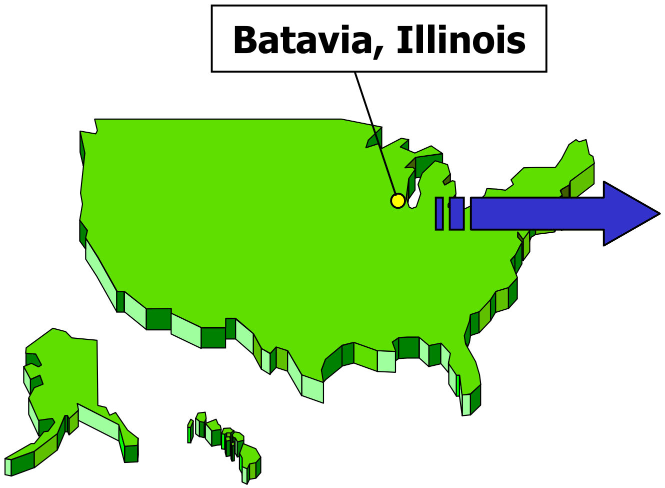
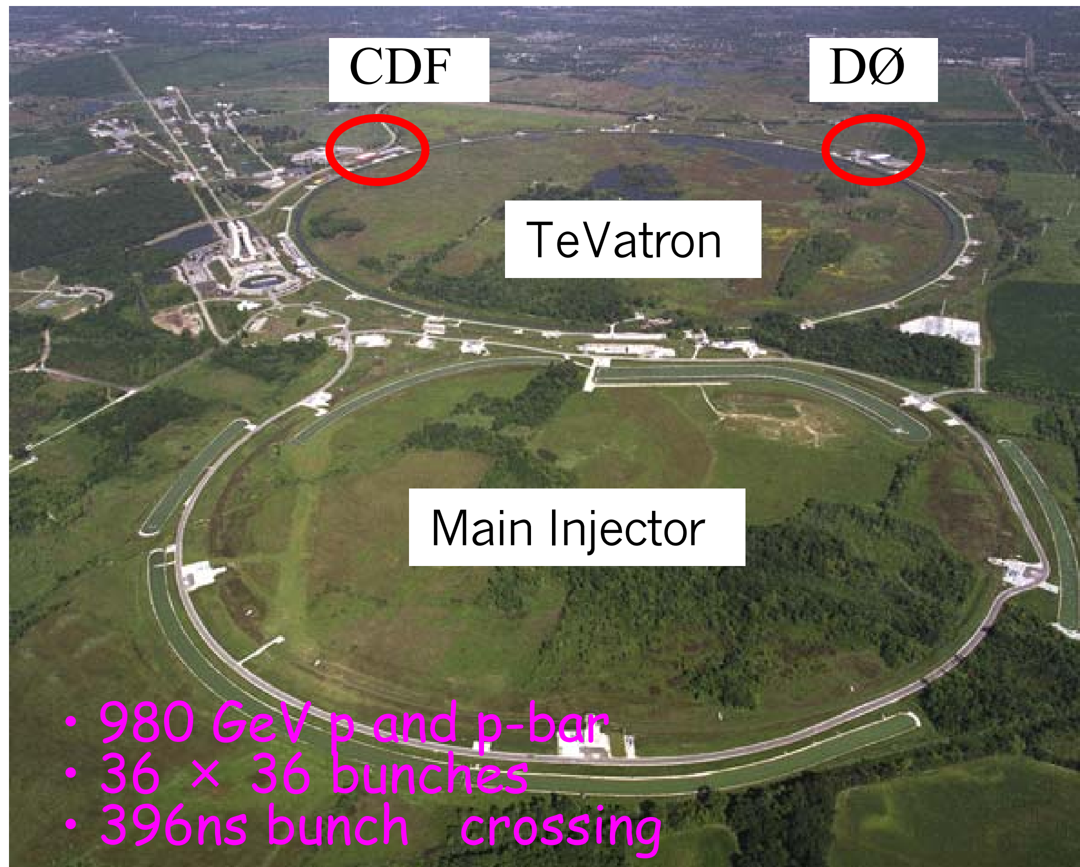
Prospects of Higgs Searches at the Tevatron





Kazu Hanagaki / Fermilab
for
CDF/DØ collaborations

The Collaborations

19 countries
80 institutions, 670 physicists

12 countries, 59 institutions
767 physicist

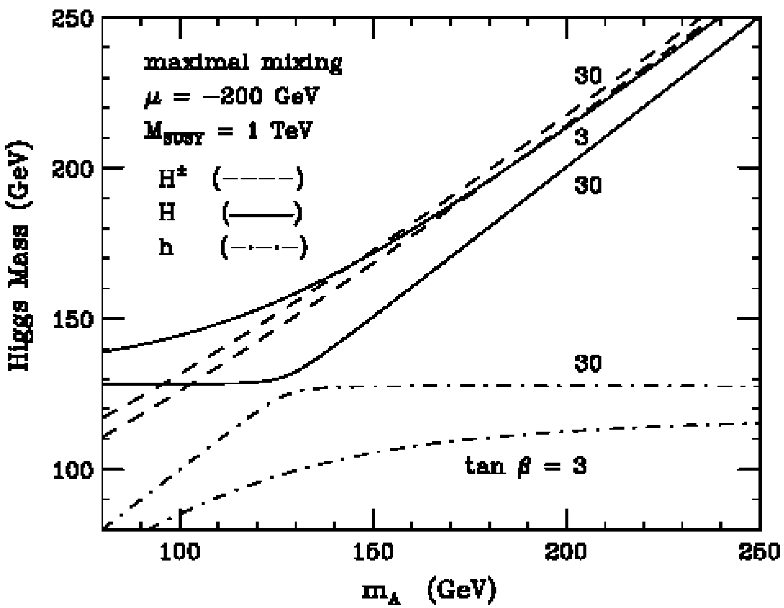
More than 50% non-US

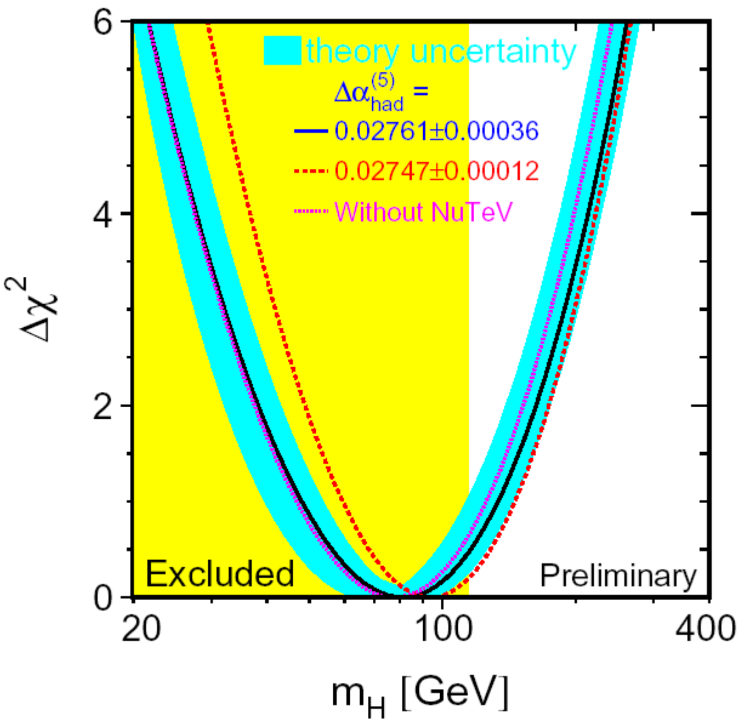
Outline

- Motivation
  - Strategy
- Detectors
  - lepton ID, b-jet tagging
- Standard Model Higgs searches
  - Towards WH
  - $H \rightarrow WW^{(*)}$ [not only SM Higgs]
- Non Standard Model Higgs searches
  - Doubly charged Higgs $H^{++/--}$
  - Susy Higgs bb(h/H/A)
- Prospects
  - Revised estimation of sensitivity
  - Luminosity
- Summary

Higgs Hunting at the Tevatron

- Last missing piece of the Standard Model
  - Light SM Higgs preferred
    - $M_H = 91^{+58}_{-37}$ GeV, $M_H < 211$ GeV @95% C.L.
    - LEP's direct search: $M_H > 114.4$ GeV/c^2 @ 95% C.L.
  - Key to understand beyond-the-SM physics like supersymmetry: a light Higgs is a basic prediction of SUSY





SM Higgs Search Strategy

- M_H below ~140 GeV
  - $qq \rightarrow W/Z+H\ (\rightarrow bb)$
  - b tag efficiency and dijet mass resolution are most relevant
  - $gg \rightarrow H(\rightarrow bb)$ overwhelmed by large QCD background…
- M_H above ~140 GeV
  - $gg \rightarrow H(\rightarrow WW)$
  - Missing E_T and lepton ID are important

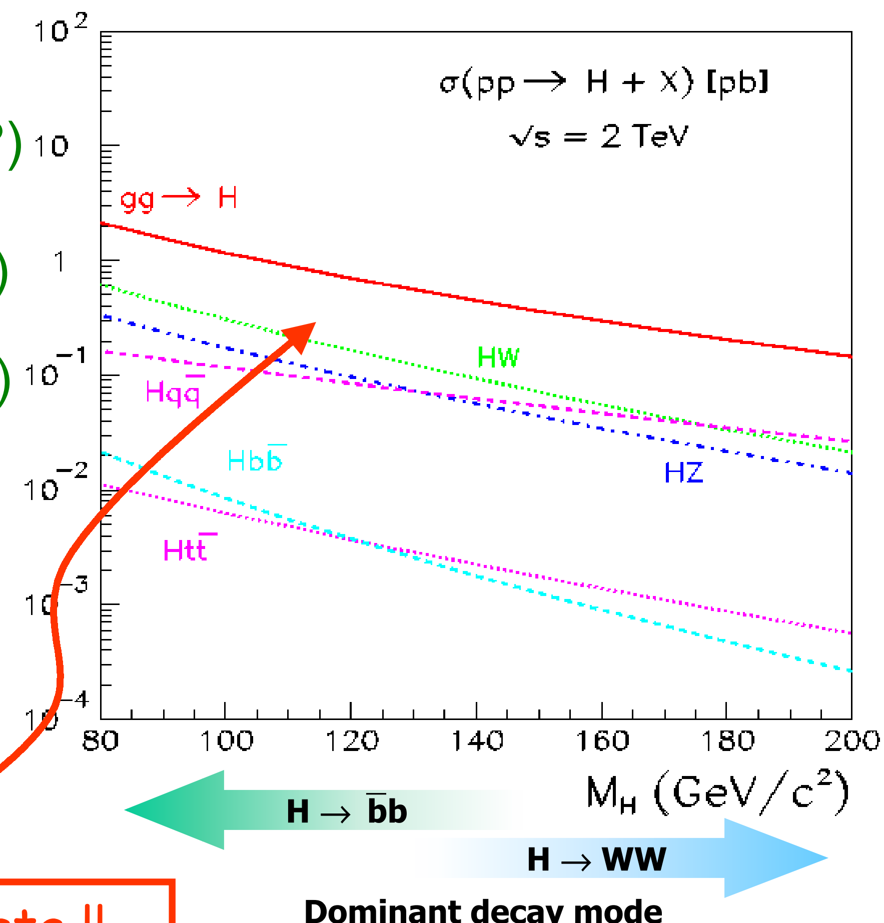
Number of Higgs produced (?) so far at DØ and CDF

7000(?)

