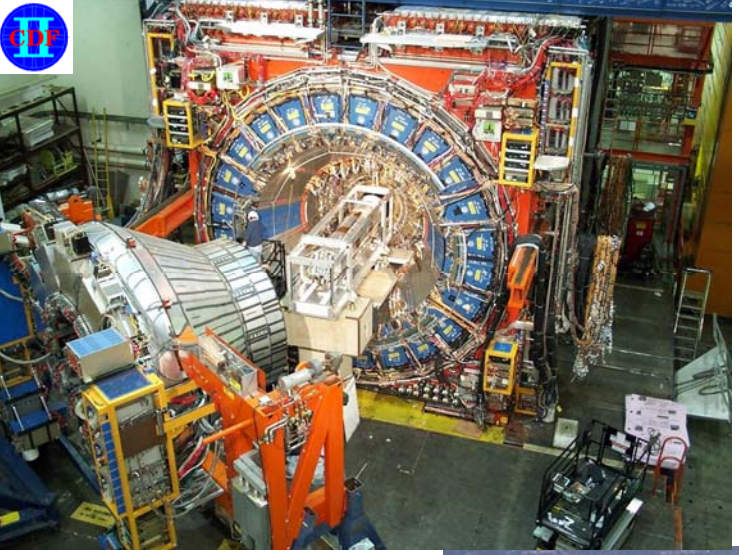
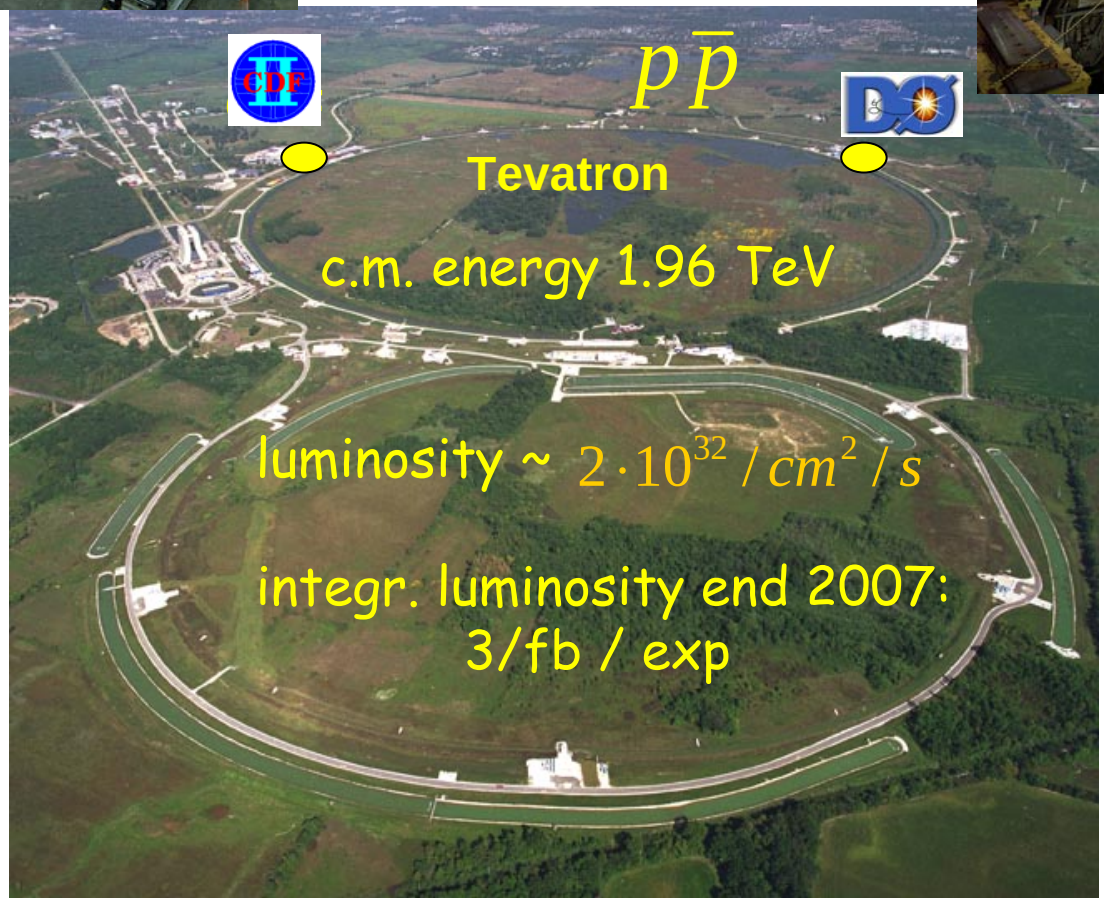


Tevatron Results

Thomas Hebbeker
Aachen
April 2008



Run I
1992-1996
0.1/fb / exp
… top …

Run II
2001-2010
8/fb/exp ?
… B_s …

RWTH AACHEN
Phys. Inst. III A

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

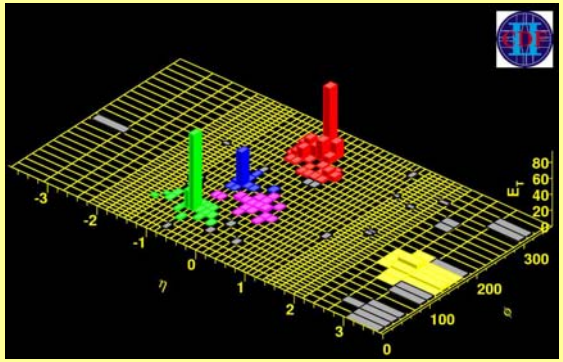
V 1.1

Tevatron

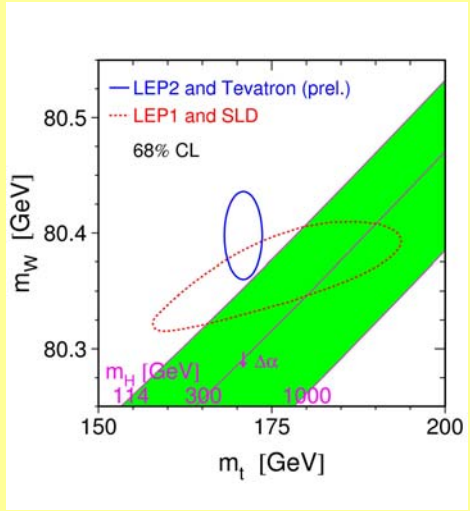
Outline

Introduction

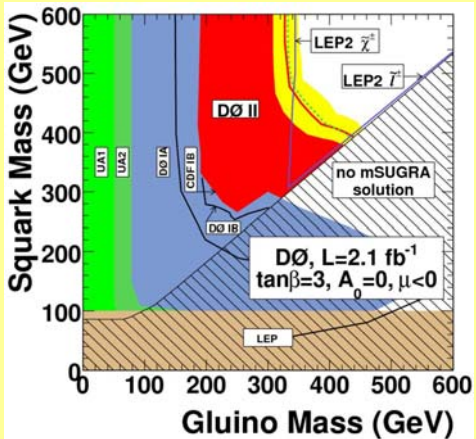
QCD Tests



Electroweak Results



Searches



Tevatron

Outline

Introduction

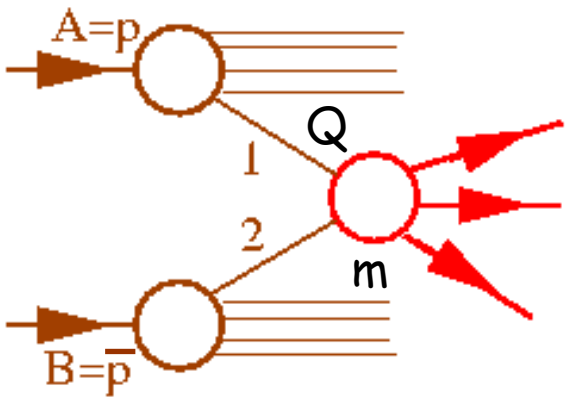
cross sections

QCD Tests

Electroweak Results

Searches

Cross Sections



strong, soft:

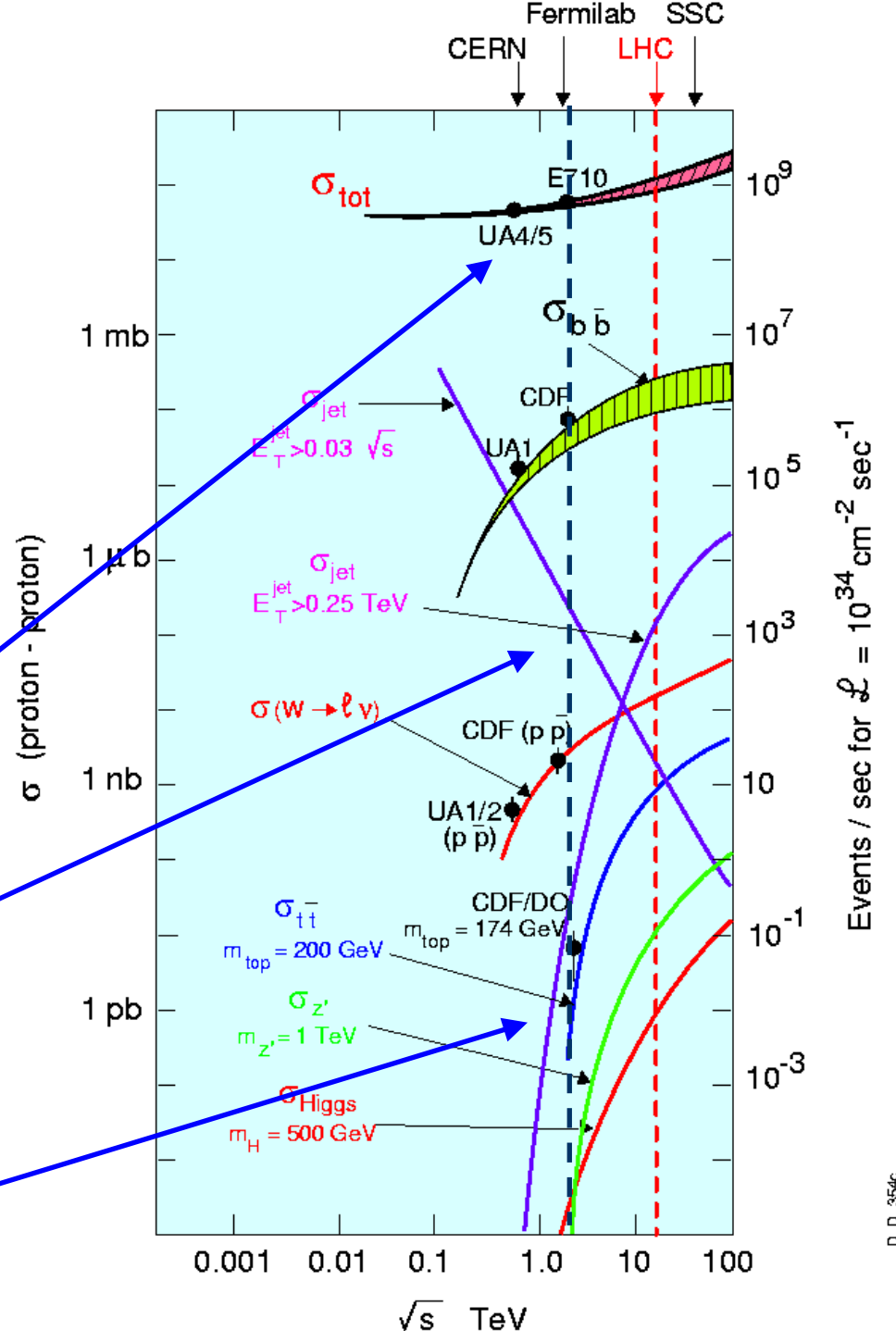
$$\sigma \approx 10\, fm^2 \approx 100\, mb$$

strong, hard:

$$\sigma \approx \frac{\alpha_s^{\,2}}{Q^2} \approx 10\, nb$$

electroweak:

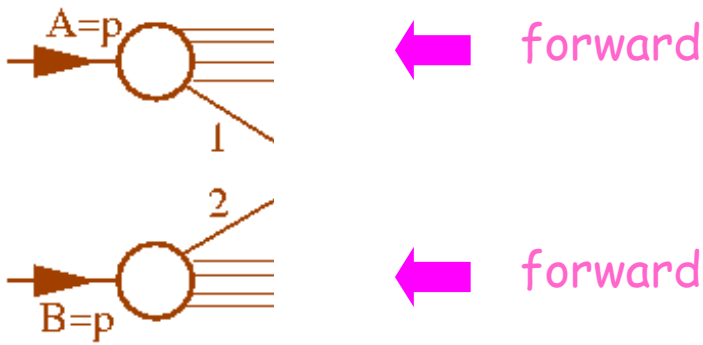
$$\sigma \leq \frac{\alpha^2}{m^2} \approx 1\, pb$$



„Dirty“ environment

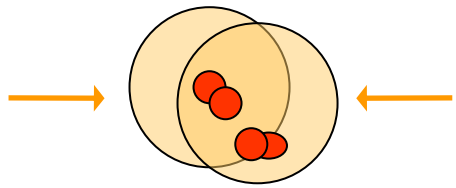
- **beam remnants**

  underlying event



- **multiple parton interactions**

  some percent

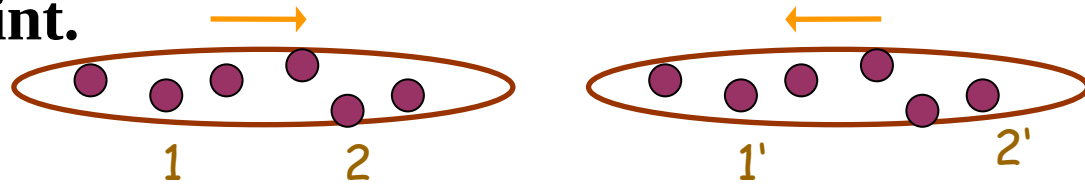


- **„pile up“ = multiple p $\bar{p}$ int.**

  minimum bias events

  2 - 10 events / bunch crossing

  every 396 ns



- **„detector pile up“**
  - drift time > bunch distance
  - thermalized neutrons

Outline

Introduction

QCD Tests

- jet production
- top
- bound states

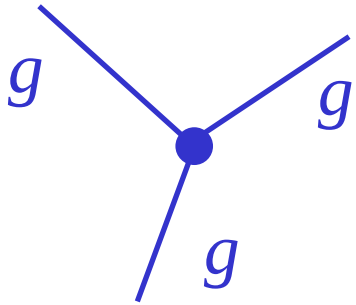
Electroweak Results

Searches

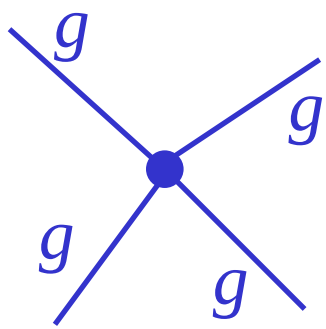
Standard Model – strong SU(3)

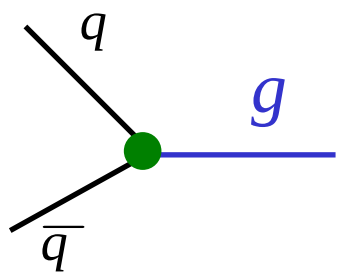
$$\begin{pmatrix} u\,u\,u \\ d\,d\,d \end{pmatrix} \quad \begin{pmatrix} c\,c\,c \\ s\,s\,s \end{pmatrix} \quad \begin{pmatrix} t\,t\,t \\ b\,b\,b \end{pmatrix} \qquad g \quad = \text{color octet}$$

… spin, **mass** ...

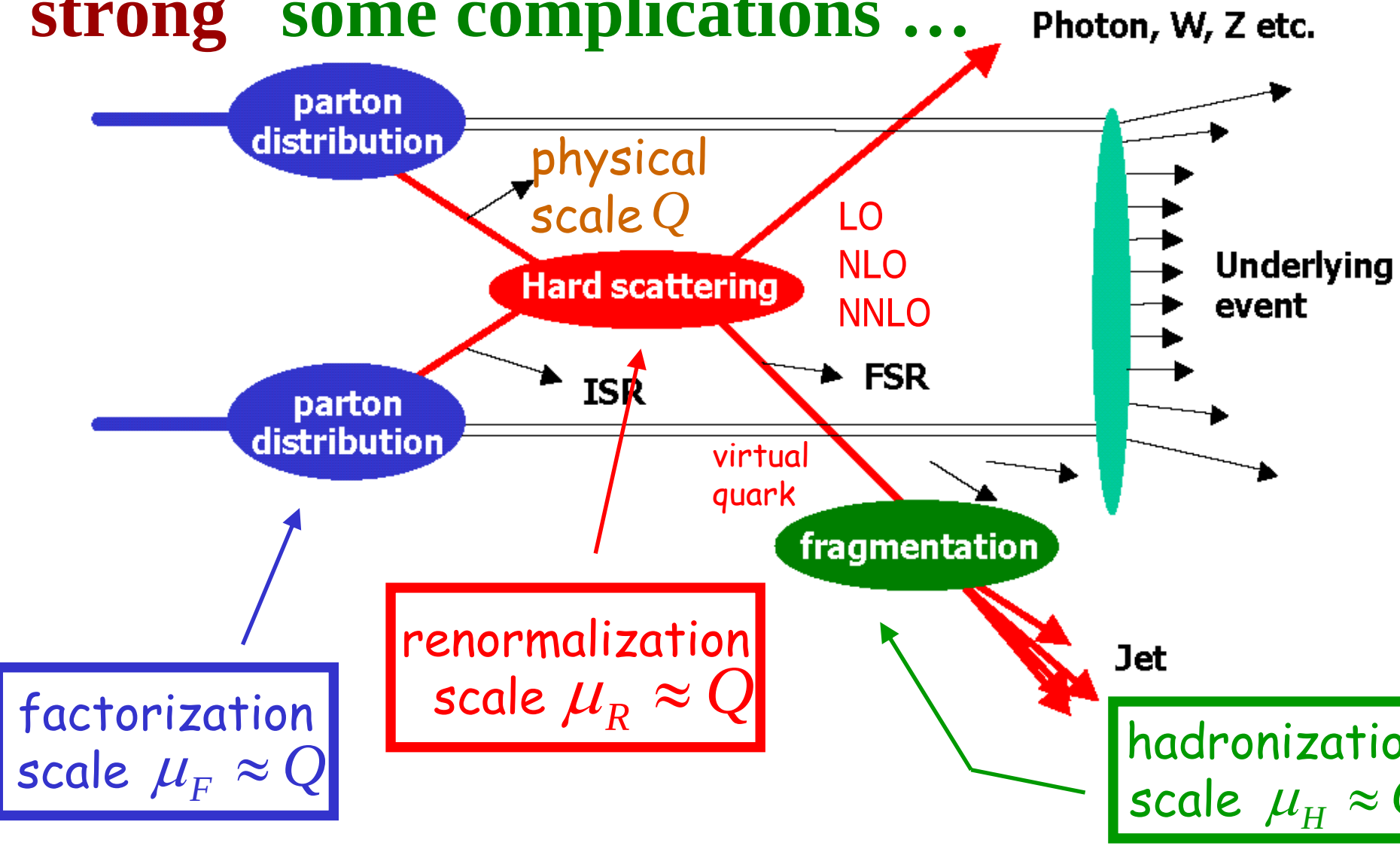


$$\alpha_s(Q^2)$$



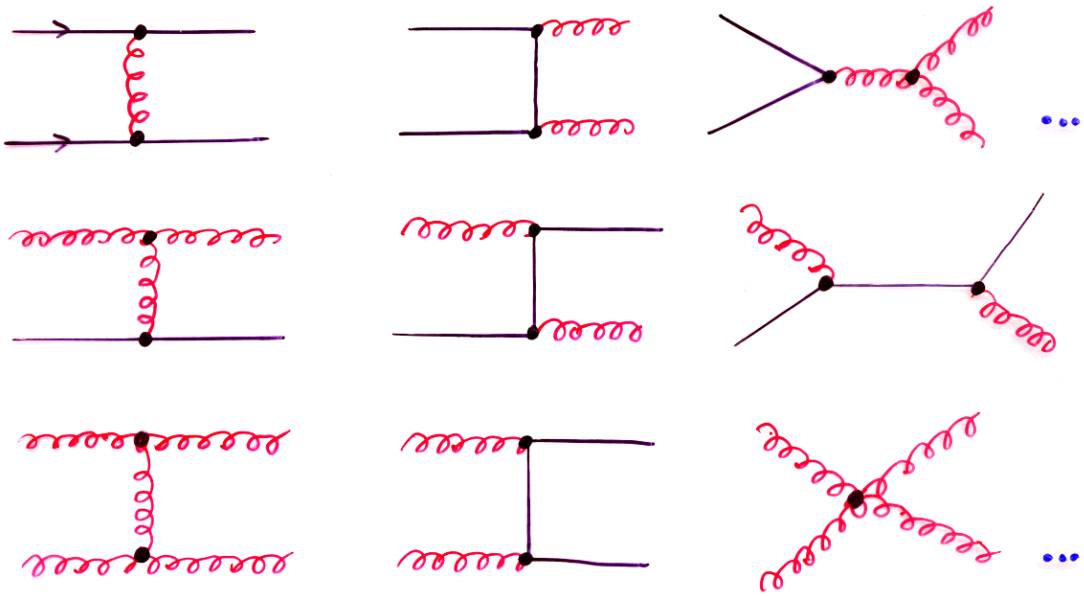


strong some complications …



$$\frac{d\sigma_F(\sqrt{s})}{dV} = \sum_{i,j} \int dx_i\, dx_j\; f_i(x_i, {\mu_F}^2)\, f_j(x_j, {\mu_F}^2)\; \frac{d\sigma_F^{ij}(x_i, x_j, {\mu_R}^2)}{dV}$$

strong jet production

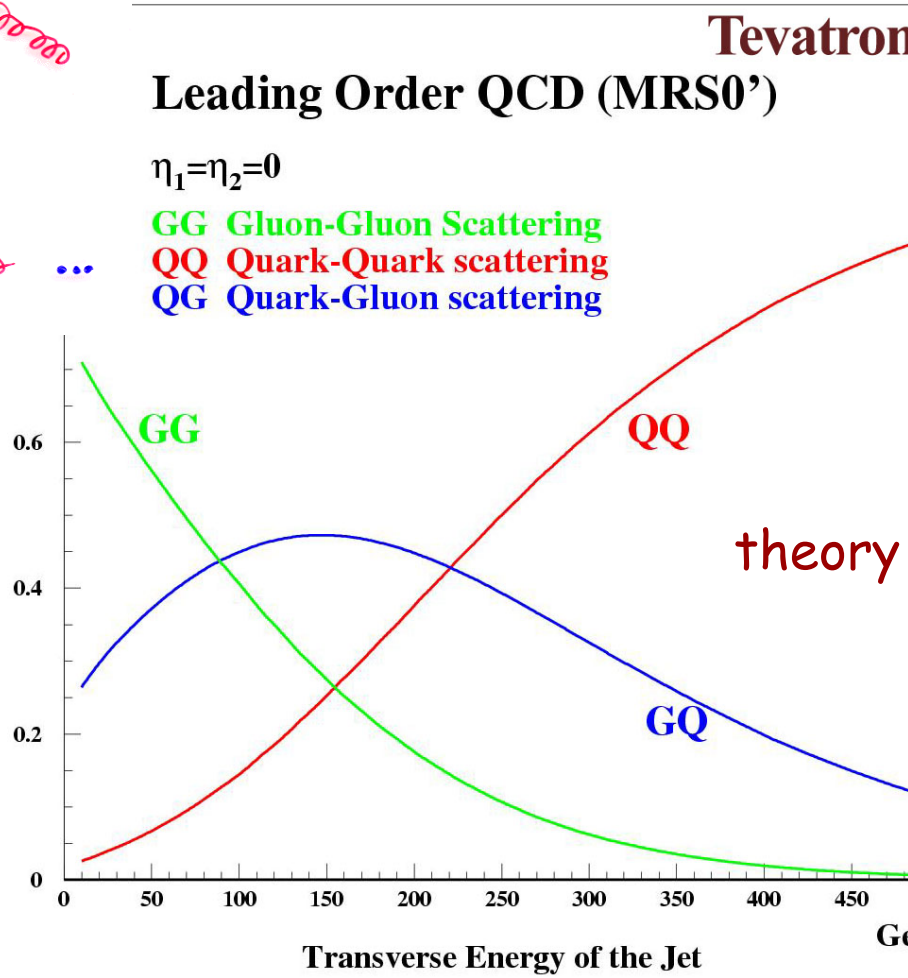


+ higher orders

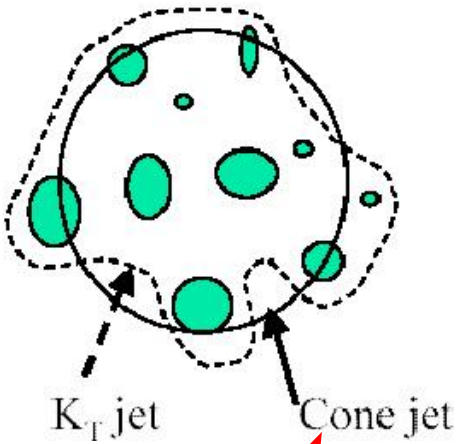
+ electroweak diagrams

note:

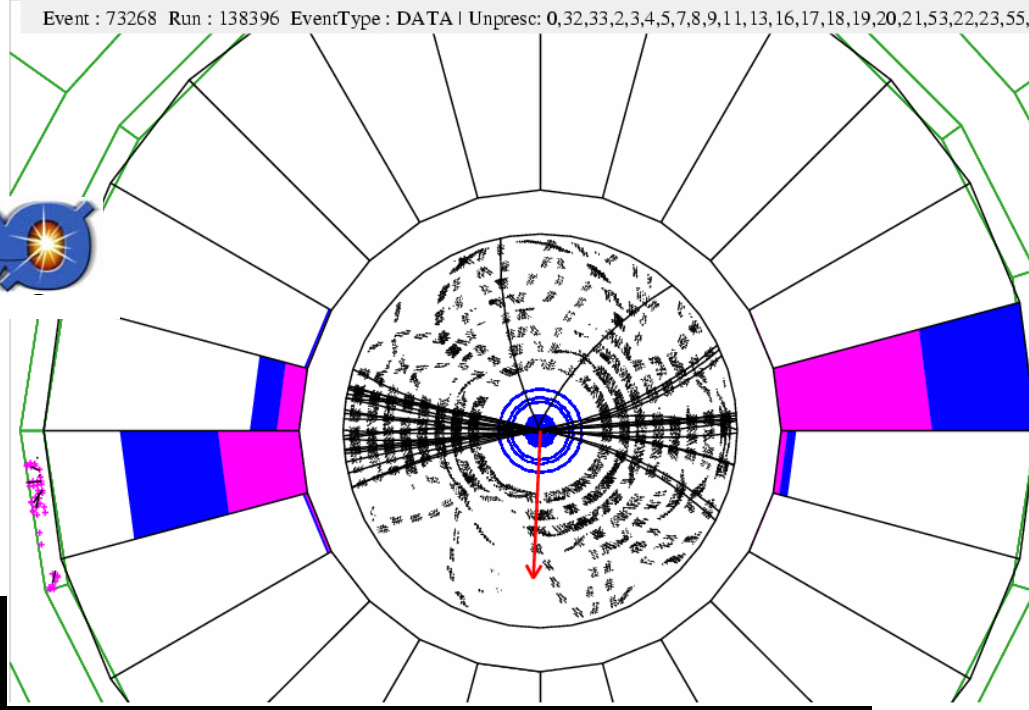
difficult to disentangle qqg and ggg contributions

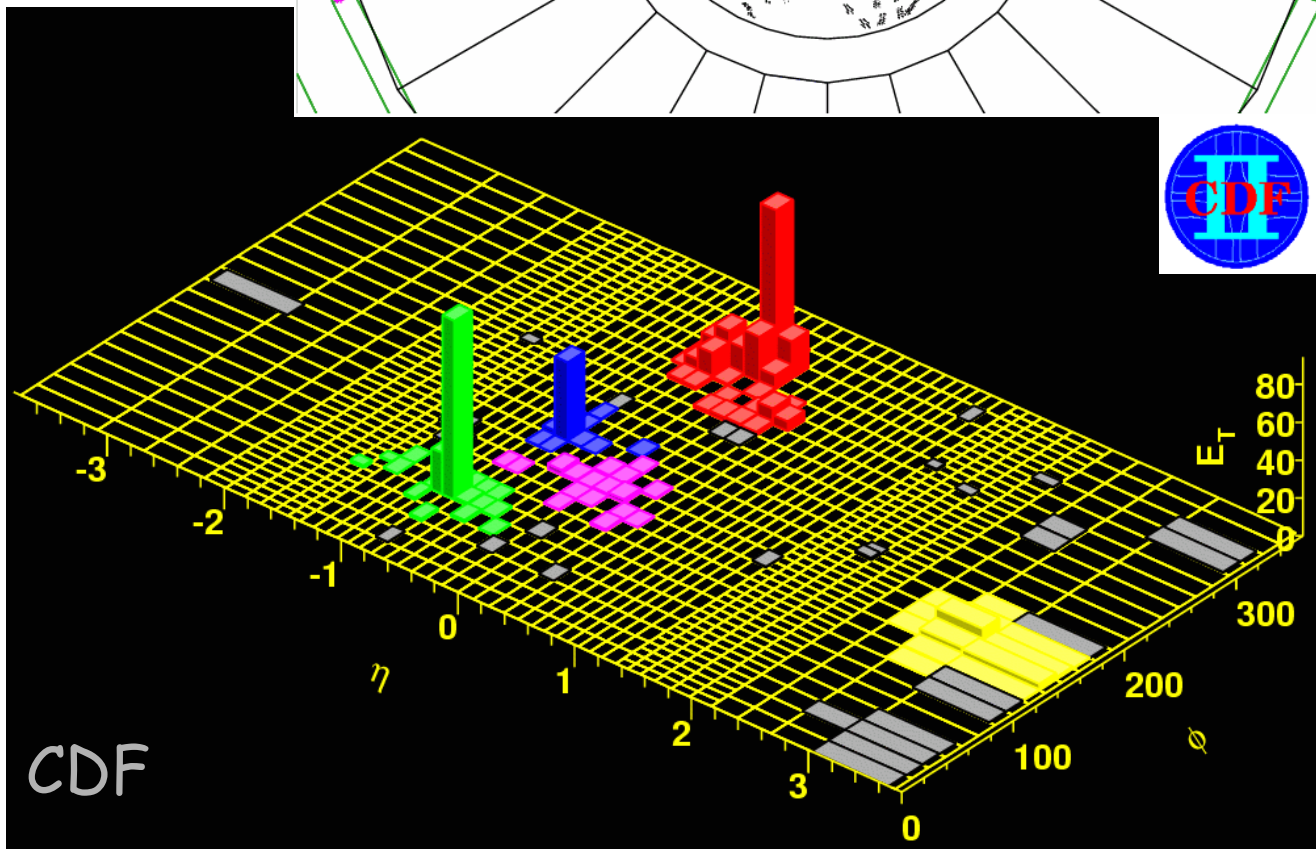


strong jets

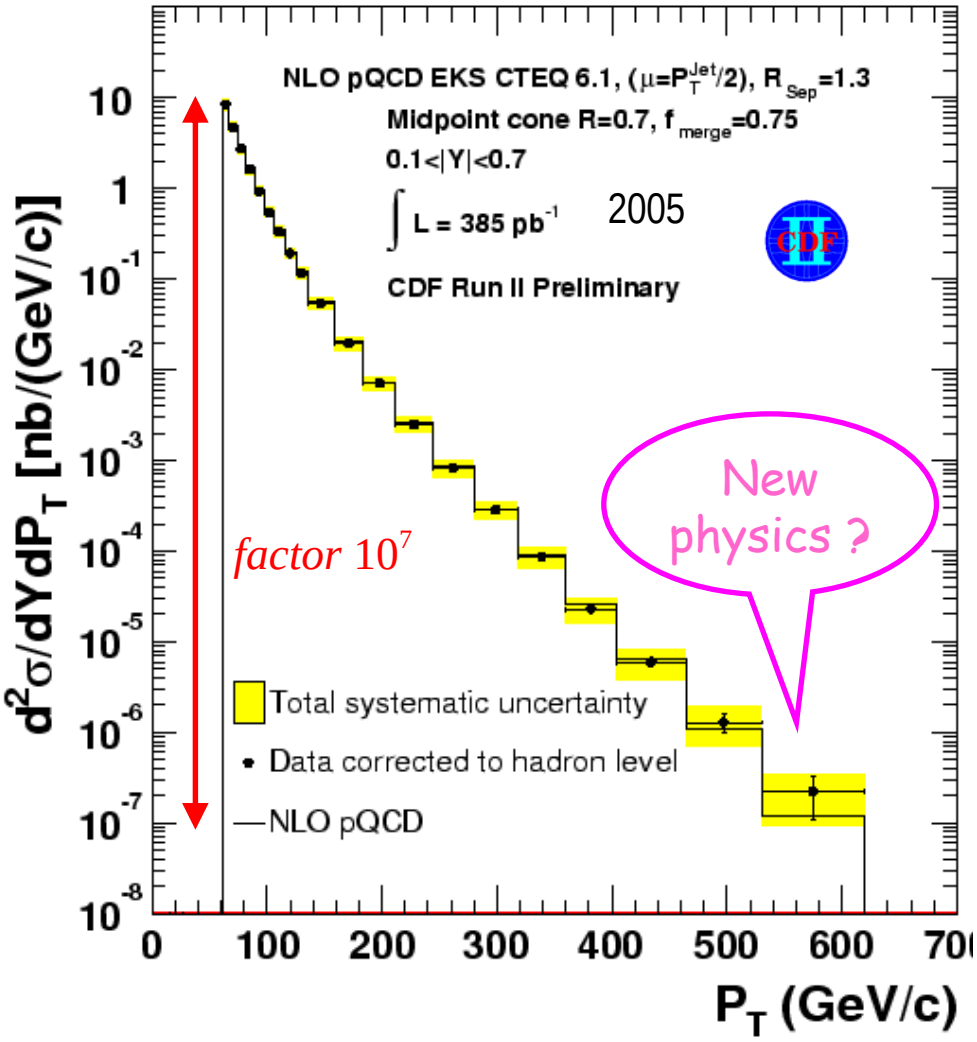


most often use cone jets with R=0.5 or 0.7

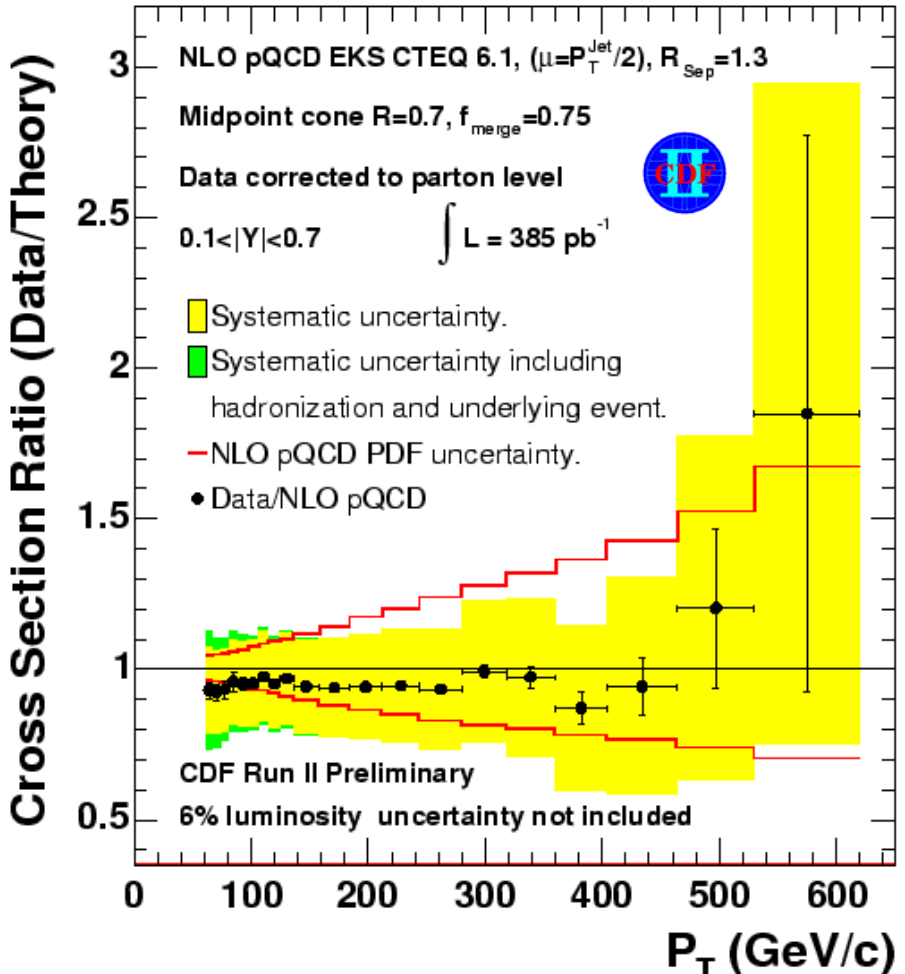




strong inclusive jet production



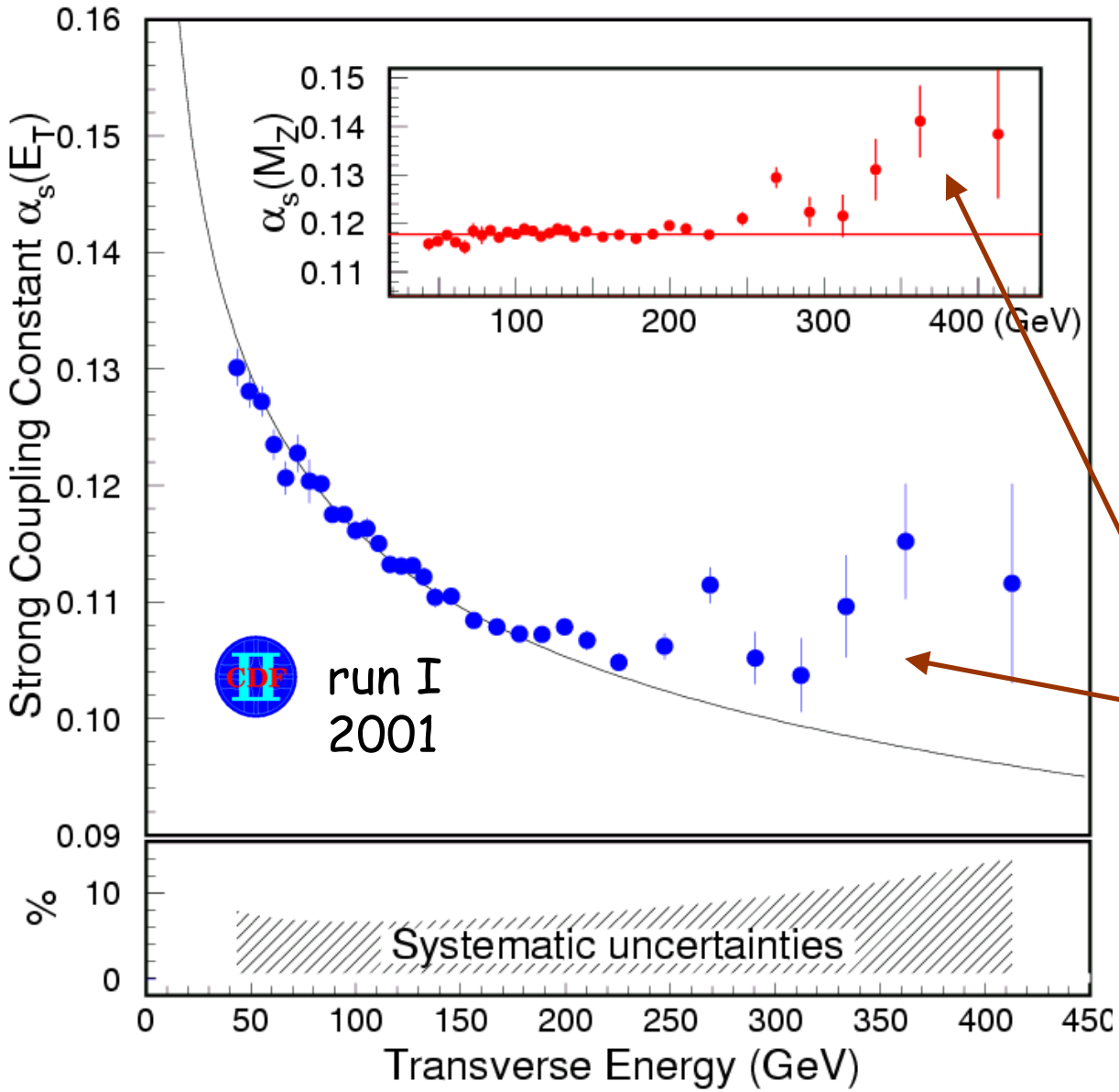
ok !



absolute normalization
(luminosity, jet scale) : ±15%

Determination of α_s

from inclusive jet production



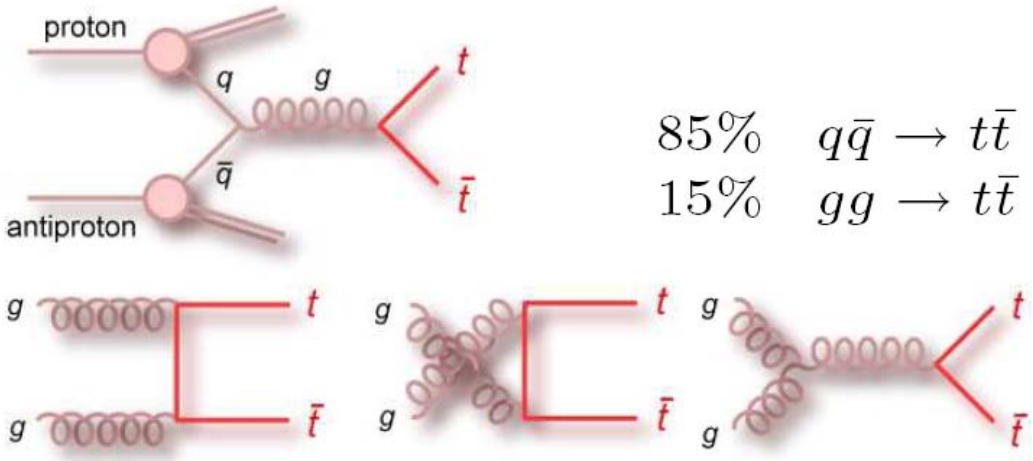
„old" pdf problem

ok !

$$\alpha_s(M_Z) = 0.118 \pm 0.012$$

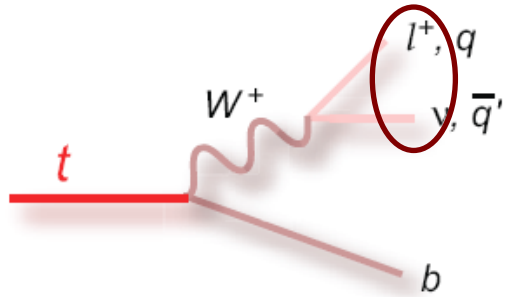
(dominated by exp. systematics, ren. scale uncertainty and pdf)

strong top pair production and decay



$$85\% \quad q\bar{q} \rightarrow t\bar{t}$$
$$15\% \quad gg \rightarrow t\bar{t}$$

