

Results from the Tevatron

Veronica Sorin
IFAE



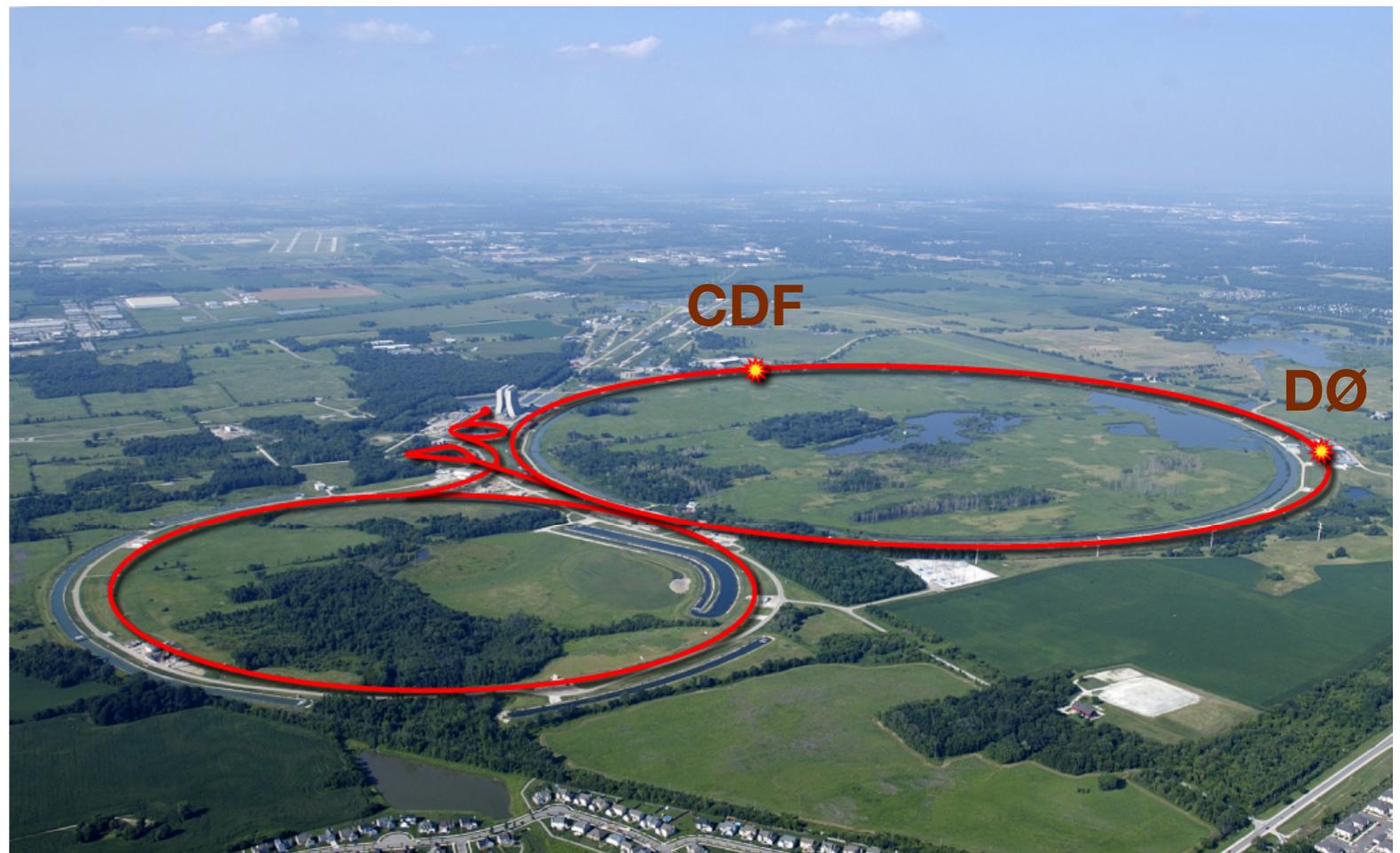
III Jornadas CPAN
Barcelona
November 2 - 4, 2011



The Tevatron

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

Physics Runs



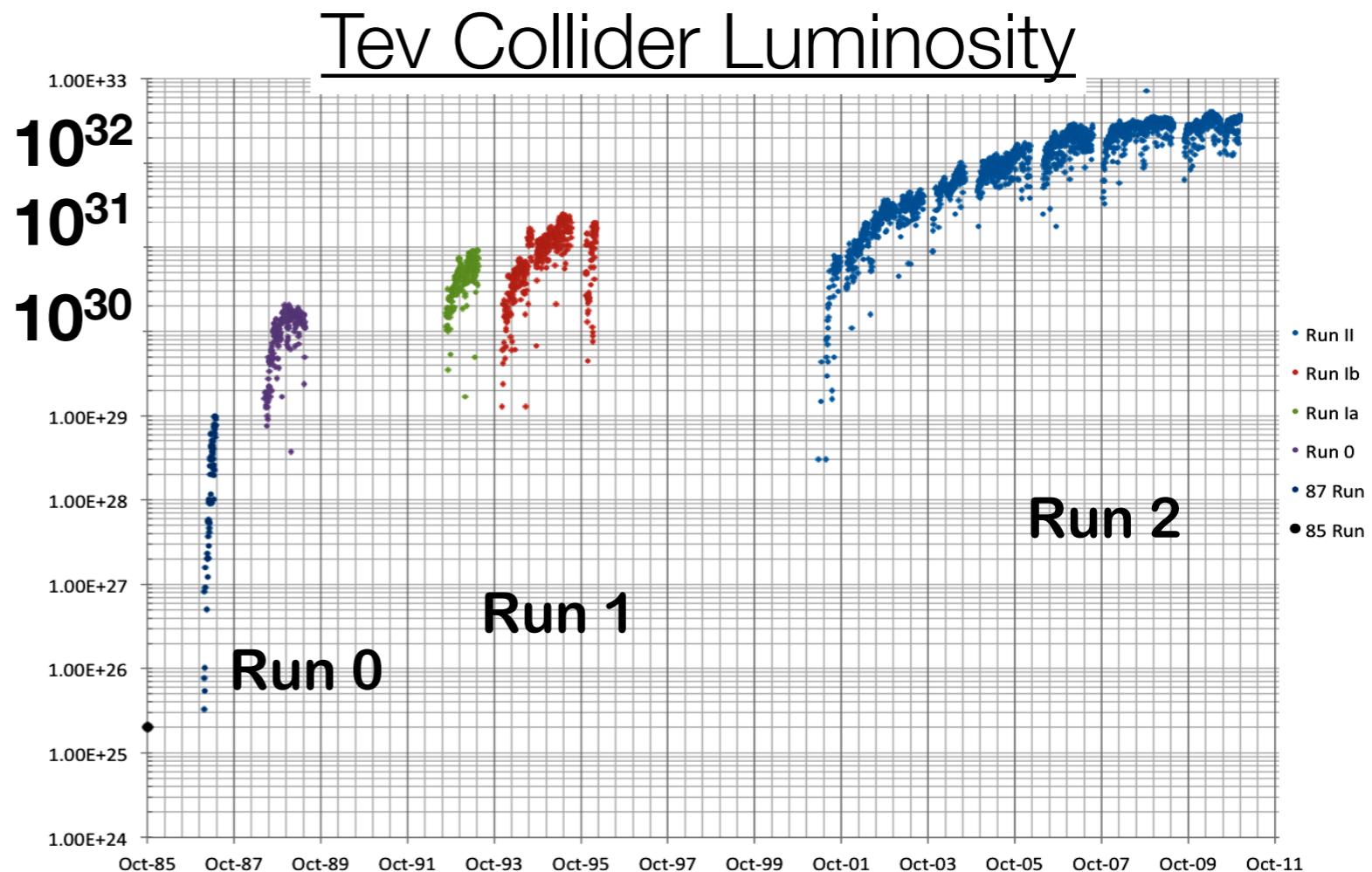
| | |
|-----------|--|
| 1987 | Run 0 - 4 pb^{-1} |
| 1992-1996 | Run 1 - 120 pb^{-1} , 1.8 TeV |
| 2001-2011 | Run 2 - 12 fb^{-1} , 1.96 TeV |

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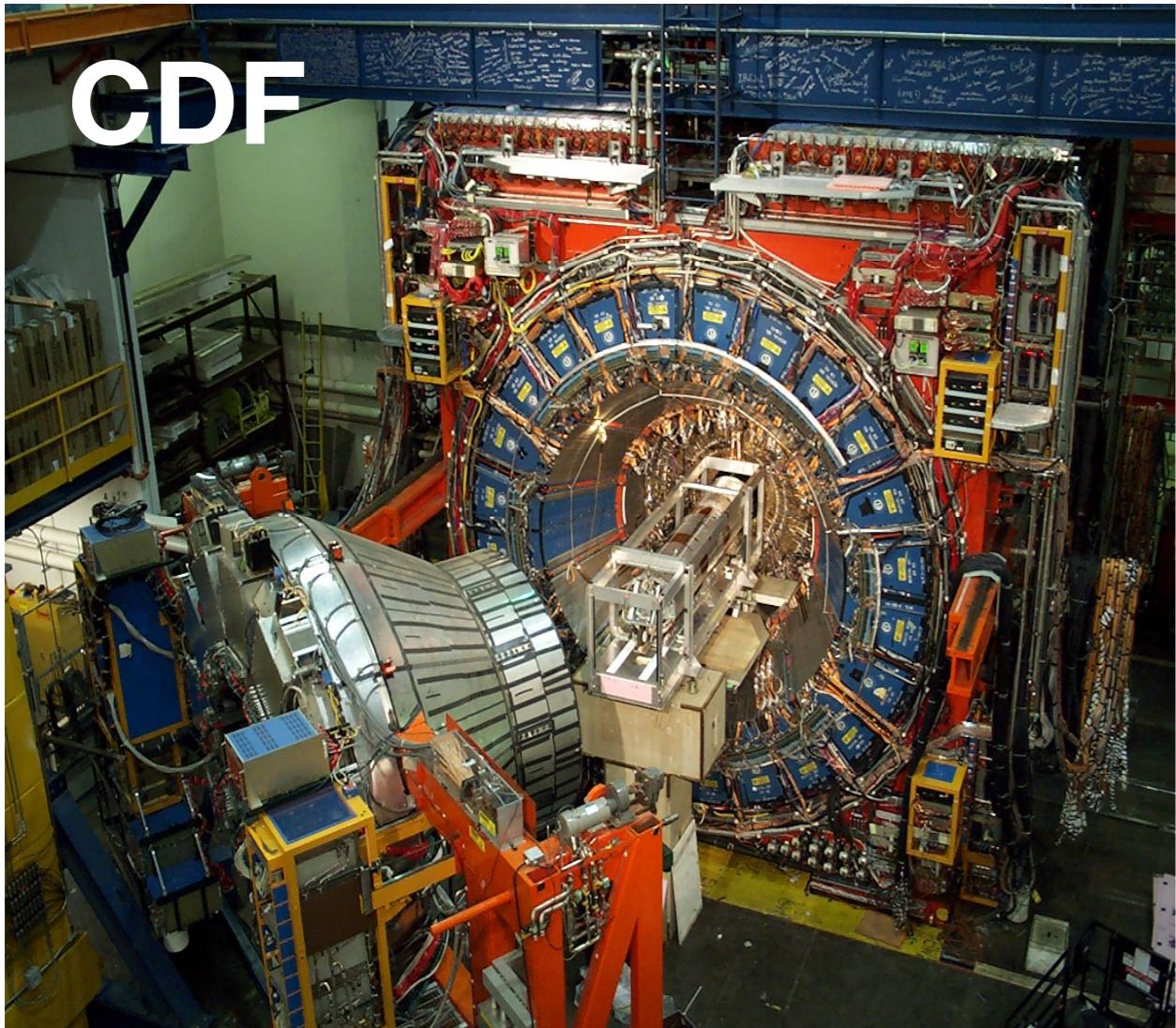
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| 1987 | Run 0 - 4 pb ⁻¹ |
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3 Spanish institutions have joined over the years, starting in 1995:
 Instituto de Física de Cantabria (**IFCA**), Instituto de Física de Altas
 Energías (**IFAE**) and Centro de Investigaciones Energéticas,
 Medioambientales y Tecnológicas (**CIEMAT**)

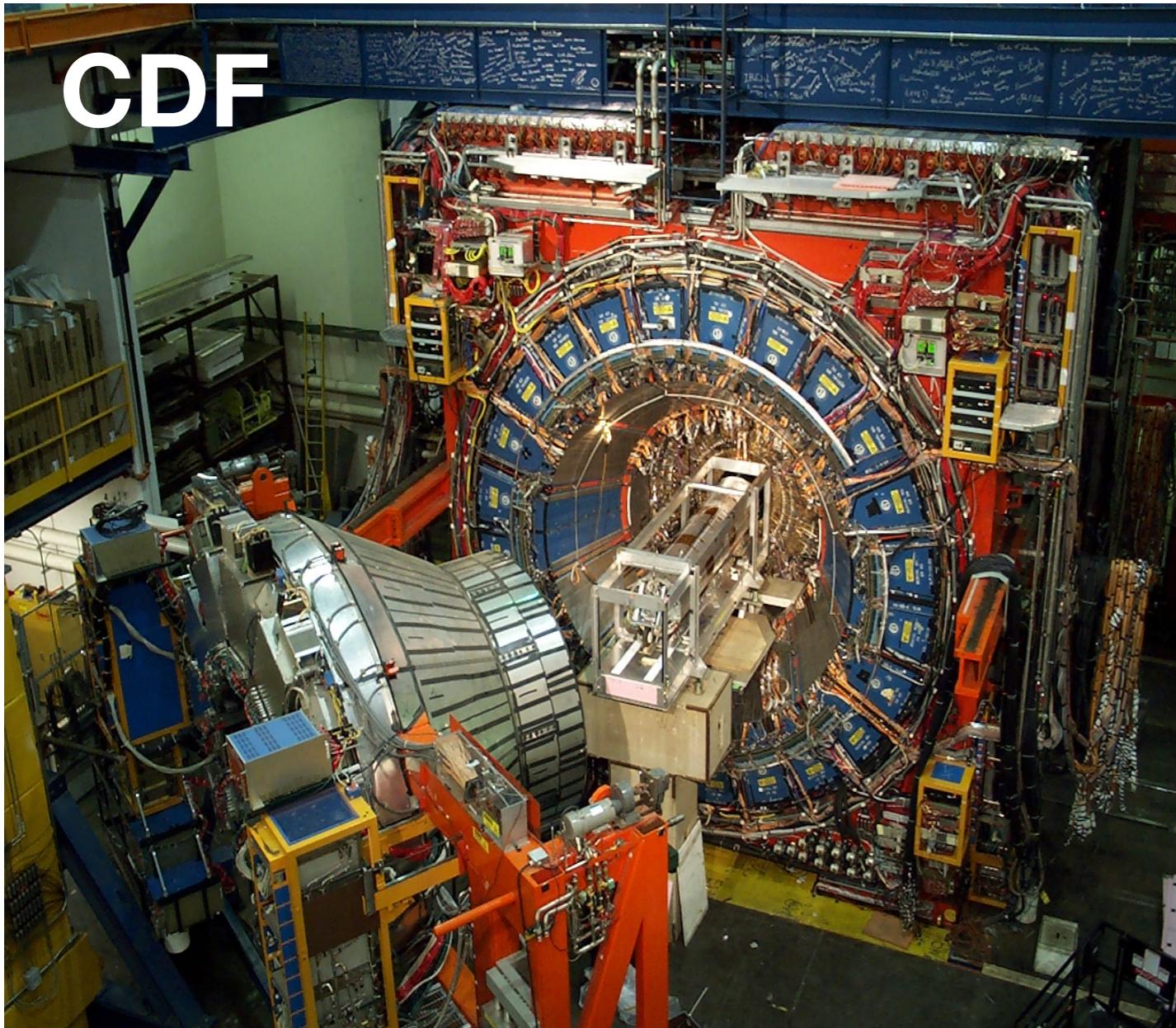
The Experiments



Major detector
upgrades for Run 2



The Experiments



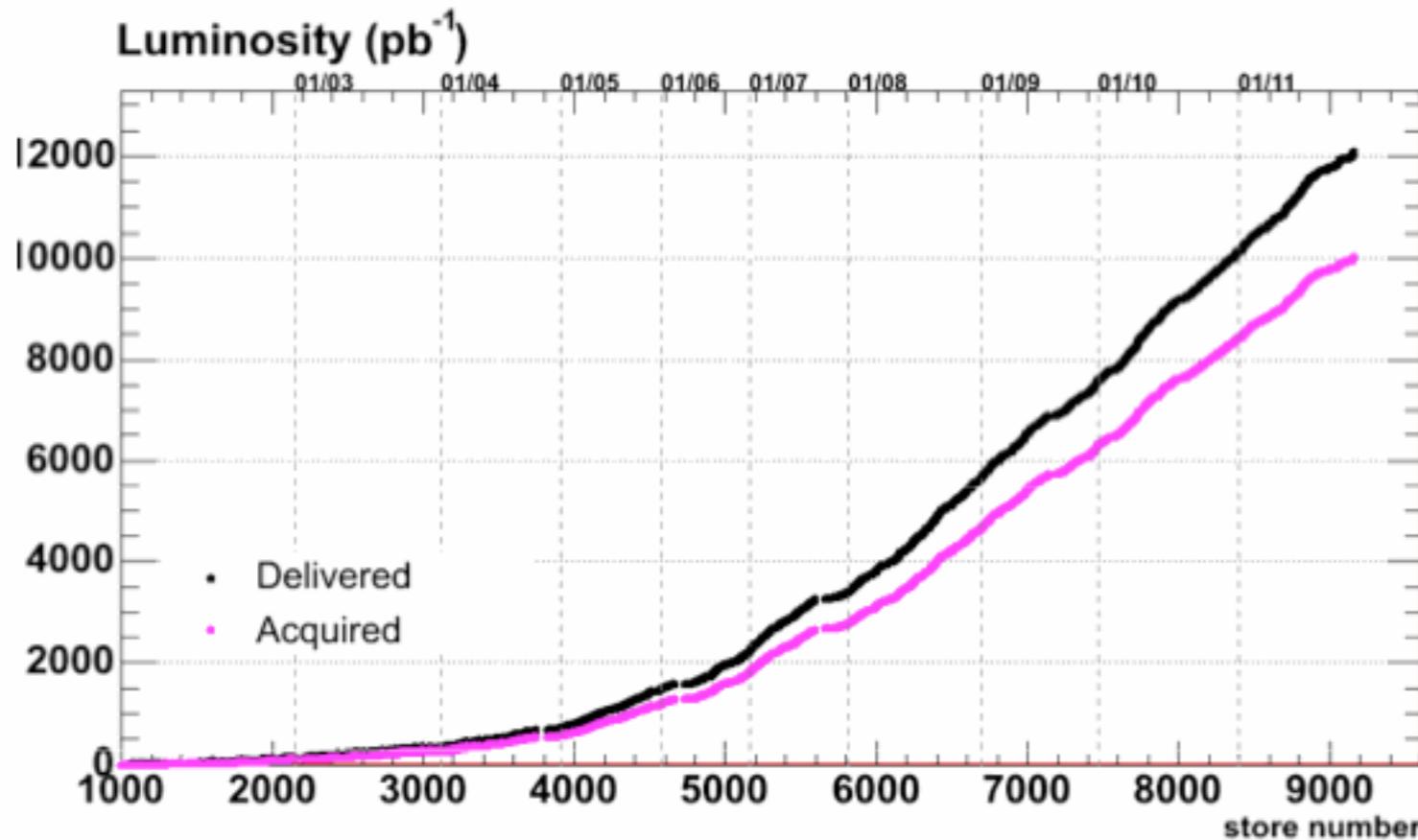
- Silicon detector : leading role in its operation (CIEMAT)

