Ricerca di Nuova Fisica in stati finali con due jet adronici in collisioni alla frontiera dell'energia con l'esperimento ATLAS a LHC

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SAPIENZA
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LHC Run-2

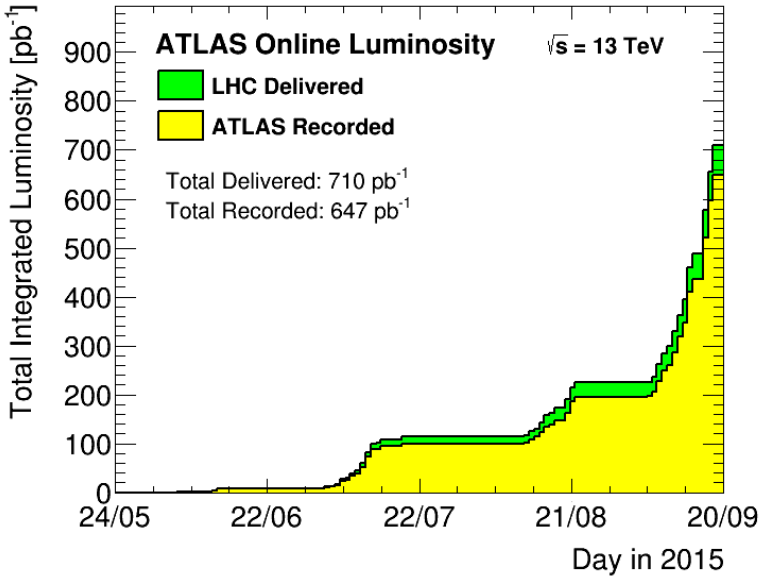
- LHC restarted at 13 TeV!
- First runs with 20 MHz bunch crossing, then started with design 40 MHz
- $\approx$650 pb^{-1} data recorded

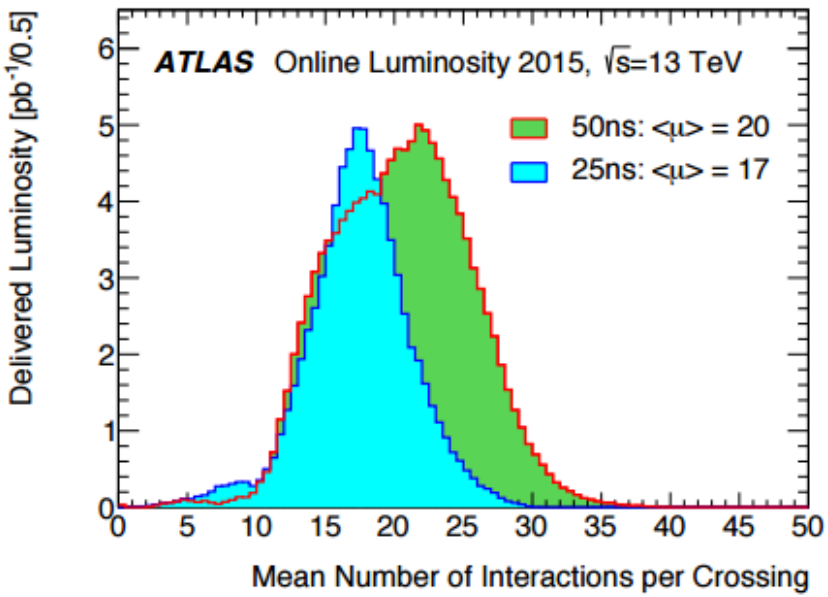
Early program

- Re-commission for the detector
- Performance assessment
- High σ SM measurements
- Explore final states at the high-mass frontier

