Argonne NATIONAL LABORATORY

Background Rejection Techniques in Measurements with Jets

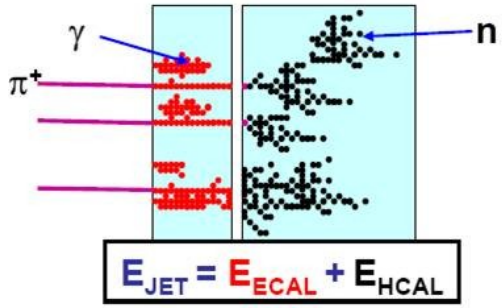
Chicago 2012 workshop on LHC physics

A.A. Paramonov

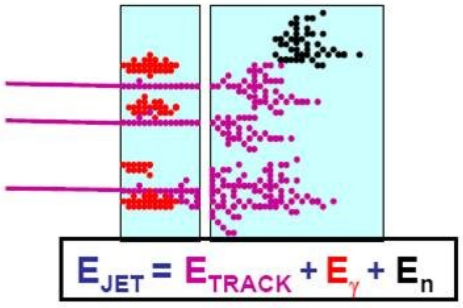
05/02/2012

Reconstruction of Particle Jets

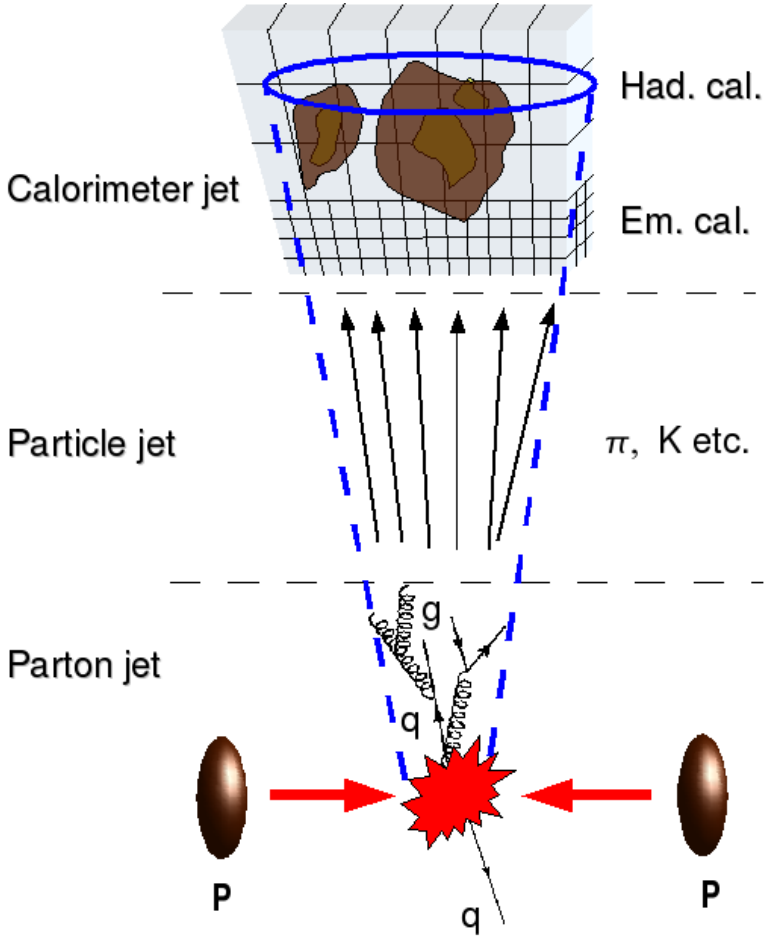
- Particle jets is a signature of energetic quarks and gluons
- Anti-k_T jet clustering algorithms are mostly used at the ATLAS and CMS
- The jet reconstruction is done a bit differently at the two experiments:



