MAYA: *MAchine learning pYthon Application for HEP*.

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September 29, 2025

Desarrolladores[1]

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[1] Agradecimientos al Dr. Jhovanny Mejía por sus valiosos comentarios.

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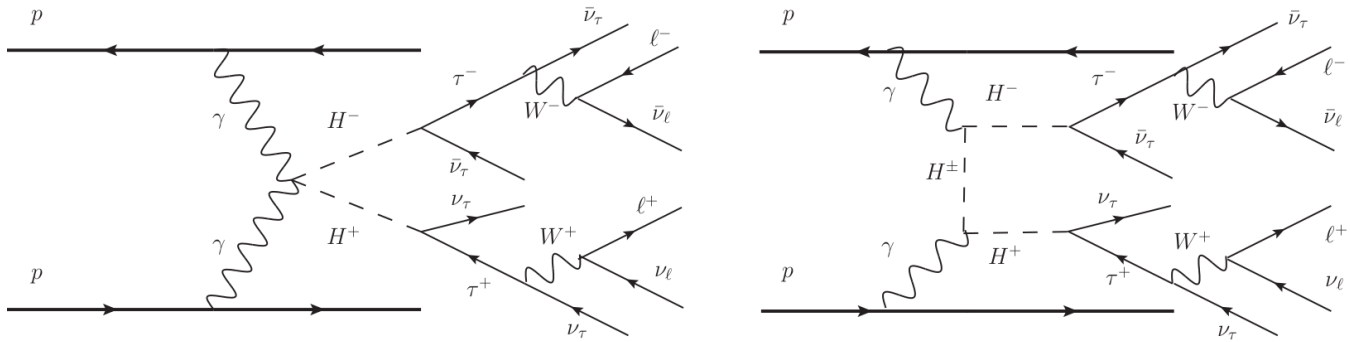
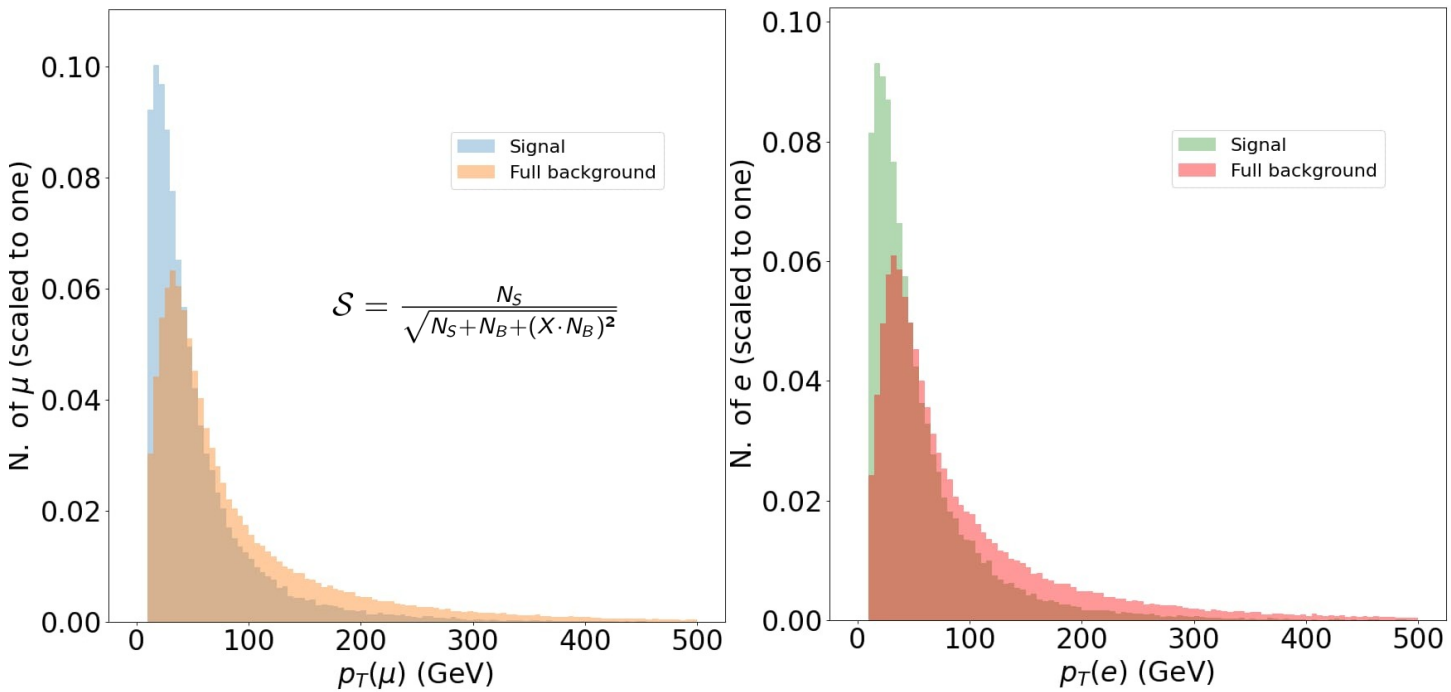
- `MAYA` es una herramienta diseñada en `python` para el análisis de eventos de colisionadores a través de una interfaz gráfica. Integra el método de árboles de decisión "potenciados" mediante la biblioteca XGBoost para la clasificación señal-ruido de fondo, optimiza hiperparámetros usando `Optuna`, y visualiza resultados con histogramas. Como principal objetivo, `MAYA` automatiza la predicción de significancias estadísticas.
  - La significancia estadística $\mathcal{S} = \frac{N_S}{\sqrt{N_S+N_B+(X\cdot N_B)^2}}$ mide qué tan improbable es que una señal observada sea producto de una fluctuación del ruido de fondo (background), en lugar de ser una señal real de nueva física: $3\sigma \rightarrow$ **EVIDENCIA**, $5\sigma \rightarrow$ **DESCUBRIMIENTO**.

Motivación

- Colisión ultraperiférica[2] $pp \to p(\gamma\gamma \to H^- H^+)p$

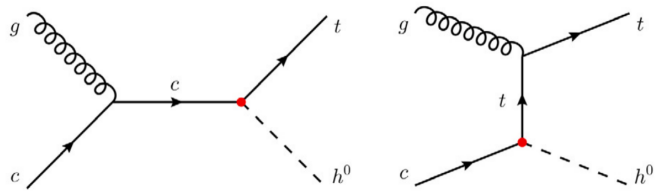




[2] Phys.Rev.D 112 (2025) 1, 015021

Motivación

- Colisiones protón-protón[3] $pp \to th$, $(t \to \ell\nu_\ell b,\ h \to \gamma\gamma)$.



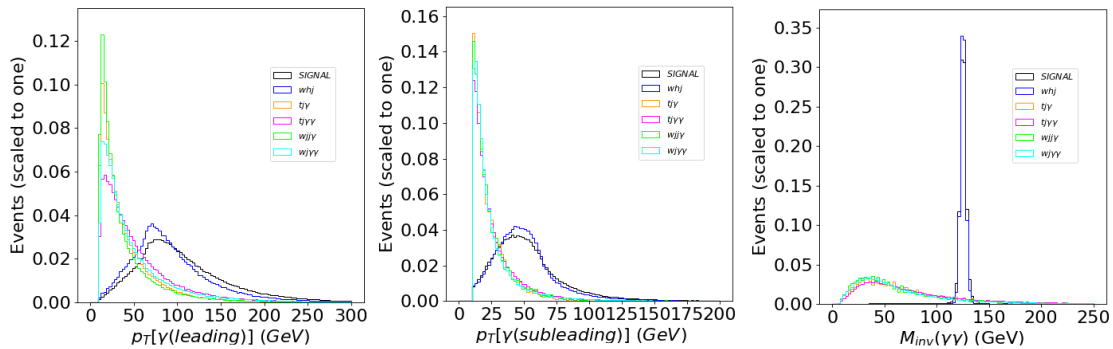


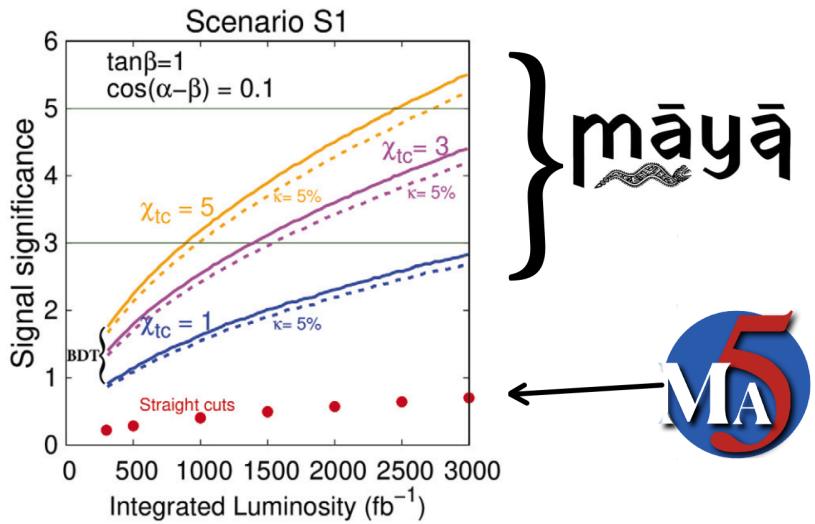
Table 3
Cross-section (σ) of the signal for the scenarios $S1$, $S2$.