$B \approx 11\%$

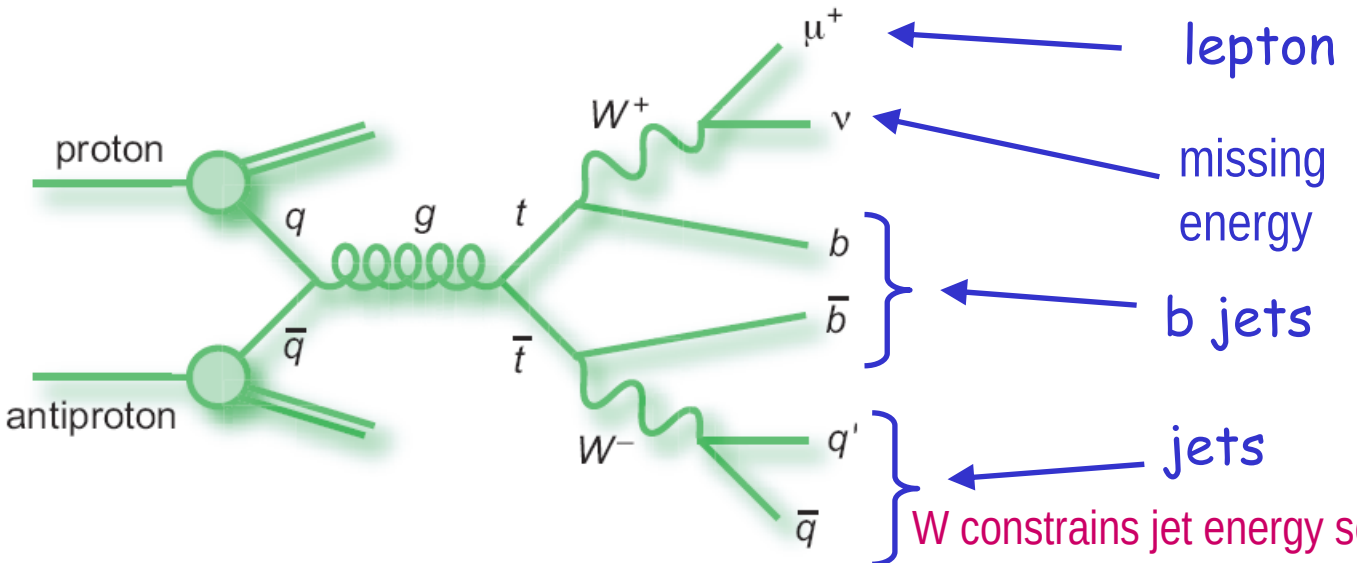


$B \approx 100\,\%$

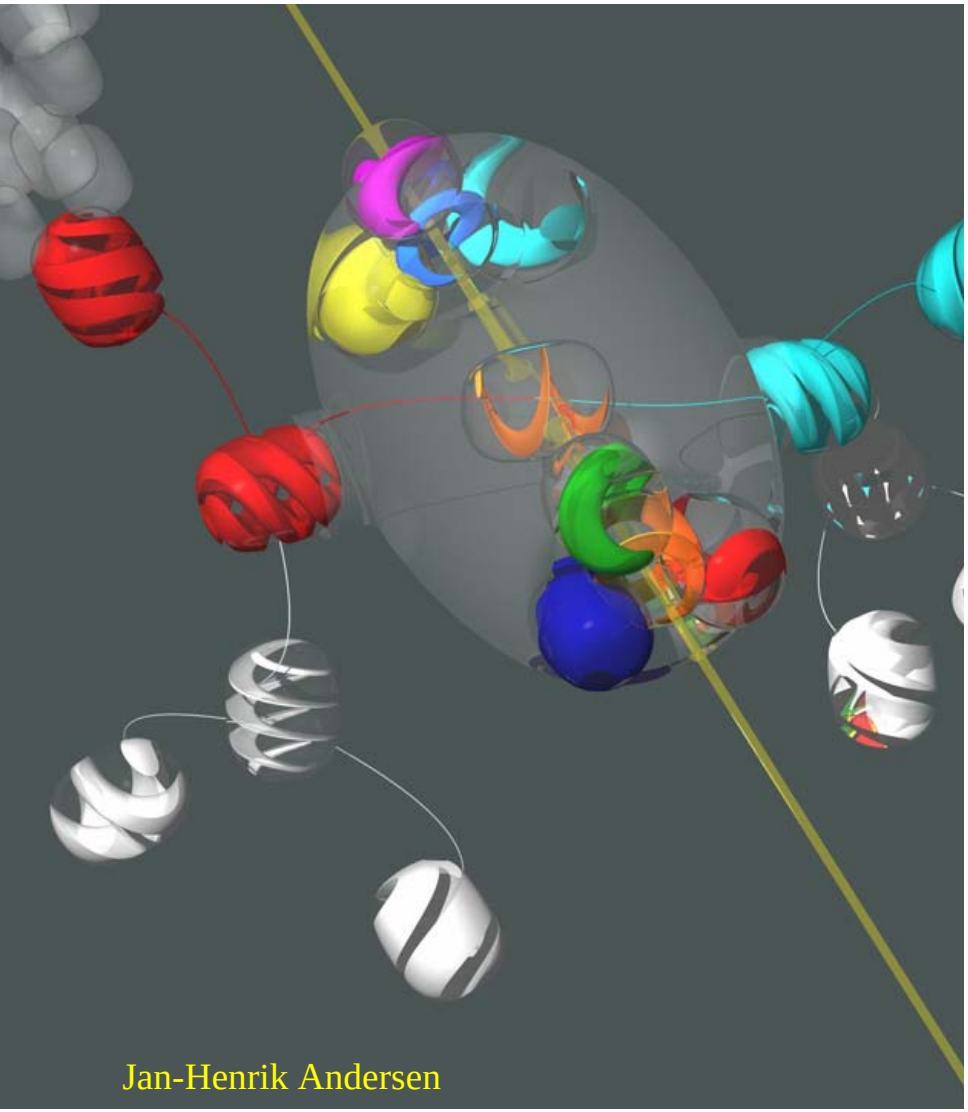
SM (NLO): $\sigma_{top} = 6.8 \pm 0.4\ pb$

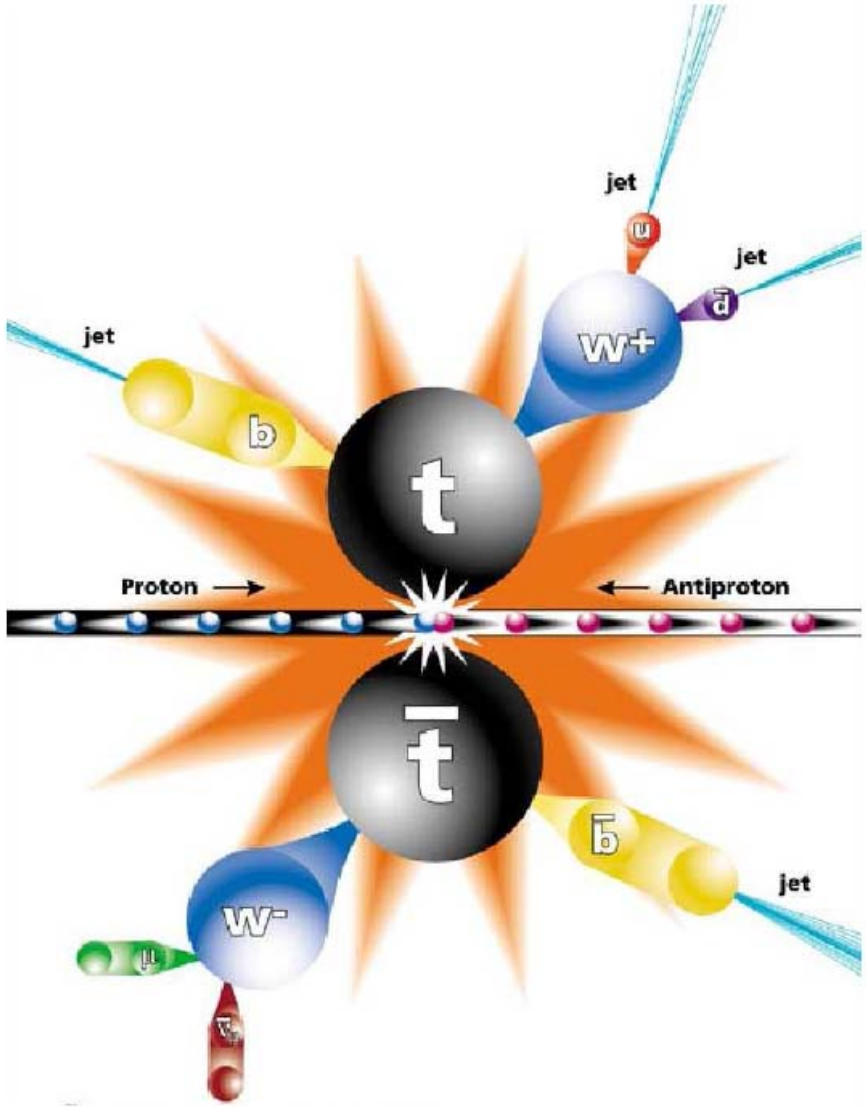
(175 GeV)

favorite signature:



strong top

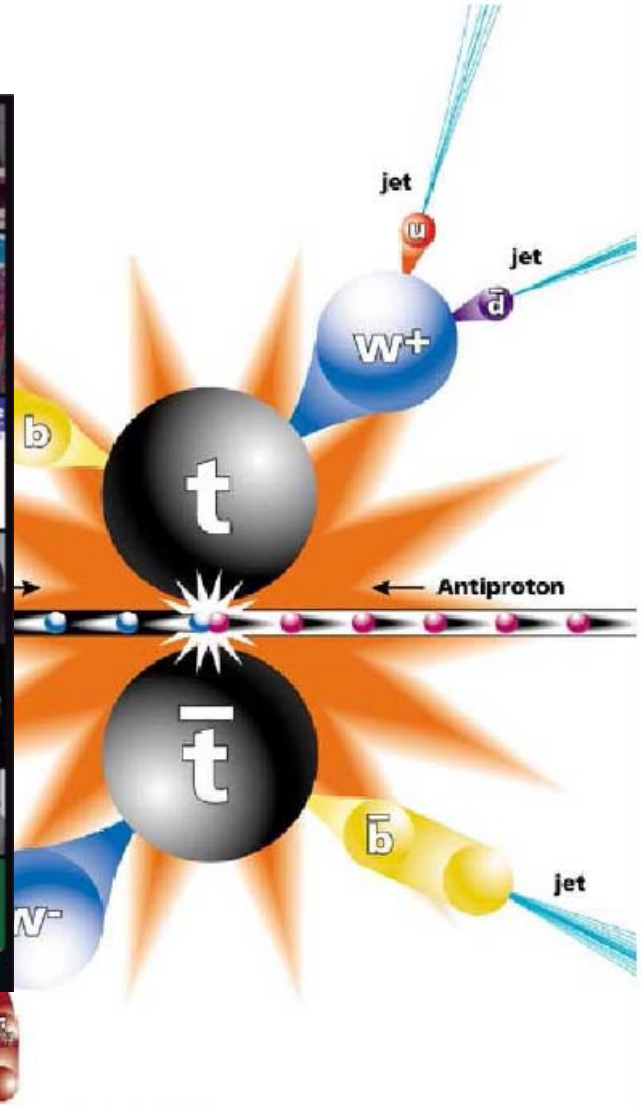

Jan-Henrik Andersen


jet
u
jet
d̄
W+
jet
b
t
Proton
Antiproton
t̄
b̄
jet
W-
l
ν̄

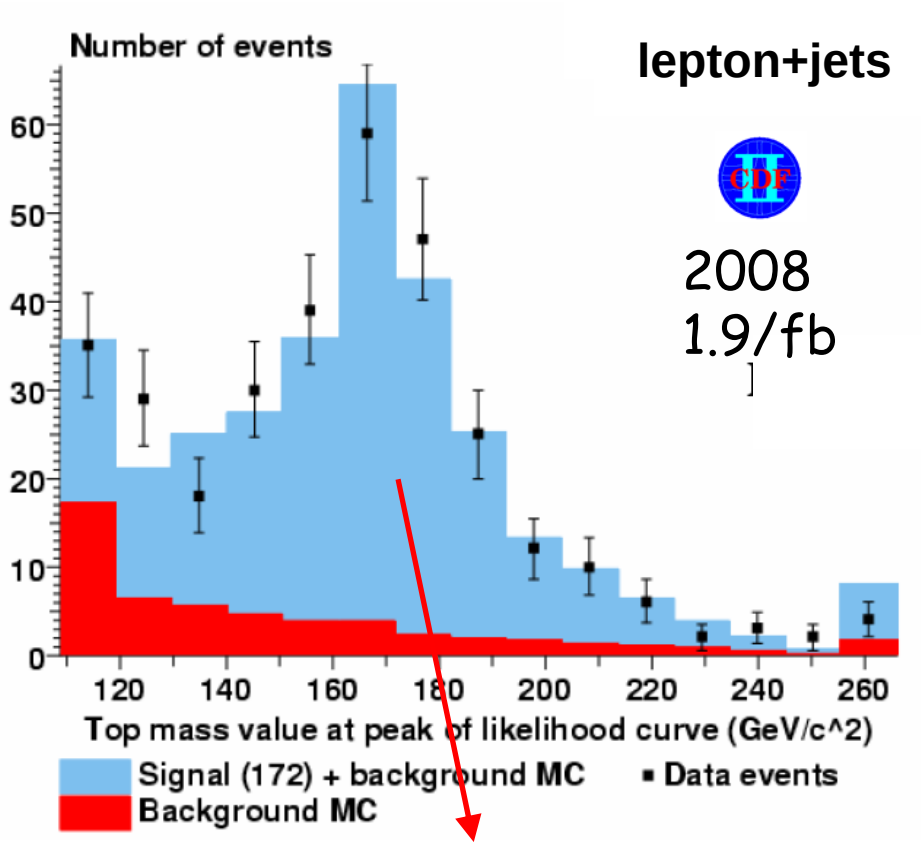
strong top


Jan-Henrik Andersen

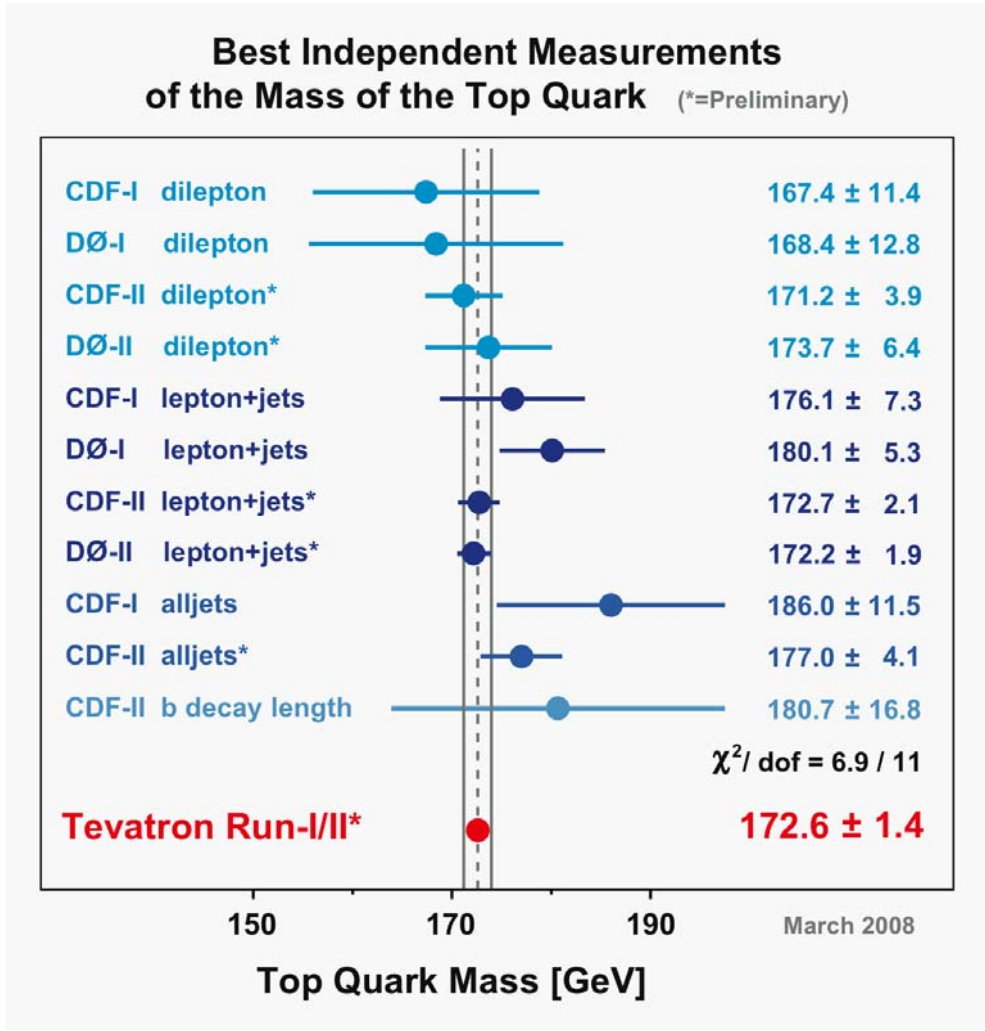
TOP TURNS TEN
10th Anniversary of the Top Quark Discovery
news release
top quark
Fermilab
October 21, 2005
An afternoon symposium in celebration of the 10th anniversary of the discovery of the Top Quark at Fermilab by the CDF and D0 collaborations. A reception in the Wilson Hall atrium will follow the symposium.
Details at http://www.fnal.gov/pub/news05/TopTurnsTen.html


jet
u
jet
d̄
W+
b
t
Antiproton
t̄
b̄
jet
W-

strong top

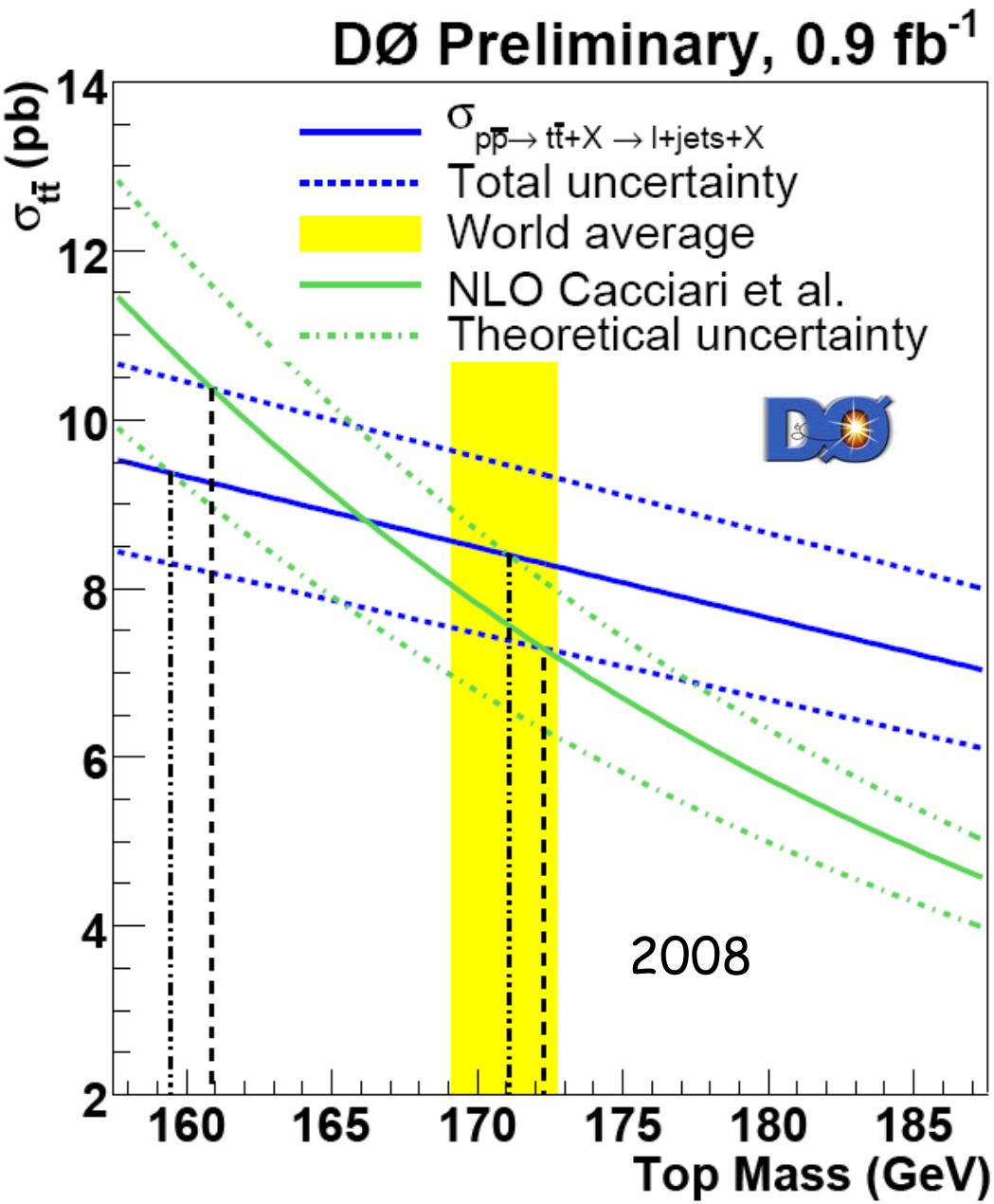


$$m_t = 172.7 \pm 1.2 \pm 1.8\ GeV$$



$$m_t = 172.6 \pm 0.8 \pm 1.1\ GeV$$

strong top



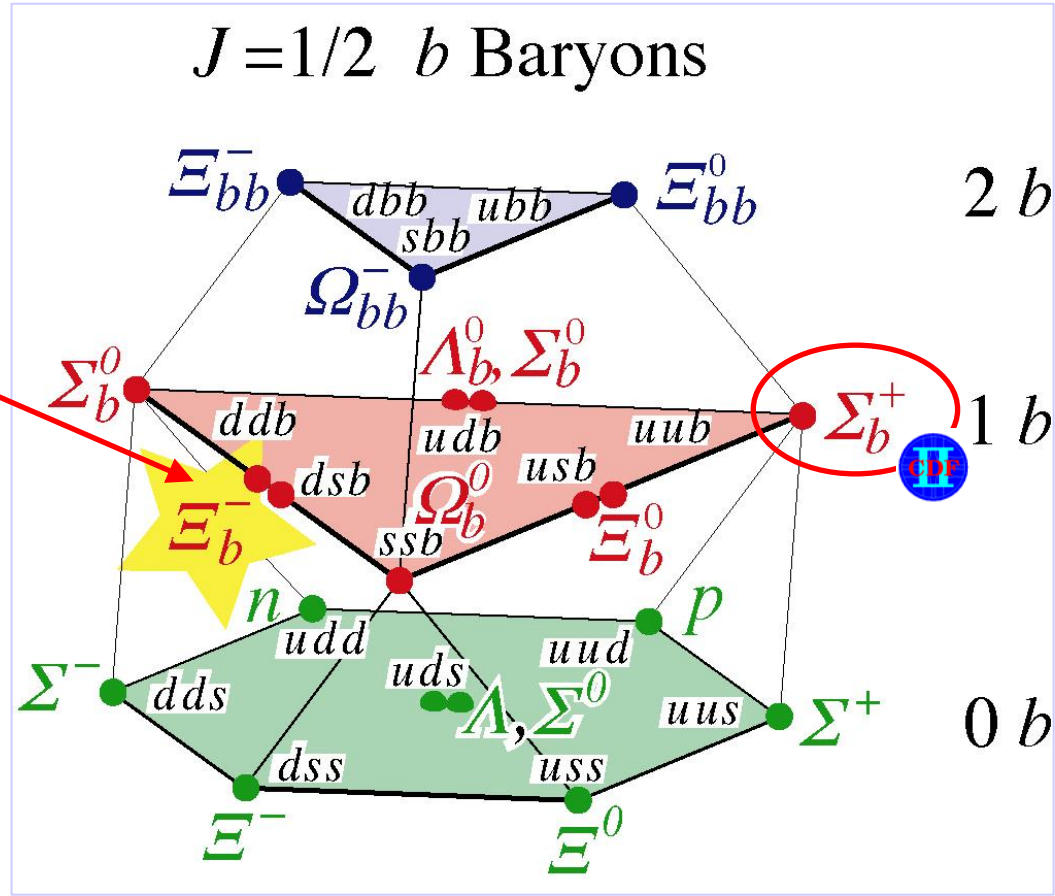
$$\sigma_{top} = 7.3 \pm 0.9\ pb$$

SM: $\sigma_{top} = 6.8 \pm 0.4\ pb$ $(175 GeV)$

QCD is flavor independent !

strong new bound state Ξ_b^-

first baryon with quarks from all three families !



