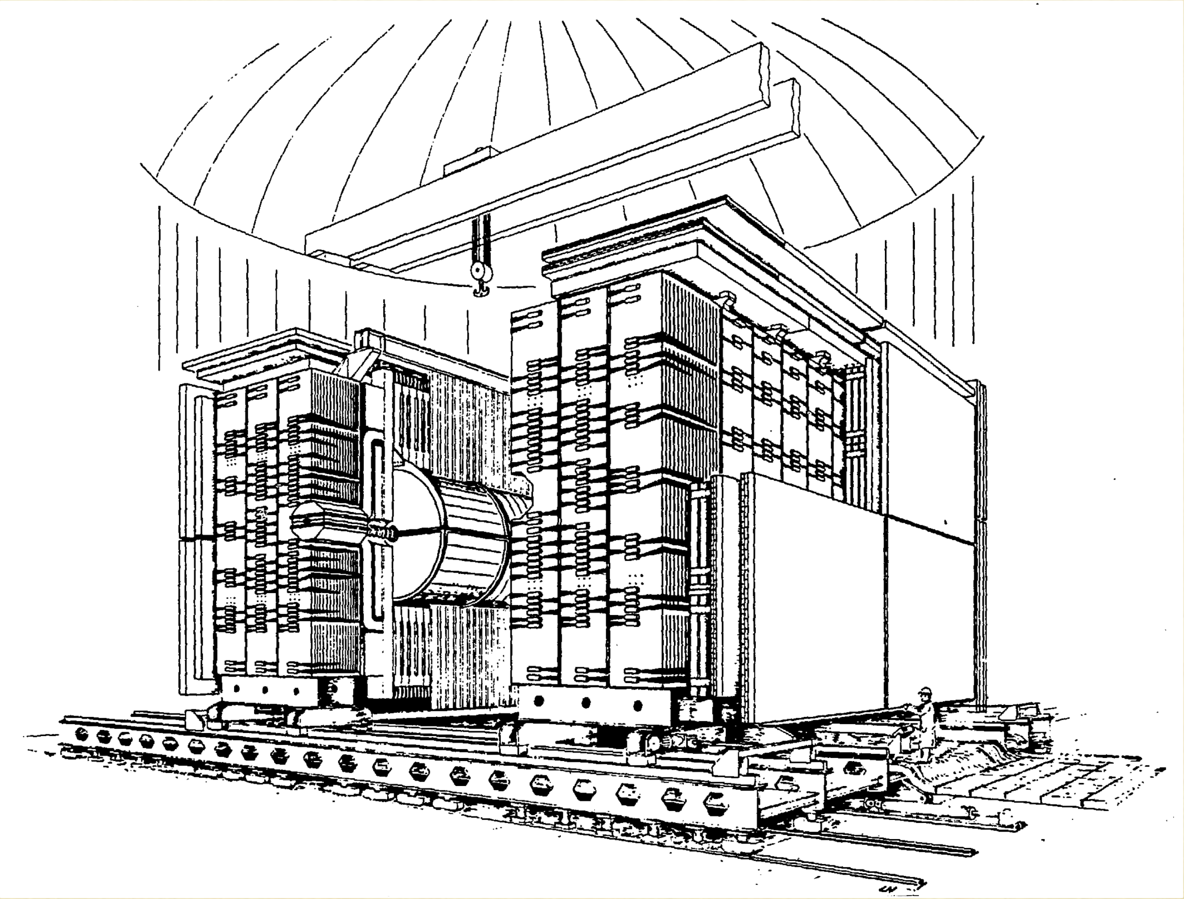
Francesco Lacava

The UA1 Experiment



Symposium in honour of Filippo Ceradini: 50 years in particle physics

Università Roma Tre - 3 February 2017

Weak interaction before UA1 (1)

In 1933 weak nuclear processes were first described by E. Fermi as a point-like interaction involving the product of four fields with coupling constant $G_F = 1.166 \times 10^{-5}$ GeV^{-2}.
In 1938 O. Klein suggested that the weak interaction could be mediated by massive charged fields.

As well known a deeper insight on weak interaction followed the discovery of parity violation in 1956.

In 1967 S. Weinberg and A. Salam proposed the unification of the electromagnetic and weak interactions with the model of the SU(2) x U(1) symmetry spontaneously broken.

In the Weinberg-Salam theory the weak interactions are mediated by massive bosons: the two charged W^+ and W^- (for charged currents) and the neutral boson Z° (neutral current).

The couplings of SU(2) and U(1) symmetries are related by the Weinberg mixing angle θ_W.
Given the weak coupling constant G_F and the fine structure constant α the theory predicts the masses of the weak intermediate bosons in terms of θ_W:

$$M_W = \left[\frac{\pi\alpha}{\sqrt{2}\,G_F}\right]^{\frac{1}{2}} \frac{1}{\sin\theta_W} \qquad M_Z = \frac{M_W}{\cos\theta_W}$$

Weak interaction before UA1 (2)

In 1973 the neutral currents were discovered at CERN by the Gargamelle bubble chamber.

In 1976 from measurements on weak neutral currents the value of the Weinberg angle was:

$$\sin^2 \theta_W = 0.3 \pm 0.1$$

and the expected masses for W and Z° were:

$$M_W = \frac{37\ GeV}{\sin\theta_W} \simeq 68 \pm 40\ GeV \qquad M_Z = \frac{73\ GeV}{\cos\theta_W} \simeq 80 \pm 25\ GeV$$

In 1976 a study group at CERN started working to prepare a report for the construction of a new e+e– collider (LEP) to produce the Z°.

At Brookhaven the proton-proton collider ISABELLE (200 + 200 GeV) with superconducting magnets was recommended by the HEP Advisory Panel in 1974 and construction began in 1978 before superconducting magnet technology had been achieved. The project was then cancelled in 1983.

But there was also a more direct and fast possibility to produce W and Z°.

The proton-antiproton collider idea

In 1975 and 1976 Carlo Rubbia presented in some seminars at Fermilab and at CERN the possibility to convert the existing proton accelerators to proton-antiproton colliders making use of a single magnet ring as for the the e^+e^- colliders. The beams of antiprotons were to be produced by means of the "electron cooling" or the "stochastic cooling".

It is well known that Rubbia presented the idea at the 1976 International Neutrino Conference in Aachen:
C. Rubbia, P. McIntyre and D. Cline:
Producing Massive Neutral Intermediate Vector Bosons with Existing Accelerators.
(Proceedings of the Conference, p. 683 – eds H. Faissner, H. Reithler and P. Zerwas)

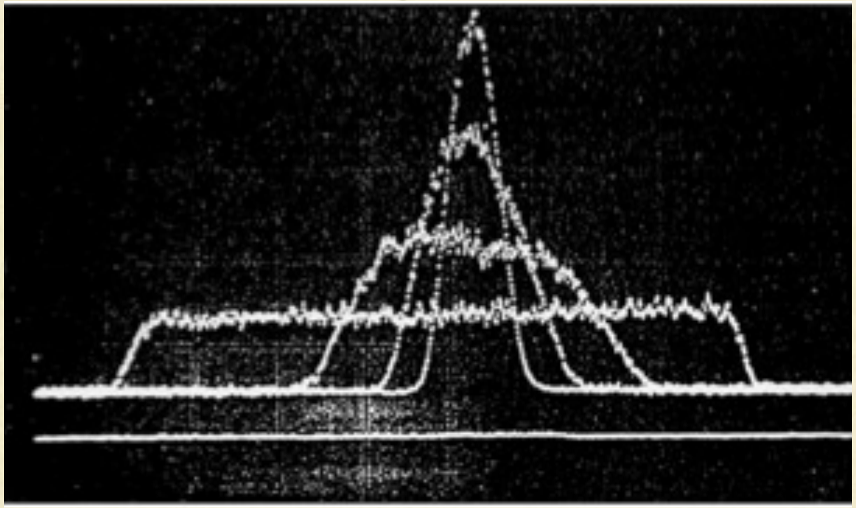
It is worthwhile to mention that in 1967, while Giorgio Salvini was the President, INFN studied the feasibility of an Italian proton synchroton with the possibility of colliding protons and antiprotons.
Carlo Rubbia and Giorgio Ghigo studied how to convert an electron storage ring from CERN (CESAR) for the cooling of antiprotons in Frascati.
These studies came after the work on the "electron cooling" by A. M. Budker in Novosibirsk and were encouraged by Bruno Touschek.
The project was abandoned because CERN decided to build the European accelerator SPS and INFN started to work to ADONE, but Rubbia continued to think to the hadron colliders. (see his presentation at meeting for the Giorgio Salvini's 90 years in Roma)

The proposal by Rubbia and collaborators was considered unrealistic at Fermilab but was appreciated by John Adam and Leon Van Hove, the CERN Directors .

The game was to convert the SPS to a proton-antiproton collider with 540 GeV c.m. energy but the first not easy step was to provide the antiproton beams.

An essential contribution to the project came from the discovery of the "stochastic cooling" of particles by Simon van der Meer in 1968-1972.
(Stochastic damping of betatron oscillations in the ISR, CERN-ISR-PO-72-31; ISR-PO-72-31).

A group lead by G. Petrucci started soon to study the stochastic and the electron coolings in ICE (Initial Cooling Experiment)*.



Momentum cooling in ICE of 5×10^7 particles.
Longitudinal Schottky signals after 0, 1, 2 and 4 minutes.
The momentum spread was reduced from 3.5×10^{-3} to 5.0×10^{-4}

In June 1978 the stochastic cooling method was demonstrated to be much superior to the electron cooling for the CERN antiproton program and the project of the collider with the AA (Antiproton Accumulator) was finally approved.

In June 1980 the AA was ready to delivery antiproton beams.

The proposal of the experiment (P92 Proposal)

In 1977 physicists and engineers worked to design the detectors of the experiment to be installed at the proton-antiproton collider.

That period was very exciting and rich in studies and discussions to search for the best detectors to be assembled in the experiment. Many clever people were contributing and Carlo Rubbia was of course the outstanding leader of the group.

The proposal was ready in January 1978:

A 4π Solid Angle Detector for the SPS used as a Proton-Antiproton Collider at Centre of Mass Energy of 540 GeV (CERN/SPSC/78-06 SPSC/P92 30 January 1978)

with 52 authors and 9 institutions :
(Aachen, LAPP Annecy, Birmingham Univ., CERN, College de France, Queen Mary College, Riverside, Rutherford Lab., Saclay)

Roma is not in the list but Giorgio Salvini and myself are present as visitors from the University of Rome and INFN Roma.

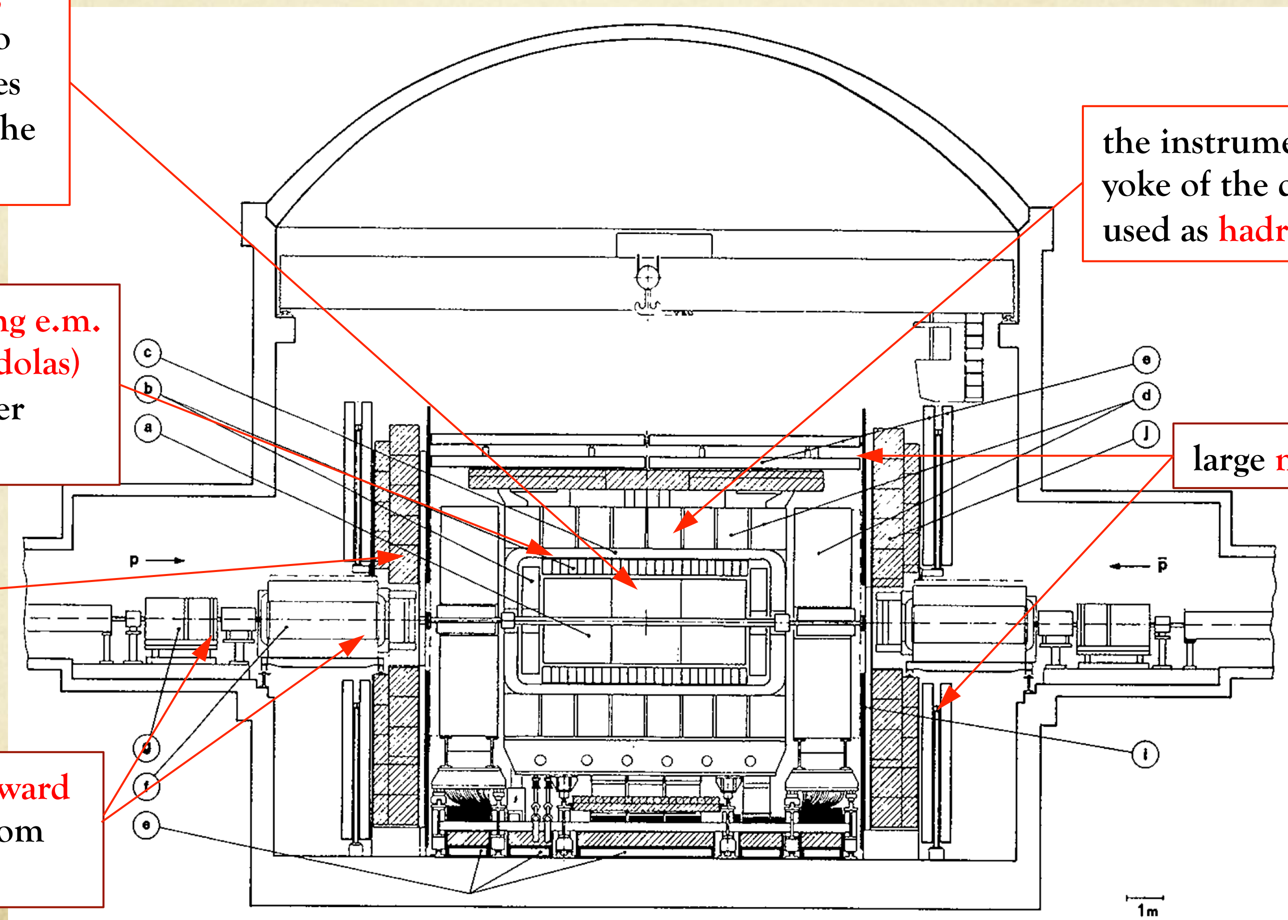
Salvini was in fact working early to the project and then he spent two years at CERN while I joined the group after the Summer 1977.

Salvini was interested and active on every part of the experiment and in the following years he was very proud of his contribution to the design of the magnet.
I was involved in the design of the e.m. calorimeter.

The UA1 Experiment

After the approval in June 1978, the experiment was named UA1 (Underground Area 1) from the name of the underground hall along the SPS ring built to host the detector.

