The CDF Run II Upgrade

Third International Conference on B Physics and CP Violation

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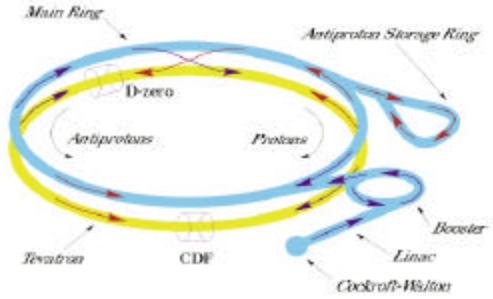
The CDF Collaboration for Run II



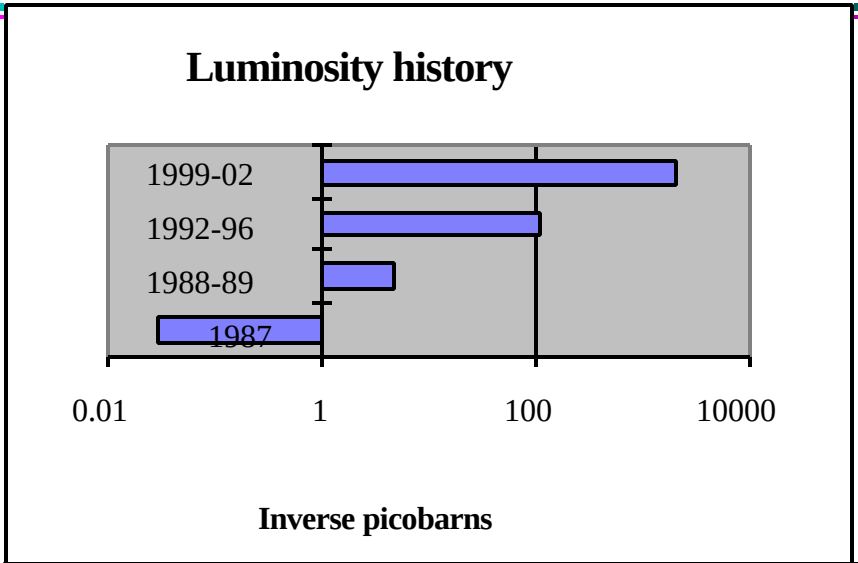
>500 Physicists from 52 Institutions Representing 11 Countries

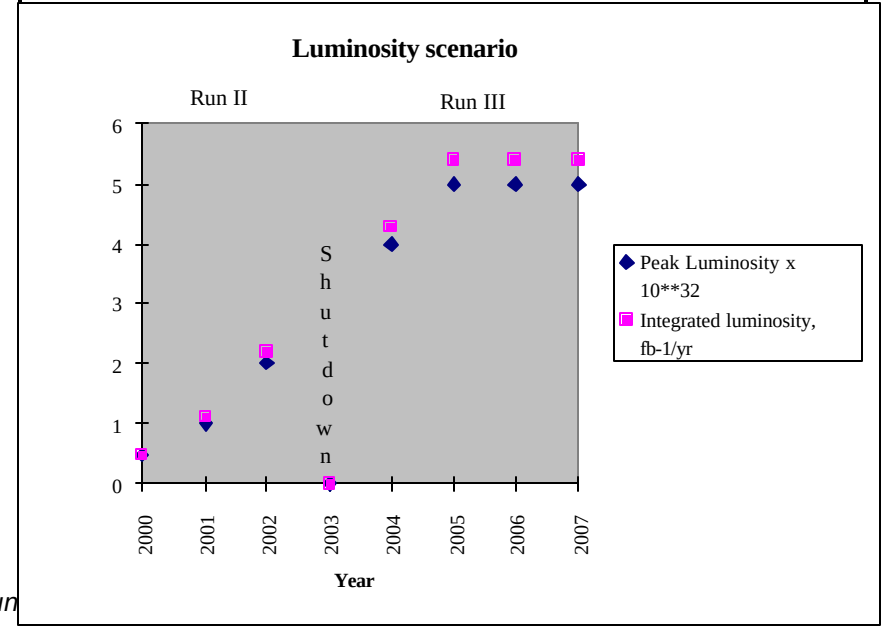
Tevatron Collider Luminosity

Many explorations limited by available luminosity ==> Improve this for Run II !

- **1985: first collisions**
- **1987: 30 nb^{-1}**
- **1988-89: 4.7 pb^{-1}**
- **1992-96: Run I 110 pb^{-1}**
- **2001-02: Run II 2 fb^{-1}**
- **2003-07: Run II >15 fb^{-1}**

Possible luminosity evolution:





Run II at the Tevatron

- **Commissioning of Main Injector**
  - **Luminosity: 2×10^{32} cm^{-2} s^{-1} (Run I: 2×10^{31} cm^{-2} s^{-1})**
  - **Proton/antiproton bunch spacing 132 ns (Run I: 3.5 μs)**
  - **Delivered Integrated Luminosity: >2 fb^{-1} (Run I: ~0.1 fb^{-1})**
- **Detector must be upgraded**
  - **Handle the shorter bunch spacing**
    - **New Front-end Electronics.**
  - **Add new components to extend physics potential**
    - **New Silicon Tracking Detectors, Pipelined Trigger/DAQ System**
  - **Build on strengths of Run I detector**
    - **Extended Silicon Tracking system**
  - **Remove weakness of Run I detector**
    - **More tracking at higher rapidity, more stereo measurements in central tracking system**

CDF Detector Components Reused for Run II

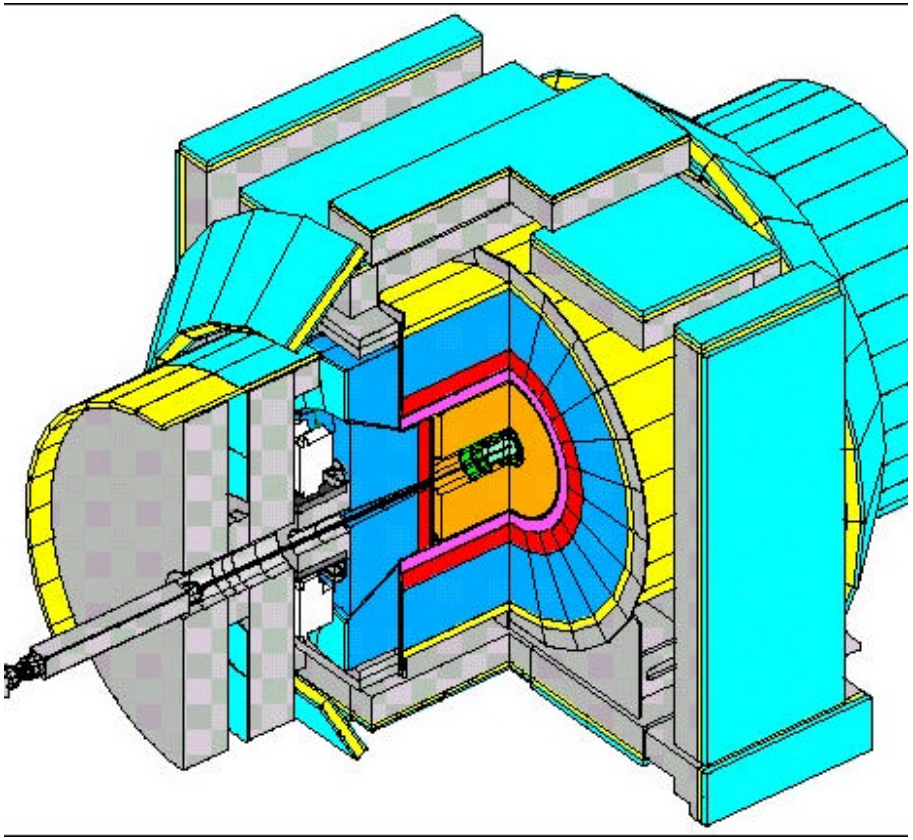
- **Central + Endwall Calorimeters**
  - ➢ **scintillator-based**
- **Central muon (CMU + CMP) system**
- **Muon Extension (CMX) system**