Main topic of this talk

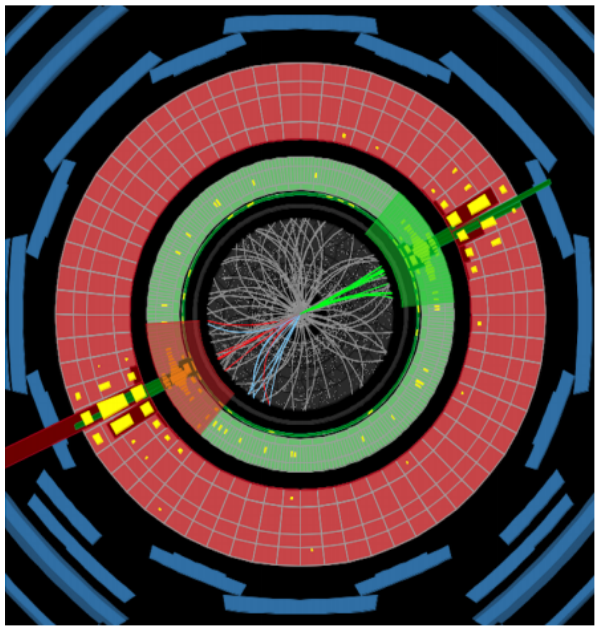
New ATLAS 13 TeV di-jet result: ATLAS-CONF-2015-042

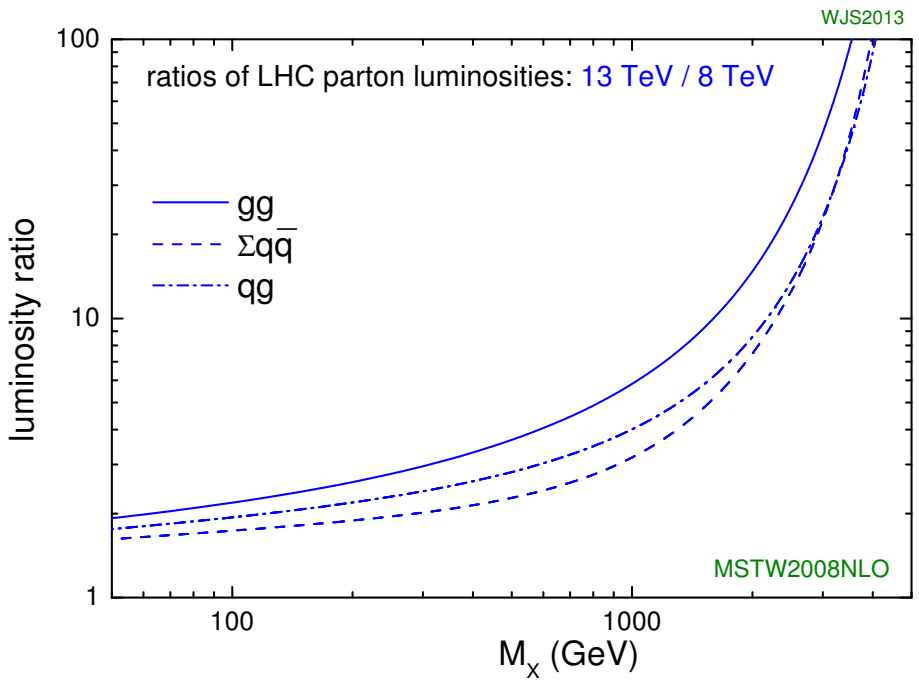




Search for new physics in di-jet events

- Events with two-jets systems with a high invariant mass m_{jj}
- High SM di-jet cross section exponentially decreasing as a function of m_{jj}
- Allow for searches at the energy frontier with very early data!
- Require complete understanding of jet reconstruction $\rightarrow$ challenging at the very beginning of a new run





- Parton luminosities greatly enhanced when 8 $\rightarrow$ 13 TeV
- New physics tipically scales faster than SM due to threshold effects

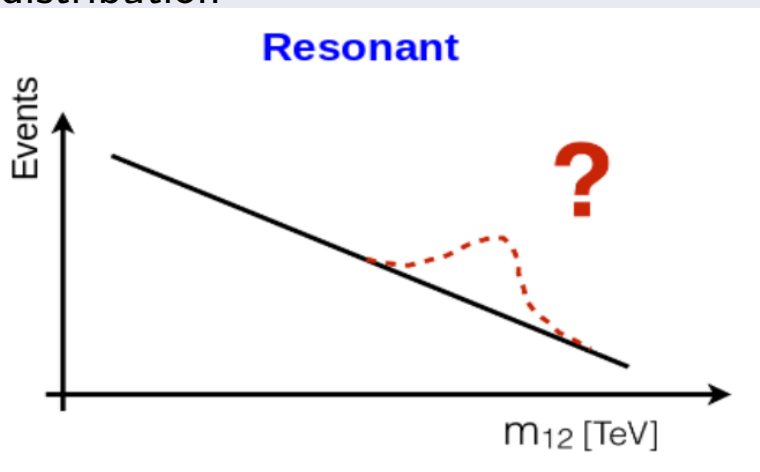
W.J. Stirling, `http://www.hep.ph.ic.ac.uk/~wstirlin/plots/plots.html`

