Reunión Red LHC

Madrid, May 10th, 2018

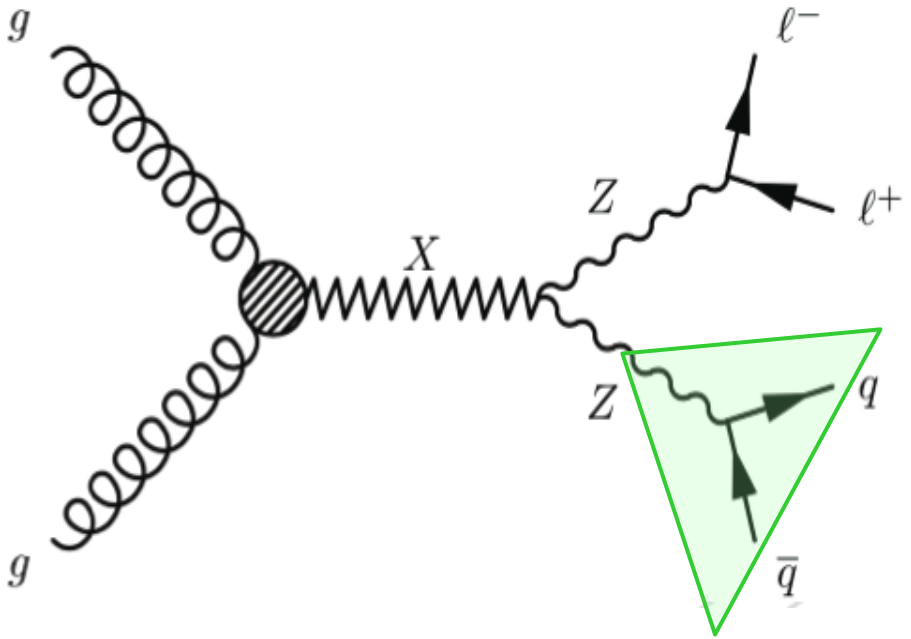
Search for Heavy ZZ / ZW Resonances in 2l2q Final States with CMS

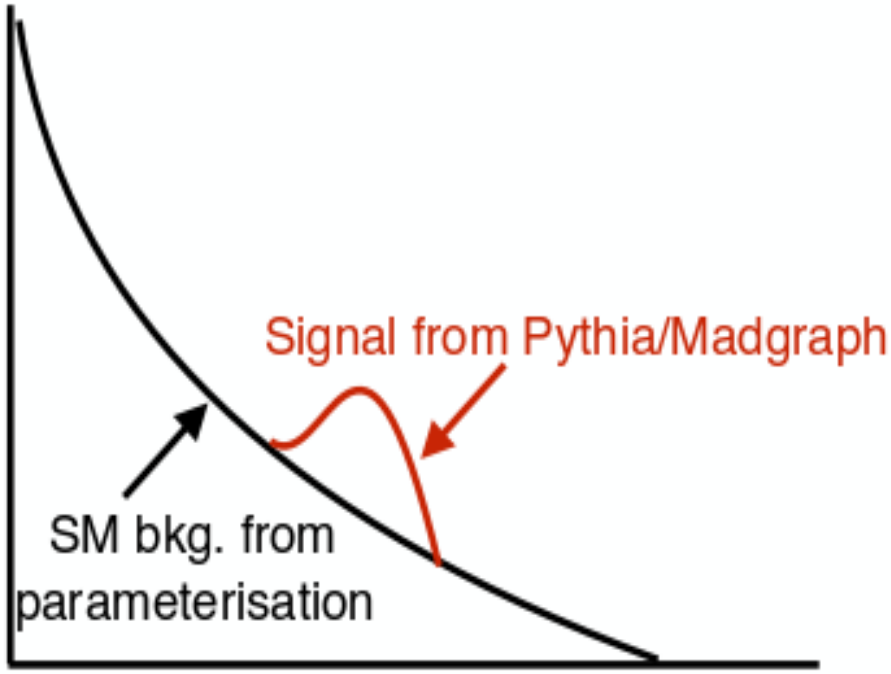
(CMS B2G-17-013)

Jorge F. de Trocóniz

Universidad Autónoma de Madrid

Hadron Z / W / H Resonances



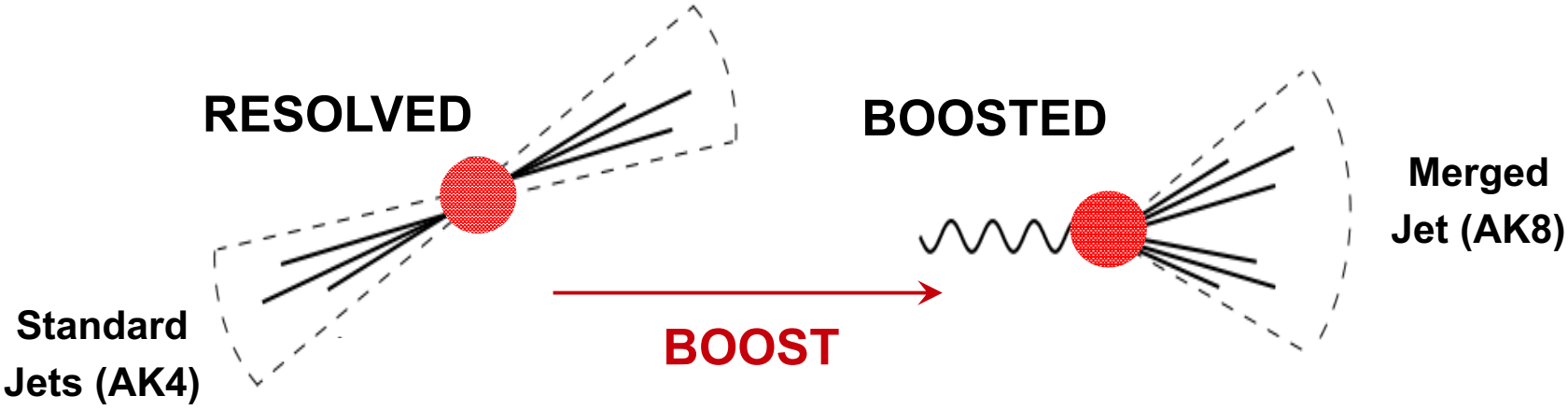


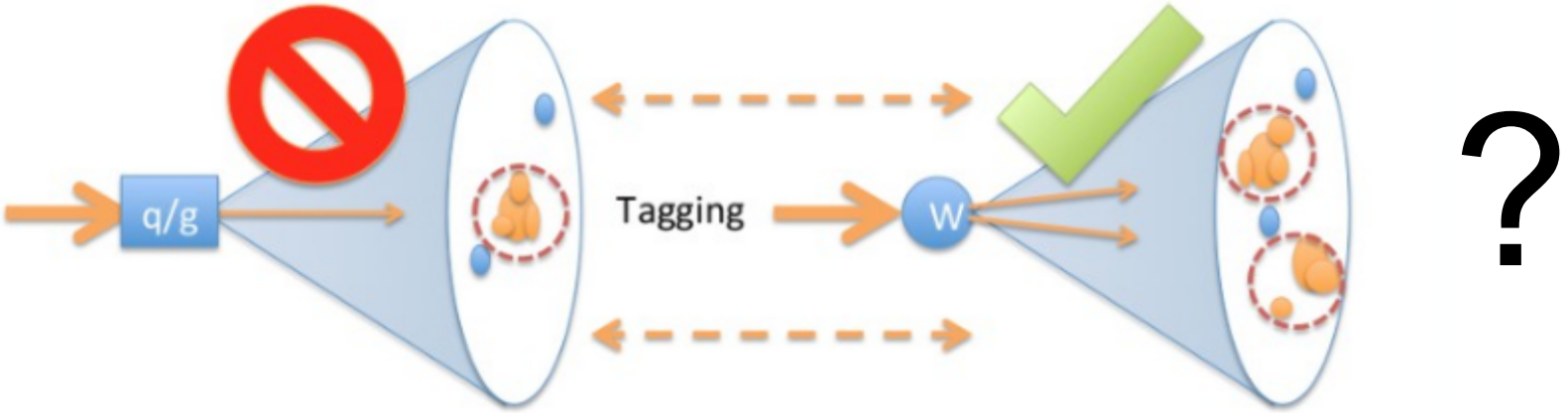
Pros: Large Branching Fractions

Cons: Large backgrounds from V+jets, QCD.

- Estimate via NLO QCD and/or sideband (SB) data.

Heavy Resonance = Boosted Regime





?

