CLUSTER ACTIVE ARCHIVE - THE RAPID CONTRIBUTION

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ABSTRACT

The Cluster Active Archive (CAA) is an ambitious project for the long term accessibility of high resolution Cluster spacecraft data gathered throughout the operating phase of the mission. As one of 11 instruments per spacecraft RAPID (Research with Adaptive Particle Imaging Detectors) detects counts of electrons with its Imaging Electron Spectrometer (IES) and protons, helium and heavier ions with the Imaging Ion Mass Spectrometer (IIMS). The particles are captured in either three electron and ion heads which are divided in 9 or 12 polar directions, respectively, over 16 azimuthal sectors. Thus the RAPID instrument is able to provide 3-D particle measurements in an energy range of 28 to 1500 keV. For CAA RAPID delivers count rates and differential fluxes of omnidirectional and 3-D data products and their standard deviations, particle flow directions and pitch angles, useful diagnostic products for expert users, caveat and instrument mode files and 6 hour overview plots.

1. THE RAPID INSTRUMENT

The instrument is physically a single structure which contains all major elements like the IIMS and IES sensor systems, the front-end electronics (called SCU), and the digital processing unit (DPU) with the low-voltage power-supply (LVPS) and the spacecraft interface. A precise description of the RAPID instrument is given in [1].

1.1. The IIMS Instrument

The centerpiece of the IIMS sensor system is the so-called SCENIC (Spectroscopic Camera for Electrons, Neutral, and Ion Composition) detector head, shown in Fig. 1. In essence, this is a miniature telescope composed of a time-of-flight and an energy detection system. The particle identifying function of the SCENIC spectrometer is obtained from a two-parameter measurement: the particle's velocity V and its energy E are measured as independent quantities; the particle's mass A is then uniquely

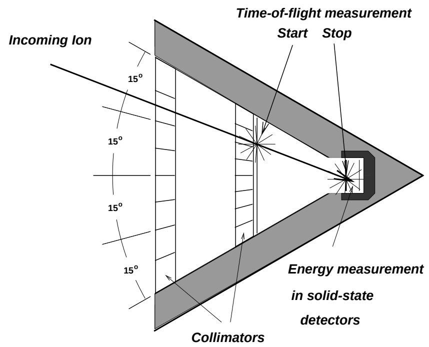

Fig. 1. *One of the three SCENIC heads making up the IIMS part of RAPID. Shown is an incoming ion that triggers a start signal at a foil, which also serves to determine the fine direction, and a stop signal when it enters the solid state detector, where its energy is measured.*

determined either by computation ($A \sim E/2$) or by statistical analysis in two-dimensional (V, E) space with the mass A as the sorting parameter. Actually the velocity detector measures the flight time T taken by the particle to travel a known distance in the detector geometry.

Each SCENIC head has a field-of-view that is 6° wide (in the direction of the spacecraft spin) and 60° in the other direction (in the plane containing the spin axis). By means of the imaging features of this instrument, the particle's incident direction is assigned to one of 4 subdivisions of this field-of-view, each of 15° height. With three detector heads in all, the full range of 0–180° is covered by 12 polar angular segments (left side of Fig. 3).

1.2. The IES Instrument

Electrons with energies from ∼35 keV to 400 keV are measured with the IES (Imaging Electron Spectrometer). Microstrip solid state detectors having a 0.5 cm × 1.5 cm planar format with three individual elements form the image plane for three acceptance "pin-hole" systems. Each system divides a 60° segment into 3 angular intervals, Fig. 2. Three of these detectors provide electron measurements over a 180° fan (right side of Fig. 3).

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The 9 individual strips on the three focal plane detectors are interrogated by a multichannel switched-charge/voltage-converter (SCVC), which provides for each particle coded information on the strip number and particle energy. This primary information is transferred to the DPU for further evaluation. Table 1 summarizes the characteristics of the two sensors.

