

Pisa and the Collider Detector at Fermilab: a History of the Establishment of Precision Physics With a Calorimetric Spectrometer at a Hadron Collider

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Sommario

This is a personal and admittedly US-centric attempt to summarize the foundational impact of the Pisa CDF Group on the conceptual design, construction, and early operation of the CDF Detector at Fermilab. I have tried to go back to original documents where possible.

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0.1 The Impact of Pisa: Three Themes

The formation and operation of the Collider Detector Facility, as it was initially named, at Fermilab, spanned the development of the modern picture of particle physics. Here I focus on three themes to discuss the impact of the Pisa/Frascati group. Harder to quantify, but most important, is the force of the senior Pisa members towards the goal of a building an innovative world-class detector in a chaotic and unfunded context, described here at the outset.

1. The leadership role of Pisa in the innovative designs of the CDF tracking and calorimeter systems, and the subsequent construction.

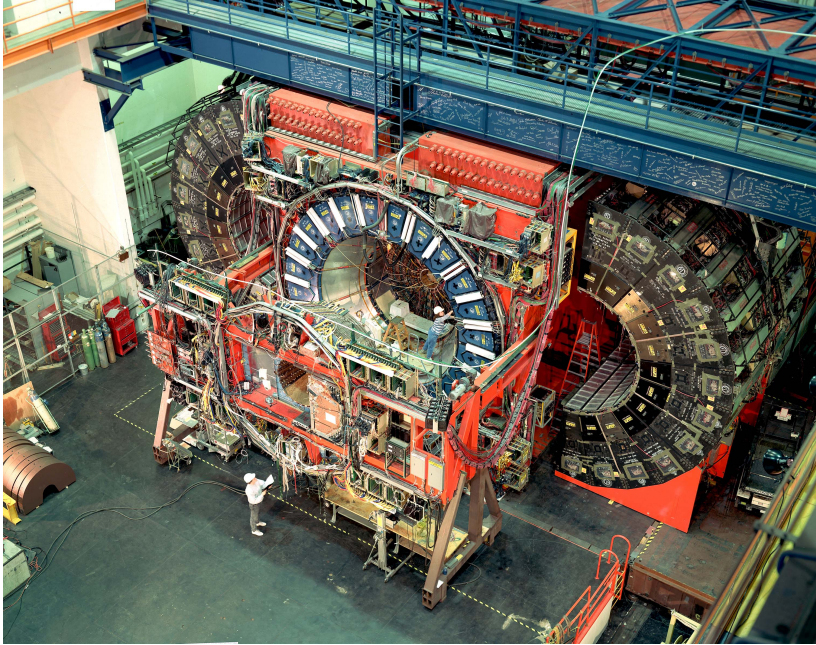


Figura 0.1: The CDF Detector with the calorimeter arches open.

2. The seminal development of precision mass measurements at hadron colliders using a magnetic spectrometer with precise tracking followed by projective calorimetry (aka 'E/p', where 'E' is the calorimeter energy measurement and 'p' is the tracking momentum measurement).
3. The essential role of Pisa hardware in the discovery of the top quark and the extensive and path-breaking results on B-physics.

In addition, Pisa played an essential role in leadership, management, and drive. CDF was a wonderful experience, and among the many wonderful groups, if I had to single out one that made the largest contribution to the exceptionally high standards, creativity, technical know-how, and collegiality of CDF, it would be Pisa.

Figure 0.2 shows a CDF event display of a beams-eye view of a pair of top quarks decaying into W-bosons and b-quark jets. The Pisa group made key contributions to the sophisticated trigger system that selected the event for recording, to the calorimeters that measured the (missing) transverse momentum carried off by the neutrino in the leptonic decay of a W boson, and the silicon vertex detector that allowed identification of the b-quarks, which are an essential part of the signature of top quark production and decay.

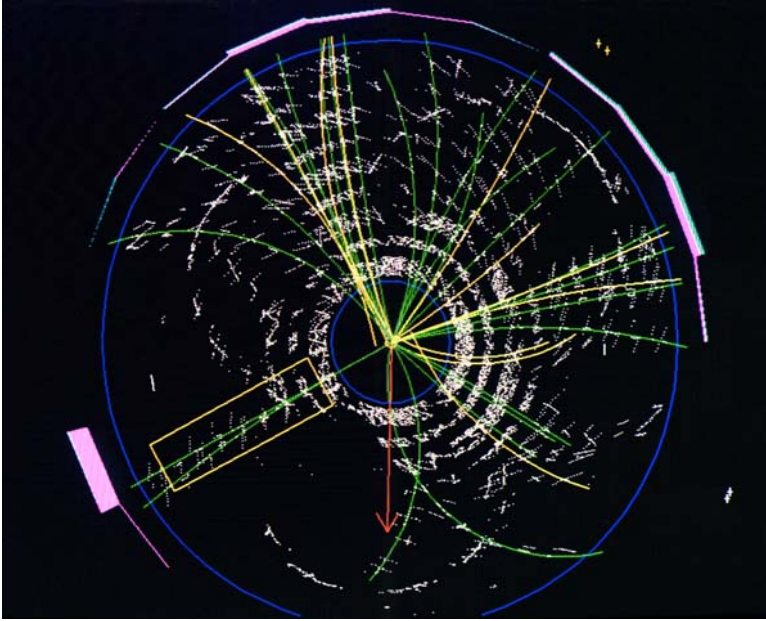


Figura 0.2: A beams-eye view of a pair of top quarks decaying into W-bosons and b-quark jets. The combination of a precise measurement of track momentum followed by a sign-independent measurement of the energy deposited pioneered high-precision measurements in complex events at hadron colliders.

0.2 The Path to Precision Electroweak and Flavor Physics at Hadron Colliders

The founding of CDF was followed by a remarkable evolution in sophistication and precision of detectors and techniques at the hadron colliders at Fermilab and CERN since the pioneering experiments at the ISR and $S\bar{p}pS$. Pisa played a crucial leadership role in this evolution.

The following steps and the initial context provide an outline for my talk. Understanding the intellectual and political context is essential to appreciating the intellectual and collaborative role of the Pisa/Frascatti group in the ultimate success of the Tevatron Collider program.

