Preliminary discussions: potentials of exotic particle searches with LHAASO

Yusheng Wu (吴雨生)

University of Science and Technology of China

Modern Physics Department & State Key Laboratory of Particle Detection and Electronics

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Outline

- Physics motivation for exotic particles (MM, Q-ball, FCP)
- Past sensitivities and searches in a nutshell
- LHAASO possibilities and sensitivity ranges

Disclaimer: (biased) materials for preliminary discussions only, no real simulation nor calculation results

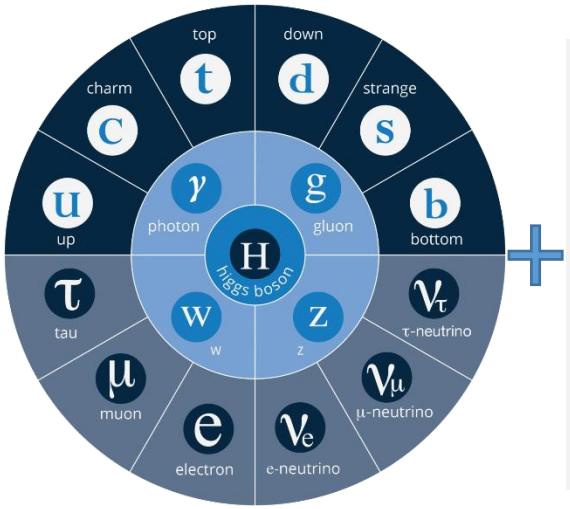
INFO: my primary focus has been collider physics studies at the Large Hadron Collider (CERN)

Frontiers at smallest scale

The "Standard Model" is very successful (verified up to 1ppm precision),

yet evidence of dark matter, ν mass, matter-antimatter asymmetry drives us to seek for more underlying truth (new physics)

