

Belle II Lab exercise: Results and discussion

Let us know if you enjoyed
it and what can we improve
in your opinion



Particle	Quark content	Process	Mass GeV	N. Events	N. Particles	Width GeV
	uu, dd		0.1322	10k	121k	0.01380
	ds		0.4962	400k	1.747M	0.01219
	(uu, dd), ss		1.019	400k	17.5k	0.0042
	cc		3.088	4M	7k	0.018
			3.090	4M	2.8k	0.014
	cu		1.857	4M	11k	0.0096
			1.862	4M	133k	0.00998
	cd		2.005	4M	4k	0.0008
			2.005	4M	4k	0.0009
	bu		5.283	7M	51	0.155
			5.299	7M	58	0.396

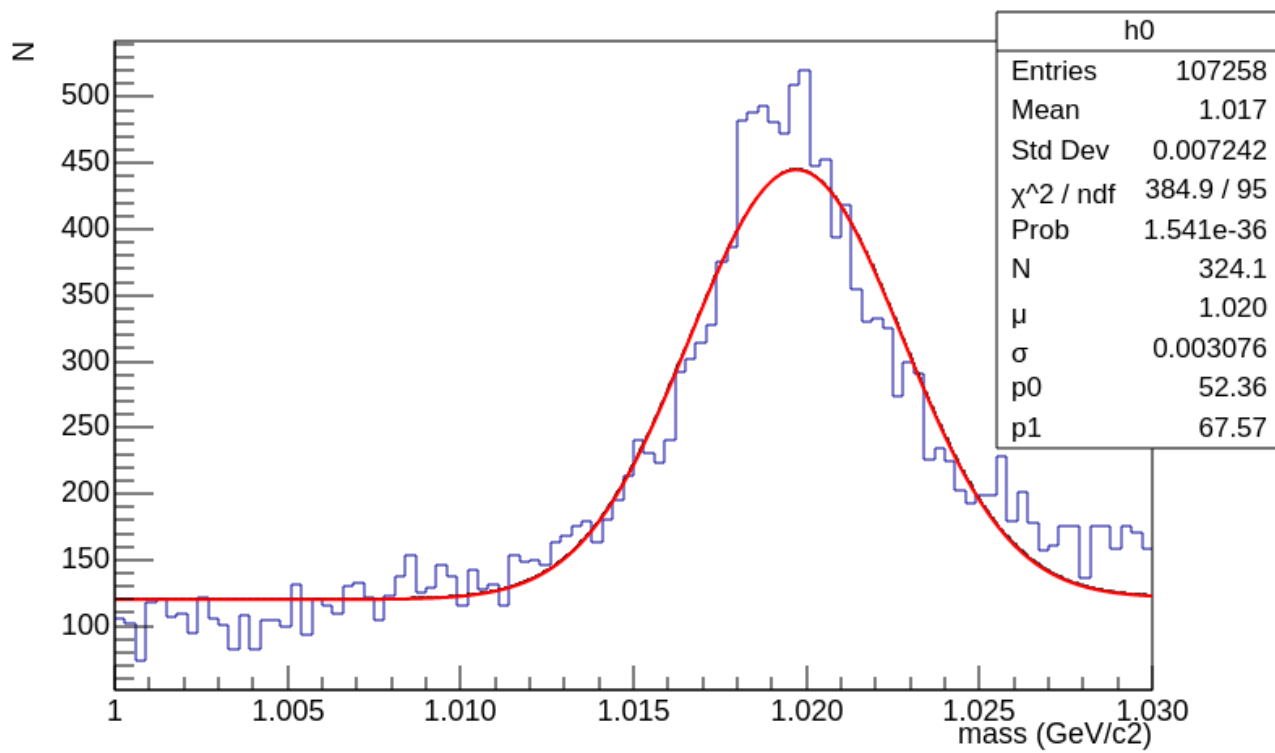
Worksheet

Sorry, I was a little slow

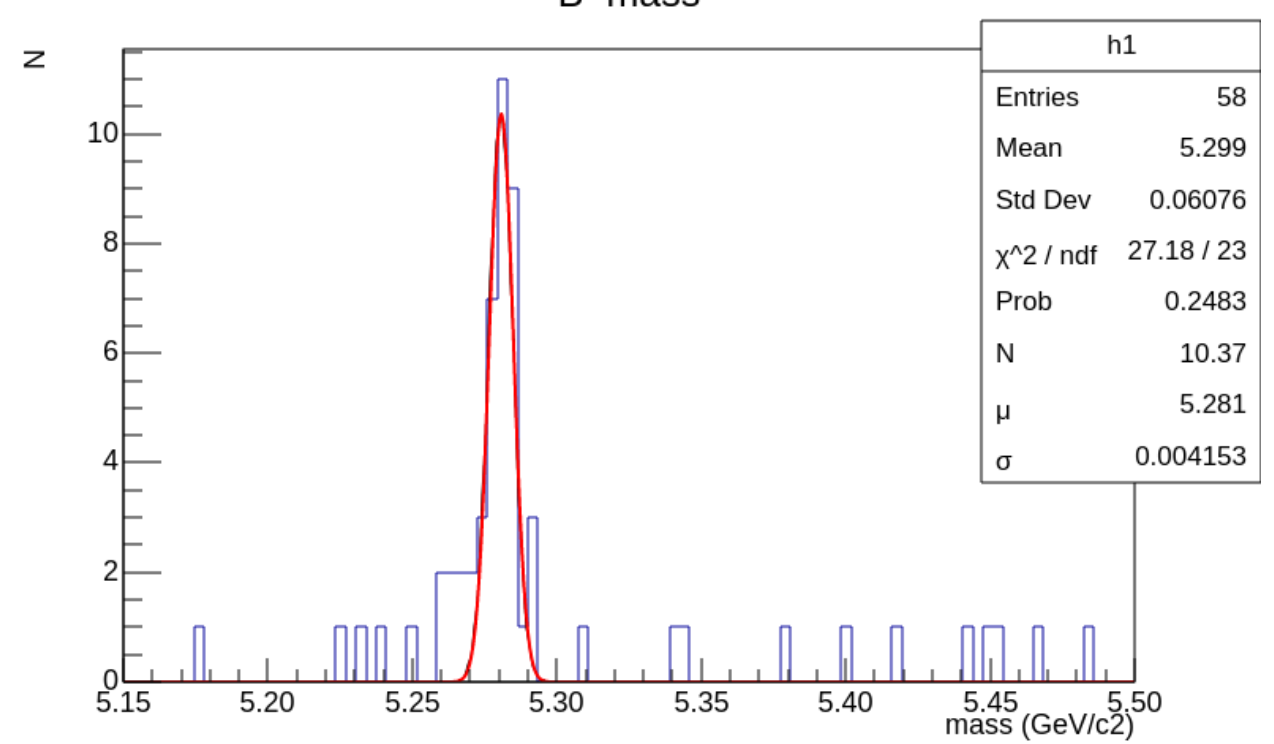
Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$				
Ks		$K_S \rightarrow \pi^+ \pi^-$				
ϕ		$\phi \rightarrow K^+ K^-$				
J/ ψ		$J/\psi \rightarrow e^+ e^-$	3.0899	1000000	1778	0.0087
		$J/\psi \rightarrow \mu^+ \mu^-$	3.0939	1000000	2648	0.007
D ⁰		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D ^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺		$B^+ \rightarrow J/\psi K^+$	5.281	7000000	58	0.004
B ⁻		$B^- \rightarrow J/\psi K^-$	5.278	7000000	86	0.017

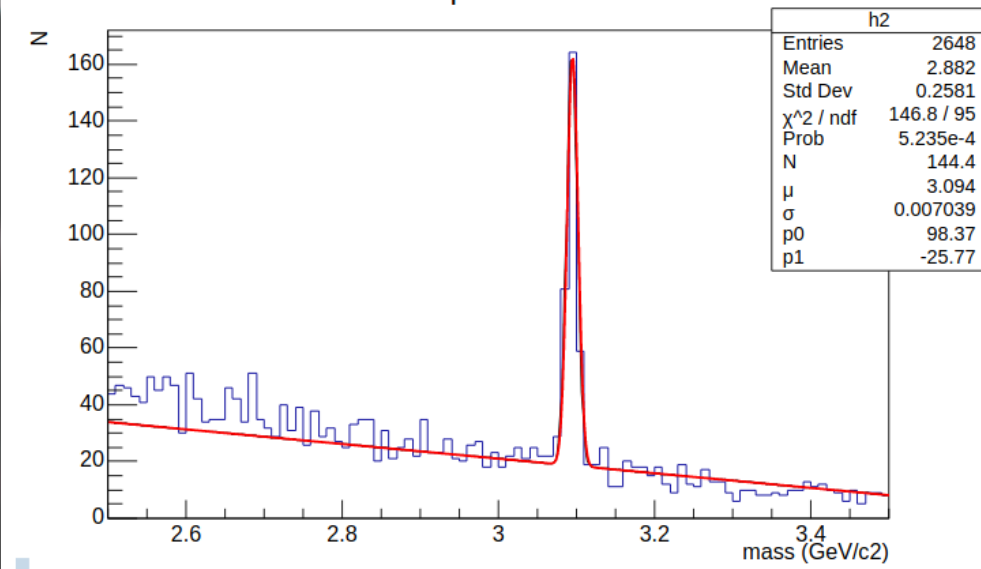
Phi mass



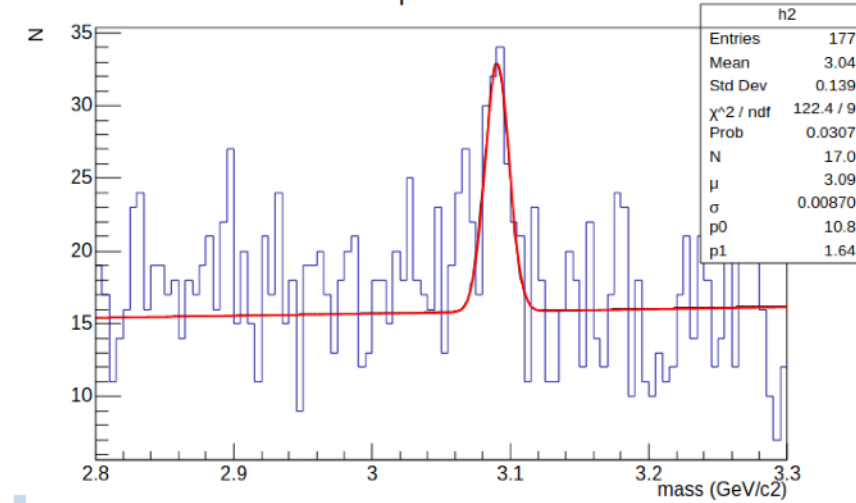
B mass



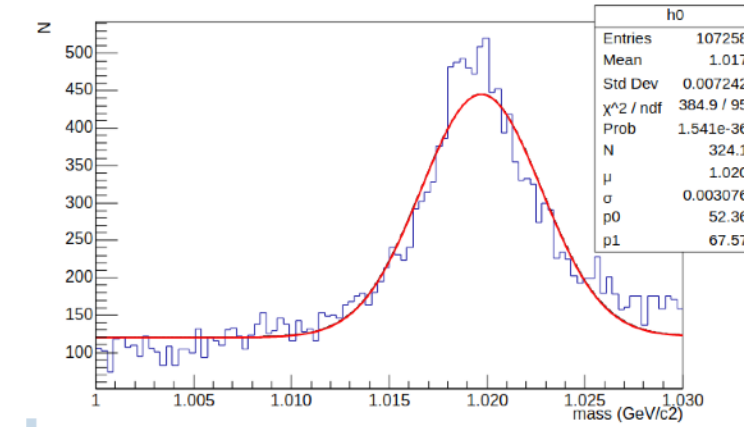
J/psi Mass



J/psi Mass



Phi mass



Click to fit

Range: min = 2.5 max = 3.5 $\chi^2/\text{ndf} = 146.8 / 95 = 1.545$ Function: Gaus + Poly $N \cdot e^{-\left(\frac{x-\mu}{2\sigma}\right)^2} + p0 + p1 \cdot x$

Name	Value	Min	Set	Max	Step
• μ :	3.0939	3		3.2	0.0001
• σ :	0.007	0		1	0.0001
• N:	144.441	0		10000	0.0001

Polynomial order: 1

Name	Value	Min	Set	Max	Step
• p0:	98.3691	-10		98.369136873914	0.0001
• p1:	-25.773	-100.4079988216		0	0.0001
• p2:	0	-10		10	0.0001
• p3:	0	-10		10	0.0001
• p4:	0	-10		10	0.0001

Click to fit

Range: min = 2.8 max = 3.3 $\chi^2/\text{ndf} = 122.4 / 95 = 1.288$ Function: Gaus + Poly $N \cdot e^{-\left(\frac{x-\mu}{2\sigma}\right)^2} + p0 + p1 \cdot x$

Name	Value	Min	Set	Max	Step
• μ :	3.0899	3		3.2	0.0001
• σ :	0.0087	0		1	0.0001
• N:	17.0292	0		10000	0.0001

Polynomial order: 1

Name	Value	Min	Set	Max	Step
• p0:	10.8001	-10		10.800194377967	0.0001
• p1:	1.6416	-10		10	0.0001
• p2:	0	-10		10	0.0001
• p3:	0	-10		10	0.0001
• p4:	0	-10		10	0.0001

Click to fit

Range: min = 1 max = 1.03 $\chi^2/\text{ndf} = 385.6 / 95 = 4.059$ Function: Gaus + Poly $N \cdot e^{-\left(\frac{x-\mu}{2\sigma}\right)^2} + p0 + p1 \cdot x$

Name	Value	Min	Set	Max	Step
• μ :	1.0197	1		1.025	0.0001
• σ :	0.0031	0		0.004	0.0001
• N:	324.1284	0		10000	0.0001

Polynomial order: 1

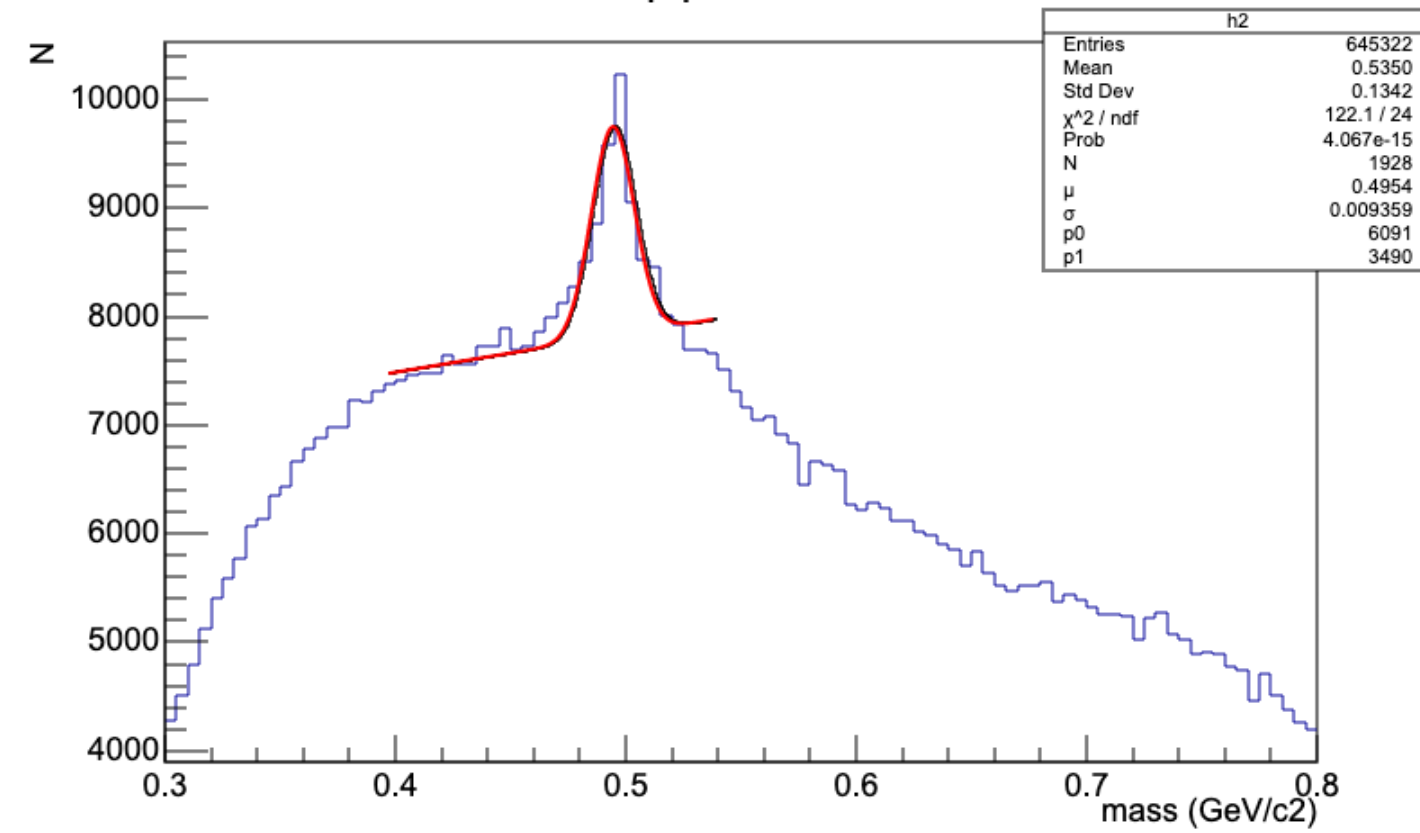
Name	Value	Min	Set	Max	Step
• p0:	52.363935054039	52.363935054039		200	0.0001
• p1:	67.5691	1		67.569163751250	0.0001
• p2:	0	-10		10	0.0001
• p3:	0	-10		10	0.0001
• p4:	0	-10		10	0.0001

Worksheet

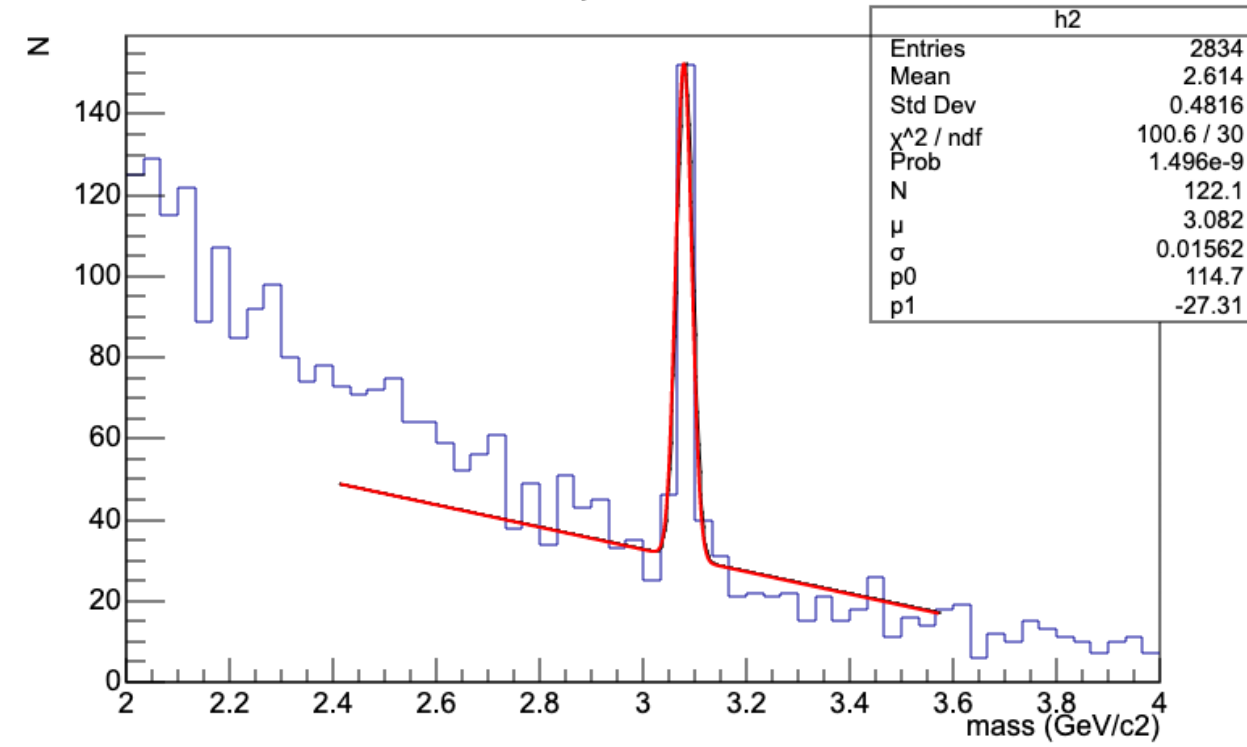
Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0,1325	50000	11467	0,00976
K_S		$K_S \rightarrow \pi^+ \pi^-$	0,4954	100000	206004	0,00936
ϕ		$\phi \rightarrow K^+ K^-$		50000		
J/ψ		$J/\psi \rightarrow e^+ e^-$	3,078	1000000	3998	0,01787
		$J/\psi \rightarrow \mu^+ \mu^-$	3,082	1000000	7817	0,01562
D^0		$D^0 \rightarrow K^+ \pi^-$	1,861	1000000	257709	0,008366
		$D^0 \rightarrow K^- \pi^+$	1,861	1000000	208395	0,009266
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B^+		$B^+ \rightarrow J/\psi K^+$				
B^-		$B^- \rightarrow J/\psi K^-$				

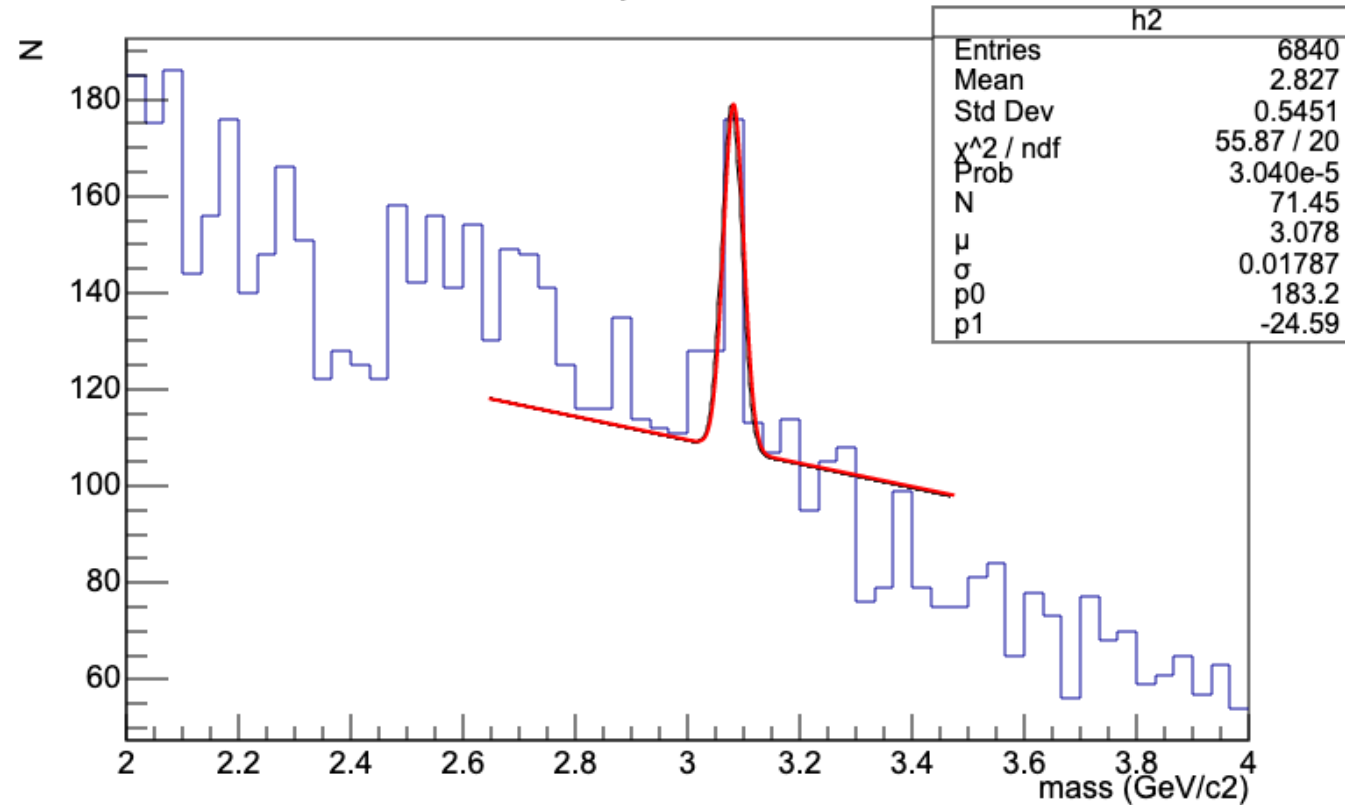
pipi Mass



J/psi mass



J/psi mass



Worksheet

Exercise table with the list of decays to examine

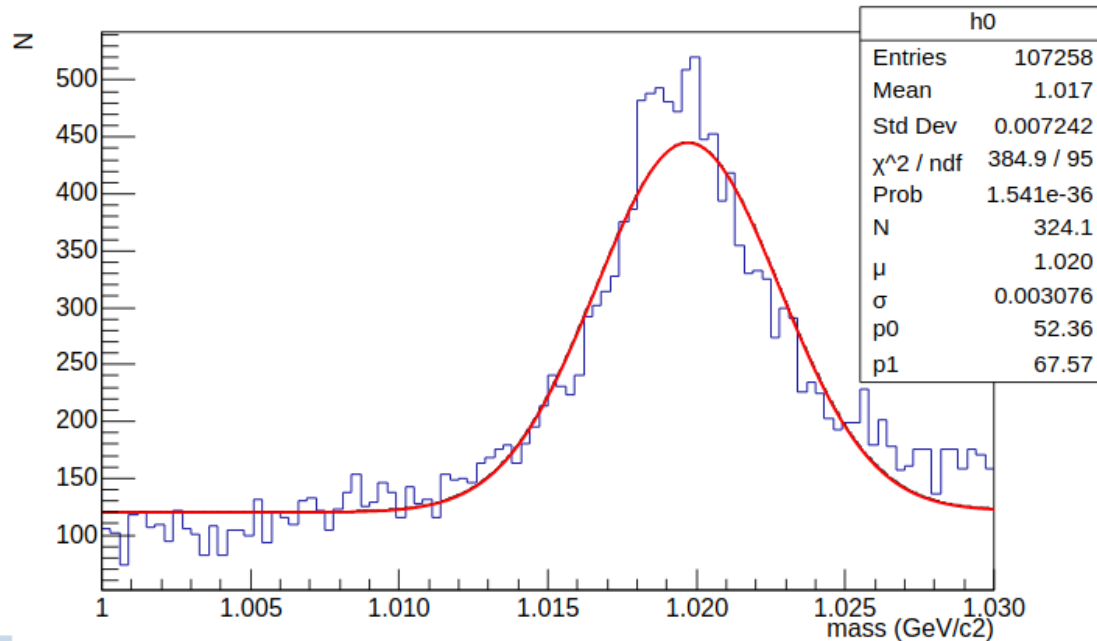
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0,1319	1000000	97347	0,0051
K_S		$K_S \rightarrow \pi^+ \pi^-$	0,4975	1000000	10387	0,0045
ϕ		$\phi \rightarrow K^+ K^-$	1,019	1000000	788	0,002
J/ψ		$J/\psi \rightarrow e^+ e^-$		1000000		
		$J/\psi \rightarrow \mu^+ \mu^-$	3,0937	1000000	58	0,0073
D^0		$D^0 \rightarrow K^+ \pi^-$	1,8639	1000000	507	0,0046
		$D^0 \rightarrow K^- \pi^+$	1,8637	1000000	475	0,0044
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$	2,0054	3000000	303	0,0004
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$	2,0054	1000000	106	0,0004
B^+		$B^+ \rightarrow J/\psi K^+$	5,2787	7000000	27	0,0094
B^-		$B^- \rightarrow J/\psi K^-$	5,2767	7000000	31	0,0095

Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	Uubar or bbbar	$\pi^0 \rightarrow \gamma \gamma$	0,136	100000	133877	
Ks		$K_S \rightarrow \pi^+ \pi^-$	0,4975	1000000	2216121	
ϕ		$\phi \rightarrow K^+ K^-$	1,020	1000000	55526	
J/ψ	ccbar	$J/\psi \rightarrow e^+ e^-$				
		$J/\psi \rightarrow \mu^+ \mu^-$	3,094	10000000	6087	
D ⁰	cubar	$D^0 \rightarrow K^+ \pi^-$	1,864	1000000	32078	
		$D^0 \rightarrow K^- \pi^+$	1,864	1000000	29785	
D ^{*+}	cdbar	$D^{*+} \rightarrow D^0 \pi^+$	2,005	10000000	95306	
D ^{*-}	cbard	$D^{*-} \rightarrow D^0 \pi^-$	2,005	1000000	2016	
B ⁺		$B^+ \rightarrow J/\psi K^+$	5,281	10000000	1367	
B ⁻		$B^- \rightarrow J/\psi K^-$	5,277	10000000	1313	

Phi mass



Click to fit

Range: min = 1 max = 1.03 $\chi^2/\text{ndf} = 385.6 / 95 = 4.059$

Function: Gaus + Poly $N \cdot e^{-\left(\frac{x-\mu}{2\sigma}\right)^2} + p0 + p1 \cdot x$

Name	Value	Min	Set	Max	Step
• μ :	1.0197	1		1.025	0.0001
• σ :	0.0031	0		0.004	0.0001
• N:	324.1284	0		10000	0.0001

Polynomial order: 1					
Name	Value	Min	Set	Max	Step
• p0:	52.363935054039	52.363935054039		200	0.0001
• p1:	67.5691	1		67.569163751250	0.0001
• p2:	0	-10		10	0.0001
• p3:	0	-10		10	0.0001
• p4:	0	-10		10	0.0001

Belle II Particle Discovery: Describe process →Analyse →Fit results →Discover

Run Analysis Save Diagram Load Diagram Hide Text Help About B meson reconstruction

100%

```
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      }
    }
  }
}
```

```
bash -c 'cd src; root -b -l <L BParticle.cc+ .L BEvent.cc+ .L Blab2.cc void Blab2::event(){
combiner(selector(-1,-1,MUON,histogram(1,0),2),selector(-1,1,MUON,histogram(1,1),3),
0,JPSI,1,4,histogram(1,2),1); } void Blab2::Init(){ fNeve=1000000; fNfirst=0; fData="hadron-2.root";
fPrint=0; h1d("GetMass","mumu Mass",100,1,4,2); h1d("GetMass","mu pos Mass",100,0,5,1);
h1d("GetMass","mu neg Mass",40,0,5,0); plist(1); plist(2); plist(3); } Blab2 *blab2 = new Blab2();
```

Number of Events in the file 5665997

Number of events processed: 1000000

Number of particles: 17836051

Average number of particles per event 17.836052

Blocks

Belle II Masterclass

Number of events: 1000000

First event: 0

Data Source hadron-2.root

Print particle list? No

Particle List

Combine 2 particles

Particle 1

Select Particles

Particle

Charge -1

Type muon

Histograms

Histogram Title mu neg M

Particle 2

Select Particles

Particle

Charge 1

Type muon

Histograms

Histogram Title mu pos M

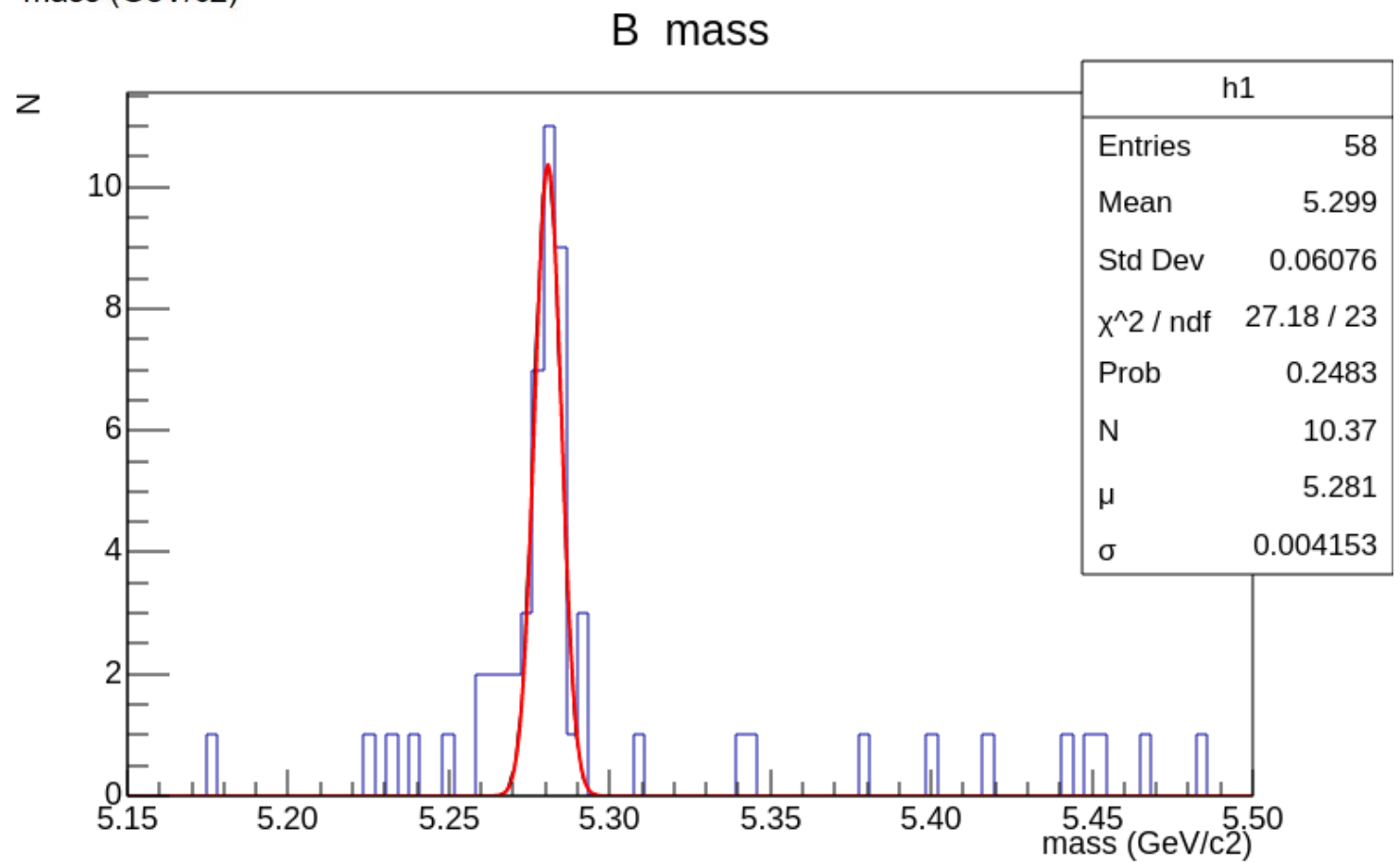
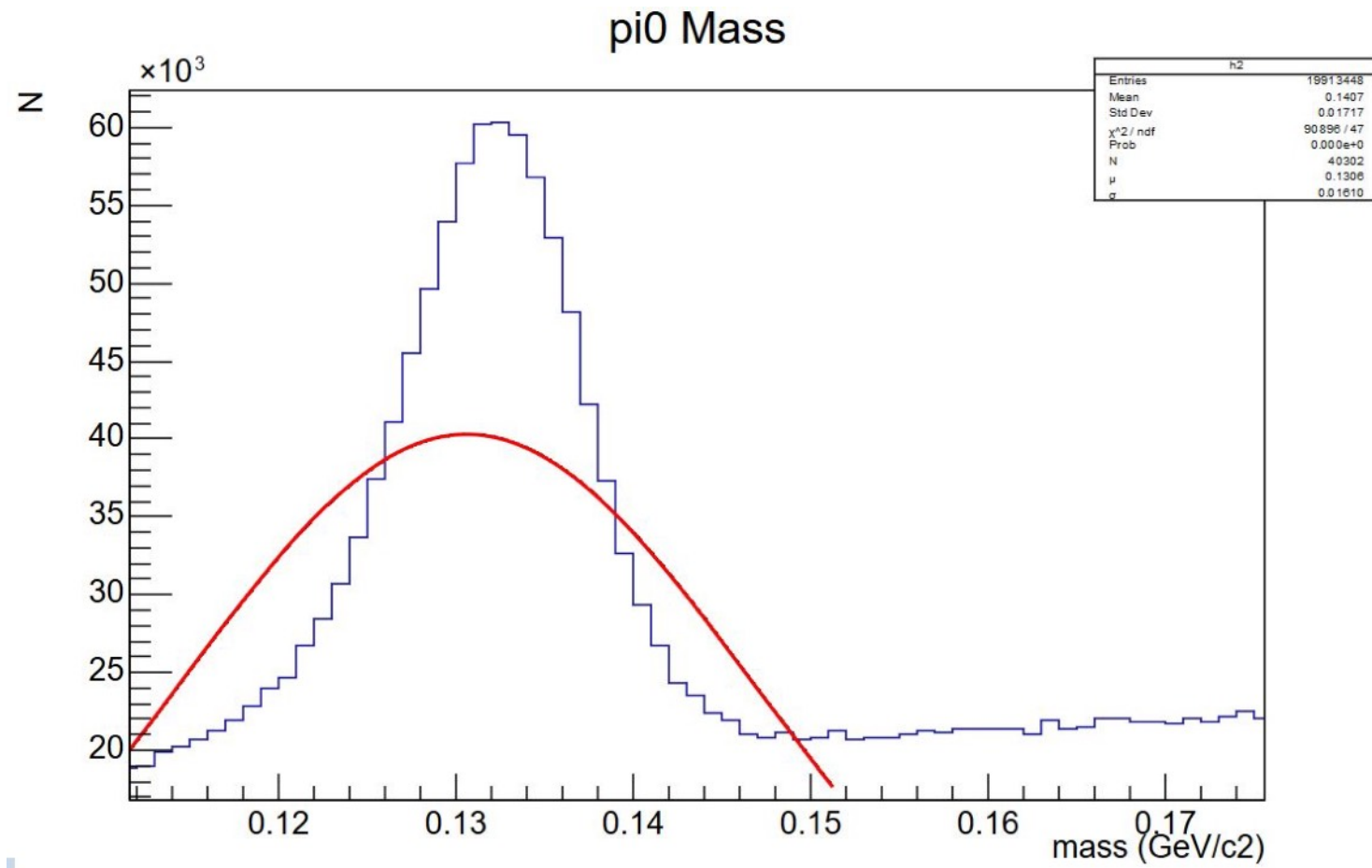
Same particle lists? No

Set identity to J/Psi meson

Min mass [GeV/c2]: 1

Max mass [GeV/c2]: 4

Histograms



Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0.033	628975	11201787	
Ks		$K_S \rightarrow \pi^+ \pi^-$				
ϕ		$\phi \rightarrow K^+ K^-$				
J/ψ		$J/\psi \rightarrow e^+ e^-$	0.03	5000000	89346763	
		$J/\psi \rightarrow \mu^+ \mu^-$	0.225	1000000	17836051	
D ⁰		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D ^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺		$B^+ \rightarrow J/\psi K^+$				
B ⁻		$B^- \rightarrow J/\psi K^-$				

Worksheet

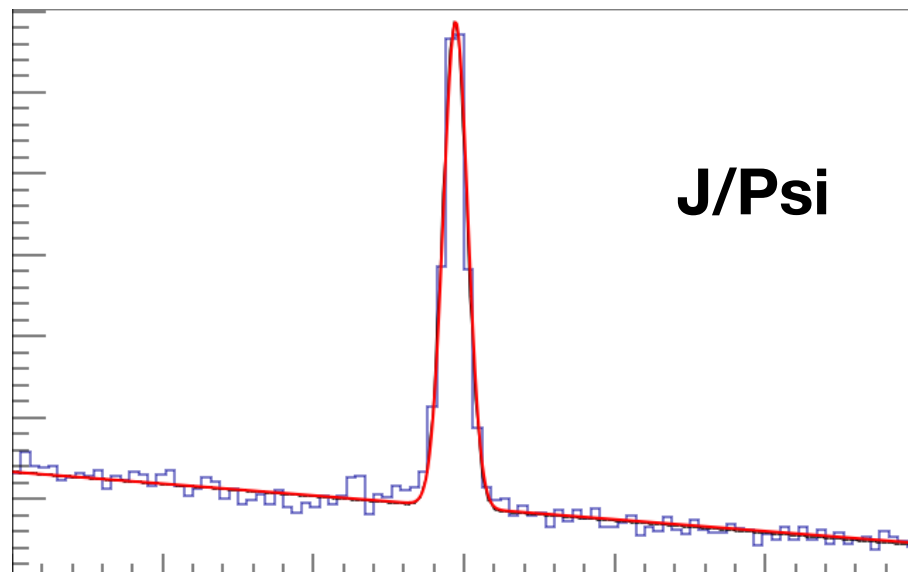
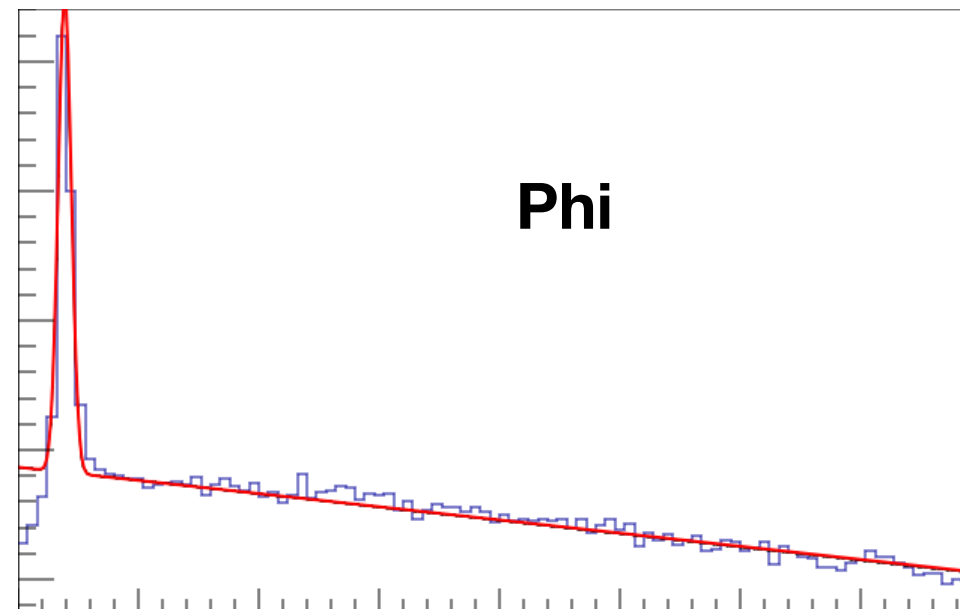
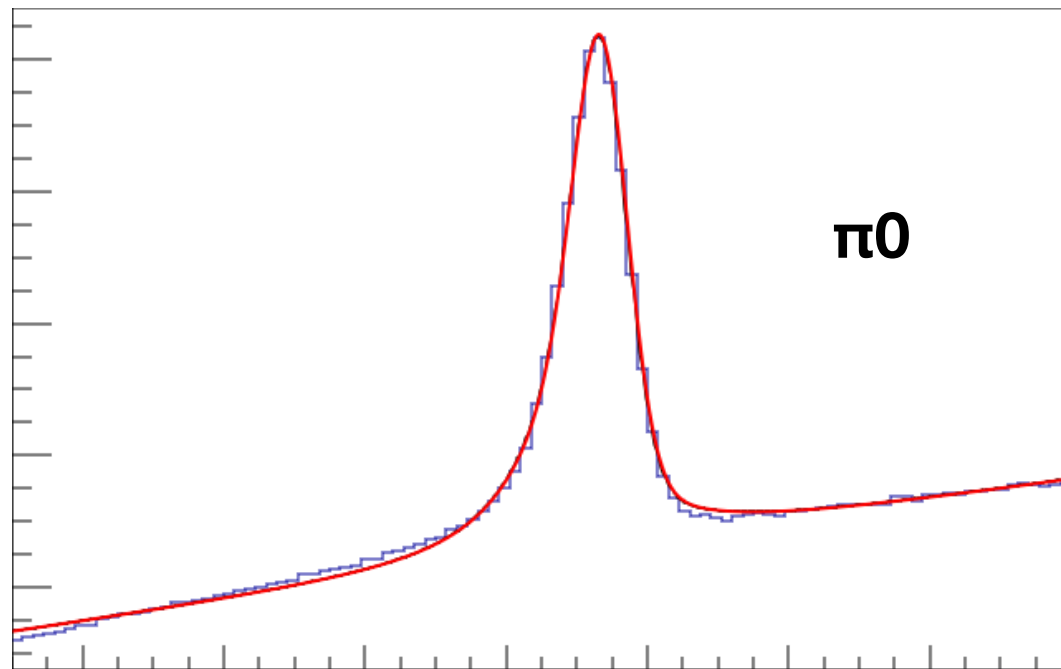
Exercise table with the list of decays to examine

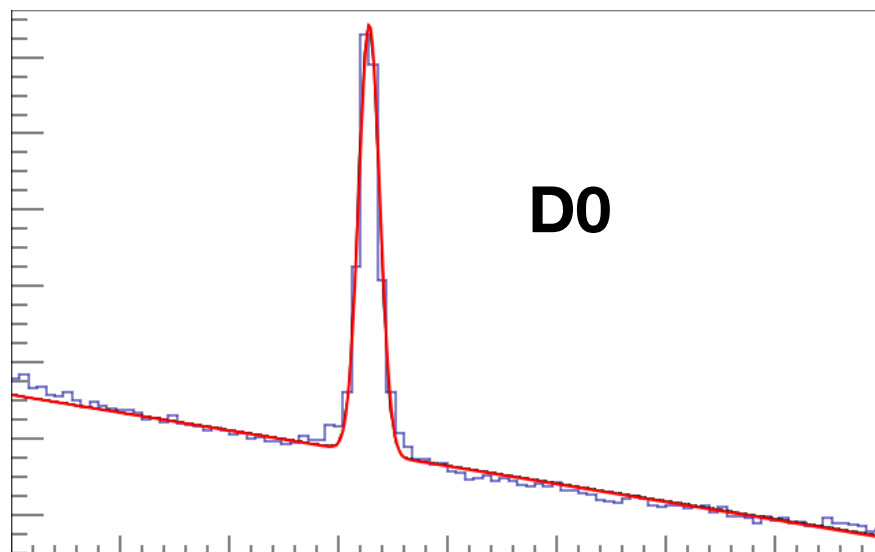
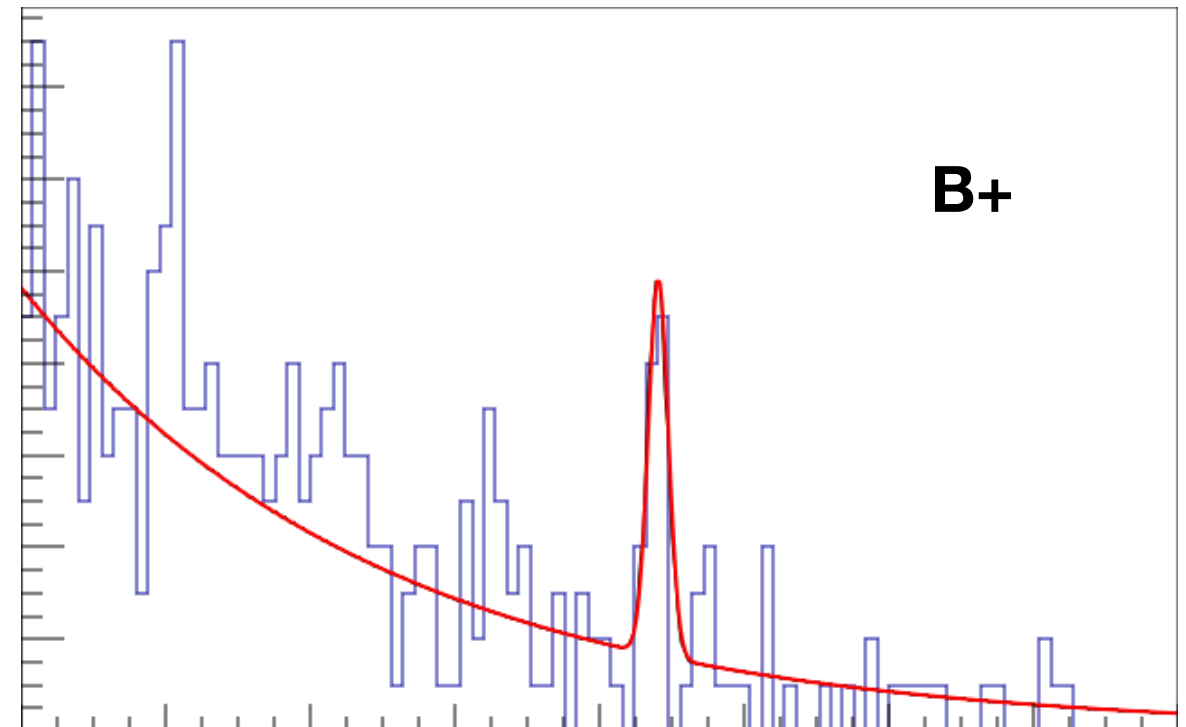
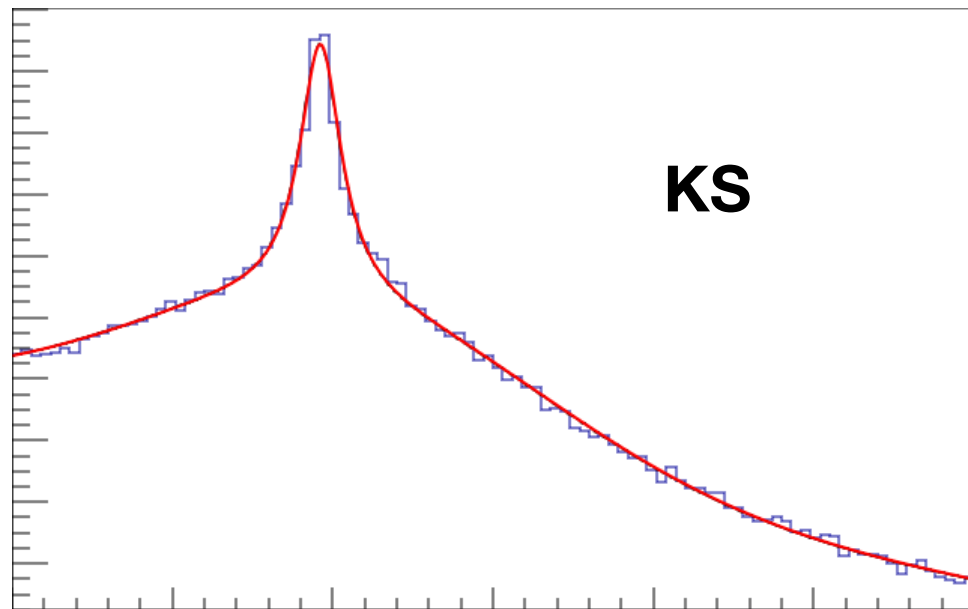
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$				
Ks		$K_s \rightarrow \pi^+ \pi^-$				
ϕ	s	$\phi \rightarrow K^+ K^-$	1,02	7085107	1029000	0,004521
J/ ψ	c	$J/\psi \rightarrow e^+ e^-$	3,086	5665997	21330	0,01362
		$J/\psi \rightarrow \mu^+ \mu^-$	3,090	5665997	17360	0,009075
D ⁰		$D^0 \rightarrow K^+ \pi^-$	1,864	7085107	1136000	0,00478
		$D^0 \rightarrow K^- \pi^+$	1,864	7085107	1034000	0,004726
D ^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺		$B^+ \rightarrow J/\psi K^+$				
B ⁻		$B^- \rightarrow J/\psi K^-$				

Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	u-ubar d-dbar	$\pi^0 \rightarrow \gamma \gamma$	0.1334	600000		0.003729
K_s	s-dbar d-sbar	$K_s \rightarrow \pi^+ \pi^-$	0.4960	600000		0.01581
ϕ	s-sbar	$\phi \rightarrow K^+ K^-$	1.019	6000000		0.002730
J/ψ		$J/\psi \rightarrow e^+ e^-$				
	c-cbar	$J/\psi \rightarrow \mu^+ \mu^-$	3.094	6000000		0.008099
D^0	c-u	$D^0 \rightarrow K^+ \pi^-$	1.864	6000000		0.004816
	c-u	$D^0 \rightarrow K^- \pi^+$	1.864	6000000		0.004825
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B^+	u-bbar	$B^+ \rightarrow J/\psi K^+$	5.280	6000000		0.01372
B^-		$B^- \rightarrow J/\psi K^-$				



