

Misura della massa del bosone W a CDF

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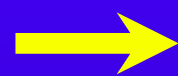
La massa del

W

- Vincoli sui parametri liberi del SM
- Valutare contributo di particelle non osservate
- Esprimere gli altri parametri in funzione di m_W

$$m_W^2 = \frac{\pi \alpha_{EM}}{\sqrt{2} G_F} (1 - m_W^2/m_Z^2) (1 - \Delta r)$$

Correzioni radiative



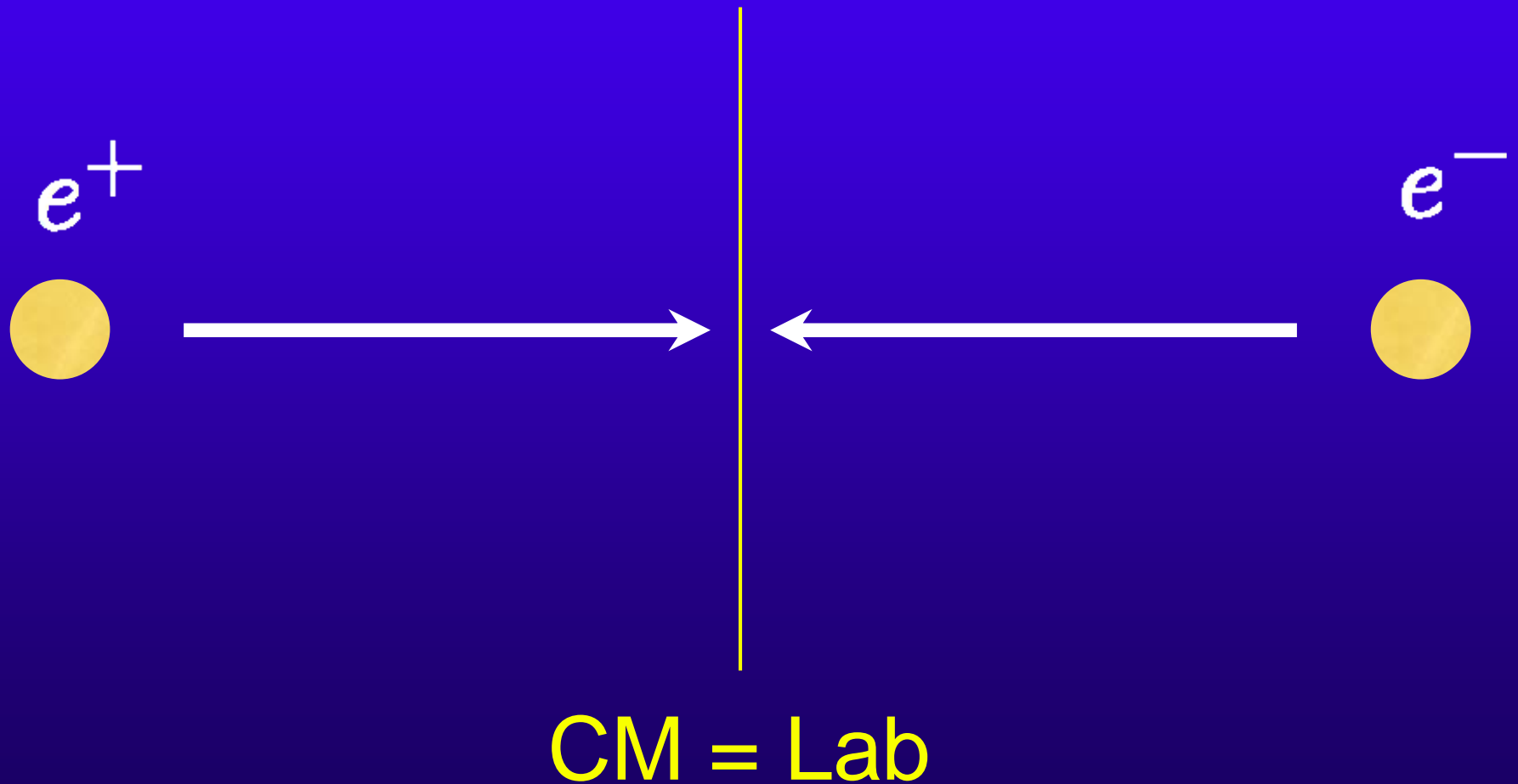
$$\Delta r_{tb} \simeq \frac{3G_F m_W^2 m_t^2}{8\sqrt{2}\pi^2(m_W^2 - m_Z^2)}$$



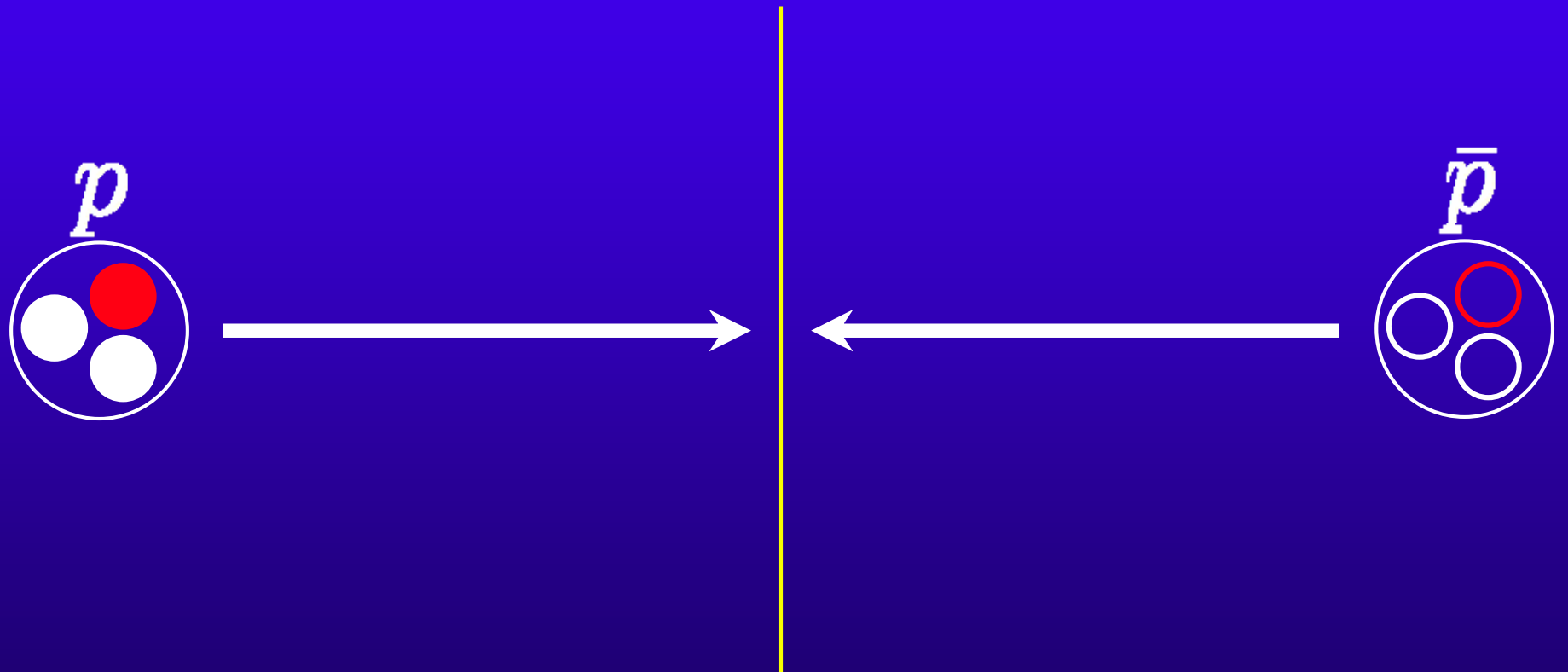
$$\Delta r_H \propto -\ln(m_H)$$

Parameter Shift	m_W Shift (MeV/c ²)
$\Delta m_H = +100 \text{ GeV}/c^2$	-41.3
$\Delta m_t = +2.1 \text{ GeV}/c^2$	12.8
$\Delta m_Z = +2.1 \text{ MeV}/c^2$	2.6
$\Delta \alpha_{EM} = +0.00013$	-2.3

