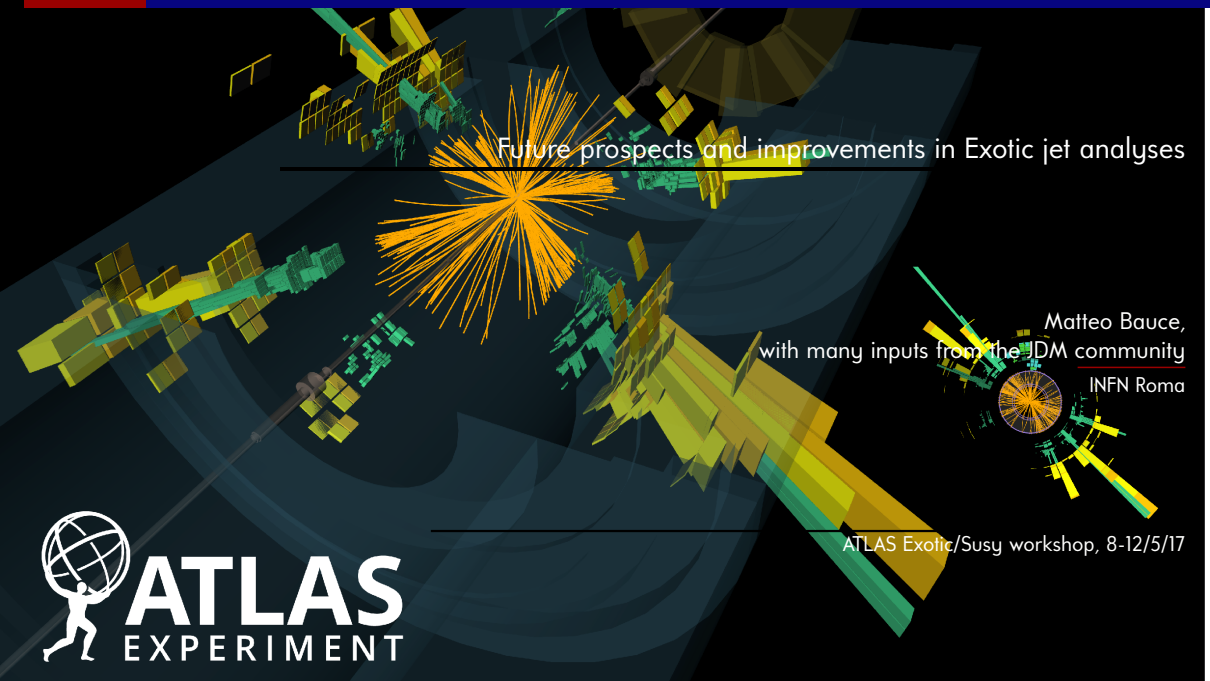
Future prospects and improvements in Exotic jet analyses

Matteo Bauce,
with many inputs from the JDM community
INFN Roma



ATLAS Exotic/Susy workshop, 8-12/5/17

ATLAS EXPERIMENT

Introduction

- Overview inspired by the following inputs
  - 203 - High-mass Dijet Analysis and the end of Run-2
  - 182 - Toward a 2D dijet search - integration of invariant mass and angular analysis
  - 193 - Heavy resonance searches in the di-jet mass spectrum using b-tagging
  - 107 - Search for new resonances with b-tagged jets in multi-jet final state
  - 130 - new physics search in the energetic photon+jet final state

Many thanks to the authors!

