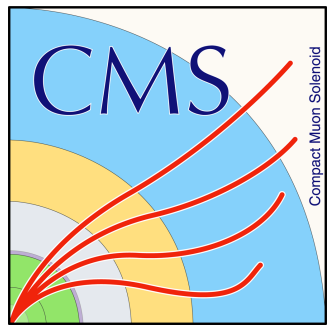
Rebalance and smear: A Fake MET Primer

Sam Bein

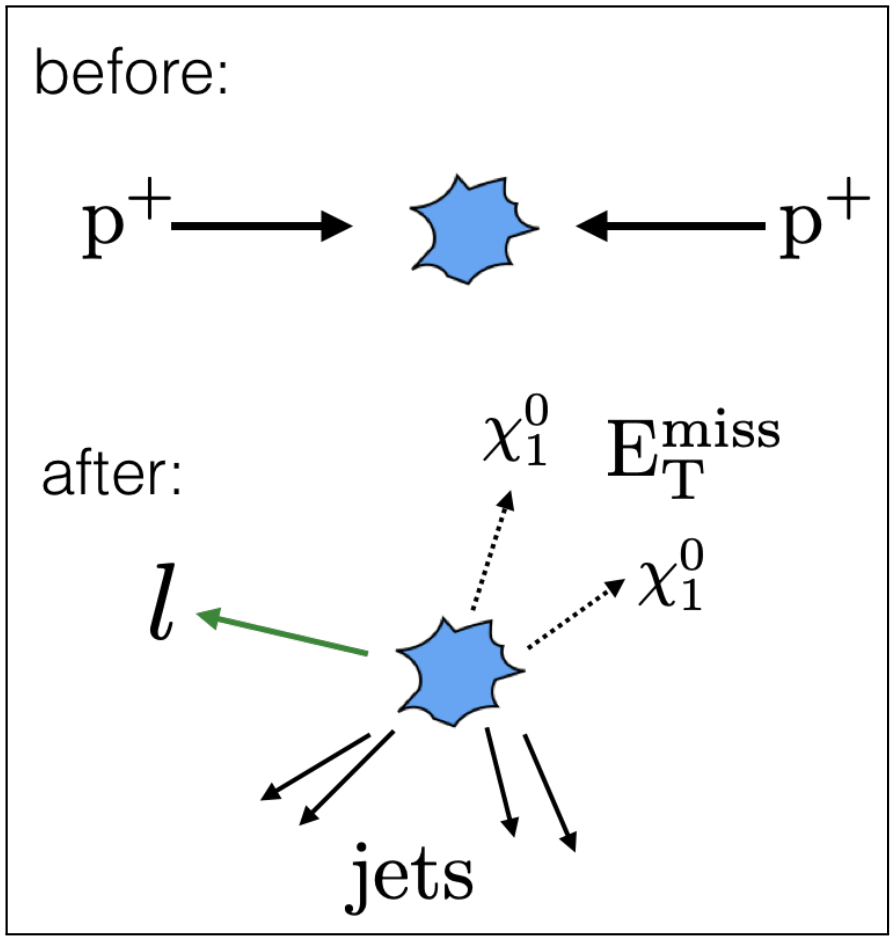
Uni. Hamburg group talk

July 17, 2019



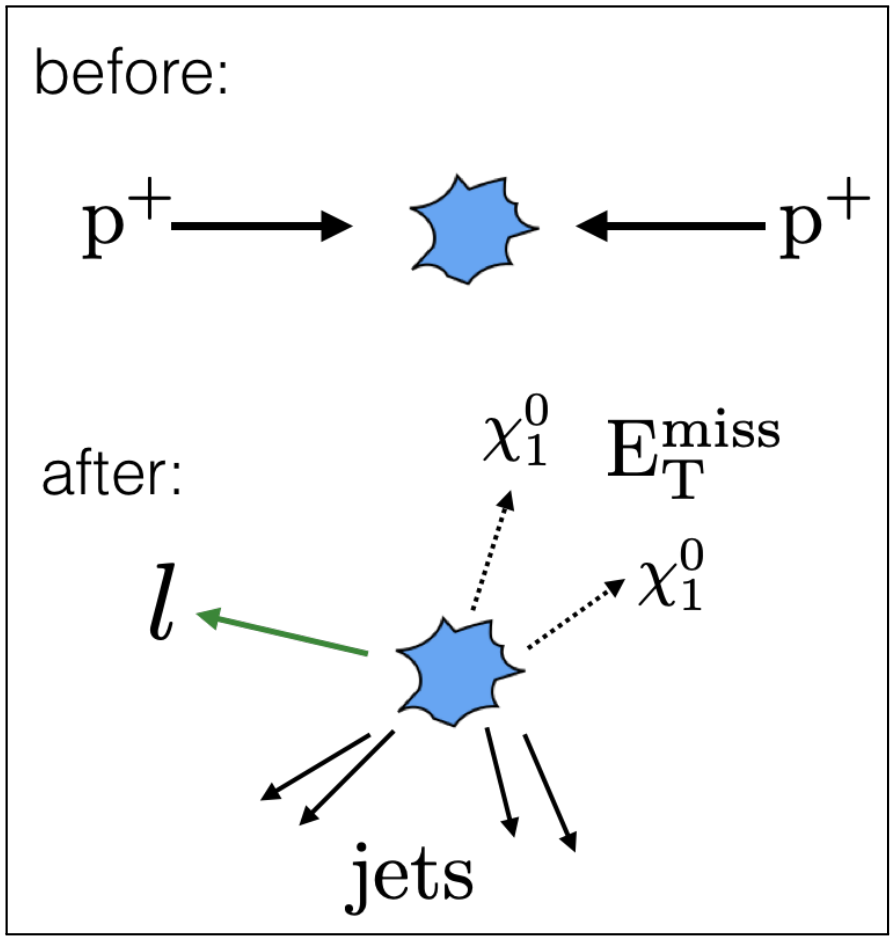
MET

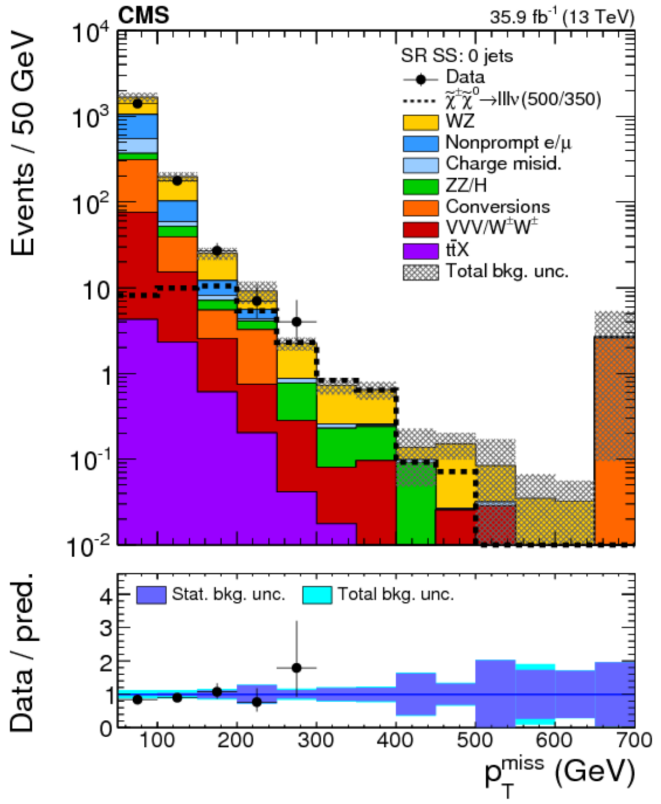
$E_T^{\text{miss}} \rightarrow$ imbalance in the transverse momentum



