# Commission MVA techniques for non-prompt J/$\psi$ in Pb—Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV

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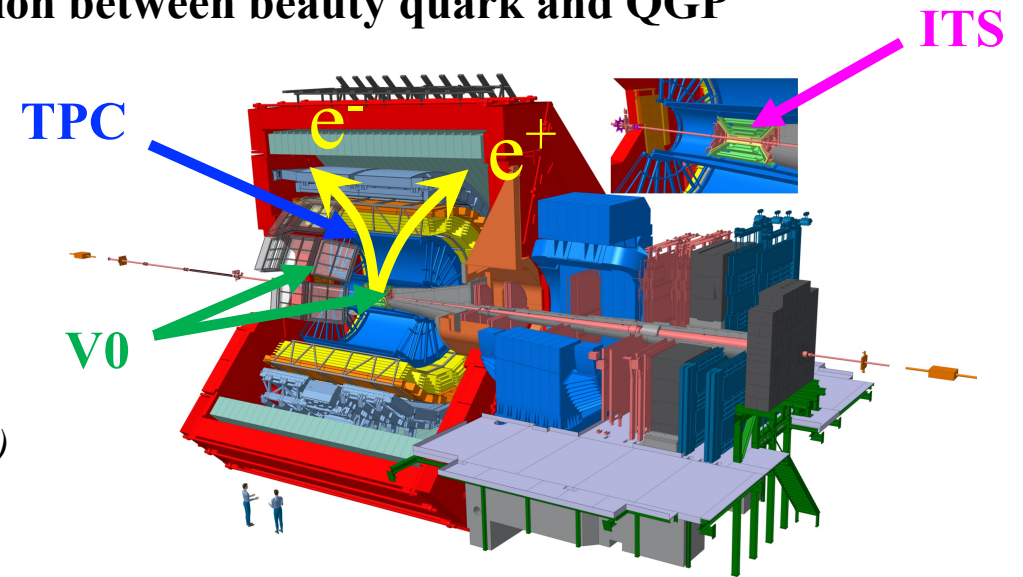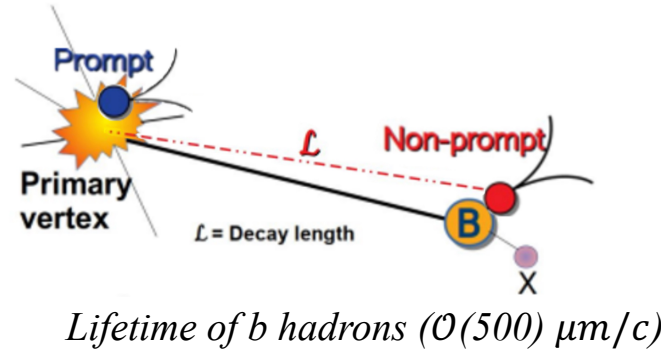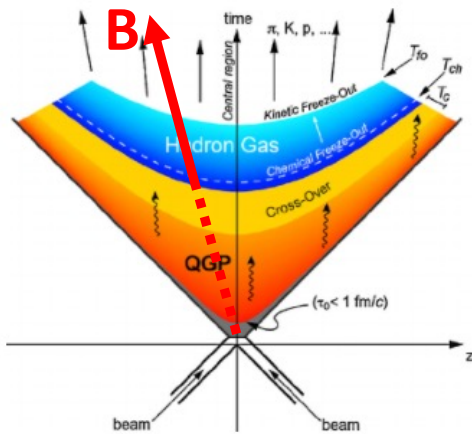
Quark Matter 2022, *Kraków*, *Poland*   08th April

➤ **Early creation:** heavy quarks created in initial hard scatterings experience the entire evolution of the quark-gluon plasma (QGP)

➤ **QGP properties:** non-prompt J/$\psi$ reflects the interaction between beauty quark and QGP



*Lifetime of b hadrons (𝒪(500) μm/c)*

➤ **Different production mechanisms between prompt and non-prompt J/$\psi$**

✓ **J/$\psi \to e^+e^-$ signal extraction in Pb—Pb is challenging due to the large amount of background**

