<u>Personal</u> memories on how particle physics apparatus and experiments evolved in the 50 years since the first Moriond

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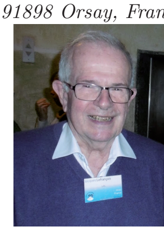


After recalling memories of the first Moriond sessions in 1966, a description of the evolution of particle physics apparatus over the past years is given. Examples are given on this evolution and especially on the concept and realisation of General Purpose Detectors.

1 Introduction

I underline in the tittle the "personal" since I hope that the flavour of the evolution is correctly given, but clearly the choice of the examples reflects a bias in my experience. Before embarking in the overview I will give a few memories of the first Moriond in 1966.

2 Moriond - 1966

The idea of the meeting was to encourage and improve communication between the experimental physicist based at LAL Orsay and the theoretical physicist which were based in LPTHE, a theory laboratory about 100 meters away. At the meetings we were only about 20 physicists (shared about equally between the two labs) with 2 secretaries a few spouses and babies. There were only 2-3 physicists from other labs. We had rented a big "chalet" in a ski station, Moriond, which was close to Courchevel. We were sharing the practical things: cleaning, cooking, dish washing etc... Experimentally, I can vouch that discussing with a theorist when jointly washing dishes is as productive as doing discussions in a chairlift or tele-cabin. Of course some meals were better than others and I remember a delicious Vietnamese meal prepared by a team of a theorist (Jean Tran Thanh Van) and an experimentalist (Nguyen Ngoc Hoan).

We had our first "not too serious" casualty: a three days snow blindness of an experimentalist who thought his youth in a south country had trained his eyes to be sun-resistant!

I remember I enjoyed presentation by Michel Gourdin on how one could calculate polarisation of recoil protons due to two photon exchange in e-p scattering but strangely I also learned about what other young physicist from my own lab were doing.

We discovered experimentally how efficient for communication was this functioning of essentially living in the same place and having ample time for discussions. This is at the core of what has become known as the "Moriond spirit".

Actually, I enjoyed the meeting so much that I remember I was shocked at first by the conclusion speech. This speech was done by a senior physicist from LAL, Pierre Lehman, who later became director of Dapnia (Saclay) and after of IN2P3. He insisted that we had discovered a very good idea but it made no sense to just repeat it (I was 29 at the time... and I thought why can't we continue?). He therefore said we should clearly open the meeting to other labs and therefore adapt to these inevitably larger meetings.

Of course he was right and, with the wonderful guidance of Tran and a few colleagues, Moriond steadily grew to what it is today, but in my opinion keeping its specificity of casual atmosphere, easy discussion and very fruitful encounters.

3 Early Particle Physics Apparatus

I will cheat a bit and define early as 1959 when I started my thesis at the Harvard Synchrocyclotron. In those days, particle physics experiments were done by two types of instruments, and very often (almost always) experimental physicist specialised in one of the two types.

There were first "visual device" experiments using initially cloud chambers and then bubble chambers after their invention in 1952. The information was very detailed and complete, one could follow each particle track in a reaction and measure angles and momenta of all particles involved in a reaction, the granularity was excellent. However the technique was not flexible, going from one experiment to another consisted most of the time of changing the incident particle type or momentum. The liquid in the bubble chamber was the target and detector, Hydrogen very often, or Heavy Liquid (Freon) if one was interested in a higher mass or of observing photons through their conversions. Also these bubble Chamber experiments were rather low rates; typically there was one event (one picture) per accelerator cycle (every few seconds) with only typically 10-20 incident particles per picture. This technique had wonderful successes in the studies of resonances or new particles, like studies of vector mesons or discovery of the Ω-baryon (1964) which was a breakthrough in the acceptance of the SU3 symmetry (1961) and the quark model. Another great success of this technique was the discovery of neutral current (1973) by the study of neutrino in the heavy liquid bubble chamber Gargamelle at CERN.

The other main technique in the early days was non visual, it was called counter experiments. It used scintillators of various shapes and numbers read by photomultiplier tubes (PMT) . These set up could study decays of particles or scattering in a target. The advantage was the flexibility, the array of counters could easily be displaced or modified one could add Cerenkov counters when needed to identify incident or scattered particles. The other advantage was the great rate possible consistent with the secondary beam from the accelerator of thousands or even million particles per accelerator cycle. However the granularity of the technique was limited by the high price of the PMT and therefore very bad, a typical set up would rarely have more than 100 PMTs. Nevertheless these techniques were quite useful to measure cross sections or for example to discover the existence of the antiprotons in 1955 or study electron scattering using spectrometer magnets.