- ✓ Longevity studies

**PhD Thesis R. Martinez
Bellarin (CIEMAT)**

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

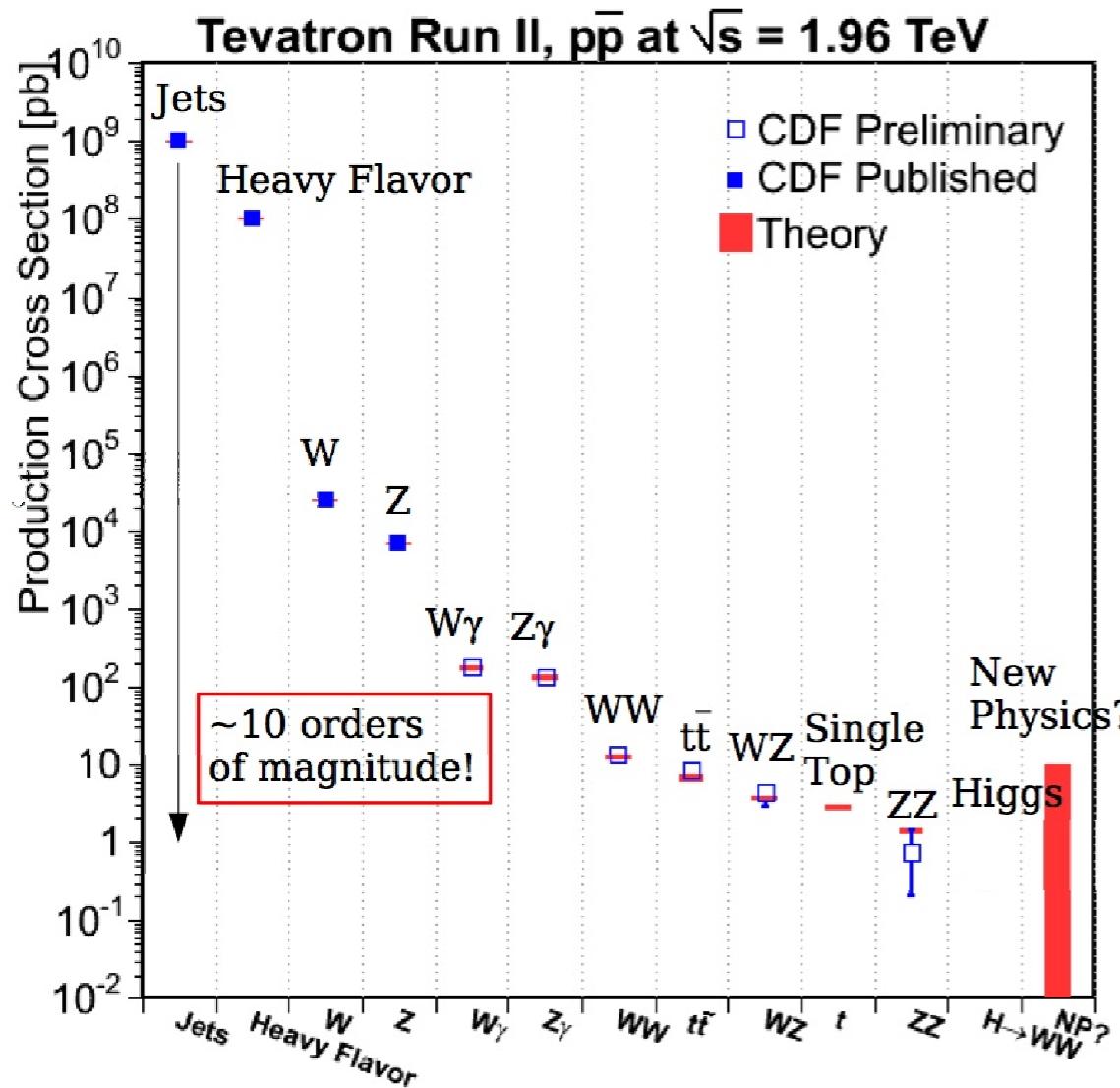
Performance



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

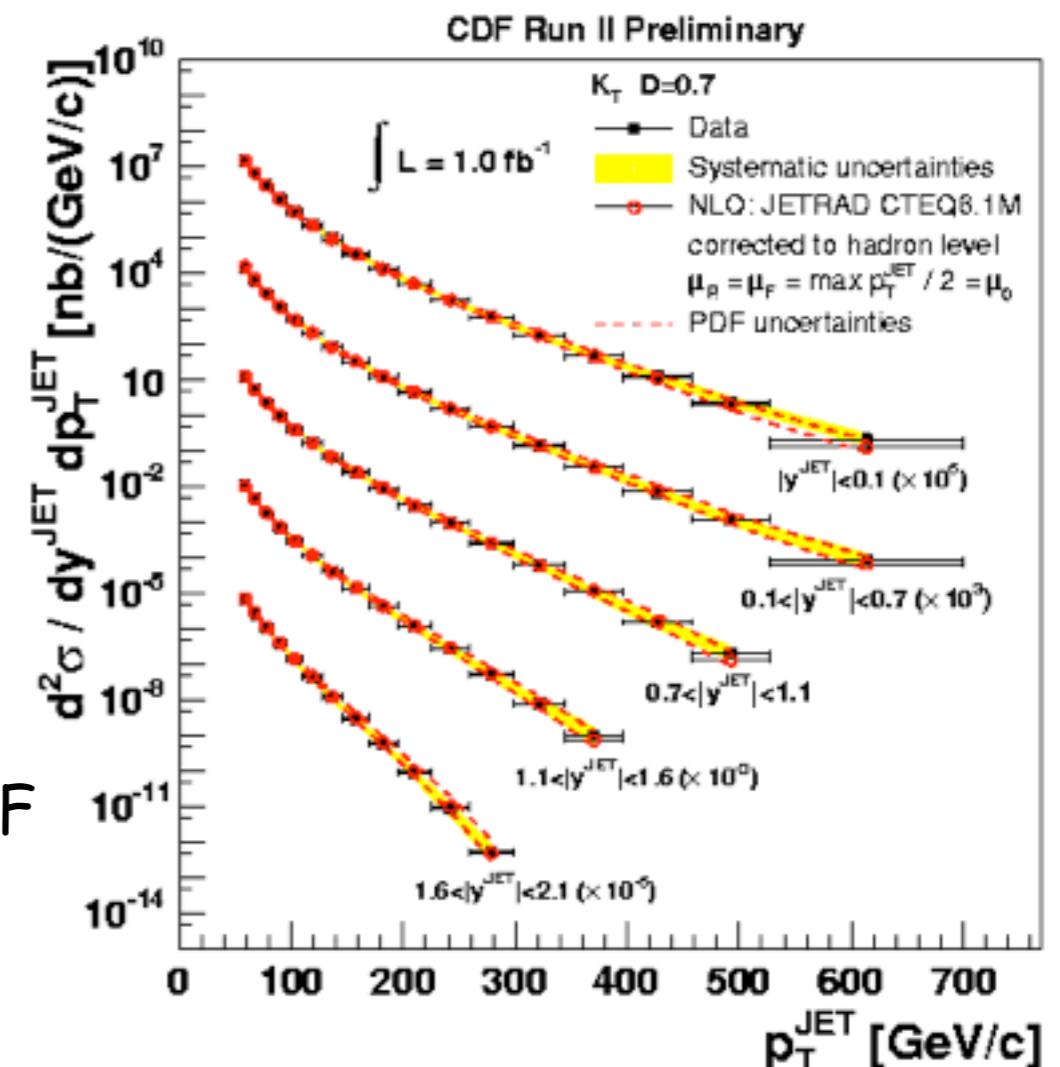
and

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. Norriella (IFAE)

QCD

- Inclusive jet cross sections

- Test pQCD over ~ 9 order of magnitude:

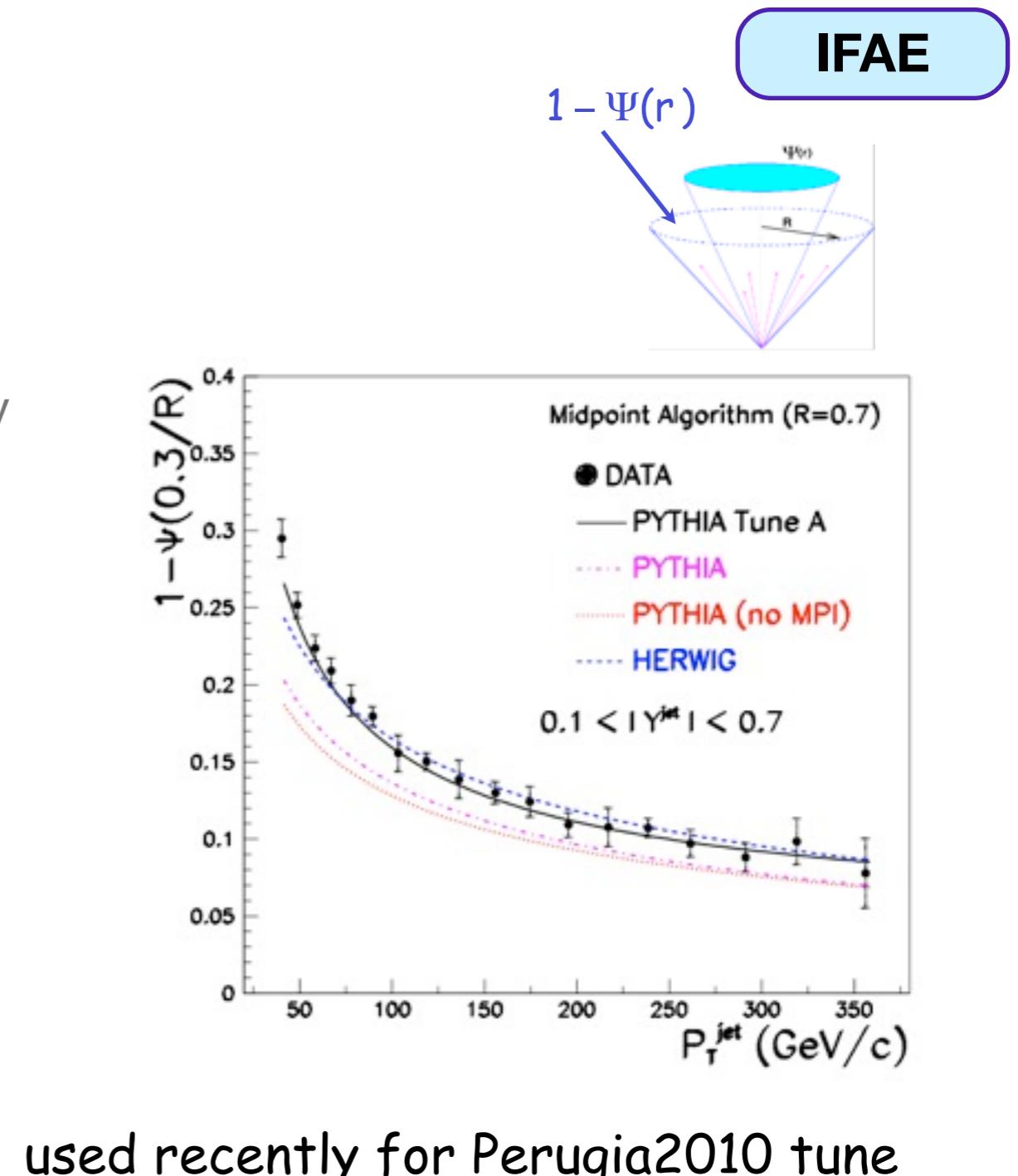
- ▶ p_T range up to 700 GeV and rapidity up to 2.4

- Constrain gluon PDF

- Jet properties

- ▶ jet shapes: internal jet structure studies

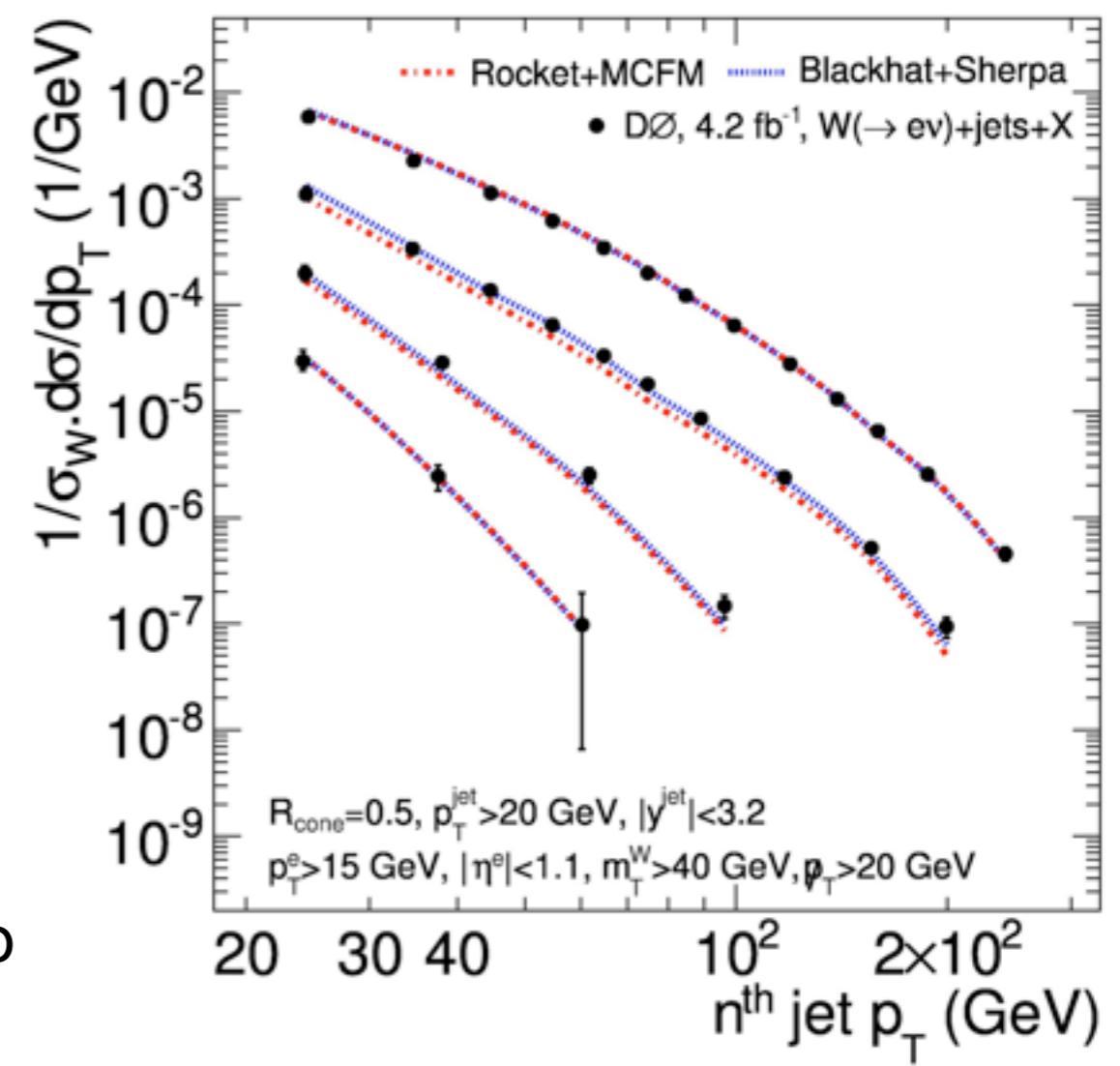
- ▶ test models for parton showers and underlying event



