Use of the Coincidence Method in Nuclear Physics

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$^{3}_{\Lambda}H$ and $^{3}_{\Lambda}H$ lifetime measurement in Pb–Pb collisions at $\sqrt{s_{NN}}$ = 5.02 TeV via two-body decay

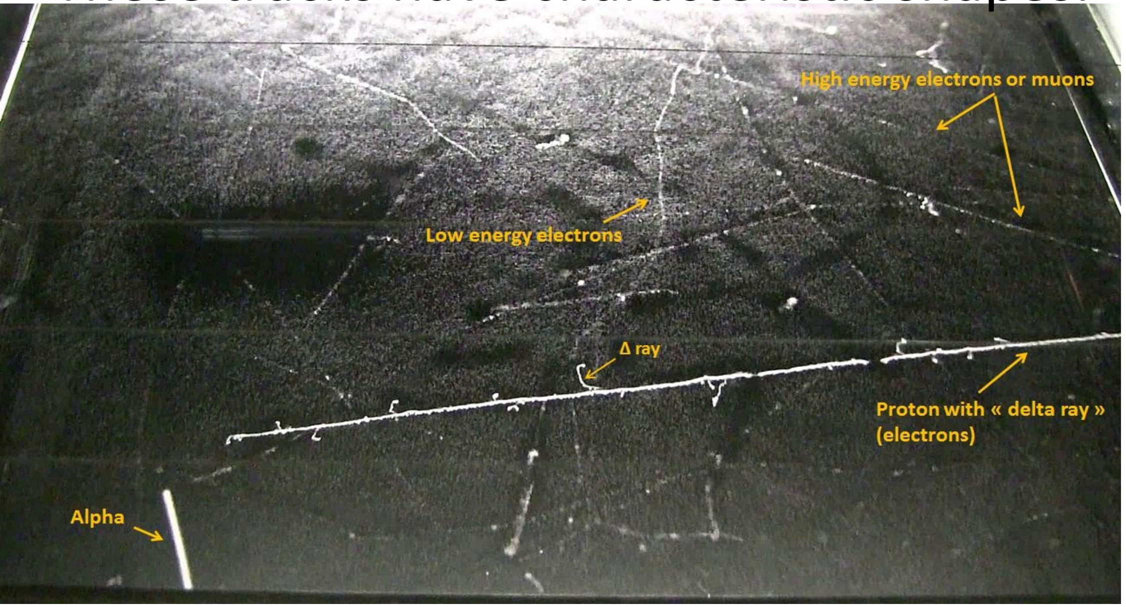
"A detailed description of the ALICE apparatus and data acquisition framework can be found in [25], [26]. The main detectors used in this analysis are the V0 detector, the Inner Tracking System (ITS) and the Time Projection Chamber (TPC), which are located inside a solenoid creating a magnetic field of 0.5 T. The V0 detector [27] consists of two arrays of scintillator counters (V0A and V0C), placed around the beam-pipe on both sides of the interaction region. They cover the pseudorapidity ranges $2.8 < \eta < 5.1$ and , respectively. The V0 detector is used to define the Minimum Bias (MB) trigger, which is characterized by a coincidence signal in the V0A and in the V0C, and to determine the centrality of the collisions [28]. The ITS [29] is the closest detector to the interaction point within ALICE."

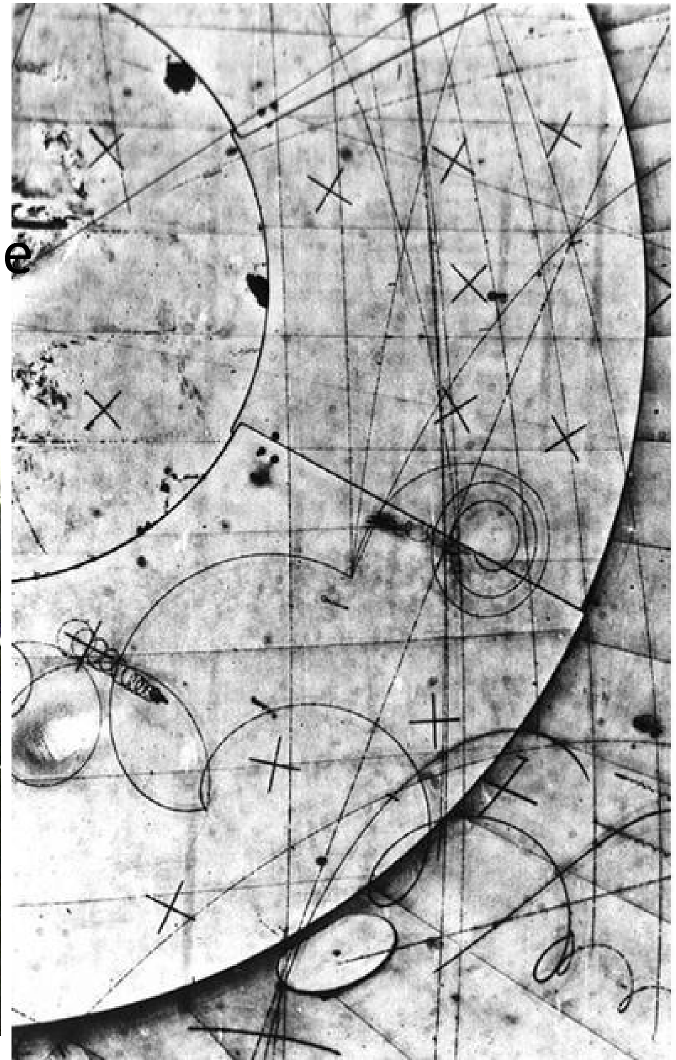
Detectors and events

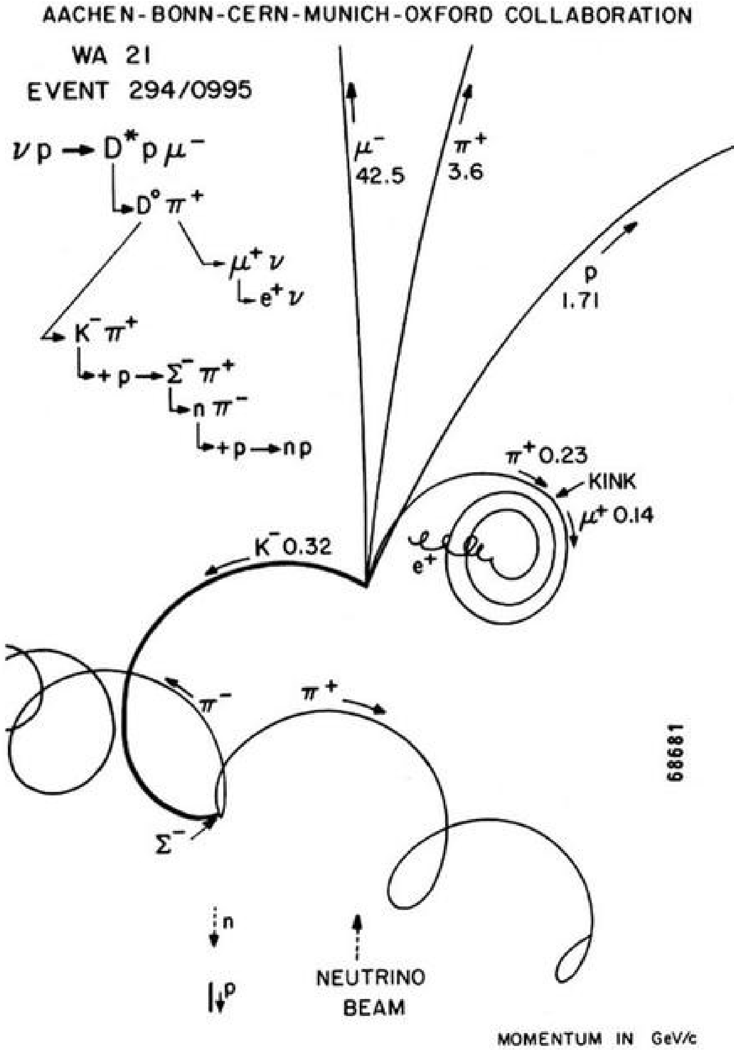
- Device where particle energy is capture in part or completely and converted into some other form more accessible to human perception
- Nuclear and elementary particle physics has seen the development of many different types of detectors, all have this basic goal
- Charged particles transfer their energy to matter through direct collisions while neutral ones need some reactions
- Modern detectors today are essentially electrical in nature, i.e., at some point along the way the information from the detector is transformed into electrical impulses which can be treated by electronic means.
- Taking advantage of the great progress that has been made in electronics and computers
- An event in particle physics refers to the results just after the interaction took place between particles, occurring in a **very short time span**, at a **well-localized region of space.**

Cloud/Bubble chamber

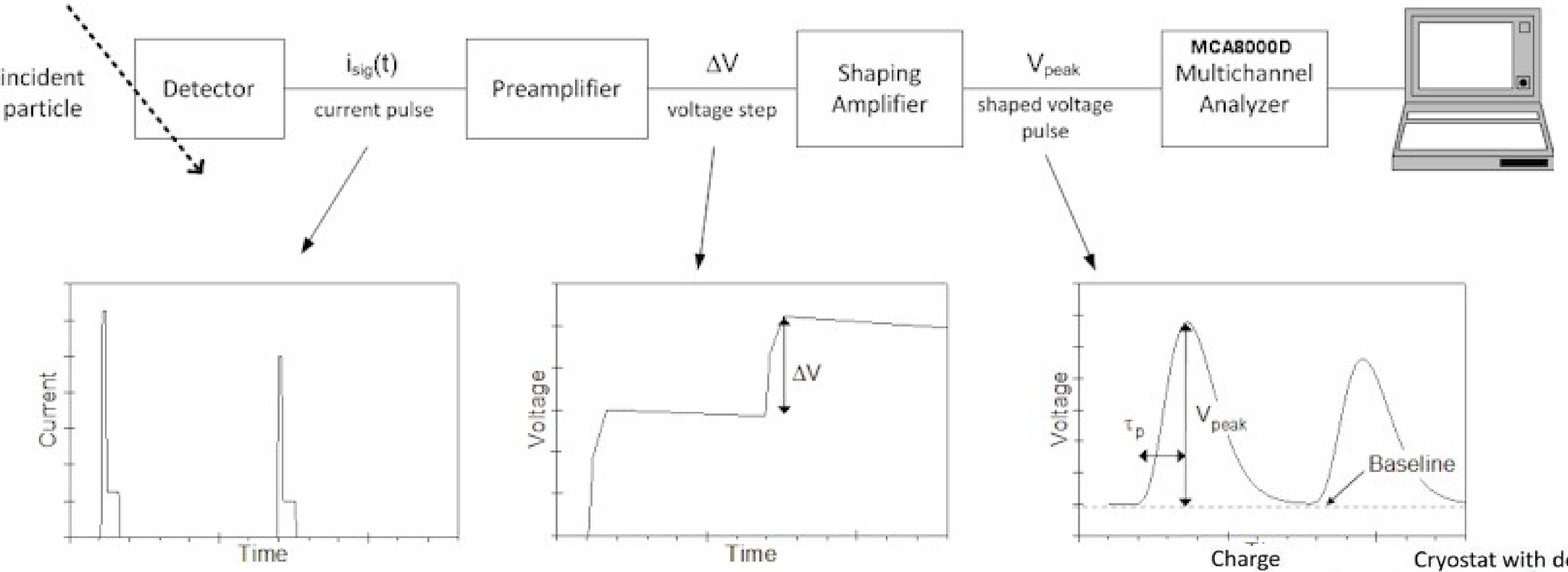
- Sealed environment with supersaturated vapour of water or alcohol
- a charged particle ionizes the atoms
- ions act as condensation centers around which a mist-like trail forms
- These droplets are visible as a "cloud" track that persists for several seconds while the droplets fall through the vapor.
- These tracks have characteristic shapes.