Scenario	σ [fb] ($\chi_{tc} = 1$)	σ [fb] ($\chi_{tc} = 5$)
$S1$	0.01	0.025
$S2$	0.004	0.014

$$\mathcal{S} = \frac{N_S}{\sqrt{N_S + N_B + (X \cdot N_B)^2}}$$

Table 4
Cross-section of the dominant SM background processes.

SM backgrounds	Cross-section [fb]
$pp \to Whj$	0.19
$pp \to Wj\gamma\gamma$	68.27
$pp \to tj\gamma\gamma$	0.019
$pp \to Wjj\gamma$	16590
$pp \to tj\gamma$	1.84

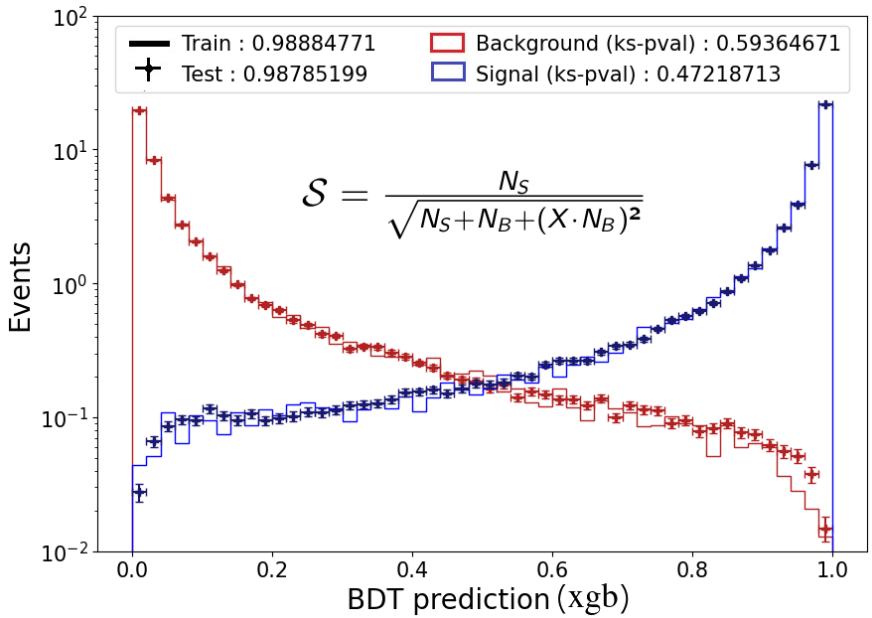


[3] Phys. Lett. B 866 (2025) 139553

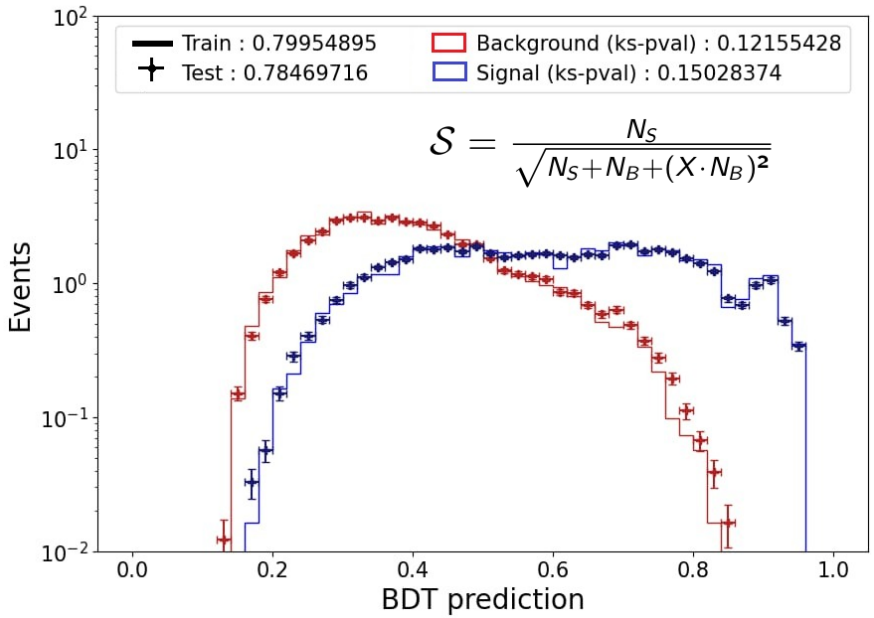
Motivación

Figure: Clasificador

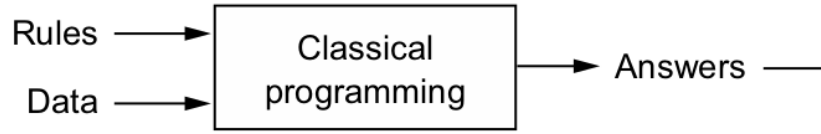
$pp \to th,\ (t \to \ell\nu_\ell b,\ h \to \gamma\gamma)$



$pp \to p(\gamma\gamma \to H^- H^+)p$

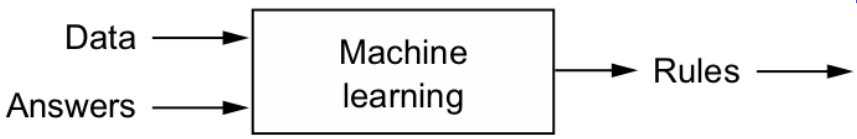


Introducción



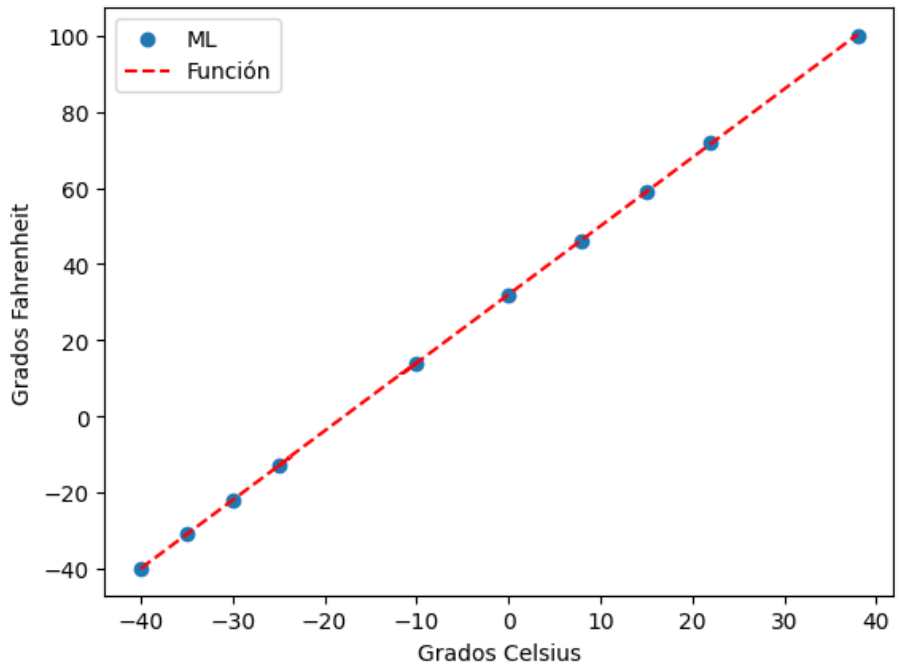
$$F(C) = \frac{9}{5}C + 32$$

```
celsius = np.array([-40, -35, -30, -10, -25, 0, 8, 15, 22, 38], dtype=float)
fahrenheit = np.array([-40, -31, -22, 14, -13, 32, 46, 59, 72, 100], dtype=float)
```



