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The ALICE definition of primary particles

ALICE Collaboration*

Abstract

In this public note, we specify what we mean by the term *primary particle*. The definition is motivated by what is in principle measurable by ALICE and that event generators and other such theoretical considerations must be able to reproduce the same requirements. To this end, we also provide a Rivet projection to be used in ALICE Rivet analyses.

*See Appendix E for the list of collaboration members

Contents

1 The definition

The following sentence constitutes the ALICE definition what we consider a primary particle.

> A primary particle is a particle with a mean proper lifetime τ larger than $1\,\mathrm{cm}/c$, which is either a) produced directly in the interaction, or b) from decays of particles with τ smaller than $1\,\mathrm{cm}/c$, restricted to decay chains leading to the interaction.

In the sentence above and else where in this note, except if otherwise indicated, the word “interaction” refers the interaction between the colliding partners.

All particles that do *not* meet the requirements are not primary particles and are therefore dubbed *secondary* particles.

1.1 Variations of the definition

Alternatively, if the analysis presented concerns only charged, primary particles, we will write

> A primary, charged particle is a charged particle with a mean proper lifetime τ larger than $1\,\mathrm{cm}/c$, which is either a) produced directly in the interaction, or b) from decays of particles with τ smaller than $1\,\mathrm{cm}/c$, restricted to decay chains leading to the interaction.

In some cases, we present measurements of identified particles that are not included in the above definition of a primary particle e.g., the π^0. In such cases, the definition of what we mean by a primary particle of type X can be replaced by

> A primary X is an X, which is either a) produced directly in the interaction; or b) from decays of particles with mean proper lifetime τ smaller than $1\,\mathrm{cm}/c$, restricted to decay chains leading to the interaction.

Finally, in some manuscripts, the caveat “restricted to decay chains leading to the interaction” may be cumbersome. In those cases, we may write

> A primary particle is a particle with a mean proper lifetime τ larger than $1\,\mathrm{cm}/c$, which is either a) produced directly in the interaction, or b) from decays of particles with τ smaller than $1\,\mathrm{cm}/c$, excluding particles produced in interactions with material.

It should be understood that the above sentence and the sentence given at the top of this Section are entirely equivalent and does not include or exclude more or less particles. The choice of exact phrase used in a given manuscript is a matter of preference.

2 Some explanatory comments

2.1 Lifetime considerations

The definition above requires that a particle is long-lived i.e., lives long enough that it may in principle be detected by the ALICE detectors. By long-lived particle, we mean a particle that has a mean proper lifetime larger than $1\,\mathrm{cm}/c$. The particle species that fulfill this requirement according to the Particle Data Group [1], are given in Tab. 1. The particle species with the longest mean proper lifetime that falls outside of this cut is the B^+ with $\tau = 0.049\,\mathrm{cm}/c$ (see also Appendix A for a full list).

Specie	Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
p^+	0	∞	∞
γ	0	∞	∞
K^0	0	∞	∞
e^-	0	∞	∞
n	7.478×10^{-28}	$8.861 \times 10^{+14}$	$2.656 \times 10^{+13}$
μ^-	2.996×10^{-19}	$2.212 \times 10^{+06}$	$6.63 \times 10^{+04}$
K^0_L	1.287×10^{-17}	$5.148 \times 10^{+04}$	1543
π^+	2.528×10^{-17}	$2.621 \times 10^{+04}$	785.7
K^+	5.317×10^{-17}	$1.246 \times 10^{+04}$	373.6
Ξ^0	2.27×10^{-15}	291.9	8.751
Λ	2.501×10^{-15}	264.9	7.943
Ξ^-	4.02×10^{-15}	164.8	4.941
Σ^-	4.45×10^{-15}	148.9	4.464
K^0_S	7.351×10^{-15}	90.14	2.702
Ω^-	8.071×10^{-15}	82.1	2.461
Σ^+	8.209×10^{-15}	80.72	2.42

Table 1: Width (Γ) and mean proper lifetime (τ) of long-lived particles, sorted by descending mean proper lifetime [1]. Here, a zero width or "∞" mean proper lifetime signifies undetermined values and are presumed small or large, respectively.

2.2 Decay radius considerations

The choice of the mean proper lifetime cut–off of $1\,\mathrm{cm}/c$ is motivated by the capability of the ALICE detectors. That is, a particle produced in a decay close to the interaction can not be distinguished from particles produced directly in the interaction. As a rule-of-thumb a particle from decay can be unambiguously be identified as a non-primary particle when the decay occurs on average more than 1 cm away from the interaction. Furthermore, particles produced by inelastic collisions with the ALICE beam-pipe, with a radius of 2.98 cm [2][1], sets a limit to how close to the interaction one can resolve decay vertices.

The mean proper lifetime of a given particle species defines the mean lifetime of particles of that species in the rest frame of the particle. In the laboratory frame, the average decay length is given by[2]

$$\lambda_{\mathrm{lab}} = \tau\beta\gamma = \tau\frac{p}{m_0} \tag{1}$$

and as such depends on the momentum of the particle. Considering the longest lived particle species with a $\tau < 1\,\mathrm{cm}/c$, the B^+ with $\tau = 0.049\,\mathrm{cm}/c$ and $m_o = 5.2793\,\mathrm{GeV}$, we find that a particle of this type with a momentum of 10 GeV/c may on average travel ≈ 1 mm, but would require a momentum of > 350 GeV/c to live long enough to decay outside of the ALICE beam-pipe. For the less heavy D^+ to decay outside the ALICE beam-pipe it would need a momentum larger than 180 GeV/c. For the shortest lived particle with $\tau > 1\,\mathrm{cm}/c$, the Σ^+, only a momentum of ≈ 2 GeV/c would be needed.

2.3 Decay product considerations

The definition requires for a particle to be primary, that there are no long-lived particles in the decay chain that leads to that particle. This is illustrated in Fig. 1. For the K^0_S and Ξ^- chains only the initial

[1] In Run 3 of the LHC, the beam-pipe will be replaced with a smaller radius between 1.72 cm and 1.92 cm [3].

[2] The convention adopted by the ALICE collaboration is to set the speed of light $c = 1$ and hence leave it out of equations, *except* in units of measure where c is explicitly given.

