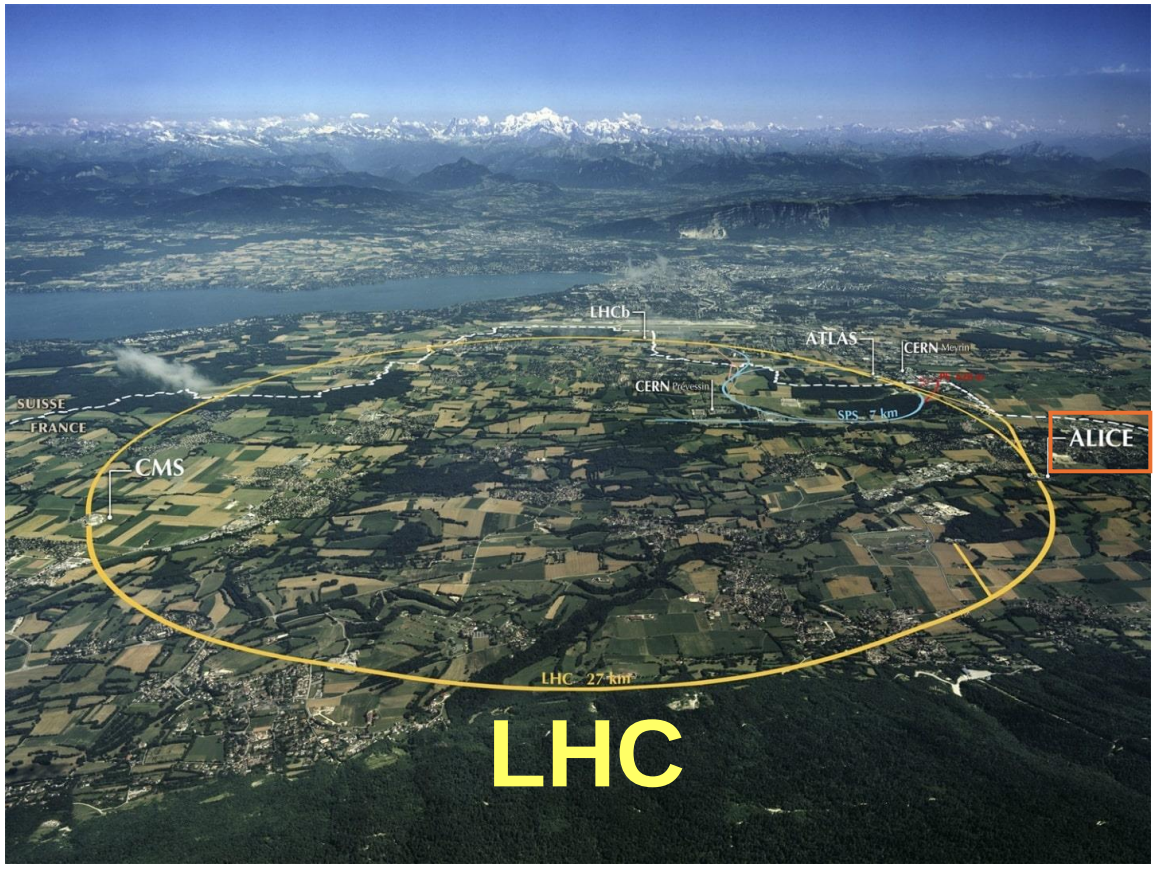
Study of open beauty production with the ALICE detector at the LHC

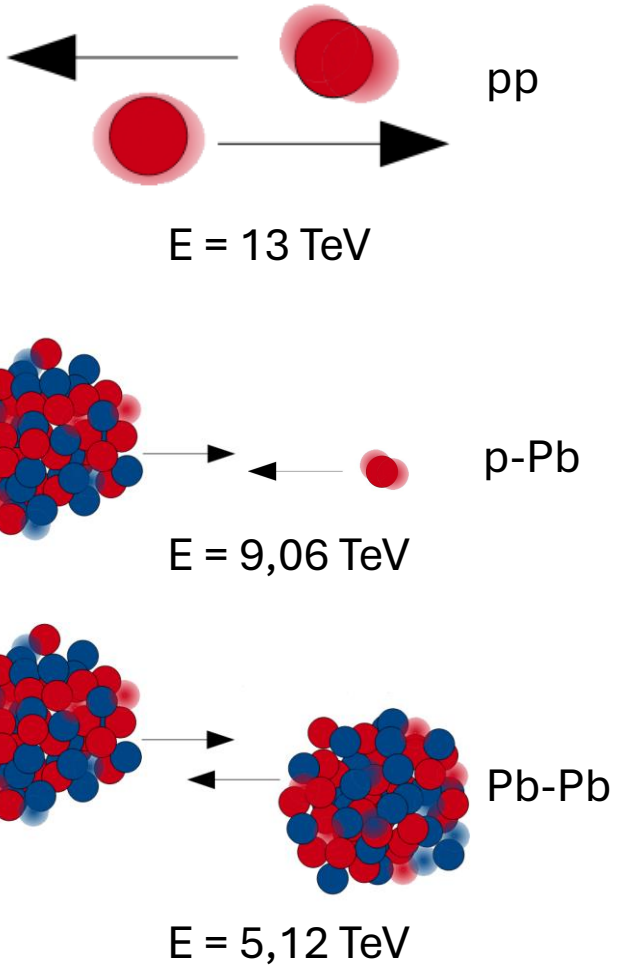
- ALICE
- Quark-Gluon Plasma (QGP)
- Analysis
- Conclusions
- Prospects