700(?)

70(?)

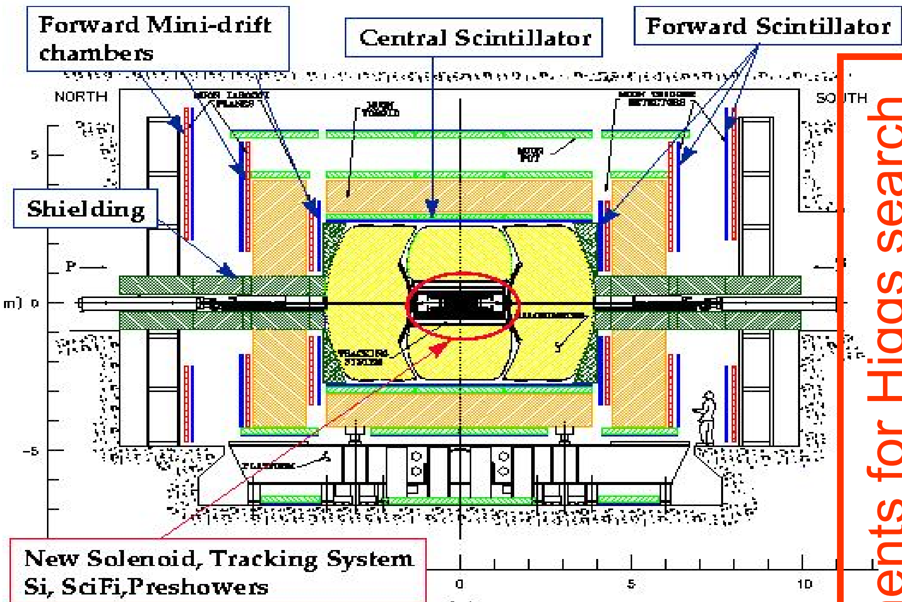
7(?)



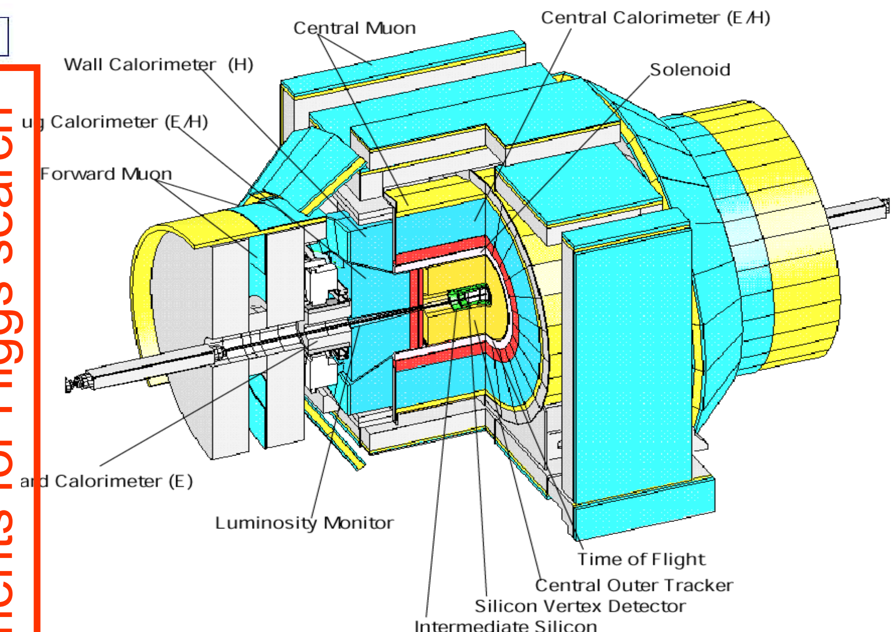
We might already have Higgs in data !!

The upgraded detectors

Almost new !!



We need all elements for Higgs search

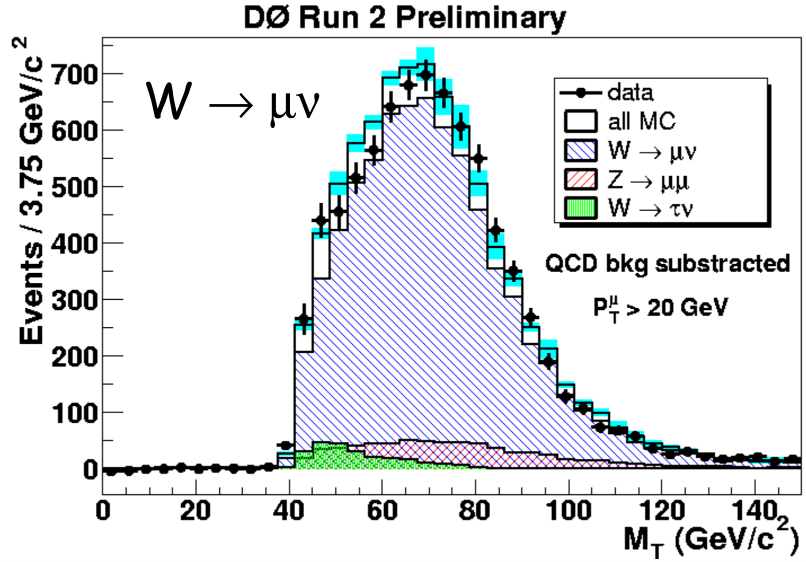


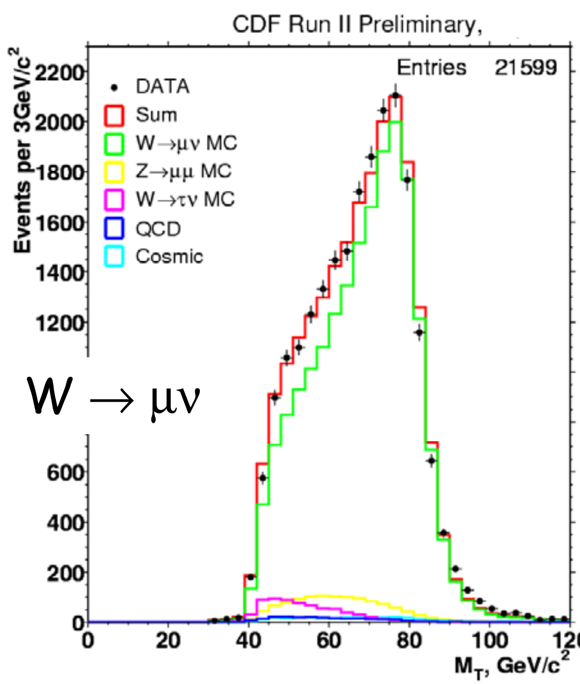
- New tracking: silicon and fibers in magnetic field
- Upgraded muon system
- Upgraded DAQ/trigger (displaced track soon)

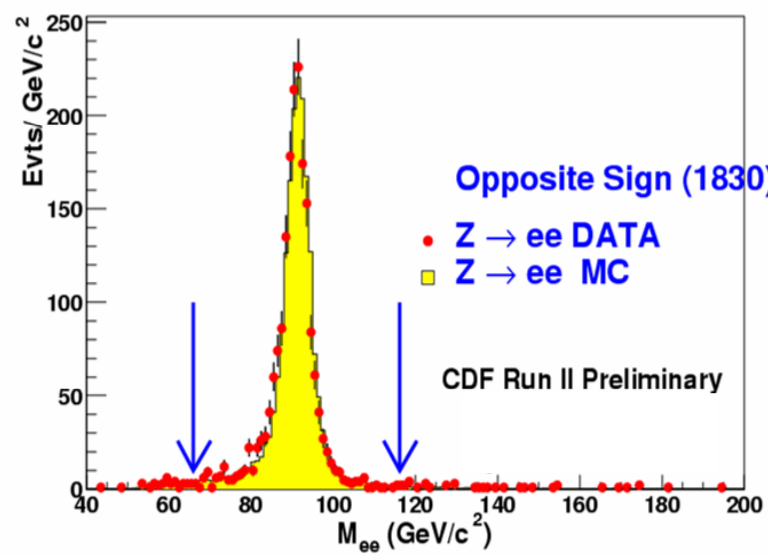
- New silicon detector new drift chamber
- Upgraded calorimeter, μ
- Upgraded DAQ/trigger, esp. displaced-track trigger
- New TOF PID system

Lepton ID

- First step for the SM Higgs search, both (W/Z)H and H→WW(*)

