# 8th BCD ISHEP Cargèse School

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IESC Cargèse

# Book of Abstracts

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## Submission test

**Author:** Jean Orloff[1]

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**Title**:

Submission test 2

**Presentations** / **23**

## Optimisation of Decay Selections $\Lambda_b^0 \to pK^-$ e $\Lambda_b^0 \to p\pi^-$ for $\mathcal{CP}$ Asymmetry Measument

**Author:** Marco Caporale[None]

**Corresponding Author:** marco.caporale3@studio.unibo.it

This work presents the optimization of the selection of the $\Lambda_b^0 \to pK^-$ and $\Lambda_b^0 \to p\pi^-$ decay modes in order to measure their $\mathcal{CP}$ asymmetries. The optimization of the selection is crucial in the study of these decays, in order to obtain the lowest possible statistical uncertainty on the measured asymmetries.
The data sample used in this work corresponds to an integrated luminosity of 6 fb$^{-1}$, collected by the LHCb experiment in proton-proton collisions at a center-of-mass energy of 13 TeV. The obtained statistical uncertainties on the individual $\mathcal{CP}$ asymmetries are:
\begin{align*}
&\sigma (\mathcal{A}^{\mathcal{CP}}(pK)) = 0.76\%,\\
&\sigma (\mathcal{A}^{\mathcal{CP}}(p\pi)) = 0.95\%,
\end{align*}
which are about a factor of two lower than the results already published by the LHCb Collaboration.

**Title**:

Optimisation of Decay Selections $\Lambda_b^0 \to pK^-$ e $\Lambda_b^0 \to p\pi^-$ for $\mathcal{CP}$ Asymmetry Measument

**Presentations** / **24**

## Machine learning techniques for heavy-flavour baryon production measurements at the LHC

**Author:** Marco Cruciani[None]

**Corresponding Author:** marco.cruciani3@studio.unibo.it

Quark-gluon plasma (QGP) is a state of matter predicted by quantum chromodynamics. The ALICE experiment at LHC has among its main goals the study of strongly interacting matter and the properties of QGP through collisions of ultra-relativistic heavy ions. For a comprehensive understanding of these properties, the same measurements made on smaller colliding systems (proton-proton and proton-ion collisions) are needed as a reference. Recent analyses of the data collected at ALICE have shown that our understanding of the hadronization mechanisms of heavy quarks is not complete, because the data obtained in pp and p-Pb collisions are not reproducible using models based on the results obtained in e+e- and ep collisions. For this reason, new theoretical and phenomenological models capable of reproducing experimental measurements have been proposed. The errors associated with these new experimental measurements at present do not allow definitive validation of the various proposed models. Therefore, increasing the precision of such experimental measurements will be crucial in the coming years; on the other hand, estimating the number of different particle species produced in a collision can be extremely complicated.
In this thesis, the number of baryons $\Lambda_c^+$ produced in a data sample was obtained using machine learning techniques, which can learn patterns and distinguish signal candidates from background candidates. Three different implementations of a Boosted Decision Trees (BDT) algorithm were also compared and the one with the best performance was used to reconstruct the $\Lambda_c^+$ baryon in pp collisions collected by the ALICE experiment.

**Title**:

Machine learning techniques for heavy-flavour baryon production measurements at the LHC

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# Machine learning techniques for the search for top-top events with the ATLAS experiment at the LHC

**Author:** Virginia Mazza[1]

[1] *Unibo*

**Corresponding Author:** virginia.mazza@studio.unibo.it

The Standard Model is currently the theory that best explains the behavior of subnuclear physics, including the definition of particles and three of the four fundamental forces acting in nature; however, it turns out to be an incomplete theory on whose integrations physicists are working in different directions: one of the most promising approaches appears to be that of effective field theories. The interaction vertex of the process that produces pairs of same-sign top quarks starting from protons is strongly suppressed in the Standard Model and must therefore be interpreted with effective field theories. The present paper focuses on this new approach for the search for same-sign top quarks and on the use of a neural network to discriminate the signal from the background. The goal is to understand whether the performance of the neural network changes when variables of different levels of reconstruction are supplied as input. Three sets of training variables have been presented to a neural network optimized for background-signal discrimination: one high-level, the second strictly low-level, the third copy of the second with in addition two main variables of b-tagging. It has been shown that the performance of the network in terms of signal-background classification remains almost unchanged: the ROC curve presents areas under itself that are almost identical. It has also been noted that for the set of low-level variables, the neural network classifies the azimuthal angles of the leptons as the most important inputs despite these having identical distributions between signal and background: this happens because the neural network is able to exploit the correlations between the variables as a discriminating characteristic. This preliminary study lays the foundations for the optimization of a multivariate approach in the search for events with two same-sign tops produced at the LHC.

