

Report of Entropy estimates based on NIST SP 800-90B non-IID track

2023-Aug-06 09:42:25.409433

1 Identification information

1.1 Identification of acquisition data from entropy source

Table 1 Identification information of acquisition data from entropy source

| | |
|--------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| URL of the acquisition data | https://github.com/usnistgov/SP800-90B_EntropyAssessment/blob/master/bin/truerand_8bit.bin |
| SHA-256 hash value of the acquisition data [hex] | c7e56911 d2657fa9 b6e86c03 d4477474 d6ec6986 91c5f32d 3918ec51 3713e3c3 |

- Name of the submitter of the acquisition data :
- Brief explanation of the acquisition data (or entropy source) :

1.2 Identification of analysis environment

Table 2 Identification information of analysis environment

| | | |
|----------------------|------------------------|--------------------------------------------------------|
| Analysis tool | Name | Another entropy estimation tool with extensions |
| | Versioning information | 1.0.50 |
| | built as | 64-bit application |
| | built by | Intel C++ Compiler (__INTEL_LLVM_COMPILER: 20230200) |
| | linked libraries | Boost C++ 1.82.0 |
| Analysis environment | Hostname | [REDACTED] |
| | CPU information | AMD Ryzen [REDACTED] |
| | Physical memory size | [REDACTED] MiB |
| | OS information | Windows 10 or greater 64-bit |
| | Username | [REDACTED] |

1.3 Identification of analysis conditions

Table 3 Identification information of analysis conditions

| | |
|------------------------|----------------------------------|
| Number of samples | 1000000 |
| Bits per sample | 8 |
| Byte to bit conversion | Most Significant bit (MSb) first |

1.4 Identification of analysis method

NIST SP 800-90B [1] 6.3 with corrections [2] is applied

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Executive summary

2.1

Numerical results of min-entropy estimates based on non-IID track

Table 4 Numerical results

| Estimator | $H_{\text{original}}^{\text{a}}$ [bit / 8 - bit] | Notes to H_{original} | $H_{\text{bitstring}}^{\text{b}}$ [bit / 1 - bit] | Notes to $H_{\text{bitstring}}$ |
|-------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------|--------------------------------|------------------------------------------------------|---------------------------------|
| The Most Common Value Estimate | 7.86512 | see 3.1 | 0.998199 | see 4.1 |
| The Collision Estimate | — | — | 0.95841 | see 4.2 |
| The Markov Estimate | — | — | 0.999439 | see 4.3 |
| The Compression Estimate | — | — | 0.904233 | see 4.4 |
| The t-Tuple Estimate | 7.86512 | see 3.2 | 0.933569 | see 4.5 |
| The Longest Repeated Substring (LRS) Estimate | 7.9392 | see 3.3 | 0.998671 | see 4.6 |
| Multi Most Common in Window Prediction Estimate | 7.98858 | see 3.4 | 0.999563 | see 4.7 |
| The Lag Prediction Estimate | 7.93976 | see 3.5 | 0.998402 | see 4.8 |
| The MultiMMC Prediction Estimate | 7.92681 | see 3.6 | 0.99966 | see 4.9 |
| The LZ78Y Prediction Estimate | 7.91928 | see 3.7 | 0.998465 | see 4.10 |
| The initial entropy source estimate [bit / 8 - bit] $H_I = \min(H_{\text{original}}, 8 \times H_{\text{bitstring}})$ | 7.23386 | | | |
| ^a Entropy estimate of the sequential dataset [source: NIST SP 800-90B [1] 3.1.3] | | | | |
| ^b An additional entropy estimation (per bit) for the non-binary sequential dataset [see NIST SP 800-90B [1] 3.1.3] | | | | |

2.2 Visual comparison of min-entropy estimates from original samples

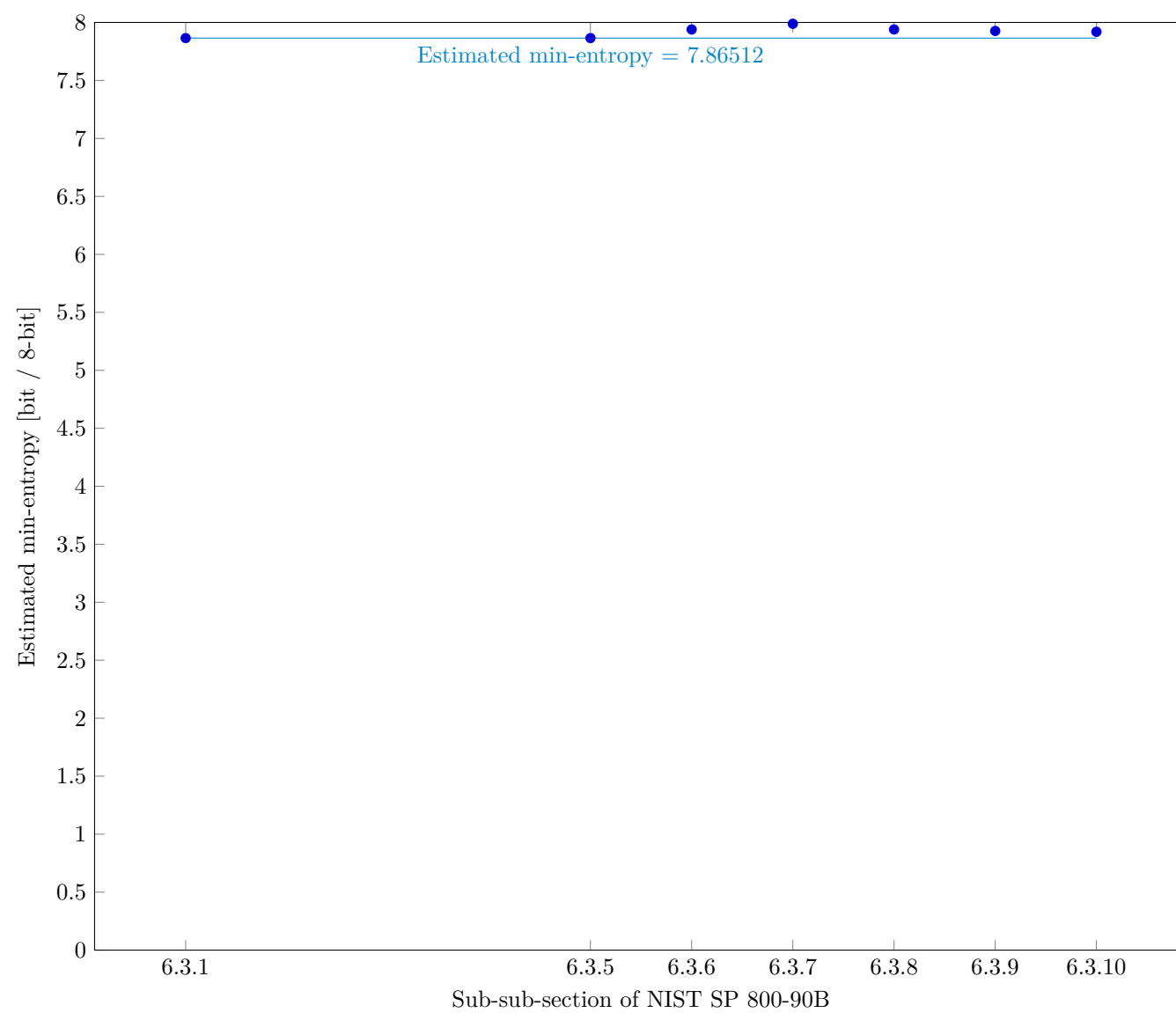


Fig. 1 Estimated Min-Entropy using §6.3 of NIST SP 800-90B

2.3 Visual comparison of min-entropy estimates by interpreting each sample as bitstring

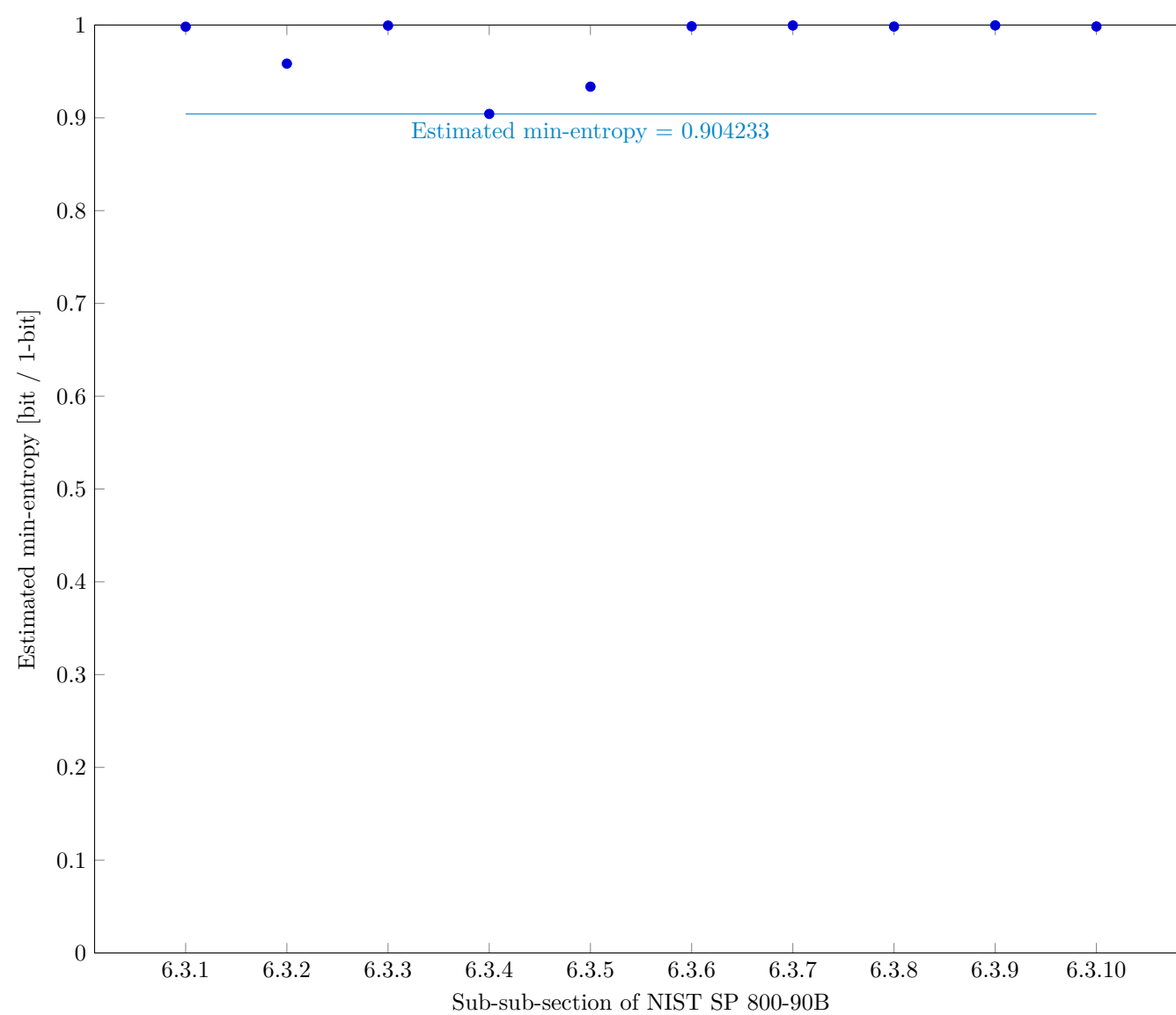


Fig. 2 Estimated Min-Entropy using §6.3 of NIST SP 800-90B

3

Detailed results of analysis from original samples

3.1

The Most Common Value Estimate (NIST SP 800-90B Section 6.3.1)

