Tracking at CDF

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Outline

The CDF Run II Detector

Tracking Algorithms

Drift Chamber Tracking

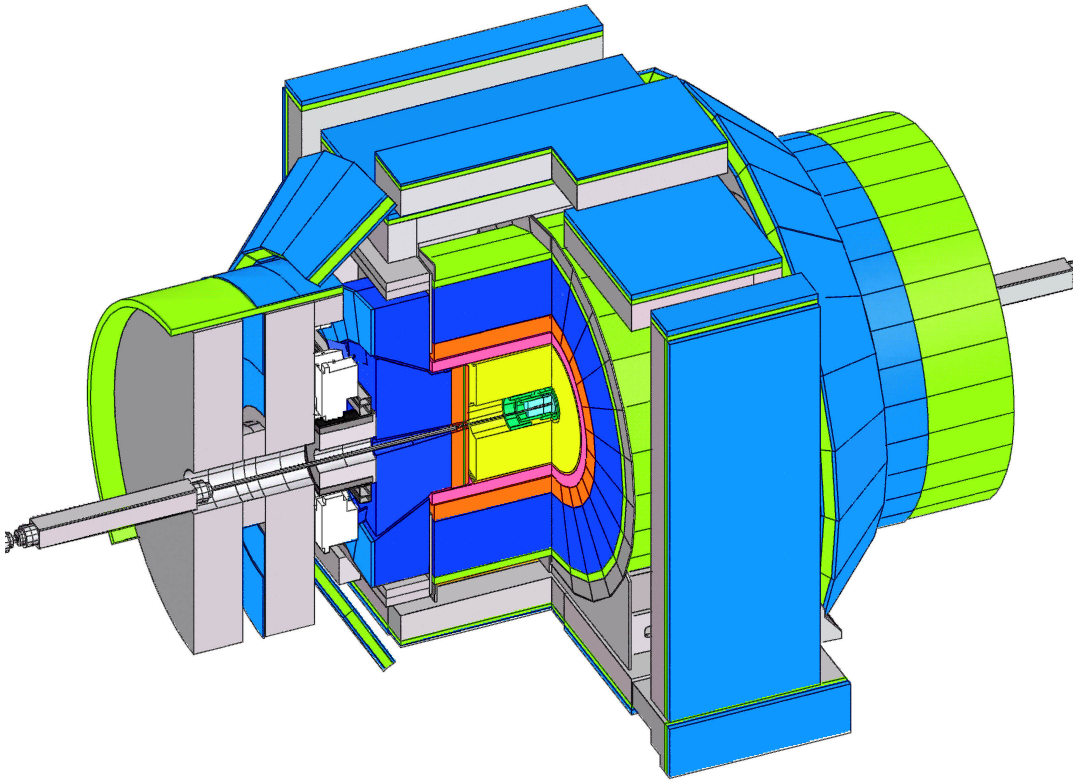
Silicon Tracking

Conclusions

CDF Run 2 Detector

Detector improvements

- Completely new central detector
  - Central Outer Tracker: Drift Chamber
  - 8 layer silicon detector
- Increased muon coverage
  - Track/Muon triggers to $|\eta| = 1.0$
  - Coverage extended to $|\eta| = 1.5$
- Time of Flight: π K p particle ID
- Central and now plug calorimeter
  - Calorimeter coverage to $|\eta| = 3.0$
- Trigger
  - Three level trigger
  - 50KHz Level 1 - 50Hz to tape

