Electroweak Prospects for TeVatron RunII

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(on behalf of the CDF and D0 Collaborations)

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Data Sets for RunII EWK Physics:

Event yields in per experiment

<table>
<thead>
<tr>
<th>Sample</th>
<th>Run I</th>
<th>Run IIa</th>
</tr>
</thead>
<tbody>
<tr>
<td>W→lν</td>
<td>77k</td>
<td>2300k</td>
</tr>
<tr>
<td>Z→ll</td>
<td>10k</td>
<td>202k</td>
</tr>
<tr>
<td>WV (W→lν, v=W,γ,Z)</td>
<td>90</td>
<td>1800</td>
</tr>
<tr>
<td>ZV (Z→ll, v=W,γ,Z)</td>
<td>30</td>
<td>500</td>
</tr>
<tr>
<td>tt (mass sample, ≥1Btag)</td>
<td>20</td>
<td>800</td>
</tr>
</tbody>
</table>

- 100 pb⁻¹/exp in RunI
- 2 fb⁻¹/exp in RunIIa
- l = e or μ

- RunI produced breadth of Electroweak physics results and provided world’s only sample of top quarks
- RunII physics EWK “program” basically the same
- RunII Upgrades ought yield many precision (<1%) results
RunII TeVatron Upgrades:

• RunIIa Luminosity Goals
  - 5-8 E31 cm$^{-2}$/sec (w/o Recycler)
  - 10-20 E31 cm$^{-2}$/sec (w/ Recycler)
  - integrated: 2-5 fb$^{-1}$ (2004)

• RunIIb Luminosity Goals
  - 40-50 E31 cm$^{-2}$/sec
  - integrated: 15 fb$^{-1}$ (2007)

• $\sqrt{s} = 1.96$ TeV
  - $\sigma(W), \sigma(Z) \sim 10\%$ higher
  - $\sigma(tt) \sim 35\%$ higher

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RunII Detector Upgrades:

• CDF
  - 8 layers of silicon ($r_{max}=30$ cm)
  - new drift chamber (COT)
  - extended lepton-ID ($|\eta|>1$)
  - displaced track trigger

• D0
  - 4 layers plus disks of silicon
  - new fiber tracker (CFT)
  - solenoid (2 Tesla)
  - extended lepton-ID ($|\eta|>1$)

Projections assume:

✓ E and P resolutions same/better RunI
✓ B-jet and lepton ID extended to $|\eta|>1$
✓ improved triggering
TeVatron RunII

At this early stage, it’s interesting to ask whether or not the detector performance looks consistent with those expectations.

Discuss present detector performance in the context of some of RunII Electroweak measurements of particular importance.
Electroweak Physics at the TeVatron

Precision $M_W, M_{\text{top}}$:
- CDF/D0 direct measurements compliment e+e- results
- provide consistency checks
- will improve indirect constraints on $M_H$ w/i SM

Search for SM Higgs:
- Light Higgs discovery possible
- Observation or not, SM will be tested by comparison of $M_H$ to indirect limits from EWK fit

→ discuss detector performance in the context of these measurements
Measuring Mw at the TeVatron

W production at the TeV:

1. Calculate transverse mass
   \[ M_T = \sqrt{\left(E_T^\ell + E_T^\nu\right)^2 - \left(P_T^\ell + P_T^\nu\right)^2} \]
   \[ \Rightarrow \text{understand } E \text{ and } P \text{ scales and resolutions} \]

2. Calculate missing transverse momentum
   \[ P_T^\nu = -(P_T^\ell + U) \]
   \[ \Rightarrow \text{must model } \text{Underlying event and recoil distributions, etc.} \]

3. From M_T distribution extract measure of Mw
   \[ \Rightarrow \text{sensitive to PDFs (use forward calorimeters)} \]
Run1 W Mass

CDF/D0 Combined
Statistical: 40 MeV
Systematic
  scale: 40 MeV +
  recoil: 20 MeV +
  modeling: 15 MeV *
  other: 15 MeV +
Sys Total: 38 MeV

From RunI
  CDF: 80.433 +/- 0.079 GeV
  D0: 80.483 +/- 0.084 GeV
  Comb: 80.456 +/- 0.059 GeV

After 2 fb-1 at RunII, expect
  \( \Delta M_w = +/-30 \text{ MeV/} \text{exp} \)
  \( \Delta M_w(\text{Wrld}) = +/-15-20 \text{ MeV} \)

+ largely statistical in nature
* correlated among experiments

RunII projections assume detectors will perform similarly to RunI so that, M uncertainty to \( \sim \)scale w/ statistics

How will \( P_t^V \) resolution scale with inst. Luminosity?
Momentum Scales & Resolutions in RunII

- Use low lying resonances to get P scale/resolution

CDF RunII Preliminary
~11 pb⁻¹

53k “golden”
J/Ψ → μμ

σ = 15 MeV

DØ Run II Preliminary
mean = 3.071 ± 0.003 GeV
σ = 0.088 ± 0.003 GeV

J/Ψ → μμ
~8 pb⁻¹

⇒ already large statistics samples available to study tracking
D0’s Central Fiber Tracker Performance:

Very different from RunI:
- fiber tracker
- $r = 0.20$-$0.51$ m
- 8 axial hits
- 8 stereo hits
- in 2T field
  - $\sigma(\text{Pt})/\text{Pt}^2(\text{design}) = 0.14\%/\text{GeV}$

Per layer hit efficiencies:
- $\varepsilon(\text{axial layers}) = 99\%$
- $\varepsilon(\text{stereo layers}) = 98\%$
(expect high tracking efficiency)

Alignment well underway, significant improvements expected.