Z / W / H-tagging vs. QCD

- Standard discrimination against QCD in CMS uses:

1. PU mitigation: CHS: Charged Hadron Subtraction, (Hybrid) Jet Area Subtraction: pT offset/area, PUPPI.

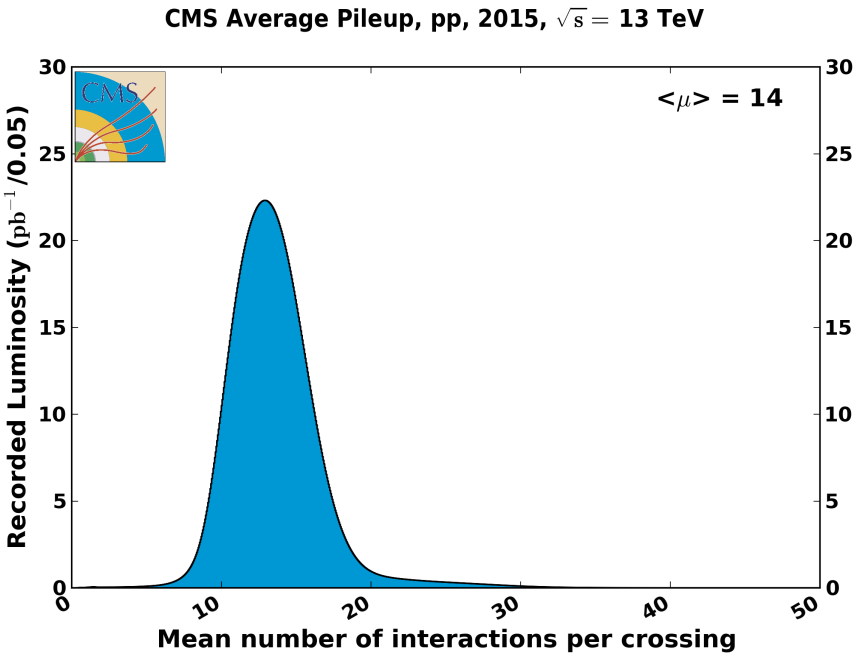
2. Jet Grooming: Recluster jet removing soft and wide angle constituents (PU, ISR, UE). Main observable is the groomed M(J); grooming pushes QCD to lower M(J) values and improves signal mass resolution. Pruning, Soft Drop.

3. Jet Substructure: N-subjettiness quantifies consistency of jet energy flow aligned along N directions / subjets. Ratio of 2-subjettiness over 1-subjetiness discriminate from single quark- or gluon-initiated jets.

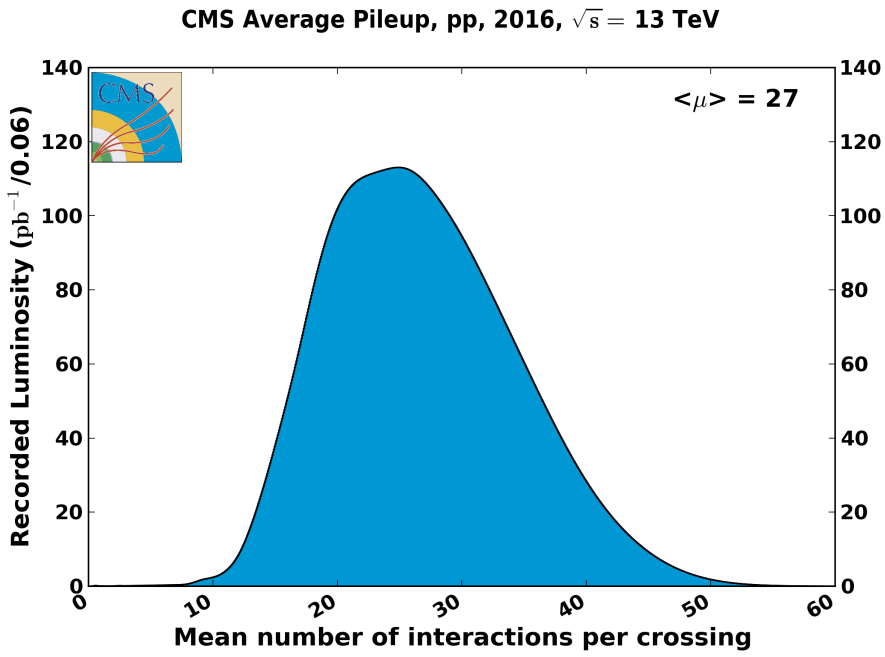
4. B-tagging in boosted topologies: Subjet CSV: Combined Secondary Vertex on SD subjets for Z-tagging; Double-B: Double b-tagging (mostly) dedicated to boosted H decays.

Pileup

<PU> ~ 15 @ 2015



<PU> ~ 30 @ 2016



2017: <PU> ~ 33, PU_{max} ~ 85

Pile Up Per Particle Identification (2014)

- Per particle pileup mitigation technique: ”redefinition” of PF event content.
- Examine particle density around PU charged tracks; get distributions for alpha using leading vertex (LV) charged tracks and others.

$$\alpha_i = \log \sum_{j \in \text{event}} \xi_{ij} \times \Theta(R_{\min} \leq \Delta R_{ij} \leq R_0),$$

$$\text{where } \xi_{ij} = \frac{p_{Tj}}{\Delta R_{ij}}.$$

Charged :

$$\alpha_i^C = \log \sum_{j \in \text{Ch,LV}} \xi_{ij}\, \Theta(R_{\min} \leq \Delta R_{ij} \leq R_0),$$

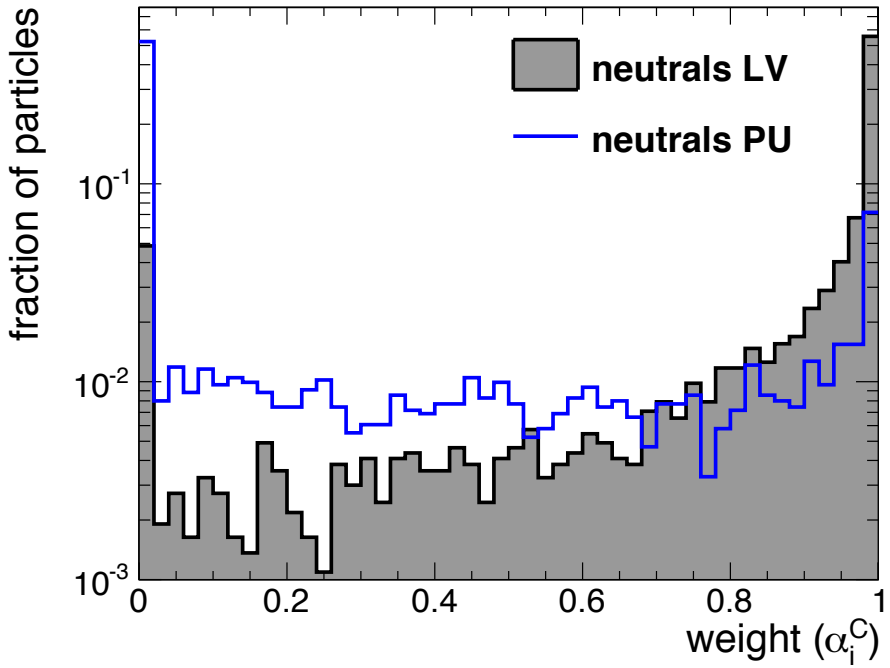
Forward :

$$\alpha_i^F = \log \sum_{j \in \text{event}} \xi_{ij}\, \Theta(R_{\min} \leq \Delta R_{ij} \leq R_0).$$

- Calculate the median and the width of event-by-event alpha distributions.
- Neutral particle 4-momentum weighted, based on 1D chi-squared probability using:

$$\chi_i^2 = \Theta(\alpha_i - \bar{\alpha}_{\text{PU}}) \times \frac{(\alpha_i - \bar{\alpha}_{\text{PU}})^2}{\sigma_{\text{PU}}^2},$$

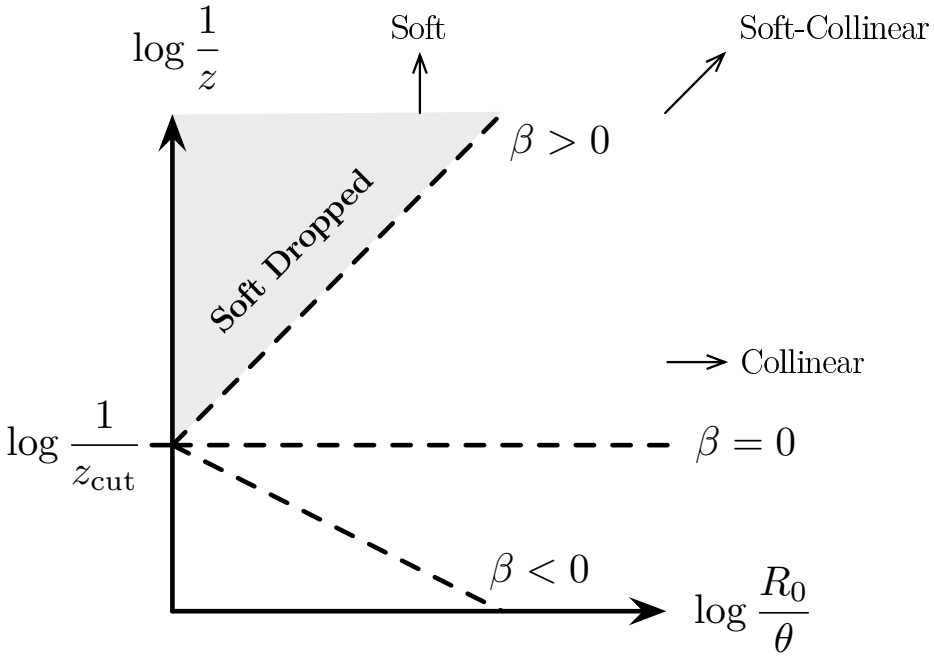
D. Bertolini, P. Harris, M. Low, N. Tran, JHEP 1410 (2014) 059



