

Search For Low Mass Dijet Resonance using Pre-Scaled Trigger Method.

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12th China LHC Physics Conference Wuhan, Hubei

31st October, 2026

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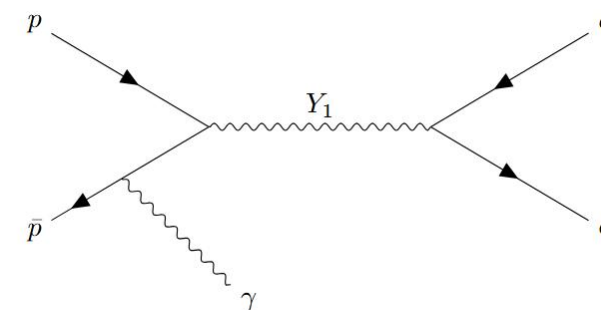
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Background



- Several beyond-the-Standard-Model (BSM) scenarios predict new particles that decay into quark pairs, producing resonances in the dijet invariant-mass spectrum.
- At higher resonance masses, energetic decay jets can satisfy unprescaled jet-trigger requirements.
- At lower masses, softer decay jets reduce the acceptance of these triggers.
- Lowering the trigger threshold increases the large QCD background rate, creating bandwidth and storage challenges.
- Inclusive dijet searches are efficient above 1 TeV because the decay jets are already hard. They pass the unprescaled trigger and parton luminosity is small enough that the rate is manageable.
- Recent searches address this problem by requiring an energetic recoil photon or jet to satisfy the trigger.
- Prescaled lower-threshold triggers offer an additional opportunity by recording a fraction of the events passing softer selections.



Feynman diagram

This is phenomenological work which uses the delphes fast simulation.



Roles of ISR and Prescale Trigger

ISR Technique	Pre-Scale Trigger
A process where an incoming parton radiates a jet or photon before producing the signal.	A data-taking strategy that records only a fraction of events passing a trigger.
An energetic recoil photon or jet can satisfy the trigger while the resonance decay jets remain relatively soft.	A lower threshold increases the available event rate, while prescaling reduces the recorded rate.
The associated-production requirement changes the selected signal process and acceptance.	Prescaling leaves the physical production cross section unchanged but reduced the recorded yields.
$p p \rightarrow Z' \gamma \rightarrow q \bar{q}$	$N_{\text{recorded}} = N_{\text{events}} / \text{Prescale}$



Data Simulation and Cross-Section

Parameter	Signal	Background
Mediator model	DMsimp_s_spin1	Standard Model
Mediator mass m_Y (GeV)	200,300,400,500,600	—
Generated events	10k per mass*pT	500k per pT
Photon p_T thresholds	50, 100, 150, 200, 250 GeV	
Jet p_T thresholds	50, 100, 150, 200, 250, 420 GeV	
Photon-jet separation	$\Delta R(\gamma, j) > 0.4$ (photon channel)	
Jet radius	$R = 0.4$	
Generator	MadGraph5_aMC@NLO	
Parton shower	Pythia 8	
Detector simulation	Delphes	

Table 1: Simulation and generator-level selection parameters for signal and background samples.