➡ **Rely on Ultra-Precision apparatus to reveal**



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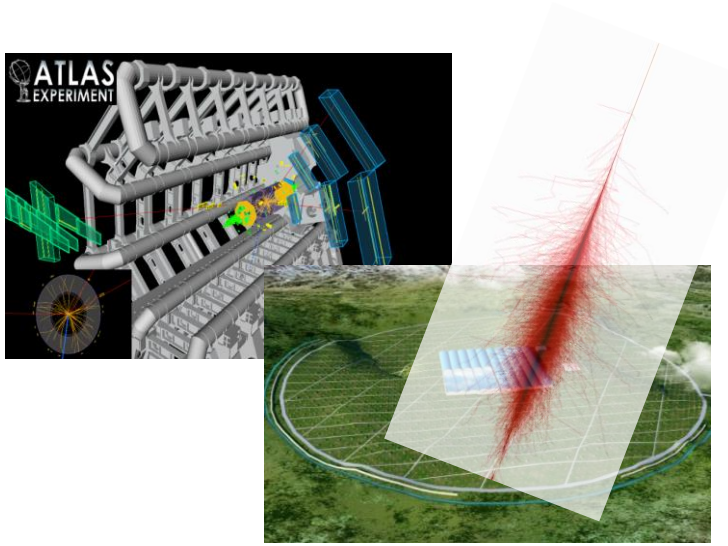
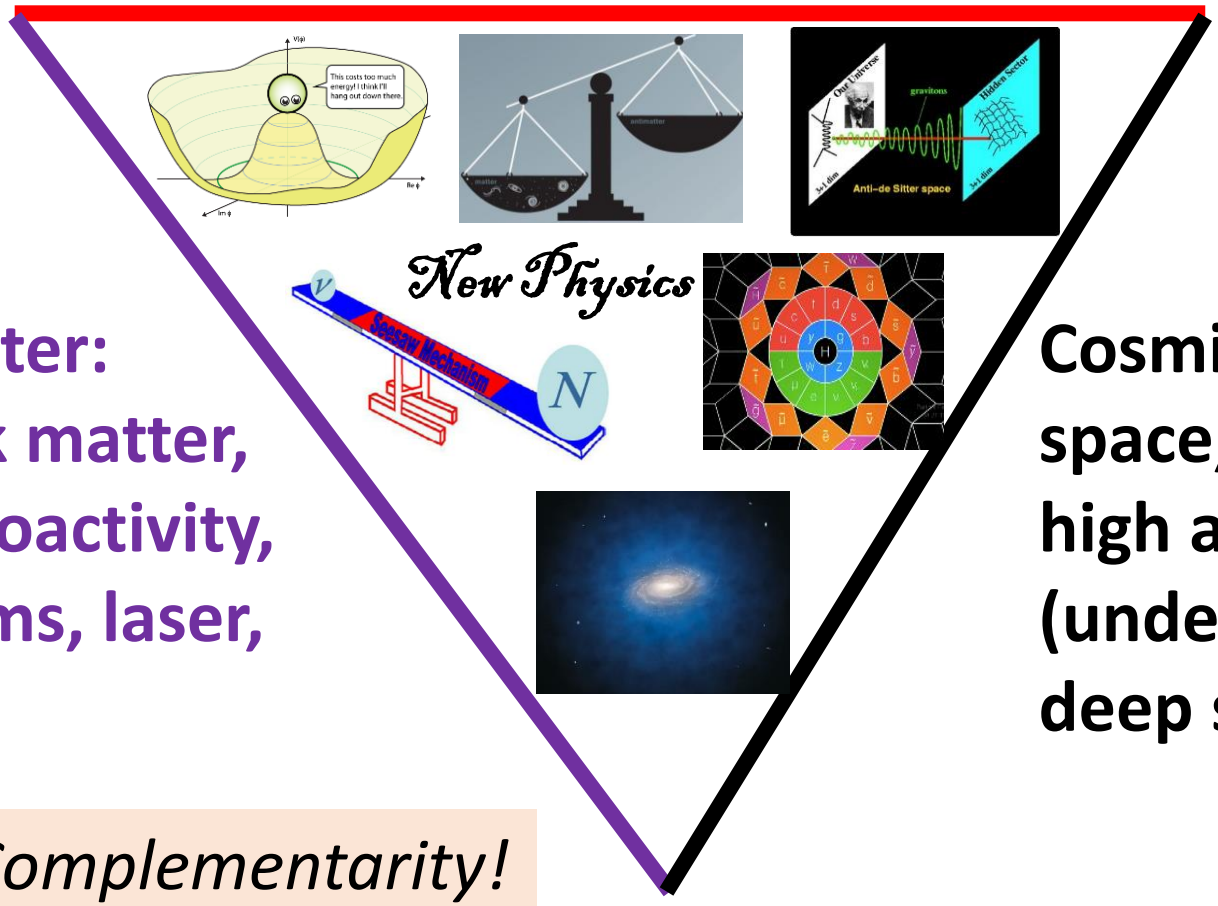
New?

SUSY,
GUT, String,
Extra dim.
ν See-saw……



The multifold means to probe new physics

Collider/Accelerator/Reactor

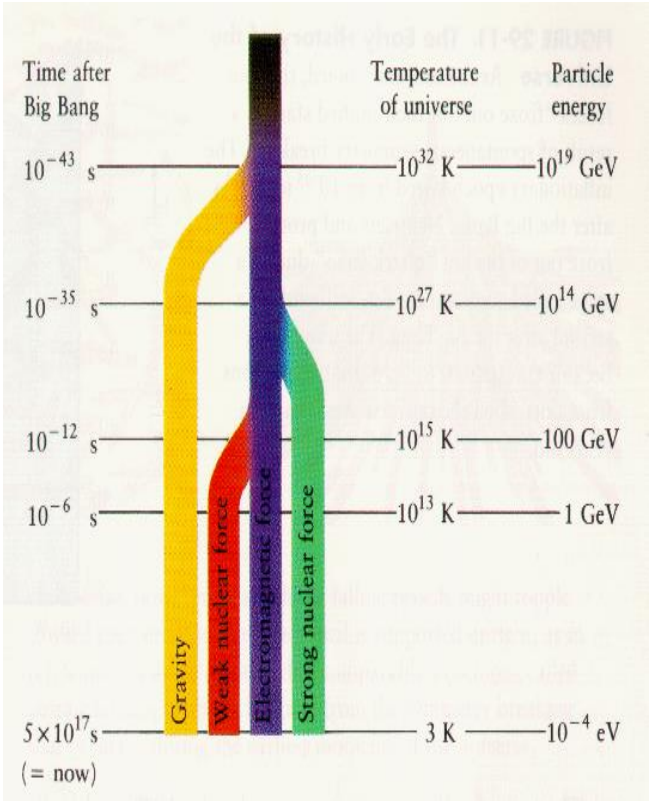


Matter:
bulk matter,
radioactivity,
atoms, laser,
……

Cosmic Ray:
space, balloon,
high altitude,
(under)ground,
deep sea …

Complementarity!