MET

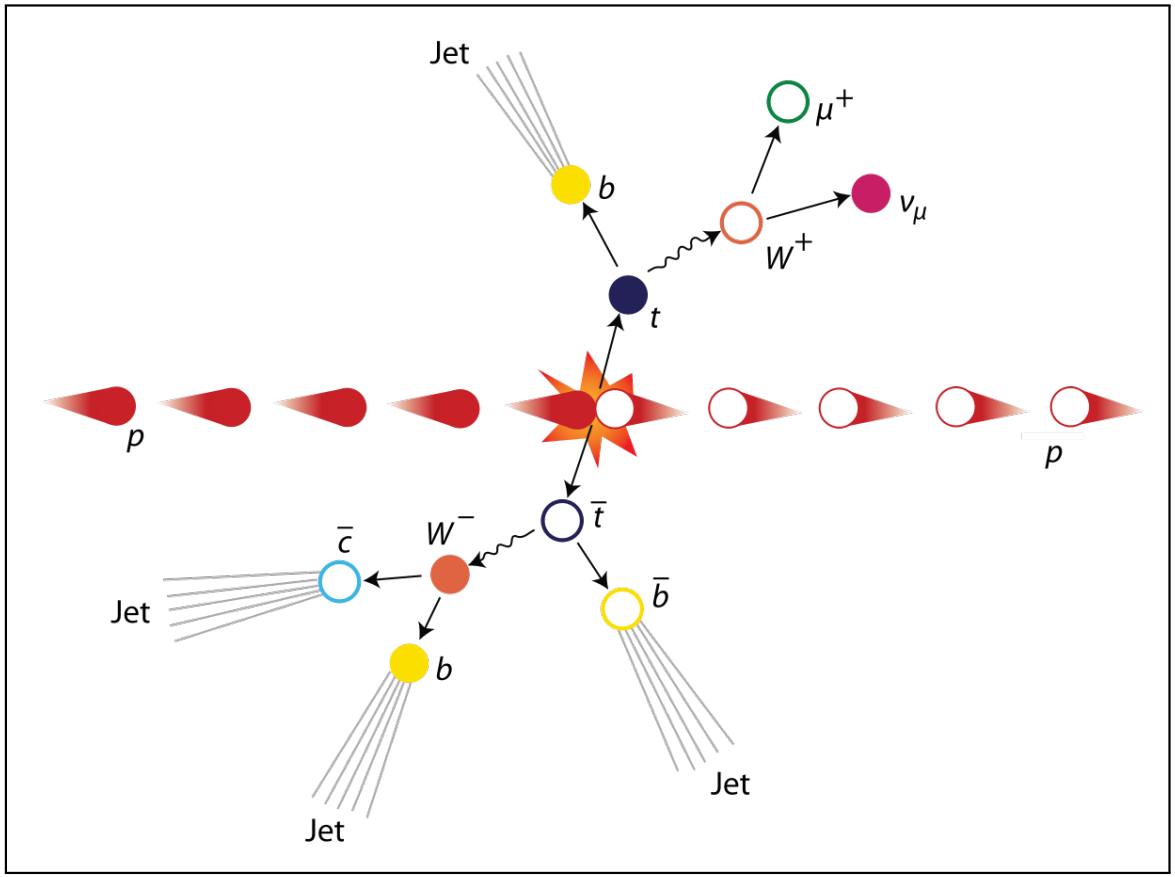
$E_T^{\text{miss}} \rightarrow$ imbalance in the transverse momentum





"Real" MET

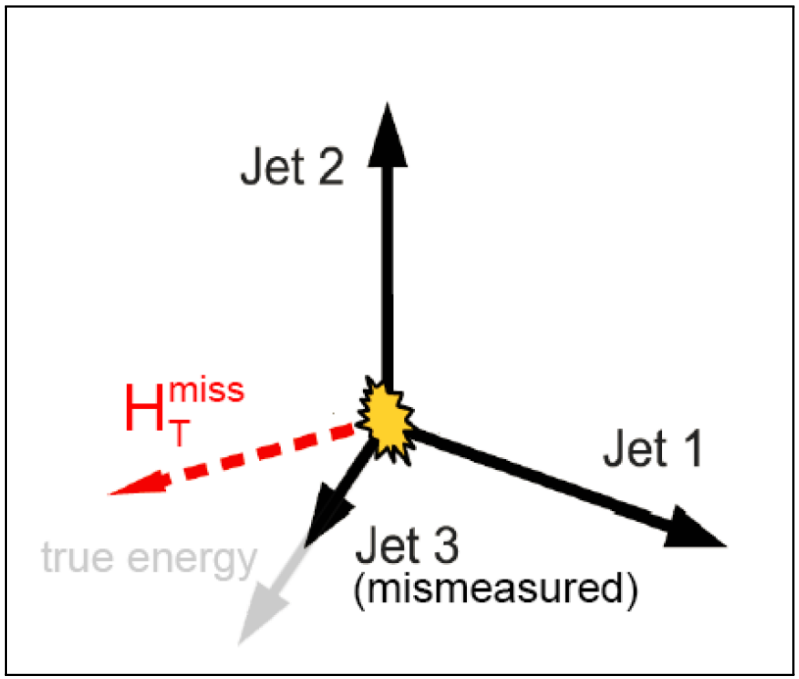
Real $E_T^{\text{miss}} \rightarrow$ is MET that comes from invisible particles (neutrinos)



