Angular Observables for Spin Discrimination in Boosted Diboson Final States

based on JHEP 1609 (2016) 036 (arXiv:1604.06096)
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PRISMA | Cluster of Excellence
Precision Physics, Fundamental Interactions and Structure of Matter

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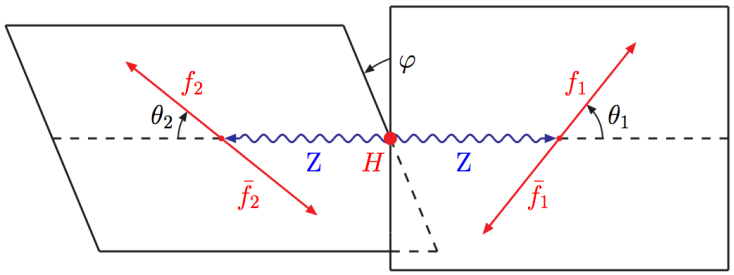
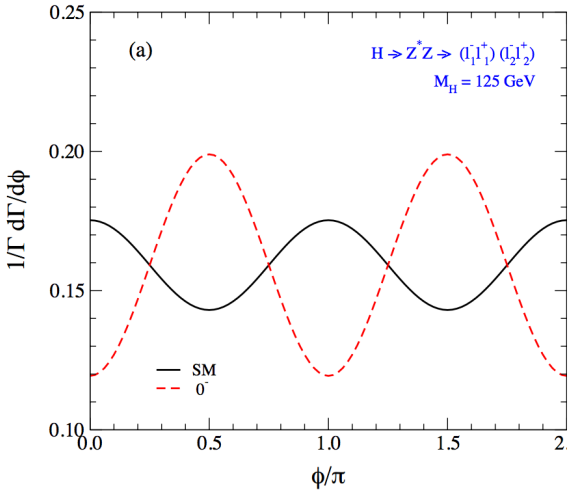
How to determine the spin of a resonance is well studied, see Higgs:



S.Choi et.al. (2002), see also: J.Dell'Aquilla, C.Nelson (1986), A.Djouadi et.al. (1994)



Angular distributions are know analytically

see e.g.: Gao et.al. (2010), Bolognesi et.al. (2012)

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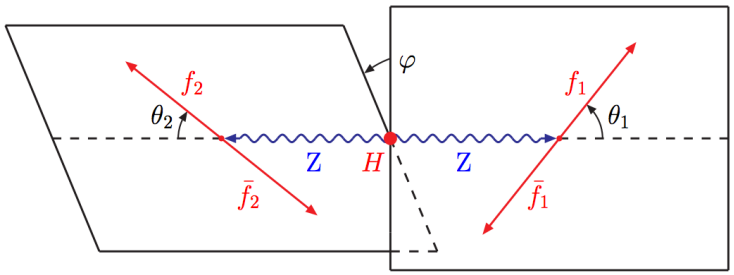

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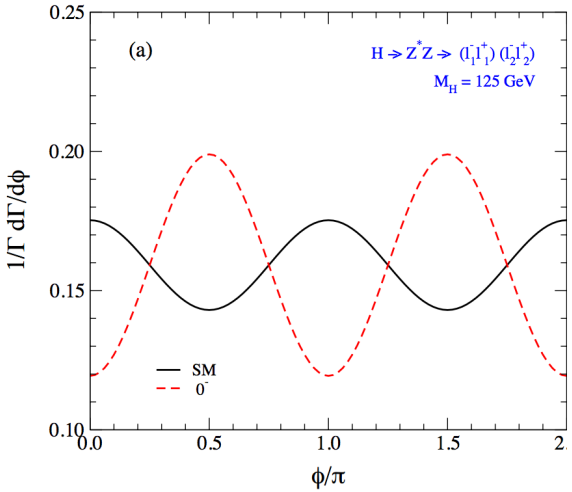

