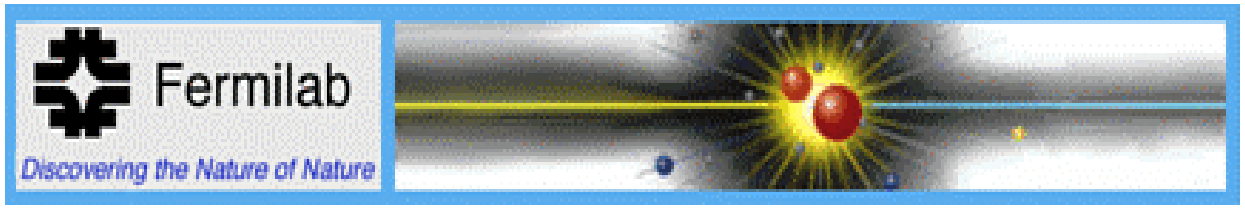
Perspectives in EW Symmetry breaking in Tevatron Run II



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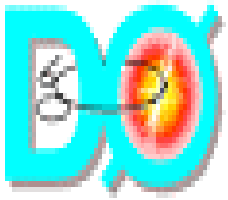
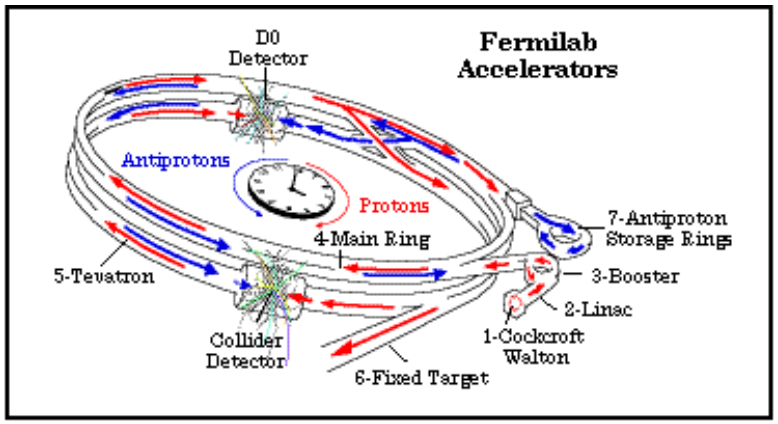
with the help of a lot of colleagues
from CDF and D0



HEP 2001, Budapest, July 2001

The Tevatron Run II



Run II: $\sqrt{s}$ = 2.0 TeV

Two data taking periods:

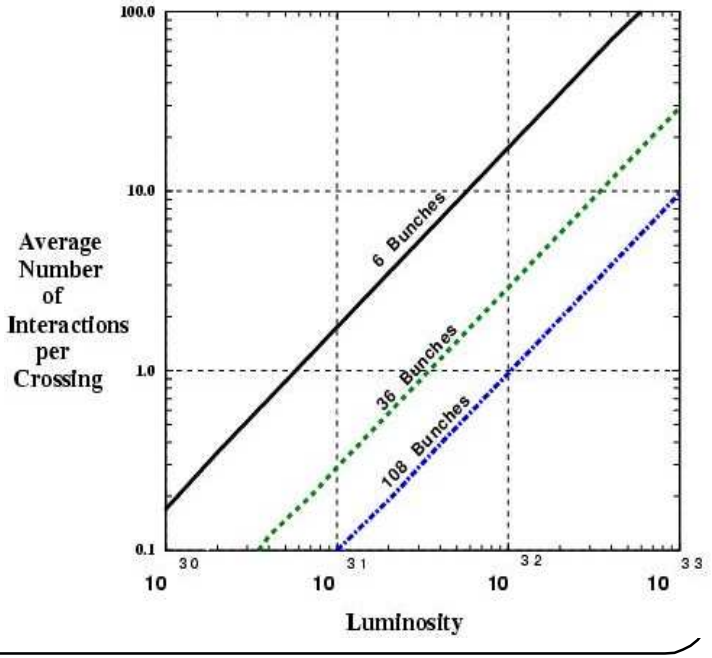
- Run IIa L_{int}=2 fb^{-1}
- Run IIb L_{int}=13 fb^{-1}

Two possible interbunches:

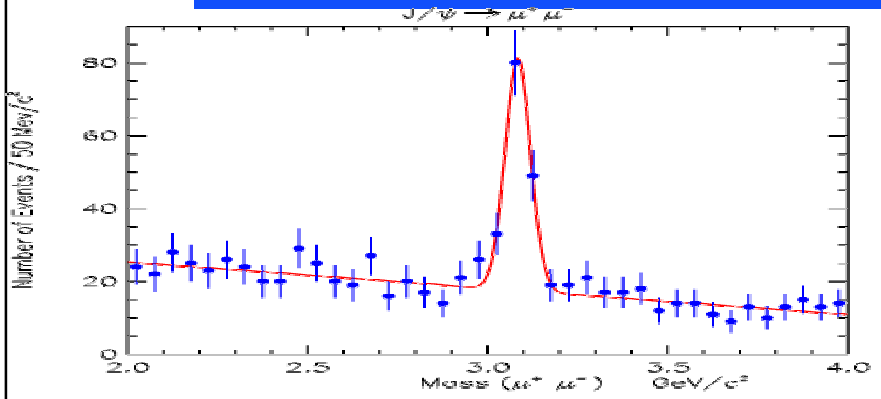
- 396 ns for 36 bunches
- 132 ns for 108 bunches

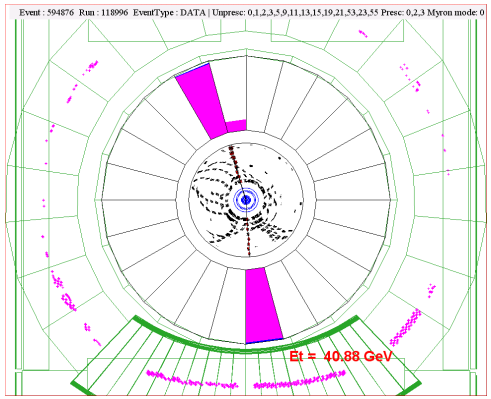
Average number of overlapping interactions in a beam x-ing:

