Effect of LHC Pile Up on Higgs searches

Michele Selvaggi
Universiteit Antwerpen
(On behalf of CMS)

Higgs Hunting 2011

Orsay, 28 July

Pile-Up

• With current LHC conditions ~ **average 5 interactions per bunch crossing** (will increase in 2011)

• In high luminosity environment hadron collider it is crucial to adress Pile Up (PU) issues

• Results in overall **higher activity** in the detector, and affects trigger rates, vertexing and tracking**, lepton isolation, missing energy and jet resolution**, b-tagging etc ...

Isolate low momentum minimum bias contribution from the hard scattering by:

• requiring **good vertexing** identification efficiency and matching of charged particles to the prompt vertex

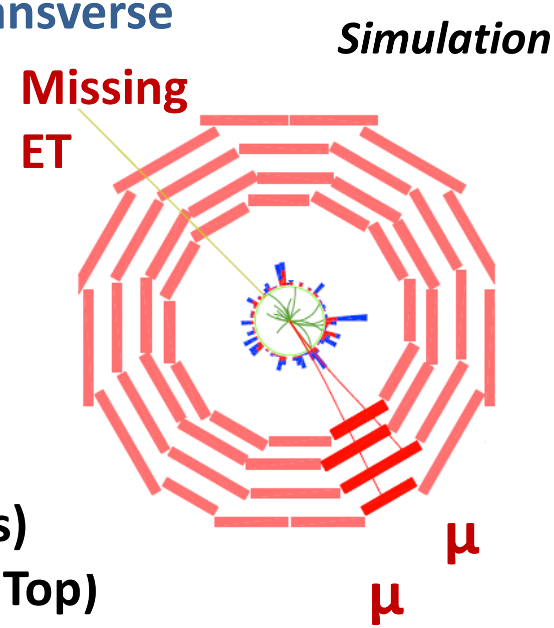
• for neutral particles (no tracking info) calculate offset on an event-by-event basis

H $\rightarrow$ WW $\rightarrow$ 2l2ν analysis

Universiteit Antwerpen

- <u>General Strategy:</u>
  $\rightarrow$ counting experiment
  $\rightarrow$ divide in 4 subchannels: ee,μμ, μe,eμ final states
  $\rightarrow$ cut-based or multivariate in 0/1/2 jet hypothesis

Signal : **2 well isolated and identified leptons plus high transverse missing energy (plus 0/1/2 jets)**



- <u>Main backgrounds</u>

$\rightarrow$WW (irreducible), W+jets , tt , Single Top , Drell-Yan

Main concerns for Pile-up are on :

- **lepton isolation (against Wjets and QCD backgrounds)**
- **Missing E_T and jet resolution (against Drell Yann and Top)**

Vertexing

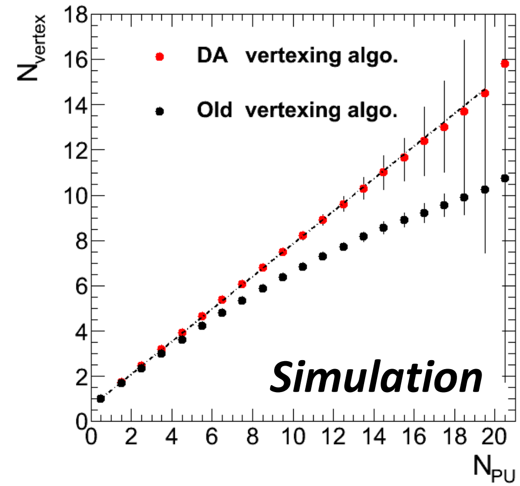
- Good vertex identification is crucial for dealing with high pile-up conditions

- In CMS Deterministic Annealing (DA) algorithm was developped to deal with high pile-up

- Able to separate vertices in very close position

- DA allows to recover vertex reconstruction inefficiencies at high pile-up (linearity)

- In order to simulate the pile-up interactions in data, the hard process is superposed with minimum bias simulation and then reweighted in order to match the number of vertices distribution observed in data



Best vertex selection

- Vertex with **highest momentum sum of tracks** is chosen as the signal vertex
- Lepton tracks are required to be **matched** within (d0,dZ) , transv. and longitudinal distance with the best vertex