1. The start of high- P_T physics (in the US): Bjorken, Feynman, Cronin
2. The chaotic road to the choice of $\bar{p}p$ collisions in the Tevatron
3. Cronin starts the Collider Experiment Dept.: ZGS-MR (pp), MR ($\bar{p}p$), Tevatron ($\bar{p}p$)
4. Collider Detector: Giorgio Bellettini, Pisa MOUs
5. The development of precision measurements at a hadron collider: calorimeter behind a precision tracking system: the E/p method
6. The silicon Vertex Detector (SVX), Silicon Vertex Tracker (SVT)- real-time tracking, vertex-selected triggering
7. CDF (Pisa) footprint on hadron collider detector development
8. W and Z precision mass measurements; top quark discovery; B_s mixing, development of Higgs and BTSM search strategies

0.3 Hard Parton Scattering– 1971: Bjorken, Feynman and Field, Cronin

The title page of a seminal paper from the summer of 1971 by Bjorken, Berman, and Kogut that still reads remarkably well is shown in Figure 0.3. The title is ‘Inclusive Processes at High Transverse Momentum’; the paper describes scattering, lepton pair production, and W and Z production, and to a large extent still describes the main thrust in HEP today.

Figure 0.4 shows the prevailing view of particle production from that era, which was an extrapolation from low P_T of an exponential, typically quoted as e^{-6P_T} , and their predicted power law deviations above the prediction.

Presciently, Jim Cronin and Pierre Piroué submitted a proposal to Fermilab in 1970 to measure the spectrum of inclusive particle production at high P_T : electrons, muons, identified hadrons (pi, K, and proton and their antiparticles), as well as short-lived new particles. This was approved and became experiment E100, in the Proton Lab.

Inclusive Processes at High Transverse Momentum*

S. M. Berman, J. D. Bjorken, and J. B. Kogut†

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

(Received 5 August 1971)

We calculate the distribution of secondary particles C in processes $A + B \rightarrow C + \text{anything}$ at very high energies when (1) particle C has transverse momentum p_T far in excess of 1 GeV/c, (2) the basic reaction mechanism is presumed to be a deep-inelastic electromagnetic process, and (3) particles A , B , and C are either leptons (l), photons (γ), or hadrons (h). We find that such distribution functions possess a scaling behavior, as governed by dimensional analysis. Furthermore, the typical behavior even for A , B , and C all hadrons, is a power-law decrease in yield with increasing p_T , implying measurable yields at NAL of hadrons, leptons, and photons produced in 400-GeV pp collisions even when the observed secondary-particle p_T exceeds 8 GeV/c. There are similar implications for particle yields from e^+e^- colliding-beam experiments and for hadron yields in deep-inelastic electroproduction (or neutrino processes). Among the processes discussed in some detail are $ll \rightarrow h$, $\gamma\gamma \rightarrow h$, $lh \rightarrow h$, $\gamma h \rightarrow h$, $\gamma h \rightarrow l$, as well as $hh \rightarrow l$, $hh \rightarrow \gamma$, $hh \rightarrow W$, and $W \rightarrow h$, where W is the conjectured weak-interaction intermediate boson. The basis of the calculation is an extension of the parton model. The new ingredient necessary to calculate the processes of interest is the inclusive probability for finding a hadron emerging from a parton struck in a deep-inelastic collision. This probability is taken to have a form similar to that generally presumed for finding a parton in an energetic hadron. We study the dependence of our conclusions on the validity of the parton model, and conclude that they follow mainly from kinematics, duality arguments *à la* Bloom and Gilman, and the crucial assumption that multiplicities in such reactions grow slowly with energy. The picture we obtain generalizes the concept of deep-inelastic process, and predicts the existence of "multiple cores" in such reactions. We speculate on the possibility of strong, nonelectromagnetic deep-inelastic processes. If such processes exist, our predictions of particle yields for $hh \rightarrow h$ could be up to 4 orders of magnitude too low, and for $\gamma h \rightarrow h$ and $hh \rightarrow \gamma$ up to 2 orders of magnitude too low.

Figura 0.3: The title page of the 1971 seminal paper by J. D.Bjorken, S. Berman, and J. Kogut that lays out the landscape of hadron collider physics: parton-parton scattering, Drell-Yan annihilation, and W/Z boson production. This was the physics in which CDF was founded to explore and discover.

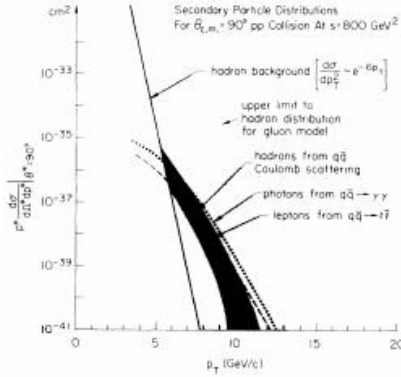


FIG. 1. Secondary-particle distributions as calculated in the parton model and compared to diffractive backgrounds for typical NAL conditions.

Figura 0.4: Predictions of high- P_T particle spectra from parton-parton scattering from the 1971 paper of Berman, Bjorken, and Kogut. The later designs of the CDF calorimeter tower geometry and calorimetric trigger were influenced by the single particle measurements at CERN and Fermilab as the properties of jets were still hotly debated at the time of the start of CDF.

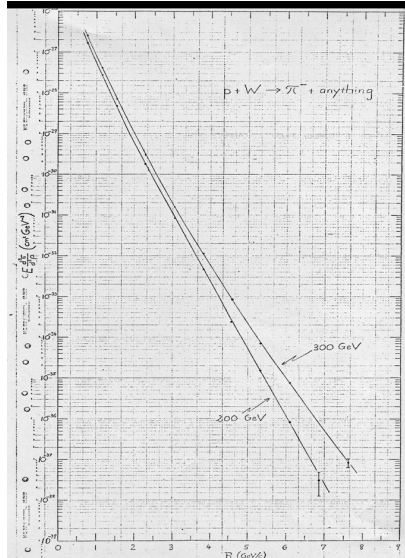


Figura 0.5: The first measurements of inclusive hadron production at high P_T at Fermilab by the Fermilab Experiment E100, with Jim Cronin and Pierre Piroué as spokesman. Cronin later become Head of the Collider Detector Department, preceding the CDF Technical Design Report and later proposal.