} **new frontend and trigger electronics**

- **Magnet**
  - ➢ **Superconducting Solenoid**
  - ➢ **Refrigerator/Power Supply (new controls)**
  - ➢ **Endplug Steel structure**

New Detector Systems

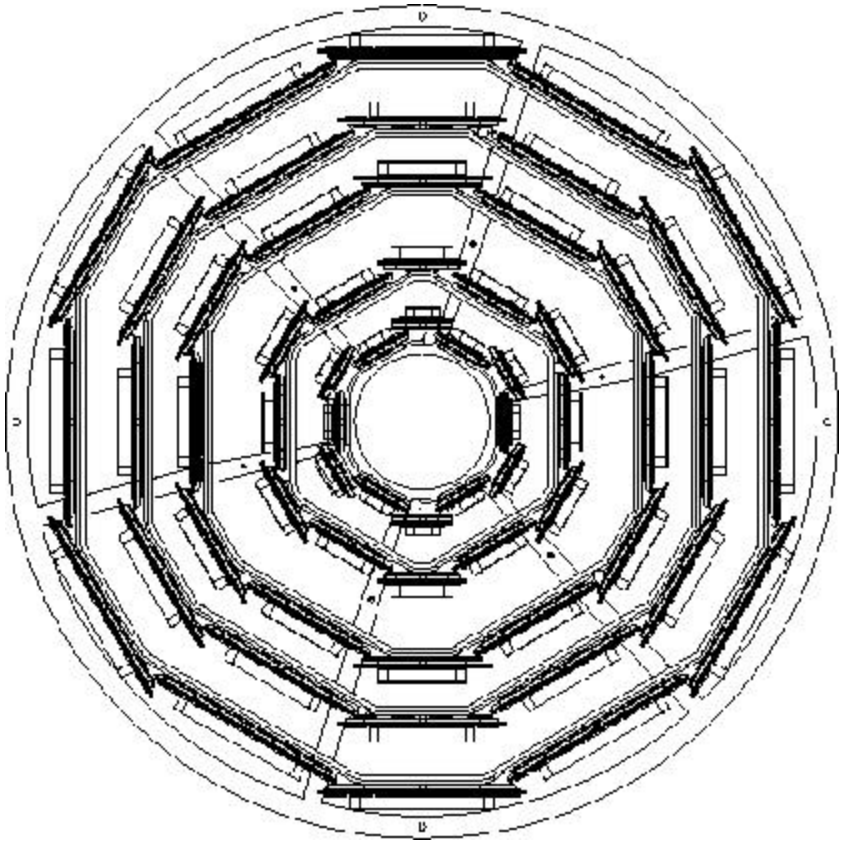
CDF II Detector cross section



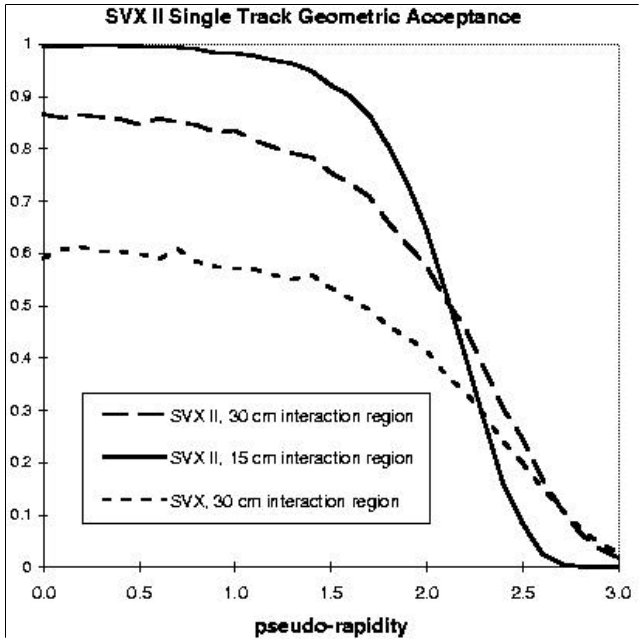
- **Tracking**
  - **Silicon Vertex Detector**
  - **Intermediate Silicon Layers**
  - **Layer 00**
  - **Central Outer Tracker**
- **Time Of Flight**
- **Muon systems**
- Endplug Calorimeter
- **Trigger (pipelined)**
- Front End Electronics
- DAQ system
- Offline software

Silicon Detectors SVX II

Endview



- **5 layers (60 μm pitch) from 2.4cm - 10.6cm**
- **Double sided Si (rf + rz)**
- **Longer ==> Better geometric acceptance:**



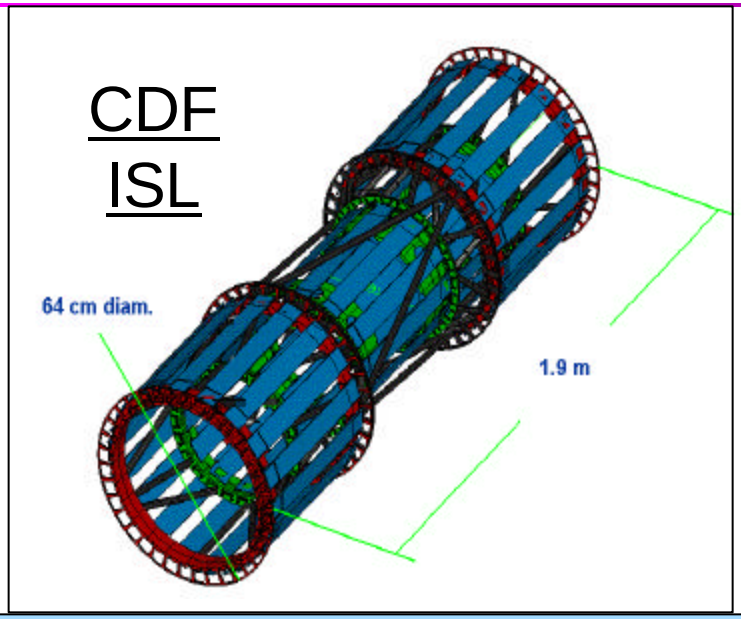
Run II SVX II vs. Run I SVX'

	SVX'	SVXII
Readout	rj	rj, rz
Barrels	2	3
Wedges	12	12
Layers	4	5
Length	51cm	87cm
Inner Radius	3.0cm	2.44cm
Outer Radius	7.8cm	10.6cm
r-phi channels	46,080	211,968
r-z channels	Absent	193,536
Total channels	46,080	405,504

- 5 double sided layers versus 4 single sided
- Much longer - covers the full interaction region
- Added rz readout
- 400k channels vs 46k

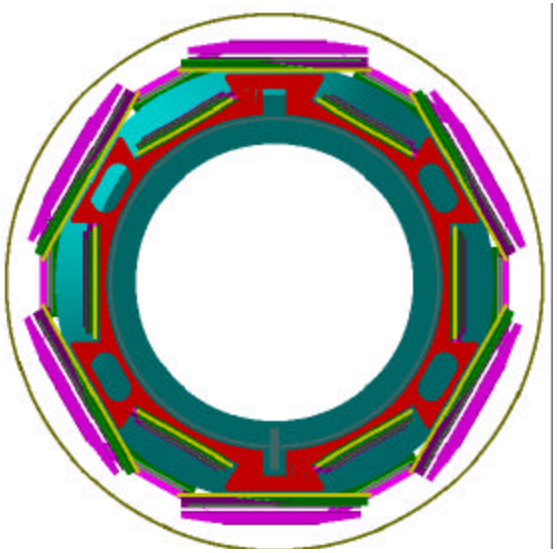
Intermediate Silicon Layers (ISL)

