Ricerca del bosone di Higgs SM a LEPII

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LEP Trieste

- Motivazioni per la ricerca del'Higgs
- Produzione e Decadimento a LEPII
- Campione di dati
- Strategie di analisi
- Risultati dei quattro esperimenti
- Risultati combinati
- Prospettive
- Conclusioni

Perché si cerca l'Higgs?

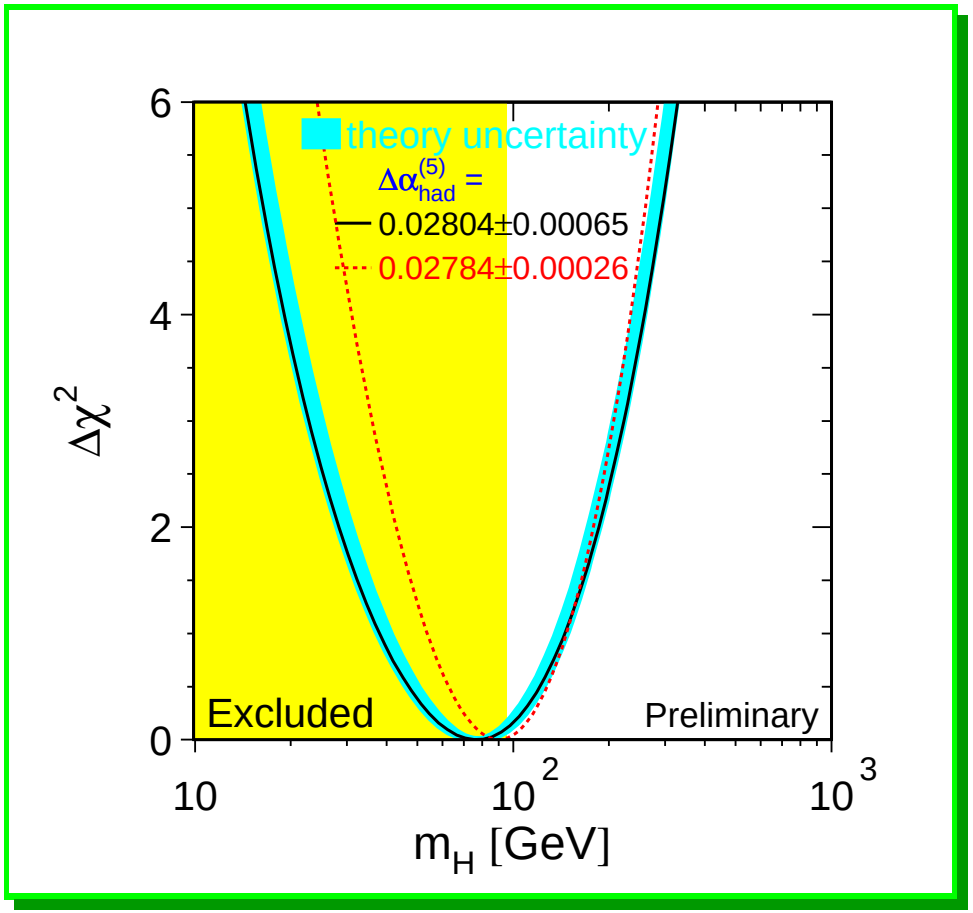
- Il Modello Standard delle interazioni elettrodeboli é in eccellente accordo con le misure sperimentali
  - es.: misure di precisione dei parametri elettrodeboli (LEP,SLC,Tevatron)
- Il Modello Standard contiene i bosoni di Gauge massivi, $\mathbf{W}$ e $\mathbf{Z}$

$\Longrightarrow$ Un meccanismo che dà massa a bosoni e fermioni mantenendo l'invarianza di Gauge della teoria

$\Downarrow$

IL MECCANISMO DI HIGGS

Correzioni radiative ad un *loop*



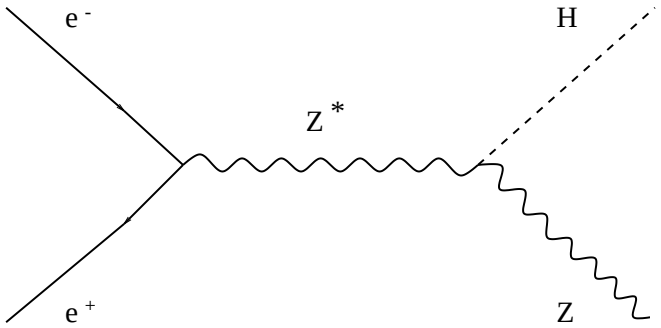
Misure indirette:

$$\mathbf{m_t = 172.2^{+1.0}_{-6.9} GeV/c^2}$$
$$\mathbf{(m_t = 174.3 \pm 5.1 GeV/c^2)}$$

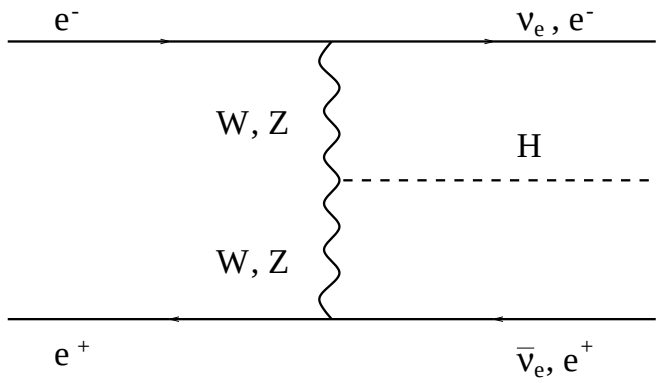
$$\mathbf{m_H < 188 GeV/c^2}$$
95% CL

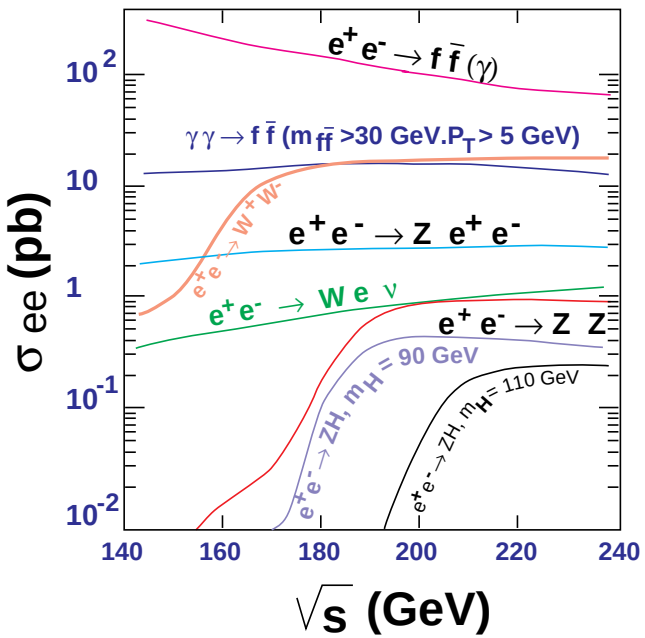
Produzione dell'Higgs a LEPII

Higgsstrahlung



WW-ZZ fusion





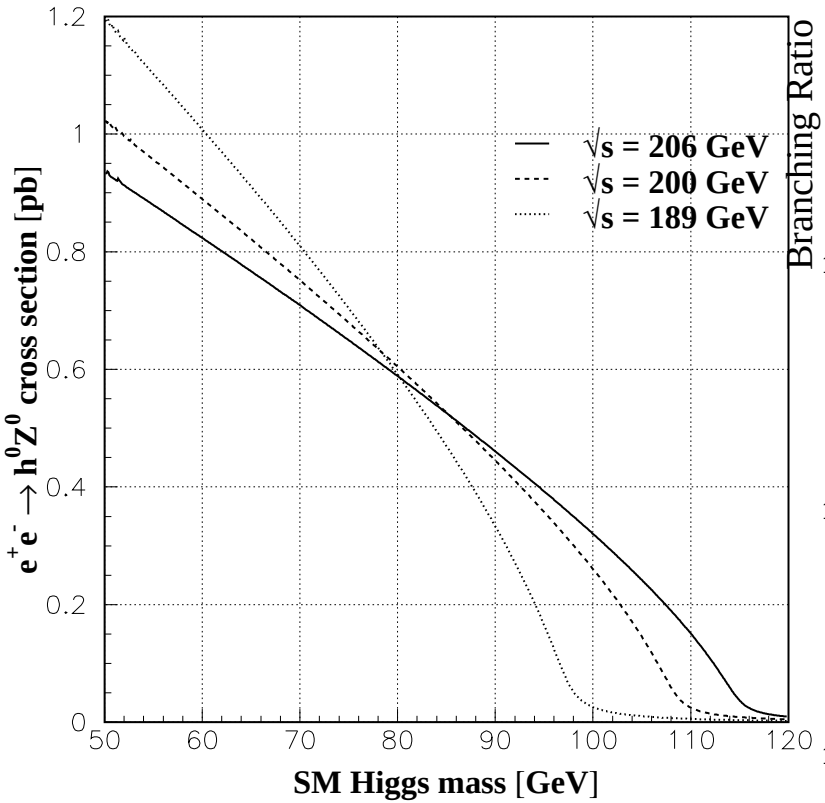
$\sqrt{s}$=202GeV es.:

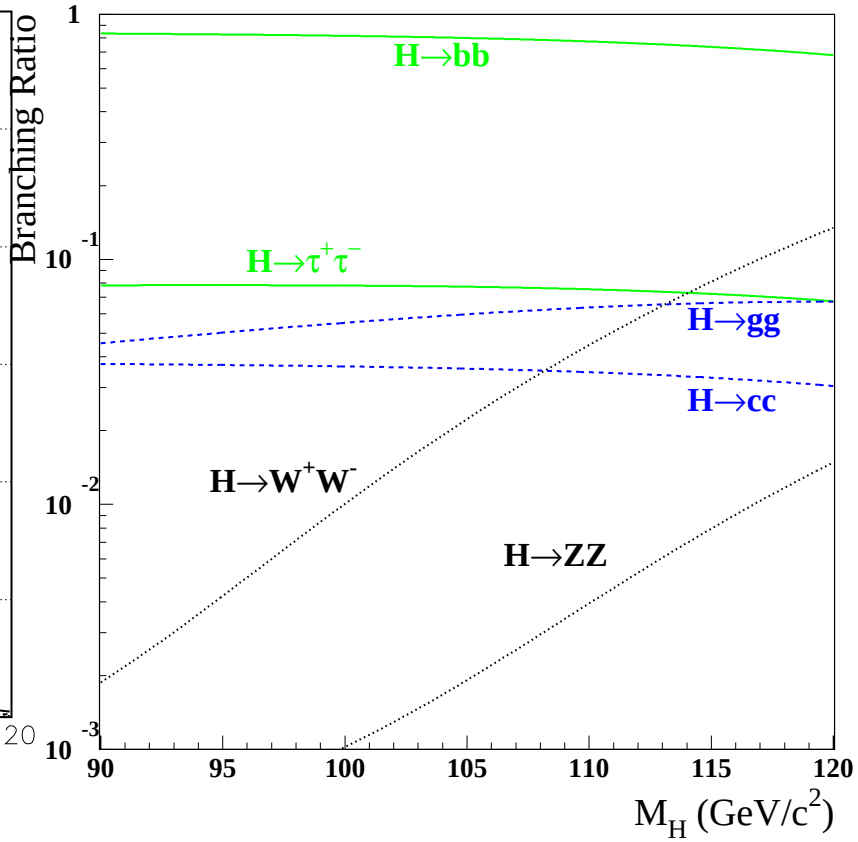
$\sigma_{\mathbf{H}}(\mathbf{105GeV/c^2}) \simeq \mathbf{0.2pb}$

$\sigma_{\mathbf{WW}} \simeq \mathbf{17.4pb}$, $\sigma_{\mathbf{q\bar{q}}} \simeq \mathbf{83.6pb}$

$\Rightarrow$ si cerca un piccolo segnale!