Soft Drop Grooming (2014)

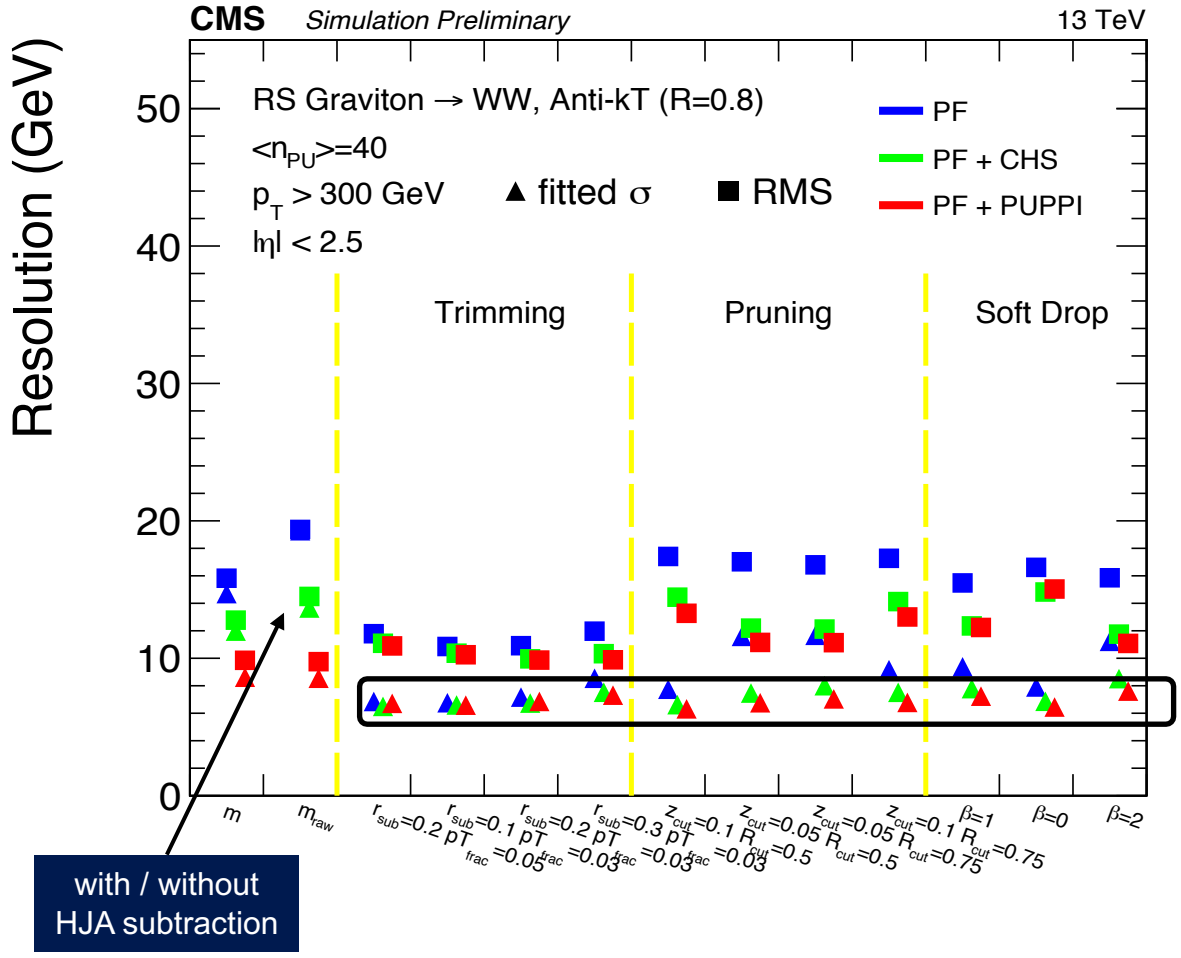
- Undo last stage of C/A jet clustering into subjets 1 and 2.
  - ❖ If $\frac{min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{cut} \left(\frac{\Delta R_{12}}{R_0} \right)^{\beta}$, declare SD jet is defined;
  - ❖ else, drop softer subjet and iterate on harder one.

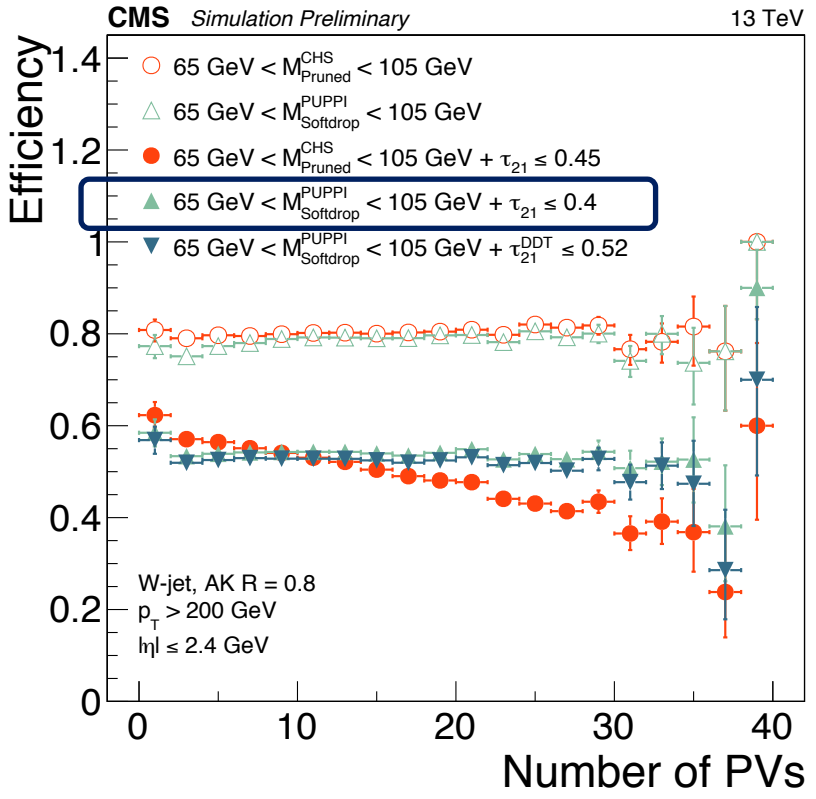
- For beta = 0, soft radiation removed (aka modified mass drop tagger).