✓ **Multivariate Analysis (MVA) is a promising method to improve the signal significance and S/B**

- ☐ **Time Projection Chamber**
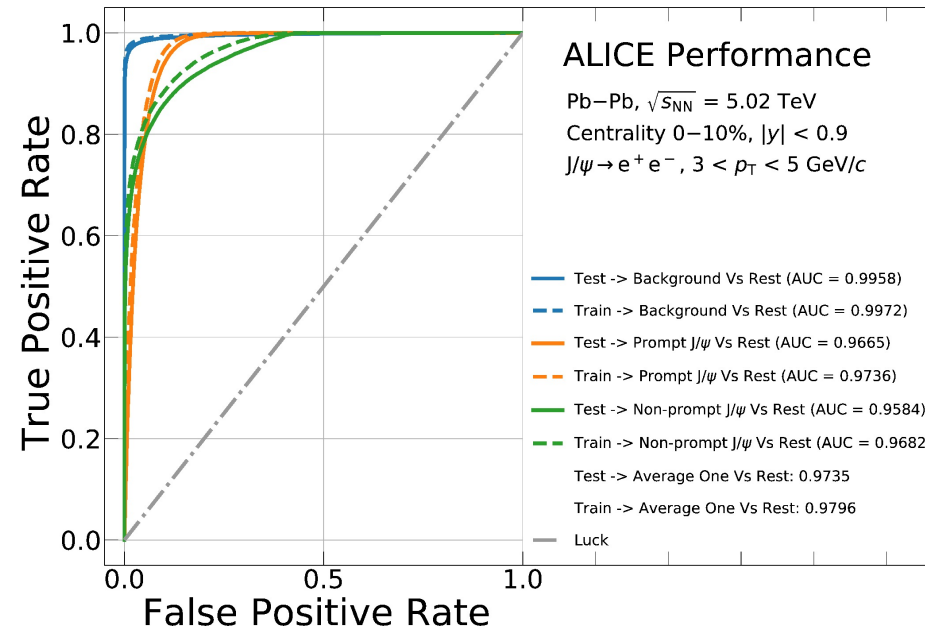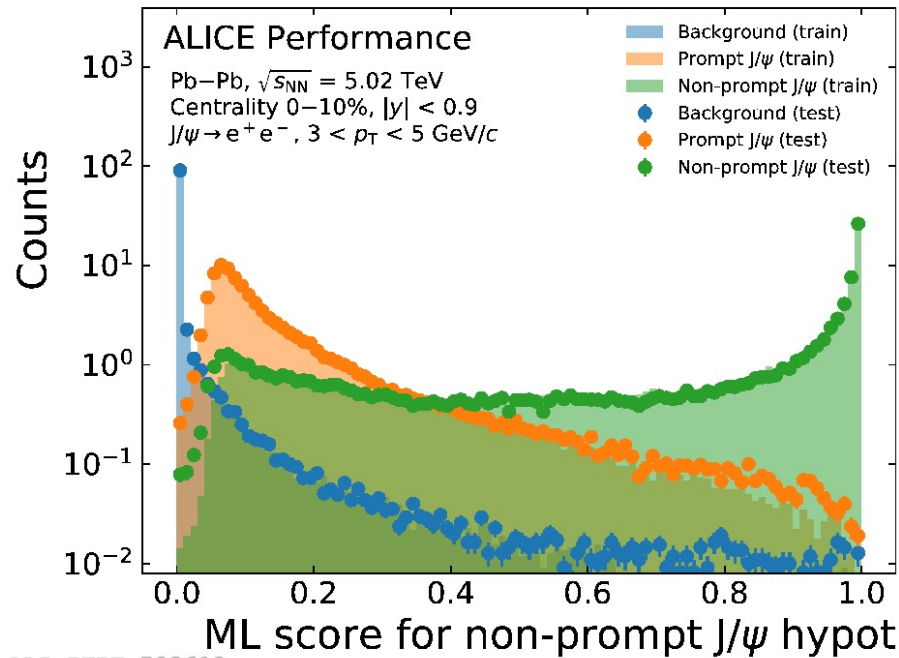  - ✓ Tracking, particle identification
- ☐ **Inner Tracking System**
  - ✓ Tracking, vertex reconstruction
- ☐ **V0 Detector**
  - ✓ Centrality determination
  - ✓ Triggering and event plane determination
  - ✓ Background rejection