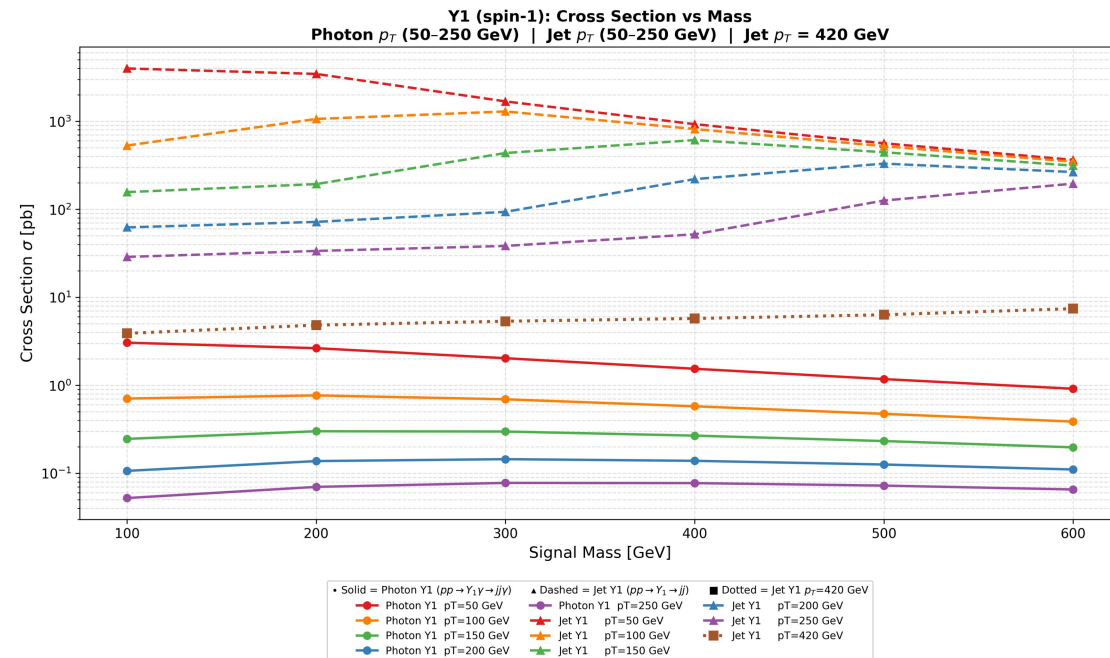


Figure 1: Signal Cross Sections Across Mass and Threshold Categories for Jet and Photon Channel.

- Lower jet thresholds give larger selected signal cross sections. At higher mediator masses, the differences between several threshold categories decrease.
- In the simulated benchmark, photon-associated production has a lower cross section than the corresponding jet-channel samples.
- Photon channel cross section fall with increasing mass, as expected from parton luminosity suppression.



Relative Signal Acceptance Across Threshold

Table 2: Jet p_T ratios relative to 420 GeV baseline.

Mass [GeV]	pT50/pT420	pT100/pT420	pT150/pT420	pT200/pT420	pT250/pT420
100	<u>1023.13</u>	136.29	40.27	16.00	7.39
200	714.34	219.93	40.02	14.88	<u>6.96</u>
300	314.44	241.79	81.54	17.49	7.17
400	161.32	142.05	106.46	38.32	9.04
500	88.80	82.31	70.29	52.19	19.86
600	48.98	46.70	42.17	35.64	26.30

$$R(p_T^{\text{cut}}, m_{Y_1}) = \frac{\sigma(p_T^{\text{jet}} > p_T^{\text{cut}})}{\sigma(p_T^{\text{jet}} > 420 \text{ GeV})}$$

$$R(p_T^{\text{cut}}, m_{Y_1}) = \frac{\sigma(p_T^\gamma > p_T^{\text{cut}})}{\sigma(p_T^\gamma > 150 \text{ GeV})}$$

- Cross sections at lower thresholds are compared with a fixed reference category to quantify the relative increase in the available signal rate.
- For the jet channel, the reference is $p_T \geq 420$ GeV. For the photon channel, the reference baseline is $p_T \geq 150$ GeV.
- At $m_{Y_1} = 100$ GeV, the cross section for the 50 GeV category is approximately 1023 times the 420 GeV reference cross section.
- These quantities represent relative acceptance ratios when the underlying process and normalization conventions are consistent.

Mass [GeV]	pT50/pT150	pT100/pT150	pT200/pT150	pT250/pT150
100	<u>10.42192</u>	2.66658	0.45630	0.23436
200	8.04764	2.45077	0.47761	0.25313
300	6.47028	2.25644	0.50364	0.27446
400	5.51386	2.10968	0.52692	0.29855
500	4.86993	1.99661	0.54922	0.32057
600	4.48190	1.93766	0.57077	0.34140

Table 3: Signal-event ratio relative to the $p_T = 150$ GeV.

Events Selection and Jet Pairing

Common	
Multiplicity	$n_{\text{jet}} \geq 2$
Jets	$p_T \geq 25 \text{ GeV}, \eta < 2.5$
Rapidity gap	$ y^* < 0.6, y^* = (y_1 - y_2)/2$
Signal window	count S, B in $\pm 10\%$ of m_{jj}
Photon channel	
Photon p_T	Same as generator-level photon p_T cut
Sub-leading jet	$p_T(j_2) > 25 \text{ GeV}$
Overlap removal	$\Delta R(\gamma, j) > 0.4$
Pairing	m_{12} only (leading jet pair)
Jet channel	
Leading jet	$p_T(j_1)$ equals the generator-level jet p_T category cut
Sub-leading jet	$p_T(j_2) > 25 \text{ GeV}$
Multiplicity	$n_{\text{jet}} \geq 2$ for m_{12}
Pairings ($n \geq 3$)	min- $\Delta\phi$ among (m_{12}, m_{23}, m_{13}) ; min- $\Delta\phi$ with- j_1

Table 4: Analysis (Reconstructed) Cuts

Filters are applied to choose best pairing from each Mass*pT combination:

- Background peak should be on the left of $\pm 10\%$ mass window.
 - Signal peak should be near the mass: $m_{\text{sig}} \in [0.6m, 1.4m]$.
 - Background should be smoothly falling inside the mass window
- $$\delta_i = n_{i+1} - n_i$$
- From the winning pairings choose the one with highest Significance $S/\sqrt{B}$.