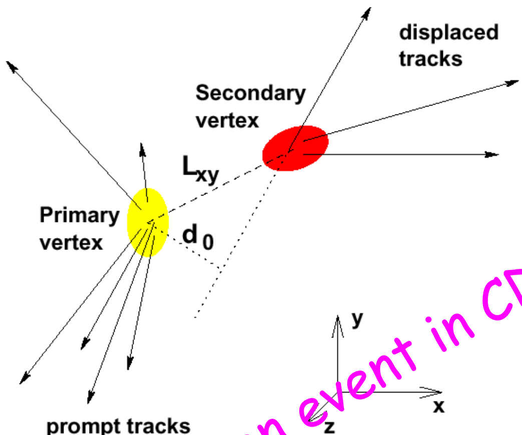




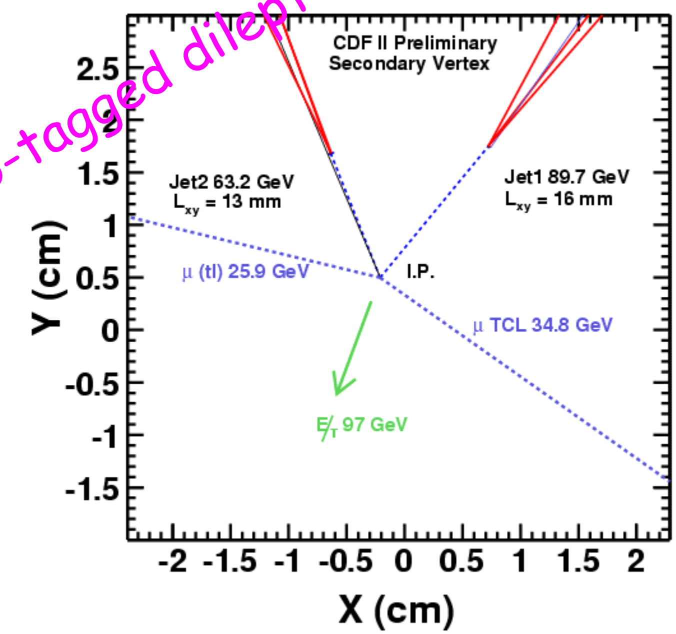


b-jet tagging

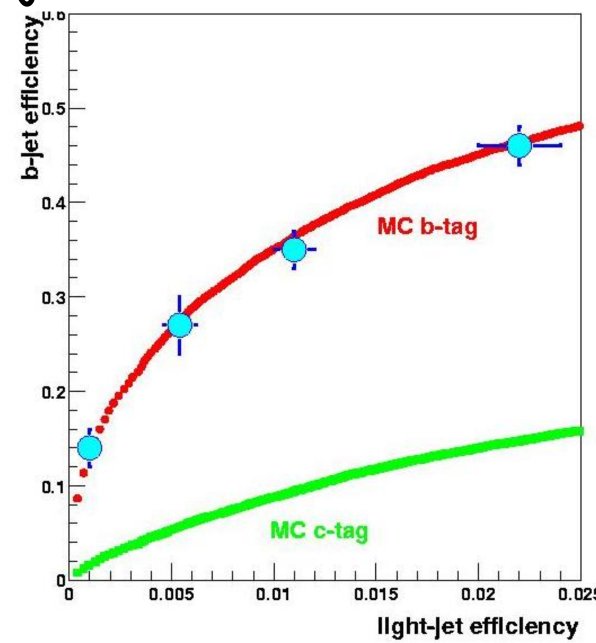
Important tool in low mass Higgs search



double b-tagged dilepton event in CDF



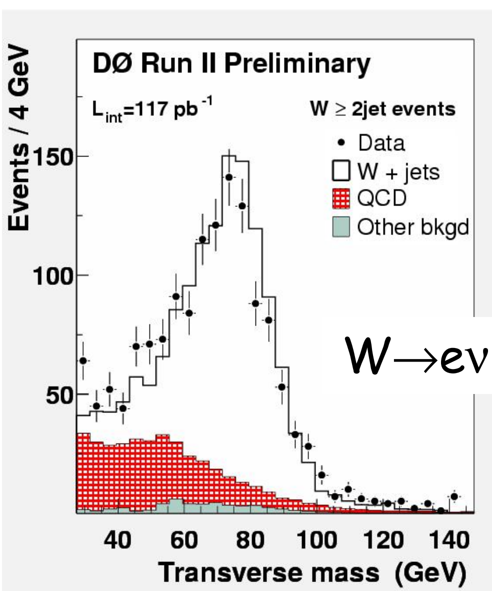
DØ: Jet lifetime probability algorithm (one of three algorithms) – using impact parameters from all tracks in a jet



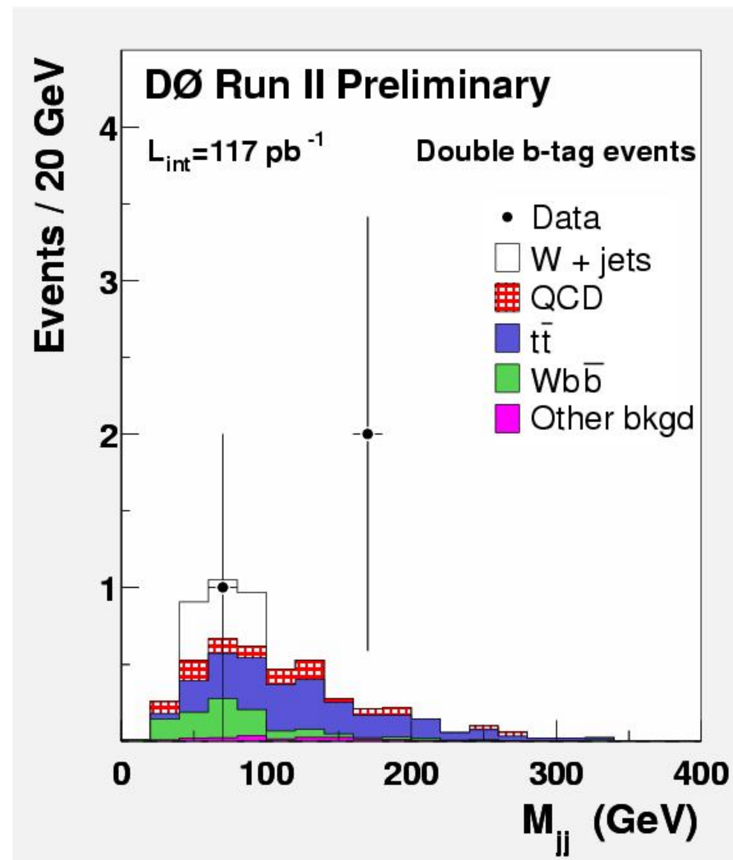
Performance is being improved

Towards WH(→bb)

- H(→bb)W(→eν)
  - Look for dijets in W(→eν) events
  - Require b-tag for both jets
- Observe 3 events
- Expect 5.5±1.6 events
  - Including 1event from Wbb
  - ➔ Upper limit of 33.4pb for Wbb cross section



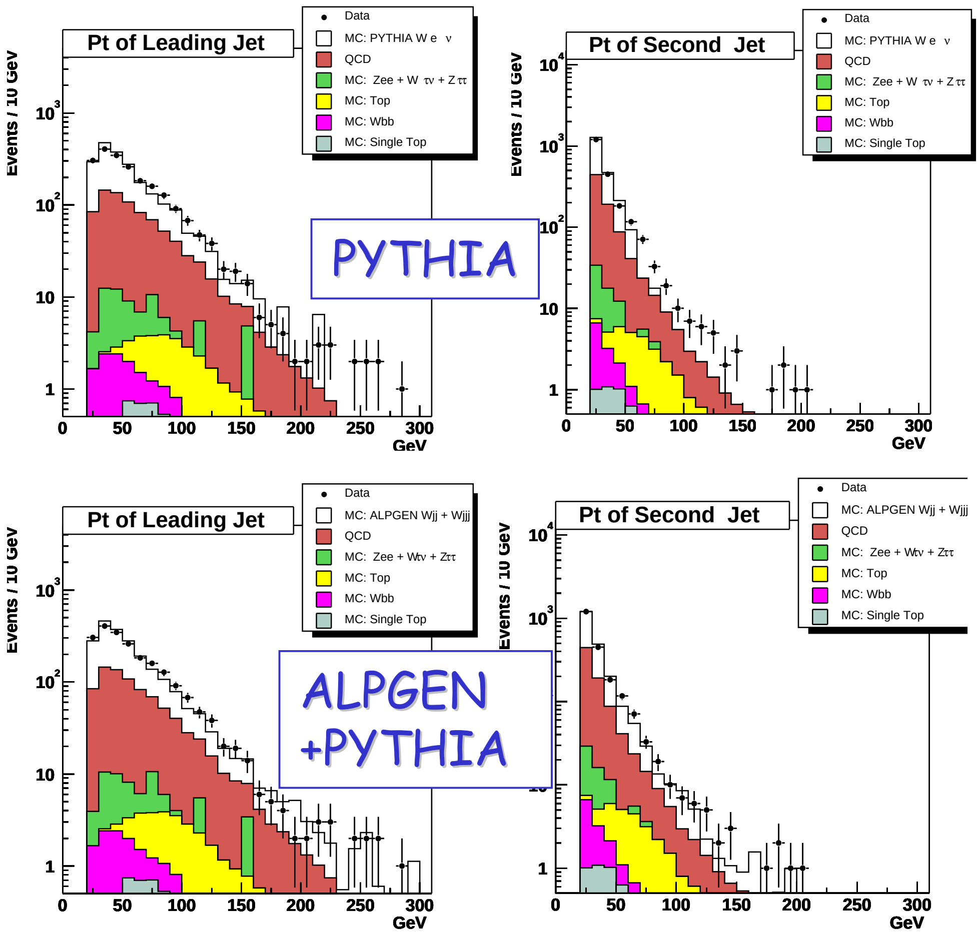
W→eν w/≥ 2 jets



W+jet

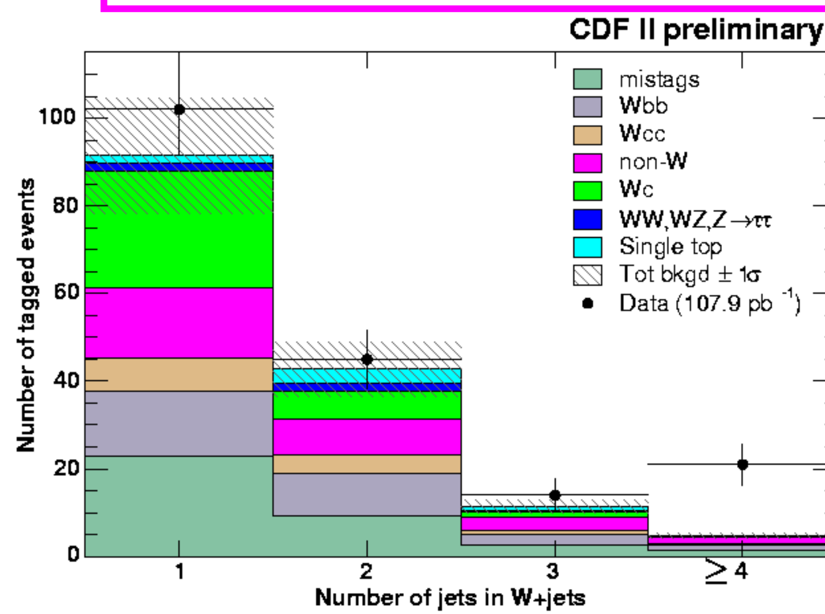
W + jet

DØ run II preliminary



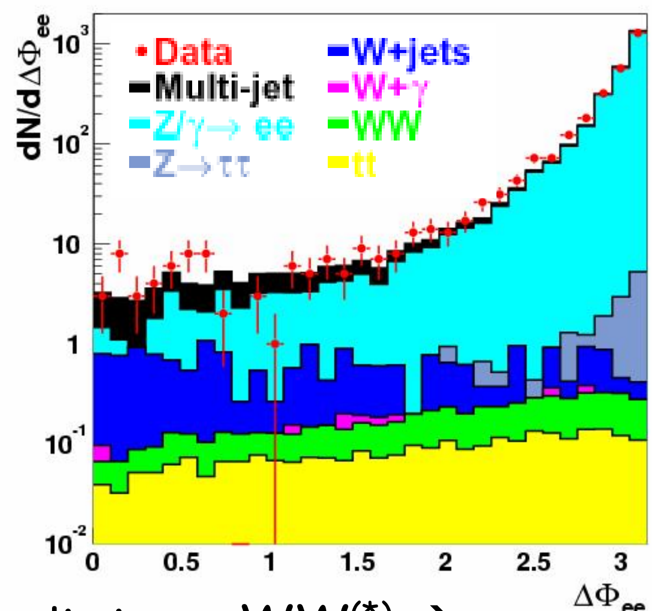
- Shape comparisons between data and MC (PYTHIA and/or ALPGEN) ← important to understand the BG

Jet Multiplicity in b-tagged events at CDF



H→WW$^{(*)}$

- High mass (>140 GeV) SM Higgs
- 4th generation fermion family enhances SM Higgs cross section by a factor of 8-9
- Fermiophobic/topcolor Higgs has larger Branching ratio
- BG: Z/γ^*, WW, t-tbar, W/Z+jet, QCD
- WW$^{(*)}$ → ee/eμ/μμ νν
- Event selection
  - Two high P_T isolated leptons
  - Large missing E_T
  - Opening angle between two leptons: flat or narrow in signal, back-to-back in most backgrounds



