Predicting the origin of first hits in the Vertex Locator

$$B^{+}_{(c)} \rightarrow \tau + \nu_{\tau}$$

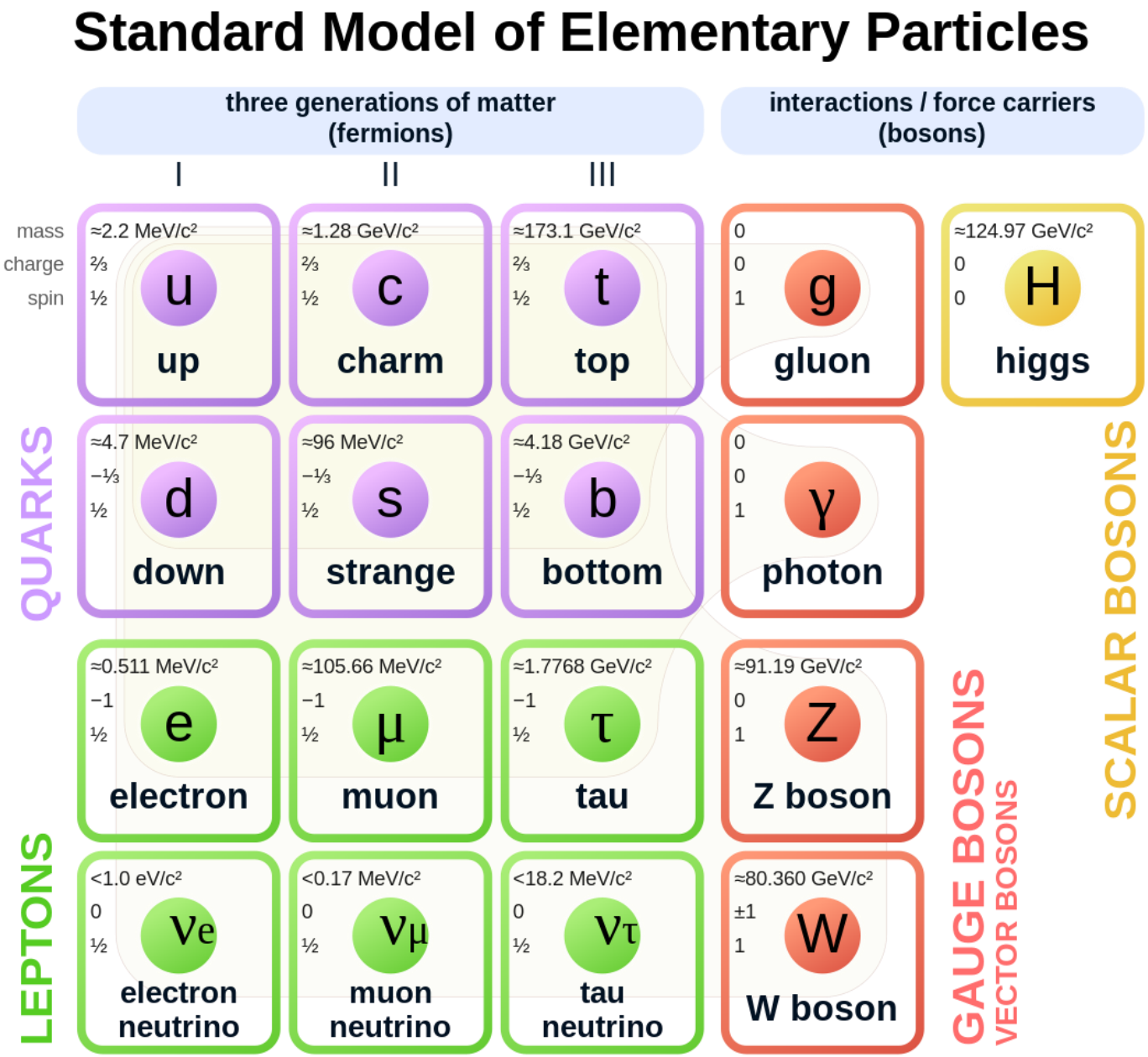
Bachelor's Research Project
Frederiek de Bruine
Supervisor: dr. Kristof de Bruyn

Introduction

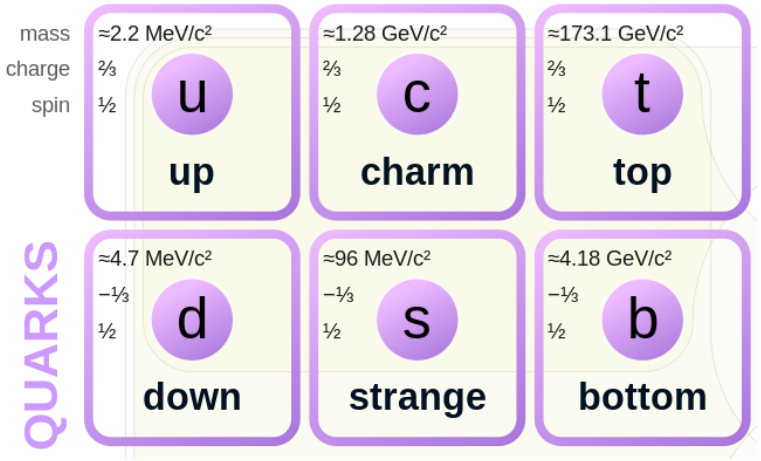
- Testing SM prediction by measuring the branching fraction

