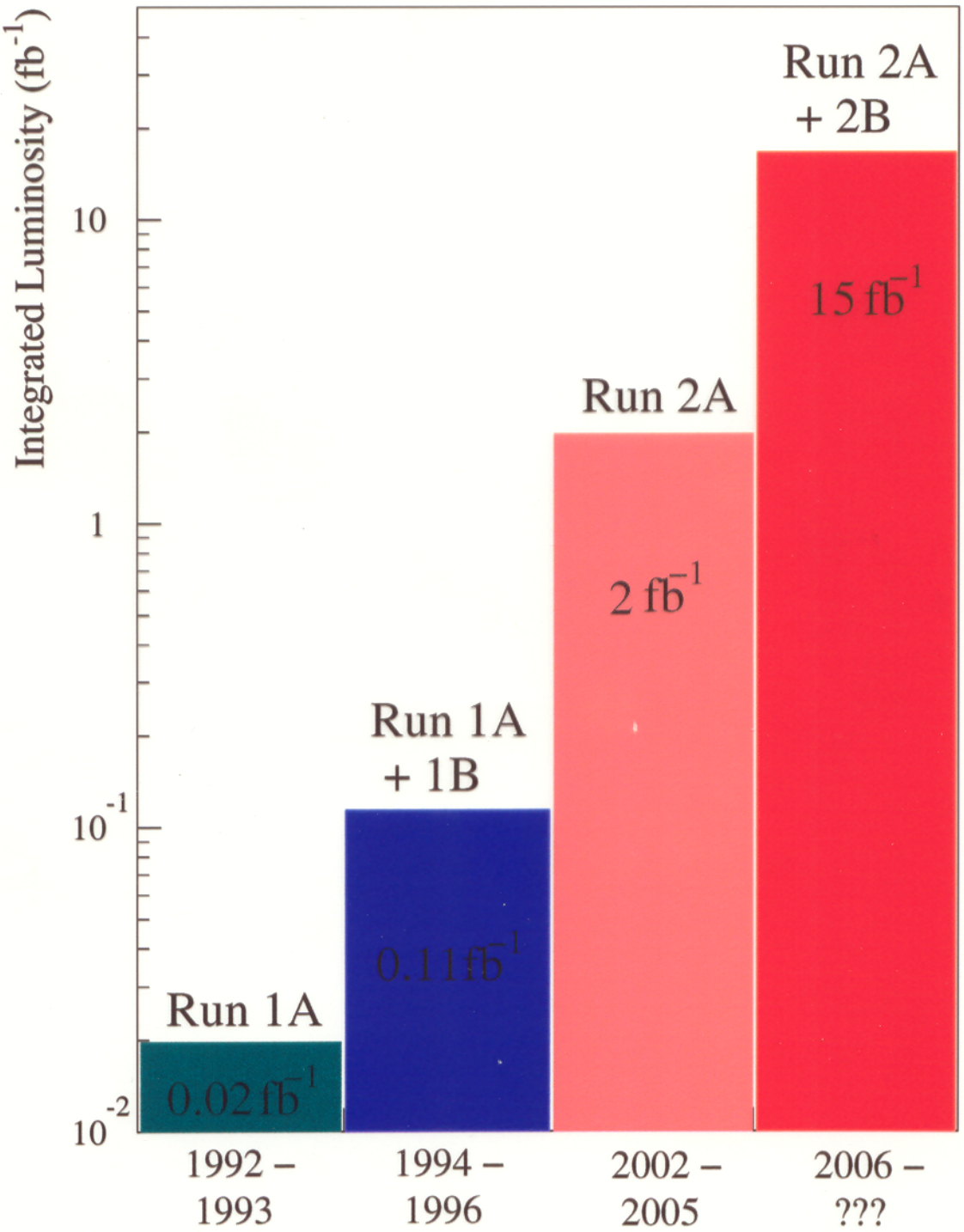
Silicon Detector Upgrades for the Tevatron Run 2

