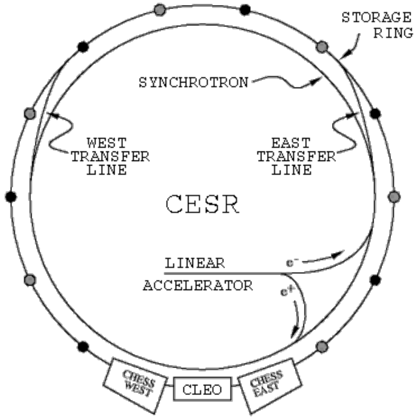
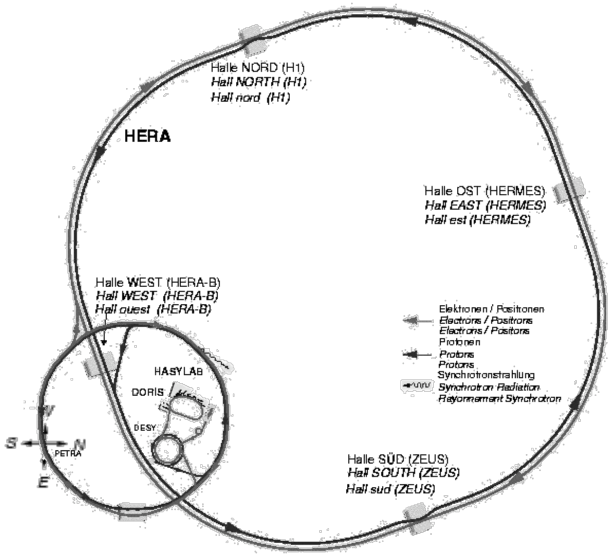
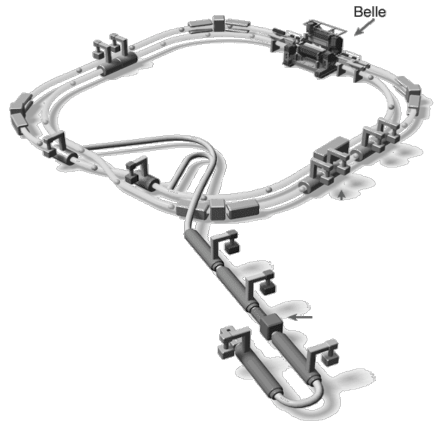
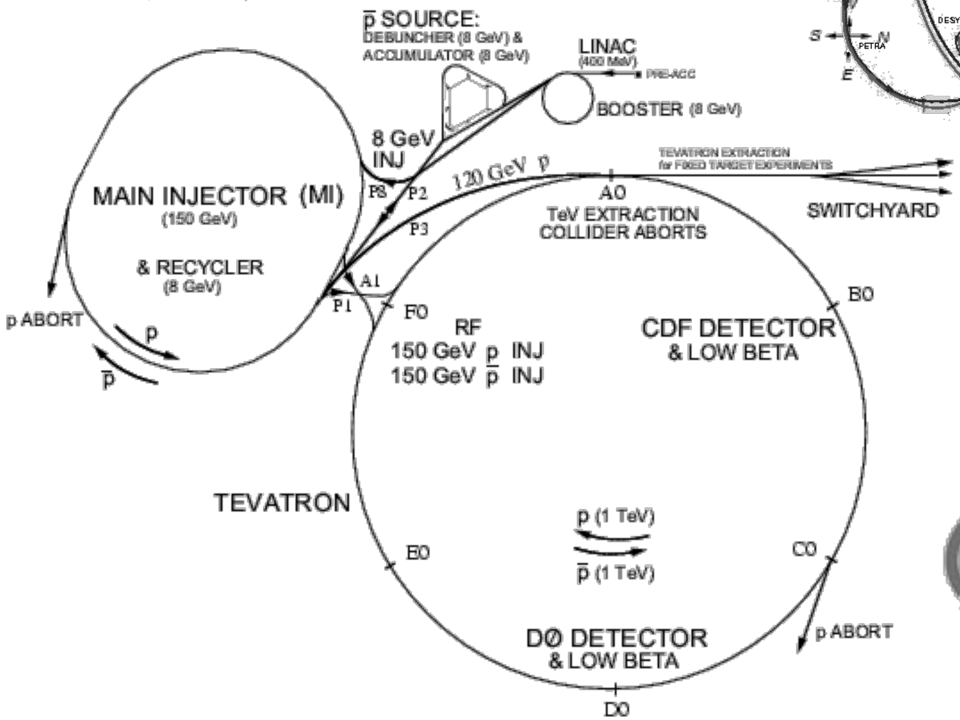
Latest Collider Results

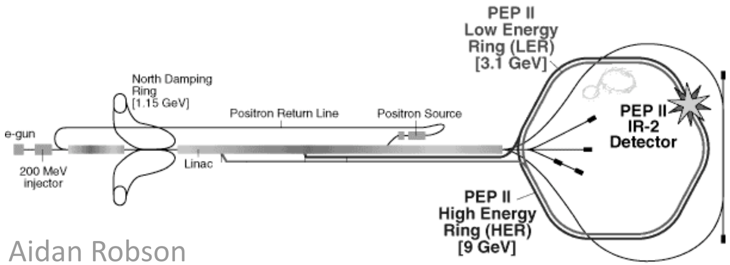
Aidan Robson
University of Glasgow
IOP HEPP/APP, 30 March 2010

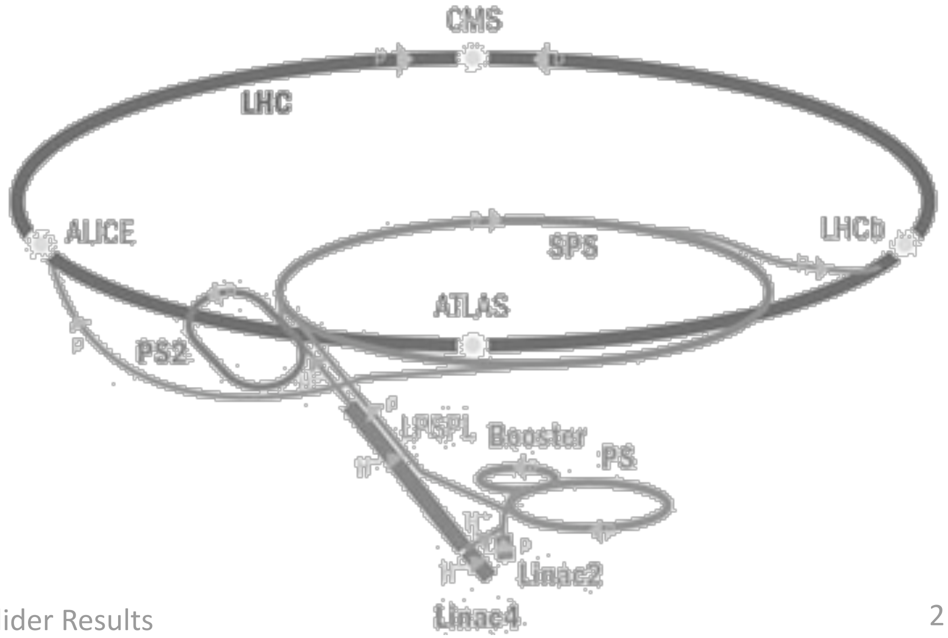

STORAGE RING
SYNCHROTRON
WEST TRANSFER LINE
EAST TRANSFER LINE
CESR
LINEAR ACCELERATOR
CHESS WEST
CLEO
CHESS EAST

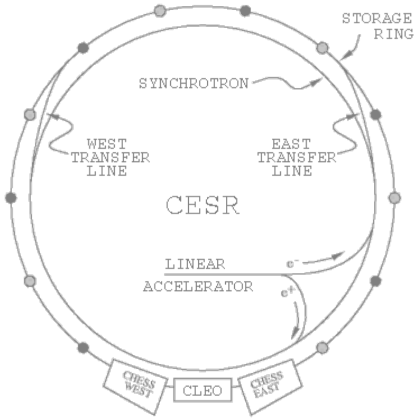

Halle NORD (H1)
Hall NORTH (H1)
Hall nord (H1)
HERA
Halle OST (HERMES)
Hall EAST (HERMES)
Hall est (HERMES)
Halle WEST (HERA-B)
Hall WEST (HERA-B)
Hall ouest (HERA-B)
HASYLAB
DORIS
DESY
PETRA
Halle SÜD (ZEUS)
Hall SOUTH (ZEUS)
Hall sud (ZEUS)


Belle


p̄ SOURCE:
DEBUNCHER (8 GeV) &
ACCUMULATOR (8 GeV)
LINAC
(400 MeV)
PRE-ACC
BOOSTER (8 GeV)
8 GeV
INJ
120 GeV p
TEVATRON EXTRACTION
for FIXED TARGET EXPERIMENTS
MAIN INJECTOR (MI)
(150 GeV)
& RECYCLER
(8 GeV)
P8
P2
P3
A1
P1
A0
TeV EXTRACTION
COLLIDER ABORTS
SWITCHYARD
p ABORT
p
p̄
F0
RF
150 GeV p INJ
150 GeV p̄ INJ
B0
CDF DETECTOR
& LOW BETA
TEVATRON
p (1 TeV)
p̄ (1 TeV)
E0
C0
p ABORT
DØ DETECTOR
& LOW BETA
D0


PEP II
Low Energy
Ring (LER)
[3.1 GeV]
North Damping
Ring
[1.15 GeV]
Positron Return Line
Positron Source
e-gun
200 MeV
injector
Linac
PEP II
IR-2
Detector
PEP II
High Energy
Ring (HER)
[9 GeV]


CMS
LHC
ALICE
LHCb
SPS
ATLAS
PS2
Booster
PS
Linac2
Linac4



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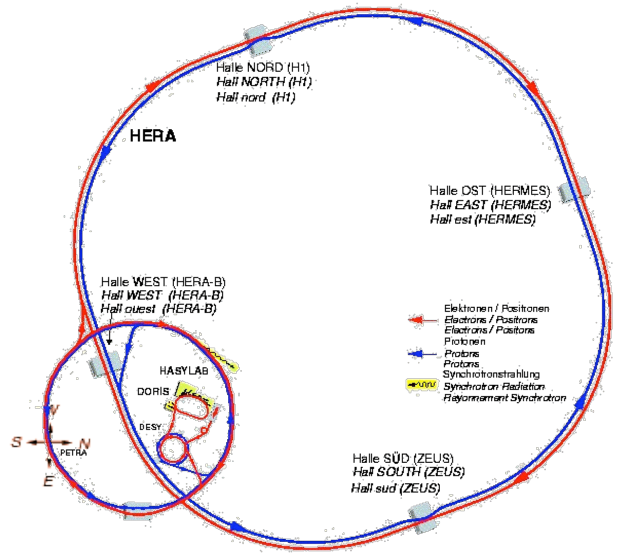

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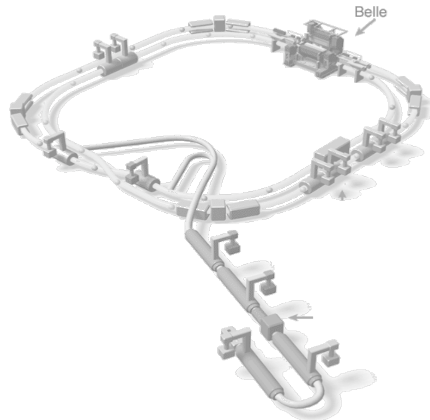
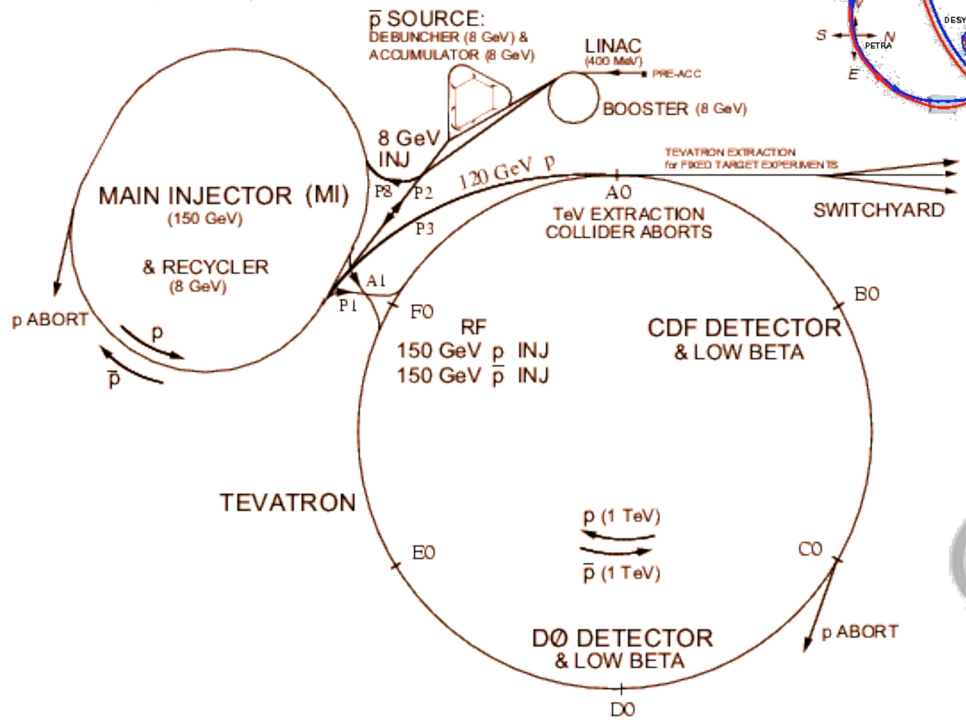


Belle



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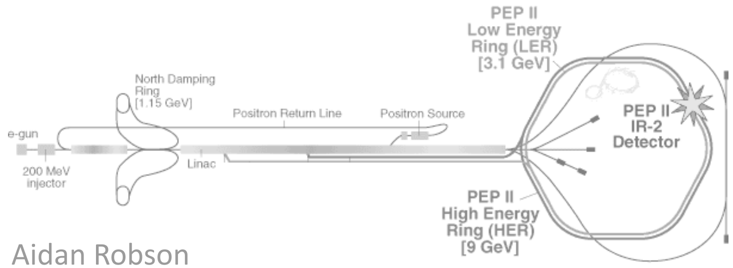
D0



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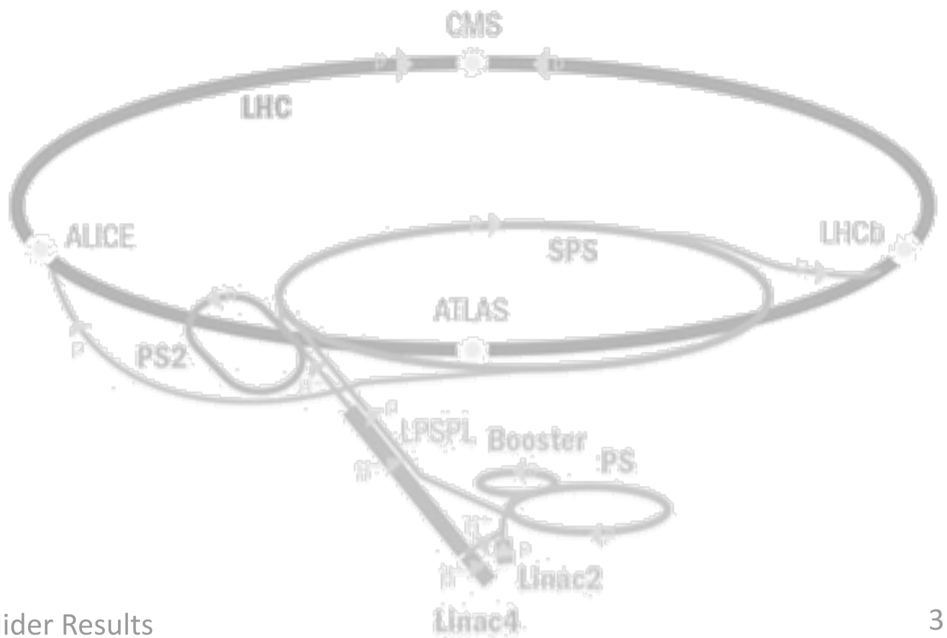

CMS
LHC
ALICE
LHCb
SPS
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PS2
Booster
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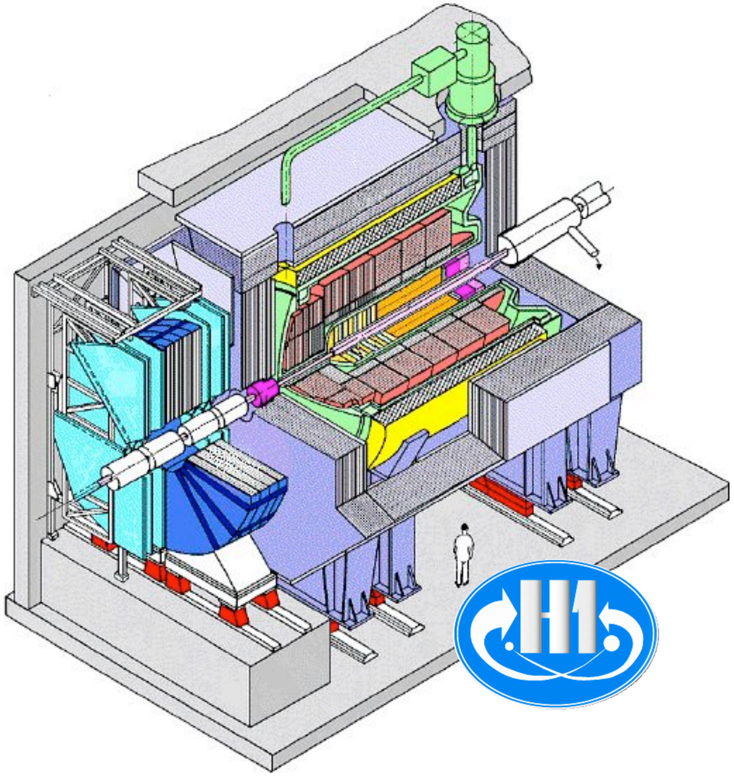
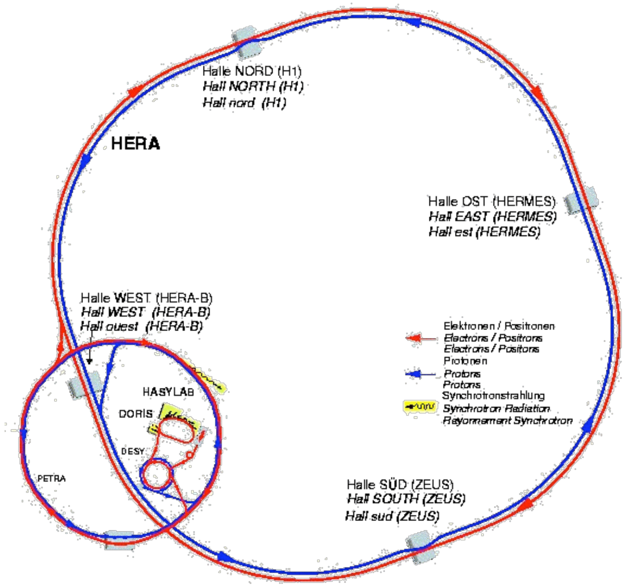
Linac2
Linac4

HERA

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Hall ouest (HERA-B)
Elektronen / Positronen
Electrons / Positrons
Electrons / Positons
Protonen
Protons
Protons
Synchrotronstrahlung
Synchrotron Radiation
Rayonnement Synchrotron
HASYLAB
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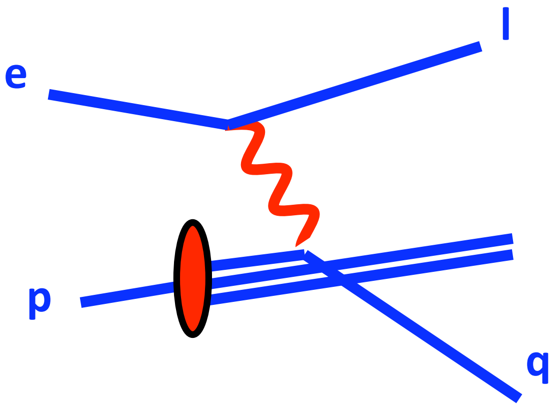
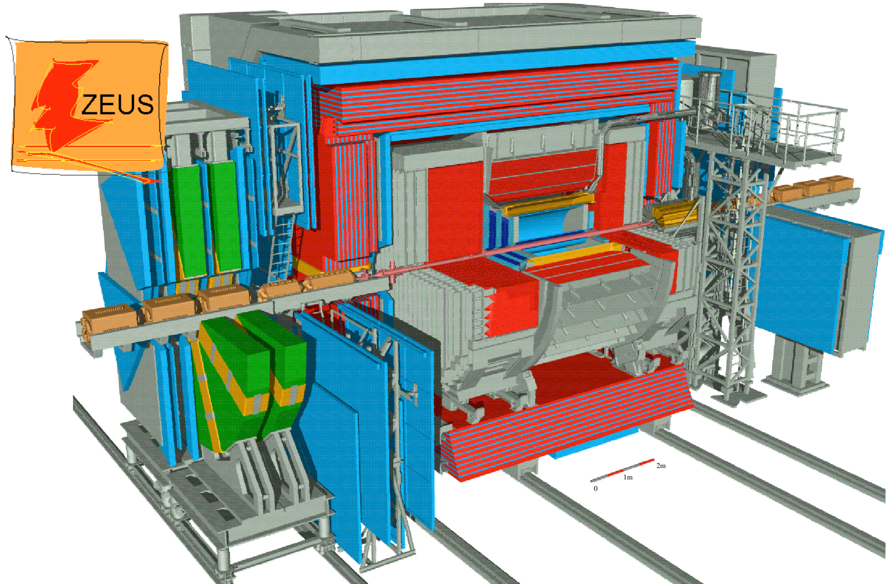
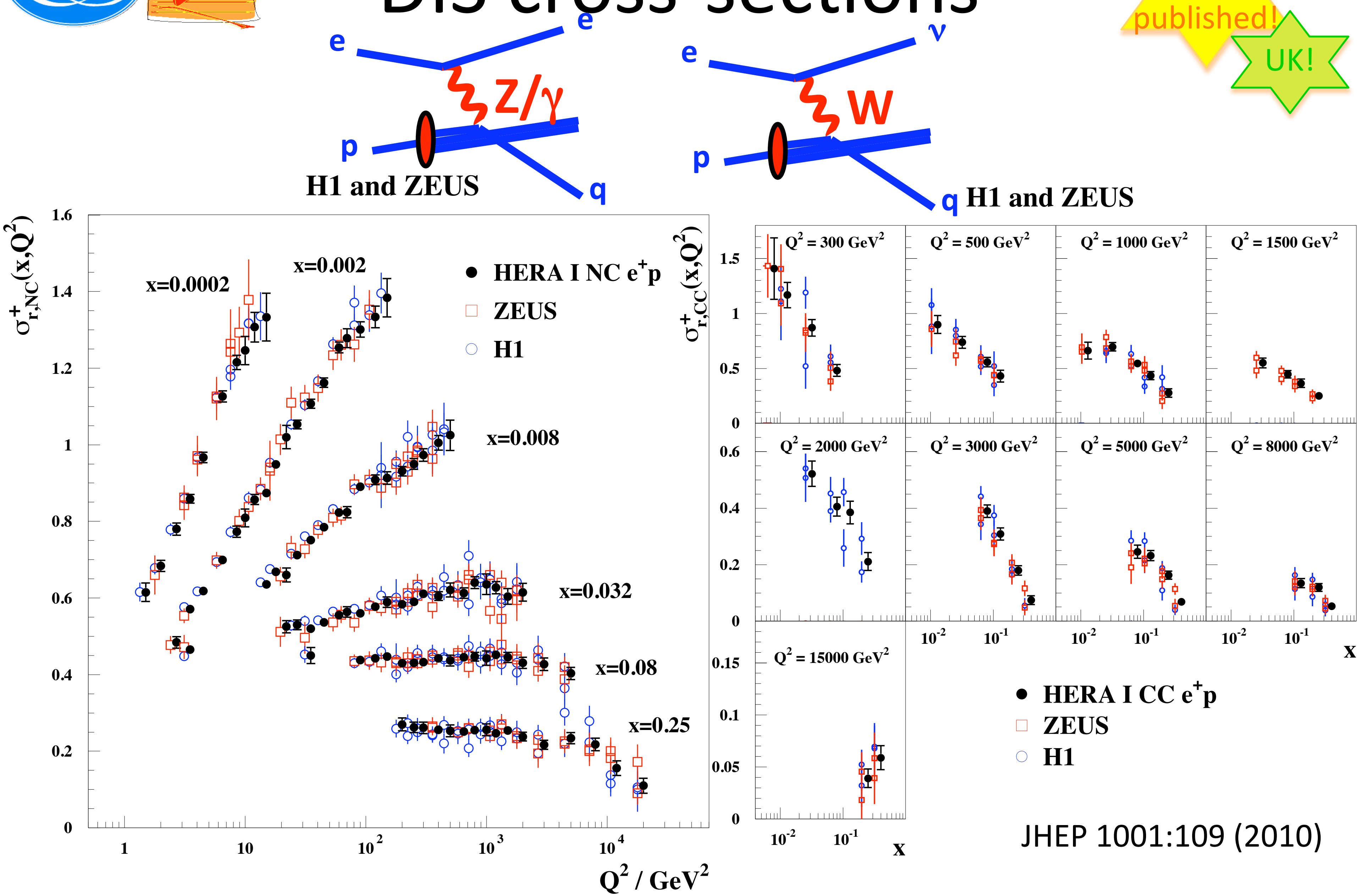

e
l
p
q


ZEUS

DIS cross-sections

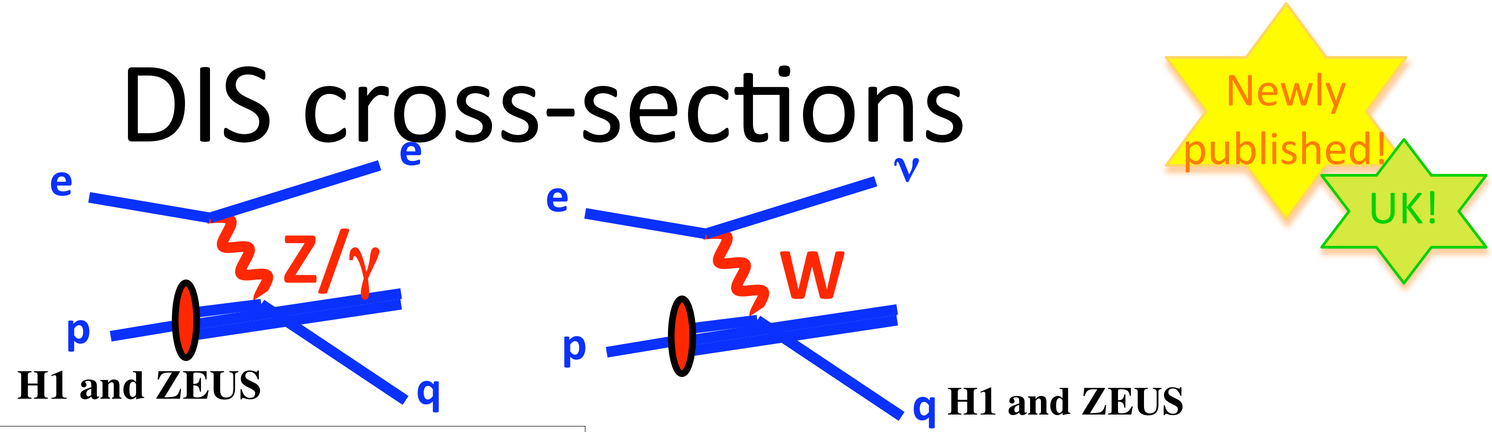
Newly published!

