THE TASSO LIQUID ARGON CALORIMETERS

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Summary

The shower counter system of the TASSO-collaboration consists of large lead/liquid Argon Calorimeters. The calorimeters are subdivided into 4 barrel- and 2 end cap counters. The highly granulated lead stacks are composed into towers looking onto the interaction point of the experiment. Altogether there are 16 000 electronic channels, which allow for a precise energy and position measurement of high energy photons and electrons even in jets. A description of the design of the calorimeters, operational experience and performance of 2 years running time, together with results on the data taken in the TASSO experiment are presented.

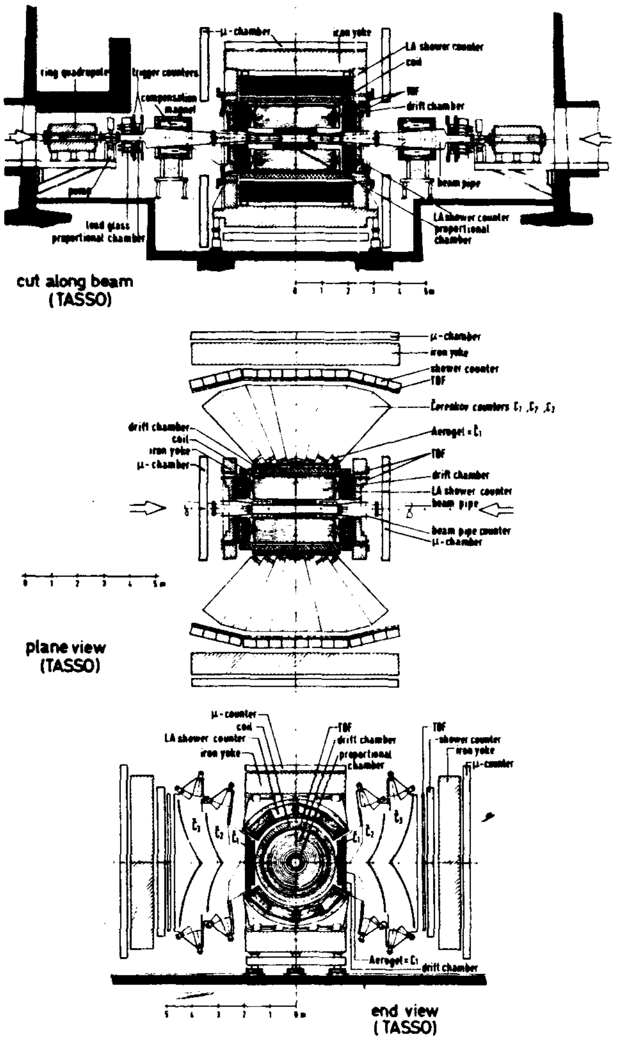
Description of the calorimeters

In Fig. 1 cross sectional views of the TASSO detector[1] are shown. As can be seen there are 4 barrel liquid Argon shower counters and two endcap counters, while the so called hadron arms have shower counters in lead-scintillator-sandwich technique with wave length shifters. Since the principal design of the endcap counters is similar to the barrel counters I will concentrate here on the barrel counters only. The barrel counters are each 4 m long, 2 m wide and 0.5 m high. All counters are vacuum insulated, with superinsulation on the inner surface of the vacuum tank. Two barrel counters on top or bottom are mechanically coupled together in the middle, so that the vacuum forces on the middle wall are compensated. By this, the middle wall of the vacuum tanks can be kept rather thin, thereby reducing the loss of sensitive area in the center to a minimum. Each of the 4 modules have 12 feed through flanges on the back circular vacuum wall, to allow for the 3000 electronic channels to be connected to the preamplifiers sitting in crates close to the flanges. The preamplifiers are double shielded, the inner shielding is connected to the inner liquid Argon tank, while the outer shielding is in contact with the vacuum tank, sitting on rails with insulated rollers inside the large magnet yoke. These precautions have been taken to avoid ground loops and to keep the noise level low. The entrance face of the vacuum tank is made of thin stainless steel, 1.5 mm only, equivalent to 0.085 rad. length. The inner tanks for the liquid argon and lead stacks are made of aluminum. Here, the entrance face is made from two 5 mm Aluminum plates with 50 mm spacers inbetween, every 100 mm repeated. The average thickness of this structural beam entrance is 0.14 rad. length. Altogether with superinsulation, liquid Argon and tank walls, a particle entering the calorimeter sees approximately 0.25 r.l. before entering the first ionizing gap, while the total amount of material in front of the calorimeter, due to beam pipe, proportional chamber, drift chamber and magnetic coil is 1.3 r.l.

