Performance of missing energy at the CMS detector

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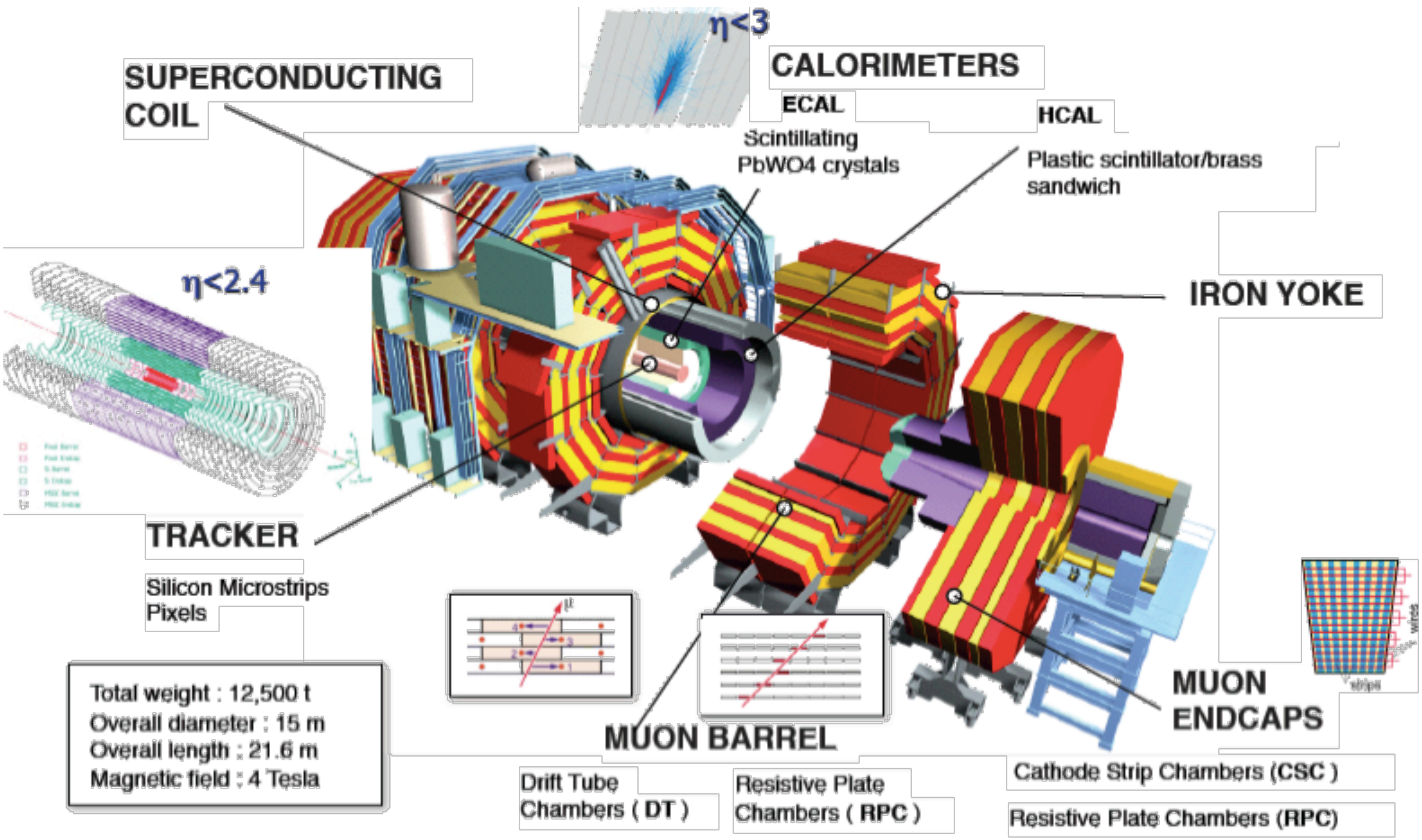
on behalf of the CMS collaboration