Link will appear here

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  - 130 - new physics search in the energetic photon+jet final state

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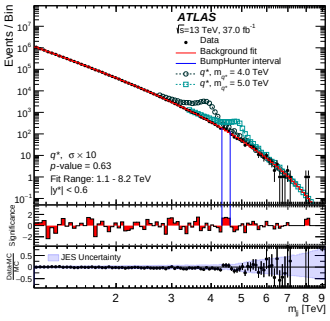
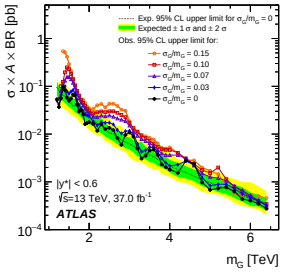
High-mass dijet analysis - current status

More info here

A very simple search:

- Trigger on lowest unprescaled single jet trigger (HLO_j380)
- Leading (sub-lead.) jet p_T >440 (60) GeV (LooseBad cleaning on all jets)
- Kinematic selections optimized for different benchmarks:
  - Resonance: $|y^*| < 0.6$, m_{jj} >1.1 TeV;
  - W^*: $|y^*| < 1.2$, m_{jj} >1.7 TeV;
  - Angular: $|y^*| < 1.7$, m_{jj} >2.5 TeV;
- Resonance Search uses a sliding window fit to get background prediction from data
- Angular search uses pythia8 MC for background shape, scaled to data
- Jet energy folding included in Gaussian limits



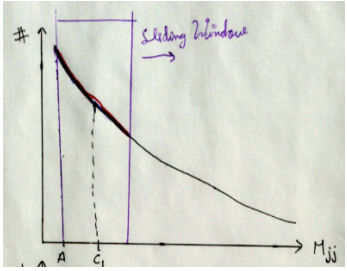


High-mass dijet analysis - targeting >100 fb^{-1}

More info here

- New fitting method developed for Moriond (SWiFt), still other under development
  - Further integration with the current analysis limit calculation
  - Finer granularity through signal morphing

See Karishma's talk in less than 1 hour!



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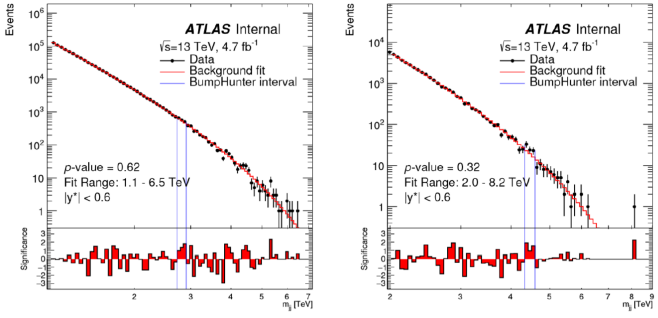
- New fitting method developed for Moriond (SWiFt), still other under development
- Investigate the possibility of using Large-R/Variable-R/Reclustered jets instead of the standard R=0.4 jets
  - MC studies using reclustered jets (R=1.0) showed an improvement in expected limits of 0.1-0.2 TeV for q^* signals, no change for W'
  - Loss of sensitivity in low invariant mass region due to trigger turn-ons
  - CMS uses *wide-jets* (R=1.1), 2016 preliminary expected limits equal to ATLAS



(a) small R (b) reclustered R=0.8

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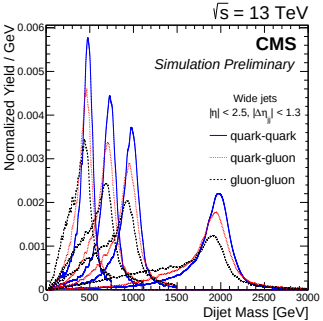
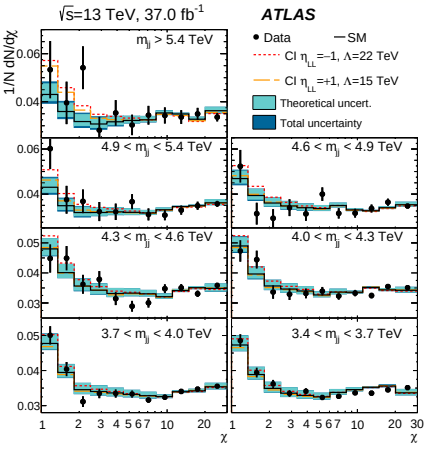
- Preliminary investigations into using quark-gluon tagger
- Breit-Wigner signal limit requested by phenomenological colleagues
- Jet energy unfolding - in collaboration with SM experts



