Opportunities at the Tevatron with CDFII

Bill Carithers

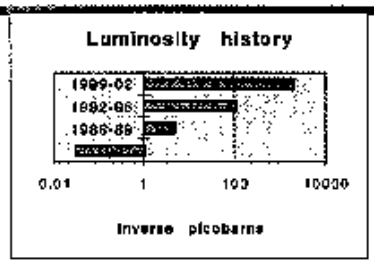
Overview

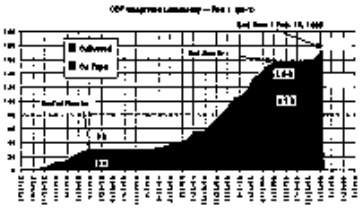
- Historical review of CDF collaboration and detector
- CDFII physics goals touch the major questions of HEP today:
  - ➢ origin of EWK symmetry breaking...
    - M_{top} , M_W ➡ M_{higgs}
  - ➢ Is the top quark a Standard Model object?
  - ➢ CP violation in the b quark sector
  - ➢ Is QCD a correct theory at smallest distance scales?
  - ➢ Beyond the SM... SUSY?, something else?
- Good start on most from Run I results

Historical context of Tevatron runs

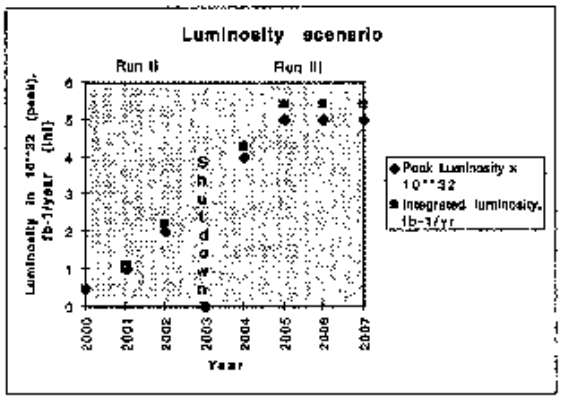
- 1985: first collisions
- 1987: 30 nb-1
- 1988-89: 4.7 pb -1
- 1992-96: Run I 110 pb -1
  - Run Ia 20 pb -1
  - Run 1b 90 pb -1

Run II 2 fb-1

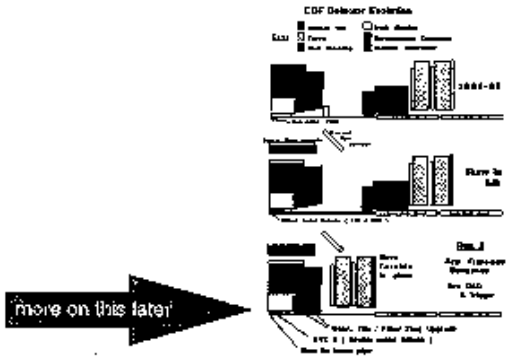




Possible luminosity evolution



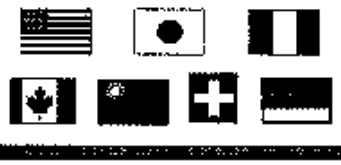
CDF Detector evolution



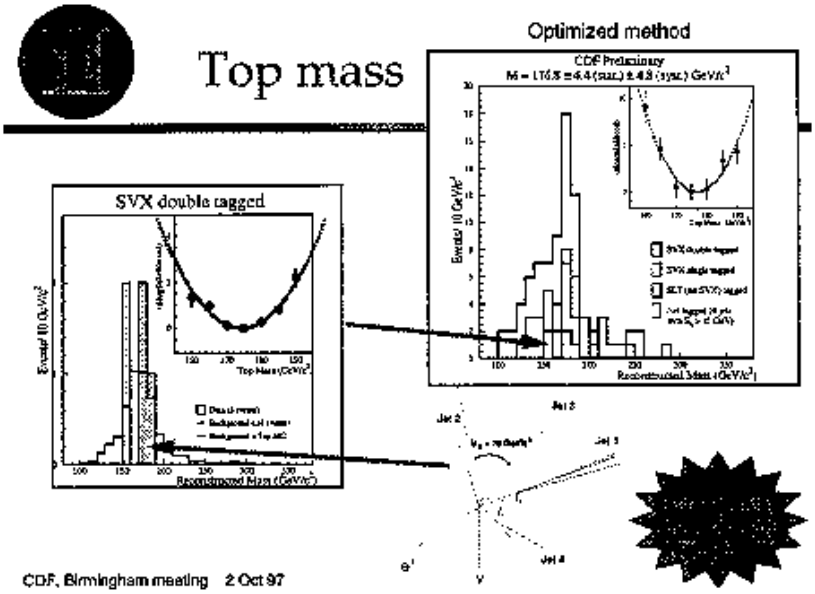
The CDF Collaboration

Argonne, Bologna, Brandeis, UCLA, Chicago, Duke, FNAL, Florida, Frascati, Geneva, Harvard, Hiroshima, Illinois, IPP/Canada, Johns Hopkins, Karlsruhe, KEK, LBNL, MIT, Michigan, Michigan State, New Mexico, OSU, Osaka, Padova, Pennsylvania, Pittsburgh, Pisa, Purdue, Rochester, Rockefeller, Rutgers, Academia Sinica, Texas A&M, Texas Tech, Tsukuba, Tufts, Wisconsin, Yale