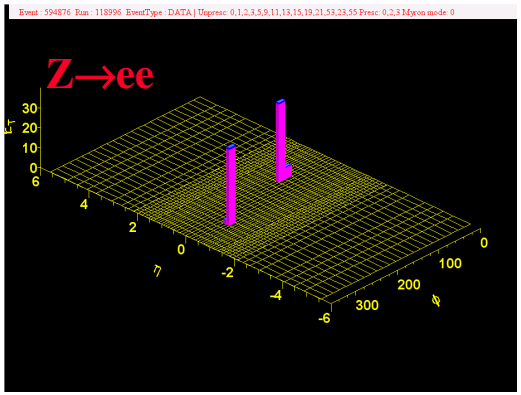
- N = **3** for L_{inst} = $1x10^{32}$ cm^{-2} s^{-1} @396 nsec
- N = **1** for L_{inst} = $1x10^{32}$ cm^{-2} s^{-1} @132 nsec



CDF Run II Upgrades

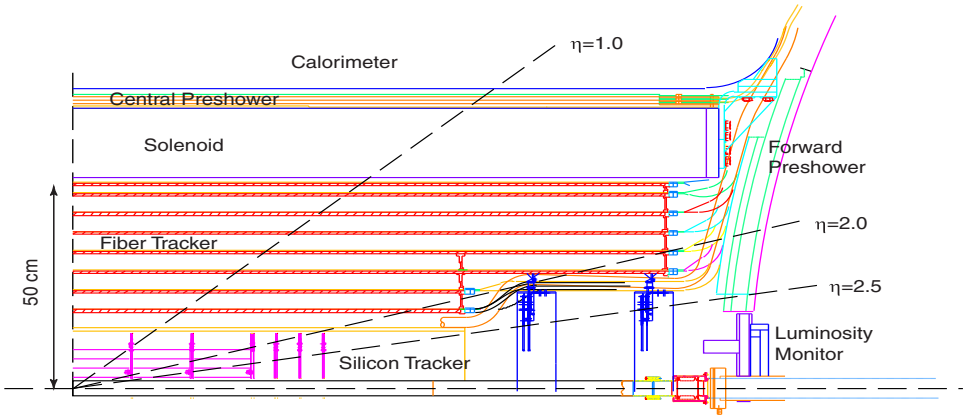


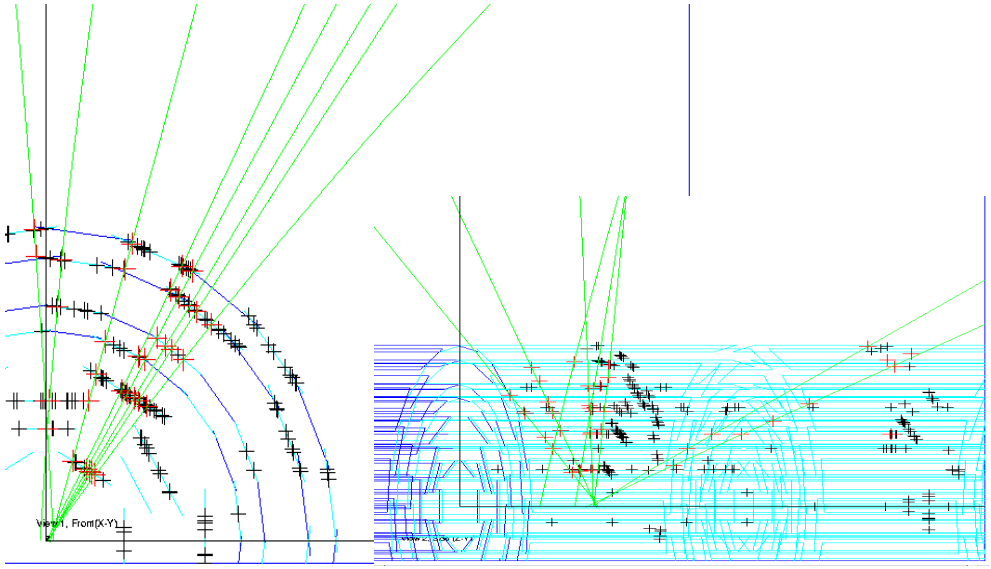




- new front-end,DAQ
- trigger
  - new L1 track trigger
  - new L2 secondary vertex tracker (SVT)
- new silicon tracker
  - 7 layers $|\eta|<2$
  - tracks up to $\eta=2$
  - $\varepsilon_b=65\%$ (per jet)
    - → top 1 bjet $\varepsilon=85\%$
    - → top 2 bjet $\varepsilon=42\%$
- new central tracker
  - $N_{stereo}=N_{axial}=48$
  - $\Delta p_t/p_t<0.001 p_t$
- Time of flight
- new plug calorimeter
- μ,e id to $|\eta|=2$

DO Run II Upgrades





- new trigger and DAQ
- new tracking system
  - 2T magnetic field
  - silicon vertex detector
  - 8 layers fiber tracker
  - preshower
  - tracks!
- b-tagging and lepton id as good as CDF
- improved muon spectrometer
- plans to install a STT (secondary vertex trigger)
- w.r.t. Run I:
  - Acc. for W,Z x2
  - Acc. for VV x 3

EW Physics in Run II

with 2 fb^{-1} we expect to see (*per experiment*)

- ⇨>3,000,000 W's (e and μ)
- ⇨a few thousands Vγ
- ⇨several hundreds VV (WW,WZ,ZZ)
- ⇨O(10,000) ttbar pairs (hundreds of Dil events)
- ⇨Higgs (some more fb^{-1} needed...)

☞> 300 pages in written reports

Hard choices for this talk

☞but I found a lead:

- →a W mass determination with $\Delta M_W < 30$ MeV/c^2
- →supplemented by a M_{top} determination by 3 GeV/c^2
- →could lead to a M_{Higgs} determination to ±30%

☞truth is in the masses

- ⇨and I will follow this with little deviations

W Mass uncertainties

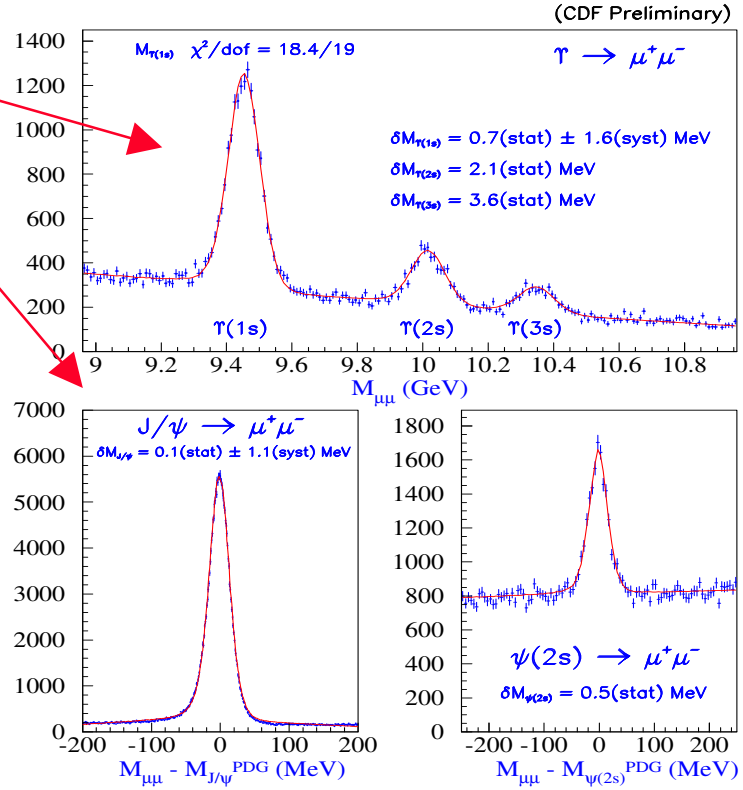
In Run I:

→80.433±0.079 (CDF)
→80.483±0.084 (D0)
→80.448±0.06 (comb.)

