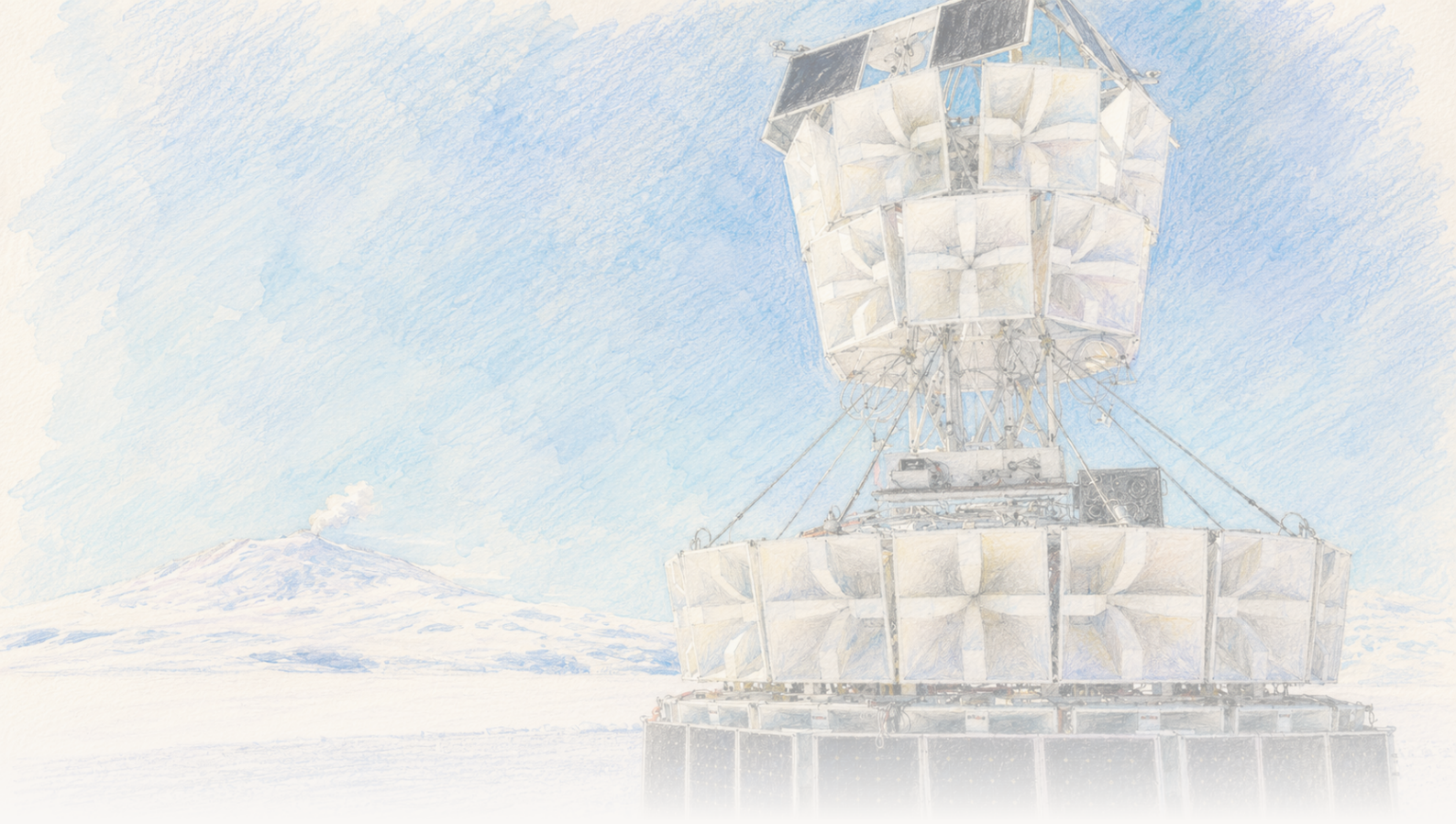




The CLEAN PAPER

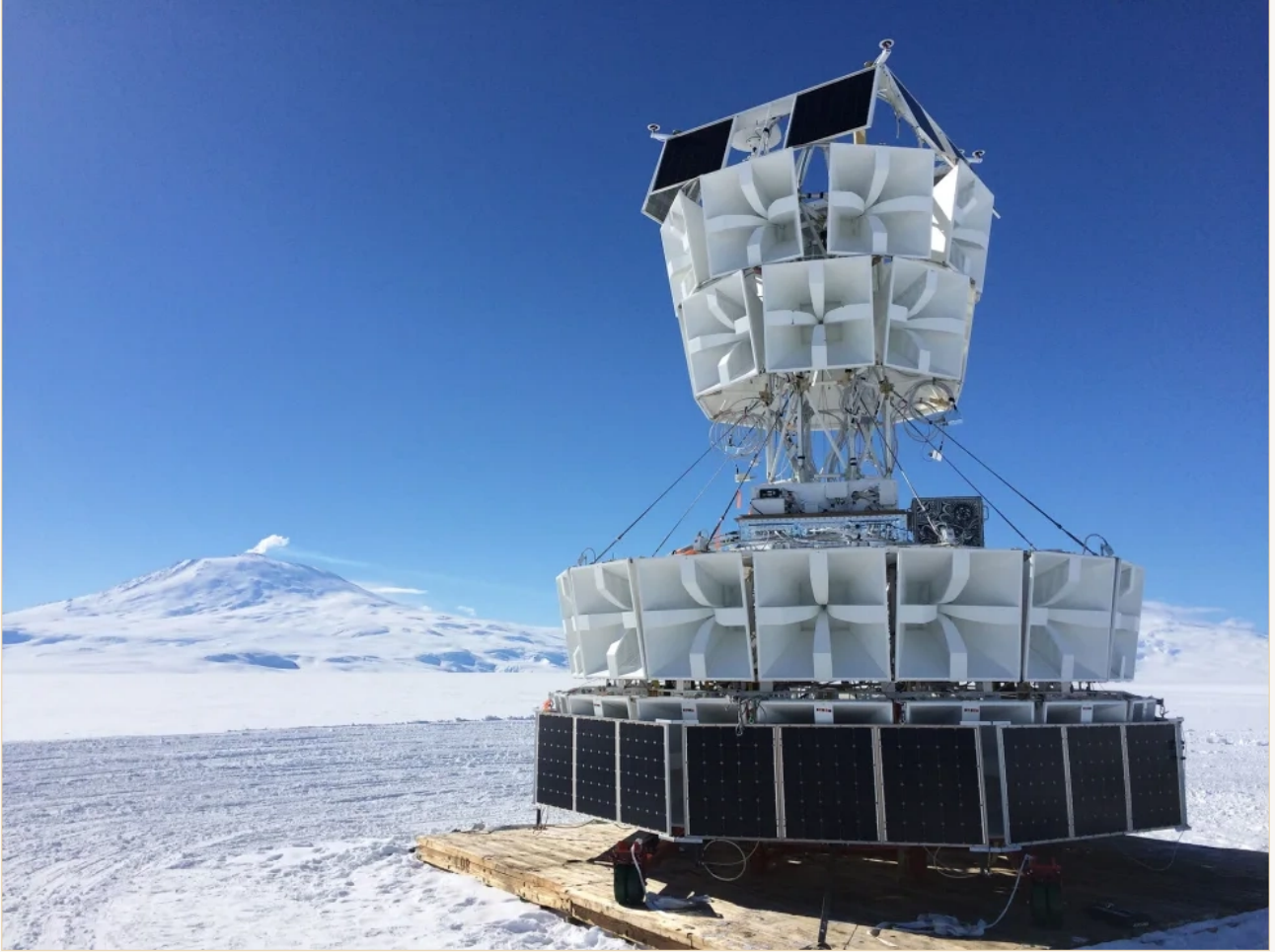
WHAT THE PAPER SAYS · WHAT IT DOESN'T · WHY IT MATTERS

Pulses raadiyoo addaa lama Antaarktikaa gubbaa jiran amma iyyuu hin ibsamne — ibsi “particle haaraa” deeggarsa dhaba jira

Pulses raadiyoo addaa lama qorannoo baaloonii Antaarktikaa irraa waggoota dura galmeeffaman amma iyyuu ibsa irratti walii galame hin qaban; barbaachi addaa Pierre Auger showers isaan irraa eegamu tokko illee hin argine, kanaan hiika addaa “particle haaraa” baay’ee dadhabsiise, anomaly garuu osoo hin furamin hafe.

Written by Lucio Vaglio · Cross-checked by Laura Nesso · Edited by Michele Renda · Figures by Laura Nesso
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Antenaawwan ANITA 48 gondolaa olka'iinsa faana 25 qabu irraa gara cabbii Antaarktikaatti qajeelfamaniiru.