A. Larkoski, S. Marzani, G. Soyez, J. Thaler, JHEP 1405 (2014) 146

Pileup Mitigation + Grooming Performance



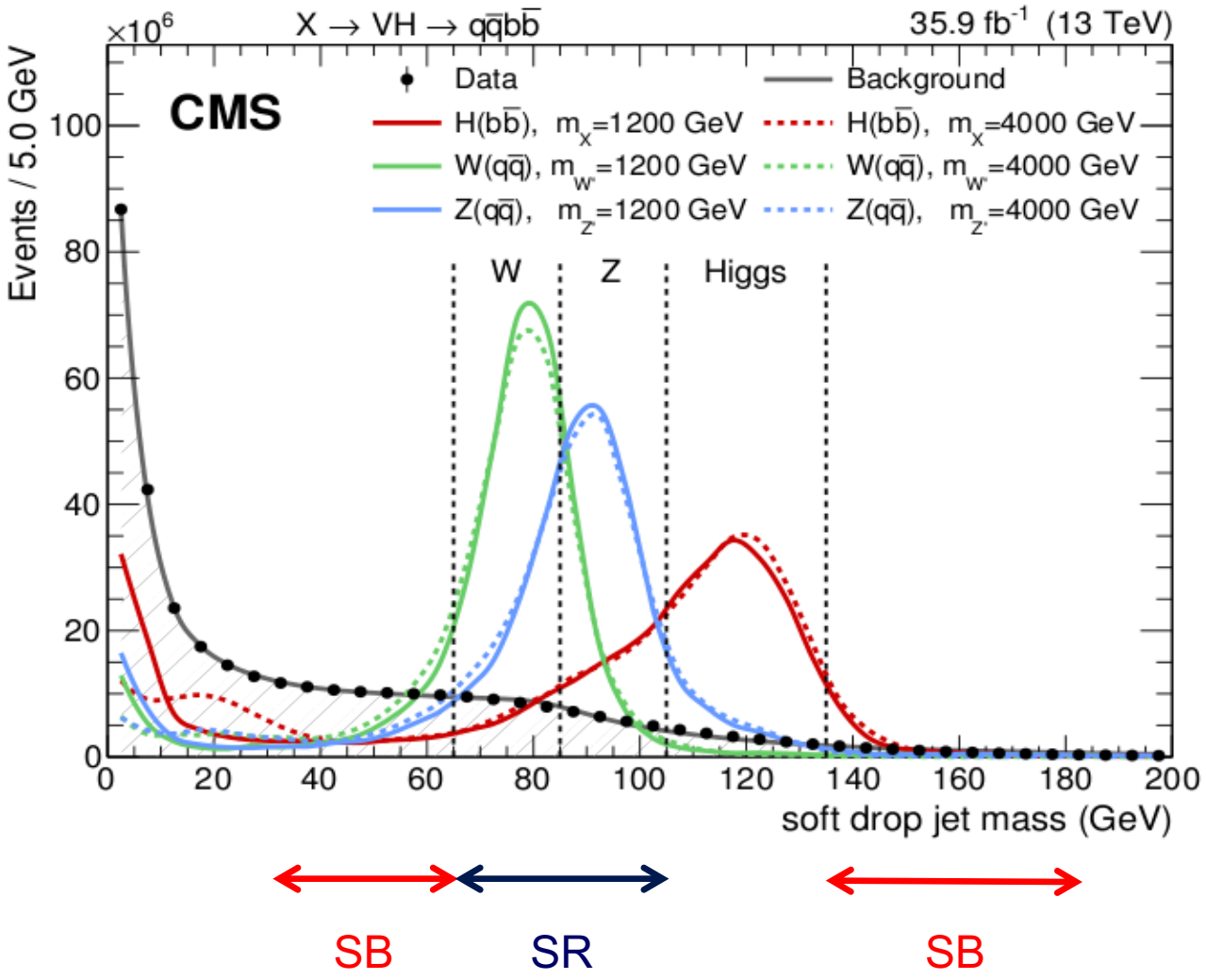


2015: PF + CHS with Hybrid Jet Area PU subtraction, Pruning.

2016: PF + PUPPI, Soft Drop (z_{cut} = 0.1, beta = 0). Improved M(J) resolution and V-tagging efficiency stability vs. number of PVs and pT(J).

Grooming: Merged Jet Mass

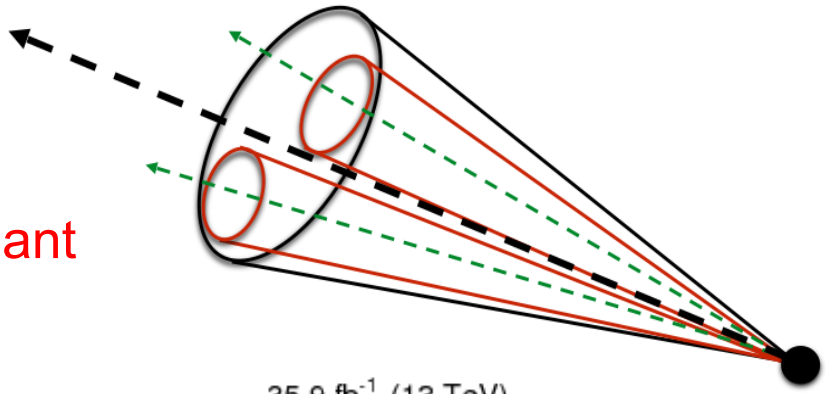
2016



Resolution M(J) ~ 9 - 10%; Resolution M(2lJ) ~ 3 - 4%

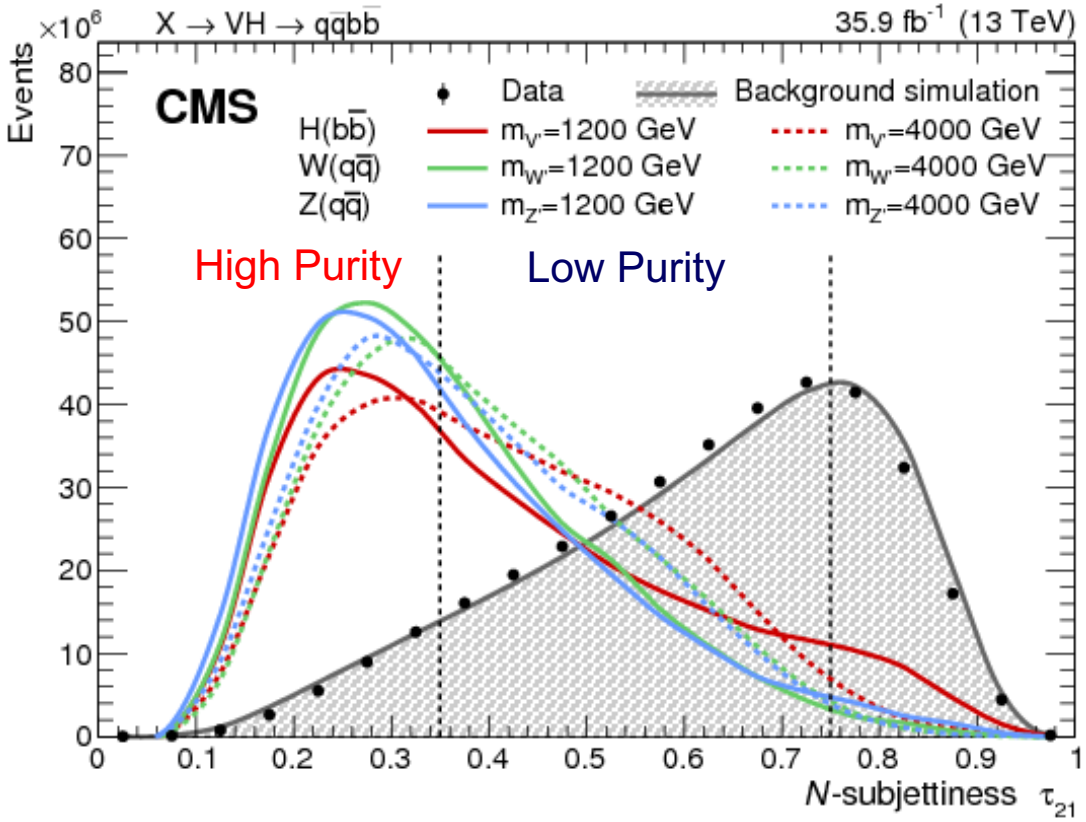
Substructure: N-Subjetiness

$$\tau_N = \frac{1}{d_0} \sum_k p_{T,k} \min(\Delta R_{1,k}, \Delta R_{2,k}, \ldots, \Delta R_{N,k}),$$



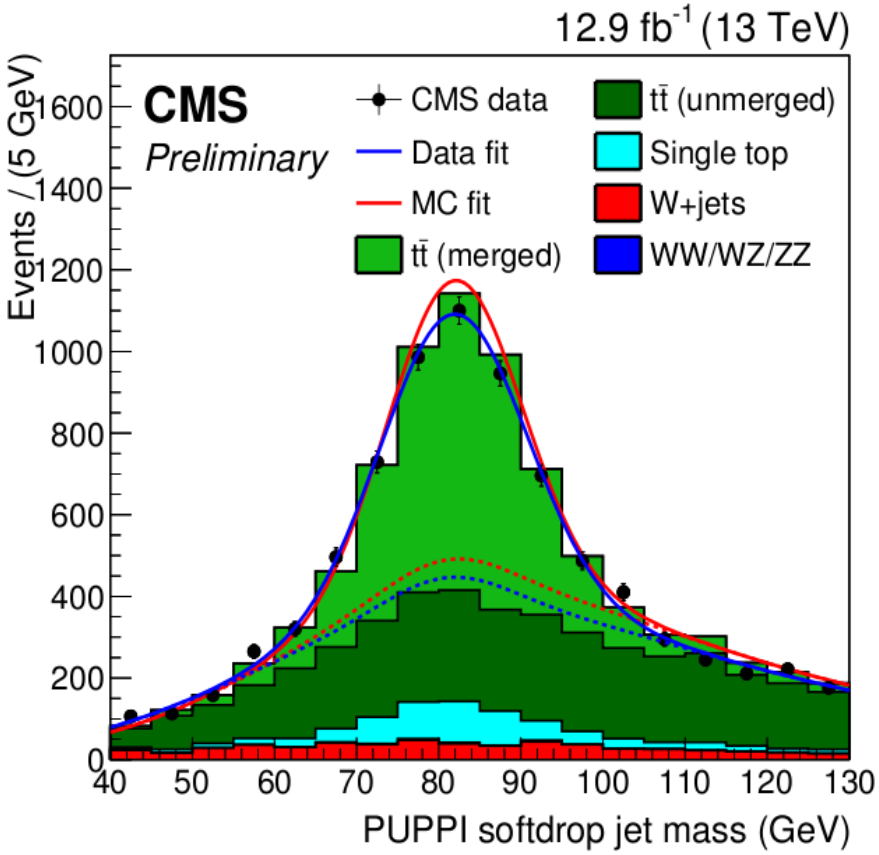
τ_2 / τ_1 is found to be a powerful discriminant

