Low Scale Gravity Black Holes at LHC

Enikő Regős

Search for Extra Dimensions

- LHC : Quantum Gravity & Extra Dims
- Stringy Quantum Black Holes
- Low-scale Gravity Black Holes at LHC
- Comparison of Black Hole Generators

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De Roeck Gamsizkan Trocsanyi

Hierarchy problem & ED

- Fundamental scales in nature :
  Planck mass : E19 GeV
  Electroweak scale : 240 GeV
  Supersymmetry : fundamental theory at M_Pl ,
  EW derived (small #) from dynamics
  Broken (particle mass) : gravity mediated
  gravitino mass determines partner masses
  EW breaking induced by radiative corrections

Extra dimensions

- EW scale fundamental, M_Pl derived
- Compact ED (radius R)
- Matter confined in 4D
- Gravity : propagates in all D ,
  weak : compact space dimensions large compared to electroweak scale
  $G = G_D / (2 \pi R)^{(D-4)}$

Stringy Black Holes : D branes

- D branes
- D = 5 type – IIB black hole :
- Q1 D1 and Q5 D5 branes intersections
- in ds^2 :
- $f = \Pi [1 + (r0 \, sh \, \delta / r)^2]$ (1, 5, p)
- 1, 5 – brane charges : electric, magnetic, KK charge
- $T = 1 / 2 \, \Pi \, r0 \, \Pi \, ch \, \delta$
- Q = N - N (1, 5, R - L)
- (anti) 1, 5 – branes, right/left moving momentum #

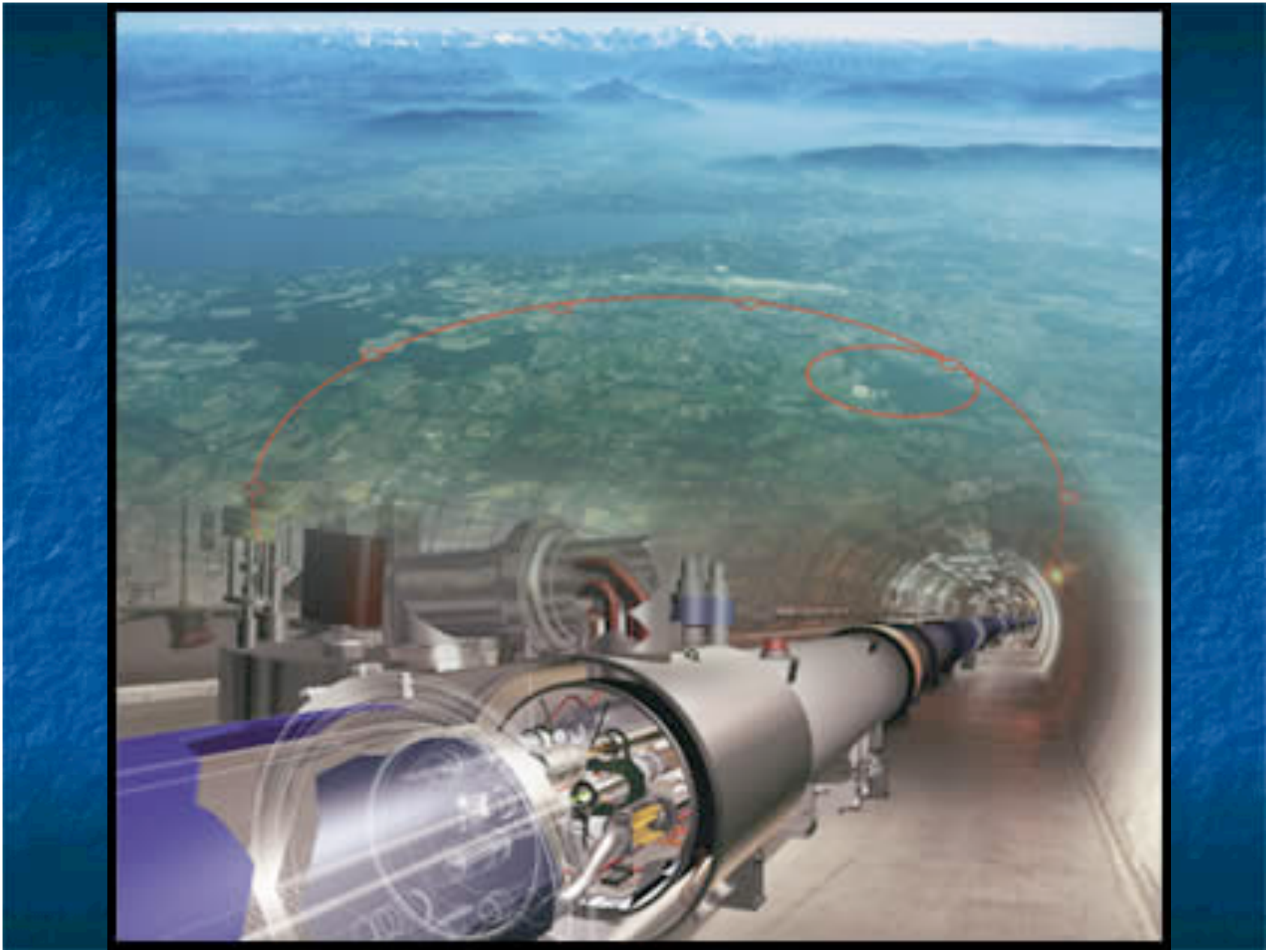
- $ds^2 = -g / \sqrt{f}\, dt^2 + \sqrt{f} (dr^2 / g + r^2 d\Omega)$
- δ-s : higher dimensions' compactification
- $f = \prod (1 + r0\, sh^2 \delta / r)$ (2, 5, 6, p)

Further examples:

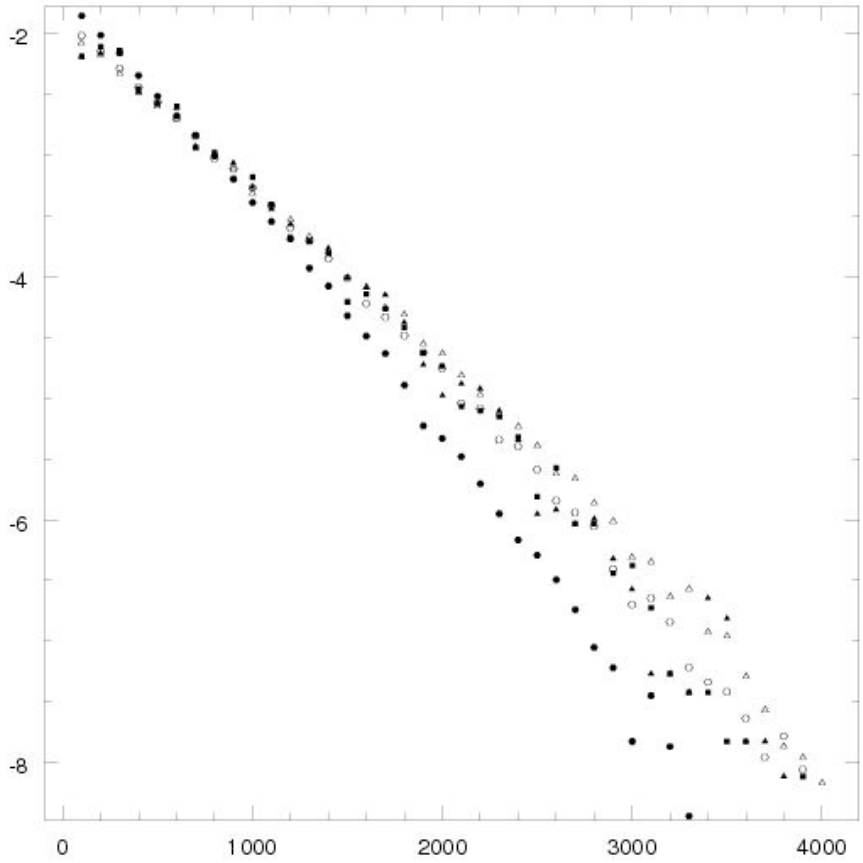
- D = 5 Type – IIB with electric charges
  - BPS black hole : Reissner – Nordstrom spacetime
- D = 5 : Rotating, spin
  - equal charges : D = 5 Kerr - Newman
- D = 4 rotating :
- D1, D5 branes' intersection
- Type –II : heterotic string on T^6 torus
- Rotating

Black holes at LHC

- Event generator for ED BHs : BlackMax I-II
- Rotation, fermion splitting, brane tension
- Experimental signatures, particle decay
- CMSSW analysis
- Comparison with Charybdis I-II
- TRUENOIR, CATFISH : no rotation
- Energy loss



Black Hole Mass function



- Log Φ ~ M - M_min

  for various models of Planck mass, ED, M_min, rotation, brane tension

BlackMax & Charybdis agree on initial mass distribution as not affected by mass loss

BH color (red-blue-green) and charge

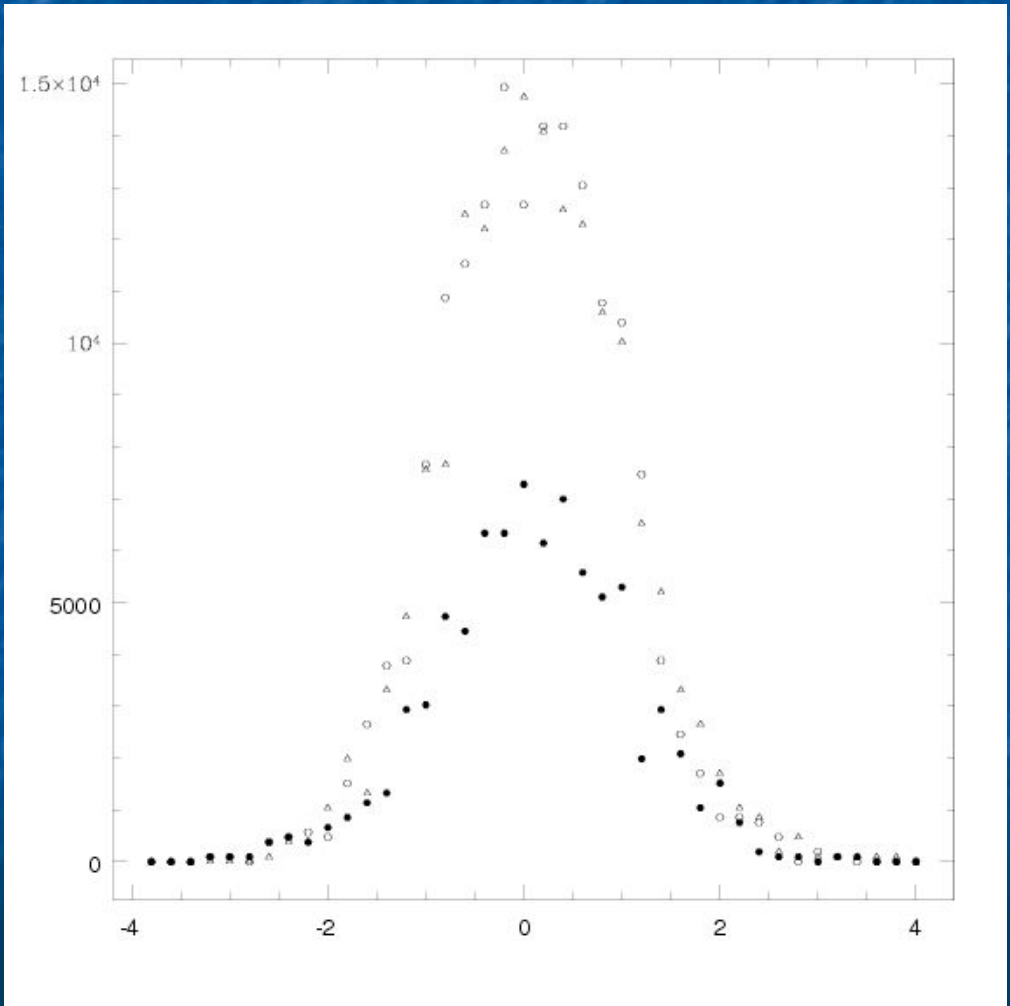
- Color distribution : -3 -> 3
- Charge distribution : -1 -> 4/3

Number of emitted particles per black hole

Varies with number of extra dimensions

- Decreases w # of fermion splitting dimensions
- Increases w brane tension
- Decreases w rotation
- Slight increase w BH mass
- around 10 (Hawking radiation + final burst)
- Average energy: slight decrease vs. BH mass

Pseudorapidity : e - μ - γ



- Ratio of $0 < \acute{\eta} < 0.5$ & $0.5 < \acute{\eta} < 1$

distinguishes among beyond standard models

All models and species have values very different from QCD

Lepton transverse momentum : models

- Planck mass : 2, 2, 5 TeV
- Extra dimensions: 5, 3, 3 (> 2)
- Center of mass energy: 14 TeV