Physics Scales and Massive Exotics Particles (MEP)



Collider

Cosmic Rays

Massive particles often expected with *theories at ultra scales* (GUT, string, …)

➔ Inaccessible with direct collider experiments

➔ Indirect probe via low-energy precision measurements (assume quantum loop effects)

➔ Direct probe ONLY possible via *cosmic rays (from Big Bang, stable enough to propagate onto earth)*

Popular MEP candidates for cosmic–ray searches [1][2][3][4]:

Magnetic monopoles (MM): Why no magnetic charge? How electric charge is quantized?

Fractional charged particles (FCP): Why no free fractional charge?

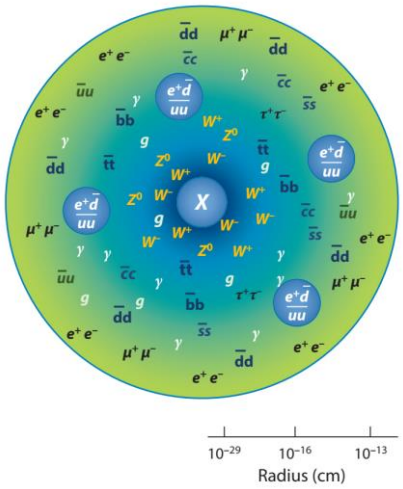
Q-balls: stable field configuration aggregating new particles

Possible cold dark matter candidates

Example: Monopoles with Multifold

* Certain level of similarities for FCP and Q-ball searches

Structured MMs relating to GUT:

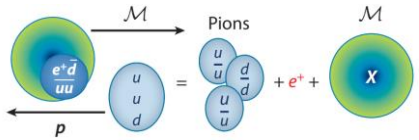


Common: much stronger energy loss in EM process due to magnetic charge

GUT scale MMs (mass >= $10^{15\text{-}16}$ GeV):

- $\beta <= 10^{-3}$
- particle dE/dx, time-of-flight measurement, nuclear tracking detector, etc. (e.g., MACRO at Grand Sasso)
- Or it can catalyze proton decays ➔ enable also searches at CR observatories (depending on catalyze σ)

Intermediate scale MMs ($10^{10\text{-}12}$ GeV)



- High β
- Cherenkov light dE/dx (ICE CUBE etc.)
- Air shower search (X_{max}, shower profile) (AUGER, LHAASO, etc.)

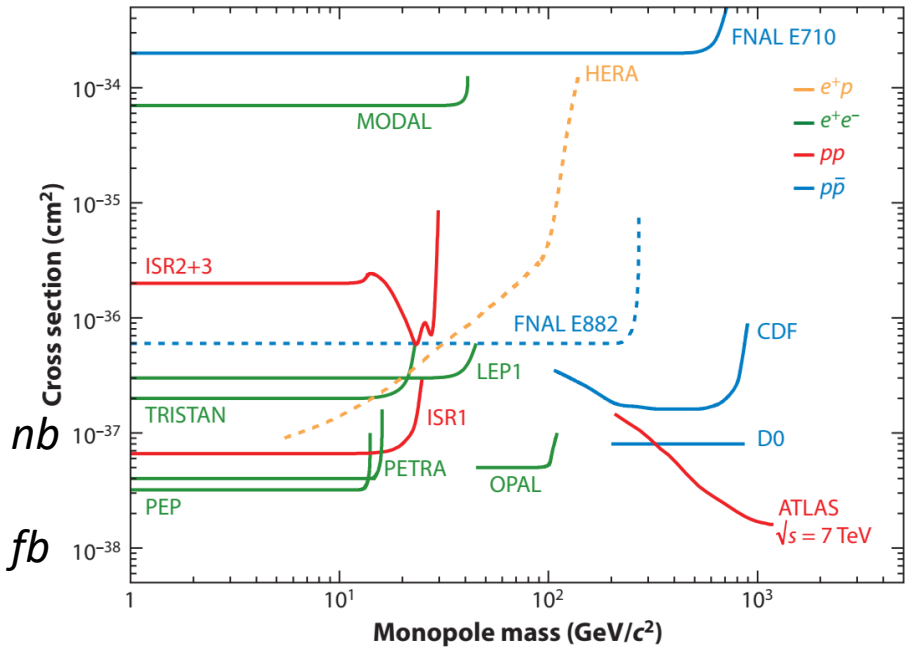
Lower scale MMs (GeV – TeV):

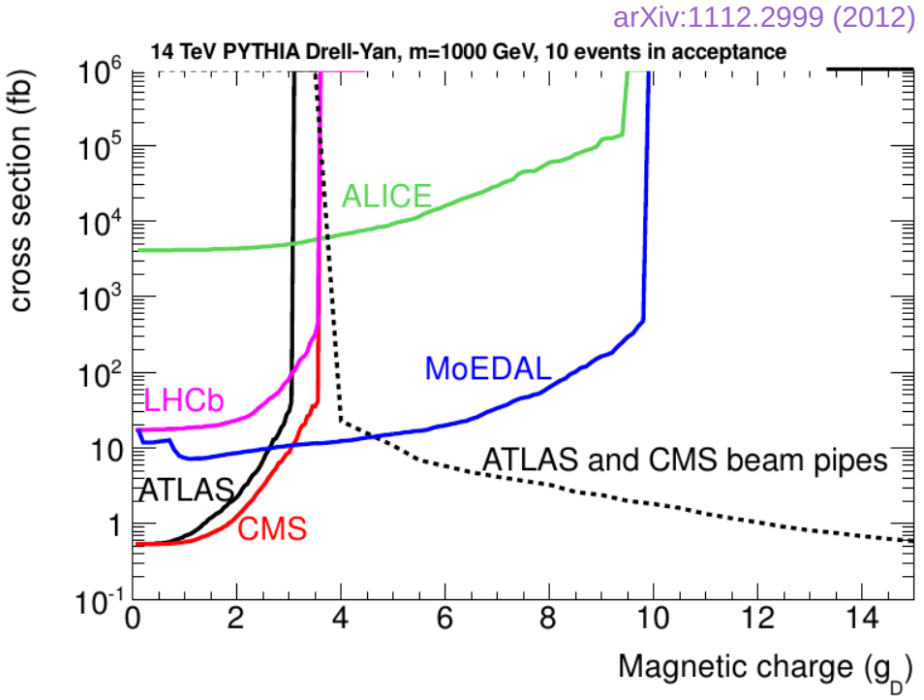
- Collider searches (e.g., Large Hadron Collider)

All mass ranges could be probed via *bulk matter searches*, provided MMs can be bounded and condensed into matter; or via *induction methods* (drawbacks as small effective area)

“Market” Survey: Collider

Long range of endeavor since start of collider experiment => upper limits on production cross-sections





