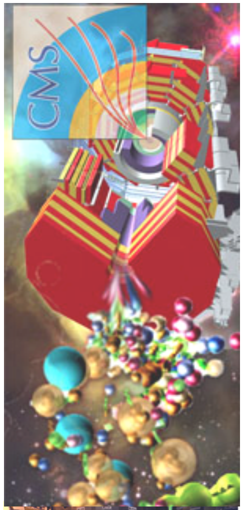


H→ZZ activities: summary

N. De Filippis - Politecnico and INFN Bari
Stathes Paganis - University of Sheffield

Comparison of generators

Higgs simulation

H→ZZ signal: 4l, 2l 2jet, 2l2ν, 2l2τ analyses

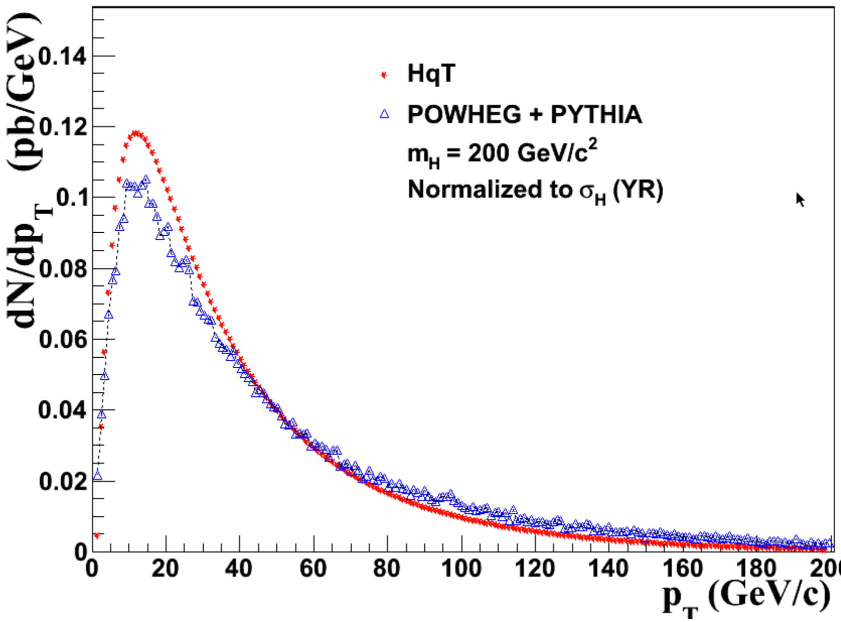
✧ POWHEG NLO (CMS official production)
✧ MC@NLO for comparison
✧ Sherpa for comparison
✧ HqT / HNNLO from Grazzini et al.
✧ JHU code for helicity treatment and spin correlations

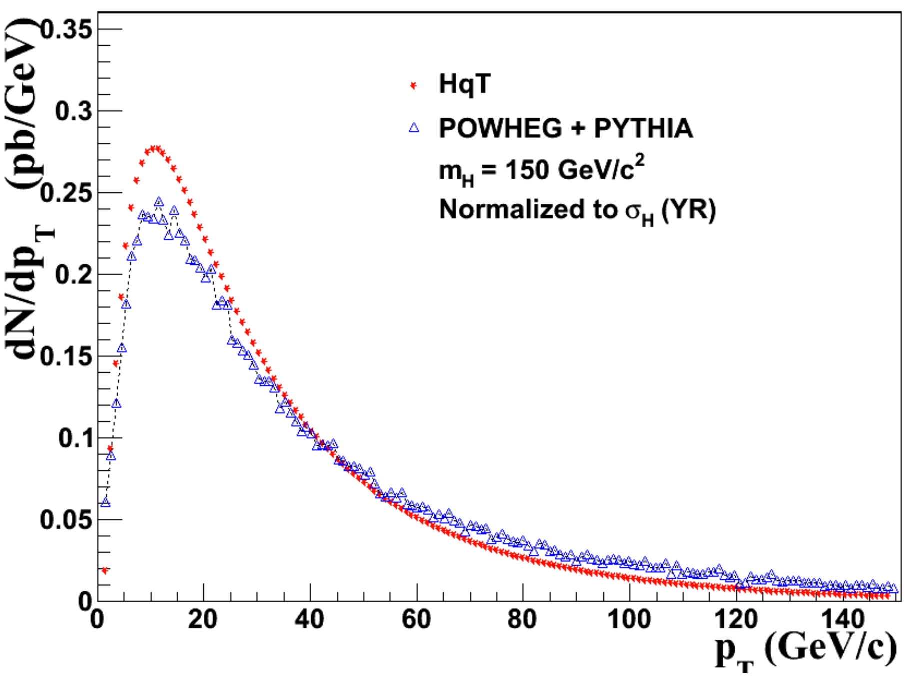
On going studies:

✧ **Hqt** for Higgs pT distribution and reweighting
✧ comparison of distribution between generators:
  ✧ POWHEG (+ PYTHIA) vs HNNLO
  ✧ SHERPA vs HNNLO
  ✧ MC@NLO vs HNNLO
  ✧ which distributions to be produced ?
    ✧ pT of higgs, pT of Z, pT of leptons
    ✧ di lepton, 4 lepton invariant mass
    ✧ eta, phi ?....
    ✧ isolation variable
✧ Effect of cuts on NNLO k-factor calculation documented for H→WW and H→ZZ
(to be quantified in the context of current analyses with common agreed cuts)

