Study of TeV cosmic Gamma-Rays using the Random Forest by the Tibet Air Shower Experiment

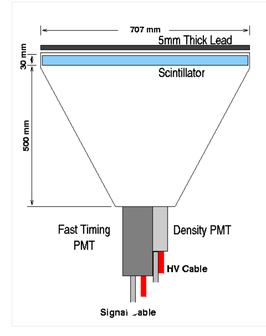
Tibet ASγ Group Yuta Nakao (E-mail : nakao@icrr.u-tokyo.ac.jp)

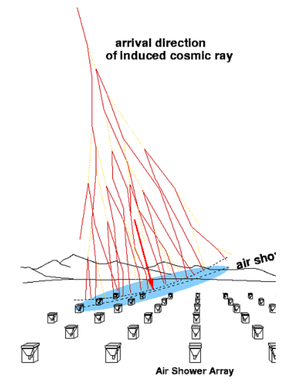
Dept. of Physics, Grad. of Science, The University of Tokyo

Tibet-III Air Shower (AS) Array

Yangbajing in Tibet, China at 4,300m a.s.l. (90.522°E, 30.102°N)

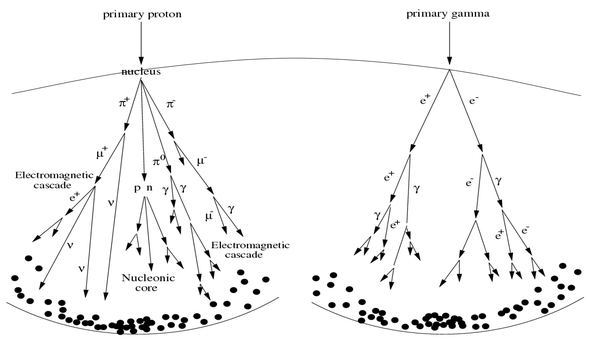
- Num. of Scinti. Counter 0.5 m^2 x 789
- Effective area ~37,000 m^2
- Observing Energy ~TeV - 100 PeV
- Angular resolution ~0.4° @10 TeV
  ~0.1° @100 TeV
- Energy resolution ~70% @10 TeV
  ~40% @100TeV
- Field of view ~2 sr





The underground water Cherenkov muon detector (MD) array - Future plan

gamma ray / background cosmic ray separation by the muon number

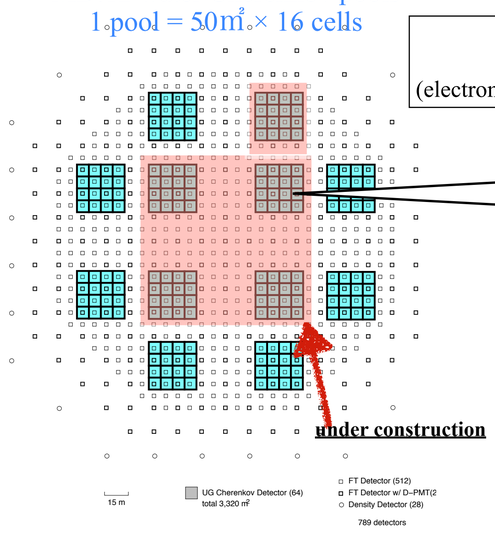


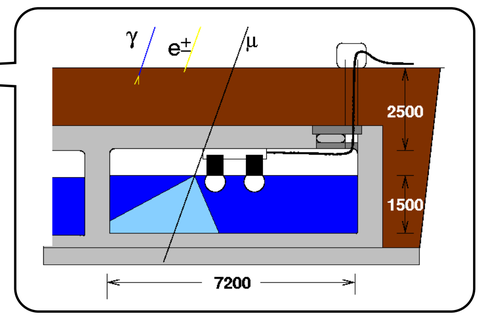
Proton : Nμ ~ 50 Gamma : Nμ ~ 1

@100TeV(/ 10,000㎡, 4300m a.s.l)