4 The rise and fall of the Spark Chambers

The techniques of the counter experiments changed completely after the invention of the Spark Chamber in 1959. It was a rather simple device; there was an assembly of plates (or later surface of wires) with a gap of about 1 cm. Upon the detection by counters of a possibly interesting event, a short high voltage pulse is applied across the gap (about 10KV/cm), the gas between the plates being most of the time an Helium Neon mixture. Then sparks form at the position of the ionisation left by the particles tracks, and the succession of sparks form a trajectory. The light from the sparks is intense enough to be photographed by a simple film camera. A very important point, is that a permanent clearing field of about 100 volts/cm was applied to the gaps, this cleared the ionisation electrons from previous tracks in about 1 microsecond, as a consequence, compared to Bubble Chambers, one could have a much higher rate of incident particles (10^4 or $10^5/s$). However the rate at which events could be recorded was limited to typically 1-10/sec both by the speed of the cameras and by the time needed for meta-stable atoms left by the sparks to disappear (otherwise electrons released by these atoms would create false sparks in the next event).

The idea spread like fire, it allowed the counter experiments to become visual, while keeping their flexibility. The chambers were quite inexpensive and fast to built, most counter physicist incorporated them in their apparatus, while the Bubble Chamber technique continued in parallel until the 80's. In the following sections a few examples of the impact of this new type of detector are given.

4.1 An early example, the neutrino experiment at Brookhaven

The experiment initiated by L. Lederman, M. Schwartz and J. Steinberger was done in 1961 with a beautiful apparatus of 10 tons of Aluminium plate spark chambers, therefore only two years after the invention of the technique (Fig.1). As it is well know, the experiment allowed to prove that the neutrino flux (mainly produced from pion decays ($\pi \to \mu + \nu$)) created mostly muons in their interaction in the chambers, not electrons, and therefore that $\nu_\mu \neq \nu_e$. Typical ν interactions are given in Fig.2, while typical events with electrons taken in a cosmotron e^- beam are shown in Fig.3.

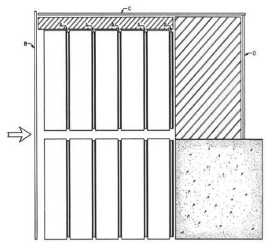


Figure 1 – The Spark chamber apparatus of the neutrino Brookhaven experiment

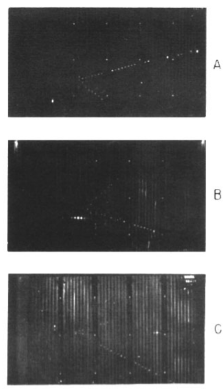


Figure 2 – A typical picture of neutrino interaction in the spark chambers. One can see clearly the long muon tracks

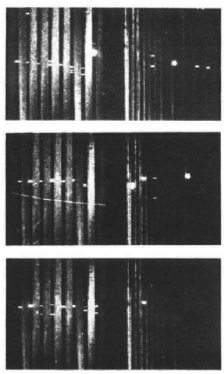


Figure 3 – Example of electron interactions in the spark chambers. One can see the shower like aspect distinguishable from the muon tracks of Fig. 2

It is clear from these figures that it is very difficult to imagine how the experiment with the needed mass and granularity would have been possible before the invention of the spark chambers.

4.2 *The initial apparatus on ACO e^+e^- ring in Orsay*

The first e^+e^- ring ADA was built in Frascati and after initial test moved to LAL Orsay in 1962 to use the Orsay Linac as injector. This is were the first e^+e^- collisions were observed. Then projects to build e^+e^- rings for analysis of the annihilation physics started at Orsay (ACO), Novossibirsk (VEPPII), Frascati (Adonne), and SLAC (SPEAR). Again without the invention of spark chamber it is difficult to imagine an efficient detector, in those years. The first ACO detector built in 1962-1965 is shown in Fig.4. Plane optical spark chambers were used, the first 3 layers were thin aluminium plate chambers to define the trajectory. The next layers were 1.5 cm brass plate, in this way $e^+e^- \to \mu^+\mu^-$ and $e^+e^- \to \pi^+\pi^-$ events could be separated by the range of the tracks, $e^+e^- \to e^+e^-$ events were identified by the showers of the electrons in the brass plates. The solid angle was rather limited but this apparatus allowed good measurements of the parameters of the ρ^0 resonance produced in the reaction $e^+e^- \to \rho^0 \to \pi^+\pi^-$.