Figure 0.5 shows the first results on inclusive hadron production at high P_T at Fermilab by E100, showing the clear deviation from the naive exponential prediction, and, strikingly, the energy-dependence of the cross-section at high P_T . However, due to delays in bringing the Fermilab machine online, the CERN ISR collider beat us to the punch, sadly, and barely.

However the interpretation of the ‘excess’ and energy-dependence of high- P_T particle production as two-body parton scattering was not yet agreed on. Figure 0.6 shows a telegram from Feynman to Rick Field after Feynman and Cronin talked about the high P_T particle production results in France. The telegram is excited, frankly, about the observation of parton scattering, with its consequent $1/P_T^4$ dependence, followed by parton fragmentation to give the observed $1/P_T^8$ at Fermilab.

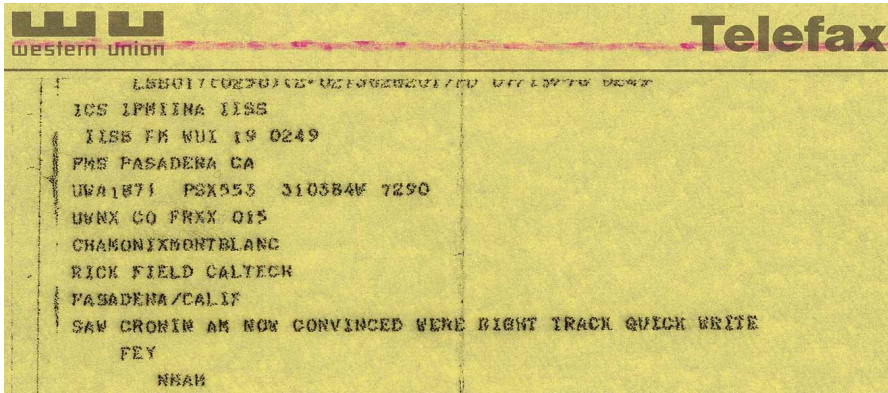


Figura 0.6: A July 1976 telegram from Feynman in France to Rick Field at Cal-Tech, urging Rick to write up their work on parton-parton scattering followed by parton fragmentation being the source of the high- P_T particles (Courtesy of R. Field).

0.4 The Chaotic Start of a Collider Program at Fermilab

With the initiatives of Rubbia and others at CERN the pressure grew on Fermilab toward a collider. Bob Wilson appointed Jim Cronin as Head of a new department, the Fermilab Colliding Beam Department. Cronin started a design for the detector, and started some basic measurements of particle flux in the MR tunnel. Figure 0.8 is from the memo announcing the start of the Department.

Unfortunately a rational approach didn’t work at Fermilab, partly because of the Federal HEPAP-determined funding constraint on accelerator construc-



Figura 0.7: Jim Cronin, the Head of the new Fermilab Colliding Beam Department. Cronin started the first designs for the detector and measurements in the MR tunnel.

tion, partly because of personnel, and partly because of organizational structure. Figure 0.9 shows the announcement of Cronin's resignation.

Some background is in order to understand the chaotic situation and the impact the international collaborators from Pisa/Frascati and Japan had in fashioning a successful program out of the initial conditions. The Main Ring (MR) accelerator was not well-suited as a collider. With remarkable foresight Wilson had made provisions for the superconducting Tevatron ring in the tunnel, mounted below the MR. However, there were a number of competing facility proposals: PEP at SLAC, Isabelle at BNL, and CESR at Cornell. The HEPAP panel held Sub-panel meetings at Woods Hole in 1974 (Weisskopf, Chair), 1975 (Low, Chair), and 1977 (Sandweiss, Chair) to evaluate and prioritize the proposals. The panels proved that they could differentiate, although with the sign wrong: we approved PEP and Isabelle for construction, leaving the (successful!) Tevatron and CESR to be funded by other means.

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DEPARTMENT OF COLLIDING BEAM EXPERIMENTS

A meeting was held at Fermilab on November 17 to discuss various possibilities for the organization of work on colliding beam experiments. In accordance with some of the ideas which were discussed at that meeting a Colliding Beam Experiments Department has now been set up. Professor James Cronin of the University of Chicago has agreed to head this new department.

The department is to be a center for a number of activities directed toward planning for the exploitation of pp and $\bar{p}p$ colliding beams in the present Main-Ring tunnel. Financial restrictions prevent adding very many

Figura 0.8: A memo announcing the start of the Fermilab Colliding Beam Department, with Jim Cronin as Head.

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- 17 -

Dec. '77

REORGANIZATION OF COLLIDING BEAMS RESEARCH

The Colliding Beam Experiments Department, originally headed by Jim Cronin, has now been disbanded. In its place there will be a Colliding Detector Facility (CDF) Department within the Research Division, a Colliding Beam (CB) Group in the Accelerator Division, and an Antiproton Cooling (AC) Group in the Accelerator Division.

Figura 0.9: A memo announcing the end of the Fermilab Colliding Beam Department. The path to a realistic collider with an adequate luminosity, built on a credible schedule, and a sophisticated detector adequate for the remarkable physics potential was not clear, and Cronin had resigned.

*Pisa and the Collider Detector at Fermilab: a History of the Establishment of Precision Physics
With a Calorimetric Spectrometer at a Hadron Collider*