Method FastJet Area

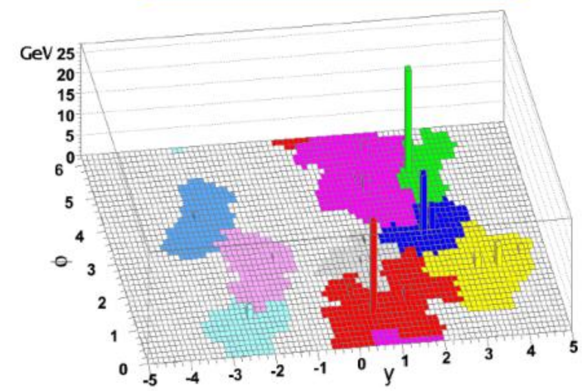
Algorithm allows to measure the jet's susceptibility to contamination from diffuse noise and a technique to measure the level ρ of this diffuse noise (and the underlying event) in any given event.

"To define a sensible area one therefore adds additional, infinitely soft particles (ghosts) and identifies the region in y, ϕ where those ghosts are clustered with a given jet. The extent of this region gives a measure of the (dimensionless) jet area."

After calculating the Area for each jet in the event, compute the median density:

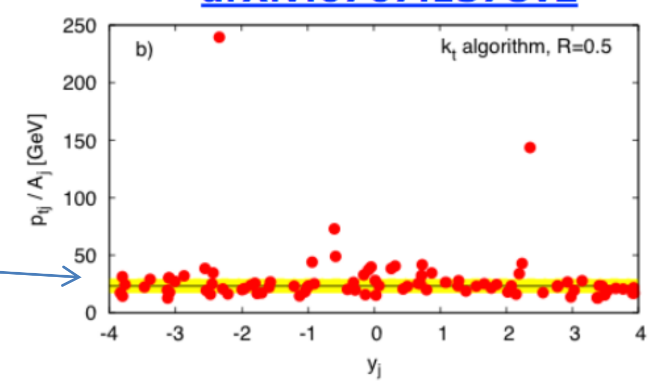
$$\rho = \text{median}\left[\frac{p_{Tj}}{A_j}\right]$$

arXiv:0802.1188v2



Cacciari, Salam, Soyez

arXiv:0707.1378v2



Lepton Isolation

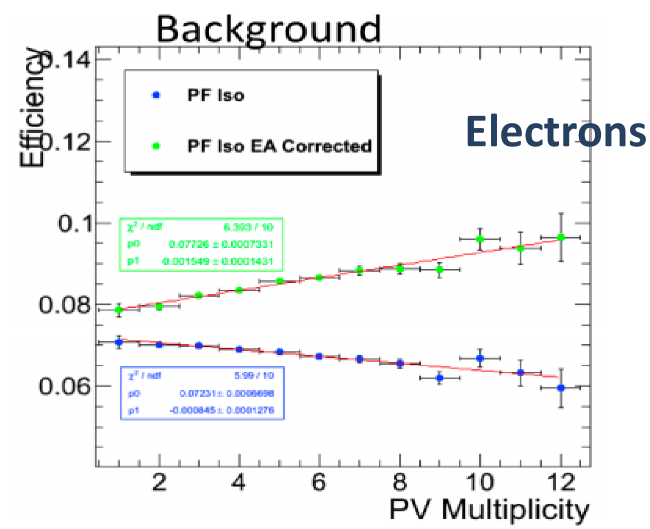
- Isolation allows to **disentangle prompt electron and muons from fake jets reconstructed as leptons** (QCD, Wjets)

- Define a cone or size ΔR (η,ϕ plane) around the lepton and require the total momentum inside the cone (minus the lepton)

$$\Sigma p_T / p_T < \alpha(|\eta|)$$

- **With high Pile-up , contributions from non-hard interaction add an offset to the Σp_T in the cone → spoils signal efficiency (especially at low Higgs mass)**

→ don't include every particle that lies in the cone in the sum **but only the ones matched to the signal vertex**



Isolation Strategy

Include in the sum particles satisfying:

- inside the cone of $\Delta R < 0.3$
- $|d_z\,(\text{part.}) - d_z\,(\text{lept.})| < 0.1$ cm (if part is charged)
- $p_T > 1$ GeV if neutral hadron or γ

Missing E_t (1)

