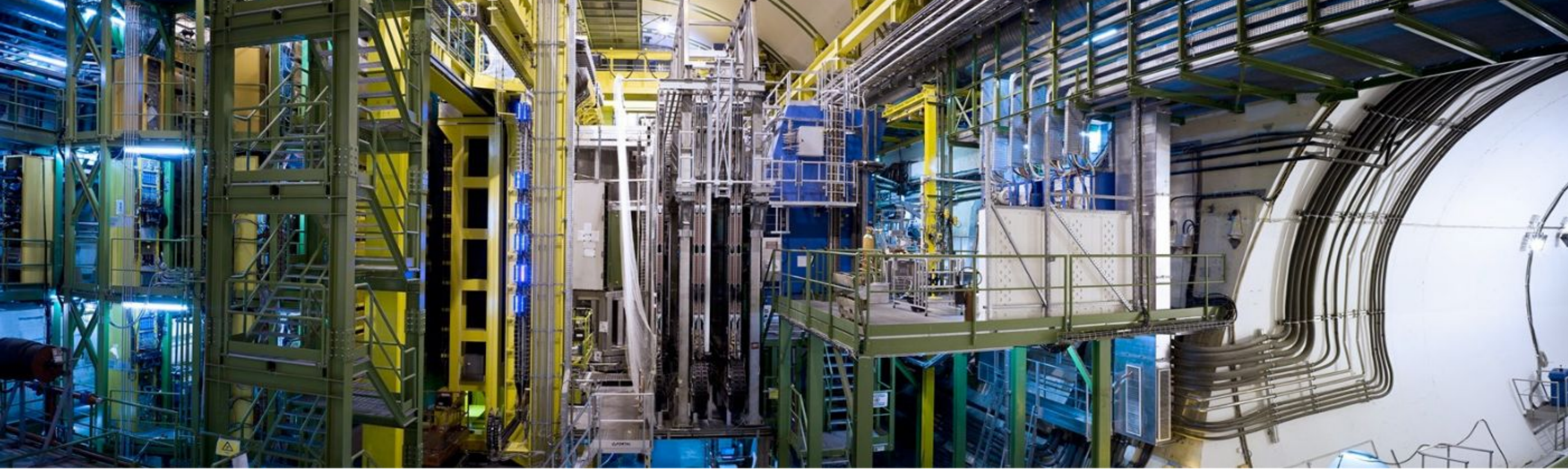

SMARTHEP Annual Meeting

University of Lund, 27/11/2023 - 01/12/2023

ESR8 Micol Olocco, Prof. Johannes Albrecht

SMARTHEP is funded by the European Union's Horizon 2020 research and innovation programme, called H2020-MSCA-ITN-2020, under Grant Agreement n. 966086

SMARTHEP Annual Meeting

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1. Brief introduction
2. Project presentation:
   a. Flavour Tagging in Run 3 at LHCb
   b. Automation of the TCK production
3. Conclusions

Introduction


technische universität dortmund

Who: Micol Olocco (ESR8), Prof. Johannes Albrecht

Where: TU Dortmund (Germany) - CERN

What: Real Time Analysis for global event triggering in LHCb

Particle Physics

“Sudy of the (anti-)deuteron production in pp collisions at 5 TeV” with ALICE (CERN)

Anomaly Detection

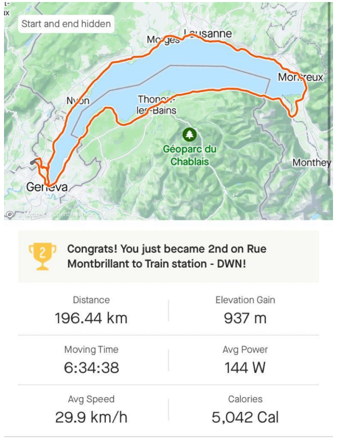
Anomaly Detection in large-radius jets, ATLAS

Natural Laguage Processing

“Natural Language Processing techniques for error message analysis in WLCG data transfer” with Operational Intelligence (CERN)