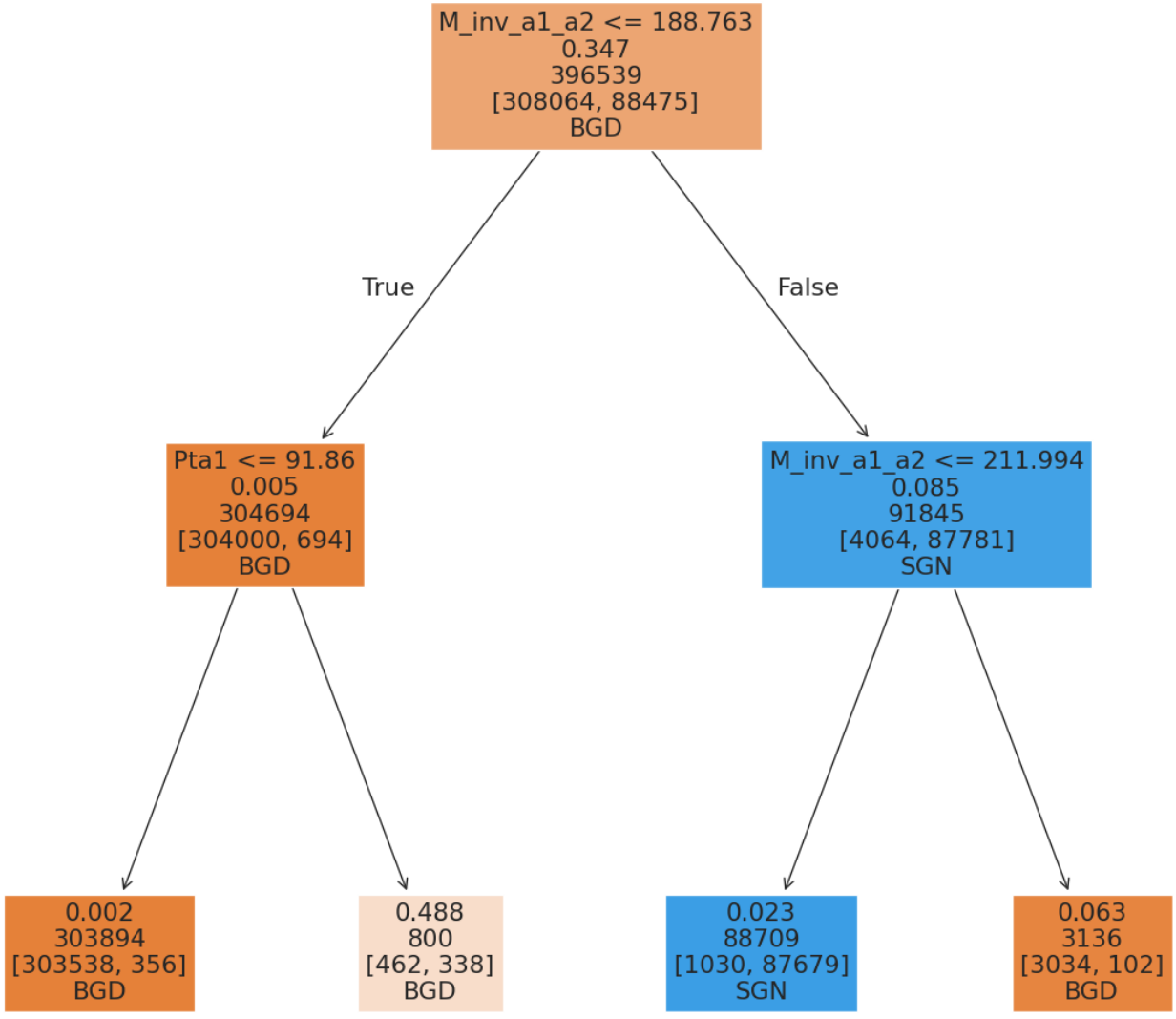

```
print("Variables internas del modelo")
print(capa.get_weights())

Variables internas del modelo
[array([[1.7981262]], dtype=float32), array([31.949242], dtype=float32)]
```



Introducción

- Árbol de decisión



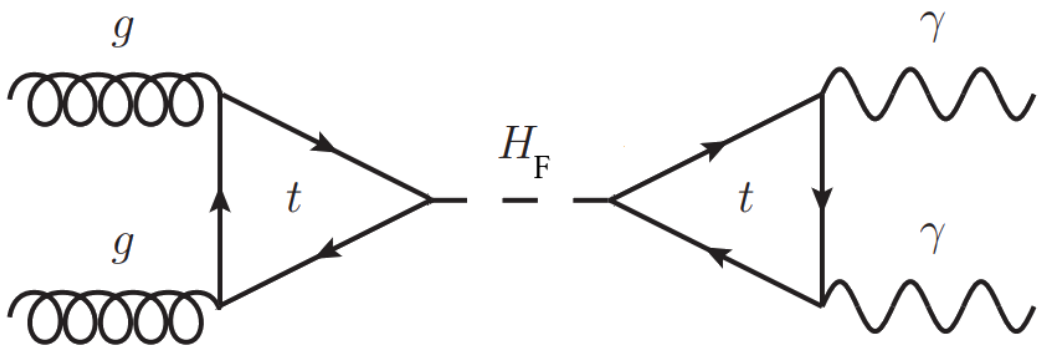
Introducción

1. Lagrangiano $\rightarrow$ $\left\{ \begin{array}{c} \texttt{LanHEP(Lenguaje C)} \\ \texttt{FeynRules (Mathematica)} \\ \texttt{Sarah (Mathematica)} \end{array} \right.$,
2. Salidas: $\left\{ \begin{array}{c} \texttt{CalcHEP, MicrOmegas} \rightarrow \textit{.mdl} \\ \texttt{MadGraph, MadDM} \rightarrow \textit{.py} \\ \texttt{FeynArts} \rightarrow \texttt{.mod} \end{array} \right.$ $\rightarrow \sigma, \mathcal{BR}, \Omega,$ ***EVENTOS***
3. **EVENTOS**$\rightarrow$lhe, hepmc, root, lhco$\rightarrow$ **bases de datos.**

Ejemplo: $H_F \to \gamma\gamma$ [4]

Búsqueda del Flavon en el canal difotónico [5]

Figure: Diagrama de Feynman del proceso $pp \to H_F \to \gamma\gamma$.