ATLAS: Calorimeter Information

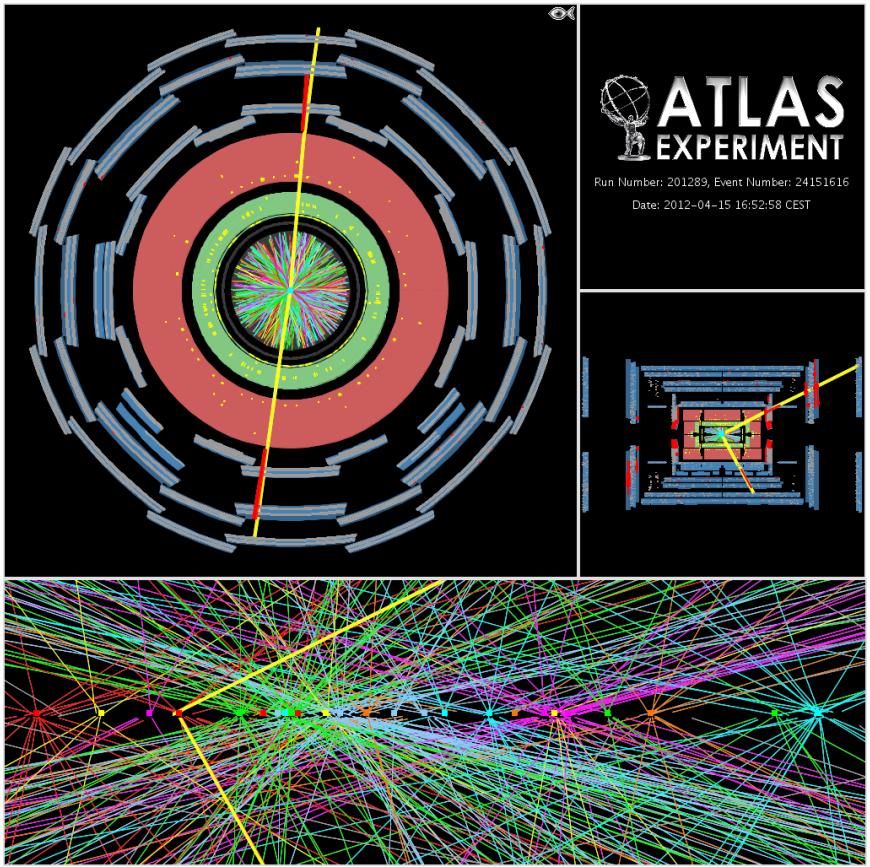


CMS: Calorimeter + Track Information



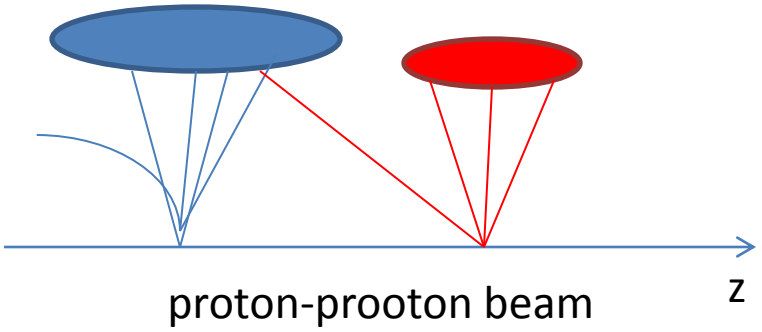
Impact of multiple pp interactions (pileup) on the jet reconstruction

- High instantaneous luminosity → Multiple proton-proton collisions in the same beam crossing can produce additional jets.
- Determination of jet origin is performed using tracks



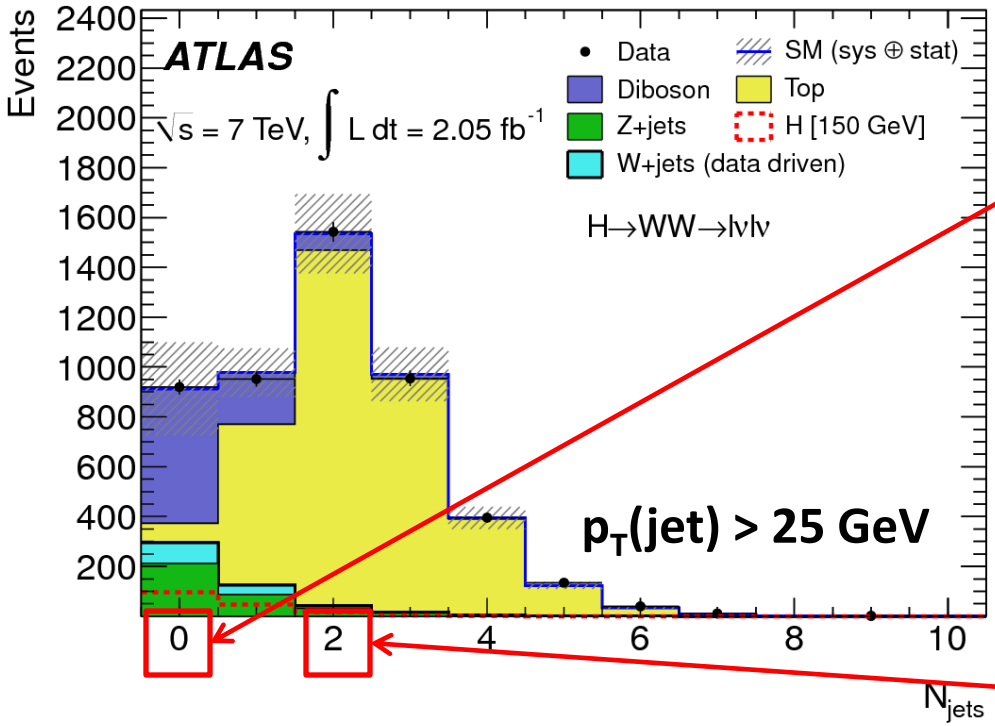
- JVF=Fraction of track jet momentum from the prim. vtx. in comparison to the total

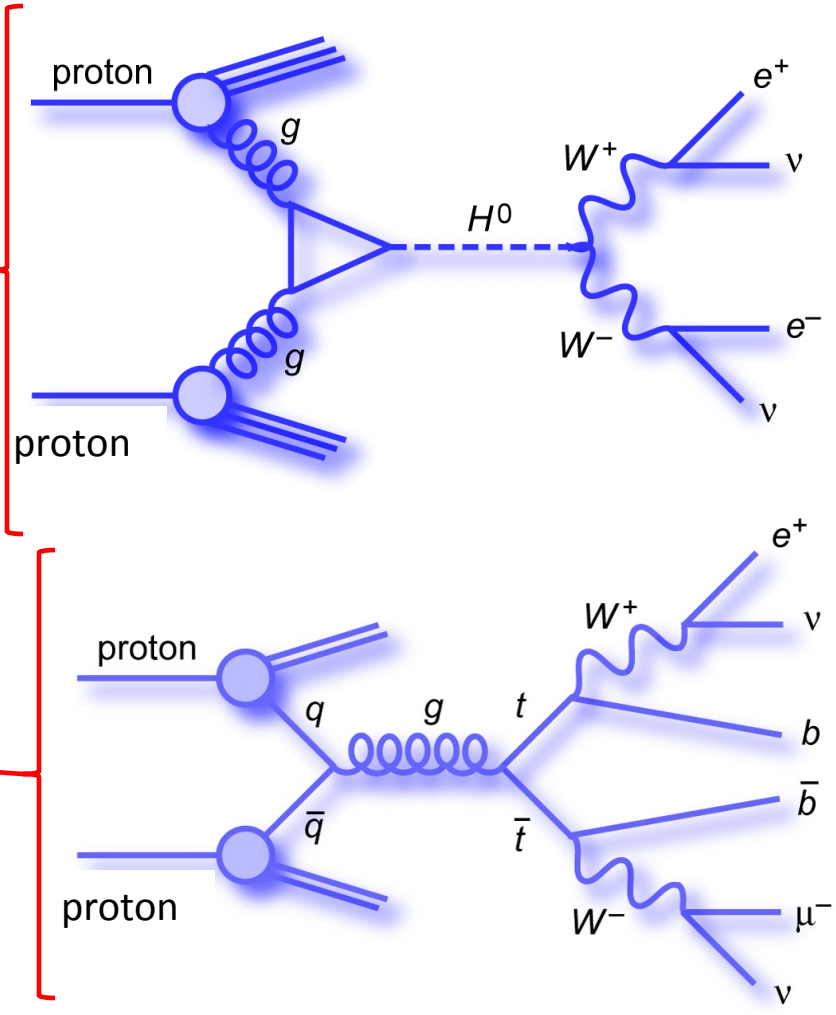
$$JVF(\mathrm{jet}_i, \mathrm{vtx}_j) = \frac{\sum_k p_T(\mathrm{trk}_k^{\mathrm{jet}_i}, \mathrm{vtx}_j)}{\sum_n \sum_l p_T(\mathrm{trk}_l^{\mathrm{jet}_i}, \mathrm{vtx}_n)}$$