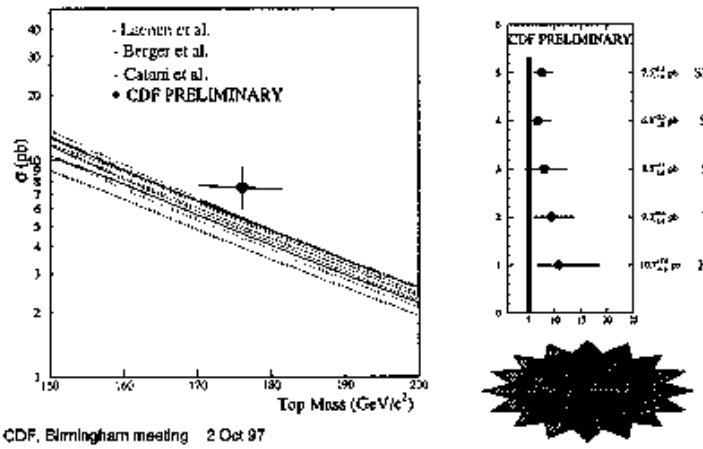
450 people, 40 institutions, 7 countries



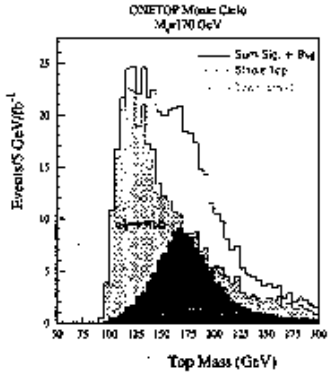
Top mass



Top production



Single top production



Top decays

In SM, top always decays to W + b

- Disappearance experiments
  - ➢ t -> W + (d,s)? Do we see right number of W + 0,1,2 b-tags? (Now : < 42%)
- Appearance experiments
  - ➢ FCNC's : t -> cγ (< 3%) , cZ(< 33%)
- Charged higgs decays (little of each)
- W polarization in top decays

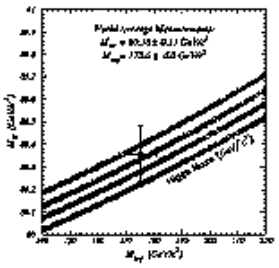
Top with CDFII

- Mass to 1%
- production σ to 9%
- Width to 25%
- limits on t → W b to few %
- V_{tb} to 13%
- FCNC decays to < 1%

Check that top is SM object to few %

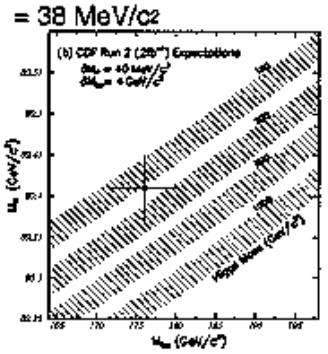
EWK with CDFII

M_W vs. M_{top}



W mass as key measurement

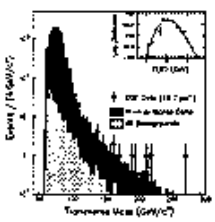
★ δMw = 38 MeV/c2

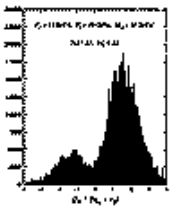


Higgs mass pens line

EWK with CDFII

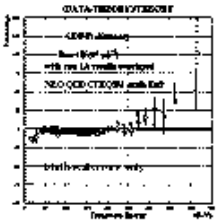
- W width to 30 MeV
- radiation zero
- anomalous couplings
- W, Z decay asymmetries
- Drell-Yan cross section

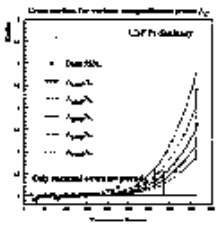




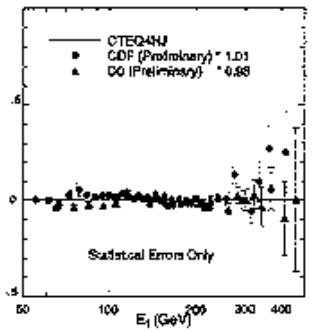
QCD at small distances

- High E_T compared to NLO QCD
- PDF, particularly high-x gluons
- other calculational subtleties
- angular distributions
- scaling behavior

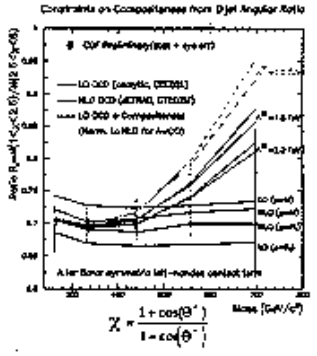




Hi E_T jets cont.