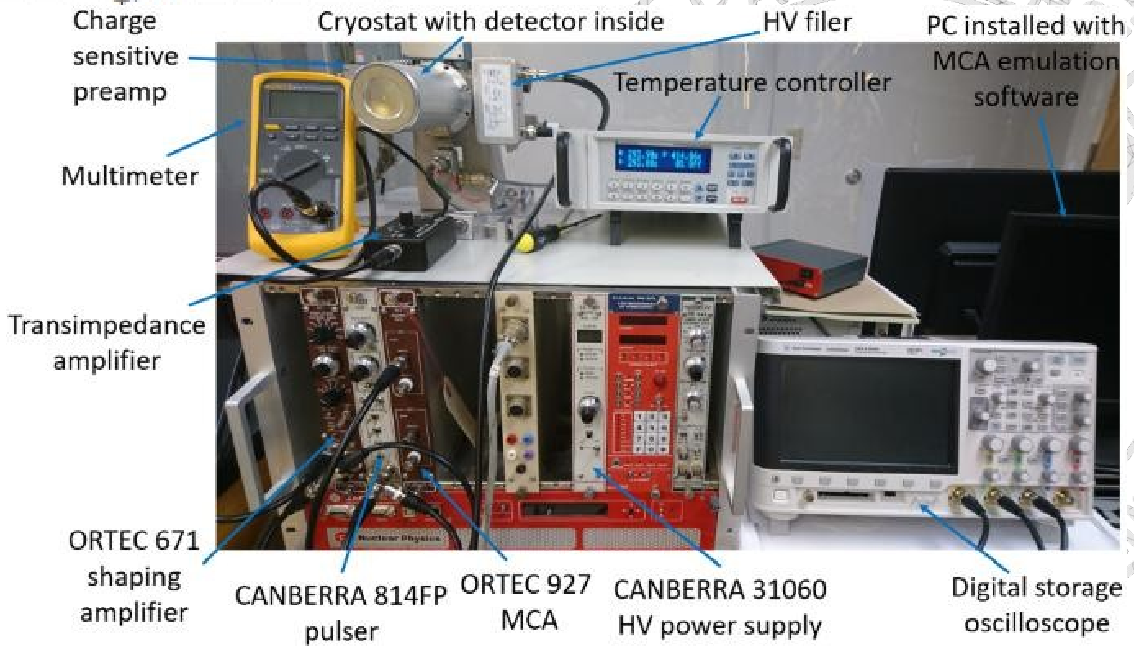






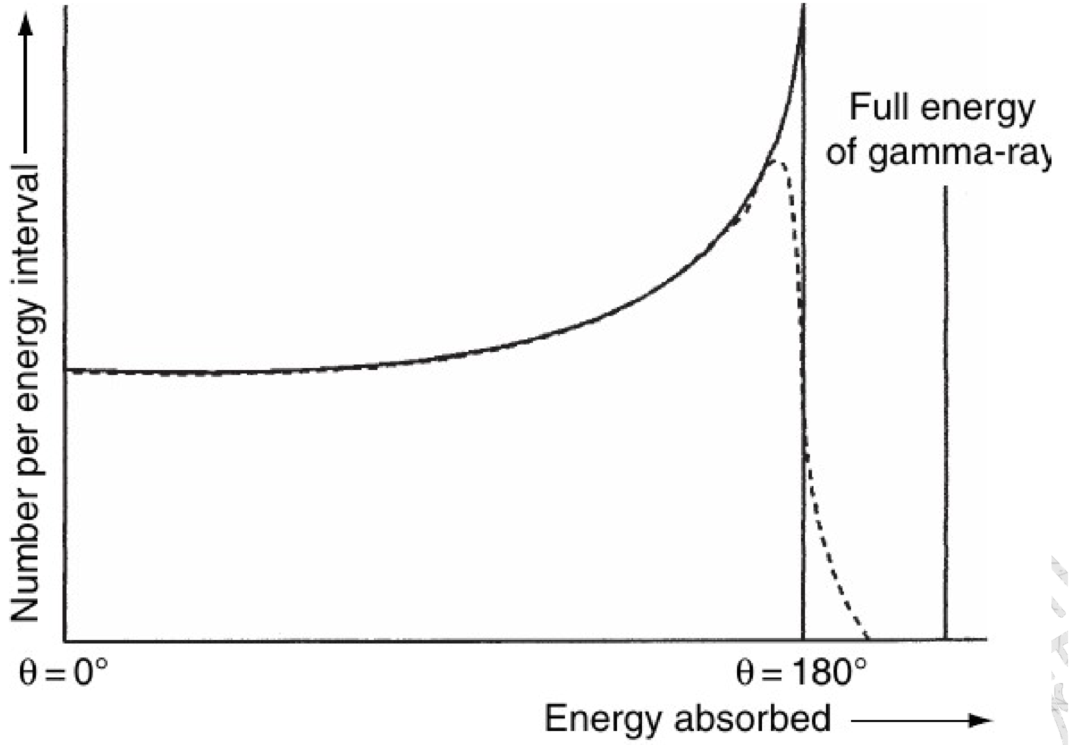
Single detector

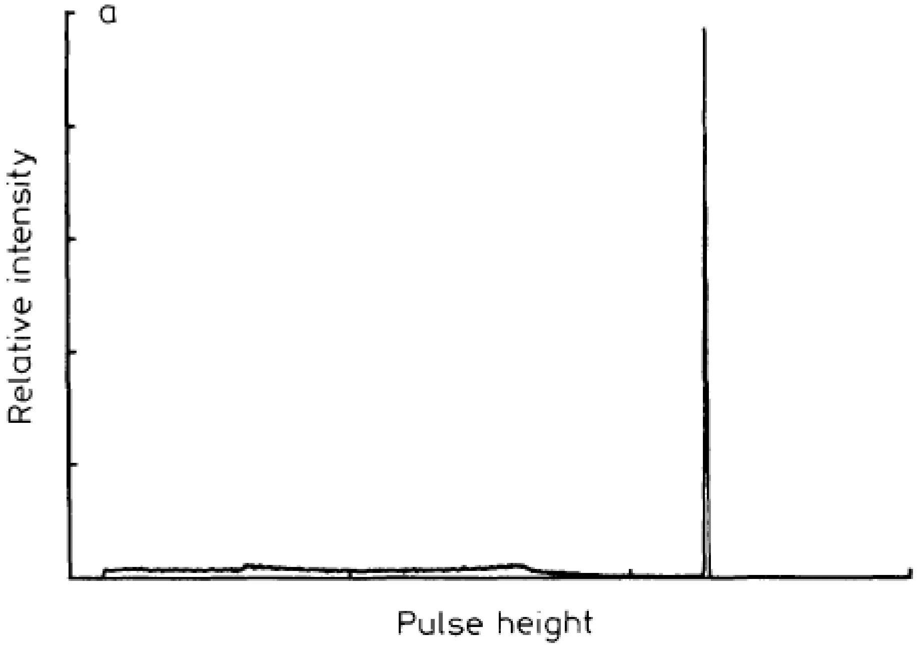


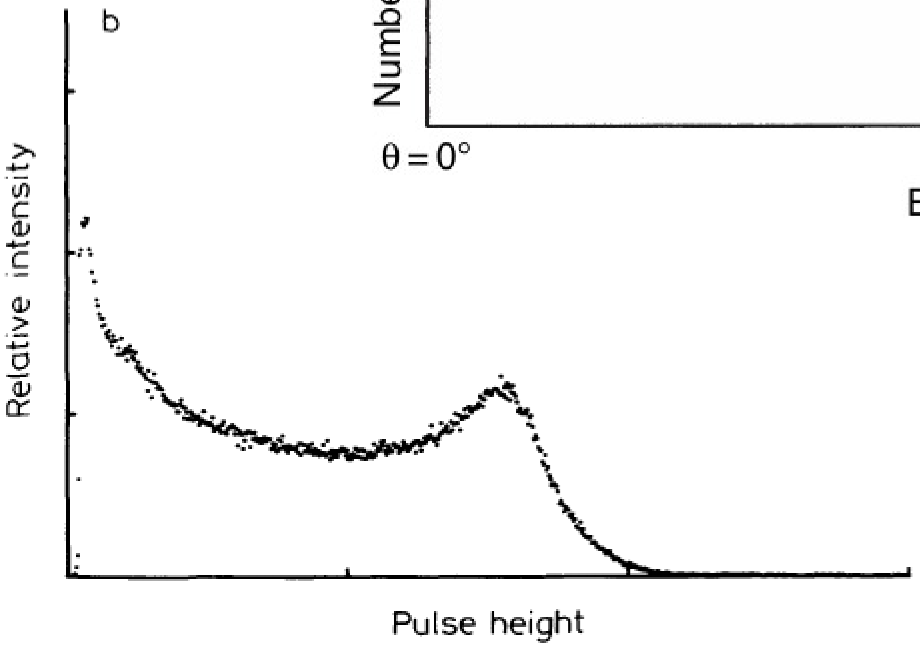


Detector response(Spectrum)

- To measure the energy spectra, an important factor which must be considered is the response function of the detector for the type of radiation being detected.
- This is the spectrum of pulse heights observed from the detector when it is bombarded by a monoenergetic beam of the given radiation.







Simplest counting setup (Integral counter)

- A basic measurement in nuclear or particle physics experiments is a simple counting of the number of signals from the detector.

- For example, measuring the activity of a source, or saturating a counter.

- In this set-up, the analog signal from the detector is shaped by a preamplifier and amplifier combination. The resulting signal is then sent through a discriminator which delivers a standard logic signal for every analog signal with an amplitude higher than the threshold. The logic signal is then sent to the scaler which counts each arriving