**Title**:

Machine learning techniques for the search for top-top events with the ATLAS experiment at the LHC

**Presentations / 26**

# Method for nuclear fragment identification in FOOT experiment.

**Author:** Giacomo Santoni[None]

**Corresponding Author:** giacomo.santoni@studio.unibo.it

Hadrontherapy is a therapy that treats tumors by irradiating cancer cells with proton or heavy ion beams. The main advantage of this technique is that charged particles can release most of their energy in the end-path region (Bragg Peak), limiting the damage to healthy tissues near the tumor.
The effects of charged particle electromagnetic interaction with biological tissue are well-known; however, other effects due to nuclear fragmentation are still partially unknown. INFN financed the FOOT experiment in 2017 to cover this lack of data evaluating the production cross-section of nuclear fragments produced in the interaction beam-human body. Thus, this work proposes to identify fragments produced in the fragmentation process, estimating the charge Z and mass number A. Analyzed data were obtained from MC simulation, done with FLUKA code, of an interaction between a <sup>16</sup>O beam @ 200 MeV/u and a $C_2H_4$ target. Precisely, the data analysis was focused on the eight most-produced fragments, which are <sup>1</sup>H, <sup>4</sup>He, <sup>7</sup>Li, <sup>9</sup>Be, <sup>11</sup>B, <sup>12</sup>C, <sup>14</sup>N, and <sup>16</sup>O.
Atomic number Z estimation had been obtained through the Bethe-Bloch formula, using two fast scintillators. The mass number A had been obtained through 3 correlated methods, each based on

the relativistic definition of four-momentum. In both cases, the final resolutions had been evaluated to be sufficiently precise for future cross-section measurements. Then, to find the best precision possible for mass number A, a systematic study on TOF resolution had been performed. The results had shown that by improving the TOF resolution, it's possible to improve the percentage resolution on A, yielding a 5% resolution for <sup>1</sup>H and 3% for the heaviest fragment. These improvements in mass number A reconstruction precision are fundamental for an optimal isotope separation of the produced fragments. The obtained results had shown that the FOOT experiment can perform an unambiguous identification of the selected fragments.

**Title**:

Method for nuclear fragment identification in FOOT experiment.

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## Measurement of the top-quark pair to $Z$-boson production cross-section ratio at a centre-of-mass energy of 13.6 TeV with the ATLAS detector

**Author:** Donna Maria Mattern[1]

[1] *Technische Universitaet Dortmund (DE)*

**Corresponding Author:** donna.maria.mattern@cern.ch

A measurement of the ratio between the top-quark-pair and $Z$-boson production cross-sections, using data corresponding to an integrated luminosity of 1.2 $\text{fb}^{-1}$, collected by the ATLAS detector in 2022 during the early Run 3 of the Large Hadron Collider (LHC) in proton-proton collisions with a centre-of-mass energy of 13.6 TeV, is presented.
This measurement is sensitive to different Standard Model variables, such as the strong coupling constant and top-quark mass, as well as the parton distribution function ratio of quarks and gluons. The analysis uses dileptonic events with two leptons of opposite charge. To target the top-quark pair events, electron-muon pairs are selected and events with $b$-tagged jets are used. For the $Z$-boson events, electron-electron and muon-muon events are used that are inclusive in jet multiplicity.
The cross-section ratio is determined using a profile-likelihood method that also includes a measurement of the efficiency to reconstruct and tag $b$-jets in the top-quark pair events in-situ. Further, the ratio setup of the analysis allows for a large cancellation of the luminosity uncertainty, which would otherwise dominate results in such an early stage of the data-taking in LHC Run 3. The results of this analysis validate the data quality, hardware and software updates.