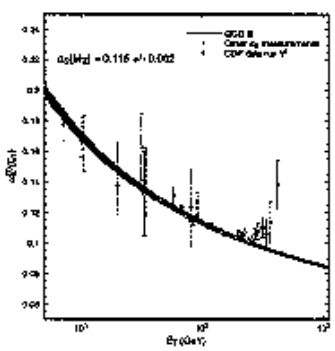
➡ Sensitive to high-x gluons in PDF



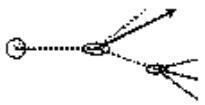
➡ Jet angular distribution

QCD tests

- Precision measurement of α_s
- Direct photons
- W,Z + jets
- multi-jet dynamics (already analyzed up to 6-jet systems)



B_d mixing: prelude to CP

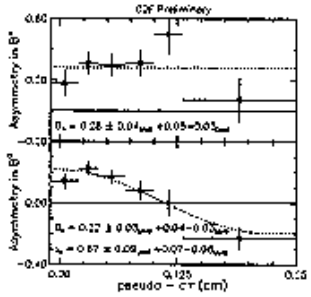


"Dilution" due to wrong tags

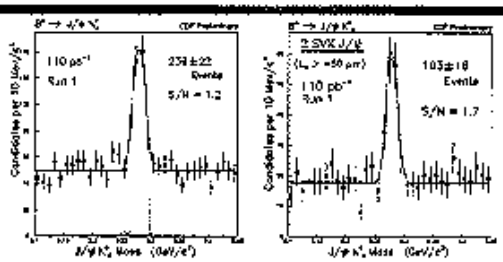
CP violation:
$A(B \to J/\psi + K_S) = D \sin(2\beta)\sin(\delta m\, \tau)$

B mixing:

$A(B \to \ell\nu + D^{(*)}) = D \cos(\delta m\, \tau)$



CP violation in the b sector

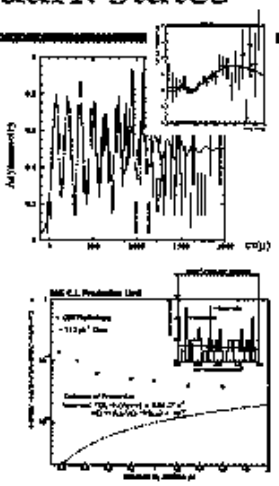


"Golden mode"

δ(sin2β) = .09

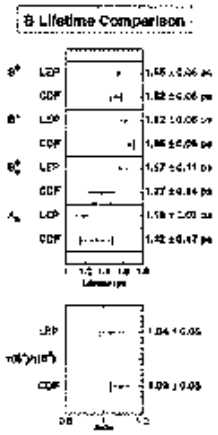
Heavy b quark states

- B_s mixing and CP violation
  - ➢ experience from Run I
  - ➢ "no lose" theorem for Δm, $\Delta\Gamma$
- B_c mass and lifetime
  - ➢ "hydrogen atom" of heavy quark states
- b baryons
- rare decays



b lifetimes and spectroscopy

- Especially important in heavy b quark systems
  - ➢ search for two-component B_s lifetime

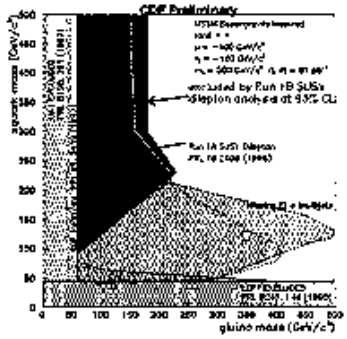


SVT-- secondary vertex trigger

- Qualitatively new for Run II
- possibility of B -> $\pi\pi$ and sin(2α)
- calibration samples
- most important application: haven't thought of yet

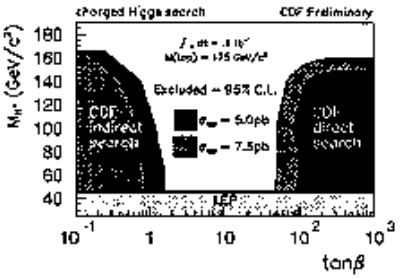
Beyond the SM

- General SUSY searches
  - ➢ trileptons
  - ➢ dilepton + missing E_T
  - ➢ jets + missing E_T
- Specialized searches
  - ➢ light stop



