The Discovery of the TOP QUARK

Seminar: 'Key Experiments in Particle Physics'
22.05.2009
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Speaker: Radoslav Rusanov

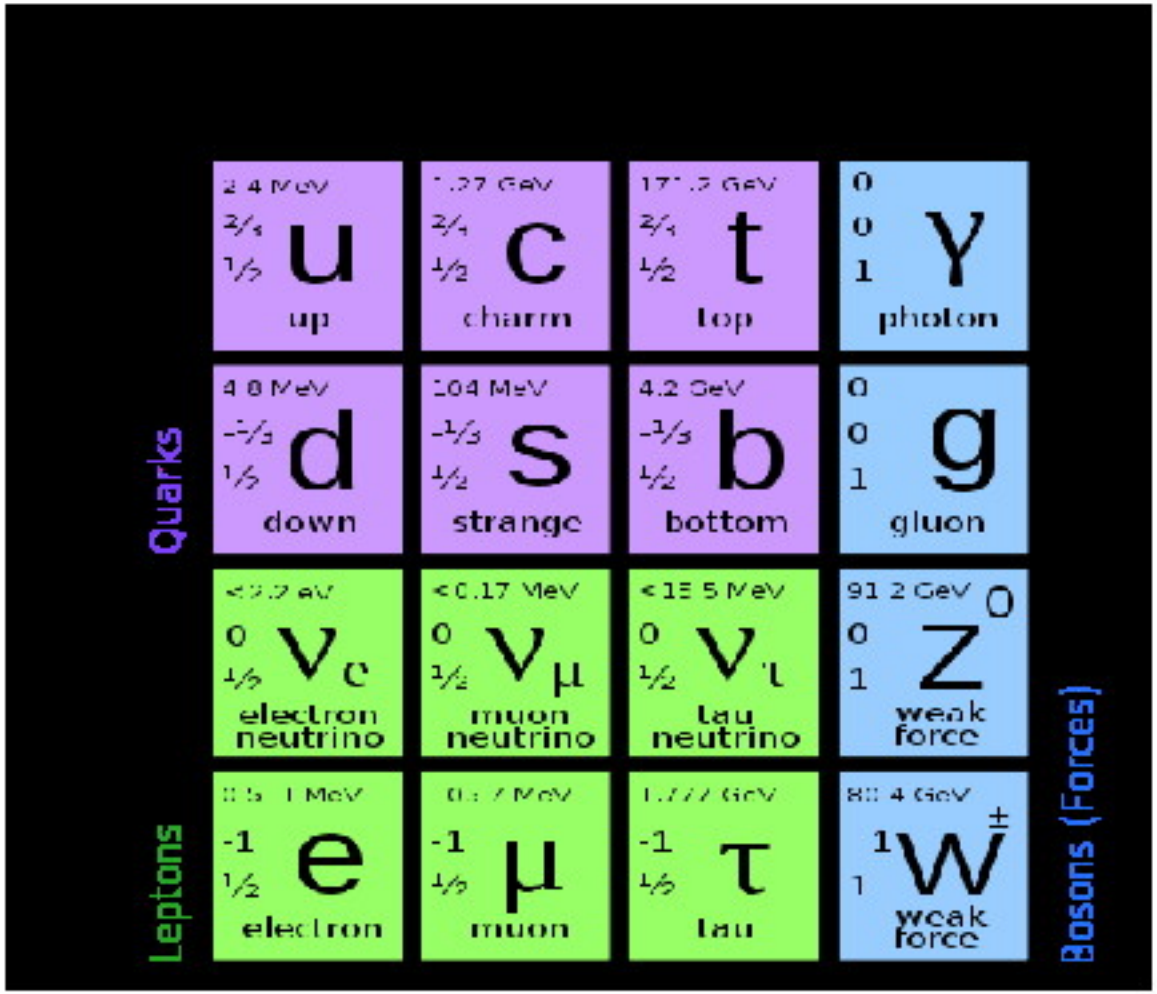
Outline

- The Top Quark within the Standard Model
- The TeVatron
- The CDF Experiment
- Results

NEXT to LAST

Why was the DISCOVERY so important ???

Standard Model



- Until the 70es: only 2 generations
- 1975: discovery of τ
- 1977: discorery of Υ

➔ 3rd generation !!??

Bottonium (p + N → Y + X)

- Q_b = -1/3 (leptonic width)
- I_3 = - 1/2 (forward backward asymmetry)

→ another 3rd generation quark

LEP (until 1995)

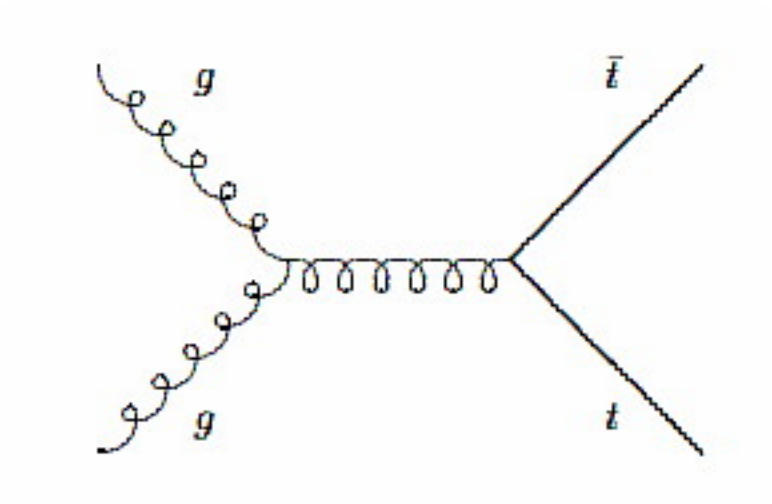
- $\sqrt{s} \approx M_Z \approx 91$ GeV (no TOP discovered)

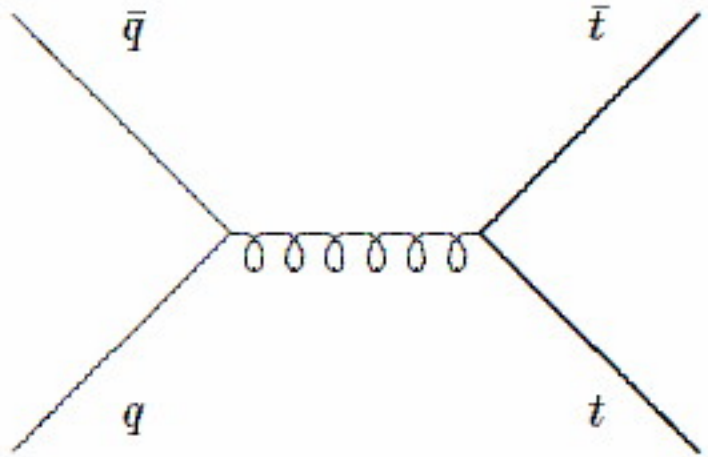
➔ $M_{top} > 46$ GeV

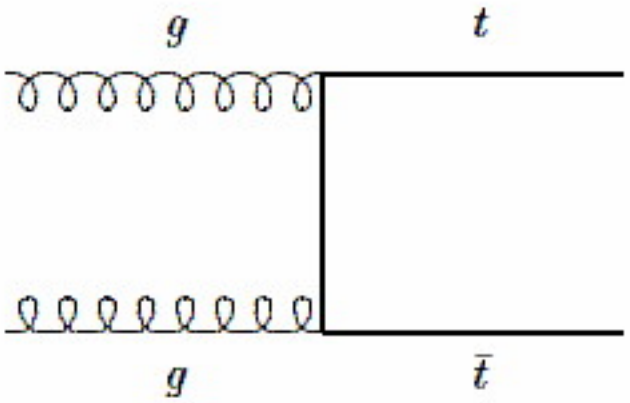
➔ ppbar collider (TeVatron $\sqrt{s} = 1.8$ TeV)

