Run IIB at the Tevatron

CDF/D-Zero DOE Technical, Cost and Schedule Review

Hugh Montgomery

September 24, 2002

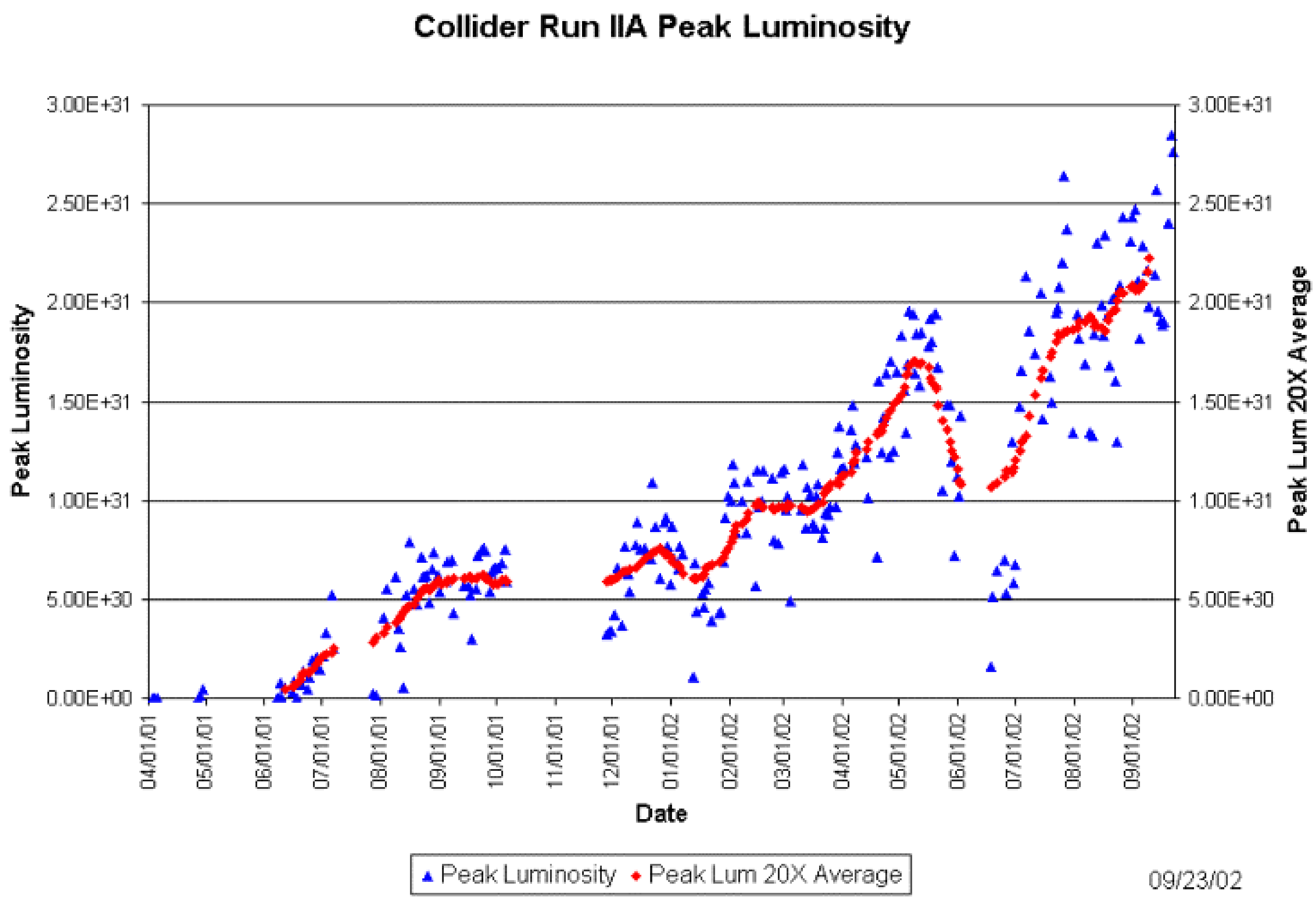
Tevatron Collider

- **Proton-antiproton Collisions**
- **2 TeV Energy**
  - Up from 1.8 TeV
  - Rates by 40%
- **Highest Energy in World**

