Electroweak Prospects for TeVatron RunII

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Data Sets for RunII EWK Physics:

Event yields in per experiment

Sample	Run I	Run IIa
$W \rightarrow l\nu$	77k	2300k
$Z \rightarrow ll$	10k	202k
WV ($W \rightarrow l\nu$, V=W,γ,Z)	90	1800
ZV ($Z \rightarrow ll$, V=W,γ,Z)	30	500
tt (mass sample, >=1Btag)	20	800

- 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)

>20x RunI

- RunIIb Luminosity Goals
  - 40-50 E31 cm^{-2}/sec
  - integrated: 15 fb^{-1} (2007)
- $\sqrt{s} = 1.96\,\mathrm{TeV}$
  - σ(W), σ(Z) ~10% higher
  - σ(tt) ~35% higher

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 ($|\eta|>1$)

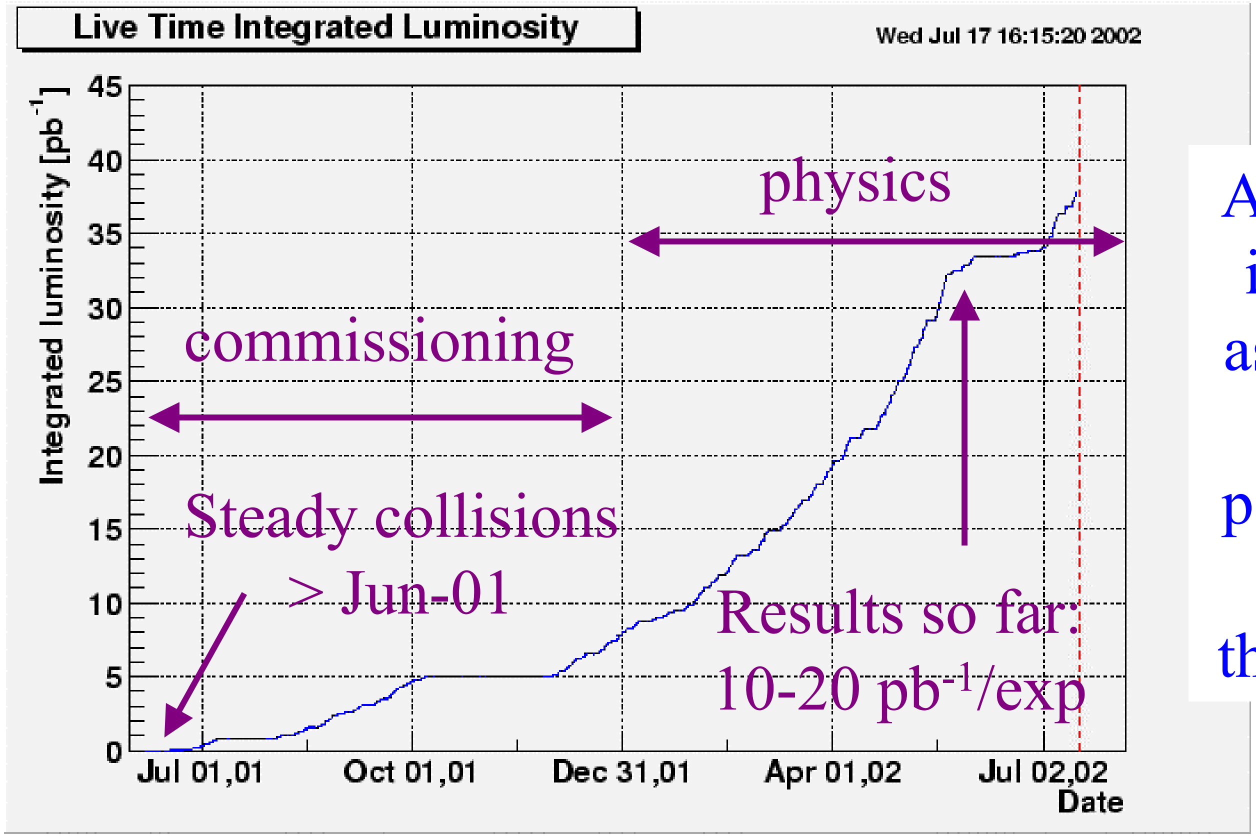
Projections assume:

✓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.

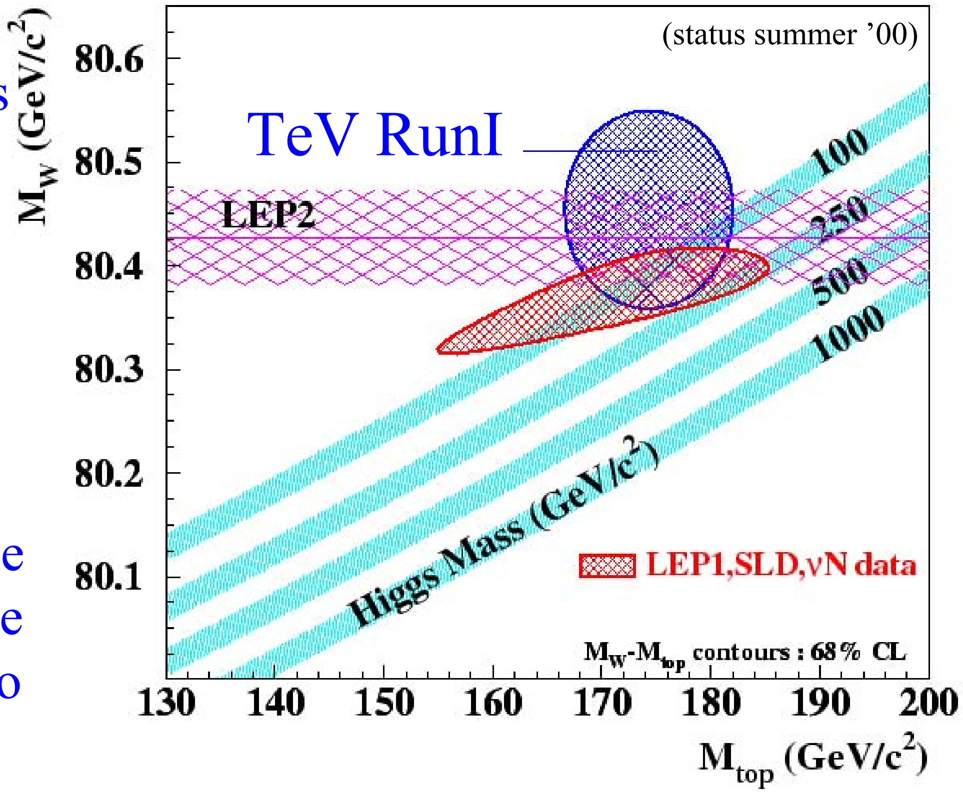
Electroweak Physics at the TeVatron

Precision M_w, M_{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:

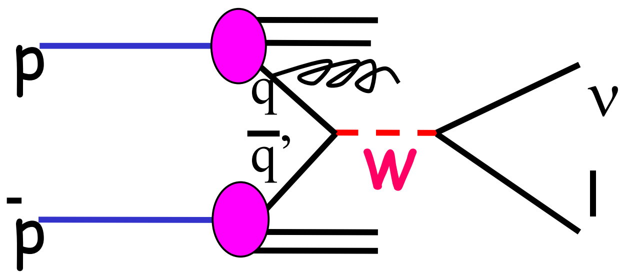
– Light Higgs discovery possible

– Observation or not, SM will be tested by comparison of M_H to indirect limits from EWK fit