ALI-PERF-508619

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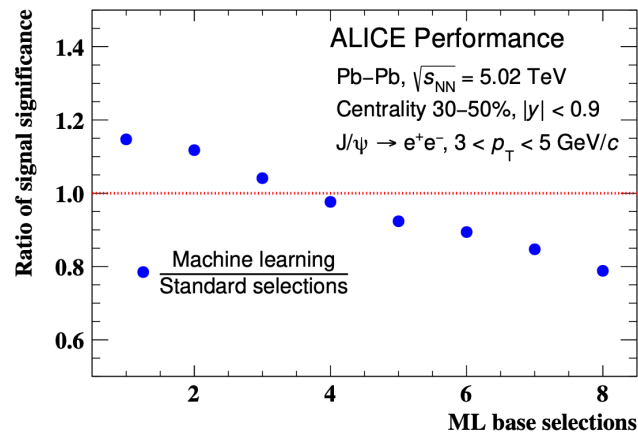- Select real data side bands ($2.0 < m_{e^+e^-} < 2.7$ or $3.2 < m_{e^+e^-} < 4.0$ GeV/$c^2$) of the J/$\psi$ mass window for background; signals are from Monte Carlo simulations with injected prompt and non-prompt J/$\psi$
- Negligible over-training effects and high quality receiver operating characteristic (ROC) curve
- Good discrimination power among background, prompt and non-prompt J/$\psi$
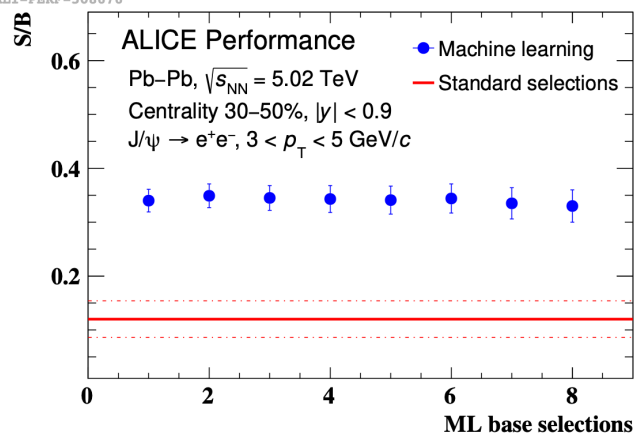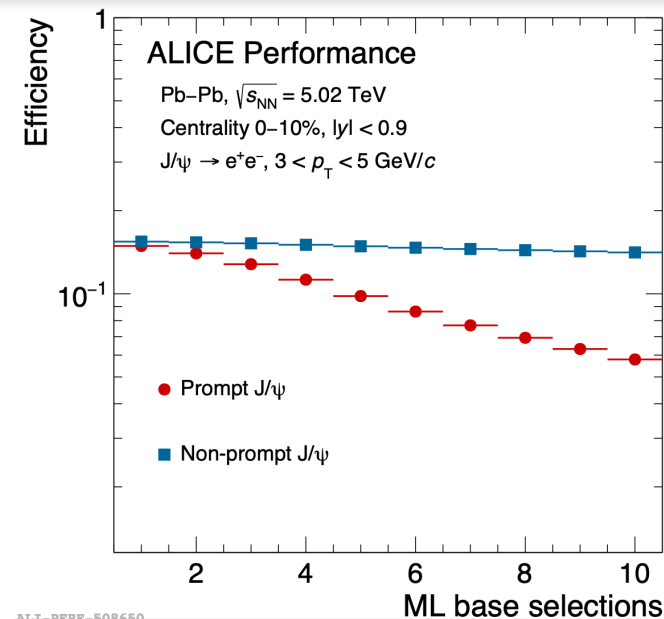
# J/ψ signal extraction



ALICE Performance
Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV
Centrality 30–50%, $|y| < 0.9$
$J/\psi \rightarrow e^+e^-$, $3 < p_T < 5$ GeV/$c$