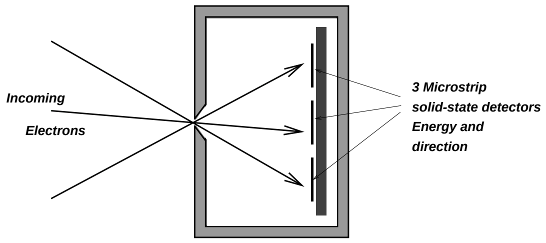

Fig. 2. *One of the three IES heads, containing three solid state detectors to determine the direction of the incoming detected electron to within 20°.*

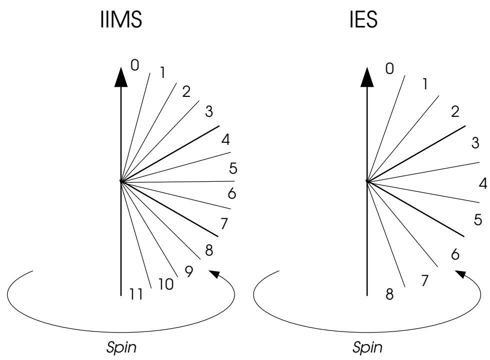

Fig. 3. *The IIMS (left) and IES (right) polar segments relative to the spin axis. Note that the spin axis actually points towards the $-Z$ GSE axis (southward).*

	IIMS	IES
Protons [keV]	28-1500	—
Helium [keV]	29-1500	—
CNO [keV]	90-1500	—
Electrons [keV]	—	35-400
Field–of–view		
Polar	180°	180°
Azimuthal	± 3°	± 17.5°
Angular coverage		
Polar (Range/intervals)	180°/12	180°/9
Azimuthal (Range/intervals)	360°/16	360°/16

Table 1. *Characteristics of the IIMS and IES sensors.*

1.3. Spin Sectorization

For both IIMS and IES, the azimuthal distribution of particle fluxes is obtained by sorting the counts into 16 sectors during one rotation of the spacecraft (see Fig. 4).

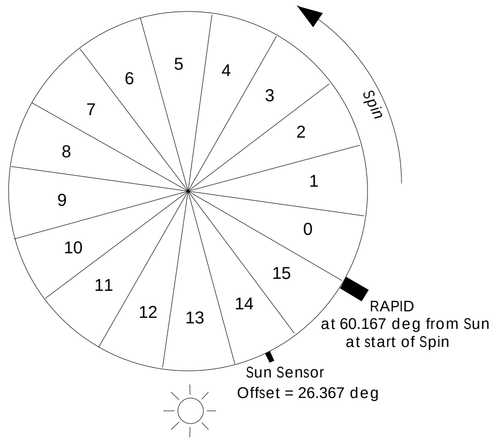

Fig. 4. *The RAPID sectorization relative to the sun.*

2. THE RAPID DATA PROCESSING CHAIN

Fig. 5 shows the data processing chain for the CAA, which starts with RAPID raw data (green blocks). These are combined with Cluster housekeeping parameters to generate the intermediate binary merged science files (MSF). The PI institute delivers MSF files, software, calibration and other support files for the final data production at CAA. These items are indicated as yellow blocks in Fig. 5. Part of the software is the routine `msf2sci`, which together with the various production support files converts the MSF files to the level 2 SCI files. The final CAA data products are generated with the call to `sci2caa`, which itself invokes the `sci_trans` program together with `sci2caa.cfg`. This configuration file defines the various outputs, the form of the output file name, the requirements on the SCI file input, and list of template files that go into each output.

In addition, summary plots (see Section 3.6 below) are produced at the PI institute and delivered to CAA.