**Title**:

Measurement of the top-quark pair to $Z$-boson production cross-section ratio at a centre-of-mass energy of 13.6 TeV with the ATLAS detector

**Presentations** / **28**

## Multivariate analysis to discriminate top quark pair production channels at LHC

**Author:** Morgan Del Gratta[None]

**Corresponding Author:** morgan.delgratta@studio.unibo.it

The top quark is one of the fundamental fermions of the Standard Model, and is observed in the highest energy collisions. Our focus is the $t\bar{t}$ pair, which is produced through strong interaction in two cases: from gluon fusion ($gg$) or quark-antiquark annihilation ($q\bar{q}$). Different production channels lead to pairs with different characteristics: one example is the $t\bar{t}$ spin state, which near the production threshold presents higher correlations in the case of a $gg$ event. A study that proposes to study the entity of such correlations can thus benefit from a way to discriminate pairs on the basis of their production channels.

This work has therefore the purpose of obtaining, through the use of multivariate analysis methods, a tool to select events in such way. Multivariate algorithms are often used to separate a signal from a background that pollutes the sample; in this case for the signal we choose $gg$ events, while for the background we select to $q\bar{q}$ events. Such a problem is called a *classification problem*.

We thus studied the performance of some classifiers, using the distributions of some variables associated to the $t\bar{t}$ production process. Then we selected the best performing algorithm evaluating its efficiency in selecting signal events and rejecting background ones. The chosen classifier turns out to be the *Boosted Decision Trees*, which allows to obtain a sample of purity 0.92, starting from an initial purity of 0.81, at the cost of a reduced efficiency of 0.74.

**Title**:

Multivariate analysis to discriminate top quark pair production channels at LHC

**Presentations** / **29**

# Measurement of y_{CP} in meson D^0 decay at LHCb

**Author:** Andrea Petrini[None]

**Corresponding Author:** andrea.petrini5@studio.unibo.it

In this thesis analysis the meson mixing observable $y_{CP}$ has been measured via $D^0 \to K^+K^-$, $D^0 \to \pi^+\pi^-$ and $D^0 \to K^-\pi^+$ decays, where the $D^0$ comes from semileptonic decays of $B$.
Data has been taken by LHCb through \textit{pp} collisions with center of mass energy of 13 TeV.
The data sample has been split into 18 bins of $D^0$ decay time and a maximum likelihood fit on the distribution of meson $D^0$ invariant mass has been performed, in order to obtain signal events for the 18 bins, in each all 3 decay channels.
Starting from those obtained signal events a second fit is performed on the ratio between $D^0 \to K^+K^-$ ($D^0 \to \pi^+\pi^-$) events with respect to $D^0 \to K^-\pi^+$ as a function of $D^0$ decay time.
From this fit the difference between decay aplitude $\Delta_\Gamma^{hh} = \Gamma_{h^+h^-} - \Gamma_{K^-\pi^+} = y_{CP}/\tau_{D^0}$, where $h$ is either a $K$ or a $\pi$.
The values of the 2 parameters given by the fit are:
\begin{equation}
\Delta_{\Gamma}^{KK} = (0.015 \pm 0.002) \hspace{1pt} \mathrm{ps}^{-1},
\end{equation}
\begin{equation}
\Delta_{\Gamma}^{\pi\pi} = (0.0063 \pm 0.0038) \hspace{1pt} \mathrm{ps}^{-1}.
\end{equation}
From those we compute $y_{CP}$ as $\Delta_\Gamma \tau_{D^0}$, where $\tau_{D^0} = (0.4103 \pm 0.0010)$ps is the well known value of $D^0$ mean half life.
\begin{equation}
y_{CP}^{KK} = (0.63 \pm 0.10)\hspace{0.5pt}\%,
\end{equation}
\begin{equation}
y_{CP}^{\pi\pi} = (0.26 \pm 0.16)\hspace{0.5pt}\%.
\end{equation}
Central values of $\Delta_\Gamma$ and $y_{CP}$ sono \textit{blind}, meaning they're shifted by an unknown value comparable with the world average mean values of the parameter's standard deviation, this value is the same for both of the fits. The blind offset is needed to avoid the fact that knowing the final value might lead to some bias on the analysis.

$y_{CP}$ values in the two different channels are consistent with each other between 2.0 standard deviations.