- **Missing transverse energy used to reject Drell Yan, and QCD backgrounds (fake missing E_T)**
- **Pile-Up introduces large tails in MET distribution**
- Can increase resolution by defining:

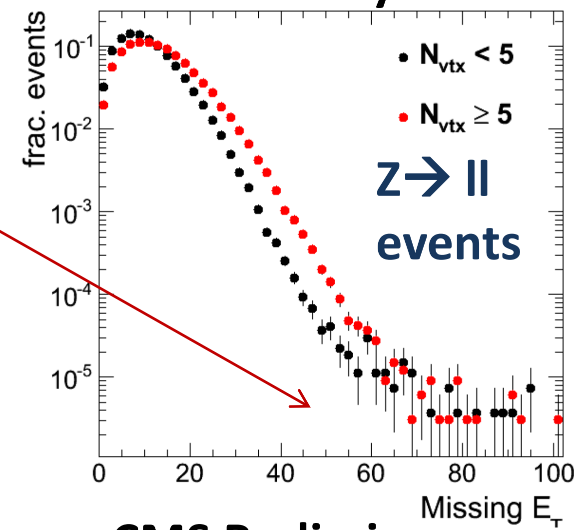
$$\text{trk-MET} \equiv -\overrightarrow{p_T}(l_1) - \overrightarrow{p_T}(l_2) - \sum_i \overrightarrow{p_T}(i)$$

pT(li) → measured lepton momenta

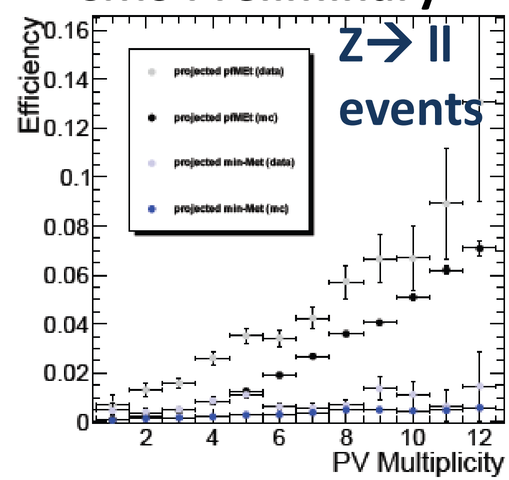
Σp_T → sum momenta of tracks matched with the signal vertex

- Then use projected ME_T (projection on orthogonal direction of closest lepton, to help Z→ττ rejection), **gives flat response vs number of pile up interactions**

CMS Preliminary 1.1 fb^{-1}



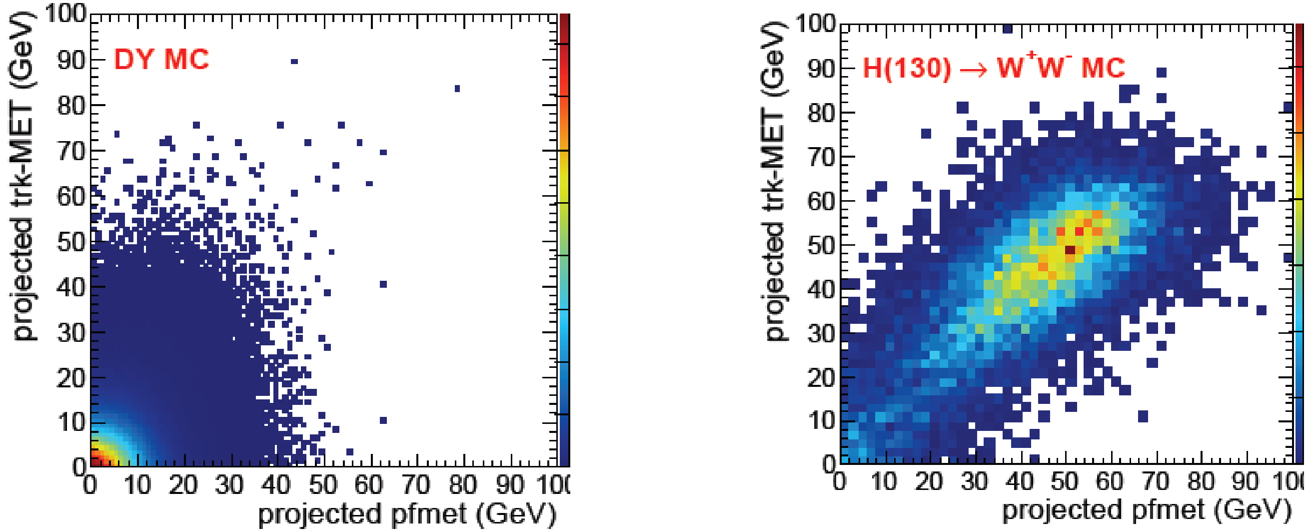
CMS Preliminary



Missing E_t (2)