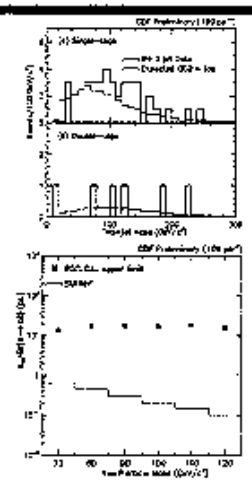
Higgs searches

- Charged higgs from top decay
- Some sensitivity to SM higgs from associated production W + h
  - → $b\bar{b}$



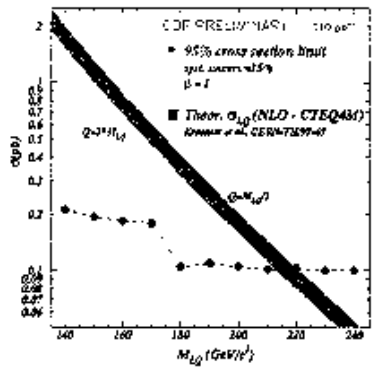
SM Higgs search

- Associated production W+h
- Sensitivity up to about 120 GeV



Recent LQ result

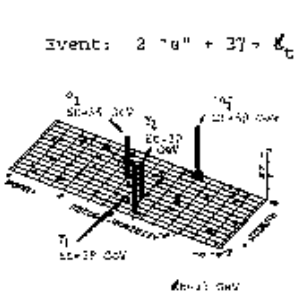
First Generation Scalar LQ Search

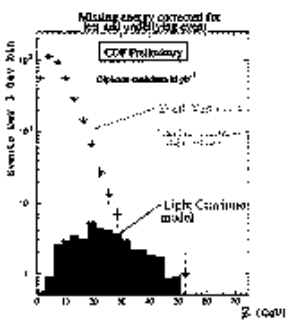


Summary of reach for new physics

Searches	current CDF limit (Run 1) Excluded region at 95% C.L.		data set	run II (GeV) with 2 fb^{-1}
$W' \to e\nu(\mu)$	< 652		1 fb^{-1} (20 pb^{-1})	< 900
$W' \to WZ$	< 360 (ref. model-dependent)	*	2 fb^{-1} (200 pb^{-1})	
$Z' \to ll$ (DY)	< 690	-	2 fb^{-1} (200 pb^{-1})	< 900
$Z\gamma(Z\eta)\to ll\gamma(\eta)$	$< 480, 610, 585, 555$	*	2 fb^{-1} (200 pb^{-1})	< 800
$Z_{SM}\to l^+l^-$ (Mass)	$< 626, 590$	*	2 fb^{-1} (200 pb^{-1})	< 800
Axigluon $\to qq$	$200 < M < 980$	*	2 fb^{-1} (200 pb^{-1})	< 1150
Technibro $\to t\bar{b}$ (pl	$200 < M < 690$	*	2 fb^{-1} (200 pb^{-1})	$200 < M < 870$
$b_8 \to t(q)$ with $\to eq$	$200 < M < 850$	*	2 fb^{-1} (200 pb^{-1})	$200 < M < 870$
topgluon $\Gamma = 1.0$	$200 < M < 690$	*	1 fb^{-1} (20 pb^{-1})	
topgluon $\Gamma = 0.3M$	$200 < M < 650$	*	1 fb^{-1} (20 pb^{-1})	
topgluon $\Gamma = 0.3M$	$200 < M < 570$	*	1 fb^{-1} (20 pb^{-1})	
leptoquarks ($\mu q, eq$)	$< 298, 98$ (scalar, $\beta = 1$)	*	2 fb^{-1} (100 pb^{-1})	< 300
Pair-Scalar LQ ($\to lb + qb$)	$< 172(90)$	*	1 fb^{-1} (88 pb^{-1})	
Pair-Scalar LQ ($\to lbl + qb$)	$< 119(80)$	-	1 fb^{-1} (88 pb^{-1})	
Compositeness Scale ($qqll$)	$4000 < \Lambda < 2000$ (-1 int)	*	1 fb^{-1} (110 pb^{-1})	< 3000
$q^* \to W(\mu\nu, e\nu)$ jet	< 540	-	1 fb^{-1} (20 pb^{-1})	< 870
$\gamma(\to e^+e^-)\nu\bar{\nu}$	$200 < M < 630$	*	2 fb^{-1} (105 pb^{-1})	< 820
massive stable pt.	< 190 (std. m. $\tilde{g}$)	-	1 fb^{-1} (48 pb^{-1})	< 300
$\tilde{g}(\to bs)^*$	< 168 (any m) < 230 (m=m$_{\tilde{g}}$)	*	1 fb^{-1} (88 pb^{-1})	$< 200 (< 250)^*$
gaugino	$\chi_1 < 68$, $\tilde{\chi}^0 < 68$	*	2 fb^{-1} (100 pb^{-1})	< 150
H	< 130 ($\sigma \cdot$ eqn 100)	*	1 fb^{-1} (88 pb^{-1})	

