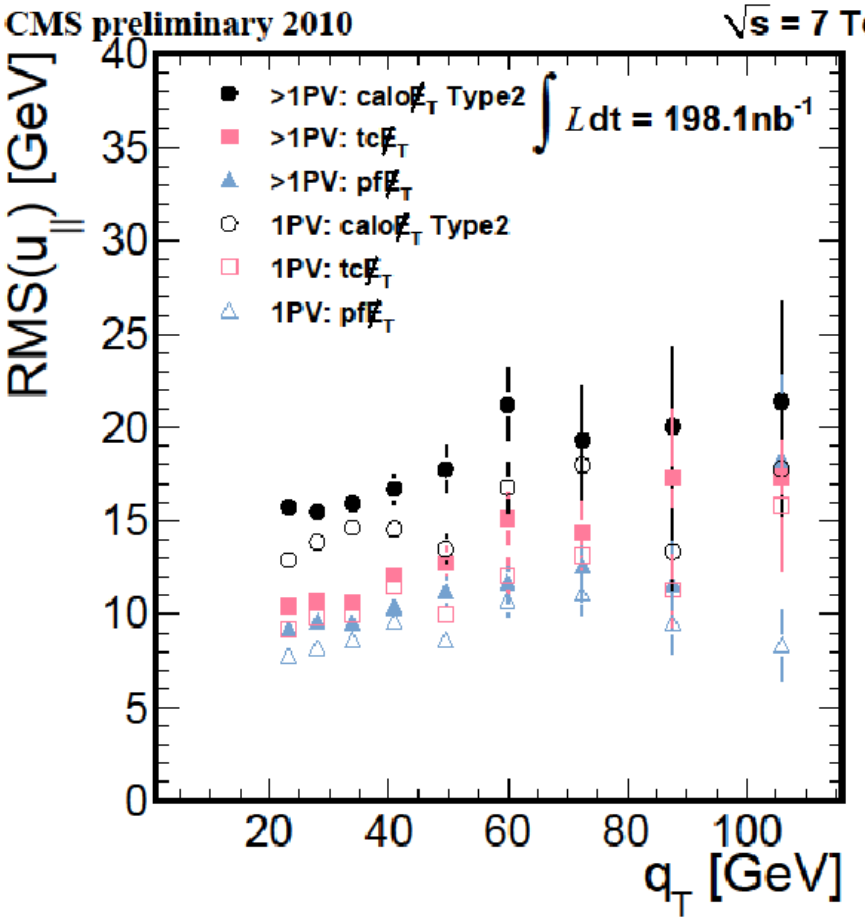


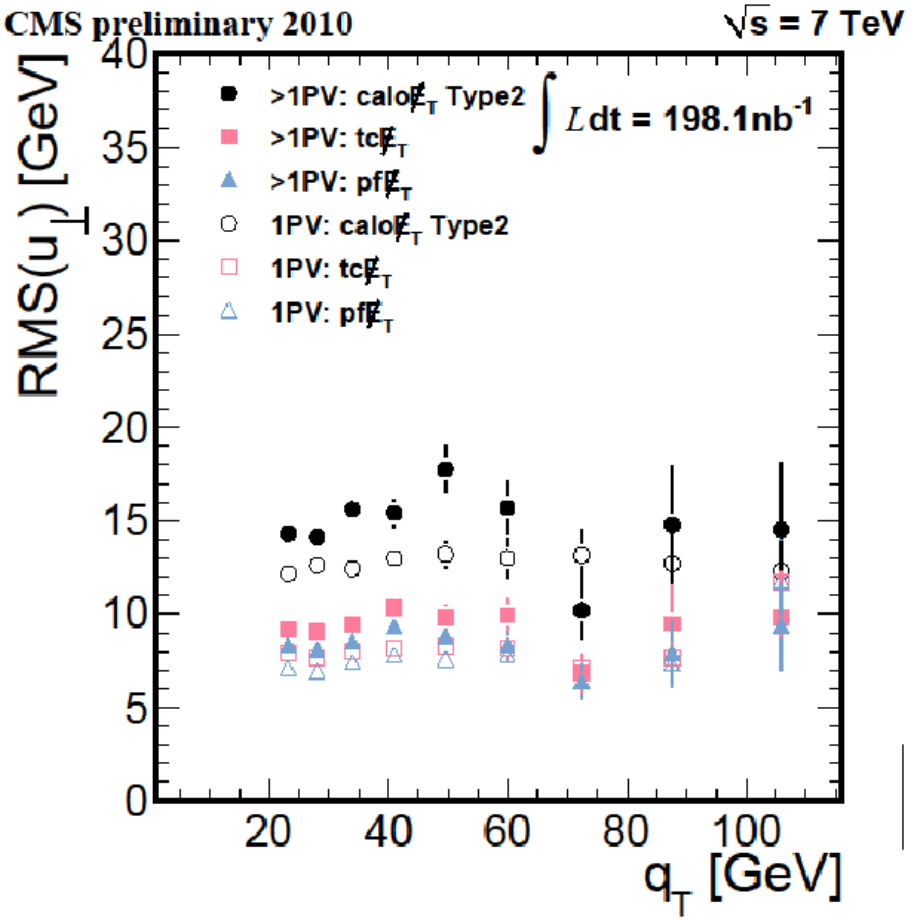


NO significant effect due to PU

Effect of PU on resolution

Resolution (RMS for $u_\perp$ and $u_\parallel$) as a function of q_T for events with 1 Primary Vertex and ≥ 2 PV for three different $\not{E}_T$ algos. Not for PAS
Data after $W \to e\nu$ pixel veto



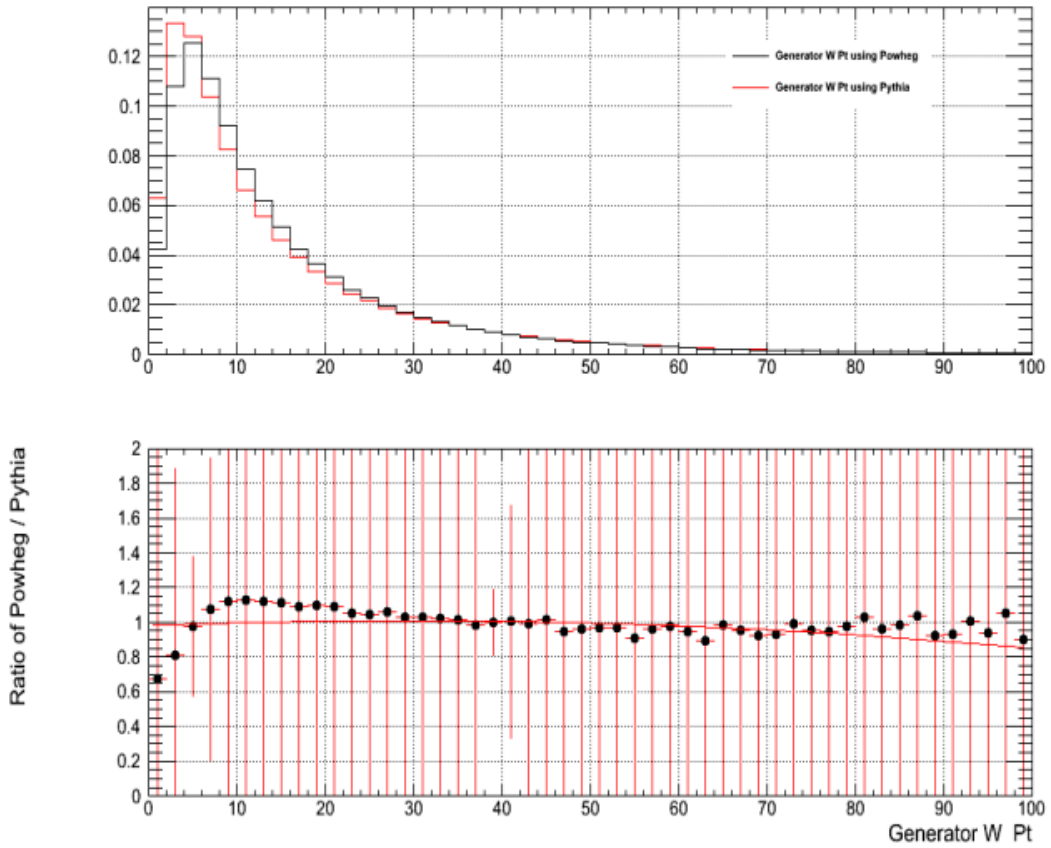


Outline

W q_T uncertainty

MC uncertainties for q_T

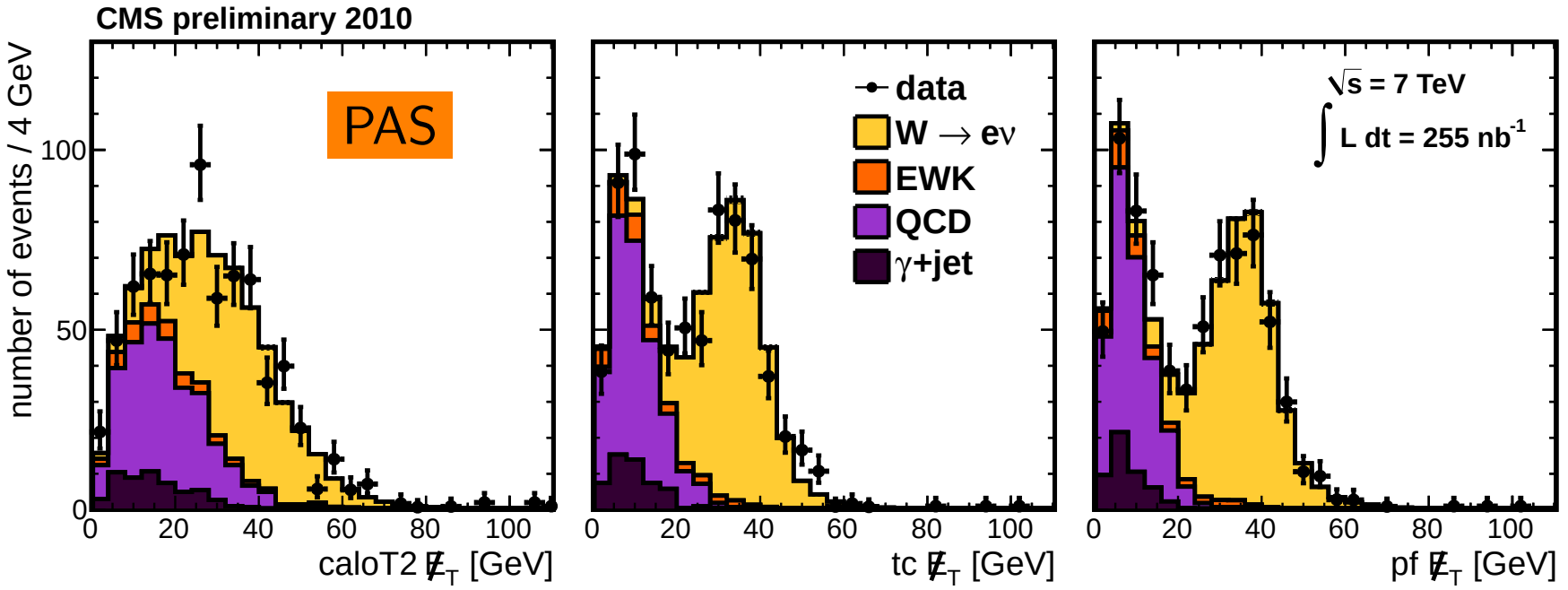
- Use standard PYTHIA and POWHEG
- Compare the two q_T distribution
- Use difference between original and reweigthed as systematic error, bin per bin.
- add this to error from PU contamination, as described before



$W \to e\nu$ selection

- Standard VBTF selection WP 80% no $\Delta\eta$ cut in endcap (EGamma prescription)
  - HLT $p_{\mathrm{T}}(e) > 10\,\mathrm{GeV}$
  - Electron id 80% efficiency.
  - $|\eta_e| < 2.5$ excluding $1.4442 < |\eta| < 1.56$
  - η dependent isolation on ECAL, HCAL and tracks
  - No second electron $p_{\mathrm{T}} > 20\,\mathrm{GeV}$
- GSF filter + supercluster $p_{\mathrm{T}} > 25\,\mathrm{GeV}$ (VTBF is > 20)
- only 1 Primary vertex
- PU contamination cleaning
- Additional cuts to enrich $W \to e\nu$
  - $\not{E}_T > 25\,\mathrm{GeV}$
  - $M_{\mathrm{T}} > 50\,\mathrm{GeV}$
- POWHEG MC used
- QCD and EWK normalization by a fit on $\not{E}_T$ shape
- $\int \mathcal{L} dt = 255\,\mathrm{nb}^{-1}$

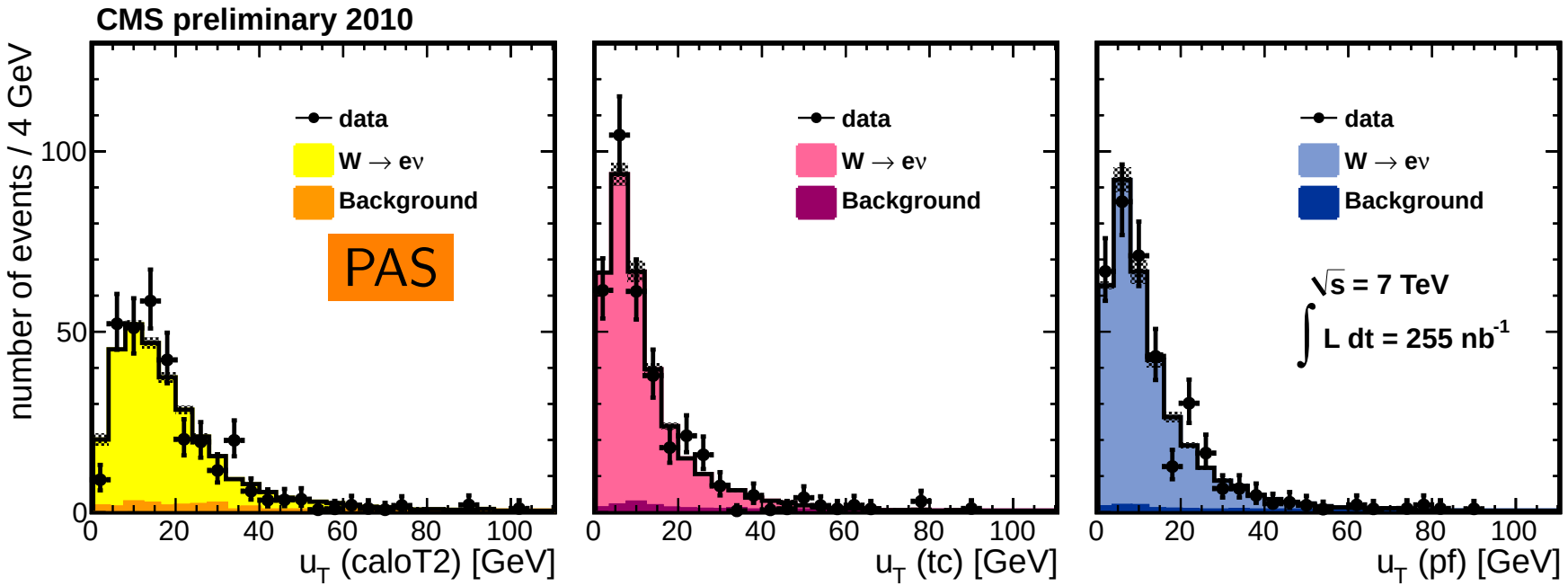
$\not{E}_T$ distribution in $W \to e\nu$ events



