Driving Missing Data at the LHC

Kemal Ozeren

UCLA

West Coast TN 2011

on behalf of the BlackHat collaboration
Z. Bern, G. Diana, L. J. Dixon, F. Febres Cordero, D. Forde, S. Hoeche, H. Ita, D. A. Kosower, D. Maitre, K. Ozeren

Outline

SUSY search at LHC, using 36 pb $^{-1}$ at 7 TeV

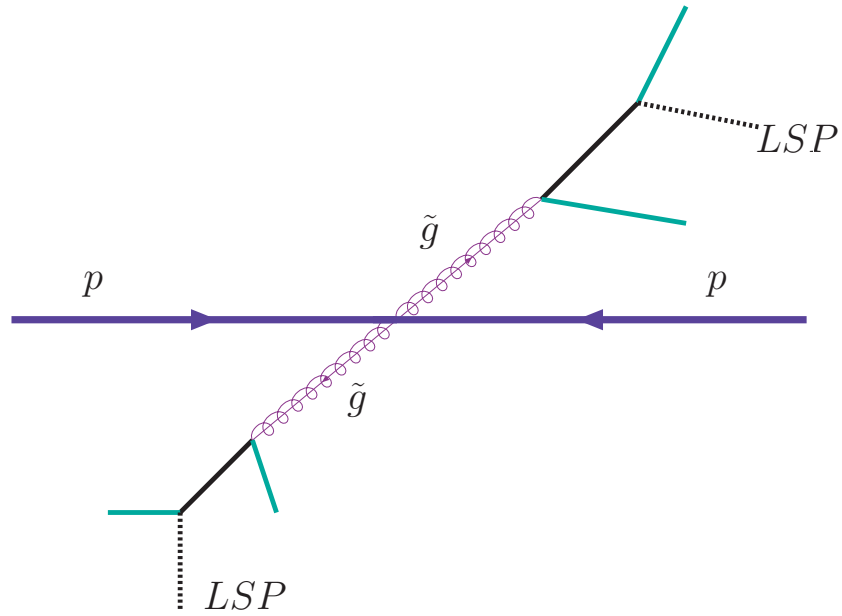
Estimating backgrounds

Role of QCD theory

SUSY searches

- Gluinos/squarks are pair produced
- Generic signature is MET + jets

Typical SUSY event:



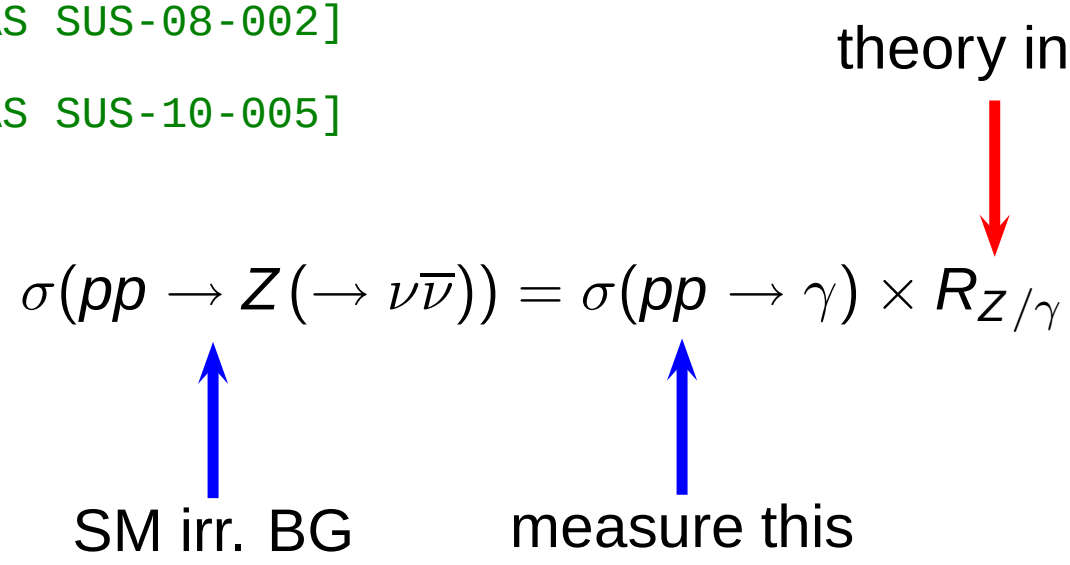
- How can SM mimic this?
  - $W \rightarrow l^{\pm}\nu$ with undetected lepton
  - QCD with mismeasured jet
  - $Z \rightarrow \nu\overline{\nu}$ Irreducible background - subject of this talk