⇨syst. gov.d by size of control samples
→l^+l^- used for lepton energy scale($J/\psi, \Upsilon$)
⇨PDF (W asimmetry)
⇨P_{TW} measured by P_{TZ}

In Run II:

☞larger statistics in control samples will reduce experimental systematics

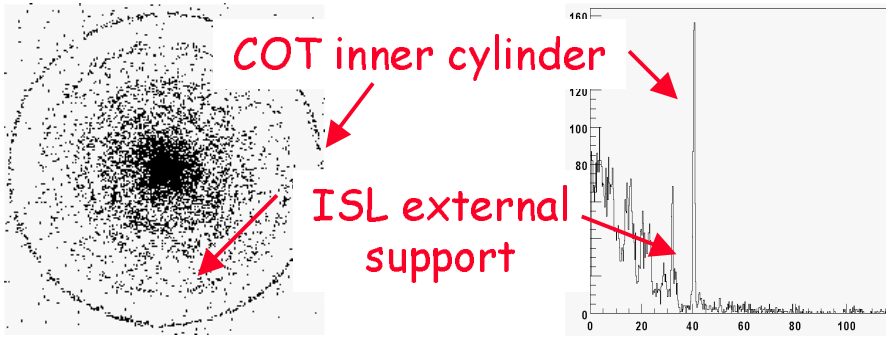


CDF Run Ib W→ μν data: uncertainties scaling stat.

Source	uncert. (MeV/c^2)
Fit statistics	100
Momentum scale	85
Recoil model	35
Background	25
Mom.resolution	20
Selection bias	18

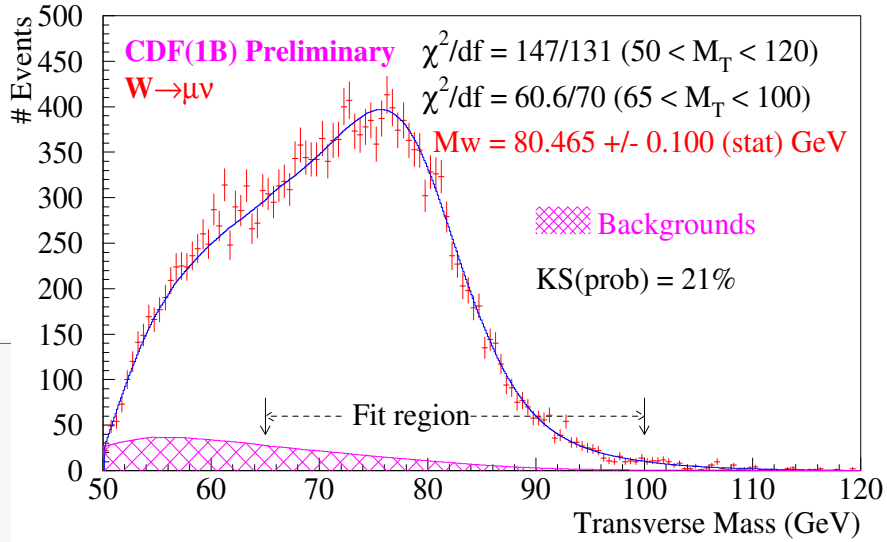
W Mass II

- In Run IIa we expect to reach:
  - 40 MeV/c^2 (e,μ chan.) *per experiment*
    - → deep knowledge of the detector



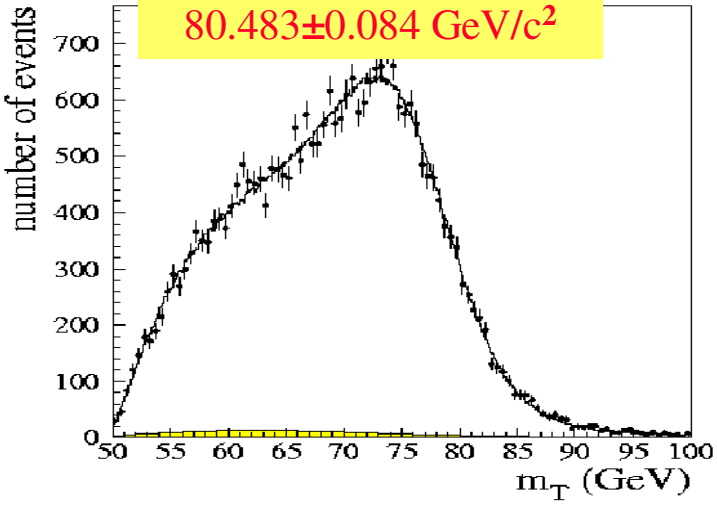
  - increase in lepton coverage (CDF) and tracking (D0)

goal: 30 MeV/c^2 *per experiment*



D0 Run I W→eν

80.483±0.084 GeV/c^2

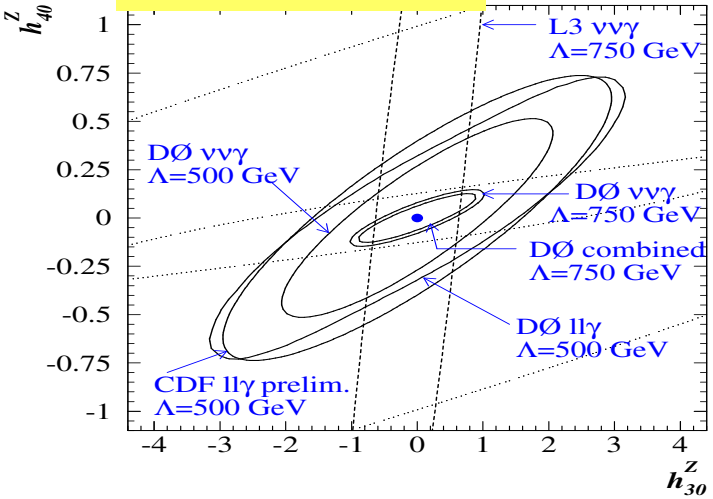


W and Z couplings

Z sector:

- param. by h^V coupling in $Z\gamma V(Z,\gamma)$vertex
- $Z\gamma \to ee(\mu\mu)\gamma$ ($\approx$700)
- $ZZ \to ee(\mu\mu)$ a few

Tevatron in Run I



Z sector: h^V in 1 fb^{-1}

$\lvert h_{30}\rvert$	<0.038
$\lvert h_{40}\rvert$	<0.0027

Limiting to a few processes in the W sec:

- $WW \to l\nu l\nu$ ($\approx$100)
- $WZ \to lll\nu$ ($\approx$30)

W sector: parametrized by Δk and $\Delta\lambda$

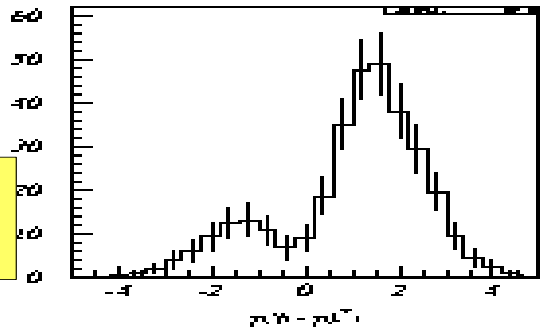
scaled from Run I, per experiment

$$-0.12 < \Delta\kappa < 0.18 \quad (\lambda = 0)$$

$$-0.09 < \lambda < 0.09 \quad (\Delta\kappa = 0)$$

- $W\gamma \to l\nu\gamma$ ($\approx$3000 evts)
  - ⇨ hints of "Zero Amplitude" @CDF

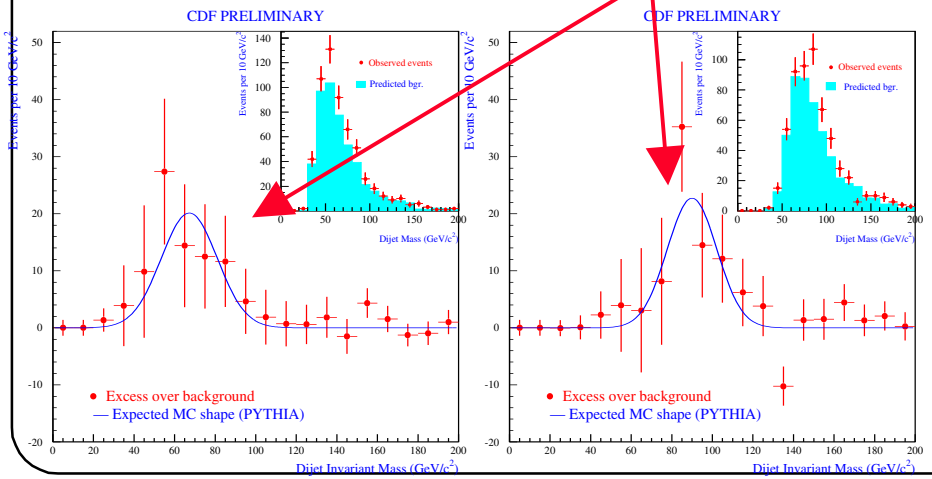
1fb^{-1} M.C.
η_γ-η_l

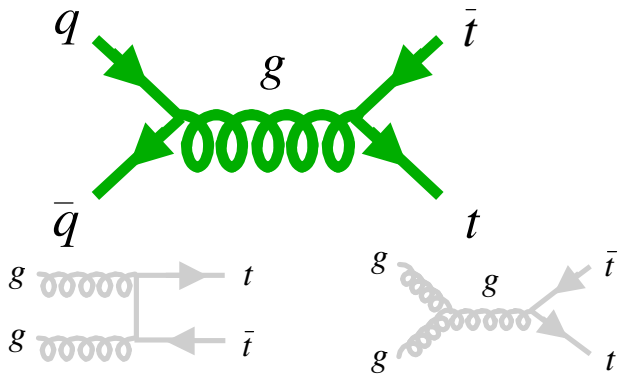


Top Physics in Run II

@√s=2 TeV:
σ up by 40% wrt 1.8 TeV
gg contribution up 15%

- ⇨ top mass
- ⇨ top properties
  - → x-section
  - → couplings(V_{tb} in CKM)
  - → decays
- ⇨ significant double b-tagged top events
- ⇨ Jet en. scale (Z→bb)





Run II expectations in 2 fb^{-1}	
Channel	CDF/D0
Dilepton(e,μ)	155
Dileptons(τ)	19
Lepton+>=3 j	1520
Lepton+>=4 j	1200
l+>=3j+ 1btag	990
l+>=4j+2btag	240