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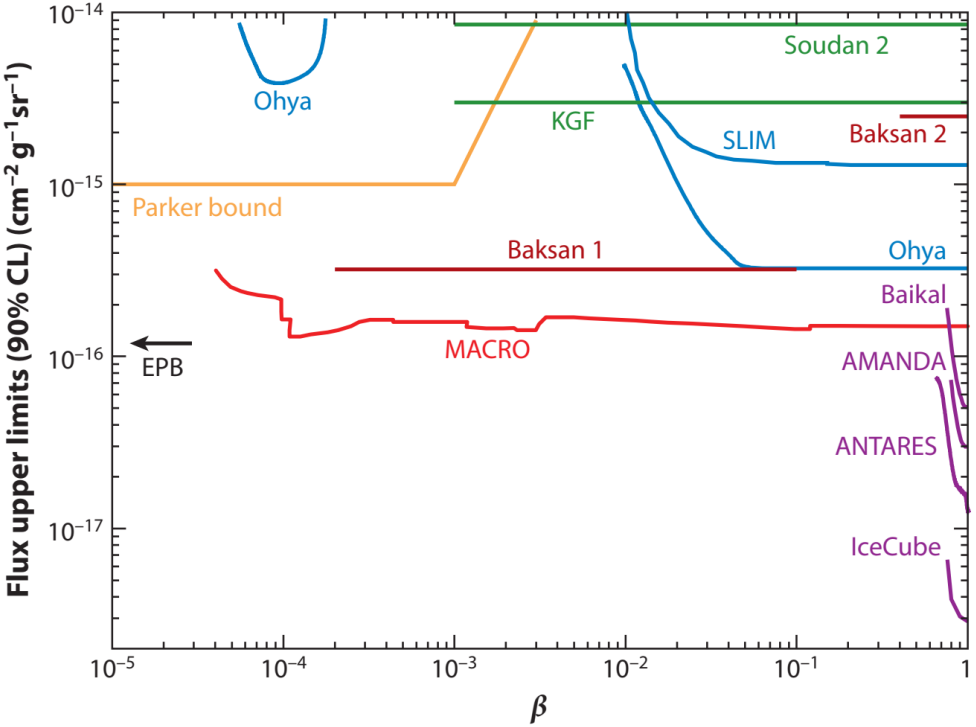
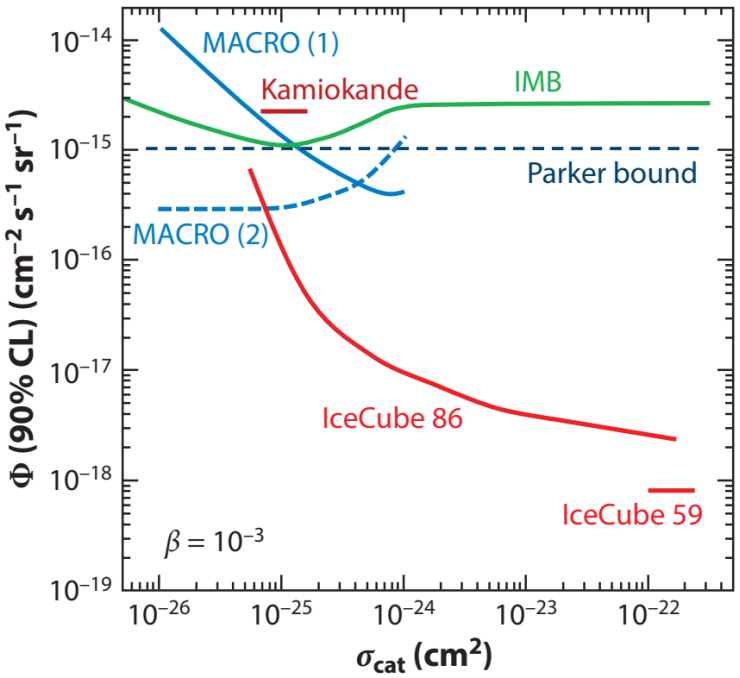
“Market” Survey: Cosmic Ray

Sensitivity v.s. β



Sensitivity v.s. catalyze σ



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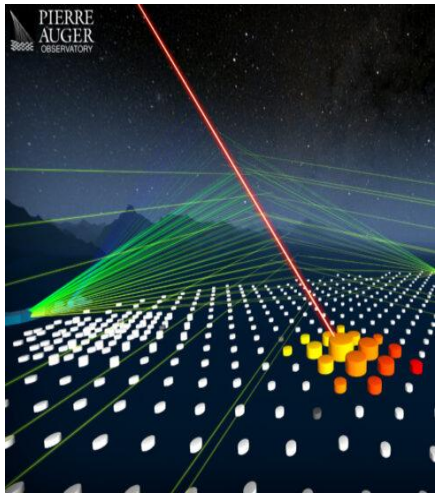
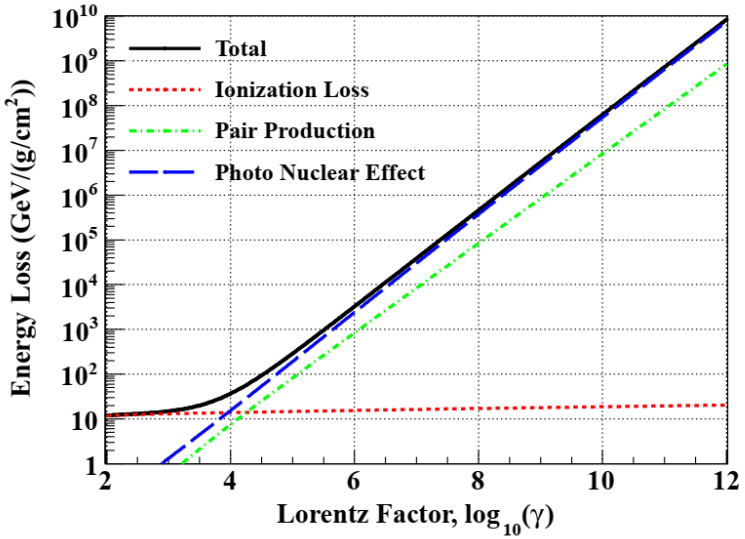
EAS searches: example from AUGER