Assuming “nominal” positioning:

\[ \chi^2 / \text{ndf} = 4.6 / 13 \]
Mean = $88.9 \pm 1.4$
Sigma = $11.6 \pm 1.5$
Bkgd = $2.8 \pm 0.7$

\[ Z \rightarrow \mu \mu \]
\[ \sigma(\text{dt})/\sigma(\text{mc}) = 1.20 \]
CDF’s Central Outer Tracker Performance:

“out of box”:
- $\sigma(\text{hit}) = 175 \text{ \(\mu\)m}$ (TDR said 180 \(\mu\)m)
- $\frac{\sigma(\text{Pt})}{\text{Pt}^2} < 0.13\% \text{ GeV}^{-1}$ (RunI = 0.10%)

Very similar to Run I:
- $r = 0.4\text{-}1.4 \text{ m}$
- 48 axial hits
- 48 stereo hits
- in 1.4T field
- $\frac{\sigma(\text{Pt})}{\text{Pt}^2}\text{(design)} < 0.1\% \text{ GeV}^{-1}$

From $W \rightarrow \text{ev}$ events:
- $\mathcal{E}(\text{COT tracking}) = 99 \pm 1\%$
- expect further improvements as alignment matures

Residual misalignments factors of $2\text{-}3 < \text{best RunI}$
Energy Scales & Resolutions in RunII

- Nominally, use E/P distributions to set absolute scale and resolution
  - assumes P-scale/resolution thoroughly understood

> at this early stage, use $Z \rightarrow ee$ to estimate E resolution
D0’s ECAL Performance:

For central & forward:

- partial corrections included
- $\sigma(\text{data})/\sigma(\text{mc}) < 1.30$
- w/ inclusion of full corrections
  expect to meet expectations

\[ \text{Number of Entries: 604} \]
\[ \text{Peak Mass: 90.8 \pm 0.2 GeV} \]
\[ \text{Width: 3.6 \pm 0.2 GeV} \]

one electron $|\eta| < 1.0$
- $N(Z\rightarrow\text{ee}) = 495$
CDF’s ECAL Performance:

For central & forward:

- includes dominant corrections
- \( \sigma(\text{data})/\sigma(\text{mc}) < 1.05 \)
- ECAL resolution as expected

- both electrons \(|\eta|<1.0\)
  - \( N(Z\rightarrow ee) = 247 \)

- one electron \(|\eta|>1.0\)
  - \( N(Z\rightarrow ee) = 391 \)
Extending lepton-ID:

extending $M_W$ and asymmetry measurements to large $|\eta|$ reduces $M_W$ PDF uncertainties (which are CDF/D0 correlated)

both electrons $|\eta| > 1.2$

- $N(Z \rightarrow ee) = 160$

Starting to collect control samples & performing first pass analyses to demonstrate thorough understanding of forward detectors.

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Measuring $M_{\text{top}}$ at the TeVatron

**tt production at the TeV:**

```
  p  \(\bar{q}q\)  t  \(\bar{t}\)
  p  \(q\)  g
```

**Final states (2 B-jets + Ws):**
- dilepton (2 $W \rightarrow l\nu$)
- lepton+jets ($W \rightarrow l\nu, W \rightarrow q\bar{q}$)
- all hadronic (2 $W \rightarrow q\bar{q}$)

**To extract $M_{\text{top}}$:**

1. Choose $W \rightarrow jj$ and $t \rightarrow Wb$ associations ➔ Combinatorics reduce sensitivity
2. Make appropriate jet energy corrections ➔ Large systematic uncertainty
3. Kinematic Fit for $M_{\text{fit}}$
4. Extract $M_{\text{top}}$ from $M_{\text{fit}}$ distribution

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Run1 Top Mass

“Typical” $M_{\text{top}}$ Uncertainties/exp

- Statistical: 5 GeV
- Systematic
  - scale: 4 GeV
  - modeling: 2 GeV *
  - other: 2 GeV
- Sys Total: 5 GeV

*correlated among experiments

From Run1
- CDF: 176.1 +/- 6.6 GeV
- D0: 172.1 +/- 7.1 GeV
- Comb: 174.3 +/- 5.1 GeV

