

Results from the Tevatron

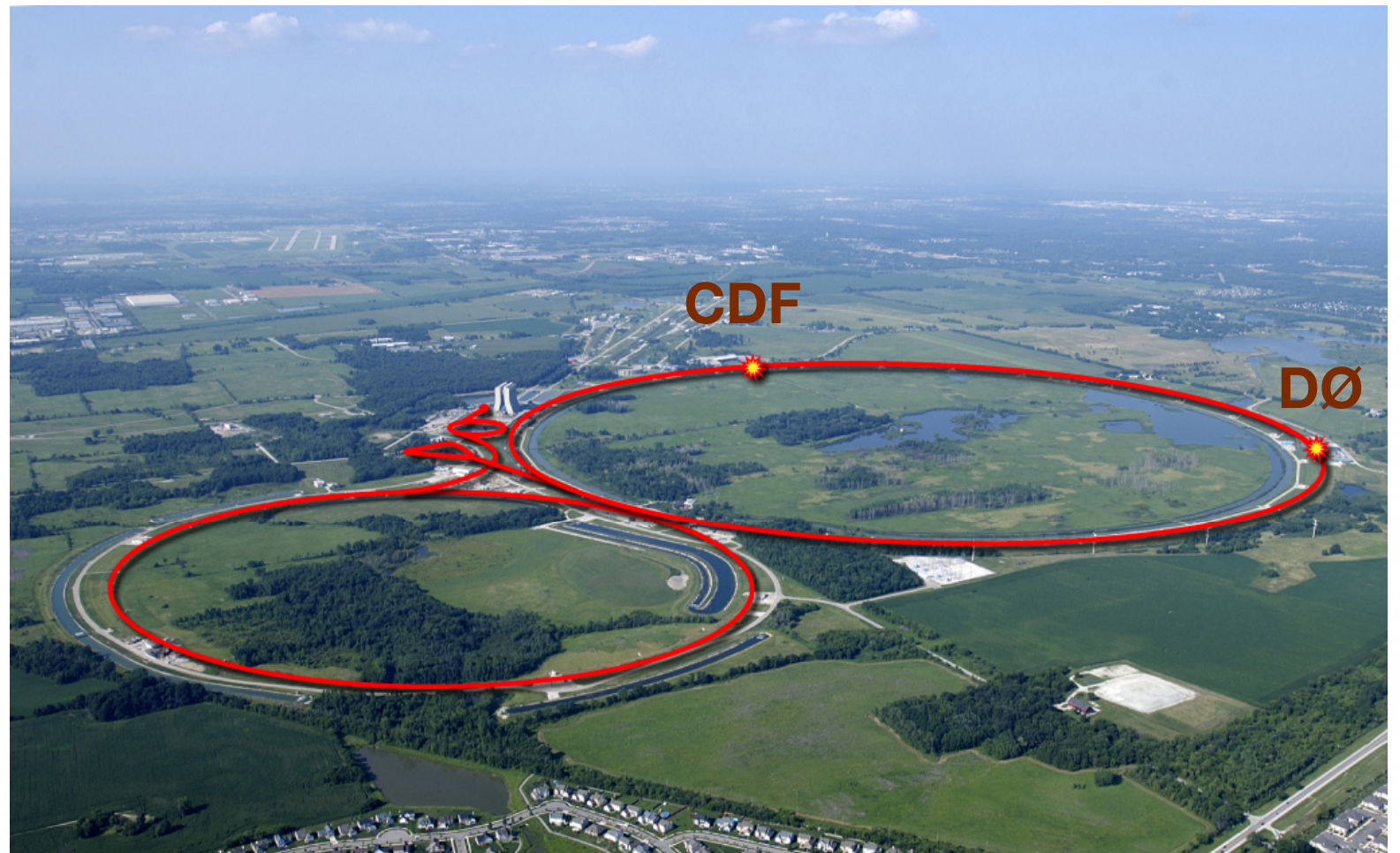
Veronica Sorin
IFAE



III Jornadas CPAN
Barcelona
November 2 - 4, 2011

The Tevatron

- In commissioning 26 years ago
- First collisions recorded in October 1985
- Last ones September 2011



Physics Runs

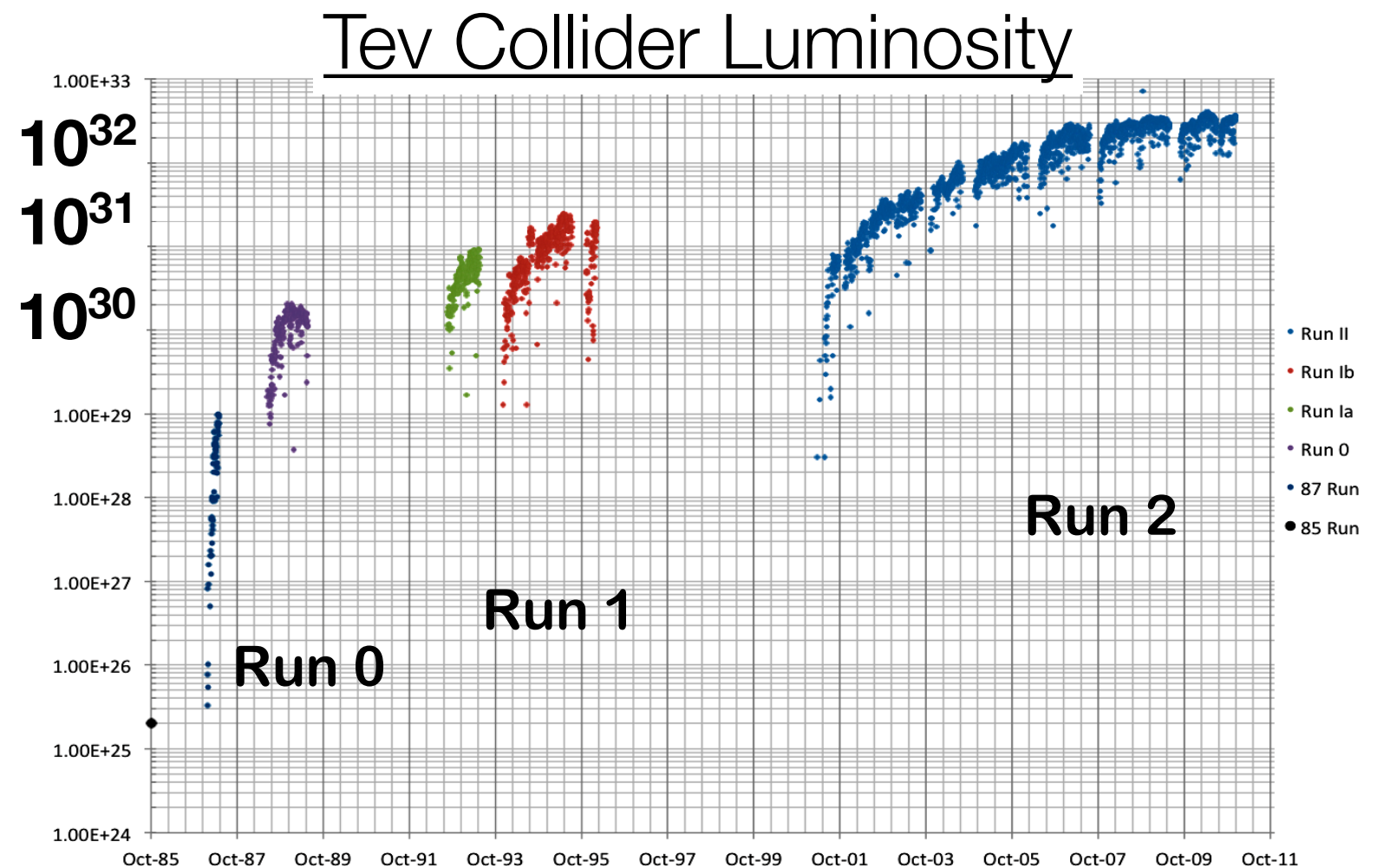
1987	Run 0 - 4 pb ⁻¹
1992-1996	Run 1 - 120 pb ⁻¹ , 1.8 TeV
2001-2011	Run 2 - 12 fb ⁻¹ , 1.96 TeV

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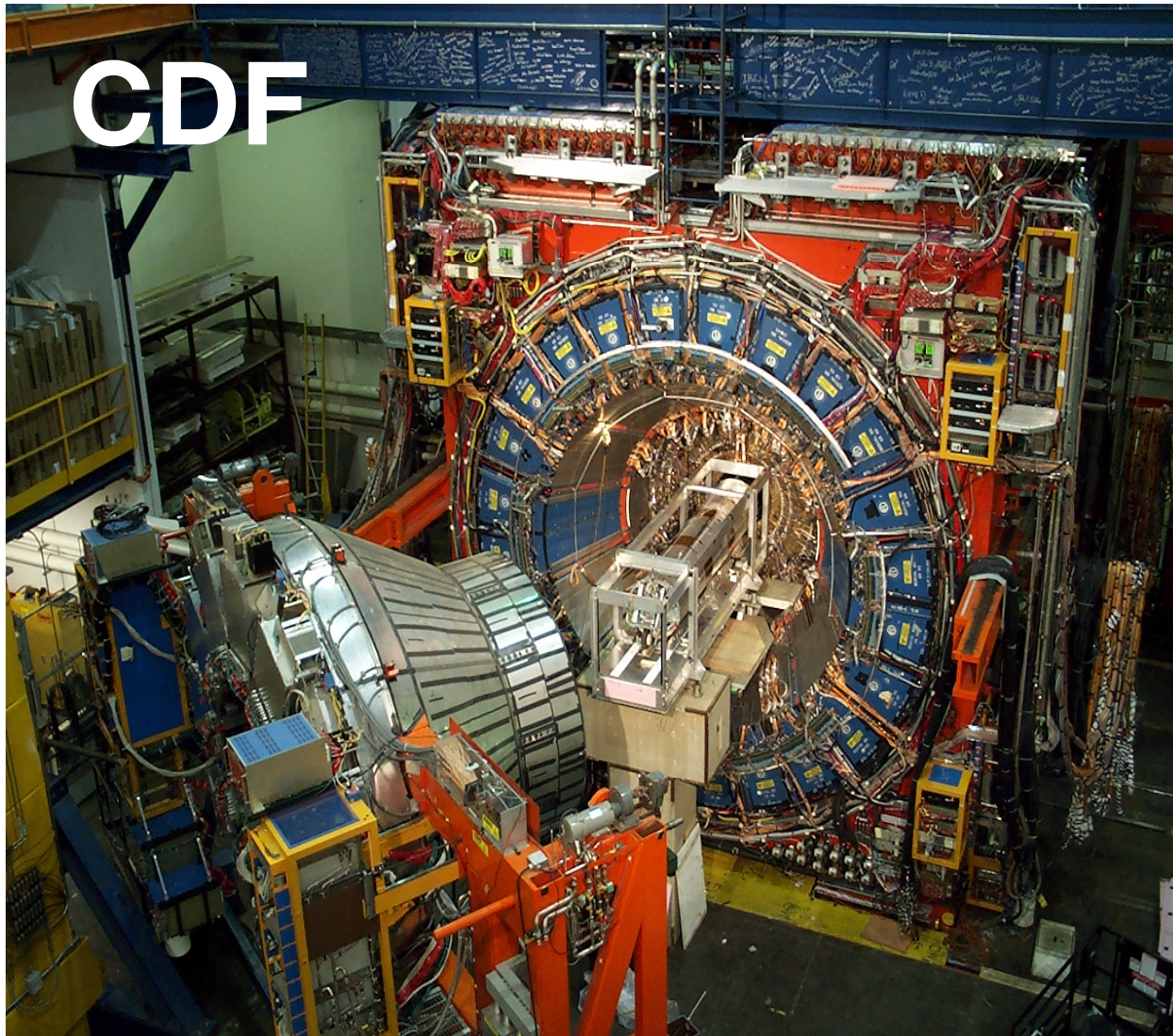
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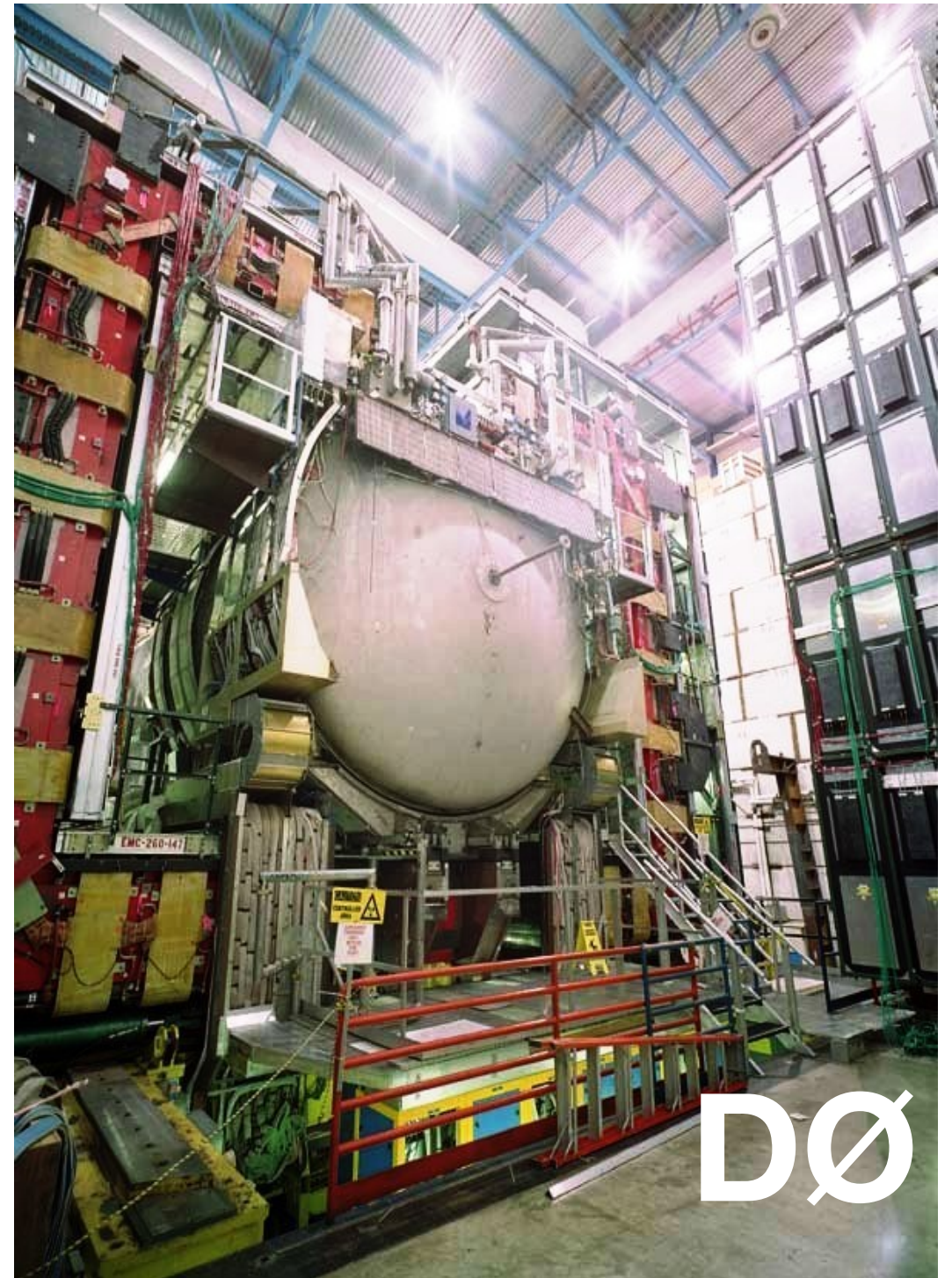


3 Spanish institutions have joined over the years, starting in 1995:
Instituto de Física de Cantabria (**IFCA**), Instituto de Física de Altas Energías (**IFAE**) and Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (**CIEMAT**)

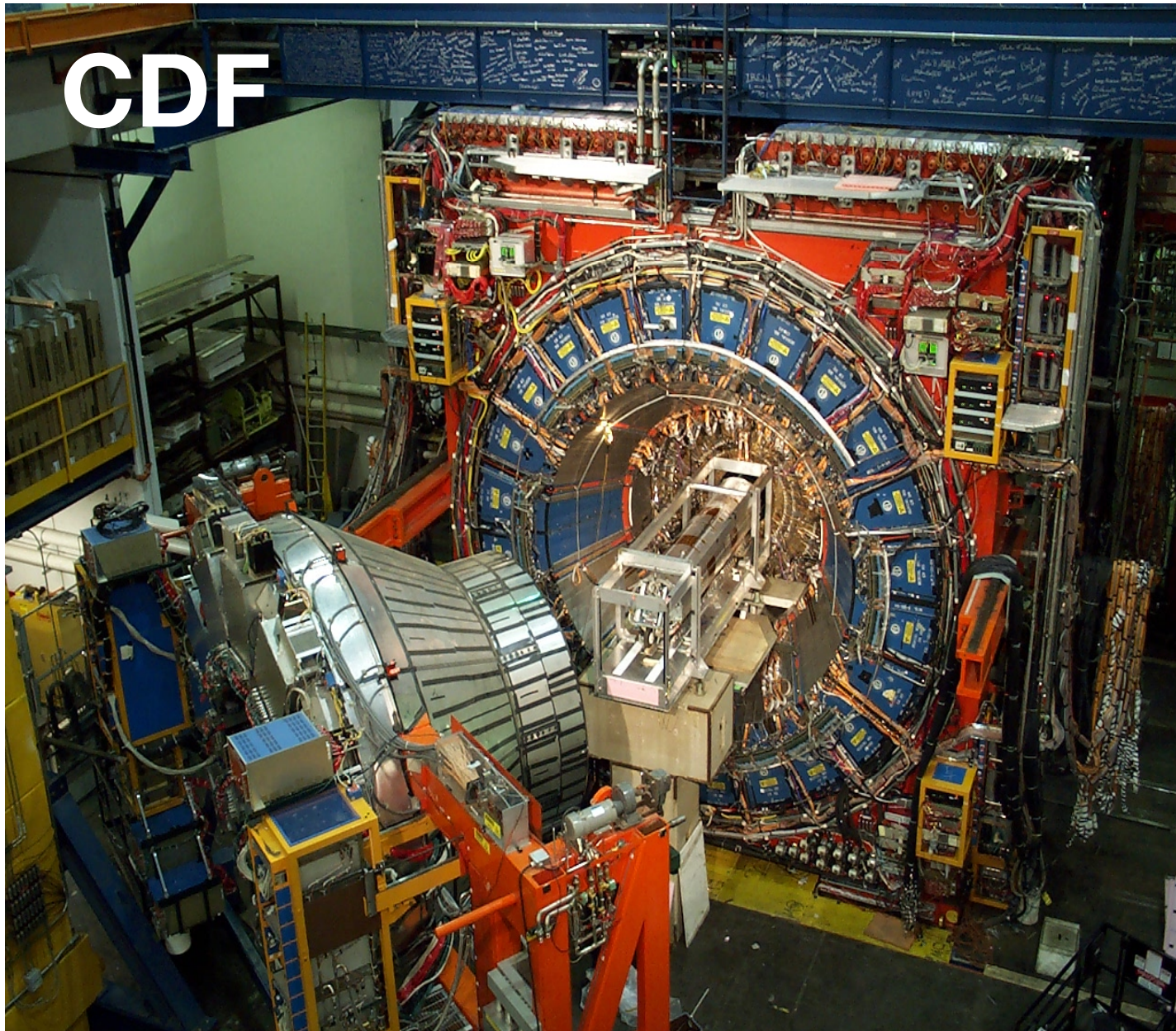
The Experiments



Major detector
upgrades for Run 2



The Experiments



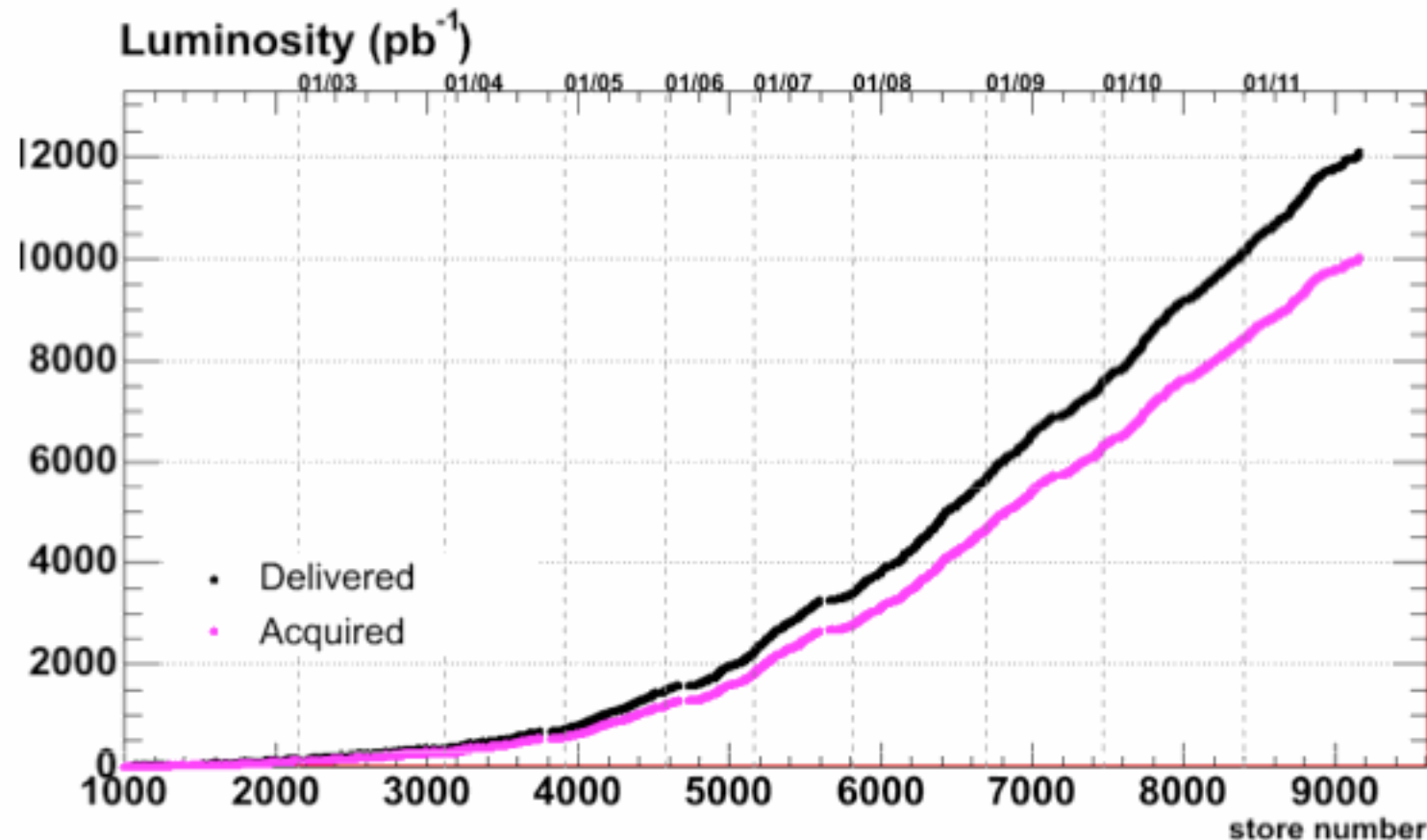
- Silicon detector : leading role in its operation (CIEMAT)

✓ Longevity studies

PhD Thesis R. Martinez Bellarin (CIEMAT)

- TOF detector : leading role in its operation (IFCA)

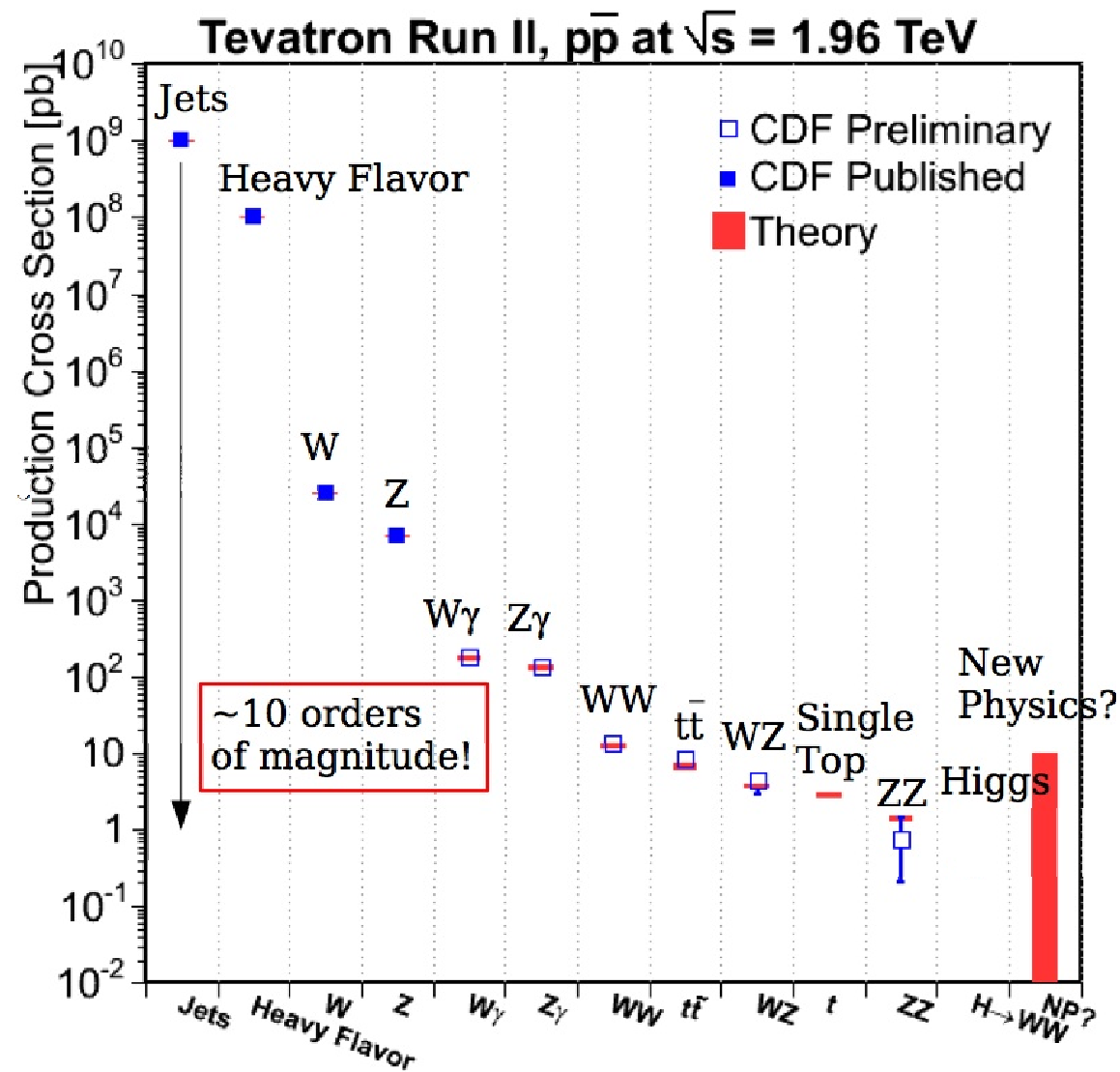
Performance



10 fb⁻¹ of good data for physics per experiment

⇒ CDF Data quality monitoring
online and offline levels (IFAE)

The Tevatron program and Results



Tevatron highlights

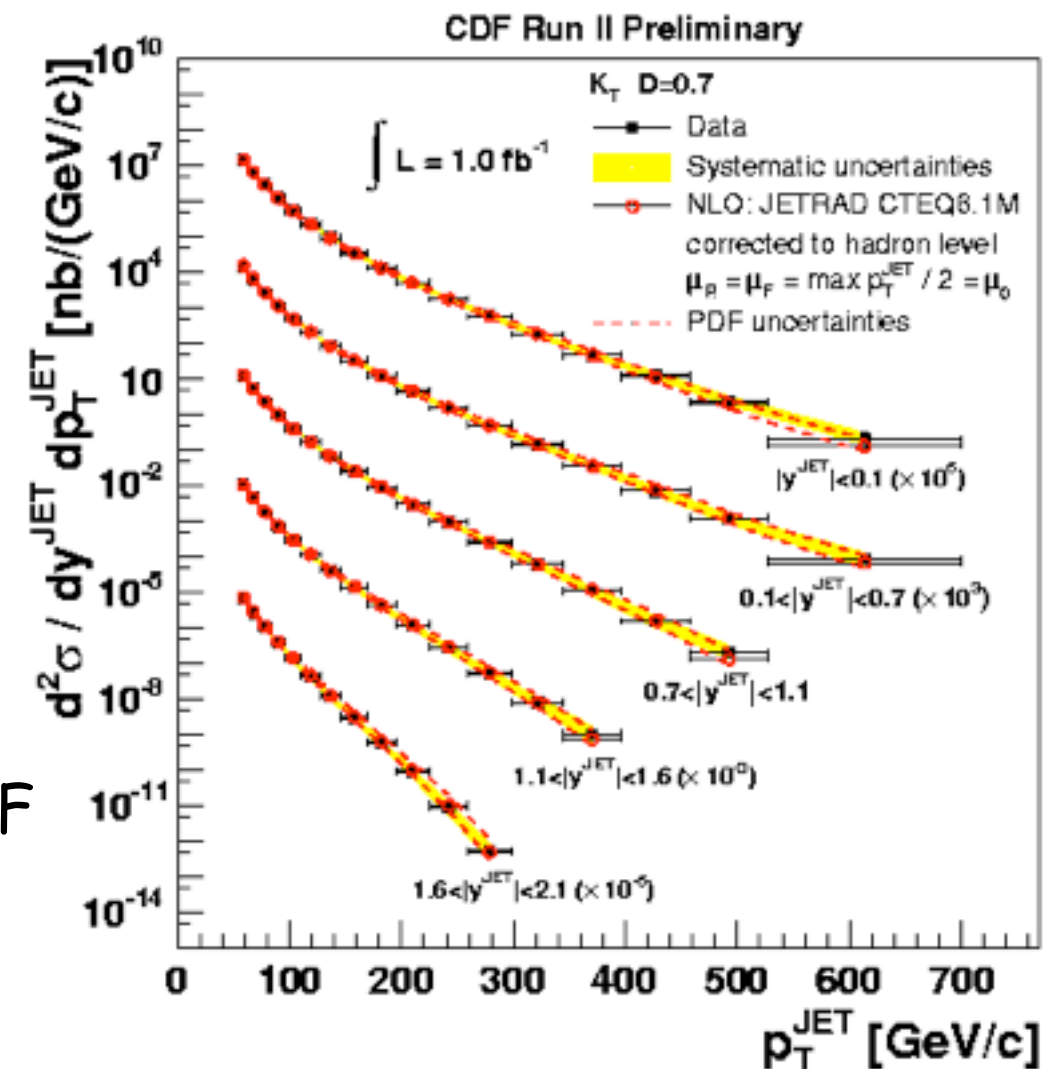
and

contributions from
spanish institutions

QCD

Contributions from IFAE
leading roles, analyses, theses

- Inclusive jet cross sections
 - Test pQCD over ~ 9 order of magnitude:
 - ▶ p_T range up to 700 GeV and rapidity up to 2.4
 - Constrain gluon PDF
 - included for MSTW08 PDF



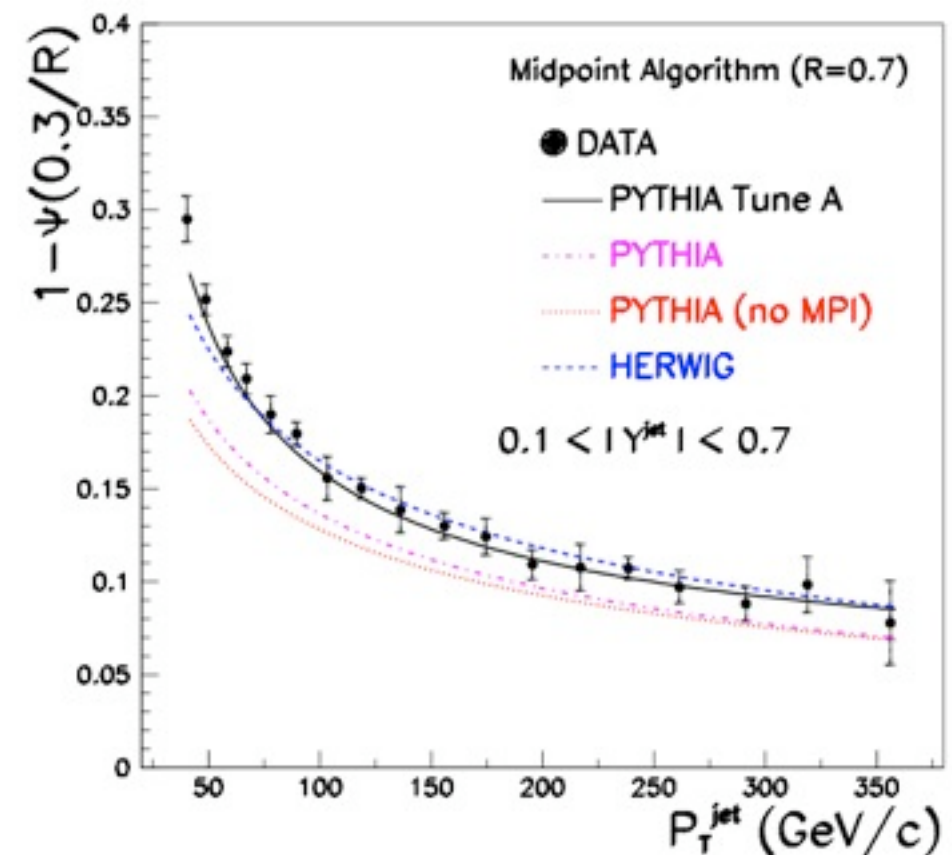
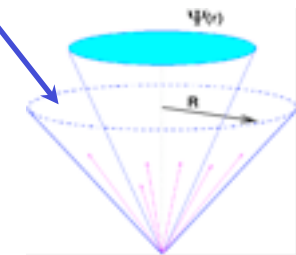
PhD Thesis O. Norniella (IFAE)

QCD

- Inclusive jet cross sections
 - Test pQCD over ~ 9 order of magnitude:
 - p_T range up to 700 GeV and rapidity up to 2.4
 - Constrain gluon PDF
- Jet properties
 - jet shapes: internal jet structure studies
 - test models for parton showers and underlying event

IFAE

$1 - \Psi(r)$

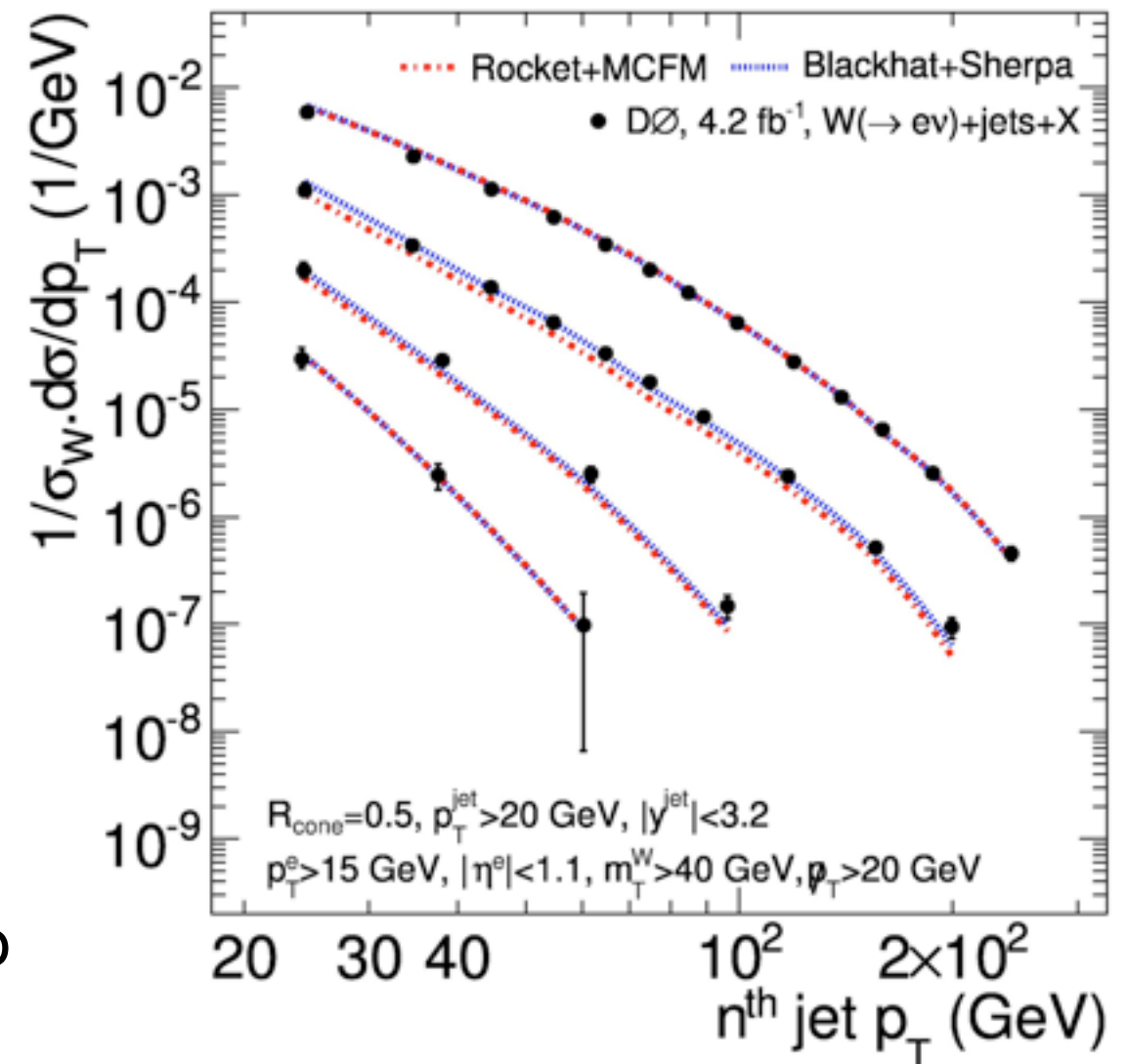


used recently for Perugia2010 tune

QCD

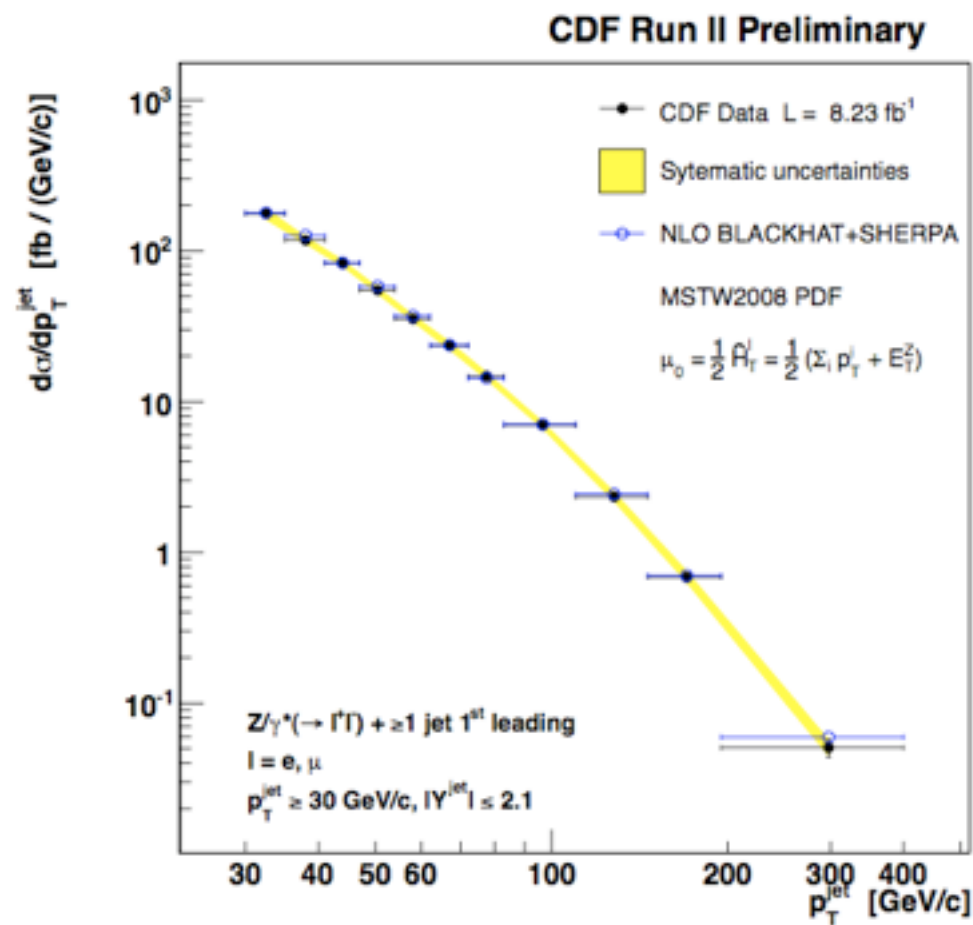
- Boson + jet production
 - Test QCD predictions
 - Background to new physics searches
 - Large theoretical uncertainties specially in the case of HF

⇒ suite of dedicated measurements up to $N_{\text{jet}} \leq 4$



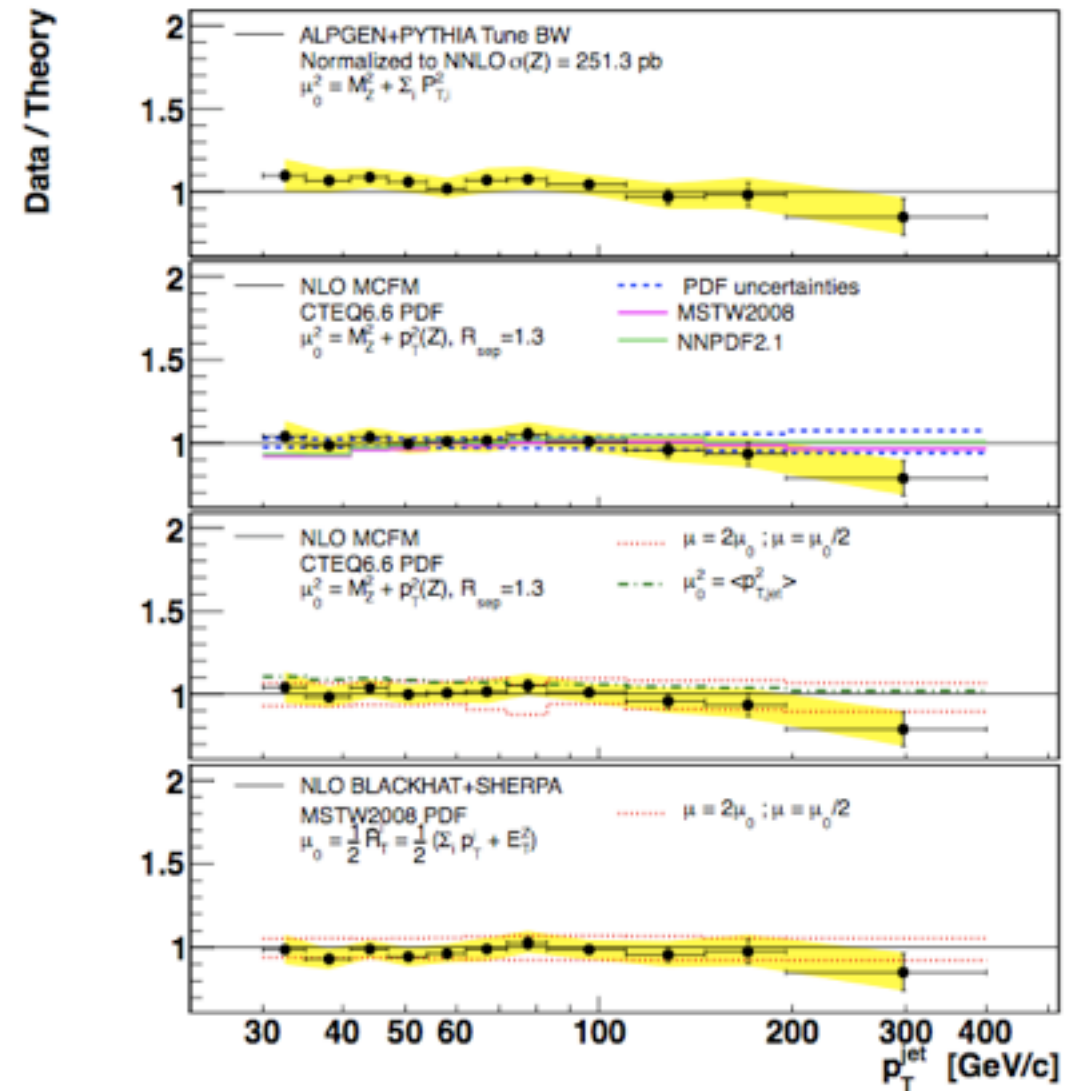
QCD

Z+jet production



in good agreement with NLO pQCD

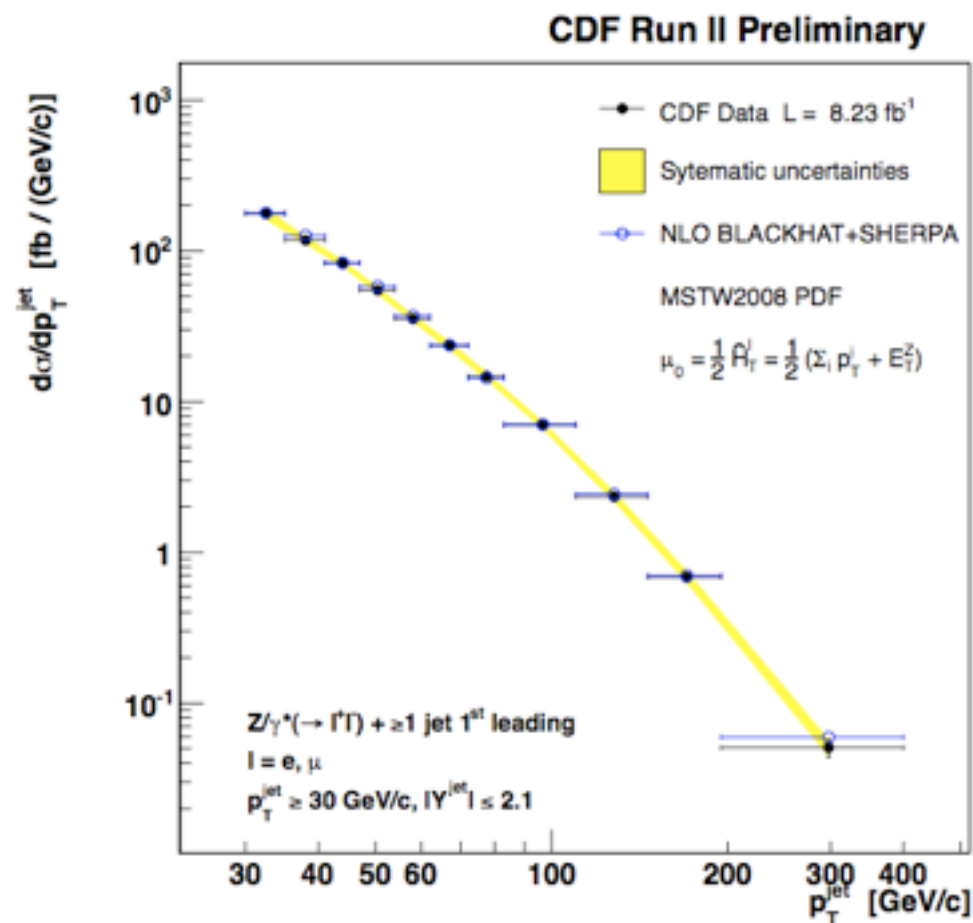
Analysis S. Camarda (IFAE)



Input for tuning MC

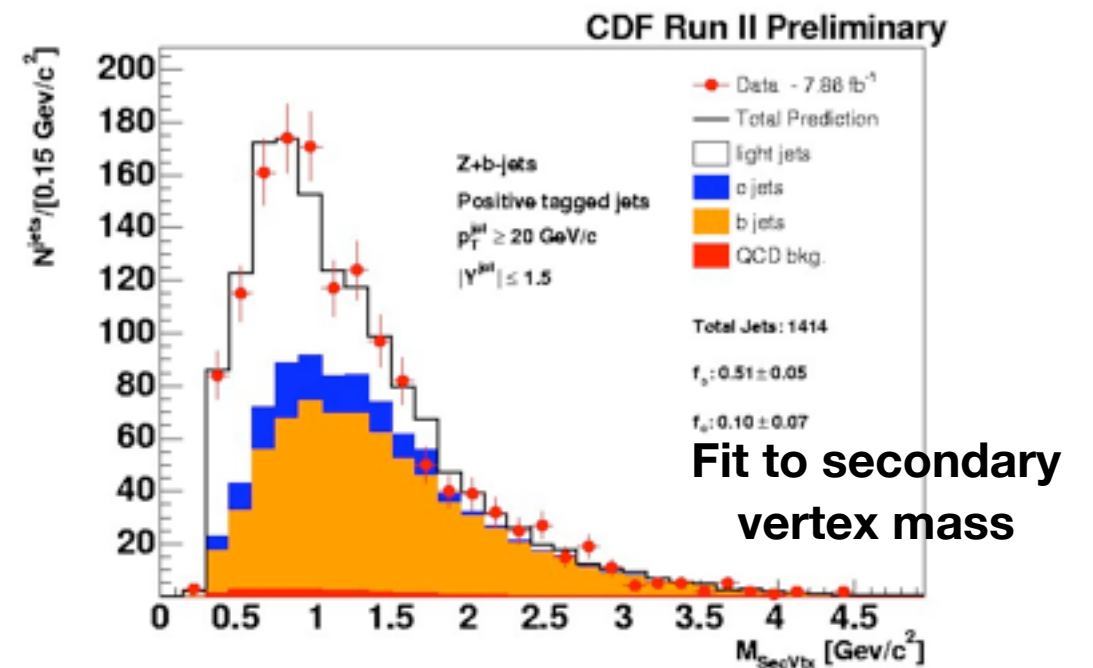
QCD

Z+jet production



in good agreement with NLO pQCD

Analysis S. Camarda (IFAE)



$z+b/z+\text{jet} = 2.24 \pm 0.36 \%$
 in agreement with NLO

Analysis L. Ortolan (IFAE)

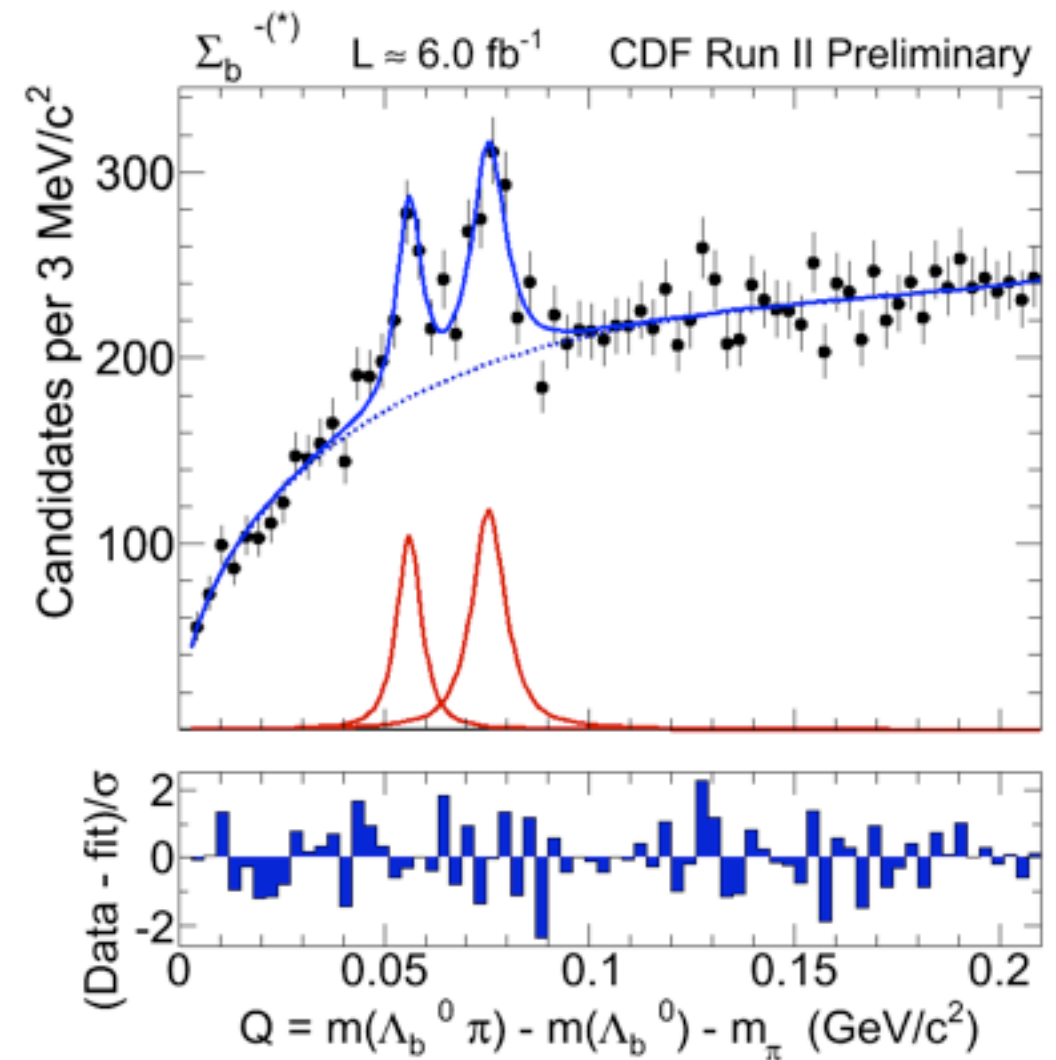
Heavy Flavor Physics

Large production cross sections , large data samples and developments such as **dedicated triggers** to select displaced tracks

⇒ broad heavy flavor physics program

First observation of b mesons and baryons : B_c , Σ_b , Ξ_b , Ω_b , $X(3872)$

- Precise measurements of b hadron properties such as mass and lifetimes



PhD Thesis C. Calancha (CIEMAT)

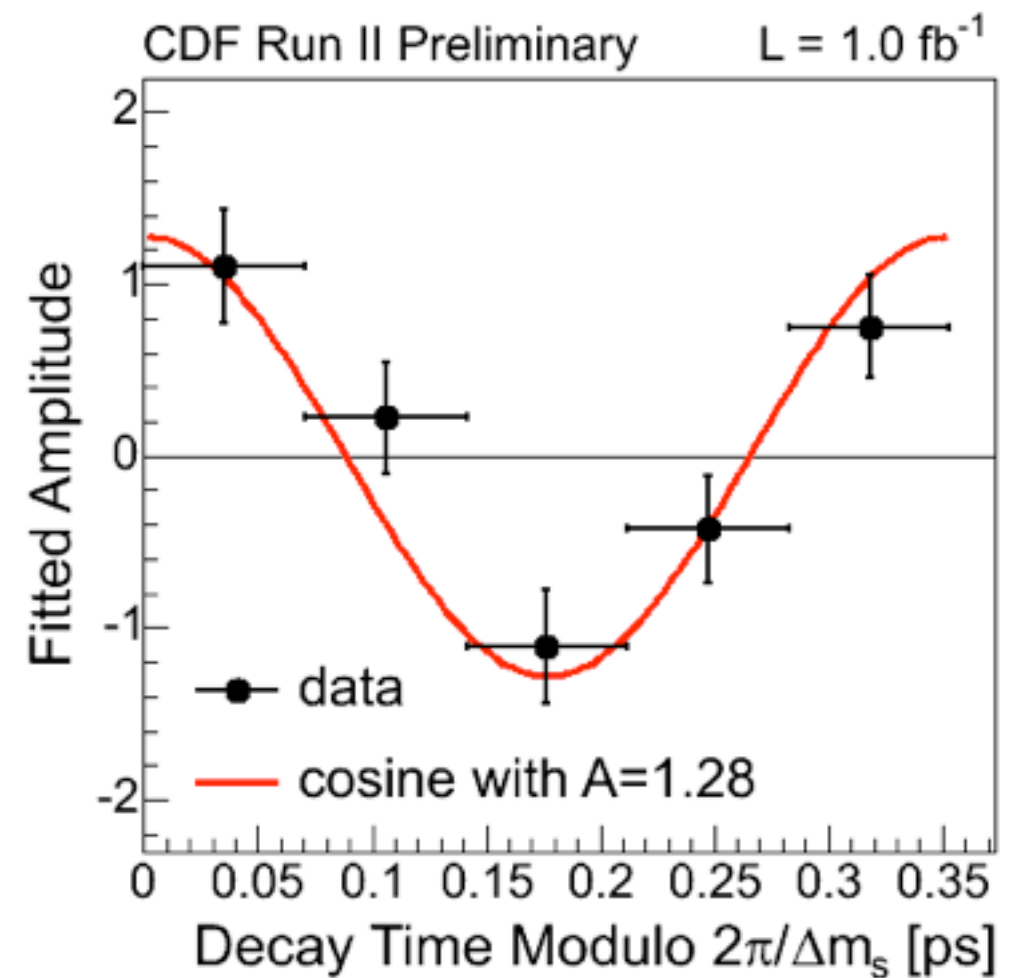
Heavy Flavor Physics

Large production cross sections , large data samples and developments such as **dedicated triggers** to select displaced tracks

⇒ broad heavy flavor physics program

Observation B_s mixing : 2006

- mixing frequency compatible with SM expectations



Participation from IFCA
PhD thesis J. Piedra

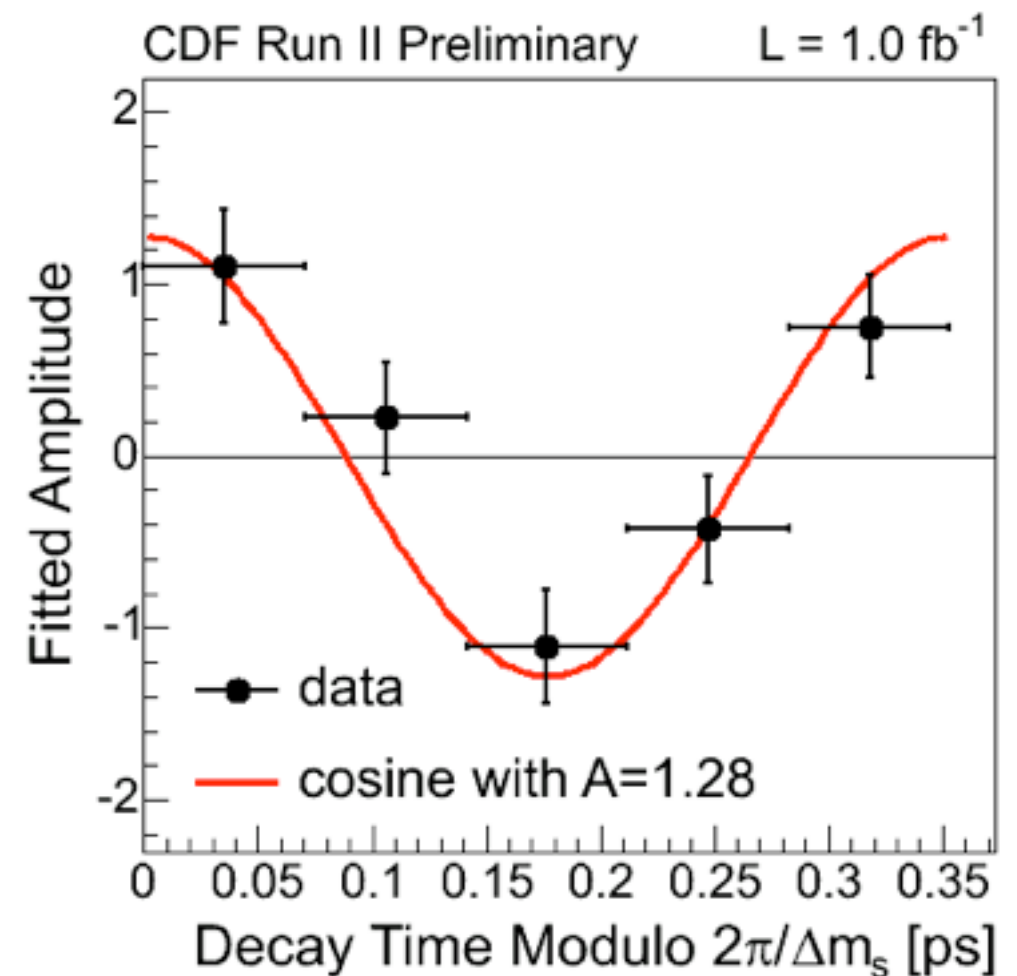
Heavy Flavor Physics

Large production cross sections , large data samples and developments such as **dedicated triggers** to select displaced tracks

⇒ broad heavy flavor physics program

Observation B_s mixing : 2006

- ▶ mixing frequency compatible with SM expectations
- ▶ Evidence of $D\bar{D}$ mixing (2008) (confirming result from BABAR)



Heavy Flavor Physics

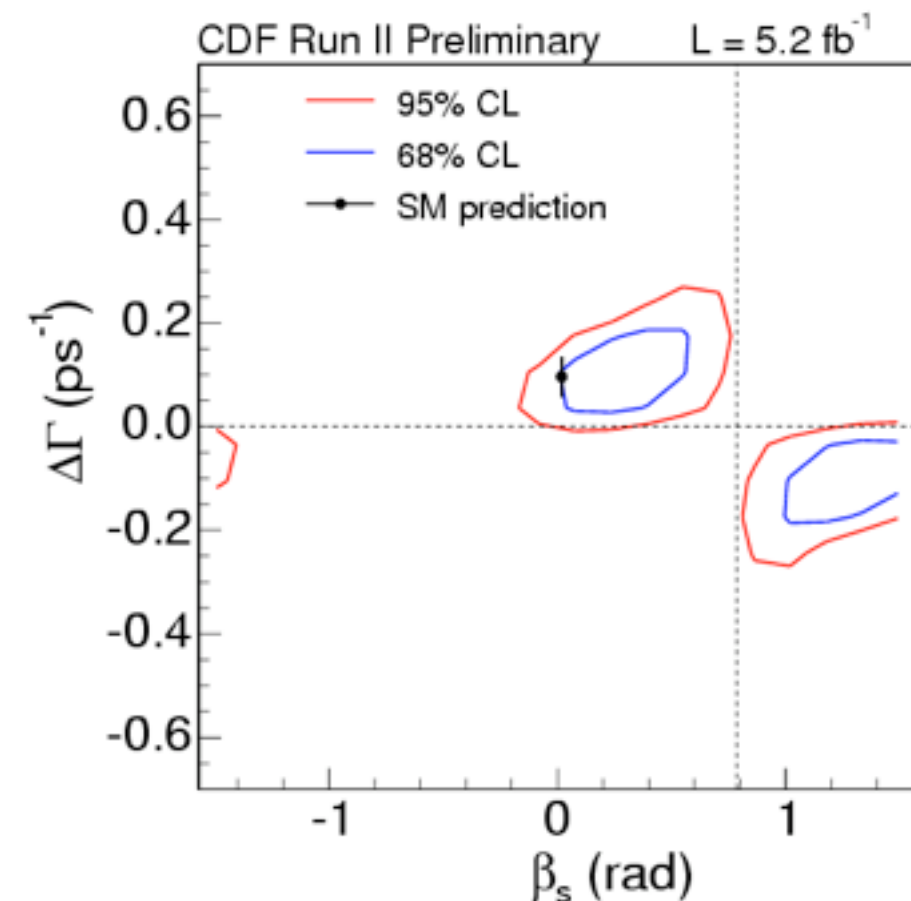
Large production cross sections , large data samples and developments such as **dedicated triggers** to select displaced tracks

⇒ broad heavy flavor physics program

New Physics ...

- ▶ CP-violation in B_s system
- ▶ dimuon asymmetry
- ▶ Rare decays...

CP violation phase



in agreement with SM

Heavy Flavor Physics

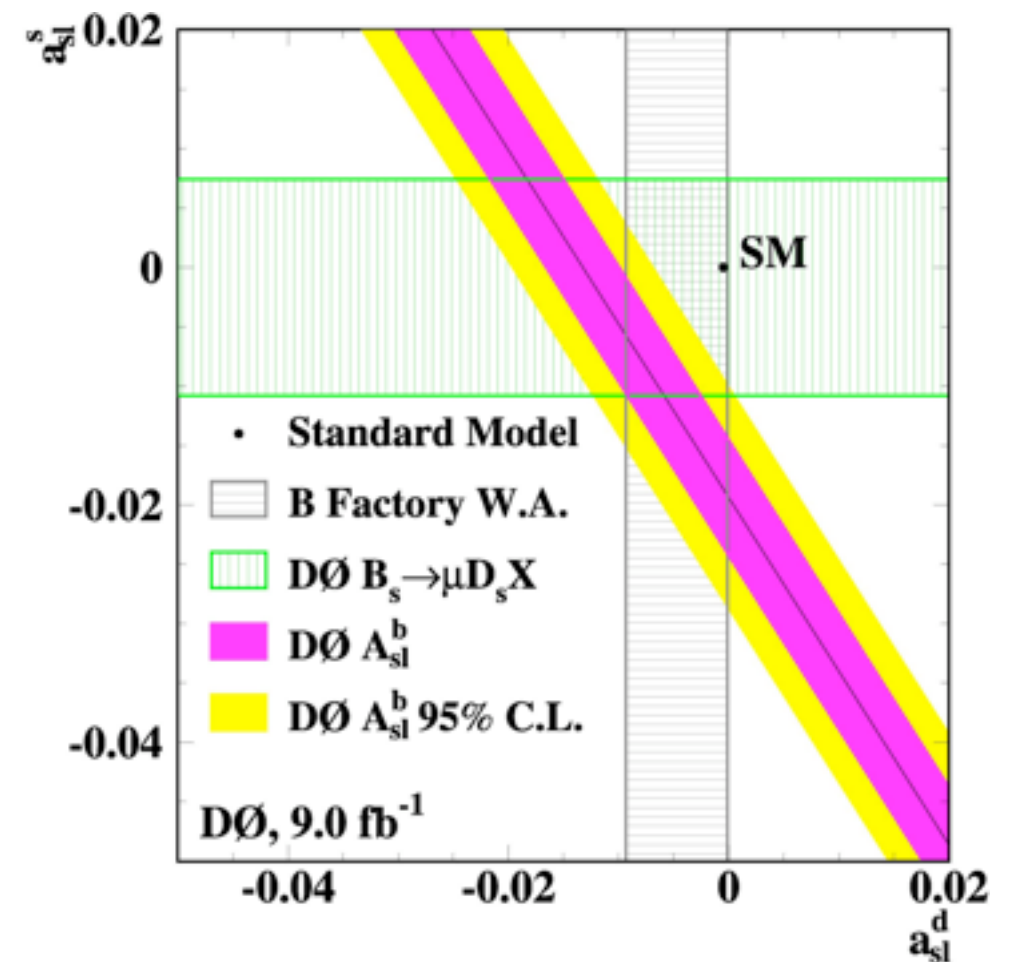
Large production cross sections , large data samples and developments such as **dedicated triggers** to select displaced tracks

⇒ broad heavy flavor physics program

New Physics ...

- ▶ CP-violation in B_s system
- ▶ dimuon asymmetry
- ▶ Rare decays...($B_s \rightarrow \mu^+\mu^-$)

anomalous like-sign dimuon asymmetry



disagree with SM by 3.9σ

Beyond the SM

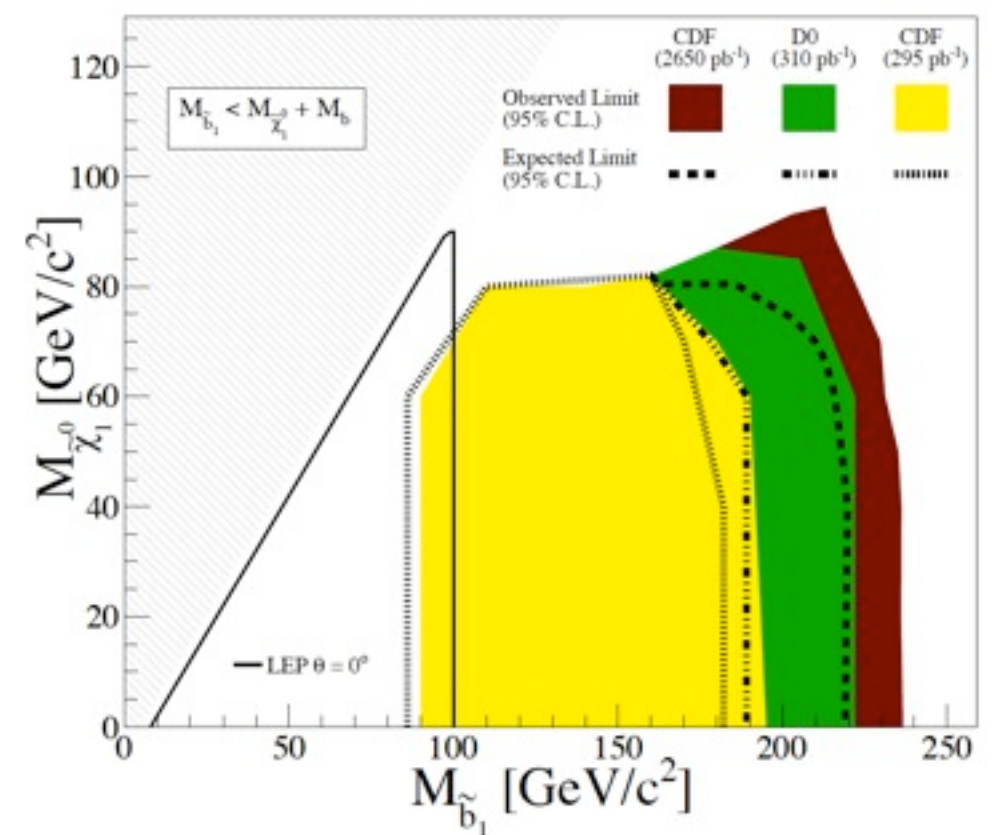
- Huge effort exploring the large data sample, work that have set constrains on many models
- One of the most attractive:
Supersymmetry

Involvement in various leading roles from CIEMAT and IFAE Analysis and several thesis

Squark and gluino search

Missing E_T + Jets

sbottom pair production



PhD Thesis G. De Lorenzo (IFAE)

Beyond the SM

- Huge effort exploring the large data sample, work that have set constraints on many models
- One of the most attractive:
Supersymmetry

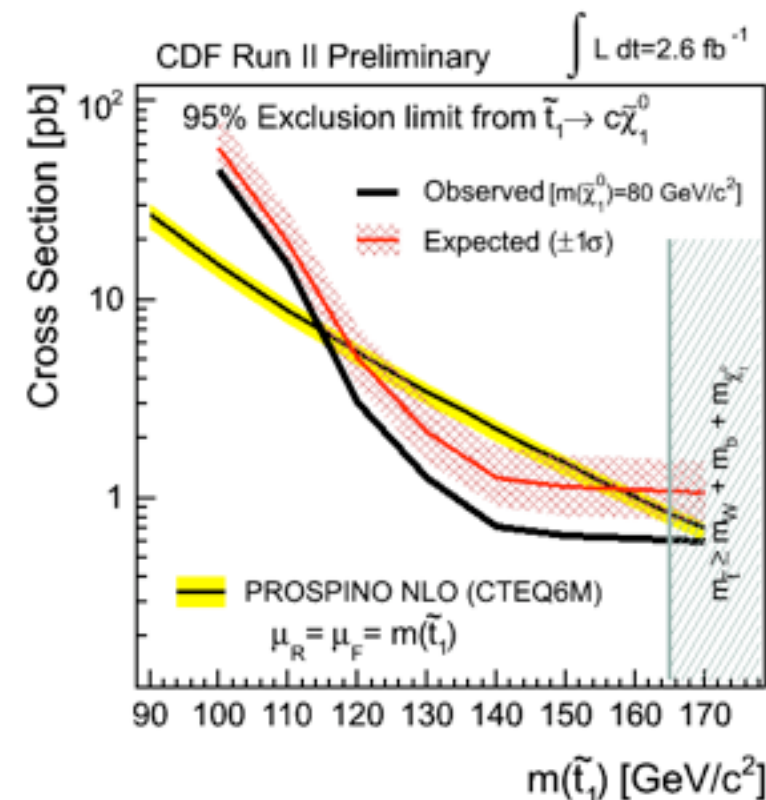
Involvement in various leading roles from CIEMAT and IFAE Analysis and several thesis

Many techniques now applied at LHC

Squark and gluino search

Missing E_T + Jets

stop into charm and neutralino



Optimized via a flavor separator to enhance charm contribution

PhD Thesis M. Vidal (CIEMAT)

Top Quark Physics

- **Discovery by CDF and DØ in 1995**



- Since then many of its properties have been studied.
- Some measured with extraordinary precision
- Most of its properties are in agreement with the SM prediction



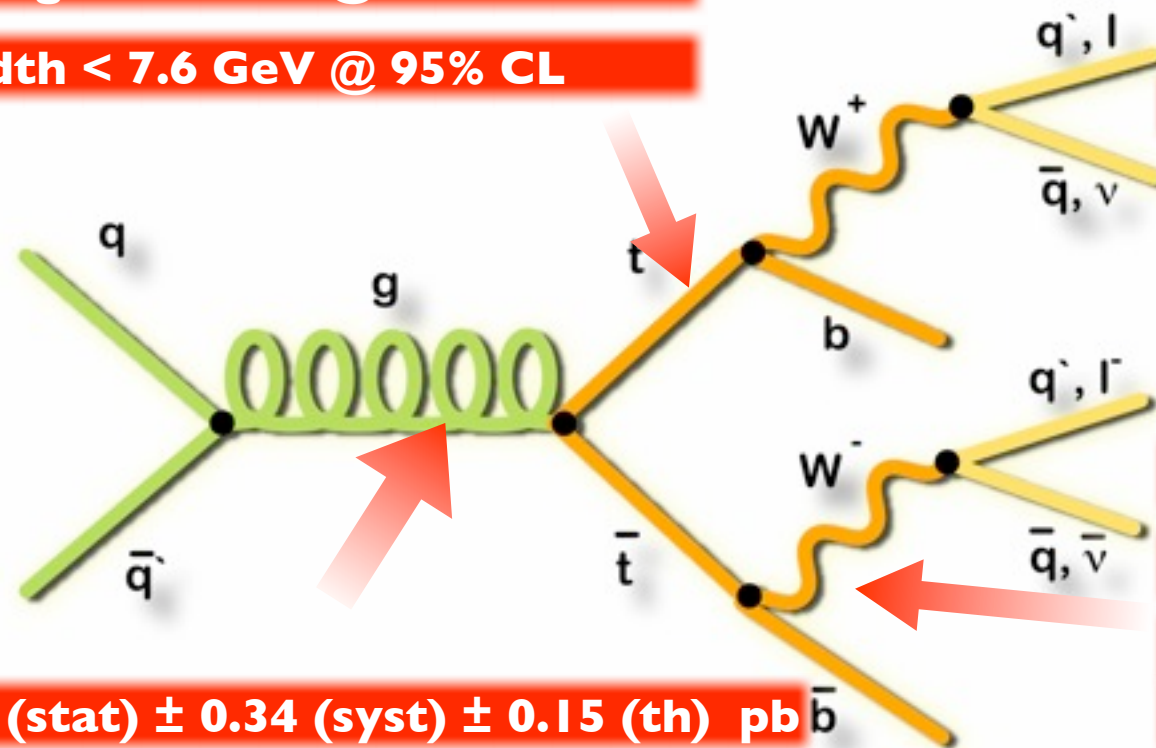
Top Quark Physics

Important involvement from IFCA and IFAE
since discovery times, leading roles,
several analysis and thesis

$M_t = 173.1 \pm 0.6 \pm 1.1 \text{ GeV}/c^2 \text{ (TeV comb.)}$

Top charge : not 4/3 @ 99% CL

Top width < 7.6 GeV @ 95% CL



anom coupl : no evidence found

$f_+ = 0.110 \pm 0.059 \text{ (stat)} \pm 0.052 \text{ (syst)}$

spin correlations in agreement with SM

$B(t \rightarrow Wb)/B(t \rightarrow Wq) = 0.97 \pm 0.09$

$BR(t \rightarrow Zq) < 3.7\% \text{ at } 95\% \text{ C.L.}$

No evidence for $top \rightarrow H^+b$

No evidence for ttH production

Excl. $M_{t'} < 358 \text{ GeV}$ at 95% CL

no evidence stop pair production

$\sigma = 7.5 \pm 0.31 \text{ (stat)} \pm 0.34 \text{ (syst)} \pm 0.15 \text{ (th)} \text{ pb}$

$A_{fb} = 20.1 \pm 6.5 \text{ (stat)} \pm 1.8 \text{ (syst)} \%$

Excl. $M_{Z'} < 900 \text{ GeV}$ at 95% CL

$d\sigma/dM_{tt}$ no discrepancy with SM

fraction via gg fusion : $0.07^{+0.15}_{-0.07}$

Single Top

$\sigma = 2.76 + 0.58 - 0.47 \text{ pb}$

Top Quark Physics

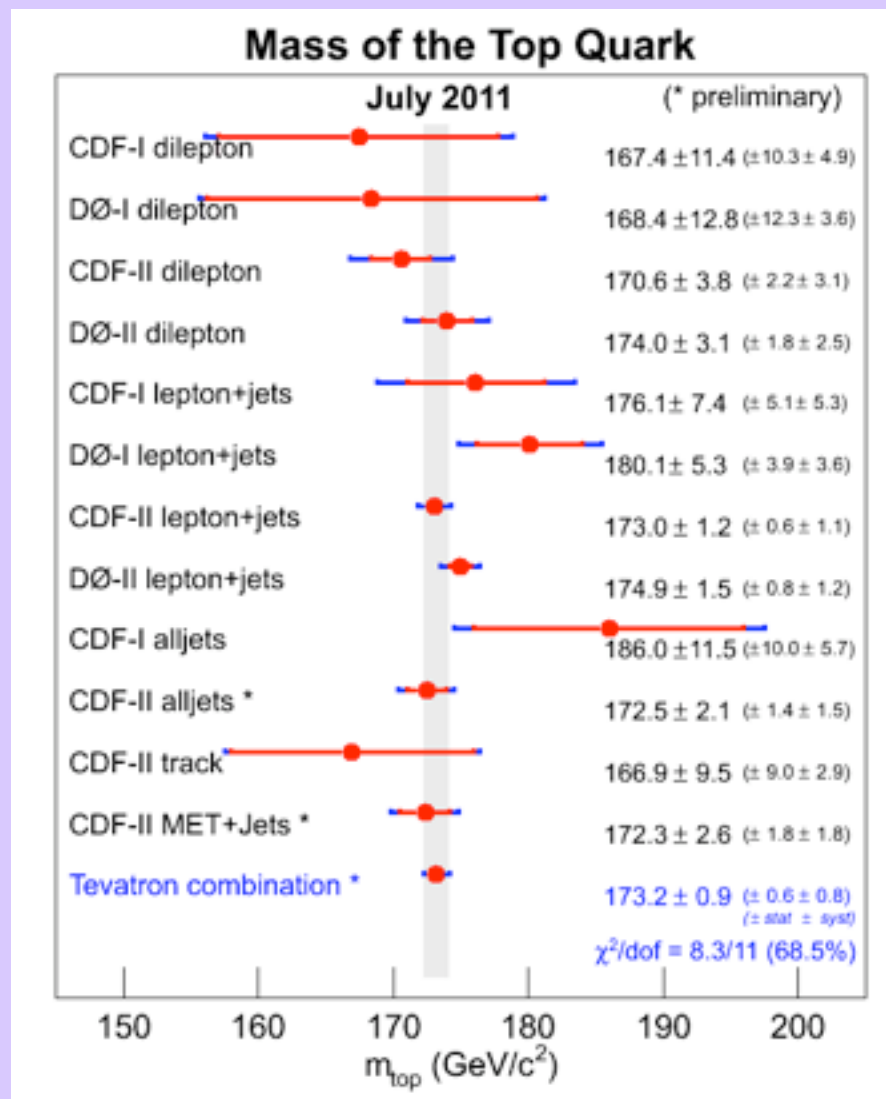
$M_t = 173.1 \pm 0.6 \pm 1.1 \text{ GeV}/c^2$ (TeV comb.)

Top charge

Top width

anom coupl : no evidence found

$\kappa = 0.110 \pm 0.050 (\text{stat}) \pm 0.052 (\text{syst})$



Tevatron
combination

$M_t = 173.2 \pm 0.9 \text{ GeV}/c^2$

uncertainty less than
1 GeV/c^2 !

systematically
dominated (JES)

$\sigma = 6.9 \pm 0.4$

Afb= 19%

Excl.

$d\sigma/dM$

fraction

± 0.09

C.L.

$t+b$

ction

% CL

uction

Top Quark Physics

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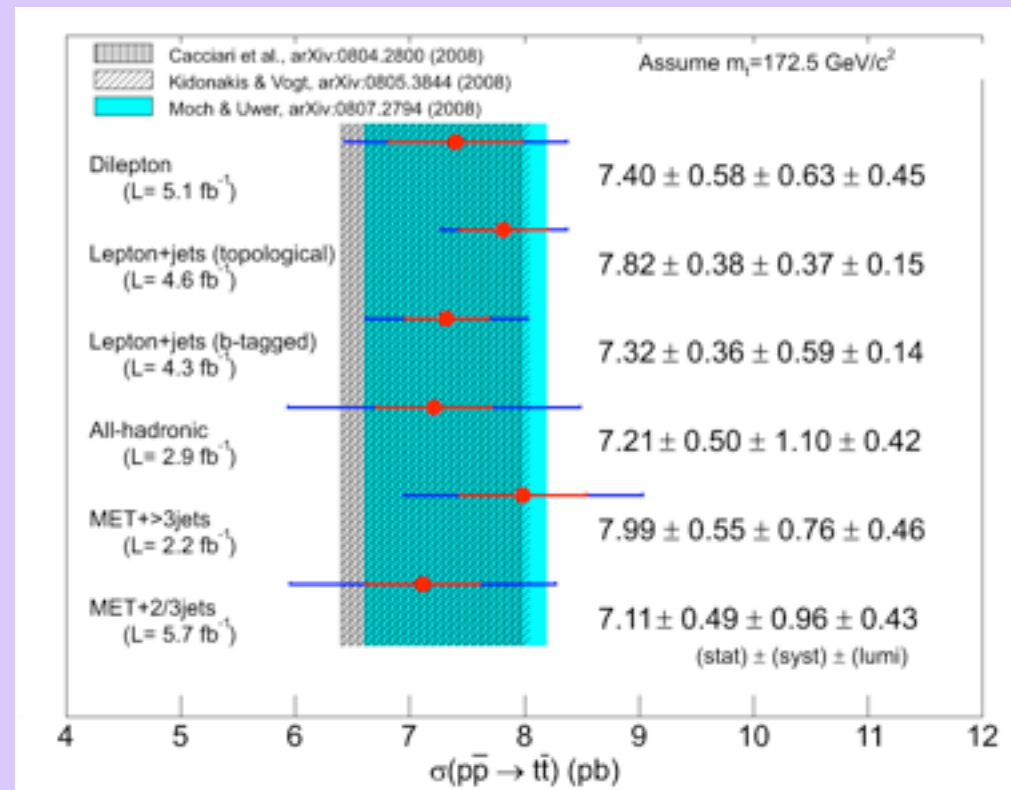
anom coupl : no evidence found

Top charge

2 (syst)

Top width

CDF combination $\sigma = 7.5 \pm 0.48 \text{ pb}$



6% uncertainty
challenging that
from theory

$\sigma = 6.9 \pm 0.4$

Afb= 19.3

Excl. M

dσ/dMt

fraction via gg fusion : $0.07^{+0.15}_{-0.07}$

0.09

C.L.

+b

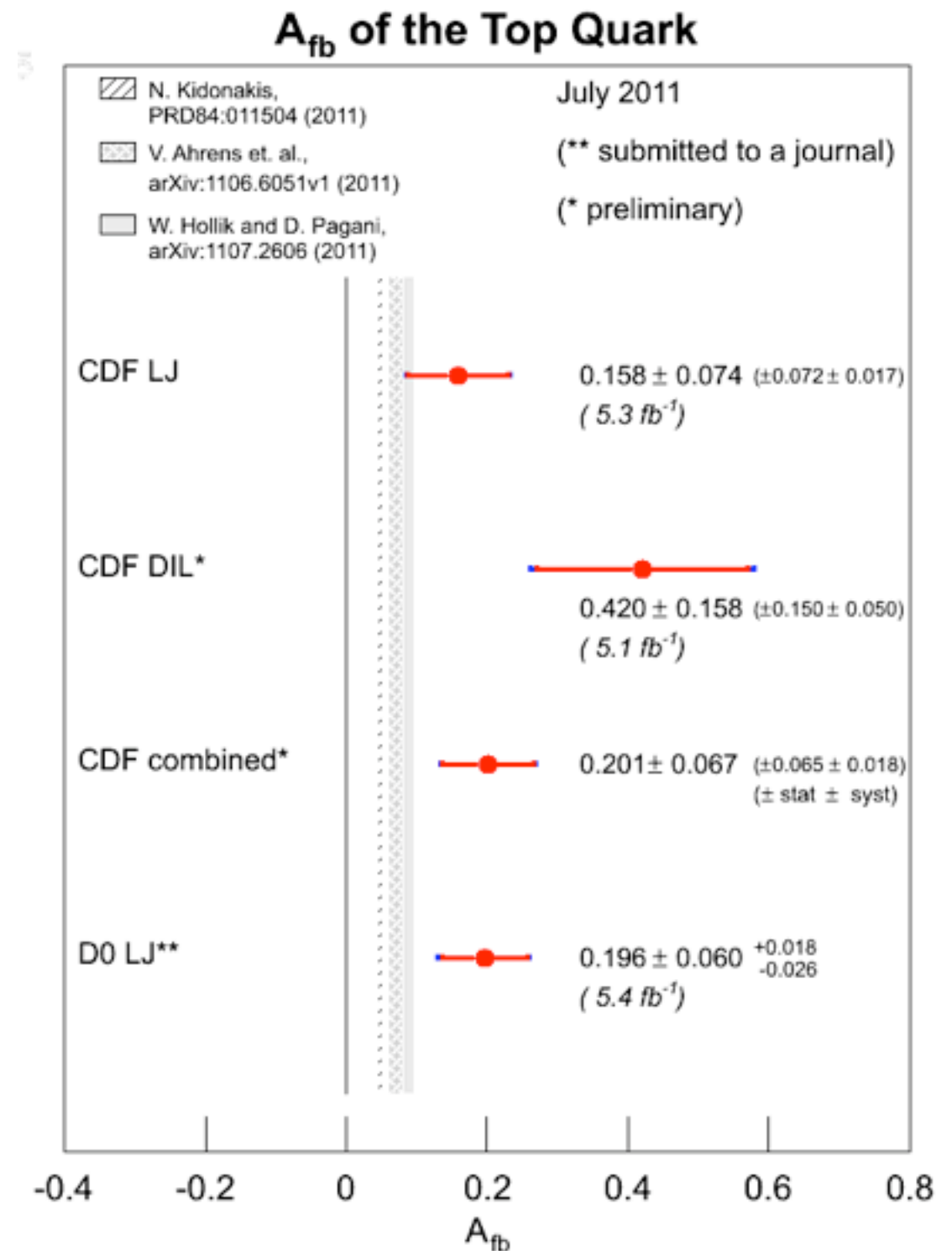
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CL

ction

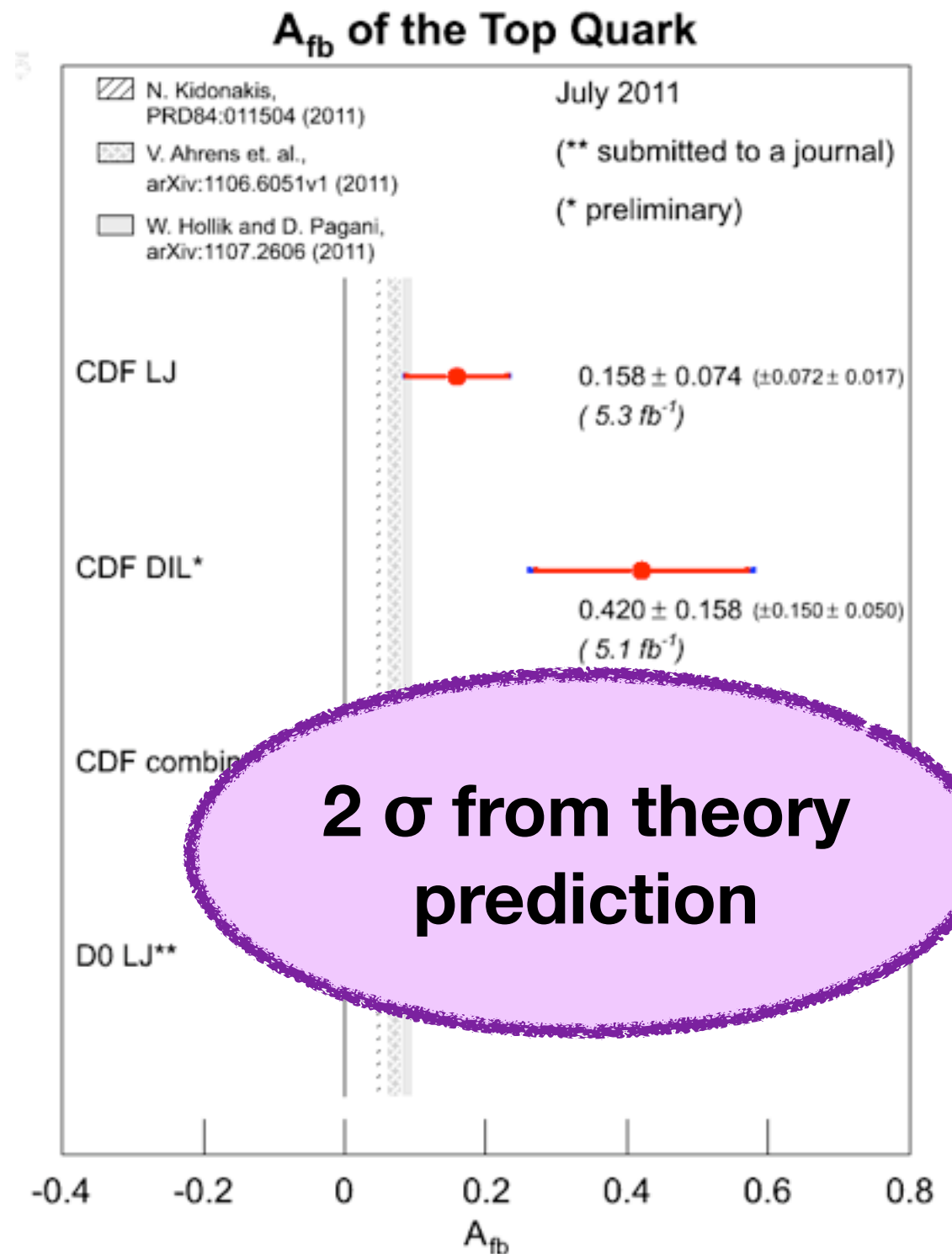
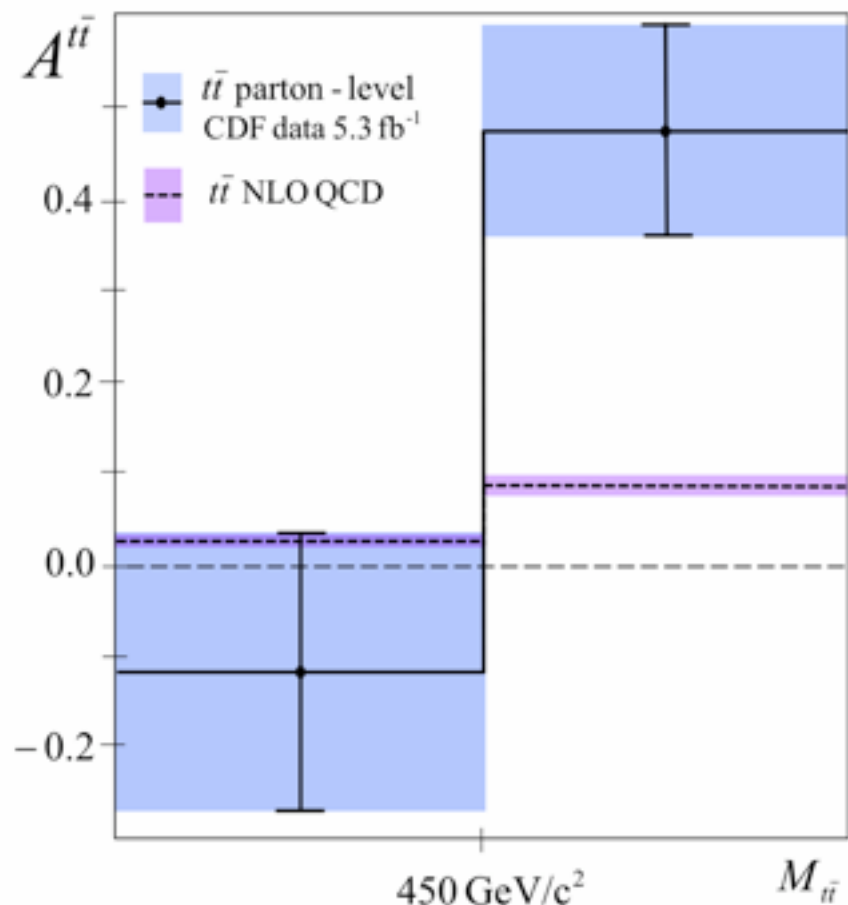
Top Quark Physics

- Top quark is mainly produced in pairs by the strong interaction
- NLO QCD calculations predicts a small forward-backward asymmetry of 5%



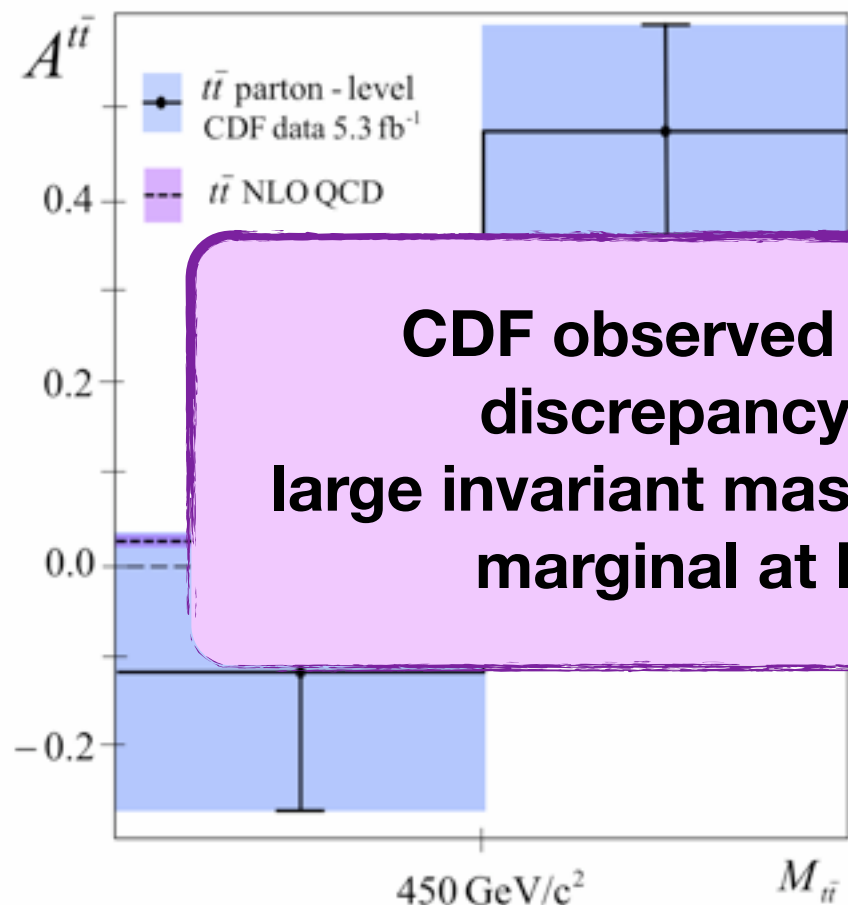
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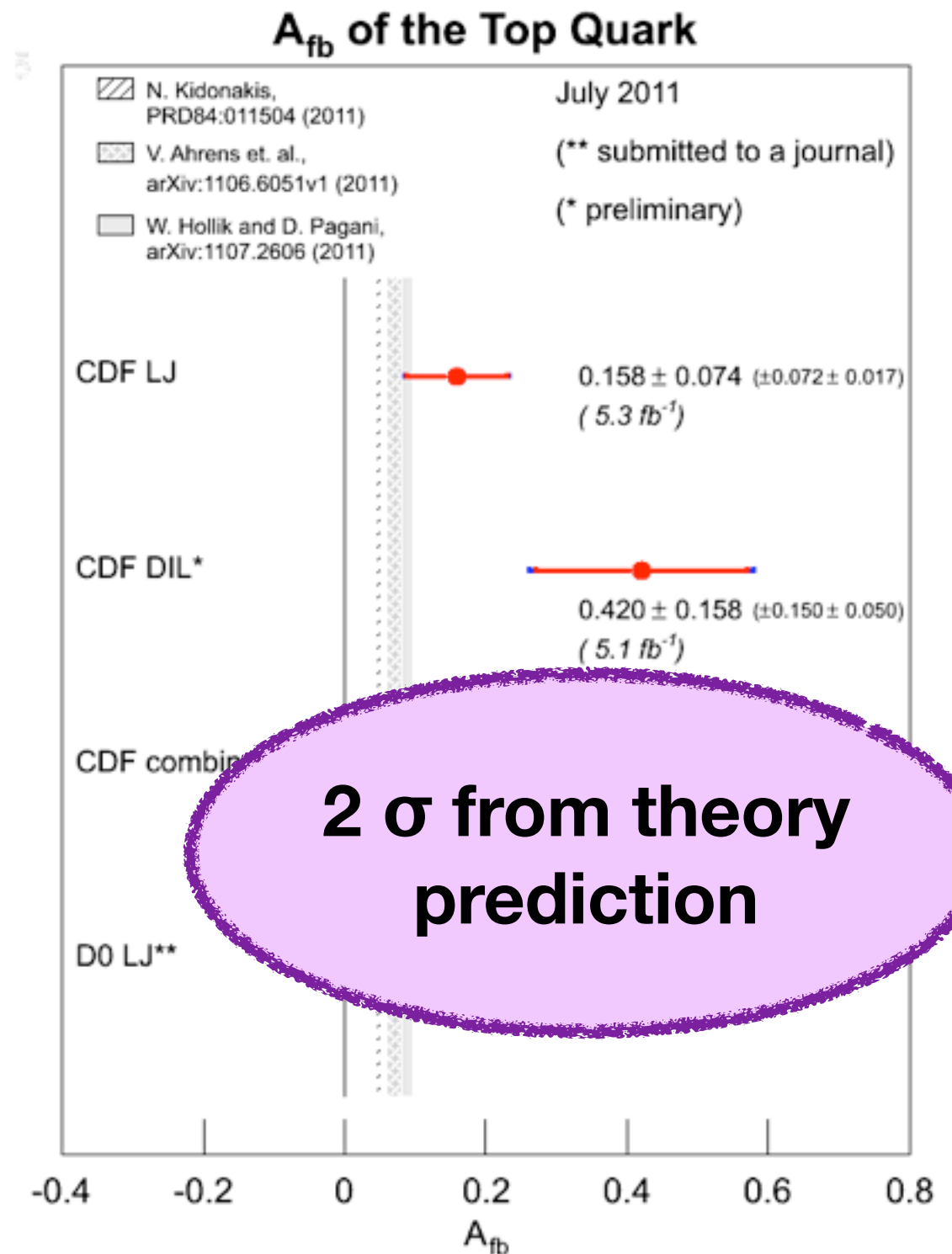


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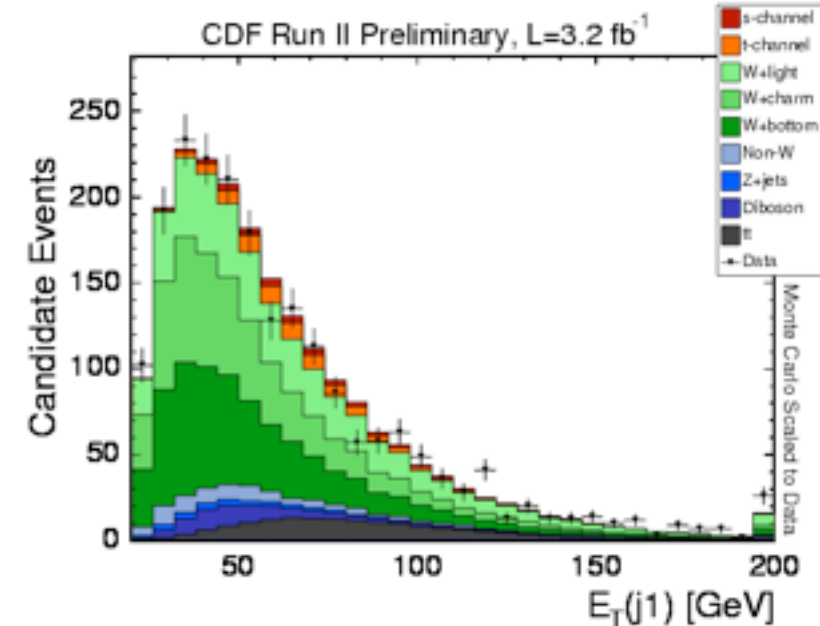
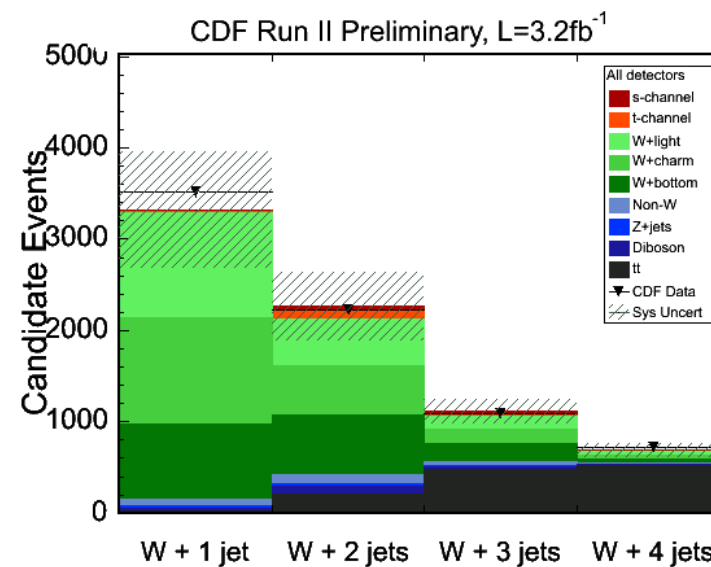


CDF observed a 3σ discrepancy at large invariant mass, though marginal at DØ

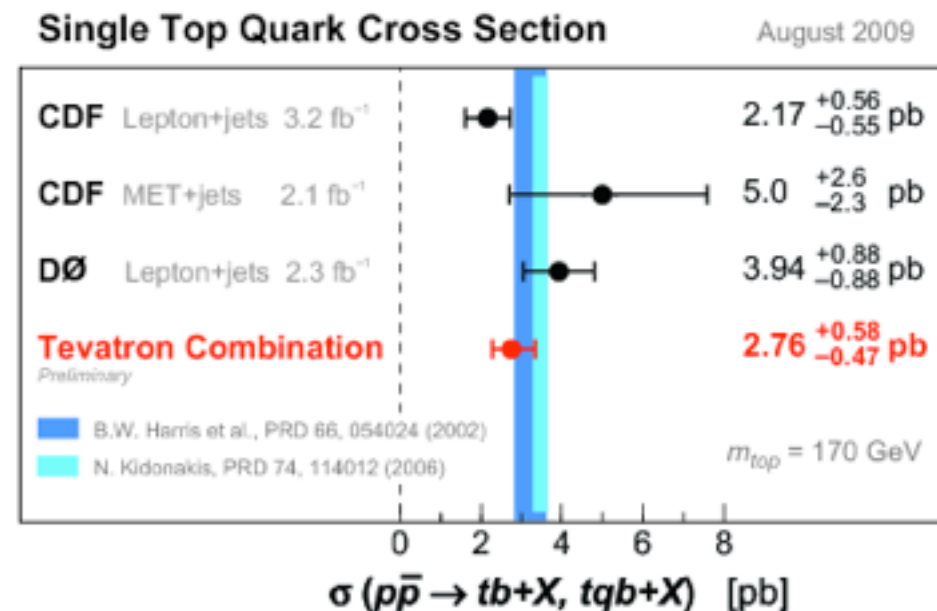


Top Quark Physics

- It is also produced singly by the EW interaction
- First observation by CDF and DØ in 2009
- Large backgrounds !
- Sophisticated multivariate analysis techniques
 - ▶ applied in searches for the Higgs boson

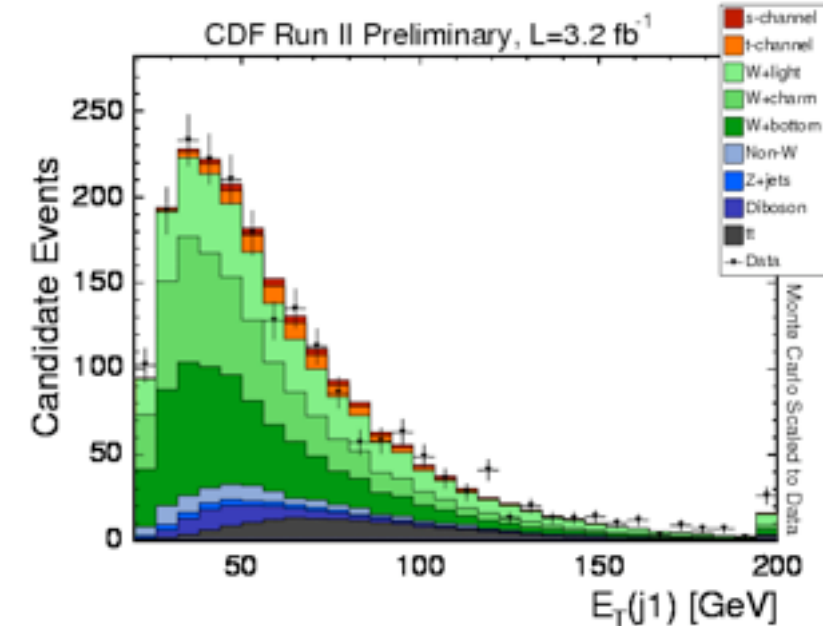
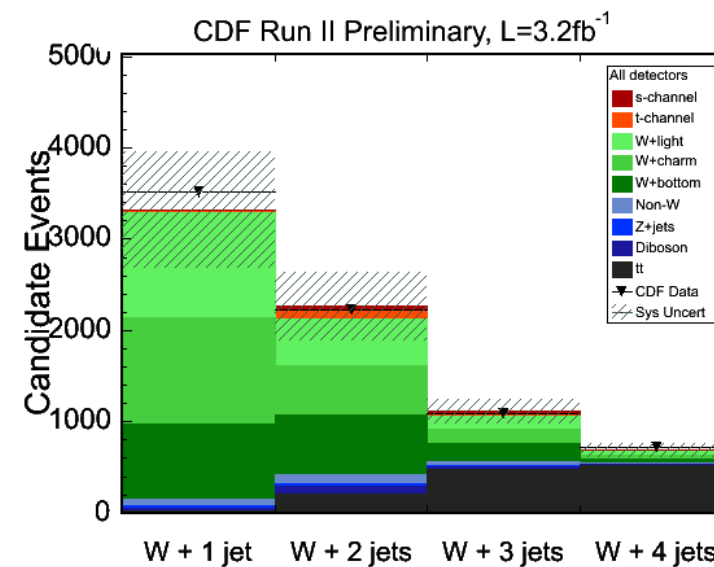


PhD Thesis B. Casal (IFCA)



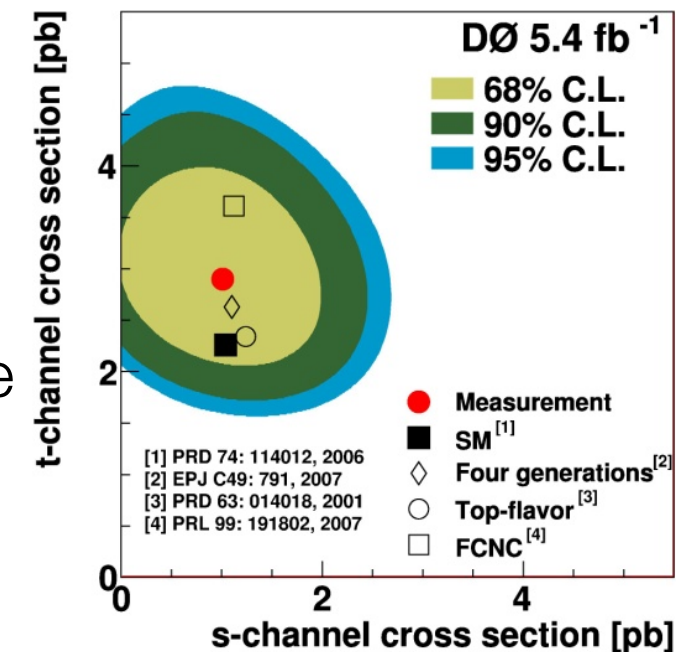
Top Quark Physics

- It is also produced singly by the EW interaction
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Separate t-channel
and s-channel

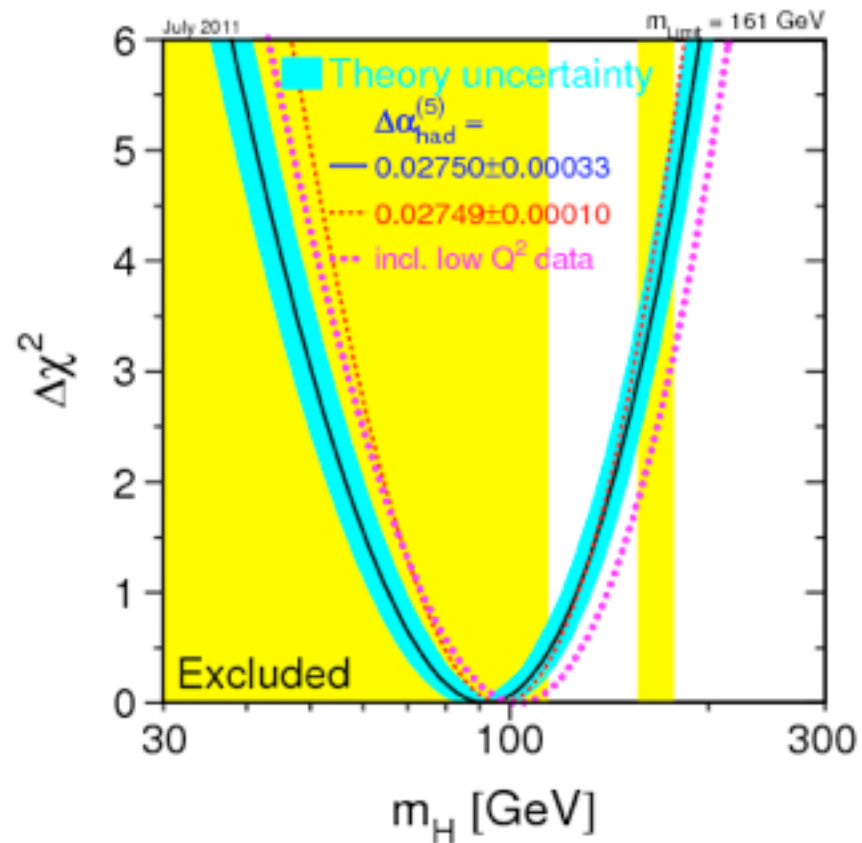
With a 5.5σ significance
for the t-channel



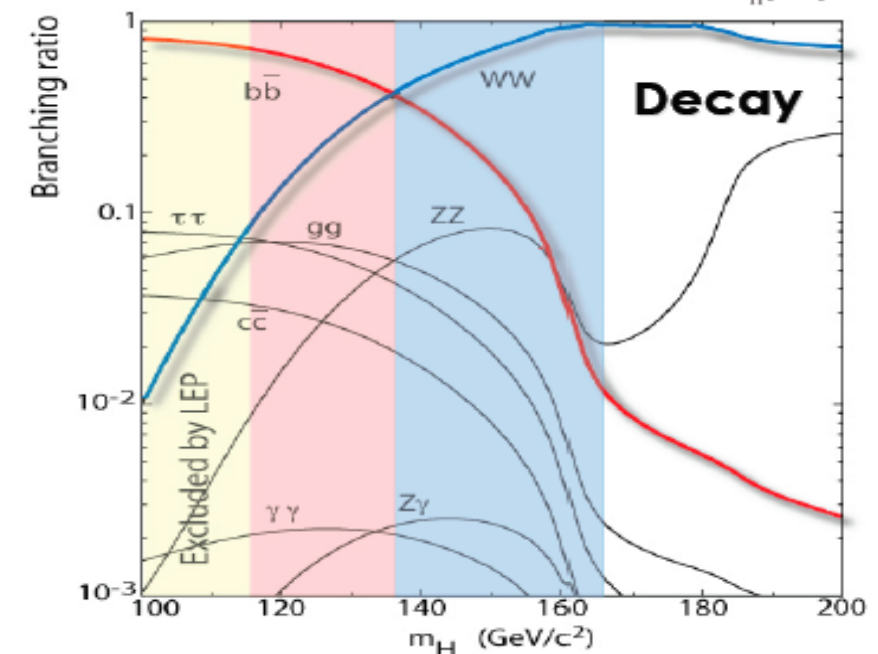
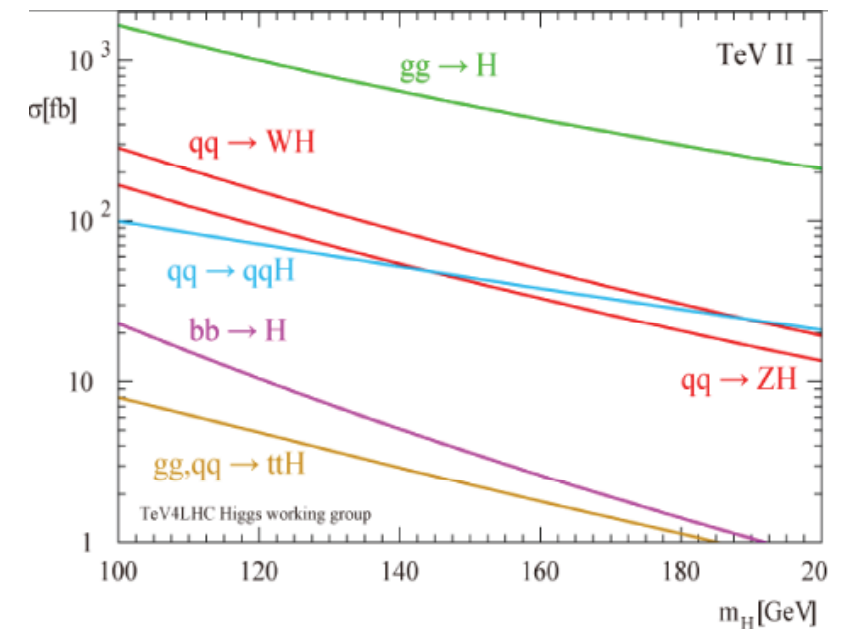
The Higgs Boson

- precision EW measurement and direct searches predicts

$$114.4 < m_H < 185 \text{ GeV (95\%CL)}$$



Tevatron

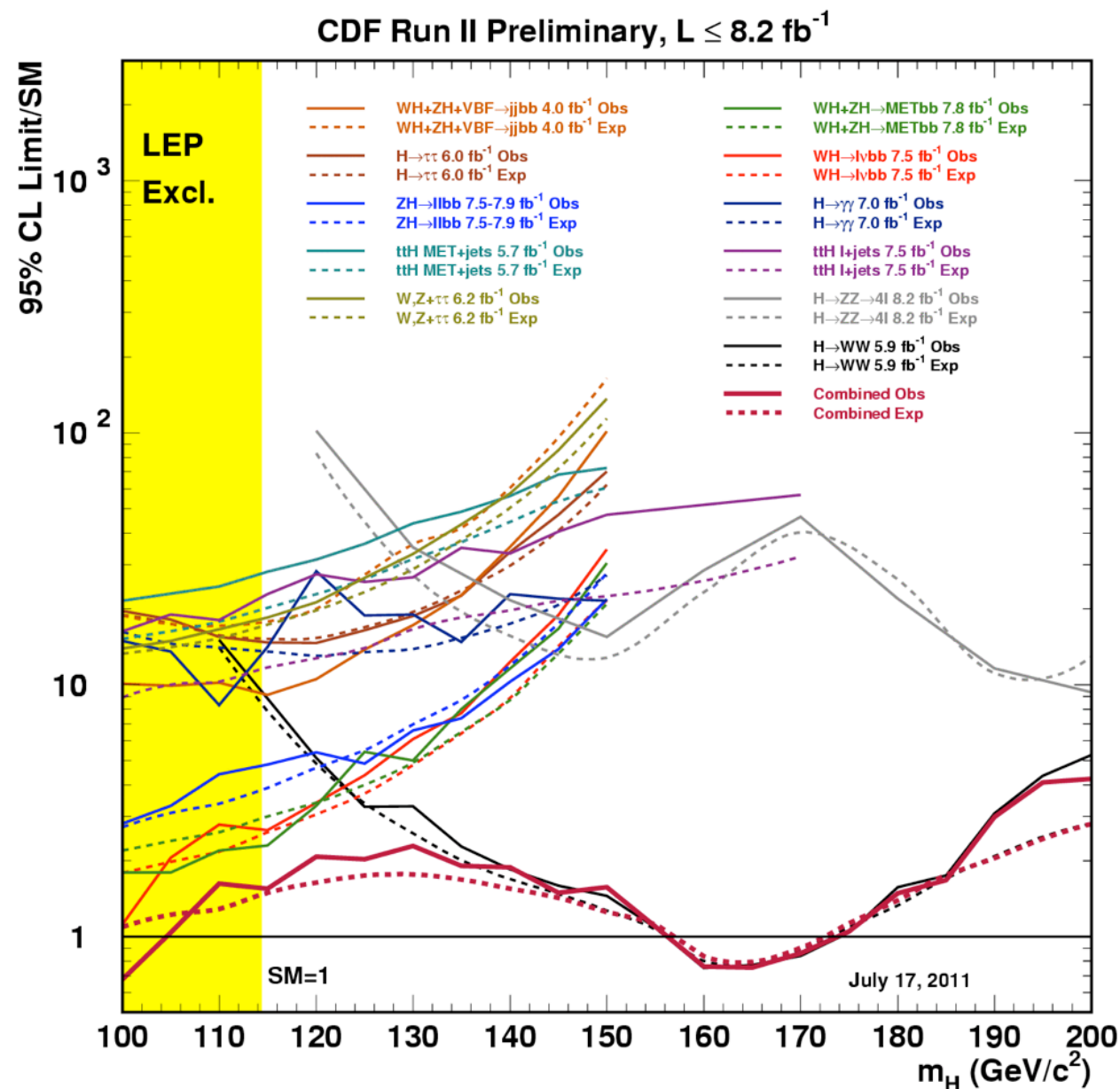


The Higgs Boson

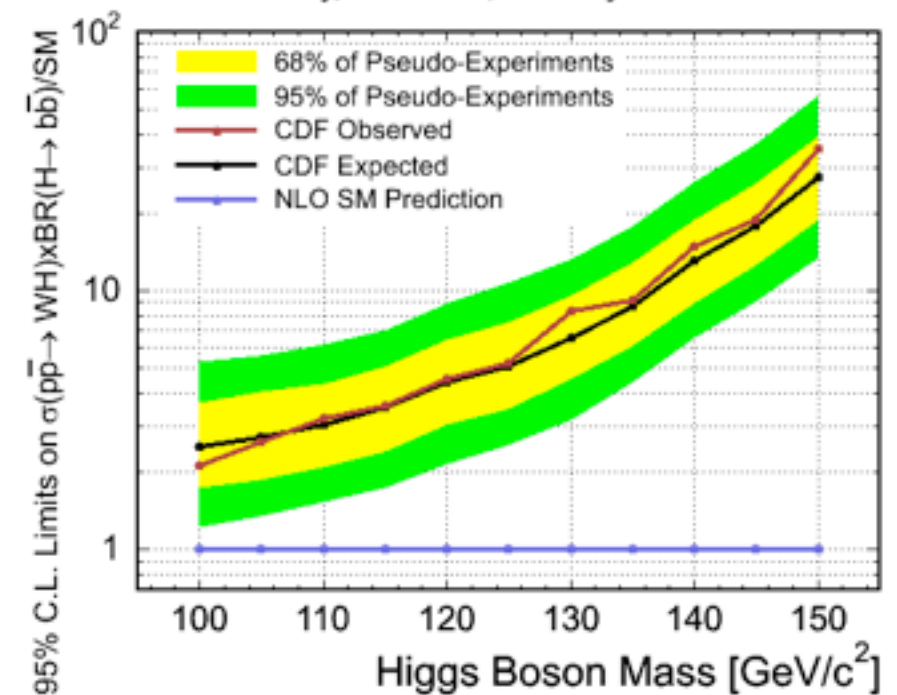
- Searches are performed in many channels

WH

IFCA



CDF Run II Preliminary, $L = 5.6 \text{ fb}^{-1}$, 2 and 3 jets



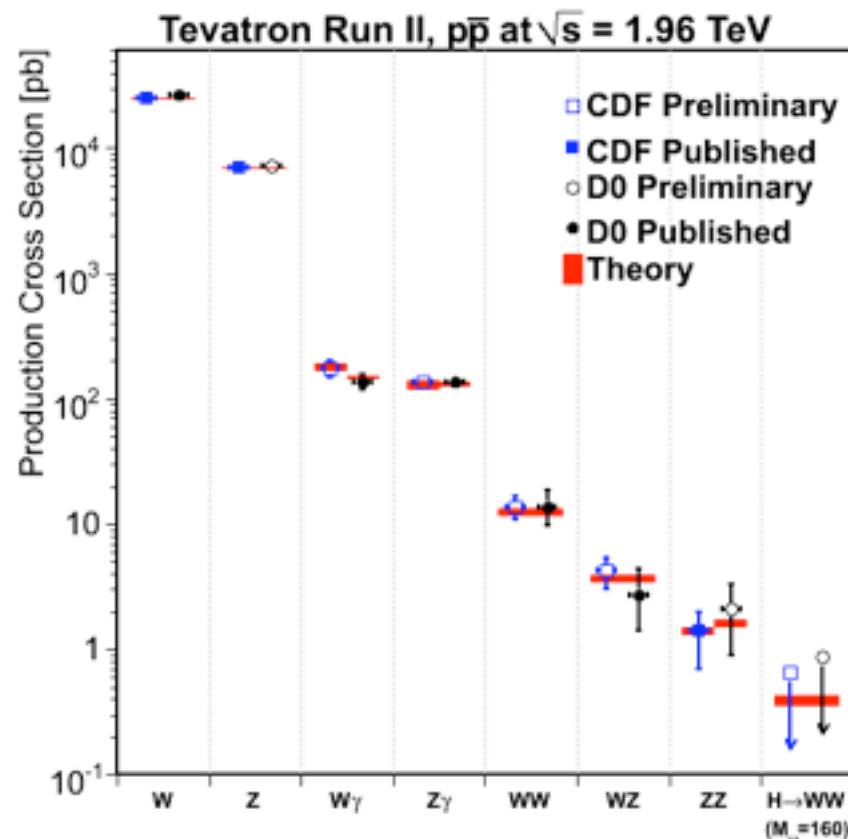
ME technique

The Higgs Boson

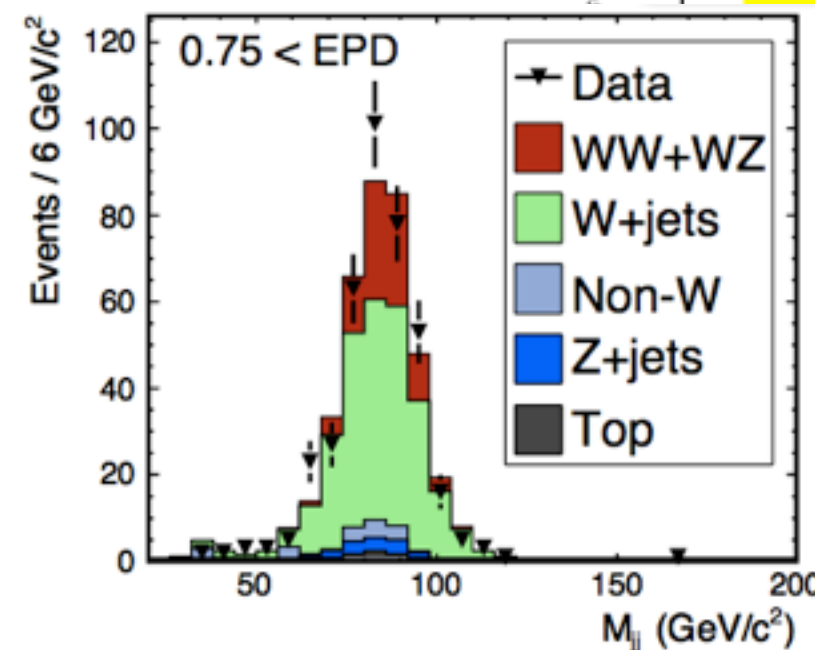
- Techniques validated : Diboson production

WH

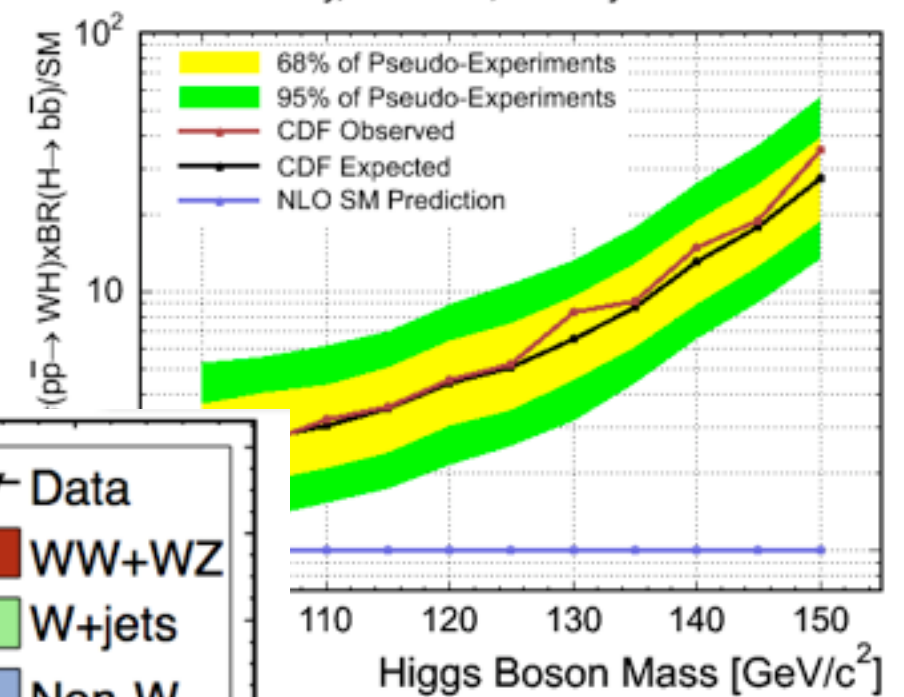
IFCA



WW/WZ in $l\nu jj$



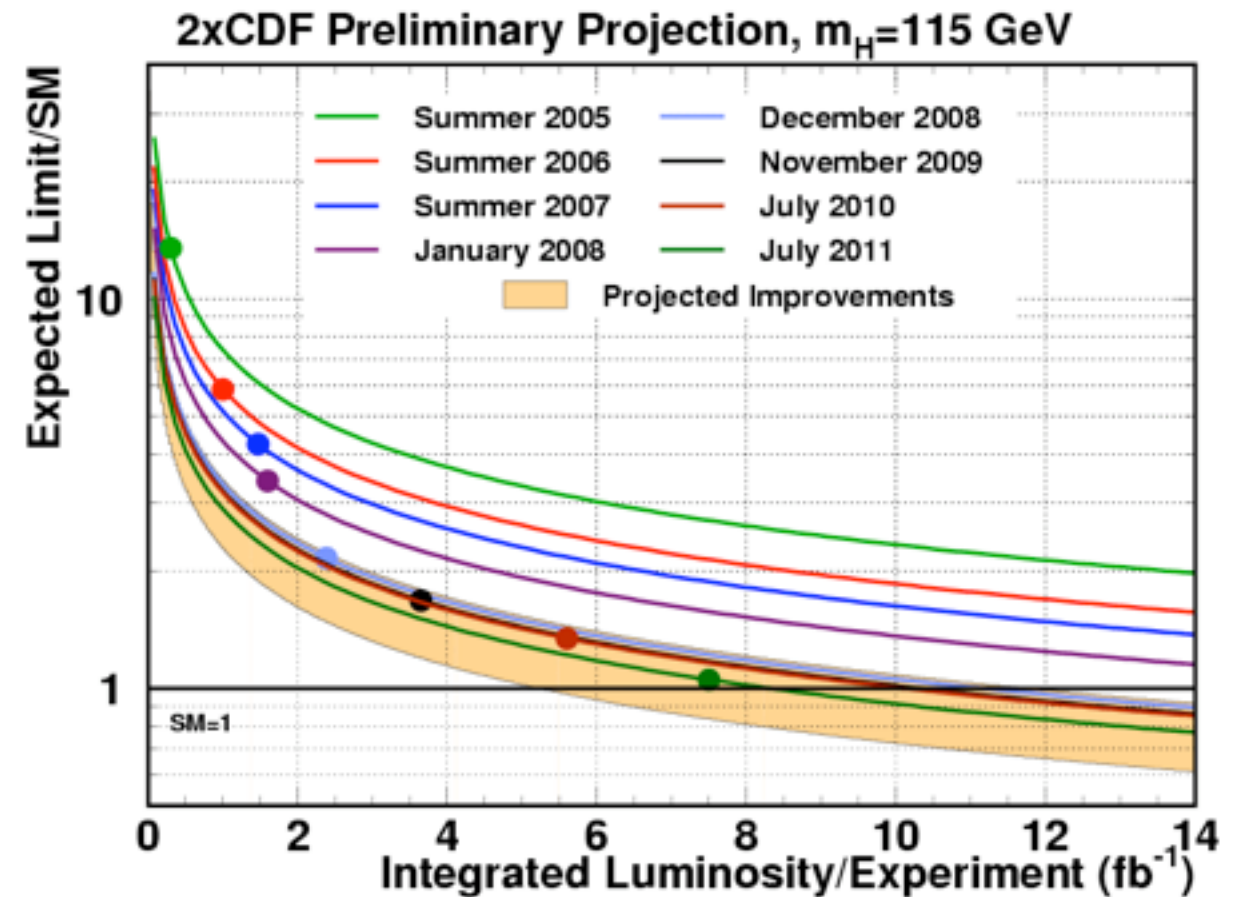
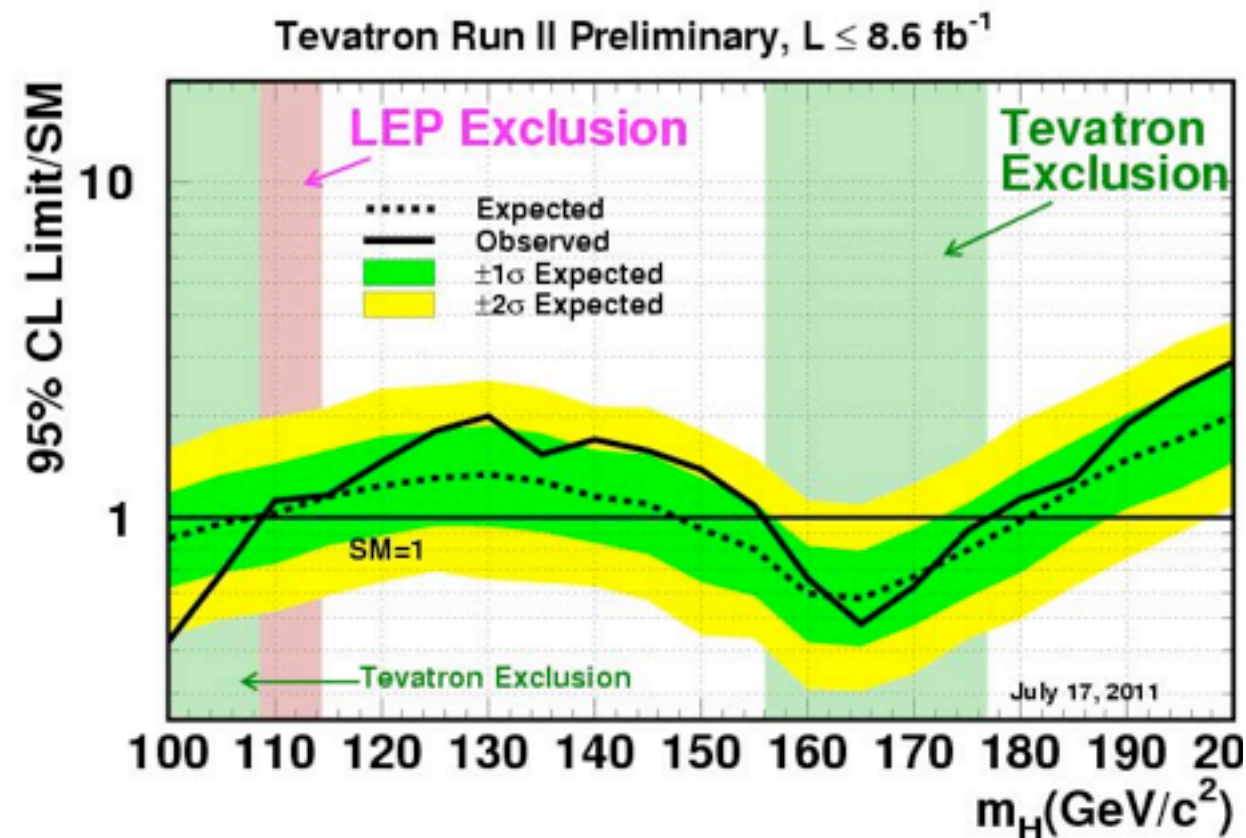
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technique

The Higgs Boson

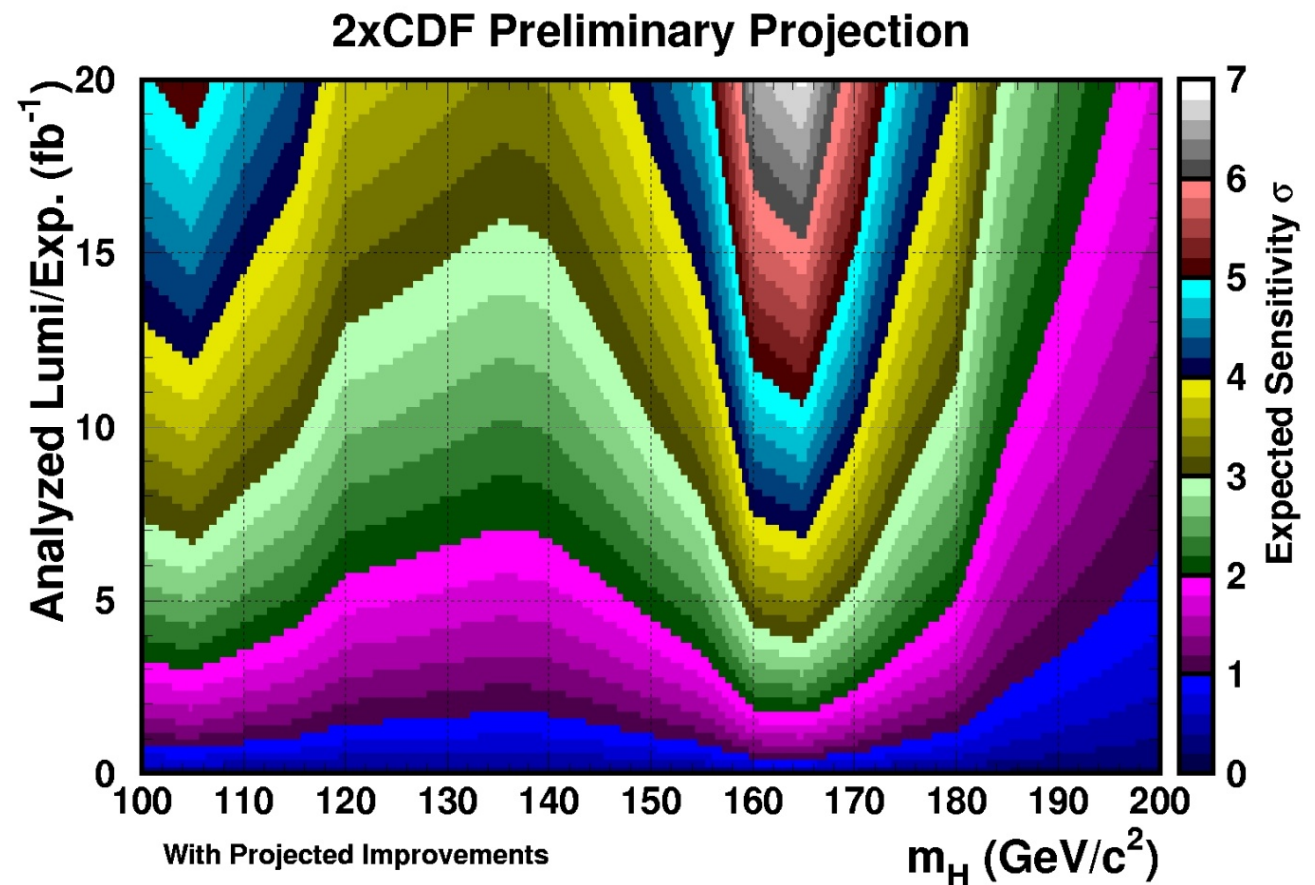
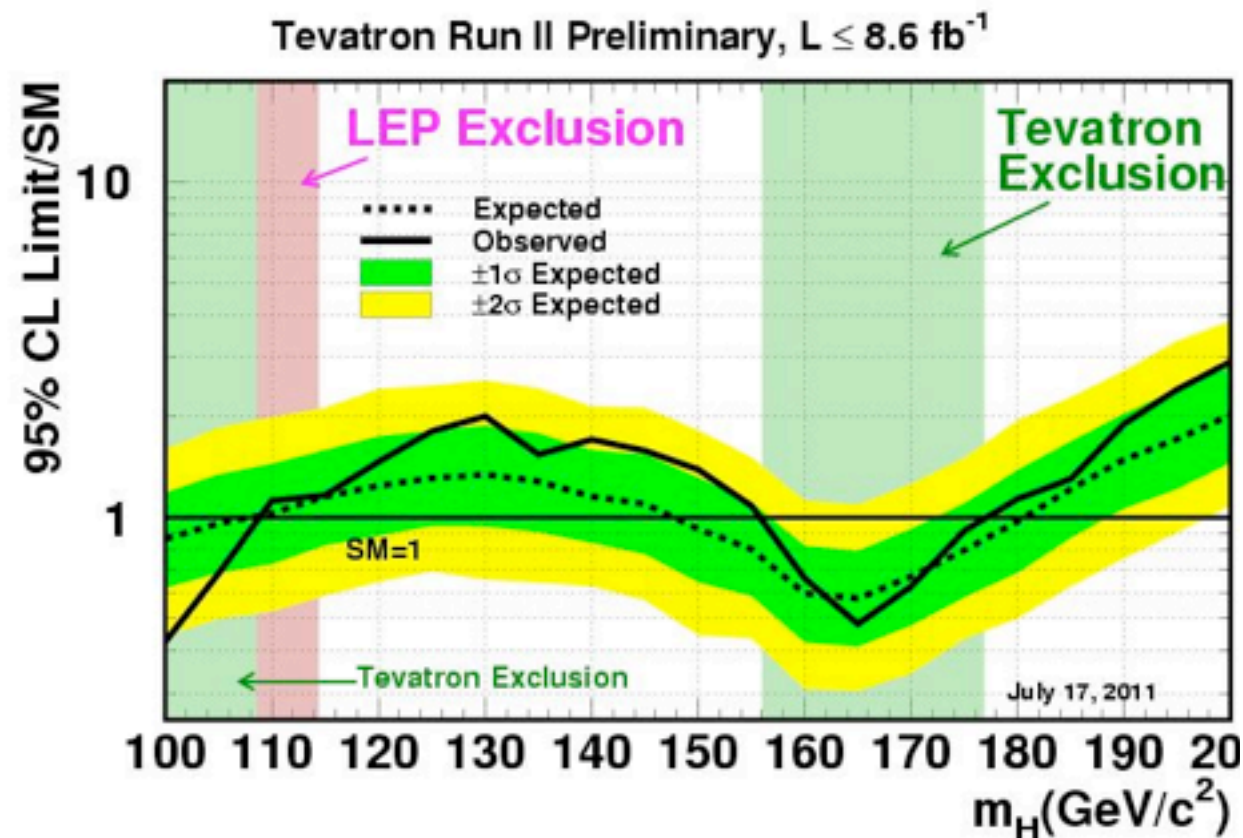
Tevatron Combination



$100 < m_H < 108 \text{ GeV}$ and
 $156 < m_H < 177 \text{ GeV}$ (95%CL)

The Higgs Boson

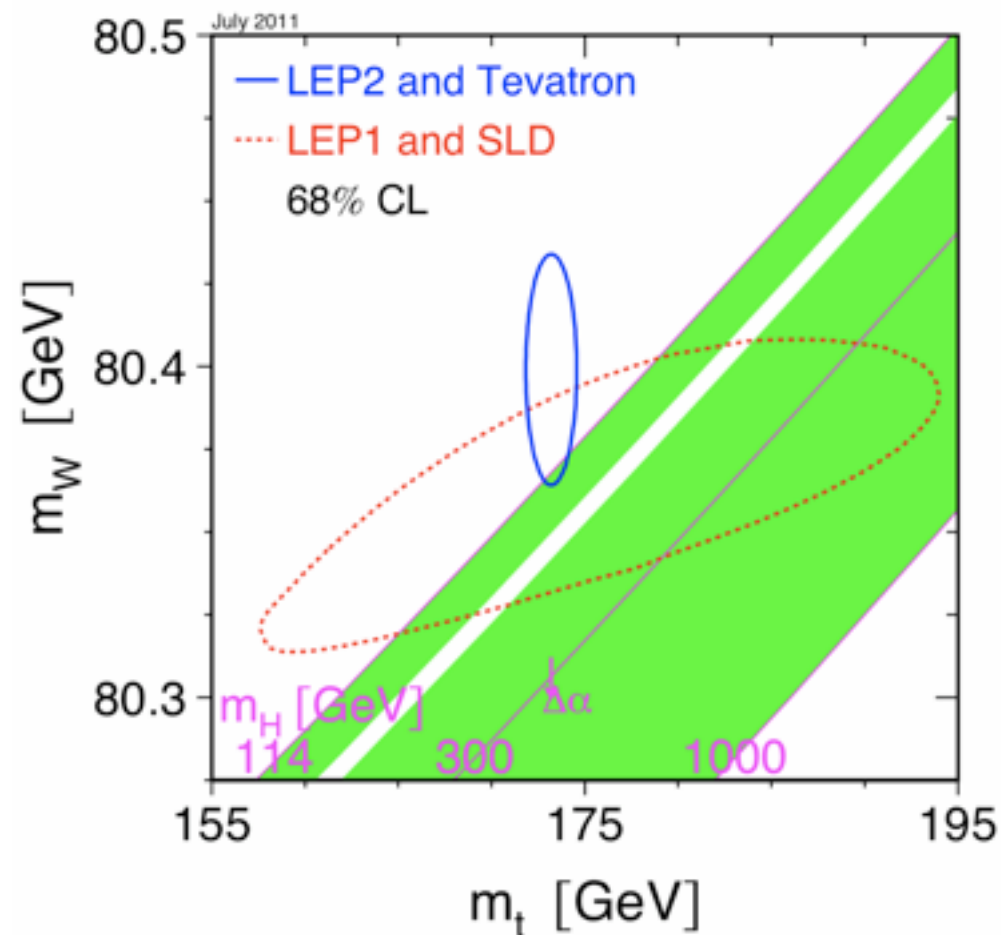
Tevatron Combination



if no Higgs , 95%CL exclusion for $m_H < 190 \text{ GeV}$
2.5 - 3 σ sensitivity for $m_H : 115 - 150 \text{ GeV}$
Complement LHC by providing a measurement $H \rightarrow b\bar{b}$

The Higgs Boson

Top and W masses modified by loop corrections involving the SM Higgs



$$m_W = 80.399 \pm 0.023 \text{ GeV (world)}$$

Tevatron $80.420 \pm 0.031 \text{ GeV}$
goal with 10 fb^{-1} : 15 MeV

Summary

- Exciting 25 years of running at the energy frontier at the Tevatron
- 10 fb^{-1} per experiment, CDF and DØ , that are still being analyzed
- Great physics program including measurements such as
 - ▶ top discovery and properties, B_s mixing, precise jet , boson + jet cross sections, W mass , Higgs boson limits,
 - ▶ maybe hints of new physics....CP violation in b-hadrons decays , Afb in $t\bar{t}$ bar, dijet mass in Wjj events.....
- and innovations and expertise that are now being exploited at LHC



THANKS !!!!



BACKUP

