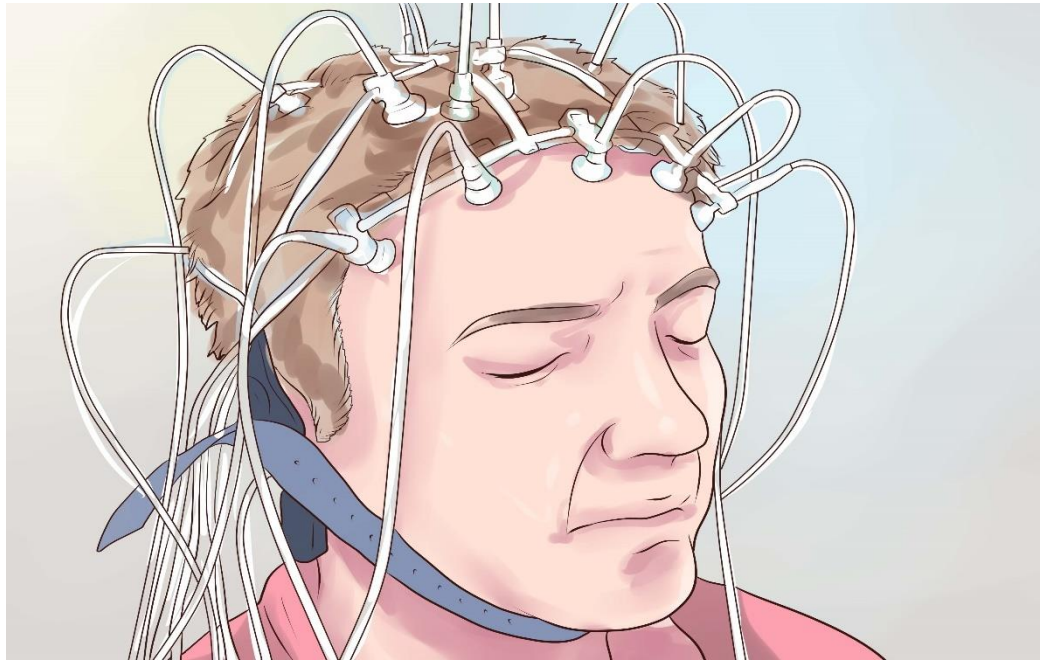
The normal Electroencephalography (EEG)



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Diploma of the Thai Board of Neurology

Subspecialty Certification in Epilepsy

A Fellow in Epilepsy and Clinical Neurophysiology, Case Western Reserve University, Cleveland, USA.

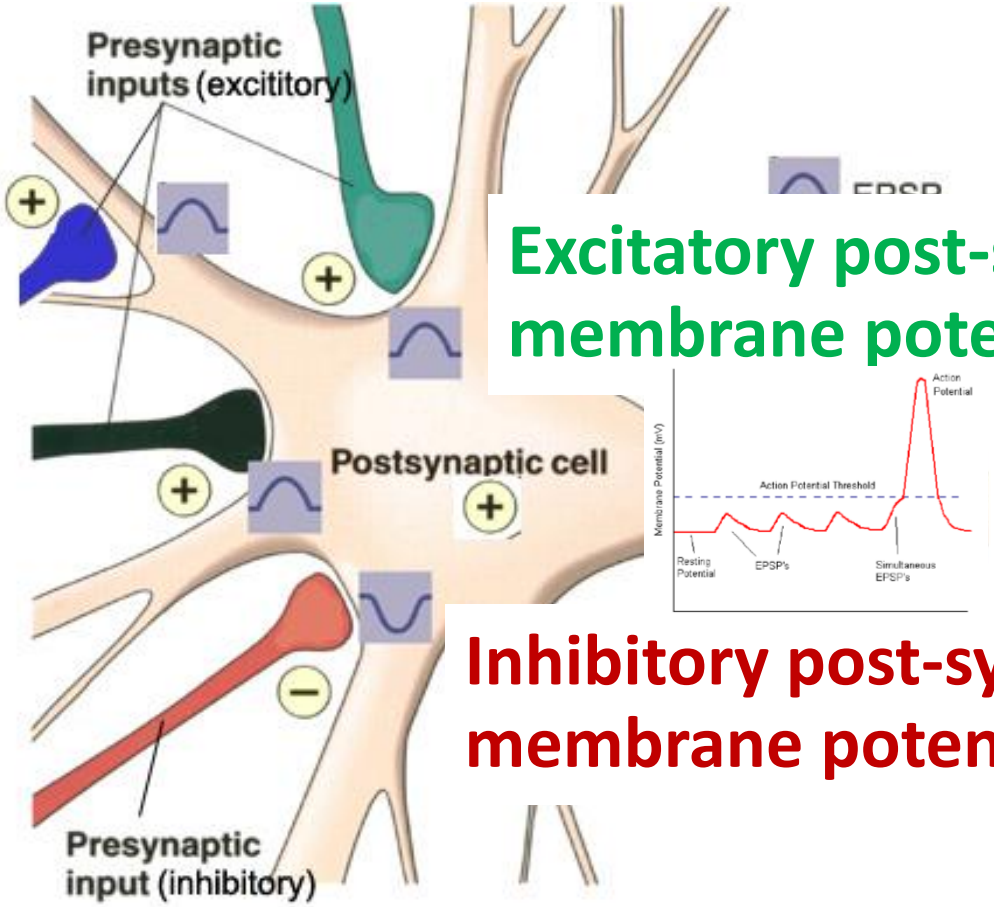
A Research Fellow in Sleep Disorders Center, Cleveland Clinic, USA.

Biophysical aspect of EEG

- Source of EEG activity
- Pyramidal cell
- EEG recorded one side, which adjacent to cortical surface, of a dipole.
- EEG recorded neuron population potentials (EPSPs, IPSPs)
- Time dilatation

Glutamate,
Acethylcholine

Synapse

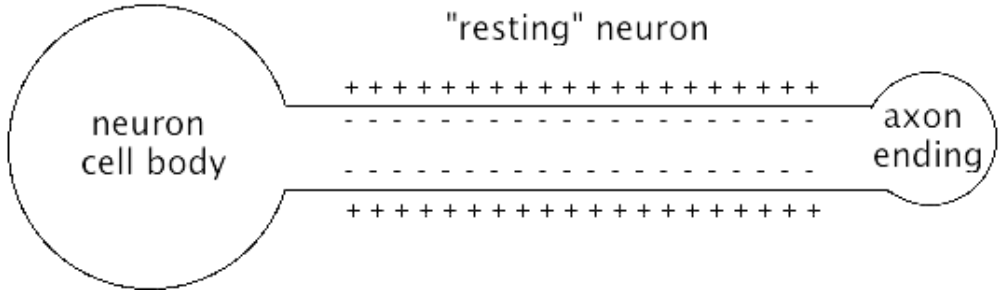


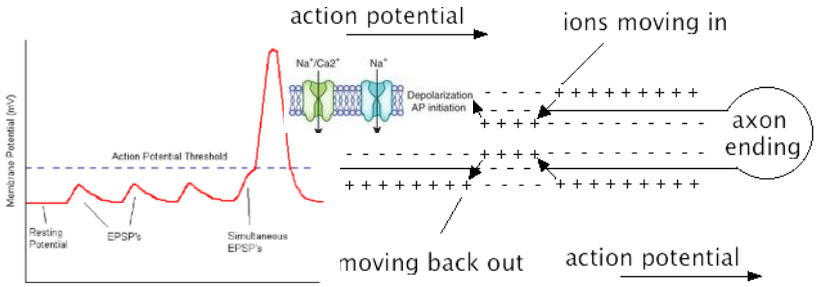
Excitatory post-synaptic membrane potential (EPSP)

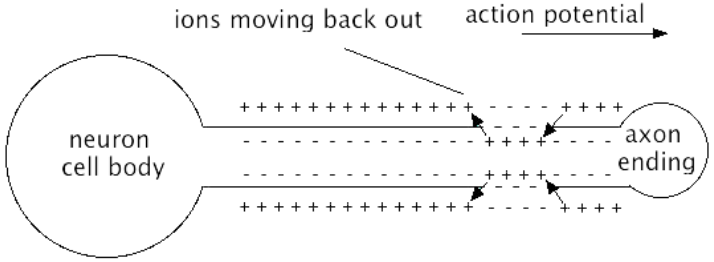
Inhibitory post-synaptic membrane potential (IPSP)

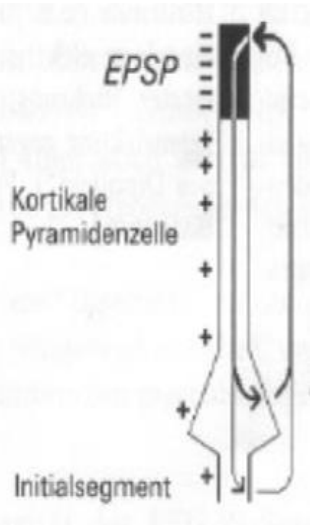
GABA

Pyramidal cell works as a dipole.