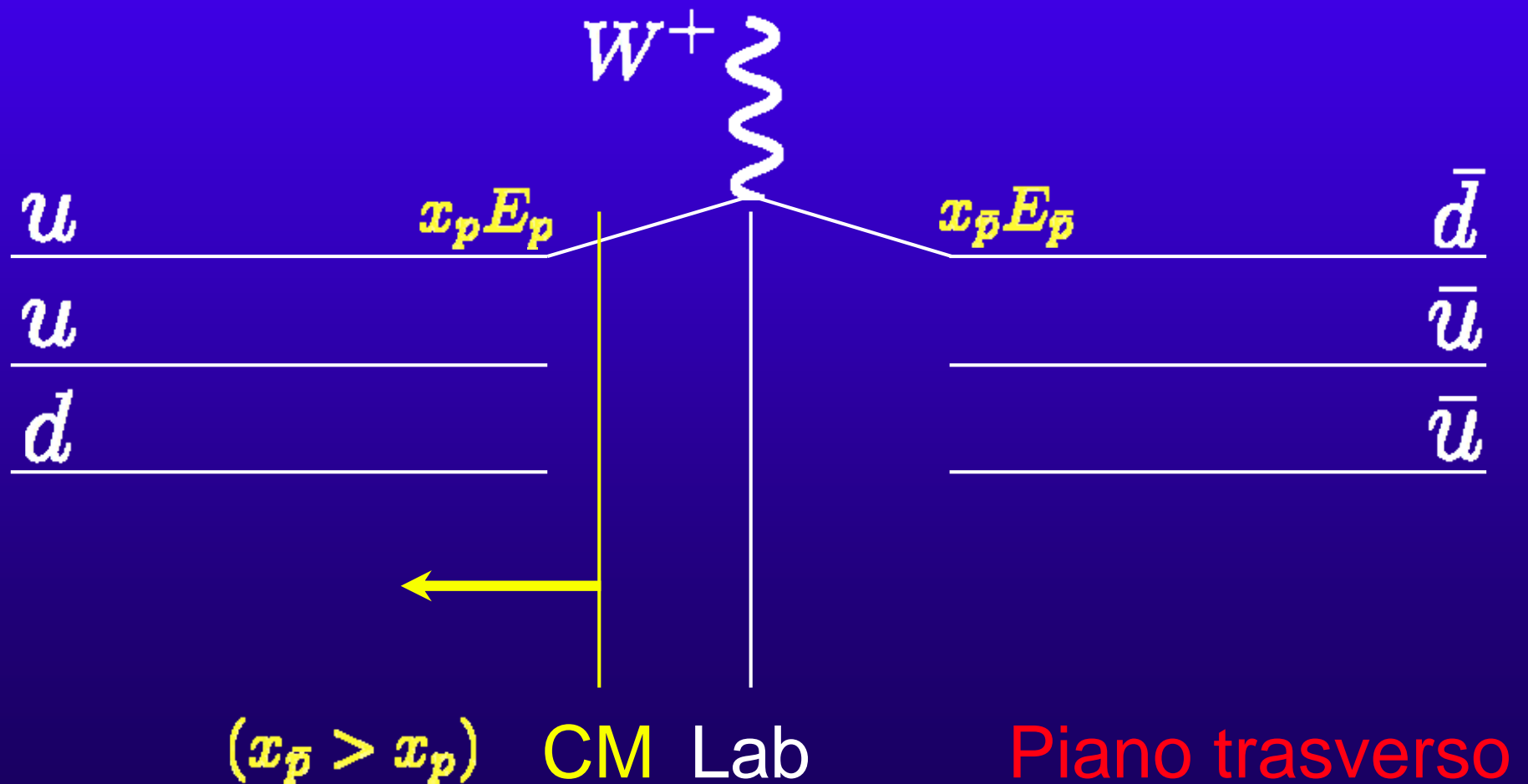
Misura di m_W in un collider: e^+e^- vs $p\bar{p}$



Misura di m_W in un collider: e^+e^- vs $p\bar{p}$



Misura di m_W in un collider: e^+e^- vs $p\bar{p}$



Formalismo

- Energia/impulso trasverso E_T p_T
- Recoil u_T
- Missing energy $\cancel{E}_T = -(\vec{p}_T + \vec{u}_T)$

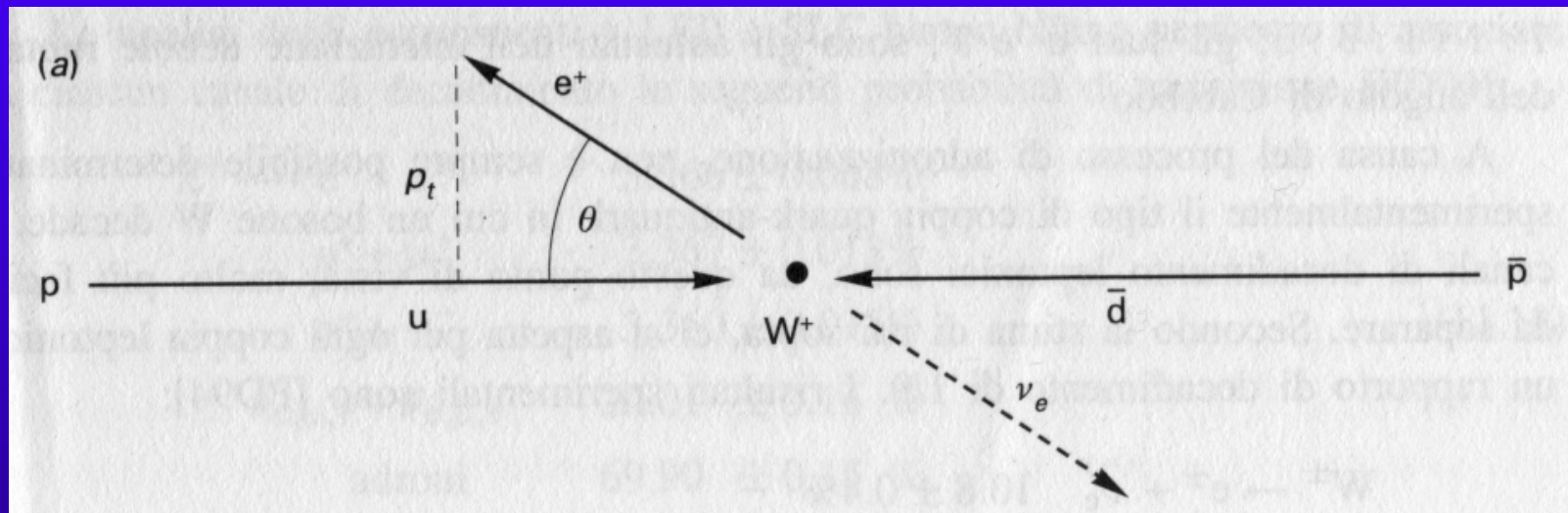
Strategia

$$W \longrightarrow l\nu$$

$$m_T^2 = 2p_T^l \cancel{E}_T (1 - \cos\Delta\phi)$$

- Misura di p_T e di u_T Il neutrino elude il rivelatore
- Misura di alta precisione del leptone carico
- Calibrazione E/p : J/ψ , Υ e poi Z
- Fit su m_T , p_T , \cancel{E}_T

La misura: il picco Jacobiano



$$p_T^{e^+} \approx \frac{M_W}{2} \sin\theta$$

$$\frac{d\sigma}{dp_T} = \frac{d\sigma}{d\cos\theta} \cdot \frac{d\cos\theta}{dp_T}$$

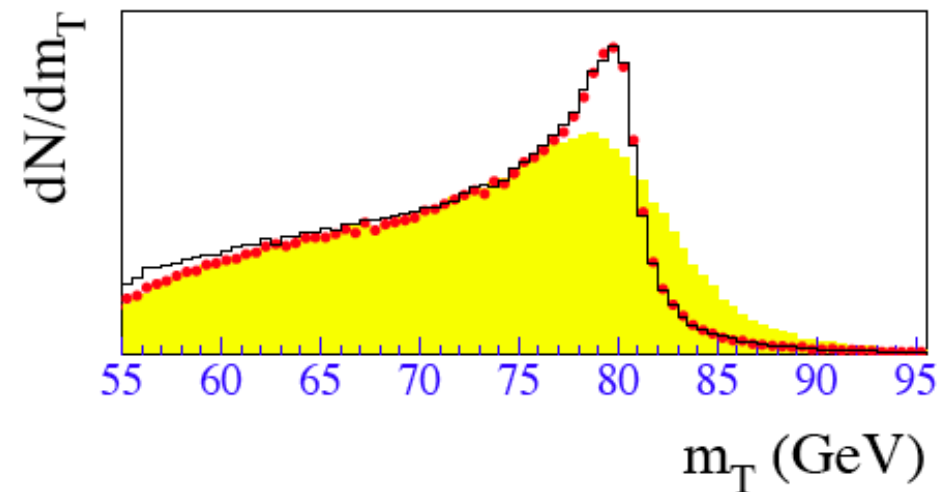
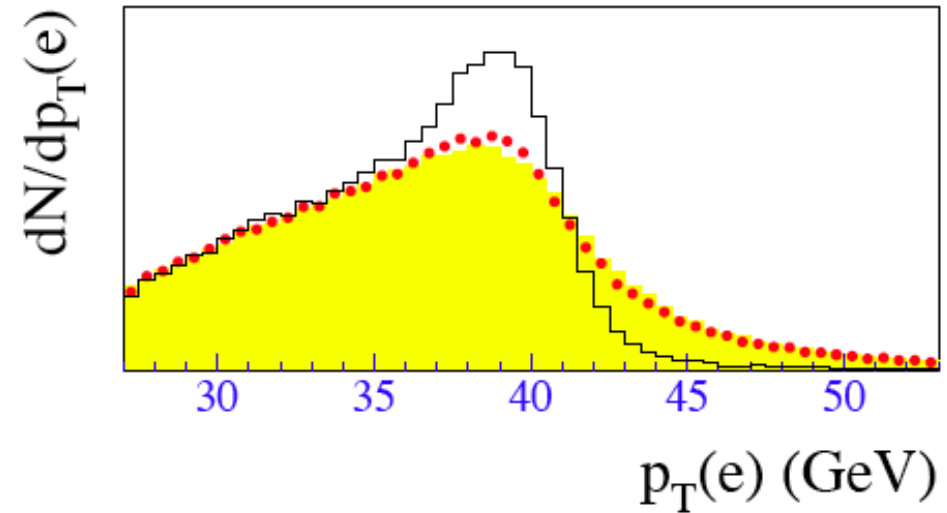
$$\frac{d\sigma}{dp_T} = \frac{d\sigma}{d\cos\theta} \cdot \frac{2p_T}{m_W} \cdot \frac{1}{\sqrt{(m_W/2)^2 - p_T^2}}$$