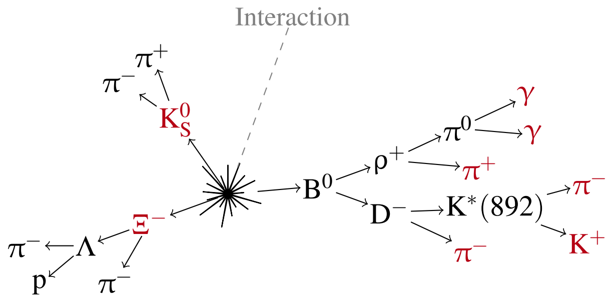

Figure 1: Various decays. Particles defined as primaries are marked in red. In both the Ξ^- and K^0_S decays, the initial particles are considered primary, since these particles are long-lived, while all the decay products are not considered primaries. In the B^0 decay chain, the π's, γ's, and the K^+ are all primary since they are the first long-lived particle in the decay chain leading back to the interaction.

particles are primaries because $\tau > 1\,\mathrm{cm}/c$. In the B^0 branch the charged π's are primaries, since when tracking back to the initial B^0 we meet no long lived particles. Similar considerations applies to the 2 γ's and the K^+. That is, we must be able to track back to the interaction and not find *any* long lived particles, but *without* considering branches of the decay tree that do not end up in the particle we are considering. Also, we require that all production processes in the chain are decays — that is, we exclude chains that contain inelastic interactions with material, hadronic interactions, and other such production mechanisms.

3 Algorithmic description

Figure 2 illustrates the algorithm used to determine if a given particle p is primary or not. If p is *neither* long-lived *nor* produced in a decay, *nor* directly in the collision, it is certainly *not* a primary. Next, we check to see if p has a mother particle m. If no such mother particle exists, we have a primary. If we can find an ancestor we step through each successive ancestor and check if the ancestor is *either* long-lived or *neither* from a decay *nor* from the interaction, then the particle under consideration p is *not* a primary. If we can continue this search back to the interaction i.e., we cannot find any more ancestors, then we *do* have a primary.

The algorithm shown in Fig. 2 is implemented into the ALICE simulation framework and is consistently used throughout all analysis that need to distinguish between primary and non-primary particles. The code is reproduced in Appendix D.

4 Definitions used in the past and by other collaborations

4.1 ALICE definition prior to 2017

> Primary [charged] particles are defined as prompt [charged] particles produced in the collision, including their decay products, but excluding products of weak decays of muons and light flavour hadrons. Secondary [charged] particles are all other particles observed in the experiment e.g., particles produced through interactions with material and products of weak decays. [4] *Parenthesis added.*

> The primary charged particles are defined as prompt particles produced in the collision including all decay products, except products from weak decays of light flavor hadrons and of muons. [5]

The above two definitions of (charged) primary particles has formed the basis in many ALICE publications so far. The definition can be construed to mean that *both* prompt (i.e., produced directly in the

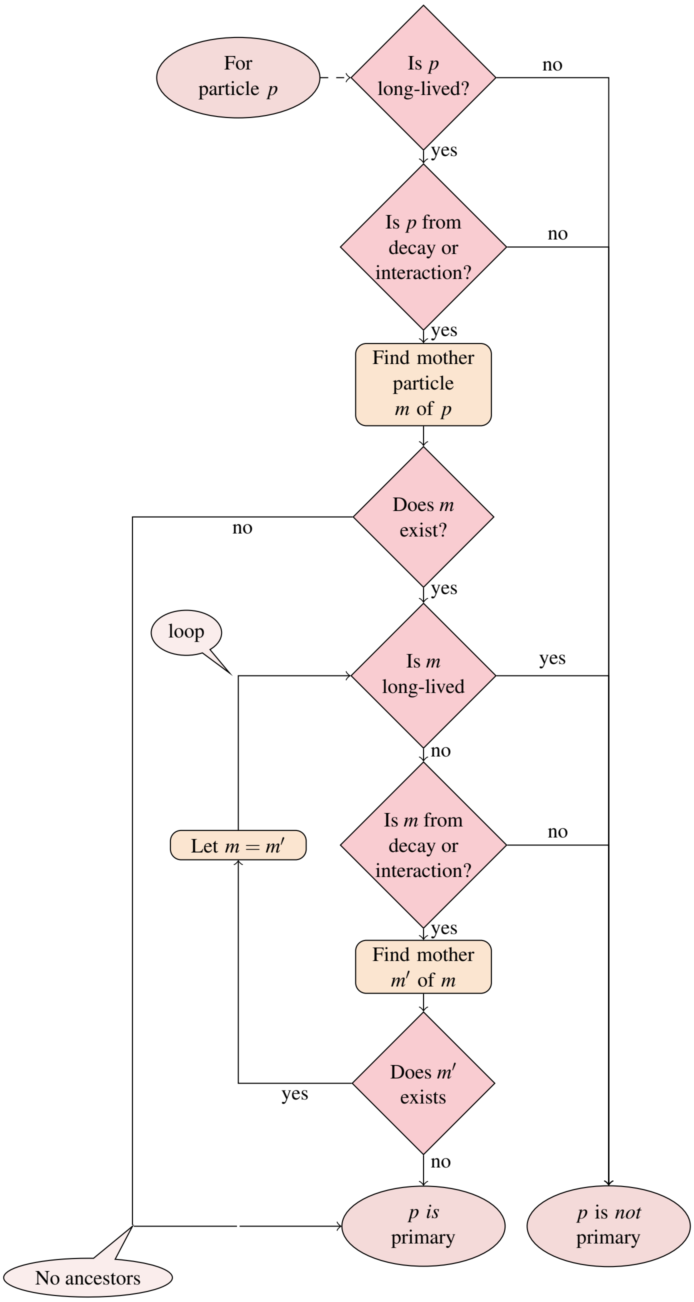

Figure 2: Flow chart of deciding if a given particle is primary or not.

interaction) particles *and* the decay products counts as primary particles, thus leading to a double count of particles. For example, in this reading of the above definitions, the D^- decay in Fig. 1 would count as 5 (rather than 3) primary particles. Clearly, this is not the *intent* of the definition, and operationally no such double counting ever took place. The wording of the definition is the cause of the confusion. The current definition remedies the misunderstanding by explicitly requiring where in the decay chain primary particles may originate from.

The second part of the definition, which stipulates that decay products from weak decays of light flavour hadrons and muons are *not* considered primaries is entirely equivalent to current definitions requirement of mean proper lifetime larger than $1\,\mathrm{cm}/c$ and that possible parent particles must have a mean proper lifetime smaller than $1\,\mathrm{cm}/c$. The known light flavour hadron with the shortest mean proper lifetime is the Σ^+ with a $\tau = 2.42\,\mathrm{cm}/c$, and as such, under the current and previous definition none of its decay products can never be primary.

The current definition, and the 3 quoted above are therefore entirely equivalent though the current definition clarifies the exact conditions and is therefore used by ALICE.

4.2 ALICE definition prior to 2013

> Primary particles are defined as prompt particles produced in the collisions, including all decay products, with the exception of those from weak decays of strange particles. [6]

> We define primary particles as prompt particles produced in the collision, including decay products, except those from weak decays of strange particles. [7]

Relative to the definitions presented in Section 4.1, these formulations would include decay products of $\mu^{\pm}$ and $\pi^{\pm}$. This was an oversight on the part of the formulation, since the operational definition has remained constant between 2013 and 2016. The reason for the oversight was that $\mu^{\pm}$ and $\pi^{\pm}$ are so long lived that they rarely decay within the ALICE acceptance, and was simply ignored by the definition.