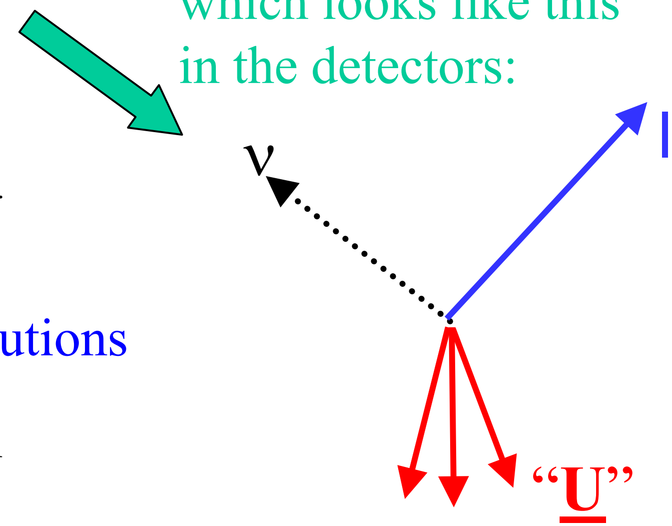
➔ discuss detector performance in the context of these measurements

Measuring Mw at the TeVatron

W production
at the TeV:



which looks like this
in the detectors:



1. Calculate transverse mass

$$M_T = \sqrt{(E_T^\ell + E_T^\nu)^2 - (\vec{P}_T^\ell + \vec{P}_T^\nu)^2}$$

➔ understand E and **P** scales and resolutions

2. Calculate missing transverse momentum

$$\vec{P}_T^\nu = -(\vec{P}_T^\ell + \vec{U})$$

➔ must model *U*nderlying event and recoil distributions, etc.

3. From M_T distribution extract measure of Mw

➔ 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

+ largely statistical in nature

* correlated among experiments

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

ΔM_W=+/-30 MeV/exp

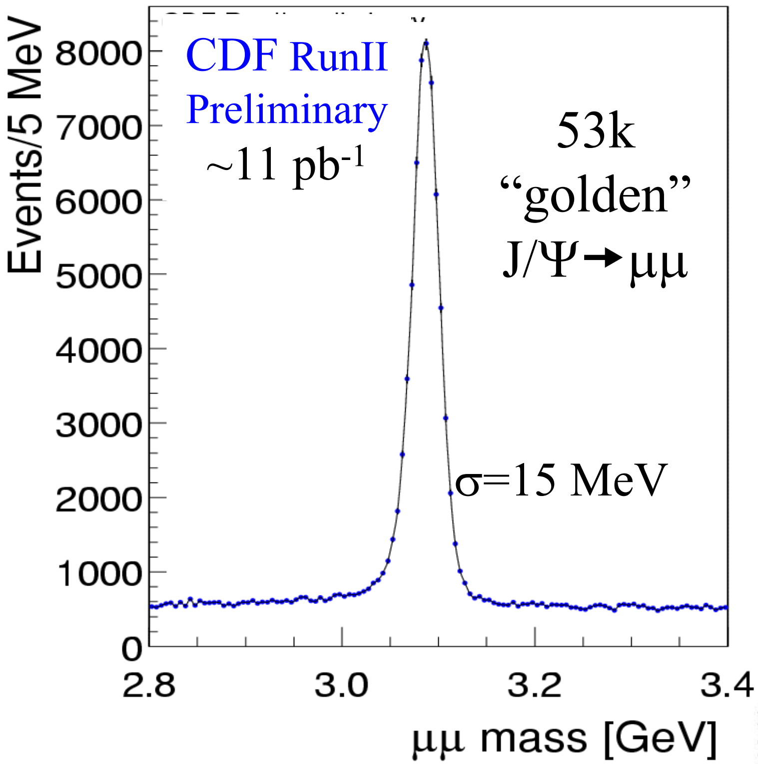
ΔM_W(Wrld)=+/-15-20 MeV

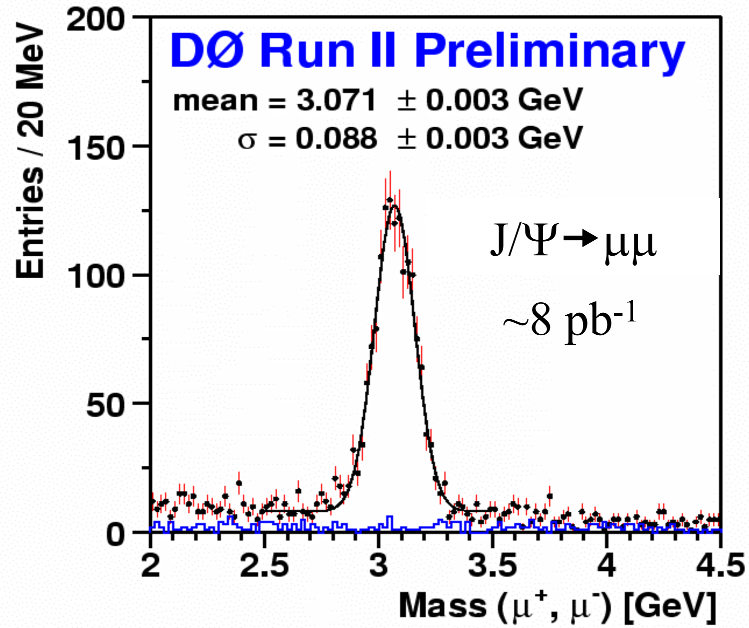
➔ **RunII projections assume detectors will perform similarly to RunI so that, M uncertainty to ~scale w/ statistics**

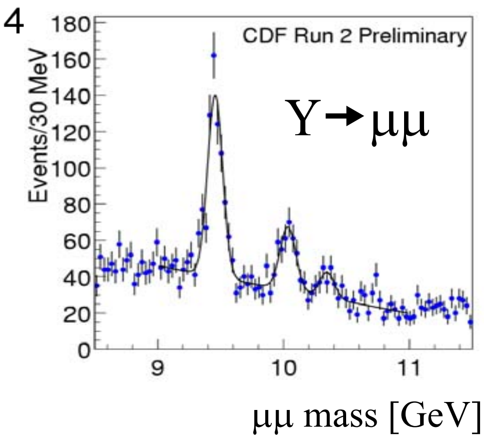
➔ **How will P_t^ν resolution scale with inst. Luminosity?**

Momentum Scales & Resolutions in RunII

- Use low lying resonances to get P scale/resolution







➔ 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
- $\sigma(Pt)/Pt^2$(design) = 0.14%/GeV

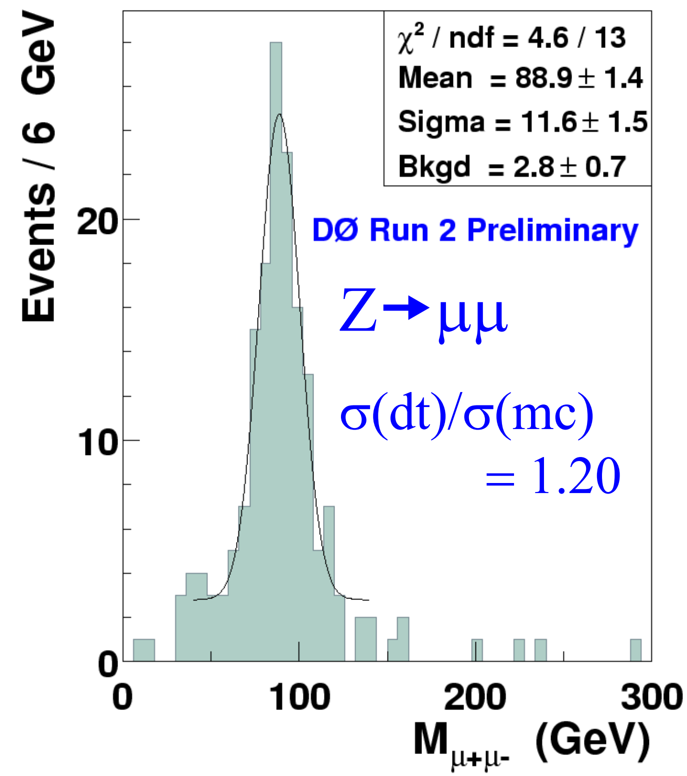
Per layer hit efficiencies:

ε(axial layers) = 99%

ε(stereo layers) = 98%

(expect high tracking efficiency)

Assuming "nominal" positioning:



➔ Alignment well underway, significant improvements expected.