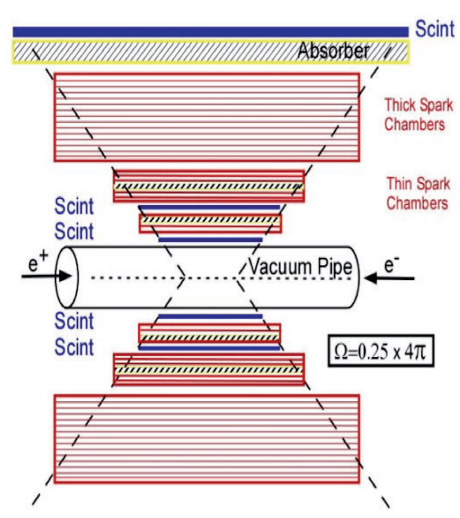


Figure 4 – The first detector at the ACO storage ring. The thin plate spark chambers measured the particles angles. The thick plate chambers allowed to indentify e, μ, π by range for μ and π or showering tracks for electrons. The absorber above stopped all products from the interaction, while a scintillating counter on top, in anticoincidence, allowed to veto cosmic ray background.

4.3 *The φ3C detector at ACO*

After the initial data taking at ACO with the detector shown in Fig.4 another specialised detector was built to study the reaction $e^+e^- \to \varphi^0 \to k^+k^-$. The kinetic energy of the kaons (and therefore their range) was very low (about 17 MeV) and the thickness of the ACO vacuum chamber and of the spark chambers had to be very thin. Than in 1969, 1970 another detector, φ3C, was built. The apparatus is shown in Fig.5 . It is clearly more complex than the first detectors, it could nevertheless be conceived and built in about 2 years. In this case the chambers were cylindrical allowing to more than double the effective solid angle observed (0.6X4π vs 0.25x4π for fig 4) To obtain this cylindrical shape , the chambers were made of 2mm low density foam material with Mylar and aluminium foils glued on each side. After the gluing in an iron cylinder of the proper radius, the chambers thus obtained were light and rigid. The registering of the sparks was still optical and therefore a hole had to be left in φ to observe the r-z view . After the first layers used to measure the tracks there were 11 cylindrical 0.5x/x0 lead sheets between each layers, thus allowing to materialize photons in reactions like $e^+e^- \to \varphi^0 \to \eta^0\gamma \to 3\gamma$ or $e^+e^- \to \omega^0$ or $\varphi^0 \to \pi^+\pi^-\pi^0 \to \pi^+\pi^-\gamma\gamma$.

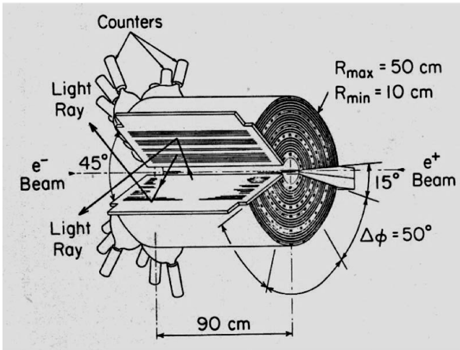
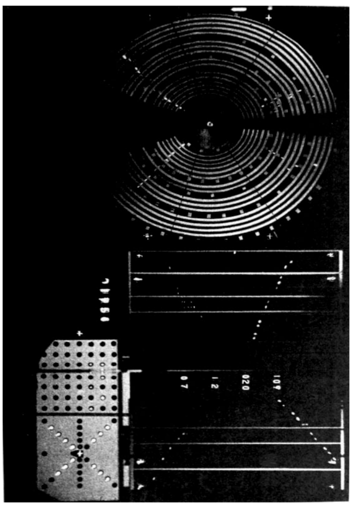


Figure 5 – The φ3C detector at the ACO storage ring. Through a 45° opening it was possible to photograph the r-z view. One can see the layers of spark chambers, 2mm lead sheets and scintillation counters.

