



INSTITUTE FOR THEORETICAL PHYSICS, HEIDELBERG UNIVERSITY

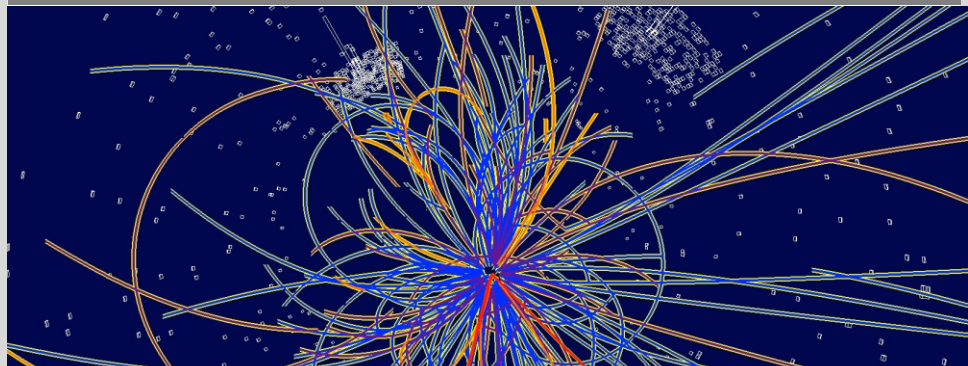
# Jets plus Missing Energy with an Autofocus

Christoph Englert | 09.05.2011

work with T. Plehn, P. Schichtel, S. Schumann

arXiv:1102.4615

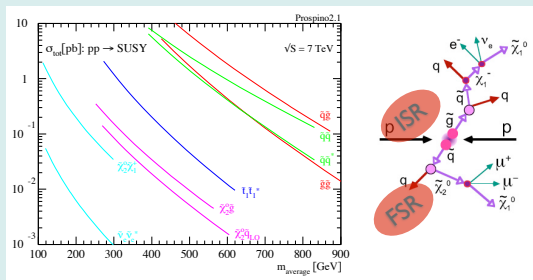
PHENO '11, MADISON



# Jets plus missing energy searches

## Jets plus missing energy

- generic signature of BSM theories with a residual  $\mathbb{Z}_2$  (DM) and QCD interactions



- large production cross sections  $\mathcal{O}(\text{pb})$  qualify for searches in early data

[CMS arXiv:1101.1628 [hep-ex], ATLAS-CONF-2010-065]

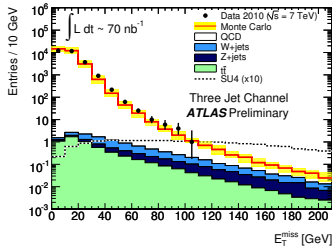
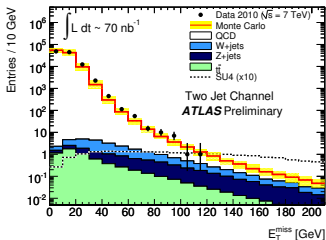
## Challenges

- huge backgrounds & uncertainties, small  $S/B$
- $\cancel{E}_T$  from detector effects
- dedicated cuts for specific scenarios  
→ loose pert. control, sculpt bckg.

# Towards digging out new physics

QCD jets dominate inclusive analysis even when fake rate is included!

	QCD jets	Z+jets	W+jets	$t\bar{t}$ + jets
$\sigma$ [pb]	$\sim 3.5 \times 10^6$	$\sim 5 \times 10^3$	$\sim 50 \times 10^3$	$\sim 300$



[ATLAS-CONF-2010-065]

Aim for a model-independent shape analysis on an sample as inclusive as possible

- Ask for at least 3 hard  $R = 0.4$  ant- $k_T$  jets with  $p_T^j \geq 50$  GeV
- Veto isolated leptons with  $p_T \geq 20$  GeV
- Ask for  $\cancel{E}_T \geq 100$  GeV, include QCD with conservative fudge factor 1/500 (flat)

..., trigger, decrease background, generically no harm to the signal

# Background vs. Signal

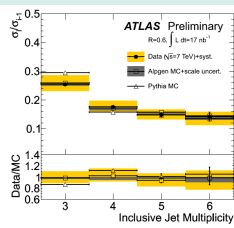
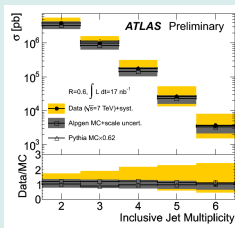
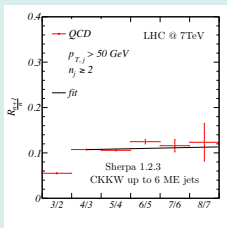
## Features of the background

- QCD dominant,  $t\bar{t}$  gone (no  $b$ -tag)

[SHERPA: Gleisberg *et al.* '09]

- "staircase scaling" of the number of jets in  $Z/W + jets$  and QCD jets

$$R = \frac{\sigma_{n+1}^{incl}}{\sigma_n^{incl}} = \frac{\sigma_{n+1}^{excl}}{\sigma_n^{excl}} = \text{const}$$



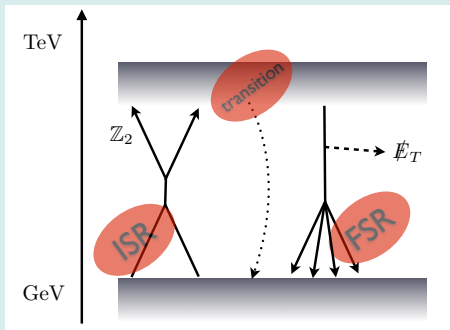
[CE, Plehn, Schichtel, Schumann '11]

[ATLAS-CONF-2010-084]