- $BR(B_c^+ \to \tau^+ \nu_\tau)^{SM} = (1.95 \pm 0.09) \times 10^{-2}$

  (Amhis et al, 2021)

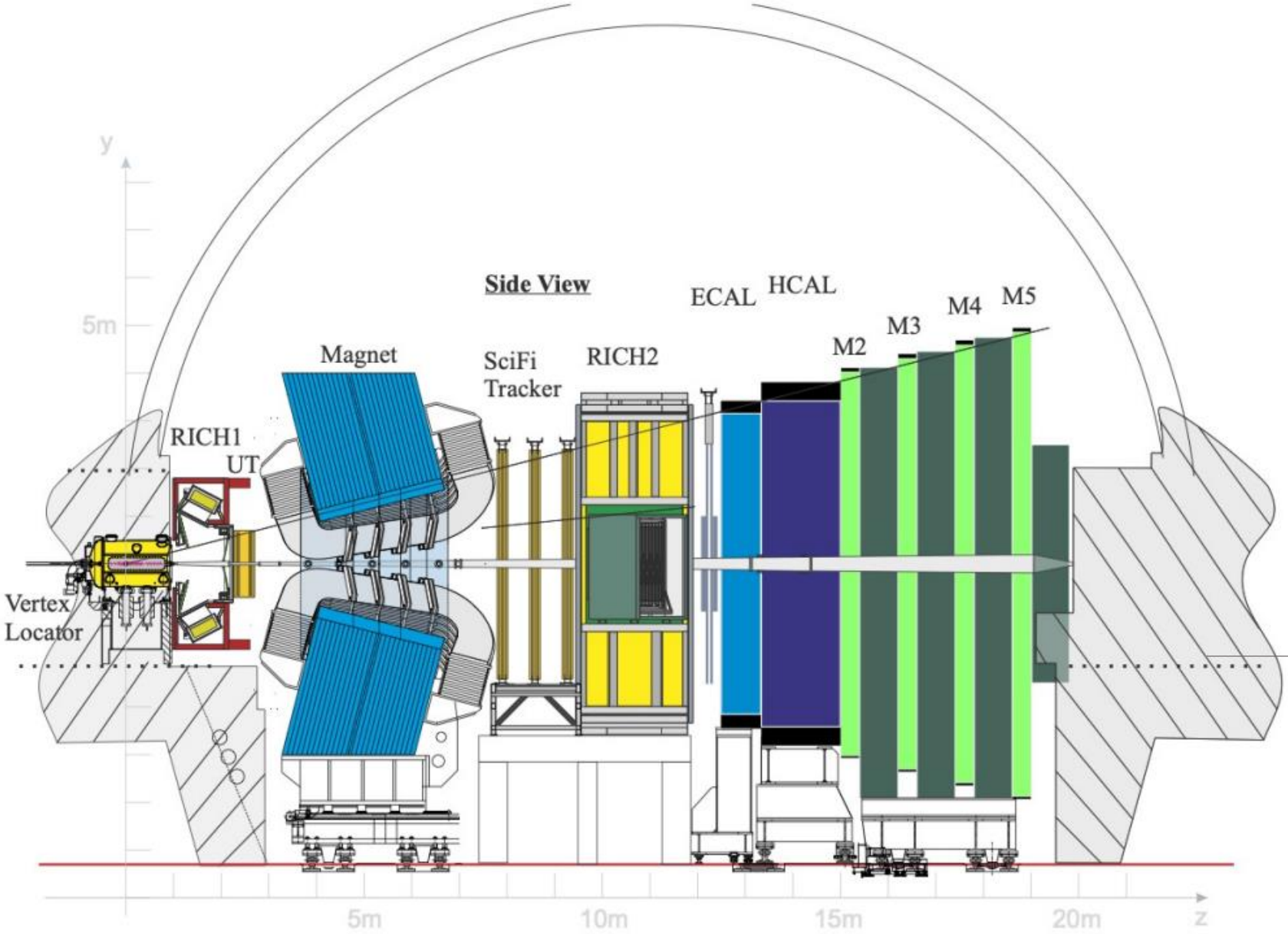


Introduction

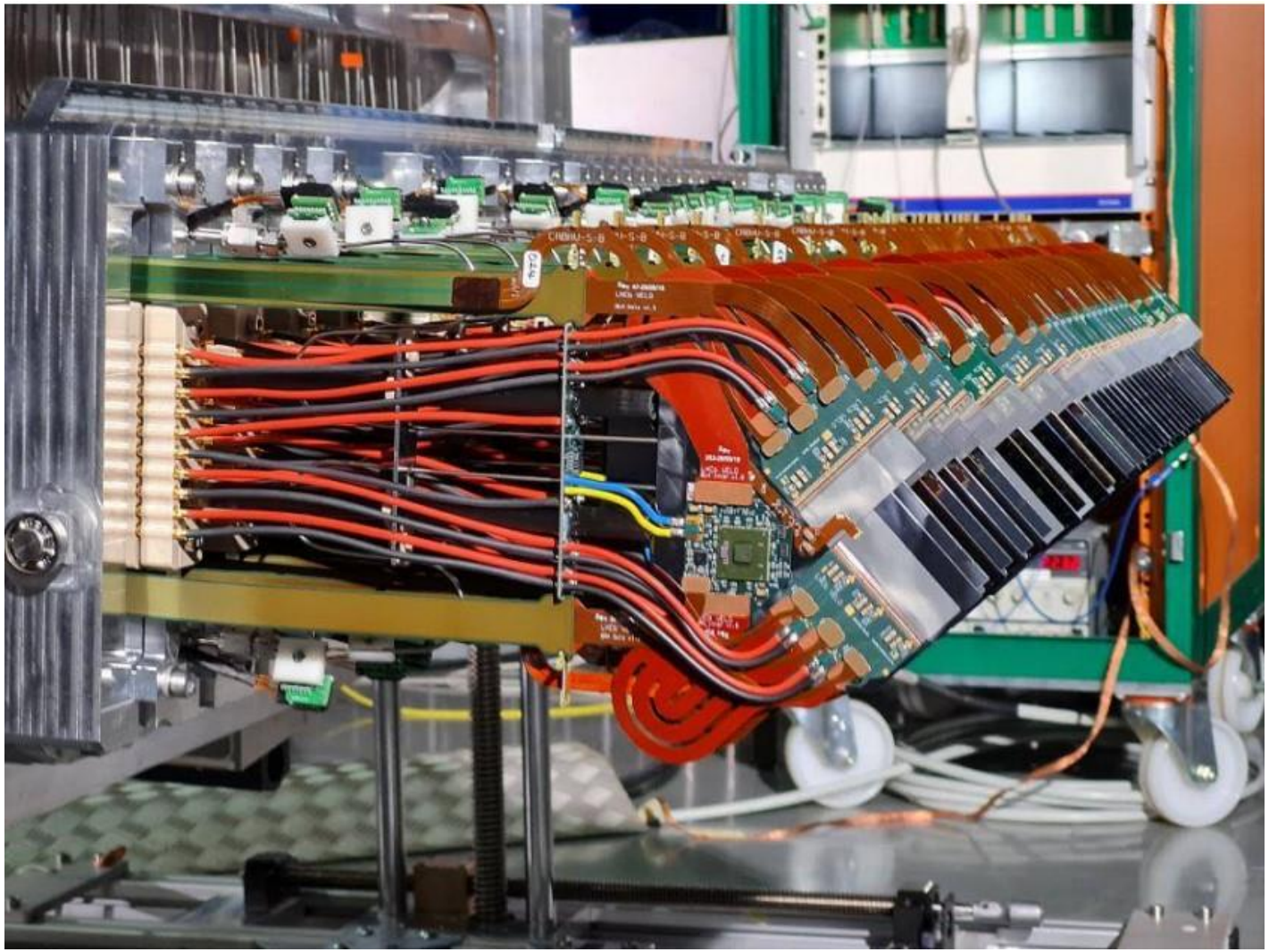


- B_c^+ : anti-beauty + charm quark
- B^+ : anti-beauty + up quark

