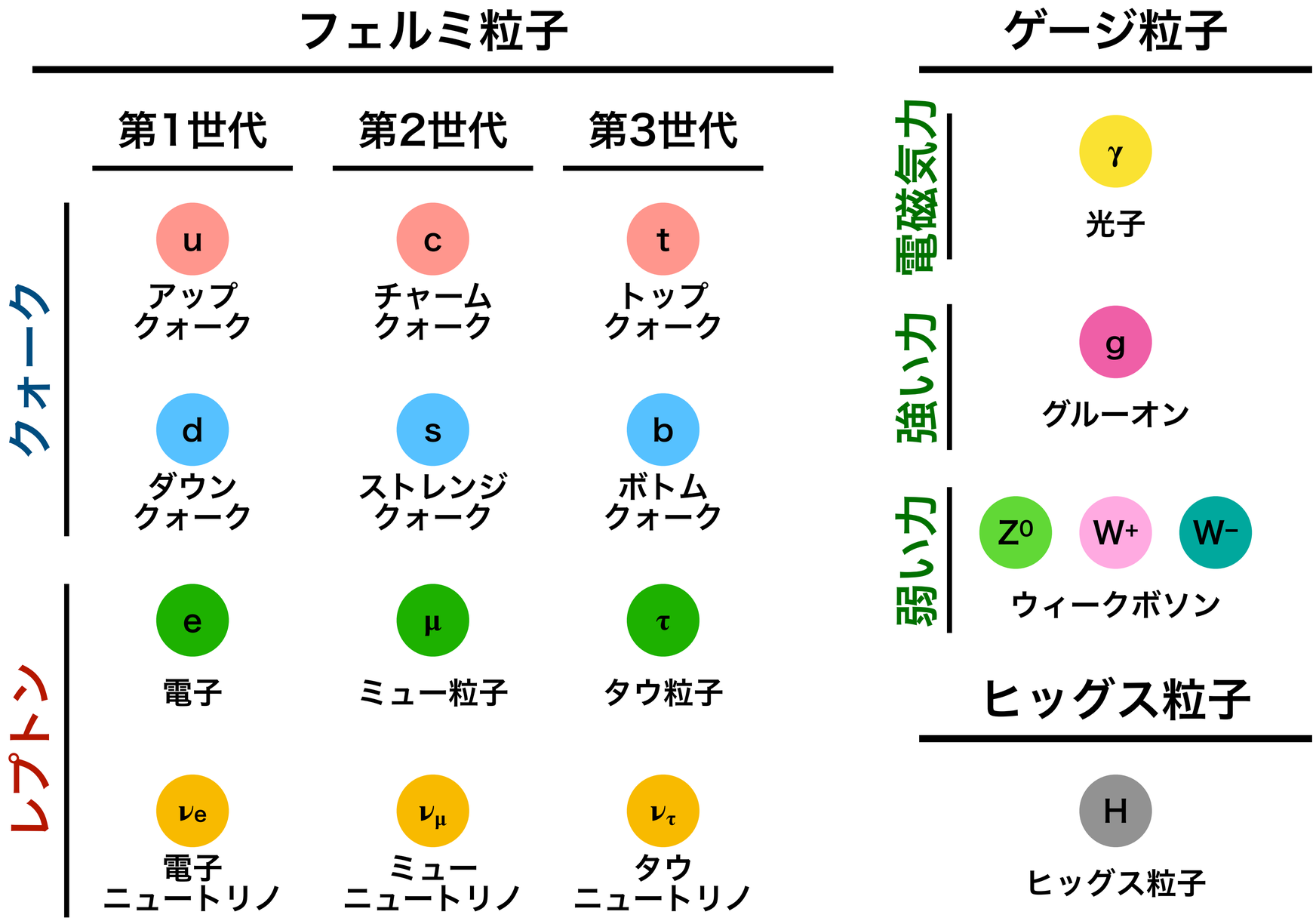
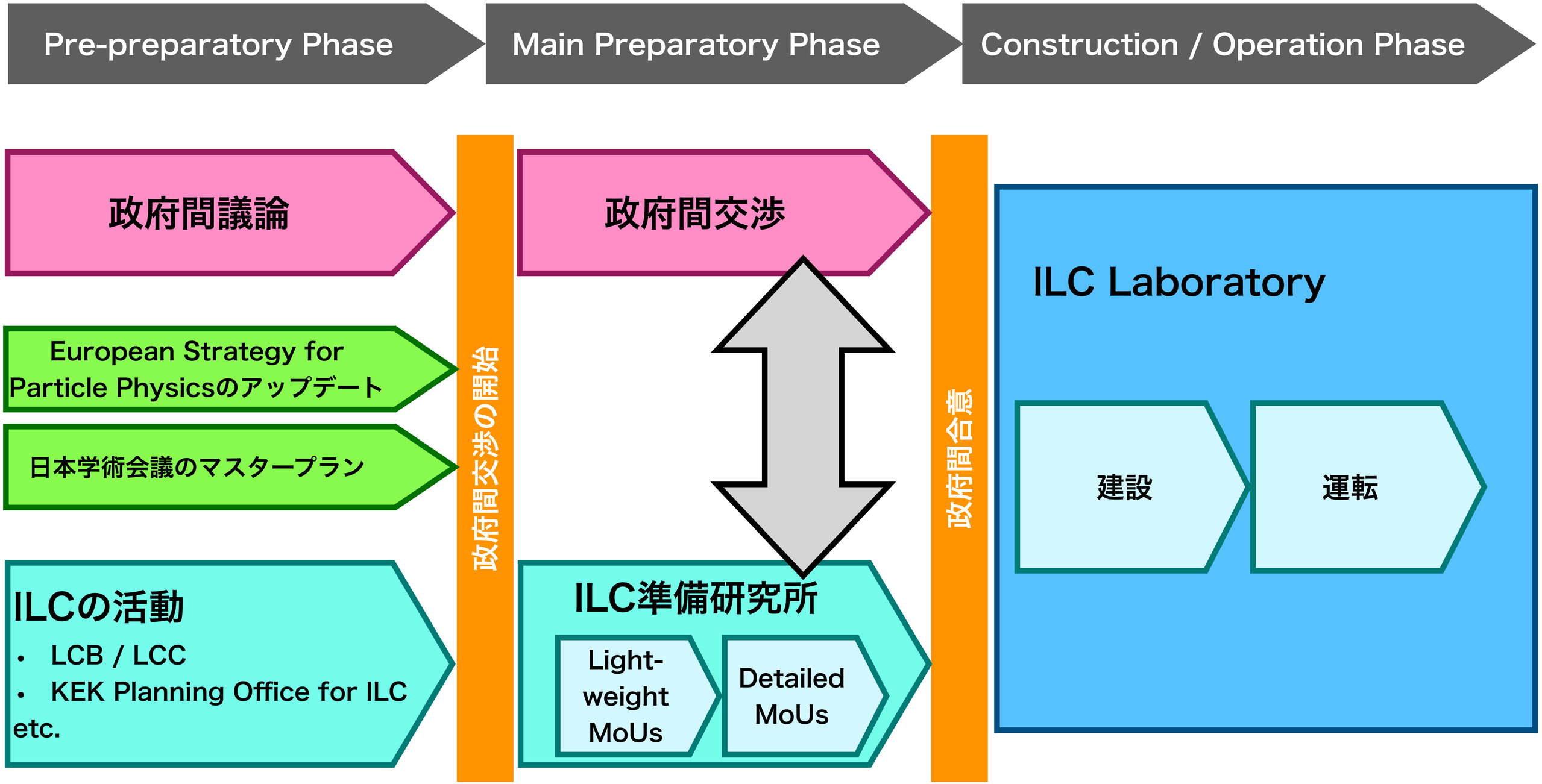
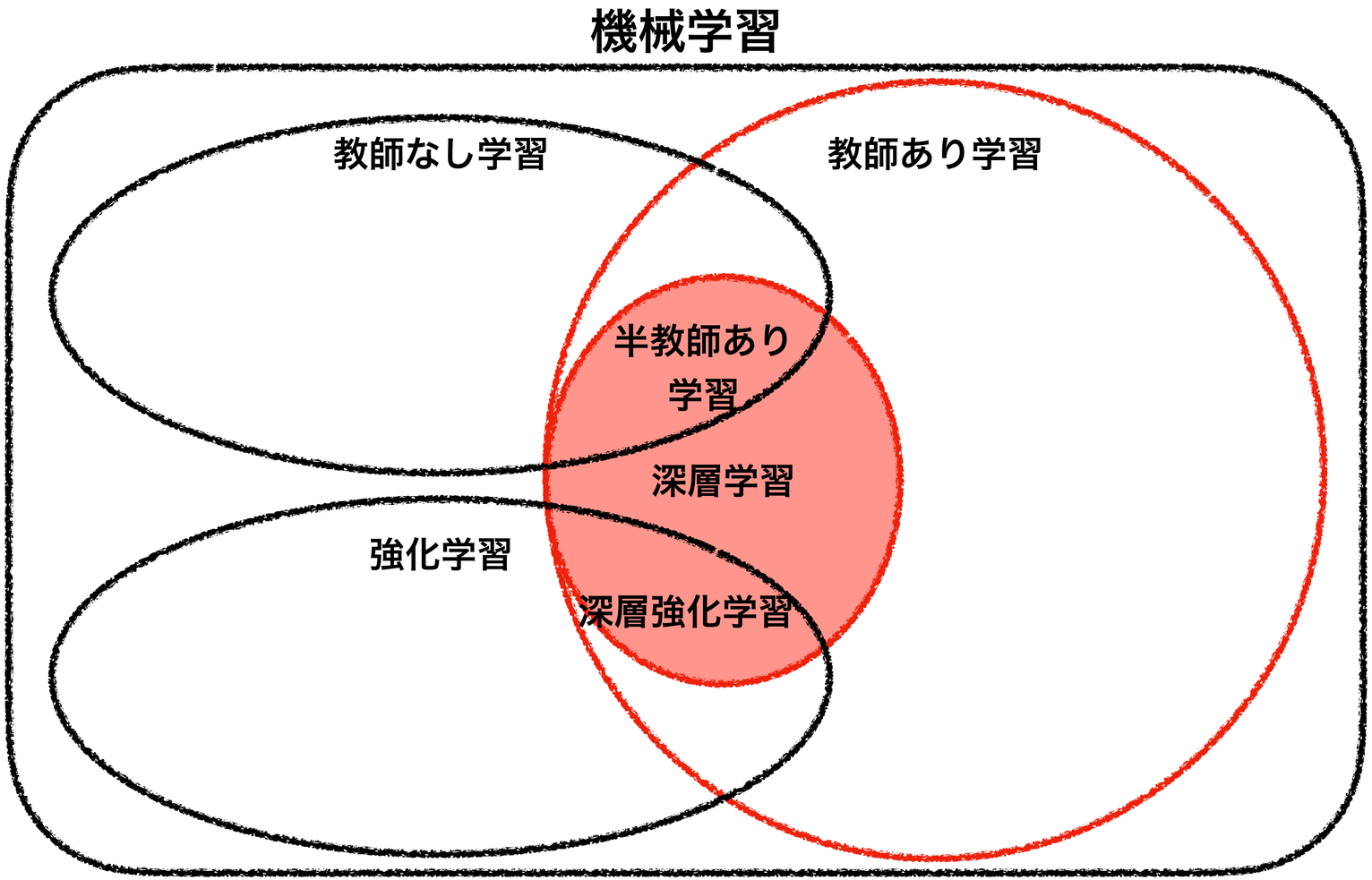
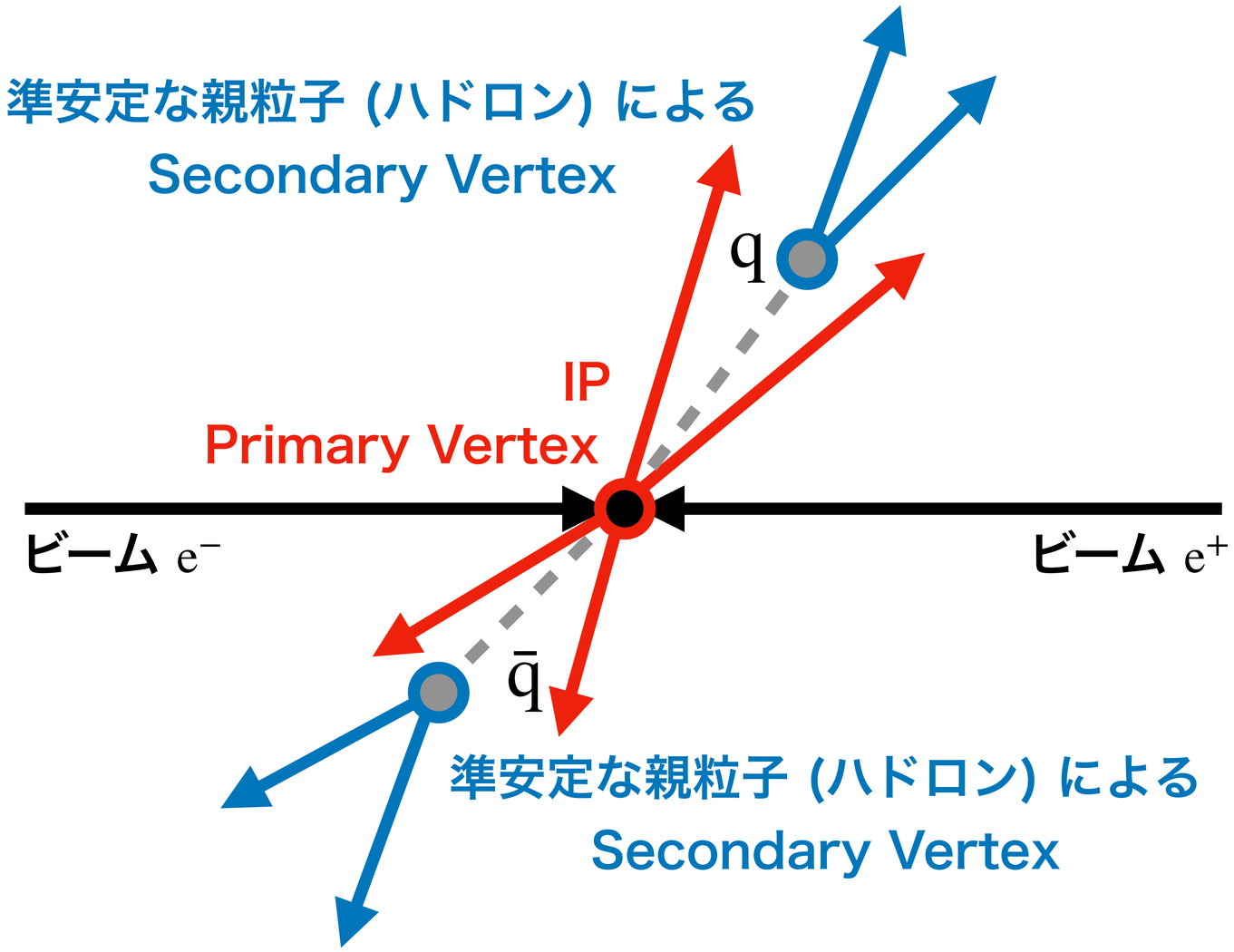
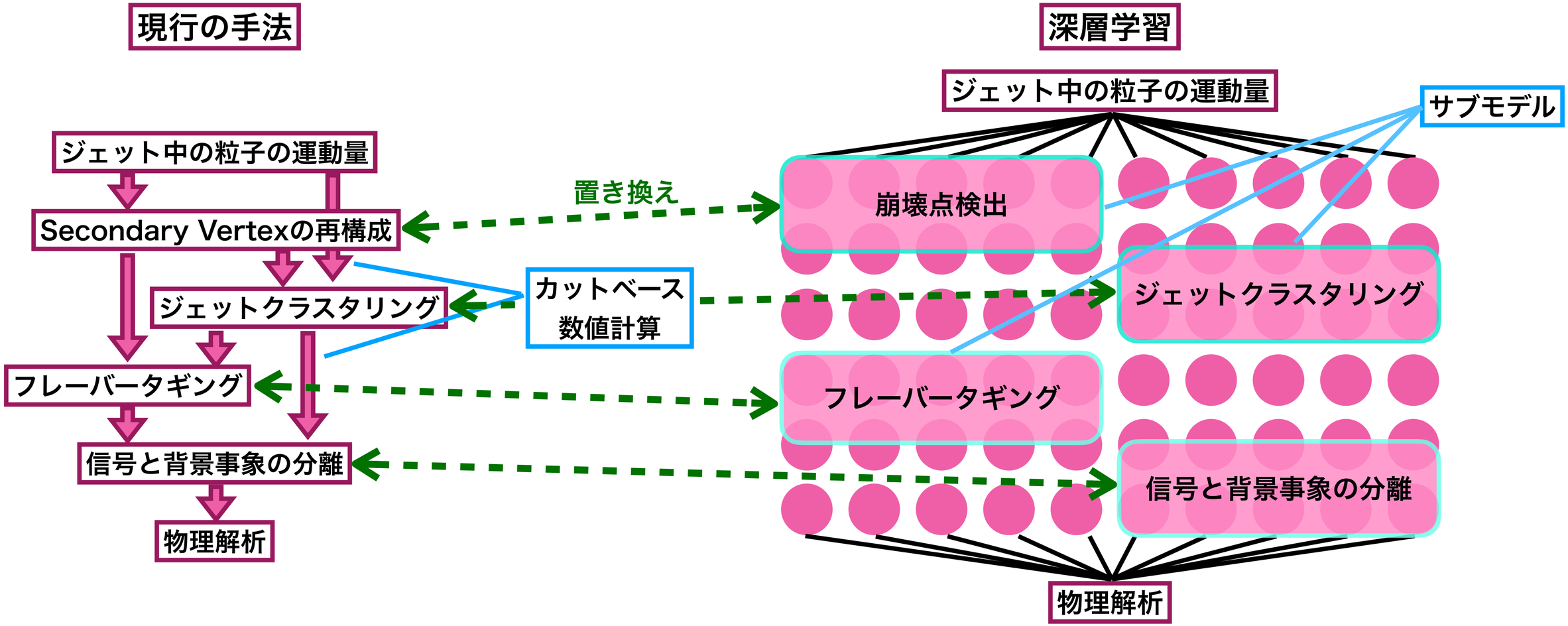
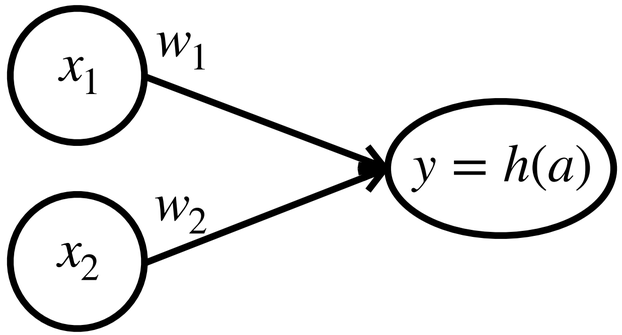

フェルミ粒子
第1世代
第2世代
第3世代
クォーク
u
アップ
クォーク
c
チャーム
クォーク
t
トップ
クォーク
d
ダウン
クォーク
s
ストレンジ
クォーク
b
ボトム
クォーク
レプトン
e
電子
μ
ミュー粒子
τ
タウ粒子
νe
電子
ニュートリノ
νμ
ミュー
ニュートリノ
ντ
タウ
ニュートリノ
ゲージ粒子
電磁気力
γ
光子
強い力
g
グルーオン
弱い力
Z0
W+
W−
ウィークボソン
ヒッグス粒子
H
ヒッグス粒子

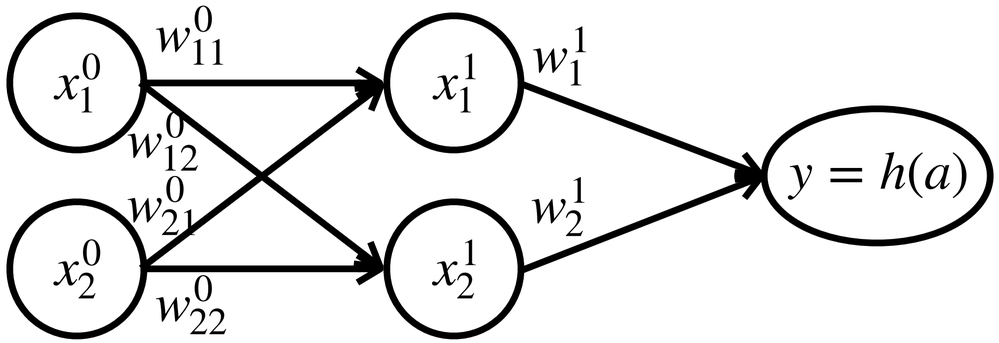

Pre-preparatory Phase
Main Preparatory Phase
Construction / Operation Phase
政府間議論
European Strategy for Particle Physicsのアップデート
日本学術会議のマスタープラン
ILCの活動
• LCB / LCC
• KEK Planning Office for ILC
etc.
政府間交渉の開始
政府間交渉
ILC準備研究所
Light-weight MoUs
Detailed MoUs
政府間合意
ILC Laboratory
建設
運転


機械学習
教師なし学習
教師あり学習
半教師あり
学習
深層学習
強化学習
深層強化学習

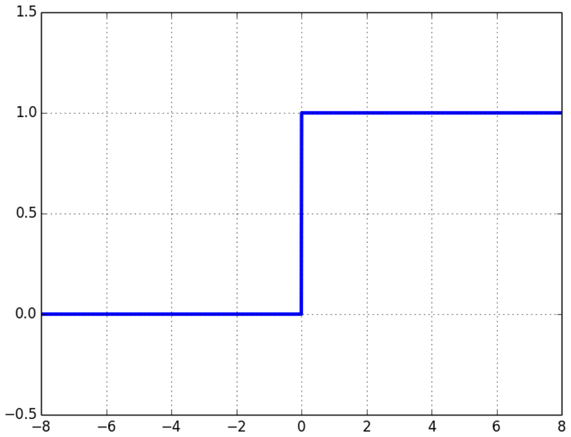

準安定な親粒子 (ハドロン) による
Secondary Vertex
q
IP
Primary Vertex
ビーム e^-
ビーム e^+
$\bar{q}$
準安定な親粒子 (ハドロン) による
Secondary Vertex


現行の手法
ジェット中の粒子の運動量
Secondary Vertexの再構成
ジェットクラスタリング
フレーバータギング
信号と背景事象の分離
物理解析
置き換え
カットベース
数値計算
深層学習
ジェット中の粒子の運動量
サブモデル
崩壊点検出
ジェットクラスタリング
フレーバータギング
信号と背景事象の分離
物理解析

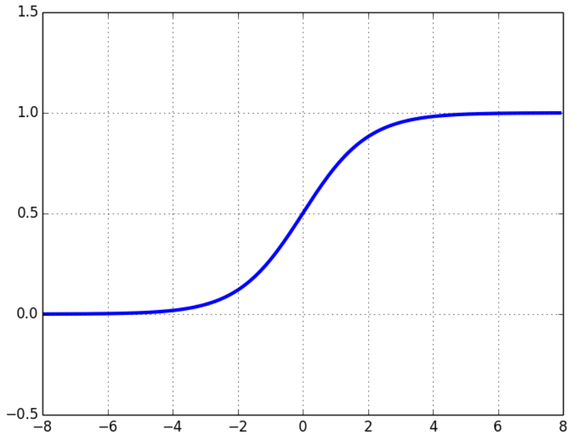

x_1
w_1
x_2
w_2
$y = h(a)$


x_1^0
x_2^0
w_{11}^0
w_{12}^0
w_{21}^0
w_{22}^0
x_1^1
x_2^1
w_1^1
w_2^1
$y = h(a)$