Hqt vs POWHEG + PYTHIA

I. Hqt ran for masses between 120 and 500 GeV/c2
II. POWHEG + PYTHIA ran for CMS official production
III. Normalization to the total cross section of higgs production of Yellow Report





I. By the ratio of histograms → weight
II. Then reweight the pT in POWHEG + PYTHIA
III. Check the impact for HZZ observables
IV. Check the weight at the POWHEG level (matrix element)

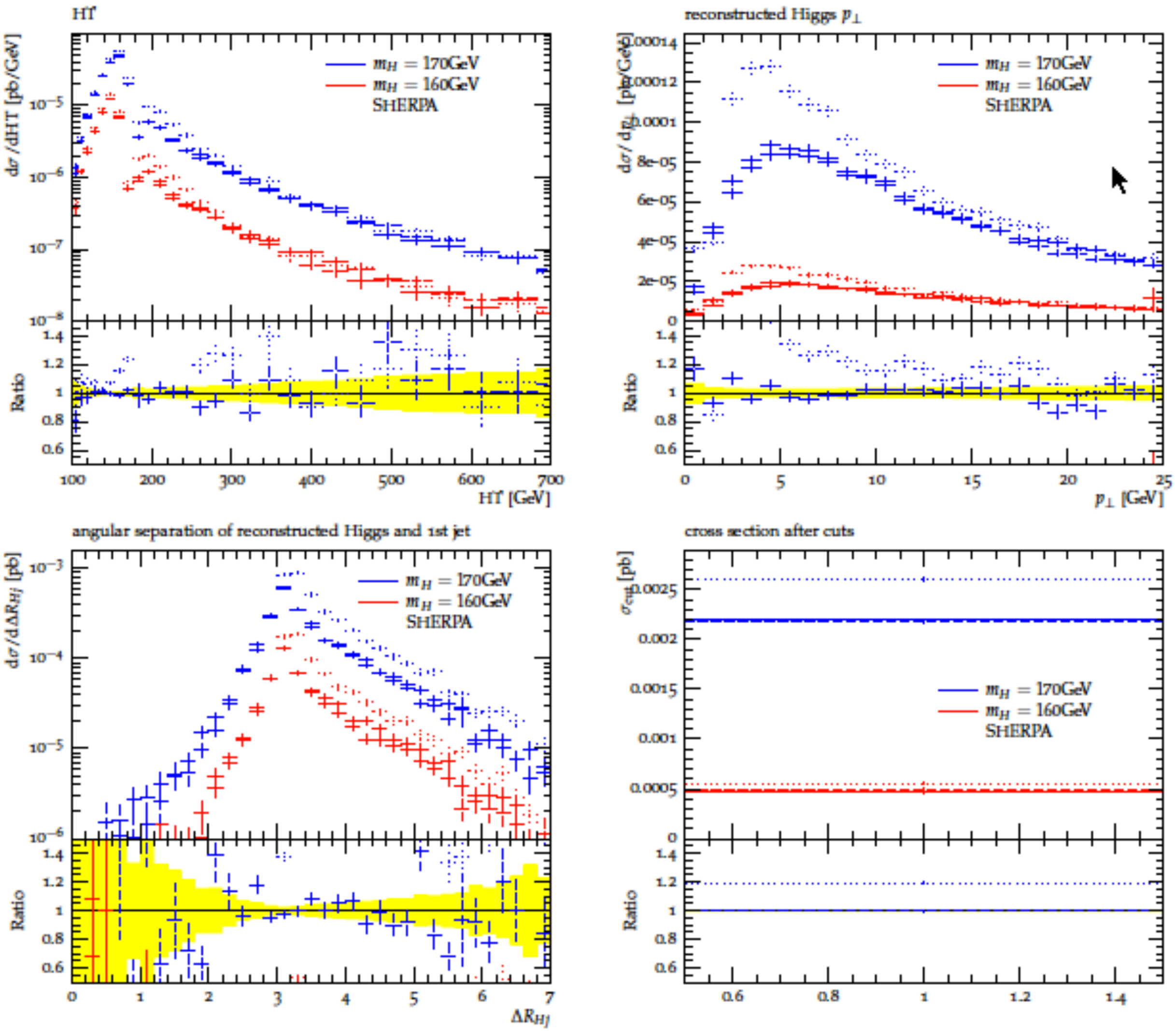
Planned Efforts for SHERPA

M. Schoenherr

- use version SHERPA-1.3.0
- SHERPA run cards provided for all setups included in working plan: → MS
    - powheg-emission only, different PDFs, scale variations
    - powheg-emission + parton shower, different PDFs, scale variations
    - full event generation, different PDF+α_s tunes
    - fixed order NLO setups (ME level) for comparisons/cross-checks

  `http://iktp.tu-dresden.de/~marek/HiggsNLO/setups/setups.html`
- reweight with local NNLO-NLO K-factor derived from HqT → NF
- Rivet analyses constructed by Frank Siegert