It was the first general purpose (multipurpose) 4π (hermetic) experiment in particle physics.
It was composed by very innovative and sophisticated detectors.



the Central Detector, a big drift chamber to track charged particles in the 0.7 T field of the dipole magnet

the instrumented return yoke of the dipole magnet used as hadron calorimeter

the fine grain sampling e.m. calorimeter (the Gondolas) readout by wave shifter bars (BBQ)

large muon chambers

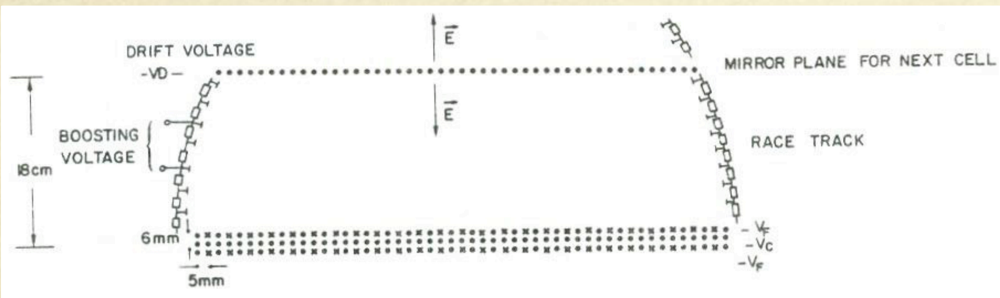
end cap detectors (the bouchons)

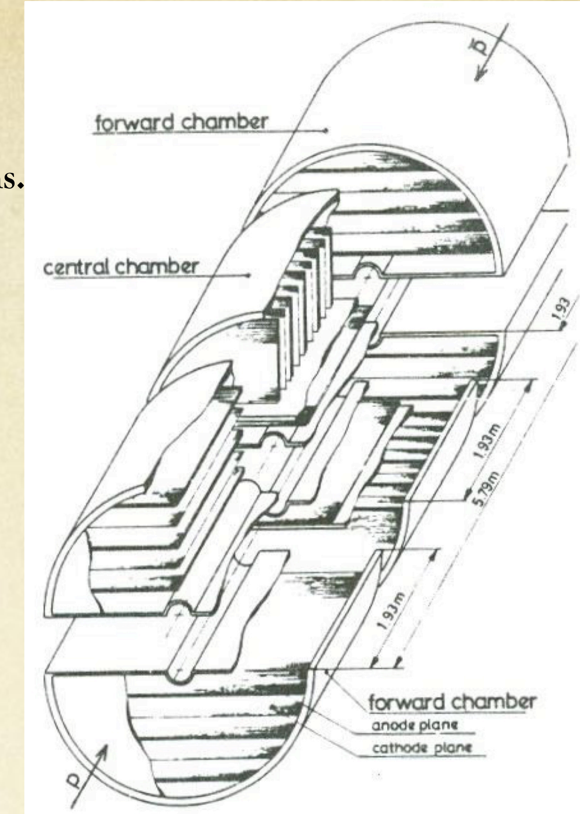
forward and very forward detectors (up to 1° from the beams)

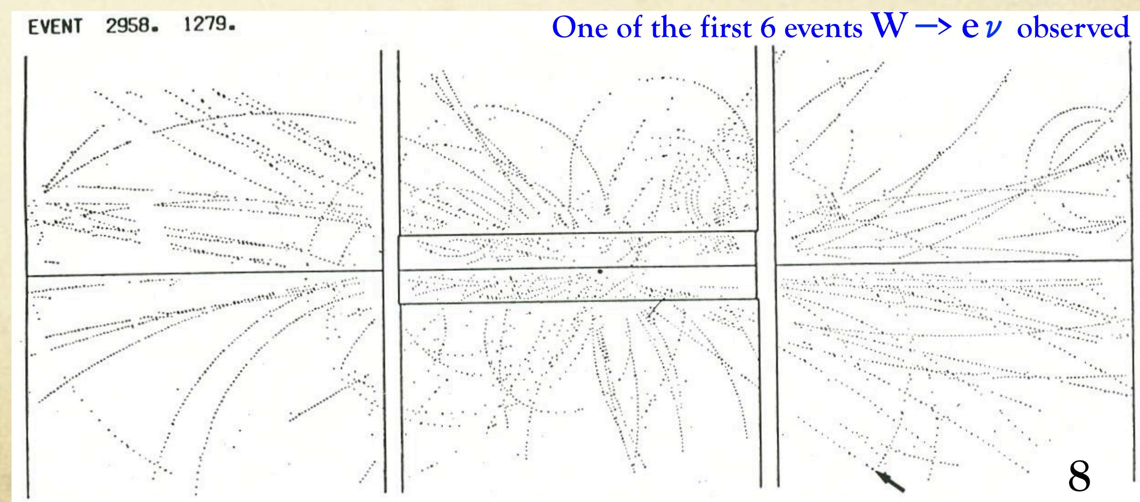
The Central Detector

Six independent half-moon shaped chambers assembled together to form a cylinder, 6 m long and 2.2 m in diameter, covering the solid angle from 5° to 175° wrt the beams. 60-40% C_2H_6-Ar mixture, 6000 sense wires and 17000 field wires parallel to the magnetic field and organized in horizontal planes in the four forward chambers and vertical planes in the two central ones. The position of the track was determined from the drift time (max drift 18 cm – 3.6 μs), the charge division, the position of the wire. In average 100 points/track, useful also for dE/dx particle identification.

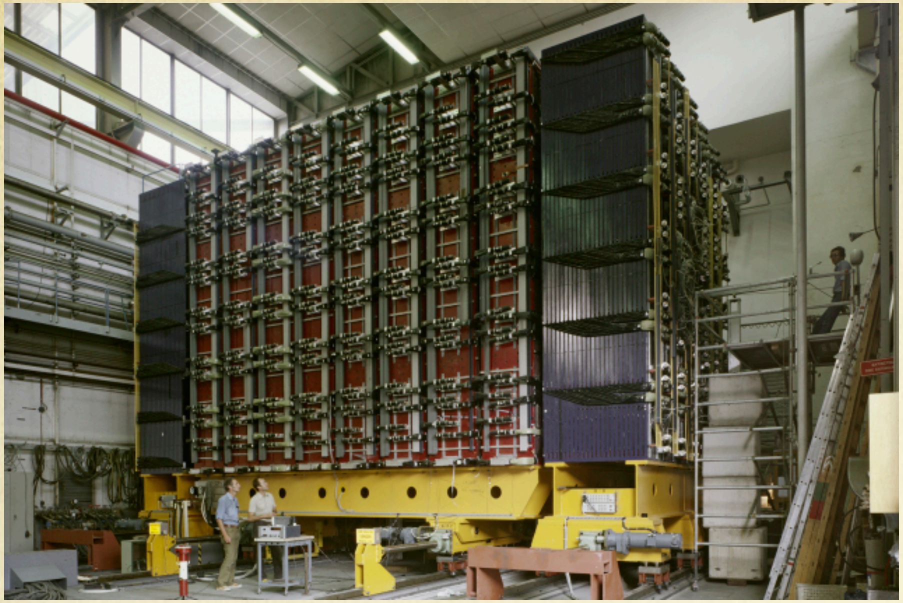
(M. Calvetti et al. (… P. Cennini, E. Chesi, S. Cittolin, S. Centro, F. Lacava, G. Piano Mortari, A. Placci, C. Rubbia …): The UA1 Central Detector. Proc. Int, Conf. Instr. Colliding Beams Physics - SLAC 1982)



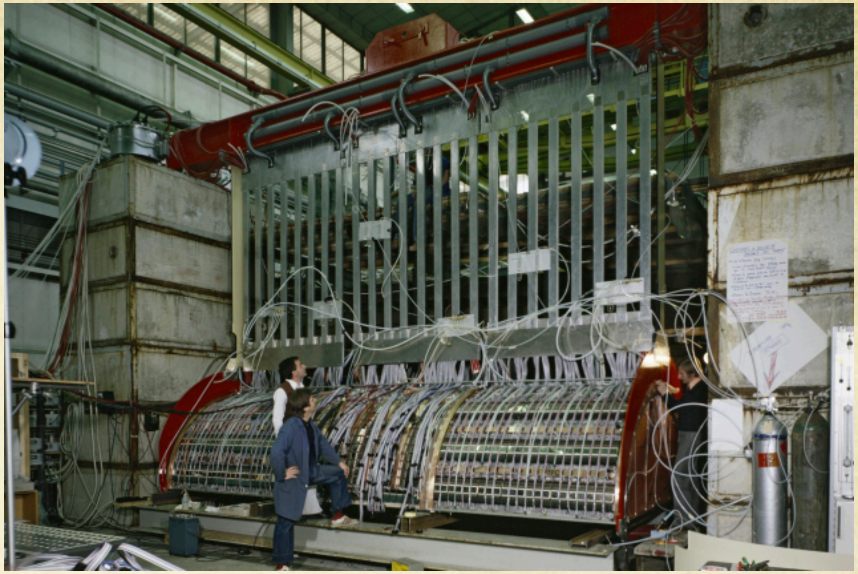




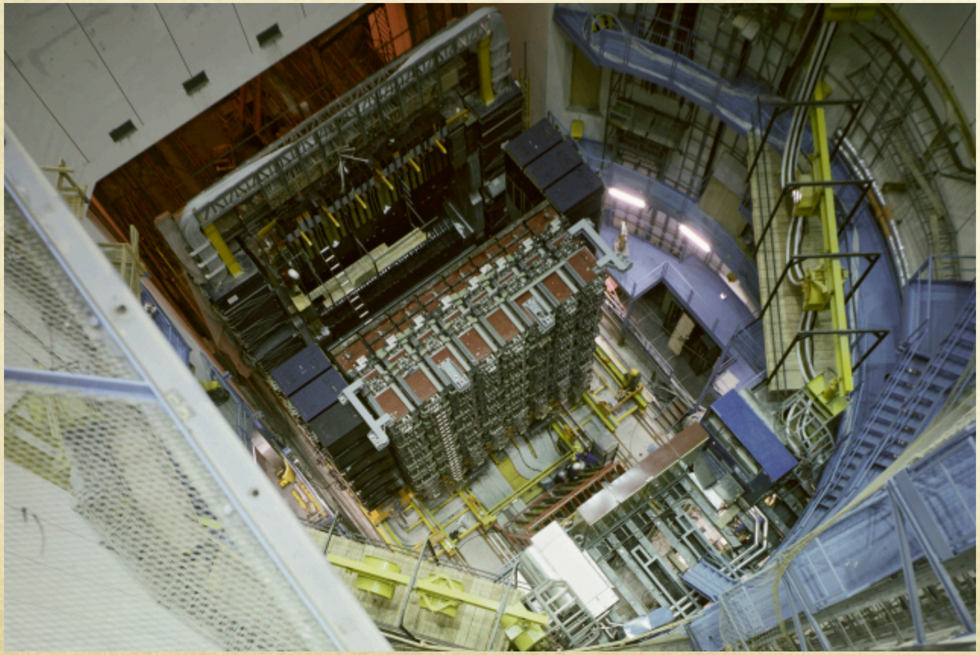
One of the first 6 events W –> eν observed



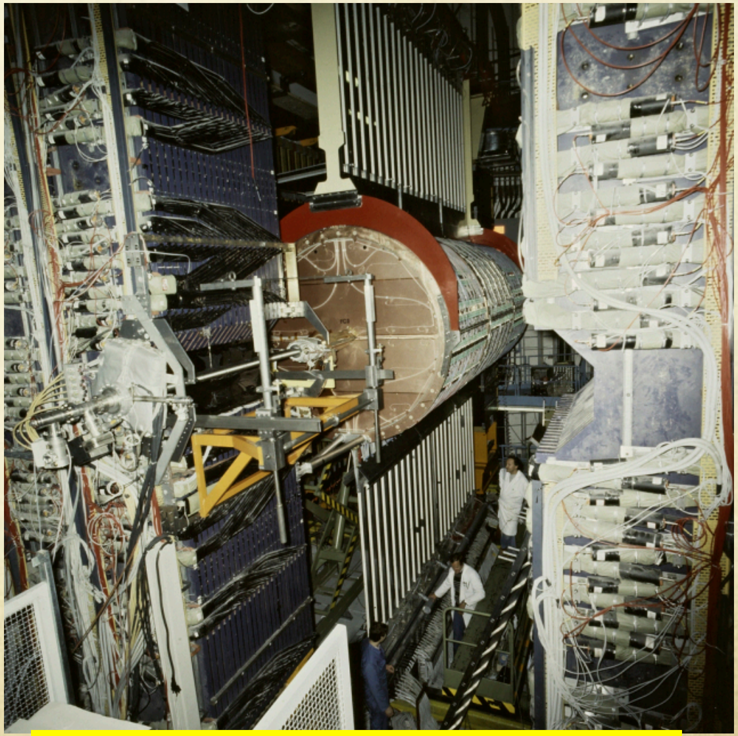
Preassembling of the UA1 magnet in the Hall 155 in August 1980.
At the bottom, Peter Kalmus and Hans Hoffmann.



Mario Calvetti and a technician near the upper half of Central Detector in the Hall 155 in March 1981 ready for the transport to the pit.



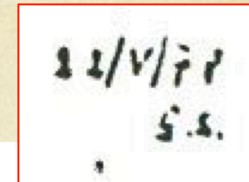
UA1 opened in May 1981 without muons chambers. At the bottom right the MEC chariot hosting the readout electronics.

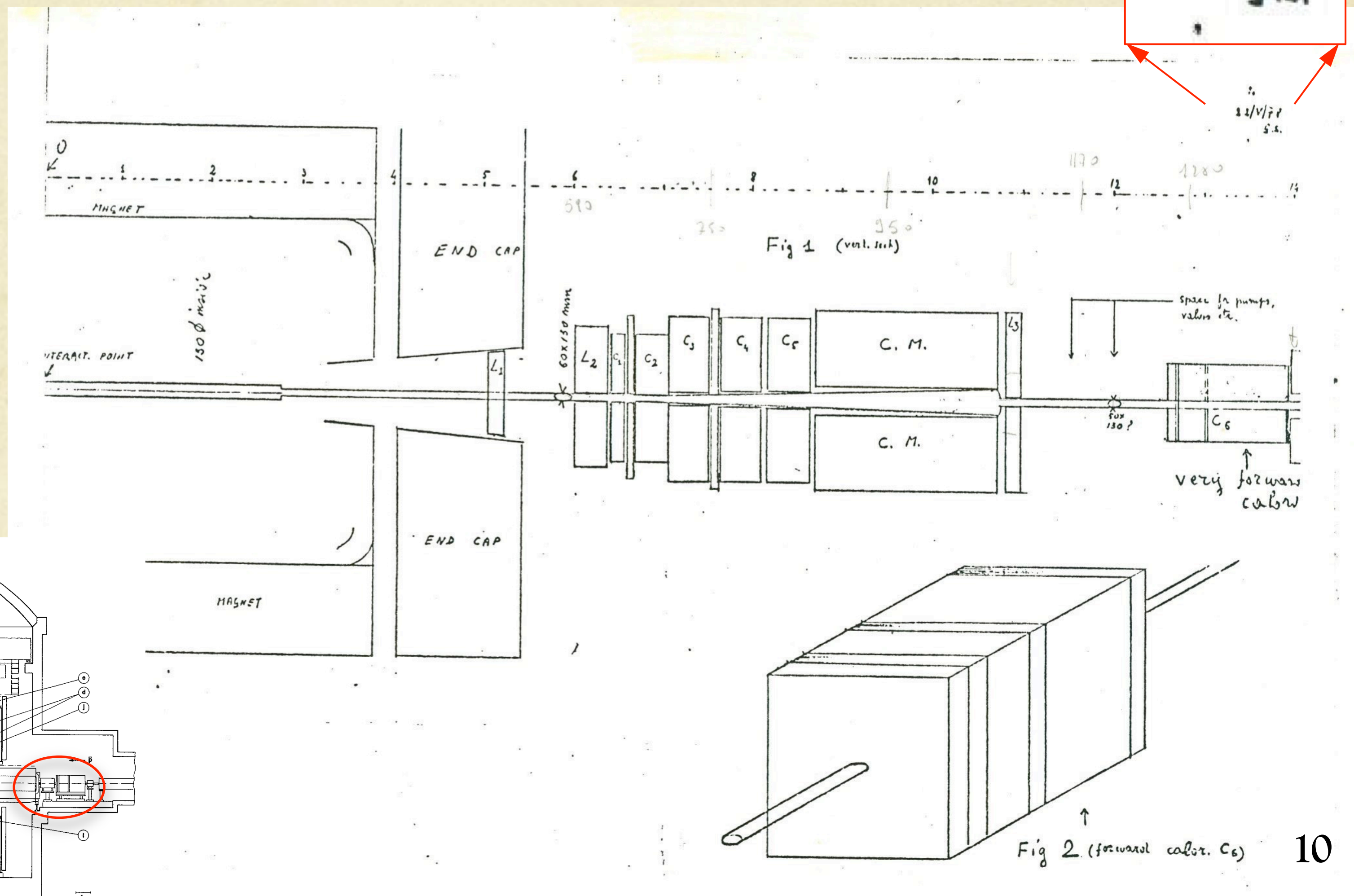


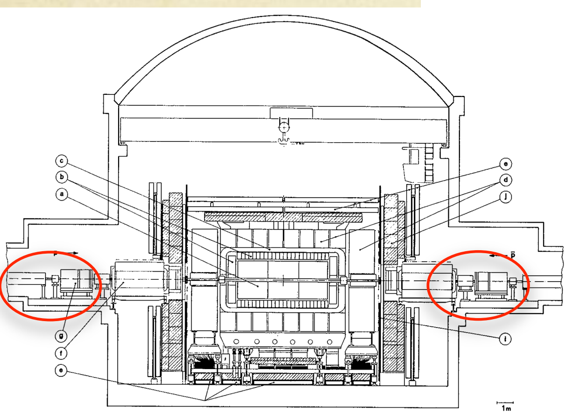
The Central Detector ready for cleaning in April 1982!!!