weakly interacting particles

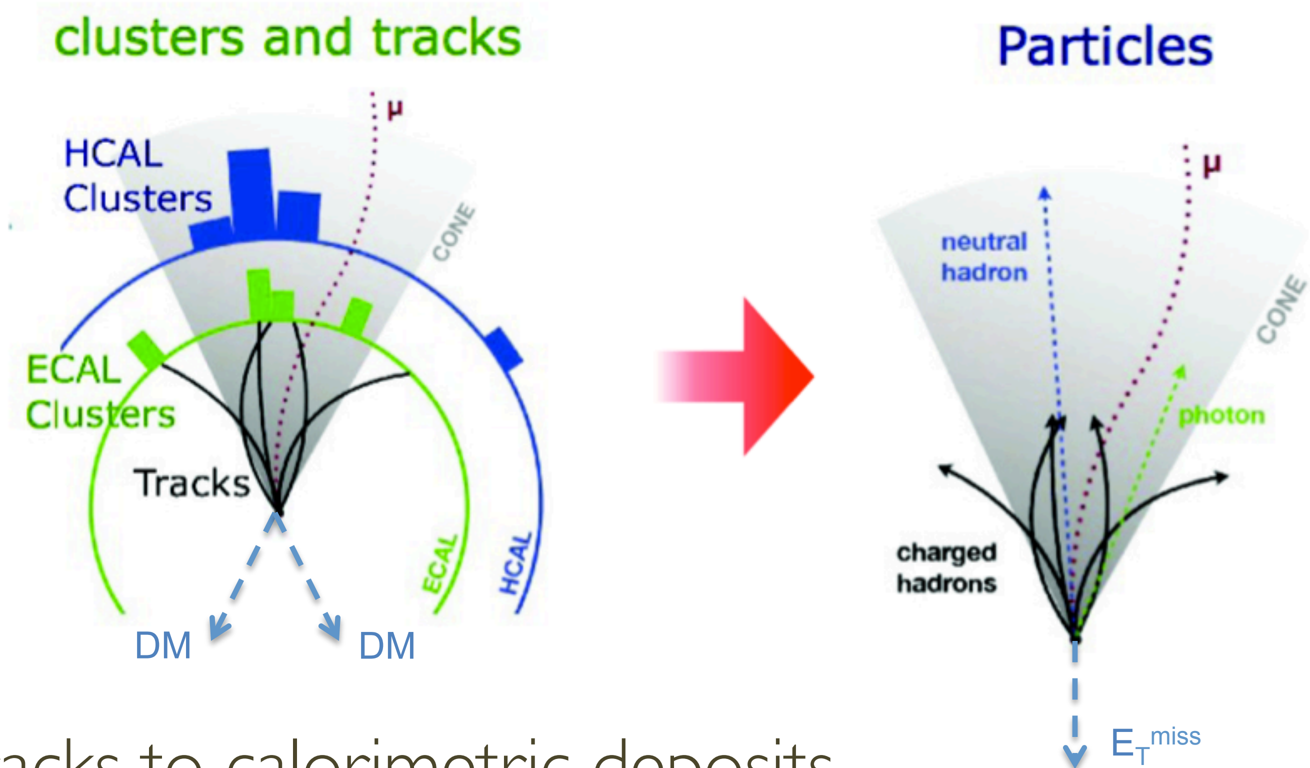
CMS-PAS-JME-16-004 SMP-PAS-15-004

- leave no trace in the detector
  - establish presence by transverse momentum imbalance: E_T^{miss}
- for SUSY WIMPs or DM: control of the tail
- for SM precision measurements
  - control of E_T^{miss} core needed for e.g. W boson mass and cross-section, $H \rightarrow WW$ etc.
- stability vs. pile-up
  - performance independent of the event sample