QCD

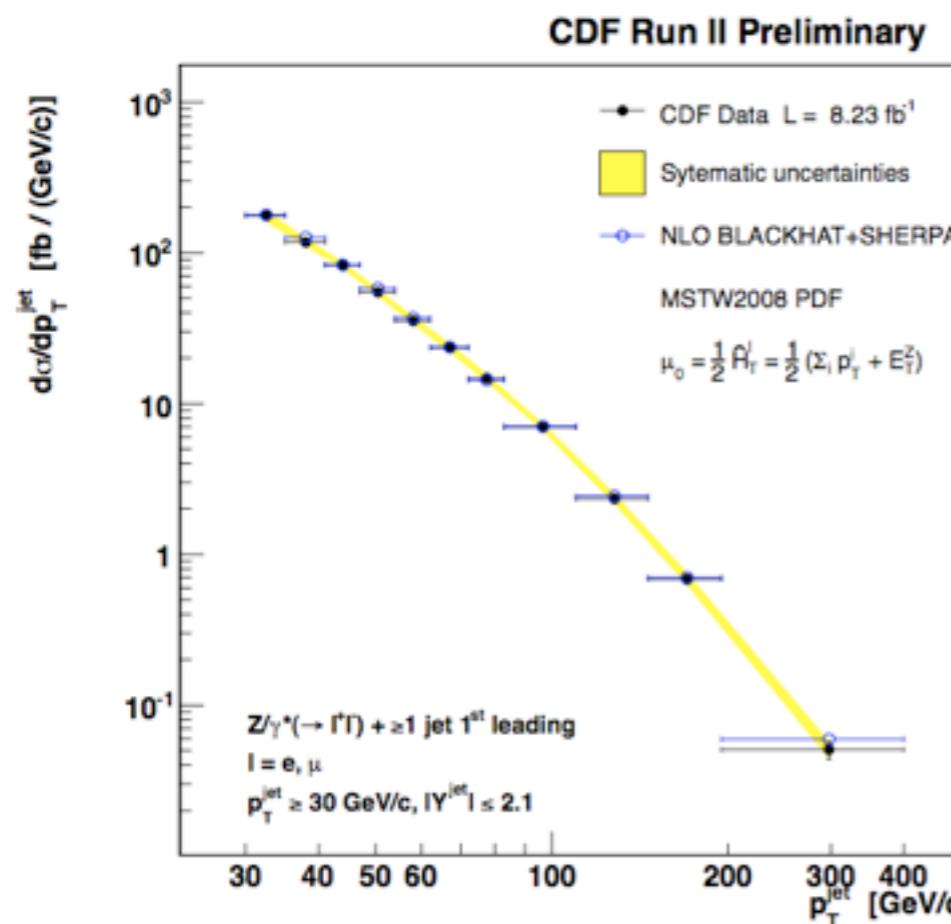
- Boson + jet production
 - Test QCD predictions
 - Background to new physics searches
 - Large theoretical uncertainties specially in the case of HF

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



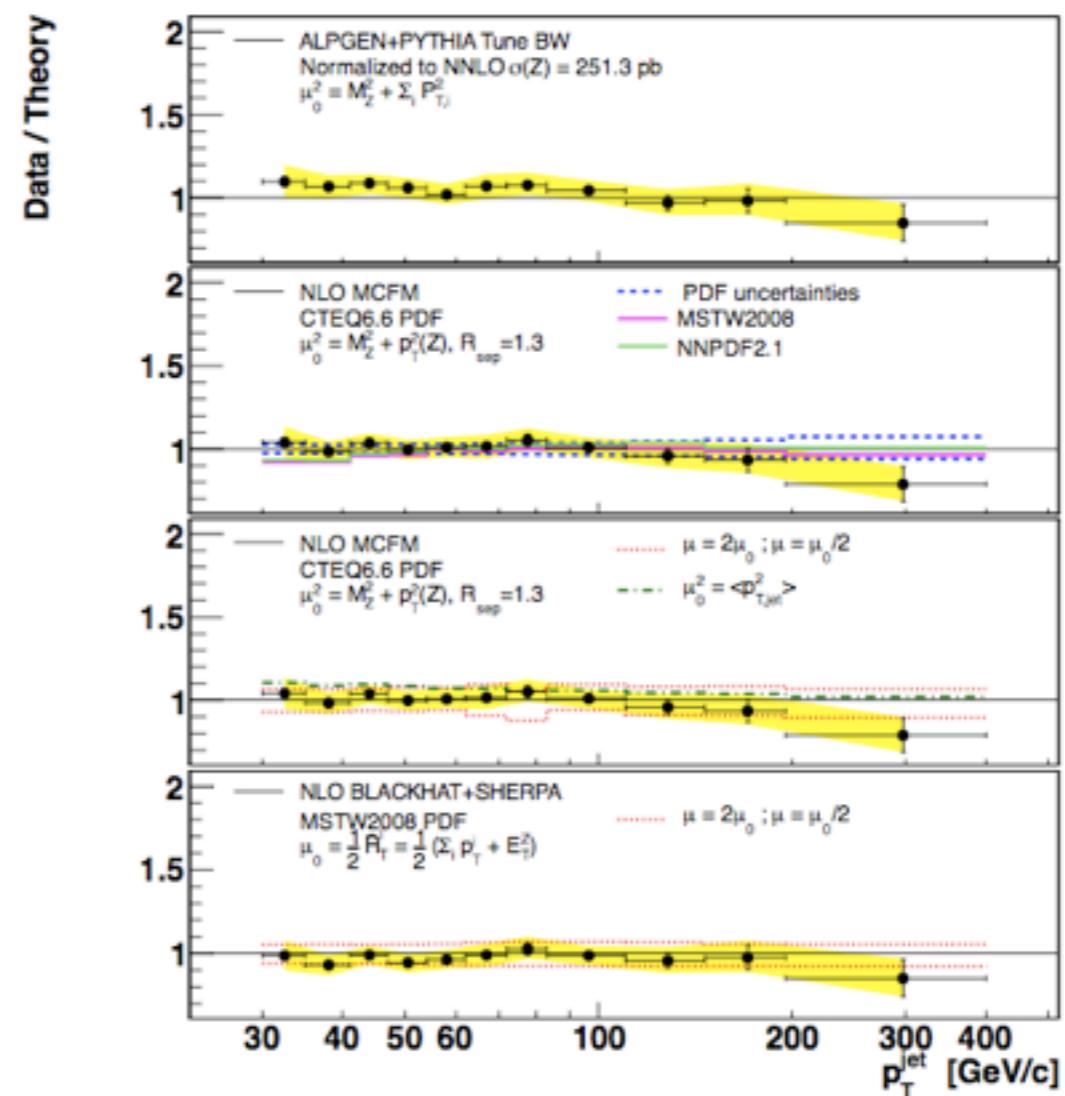
QCD

Z+jet production



in good agreement with NLO pQCD

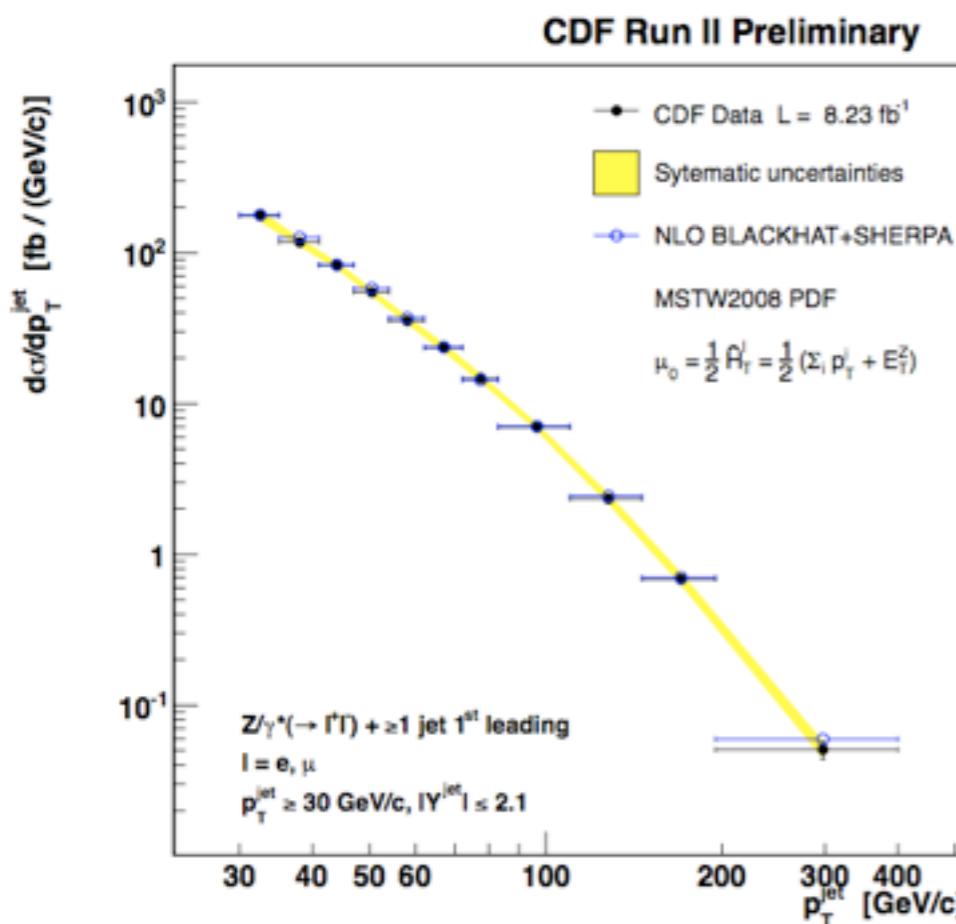
Analysis S. Camarda (IFAE)



Input for tuning MC

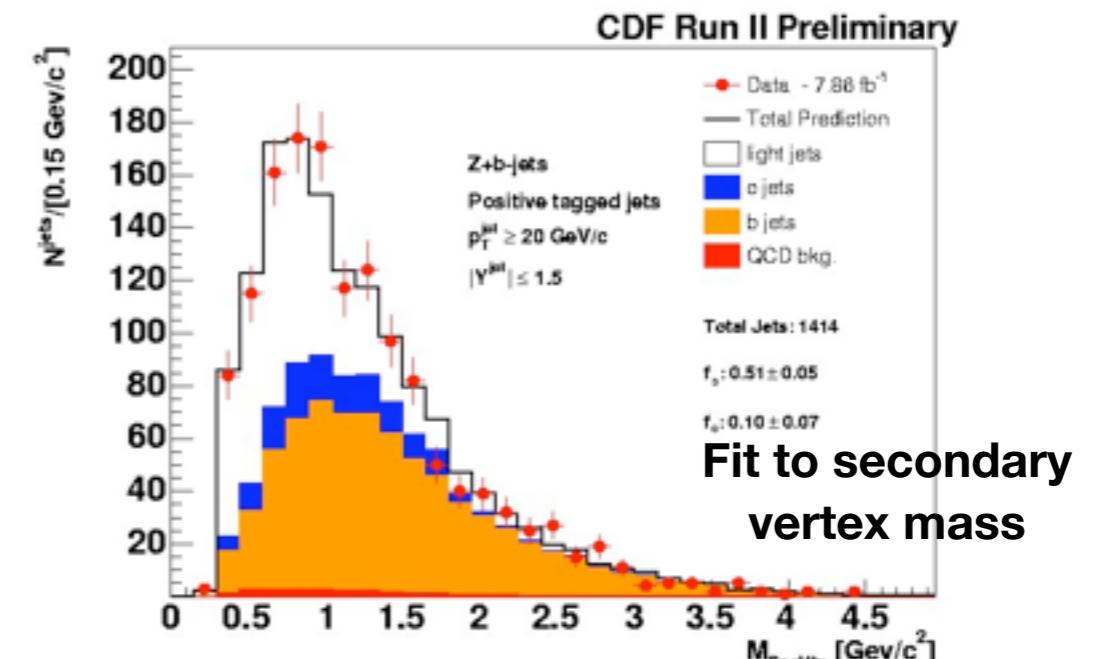
QCD

Z+jet production



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Analysis S. Camarda (IFAE)



$$z+b/z+jet = 2.24 \pm 0.36 \%$$

in agreement with NLO

Analysis L. Ortolan (IFAE)

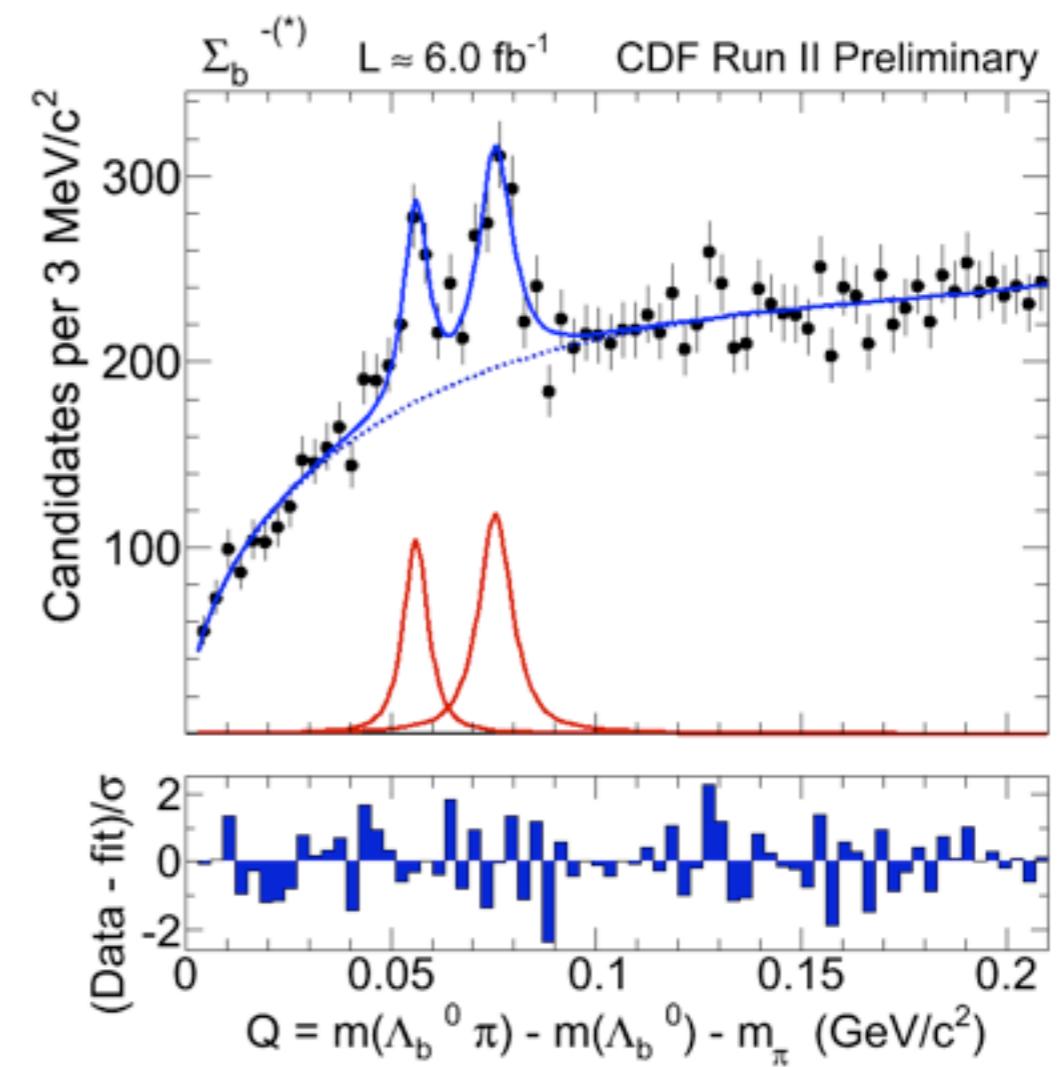
Heavy Flavor Physics

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)

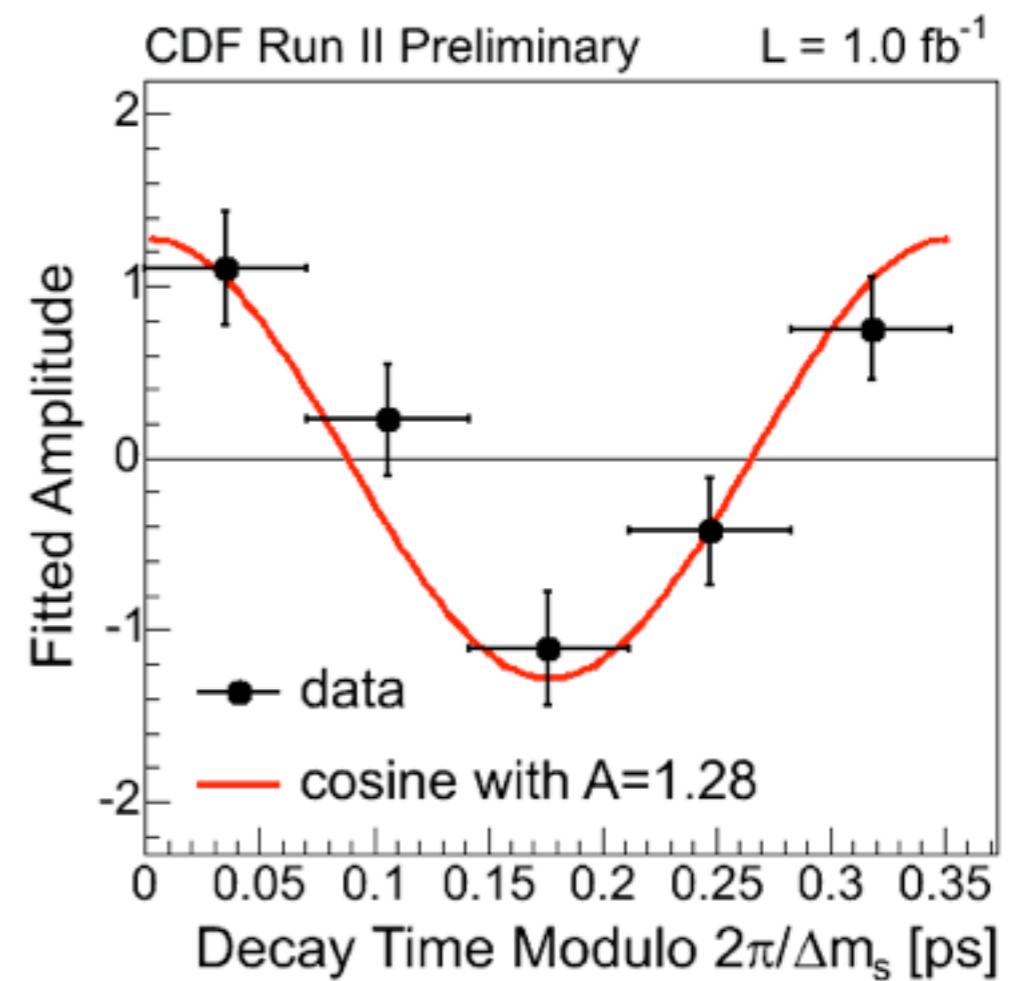
Heavy Flavor Physics

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

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Observation B_s mixing : 2006

