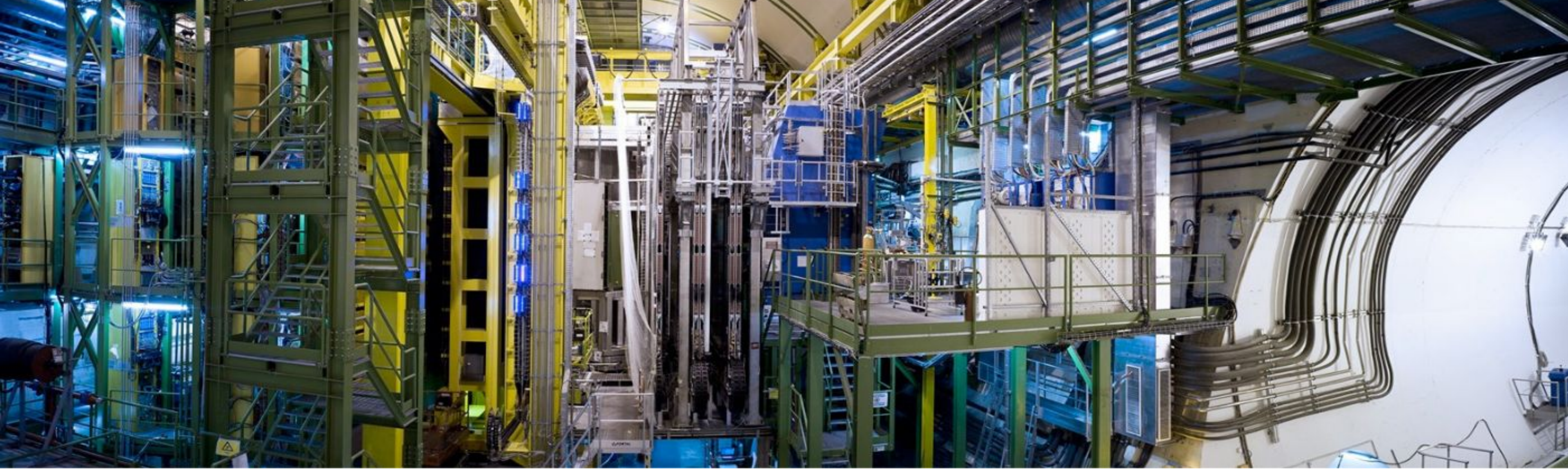


SMARTHEP Annual Meeting

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

ESR8 Micol Olocco, Prof. Johannes Albrecht

technische universität dortmund

SMARTHEP REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

MARIE CURIE ACTIONS

European Commission

Horizon 2020 European Union funding for Research & Innovation

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

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

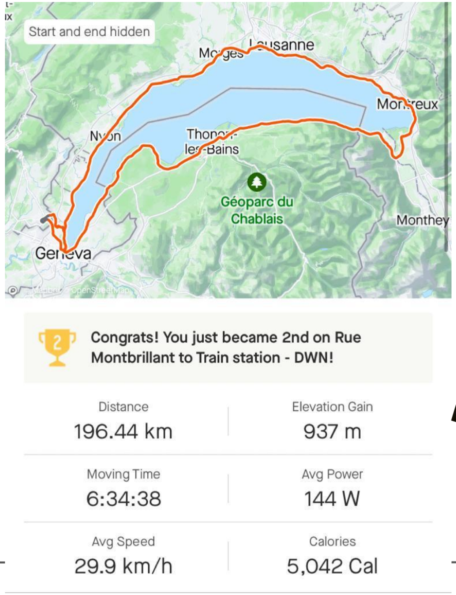
Anomaly Detection in large-radius jets, ATLAS