New angular dijet search approach

More info here

- Current analysis: $\chi = e^{|y_1 - y_2|}$ distribution for data compared to Pythia (NLO QCD and EW corr.) in different m_{jj} bins, combined in statistical analysis
  - Main syst. unc. from JES, PDF, μ_R and μ_F scale



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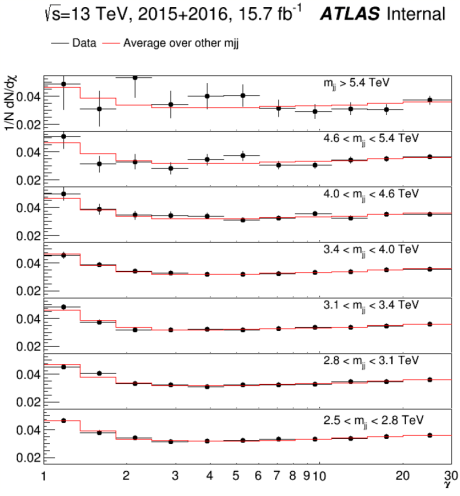

ICHEP dataset only (data)

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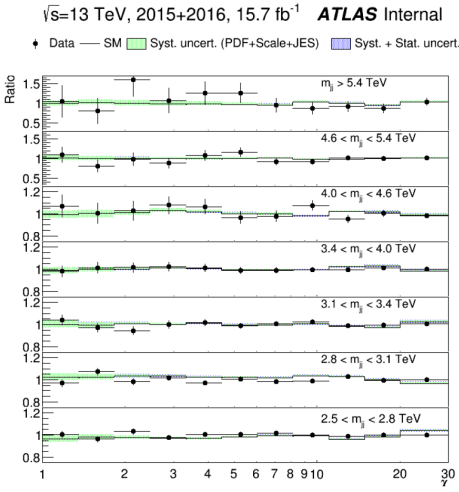
- Avoid to be systematic limited by considering ratios between different m_{jj}-bins
- Compare Data to MC ratios for residual m_{jj} dependence

► Data-driven strong reduction cancellation of syst. unc.



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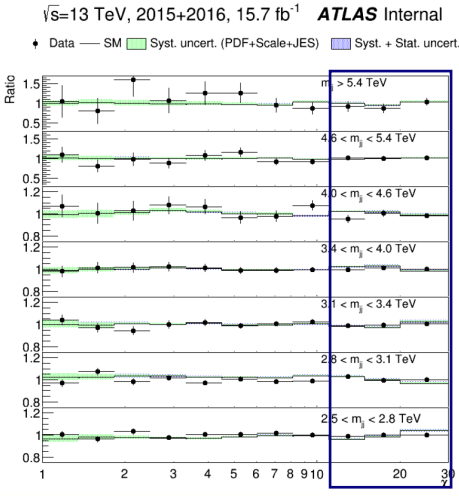
Unphysical fluctuations due to k-factor → now fixed

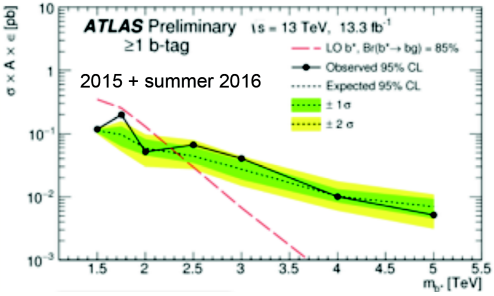


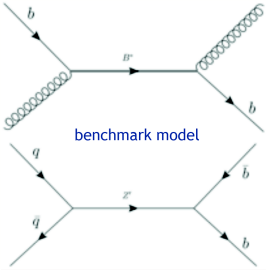
ICHEP dataset only

Dijet search using *b*-tagging

More info here

- Generic search for resonance in the high mass dijet spectrum with >=1, 2 *b*-jets
  - *b*-tagging is crucial, both online (low-mass) and offline