Il picco Jacobiano

Teoria: polo in $p_T^l = \frac{m_W}{2}$

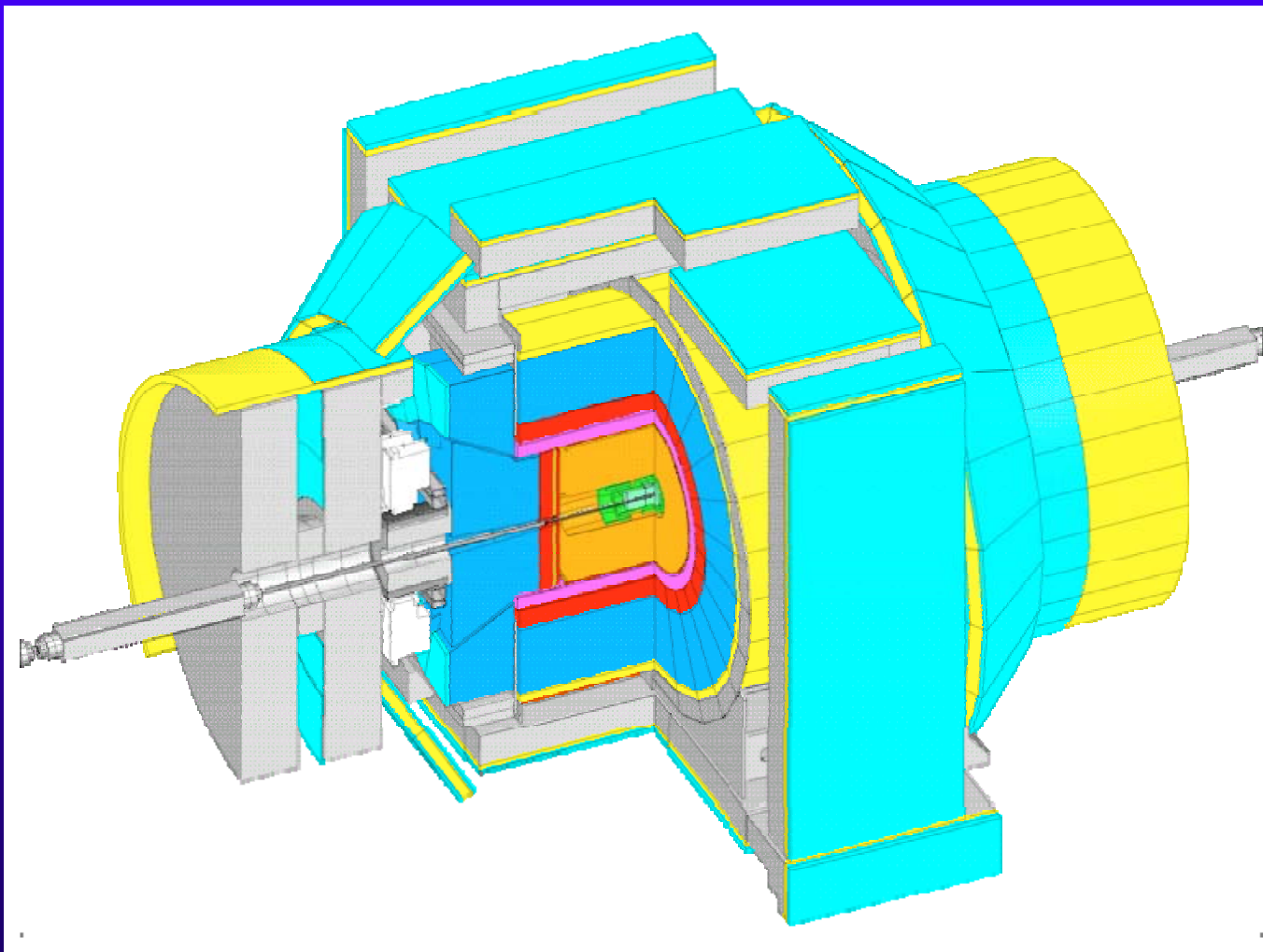
Realtà: il picco è smussato

- Il W ha $p_T \neq 0$
- Risoluzione finita degli strumenti



histogram: no detector smearing, $p_T^W = 0$
dots: finite p_T^W
shaded: adds detector resolutions (here: Run 1 DØ detector)

CDF



- Tracker
- COT
- Solenoid
- Electromagnetic Calorimeter
- Hadronic Calorimeter
- Muon Drift Chambers

Selezione eventi

- Eventi a singolo leptone

$$e : 218.1 \pm 12.6 \text{ pb}^{-1}$$

- Luminosità integrata:

$$\mu : 190.8 \pm 11.1 \text{ pb}^{-1}$$

Richieste:

- Leptone con grande p_T ($30 < p_T < 55 \text{ GeV}$)

- Grande \cancel{E}_T ($30 < \cancel{E}_T < 55 \text{ GeV}$)

- Piccolo u_T ($u_T < 15 \text{ GeV}$)

Selezione eventi

- Eventi a singolo leptone

Backgrounds:

$$Z \longrightarrow ll$$

$$W \longrightarrow \tau\nu \longrightarrow l\nu\nu\nu$$

Raggi cosmici

Background	% of $W \rightarrow e\nu$ data
$W \rightarrow \tau\nu$	0.93 ± 0.02
Hadronic jets	0.25 ± 0.15
$Z \rightarrow ee$	0.24 ± 0.01

Background	% of $W \rightarrow \mu\nu$ data
$Z \rightarrow \mu\mu$	6.6 ± 0.3
$W \rightarrow \tau\nu$	0.89 ± 0.02
Decays in flight	0.3 ± 0.2
Hadronic jets	0.1 ± 0.1
Cosmic rays	0.05 ± 0.05



63,964 eventi ($W \rightarrow e\nu$)

51,128 eventi ($W \rightarrow \mu\nu$)

Misura dei μ : COT



30,240
fili di senso

Posizione dei fili:

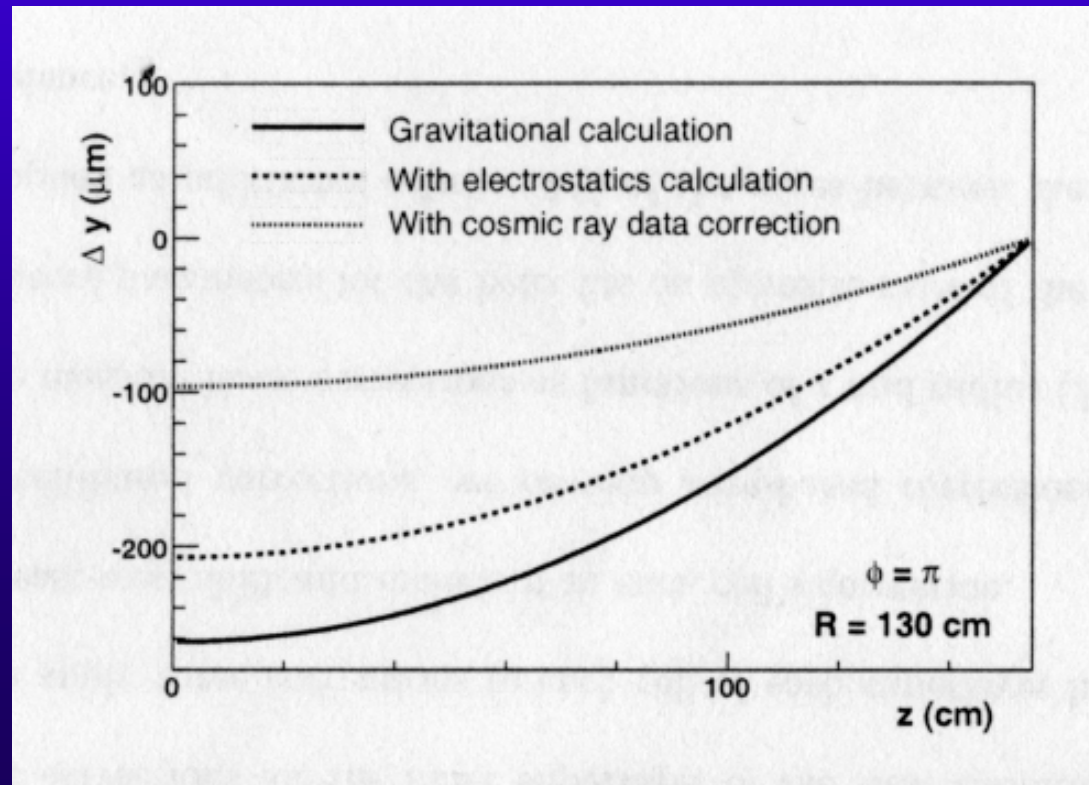
- Misura diretta
- Computer modelling
- Raggi cosmici