Data Driven Background Estimation

- CMS uses photons to measure Z (Incandela's Group)

  [CMS PAS SUS-08-002]

  [CMS PAS SUS-10-005]

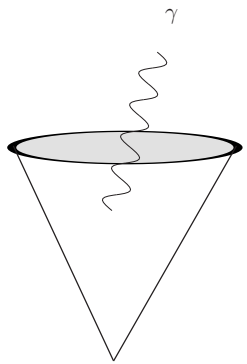


- Can also use $Z \to \mu\overline{\mu}$, but γ has better statistics
- So what is the conversion factor R?

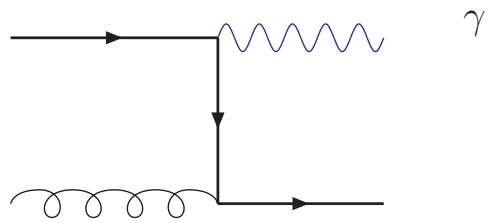
See later in this talk!

Photons at Colliders

- Two types of photon - prompt and fragmentation
- Z production related to first kind
- Require isolated photons to remove the fragmentation contribution



fragmentation



prompt

- Veto hadronic activity close to photon

Photon Isolation a la Frixione [hep-ph/9801442]

- In pQCD, have to be careful to preserve Infra-Red Safety
- Can't veto QCD radiation arbitrarily!
- Frixione: "here is a way to remove frag. photons in an IR safe way"

$$\sum_i E_{iT}\theta(\delta - R_{i\gamma}) \leq H(\delta)$$

$$H(\delta) = E_T^{\gamma}\epsilon\left(\frac{1-\cos\delta}{1-\cos\delta_0}\right)^n$$

- Important: $H(\delta) \to 0$ as $\delta \to 0$
- We choose $\epsilon = 0.025$, $\delta_0 = 0.3, n = 2$

QCD Predictions

Next-to-leading order predictions are needed to control uncertainties in LHC predictions

Need for NLO

- reduced scale uncertainties: $\mathcal{O}(50\%) \rightarrow \mathcal{O}(10\%)$
- can study appropriate scale to use
- beginnings of jet structure

But severe technical difficulty... need to automate!

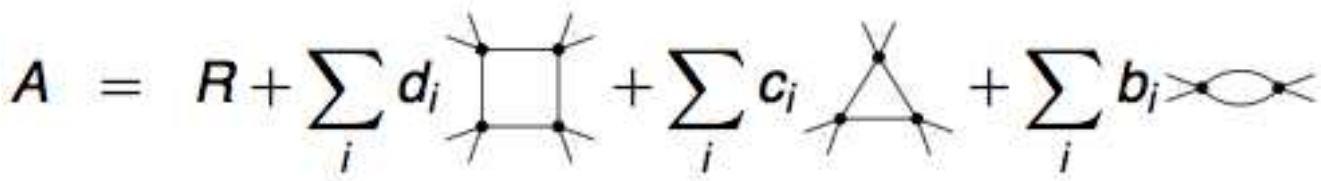
- complicated IR structure of QCD
- traditional bottleneck: virtual corrections
- dramatic progress last $\sim$ 3 years (see next slide)

BlackHat

BlackHat connects theoretical progress to LHC physics

- Implementation of modern generalised unitarity cut method
- Evaluates coefficients of integrals:

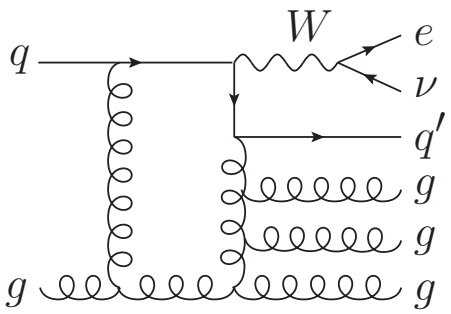
$$A = R + \sum_i d_i \; + \sum_i c_i \; + \sum_i b_i$$



- High-multiplicity one-loop QCD amplitudes
- Speed critical - require fast trees Berends Giele, BCFW, Grassmanian(new!)