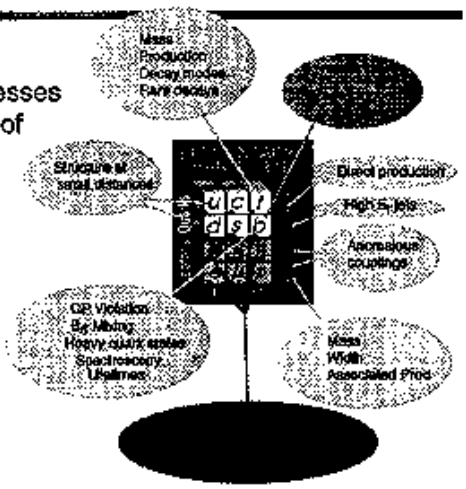
plus surprises?





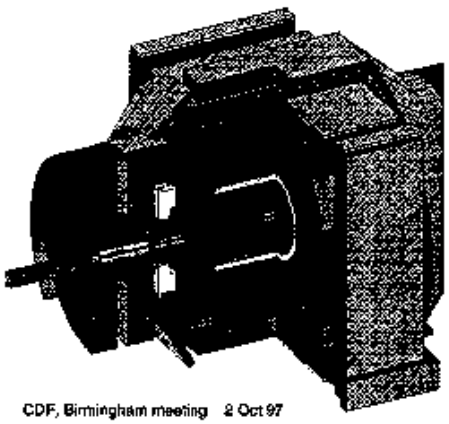
Conclusions

- Tevatron Collider accesses an enormous breadth of physics
- Almost any single topic would justify new detector
- Eager to start exploring Run II goldmine!



New Detector Systems

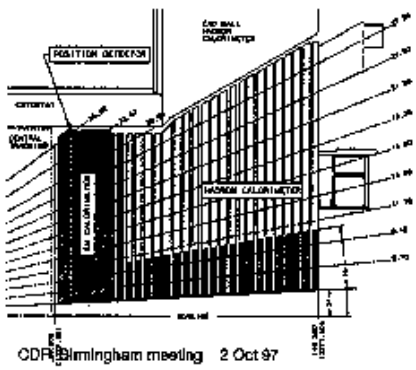
CDF II Detector cross section



- Endplug Calorimeter
- Tracking
  - Silicon Vertex Detector (SVX II)
  - Intermediate Silicon Layers (ISL)
  - Central Outer Tracker
- Front End Electronics
- Trigger (pipelined)
- DAQ system
- Muon system
- Offline software

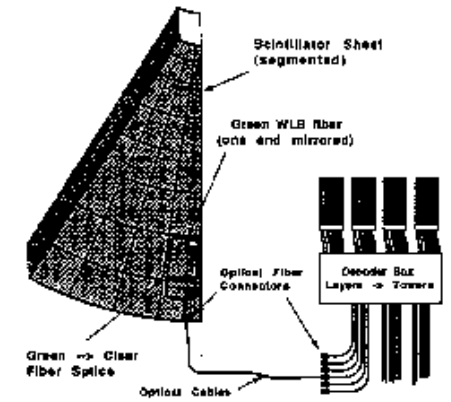
Endplug Calorimeter

Replace the old Plug and Forward calorimeters ($1.1 < |\eta| < 3.6$) with a single new fast , hermetic, scintillator based calorimeter



- 21 X_0 Electromagnetic cal. (4 mm lead radiator)
- 6.6 λ_{int} Hadronic (2" Fe)
- Shower maximum detector at 6 X_0 in the EM
- Reuse existing plug steel
- Use SS to avoid changing the flux return geometry==> Avoid remapping the field

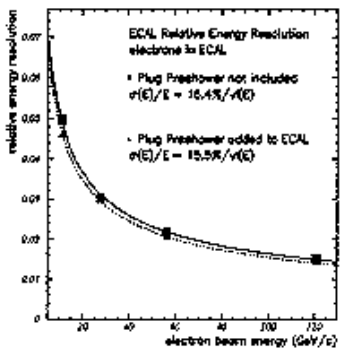
Endplug Calorimeter

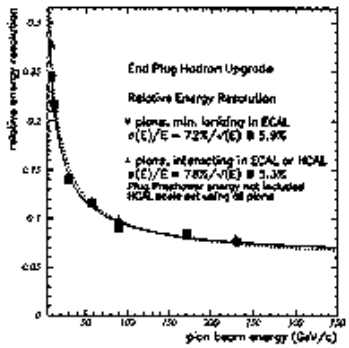


- Scintillating tiles arranged in projective towers 0.1 η x 15° (7.5° ψ
- Readout = Wavelength Shifting fiber --> clear fiber -->Decoder Box rearranges layer geometry into tower geometry --> PMT
- Common DAQ and trigger electronics for entire CDFII calorimetry.