Utility of Particle Jets

- Jet counting is used for separation of $H \rightarrow W^+W^-$ from $tt \rightarrow W^+W^- + qq$

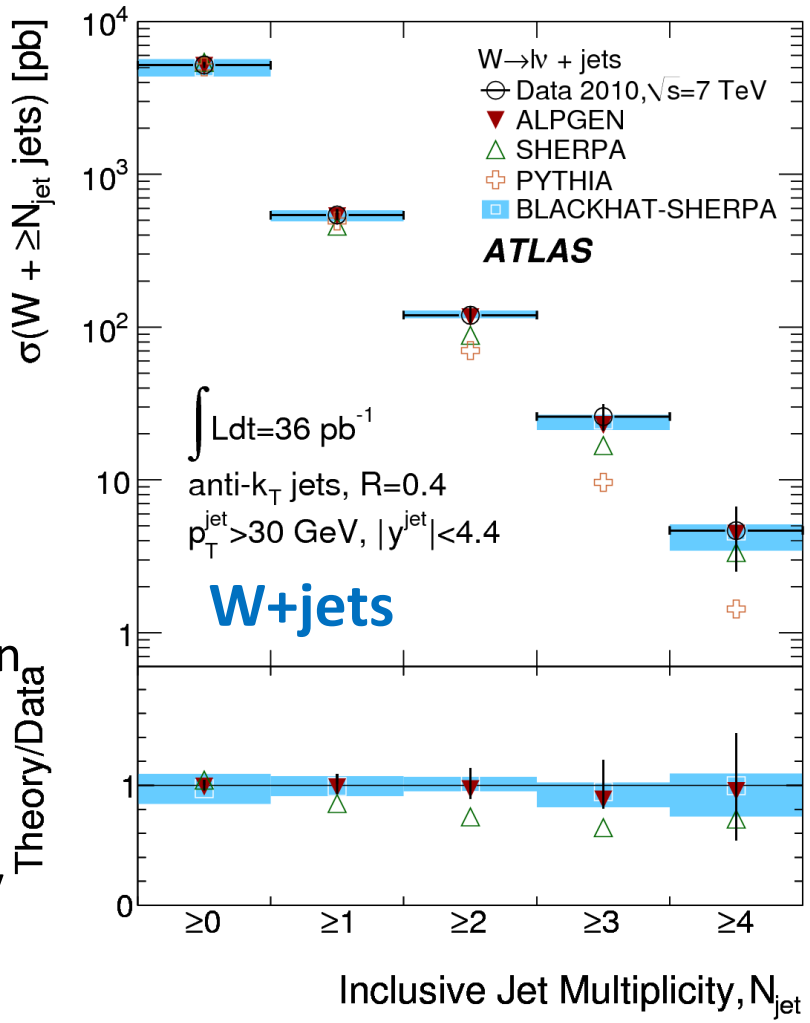




- The radiated partons (jets) are softer than from the top decays → **key for measuring of the σ(pp→H)**

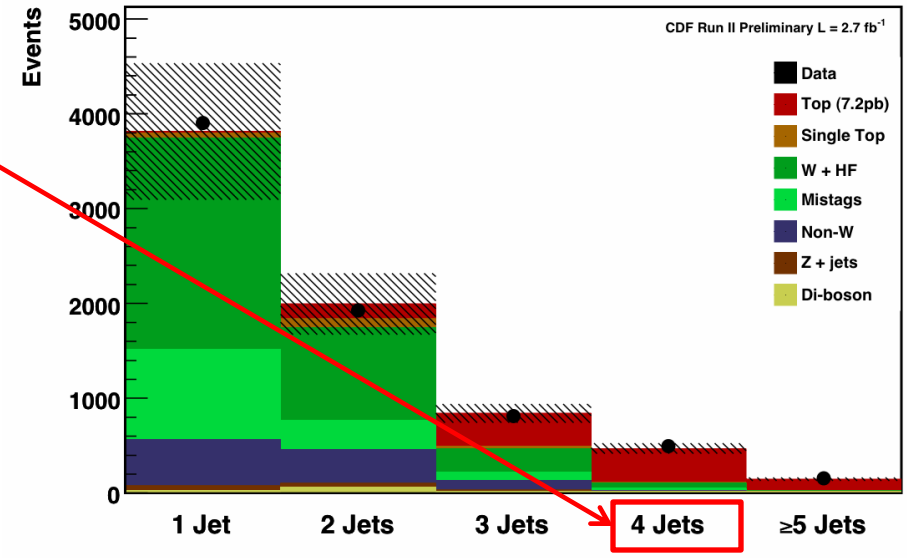
Features of the jet veto

- Radiation of jets has an impact on the kinematic of the leptons (boosts Higgs)
- That has been studies extensively using V+jets at the scale of ~M(V), V=W or Z
  - **Can we utilize WZ+jets and ZZ+jets to improve our understanding of the jet radiation at a higher scale of ~2M(V) ?**
  - **Will that help us with WW+jets (one the major backgrounds) ?**
- The background estimation relies on simulations/assumption to extrapolate from control regions into the signal region
  - **Estimation of the tt background requires extrapolation from the high multiplicity region using simulated events**
- The jet veto is simple and robust but may not be optimal… Multivariate techniques can exploit the kinematics of jets better.