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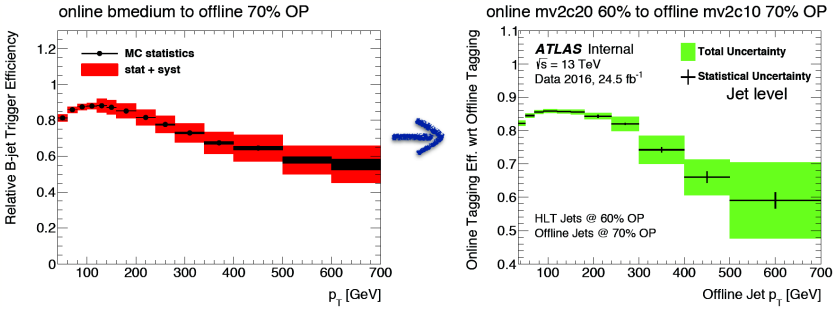

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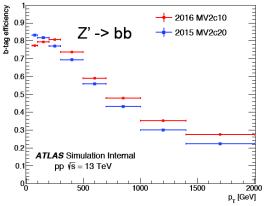
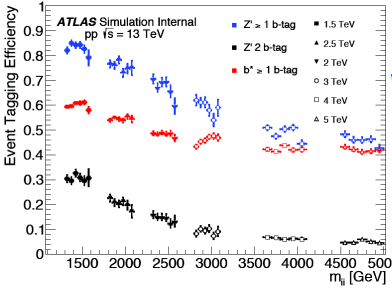
- Generic search for resonance in the high mass dijet spectrum with >=1, 2 *b*-jets
  - *b*-tagging is crucial, both online (low-mass) and offline
- *b*-trigger efficiency studied on data (including η dep.)
- Offline tagging moved from MV2c20(2015) → MV2c10(2016)
- Considering switching to flat efficiency WP for higher sensitivity





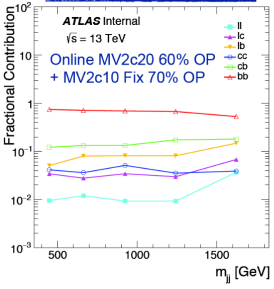
MV2c20	Z' 1.5 TeV			Z' 2.0 TeV		
b-tagging working point	1b	2b	1b+2b	1b	2b	1b+2b
fixed cut 85%	9.4	3.7	3.4	16.9	11.0	9.2
fixed cut 77%	7.4	4.3	3.7	15.3	14.7	10.5
fixed cut 70%	6.6	4.4	3.6	14.2	17.4	10.7
fixed cut 60%	6.8	6.9	4.8	16.3	29.7	13.7
flat-eff cut 85%	24.2	5.5	5.4	38.0	13.2	12.5
flat-eff cut 77%	15.8	4.2	4.0	26.2	10.7	9.9
flat-eff cut 70%	12.5	3.7	3.5	21.8	10.1	9.2
flat-eff cut 60%	9.2	3.5	3.3	17.5	9.5	8.3
flat-eff cut 50%	7.3	3.8	3.4	15.5	9.7	8.1
flat-eff cut 30%	6.5	5.3	4.1	14.0	16.5	10.4

More info here

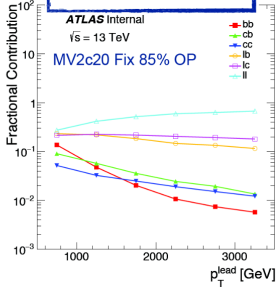
$$f(x) = p_1(1-x)^{p_2} \cdot x^{p_3+p_4 \cdot \ln x + p_5(\ln x)^2} \qquad x = m_{jj}/\sqrt{s}$$

- Usual fit function is not able to reproduce a high-stat. spectrum
  - sculpting effects from b-tagging - modify jet flavor relative fractions
  - flavor composition is depending on kinematics - as b-tagger is