$t\bar{t}$ event

Fake MET

Fake $E_T^{\text{miss}} \rightarrow$ is MET that comes from jet energy mis-measurement



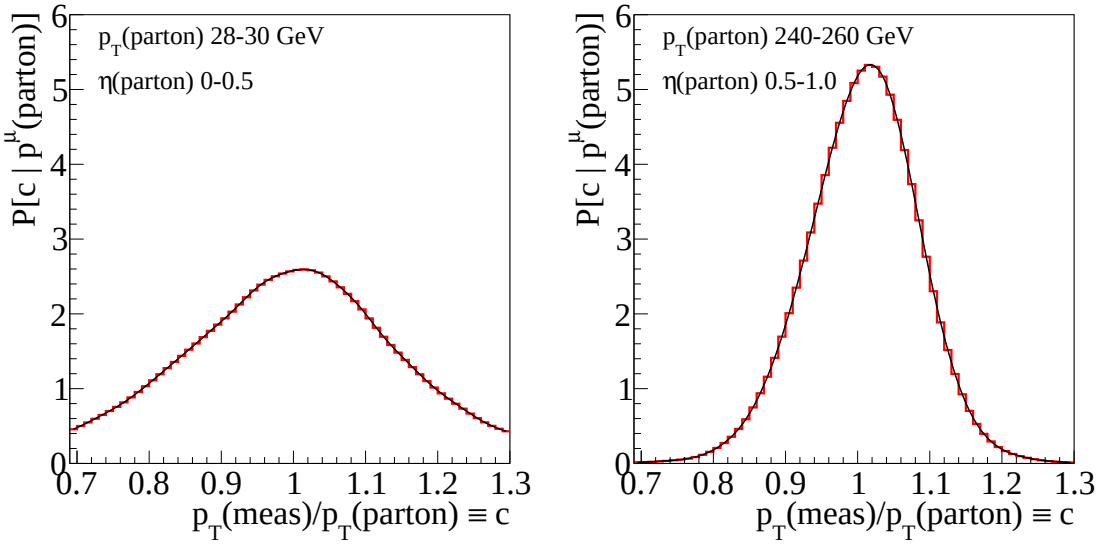
QCD event

- Most LHC events are QCD
- Fake MET also comes from Drell-Yan and γ+jets

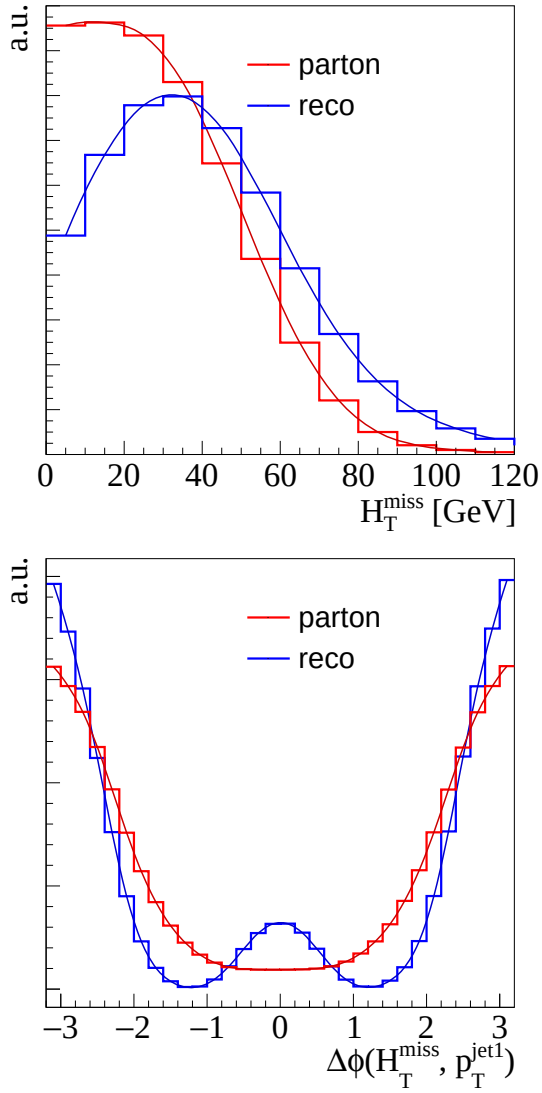
Can we get back to the truth-level jets?

Rebalance the event (rescale the jets)
by maximizing posterior density:

$$\mathcal{P}(\vec{\mathcal{J}}_{\text{true}}|\vec{\mathcal{J}}_{\text{meas}}) \sim \mathcal{P}(\vec{\mathcal{J}}_{\text{meas}}|\vec{\mathcal{J}}_{\text{true}})\,\pi(H_{T,\text{true}}^{miss}, \Delta\phi_{j(b),\vec{H}_T^{miss}}^{\text{true}})$$



