

Il Bosone di Higgs

Di cosa parlerò:

1. **Perchè** cercarlo
2. **Come** cercarlo
3. **Cosa** si è trovato

Lecture consigliate:

1. Leon Lederman, “La particella di Dio”
2. Gunion et al., “The Higgs Hunter’s Guide”
3. ALEPH Collaboration, “Observation of an excess in the search for the Standard Model Higgs boson at ALEPH”

<http://alephwww.cern.ch/ALPUB/paper/paper00/21/higgs2000.ps>

“The Higgs Particle search at ALEPH”

<http://alephwww.cern.ch/ALPUB/seminar/wds/Welcome.html>

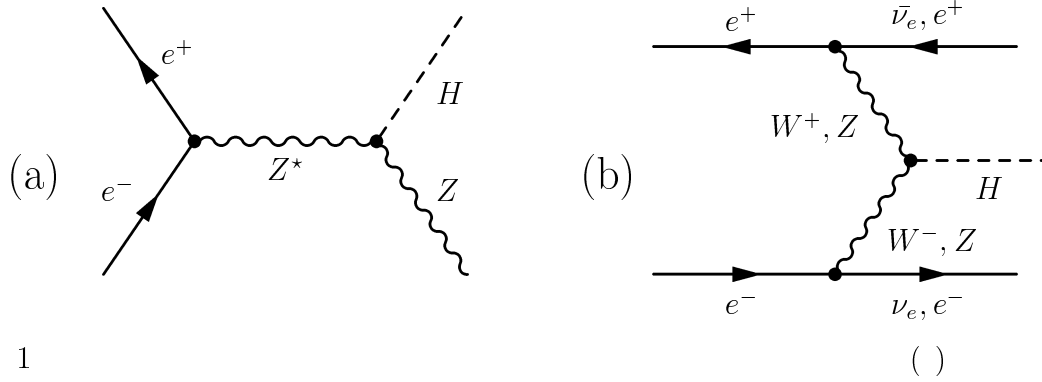
P. Igo-Kemenes, “Status of the Higgs boson searches”, presentazione al LEPC del 3 novembre 2000

<http://lephiggs.web.cern.ch/LEPHIGGS/talks/index.html>

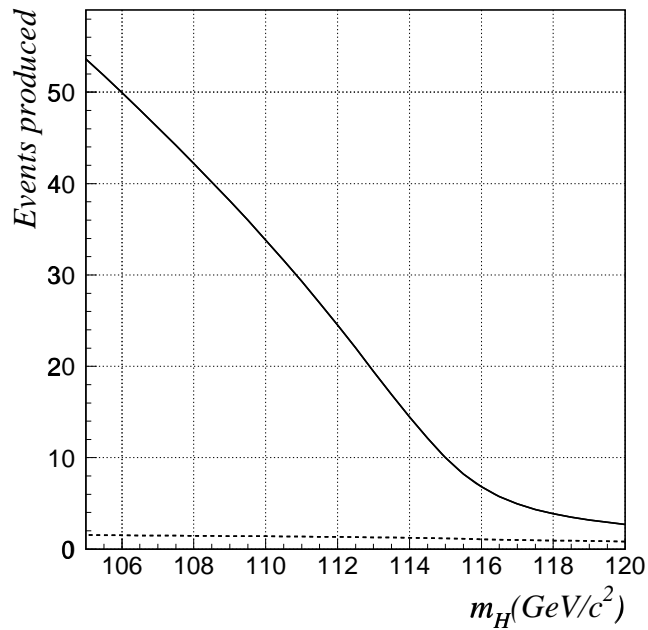
Particella	Massa	Spin
fotone (γ)	0	1
W^+	81 GeV	1
W^-	81 GeV	1
Z^0	91 GeV	1
gluone (g)	0	1
gravitone	0	2

Leptoni		Quark	
Particella	Massa	Particella	Massa
e	511 KeV	up (u)	$2 \div 8$ MeV
ν_e	< 5 eV	down (d)	$5 \div 15$ MeV
μ	105 MeV	charm (c)	$1.0 \div 1.6$ GeV
ν_μ	< 0.27 MeV	strange (s)	$100 \div 300$ MeV
τ	1.77 GeV	top (t)	$170 \div 190$ GeV
ν_τ	< 31 MeV	bottom (b)	$4.1 \div 4.5$ GeV

Come produrre un Higgs:



Numero di Higgs attesi in funzione di M_H :



Come decade un Higgs:

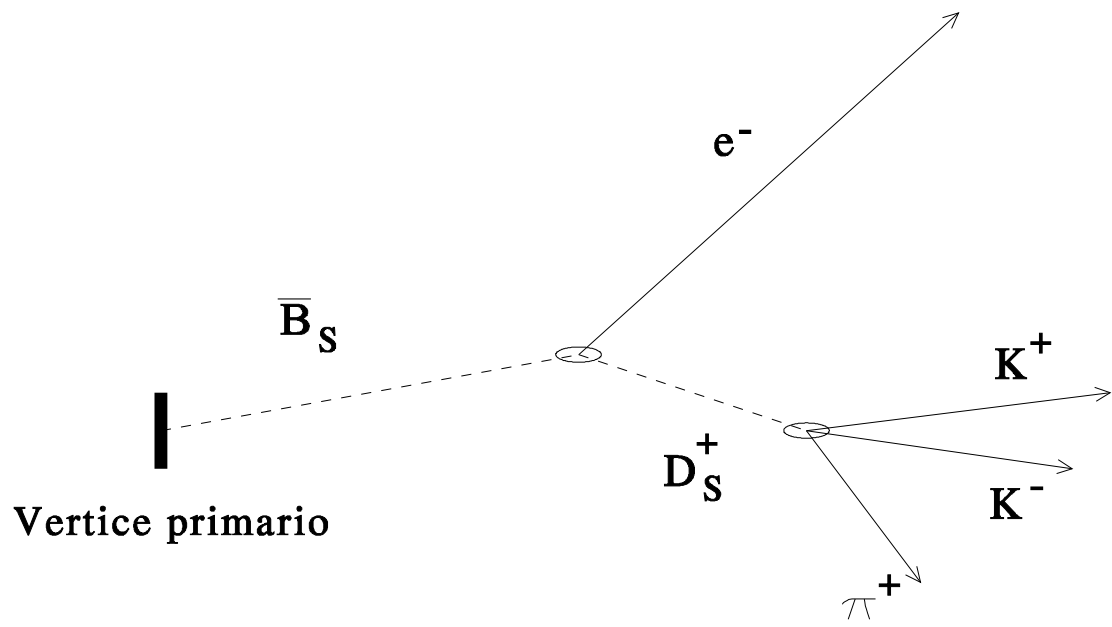
$$74\% H \rightarrow b\bar{b}$$

$$7\% H \rightarrow \tau\bar{\tau}$$

Come cercare un evento $e^+e^- \rightarrow ZH$:

- 4 jet ($H \rightarrow b\bar{b}, Z \rightarrow q\bar{q}$)
- energia mancante ($H \rightarrow b\bar{b}, Z \rightarrow \nu\bar{\nu}$)
- coppia di leptoni ($H \rightarrow b\bar{b}, Z \rightarrow l^+l^-, l = e, \mu$)
- coppia di tau ($H \rightarrow \tau^+\tau^-, Z \rightarrow q\bar{q}$ oppure $H \rightarrow b\bar{b}, Z \rightarrow \tau^+\tau^-$)

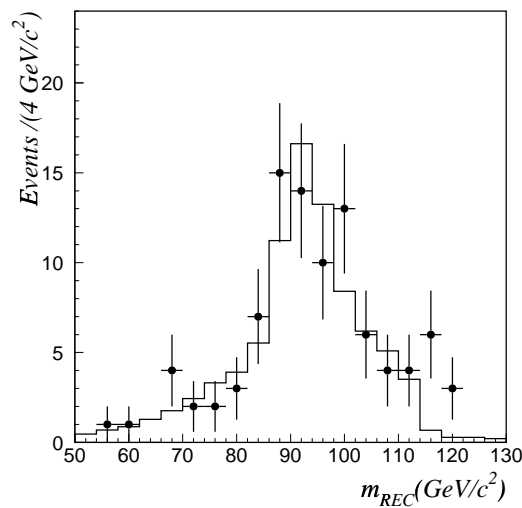
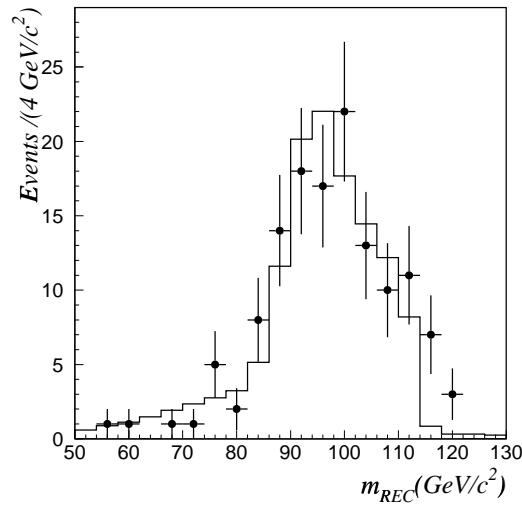
Decadimento della Z	Decadimento dell' H	B.R.
$Z \rightarrow q\bar{q}$	$H \rightarrow q\bar{q}$	64%
$Z \rightarrow \nu\bar{\nu}$	$H \rightarrow q\bar{q}$	18%
$Z \rightarrow e^+e^-, \mu^+\mu^-$	$H \rightarrow q\bar{q}$	6.2%
$Z \rightarrow \tau^+\tau^-$	$H \rightarrow q\bar{q}$	3.1%
$Z \rightarrow q\bar{q}$	$H \rightarrow \tau^+\tau^-$	5.4%



“Locked Analysis”

- Prima della presa dati, si fissano gli algoritmi di analisi.
- In questa fase si decidono i tagli (ottimizzati con MC) e si addestrano le NN.
- L’analisi avviene [online](#).

Il punto importante è che
CHI TOCCA I TAGLI MUORE!!!



- **4 jet**: $m_{REC} = m_{12} + m_{34} - m_Z$ con:
 - m_{12} massa dei jet attribuiti all' H
 - m_{34} massa dei jet attribuiti alla Z
 - m_Z massa nominale della Z
- **Energia mancante**: la massa mancante è attribuita alla Z
- **2 leptoni (non τ)**: m_{REC} è la massa che rincula contro i due leptoni
- **2 τ** : m_{REC} è ottenuta da un fit cinematico, con m_Z imposta o ai τ o al sistema adronico

$$Q = \frac{P(\text{data}|\text{signal} + \text{back.})}{P(\text{data}|\text{back.})} \equiv \frac{L_{s+b}}{L_b}$$

$$Q = \frac{e^{-(s+b)} n_{obs}}{e^{-b}} \prod_{i=1}^{n_{obs}} \frac{s f_s(\vec{X}_i) + b f_b(\vec{X}_i)}{b f_b(\vec{X}_i)}$$

b : eventi di fondo attesi

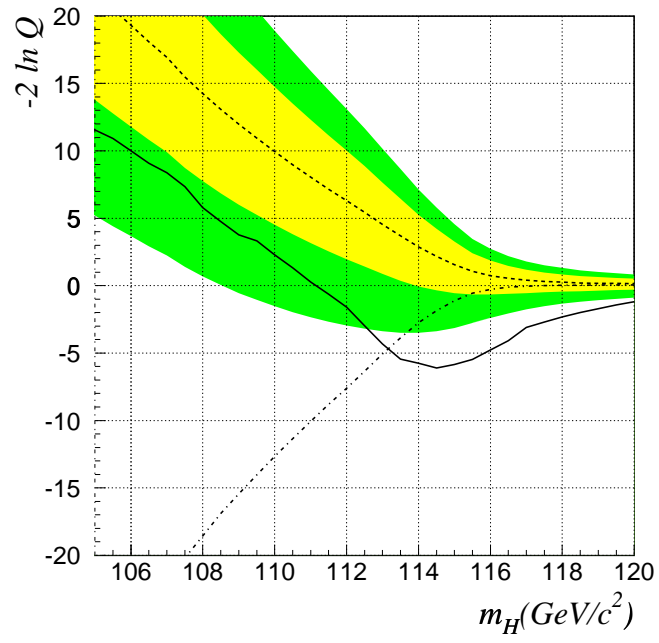
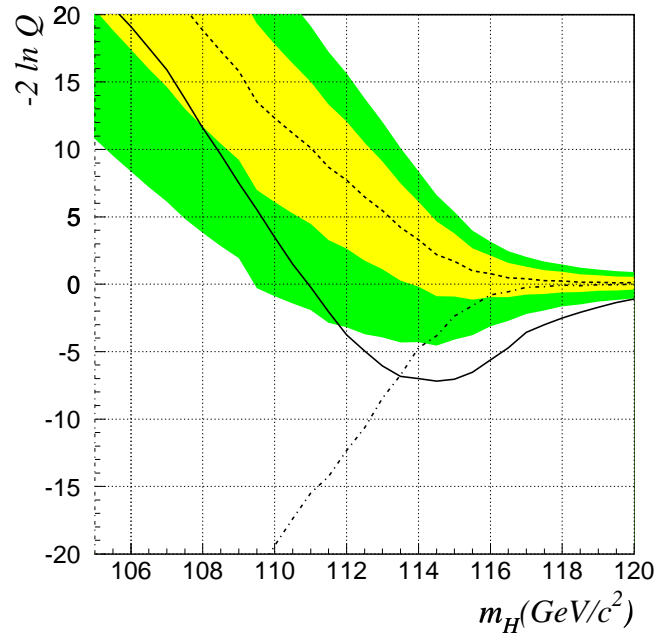
s : eventi di segnale attesi (dipende da m_H)