Bearing that oversight in mind, this definition of primary particles is entirely consistent with the current and those listed in Section 4.1.

4.3 LPCC MB+UE working group's definition of primary particles

> We reiterated the definition of "charged particle" used in the common plots: this includes hadrons and leptons, with mean lifetime $\tau > 0.3 \times 10^{-10}$ s, produced directly or from decays of shorter-lifetime particles. No particle level correction (e.g. no correction to subtract Dalitz decays) [is used]. [8] *Parenthesis added.*

This definition adopted by the LHC Physics Center at CERN Minimum Bias and Underlying Event working group is identical to the definition adopted by ALICE.

4.4 CMS definition of primary particles

> Primary [charged] particles are defined as all [charged] particles produced in the interaction with a proper lifetime τ of greater than 1 cm, including the products of strong and electromagnetic decays, but excluding particles originating from secondary interactions. The products of weak decays are only considered primary particles if they are the products of a particle produced in the interaction with a τ of less than 1 cm. [9]
>
> *Parenthesis added.*

This definition can be construed to mean, that in the decay $\Lambda \to \pi^- + \mathrm{p}$ we would count 3 particles (since all three species have a mean proper life time larger than $1\,\mathrm{cm}/c$. However, the last part of the definition, which stipulates that mother particles in weak decays must have $\tau < 1\,\mathrm{cm}/c$ for the decay products to be considered primary, rules this out and the definition only counts 1 particle, albeit it may not be immediately obvious to the reader.

The definition adopted by the ALICE collaboration *explicitly* rules out double counting. The above definition from the CMS collaboration and the one adopted by the ALICE collaboration are otherwise equivalent.

4.5 ATLAS definition of primary particles

> A primary [charged] particle is defined as a [charged] particle with a mean lifetime $\tau >$ $300\,\mathrm{ps}[\approx 9\,\mathrm{cm}/c]$, which is either directly produced in pp interactions or from decays of directly produced particles with $\tau < 30\,\mathrm{ps}[\approx 0.9\,\mathrm{cm}/c]$; particles produced from decays of particles with $\tau > 30\,\mathrm{ps}[\approx 0.9\,\mathrm{cm}/c]$ are considered as secondary particles and are thus excluded. [10]
>
> *Parenthesis and τ in length units added.*

In this definition, if a particle has a mean proper lifetime between 30 and 300 ps (or 0.9 to $9\,\mathrm{cm}/c$), it is not considered a primary particle, which excludes all hyperons and $\mathrm{K^0_S}$, nor are the decay products of these particles. If the particle has a lifetime shorter than 30 ps it is not a primary, but it decay products may be e.g., a *prompt* D^+ decaying to $\mathrm{N}+\pi$ is counted as a single primary particle. Similarly all charmed baryons and mesons cannot be primary but their decay products may.

This definition obviously differs from the definition adopted by the ALICE collaboration, in particular for hyperons and $\mathrm{K^0_S}$ which are never considered primary unless produced in the decay of much shorter lived particles. In the ALICE definition, prompt hyperons and $\mathrm{K^0_S}$ *are* considered primaries.

5 Summary

The definition presented in Section 1 provides a clear method to distinguish what ALICE means by "primary". Operationally the definition is equivalent to previous definitions used, but has the advantage of clarity and reproducability.

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A Table of lifetimes

Specie		Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
p^+		$\ll 10^{-29}$	$\gg 10^{+15}$	$\gg 10^{+14}$
γ		$\ll 10^{-29}$	$\gg 10^{+15}$	$\gg 10^{+14}$
K^0		$\ll 10^{-29}$	$\gg 10^{+15}$	$\gg 10^{+14}$
e^-		$\ll 10^{-29}$	$\gg 10^{+15}$	$\gg 10^{+14}$
n		7.478×10^{-28}	$8.861 \times 10^{+14}$	$2.656 \times 10^{+13}$
μ^-		2.996×10^{-19}	$2.212 \times 10^{+06}$	$6.63 \times 10^{+04}$
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π^+		2.528×10^{-17}	$2.621 \times 10^{+04}$	785.7
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Ξ^0		2.27×10^{-15}	291.9	8.751
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K^0_S		7.351×10^{-15}	90.14	2.702
Ω^-		8.071×10^{-15}	82.1	2.461
Σ^+		8.209×10^{-15}	80.72	2.42
B^+		4.018×10^{-13}	1.649	0.04944
Ω_b^-		4.2×10^{-13}	1.578	0.0473
Ξ_b^-		4.22×10^{-13}	1.57	0.04707
B^0		4.33×10^{-13}	1.53	0.04588
B^0_s		4.359×10^{-13}	1.52	0.04557
Λ_b		4.49×10^{-13}	1.476	0.04424
Ξ^0_b		4.5×10^{-13}	1.472	0.04414
D^+		6.33×10^{-13}	1.047	0.03138
B^+_c		1.298×10^{-12}	0.5105	0.0153
D^+_s		1.317×10^{-12}	0.5031	0.01508
Ξ^+_c		1.49×10^{-12}	0.4447	0.01333
D^0		1.605×10^{-12}	0.4128	0.01238
τ^-		2.267×10^{-12}	0.2923	0.008762
Λ^+_c		3.3×10^{-12}	0.2008	0.00602
Ξ^0_c		5.9×10^{-12}	0.1123	0.003367
Ω^0_c		9.6×10^{-12}	0.06902	0.002069
π^0		7.73×10^{-09}	8.572×10^{-05}	2.57×10^{-06}
η		1.31×10^{-06}	5.058×10^{-07}	1.516×10^{-08}
Σ^0		8.9×10^{-06}	7.445×10^{-08}	2.232×10^{-09}
Υ	(3S)	2.03×10^{-05}	3.264×10^{-08}	9.785×10^{-10}
Υ	(2S)	3.2×10^{-05}	2.071×10^{-08}	6.208×10^{-10}
Υ	(1S)	5.4×10^{-05}	1.227×10^{-08}	3.679×10^{-10}
$D*^+$	(2010)	8.34×10^{-05}	7.945×10^{-09}	2.382×10^{-10}
J/ψ^0	(1S)	9.29×10^{-05}	7.132×10^{-09}	2.138×10^{-10}
η'	(958)	0.000197	3.363×10^{-09}	1.008×10^{-10}
ψ	(2S)	0.000296	2.239×10^{-09}	6.711×10^{-11}
h_c	(1P)	0.0007	9.466×10^{-10}	2.838×10^{-11}
χ^0_{c1}	(1P)	0.00084	7.888×10^{-10}	2.365×10^{-11}
D^+_{s1}	(2536)	0.00092	7.202×10^{-10}	2.159×10^{-11}
Λ^+_c	(2625)	0.00097	6.831×10^{-10}	2.048×10^{-11}
B^*_{s2}	(5840)	0.00147	4.508×10^{-10}	1.351×10^{-11}
Σ^0_c	(2455)	0.00183	3.621×10^{-10}	1.085×10^{-11}
Σ^{++}_c	(2455)	0.00189	3.506×10^{-10}	1.051×10^{-11}
D^{*+}_s		0.0019	3.487×10^{-10}	1.045×10^{-11}
χ^0_{c2}	(1P)	0.00193	3.433×10^{-10}	1.029×10^{-11}

