Searches for effects of TeV-scale gravity in the 2010 ATLAS data

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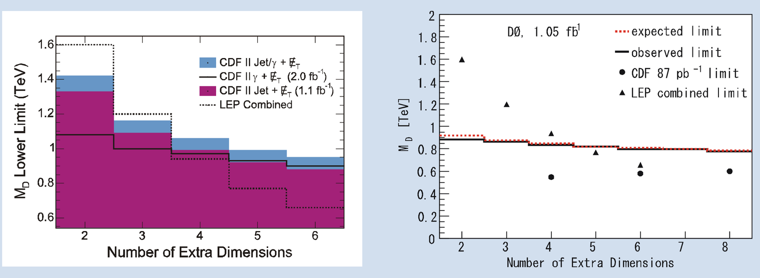
Extra Dimensions and TeV-Scale Gravity

•One of problems in the Standard Model is hierarchy problem that there is large difference between the Planck scale (M_{Pl} ~10^{19}GeV) and electroweak scale (M_W~100GeV).
•Theories of extra dimensions introduce "TeV-Scale Fundamental Planck Scale", M_D, as a solution of the problem.
→ Only the gravitational field can propagate into all dimensions. Hence, the gravitational field measured in four space-time dimensions is reduced in strength from fundamental gravitational field and M_D could be as small as the electroweak scale.
•The ADD model, proposed by Arkani-Hamed, Dimopoulos, and Dvali, is an extra dimensions model with large flat extra dimensions. Lower limits on M_D are set as ~1 TeV by collider experiments.



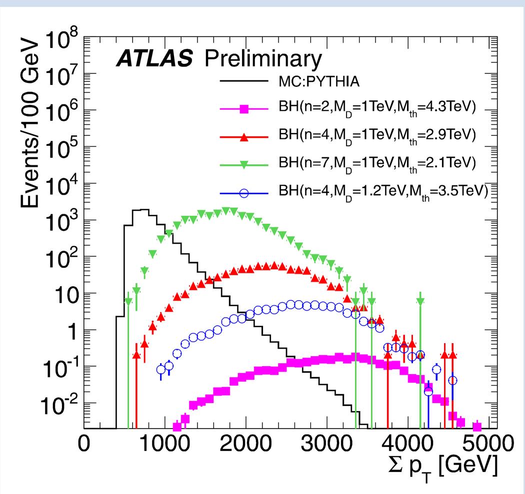
Lower limits on M_D from collider experiments
Ref: arXiv:hep-ex/0410004
Phys. Rev. Lett. 101 (2008) 181602
Phys. Rev. Lett. 101 (2008) 011601

Black Hole Search

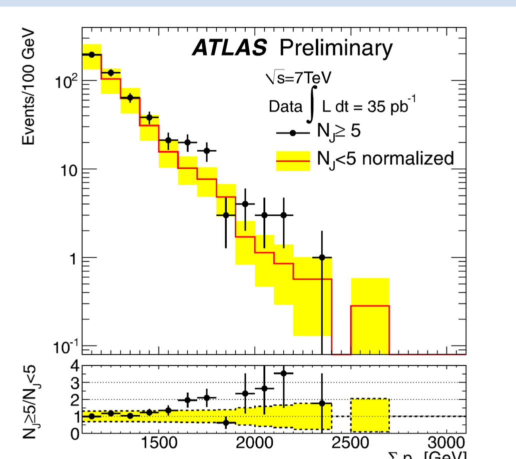
•Black holes are produced when half of the impact parameter of the two collision partons is less than horizon radius of black hole with mass, M_{BH}, equal to the invariant mass of two colliding partons.
•The mass of black hole has a continuous distribution from M_{th} (>M_D) to center of mass energy of proton-proton collision.
→ LHC is the first experiment which can produce TeV scale black holes.
•Such TeV scale black holes immediately decay (in 10^{-26}s). The black hole decay is characterized by Hawking radiation in which all fundamental particles are emitted and fractions of the emission from black holes depend on the number of degrees of freedom.
→ A typical energy of Hawking radiation from TeV scale black hole is a few hundred GeV.
→ Final state of black hole events can be characterized as high multiplicity of high energy particles.