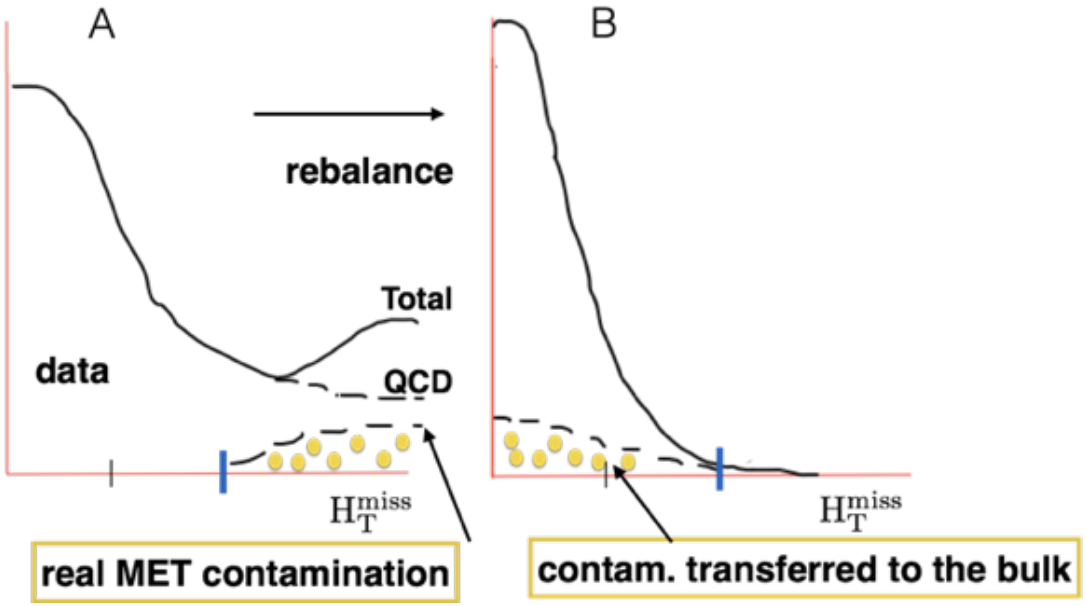
jet responses functions obtained from simulation that has been corrected by data/MC jet energy resolution scale factors (see Marek's thesis)



GEN-level MHT quantities

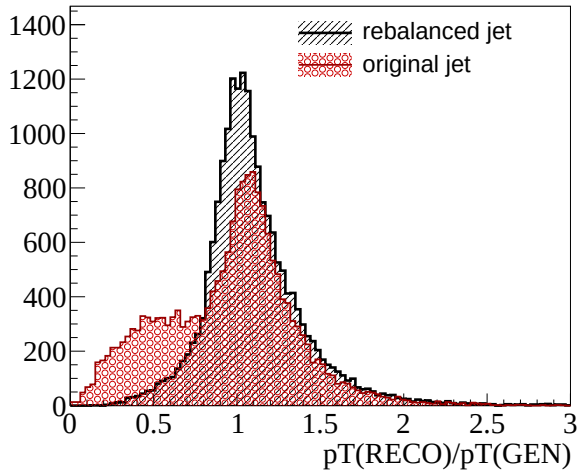
Rebalancing "restores" jet p_T

$$\mathcal{P}(\vec{\mathcal{J}}_{\text{true}}|\vec{\mathcal{J}}_{\text{meas}}) \sim \mathcal{P}(\vec{\mathcal{J}}_{\text{meas}}|\vec{\mathcal{J}}_{\text{true}})\,\pi(H_{T,\text{true}}^{miss}, \Delta\phi_{j(b),\vec{H}_T^{miss}}^{\text{true}})$$

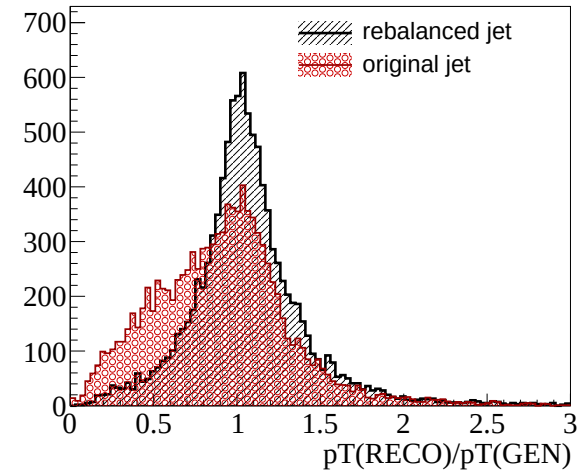


- (right) looking at jets in simulated QCD events with $H_T^{miss} > 120$ GeV
- rebalancing improves the JER, recovers missing energy