Consulting

Data Analyst in Accenture



Outreach

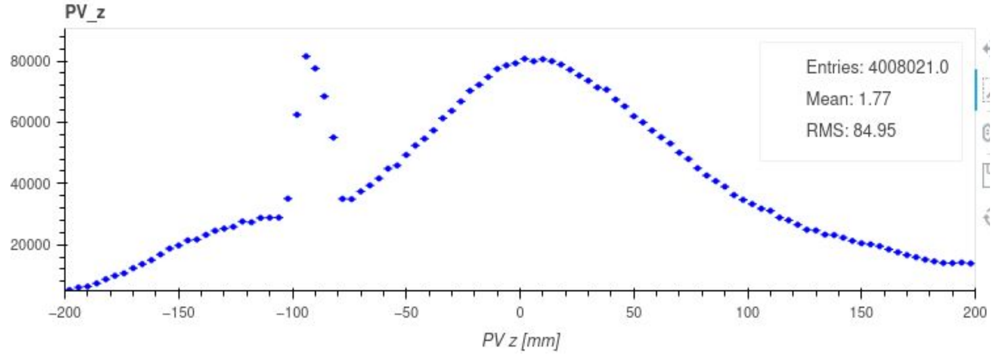
- Volunteer at the inaguration of the CERN Science Gateaway
- Planning talk in High School in Italy about High Energy Physics (and/or ML)
- Training for becoming an LHCb underground guide

Trainings & Talks

- Data Manager shifts
- Trigger expert shift
- Presentation at the 106th LHCb week
- **LHCb starterkit**, 28/11/2022 - 02/12/2022, CERN
- **3rd Terascale school of Machine Learning**
- DPG SMuk 2023 (Dresden)
- SMARTHEP school on Hadron Collider and Machine Leraning

Trigger commissioning

- Was trigger expert (online 24h/24h, 7d/7d) for the High-Level Trigger for a week
- Great opportunity for seeing our detector at work and all the team work behind
- If you love problem solving, it's for you!



"The problem is that there are always problems"

cit. Trigger Software Mainter

Project

Real Time Analysis for global event triggering in LHCb

Particle Physics and Machine Learning → Flavour Tagging in Run 3 at LHCb

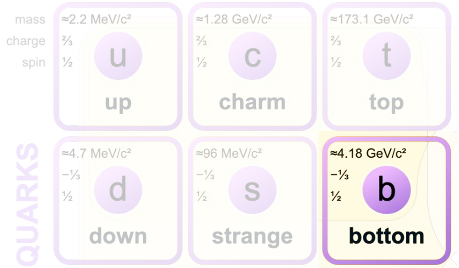
Trigger → Automation of the trigger sequence production

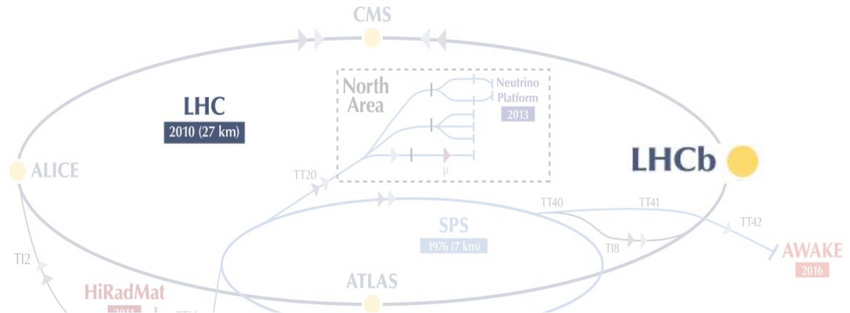
Flavour Tagging in Run 3 at LHCb

→ B mixing

The LHCb experiment

= LHC + b





A large physics program
(not limited to!) *b* physics

Neutral B mesons

- B^0 $(d\bar{b})$, B_s^0 $(s\bar{b})$
- Interesting systems for measuring:
  - frequency of neutral B oscillation (mixing) Δm_d , Δm_s
  - signals of CP (charge-parity) violation

  $\rightarrow$ Standard Model predictions:

    $\rightarrow$ way for testing the Standard Model

B mixing

B^0 **can oscillate in an** $\overline{B^0}$ (and viceversa)

How do we get the oscillation frequency?