Under the direction of BELIKOV Iouri and BIGOT Alexandre

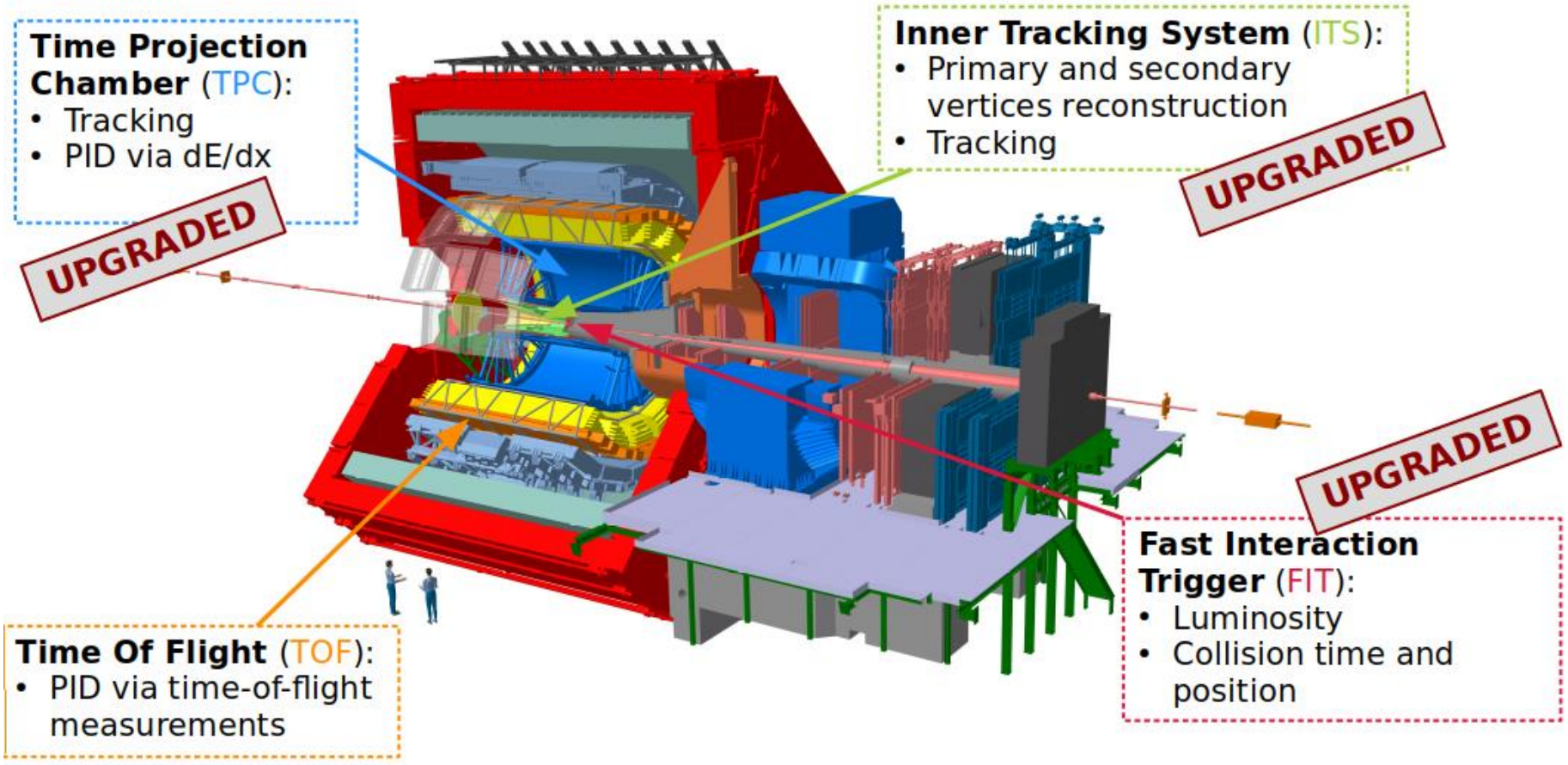
ALICE



Source : Wikipedia LHC



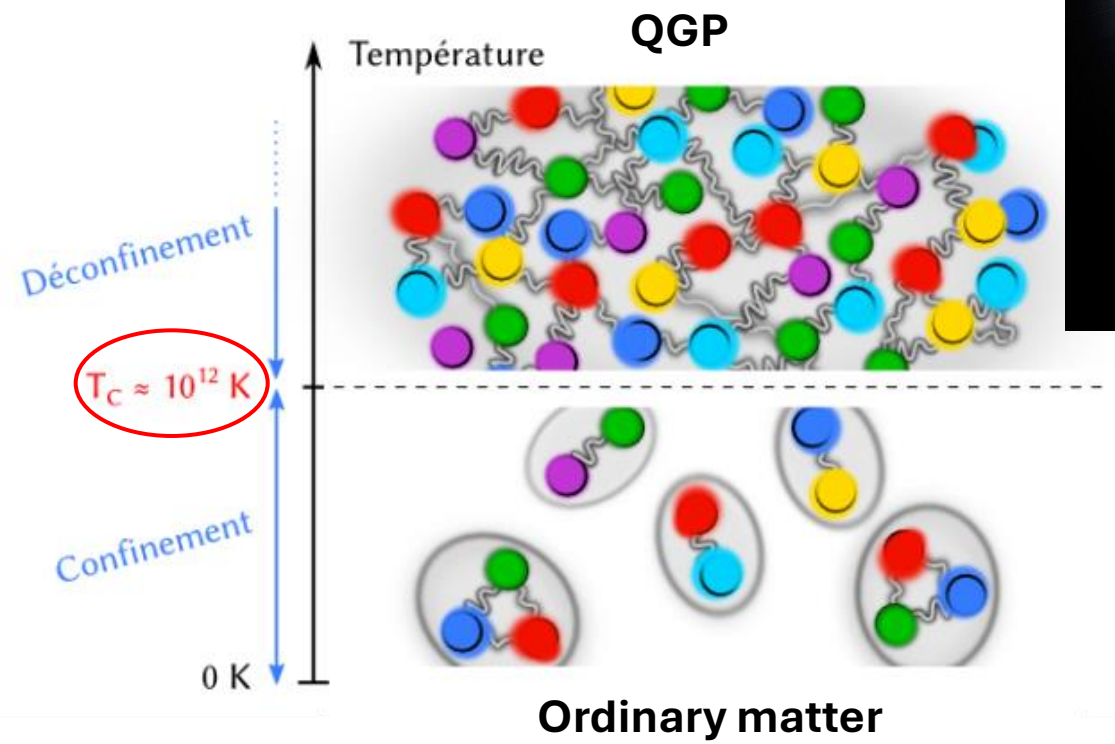
ALICE


Time Projection Chamber (TPC):
• Tracking
• PID via dE/dx
UPGRADED
Inner Tracking System (ITS):
• Primary and secondary vertices reconstruction
• Tracking
UPGRADED
UPGRADED
Fast Interaction Trigger (FIT):
• Luminosity
• Collision time and position
Time Of Flight (TOF):
• PID via time-of-flight measurements

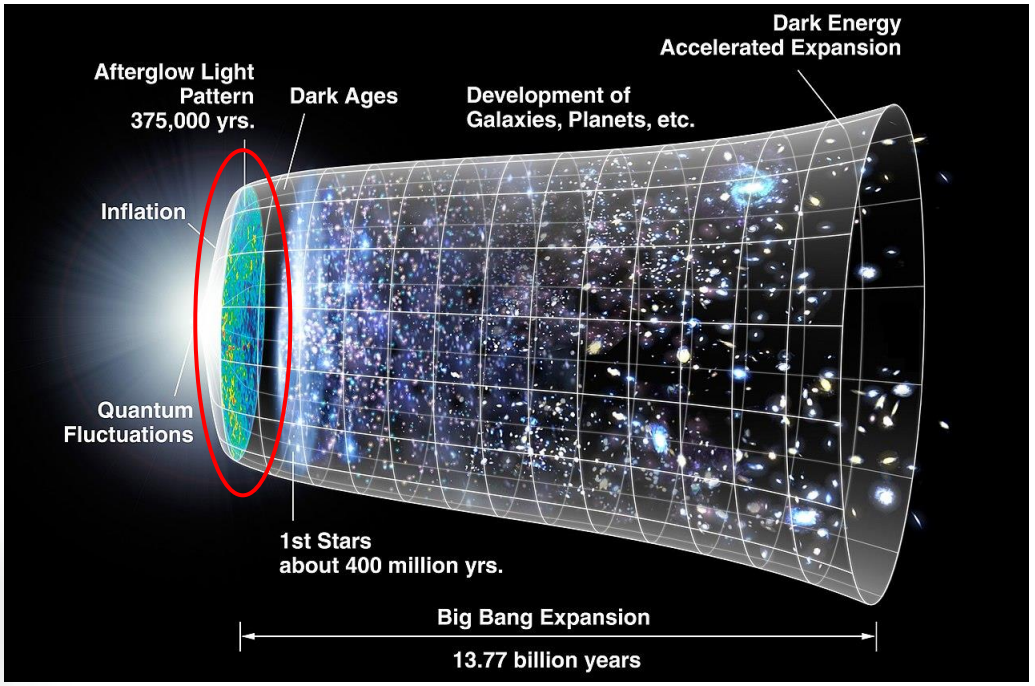
Quark-Gluon Plasma (QGP)