REMINDER: changes from previous PAS:

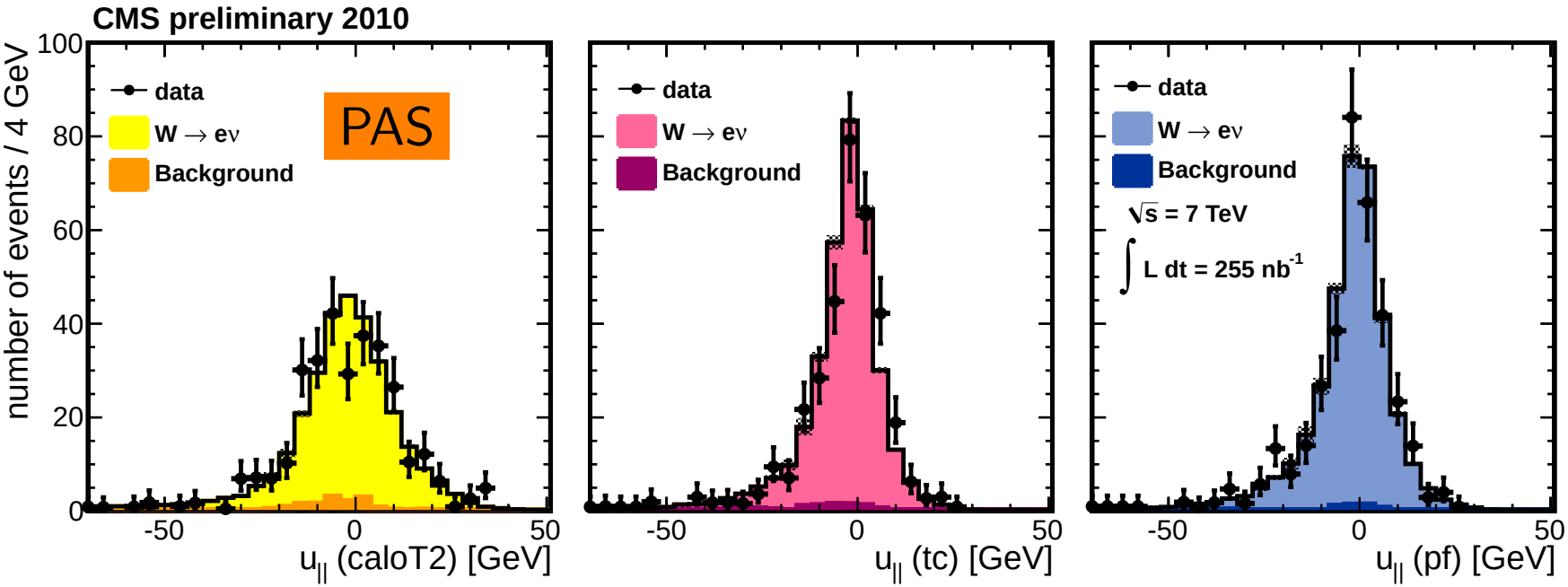
- $p_T(ele) > 25$ GeV (was 20)
- NO $\not{E}_T$ cut;
- 1 primary vertex and PU cleaning

Recoil in $W \to e\nu$ events



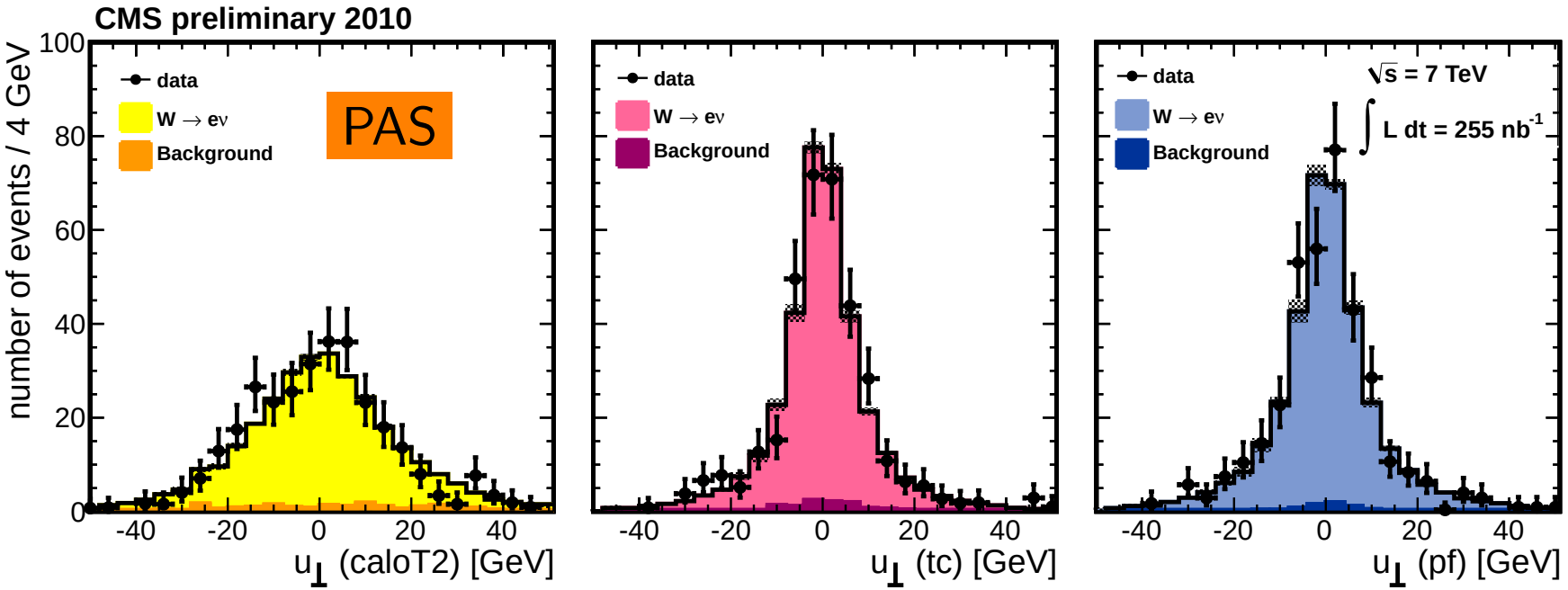
- agreement at low $u_\perp$ much better due to Primary Vertex requiremend and PU cleaning
- Uncertainties at low $u_\perp$ dominated by q_T ones.

Recoil along q_T in $W \to e\nu$ events



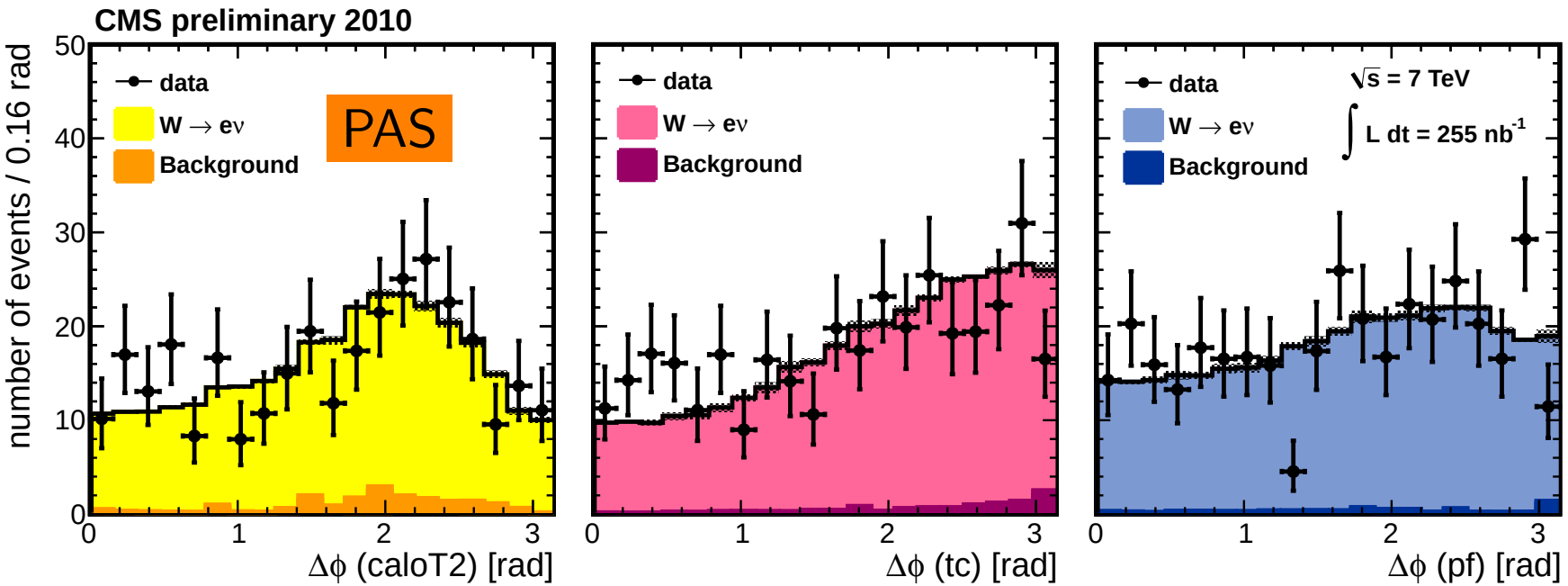
- Projection along $p_T(\ell)$, not q_T (unknown): correlation is good for boosted W
- Asymmetry due to strict isolation cut on $W \to e\nu$
- When $u_{||}$ is positive, electron and hadronic activities are in the same hemisphere, more likely that the electron is not isolated.

Recoil perpendicular to q_T in $W \to e\nu$ events



- Calo$\not{E}_T$ is clearly broader than TC and PF$\not{E}_T$
- Still dominated by true $\not{E}_T$ resolution

$\Delta\phi$ recoil-lepton in $W \to e\nu$ events

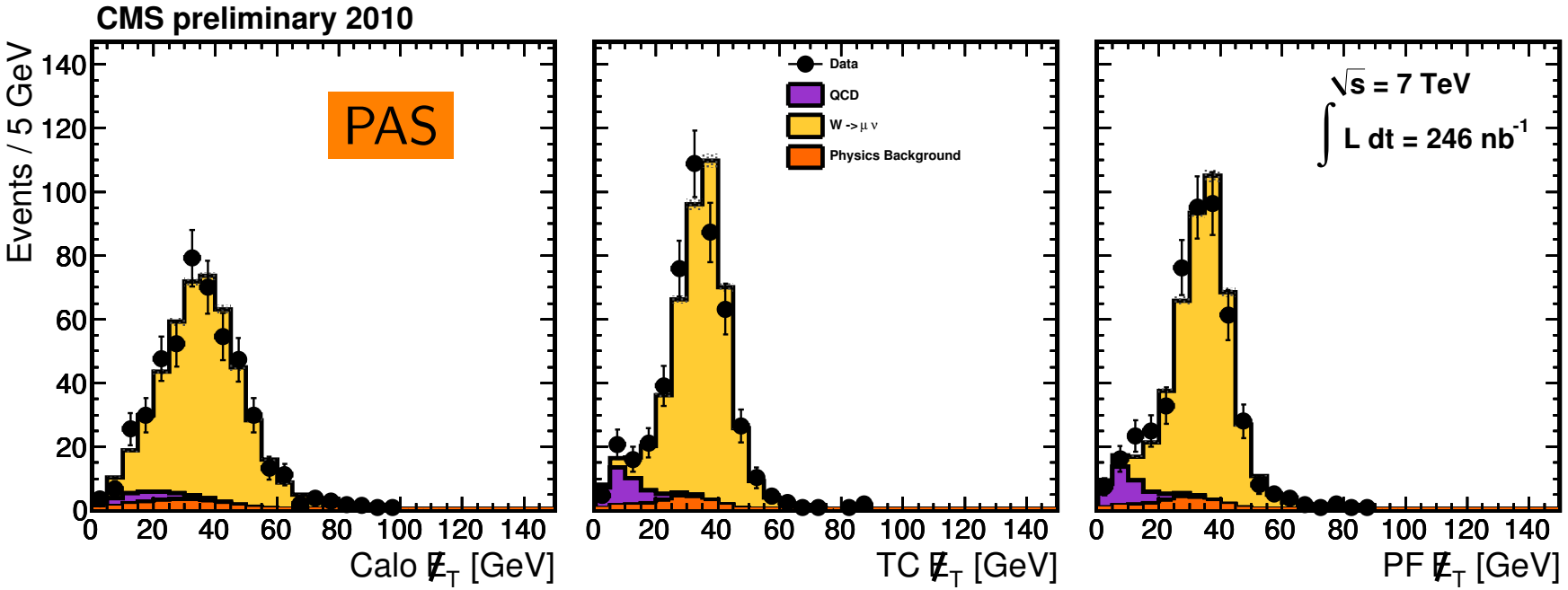


- Good agreement within statistical errors

$W \to \mu\nu$ selection

- Standard VBTF selection
  - HLT $p_T(\mu) > 9$ GeV $\mathrm{HLT\_Mu9}$
  - Muon *Global* and *Tracker*
  - Tracker hits> 10, Pixel hits> 0; Muon hits> 0;
  - EM veto < 4 GeV; Hadronic veto < 6 GeV;
  - Relative combine isolation < 0.15
  - impact parapameter (beam spot) < 2 mm
  - Global fit $\chi^2 < 10$
  - $|\eta| < 2.1$
- Muon $p_T > 25$
- only 1 Primary vertex
- PU contamination cleaning
- Additional cuts to enrich $W \to \mu\nu$
  - $\not{E}_T > 25$ GeV
  - $M_T > 50$ GeV
- QCD and EWK normalization by a fit on $\not{E}_T$ shape
- $\int \mathcal{L} dt = 246\,\mathrm{nb}^{-1}$