At these low energies it was sufficient to observe the particle angles since, using the 4 kinematical constraints, events, of the type $e^+e^- \to 4$ particles or less, can be reconstructed. A typical event is shown in Fig.6. The data obtained was purely "optical", in other word the film was the data storage medium and if extra information had to be recorded for each event, this was coded in little lamps which were photographed with the events as can be seen in Fig.6.



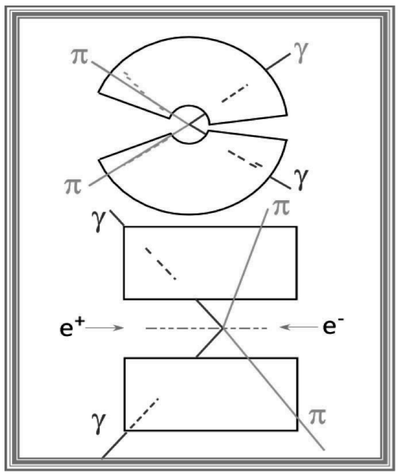


Figure 6 – One can see in Fig 6a the r-φ and r-z view a typical event of the type $e^+e^- \to \pi^+\pi^-\pi^0 \to \pi^+\pi^-\gamma\gamma$, note the small lights photographed with the event that allow to localize the scintillation counters that registered the passage of particles. To guide the eye the schematics of the event is given in fig 6b

4.4 The advent of non-optical Spark Chambers

As shown in the preceding paragraph on the φ3C apparatus, early spark chamber apparatus were purely visual. This had the inconvenient that each picture had to be scanned and measured by physicist or professional scanners, which was a huge task when the data reached the millions of pictures. In the early 70's, techniques were invented to code the spark location information but the use of these techniques had to wait for the arrival of the DAQ computers. Of course computers existed since the end of the 50's (or even before) but were not built to receive data in real time, organise it and copy the output to a storage medium usually magnetic tape. I remember my first use of a DAQ computer was a Varian in 1972 and its core memory was 12 Kilobytes (this probably seems incredible to younger physicist with their smart-phones advertising 10's of Gigabytes of memory). The memory was made with small ferrite torus , one torus per bit! Hence 4 Kbytes was about 10X10x10 cm^3. I remember these numbers since the memory being too small we had to plead to IN2P3 for a special allowance to buy an extra 4 Kbytes at a cost of about 20 thousand French Francs!!!

A first idea for coding the sparks' positions was to install microphones at the four corners of a plane spark chamber; from the time of arrival of the sound of the sparks in the microphones it was possible to calculate the positions even in the case of more than one spark. Other techniques were invented, however the technique that had the biggest impact was the magnetostrictive wire technique. In this case the surfaces of the spark chambers cathodes were made of wires, these wires carried the spark current to the edge of the chambers, a magnetostrictive wire was placed orthogonal to the cathode wires just at the edge, the cathode wires current induced a magnetic field and then a sonic signal in the magnetostrictive wire, this signal was then detected at the end of the wire in the corner of the chambers and from its arrival time the position of the cathode wire carrying the current could be calculated. Stereo wires configuration allowed in the case of cylindrical chambers to obtain the Z coordinates of the sparks.

4.5 MARK I at SLAC

The MARK I detector was designed as part of the program to build the 3GeV+3GeV Spear e^+e^- collider at SLAC. It is shown on Fig.7. It started its operation in 1973, and it is probably the most productive detector in particle physics history co-discovering the J/Ψ, and discovering the Ψ', charm particles, tau lepton, spin 1/2 of quarks, etc...

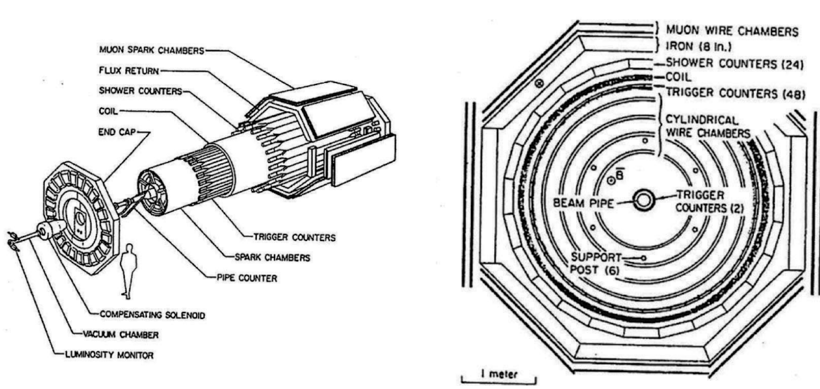


Figure 7 – The overall view of the MARK I detector (left) and the detailed transverse view (right). Note the structure that is quite close to what has become a classical structure at colliders, the cylindrical shape the solenoidal field etc...