- $B_{(c)}^+ \rightarrow \tau(\rightarrow \pi^+ \pi^+ \pi^- \nu_\tau)\nu_\tau$

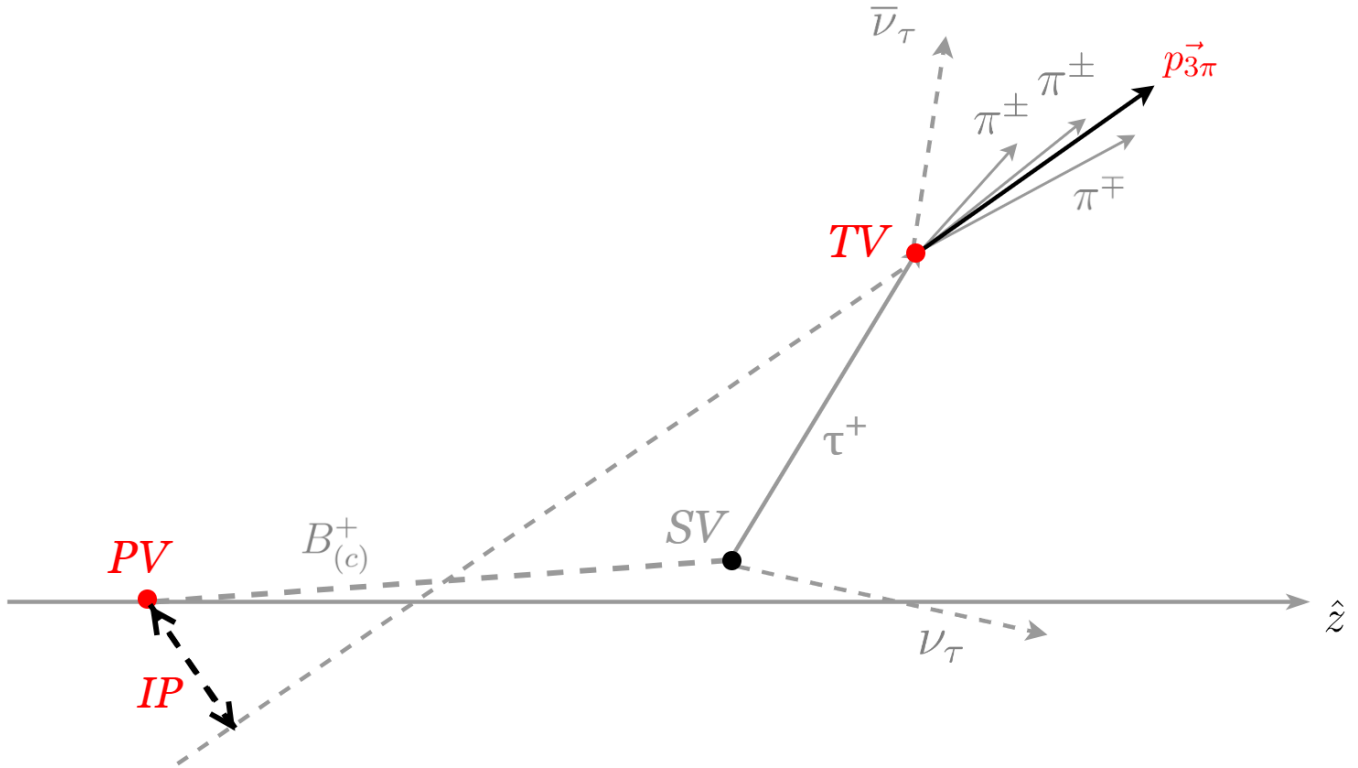

Side View
y
5m
Magnet
SciFi
Tracker
RICH2
ECAL
HCAL
M2
M3
M4
M5
RICH1
UT
Vertex
Locator
5m
10m
15m
20m
z

LHCb



Vertex Locator (VELO)