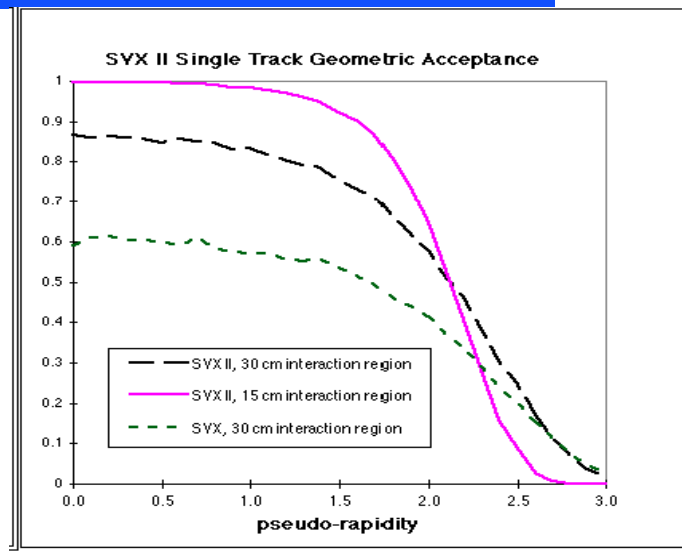
Scaled from Run I

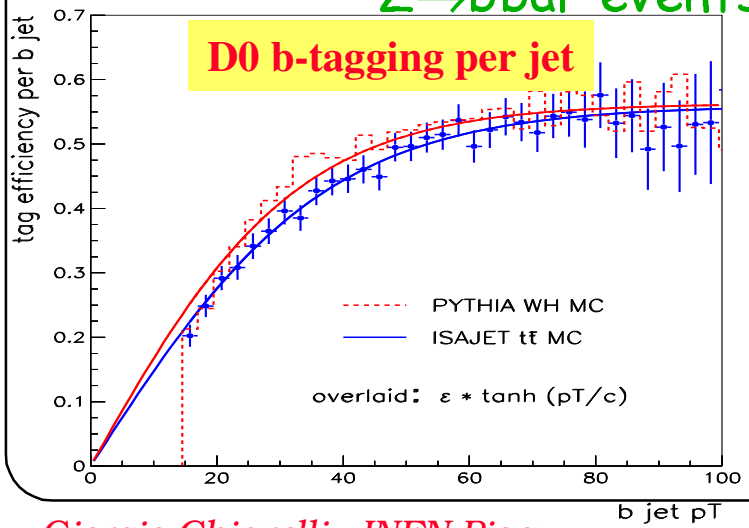
per experiment

b tagging

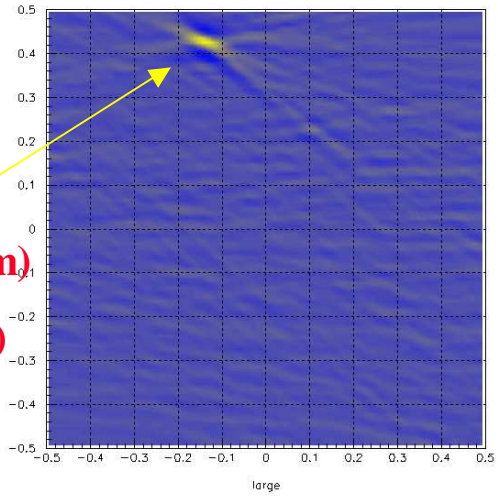
Run II:

- ⇨ good Δd resolution ($6 \oplus 19/p_t$ μm)
- ⇨ extended η coverage
  - → $\sigma_{beam} \approx 20$ cm
- ☞ SVT trigger on displaced tracks
  - → most relevant for Higgs and for $Z \rightarrow b\bar{b}$ events





beam position (in cm) from SVT (online)



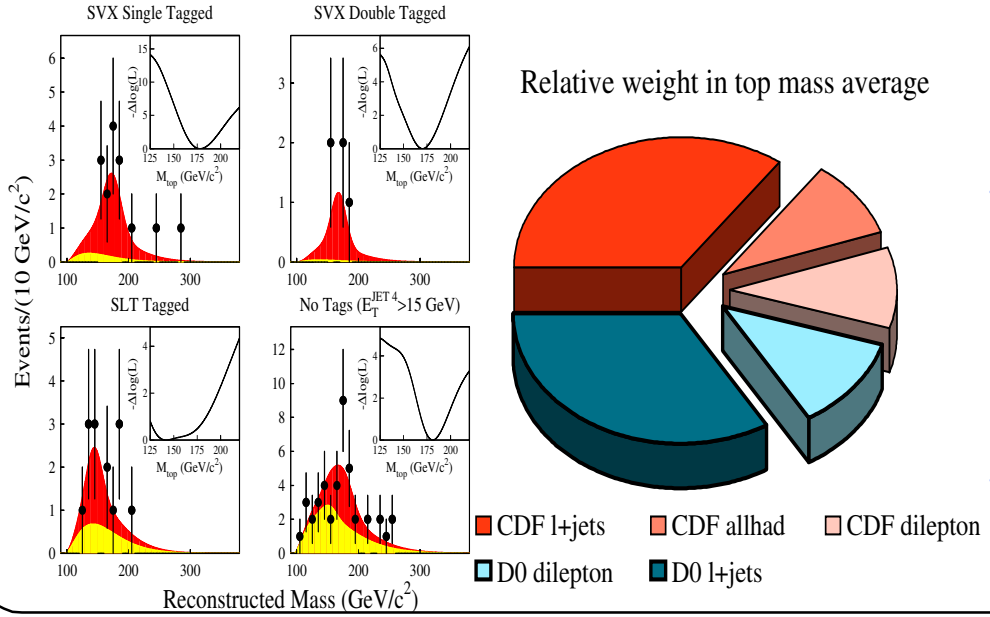
Top mass

Run I (combined)

⇨ 174.3±3.2(st.)±4 (syst) GeV/c²

- ☞ syst dominated by statistics in control samples
- ☞ most of the weight due to l+jets sample

CDF l+jets Run I(II) syst.	
Source	**Gev/c²**
Jet en.scale	4.4(2.2)
ISR and FSR	1.8(1)
background	1.3(0.5)
b-tag bias	0.4
PDF	0.3
Total	4.9(2.5)



Relative weight in top mass average

In Run II:

- ☞ uncert. down to
  - ⇨ ±3 GeV/c² (1 in 10fb^{-1})

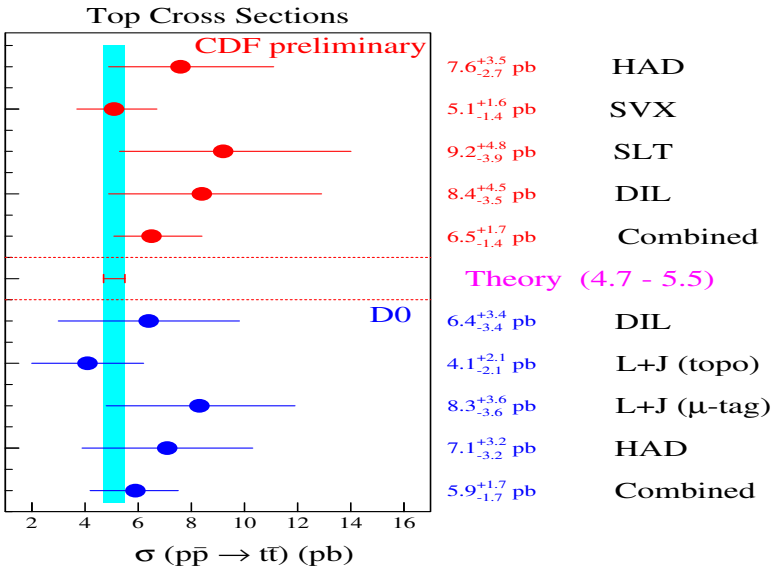
most improvements from jet energy scale:

- ☞ using W's and Z→bb

Top couplings

In Run I

⇨x-section determination



⇨V_{tb} (indirect) ratio 0:1:2
b-jet in top events

$$R = \frac{B(t \to W + b)}{B(t \to W + q)} = \frac{|V_{tb}|^2}{|V_{td}|^2 + |V_{ts}|^2 + |V_{tb}|^2}$$

$$R = 0.94^{+0.31}_{-0.24}$$

$$|V_{tb}| = 0.97^{+0.16}_{-0.12}$$

$$|V_{tb}| > 0.78 \ (@\,90\%\,\text{c.l.})$$

In Run IIa

☞xsec uncert. <10%

☞top FCNC

	$1fb^{-1}$	$10fb^{-1}$
$B(t \to Zq)$	$1.5 10^{-2}$	$3.8 10^{-3}$
$B(t \to \gamma q)$	3.10^{-3}	$4 10^{-4}$

⇨S.M. $B(t \to Ws)$(0.1%)?