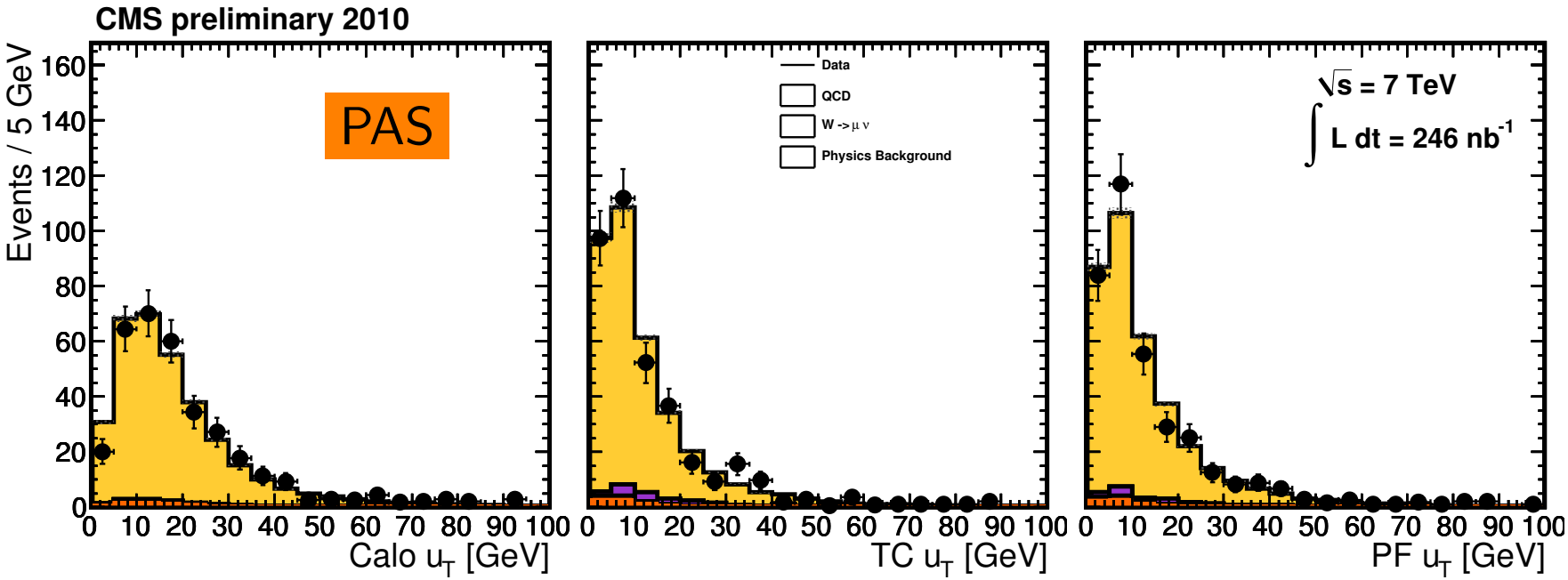
$\not{E}_T$ distribution in $W \to \mu\nu$ events



REMINDER: changes from previous PAS:

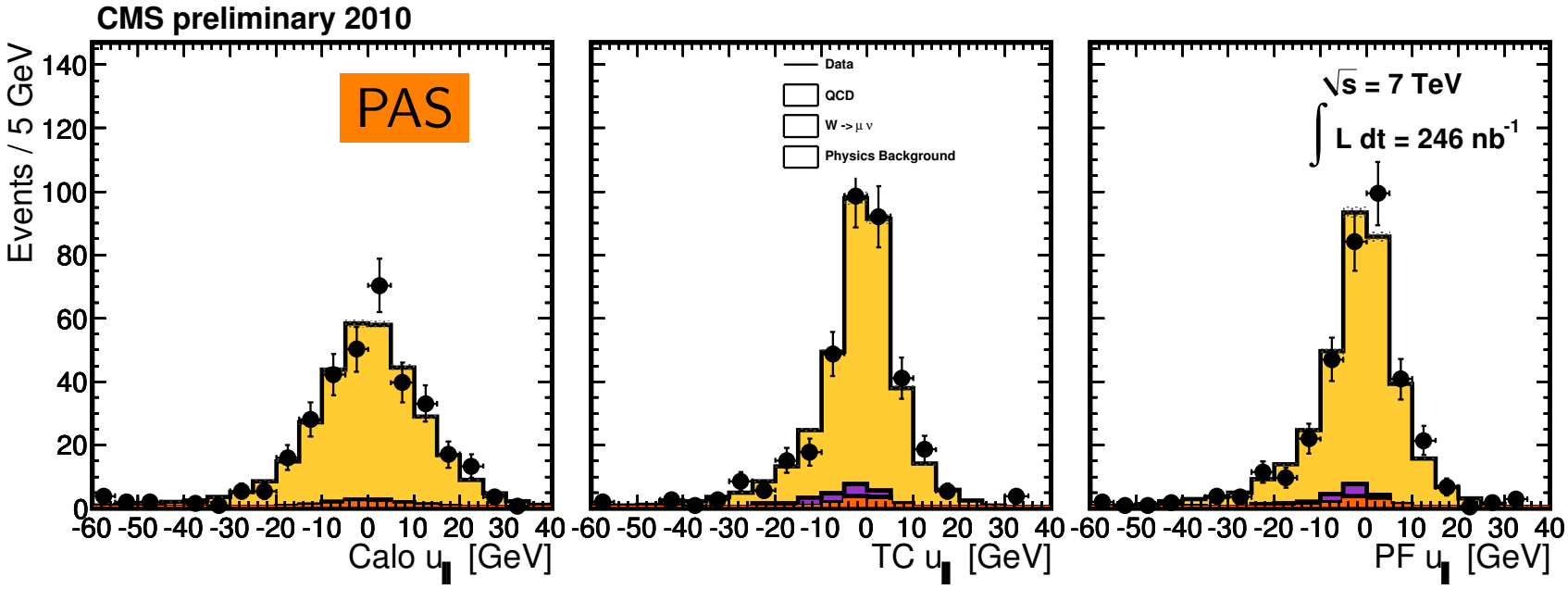
- $p_T(\mu) > 25$ GeV (was 20)
- NO $\not{E}_T$ cut;
- 1 primary vertex and PU cleaning

Recoil in $W \to \mu\nu$ events



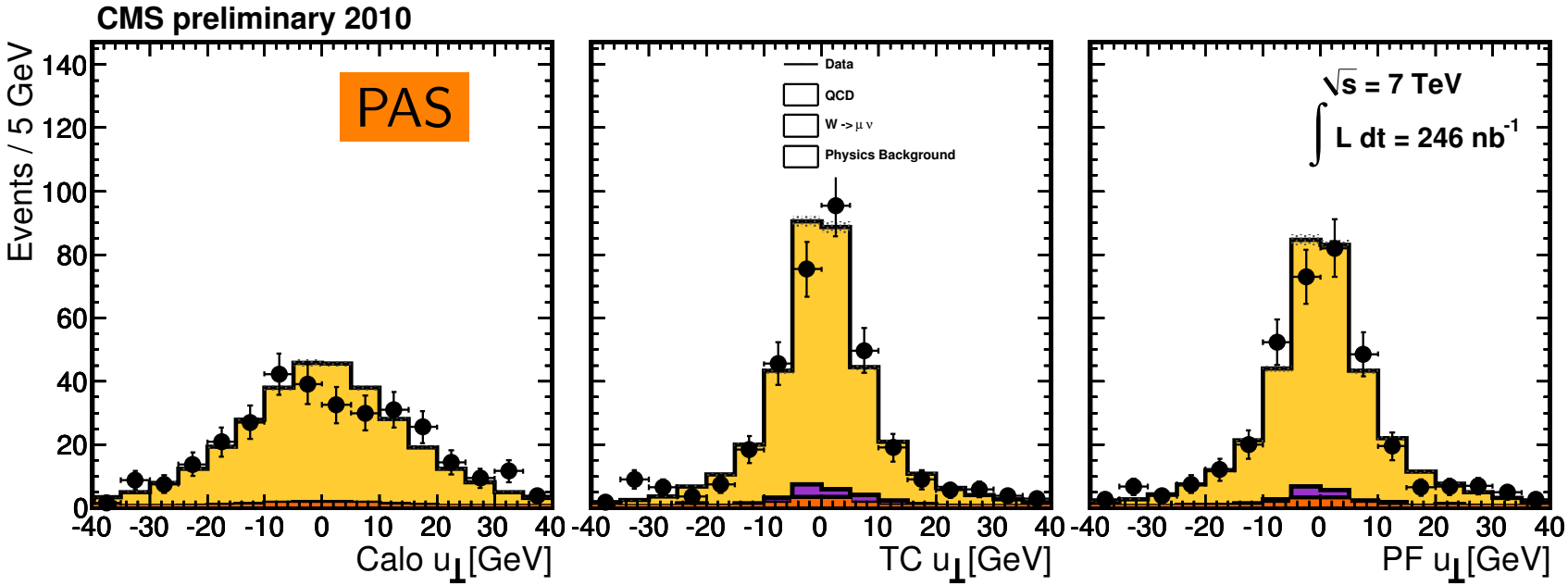
- Good agreement at low u_T thanks to PU contamination removal;

Recoil along q_T in $W \to \mu\nu$ events



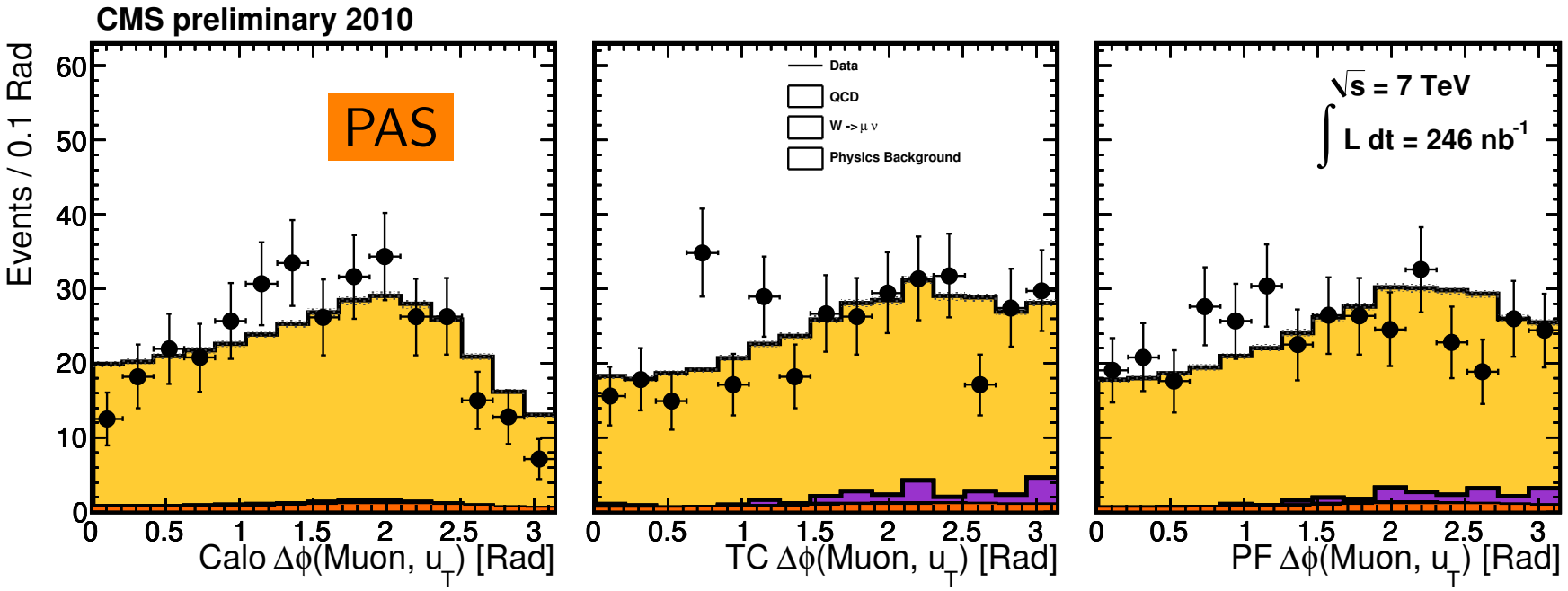
- Small/no asymmetries as compared to $W \to e\nu$ due to softer isolation cut.
- As for $W \to e\nu$, good correlation between $p_{\mathrm{T}}(\ell)$ and q_T only for boosted W