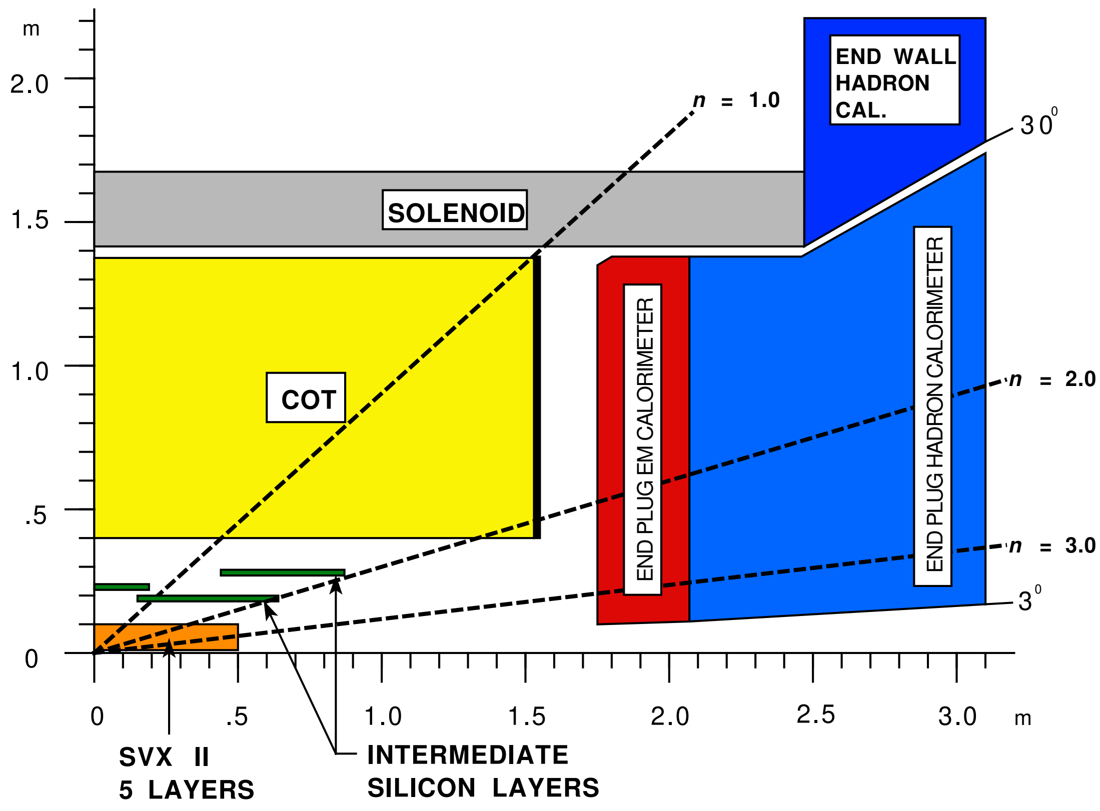


Run 2 Tracker: Drift Chamber

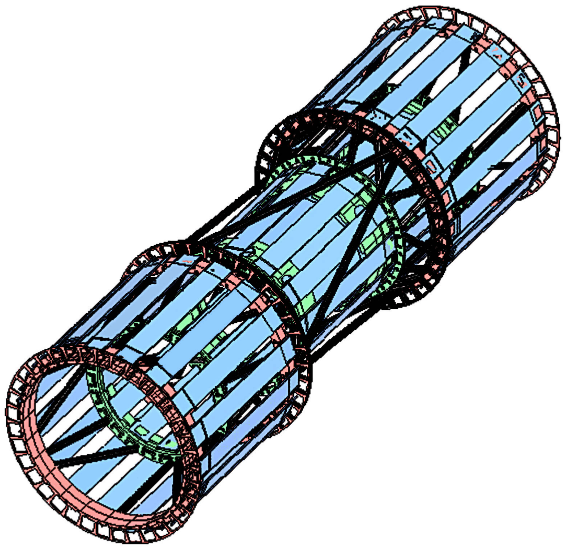
Central outer tracker: COT

- Drift chamber
  - 8 super layers: 4 axial 4 stereo
    96 measurements between
    44 and 132cm
  - All measurements used for dE/dx
  - Tracking for $|\eta| < 1.0$
- Extremely fast track trigger: XFT
  - Axial track trigger
  - 50 KHz into Level 1 trigger
- Full reconstruction of tracks in level 3 trigger
- Resolution
  - $\delta p_T / p_T^2 \sim 0.15\% (\mathrm{GeV/c})^{-1}$
  - Impact parameter resolution of 350μm