Plug Test Beam

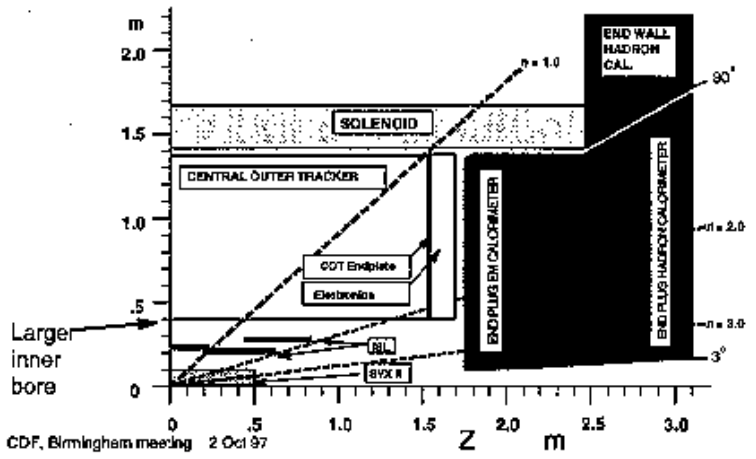
- Energy Resolution in the EM and HAD Calorimeters





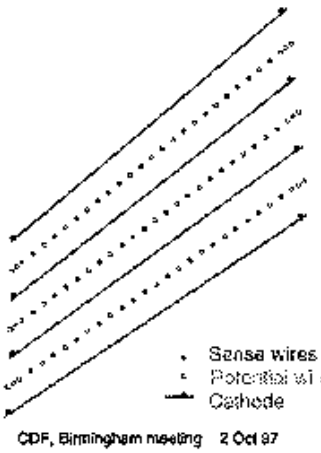
- Design specs: 16%/√E for EM, 80%/ √E for HAD.

CDF Run II Tracking System



CDF, Birmingham meeting 2 Oct 97

Central Outer Tracker (COT) Construction

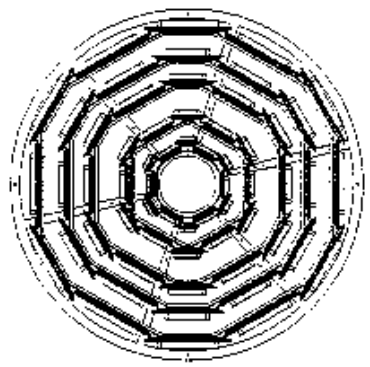


- Basic Cell :
  - 12 sense ,17 potential wires
  - 40 μ diameter gold plated W
  - Cathode: 350 A gold on 0.25 mil mylar
- Drift trajectories very uniform over most of the cell
- cell tilted 35 ° for Lorentz angle
- Novel Construction:
  - Use winding machine
  - 29 wires/pc board, precision length
  - Snap in assembly fast vs wire stringing
  - 30,240 sense wires vs 6156 in CTC
  - Total wires 73,000 vs 36,504 in CTC

CDF, Birmingham meeting 2 Oct 97

Silicon Detectors
SVX II

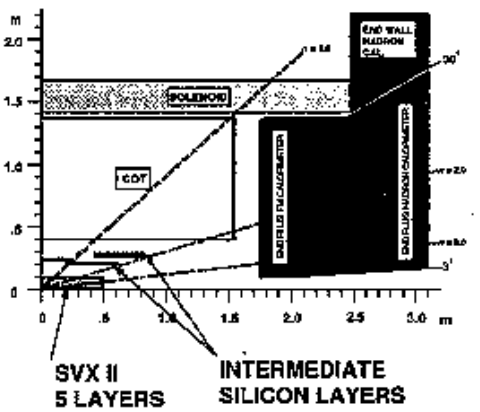
Endview



CDF, Birmingham meeting 2 Oct 97

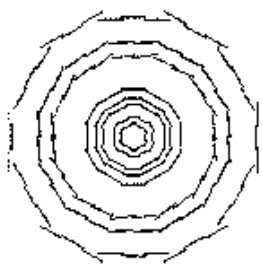
- 5 layers
- Double sided Si (rϕ + rz)
- deadtimeless readout using SVX3 chip
- Longer ==> Better geometric acceptance:
  - x 1.6 single b tag for top
  - x 2.2 double b tags WRT run I
- high speed, parallel readout ==> Secondary Vertex Trigger (SVT) will allow us to trigger on displaced tracks at Level 2.