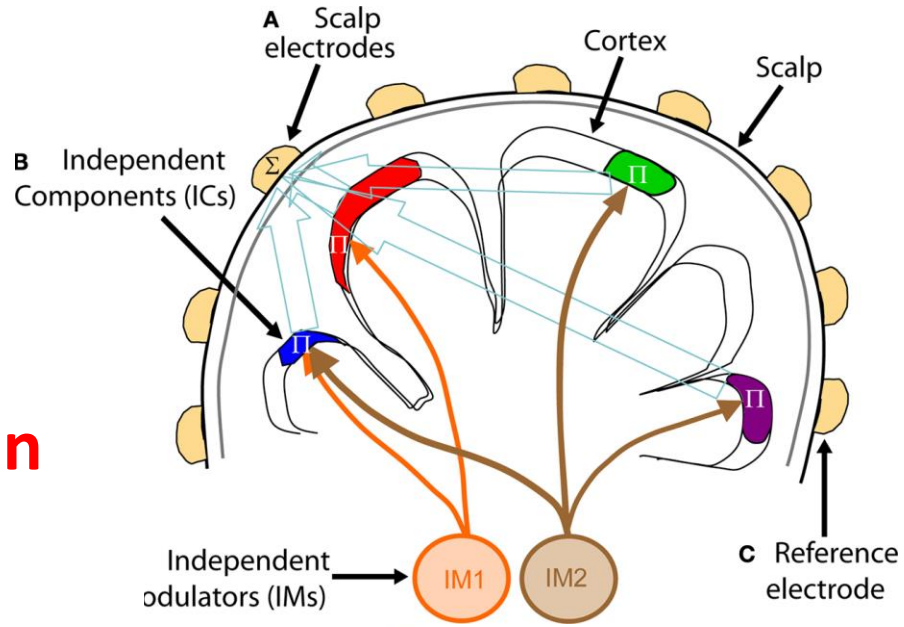


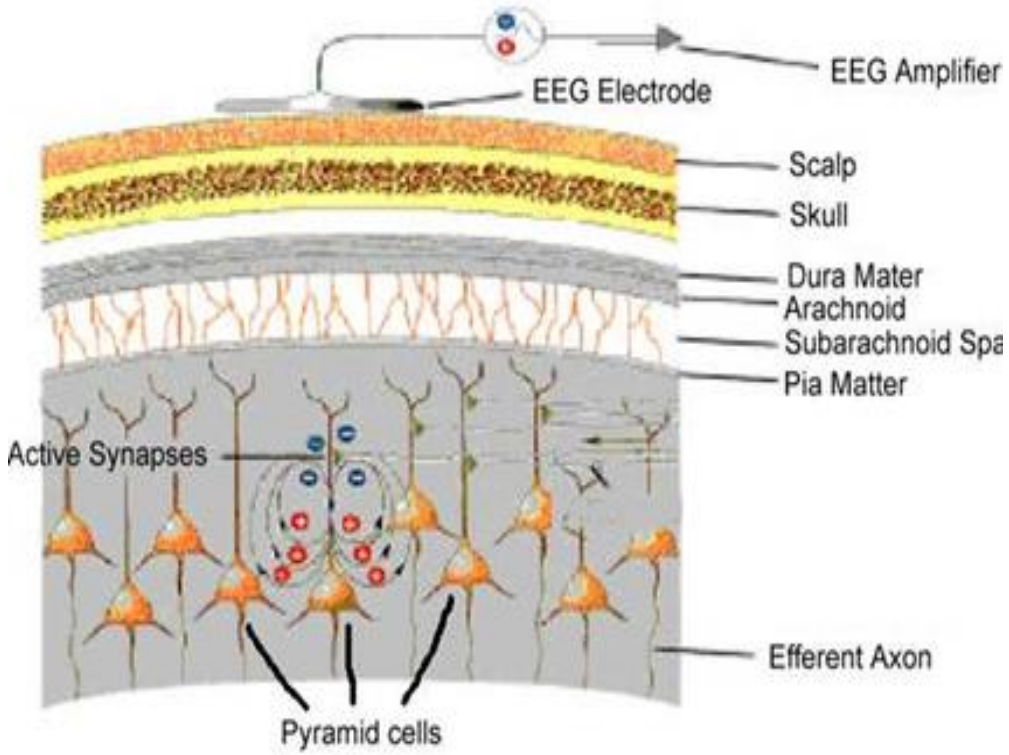




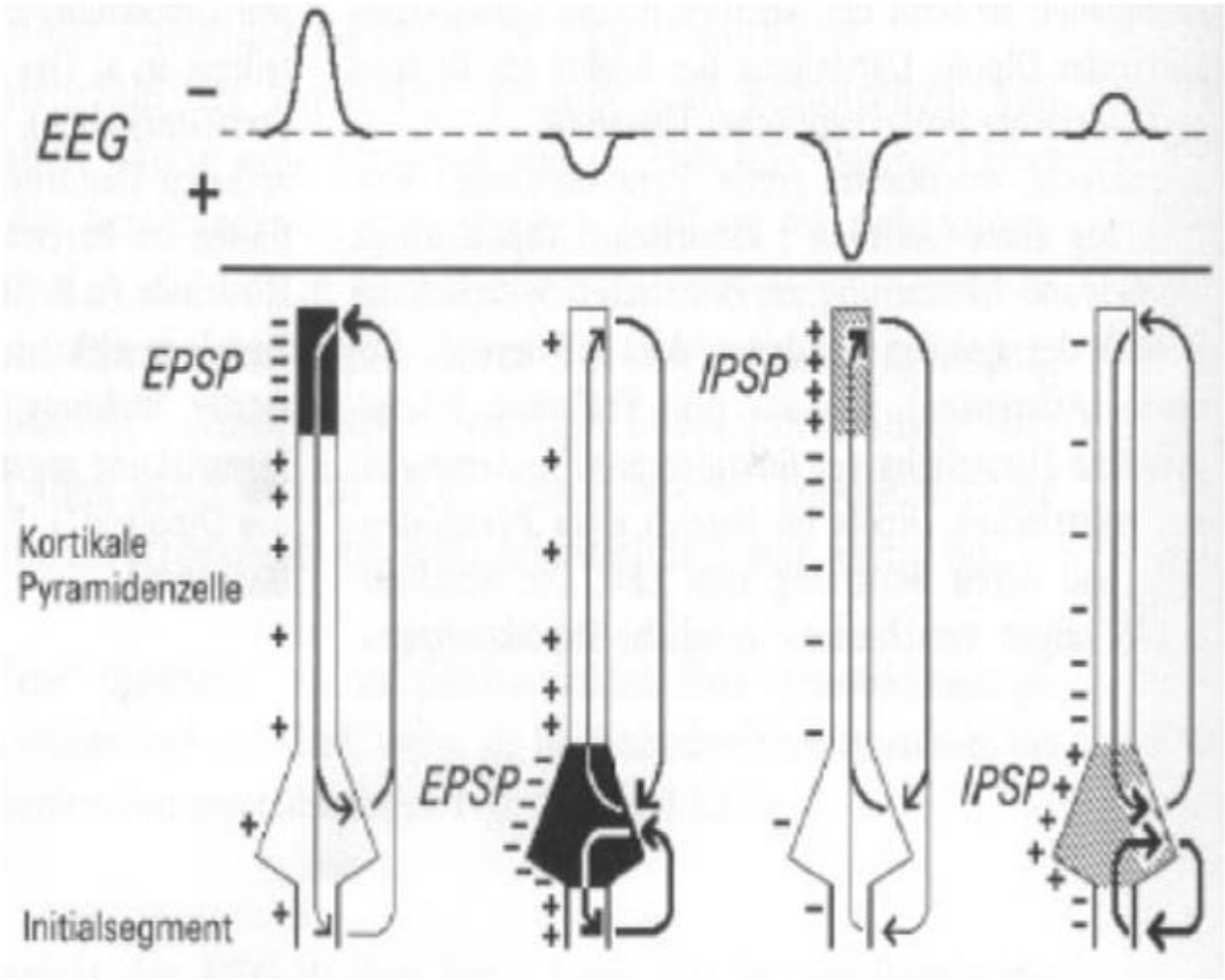


Time dilation



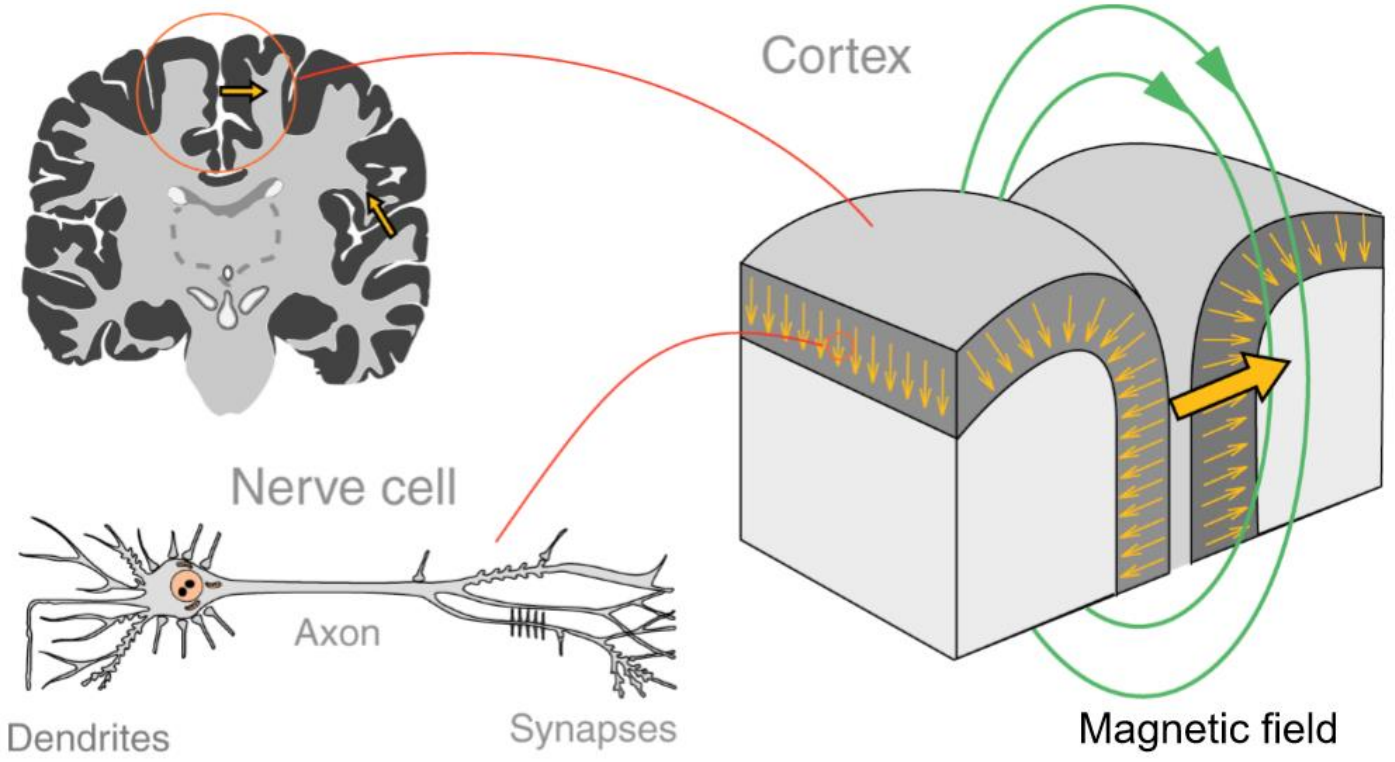


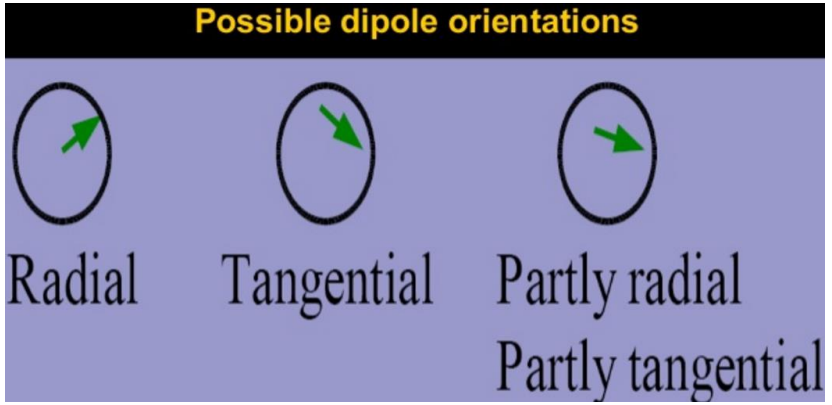
Dipole

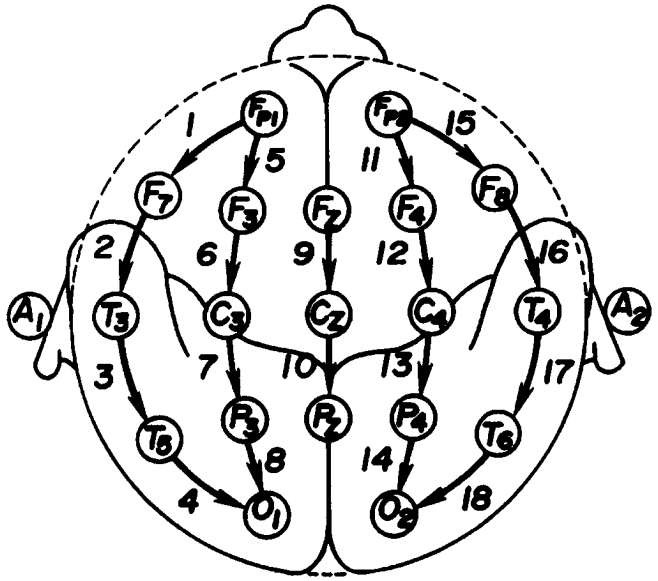


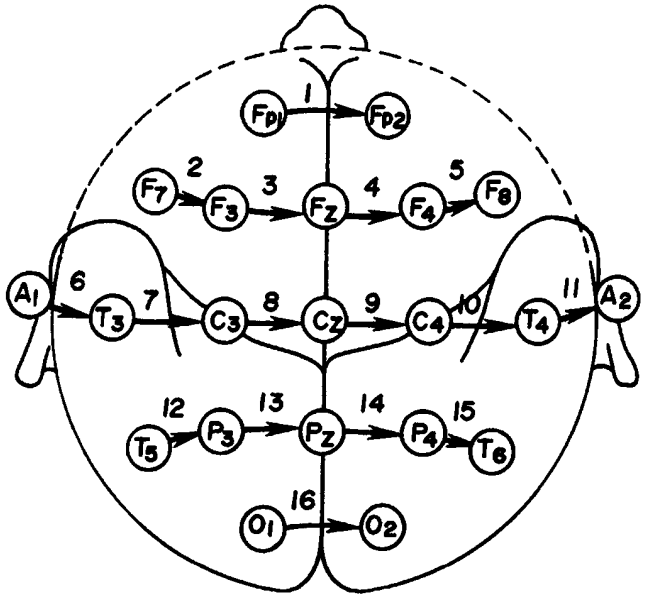
Orientation of Electrical field

At least **6** square cm of cortex must be activated in order for scalp EEG to detect a change in potential

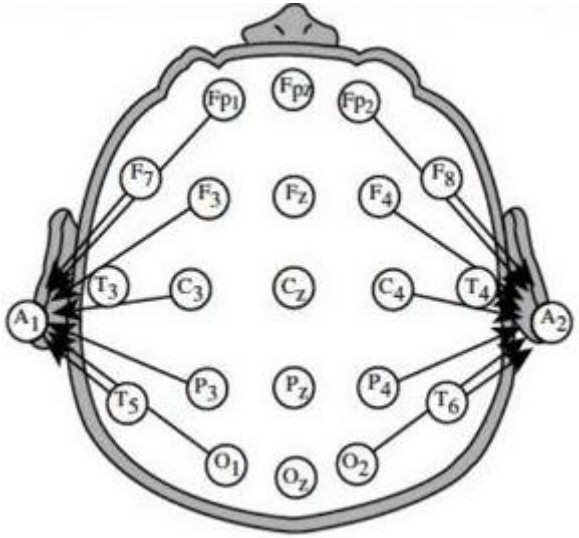








- Referential montage
  - Referential Cz
  - Referential ears
- Average reference montage
- Bipolar montage
  - AP longitudinal bipolar
  - Transverse bipolar
- Laplacian montage



Tyner FS. Fundamentals of EEG Technology: Basic Concepts and Methods. Vol 1. New York: Raven Press; 1985

Facts about Normal EEG

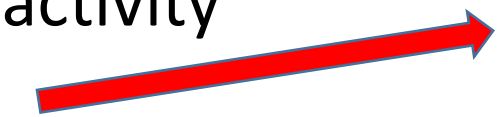
- Normal patterns
- No abnormal pattern
- Does not guarantee if brain has an exactly normal function.
- Normal variants
  - Between persons of the same age
  - More in wake than sleep

Steps of reading EEG

- Patient's age
- State of consciousness

- Description of EEG activity
  - Dominant rhythm
  - Location/ Distribution
  - Reactivity (highly responsive, nonresponsive)

  - Symmetry, synchrony, Regularity
  - Quantity (continuous, Intermittent)



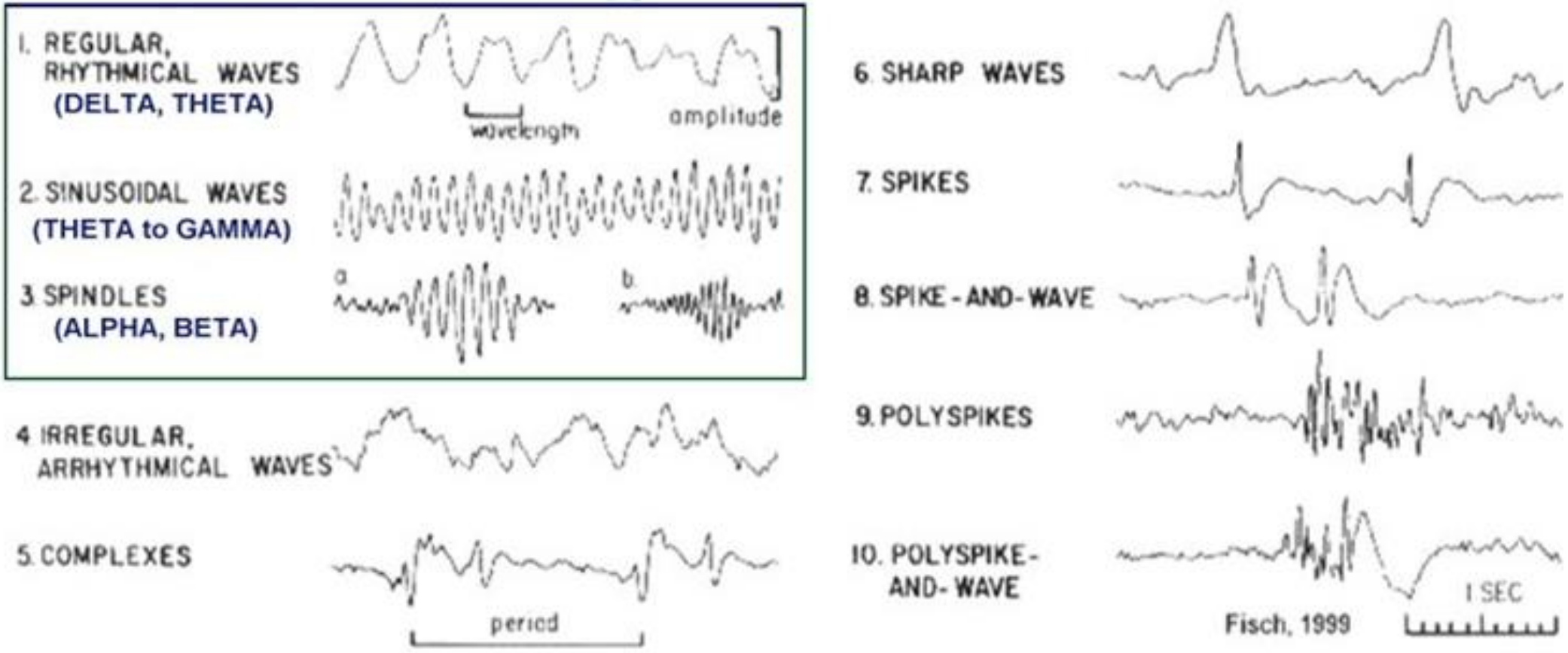
- Frequency
- Amplitude (millimeter) = voltage/sensitivity
- Wave form
  - Rhythmic, periodic, arrhythmic
  - Morphology (spike, sharp, biphasic, triphasic)

Posterior dominant rhythm : Ages dependence

- 4 months 4 Hz
- 5 months to 1 year 5-6 Hz
- 3 year 8 Hz (>80% of age group)
- 9 years 9 Hz
- 15 years 10 Hz

- Term newborn: Chronological age
- Pre-term newborn: Conceptional age

Range of EEG waveforms



Frequency (Hz)

Wave length

Bazhenov & Timofeev (2006)

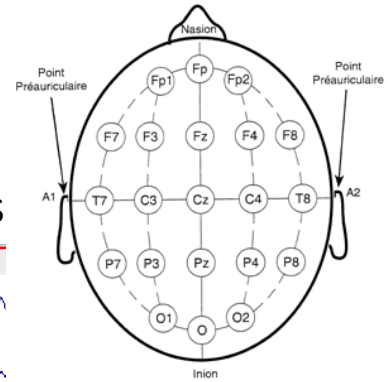
Awake EEG

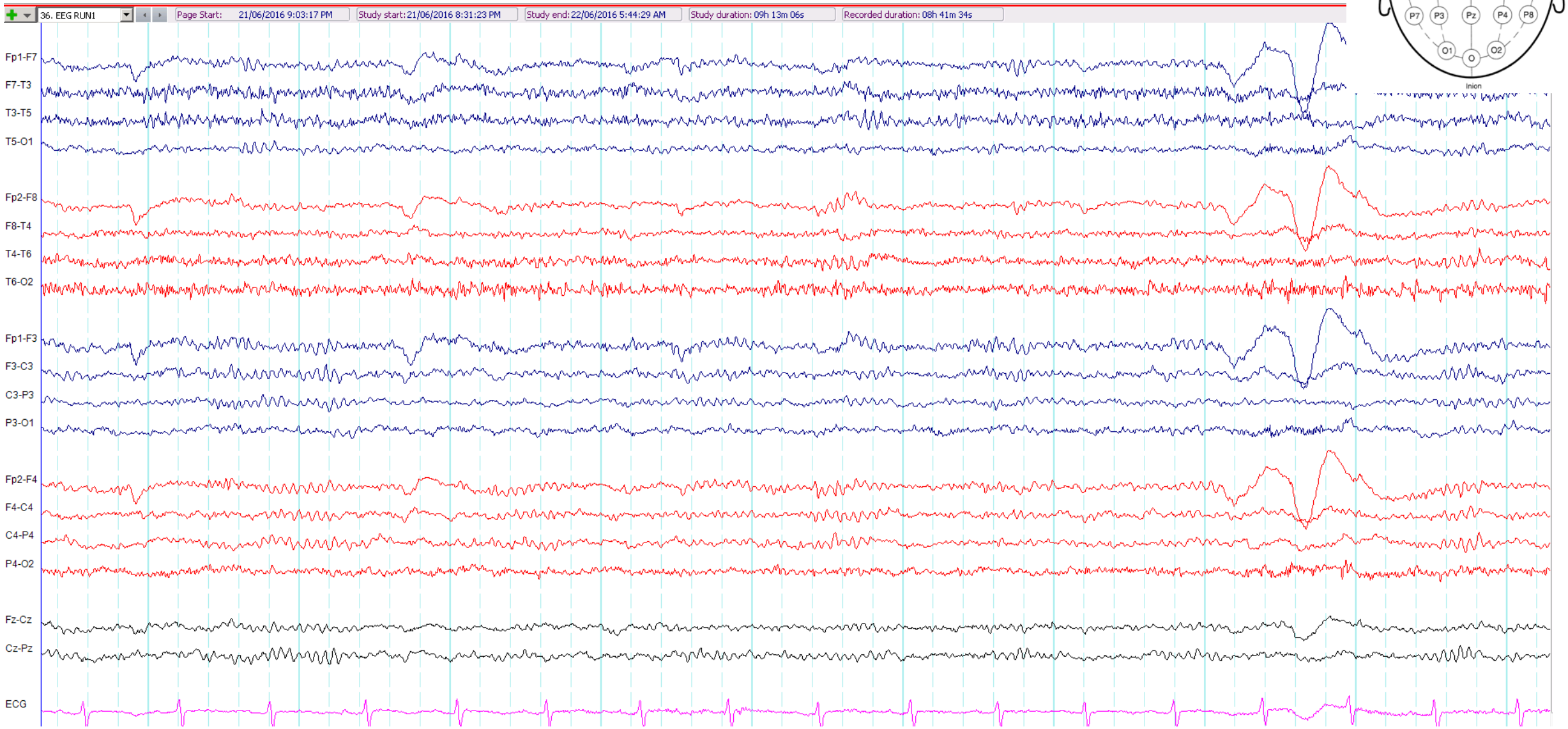
- Beta wave
- Alpha wave
- Mu rhythm
- Theta activity (in young age group)