Christian Miki / University of Hawai'i at Mānoa fair-use assertion

Baaloonii, cabbii fi pulses lama jalaa dhufan

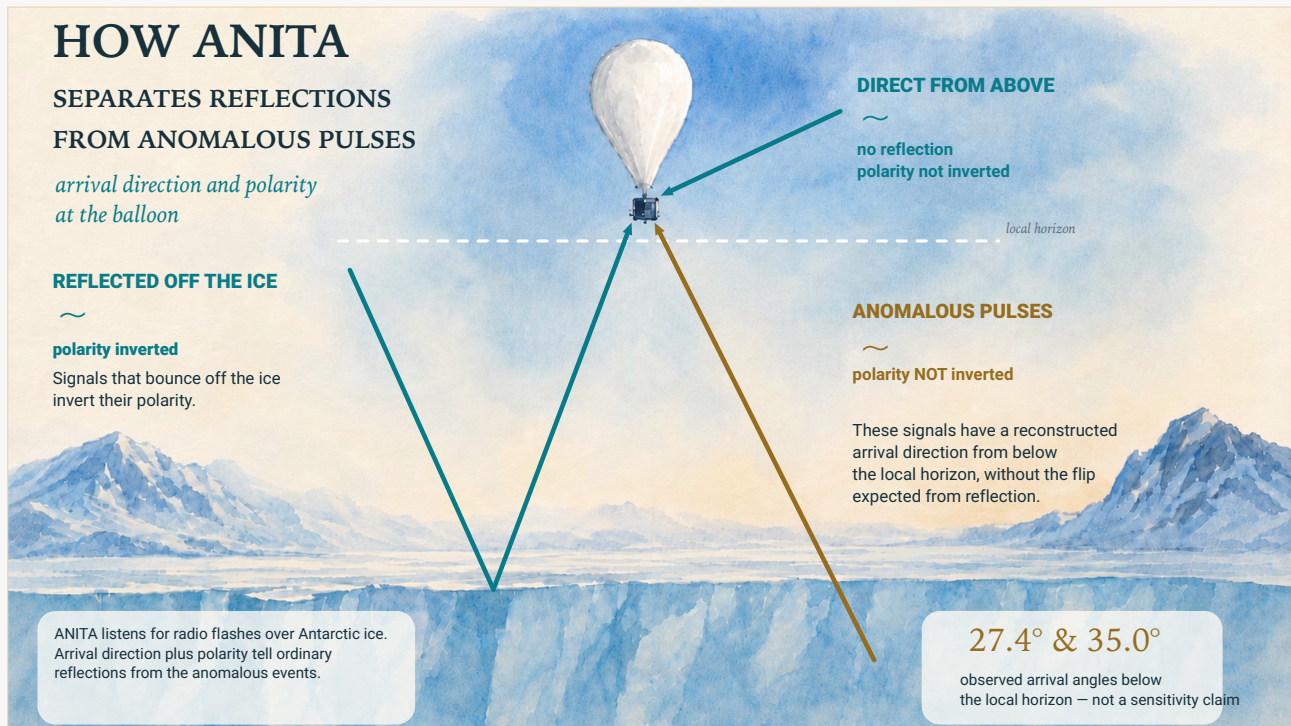
Yeroo hojii isaa irra caalaa, Antarctic Impulsive Transient Antenna — ANITA — baaloonii NASA jala, kiilomeetira soddoma caalaa olitti rarra'ee, bakka Lafa irratti hunda caalaa duwwaa ta'e irra torban hedduu yaa'aa dhaggeeffata.

Wanti inni dhaggeeffatu mallattoolee raadiyoo hawaa irraa dhufani dha. Yeroo particle anniisaa baay'ee guddaa qabu — cosmic ray yookaan neutrino — qilleensa yookaan cabbii rukutu, gara shower particles xixiqqoo ta'etti caccaba; shower sunis ifa raadiyoo yeroo gabaabaa baasa. Antaarktikaan isaan qabuuf bakka sirrii ta'uutti dhihaata: cabbii qulqulluu fi qorraa kiilomeetira hedduu, raadiyoon akka geejjibaa keessa darbu, fi wanta kiilomeetira dhibbaan lakkaa'amu keessatti mallattoo jeequ hin qabu. Hojiin ANITA ifa sana qabuun, boca fi yeroo isaa irraa maaltu akka isa uume dubbisuu dha.