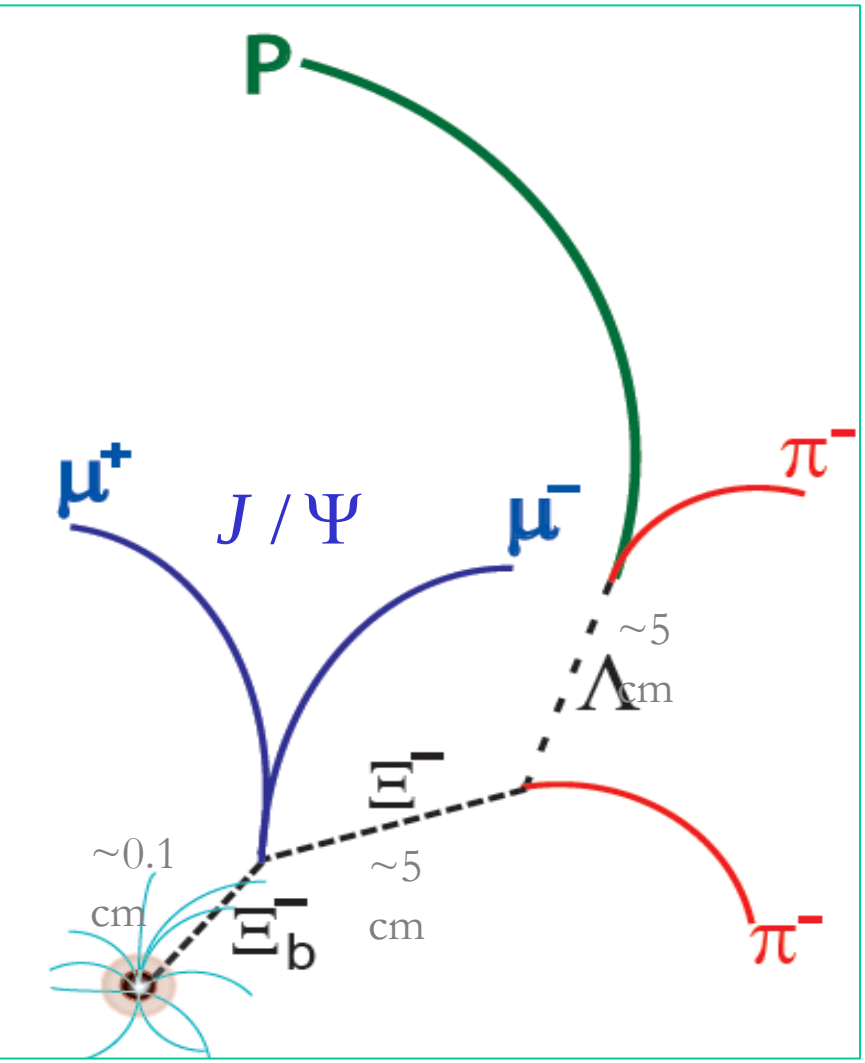
$$M(\Xi_b^-) = 5792.7 \pm 1.9 \quad \text{MeV}$$

quark model:

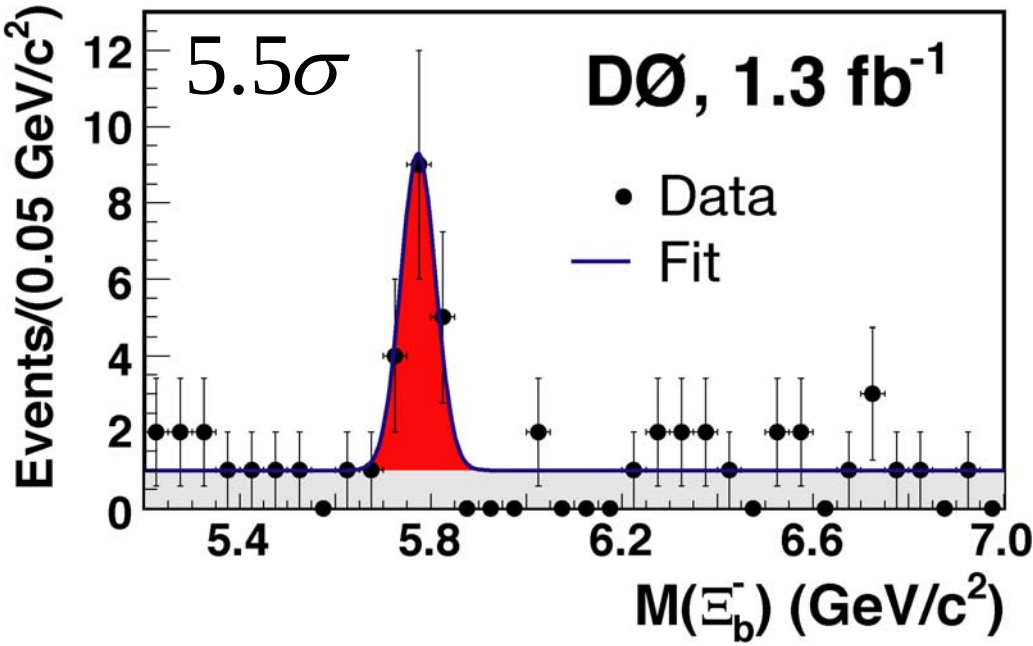
$$M(\Xi_b^-) = 5805.7 \pm 8.1\,\text{MeV}$$

Jenkins 1997

strong new bound state Ξ_b^-



1.3/fb 2007



first hints at LEP !

Outline

Introduction

QCD Tests

Electroweak Results

- masses
- boson boson couplings
- fermion boson couplings

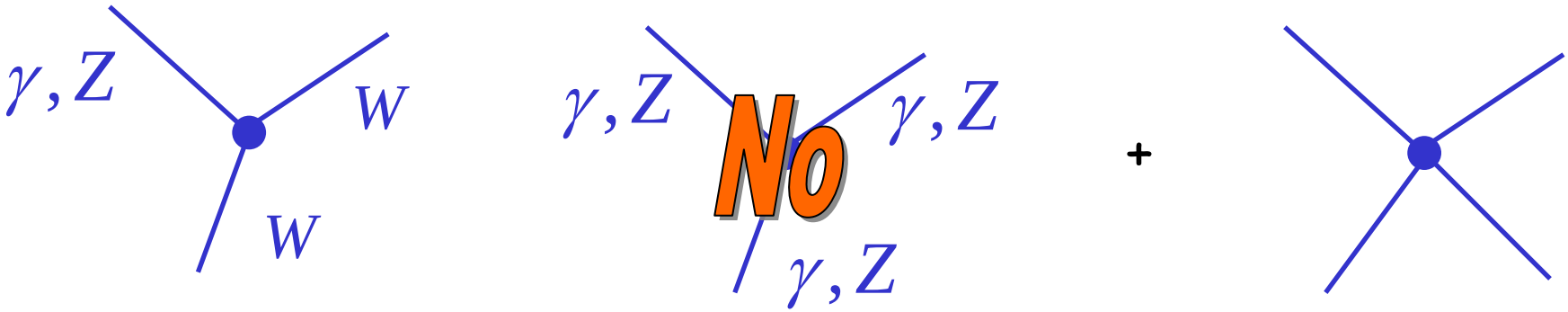
Searches

Standard Model – electroweak SU(2)xU(1)

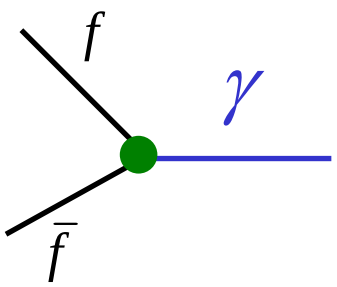
T.Hebbeker

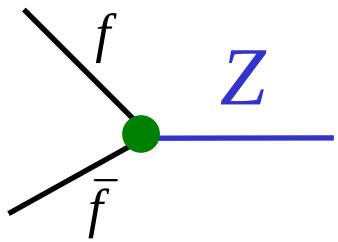
$\begin{pmatrix} \nu_e \\ e \end{pmatrix} \begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix} \begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix} \quad \begin{pmatrix} u \\ d \end{pmatrix} \begin{pmatrix} c \\ s \end{pmatrix} \begin{pmatrix} t \\ b \end{pmatrix} \quad \gamma \; W \; Z \; H$

… spin, **mass**, width ...

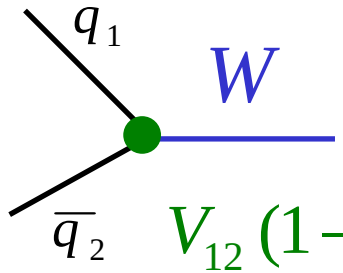


$\alpha \qquad \theta_W$





No FCNC



$V_{12}(1-\gamma^5)$

CKM

Tevatron

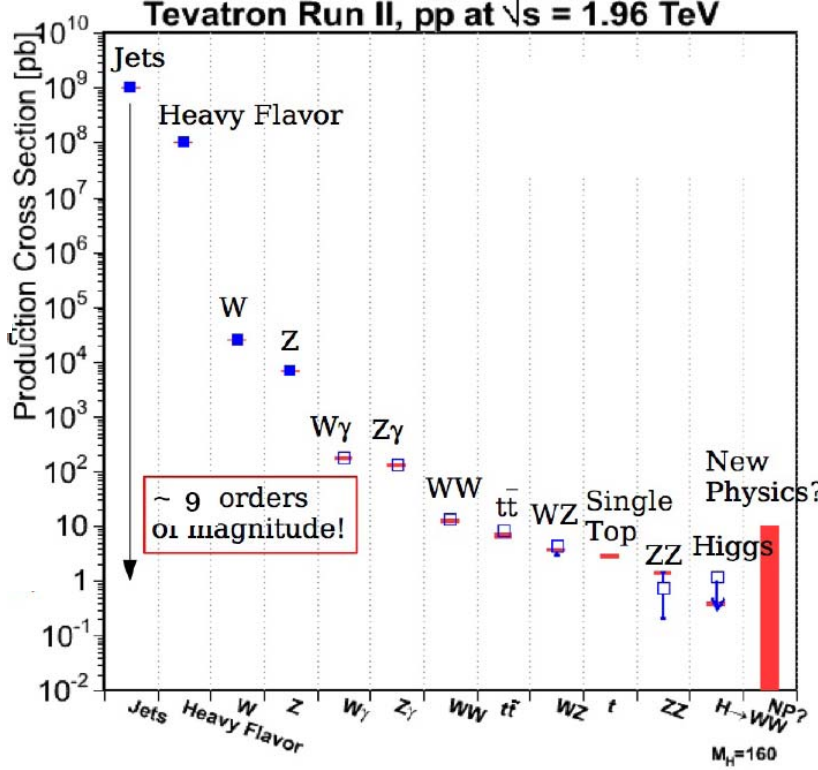
Outline

Introduction

QCD Tests

Electroweak Results

- masses
- boson boson couplings
- fermion boson couplings



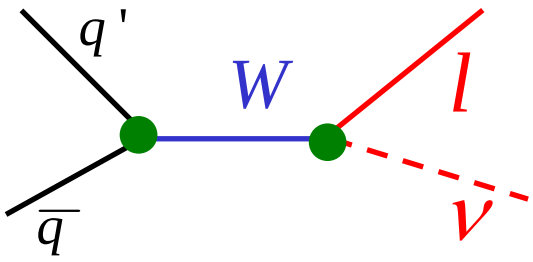
W

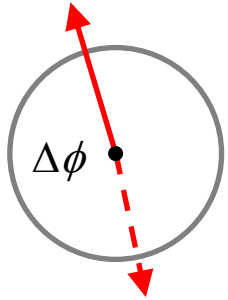
$p\,\bar{p} \rightarrow WW, WZ, ZZ$

$FCNC \quad V_{td} \quad V_{ts} \quad V_{tb}$

Searches

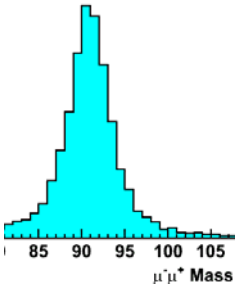
electroweak W mass measurement

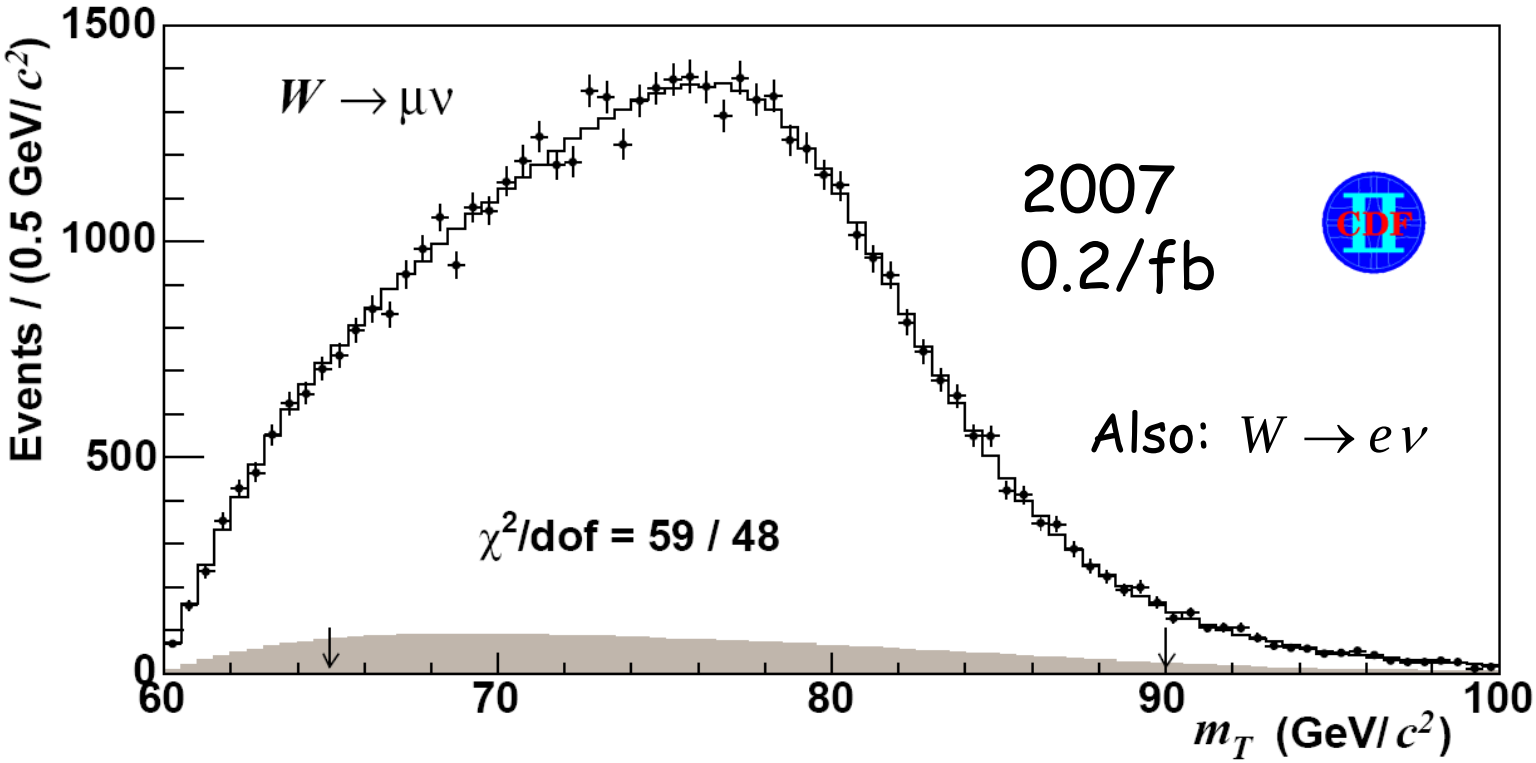




$$m_T^2 = 2 \cdot E_T^l \cdot ME_T \cdot (1 - \cos\Delta\phi)$$

Lepton energy scale ! use $Z \to ll$ for calibration



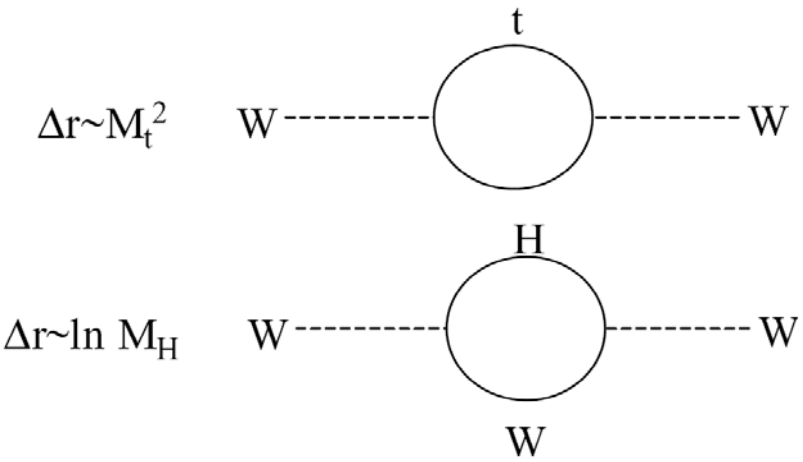


$M_W = 80413 \pm 34 \pm 34$ MeV $= 80413 \pm 48$ MeV

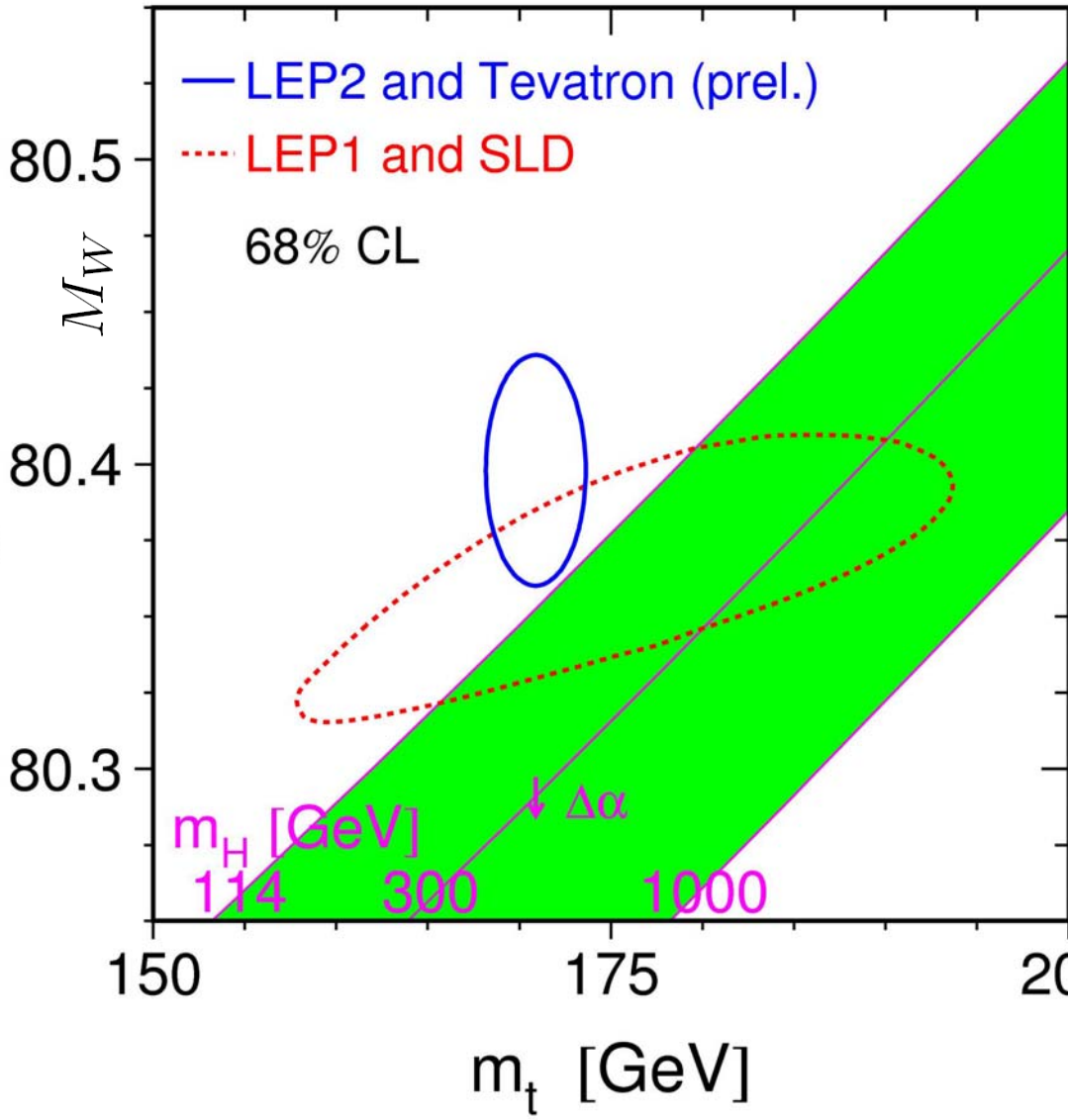
$M_W = 80367 \pm 33$ MeV

electroweak SM Higgs mass prediction

$$M_W^2 = \frac{\pi\alpha}{\sqrt{2}G_F}\frac{1}{(1-c_W^2)(1-\Delta r)}$$

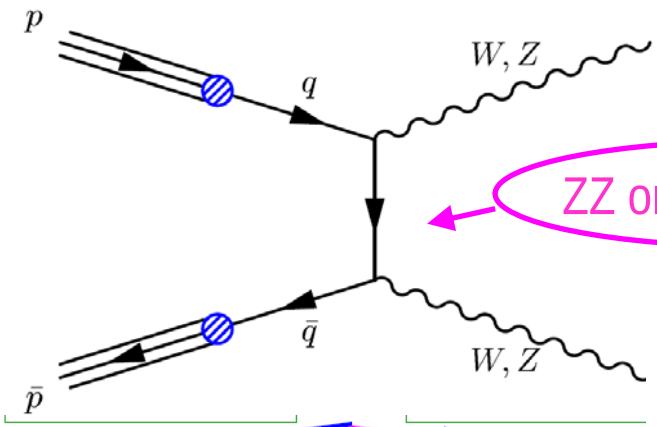


light higgs preferred !