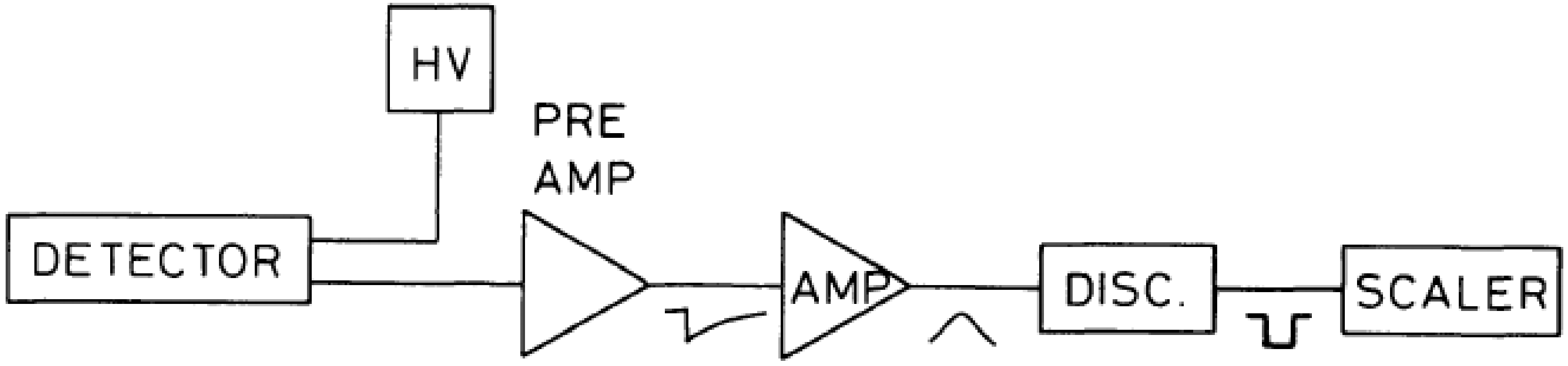


Fig. 15.1. A simple counting system

Energy measurement – pulse height

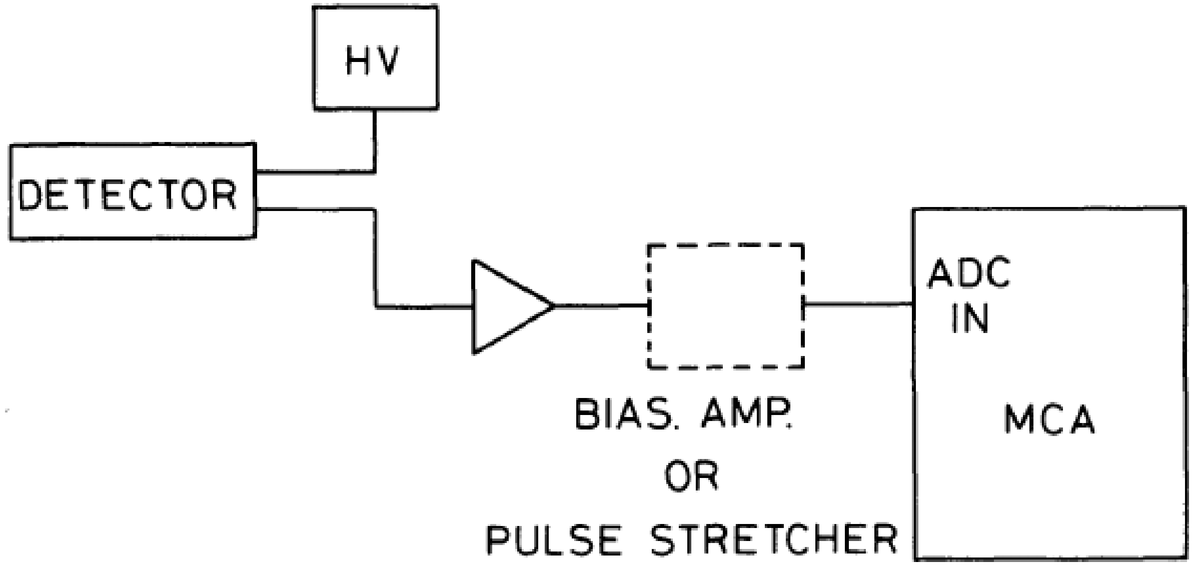
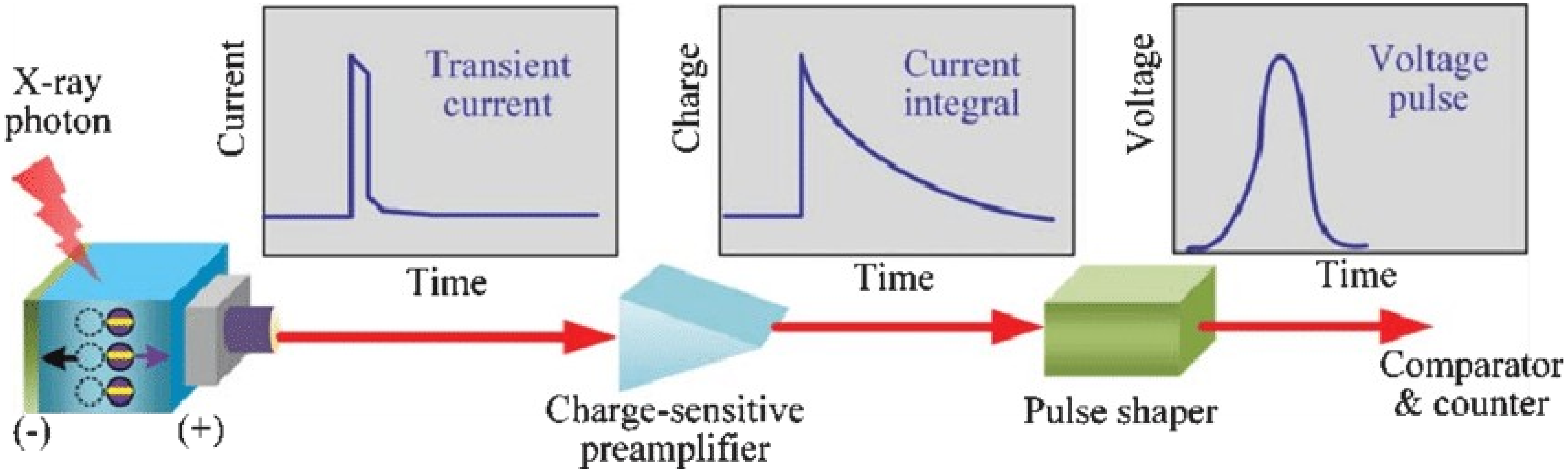
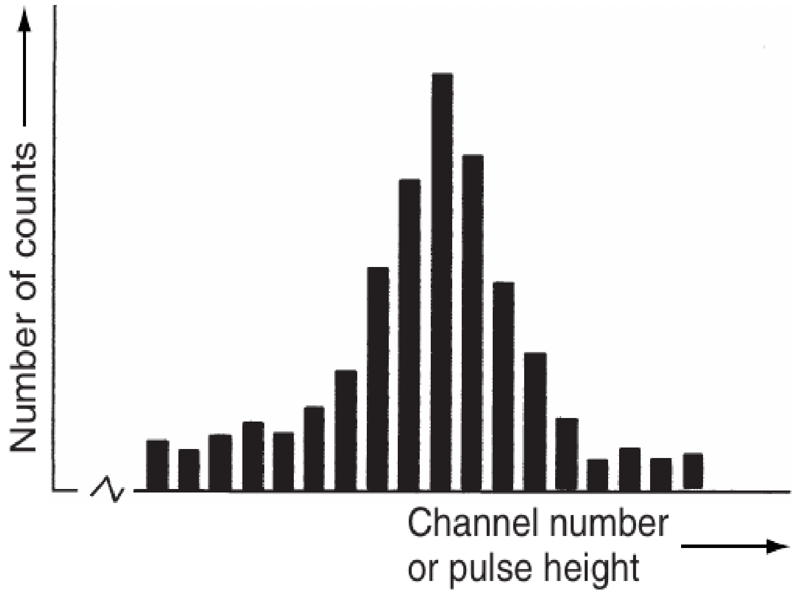
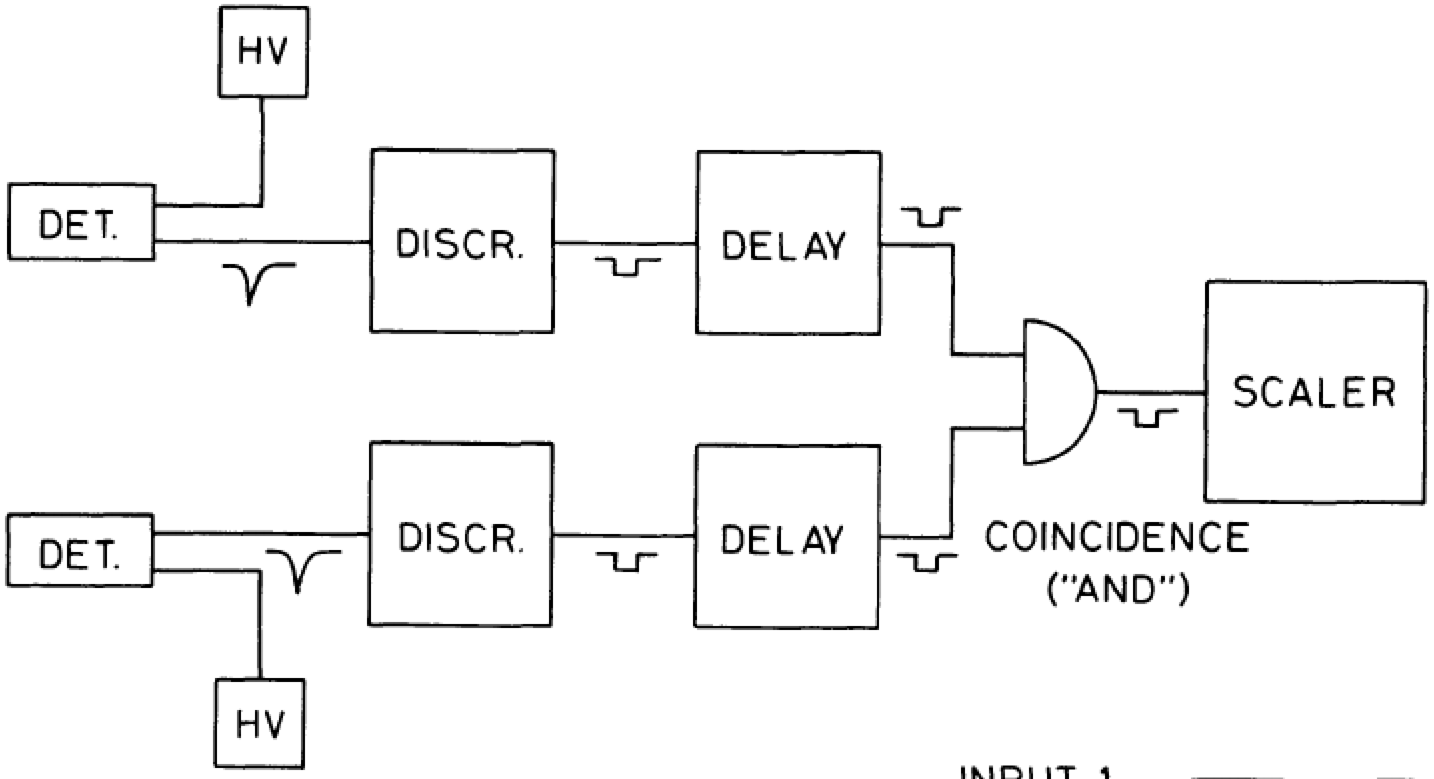


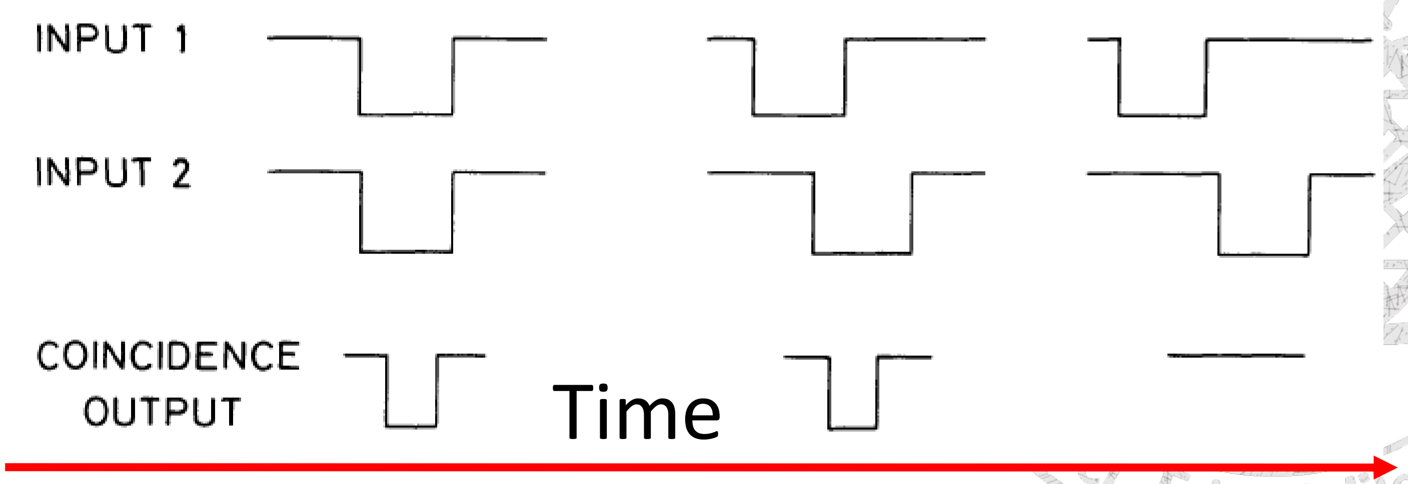
Fig. 15.5. Pulse height spectroscopy with a multichannel analyzer (MCA)



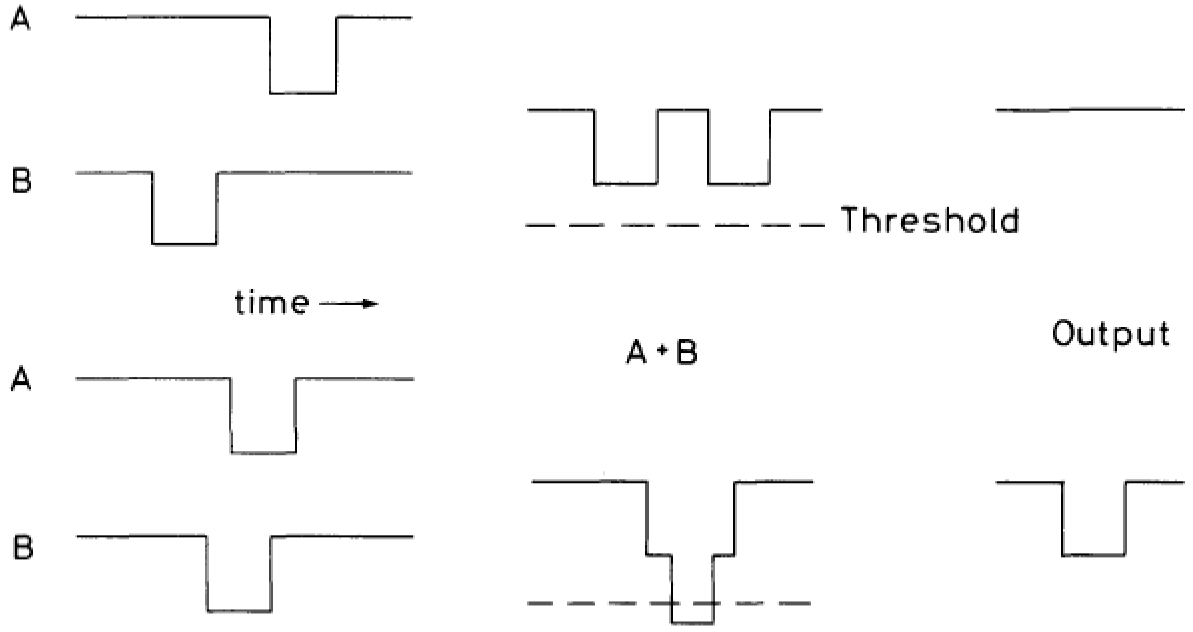


Basic coincidence setup (two detectors)





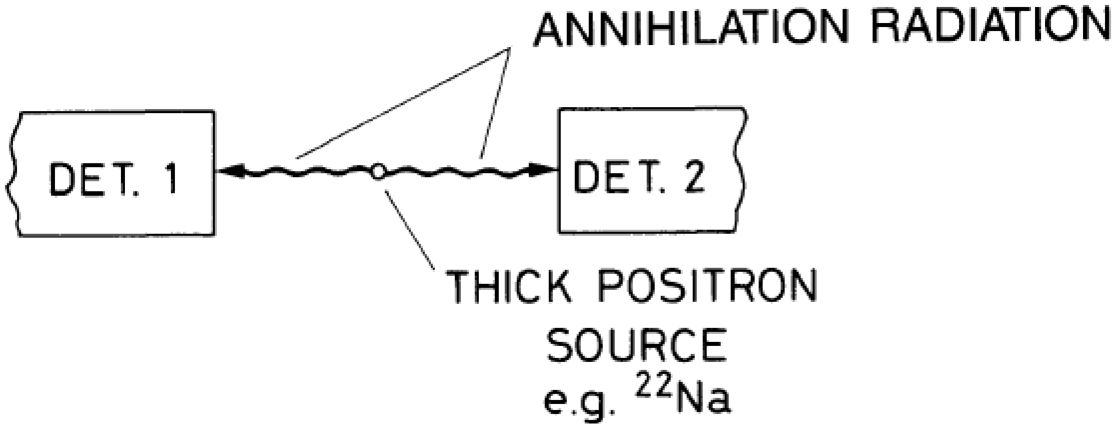
Logic

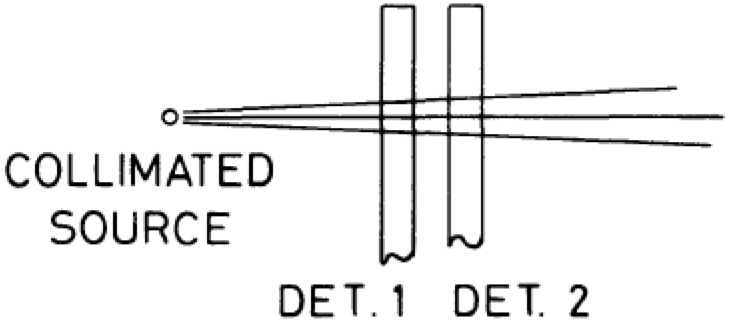


The electronic determination of a coincidence between two pulses may be made in a number of ways. A simple method often used is to sum the two input pulses and to pass the summed pulse through a discriminator set at a height just below the sum of two logic pulses. **Obviously, the sum pulse will only be great enough to trigger the discriminator when the input pulses are sufficiently close in time to overlap.** The definition of coincidence, here, actually means **coincident within a time such that the pulses overlap**. This time period determines the resolving time of the coincidence and depends on the widths of the signals and the minimum overlap required by the electronics.