PRD 94, 082002 (2016)

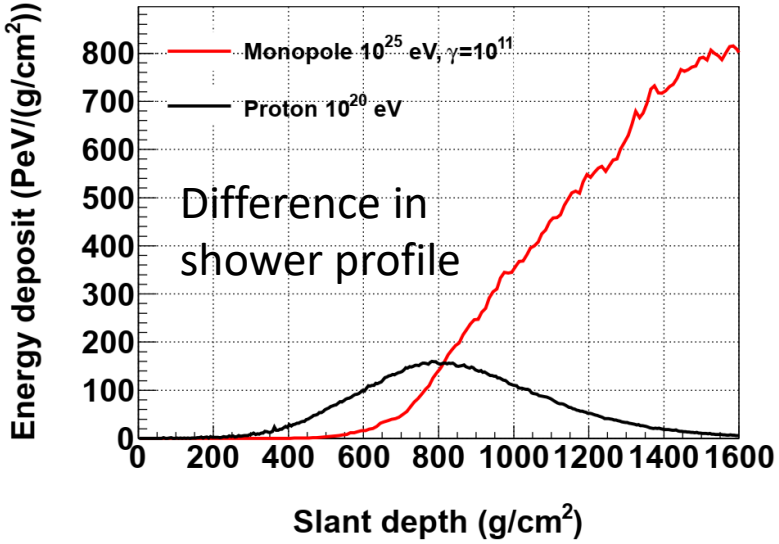


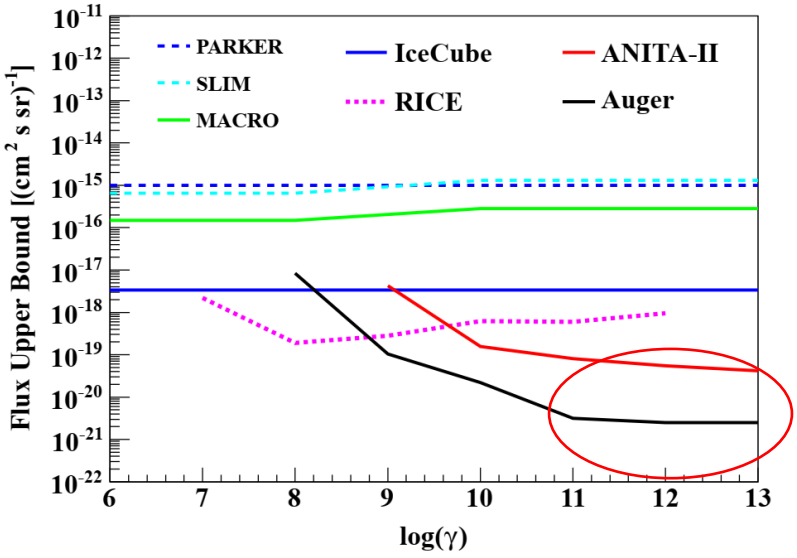


Target for ultra relativistic MMs

Deployed MM interactions in EAS simulation

Primary use of fluorescence detector for shower profile

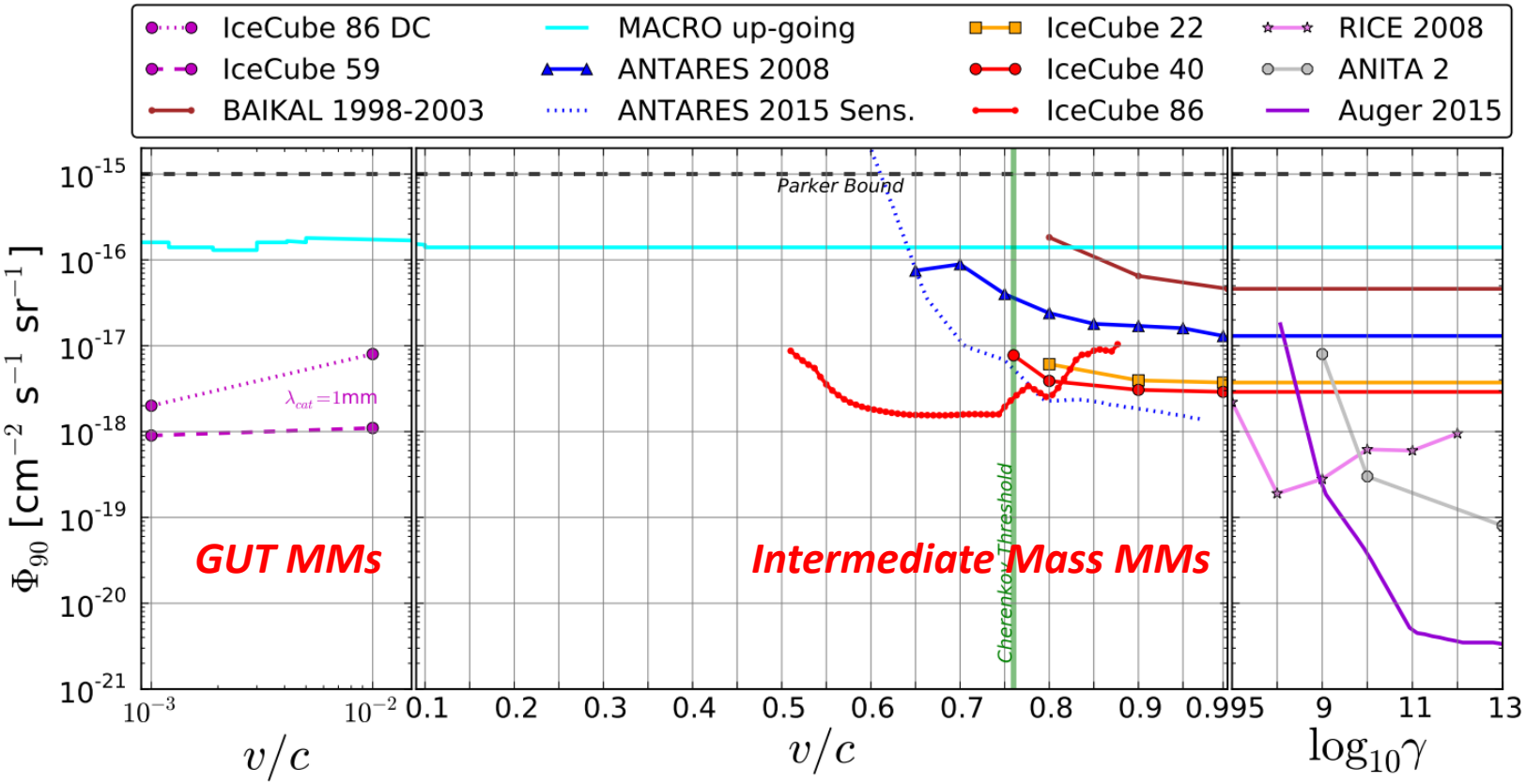




Best sensitivity for UR MMs

Possibilities with LHAASO

EPJC (2018) 78: 924



Large parameter space – awaiting next generation of experiments

***For $\log_{10}\gamma > 10$ region**, AUGER has superior sensitivity due to large exposure*

***For intermediate g region** (above Cherenkov threshold), LHAASO may have similarities in sensitivities w.r.t. ICE CUBE (assuming ~zero background level)?*

Possibilities with LHAASO

- Caveat: previous discussions based on wild assumptions

- *Actual performance of LHAASO relies on further detailed studies*
  - Cosika simulation of exotic particles in EAS (example of customized implementation by Auger collaboration)
  - Performance of WFCTA on shower profile measurements
  - Possible adoption of other detectors for signal identification as well as background rejection (KM2A, WCDA)

- *More detailed study of shower profile may bring other opportunities (signature with catalyze proton decay, lower β, …)*

Summary, Outlook

- Searches for massive exotics particles are strongly desired by particle physicists
- Searches for popular MEPs are frequently part of physics programs for cosmic ray observatories; on the contrary, CR observatories are the ONLY places for DIRECT probe
- Despite of the difficulties, experiments are pushing the sensitivity limits for those particles, such as magnetic monopoles
- LHAASO has its unique place in cosmic ray measurements, and good to conduct a search for MMs etc., while exact sensitivity shall be understood better (comparison w.r.t. ICE CUBE)
- EAS simulation incorporating MEPs is a first, next step to go

Thanks!