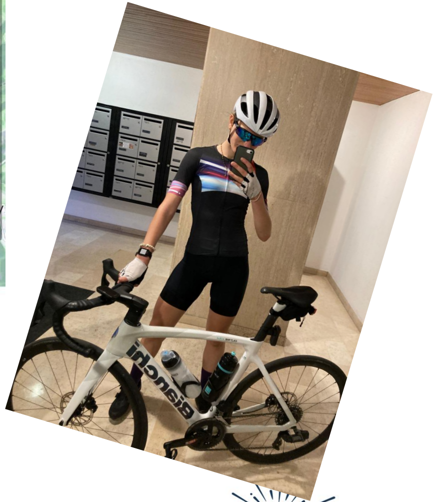
Natural Laguage Processing

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

Consulting

Data Analyst in Accenture





SMARTHEP
REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

Outreach

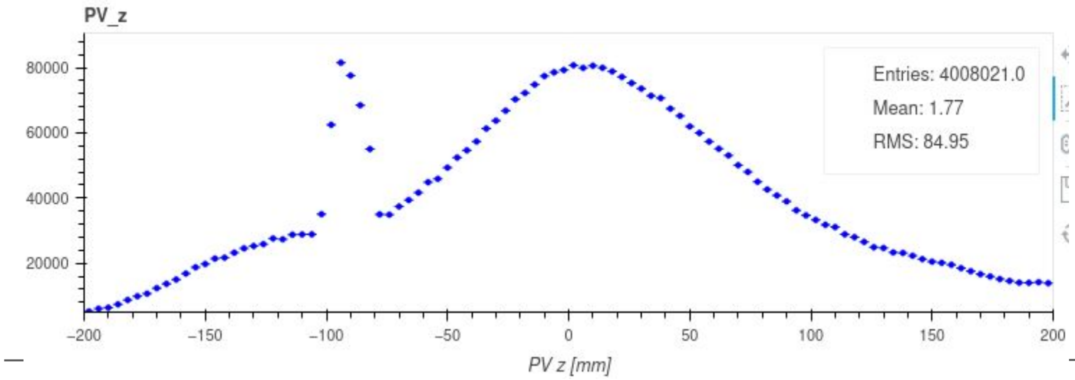
- Volunteer at the inaguration of the CERN Science Gateaway
- Planning talk in High School in Italy about High Energy Physics (and/or ML)
- Training for becoming an LHCb underground guide

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
- Very exciting, 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

SMARTHEP
REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

Project

Real Time Analysis for global event triggering in LHCb

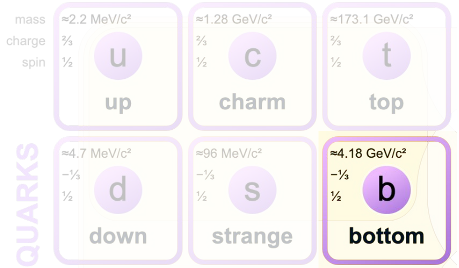
Particle Physics and Machine Learning → Flavour Tagging in Run 3 at LHCb

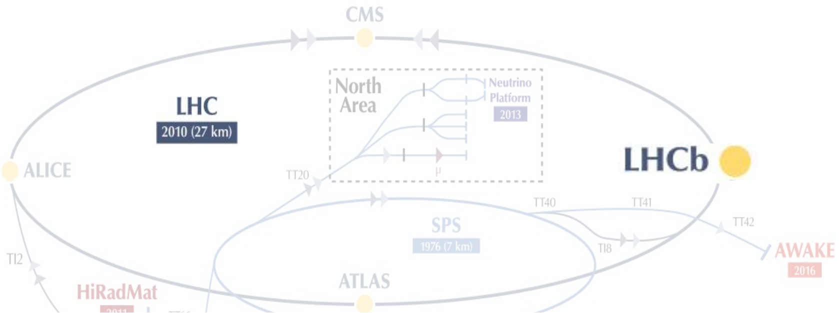
Trigger → Automation of the trigger sequence production

Flavour Tagging in Run 3 at LHCb

The LHCb experiment

= LHC + b





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

Neutral B mesons

- Neutral particles containing a b quark: $B^0\ (d\bar{b})$, $B_s^0\ (s\bar{b})$
- Interesting systems because they allow to measure:
  - the frequency of the neutral B oscillation (mixing) Δm_d , Δm_s
  - signals of CP (charge-parity) violation
- Both phenomena are predicted by the Standard Model:

  → measuring these quantities means testing the Standard Model.

