

# DELAVNICA BELLE II LAB

## (FIZIKA OSNOVNIH DELCEV)

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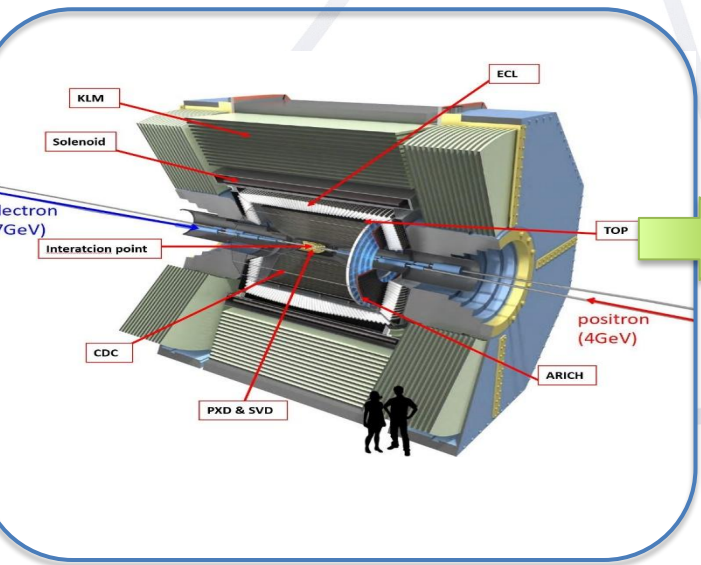
FMF, Ljubljana, Slovenia



# PREGLED

- Raziskovalci za nekaj ur
- Rekonstrukcija in analiza podatkov iz Belle II detektorja
- Spletno orodje: Belle II Lab <https://belle2.ijs.si/>
- Potek raziskovanja:

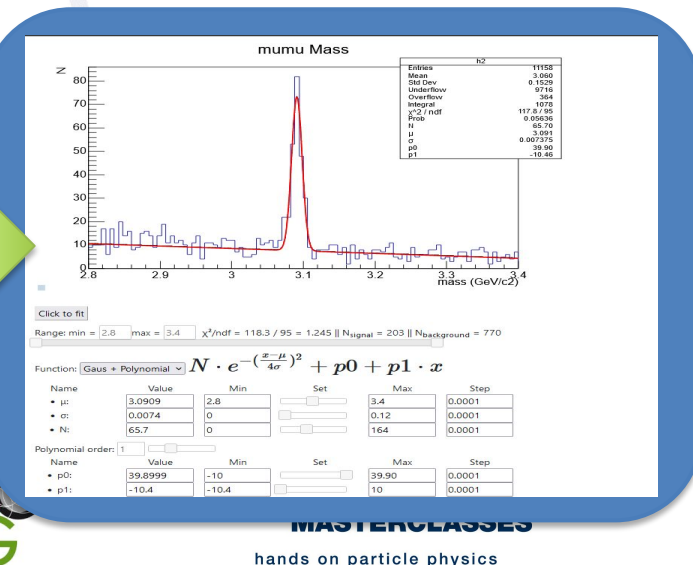
## Belle II detektor



## Podatki

N	pt[GeV/c]	py[GeV/c]	pt[GeV/c]	py[GeV/c]	Energy[GeV]	Charge	ID
1	-0.49399	0.67865	0.83219	1.37138	1.45753	1	kaon
2	-0.490319	-0.605026	0.591937	0.781007	0.79338	-1	pion
3	-0.148939	0.727243	0.647993	0.959385	0.99388	-1	electron
4	-0.331176	-0.624265	-0.300121	0.767765	0.780348	-1	pion
5	0.137009	0.624264	0.00489556	0.637415	0.652516	-1	pion
6	0.150035	0.624264	0.48407	0.835008	0.850045	1	pion
7	0.340787	0.29135	-0.250569	0.513733	1.06971	-1	proton
8	0.019395	0.372722	-0.0746089	0.380978	0.402978	-1	pion
9	0.266558	0.346506	0.0611402	0.372239	0.397545	1	pion
10	0.1525	-0.282905	-0.132328	0.340388	0.362981	-1	pion
11	-0.1012104	-0.273641	0.248796	0.371151	0.396526	1	pion
12	-0.139858	-0.273641	-0.150317	0.360883	0.37658	-1	pion
13	-0.139185	-0.0707428	-0.0686666	0.169847	0.169848	-1	electron
14	0.119075	-0.0707428	0.082761	0.169847	0.169848	1	electron
15	0.101946	0.196486	0.232244	0.335599	0.335599	0	photon
16	0.160347	0.539785	0.462977	0.746243	0.746243	0	photon
17	0.0471328	0.202798	0.066931	0.254	0.254	0	photon
18	0.0268383	-0.546354	-0.0109992	0.549544	0.549544	0	photon
19	-0.522742	-0.886541	0.133339	0.7858	1.18558	0	kaon
20	0.148004	0.396504	0.337965	0.543296	0.559811	-1	pion
21	0.150032	0.222069	0.202827	0.626112	0.646024	0	pion
22	0.233884	0.578209	0.546333	0.83916	0.840074	0	pion
23	0.207460	0.74239	0.579355	0.964565	0.973668	0	pion
24	-0.0366605	-0.56289	-0.0571373	0.566771	0.582621	0	pion

## Analiza





# BELLE II



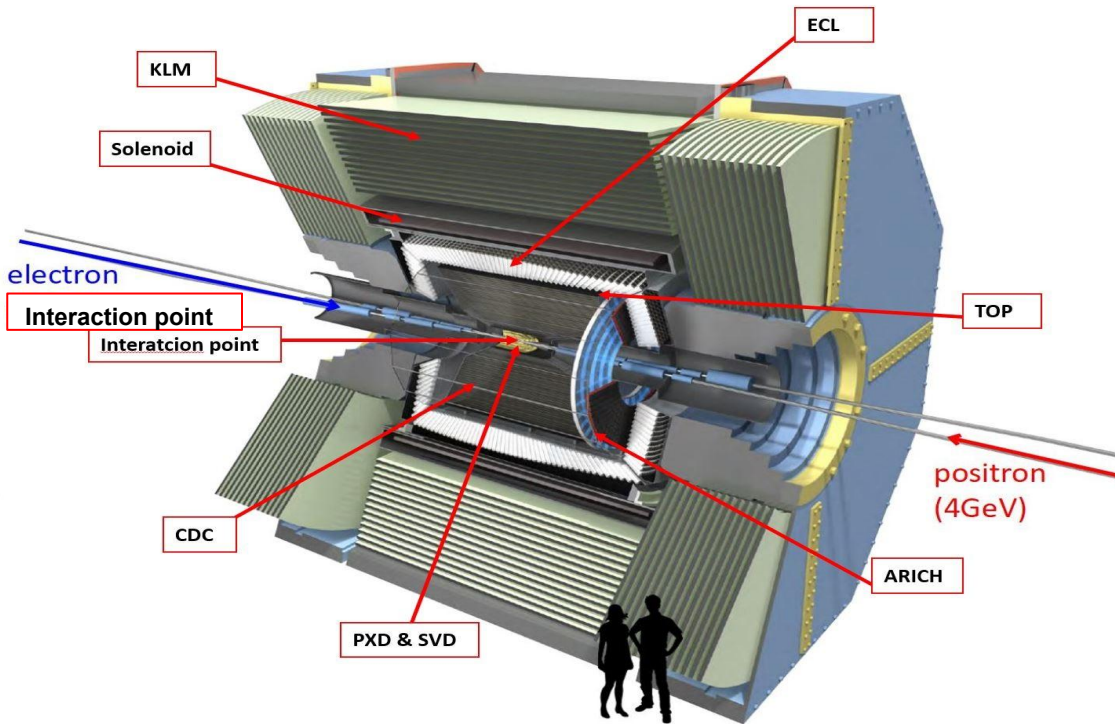
- Merimo lahko:
  - gibalno količino
  - energijo
  - identiteto delcev
- Dolgoživi delci
  - $e, \mu, \pi, K, p, \gamma, K_L$

## Rekonstrukcija



B, D mezoni,

Tau leptoni, ...