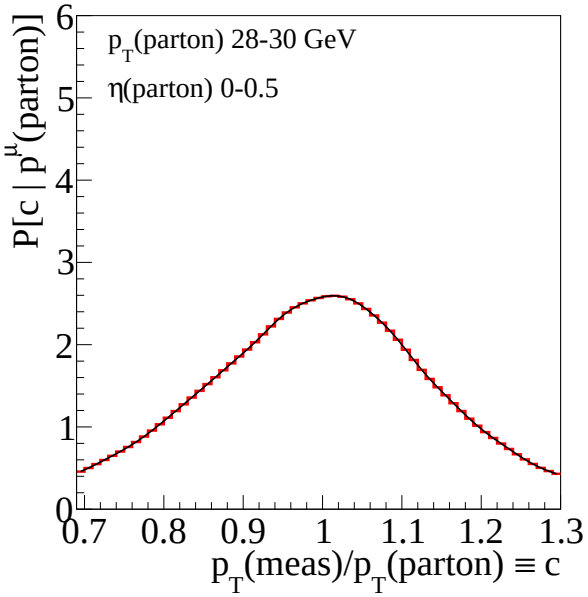
lead jet resolution

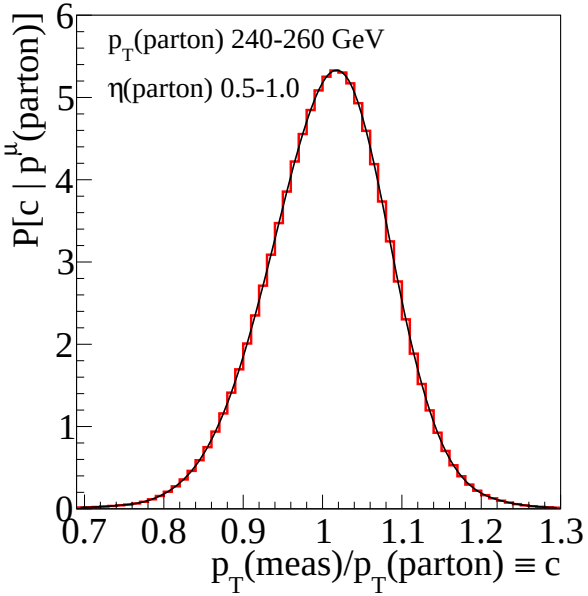


second jet resolution

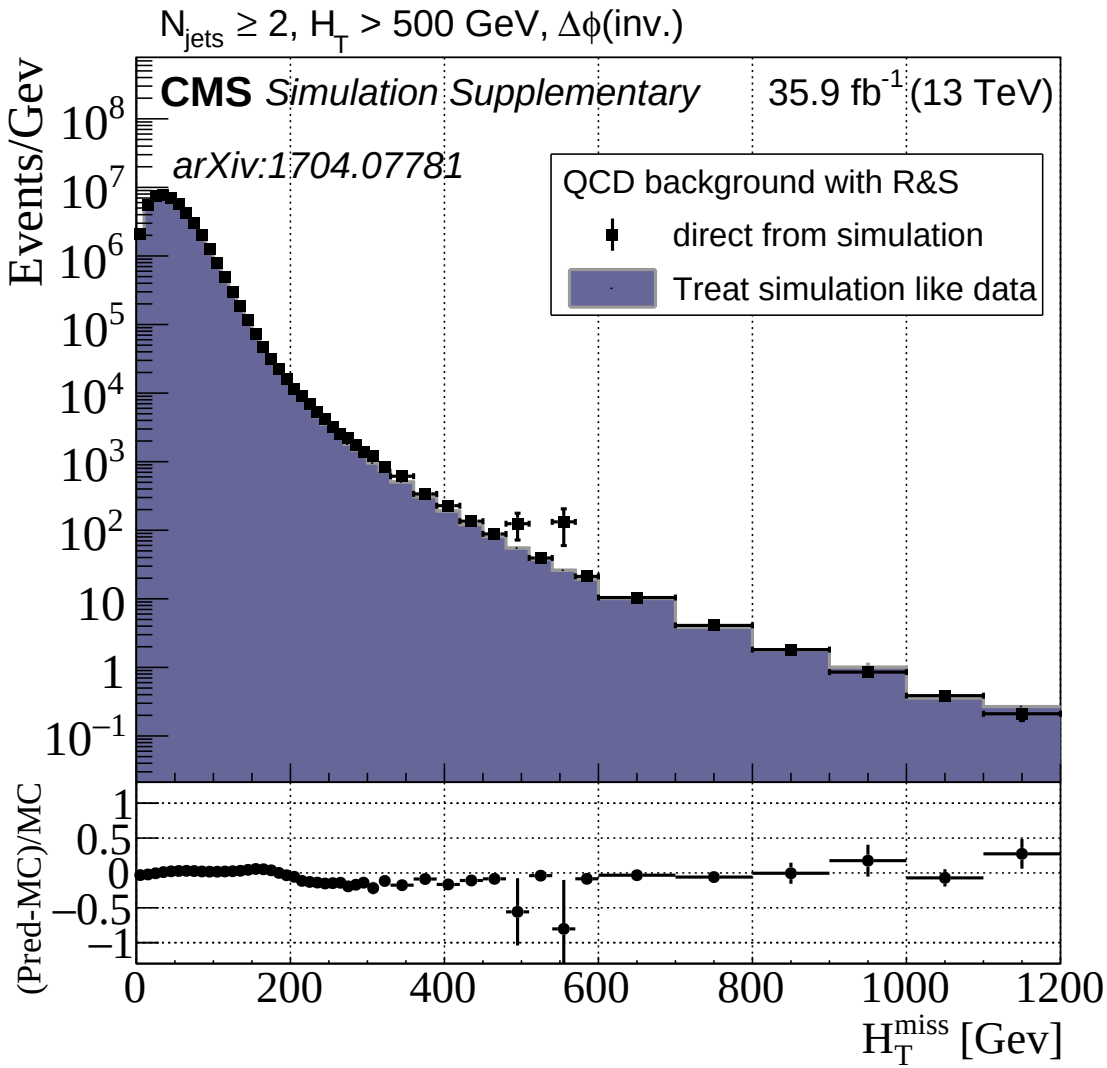


Smear jets to arrive at detector-level sample



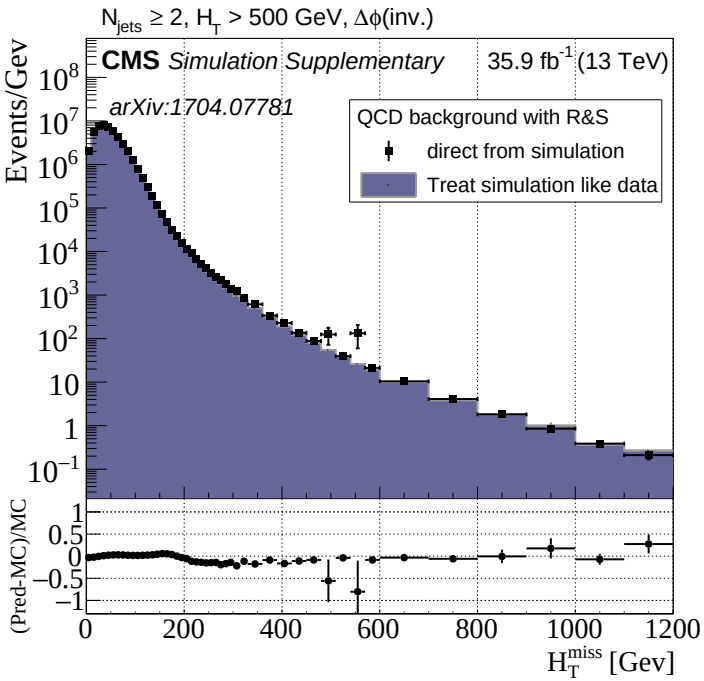


Smearing gets you back to where you started

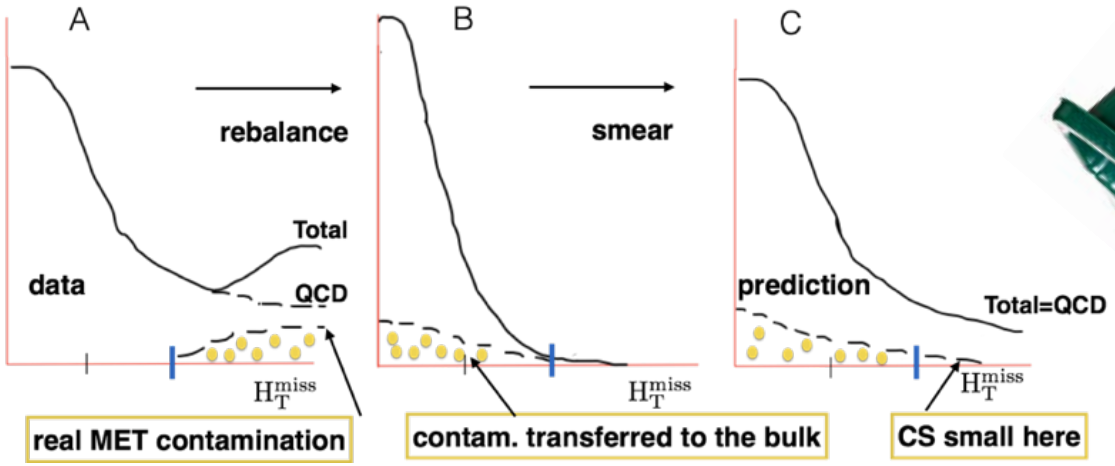


Smearing gets you back to where you started

Why this seemingly useless circle?