The coincidence unit is one example of a more general class of units known as the logic gate. These are units which perform the equivalent of Boolean logic operations on the input signals. The coincidence unit, for example, essentially, performs the logical "AND" operation. Other logic gates perform the "OR" operation, "NOT" and combinations of the above.

Adjusting the Delays. The Coincidence Curve





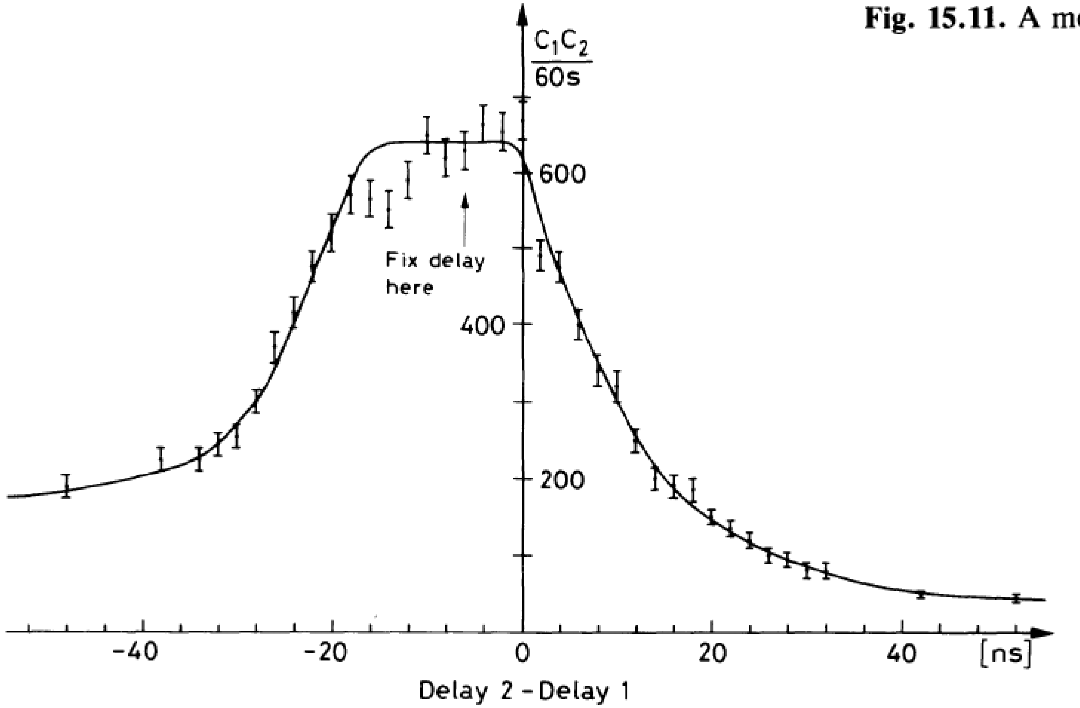
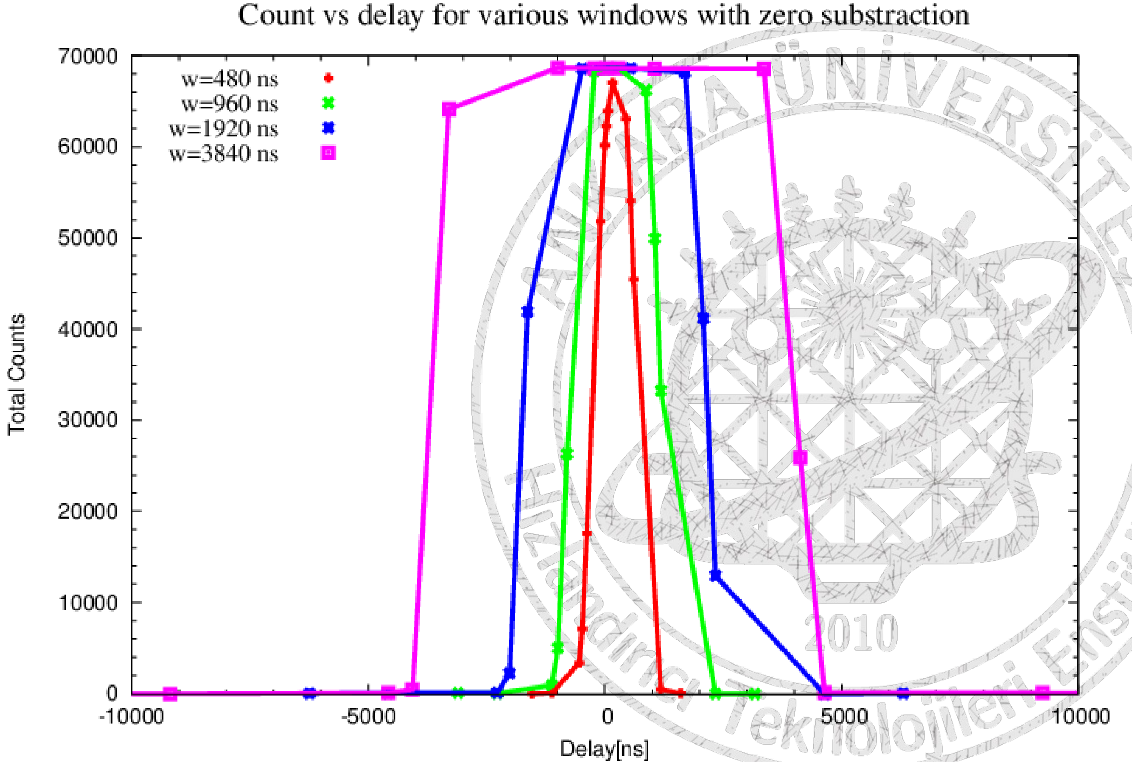


Fig. 15.11. A me

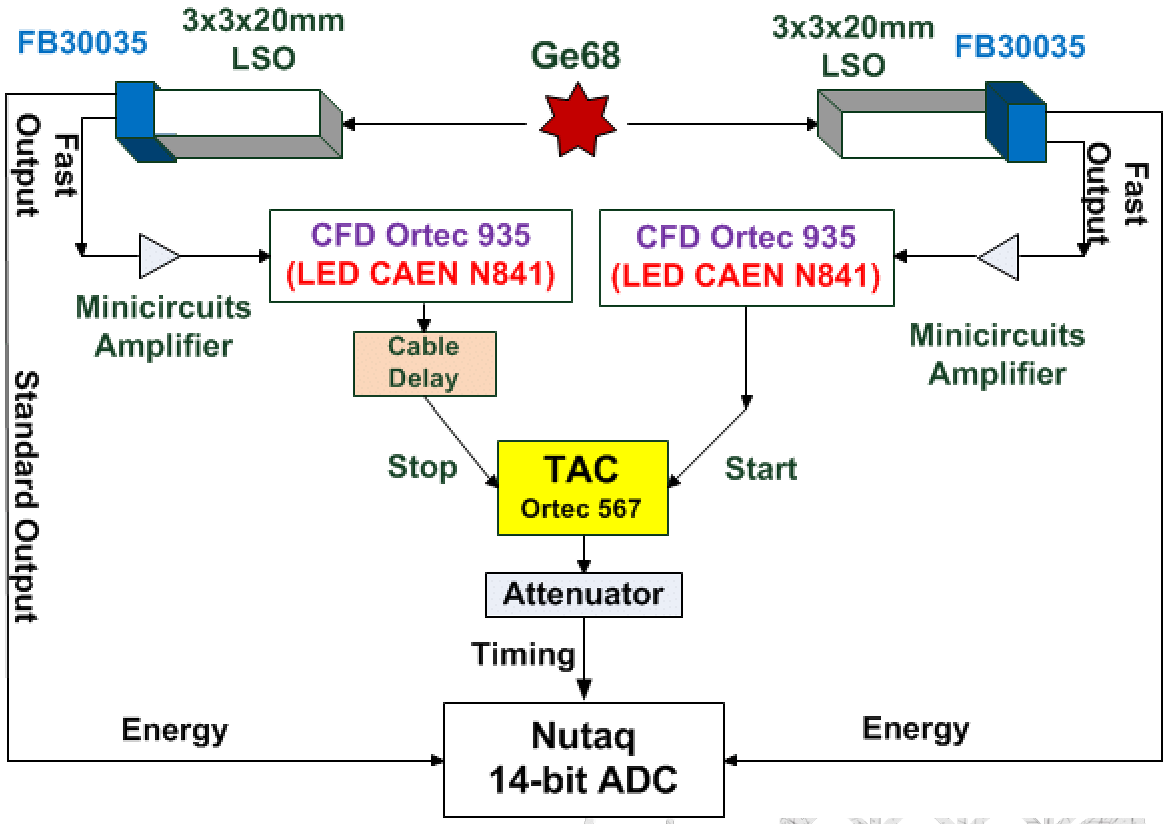


Time to amplitude conversion

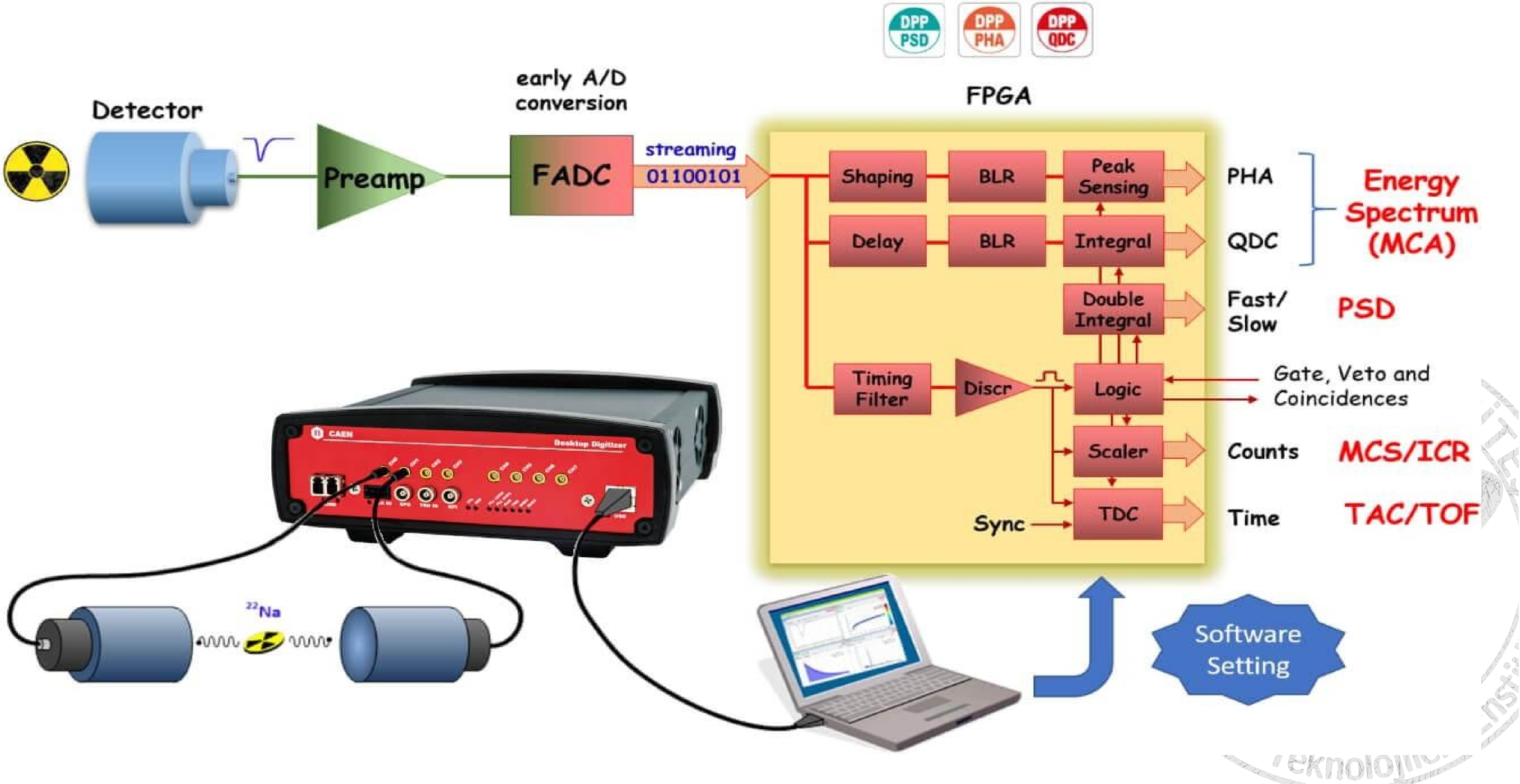
- Time to Amplitude convertor is an electronic device that detects a pulse and gives output pulse whose amplitude is proportional to the duration of the input pulse.

- This device is mostly used in Nuclear experiments where it is used to measure the time scales of the nuclear events.