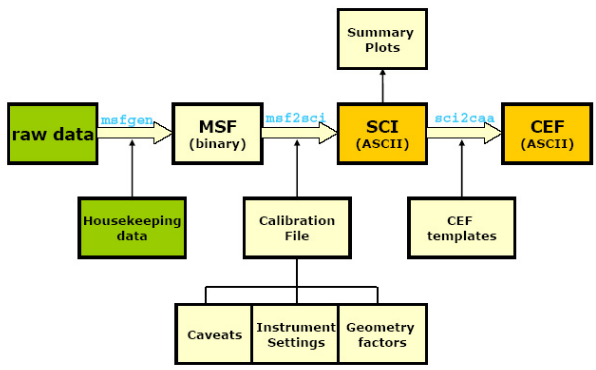

Fig. 5. *The RAPID data processing chain. Green boxes indicate raw data, yellow mark steps performed by the PI institute and orange show products produced by CAA. Core software for the data production is written in blue letters.*

3. CAA DELIVERABLES

In the following we give a brief overview of RAPID products to be archived and which a future CAA user will have access to. For a more accurate description of the RAPID data processing and archiving see [2].

3.1. Omnidirectional Products

This set of products includes differential particles fluxes and count rates in 8 energy channels with a one spin time resolution for protons and electrons and a four spin time resolution for helium and CNO. Omnidirectional differential fluxes are illustrated in panels 1-4 of Fig. 8, which will be described in section 3.6.

3.2. 3-D Products

Differential particles fluxes and count rates for protons, helium, CNO, and electrons in 8 energy channels, 9/12 (electrons/ions) polar directions, and 16 azimuthal sectors. The time resolution for electron observations is one spin. Full 3-D resolution for electrons is only available during burst mode (BM) `E3DD`; in normal mode (NM) exists a 2-D product for 8 energy channels and 9 polar directions, `E2DD`.

Since May 2004 a “light” version of the burst mode `E3DD` exists also for normal mode, the so-called `L3DD`, giving a 3-D resolution for 2 energy channels of burst mode `E3DD`.

For ions, the time resolution varies depending on the telemetry mode and spacecraft. For spacecraft 1, 3, and 4 data are accumulated over 8 spins and read out over 8 spins in BM or 32 spins in NM. For spacecraft 2 `I3DD` data are provided one out of 32 spins in NM and in BM one out of 8 spins.

For all the above products, standard deviations based on statistical and compression errors are provided for every value.

Fig. 6 displays an example of a 3-D electron distribution over one spin in spacecraft coordinates (SC) as recorded by `L3DD` in NM. From left to right we show the 16 (360°) azimuthal sectors and from top to bottom the 9 (180°) polar directions. White dots indicate 90° to the magnetic field, as measured on-board in each sector, and the red dot mark the calculated direction of the positive magnetic field vector, with the red star showing the opposite direction.

To provide an impression of visualization possibilities for a convenient physical interpretation of 3-D RAPID data, Fig. 7 shows `L3DD` measurements of April 14, 2005 from Cluster 2. The spacecraft crosses the magnetopause several times between 00:00 and 01:50 UT (see also panel 1 of Fig. 8). Here we display an 8×8 array of electron differential fluxes in the first energy range in the time range from 01:17:38-01:21:54 UT. In each array the electron distribution over one spin in GSE coordinates is drawn in a bispherical view. This means, the left spheres show northward flow and the right spheres southward flowing electrons. The magnetic field is presented as in Fig. 6.

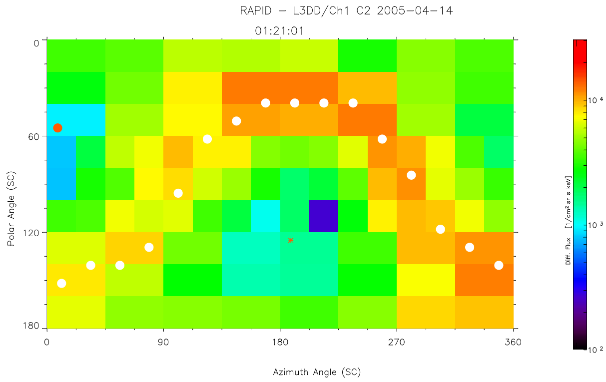

Fig. 6. *Electron 3-D distribution in SC coordinates showing 16 azimuthal sectors and 9 polar directions.*

3.3. Derived Products

1. GSE polar and azimuth angle for the flow direction of the corresponding direction/sector for 3-D products, once per hour.