Search for new physics in di-jet events

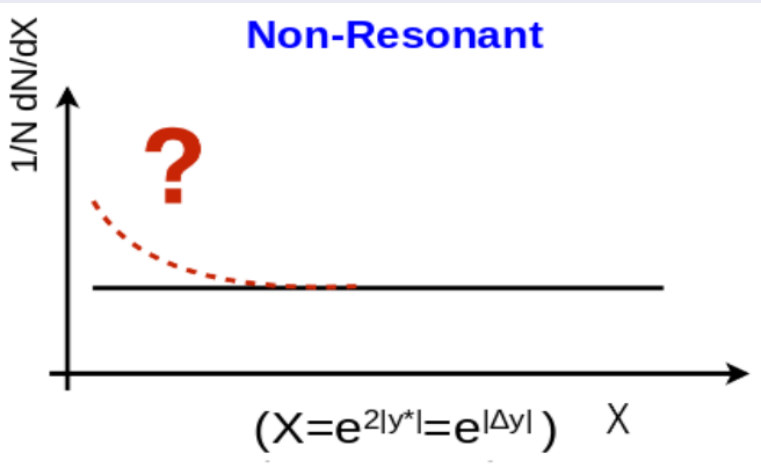
- Jet pairs produced mainly via $2 \rightarrow 2$ partons interactions
- Many models introduce new resonances or topology modifications wrt SM[1,2]
  - Excited quarks
  - Quantum Black Holes
  - W', Z'
  - ...
- Model-independent search can be performed, as well as search for benchmark models

How to search for new physics in di-jet events

Search for new resonances in the m_{jj} distribution



Search for topology modifications due to SM-BSM interference



[1] R. M. Harris and K. Kousouris, Searches for dijet resonances at hadron colliders, Int. J. Mod. Phys. A26 (2011)

[2] N. Boelaert and T. Åkesson, Dijet angular distributions at $\sqrt{s} = 14$ TeV,Eur. Phys. J. C66 (2010) 343–357

ATLAS Di-jet search in Run-2

New analysis on 80 pb^{-1} early Run-2 data: ATLAS-CONF-2015-042

- Events selected with single-jet trigger requiring p_T >360 GeV
- Jets reconstructed with a anti-k_T algorithm with a distance parameter $R = 0.4$
- Leading jet p_T >410 GeV, in the plateau of the trigger ($\epsilon_{trigger} \geq$99.5%)
- Sub-leading jet p_T >50 GeV

Topology

- Lorentz-invariant semi-difference between the rapidities of the jets $y^* = (y_1 - y_2)/2$ used to describe event topology
- Angular distribution described by $\chi = e^{2|y^*|} = \frac{1+cos\theta^*}{1-cos\theta^*}$
  - χ distribution is flat for the dominant $t-$channel in SM QCD
  - $s-$channel SM QCD and many new physics models enhance low-χ region
- Boost of the system is described by $y^B = (y_1 + y_2)/2$

Specific cuts are applied for the resonant and angular searches, in order to avoid bias from selection above and to reduce the SM QCD contribution

Resonant search

- m_{jj} >1.1 TeV
- $|y^*| < 0.6$ (i.e. $\chi < 3.3$)

Angular search

- m_{jj} >2.5 TeV
- $|y^*| < 1.7$ (i.e. $\chi < 30.0$), $|y_B| < 1.1$

Resonant search

- QCD spectrum can be described by $f(z) = p_1(1-z)^{p_2} z^{p_3} + p_4 logz$ with $z = m_{jj}/\sqrt{s}$
- With available data, description with $p_4 = 0$ is still reliable, 3-parameters function is used
- Possible biases due to BSM contribution are removed by excluding contiguous range of bins if they have excesses which leads to poor fit χ^2
- Final fit result has a probability $= 0.45$
- Search for resonances performed with the BumpHunter[1] algorithm, larger discrepancy found @ 2.91-3.17 TeV, not significant
- Predictions for 4 and 5 TeV Quantum black Holes by BlackMax MC generator are shown in the Figure