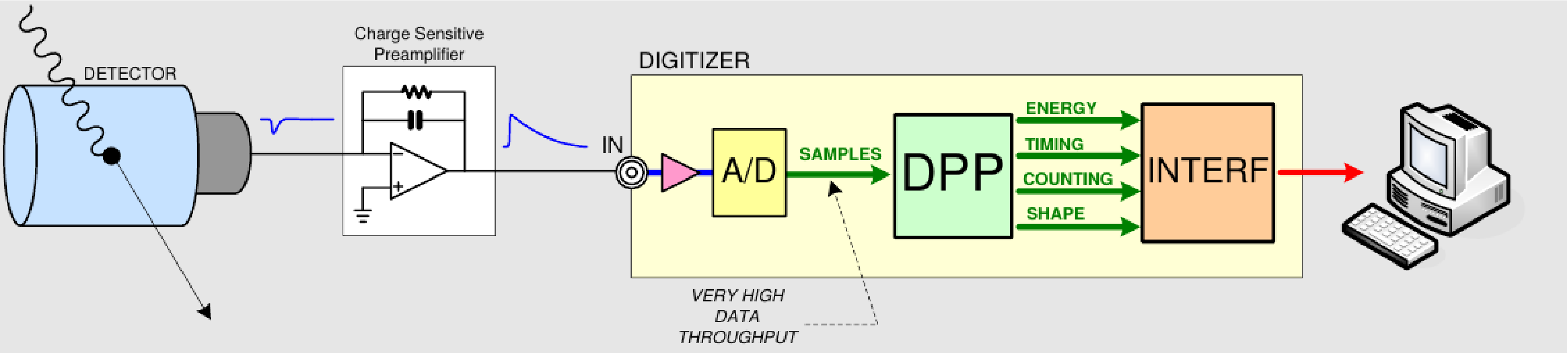
- When a timing application demands picosecond precision, a time-to-amplitude converter is a prime candidate. A TAC can achieve such exceptional precision because it uses an analog technique to convert small time intervals to pulse amplitudes.

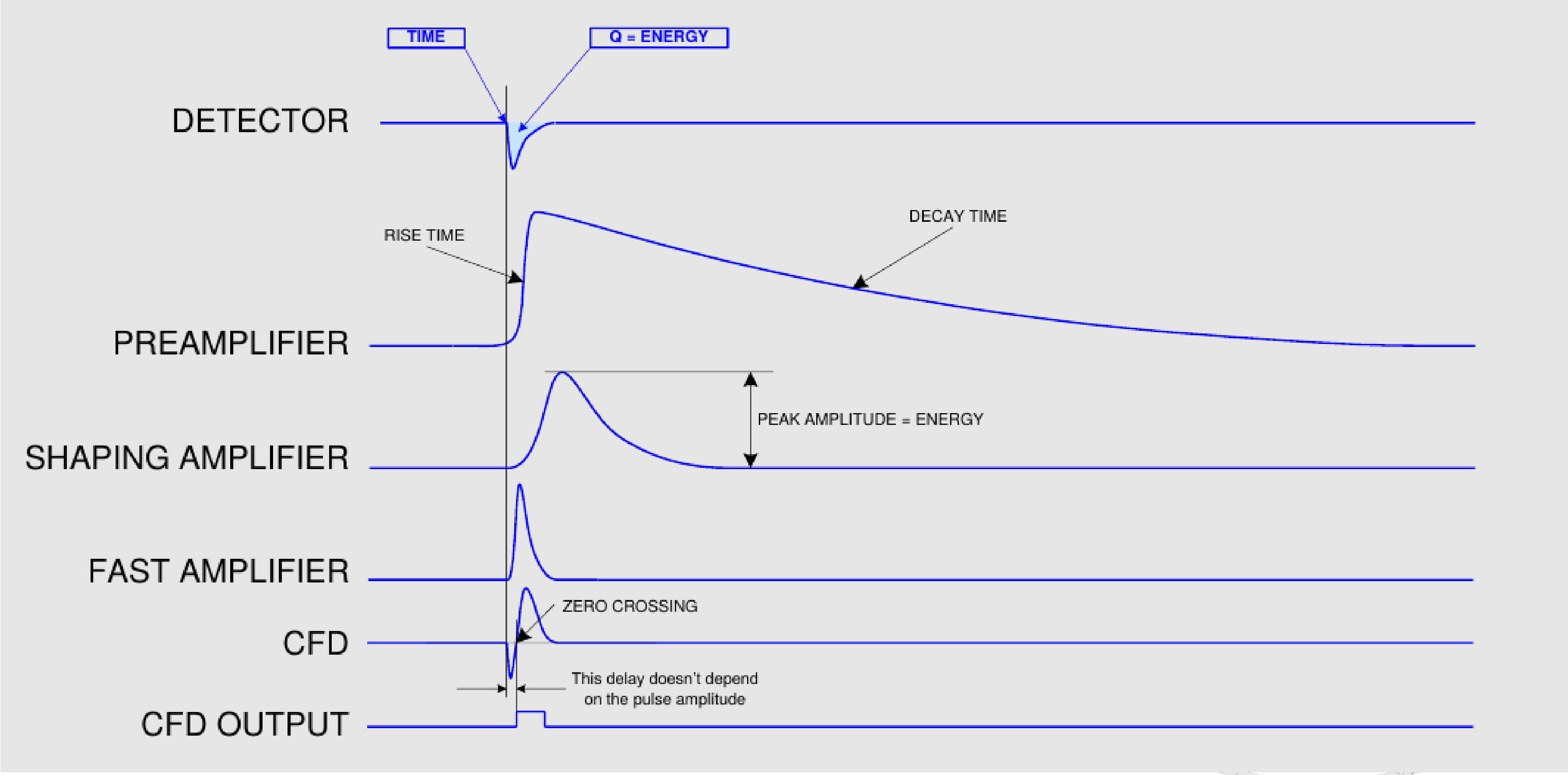


Digital electronics I

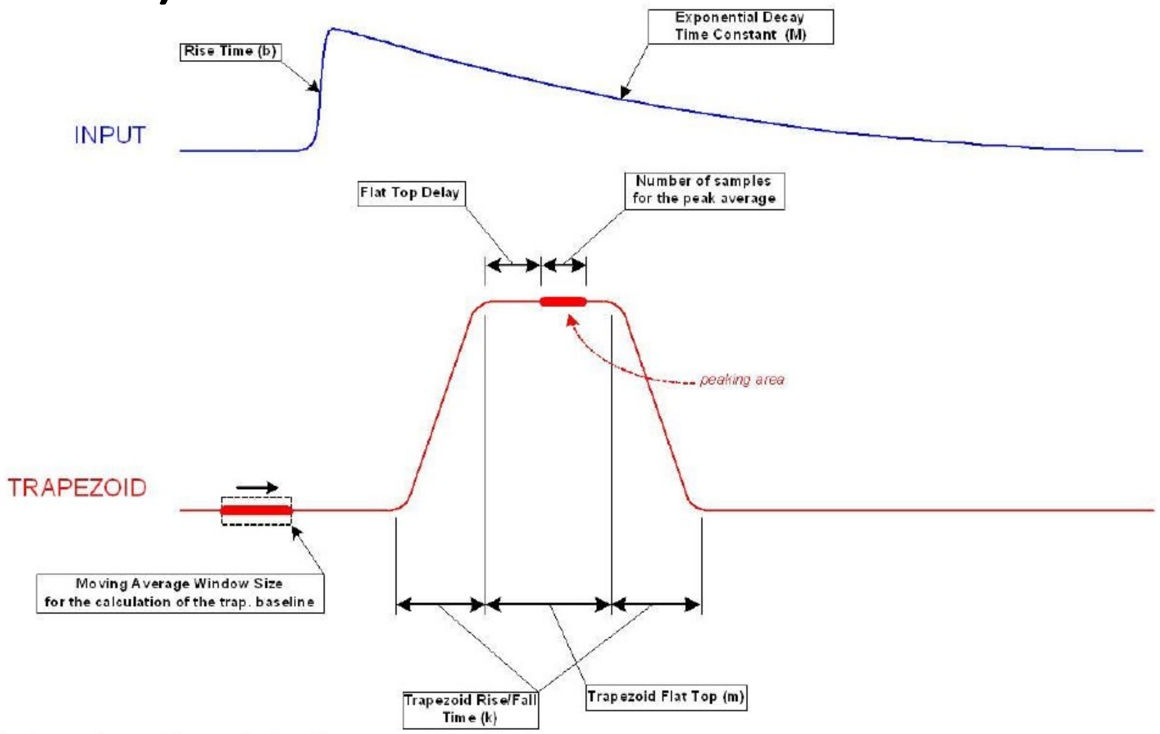


Digital electronics II





Trapezoid (shaping amplifier replacement)



- The algorithm implemented in the digitizer FPGA is based on the Jordanov trapezoidal filter.
- The trapezoidal filter is a filter able to transform the typical exponential decay signal generated by a charge sensitive preamplifier into a trapezoid whose flat top height is proportional to the amplitude of the input pulse (that is to the energy released by the particle in the detector) .
-This trapezoid plays almost the same role of the shaping amplifier in a traditional analog acquisition system. There is an analogy between the two systems: both have a "shaping time" constant and must be calibrated for the pole-zero cancellation. For both, a long shaping time gives a better resolution but has higher probability of pile-up. Both are AC coupled with respect to the output of the preamplifier whose baseline is hence removed, but both have their own output DC offset and this constitutes another baseline for the peak detection.

Energy measurement example

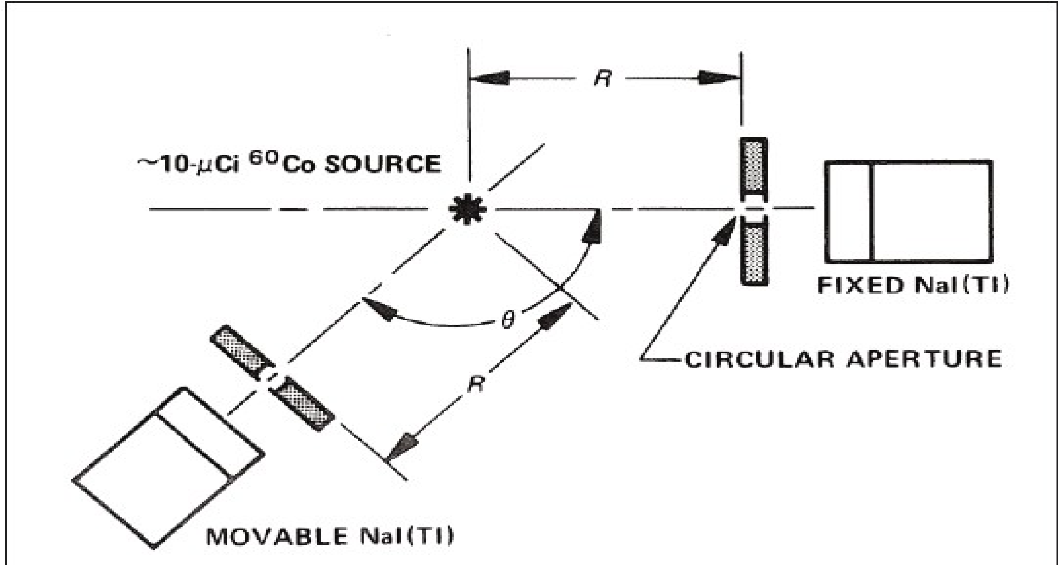
- Single detector measurements

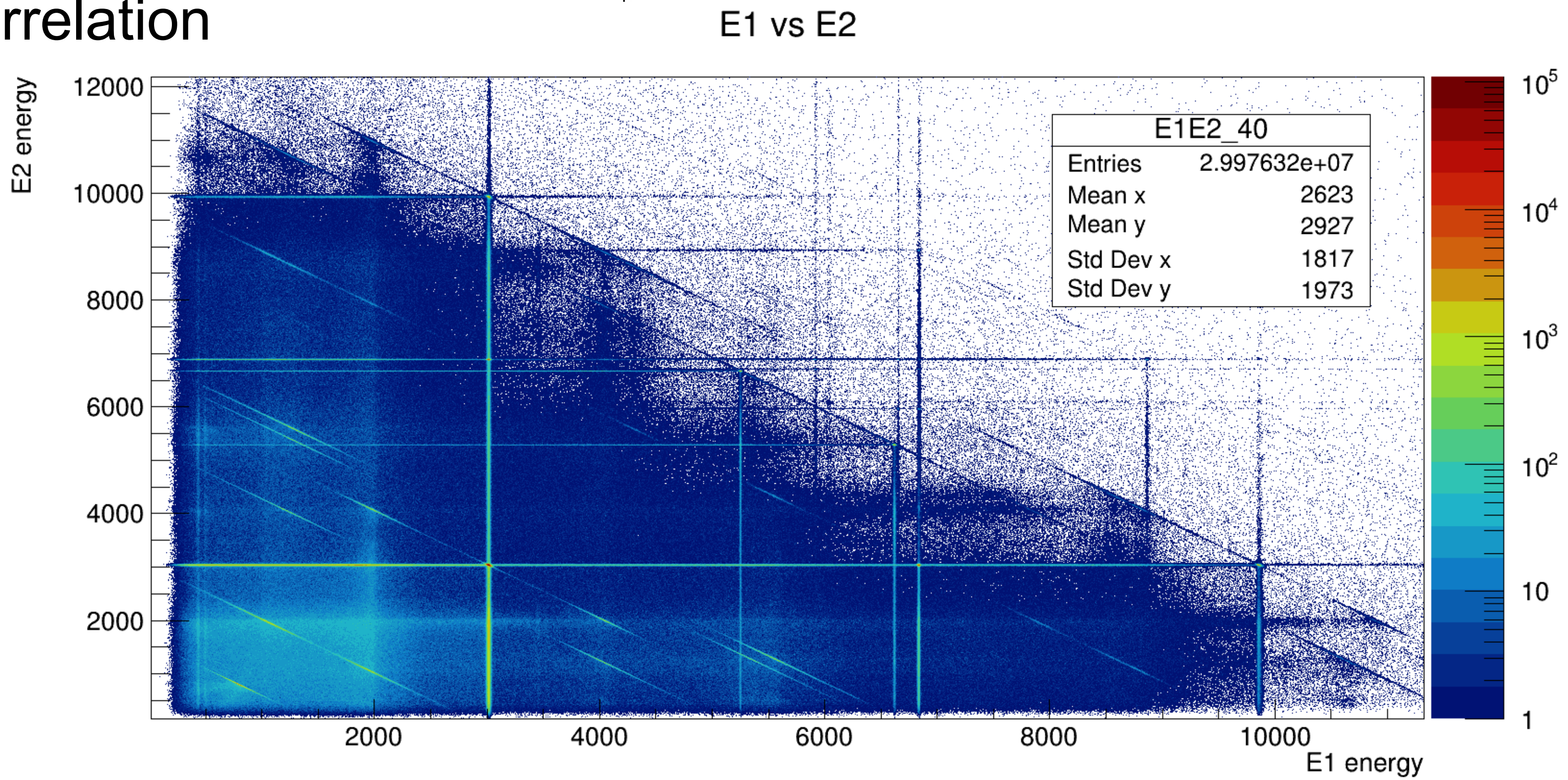
(Energy transitions, half-life)