Mark Kruse
Duke University

ICHEP02, Amsterdam, 25 July 2002

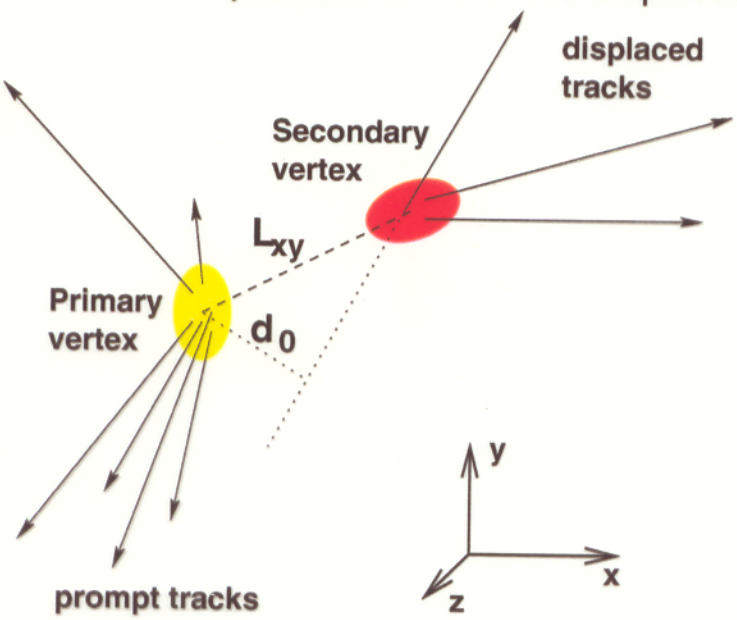
- Introduction and Motivation
- Mechanical layouts
- DAQ components and status
- Conclusions

Tevatron "Run 2"



Introduction

- Silicon Vertex detectors provide the most sensitive means for identifying b-quark jets:
  b-quarks have a "long" lifetime : $\tau(b) \sim 1.5\,\text{ps}$ ($c\tau \sim 450\,\mu\text{m}$)
  $\Longrightarrow$ B hadrons travel $L_{xy} \sim 3\,\text{mm}$ before decay
  $\Longrightarrow$ possible to find the displaced b decay vertex



- E.g. The CDF Run 1 SVX
- Used SVX tracking
- Tagged if $L_{xy}/\sigma_{L_{xy}} > 3.0$ (typically $\sigma_{L_{xy}} \sim 150\,\mu\text{m}$)

$\epsilon_b \sim 25\%$
$\epsilon(\text{top event}) \sim 50\%$
$\epsilon_c \sim 4\%$
$\epsilon_{fake} \sim 0.2\%$ per jet

- Many important physics signatures at the Tevatron contain b quarks: searches for light Higgs bosons, top quark studies, searches for new physics,....
- With good secondary vertexing capabilities discovery of a light SM Higgs could be within the reach of DØ and CDF in Run 2b.
- By the end of Run 2b the Tevatron integrated luminosity is projected to be about $15\,\text{fb}^{-1}$, beyond the design goals of the Run 2a silicon systems....