The two base plates of the inner tank serve as mounting tables for the lead stacks and carry each six feed through flanges made from stainless steel with glass-steel feed-throughs welded into the flanges. The flanges are sealed with indium, while the large mounting plates are sealed to the tank with Cefilac seals (Spring loaded C-shaped stainless tubing covered with soft Aluminum). This seal works fine, as long as the hardness of the Aluminum surfaces of tank and plates are guaranteed.

The connection of the inner feed through flanges to the outer feed throughs is done with multiwire flat cable as commonly used in computer techniques but instead of copper stainless steel leads have been used. This reduces the heat-conductivity by a factor of 50 compared to copper; so only 50 cm long cables are necessary. The cables are folded like an accordion bellow, thereby acting as superinsulation.

In Fig. 2 a drawing of the lead stack is shown. The stack is divided into front- and back towers. Four front towers cover the face of one back tower. Inbetween the front towers are immersed z,Φ strips, orthogonally to each other and dE/dx strips. The strips are made by etching copper plated fiber glass plates. A particle entering the calorimeter first traverses a front tower gap of 2 x 5 mm liquid argon, then two dE/dx gaps, which act also as z coordinates, then a



Two Arm Spectrometer Solenoid
TASSO

Central Magnet: R_i = 135 cm B = 0.5T
L = 440 cm
Weight: 600 to
Overall Dimensions: Length ~ 14m
Width ~ 14m
Height ~ 8m

Fig. 1: Sectional views of TASSO detector.

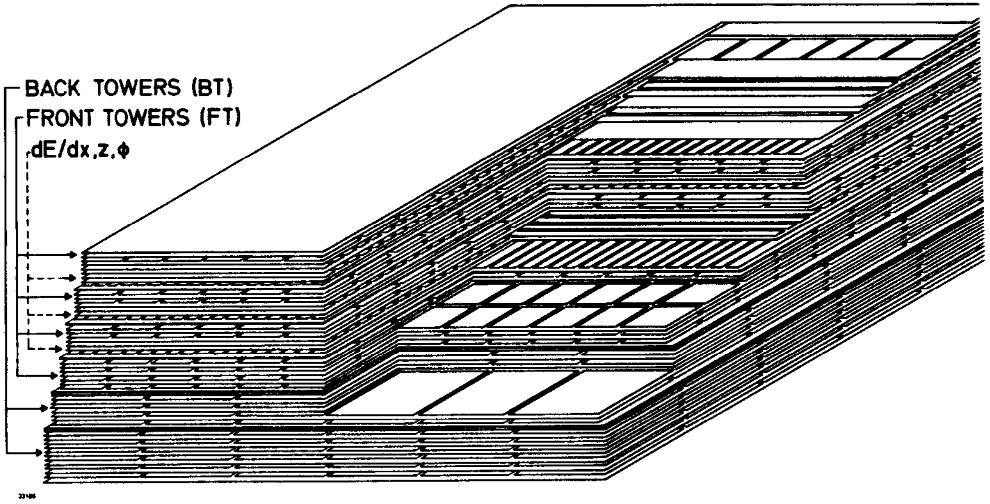


Fig. 2: Lead Stack

Φ gap. After this approximately one rad. length of lead front tower gaps is traversed. Then again z and Φ strips are hit. Thereafter again one rad. length of lead front towers and again z and Φ strips. This set up has been chosen to have a high conversion efficiency for photons and a good positioning of the photons in the 20 mm wide strips. The small size of the front towers (70 x 70 mm^2) is valuable in separating showering particles in a jet and for π^0 measurements. The division between front and back towers helps distinguishing hadrons from electrons. The electrical and mechanical connection between the tower plates is done with bolts and insulators. These bolts are stacked up together with the lead plates. Since all towers are focused onto the interaction point, the stacking bolts are in certain planes offset.