- Coincidence setups(two or more detectors)

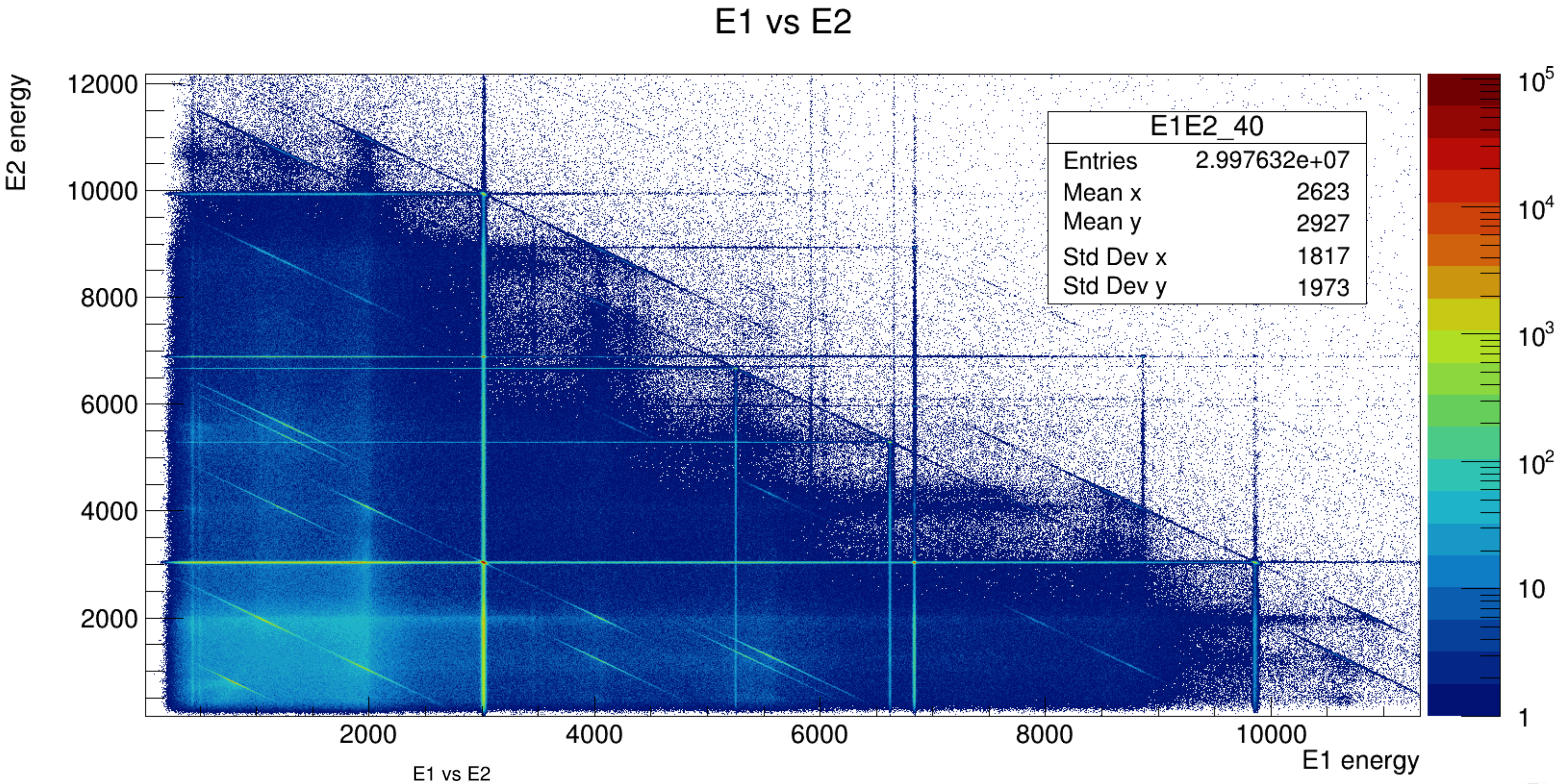
new possibilities (angular correlation

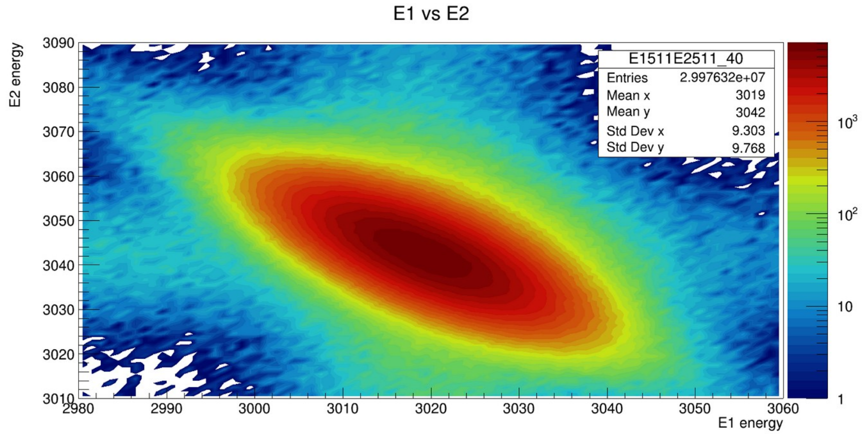
and cross section)