Observables



Corrected mass: $$m_{corr} = \sqrt{m_{3\pi}^2 + \left|\overrightarrow{p_{\perp(3\pi)}}\right|^2} + |\overrightarrow{p_{\perp}}(3\pi)|$$

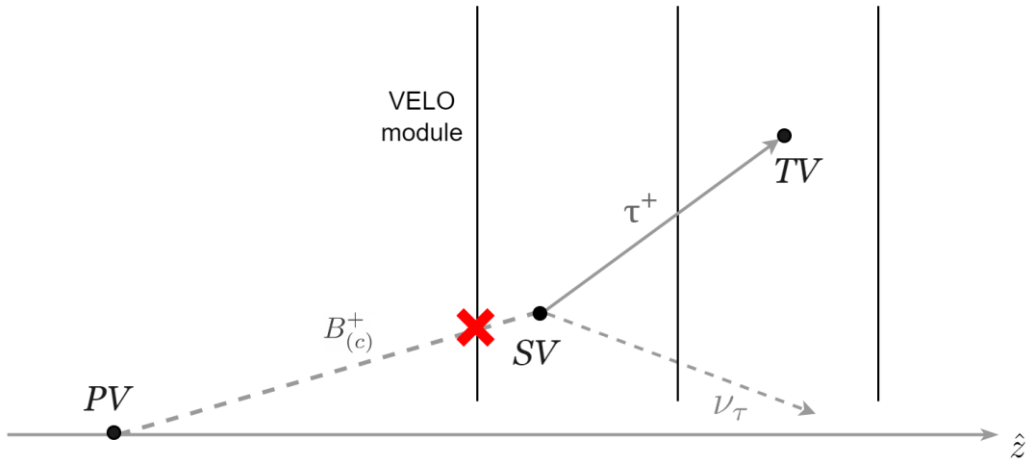
Where $$m_{3\pi} = \sqrt{E_{3\pi}^2 + \overrightarrow{p_{3\pi}}^2}$$