Wanti inni dhaga'u irra caalaan sirnaan amaluu dha. Ifni tokko tokko kallattiidhaan gubbaa irraa dhufu. Kan biroo baay'een cabbii tuqanii gara antenaatti ol deebi'u — kunis mallattoo ifa qabu: deebi'uun

sun wave sana garagalcha (*polarity* mallattoo sanaa jijjiira), mallattoo physicists battalumatti dubbisuu danda'an. Deebi'ee calaqqisuu fi wanta dhugaa akkanatti adda baasani.

Yeroo lama, wanti pattern sana cabsu dhufe.



Baaloonii bira, pulse kallattiidhaan gubbaa irraa dhufu osoo hin garagalin ga'a; pulse cabbii irraa calaqqisee dhufu ammoo polarity isaa garagalchee ga'a — mallattoo baramaa cabbii irraa deebi'uu. Pulses addaa lamaan garuu kallattii *deebi'ee shallagame* kan daangaa samii naannoo jalaa gadi fageenyaan jiru irraa, garagaluu akkanaa malee ga'u; calaqqiin garuu isaan garagalchuu qaba ture. "Jalaa" jechuun kallattii mallattoon irraa ga'e sana ibsa — particle tokko Lafa keessaa ol ba'uu miti.

Original hybrid diagram — The Clean Paper CC BY 4.0

Imala tokko irratti 2006 fi kan biraa irratti 2014 keessa, ANITA pulse daangaa samii *jalaa* gadi fageenyaan jiru irraa — tartiibaan 27.4° fi 35.0° jalaa — akka ardii keessaa ol ba'eetti, garagaluu tokko malee qabate. Kanaaf calaqqii miti. Wanti dhugumaan cabbii keessaa gara baalooniitti ol deeme fakkaata.

Kun maaliif waan nama rifachiisutti dhihaata? Pulse sana wanti uume antenaatti angle ol ka'aa akkasii irraa ga'uuf qaama pilaaneetii keessaa — dhagaa jajjabaa kiilomeetira kuma ja'a yookaan torba — ol ba'uu qaba ture. Wanti kana danda'u jechuun ni ulfaata. Particle beekamaan wanta idilee keessa akka inni achi hin jirretti darbu neutrino dha; inni Lafa guutuu keessa osoo hin hubatin siqa — kanaaf yaadni uumamaa neutrino tokko dhagaa keessa ol deemee, atom cabbii jalaa jiru tokko rukutee, shower particles ol fiigan uume; ifa raadiyoo isaanii ANITA qabate jechuu dha. Garuu rakkoon isaa akkana: neutrino mallattoo *kana* uumuuf anniisaa gahaa qabu, dhugumatti, salphaatti dhaabuu danda'ama. Dhagaa hangana keessa yeroo baay'ee xuuxamuu qaba ture. Ya'aan neutrino kan lama keessaa darbanii hafan uumuuf gahaa ta'es detectors gurguddoo kana sirriitti qabuuf ijaaraman keessatti mul'achuu qaba ture. Ibsi salphaan tokko illee guutummaatti hin cufamne.

Kanaaf pulses lamaan amala sirrii didanii achuma turan. Argannoo miti — events lama matumaa argannoo miti — garuu homaa miti jechuu illee hin danda’amu. Anomaly dhugaa dha: waan nama hawwatu, sababiin isaas namni tokko illee amma iyyuu qaawwa Standard Model physics keessaa moo amala addaa cabbii, antena yookaan herregaa ta’uu isaa dubbachuu hin dandeenye.

Asitti gabaasni gosa tokko jecha *iccitii* jedhu fudhata, ifa dukkaneessa, maalitu Antaarktikaa jala jiraachuu danda’a jedhee gaafata. Sana didi. Gaaffiin dhugaa *bineensi maali cabbii keessa jira* hin turre. Gaaffii obsaa, miidhagaa hin taane, garuu saayinsii gara fuulduraatti sochoosu ture: **akkamitti adda baasta?**

Barreessitoonni maal godhan?

Ibsa nama gammachiisu sana qoruuf karaa qulqulluun jira. Pulses ANITA yaa’a shower ol deemuu kan dhugaa fi irra deddeebi’u irraa yoo dhufan — tau-neutrinos idilee yookaan particle haaraa yaadame irraa haa ta’u — detector gahaa guddaa ta’ee events akkanaa ilaalu muraasa isaanii qabuu qaba.