- Physiologic artifacts in awake

Beta waves

- 13-30 Hz
- Amplitude < 20 uV
- Diffusely, more prominently in the frontal regions

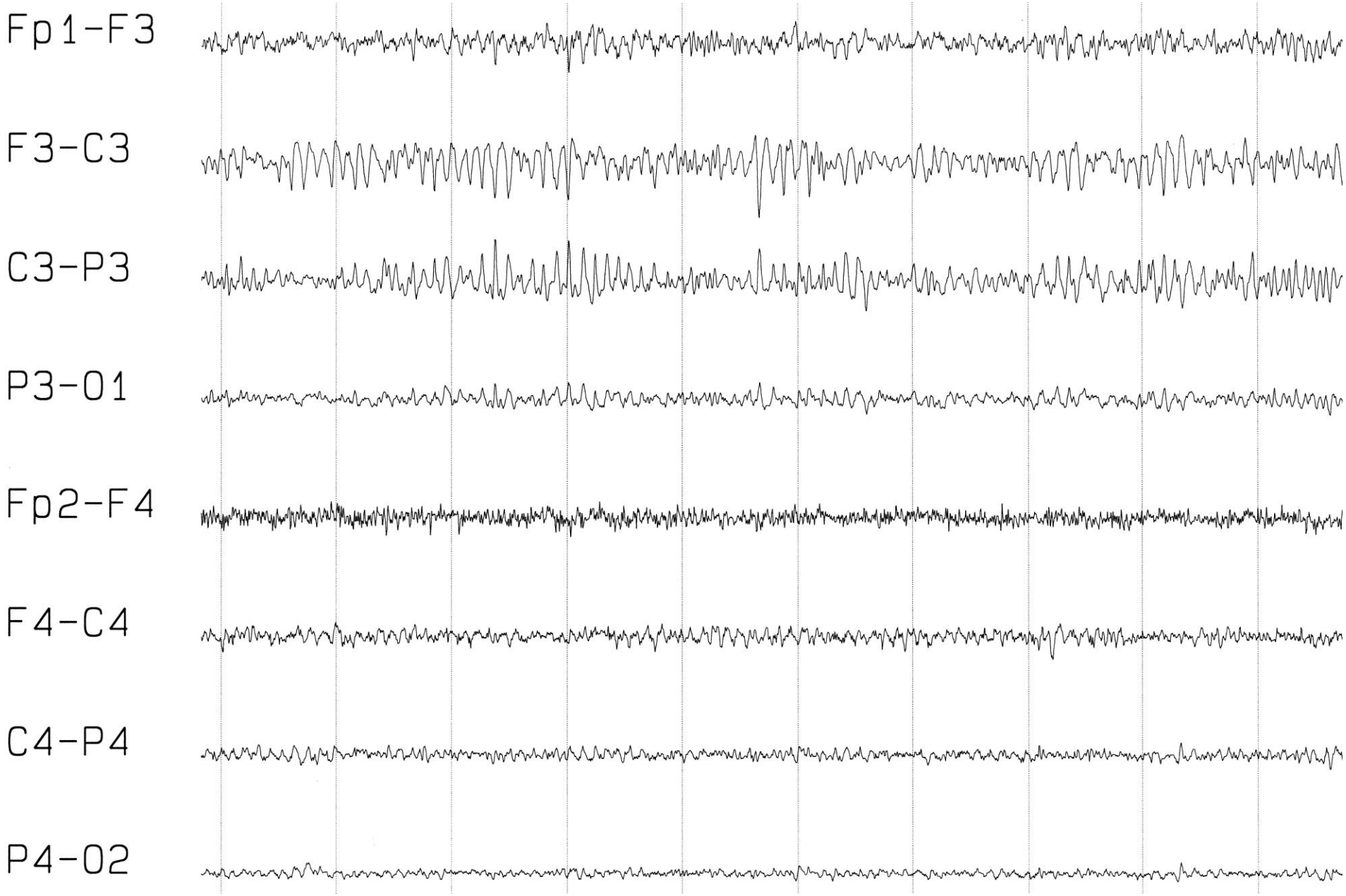




Beta waves

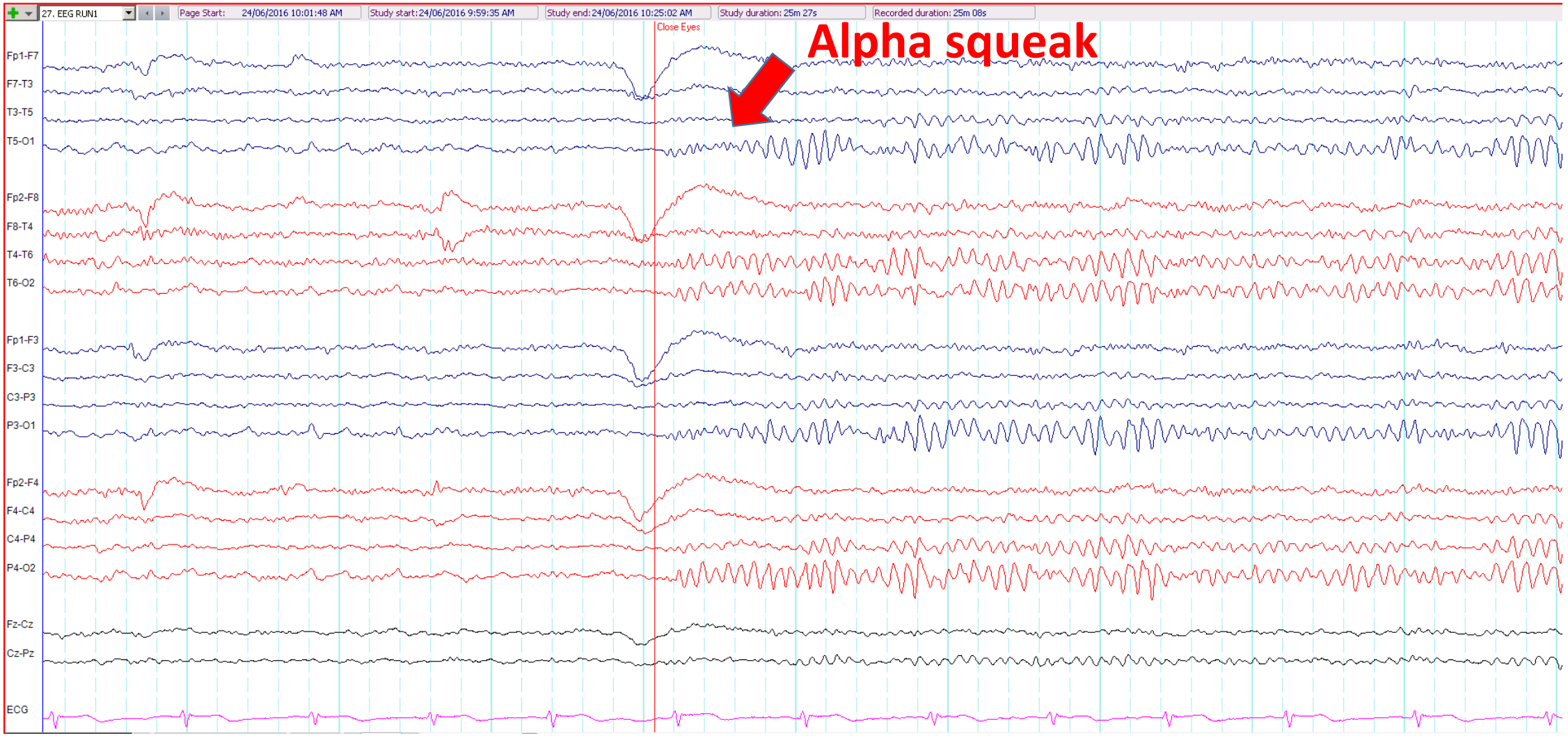
- 13-30 Hz
- Amplitude < 20 uV
- Location: Diffusely, more prominently in the frontal regions

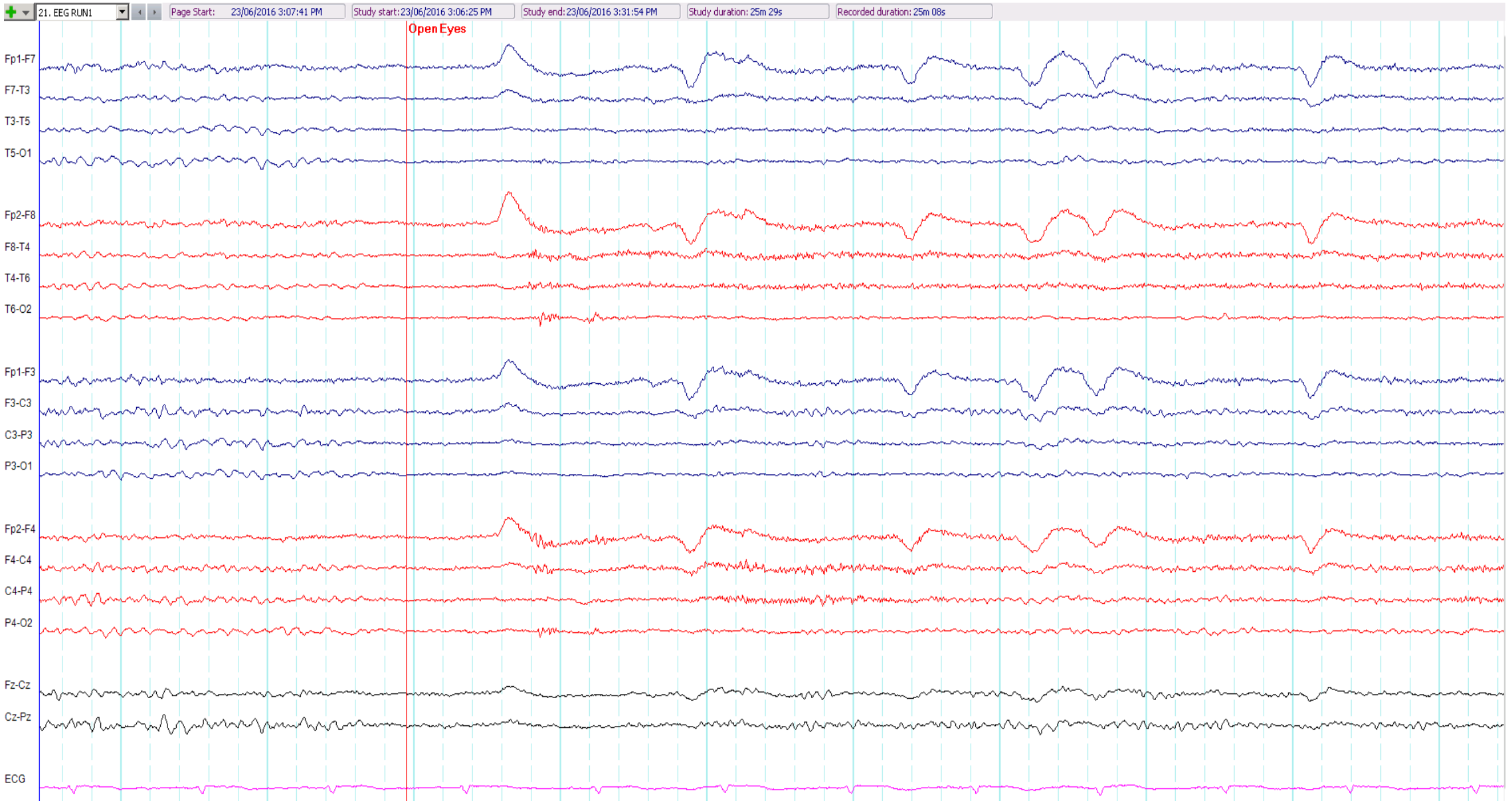
- More common in infants and young children less than 1 ½ years old.
- Enhanced by sedative, hypnotic, or anxiolytic drugs
  - Not dose dependent but up to individual's sensitivity
- Enhance in a region of skull defect called "Breach rhythm".


Fp1-F3
F3-C3
C3-P3
P3-O1
Fp2-F4
F4-C4
C4-P4
P4-O2

Alpha waves

- 8-12 Hz
- Sinusoidal wave forms
- 15-45uV
- posterior half of the head
- Reactivity: Eye closed/ eye opening





Blocked or attenuated by eye opened, attention, especially visual and mental effort.

Alpha rhythm, neurophysiological rhythm

- Frequency (age dependence) :
  - about 1 Hz different between Rt./Lt. hemisphere
  - ¼ of normal adults, alpha rhythm is poorly visualized

- Morphology: Rounded or Sinusoidal wave forms

- Amplitude:
  - Right > Left
  - Age dependence
  - variable, mostly < 50uV (15-45uV)
  - 6-7% of normal adults showed voltage of < 5 uV

Alpha rhythm, neurophysiological rhythm

- Location:
  - Posterior half of the head; occipital, parietal, posterior temporal regions
  - Might extend into central region (Demonstrable by attenuation by eye opening)
  - May occasionally extend to F3,F4 but not Fp1, Fp2. (May be prominent in referential montages.)

Alpha rhythm, neurophysiological rhythm

- Reactivity:
  - Eye closed/ eye opening
  - Blocked or attenuated by attention, especially visual and mental effort.
  - Best seen in relative mental inactivity, physical relaxation
  - Extreme upward gaze tends to facilitate the posterior alpha rhythm (Mulholland, 1969; Mulholland and Evans, 1965)
  - Lateral eye deviations may have similar effects (Fenwick and Walkier, 1969).
- Squeak effect

Clinical correlation of alpha rhythm

- Slowing of the alpha is one of the earliest signs of diffuse brain injury.
- Alpha amplitude asymmetry of > 50% indicates focal injury to the hemisphere having lower amplitude.
- Some drugs could induce slow background
  - Phenytoin
  - Carbamazepine

Mu rhythm

- Rest-state of motor neurons
- 8-13 Hz, Alpha activity in central region, arc-like central rhythm
- Often asynchronous, asymmetry

- Blocked by contralateral limb movement, intension of movement, sensory stimulation and mental activity

- Commonly seen in adolescents and young adults (17-19%)
- Less commonly in elderly and children less than 4 years old

Theta activity

- 3.5-8 Hz
- Awake state
  - Small amount theta 6-7 Hz mixed with alpha
  - Frontal, frontocentral regions

  } In young age group

  - Fm theta rhythm at the Frontal region
    - Relation to mental calculation, reading, etc.