- Use the **different correlation** between projected(trackME$_T$) and projected(ME$_T$) in signal and background

CMS Preliminary



min(MET) = min(projected(ME$_T$),projected(trackMET))

- Cut on min(MET) > 40 GeV for ee/μμ
  min(MET) > 20 GeV for eμ/μe

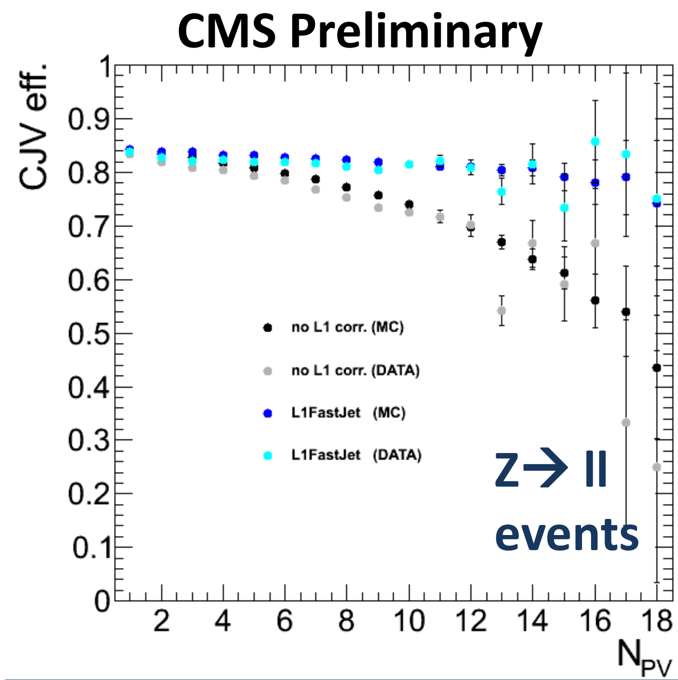
Jets

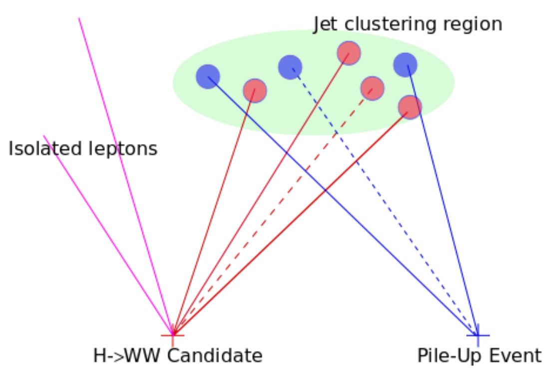
- Analysis is subdivided in 0/1/2 jets.

O jet = no jet with $p_T > 30$ GeV

1 jet = 1 jet with $p_T > 30$ GeV …

- Two ways Pile-Up can affect the jet energy:
  - presence of pure minimum bias jet $p_T > 30$ GeV (negligible in the current luminosity regime, will become more relevant later)
  - **positively bias the jet momentum (therefore decreasing signal efficiency)**





<u>Jet Area Method</u>

Calculate on an event-by event basis a density of contamination in (pT/Area)

Conclusions

Problems

Higher activity in the detector: trigger rates, vertexing and tracking**, lepton isolation, missing energy and jet resolution**, b-tagging etc ...

Methods

- When tracking info available, use vertex track association
- FastJet is able to estimate diffuse bias coming from additional min. bias interactions

→**In time Pile-Up issues are SOLVED**

Next?

- Will be running soon at 2-5 10^{33} cm^{-2}s^{-1} → **up to x4 more pile-up** foreseen
- Bunch spacing smaller , **out-of-time** pile-up issues become important