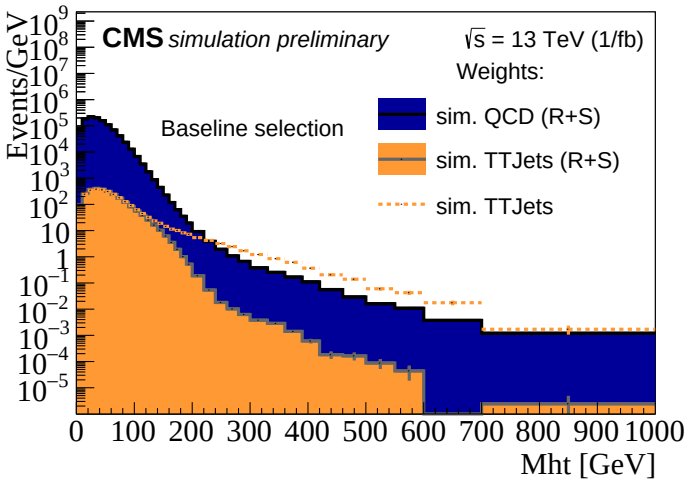


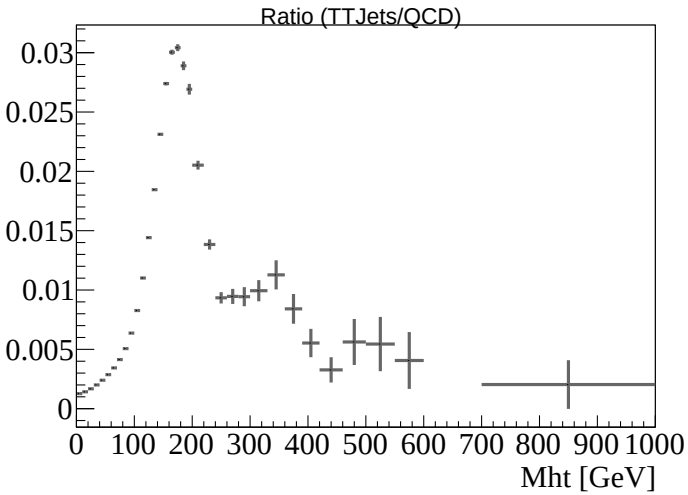
Why this seemingly useless circle?



1. after R&S, the real-E_T^{miss} is gone

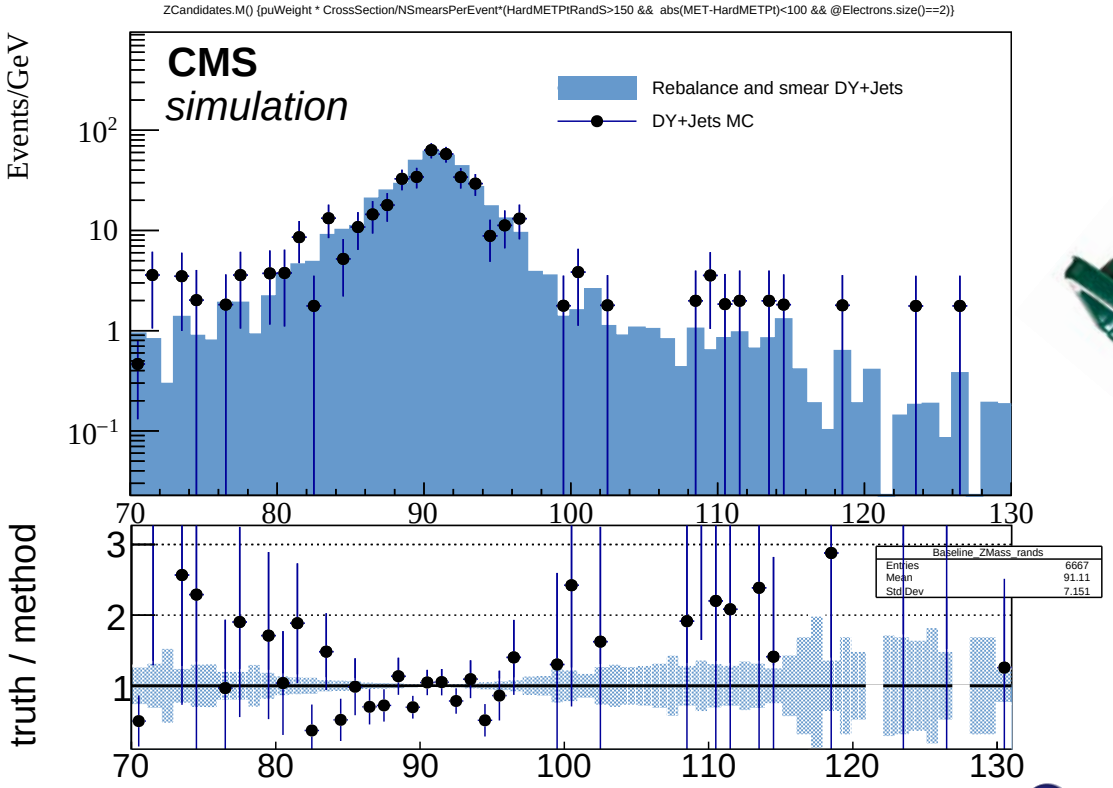
Why this seemingly useless circle?