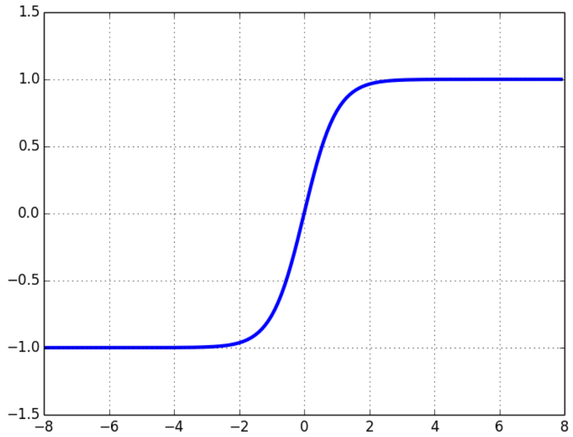
階段関数



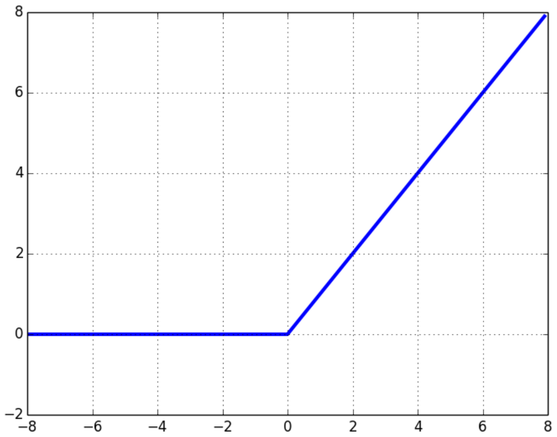
シグモイド関数

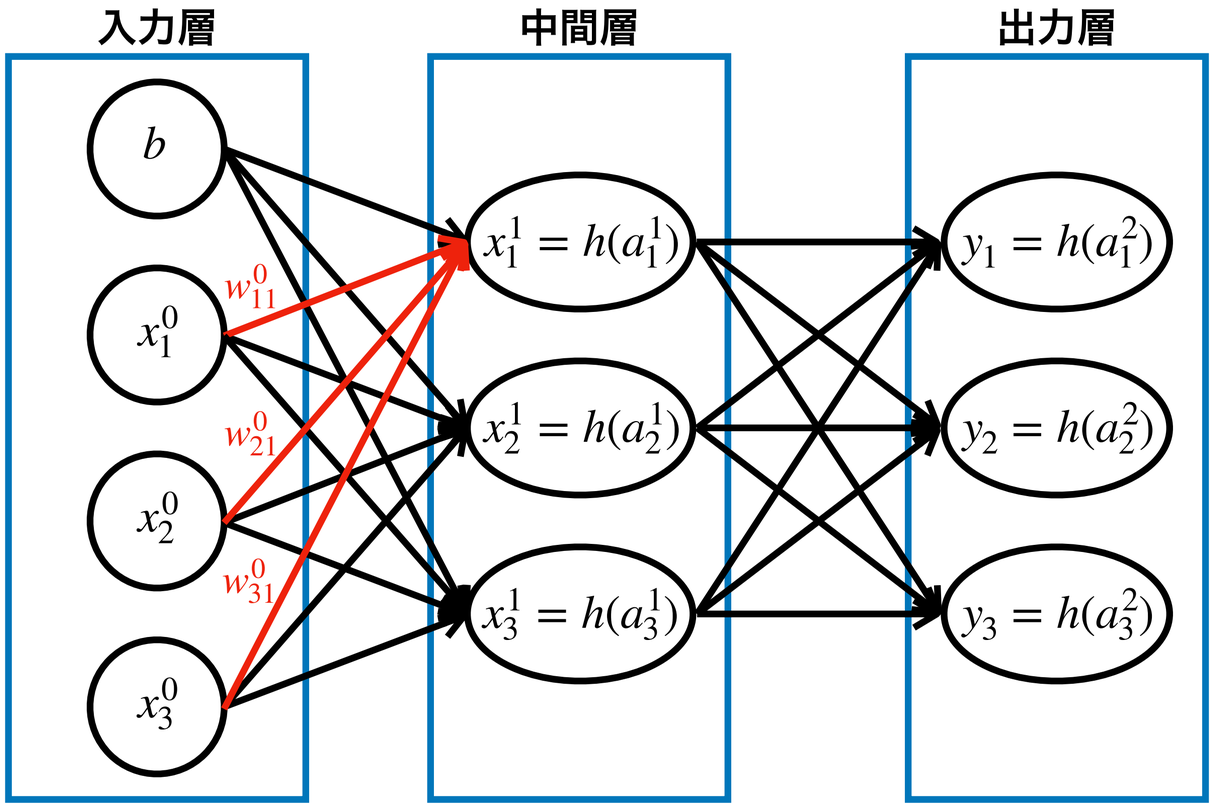


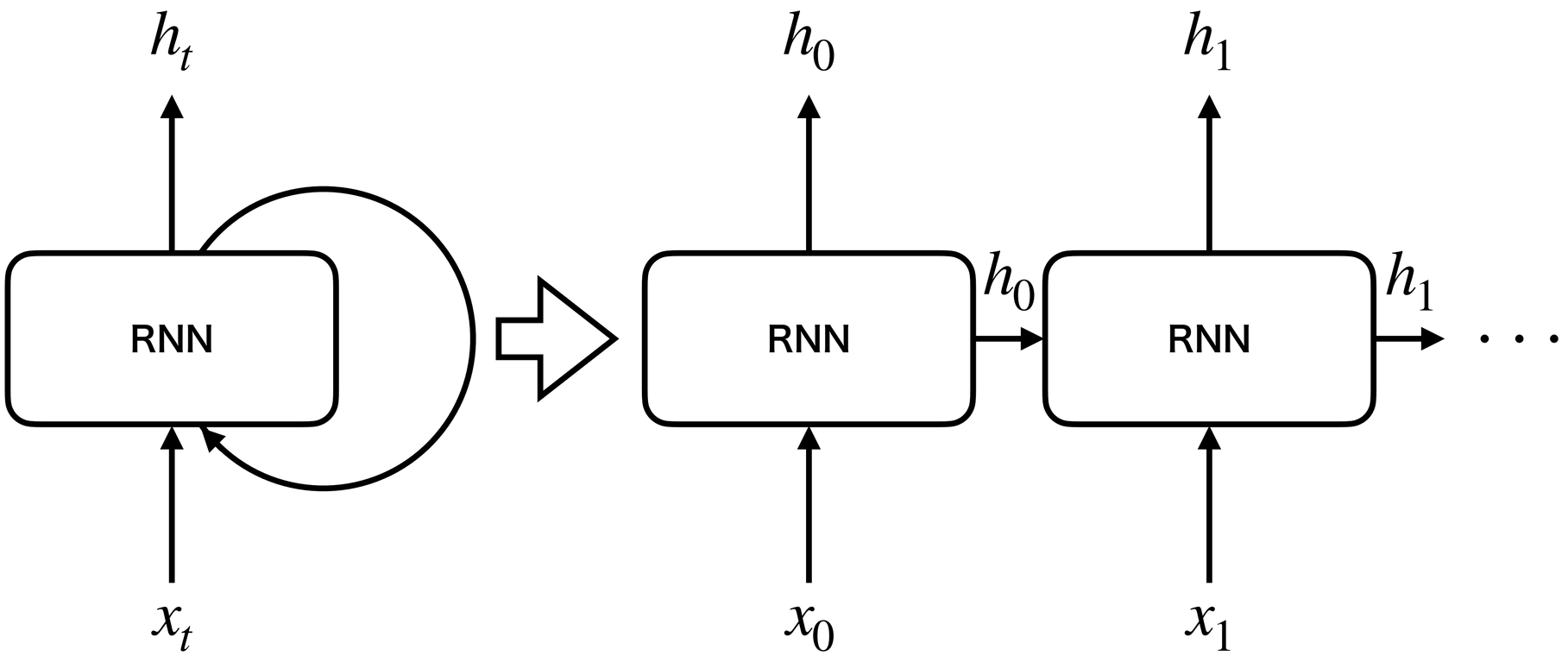
tanh関数

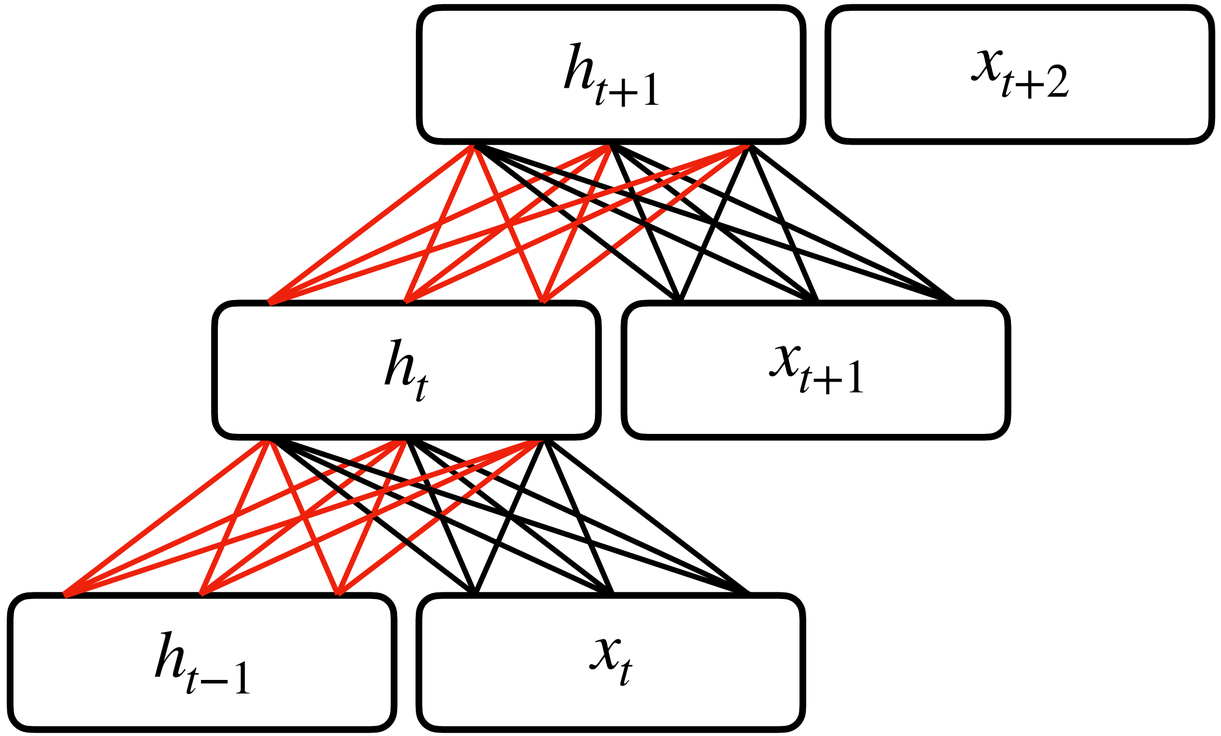


ReLU関数

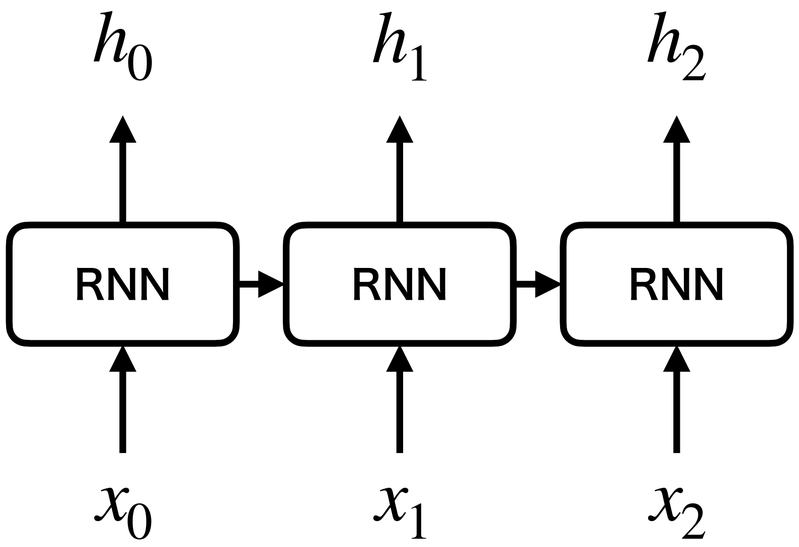



入力層
中間層
出力層
b
x_1^0
x_2^0
x_3^0
w_{11}^0
w_{21}^0
w_{31}^0
$x_1^1 = h(a_1^1)$
$x_2^1 = h(a_2^1)$
$x_3^1 = h(a_3^1)$
$y_1 = h(a_1^2)$
$y_2 = h(a_2^2)$
$y_3 = h(a_3^2)$

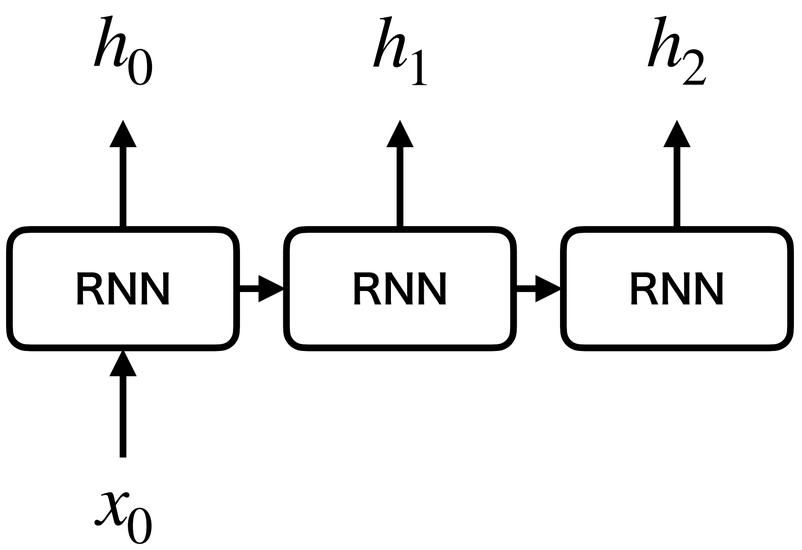

h_t
RNN
x_t
h_0
RNN
x_0
h_0
h_1
RNN
x_1
h_1
. . .


h_{t+1}
x_{t+2}
h_t
x_{t+1}
h_{t-1}
x_t

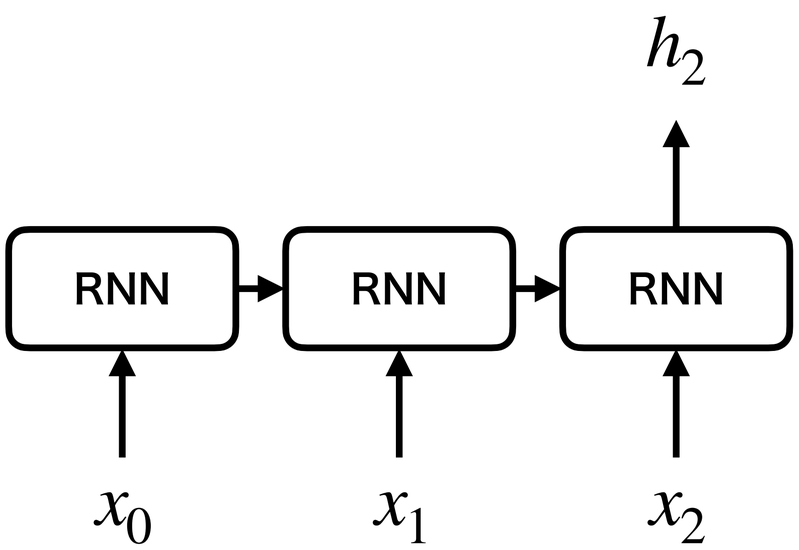
Many to Many

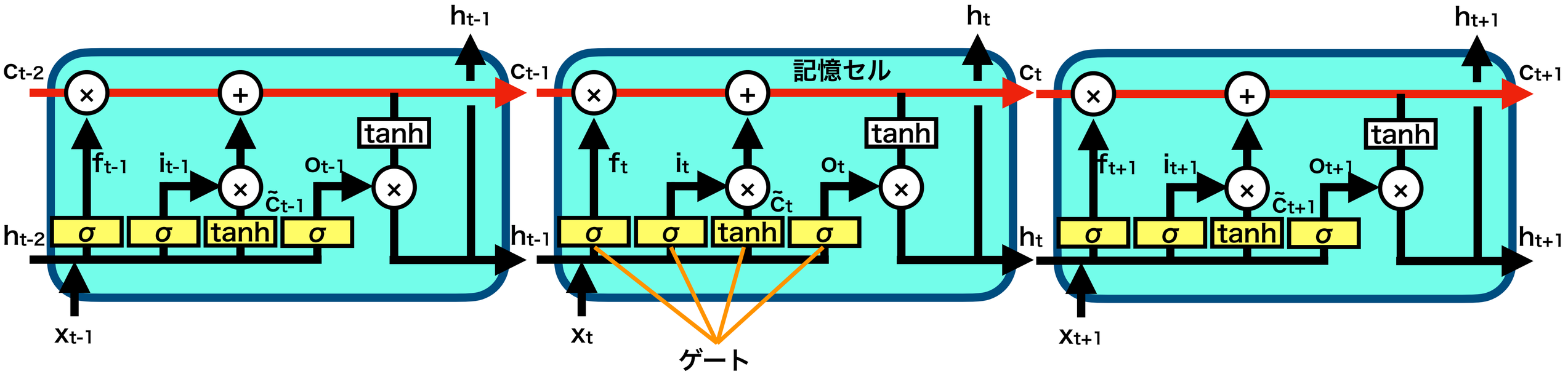


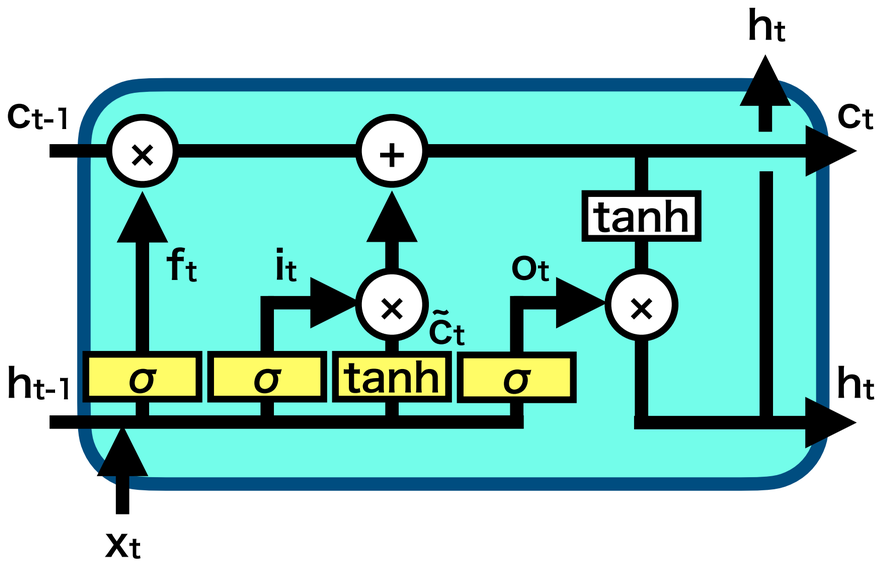
One to Many

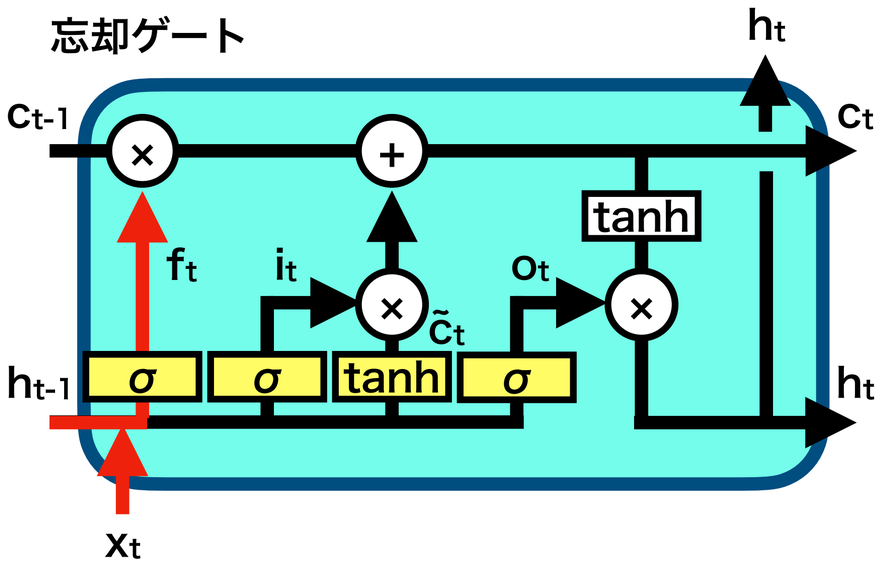


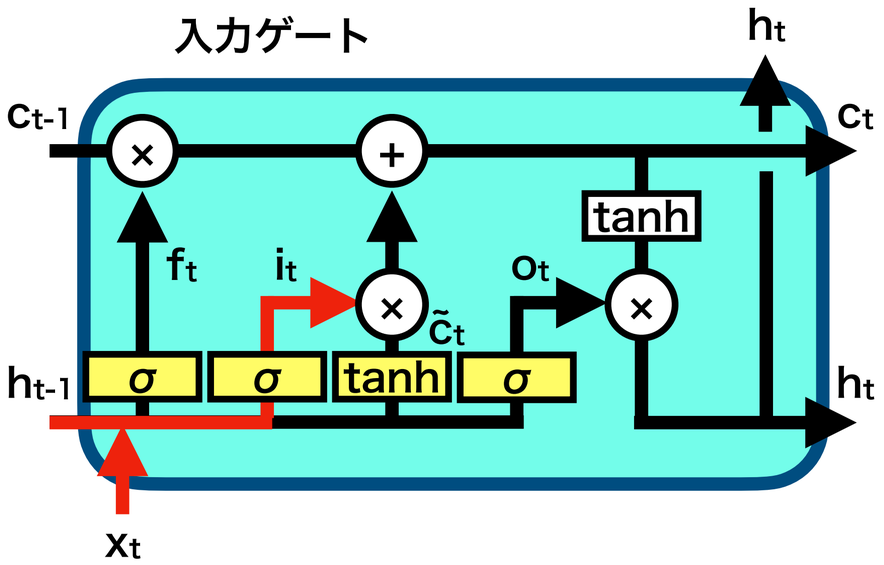
Many to One

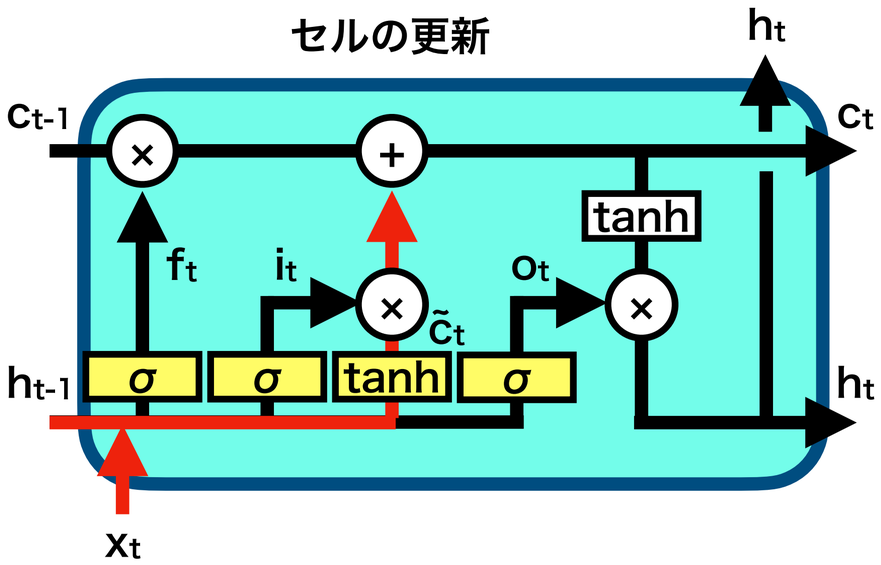


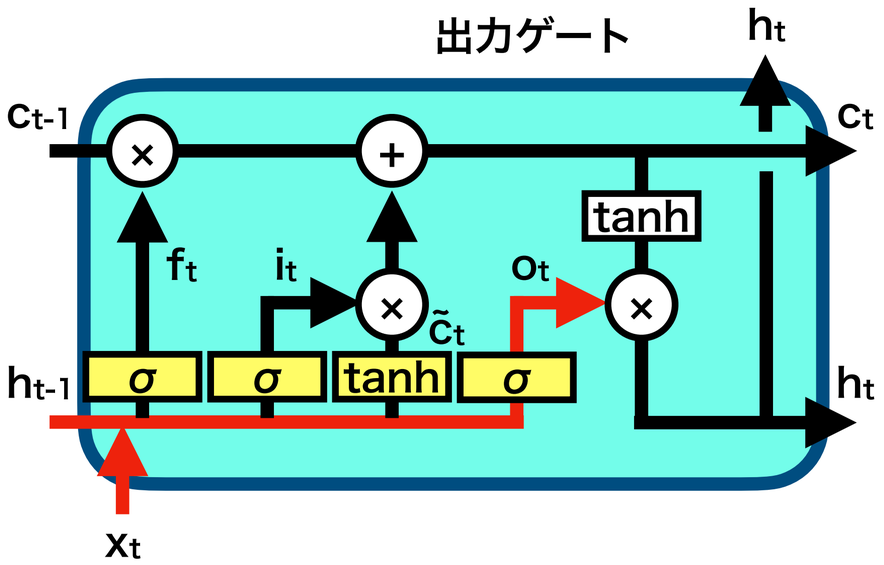

h_{t-1}
h_t
h_{t+1}
C_{t-2}
C_{t-1}
記憶セル
C_t
C_{t+1}
tanh
f_{t-1}
i_{t-1}
o_{t-1}
$\tilde{C}_{t-1}$
h_{t-2}
σ
σ
tanh
σ
h_{t-1}
f_t
i_t
o_t
$\tilde{C}_t$
h_t
f_{t+1}
i_{t+1}
o_{t+1}
$\tilde{C}_{t+1}$
h_{t+1}
x_{t-1}
x_t
x_{t+1}
ゲート