The Roma Group

After the proposal, Giorgio Salvini considered how to involve a roman group in the experiment.
He suggested to extend the hermeticity of the experiment down to 1° from the beams.
He prepared many drawings and made calculations while I was running Monte Carlo.
So in mid 1978 a group of roman physicists joined the experiment to prepare
the detectors for the very forward regions.



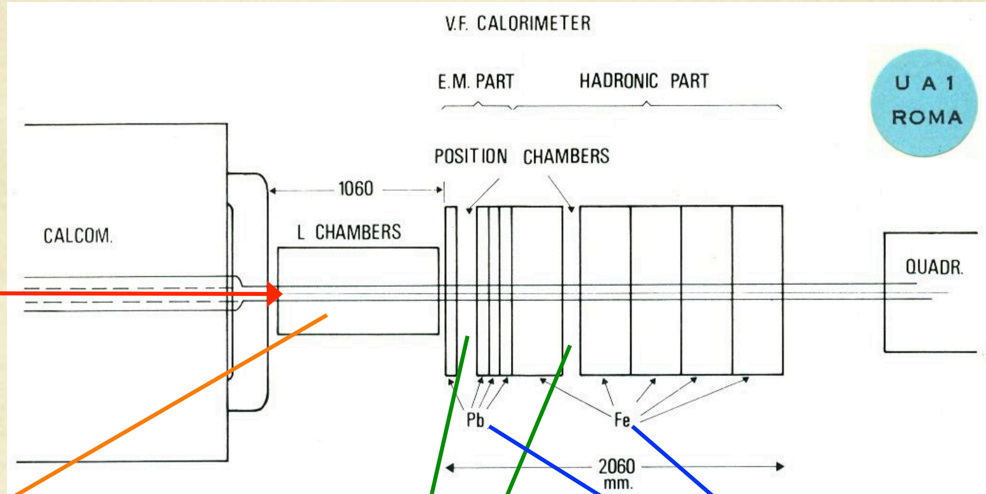


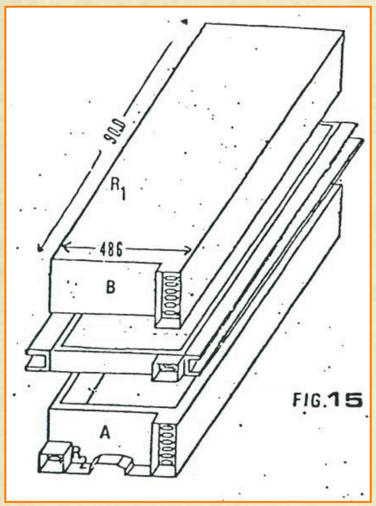


The Very Forward Detectors (4 <|y|< 7)

C. Bacci, R. Bernabei, V. Bidoli, F. Ceradini, F. Cesaroni, S. D'Angelo, F. Lacava, M. Moricca, L. Paoluzi, E. Petrolo, G. Salvini

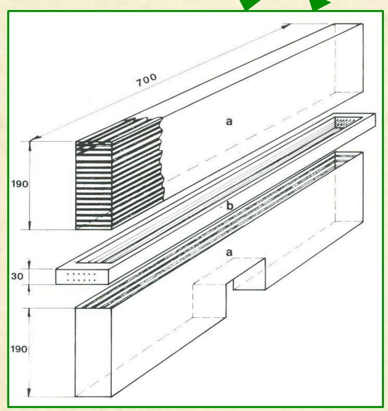
I.P. 14 m





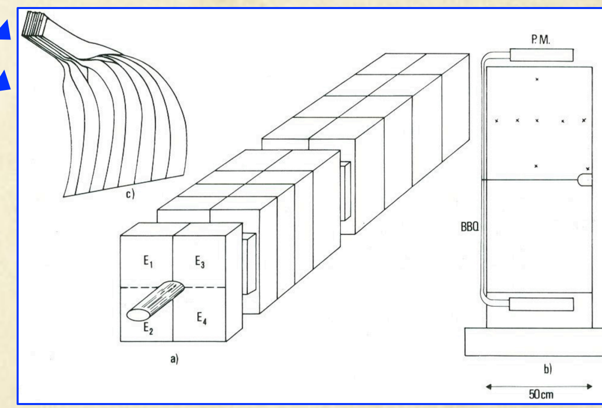
L. Paoluzi , V. Bidoli et al. Nota INFN Roma n. 784 1981

Large cell drift chamber with image readout to track particles with about 100 sense wires



F. Ceradini et al.: Physica Scripta 23, 662-667, 1981

Large cell drift chambers with image readout to localize high energy showers in very forward e.m. and hadronic calorimeters



C. Bacci et al.: NIM 200 (1982) 195-198

An e.m. calorimeter 25 X_0 divided in 4 samplings + a hadronic calor. 6 λ_I in 5 samplings. Divided in 4 sections in ϕ, with wave shifter bar readout.

Other Italians joined the experiment:

- A. Di Ciaccio in January 1983 (thesis in 1979)
- The Padova Group in Summer 1983: S. Centro (in 1981), A. Bettini, G. Busetto, M. De Giorgi, A. Meneguzzo, P. Rossi (in 1982), P. Zotto
  They prepared the limited streamer tube chambers to improve muon detection
- G. Ciapetti and L. Zanello in Fall 1983.
  They started their collaboration working to the upgrade of the scintillators of the "bouchon" (the e.m. calorimeters in the end caps)
- R. Bonino, F. Ghio (thesis) in 1984
- F. Cavanna, A. Nisati, C. Zaccardelli (thesis) in 1985
  They started working in the analysis
- M. Passasseo, L. Pontecorvo and S. Veneziano in 1987
  They started working at the upgrade of the barrel calorimeter (U-TMP)

✓ R. Bernabei and S. D'Angelo left the Collaboration in 1982

The Collider performances

Antiproton stack accumulated: 10^{11} /day, beams lifetime in SPS : several hours.

On July 7, 1981 the first antiproton beam was injected and accelerated in the SPS at 270 GeV and on July 10 the first collisions were registered in the UA1 experiment.

After exactly 3 year from the project approval: pits, accelerators and detectors had been completed.

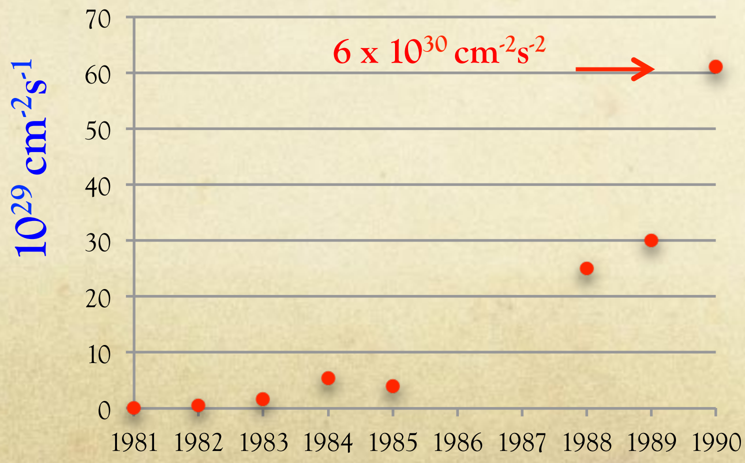
In October 1981 the tracks of charged particles from the collisions at 540 GeV c.m energy were recorded in UA1 and UA5 experiments. first events of minimum bias

In 1982 the luminosity was 10^{29} $cm^{-2}s^{-1}$ and integrated 28 nb^{-1} W discovery

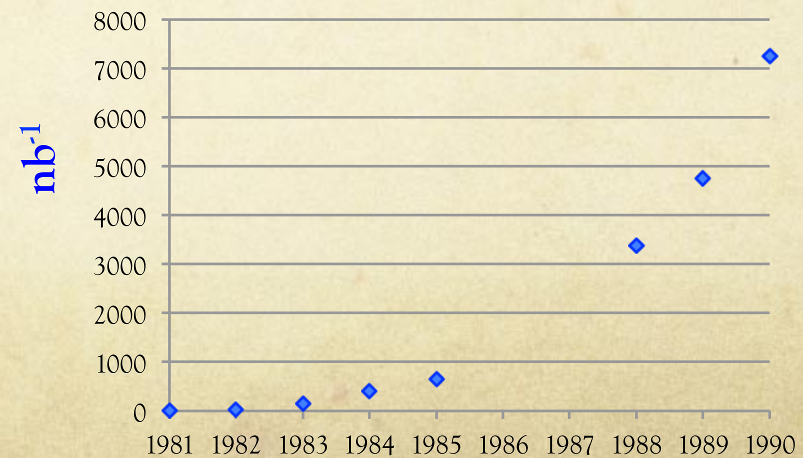
In 1983 1.7 x 10^{29} $cm^{-2}s^{-1}$ and 153 nb^{-1} Z° discovery

From 1988 with Antiproton Collector added to AA luminosity up to 6 x 10^{30} $cm^{-2}s^{-1}$

Initial luminosity



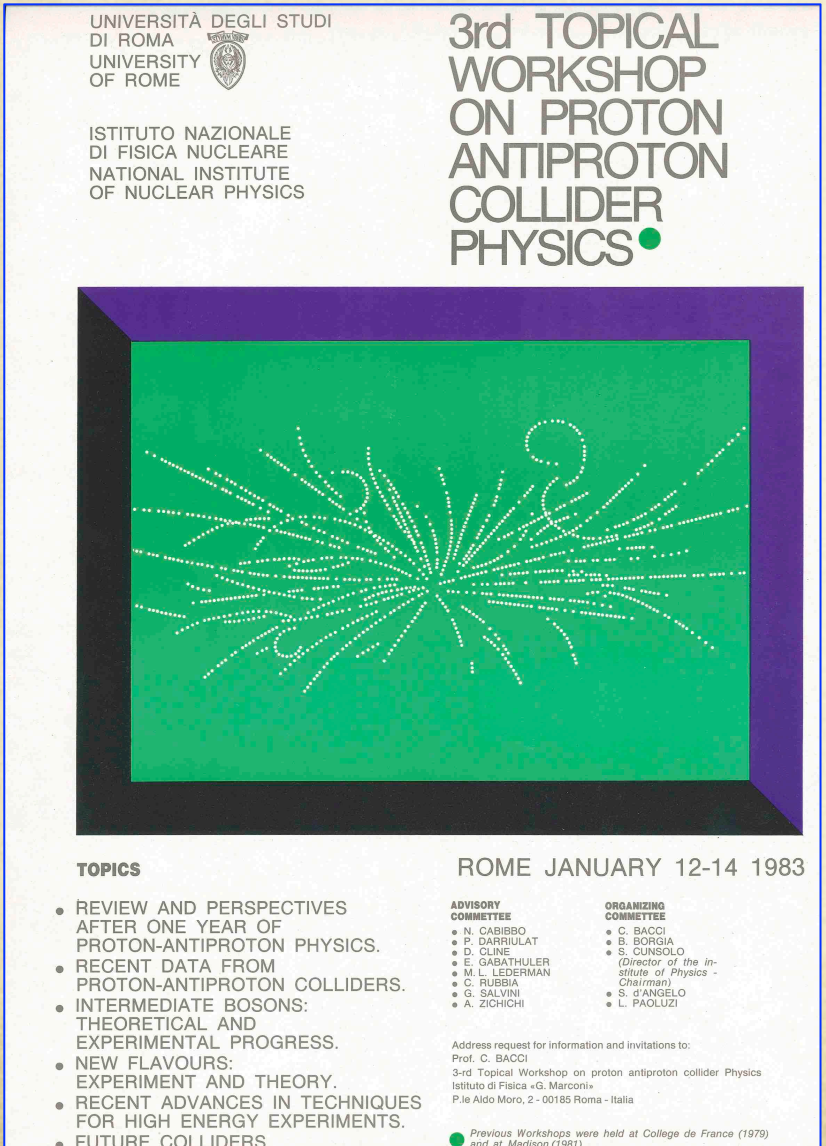
Integrated luminosity /year



1981 The first data taking in October-November, $L_{int} \approx 1\,\mu b^{-1}$ ($L_{max} \approx 2 \times 10^{25}$ cm^{-2} s^{-1})

first paper: "Some observations on the first events seen at the CERN proton-antiproton collider"

1982 30 days in October-December, $L_{int} \approx 18$ nb^{-1} ($L_{max} \approx 5 \times 10^{28}$ cm^{-2} s^{-1}) = 10^9 collisions



Although running and computing seemed to be going well, there were no sign of W in October.
Early November a high energy electron-like event with missing energy appeared on MEGATEK display. This was a very exciting moment, but some energy was discovered after in the hadronic calorimeter behind.

Two days later a second true electromagnetic W candidate was found with its 40 GeV transverse momentum track.

At the end of the years 6 W –> eν candidates had been found by UA1 and were studied in the following weeks.

A workshop on proton-antiproton physics was held at the Roma University in January 12-14, 1983.

Rubbia presented the analysis of the 6 W –> eν candidates,
Pierre Darriulat for UA2 presented 4 W –> eν candidates.

Rubbia's conclusion was "se sono rose, fioriranno".

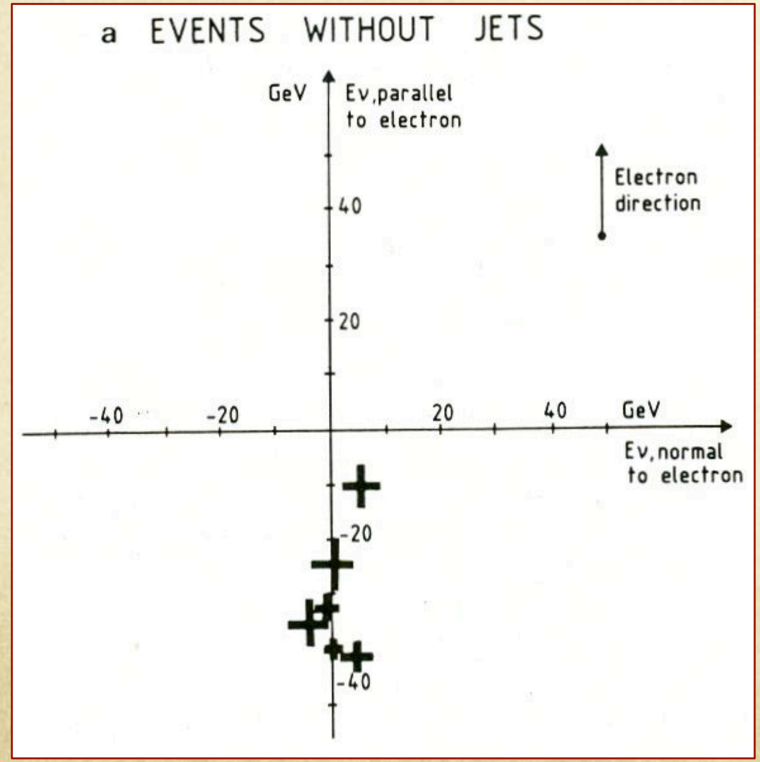
More work was needed to the two experiments to check for all possible backgrounds.