2016

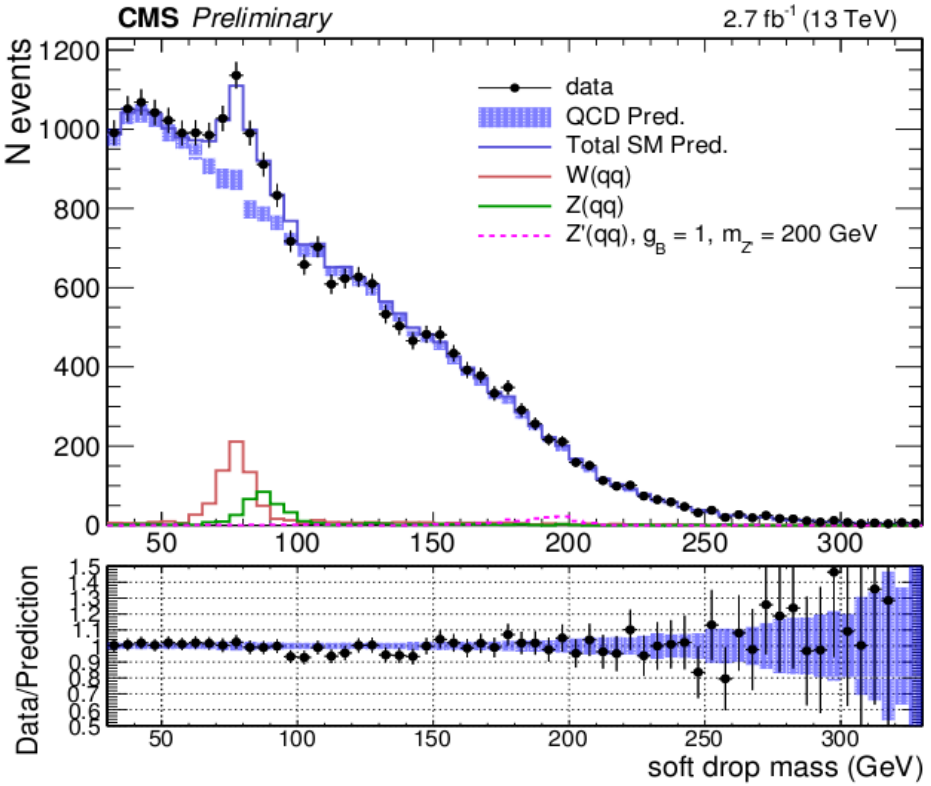


Boosted W/Z Tagging Calibration

2016



2015



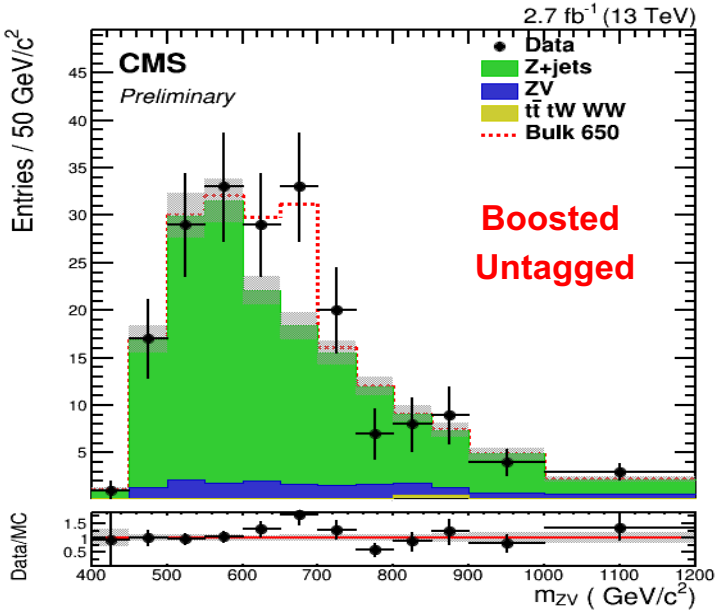
Lepton + jets top-enriched data sample.

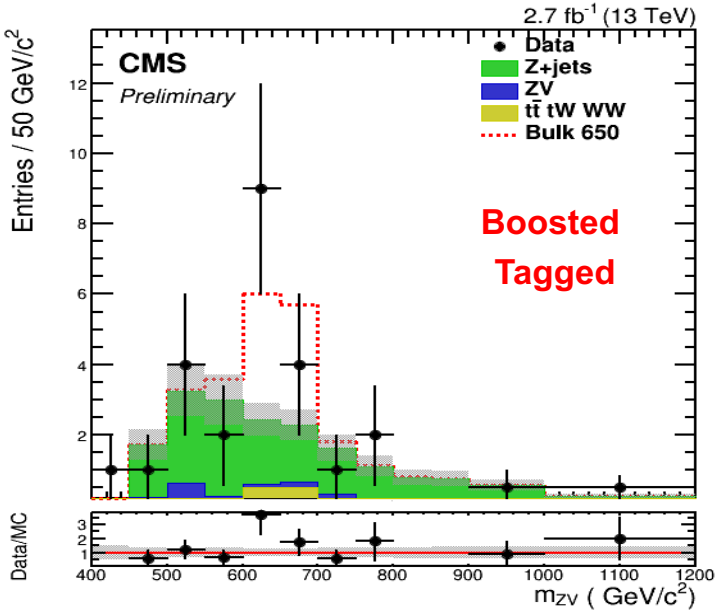
- W signal used to extract V-tagging data/MC scale factors

Inclusive high-pT AK8 jet data sample.

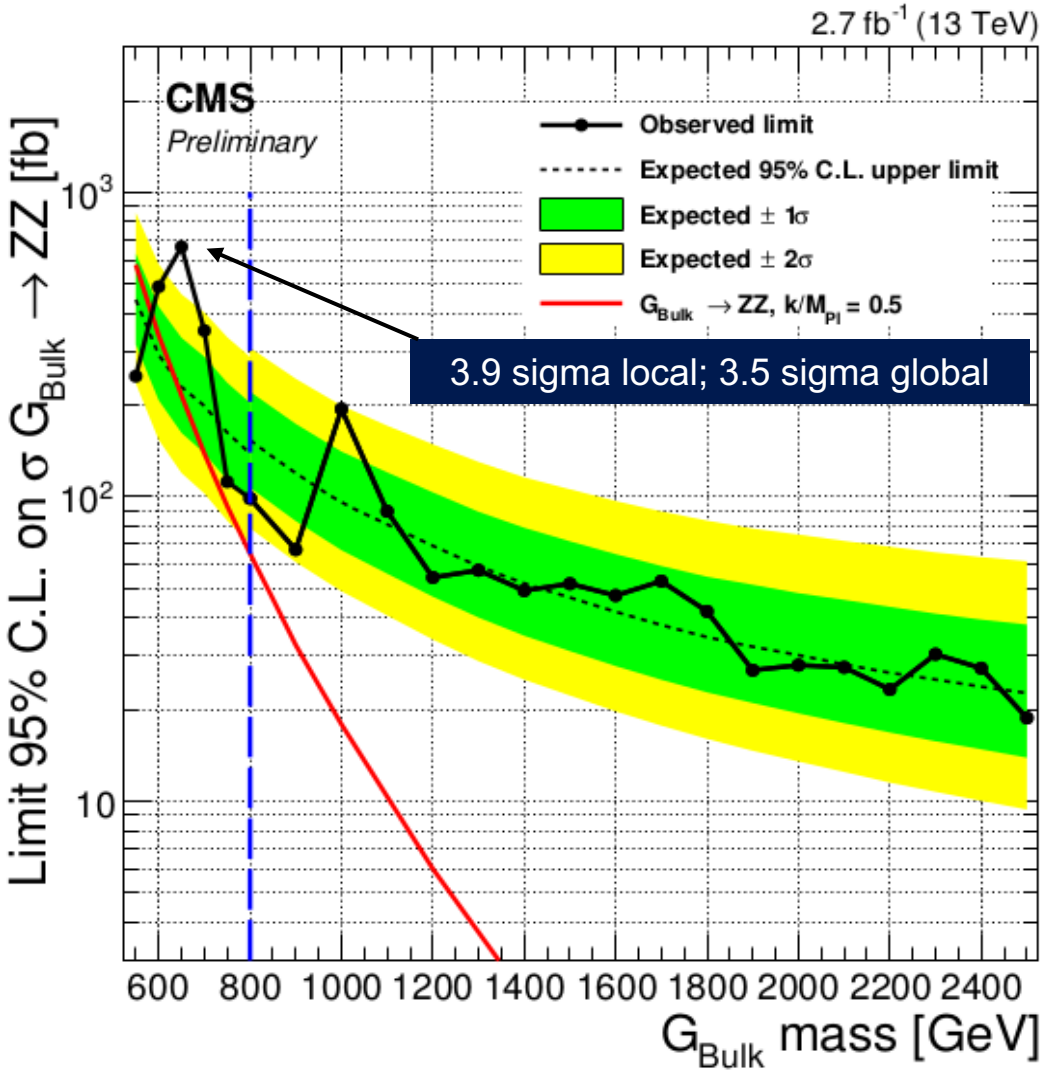
- Very clear Z/W bump above QCD continuum in M(J) distribution.