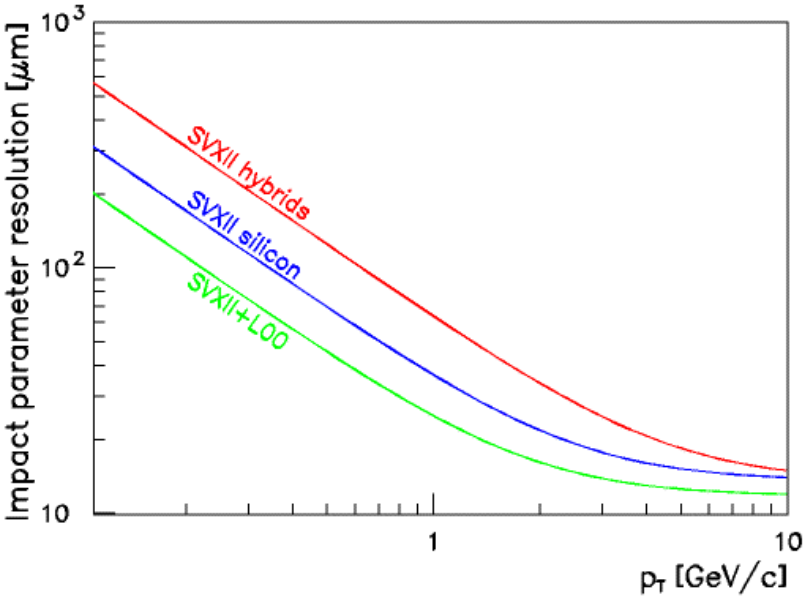
- Intermediate/FWD angle tracking
- Additional layers of silicon outside SVX II:
  - 6th full layer at r = 20 cm.
  - 7th partial layer at r = 28 cm, 1< |η|<2
- Combined with SVX II => New powerful stand-alone tracking capability for |η| < 2.
- Extends lepton ID and b-tagging to cover entire end plug region 1< |η| < 2.
- Allows in situ calibration of new Plug Calorimeter.



	Single tag eff. (%)	Double tag eff.(%)
SVX' + CTC (Run 1)	37.6 ± 1.0	6.9 ± 0.5
SVXII + COT	46.7 ± 1.1	8.7 ± 0.6
SVXII + ISL + COT	60.1 ± 1.0	15.1 ± 0.8

Layer 00





- **Beam pipe layer of 1-Sided Silicon**
  - **Improve IP resolution:**
  - **Extend useful lifetime**
  - **Long-term operational experience with LHC rad-hard silicon**
- **Layer Geometry**
  - **6 readout groups in z**
  - **6 narrow + 6 wide groups in f**
    - **72 narrow, 72 wide sensors**
    - **13,824 channels= 1.7 % of SVXII/ISL**
  - **Silicon Radii: 1.4 and 1.6 cm.**
  - **Hybrids:**
    - **Will use long flex from silicon**
    - **Chips at radii of 3 to 7 cm**

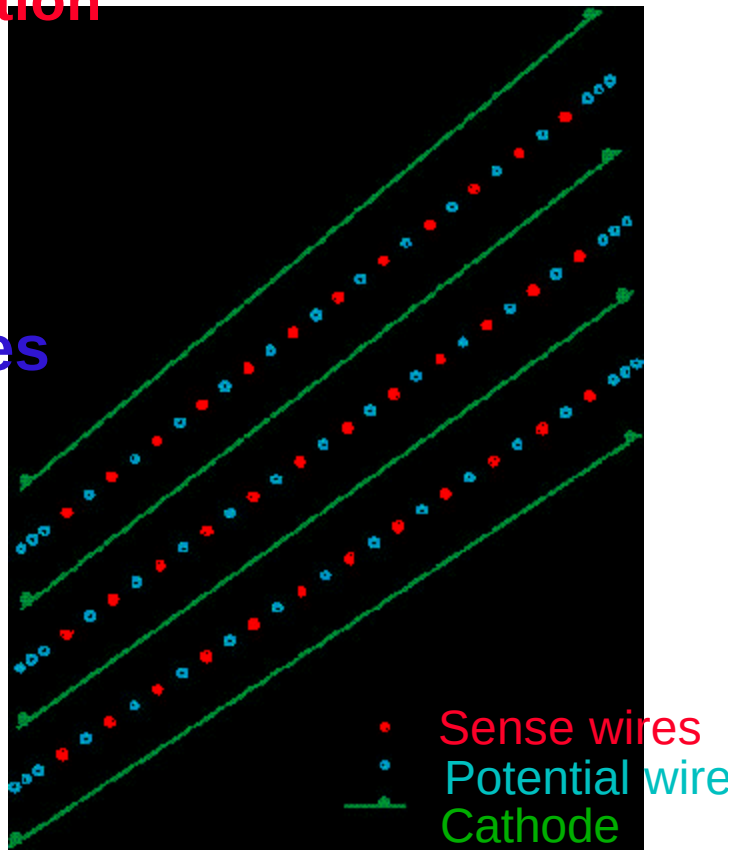
Silicon System Final Assembly

- **Sensors:**
  - **SVXII/ISL: May 2000**
  - **Layer 00: Jan, 00**
- **Chips:**
  - **>90% in hand now**
- **Hybrids:**
  - **Apr-May 2000**
- **Ladders**
  - **Finished Jun-Aug 2000**
- **Barrels:**
  - **Finished Aug-Sep 2000**
- **Integration**
  - **L00/BP in SVXII Oct, 2000**
  - **SVXII/L00 in ISL Nov, 2000**

Silicon System ready to install in the COT by November, 2000

Central Outer Tracker (COT)

- **New open cell drift chamber**
  - **3m sense wires strung along z direction**
- **8 "superlayers"**
  - **4 with axial wires for r - ϕ**
  - **4 with stereo wires for z**
- **Layer made of Cells of 12 sense wires**
  - **2540 cells**
  - **96 radial measurements**
  - **30240 channels**
- **Basic Cell :**
  - **12 sense wires, 17 potential**
  - **Drift time < 132 ns (Fast Gas)**
  - **cell tilted 35 ^{o} for Lorentz angle**