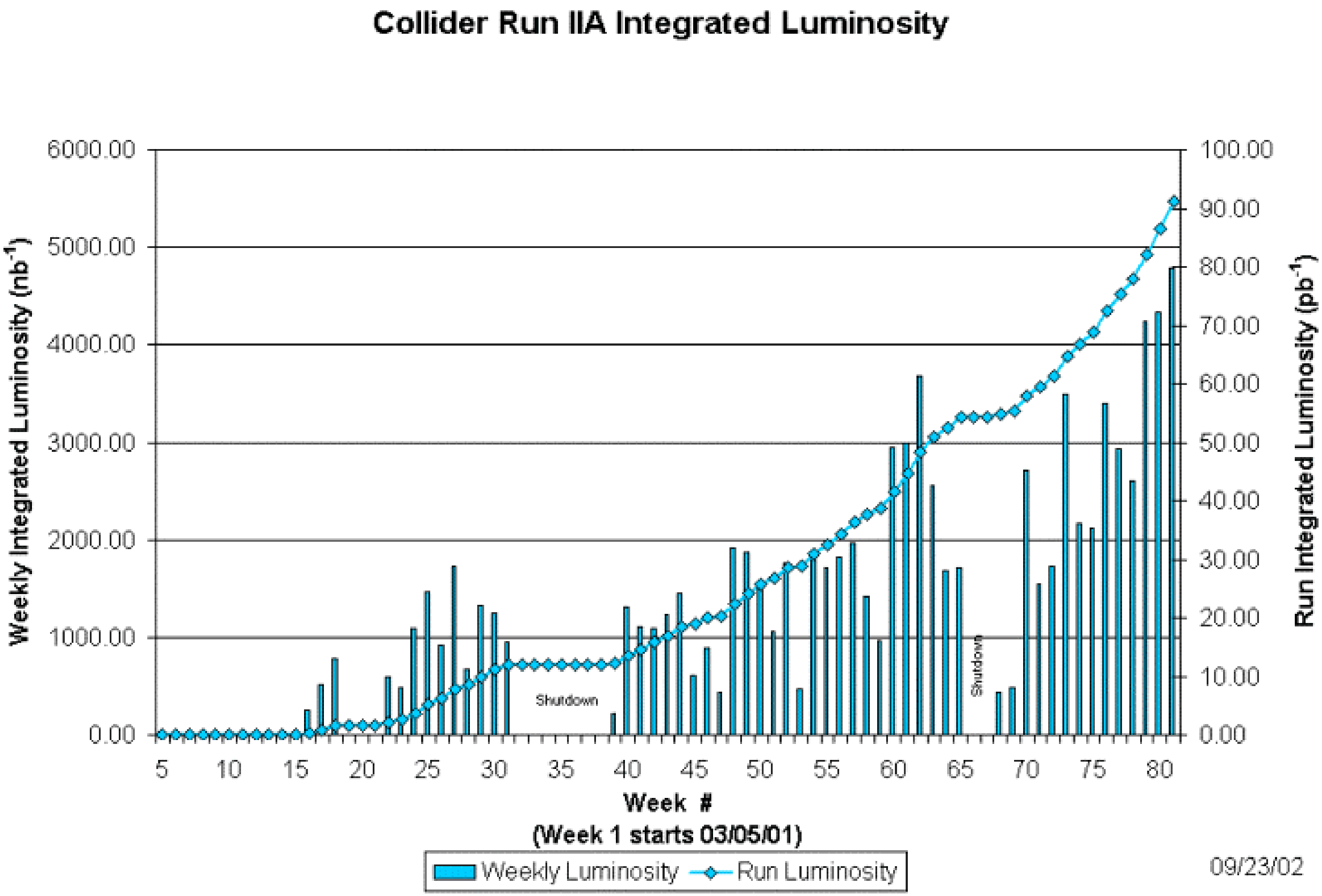
Status

- Two first class detectors
  - the most complex systems so far
  - silicon: more than 1.3 Million channels!
- Data
  - Acquired -- online data acquisition systems working well
  - Analyzed – large scale data analysis is operational
- Initial Results
  - Were presented some weeks ago at, Amsterdam.
- The energy frontier is HERE!
- Physics increases continuously with Luminosity

Current Accelerator Performance



Current Accelerator Performance



Run IIA Accelerator Projections

- Near Term