Pierre Auger Observatory kan Argentina keessatti argamu — detector cosmic ray yeroo kamiyyuu ijaarame keessaa hunda caalaa guddaa — barbaaduuf bakka gaarii irra jira. Fluorescence Detector isaa fayyadamuun, collaboration sun daataa 2004 hanga 2018 keessatti showers qilleensaa ol deemaa (jalaa dhufan, zenith angle 110° ol fi anniisaa 0.1 EeV ol qaban) barbaade. Murteessaan, filannoon guutuun daataan guutuun osoo hin ilaalamu *dura* murtaa’e — xiinxala “blind”, akka deebiin gara bu’aa hawwametti hin qindaa’amneef.

Maal argan?

Erga blindness bananii booda, event candidate **tokko** qofa hafe — events 0.27 ± 0.12 cosmic rays idilee yeroo muraasa keessatti akka ol deemutti dogoggoraan deebi’anii shallagaman irraa eegaman wajjin guutummaatti wal-sima. Jecha biraatiin, mallattoo dhugaa ol deemu hin jiru; background xiqqoo eegamu qofa.

Humni bu’aa kanaa wal bira qabuu keessa jira. Pulses ANITA yaa’a shower ol deemuu dhaabbataa irraa yoo dhufan, Auger **hedduu** galmeessuu qaba ture — energy spectrum tokko ta’uu danda’uuf events tilmaamaan 34 hanga 69, fi yaadota baay’ee of eeggannoo ta’an jalattillee yoo xiqqaate tilmaamaan 8. Tokko argate; innis background wajjin wal-sima. Barreessitoonni kana hiika shower ol deemuu wajjin “wal-dhabdee cimaa” jedhanii ibsu.

Kun maal jechuu ta'uu danda'a?

Argamuu dhabuun hangana guddaan odeeffannoo kenna. Events ANITA particles kallattii sana irraa dhufan kan dhugaa irraa yoo dhufan — tau-neutrinos idilee yookaan particles haaraa isaan ibsuuf yaadaman — yeroo dheeraa Auger itti ilaale keessatti lakkoofsa guddaa qabaachuu qaba ture. Hin qabne. Kun, haala addaa dirqisiisaa ta'e malee, ibsa “yaa'a bal'aa showers ol deemuu” — category yaadota Standard Model bira darban irra caalaan keessatti kufan — hojii irraa baasa.

Ibsi hafuu danda'u yaa'a particles shower uuman *hin taane*: kan baay'ee mari'atamu, calaqqii yookaan propagation effect cabbii fi geometry daangaa samii biraa irratti addaa ta'e, yookaan artifact meeshaa yookaan xiinxalaa. Tokko illee hin mirkanoofne. Kanaaf cuunfaan amanamaan: hiikni nama hunda caalaa gammachiisu miidhaa guddaa argate; sababni dhugaa ammoo amma iyyuu hin beekamu.

Kun maal *hin mirkaneessu*?

- Pulses lamaan maal akka ta'an **adda hin baasu**. “Physics haaraa cimsee dadhabsiisa” jechuun “furameera” jechuu miti.
- Sababa idilee tokko **hin mirkaneessu**. Candidate duraa tokko — calaqqii fuula Antaarktikaa jalaa — yaada qofa, bu'aa miti.
- Hiika kallattii ta'een waan “cabbii jalaa” dhufe tokko **hin arganne**. Antenaawwan ANITA baaloonii Antaarktikaa *gubbaa* jiru irraa rarra'u; “jalaa” kallattii pulse raadiyoo deebi'ee shallagame ibsa — sagalee, dubbii namaa yookaan waan cabbii keessaa maddu miti.
- Particle haaraa mirkanaa'e jedhu **hin deeggaru**. Bifni seenaa kanaa hunda caalaa qoodame ragaan gara itti akeeku faallaa isaa dha.

Ragaan hammam cimaa dha?

Giddu-galeessa; akkasumas akkasuma jedhamee ibsame.

- Fedhiin Standard Model bira darbuu events **lama** irraa, imalawwan ANITA lama keessaa, jechuun ni danda'ama.
- Barruun kun **bu'aa duwwaa** dha: carraawwan tokko tokko haquuf humna qaba, garuu events sun *maal* akka ta'an dubbachuu hin danda'u.
- Haquun sun lakkoofsaan ifa fi cimaa dha (events kudhan hedduu eegaman, tokko background fakkaatu argame) — garuu hiika “yaa'a shower ol deemuu” irratti xiyyeeffata, sababa yaadamuu danda'u hunda irratti miti.
- Ibsi idilee duraa (calaqqii fuula dhihoo) ta'uu danda'a, garuu hin mirkanoofne; filannoowwan tokko tokko (models transition-radiation muraasa) hojii biraatiin dadhabsiifamaniiru.
- Qorannoon tokko illee anomaly jalqabaa of danda'ee irra deebi'ee hin argine.