Its design has now become classical for apparatus at colliders with its solenoid and cylindrical geometry but it was very innovative at the time, the most important innovation was the insistence that the most effective apparatus at a collider was a general purpose detector (GPD). A second collision point at Spear allowed for the use of specialised detectors but they were never as productive as MARK I. The MARK I tracking was performed by magnetostrictive spark chambers and the detector included shower counters and muon detectors. It should be noted however (according to the users themselves) that the shower counters to detect gammas or identify electrons were not of very good performance, lacking in granularity and resolution.

4.6 The drawbacks and end of the Spark Chambers

Even after the invention of non optical-readout, there were still some drawbacks, first the data rate was limited as mentioned at the beginning of section 4, another problem was the difficulty in case of multi-particle events, it was quite difficult to insure that the different sparks shared equally the available charge, often one sparks would start slightly sooner and rob all the energy. This problem was somewhat alleviated with chambers made of wires (like the magnetostrictive spark chambers) since the resistance of the wires played a role in equalizing the energy. I remember that for the φ3C chambers (that were optical spark chambers) we added a dopant in the Helium Neon gas to increase the resistance of the sparks and keep good multi-sparks efficiency. Then in 1968 Georges Charpak invented the MWPC, as usual the invention was possible since the technology available had evolved; in this case the cost of amplifier was dropping rapidly and the integrated circuit needed started to arrive. With this new device the problems of rates and of multi-tracks efficiency were much smaller, and therefore it signalled the end of the spark chambers within 3 to 6 years.

5 The development of General Purpose Detectors

It may seem strange to younger physicist who have always known the GPD, but it is a concept that took some time to arrive in particle physics. In a certain sense, the Bubble Chamber experiments were using the same instrument which could be called "general purpose" whether using it with antiproton beam or kaon beam etc..., high energy beam or particle at rest etc...

However typically in the 60's and 70's, counter experiments at the PS and SPS at CERN were proposed for a precise aim and, if approved by the experimental committee, a dedicated apparatus was built and then a certain beam period was allocated. (The procedure was similar at Brookhaven and and Fermilab) The criteria for a good detector were therefore simple, it was the adequacy with the declared purpose. This is of course simpler to optimise, for example if you want to study the ratio of decay rate $\pi \to e\nu/\pi \to \mu\nu$, it is rather simple to understand the criteria. Even when e^+e^- colliders were developed, initially the procedure was similar, as was discussed above at ACO with a succession of dedicated apparatus obtaining each 12 to 18 months of data taking. The Adonne collider at Frascati had similarly a series of dedicated detectors but a greater number could be operated in parallel. As explained above, the fantastically successful MARK I detector was an exception in that respect.

In the early 70's, the idea of GPD started to be discussed, actually there is already in 1968 a proposal for a large magnet and spark chamber system to be installed in the west area of the CERN PS which became the Omega spectrometer, and in 1969 a GPD for the ISR at CERN was proposed, the Split Field Magnet (SFM).

But there was a subtle difficulty with GPD: contrary to dedicated system, the proponents had to guess also the main physics questions to be covered at later time by the GPD and a good example of this difficulty is the SFM.

5.1 *The SFM*

The ISR was the first collider with proton beams the beam energy was about 30+30 GeV. In 1968 and 1969 SLAC deep inelastic e-p scattering had shown that there were point-like constituents inside protons, however all hadronic interaction experiments up to then had shown that the products had limited transverse momentum (Pt) with cross section decreasing exponentially with Pt. Therefore the aim of the SFM apparatus, proposed in 1969 and operational in 1973, was to be able to measure accurately high energy and limited Pt particles. The device is shown Fig.8. The technique for the tracker was very ambitious, proposing in 1969 to use the Charpak MWPC that had just been invented in 1968, and use them in large quantities almost 10^5 channels!!! The magnet design seemed a very clever idea, it used vertical field and the two halves had field in opposite directions, this minimized the required amount of iron and also partially cancelled the effect of the SFM field on the stored protons. This was an excellent design for forward or backward reactions but there was no field at 90° and therefore the SFM was essentially blind in this region. However it turned out that by the time of the start of the detector the most important physics was the study of high Pt phenomena around 90°!