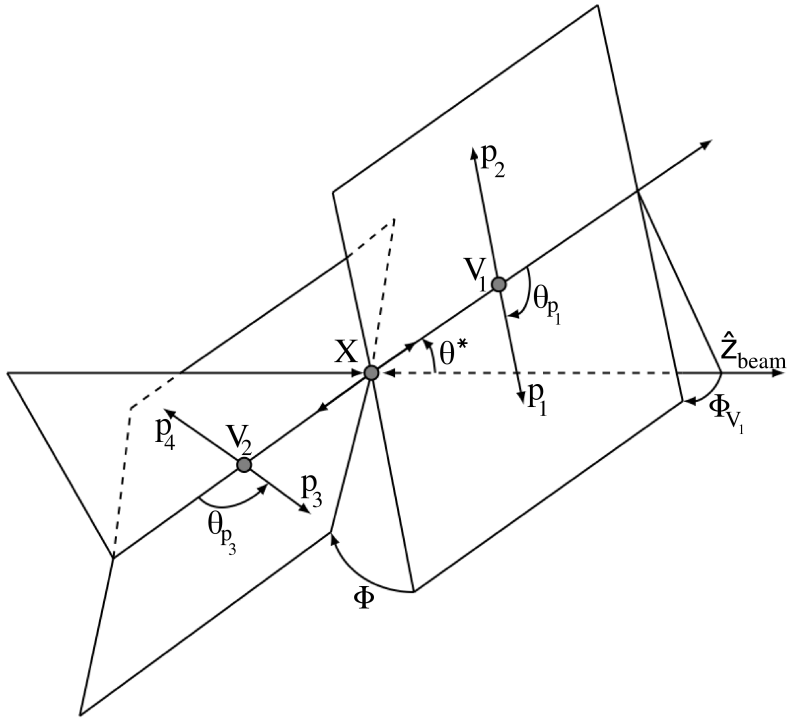

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So what is different?

Resonance masses are heavier ($\mathcal{O}(TeV)$), thus

- Very different background rates
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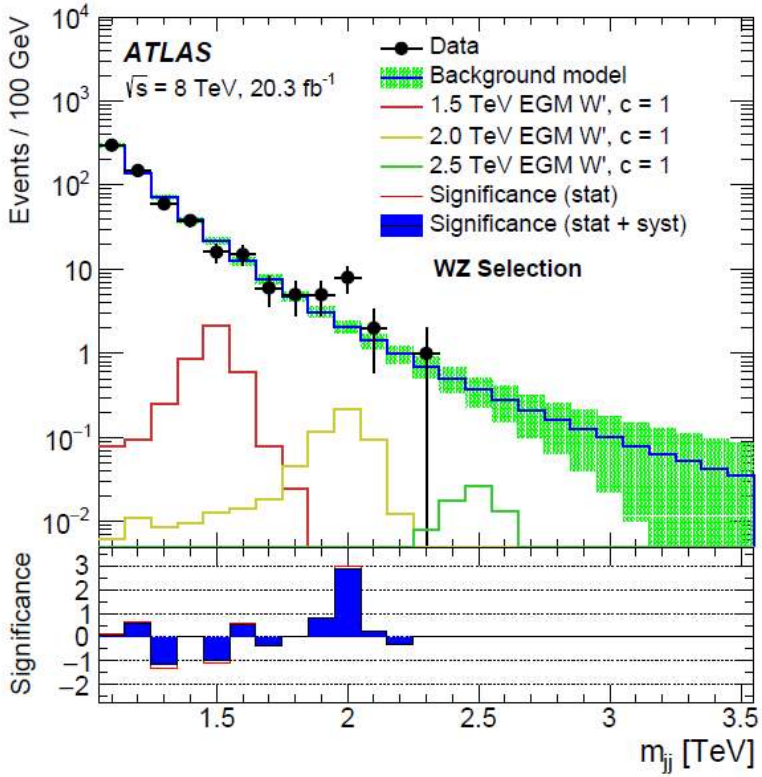


2 TeV excess taught us:

- From spin-0 to spin-2 everything seems viable
- Signal can very well show up in the hadronic channels first (higher rate than (semi-)leptonic channels)

We have to study the hadronic channel, but reconstruction difficult:

Spin discrimination still possible?

How do jet substructure techniques affect angular observables?

Can you optimize searches?