Misura dei μ : i fili

Si misura la posizione (ideale) dei fili

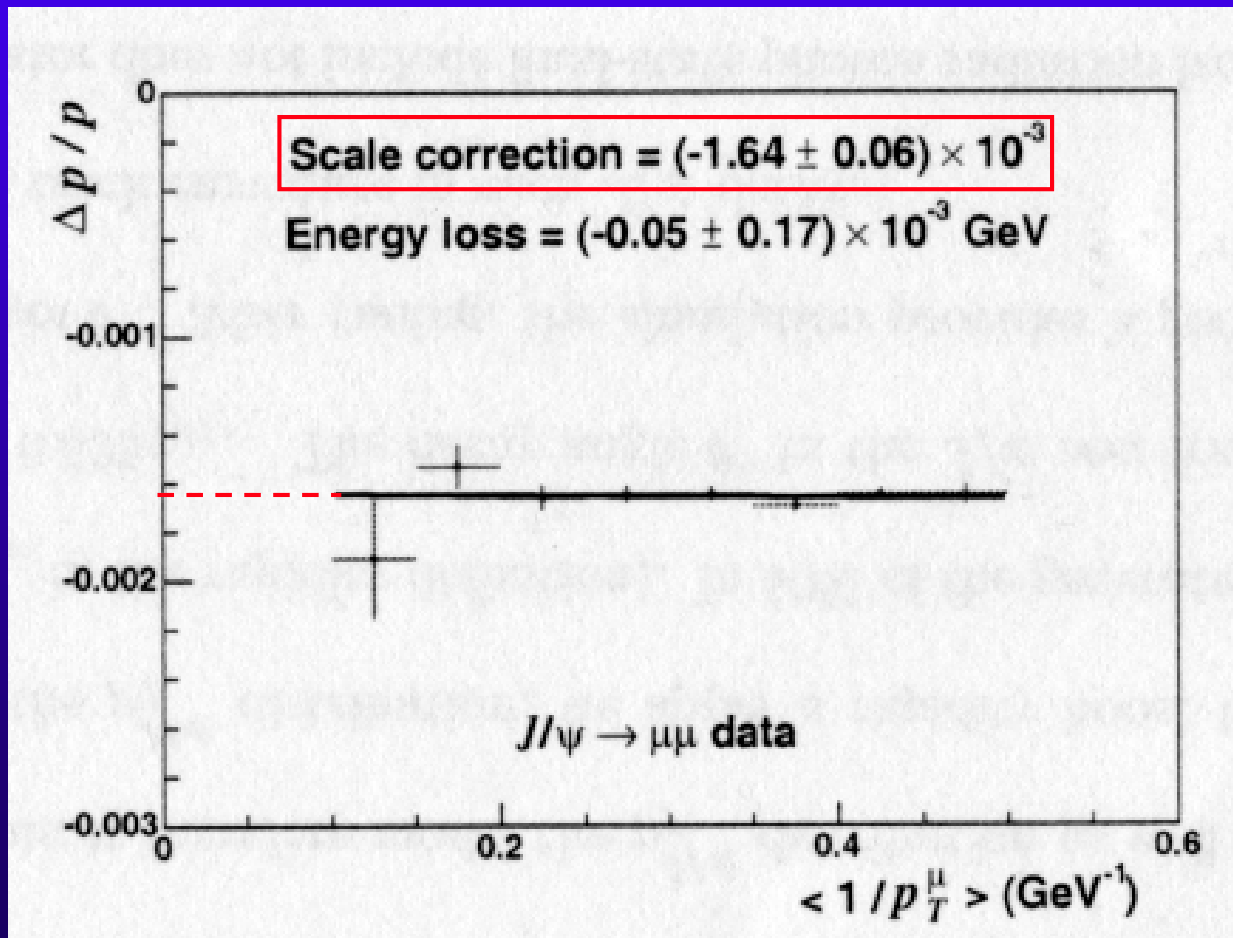
Correzioni:

- 1) Gravità \longrightarrow $\approx 260 \mu\text{m}$
- 2) Elettrostatica \longrightarrow max $74 \mu\text{m}$



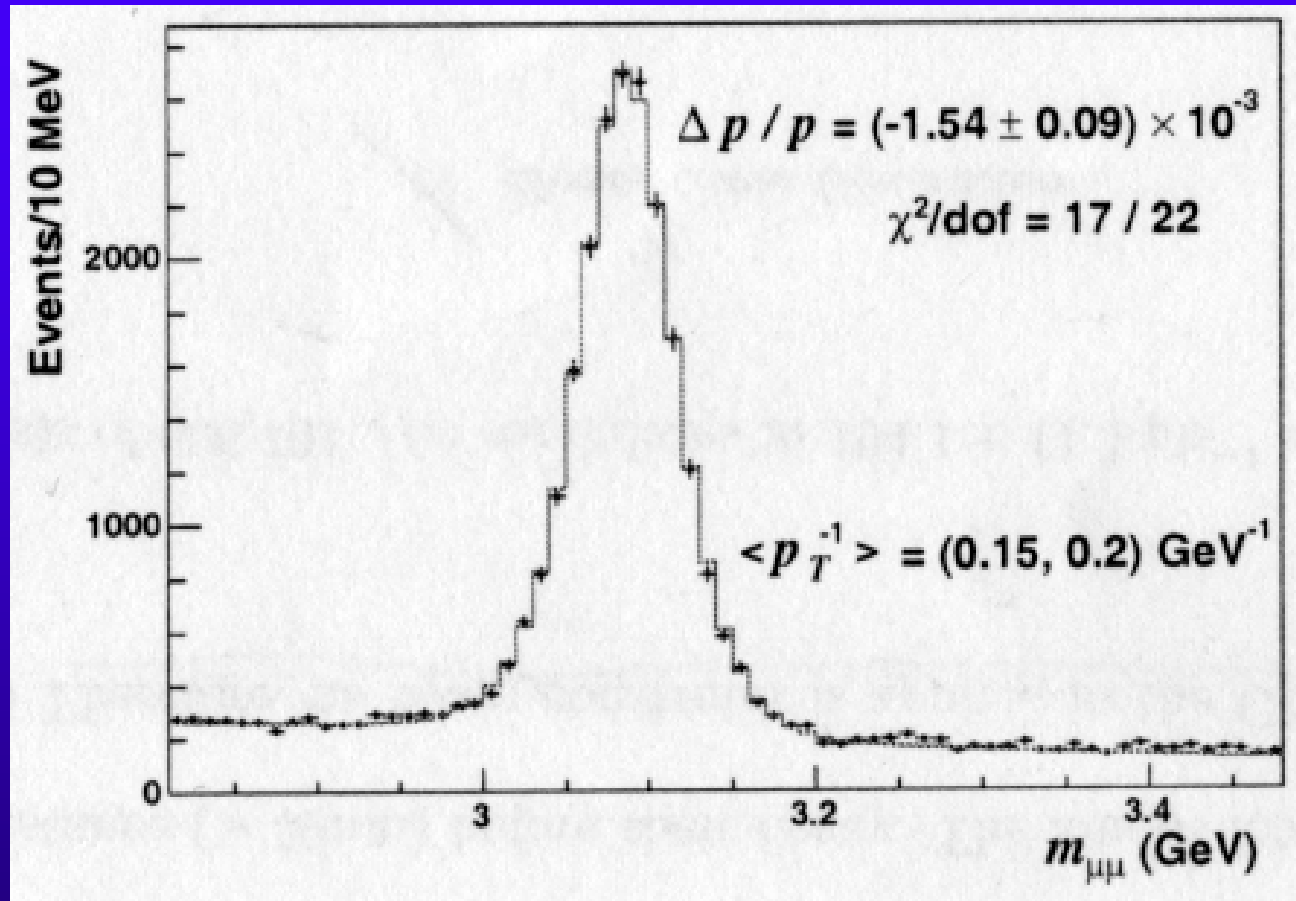
Misura dei $\mu : J/\psi$

$$J/\psi \longrightarrow \mu\mu$$



$$\frac{\Delta m}{m} \approx \Delta p_T \langle p_T^{-1} \rangle$$

Misura dei μ : J/ψ



Fit:

$$m_{\mu\mu} = 3.08 \pm 0.12 \text{ GeV} \quad \longrightarrow \quad \Delta p/p = (-1.54 \pm 0.09) \times 10^{-3}$$