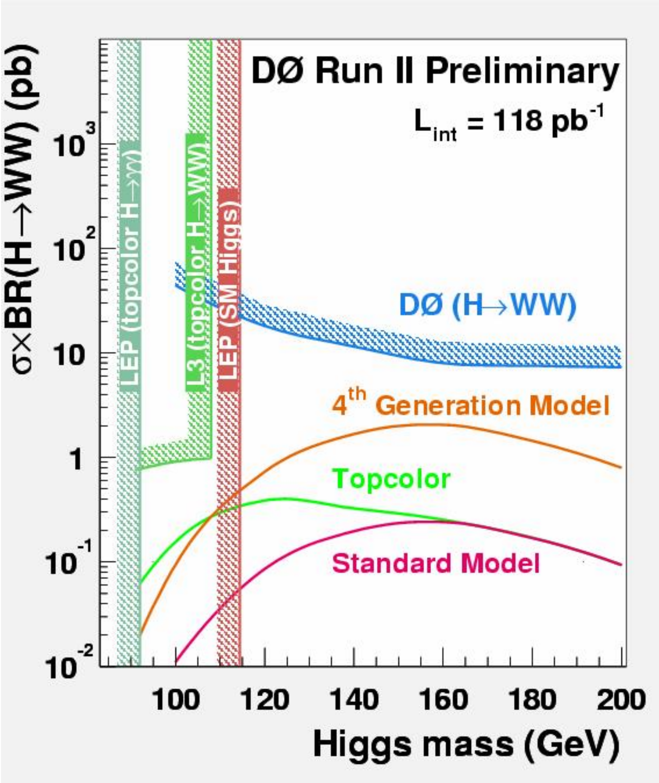
DØ run II preliminary WW$^{(*)}$ → eeνν

$H \rightarrow WW^{(*)}$ cont'd

Cut flow in eμ channel

cut	Expected BG	data
ID, Pt	183.0 ±6.9 ±18.3	184
$\not{E}t$	62.9 ±3.5 ±6.3	52
Min(Mw)	28.2 ±2.1 ±2.8	22
Jet veto	27.1 ±2.0 ±2.7	22
Anti Z	20.7 ±1.7 ±2.1	17
Anti W	8.8 ±1.2 ±0.9	9
Track iso	2.0 ±0.8 ±0.2	3
$M_{e\mu}$	1.6 ±0.8 ±0.2	2
Pt + $\not{E}t$	1.0 ±0.5 ±0.1	1
Mt	0.9 ±0.5 ±0.1	1

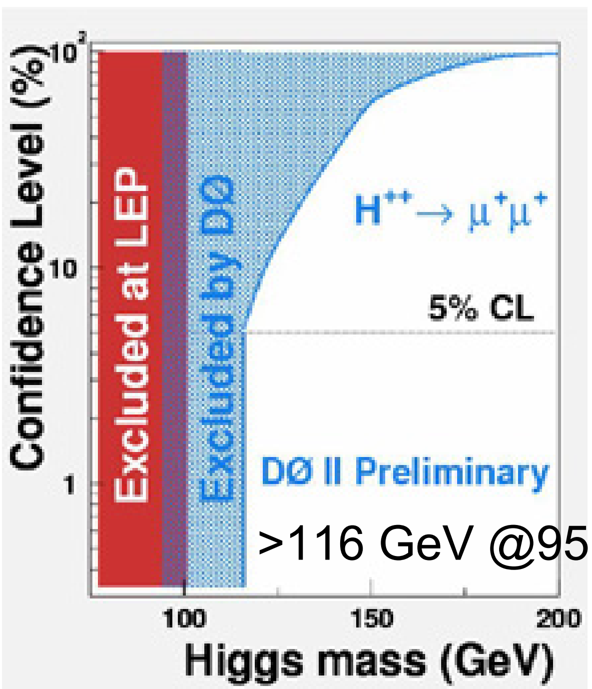
- Background well understood
- Newer result will show up soon with more statistics



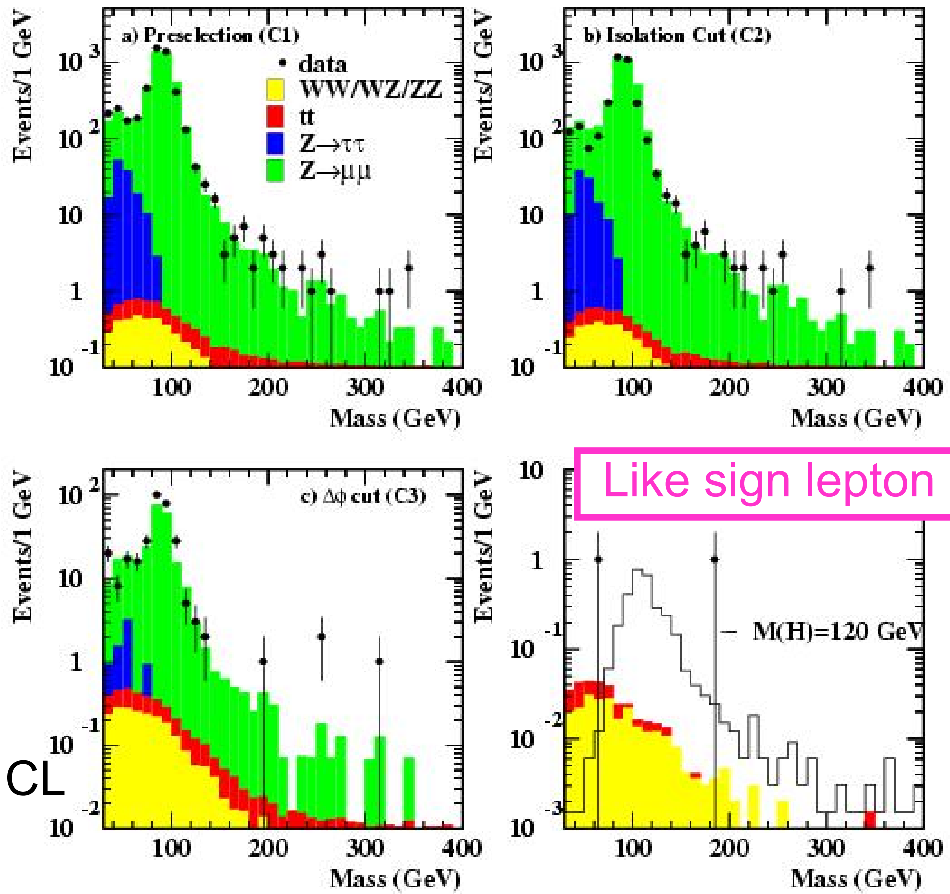
$H^{++/--}$ Search

- $H^{++/--} \rightarrow \mu^{\pm}\mu^{\pm}$
  - Higgs triplet
  - Left-right symmetric models
  - Searching for same sign dilepton

DØ preliminary 107 pb^{-1}

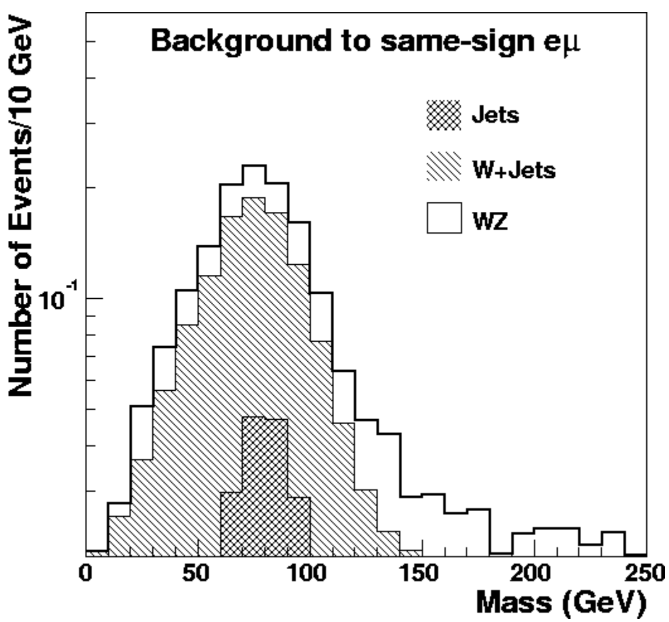


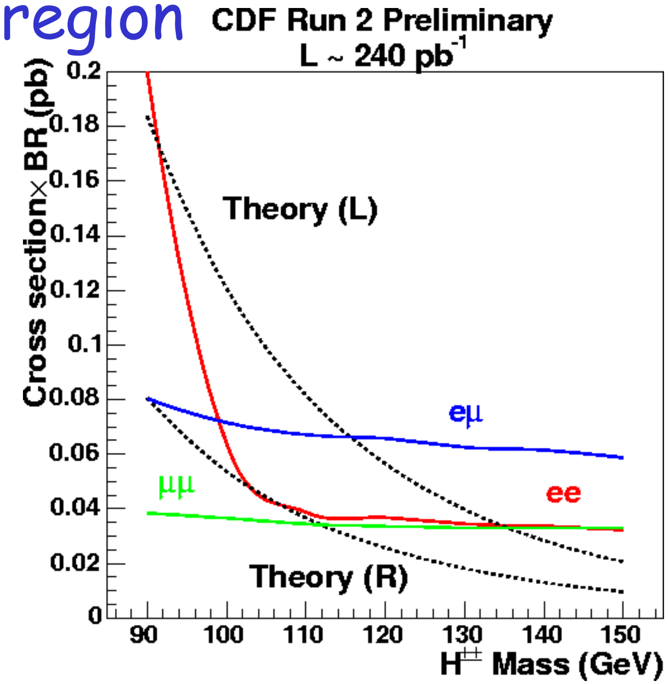
>116 GeV @95% CL



$H^{++/--}$ Search – cont'd

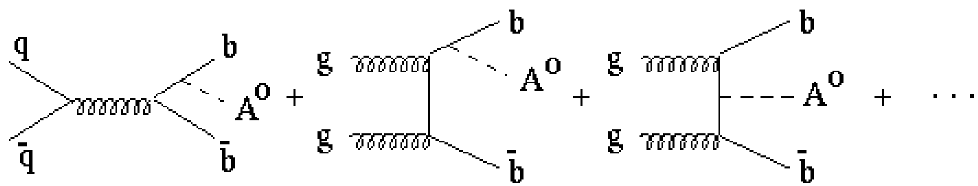
- CDF employs ee, eμ, and μμ (assume 100% branching ratio each)
  - Use low mass (<80 or 100 GeV) region as a control sample: expect 1.1±0.4 (ee), 1.0±0.6 (μμ), 0.8±0.3 (eμ) events, while 1 event observed in ee
  - No events in the search region