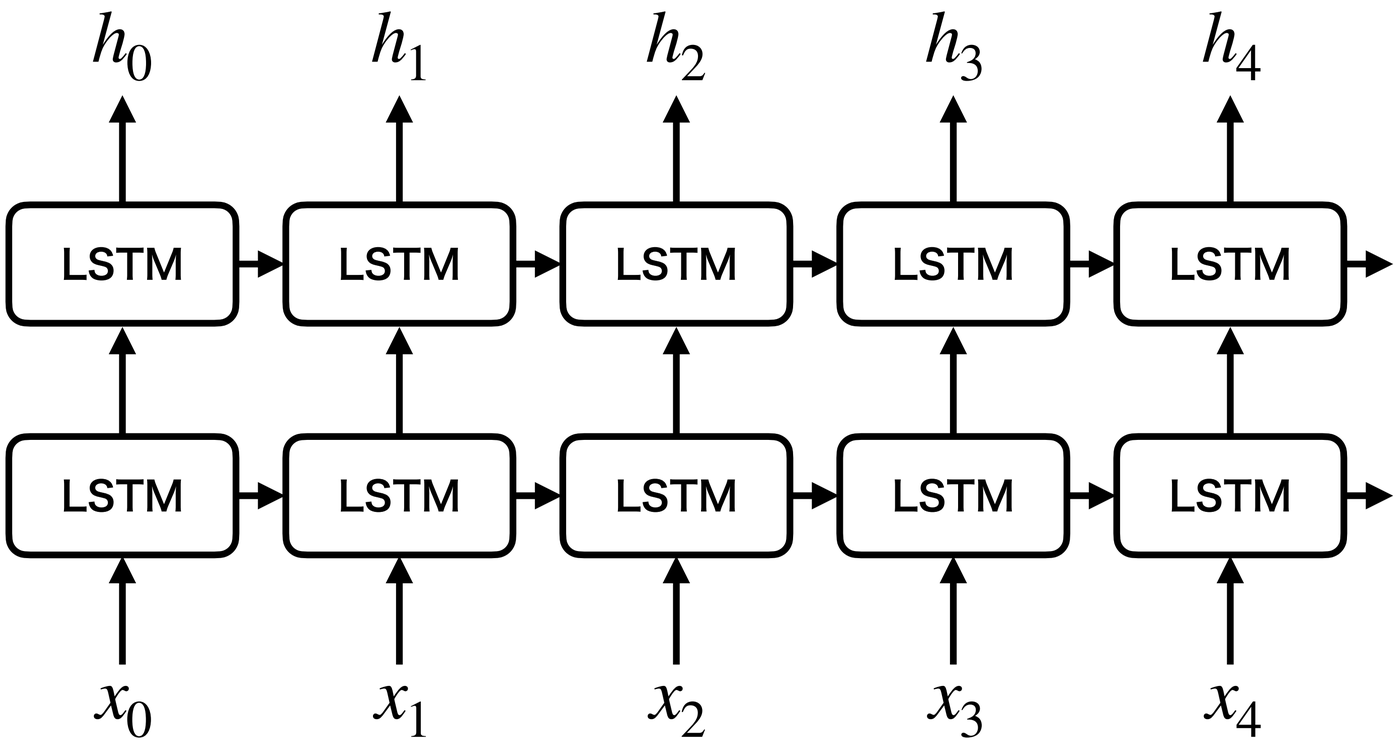

h_t
c_{t-1}
c_t
tanh
f_t
i_t
o_t
$\tilde{c}_t$
h_{t-1}
σ
σ
tanh
σ
h_t
x_t

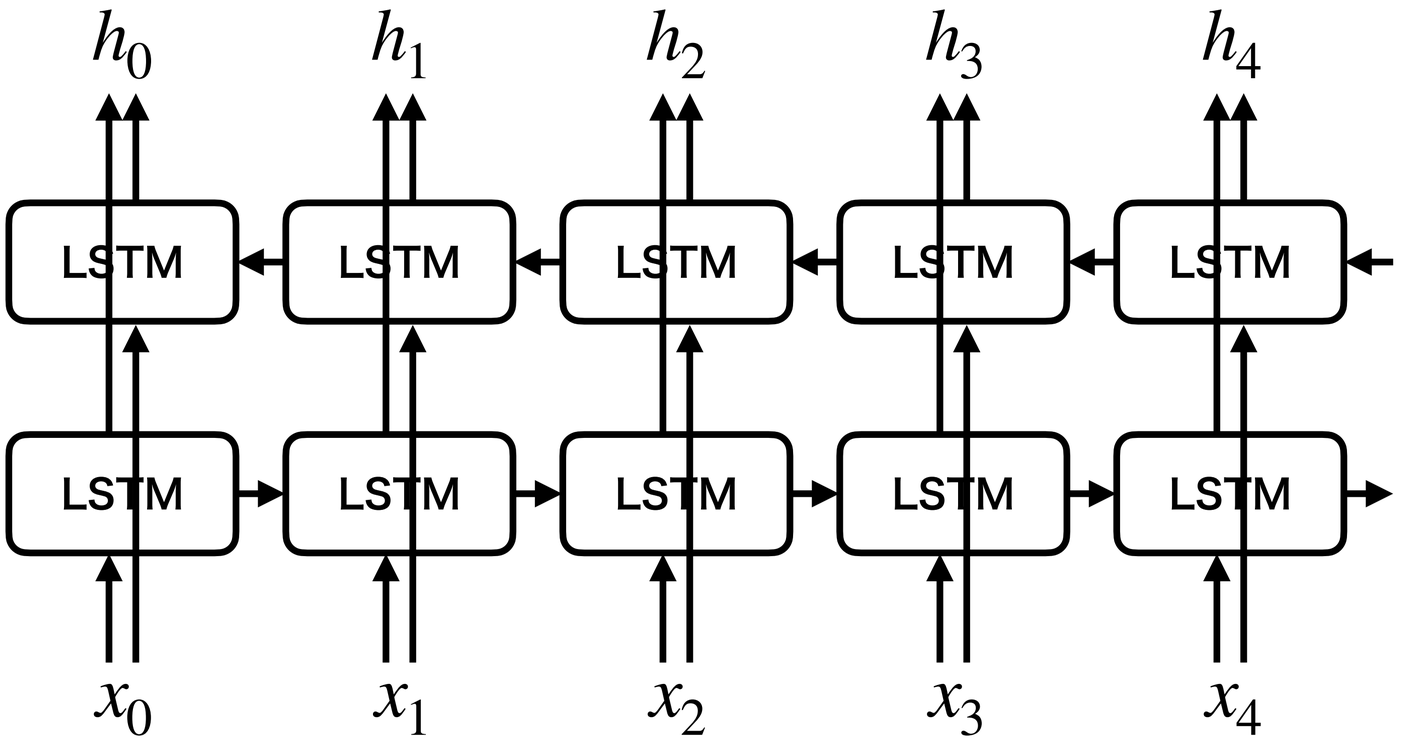

忘却ゲート
h_t
c_{t-1}
c_t
×
+
tanh
f_t
i_t
o_t
×
×
$\tilde{c}_t$
h_{t-1}
σ
σ
tanh
σ
h_t
x_t

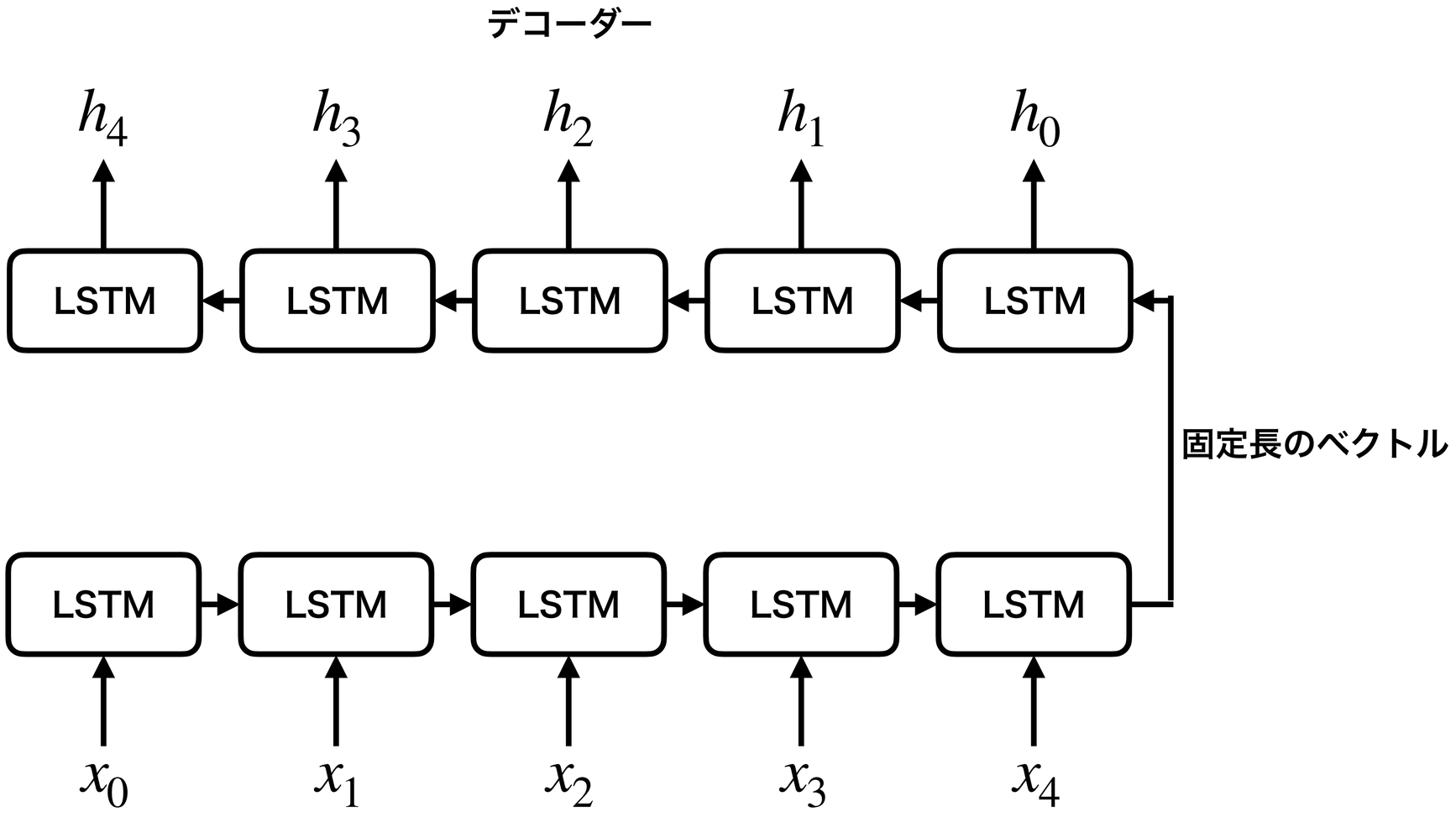

入力ゲート
h_t
c_{t-1}
c_t
×
+
tanh
f_t
i_t
o_t
×
×
$\tilde{c}_t$
h_{t-1}
σ
σ
tanh
σ
h_t
x_t


セルの更新
h_t
c_{t-1}
c_t
f_t
i_t
o_t
$\tilde{c}_t$
tanh
h_{t-1}
σ
σ
tanh
σ
h_t
x_t

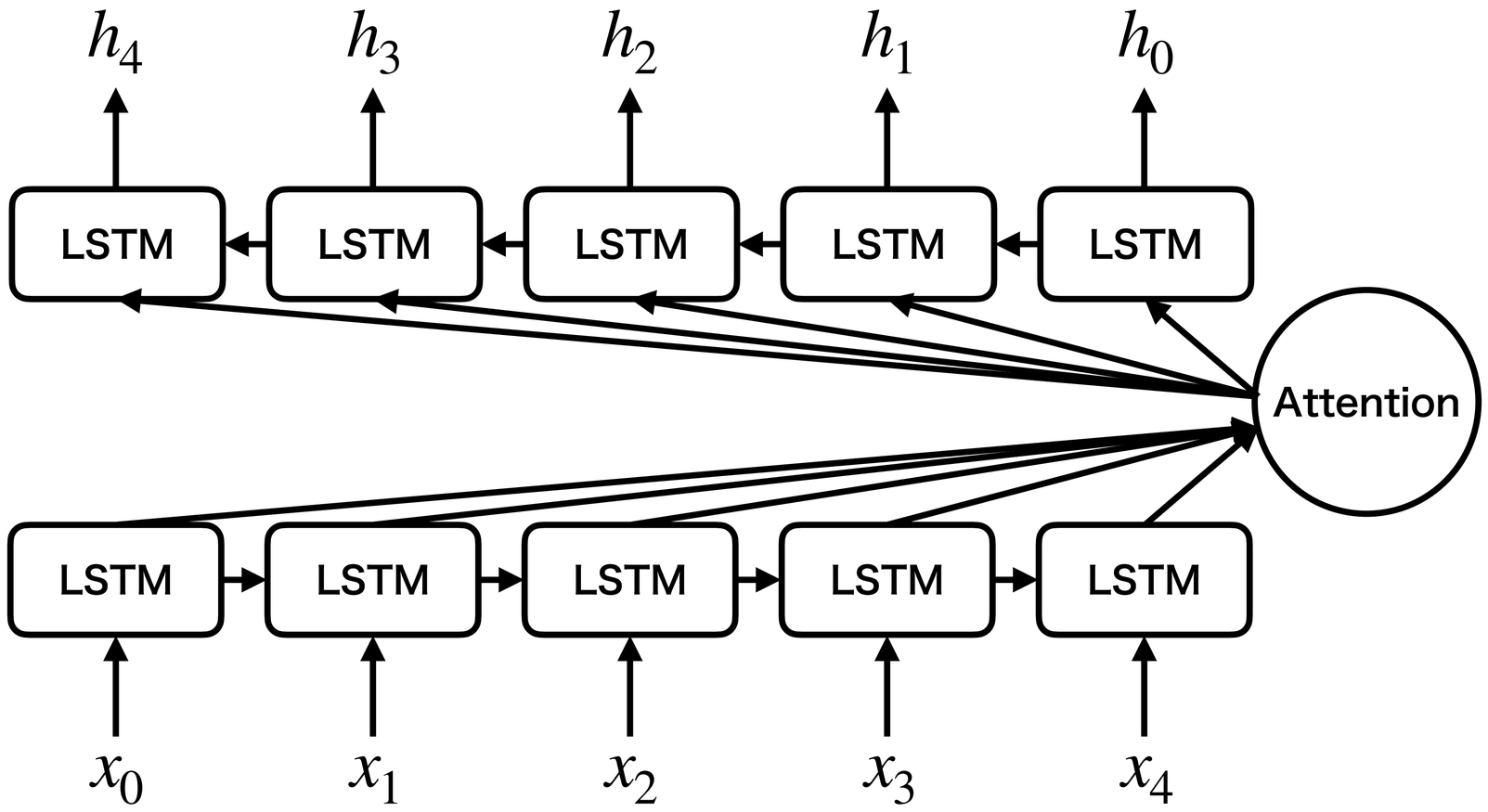

出力ゲート
h_t
c_{t-1}
c_t
×
+
tanh
f_t
i_t
o_t
×
×
$\tilde{c}_t$
h_{t-1}
σ
σ
tanh
σ
h_t
x_t


h_0
h_1
h_2
h_3
h_4
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
x_0
x_1
x_2
x_3
x_4

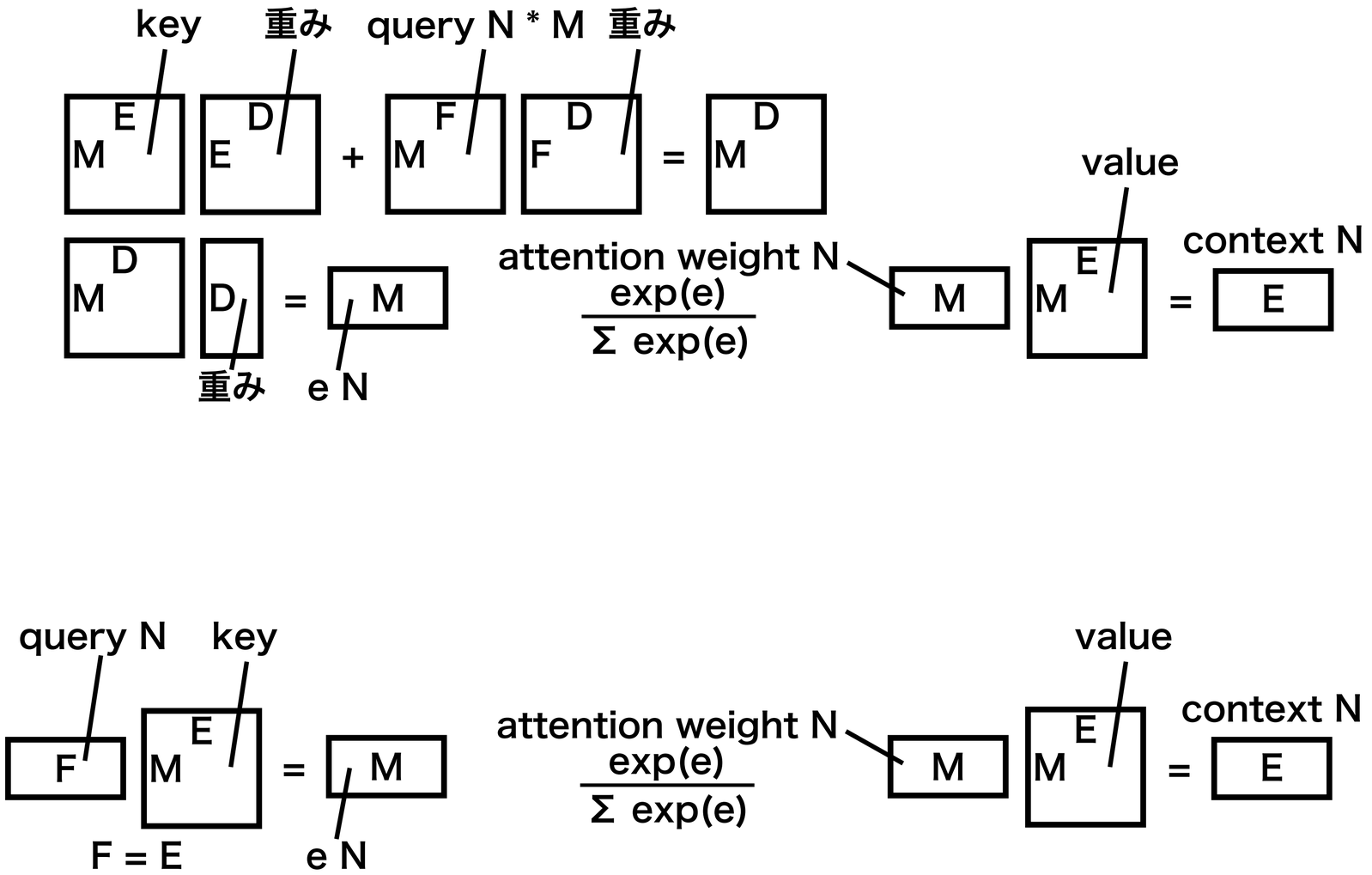

h_0
h_1
h_2
h_3
h_4
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
LSTM
x_0
x_1
x_2
x_3
x_4

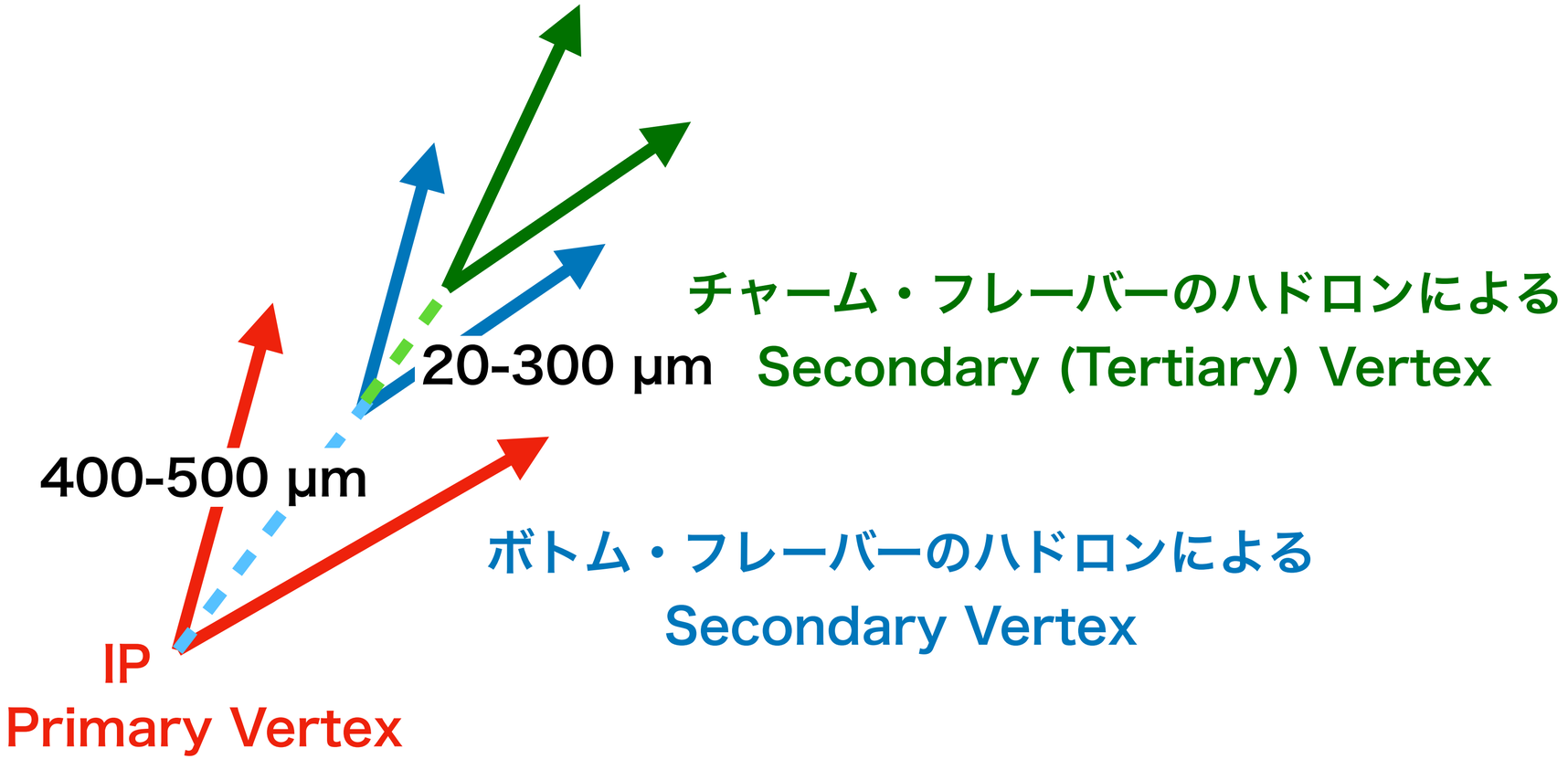

デコーダー
h_4
h_3
h_2
h_1
h_0
LSTM
LSTM
LSTM
LSTM
LSTM
固定長のベクトル
LSTM
LSTM
LSTM
LSTM
LSTM
x_0
x_1
x_2
x_3
x_4
エンコーダー

デコーダー



エンコーダー


key
重み
query N * M
重み
M
E
E
D
+
M
F
F
D
=
M
D
M
D
D
=
M
重み
e N
attention weight N
exp(e)
Σ exp(e)
value
M
M
E
=
E
context N
query N
key
F
M
E
=
M
F = E
e N
attention weight N
exp(e)
Σ exp(e)
value
M
M
E
=
E
context N


チャーム・フレーバーのハドロンによる
20-300 μm Secondary (Tertiary) Vertex
400-500 μm
ボトム・フレーバーのハドロンによる
Secondary Vertex
IP
Primary Vertex

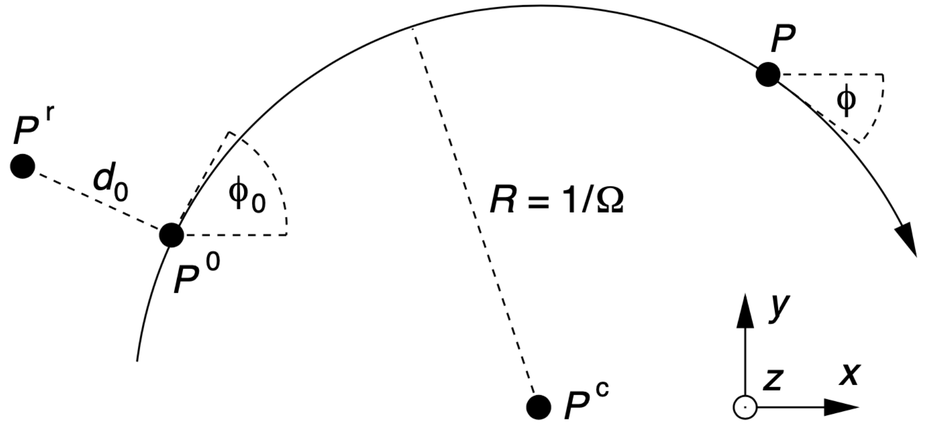


Figure 1: The projection of a helix segment in the xy plane is a part of an arc with centre $\boldsymbol{P}^{\mathrm{c}}$ and radius R. The direction of the particle is shown with the arrow at the arc. All track parameters are given relative to the reference point $\boldsymbol{P}^{\mathrm{r}}$.