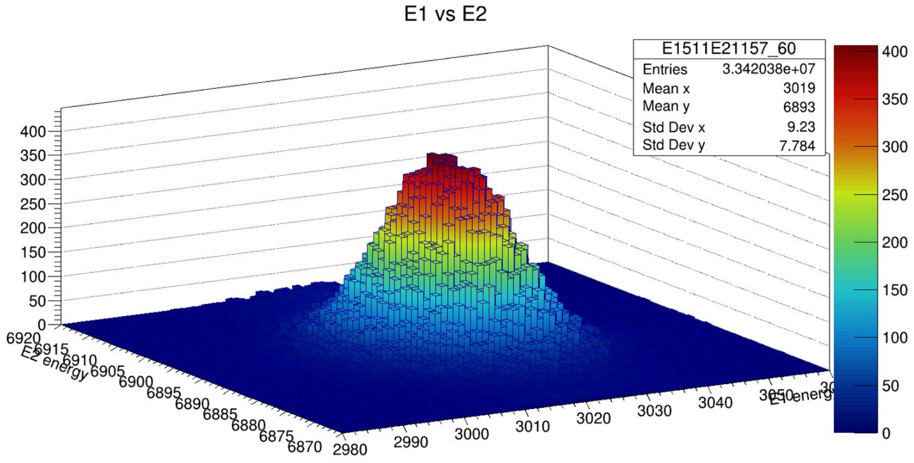


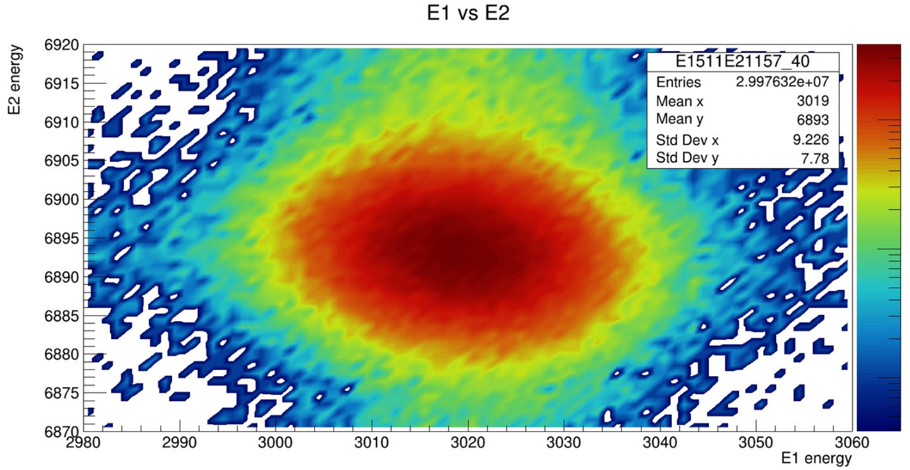


Coincidence in two detector gamma system

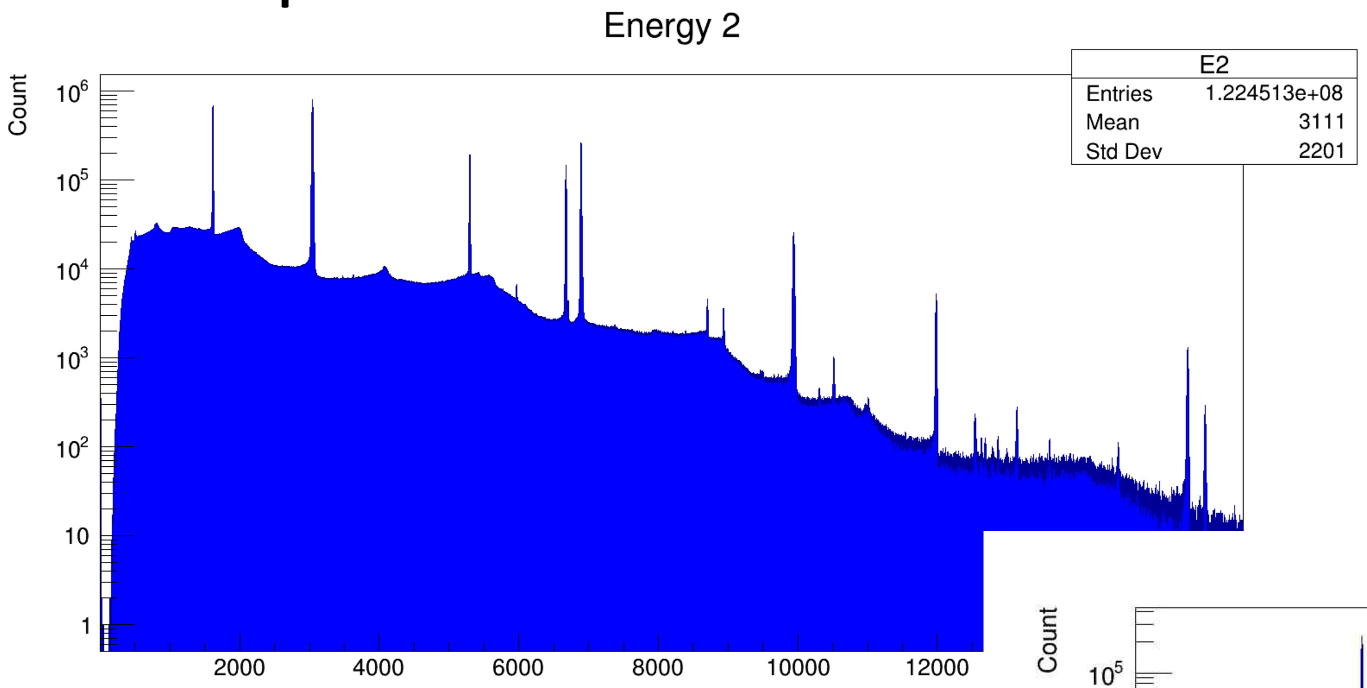


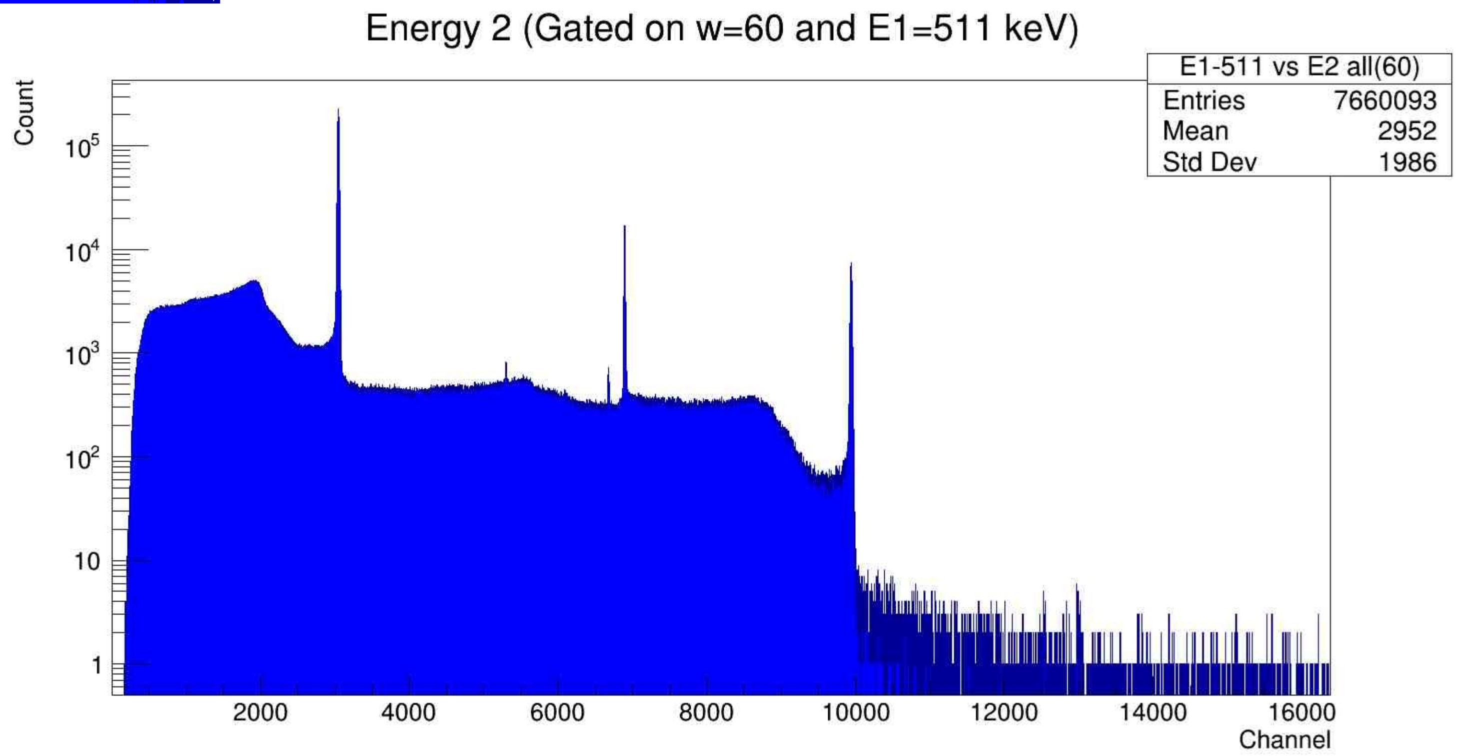






Gated spectra





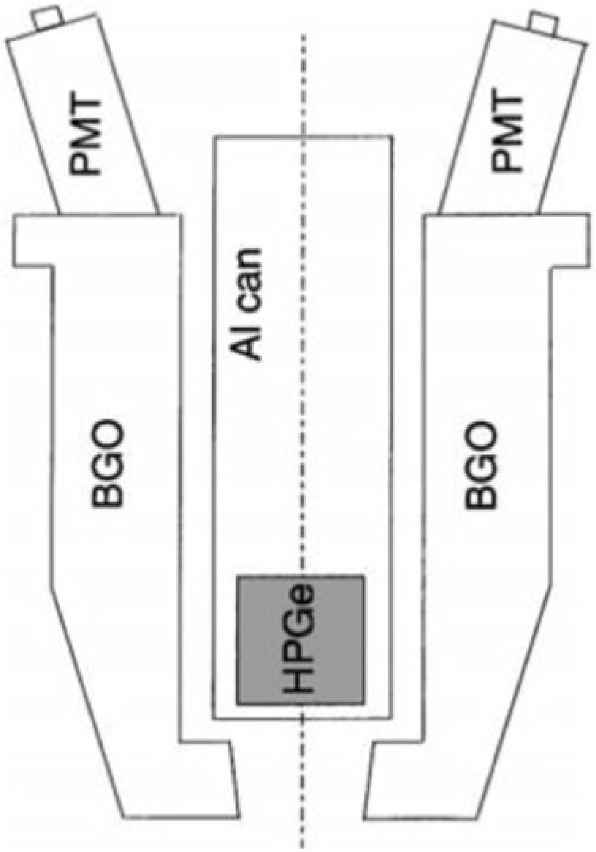
Anti-coincidence (Veto)

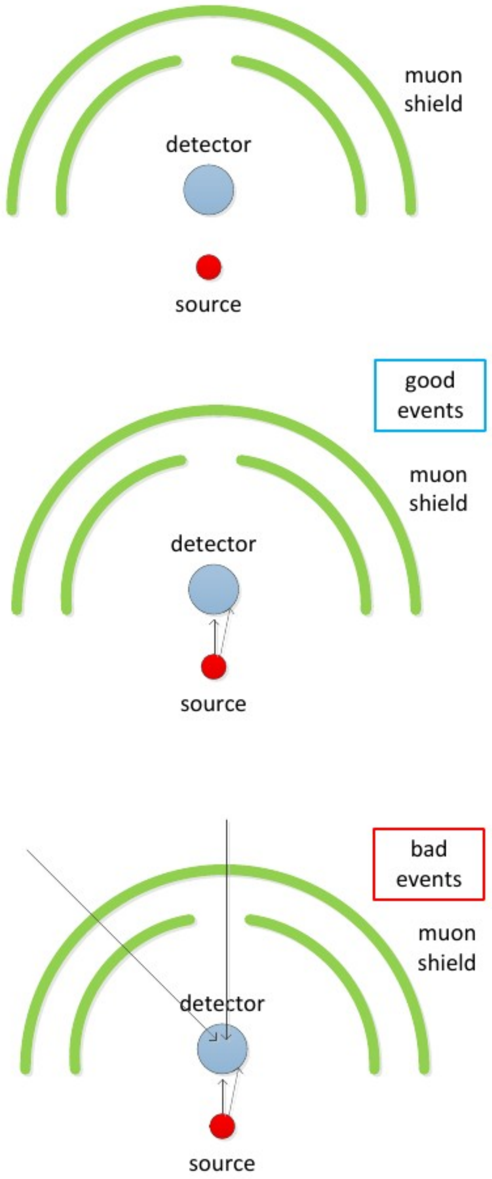
- Electronic anti-coincidence (“NOT” logic) is a method widely used to suppress unwanted, "background" events in many fields.

- In the typical case, a high-energy interaction, or event, that it is desired to study occurs and is detected by some kind of electronic detector, creating a fast electronic pulse in the associated nuclear electronics.

- The desired events are mixed up with a significant number of other events, produced by other particles or other processes, which create indistinguishable events in the detector.

- Very often it is possible to arrange particle detectors to intercept the unwanted background events, producing essentially simultaneous pulses that can be used with fast electronics to reject, or veto, the unwanted background.





Trigger

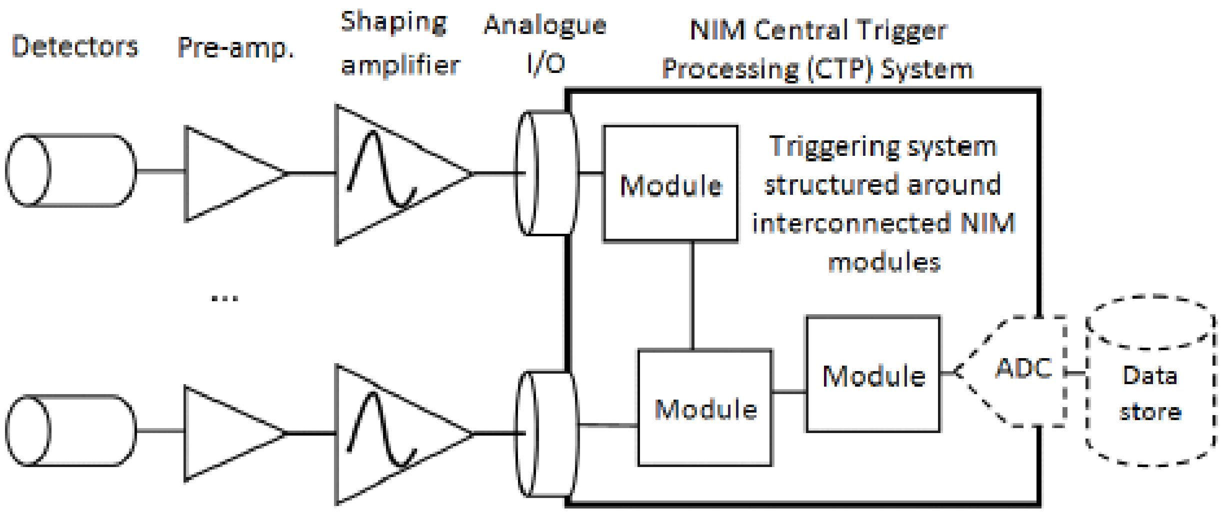
- In particle physics, a trigger is a system that uses criteria to rapidly decide which events in a particle detector to keep when only a small fraction of the total can be recorded.

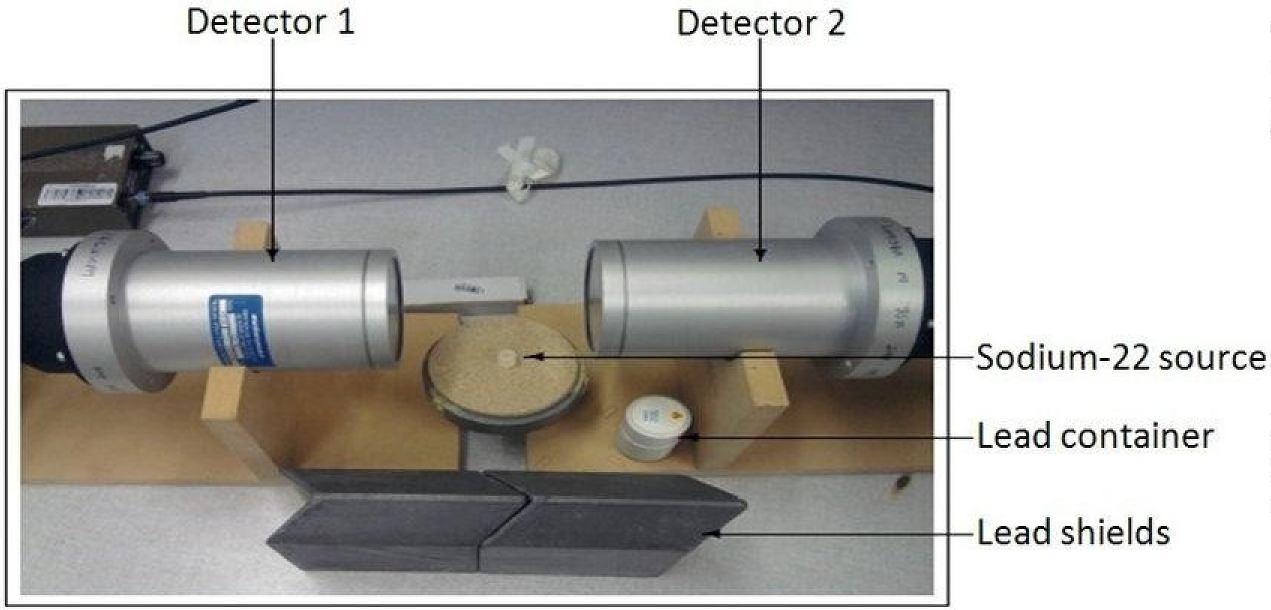
- Trigger systems are necessary due to real-world limitations in computing power, data storage capacity and rates.

- Experiments are typically searching for "interesting" events (such as decays of rare particles) that occur at a relatively low rate, trigger systems are used to identify the events that should be recorded for later analysis.

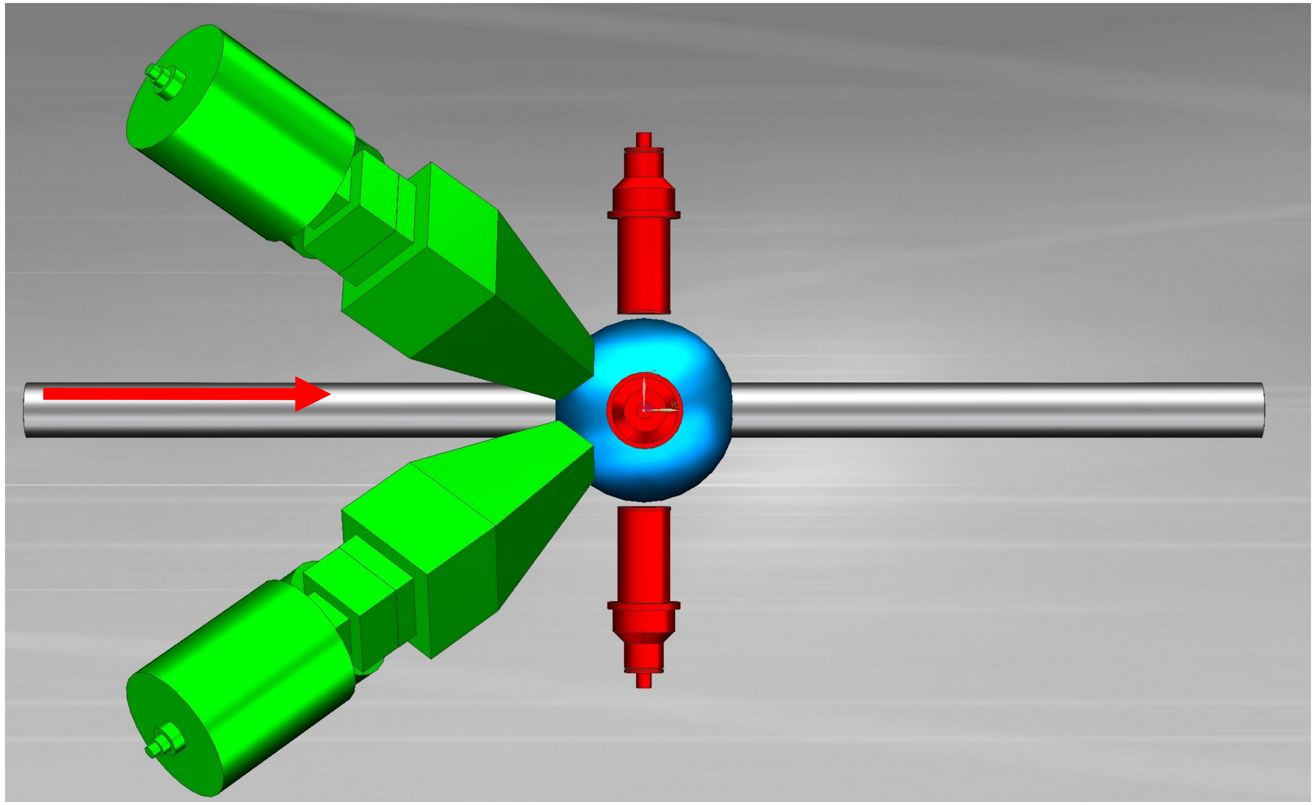
- Often total event rates greater are greater than 1 MHz (pions everywhere), but interesting trigger rates that can be below 10 Hz. The ratio of the trigger rate to the event rate is referred to as the selectivity of the trigger.