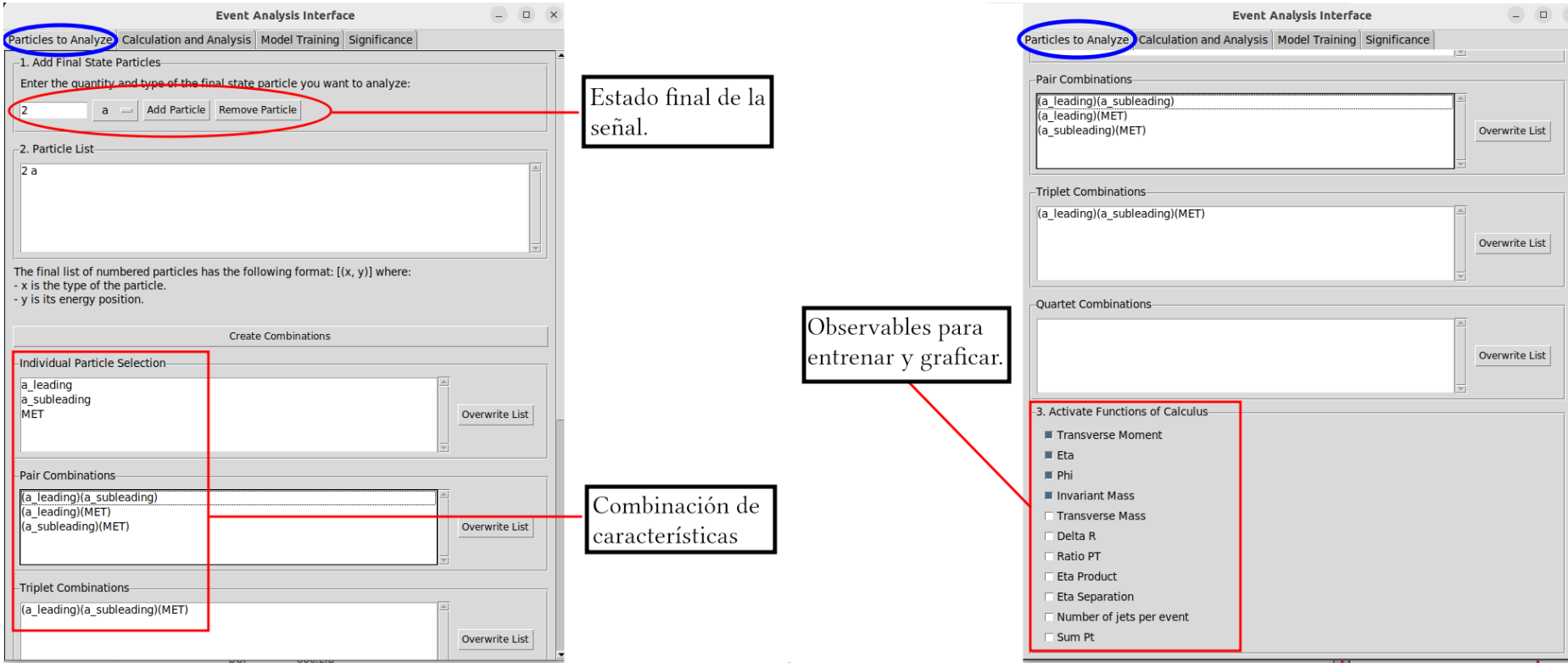


[4] Phys. Rev. D 111, 115037

[5] Ver charla de Diego Carreño: miércoles 9:50 hrs.