  - MI Data Sheet performance: 5. 10^{31} cm^{-2}. sec^{-1}
- Late 2003
  - without recycling: 6-8. 10^{31} cm^{-2}. sec^{-1}
- 2004
  - With recycling: 1-2 10^{32} cm^{-2}. sec^{-1}
- Integrated Luminosity ~1-2 fb^{-1} by end of 2004 (20 times Run I)

Limit of performance of present (Run IIA) detectors

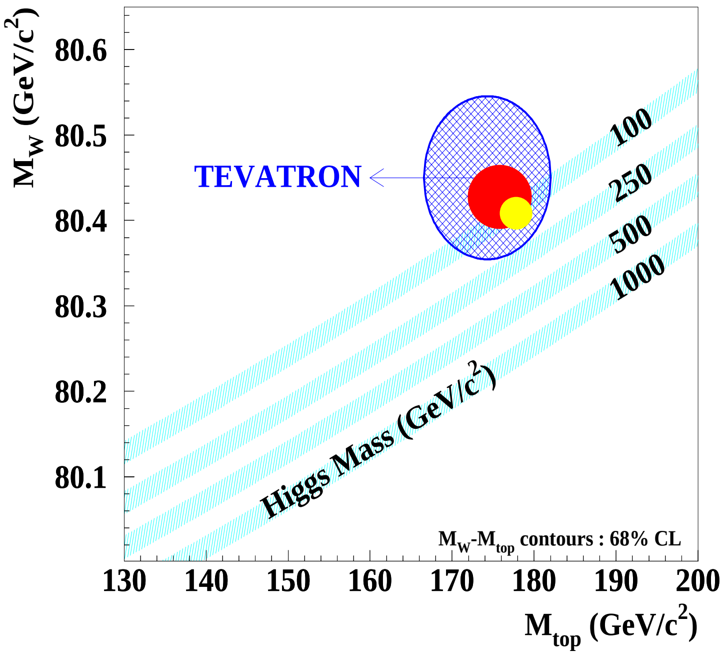
Physics: The Big Questions

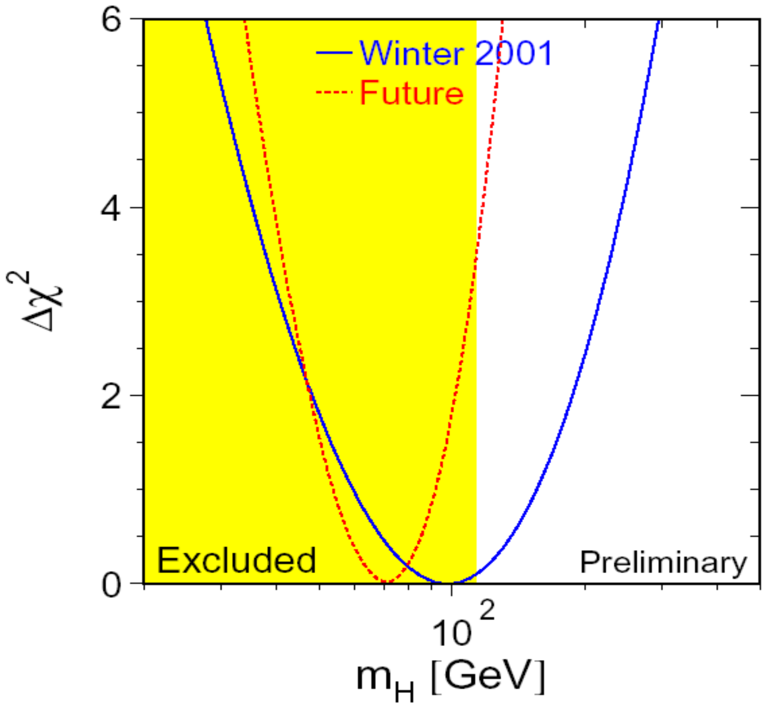
- The origin of Mass?
  - Masses of the electroweak bosons
  - Mass of the top quark
  - The Higgs Particle?
    - Constraining its Mass
    - Direct Searches