    Yamaguchi Y et al, 1985

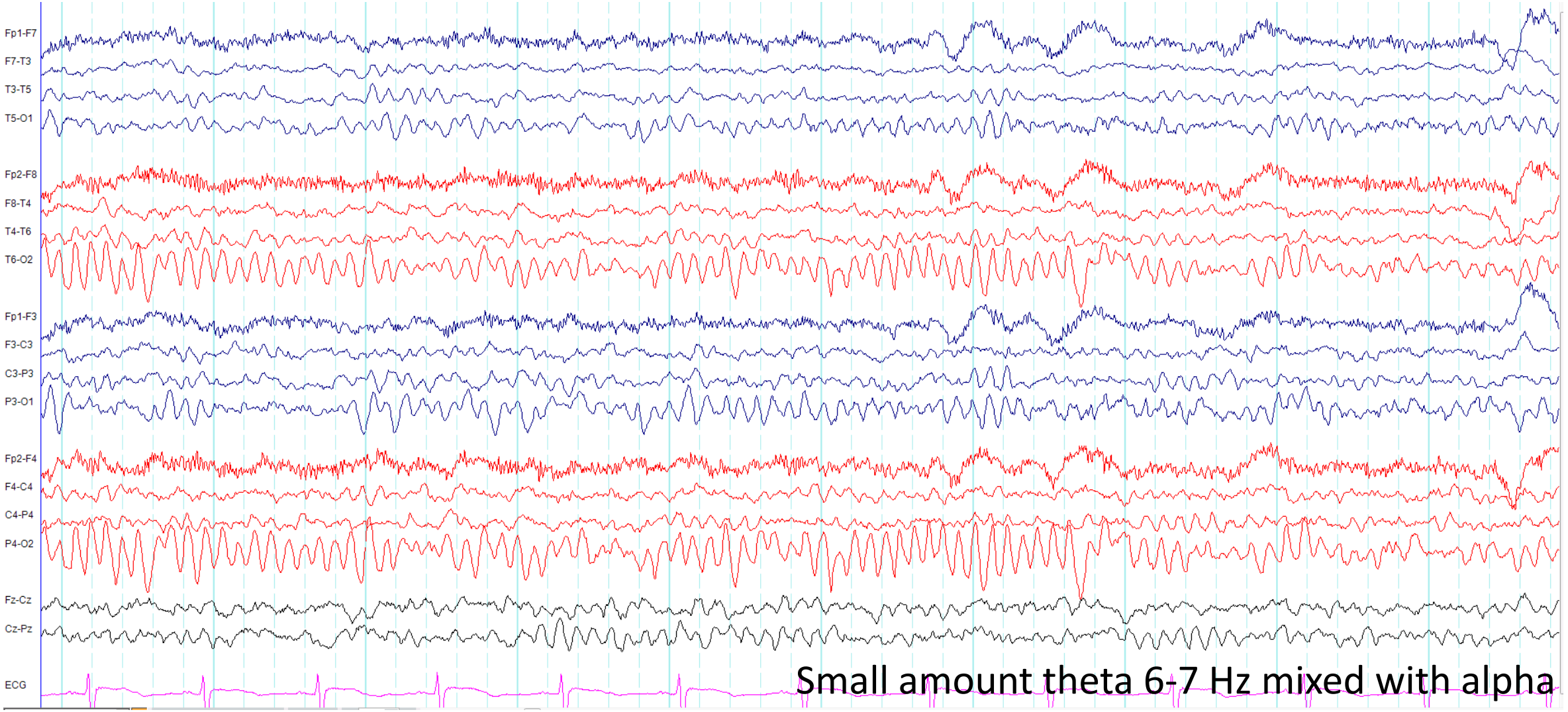
  - Theta , midline theta rhythm
    - Temporal lobe epilepsy Ciganek et al, 1961
    - ¼ of non-epileptic group

    Westmoreland BF et al, 1985

- Sleep state

Theta activity in young age group

Girl, 6 y/o



Small amount theta 6-7 Hz mixed with alpha

Delta activity

Normal

- Posterior slow wave of youth
  - Young children to 20 years old or could be late as 25 years old
  - Maximum at 9-14 years old
  - Uncommon in age group less than 2 years old

  - Amplitude not > 1.5 time of alpha rhythm or > 200 uV

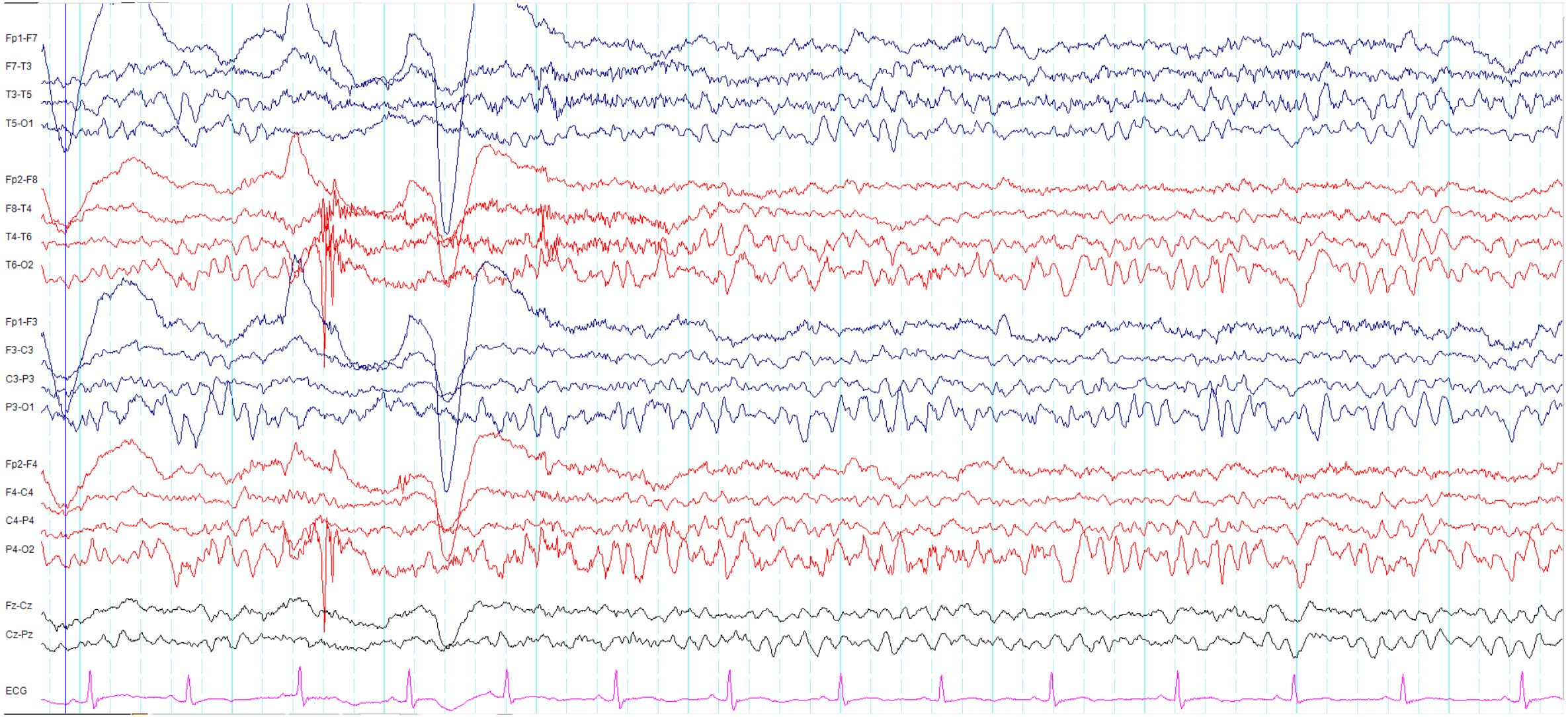
  - Attenuated by eye opening
  - May be accentuated by hyperventilation or stress

Abnormal

- Consistent or persistent as ORIDA

Posterior Slow Wave of Youth (PSWYs)

12 y/o



Sleep EEG

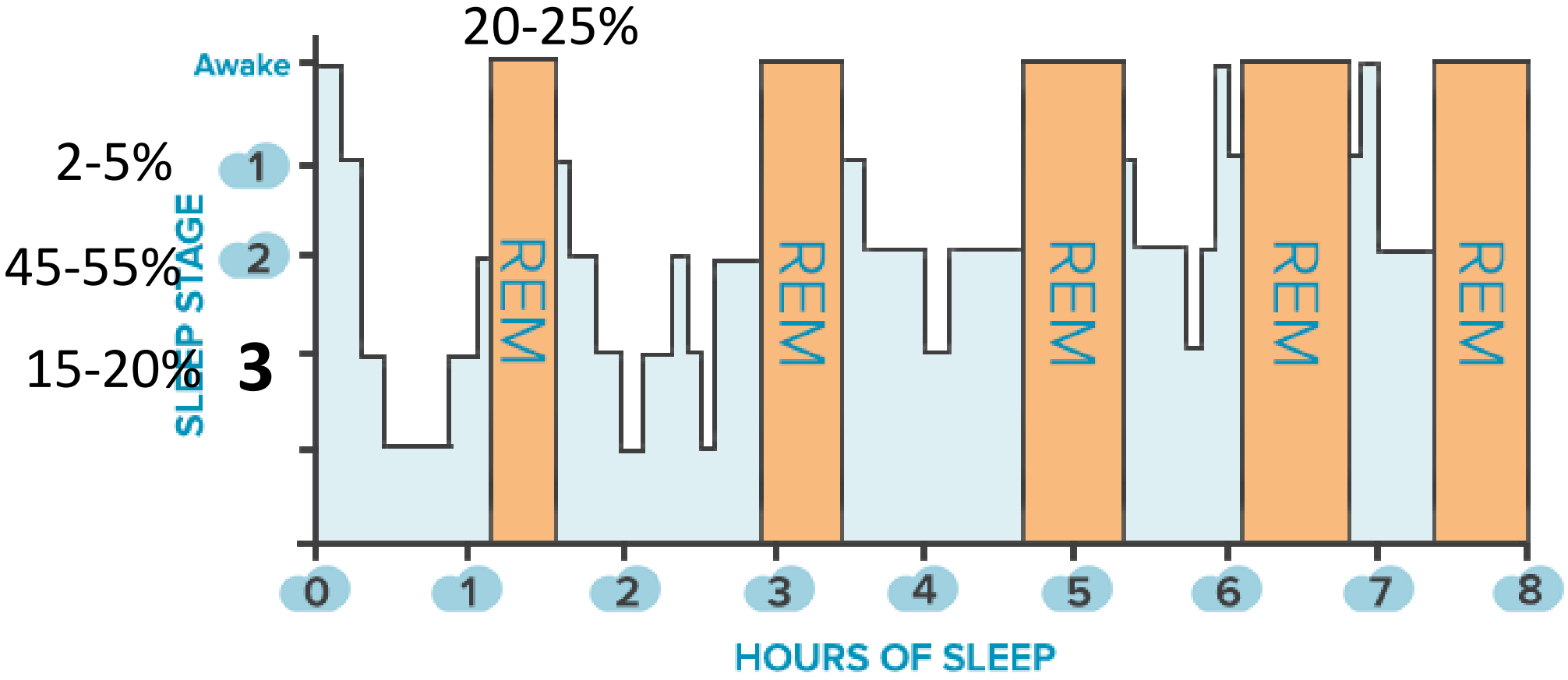
- Non-Rapid Eye Movement (NREM) sleep
  - Stage 1 : Drowsiness
  - Stage 2
  - Stage 3 : Slow Wave Sleep > 20 -50%
  - Stage 4 : Slow Wave Sleep > 50%

} Stage 3: SWS > 20%

- Rapid Eye Movement (REM) sleep

Sleep stages

Slow down muscle activity, muscle twitching



90-120 minutes / cycle

5-7 cycles/night

Adapted from
www.centerforsoundsleep.com

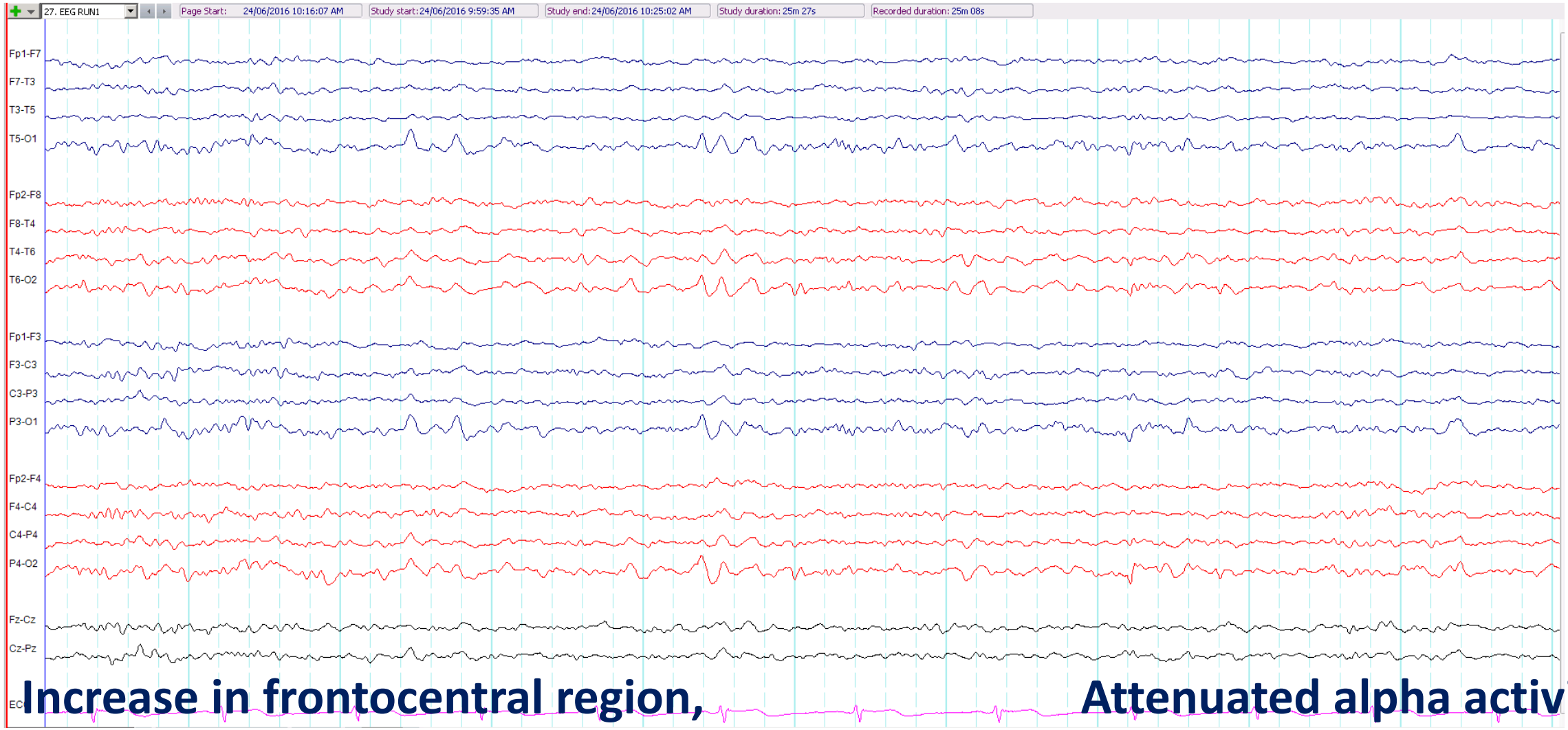
Sleep NREM stage 1 (drowsiness)

- EEG activity in Transitional state
  - Attenuated alpha activity, 4-7Hz (Theta activity)
  - low amplitude, mixed frequency, waning of waking background
- Posterior Occipital Sharp Transient of sleep (POSTs)
  - Appear around ages 3 – 4 y/o
- Vertex wave
  - First appear at 6-8 weeks post term

- Hypnagogic hypersynchrony
- Hypnapompic hypersynchrony

- Slow rolling eye movements (< 0.5 Hz)
- Reduction of muscle artifact

Posterior Occipital Sharp Transients of sleep (POSTs)