nearly hermetic CMS detector



reconstruction: Particle Flow

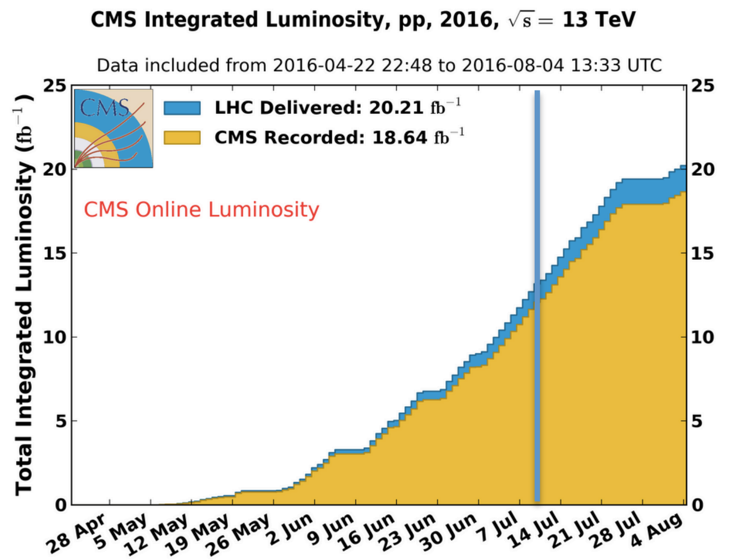


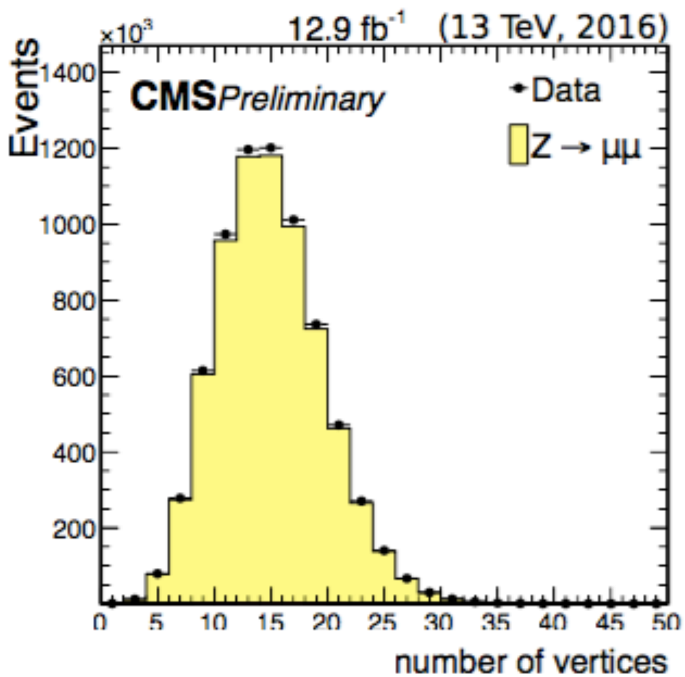
- link tracks to calorimetric deposits
  - charged/neutral hadrons, photons, electrons, muons
  - fully exploit tracking resolution and ECAL granularity
- missing energy is calculated at the particle level

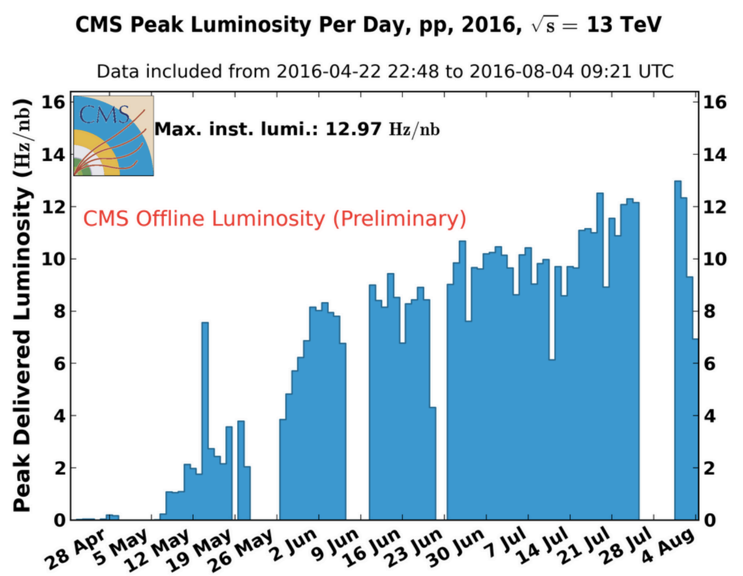
the 2016 dataset

based on 12.9/fb at 25ns BX

- LHC operating L=1.2 10^{34} cm^{-2} s^{-1}
- alignment and calibration not final