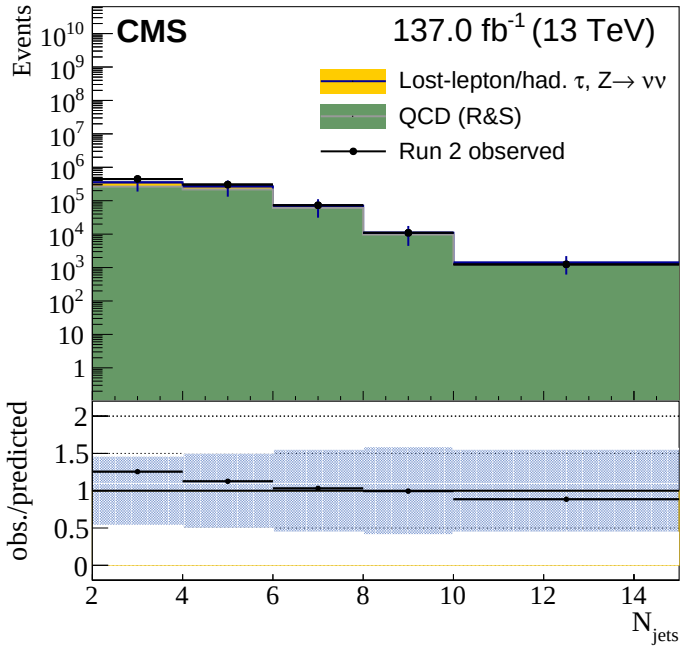
1. after R&S, the real-E_T^{miss} is gone

Why this seemingly useless circle?



1. after R&S, the real-E_T^{miss} is gone
2. you can smear the rebalanced event multiple times

Why this seemingly useless circle?



1. after R&S, the real-E_T^{miss} is gone
2. you can smear the rebalanced event multiple times
3. it's performed in real data, so good fidelity w.r.t. jet multiplicity, other

History of R&S

- Sue Ann Koay - *link to dissertation*
- Christian Sander - *link to talk*
- Christian Auterman - *Hamburg talk*
- Sam Bein - *link to dissertation*
- Marek Niedziela - *link to dissertation*

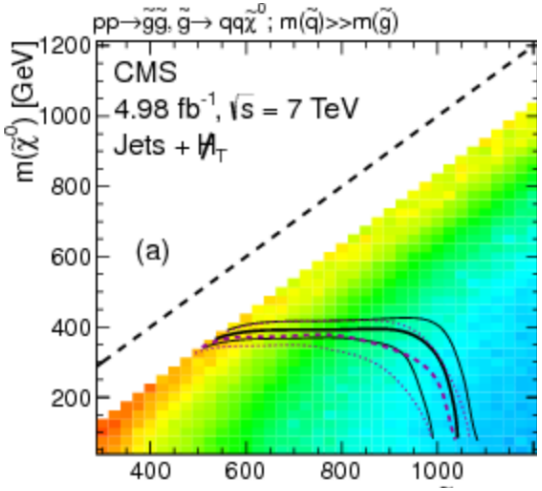


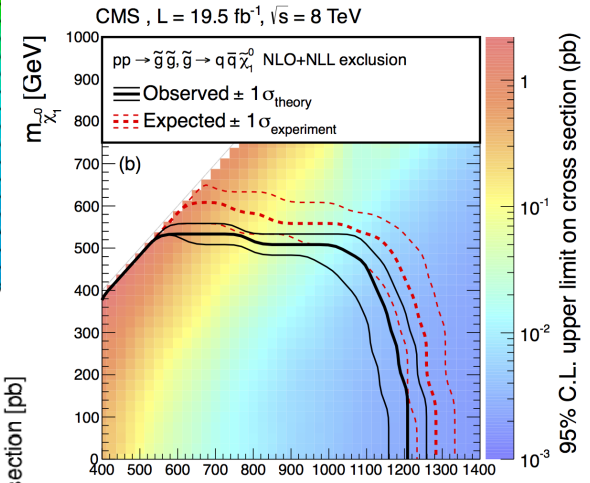


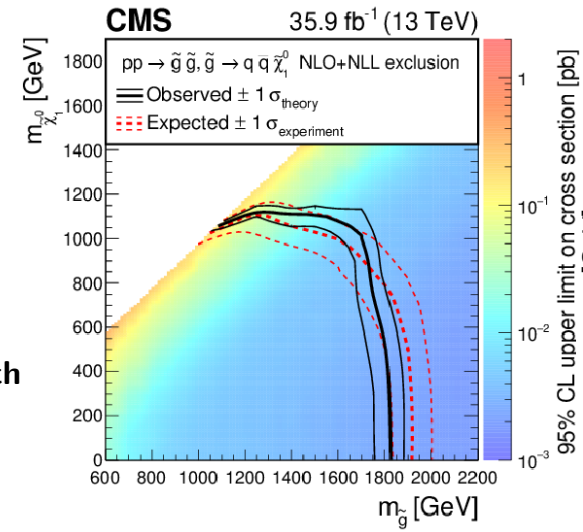
History of R&S (part 2)

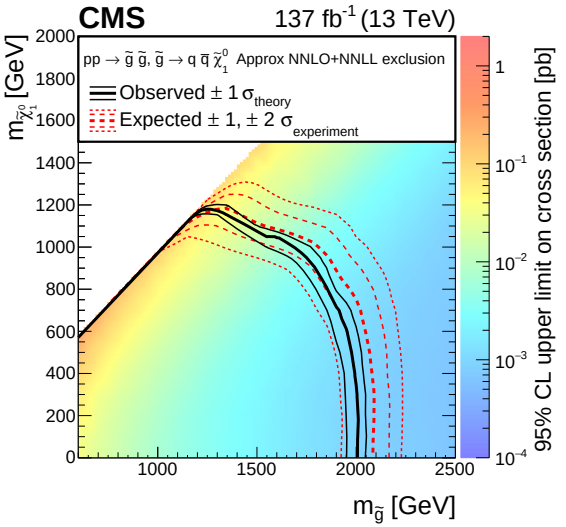
- published in Ra2/b analyses
- generic search in final states with:
  - $H_T^{miss} > 250$ GeV
  - $n_{\text{jet}} > 1$
  - $n_{\text{lepton}} == 0$

- **Search for New Physics in the Multijet and Missing Transverse Momentum Final State in Proton-Proton Collisions at $\sqrt{s}$=7 TeV** - *CMS Collaboration* Phys.Rev.Lett. 109 (2012) 171803
- **Search for new physics in the multijet and missing transverse momentum final state in proton-proton collisions at $\sqrt{s}$= 8 TeV** - *CMS Collaboration* - JHEP 1406 (2014) 055
- **Search for supersymmetry in multijet events with missing transverse momentum in proton-proton collisions at 13 TeV** - *CMS Collaboration* Phys. Rev. D 96, 032003 (35 fb^{-1})
- **Search for supersymmetry in proton-proton collisions at 13 TeV using 137 fb^{-1} of data in final states with jets and large missing transverse momentum** - *CMS Collaboration* SUS-19-006









Expanding horizons?