CDF Tracking Volume

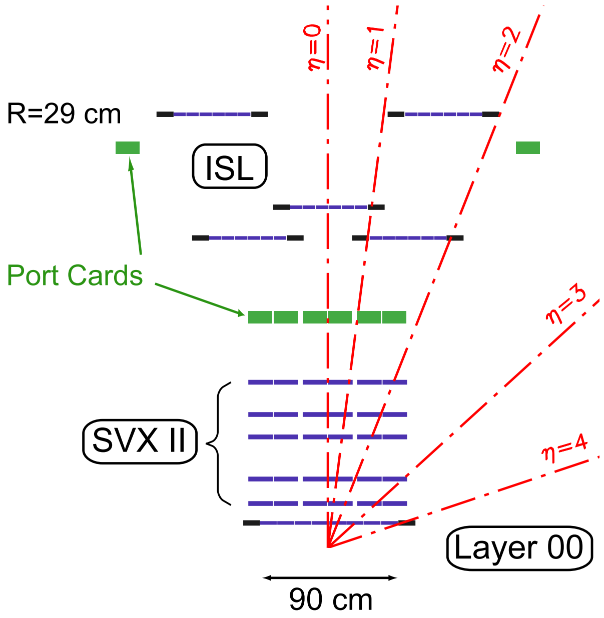


Run 2 Silicon



Features

- 8 layers(7 double sided)
- Standalone tracking for $|\eta| < 2.0$
  - ISL extends range
- 3D tracking - 3 layers of 90^o strips
- L00
  - Precision measurement point at $1.3 - 1.6\mathrm{cm}$



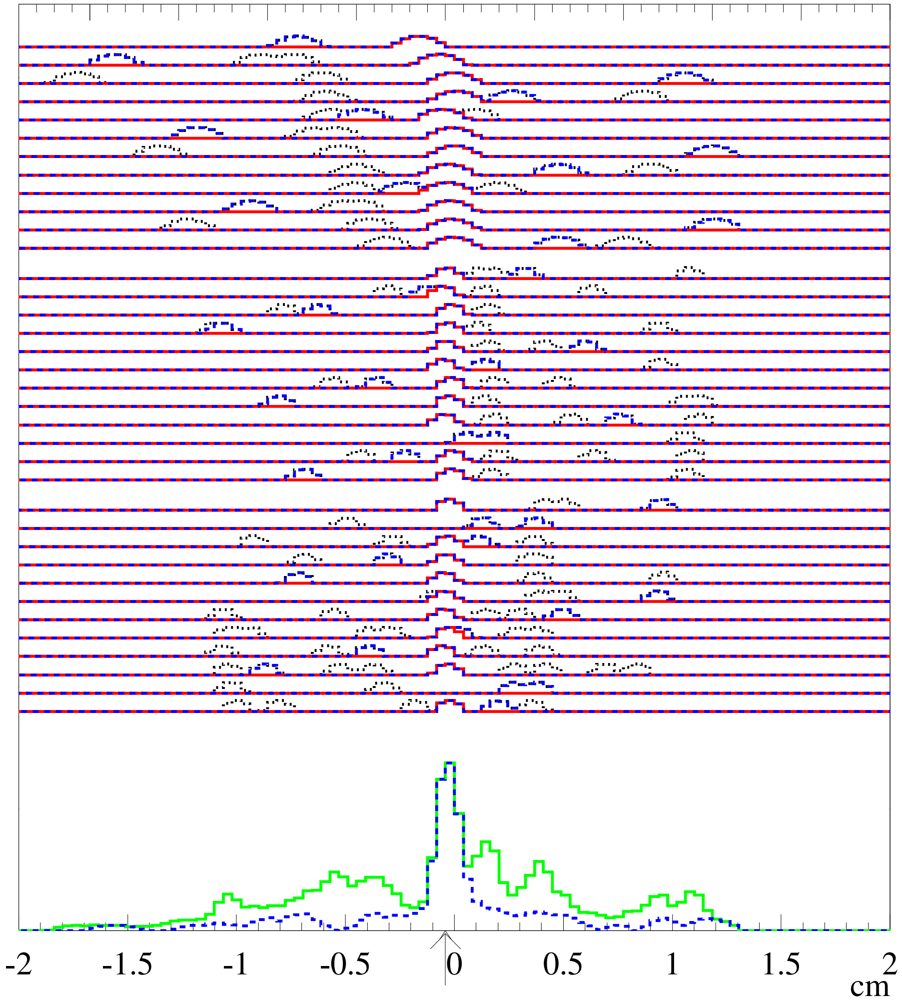
Silicon Vertex Trigger(SVT)