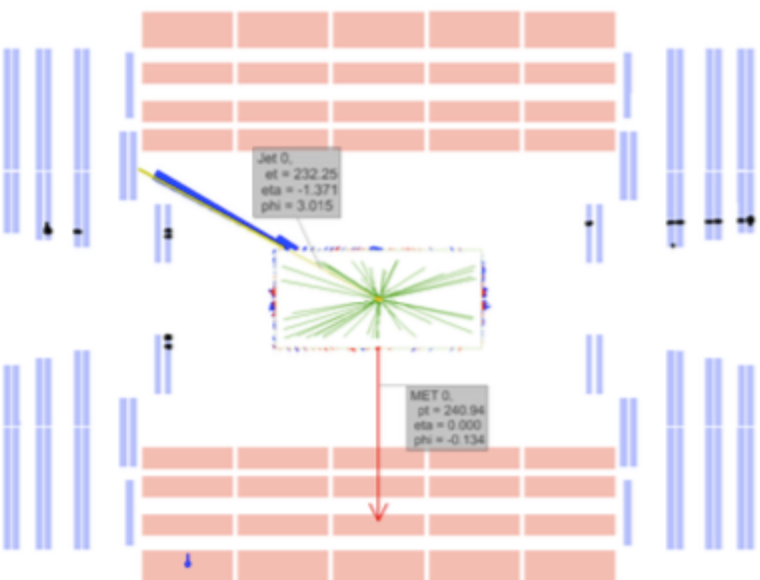


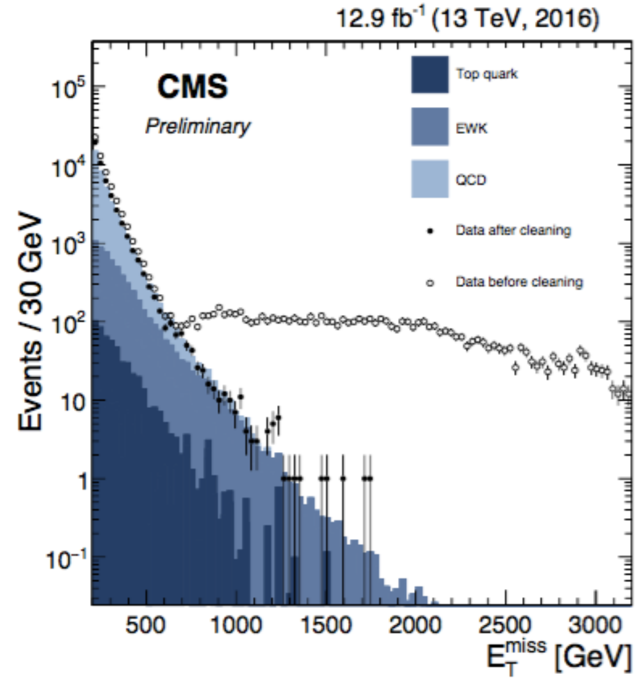




the E_T^{miss} tail performance

- assess tail contributions in high p_T dijet events
  - leading/sub-leading jet p_T > 400 / 200 GeV



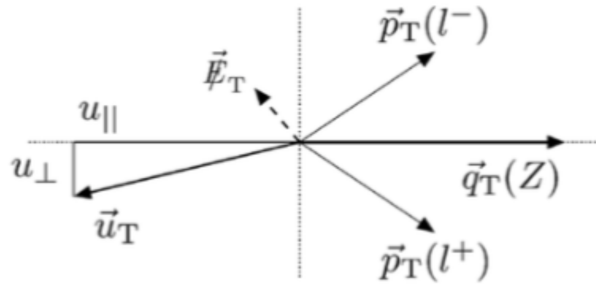


- clean anomalous deposits
  - from beam-halo, electronic noise
  - by dedicated filters based on e.g. pulse-shapes and topological information