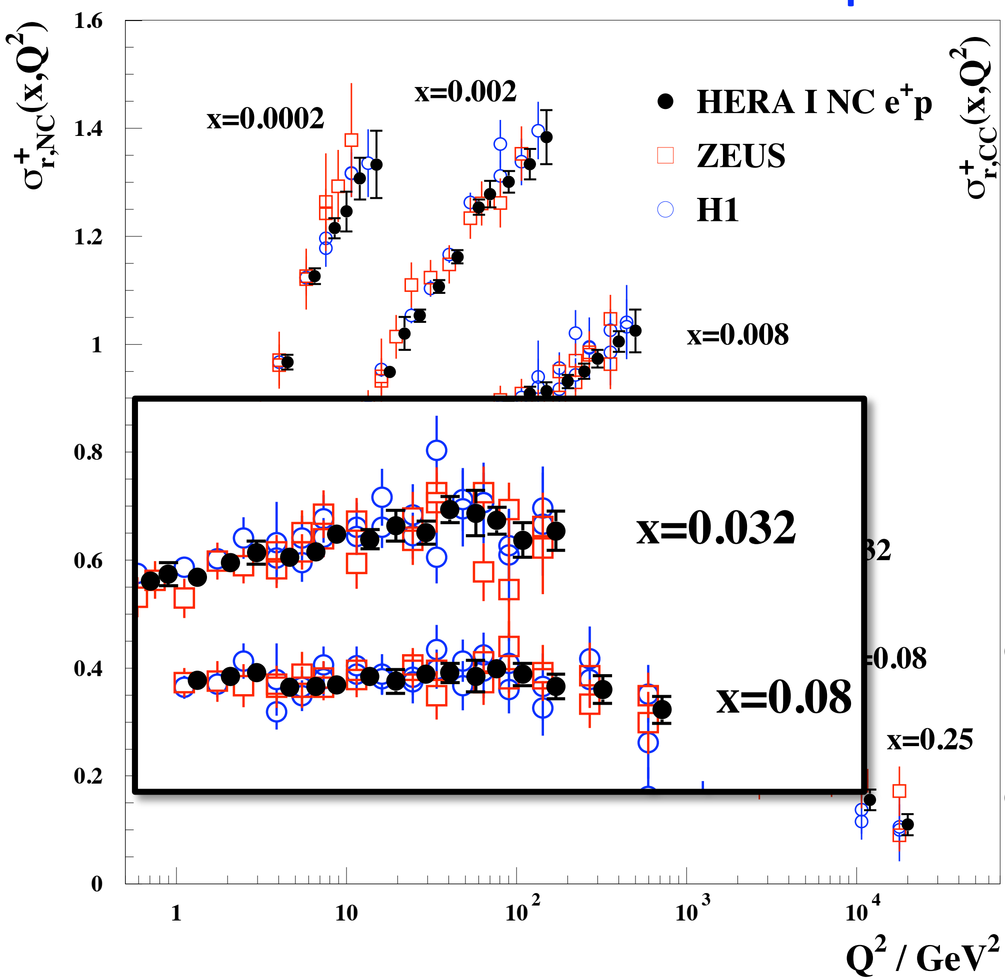
UK!

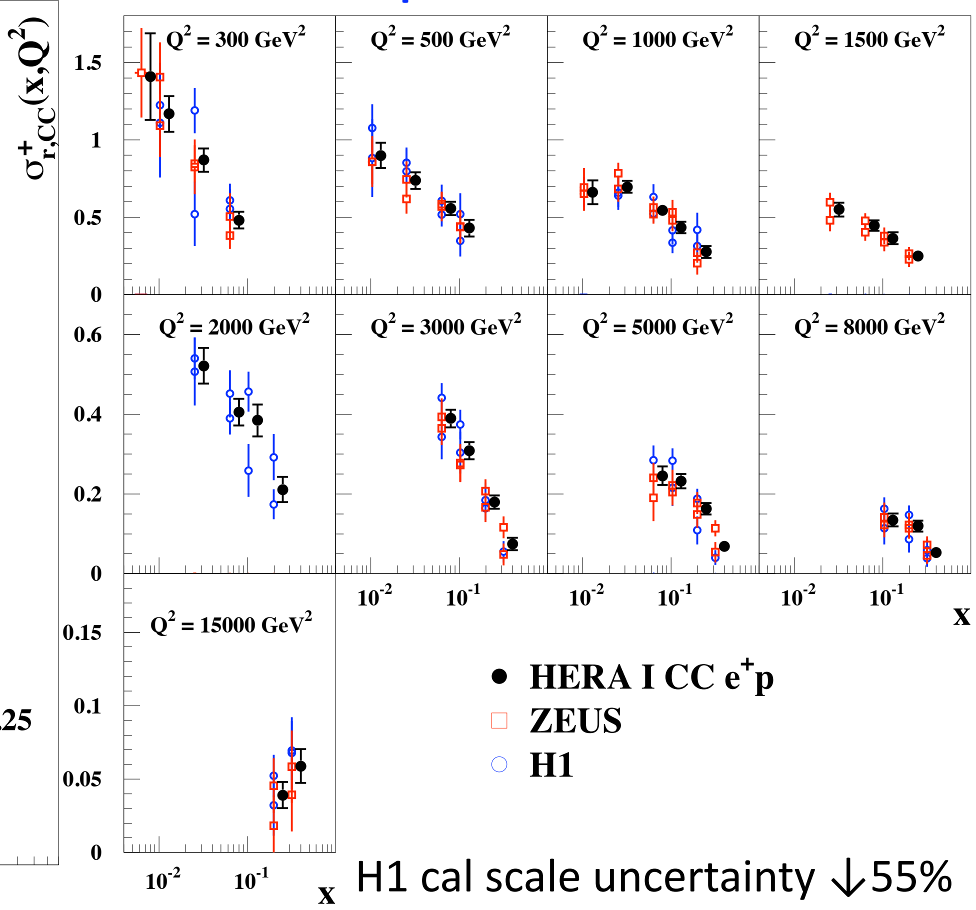


JHEP 1001:109 (2010)

DIS cross-sections



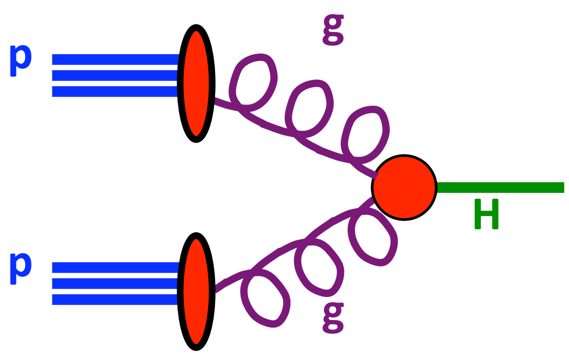




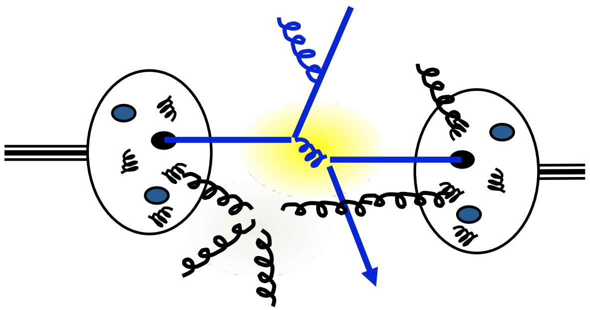
H1 cal scale uncertainty ↓55%

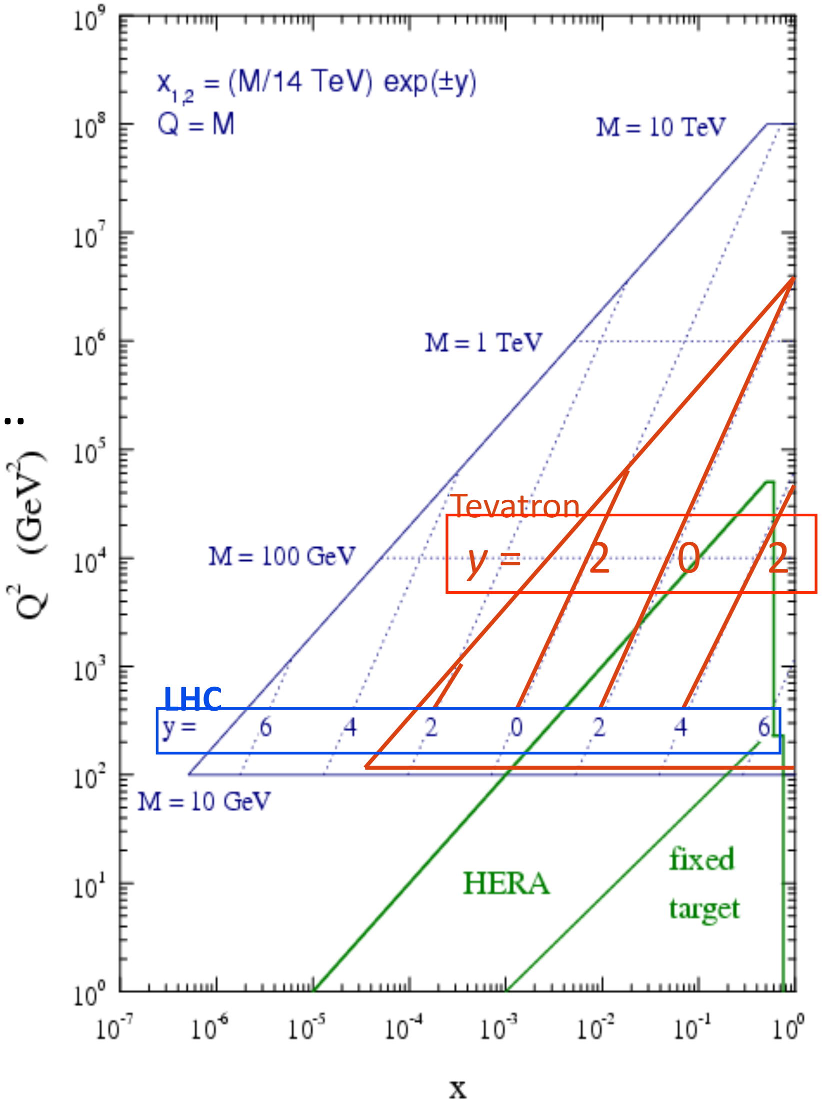
Zeus photoprod bck unc ↓65%

PDFs



$$\sigma_{pp\to H} = \hat{\sigma}_{gg\to H} f_{g/p}(x_1, Q{=}M_H)\, f_{g/p}(x_2, Q{=}M_H) + \ldots$$





HERAPDF

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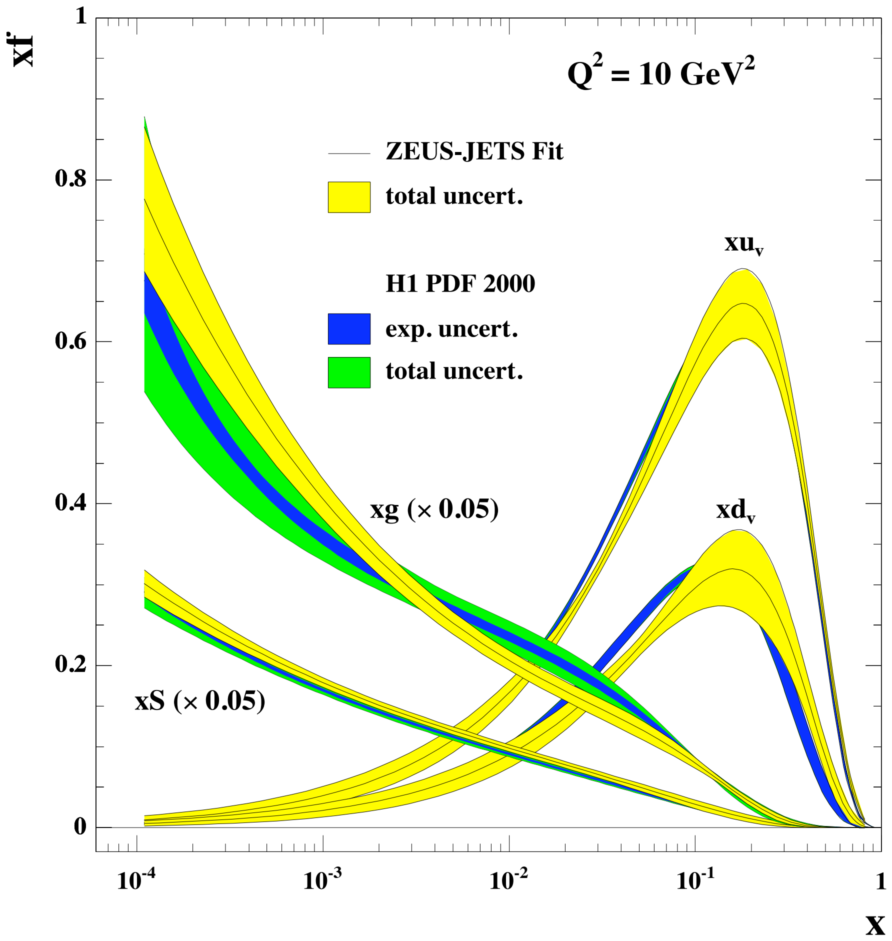
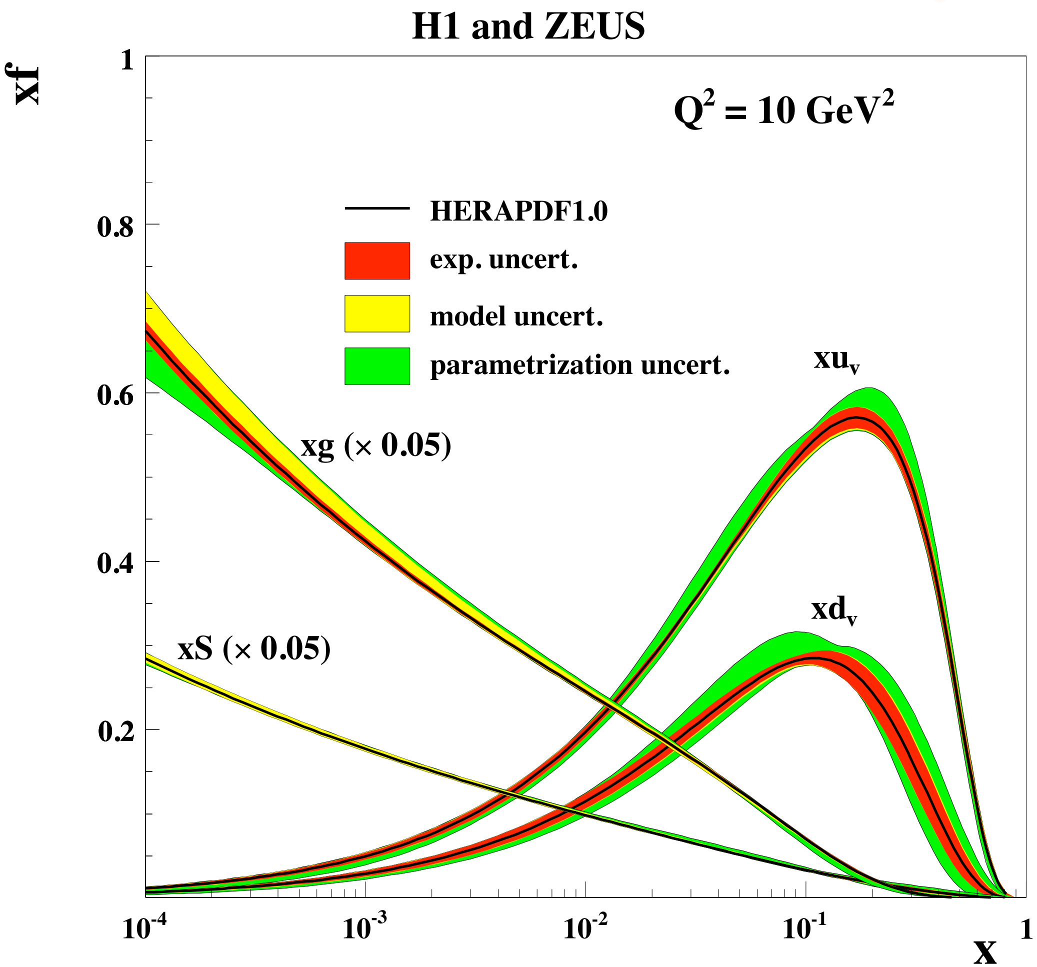
UK!



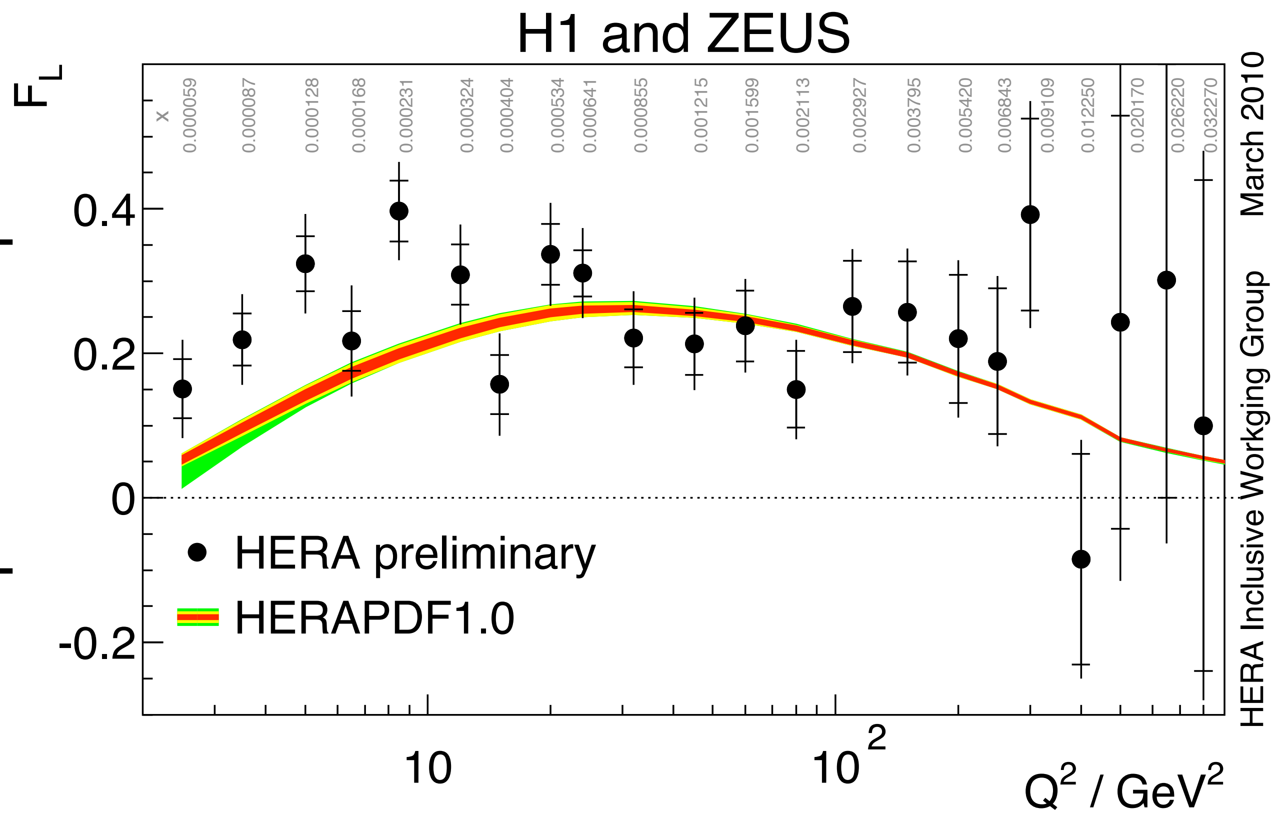


JHEP 1001:109 (2010)

F_L

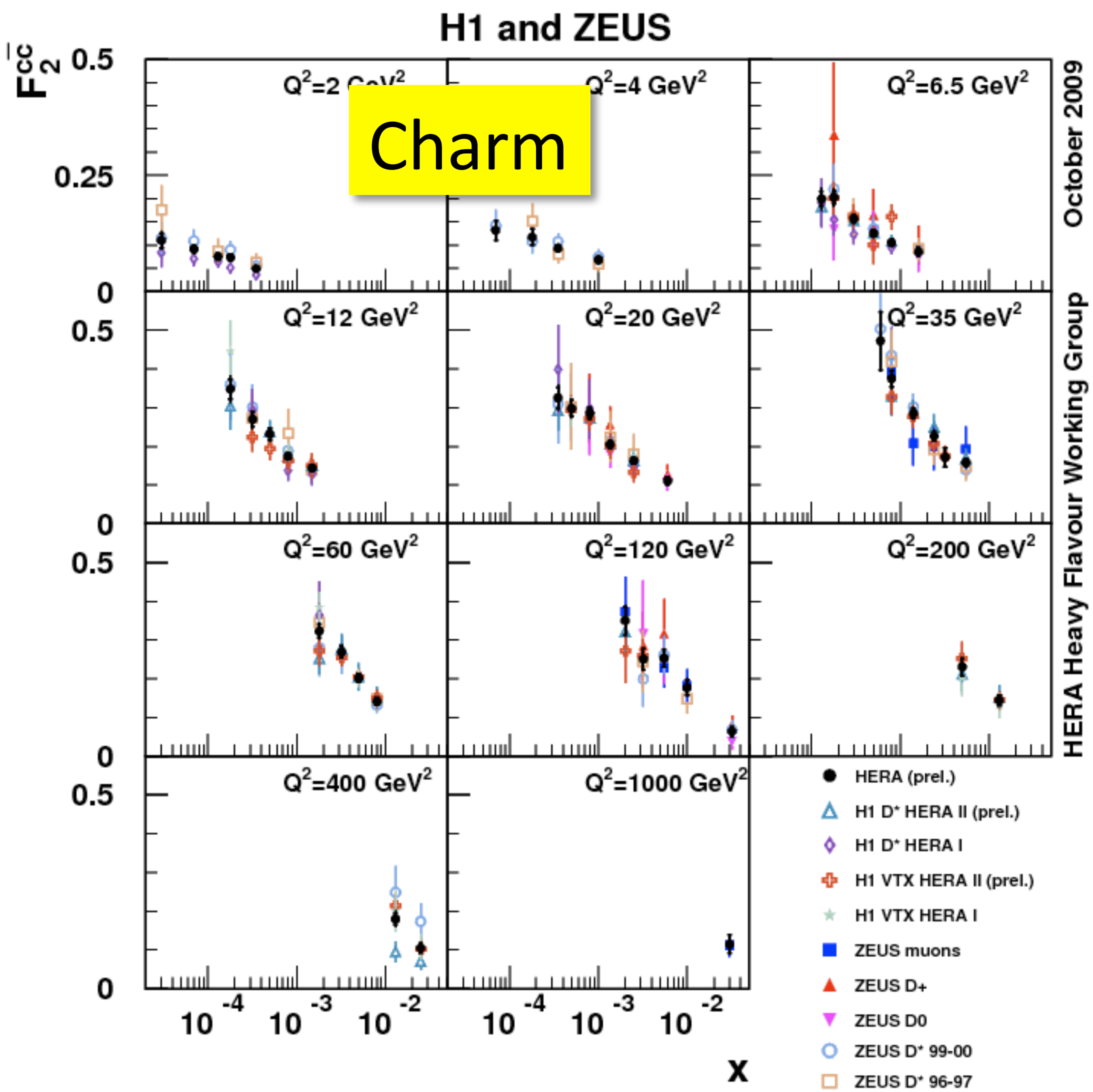
New!