ISL Layout

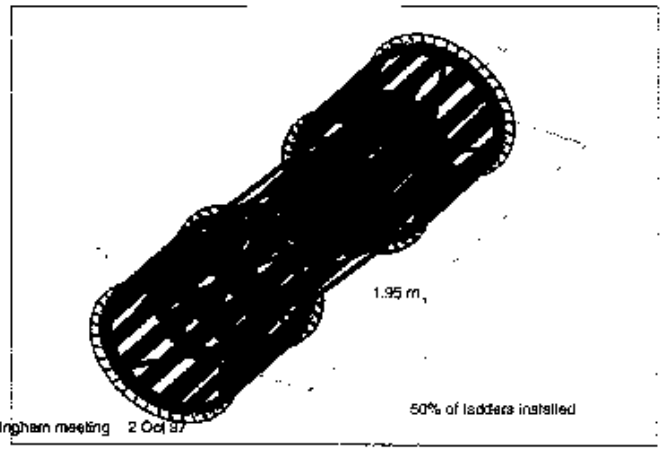


CDF, Birmingham meeting 2 Oct 97

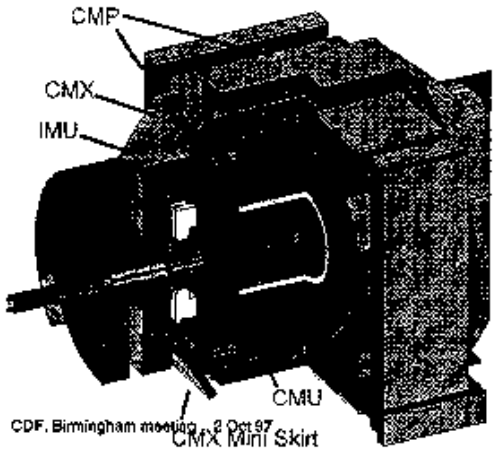
Endview
SVXII + ISL



ISL Space Frame

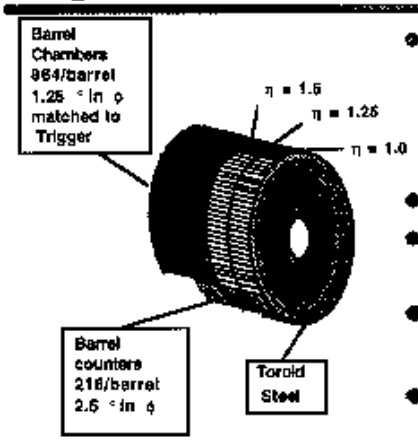


Muon System Upgrades



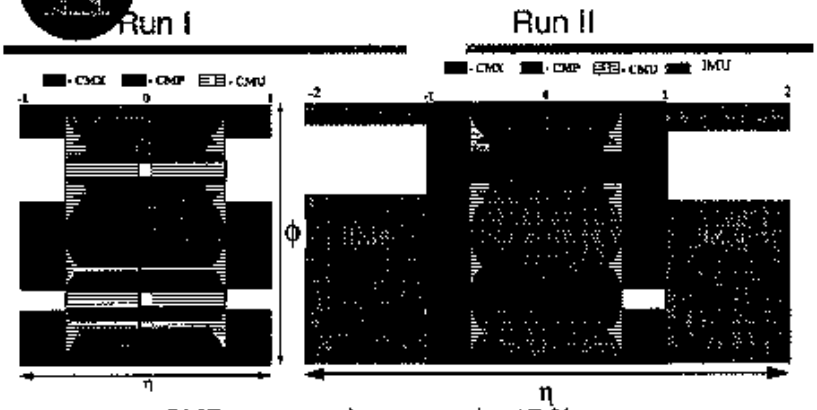
- Fill gaps in ϕ in CMP/ CMX muon systems
- Higher rate capability
- Shield CMX - trigger
- Add IMU system to extend η coverage
  - Move Toroids closer by 5.5 m
  - New Barrel chambers and scintillator
  - Endwall and Toroid scintillator

Intermediate Muon System (IMU)



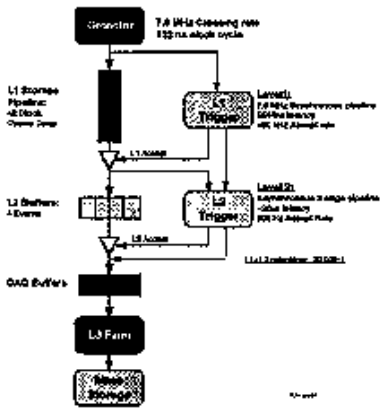
- Barrel
  - ➢ chambers (4 layers)
  - ➢ scintillation counters
  - ➢ Located on outside of Run I Toroid Steel 270° in ϕ
- Endwall + Toroid Scintillators
- Same preamps and TDC's as Central Muon system
- Trigger 1.0< |η| <1.5 : match stub-XFT-Scint.
- Identify to |η| < 2.0

proved Central Muon Coverage



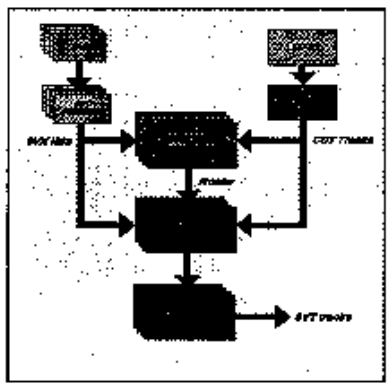
CMP coverage increases by 17 %
CMX coverage increases by 45 %
With the IMU: CDF's muon coverage ~doubles