# Javno dostopna analiza 6 milijonov dogodkov iz Belle

Plot the mass distribution of a neutral pion  $\pi^0$  which decays to two photons:

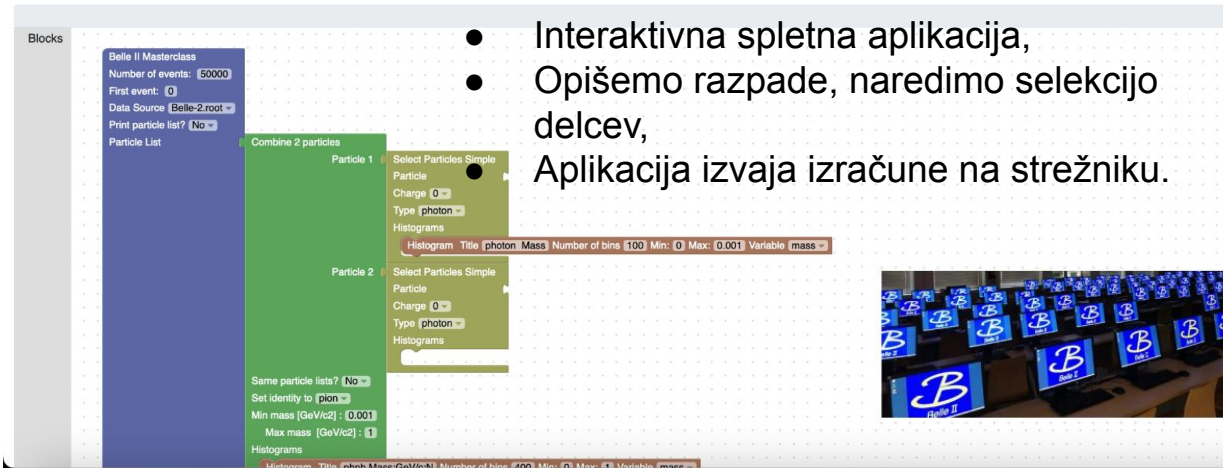
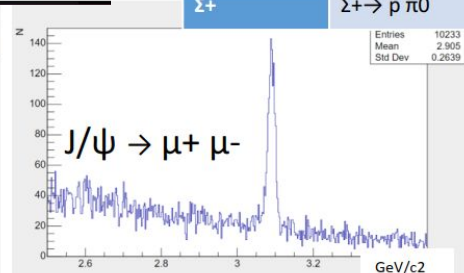
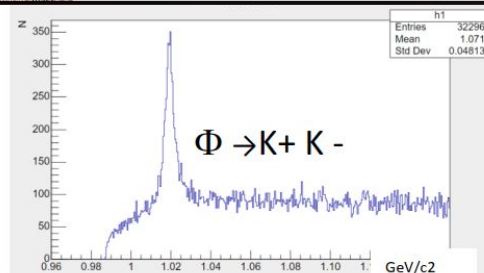
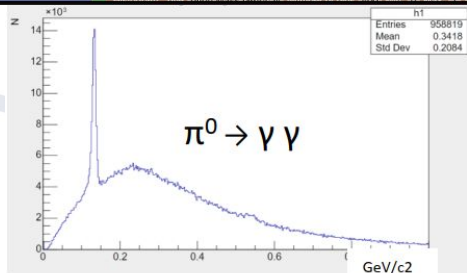


You will find a peak at 0.135 GeV/c<sup>2</sup>, which is exactly the mass of a neutral pion  $\pi^0$ .

- Interaktivna spletna aplikacija,
- Opišemo razpade, naredimo selekcijo delcev,
- Aplikacija izvaja izračune na strežniku.



Particle	Process
$\pi^0$	$\pi^0 \rightarrow \gamma\gamma$
Ks	$K_s \rightarrow \pi^+ \pi^-$
$\phi$	$\phi \rightarrow K^+ K^-$
J/ $\psi$	$J/\psi \rightarrow e^+ e^-$
	$J/\psi \rightarrow \mu^+ \mu^-$
D <sup>0</sup>	$D^0 \rightarrow K^+ \pi^-$
	$D^0 \rightarrow K^- \pi^+$
D <sup>*+</sup>	$D^{*+} \rightarrow D^0 \pi^+$
D <sup>*-</sup>	$D^{*-} \rightarrow D^0 \pi^-$
B <sup>+</sup>	$B^+ \rightarrow J/\psi K^+$
B <sup>-</sup>	$B^- \rightarrow J/\psi K^-$
$\Lambda$	$\Lambda \rightarrow p \pi^-$
$\Sigma^+$	$\Sigma^+ \rightarrow p \pi^0$