Central Outer Tracker Status

Status

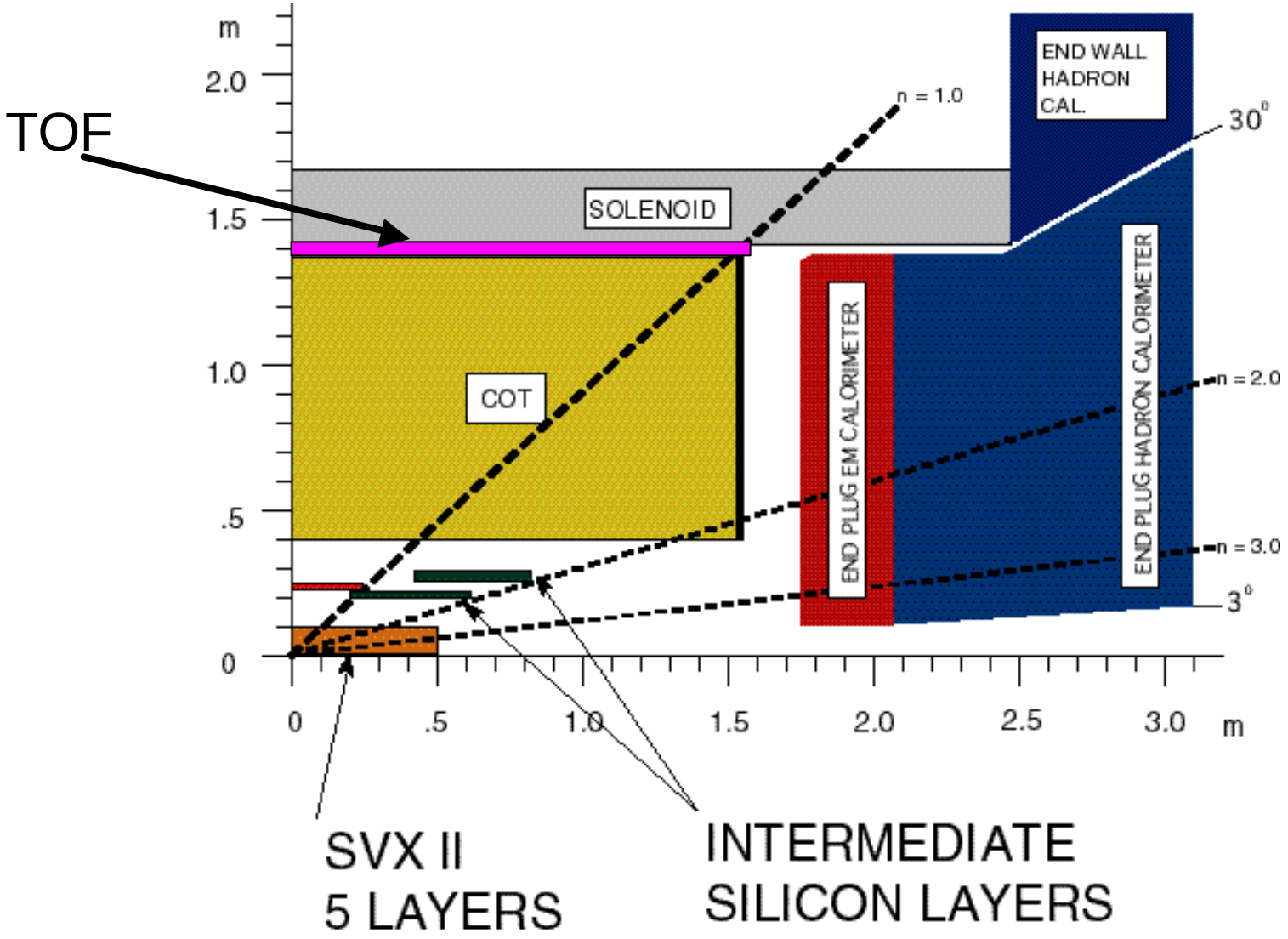
- Stringing was completed in May
- Problems found/fixed
  - some wire planes not correctly seated
  - Tension problems in stereo field sheets
  - Problems fixed but cost 5 months in schedule

Remaining tasks :

- Gas Seal :
  - Determine feature locations, machine features, mount extrusions, attach motherboards, electrical testing, epoxy, leak check seal (estimate 12 weeks)
- High Voltage:
  - Plug in daughter boards, HV checks in N_2, then **Ar-Ethane (estimate 8 weeks)**

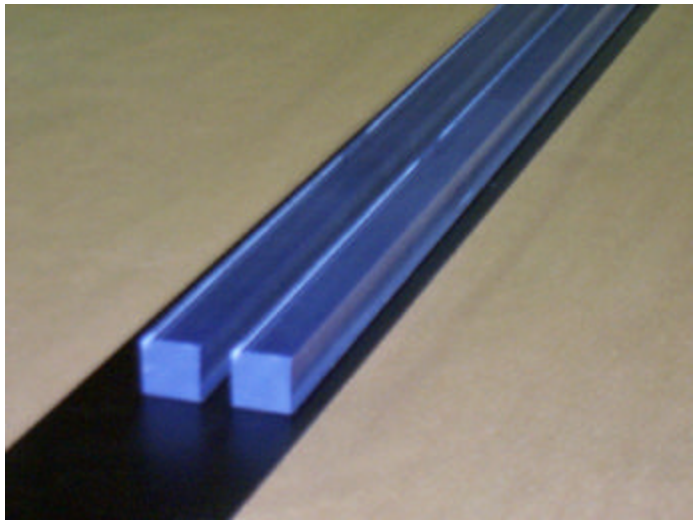
COT completion date ~April, 2000

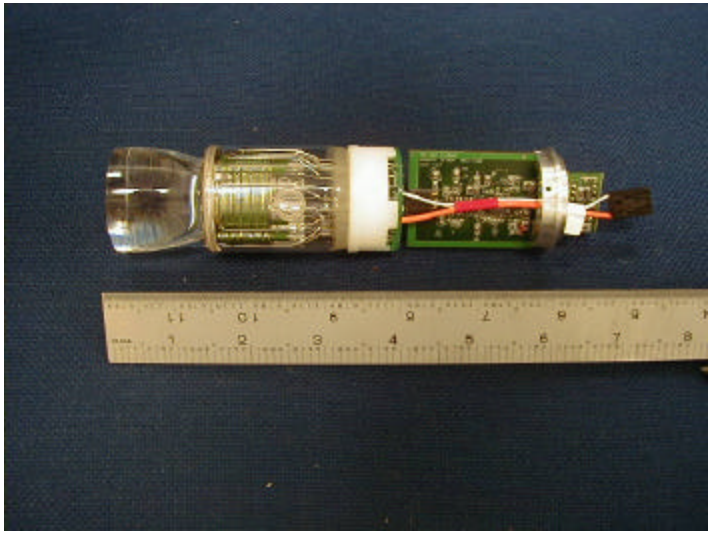
Time Of Flight System



Time Of Flight System

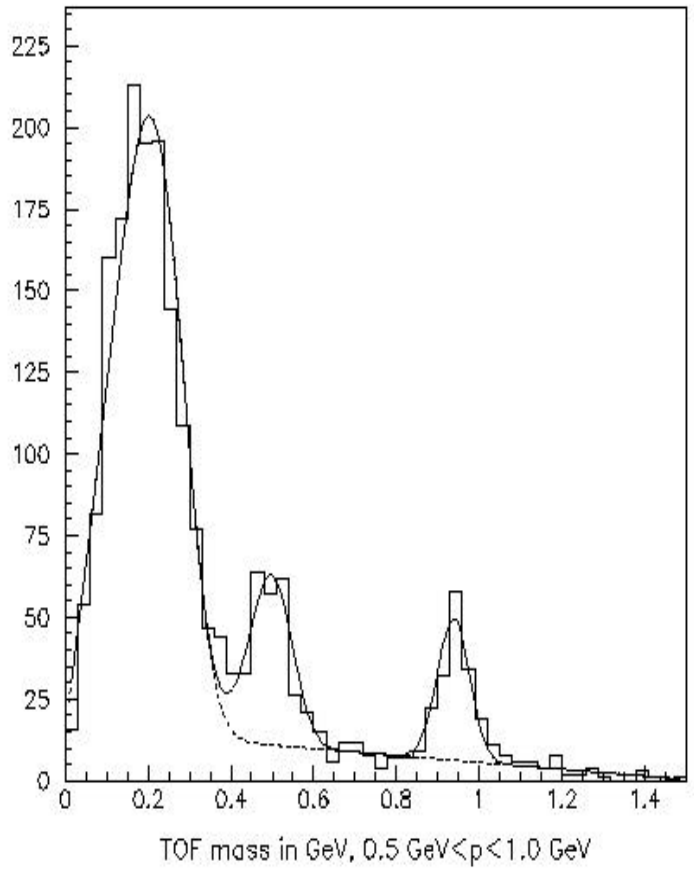
- **Scintillator**
  - 216 bars Bicron BC408
  - 2.8 m long
  - ~4x4cm trapezoidal xsec
  - L_{att} ~2.1m, rise time 0.9nsec
  - All scintillator by Jan, 2000
- **Photomultiplier**
  - Hamamatsu R5946M, 19 stage, 1.5in diameter, fine mesh
  - Testing in progress
- **Expect to achieve 100 ps resolution**
  - Based on 20 bar in-situ test
  - UV Laser test
  - Assumes combined left and right PMTs



