Search for Black Holes in Atlas
work in progress

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- There exist two seemingly fundamental energy scales in nature. The electroweak scale $m_{EW} \sim 10^3 GeV$ and the Planck scale $M_{Pl} = {G_N}^{-1/2} \sim 10^{18} GeV$
- Models with large extra dimensions may solve the hierarchy problem
- Micro black holes are an exciting consequence of large extra dimensions

- ADD scenario, proposed by Nima Arkani-Hamed, Savas Dimopoulus and Gia Dvali. One assume that there exist n extra compact spatial dimensions, of size $\sim R$
- The extra dimensional Planck scale, is $M_{Pl(n+4)}$
- The relationship between the 4 dimensional Planck scale (M_{Pl}) and the extra dimensional Planck scale $M_{Pl(4+n)}$ can be derived by using Gauss law. Two test masses m_1 and m_2 are placed at a distance $r \ll R$, the gravitational potential they feel is

$$V(r) \sim \frac{m_1 m_2}{M_{Pl(4+n)}^{n+2}} \frac{1}{r^{n+1}} \tag{1}$$

If the two test masses was placed at a distance $r \gg R$, the gravitational potential changes to

$$V(r) \sim \frac{m_1 m_2}{M_{Pl(4+n)}^{n+2} R^n} \frac{1}{r} \tag{2}$$

- By comparing, one finds the relationship between the M_{Pl} and $M_{Pl(4+n)}$.

$$M_{Pl}^2 \sim M_{Pl(4+n)}^{2+n} R^n \tag{3}$$

- Assuming extradimensional Planck scale $(M_{Pl(4+n)}) \approx$ electroweak scale
- For $M_{Pl(4+n)} = 1 TeV$ and $n = 2$, the size of $R \sim 100 \mu m$ and for increasing n, R is decreasing.

- Consider two partons with a center-of-mass energy $\sqrt{\hat{s}} = M_{BH}$ moving in opposite directions. If the impact parameter is less than the higher-dimensional Schwarzschild radius, a black hole with mass M_{BH} forms. ($R \gg R_S$)
- The parton cross section is

$$\hat{\sigma}\left(M_{BH}\right) \approx \pi R_s^2 \tag{4}$$

- A Black Hole will decay by Hawking radiation into any type of standard model particles. (leptons, quarks photons, W, Z)
- The number of decay products is dependent on the Hawking temperature T_H

$$\begin{aligned} < N > &\approx \frac{M_{BH}}{2T_H} \\ &= \frac{2\sqrt{\pi}}{n+1}\left(\frac{M_{BH}}{M_{Pl(4+n)}}\right)^{\frac{n+2}{n+1}}\left(\frac{8\Gamma\left(\frac{n+3}{2}\right)}{n+2}\right)^{\frac{1}{n+1}} \end{aligned} \tag{5}$$

- For $n = 2$ and $M_{BH} = 5\text{TeV}$, the black hole will on average decay to 14 particles.
- For increasing space dimensions, the number decay products are decreasing.

- Black hole properties
  - Large number of high P_T final state particles
  - Large $\sum P_T$
  - Large miss $\not{E}_T$

- Analyze Strategy

Electron	Muon
$P_T > 15$ GeV	$P_T > 15$ GeV
$\|\eta\| < 2.5$ except for	$\|\eta\| < 2.5$
$1.00\,\|\eta\| < 1.15, 1.37\,\|\eta\| < 1.52$	

Photons	Jet
$P_T > 15$ GeV	$P_T > 20$ GeV
$\|\eta\| < 2.5$	$\|\eta\| < 2.5$

- Where $\eta = -ln\left(tan\left(\frac{\theta}{2}\right)\right)$, where θ is the angle form the beam axis.

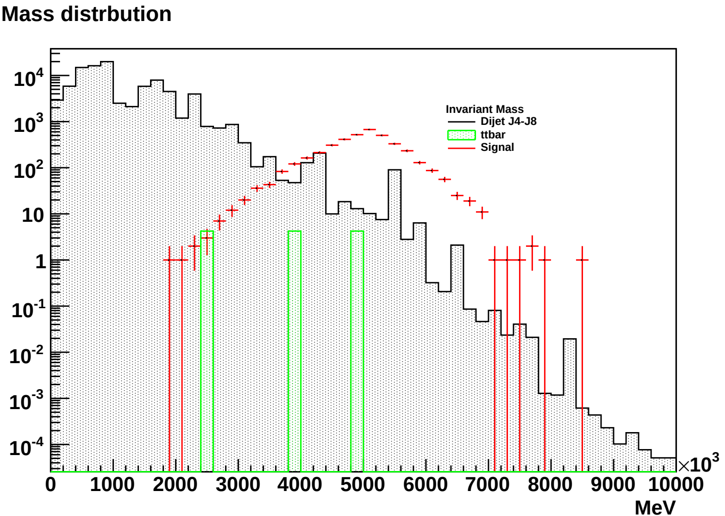
Data Set	Events	Cross section(pb)
Signal	14 750	3
Dijet J4 (140 GeV $< P_T <$ 280 GeV)	72 000	$1,5 * 10^5$
Dijet J5 (280 GeV $< P_T <$ 560 GeV)	77 000	$5,122 * 10^3$
Dijet J6 (560 GeV $< P_T <$ 1120 GeV)	76 000	120
Dijet J7 (1120 GeV $< P_T <$ 2240 GeV)	76 000	1,075
Dijet J8 ($P_T >$ 2240 GeV)	58 000	$1,1 * 10^{-3}$
ttbar	65 000	$2,05 * 10^2$

- Invariant mass distribution

$$p_{BH} = \sum_i p_i + \left(\not{E}_T, \not{E}_{T_x}, \not{E}_{T_y}, 0\right)$$
$$M_{BH} = \sqrt{p_{BH}^2} \tag{6}$$

- Cut on the invariant mass distribution
  - $\sum P_T > 2.5$ TeV
  - One lepton with $P_T > 50$GeV

- Invariant mass distribution, for black hole in $n = 2$ and $M_{BH} = 5$ TeV



- Atlas may discover ADD black holes
- But the discovery potential is dependent on extra dimensions, the mass M_{BH} and the beam energy.