$\Longrightarrow$ Run 2b silicon upgrades

General Philosophy

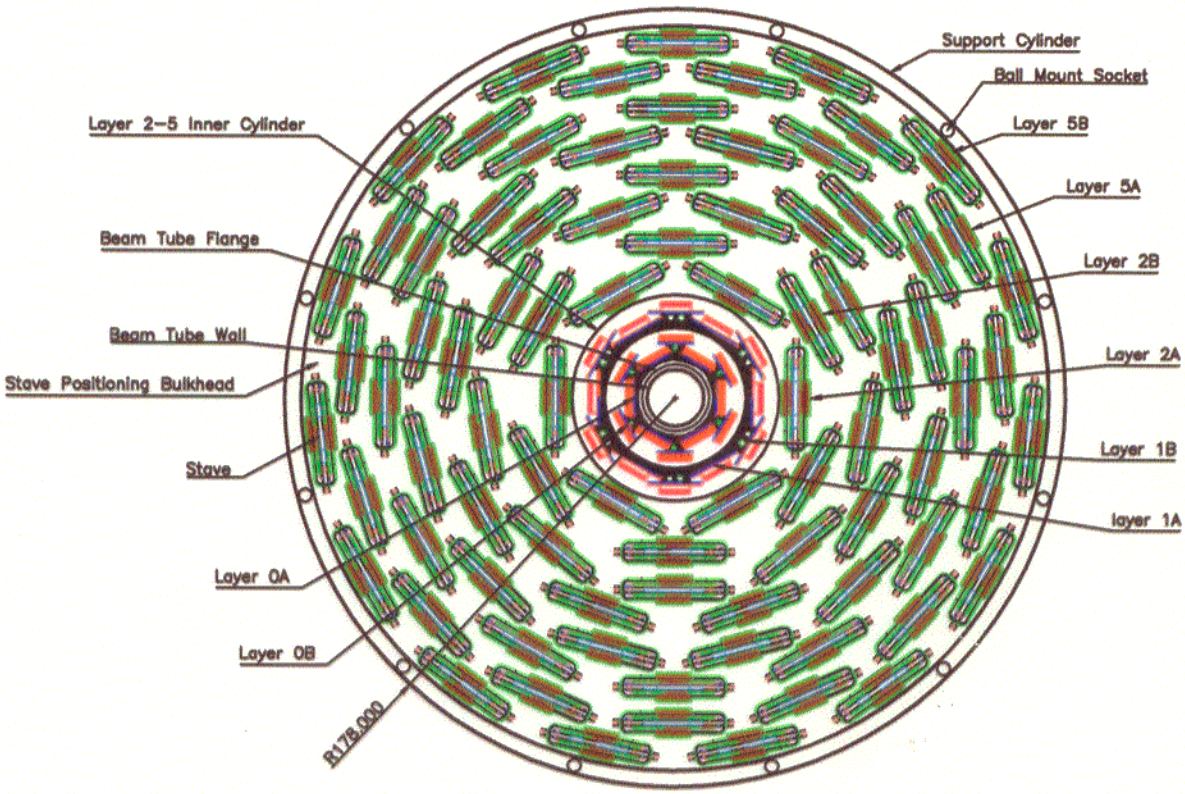
- Greater radiation tolerance - need to operate for at least $15\,\mathrm{fb}^{-1}$
- Easy to build - new detectors need to be ready in 2005
- Retain or improve the tracking capabilities of Run 2a
- Maintain as much as possible of existing infrastructures (DAQ, external cooling, space/support) present in DØ and CDF
- Given the infrastructure differences exploit the areas where we can benefit from common design features (e.g. readout chips, sensor specs)

Main features relative to Run 2a

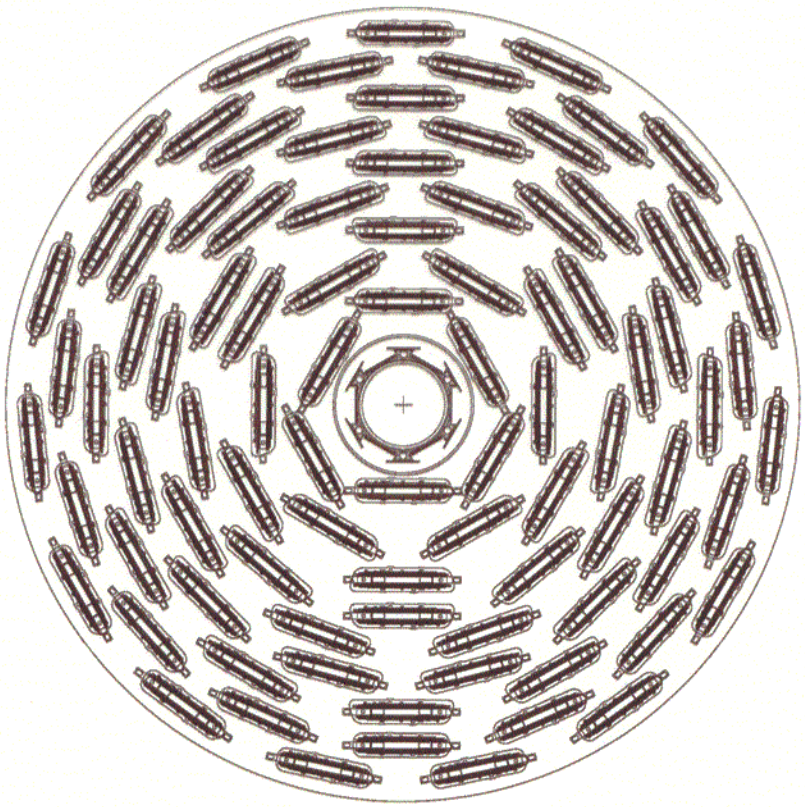
- CDF will replace SVXII + L00 (ISL stays)
  DØ will have a full silicon tracker replacement
- Singled sided silicon sensors only, operated at high voltage. No 90° stereo
- 2 barrels:
  CDF: each 66 cm long, 5 "layers" of 4-chip wide "staves" plus layer 0
  DØ: each 60 cm long, 4 "layers" of 5-chip wide "staves" plus L0+L1
- Layers cover greater range of radii than in Run 2a (most electronics pushed out to the ends)
- New DAQ features: new readout chip, and other frontend readout components.