→ **by measuring the time dependent oscillation asymmetry** $\mathcal{A}^{\text{signal}}_{\text{mix}}(t)$

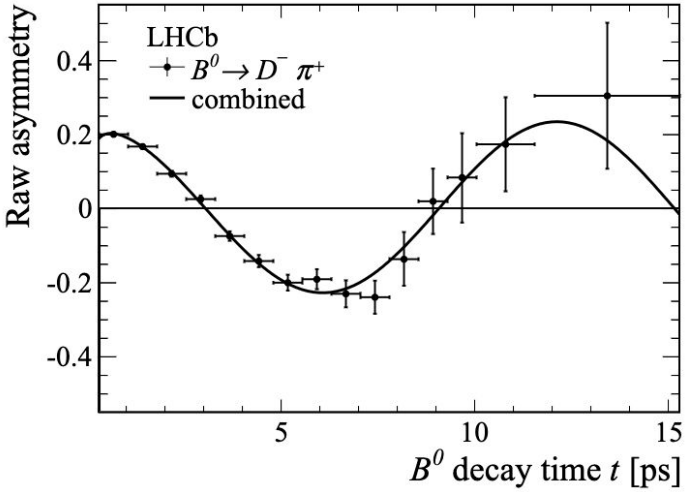


Fig: Raw mixing asymmetry A_{mix} (black points) for B0 → D−π+ [CERN-PH-EP-2012-315]

$$\mathcal{A}^{\text{signal}}_{\text{mix}}(t) = \frac{N_{\text{unmixed}}(t) - N_{\text{mixed}}(t)}{N_{\text{unmixed}}(t) + N_{\text{mixed}}(t)} = \cos(\Delta m_d t)$$

$N\,(B^0 \to \textit{final state})$

$N(B^0 \to \overline{B}^0 \to \textit{final state})$

t = B^0 decay time

B mixing

In order to tag a B^0 or B_s^0 candidate as mixed or unmixed →necessary to determine its flavor:

- initial state: production time
- final state: decay time

If $\mathrm{B(flavour)}_{\mathrm{final}} \neq \mathrm{B(flavour)}_{\mathrm{initial}}$ → **there was an oscillation!**

If $B(\text{flavour})_{\text{final}} \neq B(\text{flavour})_{\text{initial}} \rightarrow$ **there was an oscillation!**

How do we access the flavour at the decay time?

If $B(\text{flavour})_{\text{final}} \neq B(\text{flavour})_{\text{initial}}$ → **there was an oscillation!**

How do we access the flavour at the decay time?

Through the decay products!

ex. $$B_s^0 \rightarrow D_s^- \pi^+$$ [PDG]

If $B(\text{flavour})_{\text{final}} \neq B(\text{flavour})_{\text{initial}} \rightarrow$ **there was an oscillation!**

How do we access the flavour at the production time?

If $B(\text{flavour})_{\text{final}} \neq B(\text{flavour})_{\text{initial}} \rightarrow$ **there was an oscillation!**

How do we access the flavour at the production time?

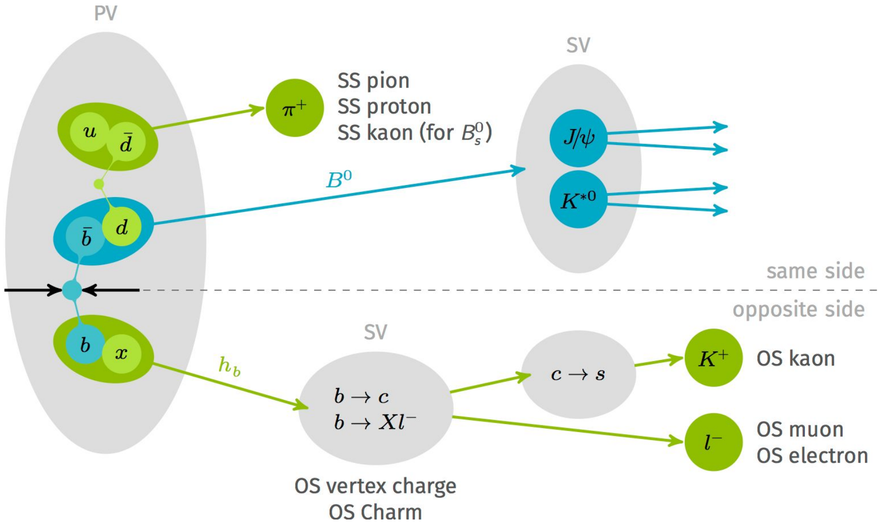
Flavour Tagging Algorithms!