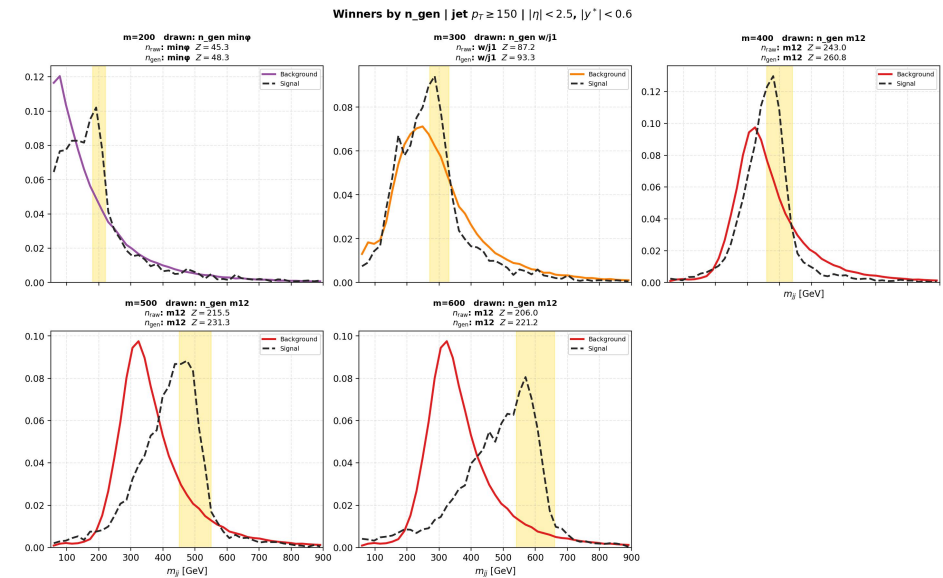


Figure 2: Selected Jet Pairings at a 150 GeV Leading-Jet Threshold

Statistical Sensitivity $S/\sqrt{B}$

Photon Channel:

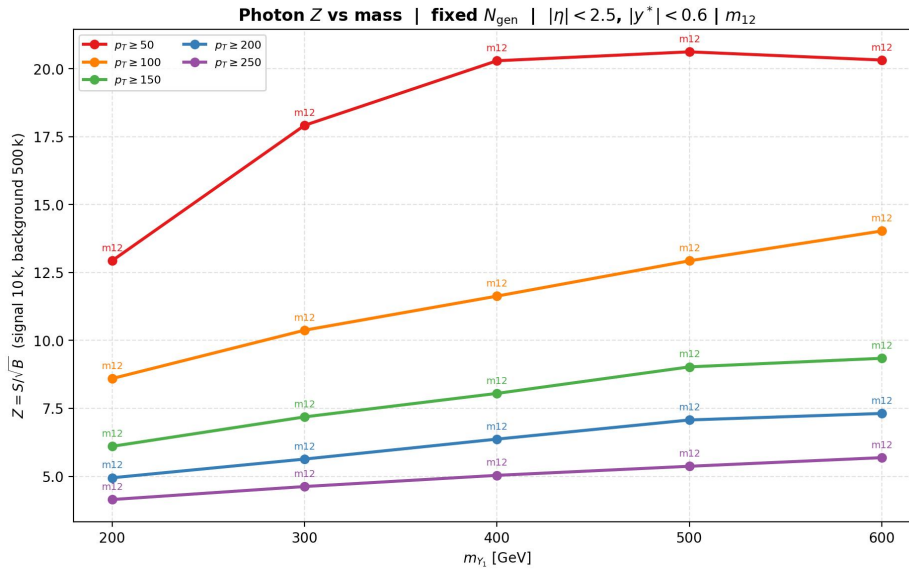


Figure3: Photon-Channel Statistical Sensitivity Across Thresholds

The Signal and background sample is normalised to the integrated luminosity $L = 140 \text{ fb}^{-1}$ through per-event weight.
In Photon Channel, photon acts as the ISR, so the leading jet pairing (m_{12}) is used to calculate the significance.

$$B = N_{b,\text{sel}} \times \frac{\sigma_b \times L}{N_{b,\text{gen}}}$$

$$S = N_{s,\text{sel}} \times \frac{\sigma_s \times L}{N_{s,\text{gen}}}$$

$$Z = S/\sqrt{B}$$

Jet Channel:

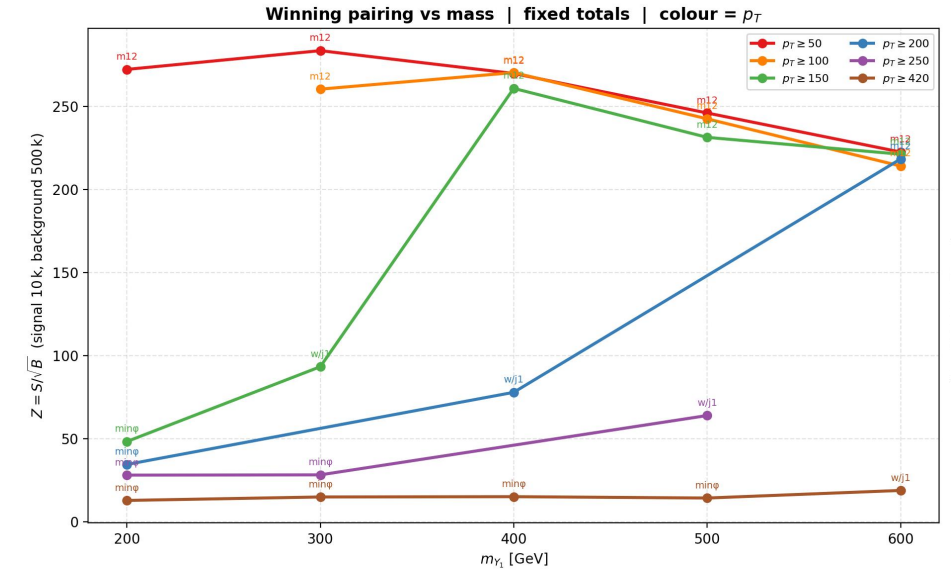


Figure 4: Jet-Channel Statistical Sensitivity and Selected Pairing

- The Significance is calculated from the signal and background events inside the $\pm 10\%$ window.
- For the high mass and lower pT cuts, leading jet pairing (m_{12}) wins.
- For the lower mass and high pT, min $\Delta\Phi$ wins. It worked on the principle of $m_{jj} \sim 2p_T$

Critical Prescale

Photon Channel:

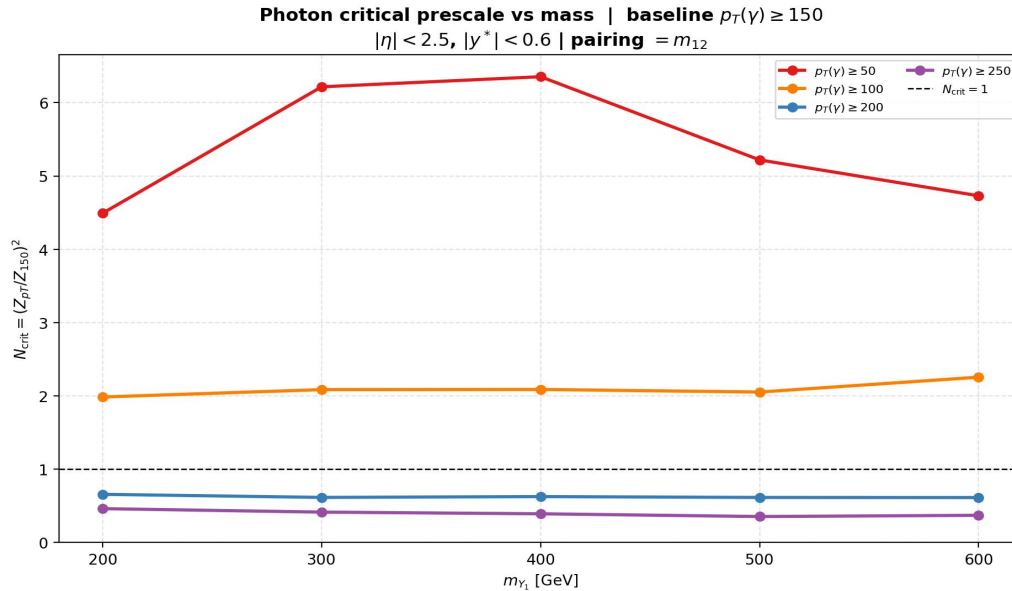


Figure 5: Photon-Channel Critical Prescale Relative to the 150 GeV Reference

- The 50 and 100 GeV categories have higher statistical sensitivity and can tolerate precaling.
- The high pT cuts, $N_{\text{crit}} < 1$. It indicates that the category has a smaller sensitivity than the reference before prescaling.
- Critical Prescale will help us with a trigger to reduce number of events from the low pT trigger and still beats the unprescaled trigger at the same mass.

$$\frac{1}{\sqrt{P_S}} \frac{S_{pT}}{\sqrt{B_{pT}}} = \frac{S_{(base)}}{\sqrt{B_{(base)}}} \quad \left(\frac{Z_{pT}}{Z_{base}} \right)^2 = N_{crit}$$

Jet Channel:

- For the low masses Significance is higher than the baseline pT cut (420 GeV). $Z_{pt} \gg Z_{420}$.
- For some threshold categories, the relative advantage decreases with mass, but it remains significant within the statistical approximation.
- For $N_{\text{crit}} \gg 1$; Soft pT cuts can have much more acceptance, even if we discard number of events.