Layouts - transverse view

DØ

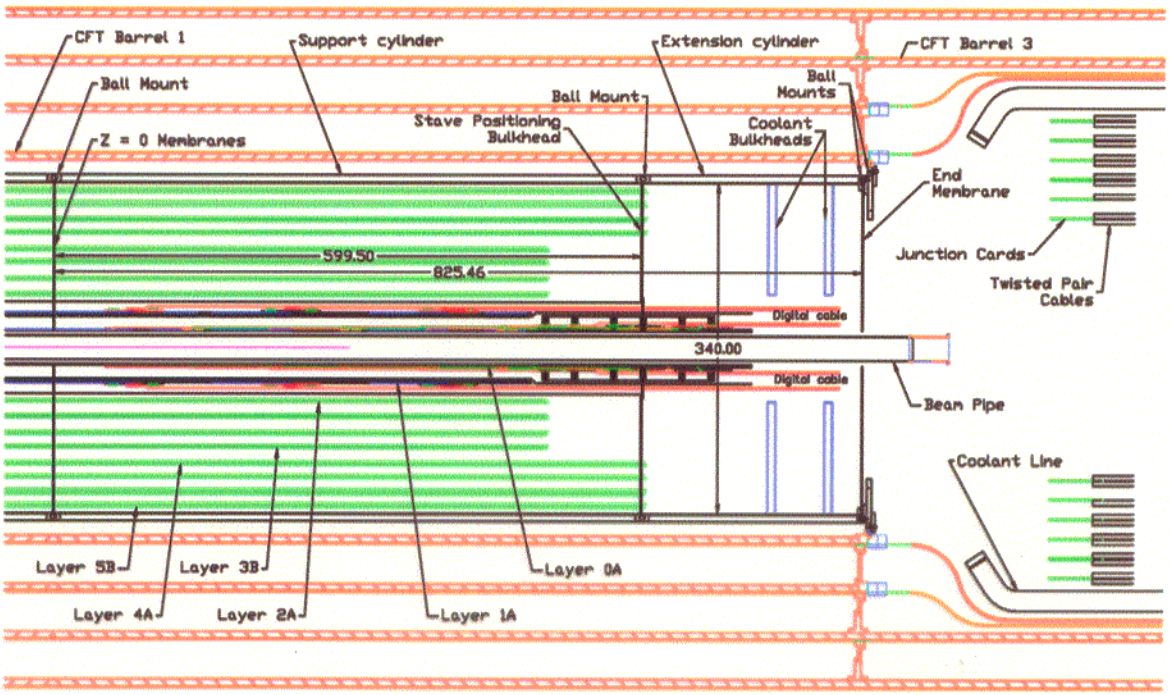


CDF

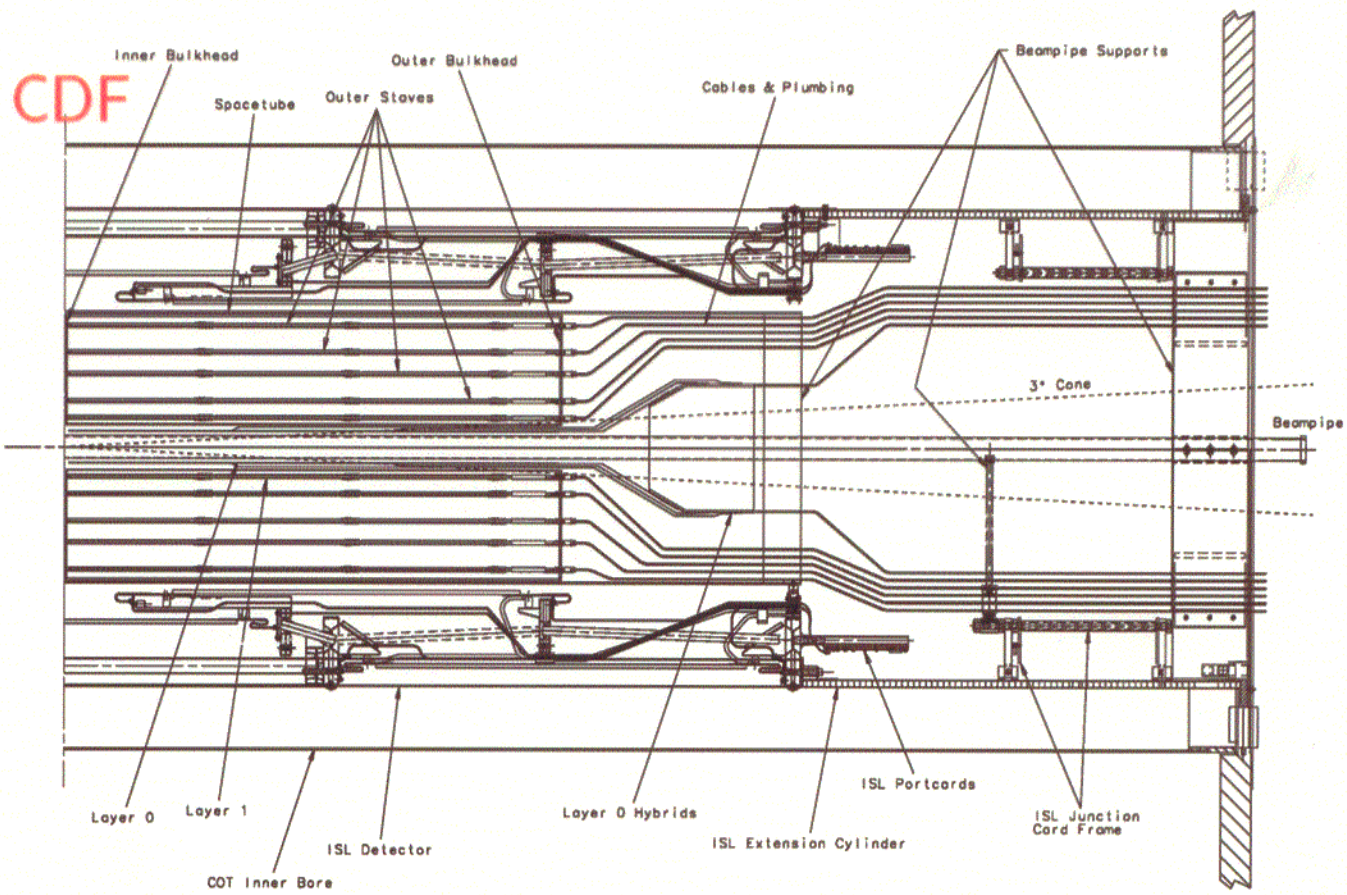


Layouts - side view

DØ



CDF



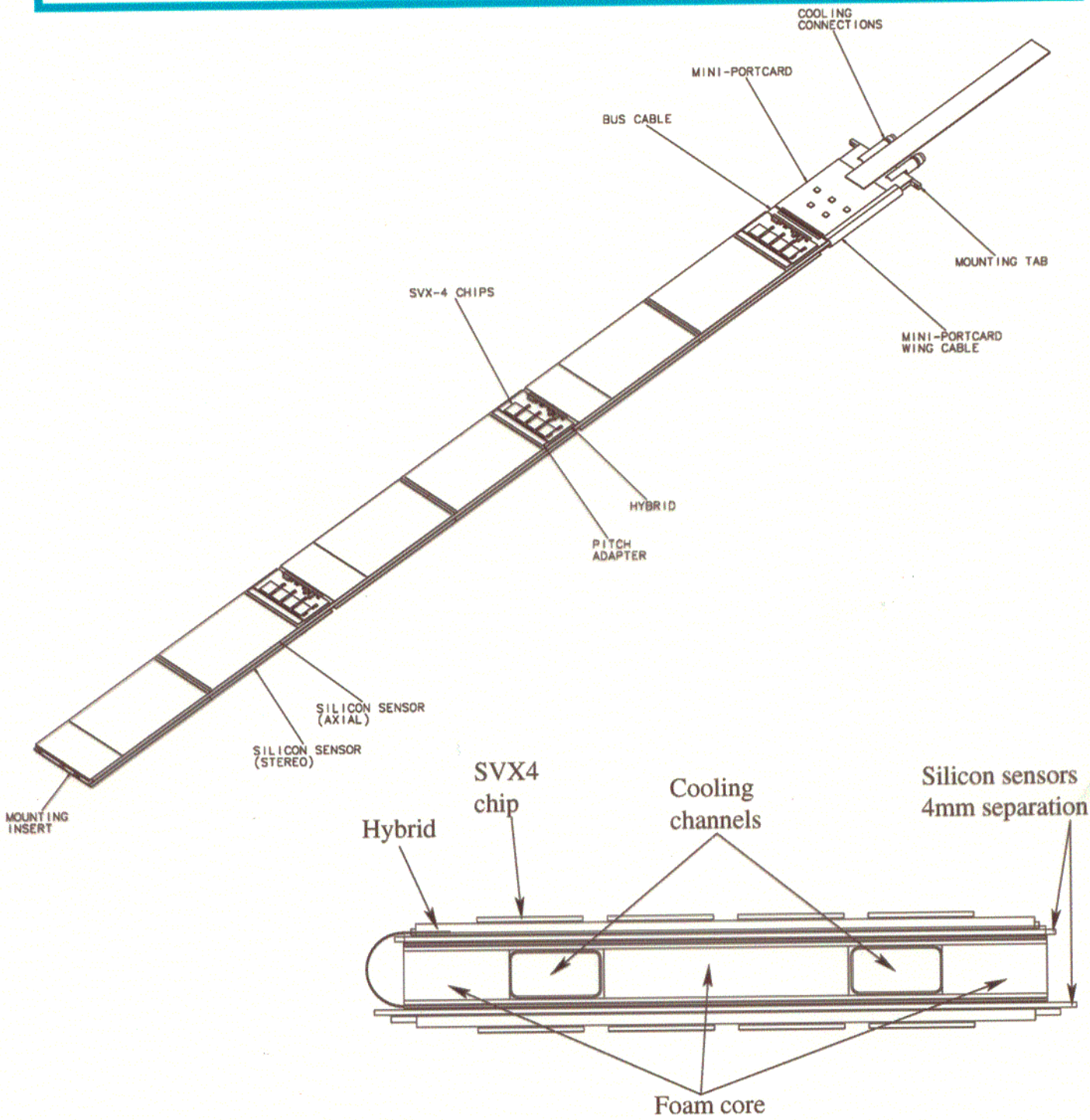
Layouts - main features

DØ :
- Same stave design for outer layers (2-5)
- Inner layers (0-1) have different design
- 3 types of sensors (axial/stereo, L0, L1)
- 4 types of hybrids (2 chips for L0, 6-chips double-ended for L1, 10-chips double-ended for layers 2-5 (axial and stereo being different))

CDF :
- Same stave design for outer layers (1-5)
- L0 $\approx$ L00
- 3 types of sensors (axial, stereo and L0)
- 2 types of hybrids (4-chips for outer layers, 2-chips for L0)

	DØ		CDF	
Layer	radius(cm)	type	radius(cm)	type
0A	1.9	axial	2.1	axial
0B	2.5	axial	2.5	axial
1A	3.5	axial	3.5	axial
1B	3.9	axial	4.4	axial
2A	5.3	axial	6.0	axial
2B	6.9	2.5°	7.5	1.2°
3A	8.6	axial	9.5	axial
3B	10.0	2.5°	10.9	1.2°
4A	11.7	axial	12.4	axial
4B	13.1	1.2°	13.8	1.2°
5A	14.7	axial	14.8	axial
5B	16.1	1.2°	16.2	axial

CDF Stave Design



- Same stave design for all outer layers (1 through 5)
- Material/stave = 1.8% RL = 124g