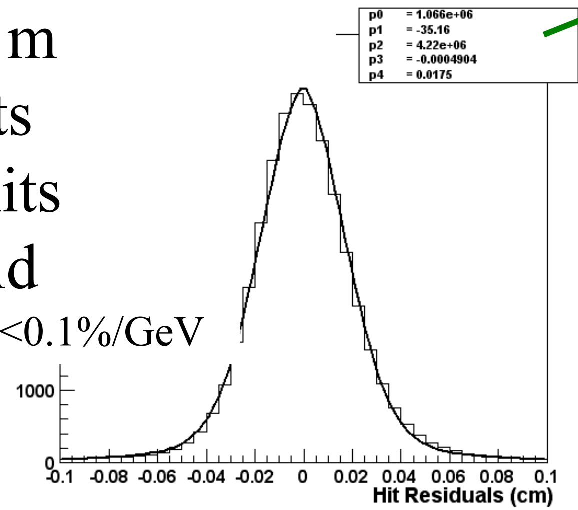
CDF's Central Outer Tracker Performance:

"out of box":

Very similar to Run I:

- r = 0.4-1.4 m
- 48 axial hits
- 48 stereo hits
- in 1.4T field

–$\sigma(Pt)/Pt^2$(design)<0.1%/GeV

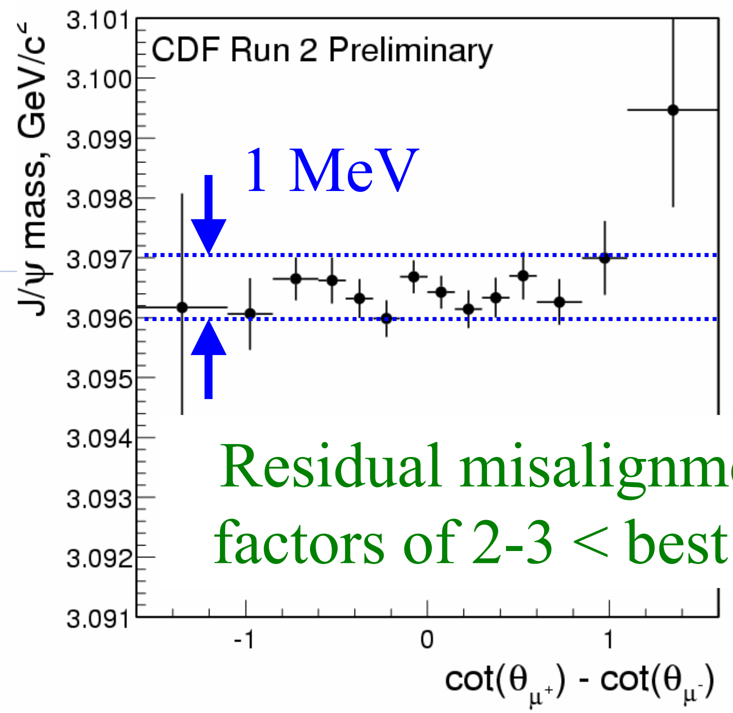


– σ(hit) = 175 μm

(TDR said 180 μm)

– $\sigma(Pt)/Pt^2 < 0.13\%\ GeV^{-1}$

(RunI = 0.10%)



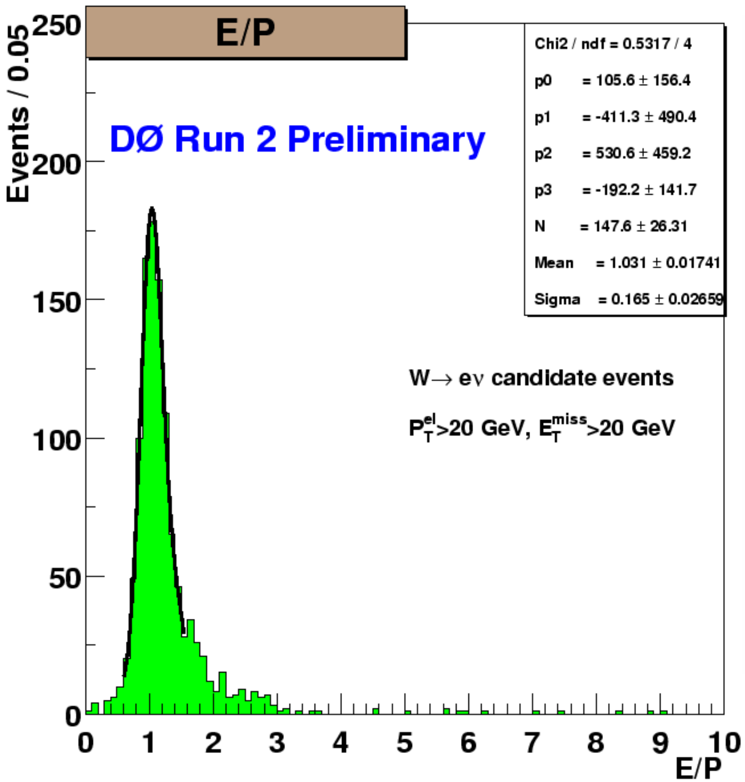
From W→ eν events:

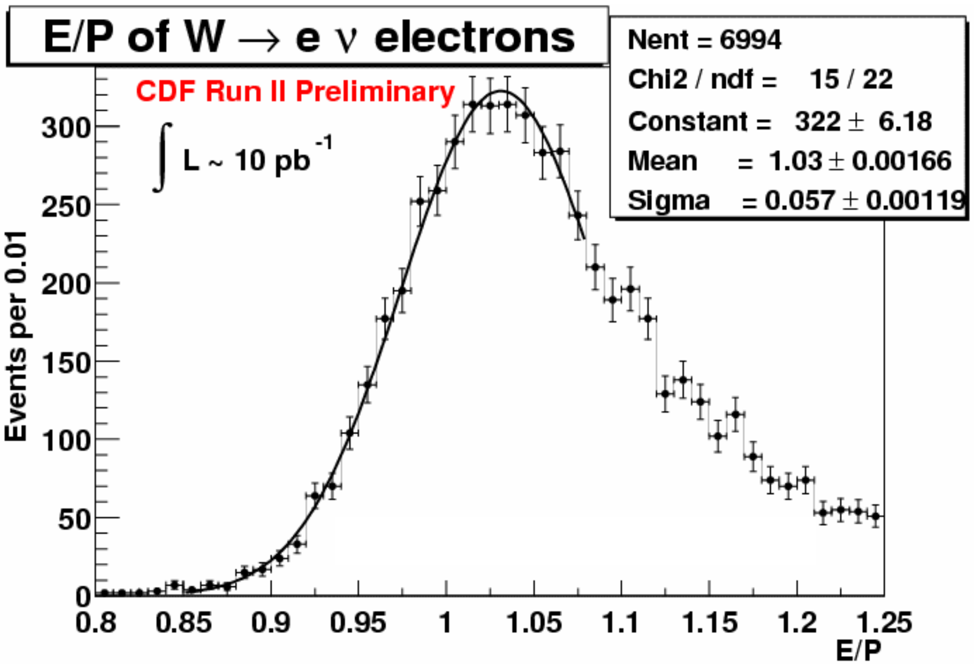
ε(COT *tracking*) = 99 +/- 1%

➔ expect further improvements as alignment matures

Energy Scales & Resolutions in RunII

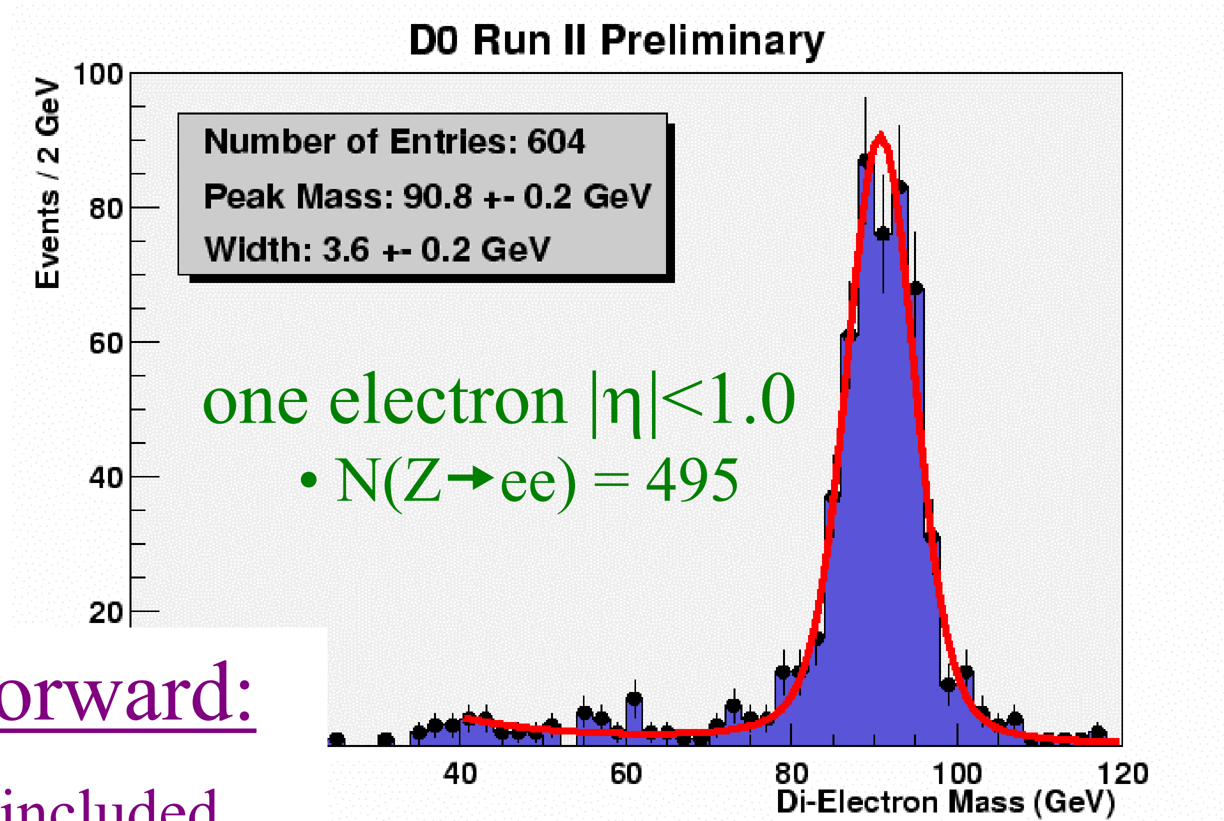
- Nominally, use E/P distributions to set absolute scale and resolution
  - assumes P-scale/resolution thoroughly understood





➔ at this early stage, use Z→ee to estimate E resolution

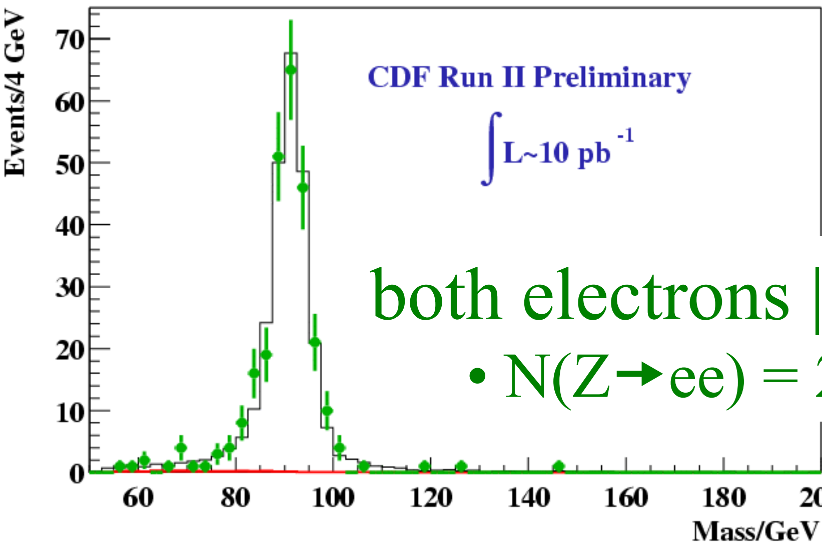
D0's ECAL Performance:



For central & forward:

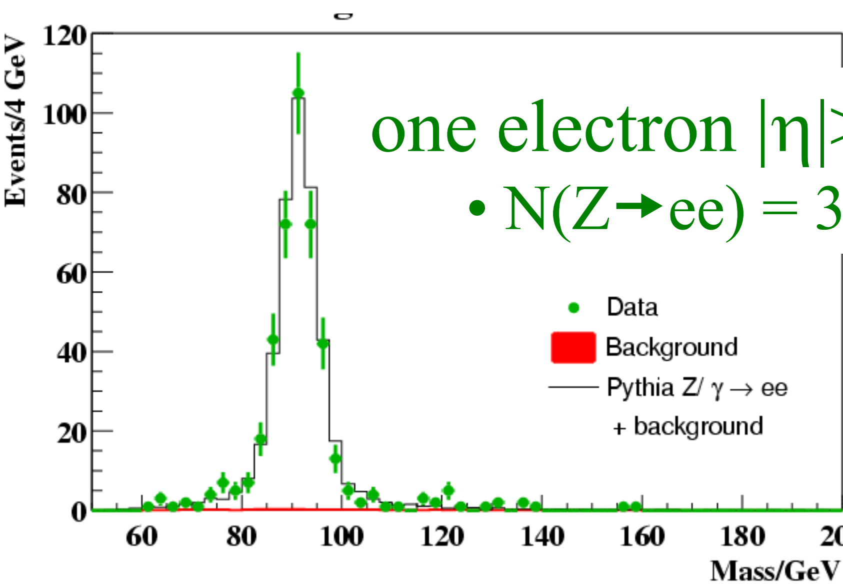
- partial corrections included
- σ(data)/σ(mc) < 1.30
- w/ inclusion of full corrections expect to meet expectations