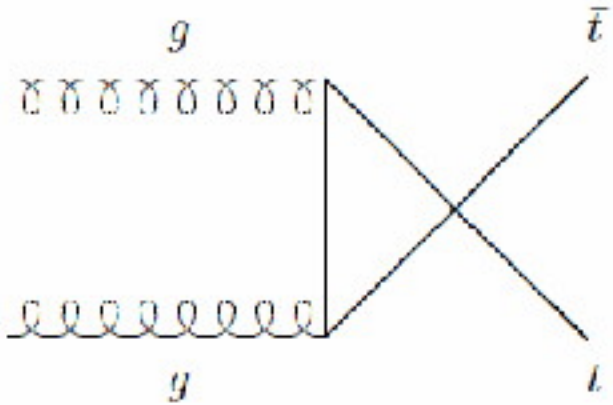
➔ quarks, gluons and antiquarks collisions

ttbar pair production

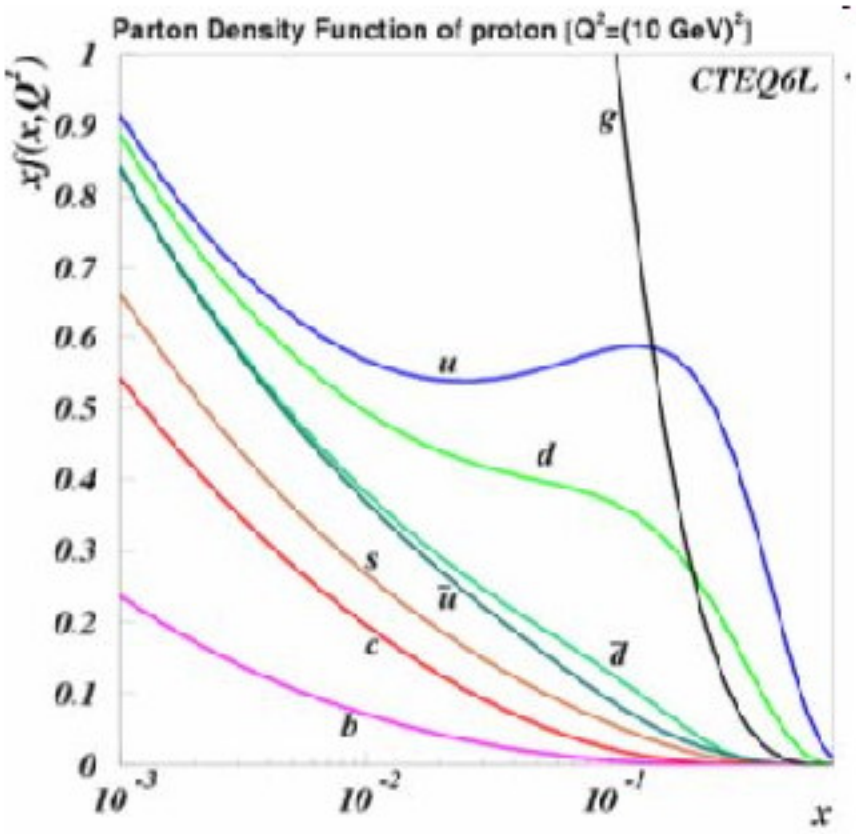








Parton Distributions

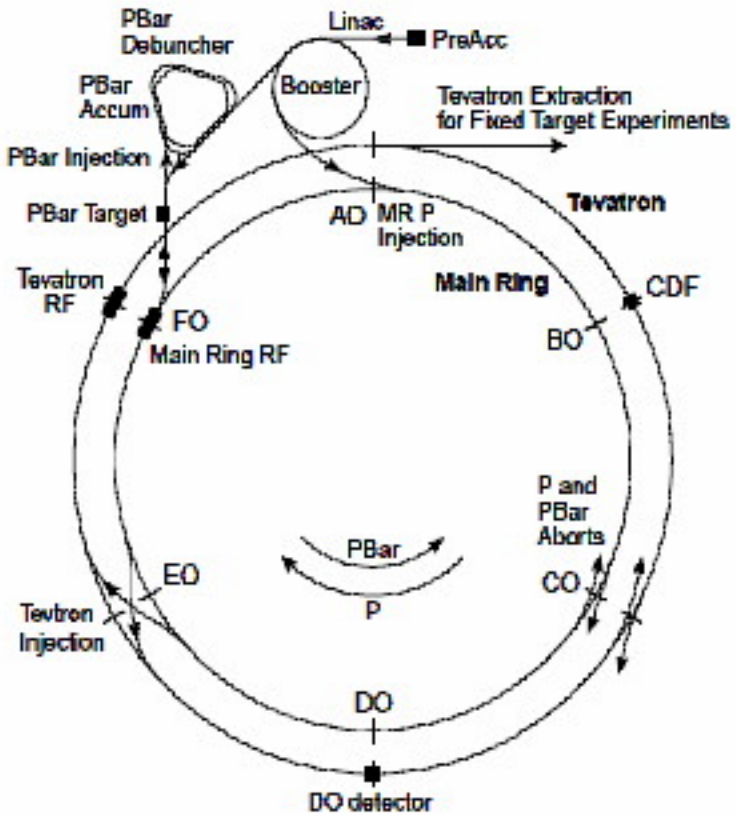


- for M_{top} = 180 GeV
  ($\sqrt{s}$ = 1.8 TeV)

x > 0.2 !!!

AntiProtons

The TeVatron at Fermilab



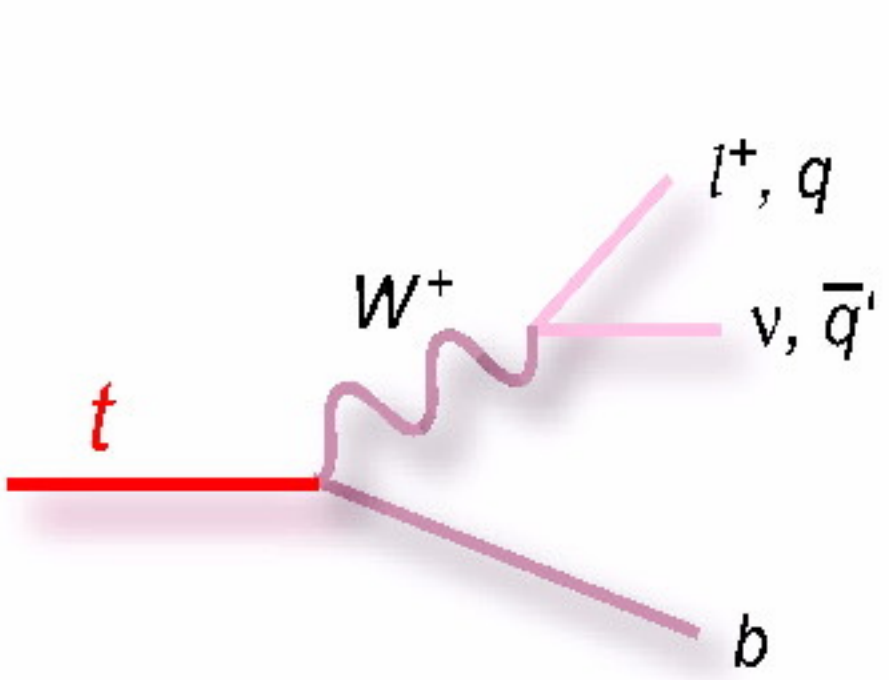
- Booster: 8 GeV
- Main Ring: 120 GeV
- TeVatron: 900 GeV
- $B_{\text{Main Ring}} = 0.65$ T
- $B_{\text{Tevatron}} = 4.4$ T
- pbar: peak at 8GeV
  - Debuncher
  - stochastic cooling
  - electron cooling

Collider

Accelerator radius	1000 m
Maximum beam energy	900 GeV
Injection energy	150 GeV
Peak luminosity	2×10^{31} cm $^{-2}$ s $^{-1}$
Number of bunches	$6p, 6\bar{p}$
Intensity per bunch	$\approx 10^{11} p$, $5 \times 10^{10} \bar{p}$
Crossing angle	0^{o}
Bunch length ($1\ \sigma$)	50 cm
Transverse beam radius ($1\ \sigma$)	$\approx 25\ \mu$m
Energy spread	0.15×10^{-3} GeV
RF frequency	53 MHz
p stacking rate	$\approx 3.5 \times 10^{10}$/hour
Beam crossing frequency	290 kHz
Period between crossings	3.5 μs