DØ Staves

L4-5

L2-3

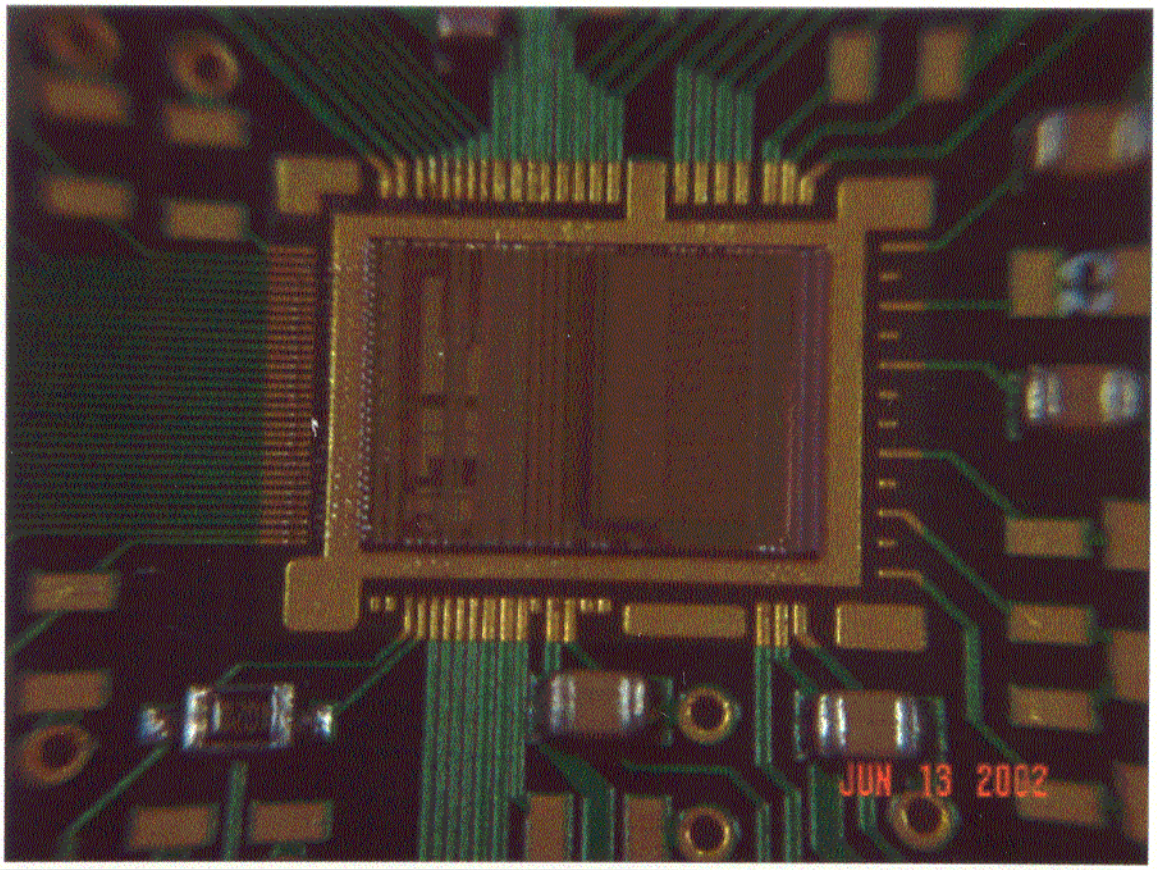
L1

Silicon Status

- Sensor pitches (strip/readout):
  DØ : layers 2-5, 30/60 μm ; layer 1, 29/58 μm, layer 0 25/50 μm
  CDF : layers 1-5, 37.5/75 μm ; layer 0, 25/50 μm
- CDF prototype sensors arrived at Tsukuba this month
- Initial test results are very encouraging - leakage currents are $\sim 0.15\mu A$ all the way to 1000 volts (the spec on leakage current was $0.2\mu A$)
- DØ ordered similar sensors from Hamamatsu. Also, DØ have L0 and L1 sensors from ELMA in hand and which look good
- We are proceeding to build prototype modules and staves in the next couple of months

The SVX4 readout chip

- DØ and CDF are using the same SVX4 readout chip designed by Fermilab/LBL/Padova
- Submicron processing ($0.25\mu m$) leads to high radiation tolerance (also, operating voltage has halved to 2.5V)
- Based on previous incarnations with analog front-end and digital back-end, 128 channels wide, 42 cell pipeline
- Status:
  - ⇒ Prototypes received in June 2002 and are fully functional
  - ⇒ Tests going well (short list of fixes compiled)
  - ⇒ No noise tests yet, but if OK, next round could be production chips

