Silicon Tracking for Forward Electron Identification at CDF

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Outline

• Motivation and History
• CDF Run II upgrade
• Forward Tracking algorithm
• Physics Prospects
In Run 1, CDF had tracking only in central region.
Physics beyond $|\eta|=1$ e.g., look at \eta of e in $Z \rightarrow e^+e^-$

$|\eta|<1 = 50\%$

$|\eta|<2 = 83\%$

...but what matters is finding both $e^+$ and $e^-$...
What is $\eta$ of $\text{max } \eta \text{ e}^\pm$ in $Z \rightarrow e^+e^-$

$|\eta| < 1 = 25\%$

$|\eta| < 2 = 70\%$

$E_T > 20 \text{ GeV}$
More central at high mass, e.g. 800 GeV/c²  $Z' \rightarrow e^+e^-$

$|\eta|<1 = 53\%$

$|\eta|<2 = 90\%$
Plug Electron ID in Run 1

Some plug e ID

- Had/EM < 0.05
- Isolation < 0.1
- VTX Occupancy
Two electrons with $|\eta|<1$, $S:B \sim 20$

One electron with $|\eta|<1$ and one with $|\eta|>1$, $S:B \sim 1$

...but poor purity even in di-electron case
Silicon tracking coverage to higher $\eta$
Using forward silicon hits in Run 1

1. Stand-alone silicon pattern recognition
   • Fit for $\phi_0, d_0, p_T$ (curvature)
     with 4 hits, $\leq 1$ dof.

   • It worked, but was limited by
     • lever arm ($L^2$)
     • Too few hits
     • Poor curvature resolution degraded impact parameter resolution
     • 4% relative increase in b-tagging for top
2. Calorimeter-seeded tracking for electrons
   • Constrains $p_T$ and $\phi_0$
   • Adds 1 d.o.f.
   • Used same pattern recognition as standard outside-in tracking
   • But, lever arm still too small to measure curvature, just an initial direction so you have to rely on the calorimeter’s position measurement.
$ee\gamma\gamma E_T$ event

$e_1$
$E_T = 36$ GeV

$\gamma_1$
$E_T = 36$ GeV

$\gamma_2$
$E_T = 30$ GeV

$e$ Candidate
$E_T = 63$ GeV

$E_T = 55$ GeV
$ee\gamma\gamma\not{E}_T$ event
Significant Improvements for Run II

ISL

SVXII

L00

SVX’ (Run 1)
Intermediate Silicon Layers for Run II

5 m² of silicon
Performance goals

• 8 layers over 30cm lever arm
  • 3x the lever arm
  • At 30 cm occupancy is low enough to attach single hits with minimal ambiguity because a typical jet, ~10 tracks in a $\Delta \phi < 0.2$ cone, covers 1000 channels
Performance goals

- 8 layers over 30cm lever arm
- Sufficient $p_T$ resolution to
  - Determine $d_0$
  - Determine charge over a large $p_T$ range
Performance goals

- 8 layers over 30cm lever arm
- Sufficient pT resolution
- Sufficient pointing resolution into COT to pick up more hits
  - $< 2$ track resolution for $\sim$ all $p_T$
  - $\sim$ hit resolution for $p_T > 10$ GeV
  - rz view is also comparable

- This will allow stand-alone, inside-out tracking once we reach design resolution.
Silicon Commissioning in progress
Alignment in progress

- Global ~finished
- Internal starting

But, even with a rough alignment we are now tracking forward electrons with a calorimeter seeded approach similar to the original Run 1 algorithm.
Forward Electron Tracking Algorithm

1. Form 2 seed tracks, one of each sign, from calorimeter & beam spot
Forward Electron Tracking Algorithm

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2. Project into silicon and attach hits using standard silicon pattern recognition
Forward Electron Tracking Algorithm

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3. Select best $\chi^2$ match
Plug Alignment

Align plug to COT using the subset of COT tracks which match plug electrons just above $|\eta|=1$. Then align silicon to the COT.
Plug Alignment
Plug Alignment
Performance

1. Efficiency
2. Fake Rate
3. Charge MisId

Measured using $Z \rightarrow e^+e^-$ with one “leg” in the central to reduce background and identify charge
Performance

1. Efficiency
   ~80% in Monte Carlo
   ~30% in data due to remaining commissioning effects
   Improvements coming.
Performance

1. Efficiency
2. Fake Rate

...In progress...

In addition to the standard techniques, we are pursuing a silicon occupancy measure.
Performance

1. Efficiency
2. Fake Rate
3. Charge MisId

Comparable to COT for $|\eta|<1$ because of CES resolution and lever arm.

$\sim 10\%$ for $1<|\eta|<2$

Barely “non-random” for $|\eta|>2$
1. **Alignment**
   For $|\eta| > 2$, need full silicon and PES resolution to determine charge.

   Meanwhile, can improve with seed covariance pulls
Future Improvements

1. Alignment
2. 3D hits
Future Improvements

1. Alignment

2. 3D hits

3. Adding COT hits
   1 axial layer to $|\eta| \sim 1.6$
   1 stereo layer to $|\eta| \sim 2.0$
Future Improvements

1. Alignment

2. 3D hits

3. Adding COT hits

4. Muons

IMU coverage to $|\eta|=1.5$
fully within ISL and $\geq 1$
axial COT superlayer

Momentum constraint becomes asymmetric but still powerful.
Future Improvements

1. Alignment
2. 3D hits
3. Adding COT hits
4. Muons
5. Level 3 Trigger

Silicon outside-in tracking for L3 will be ready soon. CAL seeded tracking is then a small, fast, addition
Impact on acceptance

Single electron case

Gain, $|\eta|<3$ v.s. $|\eta|<1$

- **Ideal**
- **With $\sim$eff**

Categories:
- **W**
- **WH**
- **top**
Impact on acceptance

Multi electron modes
Our first step was using this for tracking $Z \rightarrow e^+e^-$ with both $e^\pm$ in the plug.
Now measuring charge asymmetry in $W^{\pm} \rightarrow e^{\pm}\nu$
\sim 30 \text{ pb}^{-1} \text{ processed so far}
Cross-check to COT in the central
CDF Run II Preliminary

W Charge Asymmetry

|Lepton Rapidity|

- CTEQ-3M (RESBOS)
- MRS-R2 (DYRAD)
- MRST (DYRAD)

Data points:
- □ 110 pb\(^{-1}\) Run I (e+mu) PRL 81, 5754 (1998)
- ● 32 pb\(^{-1}\) Run II (e only)
Improvements beyond statistics

At highest $\eta$, error currently dominated by charge ID
Adding COT hits will significantly improve this.
Conclusion

Calorimeter seeded algorithm implemented

Promising gains in acceptance

$W$ asymmetry despite low luminosity

Electron ID is moving forward in Run II