QGP lifespan$_{lab}$: ~10^{-23}s

Instrument minimal temporal resolution : ~10^{-12}s

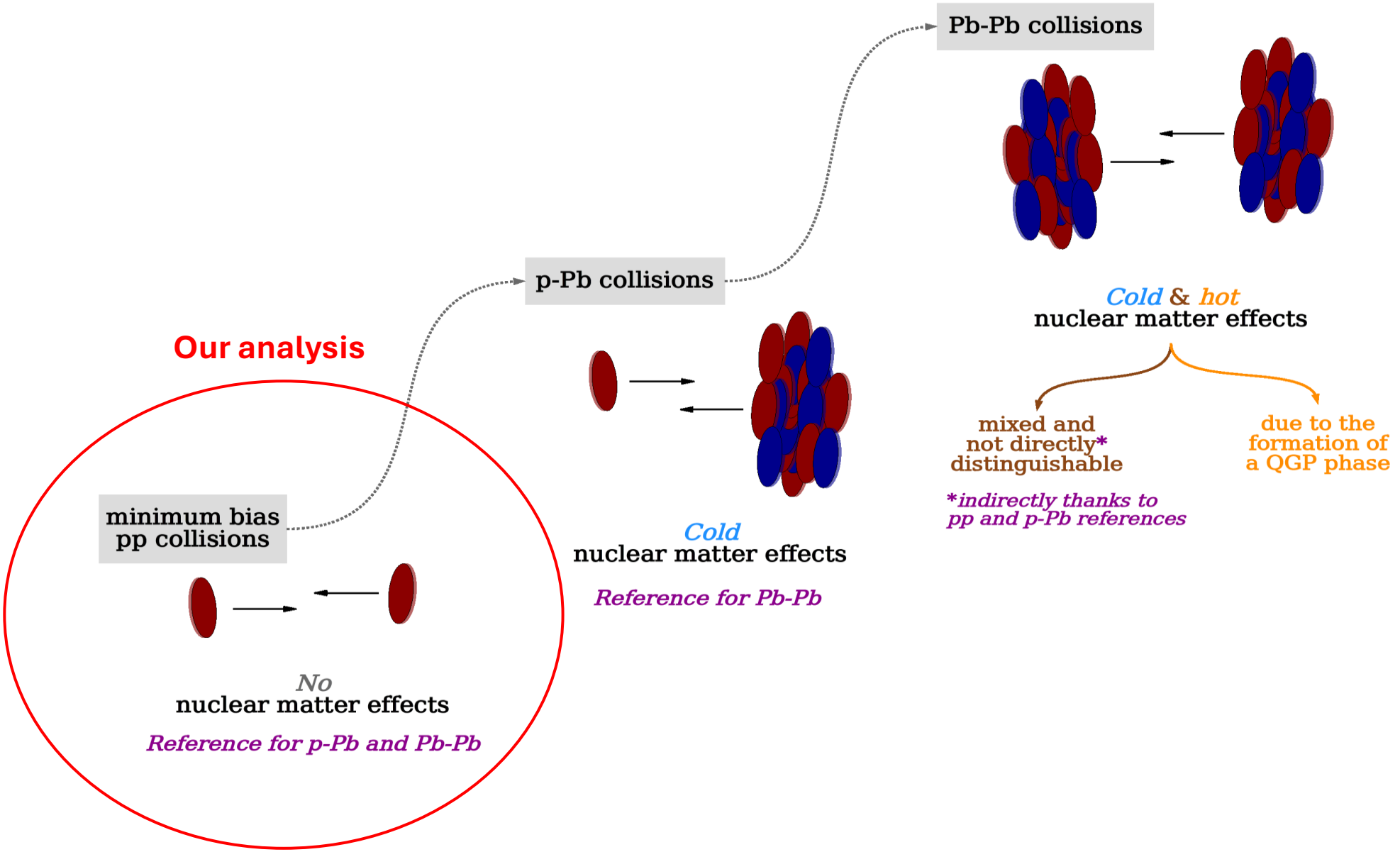


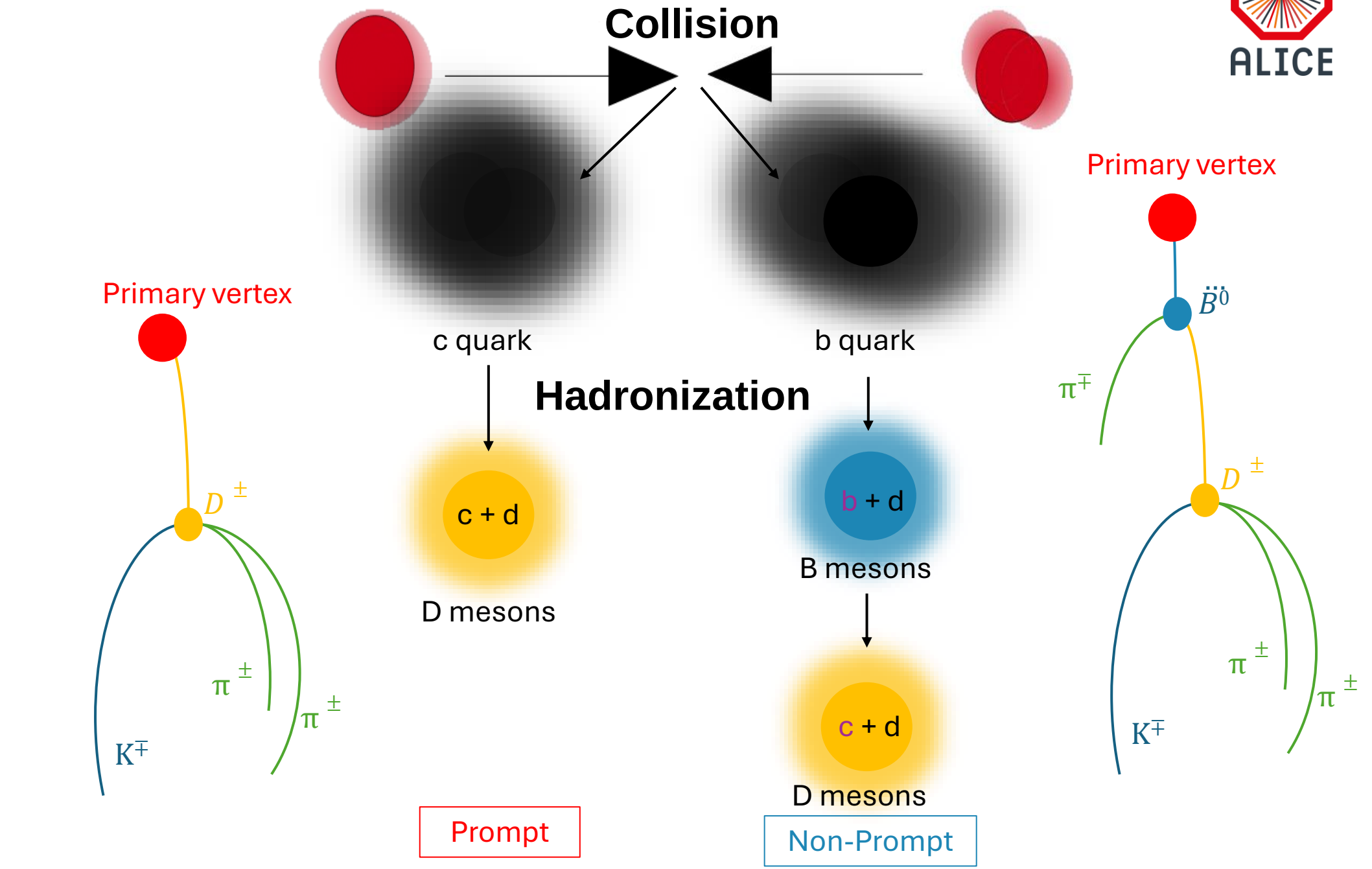
Source : ALICE sketches



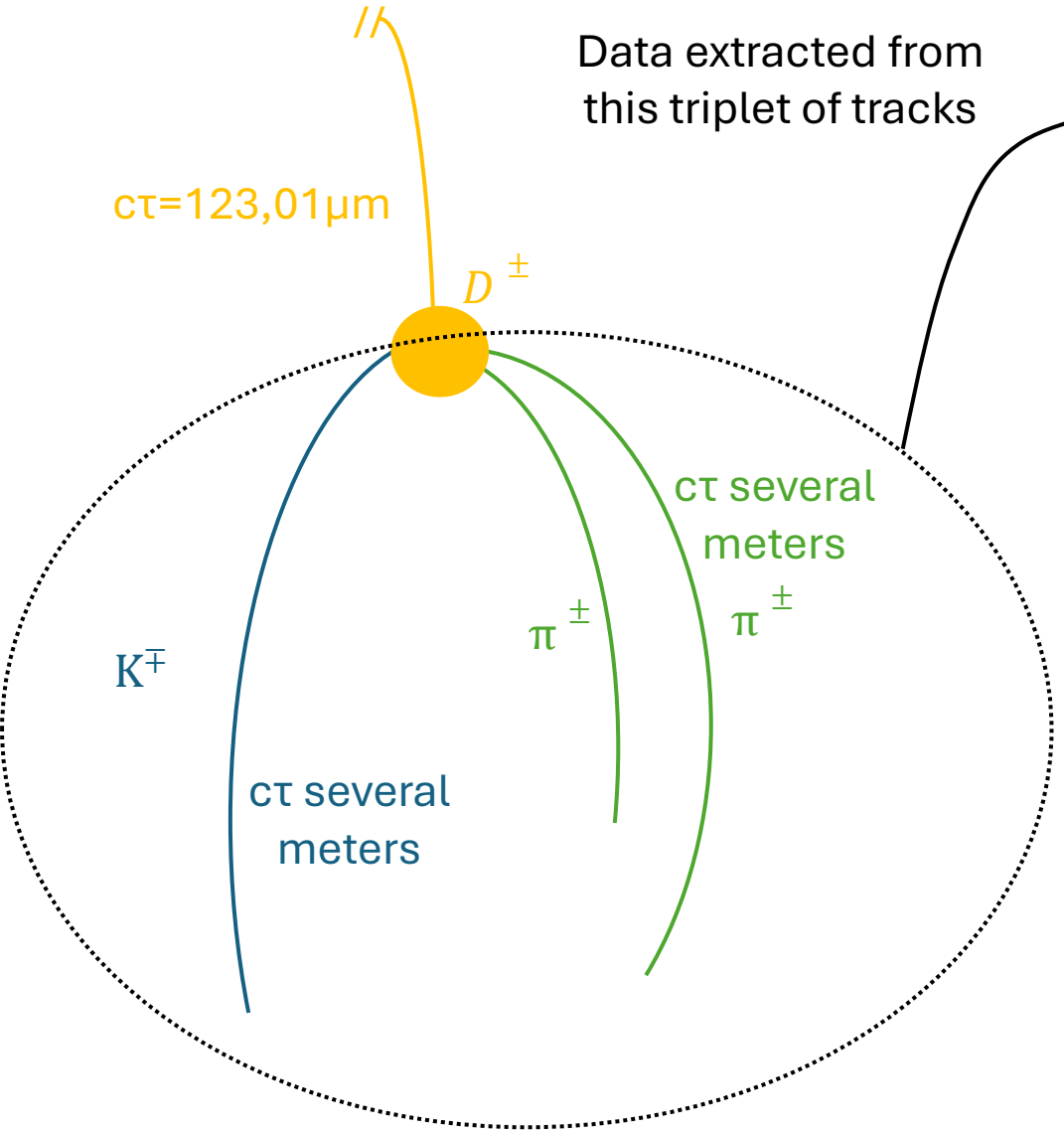
Source : Wikipedia Big Bang

QGP study


Pb-Pb collisions
p-Pb collisions
Our analysis
minimum bias
pp collisions
No
nuclear matter effects
Reference for p-Pb and Pb-Pb
Cold
nuclear matter effects
Reference for Pb-Pb
Cold & hot
nuclear matter effects
mixed and
not directly*
distinguishable
due to the
formation of
a QGP phase
*indirectly thanks to
pp and p-Pb references


Collision
c quark
b quark
Hadronization
Primary vertex
$D^{\pm}$
$\pi^{\pm}$
$\pi^{\pm}$
$K^{\mp}$
c + d
D mesons
b + d
B mesons
c + d
D mesons
Primary vertex
$\bar{B}^0$
$\pi^{\mp}$
$D^{\pm}$
$\pi^{\pm}$
$\pi^{\pm}$
$K^{\mp}$
Prompt
Non-Prompt

Analysis strategy



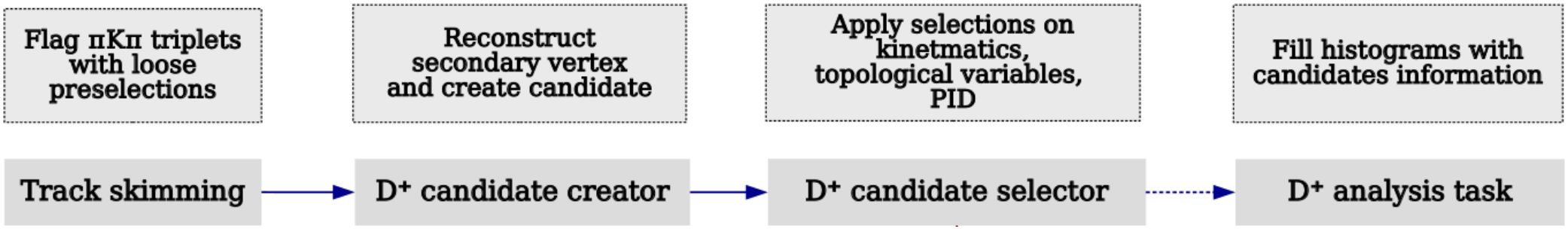
Data extracted from this triplet of tracks