CDF's ECAL Performance:



both electrons |η|<1.0

- N(Z→ee) = 247



one electron |η|>1.0

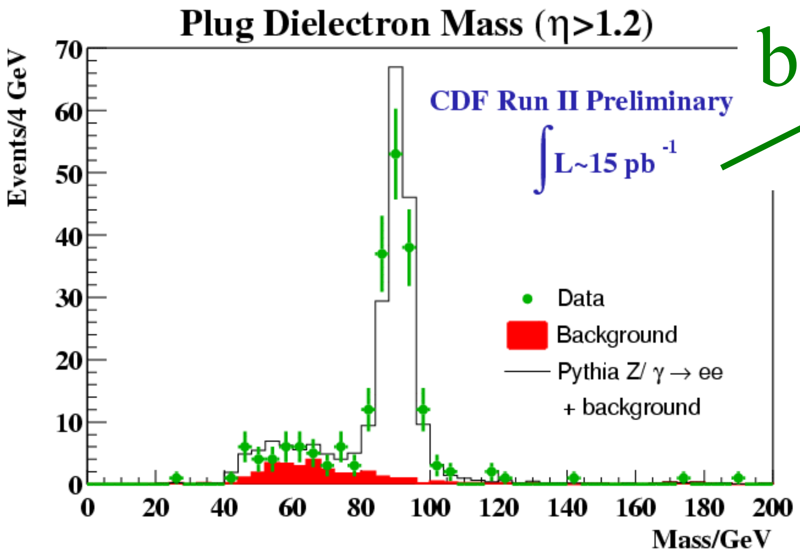
- N(Z→ee) = 391

For central & forward:

- includes dominant corrections
- σ(data)/σ(mc) < 1.05
- ECAL resolution as expected

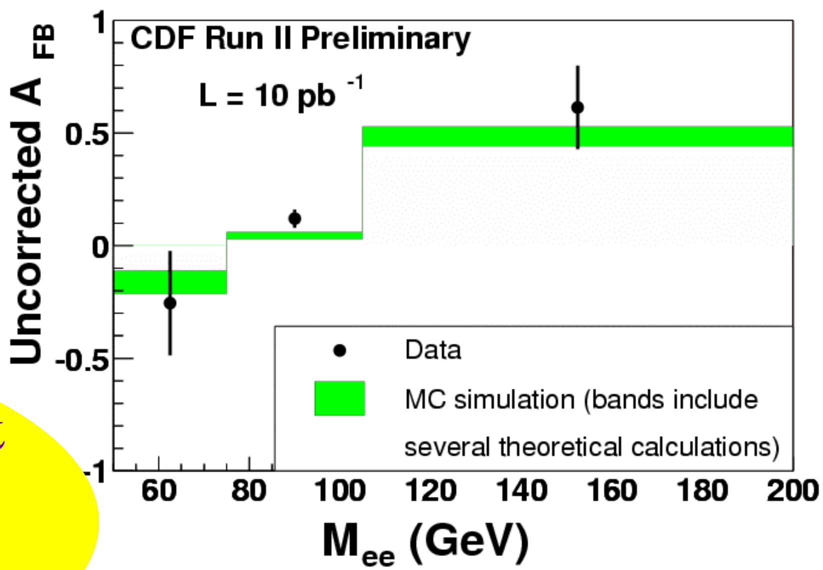
Extending lepton-ID:

extending Mw and asymmetry measurements to large |η|
reduces Mw PDF uncertainties (which are CDF/D0 correlated)



both electrons |η|>1.2

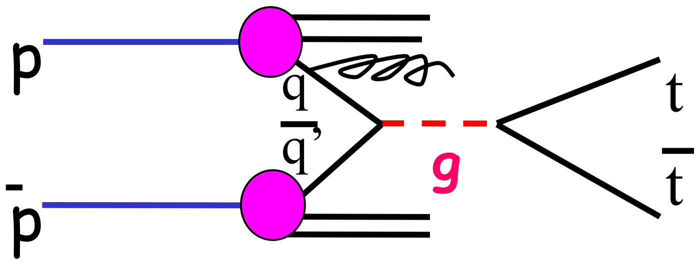
- N(Z→ee) = 160



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

Measuring M_{top} at the TeVatron

tt production at the TeV:



$t\bar{t} \rightarrow W^+bW^-b$

Final states (2 B-jets + Ws):

- dilepton (2 $W \rightarrow l\nu$)
- lepton+jets ($W \rightarrow l\nu$, $W \rightarrow qq$)
- all hadronic (2 $W \rightarrow qq$)

most important channel

To extract M_{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_{fit}
4. Extract M_{top} from M_{fit} distribution

Run1 Top Mass

“Typical” M_{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
ΔM_{top}=+/- 2-3 GeV/exp

➔ increased acceptance and σ_{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→bb, W→qq) too small to be of use in RunI