SMARTHEP
REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

B mixing

Due to flavour-changing currents in the weak interaction, a B^0 **can oscillate in an** $\overline{B^0}$ and viceversa)

The oscillation frequency of the B^0 meson can be determined using the time dependent mixing asymmetry:

t = B^0decay time

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

$N\ (B^0 \rightarrow final\ state)$

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

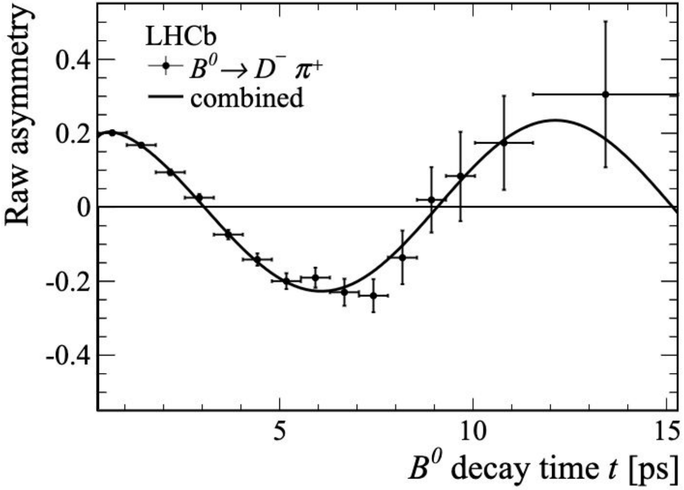


Fig: Raw mixing asymmetry A_{mix} (black points) for B0 → D−π+ [CERN-PH-EP-2012-315]

SMARTHEP
REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

B mixing

In order to tag a B^0 or B_s^0 candidate as mixed or unmixed, it is necessary to determine its flavor in both states:

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

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

SMARTHEP
REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

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

How do we access the flavour at the decay time?

Through the decay products!

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

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?

SMARTHEP REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

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?

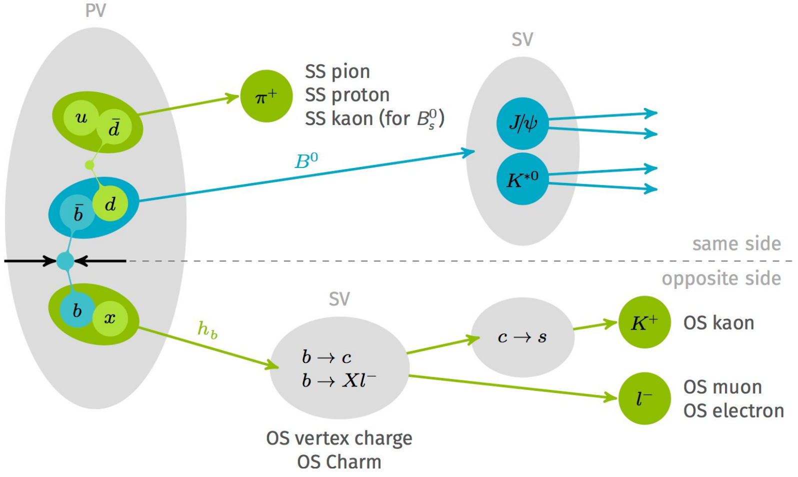
Flavour Tagging Algorithms!

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.**

According to the particle used as tagging particles, two tagger categories:

- Same-Side
- Opposite-Side



Flavour Tagging

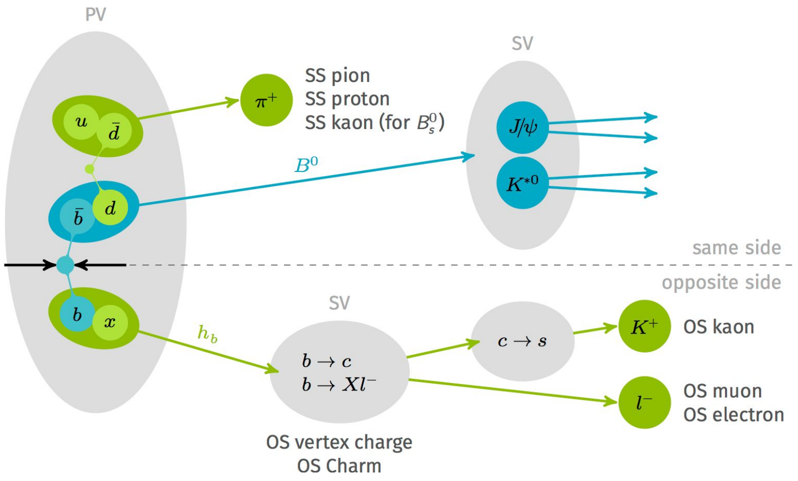
Flavour Tagging algorithms access the B meson flavour at production time by exploiting the **correlation between the B flavour and the charge of the tagging particle.**

If Q_{tag} is the charge of the tagging particle and d is the 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).