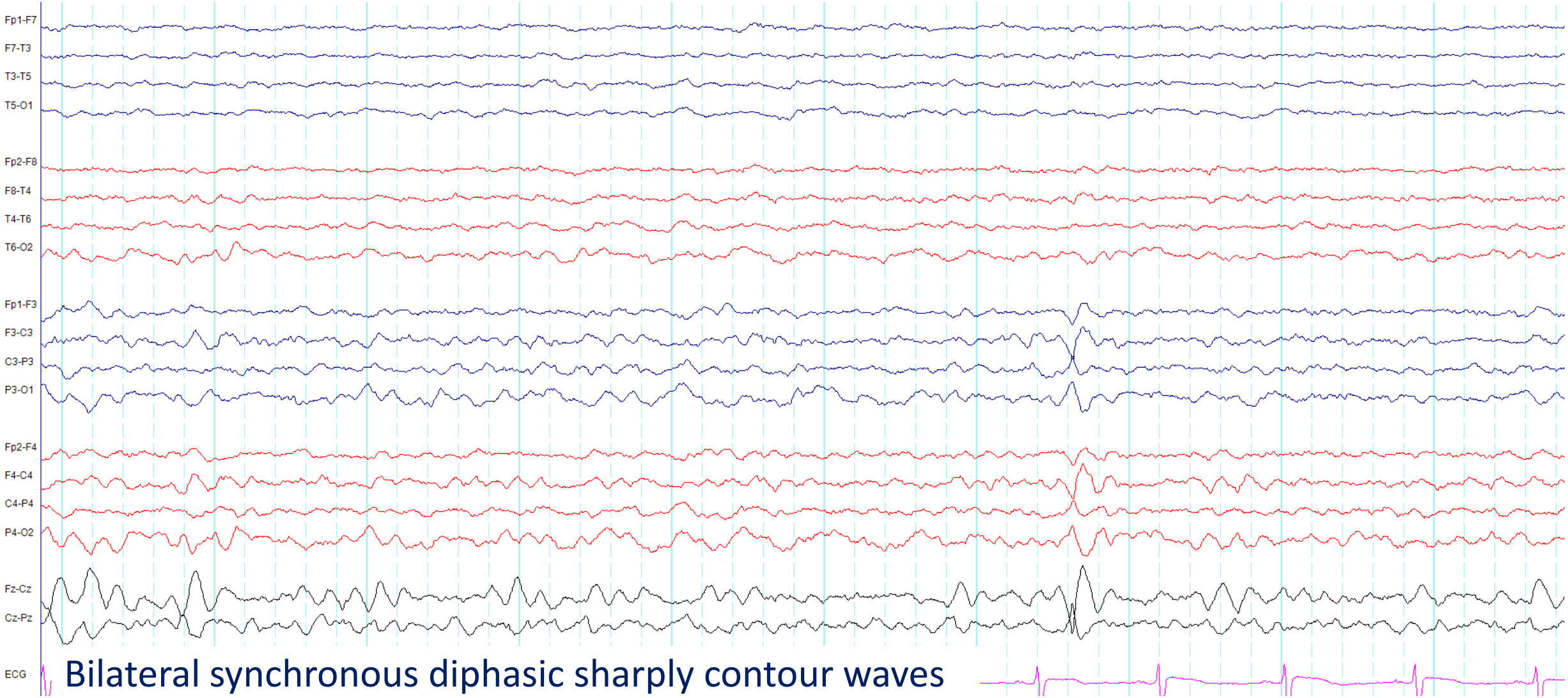


Increase in frontocentral region, occipital theta

Attenuated alpha activity
Fragmented background

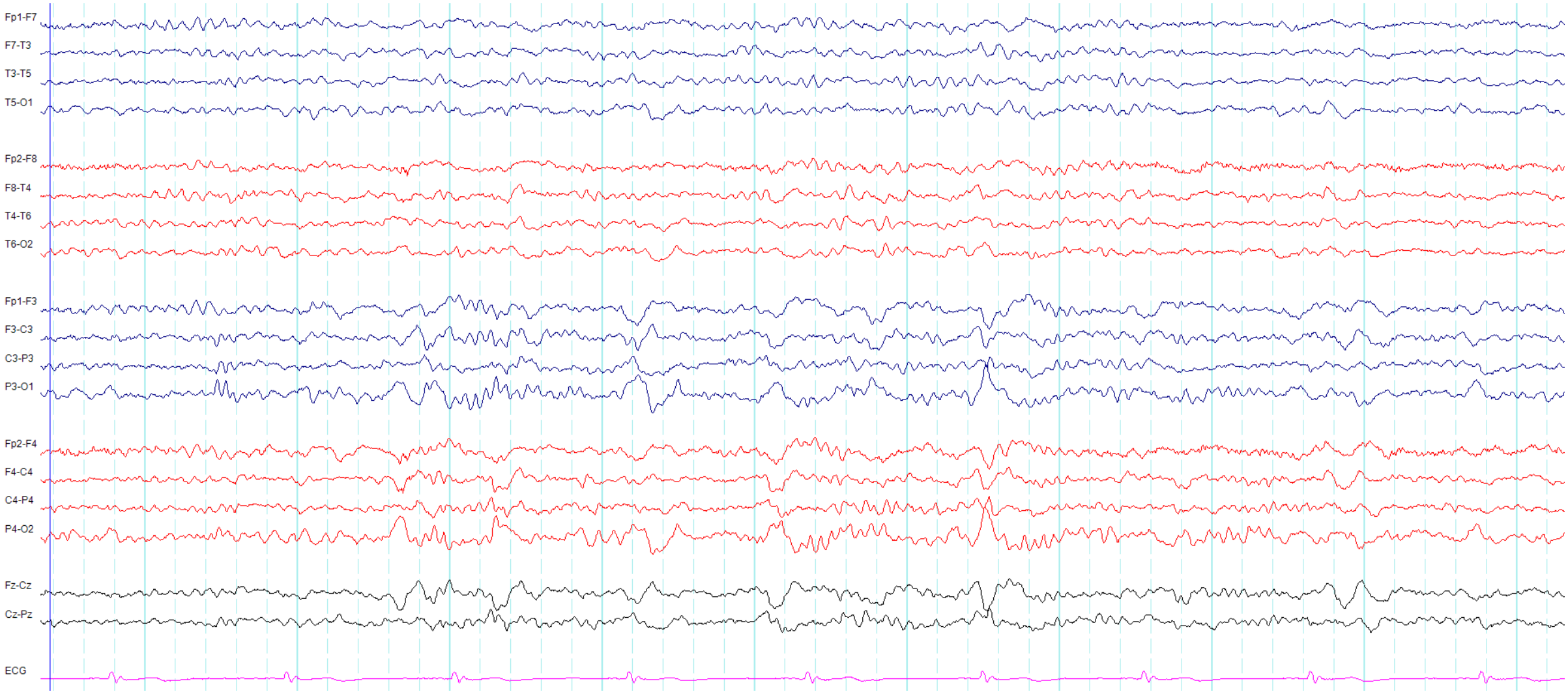
Vertex (V) wave

Maximum amplitude at Cz, C3, C4
Might asymmetry but not persistent
At the end of stage 1 or beginning of stage 2



Bilateral synchronous diphasic sharply contour waves

Asymmetrical V wave

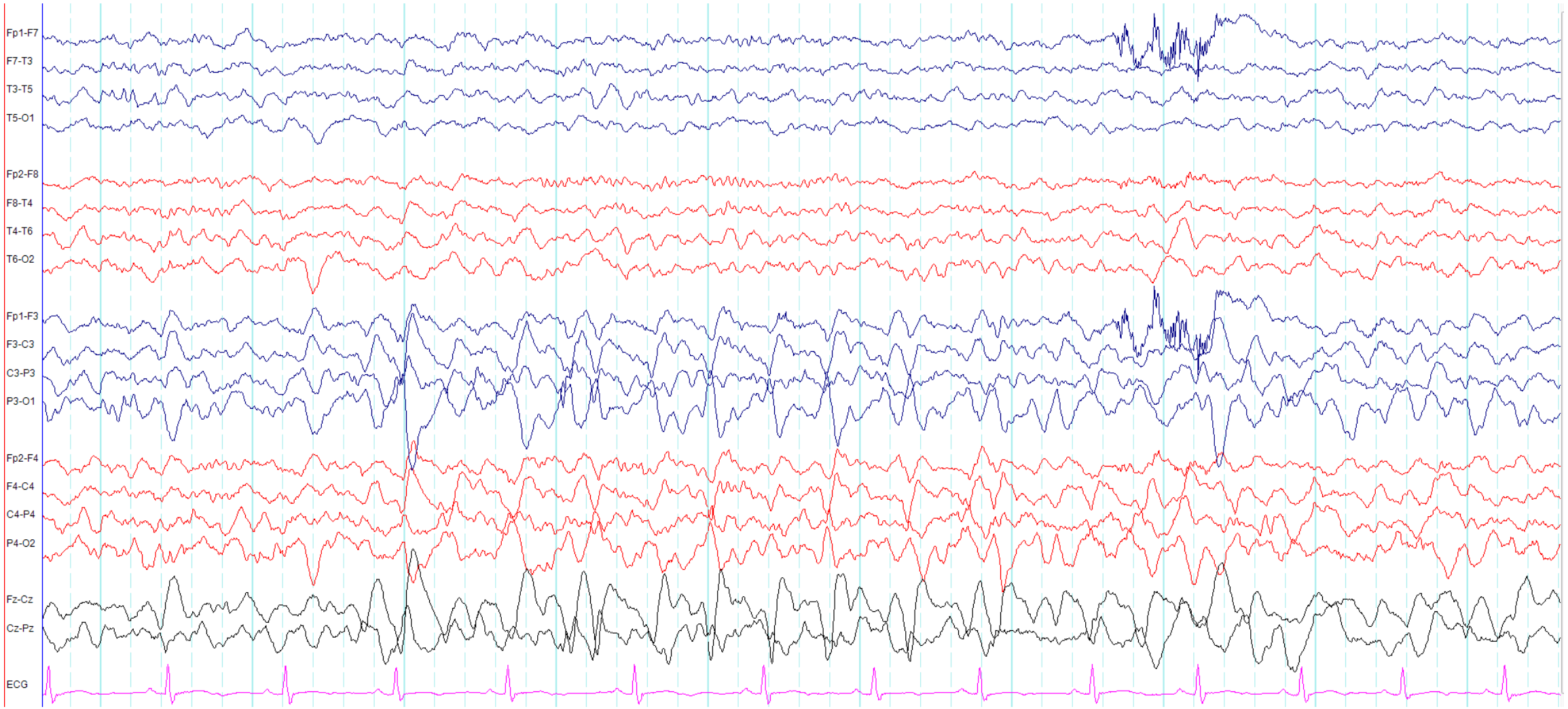


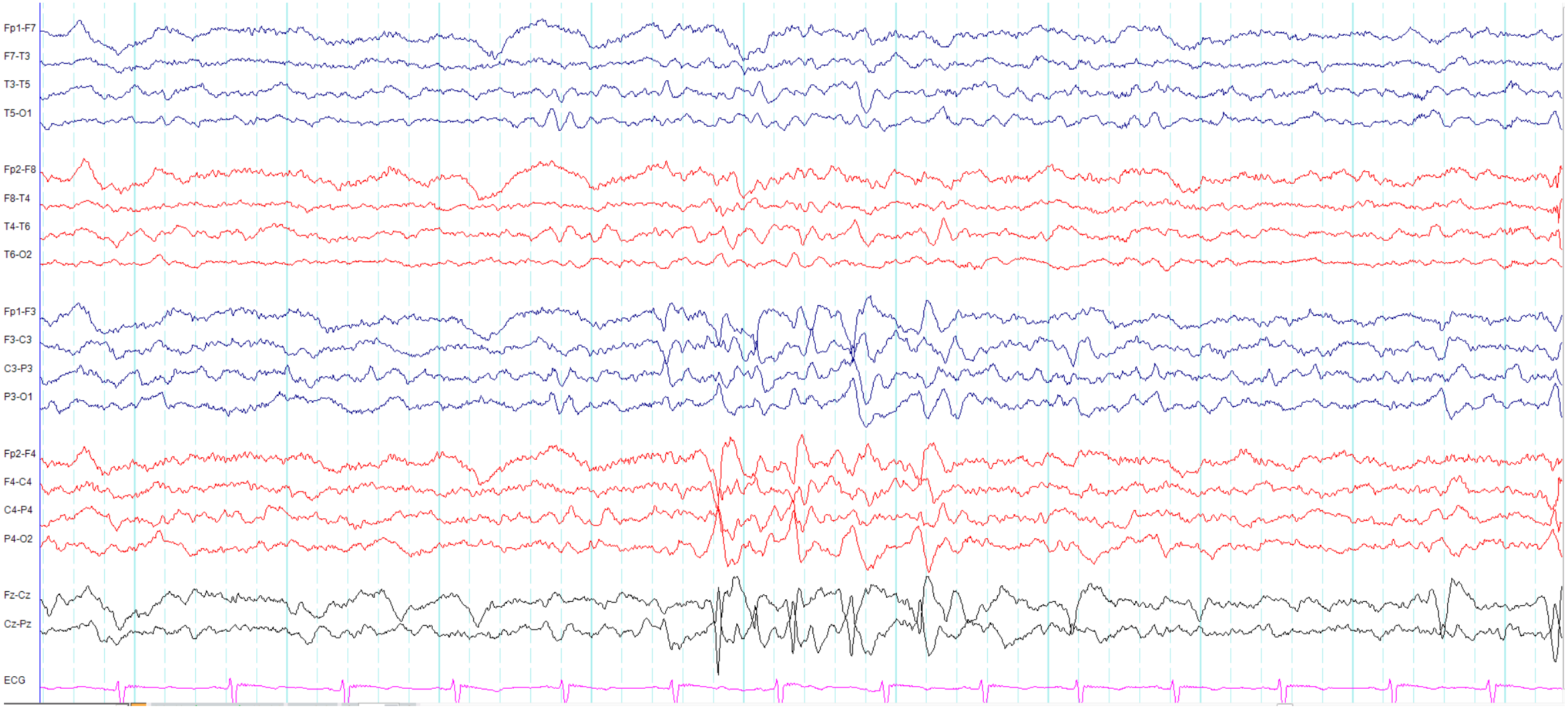
Vertex (V) sharp waves

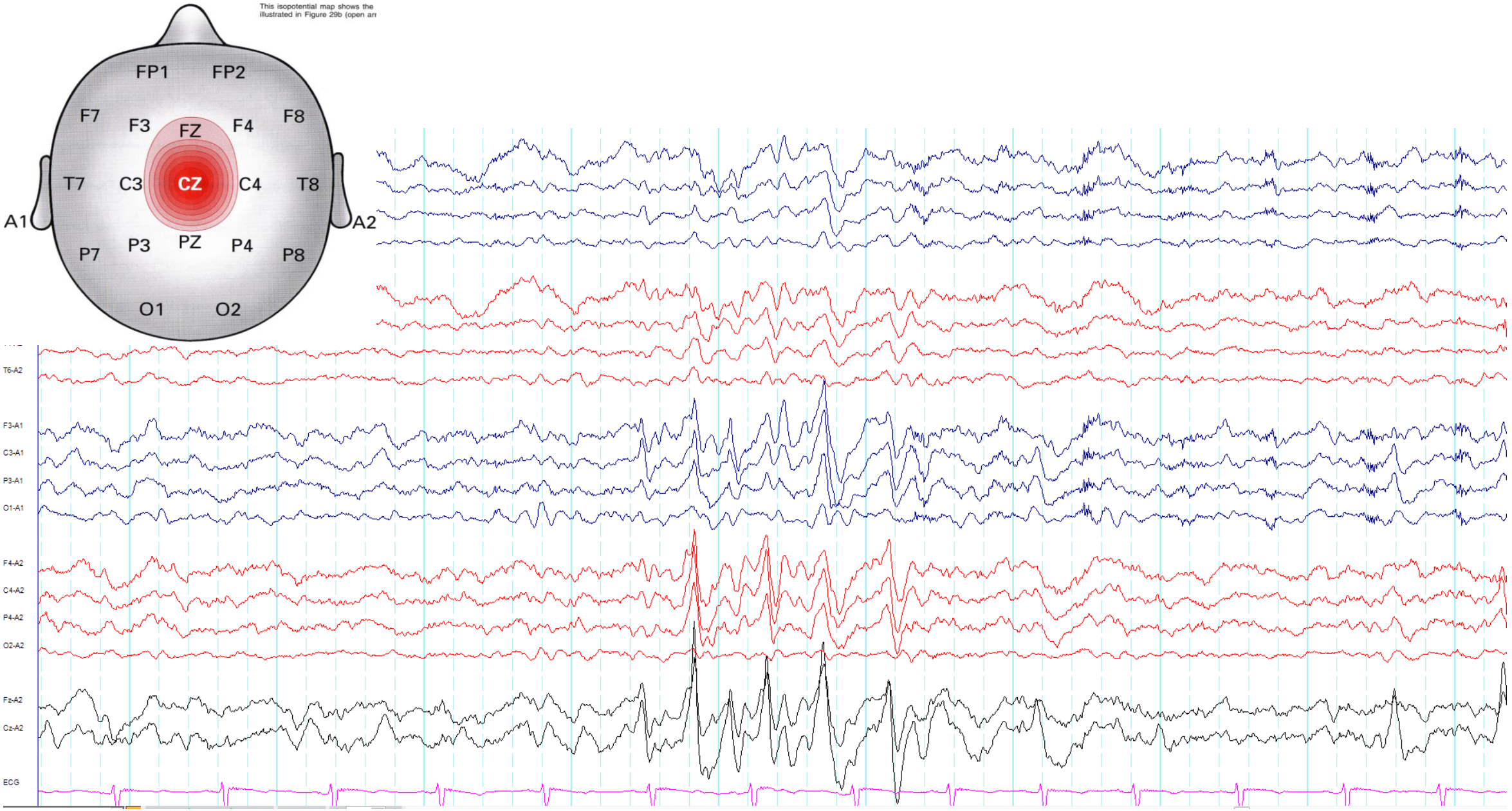
- Bilateral synchronous diphasic sharply contour waves in central regions
  - initial negative / then positive deflection
- Appear by 6-8 weeks post-term
- Abnormal:
  - Persistent asymmetry >20%
  - Asynchrony : in hydrocephalus,