Figure 0.10

| OPTIMISTIC COLLIDING BEAM SCHEDULE | | | F. R. Huson 4/26/78 |
|-------------------------------------------------------------------------|---------|------------------------------------------------------------------------------------------------------------------------------|------------------------|
| Craig Moore | May 78 | Eq. Beam to cooling ring. Oper. | |
| Stan Ecklund Lee Pondrom | Aug. 78 | AIP B0 colliding beam area (pit). | |
| Jim Griffin Jim Bridges | Oct. 78 | Oper. Test rf bucket bunching in Main Ring (~ 10 to 1). | |
| Jim Griffin Gil Nicholls | Oct. 78 | Oper. High harmonic cavity. | |
| Don Young Fred Mills Peter McIntyre Ed Gray | Oct. 78 | AIP Cool protons. GPP Oper. Eq. | May 15 May 10-16 |
| Don Young Fred Mills Jim Griffin | Dec. 78 | Oper. RF in cooling ring - accumulate 10^{10} protons. | |
| Bruce Chrisman Don Edwards Stan Snowdon George Chadwick | Dec. 78 | Oper. Extract 100-GeV protons at F17, target for p production. | |
| Carlos Hojvat Keith Meisner | Jan. 79 | Oper. 10^7 protons in Booster - acceleration and deceleration - H ⁺ in Booster - quick reversing of GMPS. | |
| Bruce Brown Craig Moore Dave Johnson | Jan. 79 | AIP Cooling ring to Booster connection. | |
| Stan Ecklund | Feb. 79 | GPP Low β in Main Ring and B0. Oper. Equip. | |
| Bruce Chrisman Bruce Brown Don Edwards Stan Snowdon | Feb. 79 | AIP P's to Booster and Cooling Ring - 10-GeV Equip. protons to Main Ring in reverse line and circulating at 10 GeV. | |
| Stan Pruss | Mar. 79 | Oper. Main Ring vac. $< 5 \times 10^{-9}$ torr. | |
| Stan Ecklund | Mar. 79 | Oper. Luminosity lifetime at 250 GeV > 3 hours. | |
| Roy Rubinstein | Mar. 79 | AIP Main Ring abort - both directions. | |
| Don Young et al. | Mar. 79 | Oper. P's cooled, accumulated and injected into M.R. | |
| Stan Ecklund Lee Pondrom | June 79 | AIP Finish B0 colliding beam area. | |
| Stan Ecklund John Dinkel | July 79 | Eq. Circulating protons in reverse direction in Main Ring at 250 GeV. | |
| Stan Ecklund | Oct. 79 | Eq. Test kissing scheme in Main Ring. | |
| Notes to: Those listed above Accel. Div. Group Ldrs. R. R. Wilson | | | |

Figure 0.10: An April 1978 "Optimistic Colliding Beam Schedule" for $\bar{p}p$ collisions in the Main Ring, with first collisions planned for 18 months later. This was optimistic in many ways.

Figure 0.11 illuminates the lack of consensus on what to do. Among the options for the accelerator were colliding the Main Ring with the Argonne ZGS (yes, really) for proton-proton collisions. The estimates of achievable luminosities for several of the options disagreed by orders-of-magnitude. The options for the detector were equally all over the map; one proposal had a detector in a pit barely big enough to hold it, but on cables so that it could be raised for access.

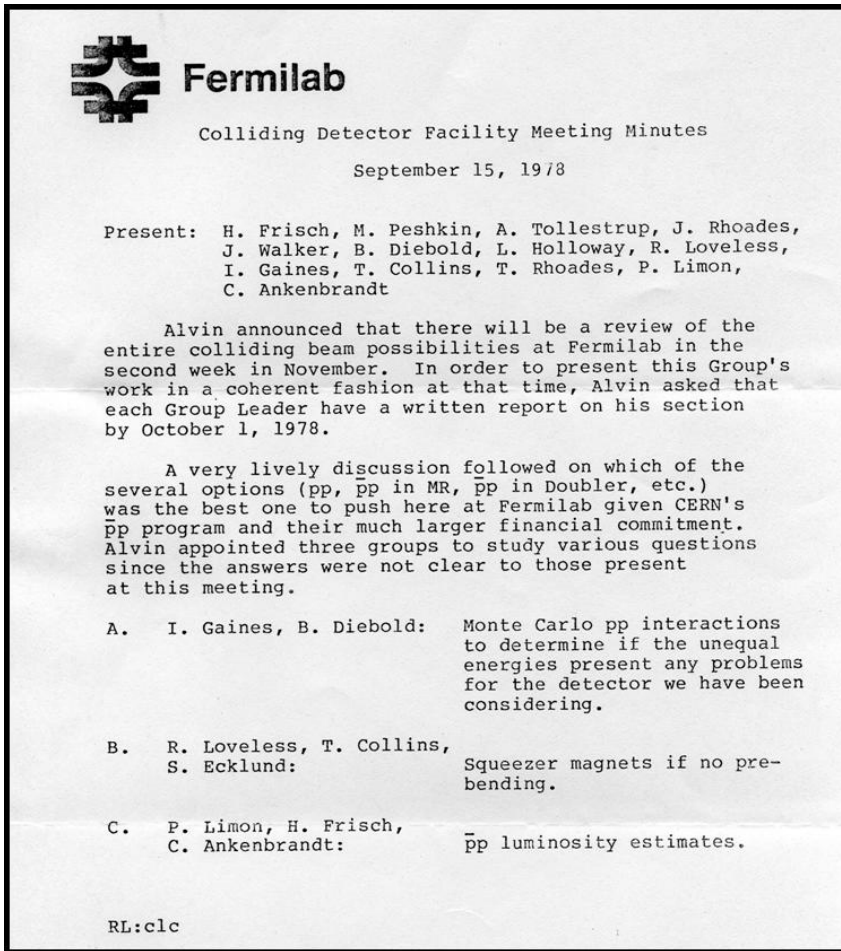


Figure 0.11: The minutes of a 1978 CDF meeting discussing the options for the accelerator itself ("pp, $\bar{p}p$ in MR, $\bar{p}p$ in Doubler, etc."). The words "A very lively discussion followed" are a diplomatic way of saying that it was a mess, with many competing options and unsupported claims of luminosities, schedules, and costs. Note the last sentence and the three groups.