- The structure of space-time?
  - Supersymmetry
  - Extra dimensions

- Phenomena beyond our current thinking?

Higgs mass constraints



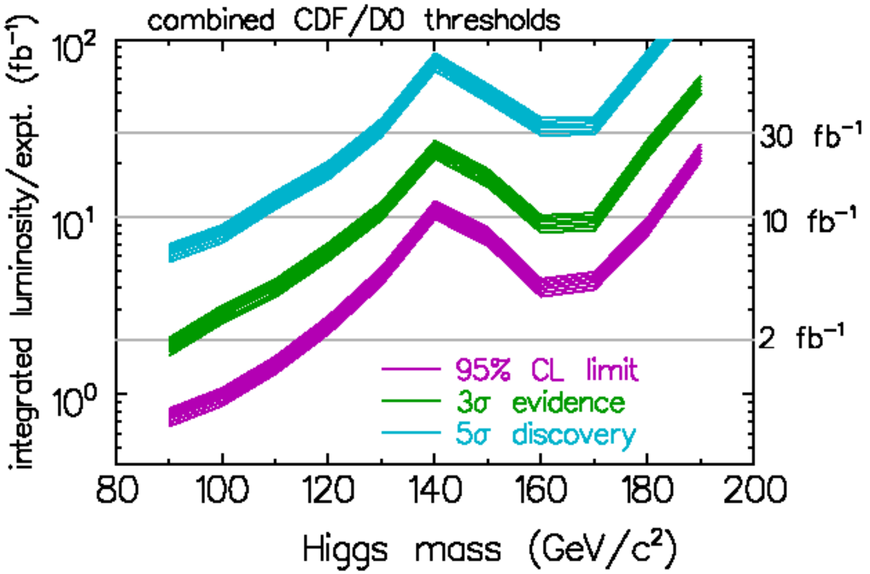


● @ ~2 fb^{-1}

● @ ~10-15 fb^{-1}

Higgs Search

- The plot at right shows the integrated luminosity needed to reach 3 stages for each value of the Higgs mass.
  - 95% confidence level upper limit if no signal is seen
  - a 3σ signal above background, conventionally called "Evidence"
  - a 5σ signal above background, conventionally called "Discovery"



- For a Higgs mass of ~115 GeV, the value of the LEP "hint":
  - upper limit @ ~2 fb^{-1}
  - evidence @ ~5 fb^{-1}
  - discovery @ ~15 fb^{-1}

Sensitivity at every scale of Luminosity!

Higher Luminosity?