Repetitive V waves

8 years old

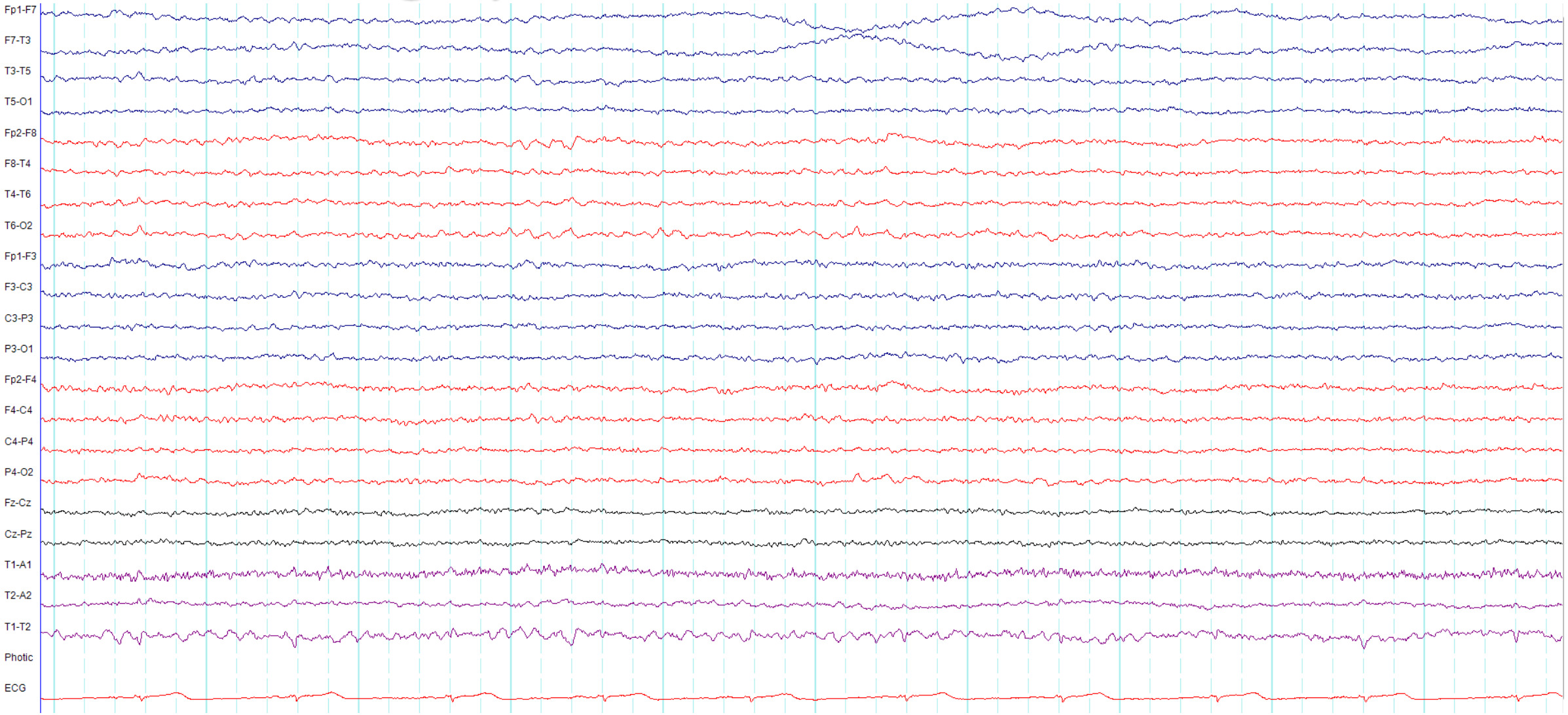



Fp1-F7
F7-T3
T3-T5
T5-O1
Fp2-F8
F8-T4
T4-T6
T6-O2
Fp1-F3
F3-C3
C3-P3
P3-O1
Fp2-F4
F4-C4
C4-P4
P4-O2
Fz-Cz
Cz-Pz
ECG

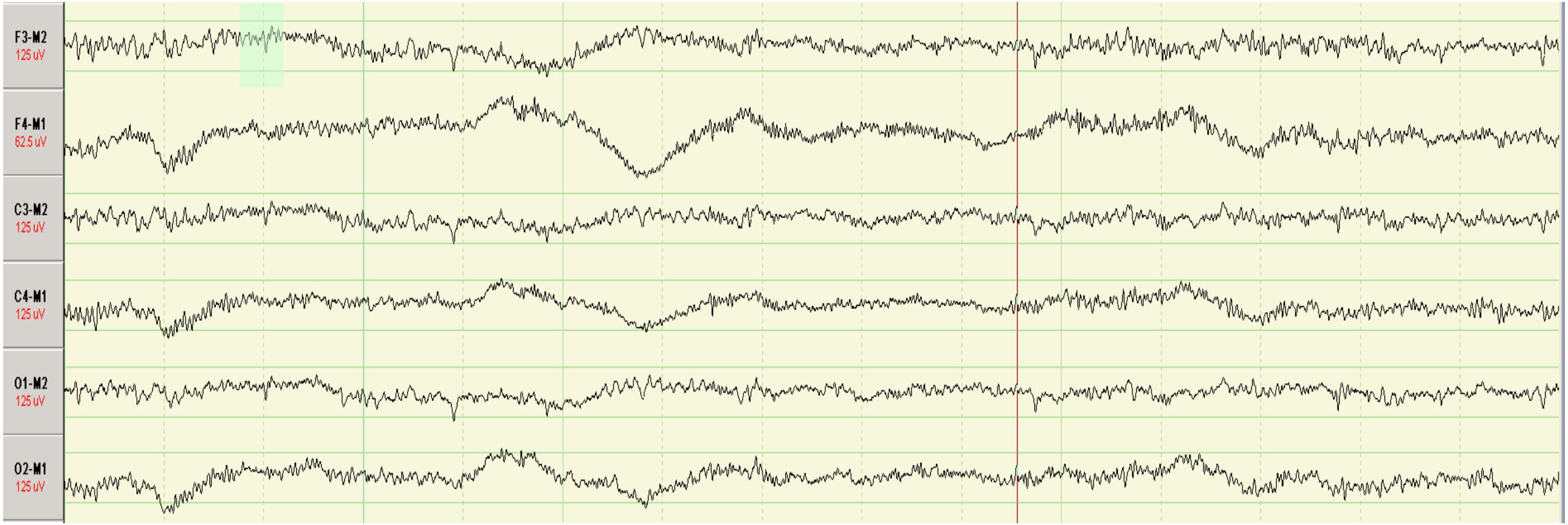

This isopotential map shows the
illustrated in Figure 29b (open ar
FP1
FP2
F7
F3
FZ
F4
F8
T7
C3
CZ
C4
T8
A1
A2
P7
P3
PZ
P4
P8
O1
O2
T6-A2
F3-A1
C3-A1
P3-A1
O1-A1
F4-A2
C4-A2
P4-A2
O2-A2
Fz-A2
Cz-A2
ECG

Slow rolling eye movements

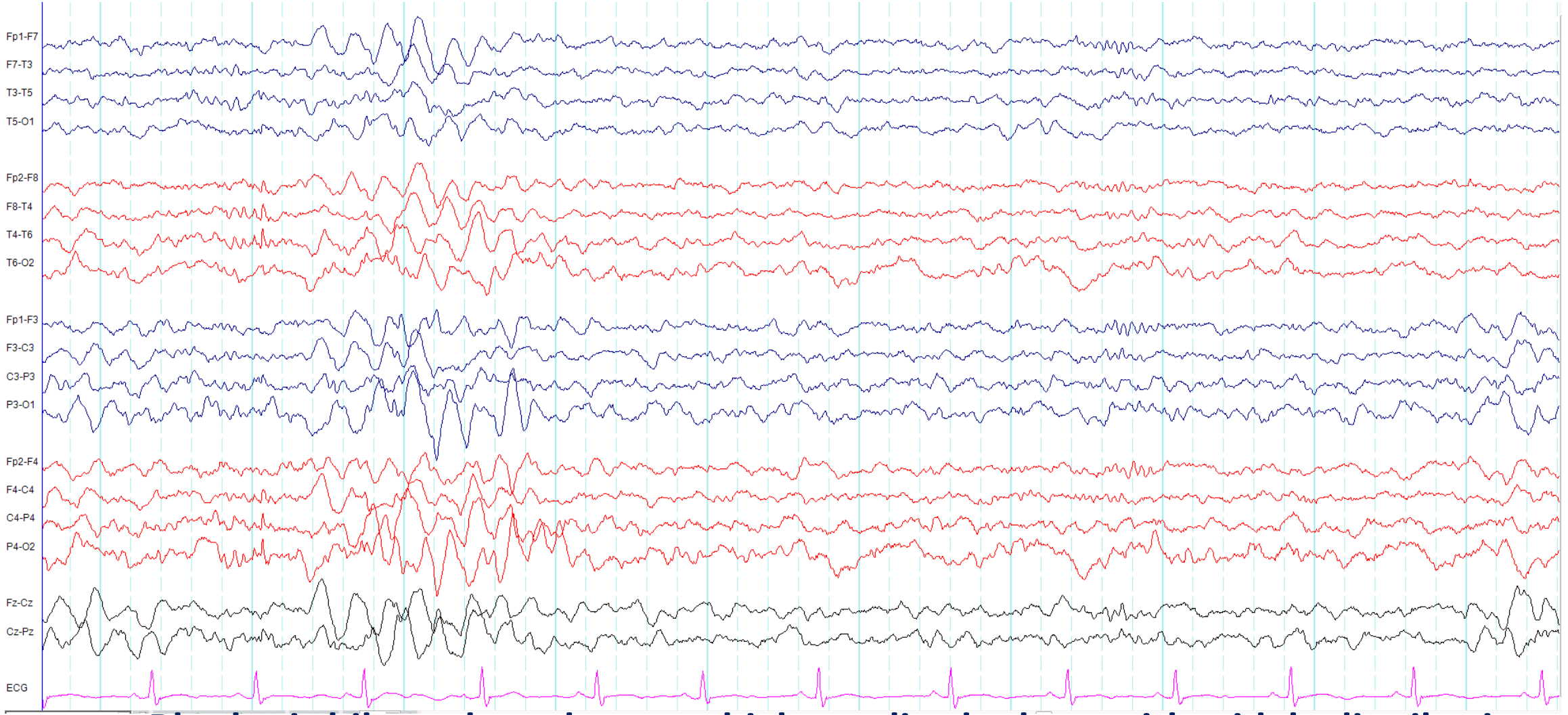
<0.5 Hz



Slow rolling eye movements (reference montage)



Hypnagogic hypersynchrony



Rhythmic bilateral synchronous high amplitude theta with widely distribution

Hypnagogic hypersynchrony

- Abrupt onset during drowsiness

Hypnapompic hypersynchrony

- Associated with brief arousal from light sleep

- Rhythmic bilateral synchronous theta burst with widely distribution
- Amplitude 200-300 uV

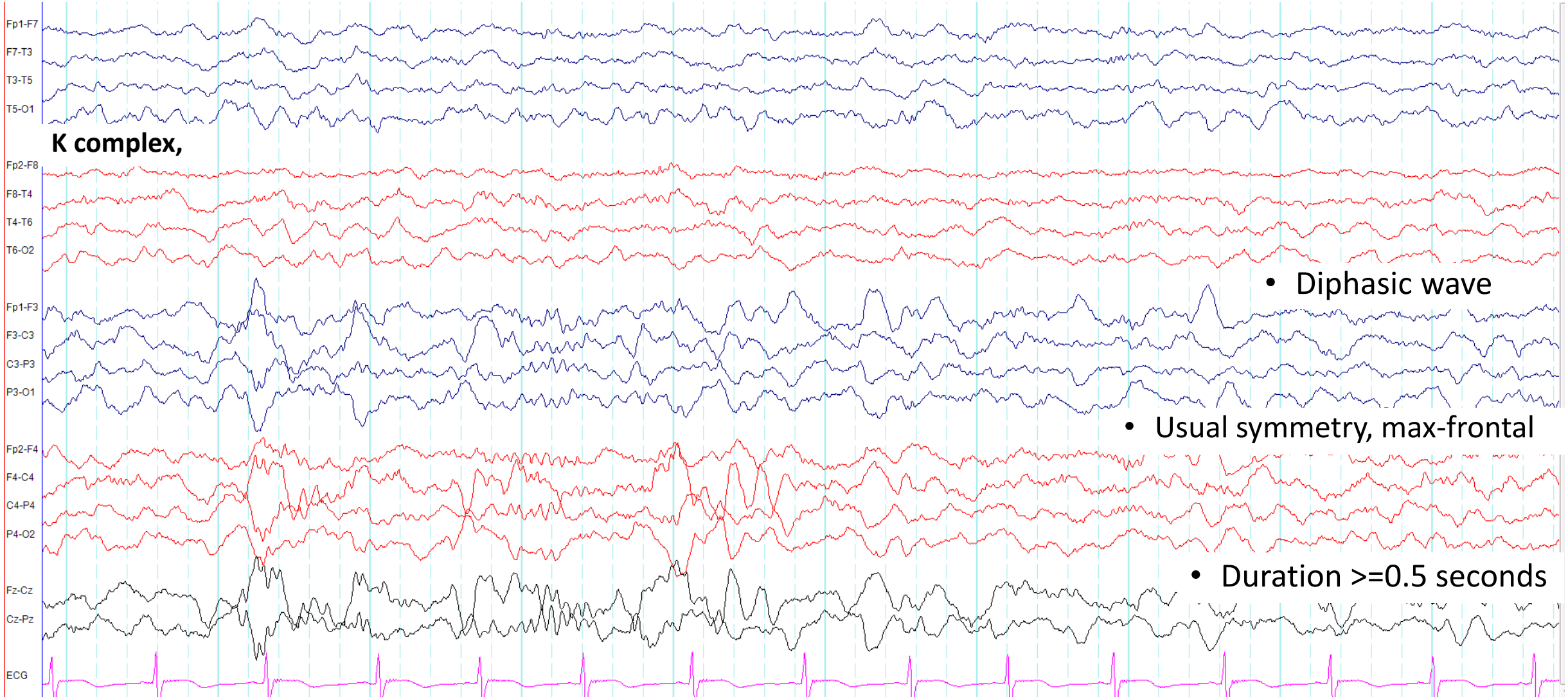
- Most prominent at around 1 year, decrease toward 10 years old

NREM stage 2

- K complexes
  - A well-delineated diphasic wave, negative followed by positive
  - Duration >= 0.5 seconds
  - Maximum amplitude in frontal derivations