- Define  $n_j$  control region (signal-free)  $\rightsquigarrow$  extrapolate high bins using measured  $R$
- Consistently reduce systematic uncertainties of other distributions, scale variation becomes a "tuning parameter" of the MC simulation

# Background vs. Signal

## Features of the signal



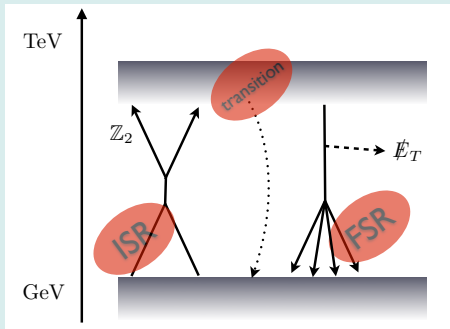
- produce massive TeV-scale particles, large  $x$   
 $\leadsto$  enhanced ISR
- transition radiation  
 $\leadsto$  additional (soft) radiation
- decay of massive TeV-scale particles, large  $x$   
 $\leadsto$  hard decay jets
- boosted decay products  
 $\leadsto$  enhanced FSR

spectrum-characteristic  $d\sigma^{\text{excl}}/dn_j$   
no staircase scaling

- $d\sigma^{\text{excl}}/dn_j$  provides discriminative power in a background which can be well extrapolated due to scaling
- SUSY is a phenomenological paradigm for this situation [HERWIG++: Bähr *et al.* '08]  
cross check against MLM matched [MADGRAPH: Alwall *et al.* '07]

# Background vs. Signal

## Features of the signal

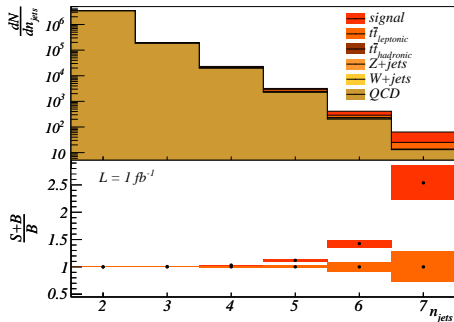


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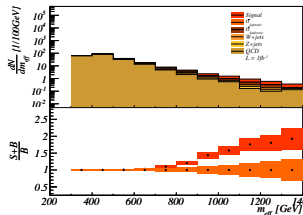
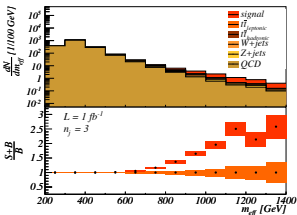
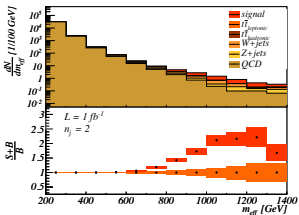
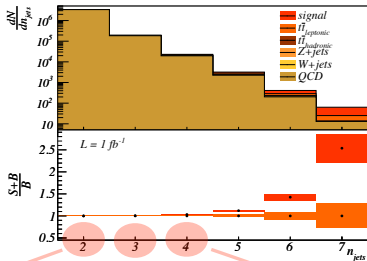
Shape log likelihood analysis  $\mathcal{Q}(n_j)$   
[LEPHWG '03]

	signal significance for $35 \text{ pb}^{-1}$
inclusive	$0.2 \sigma$
$n_{jets} (1D)$	$1.6 \sigma$

- $n_j$  encodes both mass scale and BSM particle decays
- resolve ambiguity and gain statistical sensitivity by singling out the exclusive  $n_j$ 's mass scale:

$$\leadsto \mathcal{Q}(n_j, m_{\text{eff}}) \quad \text{with } m_{\text{eff}} = \cancel{E}_T + \sum_{n_j} p_T^j$$

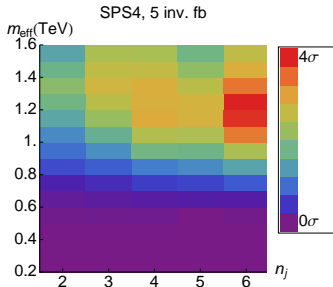
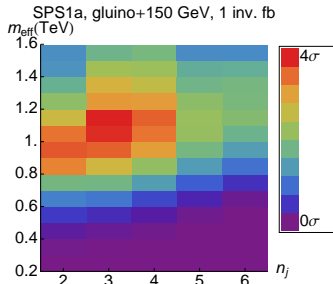
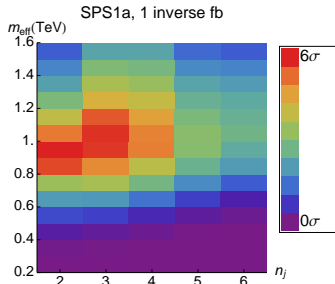
# Background vs. Signal



$[m_{eff} \text{ binning } 100 \text{ GeV} \sim \text{experimental resolution}]$



# Autofocussing with $Q(n_j, m_{\text{eff}})$



# Summary

## backgrounds in inclusive jets+missing energy seem well under control

- scaling property in pure QCD jets and  $W/Z$ +jets backgrounds allows precise predictions of  $n_j$  rates
- handle to extrapolate to high jet multiplicities and constrain theoretical systematics in a data driven approach

## simple hypothesis testing can identify signal-dominated regions

- conservative treatment of fake- $\cancel{E}_T$  (no  $\alpha_T, \dots$ )
- inclusive cuts: normalizations and shapes are governed by perturbation theory
- scaling remains valid for exclusive jet numbers
- $\mathcal{Q}(n_j, m_{\text{eff}})$  isolates regions not consistent with the background-only hypothesis, this *can* be the first glimpse of the BSM spectrum
- No spectrum-specific cuts necessary