- Need Accelerator complex capable of delivering:
  - Integrated Luminosity > 10 fb^{-1}.
  - This requires effective instantaneous luminosity > 2 10^{32} cm^{-2}. sec^{-1}
- Need Detectors capable of handling:
  - Integrated Luminosity > 10 fb^{-1}.
  - Detectors capable of handling several interactions per crossing
- Implications:
  - Replace silicon detectors
  - Some other enhancements to maintain capability

132/396 nsec Bunch Spacing

- Major Performance Driver for Detectors is the number of interactions per crossing.
- Planning for Tevatron and detectors had assumed 132 nsec for luminosities in excess of ~1 10^{32} cm^{-2}. sec^{-1}
- Run IIA designs were for 132 nsec with 1 10^{32} cm^{-2}. sec^{-1}
- Initial RunIIB designs assumed 132 nsec with 5 10^{32} cm^{-2}. sec^{-1}

132/396 nsec Bunch Spacing

- Recent study (Chaired by Finley, with Spokes of CDF and D0 on Committee):
  - laid out the issues
  - articulated a number of concerns with respect to operation with 132 nsec.
  - For example:
    - **132 nsec spacing demands a crossing angle which reduces the luminosity by factor 2 from that given by the other machine parameters.**
    - **As a result of experience with 36 bunches in RunIIA there is concern about beam-beam interaction effects and the consequent dynamic aperture**
    - **With approximately three times the bunches, the proton load and hence the total proton load increases by the same factor for a given luminosity.**
      - **Backgrounds up**
      - **Instabilities in machine**
    - **A machine with three times the numbers of bunches would likely take significant time to (re)commission.**