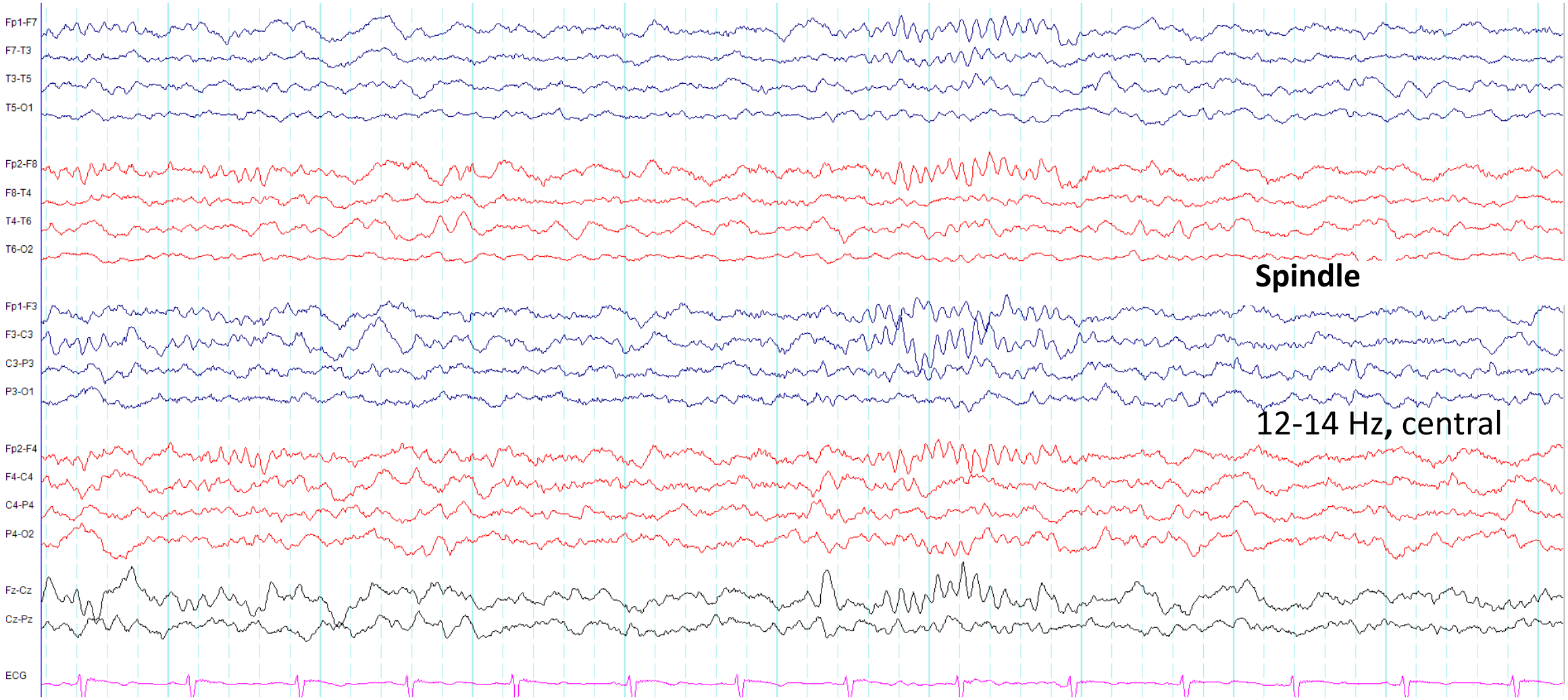
- Sleep spindles
  - A train of sinusoidal waves, 11-16 Hz (most commonly 12-14Hz)
  - Maximum amplitude in central derivations

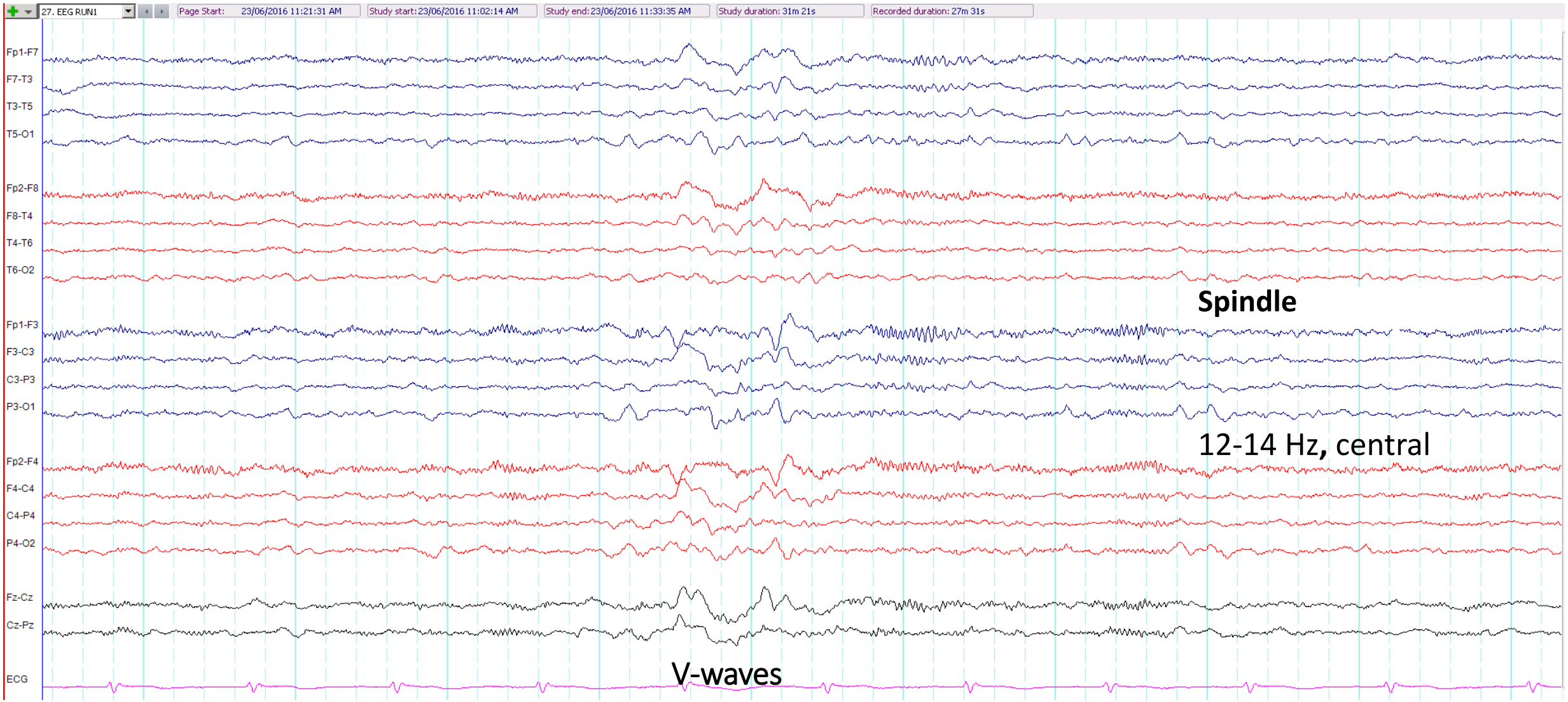
K complexes– sleep spindle



- Diphasic wave
- Usual symmetry, max-frontal
- Duration >=0.5 seconds

Sleep spindle




27. EEG RUN1
Page Start: 23/06/2016 11:21:31 AM
Study start: 23/06/2016 11:02:14 AM
Study end: 23/06/2016 11:33:35 AM
Study duration: 31m 21s
Recorded duration: 27m 31s
Fp1-F7
F7-T3
T3-T5
T5-O1
Fp2-F8
F8-T4
T4-T6
T6-O2
Fp1-F3
F3-C3
C3-P3
P3-O1
Fp2-F4
F4-C4
C4-P4
P4-O2
Fz-Cz
Cz-Pz
ECG
Spindle
12-14 Hz, central
V-waves

NREM stage 2

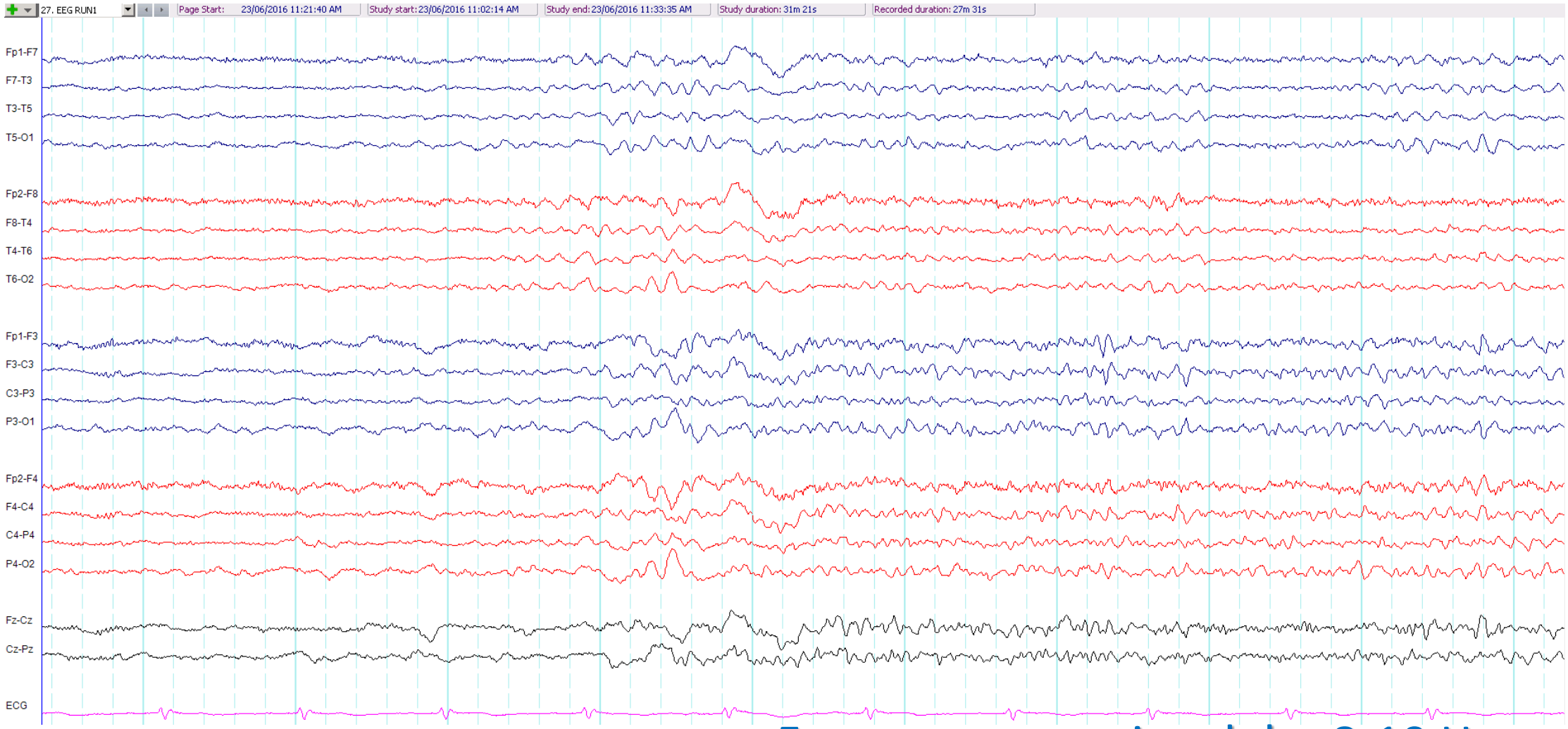
- K complexes
  - First appear between 8 and 12 weeks post-term
  - Spontaneous or in response to abrupt sensory stimulus (usually auditory)

NREM stage 2

- Sleep spindles
  - A burst of oscillatory brain activity
  - First appear between 6 and 8 post term; bilateral asynchronous
  - At age of one and a half years (18 months); bilateral synchronous
  - At age of 2 years; asynchronous = abnormal

  - Three types:
    - Central 14 Hz: adults sleep, spindle coma
    - Frontal 10-12Hz: 5% of normal kids 3-12 years old
    - Nearly continuous 10Hz: related to drug effect (morphine)

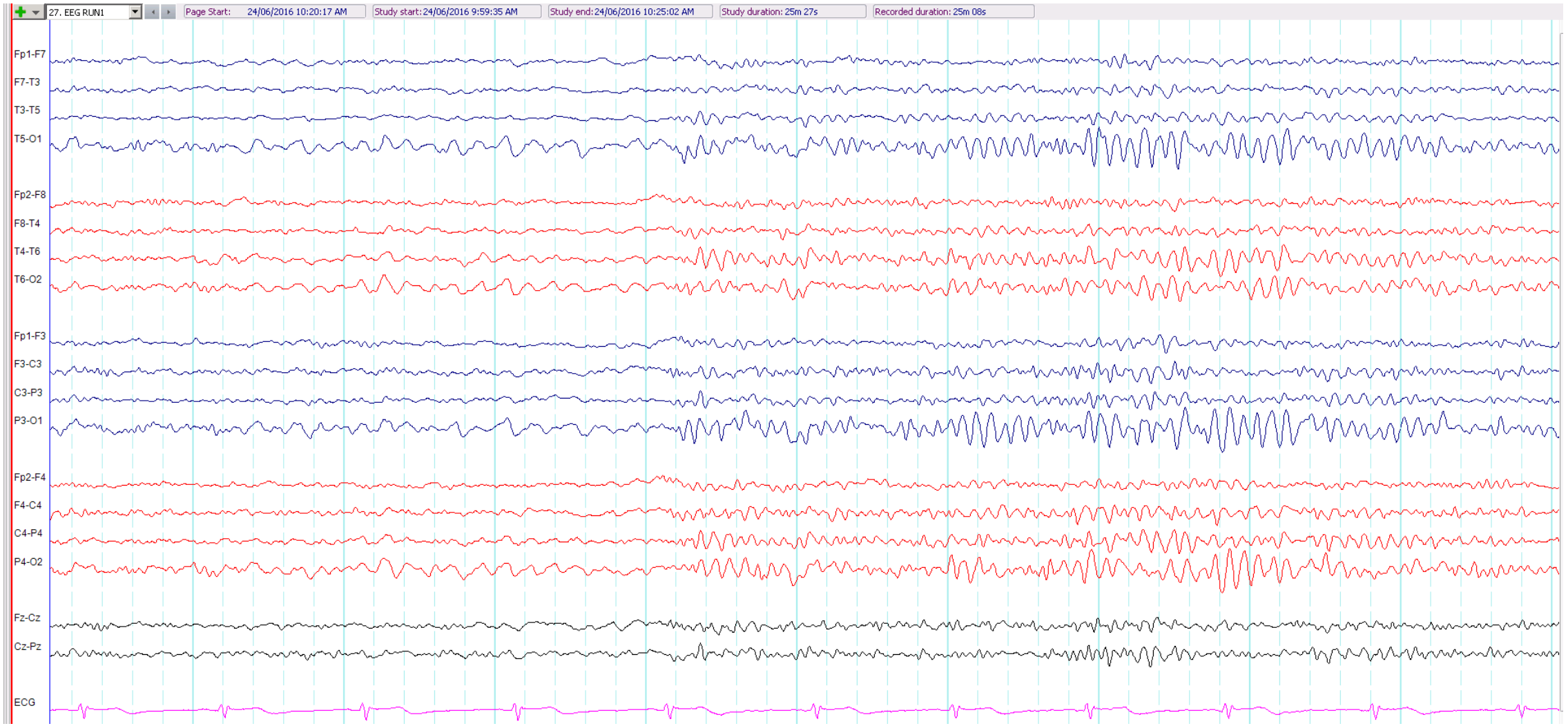
K complexes with arousal



Fast component in adult : 8-10 Hz

Arousal

Fast component in adult : 8-10 Hz



Arousal

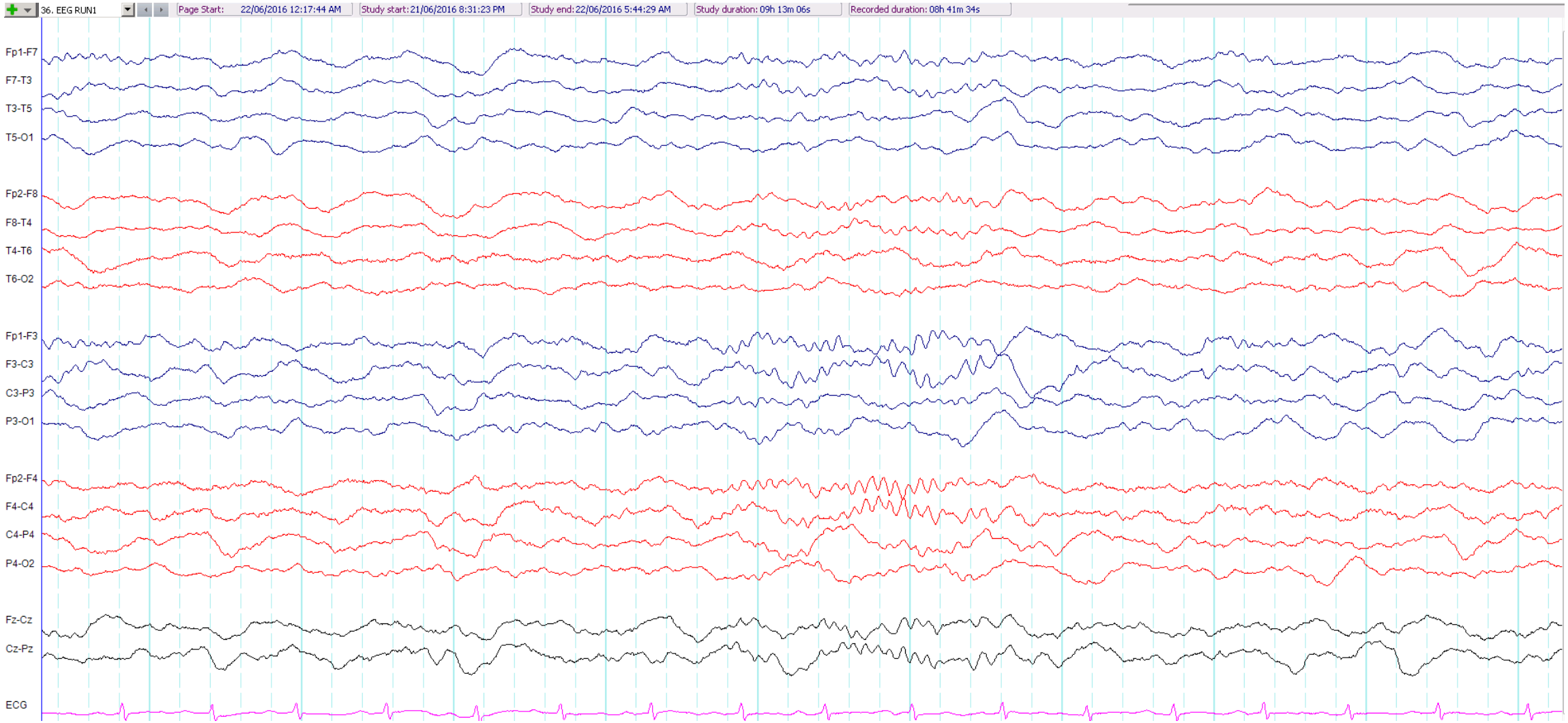
- Post 2 months → slow component
- Post 7 months → 4-4.5 Hz
- Adult → 8-10 Hz