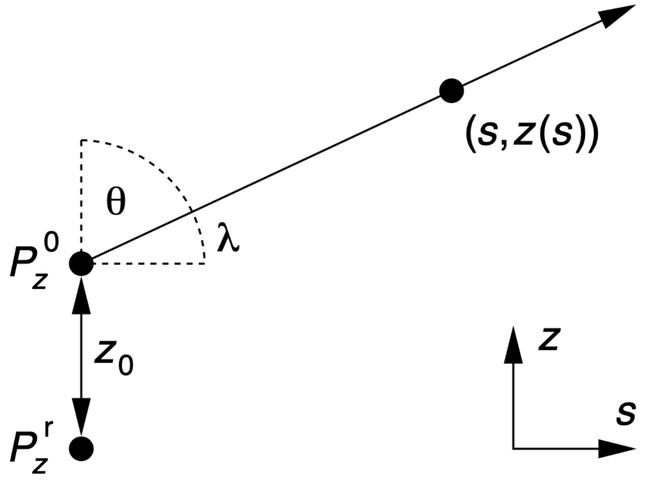
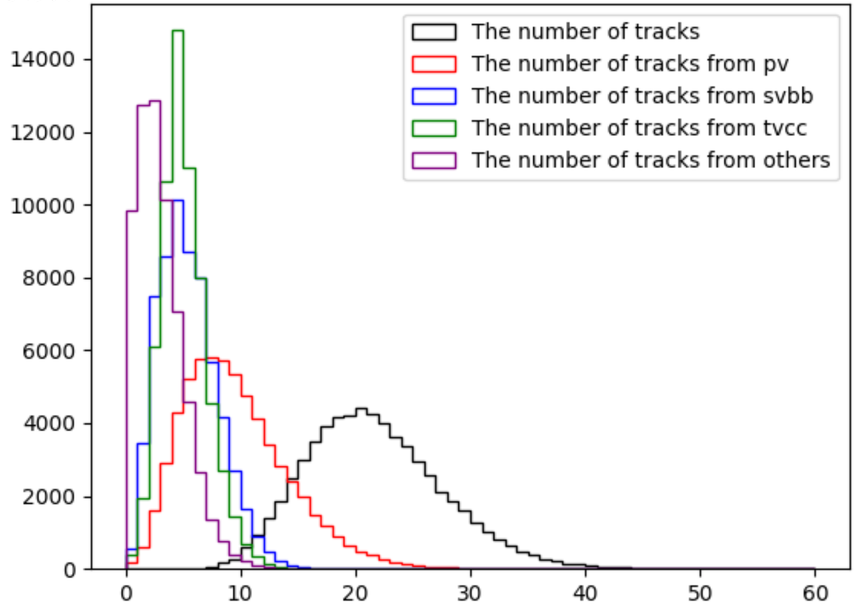


Figure 2: The projection of a helix in the sz plane is a straight line (see Eq. 10). The variable s at a point $\boldsymbol{P}$ is the arc length in the xy plane from $\boldsymbol{P}^0$ to $\boldsymbol{P}$. This also implies that $s = 0$, if $z = z_0$.