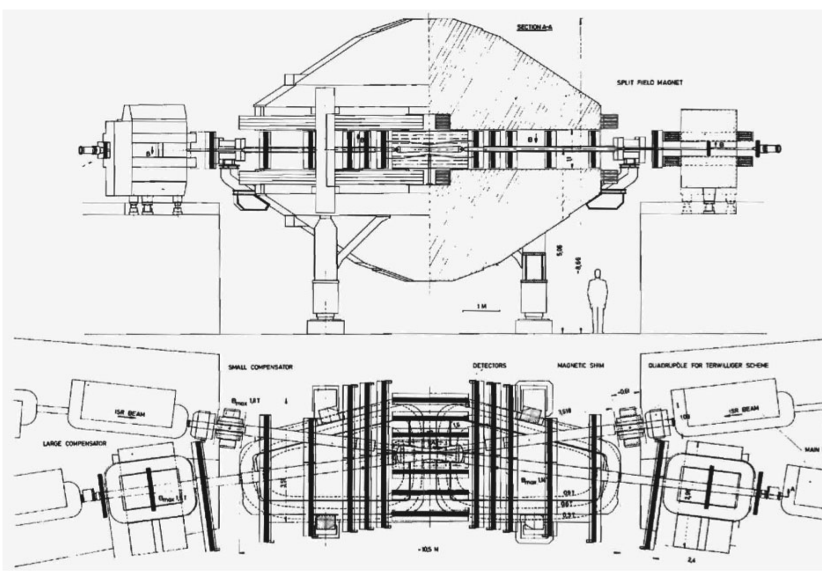
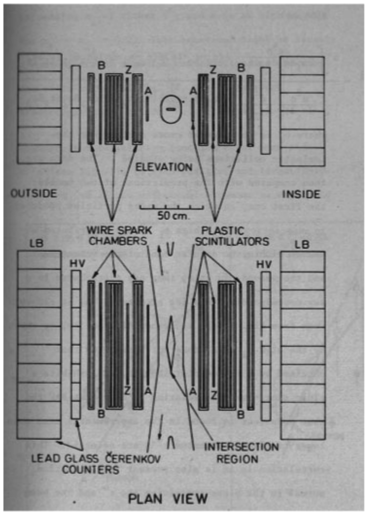


Figure 8 – Above, the side view of the Split Field Magnet detector at the ISR. Below a top view of a schematics of the MWPC layout is shown.

5.2 *Examples of other ISR detectors*

There had been other proposals for the ISR GPD, optimised for central physics, but they were turned down by the experiments committee in favour of the SFM.

Luckily other specific detectors optimised for the central region were approved however they were less efficient, using magnetostrictive spark chambers instead of MWPC. As an example the CCR (CERN Columbia Rockfeller) and CCRS (same+ Saclay) are given in Fig.9. Such set up did very good physics on high Pt studies of hadrons or electrons but its limited data taking rate prevented the threshold in Pt to be low enough to see the J/Ψ. This was certainly a lesson learned for future collider detectors.



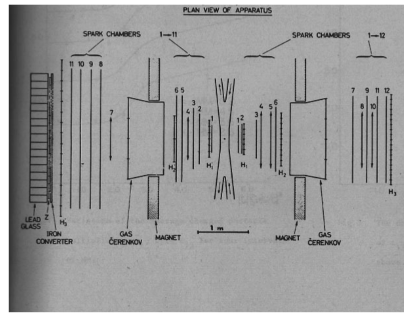


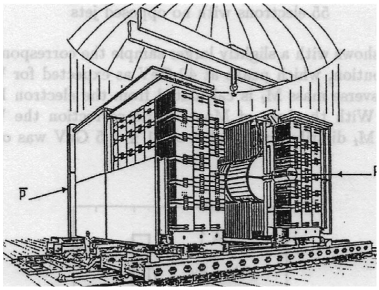
Figure 9 – This was the apparatus of the CERN Columbia Rockefeller (CCR) experiment at the ISR. As shown this apparatus was well adapted to studies of high Pt particle production around 90 in the center of mass system. (left) This represents the CCRS apparatus (CCR+Saclay) it was a further evolution of the CCR detector, nevertheless both detectors still used spark chambers as tracking detectors.(right)