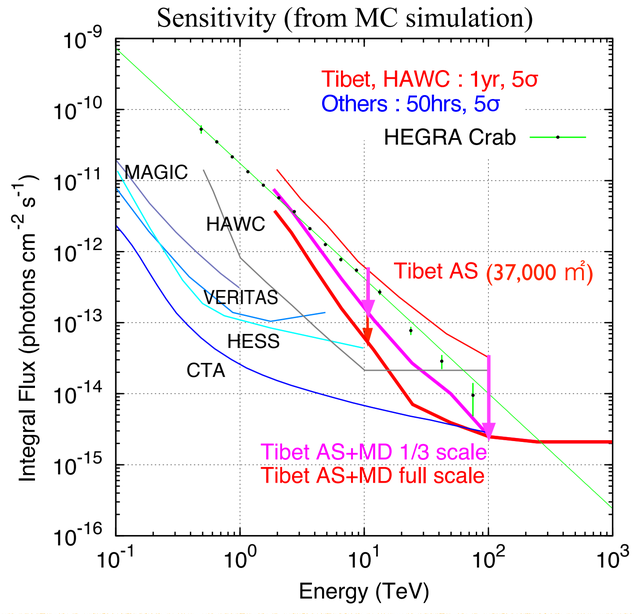
MD:12 water Cherenkov pools
1 pool = 50㎡× 16 cells

measure the amount of Cherenkov light emitted by air-shower muons (electromagnetic components absorbed by 2.5m-thick soil)





Sensitivity (from MC simulation)

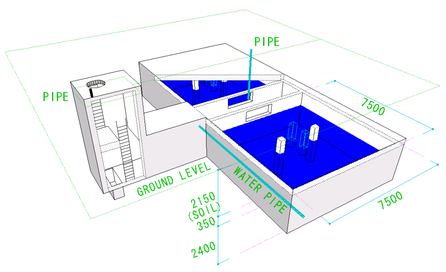


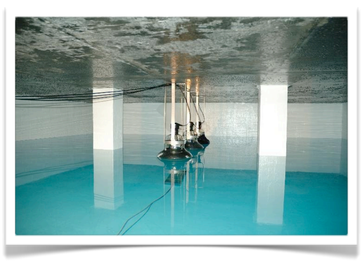
Prototype Muon Detector

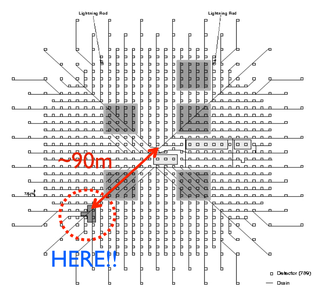
Constructed in 2007
Data taking start : 2007 Dec.
finish : 2010 Jan.

50㎡×2 cells

1.5m depth clear water
20 inch PMT×3 for each cell

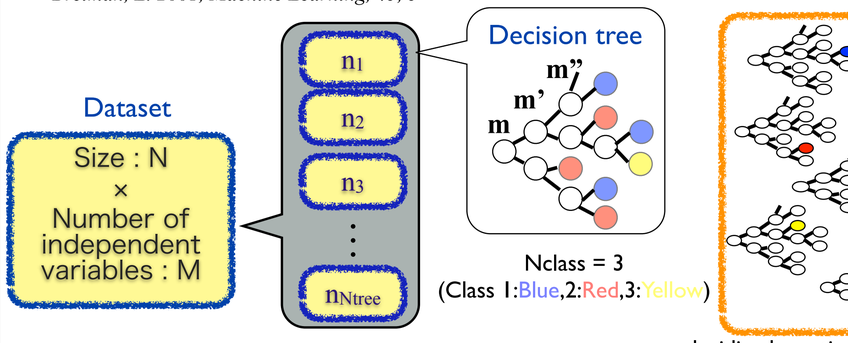






Random Forest (RF): Machine Learning

Breiman, L. 2001, Machine Learning, 45, 5



Advantages

- Scalability (capacity for processing large data volumes)
- High training speed
- High quality of the models derived (comparable with neural networks)
- Small quantity of parameters to be adjusted

Experimental DATA consistent with MC simulation and 1. There is no significant improvement by using RF.