'The discovery of the top quark'
Review of Modern Physics 08/1996

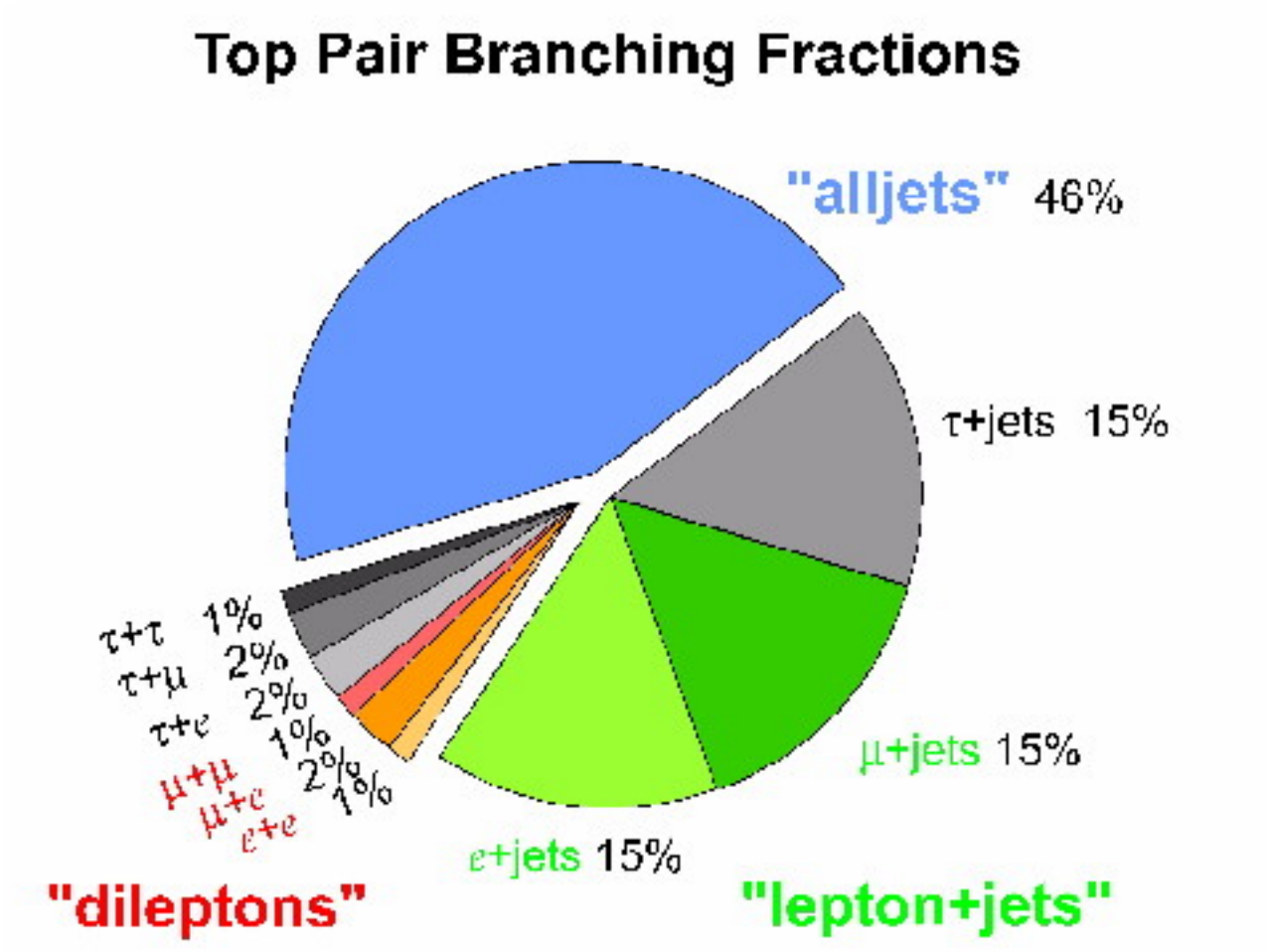
Top Decays (no handronisation)



1) t → Wb (one jet)

2) a) W → lν
   b) W → qqbar (2 jets)

Top Decays

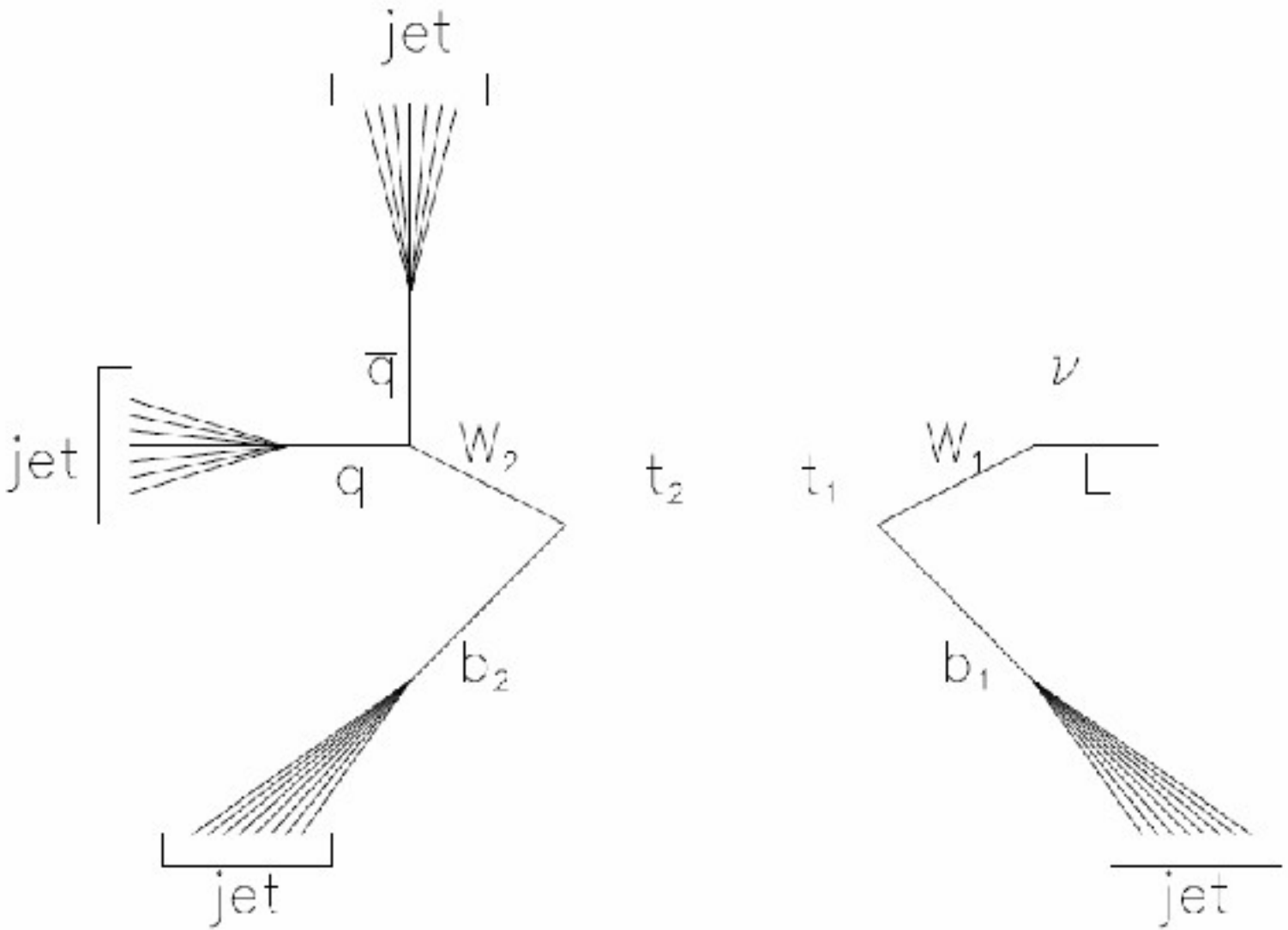


We use:

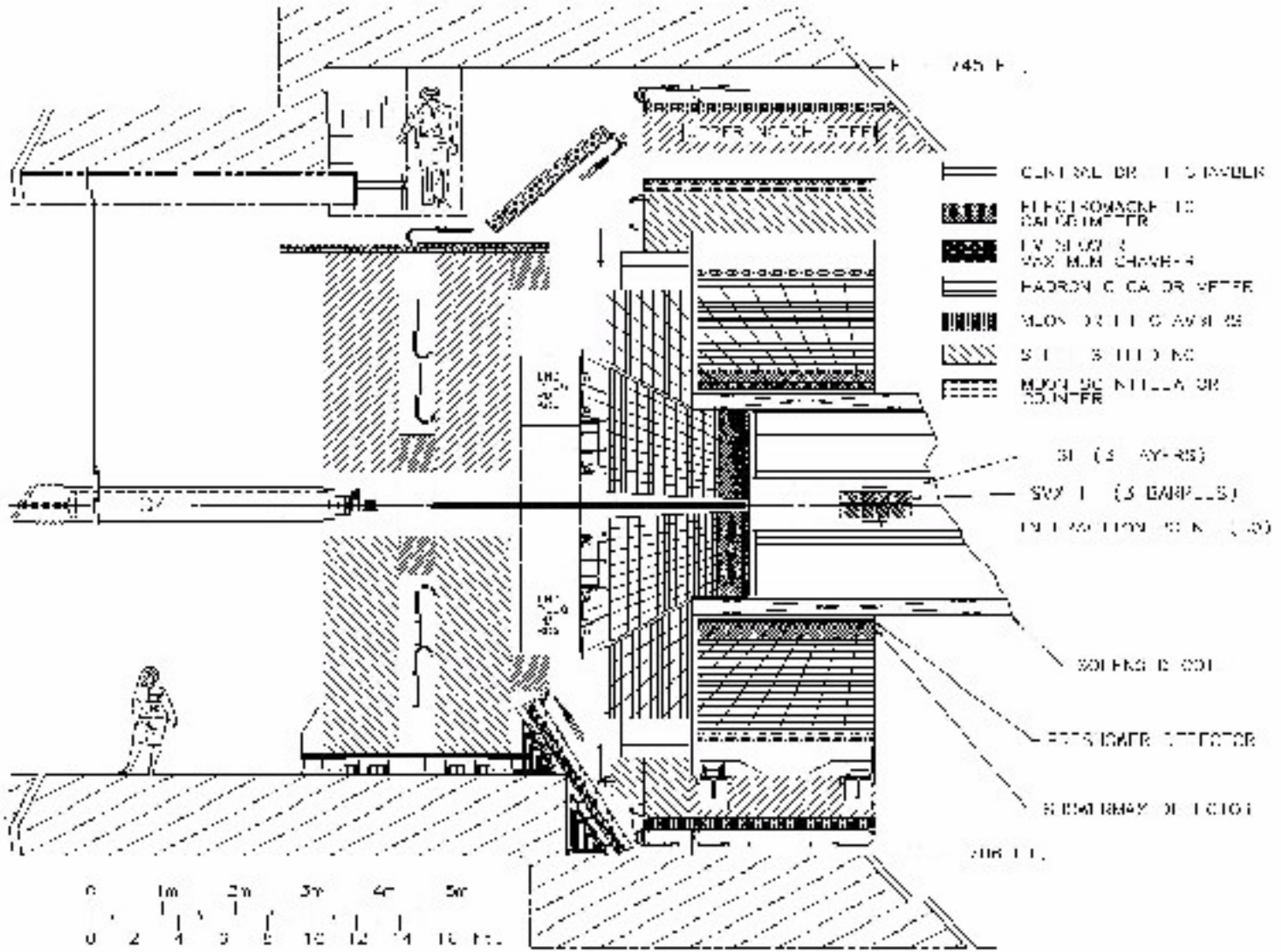
dilepton (DIL)

lepton + jets (L+J)

