Review on Radiation Detection

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What types of radiation you may expect to “see” during the workshop?

- $\alpha$ particles (calibration of particle detectors, target thickness measurements, nuclear reactions in ICARE)
- Heavy ions (ICARE experiments)
- $\gamma$ rays ($\gamma - \gamma$ coincidence measurement on EAGLE, timing measurement)
- X-rays (cyclotron RF voltage measurement)
- Neutrons (unlikely but we are prepared)
Principles of radiation detection

All types of radiation I am going to discuss are called *ionising radiation* – just because its energy is high enough to ionize an atom.

- Ionization is the main phenomenon that makes radiation detection and measurement possible.
- Charged particles cause ionization of the matter along its path until they stop.
- Neutral particles (photons included) need to interact with something that would emit charged particles, this badly affects efficiency.
Obsolete detectors

- Electrometers
  - Curie electrometer
  - Some still used for radiation protection
- Photographic plate/film
  - Still used for radiation protection
- Cloud / bubble chamber
Gas detectors:
Geiger-Müller tube, proportional chamber
Scintillation detectors

- Scintillator
- Light Guide
- Photomultiplier Tube (PMT)
- Photocathode
- Dynodes
- Anode

Signal

Photocathode

Secondary Emission

Photoelectric

Voltages:
- -1000 V
- -500 V
- -300 V
- -200 V
- -100 V
- 0 V
Scintillation detectors in EAGLE

- Anti-Compton shields (BGO)
- Elements of gamma multiplicity filter (BaF$_2$) *(not in use at the moment)*
Scintillation detectors

Lanthanum Bromide  Caesium Iodide and plastic
Semiconductor detector – principle of operation
Semiconductor detector – principle of operation
A 3-coil zone refiner
A zone-refined ingot
Czochralski method of monocrystal production
A crystal being grown
Grinding and slicing of a crystal
Charged Particle detector
how it is made?

• Surface Barrier Si Detector
• Ion-Implanted Si Detector
Charged Particle detector
form factors
Charged Particle detector

ICARE Si Detector
Particle detectors

- We will be using two types: silicon barrier detectors and gas detectors.
- ICARE uses gas/silicon combination as a particle identification \( E/\Delta E \) telescope.
ICARE telescope – disassembled

- Silicon part below
- Gas part put aside
Charged particle identification: $E - \Delta E$ telescope
$\gamma$-ray interaction with matter

- Photoelectric effect
- Compton effect
- Pair creation
γ-ray energy spectrum from a single crystal HPGE detector

\[ E_{\text{det}} = E_1 - E_2 \]
Anti-Compton shield

- 1.49 MeV Double-escape
- 2.0 MeV Single-escape
- 2.511 MeV Full-energy peak

Counts/Channel vs. Channel
No anti-Compton shield
Anti-Compton shield (EAGLE)
How a HPGe detector looks inside?
What you need to run it?

- Bias power supply
- Spectroscopy Amplifier
- Fast (timing) Amplifier
Neutron detector – \((n,\alpha)\) capture

辐射防护 neutron detector (outside the HIL cyclotron vault)
Calibration of detectors
silicon detectors for charged particles

- Energy calibration – usually a good, linear response (*unless used for heavy, energetic particles*)
- Efficiency – one may safely assume they are 100% efficient
Calibration of detectors
scintillation detectors for charged particles

- Energy calibration – non-linear response
- Efficiency – 100% efficient
Calibration of detectors
HPGe detectors for gammas

- Energy calibration – linear response
- Efficiency – kind of complicated