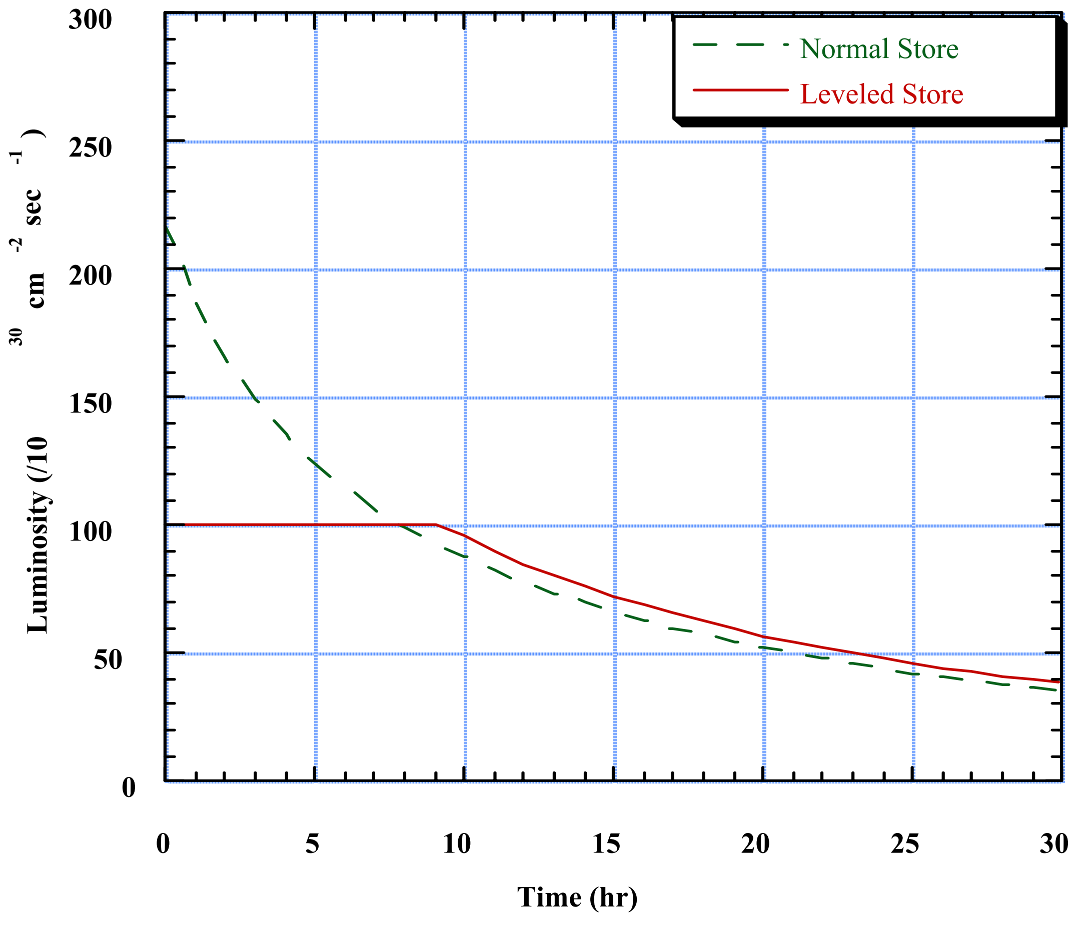
Bunch Spacing Strategy

- Baseline is 396 nsec.
  - moderates accelerator issues
  - improves the prospects for high luminosity
- Mitigate the number of interactions per crossing with luminosity leveling, with modest (15%) penalty in integrated luminosity.
- Since Luminosity Leveling has not been demonstrated:
  - do nothing to exclude 132 nsec in accelerator complex
  - retain 132 nsec capability in detectors

Instantaneous Luminosity

- **Baseline Parameters (to be handled by detectors)**
  - **Assumes Luminosity Levelling**
  - **Bunch Spacing --- 396 nsec**
  - **Peak Instantaneous Luminosity --- 2 10^{32} cm^{-2}. sec^{-1}**
  - **Mean of 5 to 7 Interactions per crossing**
    - **Approx same as initial design parameters 132 nsec and 5 10^{32} cm^{-2}. sec^{-1}**
  - **"Peak" is sustained for significant fraction of store**
  - **" With some margin"**
- **Upper Range Parameters (to be handled by detectors)**
  - **Assumes no luminosity Levelling**
  - **Bunch Spacing --- 396 nsec**
  - **Peak Instantaneous Luminosity --- 4 10^{32} cm^{-2}. sec^{-1}**
  - **Mean of 10 to14 Interactions per crossing**
  - **"Peak" only for small fraction of store**
  - **" With reduced margin"**