Table A.1: Width (Γ), and mean proper lifetime (τ) of various particles, sorted by descending lifetime

Specie		Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
$D*^0$	(2007)	0.0021	3.155×10^{-10}	9.459×10^{-12}
Λ_c^+	(2595)	0.0026	2.548×10^{-10}	7.64×10^{-12}
Ξ_c^+	(2645)	0.0026	2.548×10^{-10}	7.64×10^{-12}
Ξ^0	(1690)	0.003	2.209×10^{-10}	6.621×10^{-12}
Ξ^-	(1690)	0.003	2.209×10^{-10}	6.621×10^{-12}
D_{s1}^+	(2460)	0.0035	1.893×10^{-10}	5.676×10^{-12}
Ξ_c^+	(2815)	0.0035	1.893×10^{-10}	5.676×10^{-12}
D_{s0}^{*+}	(2317)	0.0038	1.744×10^{-10}	5.227×10^{-12}
φ	(1020)	0.004266	1.553×10^{-10}	4.656×10^{-12}
Σ_c^+	(2455)	0.0046	1.44×10^{-10}	4.318×10^{-12}
Σ_b^-		0.0049	1.352×10^{-10}	4.054×10^{-12}
Ξ_c^0	(2645)	0.0055	1.205×10^{-10}	3.612×10^{-12}
Λ_c^+	(2880)	0.0058	1.142×10^{-10}	3.425×10^{-12}
Ξ_c^0	(2815)	0.0065	1.019×10^{-10}	3.056×10^{-12}
Σ_b^{*-}		0.0075	8.835×10^{-11}	2.649×10^{-12}
ω	(782)	0.00849	7.805×10^{-11}	2.34×10^{-12}
Ξ^0	(1530)	0.0091	7.281×10^{-11}	2.183×10^{-12}
Σ_b^+		0.0097	6.831×10^{-11}	2.048×10^{-12}
Ξ^-	(1530)	0.0099	6.693×10^{-11}	2.007×10^{-12}
χ_{c0}^0	(1P)	0.0105	6.311×10^{-11}	1.892×10^{-12}
η_c	(2S)	0.0113	5.864×10^{-11}	1.758×10^{-12}
Σ_b^{*+}		0.0115	5.762×10^{-11}	1.727×10^{-12}
Ξ_c^+	(2790)	0.012	5.522×10^{-11}	1.655×10^{-12}
Σ_c^{++}	(2520)	0.01478	4.483×10^{-11}	1.344×10^{-12}
Ξ_c^0	(2790)	0.015	4.417×10^{-11}	1.324×10^{-12}
Σ_c^0	(2520)	0.0153	4.331×10^{-11}	1.298×10^{-12}
Λ	(1520)	0.0156	4.247×10^{-11}	1.273×10^{-12}
D_{s2}^{*+}	(2573)	0.0169	3.921×10^{-11}	1.175×10^{-12}
Σ_c^+	(2520)	0.017	3.898×10^{-11}	1.168×10^{-12}
Ξ^-	(2030)	0.02	3.313×10^{-11}	9.932×10^{-13}
Ξ^0	(2030)	0.02	3.313×10^{-11}	9.932×10^{-13}
Υ	(4S)	0.0205	3.232×10^{-11}	9.69×10^{-13}
Ξ^0	(1820)	0.024	2.761×10^{-11}	8.277×10^{-13}
Ξ^-	(1820)	0.024	2.761×10^{-11}	8.277×10^{-13}
χ_{c2}^0	(2P)	0.024	2.761×10^{-11}	8.277×10^{-13}
f_1	(1285)	0.0241	2.749×10^{-11}	8.243×10^{-13}
B_2^*	(5747)	0.0242	2.738×10^{-11}	8.208×10^{-13}
B_2^{*+}	(5747)	0.0242	2.738×10^{-11}	8.208×10^{-13}
ψ	(3770)	0.0272	2.436×10^{-11}	7.303×10^{-13}
D_1^0	(2420)	0.0317	2.09×10^{-11}	6.266×10^{-13}
η_c	(1S)	0.0318	2.084×10^{-11}	6.247×10^{-13}
Λ	(1670)	0.035	1.893×10^{-11}	5.676×10^{-13}
Σ^+	(1385)	0.036	1.841×10^{-11}	5.518×10^{-13}
Σ^0	(1385)	0.036	1.841×10^{-11}	5.518×10^{-13}
Σ^-	(1385)	0.0394	1.682×10^{-11}	5.042×10^{-13}
D_2^{*+}	(2460)	0.0467	1.419×10^{-11}	4.254×10^{-13}
$K*$	(892)	0.0474	1.398×10^{-11}	4.191×10^{-13}
D_2^*	(2460)	0.0477	1.389×10^{-11}	4.164×10^{-13}
Λ	(1405)	0.0505	1.312×10^{-11}	3.934×10^{-13}
$K*^+$	(892)	0.0508	1.304×10^{-11}	3.91×10^{-13}
η	(1405)	0.051	1.299×10^{-11}	3.895×10^{-13}
Υ	(10860)	0.054	1.227×10^{-11}	3.679×10^{-13}
f_1	(1420)	0.0549	1.207×10^{-11}	3.618×10^{-13}

Table A.1: Width (Γ), and mean proper lifetime (τ) of various particles, sorted by descending lifetime