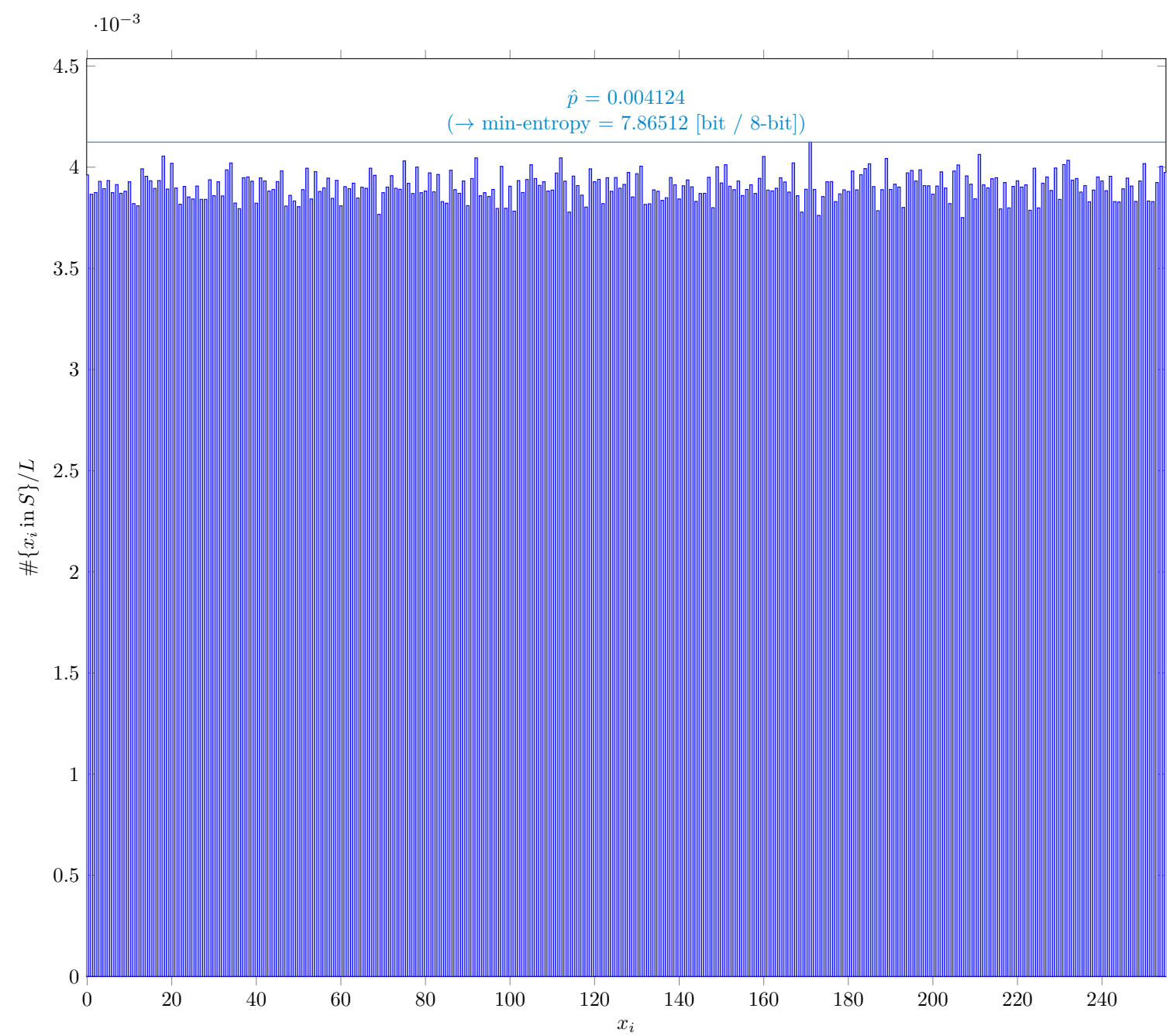


Fig. 3 Distribution of x_i

3.1.1

Supplemental information for traceability

Table 5 Supplemental information for traceability (NIST SP 800-90B Section 6.3.1)

| Symbol | Value |
|-----------|------------|
| mode | 4124 |
| \hat{p} | 0.004124 |
| p_u | 0.00428907 |

3.2 The t-tuple Estimate (NIST SP 800-90B Section 6.3.5)

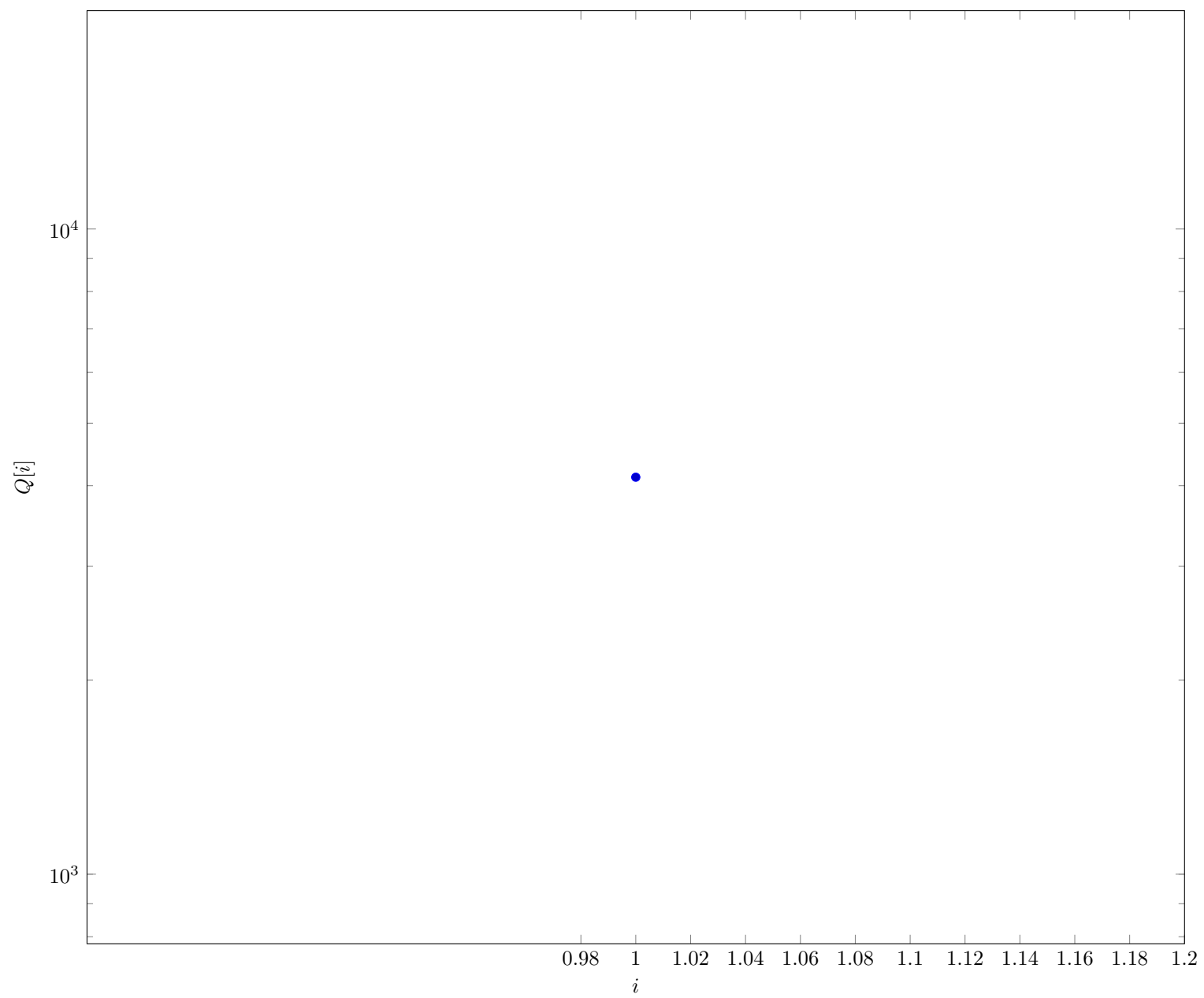


Fig. 4 Intermediate value $Q[i]$ in §6.3.5 of NIST SP 800-90B

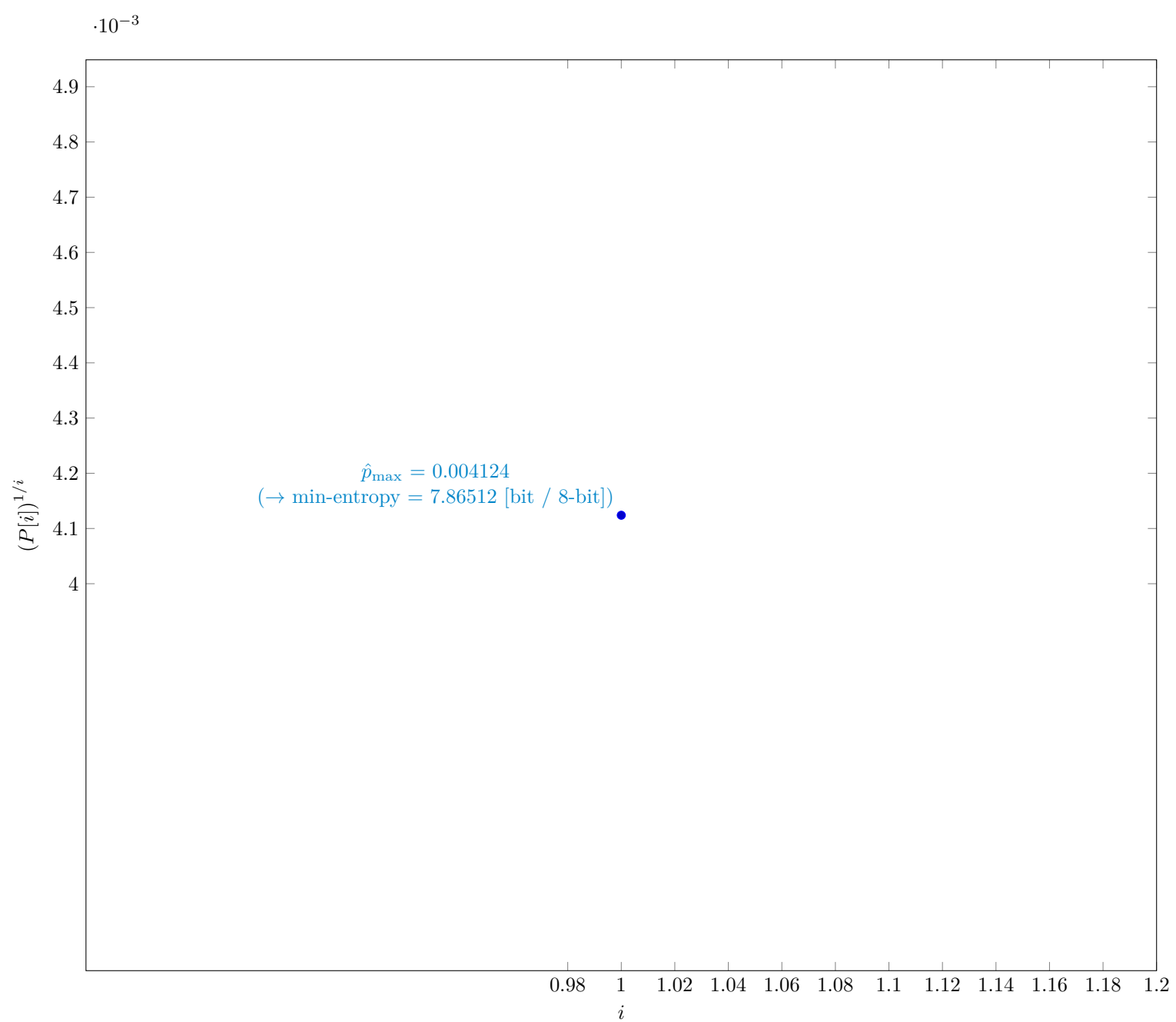


Fig. 5 $P[i]^{1/i}$ in §6.3.5 of NIST SP 800-90B

3.2.1 Supplemental information for traceability

Table 6 Supplemental information for traceability (NIST SP 800-90B Section 6.3.5)

| Symbol | Value |
|------------------|------------|
| t | 1 |
| \hat{p}_{\max} | 0.004124 |
| p_u | 0.00428907 |

3.3 The LRS Estimate (NIST SP 800-90B Section 6.3.6)

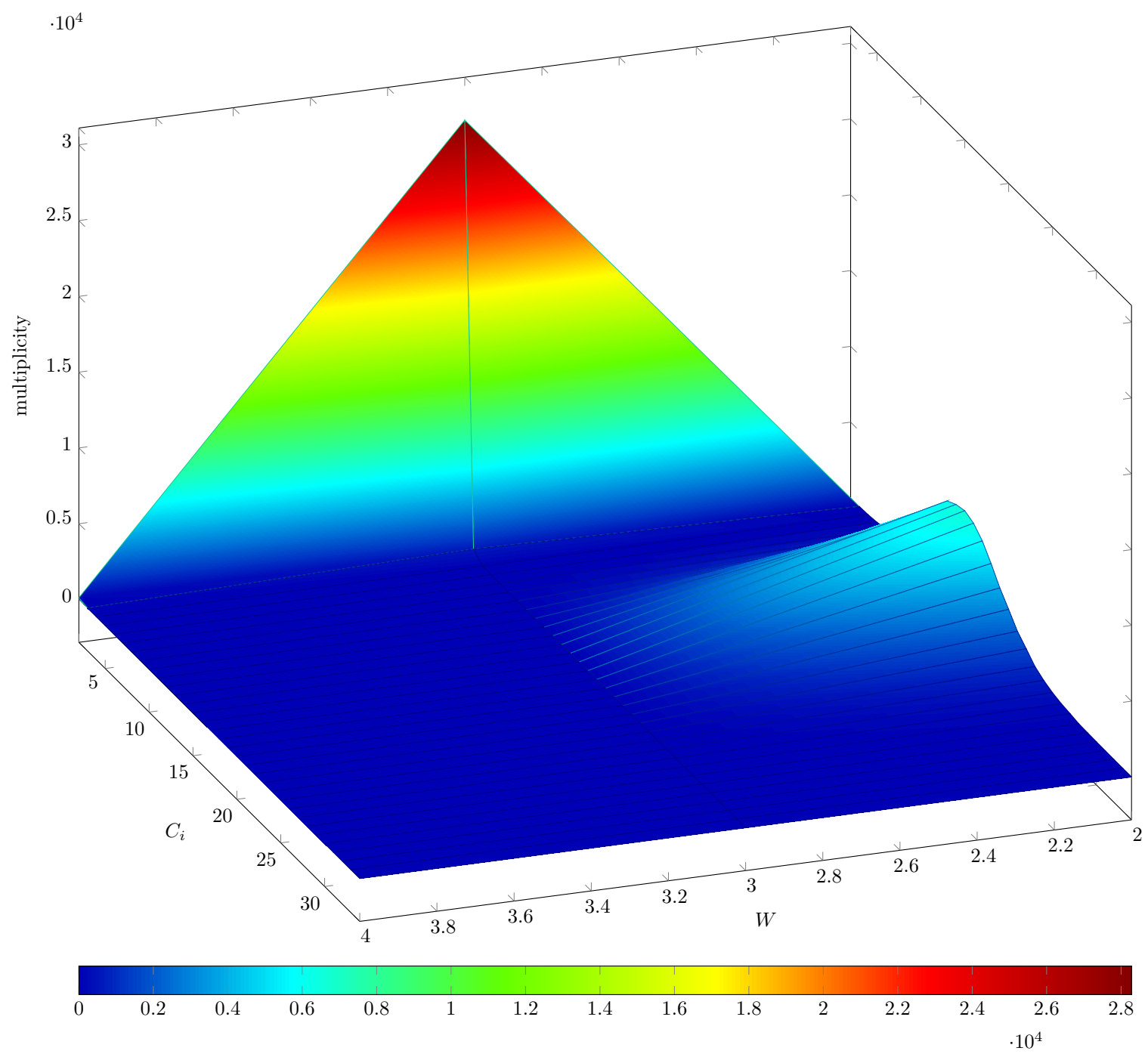


Fig. 6 Estimated W -tuple collision probability in Step 3 of §6.3.6 of NIST SP 800-90B