- mixing frequency compatible with SM expectations



Participation from IFCA
PhD thesis J. Piedra

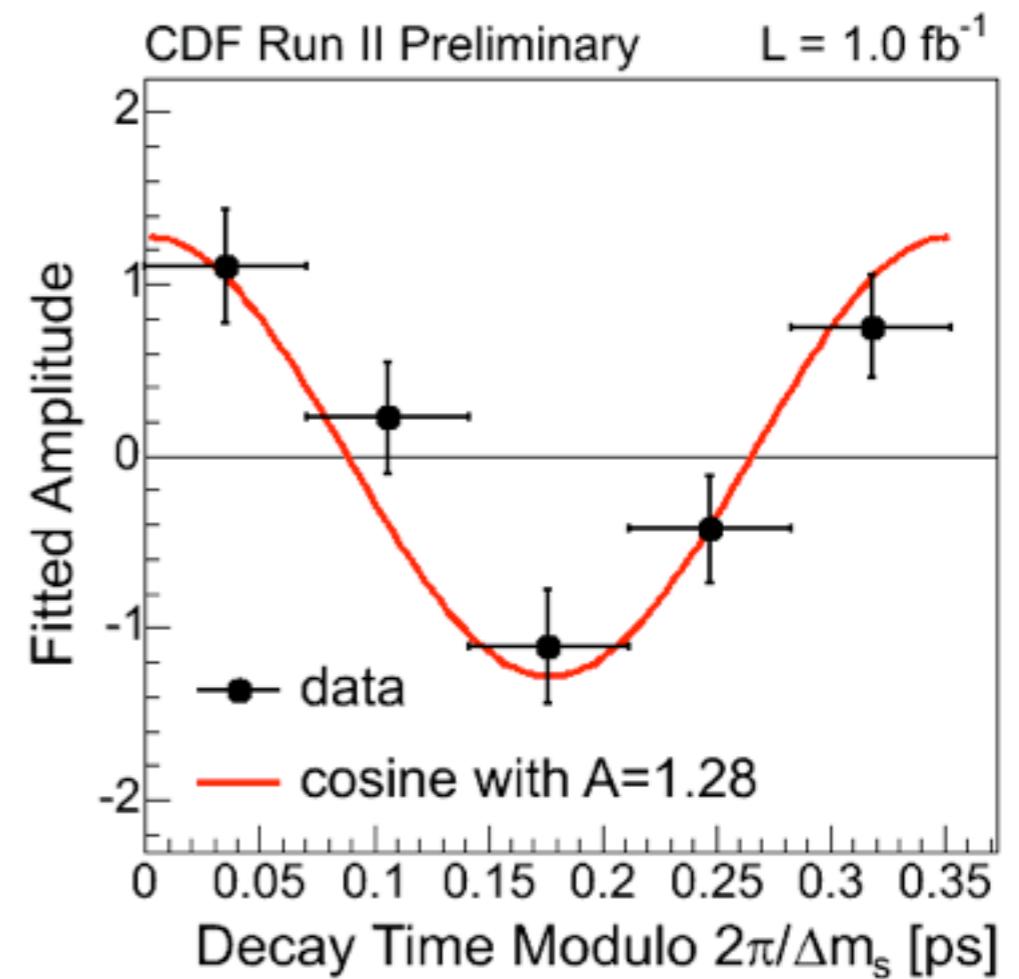
Heavy Flavor Physics

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Observation B_s mixing : 2006

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



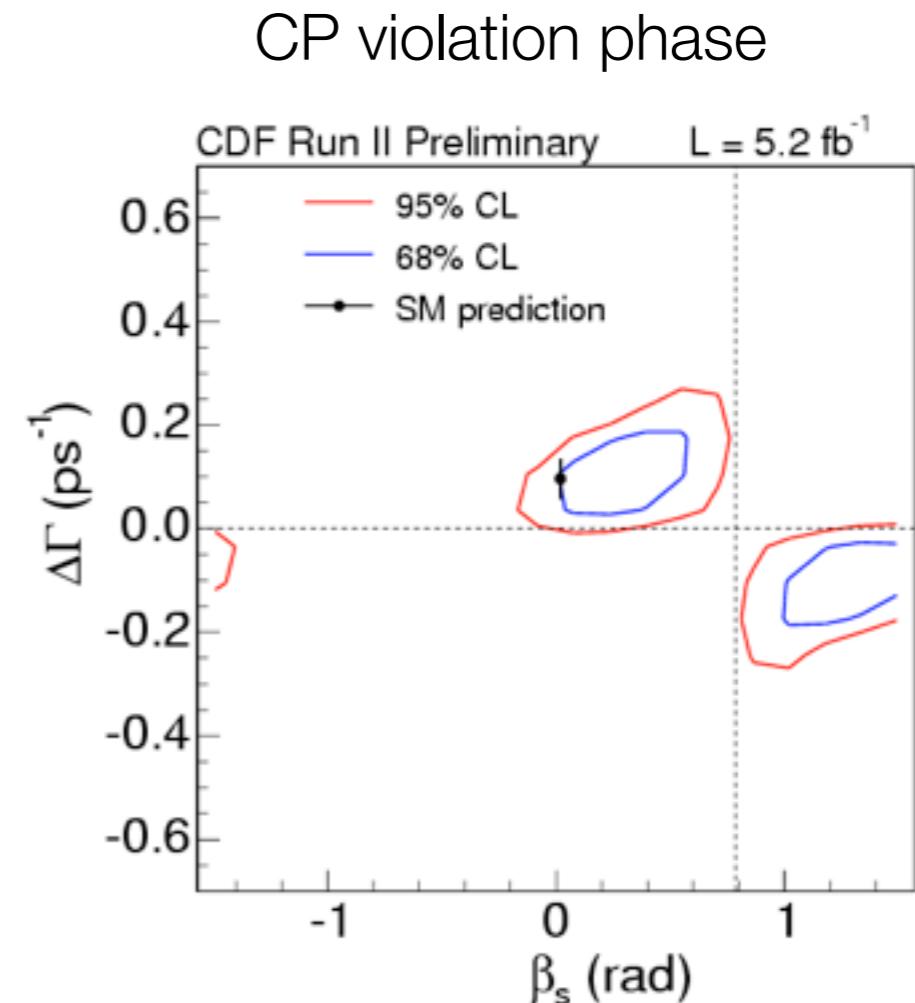
Heavy Flavor Physics

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⇒ broad heavy flavor physics program

New Physics ...

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



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

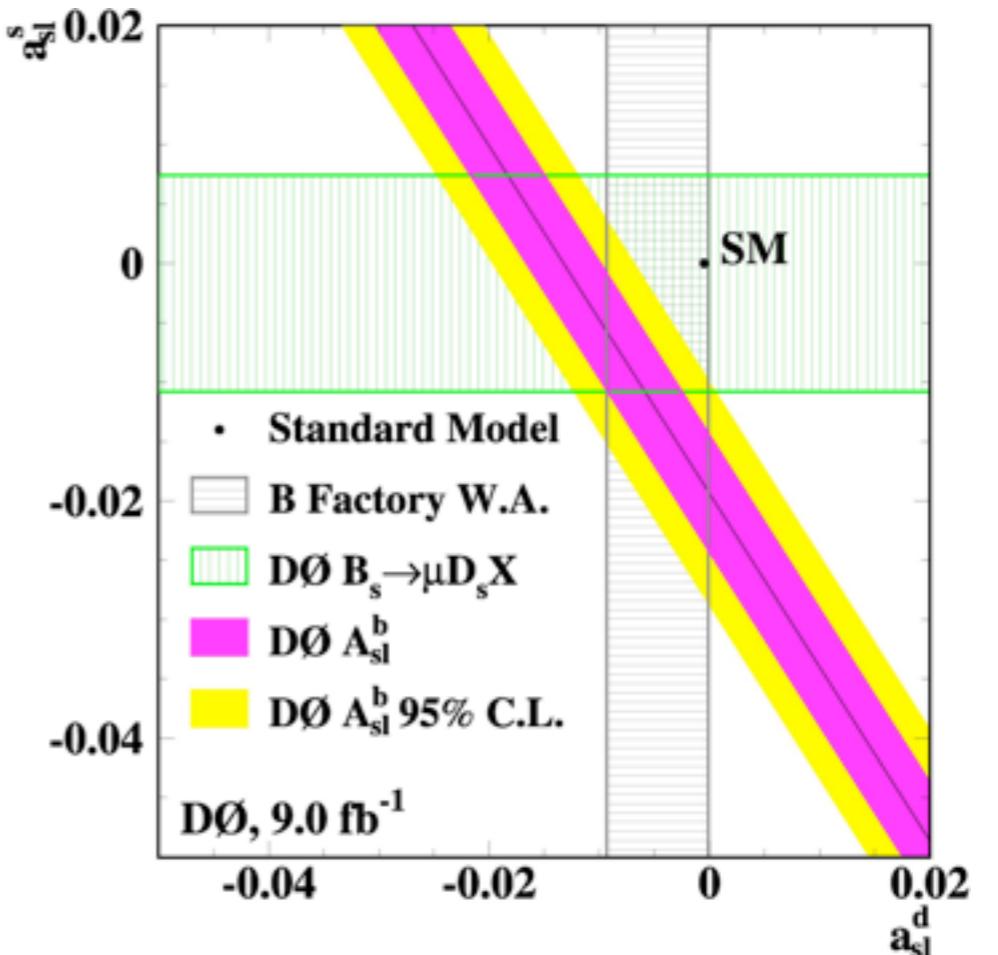
New Physics ...

► CP-violation in B_s system

► dimuon asymmetry

► Rare decays...($B_s \rightarrow \mu^+ \mu^-$)

anomalous like-sign dimuon asymmetry



disagree with SM by 3.9 σ

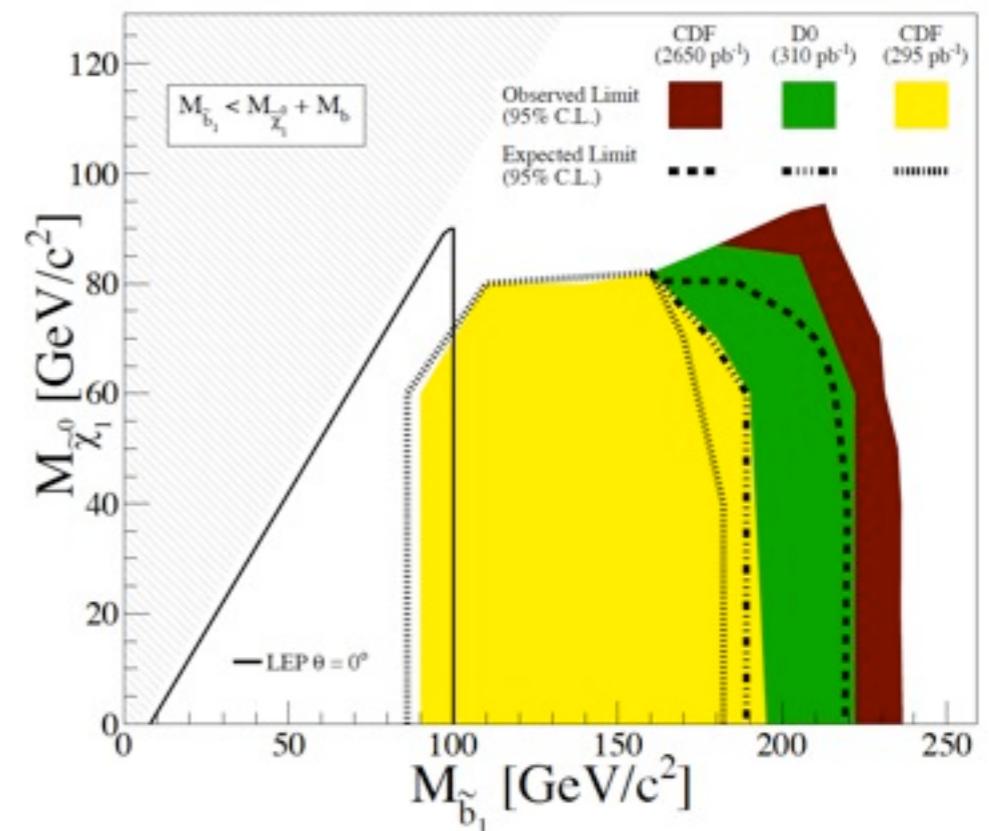
Beyond the SM

- 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

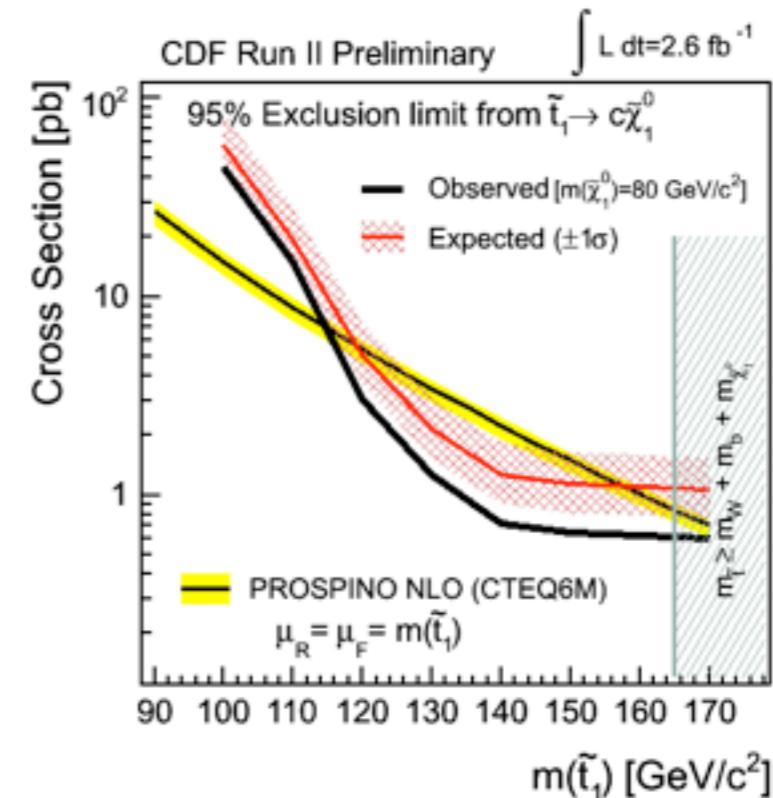
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Analysis and several thesis

Many techniques now applied at LHC

Squark and gluino search Missing $E_T + \text{Jets}$

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

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

Top charge : not $4/3$ @ 99% CL

Top width $< 7.6 \text{ GeV}$ @ 95% CL

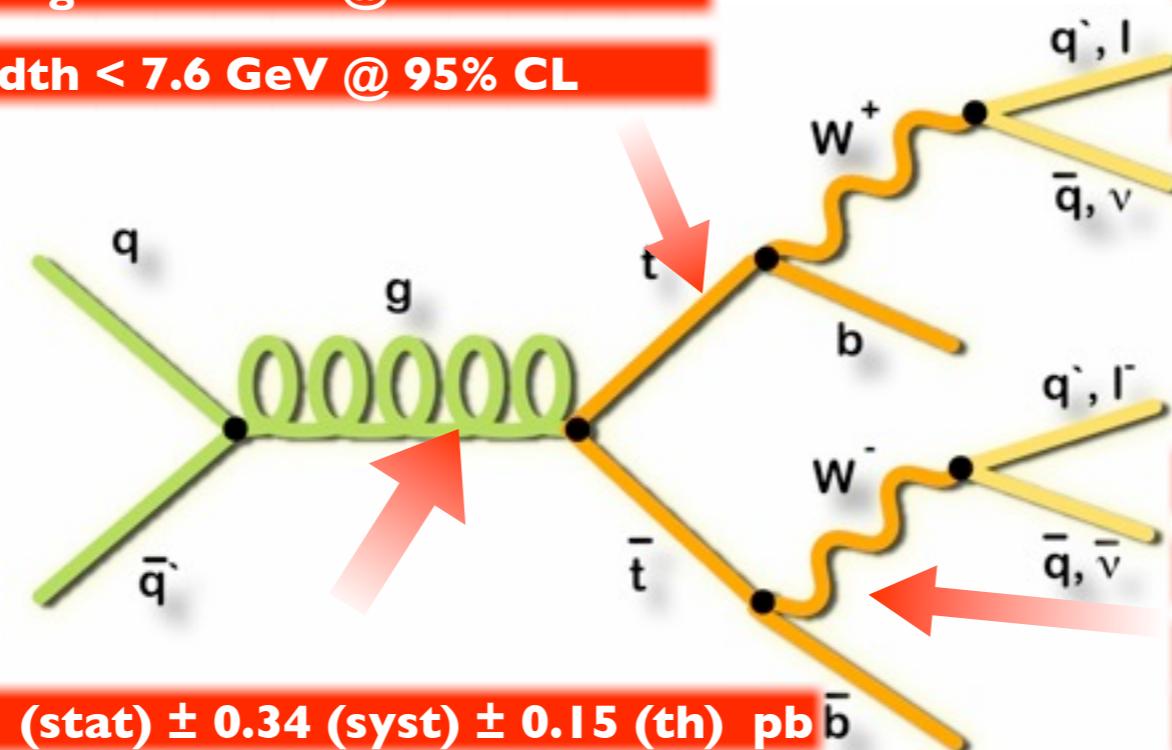
$\sigma = 7.5 \pm 0.31 \text{ (stat)} \pm 0.34 \text{ (syst)} \pm 0.15 \text{ (th)} \text{ pb} \bar{b}$