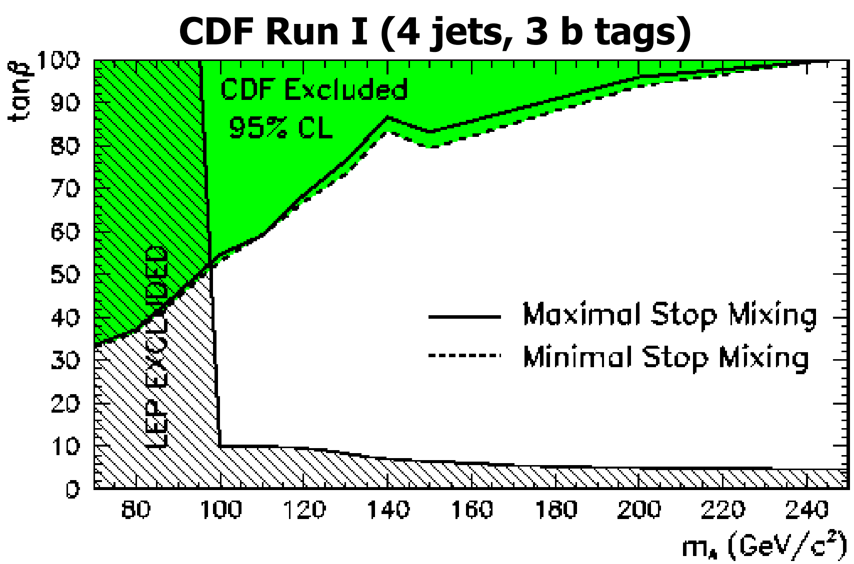


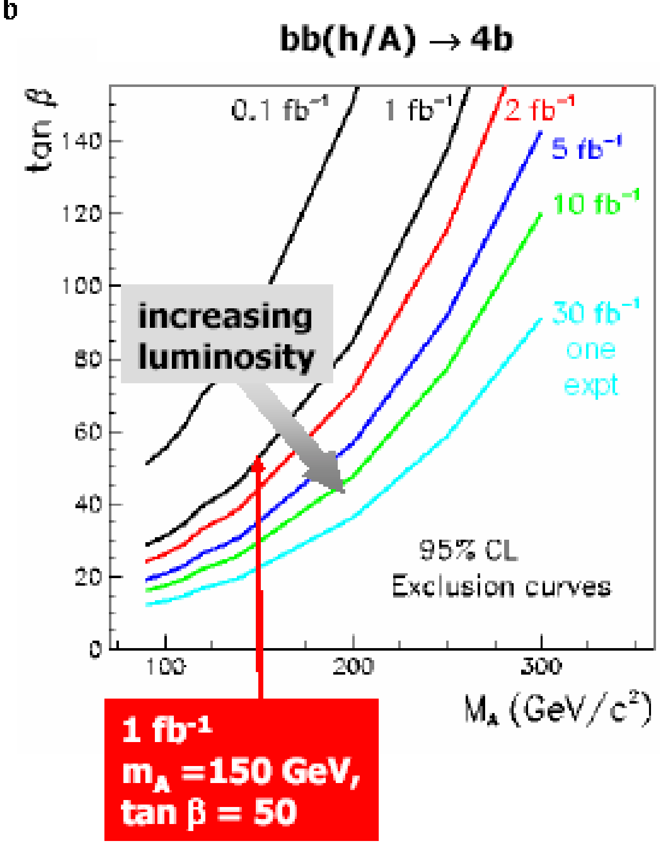


bb(h/H/A) Search

- bb(h/H/A) enhanced at large tan β



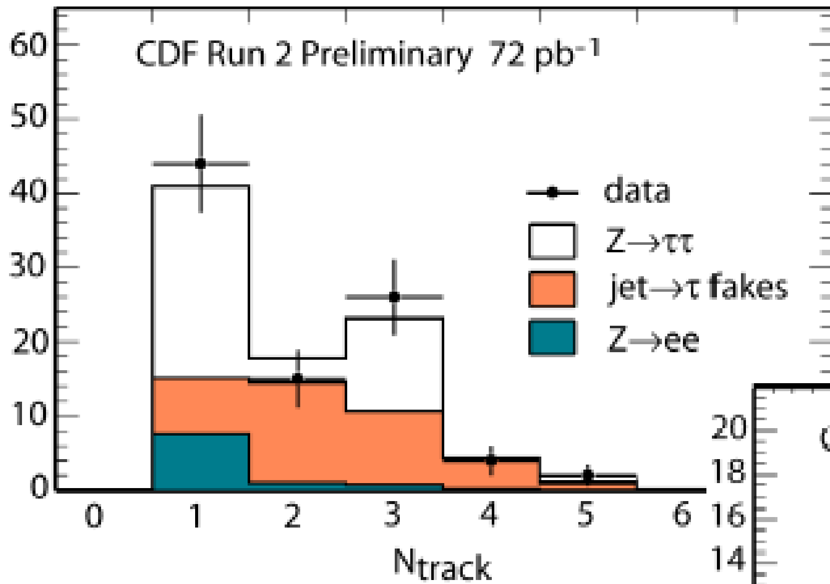




- New results will come out soon

$H \rightarrow \tau\tau$

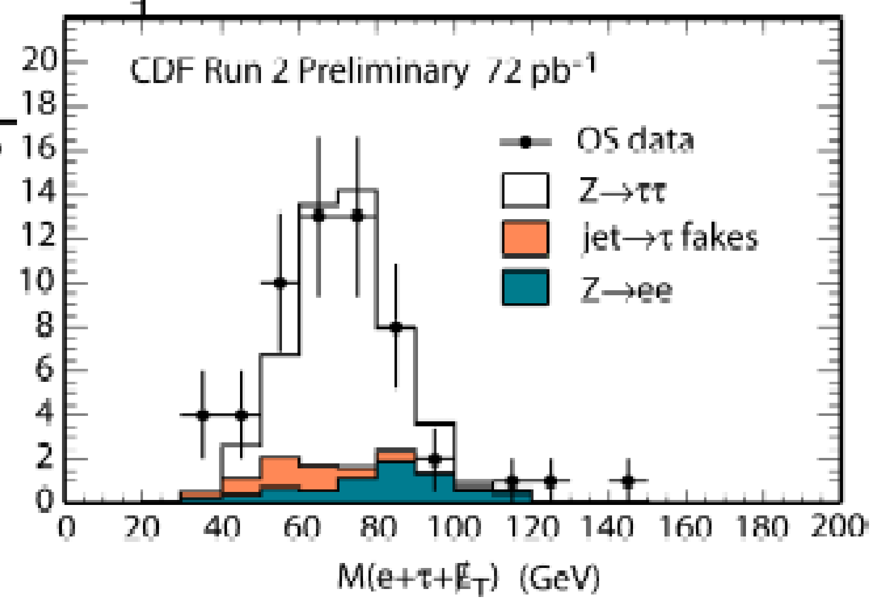
- Another place to look for bb(h/H/A)
- BR~10%



e+τ channel

Use track multiplicity to constrain jet to tau fake rate

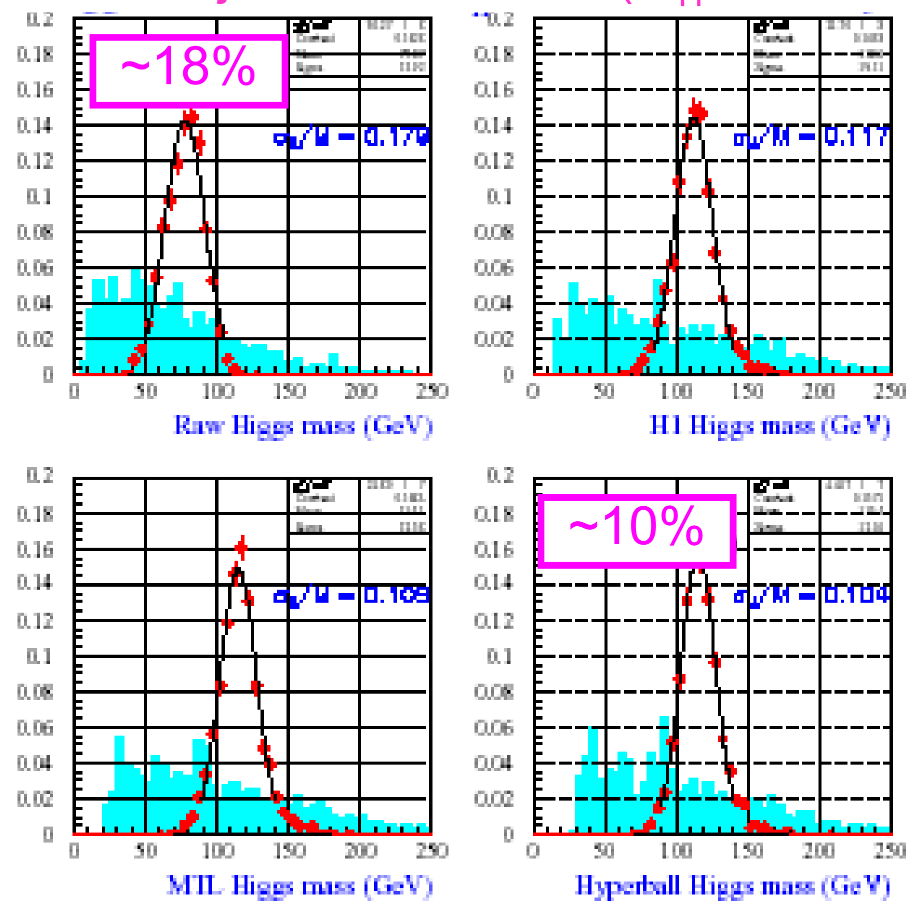
Plot mass of e, tau, and missing E_T



Higgs Sensitivity Study

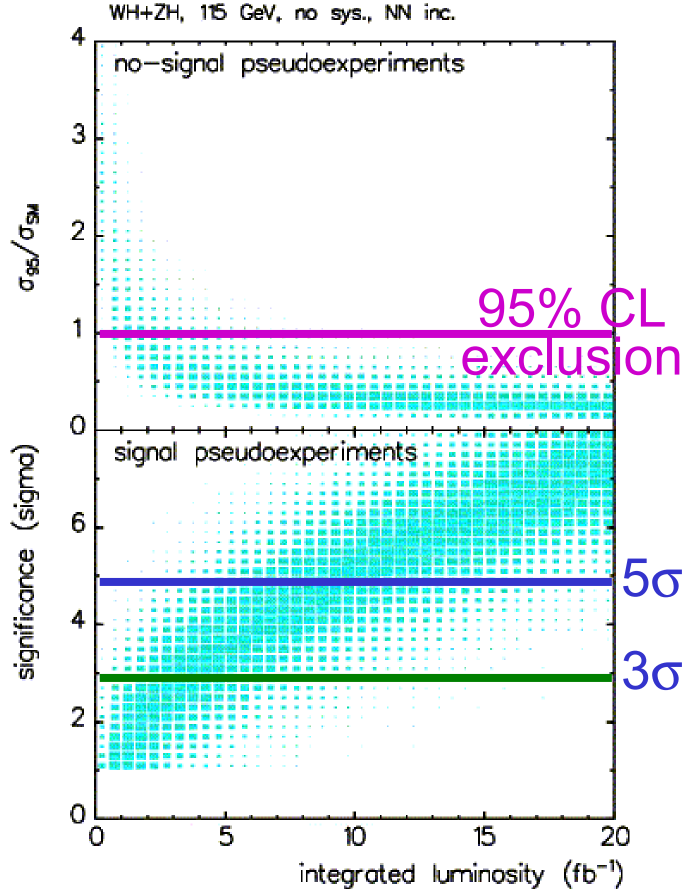
- Goal: update the famous SHWS result
- Task share between CDF and DØ
  - CDF: WH, try to understand event yield including b-tag and mass resolution
  - DØ: ZH, neural network based analysis and optimization of the cuts