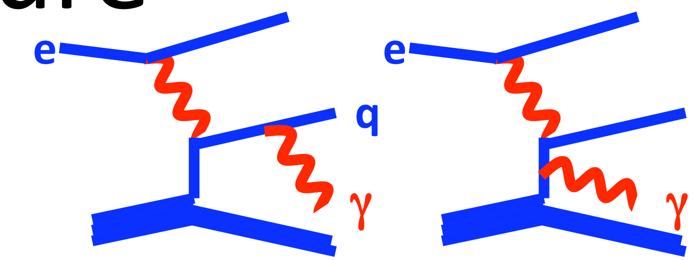
E_p(GeV)	√*s* (GeV)	*L* (pb^{-1})
920	318	21.6
575	251	6.2
460	225	12.4

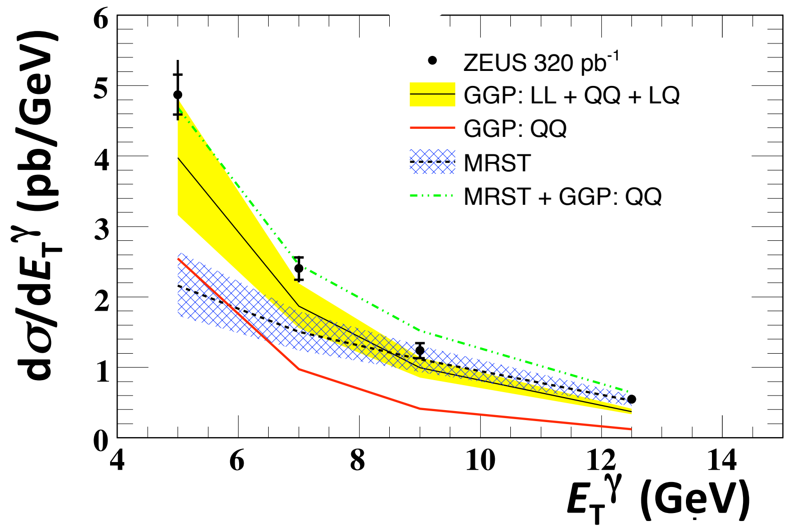


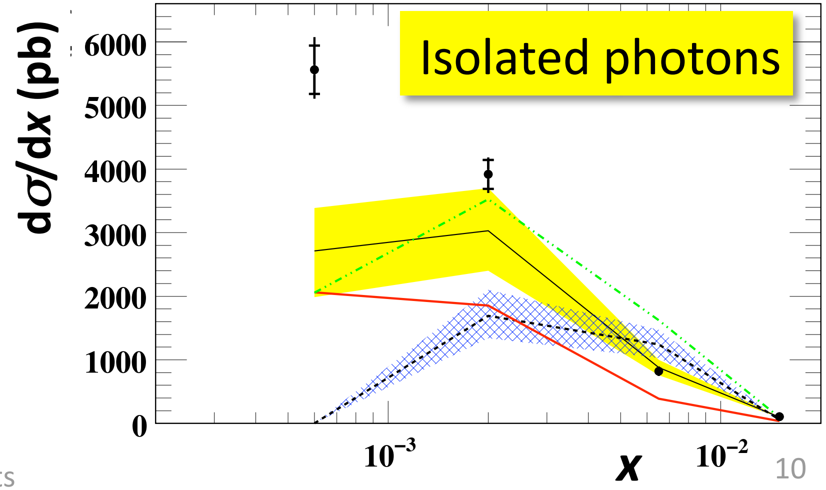
Not previously measured directly

More structure





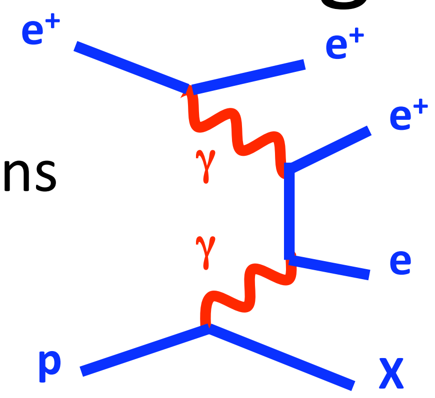


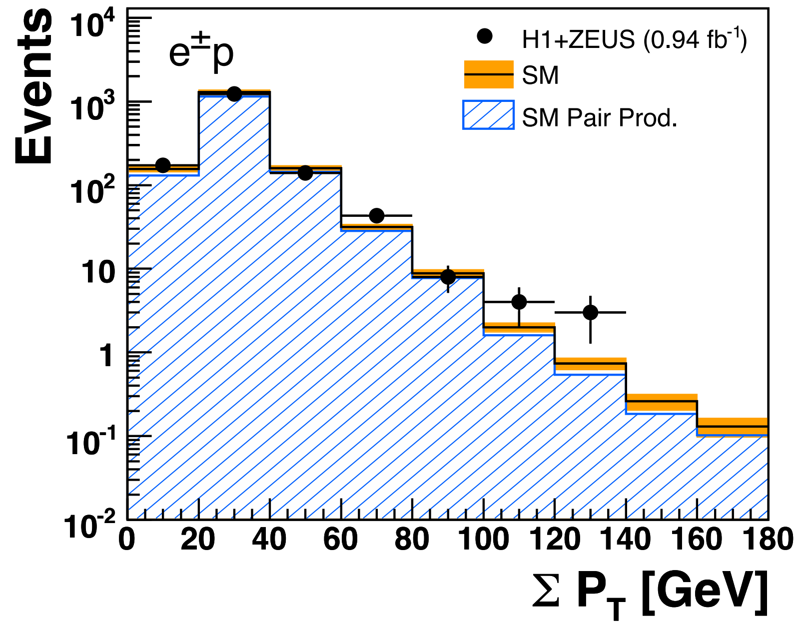


Striking signatures

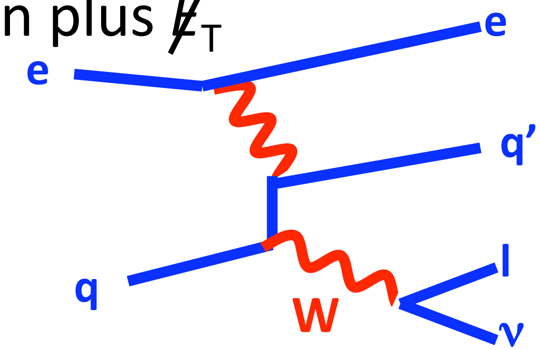
New!

Multileptons





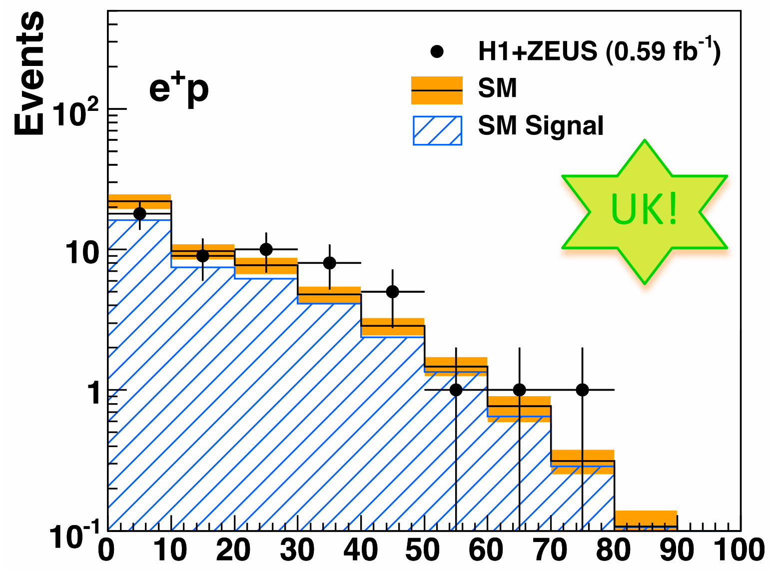
Lepton plus $\not{E}_T$



	SM signal	SM bck	Total predicted	Data
All	65±10	23±3	88±11	81
P_T^X>25GeV	20±3	4±1	24±3	29

$\sigma_{ep\to W}$ = 1.06±0.16(stat)±0.07(sys) pb

(SM: 1.26±0.19 pb)



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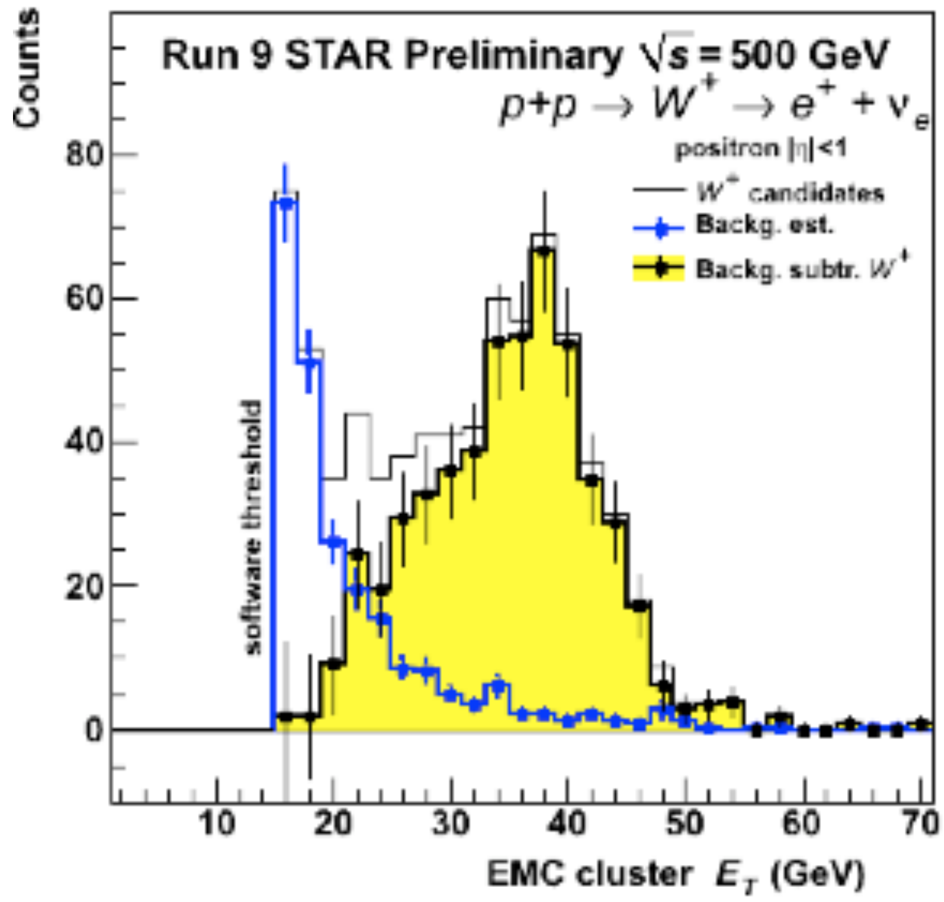
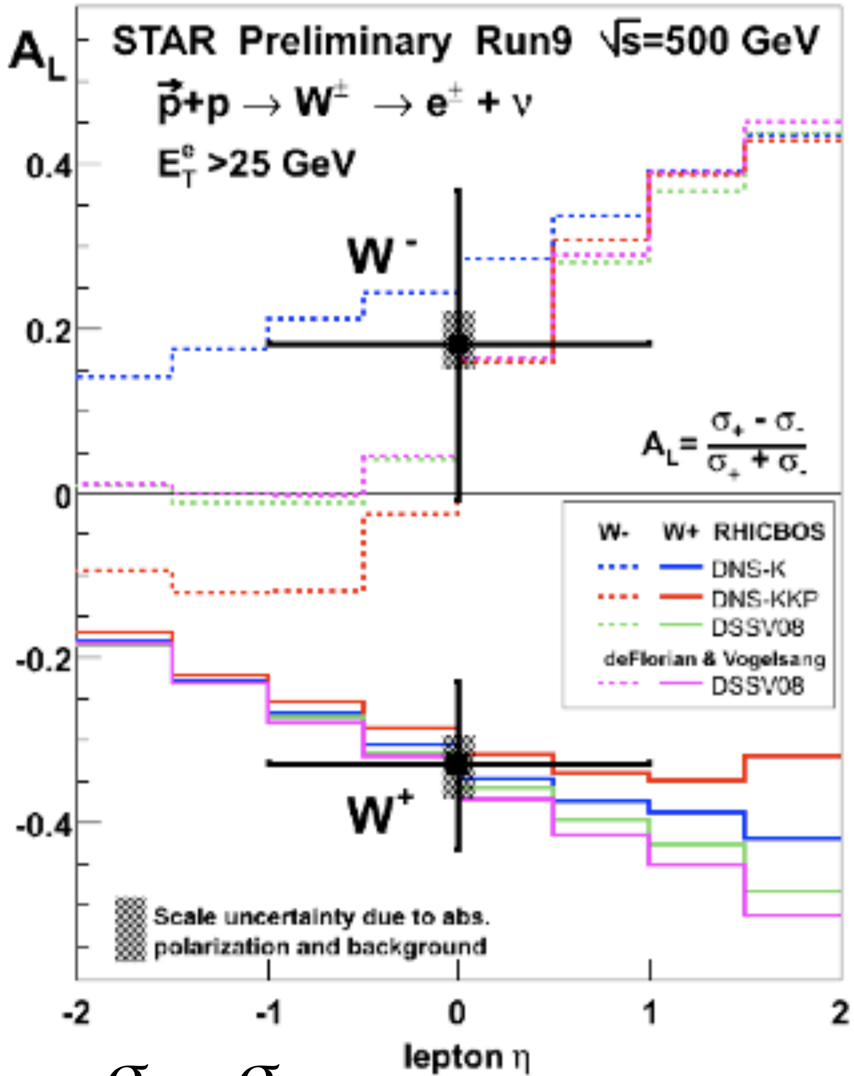
W production in pp!

RHIC: Relativistic Heavy Ion Collider





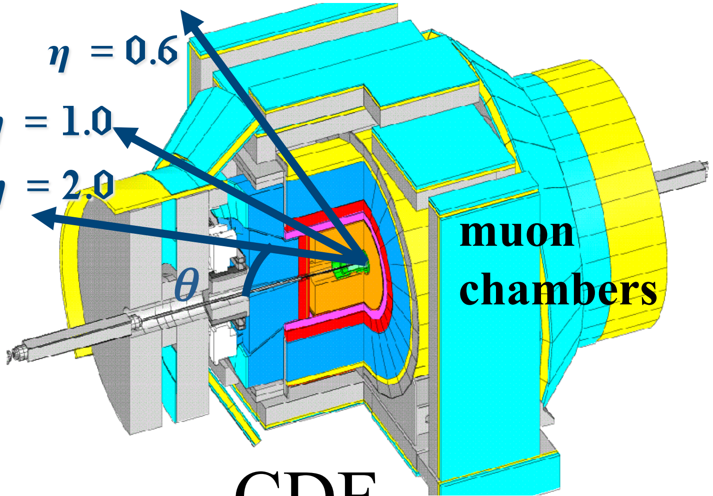
sea:
$\bar{u}$, $\bar{d}$

longitudinal parity-violating spin asymmetry

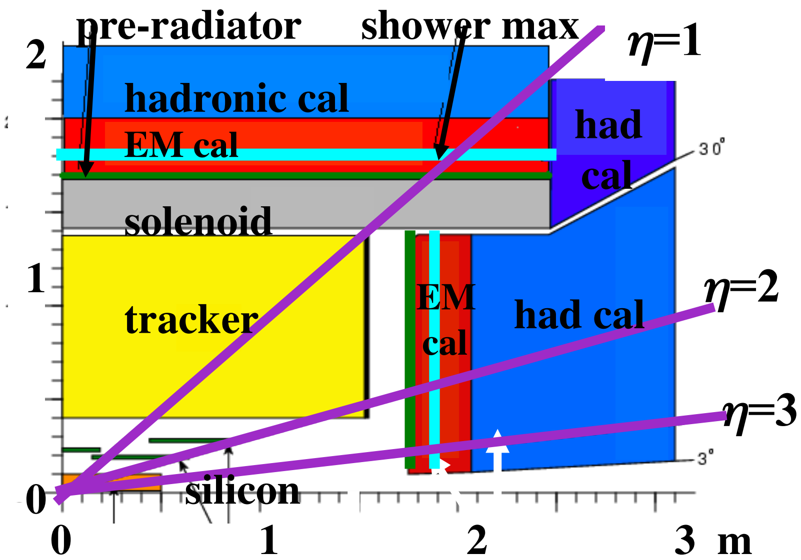
$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

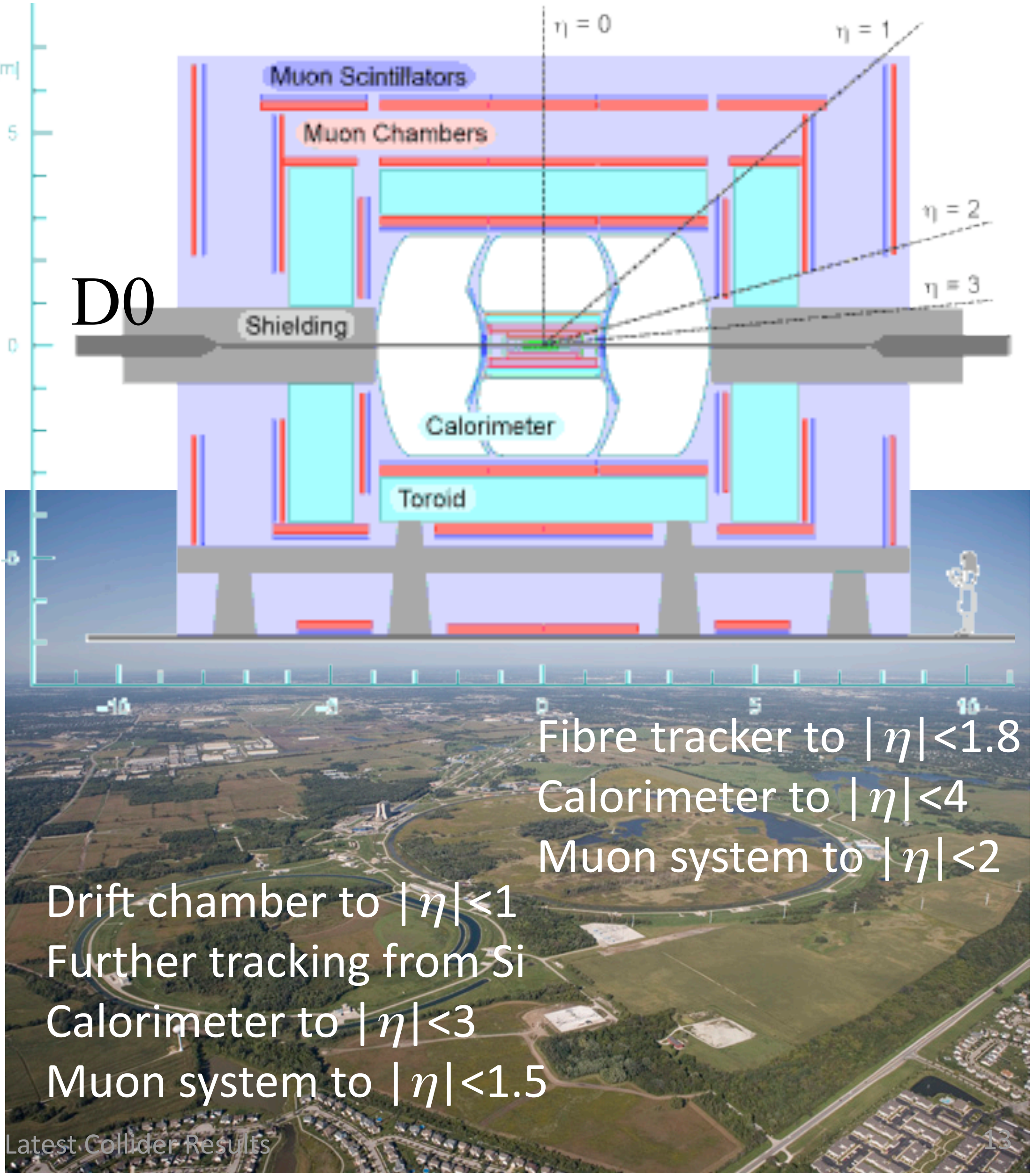
Next: more bins of η

Tevatron



CDF



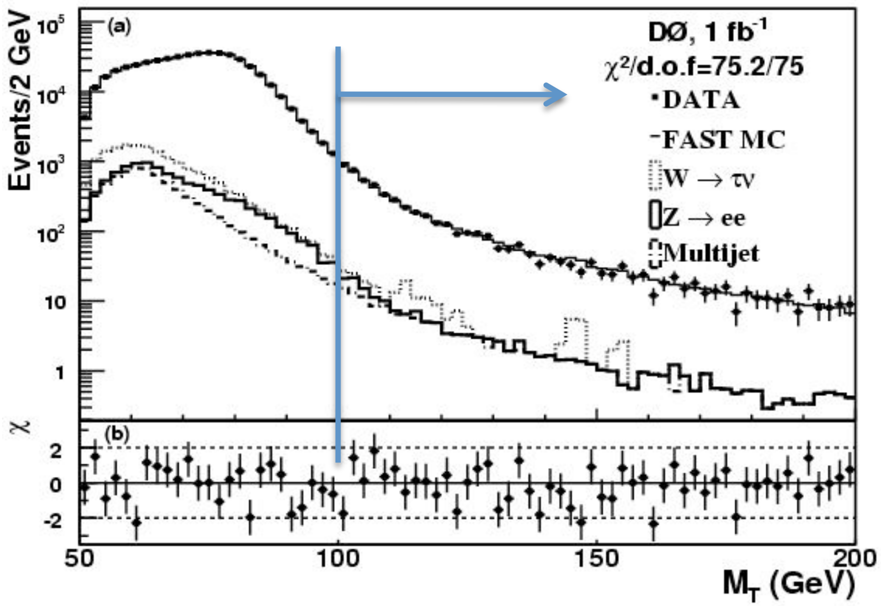


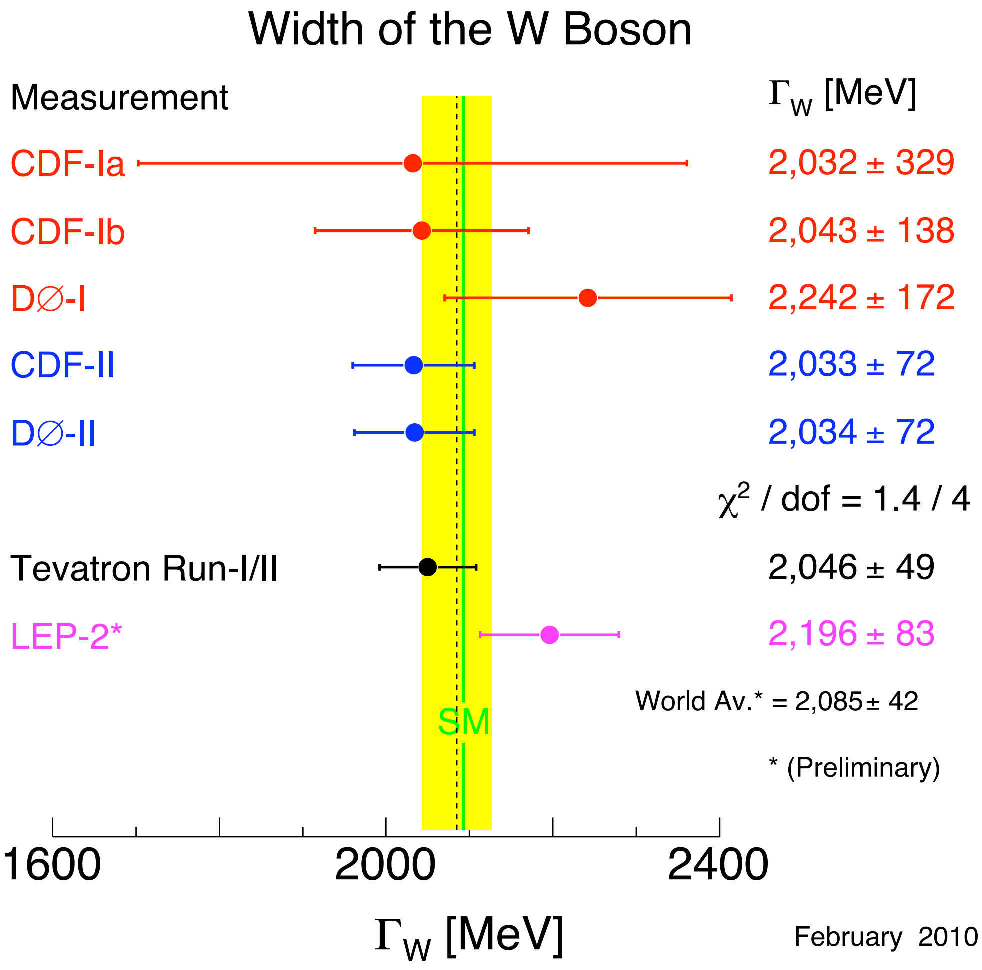
Fibre tracker to $|\eta|<1.8$
Calorimeter to $|\eta|<4$
Muon system to $|\eta|<2$