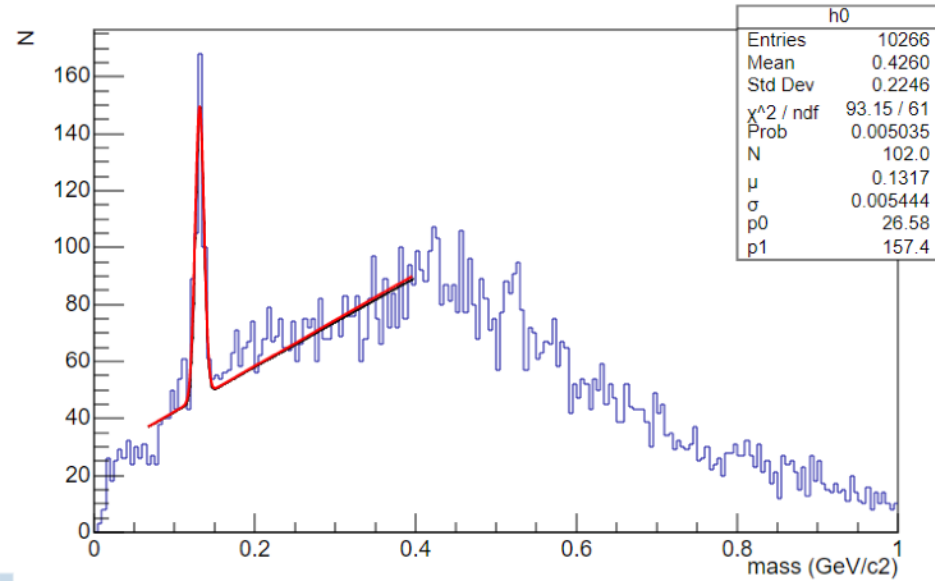


Worksheet

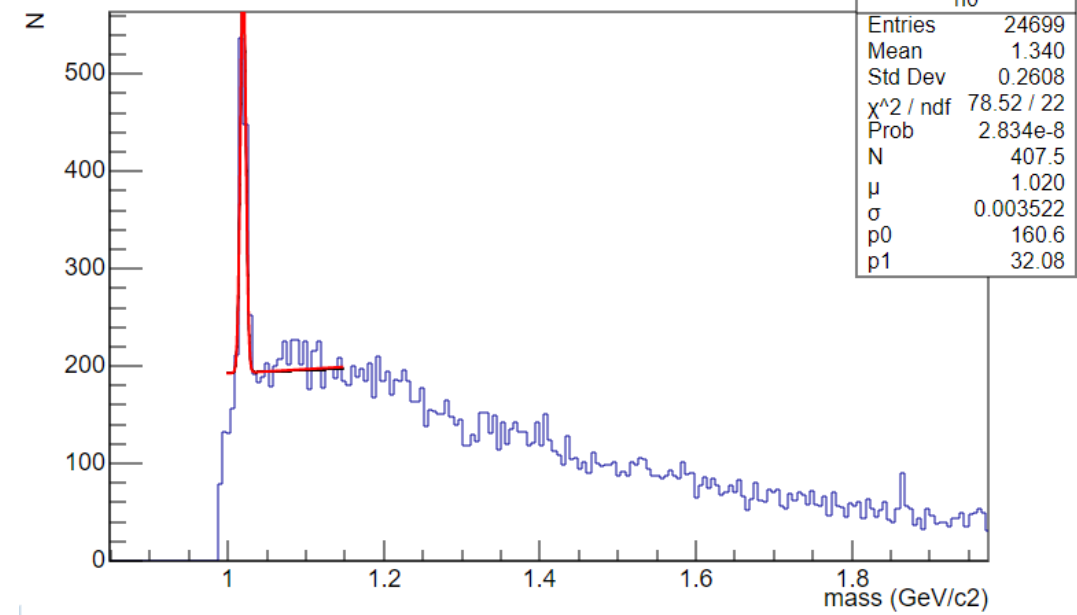
Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	uu(bar) + dd(bar) + ss(bar)	$\pi^0 \rightarrow \gamma \gamma$	0.1317	1 000	10 266	0.0054
Ks	ds(bar) - sd(bar)	$K_s \rightarrow \pi^+ \pi^-$	0.4976	10 000	77 694	0.00758
ϕ	ss(bar)	$\phi \rightarrow K^+ K^-$	1.020	100 000	24 699	0.00352
J/ψ	cc(bar)	$J/\psi \rightarrow e^+ e^-$	3.085	10 000 000 (5665997 – hadron-2)	94 226	0.01327
		$J/\psi \rightarrow \mu^+ \mu^-$	3.094	1 000 000	9 772	0.00717
D ⁰	cu(bar)	$D^0 \rightarrow K^+ \pi^-$	1.861	10 000 000 (628975 – hadron-1)	423 096	0.00535
		$D^0 \rightarrow K^- \pi^+$				
D ^{*+}	cd(bar)	$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}	dc(bar)	$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺	ub(bar)	$B^+ \rightarrow J/\psi K^+$				
B ⁻	bu(bar)	$B^- \rightarrow J/\psi K^-$				

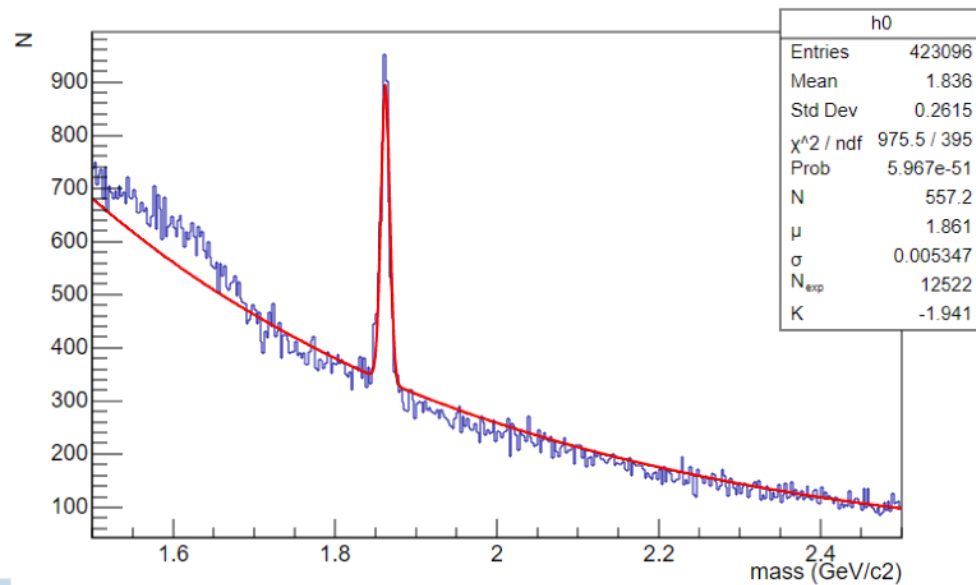
Pion Mass



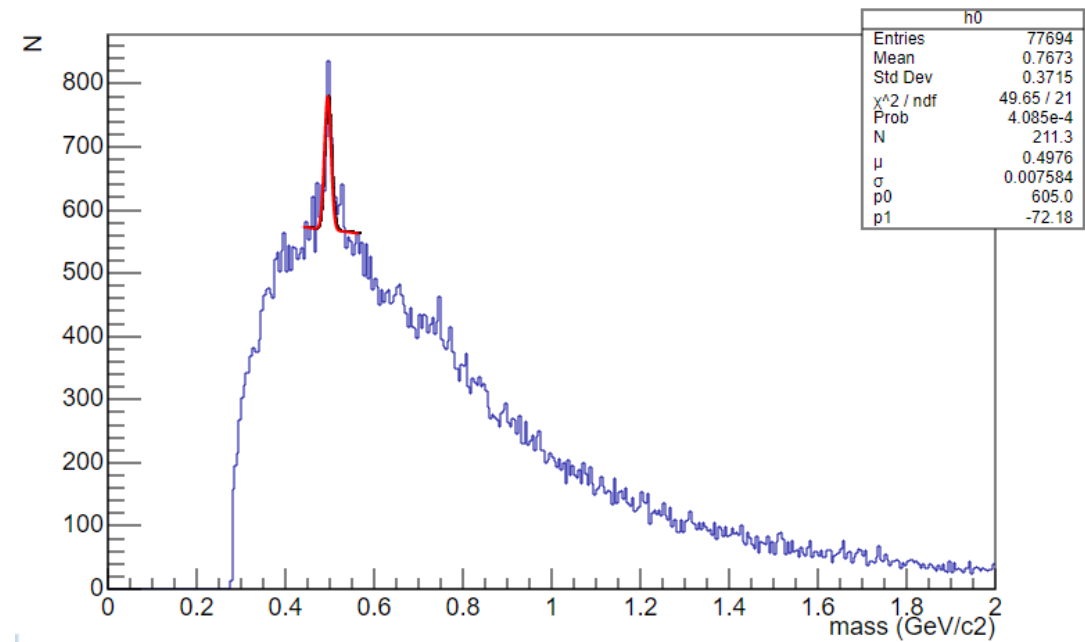
Phi Mass



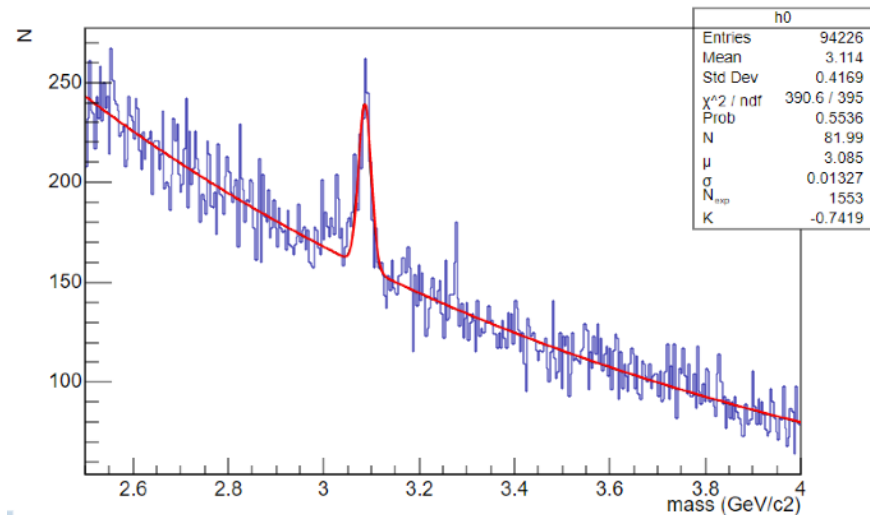
D to K Pi- Mass



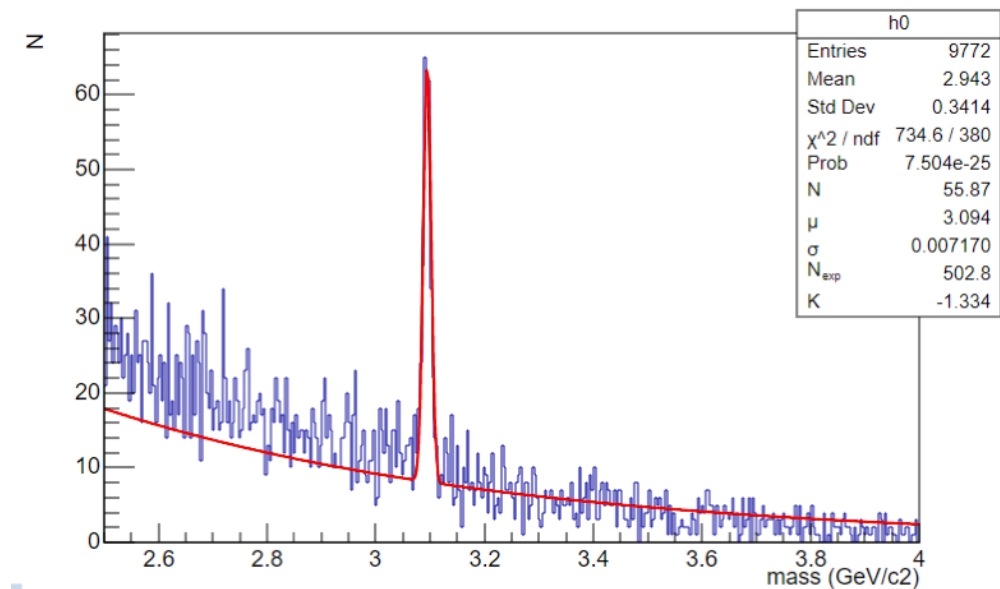
Kaon short Mass



J/Psi to ee Mass

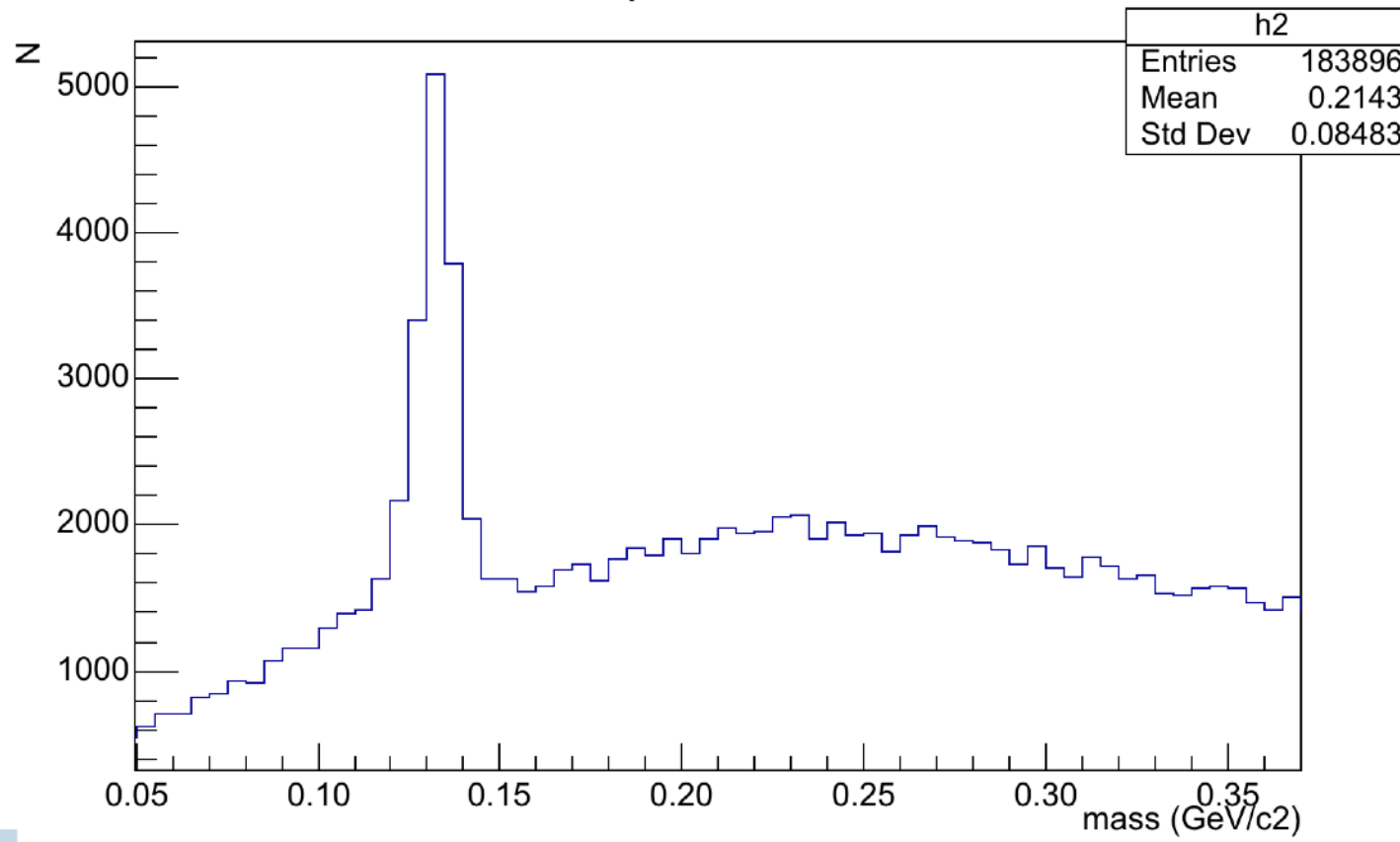


J/Psi to mumu Mass

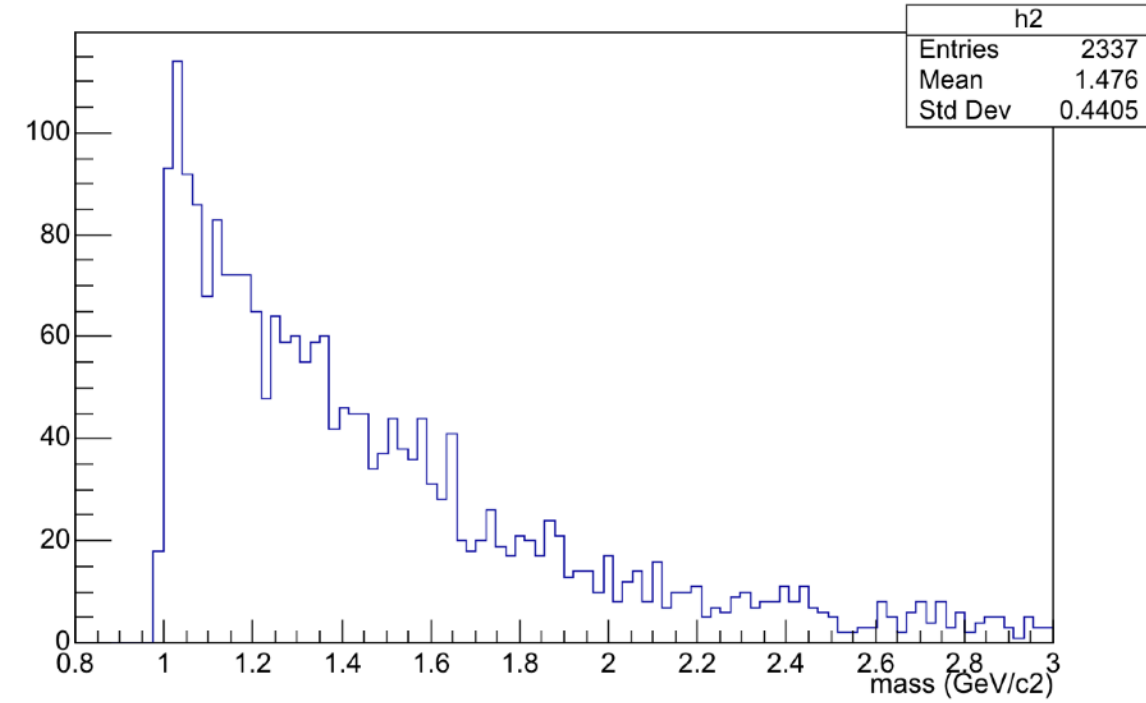


Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	$u \bar{d}$	$\pi^0 \rightarrow \gamma \gamma$	$0,137 \pm 0,003$	70000		$0,145 - 0,120$ $\sim 0,013$
K_S	$\frac{d \bar{s} - s \bar{d}}{\sqrt{2}}$	$K_S \rightarrow \pi^+ \pi^-$	$0,495 \pm 0,005$	70000		$\sim 0,033$
ϕ	$s \bar{s}$	$\phi \rightarrow K^+ K^-$	$1,024 \pm 0,007$	70000		$\sim 0,036$
J/ψ	$c \bar{c}$	$J/\psi \rightarrow e^+ e^-$	$\sim 3,09$	700000		
	$c \bar{c}$	$J/\psi \rightarrow \mu^+ \mu^-$	$\sim 3,09$	700000		
D^0	$c \bar{u}$	$D^0 \rightarrow K^+ \pi^-$	$\sim 1,861$	700000		$\sim 0,010$
	$c \bar{u}$	$D^0 \rightarrow K^- \pi^+$	$\sim 1,861$	700000		$\sim 0,075$
D^{*+}	$c \bar{d}$	$D^{*+} \rightarrow D^0 \pi^+$	$\sim 2,013$	700000		
D^{*-}	$c \bar{d}$	$D^{*-} \rightarrow D^0 \pi^-$	$\sim 2,012$	700000		
B^+		$B^+ \rightarrow J/\psi K^+$				
B^-		$B^- \rightarrow J/\psi K^-$				