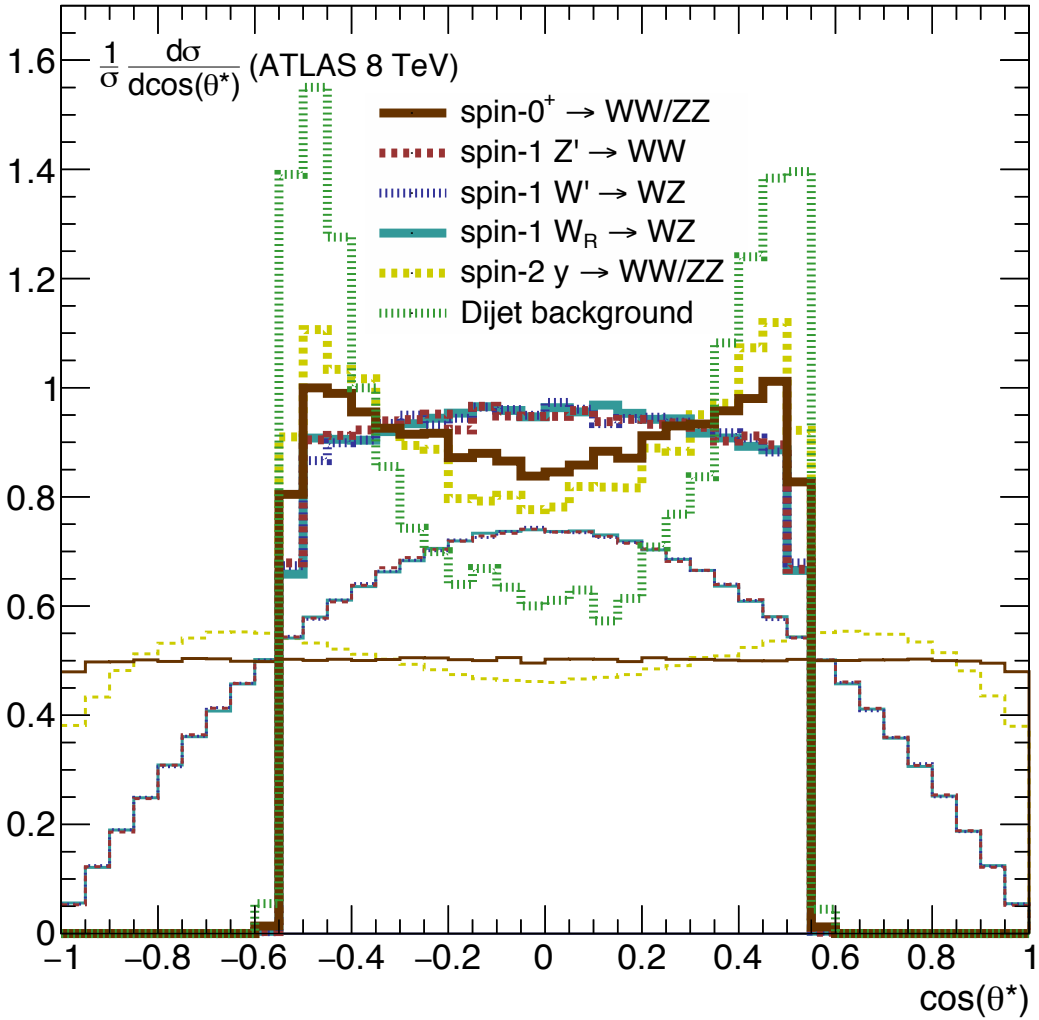
ATLAS @ 8 TeV:
Mass-drop filter

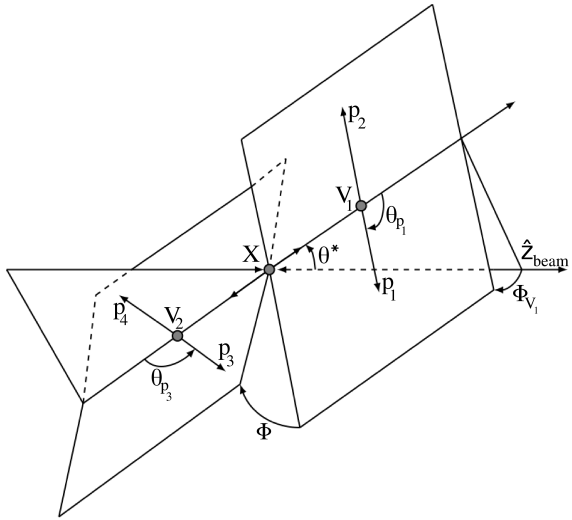
ATLAS @ 13 TeV:
Trimming + Energy correlation functions