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

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

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

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



anom coupl : no evidence found

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

spin correlations in agreement with SM

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

$BR(t \rightarrow Zq) < 3.7\%$ at 95% 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

Single Top

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

Top Quark Physics

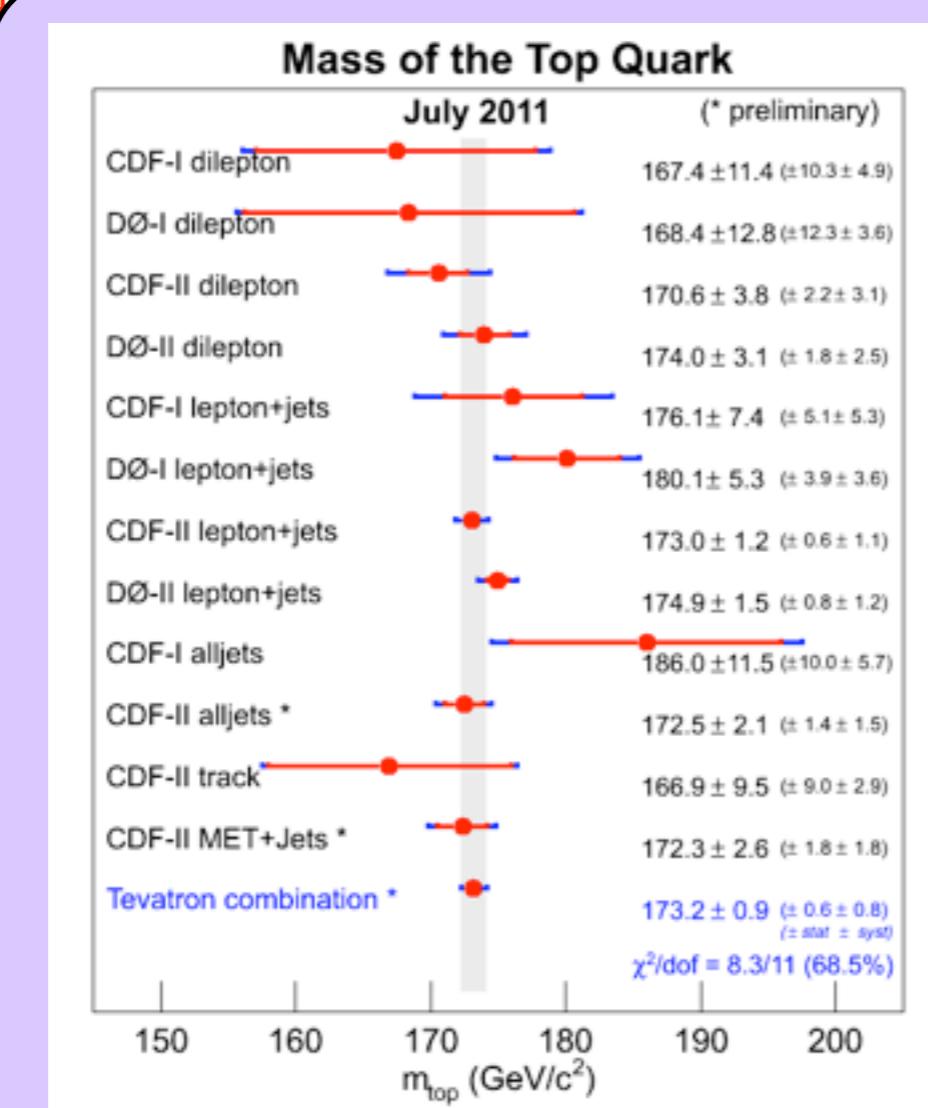
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Top wi



$\sigma = 6.9 \pm 0.4$

± 0.09

$A_{fb} = 19.$

C.L.

Excl.

I⁺b

$d\sigma/dM_t$

action

fraction

% CL

Tevatron
combination

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

uncertainty less than
1 GeV/c²!

systematically
dominated (JES)

Top Quark Physics

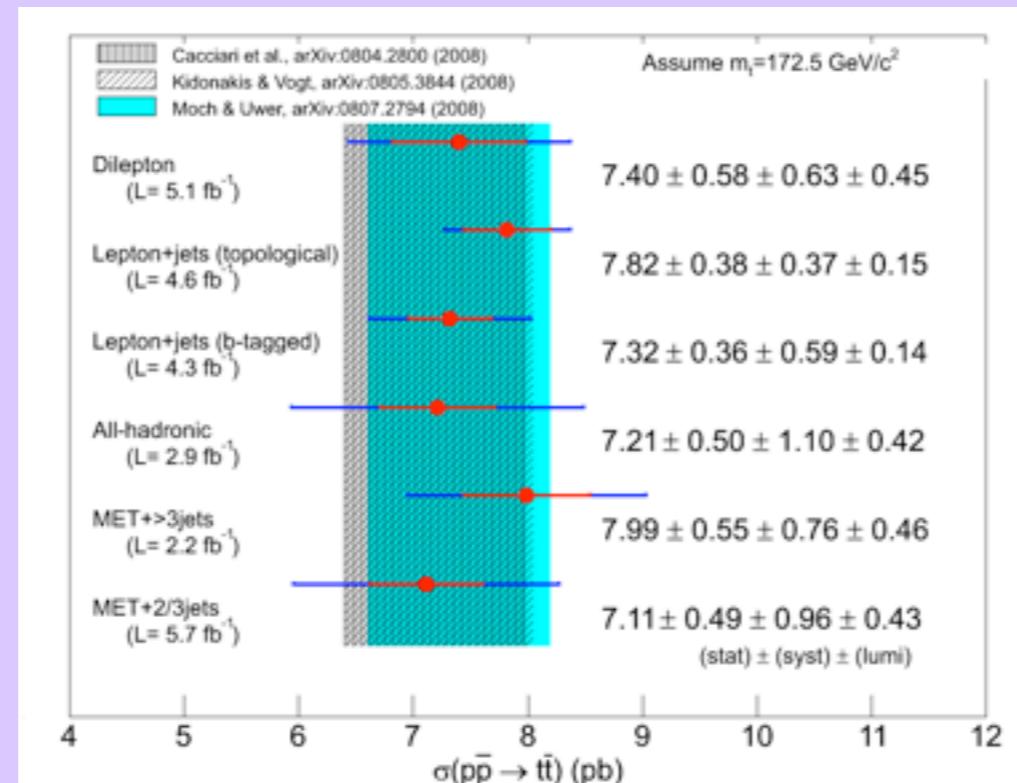
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Top char

Top wid

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



6% uncertainty
challenging that
from theory

$\sigma = 6.9 \pm 0.4$

0.09

C.L.

+b

section

5 CL

ction

$A_{fb} = 19.3$

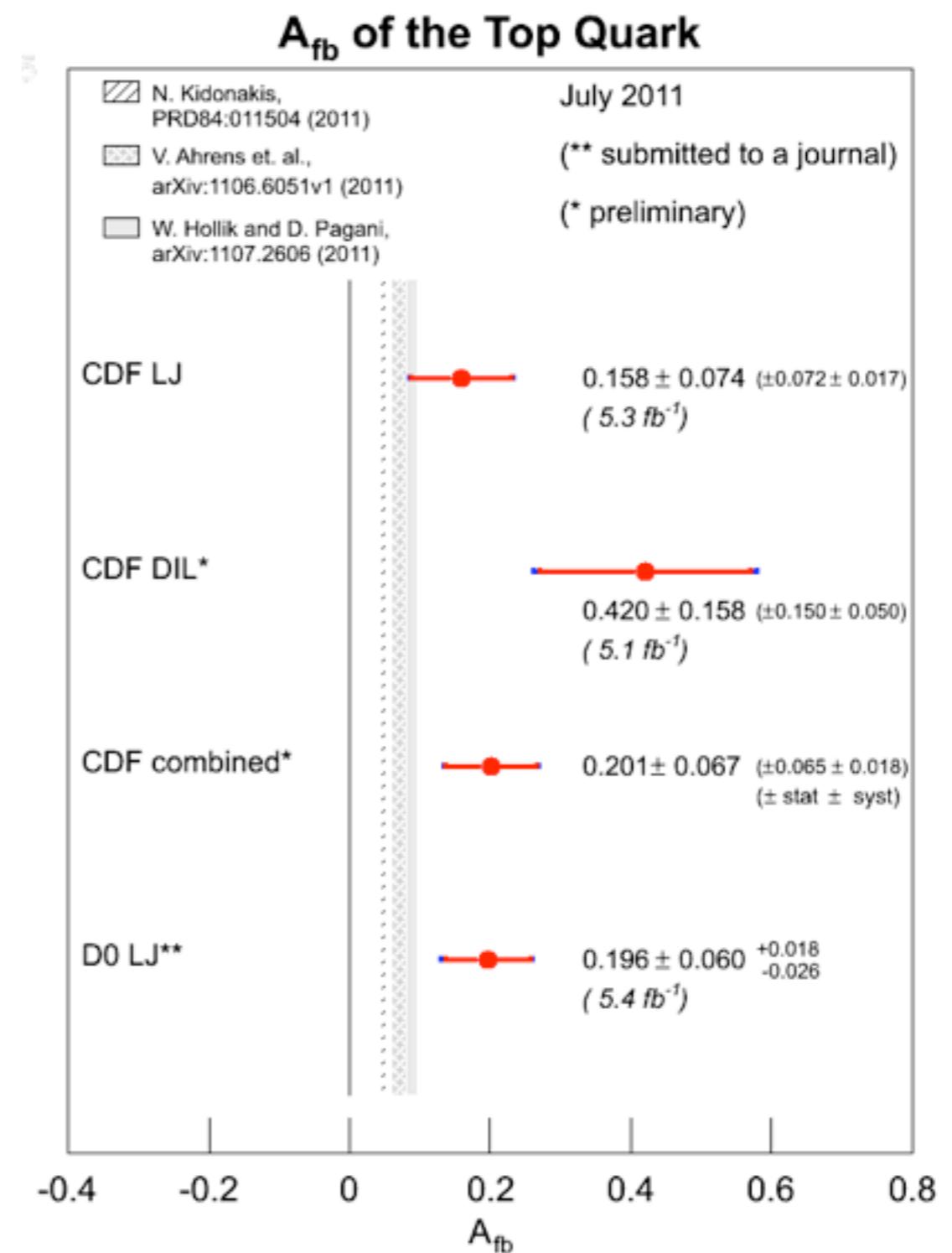
Excl. N

$d\sigma/dM_{t\bar{t}}$

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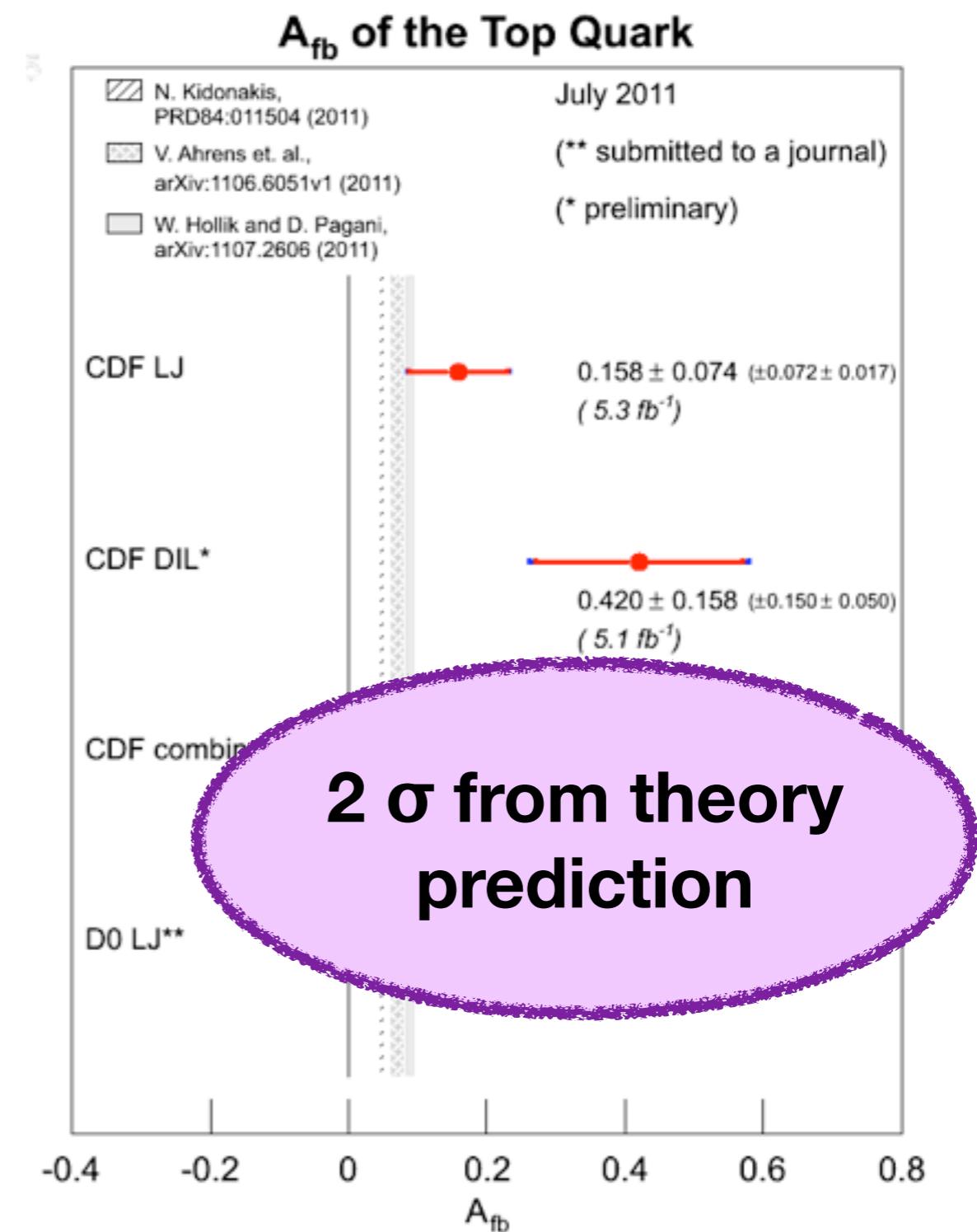
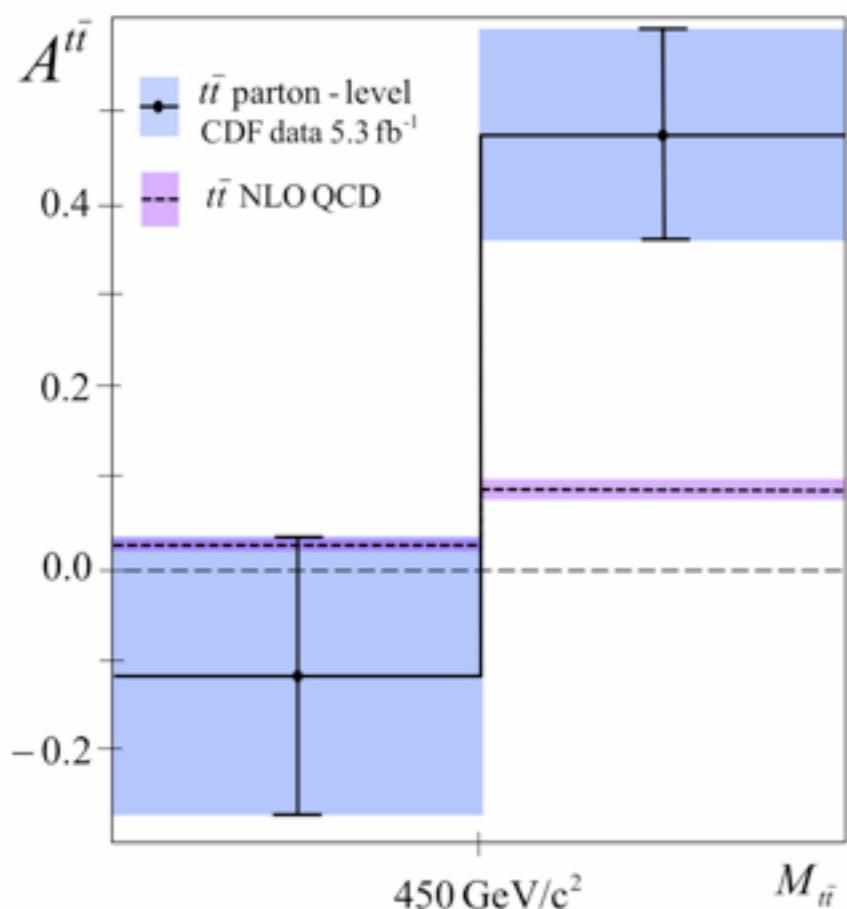
Top Quark Physics