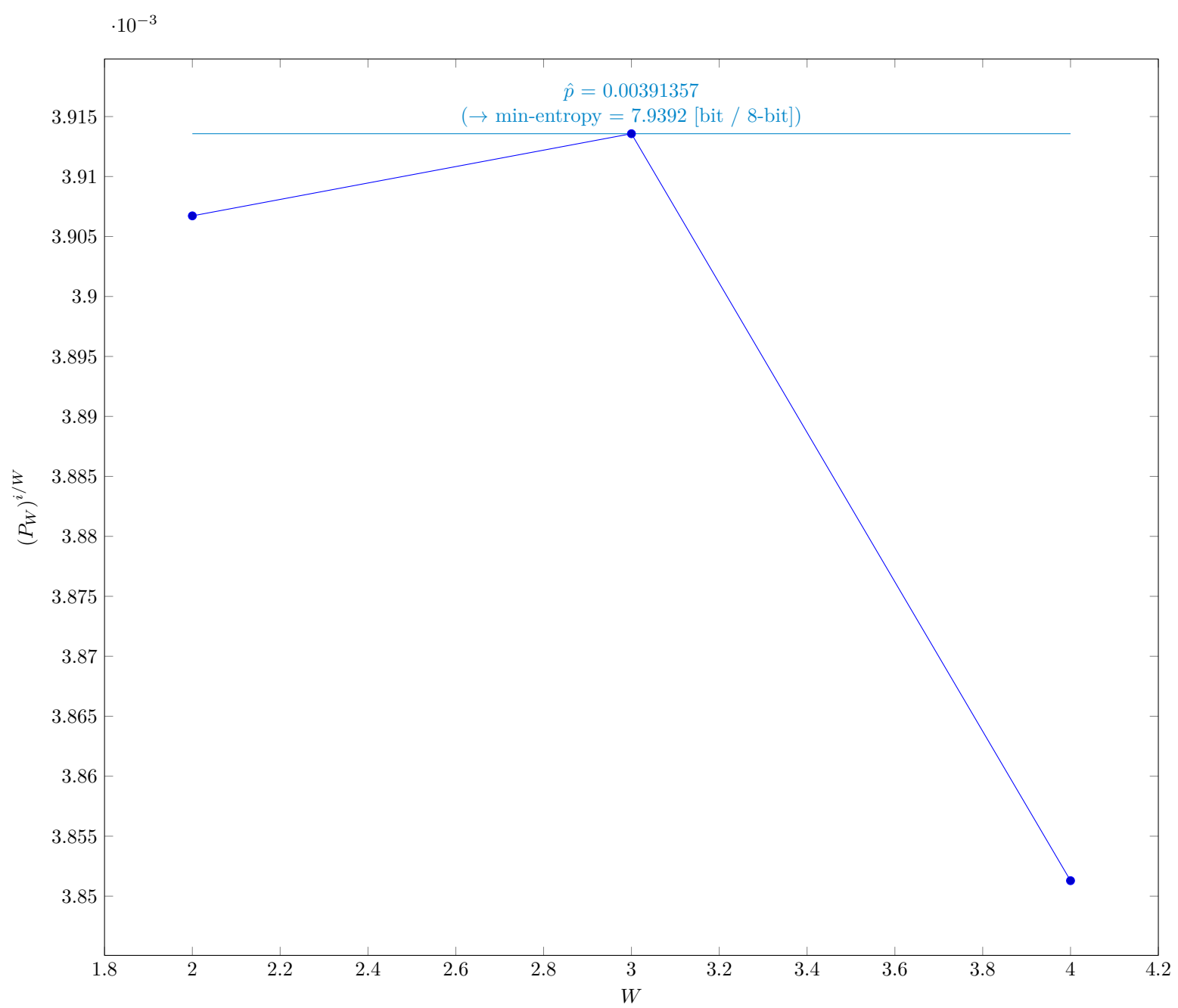


Fig. 7 Estimated average collision probability per string symbol in Step 3 of §6.3.6 of NIST SP 800-90B

3.3.1 Supplemental information for traceability

Table 7 Supplemental information for traceability (NIST SP 800-90B Section 6.3.6)

| Symbol | Value |
|-----------|------------|
| u | 2 |
| v | 4 |
| \hat{p} | 0.00391357 |
| p_u | 0.00407439 |

3.4 Multi Most Common in Window Prediction Estimate (NIST SP 800-90B Section 6.3.7)

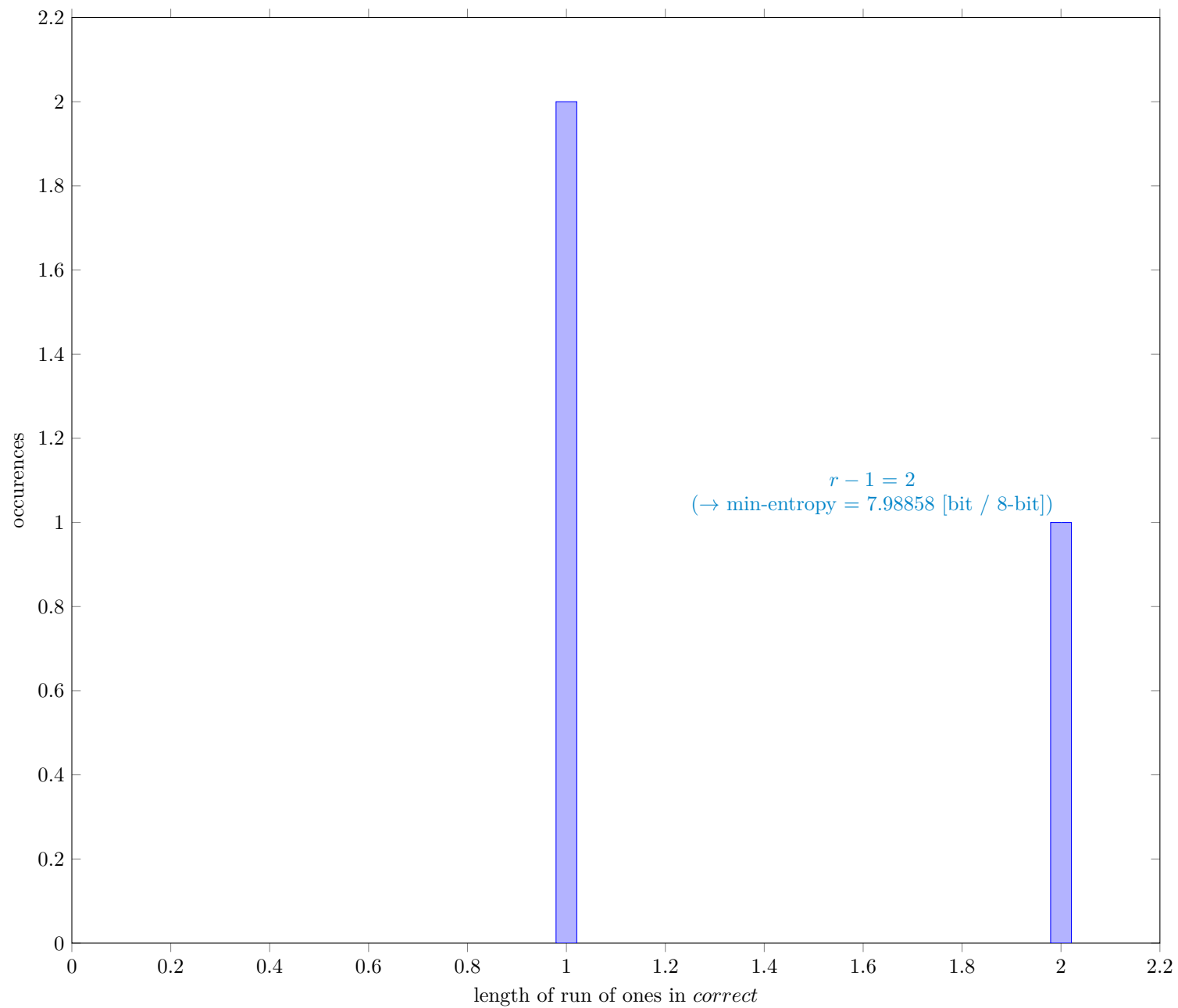


Fig. 8 Distribution of *correct*

3.4.1 Supplemental information for traceability

Table 8 Supplemental information for traceability (NIST SP 800-90B Section 6.3.7)

| Symbol | Value |
|----------------------|------------|
| N | 999937 |
| C | 3779 |
| P_{global} | 0.00377924 |
| P'_{global} | 0.00393729 |
| r | 3 |
| P_{local} | 0.00215965 |

3.5 Lag Prediction Estimate (NIST SP 800-90B Section 6.3.8)

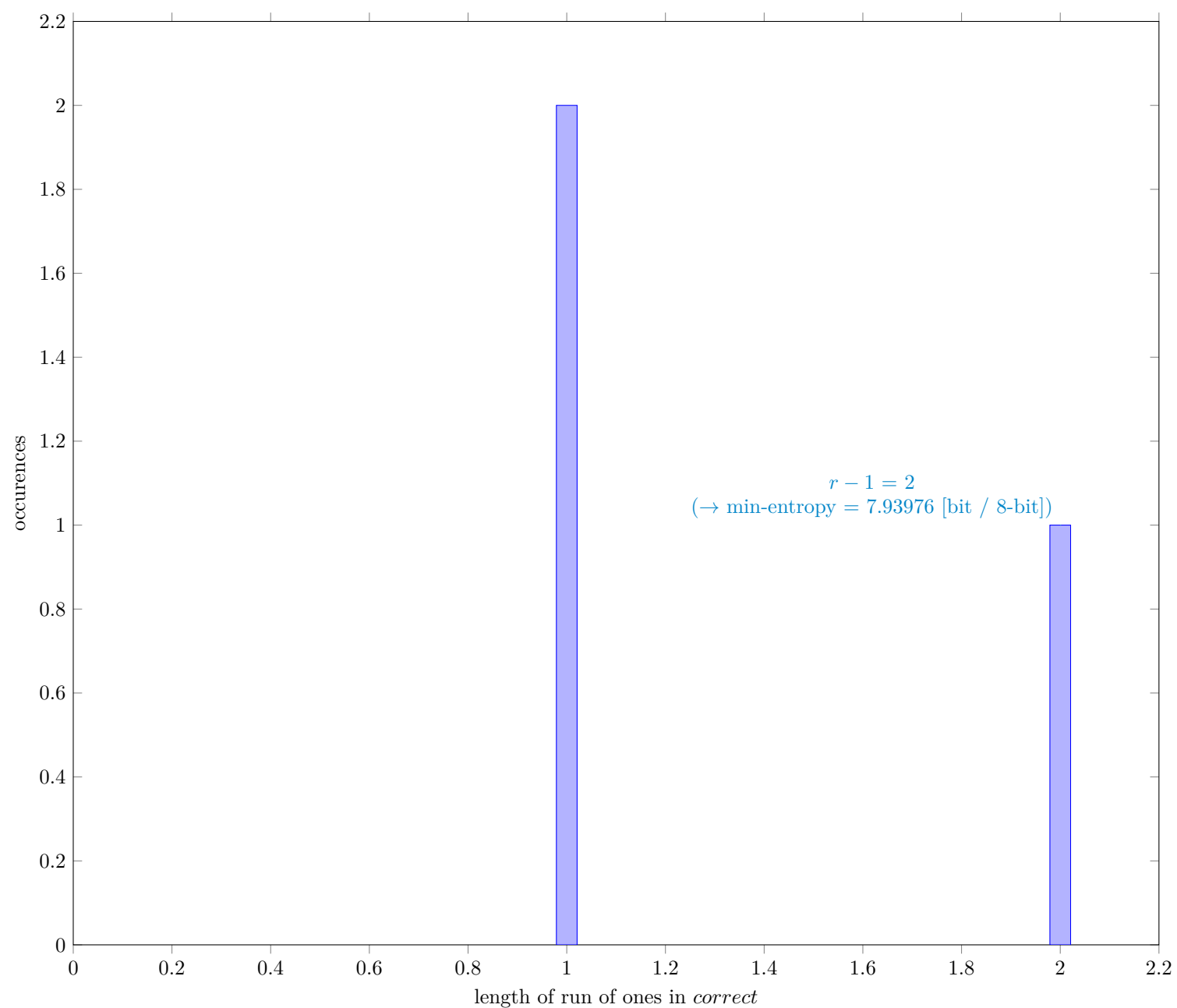


Fig. 9 Distribution of *correct*

3.5.1 Supplemental information for traceability

Table 9 Supplemental information for traceability (NIST SP 800-90B Section 6.3.8)

| Symbol | Value |
|----------------------|-----------|
| N | 999999 |
| C | 3912 |
| P_{global} | 0.003912 |
| P'_{global} | 0.0040728 |
| r | 3 |
| P_{local} | 0.0021596 |