Flavour Tagging

Flavour Tagging algorithms access the B meson flavour at production time by exploiting the **correlation between the B flavour and the charge of the tagging particle.**

Two tagger categories:

- Same-Side
- Opposite-Side



Flavour Tagging

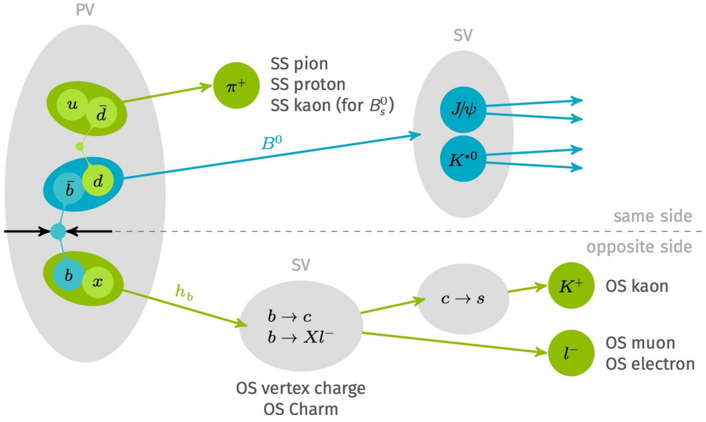
def Flavour Tagging algorithms exploit the **correlation between the B flavour and the charge** of the tagging particle to access the B meson flavour at production time

Q_{tag} = charge of the tagging particle, d = tagging decision:

- SS taggers: $d = Q_{tag}$
- OS taggers: $d = (-1) \times Q_{tag}$

The convention is that:

- $d = +1 \rightarrow \bar{b}$
- $d = -1 \rightarrow b$



Flavour Tagging: where is Machine Learning?

If Q_{tag} is the charge of the tagging particle:

- SS taggers: $d = Q_{tag}$
- OS taggers: $d = (-1) \times Q_{tag}$

Theory is simple, practice is not!

In practice, a particle can be misidentified, associated to the wrong decay etc. → together with the tagging decision it's necessary to estimate a **mistag rate** (the probability of a wrong tagging decision).

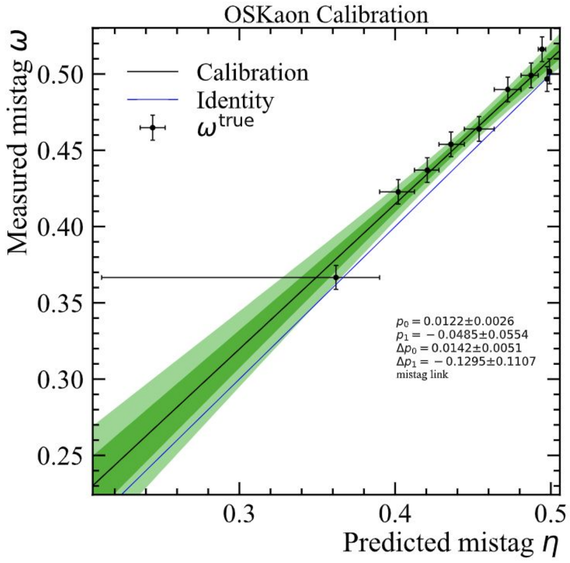
$$\text{Classifier trained on} \begin{cases} \text{label } 0 \rightarrow \text{wrong tagging decision} \\ \text{label } 1 \rightarrow \text{correct tagging decision} \end{cases}$$

The probability of getting label 0 can then be interpreted as the mistag!

Flavour tagging: my tasks

In collaboration with the Universität Heidelberg

- Train&calibrate OS/SS taggers on simulated data with 2023 data-taking conditions → provide early measurement of Δm_d with 2023 data
- Train&calibrate OS/SS taggers for 2024 data-taking + port them in the LHCb software



Work in progress! Small sample, for testing purpose. OSKaon trained on Bu2JspiK+

Automation of the TCK production

The trigger configuration key (TCK)

- The TCK is an unique identifier for a certain trigger configuration (ex. 0x10000001)
- The TCK is persisted as a tag in a git repository and contains information about a certain trigger configuration

```
TCK: 0x10000001
workflow: "new"
parameters:
    application: "Hlt1"
    type: "hlt1_pp_default"
    label: "Prescaled lines"
    stack: "RTA/2023.08.04"
    settings: "hlt1_pp_forward_then_matching_no_ut_no_gec"
```

The trigger configuration key (TCK)

- The processes to be automated:
  - checks on: correct stack, interested application, type and settings
  - TCK publication on GitLab

```yaml
TCK: 0x10000001
workflow: "new"
parameters:
    application: "Hlt1"
    type: "hlt1_pp_default"
    label: "Prescaled lines"
    stack: "RTA/2023.08.04"
    settings: "hlt1_pp_forward_then_
```