☞Vtb

⇨to 3% (indirect)

⇨to 15% (direct)

☞W helicity:

⇨SM prediction= 69% for $B(t \to W_l b)$

→Run I=70.6±1.6%

→few %

☞More ?

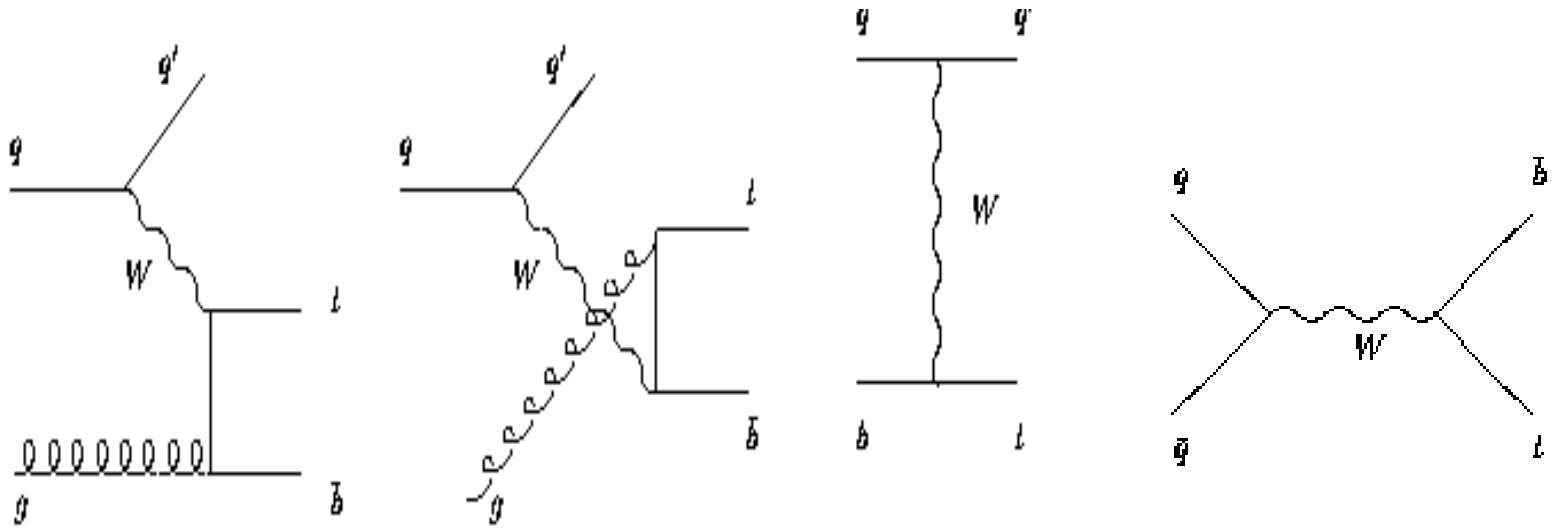
⇨Yukawa coupling:
$\lambda_t = m_t 2^{\frac{3}{4}} \sqrt{G_F} \cong 1$

Single Top production

- Production of single top through Wg fusion and W* is about 1/3 of strong pair production (for m_t=175 GeV/c^2 @ $\sqrt{s}$=2 TeV):
  - *W-gluon fusion*: $\sigma(Wg \rightarrow tb+X)$= 1.44 pb
  - *Virtual W*: $\sigma(W^* \rightarrow tb+X)$ = 0.74 pb
  - large uncertainties in the cross sections!

Effective isolation of W* process will be tried at Tevatron:

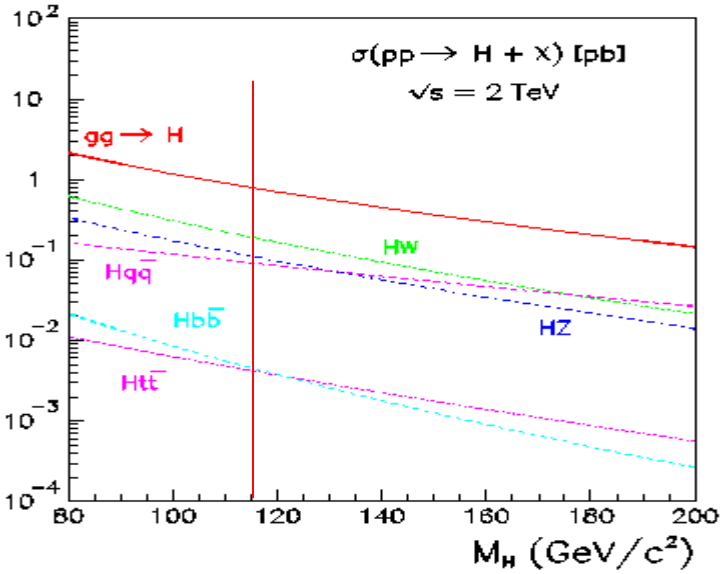
- A V_{tb} (direct) determination to 15% is feasible as cross section for this process is proportional to $|V_{tb}|^2$

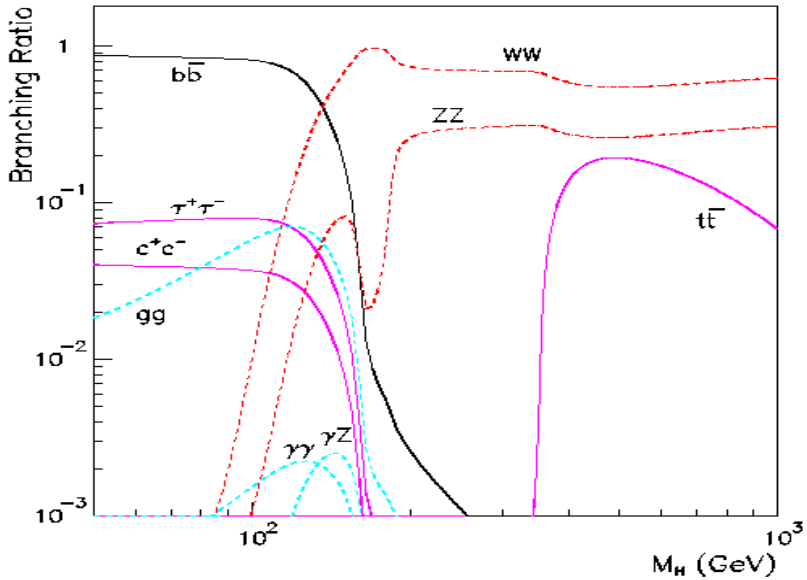


Higgs and the Tevatron

- $M_{Higgs} < 130\ GeV/c^2$.
  - ⇨ V+H (V=W,Z)
    $V \to ll$
    ($V \to jj$ large bck)
  - ⇨ $\sigma(WH)$ 0.2 pb
  - ⇨ $\sigma(ZH)$ 0.1 pb
  - ⇨ M_{jj} important, Higgs specific corrections developed