3.6 The MultiMMC Prediction Estimate (NIST SP 800-90B Section 6.3.9)

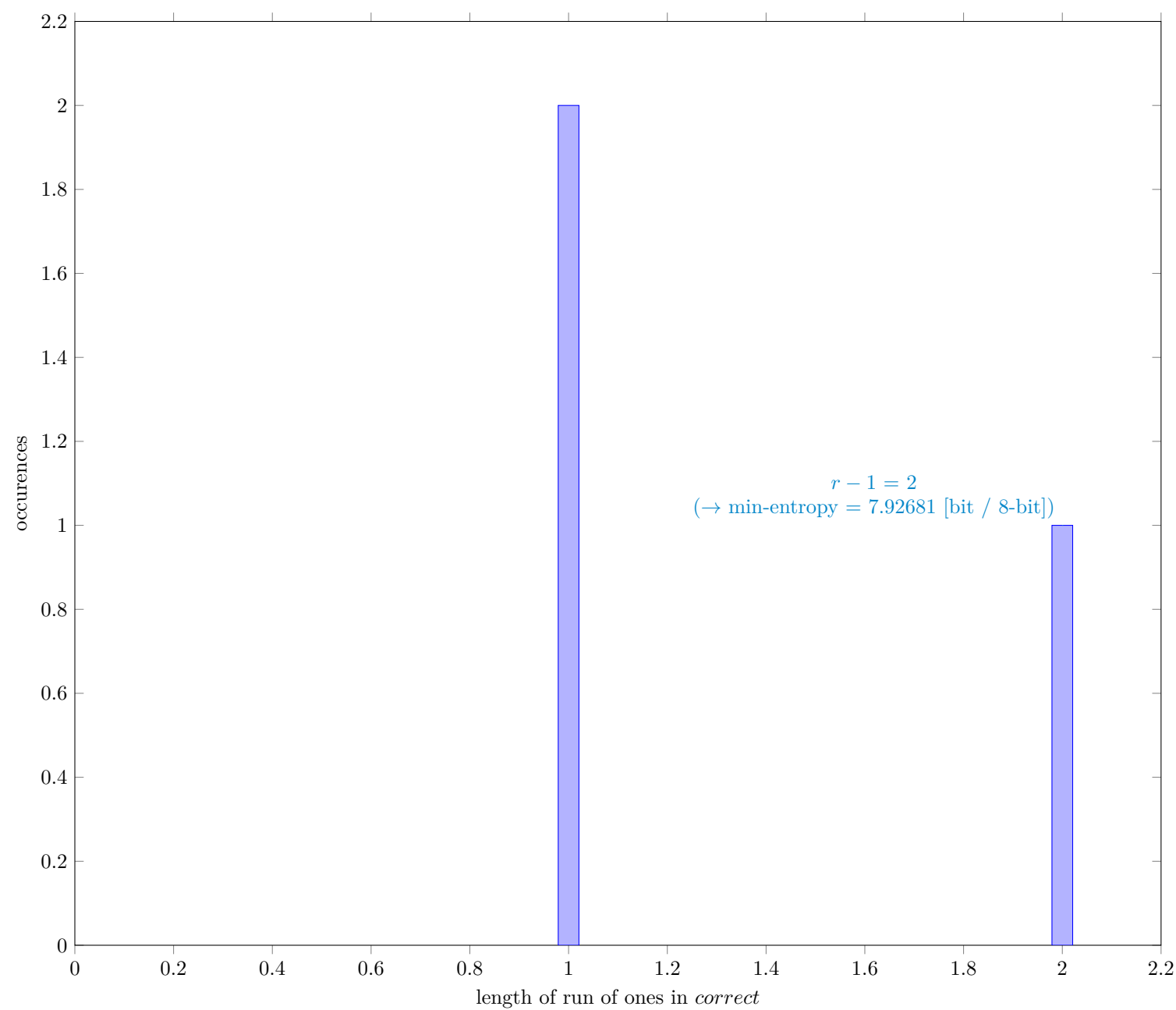


Fig. 10 Distribution of *correct*

3.6.1 Supplemental information for traceability

Table 10 Supplemental information for traceability (NIST SP 800-90B Section 6.3.9)

| Symbol | Value |
|----------------------|------------|
| N | 999998 |
| C | 3948 |
| P_{global} | 0.00394801 |
| P'_{global} | 0.00410954 |
| r | 3 |
| P_{local} | 0.0021596 |

3.7 The LZ78Y Prediction Estimate (NIST SP 800-90B Section 6.3.10)

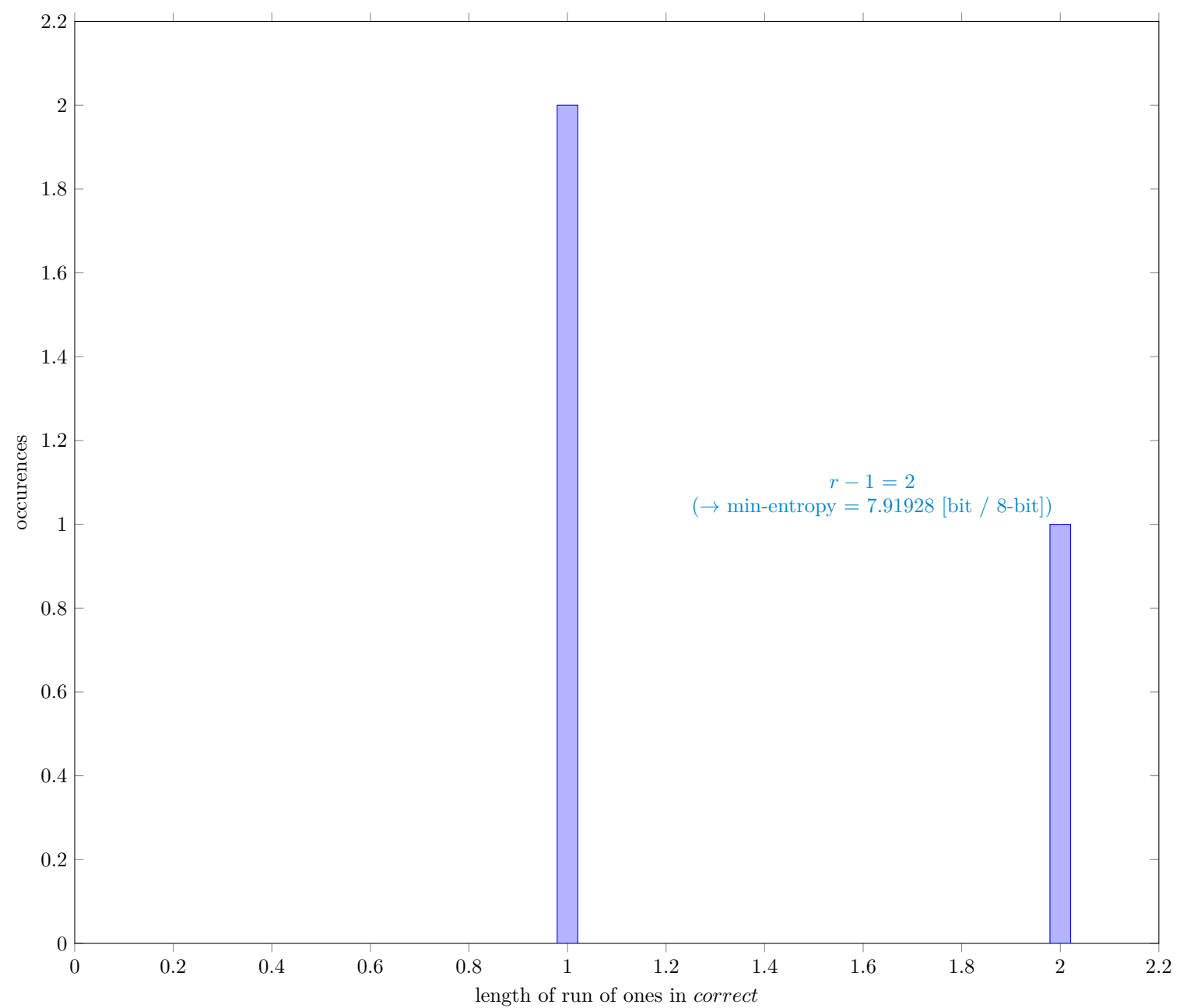


Fig. 11 Distribution of *correct*

3.7.1 Supplemental information for traceability

Table 11 Supplemental information for traceability (NIST SP 800-90B Section 6.3.10)

| Symbol | Value |
|----------------------|------------|
| N | 999983 |
| C | 3969 |
| P_{global} | 0.00396907 |
| P'_{global} | 0.00413103 |
| r | 3 |
| P_{local} | 0.00215961 |

4

Detailed results of analysis by interpreting each sample as bitstrings

4.1

The Most Common Value Estimate (NIST SP 800-90B Section 6.3.1)

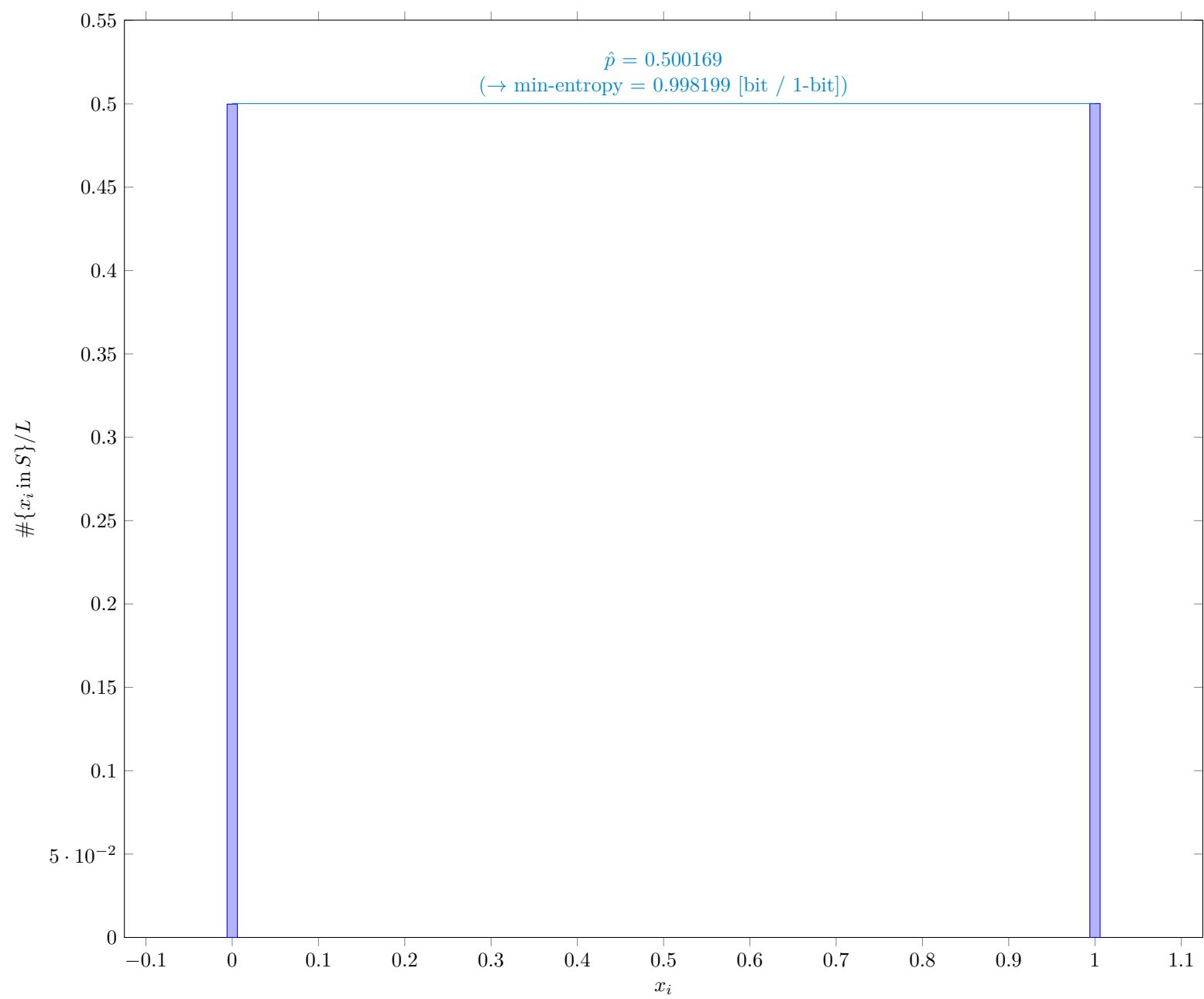


Fig. 12 Distribution of x_i

4.1.1

Supplemental information for traceability

Table 12 Supplemental information for traceability (NIST SP 800-90B Section 6.3.1)

| Symbol | Value |
|-----------|----------|
| mode | 4001353 |
| \hat{p} | 0.500169 |
| p_u | 0.500624 |