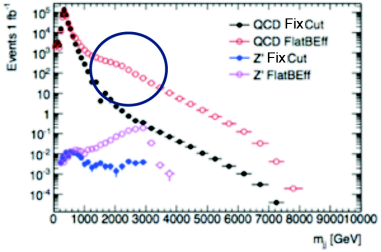
Dominated by b-b jets up to 1.5 TeV



Dominated by light-light jets from ~1.2 TeV



An extreme example (don't take it too seriously)



Di-*b*-jet spectrum fit

More info here

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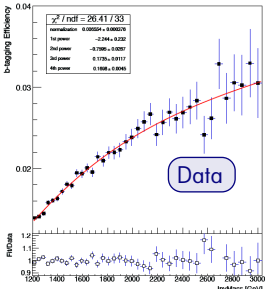
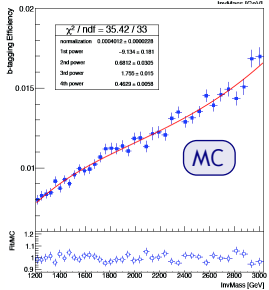
- Need to find a suitable way to describe dijet spectrum, including tagging shape
  - $F(x) \cdot g(x)$ method: $F(x)$ par. numbers from untagged, $g(x)$ from data subset or MC
  - Limited by statistics: $F(x)$,$g(x)$ independent fit provides *wrong* indications
  - Consider simultaneous fit: $F(x)$ on un-tagged + $g(x)$ on efficiencies





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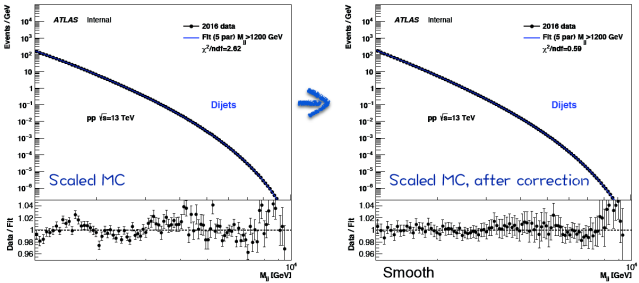
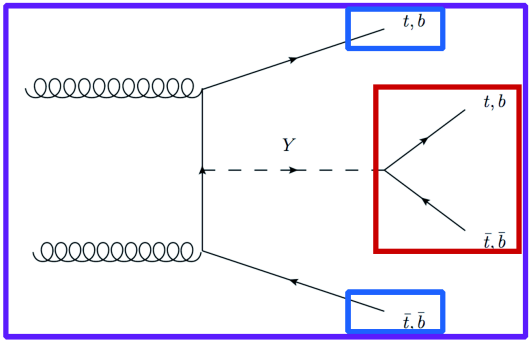
- Alternative approach for the fit:
  reweight m_{jj} shape
  - (from SM) apply SF to *b*-tagged spectra to smooth 'em like the untagged ones



More info here

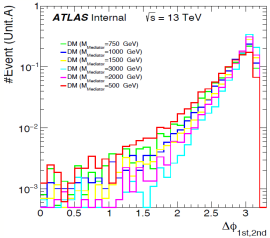
Since *"inclusive is not conclusive"*: why don't we look for $b\bar{b}$ resonances in associations with extra (b-)jets?

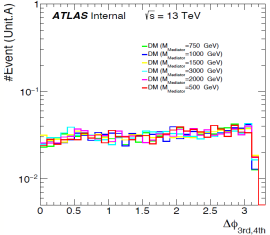


1^{st},2^{nd} - probe jets

3^{rd},4^{th} - tag jets

tagging 4 jets reduce QCD acceptance by a factor $>10^3$





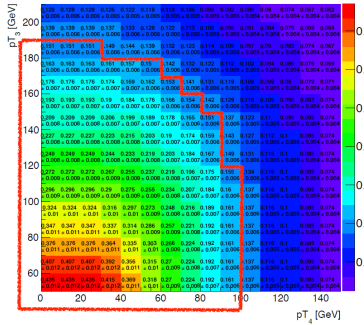
More info here

Since *"inclusive is not conclusive"*: why don't we look for $b\bar{b}$ resonances in associations with extra (b-)jets?