Specie		Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
η	(1295)	0.055	1.205×10^{-11}	3.612×10^{-13}
Ω^-	(2250)	0.055	1.205×10^{-11}	3.612×10^{-13}
Ξ^0	(1950)	0.06	1.104×10^{-11}	3.311×10^{-13}
f_0	(980)	0.06	1.104×10^{-11}	3.311×10^{-13}
Λ	(1690)	0.06	1.104×10^{-11}	3.311×10^{-13}
Ξ^-	(1950)	0.06	1.104×10^{-11}	3.311×10^{-13}
Σ^0	(1670)	0.06	1.104×10^{-11}	3.311×10^{-13}
Σ^+	(1670)	0.06	1.104×10^{-11}	3.311×10^{-13}
Σ^-	(1670)	0.06	1.104×10^{-11}	3.311×10^{-13}
ϒ	(11020)	0.061	1.086×10^{-11}	3.256×10^{-13}
ψ	(4415)	0.062	1.069×10^{-11}	3.204×10^{-13}
ψ	(4160)	0.07	9.466×10^{-12}	2.838×10^{-13}
f_2'	(1525)	0.073	9.077×10^{-12}	2.721×10^{-13}
a_0	(980)	0.075	8.835×10^{-12}	2.649×10^{-13}
a_0^+	(980)	0.075	8.835×10^{-12}	2.649×10^{-13}
ψ	(4040)	0.08	8.283×10^{-12}	2.483×10^{-13}
Λ	(1820)	0.08	8.283×10^{-12}	2.483×10^{-13}
η	(1475)	0.085	7.795×10^{-12}	2.337×10^{-13}
φ_3	(1850)	0.087	7.616×10^{-12}	2.283×10^{-13}
K_1^+	(1270)	0.09	7.362×10^{-12}	2.207×10^{-13}
Σ^0	(1750)	0.09	7.362×10^{-12}	2.207×10^{-13}
Σ^+	(1750)	0.09	7.362×10^{-12}	2.207×10^{-13}
Σ^-	(1750)	0.09	7.362×10^{-12}	2.207×10^{-13}
K_1^0	(1270)	0.09	7.362×10^{-12}	2.207×10^{-13}
Λ	(1830)	0.095	6.975×10^{-12}	2.091×10^{-13}
K_2^{*+}	(1430)	0.0985	6.727×10^{-12}	2.017×10^{-13}
Σ^0	(1660)	0.1	6.626×10^{-12}	1.986×10^{-13}
Σ^-	(1660)	0.1	6.626×10^{-12}	1.986×10^{-13}
N^+	(1710)	0.1	6.626×10^{-12}	1.986×10^{-13}
N	(1710)	0.1	6.626×10^{-12}	1.986×10^{-13}
Λ	(1890)	0.1	6.626×10^{-12}	1.986×10^{-13}
Σ^+	(1660)	0.1	6.626×10^{-12}	1.986×10^{-13}
a_2^+	(1320)	0.107	6.193×10^{-12}	1.856×10^{-13}
a_2	(1320)	0.107	6.193×10^{-12}	1.856×10^{-13}
K_2^*	(1430)	0.109	6.079×10^{-12}	1.822×10^{-13}
f_0	(1500)	0.109	6.079×10^{-12}	1.822×10^{-13}
N^+	(1520)	0.115	5.762×10^{-12}	1.727×10^{-13}
N	(1520)	0.115	5.762×10^{-12}	1.727×10^{-13}
Δ^{++}	(1232)	0.117	5.663×10^{-12}	1.698×10^{-13}
Δ^+	(1232)	0.117	5.663×10^{-12}	1.698×10^{-13}
Δ^0	(1232)	0.117	5.663×10^{-12}	1.698×10^{-13}
Δ^-	(1232)	0.117	5.663×10^{-12}	1.698×10^{-13}
Σ^0	(1915)	0.12	5.522×10^{-12}	1.655×10^{-13}
Σ^+	(1775)	0.12	5.522×10^{-12}	1.655×10^{-13}
Σ^0	(1775)	0.12	5.522×10^{-12}	1.655×10^{-13}
Σ^+	(1915)	0.12	5.522×10^{-12}	1.655×10^{-13}
Σ^-	(1775)	0.12	5.522×10^{-12}	1.655×10^{-13}
Σ^-	(1915)	0.12	5.522×10^{-12}	1.655×10^{-13}
N^+	(1680)	0.13	5.097×10^{-12}	1.528×10^{-13}
N	(1680)	0.13	5.097×10^{-12}	1.528×10^{-13}
f_0	(1710)	0.139	4.767×10^{-12}	1.429×10^{-13}
Δ^+	(1620)	0.14	4.733×10^{-12}	1.419×10^{-13}
Δ^{++}	(1620)	0.14	4.733×10^{-12}	1.419×10^{-13}

Table A.1: Width (Γ), and mean proper lifetime (τ) of various particles, sorted by descending lifetime

Specie		Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
Δ^-	(1620)	0.14	4.733×10^{-12}	1.419×10^{-13}
Δ^0	(1620)	0.14	4.733×10^{-12}	1.419×10^{-13}
N^+	(1650)	0.14	4.733×10^{-12}	1.419×10^{-13}
N	(1650)	0.14	4.733×10^{-12}	1.419×10^{-13}
b_1	(1235)	0.142	4.666×10^{-12}	1.399×10^{-13}
b_1^+	(1235)	0.142	4.666×10^{-12}	1.399×10^{-13}
ρ^0	(770)	0.1491	4.444×10^{-12}	1.332×10^{-13}
ρ^+	(770)	0.1491	4.444×10^{-12}	1.332×10^{-13}
Λ	(1600)	0.15	4.417×10^{-12}	1.324×10^{-13}
φ	(1680)	0.15	4.417×10^{-12}	1.324×10^{-13}
Λ	(1810)	0.15	4.417×10^{-12}	1.324×10^{-13}
N^+	(1700)	0.15	4.417×10^{-12}	1.324×10^{-13}
N	(1700)	0.15	4.417×10^{-12}	1.324×10^{-13}
N^+	(1675)	0.15	4.417×10^{-12}	1.324×10^{-13}
N	(1675)	0.15	4.417×10^{-12}	1.324×10^{-13}
N^+	(1535)	0.15	4.417×10^{-12}	1.324×10^{-13}
N	(1535)	0.15	4.417×10^{-12}	1.324×10^{-13}
f_2	(2300)	0.15	4.417×10^{-12}	1.324×10^{-13}
K_3^*	(1780)	0.159	4.167×10^{-12}	1.249×10^{-13}
K_3^{*+}	(1780)	0.159	4.167×10^{-12}	1.249×10^{-13}
ρ_3^+	(1690)	0.161	4.116×10^{-12}	1.234×10^{-13}
ρ_3^0	(1690)	0.161	4.116×10^{-12}	1.234×10^{-13}
ω_3	(1670)	0.168	3.944×10^{-12}	1.182×10^{-13}
K_1^0	(1400)	0.174	3.808×10^{-12}	1.142×10^{-13}
K_1^+	(1400)	0.174	3.808×10^{-12}	1.142×10^{-13}
Σ^-	(2030)	0.18	3.681×10^{-12}	1.104×10^{-13}
Σ^0	(2030)	0.18	3.681×10^{-12}	1.104×10^{-13}
Σ^+	(2030)	0.18	3.681×10^{-12}	1.104×10^{-13}
η_2	(1645)	0.181	3.661×10^{-12}	1.097×10^{-13}
K_2^+	(1770)	0.186	3.562×10^{-12}	1.068×10^{-13}
K_2^0	(1770)	0.186	3.562×10^{-12}	1.068×10^{-13}
f_2	(1270)	0.1867	3.549×10^{-12}	1.064×10^{-13}
K_4^{*+}	(2045)	0.198	3.346×10^{-12}	1.003×10^{-13}
K_4^*	(2045)	0.198	3.346×10^{-12}	1.003×10^{-13}
Λ	(2100)	0.2	3.313×10^{-12}	9.932×10^{-14}
f_2	(2010)	0.2	3.313×10^{-12}	9.932×10^{-14}
Λ	(2110)	0.2	3.313×10^{-12}	9.932×10^{-14}
π^0	(1800)	0.208	3.186×10^{-12}	9.55×10^{-14}
π^+	(1800)	0.208	3.186×10^{-12}	9.55×10^{-14}
ω	(1420)	0.215	3.082×10^{-12}	9.239×10^{-14}
Σ^+	(1940)	0.22	3.012×10^{-12}	9.029×10^{-14}
Σ^0	(1940)	0.22	3.012×10^{-12}	9.029×10^{-14}
Σ^-	(1940)	0.22	3.012×10^{-12}	9.029×10^{-14}
$K*$	(1410)	0.232	2.856×10^{-12}	8.562×10^{-14}
$K*^+$	(1410)	0.232	2.856×10^{-12}	8.562×10^{-14}
f_4	(2050)	0.237	2.796×10^{-12}	8.382×10^{-14}
π_1^+	(1600)	0.24	2.761×10^{-12}	8.277×10^{-14}
π_1^0	(1600)	0.24	2.761×10^{-12}	8.277×10^{-14}
ρ^+	(1700)	0.25	2.65×10^{-12}	7.946×10^{-14}
ρ^0	(1700)	0.25	2.65×10^{-12}	7.946×10^{-14}
N	(1720)	0.25	2.65×10^{-12}	7.946×10^{-14}
N^+	(1720)	0.25	2.65×10^{-12}	7.946×10^{-14}
a_4^+	(2040)	0.257	2.578×10^{-12}	7.729×10^{-14}