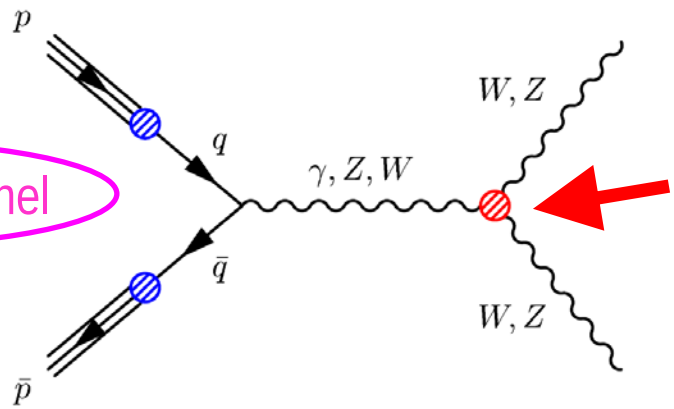


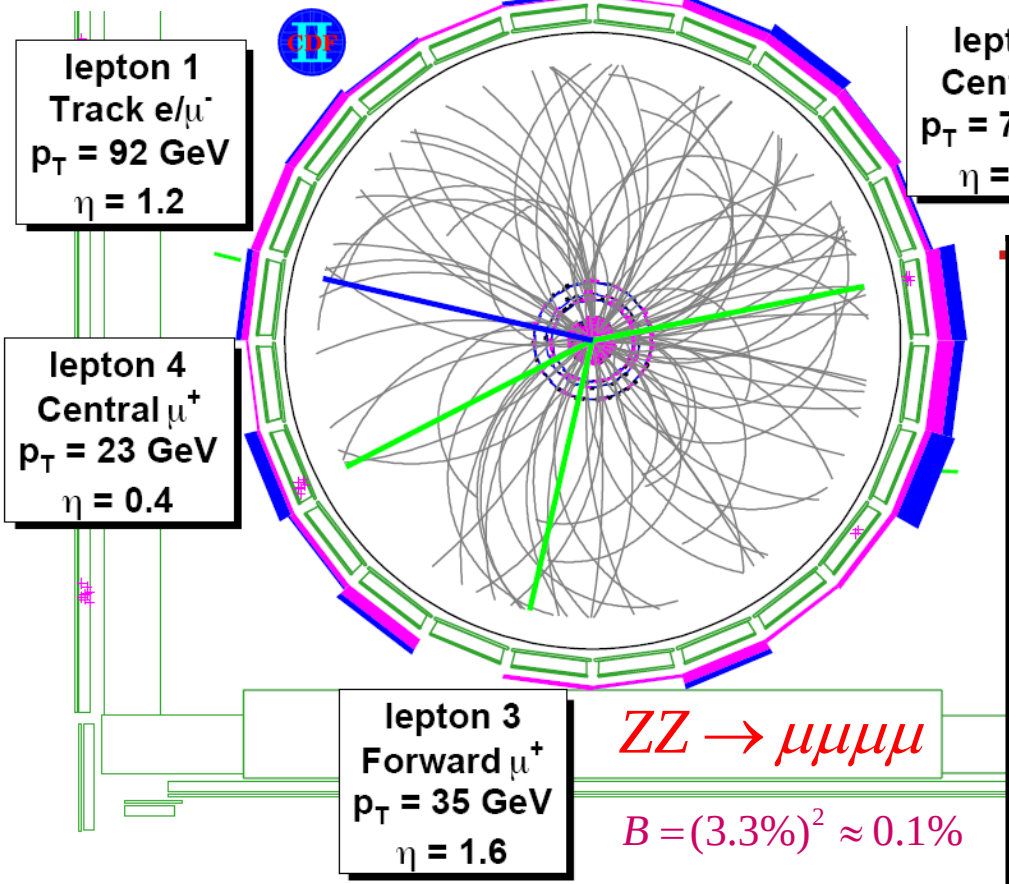
electroweak boson pair production

SM:



ZZ only via t channel



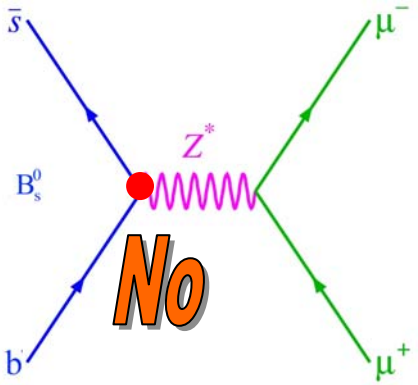


$\sigma \cdot B$ small !

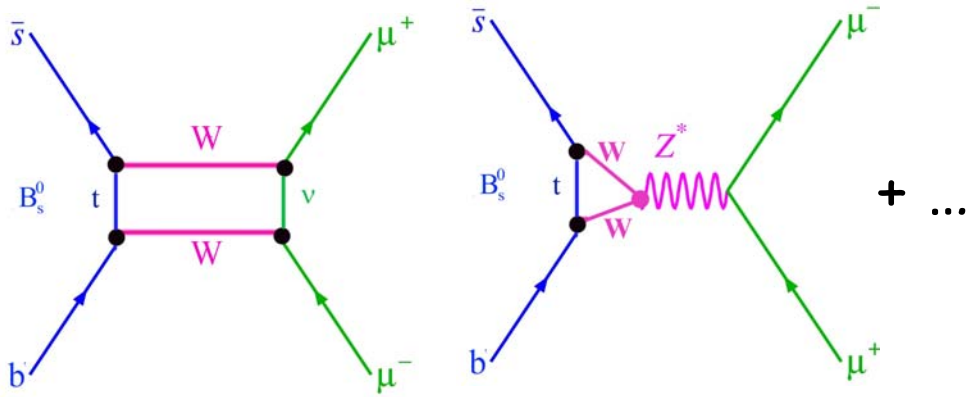
σ / pb	CDF+D0	SM (NLO)
WW	13.6 ± 3.0	12.8 ± 0.8
WZ	4.4 ± 1.0	3.7 ± 0.3
ZZ	1.6 ± 0.6	1.5 ± 0.1

electroweak FCNC $B_s \to \mu\mu$

SM:



higher orders:

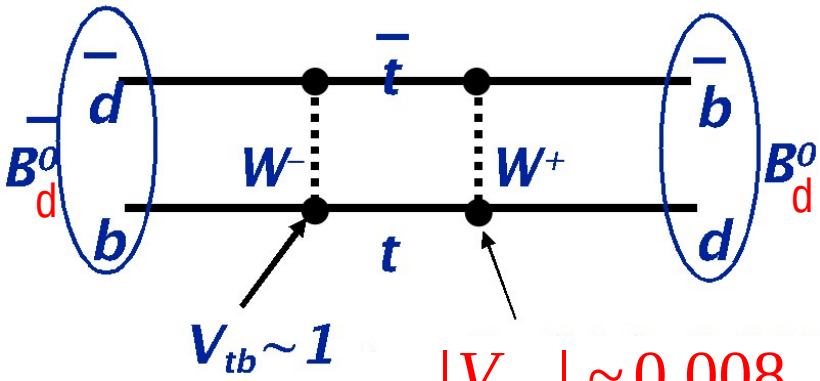


$$B(B_s \to \mu\mu) = 3 \cdot 10^{-9}$$

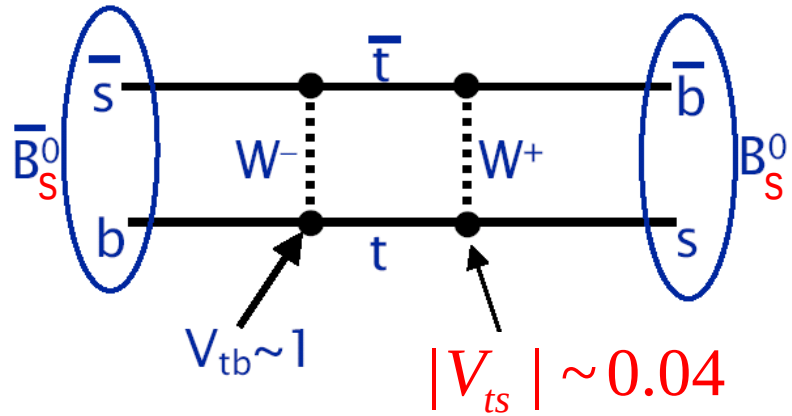
Buras 2003

$$B(B_s \to \mu\mu) < 5.8 \cdot 10^{-8} \quad (95\%)$$

electroweak B oscillations



mixing weak, oscillation slow

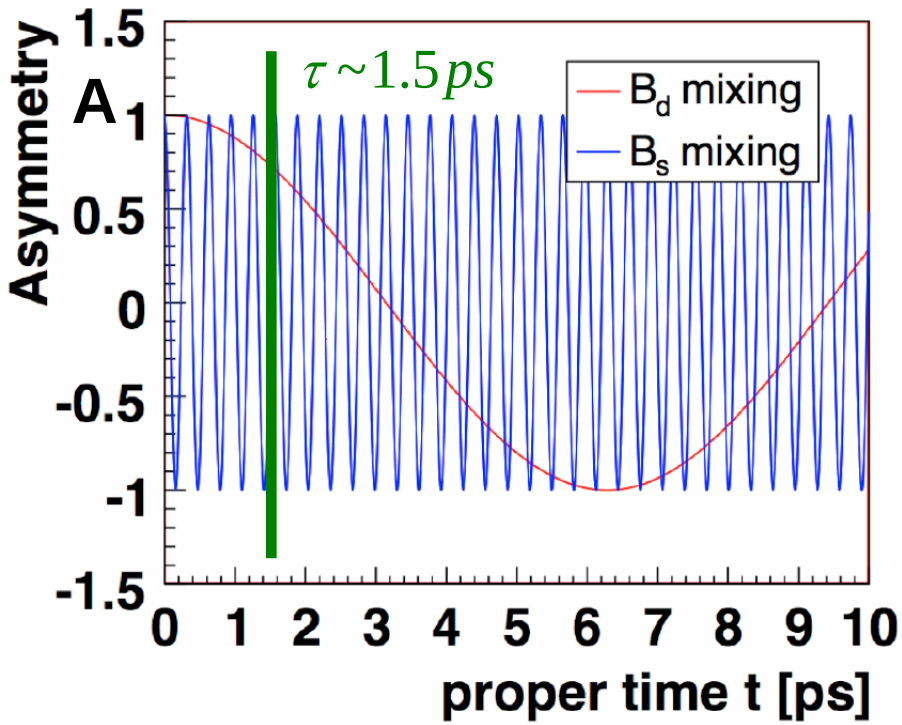


mixing strong, oscillation fast

$$A(t) = \frac{N_{osc}(t) - N_{osc}(t)}{N_{osc}(t) + N_{osc}(t)}$$

$$A(t) \propto \cos(\Delta m \cdot t)$$

$\Delta m_d \propto |V_{td}|^2$ $\quad$ $\Delta m_s \propto |V_{ts}|^2$



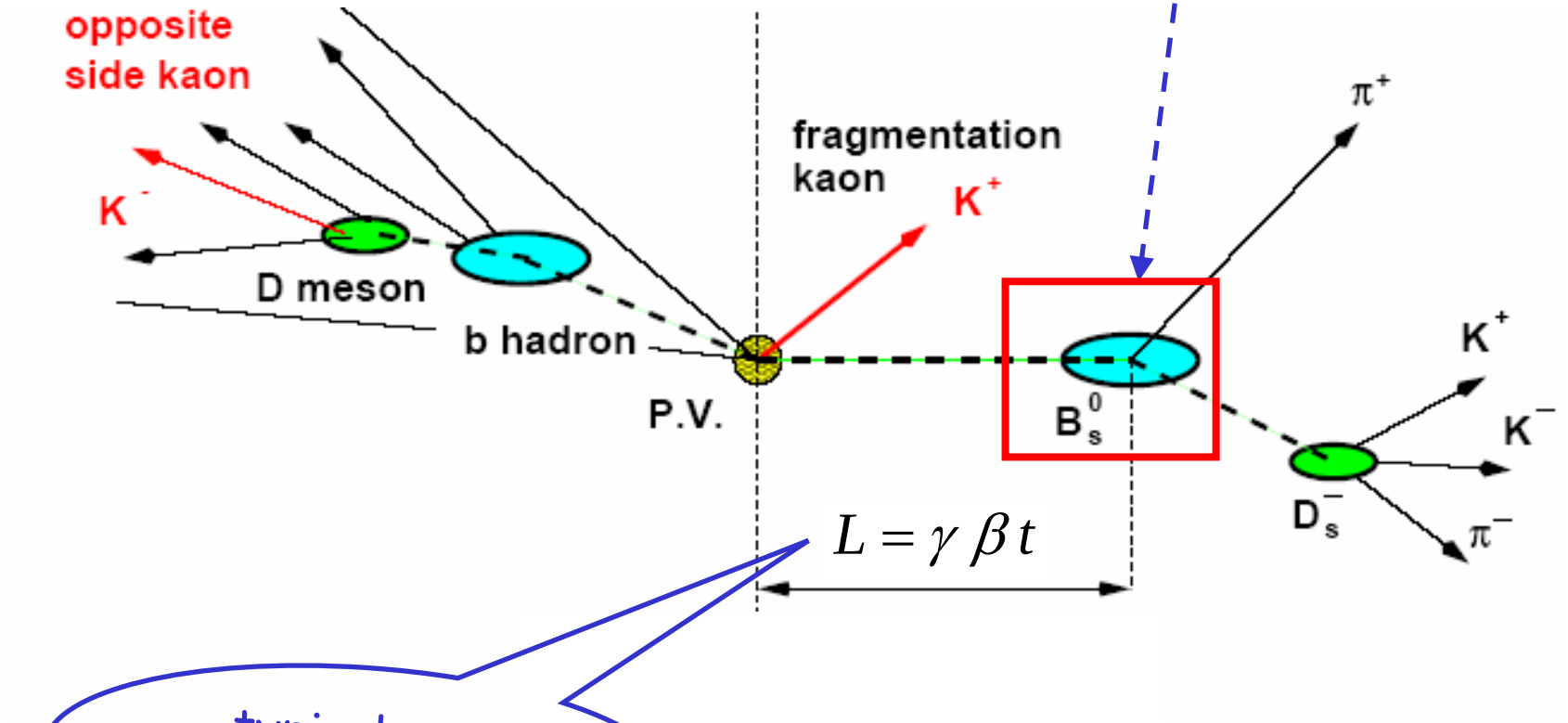
(!)

electroweak B oscillations

tag initial state: $\overline{B_s^0}$ or B_s^0

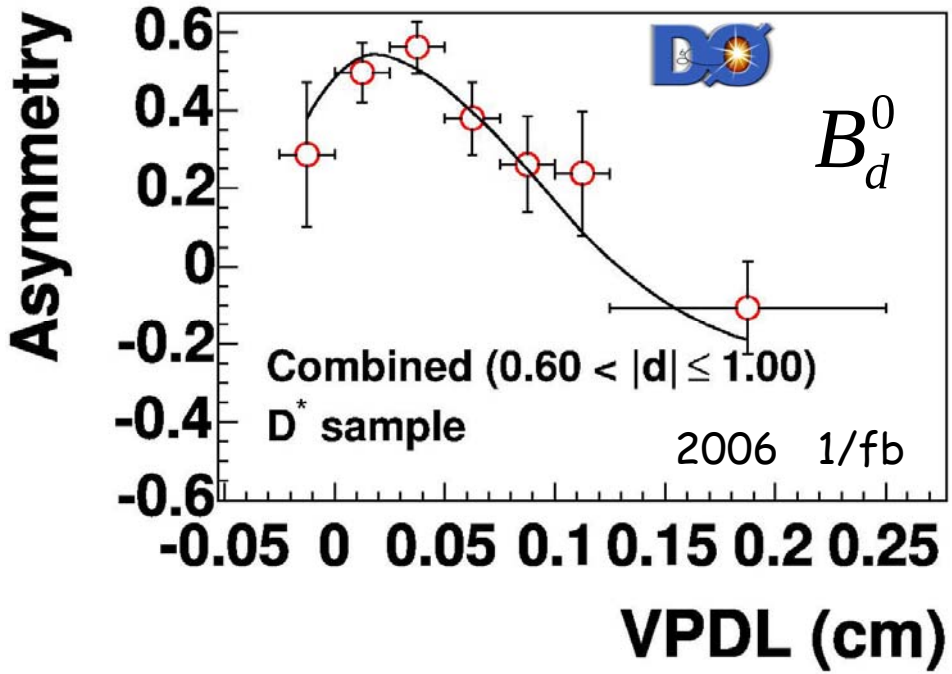
oscillation stops when B meson decays

$\tau \sim 1.5 ps$

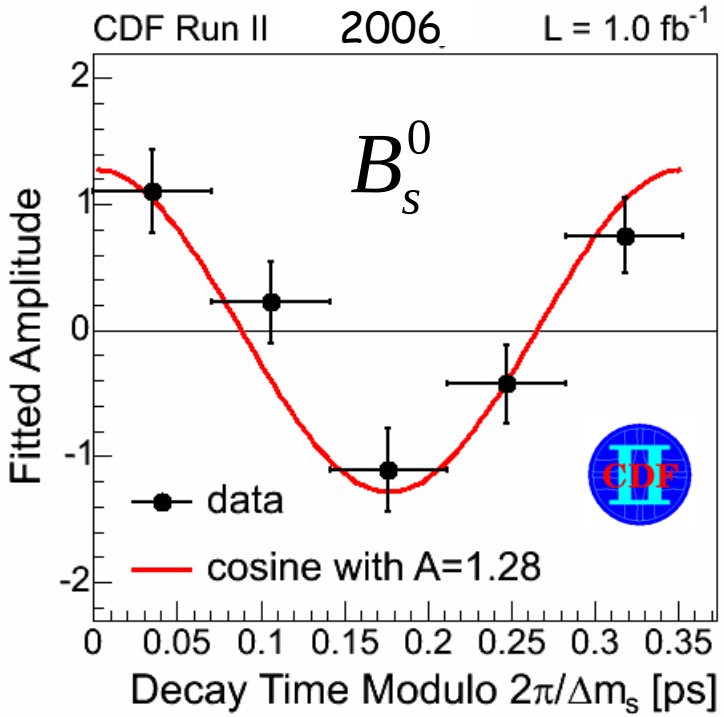


typical: mm
vertex detectors!

electroweak B oscillations



=visible proper decay length



QCD

$\Delta m_d = 0.506 \pm 0.020 \pm 0.016\ \text{ps}^{-1}$

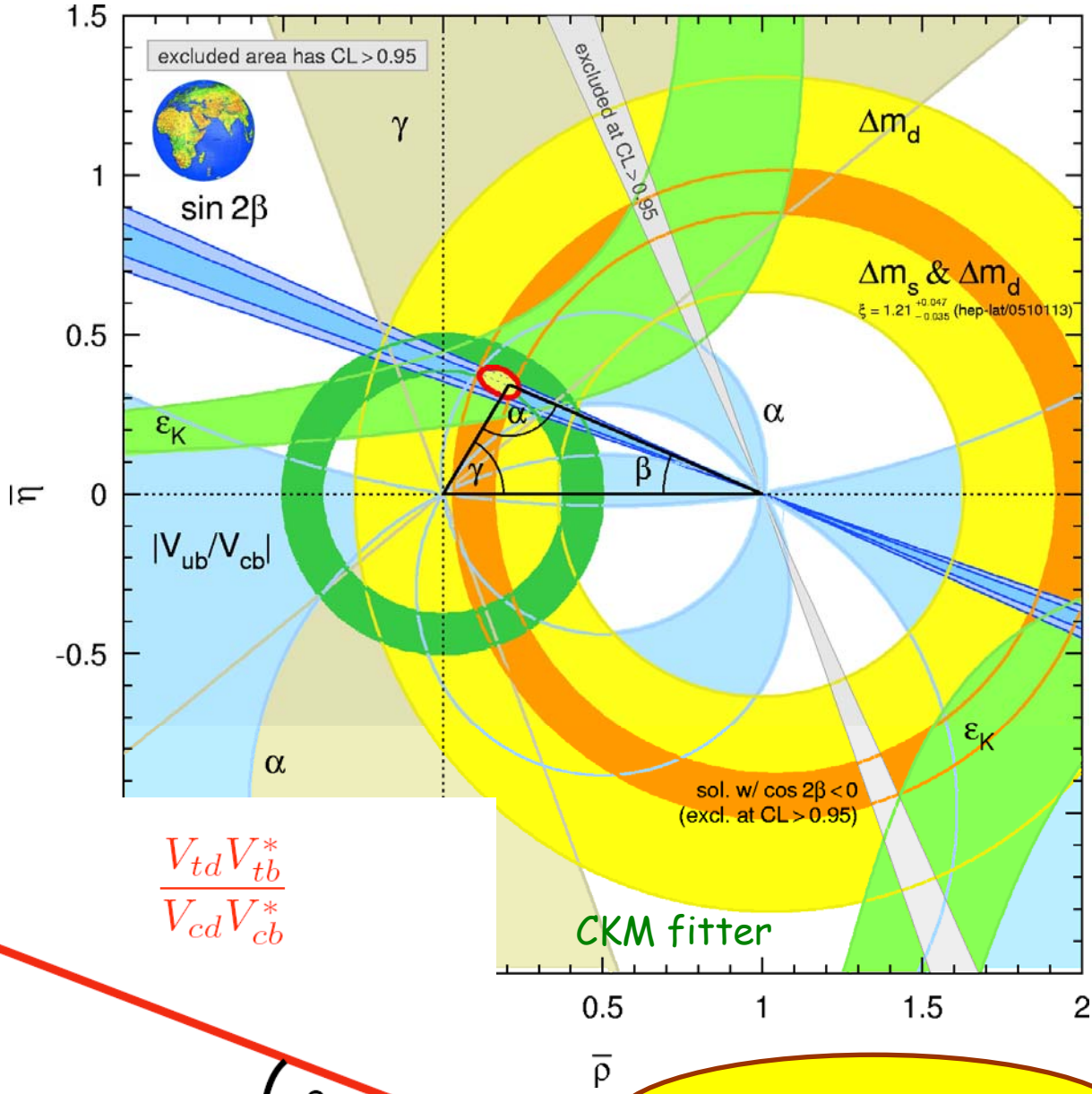
$\Delta m_s = 17.77 \pm 0.10 \pm 0.07\ \text{ps}^{-1}$

$|V_{td}| = (7.4 \pm 0.8) \cdot 10^{-3}$

$\left|\frac{V_{ts}}{V_{td}}\right| = 4.85 \pm 0.03$

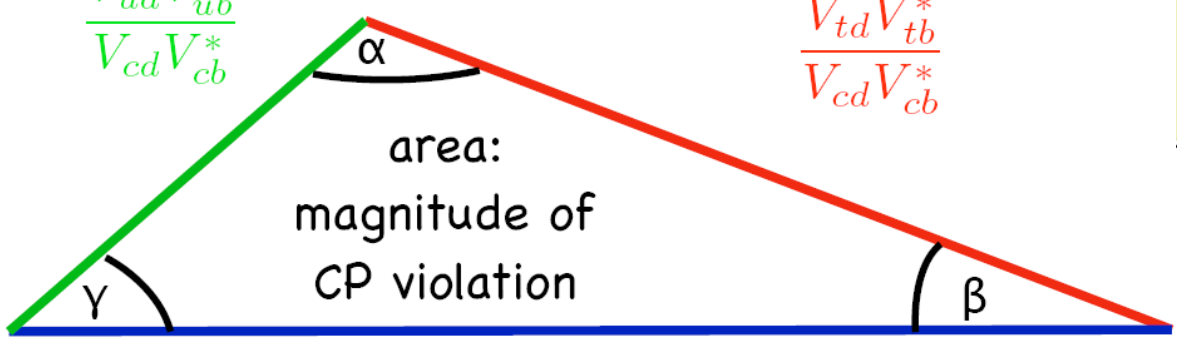
electroweak B oscillations

CKM triangle



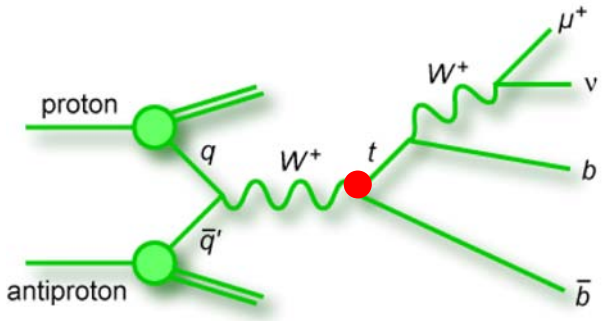
$$\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