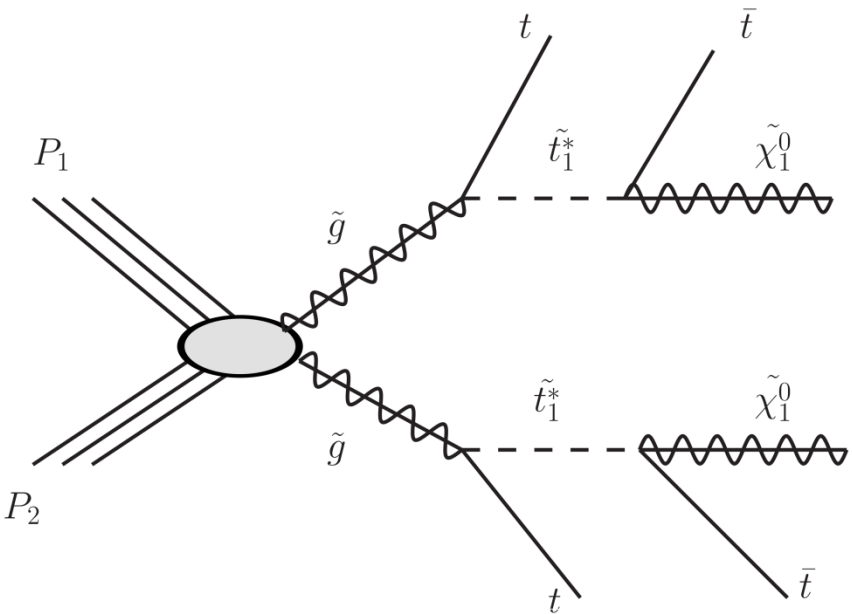
Events with high jet multiplicities

- We needed W+4 jets to study the top pair production at the Tevatron → Veto events with low jet multiplicity



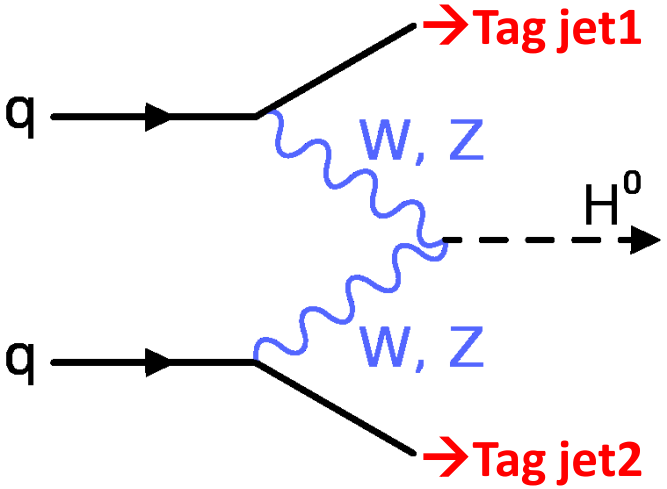
- ME+PS simulations give robust predictions for up to V+5p (or just 6p) → **Can we go higher?**

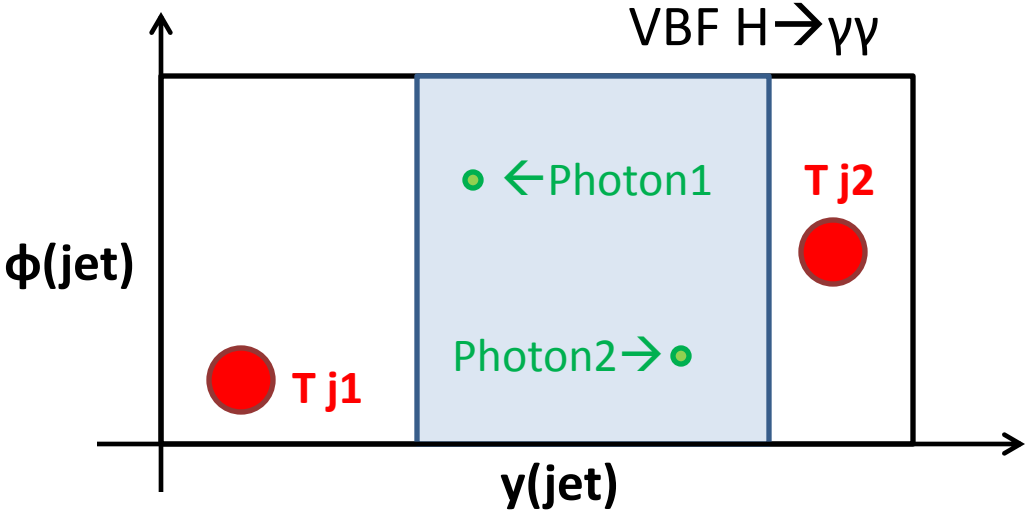
- Searches for new physics demand understanding of final states with numerous jets (e.g. 12) → Have to rely on data and assumptions/MC
- In some cases can use multi-lepton events as an alternative

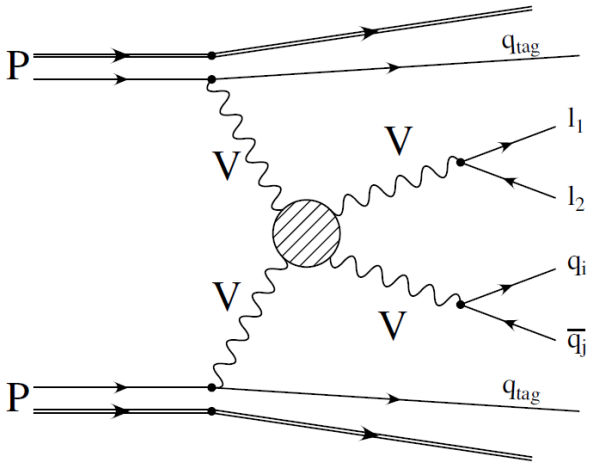


Forward Jets in VBF/VBS

- VBF production Higgs (and gauge bosons) and Vector Boson Scattering requires good understanding of forward jets (at large rapidities) → SM Backgrounds
- The useful variables are:
  - $\eta_1 * \eta_2 < 0$ (on the opposite sides)
  - $\Delta\eta = |\eta_1 - \eta_2| > 3 \ldots 4$ (separation in rapidity)
  - M(jet1, jet2) > 400 … 700 GeV (inv. Mass)
  - $\Delta\phi$(jet1, jet2) ?