Each lead stack is 4 m long by 1 m wide. Two stacks make up one module.

The electrical connections for the towers emerge from connecting fiberglass-plates on the front and back towers, while the z and Φ strips have connectors at the sides of the stack. Flat multiwire copper cables take the signals to the feedthrough flanges on the base plate.

The lead plates are 2 mm thick. They contain 3 % antimony and have been hardened by heating for 5 hours at 250°C. After that they were dumped into cold water and obtained their strength within a few days due to a recrystallization process. The surface of the plates was cleaned from oxide layers by glassperl blasting. This was a necessity, since otherwise small oxide pieces would short-circuit the gaps under high voltage. Each completed stack was tested in dry air with 5 kV on the gaps. It was judged clean when the total leakage current was smaller than 1 μA.

The cooling system

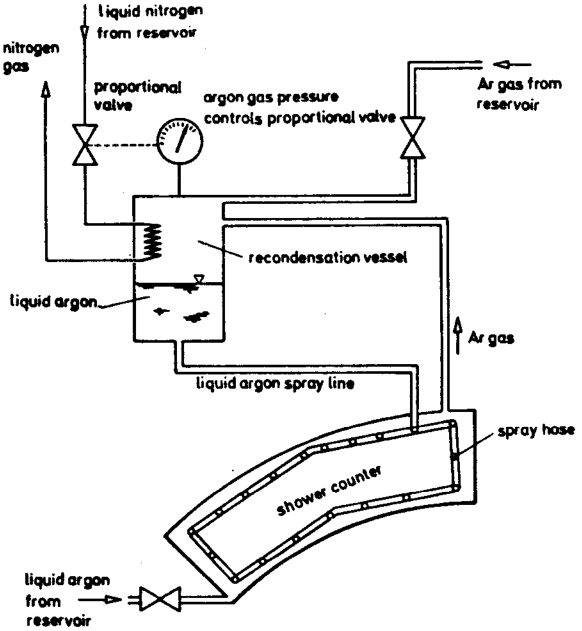


Fig. 3: Cooling System.

In Fig. 3 a drawing of the cryogenic system has been sketched. Each module is connected by two vacuum insulated lines to a recondensation vessel of about 100 l volume. The recondensation of argon is done with liquid nitrogen running through a heat exchanger. The amount of nitrogen is adjusted by the argon gas pressure acting on a proportional valve. If a cool down of a module is going to be started, argon gas is condensated by the nitrogen heat exchanger into the recondensation vessel. Since this vessel is seated 1/2 m higher than the top point of the modul, liquid argon starts flowing into the module through the so called spray line. The spraying action is achieved inside the module by Teflon tubes which have small holes (0.7 mm) in their walls. These tubes are mounted along the lead stack on the sides as well as on top and bottom. The number of holes per unit length increases from the entrance to the end exponentially, to assure a cool down with only small temperature gradients (40°C). What happens to the liquid argon in the Teflon tubes is that it evaporates due to heat taken in from the surrounding, so that cold argon gas sprays out of the fine holes, thereby cooling the lead and tank. The number of holes has to increase with tube length, because with length more gas is produced and it also warms up more. This procedure goes from room temperature down to -160°C. From here on also liquid argon drops out of the holes, but this does not harm the temperature gradient smoothness, since only 23°C are left to reach liquid argon temperature. This cooling procedure lasts 3 days with about 2.5°C/hour cooldown speed. The nitrogen heat exchanger needs about 3 kW cooling power, since $4\cdot10^8$Wattsec have to be cooled away. When the module has reached liquid argon temperature, it can be filled with liquid argon from the reservoir, which takes one more day. The amount of liquid nitrogen used for cool down and filling is about 3 m^3 per module, while only 200 l/day are needed per module to take care of the heat losses of 250 Watts under normal running conditions. This system works very reliably since now about 2 years. Since the liquid argon, once in the module, is not in contact with the outside world, it stays clean: the oxygen content is only 0.3 ppm; in two years it has never been exchanged. To get the liquid argon delivered with only 0.3 ppmO$_2$, needed some education of the people handling the argon at the delivery company and at DESY. This education was already achieved during testruns with a small module and later on with the large modules on test beams at the DESY synchrotron.