E_T^{miss} performance measurement

- select event samples with a reference scale q_T, $Z \rightarrow ee/\mu\mu$ or γ
- correct E_T^{miss} by jet energy corrections

$$\vec{E}_T^{\text{misscorr}} = \vec{E}_T^{\text{miss}} - \sum_{\text{jets}} (\vec{p}_{\text{T,jet}}^{\text{corr}} - \vec{p}_{\text{T,jet}})$$

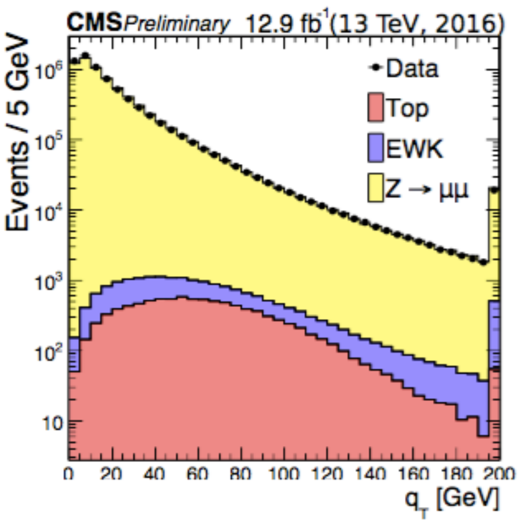


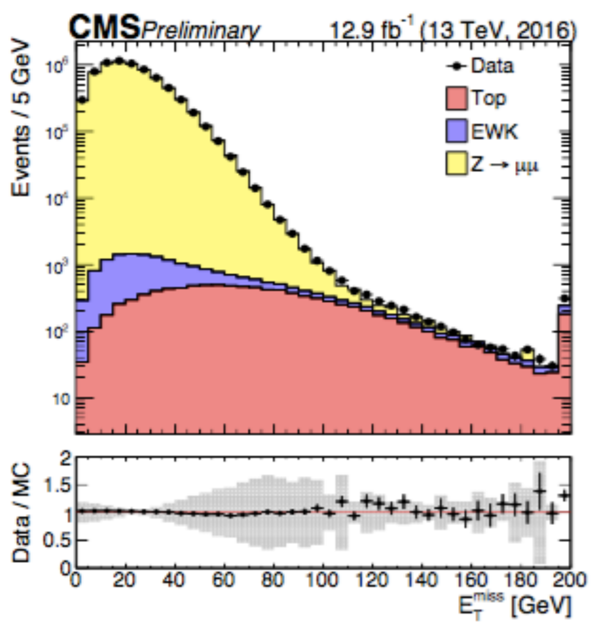
- define hadronic recoil u_T by

$$\vec{q}_T + \vec{u}_T + \vec{E}_T = 0$$

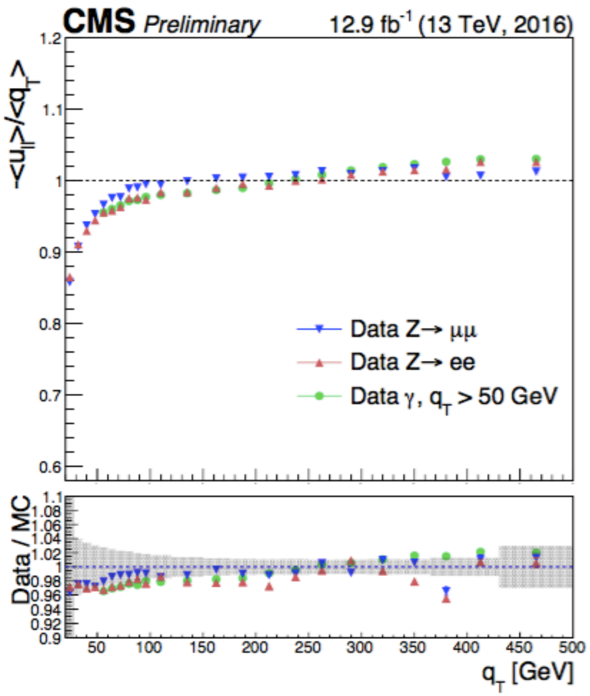
and project on ref. boson momentum

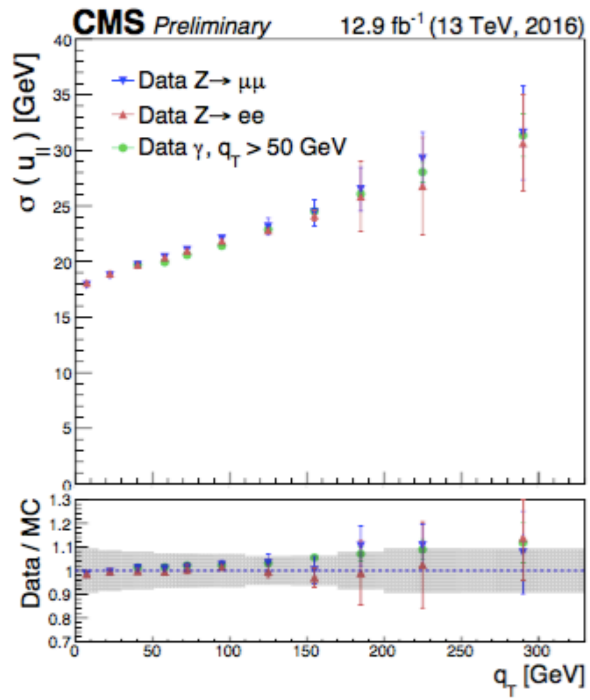
- scale $-\langle u_\parallel \rangle / \langle q_T \rangle$
- resolution $\sigma(u_\perp)$, $\sigma(u_\parallel + q_T)$