ZZ/ZW Resonances: Heavy H, W', WED



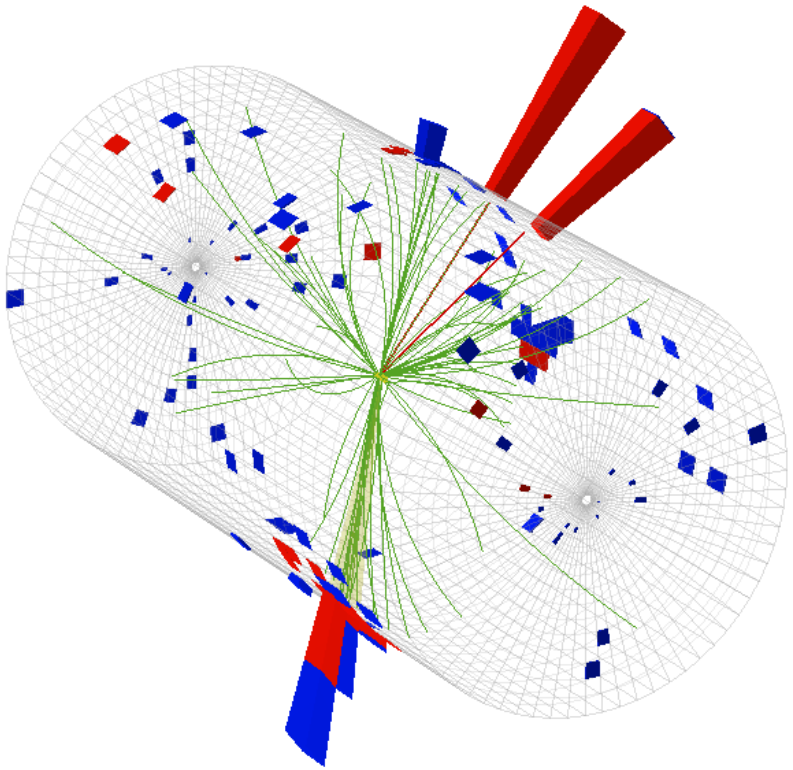


2015



2016 X → ZV Analysis

CMS Experiment at LHC, CERN
Data recorded: Sun Jul 17 00:09:52 2016 CEST
Run/Event: 276870 / 3233046529
Lumi section: 1797
Orbit/Crossing: 470828867 / 2849
m_J = 69.5 GeV
m_{ZV} = 2015 GeV



Intermediate Mass Search :

Both V-tags and dijets considered

Background estimated using SB data-corrected NLO Z+jets MC prediction

Categorization based on b-tagging

High Mass Search :

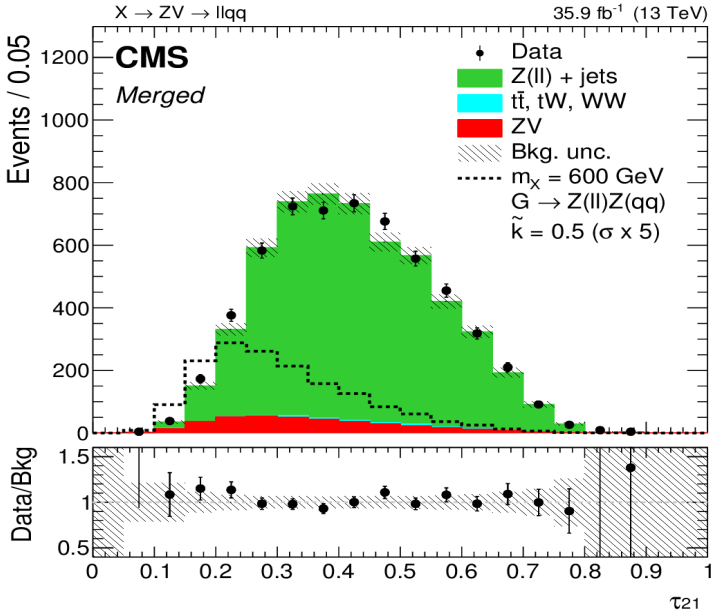
Close-by lepton effects considered

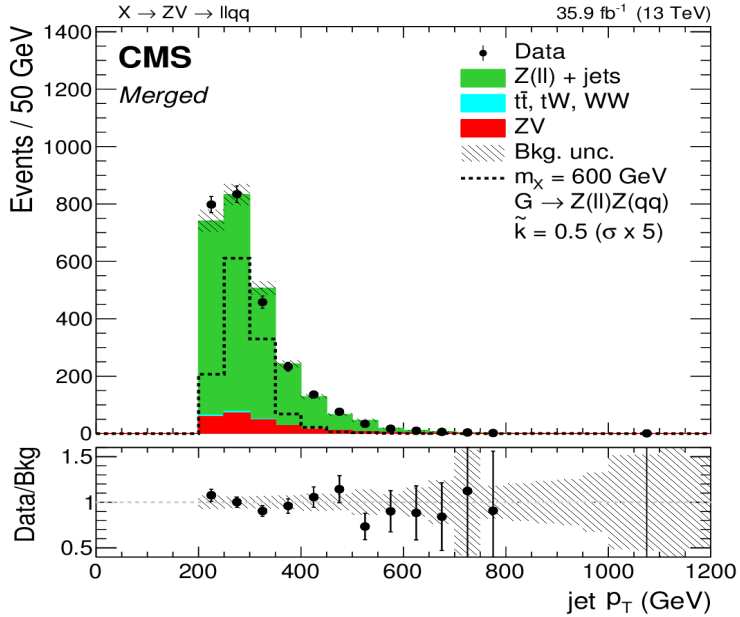
Background estimated from MC-assisted smoothed extrapolation of M(J) SB data

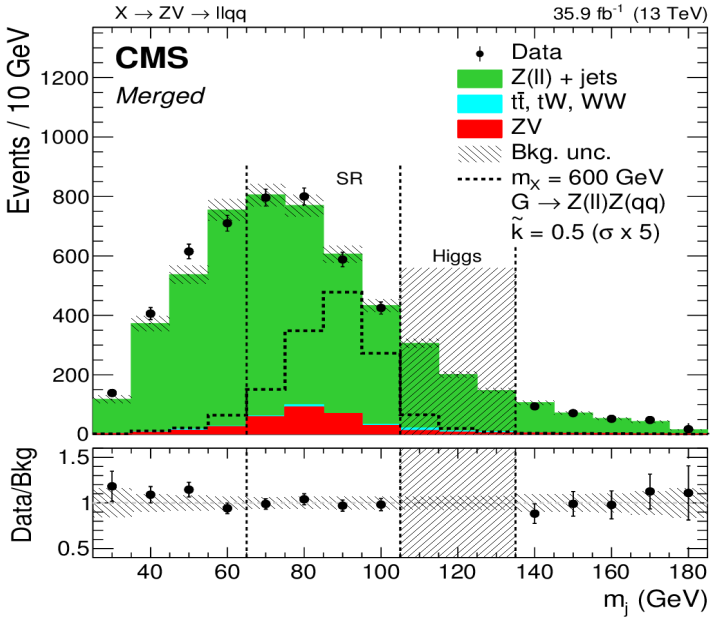
Categorizations based on τ_2 / τ_1

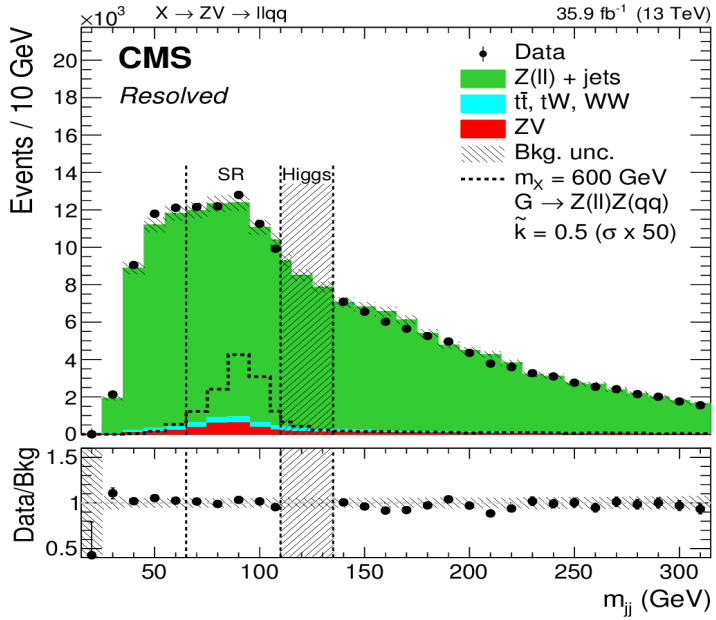
Intermediate Mass Analysis: M(J), M(JJ)