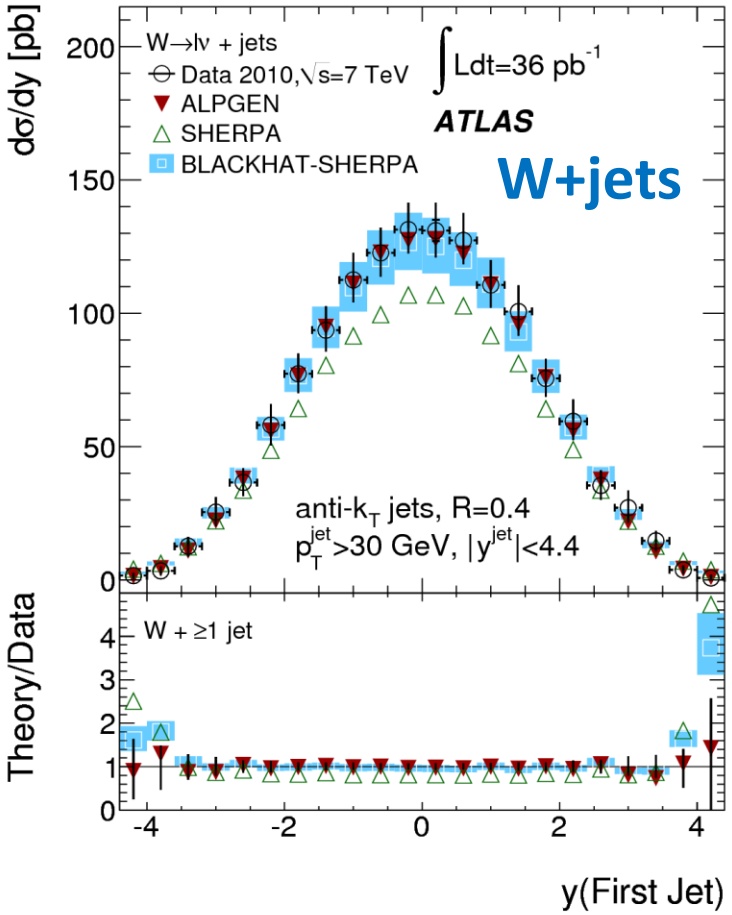


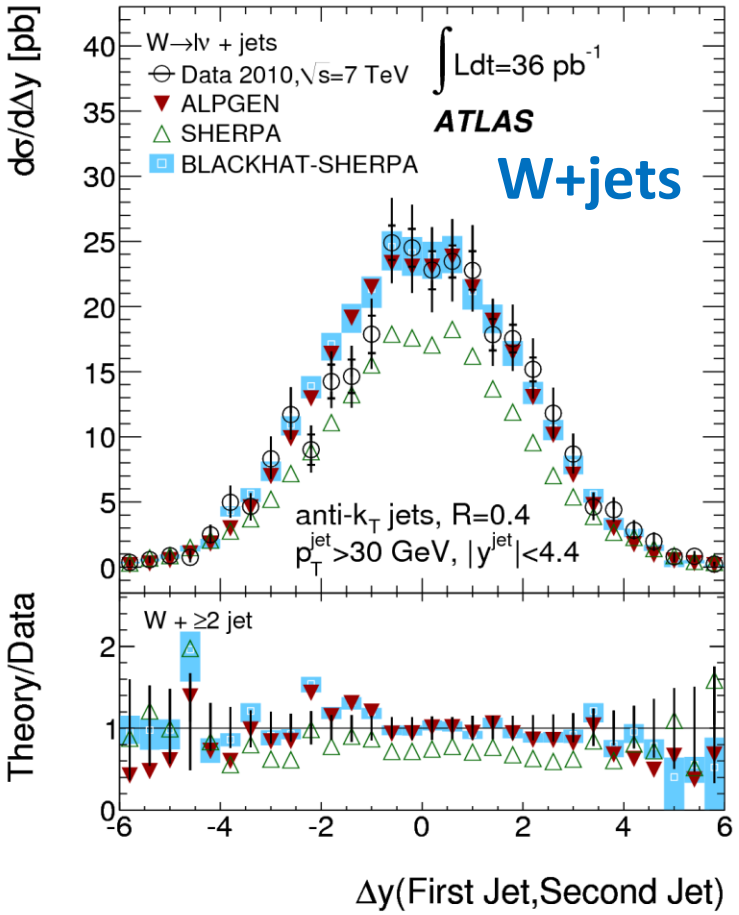




Rapidity Gaps between Jets

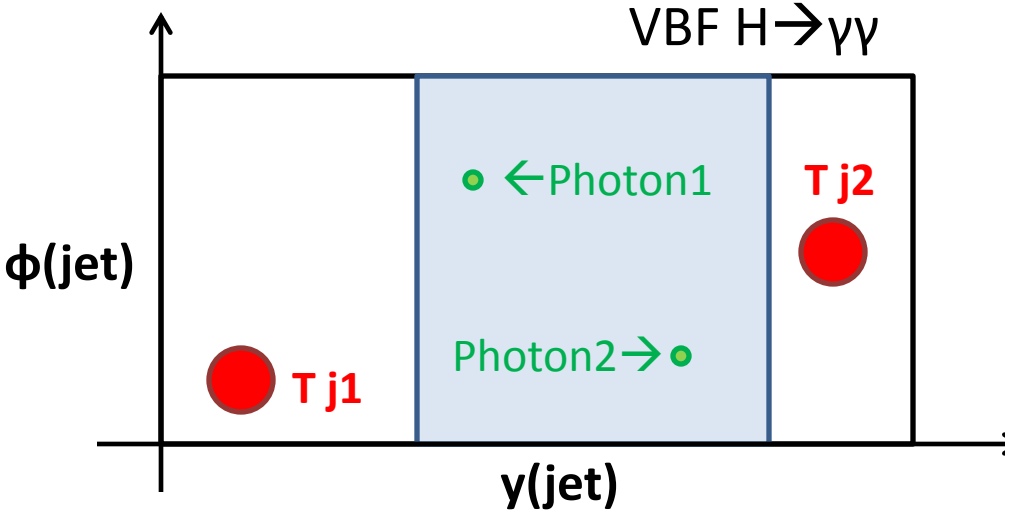
- Look at data to test production of the forward jets in the SM backgrounds: V+jets are benchmark processes
- ME+PS simulations (Alpgen, MadGraph, Sherpa) do a good job

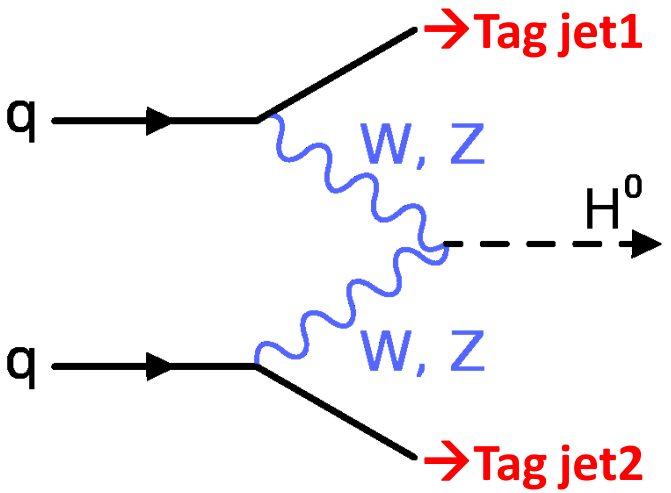