Reconstructed $D^{\pm}$ candidates

Selection made with or without Machine Learning

Selected $D^{\pm}$ candidates

ANALYSIS – WorkFlow



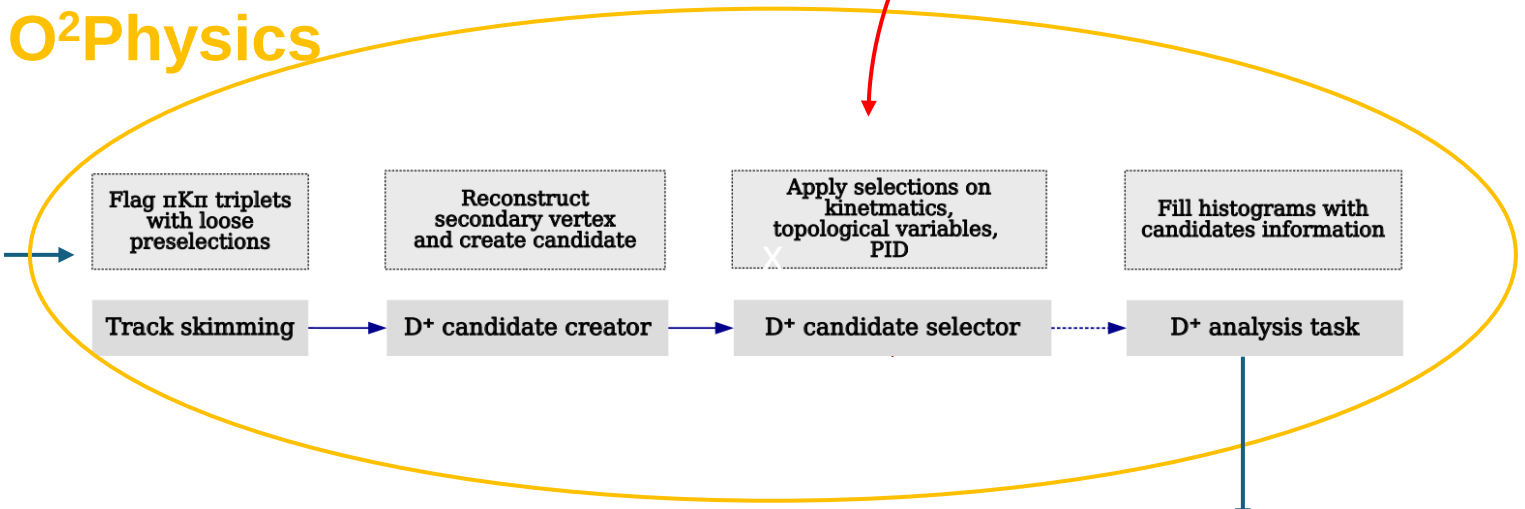
ANALYSIS – WorkFlow

Trained Machine Learning model

O²Physics

Monte Carlo simulation of Data

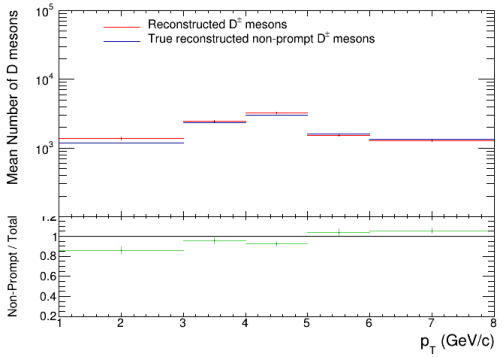
Beauty enriched + forced decay channel

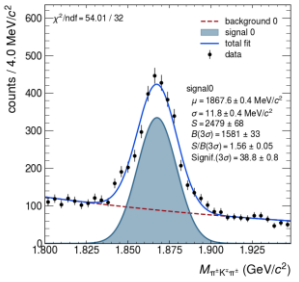


C++ ROOT macro preparation of DATA

Pyroot macro, invariant mass fitting

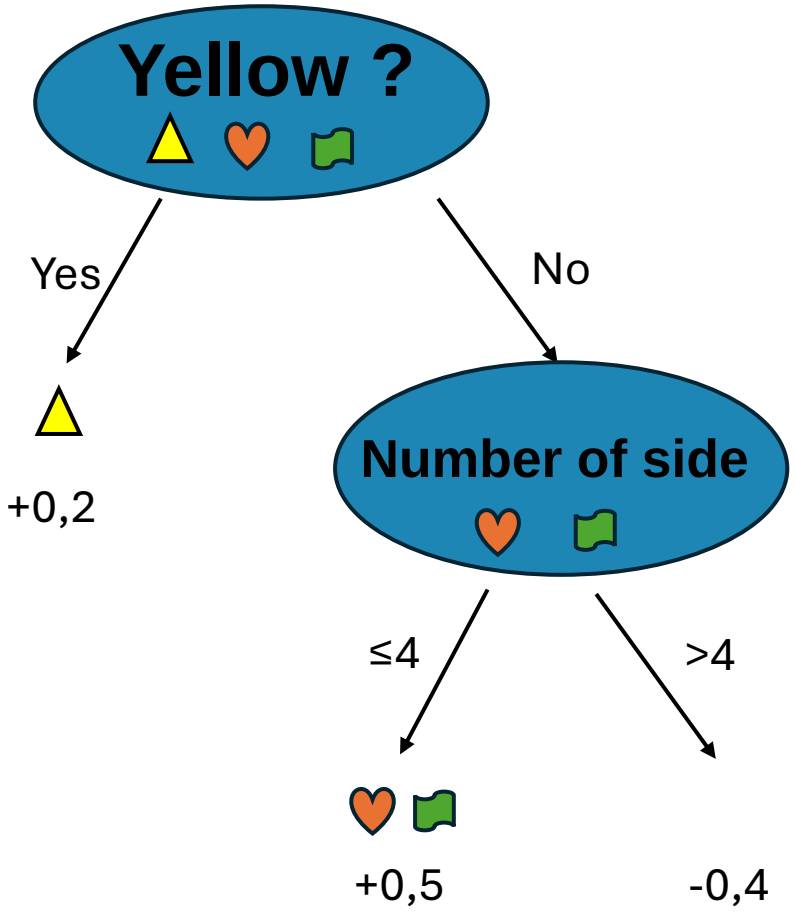
C++ ROOT macro ratio prompt non prompt D±