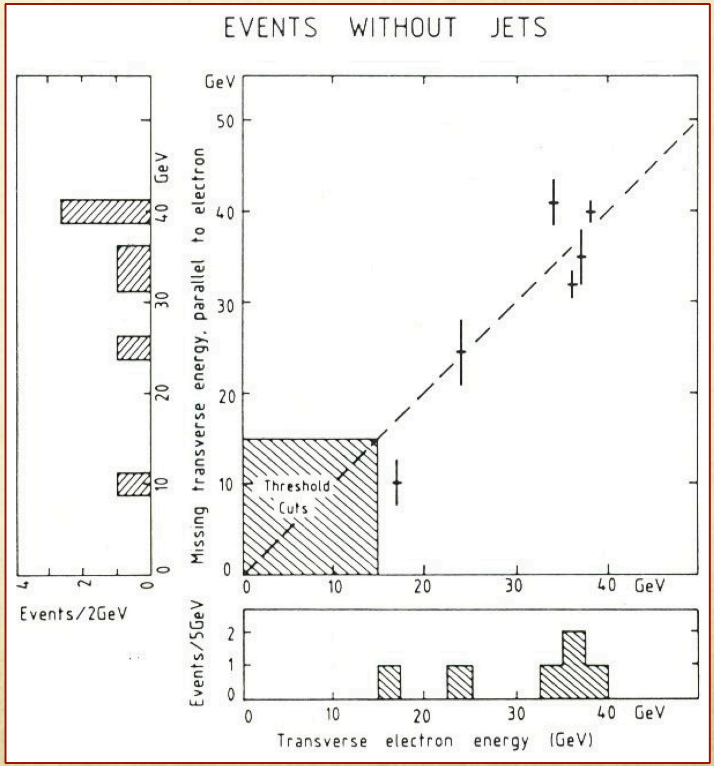
W discovery

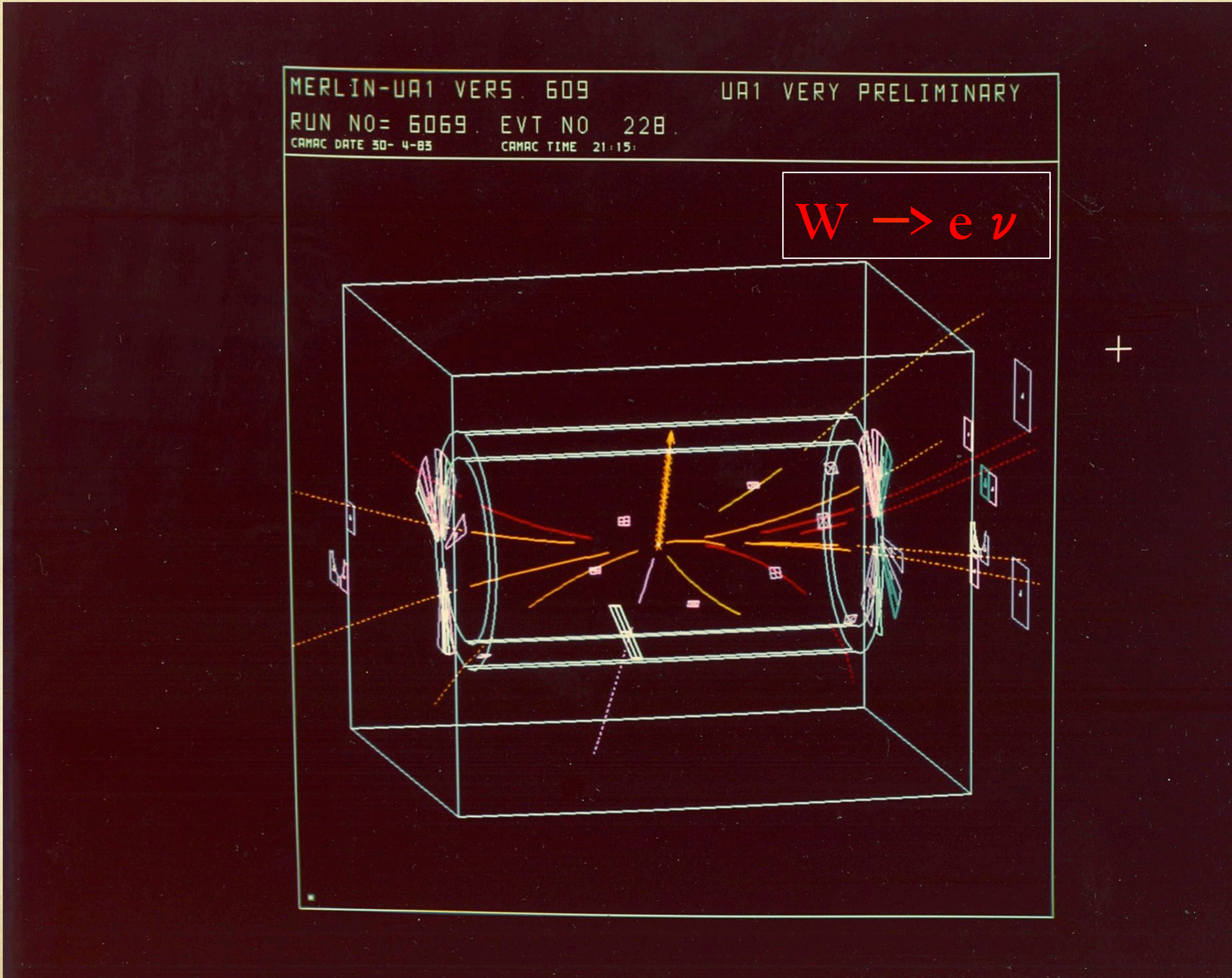
After more checks, on the 20 of January Rubbia presented the UA1 analysis at CERN Auditorium and the day after Luigi Di Lella the UA2 results.

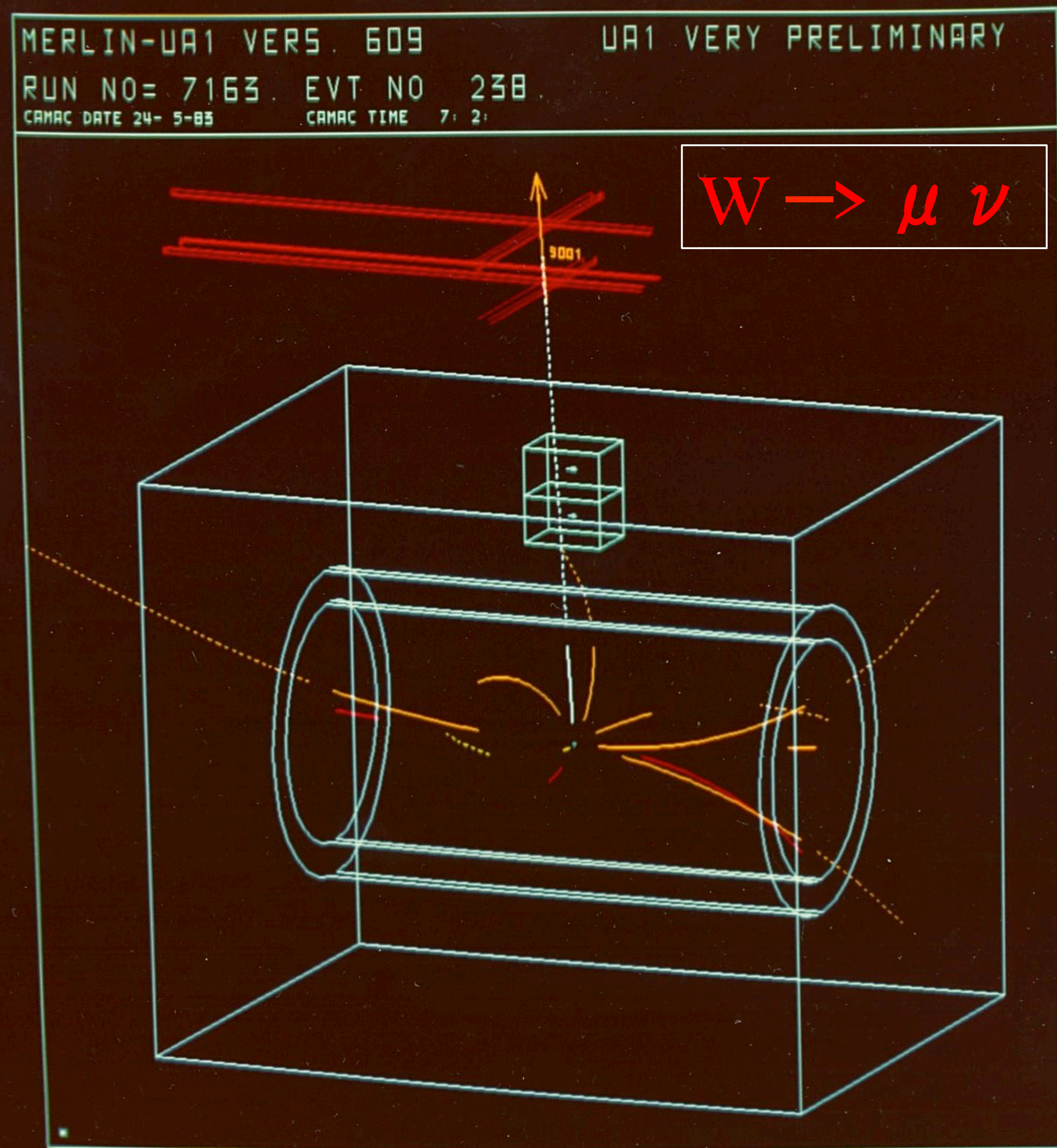
A press conference was called on the 25 of January: UA1 announced the observation of 5 events with the signature expected for W decaying in electron-neutrino. UA2 had observed 4 events consistent with the W decay but they needed more work to confirm the result.

In the meanwhile a paper was prepared:
"Experimental Observation of Isolated Large Transverse Energy Electrons with Associated Missing Energy at $\sqrt{s}$= 540 GeV", G. Arnison et al., Physics Letters 122B (1983) 103-116






MERLIN-UA1 VERS. 609
UA1 VERY PRELIMINARY
RUN NO= 6069. EVT NO 228.
CAMAC DATE 30- 4-83
CAMAC TIME 21:15:
W → e ν


MERLIN-UA1 VERS. 609
UA1 VERY PRELIMINARY
RUN NO= 7163. EVT NO 238.
CAMAC DATE 24- 5-83
CAMAC TIME 7: 2:
9001
W —> μ ν

Z° discovery

1983 data taking started on April 12th and ended on July 3rd for a luminosity L= 136 nb^{-1}.

- In first days of May a Z° candidate was observed but … Z° –> e+e– γ with a high energy photon superimposed to the electron.

  (announced by H. Shopper in Science for Peace meeting held in San Remo on May 5th)
- Few days later an event ppbar –> Z° jet + X with Z° –> $\mu^+ \mu^-$
- These two events were just presented by Rubbia in the Auditorium on June 26th.
- Just a few days after the presentation, two golden Z° –> e+e– were recorded on the same tape within 15 minutes and while studying these events one more Z° was found.

On June 1st CERN announced the Z° discovery, "its second major discovery in the space of four months" and soon UA1 prepared the paper:

"Experimental Observation of Lepton Pairs of Invariant Mass around 95 GeV/c^2 at the CERN SPS Collider", G.Arnison et al., Physics Letters 126B (1983) 398 – 410.

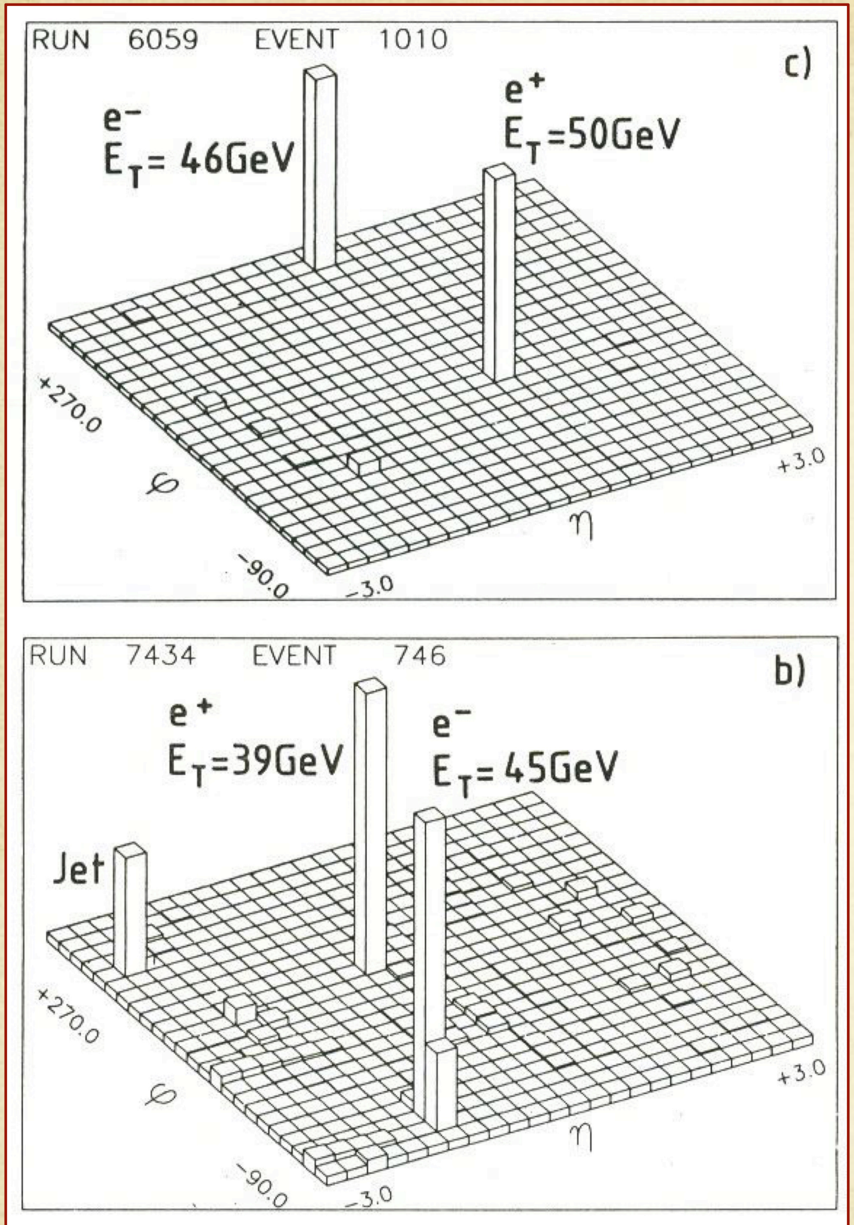
- UA2 had observed 4 events but decided to wait the end of the run before publishing.

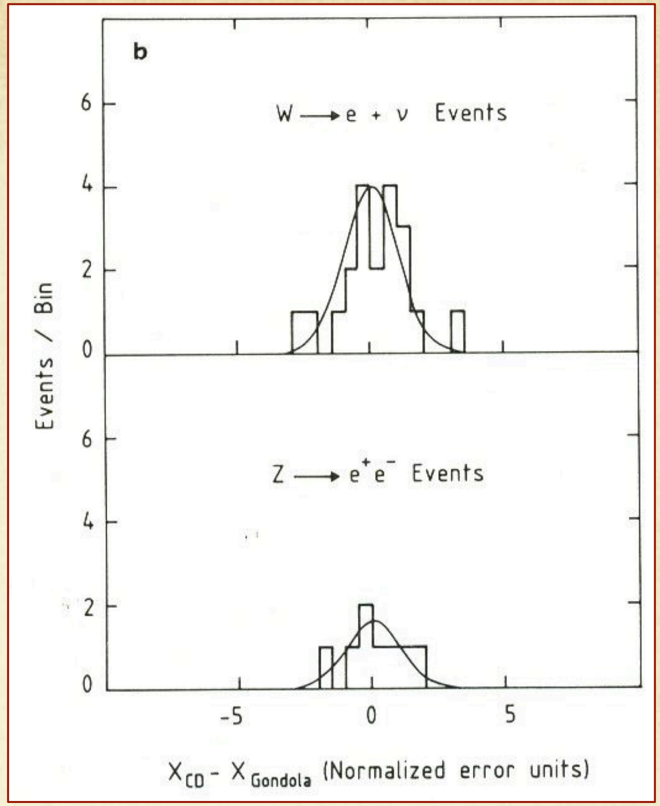
The New York Times

OPINION **Europe 3, U.S. Not Even Z-Zero**

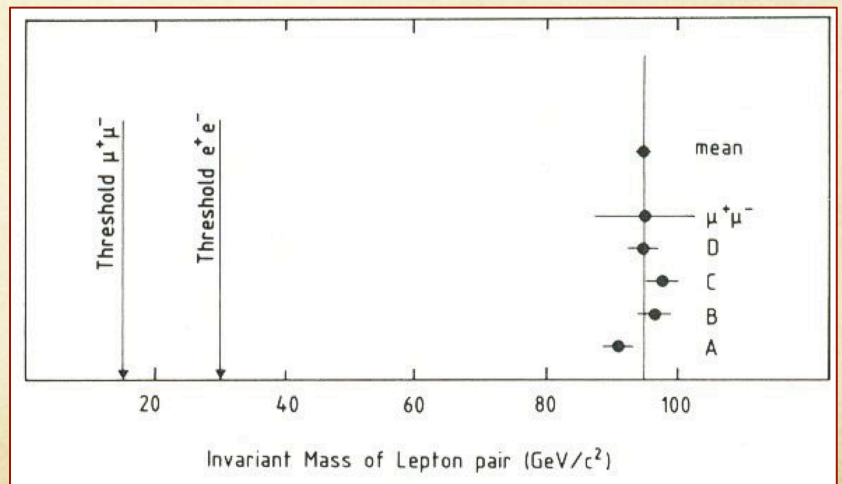
Published: June 6, 1983

A team of 126 scientists at the CERN accelerator in Geneva reports proof of an important new subatomic particle, the Z-zero. The discovery carries two messages. The good news is that it confirms a major theory about the fundamental forces of nature. The bad news is that Europeans have taken the lead in the race to discover the ultimate building blocks of matter.