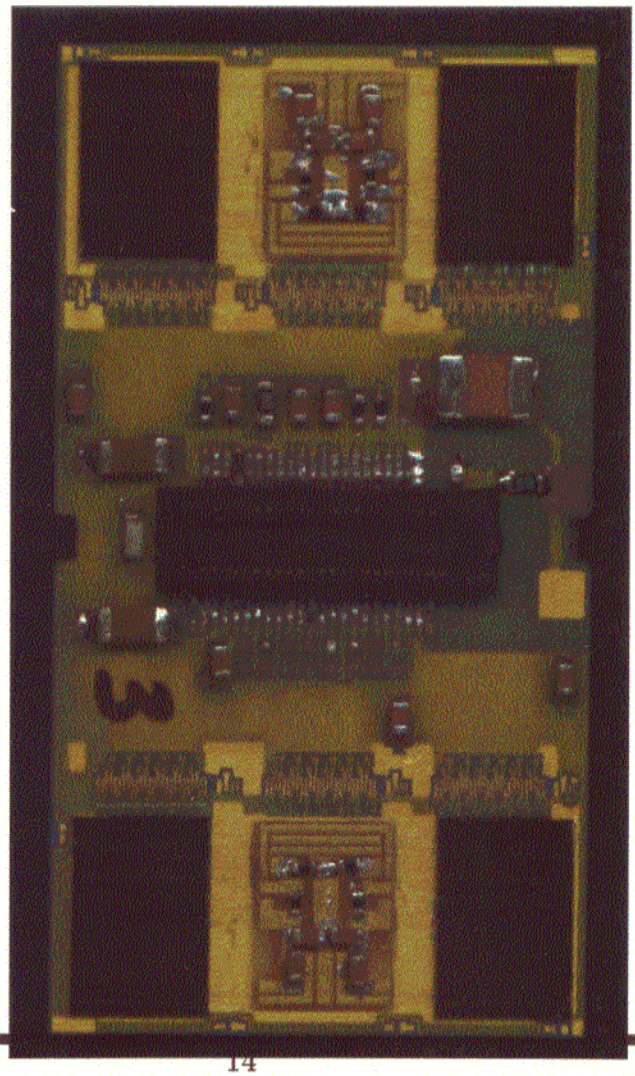


CDF Hybrids

- Circuit boards which service the front end of the SVX4 chips, and are mounted on the staves
- As with the Run 2a L00, the L0 hybrid (2-chips) will be placed outside the tracking volume and will have an alumina substrate
- The outer layer hybrids (4-chips) are smaller than in Run 2a, and have a BeO substrate, significantly reducing their impact in the tracking volume
- A total of 1080 4-chip hybrids are needed (1 for each 2-sensor module), and 72 L0 2-chip hybrids. The total number of SVX4 chips required is 4464
- Prototypes have just arrived at LBL. Chips are ready to put on them. They will be assembled and tested in the coming weeks

DØ Hybrids

- Same substrate and etching technology as used by CDF, however different design.
- A total of 672 double-ended 10-chip hybrids are needed (for layers 2-5, 1 for each 2, 3 or 4 silicon sensors), 72 double-ended 6-chip hybrids (1 for each 2-sensor L1 module), and 144 2-chip hybrids for L0. The total number of SVX4 chips required is 7440
- Prototype 6-chip hybrids received (from CPT), assembled with 4 SVX4 chips, and...they work ! 10-chip hybrids due about now.



Conclusions

- Extending the Tevatron Run 2 to $15\,\mathrm{fb}^{-1}$ opens up many exciting physics opportunities
- Due to the high radiation environment the DØ and CDF silicon detectors will need to be upgraded for Run 2b
- CDF and DØ have similar SVX 2b detector designs, based on simplicity and ease to construct given the timescale. Both experiments use the same SVX4 readout chip
- Progress on most components has been excellent – DØ already has SVX4 chips working on hybrids, CDF has just received working sensors
- We look forward to new silicon detectors in 2005, and the physics they will allow us to observe....