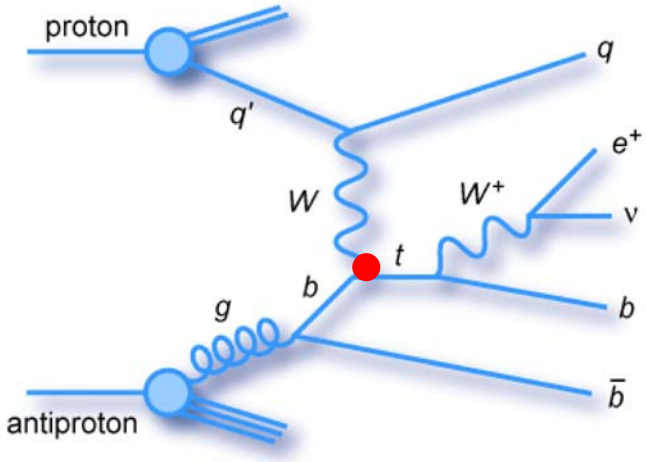
$$\frac{V_{td}V_{tb}^*}{V_{cd}V_{cb}^*}$$



all consistent !

electroweak CKM single top





SM (NLO): $V_{tb} = 1$

$0.88 \pm 0.14\ pb$ $\qquad$ $1.98 \pm 0.30\ pb$

$$\sigma_{top} = 2.9 \pm 0.4\ pb \sim |V_{tb}|^2$$

$\sigma_{top} = 4.7 \pm 1.3\ pb$

$|V_{tb}| = 1.31^{+0.25}_{-0.21}$

model independent

Tevatron

Outline

Introduction

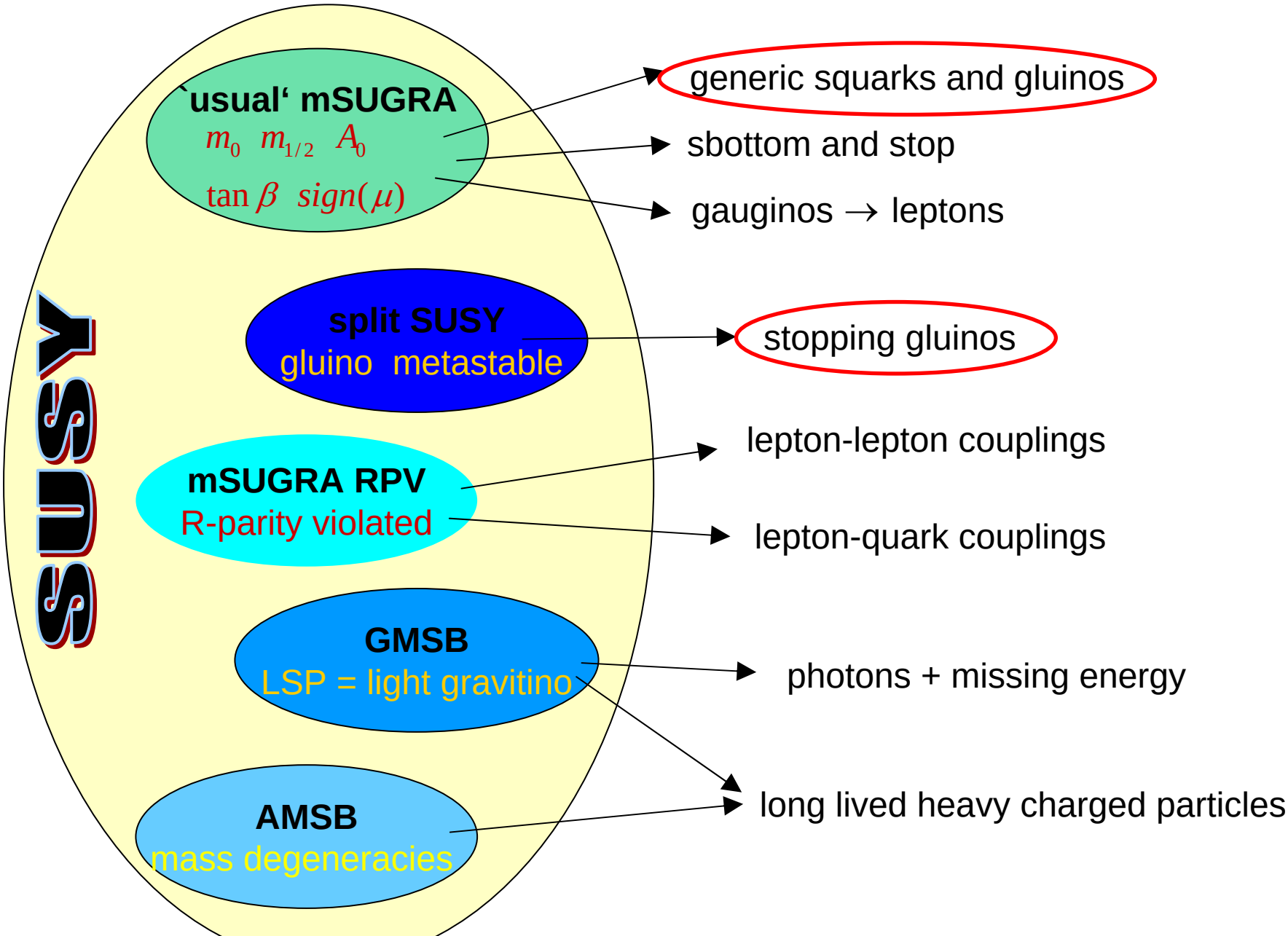
QCD Tests

Electroweak Results

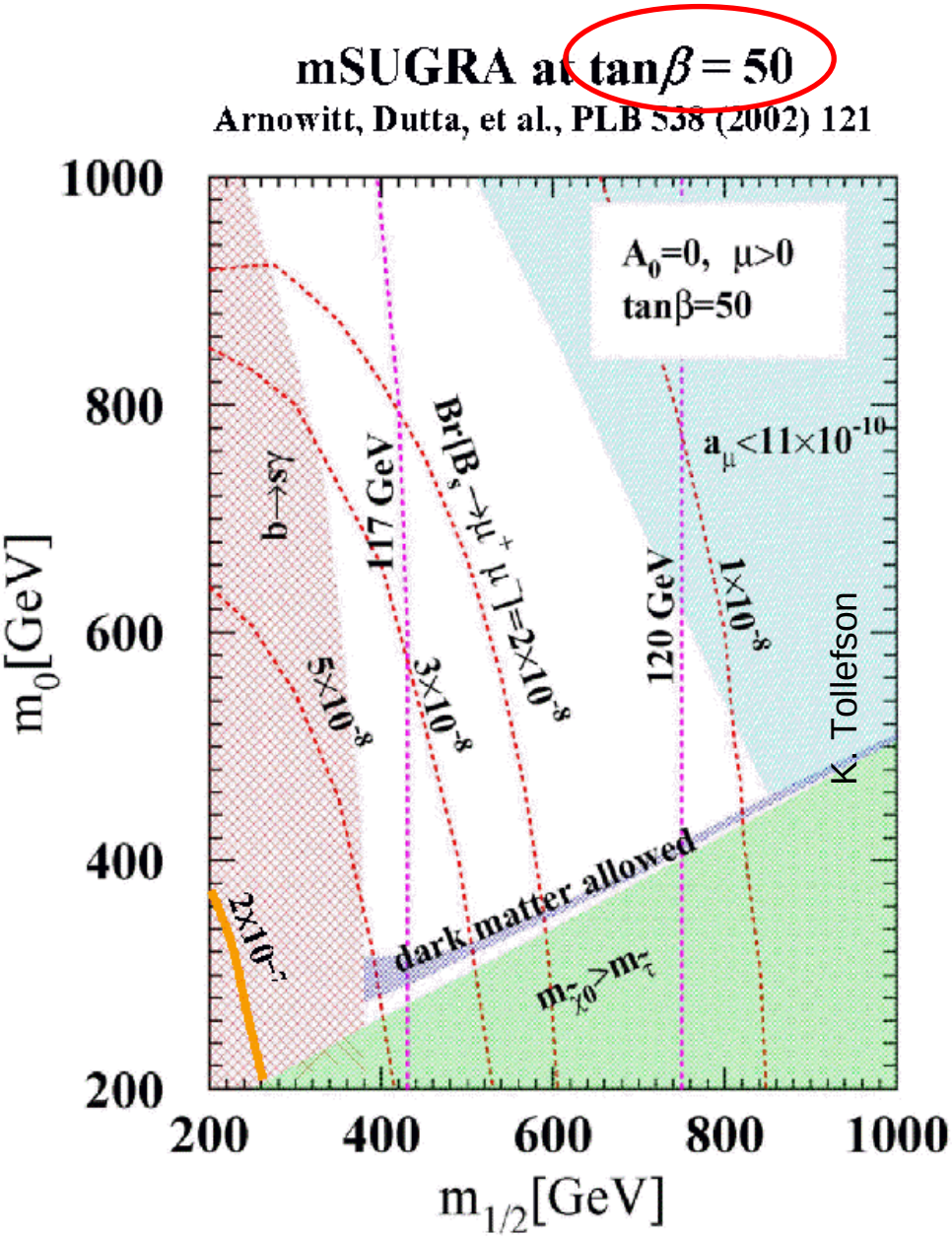
Searches

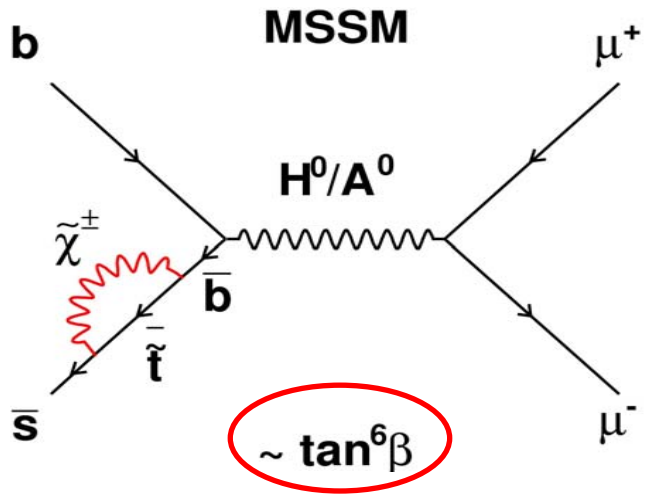
- indirect
- higgs
- susy
- exotica

searches SUSY Models and Signatures



indirect B decays and MSSM

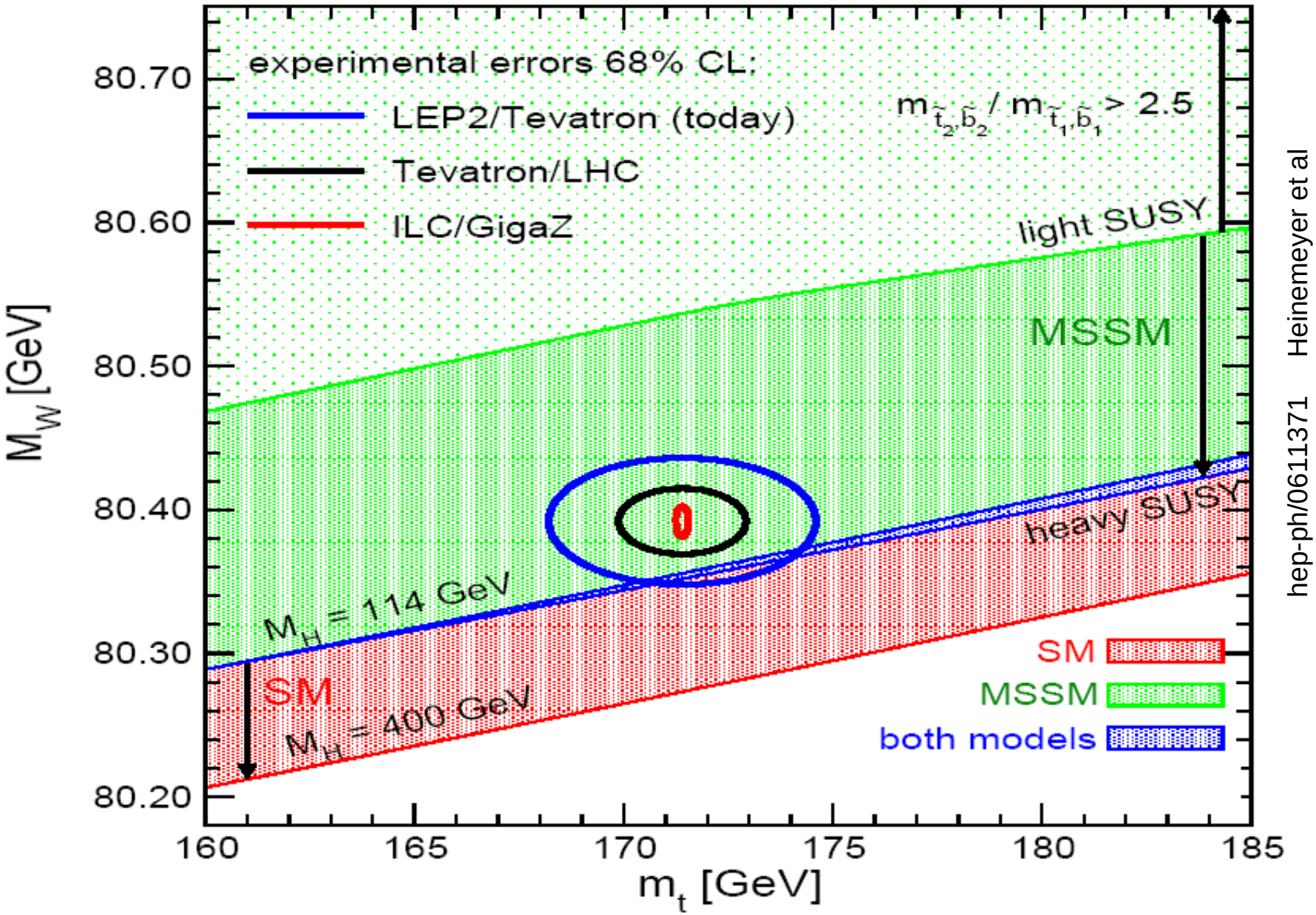




CDF (prel.):

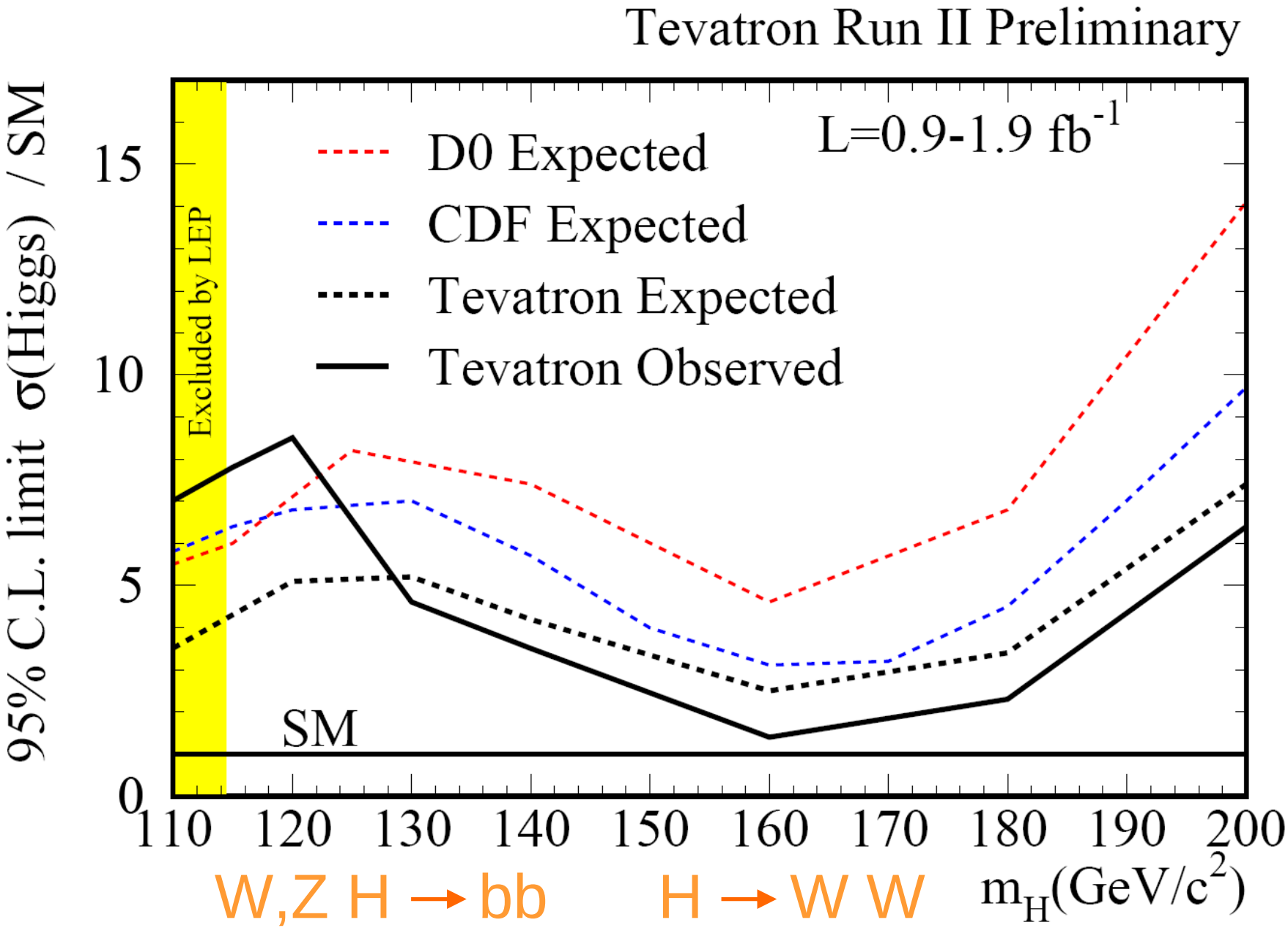
BR($B_s \rightarrow \mu\mu$)<5.8×10^{-8} @95%C.L.

indirect electroweak and MSSM



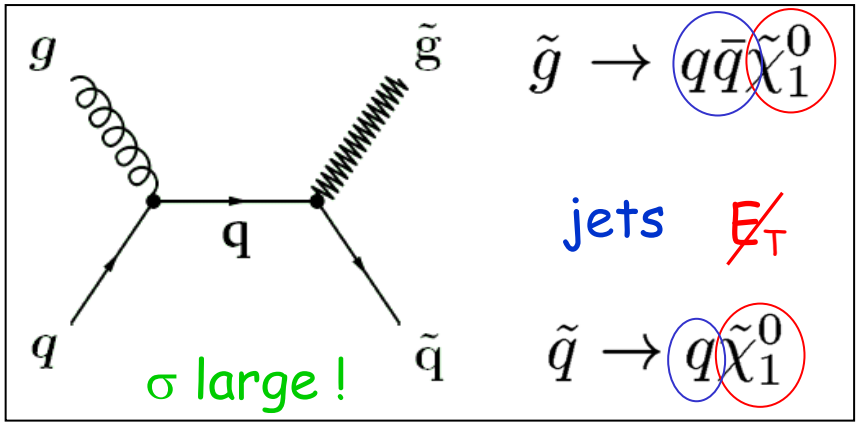
hep-ph/0611371 Heinemeyer et al

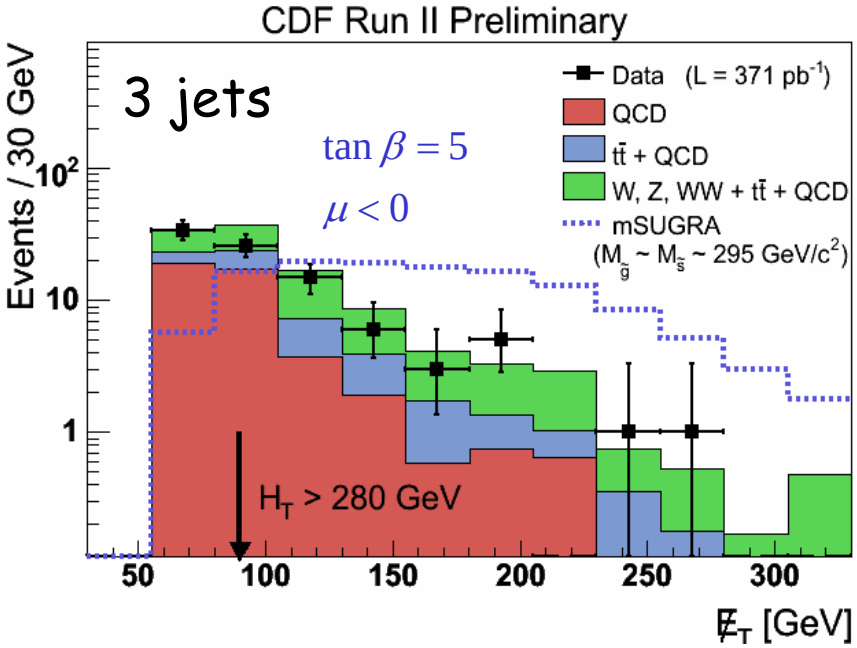
searches SM higgs

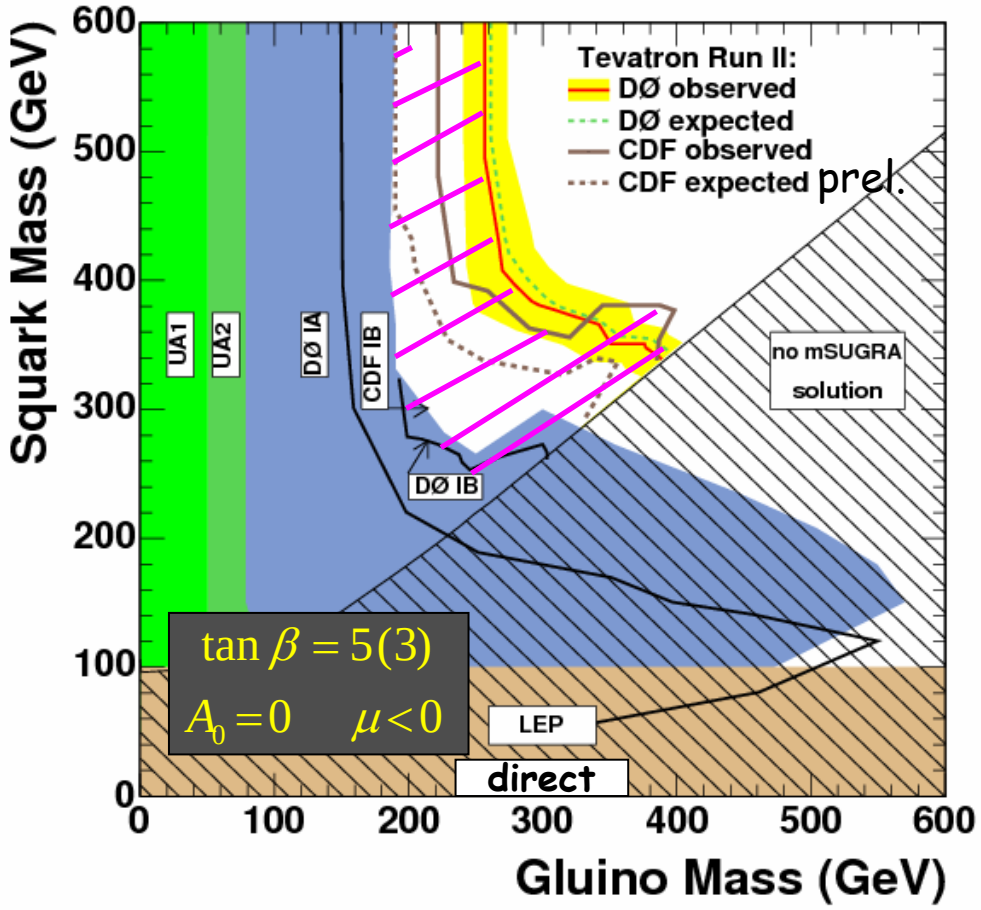


searches squarks and gluinos: jets and missing energy

e.g:







$\tilde{g} > 308\,GeV$ absolute

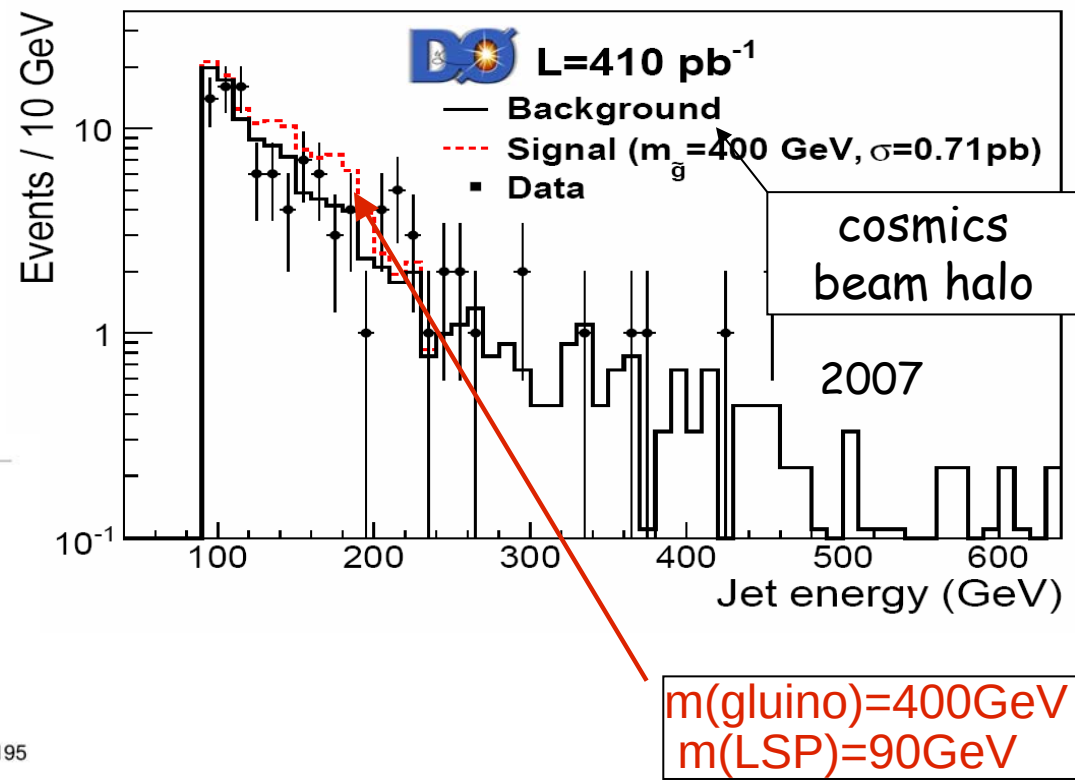
$\tilde{g}, \tilde{q} > 392\,GeV$ for equal masses

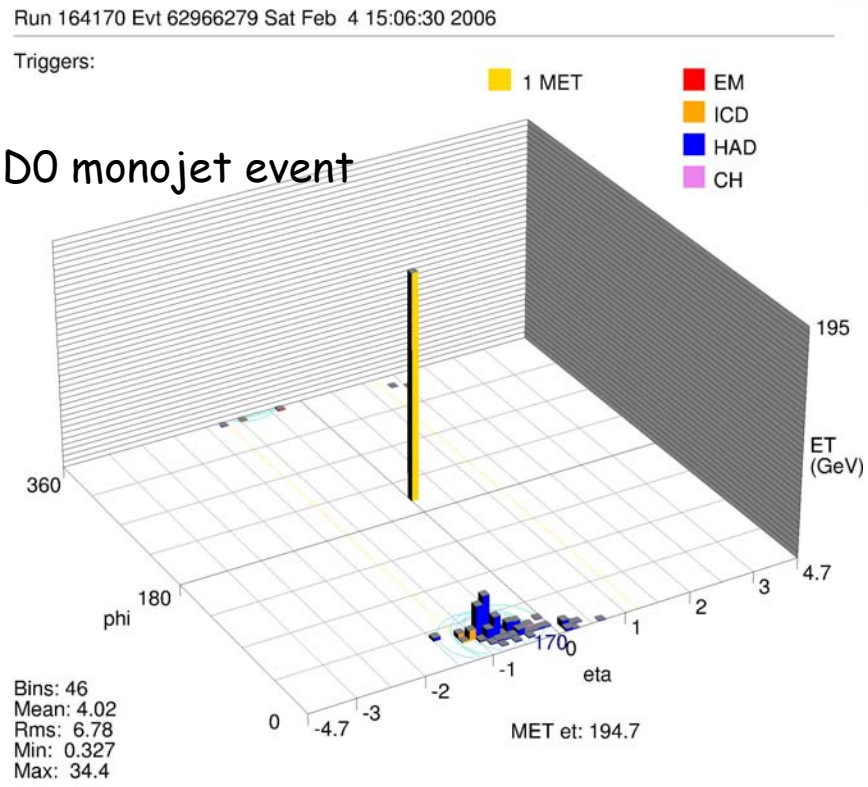
DØ 2.1/fb

CDF 2/fb prel.

searches split SUSY: stopping gluinos

gluino forms charged hadron
stops in detector
isotr. decay $\rightarrow jet + \chi^0$ $\tau > 10\mu s$
! monojet !





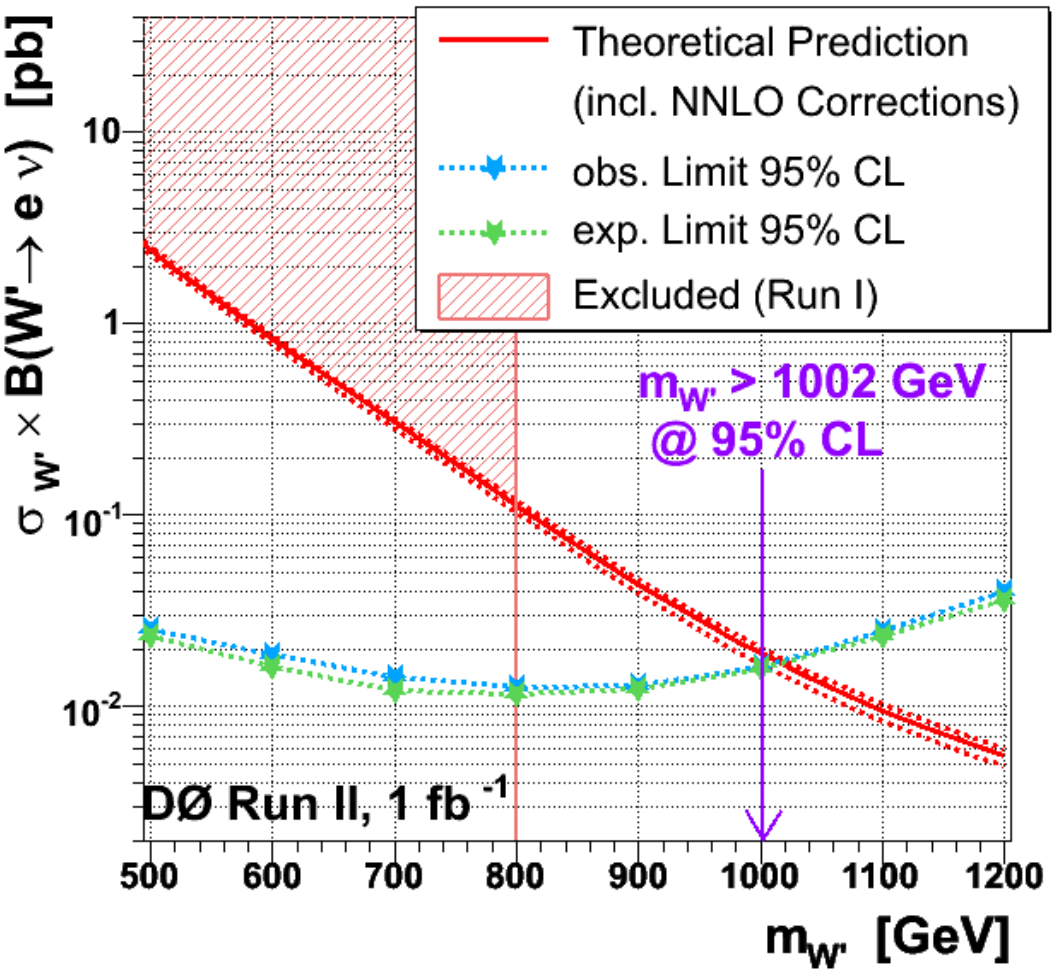
cross section limits ~ 1 pb
for gluinos 200-550 GeV

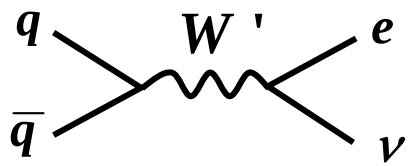
$\rightarrow \tilde{g} > 270\ GeV$

if LSP light

searches new vector bosons

$Z', W', \ldots ?$





first direct search limit > 1 TeV

$W' \to e\,\nu$, $L = 1$ fb^{-1} $\quad m_{W'} > 1002$ GeV @ 95% CL

Summary/Outlook

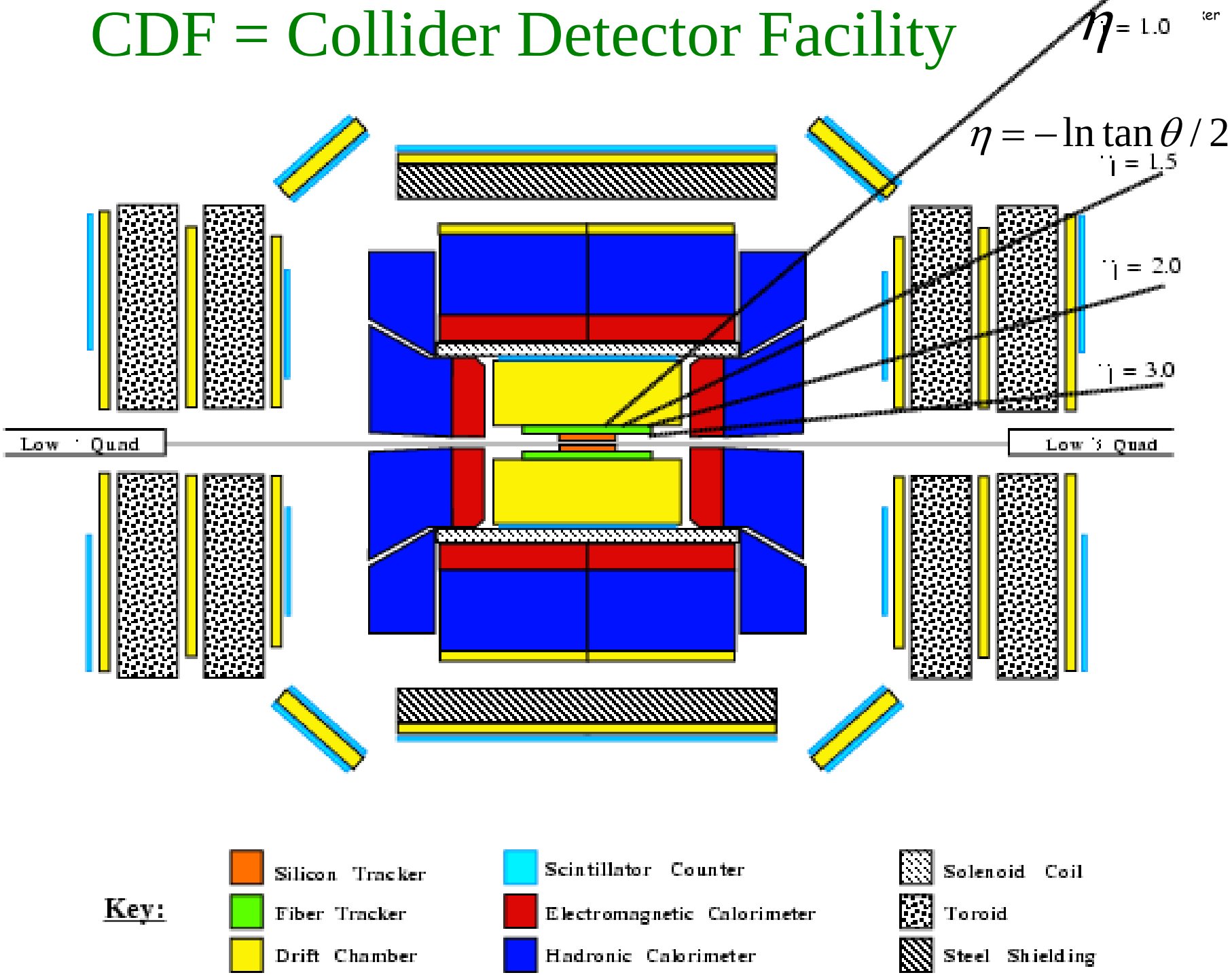
Tevatron II: great results, already > 200 papers

many more to come !

expect 3fold increase in integr. luminosity

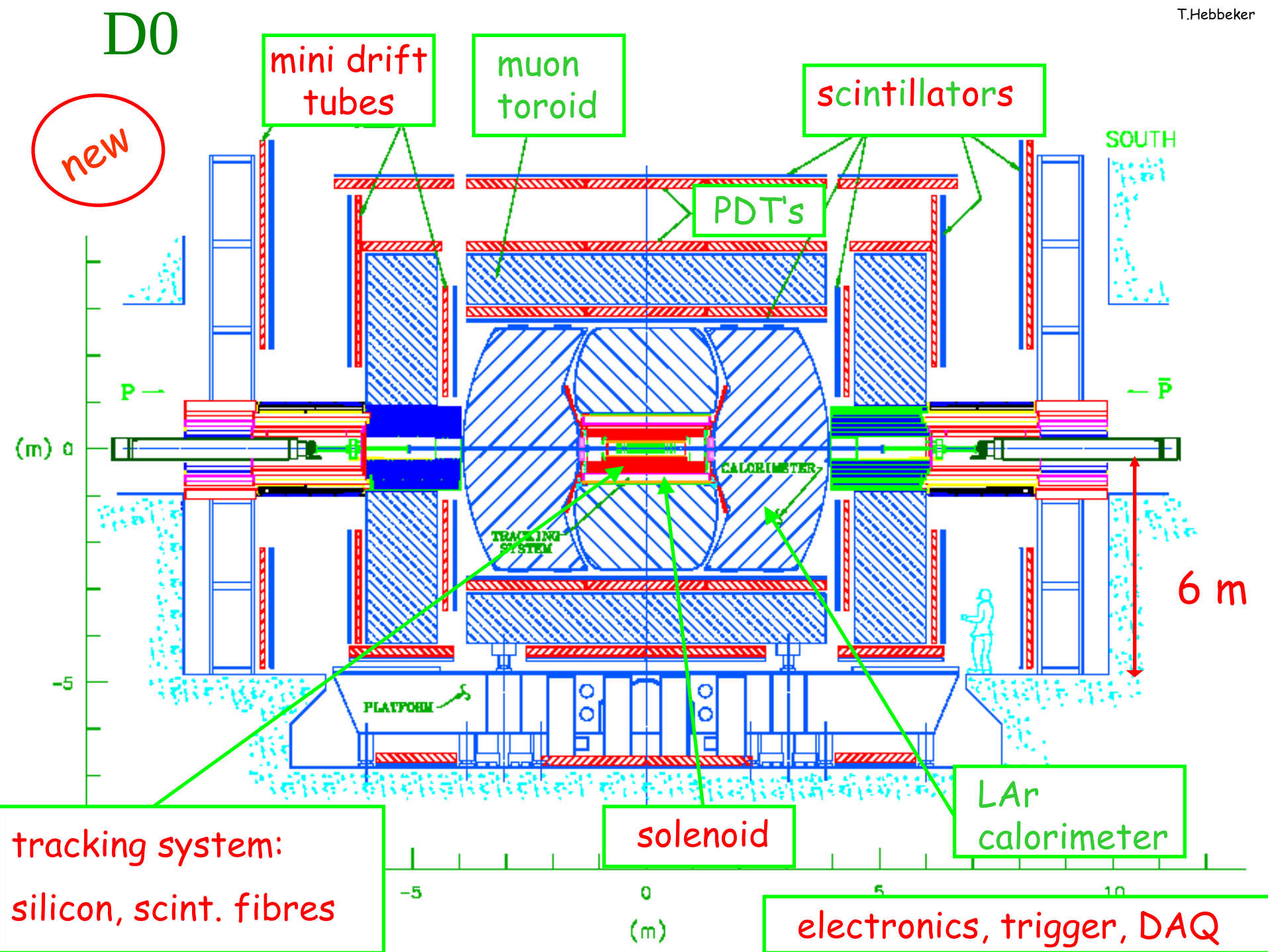
APPENDIX

CDF = Collider Detector Facility

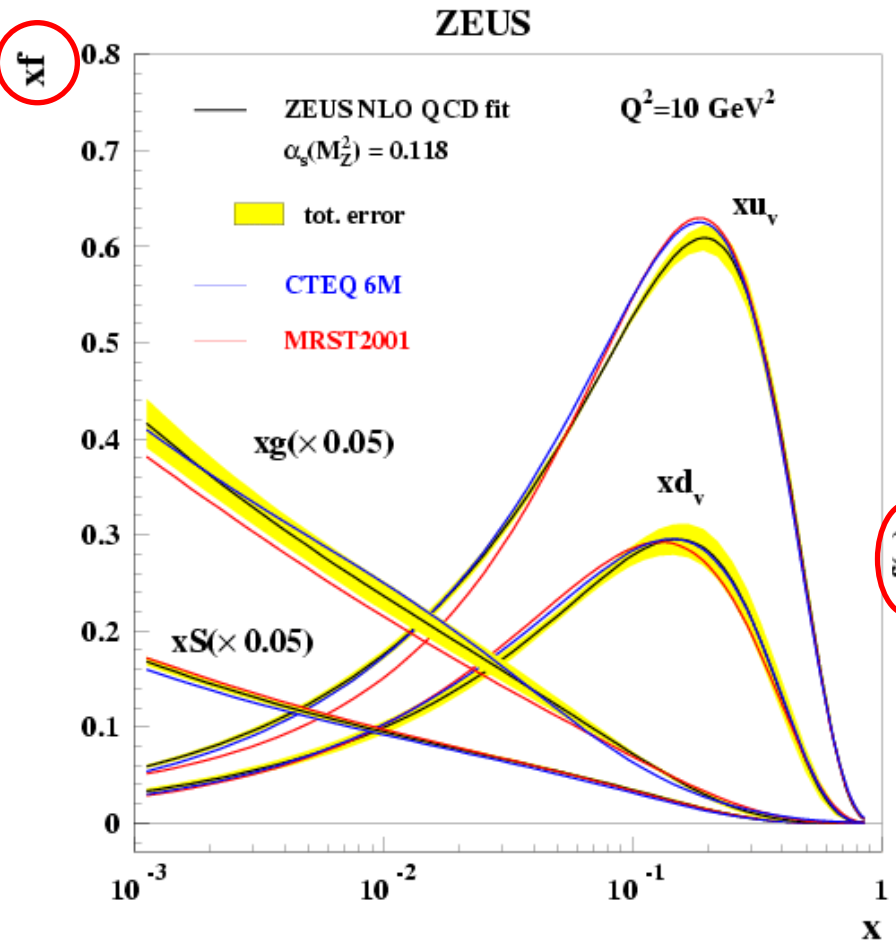


T.Hebbeker

D0



Structure functions

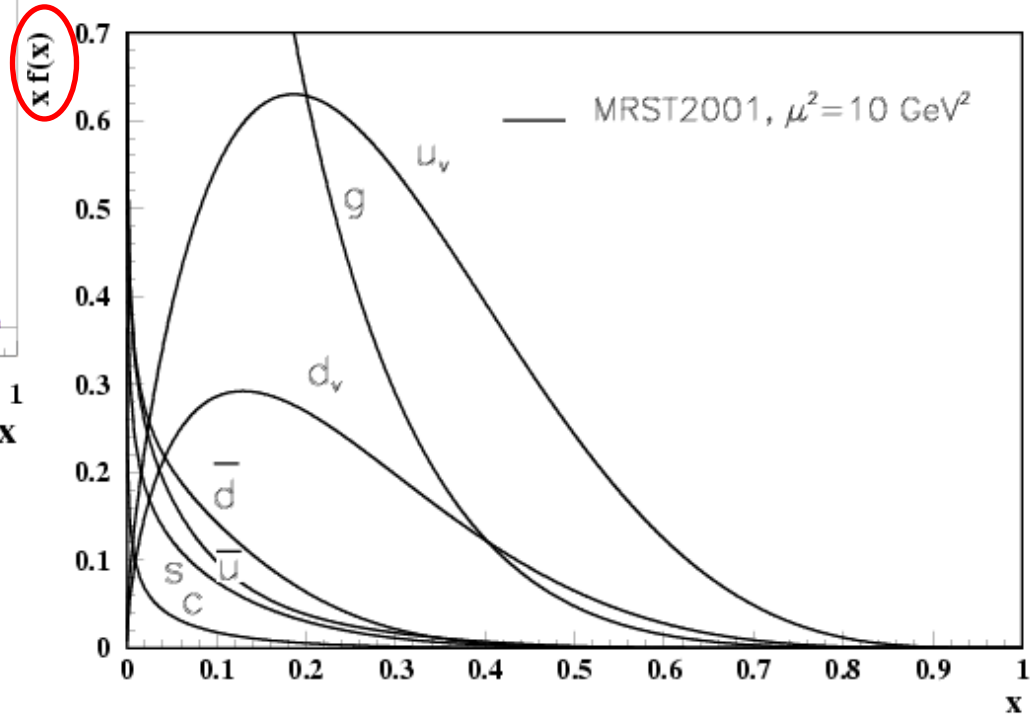


Measurements:

F_2 , F_3 ... in DIS

(n,p,elm.,weak, Q^2-depend.)