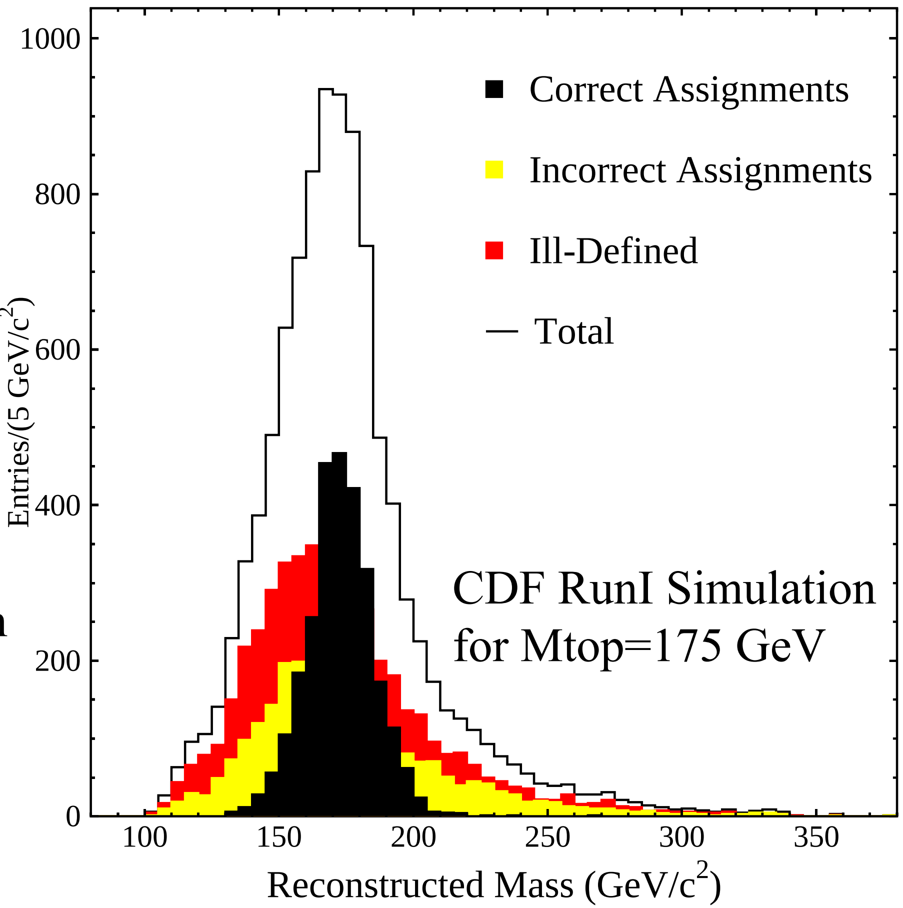
Top Mass: Combinatorics

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

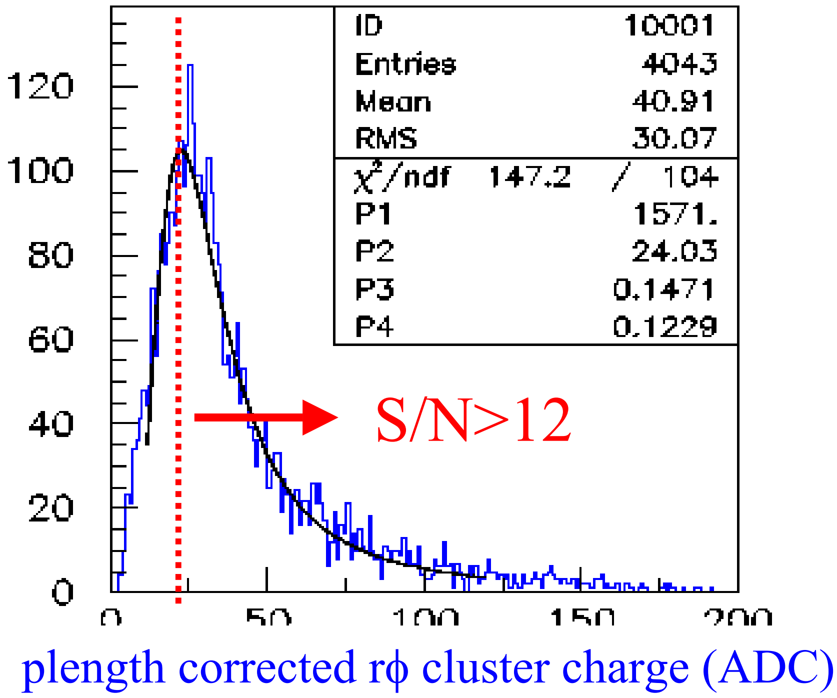


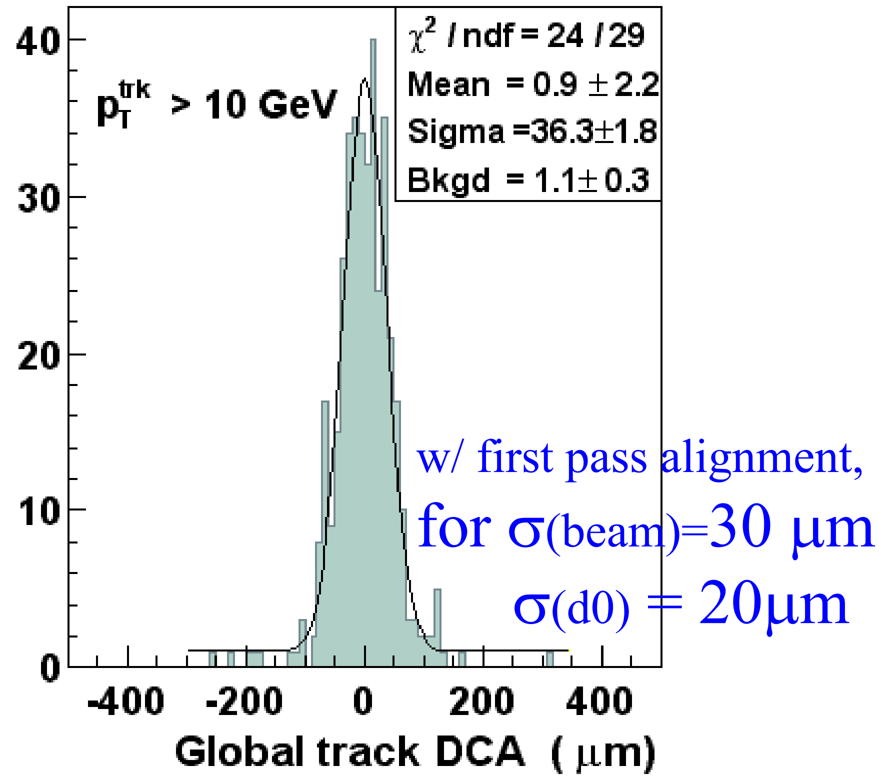
➔ Increased B-tagging acceptance most important factor in improving Mtop

- increases statistics
- improves purity
- reduces combinatorics

→ improved Mtop sensitivity

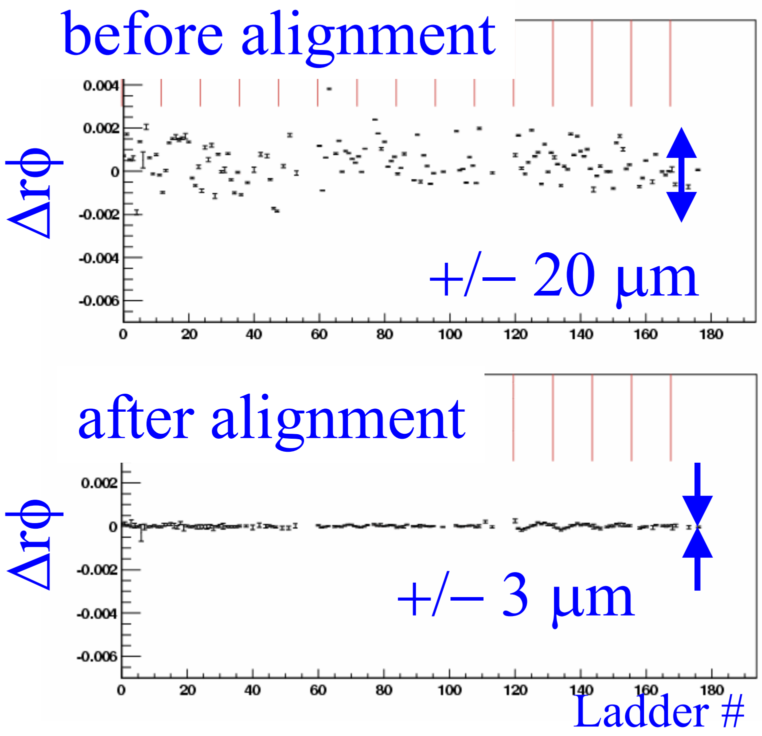
D0's Silicon Microstrip Tracker Performance:

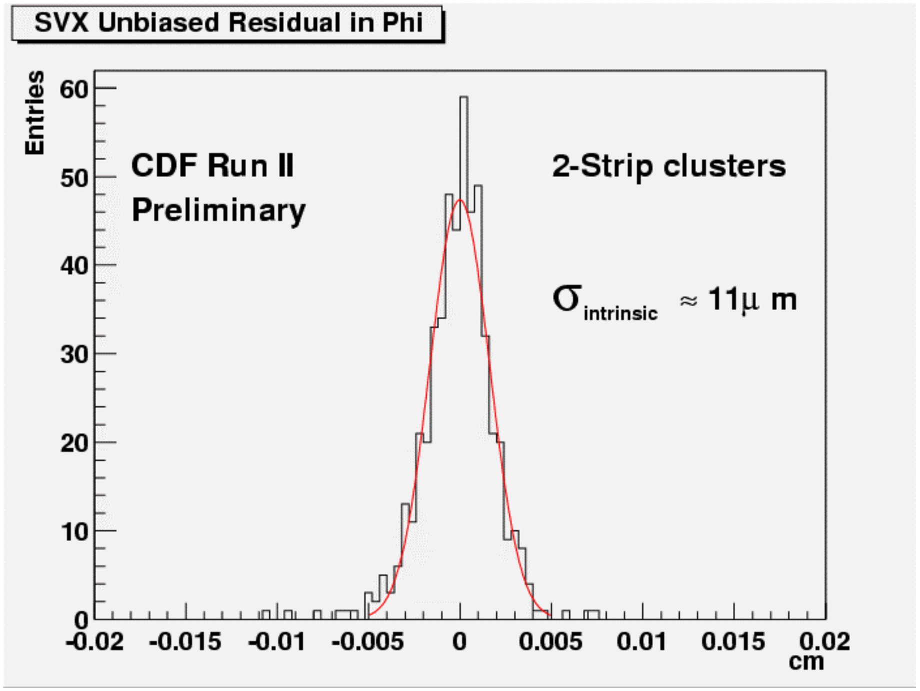




- Performing as expected
- 95% working channels (and regularly taking data)
- precision alignment of "z"-strips underway

