MEDIDA DE LA POLARIZACIÓN DEL TAU EN EL DETECTOR L3

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(URL: http://wwwae.ciemat.es/~pablog/esp/tesis.html)

1. Introducción: $\sin^2\theta_W \longrightarrow A_p$

2. Método de Análisis: $h(x) = f(A_p)$

3. L3, Identificación y Medida de la Energía:

   $(\mathrm{e},\ \mu,\ \pi,\ \rho)$

4. Análisis. Medida de A_p:

   $\tau \to \mathrm{e}\nu\overline{\nu},\ \tau \to \mu\nu\overline{\nu},\ \tau \to \pi/\mathrm{K}\,\nu,\ \tau \to \rho/\mathrm{K}^*\nu$

5. Resultados y Conclusiones

$$\boxed{\text{ME} \longrightarrow \mathcal{L}\ \text{Inv. Gauge}\ SU(2) \otimes U(1):\ \ g_1,\ g_2}$$

Parámetros:

g_1 y g_2	—	constantes de acoplo del grupo
v	—	valor esperado campo Higgs en vacío
m_f	—	masa de los fermiones
m_H	—	masa del bosón de Higgs
$C.K.M.$	—	ángulos de mezcla de los quarks

$$\boxed{\tan\theta_W \equiv \frac{g_1}{g_2}}$$

(1) relación de masas: $$\sin^2\theta_W = 1 - \frac{M_W^2}{M_Z^2}$$

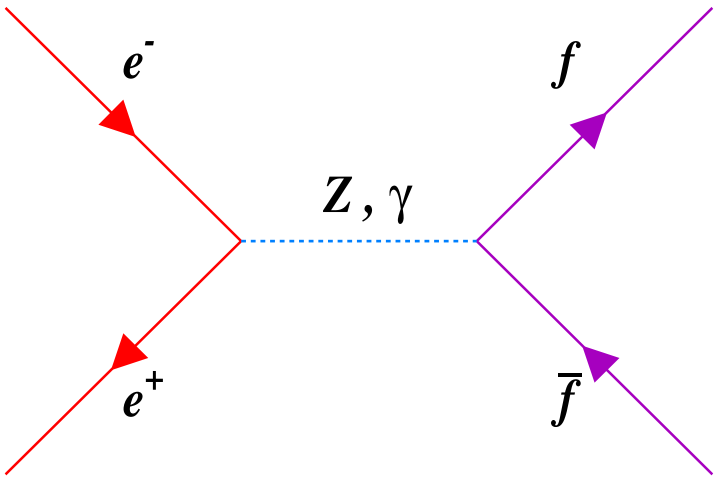
(2) acoplo de bosones cargados: $$\sin^2\theta_W = \frac{\pi\,\alpha}{\sqrt{2}\,G_F\,M_W^2}$$

(3) constantes de acoplo del bosón Z a los fermiones:

$$v_f = \frac{T_3^f - 2\,Q^f\,\sin^2\theta_W}{2\,\sin\theta_W\,\cos\theta_W}$$

$$a_f = \frac{T_3^f}{2\,\sin\theta_W\,\cos\theta_W}$$

LEP



$$\frac{d\sigma}{d\cos\theta} = \frac{\pi\alpha^2}{2s}\left\{\left[G_1^L(s)+G_1^R(s)\right]\cdot(1+\cos^2\theta)+2\left[G_2^L(s)-G_2^R(s)\right]\cdot\cos\theta\right\}$$

donde $\qquad G_i^{L,R} \;\approx\; f(v_f,\; a_f) \;\approx\; f(\sin^2\theta_W)$

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$$\sigma_F(\cos\theta > 0) \neq \sigma_B(\cos\theta < 0)$$

$$\sigma_L(\mathrm{e^+e^-} \to \mathrm{f_L\,\bar{f}_R}) \neq \sigma_R(\mathrm{e^+e^-} \to \mathrm{f_R\,\bar{f}_L})$$

etc. . .

$$\sqrt{s} \approx M_Z$$

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B} = \frac{3}{4}\mathcal{A}_e\mathcal{A}_f$$

$$A_p = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \mathcal{A}_f$$

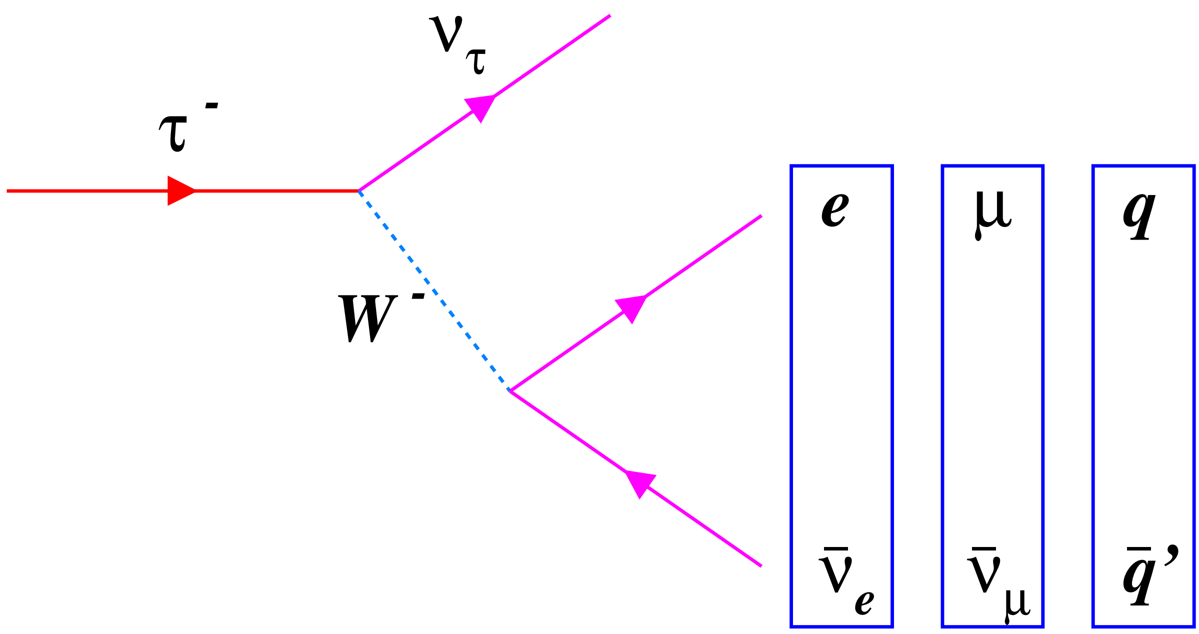
$$A_p^{FB} = \frac{\sigma_F^L - \sigma_F^R - \sigma_B^L + \sigma_B^R}{\sigma_F^L + \sigma_F^R + \sigma_B^L + \sigma_B^R} = \frac{3}{4}\mathcal{A}_e$$

$$\mathcal{A}_f = \frac{C_L^2 - C_R^2}{C_L^2 + C_R^2} = \frac{2\, v_f\, a_f}{v_f^2 + a_f^2} = \frac{2\,(1 - 4\sin^2\theta_W)}{1 + (1 - 4\sin^2\theta_W)^2}$$

$$\Delta(\sin^2\theta_W) = \frac{1}{8}\,\Delta A_p$$

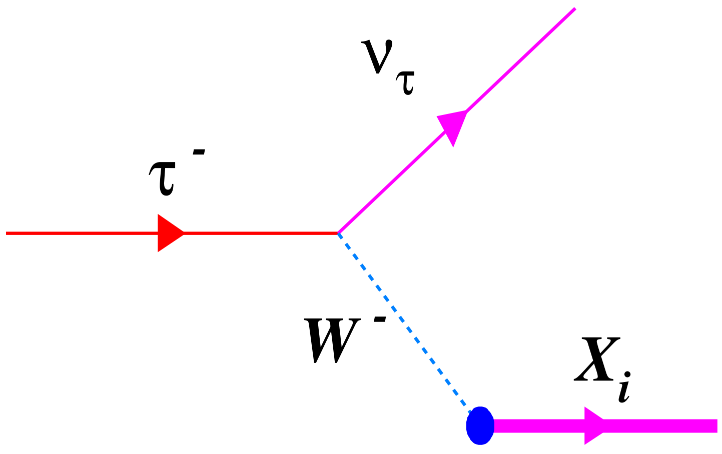
$$e^+e^- \rightarrow \tau^+\tau^-$$

la helicidad del τ es observable a partir del espectro de Energía de sus productos de desintegración



Medida de A_p a partir de las Distribuciones de Energía (τ):

- Distribuciones de Energía
- Efectos del Detector



$$x = \frac{E_i}{E_\tau}$$

$$\frac{dN}{dx} = \sigma_L \cdot \frac{dN^L}{dx} + \sigma_R \cdot \frac{dN^R}{dx}$$

$$\frac{1}{N}\frac{dN}{dx} = h_0(x) + h_1(x) \cdot A_p$$

$$\int_\eta^1 h_0(x)dx = 1 \qquad ; \qquad \int_\eta^1 h_1(x)dx = 0$$

Mesones de espín 0 (π, K) y espín 1 (ρ, K^*, a_1):

$$h_0(x) = \frac{1}{1-\eta} \qquad ; \qquad \eta = \left(\frac{m_i}{m_\tau}\right)^2$$

$$h_1(x) = \frac{1}{1-\eta}\Big[p(\eta) - x \cdot q(\eta)\Big]$$

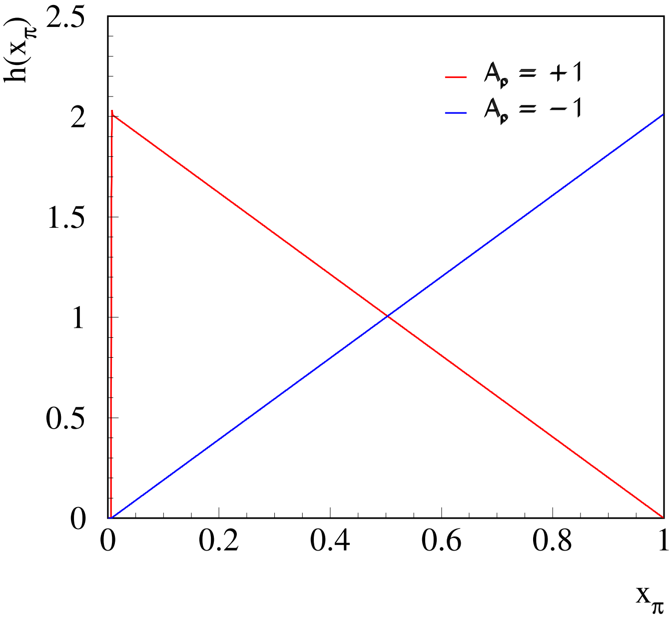
	espín 0	espín 1
$p(\eta)$	$\frac{1+\eta}{1-\eta}$	$\frac{(1-2\eta)(1+\eta)}{1+\eta(1-2\eta)}$
$q(\eta)$	$\frac{2}{1-\eta}$	$\frac{2(1-2\eta)}{1+\eta(1-2\eta)}$

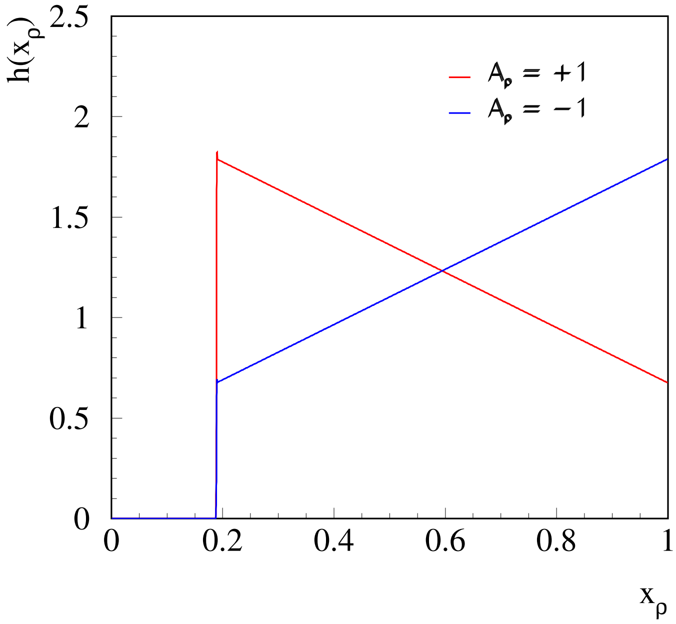
Leptones (e, μ):

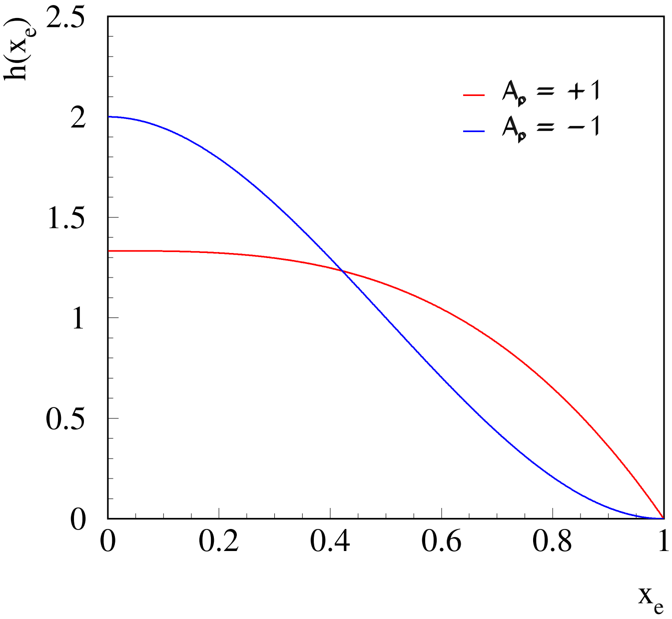
$$\left.\begin{array}{c} h_0(x) \\ \\ h_1(x) \end{array}\right\} \sim f\big(P_3(x)\ ;\ m_l\big)$$

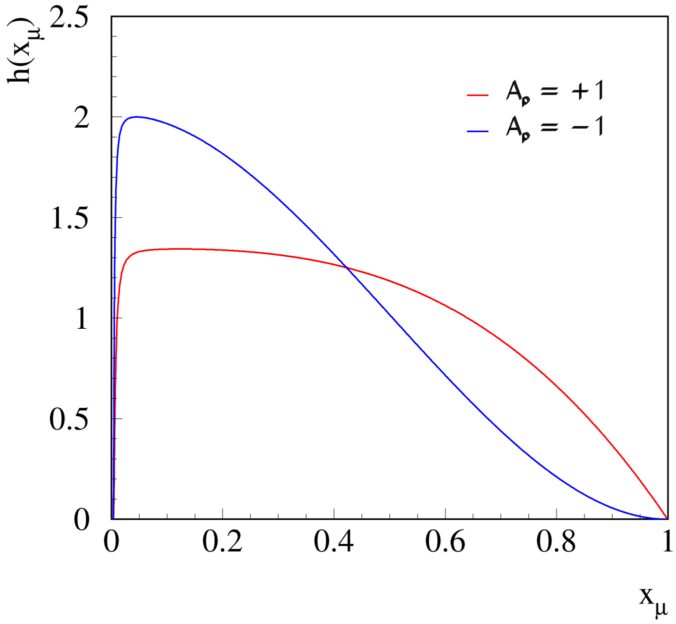
Espectros a Orden Cero

$\tau \rightarrow \pi\nu$ $\tau \rightarrow \rho\nu$

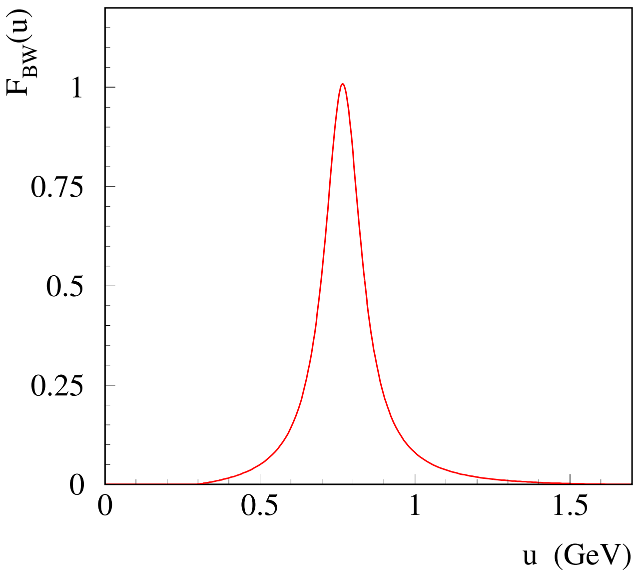






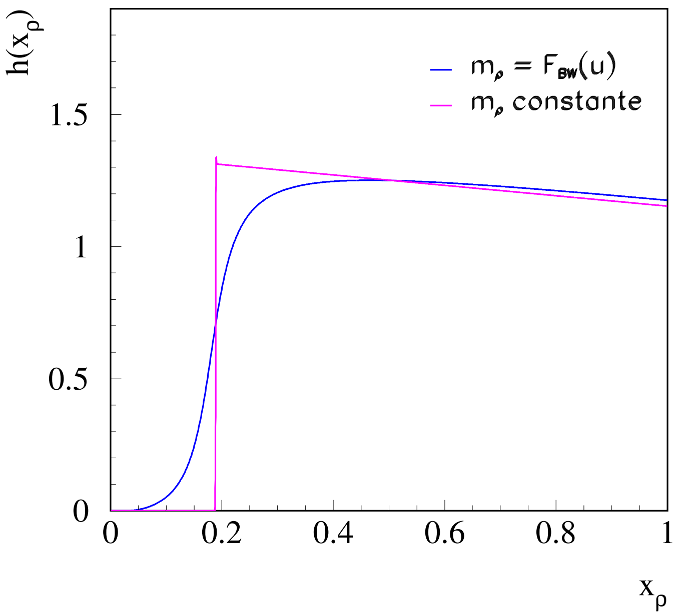


$\tau \rightarrow e\nu\overline{\nu}$ $\tau \rightarrow \mu\nu\overline{\nu}$



$$h(x) = \int_{u_{min}}^{m_\tau\sqrt{x}} du \cdot F_{BW}(u) \cdot h(x, \eta(u))$$

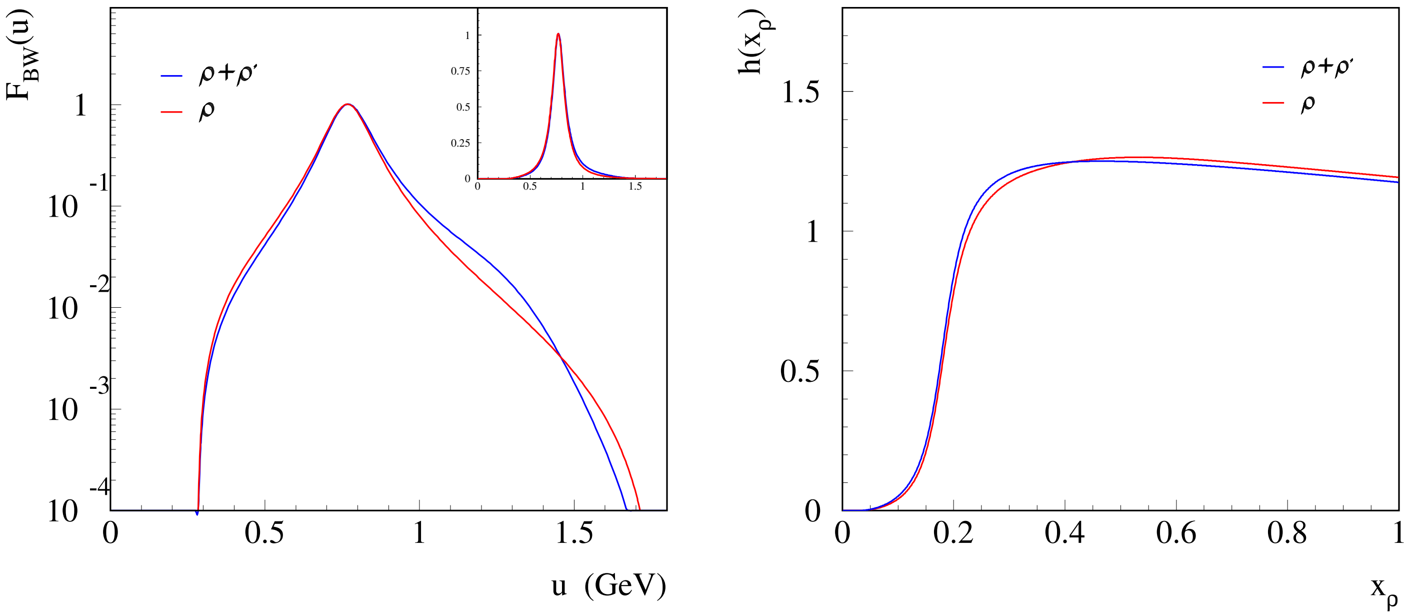
donde $\eta(u) = \left(\frac{u}{m_\tau}\right)^2$ y $F_{BW}(u) \propto \left[R_V^2(u) + C_V^2(u)\right] \cdot g(u)$



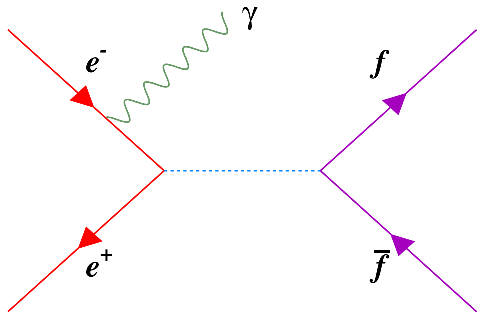
$$R_V(u) \equiv \frac{m_V^2(m_V^2 - u^2)}{(m_V^2 - u^2)^2 + u^2\Gamma_V^2(u)}$$

$$C_V(u) \equiv \frac{m_V^2\Gamma_V^2(u)}{(m_V^2 - u^2)^2 + u^2\Gamma_V^2(u)}$$

$$R_V^2(u) + C_V^2(u) \quad \Longrightarrow \quad \frac{\left[R_\rho^2(u) + \phi \cdot R_{\rho'}^2(u)\right]^2 + \left[C_\rho^2(u) + \phi \cdot C_{\rho'}^2(u)\right]^2}{1+\phi}$$

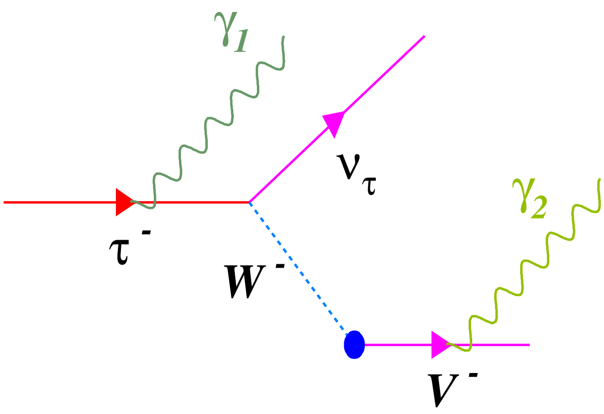


ISR



$$\text{Emisión } \gamma \implies \sqrt{s'} < \sqrt{s} \quad (\sin \gamma)$$

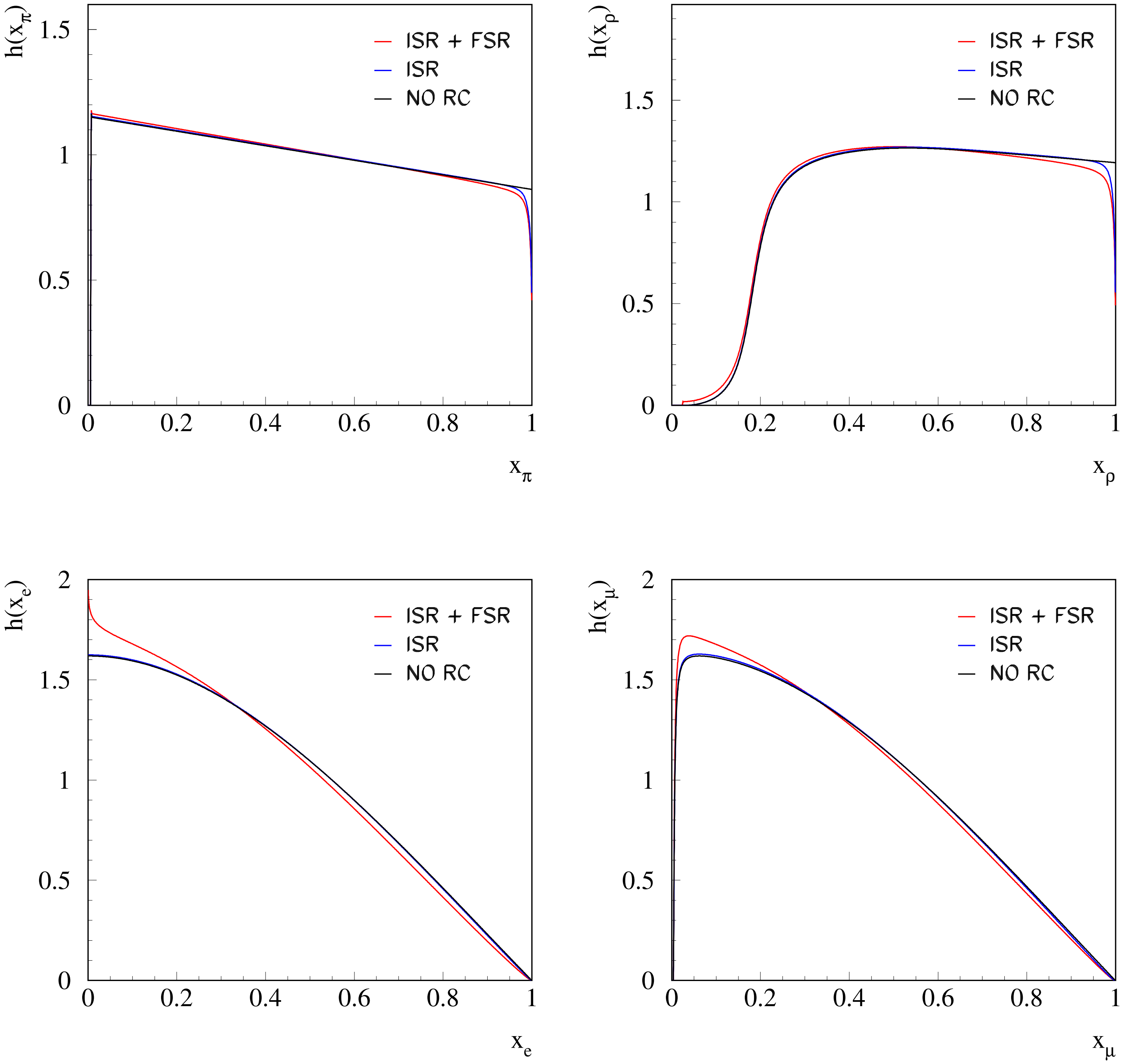
FSR



$$E_V = E_V^0 - E_{\gamma_1} - E_{\gamma_2}$$

Correcciones Radiativas

$\tau \to \pi\nu$ $\tau \to \rho\nu$



$\tau \to e\nu\overline{\nu}$ $\tau \to \mu\nu\overline{\nu}$

- Aceptancia: $h(x) \longrightarrow h(x) \cdot A(x)$

- Resolución: $h(x) \longrightarrow h(x) \cdot A(x) \cdot R(x, x')$

- Calibración: $x' \longrightarrow x' + \Delta x$

$$\mathcal{L} = R \prod_{i=1}^{N} \rho(x_i) \qquad ; \qquad \rho(x) = f(x, A_p)$$

$$\rho(x) = \alpha \cdot \rho^{d}(x) + (1 - \alpha) \cdot \rho^{bg}(x)$$

Señal

$$\rho^{d}(x) = \tilde{h}^{d}(x) = h_0^{d}(x) + h_1^{d}(x) \cdot A_p$$

Contaminación

$$\rho^{bg}(x) = g_0 \, \rho_{\tau}^{bg}(x) + \sum_{i=1}^{B} g_i \, \rho_i^{bg}(x) \qquad ; \qquad \sum_{i=0}^{B} g_i = 1$$

	π	ρ	e	μ
Orden cero	1.00	0.45	0.39	0.39
ISR, FSR	1.00	0.44	0.37	0.38
Aceptancia	0.98	0.43	0.37	0.38
Resolución	0.91	0.41	0.37	0.37

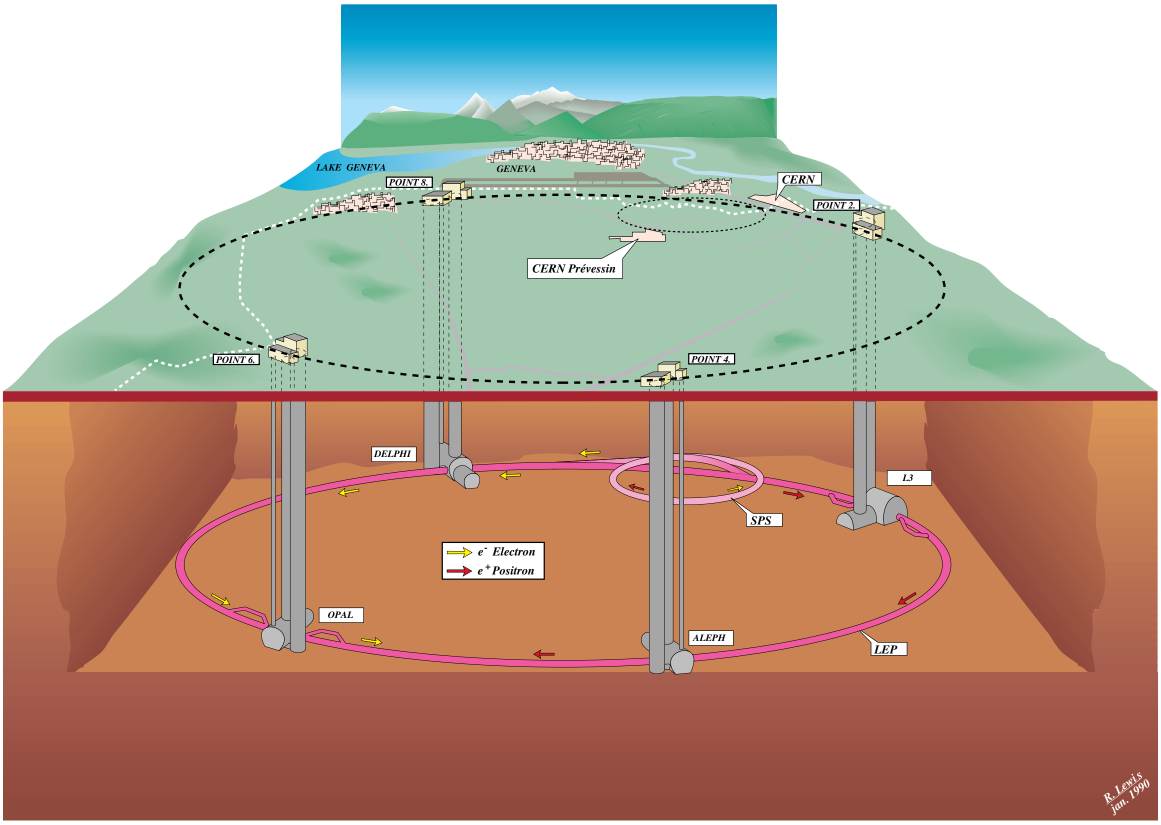
	π	ρ	e	μ
Abundancia Relativa	1.00	0.91	0.67	0.65

L3, Identificación y Medida de la Energía:

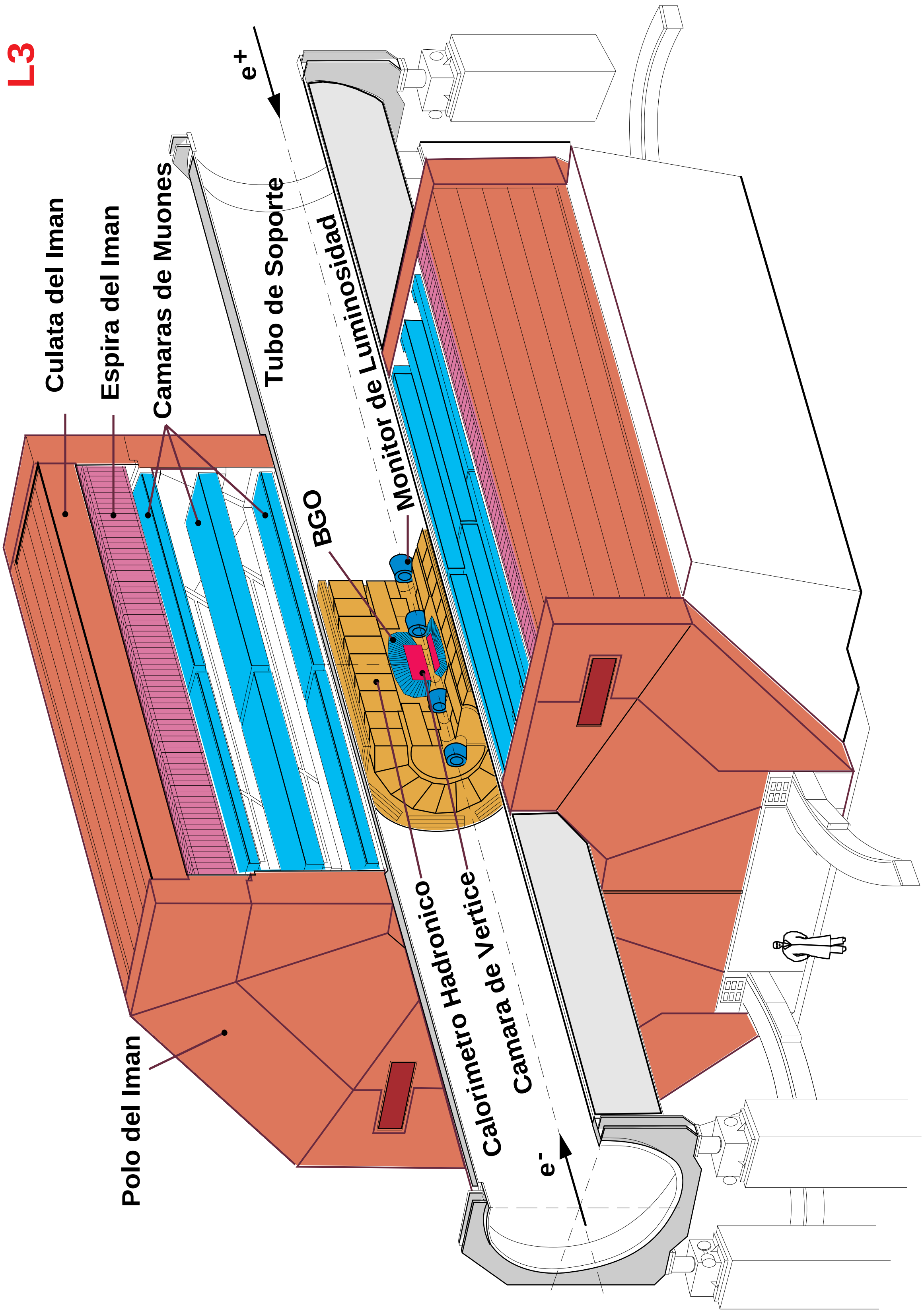
(e, μ, π, ρ)

$$e^+e^- \to f\,\bar{f} \qquad ; \qquad \sqrt{s} \sim M_Z$$

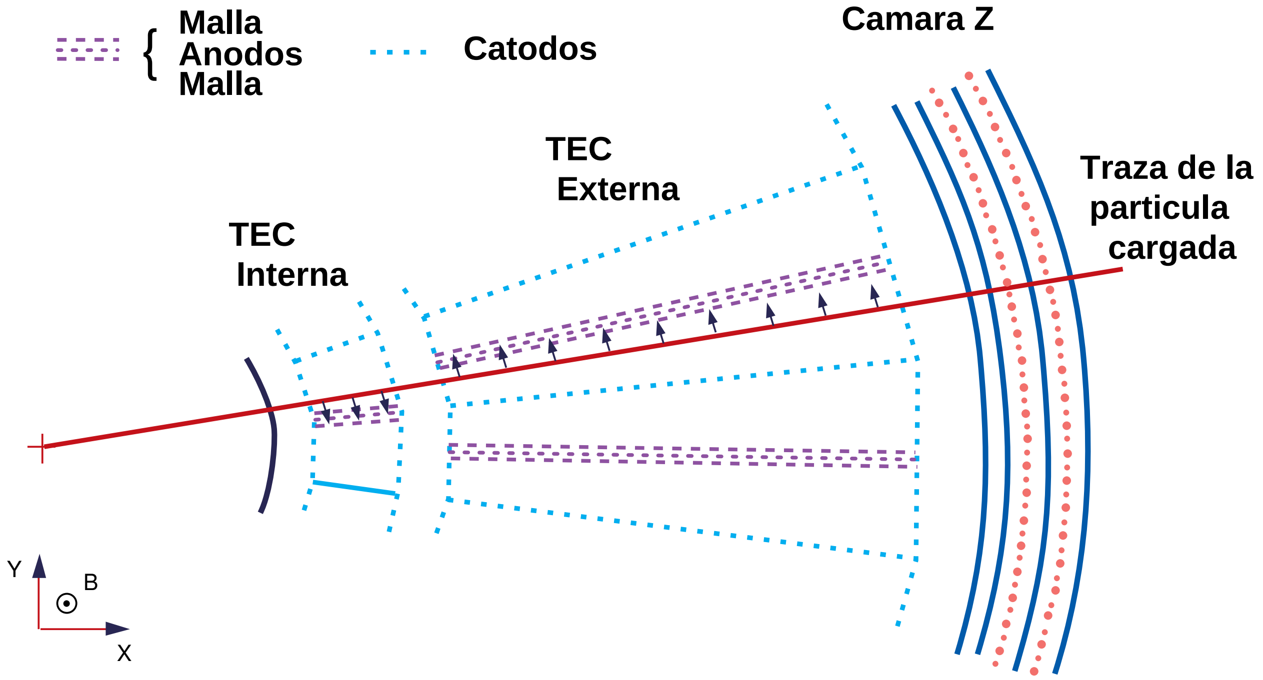
Aleph, Delphi, Opal, L3



	Luminosidad (pb^{-1})				
$\sqrt{s}$ (GeV)	1991	1992	1993	1994	Total
88.5	0.8	–	–	–	0.8
89.4	0.9	–	8.6	–	9.5
90.2	0.8	–	–	–	0.8
91.2	8.6	22.7	15.7	49.6	96.6
92.0	0.7	–	–	–	0.7
93.0	0.8	–	8.8	–	9.6
93.7	0.8	–	–	–	0.8
Total	13.4	22.7	33.1	49.6	118.8


L3
e+
Culata del Iman
Espira del Iman
Camaras de Muones
Tubo de Soporte
Monitor de Luminosidad
BGO
Calorimetro Hadronico
Camara de Vertice
e-
Polo del Iman

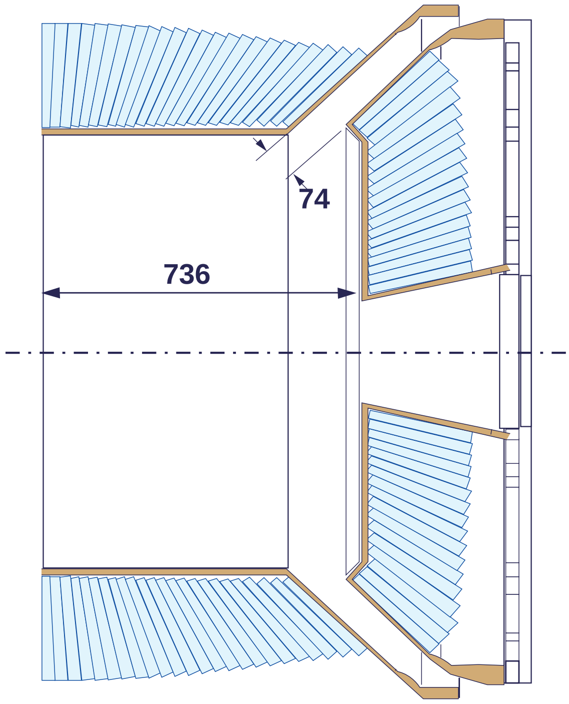
Cámara de Vértice



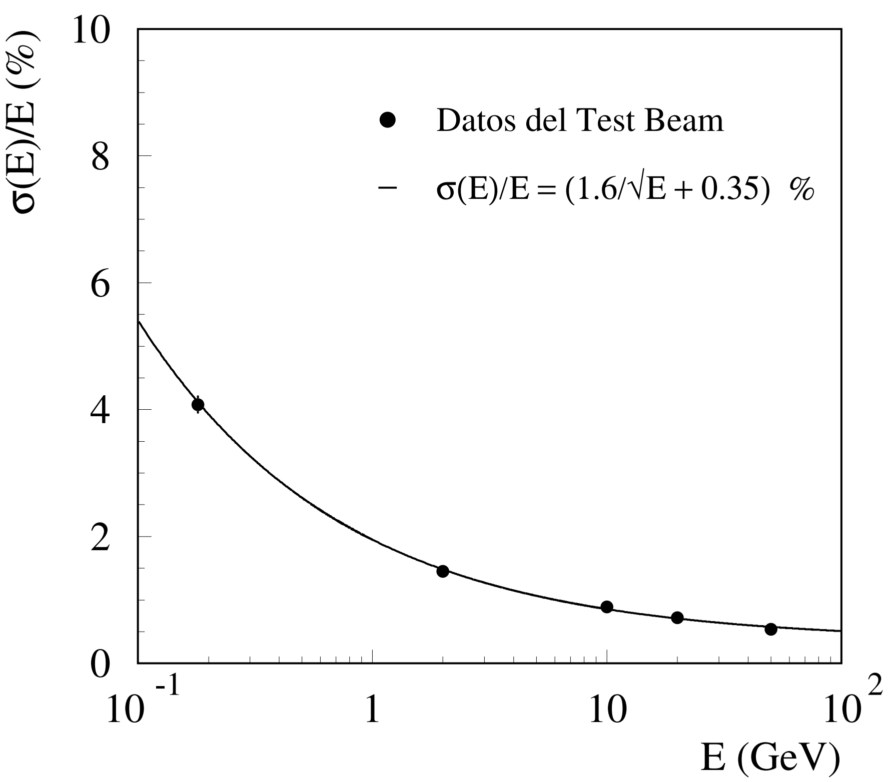
$\longleftarrow$ 37cm $\longrightarrow$

$$e^+e^- \rightarrow \mu^+\mu^- \quad \Longrightarrow \quad \sigma(1/\mathrm{p_t}) = 0.022\ \mathrm{GeV}^{-1}$$

Vértice del Suceso: $\begin{cases} 30\ \mu\mathrm{m(xy)} \\ 1\ \mathrm{mm}(z) \end{cases}$

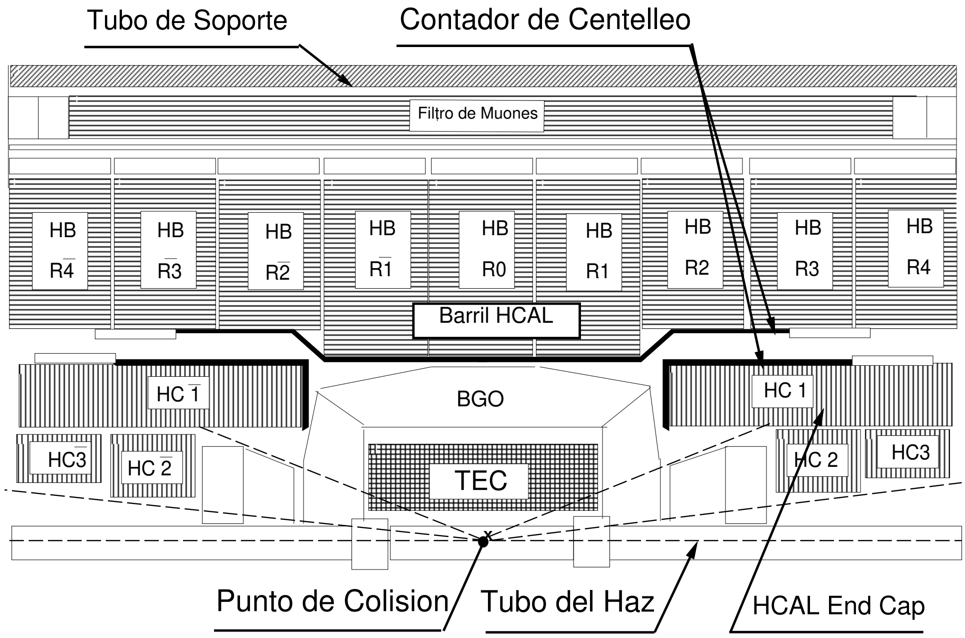


Propiedades del BGO	
Densidad	7.13 $\mathrm{g/cm^3}$
Longitud de Radiación	1.12 cm
Longitud de Interacción	22 cm
Radio de Molière	2.3 cm
$dE/dx \quad (mip)$	9 MeV/cm

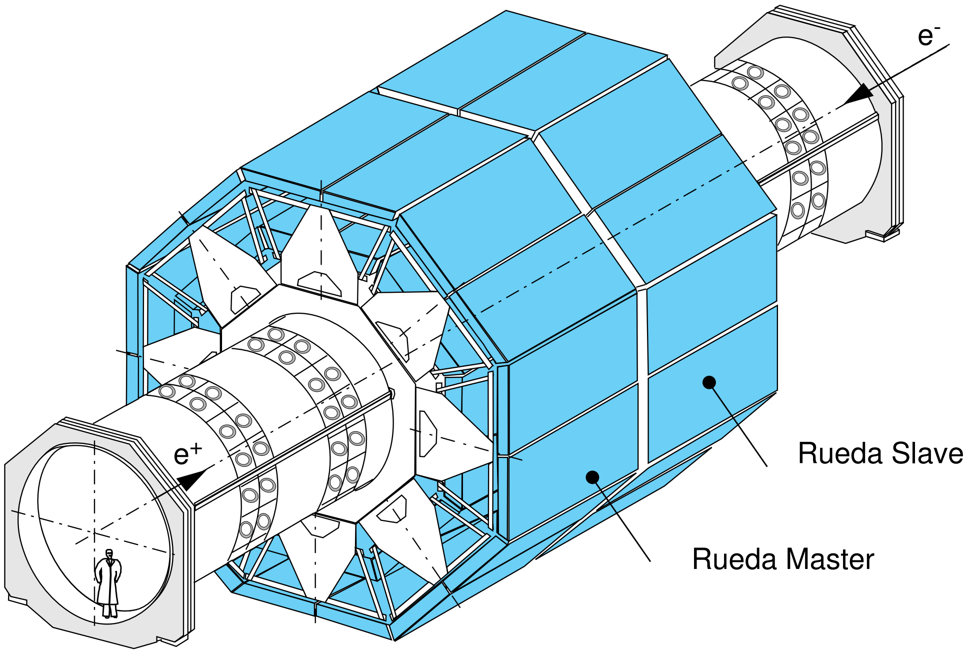


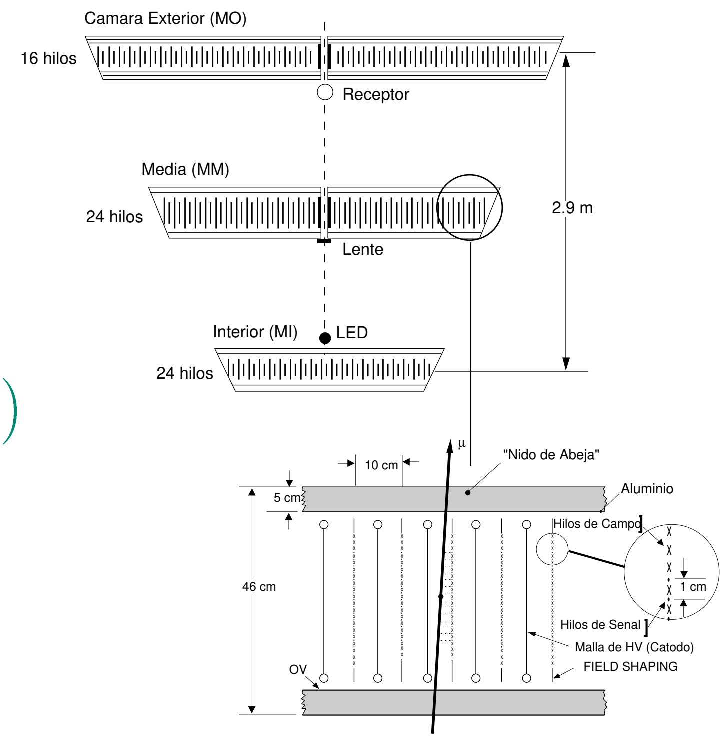
$$\frac{\sigma(E)}{E} \approx 1\%$$

$$(E \approx 45 \text{ GeV})$$



Test Beam: $\frac{\sigma(E)}{E} \approx 5\% + \frac{55\%}{\sqrt{E}}$; E *en* GeV

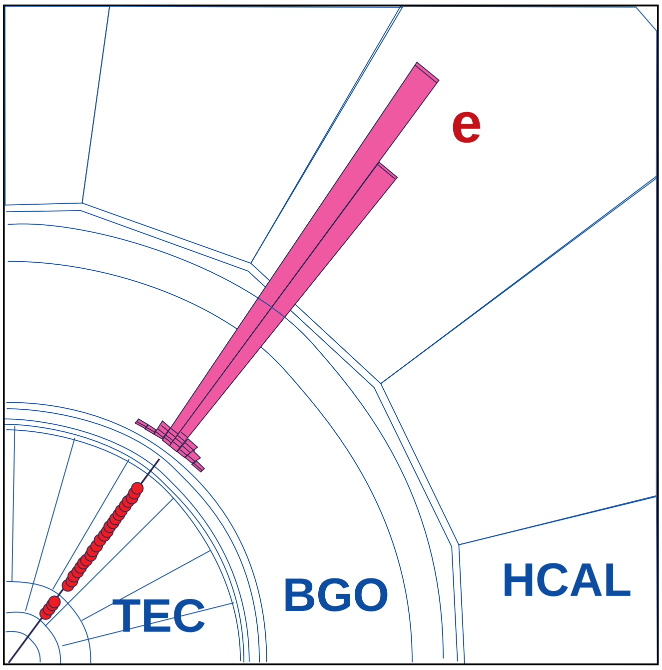




$$\sigma \approx 200\ \mu\text{m/hilo}$$

$$\frac{\Delta p}{p} \approx 2.5\% \quad (p \approx 45\ \text{GeV})$$

$$\sigma_Z \approx 500\ \mu\text{m}$$

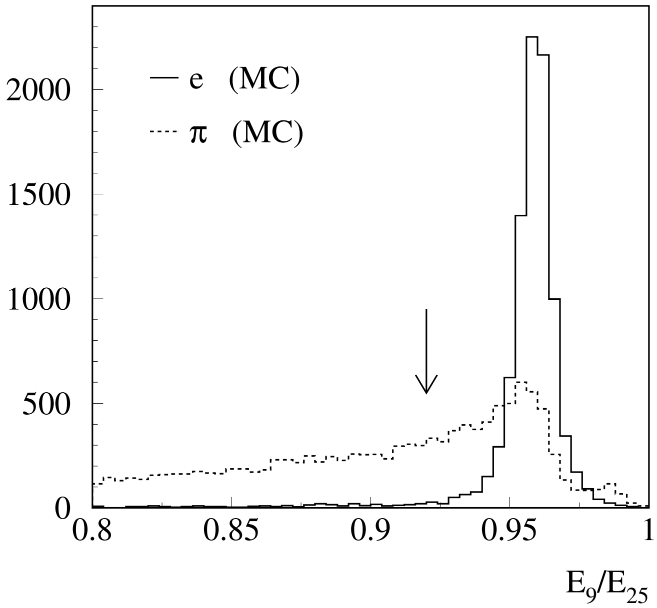


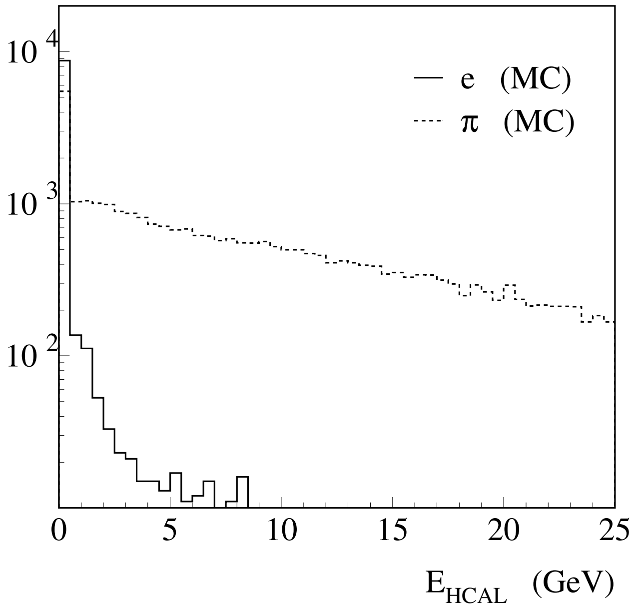
* TEC + BGO
* Cascada muy colimada

  $(E_9/E_{25},\ \chi^2_{e.m.})$
* TEC y BGO *matching*

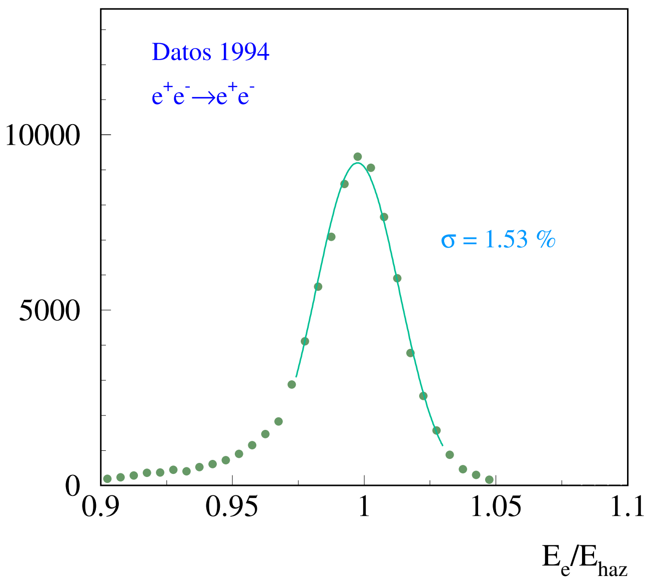
  (energía y angular)

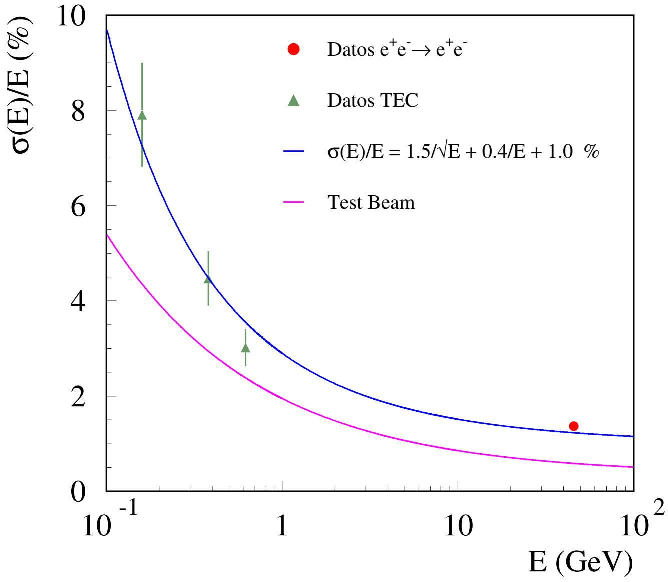
$\epsilon \approx 95\%$ $\qquad$ E_e medida en el BGO



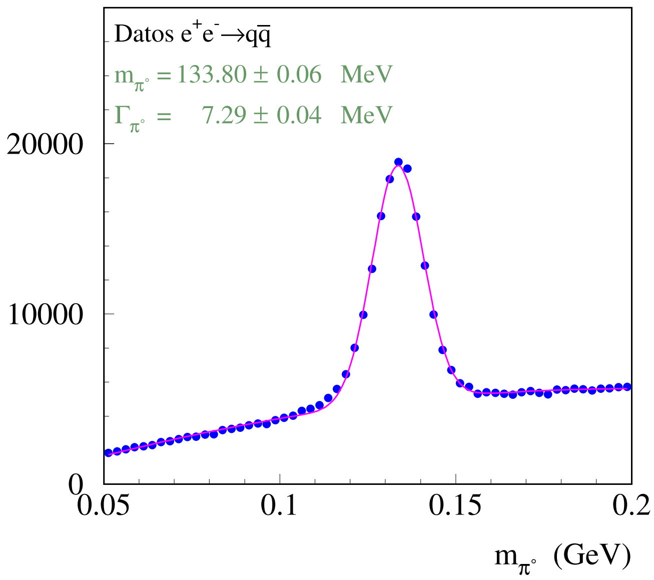


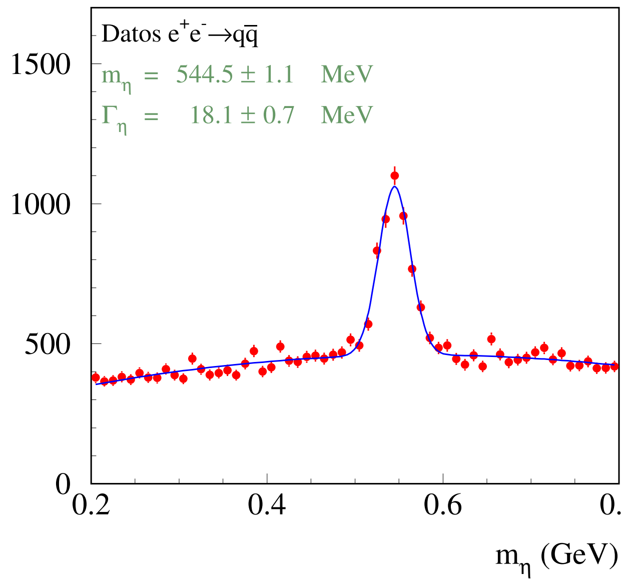
Calibración de E_e



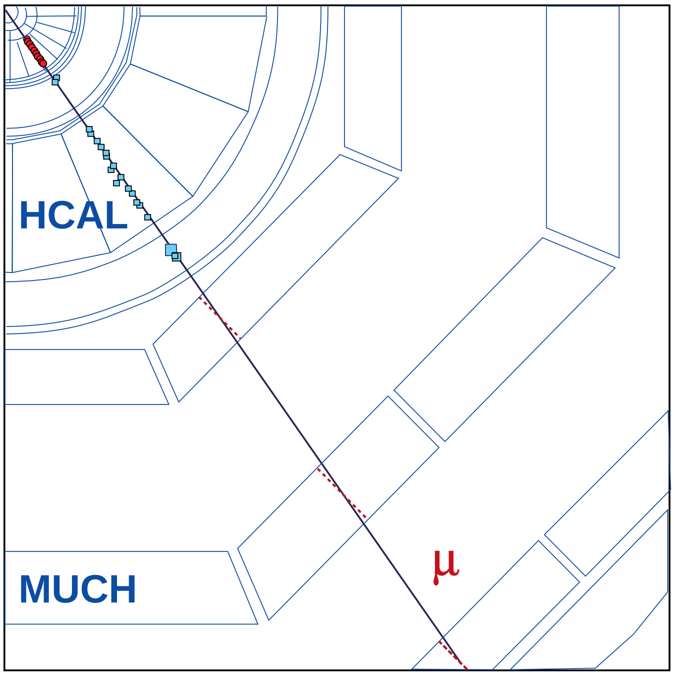


$$\frac{\sigma(E)}{E} = \frac{0.015}{\sqrt{E}} + \frac{0.004}{E} + 0.01 \qquad \text{(E en GeV)}$$



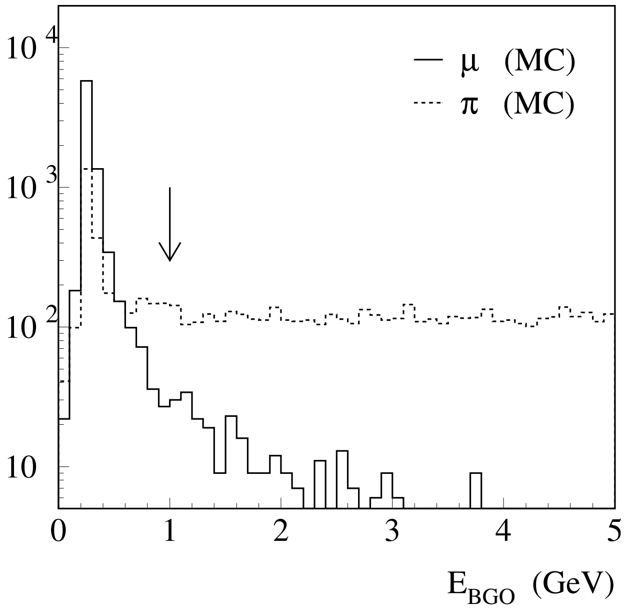


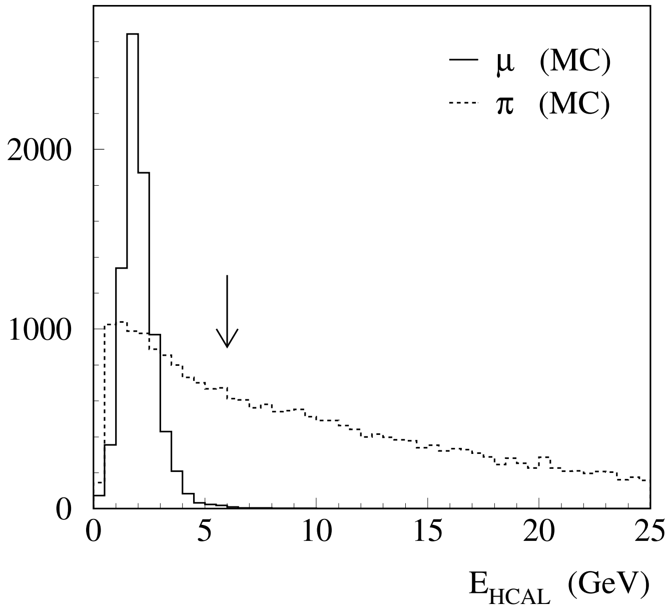
- $E_e \approx 45$ GeV : $\mathrm{e}^+\mathrm{e}^- \to \mathrm{e}^+\mathrm{e}^-$ $\Longrightarrow$ $\pm\, 0.1\,\%$
- $E_e < 500$ MeV : TEC, m_{π^0}, m_η $\Longrightarrow$ $\pm\, 1\ \ \%$

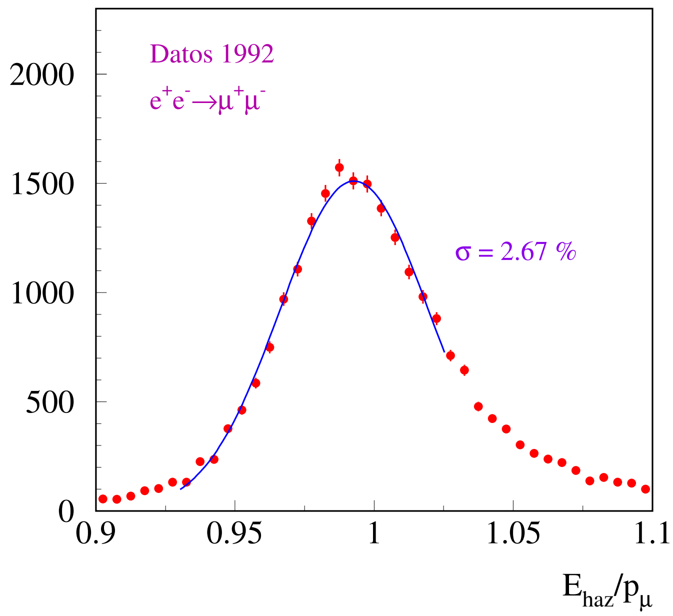


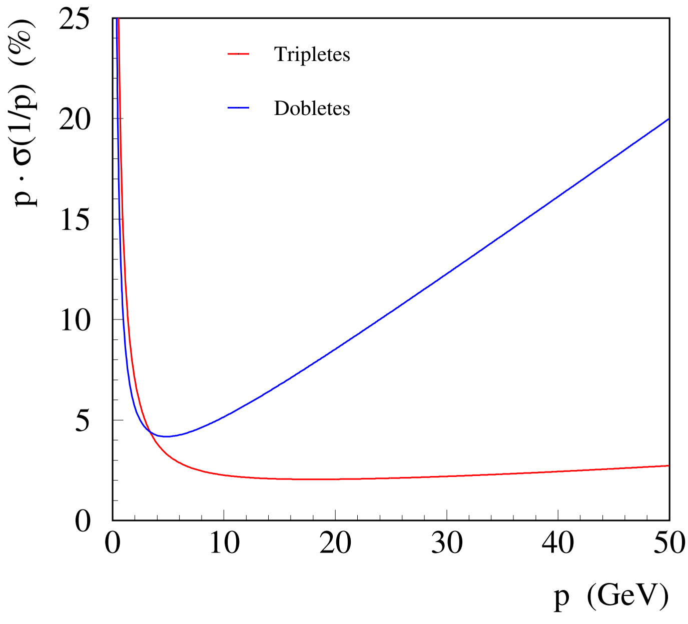
* TEC + MUCH
* Traza en las Cámaras de muones (Tripletes, Dobletes)
* *mip* en el BGO y HCAL
* dca_μ, Δt_{sc}

$\epsilon \approx 99\%$ $\qquad$ P_μ medido en MUCH



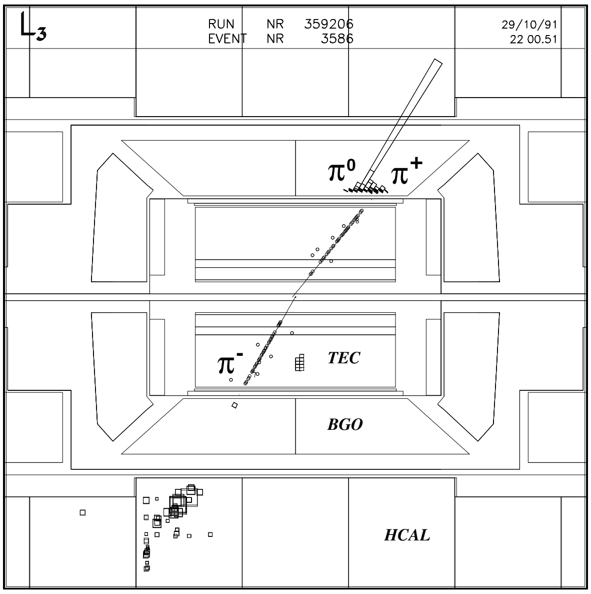






$$\frac{\sigma(1/p)}{1/p} = \sqrt{A^2 \cdot p^2 \cdot \sin^2\theta + B^2 + \frac{C^2}{p^2 \cdot \sin^2\theta}}$$

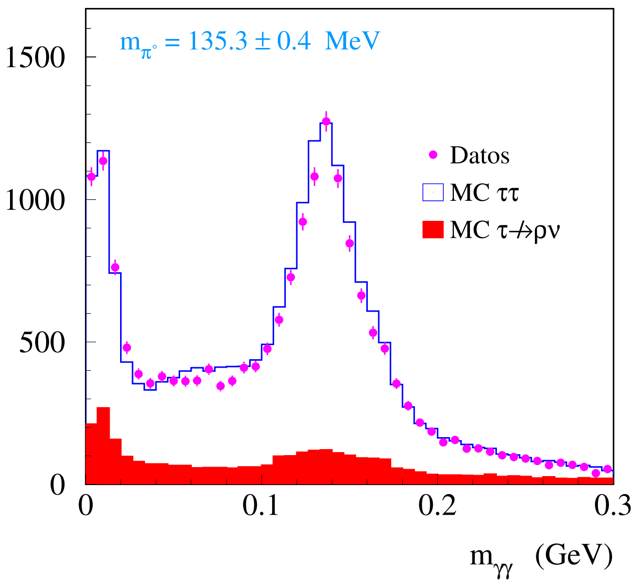
- $P_\mu \approx 45$ GeV: $e^+e^- \to \mu^+\mu^- \Longrightarrow \pm\, 0.2\%$
- bajo P_μ: HCAL $\Longrightarrow \pm\, 1\%$



* TEC + HCAL (BGO)
* Ni electrón ni muón
* ¿ π/K, ρ/K^* ? (dE/dx)
* $\pi^0 \Longrightarrow$ reconstrucción clusters neutros

$\epsilon_{\pi/\mathrm{K}} \approx 90\%$: $\nexists \pi^0$ o neutros

$\epsilon_{\rho/\mathrm{K}^*} \approx 85\%$: $\exists \pi^0$ en 40 MeV

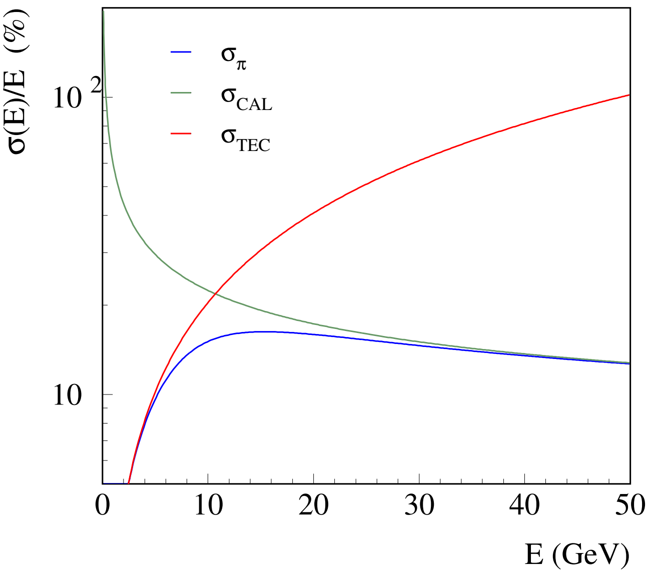


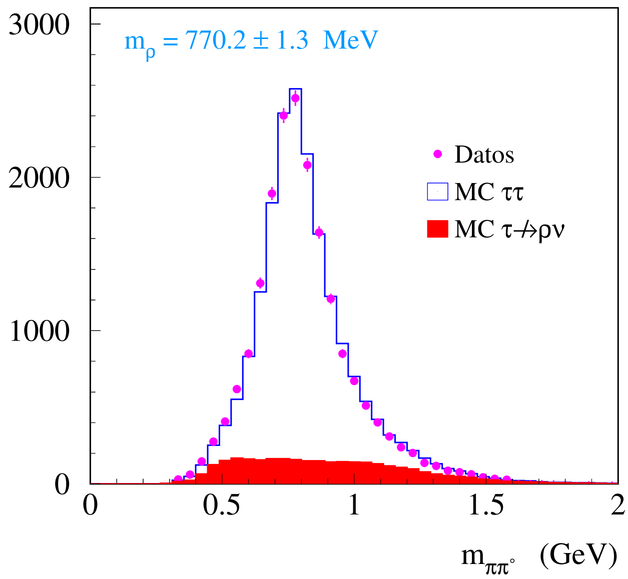
Resolución en E_π y E_ρ

π

$$E_{\pi^\pm} \sim E_{cal} \quad ; \quad E_{\pi^\pm} \sim \chi^2(E_{cal}, P_{tec})$$

$$\frac{1}{\sigma^2(E_{\pi^\pm})} = \frac{1}{\sigma_E^2} + \frac{1}{\sigma_P^2}$$



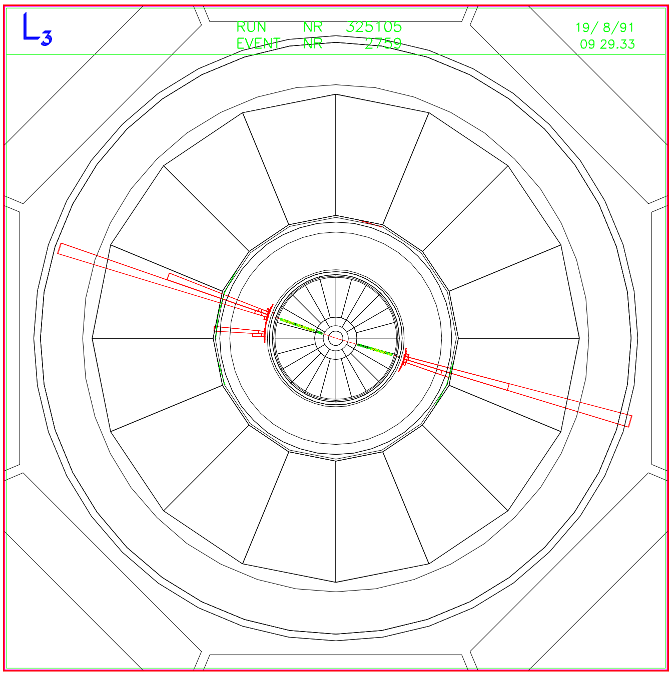


ρ

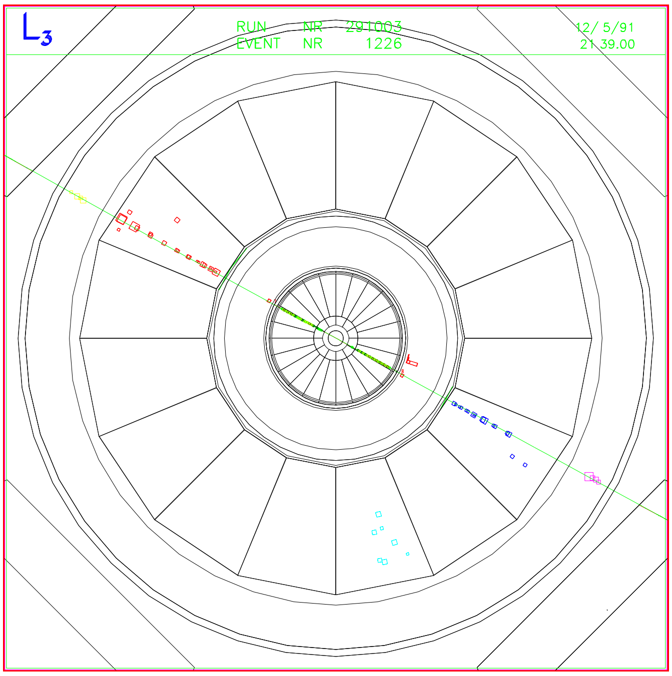
$$E_\rho = E_{\pi^\pm} + E_{\pi^0}$$

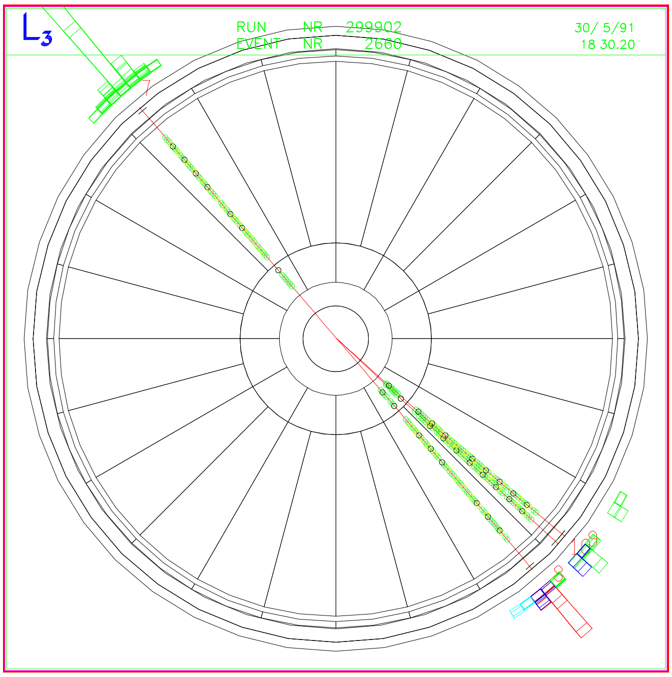
$\star$ Escala: 1.5 % en E_{cal}

$e^+e^- \rightarrow e^+e^-\gamma$

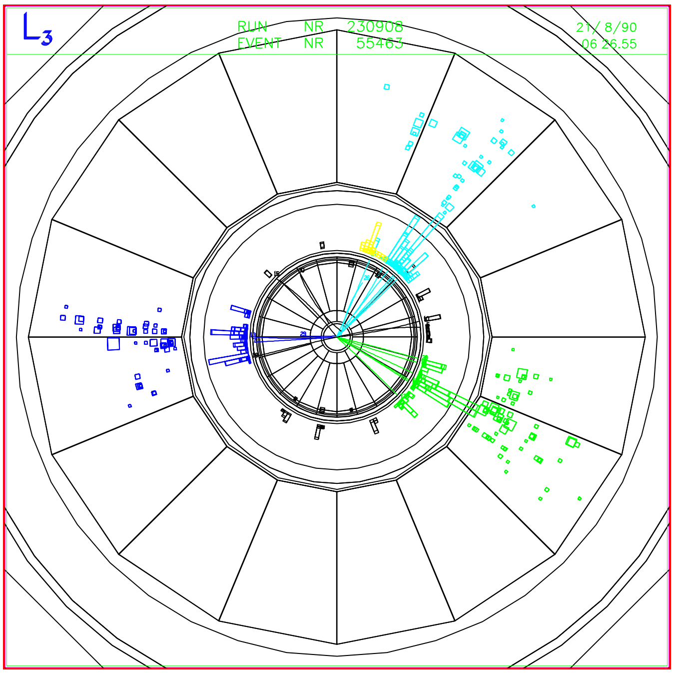


$e^+e^- \rightarrow \mu^+\mu^-\gamma$





$e^+e^- \rightarrow \tau^+\tau^-$



$e^+e^- \rightarrow$ hadrones

$$e^+e^- \rightarrow l^+l^- \quad \Longrightarrow \quad \text{Eficiencia} \approx 99\%$$

- Datos '91–'94 tomados con L3, $\mathcal{L} = 118.8\ \mathrm{pb}^{-1}$, $\sqrt{s} \sim M_Z$ hemos identificado las muestras de e, μ, π/K y ρ/K*.

- Eficiencia de preselección de $\mathrm{e}^+\mathrm{e}^- \to \mathrm{l}^+\mathrm{l}^-$: $\epsilon \approx 99\ \%$

- A partir de $\mathrm{e}^+\mathrm{e}^- \to \mathrm{l}^+\mathrm{l}^-$:

Datos		MC $\mathrm{e}^+\mathrm{e}^- \to \tau^+\tau^-$	
partícula	candidatos	eficiencia (%)	pureza (%)
e	280 074	95	13
μ	185 219	99	19
π/K	42 625	87	50
ρ/K*	46 424	84	88

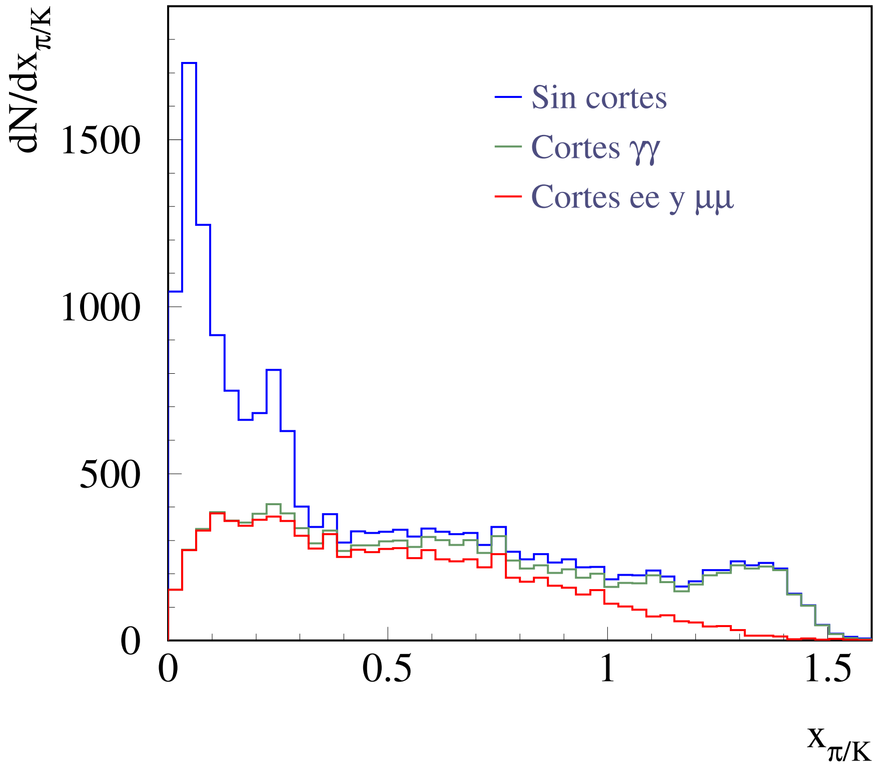
Análisis. Medida de A_p:

- $\tau \rightarrow \pi/\mathrm{K}\,\nu$
- $\tau \rightarrow \rho/\mathrm{K}^*\nu$
- $\tau \rightarrow \mathrm{e}\nu\overline{\nu}$
- $\tau \rightarrow \mu\nu\overline{\nu}$

Canal $\tau \to \pi/\mathrm{K}\,\nu$

40 000 candidatos

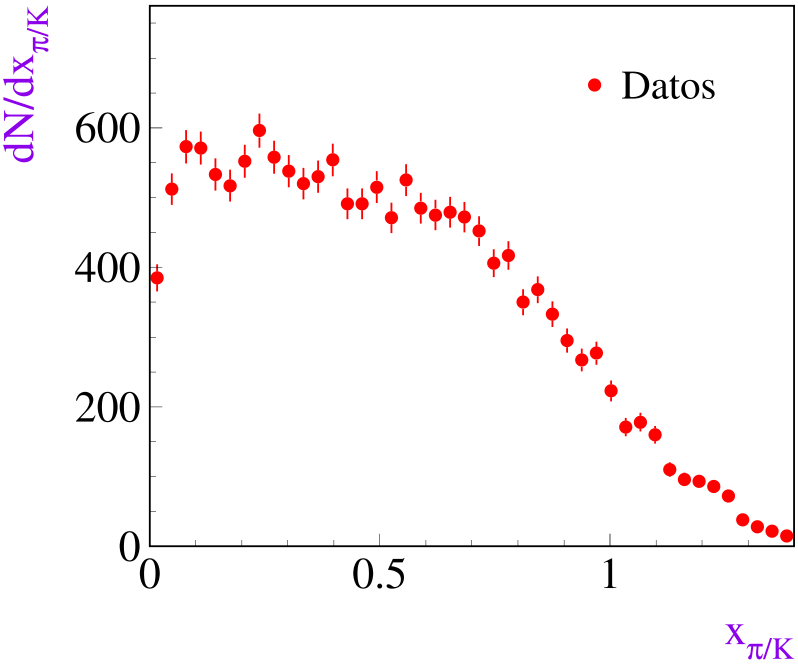
($\approx$ 20 000 $\tau \to \pi/\mathrm{K}\,\nu$)



- $E_{e2} < 40$ GeV
- $E_{\mu 2} < 40$ GeV
- $E_{bgo} < 0.65\,\sqrt{s}$
- $|E_T^1 - E_T^2| > 1$ GeV

y si $\exists$ 2 trazas μ:

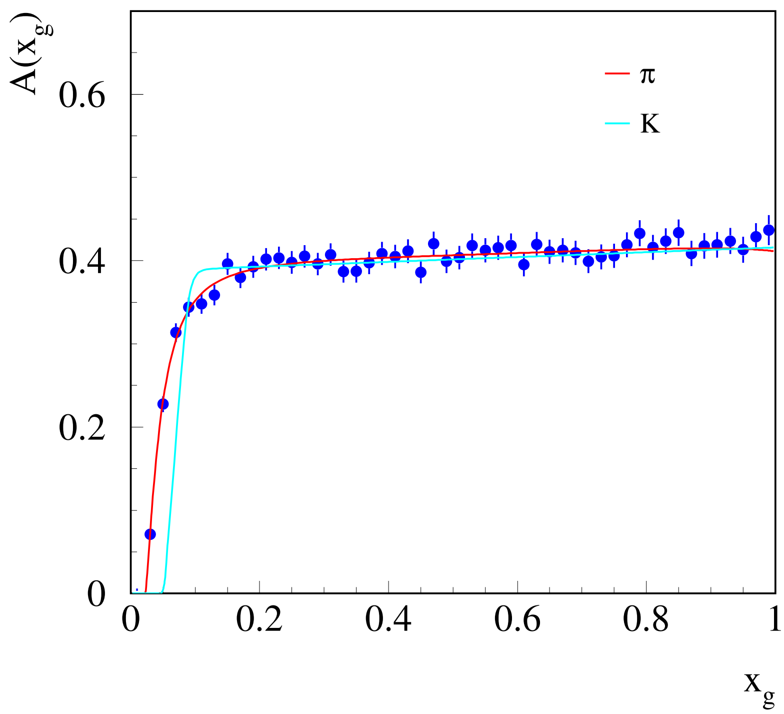
- $E_{bgo}^{1,2} > 2$ GeV
- $E_{hcal}^{1,2} > 5$ GeV



$\#\tau \to \pi/\mathrm{K}\,\nu = 15\,433$

Pureza $\approx$ 87 %

$\delta A_p = \pm\ 0.006$



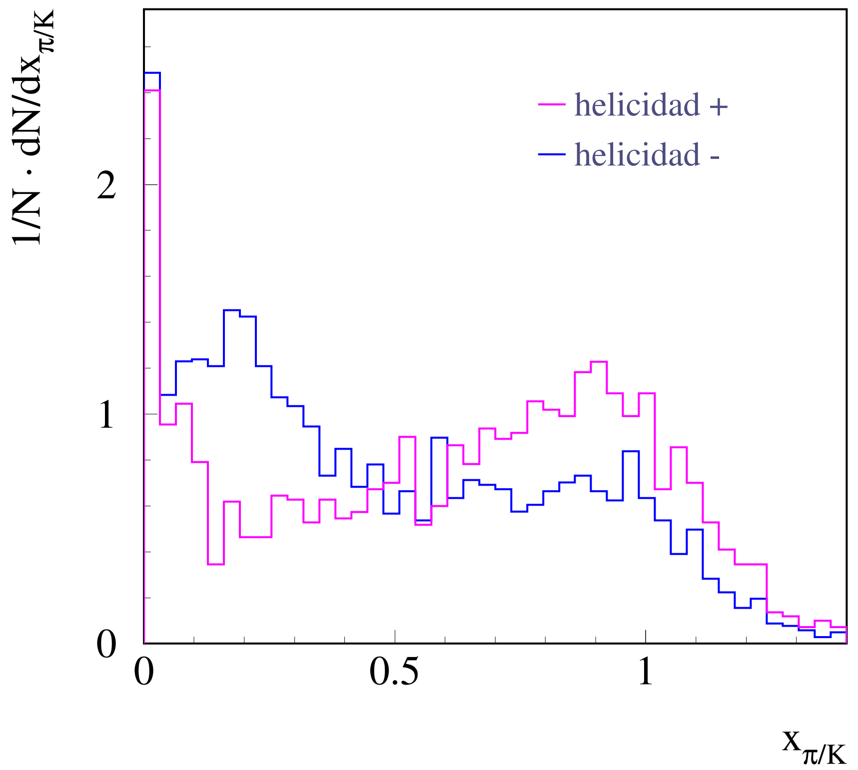
* $\tau \not\to \pi/\mathrm{K}\,\nu$

- $\mathrm{e^+e^-} \to \mathrm{e^+e^-}$
- $\mathrm{e^+e^-} \to \mu^+\mu^-$
- Sucesos de 2 fotones

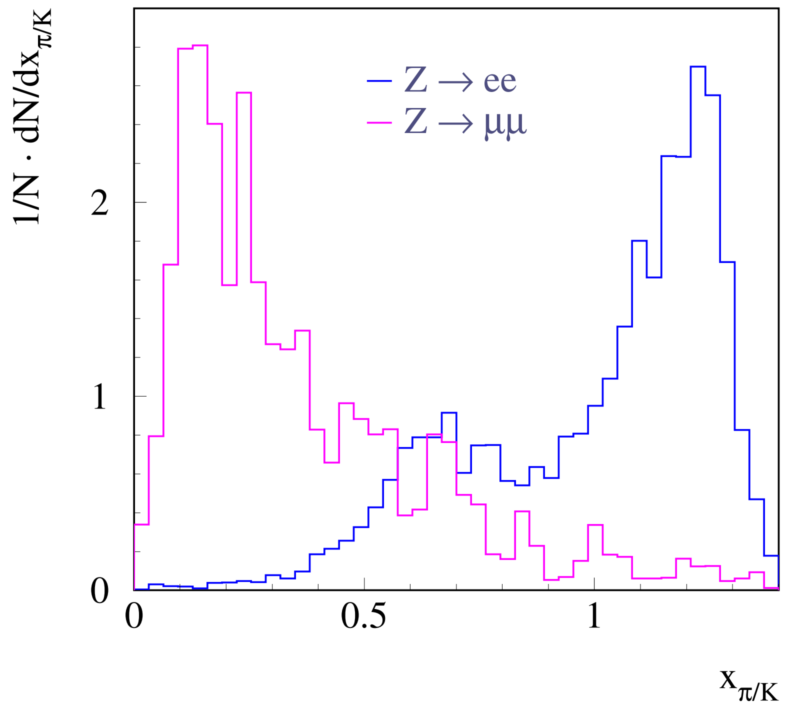
□ cósmicos, haz–gas

— g_i , $\rho_i^{bg}(x)$ —

$$\tau \not\to \pi/\mathrm{K}\,\nu : \qquad \tau \to \rho\nu, \quad \tau \to \mathrm{a}_1\nu$$

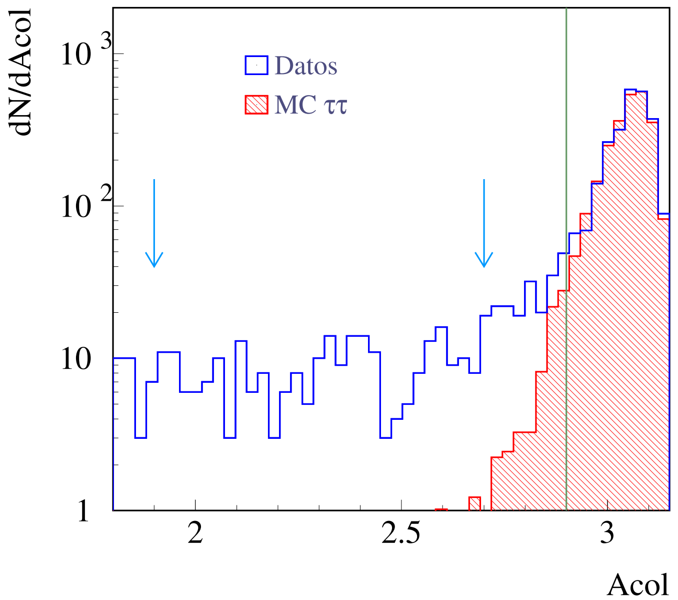


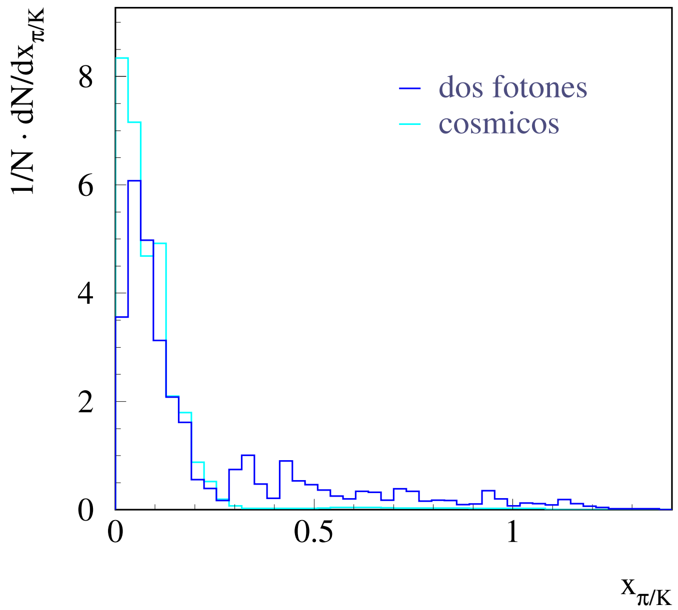
- proporción ≈ 9.1 %
- $\delta A_p = 0.005$



- Datos
- proporción ≈ 3 %
- $\delta A_p(est) = \pm\ 0.008$

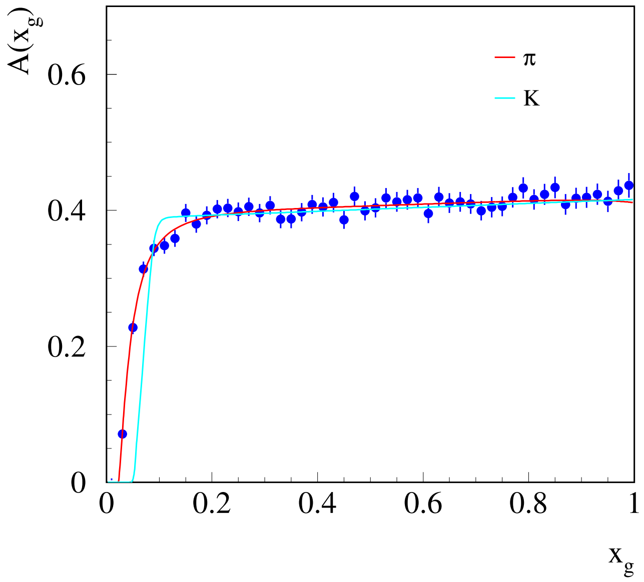
⋆ $1.9 \text{ rad} < Acol < 2.7 \text{ rad}$

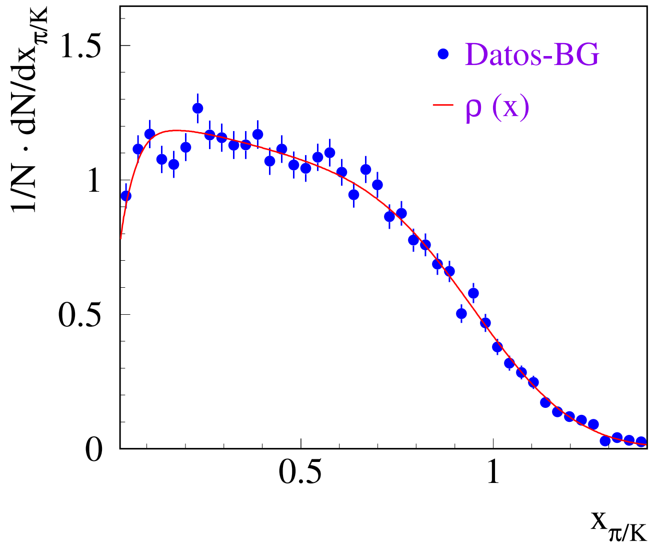




- dos fotones ≈ 0.8 %
- cósmicos ≈ 0.5 %
- $\delta A_p < 0.001$

15 433 π/K





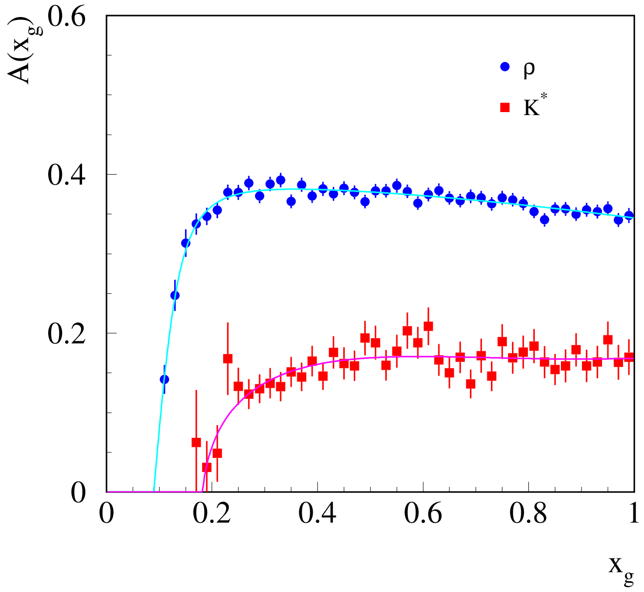
Período	A_p	% BG Total	χ^2/dof
1991	0.167 ± 0.065	13.2 ± 0.6	$39/42$
1992	0.107 ± 0.042	12.9 ± 0.4	$94/43$
1993	0.095 ± 0.042	13.3 ± 0.4	$79/43$
1994	0.180 ± 0.029	13.9 ± 0.3	$58/43$

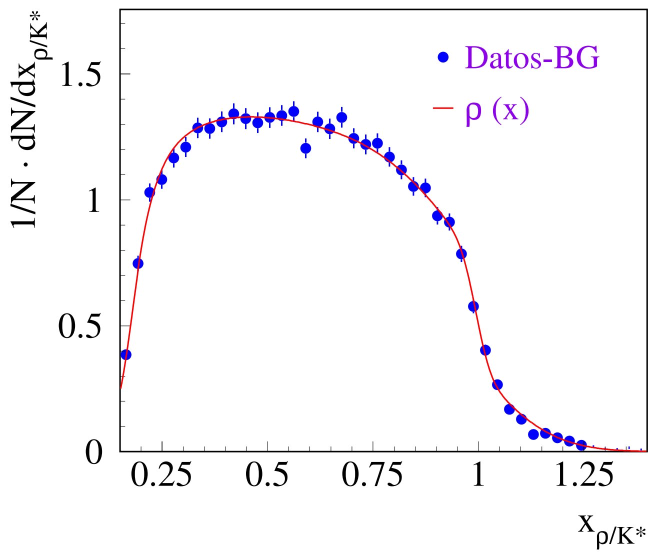
$$\boxed{A_p = 0.143 \pm 0.020 \pm 0.016}$$

fuente	σ
Selección y aceptancia	0.006
Contaminación	0.005
Resolución	0.002
Calibración	0.012
Espacio de Fases	0.004
Anchuras Parciales	0.005

Resultados con $\tau \to \rho/K^*\nu$

31 025 ρ/K^*



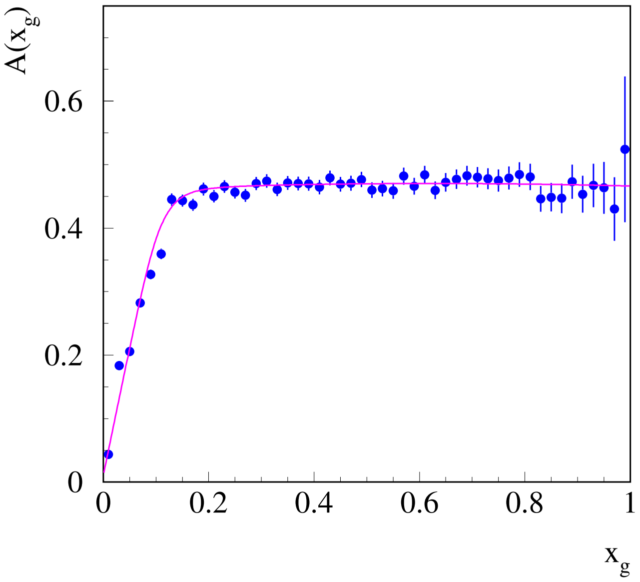


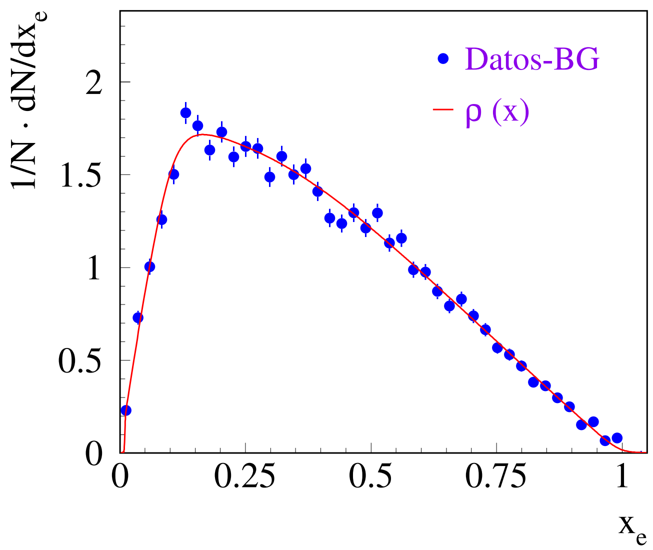
Período	A_p	% BG Total	χ^2/dof
1991	-0.014 ± 0.082	11.2	109/42
1992	0.143 ± 0.058	11.4	55/43
1993	0.150 ± 0.058	11.1	74/43
1994	0.179 ± 0.038	11.1	54/43

$$\boxed{A_p = 0.146 \pm 0.027 \pm 0.022}$$

fuente	σ
Selección y aceptancia	0.006
Contaminación	0.007
Resolución	0.003
Calibración	0.013
Espacio de Fases	0.007
Anchuras Parciales	0.004
ρ'	0.012

22 860 electrones



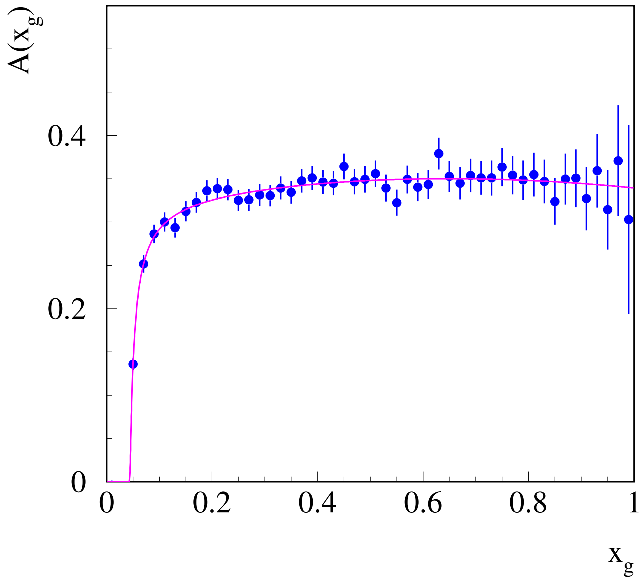


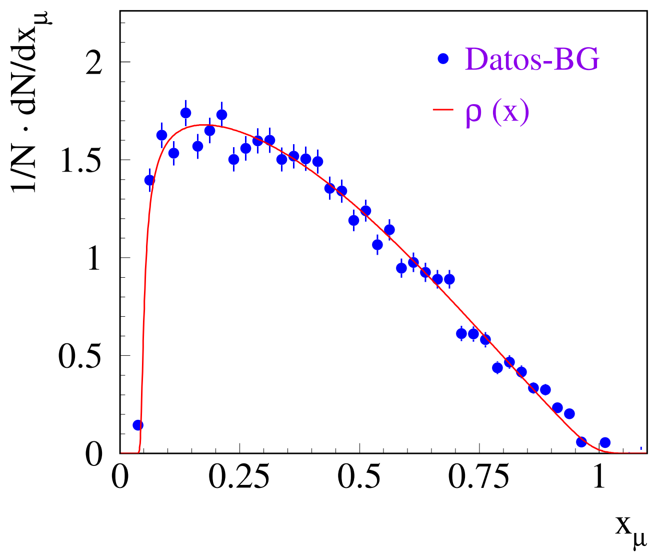
Período	A_p	% BG ee	% BG Total	χ^2/dof
1991	0.010 ± 0.115	2.4 ± 0.4	4.5	55/42
1992	0.118 ± 0.078	2.8 ± 0.3	4.9	57/43
1993	0.163 ± 0.078	3.1 ± 0.3	5.5	83/42
1994	0.167 ± 0.054	2.9 ± 0.2	4.6	68/41

$$\boxed{A_p = 0.150 \pm 0.036 \pm 0.018}$$

fuente	σ
Selección y aceptancia	0.009
Contaminación	0.006
Resolución	0.003
Calibración	0.012
Espacio de Fases	0.007

16 529 muones





Período	A_p	$\%\mathrm{BG}\mu^+\mu^-$	% BG Total	χ^2/dof
1991	0.029 ± 0.118	3.1 ± 0.5	4.9	74/39
1992	0.119 ± 0.083	4.8 ± 0.4	6.3	62/40
1993	0.173 ± 0.084	3.7 ± 0.4	6.0	66/40
1994	0.132 ± 0.055	3.7 ± 0.2	5.2	81/39

$$\boxed{A_p = 0.125 \pm 0.039 \pm 0.019}$$

fuente	σ
Selección y aceptancia	0.008
Contaminación	0.004
Resolución	0.002
Calibración	0.014
Espacio de Fases	0.009

canal	A_p
$\tau \to \pi/\mathrm{K}\,\nu$	$0.143 \pm 0.020 \pm 0.016$
$\tau \to \rho/\mathrm{K}^*\nu$	$0.146 \pm 0.027 \pm 0.022$
$\tau \to \mathrm{e}\nu\overline{\nu}$	$0.150 \pm 0.036 \pm 0.018$
$\tau \to \mu\nu\overline{\nu}$	$0.125 \pm 0.039 \pm 0.019$

$$\boxed{A_p = 0.143 \pm 0.014 \pm 0.010}$$

(LEP: $A_p = 0.1418 \pm 0.0075$)

$$A_p = \frac{2\,(1 - 4\sin^2\overline{\theta}_W)}{1 + (1 - 4\sin^2\overline{\theta}_W)^2}$$

$$\boxed{\sin^2\overline{\theta}_W = 0.2320 \pm 0.0018 \pm 0.0013}$$

$$\frac{g_V}{g_A} = 0.072 \pm 0.007 \pm 0.005$$

- Hemos medido A_p a partir de $h(x)$ para e, μ, π/K y ρ/K^*:

  – Cálculo de $h(x)$

  – Efectos del Detector

  – Calibraciones off–line

- Con los datos '91–'94 tomados con L3, $\mathcal{L} = 118.8\ \mathrm{pb}^{-1}$, $\sqrt{s} \sim M_Z$ hemos identificado y seleccionado las muestras de $\tau \rightarrow \mathrm{e}\nu\overline{\nu}$, $\tau \rightarrow \mu\nu\overline{\nu}$, $\tau \rightarrow \pi/\mathrm{K}\,\nu$ y $\tau \rightarrow \rho/\mathrm{K}^*\nu$.

canal	A_p
$\tau \rightarrow \pi/\mathrm{K}\,\nu$	$0.143 \pm 0.020 \pm 0.016$
$\tau \rightarrow \rho/\mathrm{K}^*\nu$	$0.146 \pm 0.027 \pm 0.022$
$\tau \rightarrow \mathrm{e}\nu\overline{\nu}$	$0.150 \pm 0.036 \pm 0.018$
$\tau \rightarrow \mu\nu\overline{\nu}$	$0.125 \pm 0.039 \pm 0.019$

$$\boxed{A_p = 0.143 \pm 0.014 \pm 0.010}$$

$$\boxed{\sin^2\overline{\theta}_W = 0.2320 \pm 0.0018 \pm 0.0013}$$