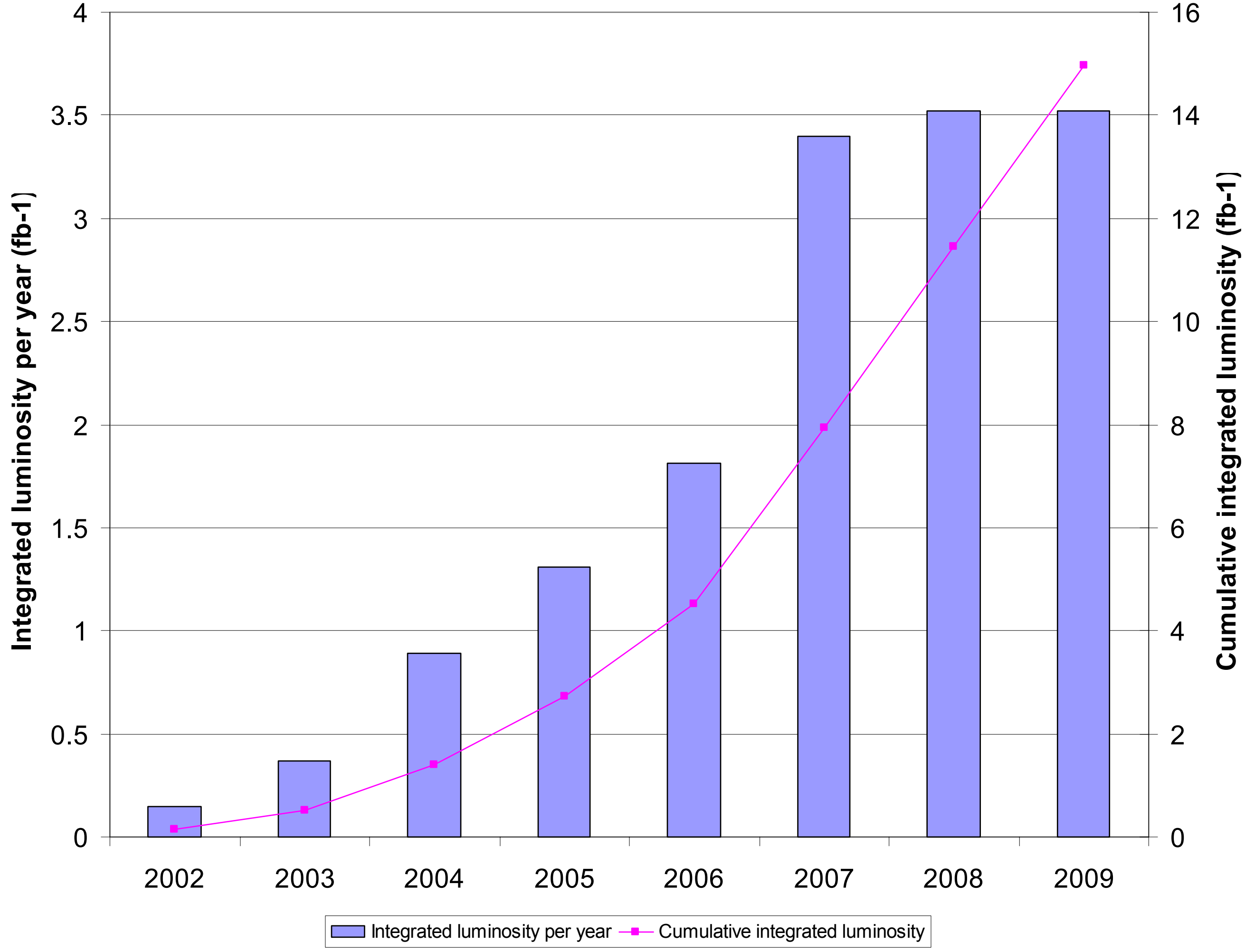
Luminosity during Store



Integrated Luminosity

- Instantaneous luminosity of 4 10^{32} cm^{-2}. sec^{-1} yields about 4 fb^{-1} per year.
- Instantaneous luminosity of 2 10^{32} cm^{-2}. sec^{-1} with luminosity levelling yields about 3-3.4 fb^{-1} per year, about 75 - 85% of the unlevelled luminosity.
- Such performance would put the total Run II luminosity into the range 10-15 fb^{-1}
- Detectors should be radiation hard at this level.

Luminosity Projection.



Installation

- Detailed strategy and timing of installation of the upgraded silicon detectors will depend on the extant operations of both the Run IIA detectors and accelerator complex.

- In project terms we have decoupled:
  - Detector construction and assembly
  - Installation
- The projects you are considering DO NOT contain the installation.
- Nevertheless, the installations have been fully planned, with designs, costs and schedules which are available.

Schedule

- Proposed Baseline Schedule is represented by the "Directors" Milestones.
  - Project developed with no explicit or implicit contingency, with which the Project Managers will work.
  - Director's Baseline Milestones constructed by adding explicit schedule contingency distributed through the schedules/milestones.
  - Further contingency inserted to set DOE-CD4
- Project Completions from the schedules without contingency are May/July 2005.
- Baseline Project Completions including contingency are November/December 2005
- Proposed CD-4 is November 2006.

Costs/Manpower

- Equipment cost of each project to DOE is approximately $25M

- Staffing
  - Technical effort estimates from the projects have been checked against Run I estimates.
  - Approximately half of the required increase in Silicon Detector Facility effort has been identified by name.
  - The balance of the required increase in the SiDet Facility effort has been generally identified.

- The Laboratory plan for FY2003 accommodates both M&S and effort estimates.

