Pisa and the Collider Detector at Fermilab: a brief history of the establishment of precision physics with a calorimetric magnetic spectrometer at a hadron collider- very US-centric

Henry Frisch
Enrico Fermi Institute, University of Chicago
Three Themes in my talk:

1. The leadership role of Pisa in the CDF tracking and calorimeter design and construction

2. The development of precision mass measurements at a hadron collider using a magnetic spectrometer with precise tracking followed by good calorimetry (aka `E/p’)

3. The essential role of Pisa hardware in the discovery of the top quark and the extensive B-physics results
A. Mukherjee and A.B. Wicklund: development of E/p method for the Z-mass measurement

A top quark event with b-tags
The path to precision physics at a hadron collider (heresy among some in Calif.)

- The start of high-PT physics (in US)
- The chaotic road to pbar-p in Tevatron
- Cronin starts the Collider Experiment Dept.- ZGS-MR (pp), MR, Tevatron
- Collider Detector: Giorgio Pisa MOUs
- Precision physics: calorimeter behind a precision tracking system: E/p
- Silicon Vertex Detector, Silicon Vertex Tracker- real-time tracking
- CDF (Pisa) footprint on hadron collider detector development
- W and Z precision masses; top, B_s mixing, …. and the end… (almost)
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 + 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 (\ell), photons (\gamma), 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 electron-production (or neutrino processes). Among the processes discussed in some detail are \ell\bar{\ell} \rightarrow h, \gamma\gamma \rightarrow h, hh \rightarrow h, \gamma h \rightarrow h, \gamma h \rightarrow \ell, 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 \textit{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.
Hard Parton Scattering

BBK Predictions on hard parton scattering, annihilation to the W and Z, direct leptons,…
First Results- 1972- see power-law behavior and energy dependence at large Pt

BUT- ISR beat us to punch line (sadly, and barely)

Note energy-dependence at high Pt- evidence of hard scatters
SAW CRONIN AM NOW CONVINCED WERE RIGHT TRACK QUICK WRITE
FEYNMAN
What Collides at Fermilab?

<table>
<thead>
<tr>
<th>OPTIMISTIC COLLIDING BEAM SCHEDULE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Craig Moore</td>
</tr>
<tr>
<td>May 78  Eq. Beam to cooling ring.</td>
</tr>
<tr>
<td>Aug. 78  AIP  B0 colliding beam area (pit).</td>
</tr>
<tr>
<td>Oct. 78  Oper. Test rf bucket bunching in Main Ring (~10 to 1).</td>
</tr>
<tr>
<td>Oct. 78  Oper. High harmonic cavity.</td>
</tr>
<tr>
<td>Oct. 78  AIP  Cool proton.</td>
</tr>
<tr>
<td>Dec. 78  Oper. RF in cooling ring - accumulate $10^{10}$ protons.</td>
</tr>
<tr>
<td>Dec. 78  Oper. Extract 100-GeV protons at F17, target for p production.</td>
</tr>
<tr>
<td>Jan. 79  Oper. $10^7$ protons in Booster - acceleration and deceleration - H in Booster - quick reversing of CMPS.</td>
</tr>
<tr>
<td>Jan. 79  AIP  Cooling ring to Booster connection.</td>
</tr>
<tr>
<td>Feb. 79  GPP  Low $\beta$ in Main Ring and B0.</td>
</tr>
<tr>
<td>Feb. 79  AIP  $\bar{p}$'s to Booster and Cooling Ring - 10-GeV protons to Main Ring in reverse line and circulating at 10 GeV.</td>
</tr>
<tr>
<td>Mar. 79  Oper. Main Ring vac. &lt; $5 \times 10^{-9}$ torr.</td>
</tr>
<tr>
<td>Mar. 79  Oper. Luminosity lifetime at 250 GeV &gt; 3 hours.</td>
</tr>
<tr>
<td>Mar. 79  AIP  Main Ring abort - both directions.</td>
</tr>
<tr>
<td>Mar. 79  AIP  $\bar{p}$'s cooled, accumulated and injected into M.R.</td>
</tr>
<tr>
<td>June 79  AIP  Finish B0 colliding beam area.</td>
</tr>
<tr>
<td>July 79  Eq. Circulating protons in reverse direction in Main Ring at 250 GeV.</td>
</tr>
<tr>
<td>Oct. 79  Eq. Test kissing scheme in Main Ring.</td>
</tr>
</tbody>
</table>

Yes to: Those listed above
R. R. Wilson
Fermilab (not Jim’s Dept.) still a mess a year later…

But, with Dennis Theriot and a really good crew derived from the group… (Dennis is a much unsung hero):

Delegated to meet with Huson and settle MR (on ZGS?) luminosity
Report of the Review Committee
for the Fermilab Antiproton Source Design Report
June 1981

Introduction

The Committee met June 8, 9, 10, 11 to consider the \( \bar{p} \) source Design Report. We have concentrated on the \( \bar{p} \) production and accumulation aspects of the design and have not reviewed the Colliding Scenario described in Part 6 of the Design Report.