Drift chamber to $|\eta|<1$
Further tracking from Si
Calorimeter to $|\eta|<3$
Muon system to $|\eta|<1.5$

Γ_W

New! UK!





m_W:

CDF: $m_W = 80413 \pm 48$ MeV/c^2

D0: $m_W = 80402 \pm 43$ MeV/c^2

Tev: $m_W = 80420 \pm 31$ MeV/c^2 (includes Run 1)

LEP: $m_W = 80376 \pm 33$ MeV/c^2

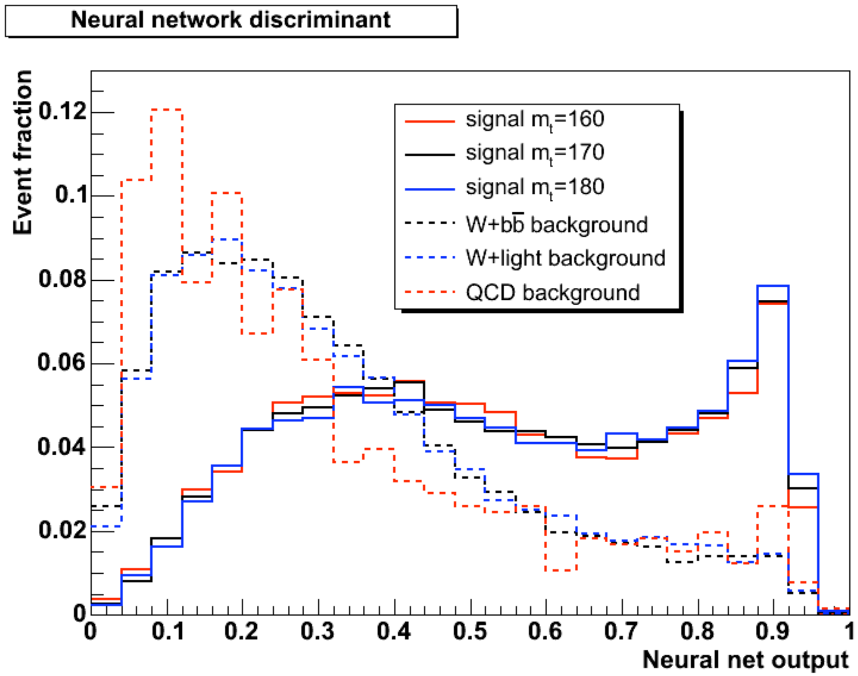
Heading to CDF 25MeV/c^2 measurement

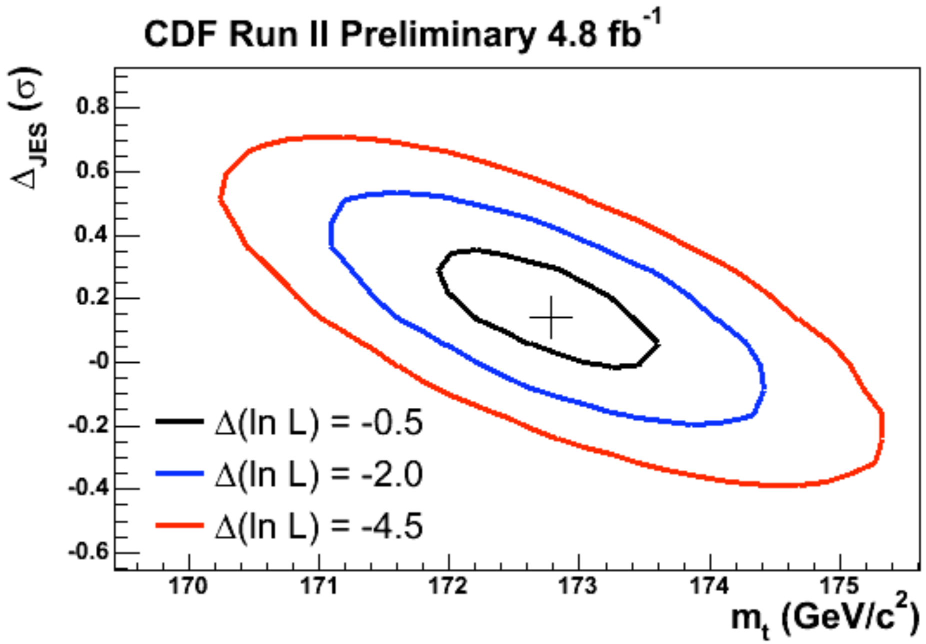
Tev error improves from 62 to 49 MeV

m_t

New!

Matrix element-based top mass measurement
Lepton+jets with 4.8fb^{-1}
NN for background discrimination
Likelihood fit over variables sensitive to top mass
Simultaneous constraint of jet energy scale using W in lepton+jets

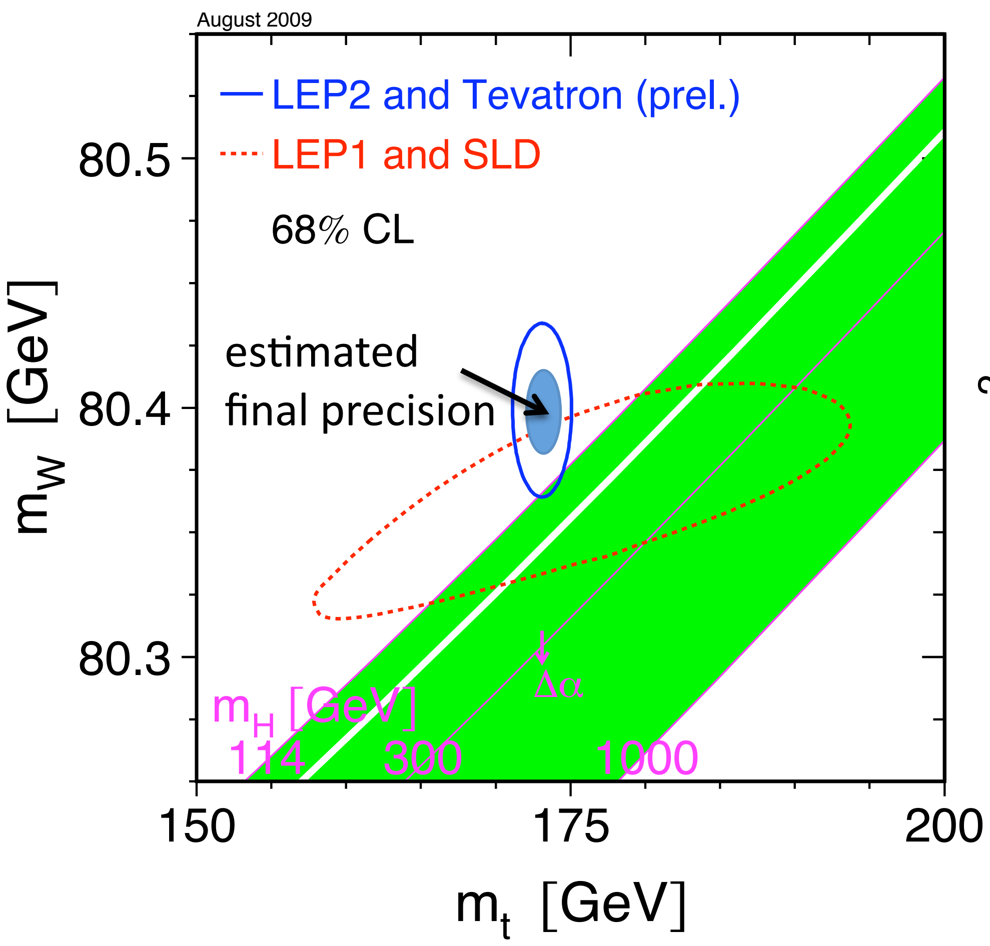


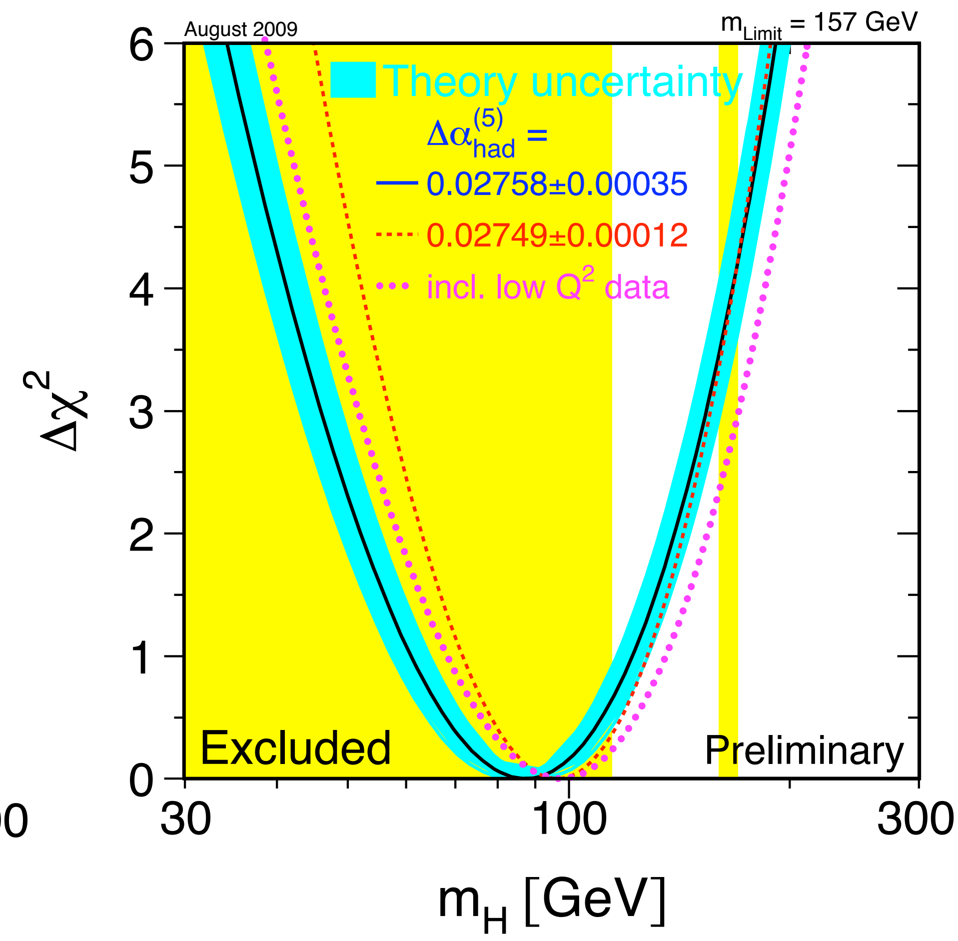


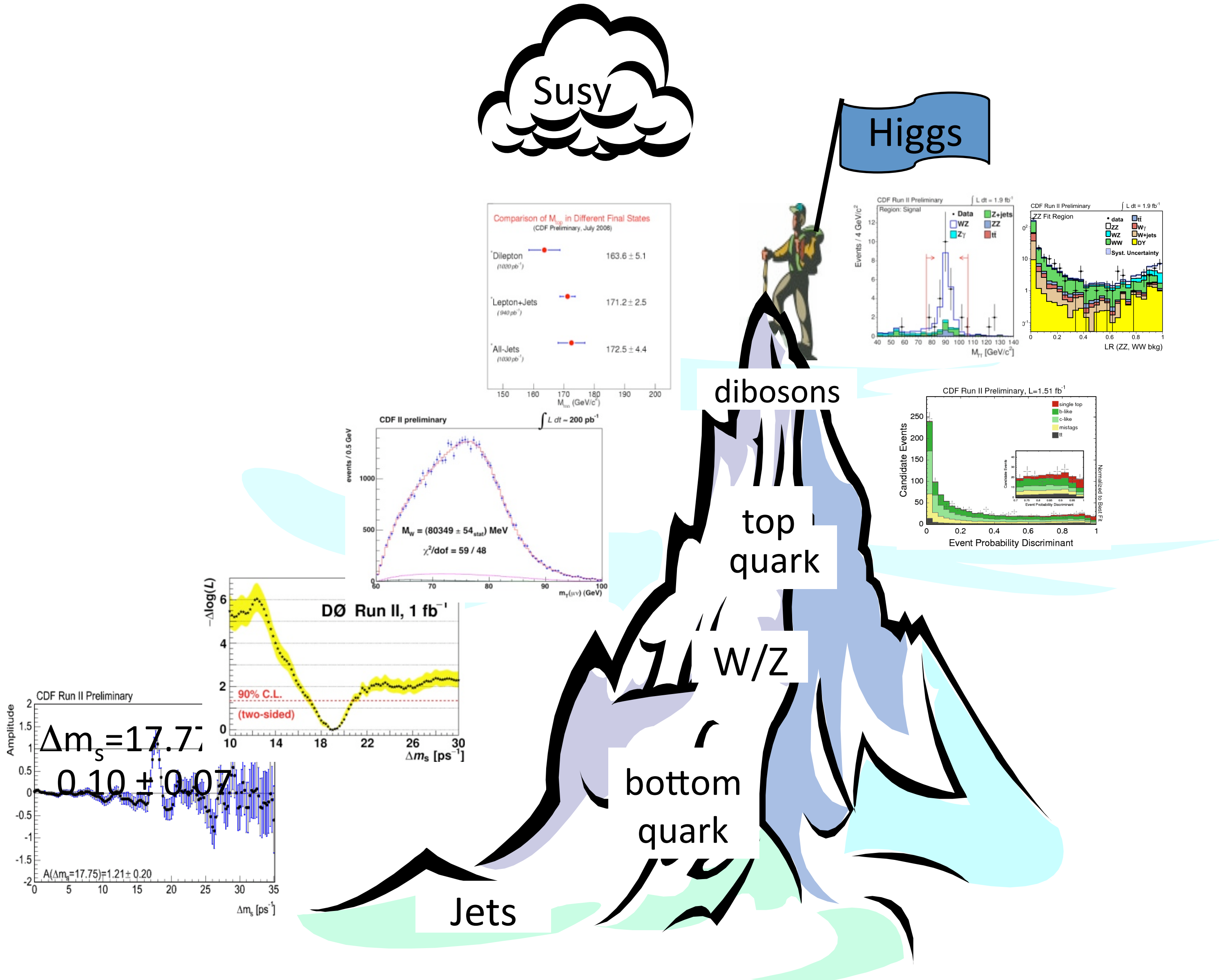
More precise than CDF 2009!
Expect 1GeV precision achievable

m_t =172.8 ± 1.3$_{total}$ GeV
(0.7$_{stat}$ 0.6$_{JES}$ 0.8$_{sys}$)

Indirect constraints



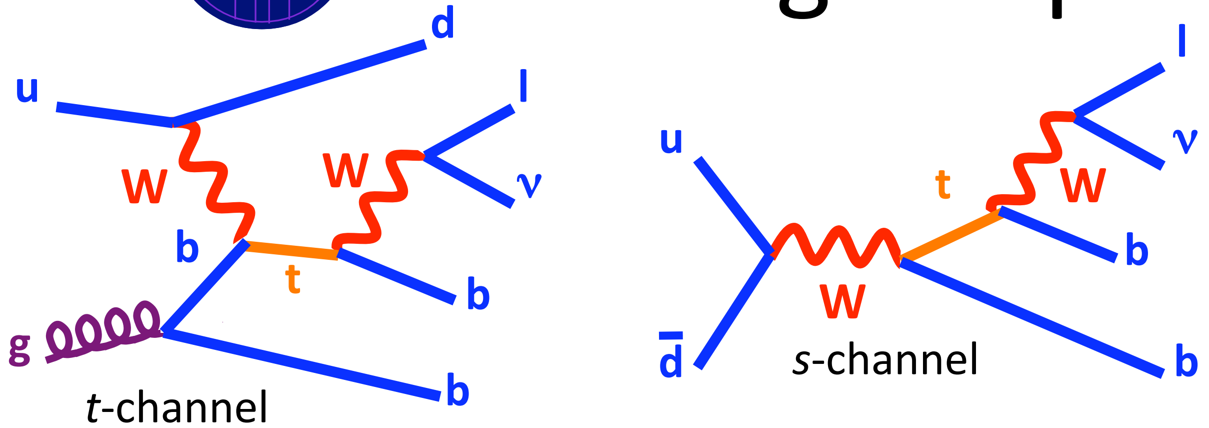




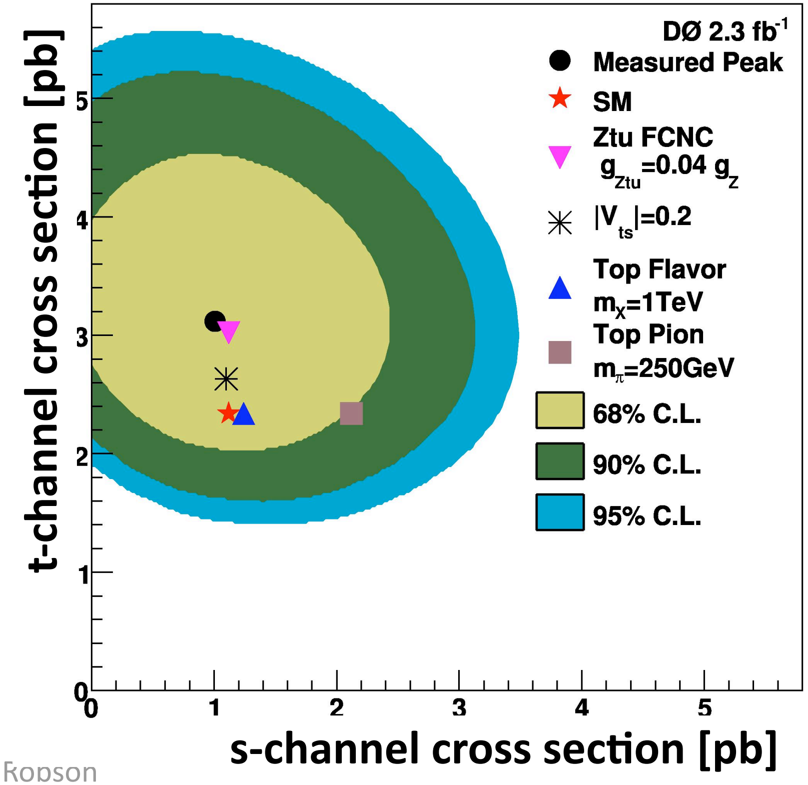
Susy
Higgs
dibosons
top quark
W/Z
bottom quark
Jets
Δm_s=17.77 ± 0.10 ± 0.07
DØ Run II, 1 fb^{-1}
90% C.L.
(two-sided)
CDF Run II Preliminary
CDF II preliminary
M_W = (80349 ± 54$_{stat}$) MeV
χ^2/dof = 59 / 48
Comparison of M_{top} in Different Final States
Dilepton 163.6 ± 5.1
Lepton+Jets 171.2 ± 2.5
All-Jets 172.5 ± 4.4
CDF Run II Preliminary, L=1.51 fb^{-1}
Event Probability Discriminant
Candidate Events
LR (ZZ, WW bkg)

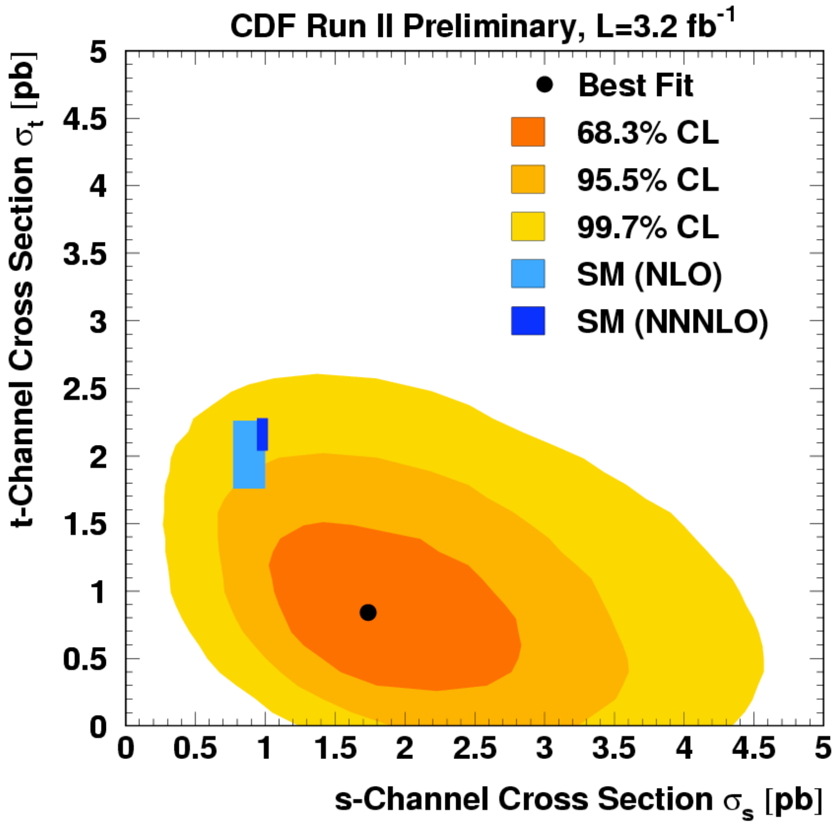
Single top

New!

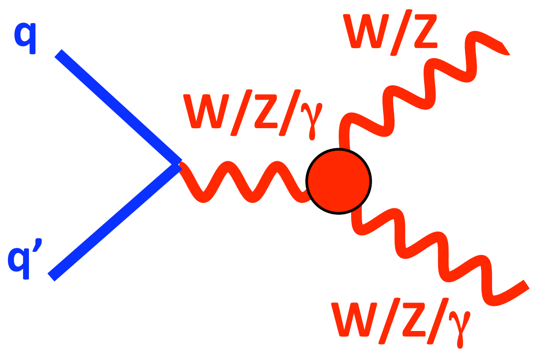


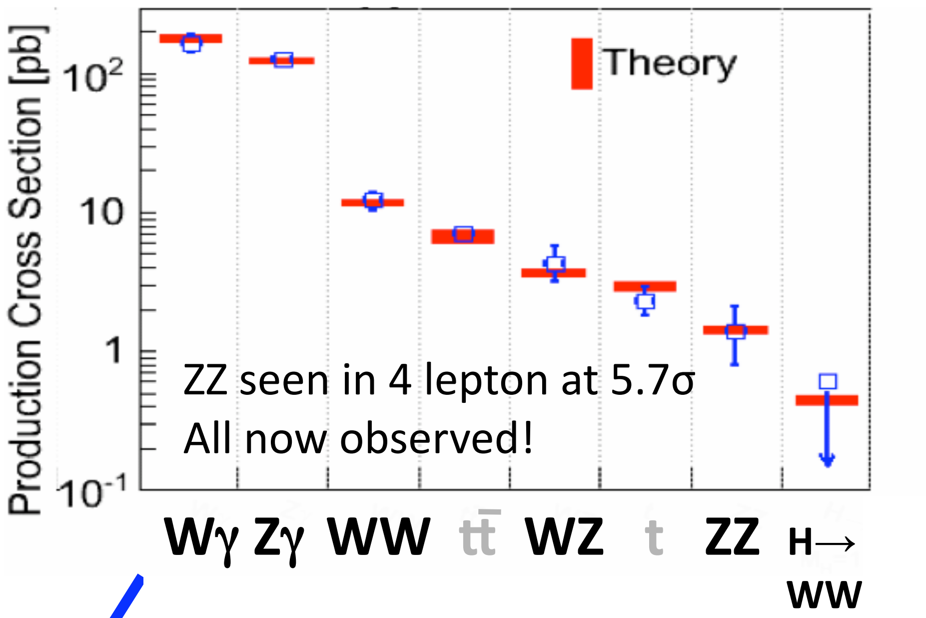
Single top observed 2009.