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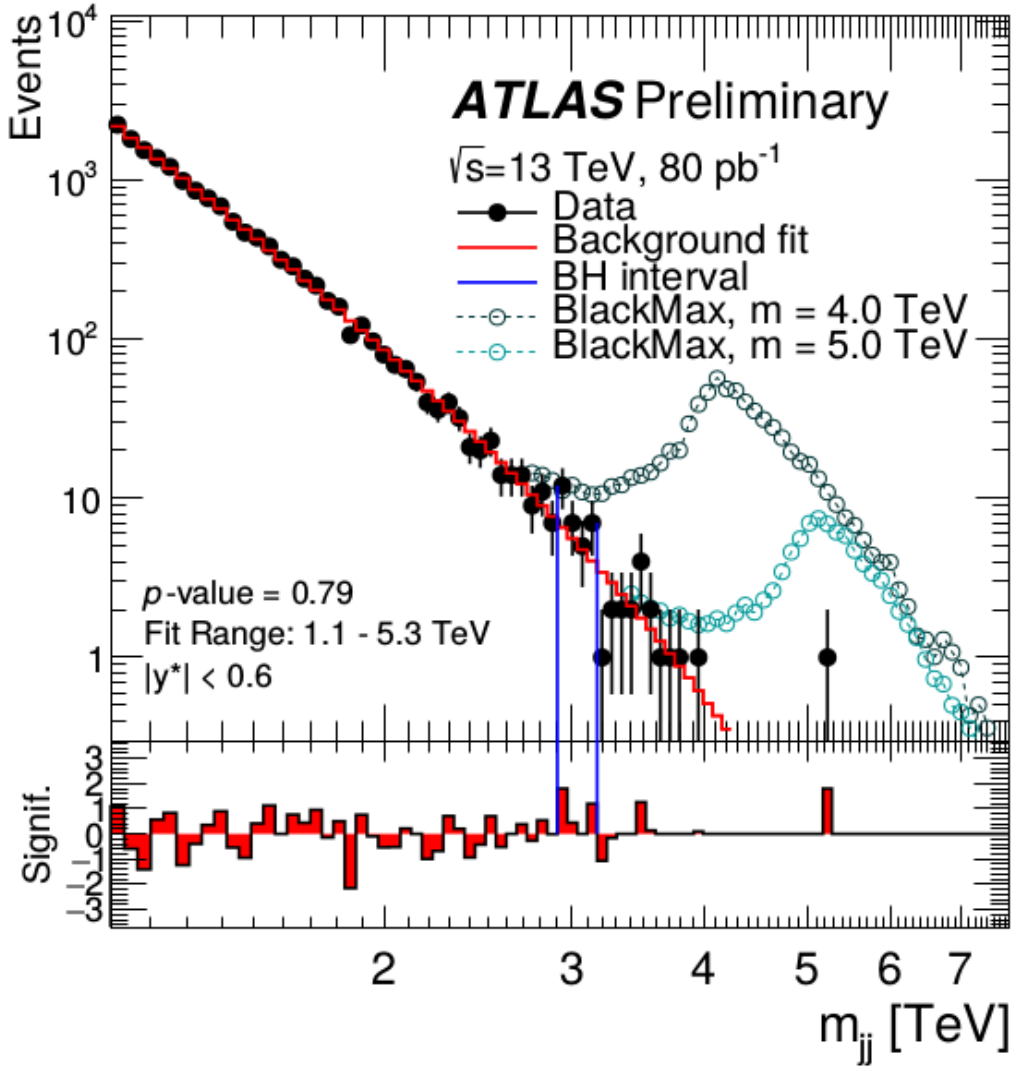

Highest measured m_{jj}=5.2 TeV

[1] CDF Collaboration, T. Aaltonen et al., Phys. Rev. D79 (2009) 011101; G. Choudalakis, arXiv: 1101.0390