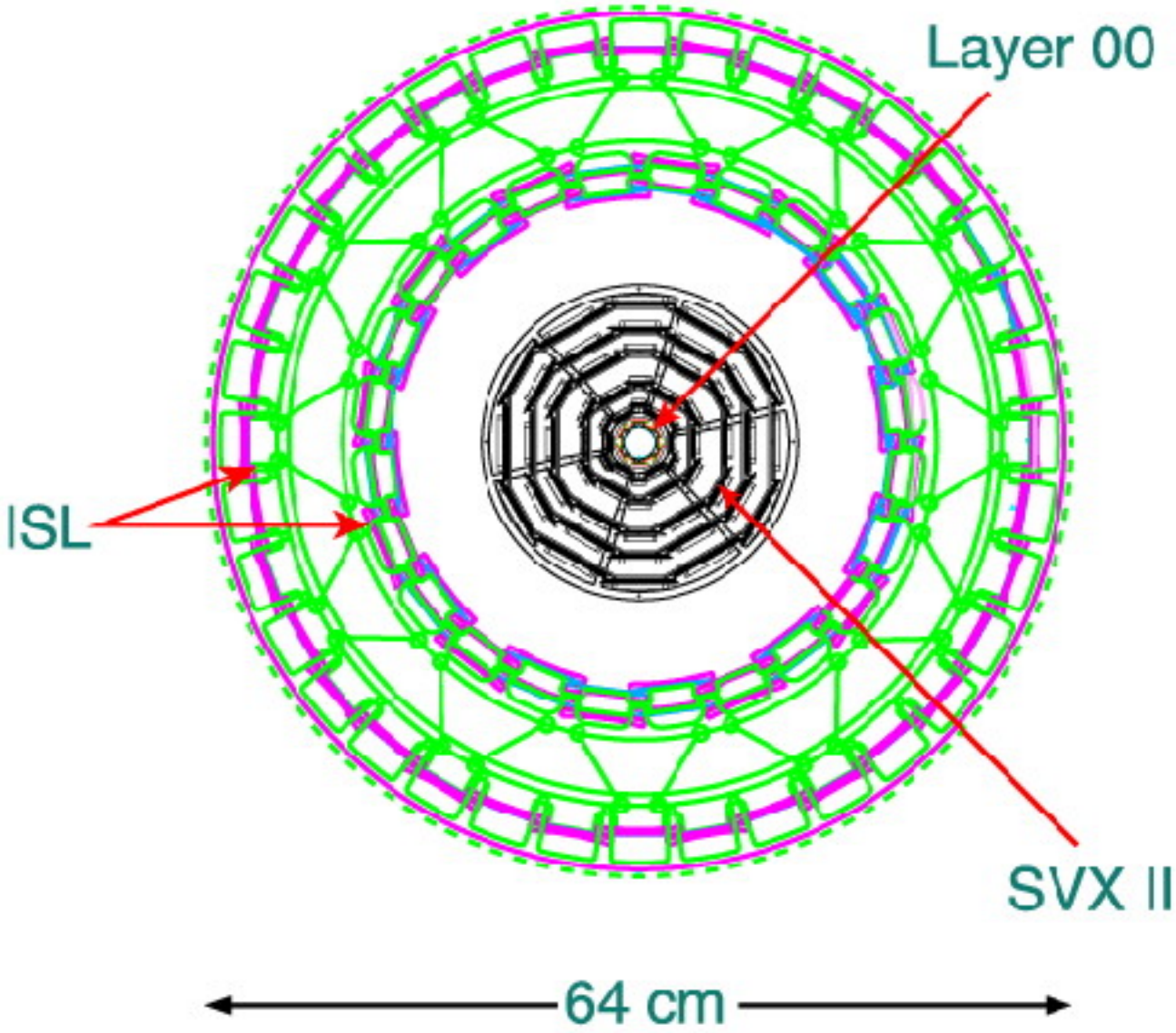
Semi Leptonic Decay



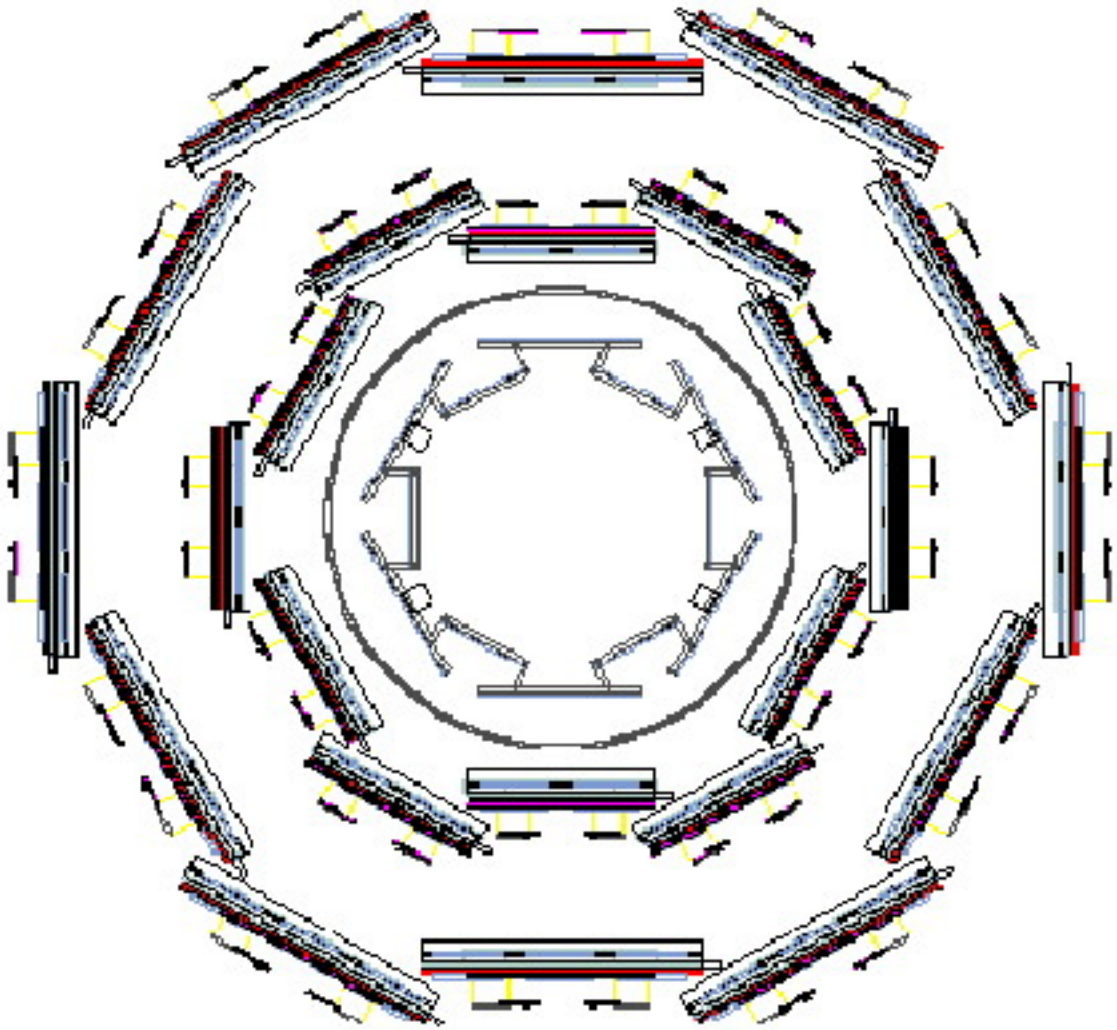
The CDF detector



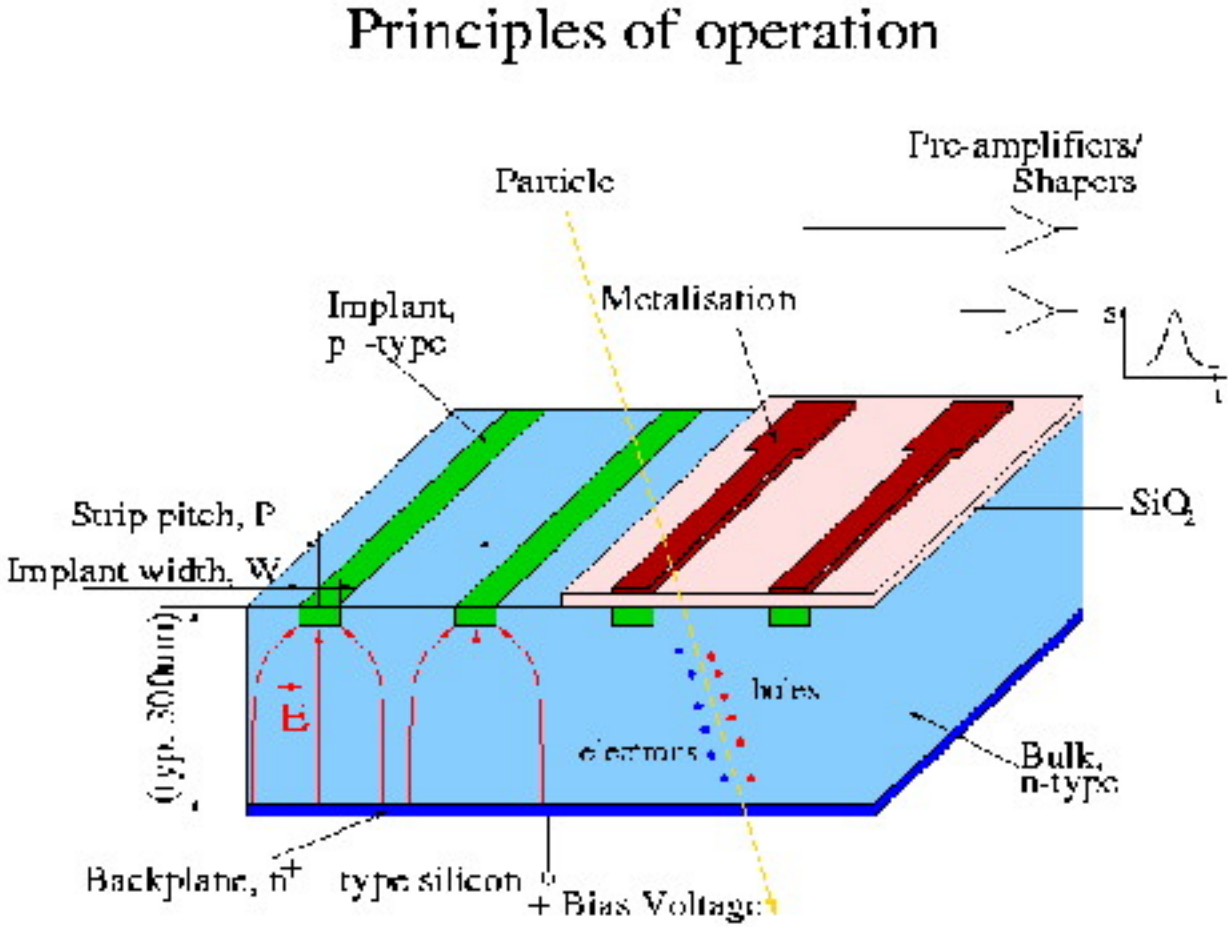
Vertex Detector



Vertex Detector