NREM stage 3 (Slow Wave Sleep)

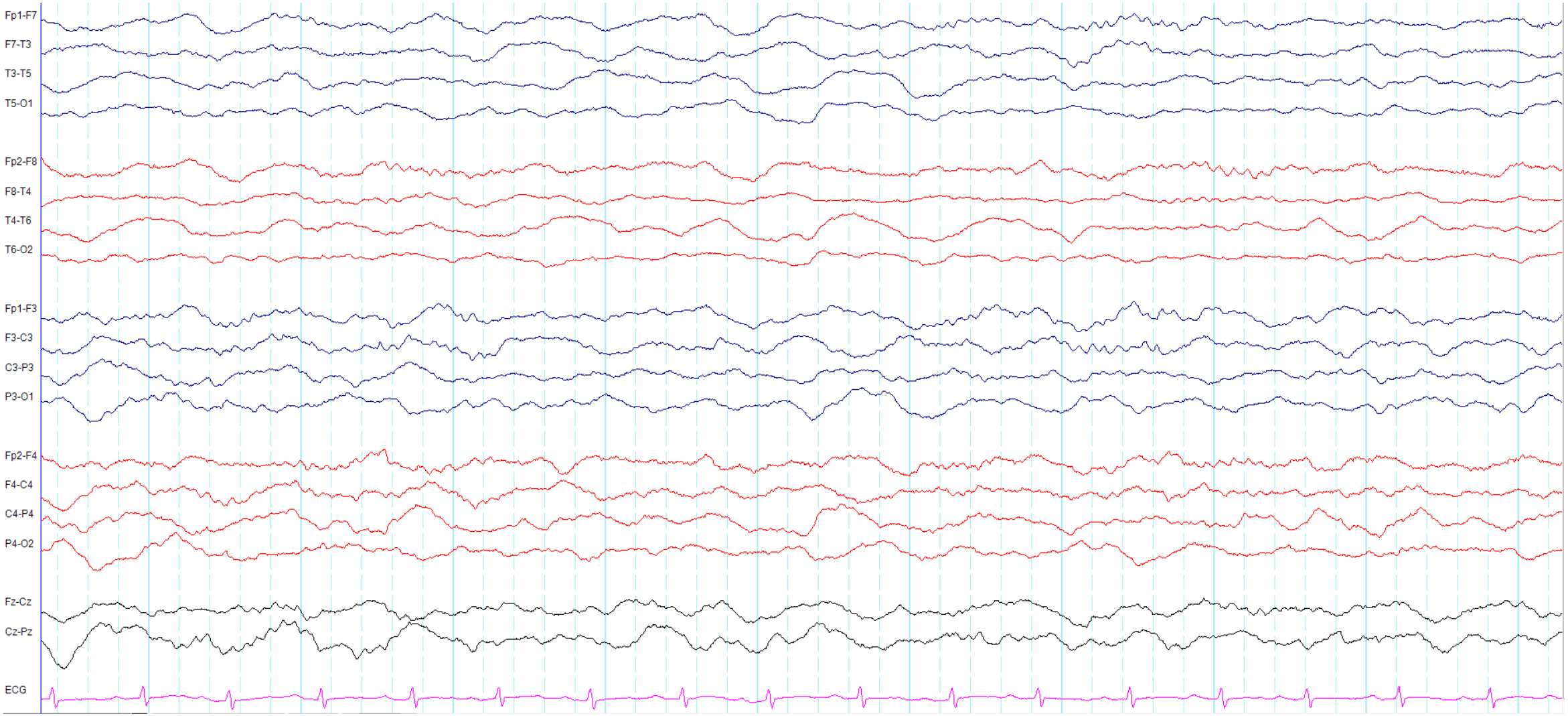
- Wave frequency 0.5-2 Hz (Delta activity)
- Peak to peak amplitude > 75 uV (frontal regions)

Slow wave sleep

High voltage >75 uV
Polymorphic, asynchronous
Slow wave - Delta activity (0.5-2Hz)



Slow wave sleep

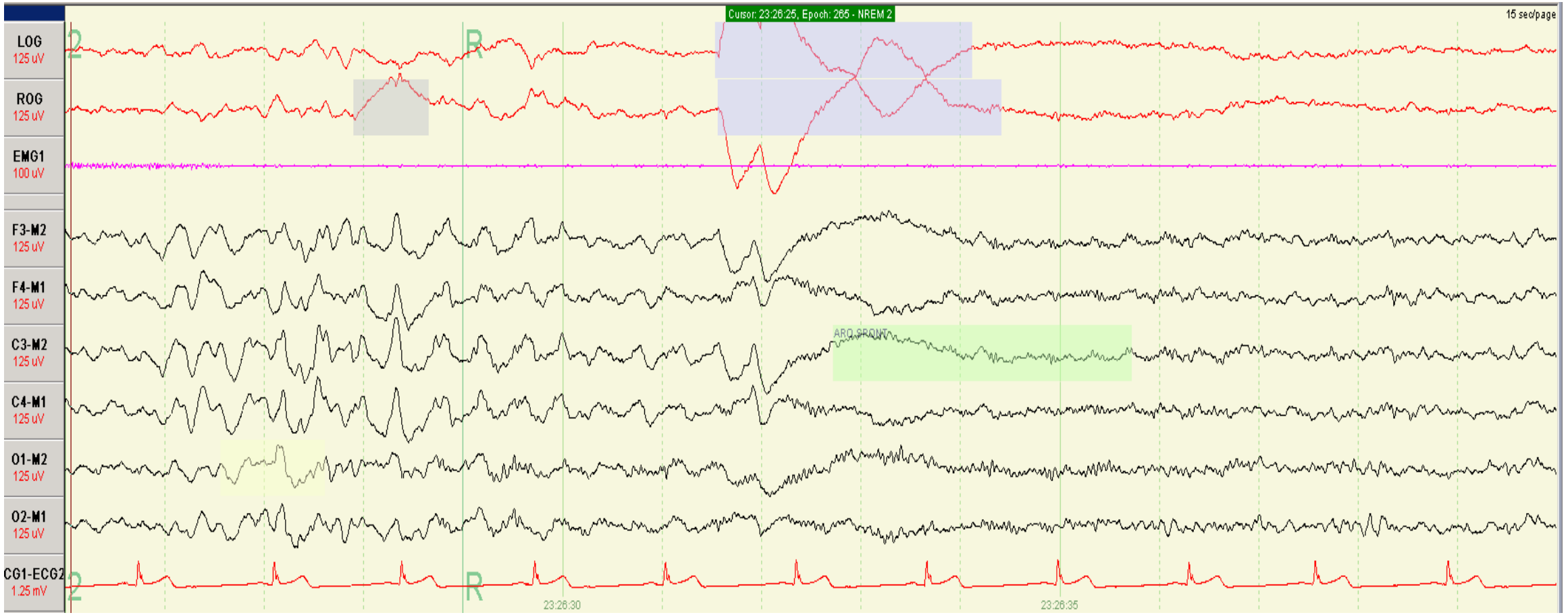


Before Rapid Eye Movement (REM) sleep

- Saw tooth waves
  - Trains of 2-6 Hz sharply contour, triangular wave
  - Maximum amplitude over central head region

- Do not usually found in REEG

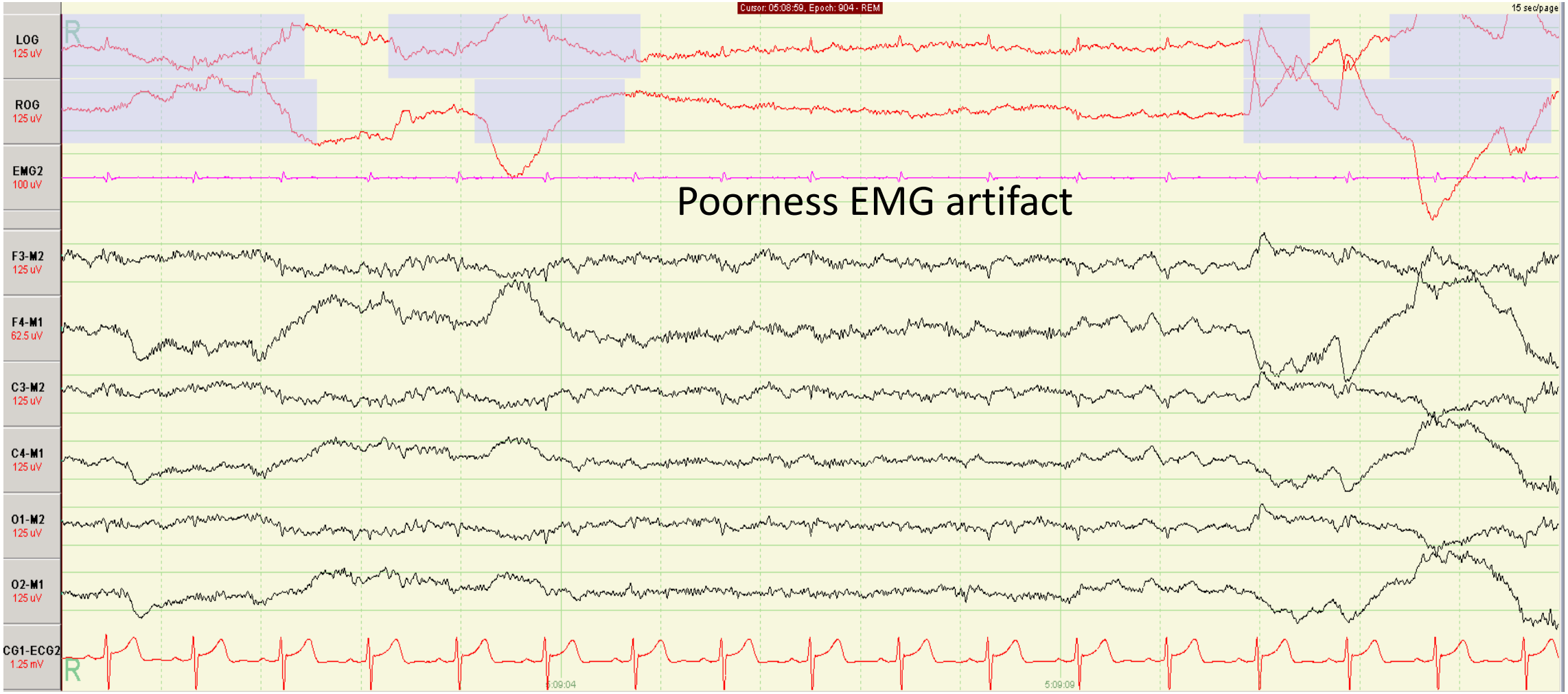
Sawtooth waves (15 sec/ page)



- Trains of 2-6 Hz sharply contour, triangular wave
- Maximum amplitude over central head region

REM -phasic

Chaotic, multidirectional eye movement

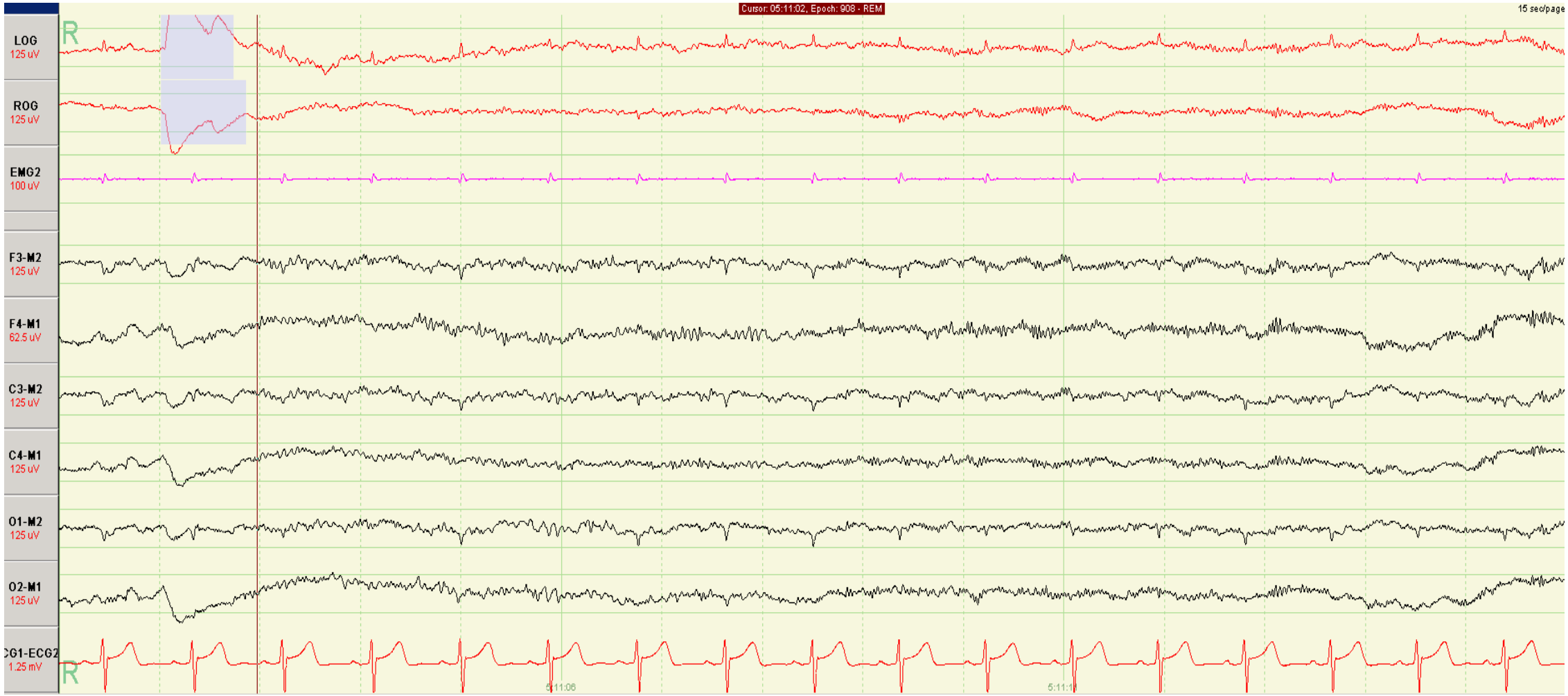


Low voltage

Mixture of fast, theta, and delta rhythms, usually alpha activity 1-2 Hz slower than awake

Without K or sleep spindle

REM - tonic


Cursor: 05:11:02, Epoch: 908 - REM
15 sec/page
LOG
125 uV
ROG
125 uV
EMG2
100 uV
F3-M2
125 uV
F4-M1
62.5 uV
C3-M2
125 uV
C4-M1
125 uV
O1-M2
125 uV
O2-M1
125 uV
CG1-ECG2
1.25 mV
R
R
5:11:06
5:11:1

Pediatric awake EEG

- Full term to age of 3 months old
  - Mixed delta-theta activities with central predominance
- 3 months old to 1 year old
  - Clearly identified PDR followed age groups
- 1 – 19 years old
  - Similar to adults
  - Higher amplitude than adults

Sleep EEG

Pediatrics

- NREM sleep
  - **Hypnagogic/ Hypnapompic hypersynchrony**
  - Arousal response
  - POSTs
  - Vertex sharp waves
  - K complexes
  - Sleep spindle
  - Slow Wave Sleep
- REM sleep

Adults

- NREM sleep
  - Arousal response
  - POSTs
  - Vertex sharp waves
  - K complexes
  - Sleep spindle
  - Slow Wave Sleep
- REM sleep


THANK YOU