4.2 The Collision Estimate (NIST SP 800-90B Section 6.3.2)

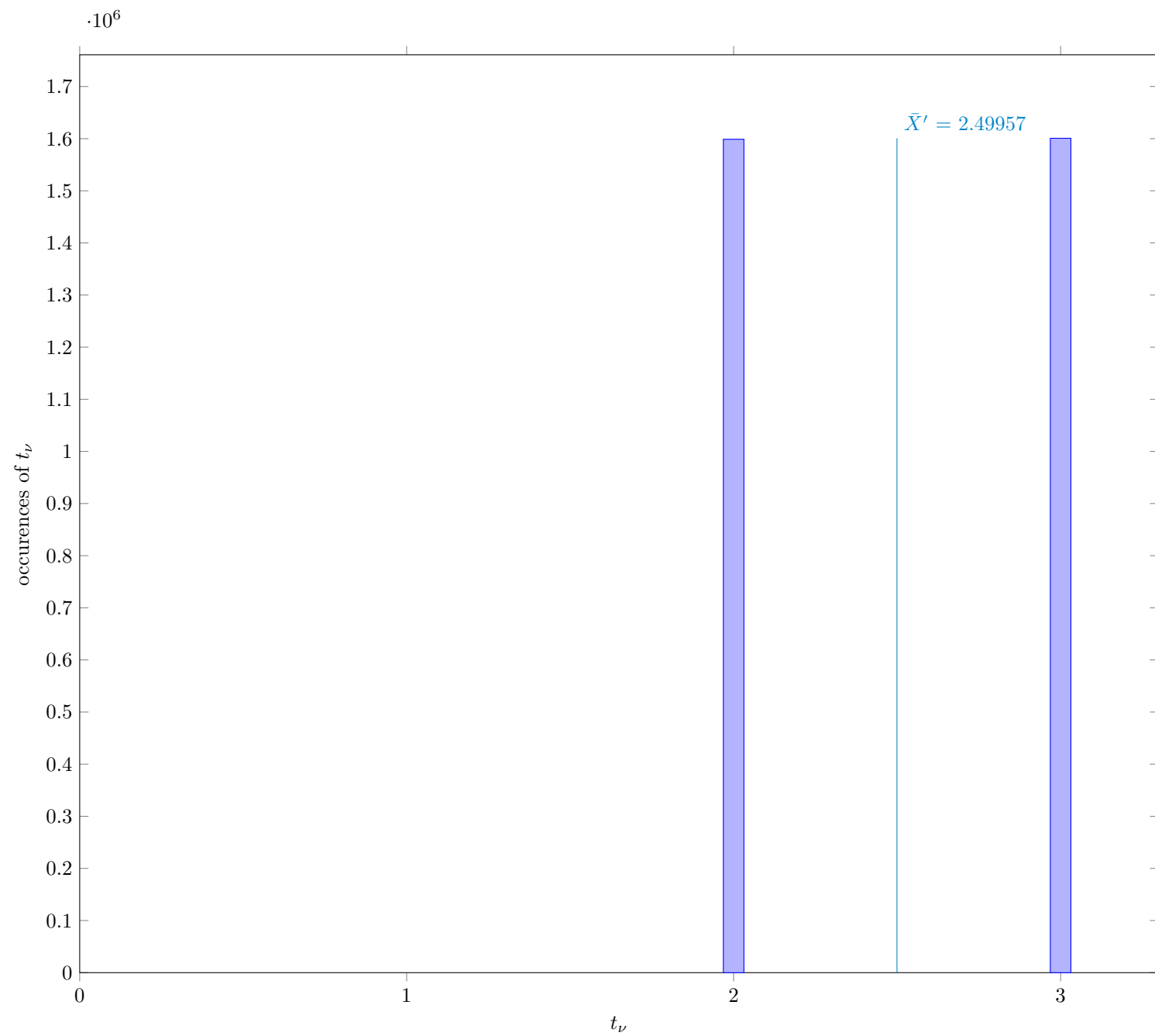


Fig. 13 Distribution of intermediate value t_ν

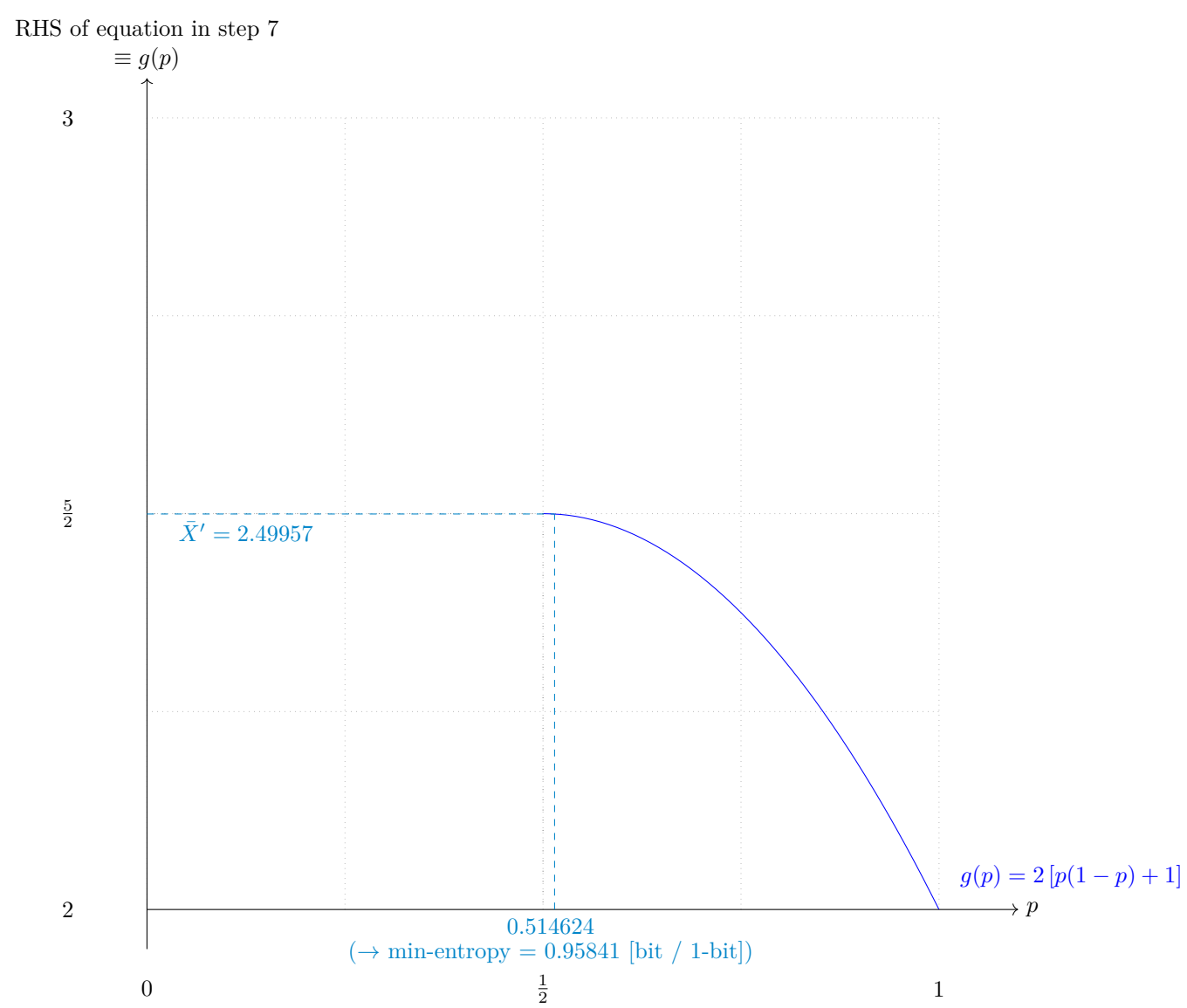


Fig. 14 Solution to the equation in step 7

4.2.1 Supplemental information for traceability

Table 13 Supplemental information for traceability (NIST SP 800-90B Section 6.3.2)

| Symbol | Value |
|----------------|----------|
| p | 0.514624 |
| \bar{X} | 2.50029 |
| \bar{X}' | 2.49957 |
| $\hat{\sigma}$ | 0.5 |