Table A.1: Width (Γ), and mean proper lifetime (τ) of various particles, sorted by descending lifetime

Specie		Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
a_4	(2040)	0.257	2.578×10^{-12}	7.729×10^{-14}
π_2^+	(1670)	0.26	2.548×10^{-12}	7.64×10^{-14}
Δ^0	(1920)	0.26	2.548×10^{-12}	7.64×10^{-14}
Δ^-	(1920)	0.26	2.548×10^{-12}	7.64×10^{-14}
π_2^0	(1670)	0.26	2.548×10^{-12}	7.64×10^{-14}
Δ^{++}	(1920)	0.26	2.548×10^{-12}	7.64×10^{-14}
Δ^+	(1920)	0.26	2.548×10^{-12}	7.64×10^{-14}
a_0	(1450)	0.265	2.5×10^{-12}	7.496×10^{-14}
a_0^+	(1450)	0.265	2.5×10^{-12}	7.496×10^{-14}
D_0^*	(2400)	0.27	2.454×10^{-12}	7.357×10^{-14}
K_0^*	(1430)	0.27	2.454×10^{-12}	7.357×10^{-14}
K_0^{*+}	(1430)	0.27	2.454×10^{-12}	7.357×10^{-14}
D_0^{*+}	(2400)	0.27	2.454×10^{-12}	7.357×10^{-14}
K_2^+	(1820)	0.276	2.401×10^{-12}	7.197×10^{-14}
K_2^0	(1820)	0.276	2.401×10^{-12}	7.197×10^{-14}
Δ^+	(1950)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^{++}	(1950)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^-	(1910)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^0	(1950)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^{++}	(1910)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^+	(1910)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^-	(1950)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^0	(1910)	0.28	2.366×10^{-12}	7.094×10^{-14}
Δ^{++}	(1700)	0.3	2.209×10^{-12}	6.621×10^{-14}
Δ^+	(1700)	0.3	2.209×10^{-12}	6.621×10^{-14}
Δ^0	(1700)	0.3	2.209×10^{-12}	6.621×10^{-14}
Δ^-	(1700)	0.3	2.209×10^{-12}	6.621×10^{-14}
Λ	(1800)	0.3	2.209×10^{-12}	6.621×10^{-14}
ω	(1650)	0.315	2.104×10^{-12}	6.306×10^{-14}
Δ^+	(1600)	0.32	2.071×10^{-12}	6.208×10^{-14}
$K*$	(1680)	0.32	2.071×10^{-12}	6.208×10^{-14}
$K*^+$	(1680)	0.32	2.071×10^{-12}	6.208×10^{-14}
f_2	(2340)	0.32	2.071×10^{-12}	6.208×10^{-14}
Δ^{++}	(1600)	0.32	2.071×10^{-12}	6.208×10^{-14}
Δ^-	(1600)	0.32	2.071×10^{-12}	6.208×10^{-14}
Δ^0	(1600)	0.32	2.071×10^{-12}	6.208×10^{-14}
Δ^-	(1905)	0.33	2.008×10^{-12}	6.02×10^{-14}
π_1^0	(1400)	0.33	2.008×10^{-12}	6.02×10^{-14}
π_1^+	(1400)	0.33	2.008×10^{-12}	6.02×10^{-14}
Δ^0	(1905)	0.33	2.008×10^{-12}	6.02×10^{-14}
Δ^+	(1905)	0.33	2.008×10^{-12}	6.02×10^{-14}
Δ^{++}	(1905)	0.33	2.008×10^{-12}	6.02×10^{-14}
f_0	(1370)	0.35	1.893×10^{-12}	5.676×10^{-14}
N^+	(1440)	0.35	1.893×10^{-12}	5.676×10^{-14}
N	(1440)	0.35	1.893×10^{-12}	5.676×10^{-14}
Δ^{++}	(1930)	0.36	1.841×10^{-12}	5.518×10^{-14}
Δ^+	(1930)	0.36	1.841×10^{-12}	5.518×10^{-14}
Δ^0	(1930)	0.36	1.841×10^{-12}	5.518×10^{-14}
Δ^-	(1930)	0.36	1.841×10^{-12}	5.518×10^{-14}
h_1	(1170)	0.36	1.841×10^{-12}	5.518×10^{-14}
ρ^+	(1450)	0.4	1.657×10^{-12}	4.966×10^{-14}
ρ^0	(1450)	0.4	1.657×10^{-12}	4.966×10^{-14}
π^+	(1300)	0.4	1.657×10^{-12}	4.966×10^{-14}

Table A.1: Width (Γ), and mean proper lifetime (τ) of various particles, sorted by descending lifetime

Specie		Width Γ (GeV)	Mean proper lifetime τ (ps)	(cm/c)
π^0	(1300)	0.4	1.657×10^{-12}	4.966×10^{-14}
a_1^+	(1260)	0.42	1.578×10^{-12}	4.73×10^{-14}
a_1	(1260)	0.42	1.578×10^{-12}	4.73×10^{-14}
f_2	(1950)	0.472	1.404×10^{-12}	4.209×10^{-14}
N^+	(2190)	0.5	1.325×10^{-12}	3.973×10^{-14}
N	(2190)	0.5	1.325×10^{-12}	3.973×10^{-14}
f_0	(500)	0.55	1.205×10^{-12}	3.612×10^{-14}
t		1.41	4.699×10^{-13}	1.409×10^{-14}
H		1.7	3.898×10^{-13}	1.168×10^{-14}
W^+		2.085	3.178×10^{-13}	9.527×10^{-15}
Z^0		2.495	2.656×10^{-13}	7.961×10^{-15}

Table A.1: Width (Γ), and mean proper lifetime (τ) of various particles, sorted by descending lifetime

B LaTeX code of the definition

The definition given in Sect. 1 can be typeset in LaTeX using the code below

```
A primary particle is a particle with a mean proper lifetime $\tau$
larger than $1\,\mathrm{cm\kern-.03em/\kern-.05em c}$, which is
either a) produced directly in the interaction, or b) from decays of
particles with $\tau$ smaller than
$1\,\mathrm{cm\kern-.03em/\kern-.05em c}$, restricted to decay
chains leading to the interaction.
```

The additional "kerning" used is to make the unit more compact and appear as a single entity. The spacing macro `\,` can be avoid if the units package is used.