2. Pitch angle and magnetic azimuth for 16 azimuthal sectors and 9/12 polar directions, which are derived using the onboard magnetic field data, for each spin.

3.4. Products for Diagnostic Purposes

These require detailed knowledge of the instrument and are primarily meant for expert users.

`HIST`: Histogram mode, which is a test mode that is commanded about once a month for analysis of the electron sensor performance.

`SGL`: “Singles” counters, allowing analysis of time-of-flight performance.

`DE`: Direct events, which are a fraction of unprocessed (E, T, D) events, are selected to bypass the classification for transmission to the ground. Since the number of events per spin is limited, a prioritization scheme is employed to ensure that the rarer heavier masses are output over the abundant protons.

`HK`: Housekeeping parameters, 137 words per spin.

`PED`: Electron “pedestal” counts below zero energy.

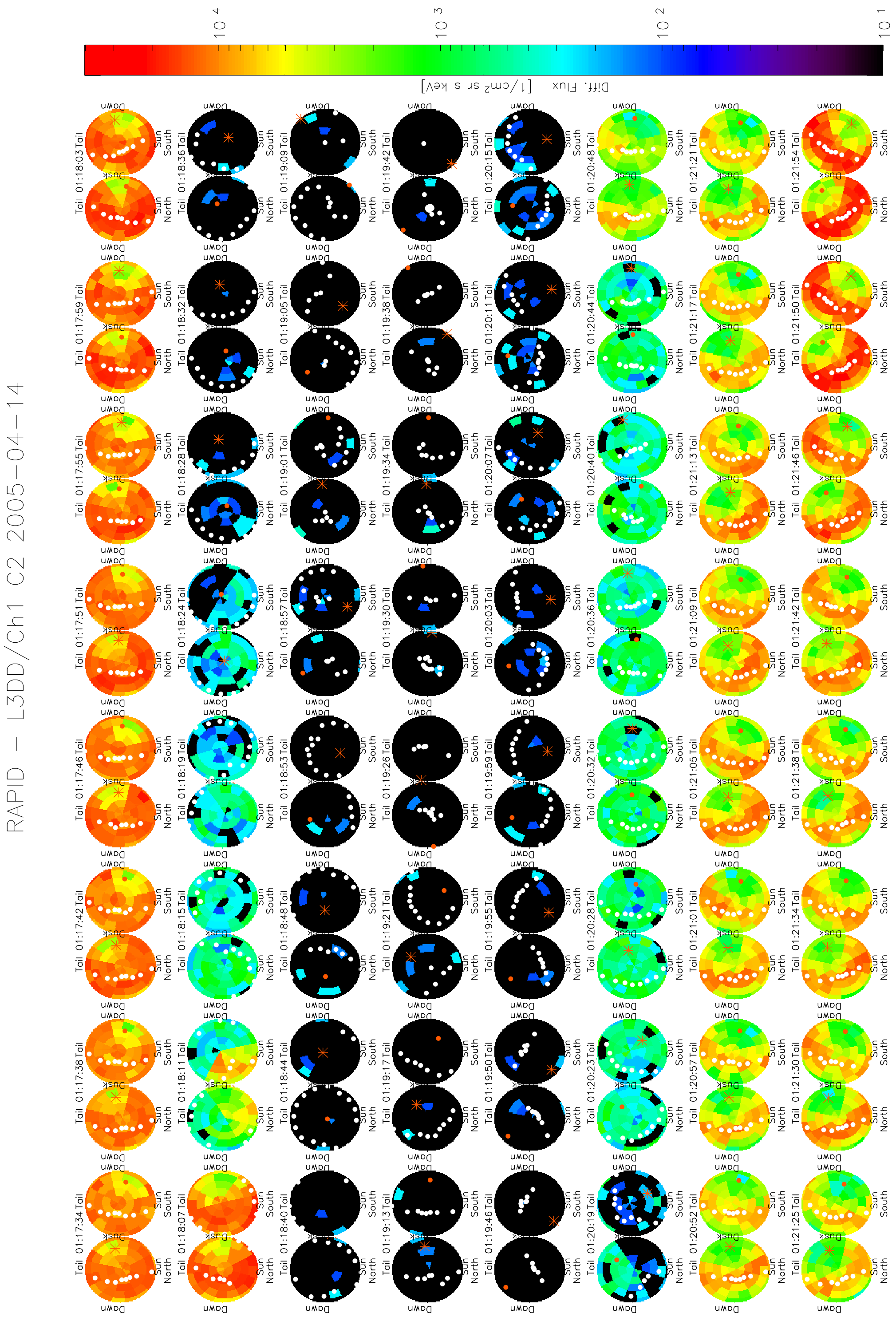

Fig. 7. *Example of 3-D electron distribution over one spin in GSE coordinates in a bispherical view of April 14, 2005, when Cluster 2 crosses the magnetopause several times between 00:00-01:50 UT (see also Fig. 8). We present the time interval 01:17:38-01:21:54 UT.*