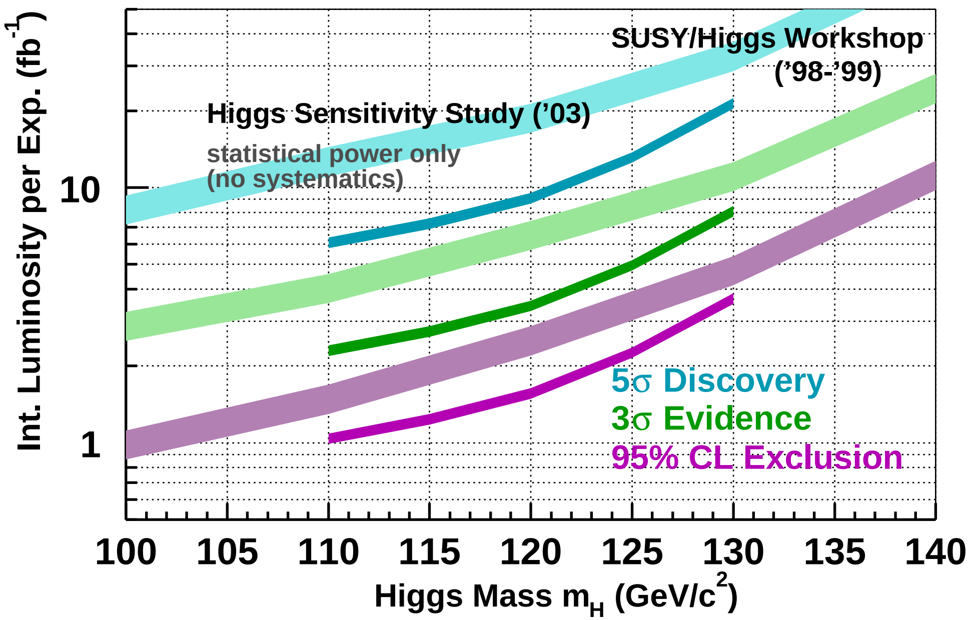
CDF: dijet mass studies (M_H=115GeV)



Revised Higgs Sensitivity

Pseudoexperiment at 115 GeV Higgs by CDF

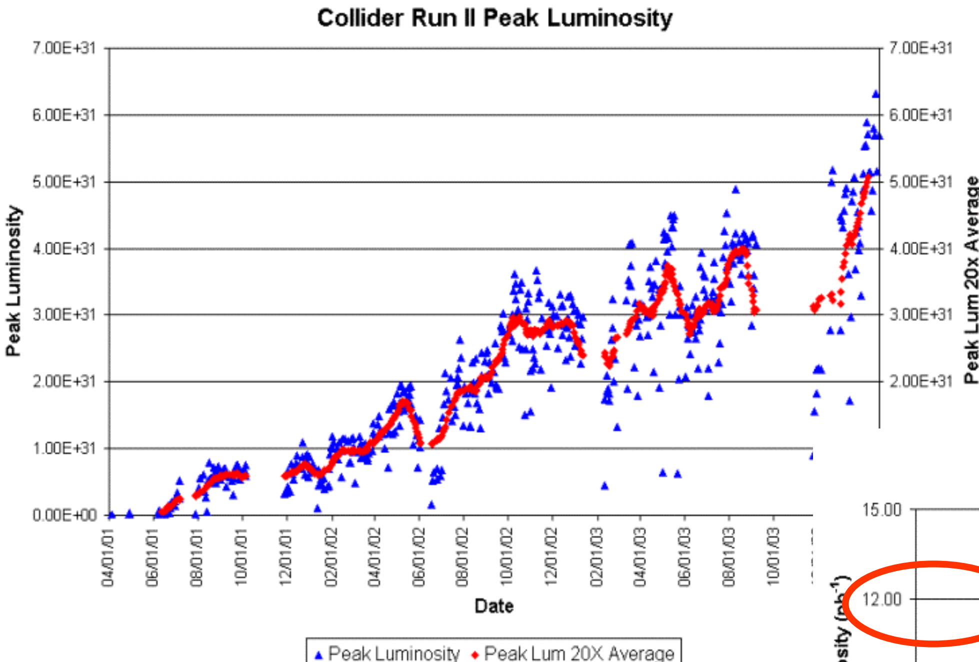




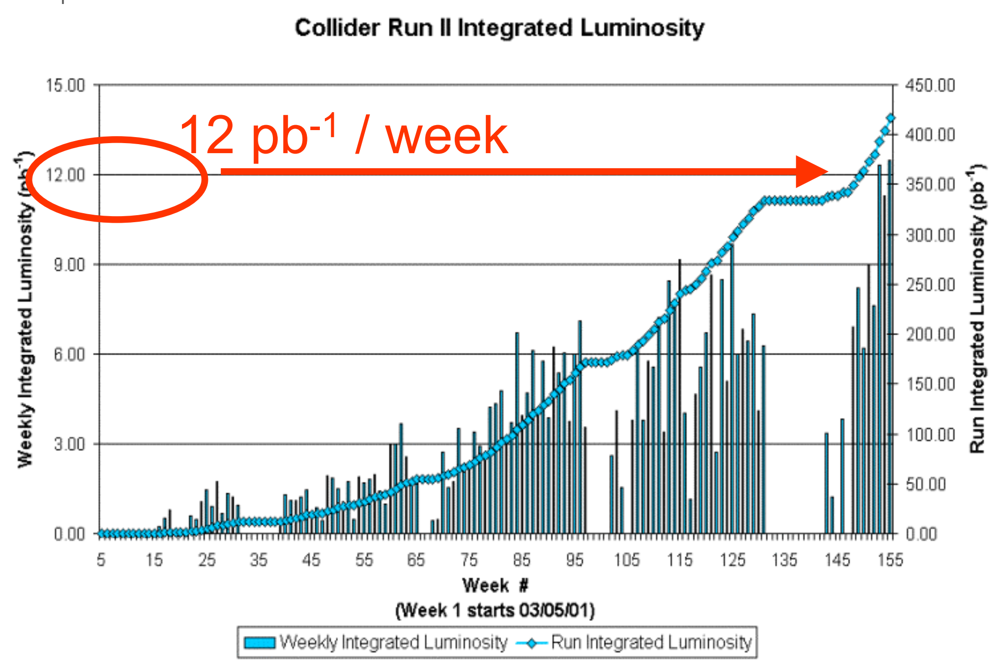
- SHWG estimate were not over optimistic
- Sophisticated analysis may improve the sensitivity
- RunIIb silicon was cancelled, but the impact is minimal

Addition of innermost layer at DØ

Present Luminosity

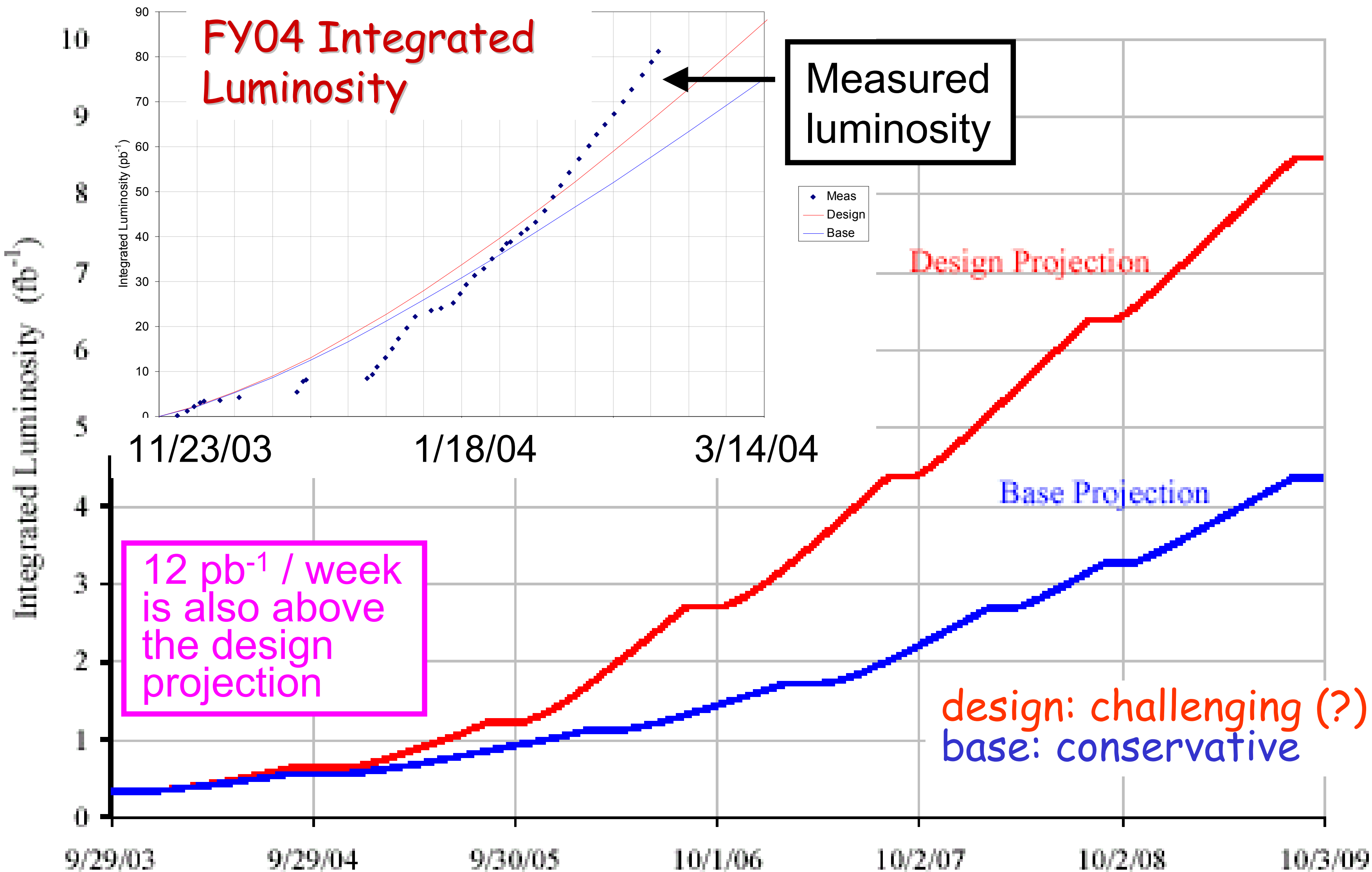


- $12\ pb^{-1}$ per week
- Shot from the Recycler ← important milestone for the future upgrade
- Peak luminosity record 63.3E10 $cm^{-2}s^{-1}$ (Feb. 18)



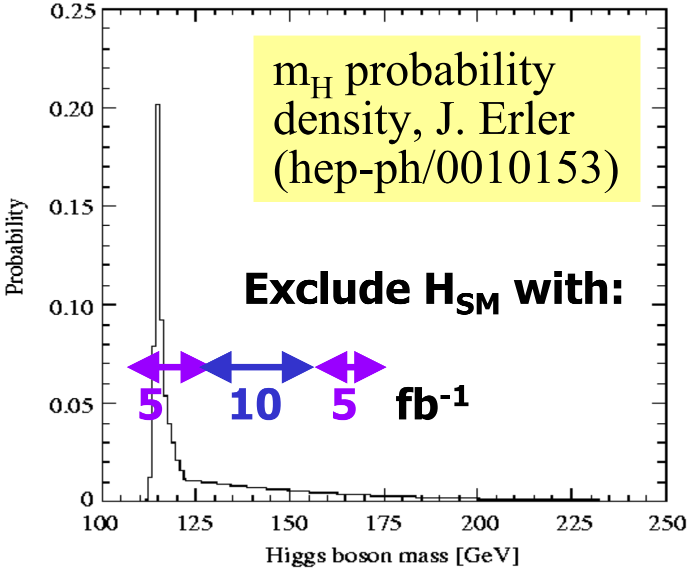
- Store hours per week: 88 (FY03) → > 120
- Antiproton transfer efficiency : 63% (FY03) →~80%

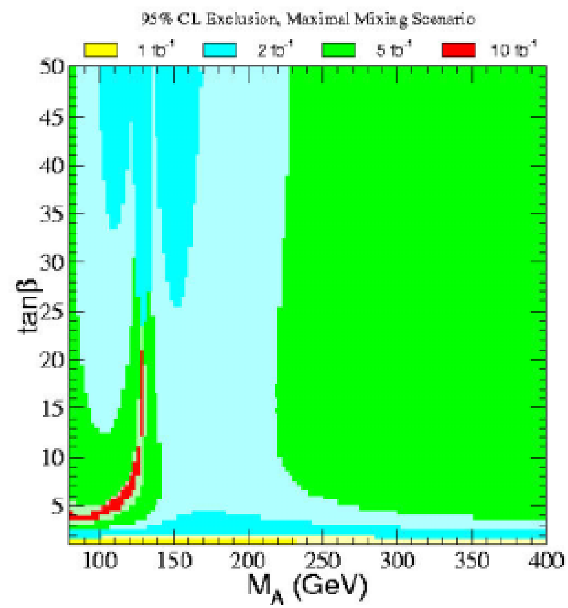
Projected Integrated Luminosity



What if we see nothing?