6 The CERN ppbar collider and the GPD UA1 and UA2

Everybody knows the story of the CERN ppbar collider and the discovery of the W and Z, nevertheless it is interesting to look at the detectors UA1 and UA2 as example of the evolution of GPD. In this case the main physics motivation was clear: the discovery of the W and Z and this required good momentum/energy measurement, good lepton identification, complete detector for missing pt measurement (a new concept), this was very well done and the results speaks for itself. The apparatus UA1 and UA2 are shown in Fig.10 and 11. UA2 was a less complete (and less expensive!) detector with no magnetic field in the central region the field being only in the forward backward region to have access to the predicted charge asymmetry in W decay produced in ppbar collisions, the lack of field meant UA2 could not study decays of W and Z to muons certainly a rate handicap. However the calorimeters (ECAL and HCAL) had a tower structure with a reasonable granularity in θ and φ which is now "classical" in collider experiments.

The UA1 detector had a vertical magnetic field a very complete acceptance for the tracker and calorimeters however the calorimeters had a rather coarse granularity both for HCAL and especially for the ECAL that was built as "gondola" having in φ a granularity of $\pi/2$. This had an impact on the observation of jets in ppbar collisions.

Before mentioning this measurement, one has to realize that jets had been seen and studied at e^+e^- colliders before at SPEAR and PEP and PETRA, however they had not been seen in a convincing way in hadronic collisions, neither at the ISR nor in fixed target experiments at the SPS or Fermilab. For example at the SPS the NA5 experiments was built with an ensemble of tower calorimeter cells to trigger in an unbiased way on total transverse energy, hoping to observe jets. However the energy was too low (about 20 GeV in the center of mass) and therefore the trigger selected only high multiplicity events without clear structure.



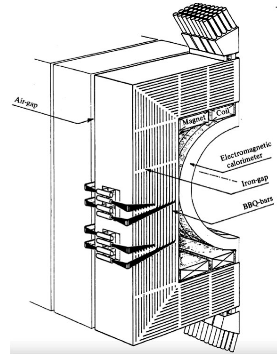
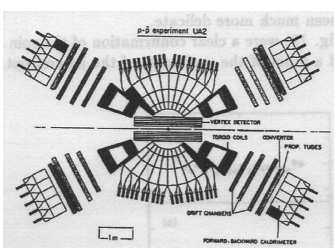


Figure 10 – Overall view of the UA1 apparatus (left) and detailed view of the calorimeter part. (right)



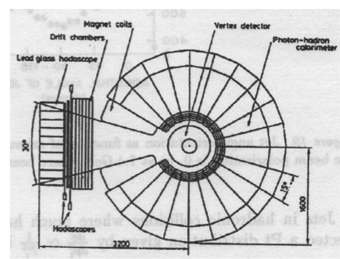


Figure 11 – The polar view of the UA2 apparatus (left) and the φ view (right). Note the insertion in φ of a special region to allow an analysis with a magnets for a fraction of the particles produced around $\theta = 90^{\circ}$ in the center of mass; this system was removed after initial data taking in favor of a detector uniform in φ.

While the UA2 experiment, could present at the ICHEP 1982 the results with a similar trigger on the sum of transverse energy obtained in the calorimeter. This is shown in Fig.12 and 13 and was a clear first evidence for the observation of Jets in hadronic collisions. UA1 succeeded after, to do similar jet studies but nevertheless, the clear lesson was that high energy physics would be dominated by jet studies and this therefore required good granularities of the trackers and calorimeters.

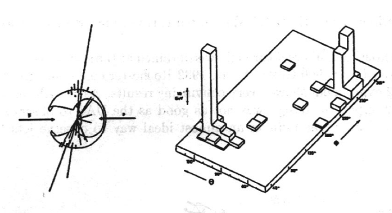


Figure 12 – Angular distribution of an event with the sum of transverse energy equal to 150 GeV . The jet structure of the event is obvious.