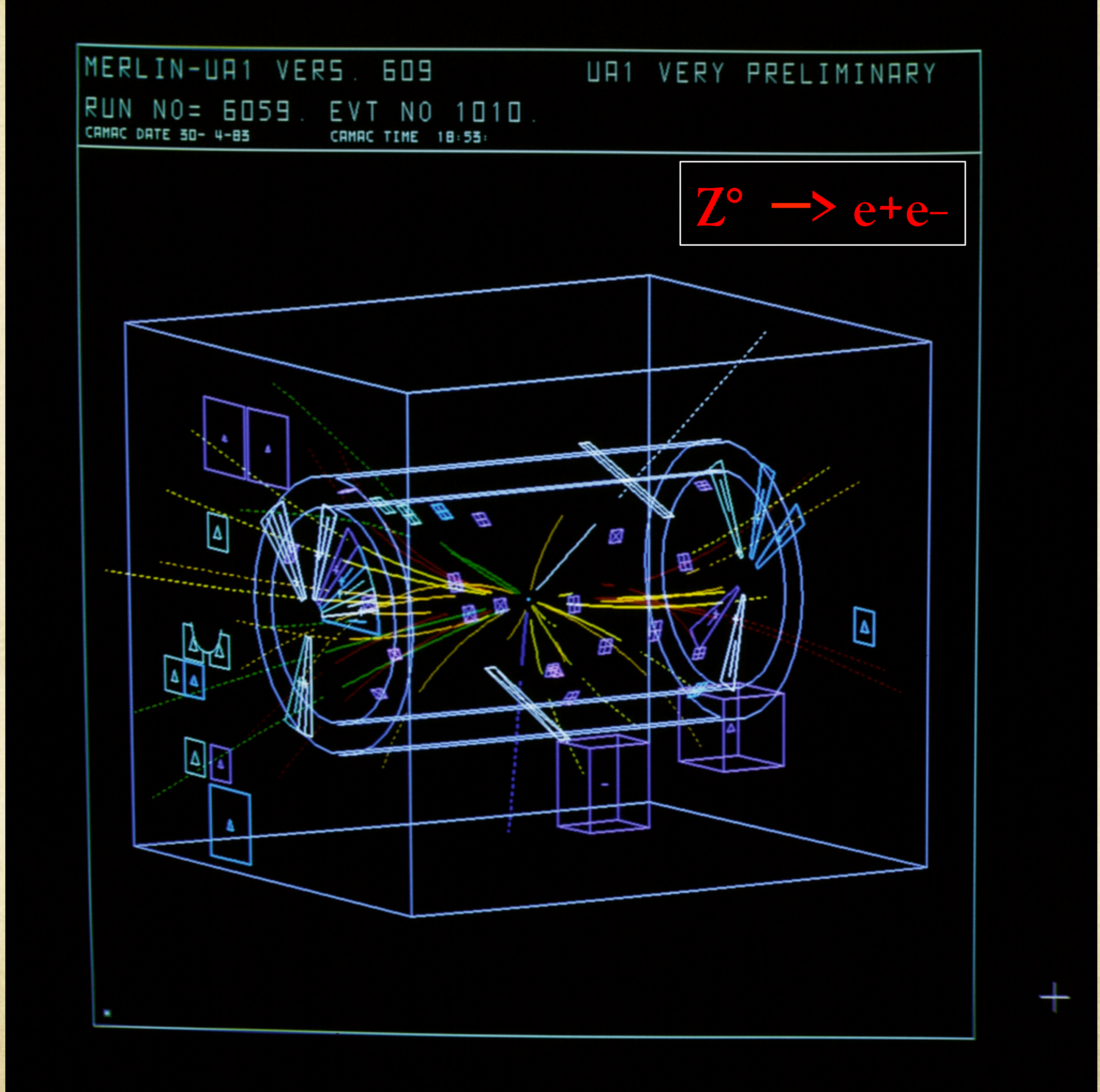


Deviation between track in CD and e.m. cluster in Gondolas for electrons from W and Z° decays.



LEGO plots for two Z° events.
Energy at angle > 5° from the beams.

Measured mass of the 5 Z° events.
Average: 95.2±2.5 GeV/c^2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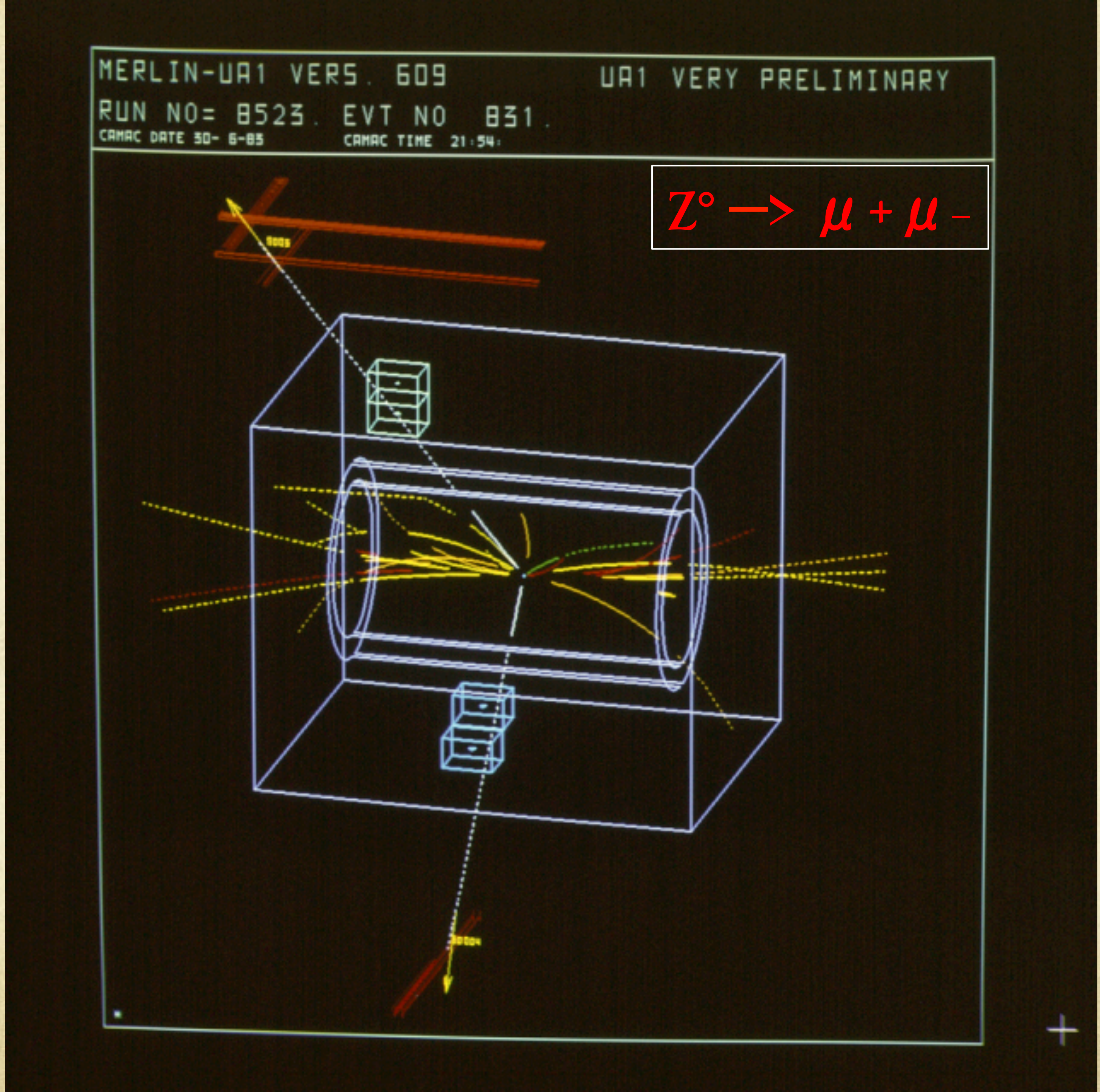
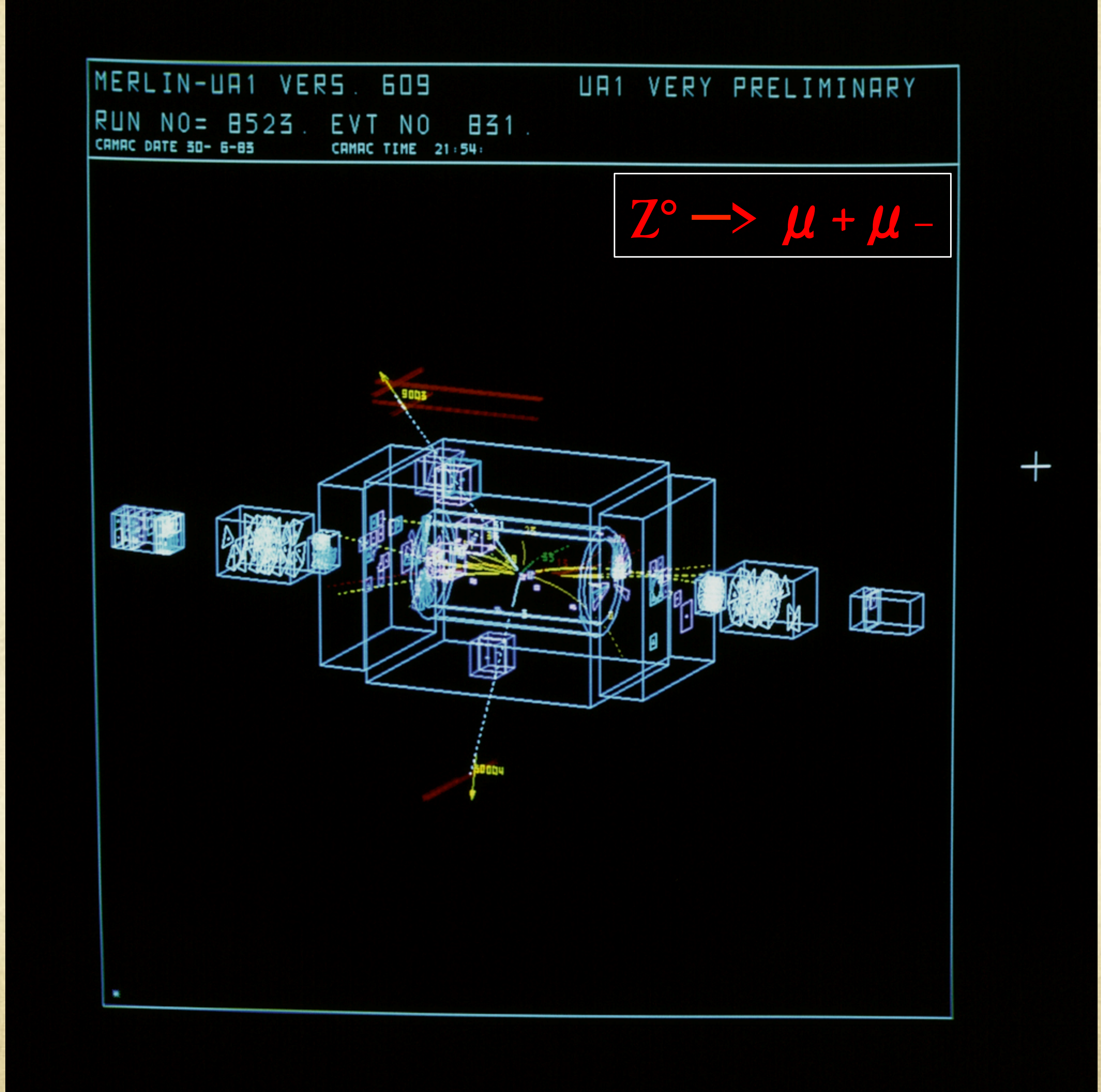
UA1 VERY PRELIMINARY
RUN NO= 6059. EVT NO 1010.
CAMAC DATE 30- 4-83
CAMAC TIME 18:53:
Z° → e+e−

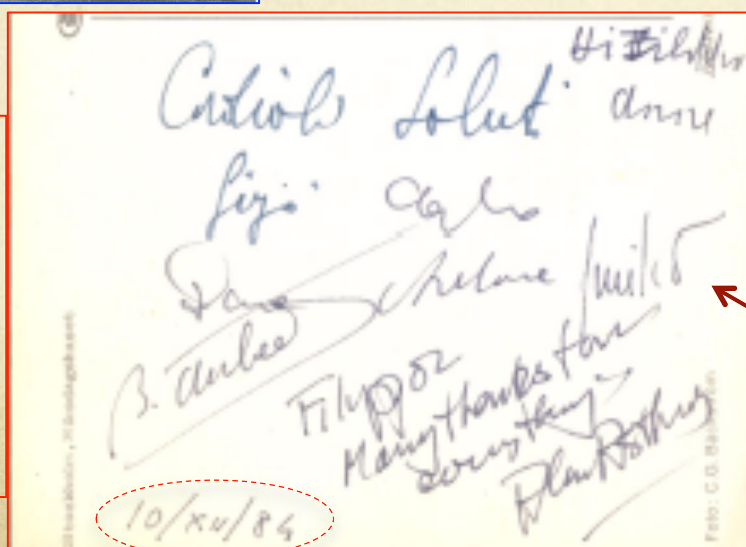

MERLIN-UA1 VERS. 609
UA1 VERY PRELIMINARY
RUN NO= 8523. EVT NO 831.
CAMAC DATE 30- 6-83
CAMAC TIME 21:54
Z° —> μ + μ –


MERLIN-UA1 VERS. 609
UA1 VERY PRELIMINARY
RUN NO= 8523. EVT NO 831.
CAMAC DATE 30- 6-83
CAMAC TIME 21:54:
Z° —> μ + μ −

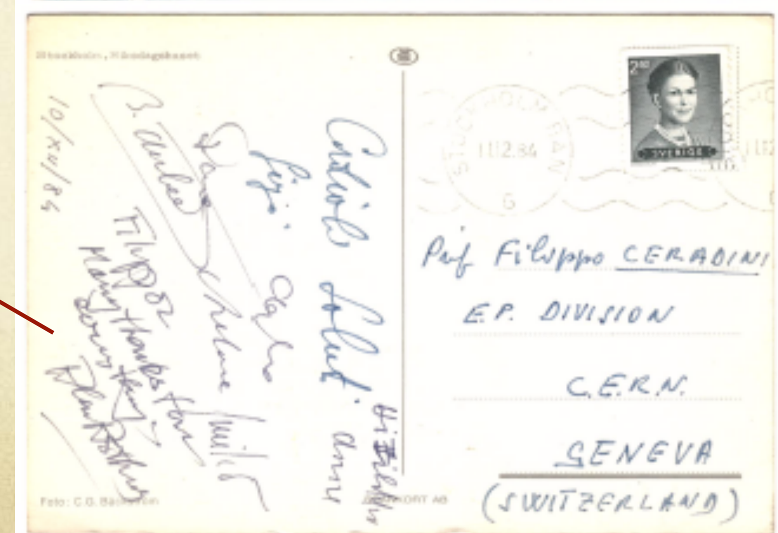
The Nobel Prize in Physics 1984 was awarded jointly to Carlo Rubbia and Simon van der Meer *"for their decisive contributions to the large project, which led to the discovery of the field particles W and Z, communicators of weak interaction"*

A group of fellows from UA1 and UA2 went to Stockholm with Rubbia and van der Meer for the ceremony on December 10th. The same day a postcard was sent from Stockholm to Filippo!