- 5 layer trigger
  - Displaced track trigger
  - Cuts at 120μm
  - 35μm resolution (few μm worse than offline) $\sim 47\mu\mathrm{m}$ with beam line$(31\mu\mathrm{m})$

COT Tracking Algorithms

Central Outer Tracker(COT)

- Axial segment linking
  - Form segments with hits in axial layers
  - Link segments together into tracks
- Axial histogram linking
  - Start with segment in outer super layers
  - Use segment curvature and beamline to form road
  - Add hits using histograming method
  - Fast method suitable for low mass chamber: minimal multiple scattering
  - Complementary to segment linking method
- Followed by stereo segment linking
- Merge tracks from axial methods
  - Two methods help increase efficiency and reduce fake rate(3% gain)

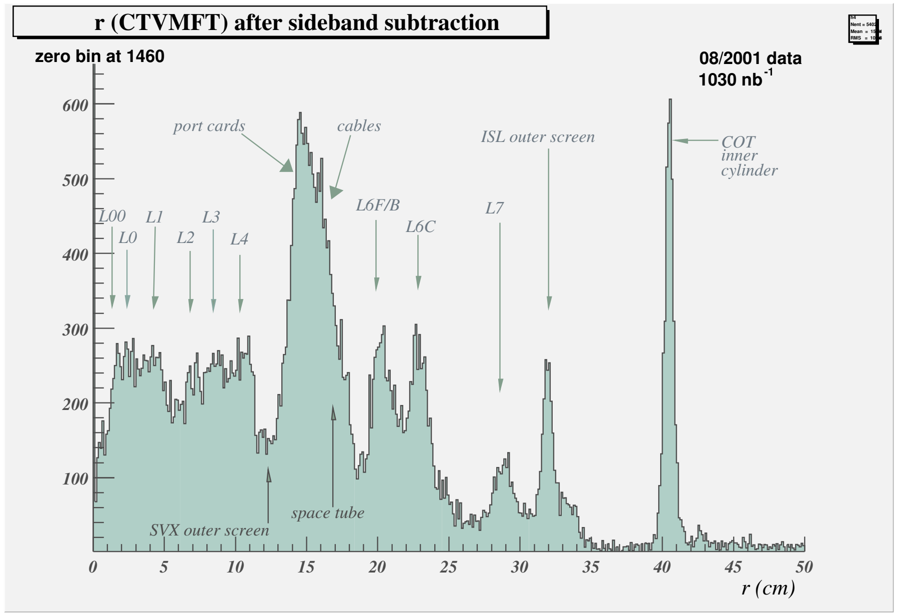


Histogram formed relative to the nominal search path

Silicon Tracking Algorithms

Silicon detector

- Outside-In tracking
  - Uses COT track as seed
  - Progressive road search
  - Fitting performed using a kalman filter approach
  - Excellent for progressively incorporating discreet measurement points with errors
  - Tracking done in 2 passes: r-phi and r-z
  - OI silicon reconstruction fast enough to be used in level 3 trigger
- Standalone silicon tracking
  - Tracking outside of acceptance of COT
  - Start with two 3D measurement points on the outer silicon layers
  - Road from the points and the beamline
  - Progressive road search as in OI case (uses same fitter)