- Extremely powerful - e.g. W + 4 jet

  [BlackHat Collaboration 1009.2338]



Setup

- We calculate the ratio Z/γ in association with 2 jets, following the CMS cuts
- Use SHERPA for real emission and integration

  [Gleisberg, Hoeche, Krauss, Schonherr, Schumann, Siegert, Winter]
- The critical variables are

$$H_T = \sum_j E_T^j, \qquad \mathrm{MET} = -\sum_j p_j$$

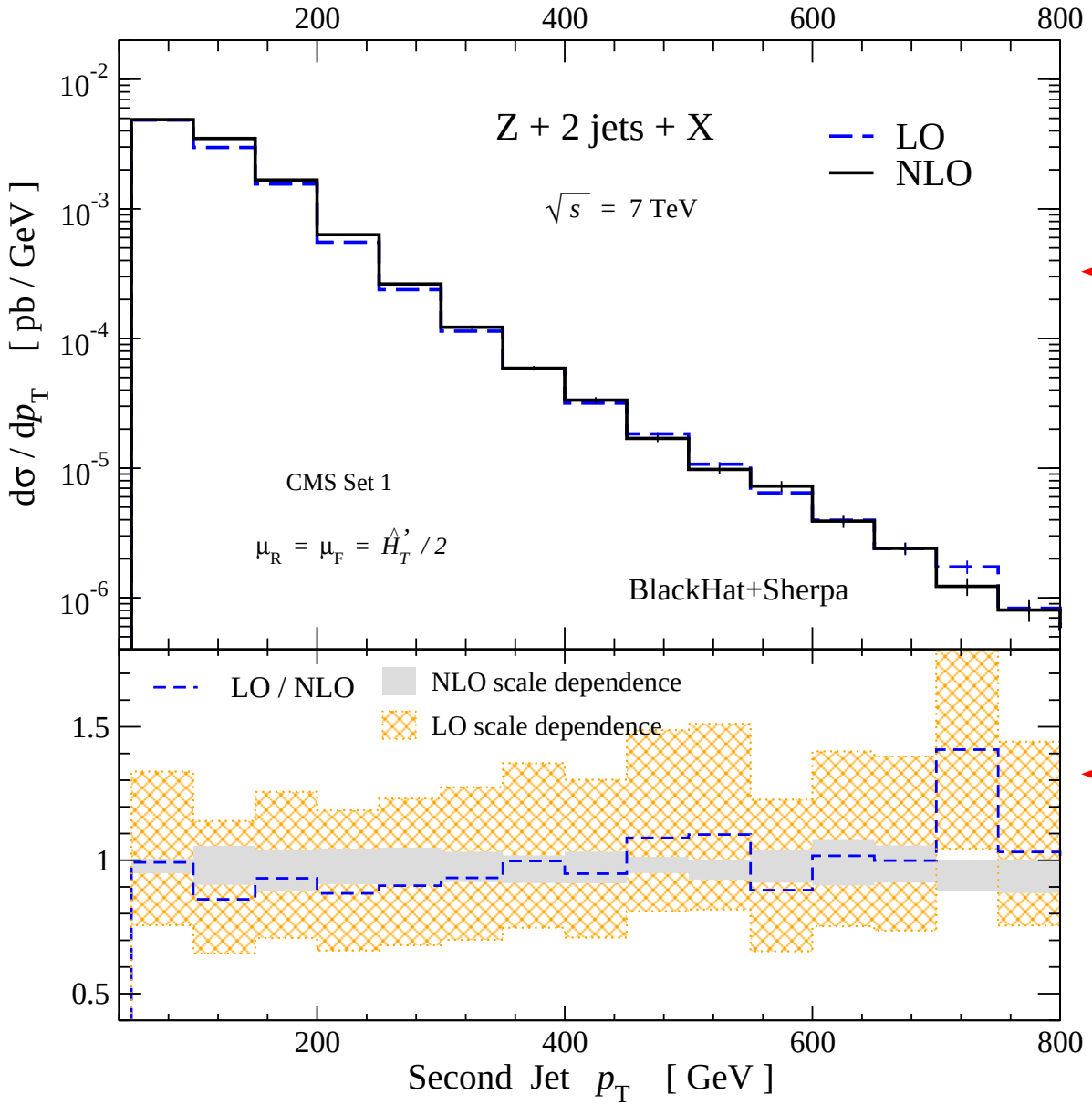
- three sets of cuts:
  1. $H_T > 300$, MET> 250 high MET
  2. $H_T > 500$, MET> 150 high H_T
  3. $H_T > 300$, MET> 150 "baseline"
- impose