CMS @ 8+13 TeV:
Pruning + N-subjettiness

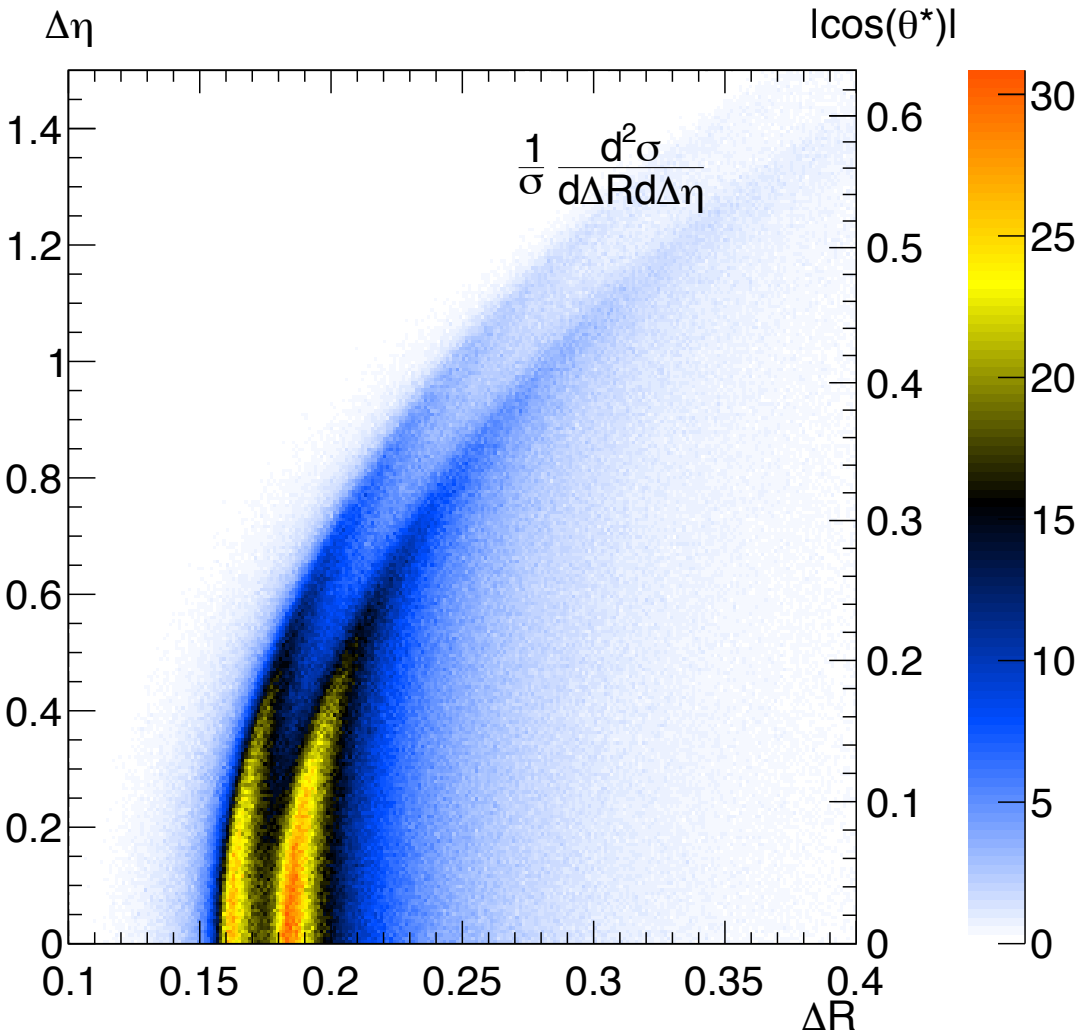
Idea of jet substrucure (simplified):

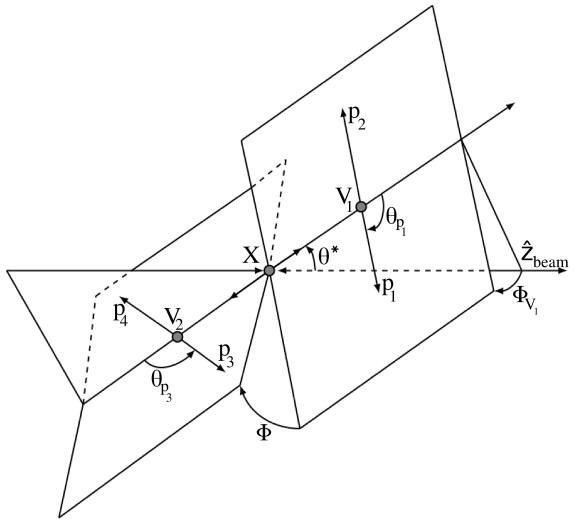
- Start with fat jet (R=0.8-1.2)
- Remove contamination from soft radiation
- Identify subjets
- To distinguish between QCD jets (1-prong) and V jets (2-prong) for example require subjets to be balanced ($y = p_{T,j2}/p_{T,j1} > y_{\text{min}}$). y_{min} typically 0.1-0.2





$$|\cos\theta^*| = \tanh\frac{|\Delta\eta|}{2} \leq \tanh\frac{|\Delta\eta_{\text{max}}|}{2}$$
$$\text{with } \Delta\eta_{\text{max}} = 1.2\text{–}1.3$$