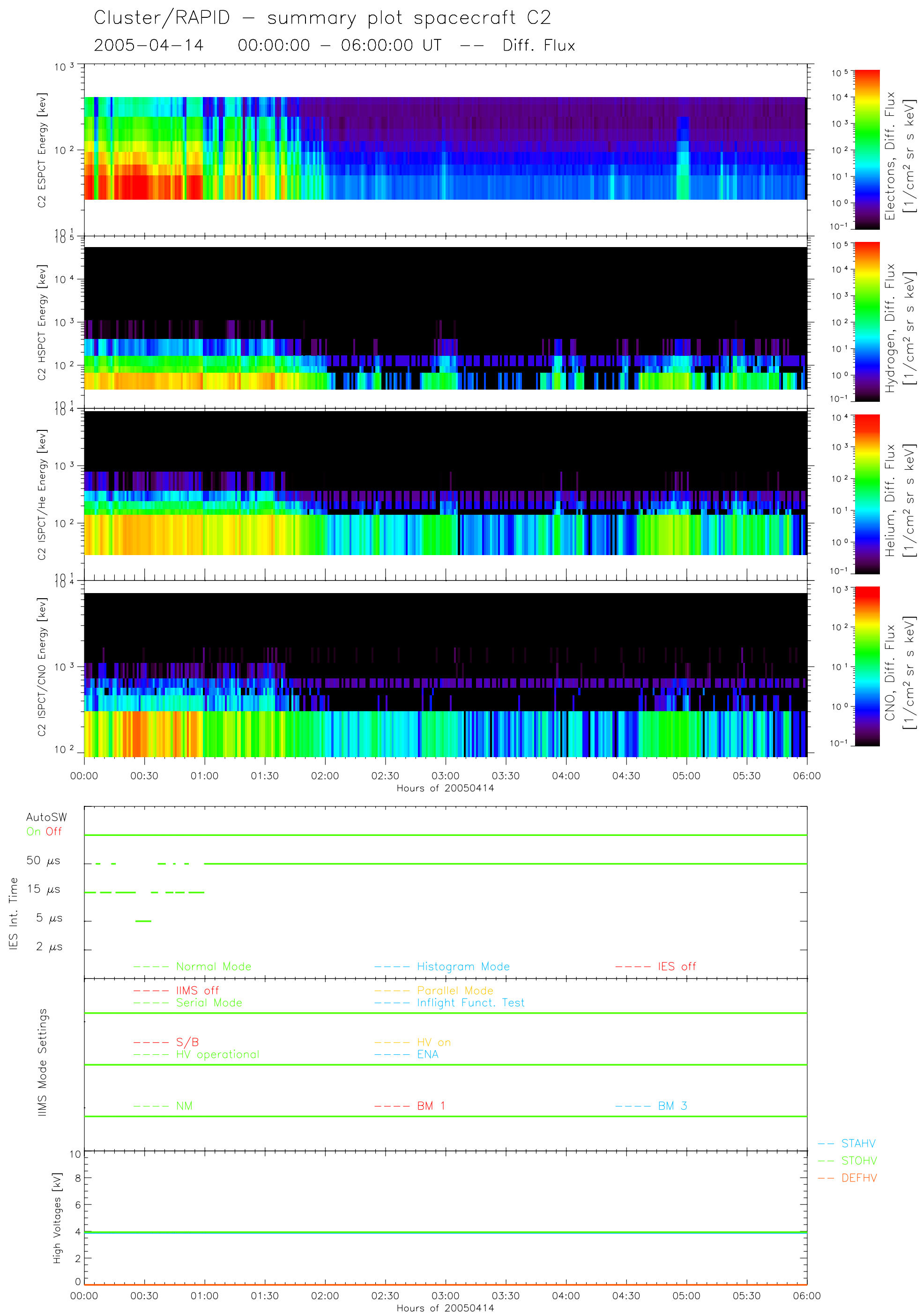

Fig. 8. *Example of a CAA RAPID summary plot. Panels 1-4 show from top to bottom differential fluxes of ESPCT, HSPCT, ISPCT_He, and ISPCT_CNO observed by Cluster 2 on April 14, 2005 between 0-6 UT. Panels 5-7 display several instrument settings.*

3.5. Caveat Files and Instrument Mode Settings

Caveat files will contain time tagged information of known problems and warnings concerning the instruments and data.

Knowledge of the instrument mode is required to understand the products. Thus, instrument mode settings tell the user of the current status of the instruments as shown in the bottom panels of the summary plots and in Table 2.

3.6. Summary Plots

For CAA summary plots of differential fluxes and count rates, respectively, covering a period of 6 hours will be available as `.png` and `.pdf` files. Fig. 8 shows from top to the bottom omnidirectional differential fluxes of electrons, protons, helium, and CNO in 8 energy channels with 1 min time resolution of April 14, 2005 between 00-06 UT. At the right hand side of each plot panel a color bar defines the color code of the spectra. This range is autoscaled, which has to be considered when comparing several plots.

Panel 5 gives some information about the status of the IES instrument. In the top line the status of the IES autoswitching is drawn, i.e., green line – Autoswitching on; red line – Autoswitching off. In autoswitching mode, the integration time t in the detector read-out system is not fixed but changes