Misura dei $\mu : \Upsilon$

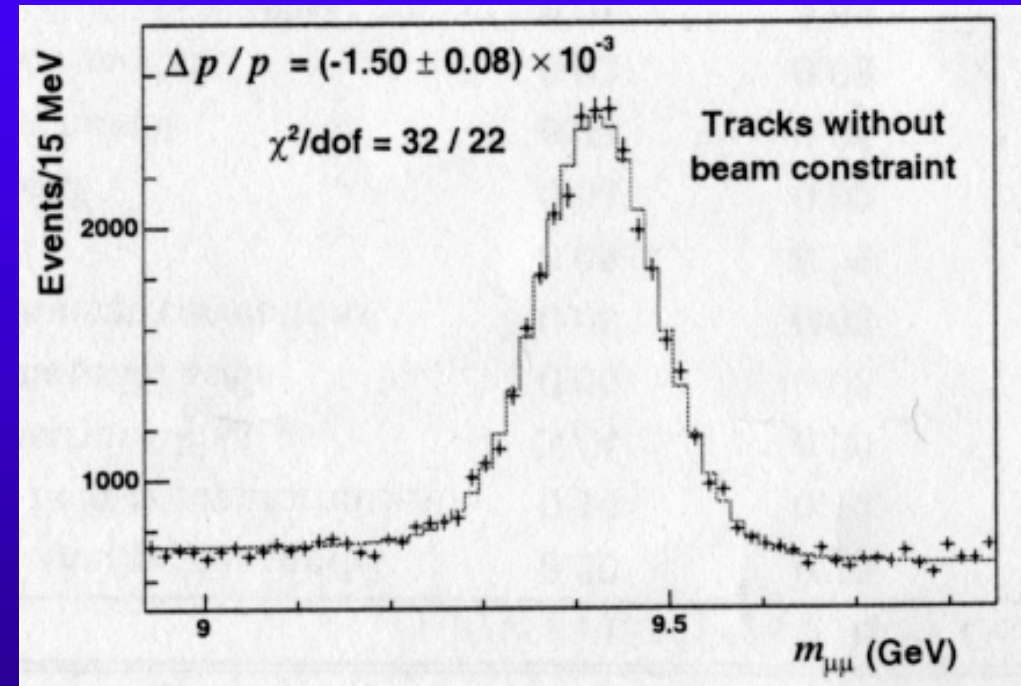
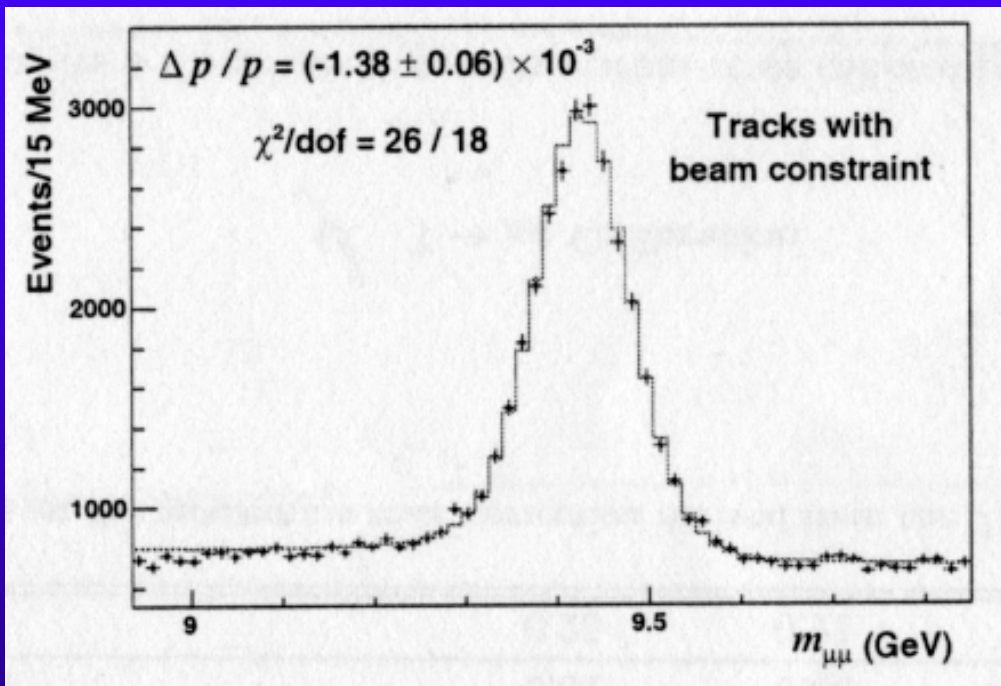
$$\Upsilon \longrightarrow \mu\mu$$

Complementare a J/ψ
:

$$m_{\Upsilon} = 9460.30 \pm 0.26 \text{ MeV} \approx 3m_{J/\psi}$$

- Meno sensibile al materiale
- Riferimento a energie maggiori

Misura dei $\mu : \gamma$



→ $\Delta p/p = (-1.44 \pm 0.21) \times 10^{-3}$

Misura dei $\mu : \Delta p/p$

Source	$J/\psi (\times 10^{-3})$	$\Upsilon (\times 10^{-3})$	Common ($\times 10^{-3}$)
QED and energy loss model	0.20	0.13	0.13
Magnetic field nonuniformities	0.10	0.12	0.10
Beam constraint bias	N/A	0.06	0
Ionizing material scale	0.06	0.03	0.03
COT alignment corrections	0.05	0.03	0.03
Fit range	0.05	0.02	0.02
p_T threshold	0.04	0.02	0.02
Resolution model	0.03	0.03	0.03
Background model	0.03	0.02	0.02
World-average mass value	0.01	0.03	0
Statistical	0.01	0.06	0
Total	0.25	0.21	0.17

$$\Delta p/p = (-1.50 \pm 0.19) \times 10^{-3}$$

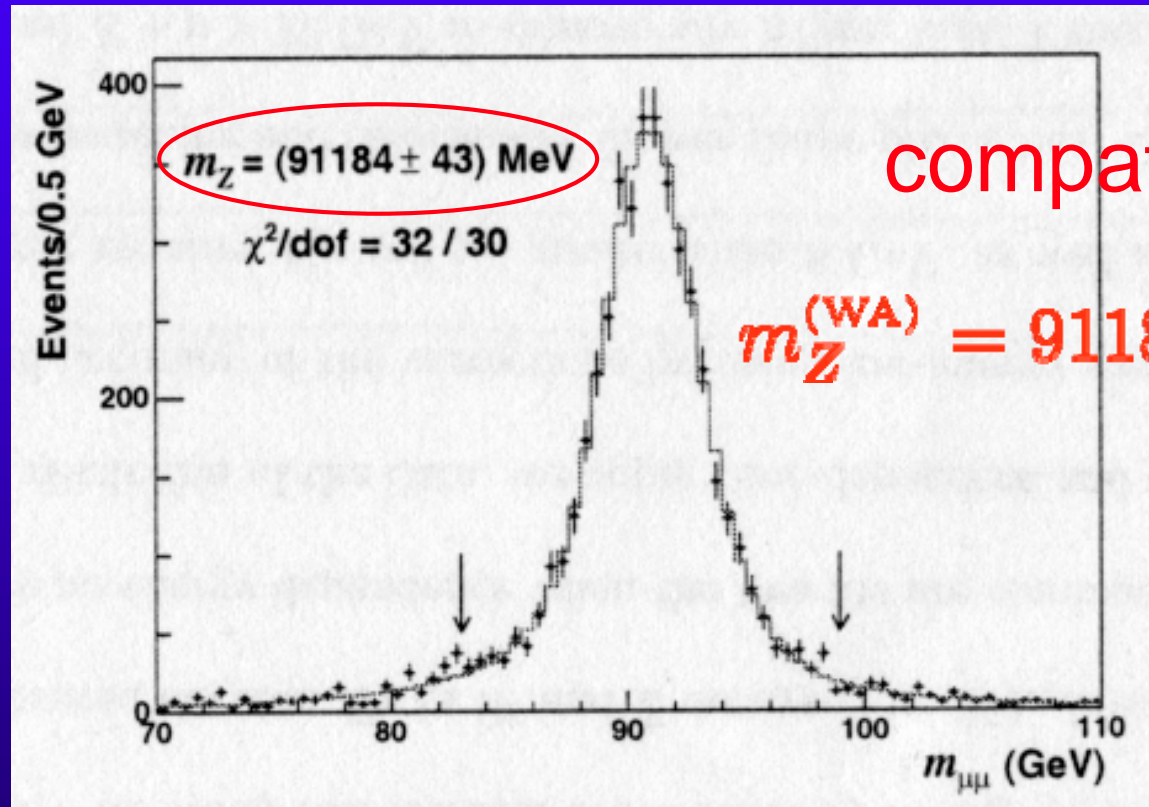
Misura dei $\mu : Z$

$$Z \longrightarrow \mu\mu$$

- Ulteriore controllo a alte energie
- Eventuale correzione

Misura dei $\mu : Z$

$$Z \longrightarrow \mu\mu$$



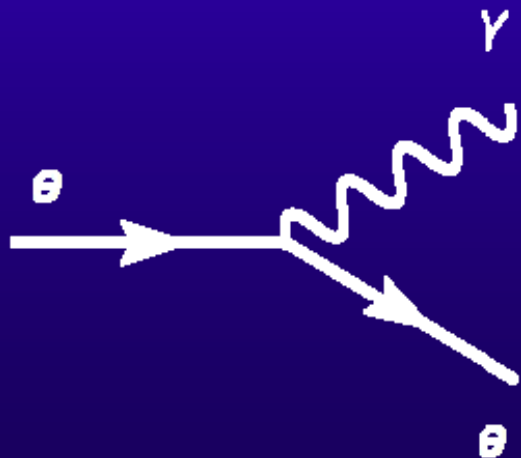
$$\Delta p/p = (-1.50 \pm 0.21) \times 10^{-3}$$