After 2 fb-1 at Run2, expect
$\Delta M_{\text{top}}$ = +/- 2-3 GeV/exp

- increased acceptance and $\sigma_{tt}$ gives factor of 50 in statistics
  (RunIIa will have ~800 lepton+jet evts in mass sample, RunI ~20)
  so expected RunIIa stat uncertainty: less than +/- 1GeV

- reducing total systematic to 2 GeV level requires use of special
  control samples ($Z+$jets, $Z\rightarrow bb$, $W\rightarrow qq$) too small to be of use in RunI

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**Top Mass: Combinatorics**

Combinatoric background a function of # of B-jet tags in events:
- 2, 6 or 12 jet-jet combos vs N(B-tag)

For events with >= 1 b-tag:
- **30%** correct jet assignment (black)
- **20%** correct jets but wrong combination (yellow)
- **50%** mismatch between parton and its jet (red)
  - ie. extra jets from gluon radiation

→ Increased B-tagging acceptance most important factor in improving $M_{top}$
- increases statistics
- improves purity
- reduces combinatorics

**CDF RunI Simulation for $M_{top}=175$ GeV**

improved $M_{top}$ sensitivity
D0’s Silicon Microstrip Tracker Performance:

- Performing as expected
- 95% working channels (and regularly taking data)
- Precision alignment of “z”-strips underway

S/N > 12

\[ \chi^2 / \text{ndf} = 24 / 29 \]
\[ \text{Mean} = 0.9 \pm 2.2 \]
\[ \text{Sigma} = 36.3 \pm 1.8 \]
\[ \text{Bkgd} = 1.1 \pm 0.3 \]

\[ \sigma(d0) = 20 \mu m \]

Δ Length corrected \( r \phi \) cluster charge (ADC)
CDF’s Silicon VerteX Detector Performance:

before alignment

\[ \Delta r \phi \]

\[ \pm 20 \mu m \]

after alignment

\[ \Delta r \phi \]

\[ \pm 3 \mu m \]

S/N = 12, Hit efficiency >99% , \( \sigma \) (intrinsic 2strip r\( \phi \)) = 11\( \mu m \)

• Performing as expected
• 92% working channels (presently, 85% regularly taking data)
• precision alignment of “z”-strips underway
SM Higgs Search at the TeVatron

Need to use $H \rightarrow bb$ and $H \rightarrow WW$ to maintain sensitivity over wide mass range.
SM Higgs Search at the TeVatron

Observation possible with >2 fb$^{-1}$ of integrated luminosity

- assumes good B-jet and lepton ID to full acceptance
- assumes detector resolutions at least as good as RunI
- assumes triggers efficient at large inst. luminosities
Triggers

CDF rates
• now (L\sim10^{31}):
  \[ L1/L2/L3 = 6000/240/30 \text{ Hz} \]
• goal (L\sim10^{32}):
  \[ L1/L2/L3 = 50000/300/50 \text{ Hz} \]

D0 rates
• now (L\sim10^{31}):
  \[ L1/L2/L3 = 200/140/50 \text{ Hz} \]
• goal (L\sim10^{32}):
  \[ L1/L2/L3 = 7000/1500/50 \text{ Hz} \]

* lepton triggers operating at high \( \varepsilon \)… important to maintain at high instantaneous luminosities!
SM Higgs Background Studies

$H \rightarrow WW \rightarrow e e \nu \nu$ in 9 pb$^{-1}$ of data

- do we understand our backgrounds?

<table>
<thead>
<tr>
<th>Cut</th>
<th>Predicted</th>
<th>Obsrvd</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID, $Pt&gt;20$ GeV</td>
<td>430±58</td>
<td>452</td>
</tr>
<tr>
<td>+Me $&lt;78$ GeV</td>
<td>35±6</td>
<td>46</td>
</tr>
<tr>
<td>+Et $&gt;20$ GeV</td>
<td>4.9±1.3</td>
<td>5</td>
</tr>
<tr>
<td>+jet veto</td>
<td>3.1±1.3</td>
<td>2</td>
</tr>
<tr>
<td>+$\Delta\phi_{ee}&lt;2$ rads</td>
<td>0.3±1.2</td>
<td>1</td>
</tr>
</tbody>
</table>

$\Rightarrow$ continue to develop analyses which build confidence in background modeling/expectations for larger data sets
RunIIa: Electroweak Physics

With 2 fb\(^{-1}\) of RunII (per experiment):

- \(\Delta M_w = 30 \text{ MeV/\text{exp}}\)
- \(\Delta M_{\text{top}} = 3 \text{ GeV/\text{exp}}\)
- start having sensitivity to SM \(M_H > 115 \text{ GeV}\)

Tevatron upgrades:

- luminosities of \(2 \times 10^{32}\fbox{2 fb^{-1}}\) in 2 years
  - \(\sqrt{s} = 1.96 \text{ TeV}\)
  - \(\sigma(W), \sigma(Z) \sim 10\%\) higher
  - \(\sigma(tt) \sim 35\%\) higher

Detector upgrades:

- increased B-jet and lepton ID acceptance and triggering
- performance on track to meet expectations

EWK Prospects are good!