Sezione d'urto e Rapporto di Decadimento in funzione di $\mathbf{m_{Higgs}}$





Nel 1999 $\sqrt{s} = 192$, 196, 200 e 202 GeV

Luminositá integrate $(\mathbf{pb^{-1}})$

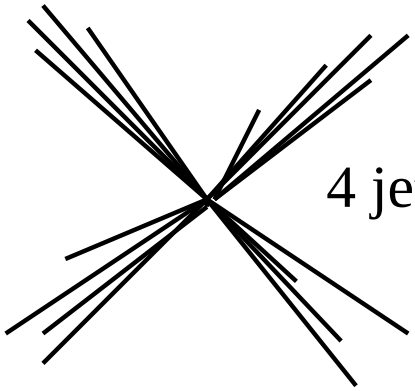
$\sqrt{s}(\mathbf{GeV})$	ALEPH	DELPHI	L3	OPAL
192	28.9	25.9	29.7	28.9
196	79.9	76.9	83.7	74.8
200	86.3	84.3	82.8	77.2
202	41.9	41.1	37.0	36.1
TOT.	237	228	232	217

Risultati con tutta la statistica

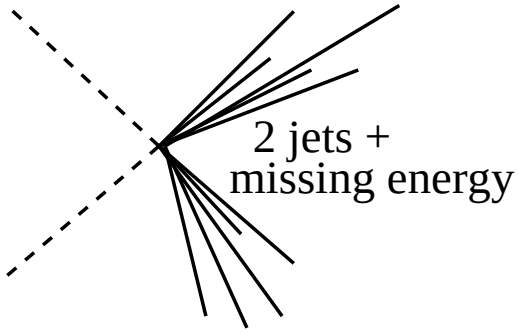
Limiti al 95% di Livello di Confidenza

Topologie degli stati finali

$$\mathbf{HZ \rightarrow b\bar{b}q\bar{q}}$$

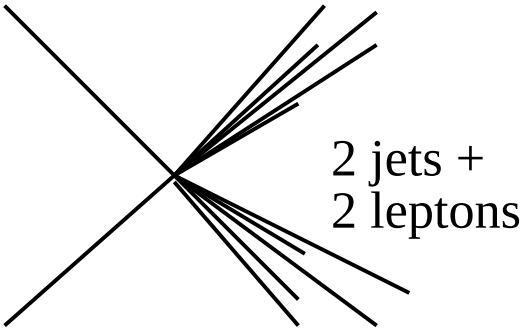


$$\mathbf{HZ \rightarrow b\bar{b}\nu\bar{\nu}}$$



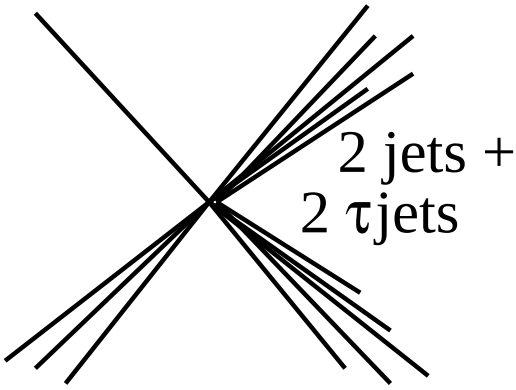
$$\mathbf{HZ \rightarrow b\bar{b}l^+l^-}$$

$$\mathbf{l = e, \mu}$$



$$\mathbf{HZ \rightarrow b\bar{b}\tau^+\tau^-}$$

$$\mathbf{HZ \rightarrow \tau^+\tau^-q\bar{q}}$$



B-Tagging

$$\mathbf{BR(H \to b\bar{b}) \sim 86\%}$$

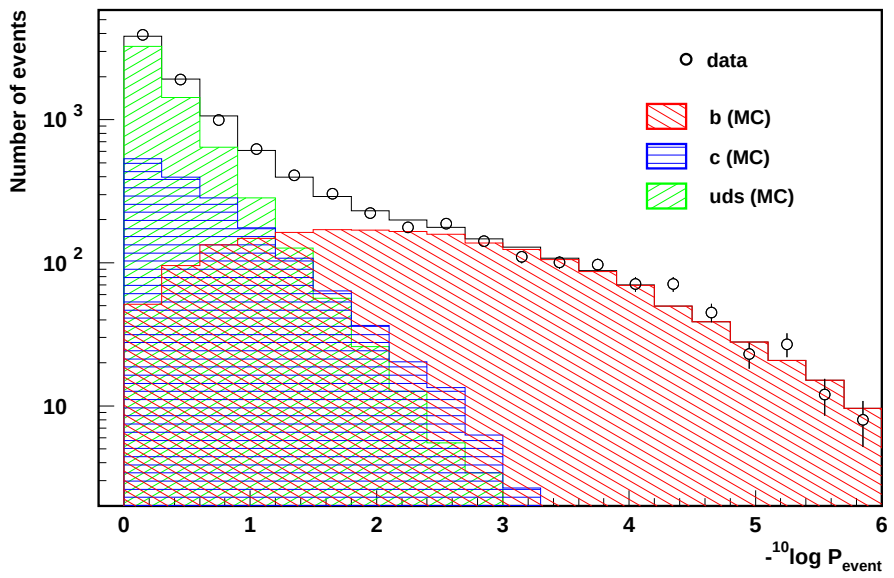
$\Rightarrow$ Fondamentale l'identificazione di adroni b

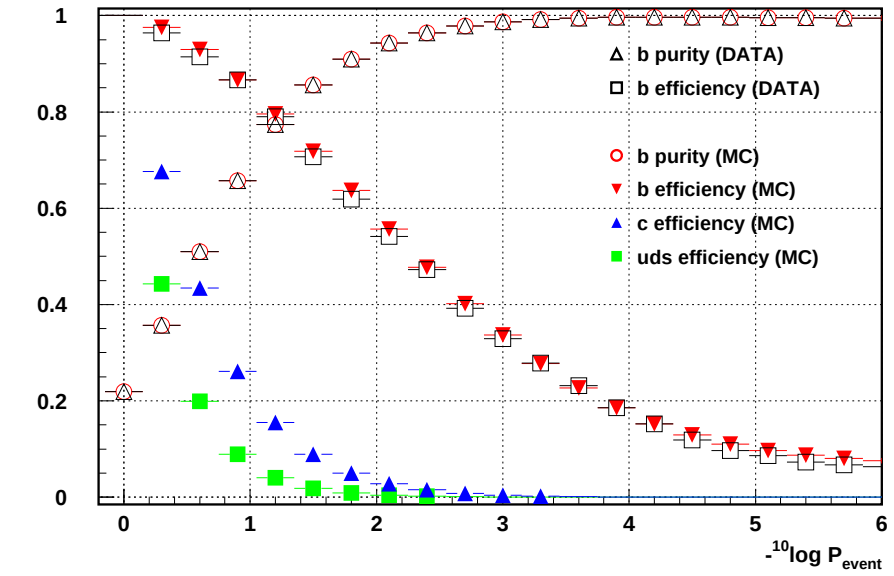
- lunga vita media $\Rightarrow$ lunghezza di decadimento $\sim$3mm alle energie del LEP
- frammentazione dura dei jet b $\Rightarrow$ la frazione di tracce con alto momento é maggiore che per jet $ucds$
- leptoni presenti nel jet $\Rightarrow$ $\sim$ 6% di jet b contiene elettroni e $\sim$ 12% muoni

Tutti gli esperimenti usano una rete neurale per combinare le informazioni e ottenere il B-tagging del jet

- B-tag di singolo jet combinato in un B-tag dell'evento

L3 dati 1999-picco allo Z





Analisi ottimizzate per $\mathbf{H \to b\bar{b}}$ e divise in:

- Preselezione:
  - ridurre il fondo piú distinguibile (es. $\gamma\gamma$)
  - alta efficienza di segnale
- Selezione finale e costruzione di una variabile discriminante mediante combinazione di probabilitá (likelihood) o Rete Neurale:
  - B-tagging
  - variabile topologiche (thrust, angoli di produzione...)