Misura degli e : calibrazione E/p

Calorimetro EM **vs** COT

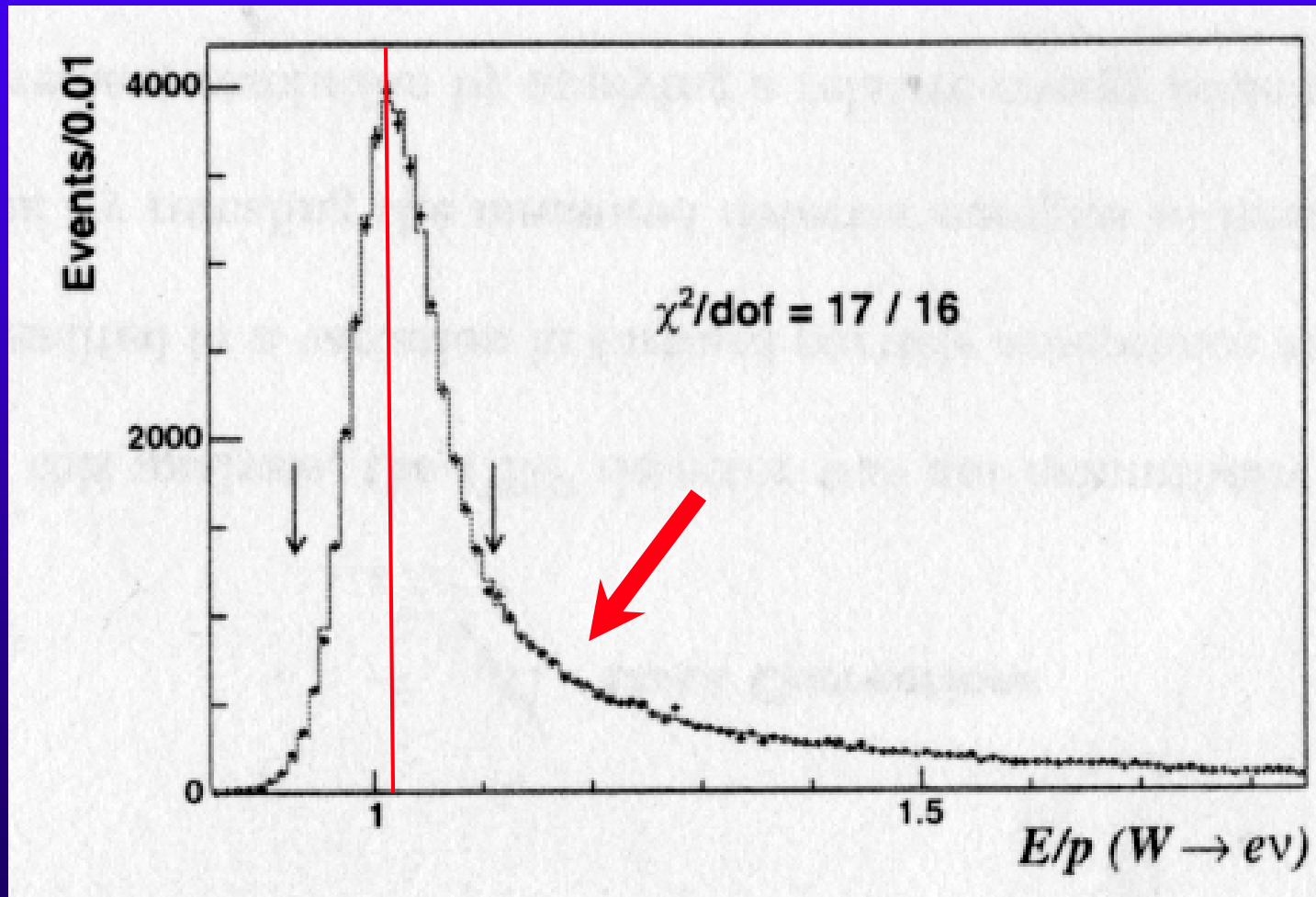
$$m_e \simeq 0 \quad \Rightarrow \quad E/p = 1$$