$$\Delta(\Phi)(\mathrm{MET}, \mathrm{jet}) > 0.5$$

  to suppress QCD multijet background

Preliminary Results

Z+2j with CMS cuts



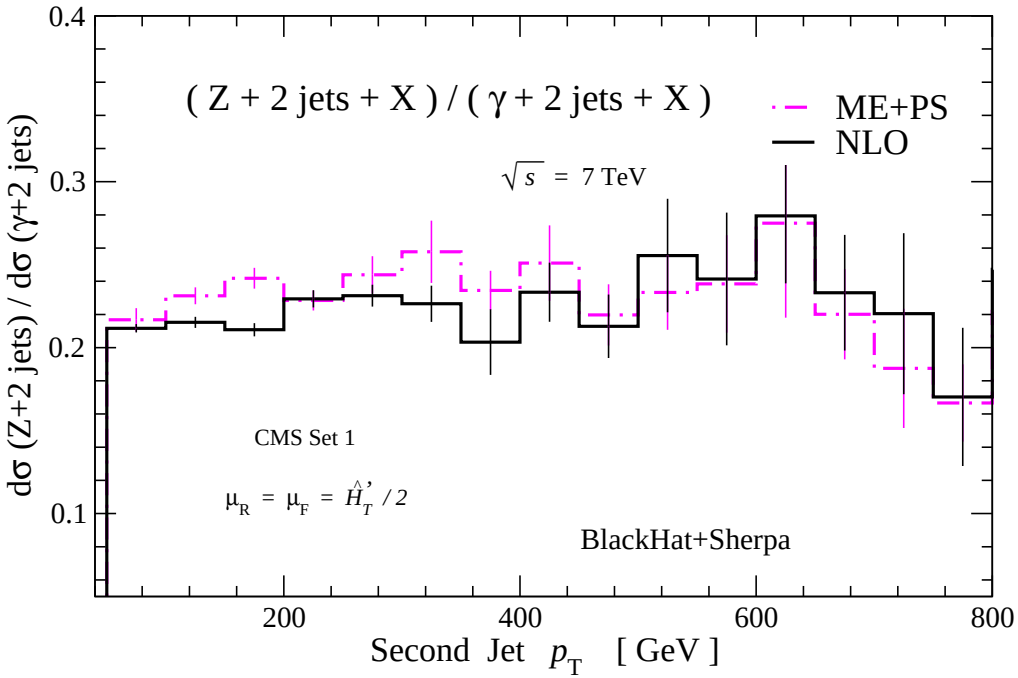
cross section

scale variation

(significantly reduced at NLO)

Preliminary Results Z/γ ratio

Plot of Z/γ ratio



process	LO	ME+PS	NLO
$\gamma + 2j$	$2.220^{+0.762}_{-0.526}$	2.110	$2.609^{+0.159}_{-0.241}$
$Z + 2j$	$0.521^{+0.180}_{-0.124}$	0.478	$0.560^{+0.012}_{-0.043}$
ratio	0.235	0.226	0.214

- Ratio roughly constant across phase space
- Good agreement between NLO / MEPS
- Take difference as error estimate, as scale variation largely cancels in ratio

Summary

- CMS uses γ+jets measurement to predict Z+jets
- Important background to SUSY (MET+jets)
- Data driven methods require precision theory for extrapolation: ratio is calculated in pQCD
- I presented a NLO+MEPS study using BlackHat+Sherpa
- Our results used directly for estimating error in γ/Z conversion in CMS analysis