Figure of merit (from MC simulation)

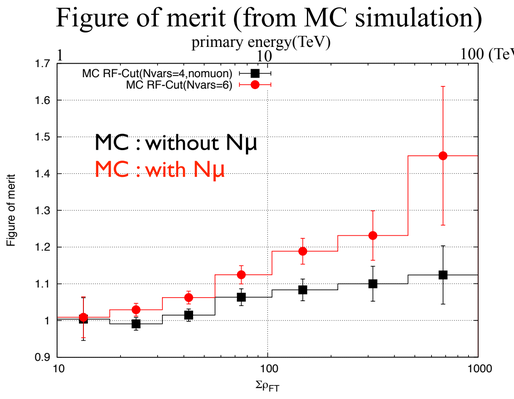
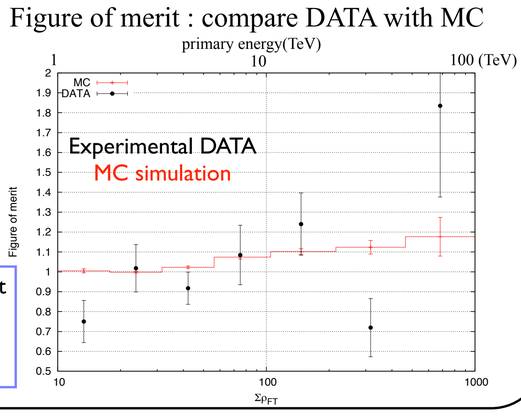