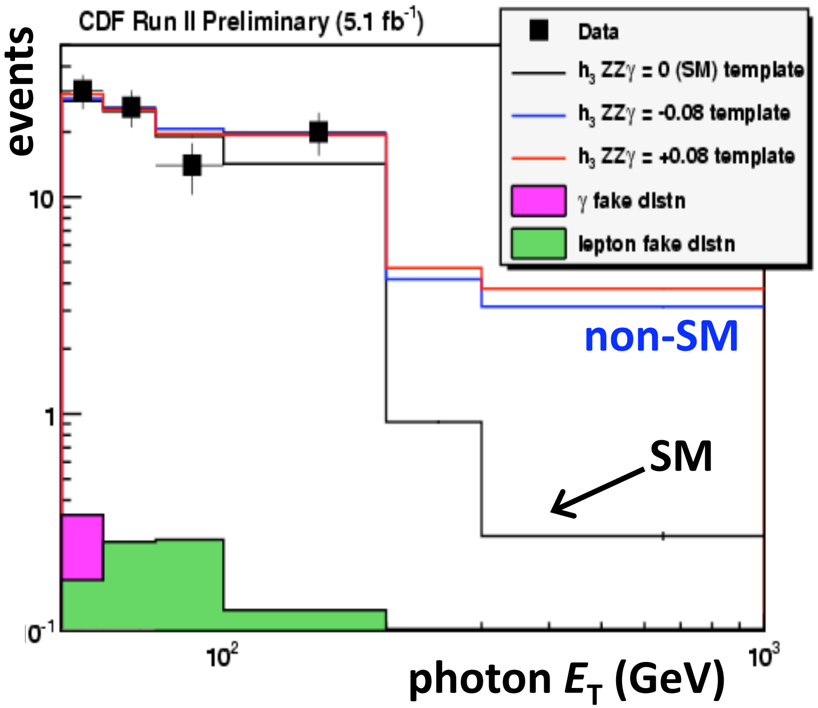


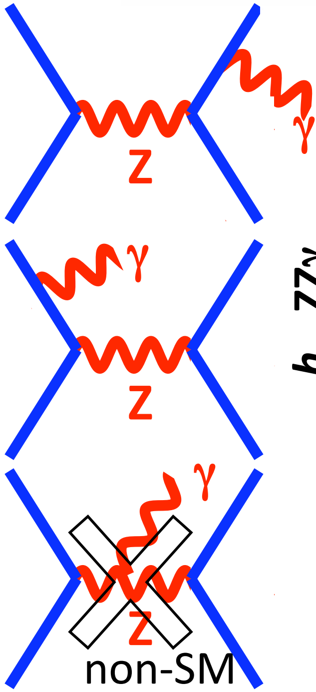


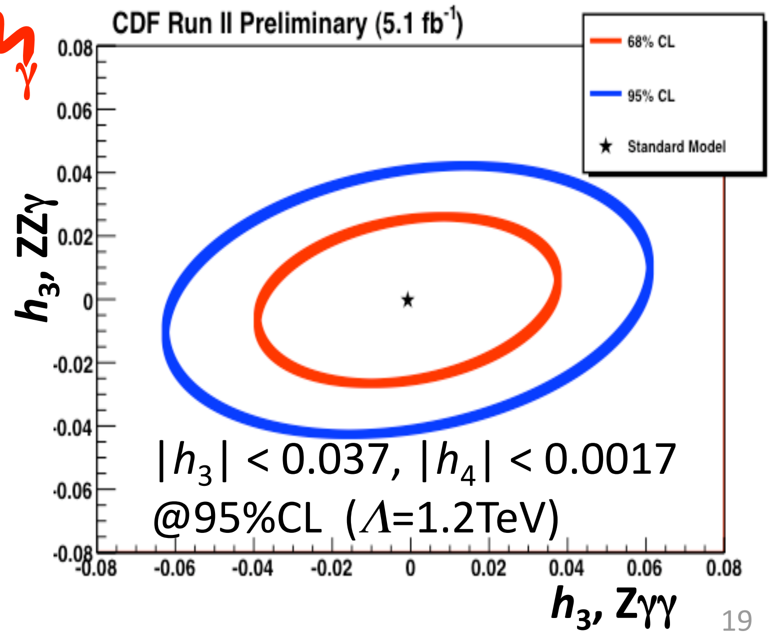
Dibosons





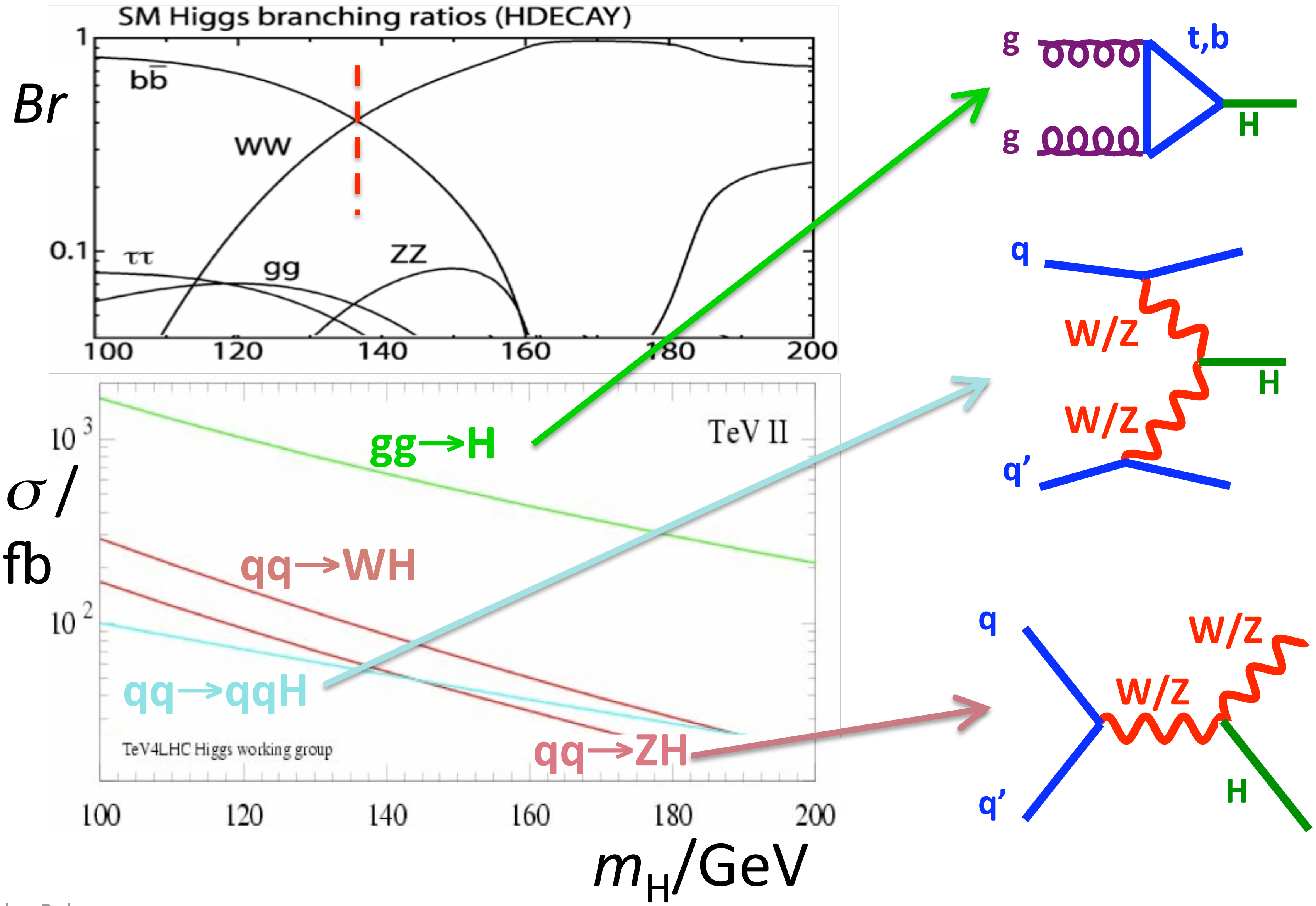




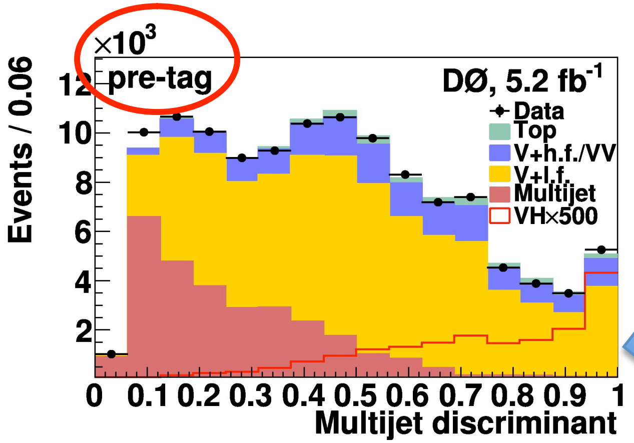


$|h_3| < 0.037$, $|h_4| < 0.0017$
@95%CL (Λ=1.2TeV)

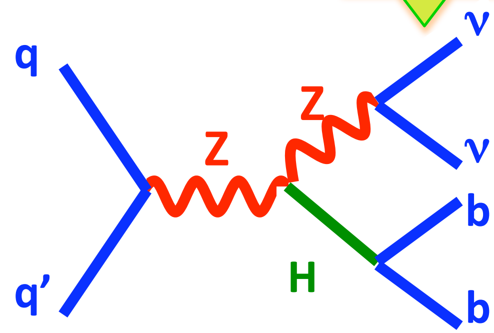
SM Higgs searches

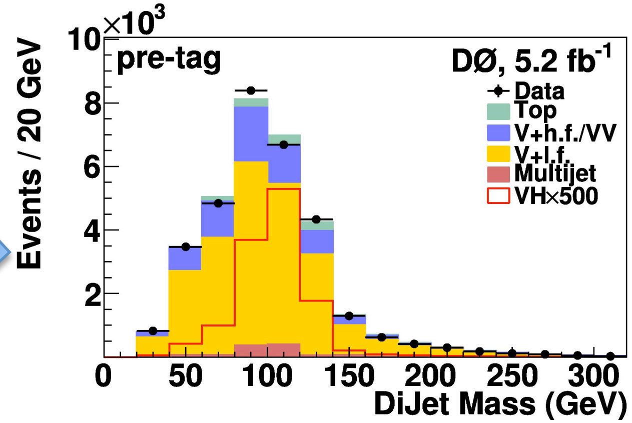


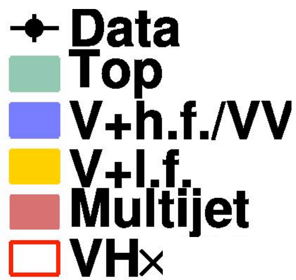
ZH → ννbb

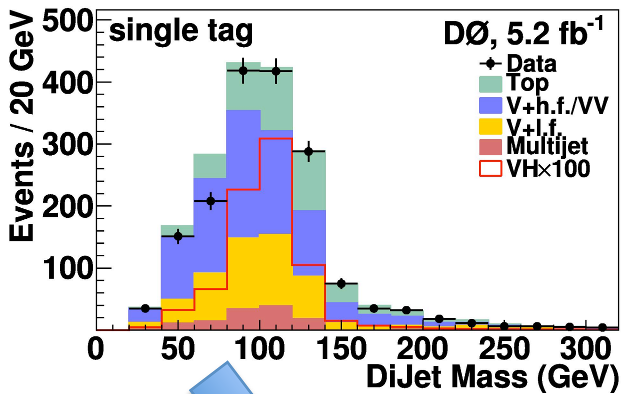


cut at 0.6 removes 95% of the QCD background, 65% of the non-QCD background, and keeps 70% of signal

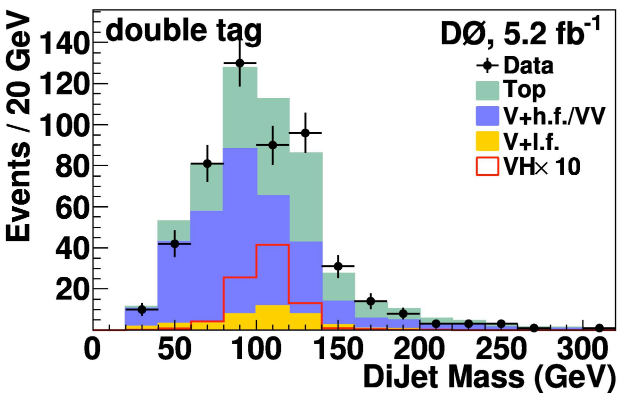


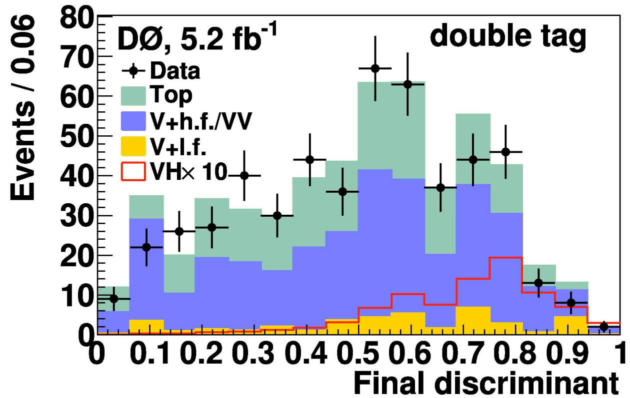






most difficult final state among most sensitive channels

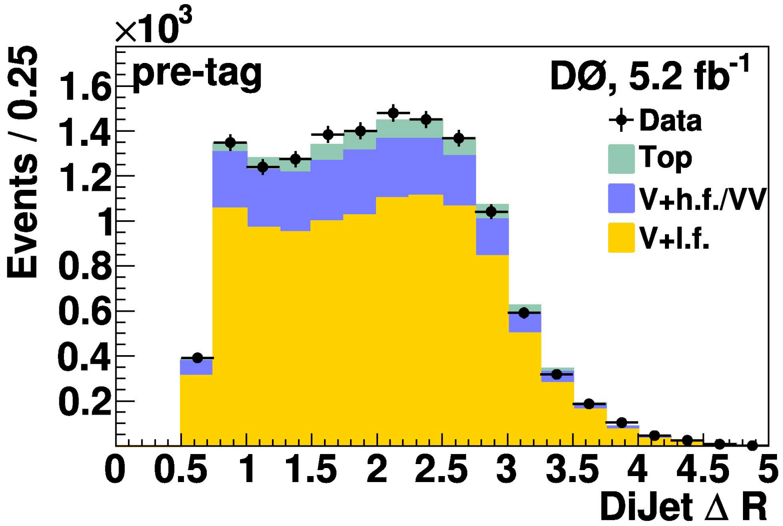


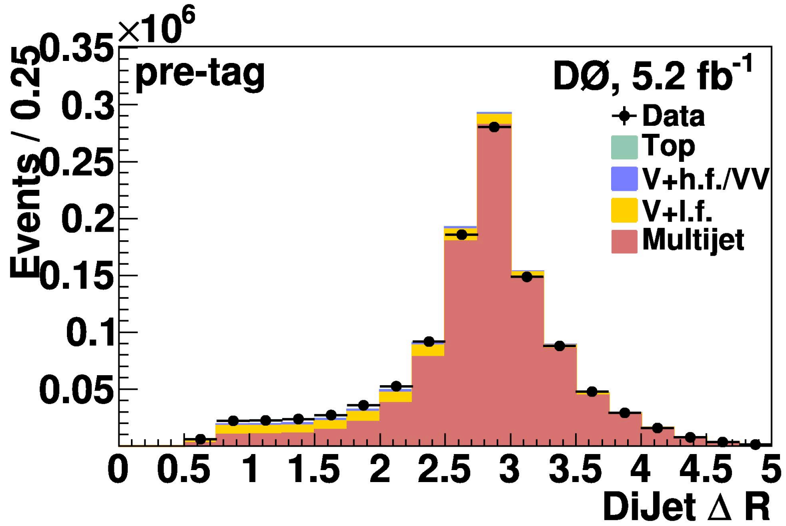


ZH → ννbb

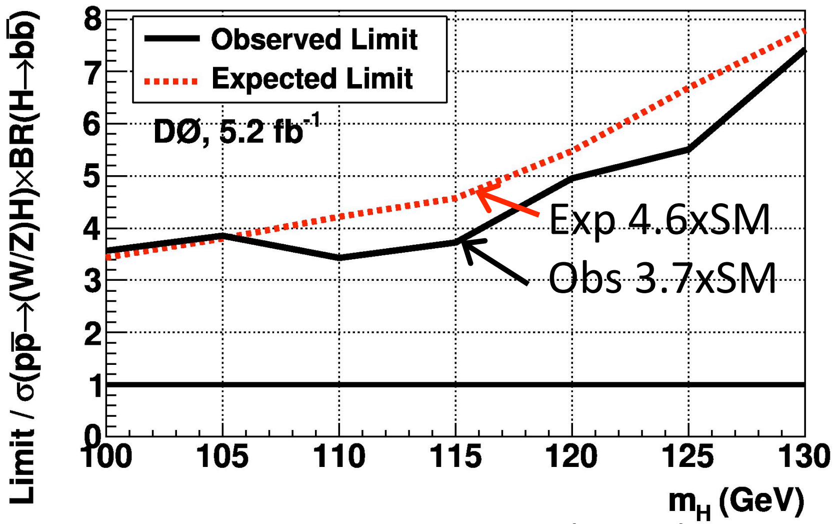
New!

UK!



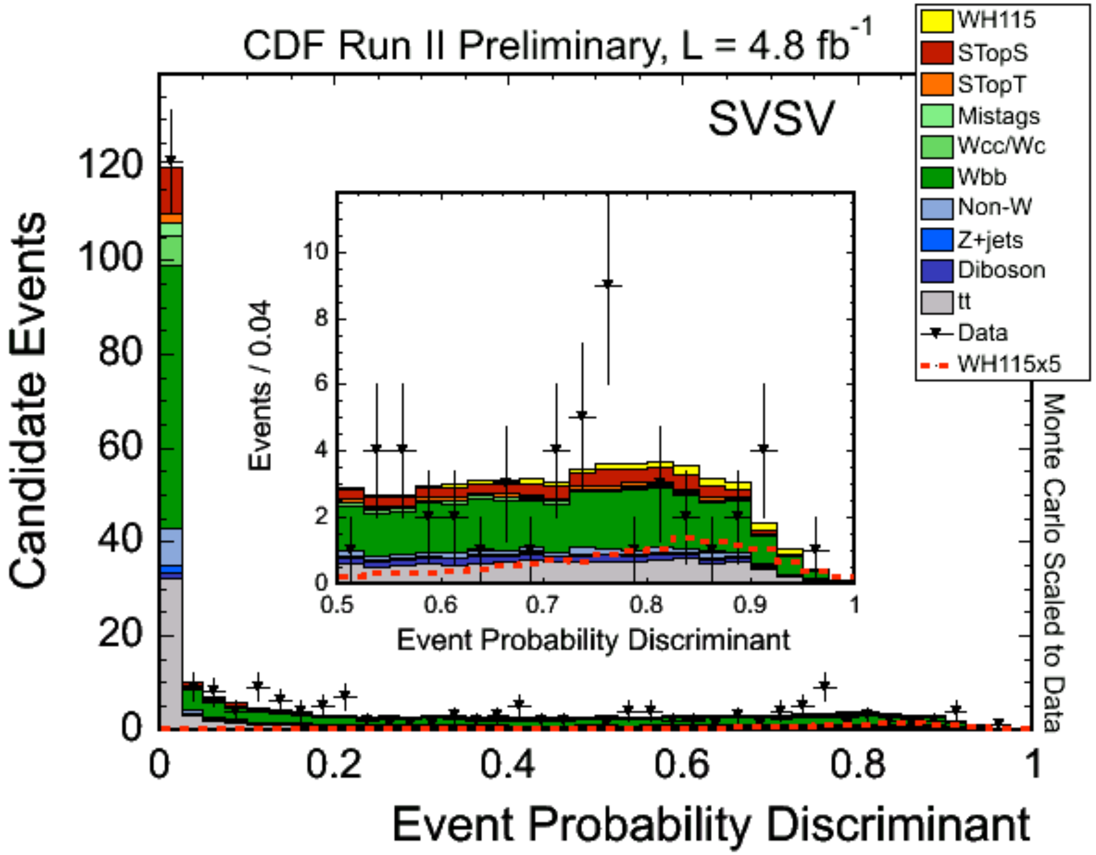


EWK and jets control regions



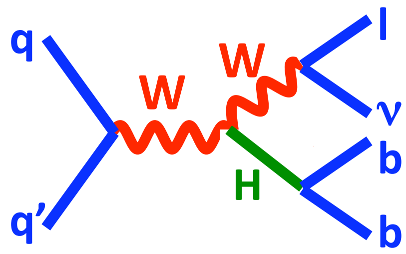
Observe VZ with Z⟶bb?