Angular search

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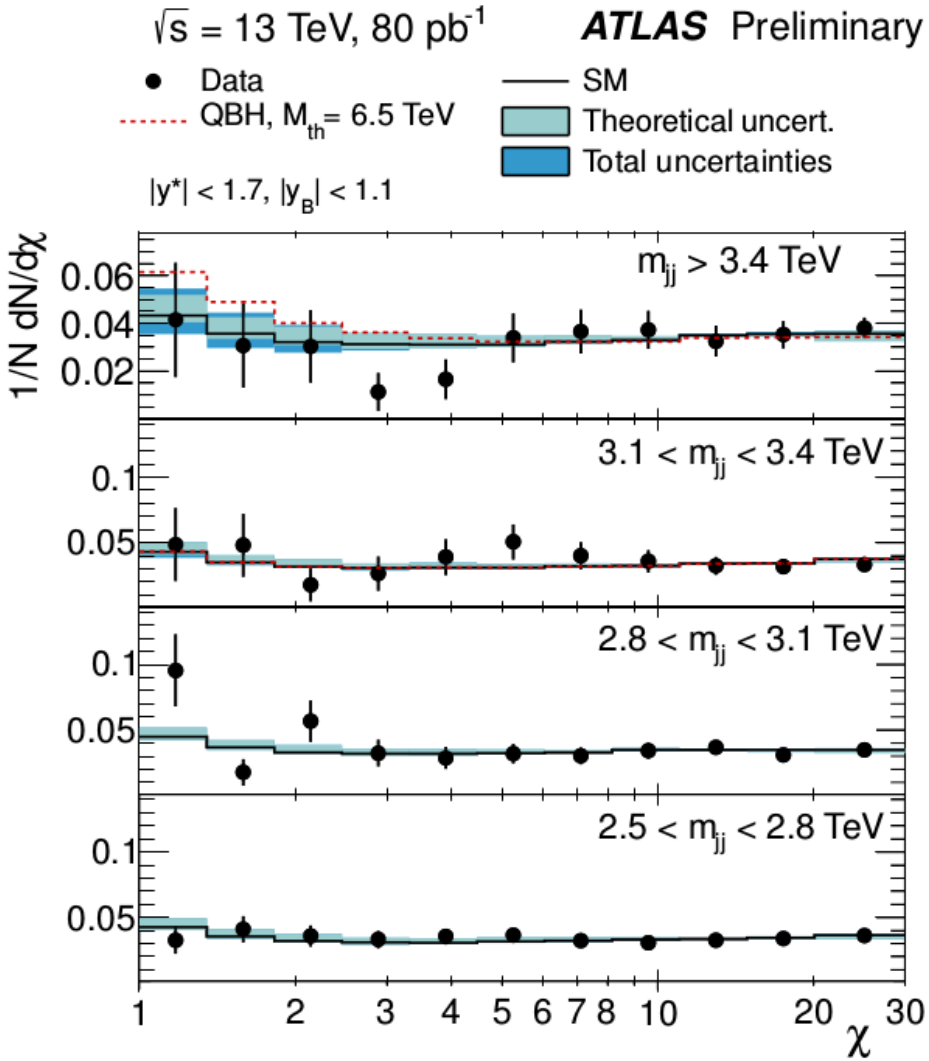

- SM QCD described by simulated data: Pythia 8 (LO)
- QCD NLO corrections by NLOJET++ as a function of m_{jj}, χ (max. corr. 15%)
- Applied also EW corrections[1] (max. corr. 3%)
- χ distribution compared for SM only and SM + Quantum Black Hole (6.5 TeV) hypotheses
- Data compatible with SM only hyp., with a $p(\chi^2)$=0.57

Highest measured m_{jj}=6.9 TeV

[1] S. Dittmaier, A. Huss and C. Speckner, Weak radiative corrections to dijet production at hadron colliders, JHEP 11 (2012) 095

Uncertainties

Resonant analysis

- Statistical uncertainties evaluated with pseudo-experiments (fitting pseudo-data drawn with Poissonian fluctuactions around nominal bkg)
- Function choice unc. assessed comparing with the 4-parameters fitting function results

