

Belle II Lab Manual

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You Tube introduction:

- Start: https://youtu.be/q6M2_dnp3pl
- Particle distribution: https://youtu.be/q6M2_dnp3pl
- J/psi to mumu: <https://youtu.be/xUYmXoPfZOU>
- J/psi to ee: <https://youtu.be/3TGsHJ8j8pE>
- B to J/psi K <http://youtube.com/watch?v=e-GErqzY3HM>

Server to connect to, used for the exercises: <https://belle2.ijs.si/masterclass/>

Suggested browsers to be used: Firefox and Chrome

Comment on dataset used

As you already know, in 2020 the BelleII experiment did not stop because of the Covid-19 pandemic

A huge effort have been made by all collaborators to let this happened and this have been appreciated worldwide

This is one of the reasons why the 2020 data collected so far has even more importance than usual

The BelleII experiment gave us the possibility to use the most recent data to give you the possibility to have the most realistic and up to date experience possible

We want to thank the BelleII collaboration for that

Quick start to analyze the data

Belle II Masterclass: Describe process → Run analysis → Fit results → Save/load process locally

Run Analysis

Save Diagram

Load Diagram

Blocks

The exercises are any carried out by transferring blocks on the workspace and connecting them together. That represents parts of the data analysis code:

Inside "Blocks" we find:

A BLUE block that allows you to load events.

You can choose between 3 data sources:

Belle II dataset which contains **7 Milion events**

hadron-1 Which contains 629000 events (Belle data)

hadron-2 Which contains 5.6 Milion events (Belle data)

You can select the number of events to analyze

Note: processing of 7 Milion events takes up to 5 minutes.

A MUSTARD block that allows to select only certain particles (electrons, muons, kaons, protons, photons) and also allows to choose the charge of the particle (-1, 0, +1, any).

Belle II Masterclass

Number of events: 10000

First event: 0

Data Source hadron-1

Print particle list? No

Particle List

Select Particles

Particles

Charge -1

Type muon

Histogram

Quick start to analyze the data

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Save Diagram

Load Diagram

Blocks

A GREEN block that allows you to combine two particles and to calculate their invariant mass

You can choose to combine different particles and avoid considering the same particle twice.

The minimum and maximum of the invariant mass can be specified for further analysis

Combine 2 particles

1. Particle

2. Particle

Same particle lists? No

New Particle J/Psi

Min mass [GeV]: 1

Max mass [GeV]: 4

Histogram

A BROWN block that allows you to produce histograms – distributions of selected variables, you can define a range and a variable to plot

Histogram

Title mu neg Mass

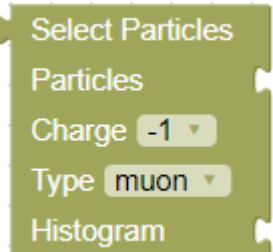
Number of bins 40

Min: 0

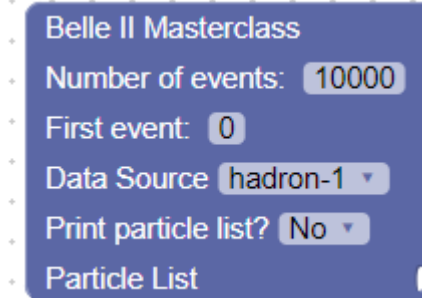
Max: 5

Variable mass

Basic blocks

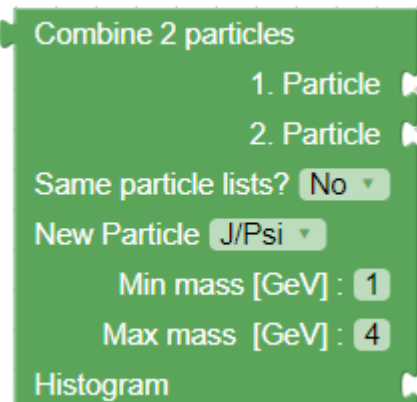


Select particle type
for analysis and
append histogram for
plotting the
properties

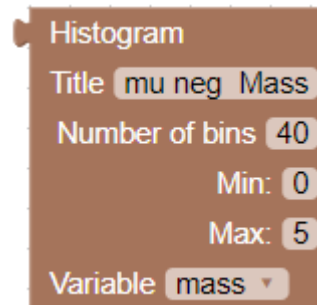


Define main analysis parameters

- Number of events to process
- First event to process
- Data Source
- Print particle list for first 100 events
- Particle list to process/
by default the list from
the file is used



Make a combination
of particles from two
lists



Plot a distribution

Define a range and
a variable to plot

Particle list

- Without any connected blocks the particle list is listed if only a main block is included in the sketch

Belle II Masterclass

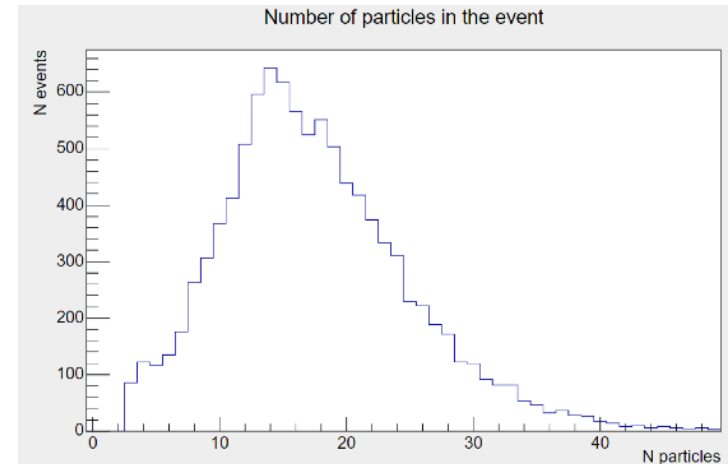
Number of events:

First event:

Data Source

Print particle list?

Particle List



Primary particle list for Event 1

N	px(GeV/c)	py(GeV/c)	pz(GeV/c)	p(GeV/c)	Energy(GeV)	Charge	ID
1	-0.99205	0.255215	-0.298016	1.06682	1.06682	-1	electron
2	0.379417	0.416063	0.292391	0.634475	0.634475	-1	electron
3	0.448819	0.279332	0.857395	1.00727	1.01689	1	pion
4	-0.381274	0.317797	0.666425	0.830956	0.842596	-1	pion
5	-0.404262	0.0618774	0.419536	0.58589	0.602285	-1	pion
6	0.0363708	-0.337713	0.696636	0.775032	0.787499	1	pion
7	-0.125205	0.251112	0.201202	0.345276	0.372418	-1	pion
8	0.111522	0.10243	0.139017	0.205559	0.248464	1	pion
9	0.0599534	0.0198644	0.0726116	0.0962364	0.169532	-1	pion
10	-0.0335806	0.0421883	0.0666954	0.0857659	0.163816	1	pion
11	0.180846	-0.00941455	0.265317	0.321227	0.321227	0	photon
12	0.354789	0.0498766	0.227253	0.424272	0.424272	0	photon
13	0.393443	-0.310244	0.28901	0.578425	0.578425	0	photon
14	0.254512	-0.0893971	0.113315	0.29259	0.29259	0	photon
15	0.152624	-0.0325375	0.296991	0.335494	0.361627	0	pion
16	0.650451	-0.401558	0.403939	0.864582	0.875054	0	pion

Combine the blocks

The particle lists for each event are stored in an ROOT tree.

By combining different blocks the event loop is generated. Inside the loop, new particle lists can be generated by combining the existing lists.

Distribution of different particle quantities can be plotted

Plot different variables :

- mass,
- momentum,
- energy,
- charge,
- identity,
- px,py,pz,pT
- cos(theta),
- theta

Belle II Masterclass

Number of events: 10000

First event: 0

Data Source hadron-1

Print particle list? No

Particle List

Select Particles

Particles

Charge Any

Type all particles

Histogram

Histogram

Title All particles;cos(polar angle);N

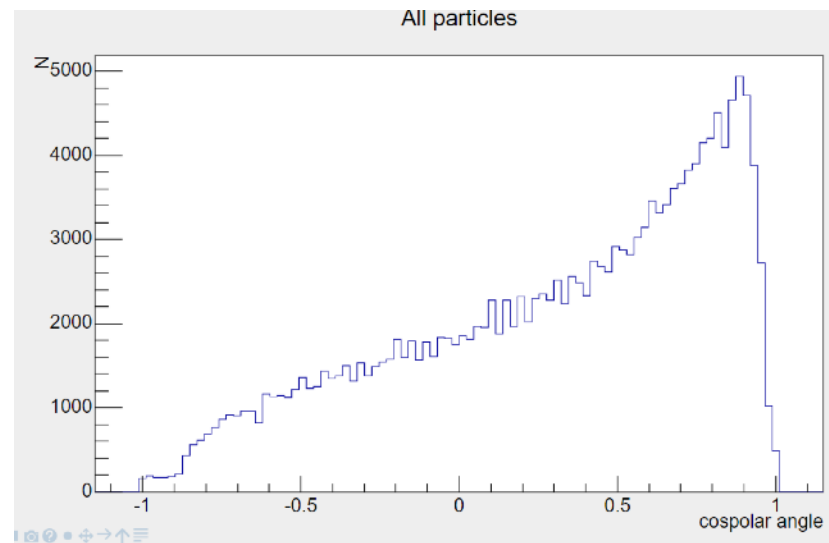
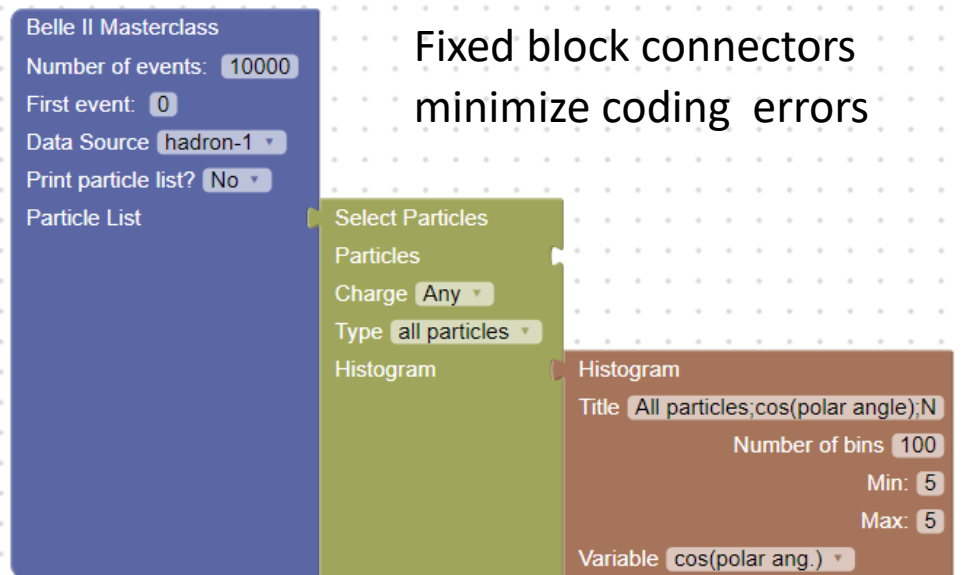
Number of bins 100

Min: 5

Max: 5

Variable cos(polar ang.)

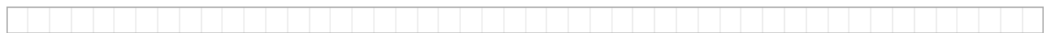
Fixed block connectors
minimize coding errors



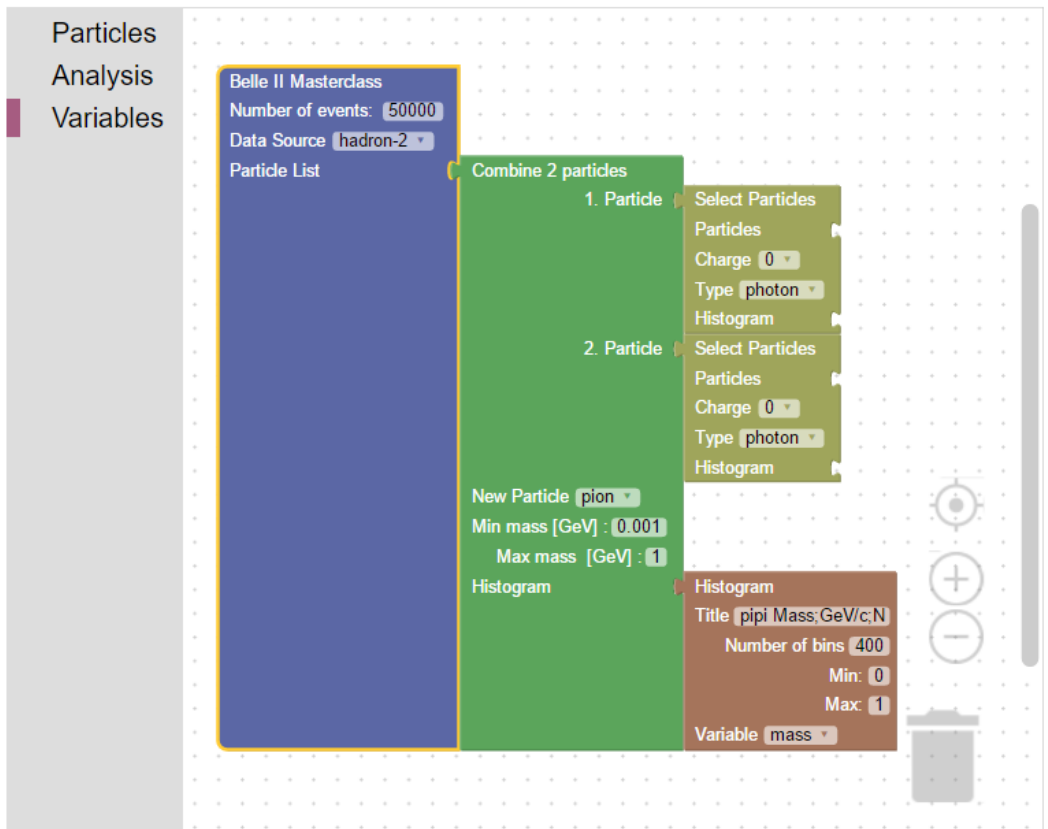
Decay to two particles

Belle II Masterclass: Define process → Analyse data → Visualise results → Save/load process locally

Run Analysis Interrupt Switch between Diagram and Results Save Diagram Load Diagram



0



The screenshot shows the Belle II Masterclass interface with a workflow diagram on a grid background. On the left, a sidebar contains 'Particles', 'Analysis', and 'Variables'. The main workspace contains the following components:

- Belle II Masterclass** (blue box):
 - Number of events: 50000
 - Data Source: hadron-2
 - Particle List
- Combine 2 particles** (green box):
 - 1. Particle: Select Particles, Particles, Charge 0, Type photon, Histogram
 - 2. Particle: Select Particles, Particles, Charge 0, Type photon, Histogram
- New Particle** (green box):
 - particle: pion
 - Min mass [GeV]: 0.001
 - Max mass [GeV]: 1
 - Histogram
- Histogram** (brown box):
 - Title: ppi Mass; GeV/c; N
 - Number of bins: 400
 - Min: 0
 - Max: 1
 - Variable: mass

Control icons for zooming and deleting are visible on the right side of the grid.

Combination of three particles

Belle II Masterclass
Number of events: 7000000
First event: 0
Data Source BelleII.root
Print particle list? No
Particle List

Combine 2 particles
Particle 1
Combine 2 particles
Particle 1
Select Particles
Particle
Charge 1
Type kaon
Histograms
Histogram Title kaon pos Mass Number of bins 40 Min: 0 Max: 5 Variable mass

Particle 2
Select Particles
Particle
Charge -1
Type pion
Histograms
Histogram Title pion neg Mass Number of bins 100 Min: 0 Max: 5 Variable mass

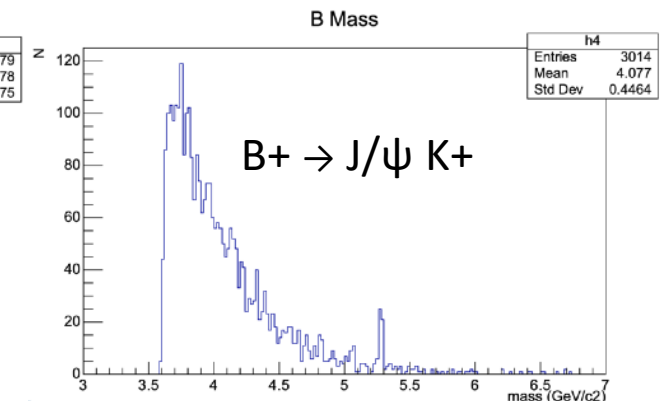
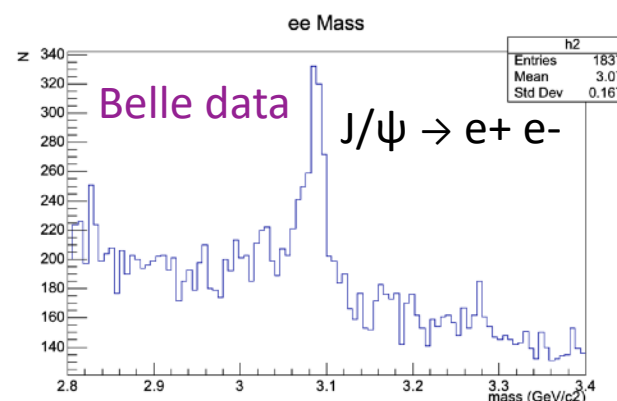
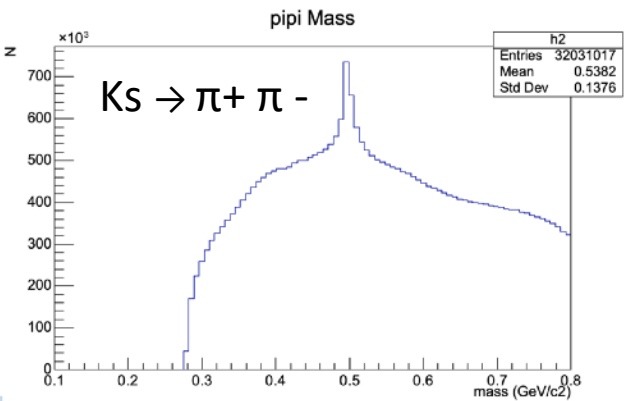
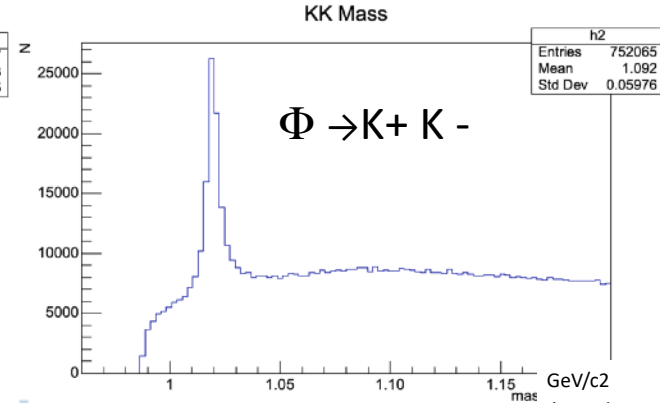
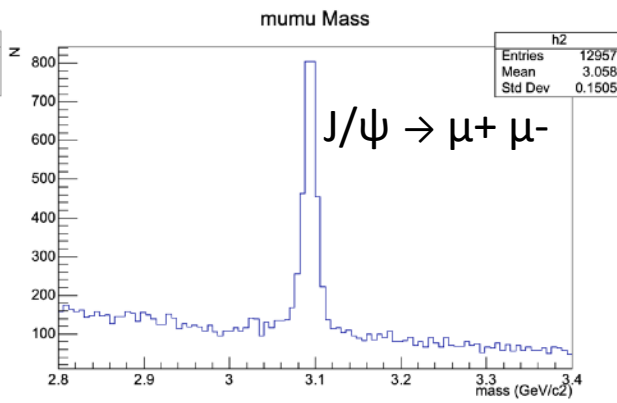
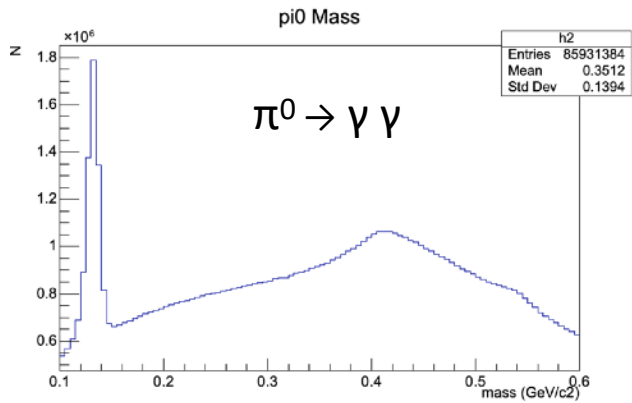
Same particle lists? No
Set identity to D meson
Min mass [GeV/c²] : 1.85
Max mass [GeV/c²] : 1.87
Histograms
Histogram Title D Mass Number of bins 100 Min: 1.85 Max: 1.87 Variable mass

Particle 2
Select Particles
Particle
Charge -1
Type pion
Histograms
Histogram Title pion neg Mass Number of bins 100 Min: 0 Max: 5 Variable mass

Same particle lists? No
Set identity to D* meson
Min mass [GeV/c²] : 1.6
Max mass [GeV/c²] : 2.35
Histograms
Histogram Title Dstar Mass Number of bins 100 Min: 1.6 Max: 2.35 Variable mass

Different decays

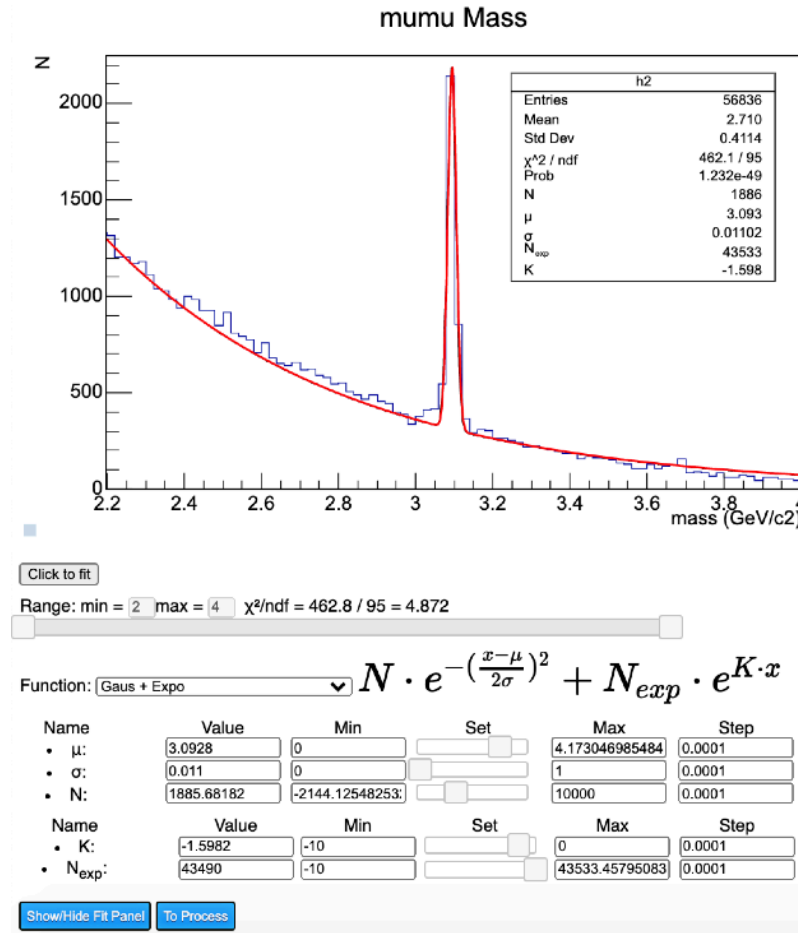
Invariant mass plots for different decays



This plot are a reference for your results \rightarrow they should not necessary be exactly like yours

Advanced level

A resulting panel offers the possibility to **fit a resulting distribution** with a ROOT function and calculate width and number of events in the peaks



Exercises

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		$\pi^0 \rightarrow \gamma \gamma$				
K_S		$K_S \rightarrow \pi^+ \pi^-$				
ϕ		$\phi \rightarrow K^+ K^-$				
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^-		$B^- \rightarrow J/\psi K^-$				

This table can be downloaded from here: <https://indico.belle2.org/event/1045/contributions/12229/>

Worksheet

Server to connect to, used for the exercises: <https://belle2.ijs.si/masterclass/>
Please use Firefox or Chrome as browsers

Click on this button at
the top of the page



Fill all the spots with the values that you find from your analysis.

**At the end we will compare the results of each group.
Please send a pdf with document with your plots/tables/
considerations to this email address: alberto.martini@roma3.infn.it**

Backup slides

Server connections

- Ljubljana: <https://belle2.ijs.si/masterclass/> 48 CPUs 32GB RAM
- backup servers:
 - Prague: <http://ipnp30.troja.mff.cuni.cz/masterclass/>
 - Bonn: <http://b2-masterclasses.physik.uni-bonn.de/masterclass/>
 - Munich: <https://kuhrios.universe-cluster.de/masterclass/>
 - Krakow: <http://192.245.169.98/masterclass/>