PRL **104** 071801 (2010)



WH → $l\nu bb$

Key issue: estimating W+bb background
Shape from MC with normalization from data control regions
Matrix element analysis

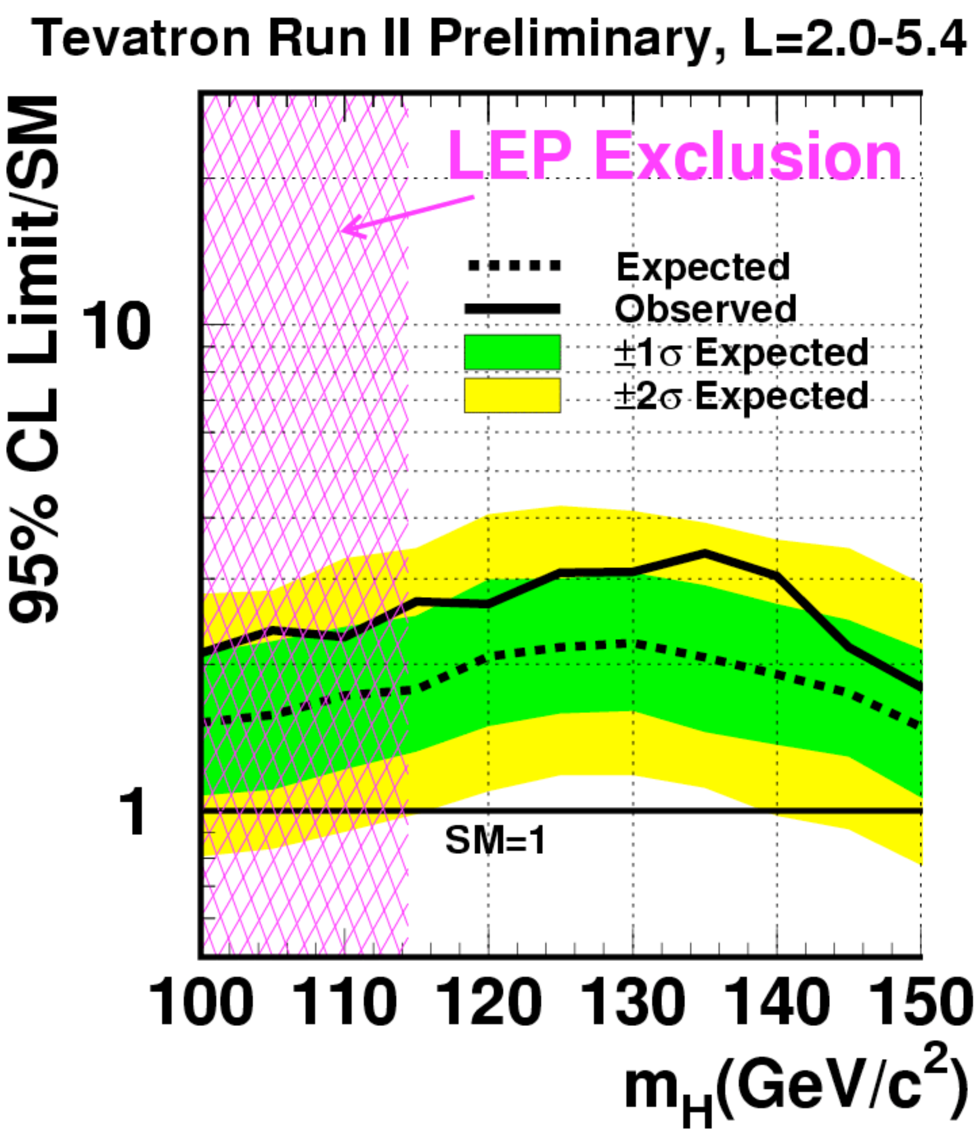


Results at mH = 115GeV: 95%CL Limits/SM

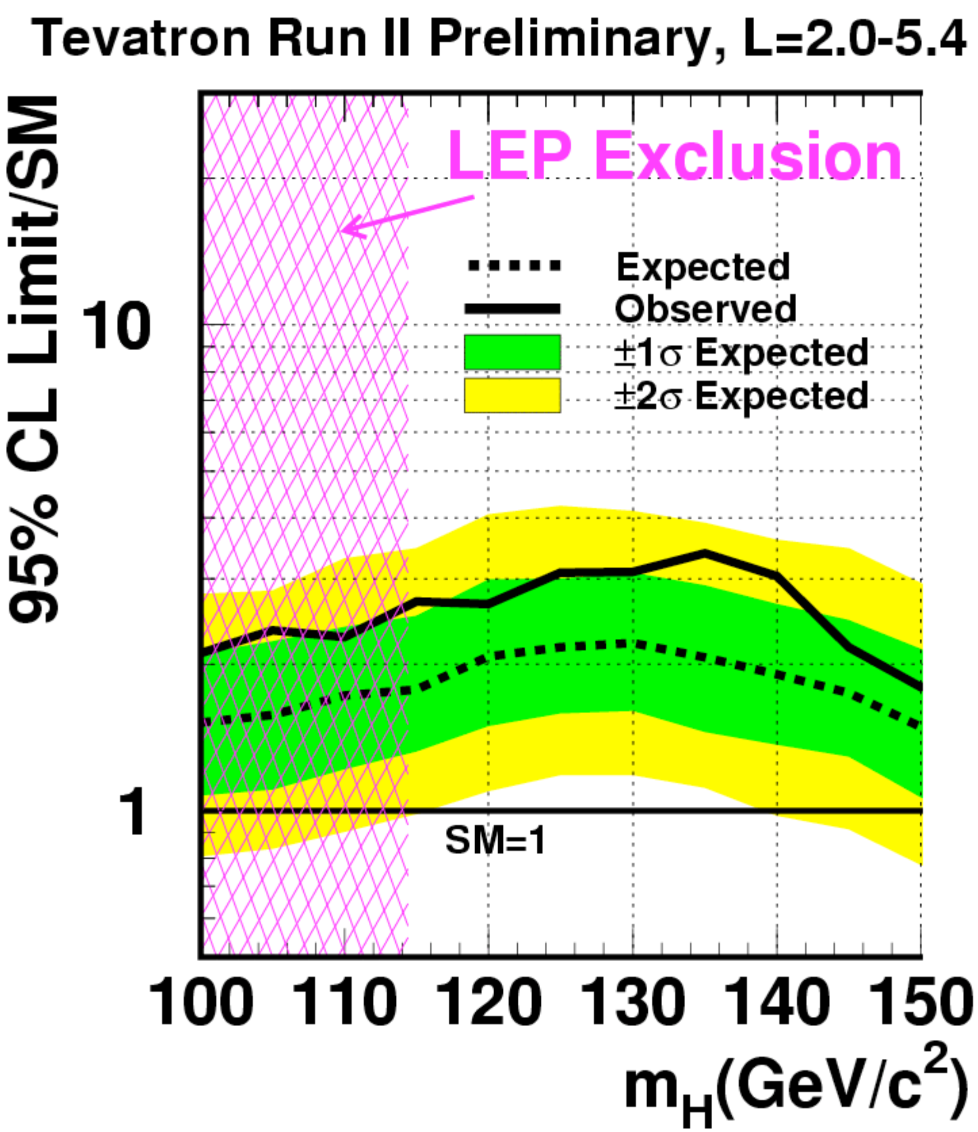
Higgs Events	**Exp. Limit**	**Obs. Limit**
18.6	3.9	4.4

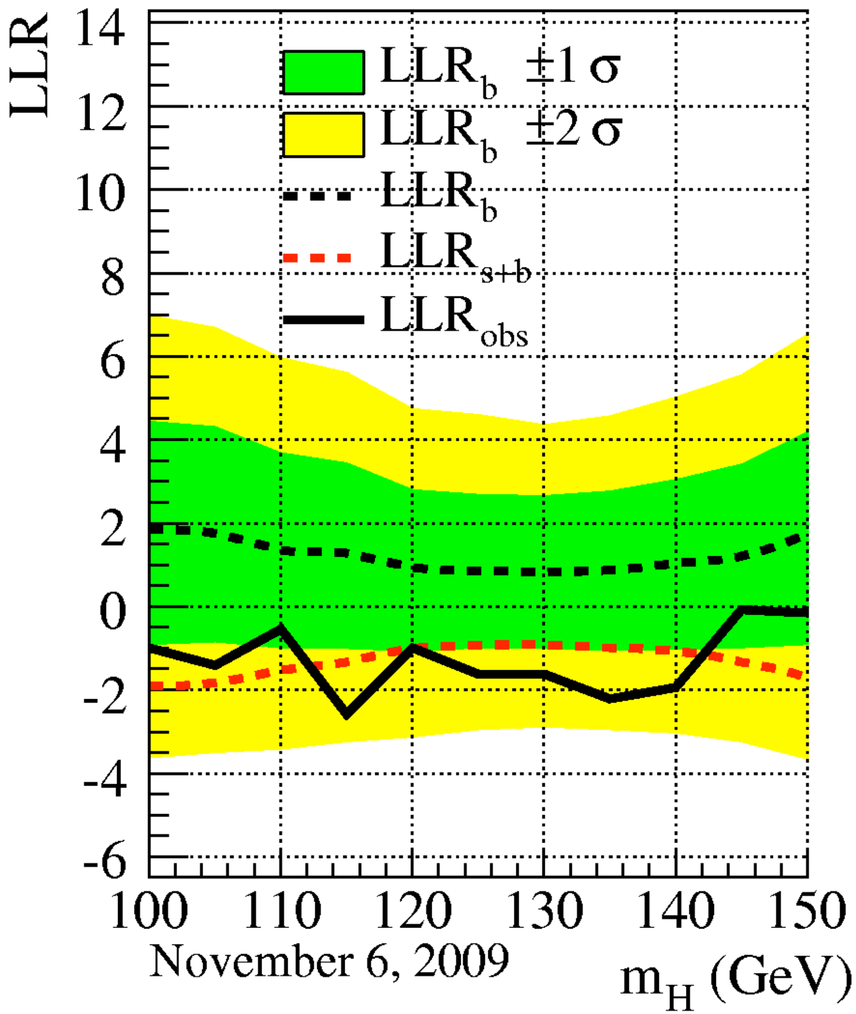
World's most sensitive low-mass Higgs search

Low mass Higgs searches

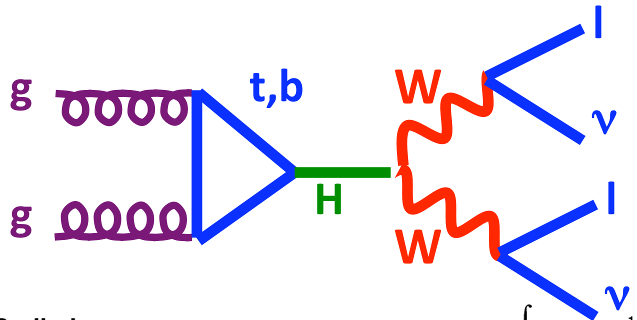


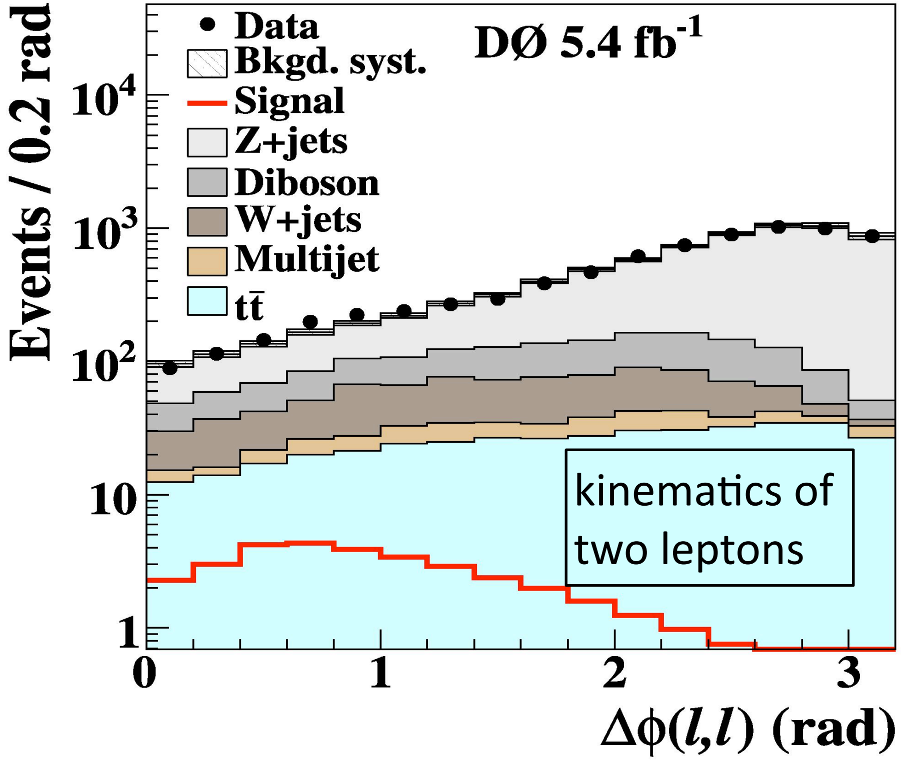
Low mass Higgs searches

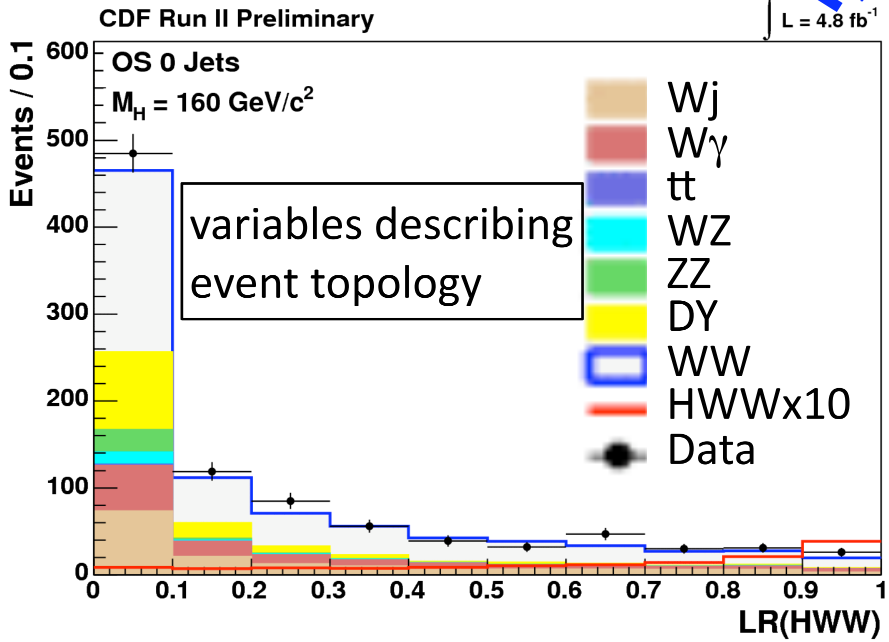


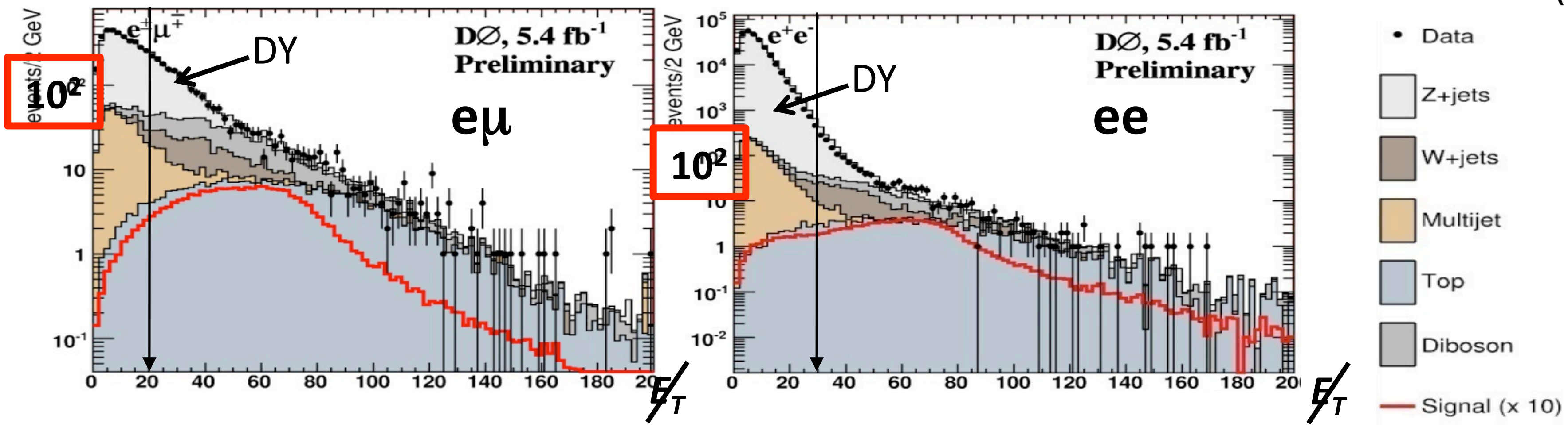


H→WW


g
g
t,b
H
W
W
l
ν
l
ν


Data
Bkgd. syst.
Signal
Z+jets
Diboson
W+jets
Multijet
$t\bar{t}$
DØ 5.4 fb^{-1}
Events / 0.2 rad
kinematics of two leptons
$\Delta\phi(l,l)$ (rad)

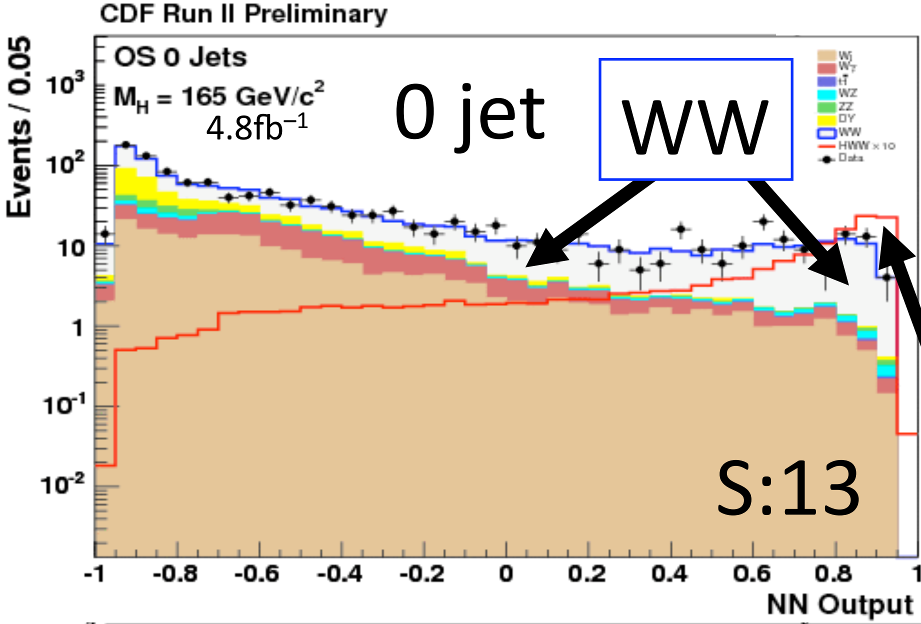

CDF Run II Preliminary
$\int L = 4.8\ fb^{-1}$
OS 0 Jets
$M_H = 160\ GeV/c^2$
Events / 0.1
variables describing event topology
Wj
Wγ
tt
WZ
ZZ
DY
WW
HWWx10
Data
LR(HWW)

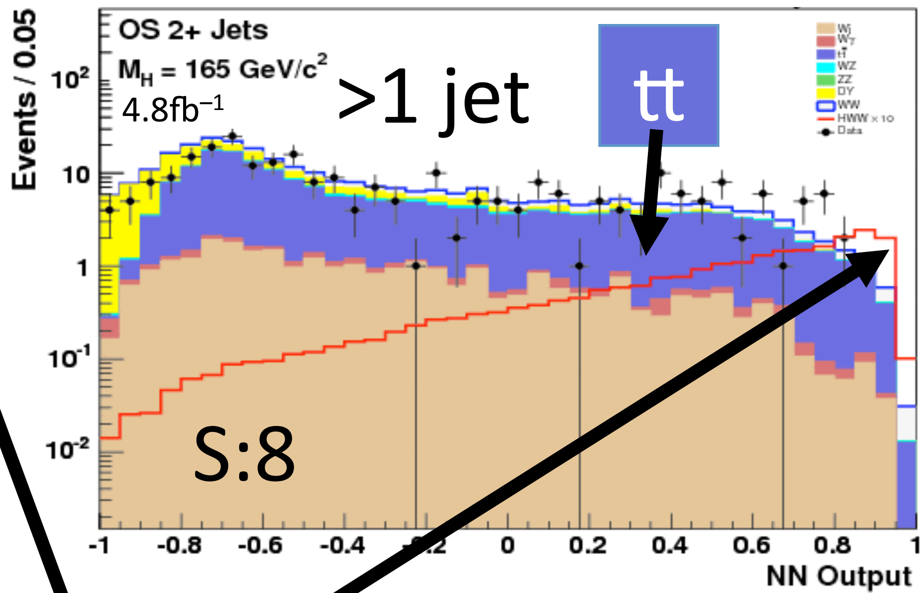

$e^{\pm}\mu^{\mp}$
DY
DØ, 5.4 fb^{-1}
Preliminary
eμ
10²
e^+e^-
DY
DØ, 5.4 fb^{-1}
Preliminary
ee
10²
events/2 GeV
$\not{E}_T$
Data
Z+jets
W+jets
Multijet
Top
Diboson
Signal (x 10)

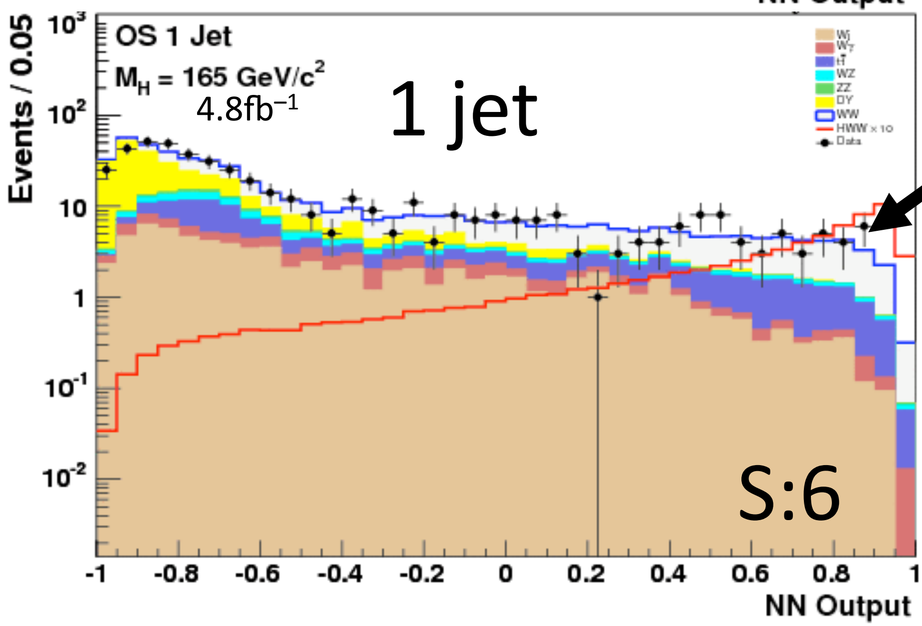
H→WW

New!

UK!





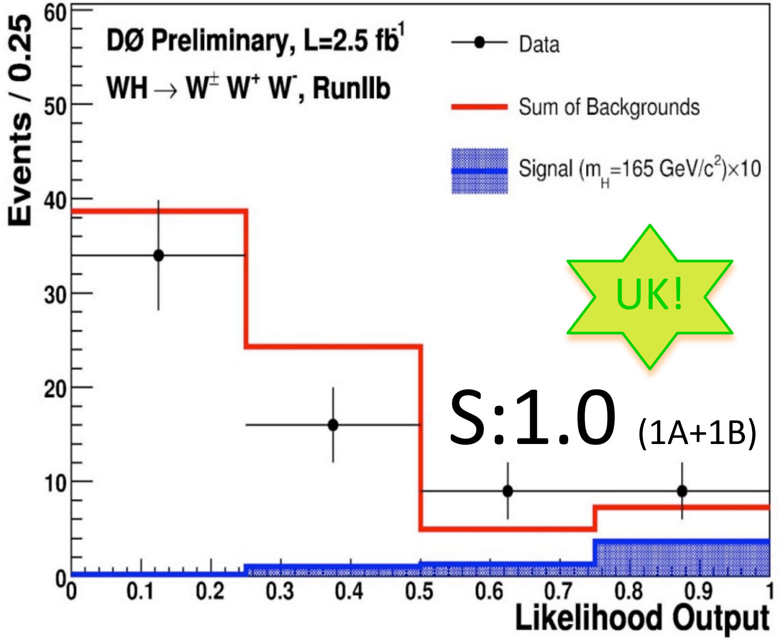


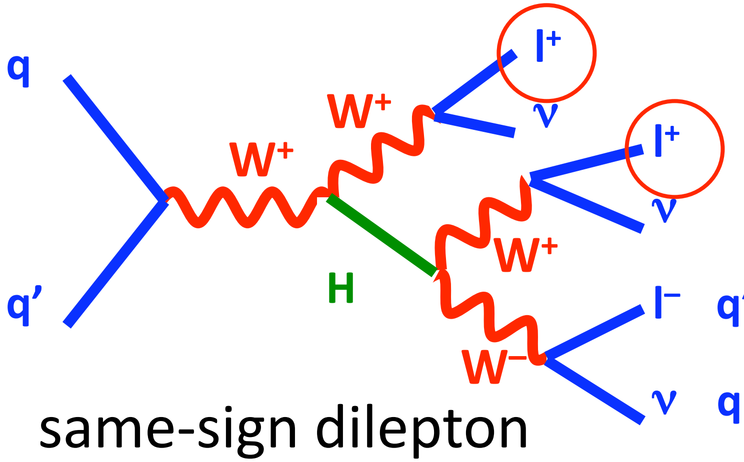
Hx10

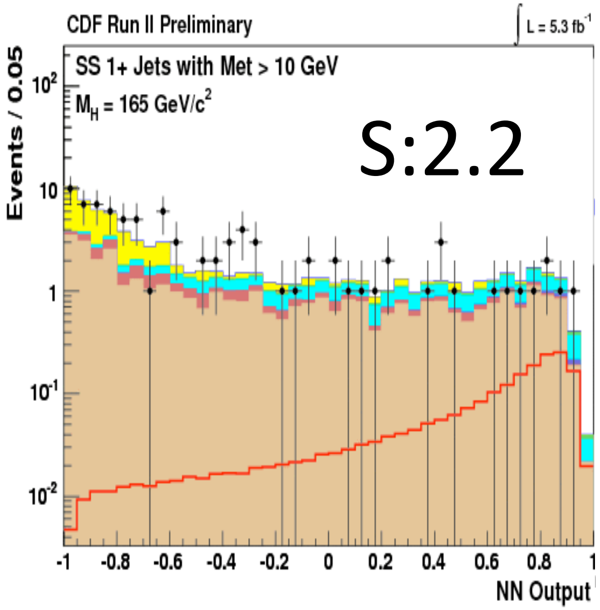
Jet multiplicity:
different background
contributions

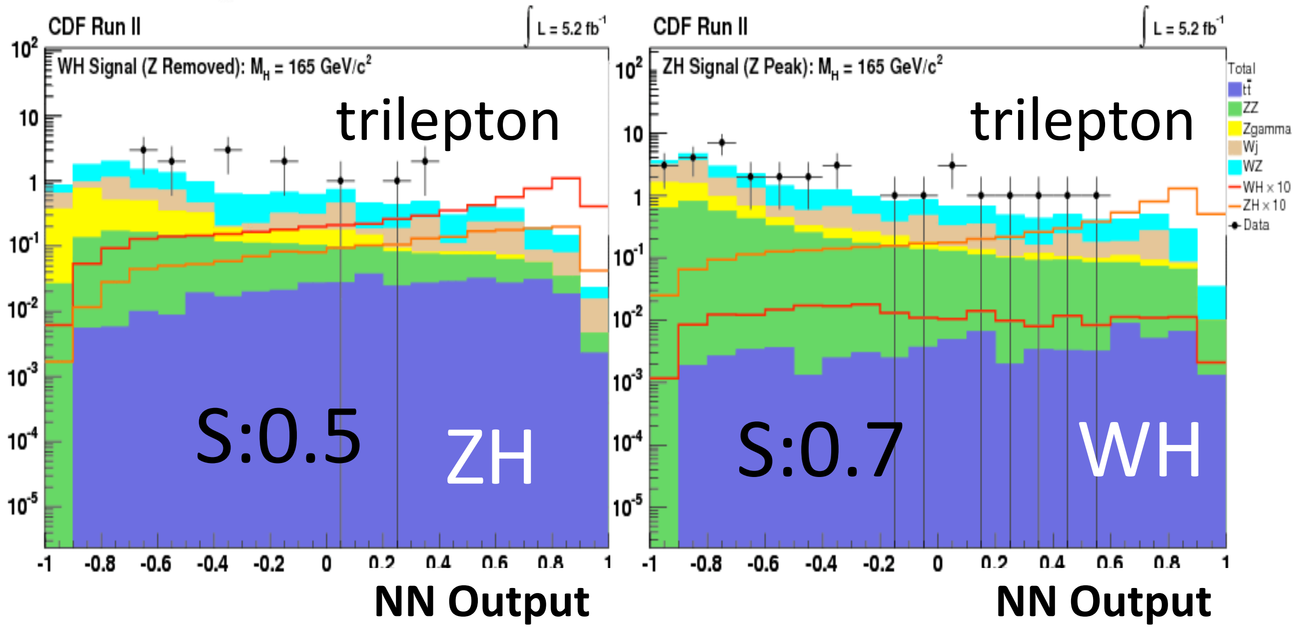
No channel too small!