**Title**:

Measurement of $y_{CP}$ in meson $D^0$ decay at LHCb

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## Lepton masses for a non Universal U(1) model with 2 right-handed massive neutrinos

**Author:** Ricardo Jaimes[1]

[1] *Università di Bologna*

In a model with additional U(1) gauge symmetry, free of anomalies, the mass of the active neutrinos are generated by type I see saw mechanism by introducing two right handed neutrinos. The muon and tau get mass at the tree level and the masses of the electron is generated by effective operators of dimension 7 by introducing a Lambda scale. Using a Monte Carlo, the model parameters are adjusted according to the mass of the charged leptons, the squared mass differences of the neutrinos and the PMNS mixing matrix.

**Title**:

Lepton masses for a non Universal U(1) model with 2 right-handed massive neutrinos

**Presentations / 31**

## Jet Reconstruction and Global Particle Flow in the ATLAS Experiment for Run 3 of the LHC

**Author:** Anubhav Gupta[1]

[1] *Technische Universitat Dortmund(DE)*

In the ATLAS experiment, jets have been constructed using the calorimeter information. In a new algorithm called Particle Flow (PFlow), jets are reconstructed using the information from both the tracking system and the calorimeter. For Run-2 of the LHC, PFlow has been used and results in improved energy resolution. For Run-3, PFlow is being extended to reconstruct physical objects (electrons, muons, taus, photons) other than jets, and referred to as global PFlow (GPFlow). PFlow reconstruction of jets has been modified to take a small step towards GPFlow.

**Title**:

Jet Reconstruction and Global Particle Flow in the ATLAS Experiment for Run 3 of the LHC

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## Search for a neutrinoless conversion of a muon to an electron in muonic atoms with the COMET experiment at J-Parc

**Author:** Thomas Clouvel[None]

**Corresponding Author:** thomas.clouvel@cern.ch

Neutrino experiment results suggest that flavor can be violated for neutral leptons through neutrino oscillation, but no flavor violation has been measured for charged leptons yet. The COMET experiment at J-Parc searches for coherent neutrinoless conversion of a muon to an electron in muonic atoms ( μ- + N(A,Z) ⟶ e- + N(A,Z) ). The goal for COMET Phase-I is to reach an experimental sensitivity of $10^{-15}$ and then a sensitivity of $10^{-17}$ for the Phase-II, improving existing limits by a factor 10,000. To reach the expected sensitivity, the detector needs to be protected from the atmospheric muons, which are the main background source. For this purpose, a sub detector called Cosmic Ray Veto (CRV) is needed to operate in this very high radiation environment.

**Title**:

Search for a neutrinoless conversion of a muon to an electron in muonic atoms with the COMET experiment at J-Parc

**Presentations** / **33**

## Neutrino mass hierarchy measurement with DUNE

**Author:** Giulia Lupi[None]

**Corresponding Author:** giulia.lupi5@studio.unibo.it

Neutrinos oscillations are a quantum mechanics phenomenon for which an initial state neutrino emitted with a known flavour can be subsequently detected in a different flavour state violating the conservation of the lepton number.
In 1957 Bruno Pontecorvo presented a new theoretical model which made a breakthrough into the neutrino's description: the possibility that each flavour eigenstate, which is associated depending on the charged lepton a neutrino is emitted with, does not correspond uniquely to a single mass state but is instead a superposition of three independent mass eigenstate. This probability of oscillation obtained, depends directly on the mass squared difference between the initial and final state thus, as the opposite assumption in the Standard Model, neutrino can't be considered a massless particle anymore. Although the study of solar and atmospheric neutrino fluxes allowed the measurement of the order of magnitudes of these mass differences, is impossible to extract neutrino absolute mass from this phenomenology. The configurations that can be derived from the knowledge of the third mass square difference are known as hierarchies labelled as normal, as intuition suggests if the third mass will be the heaviest or inverted if is the lightest.
The MSW model provides an experimental way to discriminate the two hierarchies. It is possible to introduce a controllable interference between the oscillation phase in the vacuum and a phase, whose sing is known a priori, due to the propagation of a neutrino in a dense matter. Conceiving this kind of experiment is typically tough since neutrinos are tiny neutral particles. Their revelation requires maximising the cross section for neutrinos interactions with precautions like the capability to produce very high neutrino beams as pure as possible. High statistics standards, precise awareness of the energy distribution of the neutrino beam and of which leptonic families are present in the initial state can be achieved through accelerator experiments such as DUNE where two different detectors are placed at different distances to obtain
The future result from these measurements will establish which hierarchies are correct and are going to improve the actual estimation of the other parameters necessary to characterize the neutrino oscillation phenomenology. This essay has concluded with a future perspective on the fundamental role played by the research in neutrino physics that will (and it already did) imply new beyond Standard Model theories for our understanding of Physics