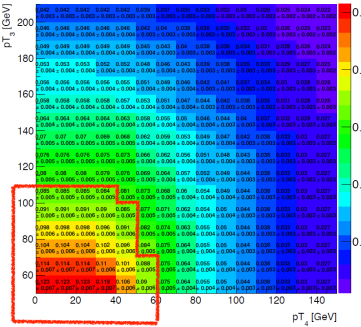
- Trigger those events it's crucial:
  - HLT_j420 has an offline plateau ~480 GeV, HLT_4j110 has low efficiency
  - Pursuit a HLT_2j250_j3_j4 (L1_J100) option

$m_{Z'} = 1$ TeV - ϵ ~15%
$m_{Z'} = 0.7$ TeV - ϵ ~9%

$m_{Z'} = 1$ TeV



$m_{Z'} = 0.7$ TeV

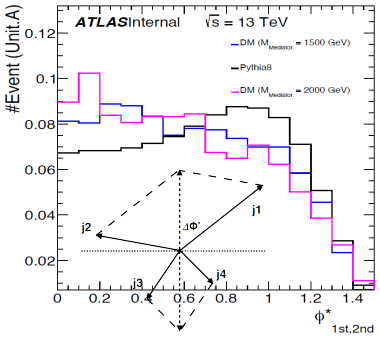


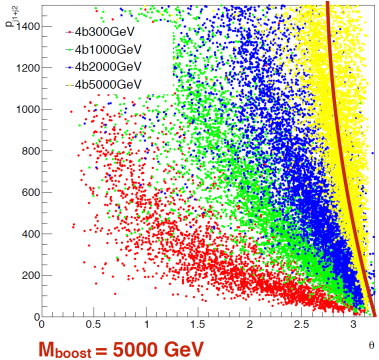
Anything in the red box is more efficient

Proposed new trigger: HLT_2j220_j120_v

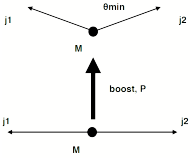
Since *"inclusive is not conclusive"*: why don't we look for $b\bar{b}$ resonances in associations with extra (b-)jets?

- Trigger those events it's crucial:
  - HLT_j420 has an offline plateau $\sim$480 GeV, HLT_4j110 has low efficiency
  - Pursuit a HLT_2j250_j3_j4 (L1_J100) option
- More jets $\rightarrow$ more objects $\rightarrow$ more kinematics for signal discrimination - two examples $\Delta\Phi^*$, M_{boost}