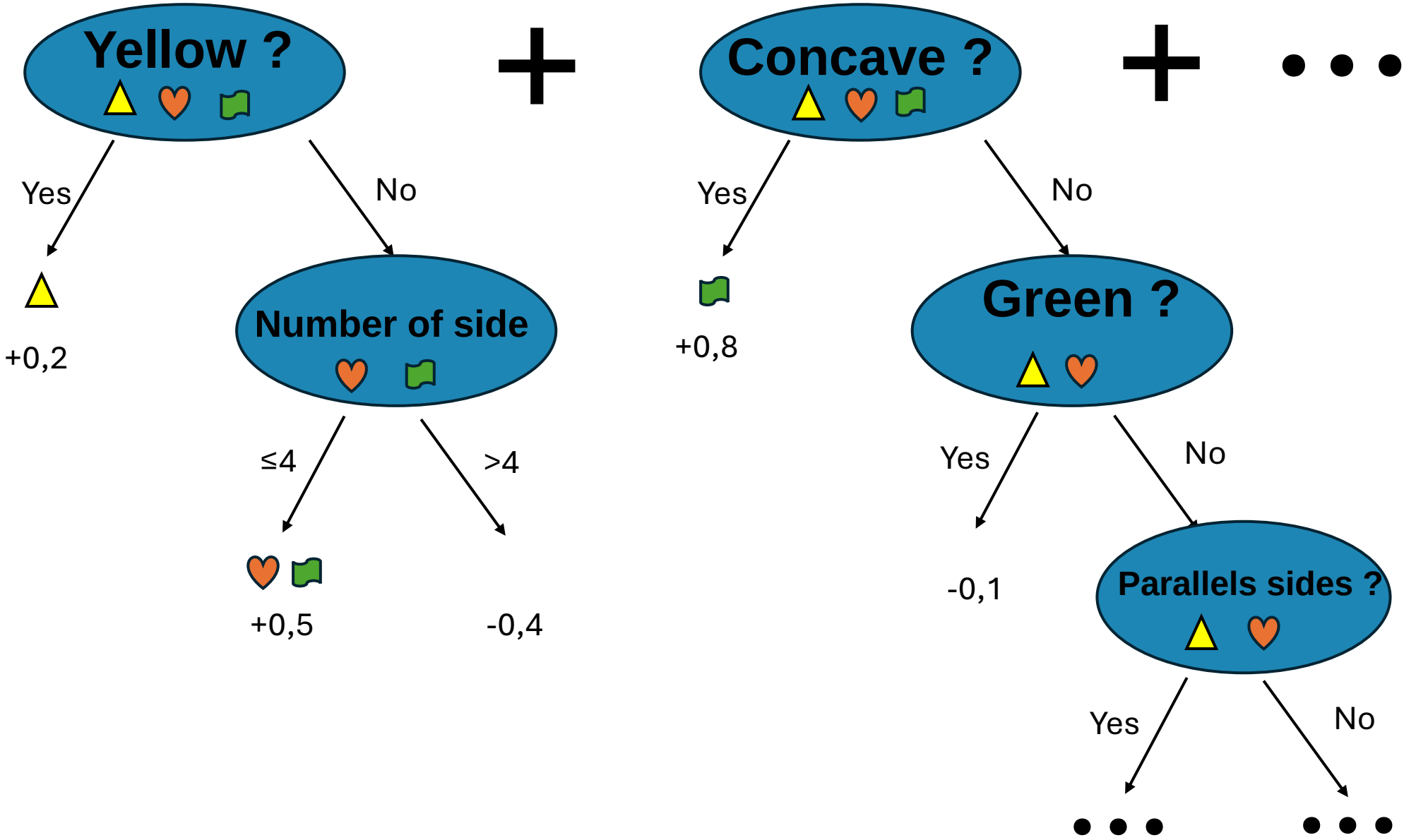


Flarefly library

ANALYSIS – Decision Tree



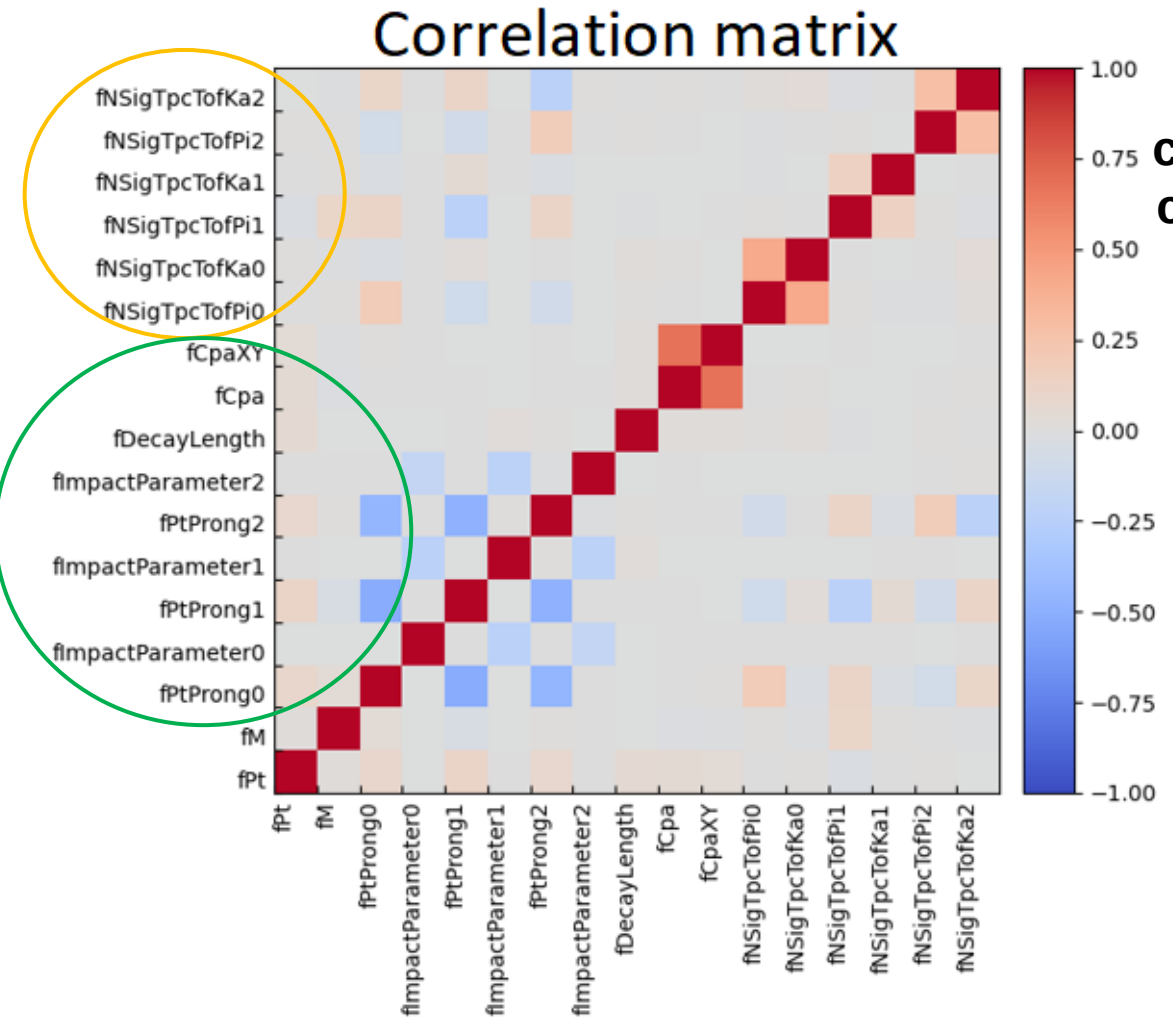
ANALYSIS – Boosted Decision Trees



Analysis – Selection parameters

PID variables

Topological variables

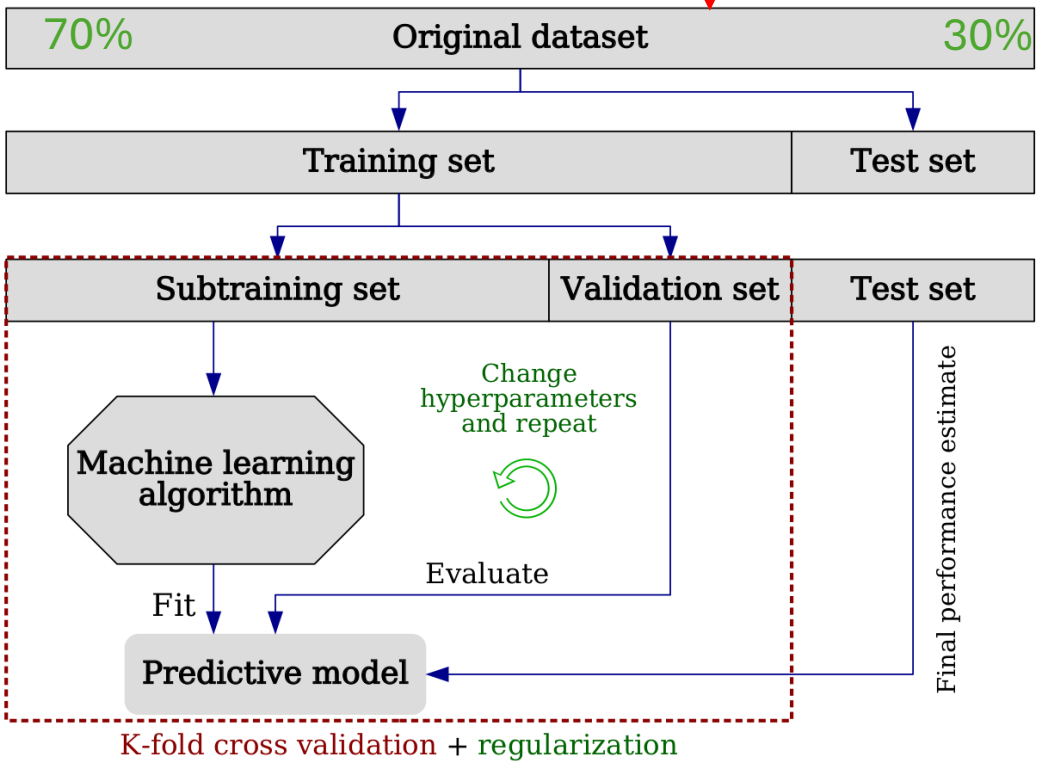


Pearson correlation coefficient

ANALYSIS – Machine Learning

Monte Carlo Data

tagged background, prompt and non-prompt candidates



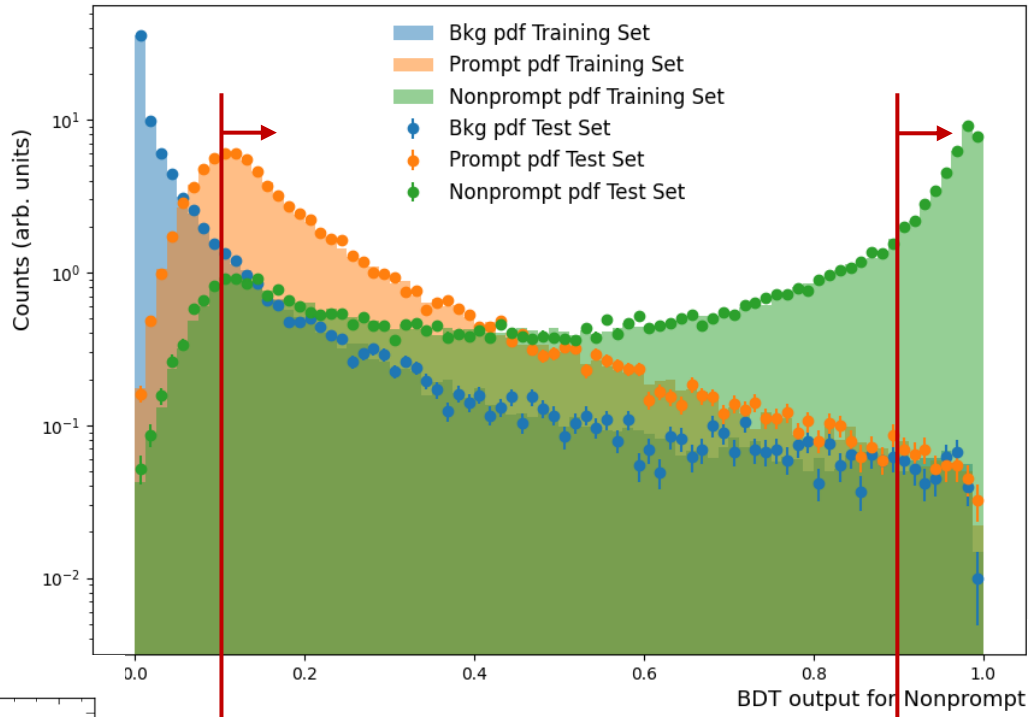
Reconstructed D±

BDT model + threshold

Selected D±

ANALYSIS – BDT based selections

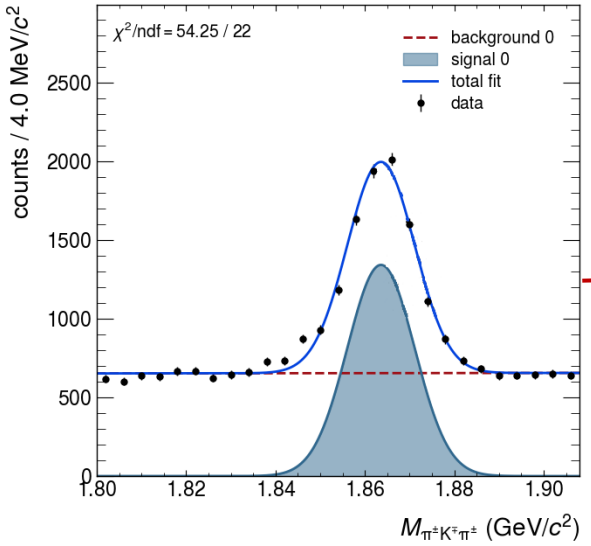
Invariant mass distribution of the selected particles obtained with a BDT threshold of 0,1