Figure 0.12

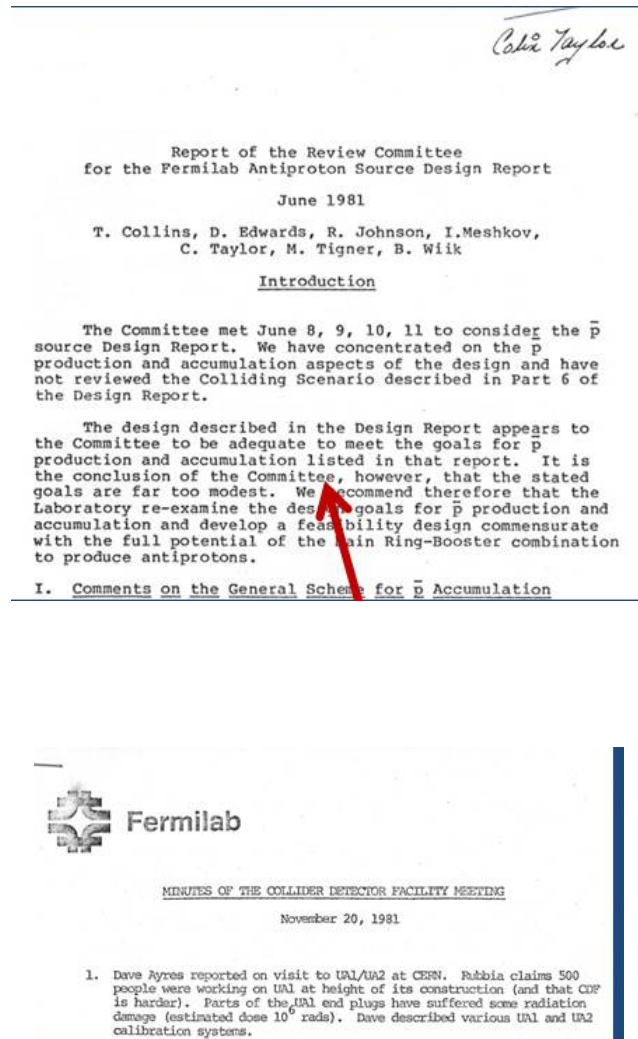


Figura 0.12: Top: The June report of the 1981 (distinguished!) review committee on the Fermilab antiproton source. Bottom: An excerpt from the minutes CDF meeting the following November, showing the awareness at Fermilab of the rapidly-moving CERN program. Both the UA1 and UA2 trigger and tracking designs had impact on the CDF designs; we studied them and wanted to do better.

That a technically sound and exceptionally successful solution came out of the chaos was due to a number of remarkable people and the very strong staff and attitude at the Lab. Key elements were Wilson's plans for a superconducting ring in the MR tunnel, Alvin Tollestrup's solutions to the superconducting magnet problems, and John Peoples's leadership of the pbar source. Figure 0.13 shows the current Fermilab facility, including the Recycler storage ring for which Bill Foster played an essential role.

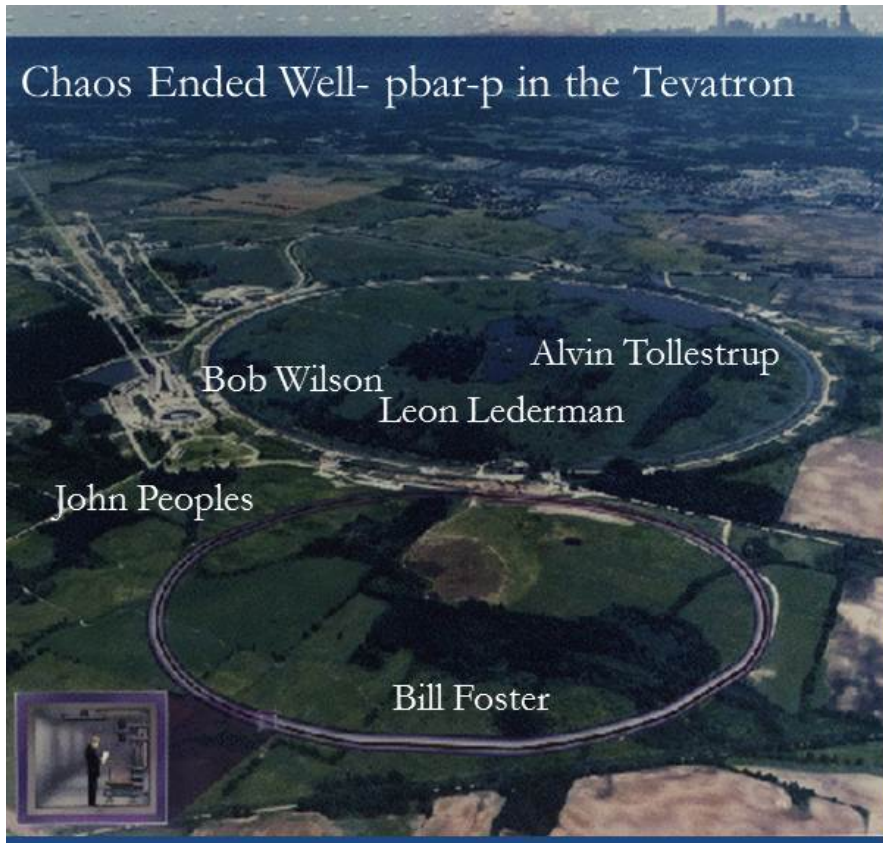


Figura 0.13: The completed Fermilab accelerator complex showing the remarkable solutions by Wilson, Tollestrup, Peoples, and many others to the lack of adequate funding, the technical challenge of a large ring high-field superconducting magnets, the pbar source, and the development of a sophisticated hadron collider detector with both precise tracking and projective calorimetry.

0.5 The Foundational Contributions of Pisa to the CDF Detector Design

In his contribution to this conference, Giorgio Bellettini describes how in 1979 he and Paolo Giormini met with Alvin Tollestrup and Bob Diebold to discuss Pisa and Frascati joining CDF.



Figura 0.14: Giorgio Bellettini, the leader of the Pisa CDF group, in the CDF Trigger Room in 1995. One of the Silicon Vertex Trigger (SVT) racks is visible behind him.

Figure 0.15 is a copy of the 1983 Memorandum of Understanding (MOU) between Pisa, Frascati, and Fermilab. Each of the collaborating institutions ended up signing such an MOU. Note the original cast members. The original institutions included Tsukuba and KEK in Japan, with the strong Japanese effort led by Kuni Kondo.

Figure 0.16 shows the essential role played by Pisa and Frascati in the design, construction, and subsequent operation of CDF by listing the extensive responsibilities of the group. The remarkable characteristics of the tracking and calorimeter systems were heavily influenced (or more) by the group.

November 1983

AGREEMENT CDFA4
 between the
 RESEARCH DIVISION of
 FERMILAB NATIONAL ACCELERATOR LABORATORY
 and the
 ISTITUTO NAZIONALE DI FISICA NUCLEARE
 Italy

I. Composition and Purpose of the Collaboration

This agreement covers the activities that a team of the Istituto Nazionale di Fisica Nucleare (INFN) of Italy, comprising a group from Frascati and one from Pisa, will carry out in collaboration with groups from Argonne, Brandeis, Chicago, Fermilab, Harvard, Illinois, KIN, LBL, Pennsylvania, Purdue Rutgers, Texas, Tsukuba, and Wisconsin.