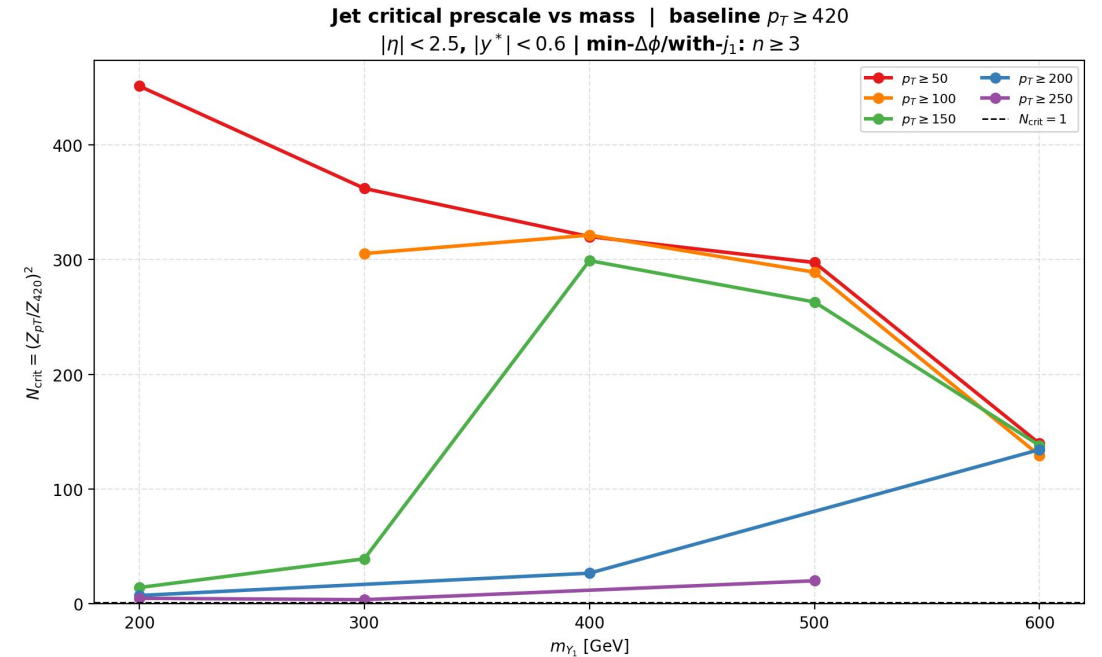


Figure 6: Jet-Channel Critical Prescale Relative to the 420 GeV Reference

Photon Critical Prescale with jet channel baseline

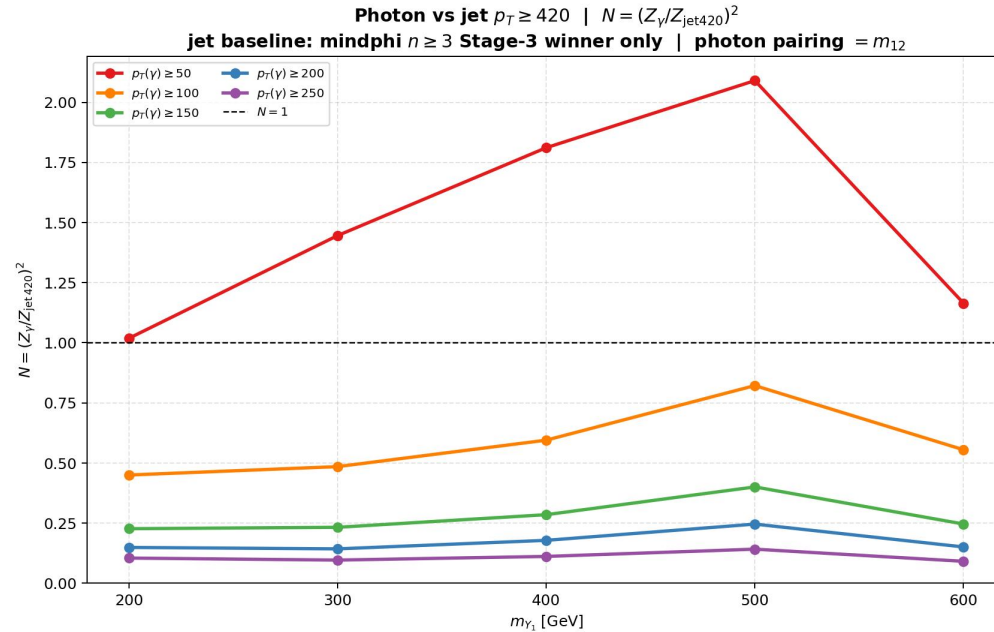


Figure 7: Photon-Channel Sensitivity Relative to the Jet Reference

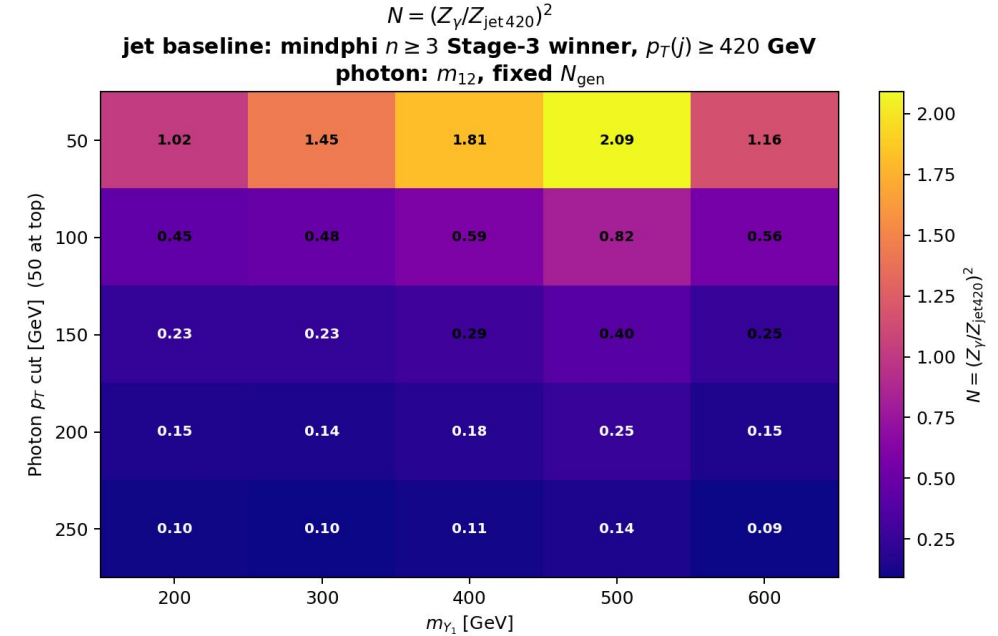


Figure 8: Photon-to-Jet Relative Sensitivity: Critical-Prescale Map

- The photon-channel sensitivity is compared with the jet-channel reference at $p_T \geq 420$ GeV.
- The photon-associated process has a lower production rate. Its sensitivity relative to the jet reference also depends on background rejection and reconstruction efficiency.
- Values above one identify photon categories with statistical headroom relative to the jet reference under the stated assumptions.
- Compare the $Z\gamma$ with the jet channel unprescaled trigger $p_T(j) \geq 420$ GeV:

$$N = \left(Z_\gamma / Z_{\text{jet } 420} \right)^2$$



- This phenomenological study uses simulated signal and background samples to explore low-mass dijet sensitivity across masses and thresholds.
- Jet pairing balances resonance reconstruction with an acceptable background shape.
- Statistical sensitivity $S/\sqrt{B}$ for the preferred pairing at each mass and threshold.
- Critical-prescale estimates quantify how much statistical sensitivity a lower-threshold category can retain relative to a harder reference.

$$\left(\frac{Z_{pT}}{Z_{base}}\right)^2 = N_{cric}$$

- Selected lower-threshold categories show statistical headroom for prescaling. The practical benefit requires validation with realistic trigger and uncertainty models.
- This work explores a comparatively understudied opportunity that could help exploit the full physics potential of the high luminosity LHC, motivating dedicated studies of pile-up and detector performance.