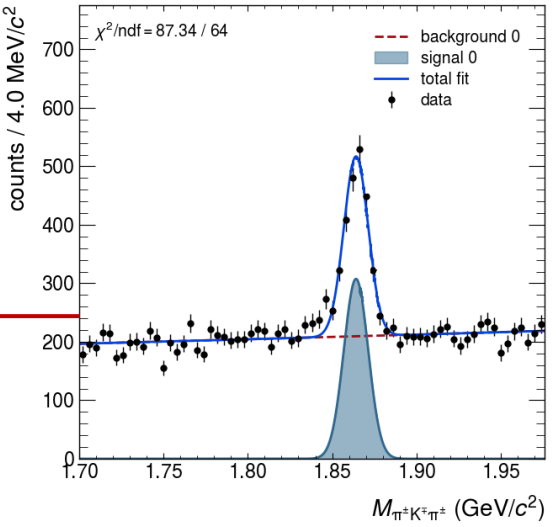
Invariant mass distribution of the selected particles obtained with a BDT threshold of 0,9

Classification = regression + threshold

BDT score > 0,1



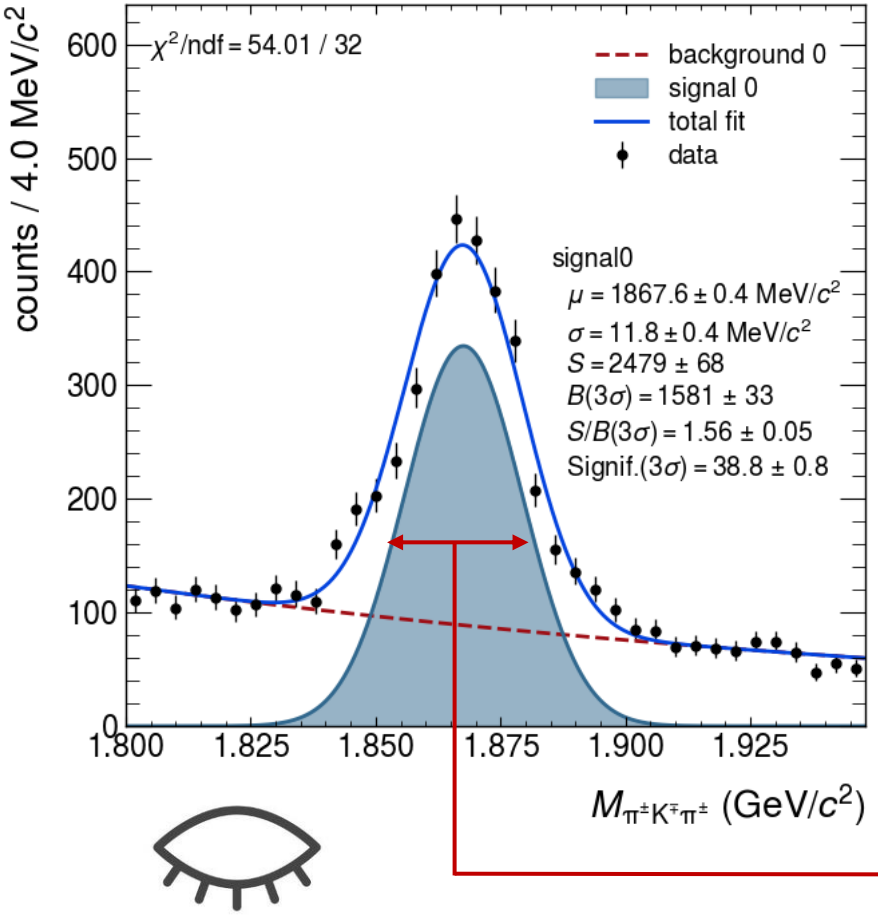
BDT score > 0,9



ANALYSIS – Yield Extraction

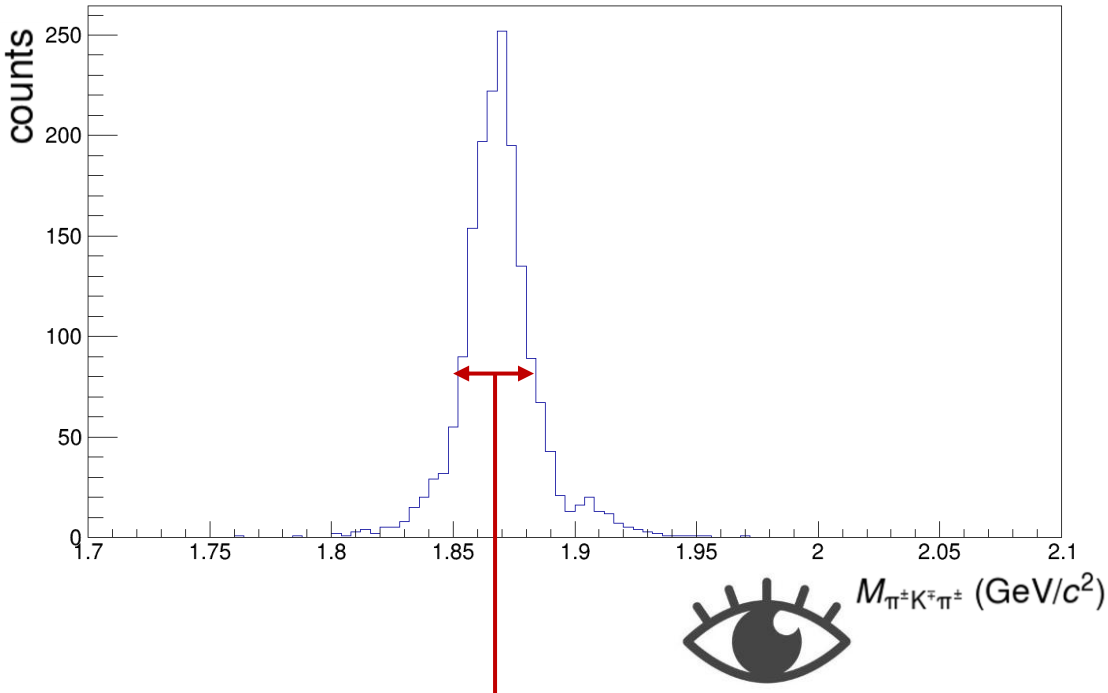
Signal PDF : Gaussian ⟶ **Extracted raw yield = integration of Signal PDF**

Background PDF : negative exponential



Monte Carlo truth not known

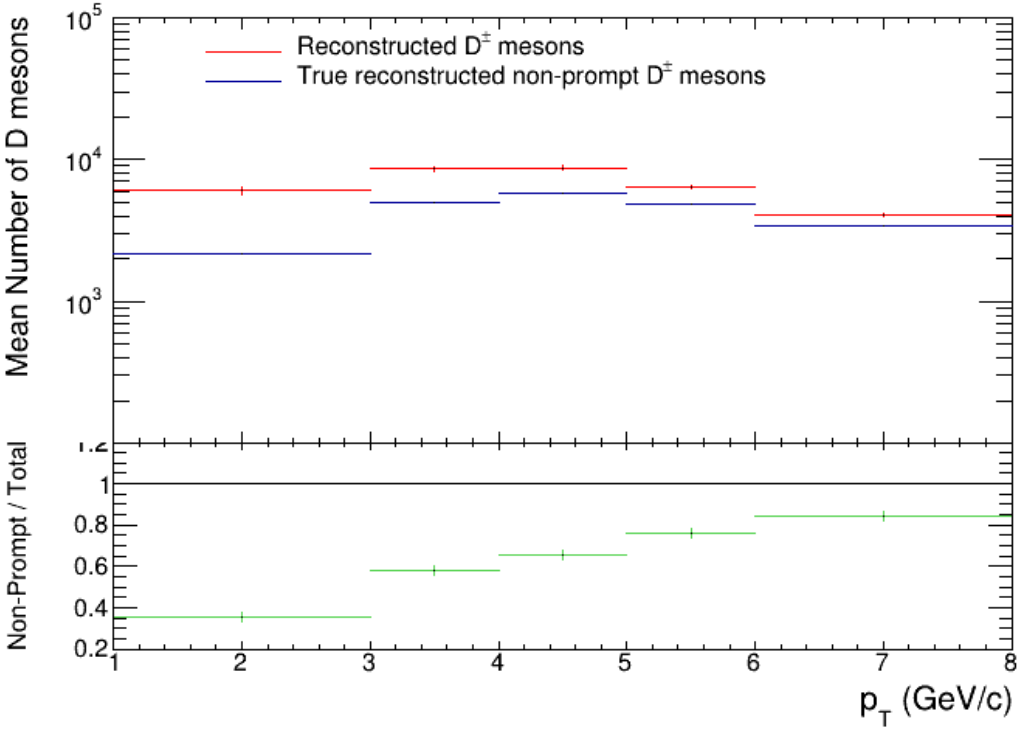
Number of non-prompt D^+ in our reconstructed particles obtained with looking into Monte Carlo truth



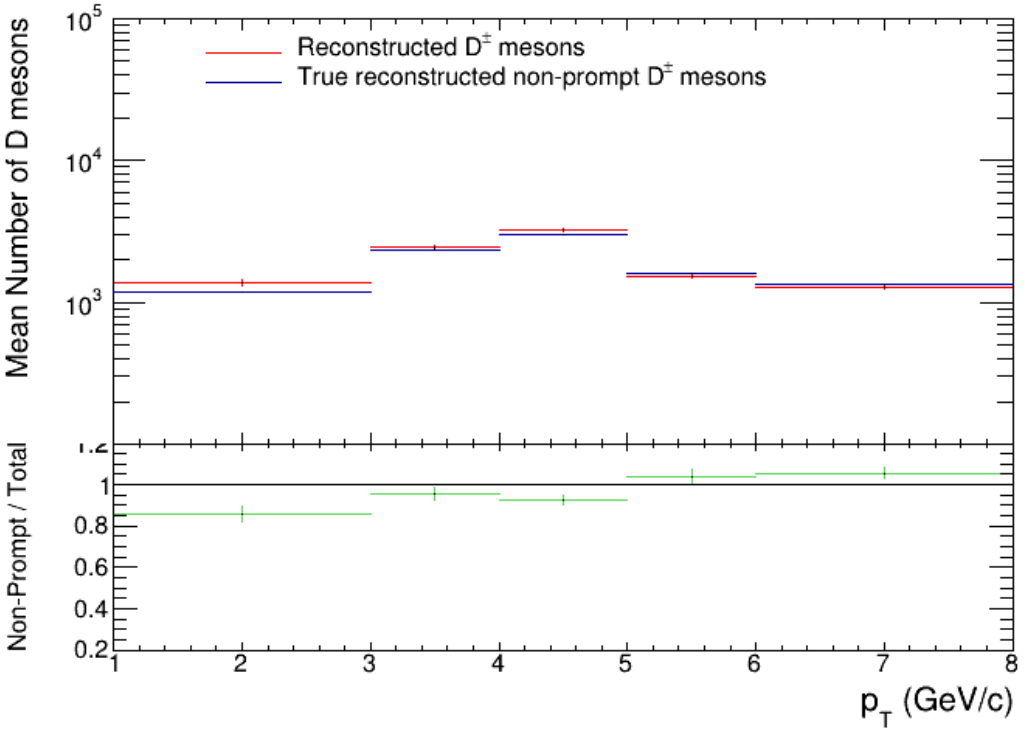
Monte Carlo truth known

MAIN RESULTS

Mean number of reconstructed $D^{\pm}$ in proton-proton collision
and mean number of non-prompt $D^{\pm}$
At the bottom is the non-prompt fraction



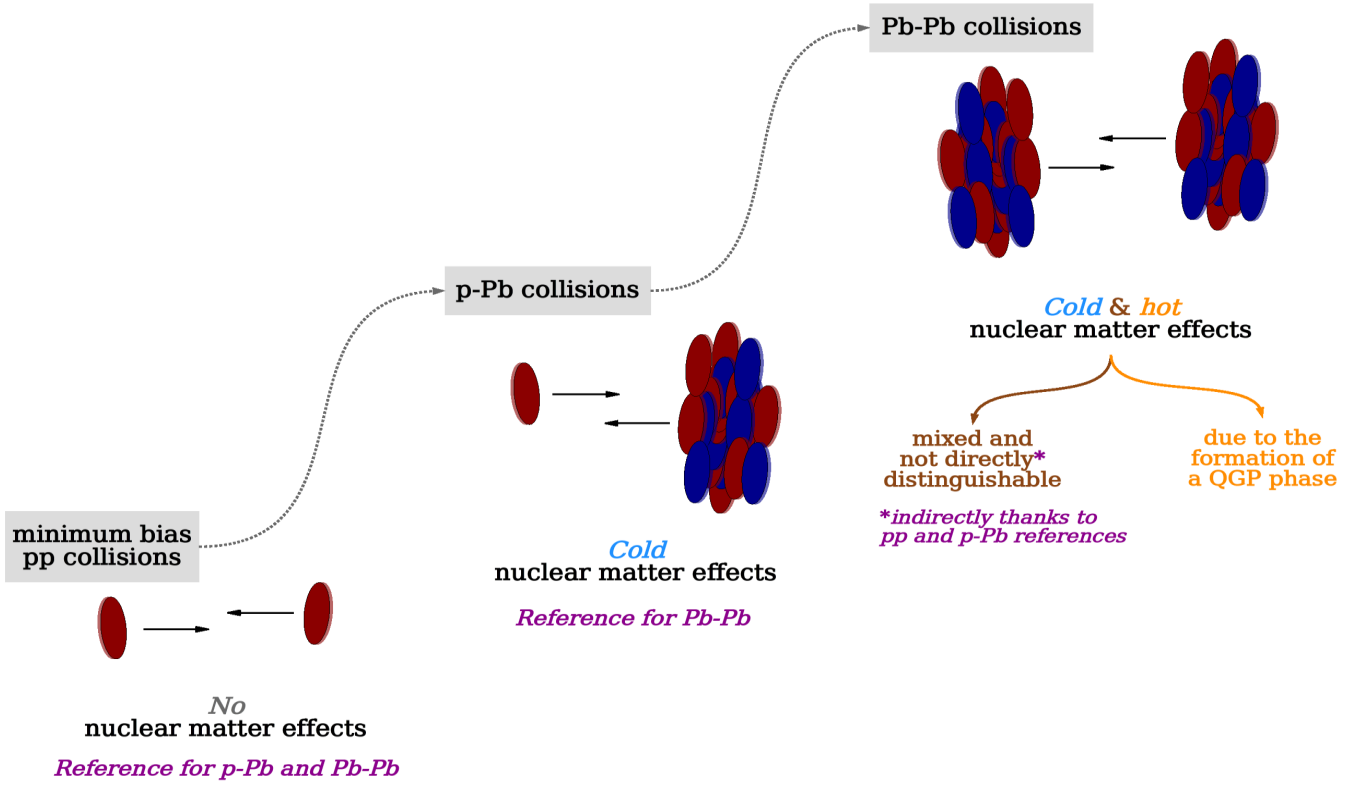
Without Machine Learning



With Machine Learning

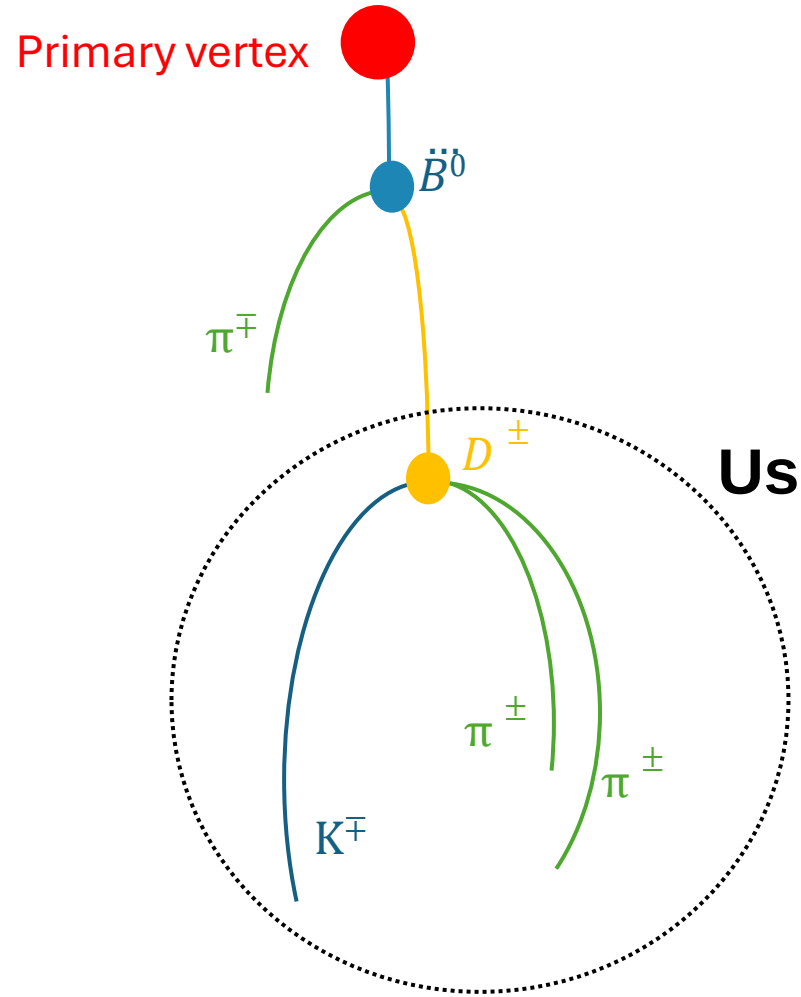
PERSPECTIVES

Perform the reconstruction of non-prompt $D^{\pm}$ in Pb-Pb



PERSPECTIVES

Perform a full topological reconstruction of B^0 meson in both pp and Pb-Pb collisions.



Use of my analysis

PERSPECTIVES

CERN Summer Student program 2024

Data-driven studies of tracking efficiency with charm-hadron tag-and-probe method

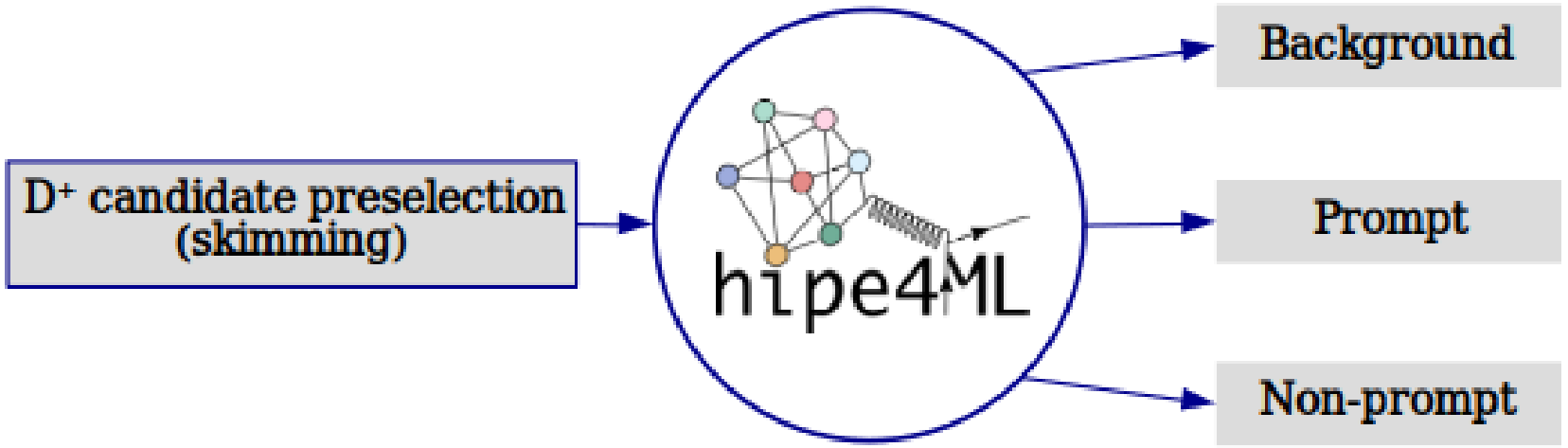
REFERENCES

[1] ALICE Collaboration, *Technical Design Report for the upgrade of the ALICE Inner Tracking System, ITS2*, J. Phys. G41, 087002 (2014). DOI:10.1088/0954-3899/41/8/087002. Section 1 (General description to the ALICE experiment and its physics objectives) Section 8.2.1 (Motivation for Heavy Flavour measurements) Section 8.2.4 (Full kinematics reconstruction $B \to D + \pi$)