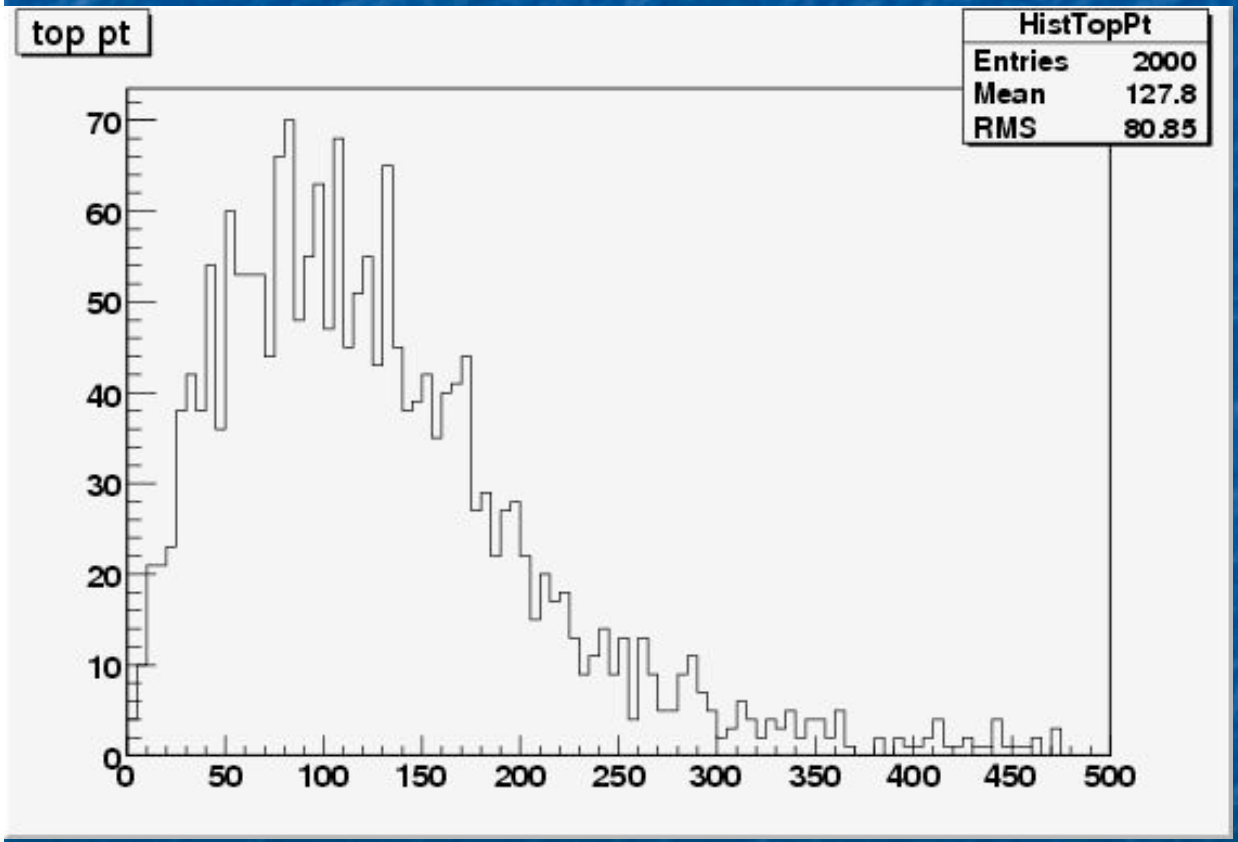
Minimum black hole mass : 4, 5, 7 TeV

Multiplicity decreases with Planck mass
(fermions dominate)

Energy and momentum increase

Model comparisons

Model comparisons



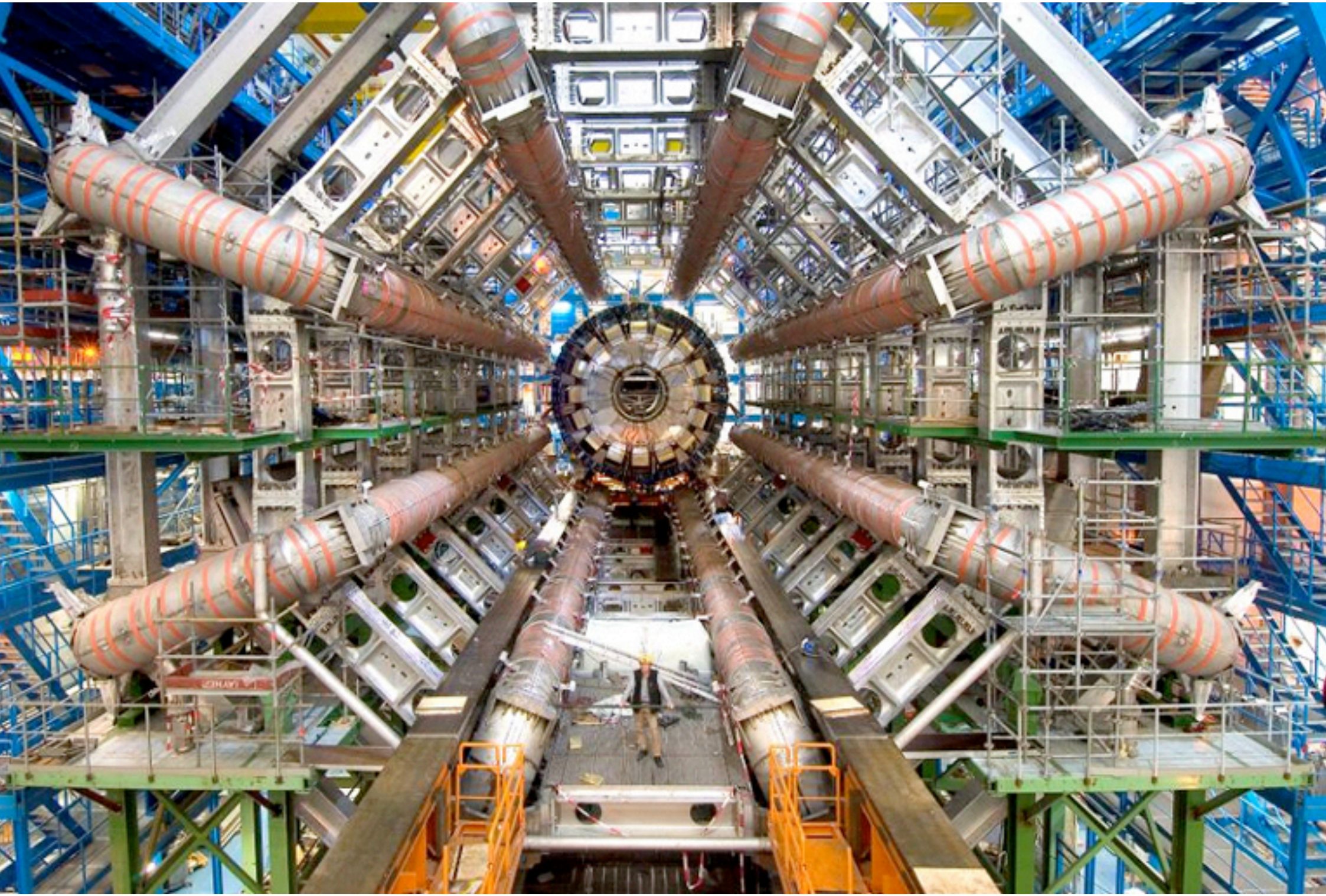
Models

Vs.