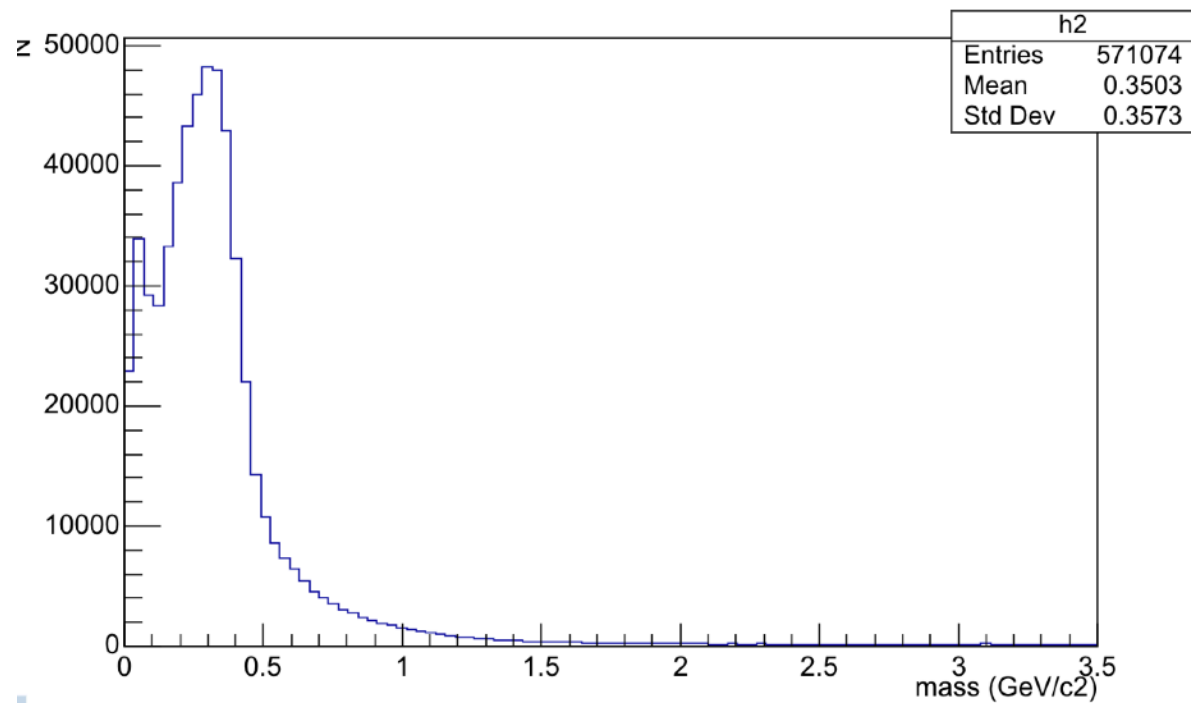
pi0 mass



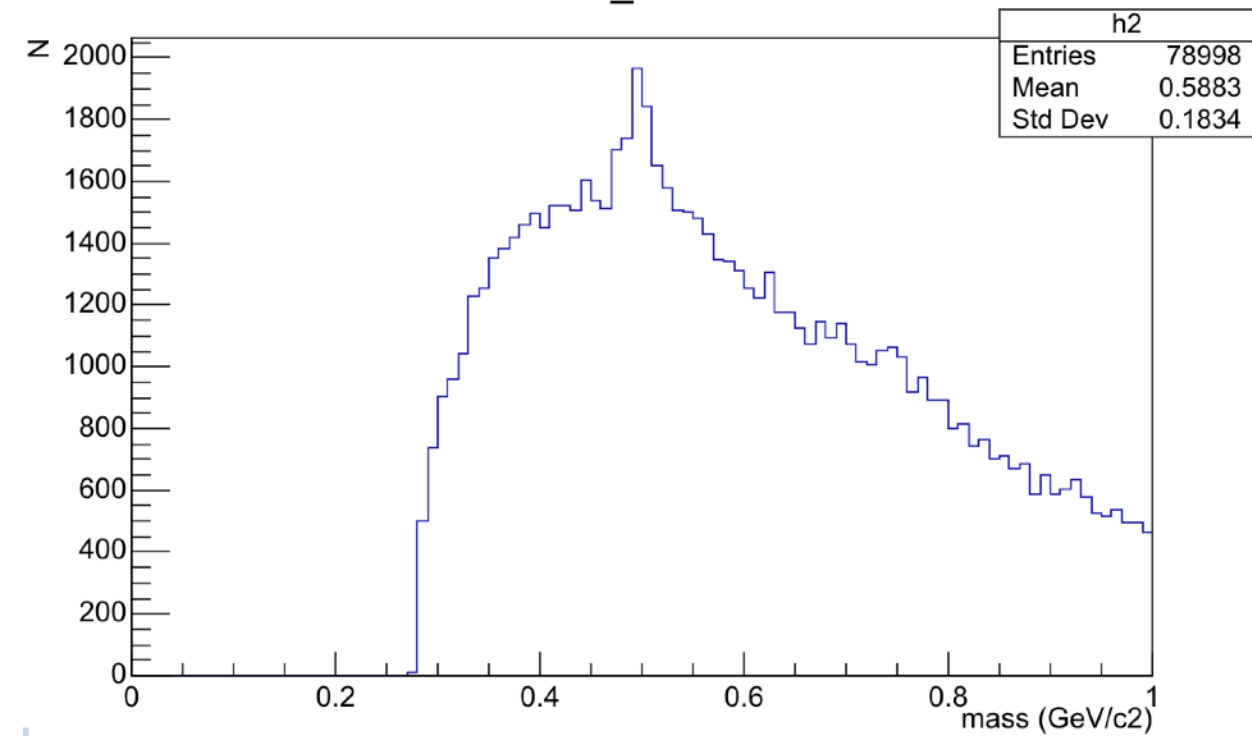
Phi meson Mass



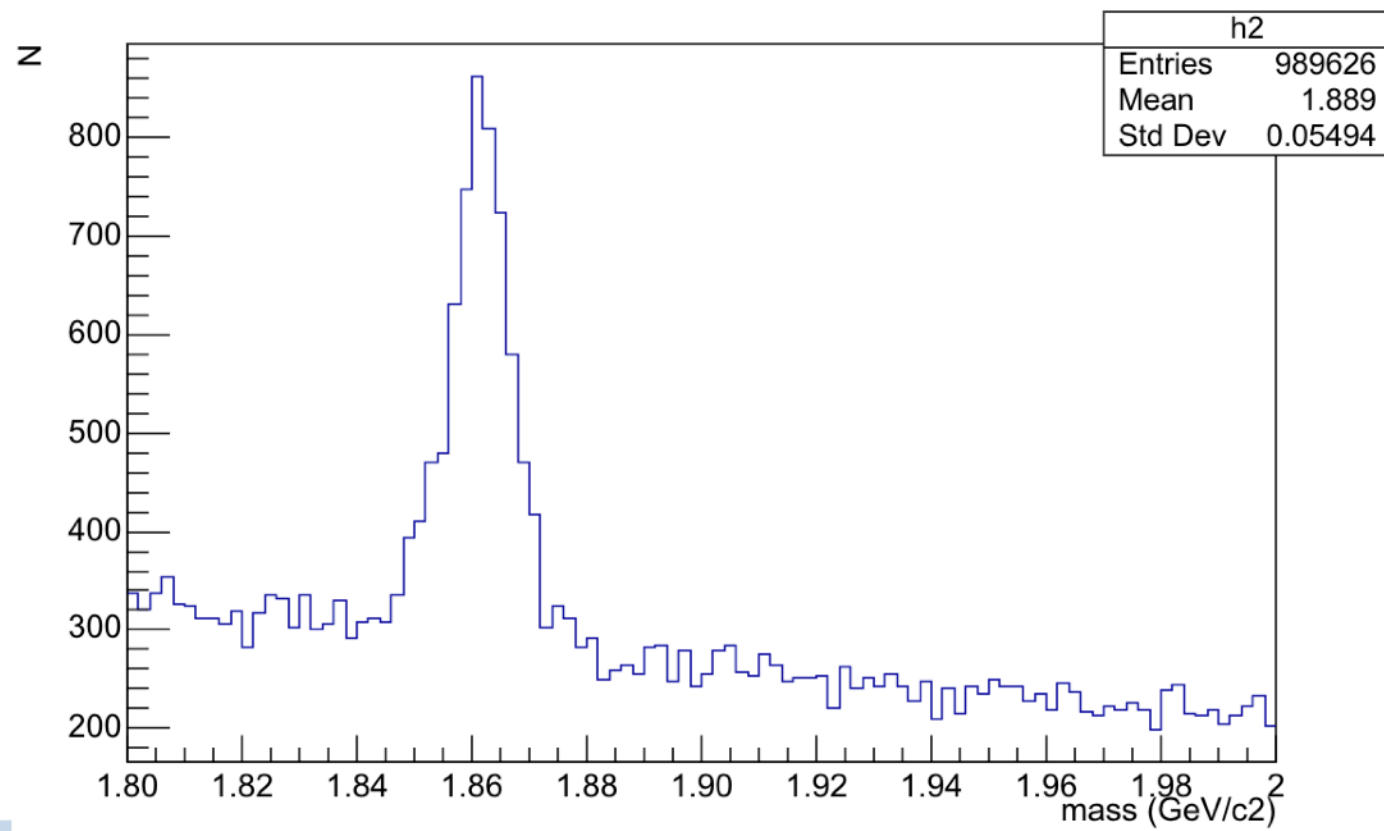
J/Psi meson mass



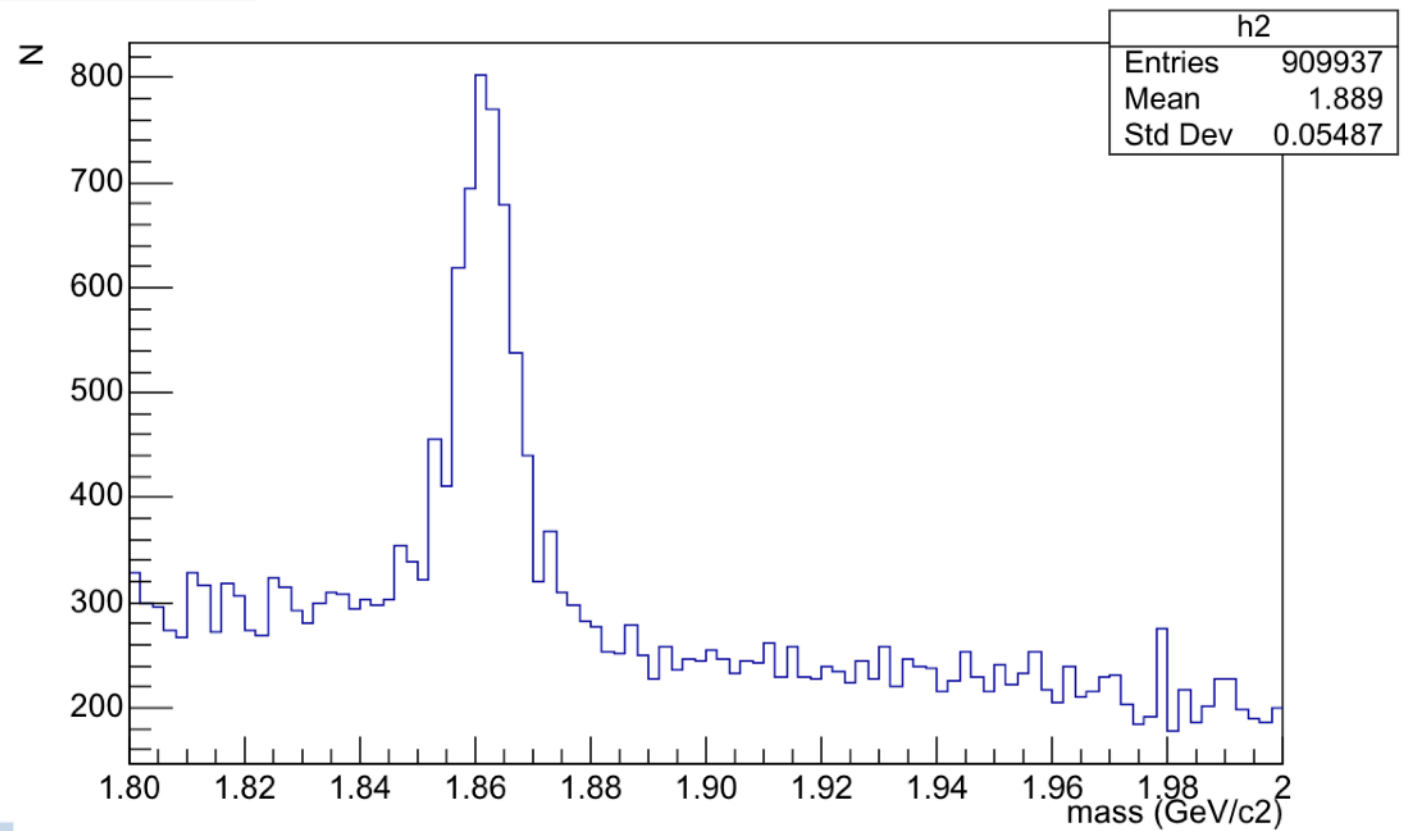
kaon_s mass



D0 meson mass



D0 meson K- mass



Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	u ubar d dbar	$\pi^0 \rightarrow \gamma \gamma$	0.1327	10000	8371	
Ks	d sbar s dbar	$K_s \rightarrow \pi^+ \pi^-$	0.4206	100000	65957	
ϕ	s sbar	$\phi \rightarrow K^+ K^-$	1.025	10000	398 (?)	
J/ψ	c cbar	$J/\psi \rightarrow e^+ e^-$	0.2129	10000	338	
	c cbar	$J/\psi \rightarrow \mu^+ \mu^-$	3.090/(0.9537)?	2000000	738832	
D ⁰	c ubar	$D^0 \rightarrow K^+ \pi^-$	1.586	1000000		
	c ubar	$D^0 \rightarrow K^- \pi^+$	1.860	1000000		
D ^{*+}	c dbar	$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}	c dbar	$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺		$B^+ \rightarrow J/\psi K^+$	3.630	100000		
B ⁻		$B^- \rightarrow J/\psi K^-$	3.617	100000		

Worksheet

Exercise table with the list of decays to examine

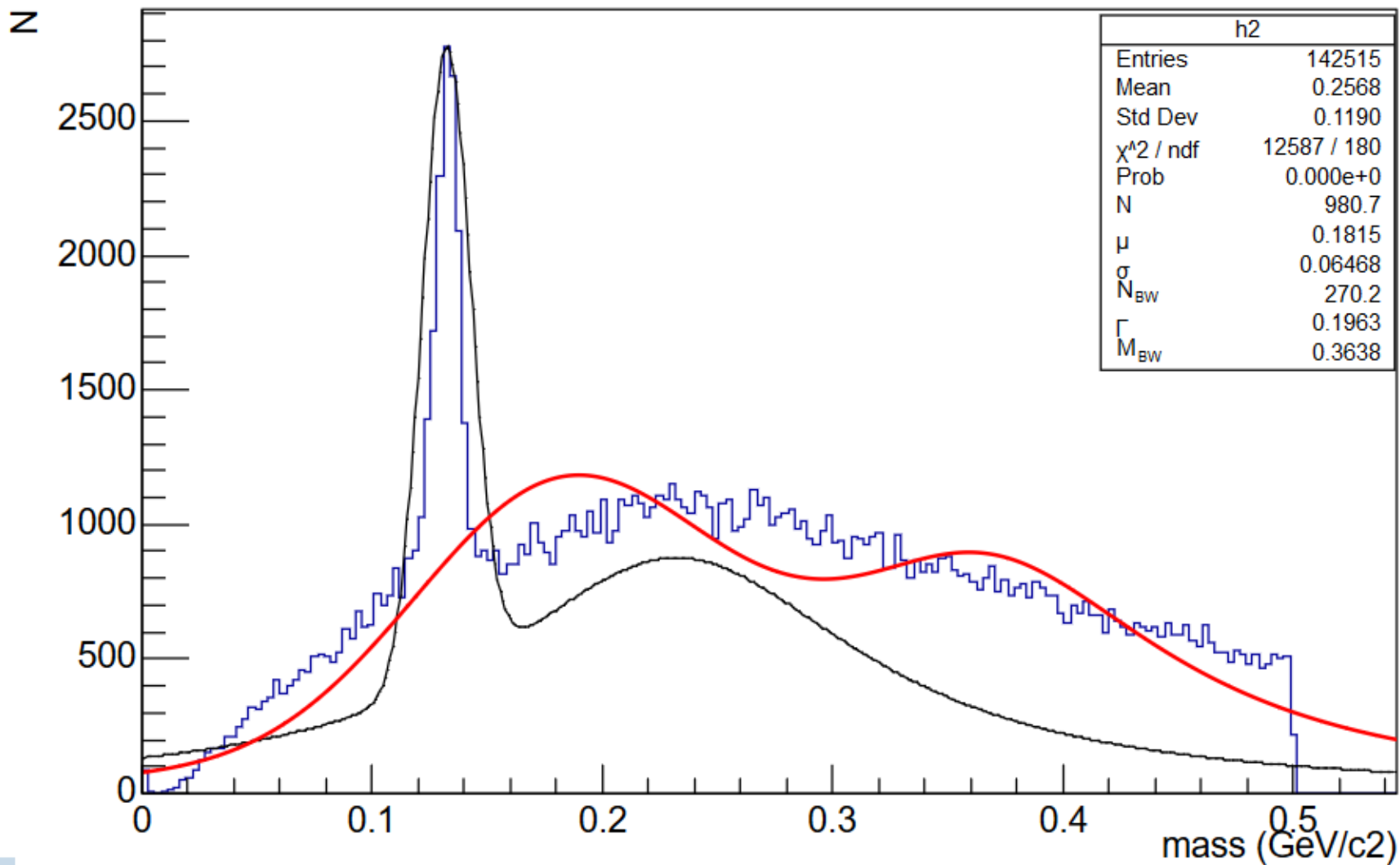
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	$u\bar{u}, d\bar{d}$	$\pi^0 \rightarrow \gamma \gamma$	.1321	100k	267754	.004756
K_s	$u\bar{s}, c\bar{c}$	$K_s \rightarrow \pi^+ \pi^-$	.4972	1M	5819244	.0104
ϕ	$S, \bar{s}$	$\phi \rightarrow K^+ K^-$	1.020	1M	338762	.002384
J/ψ	$c\bar{c}$	$J/\psi \rightarrow e^+ e^-$	3.087	5665997	4002320	.008503
		$J/\psi \rightarrow \mu^+ \mu^-$	3.0892	5665997	1691552	0.01579
D^0	$C\bar{u}$	$D^0 \rightarrow K^+ \pi^-$	1.8613	5665997		
		$D^0 \rightarrow K^- \pi^+$	1.8615	5665997	1315173	0.005398
D^{*+}	$c\bar{d}, c\bar{s}$	$D^{*+} \rightarrow D^0 \pi^+$	2.005			
D^{*-}	$\bar{c}d, \bar{c}s$	$D^{*-} \rightarrow D^0 \pi^-$	2.005			
B^+	$\bar{b}u, \bar{b}c$	$B^+ \rightarrow J/\psi K^+$				
B^-	$b\bar{u}, b\bar{c}$	$B^- \rightarrow J/\psi K^-$				

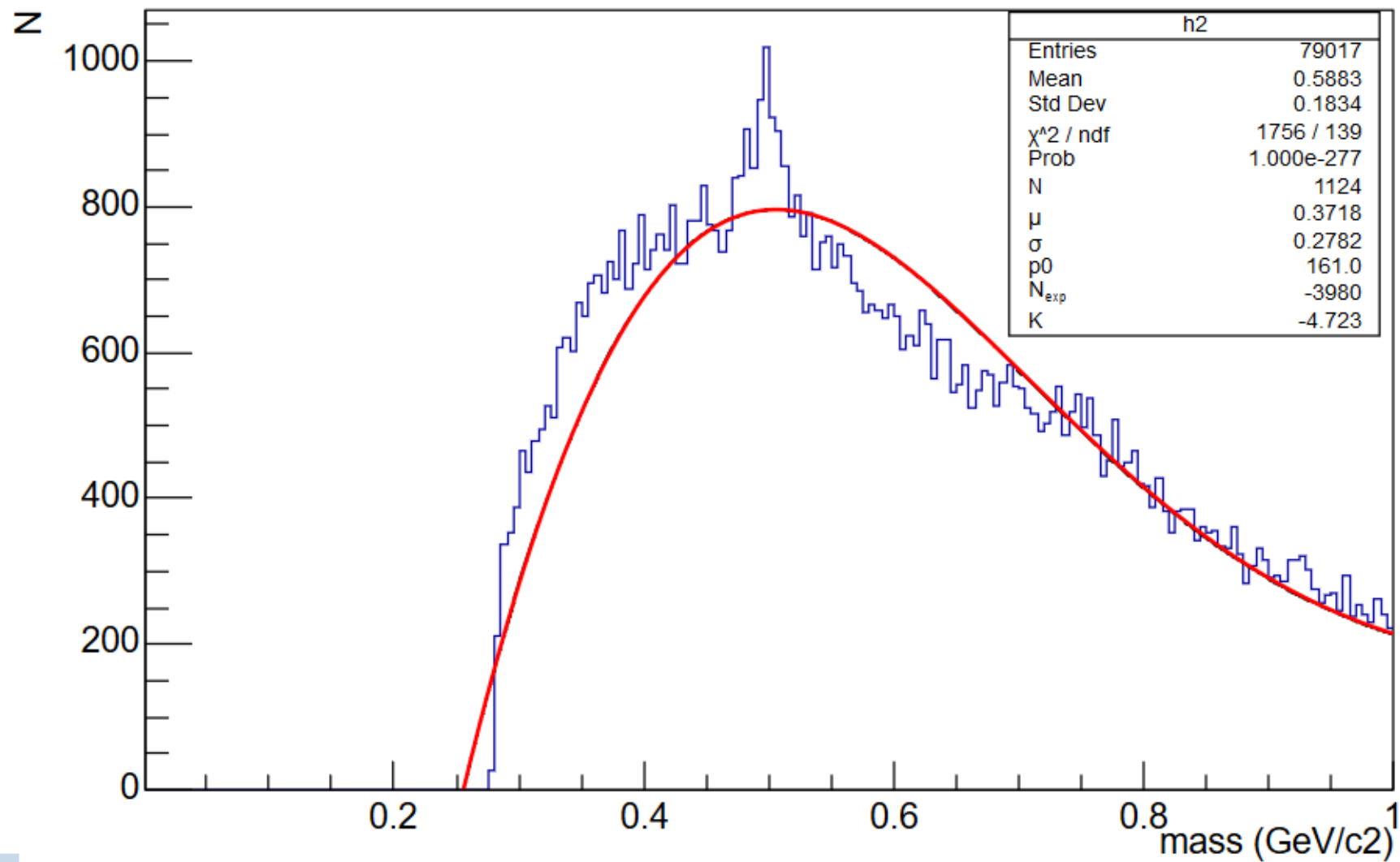
Worksheet

Exercise table with the list of decays to examine

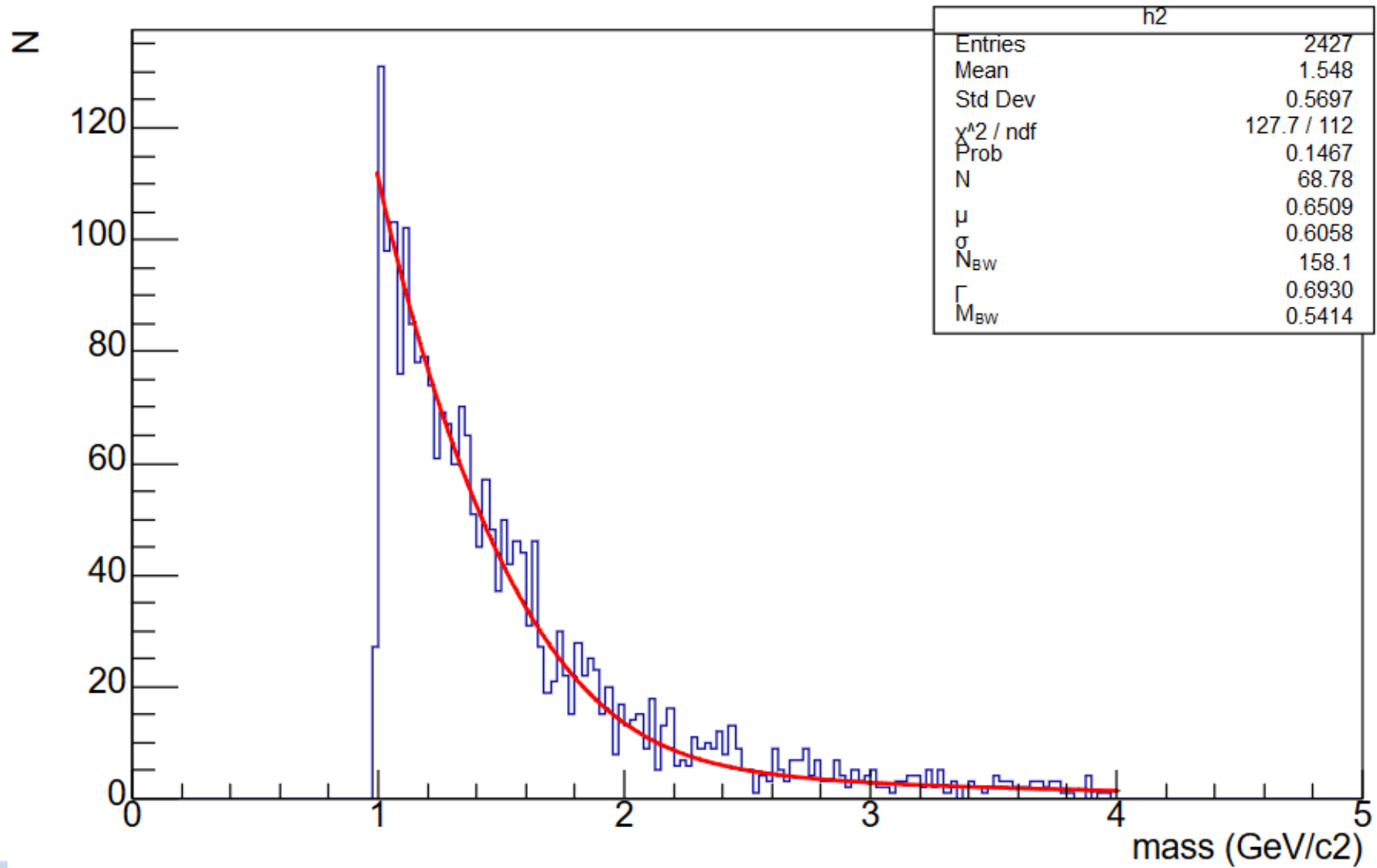
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0.1			
Ks		$K_s \rightarrow \pi^+ \pi^-$	0.5			
ϕ		$\phi \rightarrow K^+ K^-$	1.25			
J/ ψ		$J/\psi \rightarrow e^+ e^-$	3.1			
		$J/\psi \rightarrow \mu^+ \mu^-$	3.1			
D ⁰		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D ^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺		$B^+ \rightarrow J/\psi K^+$				
B ⁻		$B^- \rightarrow J/\psi K^-$				