The goal of this collaborative effort is the design, construction, and initial operation of the Collider Detector at Fermilab (CDF), a large detector which will be placed in the B0 interaction region to study collisions between p and \bar{p} beams stored in the Fermilab Energy Doubler. The scope of the detector is given in the Design Report. The collaboration can be extended to other groups, as provided for in Paragraph VII.

II. Personnel

The following physicists are participants in the collaboration as members of the Italian team: S. Bartalucci**, G. Bellettini*, F. Bedeschi*, S. Bartolucci**, L. Bosio*, F. Corvelli*, M. Cordelli**, R. Del Fabbro*, A. Di Virgilio*, E. Focardi*, P. Giannotti*, M. A. Giorgi*, P. Giromini**, A. Menzione*, M. Pallotta**, L. Ristori*, A. Sansoni**, A. Scribano*, G. Tmelli*, R. Tripicciomo*.

It is expected that other INFN physicists might join this group in the future.

The leader of the Frascati group is P. Giromini.

The leader of the Pisa group is G. Bellettini.

The spokesman for the INFN team is G. Bellettini.

*Sezione di Pisa dell'INFN

**Laboratori Nazionale di Frascati dell'INFN

Figura 0.15: The 1983 Memorandum of Understanding (MOU) between Pisa/Frascati and Fermilab. The group was both large and very strong, bringing collider experience and extraordinary detector development skills to CDF.

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II. Responsibilities of the Italian Group

The responsibilities of the Italian team are as follows:

- A. Fabrication of the scintillator/BBQ towers, the light pipes, and the associated photomultipliers, bases, and HV supplies for the central and endwall hadron calorimeters, and the shipping of this material to Fermilab. This will have to be done according to the time schedule indicated in Paragraph VI.

The iron structure of the calorimeters will be fabricated by Purdue and Fermilab.

The electromagnetic shower calorimeters of the central units will be fabricated by Argonne and KEK.

- B. Assembly of the hadron calorimeters at Fermilab, jointly with Purdue and Fermilab.
- C. Calibration of the calorimeters with cosmic rays, light flashers, and particle beams jointly with Pennsylvania, Purdue, and Fermilab. The Italian group will dedicate to the assembly and calibration work at Fermilab a minimum of:
1. One physicist and two technicians during the period October 1982-December 1983.
 2. Three physicists and three technicians during 1984.
 3. Approximately four physicists and two technicians during 1985.
- D. Development, construction, and operation of a light-flasher system for the hadron calorimeters that is compatible with overall CDF calibration requirements.
- E. Development and construction of a HV system for the central and end-wall hadron calorimeters.
- F. Coordination of the above scintillator construction, assembly, and calibration work.
- G. Development, construction, and running-in of a prototype small angle luminosity monitor and elastic scattering silicon detector, as outlined in Chapter 7 of the Design Report.
- H. Development, construction, and running-in of a prototype vertex tracking and dE/dx detector, as outlined in Chapter 7 of the Design Report.

The installation of these detectors in CDF will depend on their performance and on possible interference with the rest of the CDF activities.

Figura 0.16: The list from the 1983 MOU of Pisa and Frascati responsibilities.

0.5.1 The Technical Design Report (TDR)

Design and even construction of the Collider Detector Facility, as it was initially named, started before a proposal had been written¹. Instead, the Collaboration wrote a Technical Design Report (TDR), released in August of 1981 (H. Jensen and HJF editors). Figure 0.17 shows the cover, with its logo of the projective calorimeter towers put forward by the Pisa group.

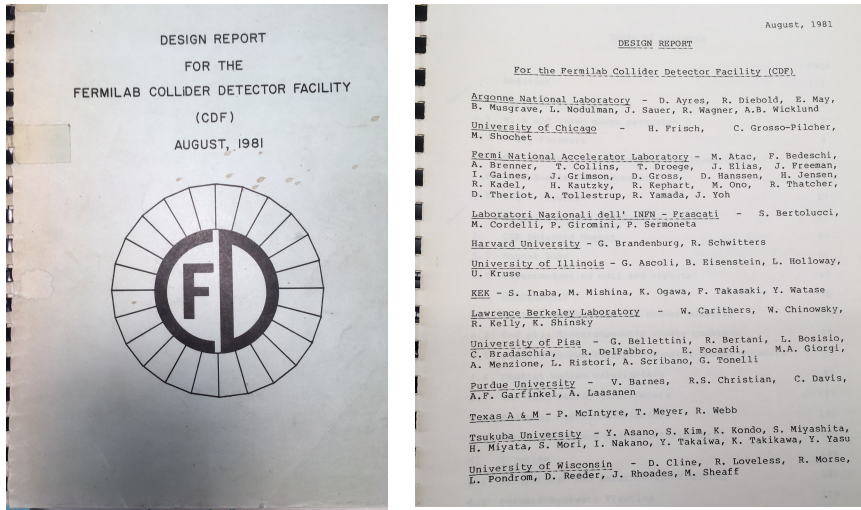


Figura 0.17: caption

The titles of the 1981 CDF Notes (internal collaboration technical notes) proposing designs for the vertex silicon detectors and hadron calorimeters are shown in Figure 0.18. The as-built detectors corresponded remarkably faithfully to these initial innovative designs.

0.5.2 Projective Hadron Calorimetry: Pisa and Frascati

A very strong contingent from Pisa and Frascati, in collaboration with Argonne, Fermilab, Purdue, Urbana, and other institutions, led the adoption and design of the (largely) hermetic calorimeters based on a projective tower geometry of uniform segmentation in rapidity and polar angle. Transporting the light out of the calorimeter to the photomultipliers outside was a tour-de-force, both in design and implementation. The left-hand panel of Figure 0.19 shows Franco Cervelli and Aldo Menzione working on hadron calorimeter modules. The

¹ When a group of us, probably led by Tollestrup, presented the idea to Bob Wilson, he said "OK, but it can't cost more than 10 million dollars". We knew, and I'm sure he knew, that this was low by an order-of-magnitude; we looked at each other, and said "sure".