事象数

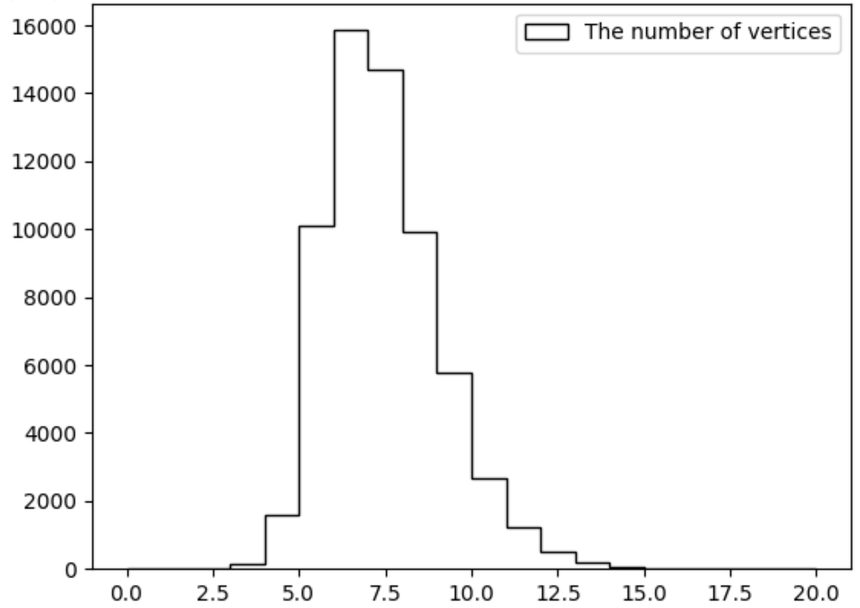
飛跡数（終状態 $b\bar{b}$）



飛跡数

事象数

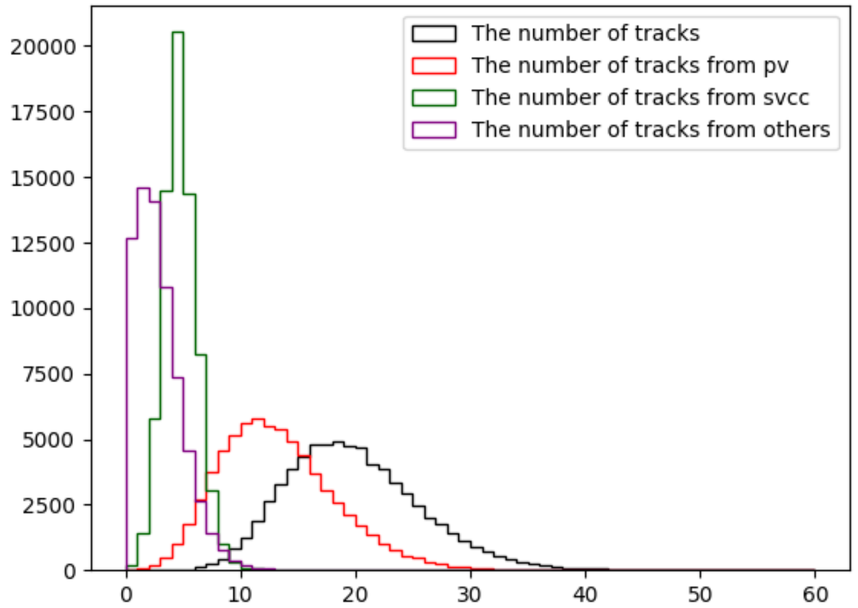
崩壊点数（終状態 $b\bar{b}$）



崩壊点数

事象数

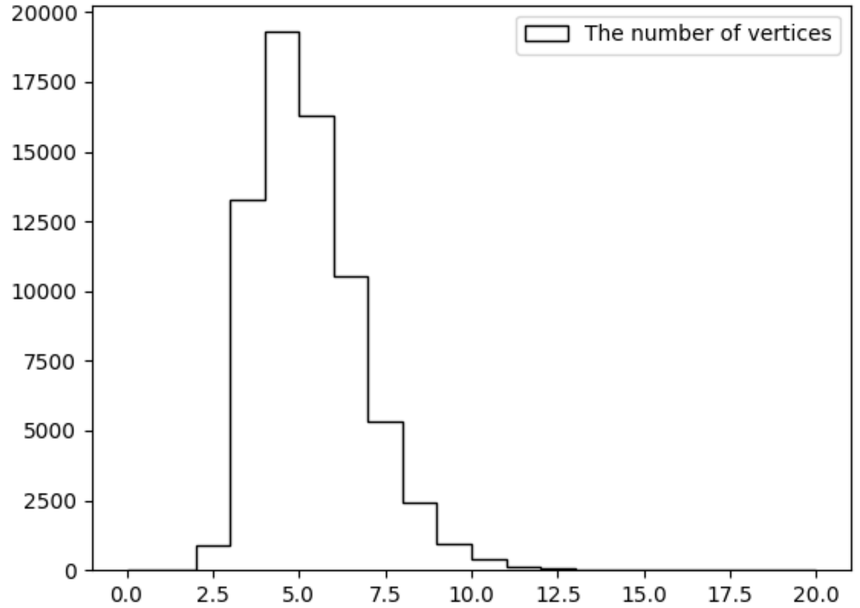
飛跡数（終状態 $c\bar{c}$）



飛跡数

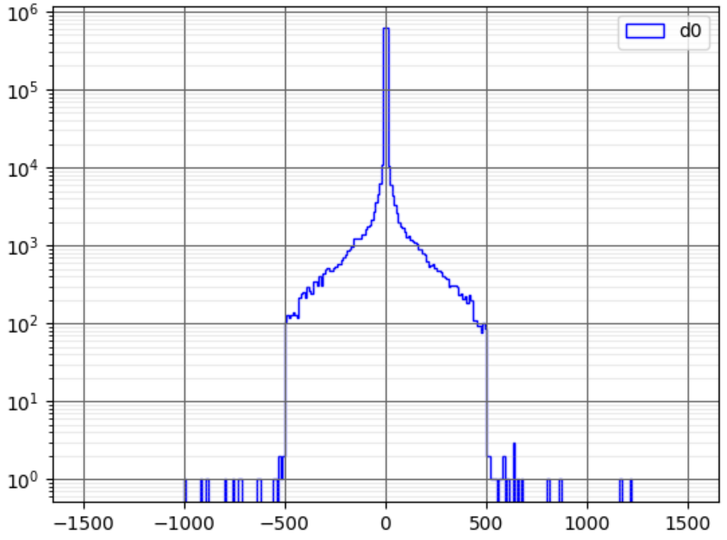
事象数

崩壊点数（終状態 $c\bar{c}$）

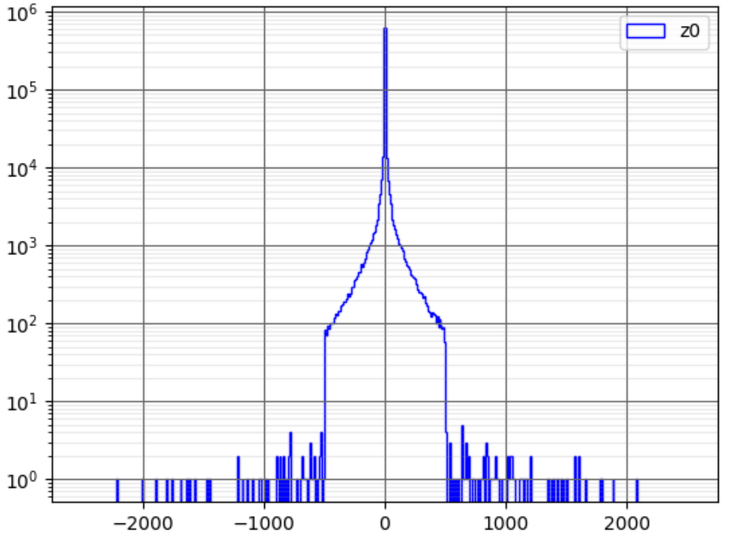


崩壊点数

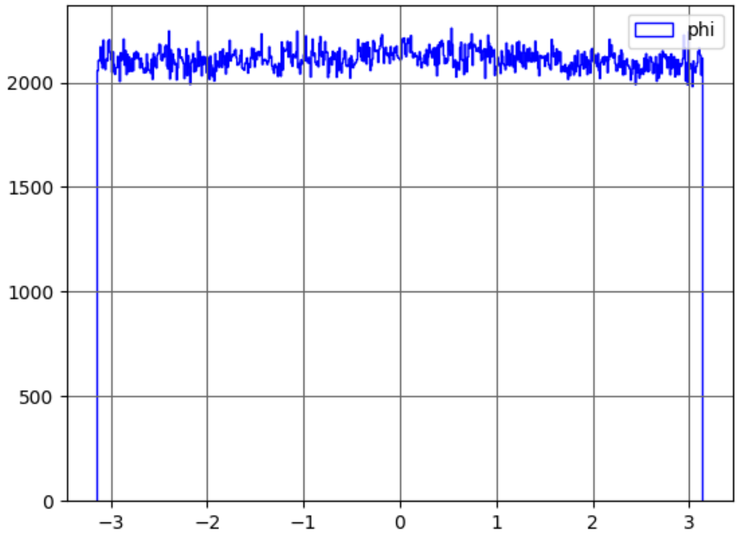
終状態 $b\bar{b}$



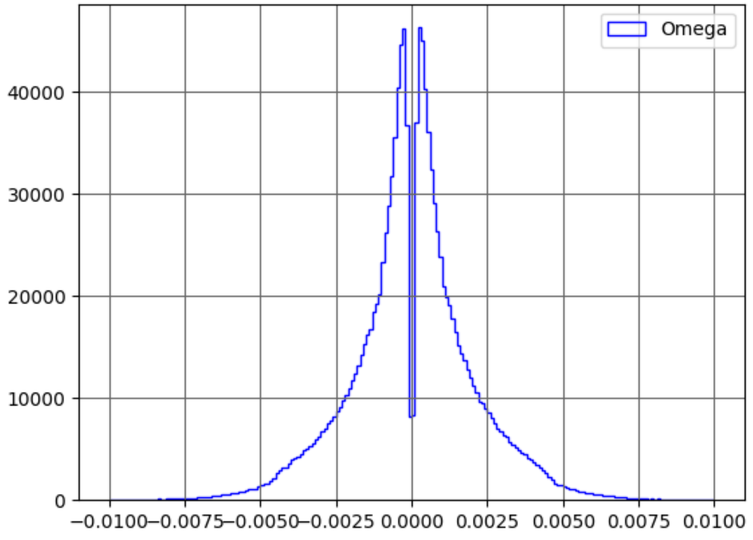
d_0



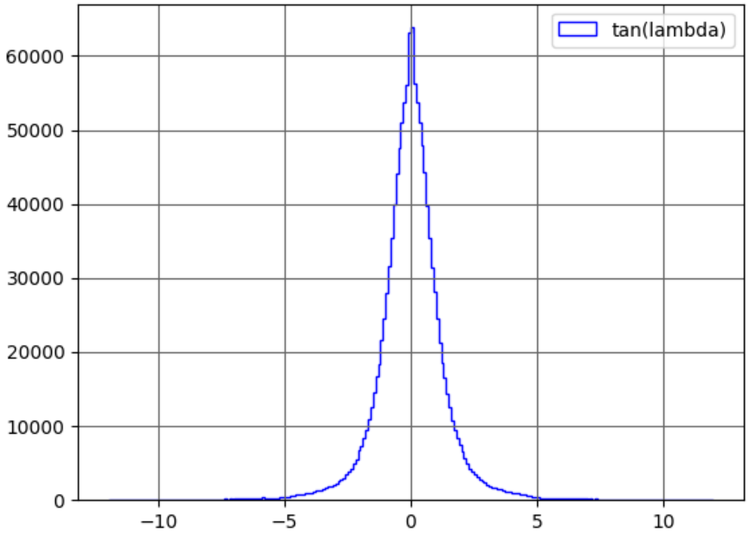
z_0



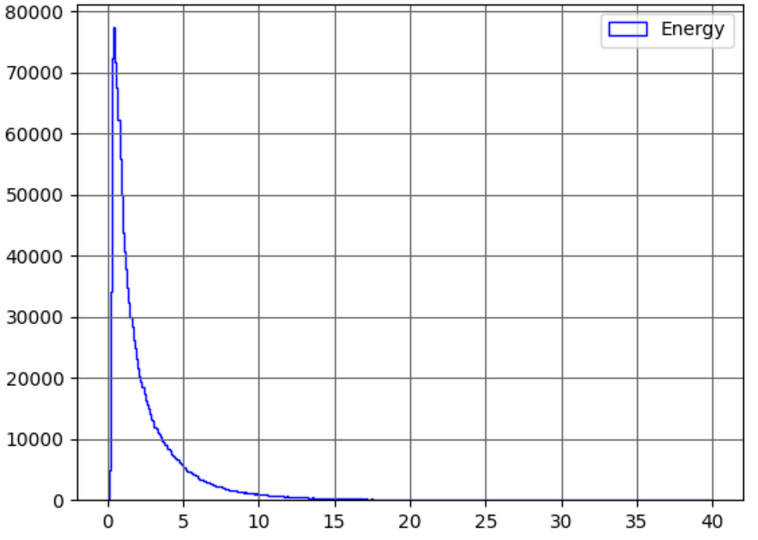
ϕ



Ω

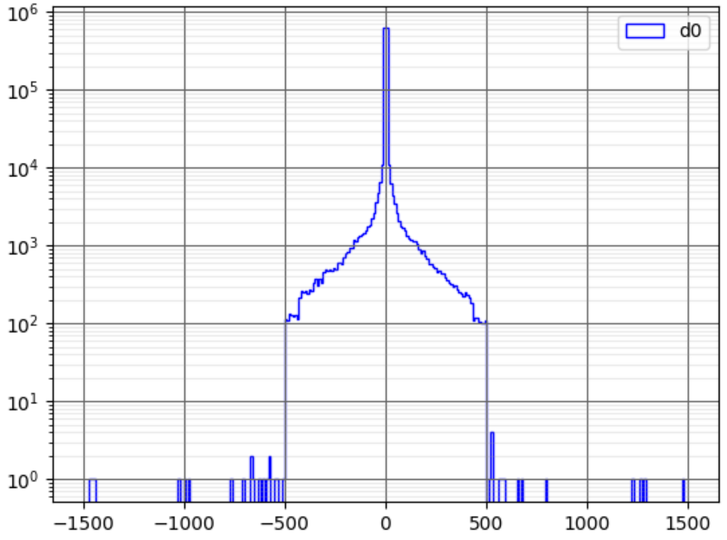


$\tan(\lambda)$

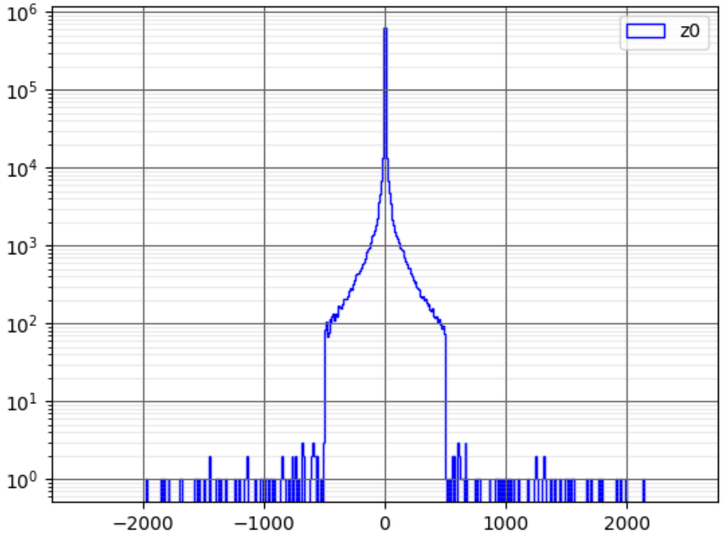


Energy

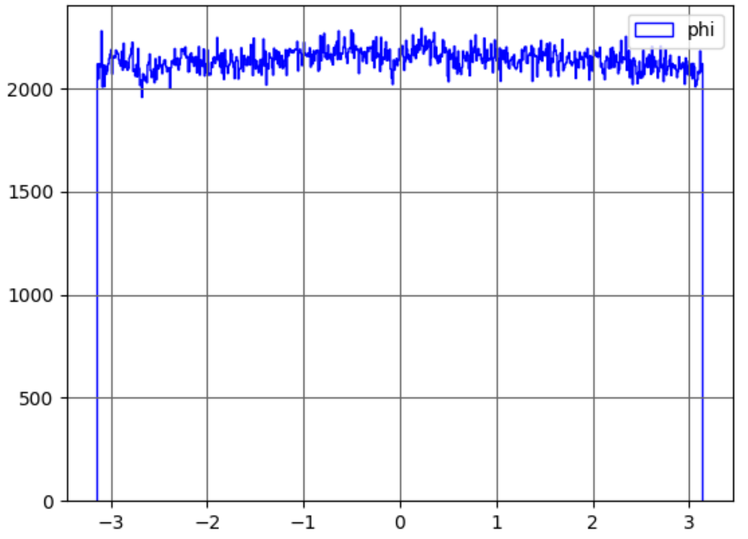
終状態 $c\bar{c}$



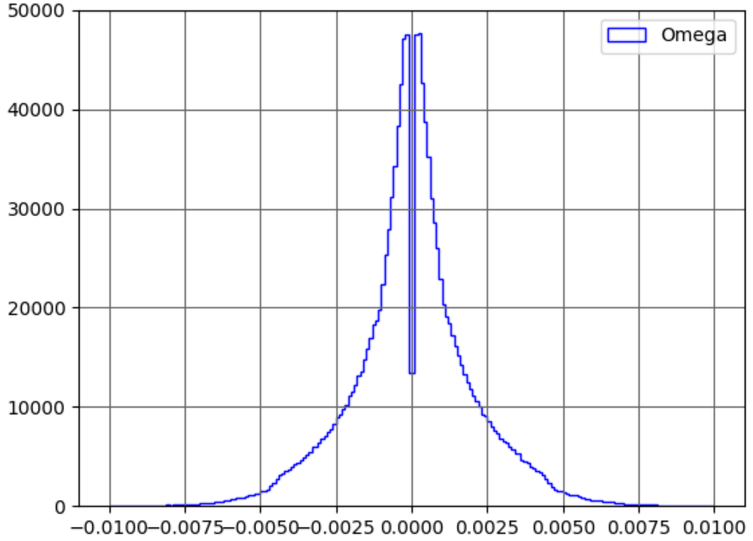
d_0



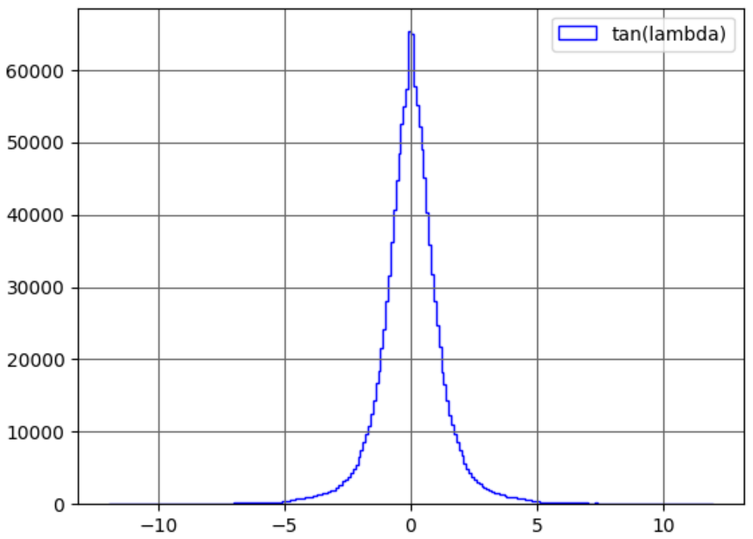
z_0



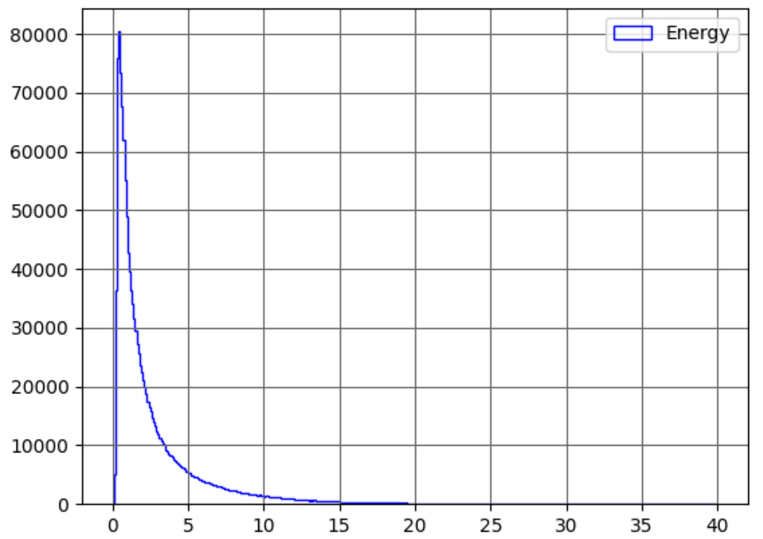
ϕ



Ω

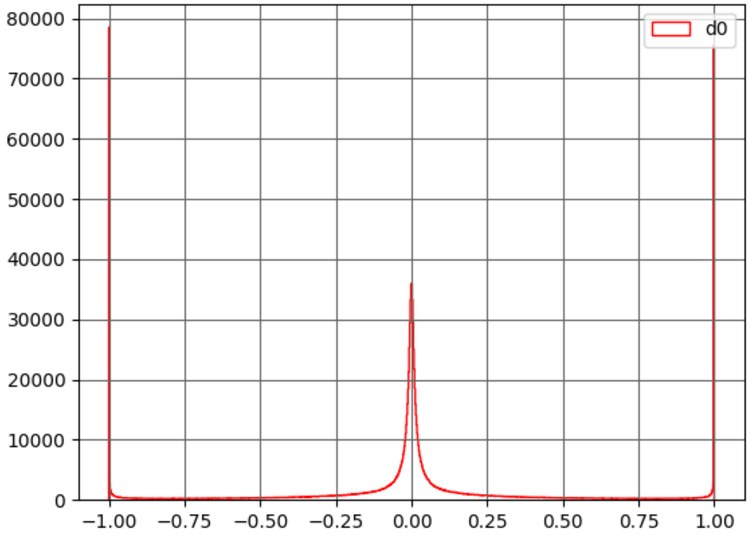


$\tan(\lambda)$

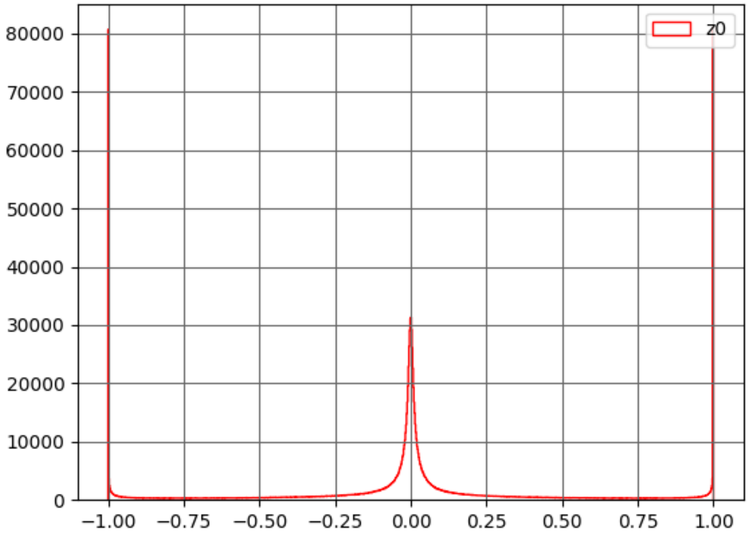


Energy

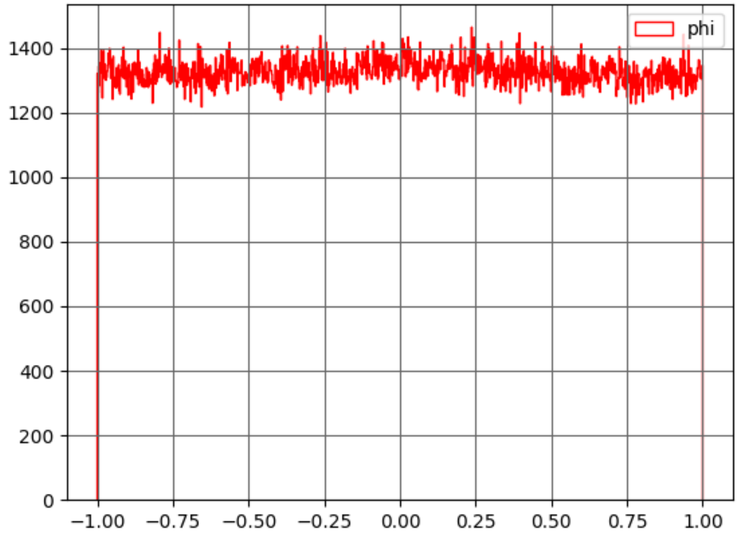
終状態 $b\bar{b}$



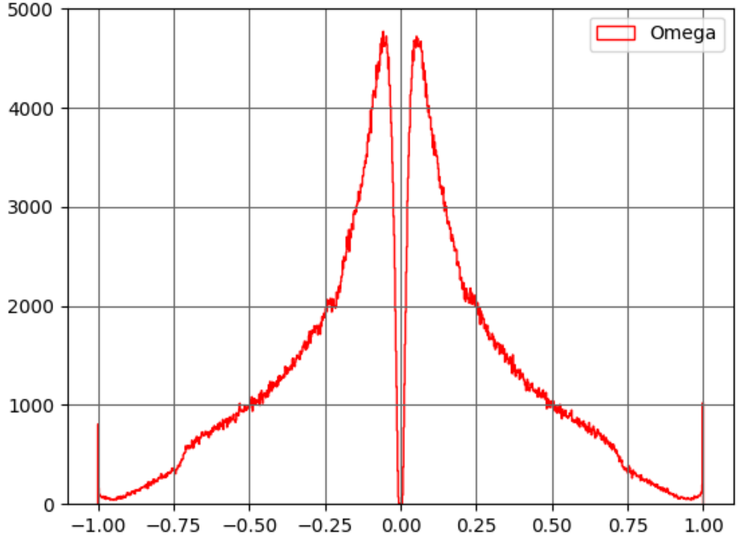
d_0



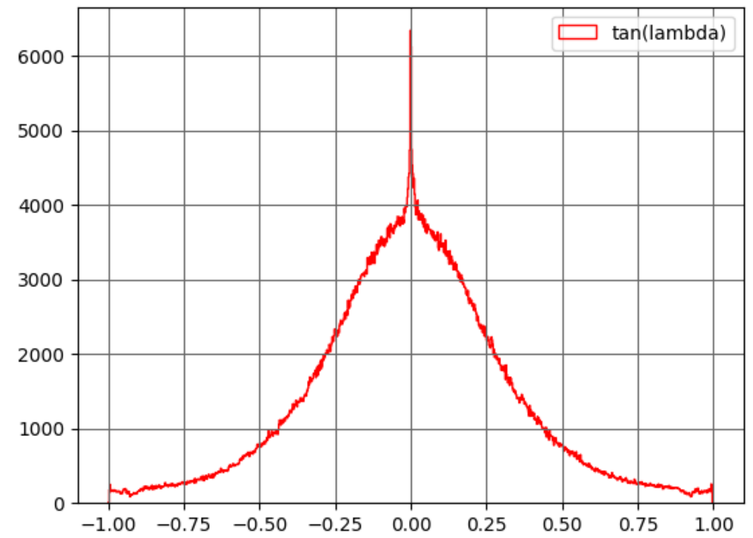
z_0



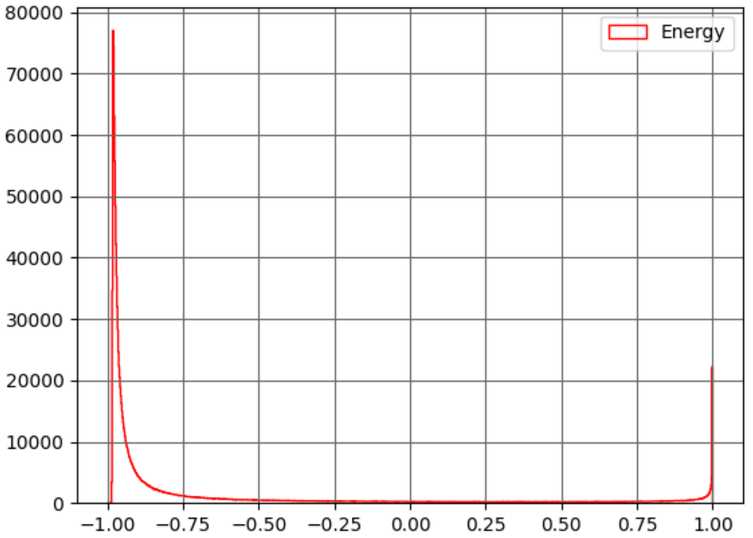
ϕ



Ω

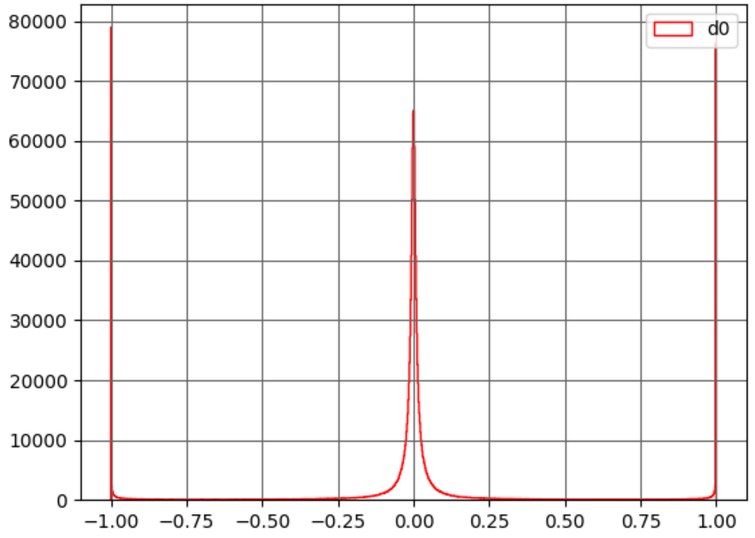