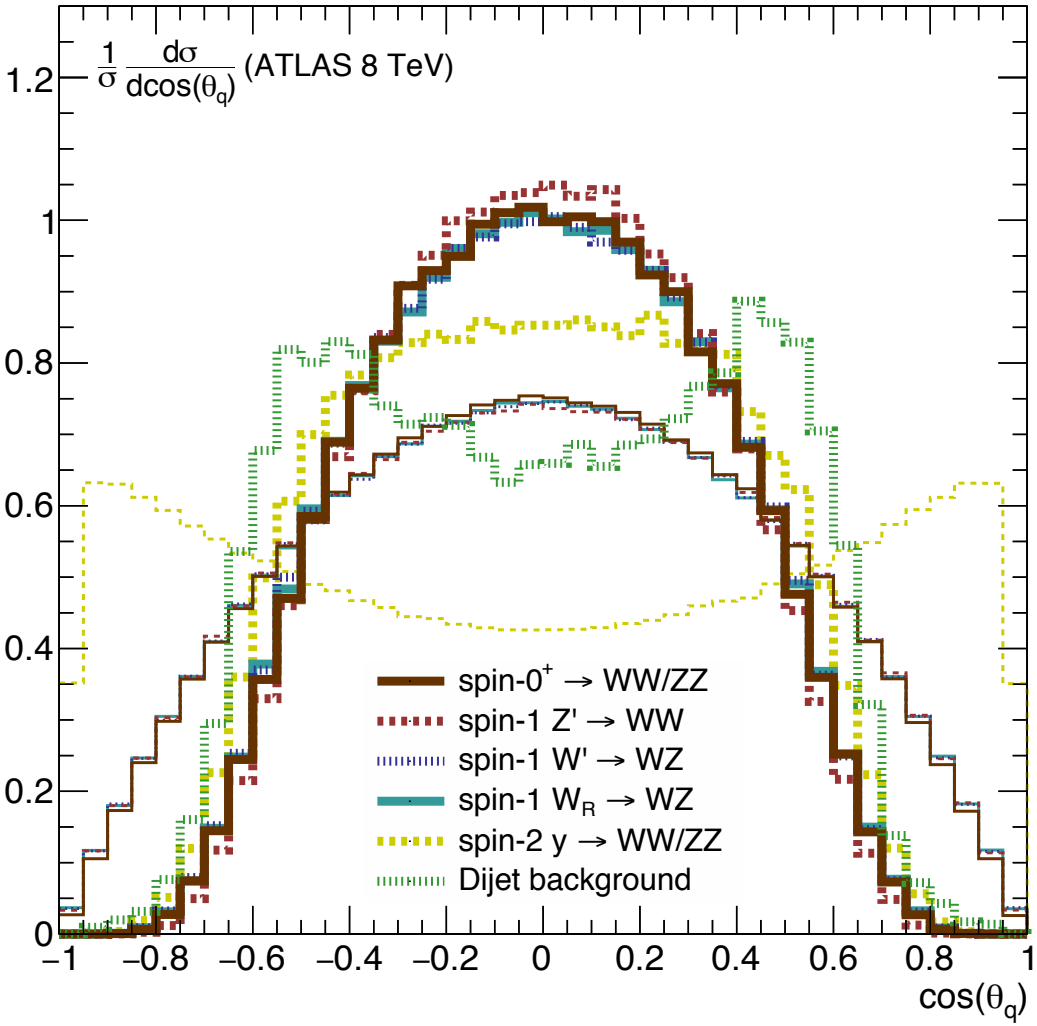


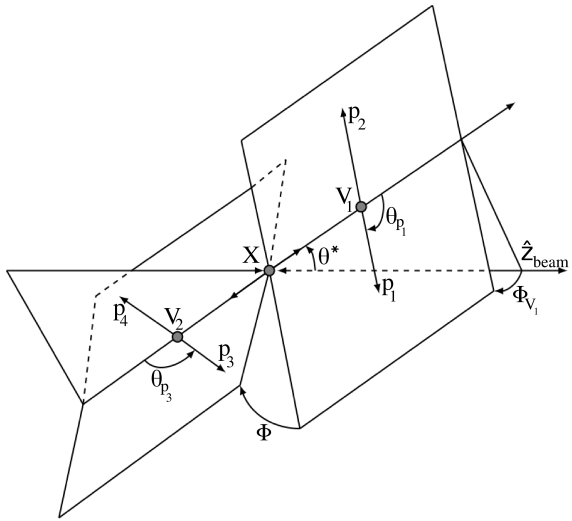


Strong correlation between ΔR separation (between subjets) and $\Delta\eta$

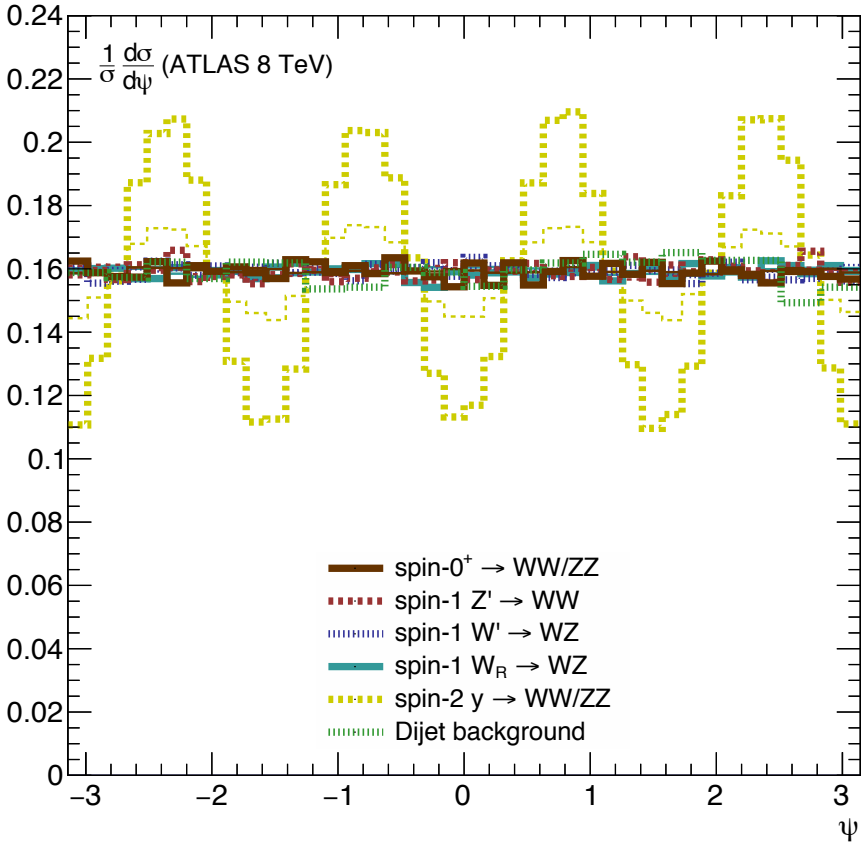
+

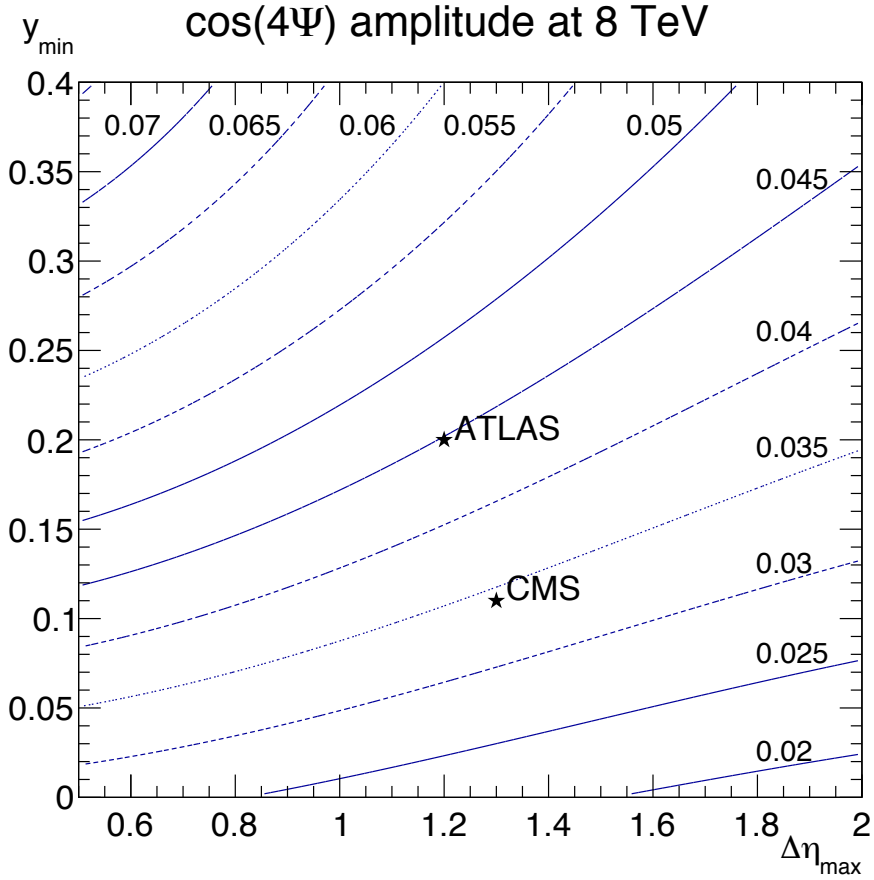