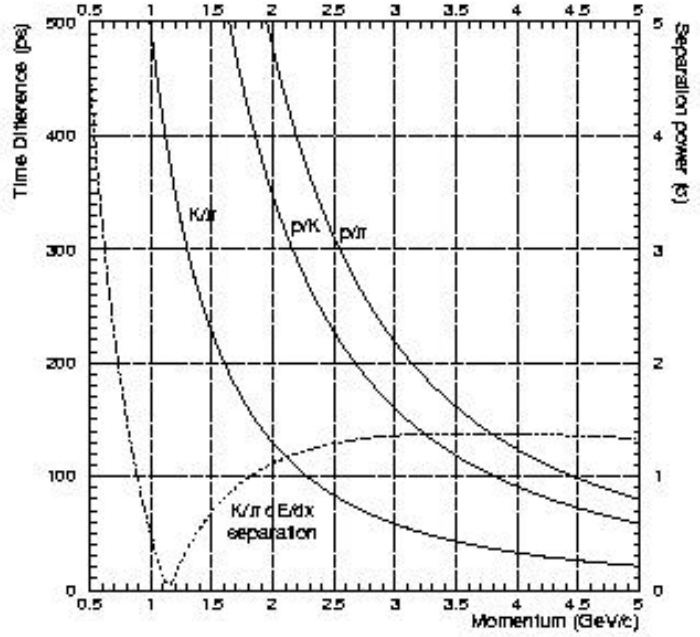


TOF Performance and Status

Result using 20 Bar prototype



Particle Identification with TOF

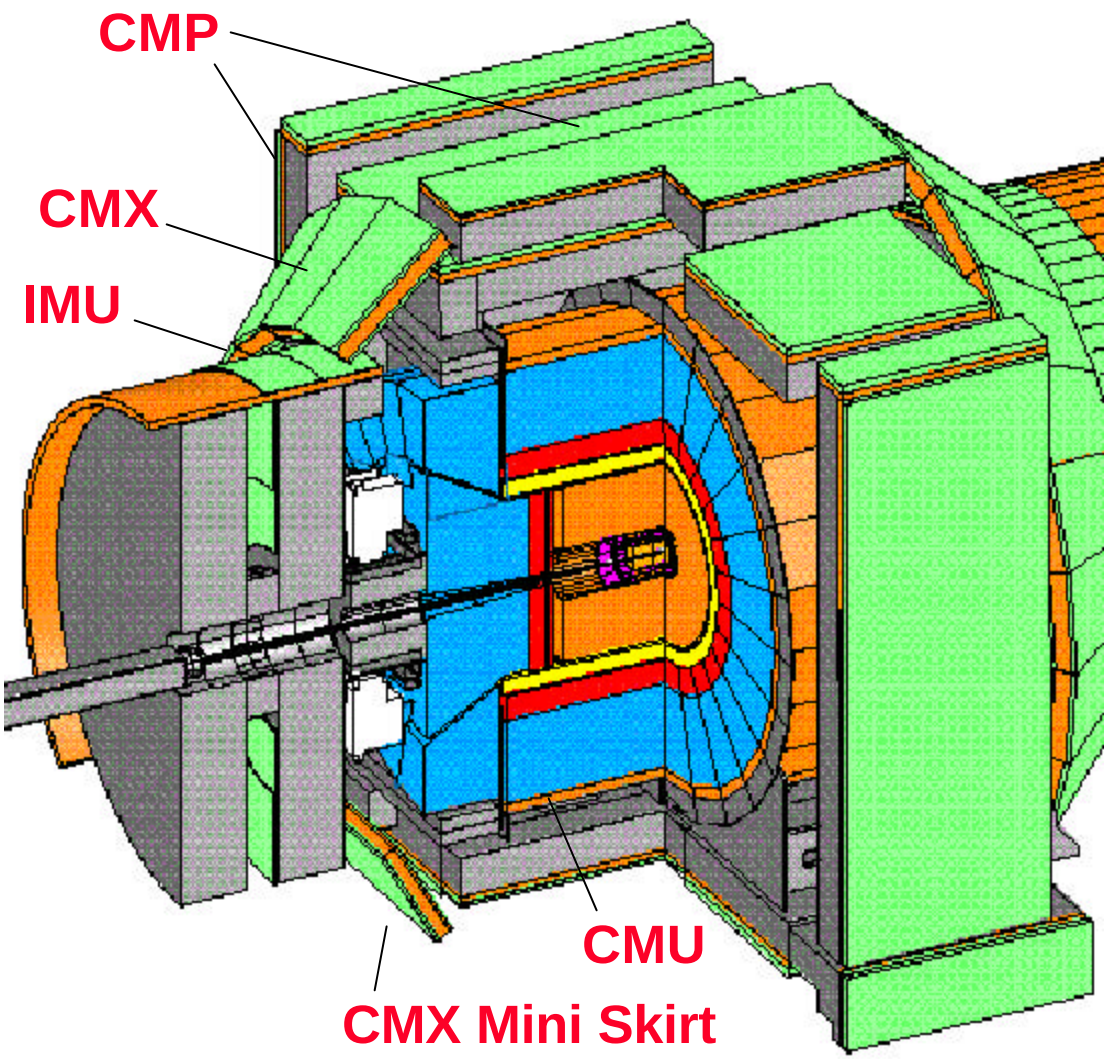


With 100 ps resolution: 2σ separation of

- **K and π for $p < 1.6$ GeV/c**
- **p and K for $p < 2.7$ GeV/c**
- **p and π for $p < 3.2$ GeV/c**