$\tan(\lambda)$

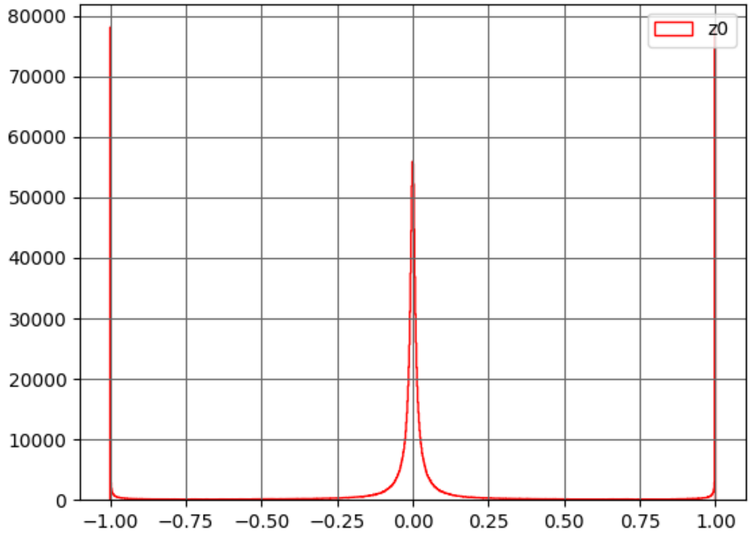


Energy

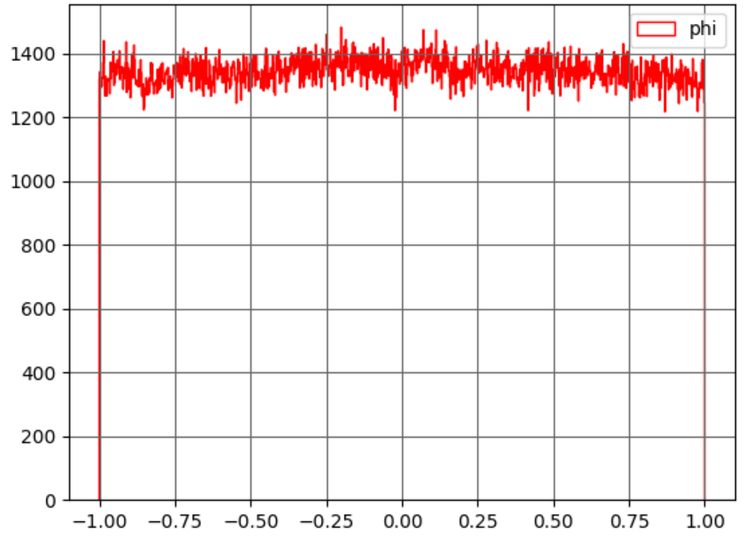
終状態 $c\bar{c}$



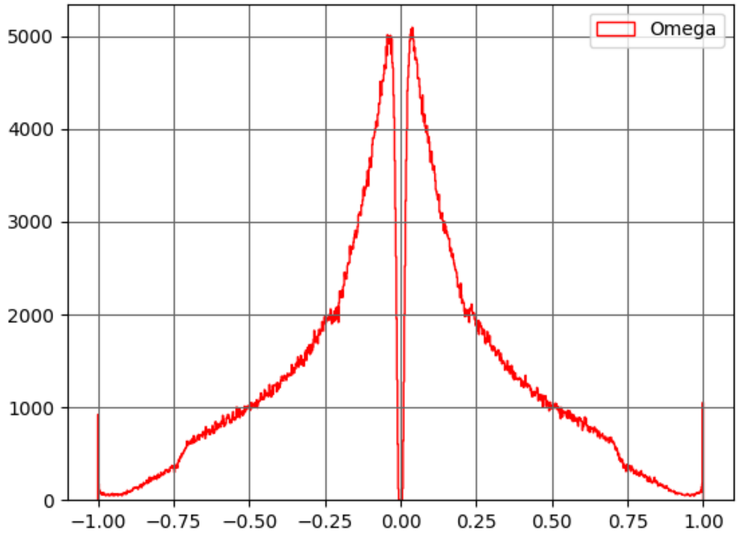
d_0



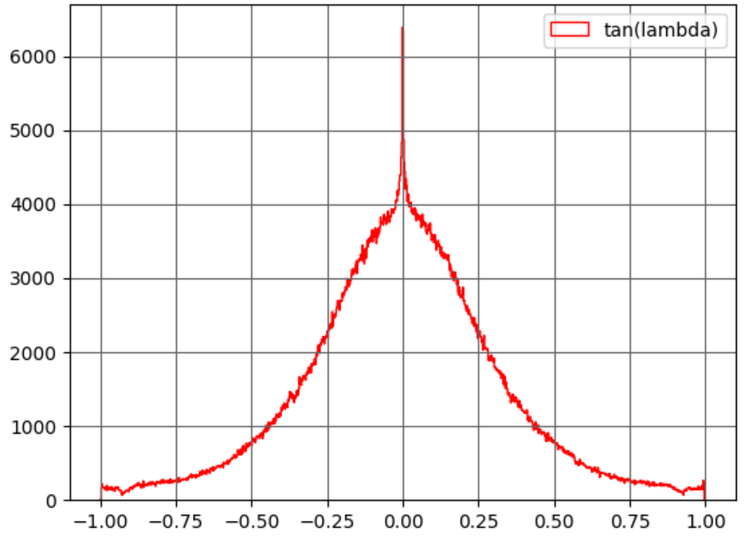
z_0



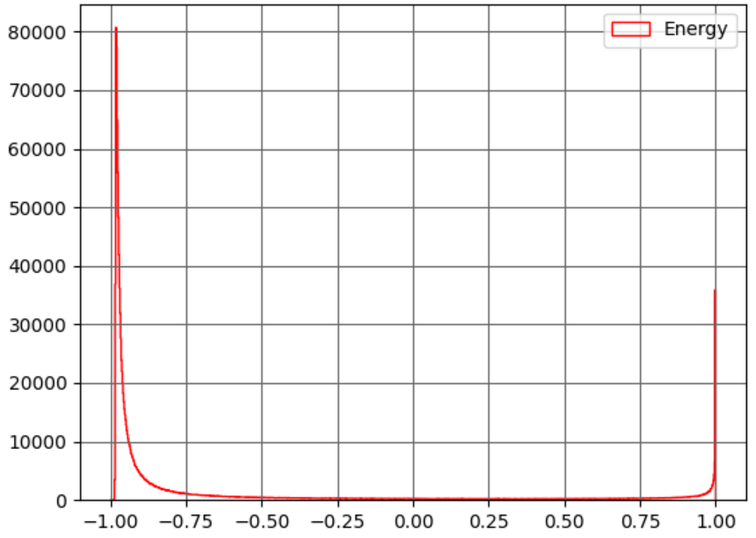
ϕ



Ω

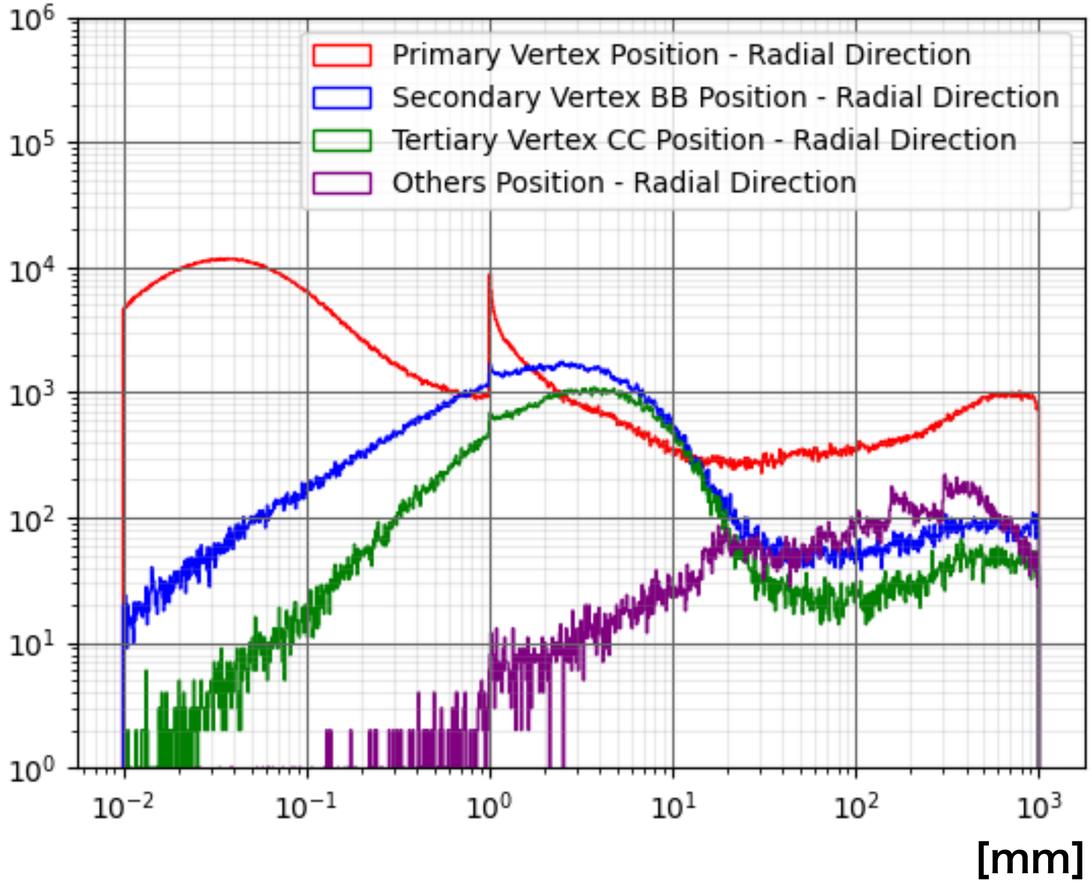


$\tan(\lambda)$

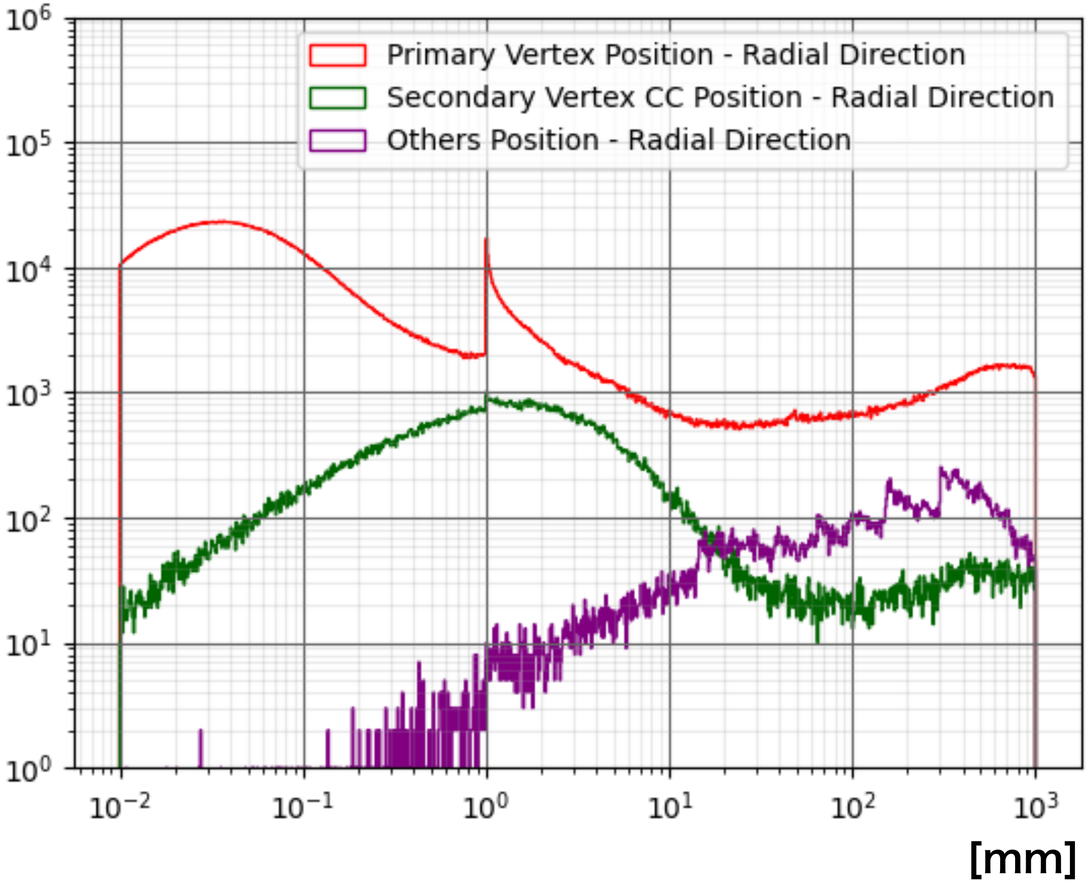


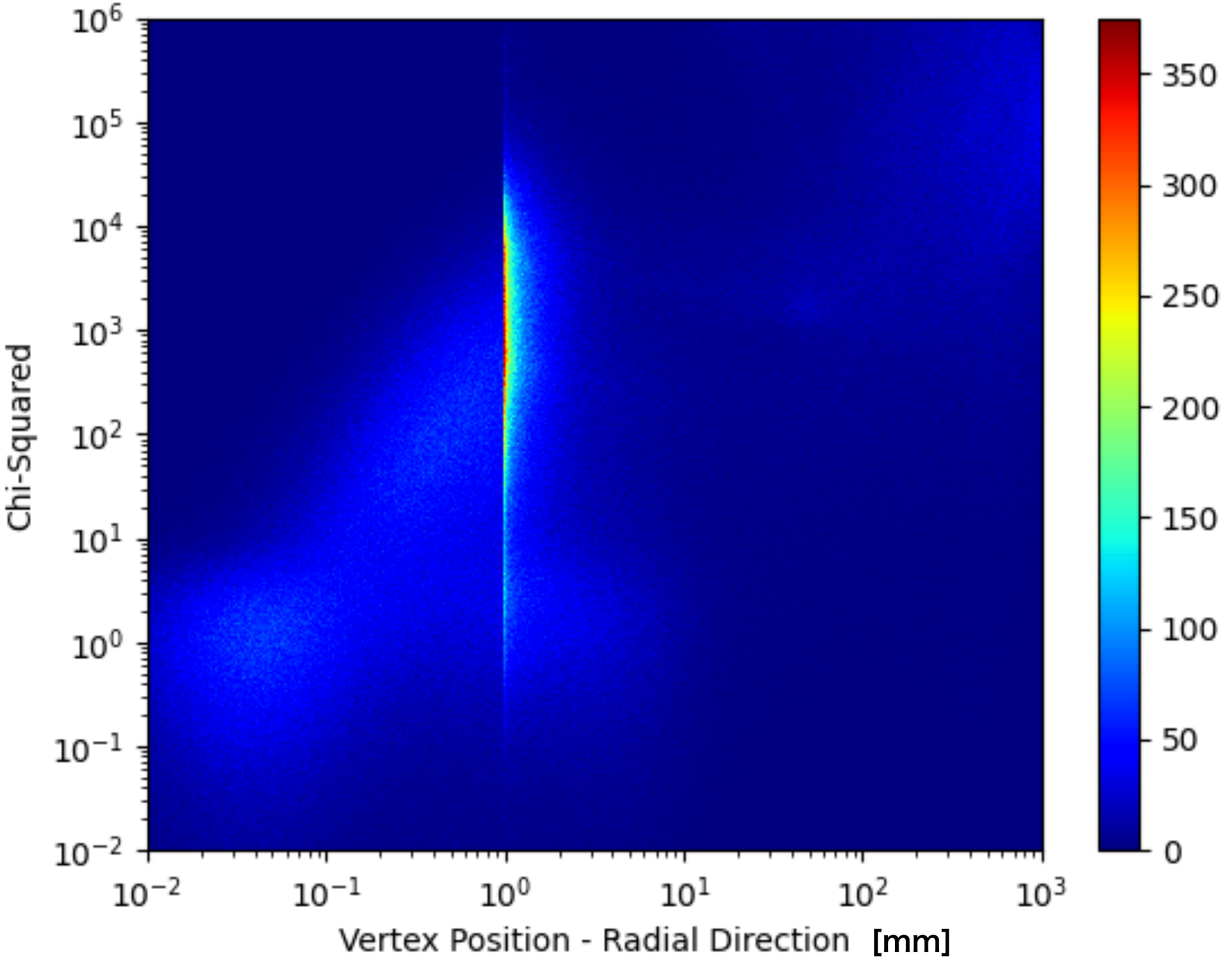
Energy

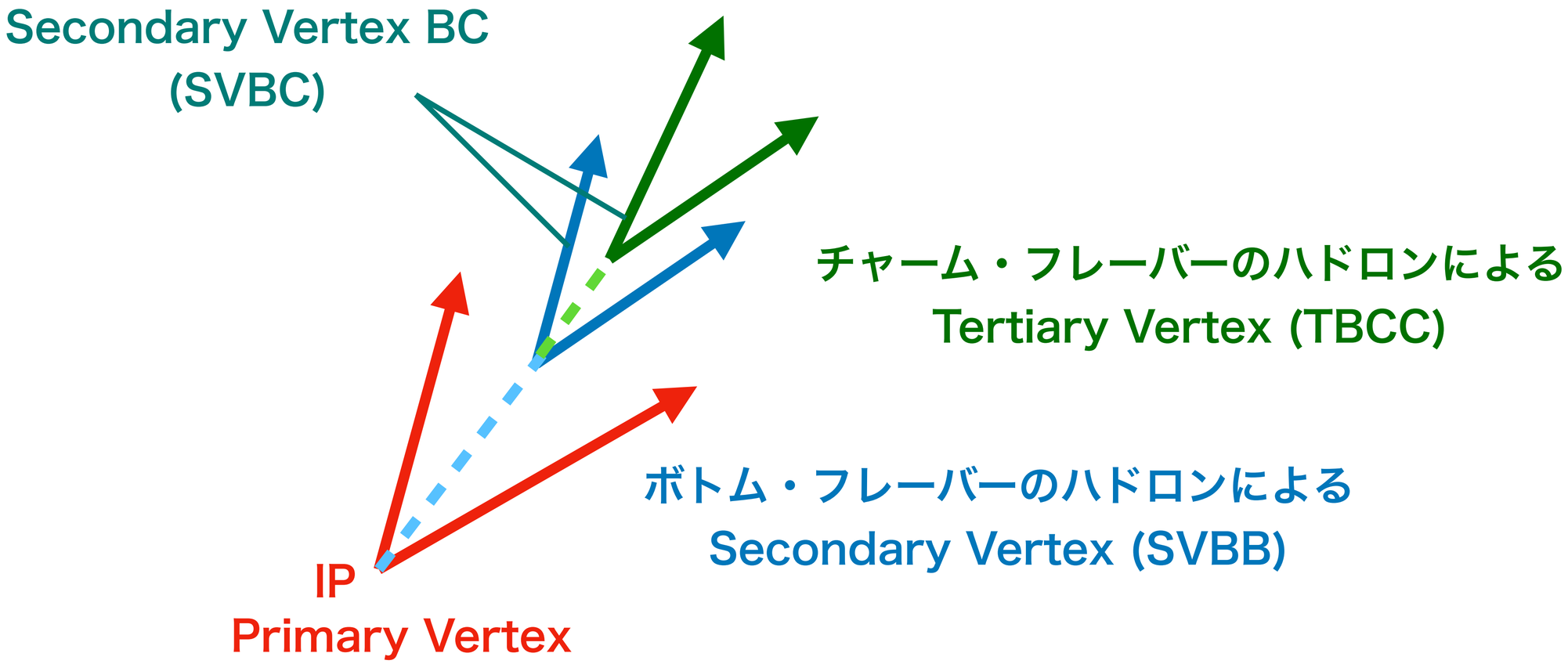
終状態 $b\bar{b}$

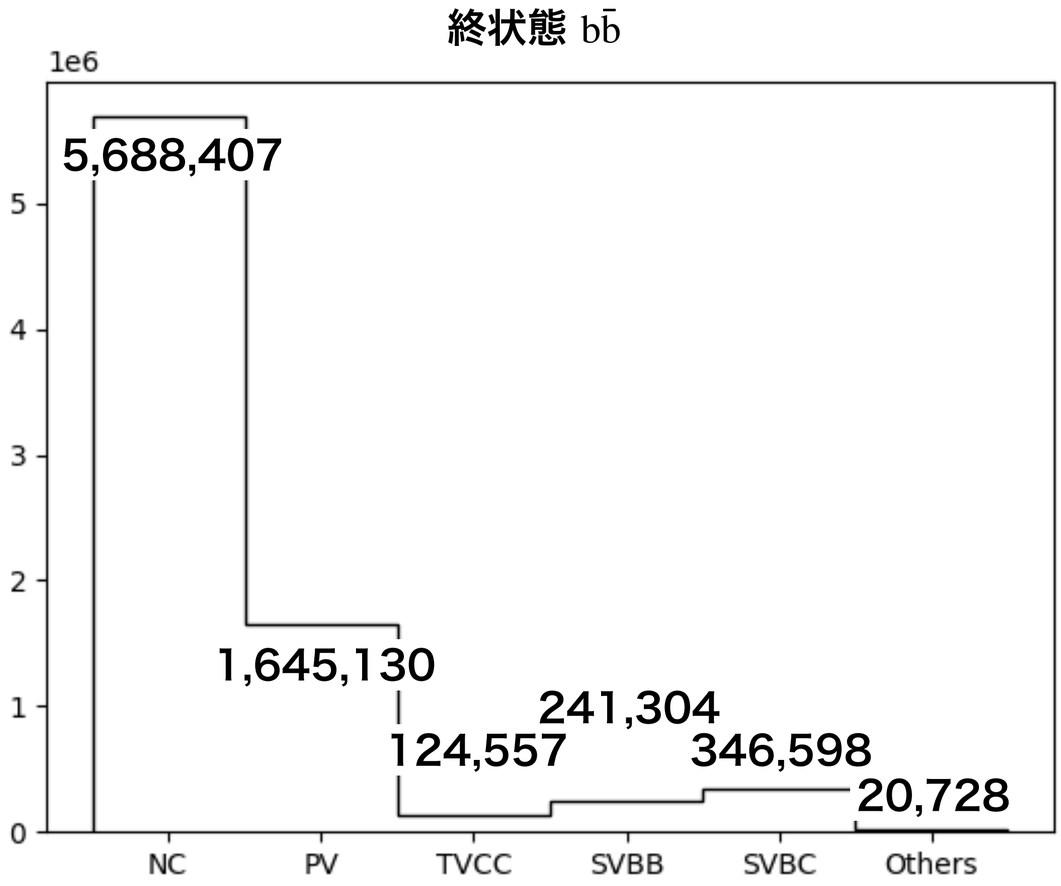


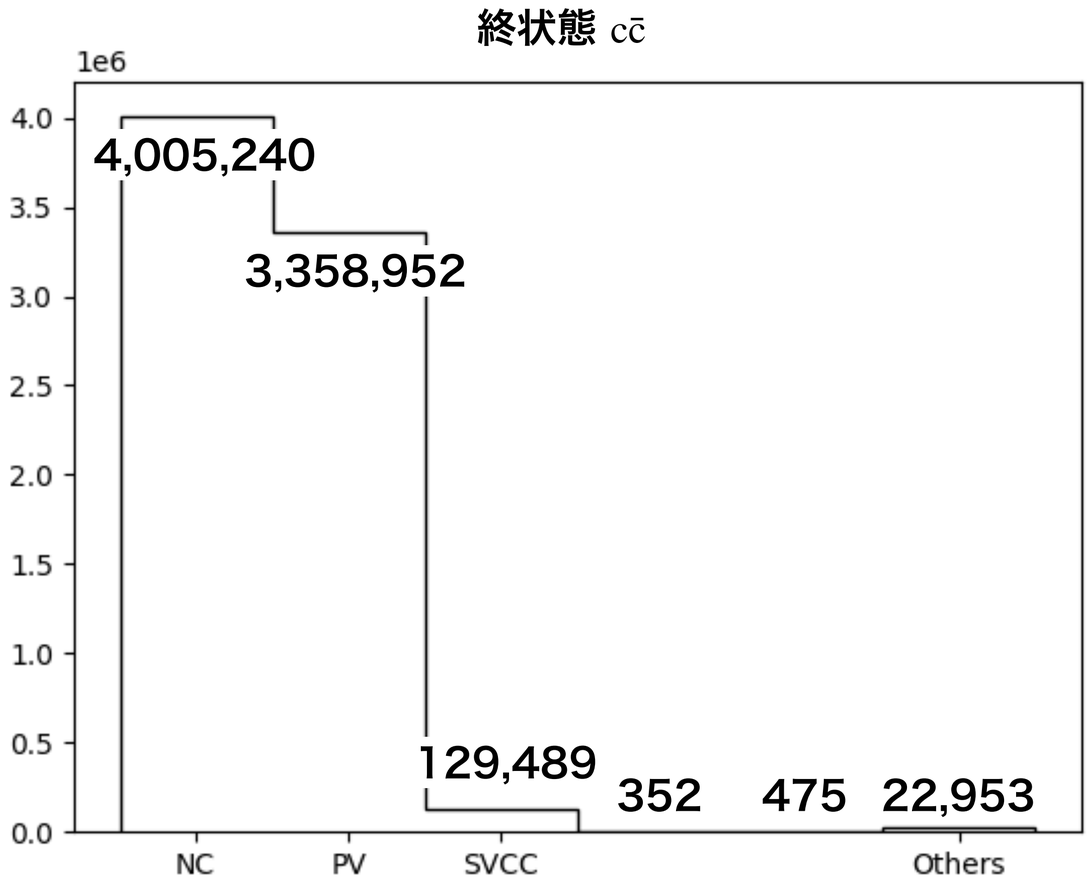
終状態 $c\bar{c}$



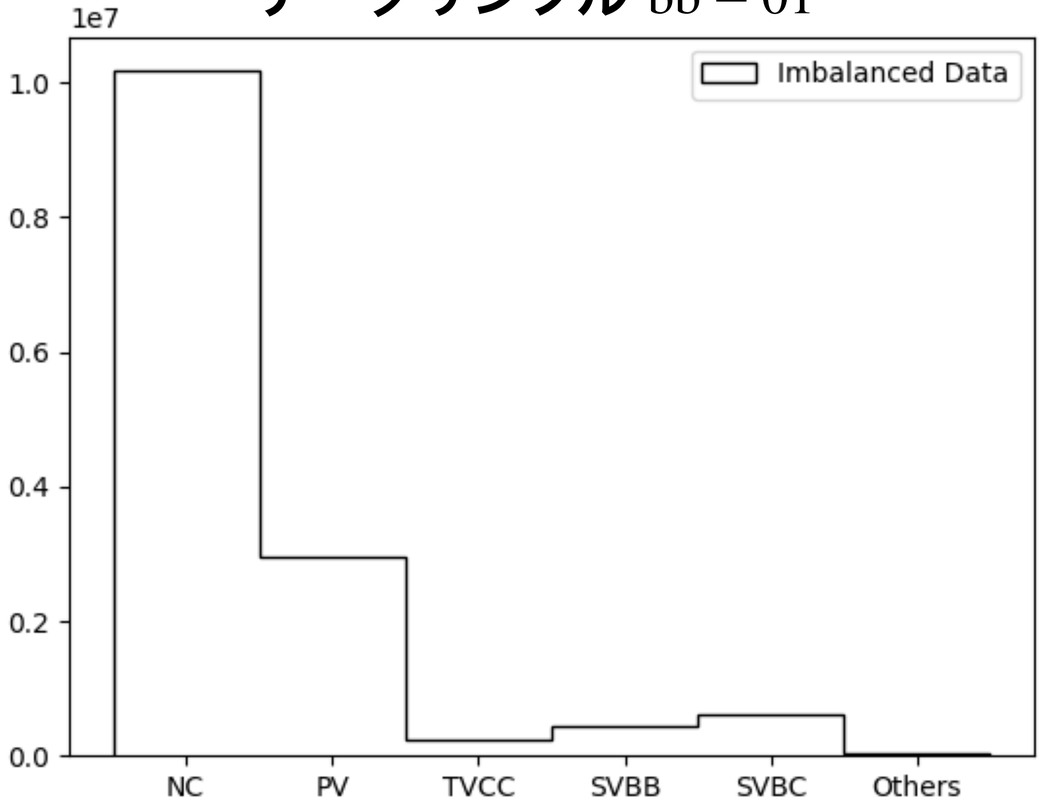

終状態 $b\bar{b}$
Chi-Squared
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Vertex Position - Radial Direction [mm]
350
300
250
200
150
100
50
0


Secondary Vertex BC
(SVBC)
チャーム・フレーバーのハドロンによる
Tertiary Vertex (TBCC)
ボトム・フレーバーのハドロンによる
Secondary Vertex (SVBB)
IP
Primary Vertex

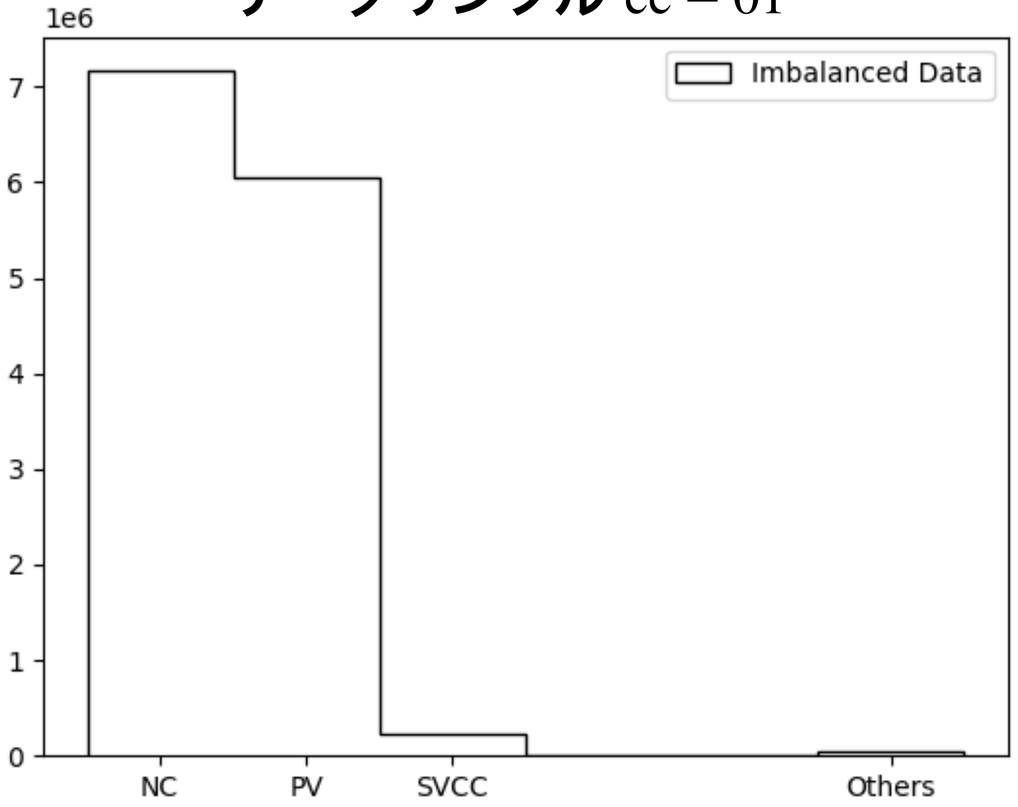

終状態 $b\bar{b}$
1e6
5
4
3
2
1
0
5,688,407
1,645,130
124,557
241,304
346,598
20,728
NC
PV
TVCC
SVBB
SVBC
Others


終状態 $c\bar{c}$
1e6
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
4,005,240
3,358,952
129,489
352
475
22,953
NC
PV
SVCC
Others