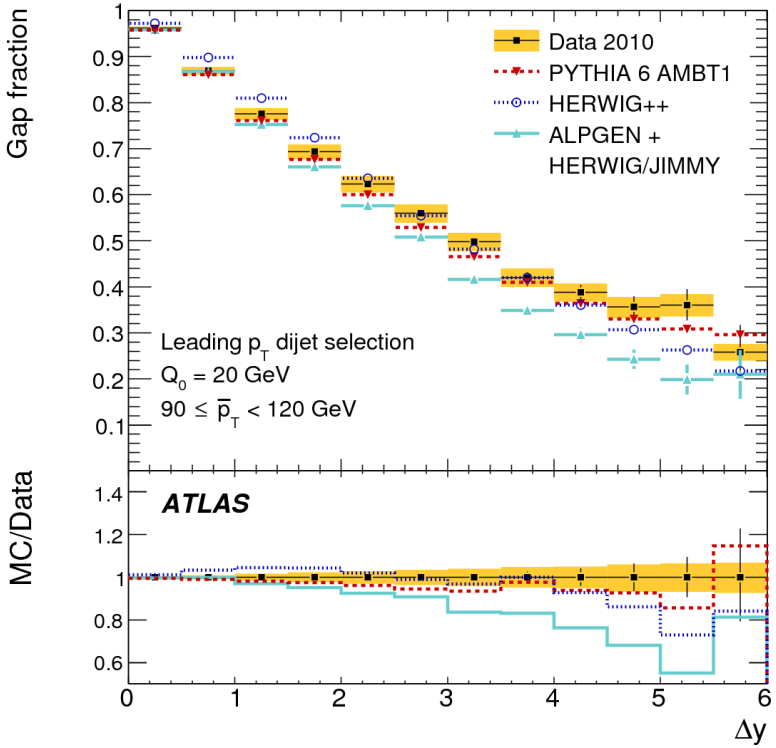


Central Jet Veto

- No color reconnection between the two tag jets at the leading order → Probability of the parton emission between the two jets is suppressed
- The color reconnection is present in the background processes
- Often require no additional jets with p_T>20…30 GeV in |y|<2 … 3