4.3 The Markov Estimate (NIST SP 800-90B Section 6.3.3)

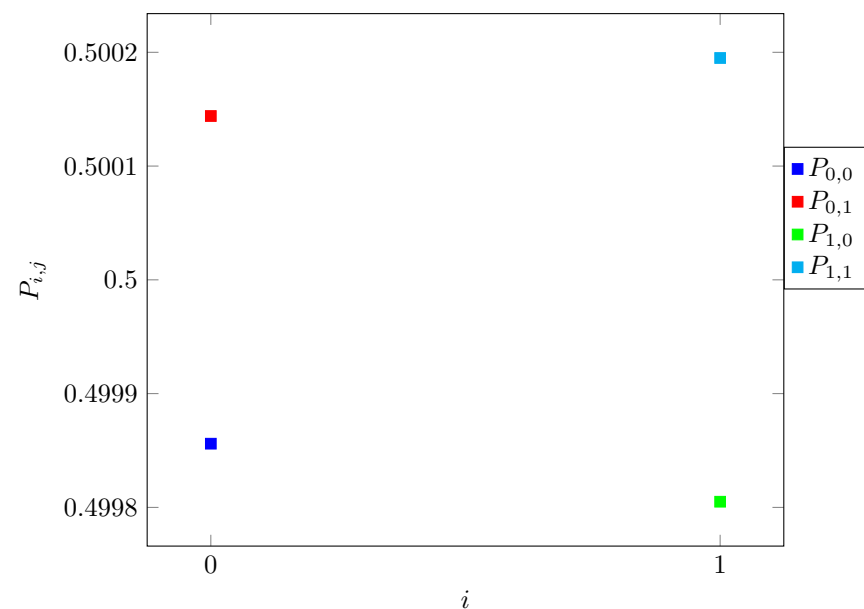


Fig. 15 Transition probability $P_{i,j}$ of §6.3.3 of NIST SP 800-90B

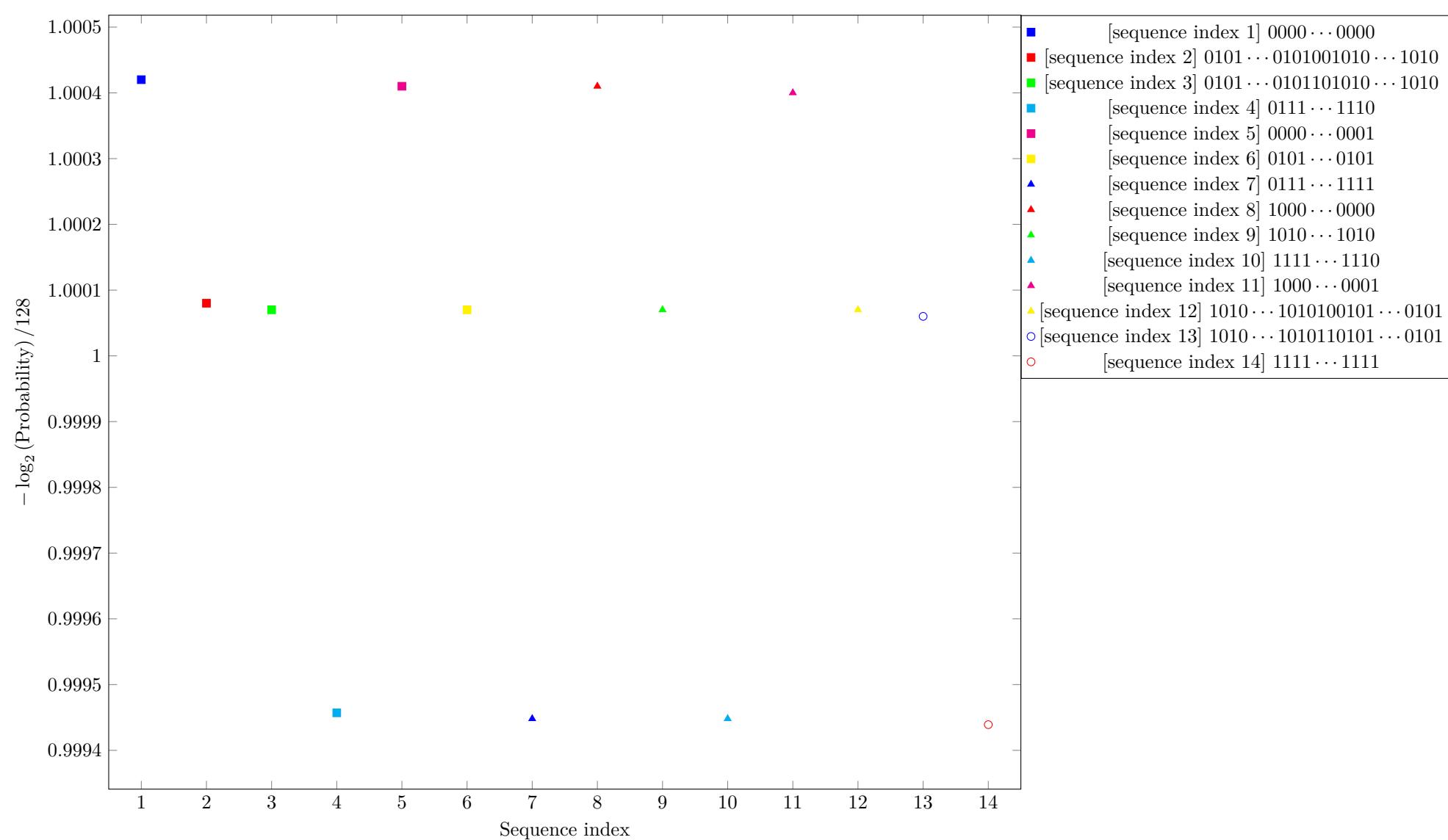


Fig. 16 Estimated Min-Entropy using §6.3.3 of NIST SP 800-90B

4.4 The Compression Estimate (NIST SP 800-90B Section 6.3.4)

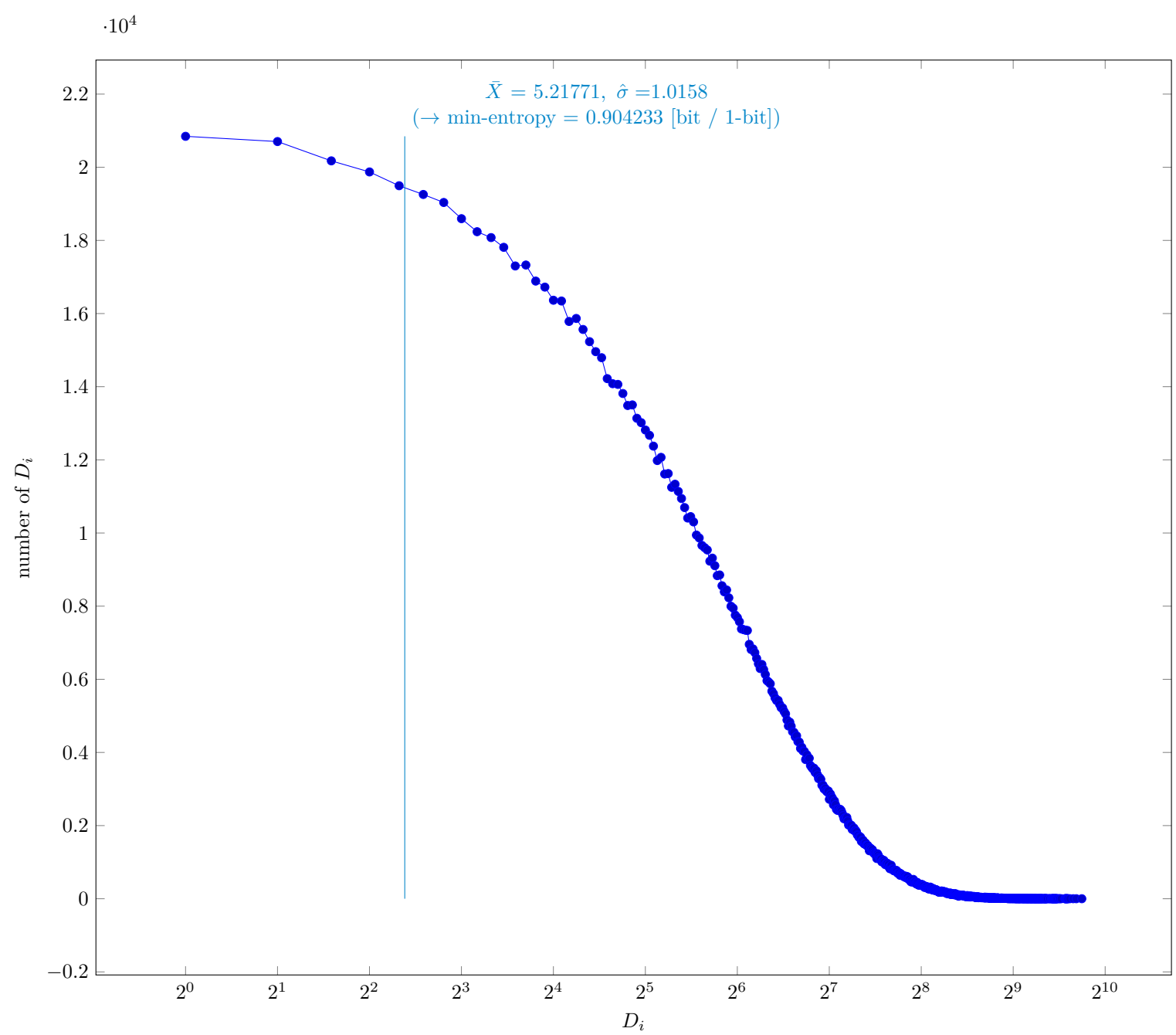


Fig. 17 Distribution of intermediate value D_i

4.4.1 Supplemental information for traceability

Table 14 Supplemental information for traceability (NIST SP 800-90B Section 6.3.4)

| Symbol | Value |
|----------------|-----------|
| p | 0.0232698 |
| \bar{X} | 5.21771 |
| $\hat{\sigma}$ | 1.0158 |
| \bar{X}' | 5.21545 |

4.5 The t-tuple Estimate (NIST SP 800-90B Section 6.3.5)

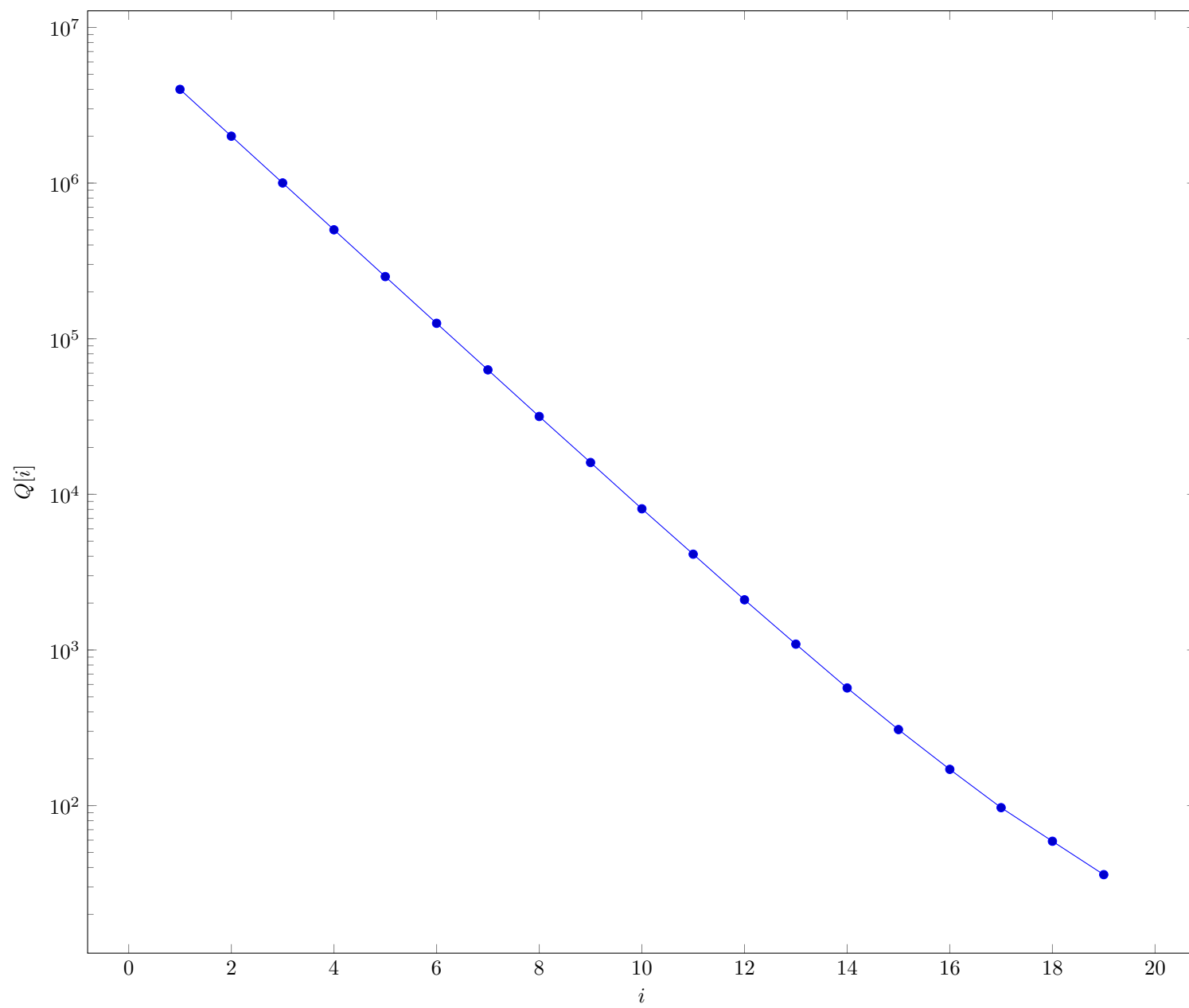


Fig. 18 Intermediate value $Q[i]$ in §6.3.5 of NIST SP 800-90B

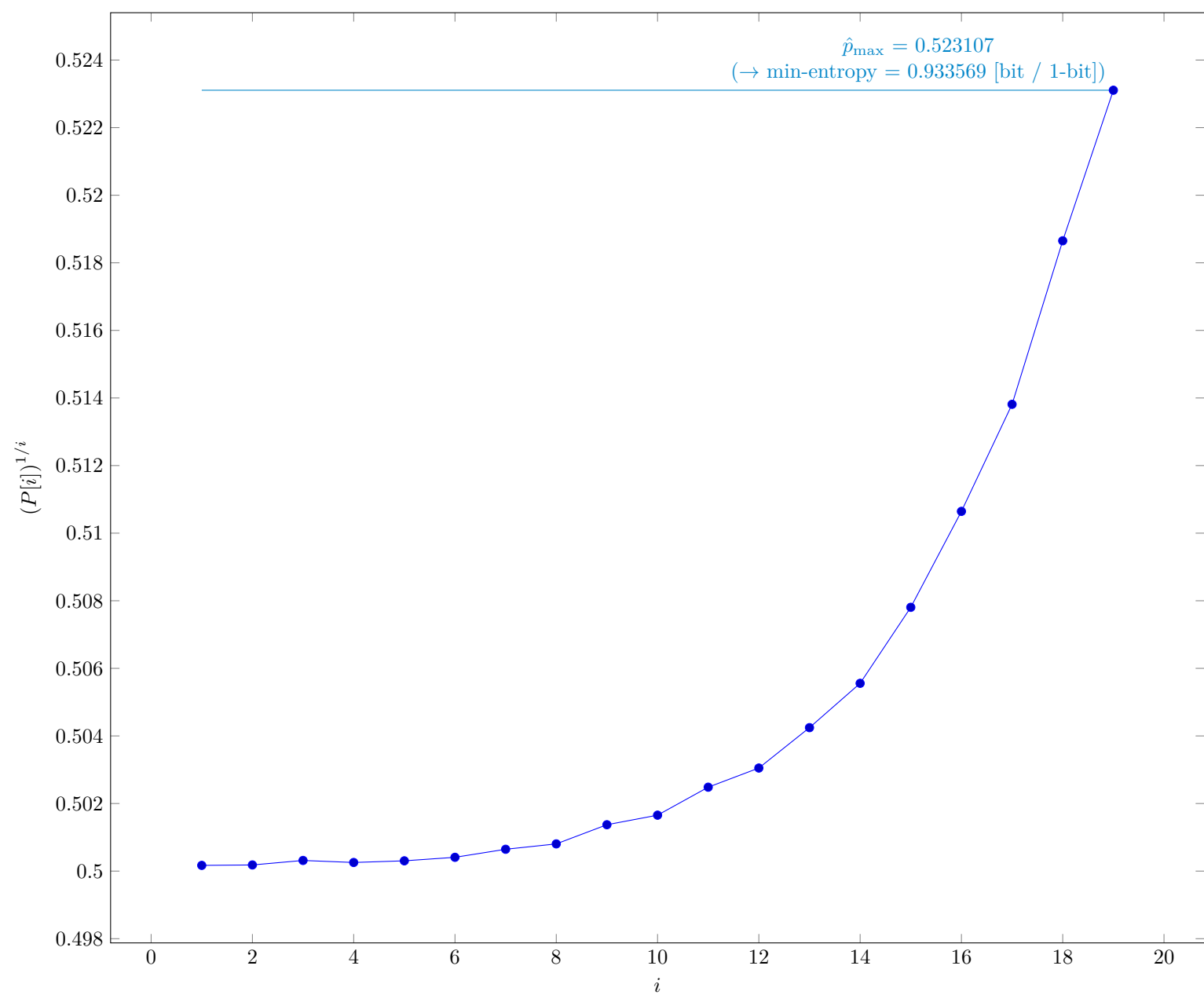


Fig. 19 $P[i]^{1/i}$ in §6.3.5 of NIST SP 800-90B

4.5.1 Supplemental information for traceability

Table 15 Supplemental information for traceability (NIST SP 800-90B Section 6.3.5)

| Symbol | Value |
|------------------|----------|
| t | 19 |
| \hat{p}_{\max} | 0.523107 |
| p_u | 0.523561 |