New!





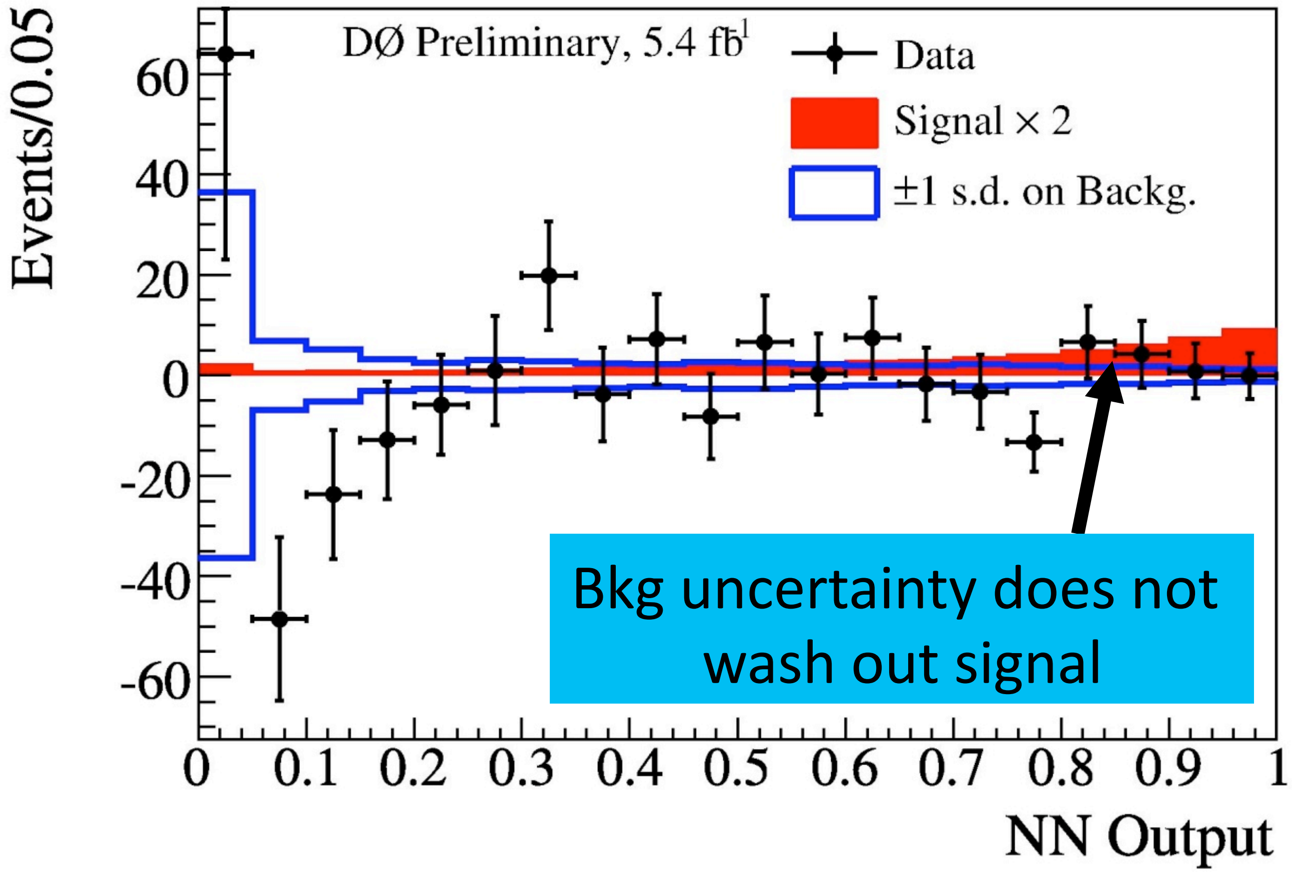




H→WW

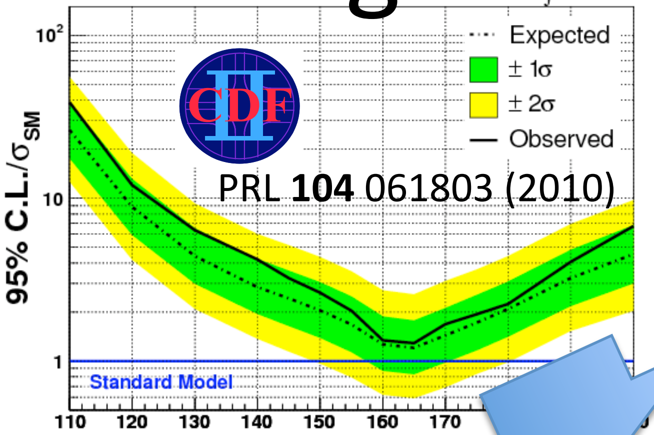
D0: Expect 35 Signal Events

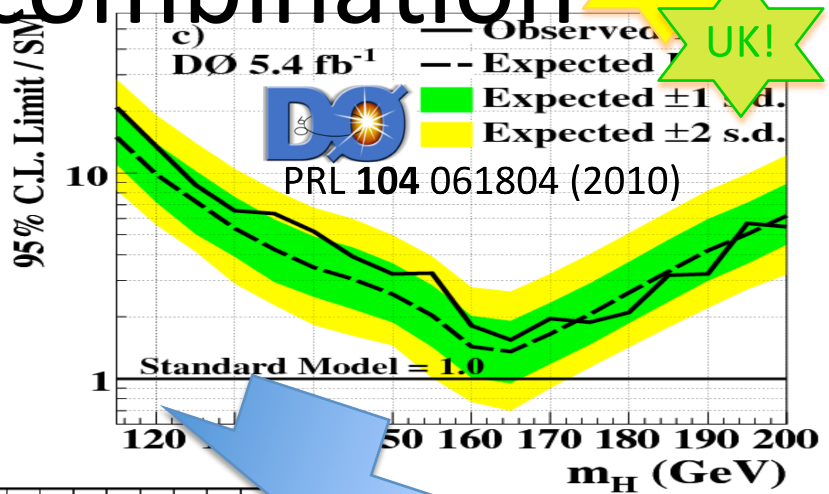
CDF: Expect 32 Signal Events

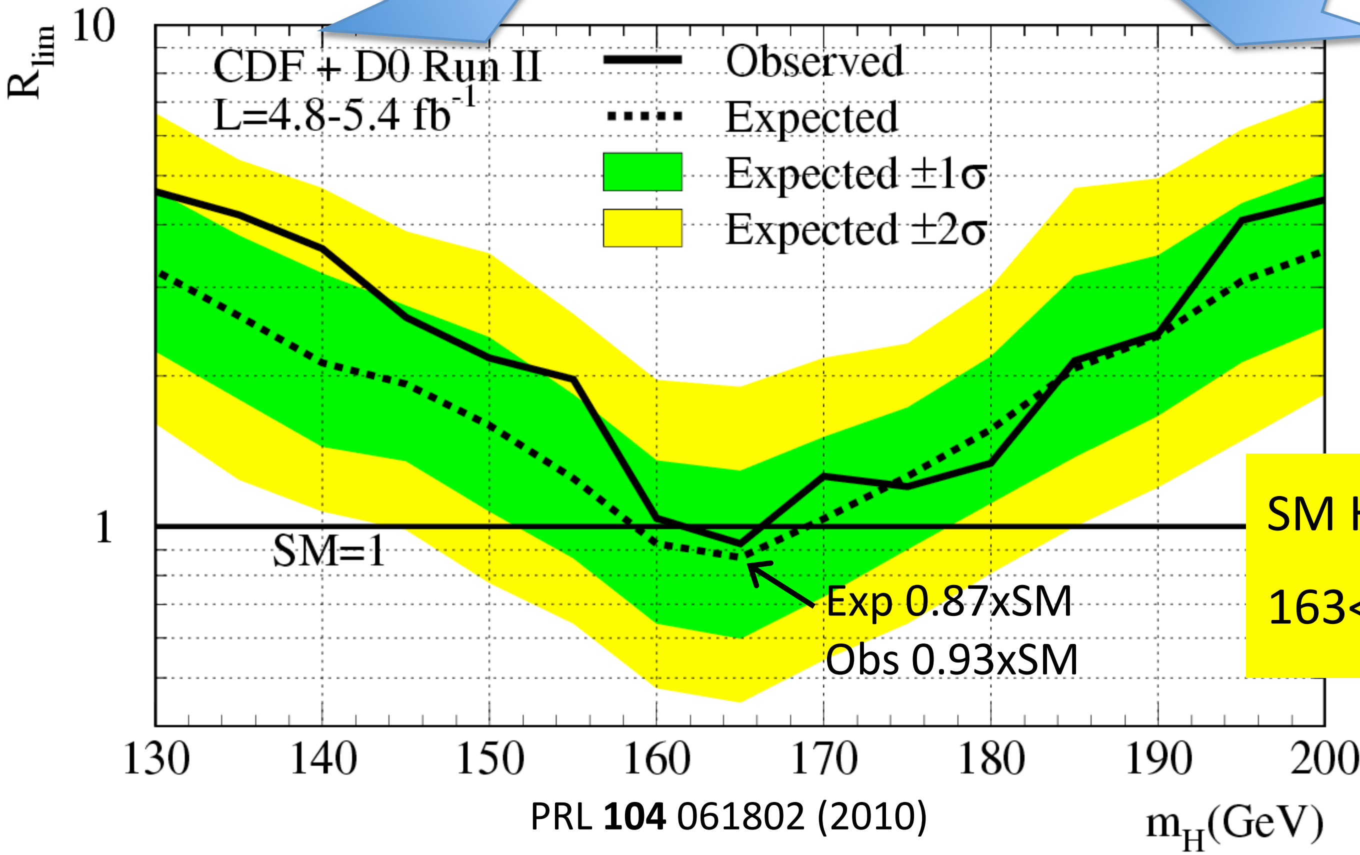


High mass Higgs combination

New!
UK!





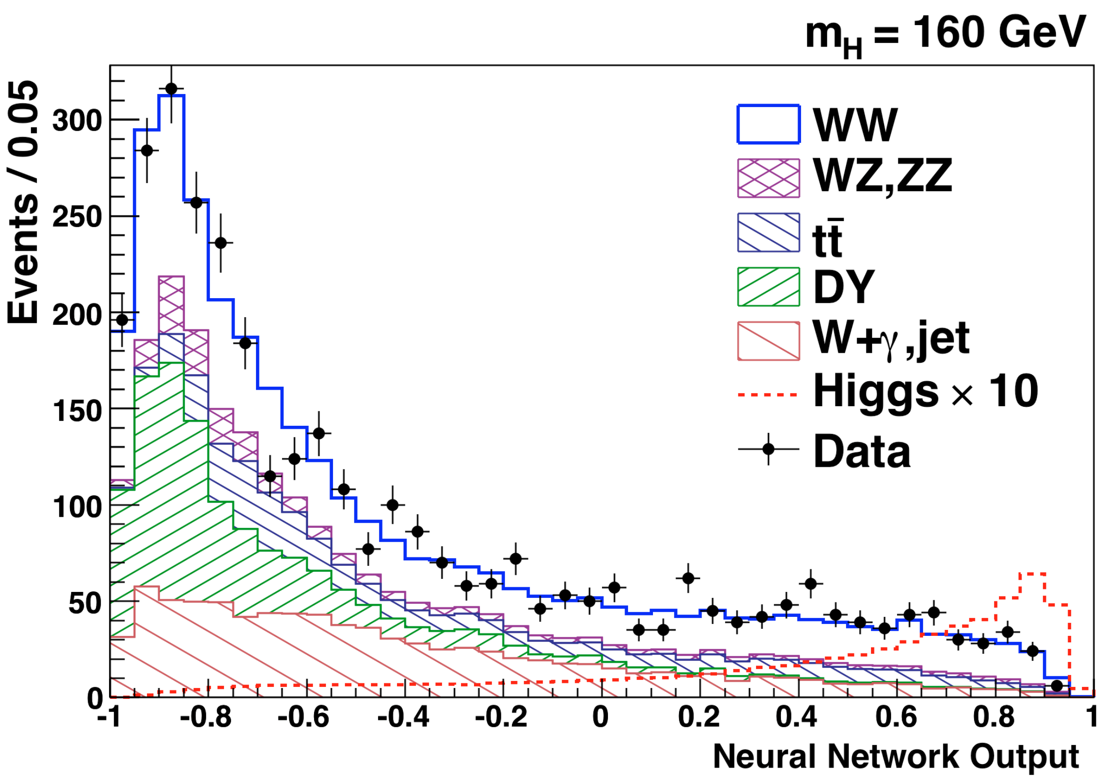


SM Higgs excluded:

163<m_H<166 GeV

New CDF HWW

New! UK!



CDF Run II Preliminary $\int \mathcal{L} = 5.3\ \mathrm{fb}^{-1}$

$M_H = 165\ \mathrm{GeV}/c^2$

$t\bar{t}$	222	±	38
DY	409	±	61
WW	689	±	73
WZ	78	±	11
ZZ	54.0	±	7.4
W+jets	362	±	87
$W\gamma$	245	±	33
Total Background	2060	±	170
$gg \to H$	25.4	±	5.2
WH	6.04	±	0.82
ZH	2.96	±	0.39
VBF	2.02	±	0.34
Total Signal	36.4	±	5.6
Data	2082		

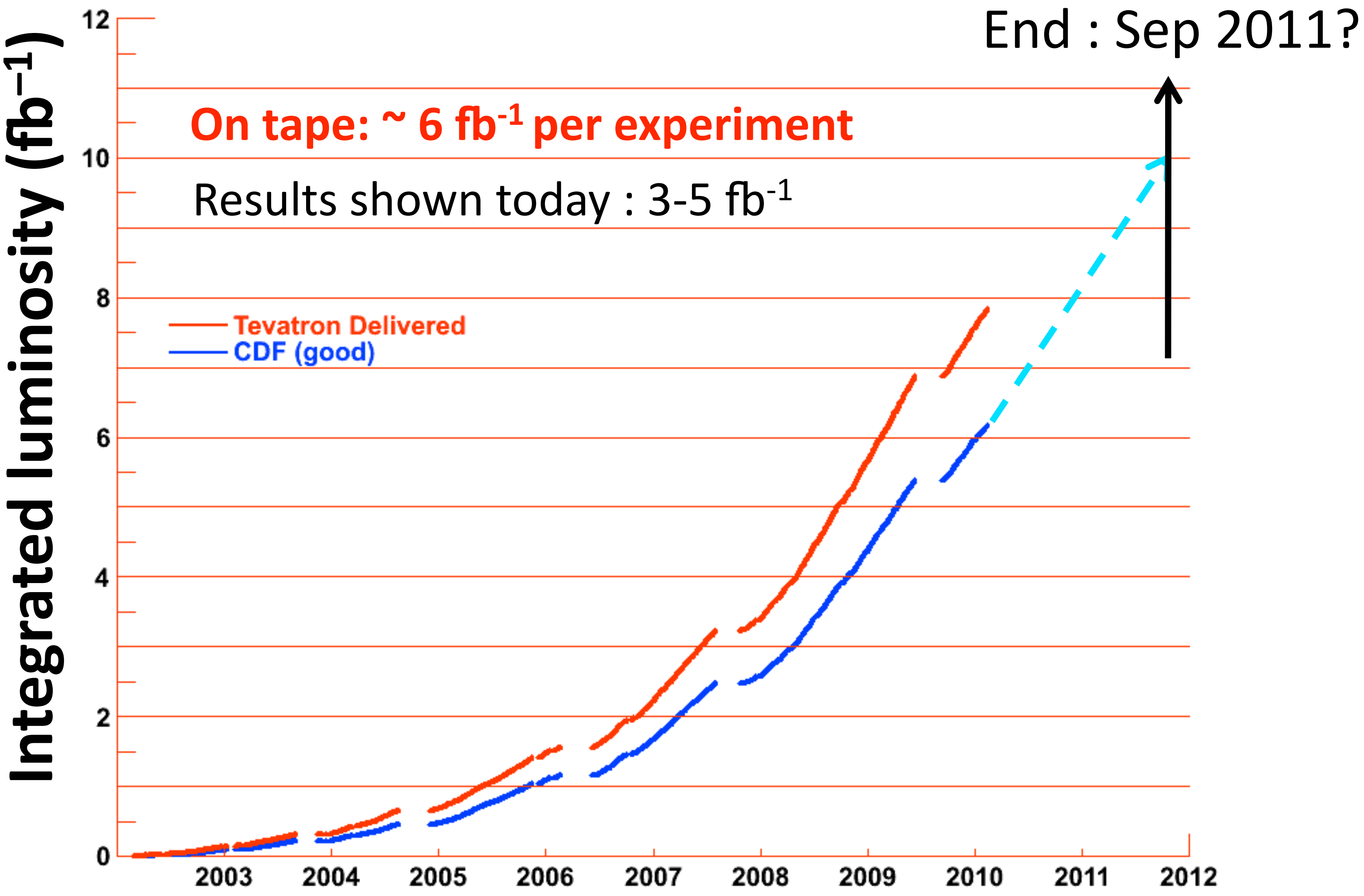
All $H \to WW$ Channels

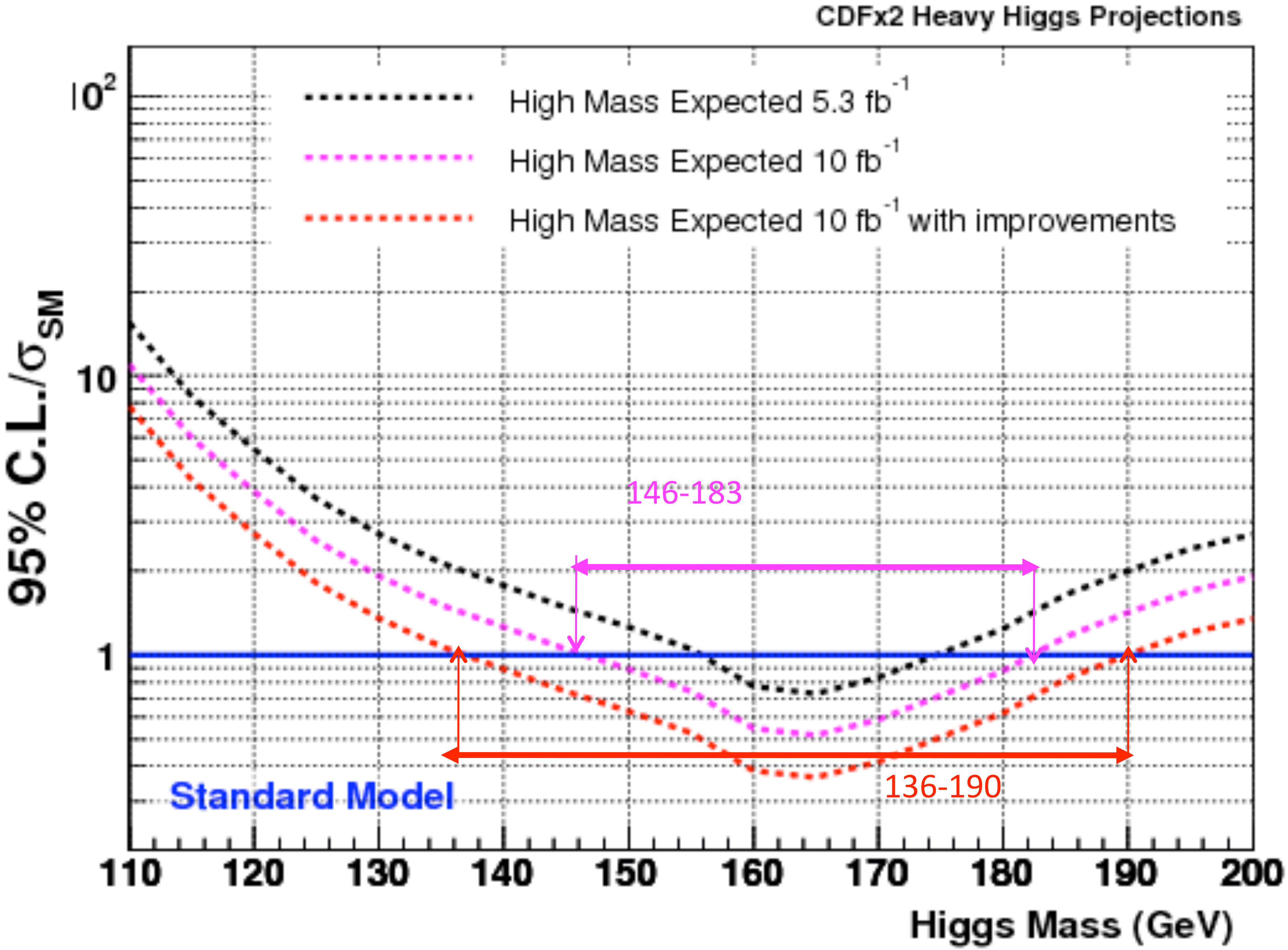
- 4.8→5.3 fb^{-1}: 5% better from statistics
- Optimized e^- selection
- Added Trileptons, Low M_{ll}, VH, VBF for 0 Jet
- All together: 15% better!
- Improvements continue (τ modes add a few %)