Prel. First Results – $pp \to h \to Z[\to ee] + Z[\to \mu\mu]$



M. Schoenherr

$m_h = 160, 170$ GeV

dotted –
powheg-emission only

dashes –
powheg-emission plus parton shower and QED corrections

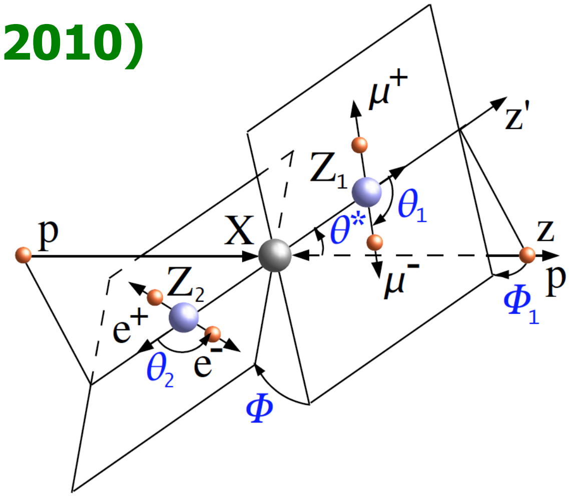
solid –
full event simulation incl. hadronisation, hadron decays, underlying event

John Hopkins U. generator vs POWHEG

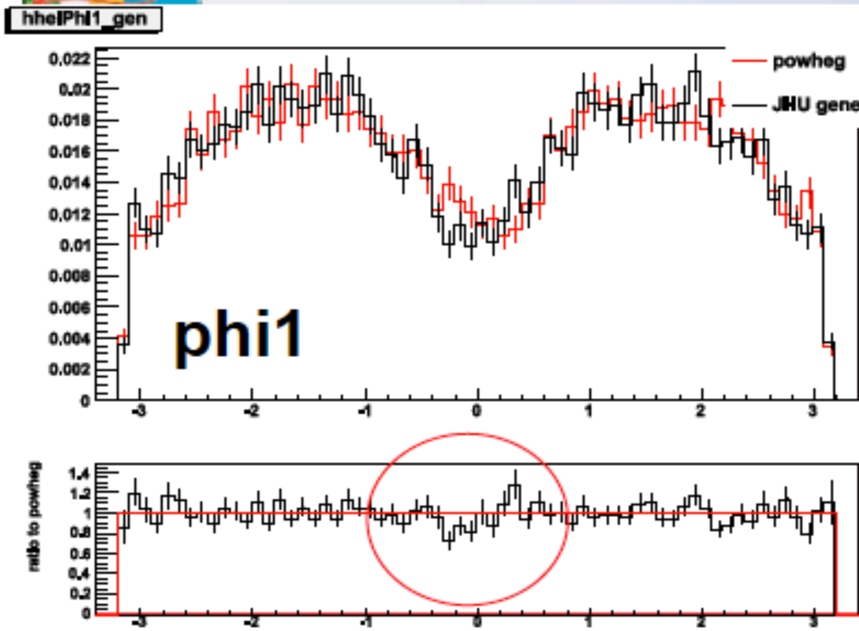
S. Bolognesi

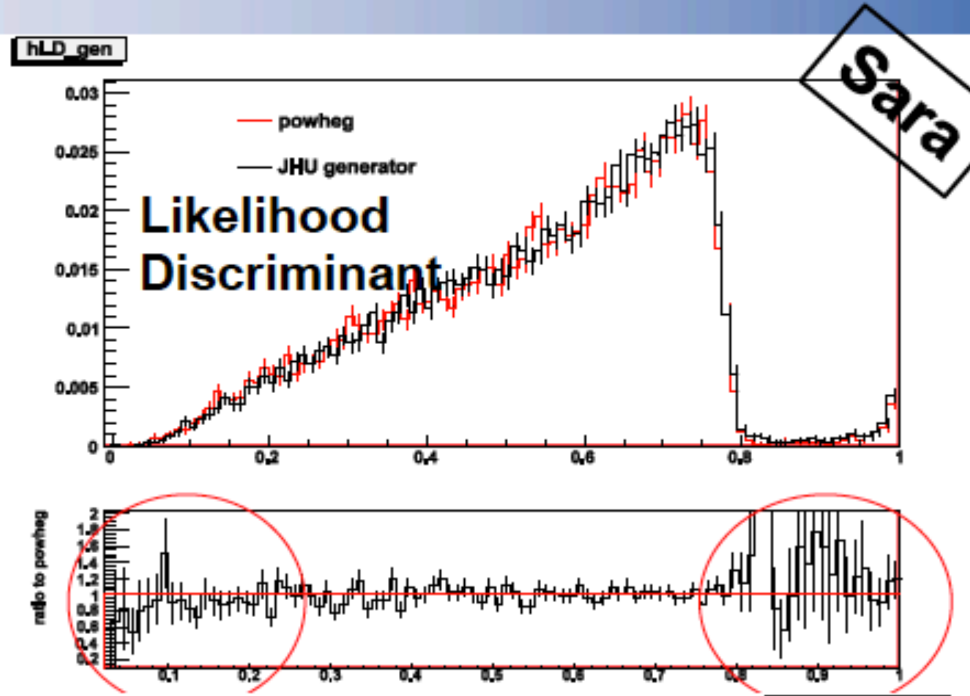
- Currently use JHU generator
  - Includes all spin correlations
  - LO + parton showers
  - Winter10
- Assess:
  - Uncertainties in acceptance (feeds into limits)
  - Uncertainties from higher order effects
- Use POWHEG for comparison
  - Proper NLO calculation
  - Biggest effects expected from NLL resumation (not included)
  - Winter10
- Currently parton level only