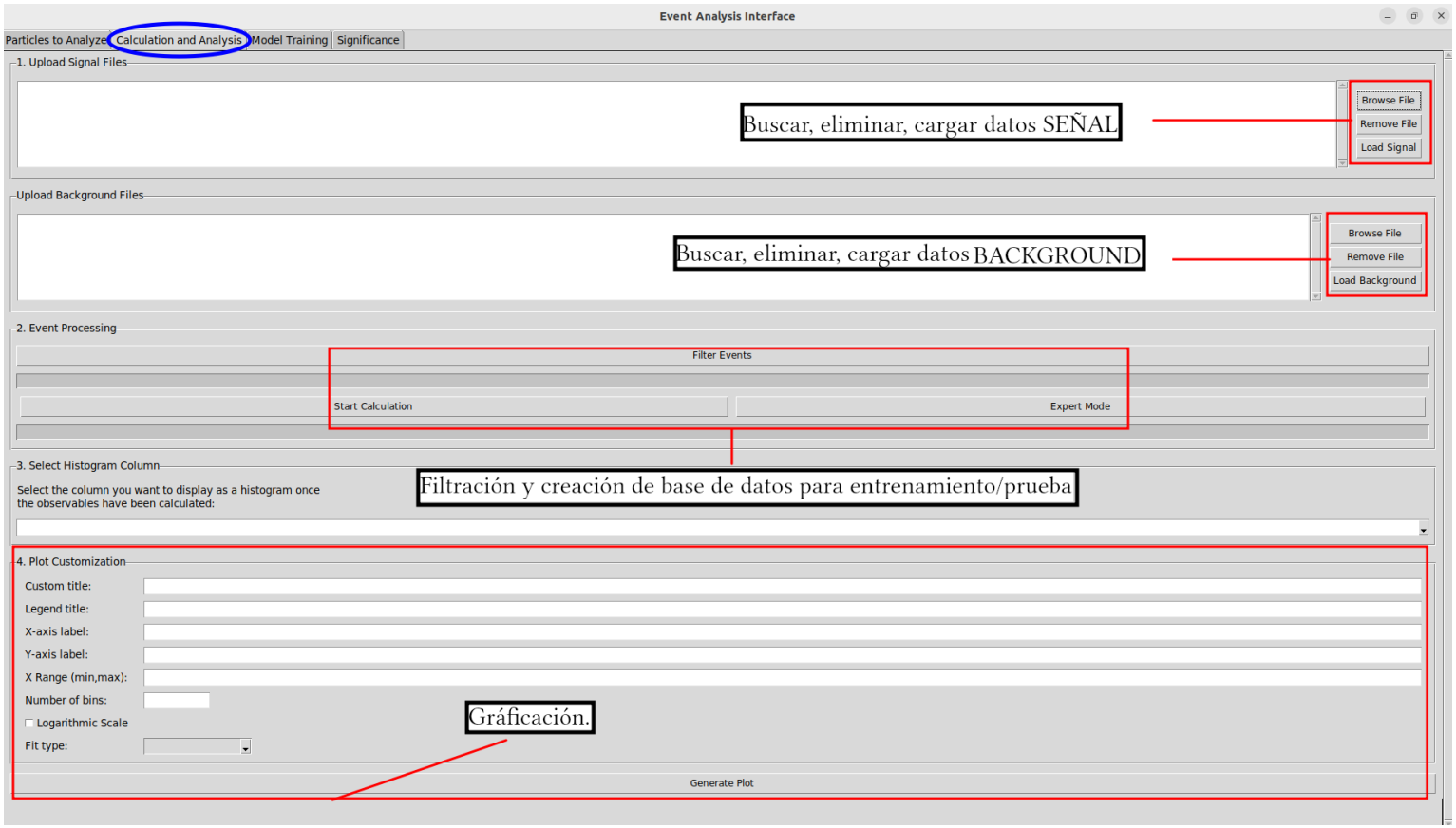
Ejemplo: $H_F \to \gamma\gamma$

Figure: Interfaz de MAYA



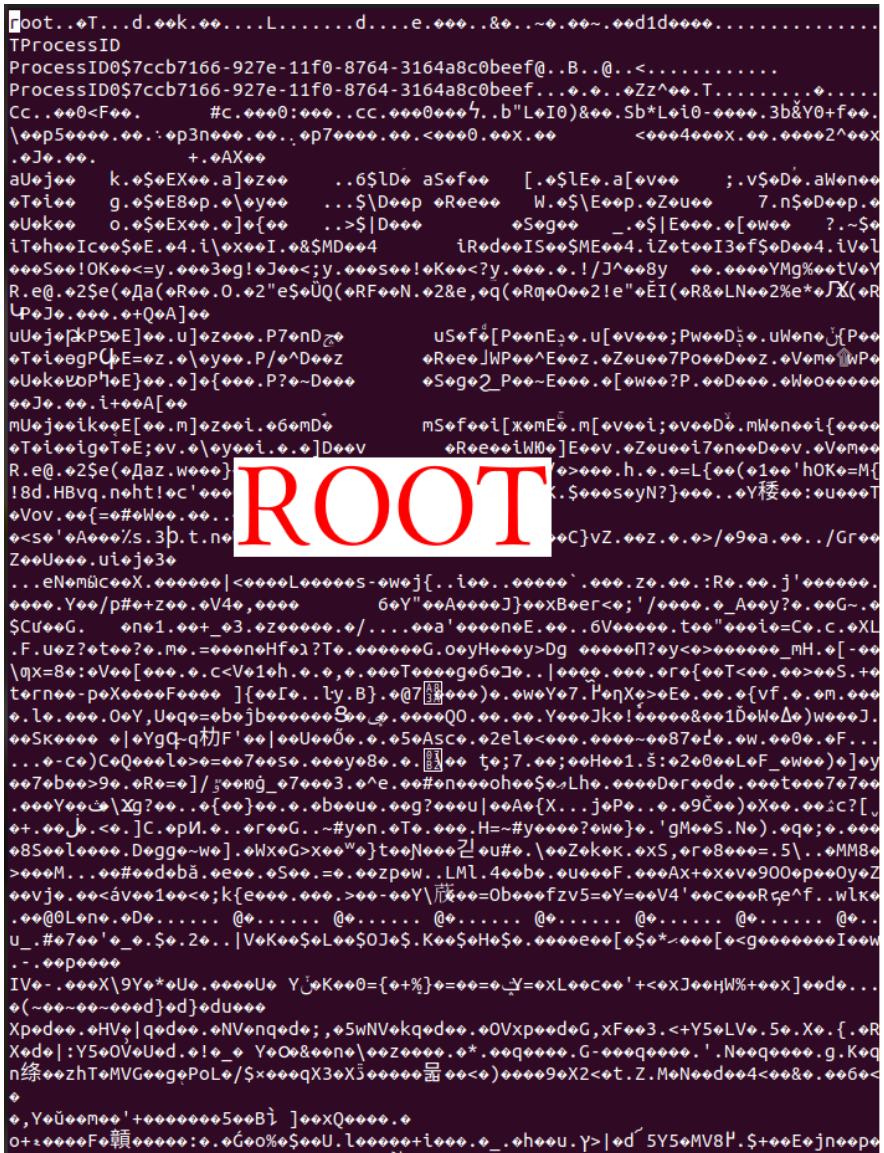
Ejemplo: $H_F \to \gamma\gamma$

Figure: Interfaz de MAYA



Ejemplo: $H_F \to \gamma\gamma$

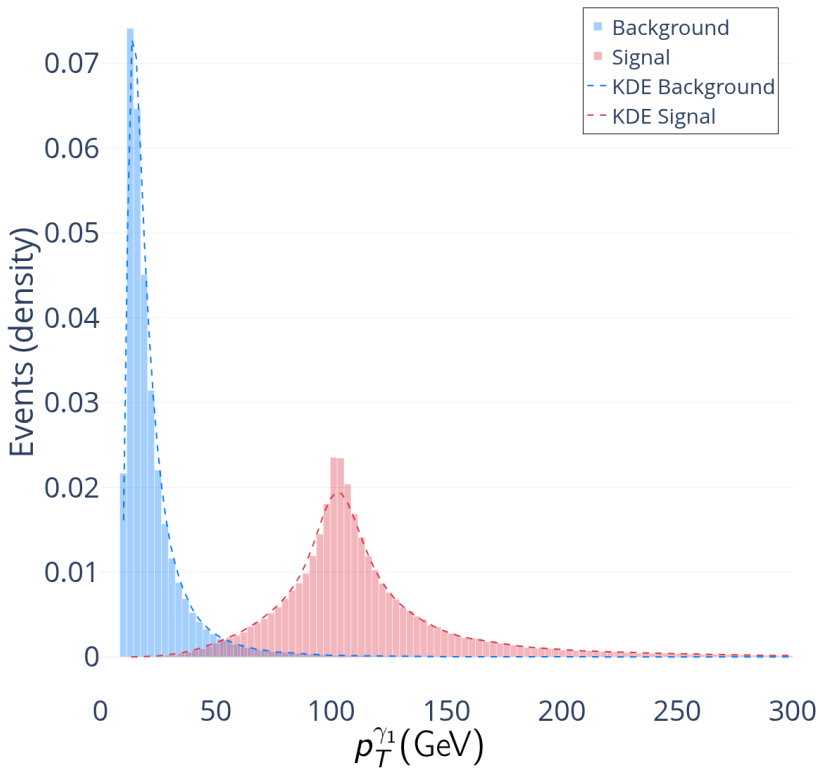
Figure: root - lhco

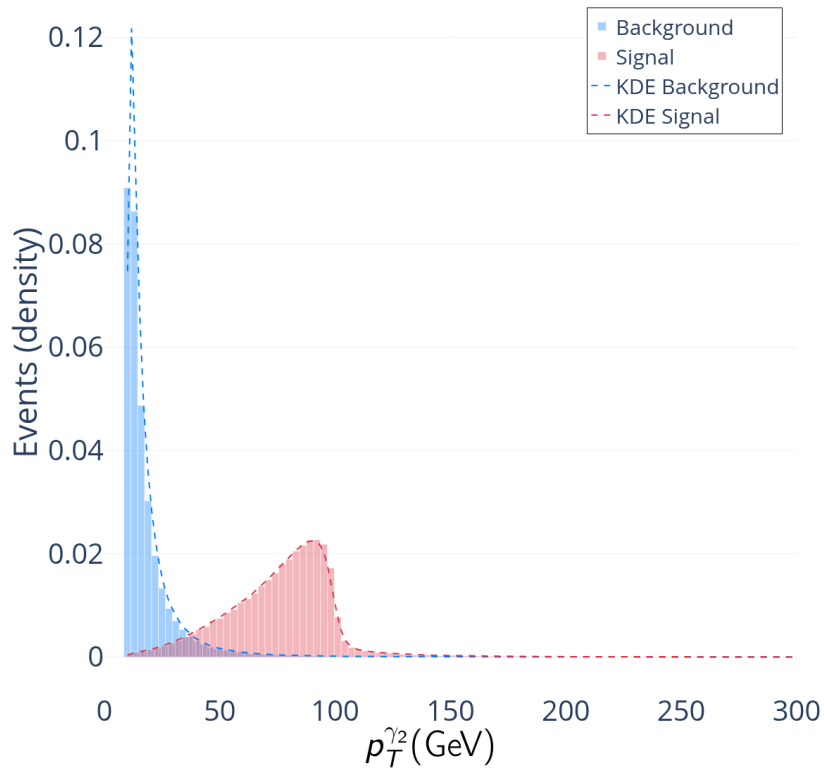


#	typ	eta	phi	pt	jmas	ntrk	btag	had/em	dum1	dum2
0		0	0							
1	0	-0.496	1.673	125.56	0.00	0.0	0.0	0.00	0.0	0.0
2	4	-3.152	-2.177	67.88	-0.00	0.0	0.0	0.00	0.0	0.0
3	4	-1.553	-0.476	38.68	7.50	9.0	0.0	0.00	0.0	0.0
4	6	0.000	-1.111	34.77	0.00	0.0	0.0	0.00	0.0	0.0
0		1	0							
1	4	2.150	0.876	158.01	1.55	1.0	0.0	0.00	0.0	0.0
2	4	-0.550	-2.555	65.93	10.86	3.0	0.0	0.84	0.0	0.0
3	4	-1.981	-1.464	63.86	16.05	5.0	0.0	0.19	0.0	0.0
4	4	3.070	-2.397	22.86	3.97	0.0	0.0	3.83	0.0	0.0
5	6	0.000	0.793	19.67	0.00	0.0	0.0	0.00	0.0	0.0
0		2	0							
1	0	-2.170	-1.792	276.22	0.00	0.0	0.0	0.00	0.0	0.0
2	1	-2.053	0.050	182.41	0.00	1.0	0.0	0.00	0.0	0.0
3	1	-2.026	0.163	38.20	0.00	-1.0	0.0	0.00	0.0	0.0
4	4	0.080	1.657	222.64	14.28	11.0	0.0	0.10	0.0	0.0
5	4	-2.569	-3.124	119.92	19.52	1.0	0.0	2.48	0.0	0.0
6	6	0.000	2.312	31.06	0.00	0.0	0.0	0.00	0.0	0.0
0		3	0							
1	0	-0.692	-1.615	1				0.00	0.0	0.0
2	4	-1.834	1.370	1				0.02	0.0	0.0
3	6	0.000	0.194					0.00	0.0	0.0
0		4	0							
1	0	0.786	-1.300	199.54	0.00	0.0	0.0	0.00	0.0	0.0
2	0	1.437	1.635	180.03	0.00	0.0	0.0	0.00	0.0	0.0
3	4	1.042	-2.835	80.99	15.65	14.0	0.0	0.49	0.0	0.0
4	4	-1.930	0.422	59.63	10.18	9.0	0.0	0.92	0.0	0.0
5	4	-2.805	0.513	33.87	7.29	0.0	0.0	3.63	0.0	0.0
6	4	-0.516	-2.802	26.82	8.99	7.0	0.0	0.00	0.0	0.0
7	6	0.000	1.705	22.69	0.00	0.0	0.0	0.00	0.0	0.0
0		5	0							
1	0	-2.245	-2.720	178.85	0.00	0.0	0.0	0.00	0.0	0.0
2	0	-1.148	0.433	170.04	0.00	0.0	0.0	0.00	0.0	0.0
3	6	0.000	-1.791	9.52	0.00	0.0	0.0	0.00	0.0	0.0
0		6	0							
1	0	-2.286	-1.132	167.37	0.00	0.0	0.0	0.00	0.0	0.0
2	0	-1.023	2.228	165.92	0.00	0.0	0.0	0.00	0.0	0.0
3	4	-3.304	0.666	31.93	7.85	0.0	0.0	10.46	0.0	0.0
4	4	0.174	2.300	23.14	7.33	8.0	0.0	0.00	0.0	0.0
5	6	0.000	-0.654	20.49	0.00	0.0	0.0	0.00	0.0	0.0
0		7	0							
1	0	0.151	0.729	164.42	0.00	0.0	0.0	0.00	0.0	0.0
2	4	1.539	-2.860	165.98	0.00	0.0	0.0	0.00	0.0	0.0
3	4	0.282	-1.251	61.85	9.88	7.0	0.0	1.64	0.0	0.0
4	6	0.000	-1.318	6.79	0.00	0.0	0.0	0.00	0.0	0.0
0		8	0							
1	0	0.234	0.853	221.96	0.00	0.0	0.0	0.00	0.0	0.0
2	0	0.319	-2.020	184.40	0.00	0.0	0.0	0.00	0.0	0.0
3	4	2.011	-2.518	87.99	11.78	5.0	0.0	0.14	0.0	0.0
4	4	0.408	-2.836	35.42	7.90	7.0	0.0	0.00	0.0	0.0