Results at m_H = 165GeV: 95%CL Limits/SM

	Exp events	Exp.	Obs.
Publication	32	1.20	1.29
New	36	1.03	1.13

Tevatron projection





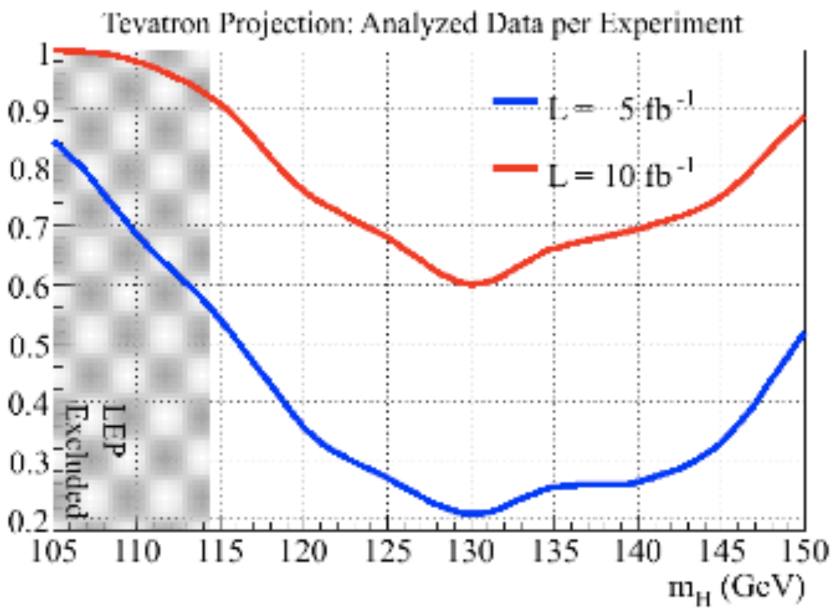
CDFx2 Heavy Higgs Projections
High Mass Expected 5.3 fb-1
High Mass Expected 10 fb-1
High Mass Expected 10 fb-1 with improvements
146-183
136-190
Standard Model
95% C.L./σSM
10²
10
1
110
120
130
140
150
160
170
180
190
200
Higgs Mass (GeV)

Low mass projections

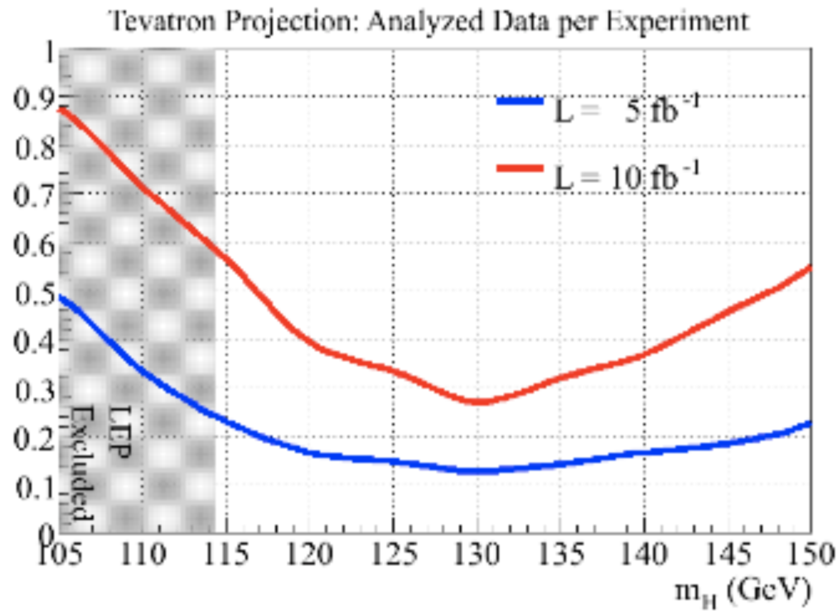
	equivalent luminosity gain
charm discrimination	30%
improved b-tagging	20%
improved dijet mass resolution	15%
extra final states	5–10%
improved lepton id	5–10%

total : 1.4x in the limit (~ 2x in effective luminosity)

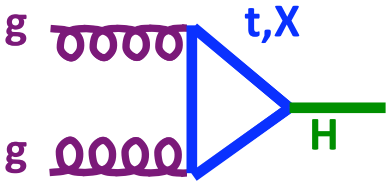
Probability of 95% CL Exclusion



Probability of 3σ evidence

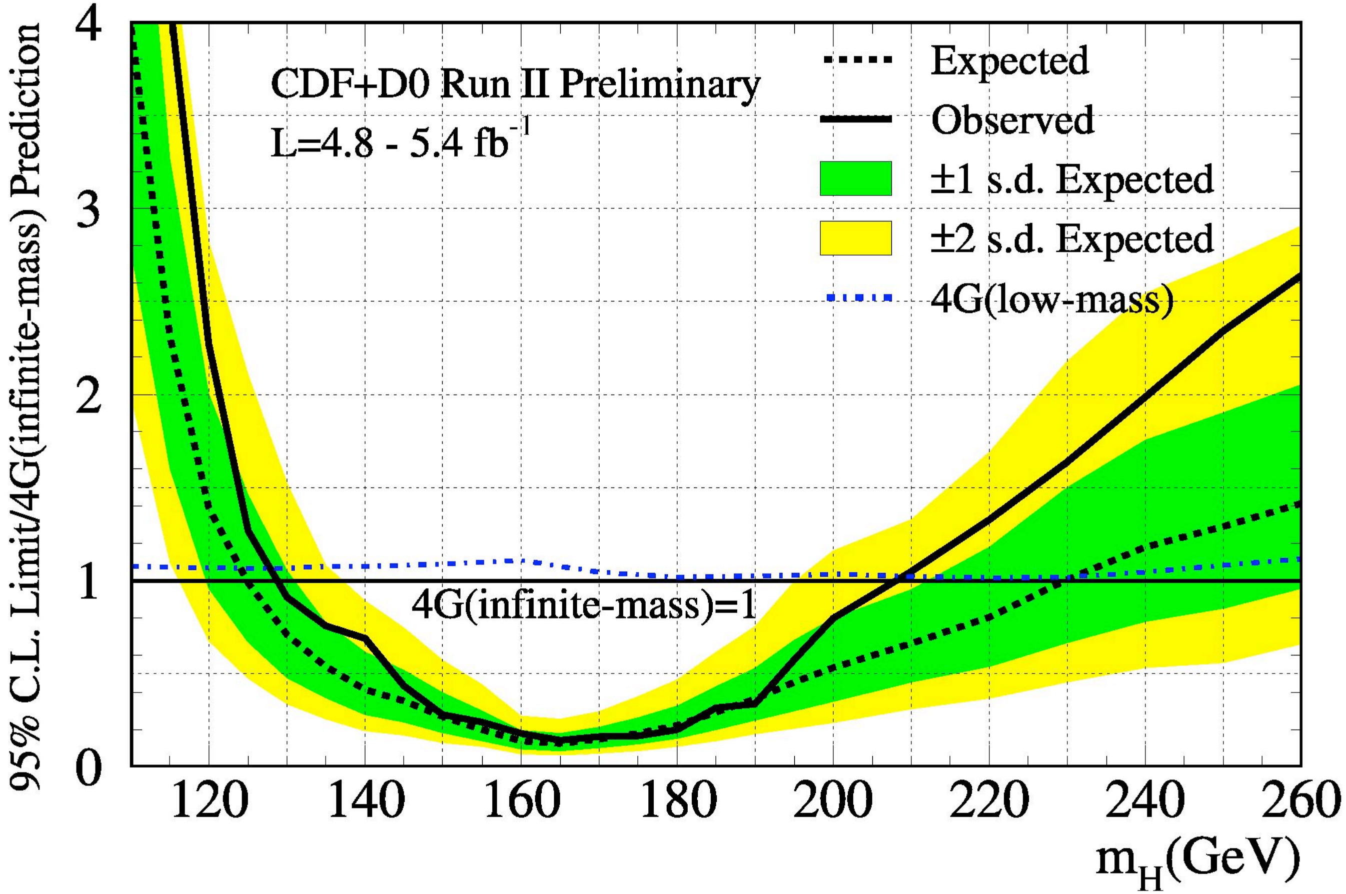


4^{th} generation



Low-mass scenario:
masses close to experimental limits

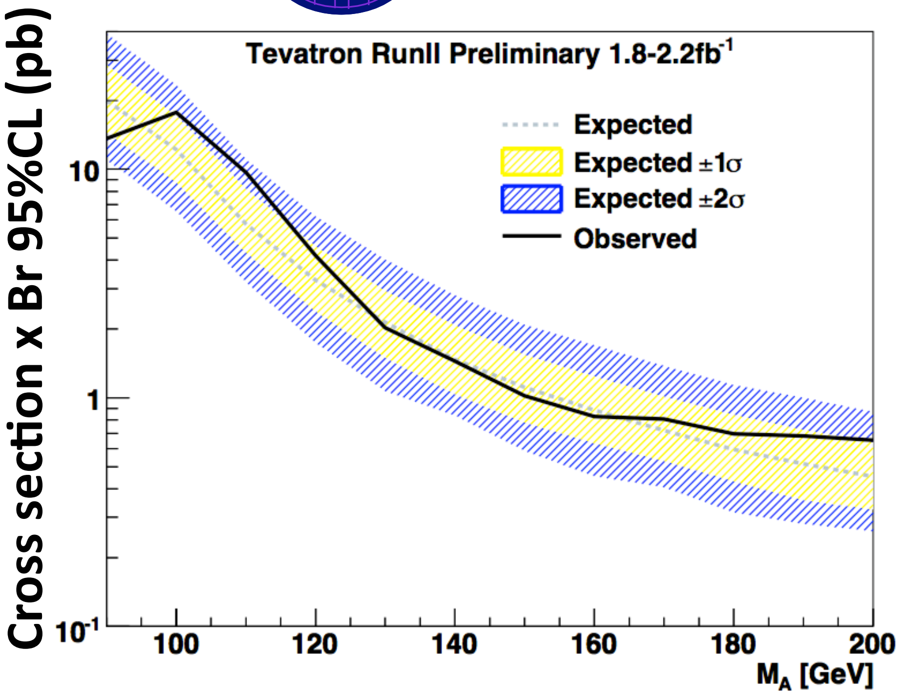
m_{l4}=100GeV
$m_{\nu4}$=80GeV
m_{u4}=256GeV
m_{d4}=128GeV



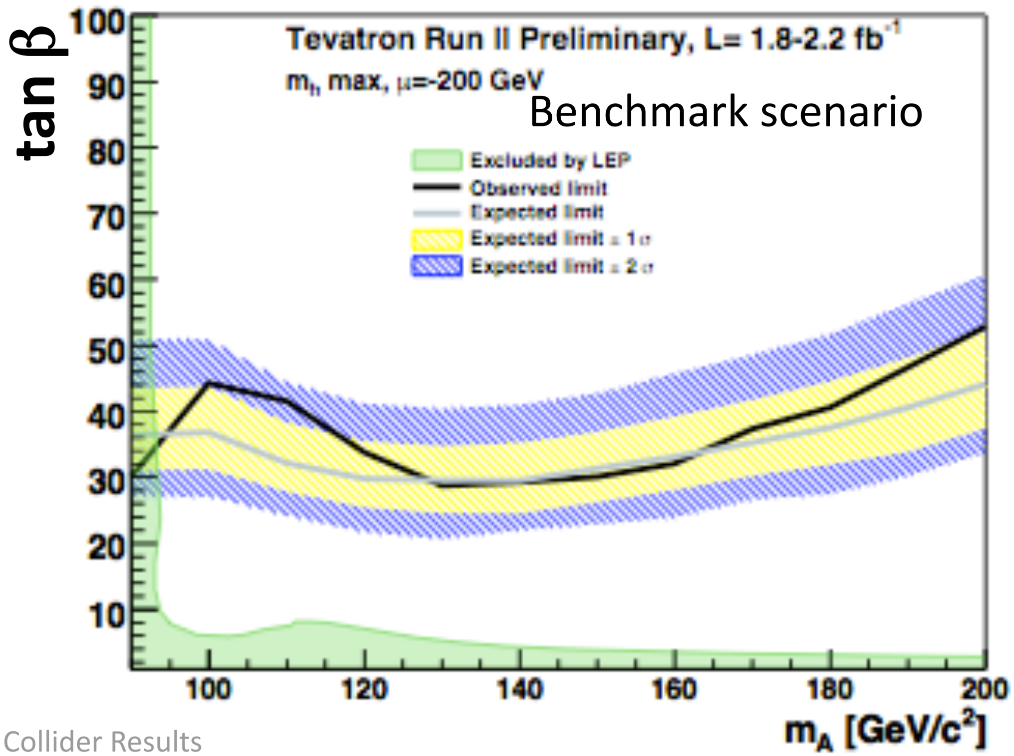
MSSM H→ττ

New!

UK!



Key issue: understanding τ ID efficiency
Large calibration samples:
- W for ID optimization
- Z for efficiency confirmation

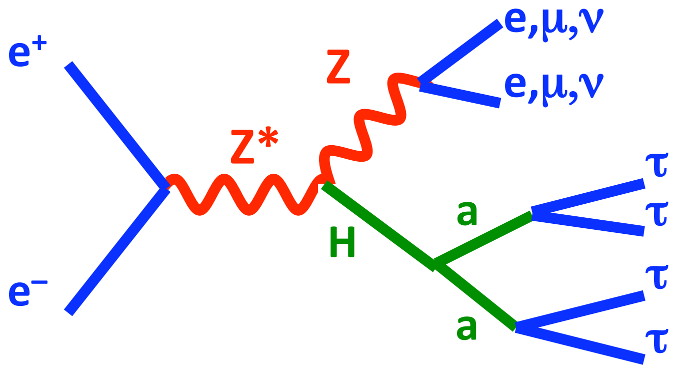


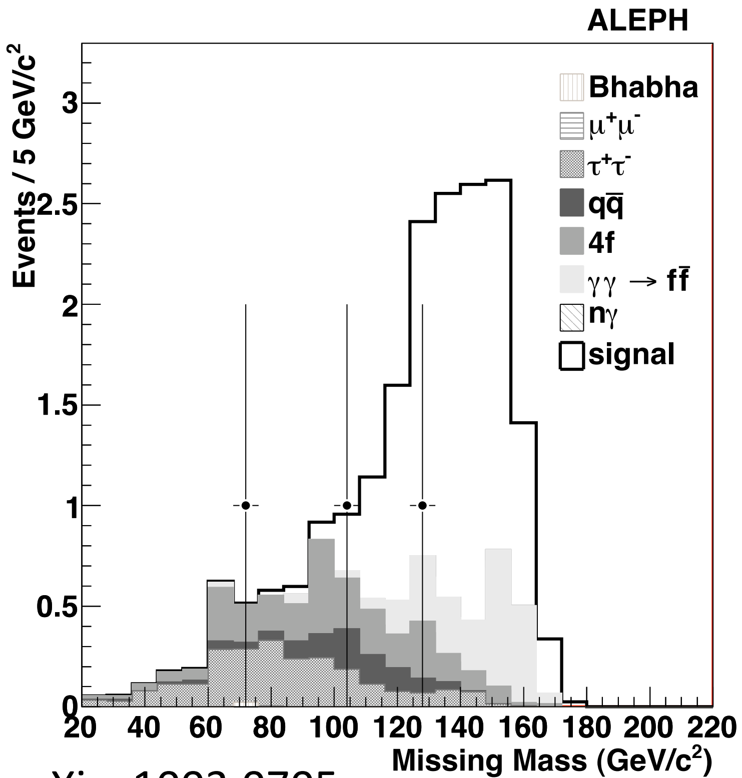
No Evidence for SUSY Higgs
φ→ττ sensitive at high tanβ

in future will include
bφ→bττ, bφ→bbb

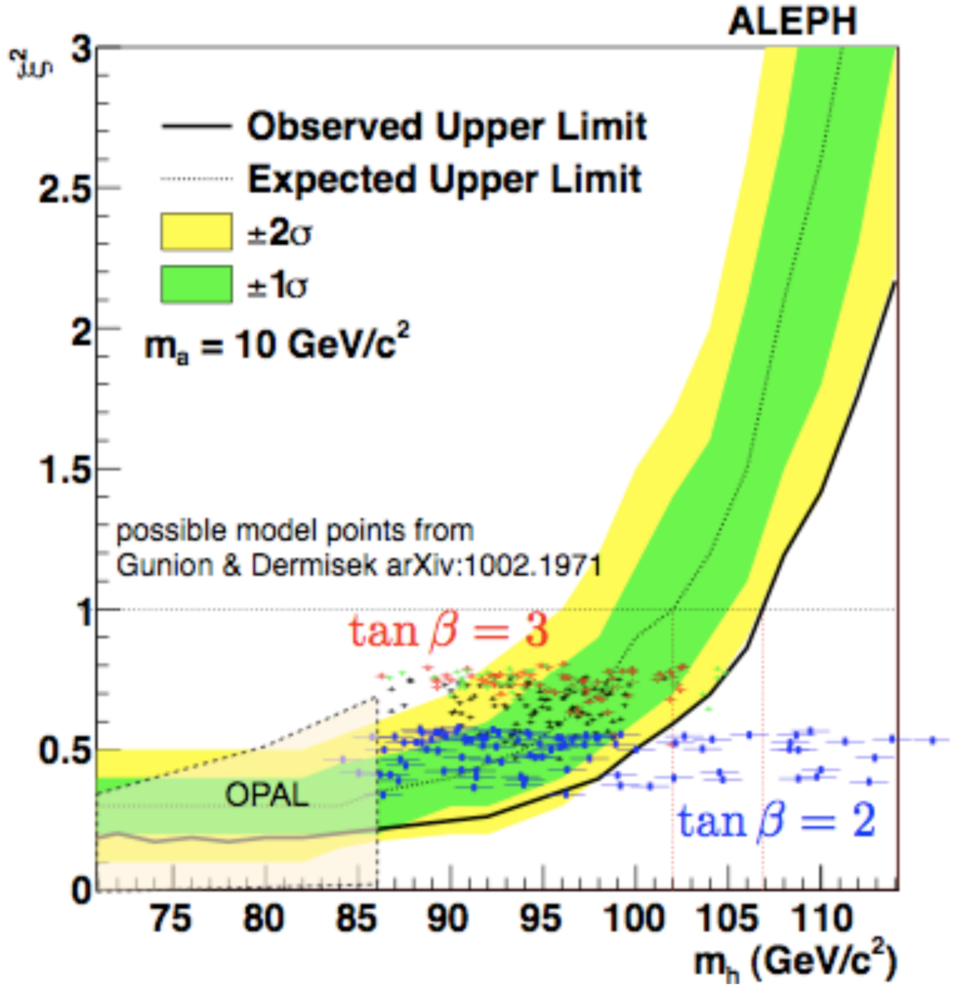
UK!

nMSSM constraints from LEP





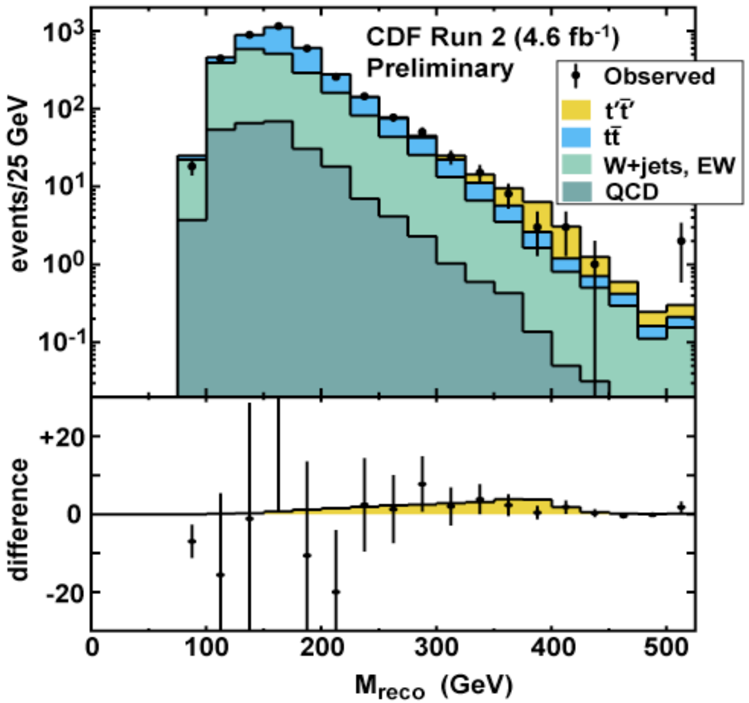
arXiv: 1003.0705

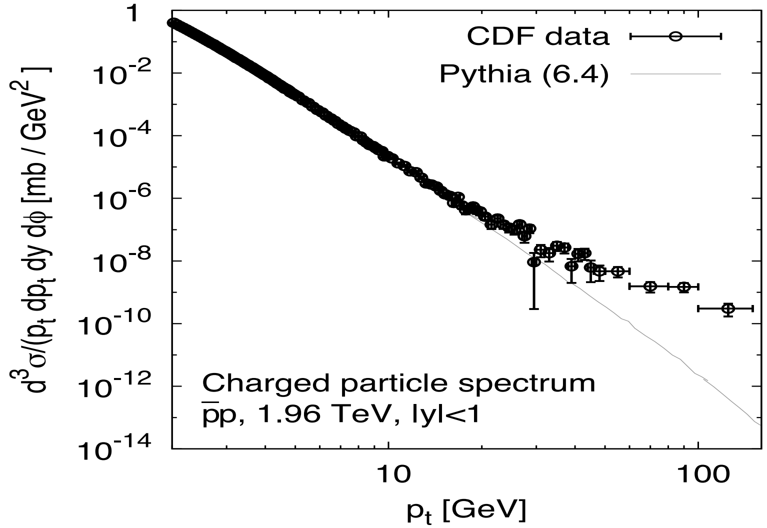


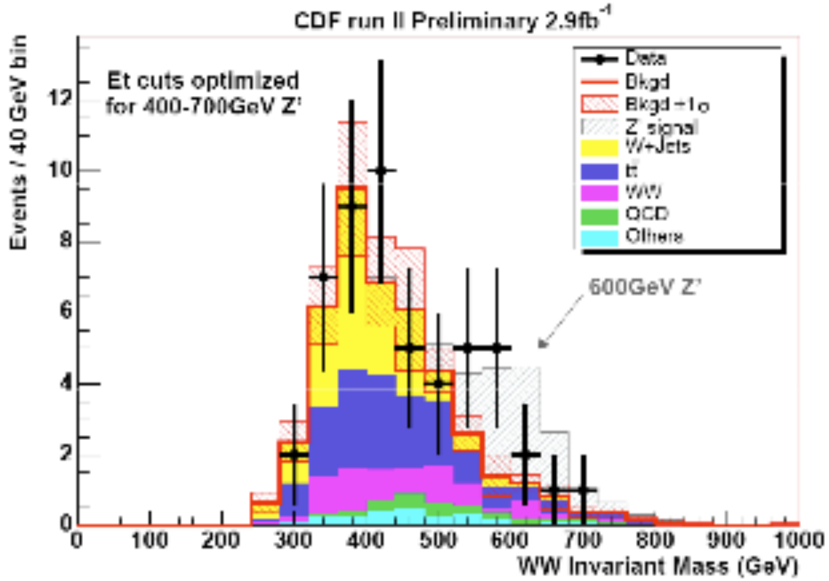
From Kyle Cranmer, Moriod QCD 10

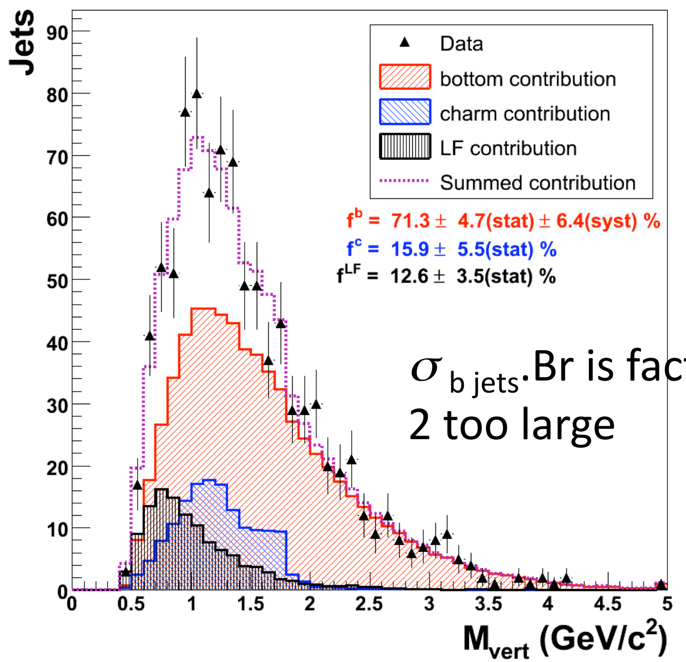
$$\xi^2 = \frac{\sigma\, \mathrm{BR}(h \to aa)\, \mathrm{BR}(a \to \tau\tau)^2}{\sigma_{SM}}$$

Ones to watch?









$\sigma_{\text{b jets}}$.Br is factor 2 too large

All the other things I didn't have time for:

- SUSY limits
- limits on new heavy bosons
- observations of new baryons
- new jet measurements
- measurements of α_s
- diffraction

…

Outlook

- Strong physics programs with UK people at the centre.
- Legacy results still coming from HERA
- Many of the primary Tevatron goals have been achieved
  – and now we are focused on Higgs physics

- Themes: complex analyses, eg taus; combinations
- SUSY under pressure!
- Higgs within reach!
  – remarkable times.

Thanks to Gavin Davies, Paul Newman, Katie Oliver and Matthew Wing for input.