automatically with count rate. The second line in panel 5 displays the current IES integration time (Y-Axis) and the IES operation mode (color coded with green – normal science operations; red – IES off; blue – Histogram mode)

Panel 6 provides some general information about the IIMS status and operation settings.

color code	top line IIMS status	center line high voltages	bottom line telemetry
red	IIMS off	standby	BM1
green	IIMS in serial mode	HV operational	NM
yellow	IIMS in parallel mode	HV on but not operational	
blue	Inflight functional test	ENA	BM3

Table 2. *Instrument settings as shown in the CAA summary plots. These settings will be saved for CAA as an individual product.*

If the IIMS instrument is in serial mode then the DPU activates a single sensor head S_y at any given time and cycles through the sensor heads S_y (y = 1, 2, 3) in a preprogrammed sequence. In parallel mode all three sensor heads are active and particles are accepted on a first-come-first serve basis.

Finally, the last panel shows to which level the high voltages, Start green), Stop (blue), and Deflector (red) are set.

ACKNOWLEDGMENTS

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REFERENCES

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[2] Mühlbachler S. and P. W. Daly, Cluster Active Archive - Interface Control Document for RAPID, Issue 1, Rev. 0, Max-Planck-Institut für Sonnensystemforschung, Katlenburg/Lindau, Germany, May 2005. `http://www.mps.mpg.de/dokumente/projekte/cluster/rapid/rap_caa_icd_10.pdf`.