C Rivet projection

The code below[3] implements a Rivet [11] projection to project out primary particles according to the definition.

```
#ifndef ALICEPRIMARY_CC
#define ALICEPRIMARY_CC
#include <Rivet/Particle.hh>
#include <Rivet/Event.hh>
#include <Rivet/Tools/ParticleIdUtils.hh>
#include <Rivet/Projections/ParticleFinder.hh>
#include <Rivet/ParticleName.hh>
#include <Rivet/Tools/Cuts.hh>
#include <HepMC/GenParticle.h>
#include <HepMC/GenVertex.h>

namespace Rivet
{
  /**
   * A Rivet projection that projects out primary particles - according
   * to the ALICE definition - from an event.  The projection filters
   * all charge states.  If one needs to have only charged particles
   * one need to apply another projection on top of this one.
   *
   * This version is for Rivet version 2 and higher, which allows for
   * the use of a Cut class and the base class ParticleFinder.
   */
  class AlicePrimary : public ParticleFinder
  {
  public:
    /**
     * Consturctor
     * @param cut If specified, use this cut when projecting
     * @param pdg If specified, check for this PDG rather than long-lived
     */
    AlicePrimary(const Cut& c=Cuts::open(),int pdg)
      : ParticleFinder(c), _pdg(pdg)
    {
      setName("AlicePrimary");
    }
    /**
     * Copy constructor
     *
     * @param o Object to copy from
     */
    AlicePrimary(const AlicePrimary& o) : ParticleFinder(o),_pdg(o._pdg) {}
    /**
     * Destructor
     */
    virtual ~AlicePrimary() {}
    /**
     * @{
     * @name Projection interface
     */
    /**
     * Clone this projection object
     *
     * @return Copy of this projection object allocated on the heap
     */
```

[3]The code presented here is for Rivet version 2 or higher. For earlier version minor changes has to be done. Current implementation can also be found at https://gitlab.cern.ch/cholm/alice-rivet.

```
virtual std::unique_ptr<Projection> clone() const
{
  return std::unique_ptr<Projection>(new AlicePrimary(*this));
}
/**
 * Compare this projection to some other projection.  If the other
 * projection is also a AlicePrimary projection, then return @c 0,
 * otherwise @c -1.
 *
 * @param p Projection to compare to
 *
 * @return 0 if @a p is an AlicePrimary, @c -1 otherwise
 */
virtual int compare(const Projection& p) const
{
  const AlicePrimary* o = dynamic_cast<const AlicePrimary*>(&p);
  if (!o || o->_pdg != _pdg) return UNDEFINED;
  return _cuts == o->_cuts ? EQUIVALENT : UNDEFINED;
}
/**
 * Project out the primary particles of the passed event record @a
 * e.  This is the interface that does the actual projection.
 *
 * @param e Event record.
 */
virtual void project(const Event& e)
{
  _theParticles.clear(); // Clear cache
  bool open = _cuts == Cuts::open();
  for (auto p : Rivet::particles(e.genEvent())) {
    if (isPrimary(p,_pdg) && (open || _cuts->accept(Particle(p))))
      _theParticles.push_back(Particle(*p));
  }
}
/* @} */
/**
 * @{
 * @name Internal functions used
 */
/**
 * Check if a particle is a primary according to the ALICE
 * definition.
 *
 * @param p Particle to test
 *
 * @return true if the particle is considered a primary, false
 * otherwise.
 */
static bool isPrimary(const HepMC::GenParticle* p)
{
  if       (_pdg != 0 && p->pdg_id() != pdg) return false;
  else if (!isLongLived(p)) return false;
  if (!(isPrompt(p) || isDecay(p))) return false;

  const HepMC::GenParticle* m = p;
  while ((m = ancestor(m))) {
    if (m->status() == 4) return true; // found beam
    if (isLongLived(m)) return false;
    if (!(isDecay(m) || isDecau(m))) return false;
  }
  return true;
}
```

```
/**
 * Check if a particle is of a long-lived (i.e., @f$ \tau>1cm@f$)
 * species.
 *
 * @param p Particle to test
 *
 * @return true if the particle is of a long-lived species
 */
static bool isLongLived(const HepMC::GenParticle* p)
{
  int pdg = PID::abspid(p->pdg_id());
  // Check for nuclus
  if (pdg > 1000000000) return true;

  switch (pdg) {
  case Rivet::PID::MUON:
  case Rivet::PID::ELECTRON:
  case Rivet::PID::GAMMA:
  case Rivet::PID::PIPLUS:
  case Rivet::PID::KPLUS:
  case Rivet::PID::K0S:
  case Rivet::PID::K0L:
  case Rivet::PID::PROTON:
  case Rivet::PID::NEUTRON:
  case Rivet::PID::LAMBDA:
  case Rivet::PID::SIGMAMINUS:
  case Rivet::PID::SIGMAPLUS:
  case Rivet::PID::XIMINUS:
  case Rivet::PID::XI0:
  case Rivet::PID::OMEGAMINUS:
  case Rivet::PID::NU_E:
  case Rivet::PID::NU_MU:
  case Rivet::PID::NU_TAU:
    return true;
  }
  return false;
}
/**
 * Check if this is prompt
 *
 * @param p Particle to test
 *
 * @return true if the particle has no ancestors, or from a
 * quark or gluon. Some EGs (e.g., Pythia8) records the full
 * event tree, so we check if this has indeed been hadronised.
 */
static bool isPrompt(const HepMC::GenParticle* p)
{
  // Get mother
  const HepMC::GenParticle* m = ancestor(p);
  // If no mother, this is prompt
  if (!m) return true;
  // If mother is a quark or a gluon, consider daughter to be
  // prompt, irrespective of the generation status code - Pythia8,
  // for example, exports the full chain with "funny" status codes
  int mpdg = PID::abspid(m->pdg_id());
  switch (mpdg) {
  case Rivet::PID::DQUARK:
  case Rivet::PID::UQUARK:
  case Rivet::PID::SQUARK:
  case Rivet::PID::CQUARK:
  case Rivet::PID::BQUARK:
```

```
      case Rivet::PID::TQUARK:
      case Rivet::PID::GLUON:
        return true;
      }
      return m->status() == 4; // Check mother is beam
    }
    /**
     * Check if a particle is either produced in a decay (@c
     * status=2)
     *
     * @param p Particle to test
     *
     * @return true if either produced in the interaction or through
     * some decay
     */
    static bool isDecay(const HepMC::GenParticle* p)
    {
      // Get mother
      const HepMC::GenParticle* m = ancestor(p);
      // No mother, so prompt
      if (!m) return true;
      int mstatus = m->status();
      // true if mother decayed or mother is beam particle
      return mstatus == 2;
    }
    /**
     * Get the immediate ancestor of a particle
     *
     * @param p The particle to get the ancestor for
     *
     * @return Ancestor particle or null
     */
    static const HepMC::GenParticle* ancestor(const HepMC::GenParticle* p)
    {
      const HepMC::GenVertex* vtx = p->production_vertex();
      if (!vtx) return 0;
      HepMC::GenVertex::particles_in_const_iterator i =
        vtx->particles_in_const_begin();
      if (i == vtx->particles_in_const_end()) return 0;
      return *i;
    }
    /* @} */
  };
}
#endif
//
// EOF
//
```