Kun puzzle xiqqaa fi didaa irratti daangaa ifa kaa'e dha — argannoo miti.

Maaliif barbaachisaa dha?

Ibsoonni yaadaman hanga particles haaraa addaa ga'an. Kan nama gammachiisu ari'uu mannaa, dameen kun waan miidhagaa hin taane hojjete: yaada sana detector of danda'aa fi baay'ee guddaa ta'e irratti qore — daataanis lakki jedhe. Meeshaan bakka bu'aa guddaa fi caalaatti miira-qabeessa ta'e, PUEO, irra deebi'ee ilaaluuf ijaaramaa jira.

Anomaly sun dhuma irratti waan idilee ta'uu danda'a. Kun kufaatii isa hin godhu. Safartuu hin ibsamne tokko hamma inni badu yookaan argannoo dhugaa dirqisiisutti dhiphisuun *hojii sana* dha — deebiin amanamaan amma iyyuu “hin beeknu” waan ta'eef sirriitti ilaaluun gatii qaba.

Cuunfaa ifaa

Pulses raadiyoo lama kan imalawwan baaloonii Antaarktikaa ANITA 2006 fi 2014 irraa argaman, angle daangaa samii jalaa gadi fageenyaan jiru irraa dhufan fakkaatu; Standard Model kana ibsuuf rakkata. Barbaacha addaa Pierre Auger Observatory 2025 candidate tokko qofa, background wajjin wal-simu, argate; pulses sun yaa'a showers ol deemuu irraa yoo dhufan kudhan hedduu eegamu ture. Kun hiika addaa “particle haaraa” cimsee dadhabsiisa; gara calaqqii, propagation yookaan effect meeshaa ANITA irratti addaa ta'etti akeeka — garuu sababni amma iyyuu dhugumaan hin beekamu. Particle haaraa mirkanaa'e miti; mallattoo iccitii cabbii keessaa dhufe illee miti.

Sakatta'a soba-maleessa

Barruun maal agarsiisa: Barbaachi blind Pierre Auger (2004–2018) showers qilleensaa ol deemaniif godhame candidate tokko, background cosmic ray event 0.27 eegamu wajjin wal-simu, argate. Anomalies ANITA yaa'a shower akkanaa irraa yoo dhufan, Auger tilmaamaan 34–69 (yookaan yaadota of eeggannoo jala yoo xiqqaate ~8) arguu qaba ture. Kun hiika shower ol deemuu, scenarios “particle haaraa” Standard Model bira darban dabalatee, cimsee dadhabsiisa.

Wanti ta'uu danda'u garuu hin mirkanoofne: Calaqii yookaan propagation raadiyoo cabbii fi daangaa samii bira jiru, yookaan artifact meeshaa/xiinxaalaa ANITA irratti addaa ta'e.

Wanti inni hin agarsiisne: Events sun particle haaraadhaan uumamuu; mallattoolee cabbii jalaa ta'uu; waan paranormal, nam-tolchee yookaan dhaga'amu keessa jiraachuu; yookaan sababni amma beekamuu.

Daangaawwan ijoo: Fedhiin Standard Model bira darbuu events ~lama irratti hundaa'a; kun bu'aa duwwaa carraa tokko daangessu garuu adda baasuu hin dandeenye dha; haquun sun addatti hiika “yaa'a shower” irratti xiyyeeffata; anomaly jalqabaa of danda'ee irra deebiin hin argamne.

Dubbisaan waliigalaa hammam amanuu qaba? Kun particle haaraa mirkanaa'e akka hin taane, mallattoo cabbii keessaa akka hin taane, fi hiikni yaa'a addaa amma cimsee dadhabsiifamuu isaa irratti

amantaa guddaa. Sababa dhugaa amma iyyuu banaa jiru irratti amantaa xiqqaa. Haala sirrii: anomaly hin furamne, garuu irra caalaa waan idilee ta'uu malu, irratti hawwii qabaachuu.

Maddoota

Phys. Rev. Lett. 134, 121003 (2025)

<https://doi.org/10.1103/PhysRevLett.134.121003>

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