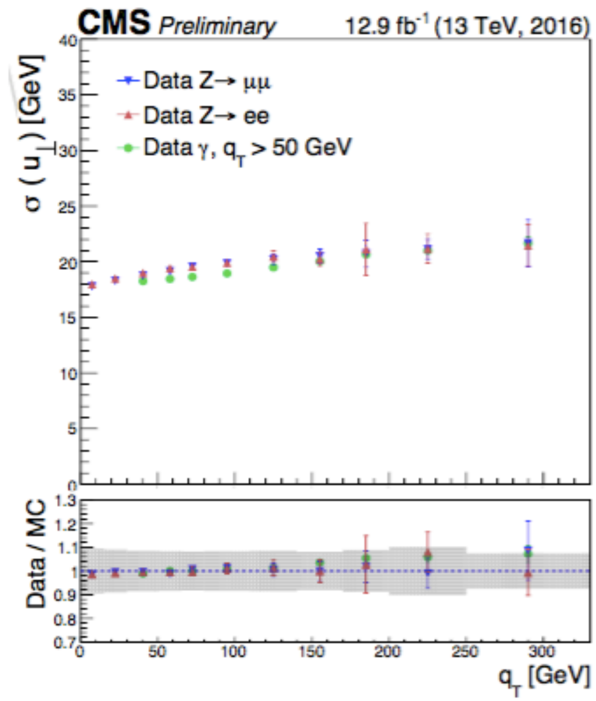




E_T^{miss} performance results





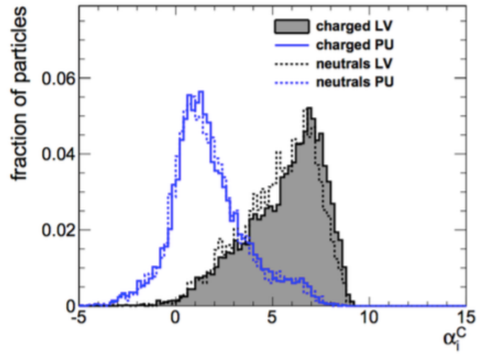


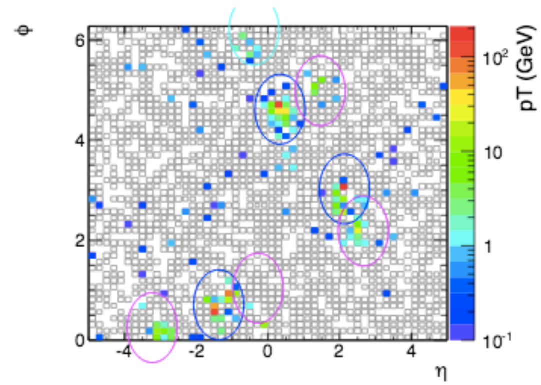
- scale > 0.95 for boson momenta > 50 GeV
- good data/MC agreement and agreement between final states

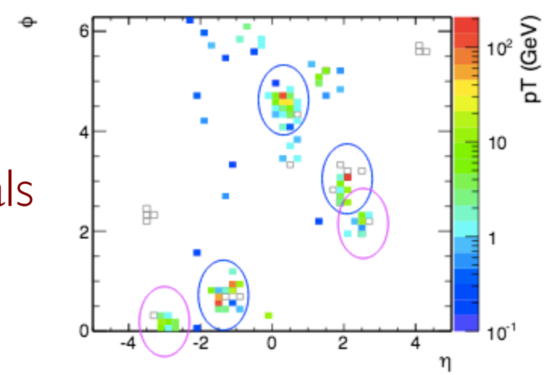
global PU mitigation

arXiv:1407.6013

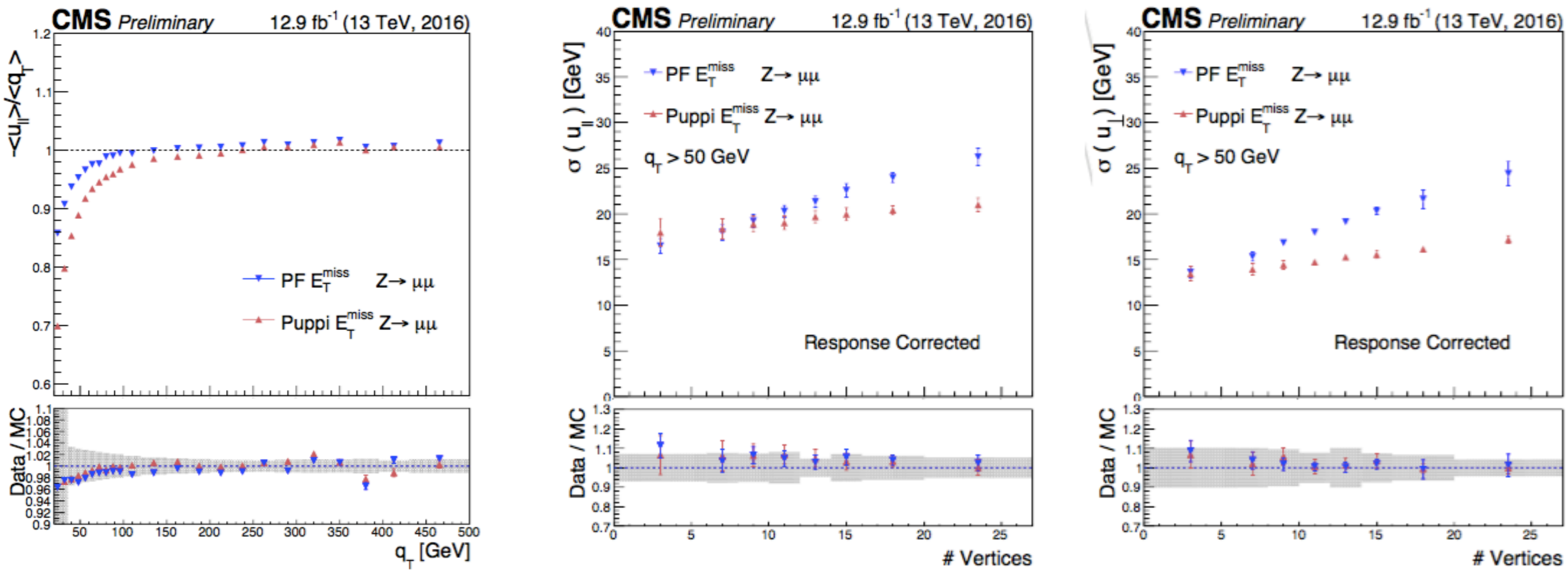
- simplest solution:
  Charged hadron subtraction (run-1)
  - remove particles that originate from PU vertices.
  - Imbalance charged and neutral PU component in missing energy
- Pile-up per particle Id: Puppi
  - Define $$\alpha_i = \log \sum_{j \in Ch,PV} \left(\frac{p_{T,j}}{\Delta R_{ij}} \right)^2 \Theta(R_0 - \Delta R_{ij})$$
    which encodes the PU-probability of a particle
  - distribution of **α** is *measured* using charged component in each event and *applied* to the neutrals
  - reweight neutrals according to PU probability