Recoil perpendicular to q_T in $W \to \mu\nu$ events



- Narrower distribution for TC and PF$\not{E}_T$

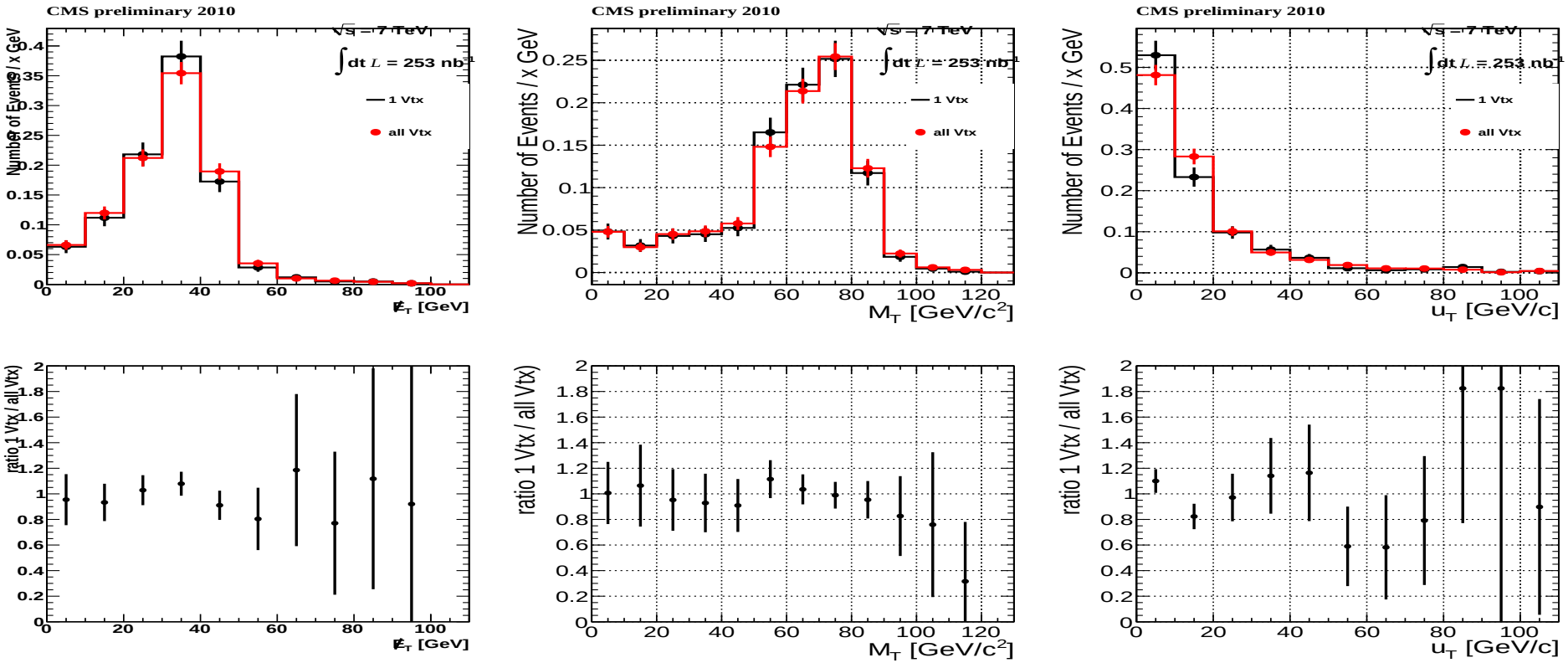
$\Delta\phi$ recoil-lepton in $W \to \mu\nu$ events



- Good agreement between data and MC

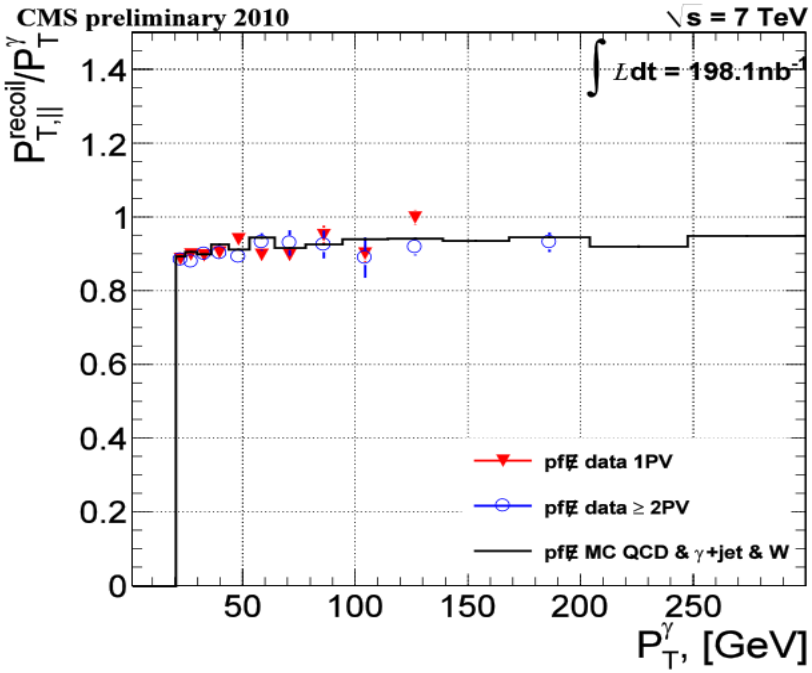
Any effect of PU in EWK studies?

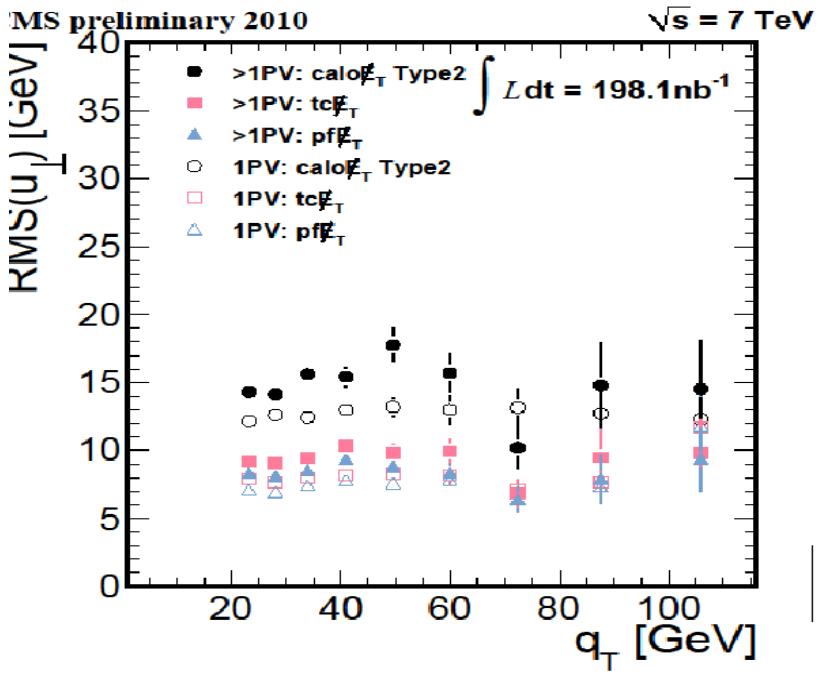
- Very limited effect of PU on M_{T} and $\not{E}_T$ distribution, on which the EWK analysis is based. Significant only for hadronic recoil
- Below: $\not{E}_T$ (l), M_{T} (c) and u_T (r) for $W \to \mu\nu$ case with Pf$\not{E}_T$



Any effect of PU in EWK studies? /II

- From $\gamma + jet$ analysis, no (or negligible) effect on MET scale from the PU.
- (limited) effect on $\not{E}_T$ resolution from PU
- will be needed for analysis such as W mass measurement (not in ICHEP EWK program)





Outline

Conclusion

$\gamma + jet$

- Studies presented with $198.1\,\mathrm{nb}^{-1}$
- Analysis updated
  - considering $W \to e\nu$ contamination
  - introducing further cut (pixel seeds) to effectively reduce it
  - reducing PU effect by requiring just 1 Primary Vertex and multi-PV cleaning
- PU effect visible in MET resolution but NOT in response (not for PAS)
- Good agreement data-MC seen

Conclusion/II

$W \to e\nu$ and $W \to \mu\nu$

- Studies presented with 255 and 246 nb^{-1} respectively
- Improvement wrt previous PAS
  - More strick cuts to select purer W sample
  - Select events with just one Primary Vertex
  - clean PU contamination in 1-vertex sample
- Uncertanties included:
  - q_T spectra using PYTHIA and POWHEG
  - from PU contamination
- Good agreement data-MC seen

Conclusion/III

PAS conclusion

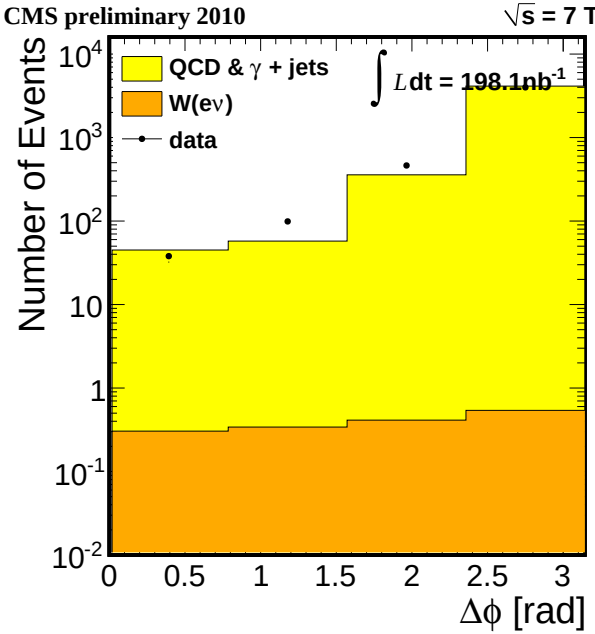
- The performance of three $\not{E}_T$ algorithms have been examined with early data
- emphasis on the calibration scale and resolution of the $\not{E}_T$ response.
- Very good agreement between data and MC
- the improvement that results from the inclusion of charged particle tracking in jet reconstruction is visible and significant.
- The difference in performance is further confirmed in $\not{E}_T$ distributions of $W \to \ell\nu$ event samples which contain genuine $\not{E}_T$.

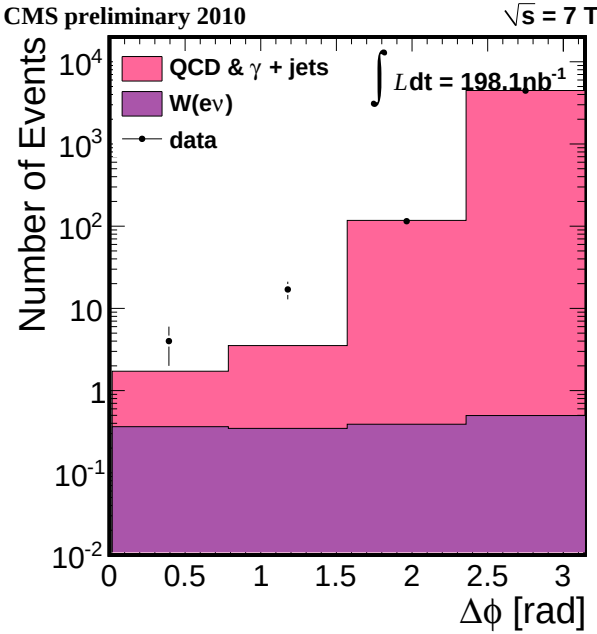
Backup

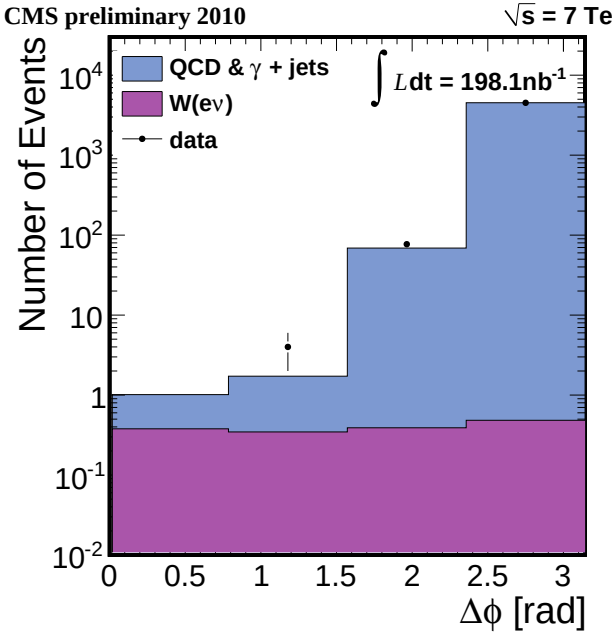
BACKUP

Angular correlation γ jet

TypeII Calo$\not\!\!E_T$, TC$\not\!\!E_T$, PF$\not\!\!E_T$



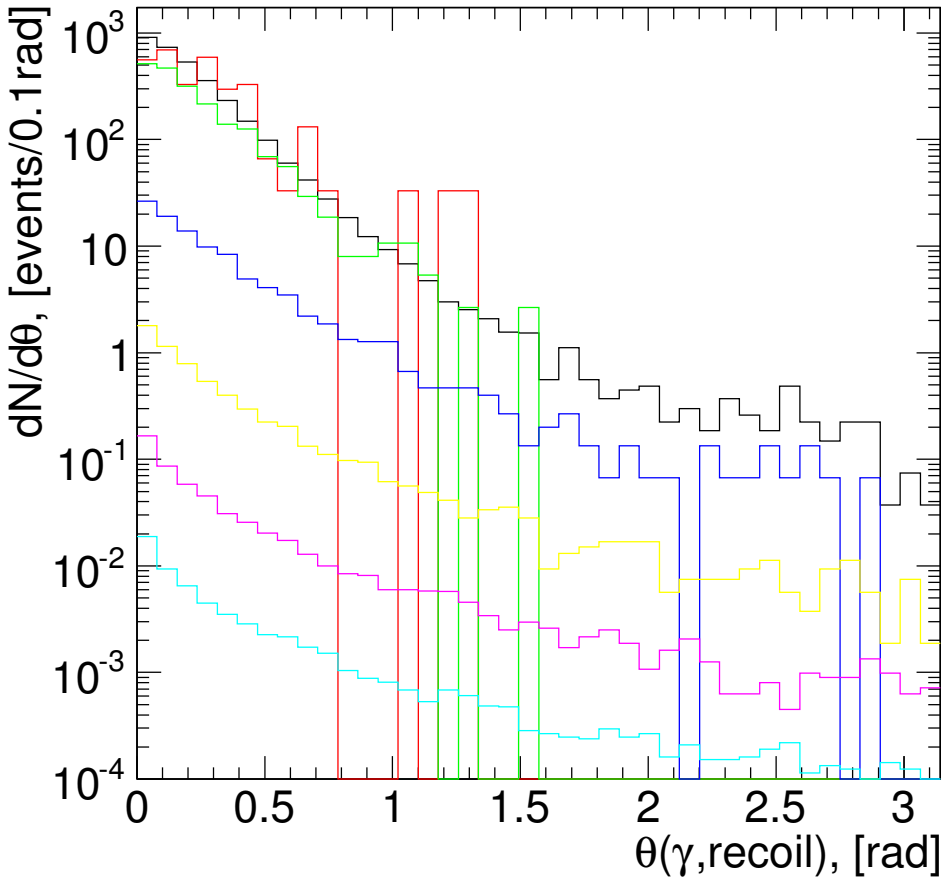




Angular correlation γ jet $\mathrm{TC}\not{E}_T$

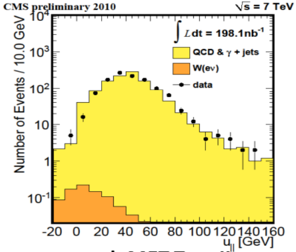
$\mathrm{TC}\not{E}_T$: $\Delta\phi = 0$ means γ-jet back to back

Colors indicate pthat bins: lowest red, then green, then blue, etc. . .