\vec{X}_i : insieme di variabili discriminanti

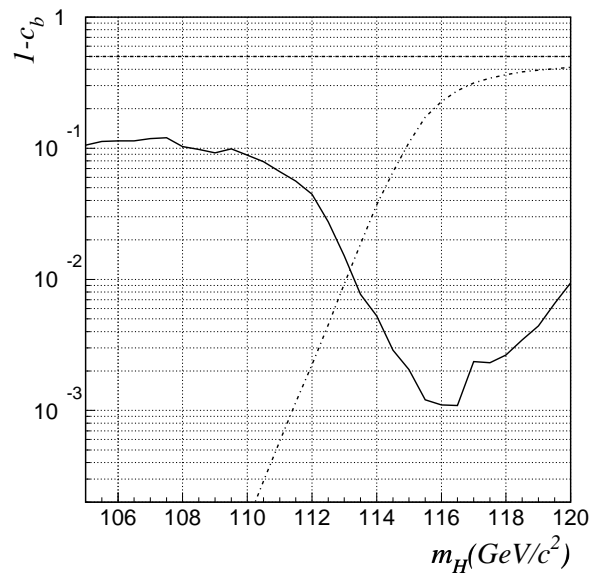
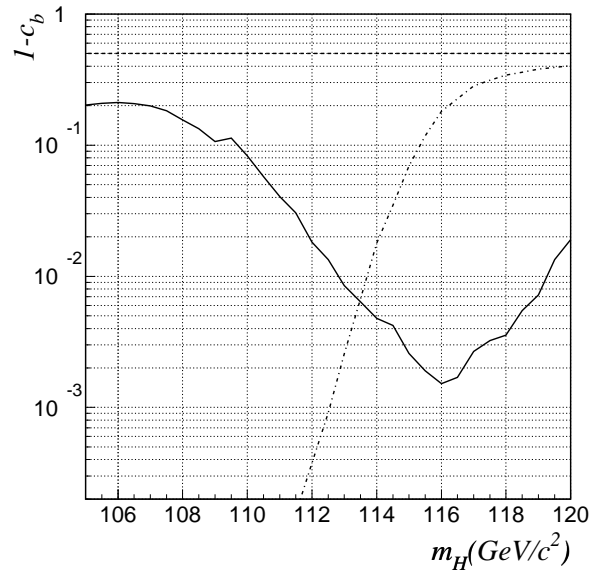
Tutte le analisi usano m_{REC} come variabile discriminante.

L'analisi a 4 jet con NN usa anche l'output della rete neurale.

L'analisi a energia mancante con NN e le analisi a 2 leptoni (non τ) usano come secondo discriminante l'output della NN specifica per i jet con b .

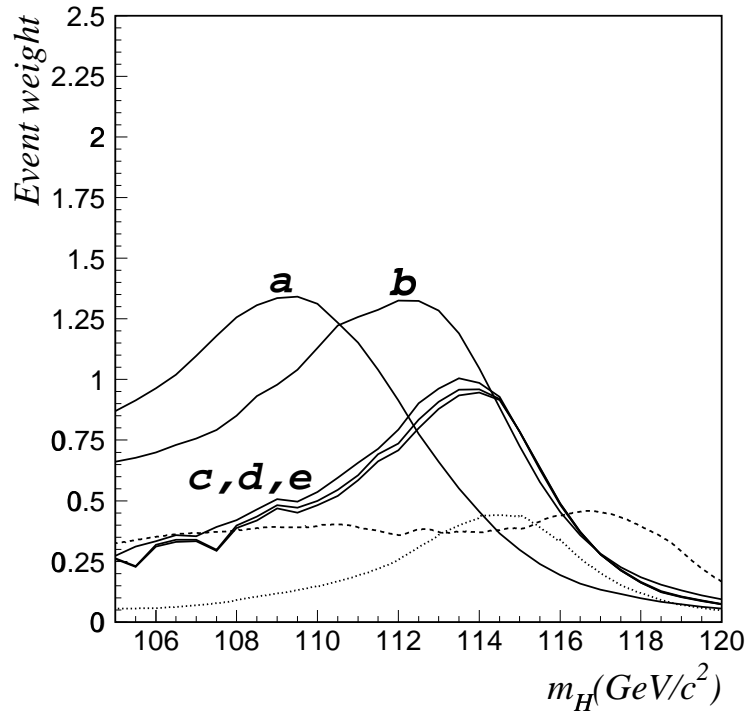
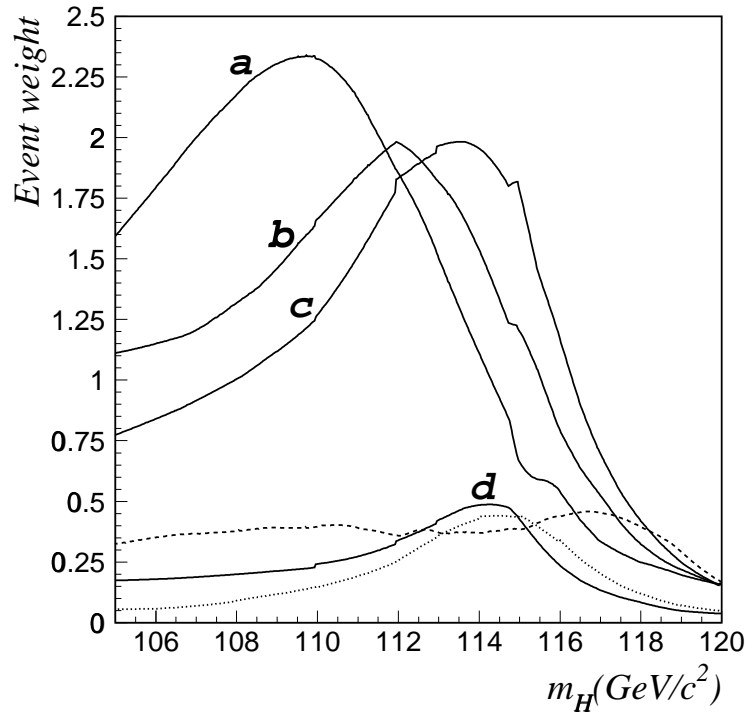


