

Searches for boosted particles in CMS



Ricardo Vásquez Sierra
BOOST 2011, Princeton University
May 22nd, 2011

Scope of the talk

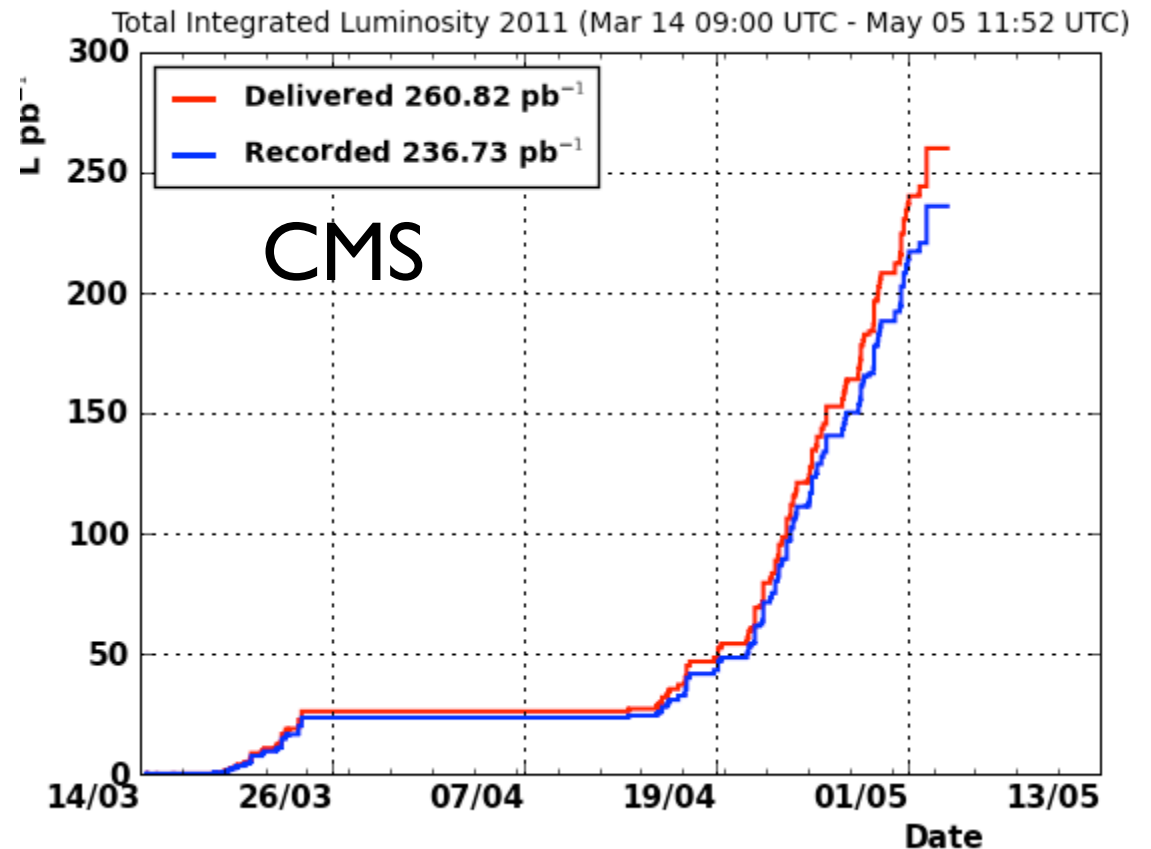
- It covers new physics searches using boosted particles in CMS performed using 2010 data
- It includes a couple of analyses that are planned using 2011 data also