- Exclusion of Higgs itself would be very important
  Exclude:
  - LEP's hint in the SM framework (~2fb^{-1})
  - Most probable mass range (~5fb^{-1})
  - Almost all the allowed range (~10fb^{-1})
- Special importance for minimal SUSY Higgs
  - can be excluded almost all parameter space with 5-10fb^{-1}



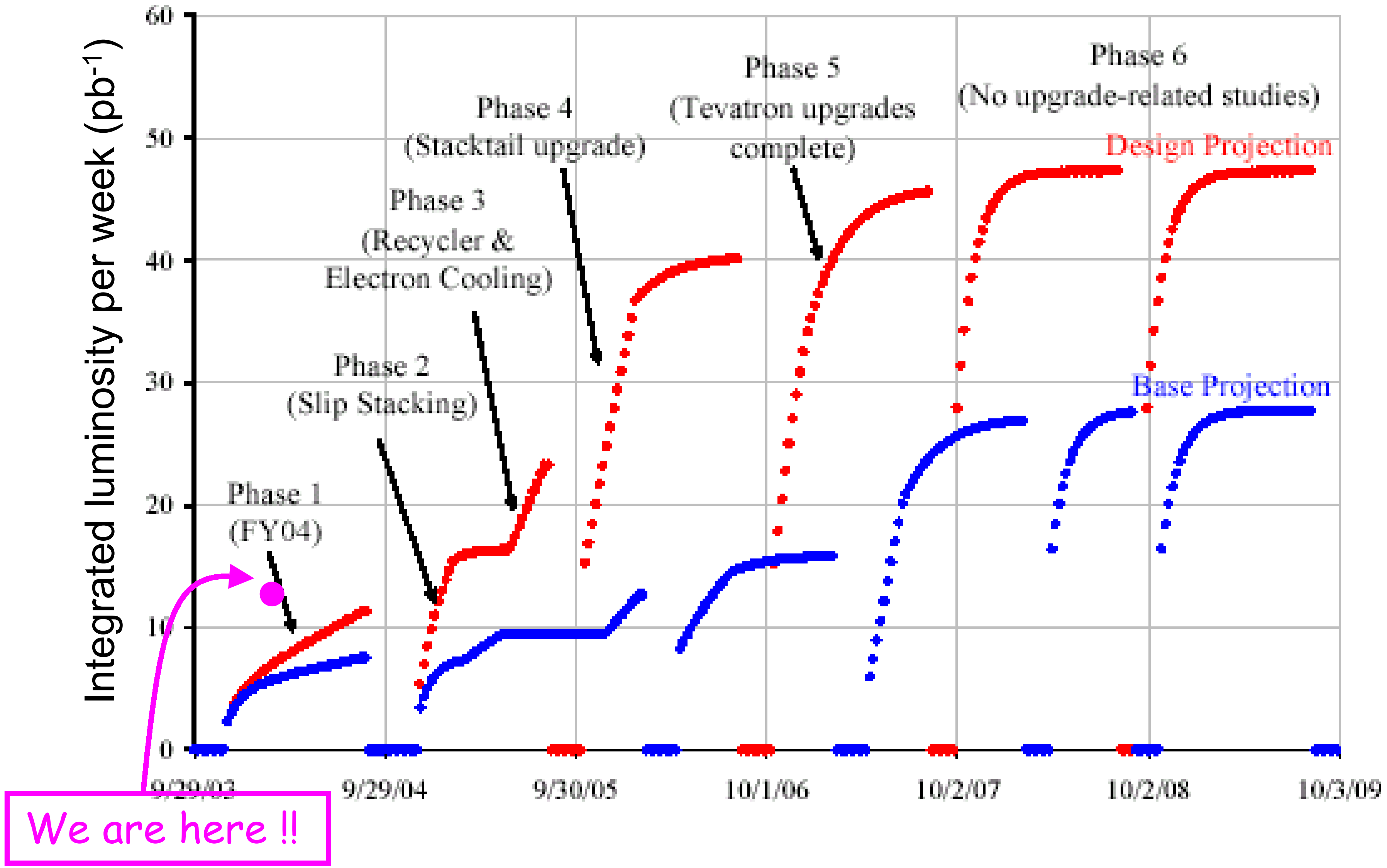


Summary

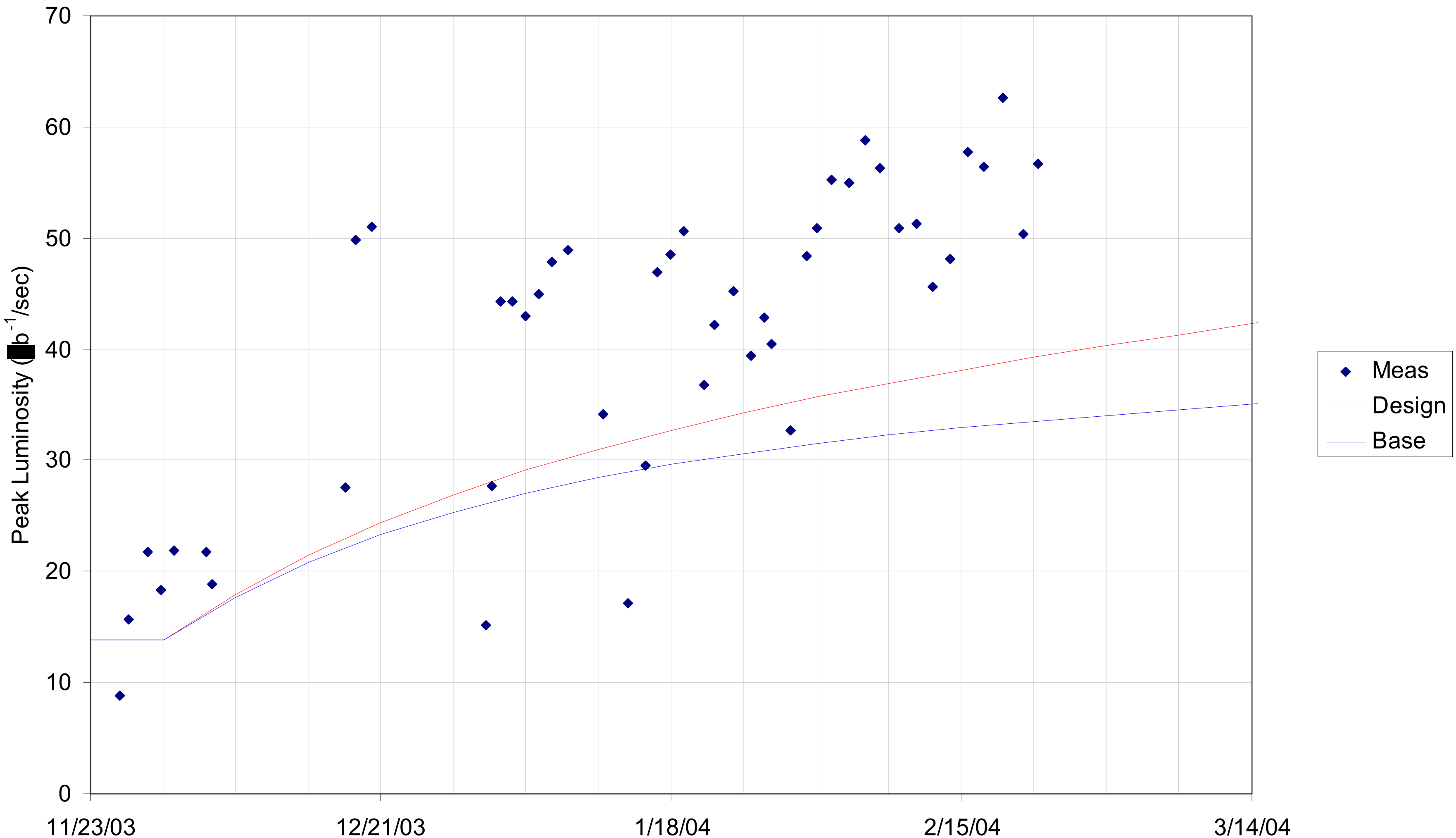
- Both CDF and DØ are taking physics quality data with high efficiency
- Many searches have been started
  - Understanding of backgrounds
  - New limit for exotic Higgs
- Higgs sensitivity was reevaluated – "famous" SHWG estimate was not over optimistic
- Accelerator performance is being improved
- EVEN IF we see nothing, still very interesting physics result
- Never surrender – stay tuned!!!