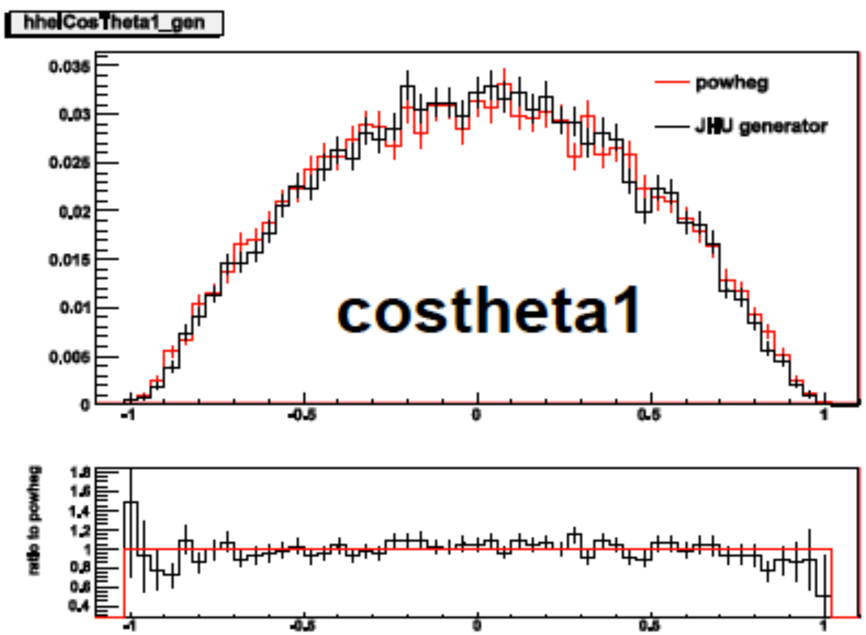
Ref. PRD81, 075022(2010)

