Tevatron History

Mark Lancaster
“The main application of the work here is spiritual, if you will. It’s because, in a philosophical sense, in the tradition of Democritus, we feel we have to understand, in simplest terms, what matter is, in order to understand who we are.”

Robert R. Wilson, 1974

“Water to the Ropes”
The Tevatron’s existence was born out of the “Main Ring” which had 126 bids but in the end reduced to the usual Berkeley vs BNL vs Argonne vs 5 newbies bidding war to build a new (200 GeV beam) National Accelerator.

Wilson was maverick and cheap ($250M) and delivered 500 GeV for less cash ....

Residents feared that the influx of physicists would “disturb the moral fiber of the community”
Site selection stalled due to lack of “fair housing laws” in Illinois (and Michigan).

But in April 1968 congress passed a “fair housing bill” in part due to the political horse trading (to the Presidential level..) of $400M coming to Illinois..

Berkeley’s view on collaborating..

“Give gladly your last drop of blood as you die!”

"In any conflict between technical expediency and human rights, we shall stand firmly on the side of human rights” : R. Wilson
Superconductivity: "the elixir to rejuvenate accelerators and open new vistas to the future".

The Doubler
The Saver
The Tevatron
A different Era

“The design process, and if carried out, the construction of the Doubler, builds upon our experience at NAL. We have not proceeded on the basis of deciding what is readily practicable, designing to that, adding up the cost and attempting the result.

Instead, we have set a cost goal and keep designing, redesigning, haggling and improving until we have done what we set out to do. Occasionally, we are forced to admit that we are not clever enough to achieve our cost goal and admit defeat, but not without a struggle.”

1976
Key People: Tollestrup, Orr, Lundy, Edwards
Alvin “Pumping Iron” Tollestrup
Ageless Alvin
Rutherford Cable
densely packed/ quench resistant superconducting cable
FNAL: 95% of the niobium-titanium the world had ever produced. Robert Marsh, the head of a major alloy supplier:
"every program in superconductivity that there is today owes itself in some measure to the fact that Fermilab built the Tevatron and it worked."

Reaction at CERN: "a big room with these guys sitting up there laughing... they thought we were nuts."

Superconductors is now a $3.5B/year industry.
A potted history

1976 – 1978 magnet design
1978 – 1983 accelerator design/construction
1983 : 512 GeV p beam and pbar construction
  : 400 GeV fixed target running started
1983 : Isabelle cancelled
1984 : 800 GeV proton beam
1985 : pbar source and 1\textsuperscript{st} collisions (Oct 13) at
  1.6 TeV
1986 (Nov) : collisions at 1.8 TeV
1987/1988 : CDF takes data (best Mz in 1989 for 3 weeks!)
1992 : D0 ready
1993 : SSC cancelled
1992-1996 : Run-1
Run-2 : 1999 !!!
Fixed Target Running (in between collider running periods)

43 experiments : 1/3 of the US output in the 1990s (1 PhD from IC !)

Muon, Kaon, Hyperon, Neutrino interactions and production

E609 - The Structure of High $P_T$ Hadronic Interactions
E683 - Photoproduction of High $P_T$ Jets
E690 - Study of Charm and Bottom Production
E704 - Experiments with the Polarized Beam Facility
E705 - Charmonium and Direct $\gamma$ Production at 300 GeV/c
E706 - Direct $\gamma$ Production in Hadron Induced Collisions
E711 - Dihadron Production
E772 - The Quark-Antiquark Sea in Nuclei
Fixed Target Innovations

- 20 secs of beam every minute vs 1 sec every 15 sec (Main Ring)
- Use of micro-processors to extract beam from Tevatron (QXR system)
- Non trivial strings of s/c magnets to steer beam into different halls

E691 experiment (studying charm in late 1980s) : first Si micro-vertex detector (based on original CERN R&D) : 10k charm vs 100.
9 silicon sensors all from the UK (Micron)…..

E715 first large scale TRD achieved e/π separation of several thousand.

kTeV : CsI calorimeter with 0.75% energy resolution from 5-100 GeV photons and bespoke ASIC QIE now in Japan….

E605 : Ring Imaging Cerenkov detector
Offline computing farms e.g. E791 processed 50 Tb of data and the first large scale use of 8mm (and 2.5mm) magnetic tapes.
Fixed Target Innovations
Fixed Target Physics : 300 papers

- Establishing QCD as the theory of the strong interaction
- Neutrino/EWK measurements (NuTeV/CCFR)
- First measurement (KTeV) of direct CP violation in the K-system (1999)
- Discovery of the tau-neutrino (DONUT in 2000)

So accelerator discovered new fundamental particle score is:

FNAL : 3 : b, top, tau-neutrino
CERN : 2 : W, Z
SLAC : 2 : tau, charm
BNL : 2 : charm, muon-neutrino
DESY : 1 : gluon

So USA 6 : Europe 3 .... or 6-4 if you believe the Higgsteria
Conception to birth of CDF was less than 8 years. D0 similarly quick.

Dear Colleagues:

On November 17 a meeting was held to discuss various possibilities for the organization of work on colliding beam experiments. After considering the ideas set forth in that meeting, I am proceeding to set up a Colliding Beam Experiments Department within the Research Division.
Colliding Beams Meeting

May 6, 1977


1) R. Loveless said that Cadillac may not get in until Tuesday.
MINUTES OF THE COLLIDER DETECTOR MEETING

May 25, 1984

1. CDF has run out of money.
1. There will be a workshop to discuss upgrades to the CDF detector in early January.
MINUTES OF THE COLLIDER DETECTOR MEETING

December 7, 1984

1. While in B0 people should watch out for falling objects. More formal safety procedures are under consideration.
ISR (pp : 1982)

LHC takes record Apr 2011
Base – Design – Optimistic

- Tevatron Delivered
- CDF (good)

Integrated Luminosity (fb⁻¹)


Luminosity Rates: 20mA/hr, 25mA/hr, 30mA/hr
Factor of 10 improvement in luminosity was achieved over 5 years by:

**Antiproton production**: increased stacking rate and rate of transfer into recycler (less time in accumulator). The recycler in the end didn’t recycle!

FNAL produces $10^{15}$ anti-protons/year at a cost of approx $30M.

Time = $O(1 \text{ billion})$ years.
Cost = 1000x world’s GDP
Slip-stacking protons: doubled # proton bunches in the main-injector for delivery onto anti-proton target.

Recycler e-cooling: stored and cooled pbars. Electron-cooling used for first time at high E (x 3 luminosity).

Tevatron beam position monitors: upgraded electronics/DAQ to 21st century & a culture that monitoring was important!

Premature ("parasitic") collisions: prevented by electrostatic separators to further separate beams as they orbit.

Luminosity optimisation: increasing initial luminosity is not the only way to maximise accumulated luminosity.
Detectors aged like fine wine with some luck
In hindsight – not upgrading the silicon was a good decision!