… Backup Slides

Luminosity Prospects



FY04 Peak Luminosity



Accelerator Parameters

Parameter		May 03 Average	Run II Design	Ratio
Peak Luminosity	$x10^{31}cm^{-2}sec^{-1}$	3.7	29	7.8
Store hours per week		75	97	1.3
Store Duration	hr	15	15	1.0
Integrated Luminosity	pb^{-1}/wk	5.9	55	9.3
Number of Bunches		36	36	1.0
Protons/bunch	$x10^{10}$	22	27	1.2
Antiprotons/bunch	$x10^{10}$	2.2	13	5.9
$\beta*$	cm	35	35	1.0
MI extraction Longitudinal Emittance	eV s	3.5	2.5	0.7
Bunch Length (rms)	m	0.6	0.5	0.9
Proton Transverse Emittance (at collision)	π-mm-mrad	20	18	0.9
Antiproton Transverse Emittance (at collision)	π-mm-mrad	18	18	1.0
Hourglass Form Factor		0.6	0.63	1.1
Pbar Transmission Efficiency	%	60	80	1.3
Stack Used	$x10^{10}$	134	583	4.4
Avg. Antiproton Production Rate	$x10^{10}/hr$	8.3	40	4.8

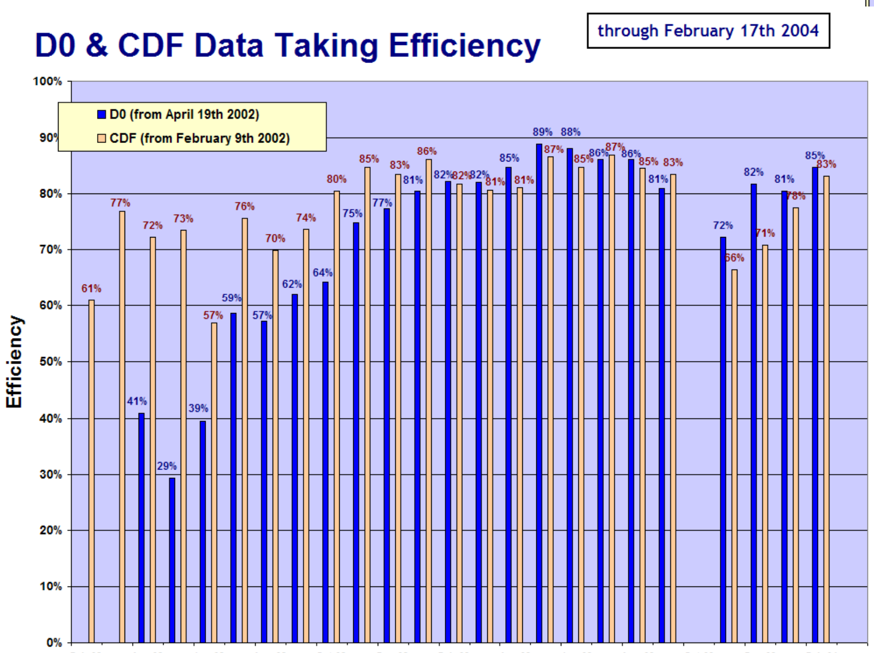
Parameter	Last Store	Last 10 stores Average	FY04 Average	End of FY03	FY04 (End) Design	FY04 (End) Base	
Store Parameters							
Initial Luminosity (Average)	56.7	53.6	40.2	36.1	61.9	43.3	$\times10^{30}cm^{-2}sec^{-1}$
Integrated Luminosity per Store (Averaged)	2531	2735	1717	1089	2000	1300	nb^{-1}
Luminosity per week (Averaged)	-	11.8	6.2	6.4	11.3	7.4	pb^{-1}
Store Length	24.0	32.9	25.2	14.9	15.0	15.0	Hours
Store Hours per week	-	140	91	88	85	84	Hours
Shot Setup Time	1.0	2.4	2.6	2.3	2.2	2.2	Hours

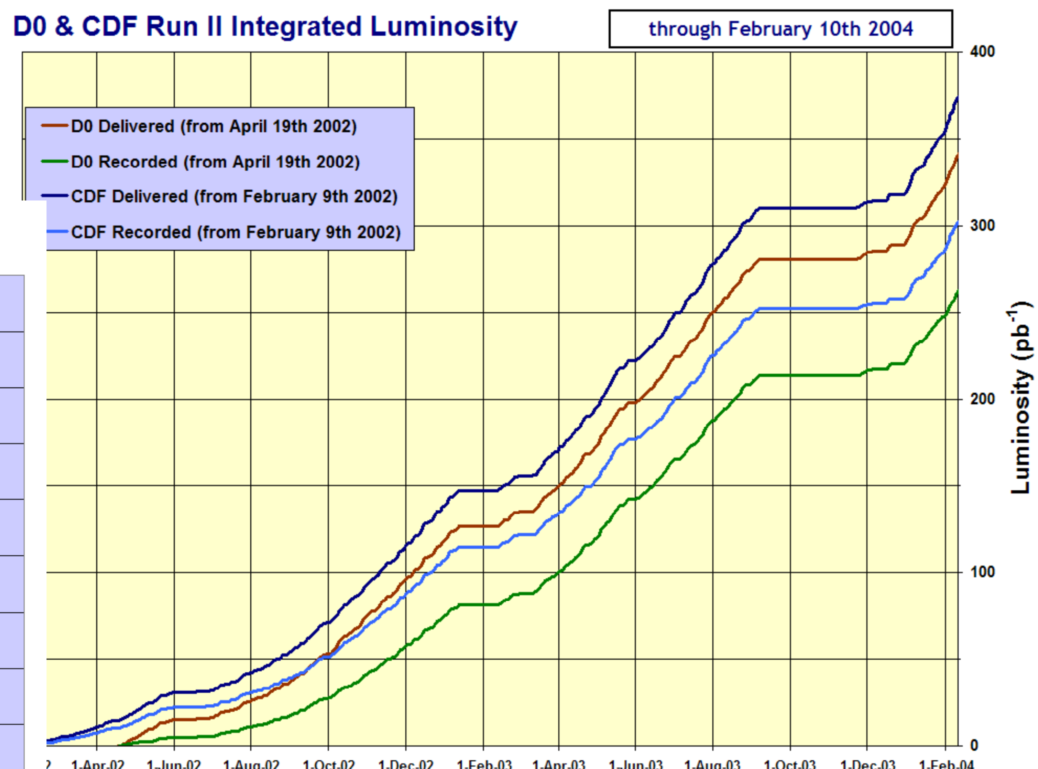
Parameter	Last Store	Last 10 stores Average	FY04 Average	End of FY03	FY04 (End) Design	FY04 (End) Base	
TEVATRON Parameters							
Protons per bunch	235	239	220	237	260	260	$\times10^{9}$
Antiprotons per bunch	33	31	24	22	31	25	$\times10^{9}$
Proton Efficiency to Low Beta	79	79	74	58	-	-	%
Pbar Transfer efficiency to Low Beta	75	76	74	63	80	77	%
HourGlass Factor	0.70	0.70	0.70	0.70	0.65	0.65	
Initial Luminosity Lifetime	8.3	8.5	9.2	9.5	8.3	7.0	hours
Asymptotic Luminosity Lifetime	26.3	25.9	25.7	25.1	25.0	25.0	hours
Effective Emittance	20.5	20.7	20.7	21.6	21.0	23.0	π-mm-mrad

Parameter	Last Store	Last 10 stores Average	FY04 Average	End of FY03	FY04 (End) Design	FY04 (End) Base	
Antiproton Parameters							
Zero Stack Stack Rate	13.1	11.0	10.2	11.5	18.0	13.7	$\times10^{10}$/hour
Normalized Zero Stack Stack Rate	2.4	2.2	2.1	2.3	3.6	2.7	$\times10^{-2}$/hour
Average Stacking Rate	6.3	5.2	5.3	7.1	9.3	7.6	$\times10^{10}$/hour
Stacking Time Line Factor	84	76	78	88	75	75	%
Stack Size at Zero Stack Rate	286	293	289	300	300	300	$\times10^{10}$
Protons on Target	5.4	5.1	4.8	5.0	5.0	5.0	$\times10^{12}$
Start Stack	194	171	143	144	155	130	$\times10^{10}$
End Stack	37	25	25	16	15	15	$\times10^{10}$
Unstacked Pbars	157	146	117	128	140	115	$\times10^{10}$

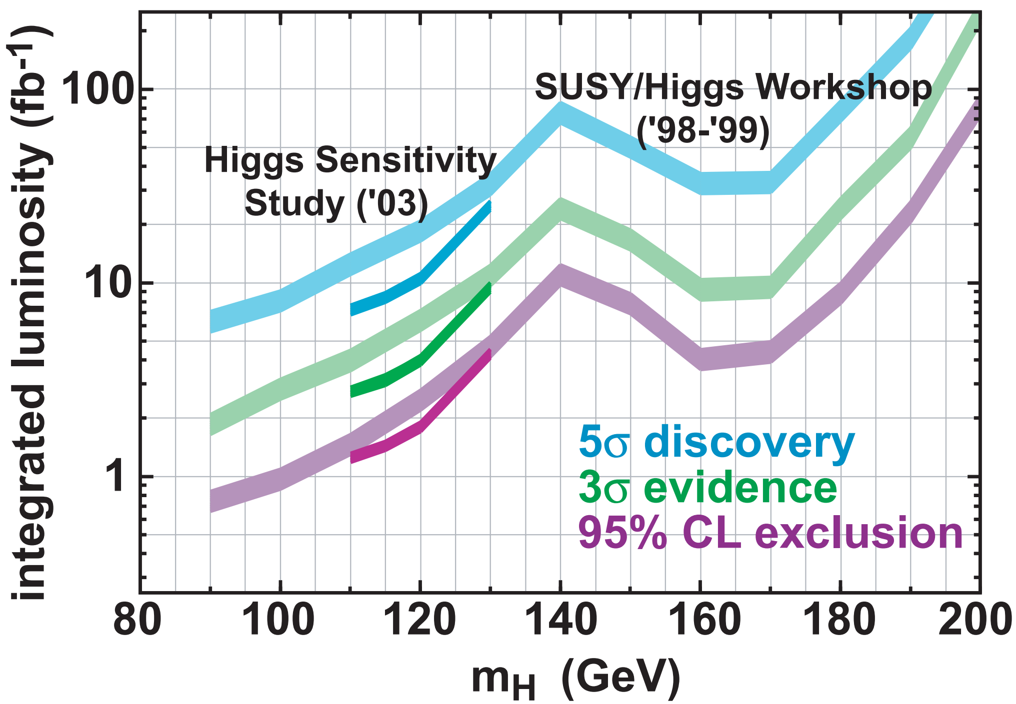
Data Collection Status

- Both CDF and DØ experiments are operating well and recording physics quality data with ~85% efficiency

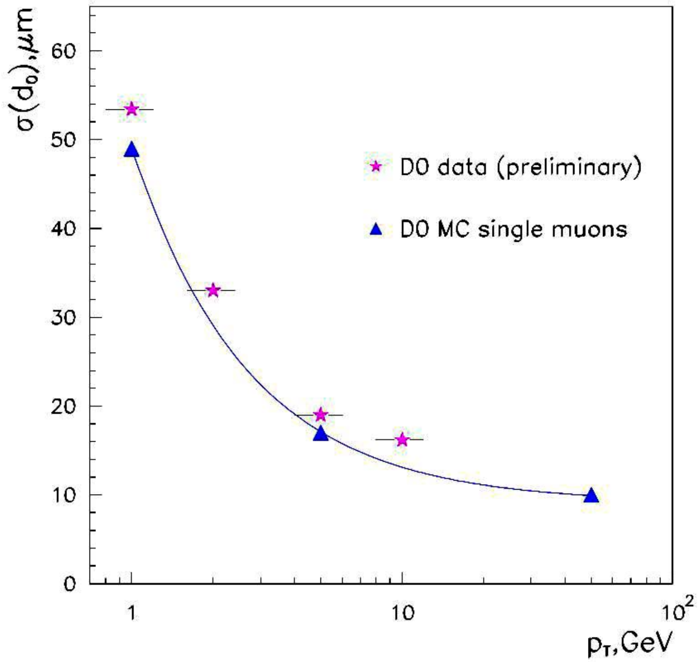




Misc.



integrated luminosity (fb^{-1})
100
10
1
80
100
120
140
160
180
200
m_H (GeV)
SUSY/Higgs Workshop ('98-'99)
Higgs Sensitivity Study ('03)
5σ discovery
3σ evidence
95% CL exclusion



σ(d$_0$),μm
60
50
40
30
20
10
0
1
10
10^2
p$_T$,GeV
D0 data (preliminary)
D0 MC single muons