**Title**:

Neutrino mass hierarchy measurement with DUNE

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## Study of Hubble Constant Anisotropies with the Zwicky Transient Facility

**Author:** Antoine SARASAR[None]

The Zwicky Transient Facility at Mont Palomar Observatory (California, United States) has started its survey in early 2018, for six years. ZTF project consists of a new camera of about 600 million-pixels mounted on the Samuel Oschin 48-inch Schmidt telescope. ZTF is good transient detection machine, like for Supernovae type Ia. The new dataset provided by ZTF of Supernovae Ia with its large statistic covering more than half of the full sky will allow to address new cosmological questions related to potential anisotropies in the nearby Universe. The goal of my internship will be to use realistic ZTF simulation of SNe Ia to develop an analysis of differential measurement of $H_0$ as a function of the sky direction with the aim of quantifying the sensitivity of the survey for such potential anisotropies.

**Title**:

Study of Hubble Constant Anisotropies with the Zwicky Transient Facility

**Presentations / 35**

## Entropic gravity

**Author:** Emiliano Pezzini[None]

**Corresponding Author:** emiliano.pezzini@studio.unibo.it

A brief presentation about my future thesis project, the topic is entropic gravity relating to the holographic principle, AdS/CFT correspondence and black hole thermodynamics as well as experimental results, such as galaxy rotation measurments, and criticisms to the theory. The actual writing has yet to start so only surface level knowledge is given.

**Title**:

Entropic gravity

**Presentations / 36**

## Automotive lidars in foggy environment

**Author:** Tom Durand[None]

**Corresponding Author:** tom.durand@etu.uca.fr

Nowadays new technologies are becoming more and more present in our daily life especially in vehicles. In this presentation, I will be focused on autonomous vehicles and their sensors and more precisely the lidar. I will define what it is, how it works. I will also present the fog and the autonomous car briefly. Then, a bit of theory on lidar with fog will be explained to understand the

problem. Finally, I will finish by talking about the different steps I have to achieve in my internship.

**Title**:

Automotive lidars in foggy environment

**Presentations / 37**

## SNIa forecast with ZTF phase III

**Author:** Andréa Antoniali[1]

[1] *UCA*

**Corresponding Author:** andrea.antoniali@etu.uca.fr

SNIa forecast with the third phase of ZTF :
seeing if it's realistic and useful to change parameters of observations to detet supernovae SNIa at a redshift of z below 0.2 and above 0.1, aiming to constrain more the cosmological parameters.

**Title**:

SNIa forecast with ZTF phase III

**Presentations / 38**

## Studying the Sensitivity of the Upgrade Phase II LHCb Calorimeter for the rare decay $B^0 \to \pi^0\pi^0$, where one $\pi^0$ decays to the Dalitz $e^+e^-\gamma$ channel

**Author:** Morvan Vincent[None]

**Corresponding Author:** mv63city@gmail.com

Motivation for studying such a rare decay with the LHCb Experiment. LHCb detector is dedicated to flavor physics. The upgrade of the phase II will increase the performance of detection. Especially, with the luminosity increase to reach a number of 50 collisions of protons. This is why it is important to developp the ECAL in order to not be blinded.
The aim of this internship is to understand the Calorimeter and this upgrade to conclude on the feasability of measure this decay.