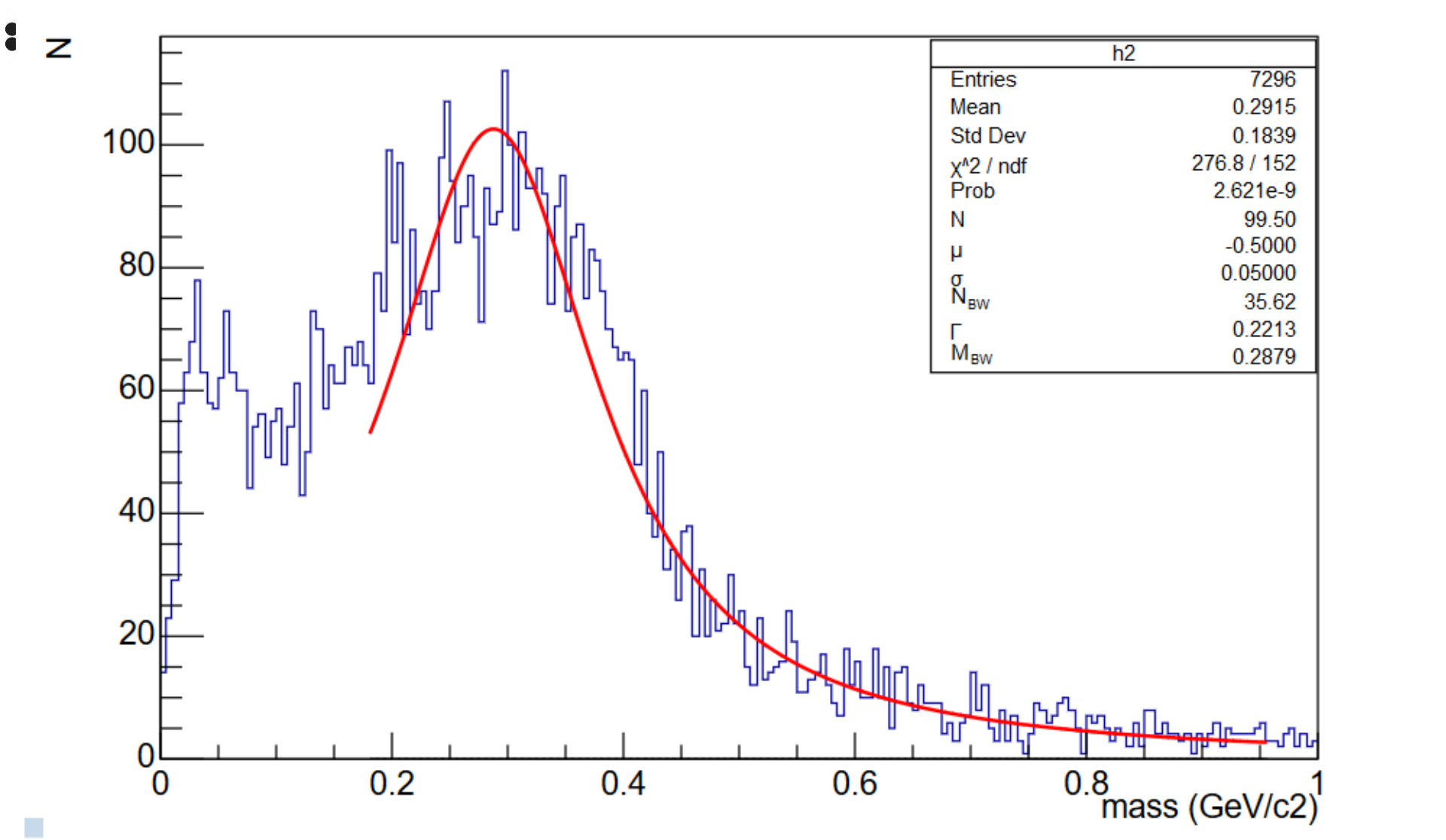
pion mass





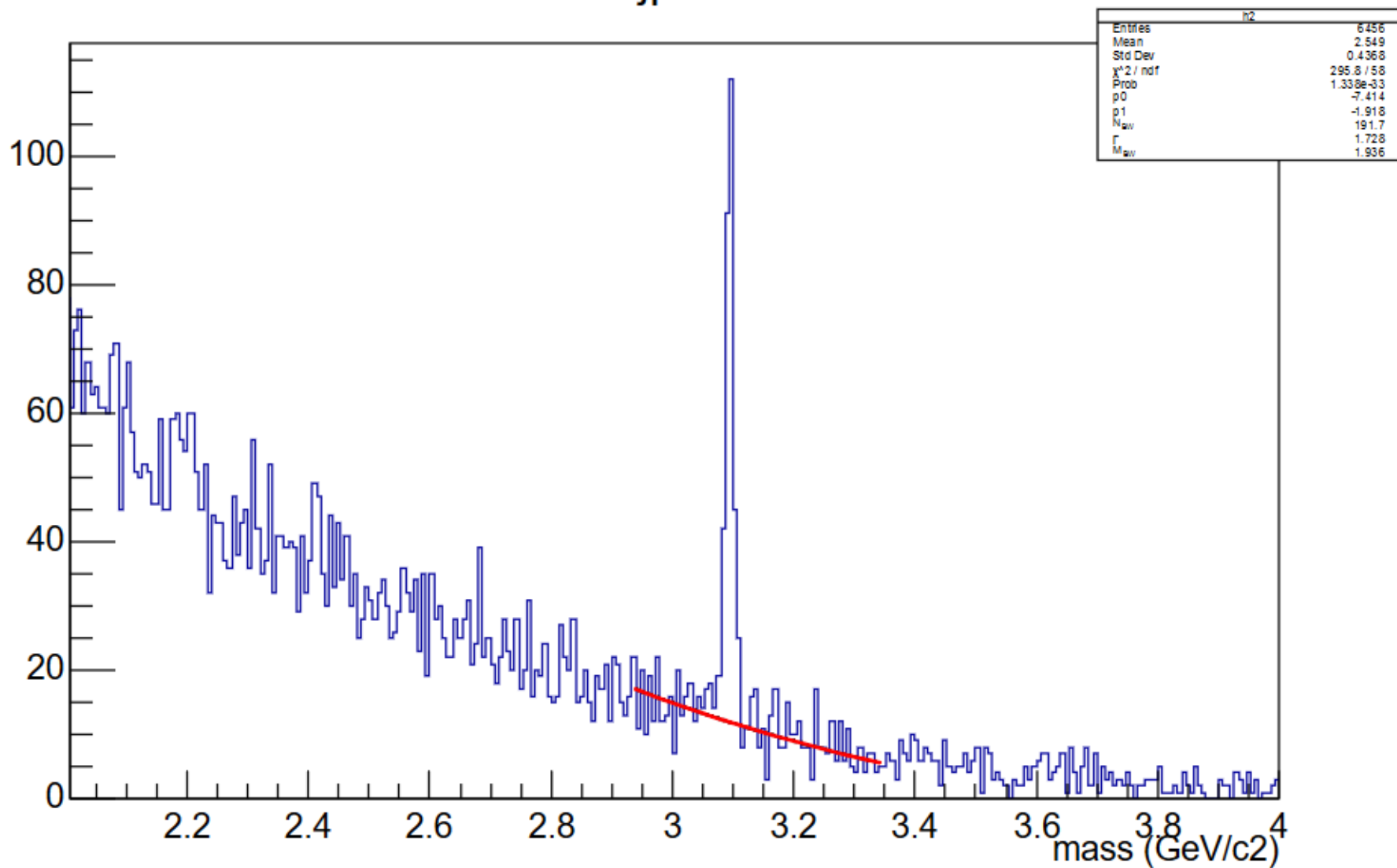
Ks





jpsi

Z

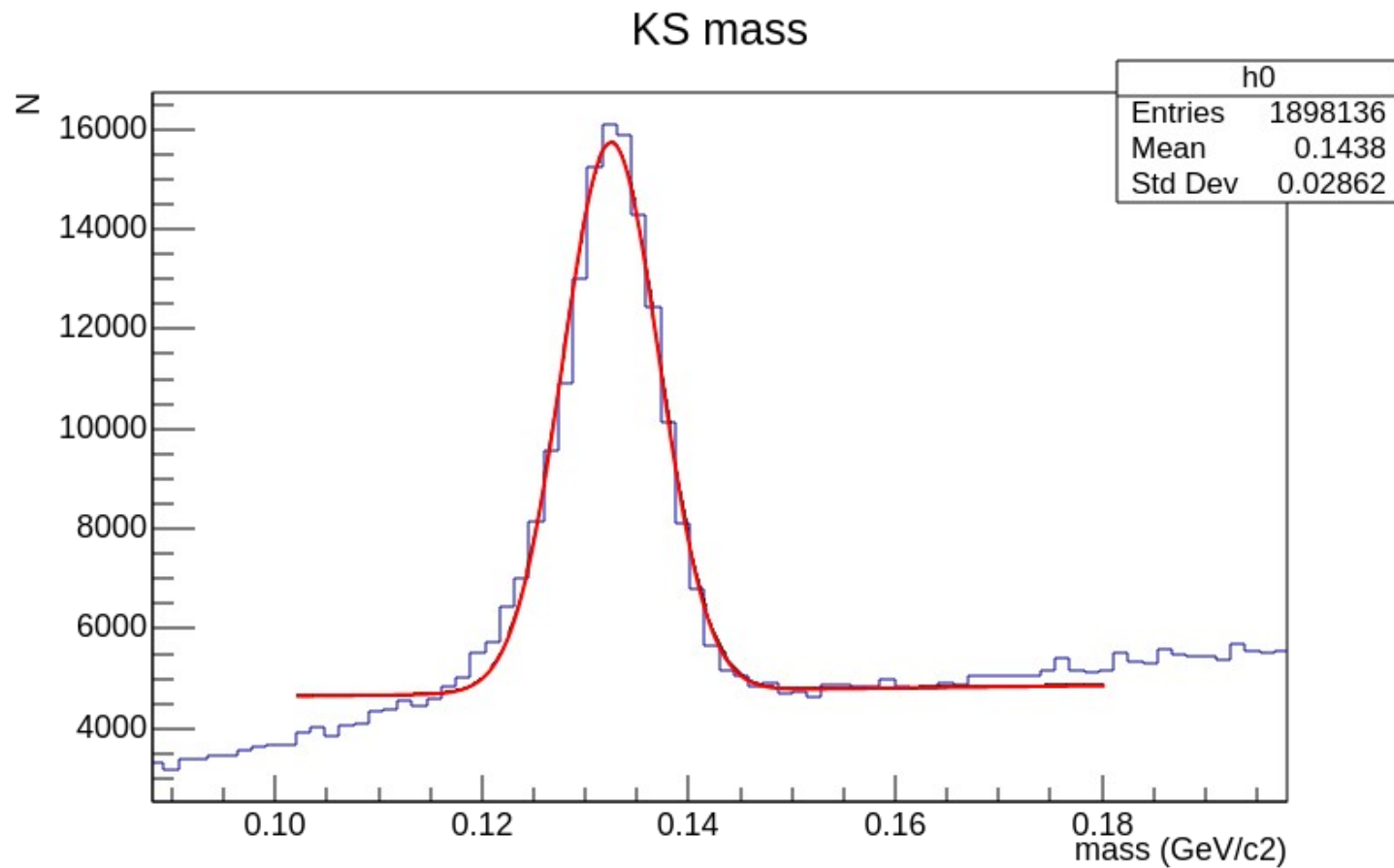


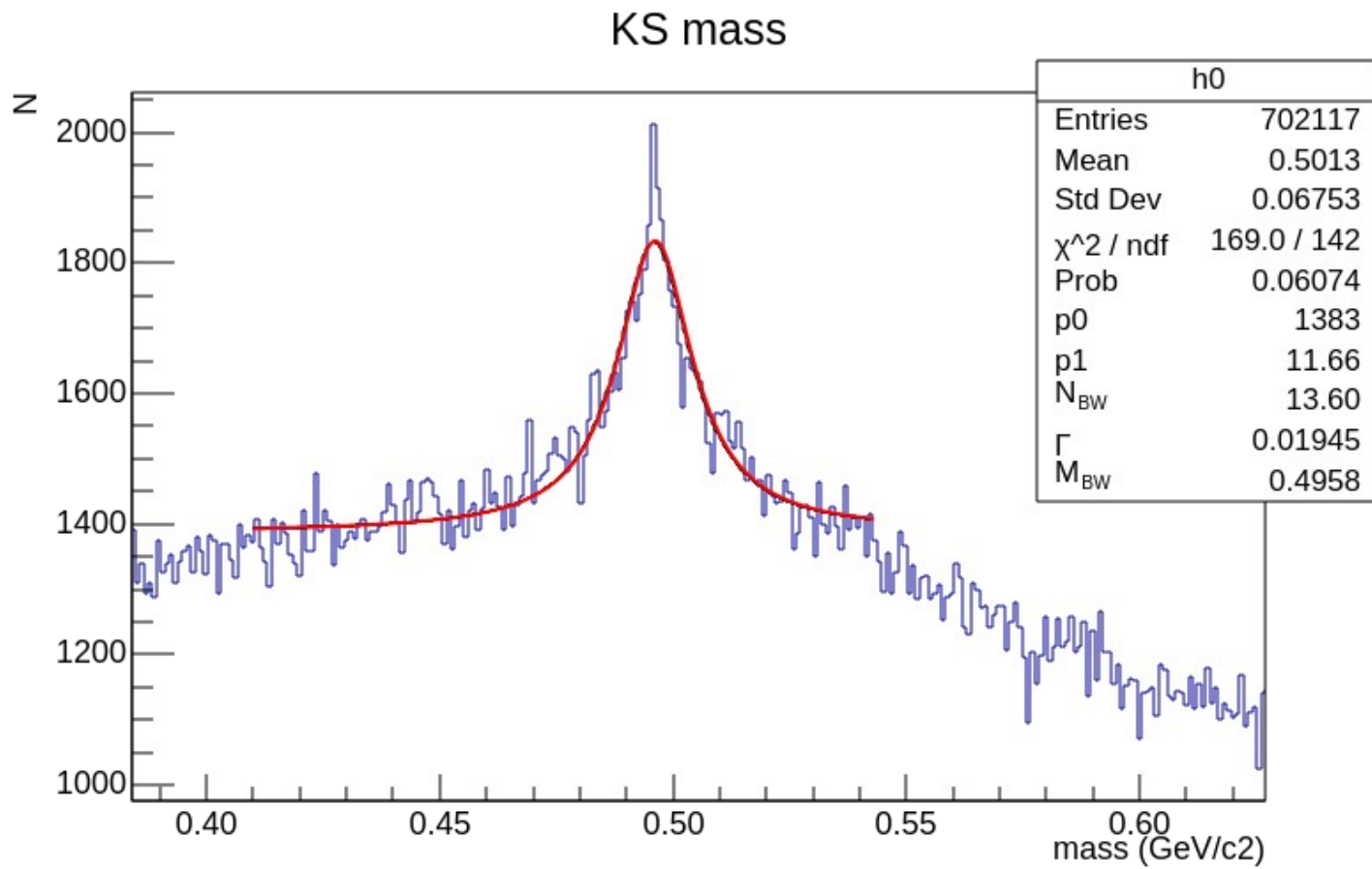
Worksheet

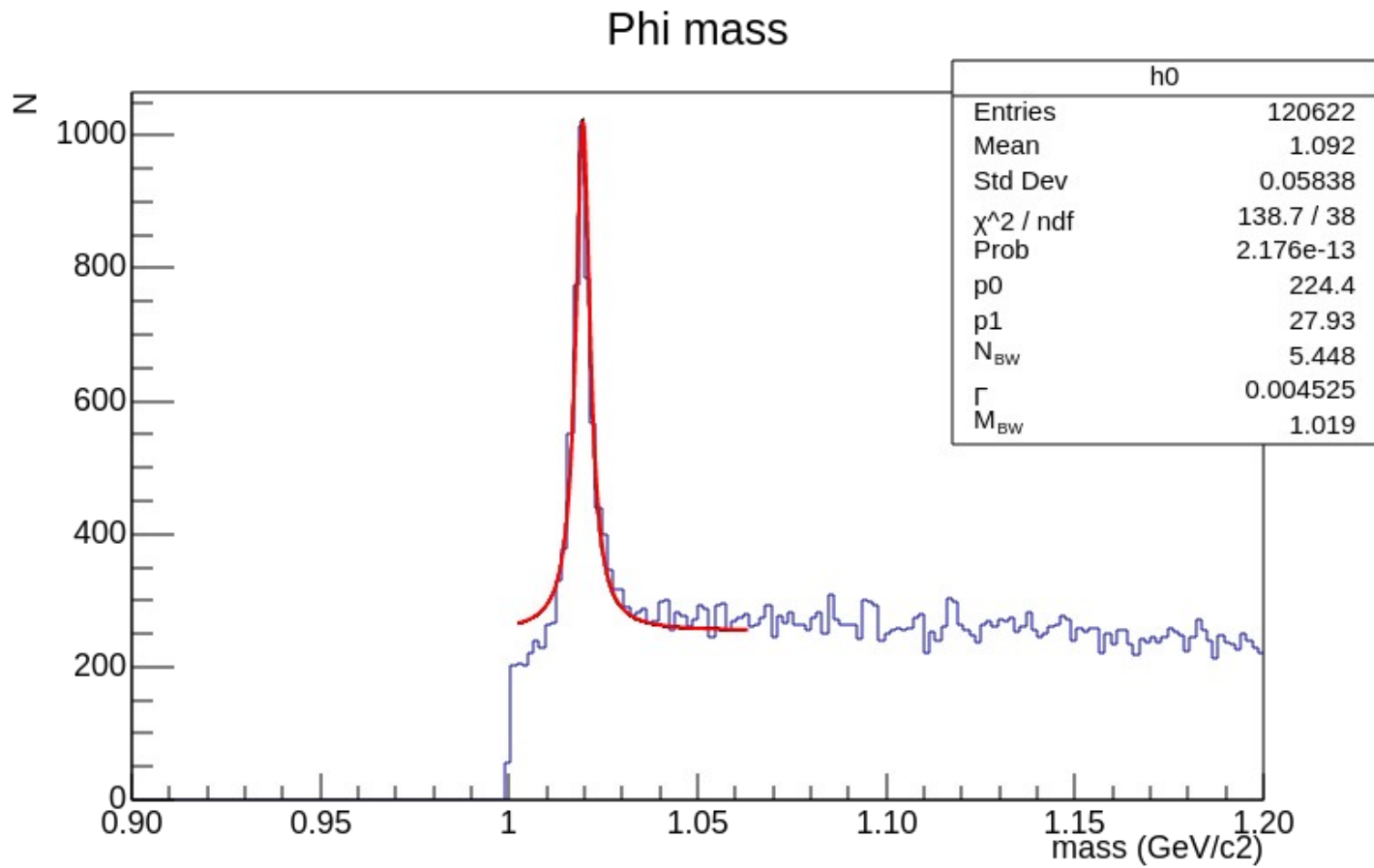
Exercise table with the list of decays to examine

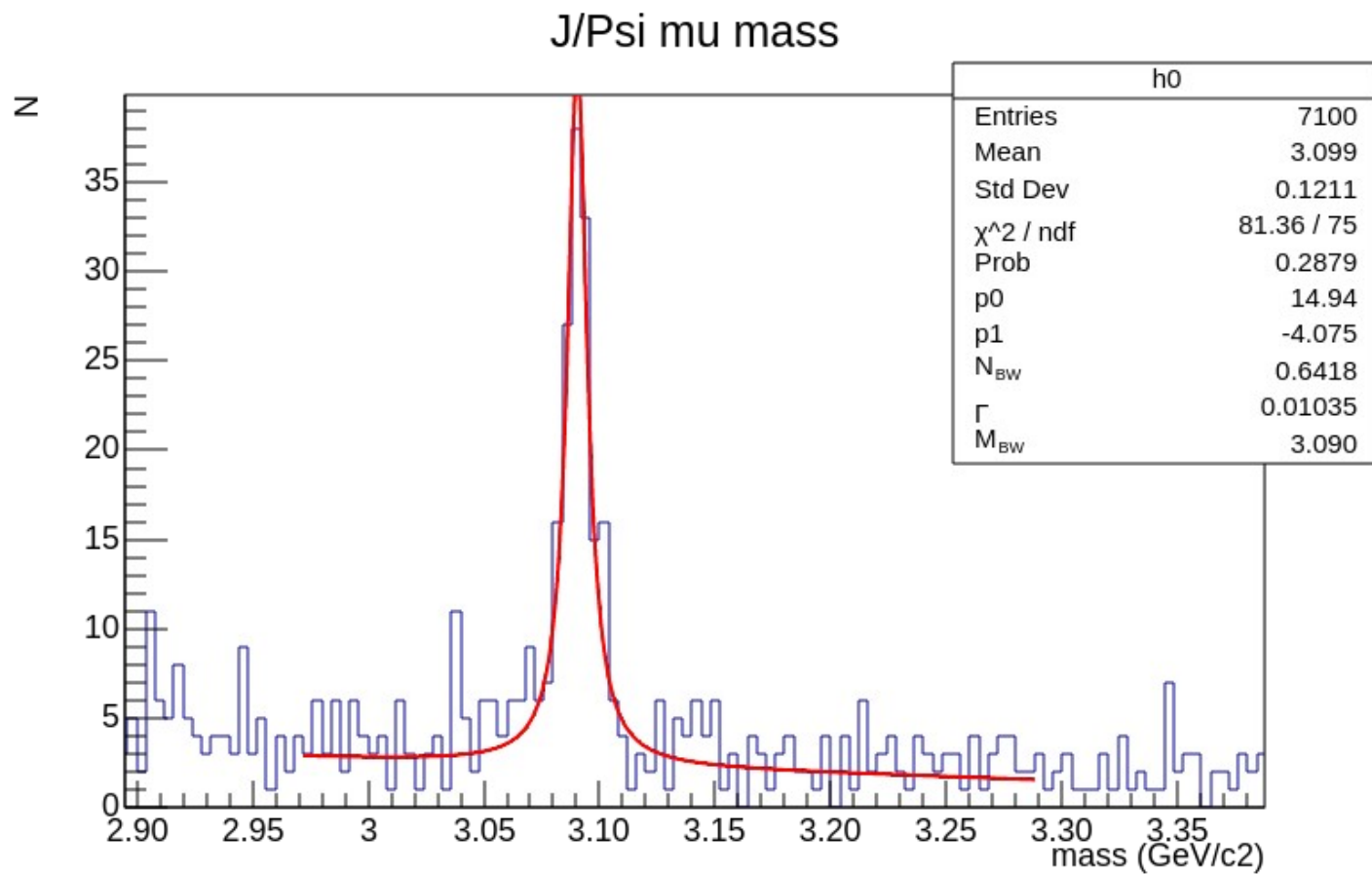
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0.133	10000	710	0.005 (detector resolution)
K_S		$K_S \rightarrow \pi^+ \pi^-$	0.496	100000	386	0.02 (detector resolution)
ϕ		$\phi \rightarrow K^+ K^-$	1.019	500000	3600	0.004
J/ψ		$J/\psi \rightarrow e^+ e^-$	3.086	5000000	5000000	0.02
		$J/\psi \rightarrow \mu^+ \mu^-$	3.090	628975	160	0.010
D^0		$D^0 \rightarrow K^+ \pi^-$	1.861	5000000	33340	0.01
		$D^0 \rightarrow K^- \pi^+$	1.862	5000000	30060	0.01
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$	2.005	4000000		
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$	2.005	1000000		
B^+		$B^+ \rightarrow J/\psi K^+$	5.278	5665997		
B^-		$B^- \rightarrow J/\psi K^-$	5.278			