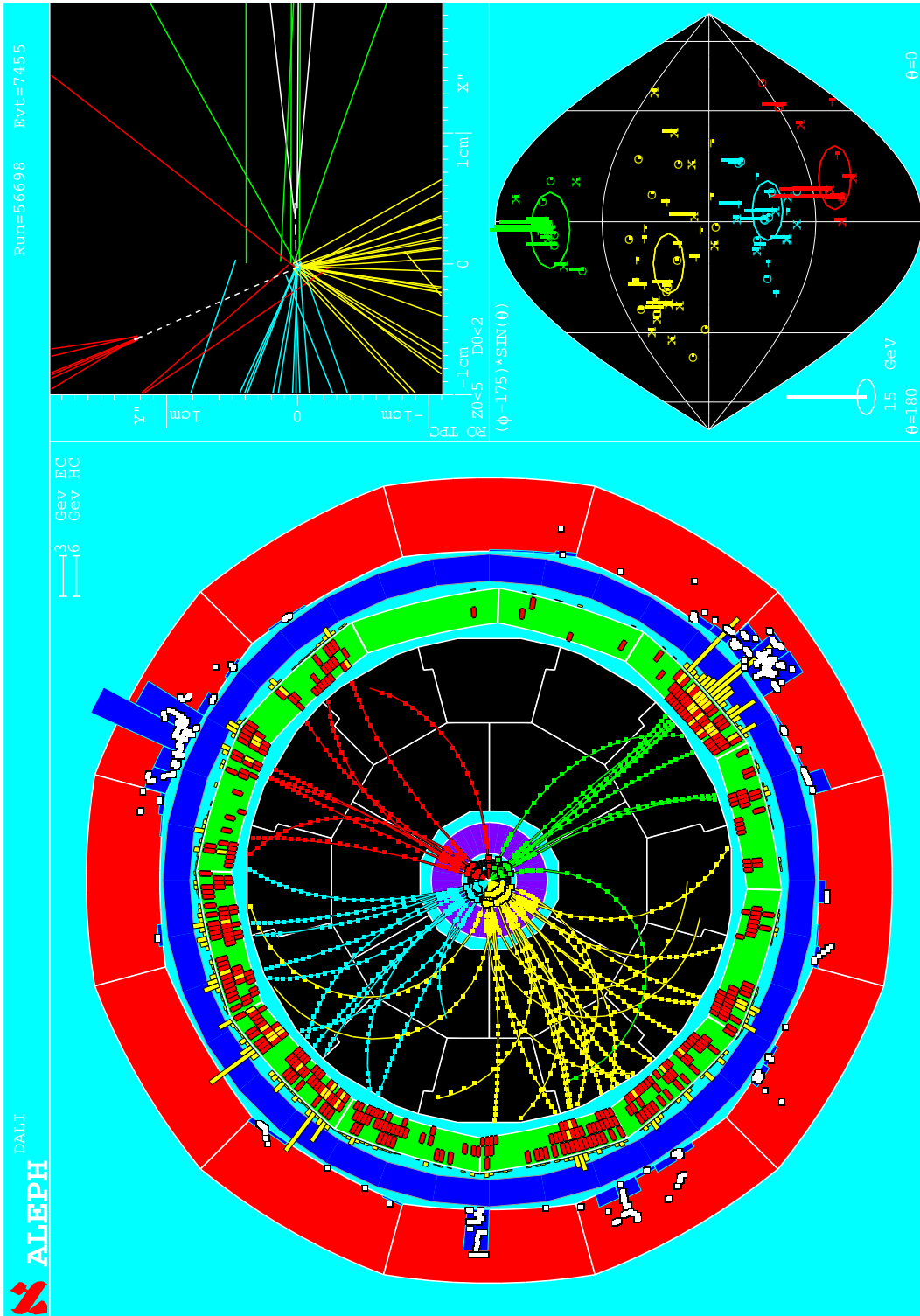
$1 - c_b$: probabilità di ottenere
 $-2 \ln Q$ più piccolo di quanto osservato,
nell'ipotesi di solo fondo