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- ATLAS Collaboration, Search for new phenomena in the dijet mass distribution using pp collision data at $\sqrt{s}= 8$ TeV with the ATLAS detector, Phys. Rev. D 91, 052007
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Thank you



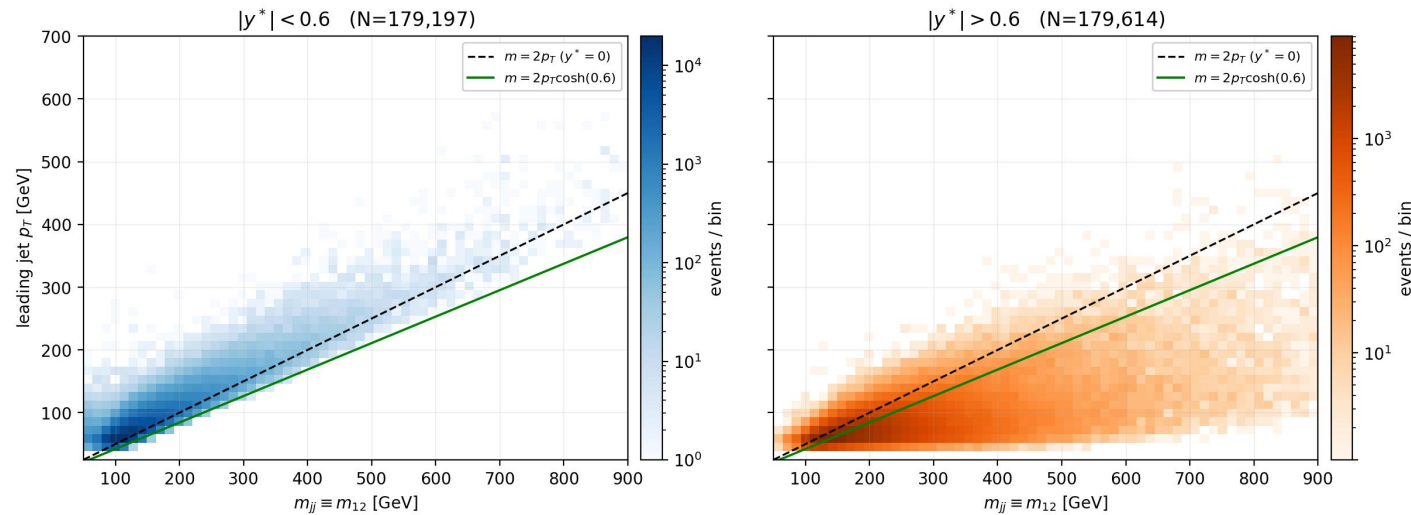
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Backup Slides



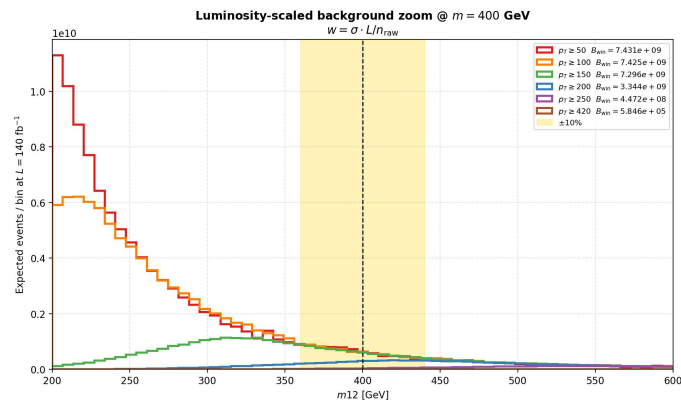
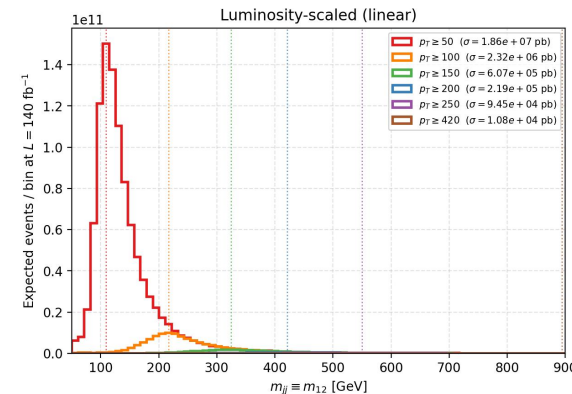
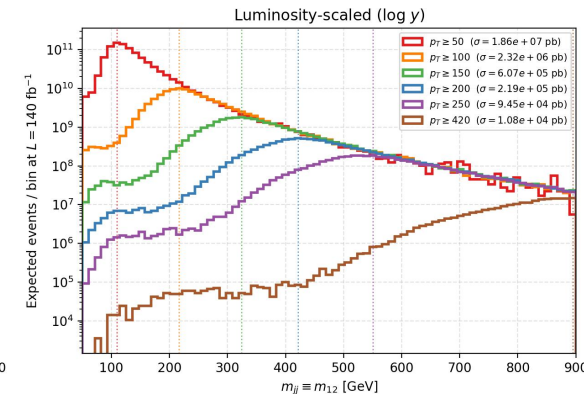
How Rapidity Cut Shapes the Spectrum?