Forte dipendenza dal materiale prima del COT

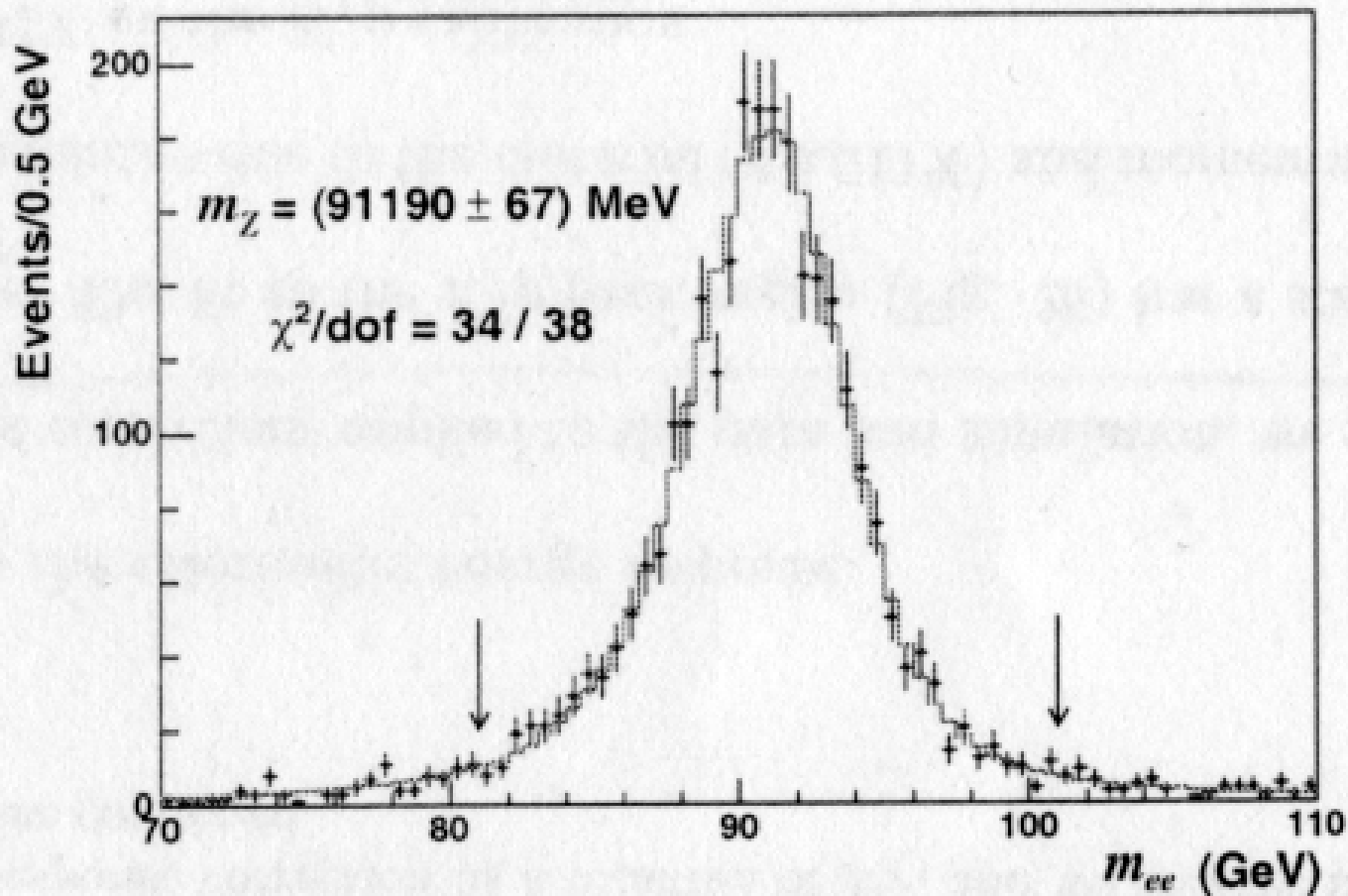


$$\Rightarrow E/p > 1$$

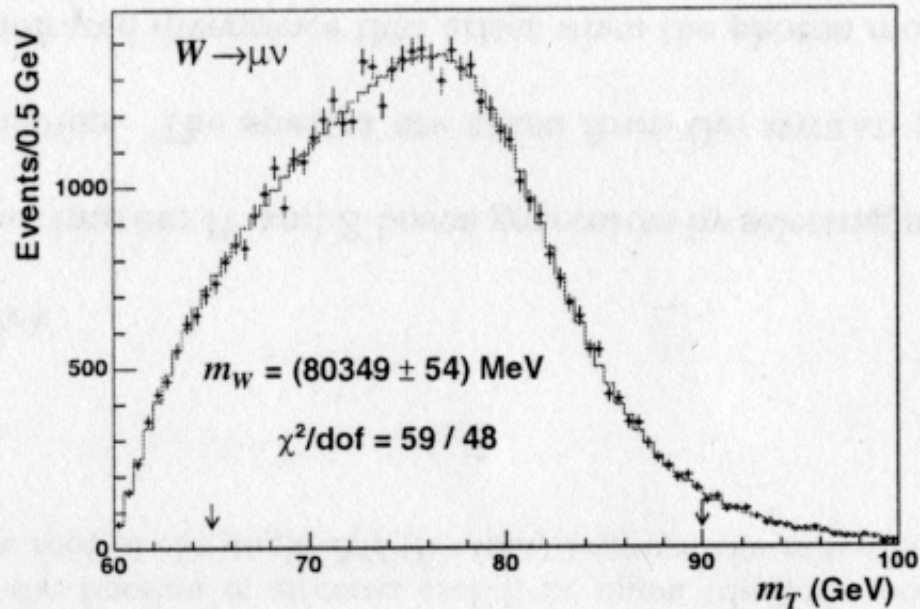
Misura degli e : calibrazione E/p



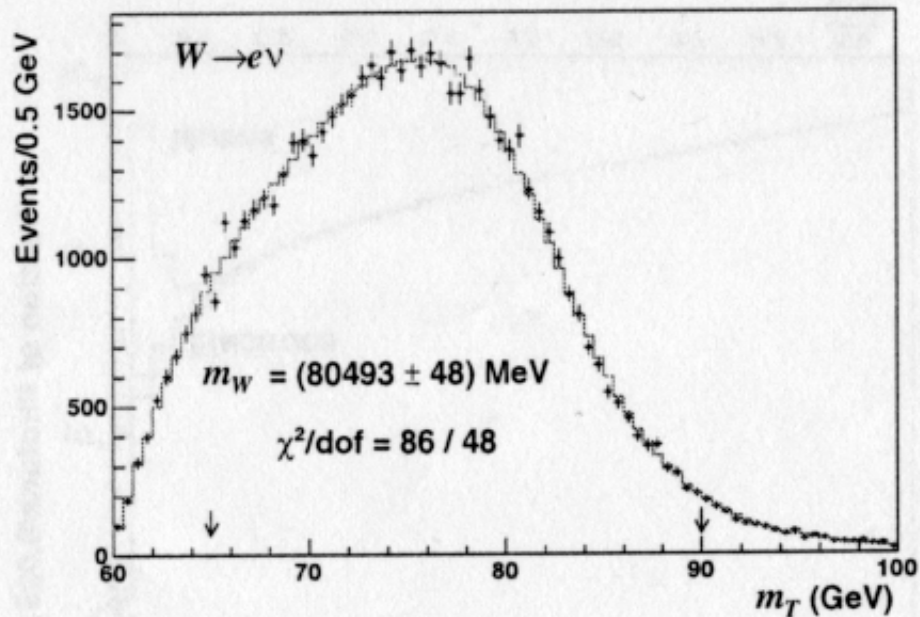
Misura degli e : calibrazione E/p



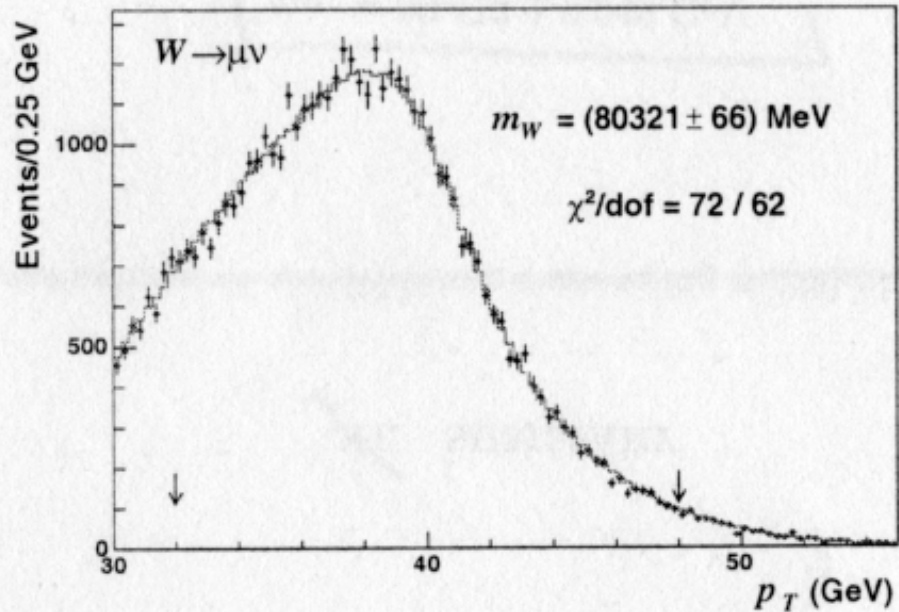
La misura: m_T fit



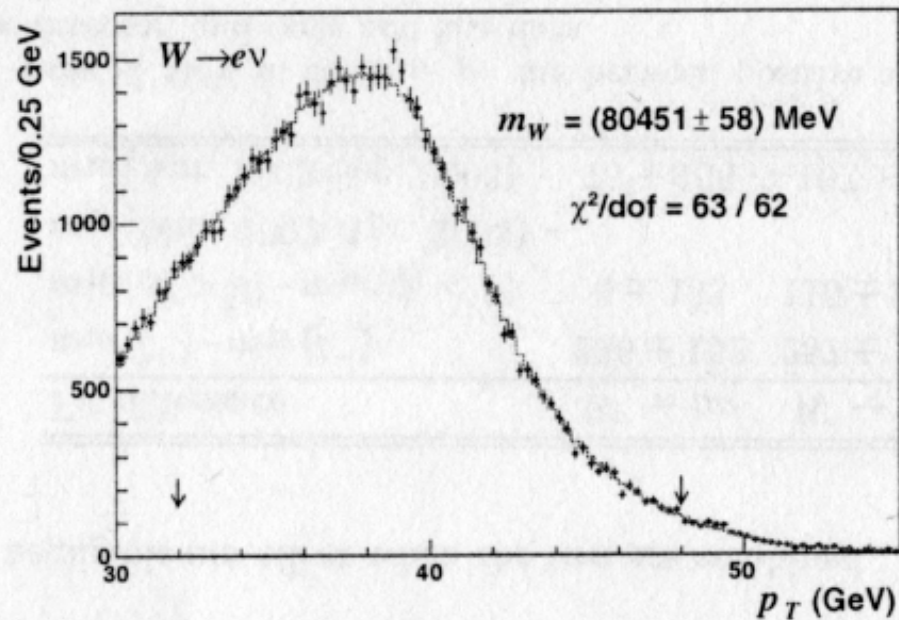
$$m_W = 80.417 \pm 0.048 \text{ GeV}$$



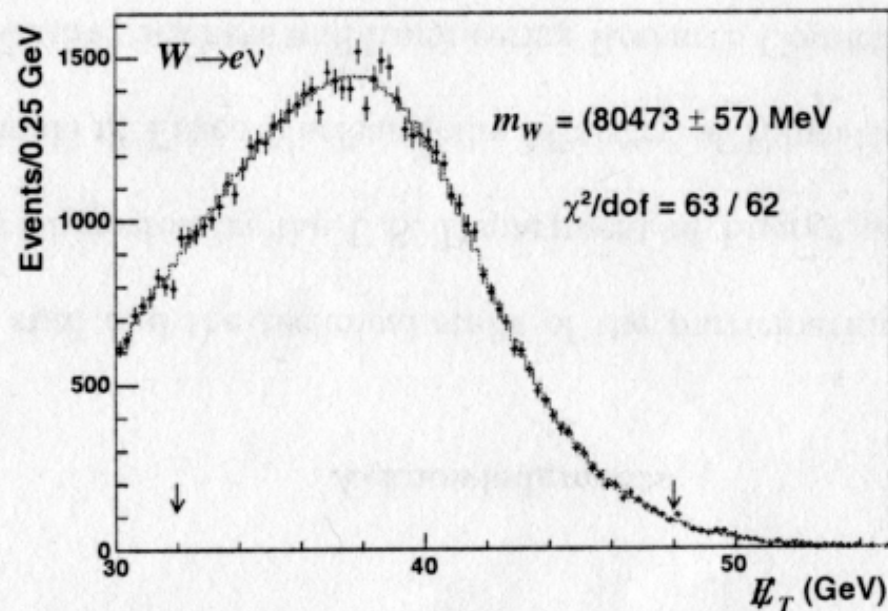
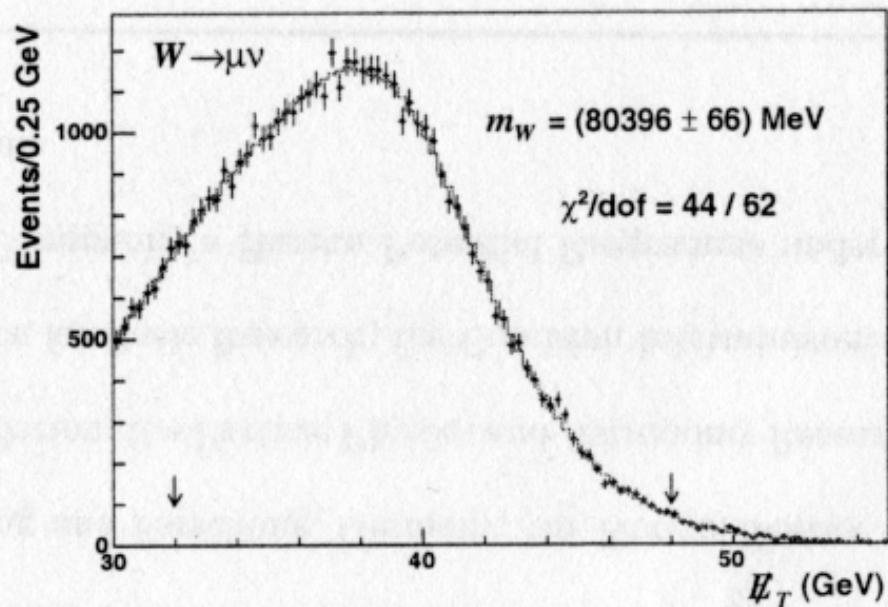
La misura: p_T fit