CDF's Silicon VerteX Detector Performance:

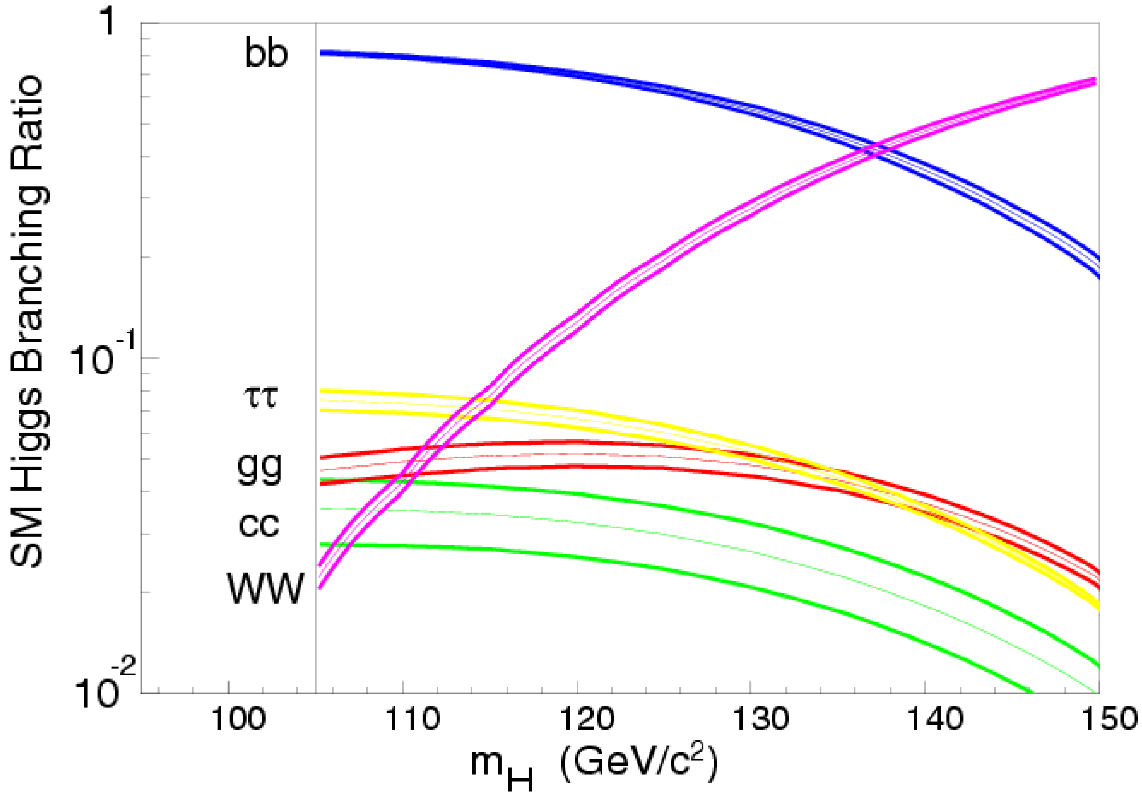




S/N = 12, Hit efficiency >99% , σ(intrinsic 2strip rφ) =11μm

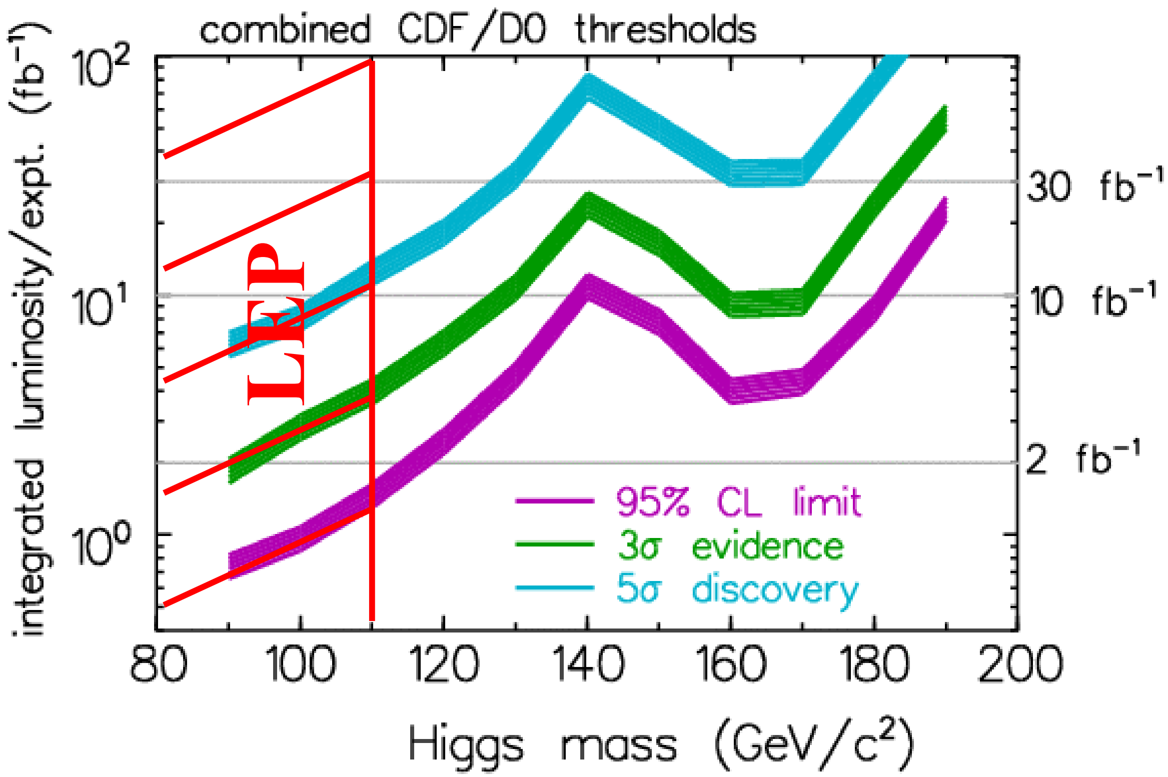
- Performing as expected
- 92% working channels (presently, 85% regularly taking data)
- precision alignment of "z"-strips underway

SM Higgs Search at the TeVatron



Need to use H→bb and H→WW to maintain sensitivity over wide mass range

SM Higgs Search at the TeVatron



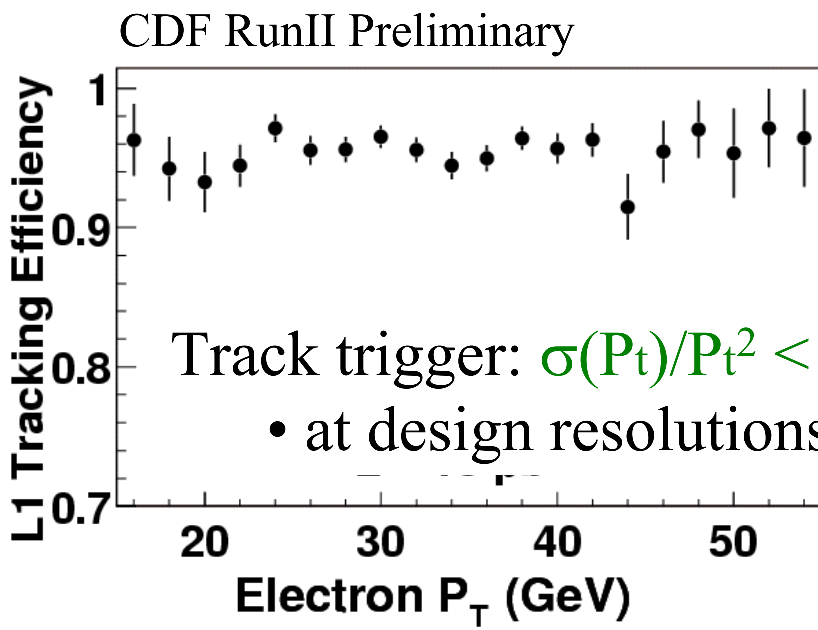
Observation possible with >2 fb^{-1} of integrated luminosity

- 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

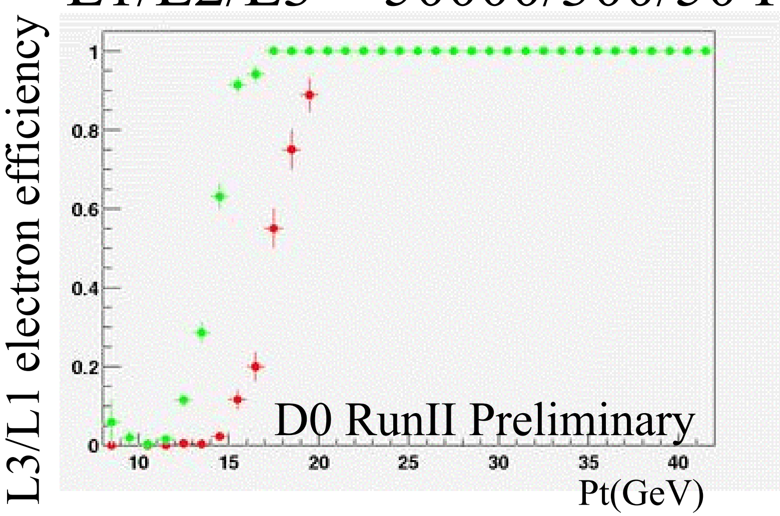
CDF rates

- now ($L \sim 10^{31}$):
  L1/L2/L3 = 6000/240/30 Hz
- goal ($L \sim 10^{32}$):
  L1/L2/L3 = 50000/300/50 Hz



Track trigger: $\sigma(P_t)/P_t^2 < 2\%$

- at design resolutions

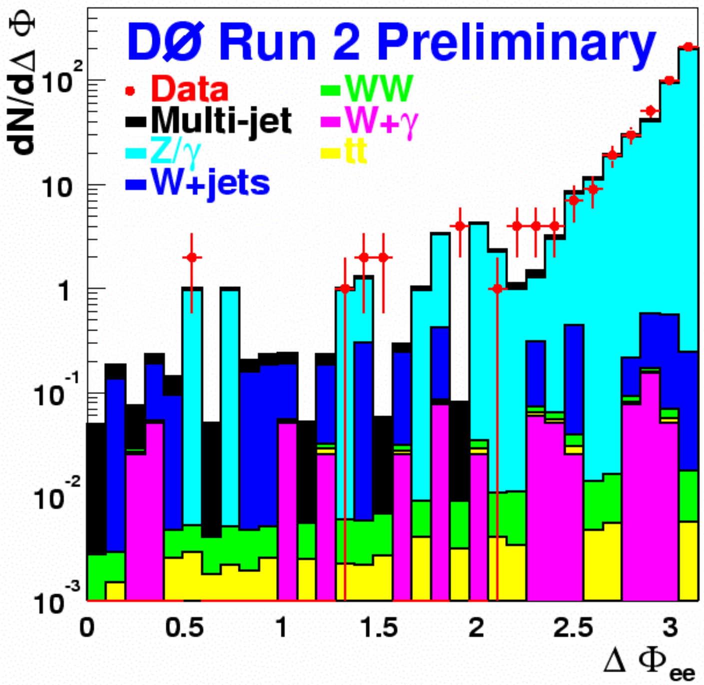


D0 rates

- now ($L \sim 10^{31}$):
  L1/L2/L3 = 200/140/50 Hz
- goal ($L \sim 10^{32}$):
  L1/L2/L3 = 7000/1500/50 Hz

➔ lepton triggers operating at high ε… important to maintain at high instantaneous luminosities!

SM Higgs Background Studies



H→WW→eeνν in 9 pb^{-1} of data

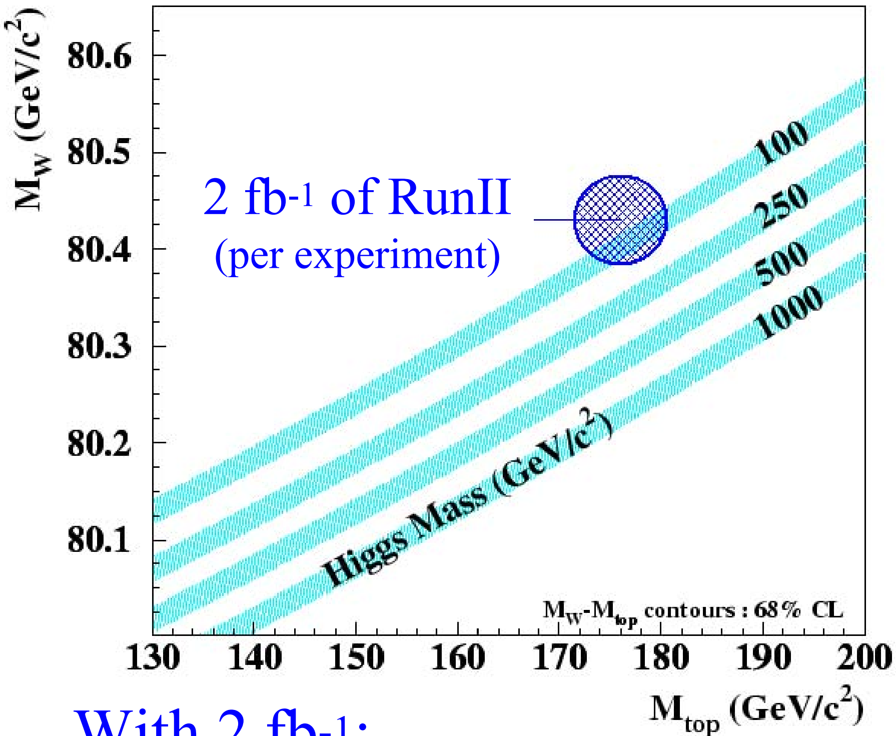
- do we understand our backgrounds?

D0 RunII Preliminary

Cut	Predicted	Obsrvd
ID,Pt>20 GeV	430+/-58	452
+M_{ee}<78 GeV	35+/-6	46
+$\not{E}_t$>20 GeV	4.9+/-1.3	5
+jet veto	3.1+/-1.3	2
+$\Delta\phi_{ee}$<2 rads	0.3+/-1.2	1

➔ continue to develop analyses which build confidence in background modeling/expectations for larger data sets

RunIIa: Electroweak Physics



With 2 fb^{-1}:

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

Tevatron upgrades:

- luminosities of $2\text{x}10^{32}$
  $\int L\,dt = 2\ fb^{-1}$ in 2 years
- $\sqrt{s} = 1.96$ TeV
  - σ(W), σ(Z) ~10% higher
  - σ(tt) ~ 35% higher

Detector upgrades:

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

EWK Prospects are good!