And $\overrightarrow{p_{\perp}}(3\pi)$ is the momentum of the 3π-system perpendicular to the direction from the PV to the first hit in the VELO

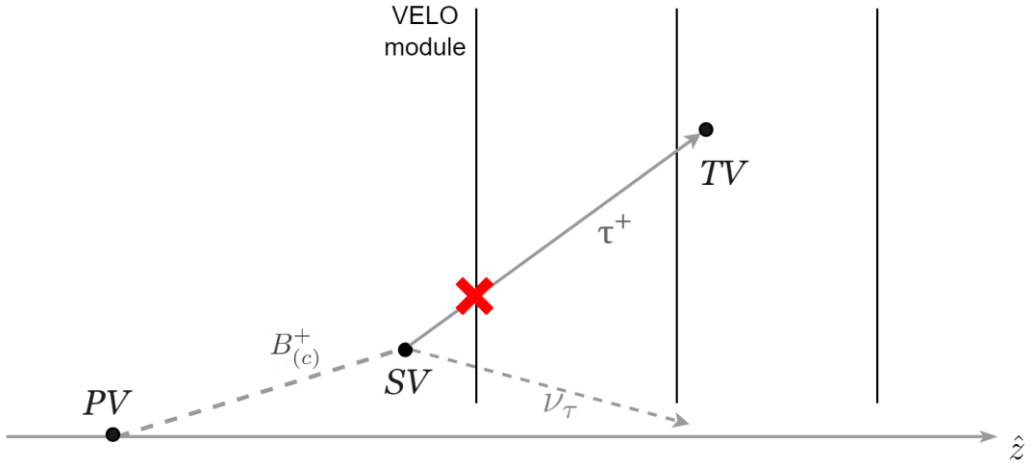
The $B^+_{(c)}$/ τ ratio of first hits in the VELO

Using simulated data

$B^+_{(c)}$ FIRST HIT



τ FIRST HIT



Motivation:

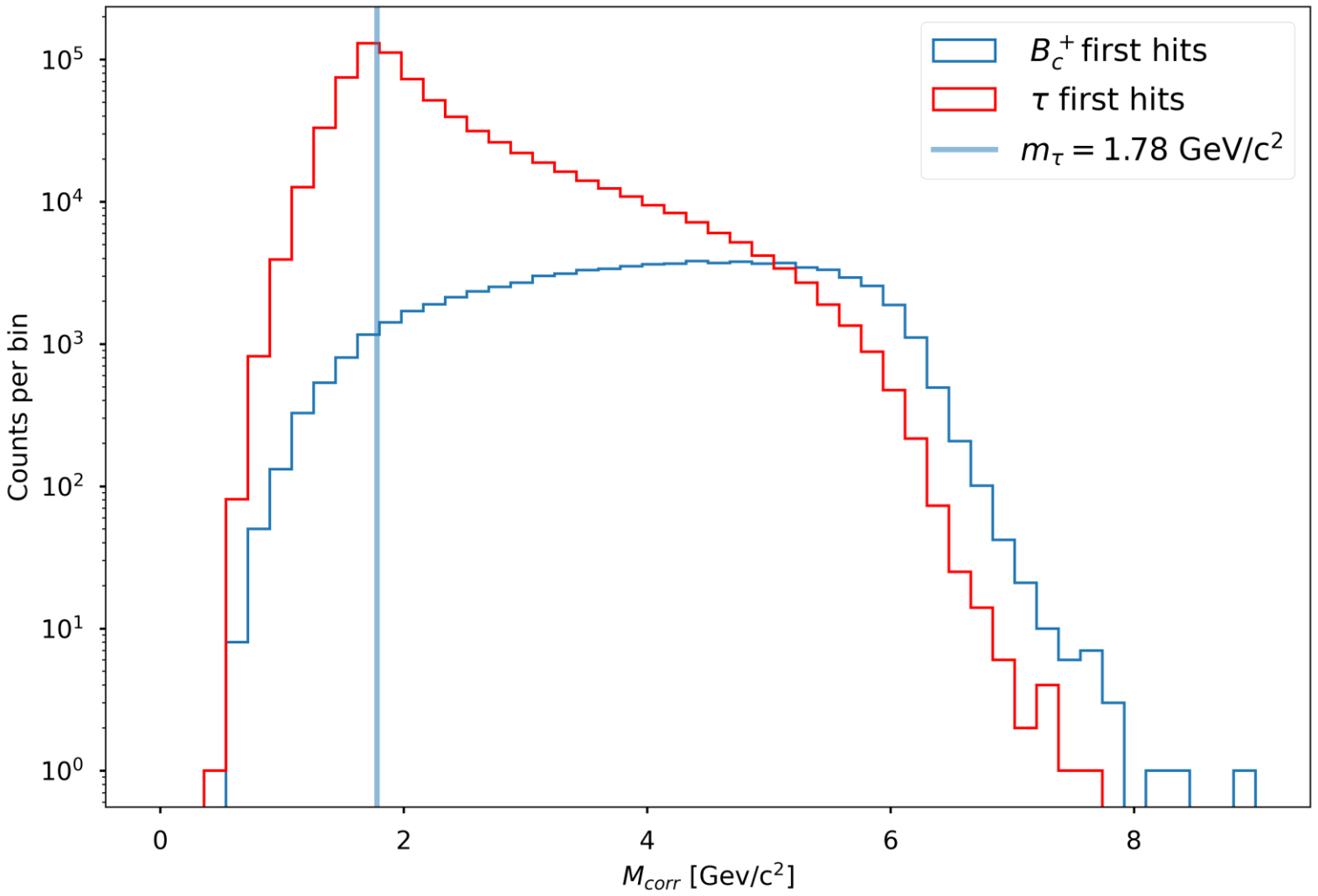
Predicting the origin of the first hit can help distinguish the signal decay from the background decays

Results

Decay	τ first hits (%)	$B^+_{(c)}$ first hits (%)
$B_c^+ \rightarrow \tau + \nu_\tau$	90.6 %	9.4 %
$B^+ \rightarrow \tau + \nu_\tau$	30.9 %	69.1 %

Particle	Mean lifetime (s)
B_c^+	$(0.510 \pm 0.009) * 10^{-12}$
B^+	$(1.638 \pm 0.004) * 10^{-12}$

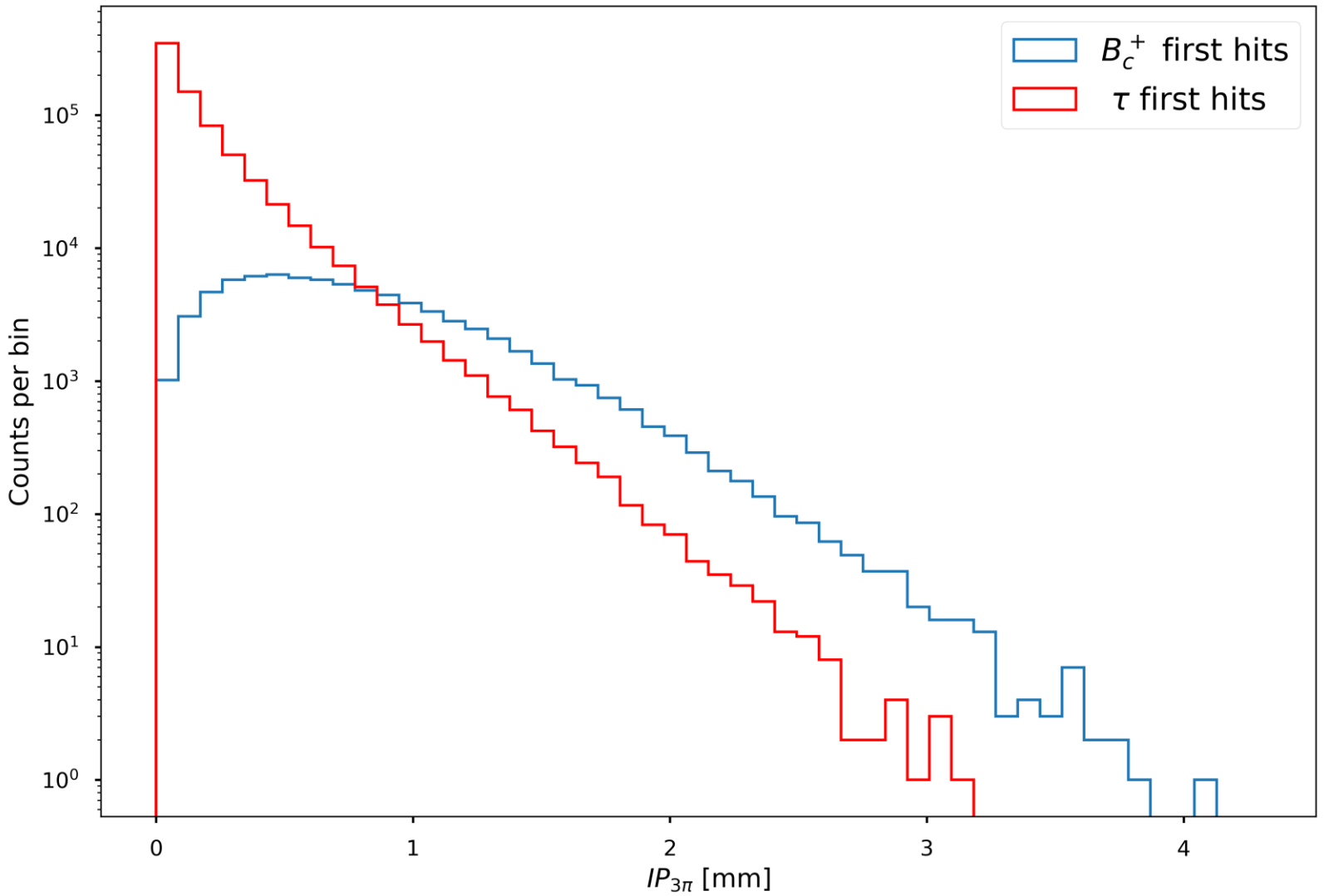
(PDG, 2022)



Corrected mass

$$B_c^+ \rightarrow \tau + \nu_\tau$$

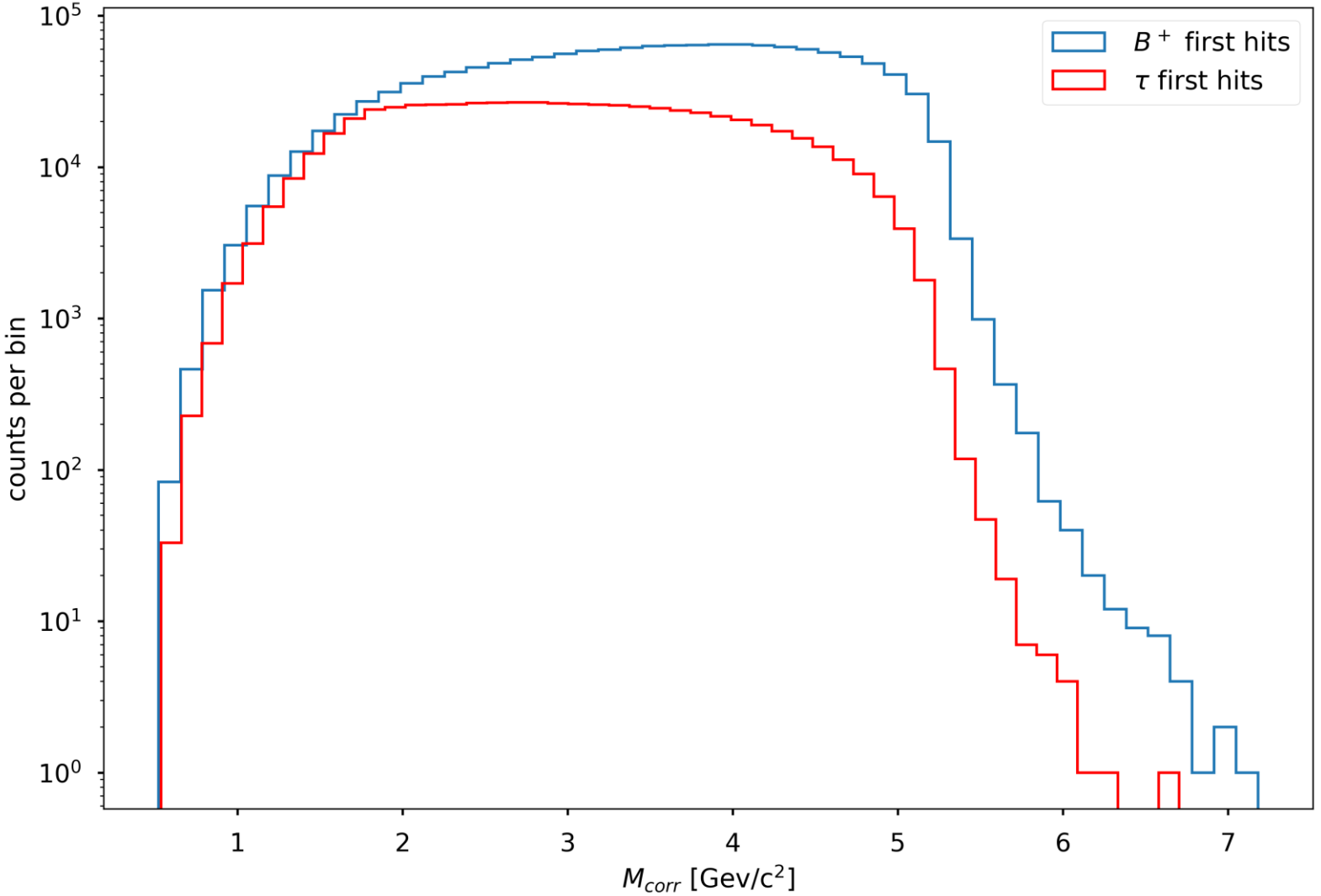
- Peak at invariant mass of the τ



Impact Parameter

$$B_c^+ \rightarrow \tau + \nu_\tau$$

- Shorter combined lifetime



Corrected mass

$B^+ \rightarrow \tau + \nu_\tau$

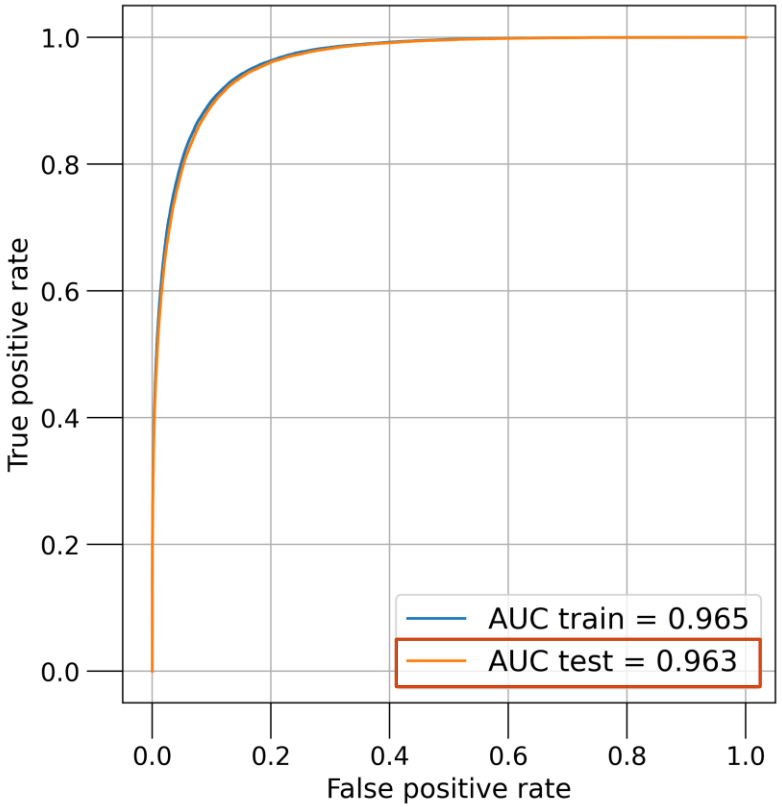
Multivariate Analysis (MVA)

- Gradient boosting classifier
  - Decision trees

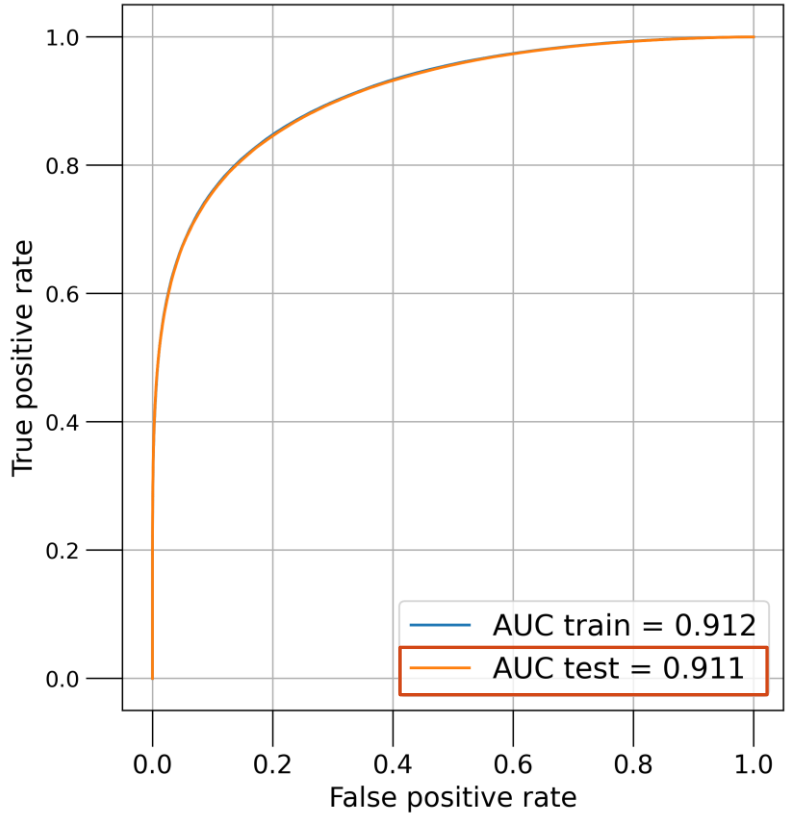
- Dataset is split into 50% train data and 50% test data

ROC curves

$B_c^+ \to \tau + \nu_\tau$



$B^+ \to \tau + \nu_\tau$



Conclusion

- Only <10% of first hits originate from B_c^+-particles
- While for the B^+-decay ≈70% of first hits originate from B^+-particles

- It is possible to classify the first hits by only using the data of observables

Outlook:

- Implement MVA for all background decays