CDF Project Funding Profile

Cost (AY $K)	2002	2003	2004	2005	2006	Totals
Silicon	$ 709	$ 4,843	$ 6,670	$ 5,056	$ 1,702	$ 18,981
Calorimeter	$ 63	$ 830	$ 307	$ 154	$ 86	$ 1,439
DAQ/Trigger	$ 141	$ 887	$ 2,784	$ 2,698	$ 663	$ 7,173
Administration	$ 163	$ 407	$ 437	$ 601	$ 150	$ 1,758
Total Equ. Cost	$ 1,076	$ 6,967	$ 10,197	$ 8,509	$ 2,602	$ 29,352
R&D Cost	$ 1,179	$ 2,008	$ 242	$ 17	$ -	$ 3,446
Total Project Cost	$ 2,255	$ 8,975	$ 10,439	$ 8,527	$ 2,602	$ 32,798
Funding (AY $K)						
DOE - Equip. Total	$ 3,500	$ 3,469	$ 9,401	$ 8,508	$ 2,602	$ 27,480
DOE - R&D	$ 1,670	$ 480	$ -	$ -	$ -	$ 2,150
Japan	$ 235	$ 1,171	$ 786	$ -	$ -	$ 2,193
Italy	$ 65	$ 374	$ 168	$ -	$ -	$ 606
University base	$ 19	$ 248	$ 83	$ 19	$ -	$ 369
Total Funding	$ 5,488	$ 5,742	$ 10,439	$ 8,527	$ 2,602	$ 32,798

D-Zero Project Funding Profile

Total Project Cost In AY k$	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
Silicon (incl. Cont + G&A)	17	1326	8963	6382	3428	354	20470
Trigger (incl. Cont + G&A)	0	453	1423	2142	676	0	4693
Online (incl. Cont + G&A)	0	0	84	418	1002	0	1503
Administration (incl. Cont + G&A)	0	0	507	527	770	0	1803
Total Project	17	1778	10977	9468	5876	354	28470
R&D (incl. Cont + G&A)	0	1376	1123	0	0	0	2499
Total Project Cost	17	3154	12100	9468	5876	354	30970
Project Funding in AY k$	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
DOE EQ	0	3500	4131	8588	5832	2354	24406
DOE R&D	0	1499	1000	0	0	0	2499
In Kind - Foreign	0	258	267	70	1	0	597
In Kind - MRI silicon	17	1326	811	306	0	0	2460
In Kind - MRI trigger	0	0	114	474	0	0	588
In Kind - US base	0	194	153	30	43	0	420
Total In-Kind contributions	17	1778	1345	880	44	0	4065
Forward Funding	0	0	2000	0	0	-2000	0
Total Funding	17	6777	8477	9468	5876	354	30970

Previous Reviews

- **PAC Fall 2000**
- **CD-0 May 2001**
- **PAC Fall 2001**
- **Director's Technical (Pilcher) Fall 2001**
- **Director's Technical (Pilcher) Spring 2002**
- **Director's Management, Cost & Schedule (Temple) Spring 2002**
- **PAC at June 2002 meeting**
  - **Physics is compelling.**
    - **"Even non-observation of the Higgs in Run IIb would be a result of extreme importance. If the Higgs is not observed, 95% CL exclusion over the mass range required by the electroweak precision data would put the Standard Model in crisis."**
  - **Upgrades are needed.**
    - **"Maintaining the capabilities of the CDF and D0 detectors throughout the run is … essential for the success of Run II."**
  - **"The Committee recommends Stage I approval for the CDF and D0 Run IIb upgrade projects."**

- **Director's Tech, Management, Cost & Schedule (Temple/Pilcher) August 2002.**

Summary

- The Tevatron Collider with the CDF and D-Zero Experiments is an important component of the Fermilab program.
- The exciting prospects of new physics in the upcoming years is well documented.
- The two projects are the result of considerable discussion and exchange between the two collaborations and the laboratory.
- We respectfully submit them for your review.