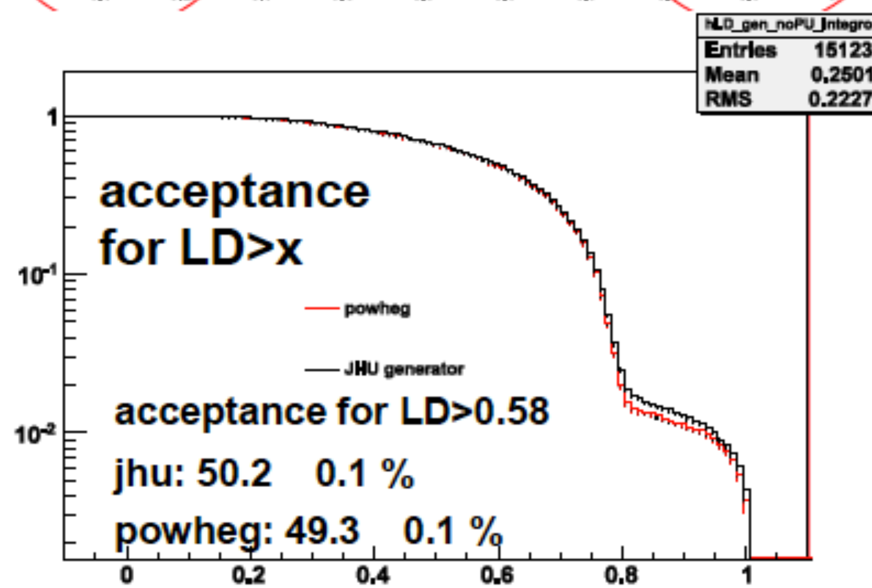


Angular Variables

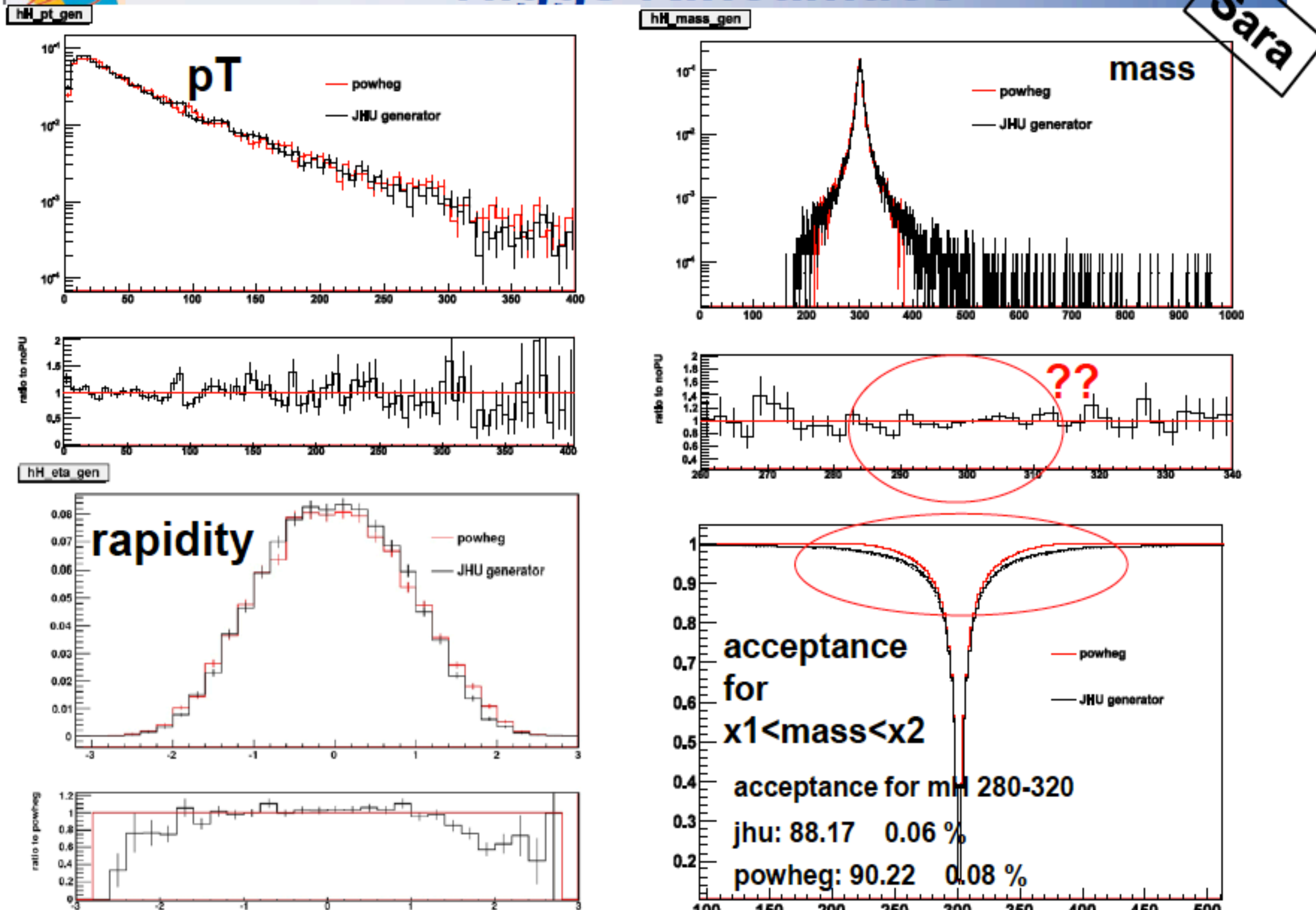








Higgs Kineamtics



JHU generator vs POWHEG: summary

- Overall good agreement between generators
- Good agreement on important angular variables
- Most prominent difference in Higgs mass shape
- Look more closely at lepton kinematics (currently sample biased due to RECO level preselection)

Sara

	powheg	jhu	difference
mjj 75-107 GeV	95.96%	96.57%	0.4%
mll 70-112 GeV	97.63%	97.42%	0.2%
LD > 0.58	49.3%	50.2%	1%
mH 280-320 GeV	88.17%	90.22%	2%

Generator studies from ATLAS

- Successfull tests with POWHEG ggF + Pythia
- Successfull tests with Sherpa (Tulay Donszelmann)
- First tests of comparing POWHEG and SHERPA on going
- Comparison in the HZZ4l phase space

- The subsequent study will concern MC@NLO

Background control from data

Background studies

Main background:

- ✧ PYTHIA LO
- ✧ MadGraph/MadEvent + PYTHIA LO
- ✧ Alpgen + PYTHIA LO
- ✧ Sherpa
- ✧ GG2ZZ LO
- ✧ POWHEG NLO

Basic concepts to assess:

- ✧ Comparison of LO generators (MadGraph/Alpgen) and w.r.t NLO generators (POWHEG)
- ✧ Definition of control region where the bkg is dominant while the signal is absent
- ✧ Extrapolation from control to signal region with MC expectation
- ✧ Definition of the uncertainty on bkg yield and shape

Evaluation and control of ZZ

The Problem:

- Not enough ZZ continuum in near side-bands
- Constraints on integrated ZZ continuum statistically limited

The Solution:

- Rely on the **measurement** of Z boson production
- Rely on theory for the shape of the $d\sigma_{ZZ}/ dM_{4l}$ differential spectrum
- Cross check with direct MC simulation of ZZ production and selection

Principles:

- Similarity between $Z^{(*)}$ and $ZZ^{(*)}$ diagrams; dominant contributions to the cross-section coming from quark currents via EWK couplings
- Measurement of σ_Z and knowledge of the ratios $(\sigma_{ZZ} / \sigma_Z)_{theory}$ and $(\varepsilon_{ZZ}/\varepsilon_Z)_{MC}$ can be exploited to partially cancel out systematics

ZZ: closure test

- Normalization to Z :

$$N_{ZZ\to 4e} = \frac{\sigma^{NLO}_{pp\to ZZ\to 4e}}{\sigma^{NNLO}_{pp\to Z}} \cdot \frac{\varepsilon^{MC}_{ZZ\to 4e}}{\varepsilon^{MC}_{Z\to ee}} \cdot N^{observed}_{Z\to ee} \pm stat \pm systematics \pm theory$$

- ZZ simulation from MC:

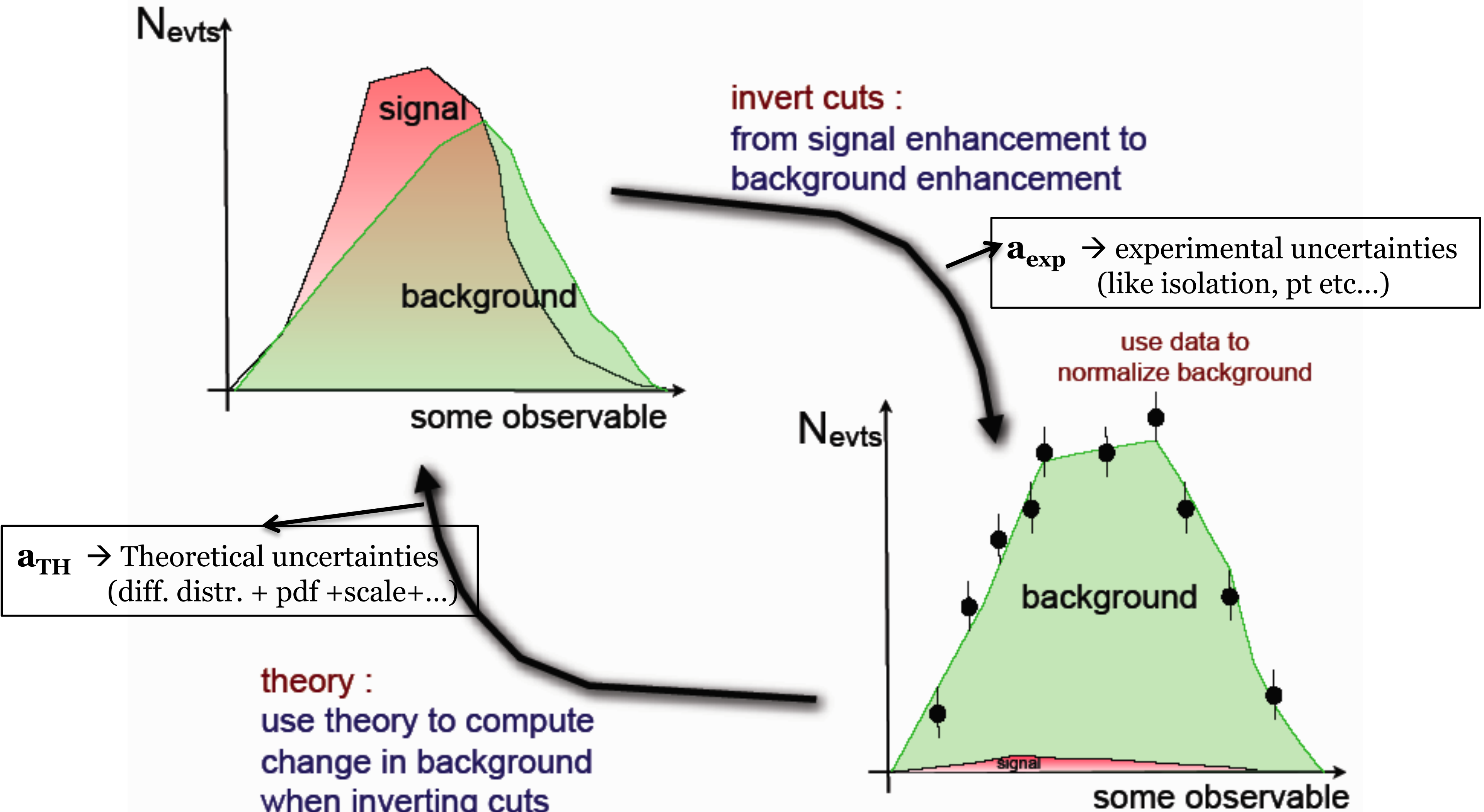
$$N^{MC}_{ZZ\to 4e} = L \cdot \sigma^{NLO}_{pp\to ZZ\to 4e} \cdot \varepsilon^{MC}_{ZZ\to 4e} \pm stat \pm (lumi \oplus systematics) \pm theory$$

<< 10% 5% 6%

$$N^{MC}_{ZZ\to 4e} = 2.95 \pm 0 \pm 0.33 \pm 0.19$$

- ZZ observation

Control region: extrapolation from SR to CR



$$N^B_{(signal\ region)} = a_{exp} * a_{TH} * N^B_{control\ region}$$

a_{exp} - uncorr between exp
a_{TH} - 100% correlated

Control of Zbb

- ✧ Prediction of alpgen and MadGrapg to be verified

- ✧ L. Reina, F. Cordero (arXiv:0906:1923 and arXiv:0809.3003) are working to integrate Zbbar diagrams in POWHEG

- ✧ Absolute cross section at NLO are currently computed with MCFM → anyway this is not enough