2016



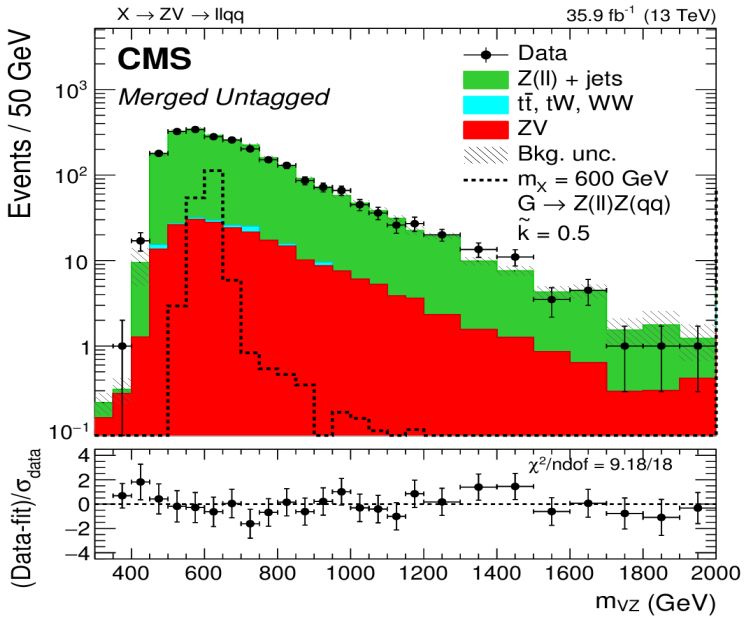


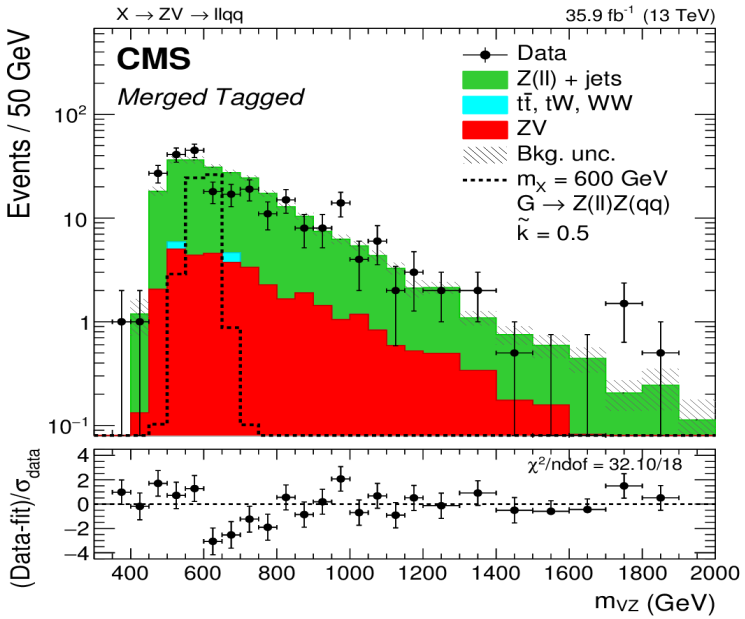


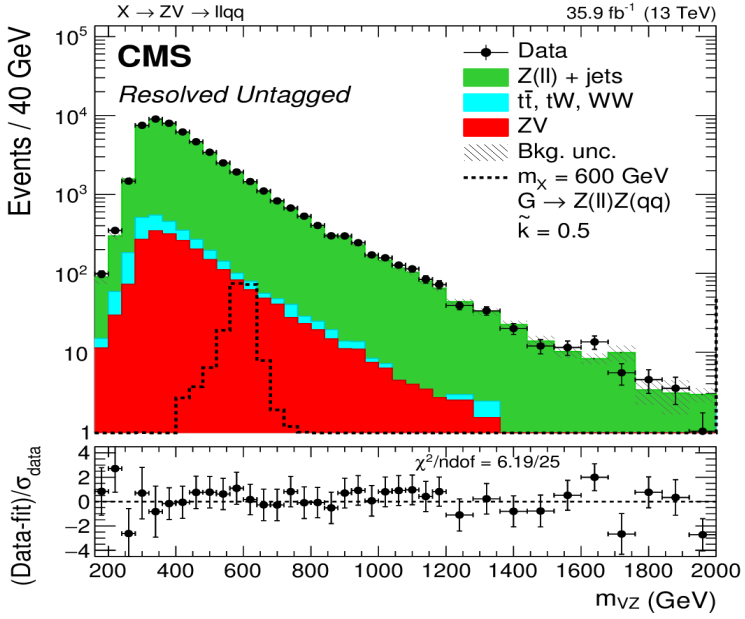


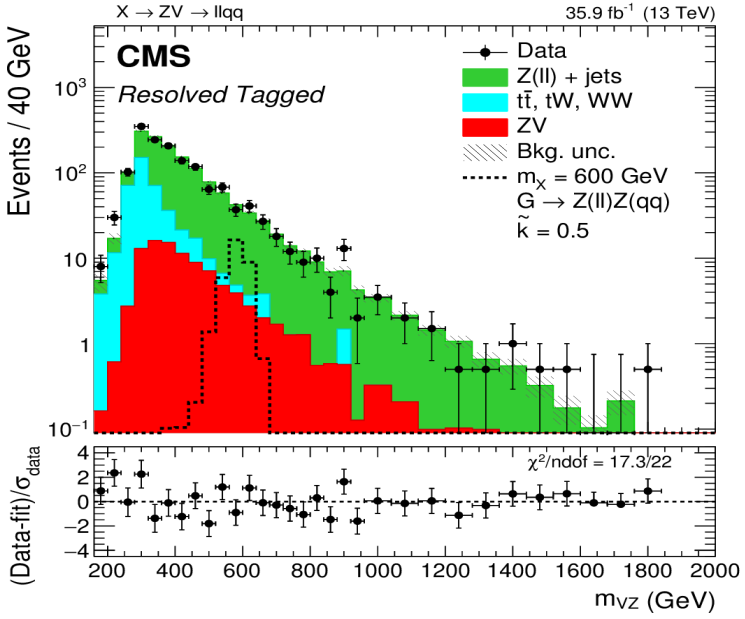
Intermediate Mass Analysis: M(2lJ), M(2l2J)