4.6 The LRS Estimate (NIST SP 800-90B Section 6.3.6)

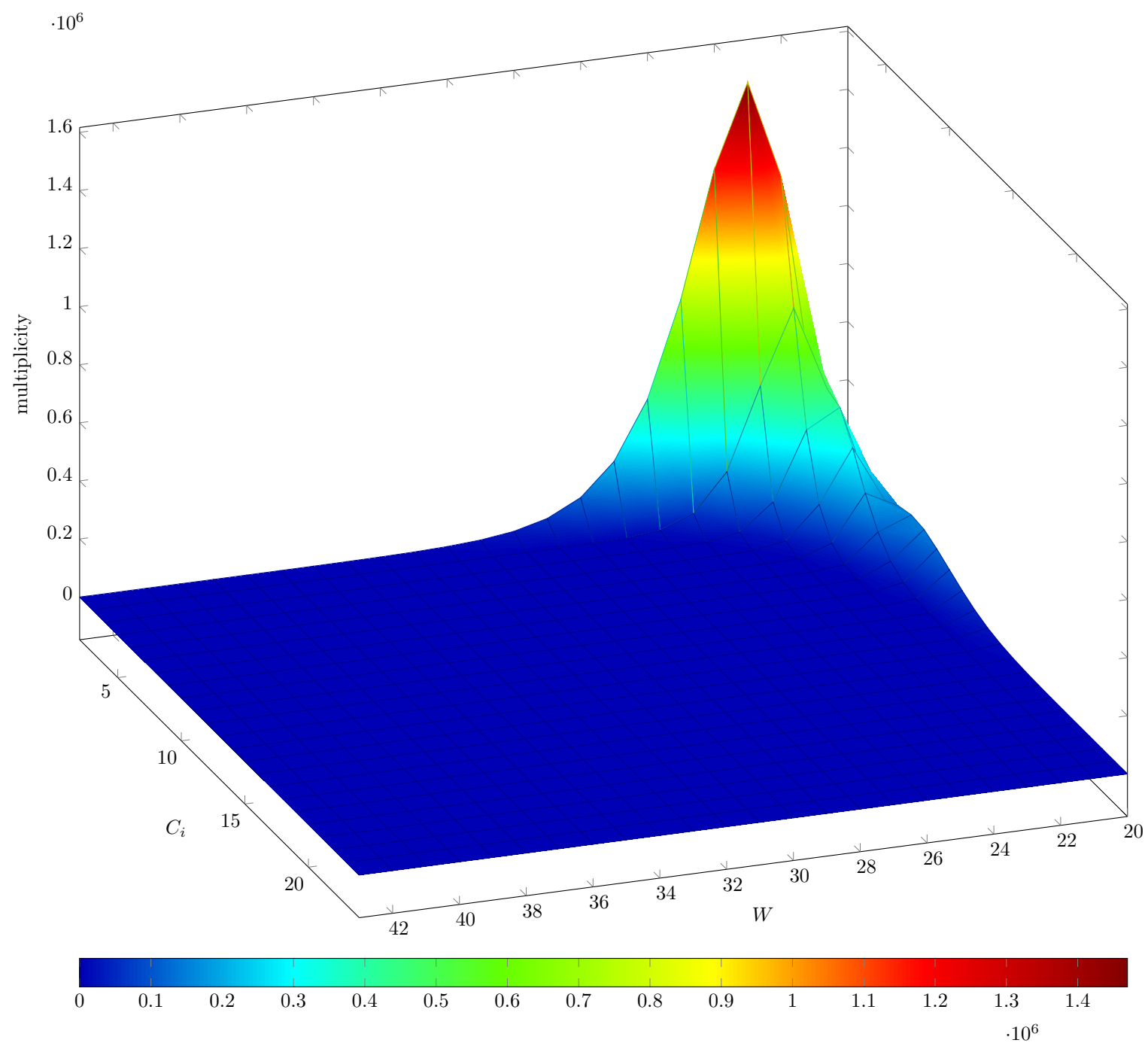


Fig. 20 Estimated W -tuple collision probability in Step 3 of §6.3.6 of NIST SP 800-90B

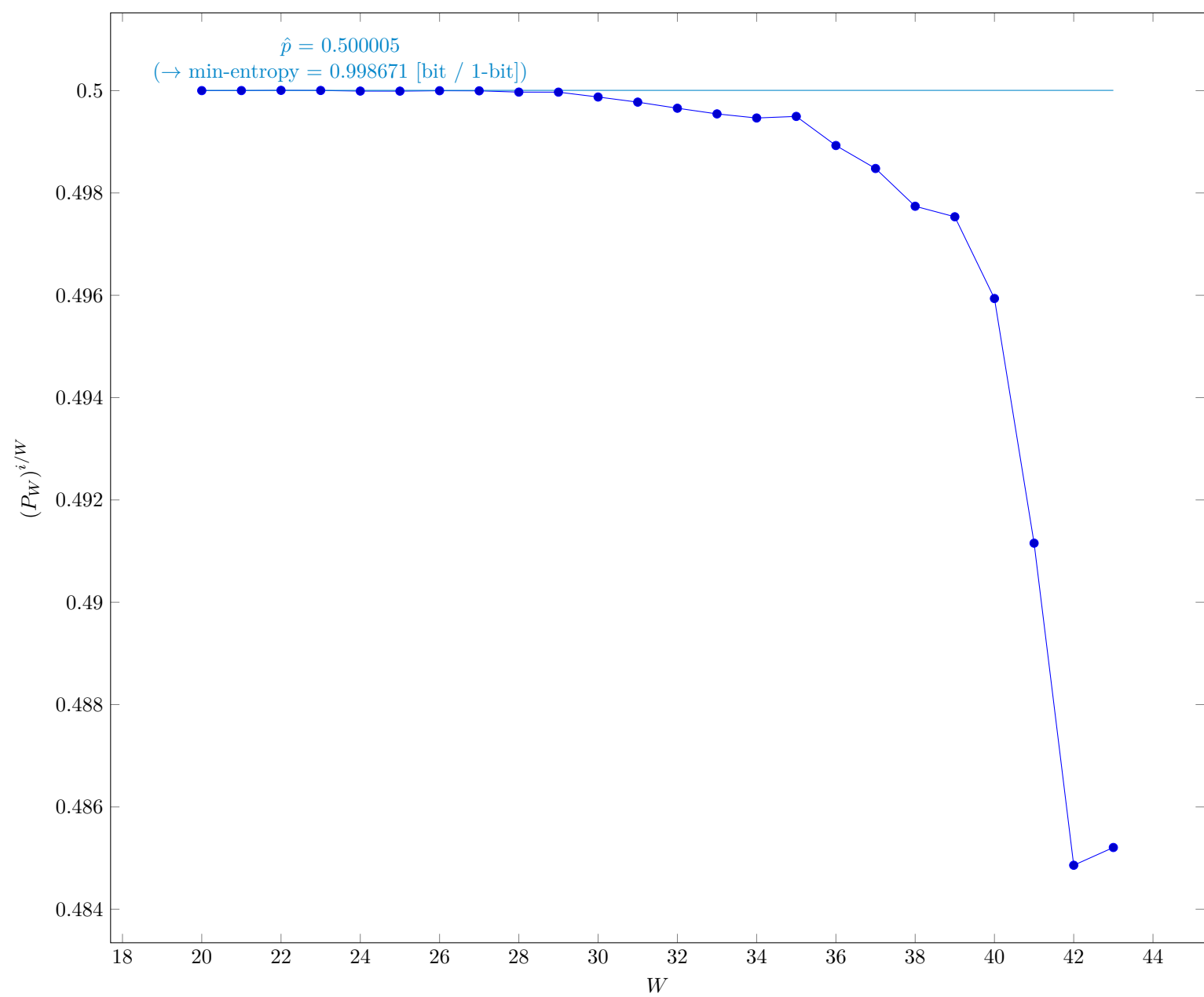


Fig. 21 Estimated average collision probability per string symbol in Step 3 of §6.3.6 of NIST SP 800-90B

4.6.1 Supplemental information for traceability

Table 16 Supplemental information for traceability (NIST SP 800-90B Section 6.3.6)

| Symbol | Value |
|-----------|----------|
| u | 20 |
| v | 43 |
| \hat{p} | 0.500005 |
| p_u | 0.500461 |

4.7 Multi Most Common in Window Prediction Estimate (NIST SP 800-90B Section 6.3.7)

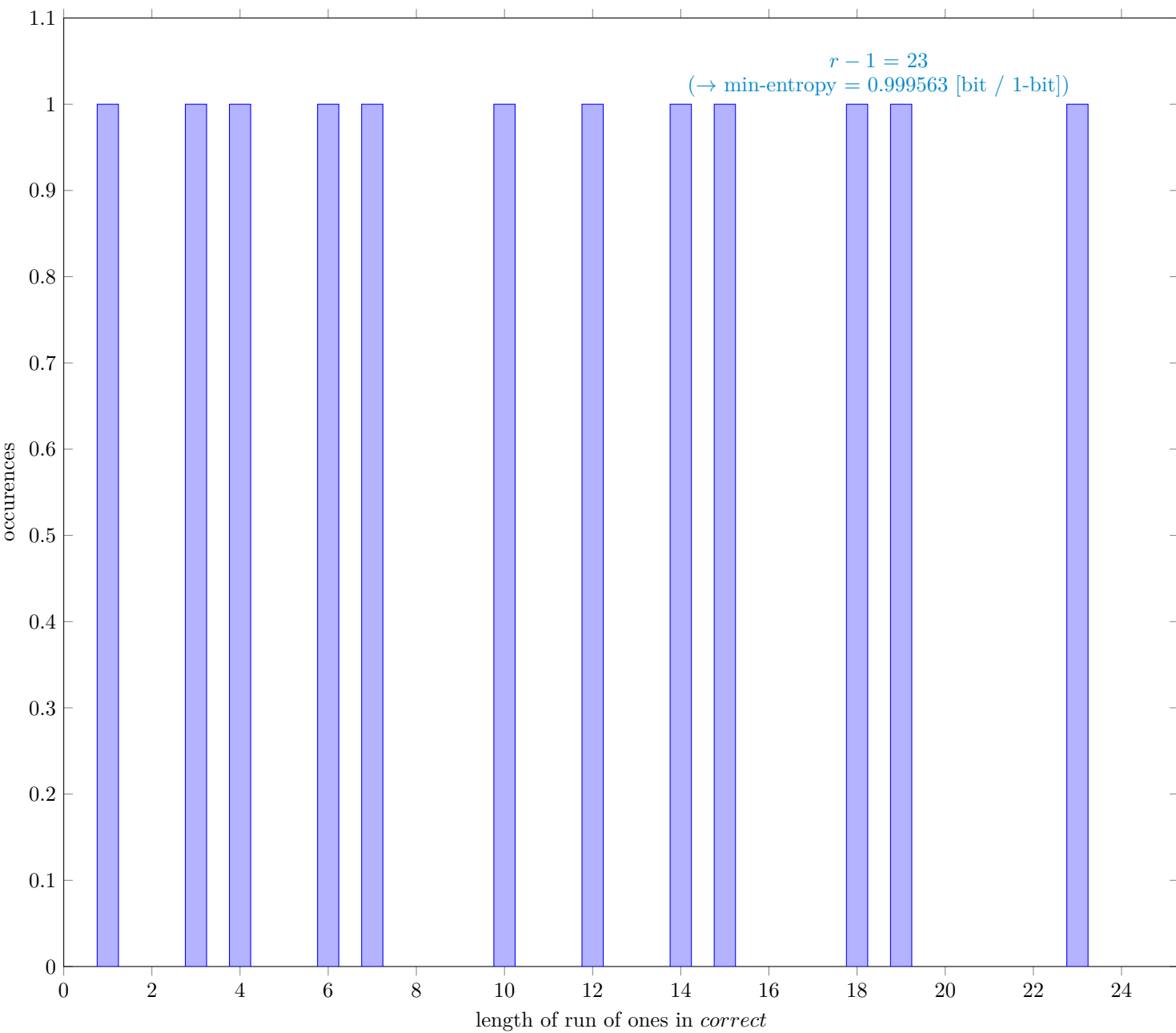


Fig. 22 Distribution of *correct*

4.7.1 Supplemental information for traceability

Table 17 Supplemental information for traceability (NIST SP 800-90B Section 6.3.7)

| Symbol | Value |
|----------------------|----------|
| N | 7999937 |
| C | 3997538 |
| P_{global} | 0.499696 |
| P'_{global} | 0.500152 |
| r | 24 |
| P_{local} | 0.436006 |