Standard Model top quark transv. momentum /GeV

Analysis at CMS

- Missing Transverse Energy :
  graviton + neutrino : model dependent
- Lepton transverse momentum :
  easy to identify, cuts off for Standard Model
  Combined cuts : ή , p_T distribution



Model settings for detector which have different signature

- Implementation of generators in CMSSW
- Interface BlackMax II
- CMSSW : signal and SM background

- Model with 4TeV minimum black hole mass experimentally most accessible

Comparison of BlackMax with Charybdis for non-rotating black holes

- BlackMax has higher multiplicity & lower momenta
- Missing Transverse Energy :

gravitons only in BlackMax (black curves)

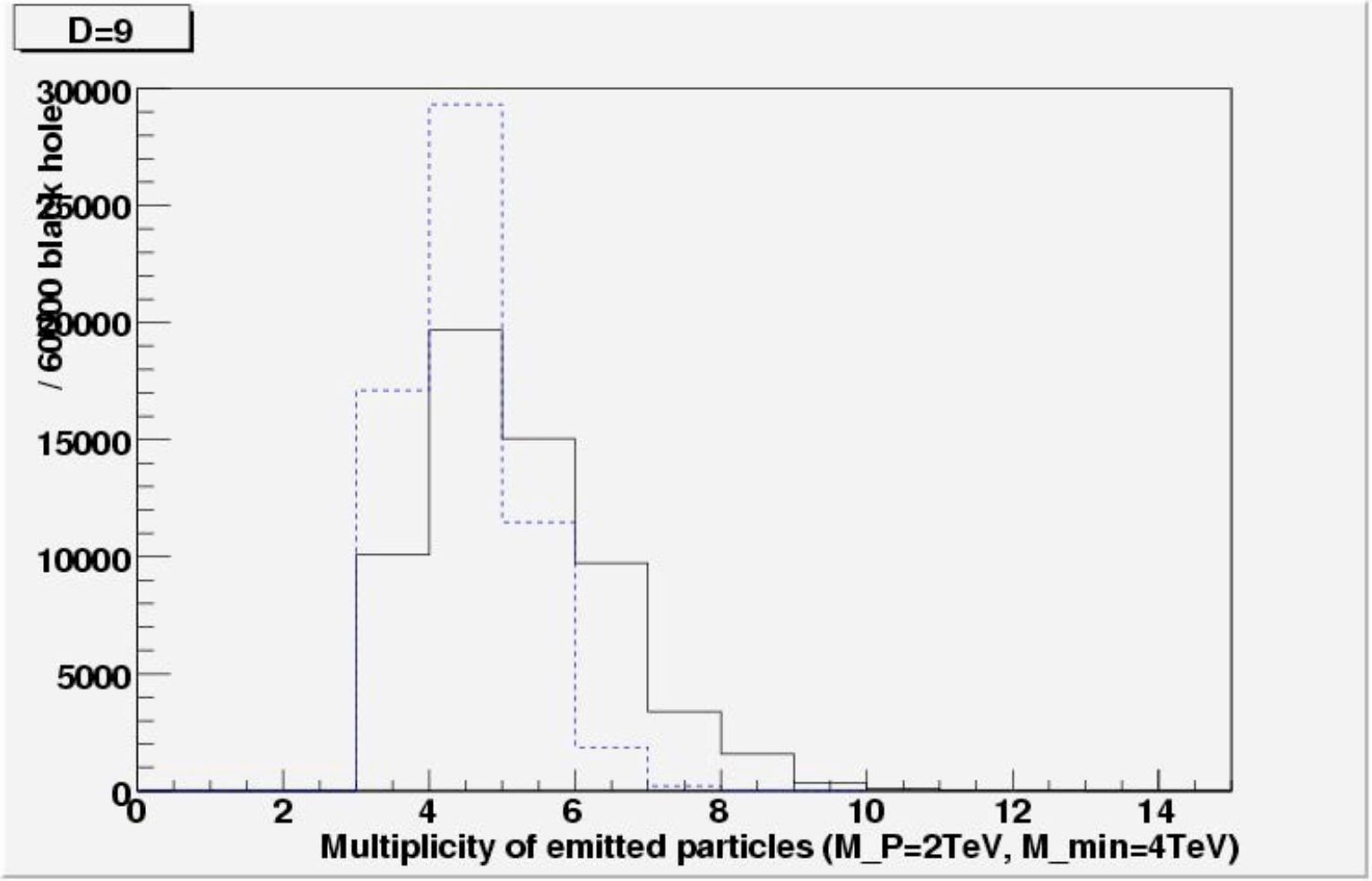
BlackMax-II : gravitons in final burst too

Higher MET

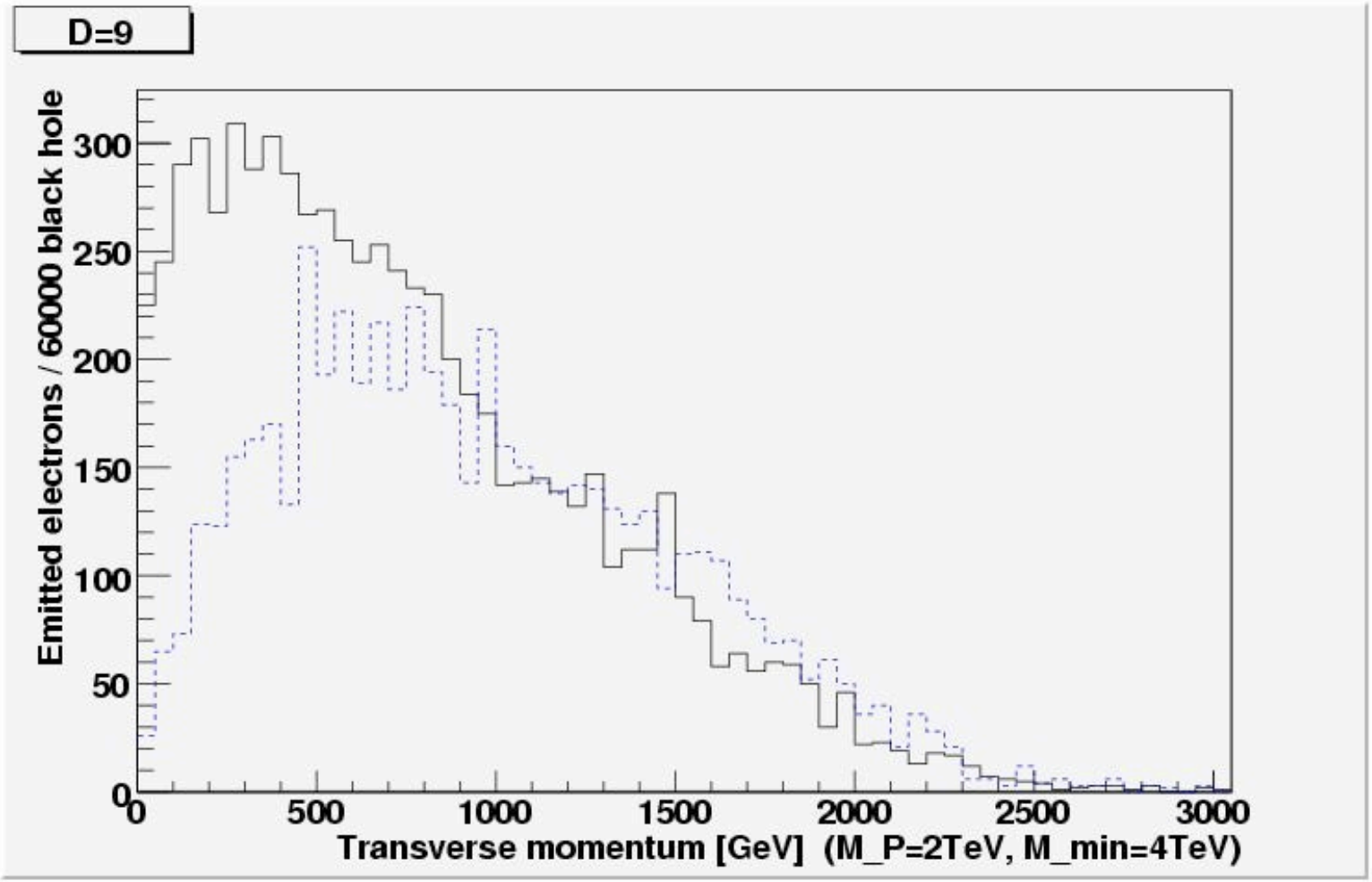
Apart from cross sections good agreement

Yoshino – Rychkov suppression decreases σ

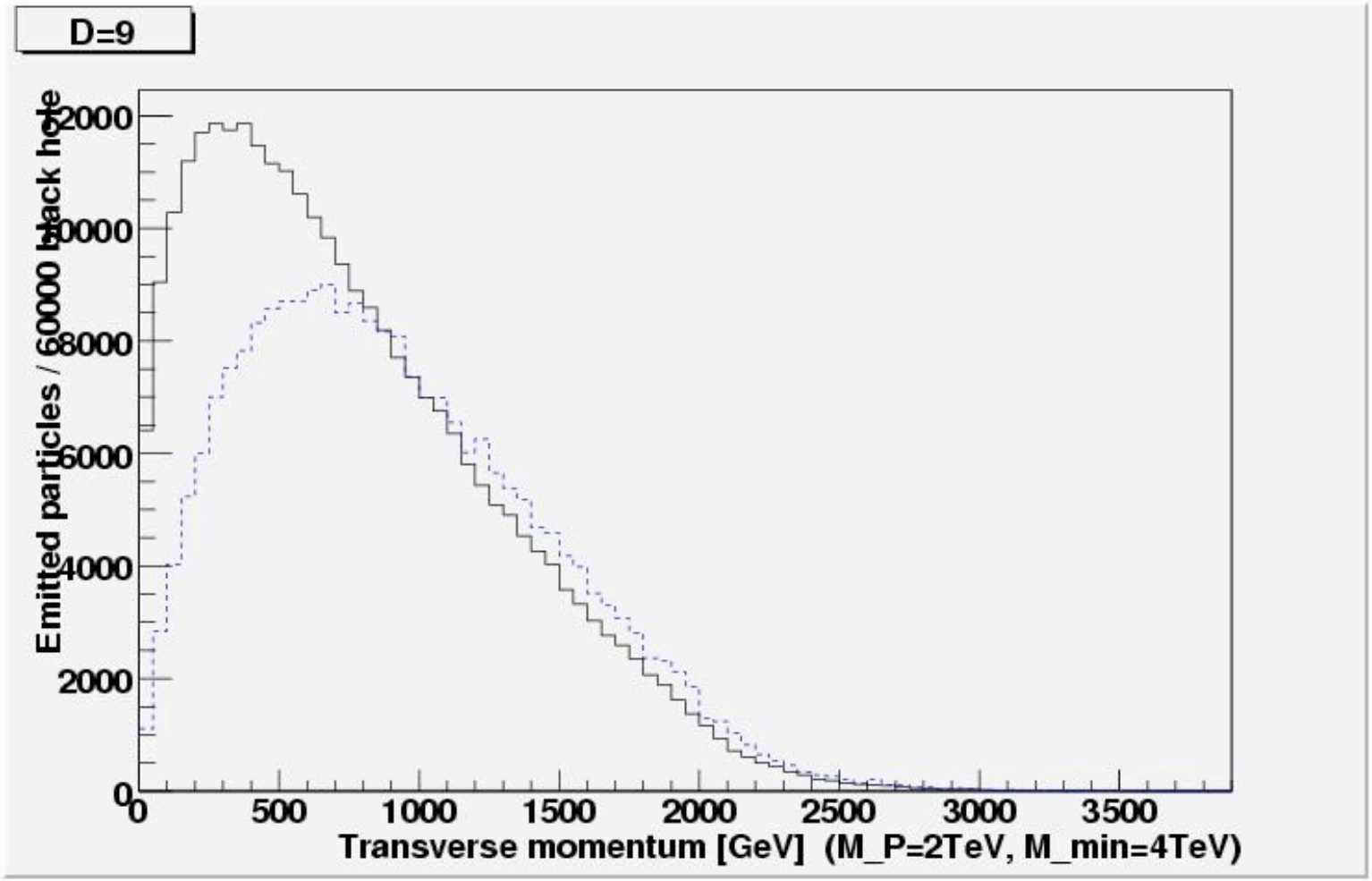
Multiplicity in BlackMax & Charybdis



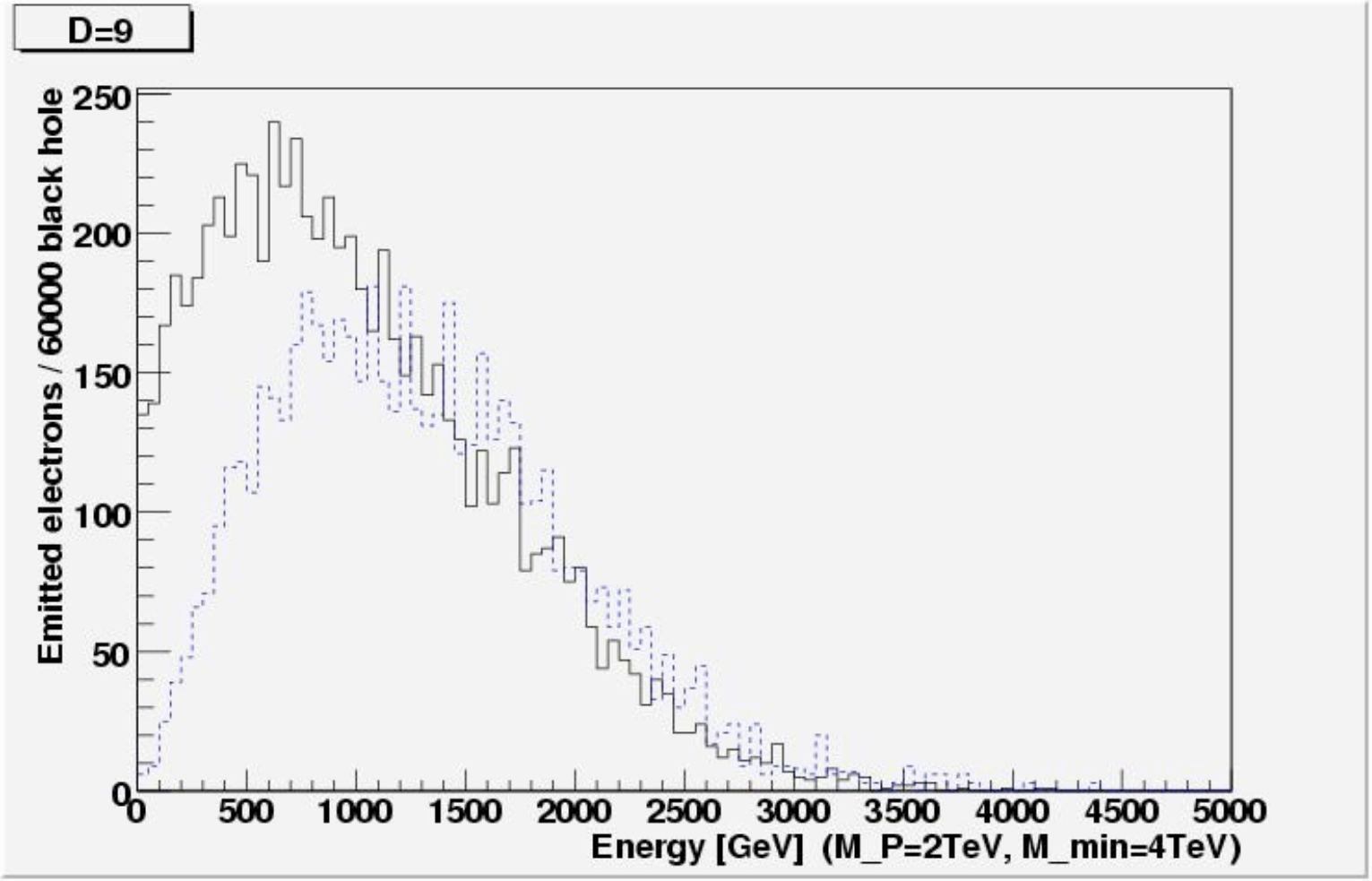
Transverse momentum of emitted electrons



