Search For Microscopic Black Holes

Parijat Banerjee

The Hierarchy Problem

Why is the weak force is 10^{24} times stronger than gravity?

A hierarchy problem occurs when the fundamental value of some physical parameter, such as a coupling constant or a mass, in some Lagrangian is vastly different from its effective value.

If the Standard Model is used to calculate the quantum corrections to Fermi's constant, it appears that Fermi's constant is surprisingly large and is expected to be closer to Newton's constant unless there is a delicate cancellation between the bare value of Fermi's constant and the quantum corrections to it.

$\alpha = 1/137, \alpha_s = 1, \alpha_w = 10^{-6}, \alpha_g = 10^{-39}$

Planck Scale

$$E_P = \sqrt{\frac{\hbar c^5}{G}} = 1.22 \times 10^{19} GeV$$

$$M_{Higgs}(Expt) = 125 GeV$$

$$M_{Higgs} = "BareMass" + corrections$$

Since the Higgs is a scalar particle, its mass is subject to quadratically divergent quantum corrections. In other words, the Higgs mass gets corrections from every particle that couples to the Higgs field. These corrections are proportional to the mass of the particle.

Higgs Mass is about $O(100) GeV$, but Planck scale is $O(10^{19}) GeV$, so Higgs mass could get contributions from undiscovered particles with masses in the range of $10^2 - 10^{19} GeV$.

SUSY Baka

Supersymmetry retains an elementary scalar Higgs (and actually adds four more), while radiative corrections with opposite signs from bosons and fermions cancel.

$$M_{Higgs} = SUSY\ \ Higgs\ \ Masses + corrections$$

If SUSY were an exact symmetry of nature, then the mass of each SM bosonic particle must be equal to its superpartner fermion mass.

Almost magical cancellation required for M_{Higgs} to be small when corrections are so large. SUSY explains the cancellation in a natural way.

Extra Dimensions ⋆

Why is gravity so weak?

Since the gravitational field propagates into the extra dimensions, it is measured at a reduced strength in the four space-time dimensions. Thus, the fundamental Planck scale in $D = 4 + n$ dimensions, M_D, could be comparable with the electroweak scale.

$$E_P = \sqrt{\frac{\hbar c^5}{G}} = 1.22 \times 10^{19}\, GeV$$

$$G = \frac{\hbar c}{M_{Pl}^2}$$

Counting Experiments

Process $X \to \mu^+\mu^+$

Can we find evidence for X in LHC data? Does X exist?

$N = L\sigma BA\epsilon$

$N_X = L\sigma_X B_{X\to\mu^+\mu^+}(A\epsilon)_{X\to\mu^+\mu^+}$

X is signal, something not predicted by SM physics.

Background: $WZ/ZZ, ttbar, W + jets, Z + jets$

N_X is for signal, $N_{Bkg} = N_{WZ/ZZ} + N_{ttbar} + N_{W/Z+jets}$ is background.

Example Limit Plot

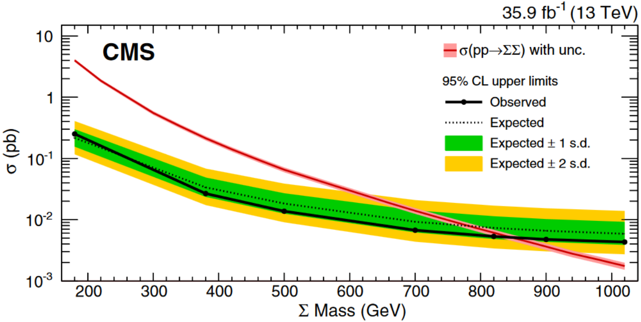
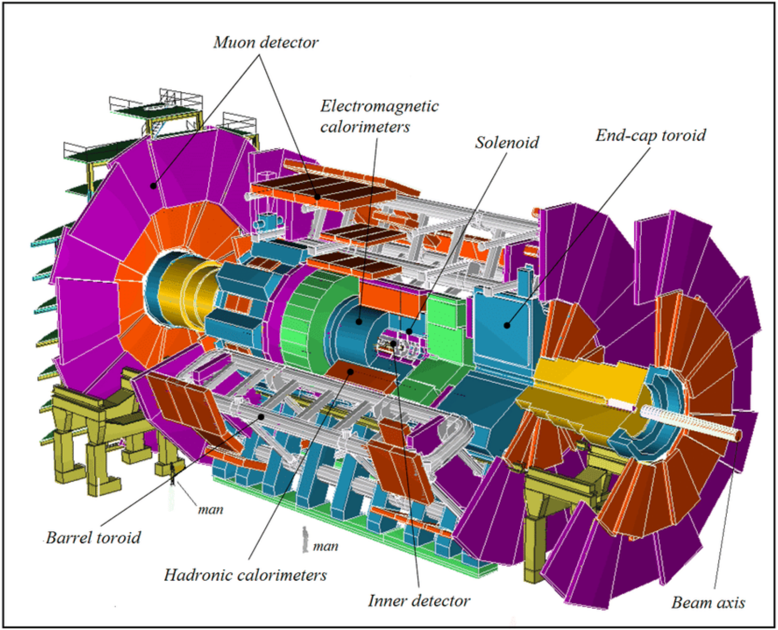


FIG. 2. The 95% confidence level upper limits on the cross section for production of heavy fermion pairs ($\Sigma^0\Sigma^+$, $\Sigma^0\Sigma^-$, and $\Sigma^+\Sigma^-$). Also shown is the theoretical prediction for the cross section of the Σ pair production via the type-III seesaw mechanism, with its uncertainty. In the flavor-democratic scenario ($B_e = B_\mu = B_\tau$), heavy fermion pair production is excluded for masses below 840 GeV.

ATLAS Detector



Data and Monte Carlo Samples

Single-muon trigger with a threshold at $36 GeV$ on the muon pT.

MC Samples + GEANT4

Background Processes: $ttbar$, diboson, $W + jets$

MC generated in BLACKMAX, hadronized in Pythia.

Samples produced for rotating and non-rotating black holes.

M_D from $1 - 4.5 TeV$ and M_{TH} from $3 - 6.5 TeV$ with $n = 2, 4, 6$.

Event Selection (Trigger: Single Muon)

Primary Vertex reconstructed from at least five tracks with $pT > 400 MeV$

The muon candidates must satisfy $|\eta| < 2.4$ and have $pT > 15 GeV$

Events are required to have at least two muons. The two muons with the highest pT are required to have the same charge.

Leading muon: $pT > 40 GeV$, $\Delta R = 0.2$, $\Sigma pT_{\Delta R=0.2} < 20\% pT$

The leading and subleading muons are required to be separated by $\Delta R > 0.2$. Subleading muon is not required to be isolated(!!!).

The total track multiplicity (N_{trk}) of the event is calculated by considering all ID tracks with $pT > 10 GeV$ and $|\eta| < 2.5$ that pass the same quality and $z0$ criteria as those for the muon ID tracks.

Why no isolation on μ_2

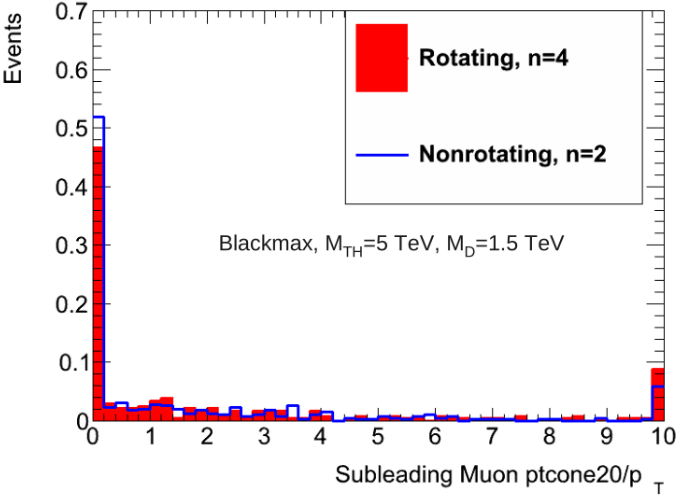


TABLE II: The predicted backgrounds in the validation regions compared to the number of observed data events. The uncertainties shown on the total background are the combined statistical and systematic uncertainties.

N_{trk}	$t\bar{t}$	Diboson	μ+fake	Total	Data
40 GeV < Leading-muon p_{T} < 100 GeV					
$N_{\mathrm{trk}} < 10$	10000	800	20000	31000 ± 4000	28988
$10 \leq N_{\mathrm{trk}} < 20$	800	3	400	1200 ± 100	1103
$N_{\mathrm{trk}} \geq 20$	16	0.1	6.8	23 ± 3	12
Leading-muon $p_{\mathrm{T}} \geq 100$ GeV					
$N_{\mathrm{trk}} < 10$	2400	140	2300	4800 ± 600	4428
$10 \leq N_{\mathrm{trk}} \leq 11$	190	3	76	270 ± 31	271
$12 \leq N_{\mathrm{trk}} \leq 14$	133	1.1	42	176 ± 21	167
$15 \leq N_{\mathrm{trk}} \leq 19$	60	0.3	17	77 ± 9	68
$20 \leq N_{\mathrm{trk}} \leq 24$	10	0.1	2.9	13 ± 2	13

Limit Plot (Non Rotating)