- Same event
- Fit signal+background
- Fit background

- Data
- Fit signal

$N_{J/\psi}$ = 1309 ± 89
$\chi^2$/ndf = 1.71

$m_{ee}$ (GeV/$c^2$)

ALI–PERF–508644

ALICE Performance
Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV
Centrality 30–50%, $|y| < 0.9$
$J/\psi \rightarrow e^+e^-$, $3 < p_T < 5$ GeV/$c$

$\frac{\text{Machine learning}}{\text{Standard selections}}$

ML base selections

ALI–PERF–508676

ALICE Performance
Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV
Centrality 30–50%, $|y| < 0.9$
$J/\psi \rightarrow e^+e^-$, $3 < p_T < 5$ GeV/$c$

- Machine learning
- Standard selections

ML base selections

ALI–PERF–508681

ALICE Performance
Pb–Pb, $\sqrt{s_{NN}}$ = 5.02 TeV
Centrality 0–10%, $|y| < 0.9$
$J/\psi \rightarrow e^+e^-$, $3 < p_T < 5$ GeV/$c$

- Prompt J/ψ
- Non-prompt J/ψ

ML base selections

ALI–PERF–508650

- J/ψ raw yields are extracted via ML based selections
- Both significance and S/B are improved w.r.t standard selections in semi-central Pb—Pb collisions (30-50%)

$$\begin{pmatrix} \varepsilon_1^p & \varepsilon_1^{np} \\ \vdots & \vdots \\ \varepsilon_n^p & \varepsilon_n^{np} \end{pmatrix} \times \begin{pmatrix} N_p \\ N_{np} \end{pmatrix} - \begin{pmatrix} Y_1 \\ \vdots \\ Y_n \end{pmatrix} = \begin{pmatrix} \delta_2 \\ \vdots \\ \delta_n \end{pmatrix} \cdot$$