| | |
|--------|---------------------------------------------------------------------------------------------------------------------|
| CDF-58 | The Criterion for Avoiding Hot Spots in Calorimeters - W. Selove |
| CDF-59 | Luminosity and Very Small Angle Physics - G. Bellettini, C. Bradaschia, A. Menzione |
| CDF-60 | Feasibility of Operating Silicon Detectors Inside the Collider Vacuum Pipe - C. Bradaschia, T. Collins, A. Menzione |
| CDF-61 | Prototype Pad Chamber Hadron Calorimeter - M. Ono and R. Yabuka |
| CDF-62 | Endcap Hadron Calorimeters - G. Bellettini, R. Bertani, R. Del Fabbro, G. Gennaro, A. Scribano |
| CDF-63 | Hybrid Shower Counters for CDF - L. Nodulman |
| CDF-64 | Conceptual Design of a Forward Detector for the Antiproton-Proton Collider - P. McIntyre et. al. |

Figura 0.18: Key 1981 CDF Notes (the internal collaboration technical papers) The CDF Note index showing the 1981 CDF Notes from the Pisa/Frascati groups, proposing designs for silicon detectors and hadron calorimeters. The titles of notes CDF-59, CDF-60, and CDF-62 are highlighted in red.

right-hand panel shows a prototype of one of the four ‘arches’ of modules being assembled at Argonne ².



Figura 0.19: Left: Franco Cervelli and Aldo Menzione working on hadron calorimeter modules. Right: Hans Kautsky supervising the assembly of prototype ‘arch’ of modules being assembled at Argonne. (Note the hard-hat).

² No mention of the detector construction would be complete without due credit being given to Dennis Theriot as overall CDF Project Manager, and Hans Jensen leading the detector assembly in the B0 collision hall.

0.5.3 Silicon Vertex Detectors (SVX) and Silicon Vertex Trigger (SVT)

Aldo Menzione was a key pioneer in the development of silicon tracking detectors, as well as single-handedly, it seemed, bulling through the adoption by CDF of the SVX silicon detector that played such an important role in the Tevatron physics program. Figure 0.20 reproduces title from papers in the development

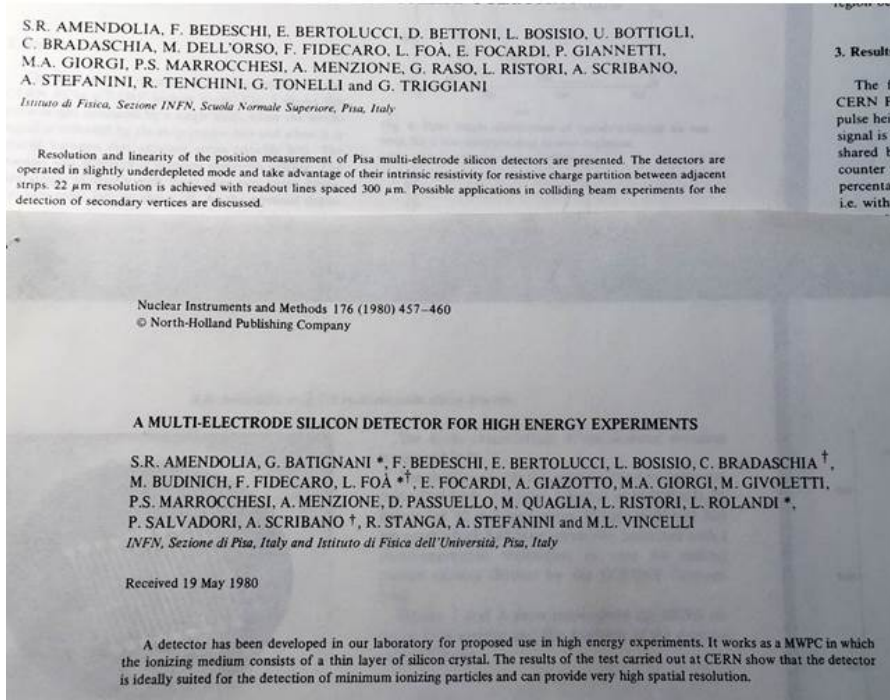


Figura 0.20: Two seminal papers by the Pisa group on the exploitation of silicon vertex detectors.

I was on the tracking 'GodParent Committee', led by Giulio Ascoli and later Willie Chinowsky, that had the charge of vetting the tracking designs. The history of vertex tracking at CERN had not been good, and there was nervousness, particularly among the less technical folk; Aldo was an irresistible force, and the GodParents approved the installation of the silicon vertex detector. The SVX, along with the remarkable central tracking chamber of Kadel, Mukherjee, Kephart, Binkley, and others, were the core of CDF performance.

Aldo's design and description in the Technical Design Report of this bold proposal are shown in Figure 0.21. What is truly remarkable to me is how this sketch corresponds to what was built and operated; even though this was completely unexplored territory for us, Aldo knew deeply what the system needed to do.

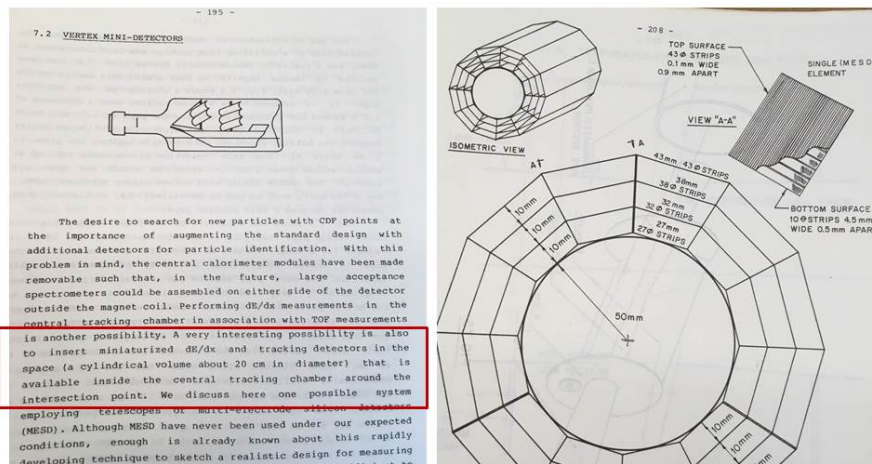


Figure 0.21: The description and layout of the Silicon Vertex Detector (SVX) in the Technical Design Report.

The ability to trigger on displaced vertices, seemingly impossible when we first contemplated the collider, was brilliantly implemented by Luciano Ristori and the Pisa group (Chicago collaborated on the hardware). The precision, data rate, and necessary monitoring/control were a large step beyond the state-of-the-art. Figure 0.22 (Left) shows a ‘cartoon’ of the operating principles; the installation, driven by over 100 optical fibers running at 1.4 Gbits/sec, is shown on the right.