⇨ valence, sea, gluons...



Fits/parametrisations:

- CTEQ
- MRST

Cross section calculation in pp

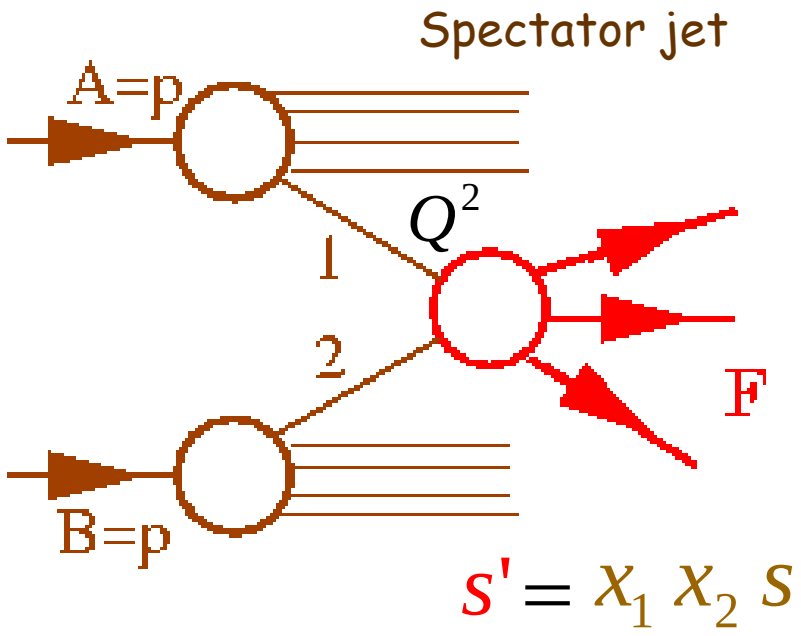
final state

Wanted: $\frac{d\sigma_F(\sqrt{s},Q^2)}{dV}$ ← kinematical variable

Calculable: $\frac{d\sigma_F^{ij}(x_i,x_j,Q^2)}{dV}$

Known: $f_i(x_i,Q^2)$ ← Q^2 = („momentum transfer")²

depends on final state



$$\frac{d\sigma_F(\sqrt{s},Q^2)}{dV} = \sum_{i,j}\int dx_i\, dx_j\; f_i(x_i,Q^2)\, f_j(x_j,Q^2)\frac{d\sigma_F^{ij}(x_i,x_j,Q^2)}{dV}$$

Luminosity determination in pp

Remember: $10^{34} / cm^2 / s \approx 100 / fb$ per „year" !

a) from collider parameters:

$$L \sim \frac{f \cdot N_p \cdot N_{\bar{p}}}{\sigma_x \cdot \sigma_y}$$

...not very precise (10%)...

b) via reference process:

$$L = \frac{\dot{N}_{ref}}{\sigma_{ref}}$$

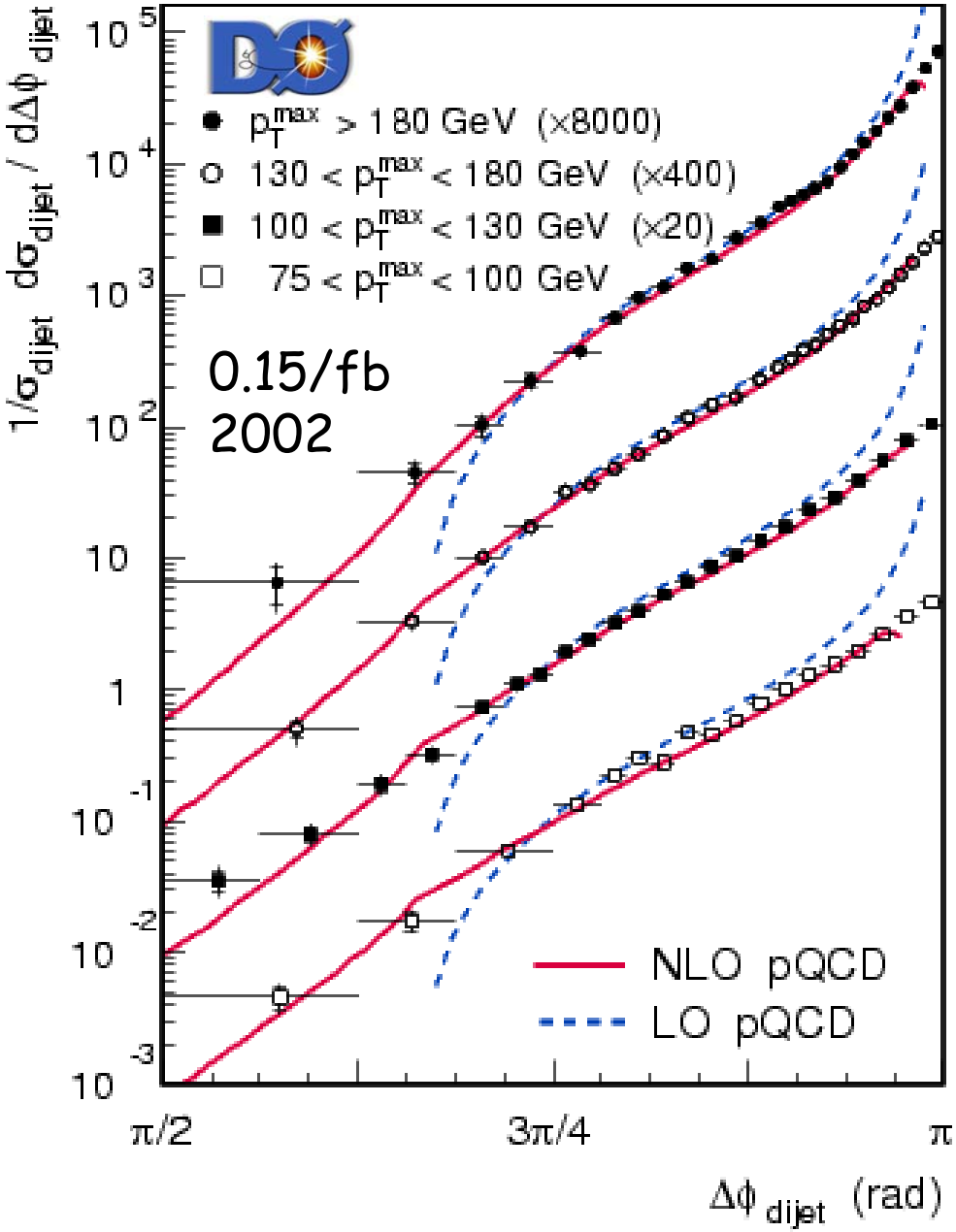
...to be measured by detector(5%)...

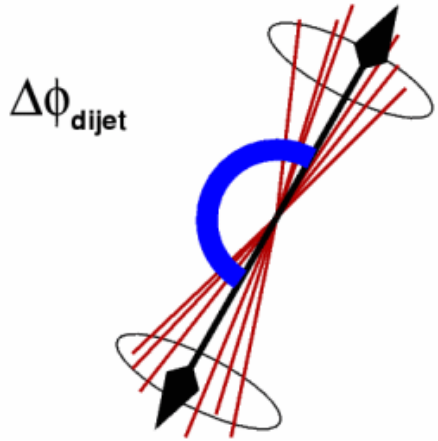
known,

large

(in)elastic forward scattering

strong inclusive dijet production





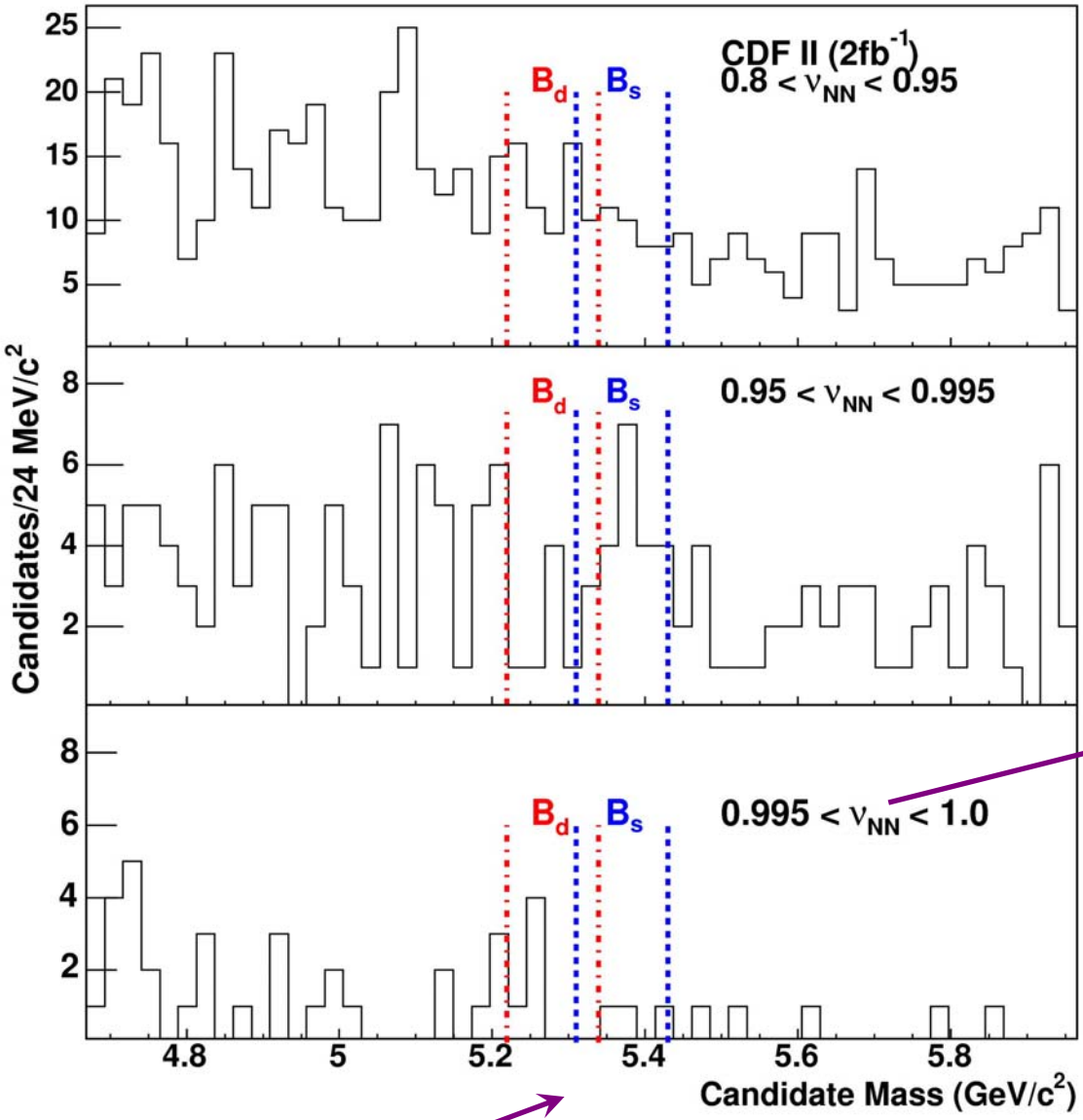
contributions at angles < π from multi parton final states

ok !

electroweak FCNC $B_s \to \mu\mu$

2/fb

2007



note:
in 2/fb
> 10^{10} B's

neural net

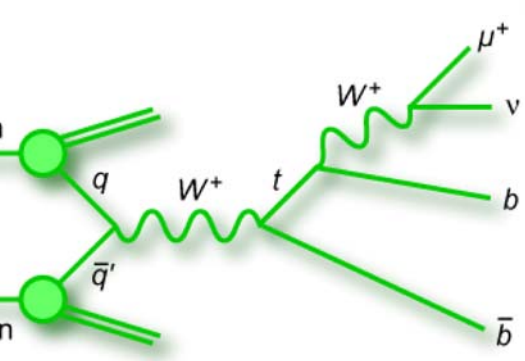
(muon id)

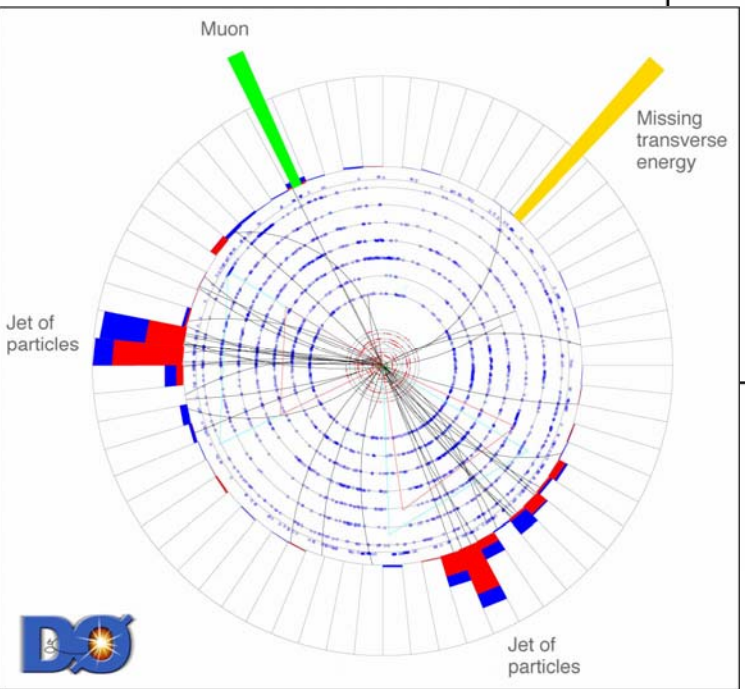
background:

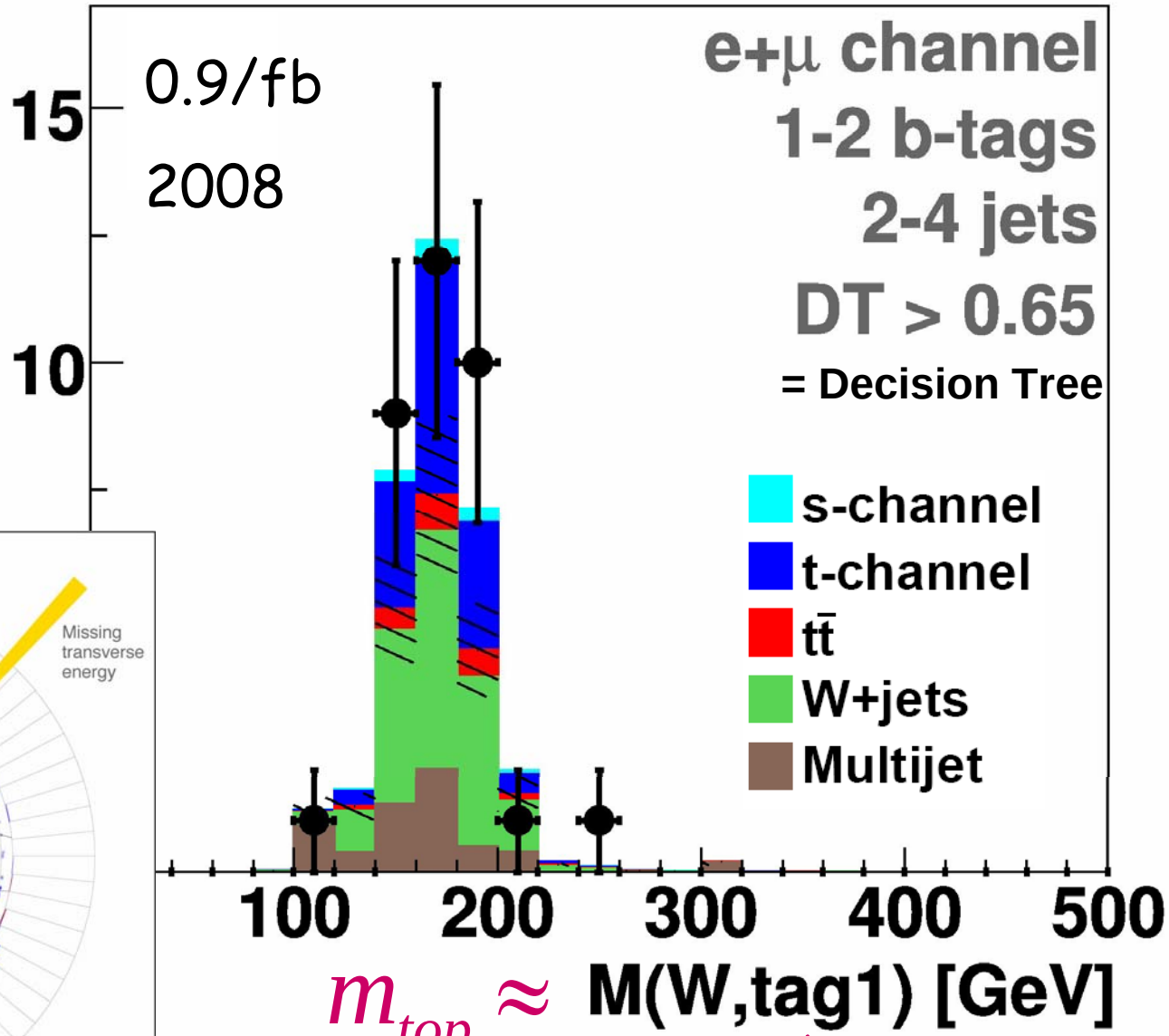
$J/\Psi\ K$ ...

high detector resolution

electroweak CKM single top







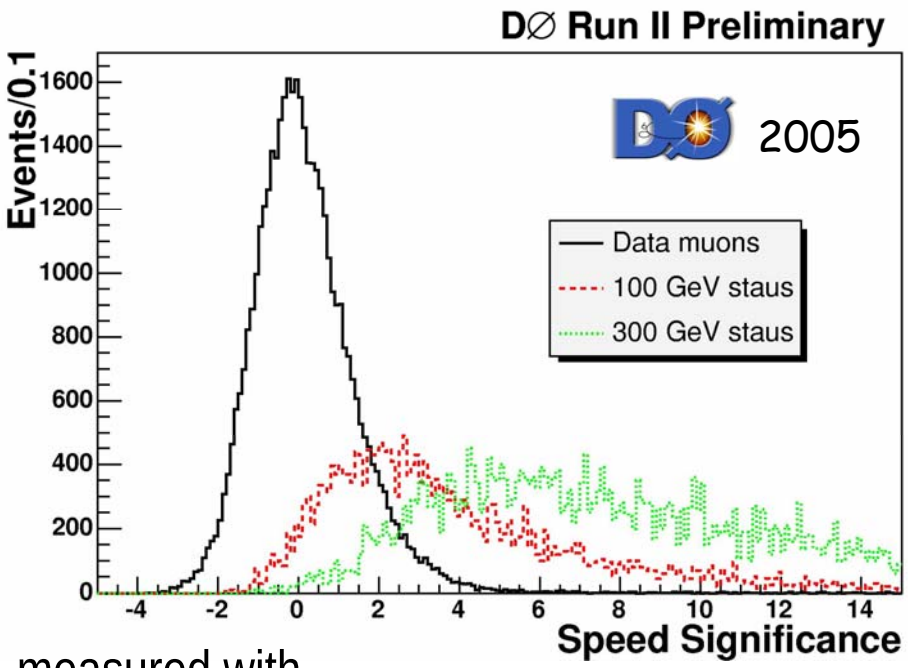
$m_{top} \approx$

b-tag via secondary vertex

searches long lived staus

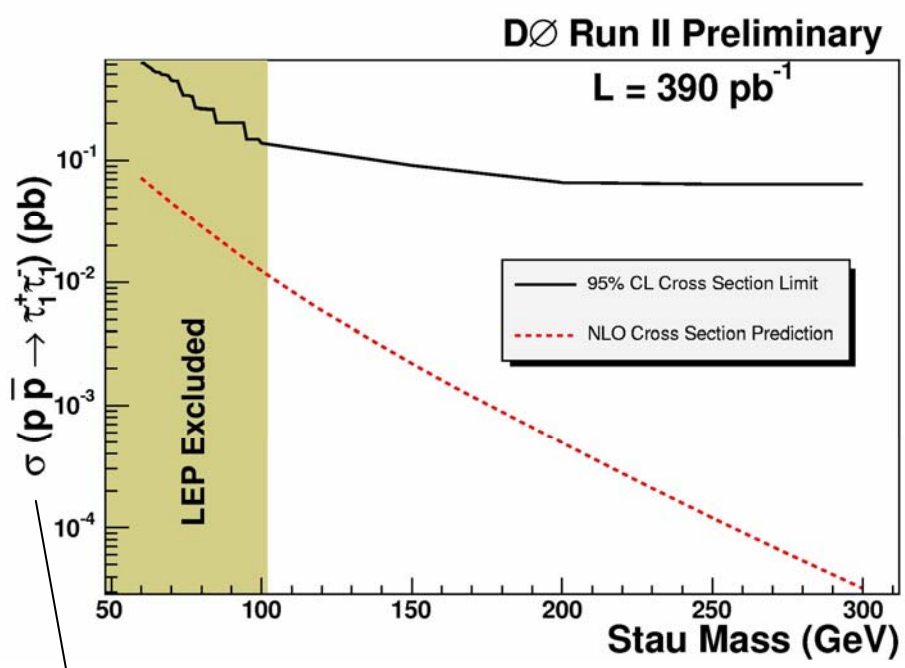
GMSB: decay $\tilde{\tau} \rightarrow \tau \tilde{G}$ suppressed

$\Longrightarrow$ heavy charged particle traversing detector slowly



measured with scintillators in muon system

$$= \frac{1 - speed}{\sigma_{speed}}$$



stau pair production