Multijet Final State

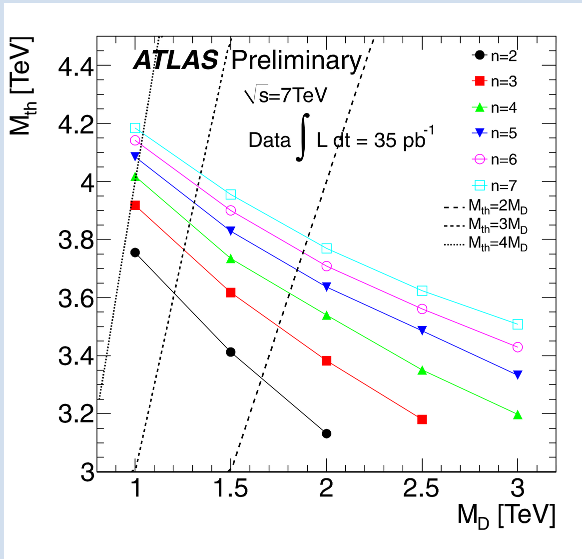
•Decay particles from black holes are dominated by gluons and quarks because of their large number of degrees of freedom for color.
→ Multijet final state is main signal of black hole events
•Signal region is defined as:
Select high p_T Jet: p_T >50GeV, $|\eta|$<2.8
Number of Jets (N_J)≥ 5
Scalar sum of jets in events (Σp_T)>2TeV
•Main background is QCD multijet. Shapes of Σp_T distributions of QCD show little dependences on N_J.
→ The distribution for N_J ≥ 5 can be assumed to have same distribution of N_J<5.
•Under a background-only hypothesis
→ Background events:3.7±1.0(stat)±1.1(syst)
→ Observed events:7
•Signal events could be contaminated in non signal region:
→ On the assumption of QCD shape and each signal MC shape, signal yield is extracted by a simultaneous fit.



Σp_T distributions for N_J ≥ 5 QCD and signal MC are shown



Σp_T distribution for N_J ≥ 5 and estimated distribution from N_J <5

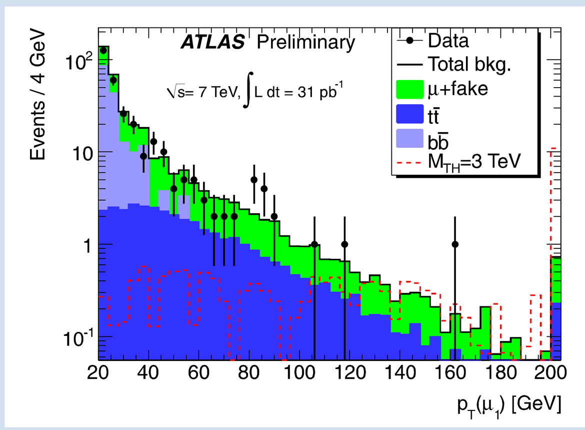


Limits on black hole production

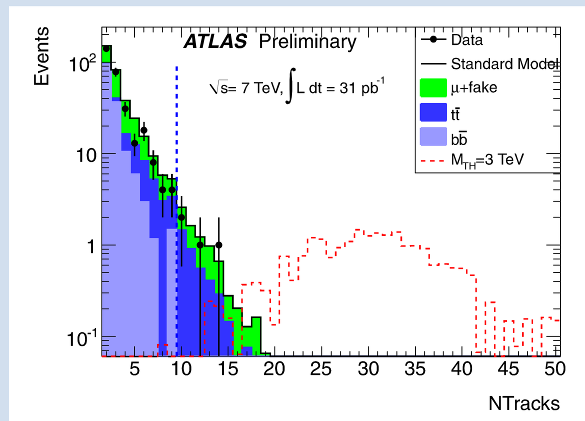
Ref: The ATLAS Collaboration, *Search for Microscopic Black Holes in Multi-Jet Final States with the ATLAS Detector at* √ *s = 7 TeV* , ATLAS-CONF-2011-068