2016



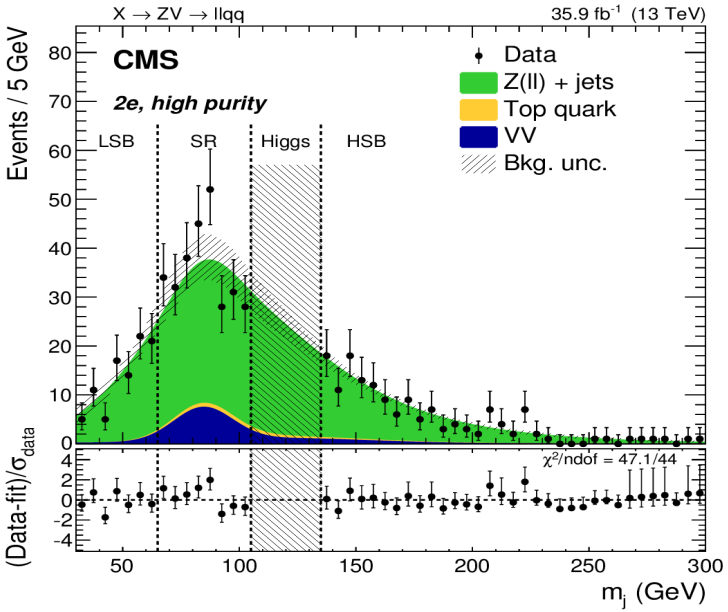


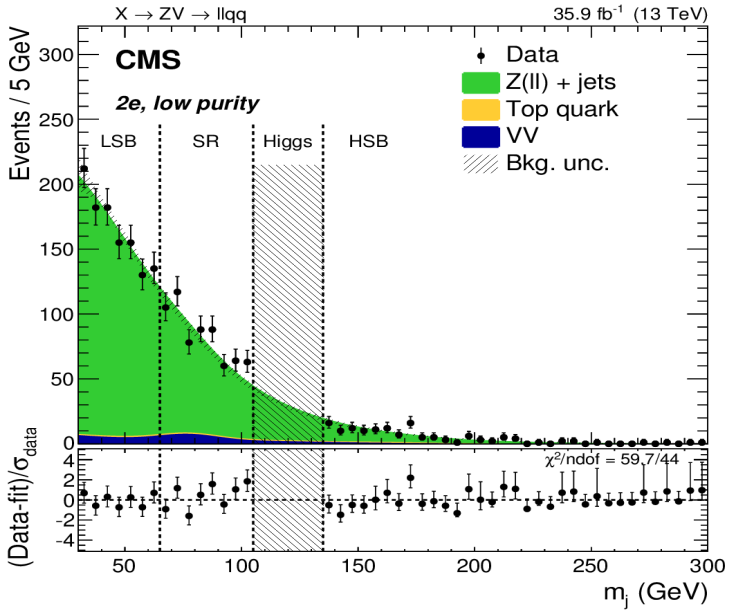


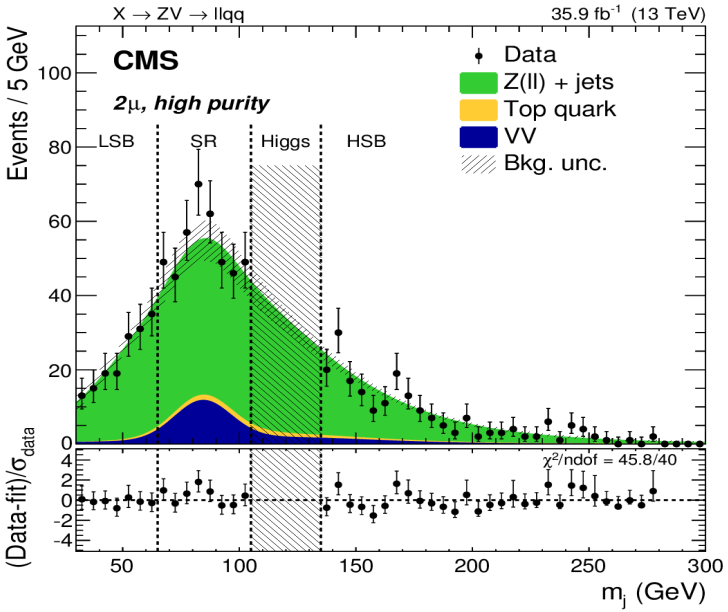


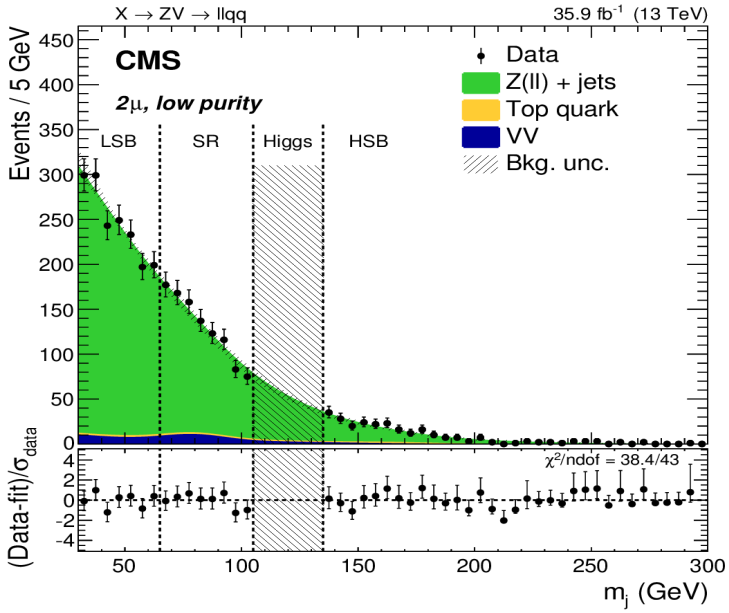
High Mass Analysis: M(J)

2016



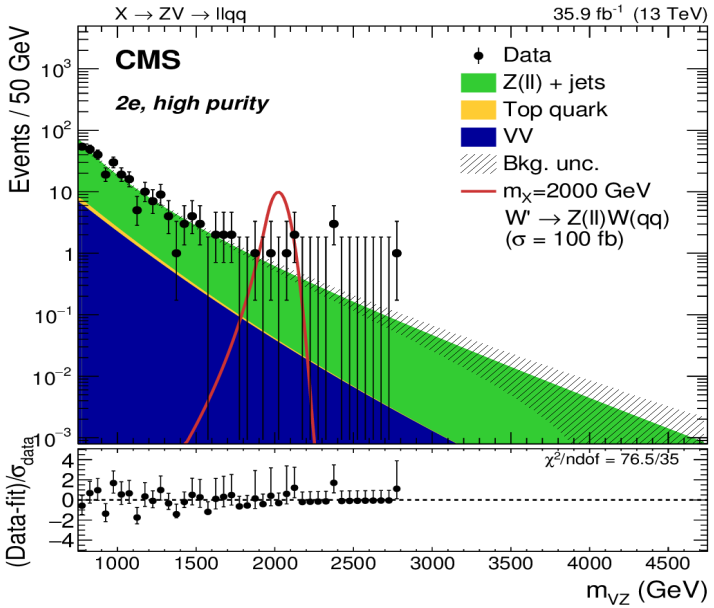


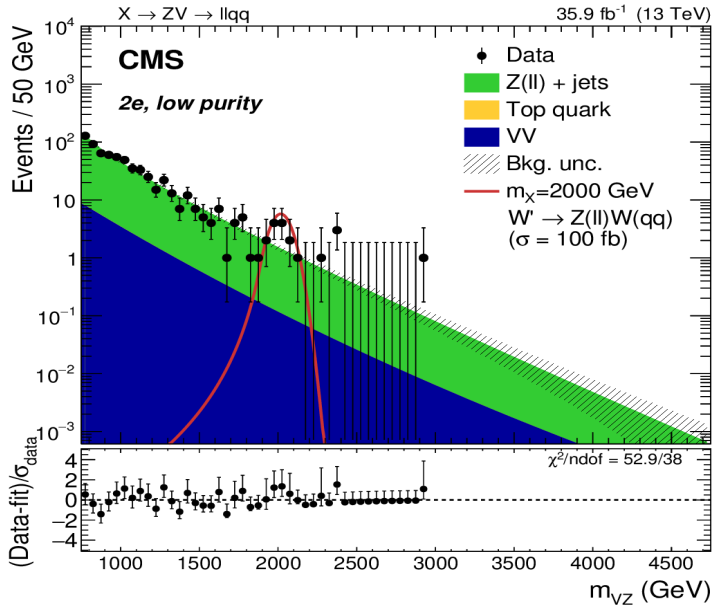


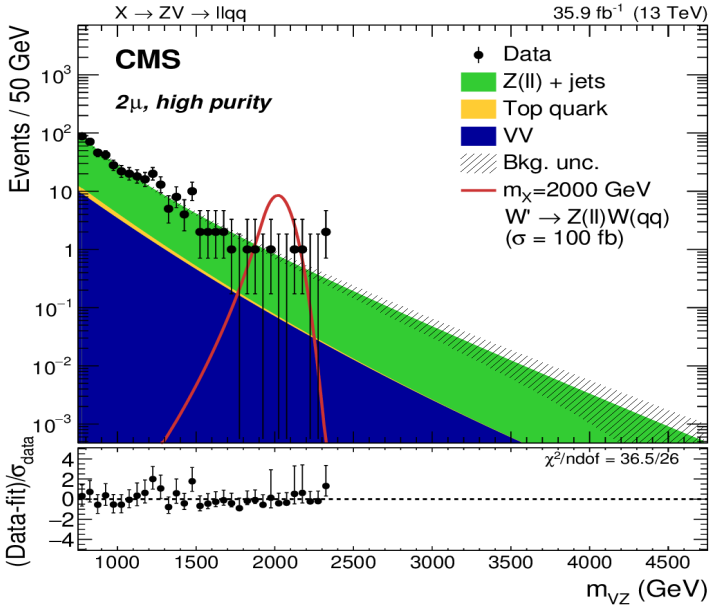


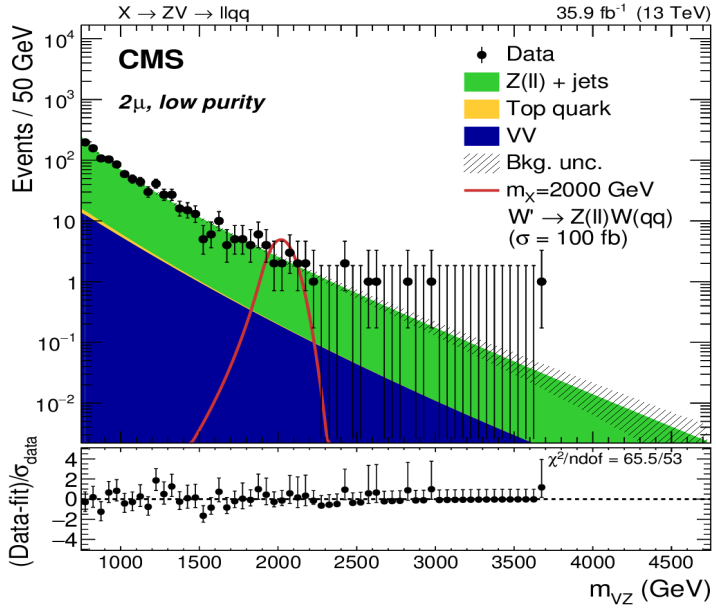
High Mass Analysis: M(2lJ)

2016









Limits on W', Bulk Graviton Production

2016: No Significant Excess