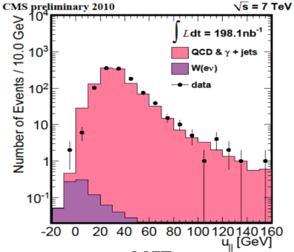


small statistics at high $\Delta\phi$

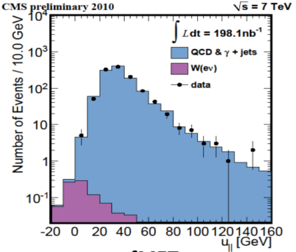
$\gamma + jet$ angular correlation with $E_\gamma > 30$ GeV



caloMET TypeII

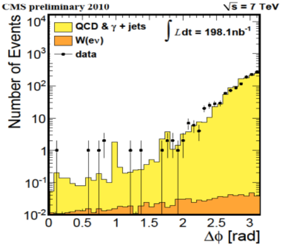


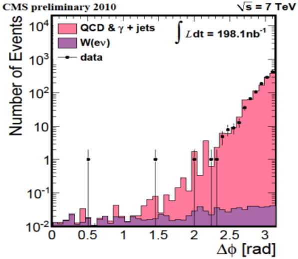
tcMET

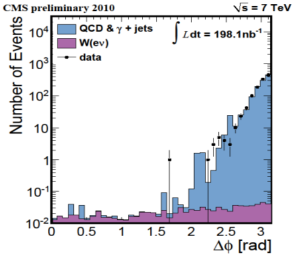


pfMET

After the "pixel seeds" cleaning . PT>30 cut is applied to enrich the sample with uncleaned W. Main W contamination is expected at 30<PT<45. Instead somewhat better DATA/MC agreement

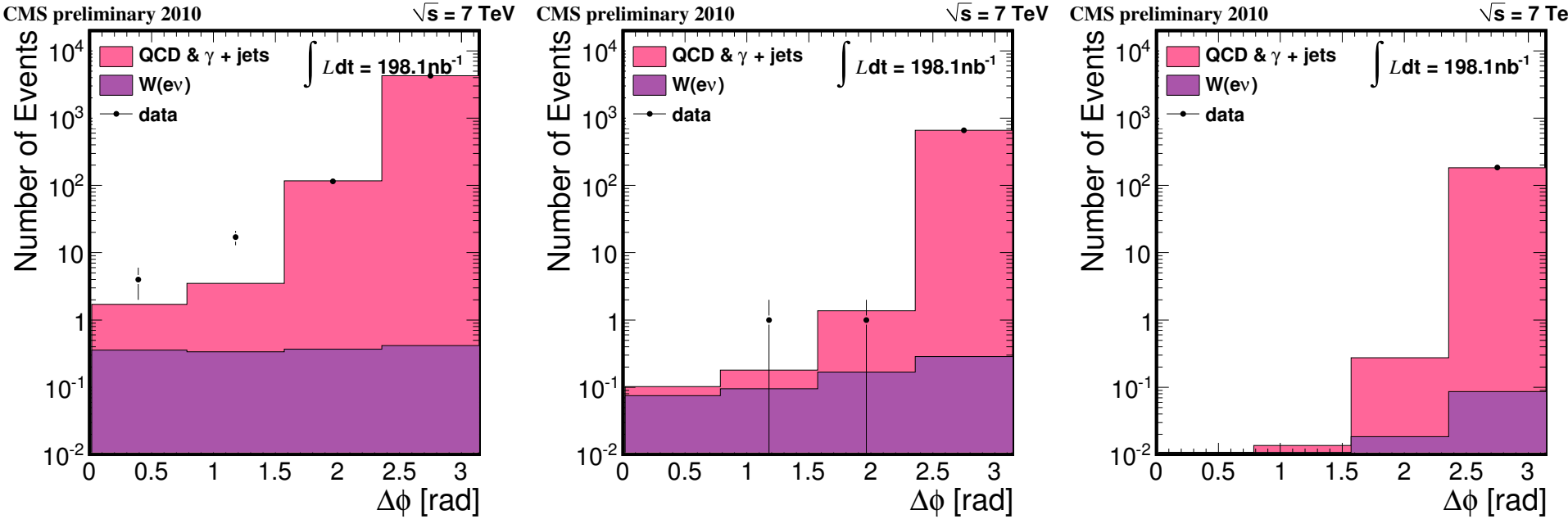






TC$\not{E}_T$: $\gamma + jet$ angular correlation at different q_T

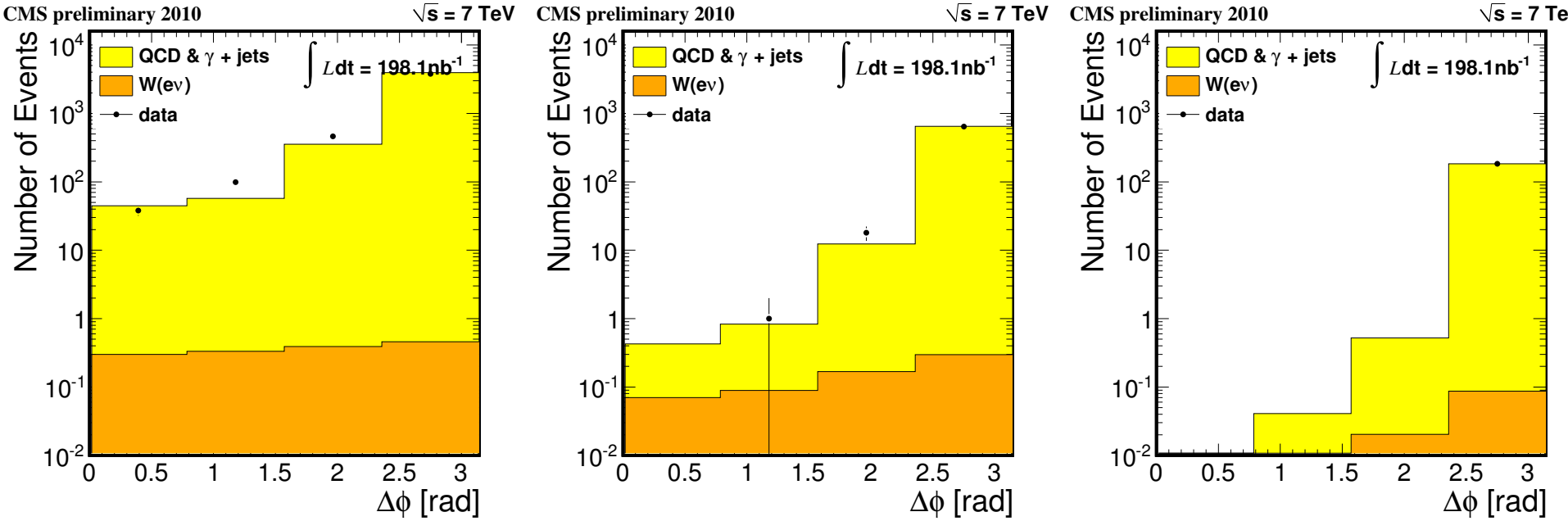
Left: $20 < q_T < 50$ GeV, Center: $35 < q_T < 100$ GeV, Right: $50 < q_T < 100$ GeV



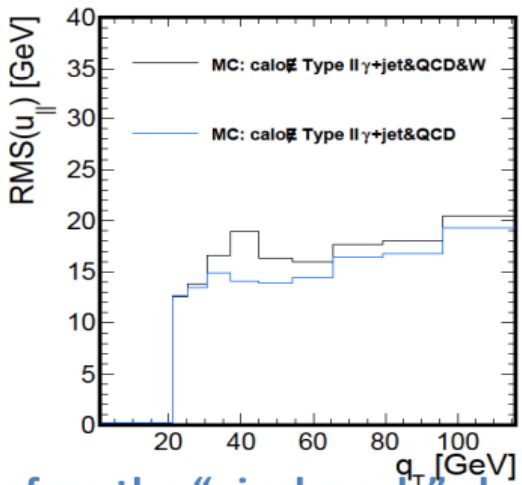
Possible NLO vs LO effect at low q_T?

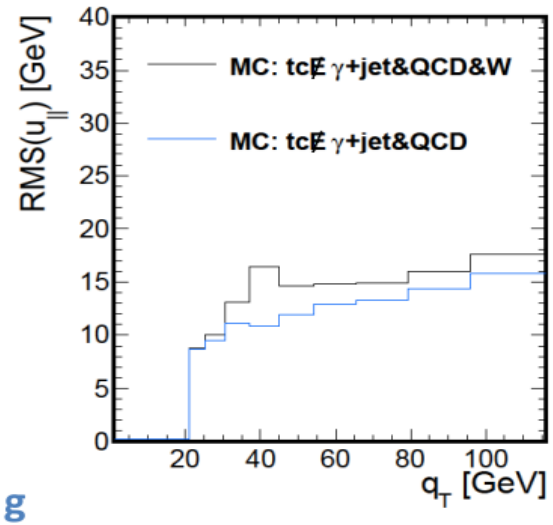
CaloMET: $\gamma + jet$ angular correlation at different q_T

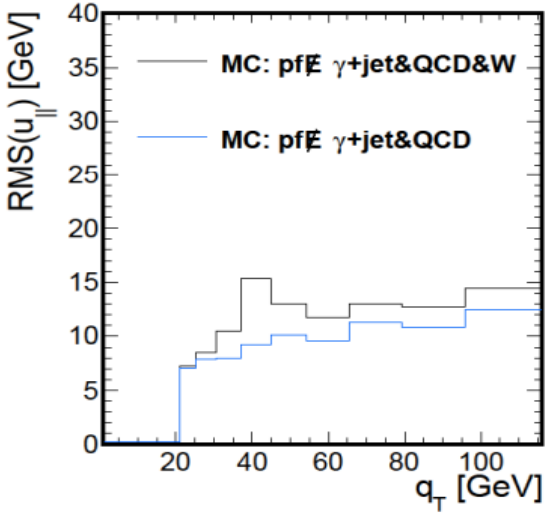
Left: $20 < q_T < 50$ GeV, Center: $35 < q_T < 100$ GeV, Right: $50 < q_T < 100$ GeV