First row: G. Salvini, E. Picasso, A.Leveque.
Second row: A. Astbury, L. DiLella, C. Rubbia, S. van der Meer, P. Darriulat, A. Kernan, D. Cline, B. Aubert.

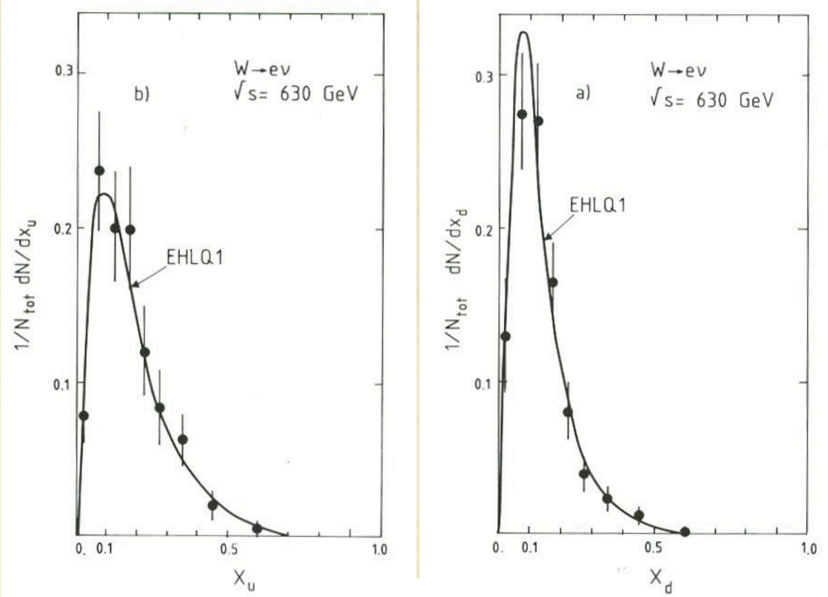


Anne (Kernan)
Giorgio (Salvini)
Carlo (Rubbia)
Dave (Cline)
Antoine (Leveque)
Emilio (Picasso)
B.(Bernard) Aubert
Alan Astbury

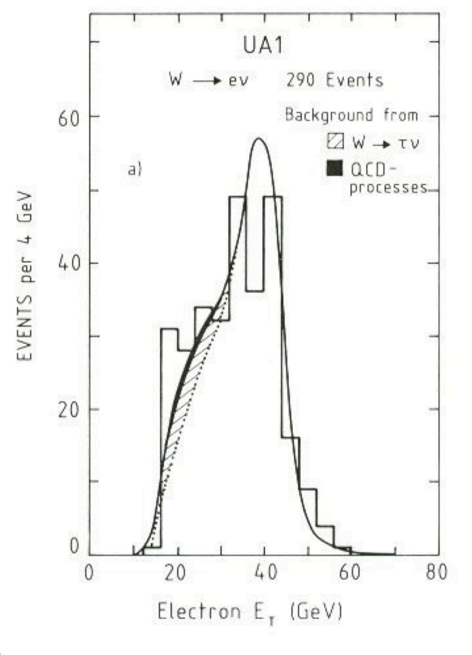


W and Z° Highlights at UA1

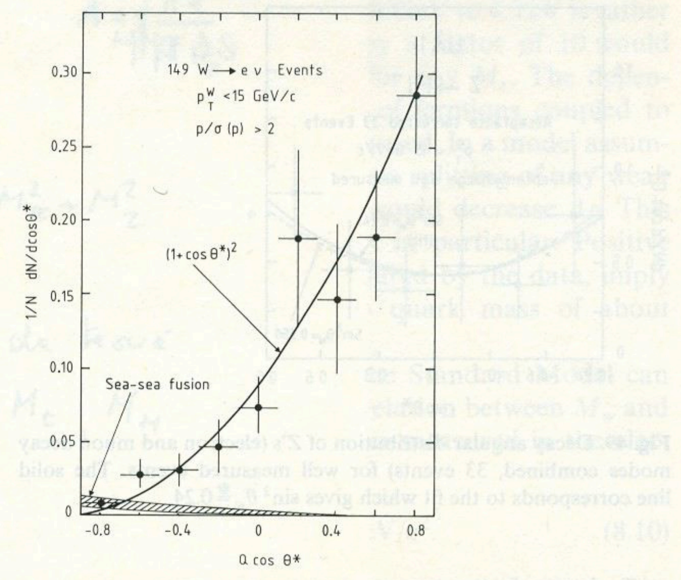
- production and decay properties of W and Z°
- $e-\mu-\tau$ universality
- M_W = 82.7±1.0±2,7 GeV
  today: M_W = 80.370±0.019 GeV
- M_Z = 93,1±1.0±3.0 GeV
  today: M_Z = 91.1876±0.0021 GeV
- $\sigma \cdot B_{We\nu}$ = 0.50/0.58 nb at 546/630 GeV
- $\sigma \cdot B_{Zee}$ = 0.039/0.068 nb at 546/630 GeV



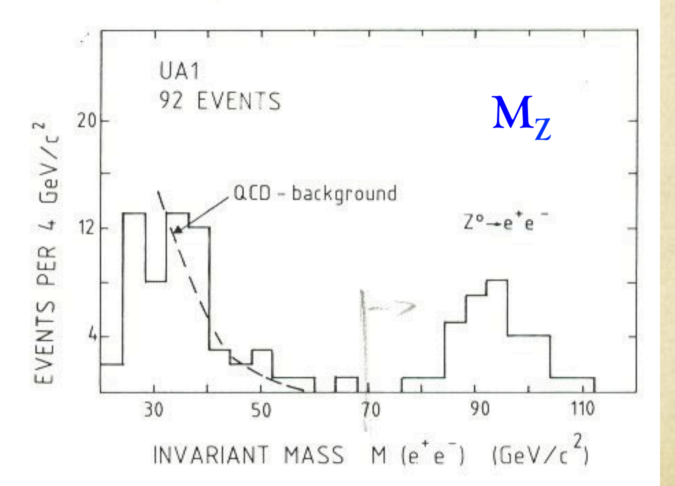
u-quark and d-quark structure functions sampled by W production



Jacobian peak for $W \rightarrow e\nu$



Decay angular distribution for W in c.m. consistent with spin=1 and V–A



The pulsed SPS Collider in 1985

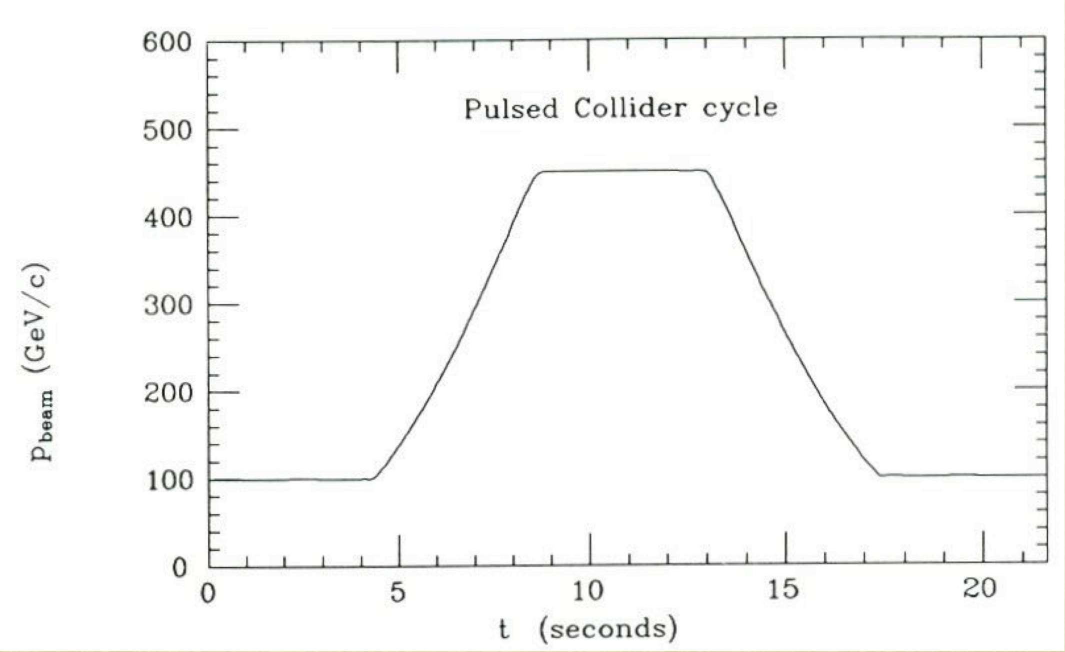
In the SPS Collider, the maximum energy of the coasting beam was limited at 315 GeV/c by the average power dissipation in the main ring magnets.

In March 1985 the Collider was operated in pulsed mode between beam momenta of 100 GeV/c and 450 GeV/c with an average dissipation equal to that as a collider at 315 GeV/c

The cycle was of 21.6 s, with a flat top of 4.0 s, a flat bottom of 8.2 and two energy ramps of 4.7 s each.

The beam lifetime was of a few hours, the average luminosity 10^{26} $cm^{-2}s^{-1}$ and the integrated luminosity 5.1 μb^{-1}.

UA1 and UA5 running.



The cycle of the SPS Collider operated in pulsed mode

The data analysis of the pulsed Collider run.

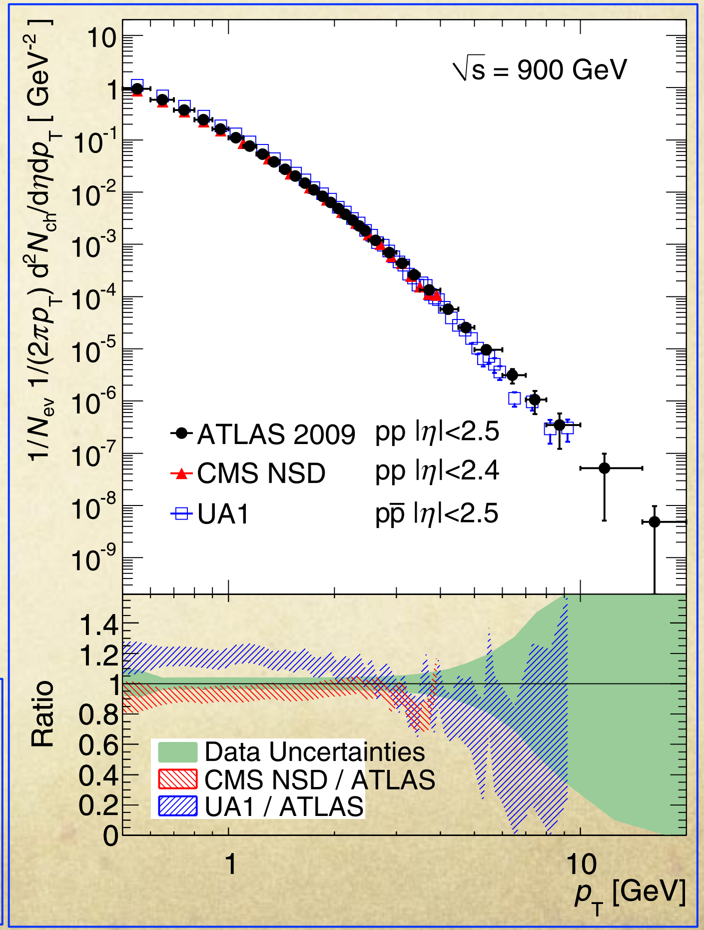
The analysis of the data was done by the Roma group (C. Bacci, F. Ceradini, G. Ciapetti, A. Di Ciaccio, F. Lacava, G. Piano Mortari, A. Nisati, G. Salvini, C. Zaccardelli, L. Zanello with the invaluable contribution by V. Cecconi).

The analysis was based on 188.000 events collected in the pulsed run, 18% at flat bottom $\sqrt{s}$=0.2 TeV, 34% at flat top $\sqrt{s}$=0.9 TeV, while 48% taken during the energy ramps were subdivided into five c.m. energy intervals centered at $\sqrt{s}$= 0.26, 0.38, 0.50, 0.62 and 0.79 TeV.

Samples of 41.000 minimum bias events at $\sqrt{s}$=546 GeV and of 66.000 minimum bias events at $\sqrt{s}$= 630 GeV from 1983 and 1984 Collider run were also used.

The results of these analysis are reported in two papers we named "Paper A" and "Paper B"

Both papers are between the most cited UA1 papers because the data at $\sqrt{s}$ = 0.9 TeV were a reference for many M.C. studies modeling the underlying events at LHC. Moreover the first ATLAS and CMS physics papers were on minimum bias events at $\sqrt{s}$=0.9 TeV collected in December 2009.



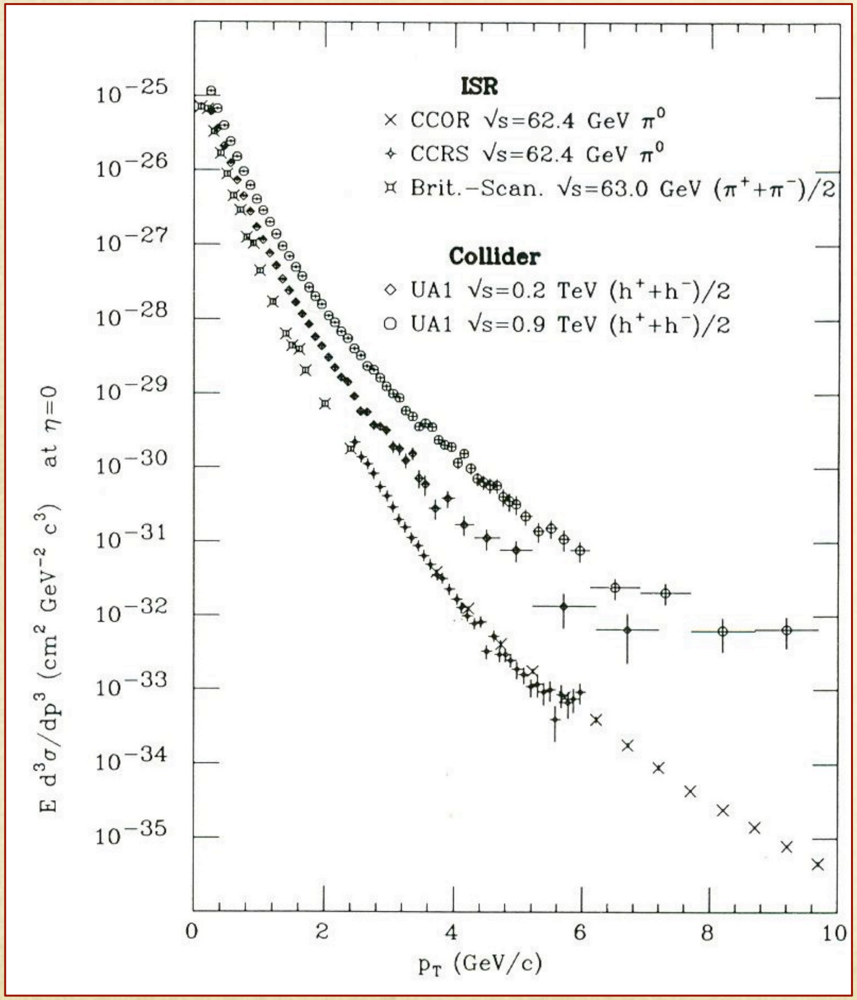
ATLAS, Physics Letters B 688 (2010) 21-42
The measured p_T spectrum of charged particle multiplicities. The ATLAS pp data (black dots) are compared to the UA1 p-anti p data (blue open squares) and CMS NSD pp data (red triangles) at the same centre-of-mass energy.