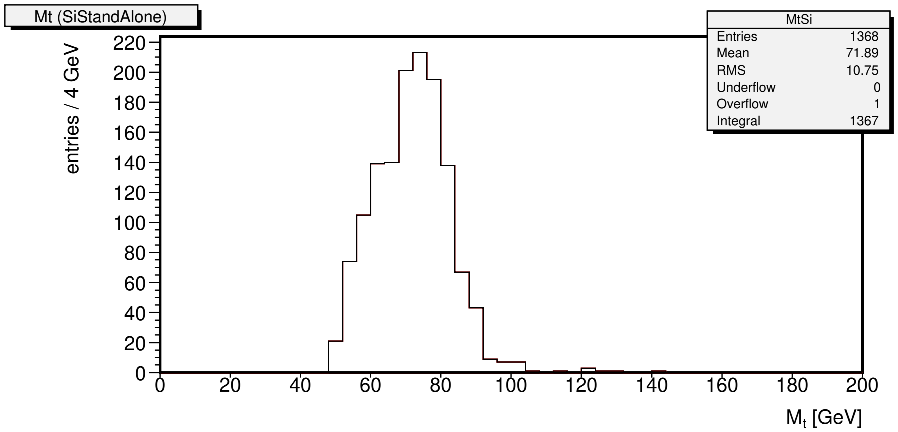


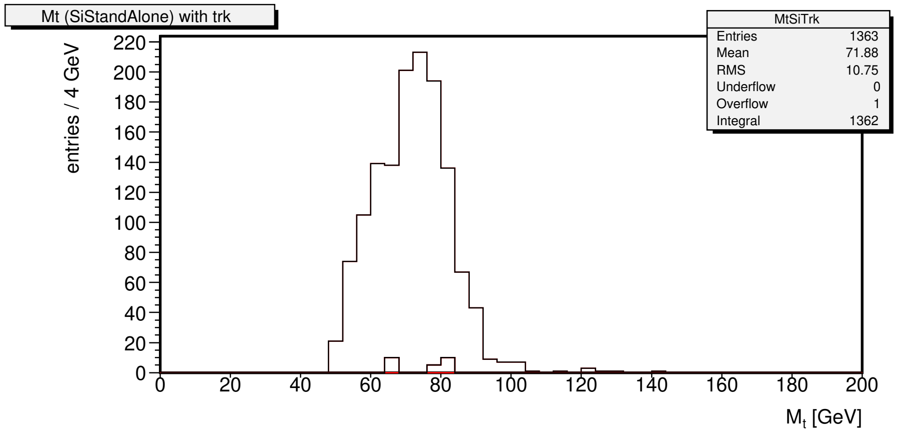
Photon conversions in the silicon detector
- Kalman filter used in conjunction with material integrator

Drift Chamber Performance: High Pt efficiency

W no track efficiency measurement

- Select clean same of $\mathrm{W} \to e\nu$ events
  - Calorimeter and silicon information
  - Isolated electromagnetic clusters (less than 10% hadronic energy)
  - Suppress backgrounds - cosmics, beam splashes ...
- Efficiency
  - Fraction with track pointing to EM tower
  - $\varepsilon_{\mathrm{COT}} = 99.93^{+0.16}_{-0.26}(\mathrm{stat})^{+0.31}_{-0.31}(\mathrm{sys})$
- Systematics
  - Correlations of failures between COT and silicon