$$m_W = 80.388 \pm 0.059 \text{ GeV}$$



La misura: E_T fit



$$m_W = 80.434 \pm 0.065 \text{ GeV}$$

Risultato finale

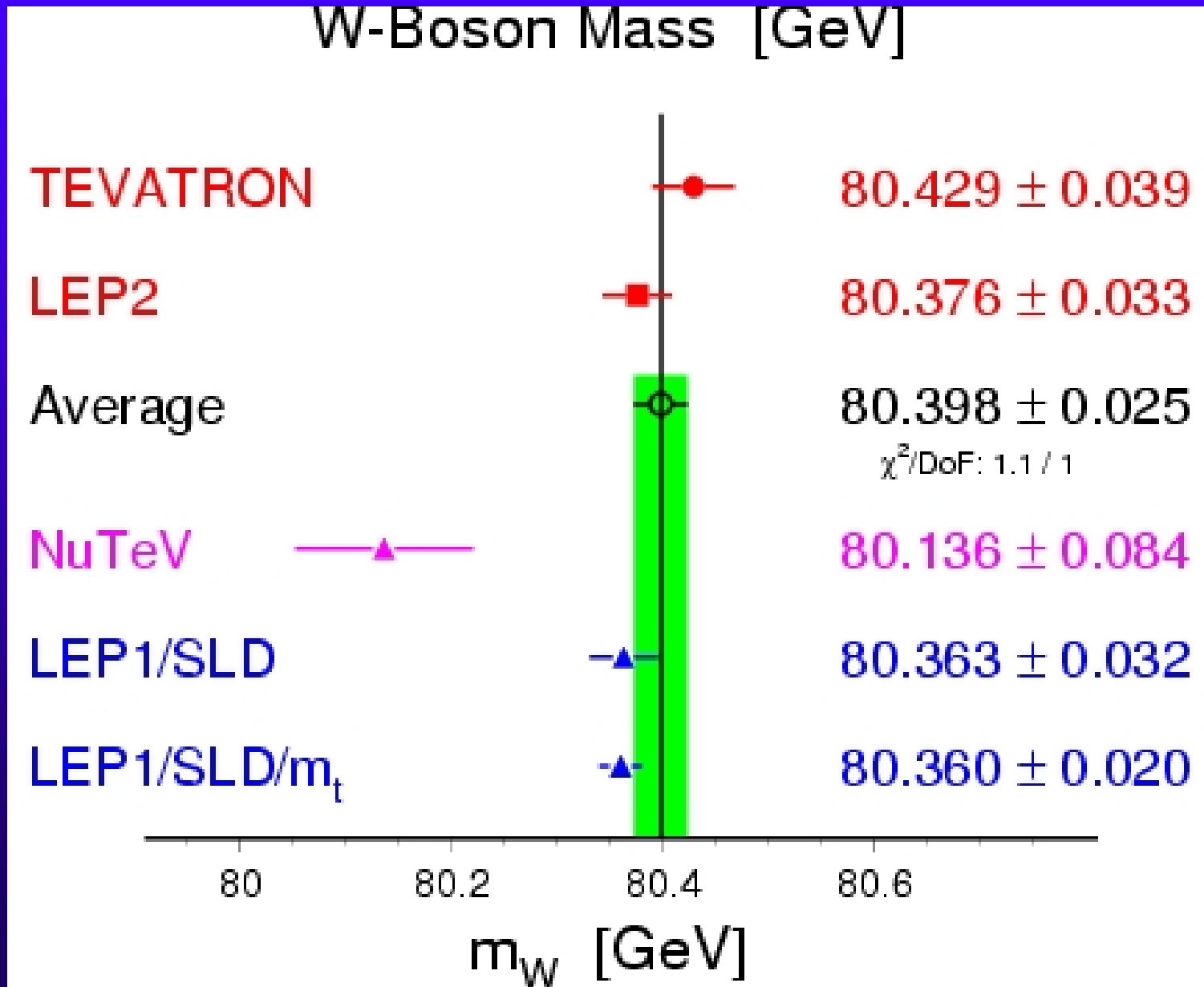
$$m_W = 80.413 \pm 0.048 \text{ GeV}$$



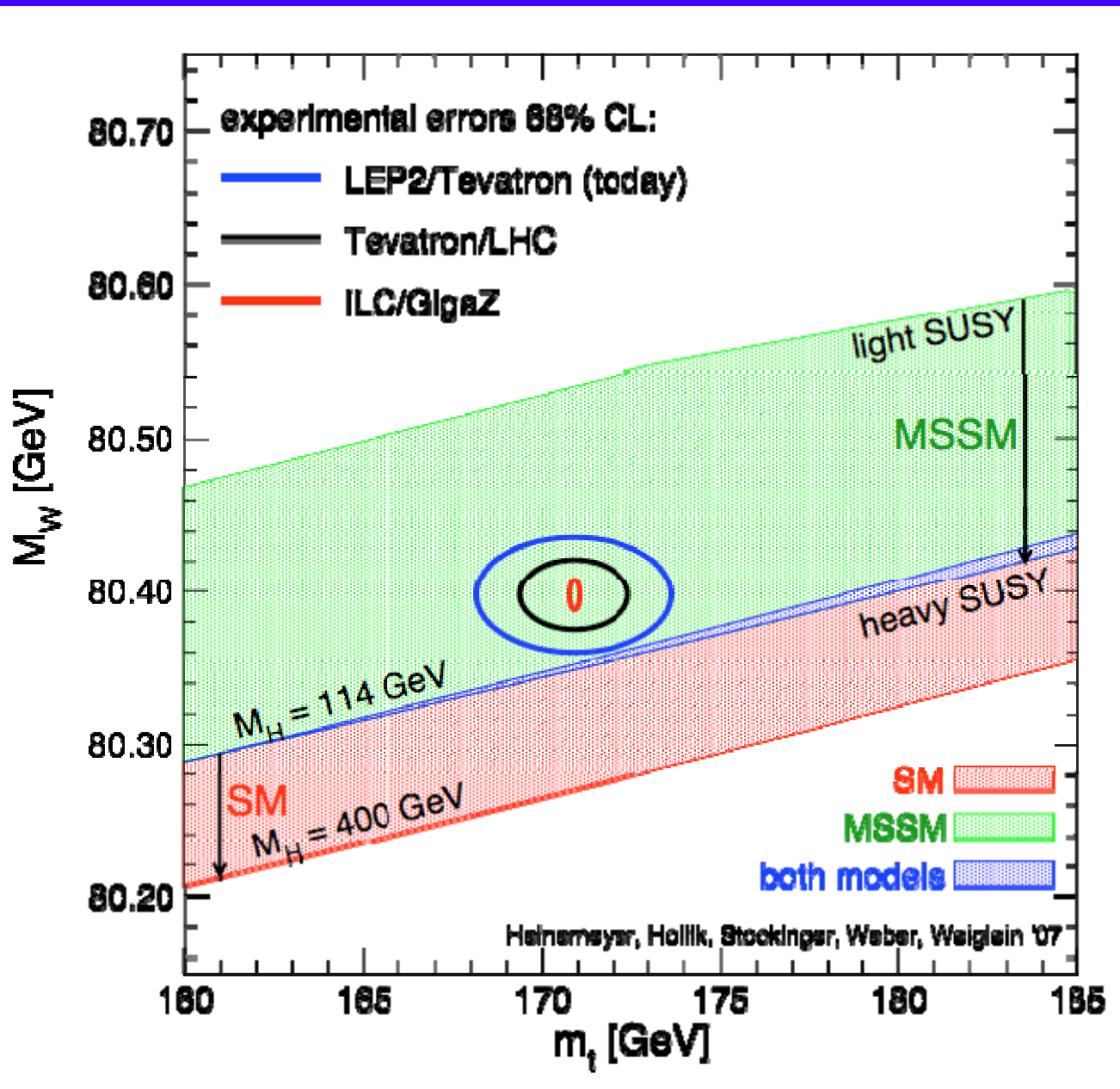
New world average:

$$m_W = 80.398 \pm 0.025 \text{ GeV}$$

La massa del W



Consequenzen



Bibliografia

- CDF coll., *First Measurement of the W Boson Mass with CDF in Run II*, CDF note n.8665 disponibile @ http://fcdfwww.fnal.gov/physics/ewk/2007/wmass/wmass_conf.ps
- CDF coll., *First Run II Measurement of the W Boson Mass with the Collider Detector at Fermilab*, paper to be submitted to Phys. Rev.
- Baur, *Measuring the W Boson Mass at Hadron Colliders*
- Smith et al., *Transverse Mass and Width of the W Boson*, Phys. Rev. Lett. 50 n.22 del 30/5/83
- Povh et al., *Particelle e nuclei*, Bollati Boringhieri
- <http://lepewwg.web.cern.ch/LEPEWWG/>