Pi0, wrong title of the histo

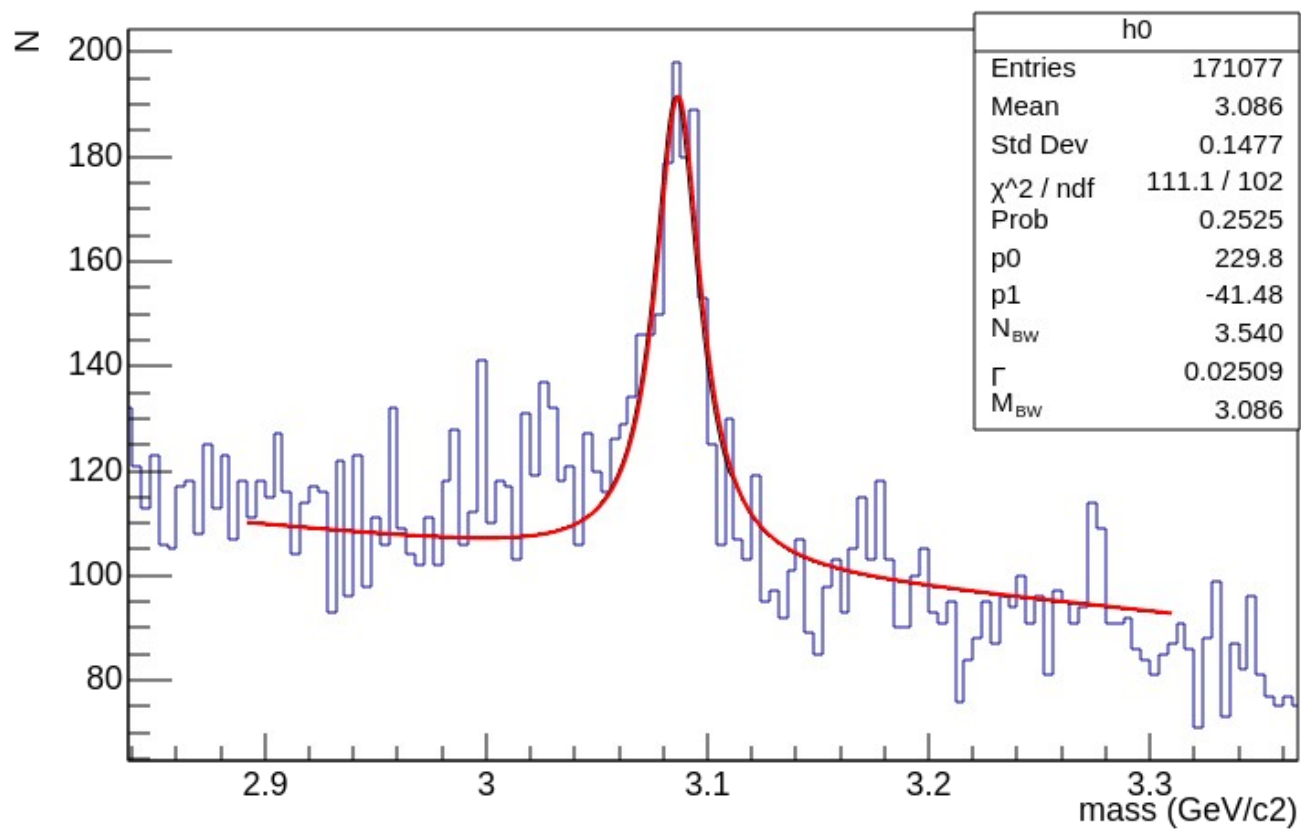


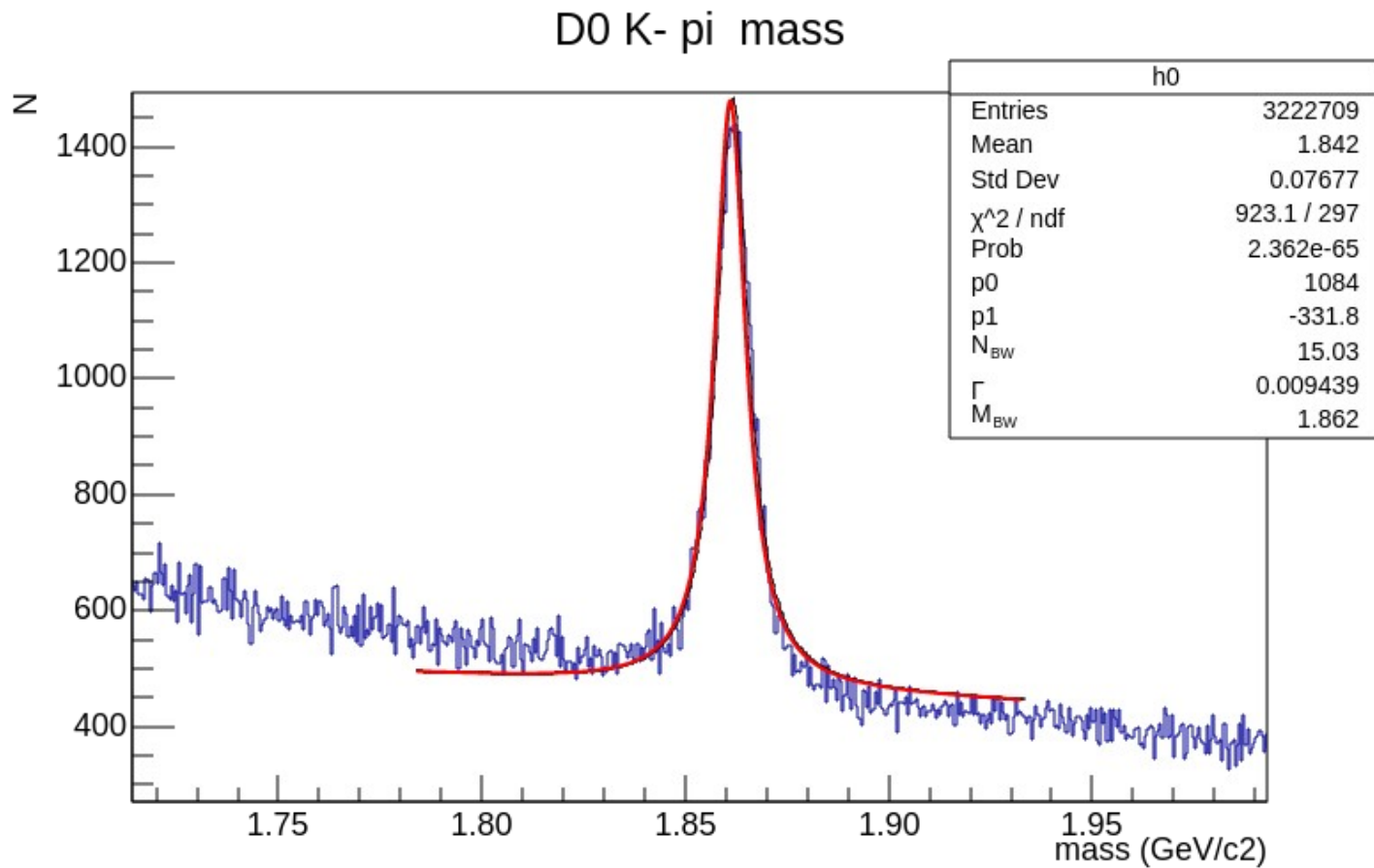


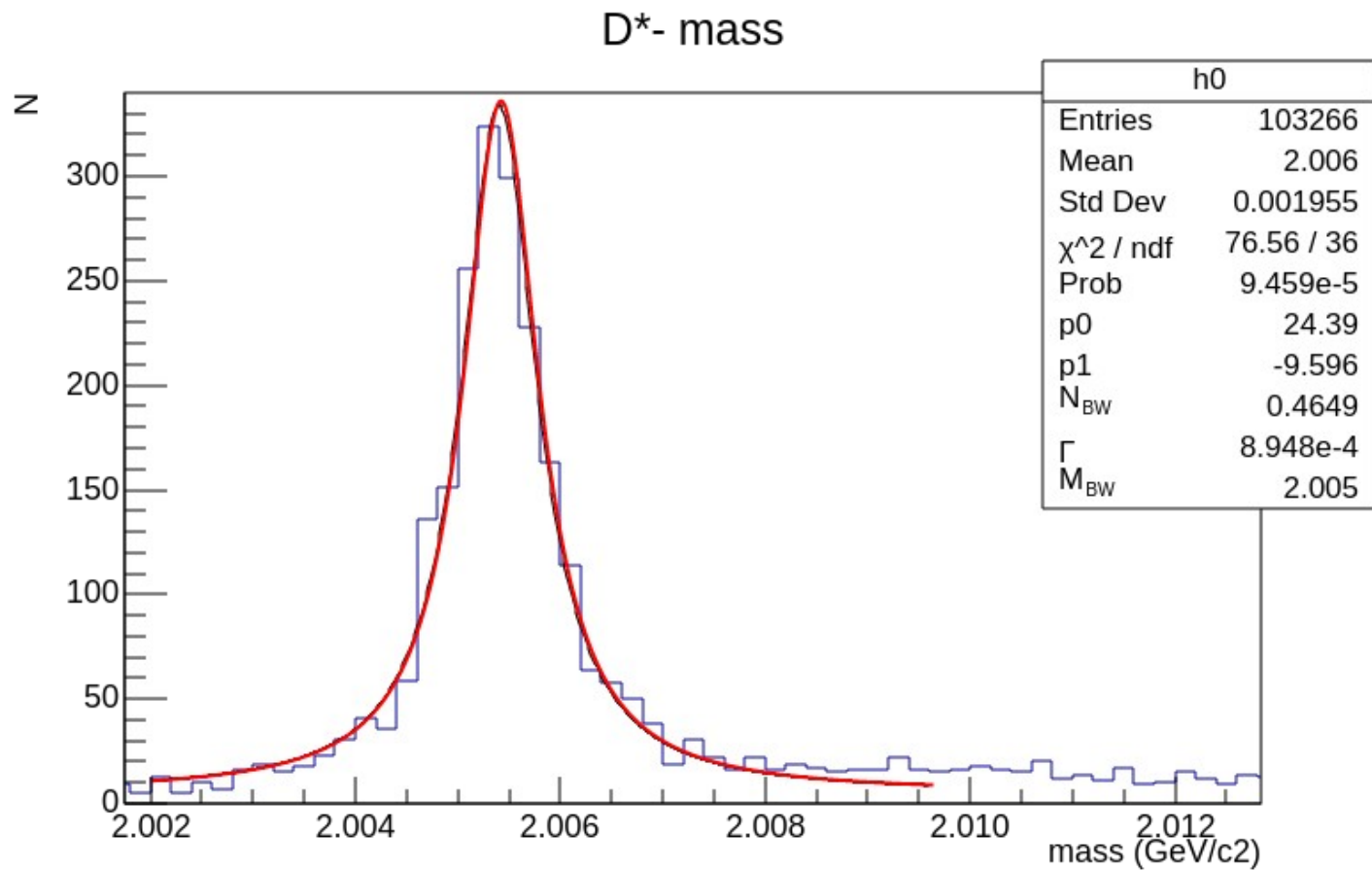




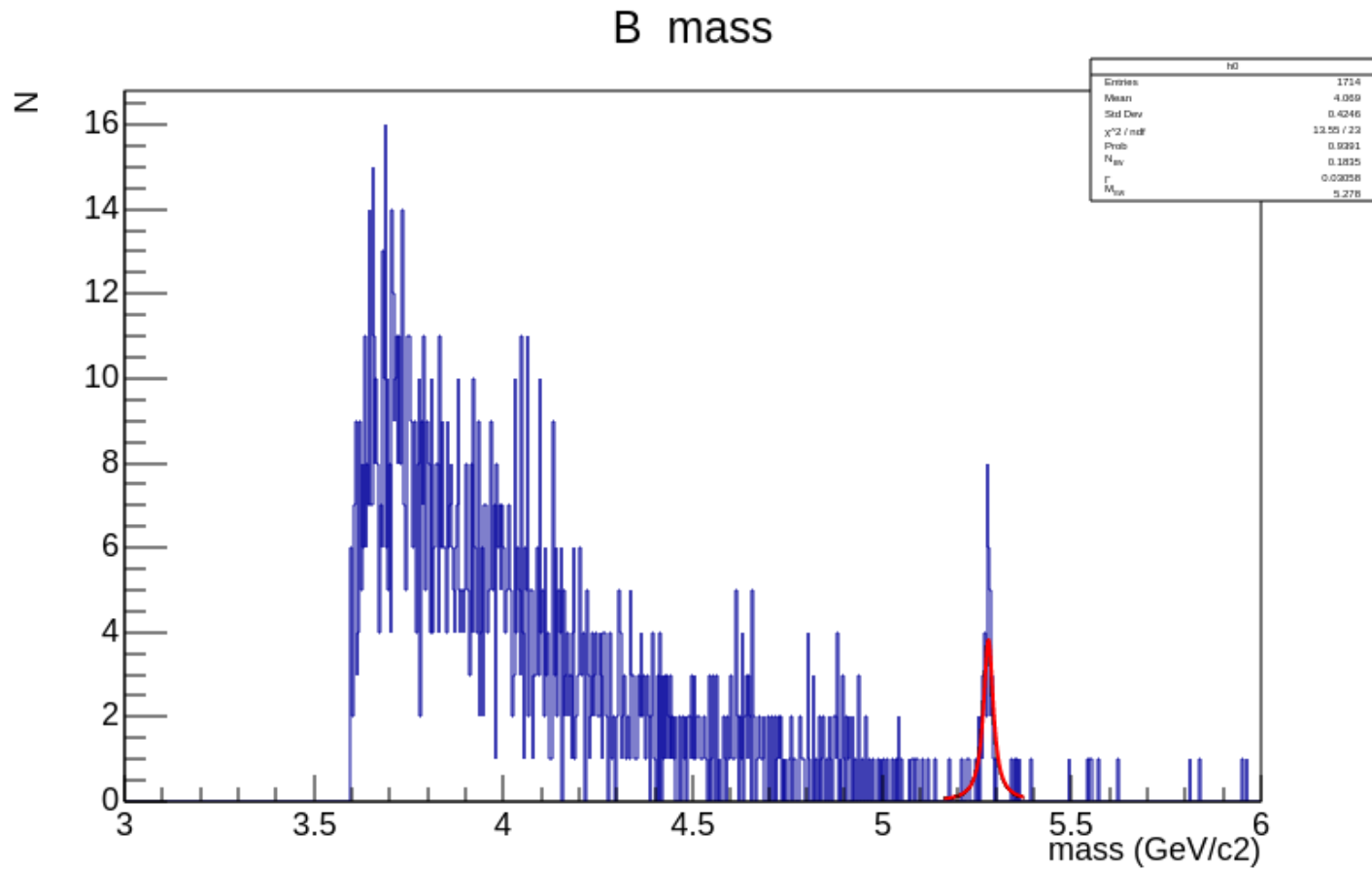
J/Psi e mass

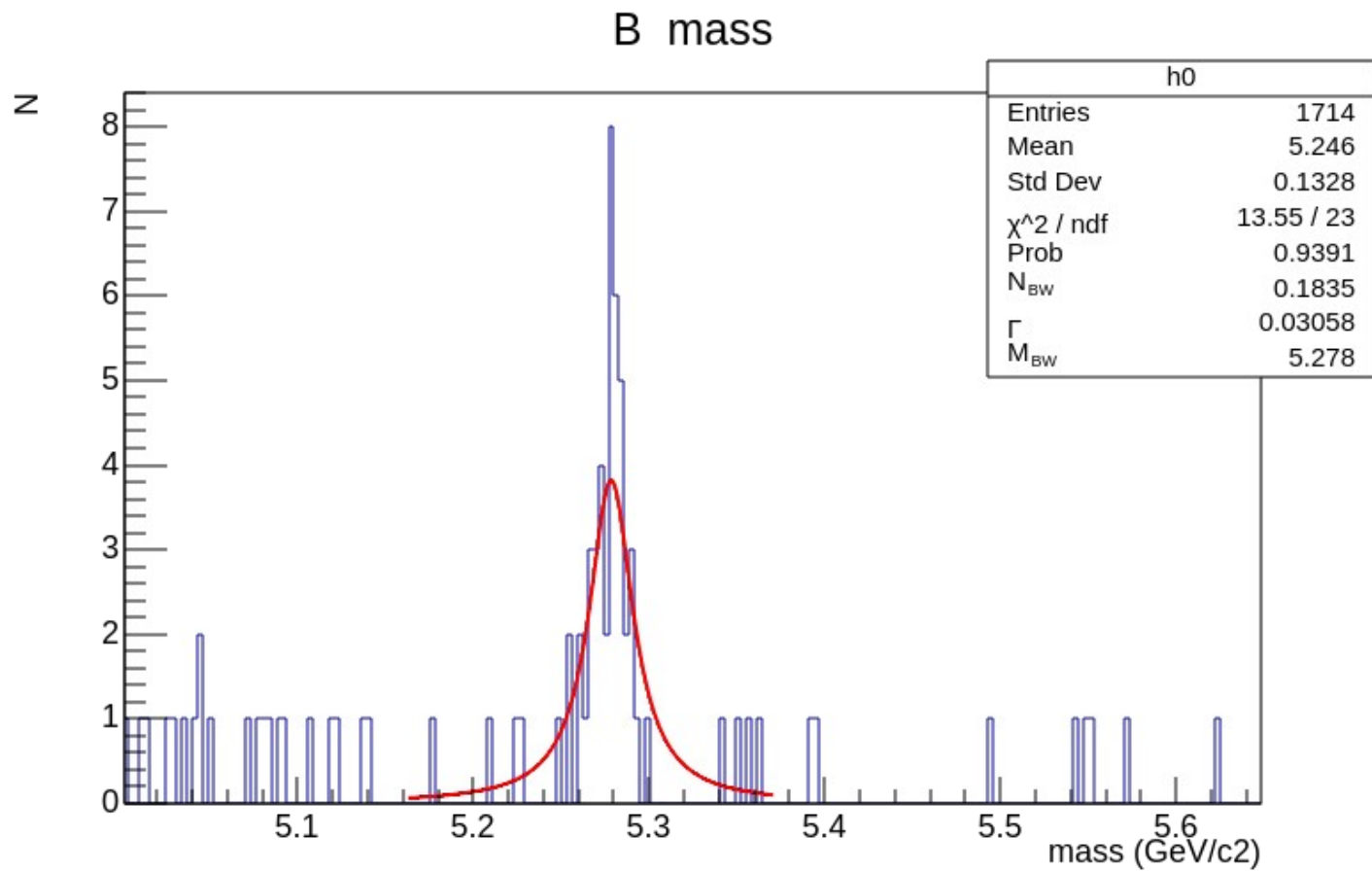






Both B+ and B- minus



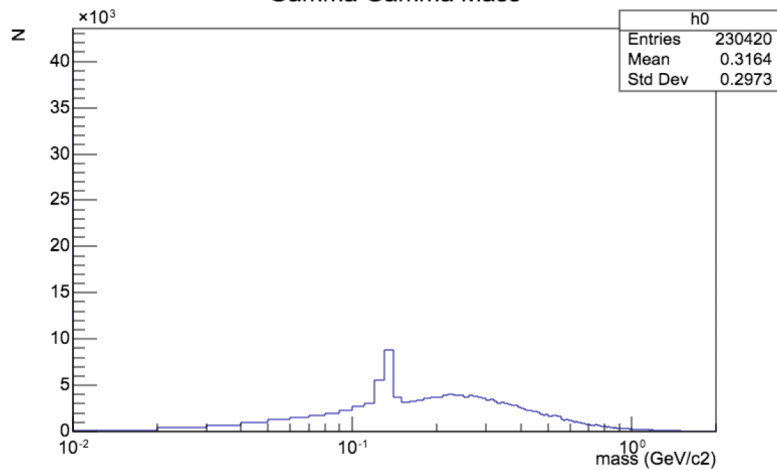


Worksheet

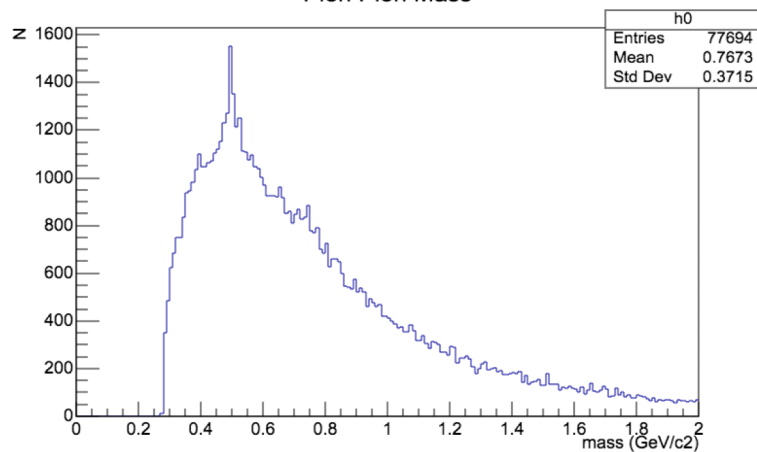
Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	$\frac{u\bar{u} - d\bar{d}}{\sqrt{2}}$	$\pi^0 \rightarrow \gamma \gamma$	0.1349			
K_S	$d\bar{s}$	$K_S \rightarrow \pi^+ \pi^-$	0.498			
ϕ	$s\bar{s}$	$\phi \rightarrow K^+ K^-$	1.019			
J/ψ	$c\bar{c}$	$J/\psi \rightarrow e^+ e^-$	3.096			
		$J/\psi \rightarrow \mu^+ \mu^-$				
D^0		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B^+		$B^+ \rightarrow J/\psi K^+$				
B^-		$B^- \rightarrow J/\psi K^-$				

Gamma Gamma Mass

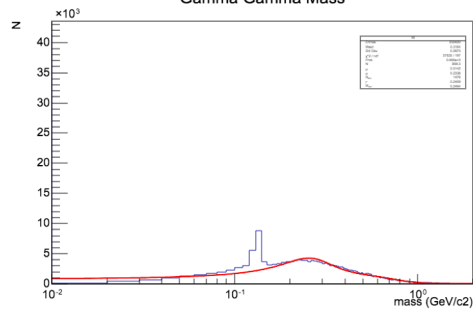


Pion Pion Mass

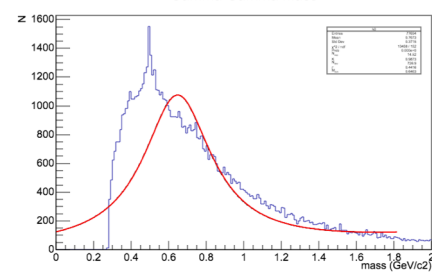


Sorry, it took me some
 time to figure stuff out
 and I had a hard time
 with fitting, as you can
 see:

Gamma Gamma Mass



Gamma Gamma Mass



Worksheet

Exercise table with the list of decays to examine

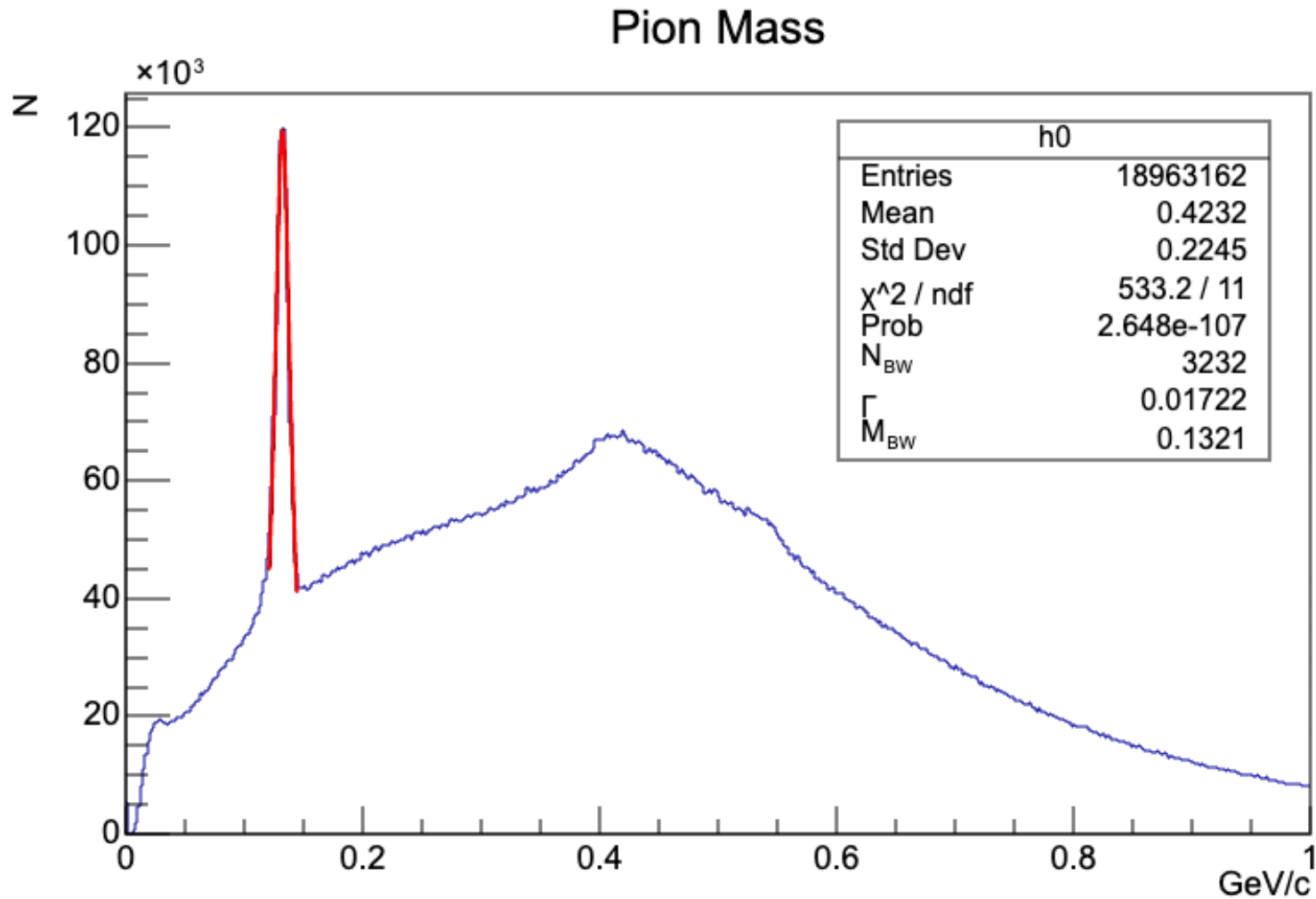
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	uu or dd	$\pi^0 \rightarrow \gamma \gamma$	0.1321	100000	267754	0.0052
K_S	$c\bar{d}$ or $c\bar{u}$	$K_S \rightarrow \pi^+ \pi^-$	0.4992	100000	242964	
ϕ	$s\bar{s}$	$\phi \rightarrow K^+ K^-$	1.02	100000	15405	
J/ψ		$J/\psi \rightarrow e^+ e^-$	No data in Belle II dataset			
		$J/\psi \rightarrow \mu^+ \mu^-$	No data in Belle II dataset			
D^0		$D^0 \rightarrow K^+ \pi^-$	1.86	1000000	26235	
		$D^0 \rightarrow K^- \pi^+$	1.86	1000000	24654	
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$	2.005	100000000	306277	
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$	2.006	100000000	275910	
B^+		$B^+ \rightarrow J/\psi K^+$	5.28	100000000	1367	
B^-		$B^- \rightarrow J/\psi K^-$	5.277	100000000	1313	0.01

Worksheet

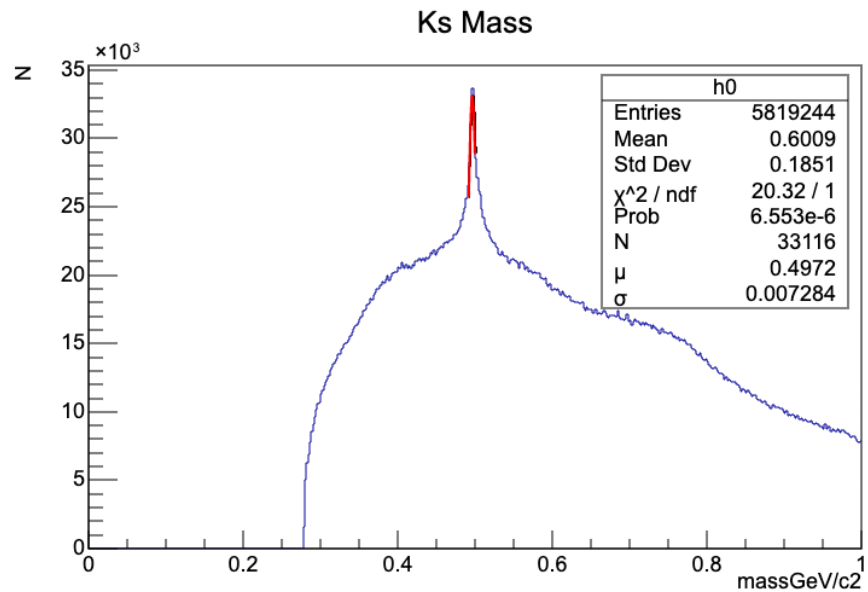
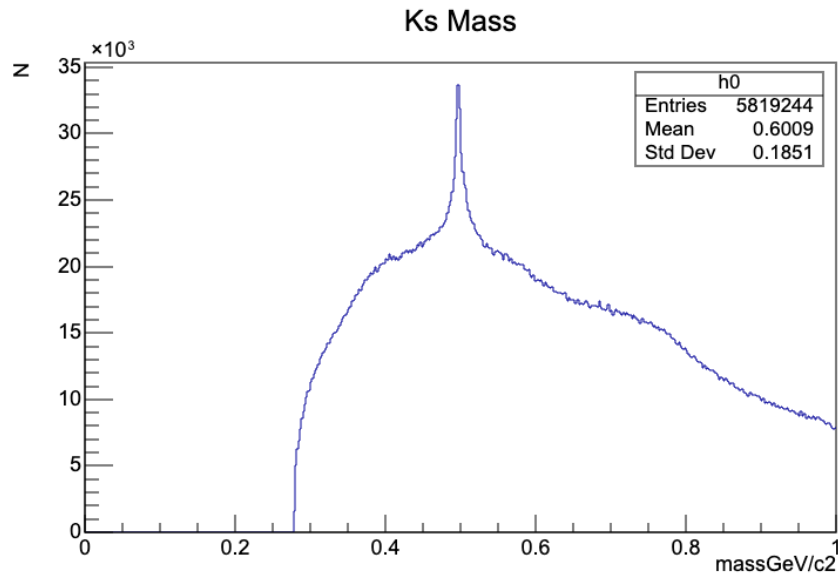
Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	U anti-U D anti-D	$\pi^0 \rightarrow \gamma \gamma$	0.1321	1000000	18963162	0.01722
Ks	d s	$K_s \rightarrow \pi^+ \pi^-$	0.4972	1000000	5819244	0.007284
ϕ	S anti-s	$\phi \rightarrow K^+ K^-$	1.020	1000000	279198	0.007728
J/ψ	C anti-c	$J/\psi \rightarrow e^+ e^-$	No peak observed	7000000		
		$J/\psi \rightarrow \mu^+ \mu^-$	3.094	1000000	6256	0.01421
D⁰	C anti-u	$D^0 \rightarrow K^+ \pi^-$	1.862	1000000	1465746	0.02345
		$D^0 \rightarrow K^- \pi^+$	1.829	1000000	1410599	0.08701
D⁺*	cd	$D^{*+} \rightarrow D^0 \pi^+$	Peak not observed	1000000		
D⁻*	anti-C anti-d	$D^{*-} \rightarrow D^0 \pi^-$	1.972	1000000	9851	0.01914
B⁺		$B^+ \rightarrow J/\psi K^+$		1000000		
B⁻		$B^- \rightarrow J/\psi K^-$		1000000		