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



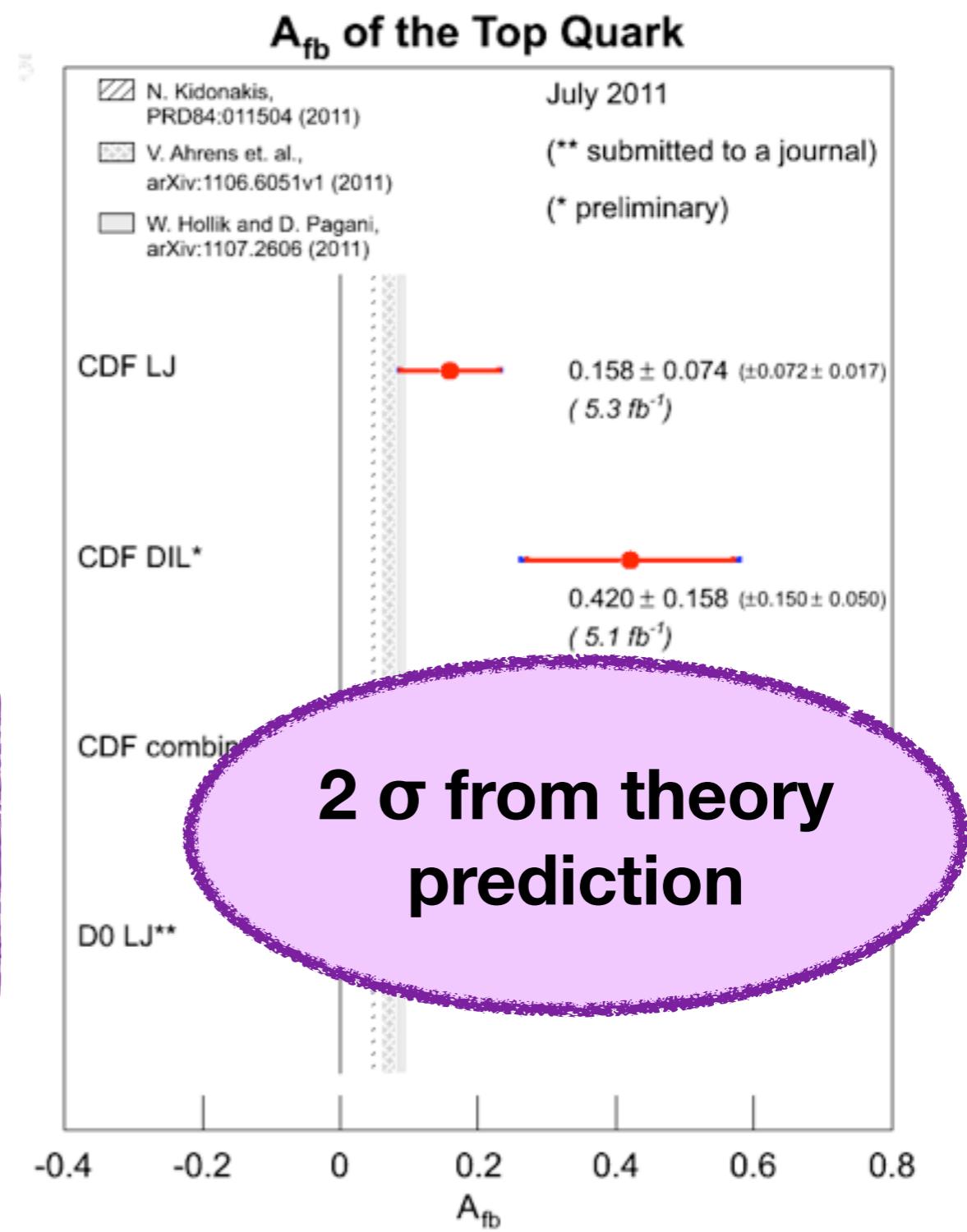
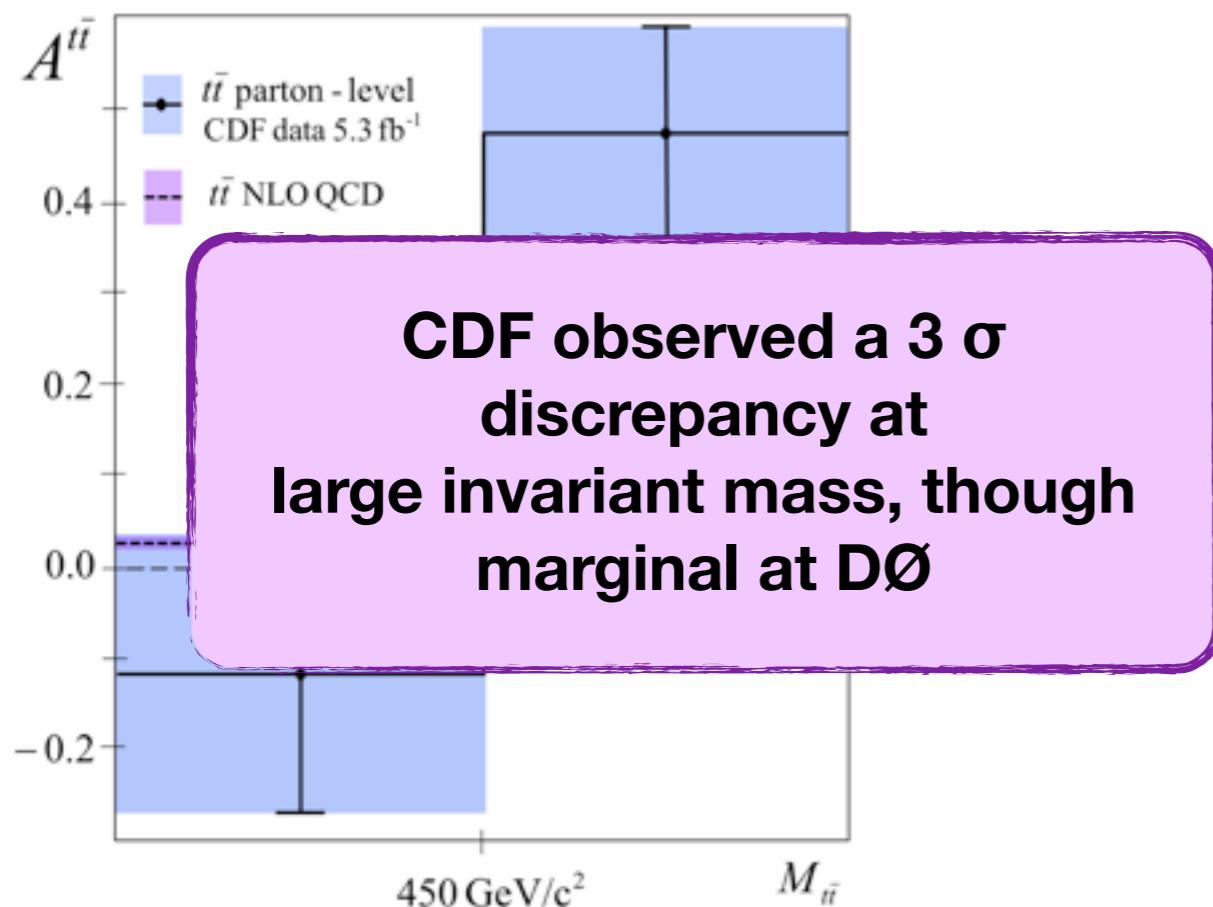
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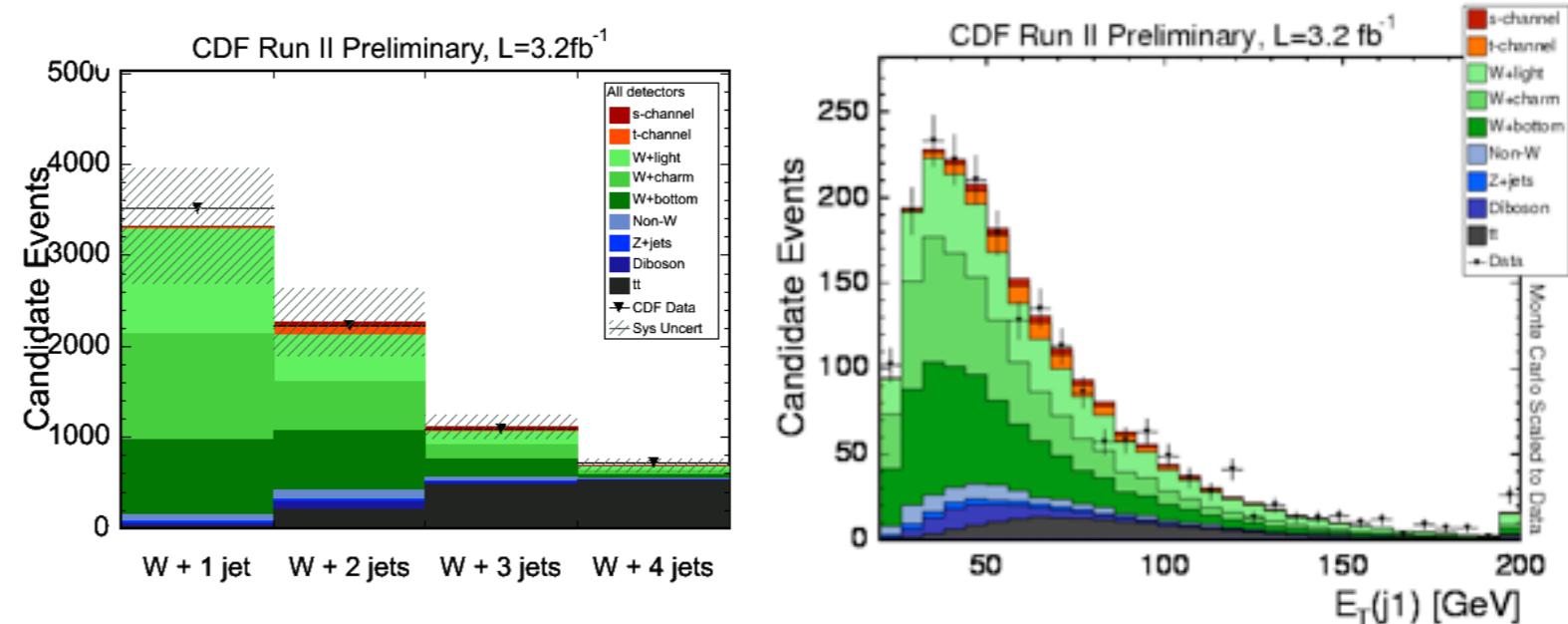
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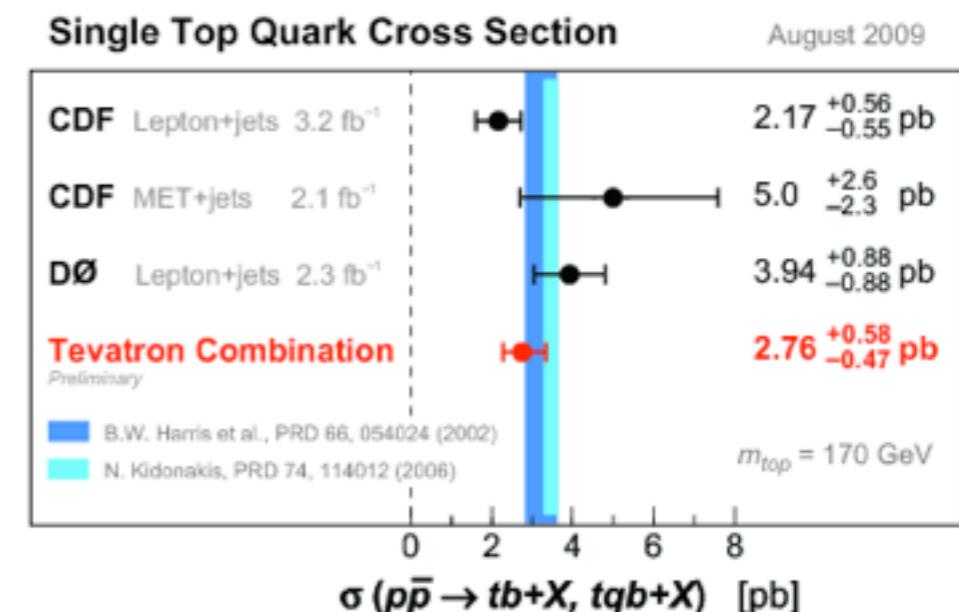


Top Quark Physics

- 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

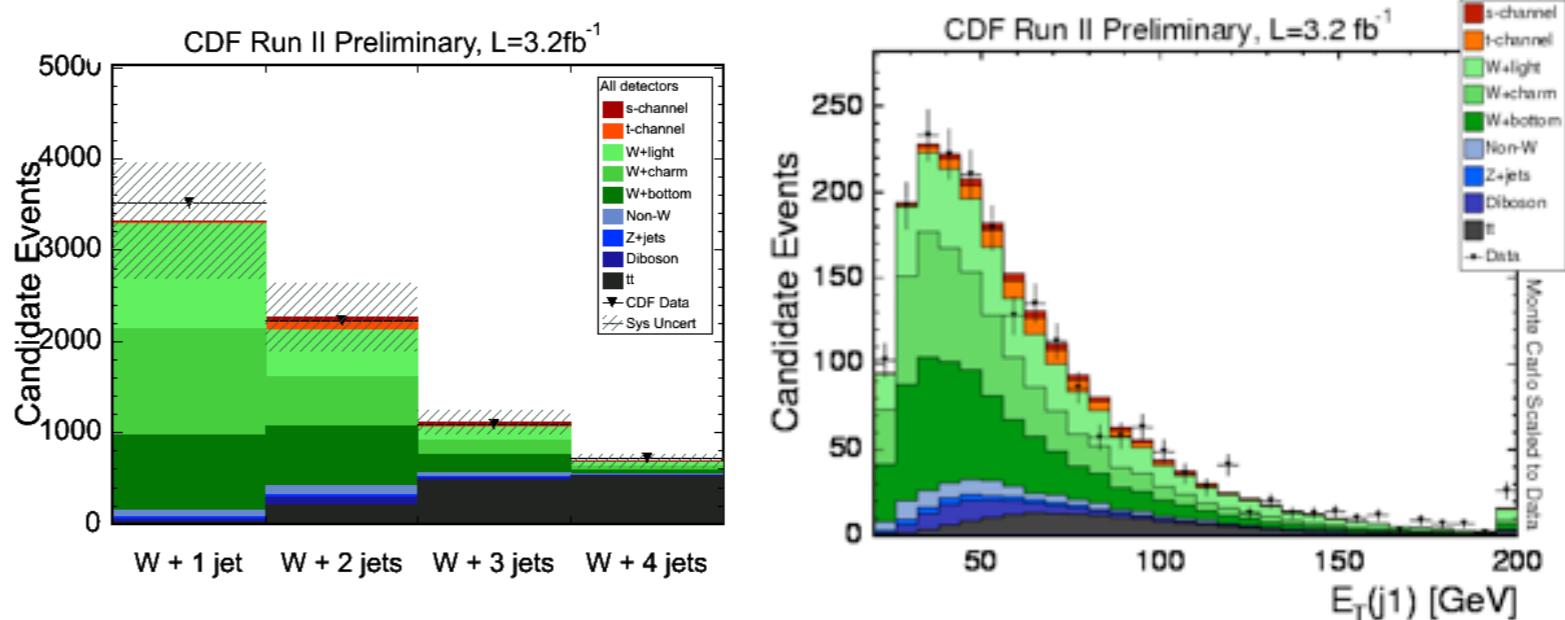


PhD Thesis B. Casal (IFCA)



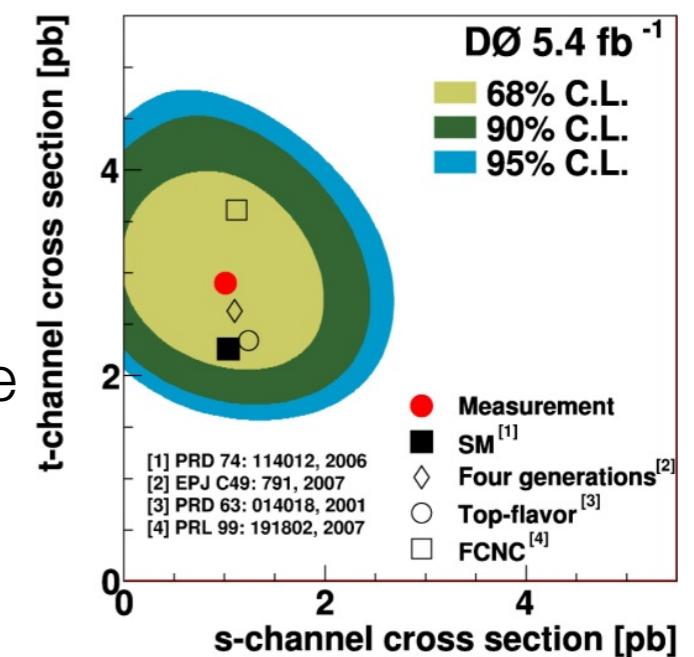
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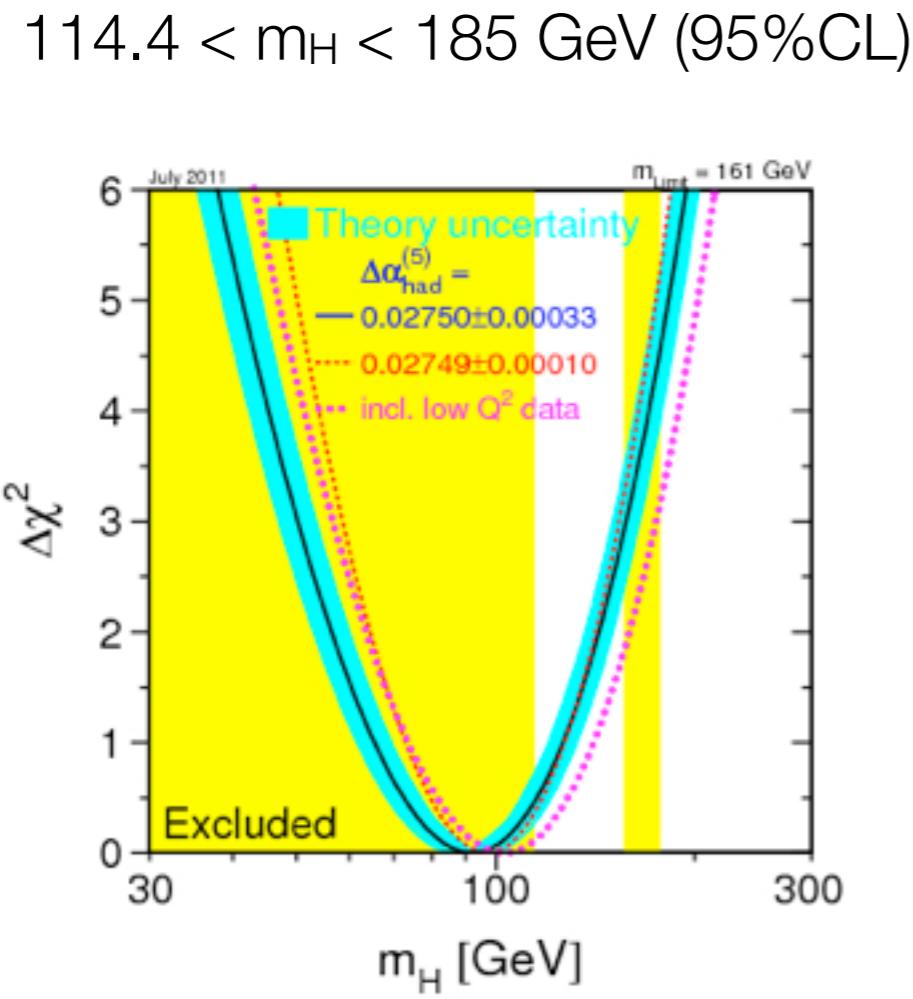
Separate t-channel
and s-channel