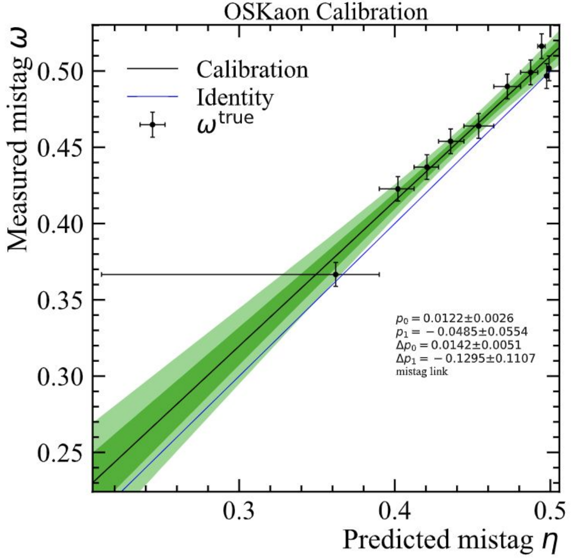
$$\text{Classifier trained on} \begin{cases} \text{label } 0 \rightarrow \text{wrong tagging decision} \\ \text{label } 1 \rightarrow \text{correct tagging decision} \end{cases}$$

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

Flavour tagging: my tasks

In collaboration with the Universität Heidelberg

- Train and calibrate the taggers on simulated data with 2023 data-taking conditions → provide an early measurement of the B_d^0–$\overline{B}_d^0$ oscillation frequency (Δm_d) with 2023 data
- Train and calibrate the taggers for 2024 data-taking and port them in the LHCb software



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

SMARTHEP REAL-TIME ANALYSIS FOR SCIENCE AND INDUSTRY

Automation of the TCK production

The trigger configuration key (TCK)

- The TCK is an unique identifier for a certain trigger configuration (ex. 0x1000001)
- The TCK is persisted as a tag in a git repository and contains information about a certain trigger configuration (such as the trigger sequence, the software version being used)
- A new TCK must be created everytime a change is integrated in the online LHCb software (ex. a prescaled line)

```
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 we want to automate are:
    - checks on: correct stack, interested application, type and settings
    - TCK publication on GitLab

```
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 (especially when the commissioning needs to be fast)
    - requiring unnecessary time (when there already are many things to do)

- Our task (with **PhD Luke Grazette**):

Develop a CI test running those checks

Final comments...

- Intense year ahead (challenging measure with 2023 data, a lot to do with the taggers) but hopefully with interesting results for the collaboration!
- I'm very curious about the differences in performances I'll see on 2023 simulation VS 2024 simulation VS 2023 data.
- Thanks to the two projects I'm working on, **I'm learning a lot**, both on software and particle physics sides (never done flavour physics before!)

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

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

B mixing

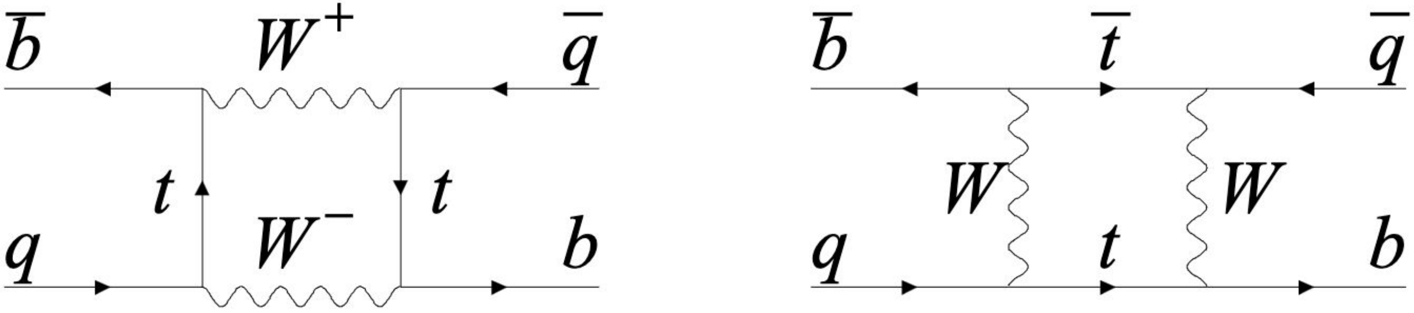


Figure 74.1: Dominant box diagrams for the $B_q^0 \to \overline{B_q}^0$ transitions ($q = d$ or s). Similar diagrams exist where one or both t quarks are replaced with c or u quarks.