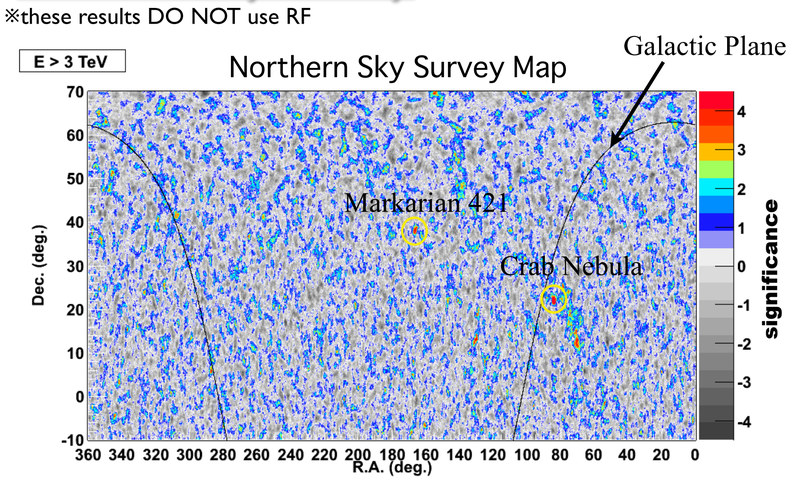
Figure of merit : compare DATA with MC



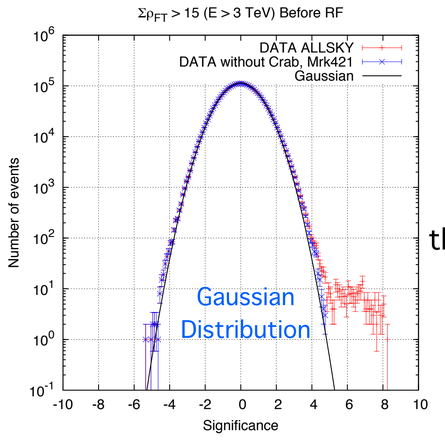
Northern Sky Survey

※these results DO NOT use RF

E > 3 TeV



Significance Distribution

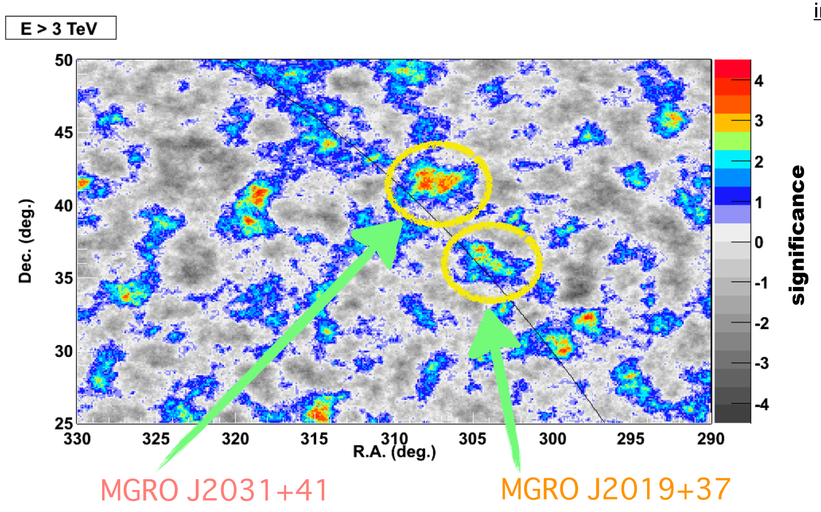


without Crab Nebula and Markarian 421, there is no significant excess

Cygnus Region

※these results DO NOT use RF

E > 3 TeV

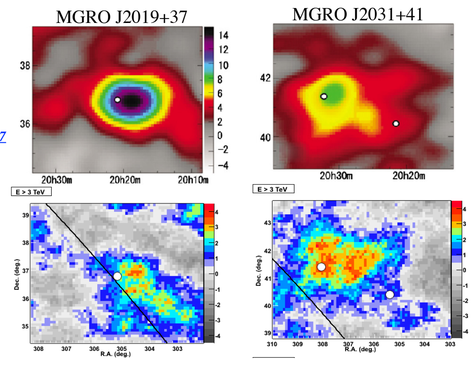


We confirmed Milagro's spectrum for the first time in the world.

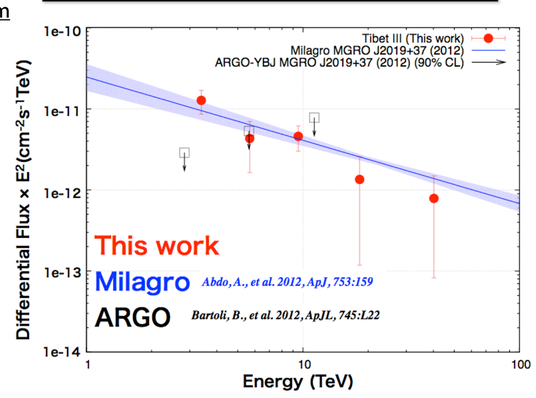
Cygnus region is the brightest diffuse γ-ray emitting region in the northern sky

Milagro 2012 @ ~35 TeV
Abdo, A., et al. 2009, APJ, 700:L127

This work E > 3 TeV



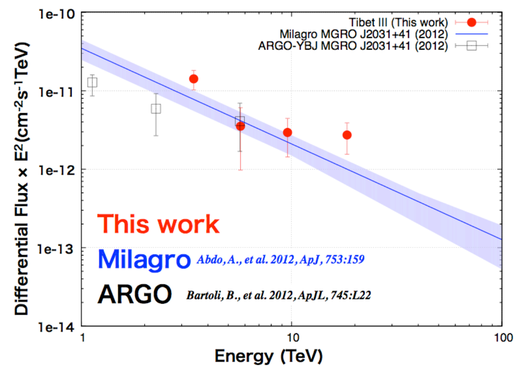
MGRO J2019+37 Differential Flux



Milagro 2012 : (4.1±0.6)×10⁻¹²(E/10TeV)^-2.78±0.10 [cm⁻²s⁻¹TeV⁻¹]
This work : (3.41±0.88)×10⁻¹²(E/10TeV)^-3.13±0.33 [cm⁻²s⁻¹TeV⁻¹]