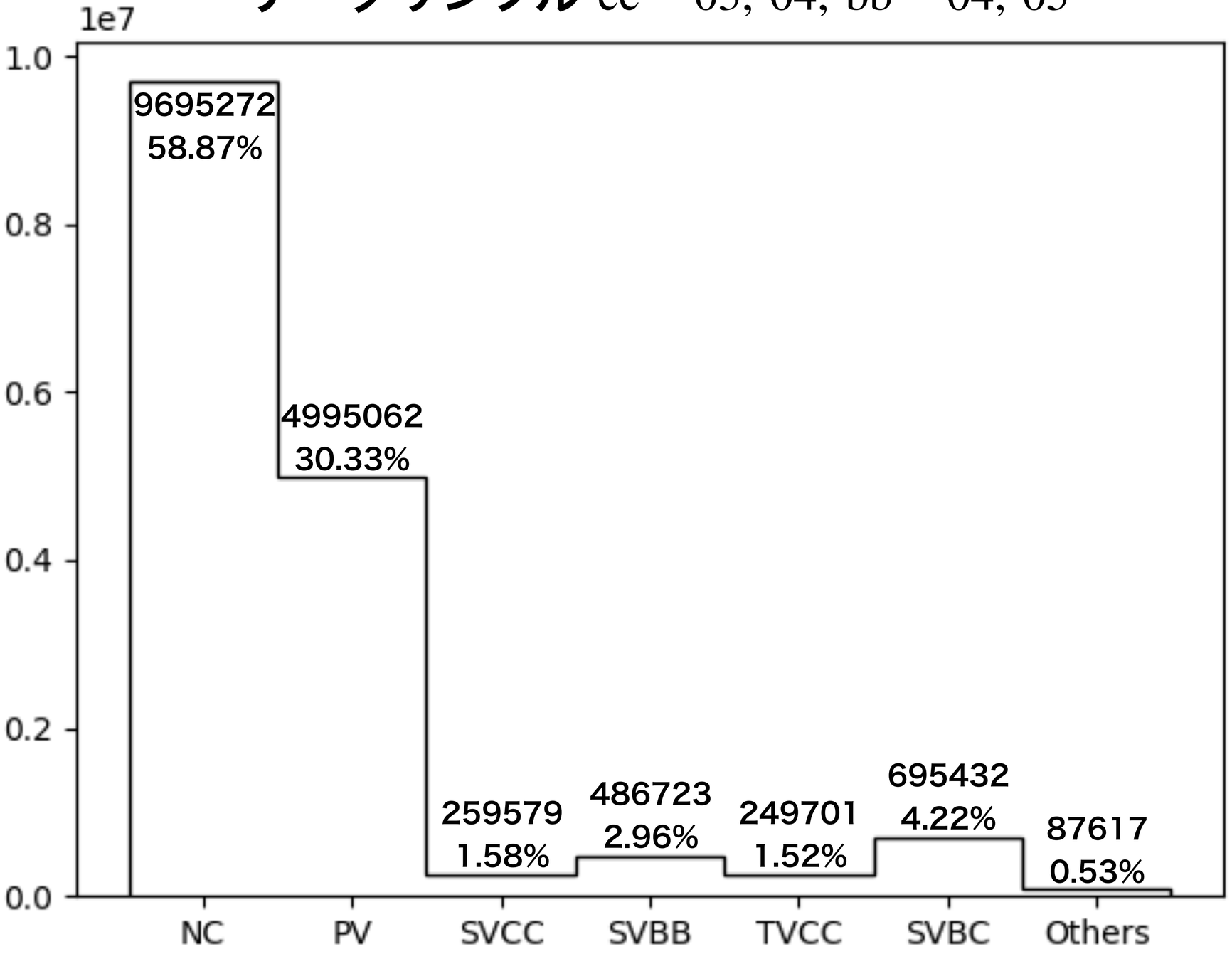
データサンプル $b\bar{b}$ – 01

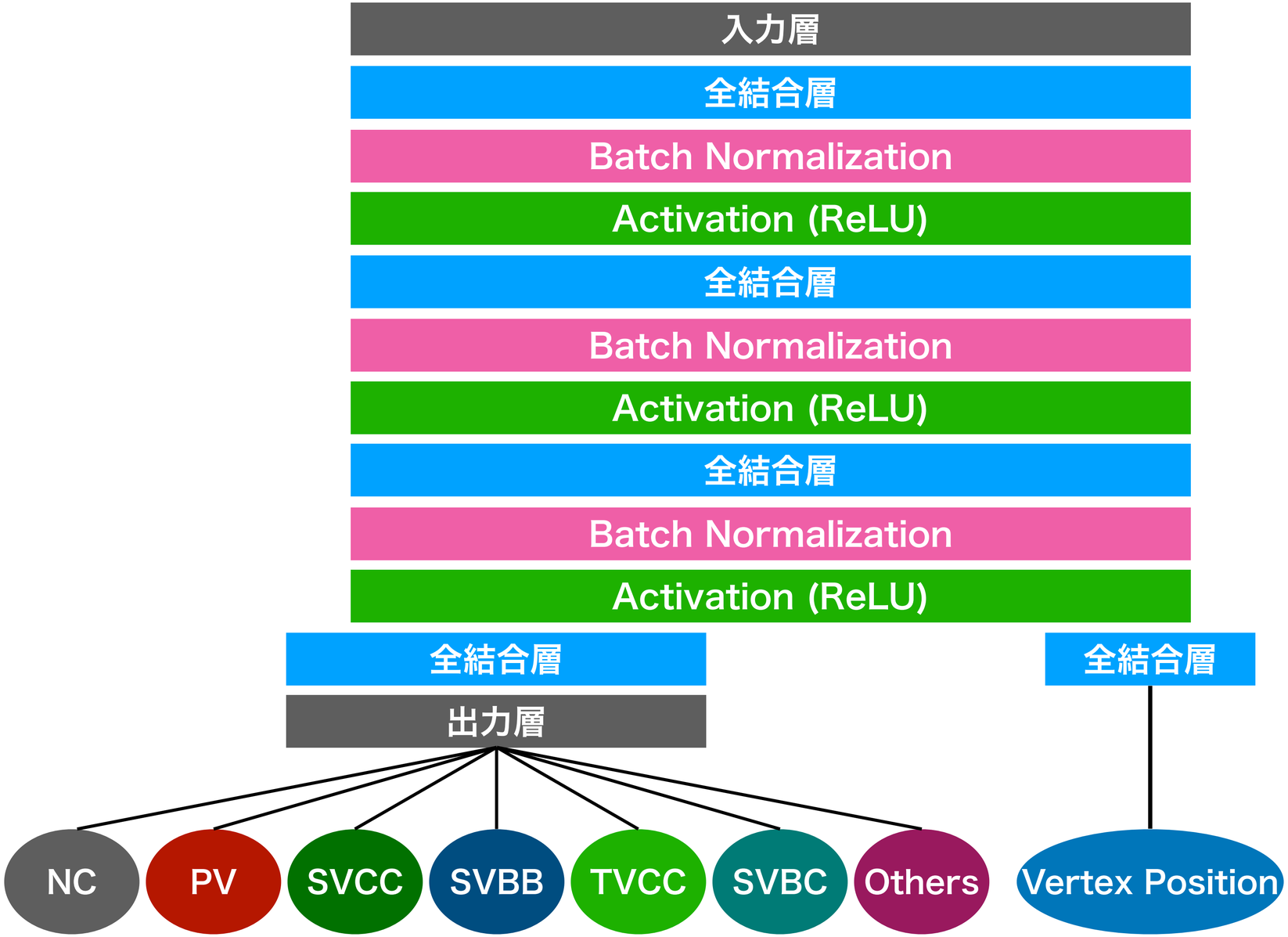


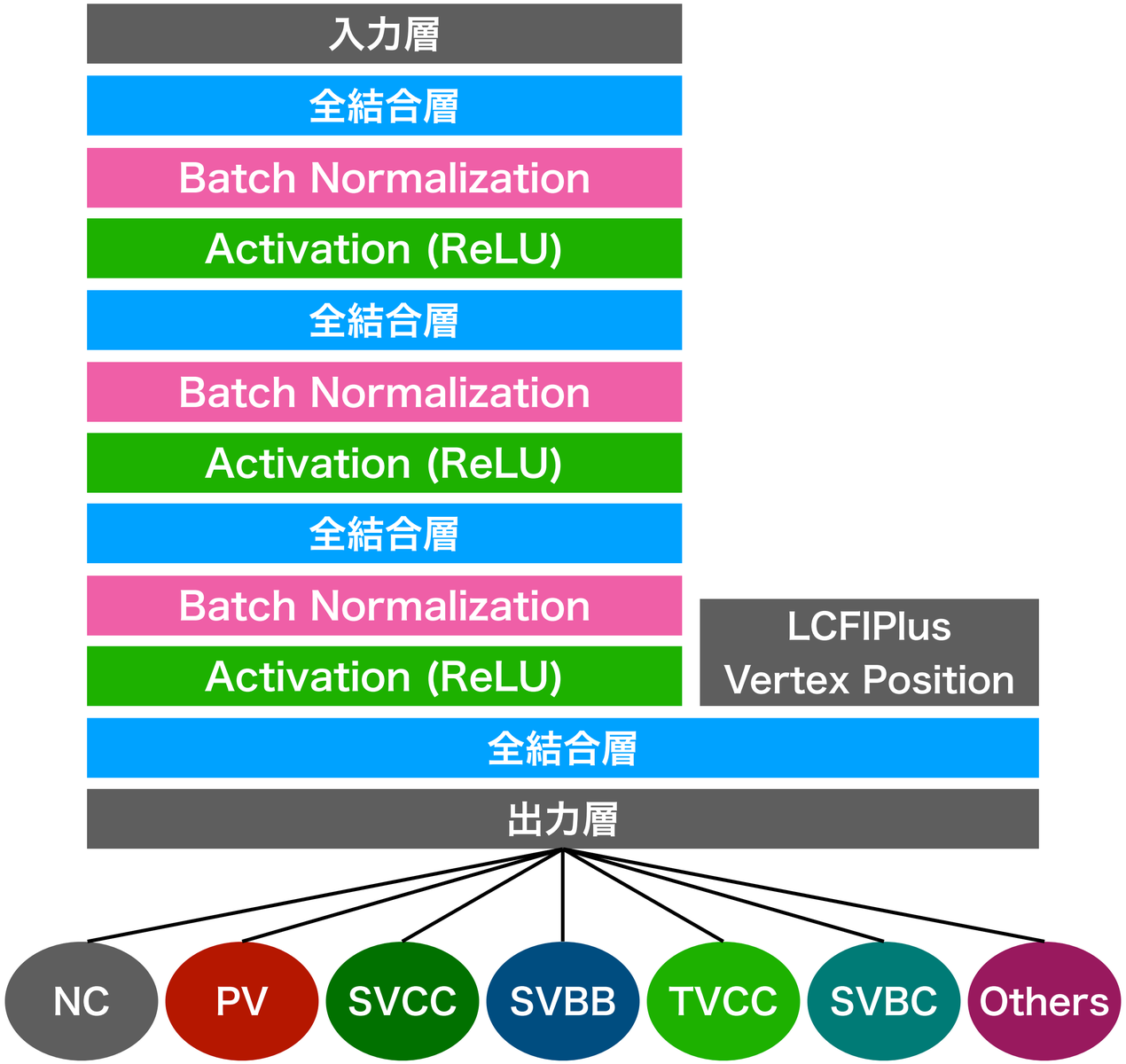
データサンプル $c\bar{c}$ – 01

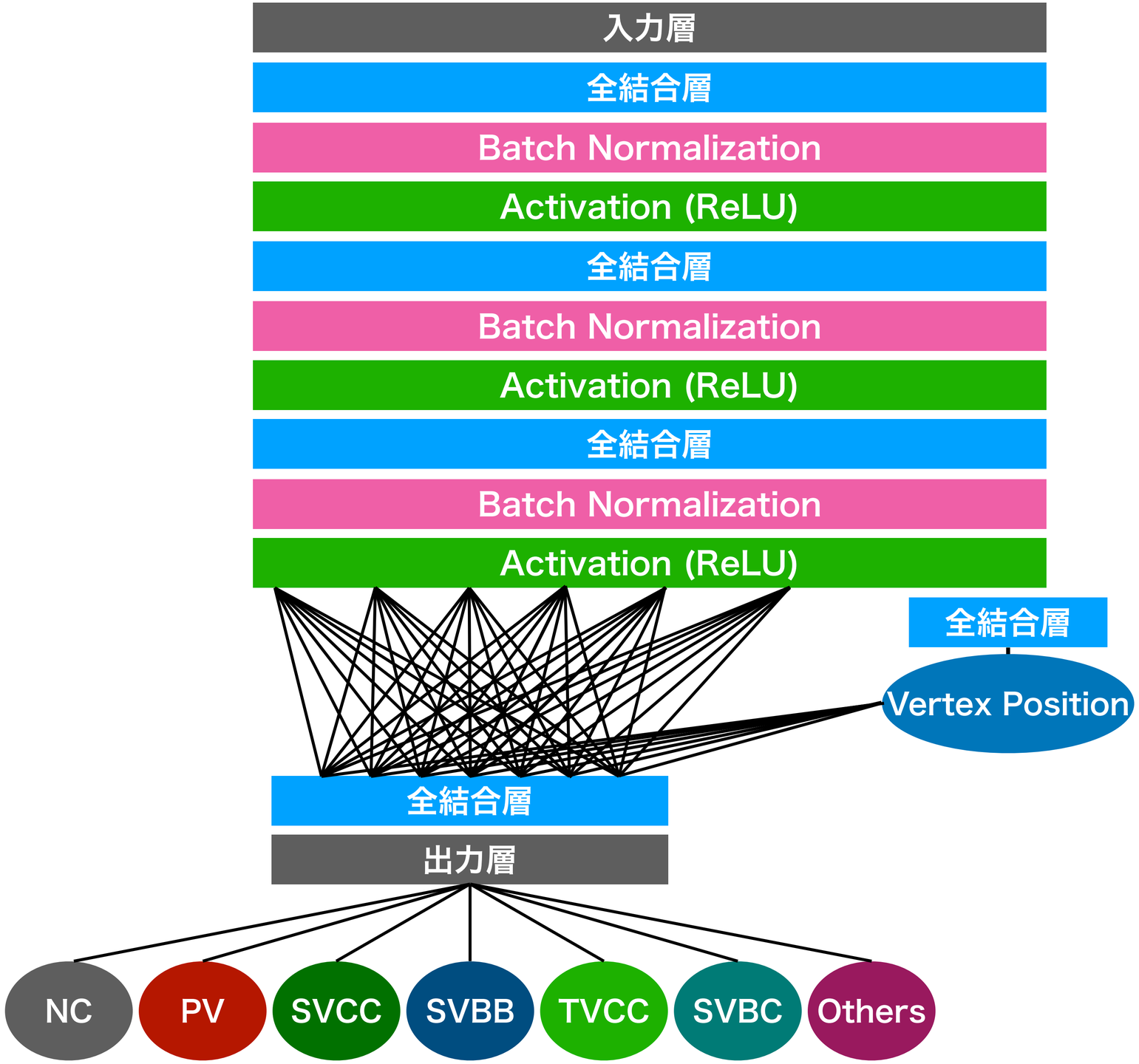


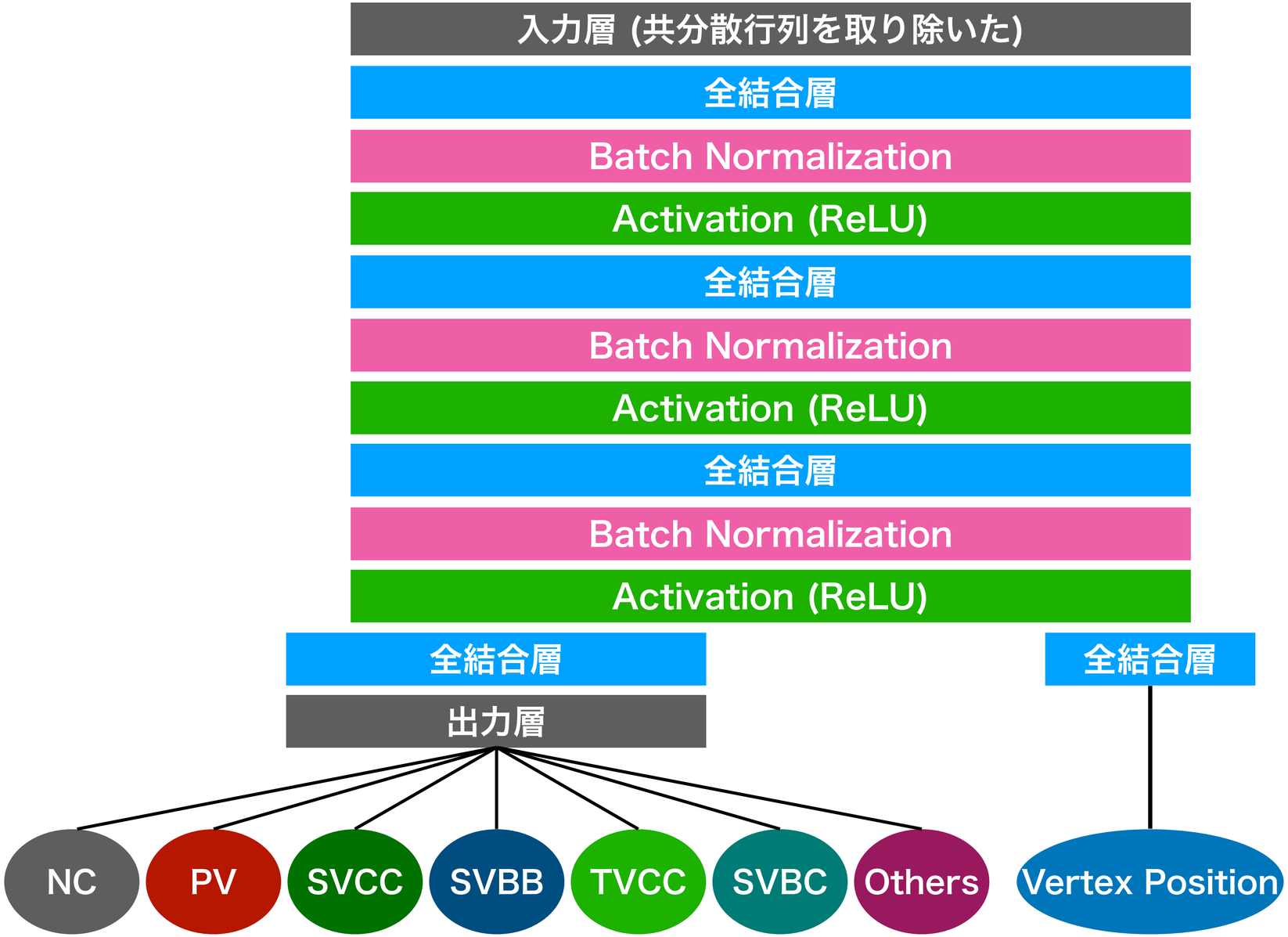
データサンプル $c\bar{c}$ – 03, 04, $b\bar{b}$ – 04, 05




入力層
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
出力層
全結合層
NC
PV
SVCC
SVBB
TVCC
SVBC
Others
Vertex Position


入力層
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
LCFIPlus
Vertex Position
全結合層
出力層
NC
PV
SVCC
SVBB
TVCC
SVBC
Others


入力層
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Vertex Position
全結合層
出力層
NC
PV
SVCC
SVBB
TVCC
SVBC
Others


入力層 (共分散行列を取り除いた)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
Batch Normalization
Activation (ReLU)
全結合層
出力層
全結合層
NC
PV
SVCC
SVBB
TVCC
SVBC
Others
Vertex Position