Angular analysis

- MC simulation
  - biggest uncertainty is due to renormalization and factorization scales (up to 20% in a single bin)
  - PDF uncertainty are small (1% level)
  - Uncertainties on NLO corrections are small as well ($< 1\%$)
- Detector unc.: dominated by Jet Energy Scale (up to 9%)

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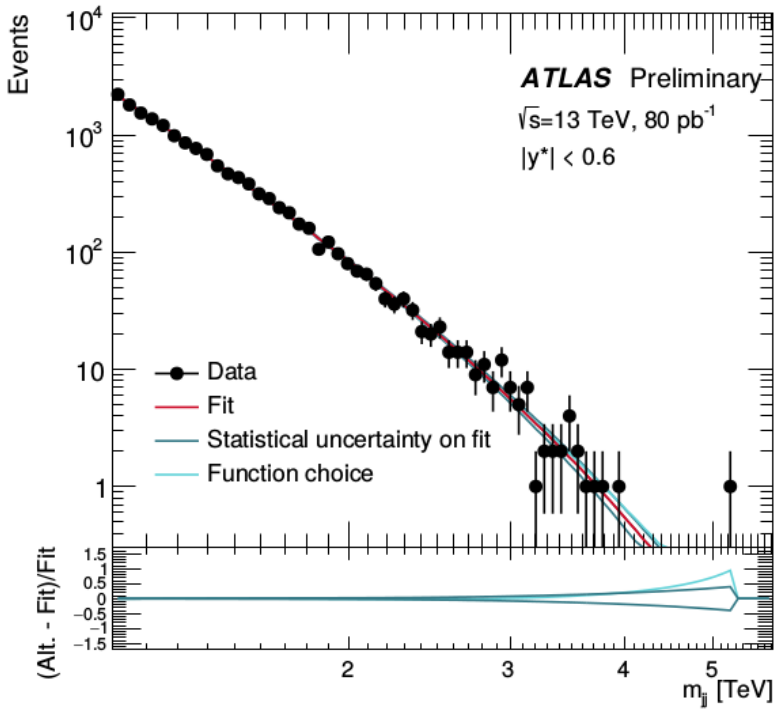

Results for Quantum Black Holes

- "ADD" model[1] is taken as a benchmark scenario
- In the model the scale of quantum gravity M_D is at a few TeV
- Therefore LHC could produce black holes above a threshold $\approx M_D$
- Limits are derived from data for an ADD scenario[2] with 6 dimensions and $M_{th} = M_D$
- Signal simulated with QBH and BlackMax generators

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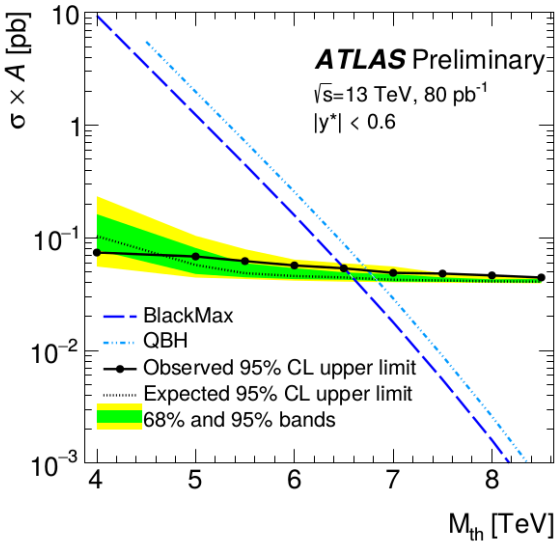
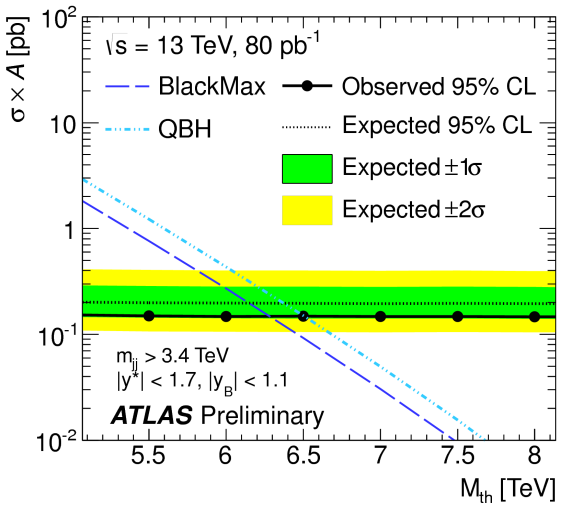