With a 5.5σ significance
for the t-channel

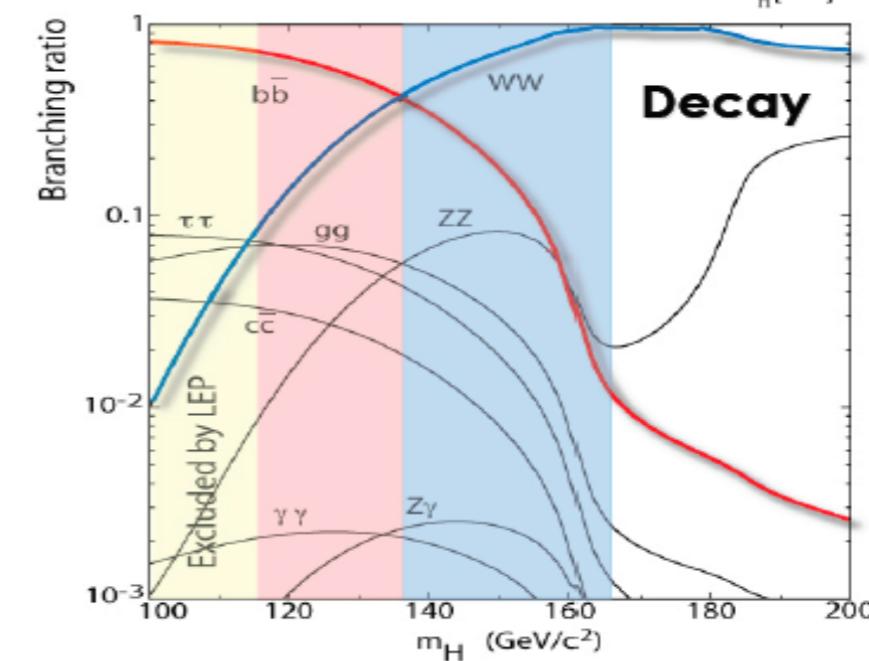
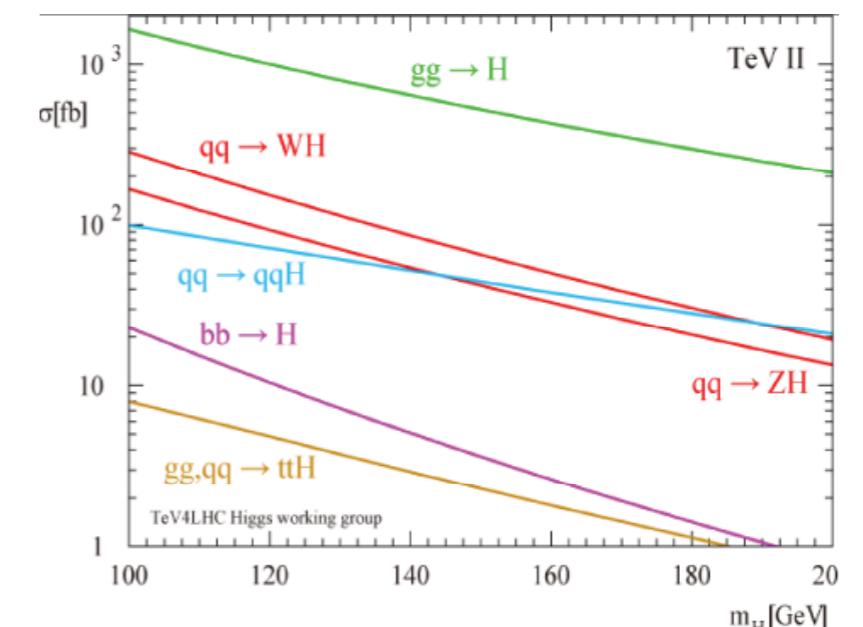


The Higgs Boson

- precision EW measurement and direct searches predicts

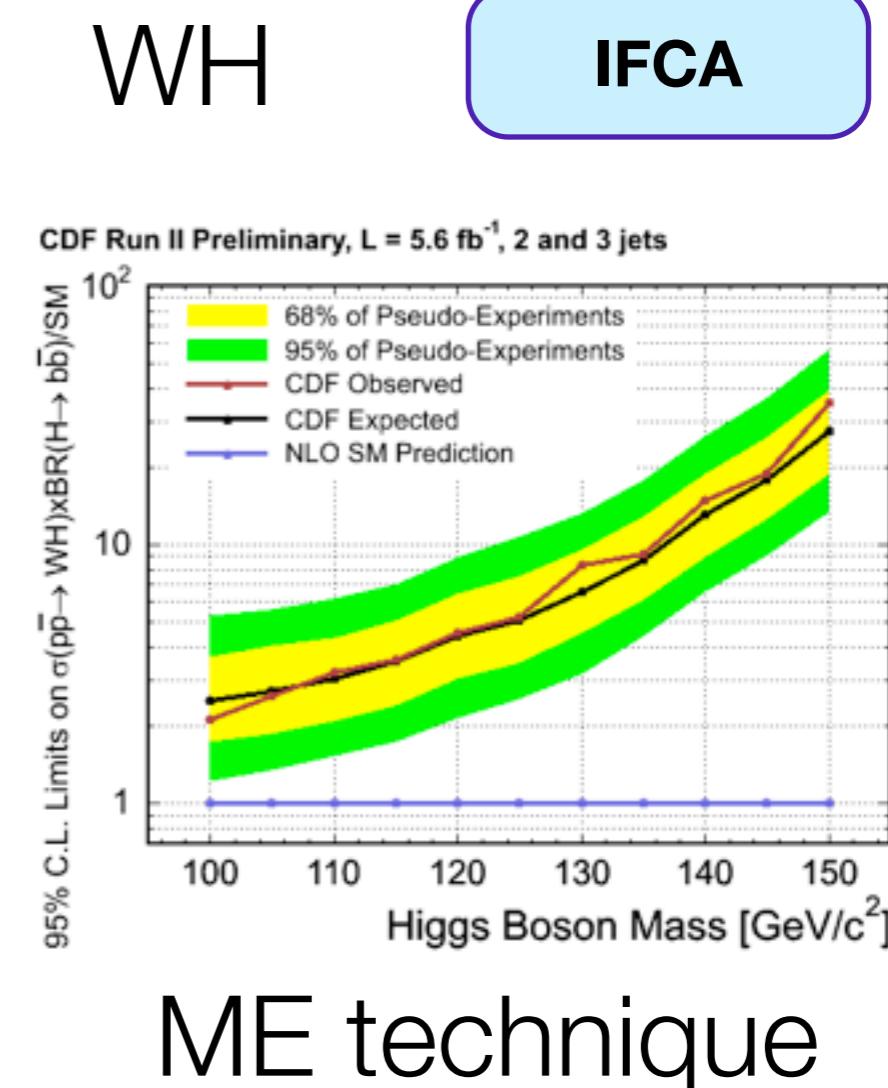
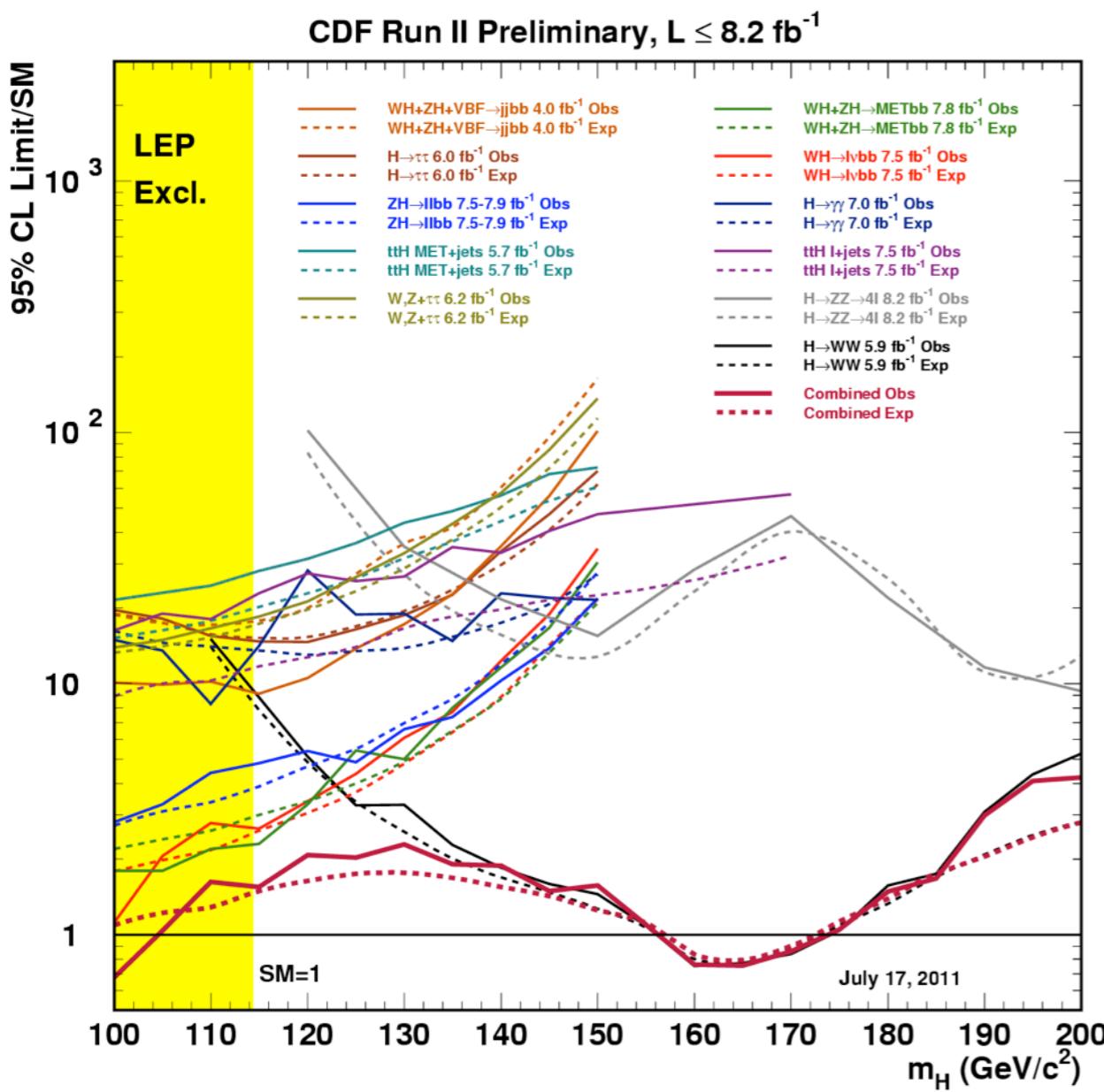


Tevatron



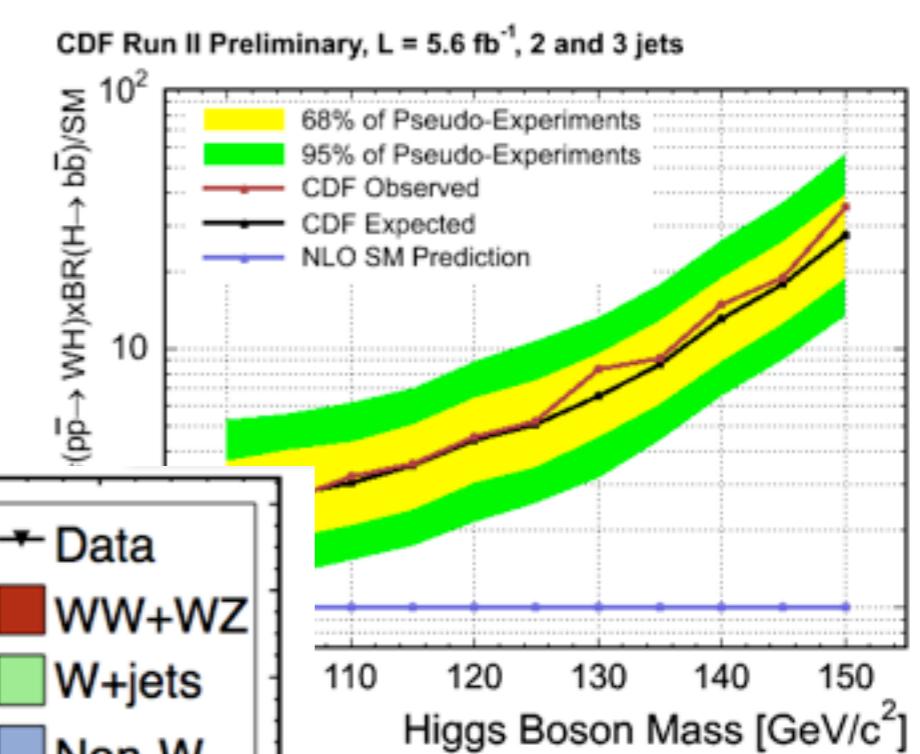
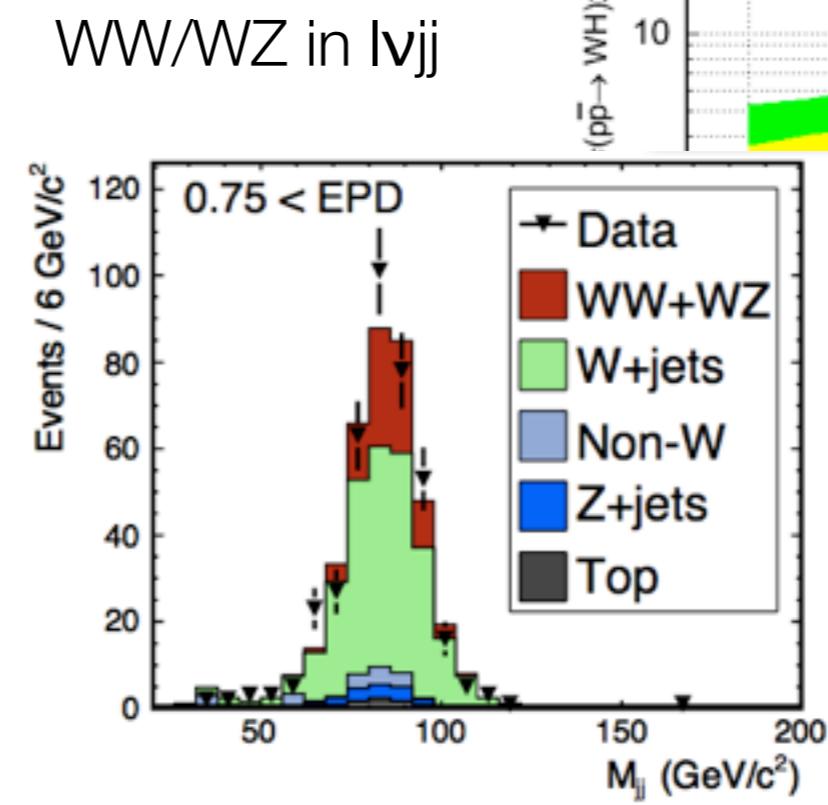
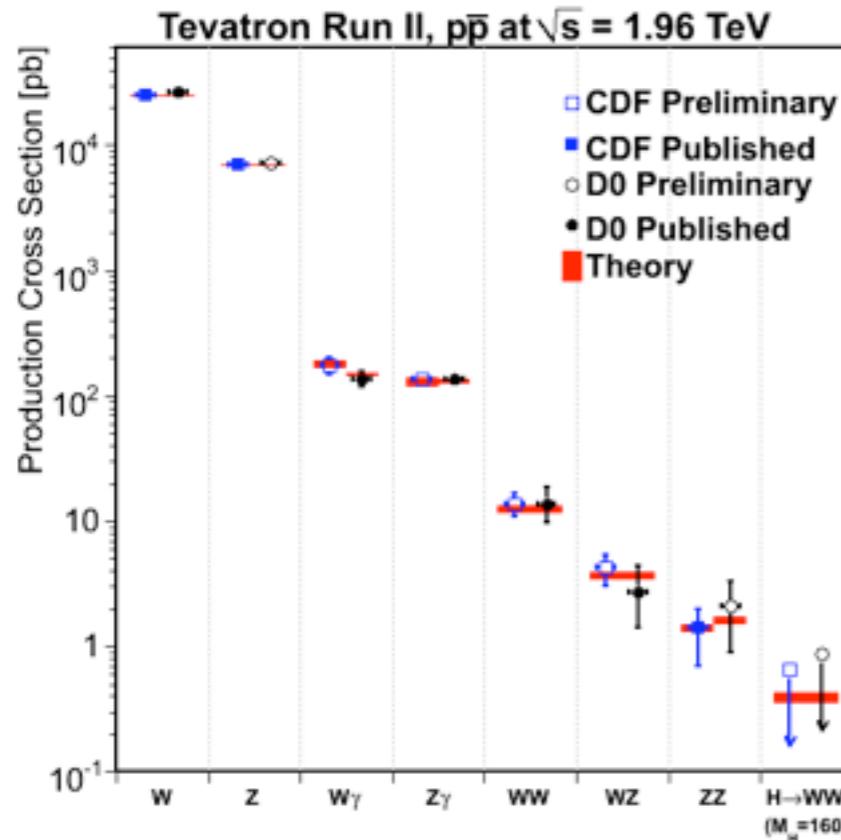
The Higgs Boson