jets with small ΔR are hard to tag

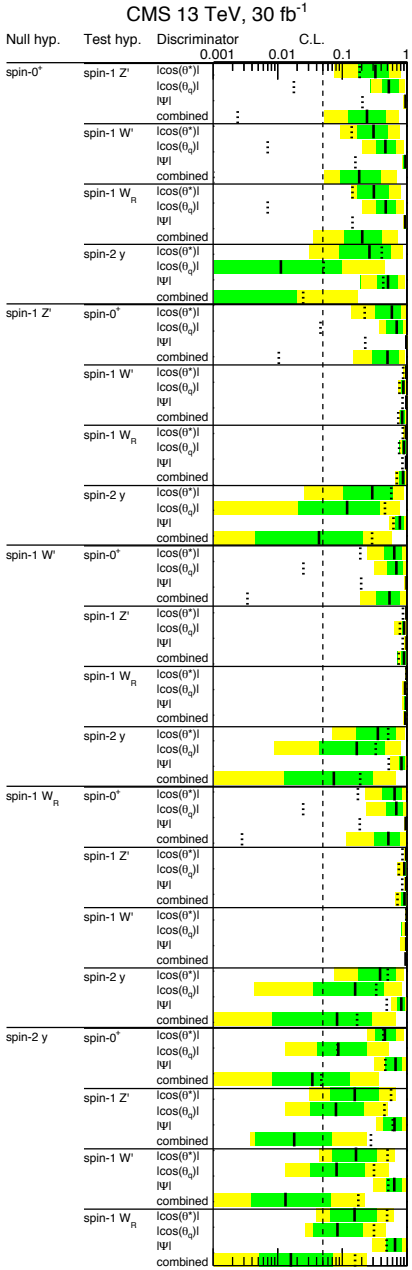




$$|\cos\theta_q| \approx \frac{1-y}{1+y} \leq \frac{1-y_{min}}{1+y_{min}}$$


$\frac{1}{\sigma}\frac{d\sigma}{d\psi}$ (ATLAS 8 TeV)
spin-$0^+ \rightarrow$ WW/ZZ
spin-1 Z' $\rightarrow$ WW
spin-1 W' $\rightarrow$ WZ
spin-1 $W_R \rightarrow$ WZ
spin-2 y $\rightarrow$ WW/ZZ
Dijet background
ψ


cos(4Ψ) amplitude at 8 TeV
y_{min}
0.07
0.065
0.06
0.055
0.05
0.045
0.04
0.035
0.03
0.025
0.02
ATLAS
CMS
$\Delta\eta_{max}$