Ricostruzione della massa dell'Higgs
$\Rightarrow$ Fit cinematico a **4 o 5 vincoli** :

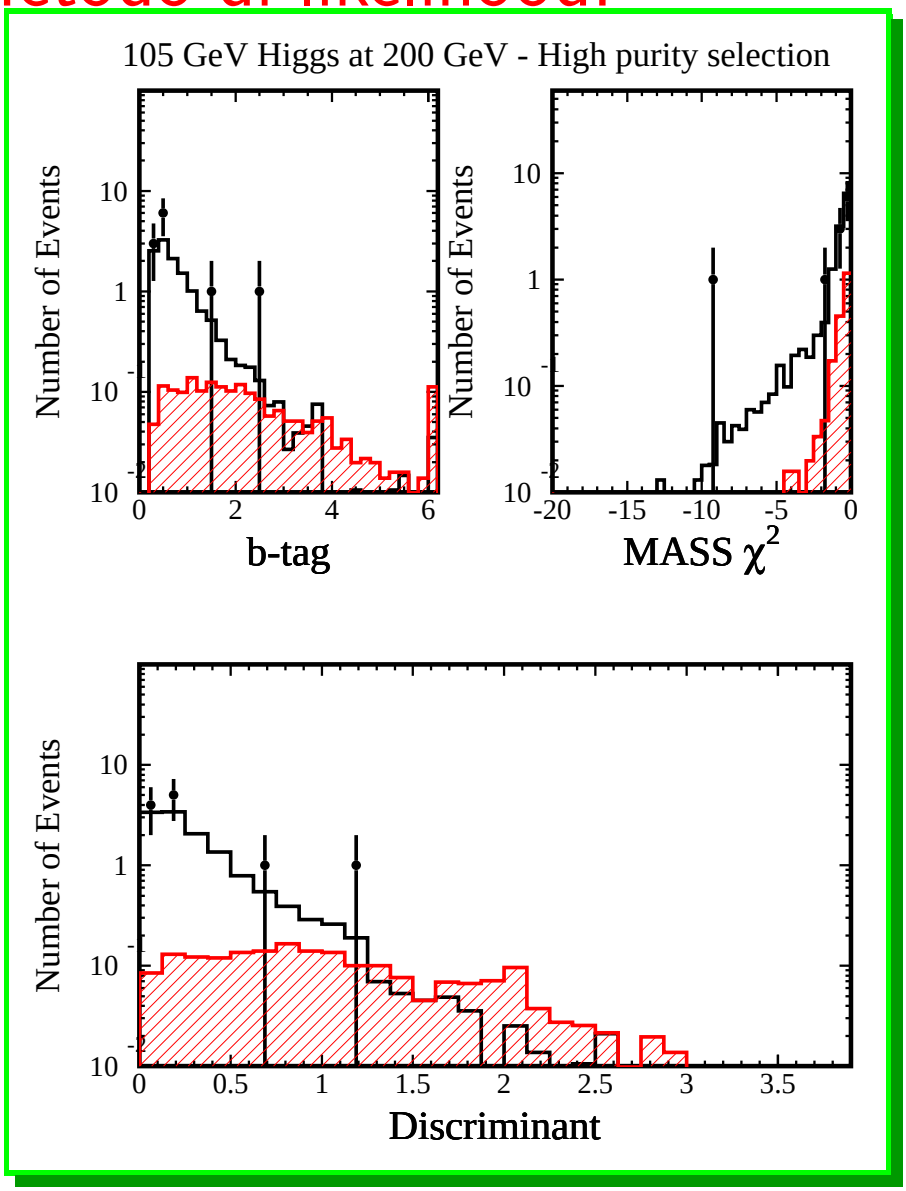
- conservazione del quadri-impulso
- una delle masse dei dijet (4 jet),
  dei leptoni, (2jet+2leptoni)
  o massa mancante (2jet+energia mancante)
  compatibile con la massa dello Z

Le informazioni di massa vengono combinate con la variabile discriminante *mass independent*

$HZ \to b\bar{b}q\bar{q}$

- $BR(Z \to q\bar{q}) = 70\%$
- fondo MS: $W^+W^- \to qqqq$, $ZZ \to q\bar{q}q\bar{q}$, $e^+e^- \to q\bar{q}(gg)$

Metodo di likelihood:



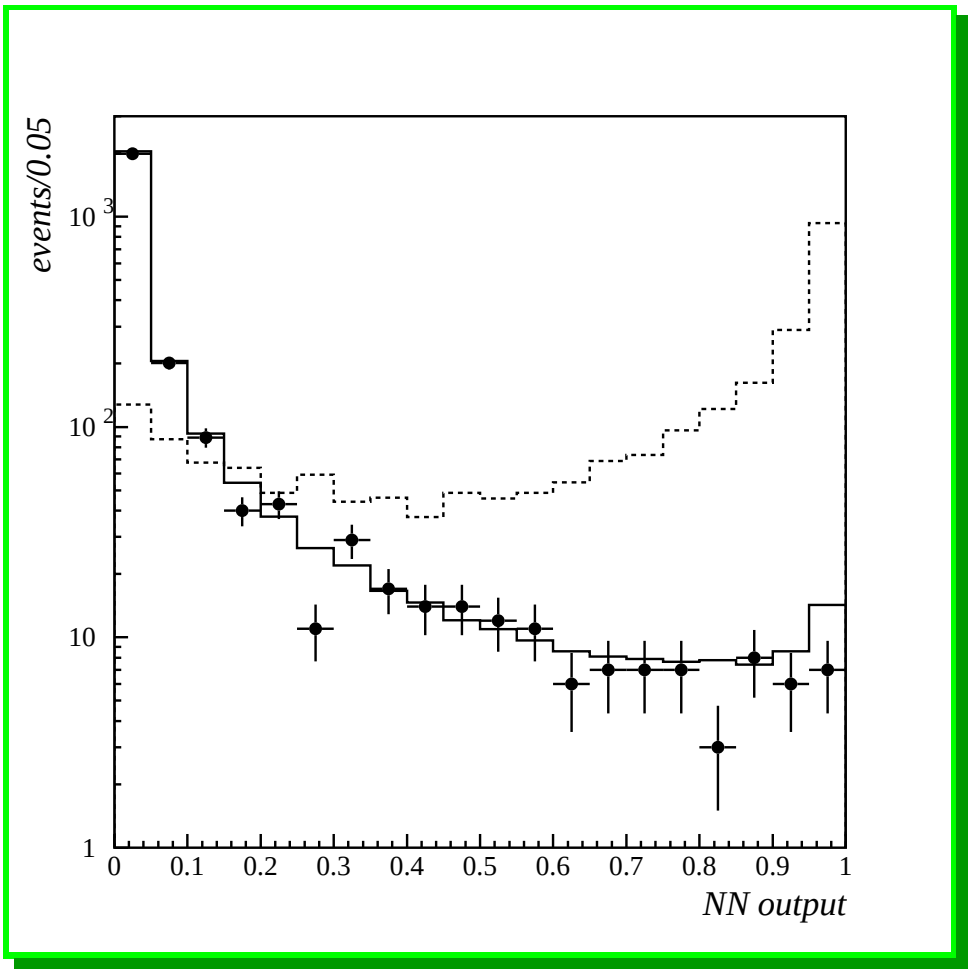
L3

$\sqrt{s}$
200GeV

Due campioni: alta e bassa purezza

Selezione basata su Rete Neurale:

ALEPH $\sqrt{s}$=200GeV $\mathbf{m_H}$ 107$\mathbf{GeV/c^2}$

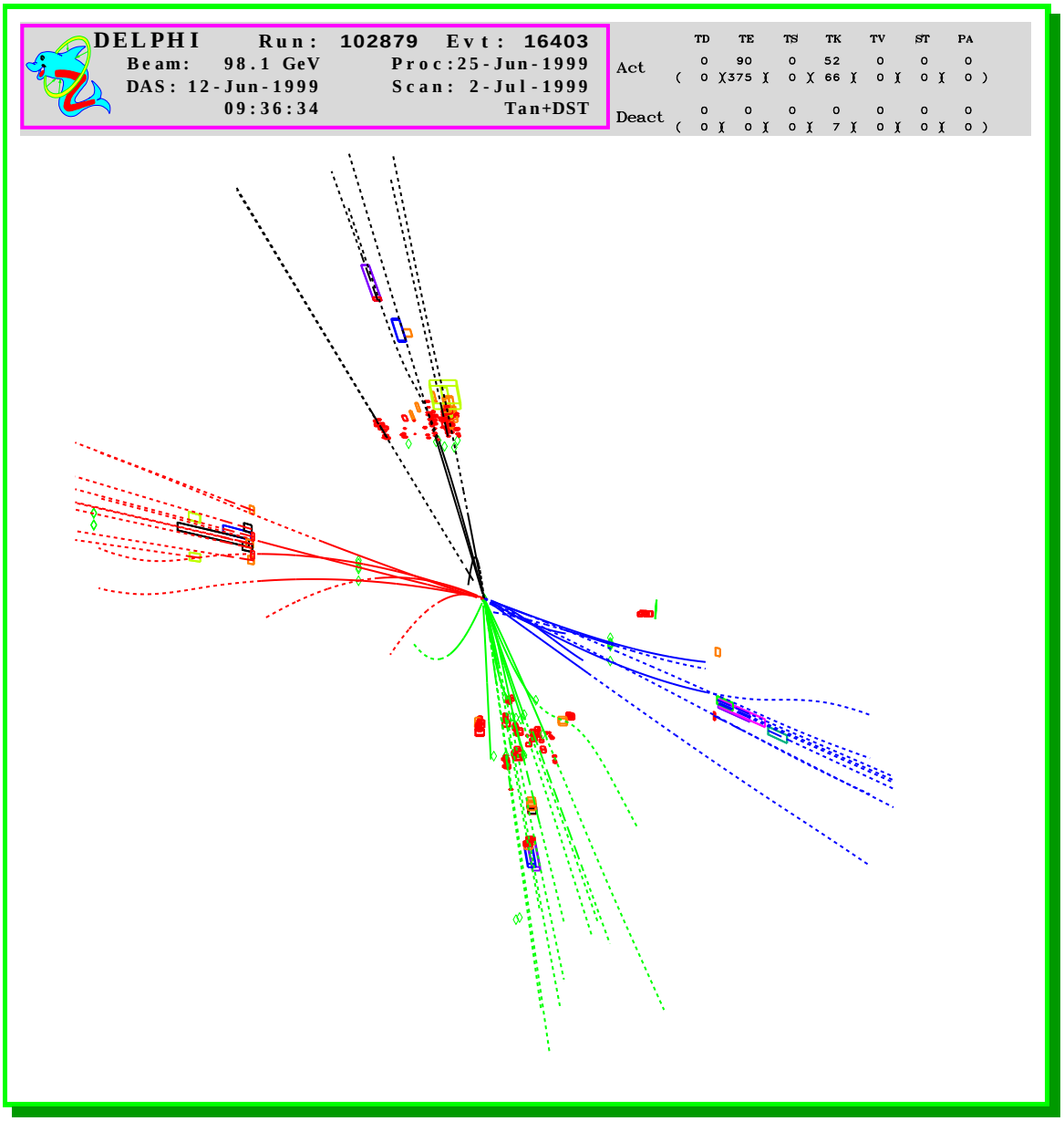


$\sqrt{s}$=192-202GeV Taglio ottimale:

DATA	BKG	WW	ZZ	$q\bar{q}$
27	39.7 $\pm$ 1.9	7.7	19.7	12.3

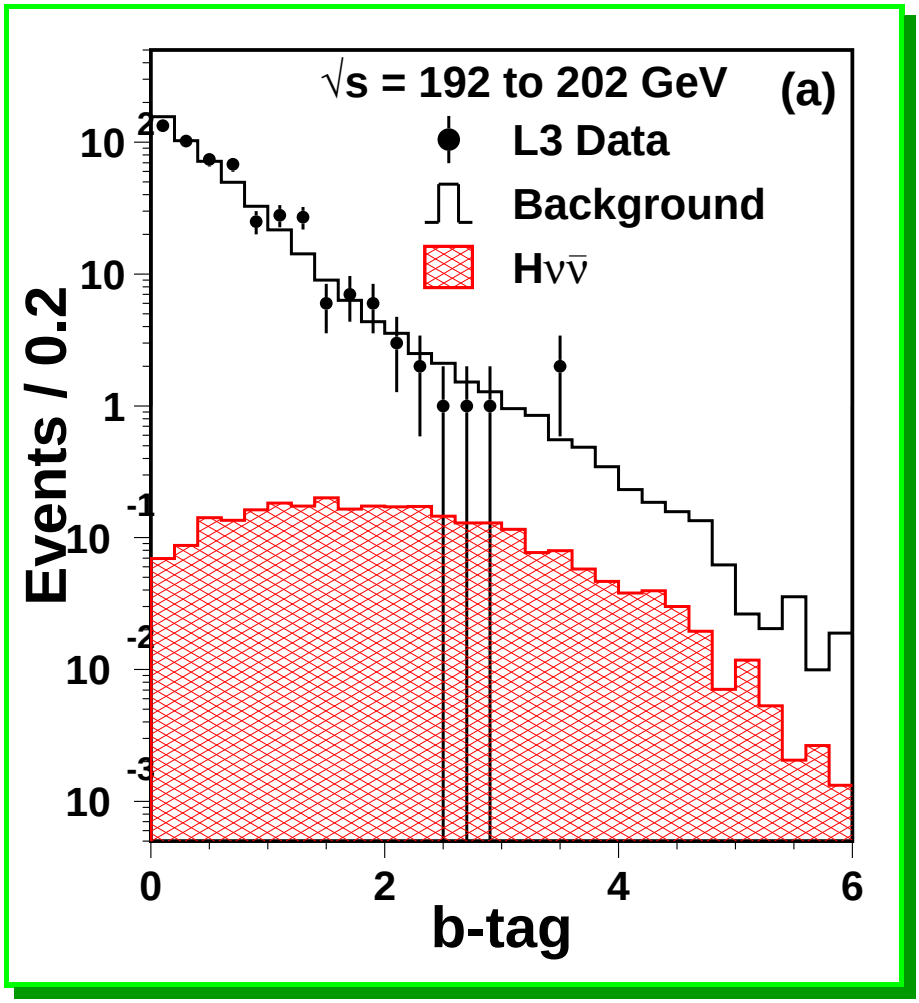
$\mathbf{HZ(m_H = 107GeV/c^2)}$=4.1 evt. aspet.

Un candidato per il canale 4-jet



$\mathbf{HZ \to b\bar{b}\nu\bar{\nu}}$

- $\mathbf{BR(Z \to \nu\bar{\nu}) = 20\%}$
- fondi principali: $\mathbf{ZZ \to q\bar{q}\nu\bar{\nu}}$, $\mathbf{e^+e^- \to q\bar{q}e\nu}$



L3

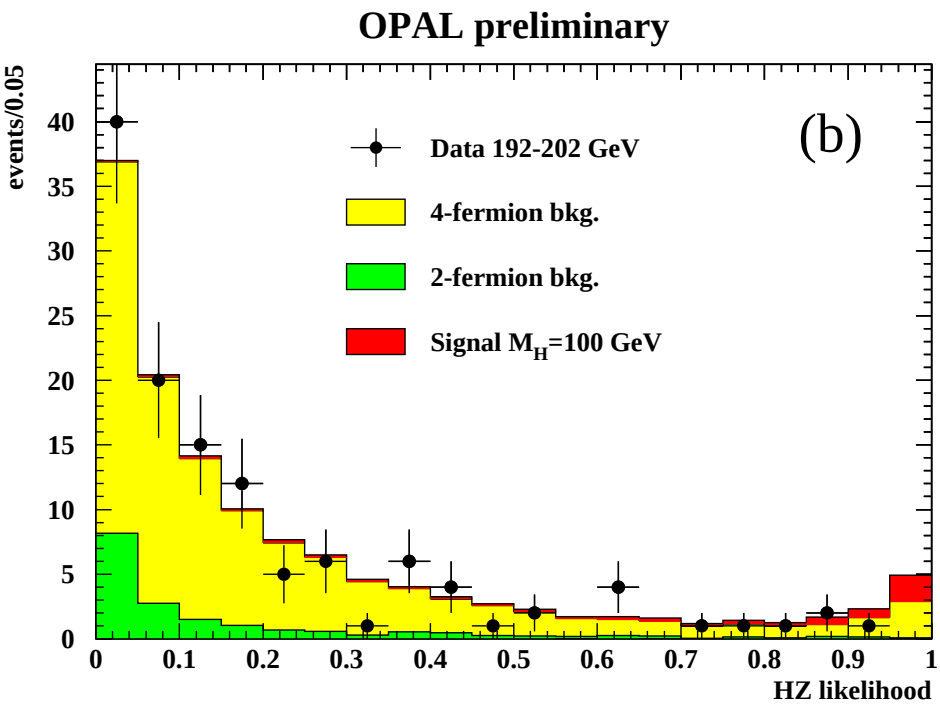
$\mathbf{m_H}$

$\mathbf{105 GeV/c^2}$

Metodo di likelihood:

variabili combinate: B-tag del jet1, del jet2, $|\cos\theta_{\mathbf{manc}}|$, $\max(\cos\theta_{\mathbf{jet}})$, $\mathbf{m_{manc}}$, $\phi_{\mathbf{acop}}$

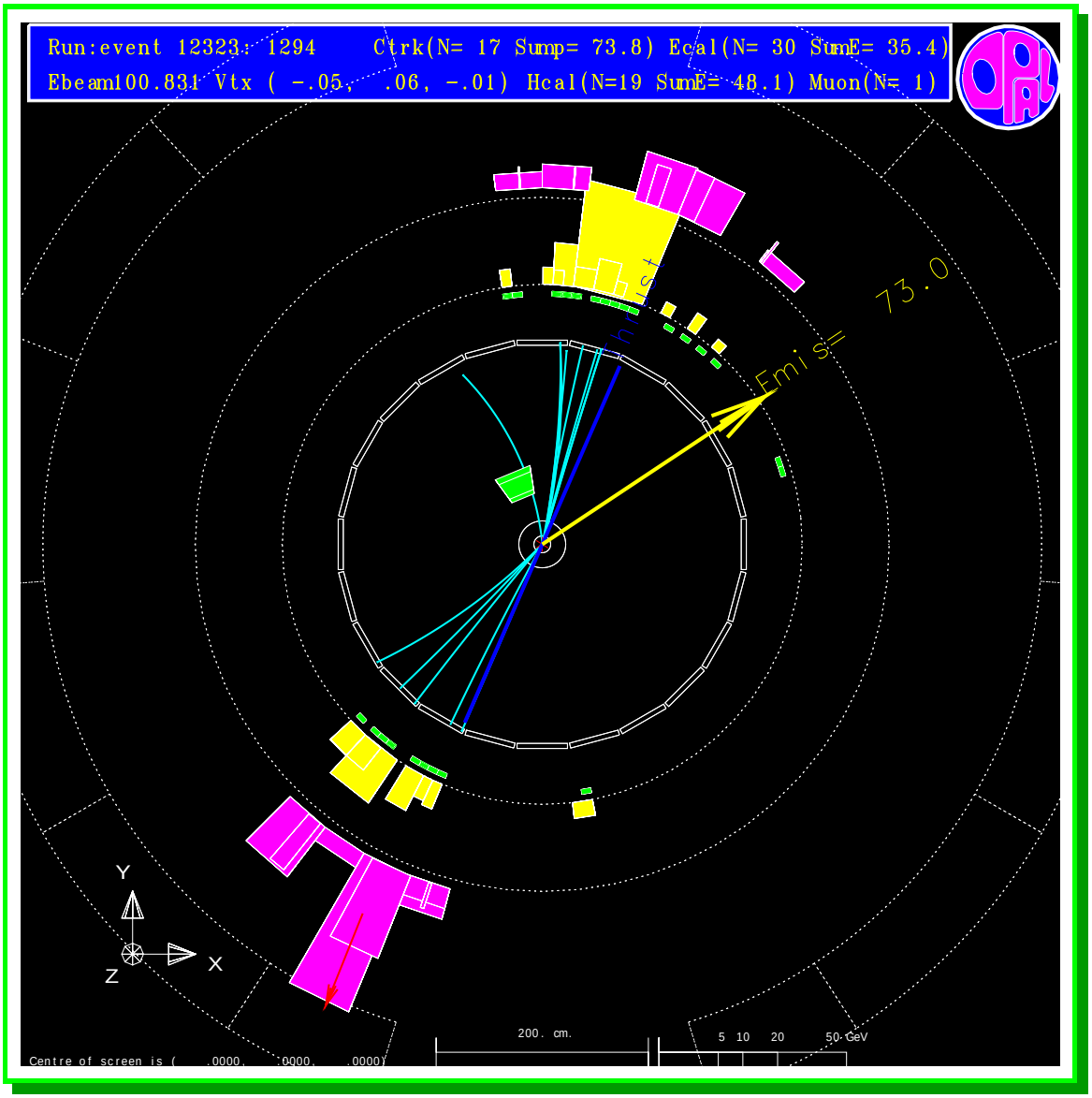
OPAL $\sqrt{s}$=192-202GeV



DATA	BKG	$q\bar{q}(\gamma)$	4-ferm.
6	9.3 ± 0.6	0.8	8.5

$$\mathbf{H\nu\bar{\nu}(m_H = 100/GeV/c^2) = 4.0evt.}$$

Un candidato per il canale $\mathbf{H}\nu\bar{\nu}$



Massa ricostruita=106.9$\mathbf{GeV/c^2}$

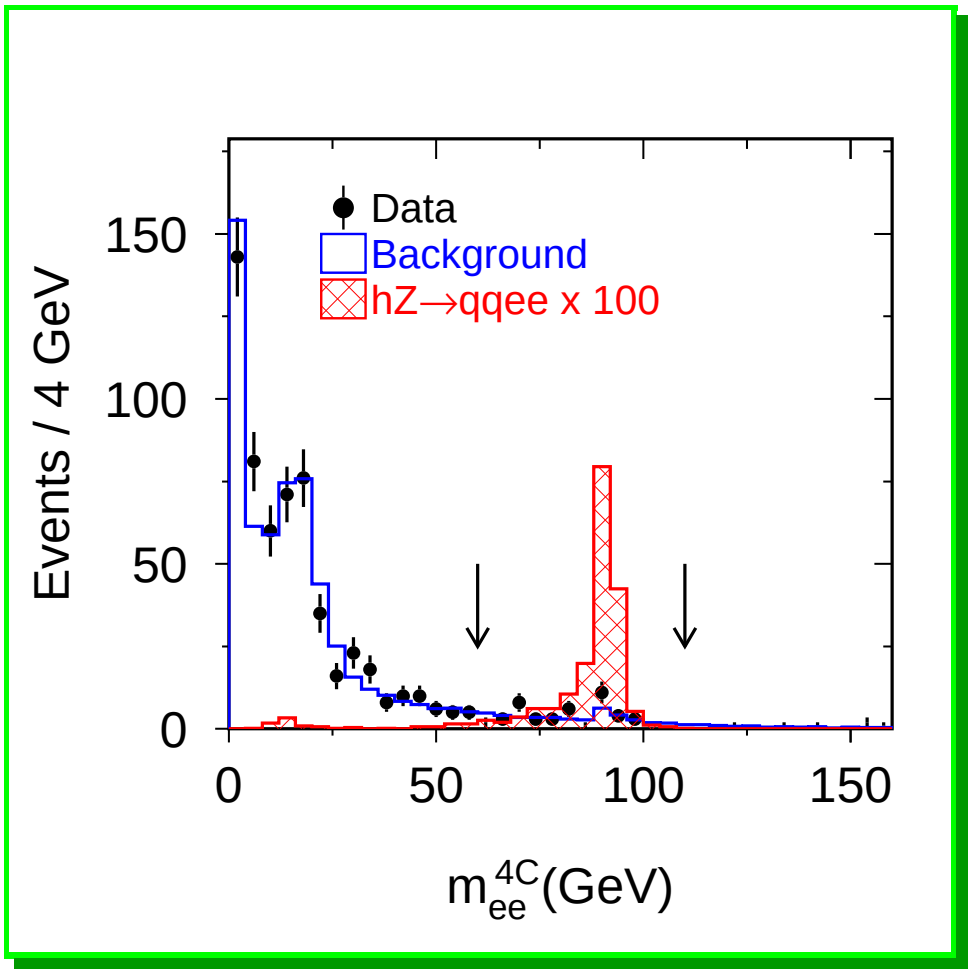
Valore di likelihood=0.867

Canale semileptonico

$$\mathbf{HZ \rightarrow b\bar{b}e^+e^-/\mu^+\mu^-}$$

- $\mathbf{BR(Z \rightarrow l^+l^-) = 6.6\%}$
- fondo principale: $\mathbf{ZZ \rightarrow l^+l^-q\bar{q}}$
- $\mathbf{m_H}$ ricostruita tramite la *recoilmass* dei leptoni

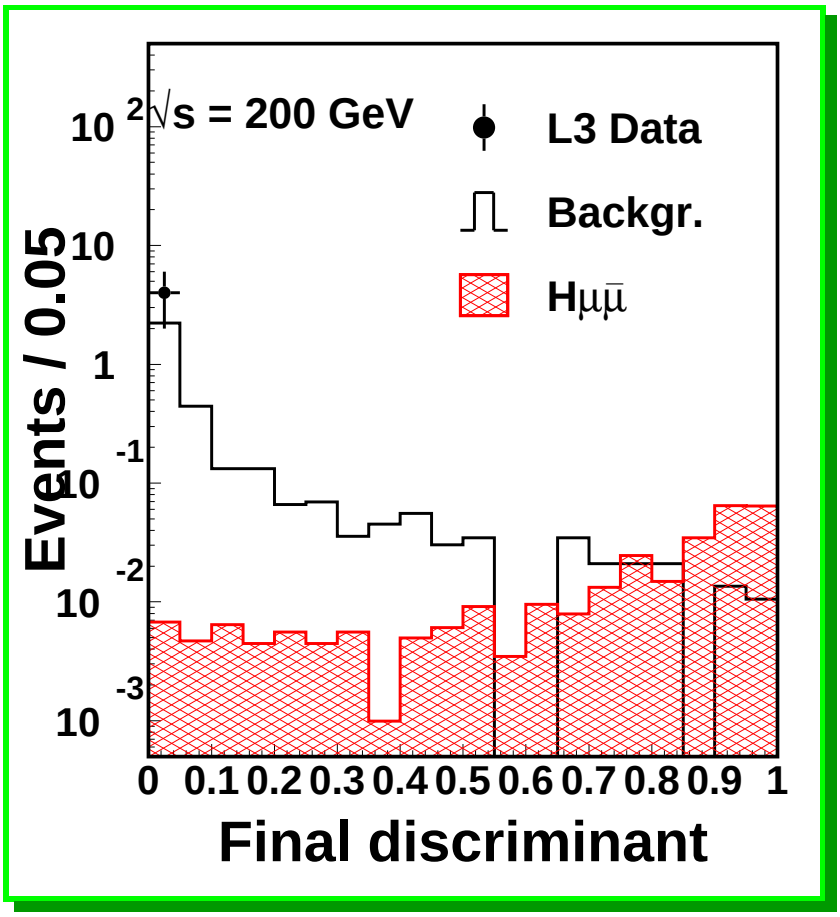
$$\mathbf{HZ \rightarrow b\bar{b}e^+e^-}$$



L3

Canale semileptonico

$$\mathbf{HZ \rightarrow b\bar{b}\mu^+\mu^-}$$



L3

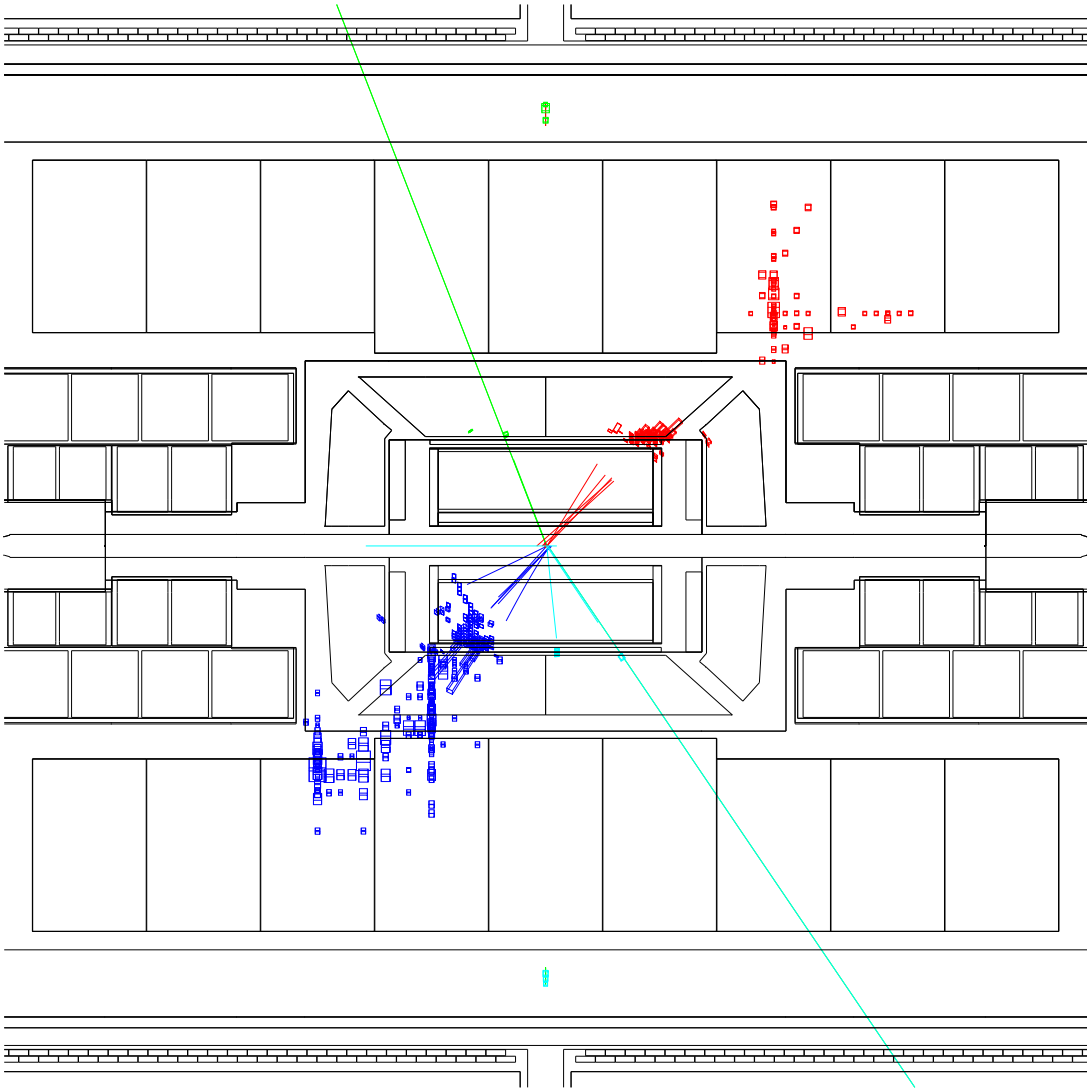
La massa ed il B-tag dei due jet adronici vengono combinate nella variabile discriminante

$\sqrt{s}$=192-202GeV SIG/BKG>0.05 :

DATA	BKG	$\mathbf{Hl^+l^-(m_H = 105GeV/c^2))}$
1	1.8	0.9

Un candidato per il canale $\mathbf{H}\mu^+\mu^-$

Run # 754203 Event # 4501 Total Energy : 199.00 GeV

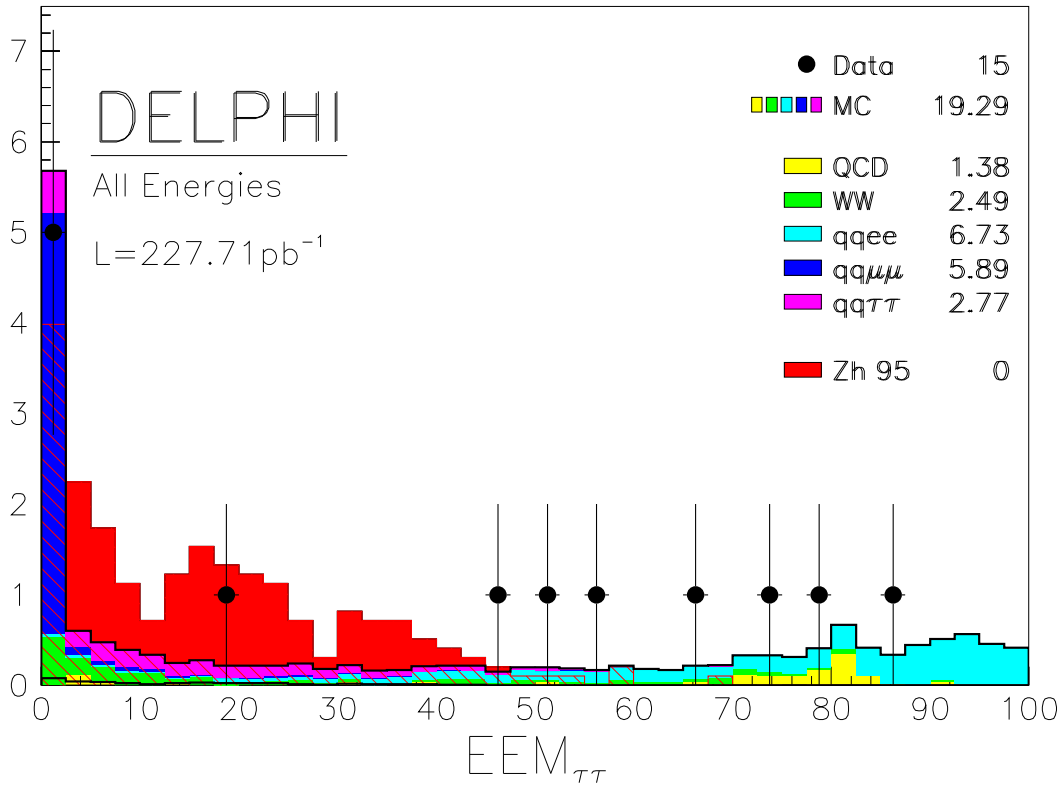


Transverse Imbalance :	.0496		**Longitudinal Imbalance :**	.0522	
Thrust :	.8047	**Major :**	.5386	**Minor :**	.1566
Event DAQ Time :	*990706 213329*				

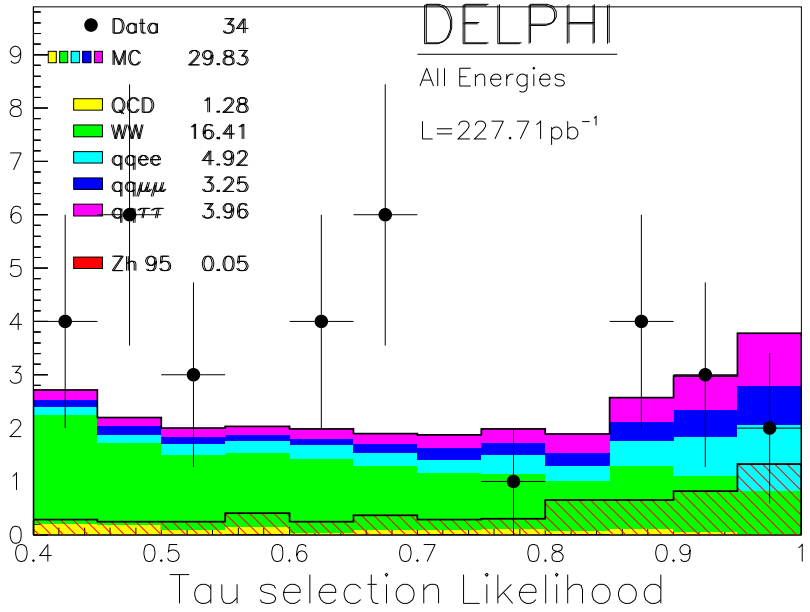
$\mathbf{HZ \to b\bar{b}\tau^+\tau^- / \tau^+\tau^- q\bar{q}}$

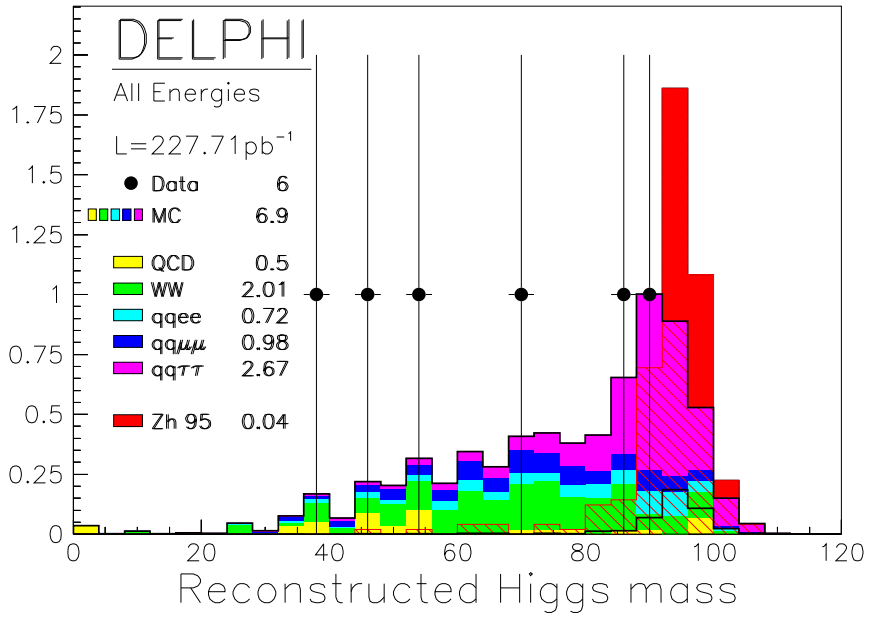
- i canali $\mathbf{HZ} \to \mathbf{b\bar{b}}\tau^+\tau^-$ e $\tau^+\tau^-\mathbf{q\bar{q}}$ distinguibili mediante B-tag
- identificazione del τ $\Rightarrow$ decadimento leptonico o jet isolato con bassa molteplicitá (1 o 3 tracce)

DELPHI $\sqrt{s}$=192-202GeV



Canale semileptonico





DATA	BKG	$q\bar{q}(\gamma)$	4-ferm.
6	7.28±0.14	0.28	7.00

$$\mathbf{EFF}_{q\bar{q}\tau^+\tau^-}(m_H = 105\mathrm{GeV}/c^2) \sim 18\%$$

Risultati dai quattro esperimenti:

I dati selzionati sono in accordo con il fondo

$\Rightarrow$ 95% di Livello di Confidenza

	ALEPH	DELPHI	L3	OPAL
LIM.OSSERVATO	107.7	103.9	106.0	103.0
LIM.ASPETTATO	$107.7^{(*)}$	106.3	105.3	105.2

(*) Aleph calcola il CL medio e non mediano

Livello di Confidenza

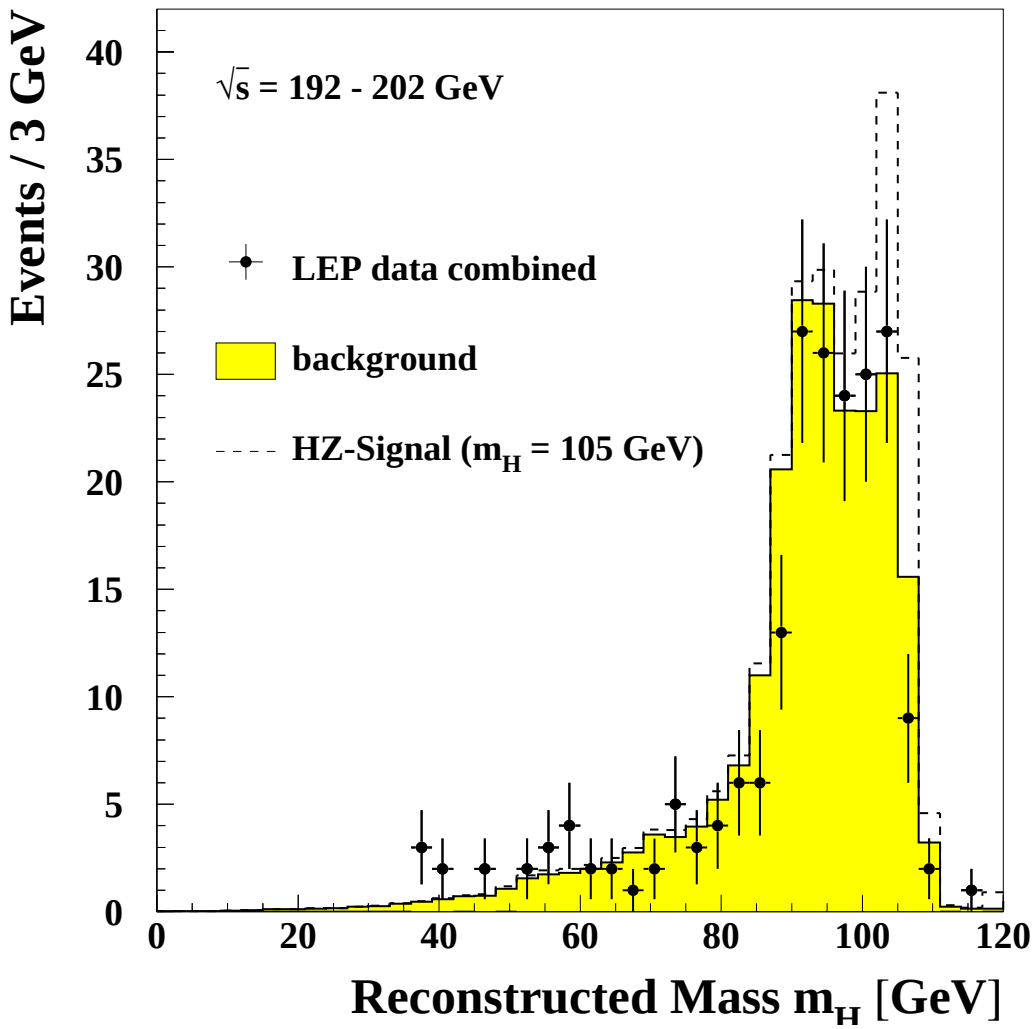
Stabilire dei criteri per l'esclusione o la scoperta

- mediante esperimenti simulati si costruisce un `test-statistico` $\mathbf{X}$ nelle due ipotesi:
  - `SEGNALE + BACKGROUND`
  - `BACKGROUND`
- il livello di confidenza é calcolato:
  - $\mathbf{CL_{s+b} = P_{s+b}(X \leq X_{obs})}$
  - $\mathbf{CL_b = P_b(X \leq X_{obs})}$

$$\boxed{\Rightarrow \mathbf{CL_s \equiv CL_{s+b}/CL_b}}$$

Risultati Combinati

$\sim 900\mathrm{pb}^{-1}$ di Luminositá integrata totale

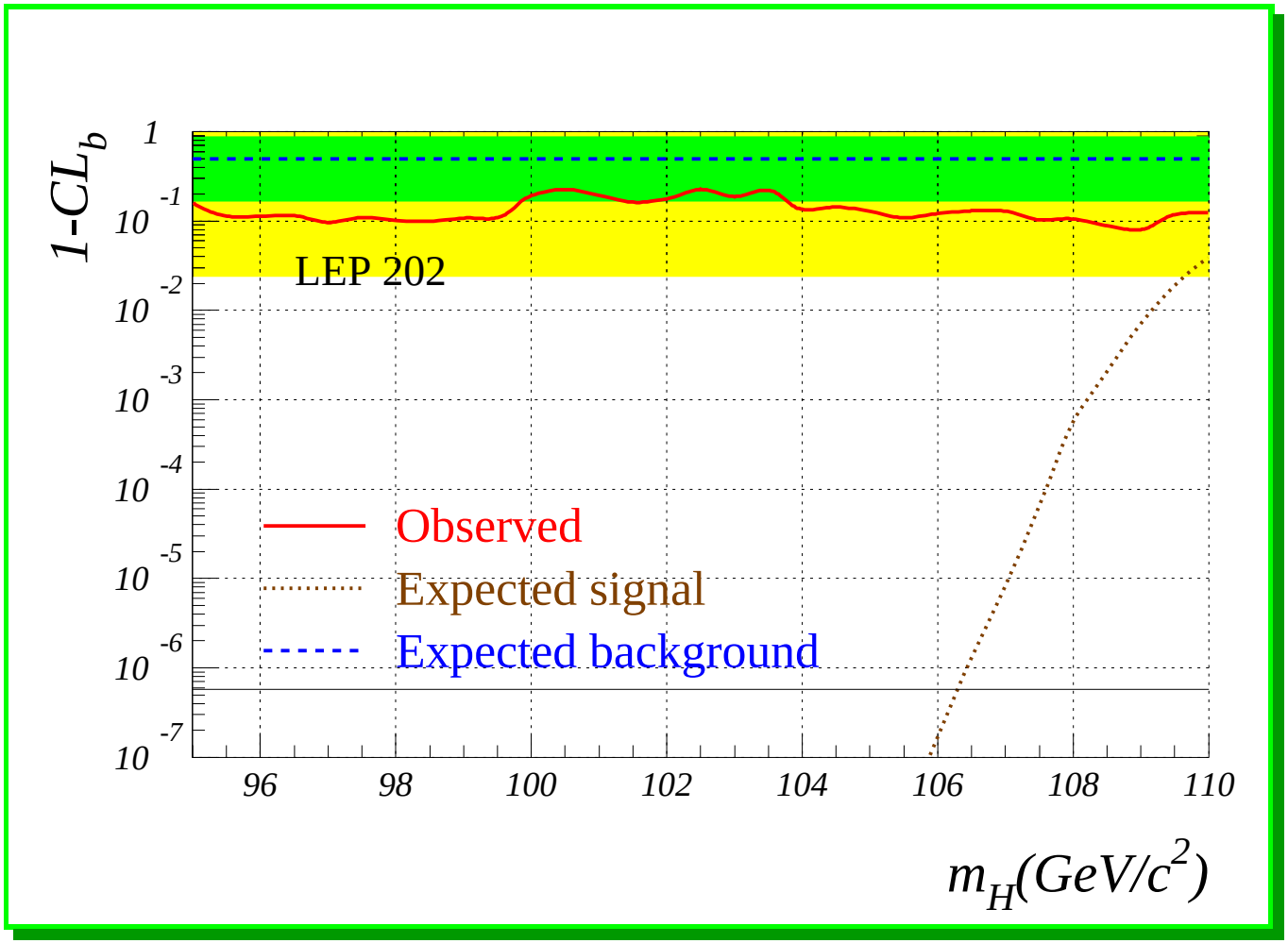


DATI=201

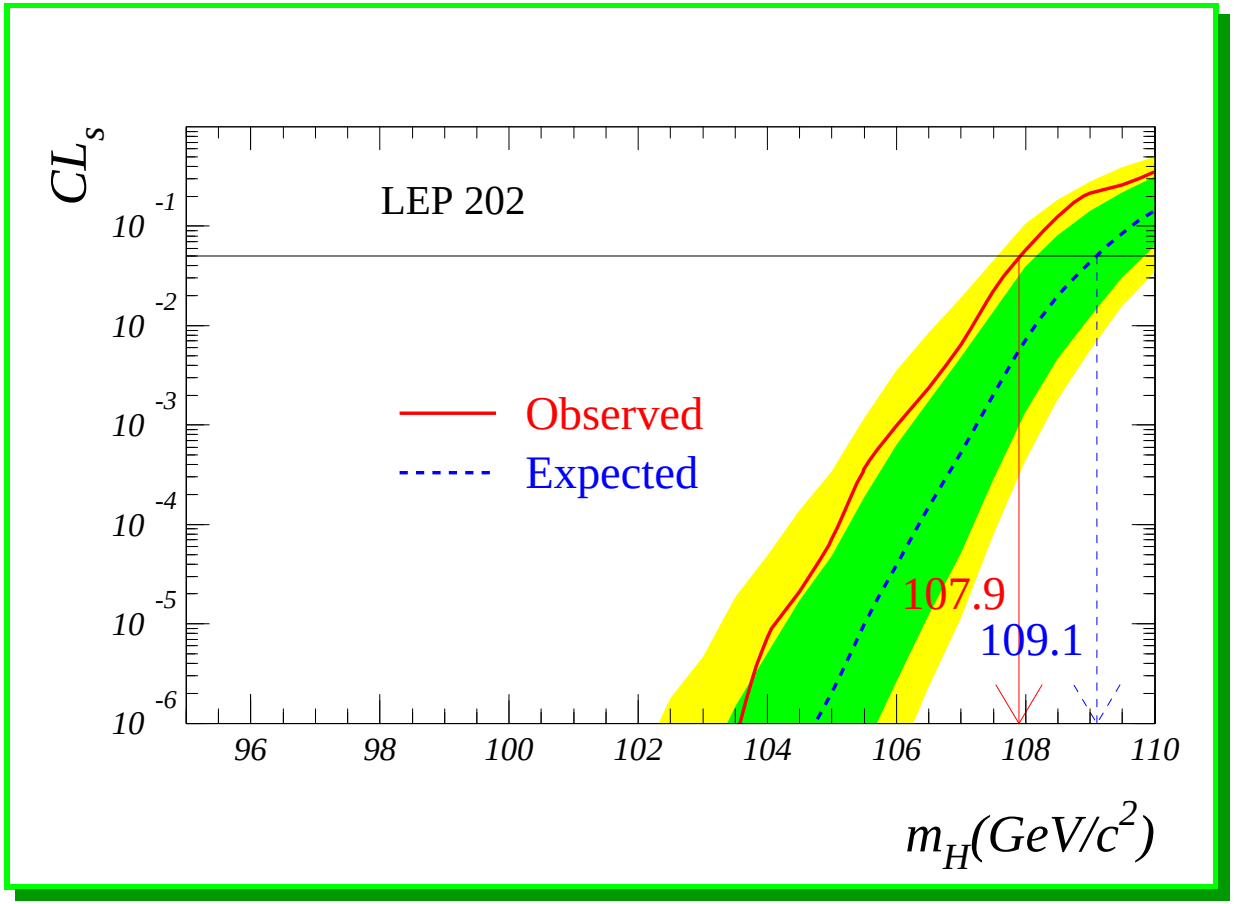
BKG=220

HZ=40.7
$(\mathbf{m_H}=105\mathbf{GeV}/\mathbf{c^2})$

Limiti Combinati



Limiti Combinati



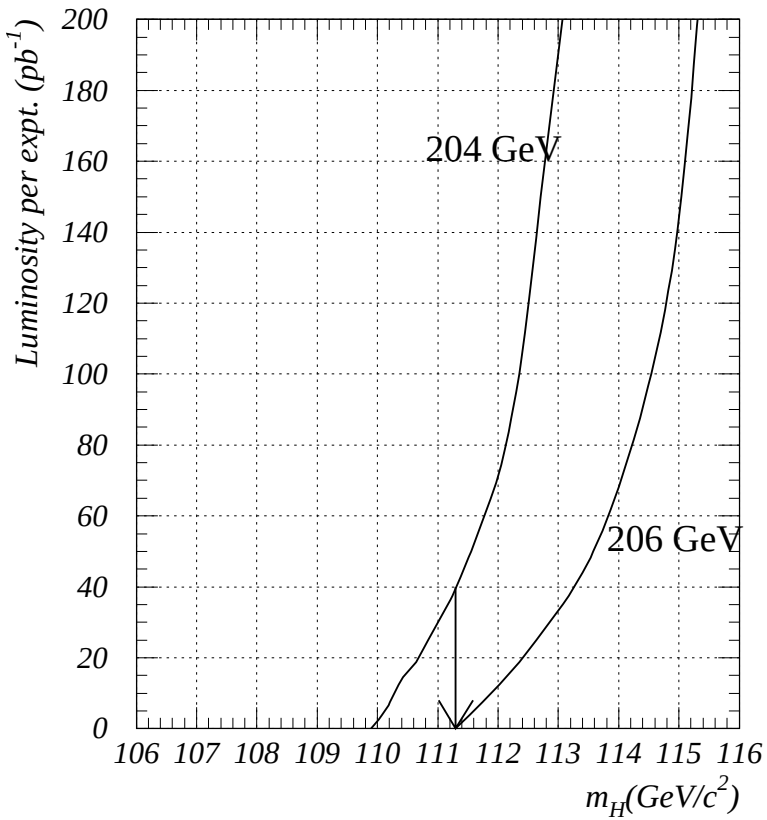
$$\Rightarrow \mathbf{m_H > 107.9 GeV/c^2}$$