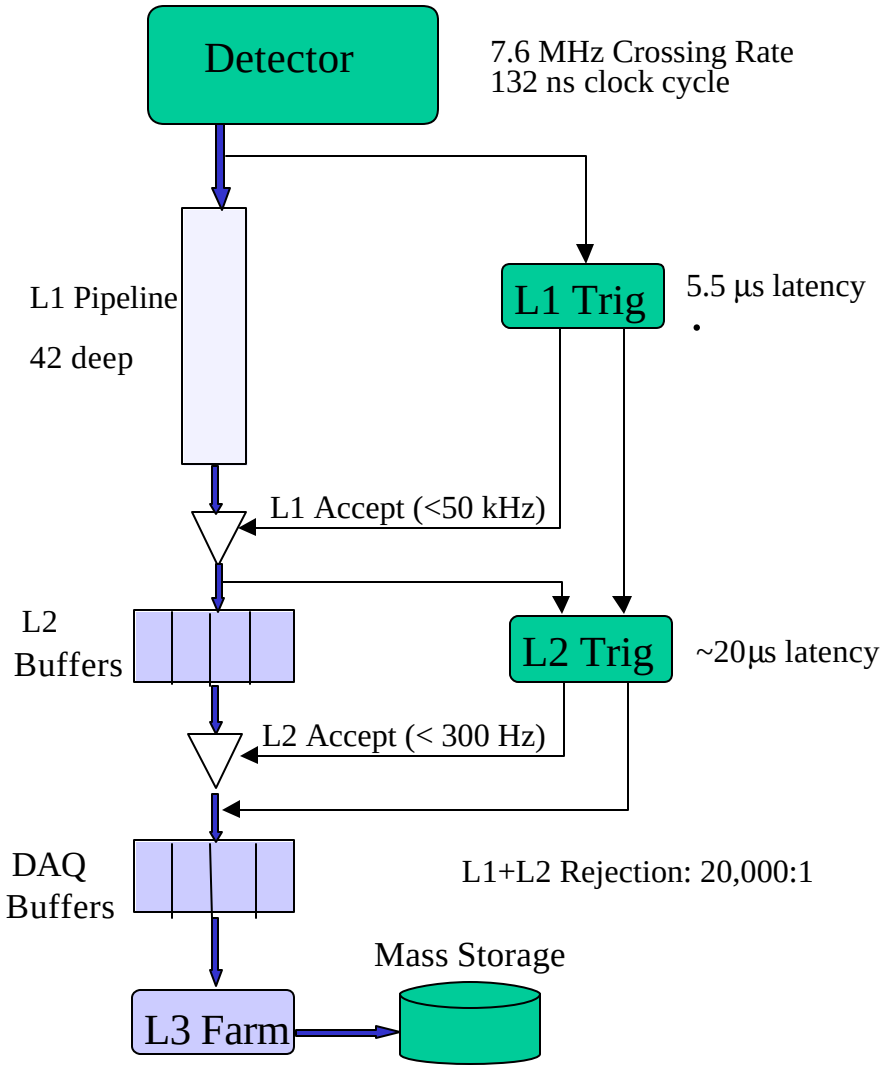
TOF and dE/dx are complementary

Muon System Upgrades



- **Fill gaps in ϕ in CMP muon system**
  - **Increase coverage 17%**
- **Fill gaps in ϕ in CMX muon system**
  - **Increase coverage 45%**
- **Add IMU system to extend η coverage**
  - **Total muon coverage almost doubles**

DAQ / Trigger System



- **Level 1 trigger:**
  - **Synchronous: new decision every 132ns. Pipelined readout.**
  - **Uses Tracking info from COT**
  - **Combines primitives from tracking, EM and HAD calorimeters, and muon chambers.**
  - **Accept rate 40-50 kHz**
- **Level 2 trigger:**
  - **Asynchronous: 20 ms**
  - **L1 tracking combined with silicon to identify tracks from ling-lived particle decays (B's)**
  - **Accept rate 300 Hz**
- **Readout ® Level 3 Farm of PC's**
  - **Accept rate 30 Hz**

Tracking Triggers

- **Top, exotic searches, W & Z event triggers require High momentum electrons and muons.**
- **B Quark event triggers need low momentum electrons and muons, or multiple charged tracks.**
- **Run II collision rate to tape:**
  - **7.6 MHz ® 30 Hz**
- **Tracking is a powerful tool to help reduce this rate and to extract the most interesting physics from large number of minimum bias events.**

e + 4 jet event

40758_44414

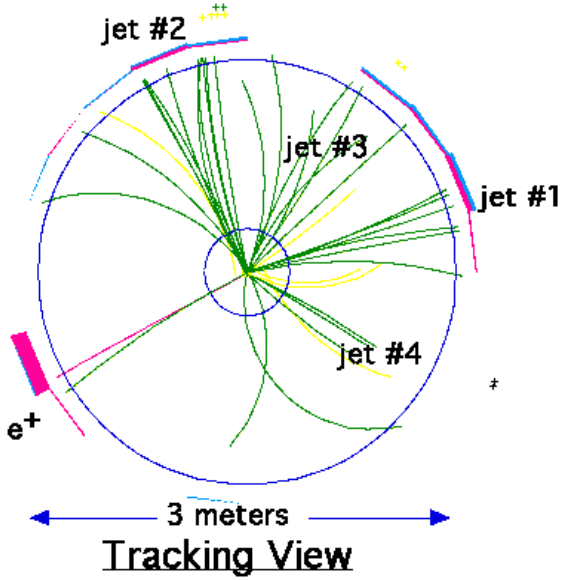
24-September, 1992

TWO jets tagged by SVX

fit top mass is 175±10 GeV/c^2

e^+, Missing E_t, jet #4 from top

jets 1,2,3 from top (2&3 from W)

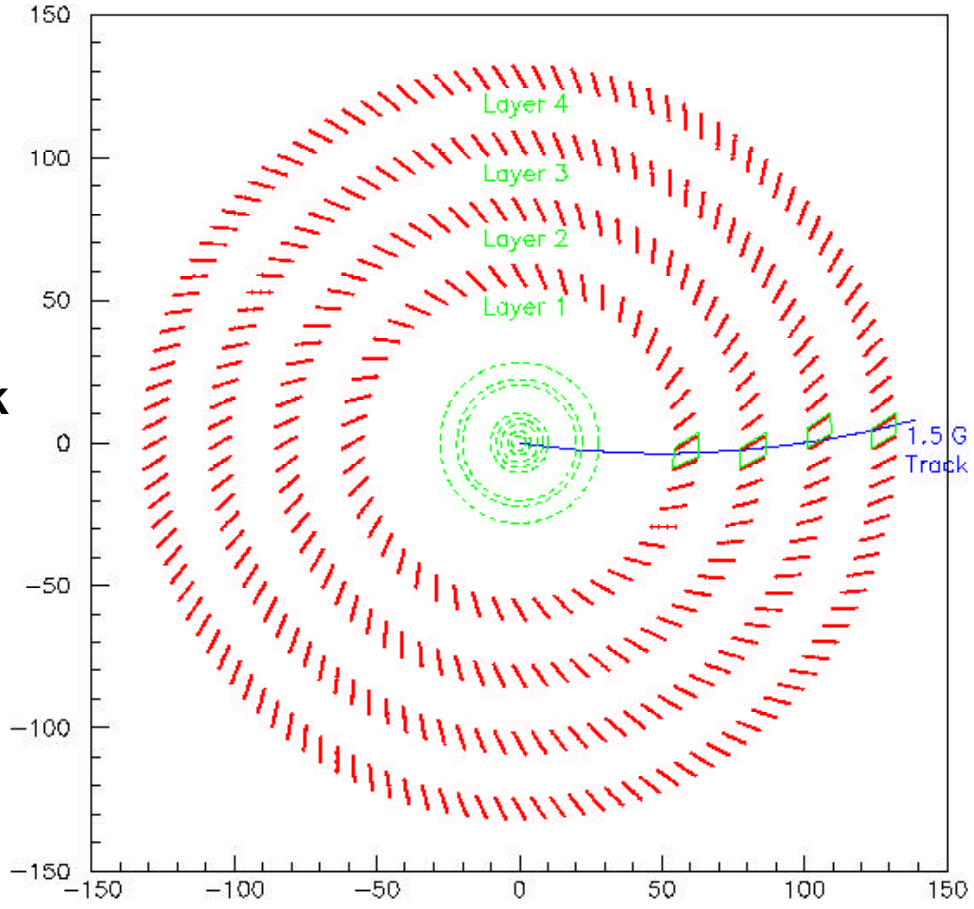


Tracking View

Level 1 Tracking Trigger: eXtremely Fast Tracker (XFT)