"A study of the general characteristics of proton-antiproton collisions at $\sqrt{s}$=0.2 to 0.9 TeV"

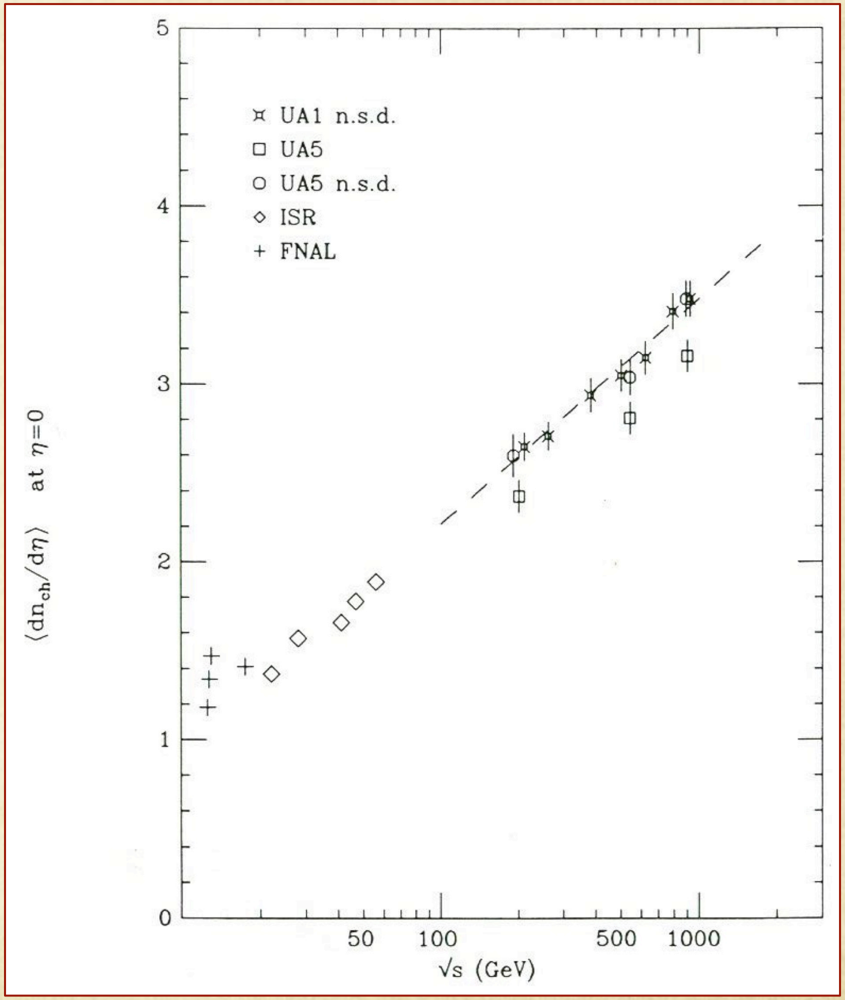
Paper A

Nuclear Physics B335 (1990) 261-287

p_T distribution, multiplicity and density of charged particle, KNO scaling, transverse energy



Inclusive cross section for single charged hadron as a function of the transverse momentum



Average charged particle density measured at η =0 as a function of the c.m. energy

Paper B

"Production of low transverse energy clusters in p - anti p collisions at √s=0.2 to 0.9 TeV and their interpretation in terms of QCD jets"

Nuclear Physics B335 (1988) 405-425.

Clusters of low transverse energy (> a few GeV) observed in minimum bias events exhibit properties in agreement with perturbative QCD expectations for parton scattering supporting their interpretation in term of jet production.

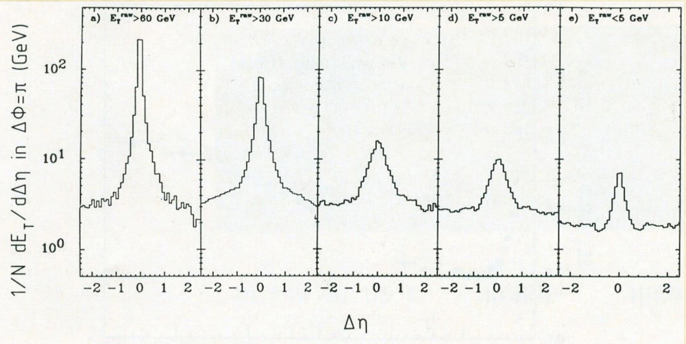


Fig. 1. Transverse energy density around the cluster axis, with $\Delta\phi = \pm\frac{1}{2}\pi$, for different E_T^{raw} thresholds from jet trigger ((a), (b)) and minimum bias ((c), (d), (e)) data.

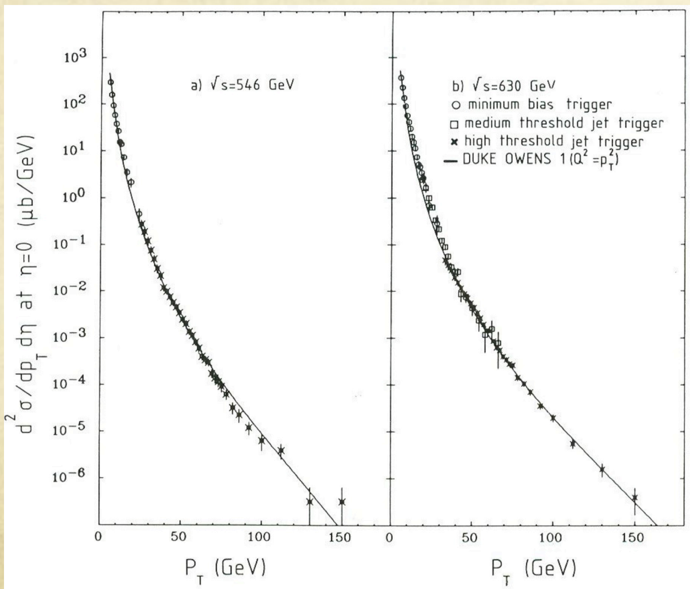


Fig. 8. Inclusive jet cross section at $\eta = 0$ as a function of the jet p_T for (a) $\sqrt{s} = 546$ GeV and (b) $\sqrt{s} = 630$ GeV. The line is a QCD calculation [24] scaled up by a factor of 1.5.

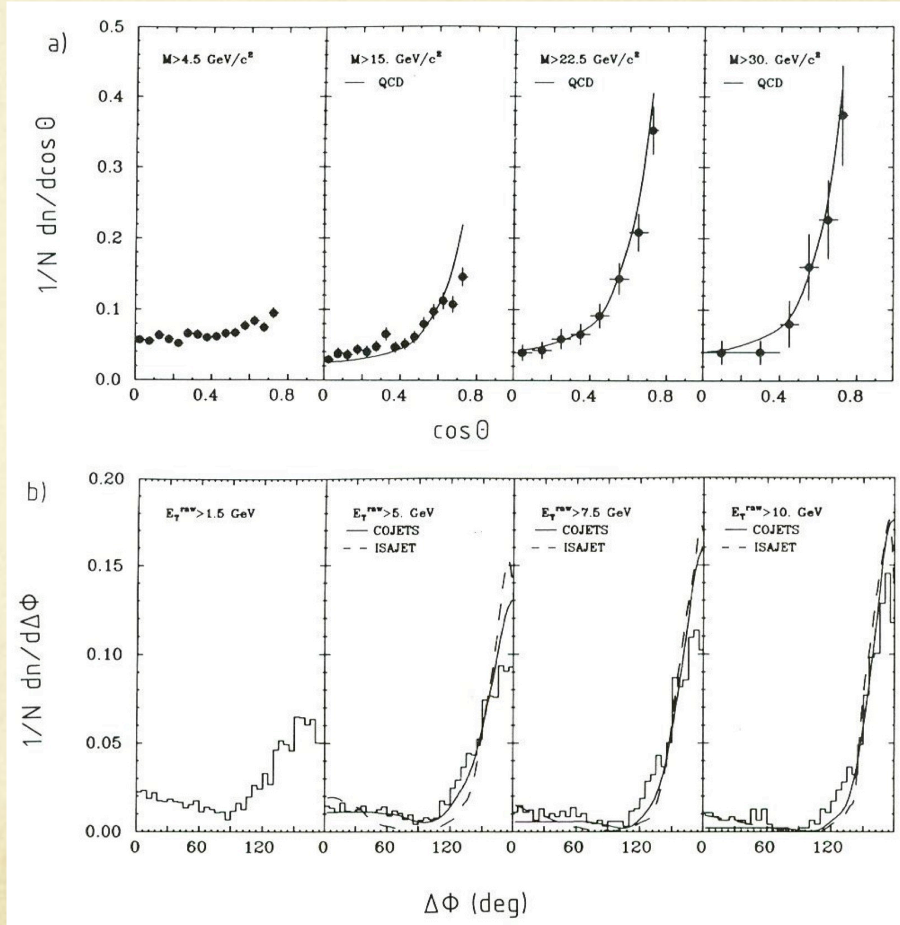


Fig. 4. Two-cluster angular distributions: (a) $(1/N)dn/d\cos\theta$ for different mass thresholds, $M \simeq (E_{T1} + E_{T2})/\sin\theta$; (b) $(1/N)dn/d\Delta\phi$ for different E_T^{raw} thresholds. Both clusters have E_T^{raw} larger than the indicated values.

UA1 Physics Highlights

- Study of high transverse energy jets: p_T and angular distributions, dijet mass, cross sections
- Study of heavy quark production, B°-B°bar mixing, Drell-Yan pair, J/ψ, Υ, Υ' production
- Studies of minimum bias events: particle distributions, Bose-Einstein correlations
- Measurements of elastic and total cross sections

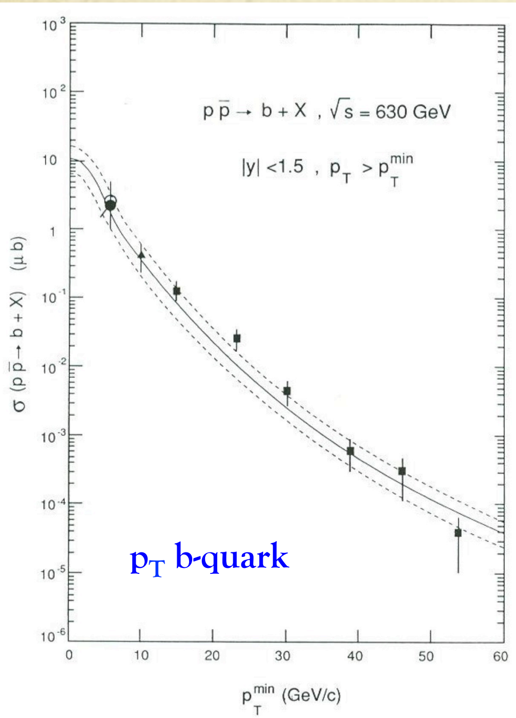


Fig. 4. The inclusive b-quark ($Q = -\frac{1}{3}$) cross-section for $|y| < 1.5$ versus the b-quark transverse-momentum threshold. The curve is the $O(\alpha_s^3)$ QCD prediction of Nason et al. [11]. The experimental points come from independent measurements discussed in this paper: $J/\psi \to \mu^+\mu^-$ (solid circle), high-mass dimuons (open circle), low-mass dimuons (triangle), muon-jets (squares).

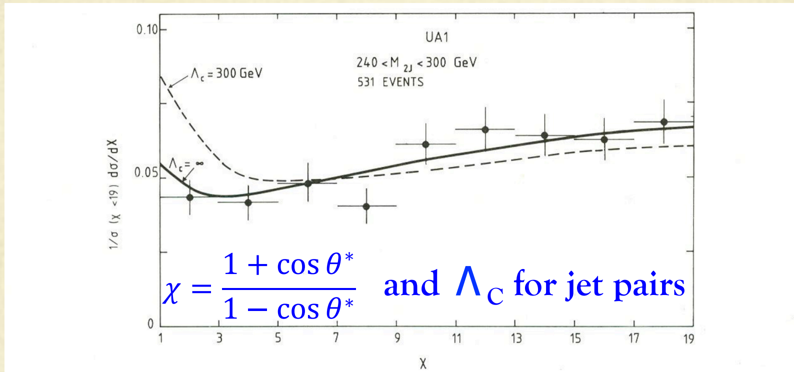


Fig. 5. The angular distribution $(1/\sigma)(d\sigma/d\chi)$ for the very high mass ($240 < m_{2J} < 300$ GeV) jet pairs shown as a function of χ, where $\chi = (1 + \cos\theta)/(1 - \cos\theta)$ and θ is the subprocess CM scattering angle. The solid curve represents the QCD prediction which corresponds to $\Lambda_c = \infty$, and is the best fit to the data. The dotted curve, which corresponds to $\Lambda_c = 300$ GeV, is clearly excluded by the data.

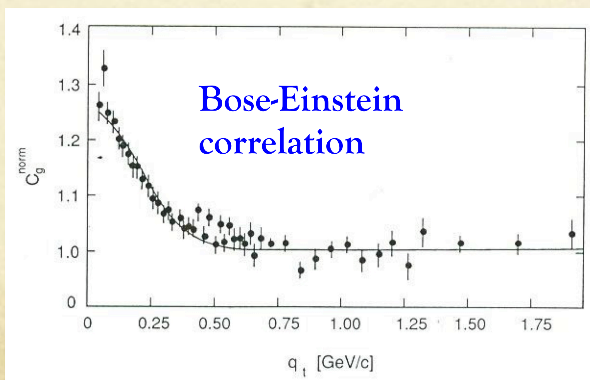


Fig. 1. C_g distribution versus q_t for a q_ℓ-interval of $0 \leq q_\ell < 0.2$ GeV with a gaussian fit. The distribution has been obtained at $\sqrt{s} = 630$ GeV for $10 < N_{ch} \leq 20$ which corresponds to $\langle \Delta n / \Delta\eta \rangle \simeq 2.9$.

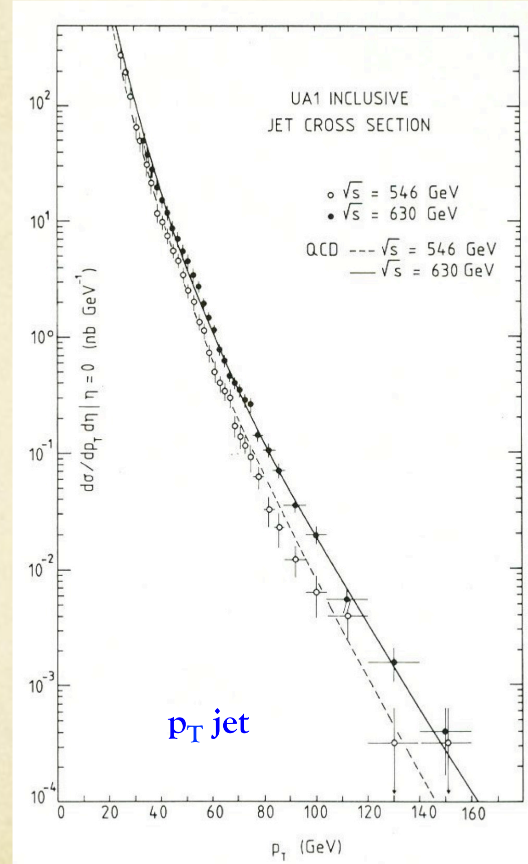


Fig. 1. The inclusive jet cross section for the pseudorapidity interval $|\eta| < 0.7$, as a function of the jet transverse momentum. The open dots correspond to the data at $\sqrt{s}$ = 546 GeV and the solid dots to those at $\sqrt{s}$ = 630 GeV. The systematic errors on both cross sections is ±70%. The curves are QCD calculations and are renormalized upward by 50%.

The Uranium - TMP Calorimeter project

Sampling calorimeters with liquid ionization chambers have several advantages: negligible statistical fluctuations, absolute and stable signals, segmentation, granularity, etc.
A drawback is that liquid argon calorimeters require cryogenic systems.
These are not required if "warm" nonpolar liquids (TMP, TMS, etc.) are used.