Loss

Loss

相対値
Efficiency Matrix

相対値
Purity Matrix

Vertex Position

相対値
Efficiency Matrix

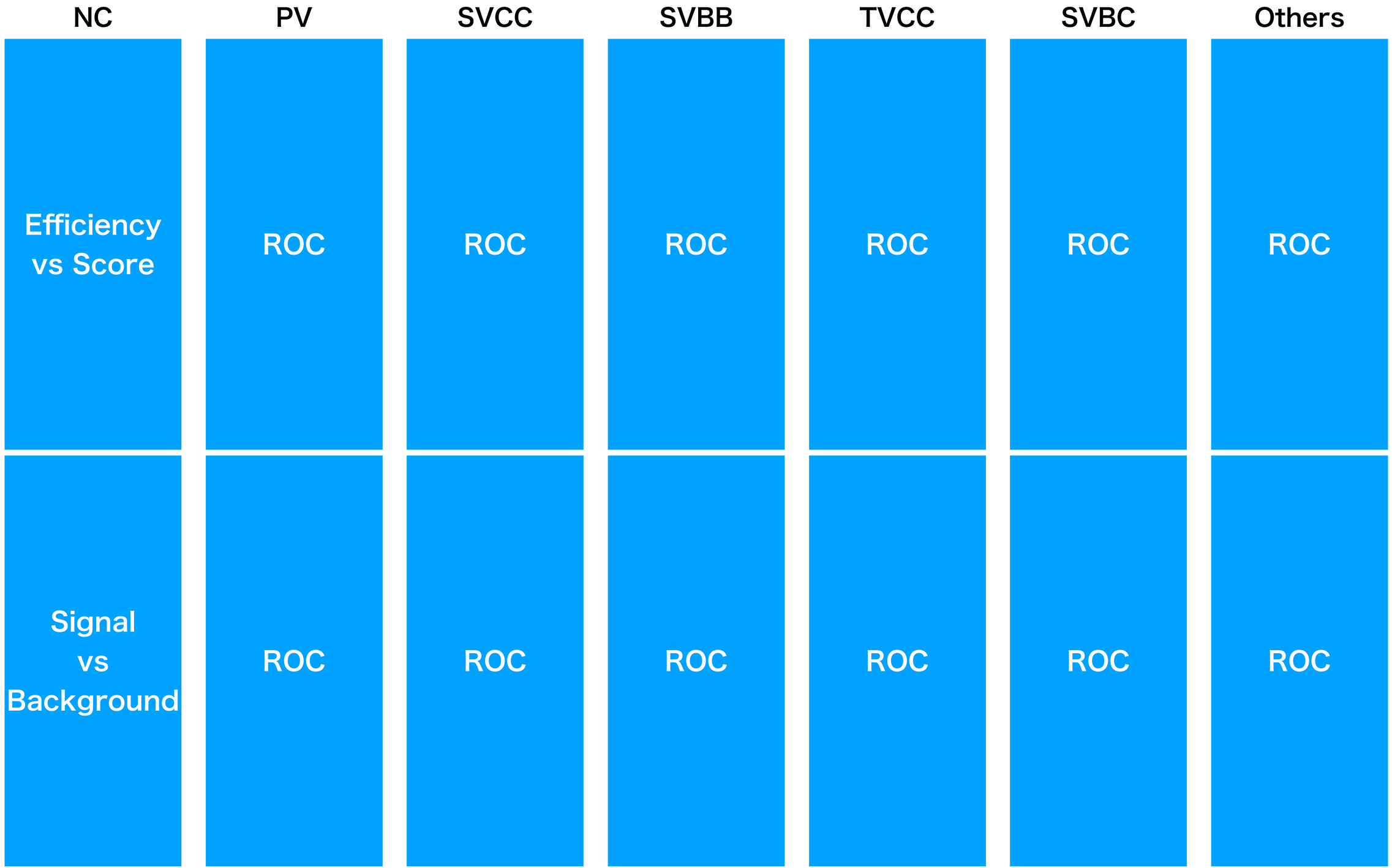
相対値
Purity Matrix

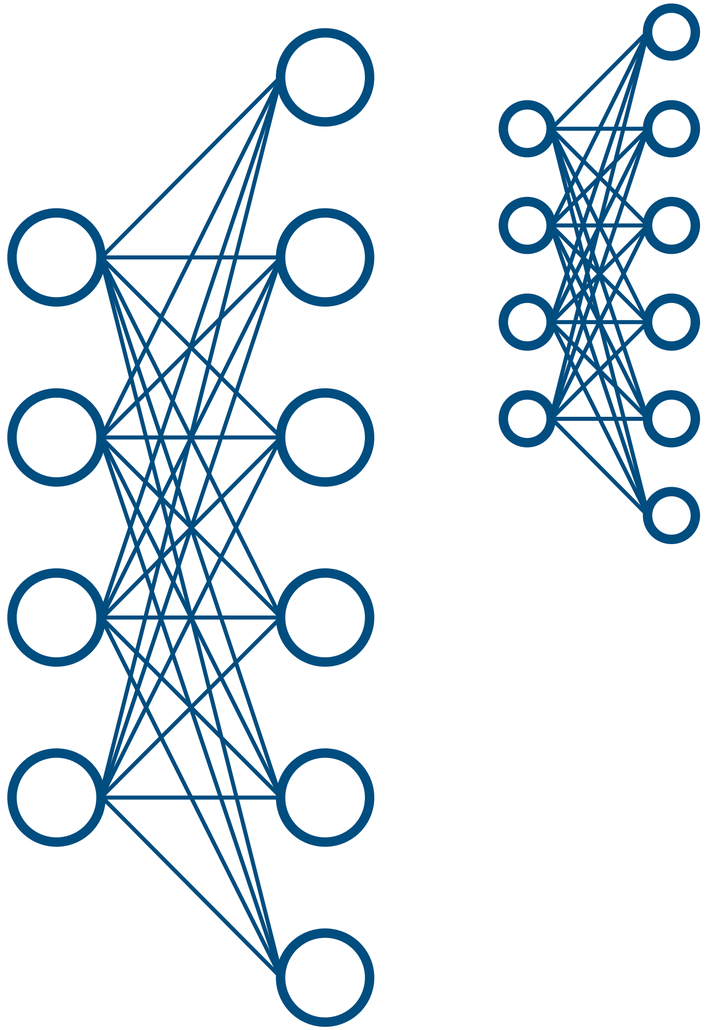
Loss

相対値
Efficiency Matrix

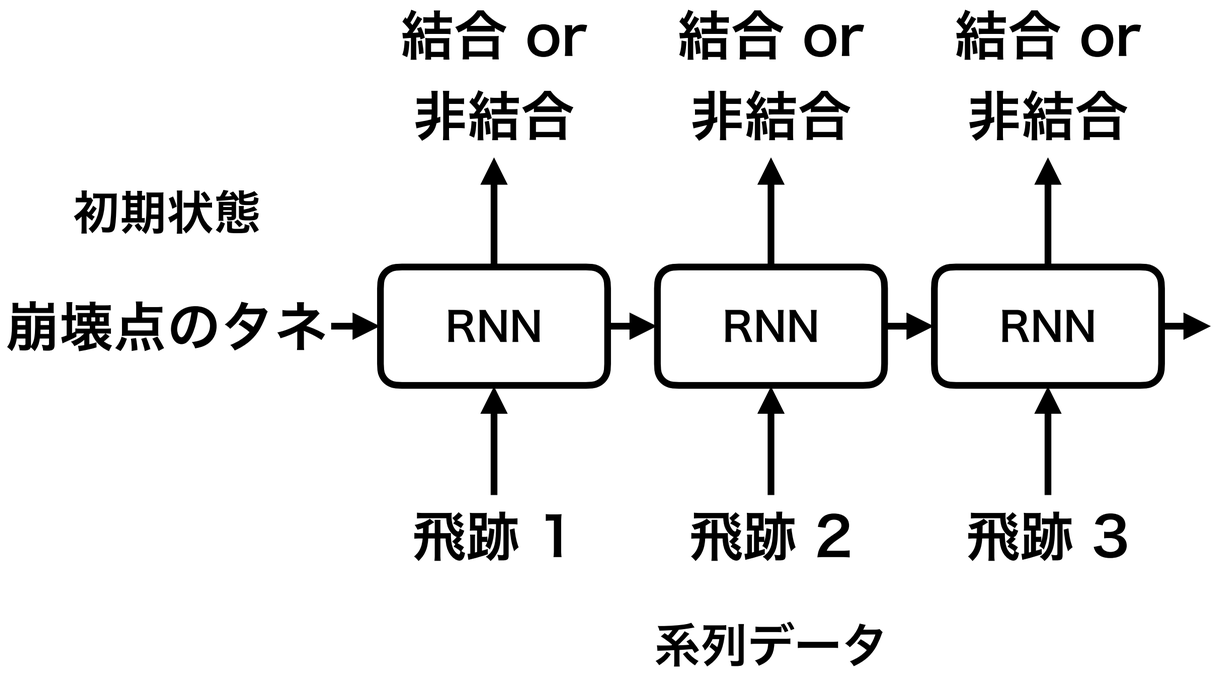
相対値
Purity Matrix

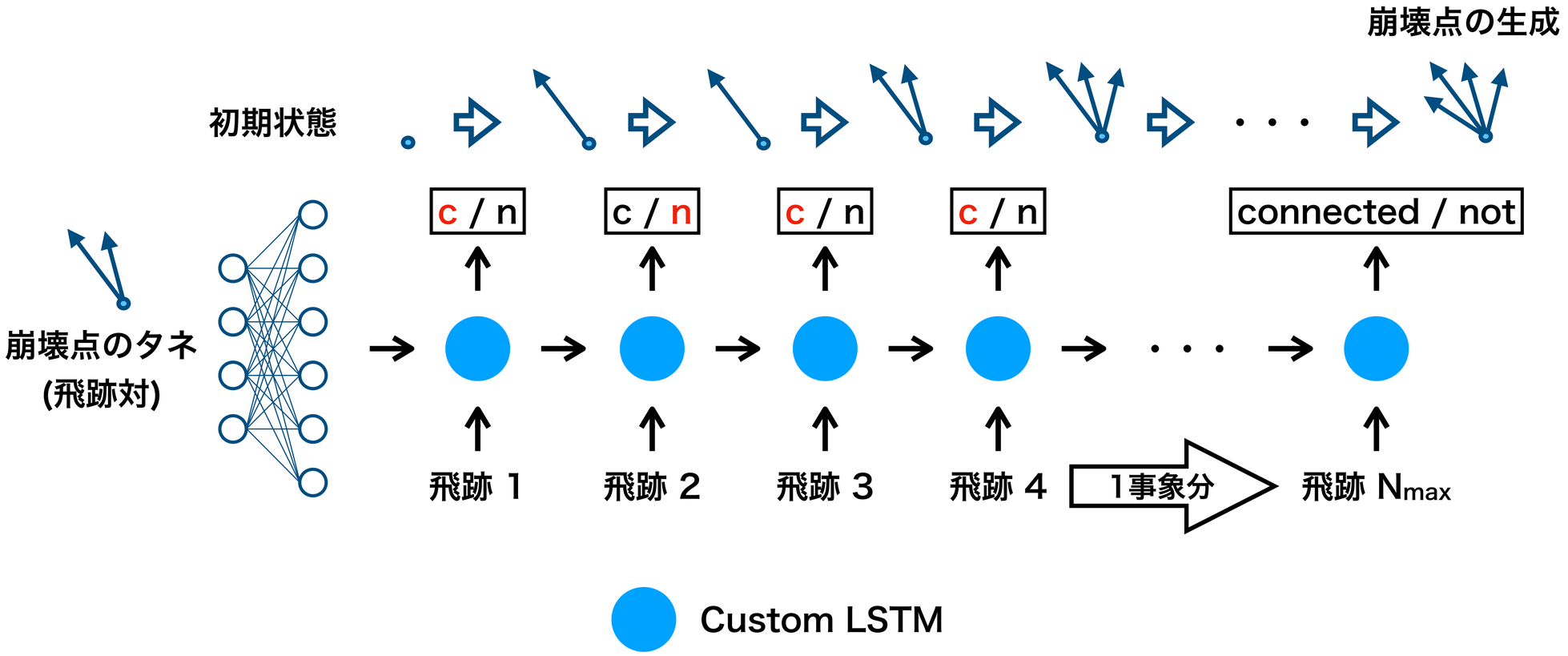
Vertex Position

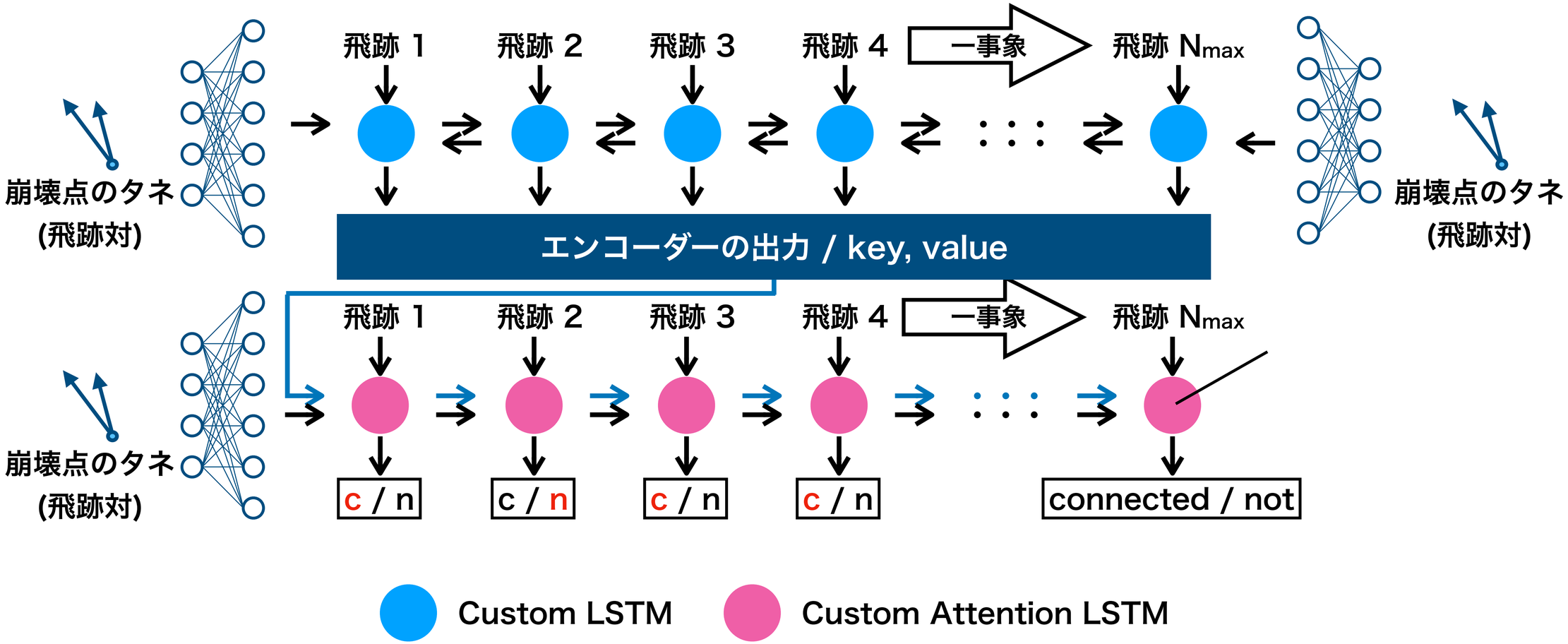

NC
PV
SVCC
SVBB
TVCC
SVBC
Others
Efficiency vs Score
ROC
ROC
ROC
ROC
ROC
ROC
Signal vs Background
ROC
ROC
ROC
ROC
ROC
ROC



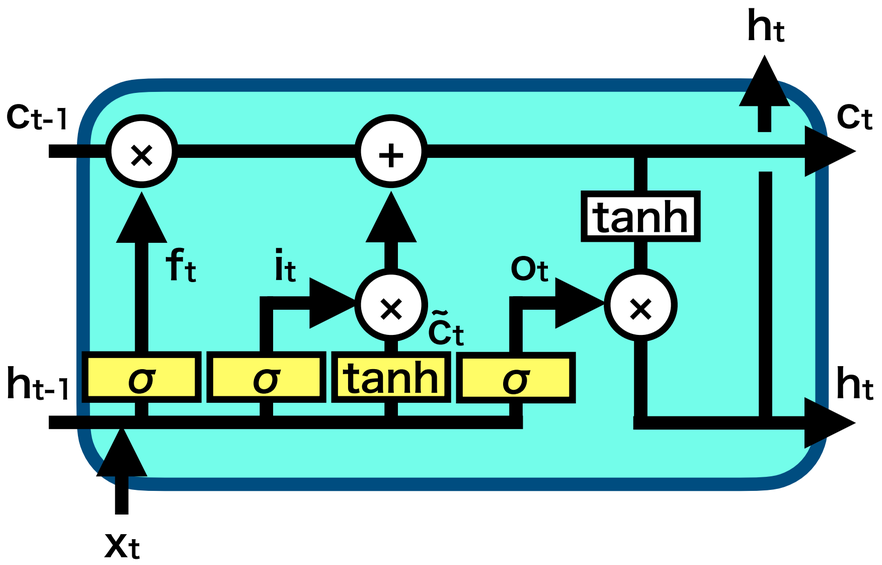
Many to Many


結合 or
非結合
結合 or
非結合
結合 or
非結合
初期状態
崩壊点のタネ
RNN
RNN
RNN
飛跡 1
飛跡 2
飛跡 3
系列データ

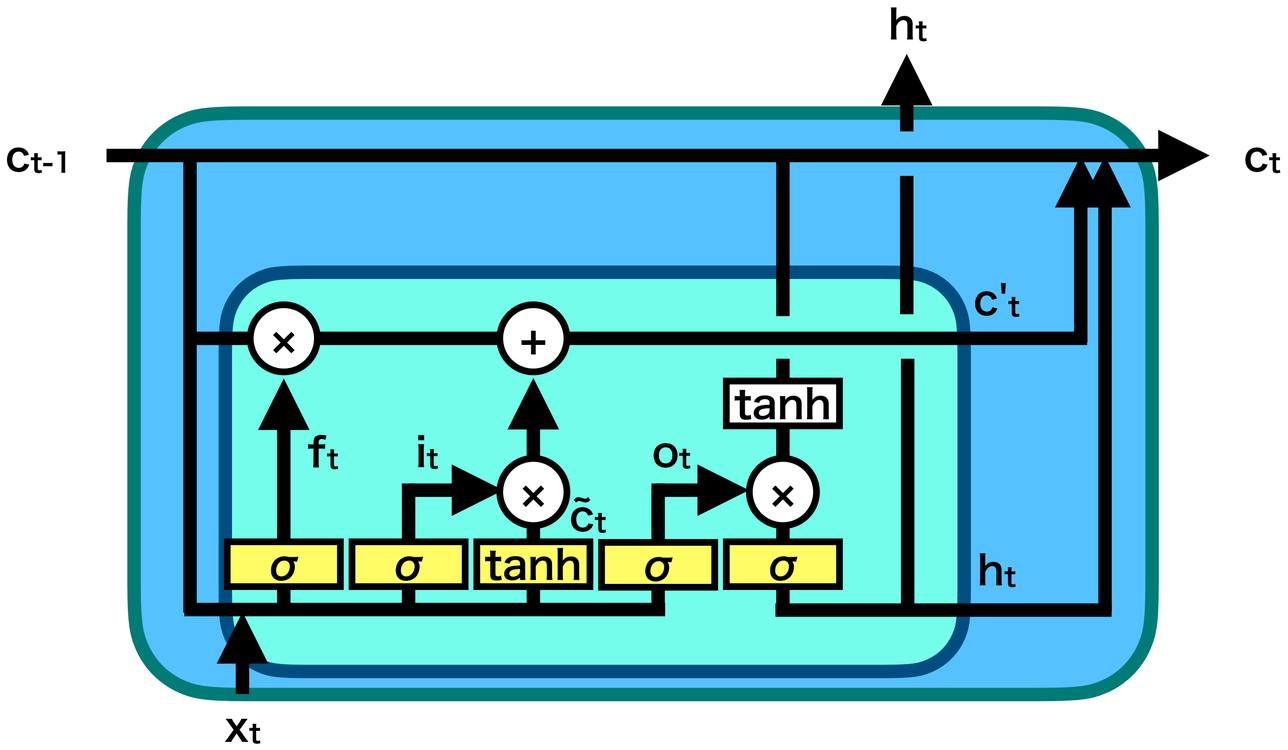

崩壊点の生成
初期状態
崩壊点のタネ
(飛跡対)
c / n
c / n
c / n
c / n
connected / not
飛跡 1
飛跡 2
飛跡 3
飛跡 4
1事象分
飛跡 Nmax
Custom LSTM

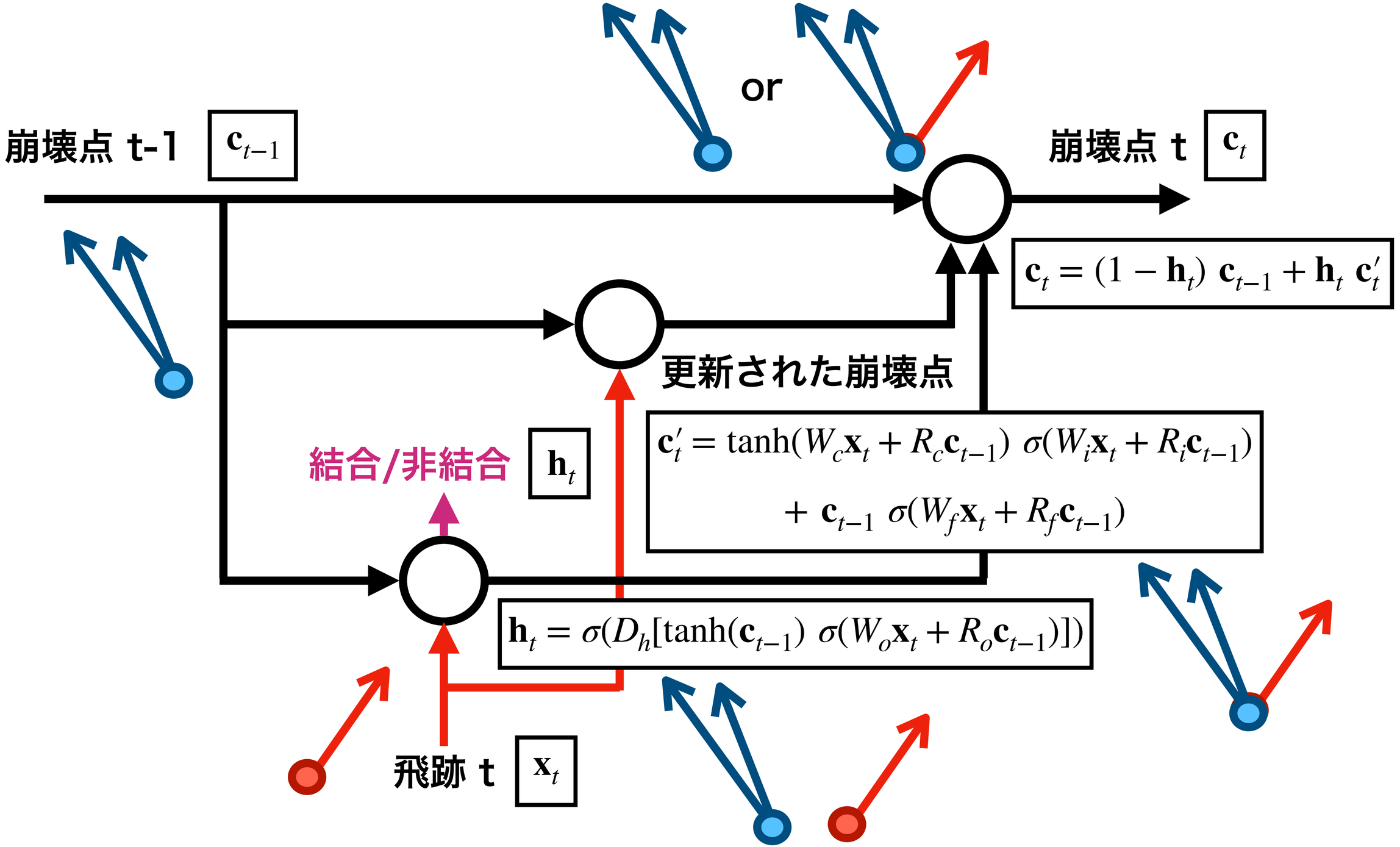

飛跡 1
飛跡 2
飛跡 3
飛跡 4
一事象
飛跡 Nmax
崩壊点のタネ
(飛跡対)
エンコーダーの出力 / key, value
崩壊点のタネ
(飛跡対)
飛跡 1
飛跡 2
飛跡 3
飛跡 4
一事象
飛跡 Nmax
崩壊点のタネ
(飛跡対)
c / n
c / n
c / n
c / n
connected / not
Custom LSTM
Custom Attention LSTM

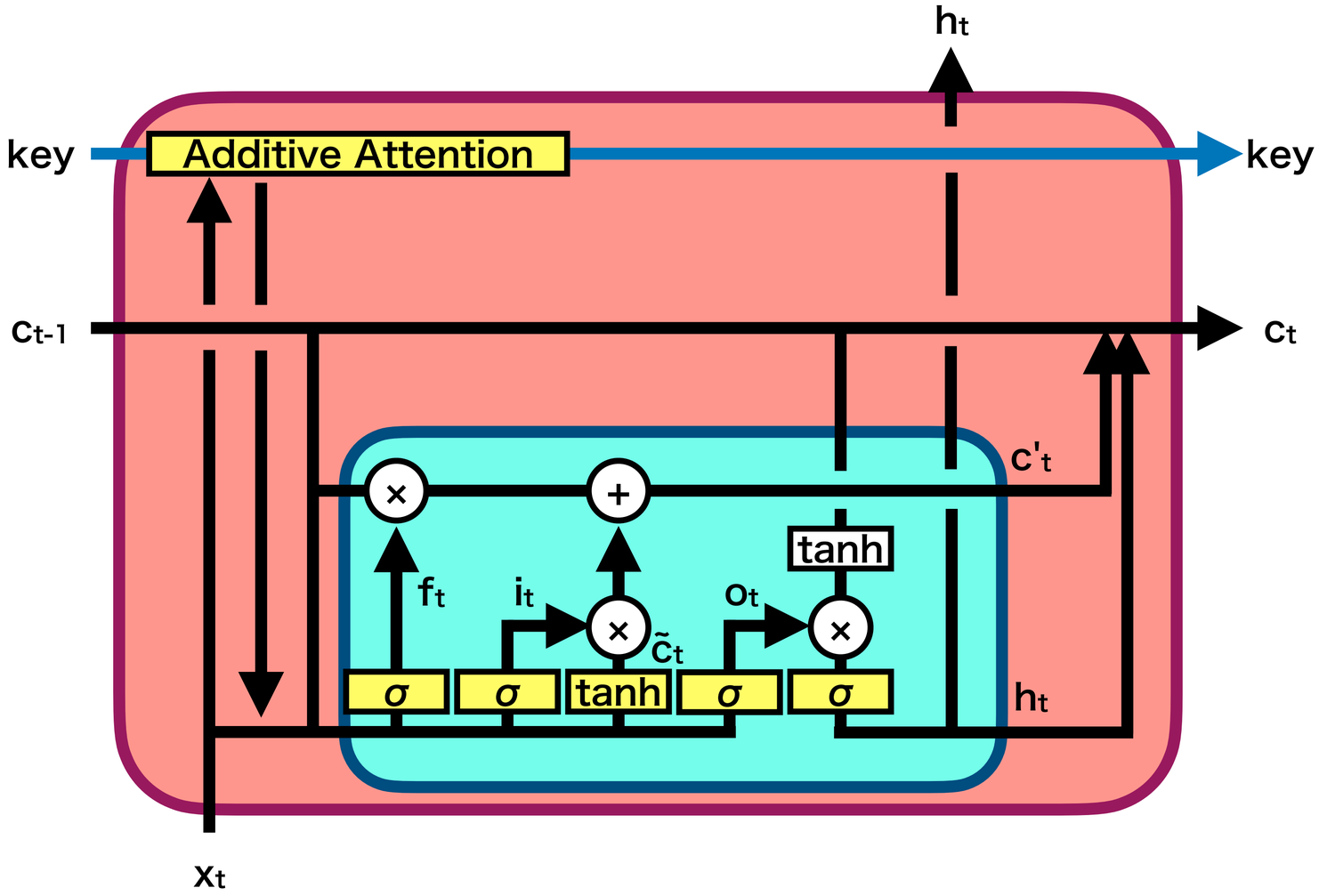
LSTM

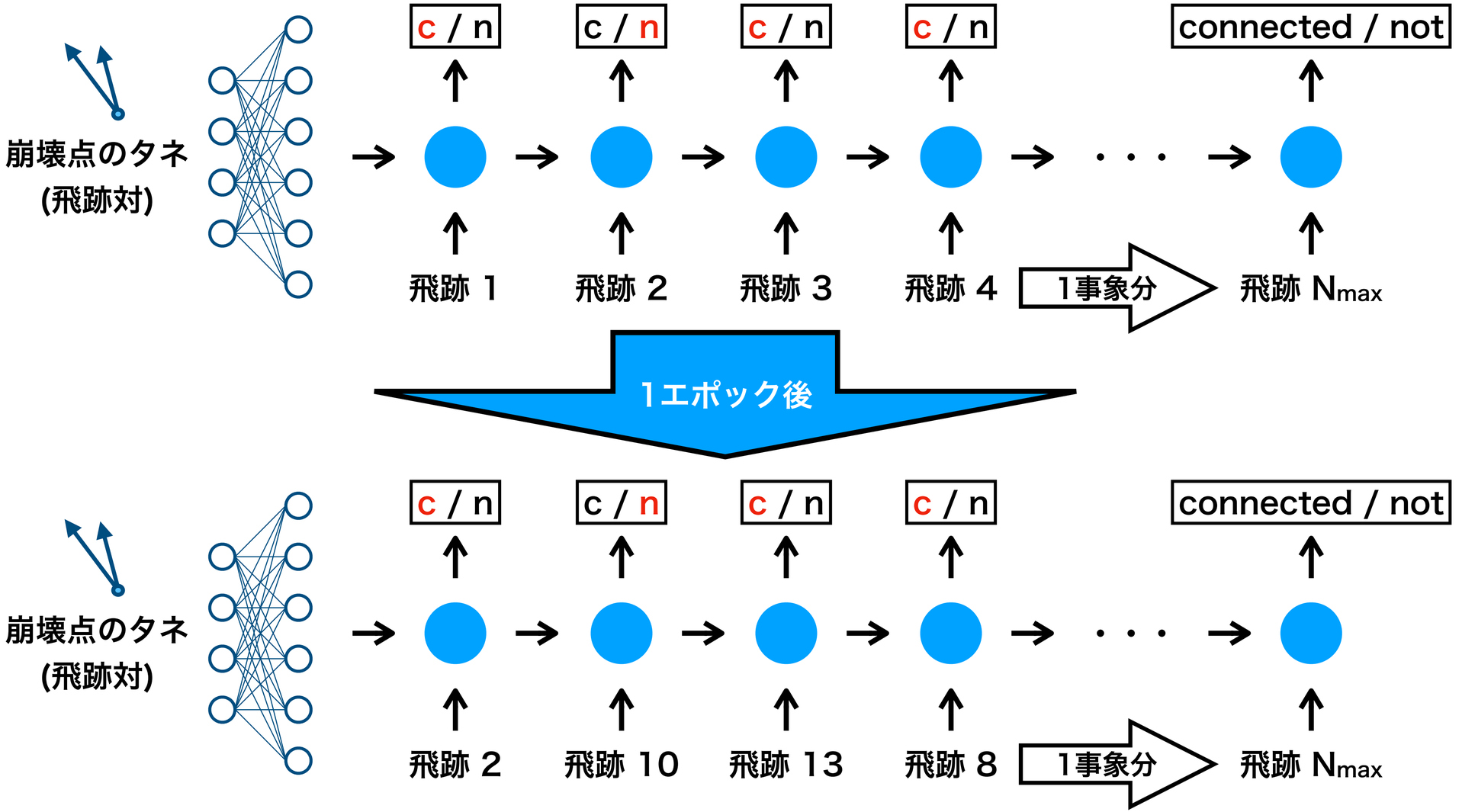


崩壊点生成のための
リカレントニューラルネットワーク




or
崩壊点 t-1
$\mathbf{c}_{t-1}$
崩壊点 t
$\mathbf{c}_t$
$\mathbf{c}_t = (1 - \mathbf{h}_t)\ \mathbf{c}_{t-1} + \mathbf{h}_t\ \mathbf{c}'_t$
更新された崩壊点
$\mathbf{c}'_t = \tanh(W_c\mathbf{x}_t + R_c\mathbf{c}_{t-1})\ \sigma(W_i\mathbf{x}_t + R_i\mathbf{c}_{t-1})$
$+\ \mathbf{c}_{t-1}\ \sigma(W_f\mathbf{x}_t + R_f\mathbf{c}_{t-1})$
結合/非結合
$\mathbf{h}_t$
$\mathbf{h}_t = \sigma(D_h[\tanh(\mathbf{c}_{t-1})\ \sigma(W_o\mathbf{x}_t + R_o\mathbf{c}_{t-1})])$
飛跡 t
$\mathbf{x}_t$


h_t
key
Additive Attention
key
c_{t-1}
c_t
c'_t
tanh
f_t
i_t
o_t
$\tilde{c}_t$
σ
σ
tanh
σ
σ
h_t
x_t


崩壊点のタネ
(飛跡対)
c / n
c / n
c / n
c / n
connected / not
飛跡 1
飛跡 2
飛跡 3
飛跡 4
1事象分
飛跡 Nmax
1エポック後
崩壊点のタネ
(飛跡対)
c / n
c / n
c / n
c / n
connected / not
飛跡 2
飛跡 10
飛跡 13
飛跡 8
1事象分
飛跡 Nmax

飛跡順のシャッフル