- For larger M_H $gg \to H$ becomes important as new decay channels open and background reduces





Low mass region: VH in 15fb^{-1}

WH,H→bbar,W→lν

- e(μ) with $E_T(p_T)$>20 GeV
- $\not\!\!E_T$>20 GeV
- two b-tagged jets
- residual bck: Wbb, tt, WZ, tb (single top)

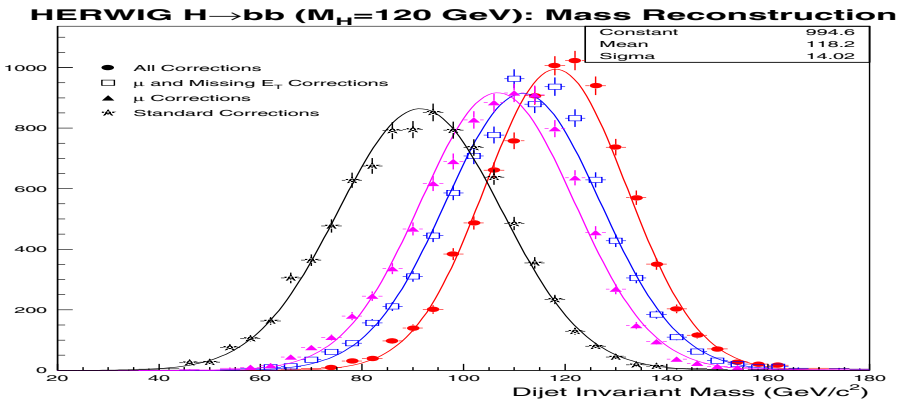
Non-physical bck. negligible

- σ_{mjj} important

In Red processes not measured in Run I

ZH,H→bbar, Z→νν

- Had.energy<175 GeV/c²
- residual bck: Wbb, tt, WZ, tb (single top)



M_H (GeV/c²)	110	120	130
Signal events (S)	75	60	45
W bbbar	435	375	285
WZ	90	60	30
ttbar	225	300	330
Single top	105	135	135
Total Background (B)	855	870	780
S / √B	2.6	2.0	1.6

M_H (GeV/c²)	110	120	130
Signal events (S)	69	48	31.5
Zbb	84	69	52.5
W bbbar	100	81	63
ZZ	43.5	3	0.0
ttbar	70.5	64.5	52.5
Single top	79.5	70.5	57
Total Background (B)	840	585	450
S / √B	2.4	2.0	1.5

High mass region

Focus on $gg \rightarrow H \rightarrow W^*W^*$
beat low x-sect $\rightarrow l^+l^-\nu\nu$

- low background

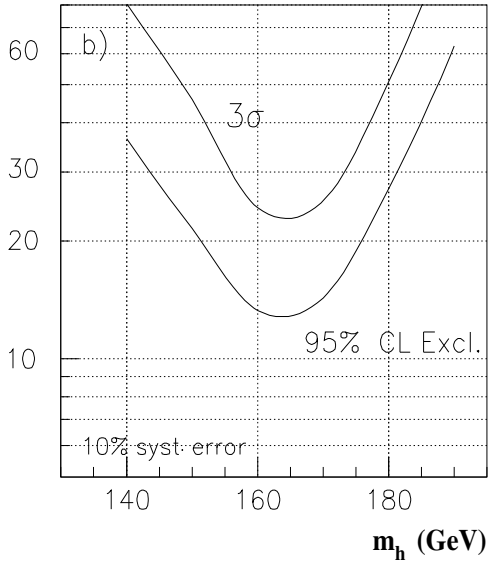
Add $qq \rightarrow W(Z)H \rightarrow W(Z)W^*W^* \rightarrow lll X$ (trilepton) mode

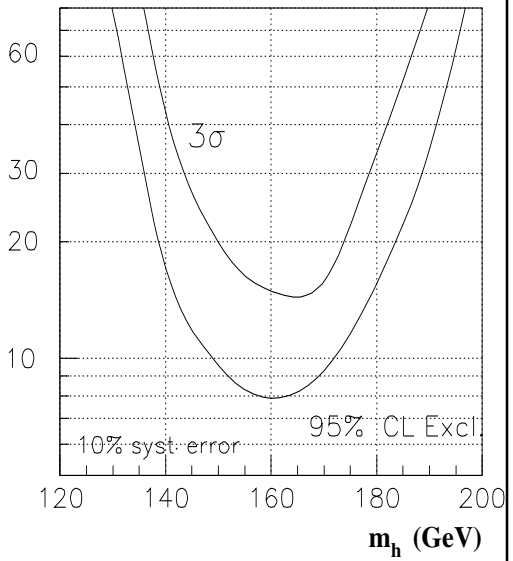
- main backgrounds: WZ,ZZ

$qq \rightarrow W(Z)H \rightarrow W(Z)W^*W^* \rightarrow l^{\pm}l^{\pm}jjX$

- veto: no b-tagged jets
- main backgrounds: WZ,ZZ,tt

Looks very hard to do, but the challenge will bring lots of people together





M_H (GeV/c^2)	140	150	160	170	180
Signal events(S)	39	42	22.5	16.5	15
Total Background(B)	660	450	66	36	57
$S/\sqrt{B}$	1.5	2.0	2.8	2.75	2.0