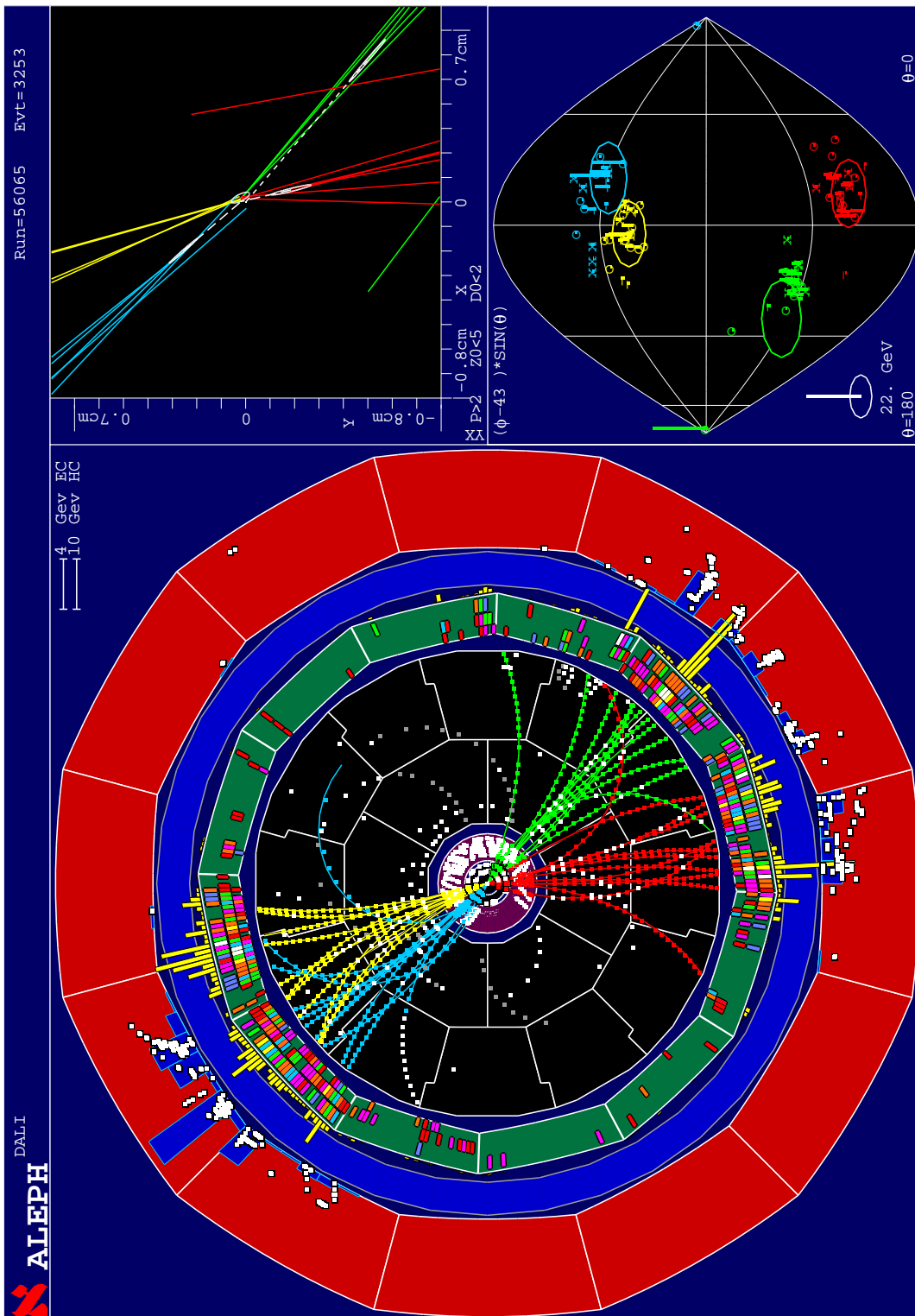
Una scoperta a 5σ significa
 $1 - c_b < 5.7 \times 10^{-7}$

$$-2 \ln Q = 2s - s \sum_{i=0}^n \ln \left(1 + \frac{s f_s(\vec{X}_i)}{b f_b(\vec{X}_i)} \right)$$