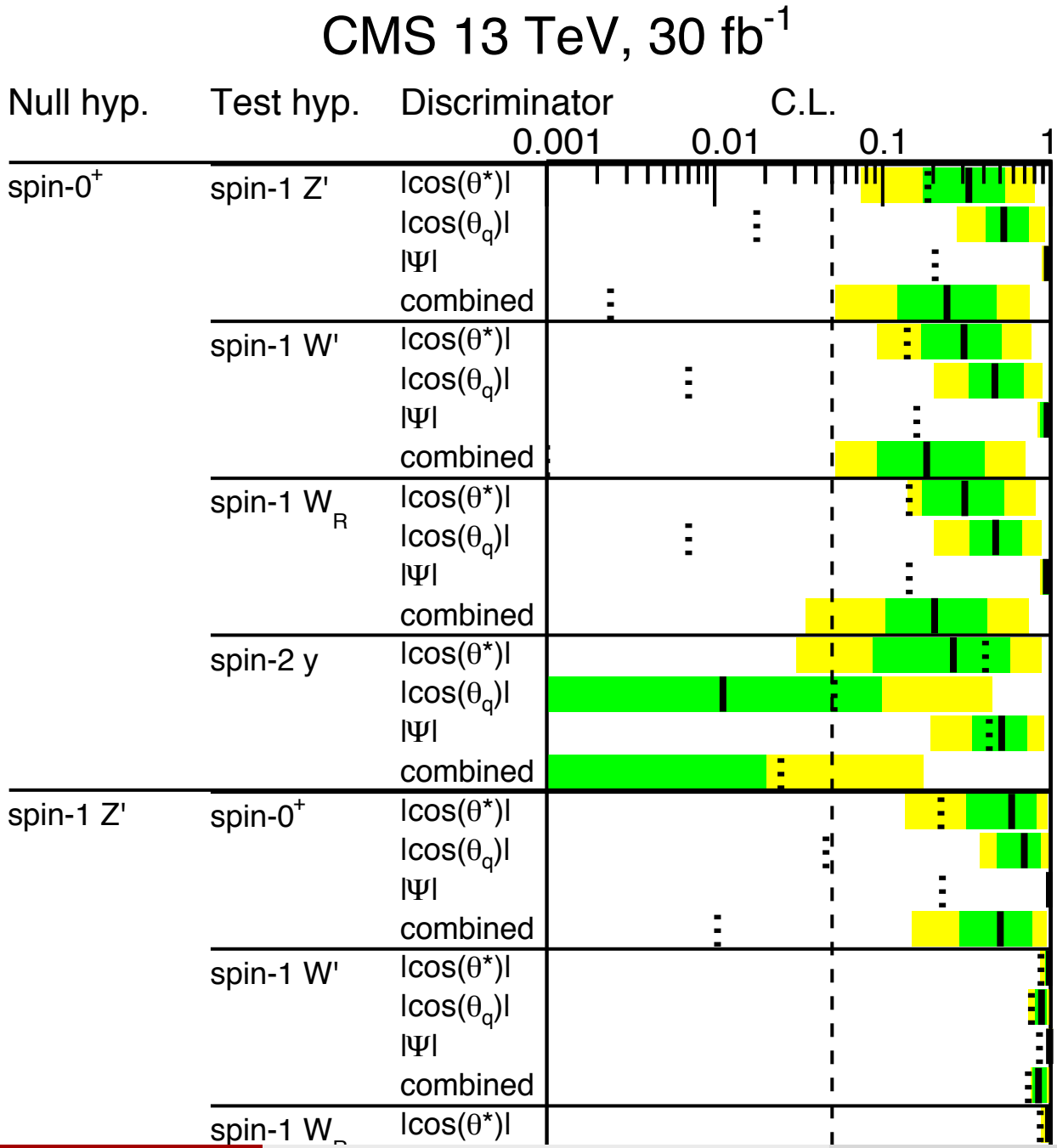


Ultimately: Test

Model A+Background

against

Model B+Background


CMS 13 TeV, 30 fb-1
Null hyp.
Test hyp.
Discriminator
C.L.
0.001
0.01
0.1
1
spin-0+
spin-1 Z'
|cos(θ*)|
|cos(θq)|
|Ψ|
combined
spin-1 W'
|cos(θ*)|
|cos(θq)|
|Ψ|
combined
spin-1 WR
|cos(θ*)|
|cos(θq)|
|Ψ|
combined
spin-2 y
|cos(θ*)|
|cos(θq)|
|Ψ|
combined
spin-1 Z'
spin-0+
|cos(θ*)|
|cos(θq)|
|Ψ|
combined
spin-1 W'
|cos(θ*)|
|cos(θq)|
|Ψ|
combined
spin-1 WR
|cos(θ*)|