Same-Sign Dimuon Final State

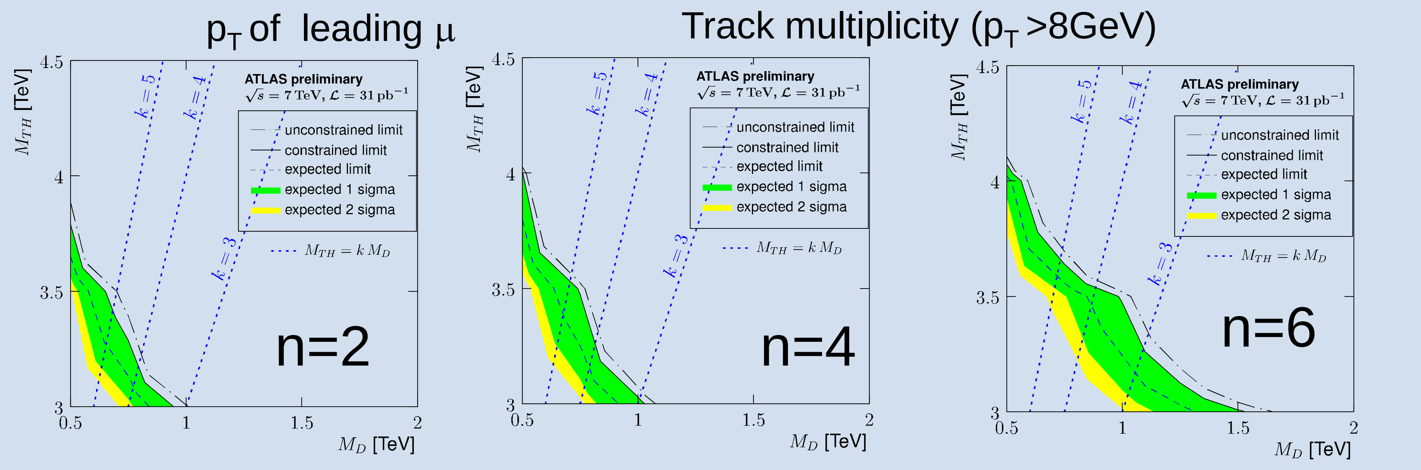
•The Standard Model background rate is law for same sign dimuon events.
•Event selection:
Leading μ: p_T >20GeV, $|\eta|$<2.4, isolated
Second leading μ: p_T >10GeV, $|\eta|$<2.4, same charge with leading μ
Number of tracks ≥ 10
• Main backgrounds are μ + fake ((di)boson+jets), ttbar, bbbar
→ μ + fake: Track faking muon rate is estimated in W+tracks sample in data.
→ ttbar and bbbar are estimated with MC (A normalization factor for bbbar is estimated from bbbar enriched control region)
→ Background events: 332± 14 (stat)± 38(syst)
→ Observed events:297



p_T of leading μ



Track multiplicity (p_T >8GeV)

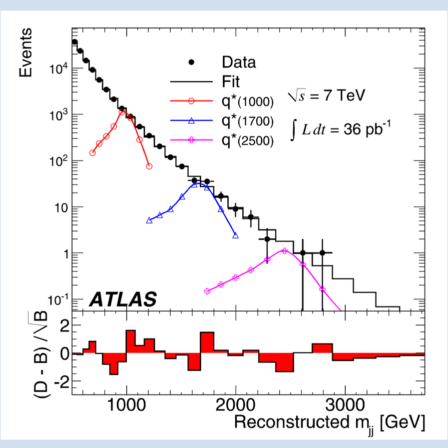


Limits on black hole production for rotating black hole

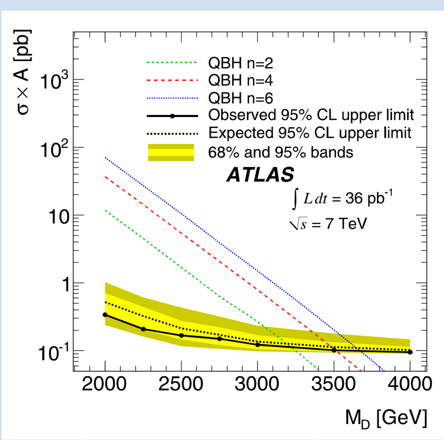
Ref: The ATLAS Collaboration, *Search for strong gravity effects in same-sign dimuon final states*, ATLAS-CONF-2011-065

Quantum Black Hole in Dijet

•Quantum black holes is a scenario in which black holes decay into two-body final state.
• Event selection:
Leading jet: p_T>150GeV, $|\eta|$<2.5, Second leading jet: p_T>30GeV, $|\eta|$<2.5
$\Delta\eta$ of them <1.3
Events with third jet with p_T >15GeV are vetoed
•Dijet invariant mass distribution is fitted with $f(x) = p_1(1-x)^{p_2}x^{p_3+p_4\ln x}$
where $x=m_{jj}/\sqrt{s}$. This function has been empirically shown to model the steeply falling QCD dijet mass spectrum.
•Data shape shows no significant disagreement.