puppi E_T^{miss} performance



- slight reduction of approx. 4-5% for puppi-E_T^{miss} scale
- greatly improved resolution at high vertex multiplicity

E_T^{miss} significance

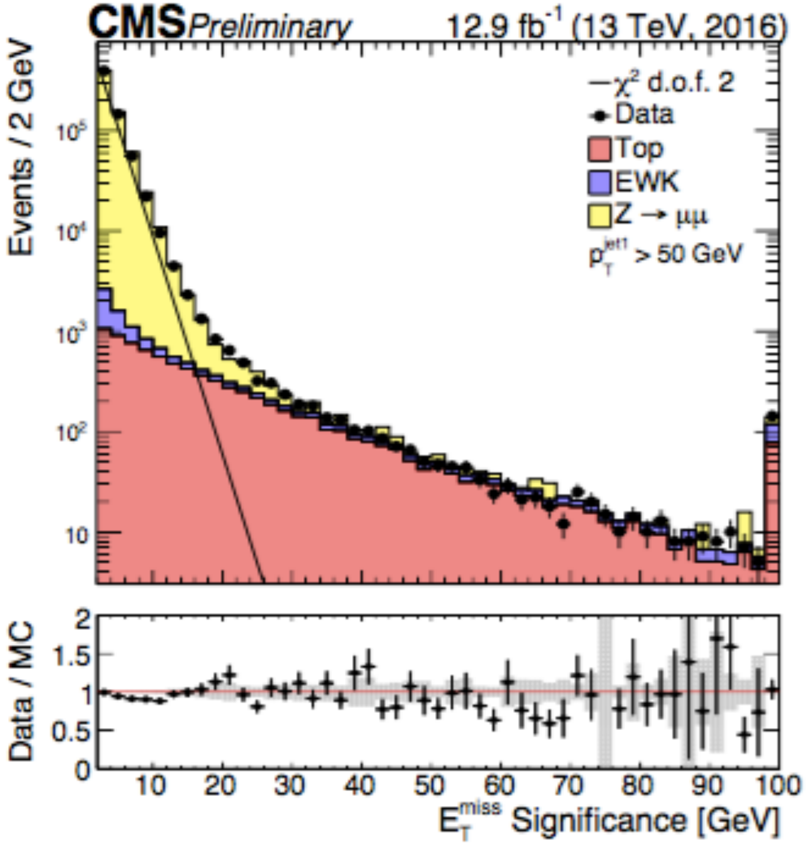
JINST **10** (2015), P02006

- distinguish events with genuine E_T^{miss} based on a log-likelihood ratio

true E_T^{miss} meas. E_T^{miss}

$$\mathcal{S} \equiv 2\ln\left(\frac{\mathcal{L}(\vec{\varepsilon} = \sum \vec{\varepsilon}_i)}{\mathcal{L}(\vec{\varepsilon} = 0)}\right)$$

- Gaussian approximation of E_T^{miss} energy resolution from different components
  - high p_T jets
  - unclustered energy
- very close to ideal χ^2 d.o.f. 2



Summary

- run-1 algorithms perform well in environment with higher pile up
- for the coming challenges at very high pile up, performance of PU mitigation techniques is promising