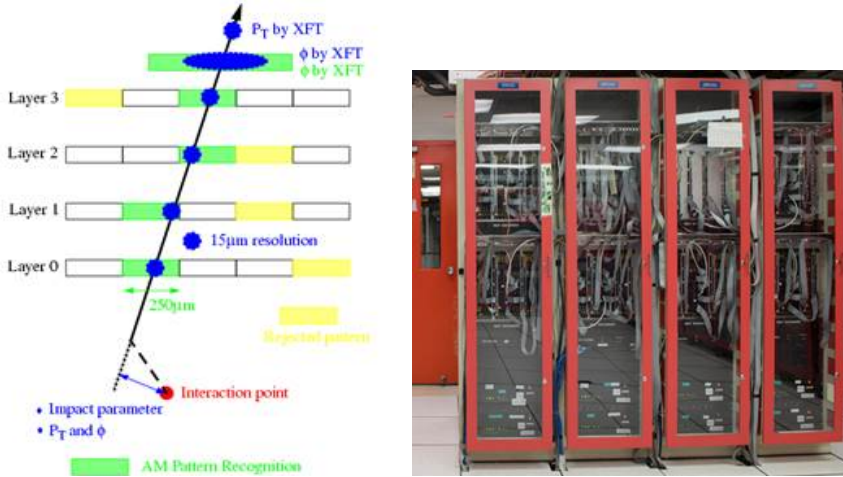


Figure 0.22: Left: The operating principle of the Silicon Vertex Tracker (SVT). Right: the SVT system installed in the CDF Trigger Room.

0.5.4 Summary

The period discussed here spans the development of precision measurements at hadron colliders and the parton model. The Pisa/Frascatti group’s contributions to CDF have set the standards for collider programs at the ‘Energy Frontier’: the precision spectrometer consisting of precision tracking back to the vertex with a silicon vertex detector followed by projective segmented calorimeters, and using a trigger on displaced vertices. The combined tracking and calorimeter systems that the group contributed so much to allowed precision calibration of both systems through the ‘E/p’ method, now a standard (as are so many of the innovations from CDF) at the LHC.

The work of Aldo Menzione on the SVX and Luciano Ristori were honored with the Panofsky Prize of the American Physical Society. Figure 0.23 gives the citations. Recognition of the importance of the entire group has been recognized by the continued election of Pisa physicists to the leadership of the Collaboration.

Pisa and the Collider Detector at Fermilab: a History of the Establishment of Precision Physics With a Calorimetric Spectrometer at a Hadron Collider

2009 W.K.H. Panofsky Prize in Experimental Particle Physics Recipient

Aldo Menzione
INFN, Pisa
Citation:



"For their leading role in the establishment and use of precision silicon tracking detectors at hadron colliders, enabling broad advances in knowledge of the top quark, b-hadrons, and charm-hadrons."

Background:

Aldo Menzione was born in Massa (Italy) on June 18, 1943. In 1961 he started his studies in University of Pisa where he graduated in 1967. Between 65 and 66 he worked on the CERN Karlsruhe Collab. The thesis work was Production of neutral mesons decaying in all neutral secondaries. 70-73 at CERN-ISR-RBQ. The reason for which this experiment is still known is the discovery of the rising $p\text{-}p$ X-section. Other interesting results were in the area of correlations among secondaries and rapidity distributions as function of energy. 73-80 at CERN-SPS Experiments NA1 NA7. These experiments led to relevant results in charm physics and meson form factors. Many technical innovations were introduced in these experiments, most important, the active target, based on semiconductors. In the period 1990-2000 he devoted part of his time to an astroparticle experiment CLUE finalized to establish a technique to detect the air shower by the UV Cherenkov light. 80 now CDF at Fermilab. He participates from the beginning to the design and the construction of the apparatus. Starting 1985 he had the responsibility of the design, construction and commissioning of the silicon vertex. The device was relevant in the top importance in a variety of measurements done by the collaboration. He has been responsible of the CDF-Pisa group until 2006.

2009 W.K.H. Panofsky Prize in Experimental Particle Physics Recipient

Luciano Ristori
INFN
Citation:



"For their leading role in the establishment and use of precision silicon tracking detectors at hadron colliders, enabling broad advances in knowledge of the top quark, b-hadrons, and charm-hadrons."

Background:

Luciano Ristori was born in Prato (Italy) on December 13, 1948. In 1967 he was admitted at the Scuola Normale Superiore in Pisa where he graduated in 1971 with the title of *Odottore in Fisica*. His thesis was on the measurement of the total $p\text{-}p$ cross at the Intersecting Storage Rings (CERN-ISR). In 1972, he joined the NA1 Collaboration at the CERN SPS for the first electronic measurement of the lifetime of charmed mesons using an active silicon target. In 1977, he obtained a permanent position at the Italian National Institute for Nuclear Physics (INFN). In 1991 he took a position of Associate Professor at the Scuola Normale Superiore in Pisa. In 1990 he conceived and proposed a trigger based on secondary vertices (SVT) to the CDF Collaboration. The SVT trigger was commissioned in 2001 and has allowed CDF to perform measurements otherwise impossible, especially in the area of hadronic decays of B mesons and baryons, including the precise measurement of the Bs oscillation frequency. Since 1998, he holds a position of Research Director at INFN in Pisa. He was Co-Spokesperson of the CDF Collaboration from 2003 to 2005. Since 2005 he is responsible for the whole Italian group in CDF.

Figura 0.23: The Panofsky Prize citations for Aldo Menzione and Luciano Ristori.

In summary, this was a remarkable group of wonderful physicists and people. It was an honor and pleasure to work closely with them; the leadership and exceptionally high intellectual standard was key to the successes of CDF.

0.6 Acknowledgements

I would like to thank the Organizers for the enjoyable opportunity to revisit wonderful memories of collaboration with the Pisa CDF physicists. I owe deep thanks to Vincenzo Cavasinni for his care and thoughtful hospitality, and Giorgio Bellettini for the invitation and help. The occasion to see old friends from CDF was particularly special. The talk is dedicated to the memories of Aldo Menzione and Mauro Dell'Orso.