<https://belle2.ijs.si/masterclass>





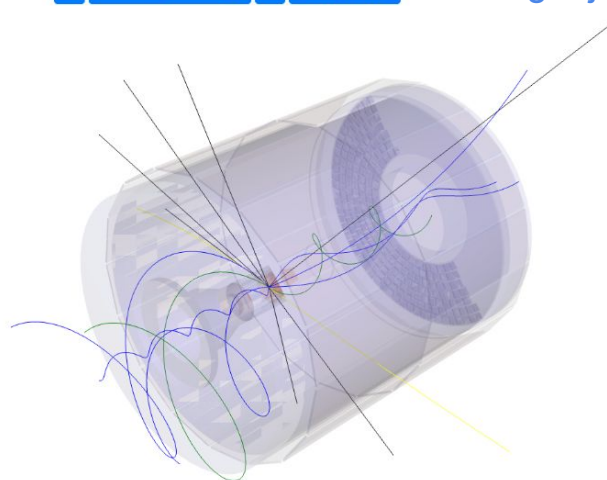
# VIZUALIZACIJA DOGODKOV

<https://belle2.ijs.si/masterclass/eventDisplay.html>

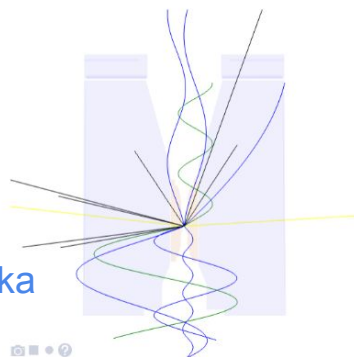
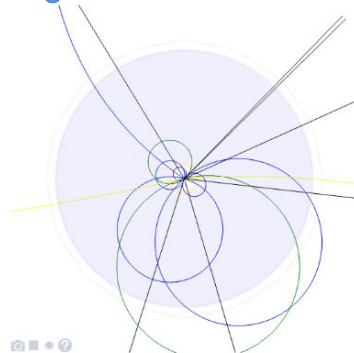
Belle II Masterclass Event Display

Event: < 5 > Close Window

Nalaganje dogodkov



Spiralen razvoj (propagacija) delcev iz interakcijske točke trkalnika



Reconstructed particles of Event 5

N	px(GeV/c)	py(GeV/c)	pz(GeV/c)	p(GeV/c)	Energy(GeV)	Charge	ID
1	-0.0583959	-0.2302	0.161984	0.287473	0.319563	1	pion
2	0.112417	0.183063	0.122853	0.247472	0.284117	1	pion
3	0.580248	0.157514	-0.0766503	0.606113	0.615254	-1	muon
4	-0.224035	-0.191422	0.049061	0.298732	0.316867	-1	muon
5	-0.555212	0.368001	0.929691	1.14368	1.15217	1	pion
6	-0.116631	-0.112259	-0.0287092	0.164405	0.215659	1	pion
7	0.439929	-0.12336	-0.0591459	0.46071	0.481387	-1	pion
8	0.436088	0.372612	-0.105938	0.583297	0.599763	-1	pion
9	-2.42432	-0.519574	0.918622	2.64408	2.68977	-1	kaon
10	1.74583	0.132125	0.367313	1.78893	1.8558	1	kaon
11	-0.167629	0.275582	0.46388	0.565004	0.565004	0	photon
12	-0.117935	-0.373889	0.180254	0.431501	0.431501	0	photon
13	0.0922474	-0.314156	0.139221	0.355789	0.355789	0	photon
14	0.213342	-0.0242391	0.0564162	0.222003	0.222003	0	photon
15	0.390728	0.386407	0.0927488	0.557298	0.557298	0	photon
16	0.233168	0.105342	-0.0301511	0.25763	0.25763	0	photon
17	0.179715	0.184747	-0.030999	0.259595	0.259595	0	photon

Seznam rekonstruiranih delcev, ki jih lahko preprosto združimo!