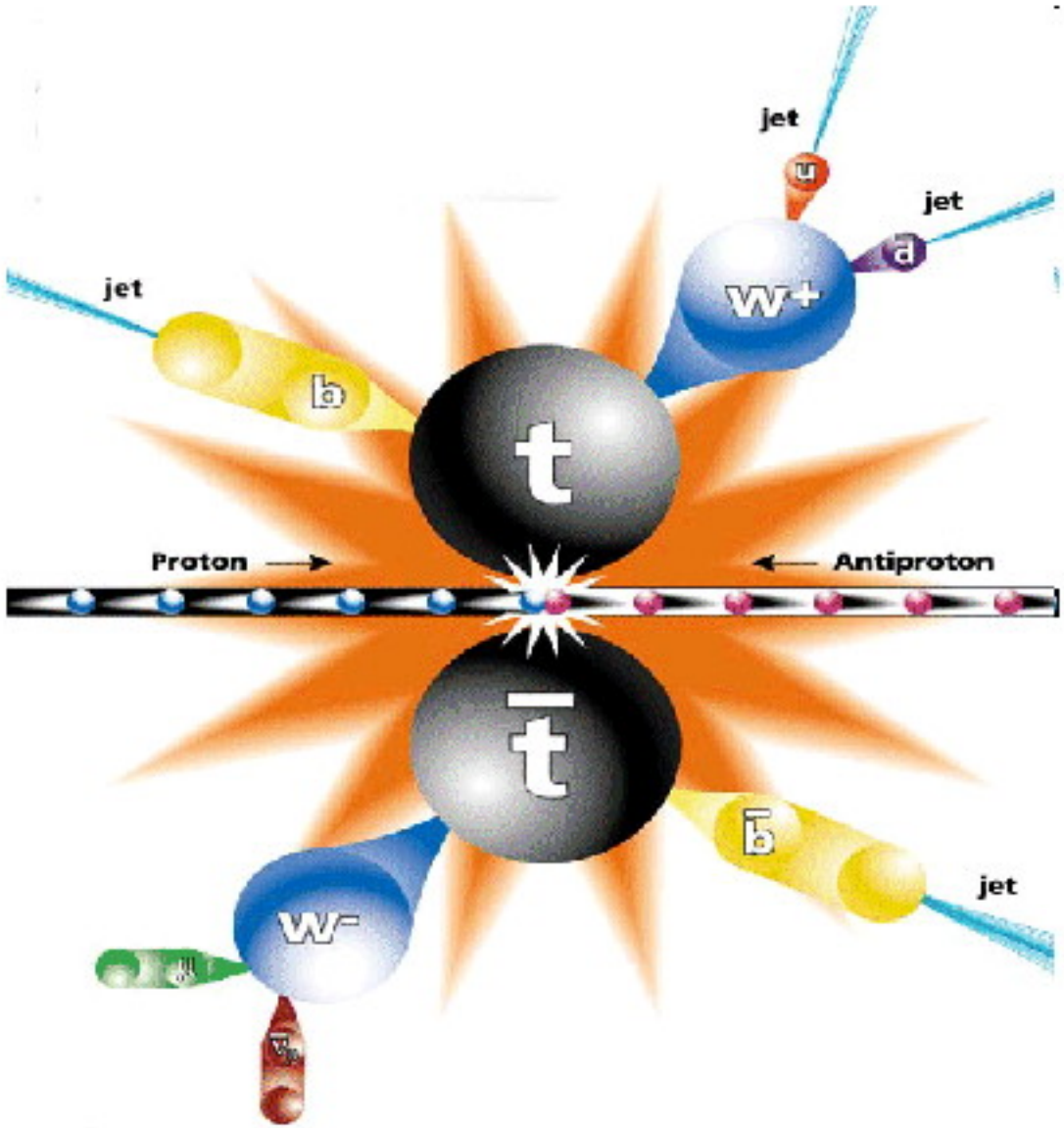


Vertex Detector

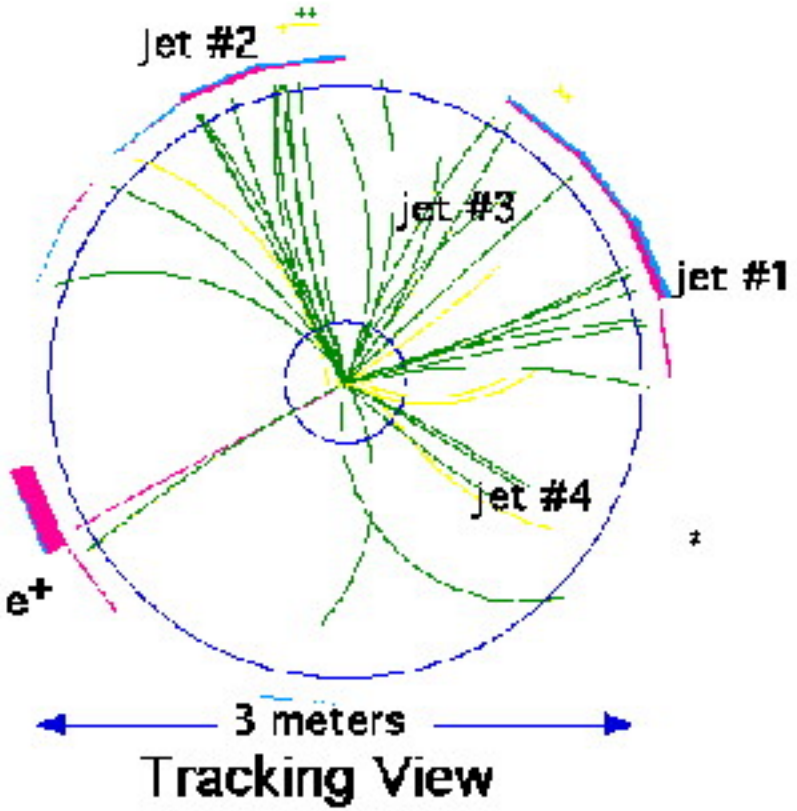


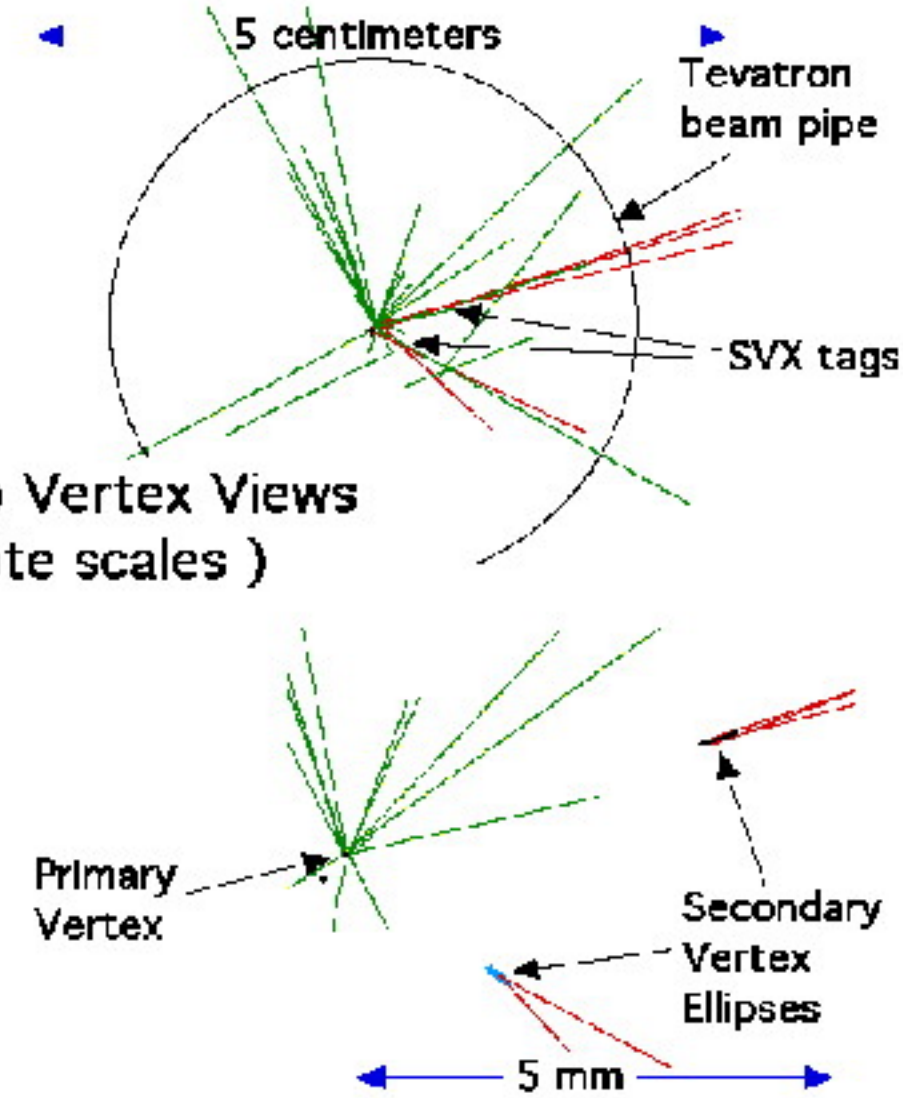
http://hep.fi.infn.it/CMS/sensors/Silicon_Detector.gif