- For example, the Large Hadron Collider (LHC) has an event rate of 40 MHz, and the Higgs boson is expected to be produced there at a rate of roughly 1 Hz. The LHC detectors can manage to permanently store about one thousand events per second. Therefore, the minimum selectivity required is 10^{-5}, with much stricter requirements for the data analysis afterwards.





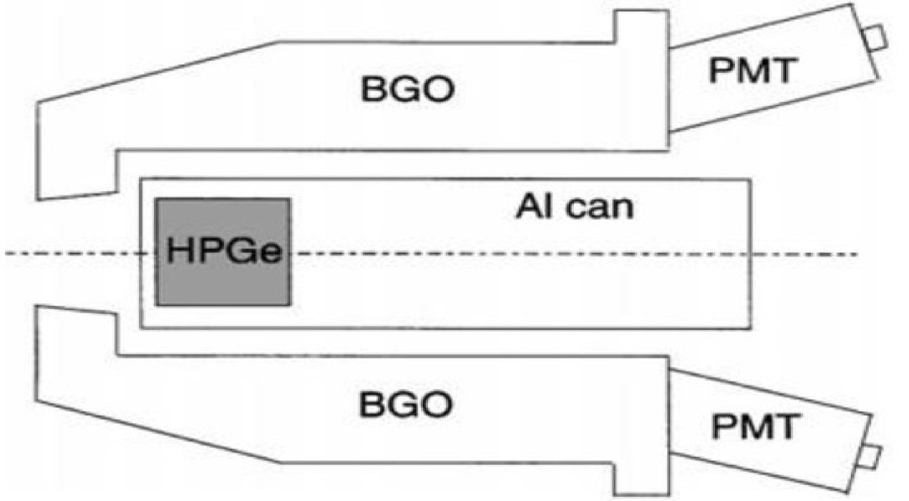
Multi HPGe Detector setup



Proposed setup would consist of:

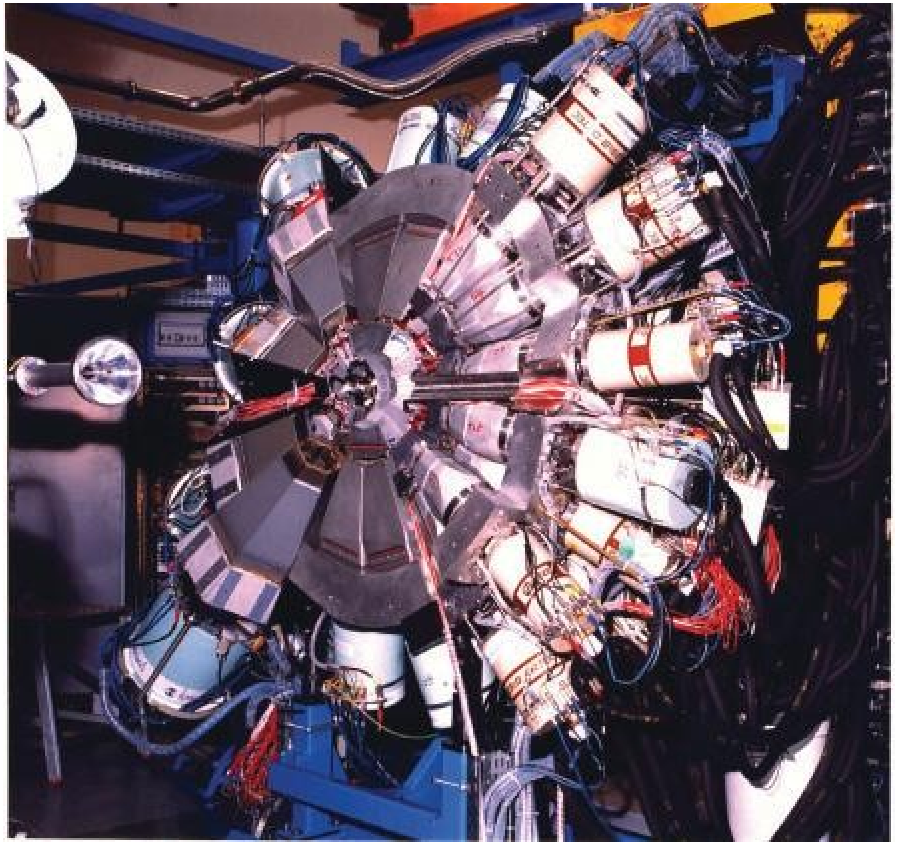
- 2 Clover HPGe (with BGO)
- 2 Single crystal HPGe (with BGO)
- 4 Large Volume $LaBr_3$

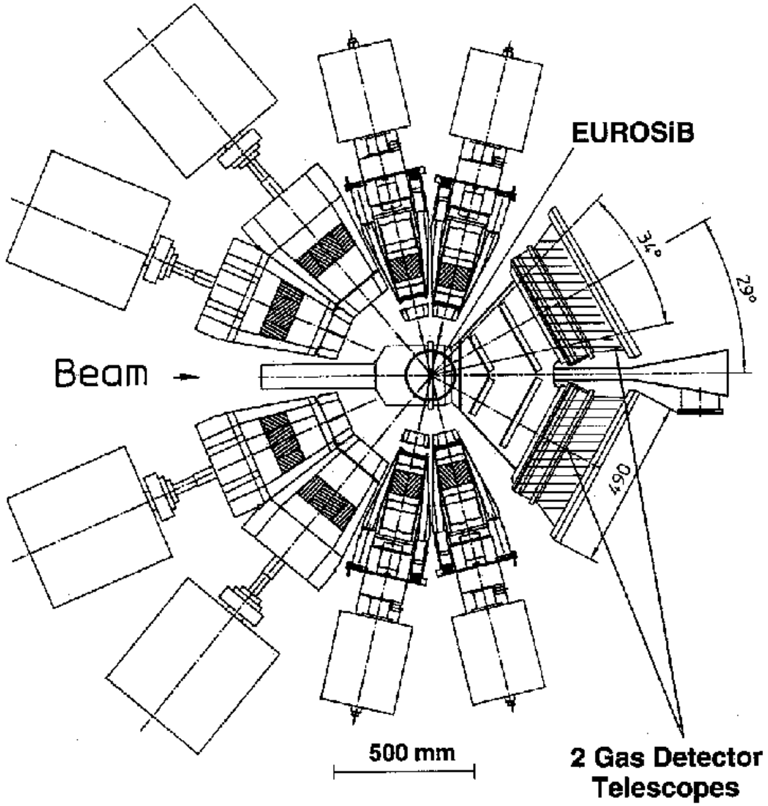
- HPGe would be 45° relative to the beam and 90° to each other
- LaBr3 would 90° relative to the beam and 90° to each other

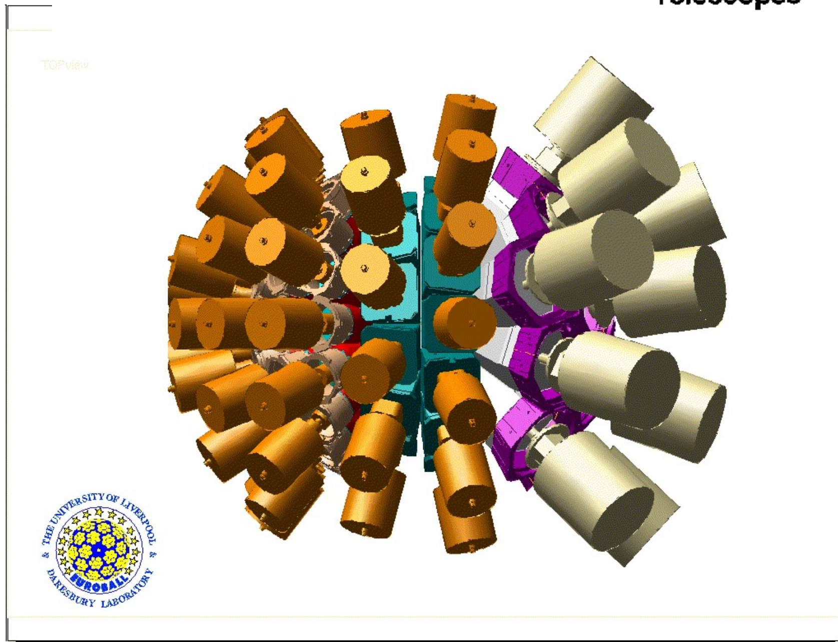


EUROBALL

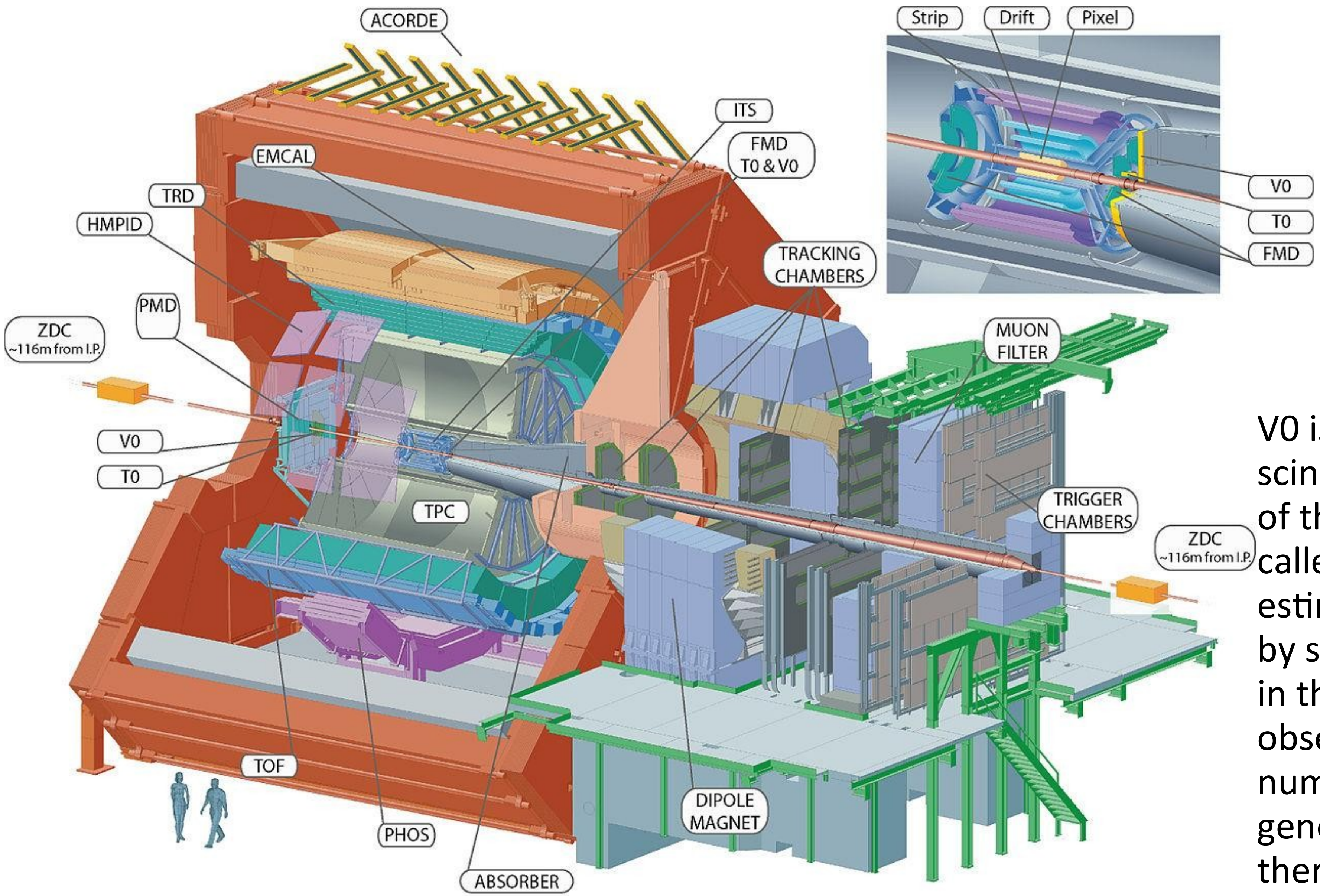
The Euroball array consists of **239 Ge** crystals geometrically arranged in order to cover 45 % of the total solid angle. Installed at two of the main nuclear structure facilities in Europe, at LNL (Legnaro-Italy) and at IReS-Vivitron (Strasbourg-France), it has allowed the investigation of atomic nuclei at extreme conditions of angular momentum values and of proton/neutron ratios.







ALICE



The Forward Multiplicity Detector consist of 5 large silicon discs with each **10240** individual detector channels to measure the charged particles emitted at small angles relative to the beam.

V0 is made of two arrays of scintillator counters set on both sides of the ALICE interaction point, and called V0-A and V0-C. It is used to estimate the centrality of the collision by summing up the energy deposited in the two disks of V0. This observable scales directly with the number of primary particles generated in the collision and therefore to the centrality.

ALICE event

After all triggers and vetos, a single event(collision) to be analyzed is stored.
All tracks, energies and such are there.