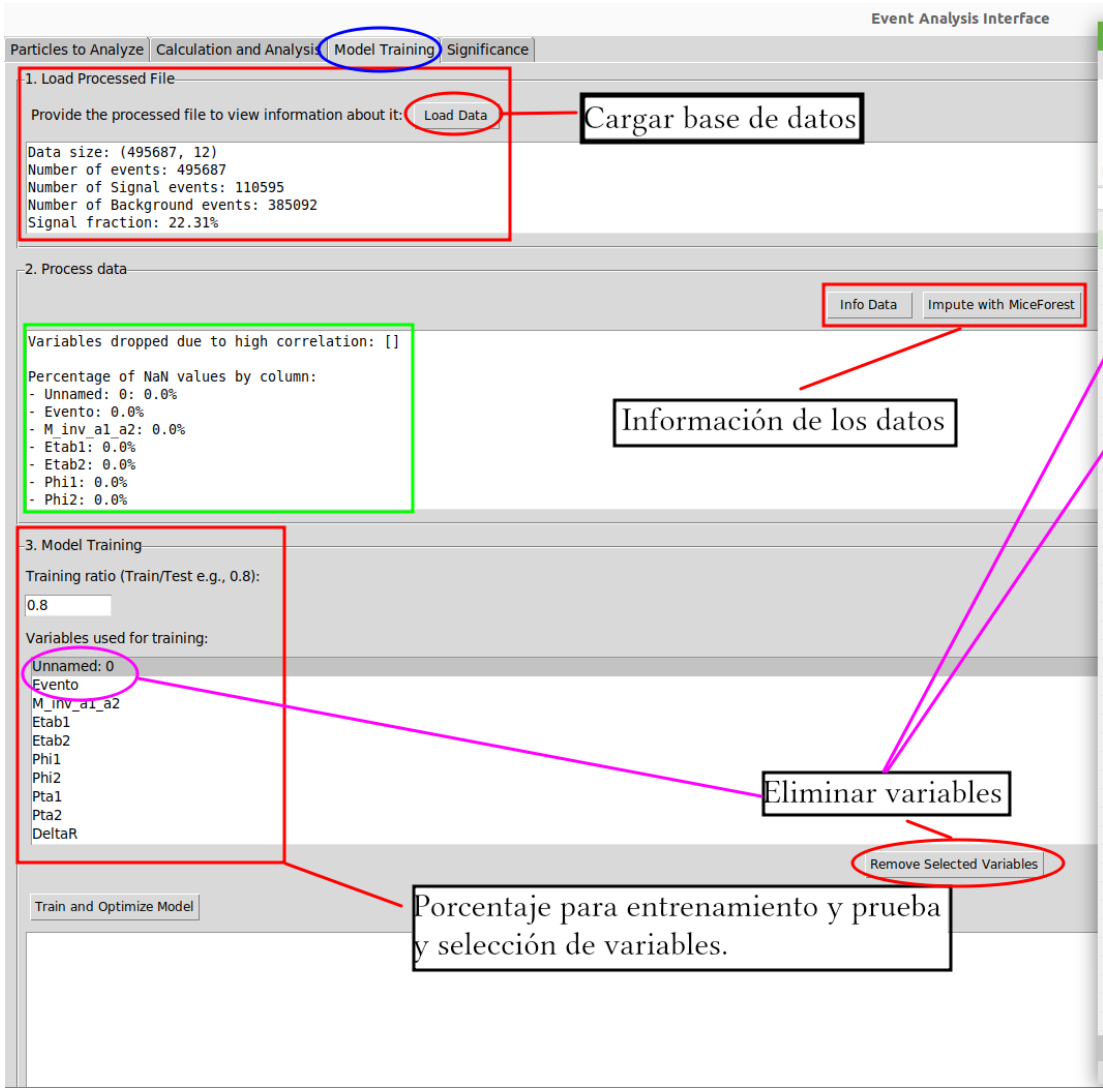
Ejemplo: $H_F \to \gamma\gamma$

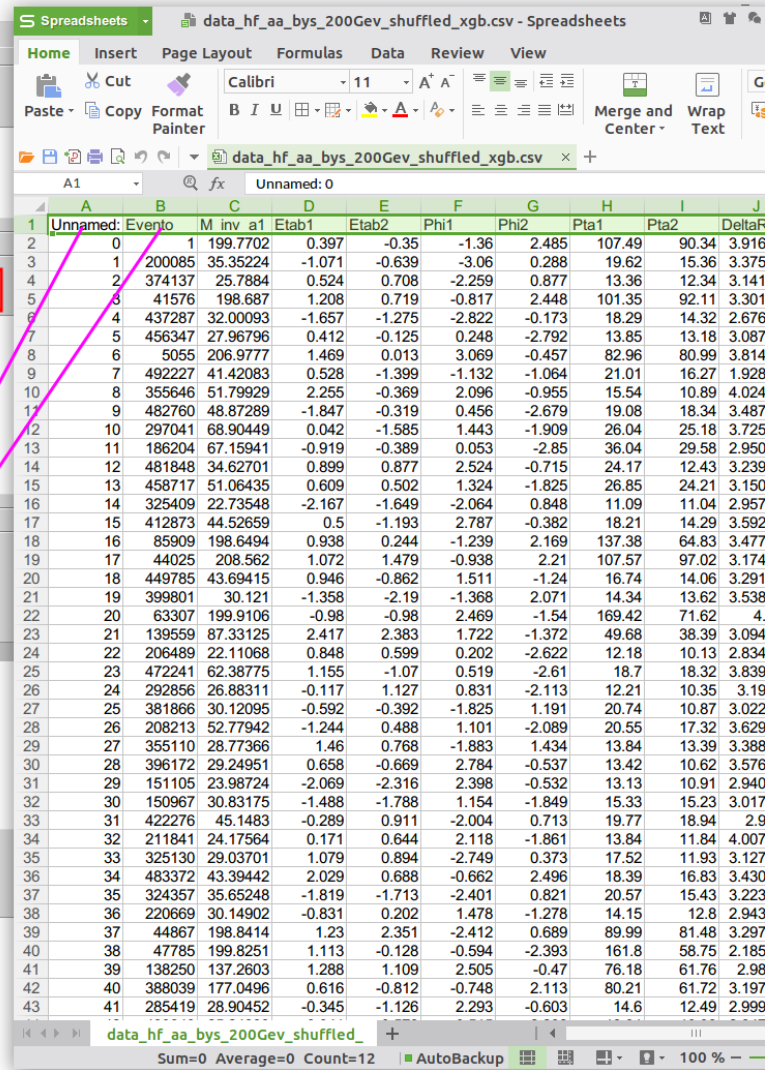
- Momentos transversos $p_T^{\gamma 1,2}$ para $M_F = 200$ GeV,



