Low-scale Gravity Black Holes at LCH

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Quantum gravity and accelerator physics

- Obtain limits from collider experiments
- Graviton interference effects at Large Hadron Collider, CERN
- Decay modes of particles with mass in TeV range
- Hadron/lepton scatterings and decays in extra-dimensional models
- Black holes at LHC, CMS

Limits from cosmology and astrophysics:
- Cosmic rays and supernovae

Particle astrophysics
- Dark matter
- Mass of particles, \textit{Ex:} Axions
  - Evidence from observations for extra D
- Quantum black holes: energy spectrum, depend on parameters of space times, strings
Black holes at LHC

- Event generator for ED BHs: BlackMax
- Rotation, fermion splitting, brane tension
- Experimental signatures, particle decay
- CMSSW analysis
- Further models of Dvali suggest BH detection even more likely
Distribution of black hole mass

Rotating and non-rotating, 2 ED, 1-5 TeV
Distribution of BH color (red – blue - green)

Rotating and non-rotating, 2 ED, 1-5 TeV
Distribution of BH charge / 3q / Rotating and non-rotating, 2 ED, 1-5 TeV
< Energy > of emitted particles vs. BH mass

Rotating and non-rotating, 2 ED, 5-14 TeV
Energy spectrum of emitted particles

Rotating and non-rotating, 2 ED, 1-5 TeV
Number of emitted particles vs. BH mass during Hawking phase

Rotating and non-rotating, 2 ED, 5-14 TeV
Multiplicity of various species (Hawking)

Rotating and non-rotating, 2 ED, 5-14 TeV, quarks, anti-quarks, leptons, anti-leptons
Number of emitted particles vs. # extra dimensions and # fermion splitting dimensions

rotating and non-rotating

ED = 7
Number of emitted particles / BH vs. brane tension B

non-rotating
ED = 2
5-14 TeV
Hawking phase
M_{Pl} = 1 TeV
The graph shows two distributions of $p_T$ for single top quark events:

- **Red Dashed Line**: $p_T$ of single top from BH ($M_{BH} = 2 \text{ TeV}, M_{Pt} = 1 \text{ TeV}, d = 8$), Mean = 370.7 GeV.
- **Blue Line**: $p_T$ of single top from $t$-channel (SM), Mean = 66.7 GeV.

The y-axis represents the arbitrary units of the distribution, and the x-axis represents $p_T$ in GeV.
Pseudorapidity with final burst

Non-rotating and rotating, 2 ED, 1-5 TeV, quarks, anti-quarks, leptons, anti-leptons
Pseudorapidity without final burst

Non-rotating and rotating, 2 ED, 1-5 TeV, quarks, anti-quarks, leptons-, anti-leptons+
Distribution of lepton transverse momentum

Leptons & anti-leptons, rotating, 2 ED, 1-5 TeV
Analysis at CMS

- Rate: $\sigma \times L_t \times \text{event}$: (same for rot & non-rot)
- Total ET, missing ET
- Missing: $G + \nu$: model dependent
- Peak (most likely) or mean for lepton & jet distributions: ratio different from Standard Model
- Jet finder for CMS
- Hardest lepton transverse momentum: lepton easy to identify, cuts off for SM
  Combined cuts: $\eta$, $p_T$ distribution
Model settings for detector which have different signature

Angular acceptance cut for detector acceptance
- $\eta_{\text{lepton}} < 2.5$  Jets, q, W, Z < 5
- t, b
- Implementation of generator in CMSSW
- Interface BlackMax
- CMSSW : signal and SM background
- Fast simulation
- Triggering
- Comparison w Charybdis : consistent
- missing ET possible difference
Further models to test at CMS

- BHs in model for SM copies:
  - BH -> SM particle rates different,
  - difference in particle decay
  - distribution of p_T, MET

Even more likely for BHs w ADD & finding them
Thank you for your attention!