Vertex Detector

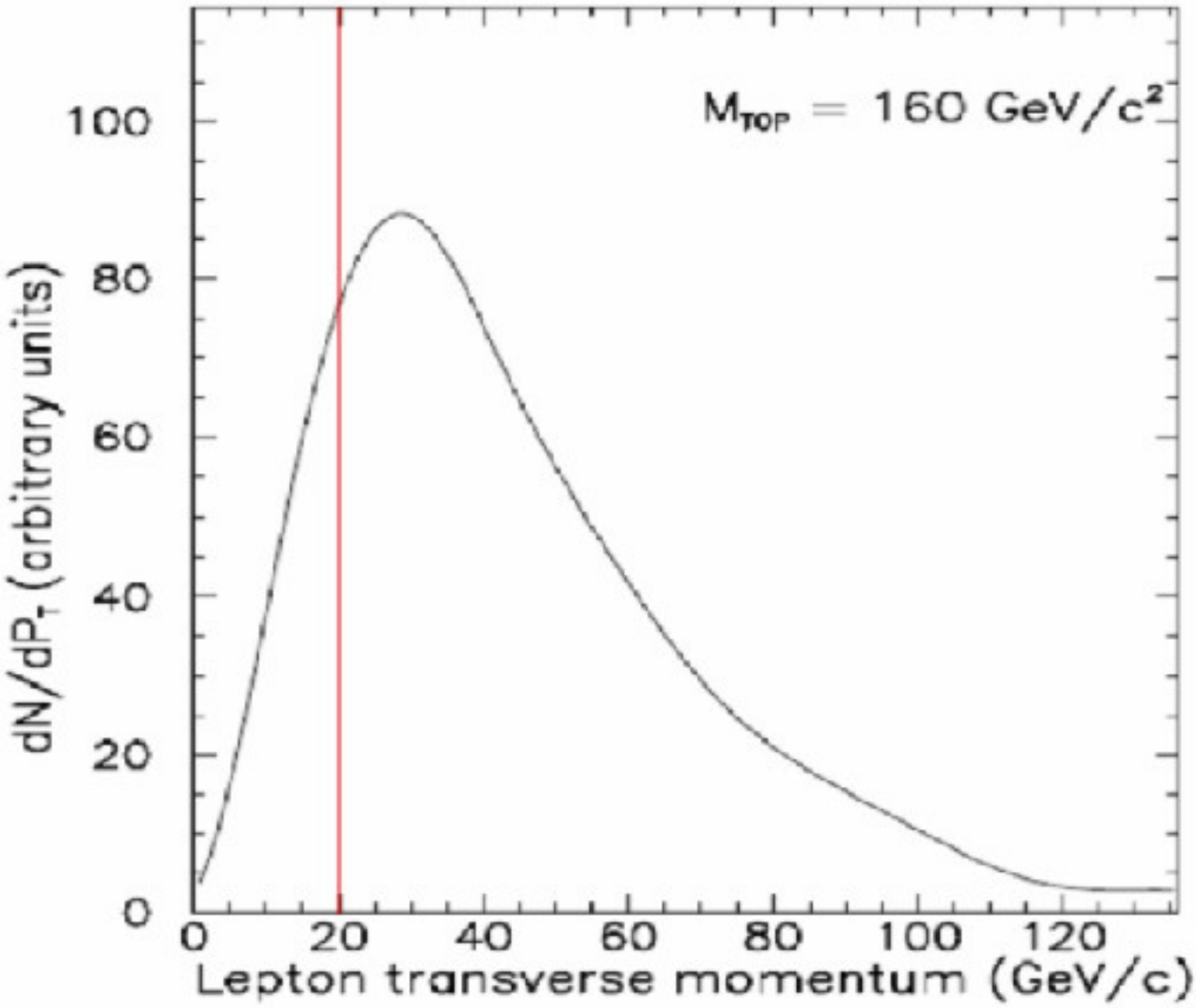


Vertex Detector





$W \rightarrow l + \nu$: l momentum distribution

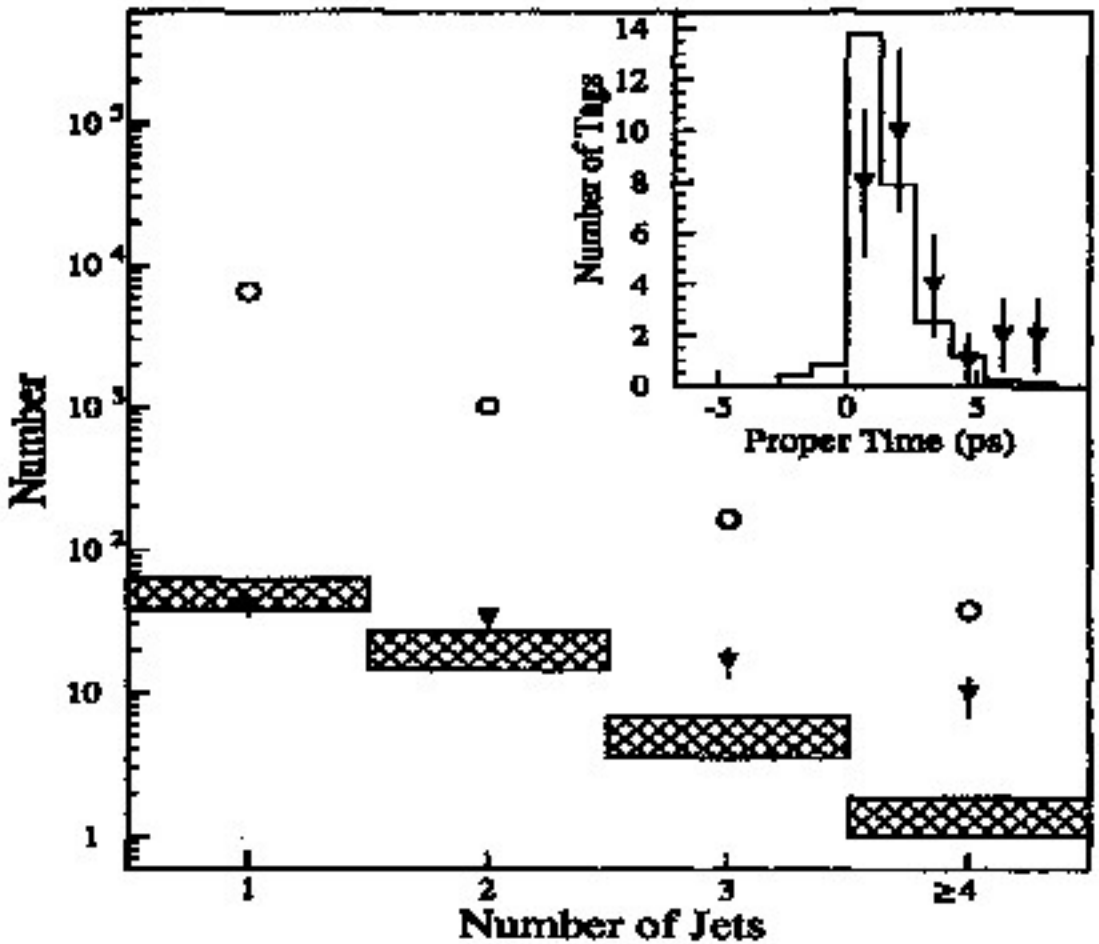


Selection Criteria CDF

- dilepton selection criteria

Channel	Leptons		Jets		$\not\!\!E_T$	$\Delta\phi(\not\!\!E_T$,lepton or jet)$> 20^o$
	E_T(e)	$P_T(\mu)$	N_{jet}	E_T		
$e\mu$ + jets	$\geq$ 20 GeV	$\geq$ 20 GeV/c	≥ 2	$\geq$ 10 GeV	$\geq$ 25 GeV	$\rightarrow \not\!\!E_T \geq 50$
ee + jets	$\geq$ 20 GeV	-	≥ 2	$\geq$ 10 GeV	$\geq$ 25 GeV	$\rightarrow \not\!\!E_T \geq 50$
$\mu\mu$ + jets	-	$\geq$ 20 GeV/c	≥ 2	$\geq$ 10 GeV	$\geq$ 25 GeV	$\rightarrow \not\!\!E_T \geq 50$

B-tagged events



- background:
- ttbar signal:
  l + 3 or 4 jets

Results

- 56 events observed (dilepton, lepton + jets)
- expected background: 23.4±2.9 events

➔ Significance: 1·10^-6 ➔ 4.8σ

Discovery of the top quark only together with D0 (4.6σ)

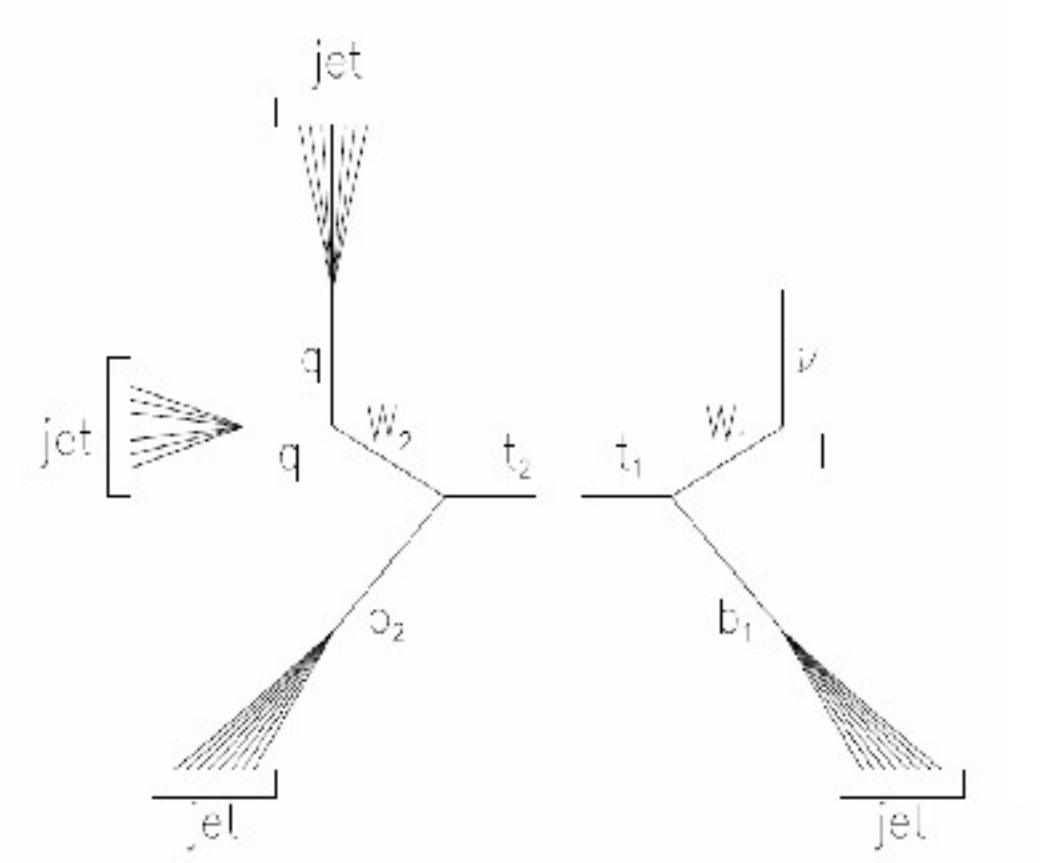
Cross Section (pair production)