Effect of pixel cleaning on Resolution



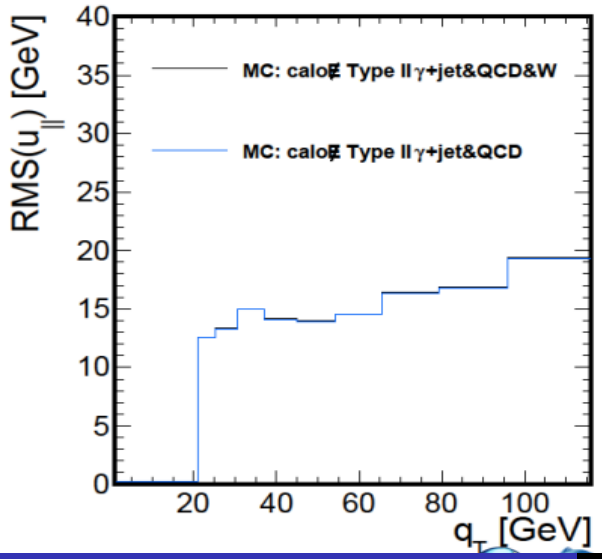


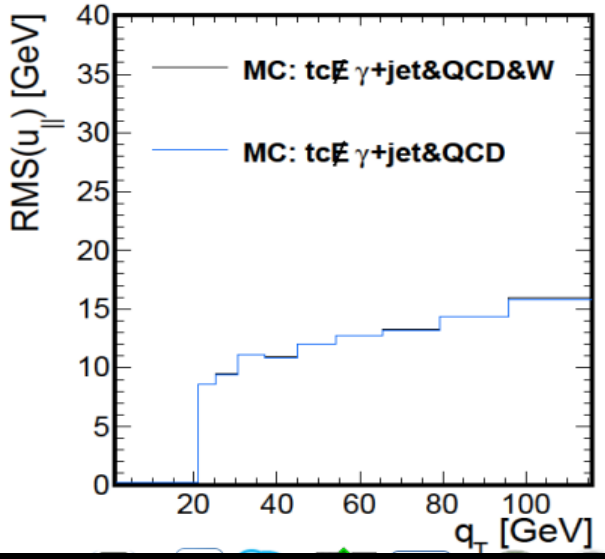


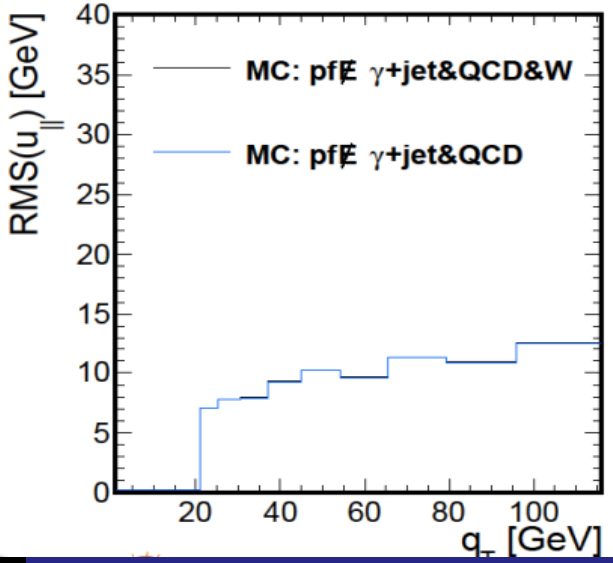
Before the "pixel seeds" cleaning

caloMET TypeII **tcMET** **pfMET**

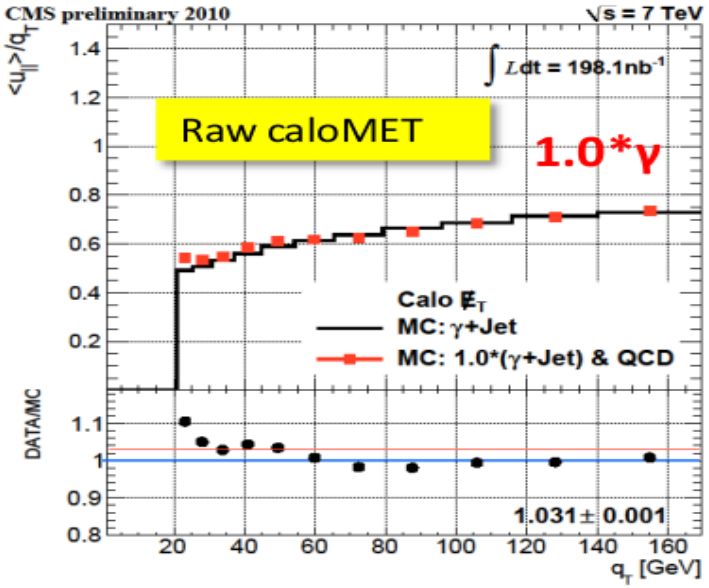
After the "pixel seeds" cleaning

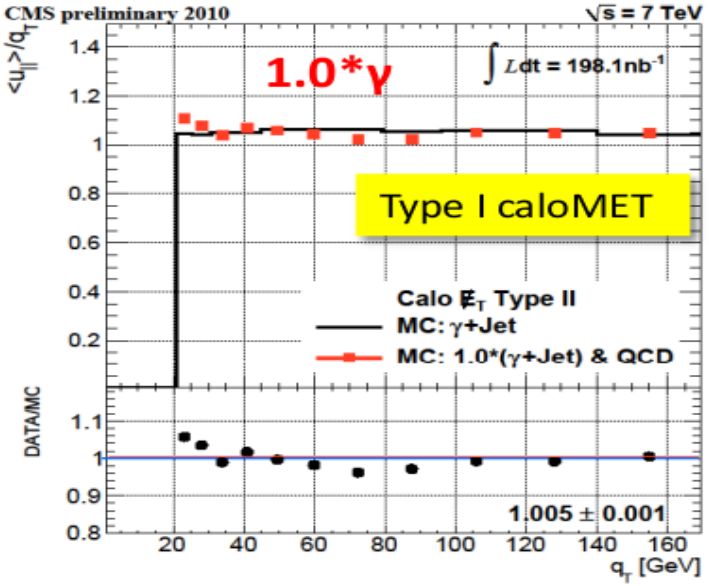


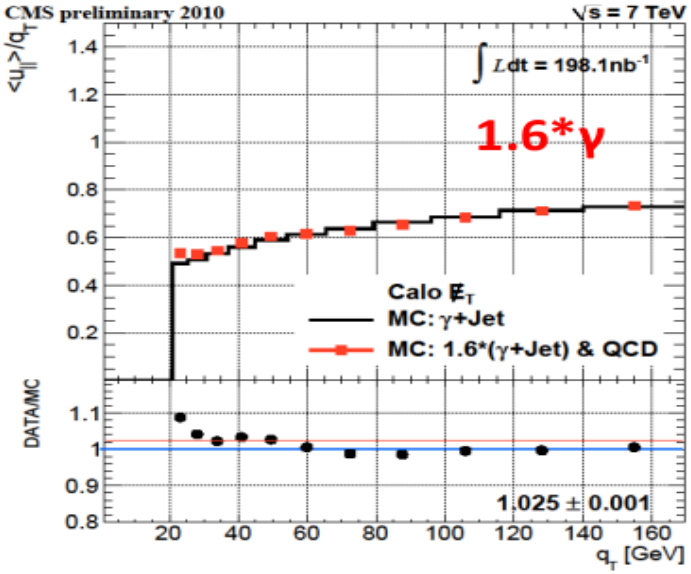


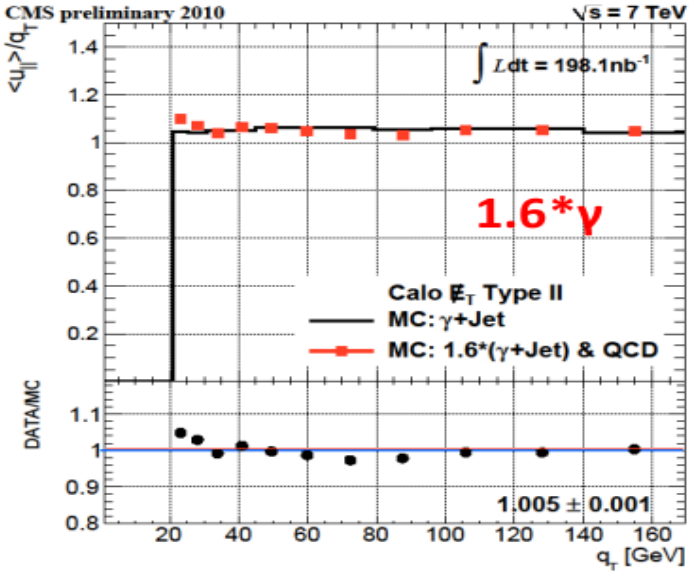


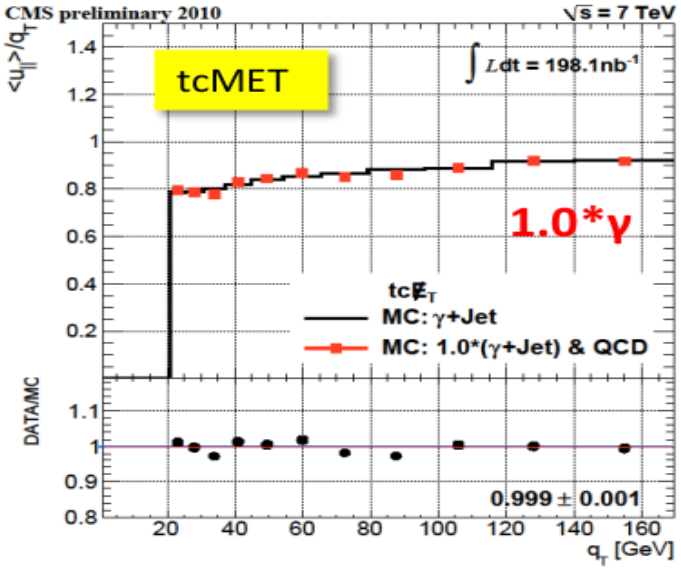
Effect of QCD contamination on Resolution

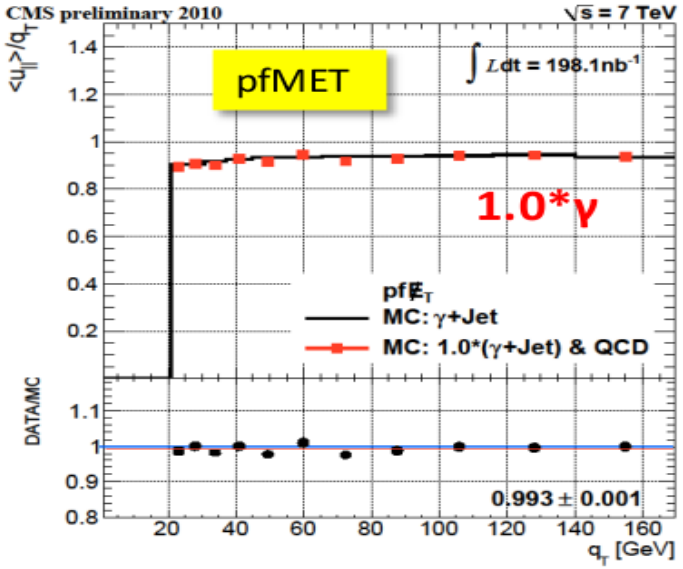


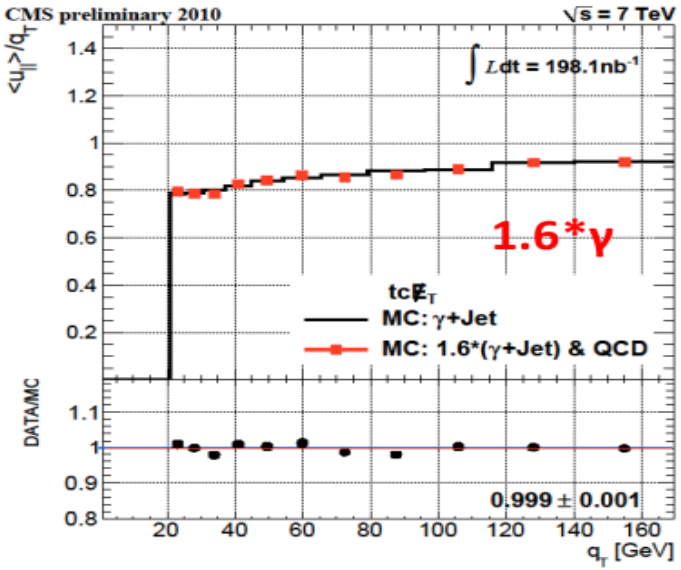


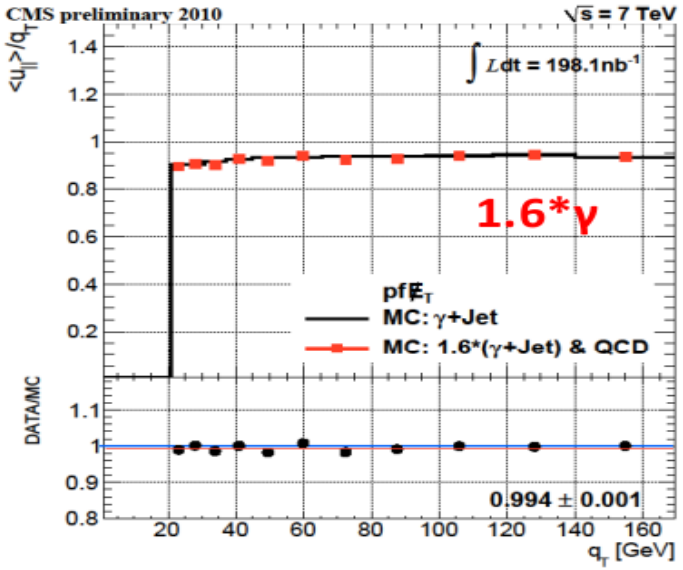




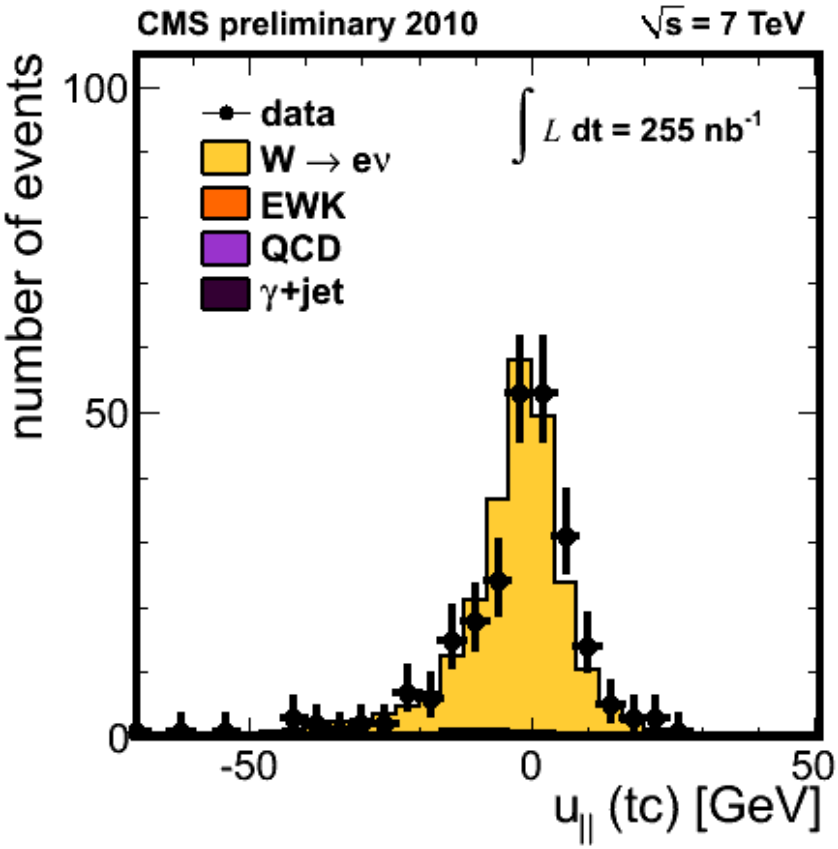

CMS preliminary 2010
√s = 7 TeV
∫ Ldt = 198.1nb⁻¹
tcMET
1.0*γ
tc$\not\!\!E_T$
MC: γ+Jet
MC: 1.0*(γ+Jet) & QCD
DATA/MC
0.999 ± 0.001
<u_∥>/q_T
q_T [GeV]