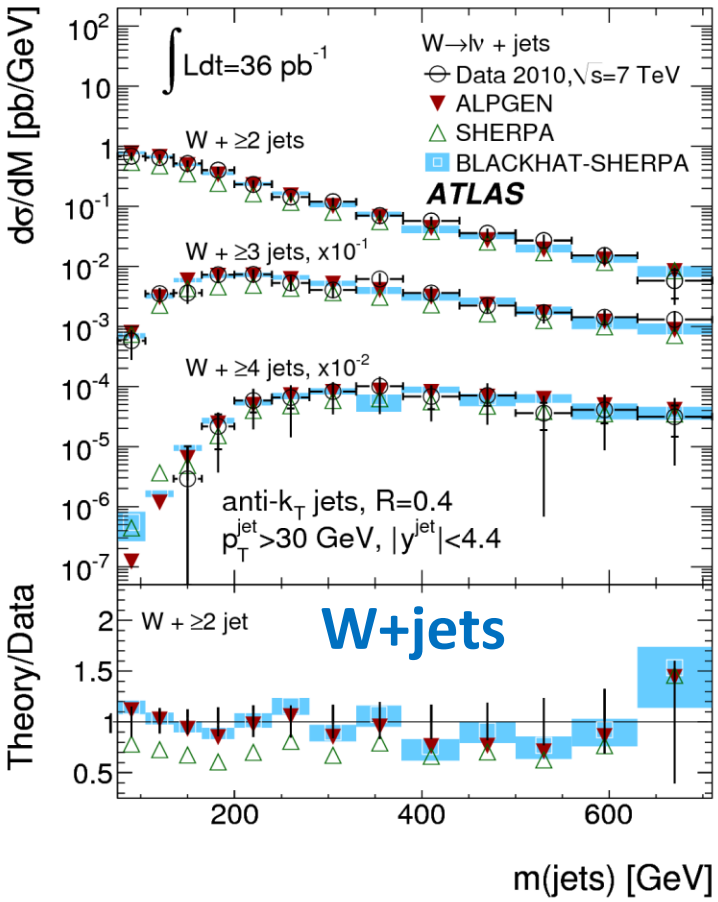


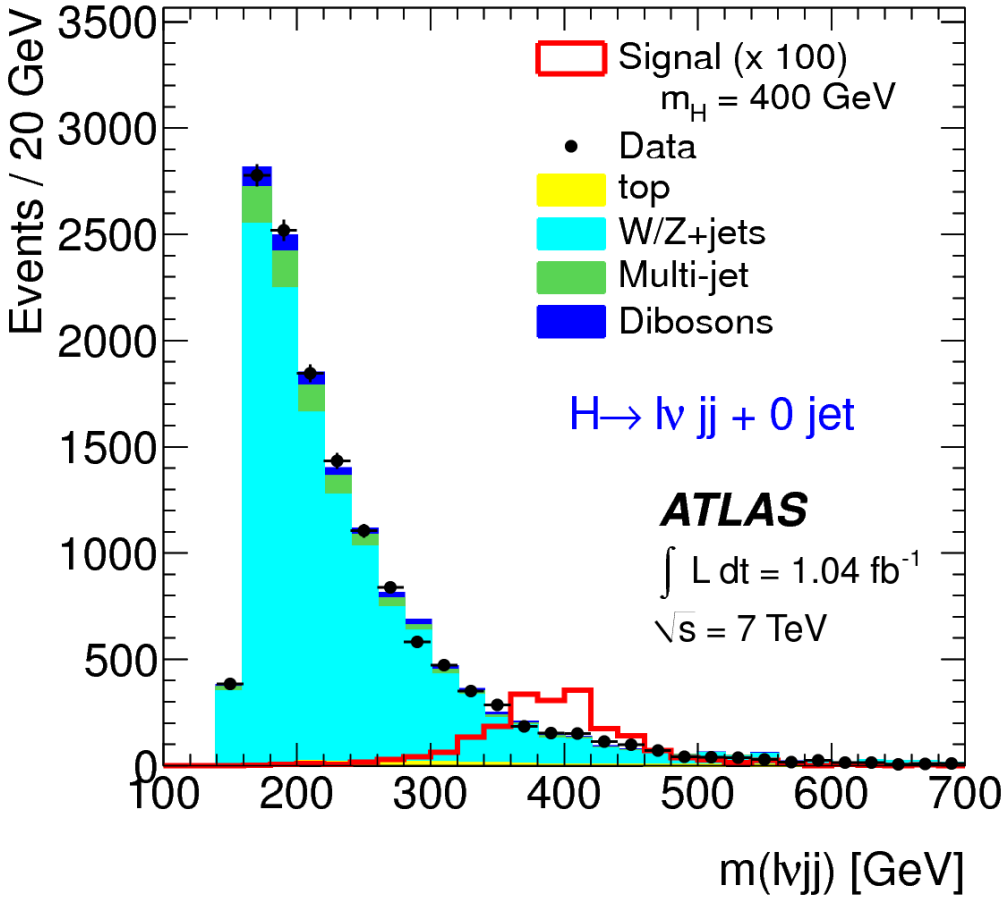




Dijet Mass

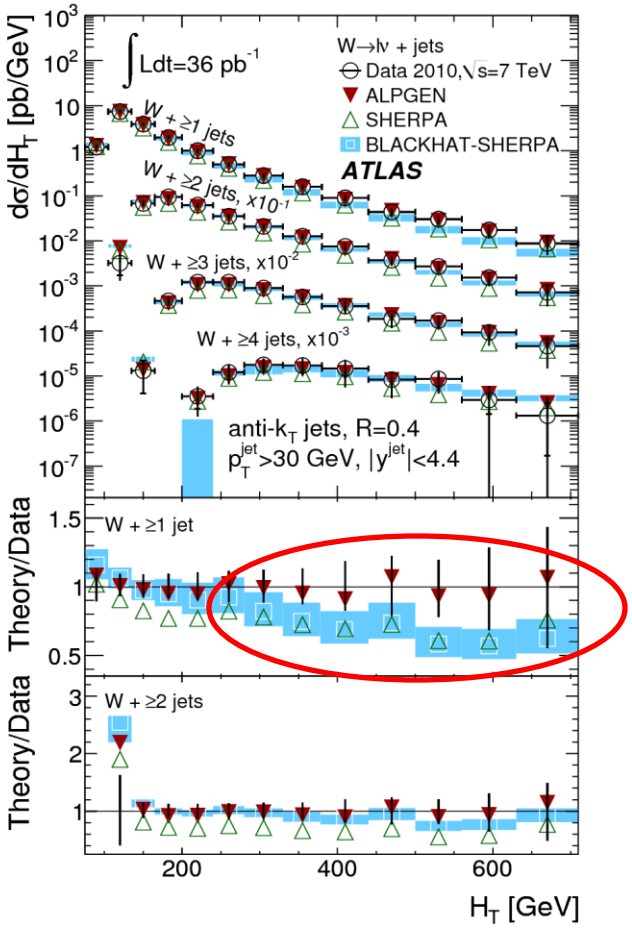
- Used for the VBS & VBF selection and for resonances and heavy objects decaying with jets (top, H→bb, WZ→ℓνjj, H→WW→ ℓνjj)
- Backgrounds are well modeled with ME+PS simulations and NLO