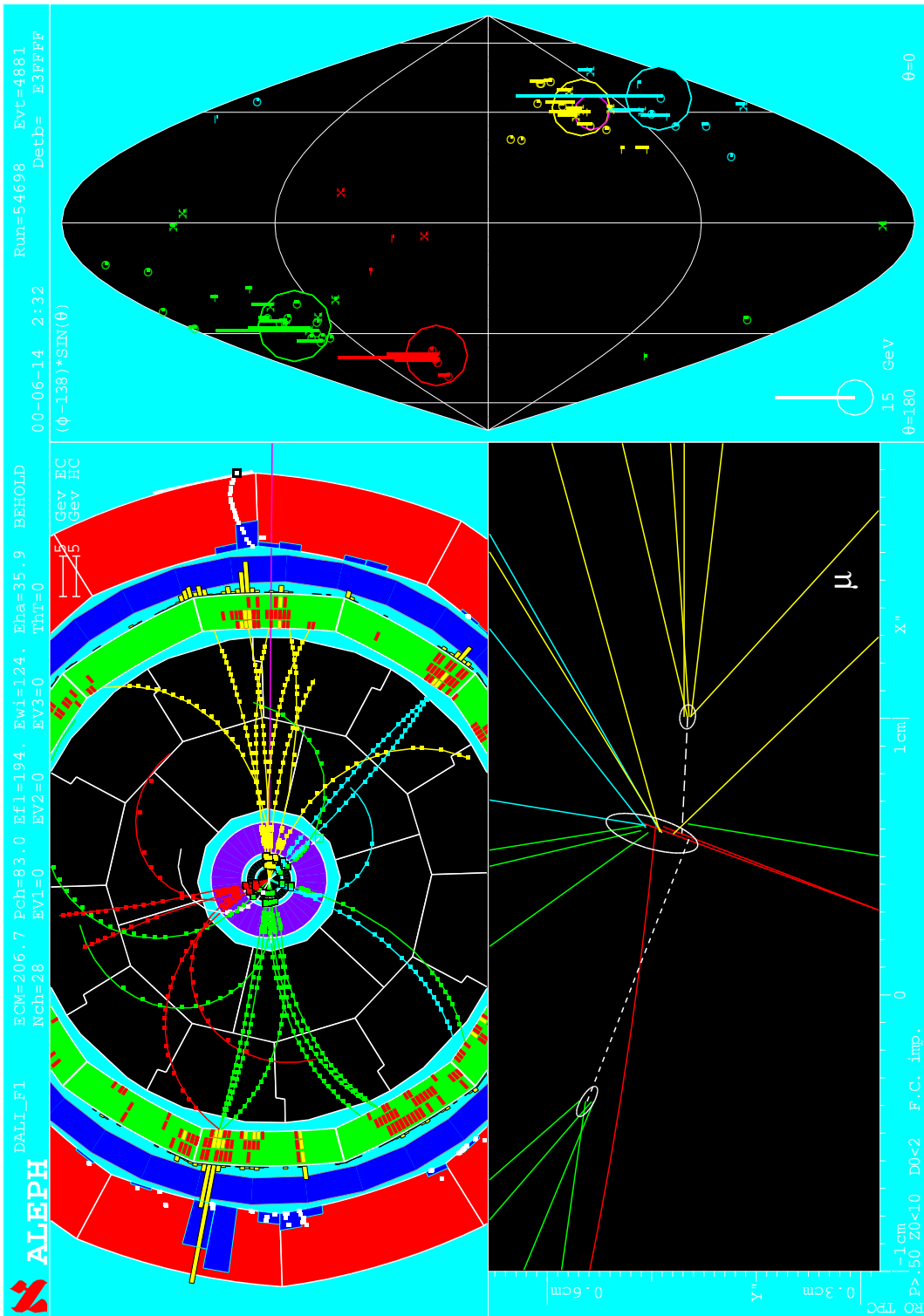


Candidato a : $b\bar{b}b\bar{b}$,
 $m_{REC}^H = 110.0 \text{ GeV}/c^2$



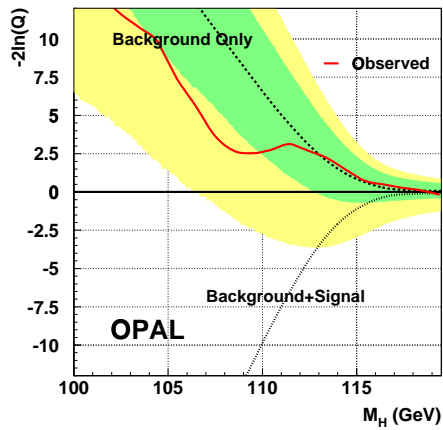
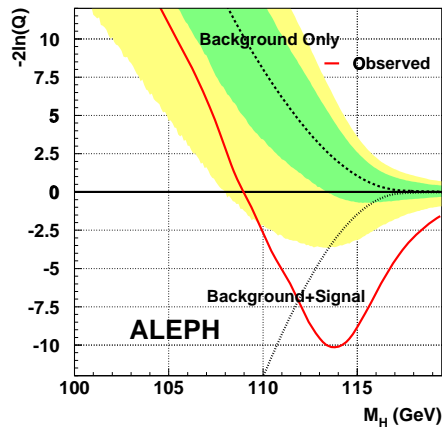
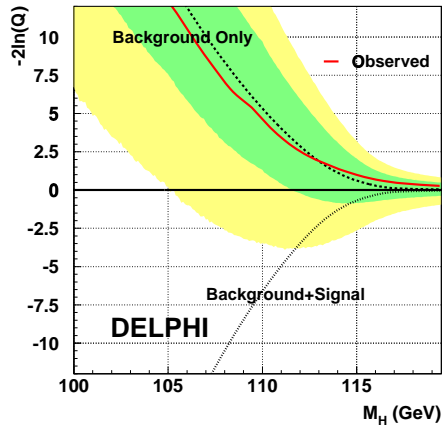
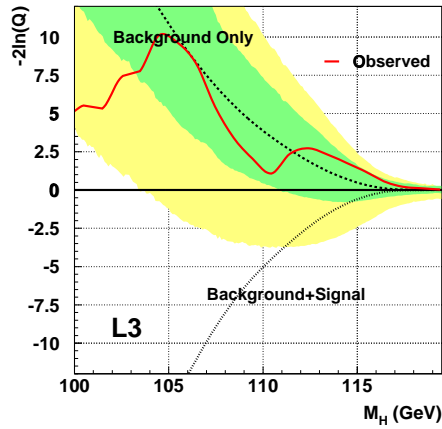
Candidato b : $b\bar{b}b\bar{b}$,
 $m_{REC}^H = 112.9 \text{ GeV}/c^2$

(Nota: escludendo un e^- spurio,
 $m_{REC}^H = 114.5 \text{ GeV}/c^2$)



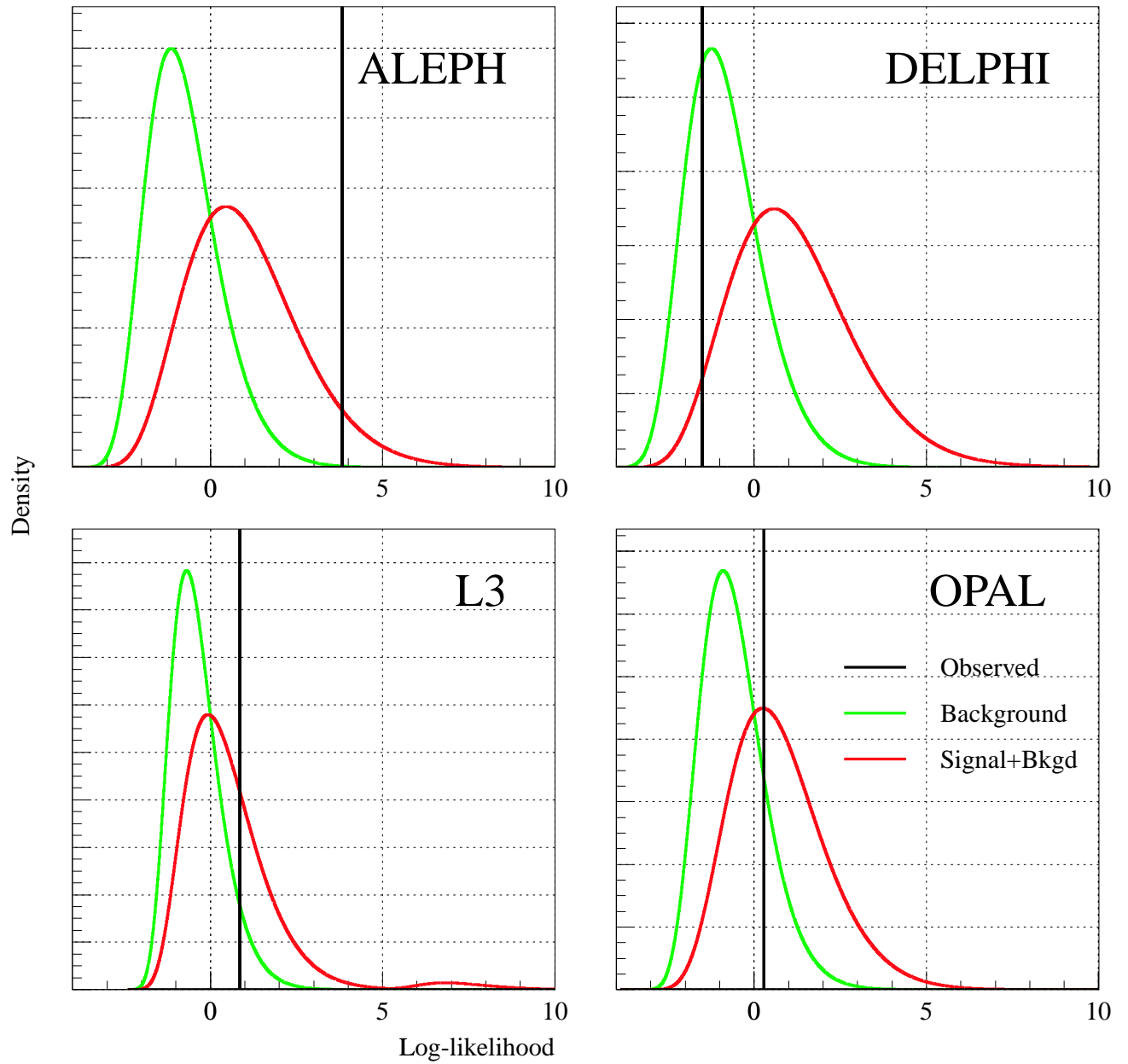
Candidato c: $q\bar{q}b\bar{b}$,
 $m_{REC}^H = 114.3 \text{ GeV}/c^2$