Outline

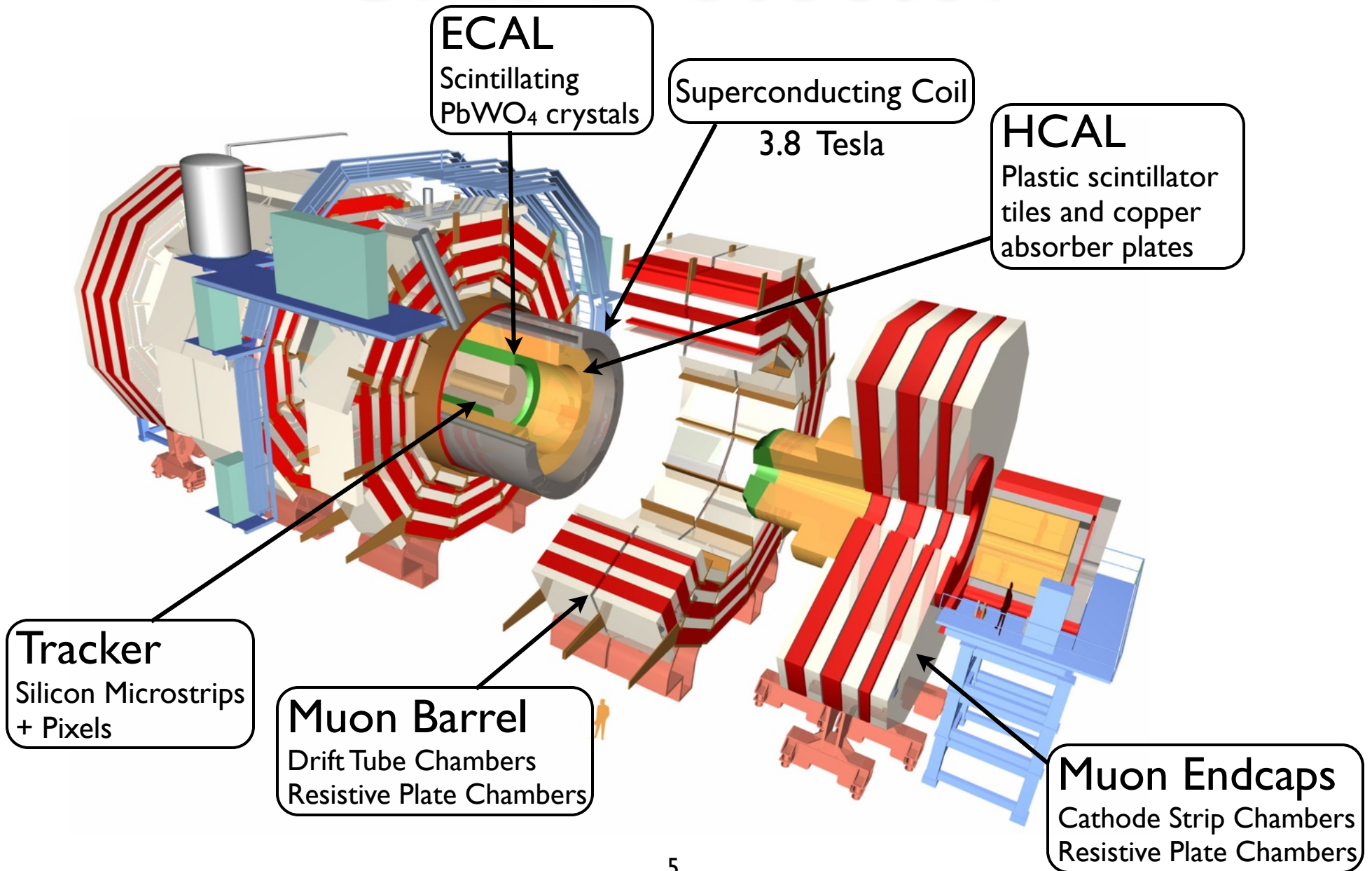
- CMS and LHC performance
- Physics Analysis
 - ▶ Boosted Z^0 into muons, search for excited quarks
 - ▶ Search for resonances in Semi-leptonic Top-Pair Decays close to production threshold
- Future results
 - ▶ Search for high mass resonances in Top-Pair Decays both in the semi-leptonic and the all hadronic decay channels
- Conclusions

LHC performance

- We have reached world record of instantaneous luminosity of:
 $4.67 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
- We are well on our way to discovery



CMS Detector



Boosted Z^0

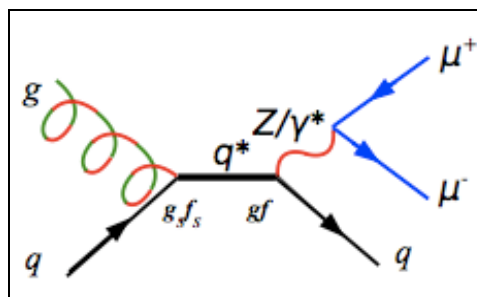
EXO-10-025

Analysis description

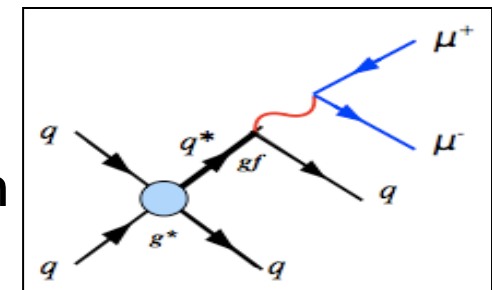
- The analysis is dedicated to the search for anomalous production of highly boosted Z^0 bosons in the dimuon decay channel
- The search is optimized for the detection of excited quark production weakly decaying:

$$q^* \rightarrow qZ^0 \rightarrow q\mu^+\mu^-$$

Gauge interaction



Contact interaction



Analysis strategy

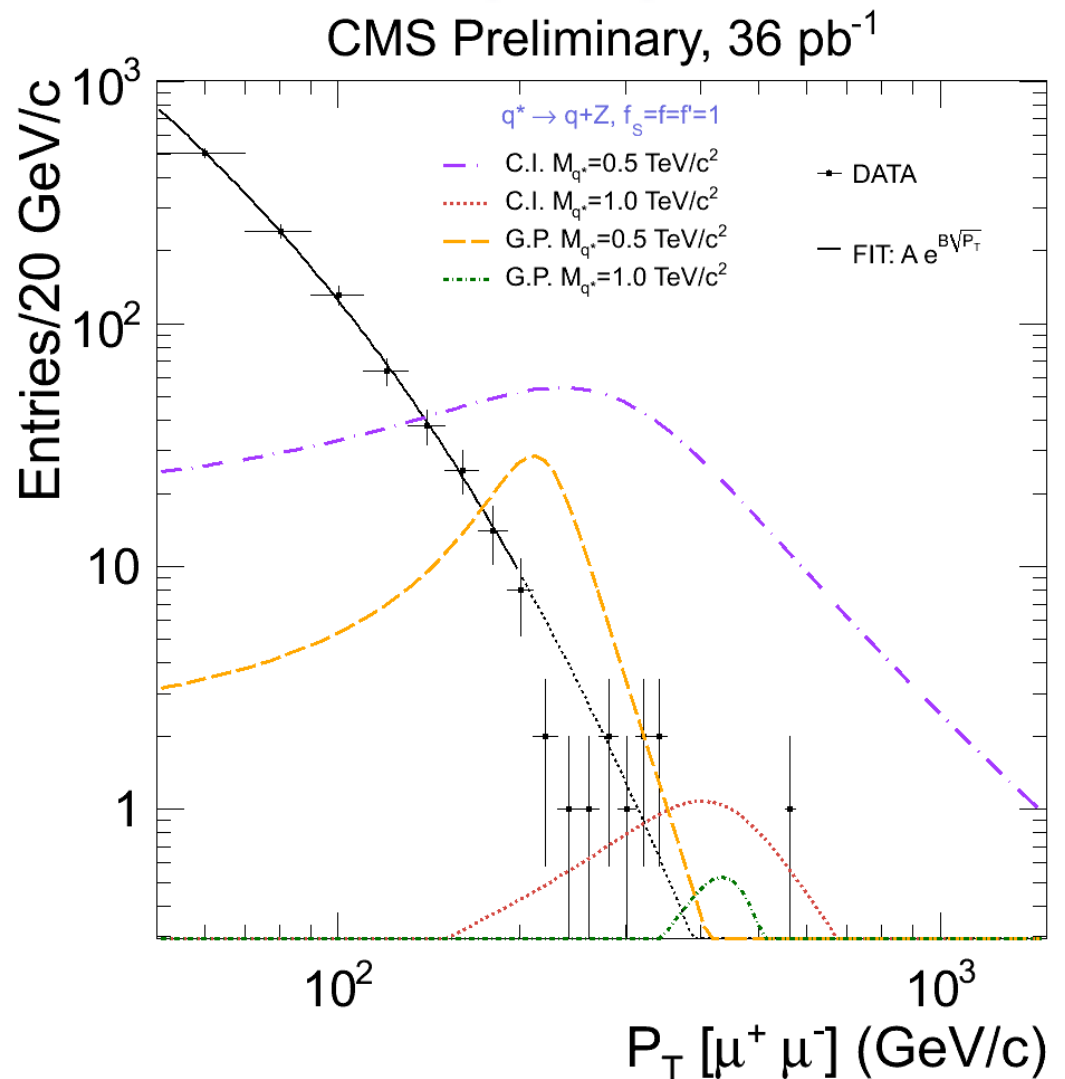
- Require at least two muons with $p_T > 20 \text{ GeV}/c$, $|\eta| < 2.4$ and opposite charge
- Each muon is required to be isolated within a cone of $\Delta R = 0.3$ containing less than 10% of the muon p_T

$$\frac{\sum p_T^{tracks}}{p_T^\mu} < 0.10$$

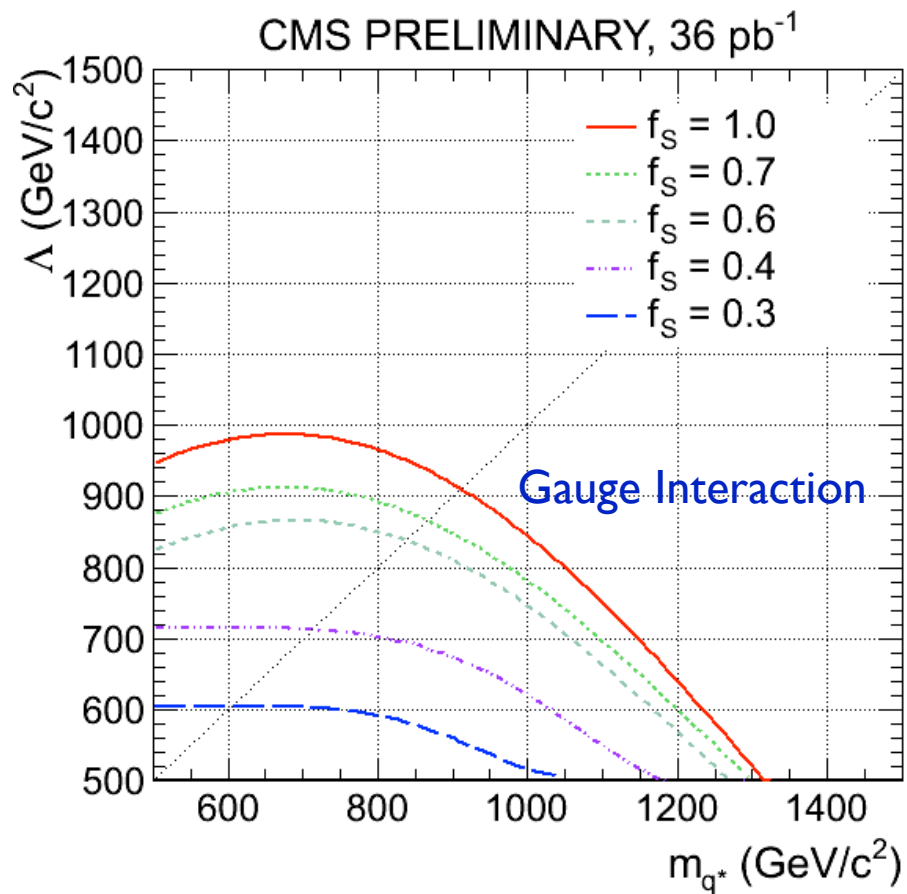
- **However, if the two muons are within the ΔR distance of 0.3 and the relative track isolation is greater than 0.9, the other muon's p_T is not counted in the sum**

Boosted $Z^0 \rightarrow \mu^+ \mu^-$

- Search for a deviation in the Z p_T spectrum expected from SM
- No deviation from SM found

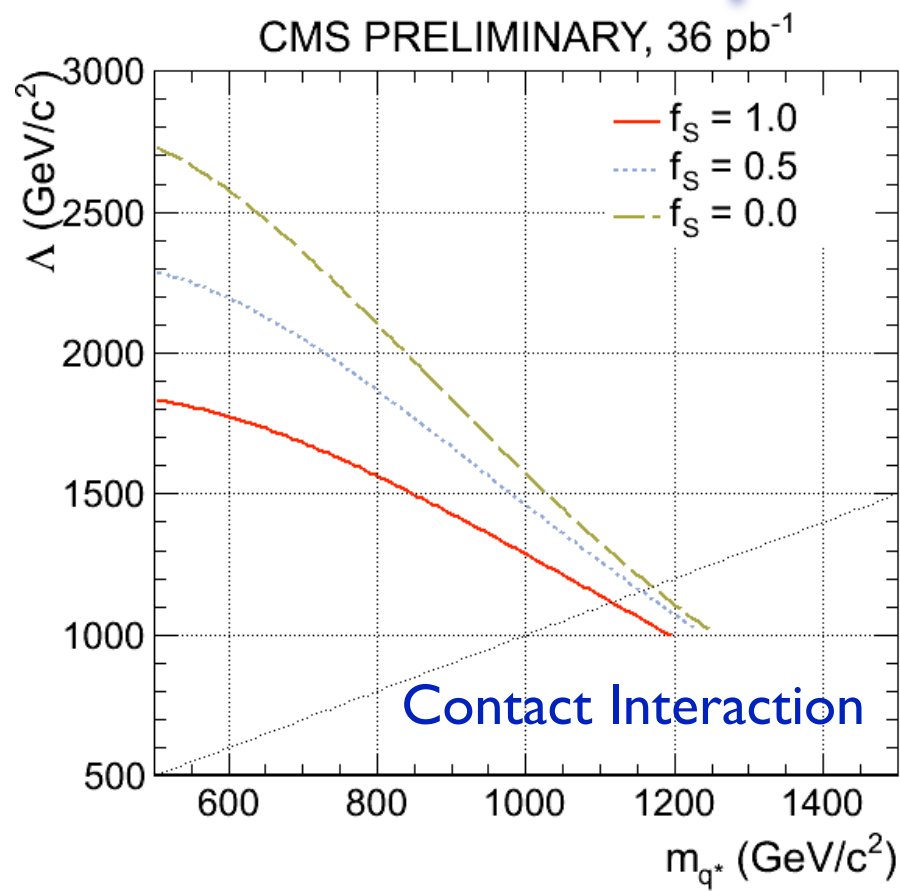


Exclusion Limits on m_q^*



$$m_{q^*} < 911 \text{ GeV}/c^2$$

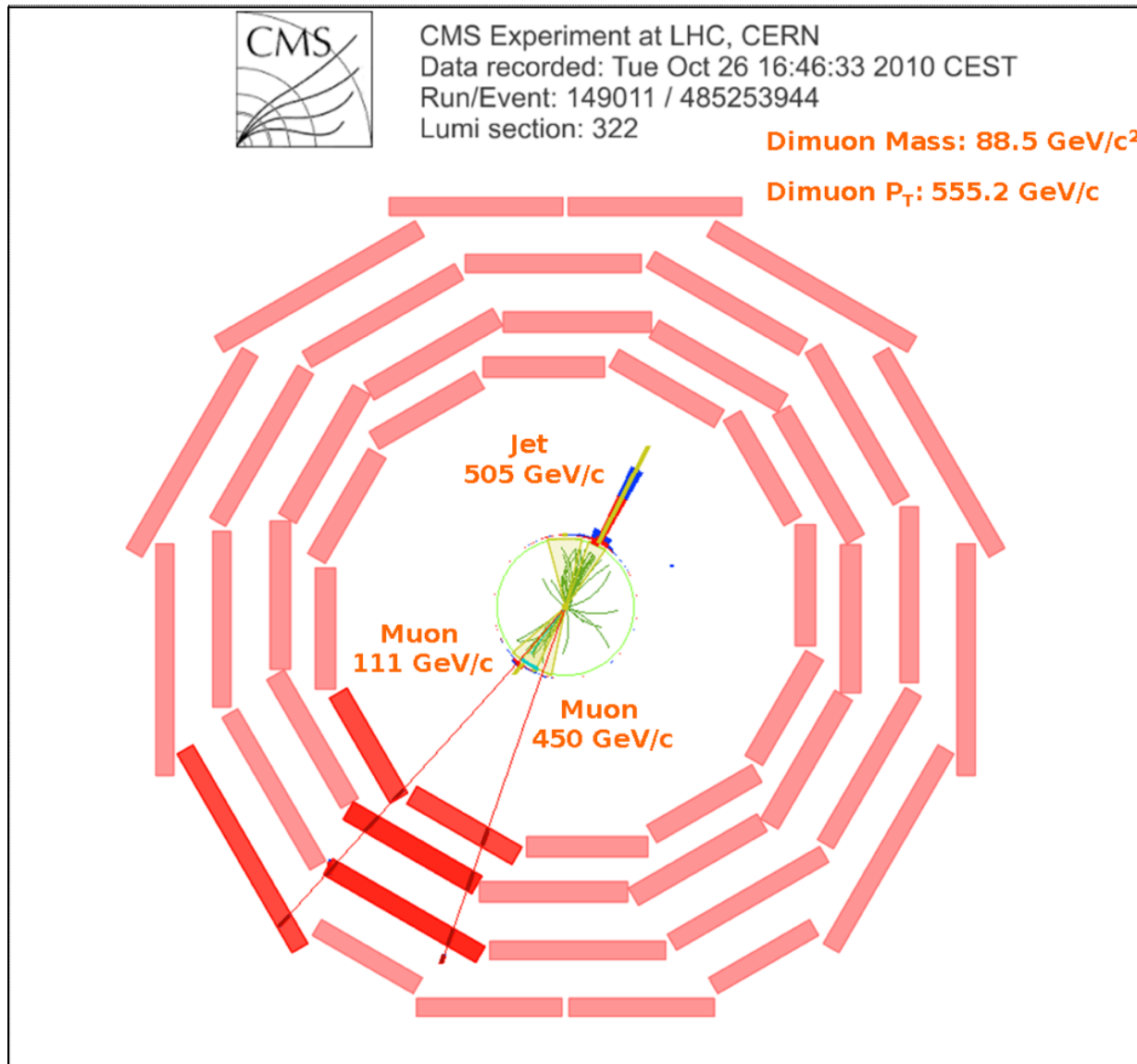
$$f_s = 1$$



$$m_{q^*} < 1170 \text{ GeV}/c^2$$

$$f_s = 0$$

Boosted $Z^0 \rightarrow \mu^+ \mu^-$



Search for resonances in Semi- Leptonic Top-pair decays (TOP-10-007)

Analysis strategy

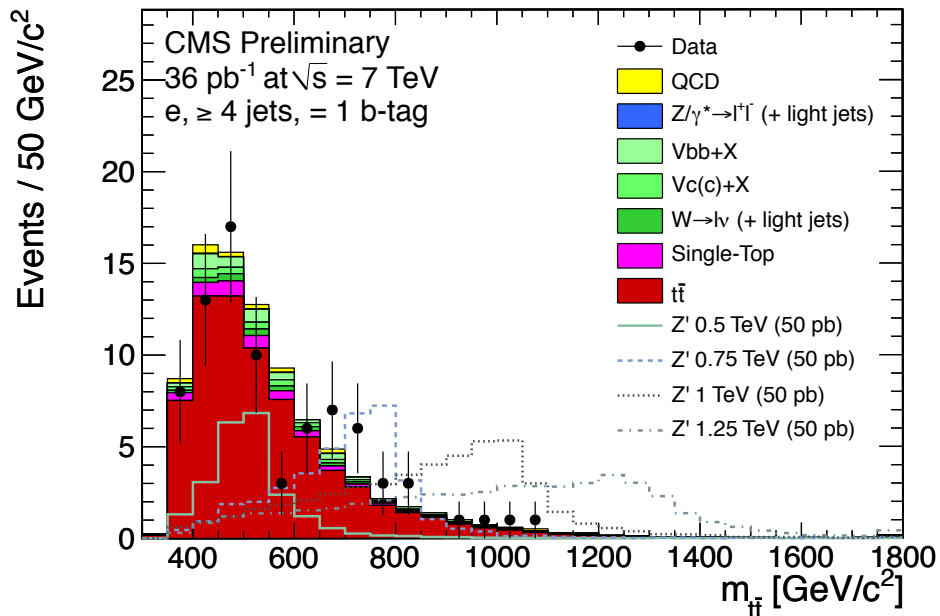
- Bump hunt in the $M(t\bar{t})$ spectrum

$$Z' \rightarrow t\bar{t} \rightarrow WbWb \rightarrow l\nu bq\bar{q}b$$

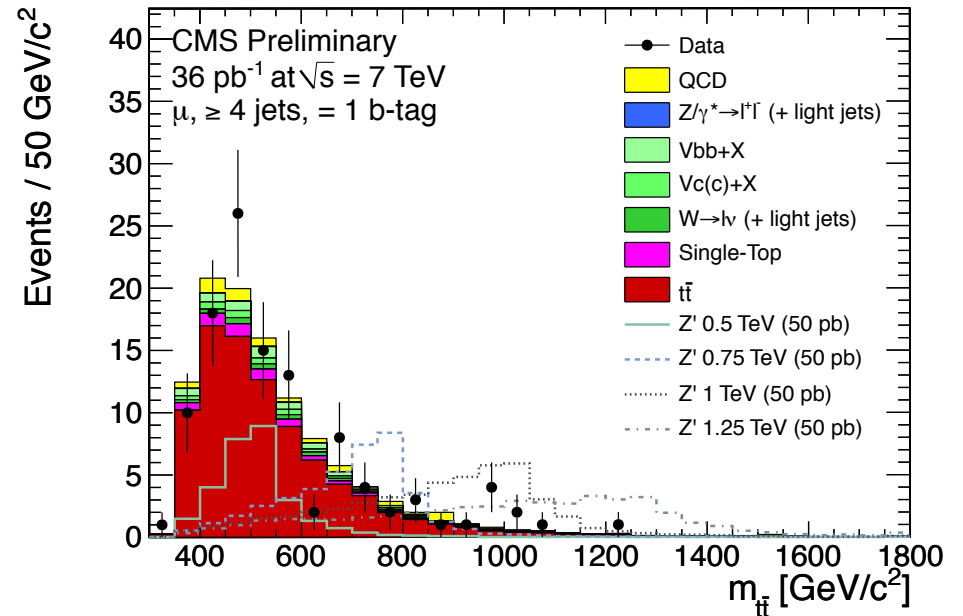
- The search is done for a Z' close to top-pair production threshold, but it reaches a higher mass regime, therefore covering some moderate boosted top
- The analysis divides the data into four categories according to the number of jets in the event and number of b-tags.
- This differentiation of samples with different signal-to-background ratios improves the overall sensitivity of the analysis.

$m_{t\bar{t}}$ Distributions

electron

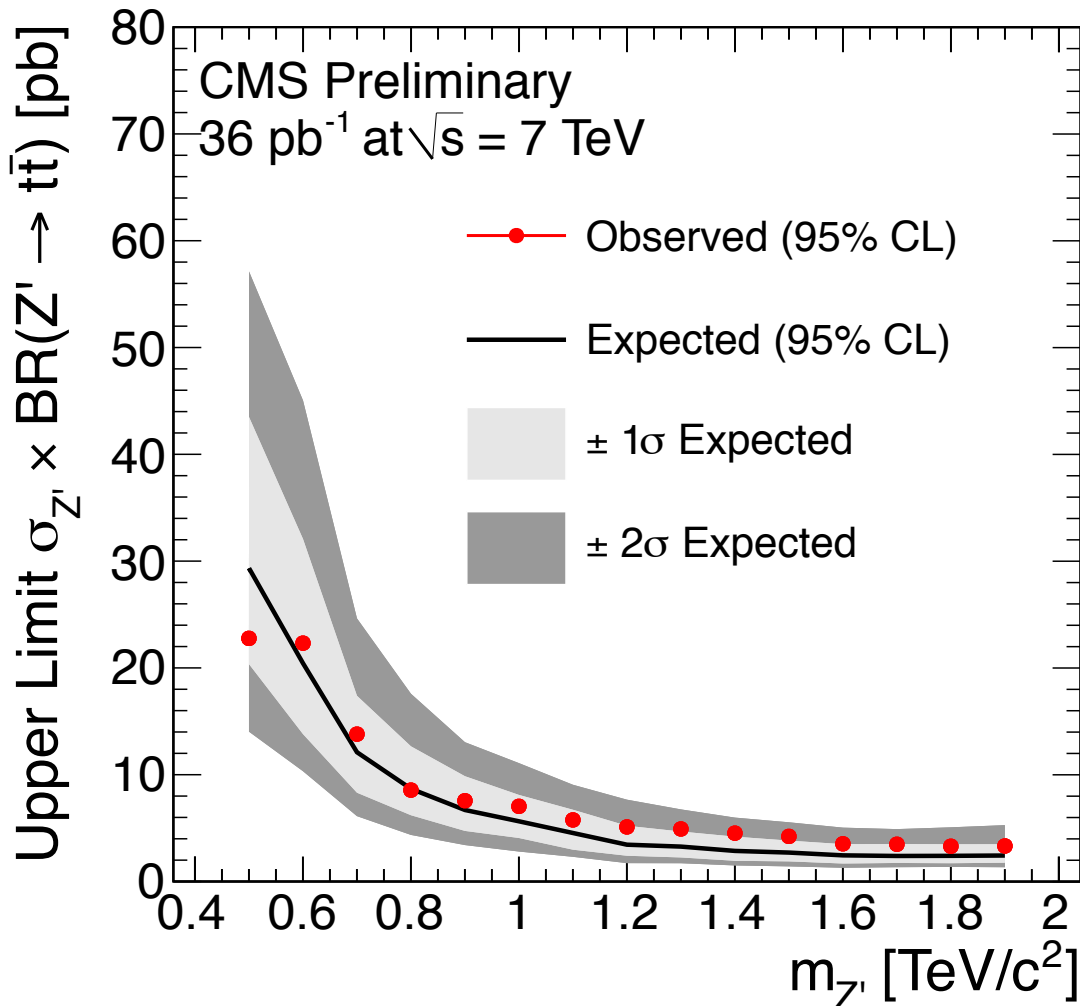


muon



- No significant excess found in any distribution
- All Z' distributions scaled to a cross section of 50 pb.

Search for resonances in Semi-Leptonic Top-pair decays



- Set limit on the production cross section:

25 pb for $m_{Z'} = 0.5$ TeV
7 pb for $m_{Z'} = 1$ TeV

Future results

High mass resonance into Top-pair semi-leptonic decay (muon)

(EXO-09-008)

$$Z' \rightarrow t\bar{t} \rightarrow WbWb \rightarrow \mu\nu bq\bar{q}b$$

- High mass will result in greatly boosted tops
 - ▶ The analysis plans to avoid regular isolation cuts on energy deposits around the lepton
 - ▶ In place, they have designed a 2-D cut vetoing events with:

$$\Delta R_{min} < 0.4$$

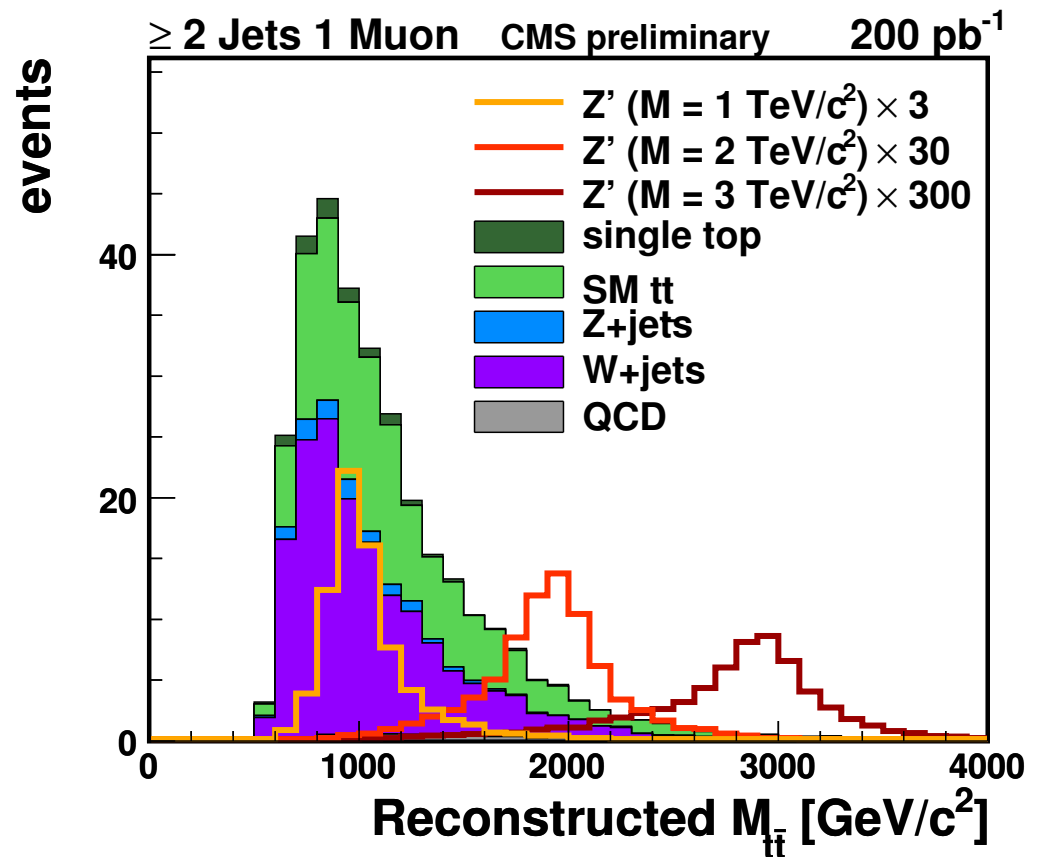
$$p_T^{rel} < 35 \text{ GeV}/c$$

ΔR_{min} = distance to the closest jet with $p_T > 30 \text{ GeV}/c$

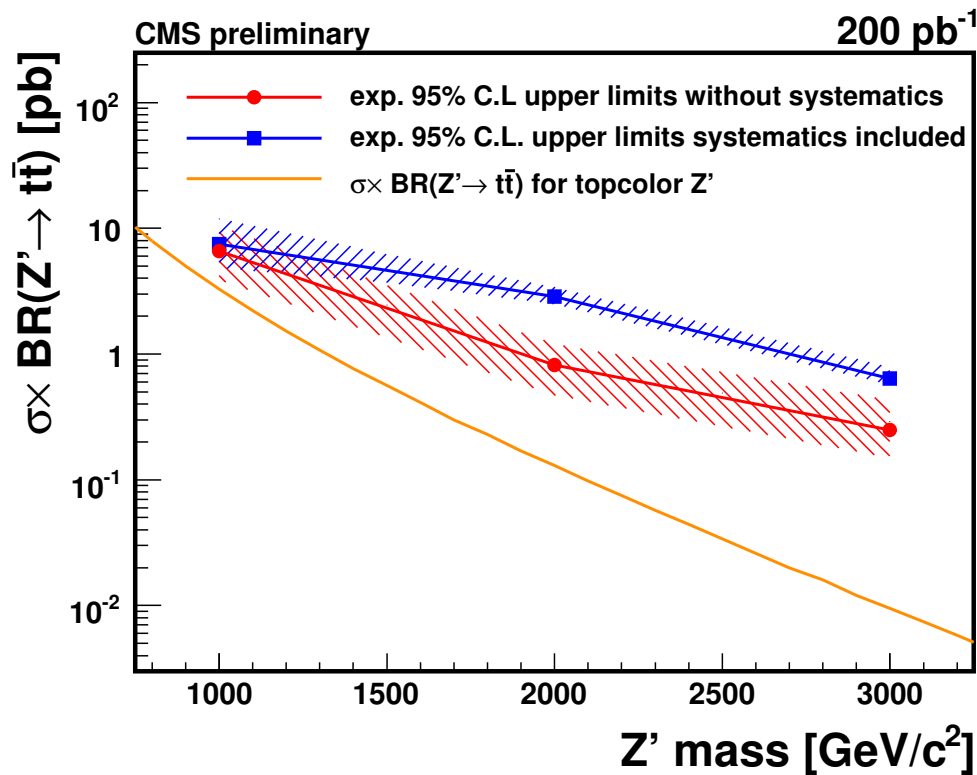
p_T^{rel} = transverse momentum of the muon relative to the direction closest jet

High mass resonance into Top-pair semi-leptonic decay (muon)

- This analysis is including 2011 data, we'll hear from them soon!



High mass resonance into Top-pair semi-leptonic decay (muon)



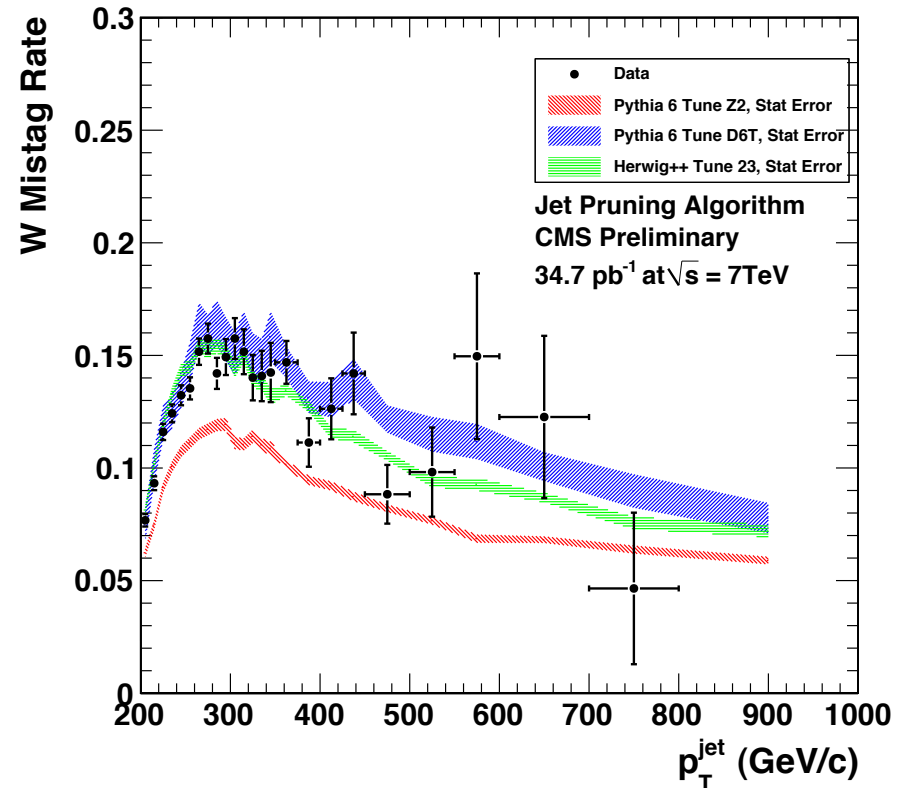
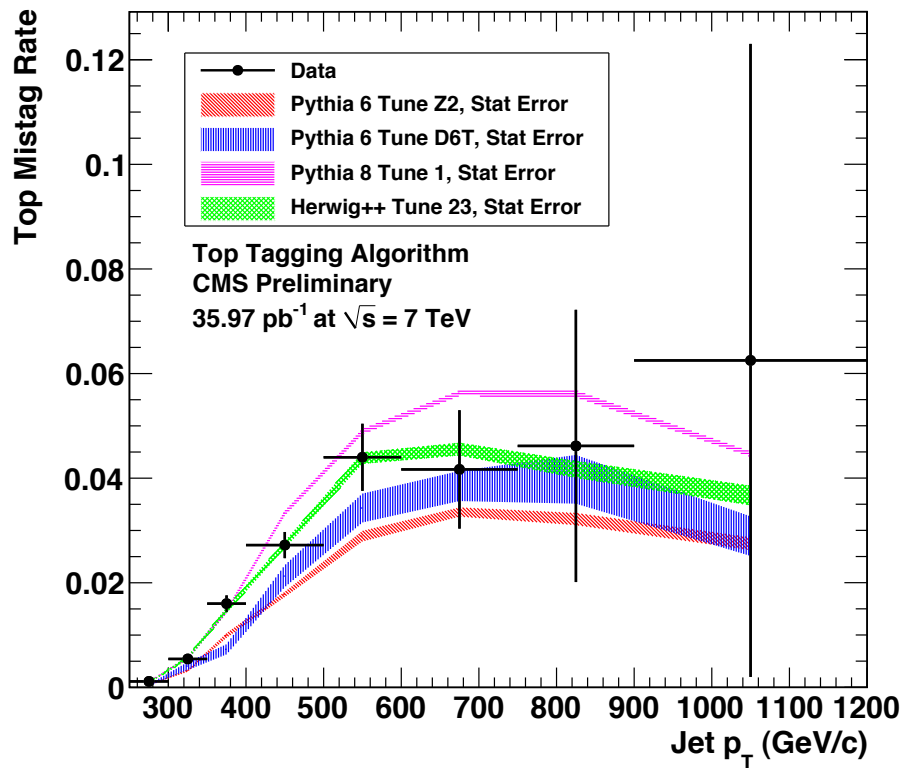
- The expected limit looks promising already for 200 pb⁻¹
- The 2D cut takes care nicely of the merging problem

High mass resonance decaying into a Top-pair in all hadronic channel

- This analysis relies on Jet substructure techniques
- Tagging boosted tops based on Kaplan et al. technique (arXiv:0806.0848)
 - ▶ Reversing the Cambridge-Aachen jet clustering sequence to find substructure in jets
- W-tagging using the jet pruning technique from Ellis et al. (arXiv:0903.5081)
 - ▶ Removes soft, large angle particles during the jet clustering sequence

See Sal's talk on Monday

Mistag rates measurements from 2010 data (JME-10-013)



- Dijet data were used to measure the mistag rates of both taggers and they were also compared to MC and different tunes

Conclusions

- CMS is looking for boosted particle signatures
- The use of some of the tools developed by theorists for this purpose have been explored (top tagging and W tagging with jet pruning)
- CMS will keep exploring these and other techniques to search for new physics
- Stay tuned, this is only a peek of a very rich physics program held by the collaboration. More results can be reached:

<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults>

THE END

Backup Slides

Jet Pruning

- Jet Pruning from Ellis et al. (arXiv:0903.5081) on Cambridge-Aachen jets with $R=0.8$ is used for W-tagging
 - ▶ Removes soft, large angle particles
- Basic description:
 - ▶ It first clusters all inputs and obtains: m_{jet} and $p_{T_{jet}}$
 - ▶ Each jet is reclustered requiring each recombination ($1+2 \rightarrow p$) meet :

$$\frac{\min(p_{T1}, p_{T2})}{p_{Tp}} > 0.1$$

$$\Delta R_{12} < 0.5 \times \frac{m_{jet}}{p_{T_{jet}}}$$

- ▶ If the requirements are not met, the softest of the two, 1 or 2, is removed from the clustering sequence

Top Tagging Algorithm

- Based on Kaplan et al. (arXiv:0806.0848)
 - ▶ Cluster particle flow candidates using Cambridge-Aachen with $R=0.8$
- Reverse clustering sequence twice to find substructure
 - ▶ During the reversal of the sequence, subclusters found must satisfy two requirements:

$$p_T^{\text{subcluster}} > 0.05 p_T^{\text{cluster}}$$

$$\Delta R_{1,2} > 0.4 - 0.0004 p_T^{\text{cluster}}$$

- If one of the subclusters is too soft, it is removed, and the procedure is repeated on the remaining cluster
 - ▶ The grooming of the jet is done for last iterations of the clustering sequence only
- If the subclusters are too close to each other they don't get split