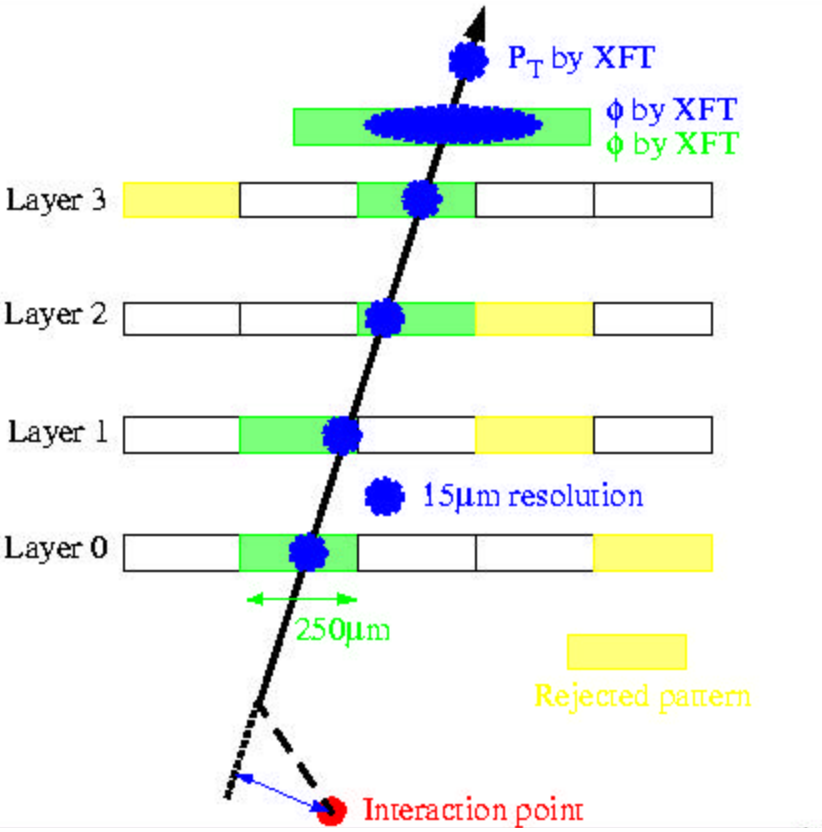
- **Process divided into several steps:**
  - ➢ **Hit Classification**
    - **Track hits near/far from wires**
  - ➢ **Segment Finding (Finder)**
    - **Track stubs within an axial SL**
    - **Works on the COT cell-by-cell**
  - ➢ **Segment Linking (Linker)**
    - **Links track stubs to form track**
    - **Determines azimuthal location**
    - **Determines Pt from curvature**
- **Highly Parallel:**
  - **Tracks found every 132 nsec**
- **Expected Performance:**
  - **Pt Resolution: ($\delta P_T/P_T^2 \sim 1\%$)**
  - **Phi Resolution: ($\delta\phi \sim 3$ mrad)**

Only axial layer shown and only every 4th cell.



SVT: Silicon Vertex Trigger

The SVT uses XFT tracks (PT, phi) plus hits in the silicon to determine 3 track parameters in the transverse plane



Combined XFT+SVT resolution:

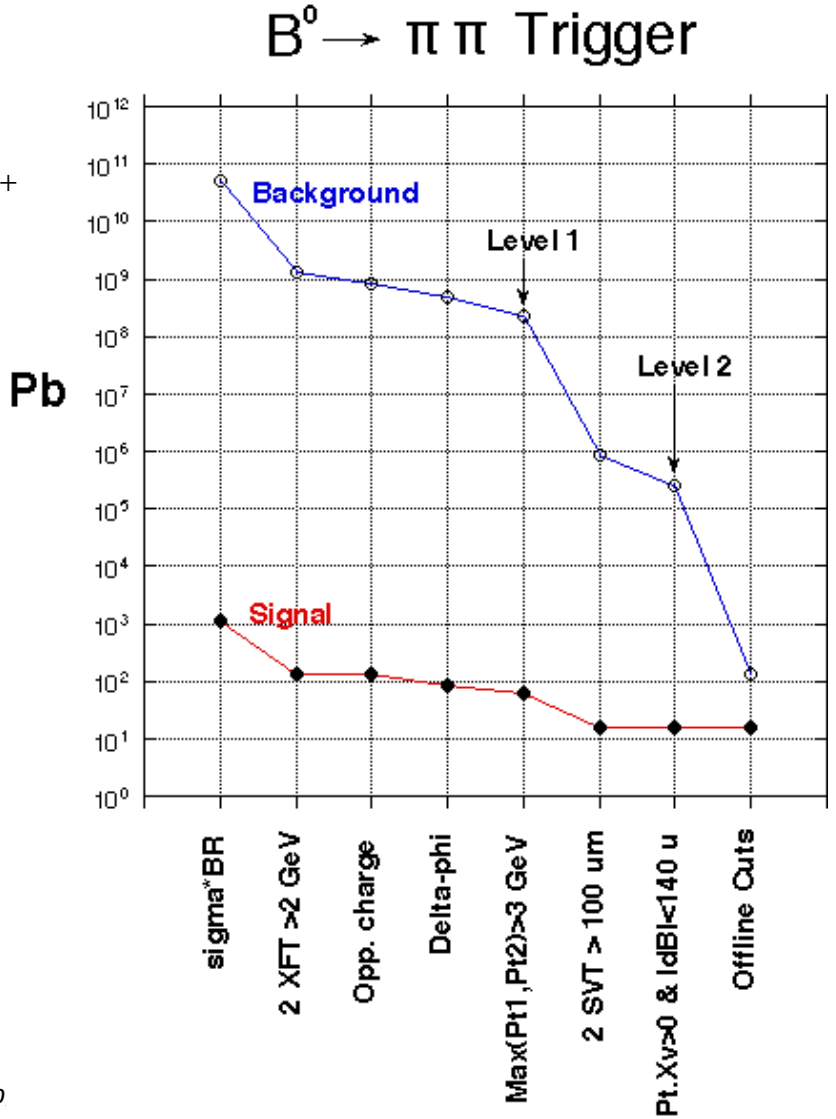
$$\frac{\Delta p_T}{p_T^2} = \frac{0.3\%}{GeV/c}$$

$$\Delta f = 1mrad$$

$$\Delta d = 35mm$$

Trigger Improvements: All Hadronic B Triggers Possible

- **Trigger selection is "or" of:**
  - **Two body decays:** $B^0 \to p^+p^-$
  - **Multi-body decays:** $B_s^0 \to D_s^- p^+, D_s^- p^+ p^- p^+$
- **Level 1**
  - **2 opp charge tracks, pt>2.0**
  - **Remove back to back tracks**
  - **Using Run I data, expect rate less than 30kHz (@2X10-32)**
- **Level 2**
  - **Require 100mm < $|d_0|$ < 1mm**
  - **Simple vertex calc, >0**
  - **Tighten Df cuts**
  - **Using Run I data, expect rate less than 70Hz**