Particle properties combined from two particles ✕

px [GeV/c]	py [GeV/c]	pz [GeV/c]	E [GeV/c <sup>2</sup> ]	charge	ID
0.436088	0.372612	-0.105938	0.599763	-1	pion
-0.167629	0.275582	0.46388	0.565004	0	photon
<b>0.2685</b>	<b>0.6482</b>	<b>0.3579</b>	<b>1.1648</b>	<b>-1</b>	

Invariant mass = 0.8581 GeV/c<sup>2</sup>

Close

Previous Next Run Analysis

Save  
Load Diagram

## Mission 6: decay of a $J/\psi$ to charged leptons

Plot the mass distribution of a  $J/\psi$  meson which decays to two leptons:

$$J/\psi \rightarrow e^+e^- \quad \text{or} \quad J/\psi \rightarrow \mu^+\mu^-$$

You will find a peak at  $3.10 \text{ GeV}/c^2$ , which is exactly the mass of the  $J/\psi$ .

The probability for the production of a  $J/\psi$  is very small, so you will have to process at least 100000 events.

Blocks

Belle II Masterclass

Number of events: 500000

First event: 0

Data Source: Belle-2.root

Print particle list? No

Particle List

Combine 2 particles

Particle 1

Select Particles Simple

Particle

Charge -1

Type muon

Histograms

Histogram Title mu neg Mass Number of bins 100 Min: 0 Max: 5 Variable mass

Particle 2

Select Particles Simple

Particle

Charge 1

Type muon

Histograms

Histogram Title mu pos Mass Number of bins 100 Min: 0 Max: 5 Variable mass

Same particle lists? No

Set identity to J/Psi meson

Min mass [GeV/c<sup>2</sup>] : 2.5

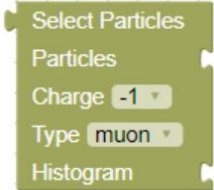
<https://belle2.ijs.si/masterclass/#>

## RESEVANJE MISIJ:

- opis fizikalnega procesa,
- zagon analize,
- program lahko shranite za kasnejšo uporabo!

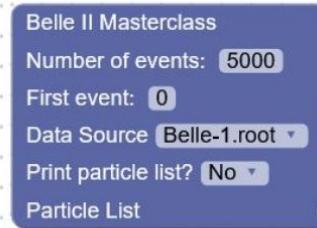
# OSNOVNI "DELČKI" (programske kode - blockly)

Ne fizikalni delci ;)



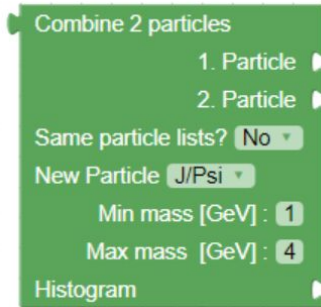
Selektor/Izbiralec:

- Izberemo selekcijo/izbor **delcev**,
- Za katere lahko narišemo različne histograme.



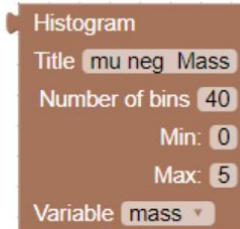
Zagon analize:

- Izberemo selekcijo/izbor **delcev**,
- Za katere lahko narišemo različne histograme.



Združevalec:

- Vzamemo razpadle produkte (dva **delca**) in jih združimo v originalen **delec**, ki je razpadel.



Risalec histogramov:

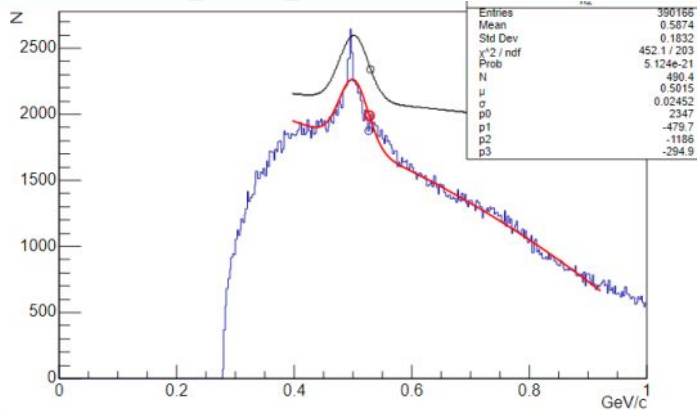
- izberemo fizikalno količino, ki jo hočemo narisati,
- določimo območje, ki nas zanima.