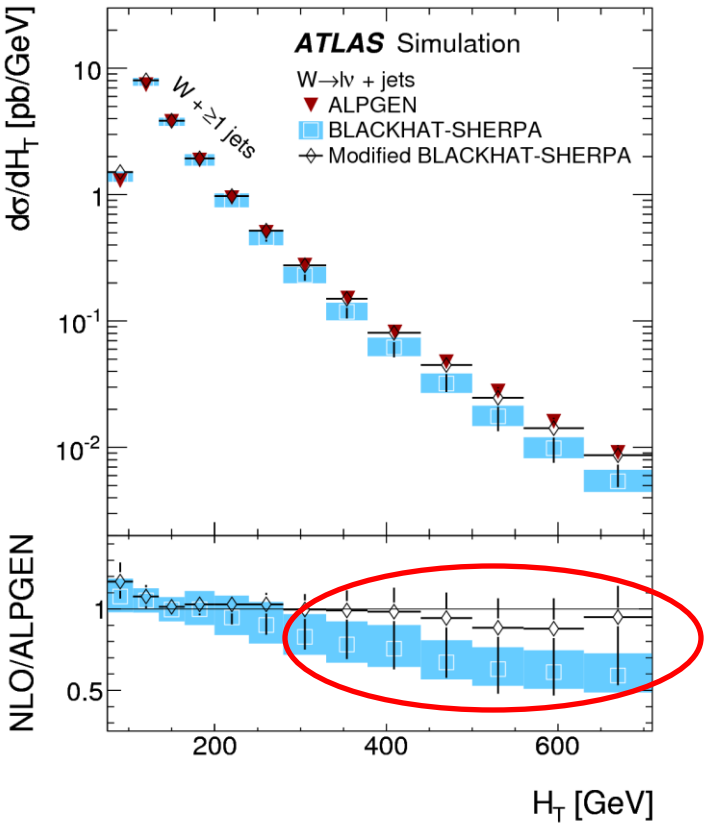




Inclusive and Exclusive Observables

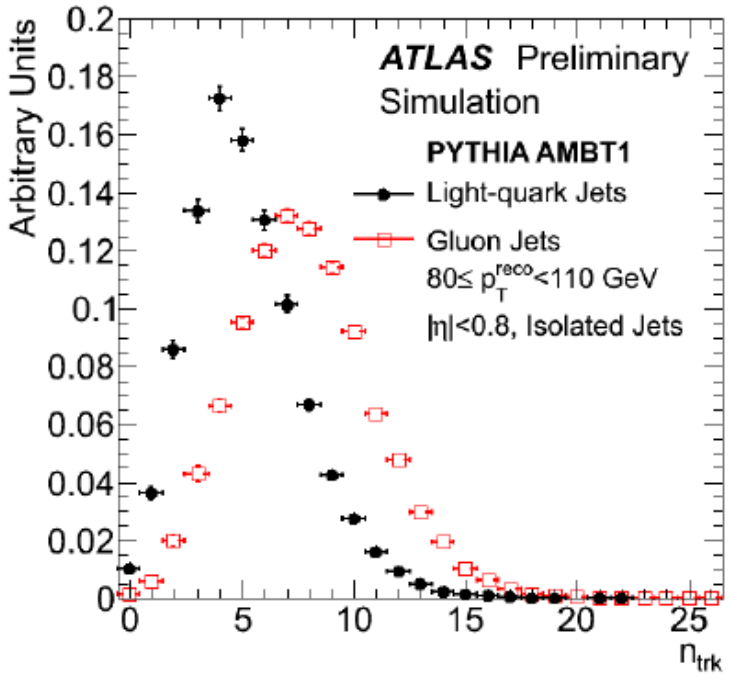
- H_T = scalar sum of p_T of all reconstructed objects (leptons, jets, missing-p_T) in event; an inclusive observable. (The di-jet mass was an exclusive observable) .
- Well modeled with ME+PS simulations but not NLO calculations

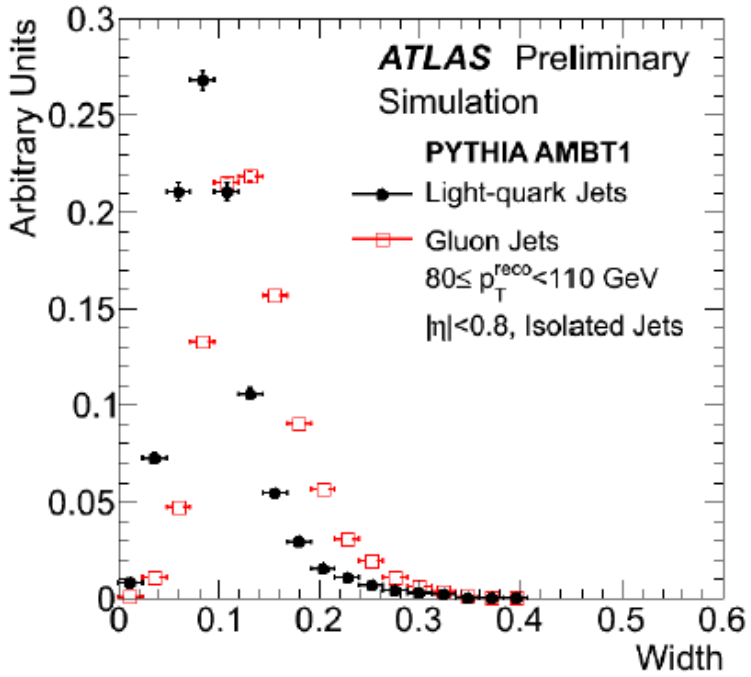




Quark- and Gluon- Initiated jets

- Fragmentation and hadronization of quark- and gluon- initiated jets differs due to the QCD color (quark → light flavor quaks only)
- Gluon jets tend to be wider and and contain higher particle multiplicity than quark jets of the same momentum
- Used in searches/measurements where the jets are from decays of bosons (e.g. W→jj or Z→jj; only quark jets; e.g. CDF10601)





Summary

- Overviewed a variety of methods for background suppression:
  - Reconstruction of jets in presence of pileup using the jet
  - Veto for the low and high jet multiplicities
  - Production of forward jets and of jet pairs separated in rapidity
  - Central Jet Veto
  - Di-jet invariant mass
  - Inclusive and exclusive kinematic variables (M(jets) and H_T)
  - Properties of quark- and gluon- initiated jets

- Looked at performance of ME+PS simulations and NLO calculations to identify the future needs from the theory predictions and experimental measurements