Session summary

The discussion focused on near- and longer-term projects, concept ideas and instrumentation for direct cosmic-ray measurements and multimessenger astrophysics. Some of the contributing speakers were otherwise not scheduled for an oral or poster presentation, since they did not submit a paper to this ICRC, but the conveners thought it to be important to the 'future instruments' topic for them to be included. Thus, this session represented a singular focus point for some of the topics discussed. The session was roughly organized along messenger type, e.g., cosmic ray electrons, nuclei, antimatter, UHECRs, VHE and UHE neutrinos, etc, with an understanding that many instruments are sensitive to multiple messenger types. The brief discussion summary below is indexed to slide numbers in the file CRD_DiscussionSession_15.pdf which contains a compendium of all slides shown at the discussion session.

1) Primary nuclei and electrons

The science case was briefly motivated by S. Coutu and J. Krizmanic (slides 4, 5, and 18), but will be the subject of different discussion sessions 17 (nuclei) and 16 (electrons).

S.-N. Zhang discussed plans for the High Energy Cosmic-Radiation Detection (HERD) facility on slides 6-9. This is a next-generation instrument expected to detect gamma rays above 100 MeV (geometric factor >0.2 m^2 sr at 200 GeV), electrons between 10 GeV and 100 TeV (geometric factor >2 m^2 sr at 200 GeV) and nuclei from 30 GeV to 3 PeV (geometric factor >1 m^2 sr at 100 TeV). HERD is planned for deployment to the Chinese Space Station around 2027.

C. De Santis discussed plans for the High Energy Particle Detector (HEPD-02) on slides 10-17. This is planned to launch on the CSES-02 satellite by the end of 2022, as a companion instrument and satellite to HEPD-01 / CSES-01 already in orbit. The two satellites will orbit the Earth180 degrees apart and make a comprehensive set of measurements of radiation belts and the Earth’s magnetospheric properties. The detector will be sensitive to electrons from 3 to 100 MeV and to protons from 30 to 200 MeV.

P. S. Marrocchesi (with P. Maestro) discussed the important issue of systematics and uncertainties affecting different measurements, on slides 19-20. A clear understanding of the issues is critical in resolving the tension that exists between some measurements of cosmic messengers, most prominently in the all-electron spectrum between about 50 and 2000 GeV, i.e., between the CALET/AMS-02 results compared with the DAMPE/ Fermi-LAT results. The presentation spurred a lively debate, with the main conclusion largely endorsed, that a concerted joint effort between collaborations to investigate the source of these systematics is needed, of the sort the Pierre Auger and TA collaborations have been carrying out successfully for many years.

2) Secondary nuclei

The science case was briefly motivated by S. Coutu (slide 21), but will be the subject of a different discussion session 18.

N. Park presented the status of the High Energy Light Isotope eXperiment (HELIX) on slide 22. This is a balloon spectrometer targeted at light isotopes, primarily 10Be and 9Be, in an energy range of 0.2 to 3 GeV/n with a first high-altitude balloon flight expected from Sweden in summer 2022 (with an extension to 10 GeV/n with an eventual Antarctic balloon flight). Interestingly AMS-02 are also showing their first 10Be and 9Be isotope measurements at this ICRC, covering a similar energy range as targeted by HELIX.

L. Derome discussed the case for B nuclei measurements on slides 23-24, in particular showing the value of extending B/C (or B/O) measurements to beyond 1000 GeV/n, to get the strongest possible handle on the Galactic diffusion coefficient driving cosmic-ray propagation. He mentioned the possible capabilities of future projects ALASInO and AMS-100 (described in Section 4) below).

3) Ultraheavy nuclei

The science case was briefly motivated by J. Krizmanic (slide 25).

B. Rauch discussed the Trans-Iron Galactic Element Recorder for the ISS (TIGERISS) on slides 26-27. This is an evolution of the SuperTiger balloon instrument that has made successful measurements of cosmic-ray abundances from Zn (Z=30) up to Ba (Z=56). TIGERISS would deploy to the JEM-EF module of the ISS and would be sensitive to an extended range of nuclei from B to Pb (Z = 5 to 82) with a geometric factor of 1.6 m^2 sr.

B. Rauch also discussed (slides 28-29) the prospects for the Advanced Particle-astrophysics Telescope (APT), and a LDB balloon prototype called ADAPT. APT is a balloon-borne stack of silicon strip detectors capable of gamma-ray detection as well as nuclei from protons up to Pb, assuming sufficient exposure. A prototype APT-Lite instrument was already flown by balloon in 2019,

4) Antimatter

The science case was briefly motivated by S. Coutu (slide 30), but will be the subject of a different discussion session 16.