(lim.aspettato $\mathbf{m_H > 109.1 GeV/c^2}$)

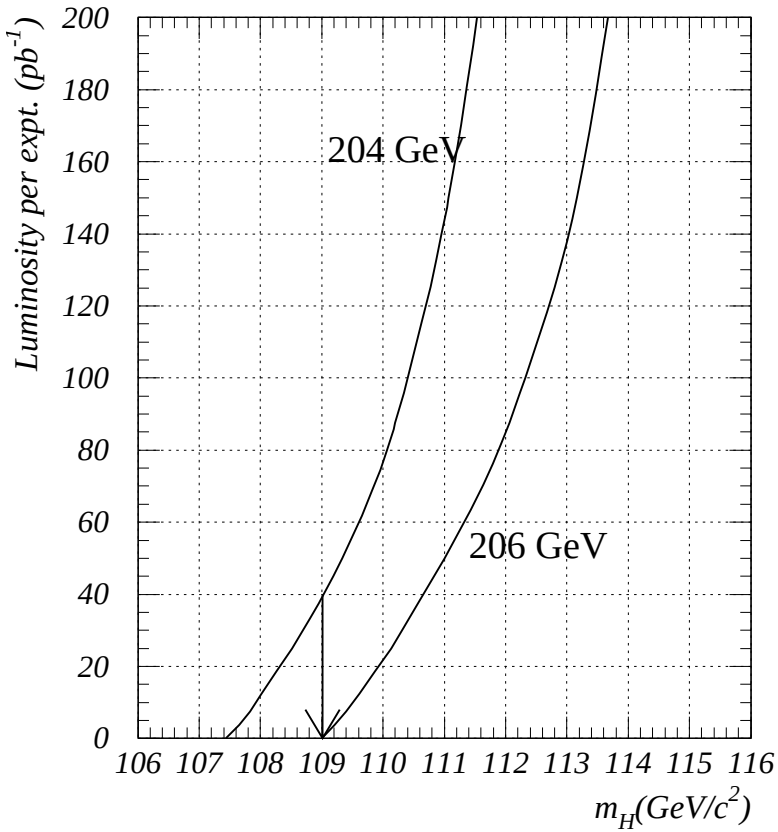
Quali prospettive di scoperta?

(E.Gross e A.L.Read CERN-EP-2000-034)- 40(1999)+40(2000)$\mathbf{pb^{-1}}$ a 202GeV

3 σ observation from 80 pb^{-1}/expt. at 202 GeV

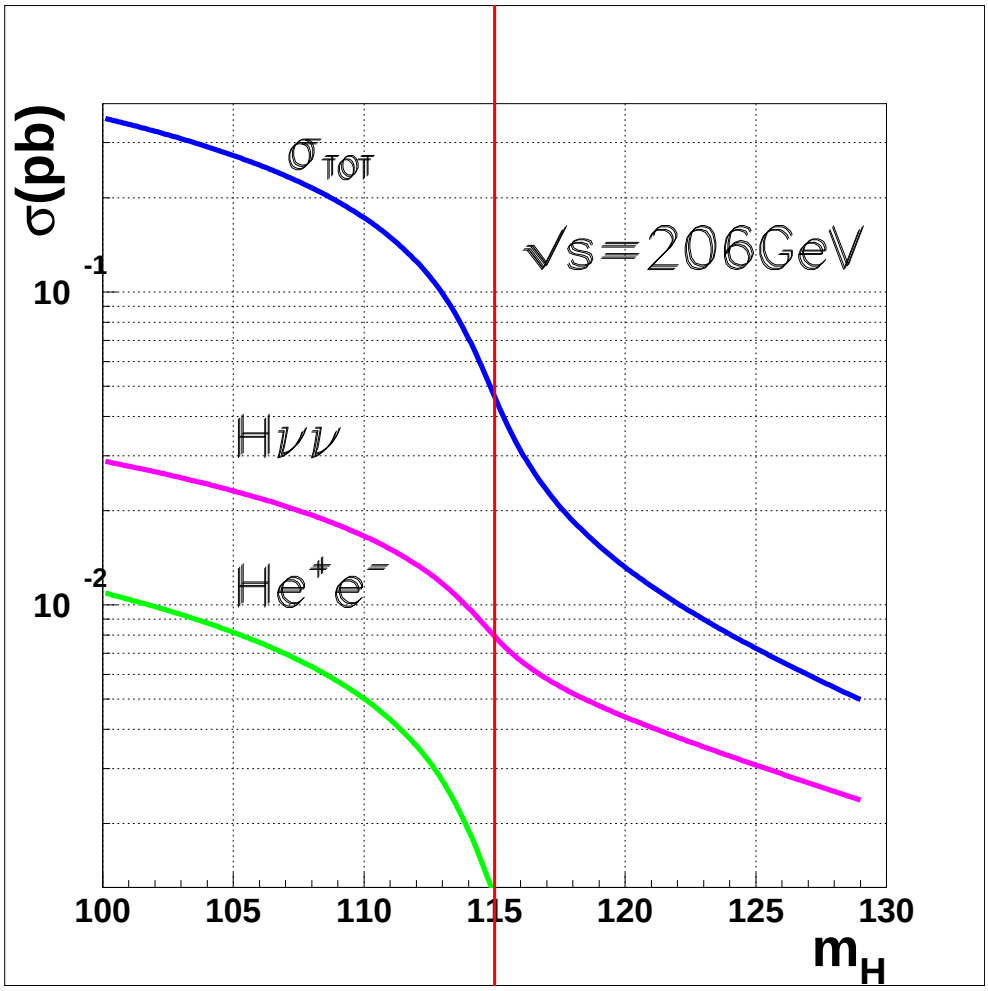


5 σ discovery from 80 pb^{-1}/expt. at 202 GeV



se c'é evidenza di segnale $\Rightarrow$ luminositá $\Uparrow$

C'é la possibilitá di andare oltre?



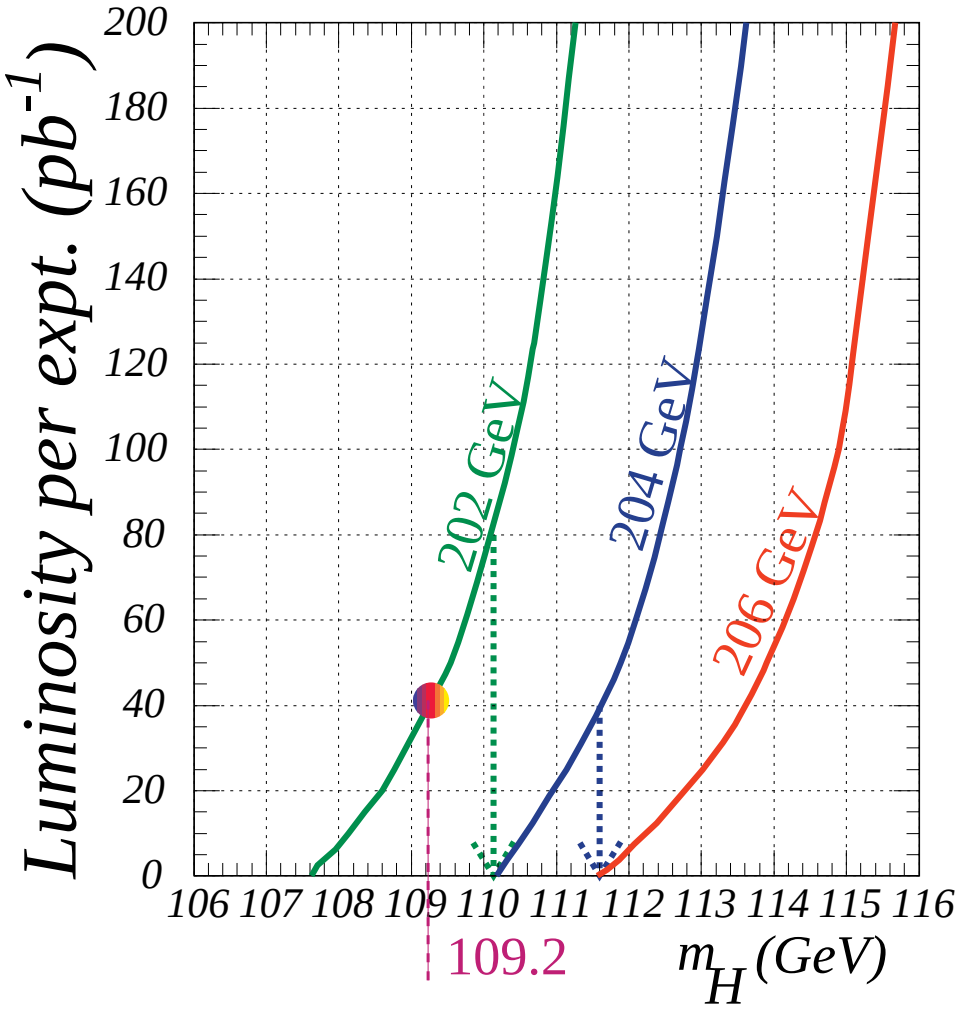
L'Higgsstrahlung contribuisce alla σ totale anche oltre il limite cinematico

$\sqrt{s} - m_Z$=115 GeV

⇒Analisi "dedicate ad alte masse" (Z off-shell) in tutti i canali

⇒Possibili miglioramenti $\sim$ **500MeV**

Esclusione



- massima energia possibile
- limite aspettato: $\sim \mathbf{114 GeV/c^2}$

Conclusioni

- Prestazioni del LEP eccellenti:
  - $\sqrt{s}$ fino a 202GeV
  - piú di $\mathbf{200pb^{-1}}$ per esperimento
- tutti i dati del 1999 sono stati analizzati e combinati

$\Rightarrow$NON C'É EVIDENZA DI SEGNALE

$$\mathbf{m_H > 107.9GeV/c^2} \text{ 95\% CL}$$

con 109.1$\mathbf{GeV/c^2}$ aspettato

PROSPETTIVE

2000: $\sqrt{s} \simeq \mathbf{206GeV}$

$\Rightarrow$ si esplora fino a $\sim \mathbf{114GeV/c^2}$