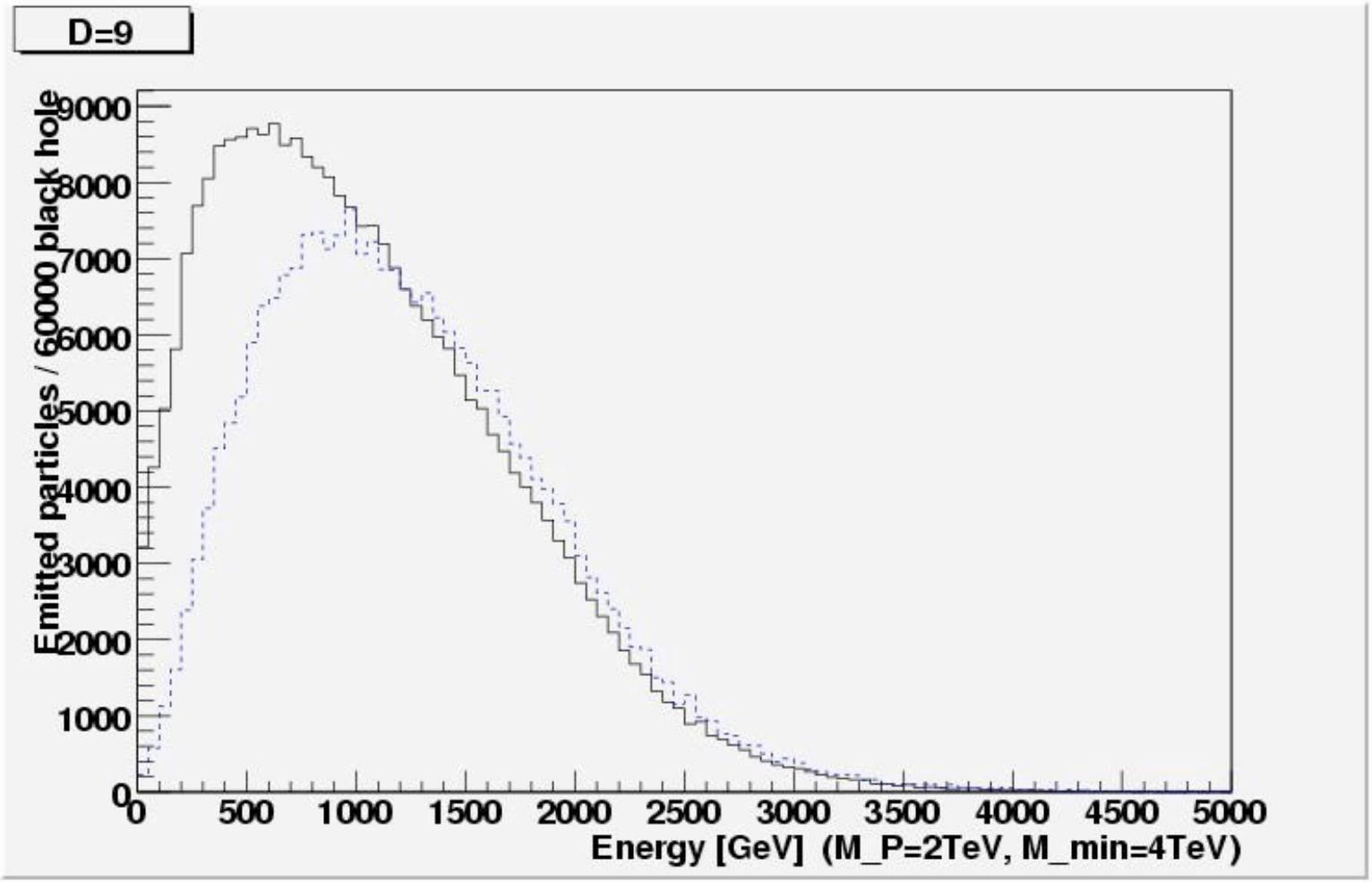
Transverse momentum of all particles



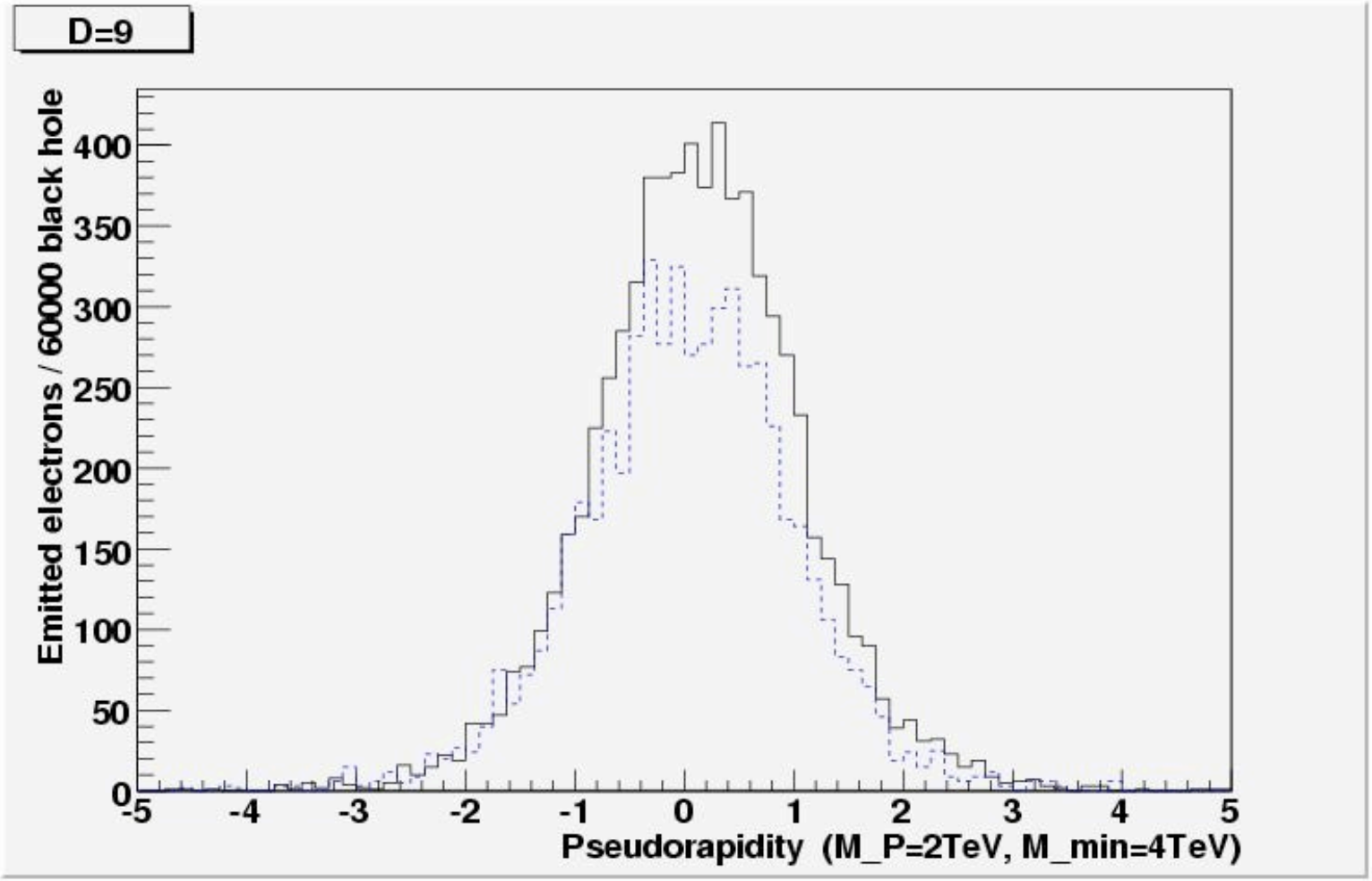
Spectrum of emitted electrons



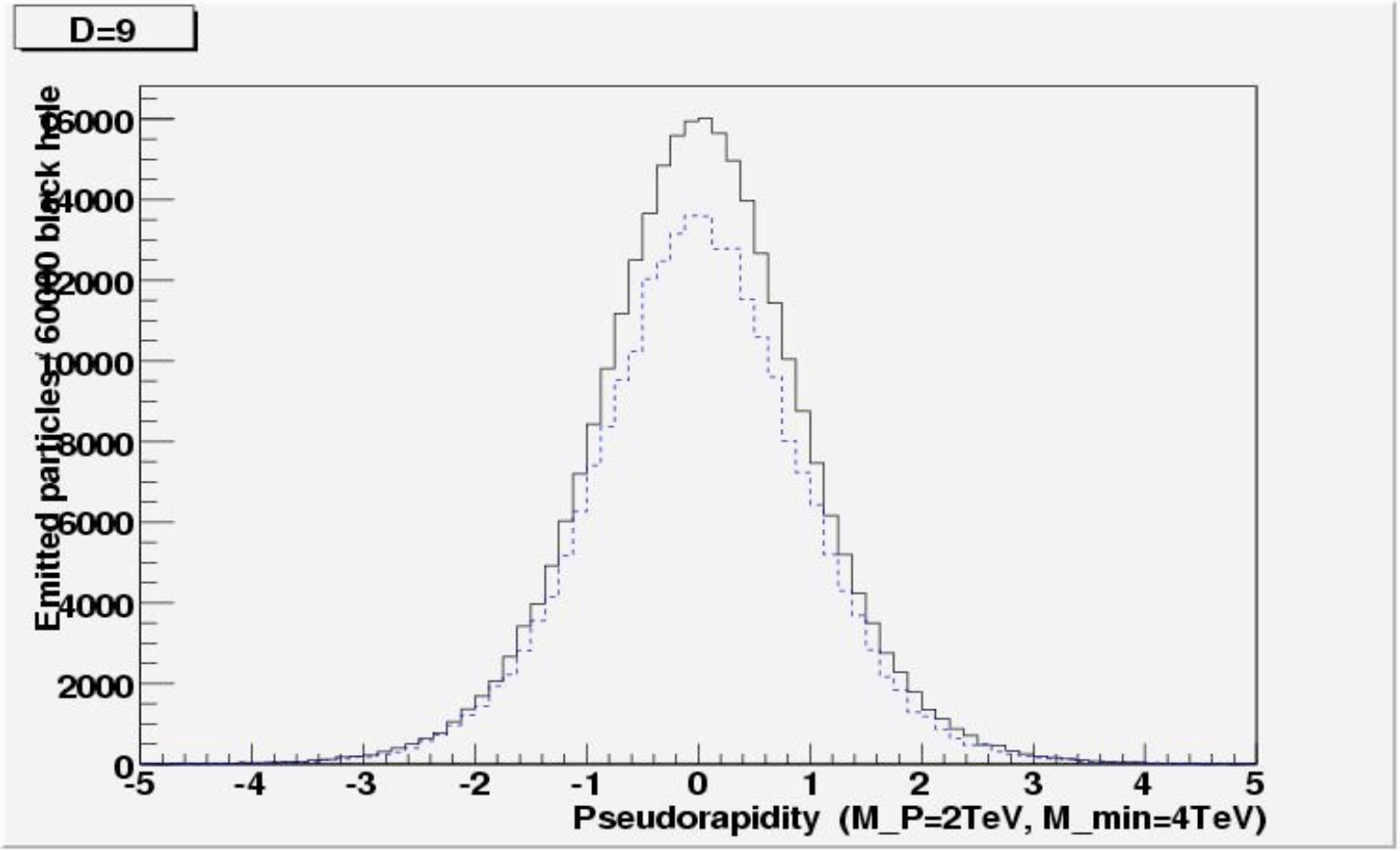
Spectrum of emitted particles



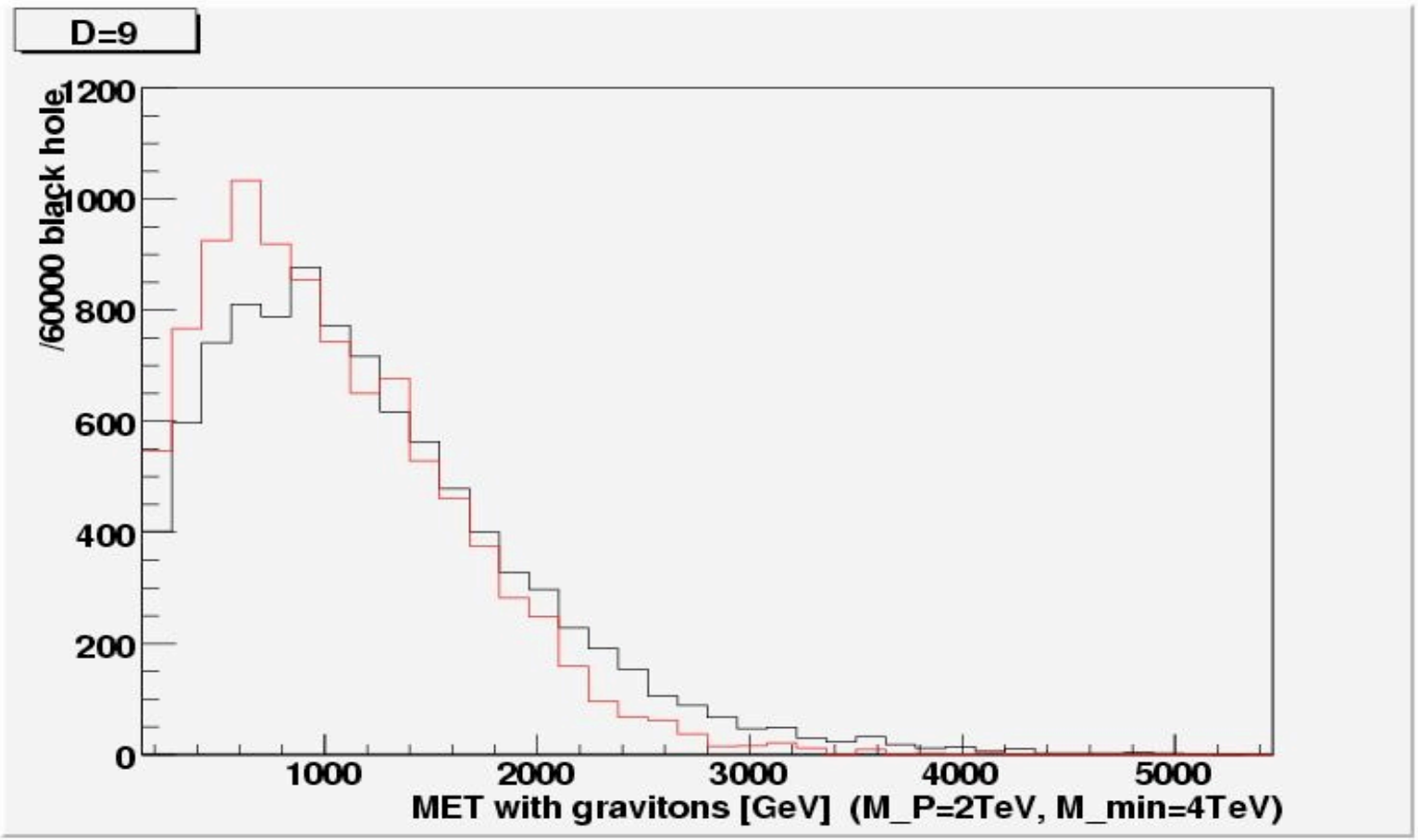
Pseudorapidity of electrons



Pseudorapidity of emitted particles



Missing Transverse Energy with Gravitons



Rotating Black Holes : Compare BlackMax II with Charybdis II

- BHs carry spin from impact parameter
- Spin : fewer, more energetic particles
- Enhanced vector emission: more gluons, photons, W, Z
- Particle spectra, angular distributions, multiplicities strongly affected by BH spin

In rotating D>5 graviton emission unknown

Rotation and Yoshino –Rychkov suppression

- Charybdis –II needs 2.5 times larger BH mass than Planck scale for a physical distribution of multiplicities, neutrinos in the remnant phase for MET, and leptons /electrons
- From our 3 models 2-5-3 is tractable for Charybdis-II due to the ratio of 2.5 – 3 for BH/ Planck mass
- Then reasonable agreement with BlackMax -II

Further models to test at LHC :

BHs in Dvali model for SM copies :

BH -> SM particle rates different,

difference in particle decay

non-integer extra dimension

MET is larger

Explanation for Dark Matter

Even more likely for BHs w ADD & finding them

BHs in Cosmic Rays

Thank you for your attention !