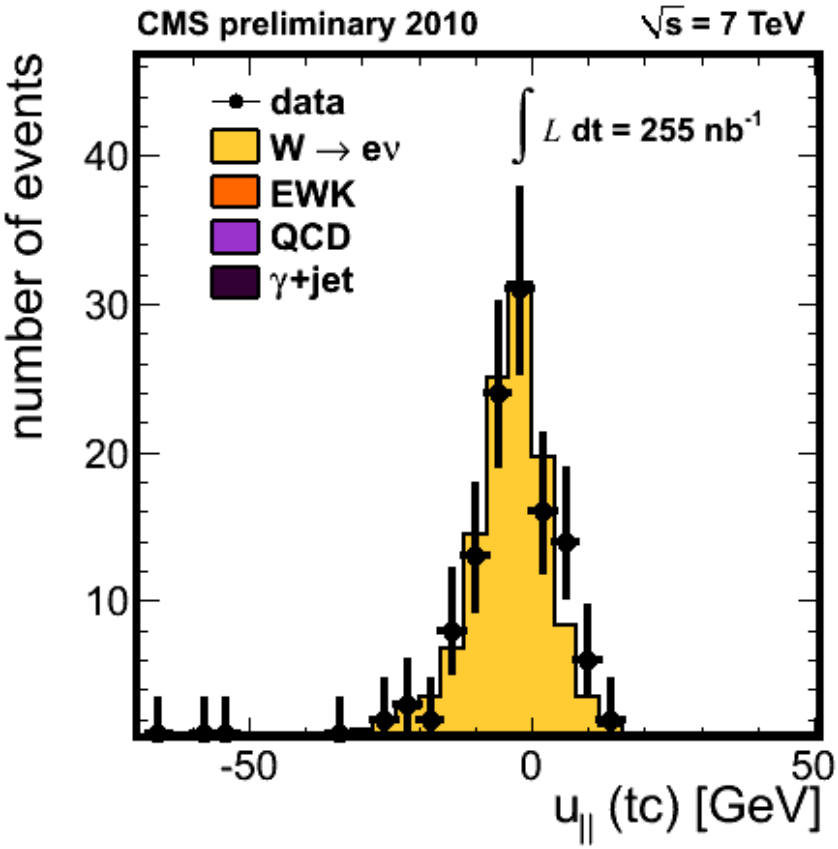

CMS preliminary 2010
√s = 7 TeV
∫ Ldt = 198.1nb⁻¹
pfMET
1.0*γ
pf$\not\!\!E_T$
MC: γ+Jet
MC: 1.0*(γ+Jet) & QCD
DATA/MC
0.993 ± 0.001
<u_∥>/q_T
q_T [GeV]


CMS preliminary 2010
√s = 7 TeV
∫ Ldt = 198.1nb⁻¹
1.6*γ
tc$\not\!\!E_T$
MC: γ+Jet
MC: 1.6*(γ+Jet) & QCD
DATA/MC
0.999 ± 0.001
<u_∥>/q_T
q_T [GeV]


CMS preliminary 2010
√s = 7 TeV
∫ Ldt = 198.1nb⁻¹
1.6*γ
pf$\not\!\!E_T$
MC: γ+Jet
MC: 1.6*(γ+Jet) & QCD
DATA/MC
0.994 ± 0.001
<u_∥>/q_T
q_T [GeV]

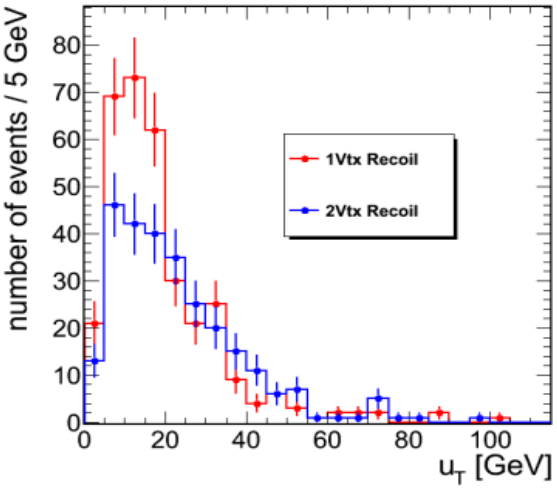
$u_{||}$ Barrel vs Endcap for TcMet

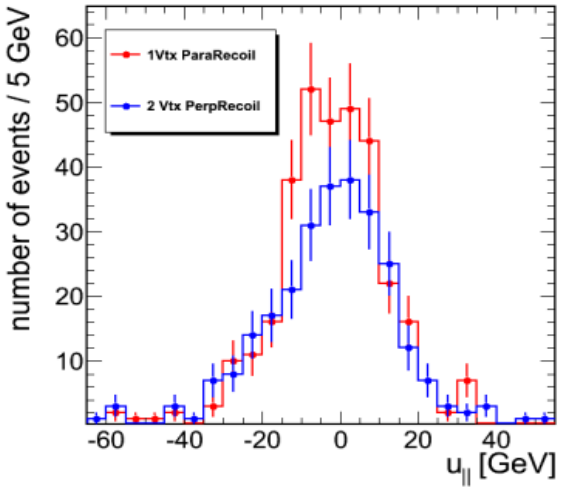


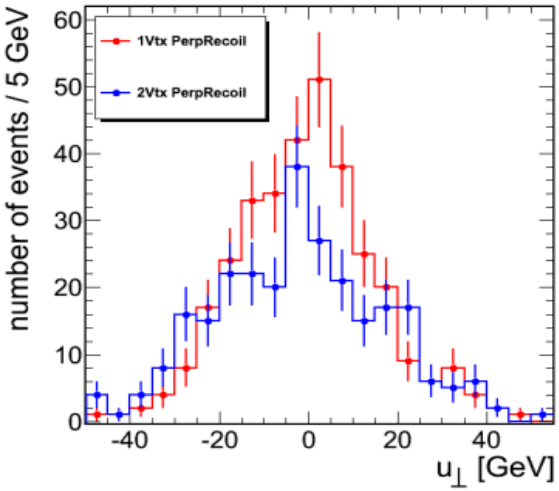


Effect of PU contamination on Recoil $W \to \mu\nu$

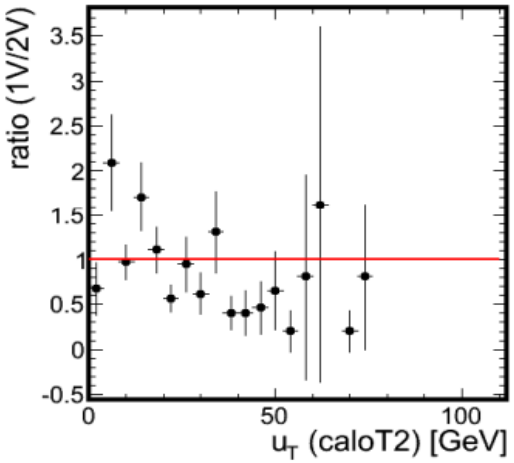
Pileup effects on caloT2 recoil variables (data only