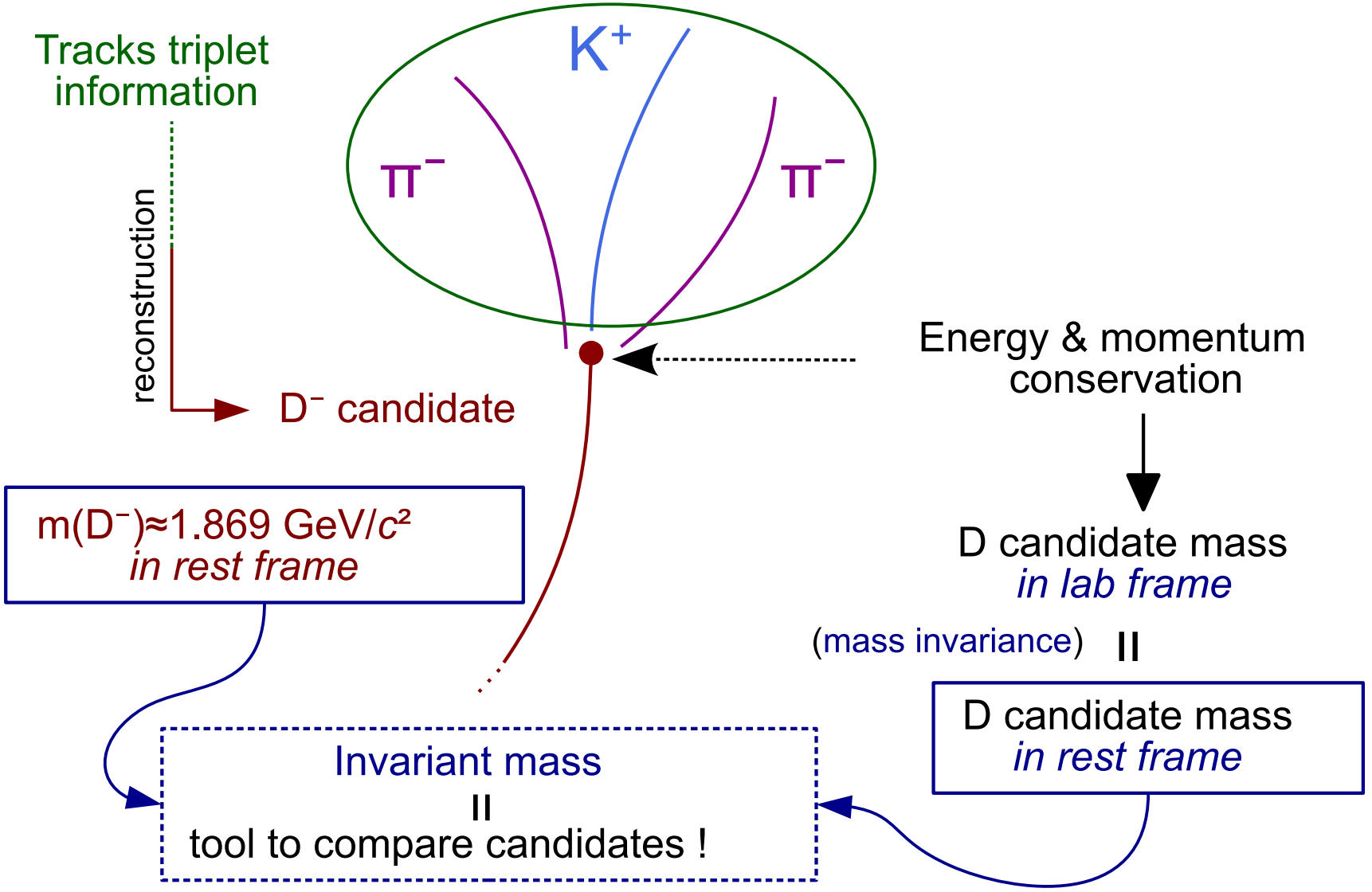
[2] ALICE collaboration, *Measurement of beauty and charm production in pp collisions at* $\sqrt{s} = 5.02$ *TeV via non-prompt and prompt D mesons*. J. High Energ. Phys. 2021, 220 (2021). DOI:10.1007/JHEP05(2021)220.

[3] ALICE collaboration, *Measurement of beauty production via non-prompt* D^0 *mesons in Pb-Pb collisions at* $\sqrt{s_{NN}} = 5.02$ *TeV*. J. High Energ. Phys. 2022, 126 (2022). DOI:10.1007/JHEP12(2022)126.

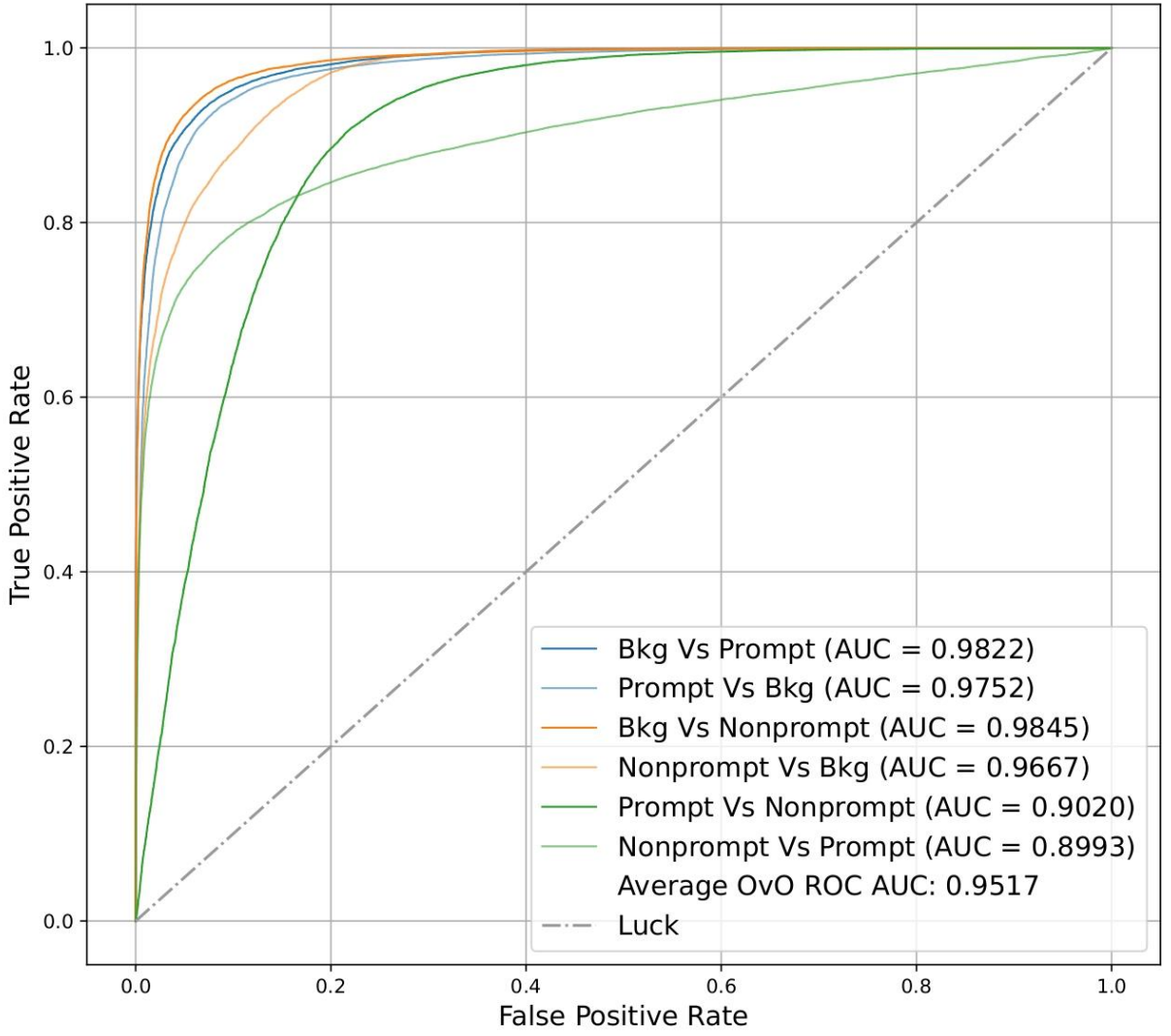
Hipe4ML


D+ candidate preselection
(skimming)
hipe4ML
Background
Prompt
Non-prompt

Invariant mass calculation



ROC curve


True Positive Rate
False Positive Rate
0.0
0.2
0.4
0.6
0.8
1.0
Bkg Vs Prompt (AUC = 0.9822)
Prompt Vs Bkg (AUC = 0.9752)
Bkg Vs Nonprompt (AUC = 0.9845)
Nonprompt Vs Bkg (AUC = 0.9667)
Prompt Vs Nonprompt (AUC = 0.9020)
Nonprompt Vs Prompt (AUC = 0.8993)
Average OvO ROC AUC: 0.9517
Luck