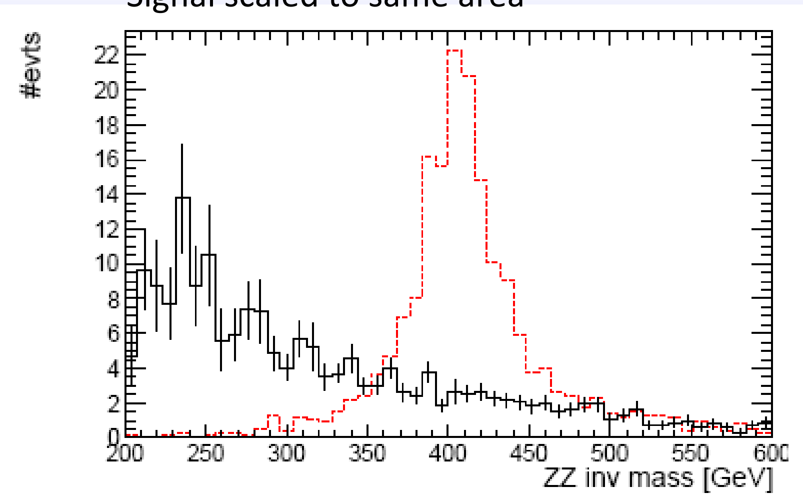
- ✧ Control region defined or 4 lepton analysis but the quite low yield at 1 fb^{-1} O(1 event) makes difficult the measurement from data → inspecting alternative methods

Background control for H→ZZ→2l2j

- Fit to mZZ distribution to separate background (Z+jets continuum) from signal peak

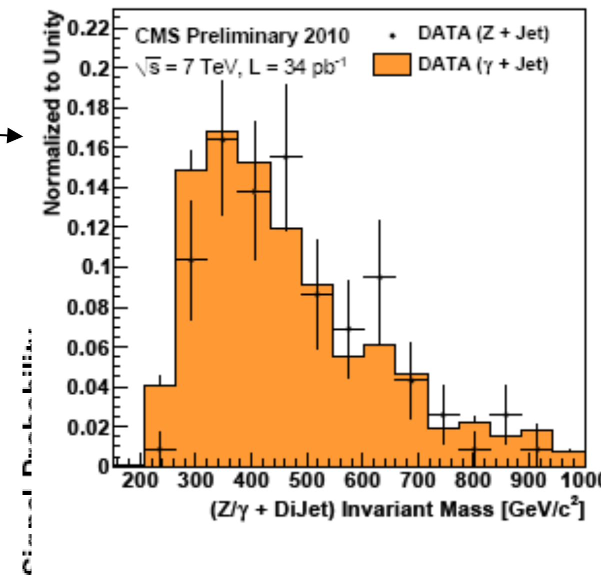
Background scaled to 1fb-1

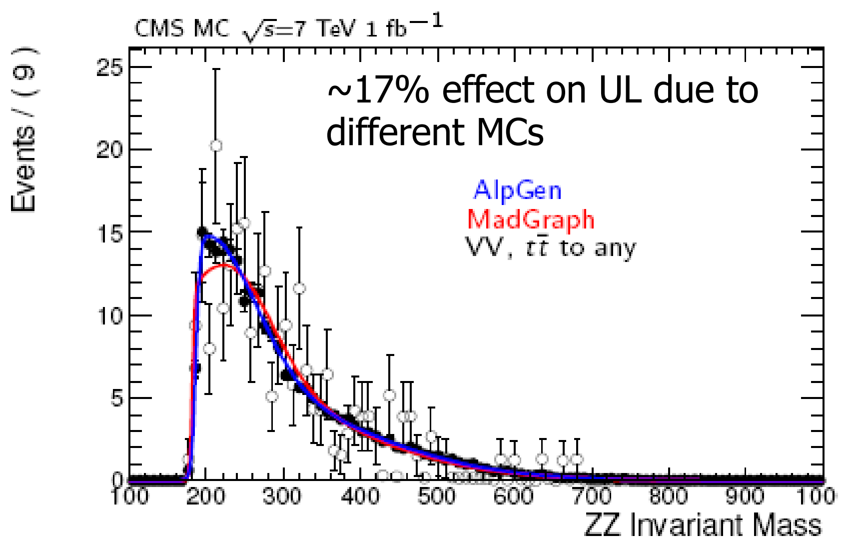
Signal scaled to same area



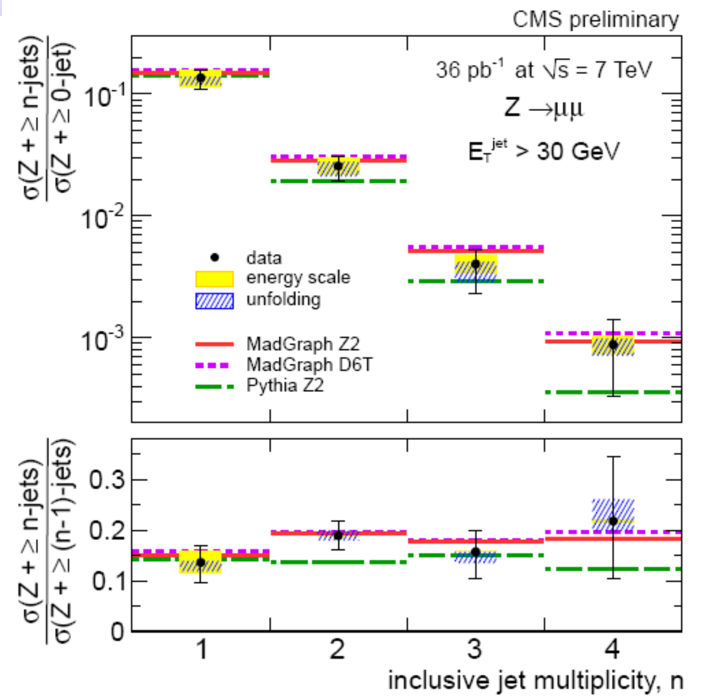
eg, unbinned maximum likelihhod fit with pdf taken from:

- γ+jets data
- mjj sidebands in data
- MC





Z+jets measurement in CMS

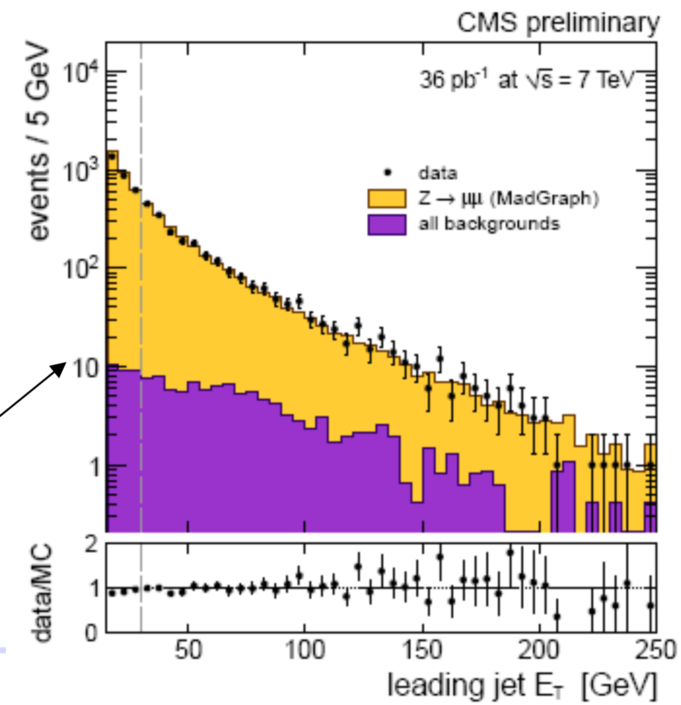


Good agreement with Madgraph (as expected, sizable disagreement with Pythia)

- leptons inside acceptance with:
  pT > 10,20 GeV
  std quality cuts and isolation
- PFjets inside acceptance with:
  pT > 30 GeV
  std loose quality uts

- Comparison with H→ZZ→2l2j phase space:
  - ~same lepton acceptance (pT>20,20 GeV),
  - same jets acceptance
  - → require at least 2 jets with mjj ~ m_Z

Since jets pt shape agree with madgraph, **this Higgs phase space is well modeled**

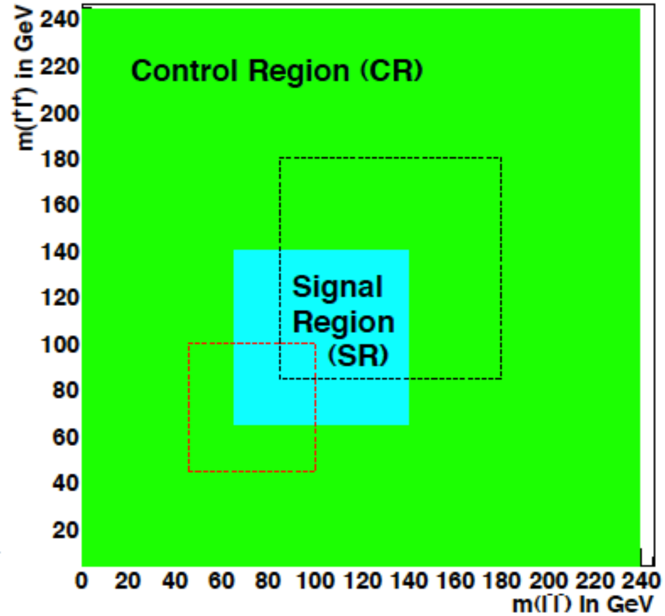


Estimate background from sidebands

Purpose: evaluate N_{BG} in signal region from data

$\alpha = N_{SR} / N_{CR}$ in MC ⇨ Evaluate a from MC (sensible to the theoretical uncert.)

$N_{BG} = \alpha\,(N_{CR}^{Data}+1)$ ⇦ Evaluate N_{CR} from data



Issues:

- if $N_{CR} = 0$ in MC → $\alpha = N_{SR}$
- if $\alpha = 0$, then instead α = statistical uncertainty on the Monte Carlo prediction.
- the probability density function N_{CR}^{Data} can be described by a Gamma distribution
  - mean is $N_{CR}^{Data}+1$
  - dispersion is $\sqrt{(N_{CR}^{Data}+1)}$
  - then the rate N_{BG} is $N_{BG} = \alpha\,(N_{CR}^{Data}+1)$
  - the relative error is: $\Delta N_{BG} = 1/\mathrm{sqrt}(N_{CR}^{Data}+1)$

R. D. Cousins, J. T. Linnemann, and J. Tucker, "Evaluation of three methods for calculating statistical significance when incorporating a systematic uncertainty into a test of the background-only hypothesis for a Poisson process", Nucl. Instrum. Meth. **A595** (2008) 480–501. doi: 10.1016/j.nima.2008.07.086

Manpower

General: no dedicated/full time manpower

CMS: S. Pelliccioni. S. Bolognesi, G. Singh, N. De Filippis, C. Mariotti, one student from I. Puljak

ATLAS: S. Paganis, Tulay + 2 students.

Theorists: M. Schoenherr. F. Krauss