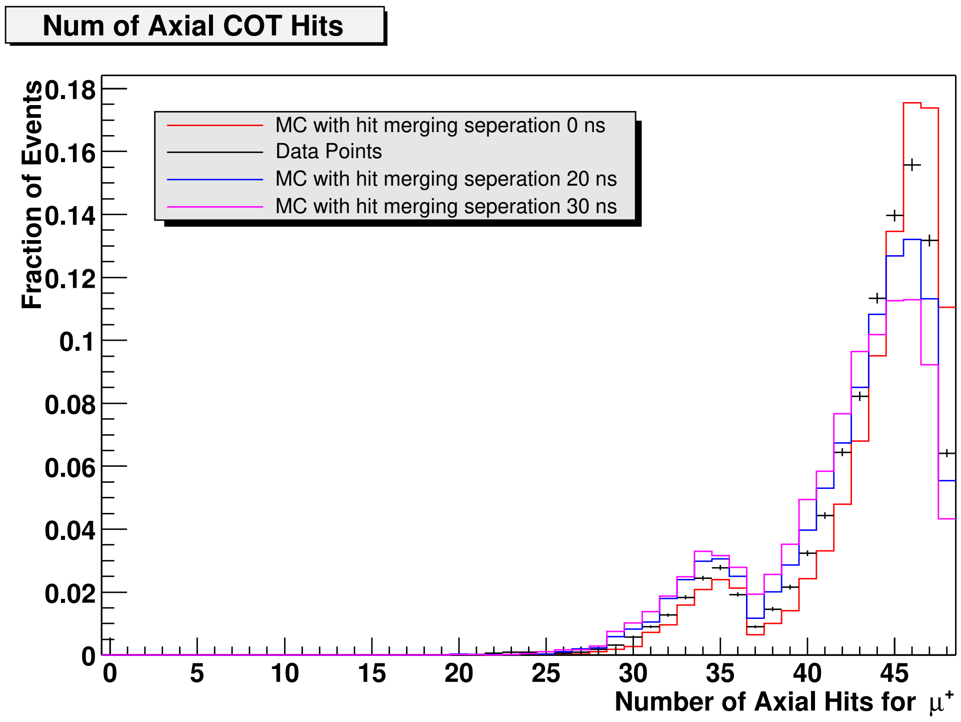


Transverse mass distribution of W candidates: overlaid are failures(scaled by a factor of five)

Drift Chamber Performance: Low Pt efficiency

Track embedding

- Data: Difficult to form a clean denominator for low pt tracks
- Simulation: sources of drift chamber occupancy not well simulated
  - Underlying event, scattering and physics
- Embed simulated track in data and measure efficiency
  - Key: reproduce the correct hit usage
  - Tunable parameter: distance at which drift chamber hits are merged
  - Loss of hits drives inefficiency

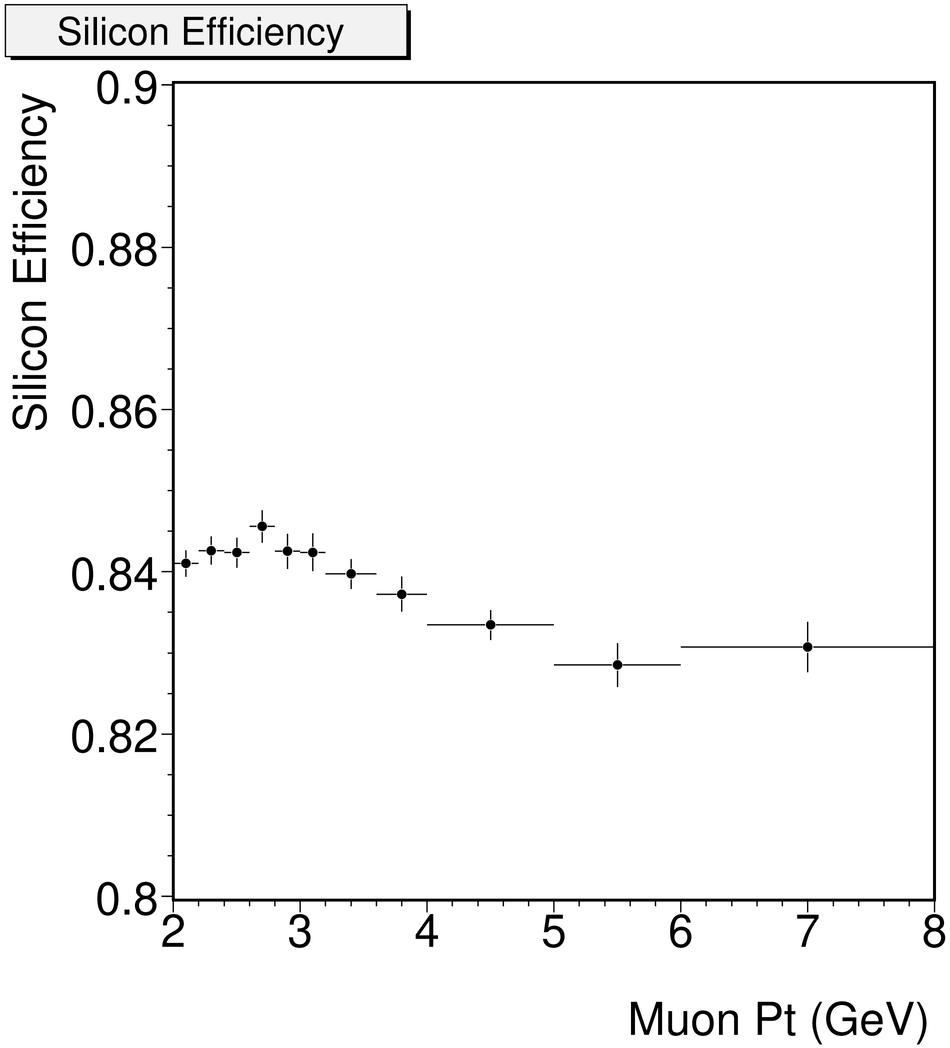


Preliminary efficiency similar to W no track result.

Silicon Tracking Performance

Efficiency as a function of $\mathrm{p_T}$

- Use $\mathrm{J}/\psi \rightarrow \mu\mu$ events
- Denominator
  - Good tracks - Muons identified in COT and muon Chambers
  - Fiducial in silicon - intersects at least 3 layers of SVXII - vertexing part of silicon detector
- Numerator: Find hits in at least N-1 of the intersected layers
  - Fake rate is quite low: 3% - Measured from tracks with negative impact paramter
  - More strict requirements have a large effect on the efficiency



Average efficiency $84.0 \pm 0.1(\mathrm{stat})\%$

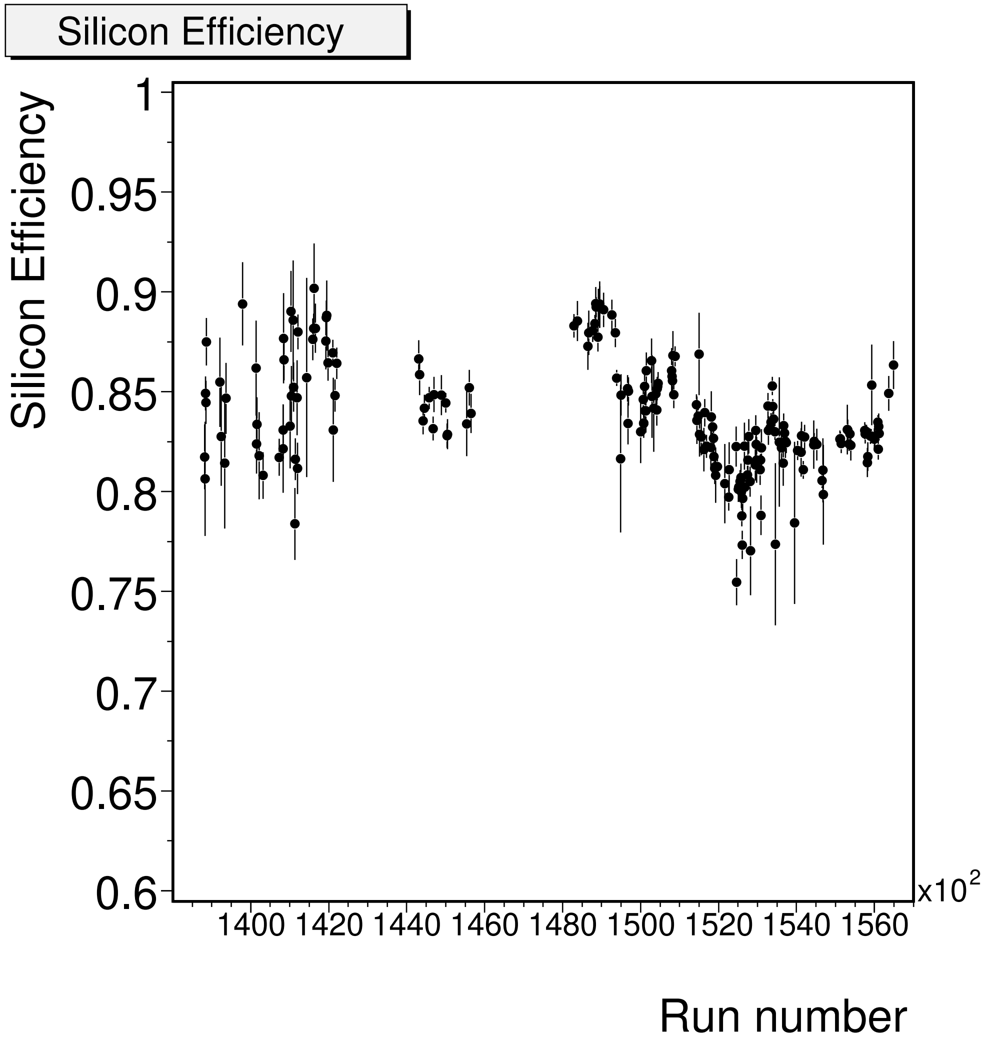
Silicon Eff: Time Dependence

Efficiency as a function of run number

- Dependence is on order $\pm 7\%$
  - Evaluate the silicon efficiency for several consistent run periods
- Why does efficiency vary
  - Detector failures/repairs
  - Errors in optical readout system
  - System performance is becoming more stable

Average efficiency: $84.0 \pm 0.1(\mathrm{stat}) \pm 1.4\%$

- Sytsematic errors
  - $\mathrm{p_T}$ dependence
  - Correlations: tracks in the same wedge (eff measured using 2 track J/ψ decay)
  - Run dependent correlations



Tracking Performance: Execution times

Execution time optimization

- Drift Chamber tracking
  - Segment linking: optimized code ported from Run 1
  - Still works well in C++
  - New complementary histogram tracking algorithm implemented
  - Intrinsically fast (simplicity)
- Silicon tracking
  - Outside-In tracking should be simple
  - Progressive road search using a kalman filter
  - Fast implementation
  - Careful optimization of memory management

Performance

- COT tracking
  - Offline - combination of two algorithms: 0.3sec
  - Only histogram method used at level 3: 0.15sec
- Silicon tracking
  - Calibration and clustering: 0.45sec
  - Outside-In tracking: 0.1sec
  - Standalone tracking: 0.25sec
  - Total offline silicon: 0.8sec
  - Level 3 - Only OI tracking and simplified calibration: 0.20sec

Conclusions

Have implemented efficient tracking for the CDF Run II drift chamber and silicon

- For high transverse momentum tracking in the drift chamber:
  - Average efficiency per track is $\varepsilon = 99.93^{+0.16}_{-0.26}(\mathrm{stat})^{+0.31}_{-0.31}(\mathrm{sys})$
- Efficiency for outside in tracking to attach silicon hits:
  - Average efficiency:$84.0 \pm 0.1(\mathrm{stat}) \pm 1.4\%$
  - Silicon inefficiency is mostly driven by hardware issues

The execution speed of the tracking is good for both level 3 and offline processing

- Full offline line tracking time is 1.1sec
- At level 3 a faster version of the tracking is run
  - Level 3 execution time is 0.35 sec
  - Level 3 version of tracking includes outside in silicon tracking