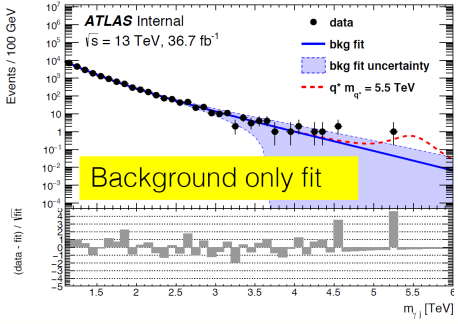
M_{boost} = 5000 GeV

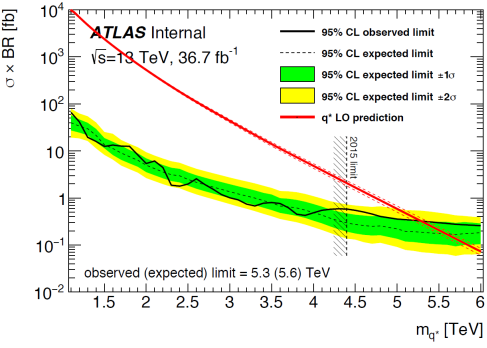


$M_{boost} = P \cdot \tan(\theta/2)$,
$\theta \sim 2\arctan(M/P)$

More info here

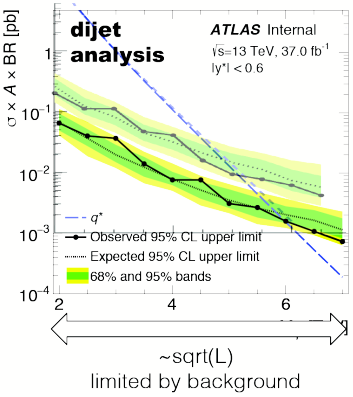
- Nice complementarity with dijet search - benchmark in commons
- Current analysis:
  - single γ trigger, >150 GeV γ and >60 GeV jet
  - Fit $m_{\gamma j}$ spectrum with analytical function

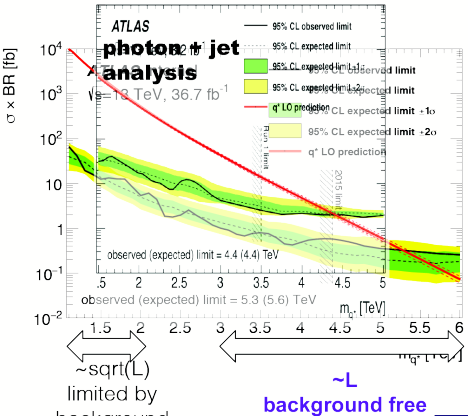




γ+jet resonance search

- Nice complementarity with dijet search - benchmark in commons
- Current analysis: ► single γ trigger, >150 GeV γ and >60 GeV jet ► Fit $m_{\gamma j}$ spectrum with analytical function
- γ+jet analysis exploring almost background-free $m_{\gamma j}$ region
  - ► sensitivity improving as $\sim \mathcal{L}$





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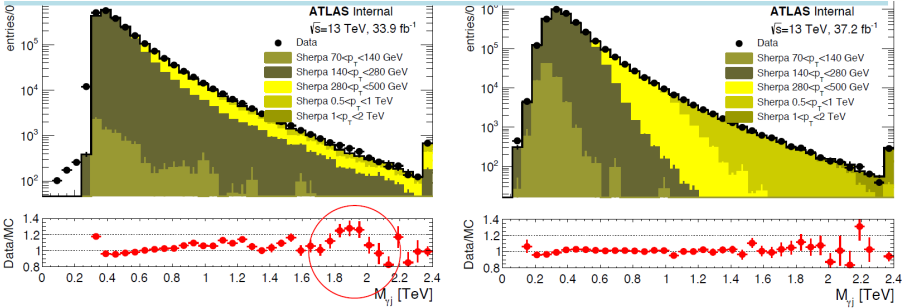
- TADA observed an excess at $m_{\gamma j}$ ~1.9 TeV, missing in default analysis
  - ▶ Mimic TADA selections in offline analysis for further investigation: secondary 50 GeV jet veto & remove $\Delta\eta(\gamma, j)$ cut



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  - Mimic TADA selections in offline analysis for further investigation: secondary 50 GeV jet veto & remove $\Delta\eta(\gamma, j)$ cut

- Low-mass background fit is becoming challenging: fit bias (spurious signal) is bigger than stat.unc.
  - Investigating various fit function, including SWiFt
  - Alternative to spurious signal needed to avoid small MC stat. limitations

- Coordination with SM γ+jet cross section group to improve knowledge on NLO effects for MC template fit

Conclusions

- Simple signature analysis developed nice strategies, worth to be shared with other signatures
  - an example: background fitting techniques
- Jet reconstruction and performances will be crucial and shared by a lot of such analysis
  - it's a nice leverage to achieve significant improvements
- Increased statistics allows exploration of more complex signatures
  - model specific signatures, we've plenty of them
- Remember to record event first: be sure trigger will not be a limitation!

BACKUP