The results exclude signals up to ≈6.5-6.8 TeV, improving the Run-1 ATLAS and CMS results (5.0-6.3 TeV depending on model assumptions)

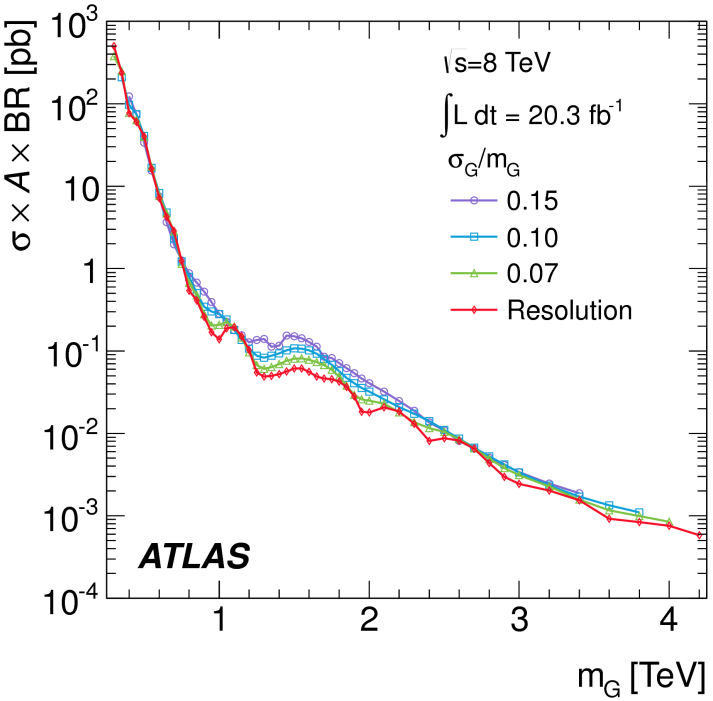
[1] N. Arkani-Hamed, S. Dimopoulos and G. R. Dvali, Phys. Lett. B429 (1998) 263–272;I. Antoniadis et al., Phys. Lett. B436 (1998) 257–263

[2] ATLAS Collaboration, Phys. Rev. D 91 (2015) 052007

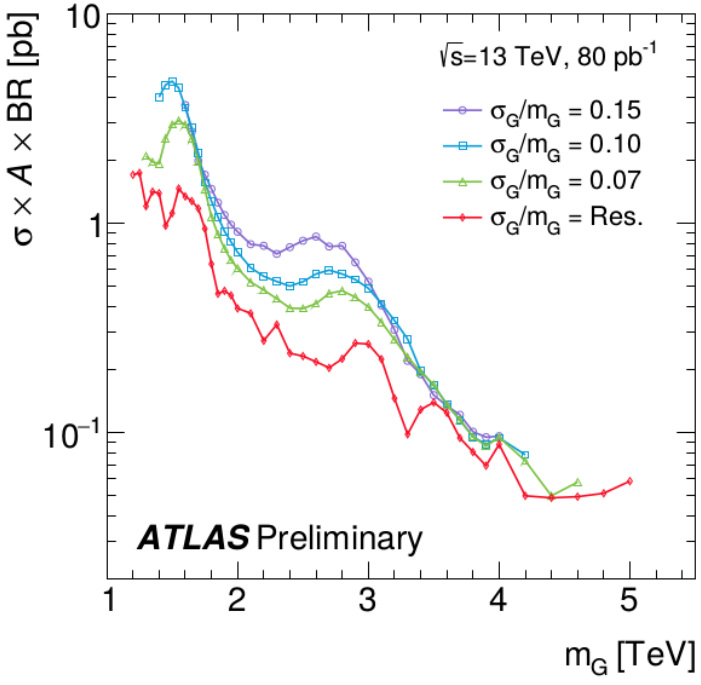
Results for gaussian resonances

Limits have been derived also for model-independent gaussian resonances for various hypotheses on the width