Electronics and readout system

In Fig. 4 a block diagram of the electronics is shown. The signal pulse from the calorimeter is on virtual ground, so no high voltage capacitors in the liquid argon are used. There are also no transformers for capacity matching, since our tests showed that we could work without them, thereby avoiding shielding problems in the stray magnetic field of the detector and inductance matching problems due to different cable lengths. The preamplifier of standard design is however protected against high voltage breakdown by diodes and a small spark gap, which short-circuits pulses of 200 Volts or larger. This protection works so well that preamplifiers do not break. From the preamplifier the pulse is send through a shaping network and a cable driver over 50 m long double shielded coax cables into the readout electronics.A fast trigger pulse (after 1 μsec) is taken off before the second shaper stage and main amplifier. Here 32 front towers and 8 back towers are ganged together for a stand alone trigger from the liquid argon calorimeter into the general TASSO trigger logics. A trigger is produced if in one liquid argon submodul 2 GeV are deposited or 0.5 GeV in 2 submodules or 5 clusters of 250 MeV. A trigger is also produced if one charged track and a cluster of 250 MeV is found, or two charged tracks in the drift chamber. If an event was found in the shower calorimeter a clock is started and a 12 bit DAC produces a voltage ramp in 4000 steps, each 1 mV for 500 channels in common. When the ramp voltage and the sample and hold voltage show the same size in the comparator a latch is produced and the addresses of towers and the clock value are stored in a data buffer. Pedestals and gain factors are then taken into the data by control of a microprocessor and a constants memory. The data are than stored in an on-line computer. Pedestals and gain factors are controlled every two weeks off line with testpulses. Only towers with more than 20 MeV true shower energy are stored. The noise level is only 10 MeV. The amount of data stored is relatively small. On average a good event has 40 data words.

Results

One of the most remarkable features of the liquid Argon calorimeter is its stability and reliability. Besides the high granularity and therefore position resolution, good energy resolution was achieved. In Fig.5 the energy resolution in a test beam up to 4 GeV is shown, while fig. 6 shows the energy resolution at 18 GeV for Bhabha scattering. In Fig. 7 π^0-production2) is shown , while Fig. 8 shows a 3 jet event with several photons releasing energy in the liquid argon calorimeters. Fig. 9 is a Bhabha event.

Table 1 collects some basic data of the barrel liquid argon calorimeters. Besides the low noise of only 10 MeV equivalent shower energy, the small heat loss of 250 Watts per module only, may be worth mentioning.