**Title**:

Studying the Sensitivity of the Upgrade Phase II LHCb Calorimeter for the rare decay $B^0 \to \pi^0\pi^0$, where one $\pi^0$ decays to the Dalitz $e^+e^-\gamma$ channel}

**Presentations / 39**

# Influence of a gravitationally induced phase on neutrino oscillation and Baryogenesis

**Author:** Sara Krieg[None]

**Corresponding Author:** sara.krieg.sk@gmail.com

In view of the fact that there is still no uncontroversial idea of quantum gravity nor an experimental evidence for its existence it is well motivated to look for the latter in neutrino oscillations.
For this a general transition probability is derived for a neutrino interacting gravitationally with background neutrinos. This induces a phase modifying the oscillation behavior which may be experimentally detectable. Therefore this could be a direct evidence for the quantum
character of gravity.
Since there are theories that explain baryon asymmetry via neutrino oscillations the effect of the phase shift may also have an impact on
the predictions of these models.
Extra dimensions are introduced to consider even larger effects.

**Title**:

Influence of a gravitationally induced phase on neutrino oscillation and Baryogenesis

**Presentations** / **40**

# HS3 - A serialization standard for statistical models in high energy physics

**Authors:** Carsten Burgard[1]; Cornelius Grunwald[1]; Oliver Schulz[2]; Robin Pelkner[3]

[1] *TU Dortmund*

[2] *Max Planck Institute for Physics, Munich*

[3] *Technische Universitaet Dortmund (DE)*

An important aspect of experimental particle physics, and science in
general, is to perform analyses in a reproducible way. In addition to
providing the observational data, this also means that the statistical
models, which are usually formulated in terms of likelihood functions,
must be provided in an accessible form as well. Currently, sharing
statistical models between different programs and communities can be
cumbersome because there is no standardized exchange format. Different software packages and toolkits usually use fundamentally different
ways for representing data and models. We present the ”high energy
physics serialization standard”(HS3), a proposed standard, which is a
language-agnostic and software-independent format for saving statistical models in exchangeable files. HS3 makes it possible to share entire
analyses and to use them across software frameworks and methods so
results can be cross-checked and models can be reused in new contexts. We give a general introduction to the HS3 standard, its design
philosophy and semantics. In addition, we focus on the ongoing implementation of HS3 in ROOT, in Python, and the Julia programming
language for use in packages like BAT.jl.

**Title**:

HS3 - A serialization standard for statistical models in high energy physics

**Presentations** / **41**

# V0 production in Run 3 at LHCb

**Author:** Noah Albin Behling[1]

[1] *Technische Universitaet Dortmund (DE)*

The LHCb detector has undergone major upgrades in the last LHC shutdown and therefore the performance of the new detector has to be evaluated. Strange hadrons have huge production cross-sections and can be studied with exclusively using the detector's tracking system. Therefore, they offer the optimal starting point of evaluating the detector's performance. Additionally, an enhancement of strangeness production in the mid-rapidity region has been observed by the ALICE experiment. To understand its possible role in solving the muon puzzle in astroparticle physics, the LHCb experiment can probe this strangeness enhancement in the very-forward region.

**Title**:

V0 production in Run 3 at LHCb

**Presentations** / **42**

# Coalescence parameter study and source characterization in the production of (anti)nuclei in high energy collisions

**Author:** Lorenzo Valla[None]

In this work, I investigated in depth the coalescence model, which is widely used in the literature to describe the formation of both light (anti)nuclei in high-energy collisions in accelerators and cosmic antinuclei, with applications to indirect searches for dark matter in the Universe.
Specifically, I studied the coalescence parameter of (anti)nuclei with mass number A<=4; using a fit to the data on the size of the proton source in pp collisions at $\sqrt{s} = 13$ TeV from the ALICE experiment, I attempted to explicate the dependence of the coalescence parameter on the transverse momentum.
Comparing the predictions of the model obtained this way with the coalescence parameter measurements collected by ALICE, it can be observed that the coalescence parameter of d and 3He does not follow the expected trend. This result therefore highlights the need to revise the adopted source model or its application limits to different collision systems.
In view of a possible implementation of the coalescence mechanism in Monte Carlo generators for the simulation of antinuclei formation, I tried to characterise the proton source using 10ˆ5 pp collisions in the PYTHIA 8.3 generator.
The distributions obtained show that the source is essentially isotropic.

**Title**:

Coalescence parameter study and source characterization in the production of (anti)nuclei in high energy collisions

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# Coalescence parameter study and source characterization in the production of (anti)nuclei in high- energy collisions

**Title**: