Search for di-jet resonance in the LHC-ATLAS experiment

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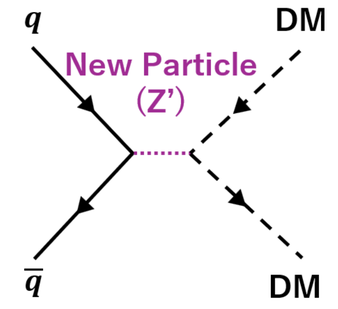
Motivation

Dark Matter(DM) mediator

- Co-production of SM and DM in the early universe ➡Suggests a mediator (e.g., Z') coupling the two.

Di jet resonance search

- Simple decay mode for high-mass reach.
  Model-independent: covers DM mediators, Z', QBH, etc...



Latest result in LHC-ATLAS experiment [1]

1. Dataset

Run2 full Data : $\sqrt{s} = 13$ TeV, 139 fb^{-1}
Jet : reconstructed by Anti-kT($\Delta R < 0.4$) algorithm
Trigger : ≥1 jet with pT > 420 GeV

2. Event selection

Leading jet > 440 GeV & sub-leading jet 60 GeV

Tab1. Event Selection requirements

Category	Inclusive		1b	2b
Jet p_T	> 150 GeV			
Jet ϕ	$\lvert\Delta\phi(jj)\rvert > 1.0$			
Jet $\lvert\eta\rvert$	-		< 2.0	
$\lvert y^*\rvert$	< 0.6	< 1.2	< 0.8	
m_{jj}	> 1100 GeV	> 1717 GeV	> 1133 GeV	
b-tagging	no requirement		⩾ 1 b-tagged jet	2 b-tagged jets
Signal	DM mediator Z' W' q^* QBH Generic Gaussian	W^*	b^* Generic Gaussian	DM mediator Z' ($b\bar{b}$) SSM Z' ($b\bar{b}$) graviton ($b\bar{b}$) Generic Gaussian

3. Signal model

Excited quark (q*)	Composite quark excitation	qg
W' / Z'	Heavy gauge boson	qq
W*	Chiral W boson	qq
Leptophobic DM mediator	DM mediator	qq
QBH	QBH from extra dimensions	qq, gg
KK graviton	Graviton KK excitation (RS model)	qq, gg

4. Background modeling

Fitting with a parametric function using the sideband region.

5. Statical method and result

- The BumpHunter algorithm scans the dijet mass spectrum to search for local excesses over the background.
- The significance of the largest deviation is evaluated using pseudo-experiments.

➡Dijet mass : No excess; no new resonance found.
p-value : inclusive = 0.89, ≧1 b-tag = 0.69, 2 b-tag = 0.83

6. 95% CL upper limit

95% CL limits on σ × BR were set for each signal model using a signal+background fit to data.

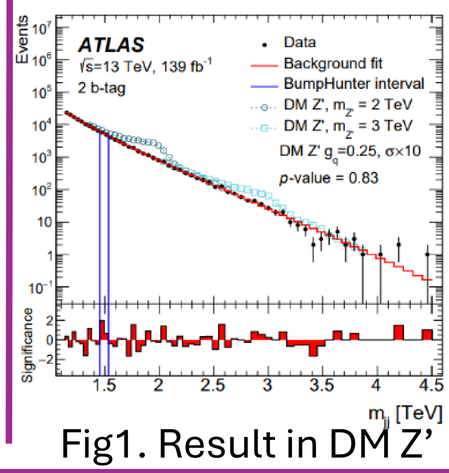


Fig1. Result in DM Z'

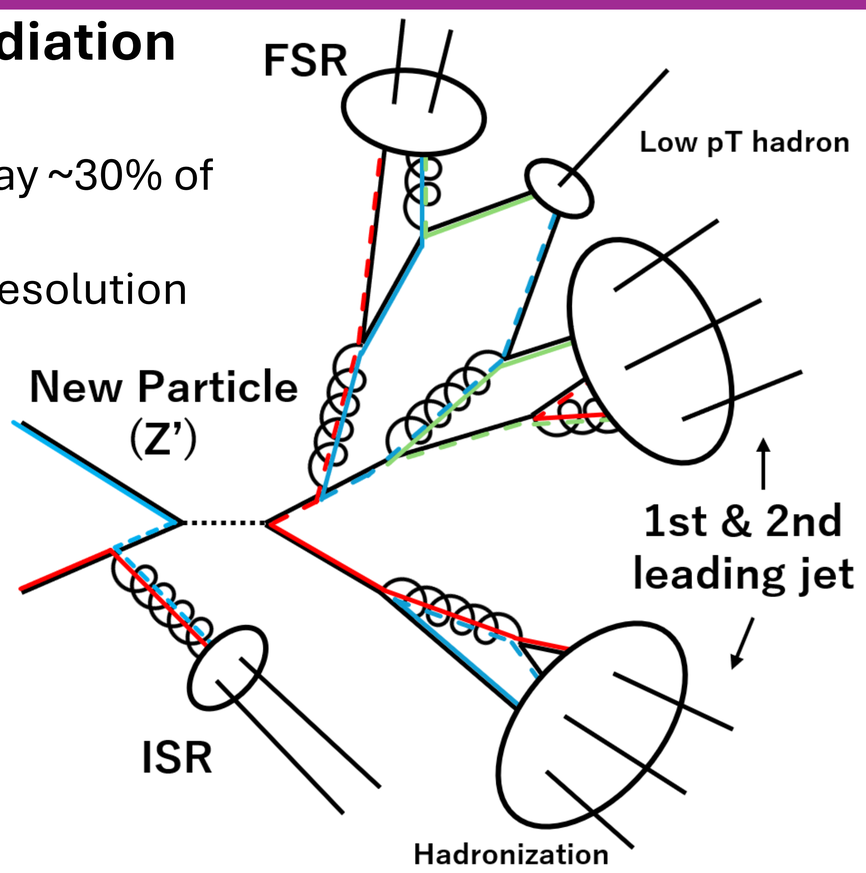
Tab2. The lower limits on the mass

Category	Model	Lower limit on signal mass at 95% CL Observed	Expected
Inclusive	q^*	6.7 TeV	6.4 TeV
	QBH	9.4 TeV	9.4 TeV
	W'	4.0 TeV	4.2 TeV
	W^*	3.9 TeV	4.1 TeV
	DM mediator Z', $g_q = 0.20$	3.8 TeV	3.8 TeV
	DM mediator Z', $g_q = 0.50$	4.6 TeV	4.9 TeV
1b	b^*	3.2 TeV	3.1 TeV
2b	DM mediator Z' $g_q = 0.20$	2.8 TeV	2.8 TeV
	DM mediator Z', $g_q = 0.25$	2.9 TeV	3.0 TeV
	SSM Z',	2.7 TeV	2.7 TeV
	graviton, $k/\overline{M}_{PL} = 0.2$	2.8 TeV	2.9 TeV

Improvement : FSR recovery

Final State Radiation (FSR)

- Gluon takes away ~30% of energy.
- Degrade mass resolution



FSR recovery based on QCD effects

Identify FSR jets from many background jets.
Leading order : FSR is concentrated near the primally jet.
Higher order : FSR and primally jet has **color-connected**.
➡soft hadrons to cluster between them

Using machine learning & Need FSR-labeled samples

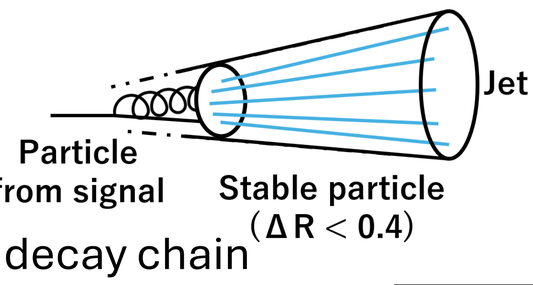
Truth FSR labeling for a jet

Need FSR-labeled samples for training
FSR is NOT always independent

- Couple to particle from initial state
- Overlap with background jets

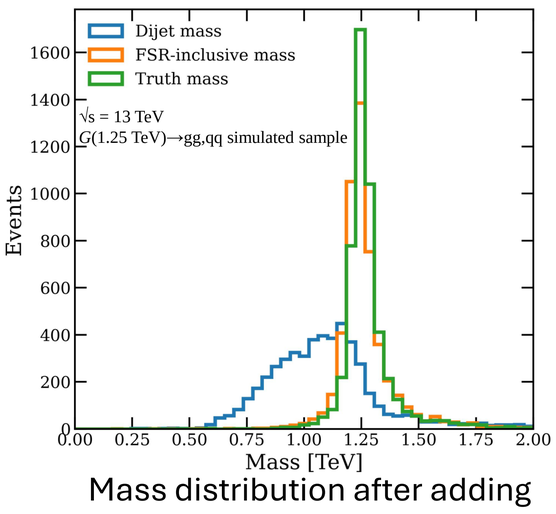
➡**Not all signal-related jets should be labeled as FSR**

Labeling method



1. Trace MC truth decay chain and list-up signal derived stable particle.
2. Sum the E_{truth} within ΔR < 0.4 of the jet (E_{truth} : Stabe particle energy)
3. Take the ratio to the jet energy (E_{jet})

$$\frac{\sum_{\Delta R_{\mathrm{jet,truth}}} E_{\mathrm{truth}}}{E_{\mathrm{jet}}} > 0.4$$



Mass distribution after adding truth-labeled FSR jets

➡FSR is well labeled

Reference

[1] ATLAS collaboration, "Search for new resonances in mass distributions of jet pairs using 139 fb−1 of pp collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector" , JHEP, 3 (2020)