4.8 Lag Prediction Estimate (NIST SP 800-90B Section 6.3.8)

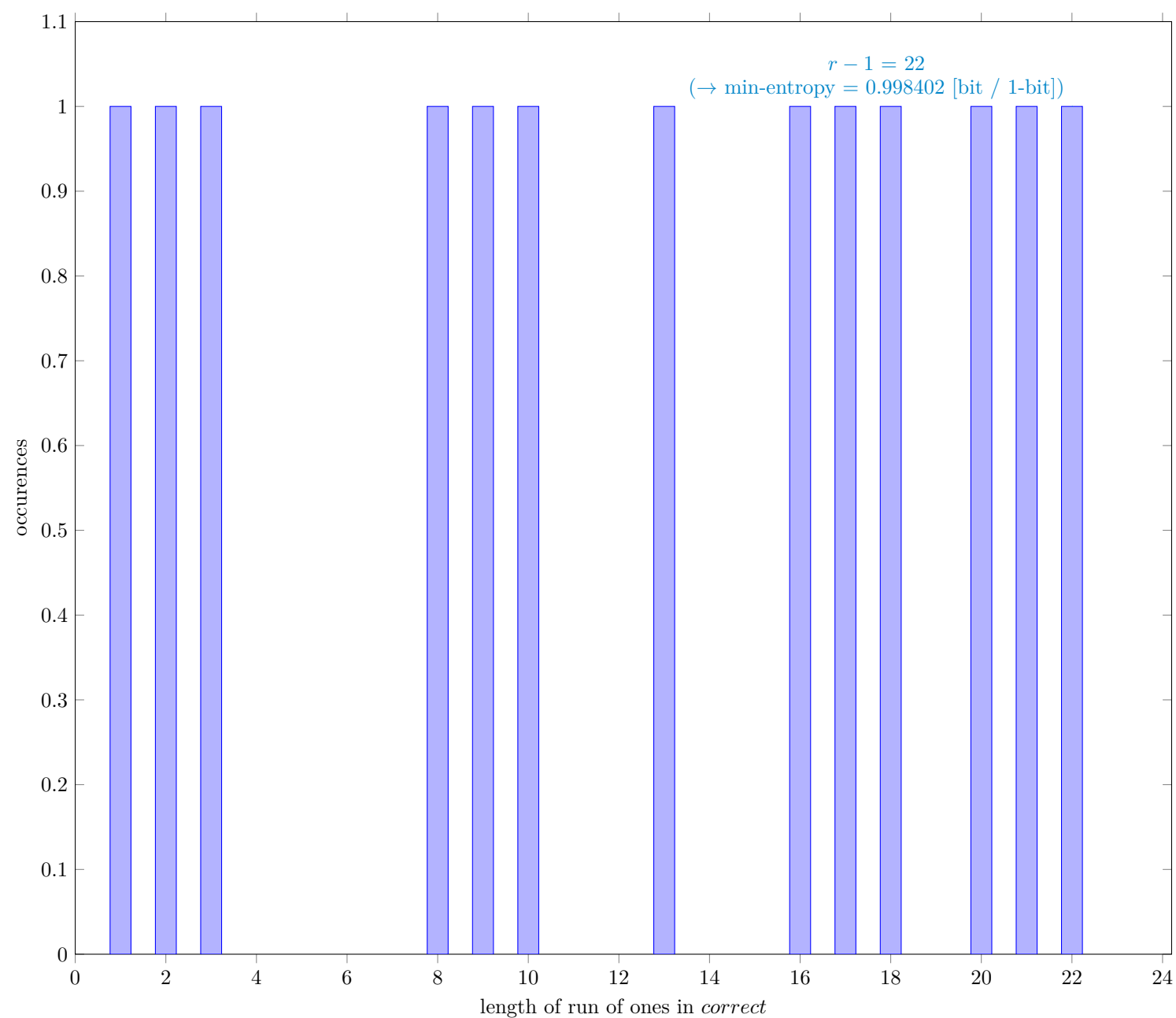


Fig. 23 Distribution of *correct*

4.8.1 Supplemental information for traceability

Table 18 Supplemental information for traceability (NIST SP 800-90B Section 6.3.8)

| Symbol | Value |
|----------------------|----------|
| N | 7999999 |
| C | 4000791 |
| P_{global} | 0.500099 |
| P'_{global} | 0.500554 |
| r | 23 |
| P_{local} | 0.42004 |

4.9 The MultiMMC Prediction Estimate (NIST SP 800-90B Section 6.3.9)

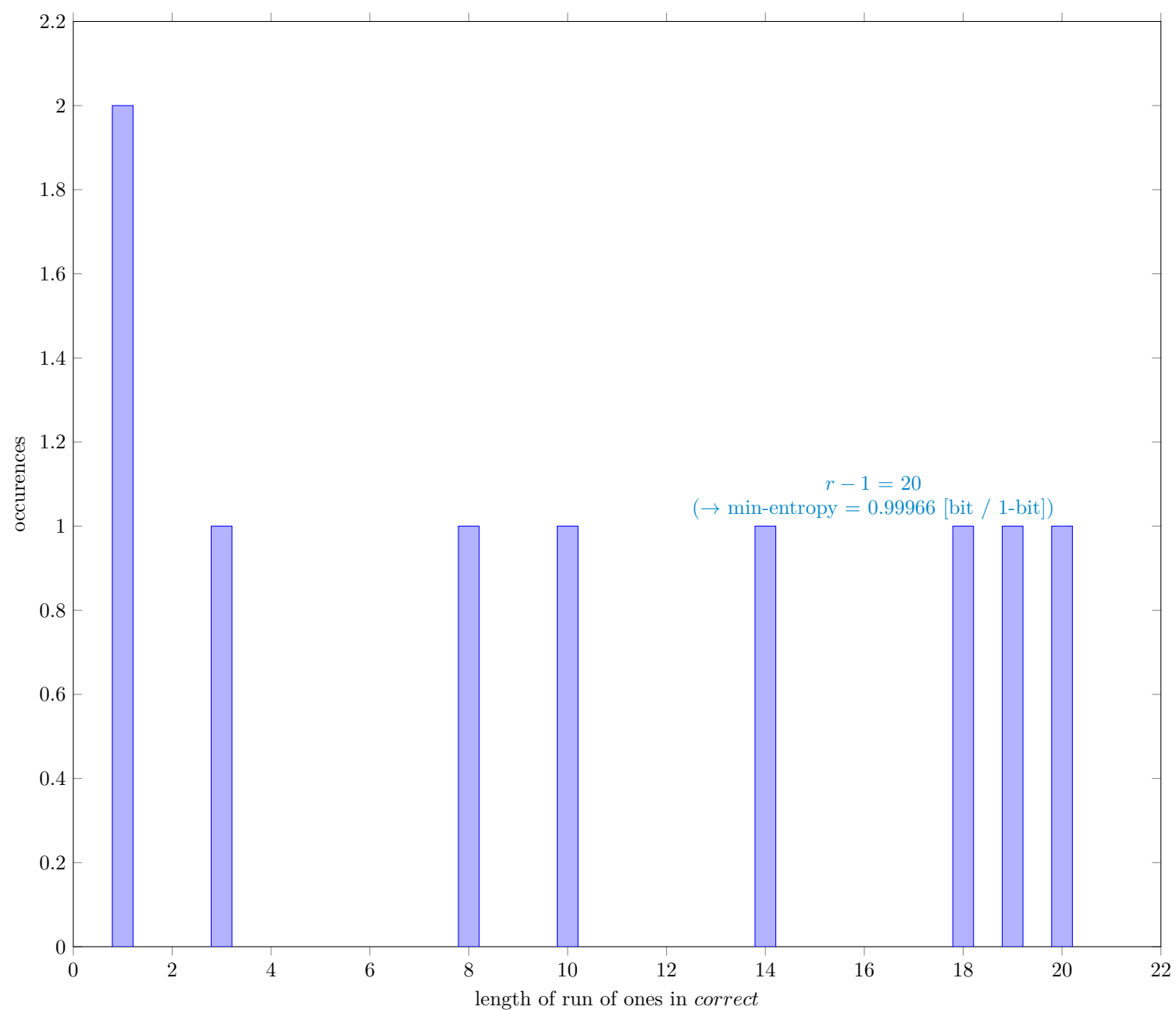


Fig. 24 Distribution of *correct*

4.9.1 Supplemental information for traceability

Table 19 Supplemental information for traceability (NIST SP 800-90B Section 6.3.9)

| Symbol | Value |
|----------------------|----------|
| N | 7999998 |
| C | 3997298 |
| P_{global} | 0.499662 |
| P'_{global} | 0.500118 |
| r | 21 |
| P_{local} | 0.385677 |

4.10 The LZ78Y Prediction Estimate (NIST SP 800-90B Section 6.3.10)

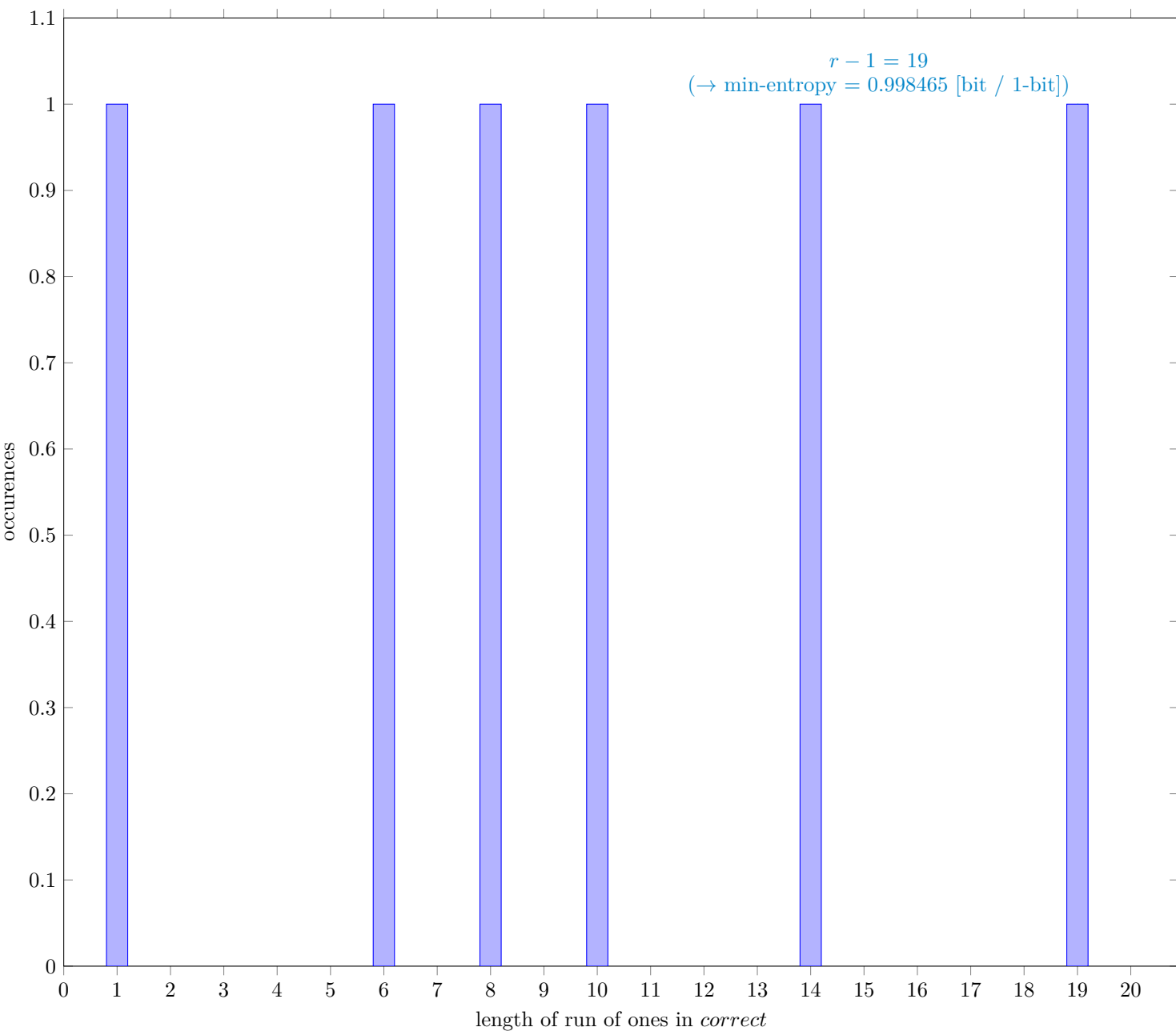


Fig. 25 Distribution of *correct*

4.10.1 Supplemental information for traceability

Table 20 Supplemental information for traceability (NIST SP 800-90B Section 6.3.10)

| Symbol | Value |
|----------------------|----------|
| N | 7999983 |
| C | 4000606 |
| P_{global} | 0.500077 |
| P'_{global} | 0.500532 |
| r | 20 |
| P_{local} | 0.36719 |

4 References

[1] Meltem Sönmez Turan, Elaine Barker, John Kelsey, Kerry A. McKay, Mary L. Baish, Mike Boyle *Recommendation for the Entropy Sources Used for Random Bit Generation*, NIST Special Publication 800-90B, Jan. 2018 <https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-90B.pdf>

[2] G. Sakurai, *Proposed list of corrections for NIST SP 800-90B 6.3 Estimators*, Dec. 2022 https://github.com/g-g-sakura/AnotherEntropyEstimationTool/blob/main/documentation/ProposedListOfCorrections_SP800-90B.pdf