In view of the advantage from the new antiproton accumulator ACOL, in 1986 UA1 decided to built a Uranium-TMP compact enough to replace the lead-scintillator calorimeter.

Moreover the use of a liquid rich in hydrogen as TMP (C_9H_{20}) with uranium plates was expected to help in e/h compensation.

The Italian groups from Padova and Roma were strongly committed in preparing the detectors, the electronics, the readout and in the test of the first modules on the beams.

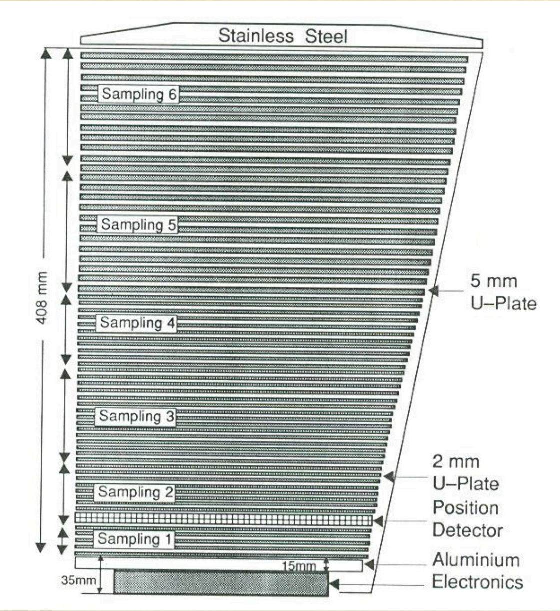
We tested and debugged the first full size prototype of the calorimeter and later we contributed to a very forward module .

Unfortunately severe difficulties were encountered in the production of clean and planar boxes filled with TMP and the project was cancelled.

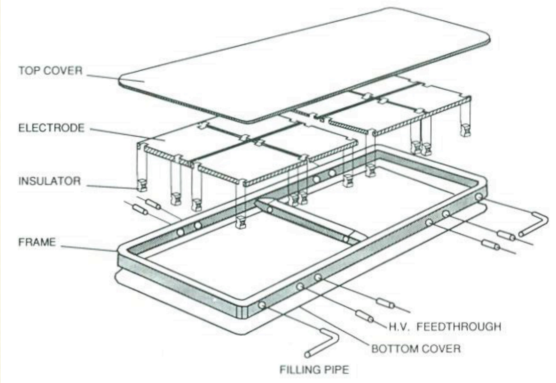
The technique was certainly valid but its realization required a different approach.
Today warm liquid calorimeters are used in some experiments (KASCADE experiment, …)

U-TMP Supergondola module + UA1 had. calorimeter

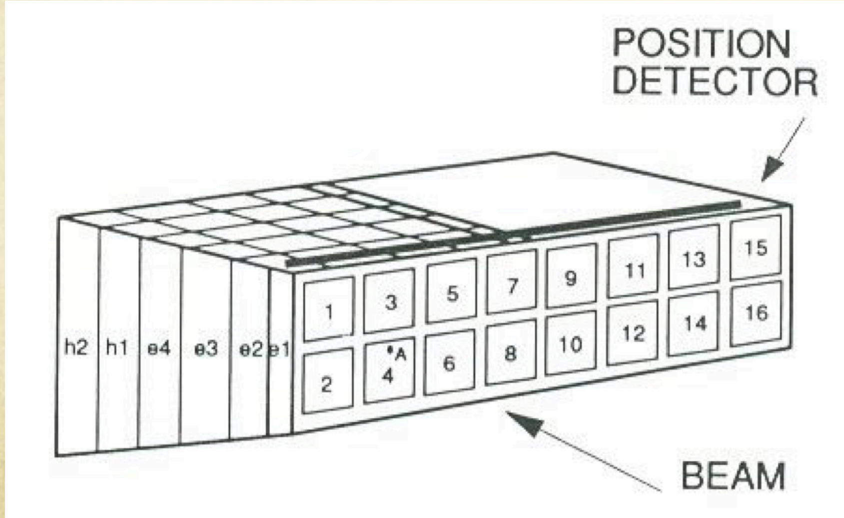
e.m. section: 39 x (2mm U + TMP box)
had. section: 10 x (5mm U + TMP box)
Total: 64.5 X0 2.35 λ_I + 2 C (75 cm Fe)

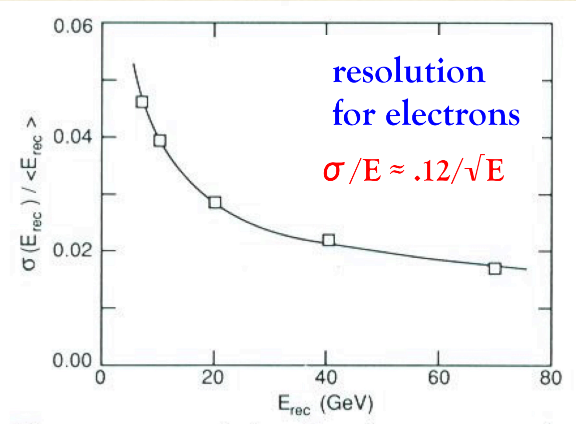


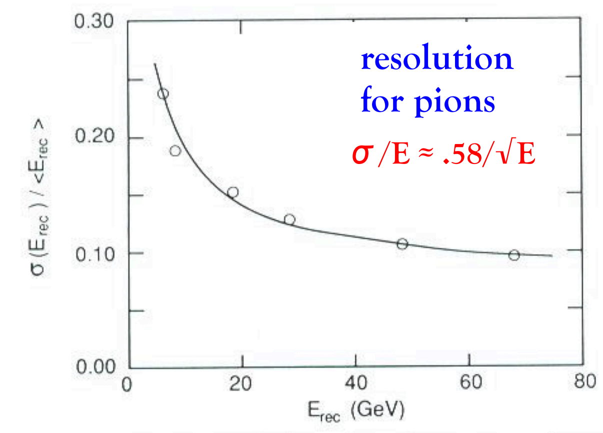
Cross section of a module

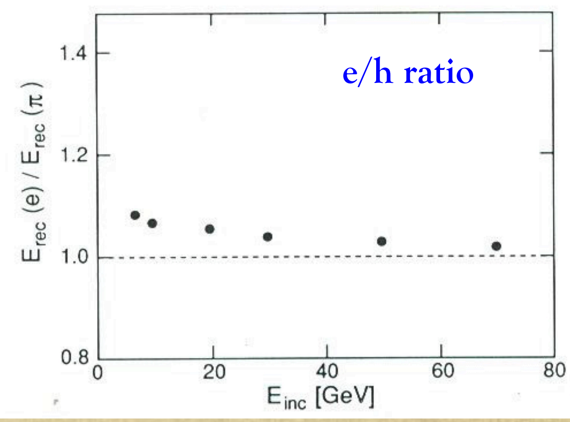


Exploded view of a ionization chamber to be filled with TMP



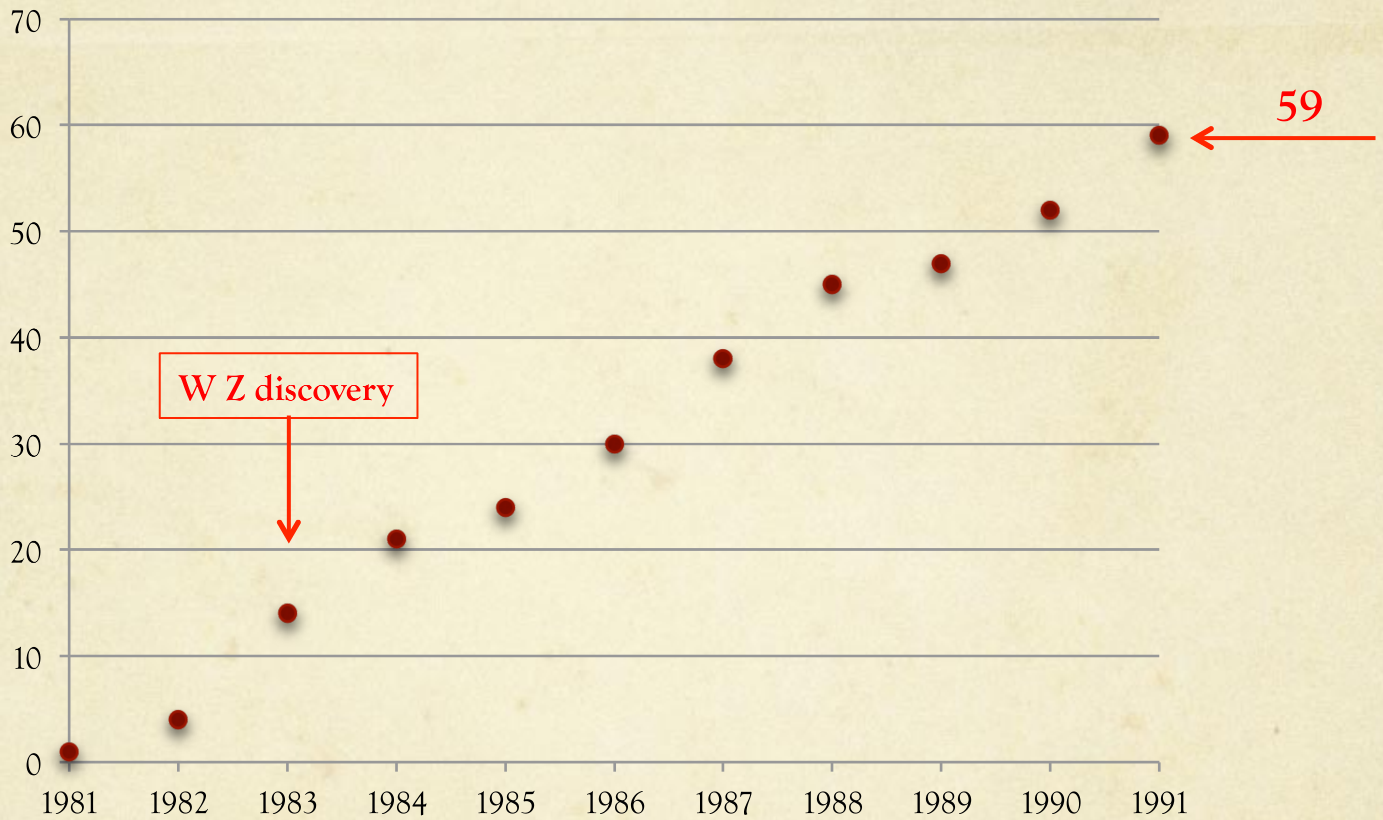




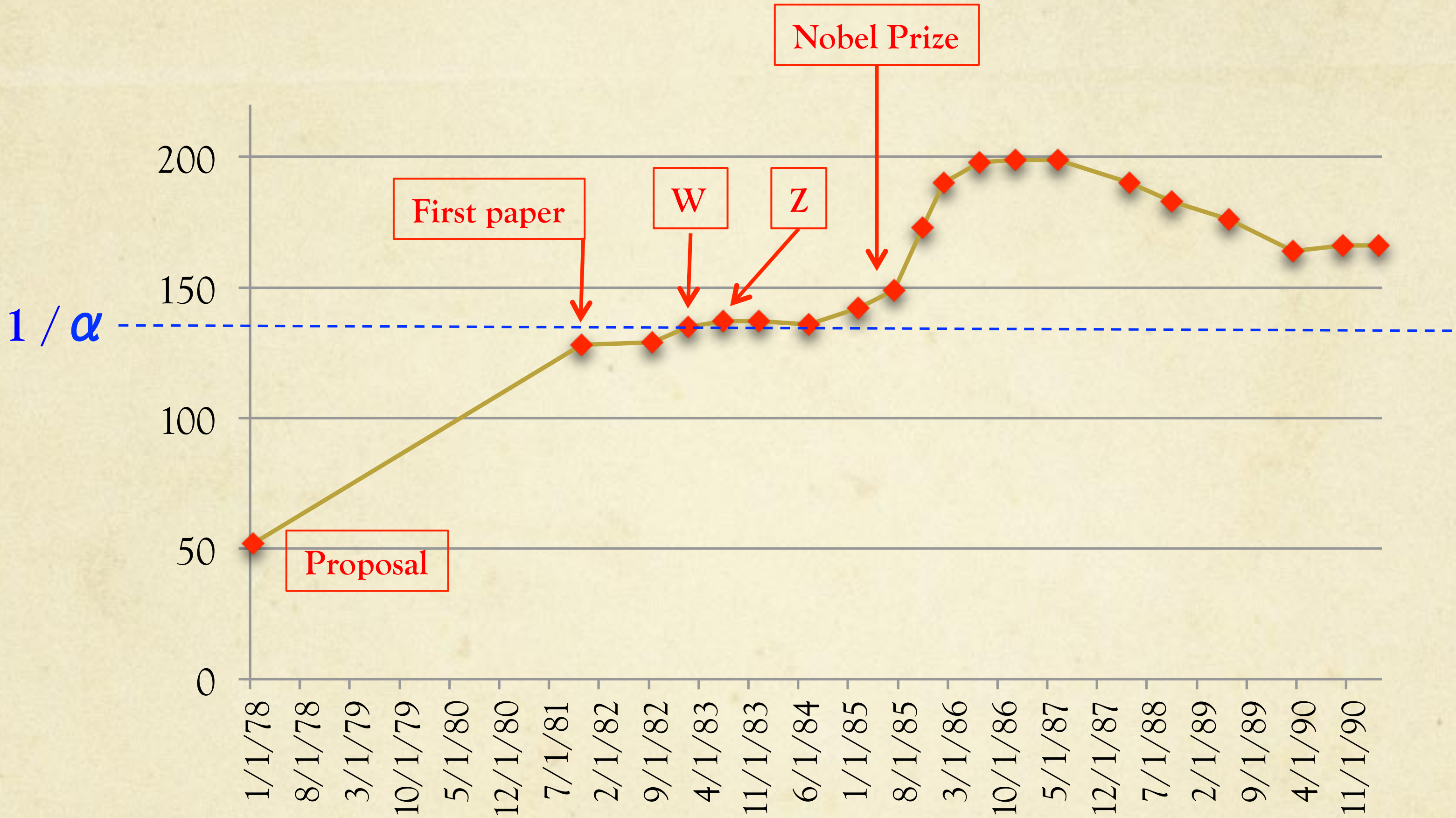


Schematic view of a module divided in 16 towers

UA1 Physics papers



UA1 Authors



Nobel Prize
First paper
W
Z
Proposal
1 / α
200
150
100
50
0
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8/1/78
3/1/79
10/1/79
5/1/80
12/1/80
7/1/81
2/1/82
9/1/82
4/1/83
11/1/83
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3/1/86
10/1/86
5/1/87
12/1/87
7/1/88
2/1/89
9/1/89
4/1/90
11/1/90

Conclusions

- The UA1 experiment was ready after three years from the approval.
  It was the hard and exciting adventure of a group of physicists, engineers and technicians led by Carlo Rubbia, an extraordinary scientist.
  They all were confident in the discovery of the intermediate vector bosons W and Z°.
- UA1 is a milestone in Particle Physics and is mentioned in all the books on the subject.
- The idea of the hermetic detector pioneered by UA1 was taken up in all LEP detectors and became a driving concept in the design of the LHC experiments.
- UA1 was the first large collaboration, the prototype of the present very large international scientific collaborations.
- Giorgio Salvini paved the way for the roman physicists to a new period of successful research at the frontier of High Energy Physics.
- Young students joined the roman group and today they are physicists with relevant responsabilities in present large experiments.
- Filippo has been the "rappresentante nazionale di UA1" in Italy and the leading person of the roman group.

→

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- ✓ C. Rubbia, Nobel Lecture 1984
- ✓ C. Rubbia talk at "Incontro per i 90 anni di Giorgio Salvini", 7 Maggio 2010.
- ✓ P. Watkins, "Story of the W and Z°", Cambridge University Press 1986
- ✓ Contributions by G. Brianti and P. Darriulat in the volume:
  "Prestigious Discoveries at CERN", Eds. R. Cashmore, L. Maiani, J.-P. Revol, Springer 2003 also in Eur. Phys. J. C 34 /1 (2004)