P. von Doetinchem presented (slide 31) an update on the General AntiParticle Spectrometer (GAPS) instrument, aimed at detecting antiprotons, antideuterons and antihelium nuclei through the decay of exotic atoms formed in nucleus-antinucleus annihilation. A prototype instrument pGAPS flew by balloon already, and the main GAPS instrument is slated for an Antarctic balloon flight in late 2022.

S. Schael discussed on slides 32-34 and ambitious concept for an AMS-100 instrument deployed at the L2 Lagrange point and comprising a 1T superconducting magnet with silicon tracker and calorimeter. The 6m long (2 m diameter) magnet + tracker would provide a MDR of 100 TV, with a geometric factor of up to 100 m^2 sr. It might have the sensitivity to detect secondary antideuterons, if such are not present in appreciable numbers from dark matter annihilation.

R. Battiston discussed on slides 35-40 another ambitious Antimatter Large Acceptance Detector In Orbit (ALADInO) concept, also ultimately a spacecraft at the L2 Lagrange point (~2040) but with an earlier pathfinder payload (~2030). A magnet spectrometer would use high-Tc superconducting coils for a MDR of > 20 TV, with a geometric factor of about 10 m^2 sr, with overall event rates roughly 100 times those of AMS-02.

4) Multimessenger astrophysics

The science case was briefly motivated by J. Krizmanic (slide 41), but will be the subject of discussion sessions 25, 26, 27, and 28.

A. Olinto discussed on slides 42-45 the Probe Of Extreme Multi-Messenger Astrophysics (POEMMA) mission, aiming to detect from Earth orbit the nitrogen fluorescence from large air showers from UHECRs or UHE neutrinos. There would be dual telescopes flying in loose formation in 525 km altitude orbits (25 km to 300 km apart), with an operational lifetime of 3-5 years starting in >2029. The technology is challenging (4 m diameter mirrors, 3.3 m diameter corrector lenses, 1.6 m diameter focal surfaces of MAPMTs and SiPMs), but in principle the fluorescence telescopes' field-of-view can lead to an exposure around a factor of 3 times the Auger exposure reported at the 2019 ICRC and 17 times that of TA in precision stereo mode, but over an order of magnitude that of Auger and a factor of seventy that of TA at E_CR > 10^20 eV in tilted limb-viewing mode. The limb-mode is also where the Cherenkov signal from upward-EAS from Earth-interacting tau neutrinos can occur.

A. Vieregg discussed (slide 46) the Payload for Ultrahigh Energy Observations (PUEO), an antenna array to fly by Antarctic balloon in late 2024 (approved and funded). This is an evolution of the ANITA balloon instrument (with upgraded antennas and electronics), targeting the coherent radio emissions from large particle showers in Antarctic air/sea/ice from UHECRs and UHE neutrinos.

L. Wiencke discussed (slides 47-48) the ongoing EUSO program of space-borne observations of nitrogen fluorescence from UHECR or UHE neutrino air showers. A MINI-EUSO instrument has flown on the ISS to measure backgrounds and flasher signals, 2 balloon EUSO prototypes have flown already, a super-pressure balloon prototype EUSO-SPB2 instrument is planned for launch from New Zealand in 2023, and ultimately a space-borne EUSO-EVA or K-EUSO are envisaged.

J. Hörandel discussed (slide 49) a concept for a Global Cosmic Ray Observatory (GCOS), a world-wide initiative to deploy a massive network of instruments to

coordinate detection of all messengers beyond 2030. A first workshop to explore ideas was held in 2021 and another is anticipated for late 2021/early 2022.

S. Wissel discussed (slide 50) the Zettavolt Askaryan Polarimeter (ZAP) idea of deploying a spacecraft in orbit around the Moon with an antenna array sensitive to coherent radio emissions from the lunar regolith arising from UHECR showers. This could in principle extend the range of measurements up to the 10^21 eV range.

M. Unger discussed (slides 51-52) the ongoing NA61/SHINE program of accelerator-based measurements of particle production in a variety of collisions at CERN, with a comprehensive program of relevance to cosmic rays (p+C air shower, deuteron, antideuteron, antiproton production, nuclear fragmentation into light nuclei, particularly isotopes). The near future is seeing detector upgrades and data runs to investigate Li, Be, B, C, N fragmentation/production.

5) The CRD/CRI connection

The science was briefly motivated by J. Krizmanic (slides 53-54), making the case for the increasing overlap in energy of direct cosmic ray measurements from below with indirect cosmic ray measurements from above, referring to CRD and CRI papers presented at this conference. Invited were T. Fujii and M. Casolino, the conveners of discussion session 13 on future projects/instrumentation for indirect cosmic ray measurements.

T. Fujii (with M. Casolino) discussed the plans for discussion session 13 on future projects in CRI on slides 55-61. J. Krizmanic and S. Coutu provided them with a digest of the slides from what was presented in session 15 and will present these in session 13. The final summary for session 13 should be reviewed after it is completed on 21-Jul-21.