SM Results from All Experiments

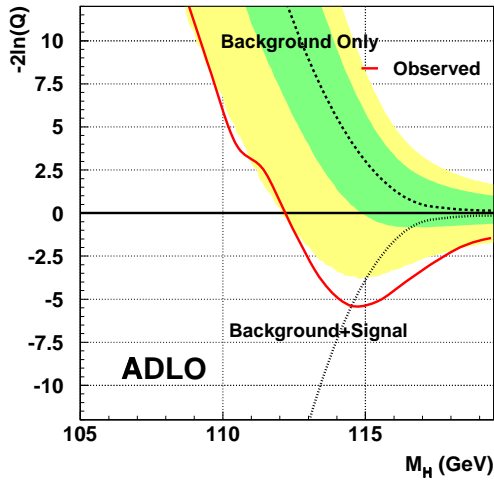


3.9 σ Excess in ALEPH Data ($1 - CL_b = 6 \cdot 10^{-5}$)

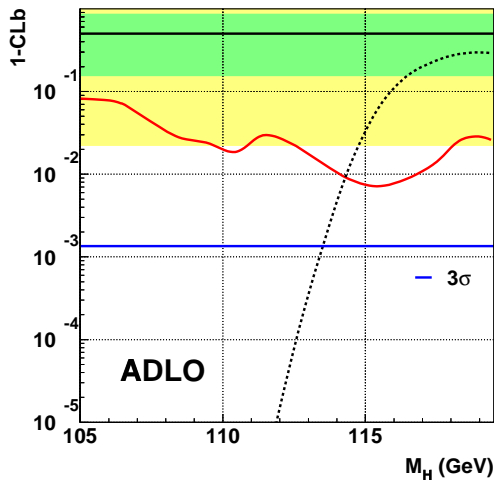
Experiments results at $115\text{GeV}/c^2$



Combined SM Results

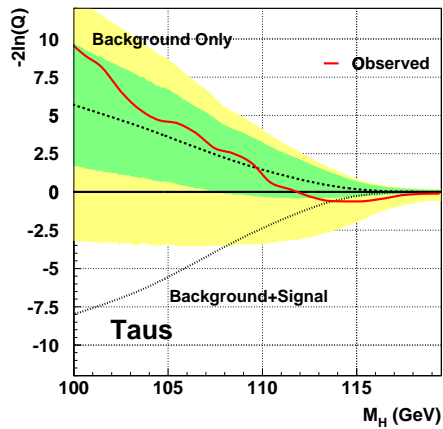
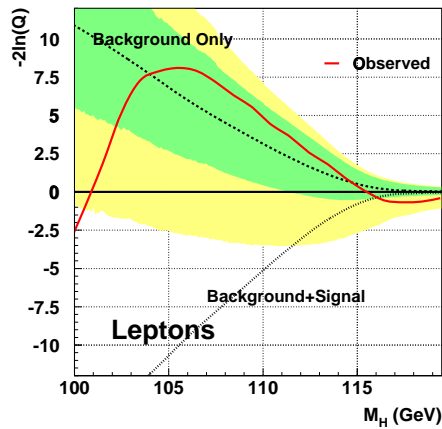
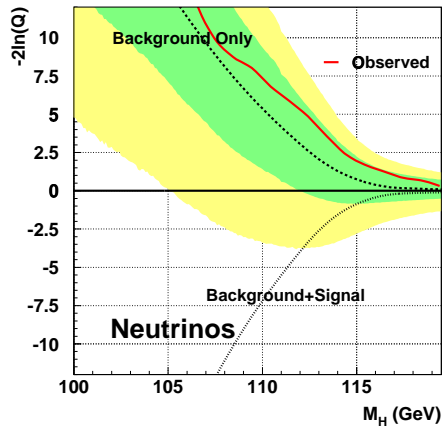
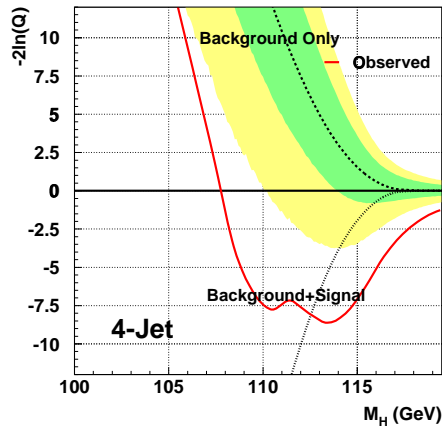


