Impact of the Tevatron on Technology and Innovation

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The Science & Technology Facilities Council

- JCMT Telescope
- ESO: Alma Array
- ESA: Top Sat
- CERN: LHC
- Research in UK universities, RAL and DL
- ILL and ESRF

Science & Technology Facilities Council
Why do governments support science?

- Science
- Understanding of the Universe
- Government
- Technological innovation, skills
- $
Impacts

• Can we try to measure the payoff from the investment made in the Tevatron?
  – At least in the UK, case studies and examples are not enough: quantitative arguments are needed

• Focus on three particular areas
  – PhD students
  – Impact on SC magnet technology
  – Impact on Computing technology
Health Warnings

- Hand Waving
- Back of envelopes
Debits
What did the Tevatron cost?

• Tevatron accelerator

• Main Injector project

• Detectors and upgrades
  – Guess: 2 x $500M (collider detectors) + $300M (FT)

• Operations
  – Say 20 years at $100M/year = $2 billion

• Total cost = $4 billion
PhD Student Training

• Value of a PhD student
  – $2.2M (US Census Bureau, 2002) = $2.8M (2012 $)

• Number of students trained at the Tevatron
  – 904 (CDF + DØ)
  – 492 (Fixed Target)
  – 18 (Smaller Collider experiments)
  – 1414 total

• Financial Impact = $3.96 billion
Superconducting Magnets

- Tevatron was the first installation of mass-produced superconducting magnets on an industrial scale
Superconducting Magnets

- National medal of Technology (1989)

- Historic engineering landmark (1993)
Superconducting Magnets

- Current value of SC Magnet Industry
  - $1.5 Billion p.a.

- Value of MRI industry (major customer for SC magnets)
  - $5 Billion p.a.

- This industry would probably have succeeded anyway – what we can realistically claim is that the large scale investment in this technology at the Tevatron significantly accelerated its development
  - Guess – one to two years faster than otherwise?

- Financial Impact = $5-10 billion
Computing

- Increases in luminosity – driven by physics – created the challenge of processing ever larger datasets
Computing – Linux PC farms

- MicroVAXes
- Unix Farms in Run I
- Computing requirements for Run II led to pioneering adoption of PC Farms running Linux for large scale data handling
  - Fermilab PC Farm Exhibit in Supercomputing Conference SC 1997
  - Linux Torvalds and Red Hat CEO Robert Young visit Fermilab; Fermi Linux released 1998
- More than 90% of the world's supercomputers now use Linux
Distributed Computing

- Concept of Computing as a Utility
- Grid resources used for Monte Carlo generation and large scale reprocessing of Run II data
  - DØ data shipped over the internet to Canada, France, Germany, Netherlands UK, and US universities, and processed data shipped back
"In the past, particle physics collaborations have used remote computing sites to carry out Monte Carlo simulations. We are one of the first experiments to process real data at remote sites. The effort has opened up new perspectives on data resources. The evaluation of our experience should provide valuable insights into the Grid development."
— Dennis Wilder, University of Wisconsin, USA

"The CDF data are a real challenge. We need to get this physics need to out."
— Dylan O’Neil, Simon Fraser University, Canada

"The machines are an integral part of the Grid. For example, the data is stored on tape or disk, which is located at Fermilab or at CERN."
— Mark Caiazza, Fermilab, USA

"We’ve participated in large-scale efforts to use remote computing sites to carry out Monte Carlo simulations. We have been able to show that we can really use the Grid Computing Grid for DZero processing. This has been a great success for the DZero collaboration."
— Paolo Gervasi, INFN, Italy

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— Dennis Wilder, University of Wisconsin, USA

"You can’t make the Grid work without motivation. It’s one thing to have a vision, and it’s another thing to stay up three in the morning to make things work because they need to get done. DZero is a real application. We need to get this physics need to out."
— Dylan O’Neil, Simon Fraser University, Canada
Cloud Computing

• Remotely accessible Linux farms are now a commercial service
  – Amazon etc.
Cloud Computing

- Value of Cloud Computing Industry today
  - $150 Billion p.a. (Gartner)

- This industry would definitely have succeeded anyway – but let’s assume that the stimulus given by the Tevatron experiments, work with Red Hat etc. gave just a 3 month speed-up to its development

- Financial Impact = $40 billion
Balance sheet

- 20 year investment in Tevatron ~ $4B
- Students $4B
- Magnets and MRI $5-10B ~ $50B total
- Computing $40B

Very rough calculation – but confirms our gut feeling that investment in fundamental science pays off

I think there is an opportunity for someone to repeat this exercise more rigorously

cf. STFC study of SRS Impact

www.stfc.ac.uk/About+STFC/19005.aspx
Global collaboration in HEP

• Tevatron experiments were also pioneers in establishing a genuine partnership between US, Japan and Europe

• We need this approach again now
  – CERN Council European Strategy Process
  – US community process
  – Japanese roadmap under development

• Breakthrough discoveries coming
  – opportunity to shape a science-driven strategy
Global collaboration in HEP

• Needs to be a **global** strategy
  – Complementary pathways through a common landscape
  – CERN’s focus will be on energy frontier at LHC
  – Main questions: how (and where) to progress neutrino physics, precision measurements and astroparticle physics?

• I hope other regions will see the scientific logic and political importance of supporting a strong US program in these areas
Conclusions

• Especially in tough economic times, the non-science impacts of major projects are an important part of the case we must make
  – “What will it do for jobs and economic growth?”

• Impacts tend to be long term and unpredictable – so one way to make the case for future investments is to look back at the benefits from past examples

• Here I’ve tried to make a plausible case that the Tevatron has returned its investment roughly tenfold over its life
  – A more detailed study along these lines may well be worthwhile