These differential fluxes consistent with MIlagro

MGRO J2031+41 Differential Flux



Milagro 2012 : (2.1±0.6)×10⁻¹²(E/10TeV)^-3.22(+0.23-0.18) [cm⁻²s⁻¹TeV⁻¹]
This work : (3.29±1.11)×10⁻¹²(E/10TeV)^-3.15±0.50 [cm⁻²s⁻¹TeV⁻¹]

The Tibet ASγ Collaboration

M.Amenomori(1), X.J.Bi(2), D.Chen(3), W.Y.Chen(2), S.W.Cui(4), Danzengluobu(5), L.K.Ding(2), X.H.Ding(5), C.F.Feng(6), Zhaoyang Feng(2), Z.Y.Feng(7), Q.B.Gou(2), H.W.Guo(5), Y.Q.Guo(2), H.H.He(2), Z.T.He(4,2),K.Hibino(8), N.Hotta(9), Haibing Hu(5), H.B.Hu(2), J.Huang(2), W.J.Li(2,7), H.Y.Jia(7), L.Jiang(2), F.Kajino(10), K.Kasahara(11), Y.Katayose(12), C.Kato(13), K.Kawata(3), Labaciren(5), G.M.Le(2), A.F.Li(14,6,2), C.Liu(2), J.S.Liu(2), H.Lu(2), X.R.Meng(5), K.Mizutani(11,15), K.Munakata(13), H.Nanjo(1), M.Nishizawa(16), M.Ohnishi(3), I.Ohta(17), S.Ozawa(11), X.L.Qian(6,2), X.B.Qu(2), T.Saito(18), T.Y.Saito(19), M.Sakata(10), T .K.Sako(12), J.Shao(2,6), M.Shibata(12), A.Shiomi(20), T.Shirai(8), H.Sugimoto(21), M.Takita(3), Y.H.Tan(2), N.Tateyama(8), S.Torii(11), H.Tsuchiya(22), S.Udo(8), H.Wang(2), H.R.Wu(2), L.Xue(6), Y.Yamamoto(10), Z.Yang(2), S.Yasue(23), A.F.Yuan(5), T.Yuda(3), L.M.Zhai(2), H.M.Zhang(2), J.L.Zhang(2), X.Y.Zhang(6), Y.Zhang(2), Yi Zhang(2), Ying Zhang(2), Zhaxisangzhu(5), X.X.Zhou(7)

(1)Department of Physics, Hirosaki University, Japan
(2)Key Laboratory of Particle Astrophysics, Institute of High Energy Physics, Chinese Academy of Sciences, China
(3)Institute for Cosmic Ray Research, University of Tokyo, Japan
(4)Department of Physics, Hebei Normal University, China
(5)Department of Mathematics and Physics, Tibet University, China
(6)Department of Physics, Shandong University, China
(7)Institute of Modern Physics, SouthWest Jiaotong University, China
(8)Faculty of Engineering, Kanagawa University, Japan
(9)Faculty of Education, Utsunomiya University, Japan
(10)Department of Physics, Konan University, Japan
(11)Research Institute for Science and Engineering, Waseda University, Japan
(12)Faculty of Engineering, Yokohama National University, Japan
(13)Department of Physics, Shinshu University, Japan
(14)School of Information Science and Engineering, Shandong Agriculture University, China
(15)Saitama University, Japan
(16)National Institute of Informatics, Japan
(17)Sakushin Gakuin University, Japan
(18)Tokyo Metropolitan College of Industrial Technology, Japan
(19)Max-Planck-Institut f\"ur Physik, Deutschland
(20)College of Industrial Technology, Nihon University, Japan
(21)Shonan Institute of Technology, Japan
(22)RIKEN, Japan
(23)School of General Education, Shinshu University, Japan