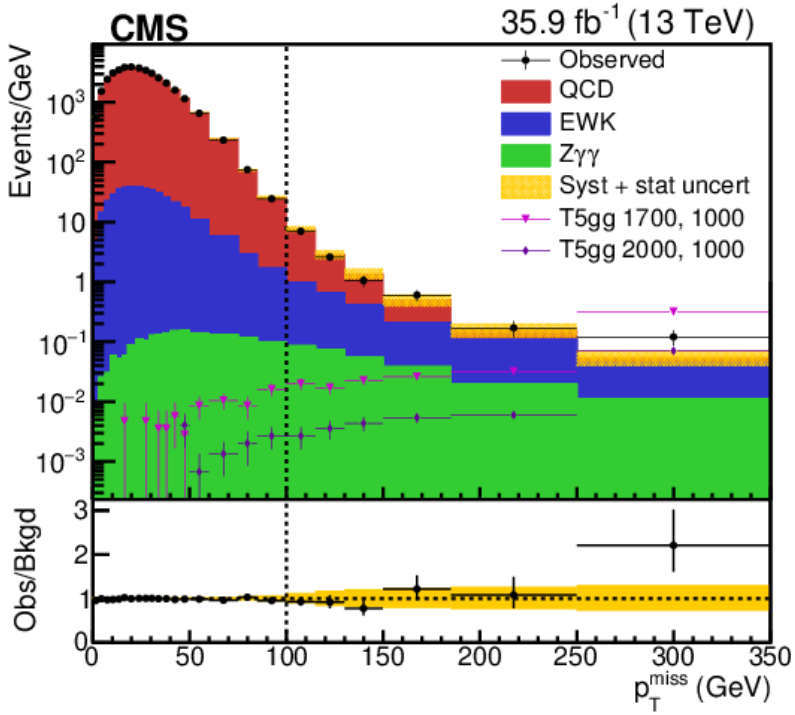
A look at a recent photon+jet search:

Search for supersymmetry in final states with photons and missing transverse momentum in proton-proton collisions at 13 TeV - *CMS Collaboration*, 10.1007/JHEP06(2019)143

main analysis selection:

- $E_T^{miss} > 120$ GeV
- $n_\gamma = 2$ (loose photons), $p_T > 75 GeV$
- binning in E_T^{miss}

p_T^{miss} bin (GeV)	QCD	EWK	Zγγ	Total background	Observed
100 – 115	99 ± 12	13.7 ± 4.2	1.3 ± 0.6	114 ± 13	105
115 – 130	$32.8^{+7.0}_{-6.7}$	9.0 ± 2.7	1.1 ± 0.6	$42.9^{+7.5}_{-7.3}$	39
130 – 150	$18.8^{+5.1}_{-4.9}$	7.4 ± 2.3	1.1 ± 0.6	$27.3^{+5.6}_{-5.4}$	21
150 – 185	$9.9^{+3.6}_{-3.4}$	6.1 ± 1.9	1.3 ± 0.7	$17.4^{+4.1}_{-3.9}$	21
185 – 250	$3.1^{+1.9}_{-1.7}$	5.8 ± 1.8	1.3 ± 0.6	$10.2^{+2.7}_{-2.6}$	11
≥250	$1.0^{+1.1}_{-0.9}$	3.3 ± 1.1	1.1 ± 0.6	$5.4^{+1.6}_{-1.5}$	12



→ largest uncertainty from QCD - can R&S be used as to reduce this or cross check?

First try at R&S with photons

Looking into 1 photon, 2-photon + E_T^{miss} in $\gamma + jets$ simulation

→ simplified selection selection:

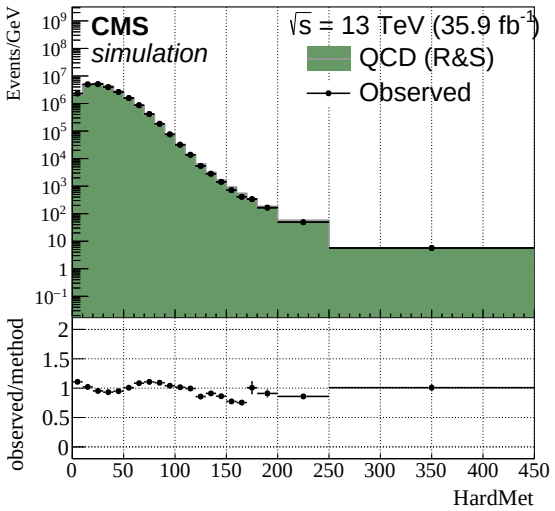
- $E_T^{miss} > 120$ GeV
- $n_\gamma = 1, 2$ (loose photons), $p_T > 75 GeV$
- a few questionable filters

Modified posterior:

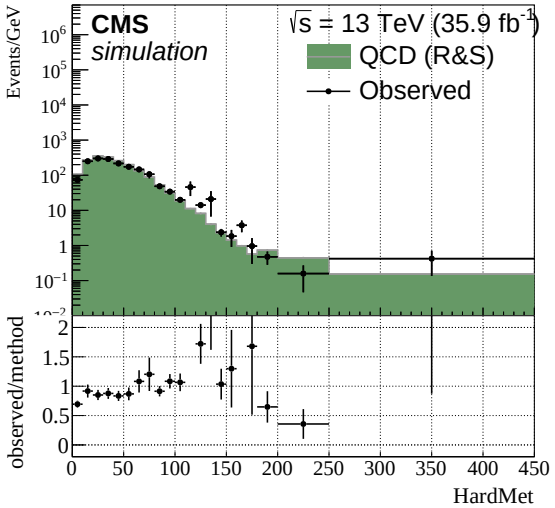
- use same prior and likelihood response templates as before
- freeze photon 4-vectors in the rebalancing and smearing
- rebalance and smear hadronic objects only

→ some non-closure is evident up to the 25% level

1-photon



2-photon



Summary

- exciting new opportunities in the field of fake MET
- photon+jet final states
- Drell-Yan final states?
- potential to produce rebalance+smeared ntuples which could be used by a wider user base
- potential to look into how well R&S models new observables