The design described in the Design Report appears to the Committee to be adequate to meet the goals for \( \bar{p} \) production and accumulation listed in that report. It is the conclusion of the Committee, however, that the stated goals are far too modest. We recommend therefore that the Laboratory re-examine the design goals for \( \bar{p} \) production and accumulation and develop a feasibility design commensurate with the full potential of the Main Ring-Booster combination to produce antiprotons.

I. Comments on the General Scheme for \( \bar{p} \) Accumulation

---

Fermilab

MINUTES OF THE COLLIDER DETECTOR FACILITY MEETING
November 20, 1981

1. Dave Ayres reported on visit to UA1/UA2 at CERN. Rubbia claims 500 people were working on UA1 at height of its construction (and that CDF is harder). Parts of the UA1 end plugs have suffered some radiation damage (estimated dose 10^6 rads). Dave described various UA1 and UA2 calibration systems.
1974, 75, 77 Woods Hole Panels; was not obvious how to compete with CERN. Present configuration shown above.

Chaos Ended Well - $\bar{p}p$ in the Tevatron
1979- Giorgio and Paolo Giornini talk to Alvin and Bob Diebold (per Giorgio)
Pisa/Frascati Took on the Hadron Calorimeters

November 1983

Central Hadron Cal- Paolo Giromini (Frascati)
End Wall Hadron Cal- Giorgio Bellettini, Aldo Menzione, Angelo Scribano, ... (Pisa)

Hans Kautsky (ANL)
The Development of Si Detectors at Pisa

A MULTI-ELECTRODE SILICON DETECTOR FOR HIGH ENERGY EXPERIMENTS

INFN, Sezione di Pisa, Italy and Istituto di Fisica dell’Università, Pisa, Italy

Received 19 May 1980

A detector has been developed in our laboratory for proposed use in high energy experiments. It works as a MWPC in which the ionizing medium consists of a thin layer of silicon crystal. The results of the test carried out at CERN show that the detector is ideally suited for the detection of minimum ionizing particles and can provide very high spatial resolution.
The desire to search for new particles with CDF points at the importance of augmenting the standard design with additional detectors for particle identification. With this problem in mind, the central calorimeter modules have been made removable such that, in the future, large acceptance spectrometers could be assembled on either side of the detector outside the magnet coil. Performing dE/dx measurements in the central tracking chamber in association with TOF measurements is another possibility. A very interesting possibility is also to insert miniaturized dE/dx and tracking detectors in the space (a cylindrical volume about 20 cm in diameter) that is available inside the central tracking chamber around the intersection point. We discuss here one possible system employing telescopes of multi-electrode silicon detectors (MESD). Although MESD have never been used under our expected conditions, enough is already known about this rapidly developing technique to sketch a realistic design for measuring masses of single particles with a resolution sufficient to
Run 2b: CDF SVX/ISL remains as is:
Silicon Vertex Tracker (SVT)

Luciano Ristori
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 Dottore in Fisica. His thesis was on the measurement of the total p-p cross at the Intersecting Storage Rings (CERN-R801). In 1973, 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 B 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.

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-R801. The reason for which this experiment is still known is the discovery of the rising p-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 1965 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.
Pisa/CDF Achievements/Contributions

(a personal list- apologies to those left out inadvertently)

1. The silicon vertex detector- the top quark discovery and all the B physics, including Bs mixing, would have been impossible without Aldo’s remarkable talents and the hard work of the Pisa group

2. The Level-2 silicon vertex trigger- also essential to the B-physics program- also impossible without Luciano’s talents and leadership

3. The technical and construction contribution to the calorimeters- led by Paolo Giromini (Frascati) and Aldo Menzione and Angelo Scribano(Pisa)

4. The honing of CDF into a precision device through in-situ calibration by playing the magnetic spectrometer tracking against the calorimeters (and vice versa)

5. The many young talented young physicists who played such a large role in running the detector and in the analyses in the Physics Groups

6. An ineffable contribution to the wonderful quality of collaboration- the senior people provided leadership and a very high intellectual standard that was felt by everybody

11/3/2017
Backup Slides
CDF Pisa Anecdotes

1. Aldo and ‘Overlook’ in writing the TDR
2. Aldo’s petition on smoking in the Control Room
3. Paola Gianetti’s “That’s what it’s supposed to do” to Myron Campbell after the FRED board worked 1st time
4. Dell’Orso’s rule on time estimates
5. Send a ‘control Italian’ for radiation measurement
E. Fermi in his 1951 Yale Lectures: “Perhaps future developments of the theory will enable to understand the reasons for the existence and strength of these various interactions....”

2. Have a predictive theory, experimentally tested widely and deeply, of the strong and electro-weak forces (the “Standard Model” (SU(3)xSU(2)_LxU(1))