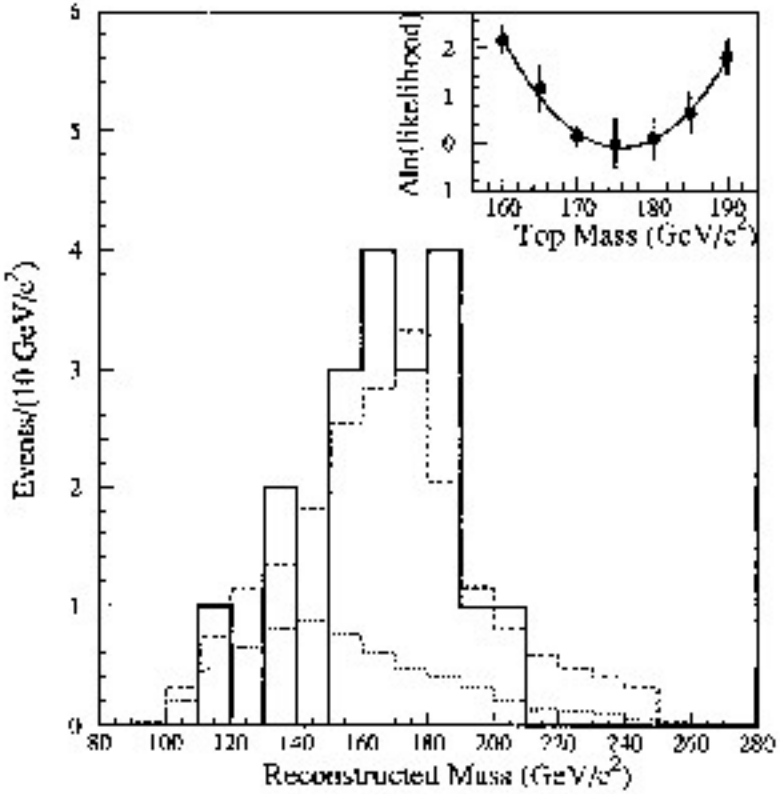
- $R = L \cdot \sigma \cdot \varepsilon \cdot A$
- Integration over the run time:
- $N = L_{int} \cdot \sigma \cdot \varepsilon \cdot A$ (L_{int}: from the background)

(ppbar → W + qqbar)

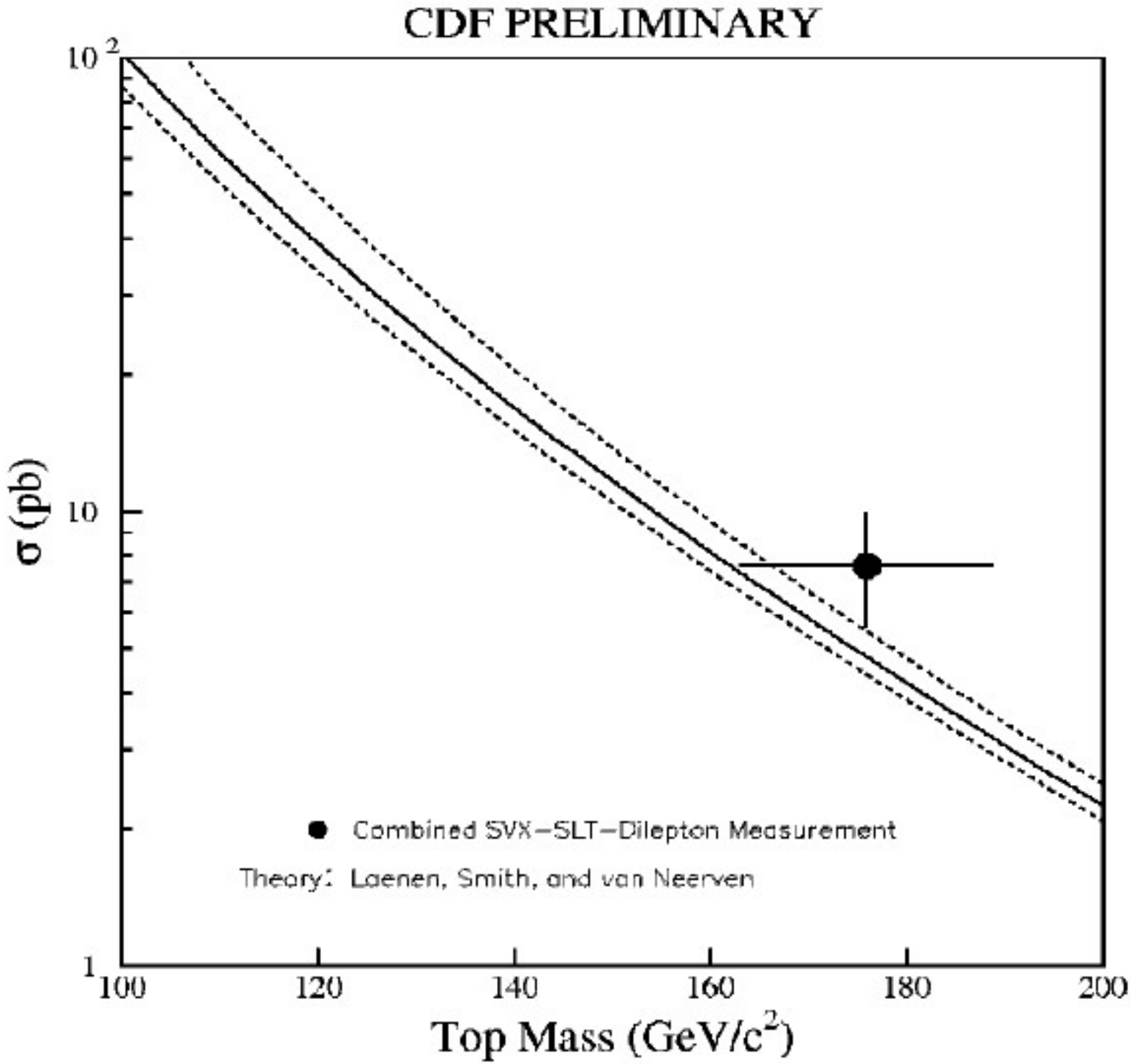
→ 7.6 ± 2.4 pb

Mass of Top Quark CDF





- $M_t = 176 \pm 8 \pm 10$ GeV/c²


CDF PRELIMINARY
10^2
10
1
σ (pb)
100
120
140
160
180
200
Top Mass (GeV/c^2)
Combined SVX−SLT−Dilepton Measurement
Theory: Laenen, Smith, and van Neerven

Top Charge (DIL and L+J channels)

- To be proven: t ➔ W+ and b
- W-charge: the lepton from its decay
- b-jet charge with an algorithm
- Pairing

➔ exotic quark excluded
(87% confidence)

Summary

- Top dicovered by CDF and D0 at TeVatron
- $M_t = 176 \pm 8 \pm 10$ GeV/c²
- $S_{ttbar} = 7.6 \pm 2.4$ pb
- $Q_{top} = +2/3$
- Spin = 1/2
- $A_{fb} = 19.3 \pm 6.5 \pm 2.4$ %

References

- CDF: PRL 74, 2626 (1995)
- D0: PRL 74, 2632 (1995)
- Charge: D0 PRL 98, 041801 (2007)
- http://www-cdf.fnal.gov/physics/new/top/2007/topProp/top_charge_1.5invfb/publicTQpage.html
- http://www-d0.fnal.gov/Run2Physics/top/top_public_web_pages/top_feynman_diagrams.html
- http://www-cdf.fnal.gov/