Run 1 results[1]:



Run 2 ATLAS-CONF-2015-042:



New results extend the range of the limits

[1] ATLAS Collaboration, Phys. Rev. D 91 (2015) 052007

Conclusion and outlook

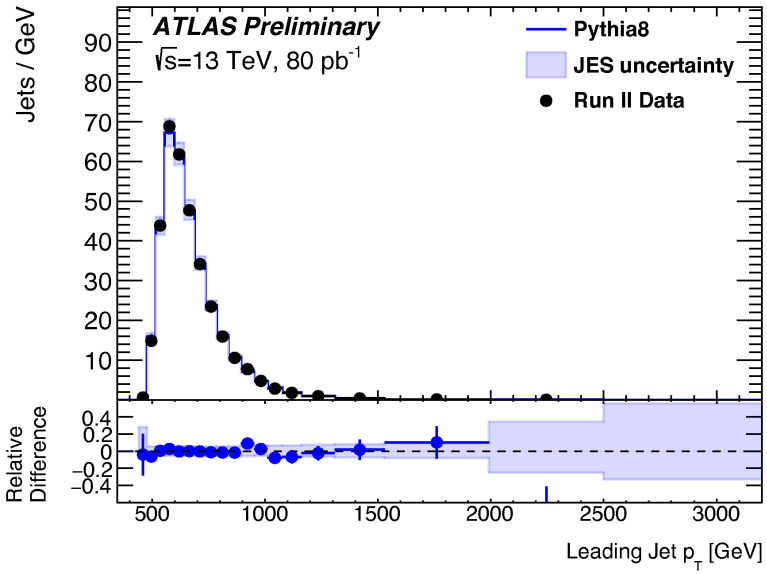
- New 13 TeV results for the search of new physics in di-jet events already public! ATLAS-CONF-2015-042
- The biggest challenge was to re-understand, measure and characterize the jet reconstruction in a new run, at a new energy regime, with 40 MHz collisions
- This goal has been achieved in a very short time
- With the first 80 pb^{-1} of data already surpassed Run-1 sensitivity for specific Quantum Black Holes models

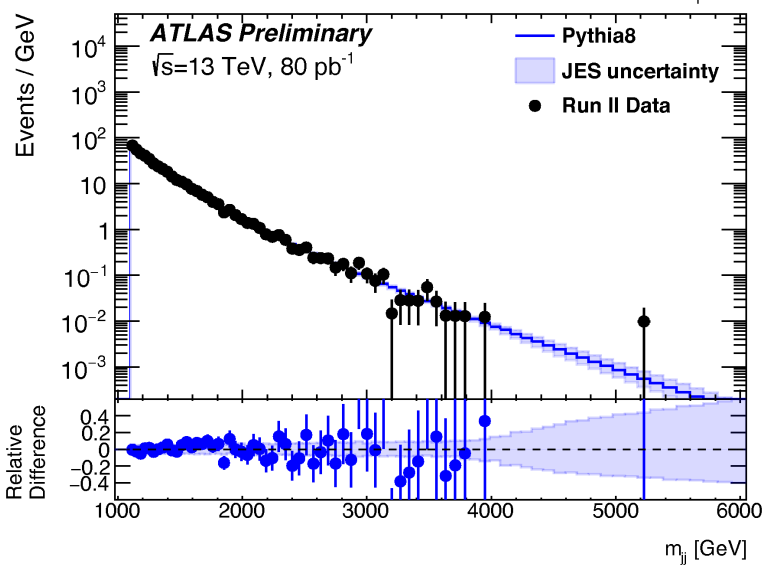
Outlook

- With more statistics, new benchmark models can be explored: excited quarks, contact interaction, ...
- There will be the opportunity also for improving the analysis:
  - angular search currently MC-based, constraining background in data could significanlty reduce uncertainties

Kinematics distribution

Resonant analysis: $|y^*| < 0.6$, $p_T^{leading} > 450$ GeV





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Angular analysis: $|y^*| < 1.7$, $|y_B| < 1.1$, $p_T^{leading} > 450$ GeV