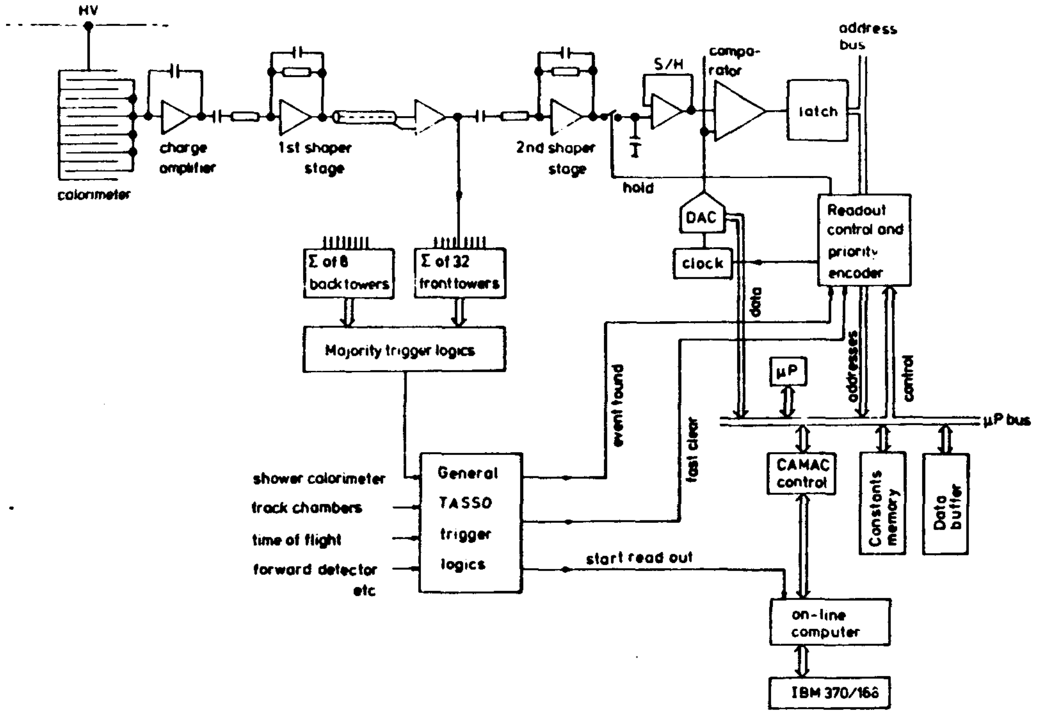


Fig. 4: Electronics and readout system.

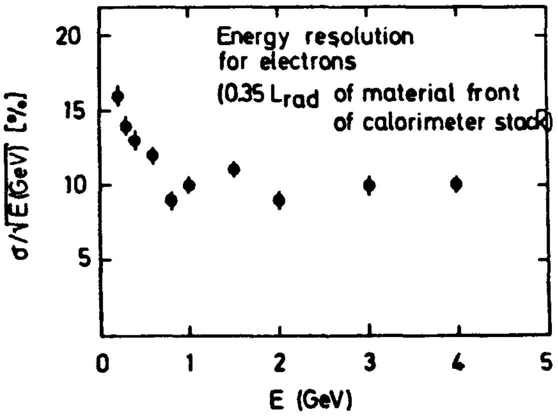


Fig. 5: Energy resolution up to 4 GeV.

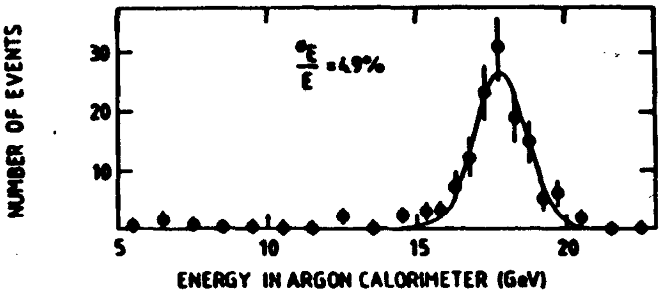


Fig. 6: Energy resolution at 18 GeV, Bhabha scattering.

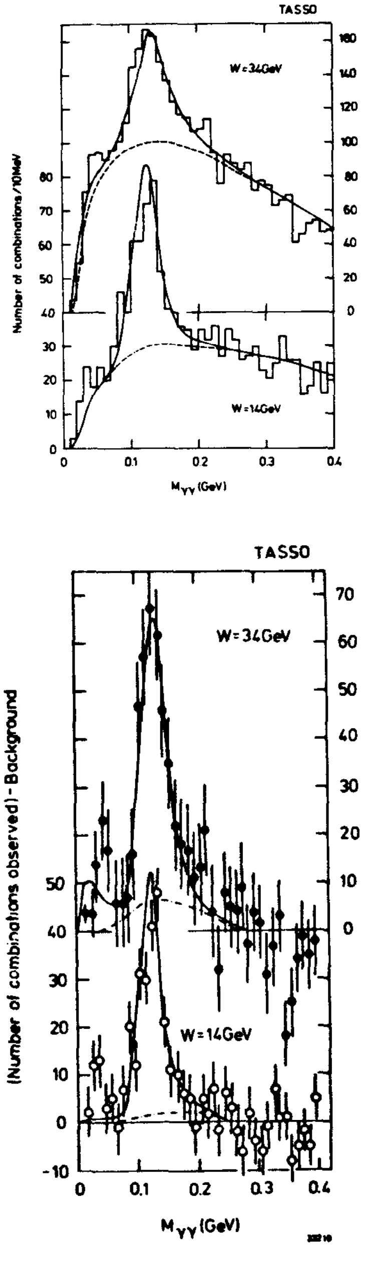


Fig. 7: π^o production.