- Searches are performed in many channels



The Higgs Boson

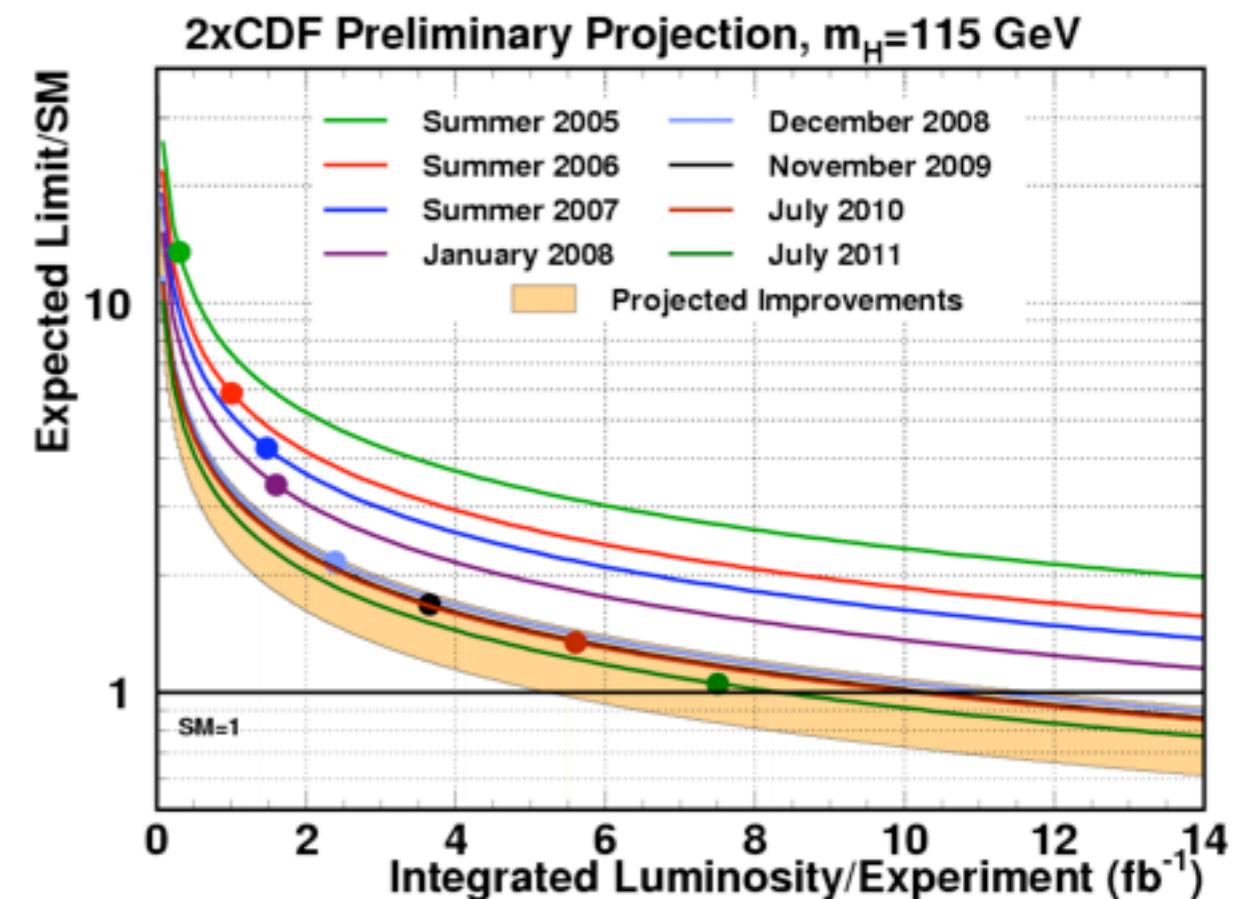
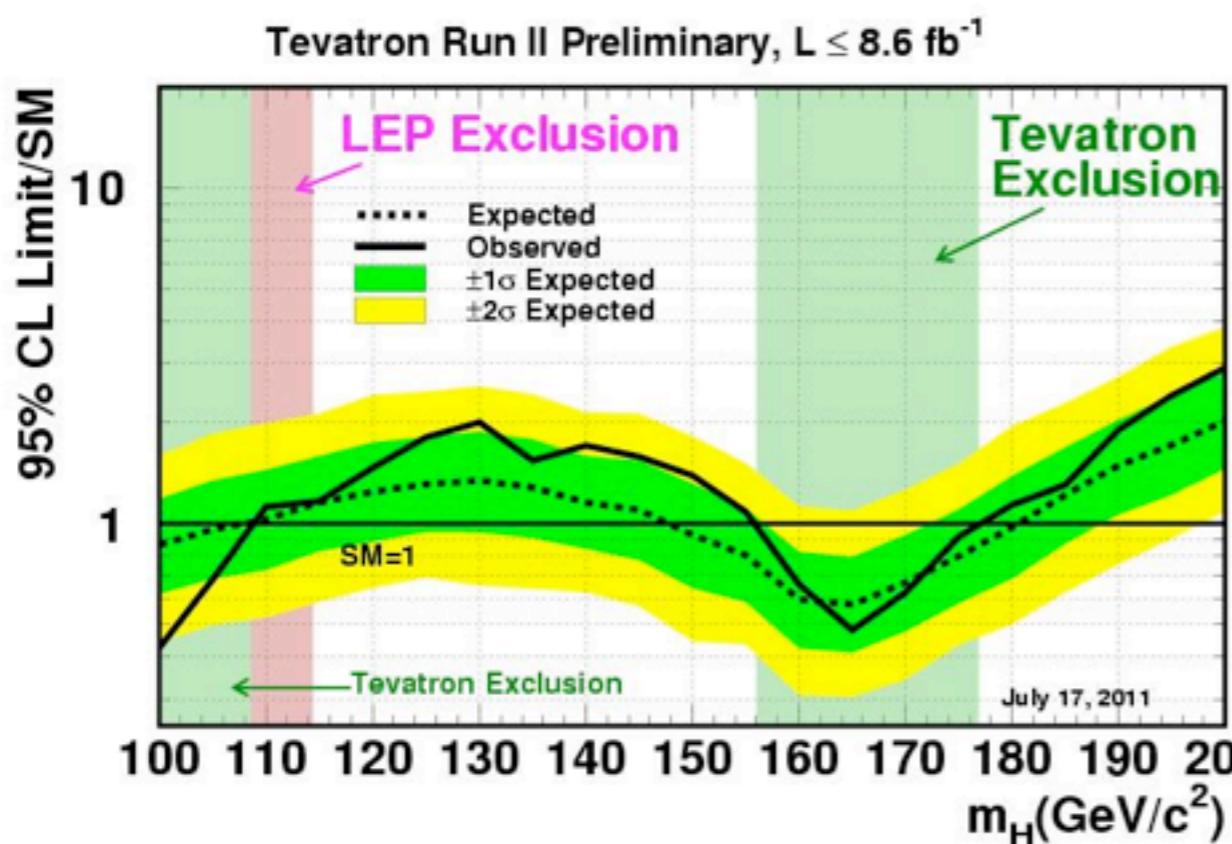
- Techniques validated : Diboson production



technique

The Higgs Boson

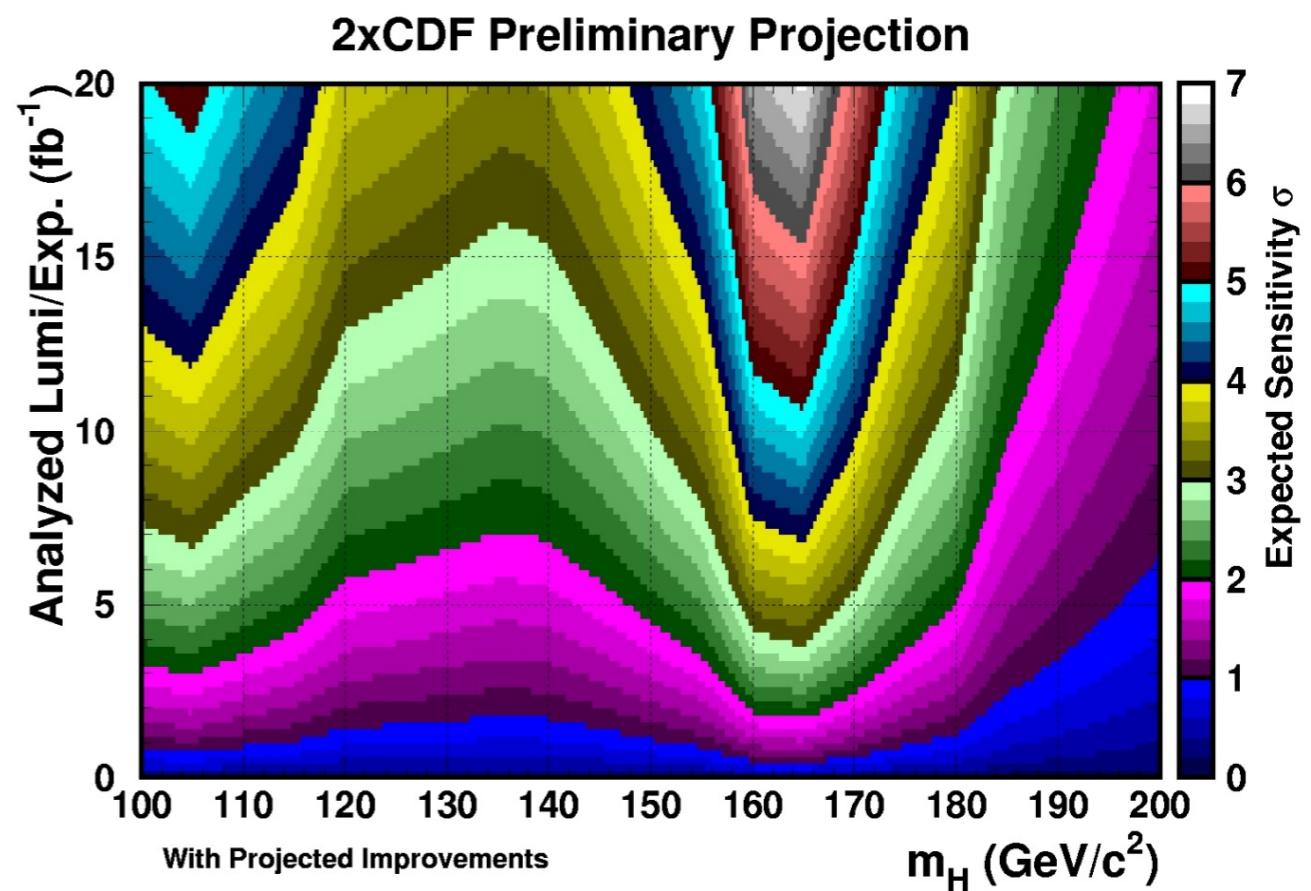
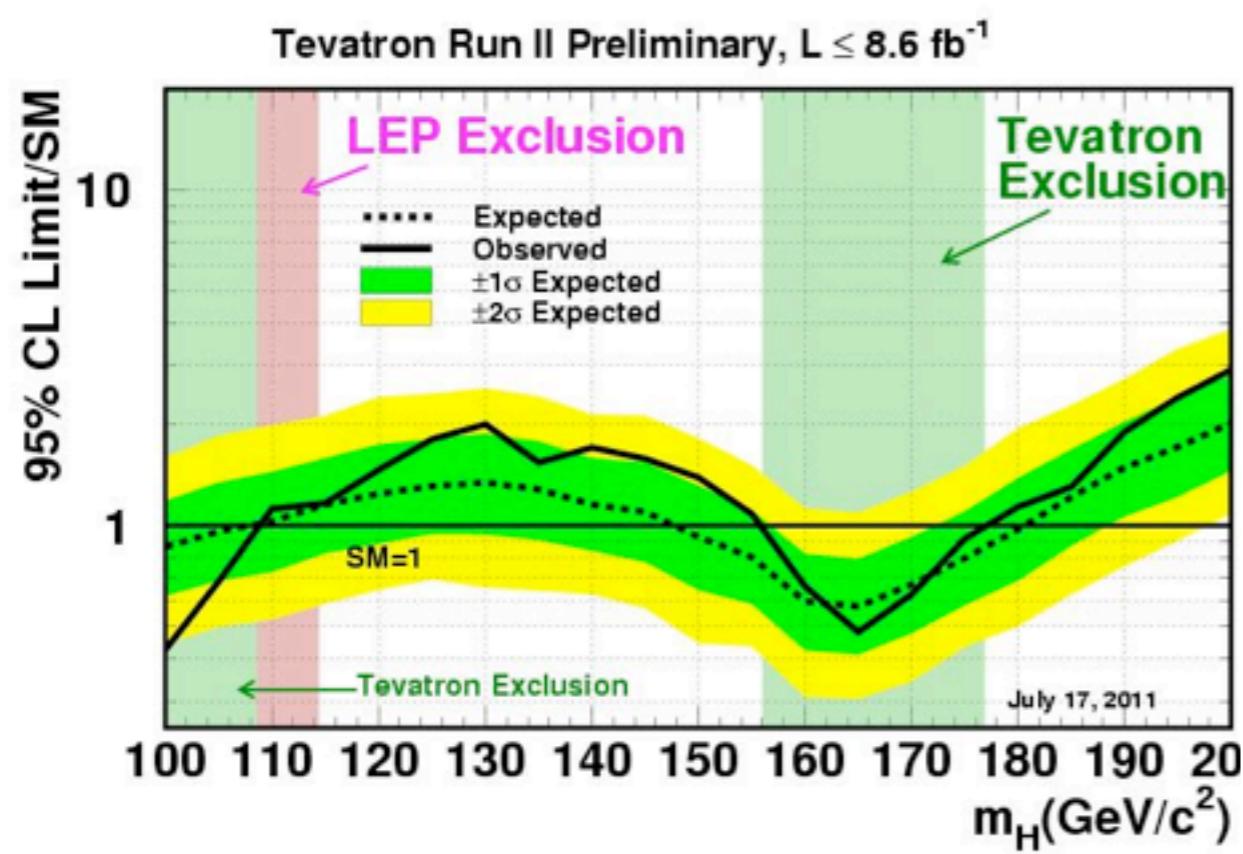
Tevatron Combination



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

The Higgs Boson

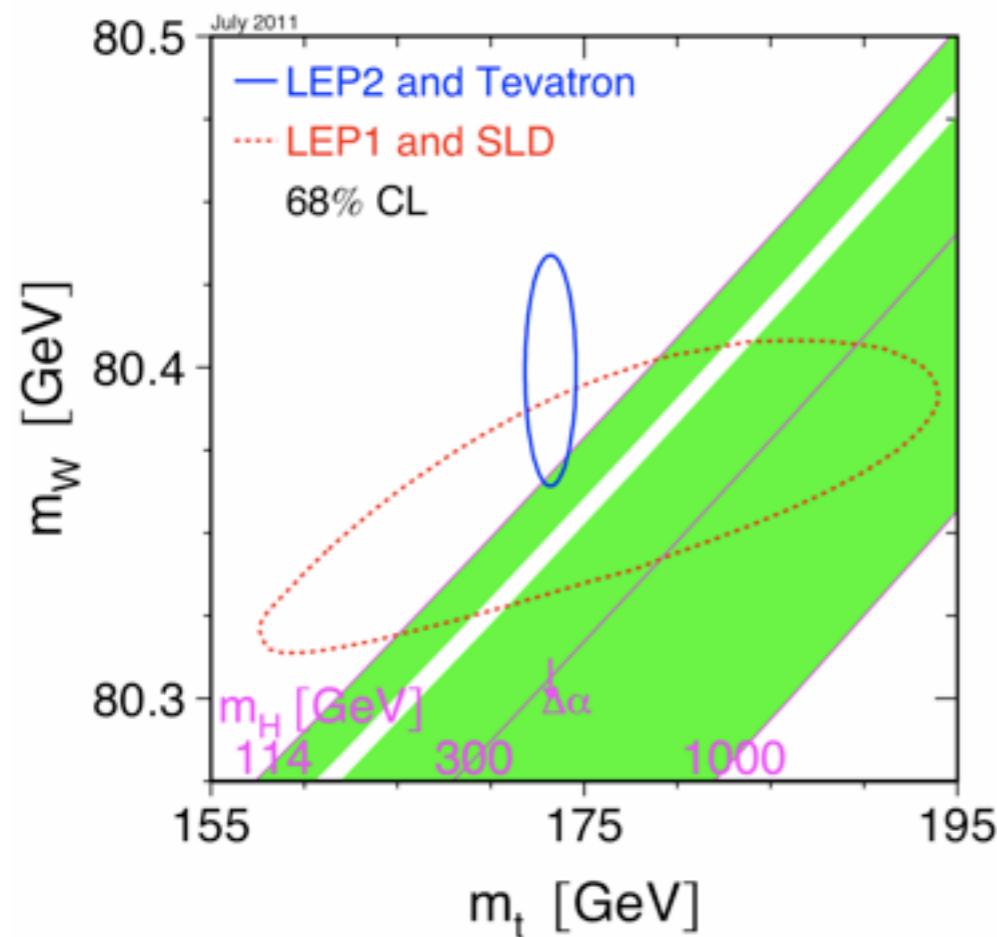
Tevatron Combination



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 $H \rightarrow bb$

The Higgs Boson

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



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

$$\text{Tevatron } 80.420 \pm 0.031 \text{ GeV}$$

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 , A_{fb} in $t\bar{t}$, dijet mass in Wjj events.....
- and innovations and expertise that are now being exploited at LHC



THANKS !!!!



BACKUP