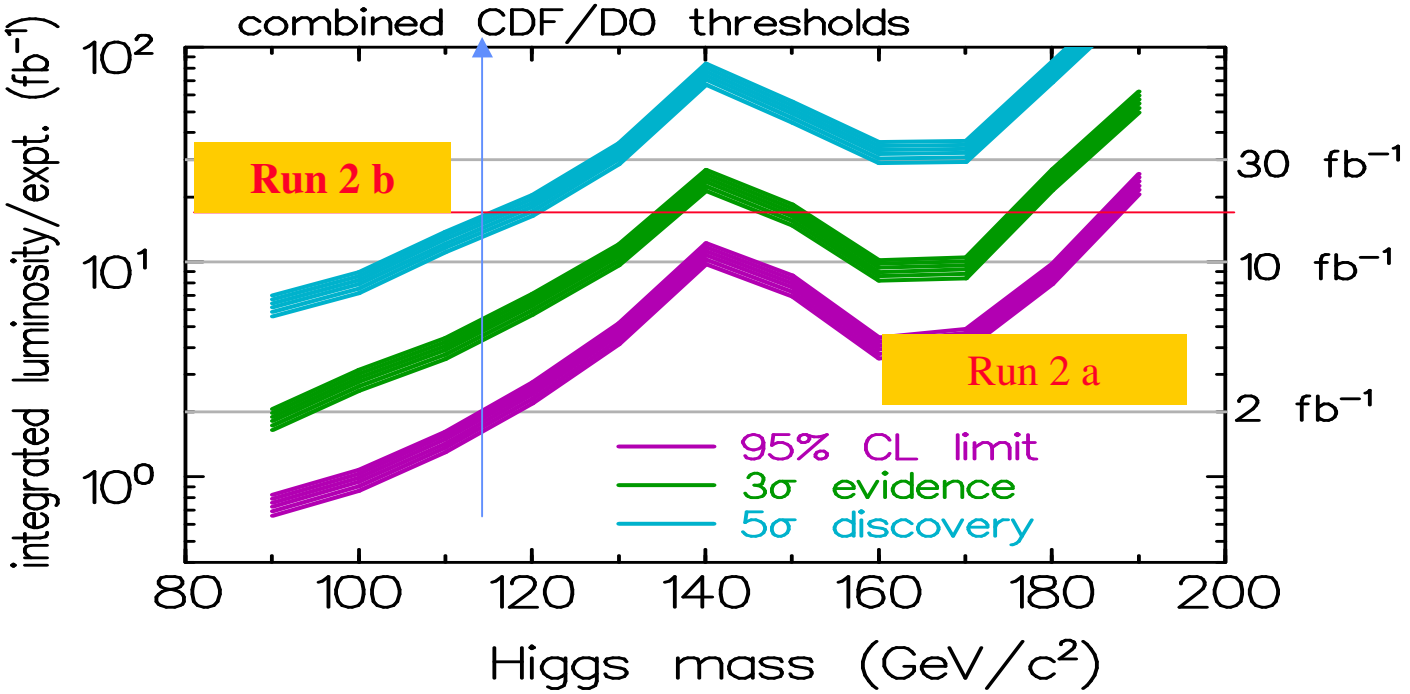
Higgs before LHC ?

Two experiments (CDF and DØ)
Band extends upward by 30% as an indication of uncertainties in:

- b-tagging efficiency
- mass resolution
- systematic effects

Results by the "Run II Higgs Working Group"

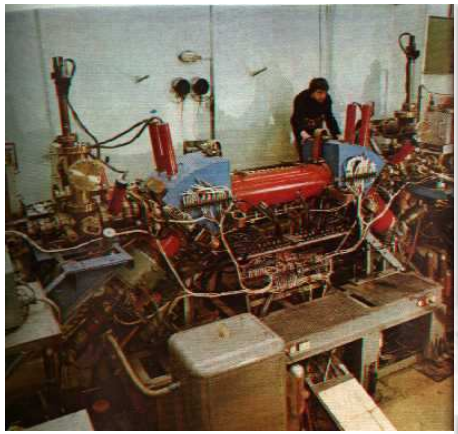
- In 2 fb^{-1} check 115 GeV/c^2 "hint of Higgs"

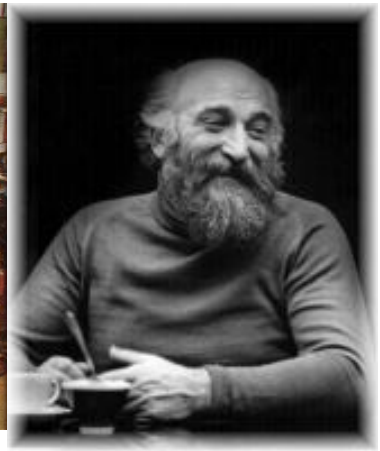


Can we (CDF&DO) get 15 fb^{-1} ?

This should be done on a relatively short time basis (before LHC, as x-sections at 2 TeV probably will not allow Higgs physics)

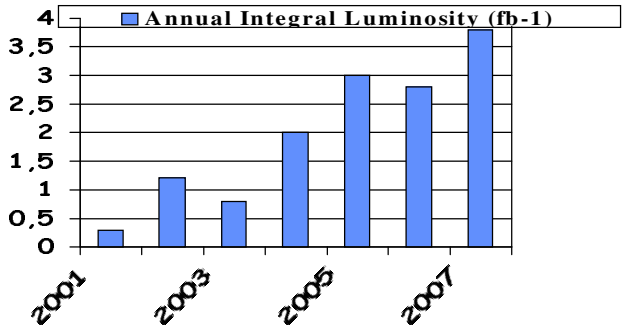
- ☞ can be done with the Run 2a detectors?
  - ⇨ yes but we have to replace silicon
- ☞ do we need serious changes to the machine?
  - ⇨ yes, R&D in progress (electron cooling)





At INP first e-cooling in 1974

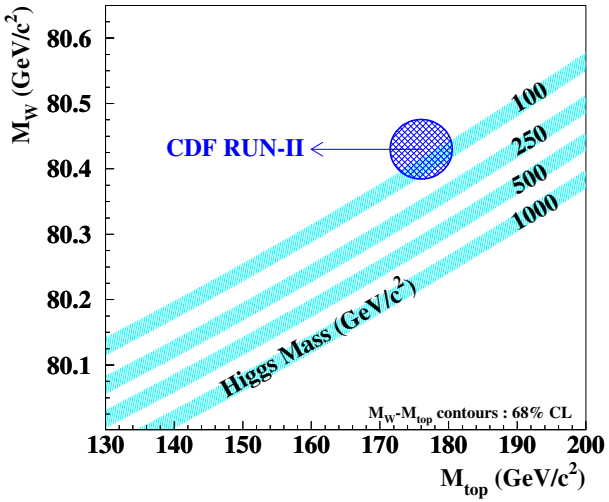
at Tevatron experiment underway



Conclusion

Run IIa with 2 fb^{-1} will provide a chance to:

- Measure M_W to ±30 MeV/c^2
- Measure M_{top} to ±3 GeV/c^2



This plot reflects a conservative approach (we expect to do slightly better and this is one experiment only). Central values from Run I

- test TGCs with VV events
- use top to test SM and look for deviations

with 15 fb^{-1} we will be looking for Higgs