Note, the projection `AlicePrimary` and `FinalState` are generally *not* equivalent.

To use this projection in an analysis, one should do

```
#include <Rivet/Projections/AlicePrimary.hh>
#include <Rivet/Analysis.hh>

namespace Rivet
{
  class AliceAnalysis : public Analysis
  {
  public:
    AliceAnalysis() {}
```

```
    void init()
    {
      const AlicePrimary ap;
      addProjection(ap, "AP");
    }
    void analyse(const Event& event)
    {
      const AlicePrimary& ap = applyProjection<AlicePrimary>(event,"AP");
      // Loop over primaries - optionally pass a cut object to
      // AlicePrimary::particles
      for (auto p : ap.particles()) {
        // Process particle p of type Rivet::Particle&
      }
    }
  };
  DECLARE_RIVET_PLUGIN(AliceAnalysis);
}
```

D Code

The code below checks if a particle is considered long-lived, i.e., has a proper lifetime $\tau > 1\,\mathrm{cm}/c$. If so, it returns `true`, otherwise `false`.

```
Bool_t IsStable(const TParticle* p, Bool_t def=false) const
{
  if (!p) return def;
  Int_t pdg = TMath::Abs(p->GetPdgCode());
  // Check for nuclus
  if (pdg > 1000000000) return true;

  Int_t stable[] = {
    kGamma,             // 22   Photon
    kElectron,          // 11   Electron
    kMuonMinus,         // 13   Muon
    kPiPlus,            // 211  Pion
    kKPlus,             // 321  Kaon
    kK0Short,           // 310  K0s
    kK0Long,            // 130  K0l
    kProton,            // 2212 Proton
    kNeutron,           // 2112 Neutron
    kLambda0,           // 3122 Lambda_0
    kSigmaMinus,        // 3112 Sigma Minus
    kSigmaPlus,         // 3222 Sigma Plus
    kXiMinus,           // 3312 Xi Minus
    3322,               //      Xi 0
    kOmegaMinus,        // 3334 Omega
    kNuE,               // 12   Electron Neutrino
    kNuMu,              // 14   Muon Neutrino
    kNuTau,             // 16   Tau Neutrino
    -1
  };
  Int_t* ptr = stable;
  while ((*ptr) >= 0) {
    if (pdg == *ptr) return true;
    ptr++;
  }
  return false;
}
```

The following code checks if the particle production mechanism either corresponds to production in the interaction or a decay. The ALICE simulation framework stores the production identifier in the field accessed by `GetUniqueID()` of the `TParticle` objects.

```
Bool_t IsPrimaryProcess(TParticle* p) const
{
  switch (p->GetUniqueID()) {
  case kPDecay:
  case kPNoProcess:
  case kPNull:
  case kPPrimary:
    return true;
  }
  return false;
}
```

Finally, we have the code that checks if a given particle is a primary. The argument of type `AliStack` gives access to the full particle history of an event in the ALICE simulation framework.

```
Bool_t IsFirstStable(AliStack* stack, Int_t iTr)
{
  TParticle* p = stack->Particle(iTr);
  // Check if this particle is stable
  if (!IsStable(p)) return false;
  if (!IsPrimaryProcess(p)) return false;
  TParticle* m  = p;
  Int_t      mi = 0;
  while ((mi = m->GetFirstMother()) >= 0) {
    m = stack->Particle(mi);
    // If there's no mother, break out
    if (!m) break;
    // If (grand)mother particle is stable, this is not primary
    if (IsStable(m)) return false;
    // If (grand)mother was produced neither in a decay nor directly
    // in the interaction (e.g., material interaction), then this
    // particle is not a primary.
    if (!IsPrimaryProcess(m)) return false;
  }
  // If we get here, then no (grand)mother was long-lived, and was
  // either produced in a decay or directly in the interaction
  return true;
}
```

To facilitate faster look-up, one may code up the above flagging particles as we search through the decay chains

```
TParticle  MarkPrimary(TParticle* p, Bool_t primary)
{
   p->SetBit(kPrimarySet);
   if (primary) p->SetBit(kPrimaryBit);
   else         p->ClearBit(kPrimaryBit);
   return p;
}
Bool_t IsFirstStable(AliStack* stack, Int_t iTr)
{
  TParticle* p = stack->Particle(iTr);
  if (p->Testbit(kPrimarySet)) return p->TestBit(kPrimaryBit);
  // Check if this particle is stable
  if (!IsStable(p) || !IsPrimaryProcess(p)) {
    MarkPrimary(p, false);
    return false;
```

```
    }
    TParticle* m  = p;
    Int_t      mi = 0;
    while ((mi = m->GetFirstMother()) >= 0) {
      m = stack->Particle(mi);
      // If there's no mother, break out
      if (!m) break;
      // If (grand)mother was flagged as primary, then this is not
      if ((m->Testbit(kPrimarySet) &&
           m->TestBit(kPrimaryBit))) {
        MarkPrimary(p, false);
        return false;
      }
      // If (grand)mother is long-lived or her production mechanism is
      // neither a decay nor the primary interaction (e.g., scattering
      // in material), then this particle is not primary
      if (IsStable(m) || !IsPrimaryProcess(m)) {
        MarkPrimary(p, false);
        return false;
      }
      // (Grand)mother is not a primary, mark it as such
      MarkPrimary(m,false);
    }
    // If we get here, then all (grand)mothers was neither long-lived,
    // nor produced in by any means but decays or in the primary
    // interaction. Thus, we have a primary particle
    MarkPrimary(m,true);
    return true;
  }
```

In this way, we do not need to fully traverse most of the decay chains.

E ALICE Collaboration

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