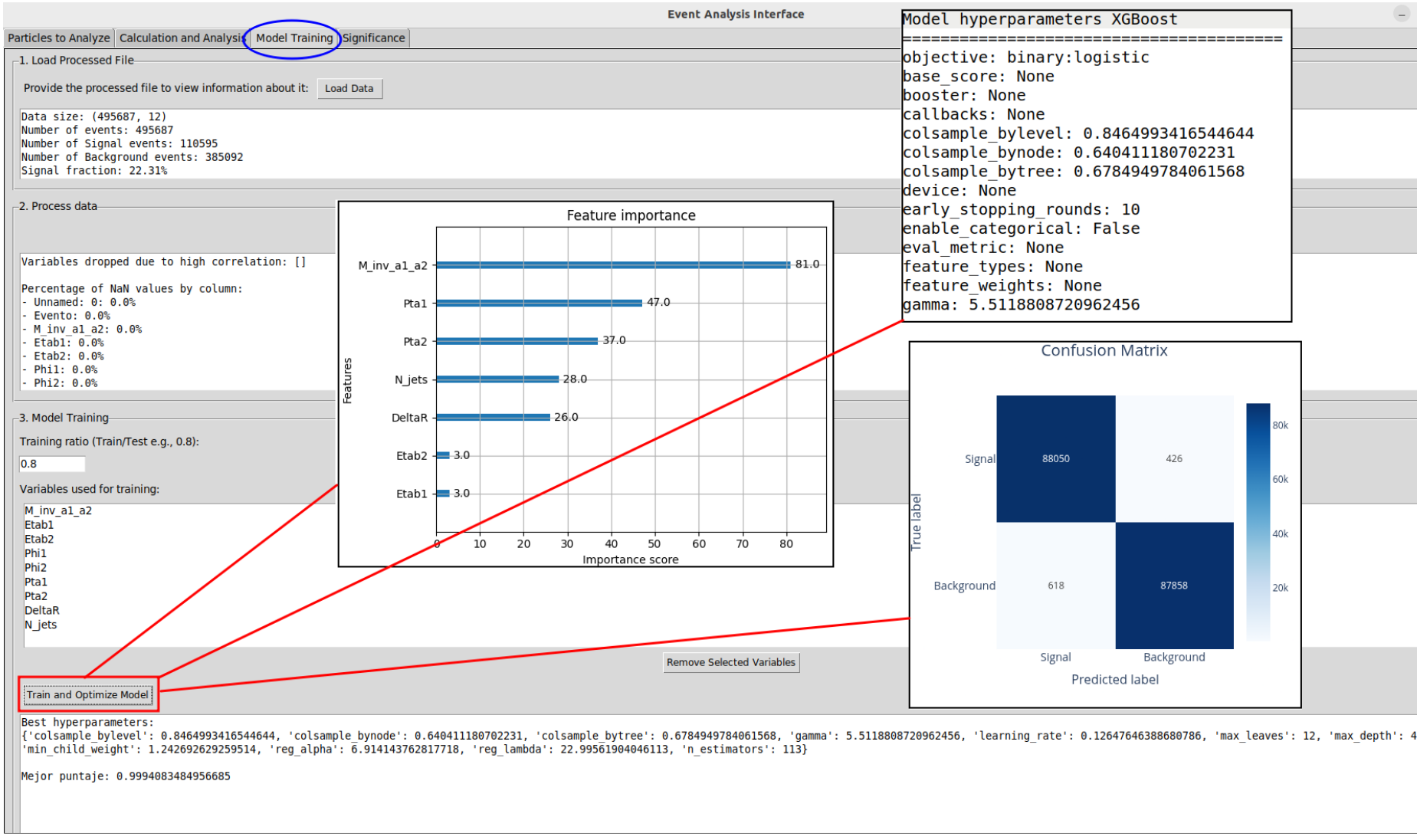


Ejemplo: $H_F \to \gamma\gamma$

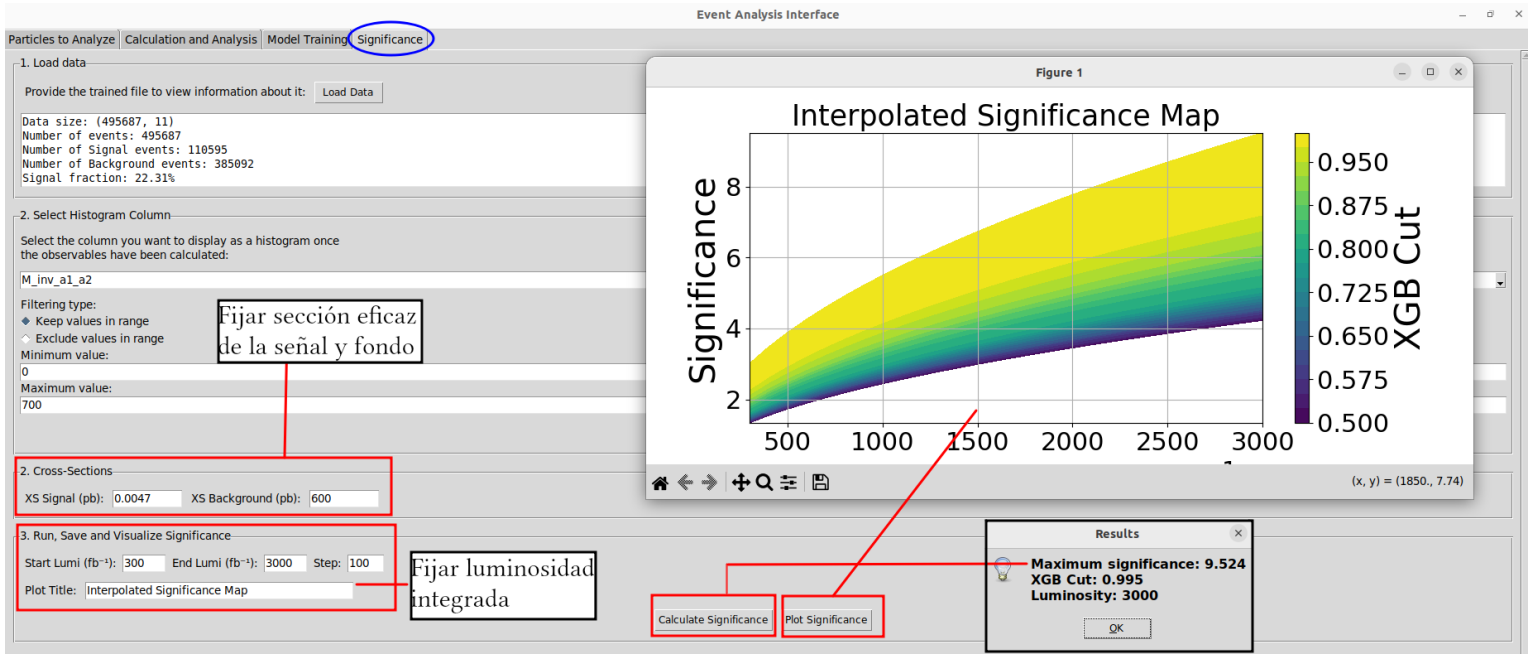




Ejemplo: $H_F \to \gamma\gamma$



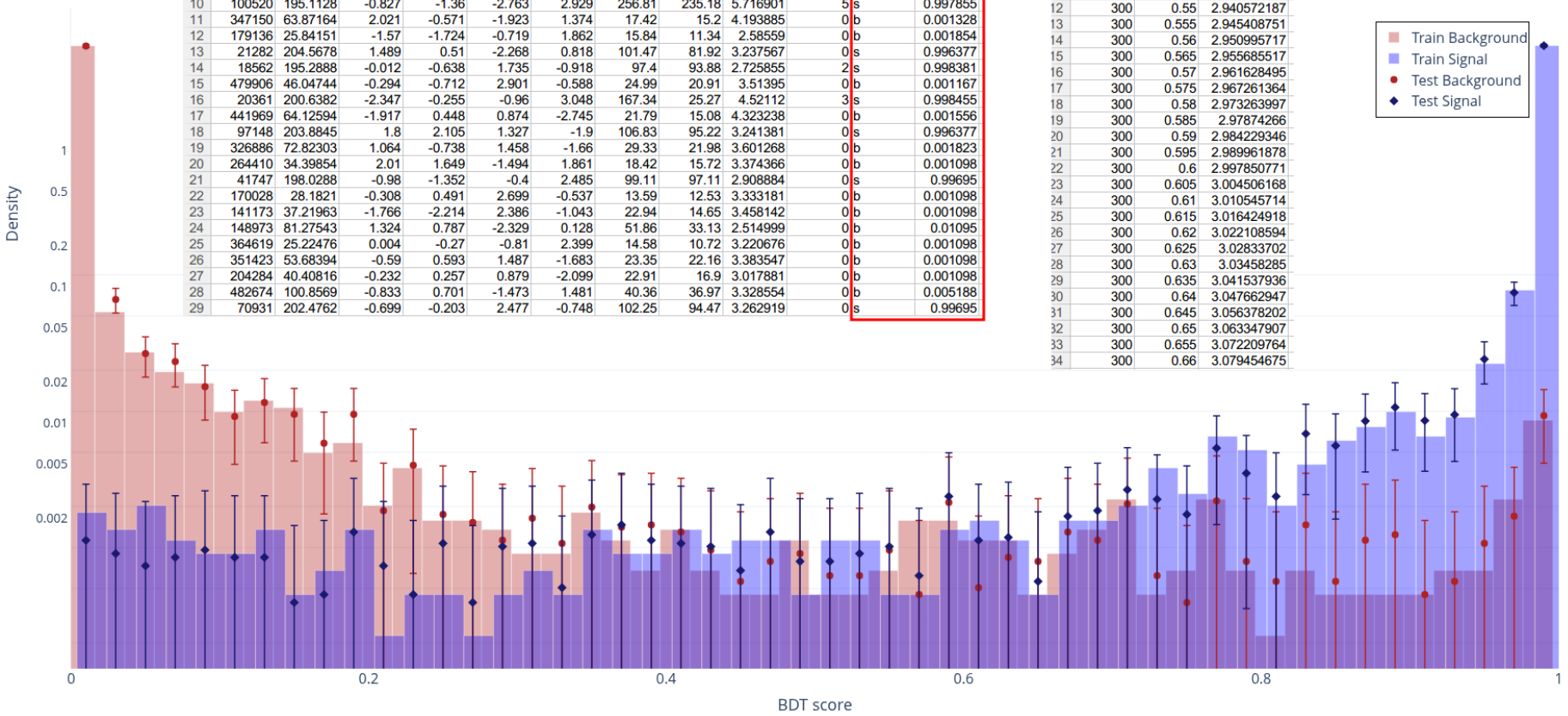
Ejemplo: $H_F \to \gamma\gamma$



Ejemplo: $H_F \to \gamma\gamma$

	A	B	C	D	E	F	G	H	I	J	K	L
1	EventId	M_inv_a1	Etab1	Etab2	Phi1	Phi2	Pta1	Pta2	DeltaR	N_jets	Label	XGB
2	1	199.7702	0.397	-0.35	-1.36	2.485	107.49	90.34	3.916891	2	s	0.998322
3	445406	35.32442	-1.244	-2.124	2.29	-1.768	18.57	16.62	4.15232	0	b	0.001328
4	41452	202.853	-0.407	0.103	0.412	-1.596	160.09	82.58	2.071754	2	s	0.998381
5	37401	200.3205	-0.467	-0.87	-2.425	-1.128	304.86	81.06	1.358167	4	s	0.998381
6	88420	201.0324	-1.307	1.158	2.627	-0.772	66.87	43.85	4.198741	0	s	0.989351
7	5668	202.3936	0.913	1.485	-3.037	-0.004	116.37	81.4	3.086466	1	s	0.997932
8	309169	36.78149	0.652	1.798	-1.749	1.482	16.03	15.47	3.428218	0	b	0.001098
9	1979	201.2773	-0.77	-0.129	-2.251	1.006	106.85	85.94	3.319477	1	s	0.997932
10	100520	195.1128	-0.827	-1.36	-2.763	2.929	256.81	235.18	5.716901	5	s	0.997855
11	347150	63.87164	2.021	-0.571	-1.923	1.374	17.42	15.2	4.193885	0	b	0.001328
12	179136	25.84151	-1.57	-1.724	-0.719	1.862	15.84	11.34	2.58559	0	b	0.001854
13	21282	204.5678	1.489	0.51	-2.268	0.818	101.47	81.92	3.237567	0	s	0.996377
14	18562	195.2888	-0.012	-0.638	1.735	-0.918	97.4	93.88	2.725855	2	s	0.998381
15	479906	46.04744	-0.294	-0.712	2.901	-0.588	24.99	20.91	3.51395	0	b	0.001167
16	20361	200.6382	-2.347	-0.255	-0.96	3.048	167.34	25.27	4.52112	3	s	0.998455
17	441969	64.12594	-1.917	0.448	0.874	-2.745	21.79	15.08	4.323238	0	b	0.001556
18	97148	203.8845	1.8	2.105	1.327	-1.9	106.83	95.22	3.241381	0	s	0.996377
19	326886	72.82303	1.064	-0.738	1.458	-1.66	29.33	21.98	3.601268	0	b	0.001823
20	264410	34.39854	2.01	1.649	-1.494	1.861	18.42	15.72	3.374366	0	b	0.001098
21	41747	198.0288	-0.98	-1.352	-0.4	2.485	99.11	97.11	2.908884	0	s	0.99695
22	170028	28.1821	-0.308	0.491	2.699	-0.537	13.59	12.53	3.333181	0	b	0.001098
23	141173	37.21963	-1.766	-2.214	2.386	-1.043	22.94	14.65	3.458142	0	b	0.001098
24	148973	81.27543	1.324	0.787	-2.329	0.128	51.86	33.13	2.514999	0	b	0.01095