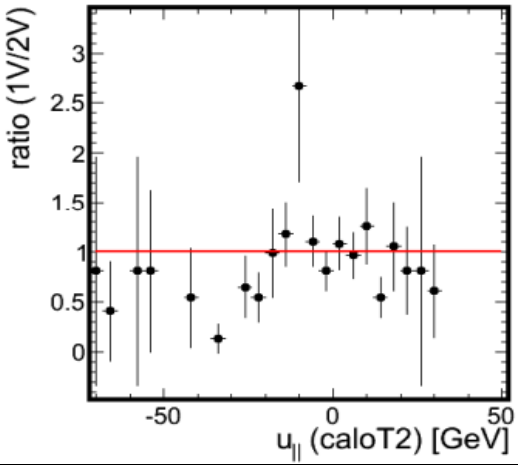


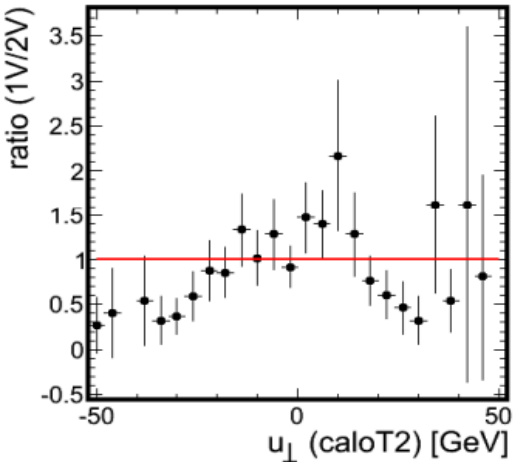




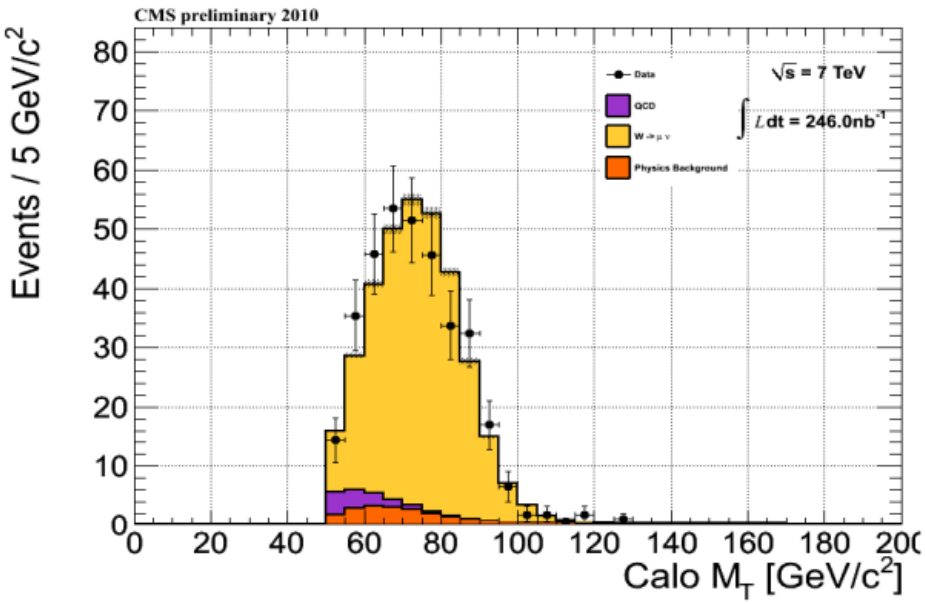
Get normalized shapes

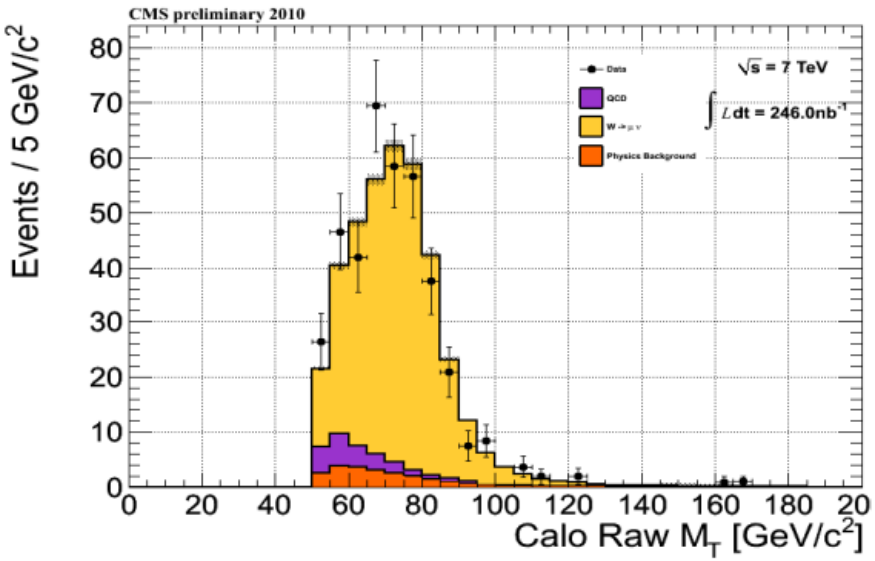


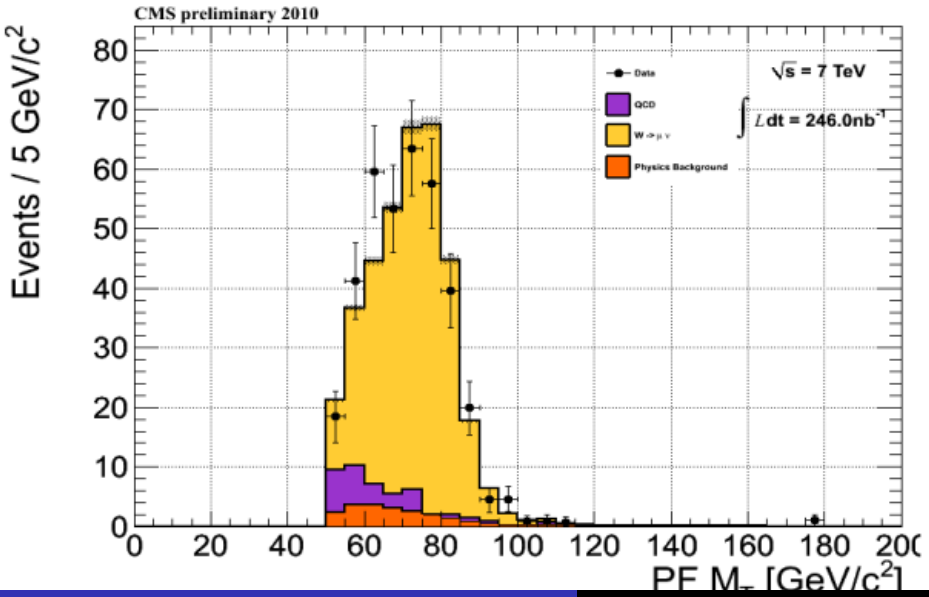


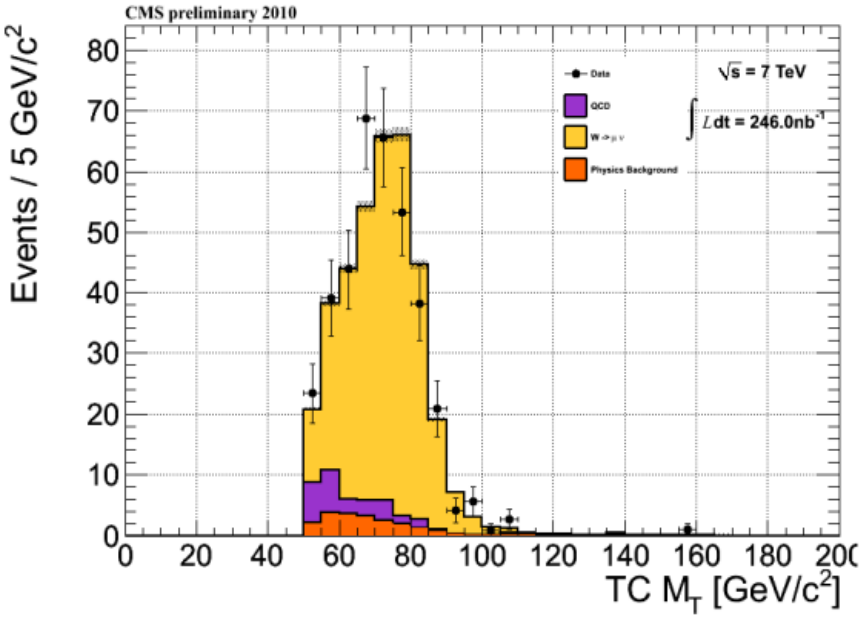


MT distribution for $W \to \mu\nu$

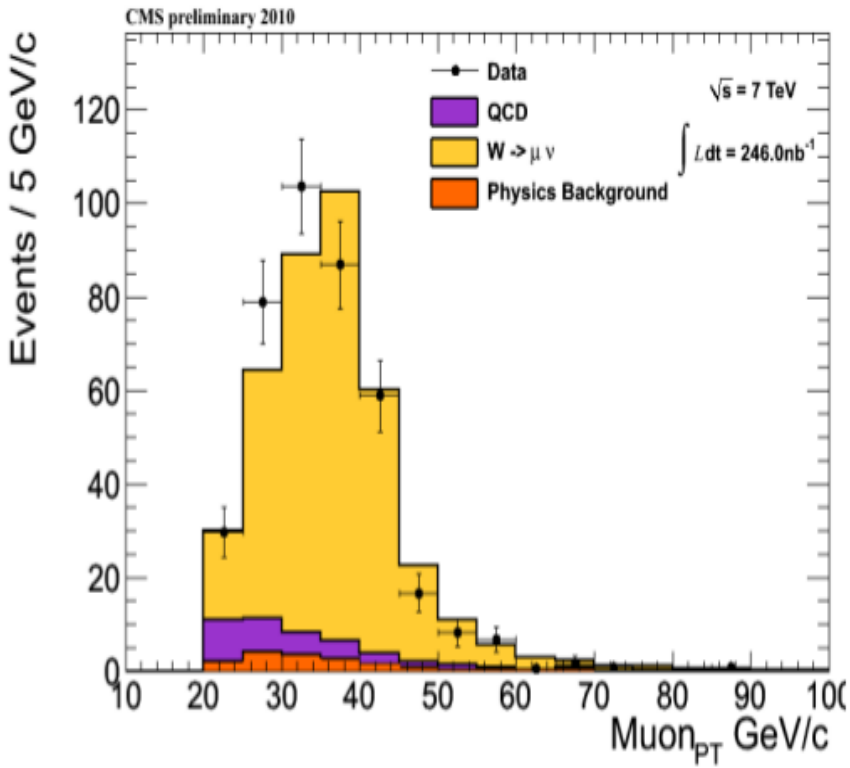


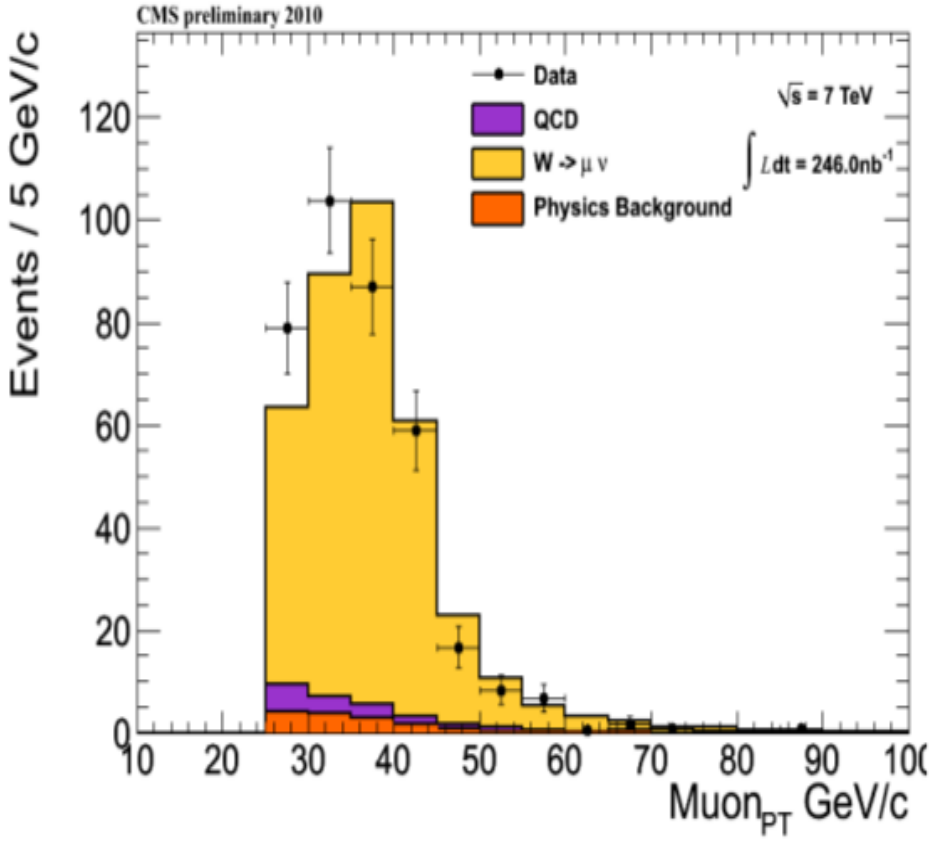






Muon p_{T} distribution for $W \to \mu\nu$



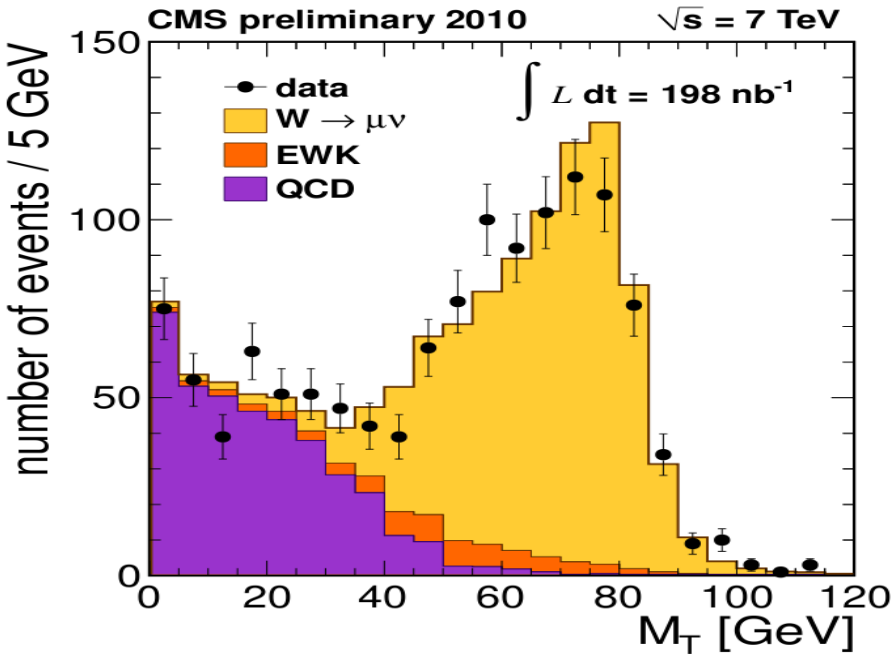


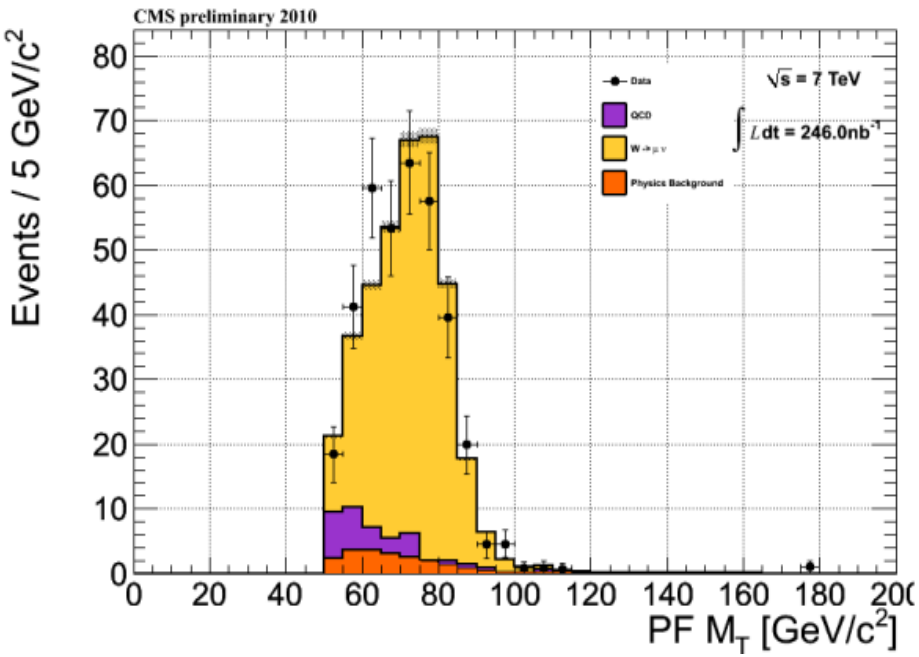
For 20 and 25 p_{T} cut

Note: different QCD/EWK normalization for MC from MET distribution

Comparison with EWK PAS at ICHEP M_T $W \to \mu\nu$

Left EWK PAS , Right Current analysis

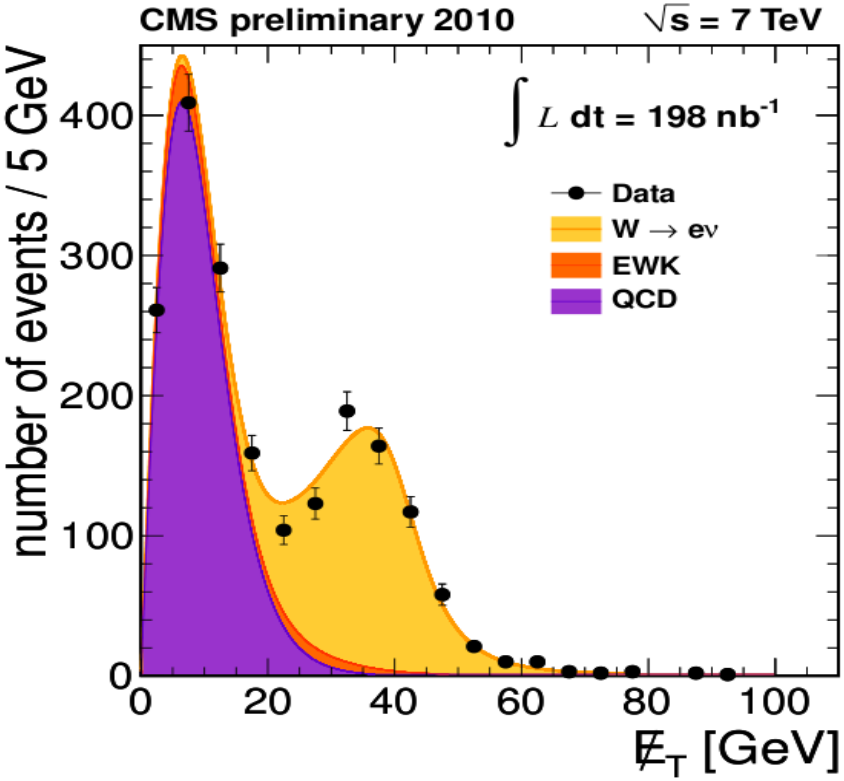


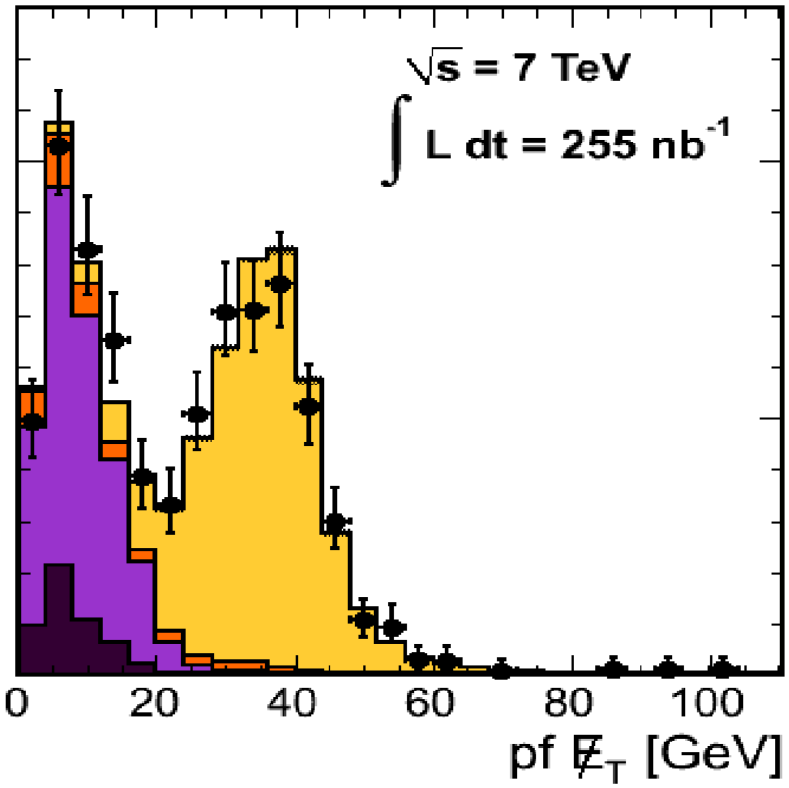


- $p_T > 25$ GeV (VTBF is > 20)
- $\not{E}_T > 25$ GeV (VTBF no cut)
- only 1 Primary vertex
- Shown only fot $M_T > 50$
- Plot NOT for current PAS!

Comparison with EWK PAS at ICHEP $\not\!\!E_T$ $W \to e\nu$

Left EWK PAS $\not\!\!E_T$, Right current work $\not\!\!E_T$





- $p_{\mathrm{T}} > 25\,\mathrm{GeV}$ (VTBF is > 20)
- only 1 Primary vertex