$\Rightarrow$

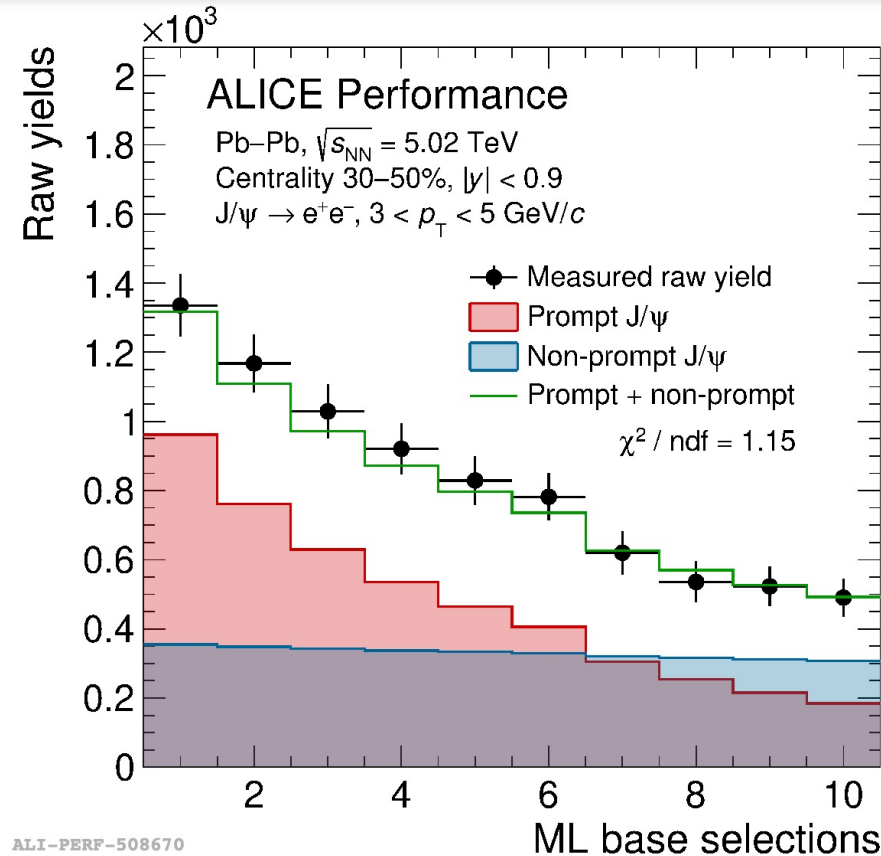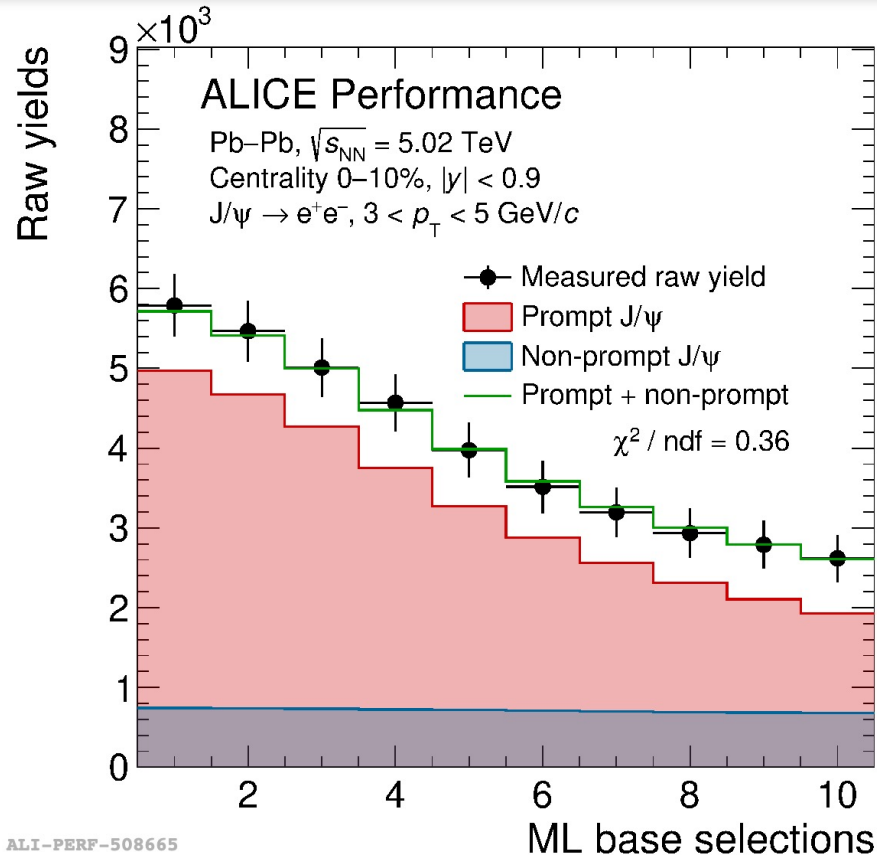$$\chi^2 = \boldsymbol{\delta}^T C^{-1} \boldsymbol{\delta}$$

Minimum $\chi^2$ $\Rightarrow$

$$N = Cov(N)\boldsymbol{\varepsilon}^T C^{-1} Y$$
$$Cov(N) = (\boldsymbol{\varepsilon}^T C^{-1} \boldsymbol{\varepsilon})^{-1}$$

4

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- ✓ **Performance of the MVA method is validated in central and semi-central Pb—Pb collisions at 5.02 TeV**
- ✓ **Both significance and S/B are improved w.r.t the standard selection method**
- ✓ **Non-prompt J/$\psi$ fraction will be extracted via this method, an improved precision can be expected**

# Backup

ML based selections (Centrality 30-50%, $3 < p_T < 5$ GeV/$c$):

| Number | BDT_background < | BDT_nonprompt > |
|---|---|---|
| 1 | 0.1 | 0.04 |
| 2 | 0.1 | 0.055 |
| 3 | 0.1 | 0.065 |
| 4 | 0.1 | 0.075 |
| 5 | 0.1 | 0.085 |
| 6 | 0.1 | 0.095 |
| 7 | 0.1 | 0.12 |
| 8 | 0.1 | 0.14 |
| 9 | 0.1 | 0.16 |
| 10 | 0.1 | 0.18 |