25	364619	25.22476	0.004	-0.27	-0.81	2.399	14.58	10.72	3.220676	0	b	0.001098
26	351423	53.68394	-0.59	0.593	1.487	-1.683	23.35	22.16	3.383547	0	b	0.001098
27	204284	40.40816	-0.232	0.257	0.879	-2.099	22.91	16.9	3.017881	0	b	0.001098
28	482674	100.8569	-0.833	0.701	-1.473	1.481	40.36	36.97	3.328554	0	b	0.005188
29	70931	202.4762	-0.699	-0.203	2.477	-0.748	102.25	94.47	3.262919	0	s	0.99695

	A	B	C
1	Luminosity	XGB Cut	Significance
2	300	0.5	2.887965818
3	300	0.505	2.89268955
4	300	0.51	2.896872844
5	300	0.515	2.902726428
6	300	0.52	2.909498702
7	300	0.525	2.914003001
8	300	0.53	2.919426816
9	300	0.535	2.924191033
10	300	0.54	2.929334129
11	300	0.545	2.934886171
12	300	0.55	2.940572187
13	300	0.555	2.945408751
14	300	0.56	2.950995717
15	300	0.565	2.955685517
16	300	0.57	2.961628495
17	300	0.575	2.967261364
18	300	0.58	2.973263997
19	300	0.585	2.97874266
20	300	0.59	2.984229346
21	300	0.595	2.989961878
22	300	0.6	2.997850771
23	300	0.605	3.004506168
24	300	0.61	3.010545714
25	300	0.615	3.016424918
26	300	0.62	3.022108594
27	300	0.625	3.02833702
28	300	0.63	3.03458285
29	300	0.635	3.041537936
30	300	0.64	3.047662947
31	300	0.645	3.056378202
32	300	0.65	3.063347907
33	300	0.655	3.072209764
34	300	0.66	3.079454675



Limitaciones

- Únicamente admite formato .lhco (por el momento),
- `MAYA` sólo hace uso de árboles de decisión boosteados,
- Dependiendo de los recursos computacionales, la generación de base de datos puede demorar.

Conclusiones y perspectivas

- Hemos presentado una aplicación programada en Python: `MAYA` , cuyo objetivo principal es evaluar significancias estadísticas mediante árboles de decisión potenciados (y/o cortes cinemáticos tradicionales),
- Si el usuario no cuenta con su propia base de datos para el entrenamiento y prueba, `MAYA` crea una base a partir de archivos a nivel detector .lhco,
- Se ha creado una base sólida para robustecer a `MAYA` a través de métodos adicionales de aprendizaje automático,
- Integrar Redes Neuronales Artificiales,
- Implementar análisis de cálculos que surgen a nivel de un lazo y materia oscura.

¡Muchas gracias!