# DODATNE FUNKCIJE:

- Prilagajanje zveznih funkcij, da ocenimo "natančnost" naše analize.
- Lahko tudi preverite, ali ste dobili pravi rezultat!



Click to fit

Range: min = 0.397 max = 0.923  $\chi^2/\text{ndf} = 1.051e+5 / 205 = 512.7$

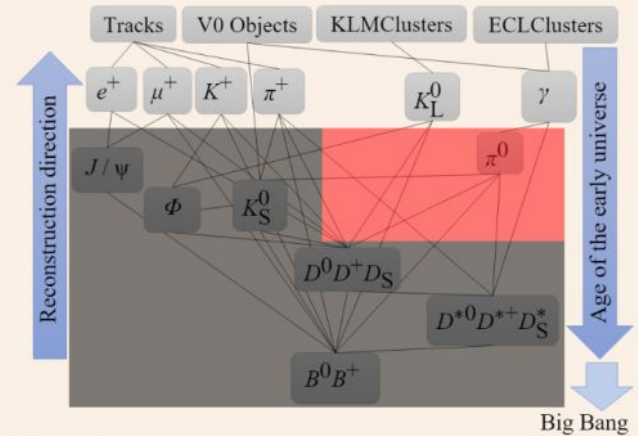
Function: Gaus + Poly  $N \cdot e^{-\frac{(x-\mu)^2}{2\sigma^2}} + p0 + p1 \cdot x$

Name	Value	Min	Set	Max	Step
• $\mu$ :	0.5015	0		1	0.0001
• $\sigma$ :	0.0245	0		0.1	0.0001
• N:	490.3655	0		10000	0.0001

Polynomial order: 1

Name	Value	Min	Set	Max	Step
• p0:	2347.1938	-10		5000	0.0001
• p1:	-479.67778	-493.746783424		10	0.0001
• p2:	-1186.24247436	-1186.24247436		10	0.0001
• p3:	-294.865183268	-294.865183268		10	0.0001
• p4:	0	-10		10	0.0001

1.	$\pi^0 \rightarrow \gamma\gamma$	$\pi^0$ mass	<input type="text" value="0"/>	GeV/c <sup>2</sup>	Sadly not correct. Did you find the right peak?	
2.	$K_S^0 \rightarrow \gamma\gamma$	$K_S^0$ mass	<input type="text"/>	GeV/c <sup>2</sup>	Please start to enter a number!	
3.	$\Phi \rightarrow \gamma\gamma$	$\Phi$ mass	<input type="text"/>	GeV/c <sup>2</sup>	Please start to enter a number!	
4.	$J/\Psi \rightarrow \mu^+\mu^-$	$J/\Psi$ mass	<input type="text"/>	GeV/c <sup>2</sup>	Please start to enter a number!	
5.	$J/\Psi \rightarrow e^+e^-$	$J/\Psi$ mass	<input type="text"/>	GeV/c <sup>2</sup>	Please start to enter a number!	
6.	$D^0 \rightarrow K^+\pi^-$ $D^0 \rightarrow K^-\pi^+$	avg. $D^0$ mass	<input type="text"/>	GeV/c <sup>2</sup>	<input type="text"/>	Please start to enter a number!
7.	$D^{*+} \rightarrow D^0\pi^+$ $D^{*0} \rightarrow D^0\pi^0$	$D^{*+}$ mass $D^{*0}$ mass	<input type="text"/>	GeV/c <sup>2</sup>	<input type="text"/>	Please start to enter a number!
8.	$B^+ \rightarrow J/\Psi K^+$ $B^0 \rightarrow J/\Psi K^0$	avg. $B^+$ mass	<input type="text"/>	GeV/c <sup>2</sup>	<input type="text"/>	Please start to enter a number!



# RAZLIČNI RAZPADNI PROCESI

Zanimajo nas porazdelitve invariantnih mas razpadlih delcev, ki jih izračunamo z združevanjem razpadlih produktov! **PREVERIMO TEORETIČNE NAPOVEDI MAS!!**