Dijet invariant mass distribution

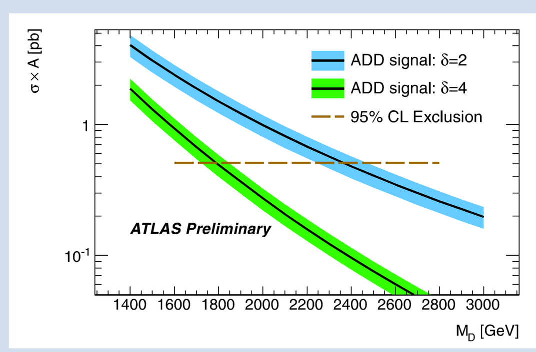


Limits on the cross section × acceptance for QBH models

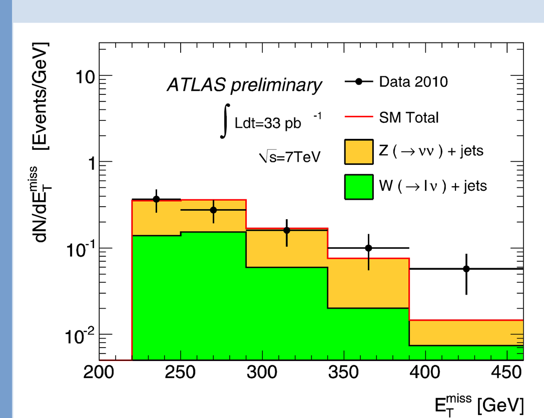
Ref: The ATLAS Collaboration, *Search for New Physics in Dijet Mass and Angular Distributions in pp Collisions at* √*s = 7 TeV Measured with the ATLAS Detector*, New J. Phys. 13 (2011) 053044

ADD Graviton in Monojet

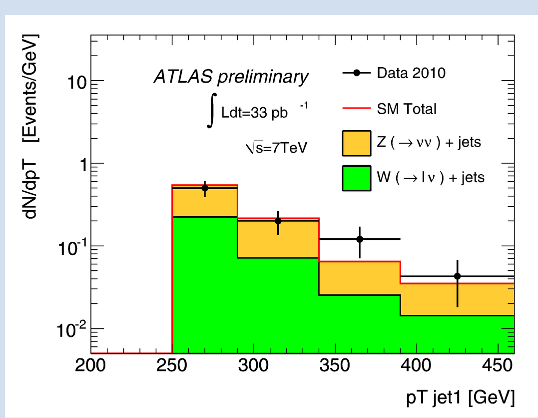
•ADD graviton doesn't interact with the detector
→ Missing energy in association with a jet is main signal.
•Event selection:
Leading jet: p_T >250GeV, $|\eta|$<2.0
Second leading jet: p_T <60GeV and $|\eta|$<4.5
Missing E_T>220GeV
$\Delta\phi$ (second jet, missing E_T)>0.5
→ Background events:
40.1±2.9(stat)±4.5(syst)
→ Observed events: 39



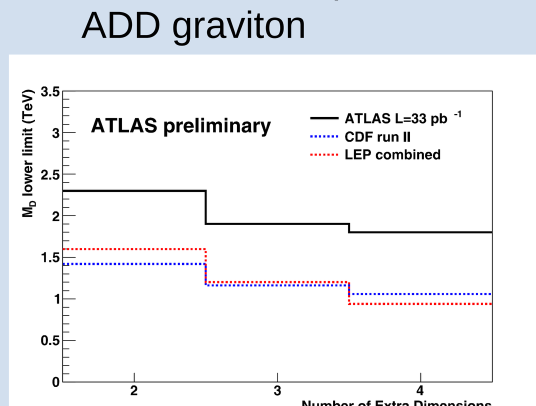
Limits on the cross section × acceptance for ADD graviton



Missing E_T distribution



Leading jet p_T distribution



Lower limits on M_D