Comparison | QCD dijet | $p_T^j \geq 50$ GeV
Comparison: soft jets $\leftrightarrow$ high m_{jj} at large $|y^*|$



- Applying the rapidity gap cut $|y^*| < 0.6$.
- QCD dijets are mostly t-channel $\rightarrow$ forward jets which cause the large y^*
 $m_{jj} \approx 2p_T \cosh(y^*)$
- The rapidity-separation requirement suppresses forward QCD configurations and changes the relationship between jet transverse momentum and dijet mass.
- The significance drops as we move to the 0.8 or much larger gap cut.

Comparison | QCD dijet | $|y^*| < 0.6$ | $|\eta| < 2.5$
 $w = \sigma \cdot L/N_{\text{gen}}$ | peaks [GeV]: 50: 109, 100: 217, 150: 324, 200: 421, 250: 550, 420: 895



Why we choose Y1 mediator over Y0?

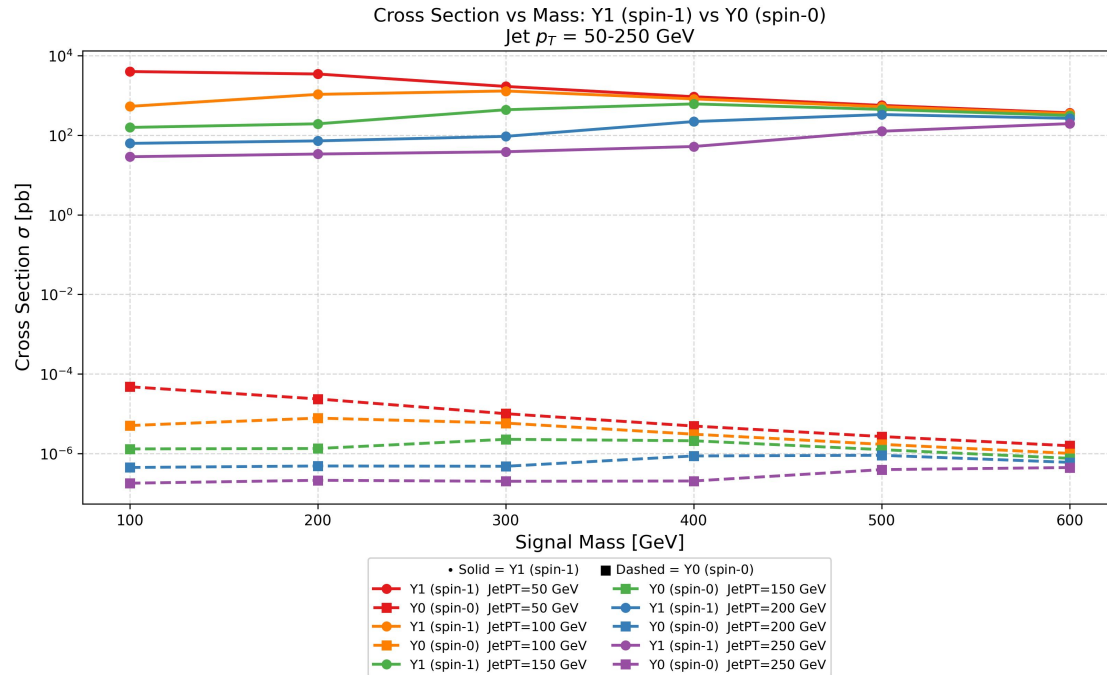


Figure 1: Cross section vs mass of y0 and y1

The significance $S/\sqrt{B}$ shows that y0 channel has approx. zero significance on different masses as compared to the y1 mediator. So for further studies Y1 channel will be considered.

- For the benchmark parameters used here, the Y1 samples have substantially larger production cross sections. We therefore focus the subsequent sensitivity study on this benchmark Y1 couples far more strongly to the production mechanism.
- Both decrease with mass, but Y0 is so suppressed it would be practically invisible compared to Y1.

Table 1: Comparison of significance of y0 and y1.

Particle Name	Mass	Jet pT	Signal_events	Bkg_events	Cross_section	$S/\sqrt{B}$
Y0	200	150	1267	297	1.33364e-06	0.00
Y1	200	150	1328	297	0.300697	6.2883
Y0	200	200	1635	368	4.84918e-07	0.00
Y1	200	200	1620	368	0.13775702	4.9214

Jet and photon Graphs