B_S^0 Flavor Oscillations in Run II

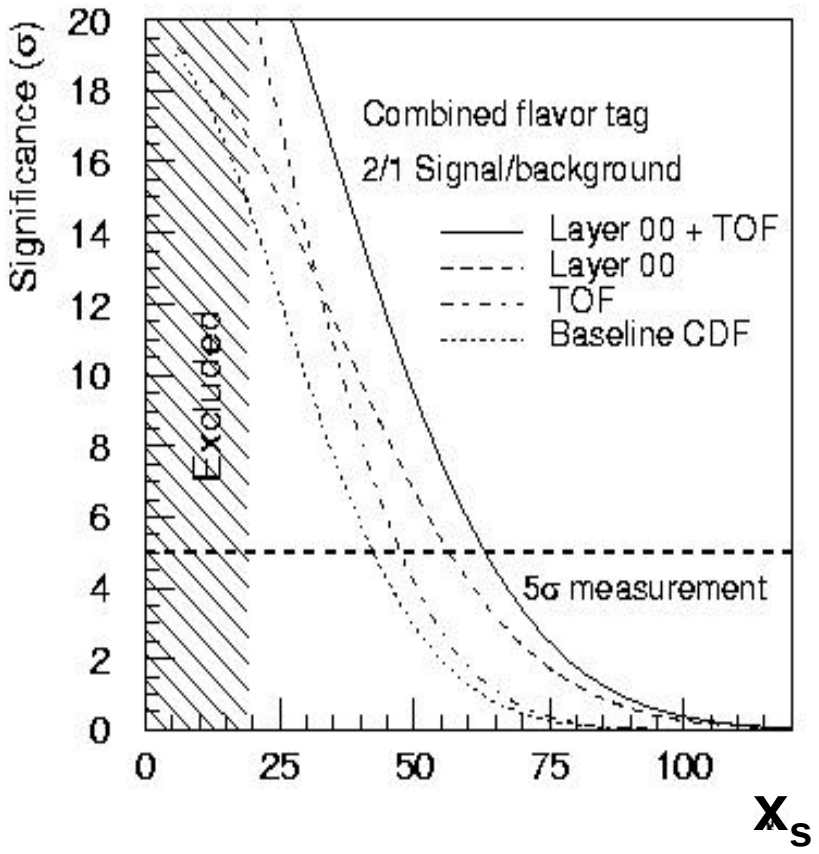
- **Expected signal: 20000 B_s^0 after trigger and selection, in modes:**

$$B_s^0 \to D_s^- p^+, D_s^- p^+ p^- p^+$$

$$D_s^- \to f p^-, K^{*0}(892) K^-$$

- **Proper time resolution:**
  - **SVXII:**
    - $s_t = 0.060 \oplus t \cdot s_{p_T} / p_T$ (ps)
  - **SVXII + L00**
    - $s_t = 0.045 \oplus t \cdot s_{p_T} / p_T$ (ps)
- **Flavor Tag effectiveness:**
  - **CDF Baseline**
    - $\varepsilon D^2 = 5.7\%$
  - **CDF Baseline + TOF**
    - $\varepsilon D^2 = 11.3\%$

Sensitive to $x_s < 63$



CDF Schedule Highlights

Electronics installation underway	**Now**
Cosmic Ray run:	**Now**
COT Ready to Install:	**April 2000**
COT Ready for Cosmics:	**Jul 2000**
CDF Engineering Run:	**Aug-Nov 2000**
Silicon System Finished:	**Nov 2000**
Silicon System Installed in COT:	**Jan 2001**
CDF Detector Moved into CollHall:	**Jan-Mar 2001**

CDF Ready for Collisions March 2001

Fermilab Schedule

October 1999 to March 2001 Schedule

CY	1999			2000								
Month	Oct	Nov	Dec	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.
Proton Source	M&D	Operation			M&D	Operation					M&D	Run II Commissioning Run
Main Injector	M&D	Operation			M&D	Operation					M&D	
Recycler	Bake out	Installation and Commissioning			M&D	Commissioning		Engineering Run			M&D	
Pbar Source	M&D	Commissioning	a)	E835 Run	M&D	E835 Run		c)			E-835 Removal	
Tevatron	1 TeV test	Operation			Changeover to Collider Configuration			Run II Engineering Run			Detector Roll-in	
Switchyard	M&D	Operation		b)	OFF							

1/17

CY	2000			2001		
Month	Oct.	Nov.	Dec.	Jan.	Feb.	March
Proton Source	Run II Comm. Run	M&D/Studies/Commissioning				Run II
Main Injector		M&D/Studies/Commissioning				
Recycler		M&D/Studies/Commissioning				
Pbar Source		M&D/Studies/Commissioning				
Tevatron		CDF Roll-out & Roll-in and D0 Roll-in				
Switchyard	OFF					

a) Band 1 & 2 Installation and E835 installation

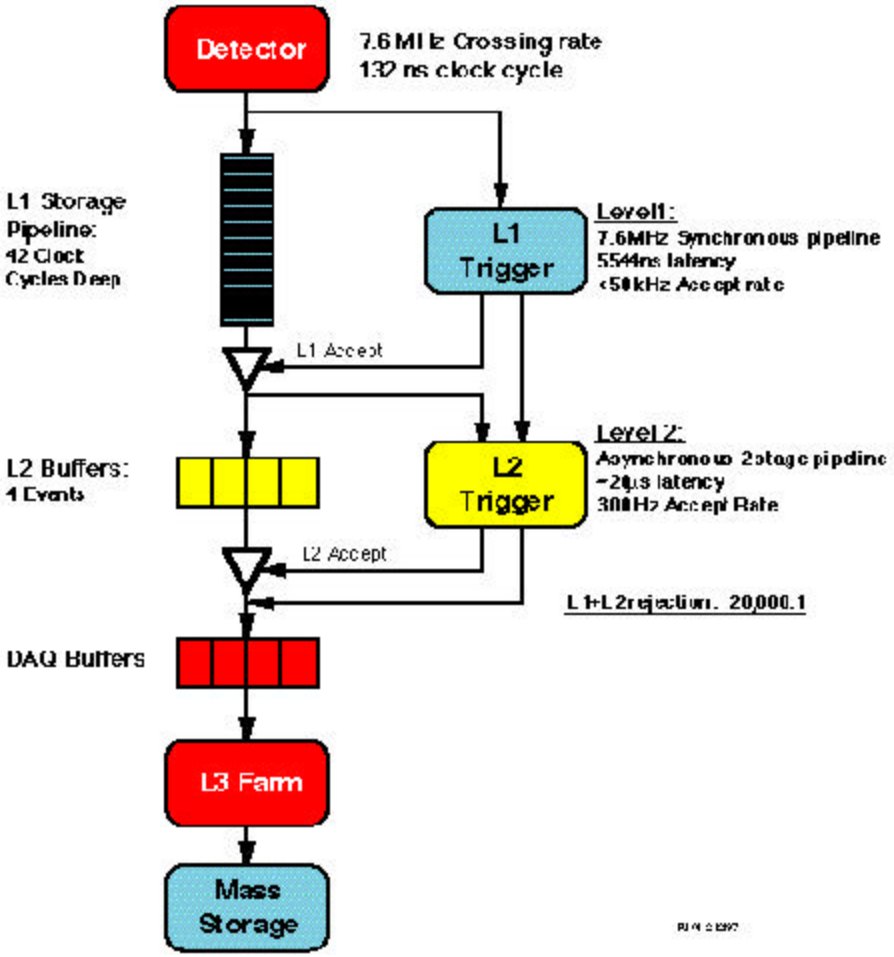
b) Possible KAMI Test

c) Operation for Pbar Source Commissioning, Recycler Engineering Run, and parasitic Run of E835

CDF Engineering Run

Start of Run II Data Taking!

Front End / Trigger Electronics



- **Pipeline Readout - 42 stages in Level 1 (5.5 ms)**
- **Data sampled every 132 ns (TDC's Calorimetry, Silicon)**
- **Level 1 trigger Decision every crossing (synchronous)**
- **Data ® Level 2 Buffer**
- **Level 2 Dec: Asynchronous, 20 ms**
- **Readout ® Level 3 Farm**
- **Accept rates x 10 more than Run I**
  - **Level 1: < 50 Khz**
  - **Level 2: 300 hz**
  - **Level 3: 30 hz ® tape**
- **deadtime < 10 %**