$-2\ln(Q)$ Minimum
at 114.9 GeV



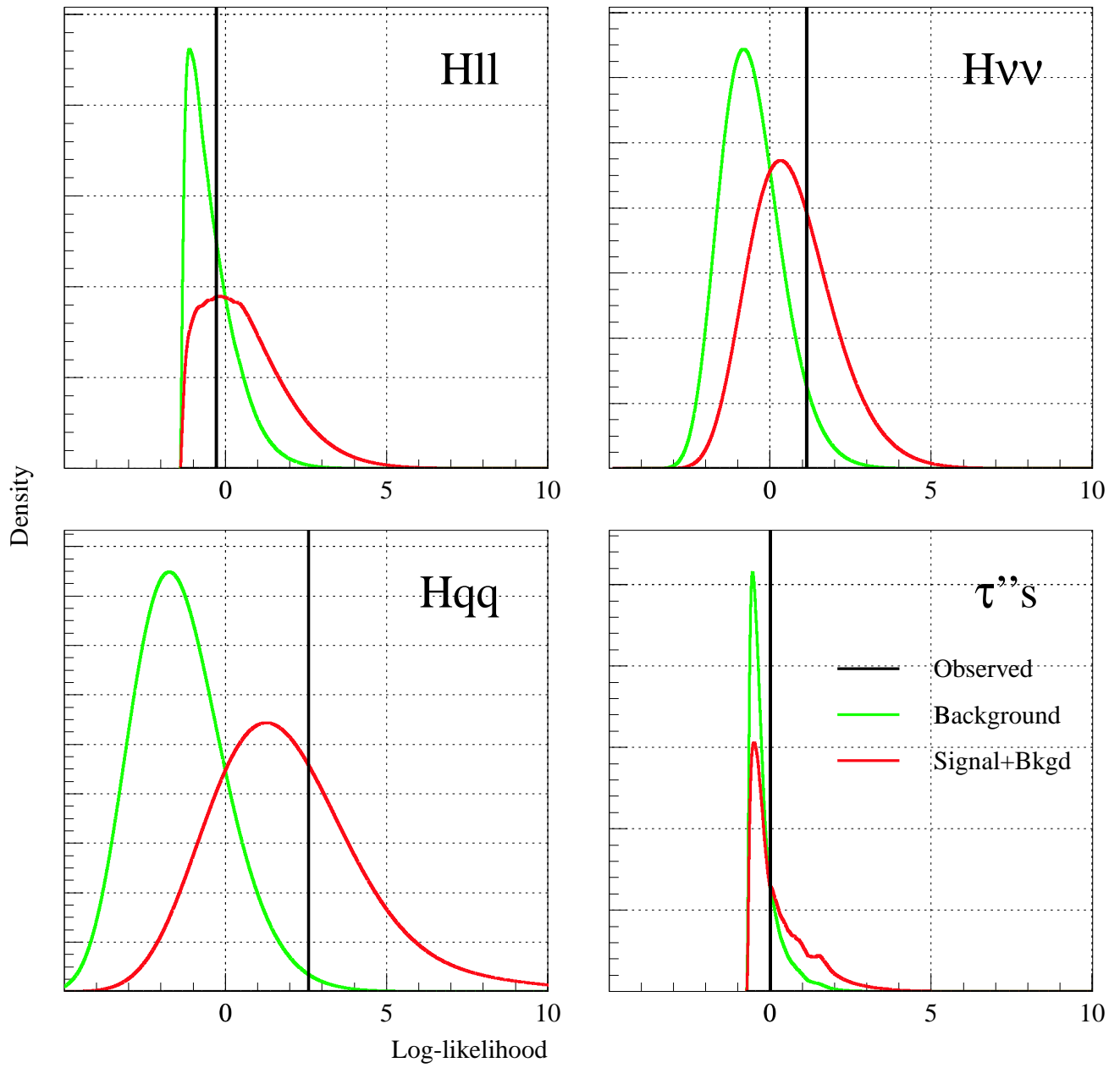
$1 - CL_b$ Minimum
at 2.6σ
Significance

SM Results from All Channels

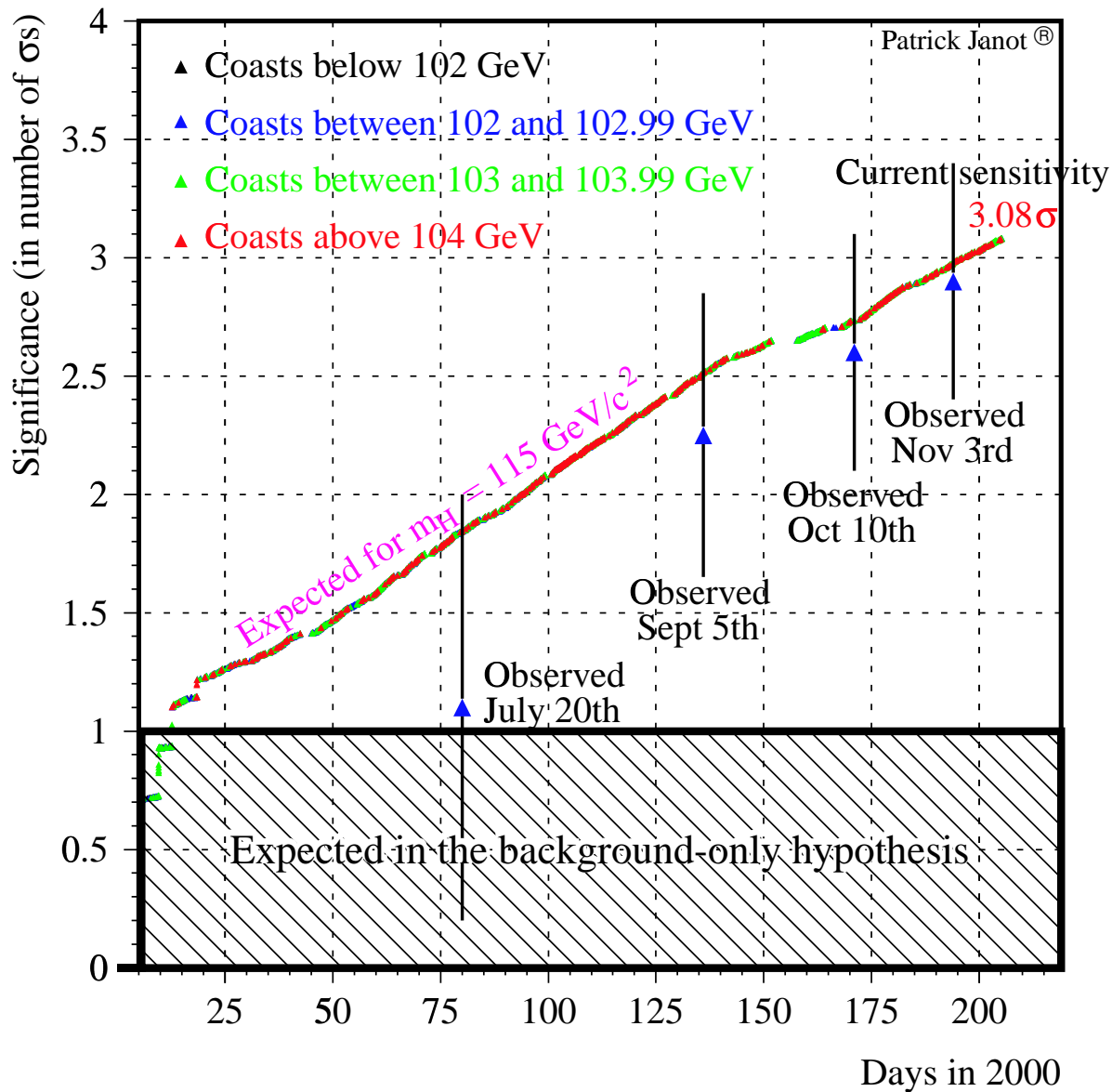


3.2σ 4-Jet Excess in ADLO Data ($1 - CL_b = 7 \cdot 10^{-4}$)

LEP results at $115\text{GeV}/c^2$



Significance for $m_H = 115 \text{ GeV}/c^2$ (02-Nov-2000)



Conclusioni

- In ALEPH entrambe le analisi (tagli e NN) mostrano un eccesso di 3σ rispetto al fondo atteso
- La combinazione dei risultati di LEP mostra un eccesso a 2.6σ
- L'osservazione è compatibile con la produzione di un bosone di Higgs di $114 \text{ GeV}/c^2$ di massa
- Il TEVATRON potrà dirci se è una fluttuazione statistica o...