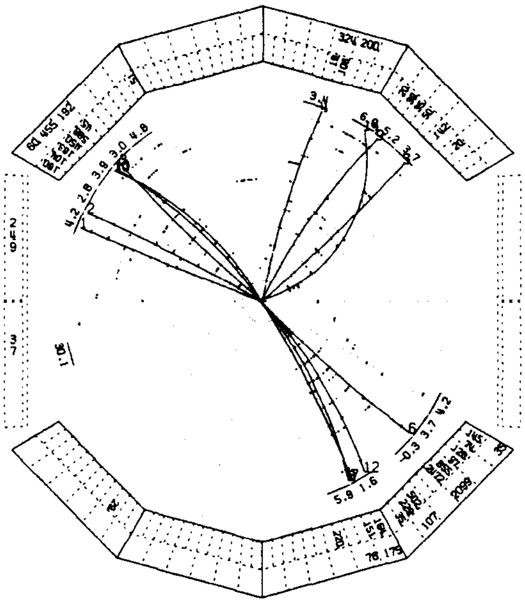


Fig. 8: 3 jet event, several photons have energy deposited in the liquid argon calorimeters.

E= 16.49 GeV

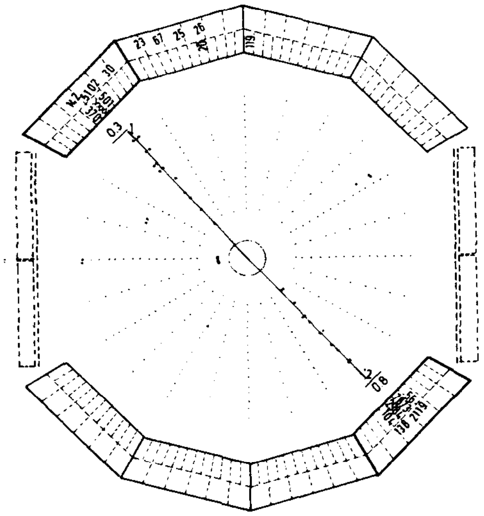


Fig. 9: Bhabha event.

Table 1: Data collection of barrel liquid Argon counters

Active area	32 m^2
Covered solid angle	42 % of 4π
Granularity for energy measurement	1.5 mster for the first 6 X_o and 6 mster for 8 X_o
Energy resolution with 1.6 rad. length before counter due to coil and walls	$\sigma_{E/E} = \begin{cases} \frac{15\,\%}{\sqrt{E}} & \text{for } E_\gamma \approx 300\text{ MeV} \\ \frac{10\,\%}{\sqrt{E}}, & 1 < E_\gamma < 4\text{ GeV} \\ 5\,\% & \text{for } E \geq 4\text{ GeV} \end{cases}$
noise	10 MeV shower energy
Shower-position resolution for γ's	$\sigma \approx 5$ mrad.
Number of electronic channels	12 000
Number of towers	6 000
of that small towers	4 800
large towers	1 200
z,Φ and dE/dx strips	6 000
Total weight	80 to
of that lead	25 to
liquid Argon 10m^3	14 to
Insulation vacuum	$10^{-4} \ldots 10^{-5}$ mbar
Cooling power per module	3 kW
Cool down speed	2.5°C/h → 3 days
Temperature gradients during cool down	40°C
Heat losses per module	250 Watts
Consumption if liquid Nitrogen for 6 counters + lines and so on	1 m^3/day
Total manufacturing costs per channel	500 DM/channel

Acknowledgements

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List of References

1) A description of the detector components used for charged particle tracking can be found in TASSO Collaboration, Z. Physik C4 (1980) 87; Phys.Lett. 83B (1979) 621.

2) TASSO Collaboration, DESY-Report 81-069; Phys. Lett. 108D (1982) 71.