- Currently manually done by the HLT piquet:
  - prone to error
  - requiring unnecessary time
- Our task (with **PhD Luke Grazette**):

Develop a CI test running those checks

Conclusions

- 1st PhD year:
  - collaboration work (shift, trigger commissioning)
  - ML/Phsyics → set up Flavour Tagging project
  - operational work → automation of the TCK production
- 2nd PhD year:
  - Intense year ahead
    - B0 mixing frequency measurement → prepare taggers
    - Tain and port taggers into LHCb software for 2024 data taking

Me crushing my head on B mixing papers… a spectrum of emotions

B mixing

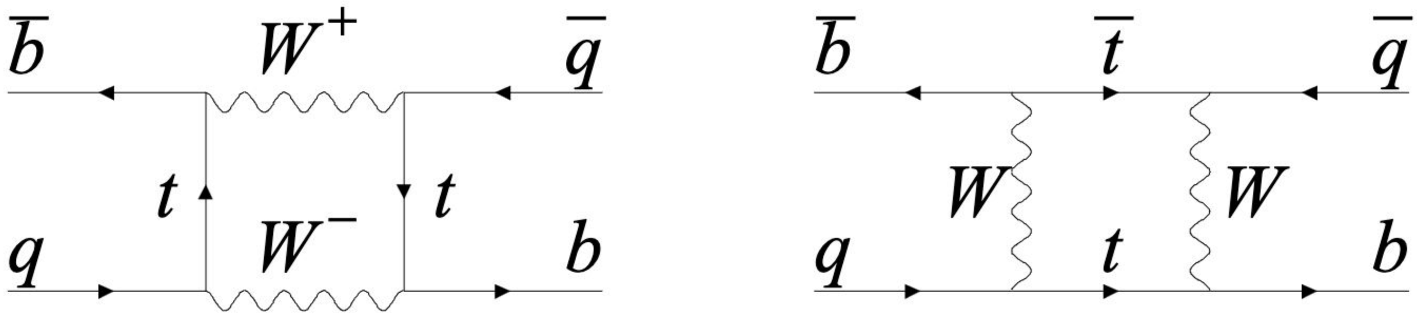
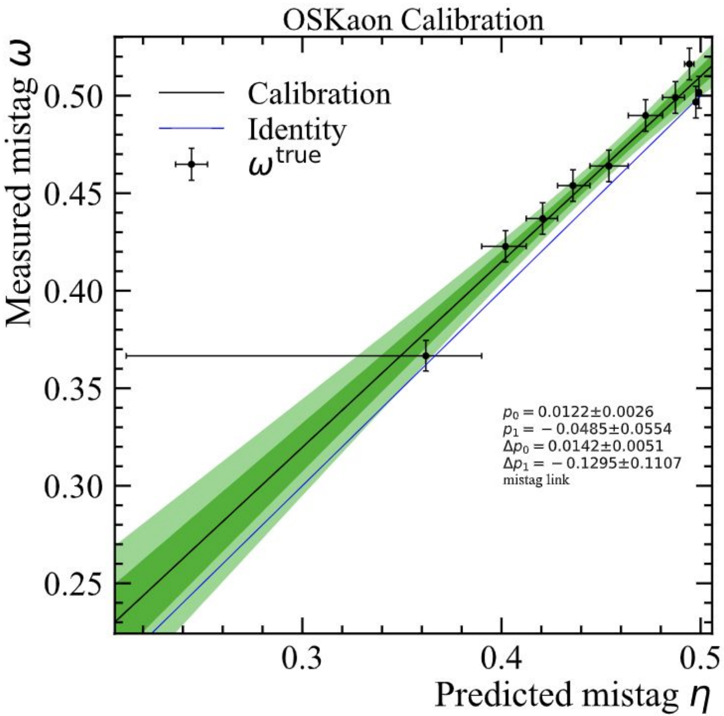


Figure 74.1: Dominant box diagrams for the $B_q^0 \to \overline{B_q}^0$ transitions ($q = d$ or s). Similar diagrams exist where one or both t quarks are replaced with c or u quarks.

Calibration



$$\omega = \frac{N_{\text{wrong}}}{N_{\text{right}} + N_{\text{wrong}}}$$

$$\eta = NN\ output$$

Work in progress! Small sample, for testing purpose.
OSKaon trained on Bu2JspiK+