pion- $\rightarrow$ gamma gamma

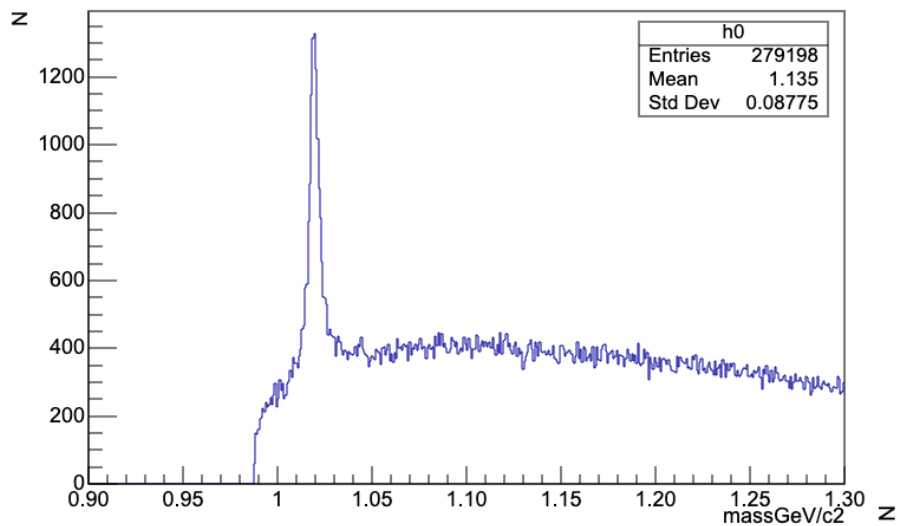


$K_S \rightarrow \pi^+ \pi^-$

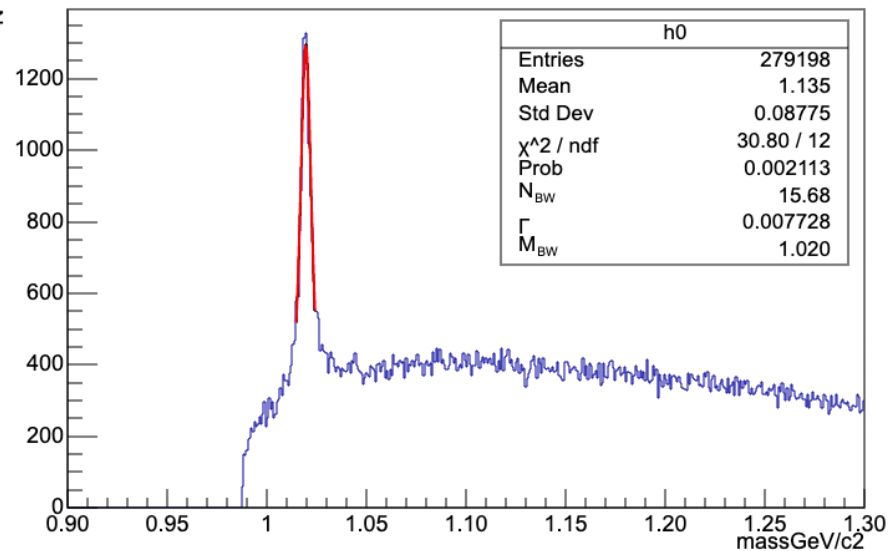


$\Phi \rightarrow K^+ K^-$

Phi Mass

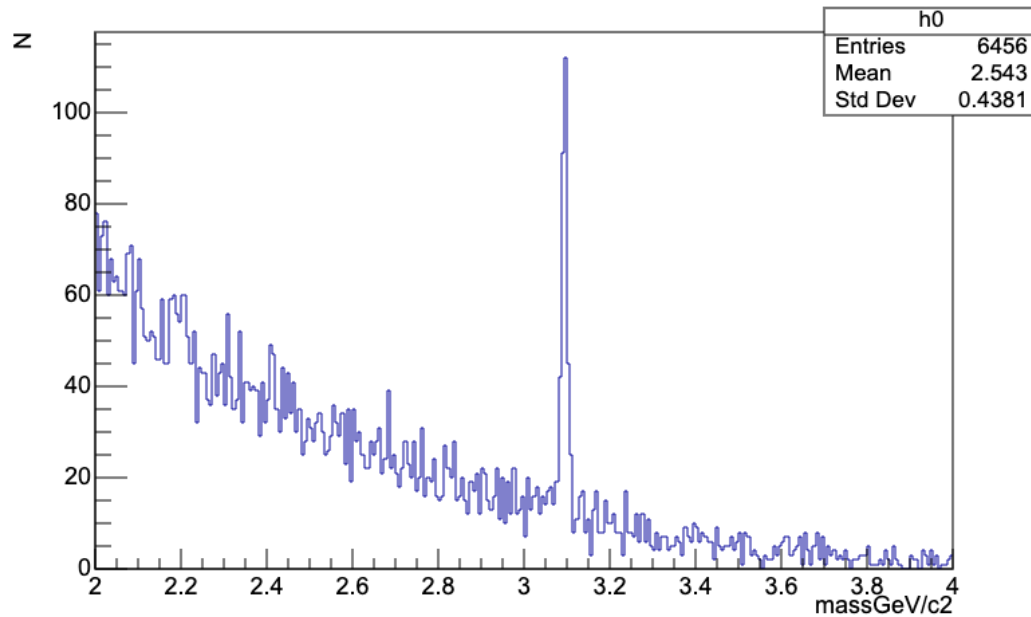


Phi Mass

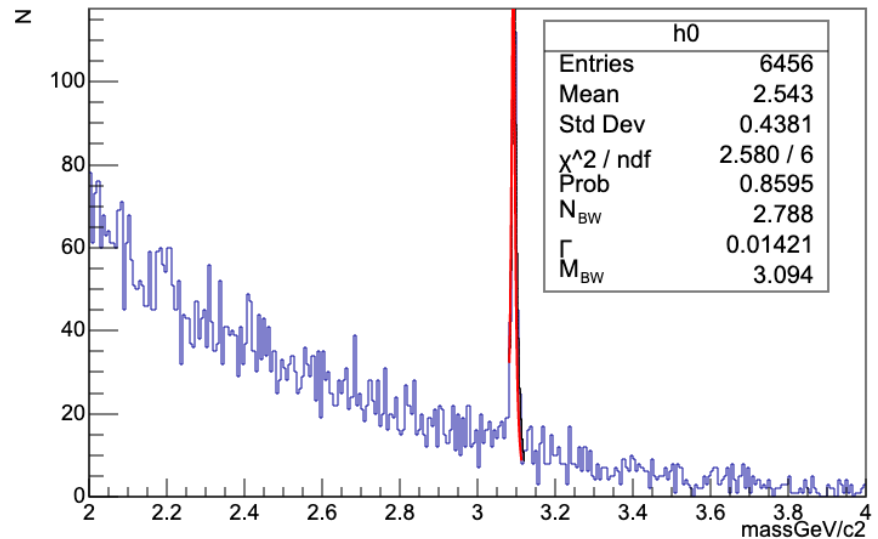


J/Psi $\rightarrow$ $\mu^+ \mu^-$

J/Psi Mass $\mu^+ \mu^-$

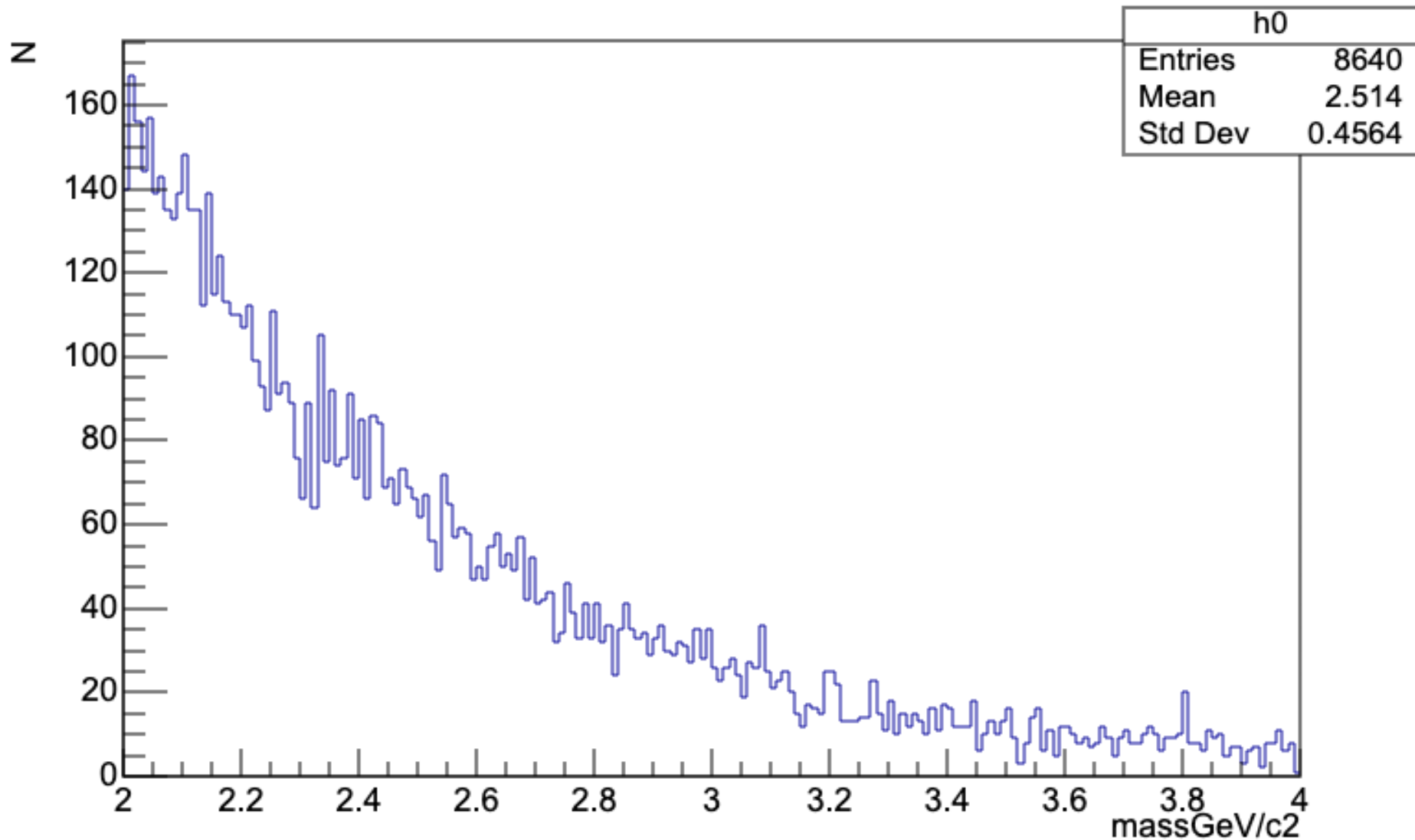


J/Psi Mass $\mu^+ \mu^-$



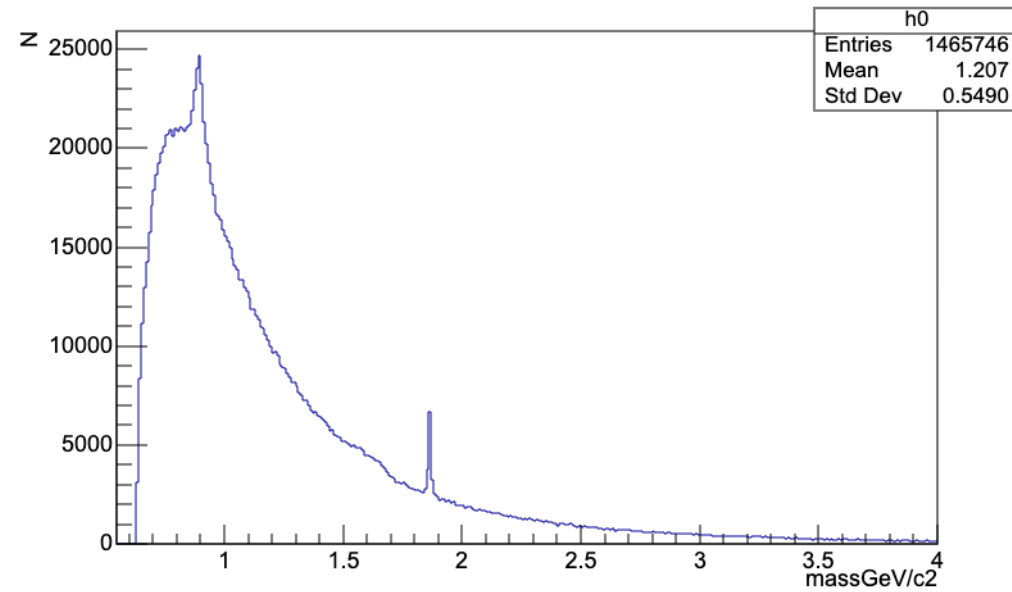
$J/\Psi \rightarrow e^+ e^-$

J/Psi Mass e e-

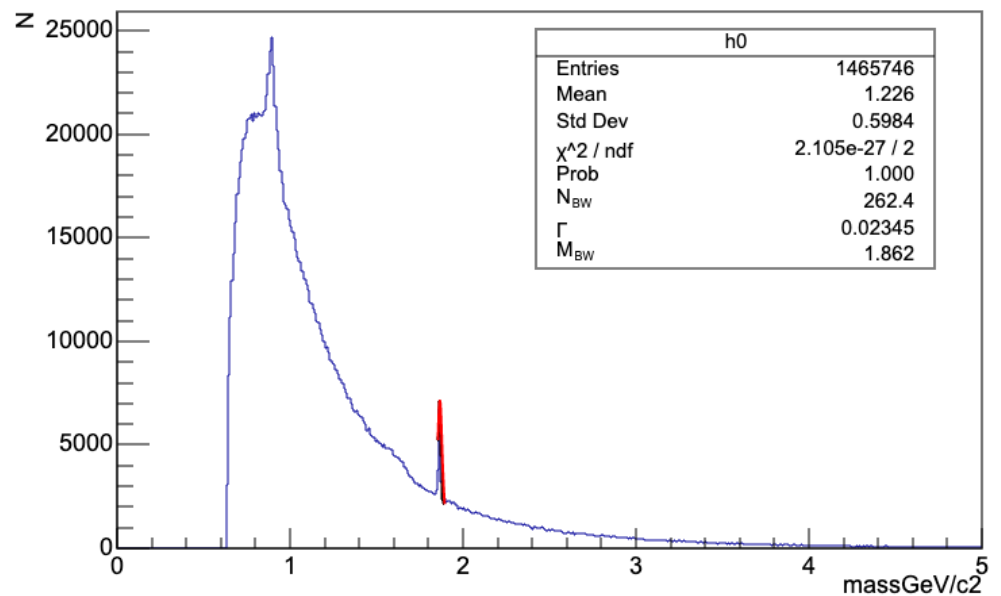


D0 → K + π⁻

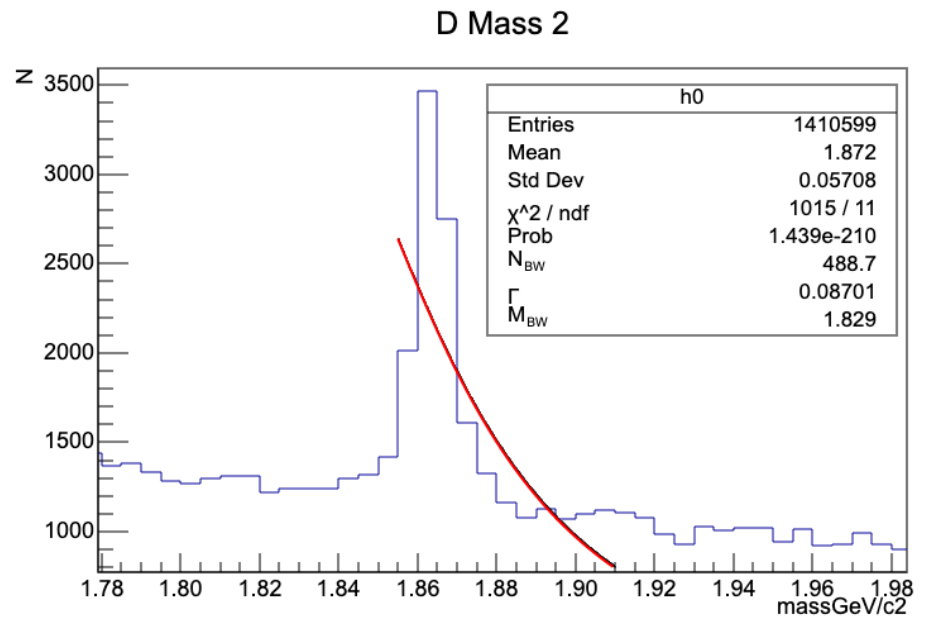
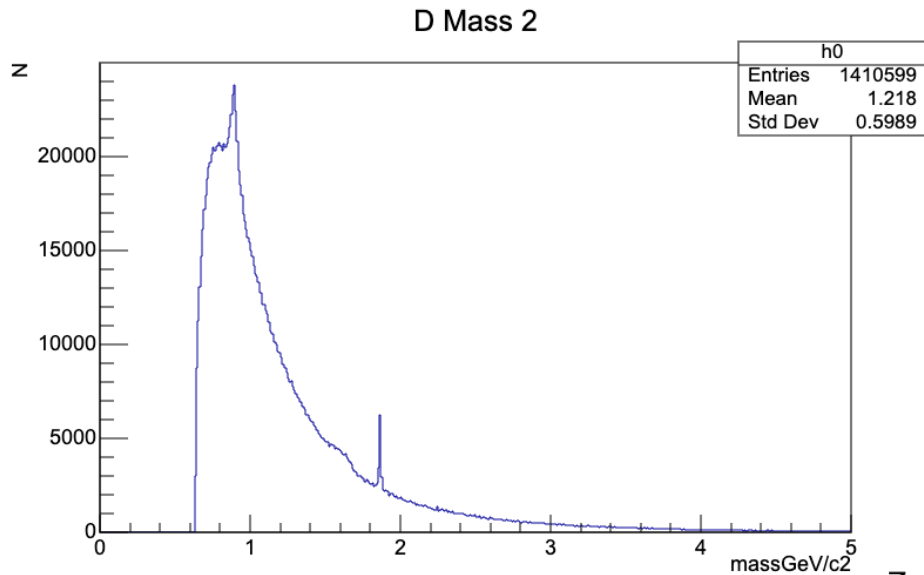
D Mass



D Mass

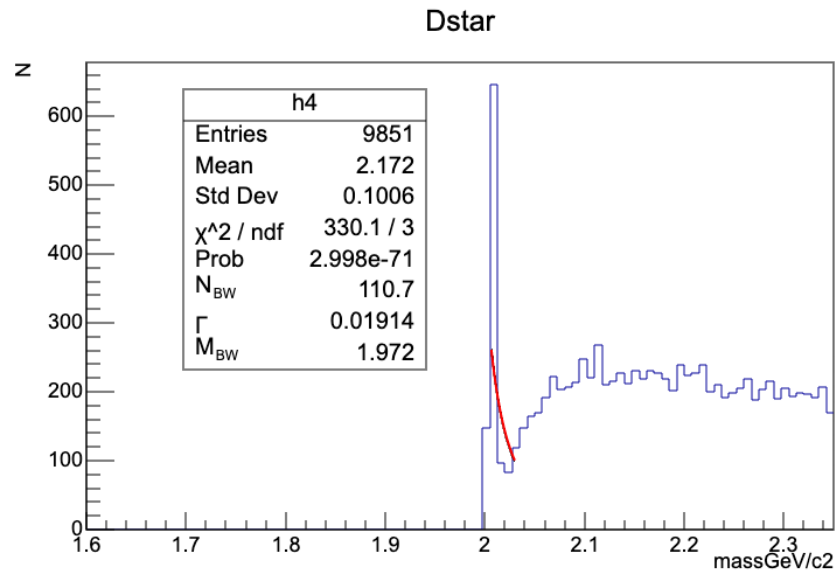
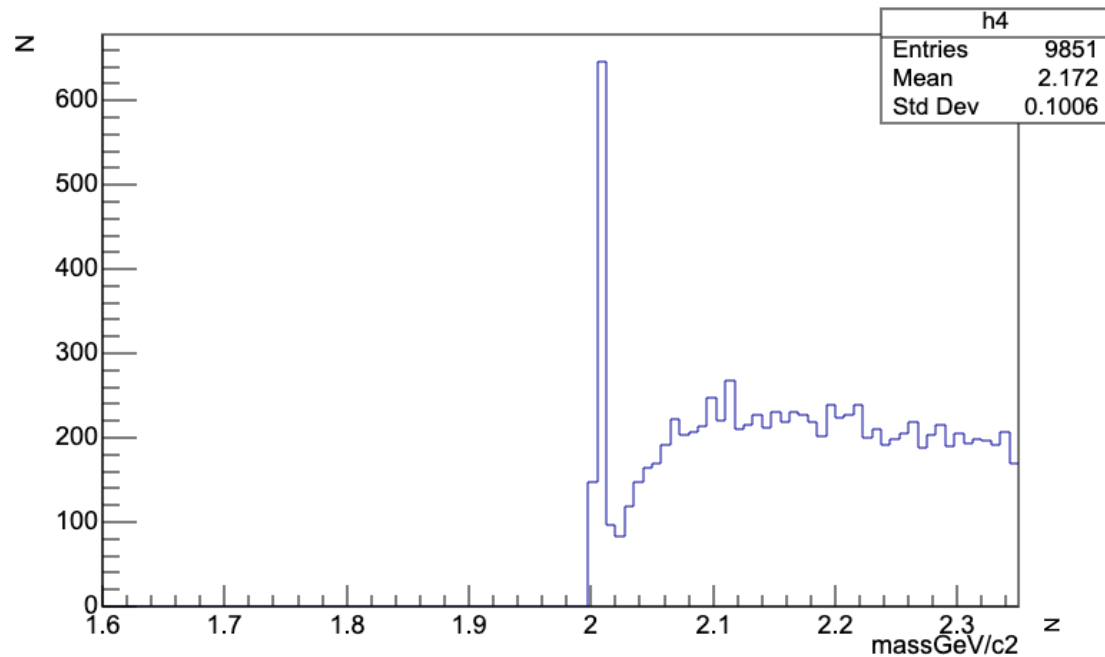


D0 → K⁻ π⁺



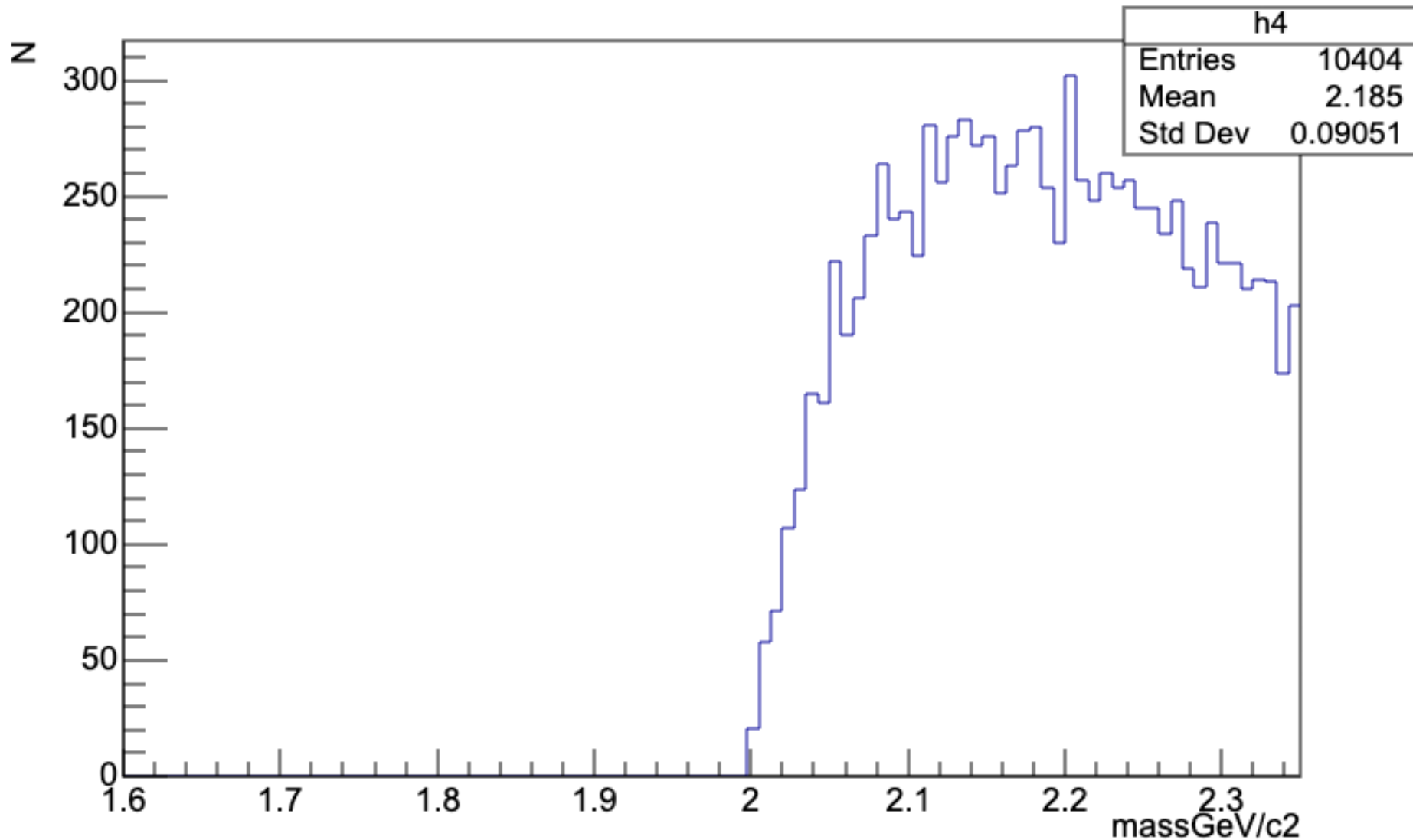
$D^{*-} \rightarrow D^0 \pi^-$

Dstar



$D^* \rightarrow D^0 \pi^+$

Dstar



Worksheet

Exercise table with the list of decays to examine

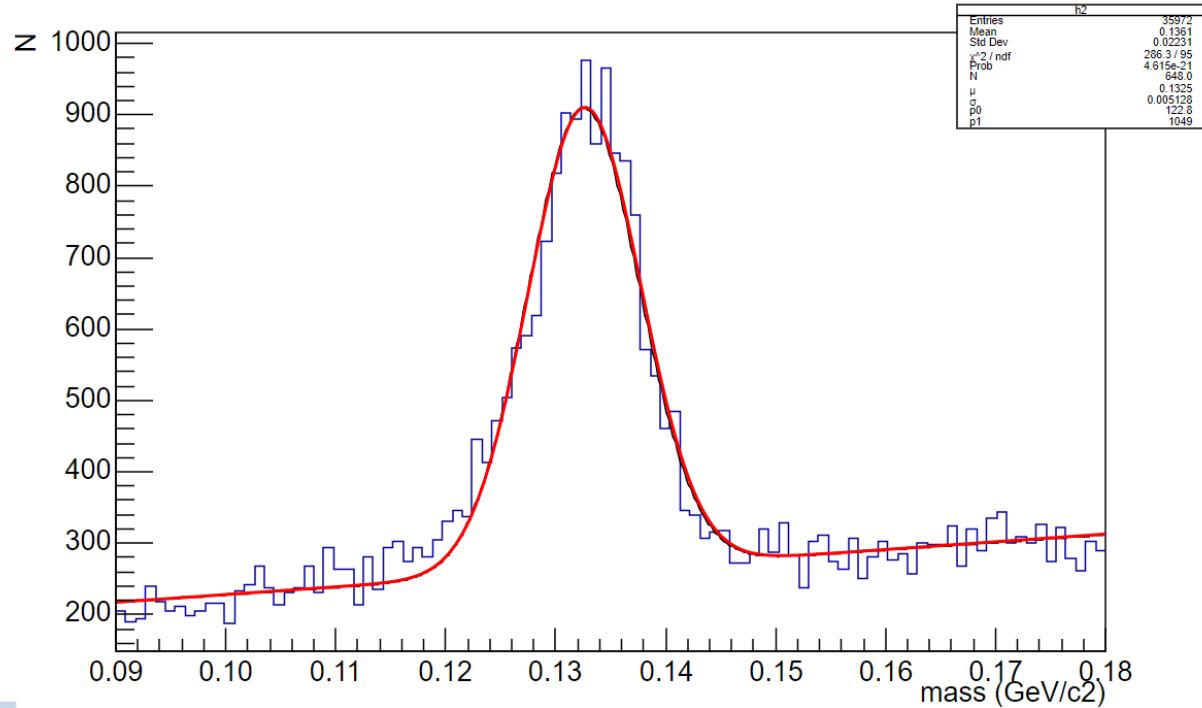
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0.1319	100000	1247031	0.0052
K_S		$K_S \rightarrow \pi^+ \pi^-$	0.4974	100000	1247031	0.0216
ϕ		$\phi \rightarrow K^+ K^-$	1.0198	1000000	12385374	0.0064
J/ψ		$J/\psi \rightarrow e^+ e^-$				
		$J/\psi \rightarrow \mu^+ \mu^-$	3.1019	1000000	12385374	0.0091
D^0		$D^0 \rightarrow K^+ \pi^-$	1.8639	1000000	12385374	0.0014
		$D^0 \rightarrow K^- \pi^+$	1.8639	1000000	12385374	0.0024
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$	2.0075	7085107	84106066	0.0007
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$	2.0117	7085107	84106066	0.0056
B^+		$B^+ \rightarrow J/\psi K^+$	5.2803	7085107	84106066	0.0062
B^-		$B^- \rightarrow J/\psi K^-$	5.2795	7085107	84106066	0.0068

Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	$u\bar{u}, d\bar{d}$	$\pi^0 \rightarrow \gamma \gamma$	0.1361	35972	41484	0.02231
Ks	$d\bar{s}, s\bar{d}$	$K_s \rightarrow \pi^+ \pi^-$	0.4980	31044	59425	0.01776
ϕ	$s\bar{s}$	$\phi \rightarrow K^+ K^-$	1.092	752	9753	0.004689
J/ ψ	$c\bar{c}$	$J/\psi \rightarrow e^+ e^-$				
	$c\bar{c}$	$J/\psi \rightarrow \mu^+ \mu^-$				
D ⁰		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D ^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺		$B^+ \rightarrow J/\psi K^+$				
B ⁻		$B^- \rightarrow J/\psi K^-$				

pi0 Mass



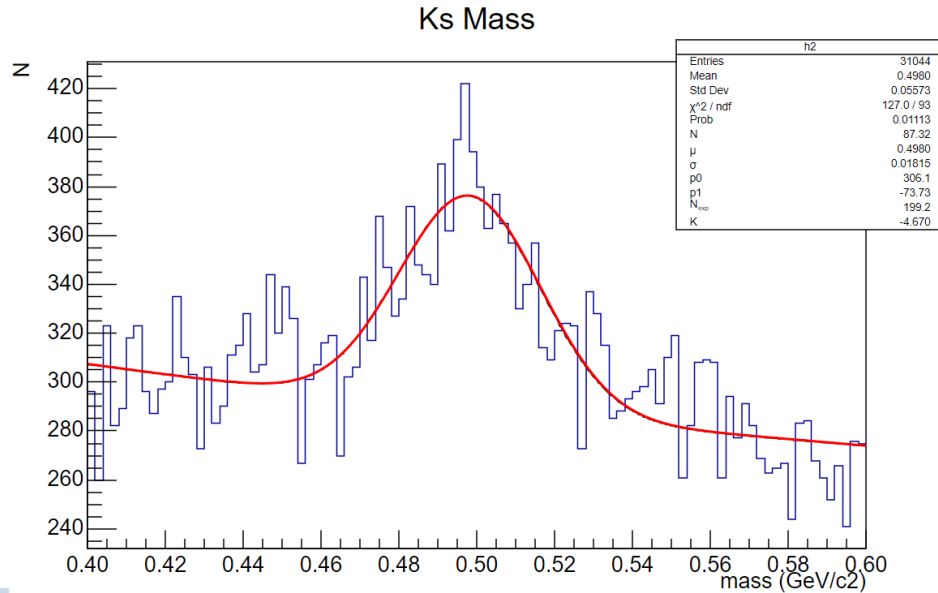
Range: min = 0.09 max = 0.18 $\chi^2/\text{ndf} = 286.8 / 95 = 3.019$

Function: Gaus + Poly $N \cdot e^{-\left(\frac{x-\mu}{2\sigma}\right)^2} + p0 + p1 \cdot x$

Name	Value	Min	Set	Max	Step
• μ :	0.1325	0		1	0.0001
• σ :	0.0051	0		1	0.0001
• N:	647.9568	0		10000	0.0001

Polynomial order: 1

Name	Value	Min	Set	Max	Step
• p0:	122.7614	-10		122.7614843305	0.0001
• p1:	1048.83	-10		1297.458173595	0.0001
• p2:	-3.5478	-10		10	0.0001
• p3:	0	-10		10	0.0001
• p4:	0	-10		10	0.0001



Range: min = 0.4 max = 0.6 $\chi^2/\text{ndf} = 127.0 / 93 = 1.366$

Function: Gaus + Poly + Expo $N \cdot e^{-\left(\frac{x-\mu}{2\sigma}\right)^2} + p_0 + p_1 \cdot x + N_{\text{exp}} \cdot e^{K \cdot x}$

Name	Value	Min	Set	Max	Step
• μ :	0.49802	-0.20508307166		1	0.0001
• σ :	0.0181	0		1	0.0001
• N:	87.3171	0		1000	0.0001

Polynomial order: 1

Name	Value	Min	Set	Max	Step
• p0:	306.1354370932	-42.4544629067		306.1355178406	0.0001
• p1:	-73.73138	-73.8665779424		100	0.0001
• p2:	-244.86595	-263.897747276		100	0.0001
• p3:	0	-10		10	0.0001
• p4:	0	-10		10	0.0001

Name	Value	Min	Set	Max	Step
• K:	-4.6696	-10		10	0.0001
• N_{exp} :	199.238	-10		199.2380166323	0.0001

Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	$(u\bar{u} - d\bar{d})/2$	$\pi^0 \rightarrow \gamma \gamma$	0.13256	10000	180893	
Ks	$d\bar{s}$	$K_s \rightarrow \pi^+ \pi^-$	0.5883	10000	78998	
ϕ	$s\bar{s}$	$\phi \rightarrow K^+ K^-$	1.025	10000	2242	
J/ ψ	$c\bar{c}$	$J/\psi \rightarrow e^+ e^-$	-	-	-	
		$J/\psi \rightarrow \mu^+ \mu^-$	3.085	628975	7087	
D ⁰	$c\bar{u}$	$D^0 \rightarrow K^+ \pi^-$	1.860	10000	12386	
		$D^0 \rightarrow K^- \pi^+$	1.861	10000	13289	
D ^{*+}	$c\bar{d}$	$D^{*+} \rightarrow D^0 \pi^+$	2.126	10000	51926	
D ^{*-}	$\bar{c}d$	$D^{*-} \rightarrow D^0 \pi^-$	2.101	10000	40304	
B ⁺	$u\bar{b}$	$B^+ \rightarrow J/\psi K^+$	5.277	7085107	1313	
B ⁻	$\bar{u}b$	$B^- \rightarrow J/\psi K^-$		7085107		

Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	U-ubar, d-dbar	$\pi^0 \rightarrow \gamma \gamma$	0.136	100000	1778086	0.006
K_S	A combination of d-sbar and s-dbar	$K_S \rightarrow \pi^+ \pi^-$	0.490	628975	11201787	0.005
ϕ	S-sbar	$\phi \rightarrow K^+ K^-$	1.044	628975	11201787	0.029
J/ψ	C-cbar	$J/\psi \rightarrow e^+ e^-$	3.082	628975	11201787	
	"	$J/\psi \rightarrow \mu^+ \mu^-$	3.088	628975	11201787	0.007
D^0	cu	$D^0 \rightarrow K^+ \pi^-$	1.9	628975	11201787	0.02
	cu	$D^0 \rightarrow K^- \pi^+$	1.83	628975	11201787	0.018
D^{*+}	cd	$D^{*+} \rightarrow D^0 \pi^+$		628975	11201787	
D^{*-}	cu	$D^{*-} \rightarrow D^0 \pi^-$				
B^+		$B^+ \rightarrow J/\psi K^+$				
B^-		$B^- \rightarrow J/\psi K^-$				

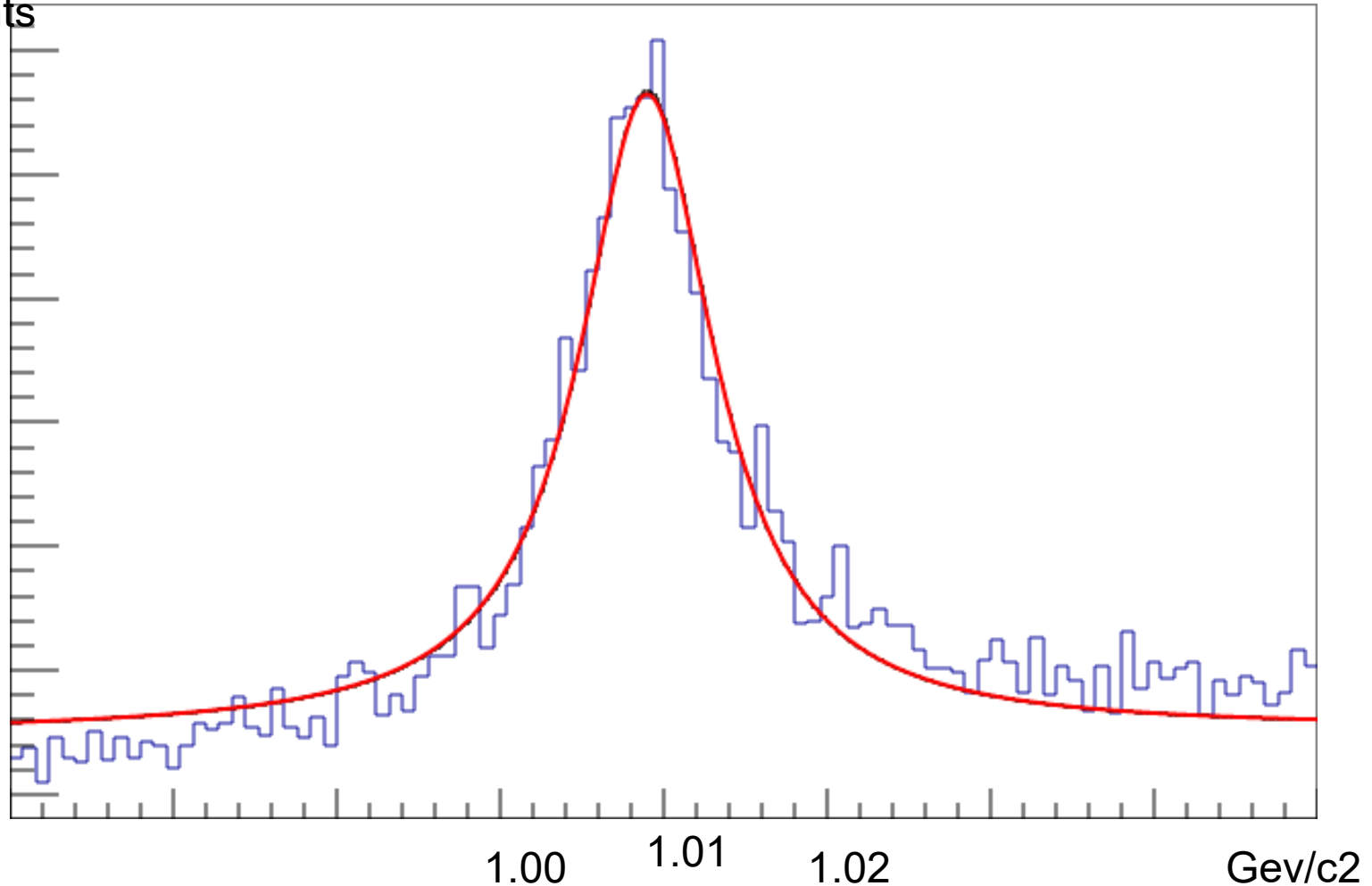
Worksheet

Exercise table with the list of decays to examine

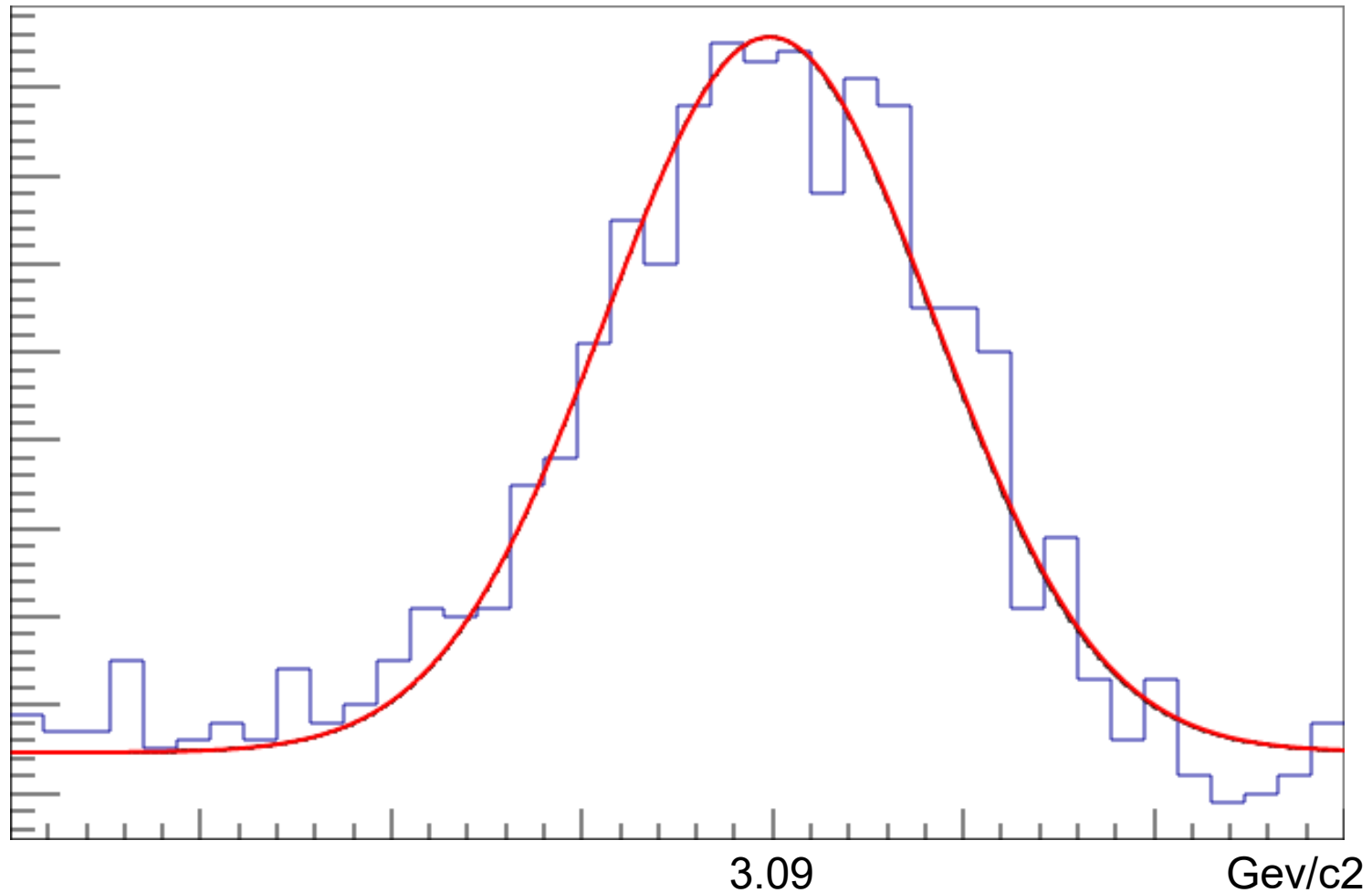
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	uubar or ddbar	$\pi^0 \rightarrow \gamma \gamma$	0.128+-0.012	500.000	8 Millions	0.06
K_S	dsbar or sdbar	$K_S \rightarrow \pi^+ \pi^-$	0.49 +- 0.02	500.000	2 Millions	-
ϕ	ssbar	$\phi \rightarrow K^+ K^-$	1.019 +- 0.009	1 Million	18000	0.05
J/ψ	cdbar	$J/\psi \rightarrow e^+ e^-$	3.08+-0.05	5 Millions	2500	-
	cdbar	$J/\psi \rightarrow \mu^+ \mu^-$	3.090+-0.003	5 Millions	1600	-
D^0	cd	$D^0 \rightarrow K^+ \pi^-$	1.861 +-0.004	5 Millions	77020	-
	cu	$D^0 \rightarrow K^- \pi^+$	1.857+-0.004	5 Millions	73000	-
D^{*+}	cd or cu	$D^{*+} \rightarrow D^0 \pi^+$				
D^{*-}	Cd or cu	$D^{*-} \rightarrow D^0 \pi^-$				
B^+		$B^+ \rightarrow J/\psi K^+$				
B^-		$B^- \rightarrow J/\psi K^-$				

The fit for the Phi meson mass with a Breit-Wigner

Number
of events



Jpsi invariant mass fit with a Gaussian



Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0.1325	893		0.005174
Ks		$K_s \rightarrow \pi^+ \pi^-$	0.4963	357		0.4454
ϕ		$\phi \rightarrow K^+ K^-$	1.019	629		0.03
J/ ψ		$J/\psi \rightarrow e^+ e^-$	3.09	435		0.23
		$J/\psi \rightarrow \mu^+ \mu^-$	3.1	349		0.45
D ⁰		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D ^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D ^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B ⁺		$B^+ \rightarrow J/\psi K^+$				
B ⁻		$B^- \rightarrow J/\psi K^-$				

Worksheet

Exercise table with the list of decays to examine

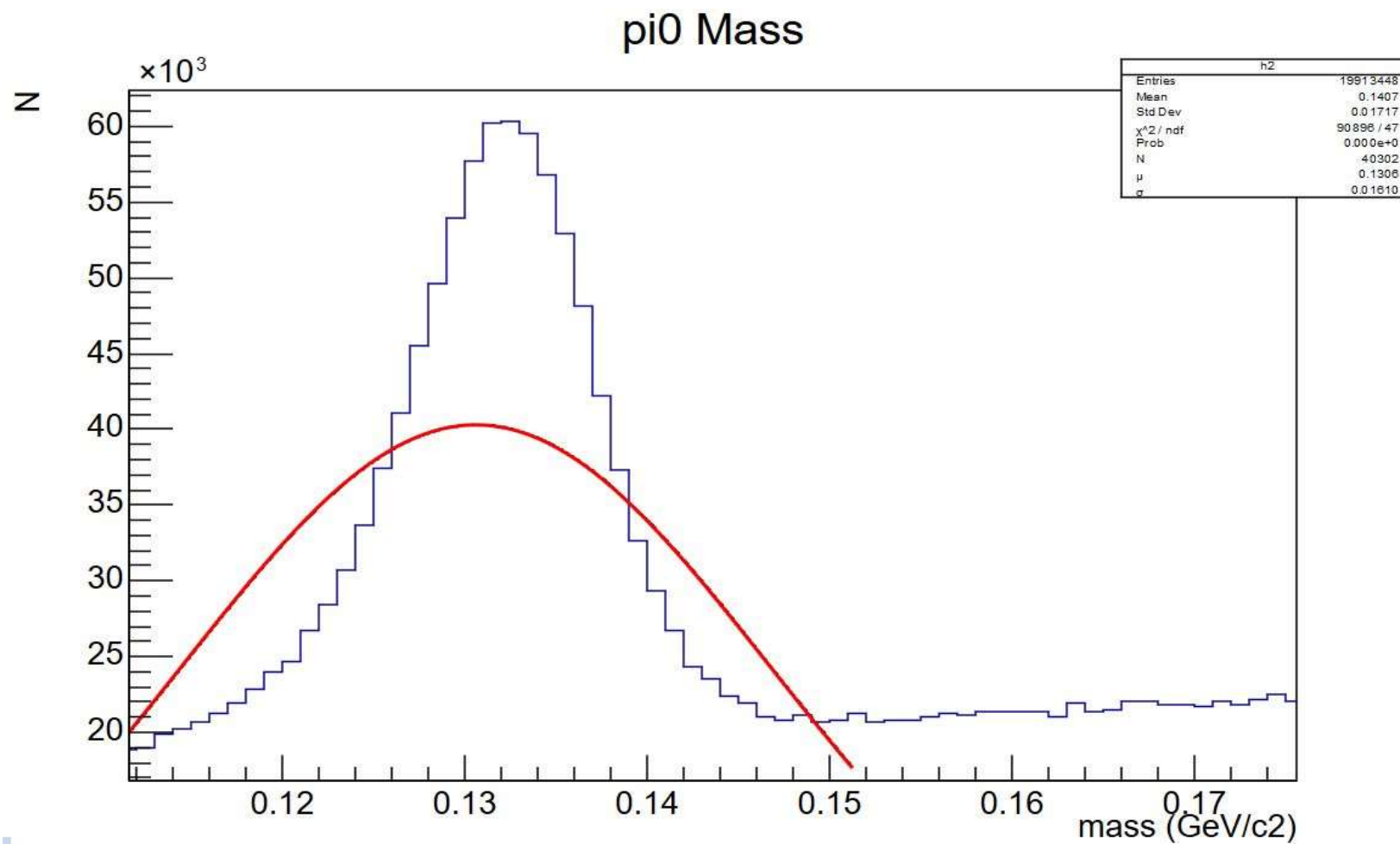
Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	U anti u / d anti d	$\pi^0 \rightarrow \gamma \gamma$	0.1318	"	"	0.0055
Ks	U s	$K_s \rightarrow \pi^+ \pi^-$	0.4973	1000000	12385374	0.0105
ϕ	S anti s	$\phi \rightarrow K^+ K^-$	1.019	"	"	0.0026
J/ψ	C anti c	$J/\psi \rightarrow e^+ e^-$				
		$J/\psi \rightarrow \mu^+ \mu^-$	3.094	"	"	0.007
D ⁰	C anti u	$D^0 \rightarrow K^+ \pi^-$	1.864	«	"	0.0087
		$D^0 \rightarrow K^- \pi^+$	1.8637	"	"	0.0086
D ^{*+}	C anti d	$D^{*+} \rightarrow D^0 \pi^+$	2.005	7085107	84106066	0.008
D ^{*-}	anti c d	$D^{*-} \rightarrow D^0 \pi^-$	2.007	"	"	0.009
B ⁺	U anti b	$B^+ \rightarrow J/\psi K^+$	5.280	"	"	0.009
B ⁻	Anti u b	$B^- \rightarrow J/\psi K^-$	5.277	7085107	84106066	0.01285

Worksheet

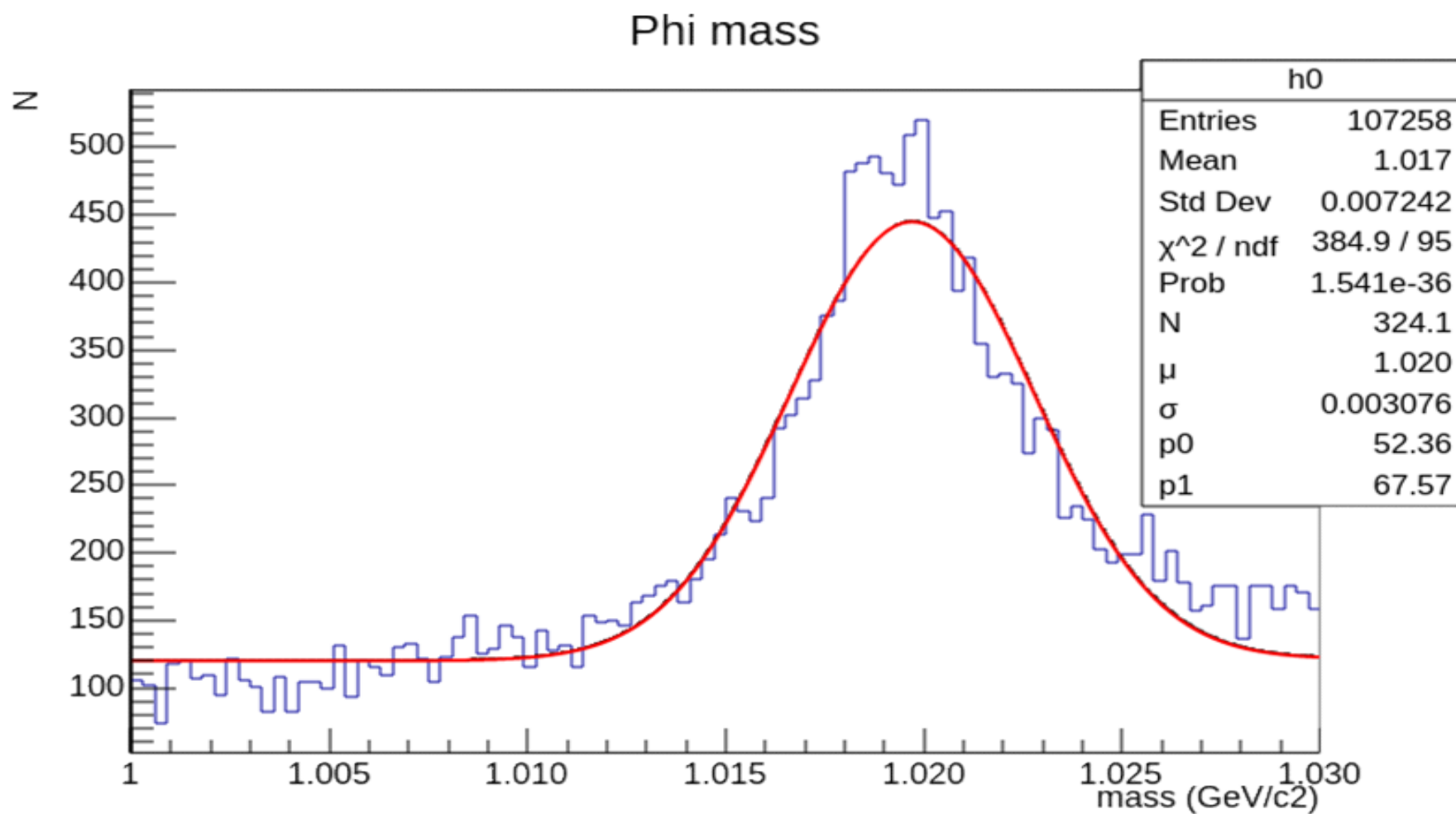
Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0	$u \bar{d}$	$\pi^0 \rightarrow \gamma \gamma$				
K_S	$d \bar{s}$	$K_S \rightarrow \pi^+ \pi^-$				
ϕ	$u \bar{d}$	$\phi \rightarrow K^+ K^-$				
J/ψ	$c \bar{c}$	$J/\psi \rightarrow e^+ e^-$	3.85	5.66 million		0.015
	$c \bar{c}$	$J/\psi \rightarrow \mu^+ \mu^-$	3.0893	7 million	66'234	0.0143
D^0		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B^+		$B^+ \rightarrow J/\psi K^+$				
B^-		$B^- \rightarrow J/\psi K^-$				

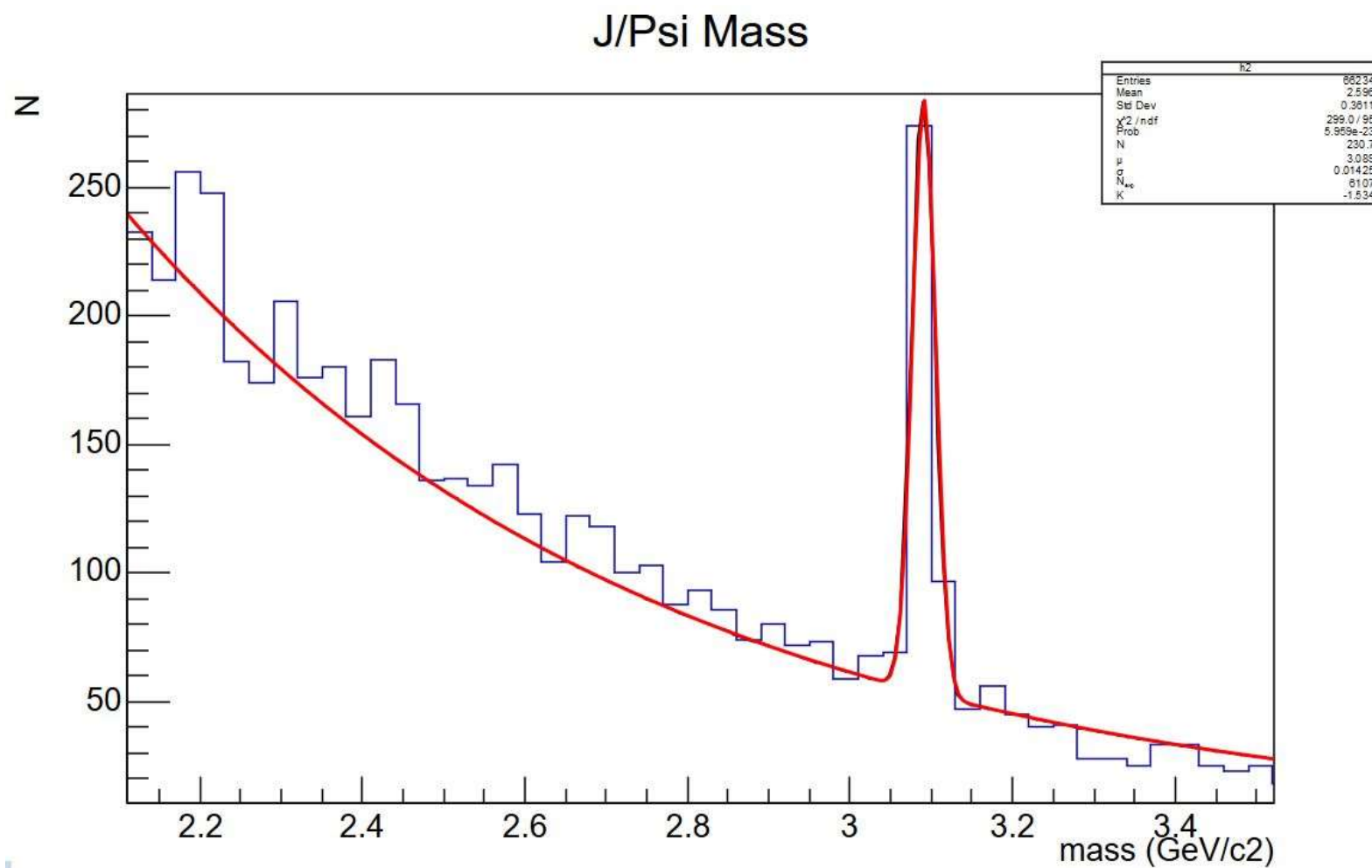
$$\pi^0 \rightarrow \gamma \gamma$$



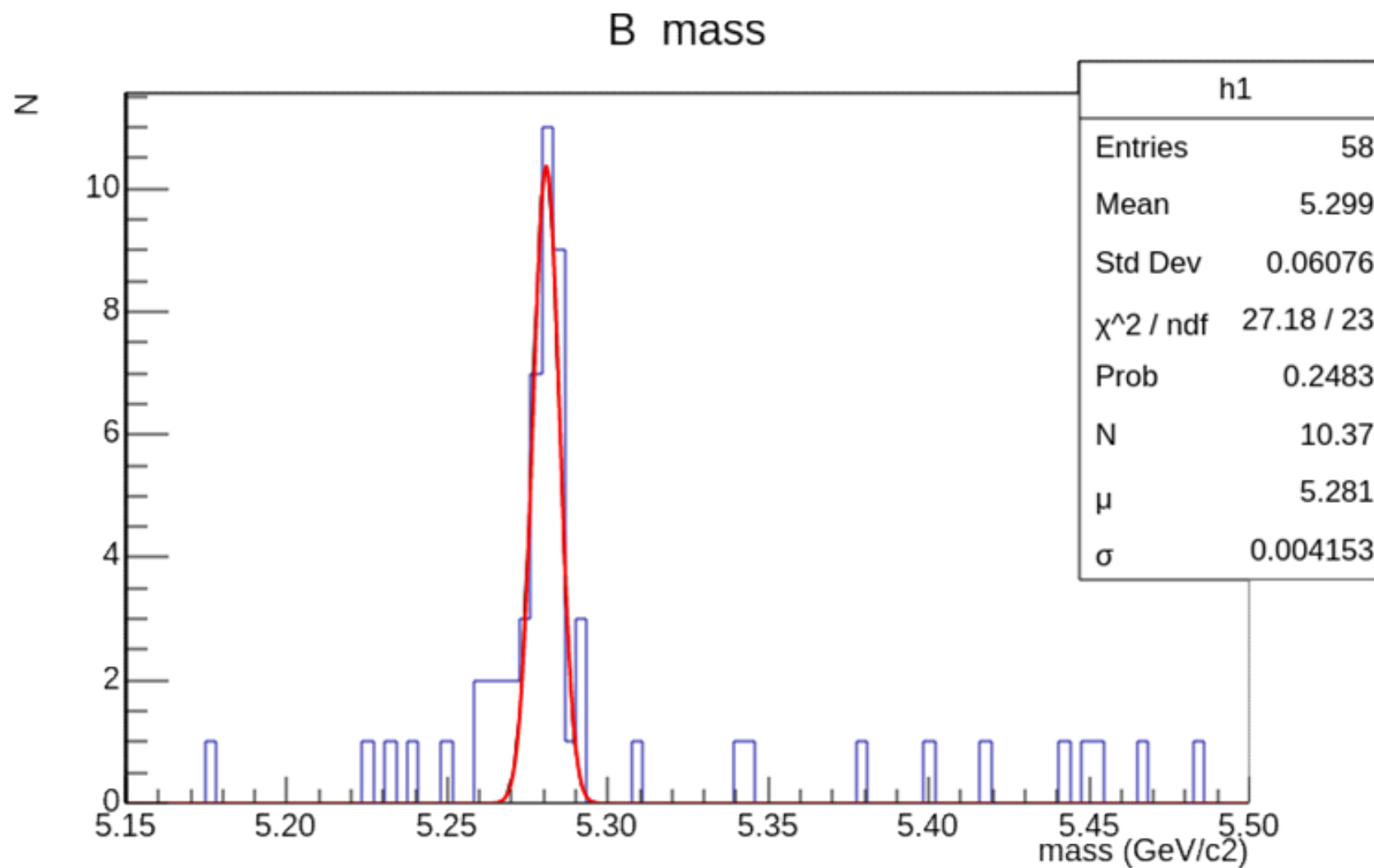
$$\phi \rightarrow K^+ K^-$$



$$J/\psi \rightarrow \mu^+ \mu^-$$



$$B^+ \rightarrow J/\psi K^+$$



Worksheet

Exercise table with the list of decays to examine

Particle	Quark content	Process	Mass (GeV/c ²)	Number of processed events	Number of detected particles	Decay width (GeV/c ²)
π^0		$\pi^0 \rightarrow \gamma \gamma$	0.132 MeV	100000	1 775 312	
K_S		$K_S \rightarrow \pi^+ \pi^-$				
φ		$\varphi \rightarrow K^+ K^-$	1.019	5000000	93 402	
J/ψ		$J/\psi \rightarrow e^+ e^-$				
		$J/\psi \rightarrow \mu^+ \mu^-$				
D^0		$D^0 \rightarrow K^+ \pi^-$				
		$D^0 \rightarrow K^- \pi^+$				
D^{*+}		$D^{*+} \rightarrow D^0 \pi^+$				
D^{*-}		$D^{*-} \rightarrow D^0 \pi^-$				
B^+		$B^+ \rightarrow J/\psi K^+$				
B^-		$B^- \rightarrow J/\psi K^-$				