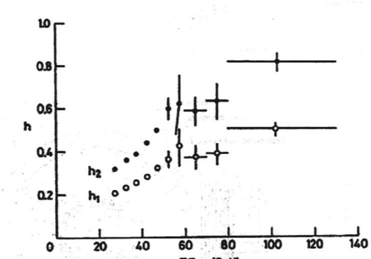


Figure 13 – The fraction h of the total transverse energy of events measured in one (open circle) or in two jets (filled circles). When Et is greater than 80 GeV, on average about 80% of the Et is found in two clusters.

7 The LEP detectors

The LEP detectors ALEPH DELPHI L3 OPAL were built in five years 1983 to 1988. By then the understanding on how to build GPD had improved a lot. This does not mean the apparatus were identical and some were better adapted to part of the physics, this reflected in measurement errors of physics parameters which could vary up to sqrt(2) from one experiment to another. Of course the correct optimisation of the detectors reflected also the fact that, contrary to the situation at the ISR for example, the expected physics was far better understood, and sadly there were no major surprises! For examples if series of onium resonances had existed at 70 GeV then the Bismuth Germanate (BGO) ECAL modules of the L3 experiment with its better accuracy at low photon energy would have played a major role, so the question was still relevant: a General Purpose Detector is never fully general so is the one you want to build general enough for the physics you think will happen.

It was clear that the physics was going to be in form of high energy jets i.e. closely spaced particles (even more closely spaced in the case of $Z \rightarrow \tau^+\tau^- \rightarrow$ few particles with high energies) so it was obvious that granularity was important ALEPH and DELPHI made it a key point in their choices. Their track detectors were TPC's giving points along the tracks in space and therefore excellent multi-track efficiency.

The calorimeter granularity was also an important argument and the ALEPH ECAL had 70,000 towers with 3 readouts in depth. An interesting observation is that while Liquid Argon ECAL had been used at the ISR, SPS, PETRA etc... no such detectors were built at LEP. At least for ALEPH, I know that the argument was the limited granularity possible for the lead liquid Argon sandwiches (because of mechanical construction difficulties) : the energy resolution would have been better compared a detector of lead MWPC sandwiches that was chosen but the better granularity of this latter design was the key arguments. As you know the argument changed at the LHC after the invention of the accordion structure for the ATLAS ECAL that allowed to obtain high granularity in Liquid Argon detectors.

The detector granularity turned out to be a very important at LEP, not only it eased studies of particles in jet or from tau decays but it allowed also the development of the particle flow technique to measure in a superior way the energy and angle of jets.

One new development arrived at LEP, the Silicon Vertex Detectors. Silicon detectors had been invented and used before LEP but it was clearly still a quite difficult technique in the 80's and their installations were delayed for all four experiments until 1991-1992

8 The LHC detectors

The information, on these detectors, being very recent and therefore well known by most listeners or readers I will be brief. The motivation for the GPD ATLAS and CMS apparatus choices did not change in a major way compared to detectors at the Fermilab collider or compared to LEP detectors. The aims continued to be completeness, hermiticity, granularity and accuracy. This did not mean there were no innovations: I have already mentioned the accordion technique for the ATLAS ECAL but one can also mention, among others, the tracker of CMS made only of Silicon or the use of RICH for particle identification in LHCb.

But, in my opinion, the biggest breakthrough, compared to previous experiments, is the key role played by the large computing farms. This is not to say these farms did not exist before but now they are playing an essential role in the event selection, the power of those farm allowing far more complete event reconstruction than before and therefore for more subtle triggers. They also allowed an event data collection rate which is indeed remarkable.

9 Conclusion and the future

The opinion of an experimentalist who started to built his first apparatus 57 years ago is probably not the most relevant to think of the future, nevertheless let me give a few worries I have when thinking of what future apparatus will be.

The main one is linked to the greater and greater time that exist now between first design of a future project and the actual construction, we are certainly far from the 2 years to build the spark chamber apparatus of the neutrino experiment mentioned in section 4.1, the worry is that, because of this, apparatus would not profit from the best ideas available at the construction time. Can we design apparatus years before construction time and nevertheless keep flexibility.

Another worry is that the qualities of the most recent detectors have been obtained at the cost of a notable increase in the amount of material in the trackers. This is certainly not optimum! Will we succeed in building lighter detectors?

Another point which is more a hope than a worry is the advent of large scale very fast detectors, timing of the order of 50 picoseconds are envisaged, if this is achieved it will certainly have an important impact.

Seeing what was achieved over the past years is certainly a good reason of hope for the future.

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