Front End / Trigger Electronics



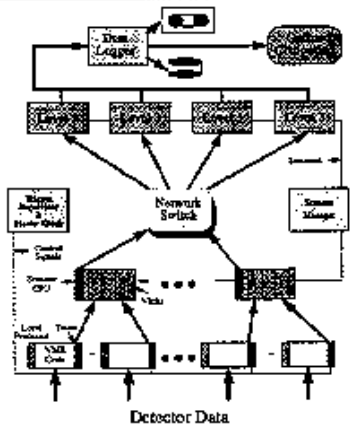
- Pipeline Readout
- Data sampled every 132 ns (TDC's Calorimetry, Silicon)
- Level 1 trigger Decision every 42 crossings (synchronous) 5.5 μs
- Data --> Level 2 Buffer
- Level 2 Dec: Asynchronous, 20 μs
- Readout --> Level 3 Farm
- Accept rates x 10 more than Run I
  - ➢ Level 1: < 50 Khz
  - ➢ Level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

SVT Architecture



- New Capability for Detector at a Hadron collider
- Trigger on displaced tracks
- Find tracks in COT at Level I ($\Delta Pt/Pt = .01*Pt$)
- Readout of SVXII in < 10 μs
- Associate SVX hits with COT tracks and fit. ($\Delta Pt/Pt = .003*Pt$)
- Trigger on track displaced from beamline at Level II.

DAQ System



- Heavy use of commercial equipment and software
- 120 VME crates on detector + counting room
- Data collected into 12 VME crates
- Scanner CPU's --> commercial Network switch

Offline

- The CDF collaboration has a large task to write new offline code for the CDF II detector.
- Issues:
  - ➢ Accurate detector simulation
  - ➢ New reconstruction software for new detectors + old
  - ➢ Access to large samples
  - ➢ C++ vs Fortran, New infrastructure = code management tools data bases
- Goal: Ready for first Run II collisions

Effort useful for the approved detector

- Electronics
  - ASIC testing
  - Board level programmers
  - Electronics testing and system integration
- Monitoring and Controls System
- Online DAQ
  - Online Data Diagnostics & Monitoring
  - Calibration data base
- Offline (lots)
  - Simulation
  - Reconstruction code (tracking, calorimetry, etc)
  - Data management and access

Possible Improvements to the approved detector

- Preshower detector in plug region
- Time-of-Flight system
- XFT extension:SL7 segment finding,Plug track trigger
- Split inner COT wires at 90 degrees
- Complete 7th layer of the ISL
- Photon isolation trigger, EM TDC's
- Add a Micro-Plug (Diffractive Physics)
- DAQ network switch (add more bandwidth)

Summary

- The CDF II project has a well-defined scope.
  - ➢ Baseline defined by TDR, approved, funding in place.
  - ➢ Other Improvements from contingency or non-US funds
- Expected funding from U.S. and abroad is well-matched to the project's estimated cost with reasonable contingency
- Receiving excellent support from FNAL.
- Good marks at recent DOE Review ($ 6--> $12 M in FY 98)
- Technical manpower and organization is mostly in place to build this detector but there are still holes.
- **Currently we are not Money or technical manpower limited for the baseline Detector. Limit is Physicists ! Additional funds and manpower needed for enhancements to baseline detector.**

I'm convinced, so how do I join?

- Case study I: small independent group
  - ➢ Karlsruhe
- Case study II: confederation of groups working coherently
  - ➢ Proposal to IN2P3 from French groups

Karlsruhe, case study I

- Admitted to CDF in November 1996
- Upgrade responsibilities: Intermed. Silicon (ISL)
  - Testing of sensors
  - Manufacturing of jigs and fixtures
  - Quality control measurements
- Staff
  - 3 faculty (average 65% on CDF)
  - 4 postdocs (average 75% on CDF)
  - 4 students
  - 6 technical staff (50% on CDF)

French groups

- Proposal to IN2P3
- Groups
  - Ecole Polytechnique
  - Lyon
  - Paris VI-VII
  - CPPM (Marseille)
  - Strasbourg
  - LPC Clermont
- Projects
  - Reconstruction and simulation
  - Trigger design and construction

Conclusions
The Tevatron offers:

- Extremely rich physics program
- Great training ground for (or alternative to) LHC
- Many opportunities to become involved
- If there is interest, we could organize a day-long meeting in England for more detailed presentations and discussions