

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

2023-Aug-20 12:10:22.139954

## 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	<a href="https://github.com/usnistgov/SP800-90B_EntropyAssessment/blob/master/bin/truerand_4bit.bin">https://github.com/usnistgov/SP800-90B_EntropyAssessment/blob/master/bin/truerand_4bit.bin</a>
SHA-256 hash value of the acquisition data [hex]	489bc841 bb364ba8 6da70b16 17138aef 76b25dd9 196ad669 eef40c14 41b6cb88

- 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++ 1.83.0
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	4
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 / 4 - bit]	Notes to $H_{\text{original}}$	$H_{\text{bitstring}}^{\text{b}}$ [bit / 1 - bit]	Notes to $H_{\text{bitstring}}$
The Most Common Value Estimate	3.97119	see 3.1	0.99773	see 4.1
The Collision Estimate	—	—	0.928362	see 4.2
The Markov Estimate	—	—	0.99947	see 4.3
The Compression Estimate	—	—	0.900627	see 4.4
The t-Tuple Estimate	3.68775	see 3.2	0.929434	see 4.5
The Longest Repeated Substring (LRS) Estimate	3.93497	see 3.3	0.986687	see 4.6
Multi Most Common in Window Prediction Estimate	3.99229	see 3.4	0.99808	see 4.7
The Lag Prediction Estimate	3.97627	see 3.5	0.998649	see 4.8
The MultiMMC Prediction Estimate	3.98526	see 3.6	0.998205	see 4.9
The LZ78Y Prediction Estimate	3.98428	see 3.7	0.999355	see 4.10
The initial entropy source estimate [bit / 4 - bit] $H_I = \min(H_{\text{original}}, 4 \times H_{\text{bitstring}})$	3.60251			
<sup>a</sup> Entropy estimate of the sequential dataset [source: NIST SP 800-90B [1] 3.1.3]				
<sup>b</sup> 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

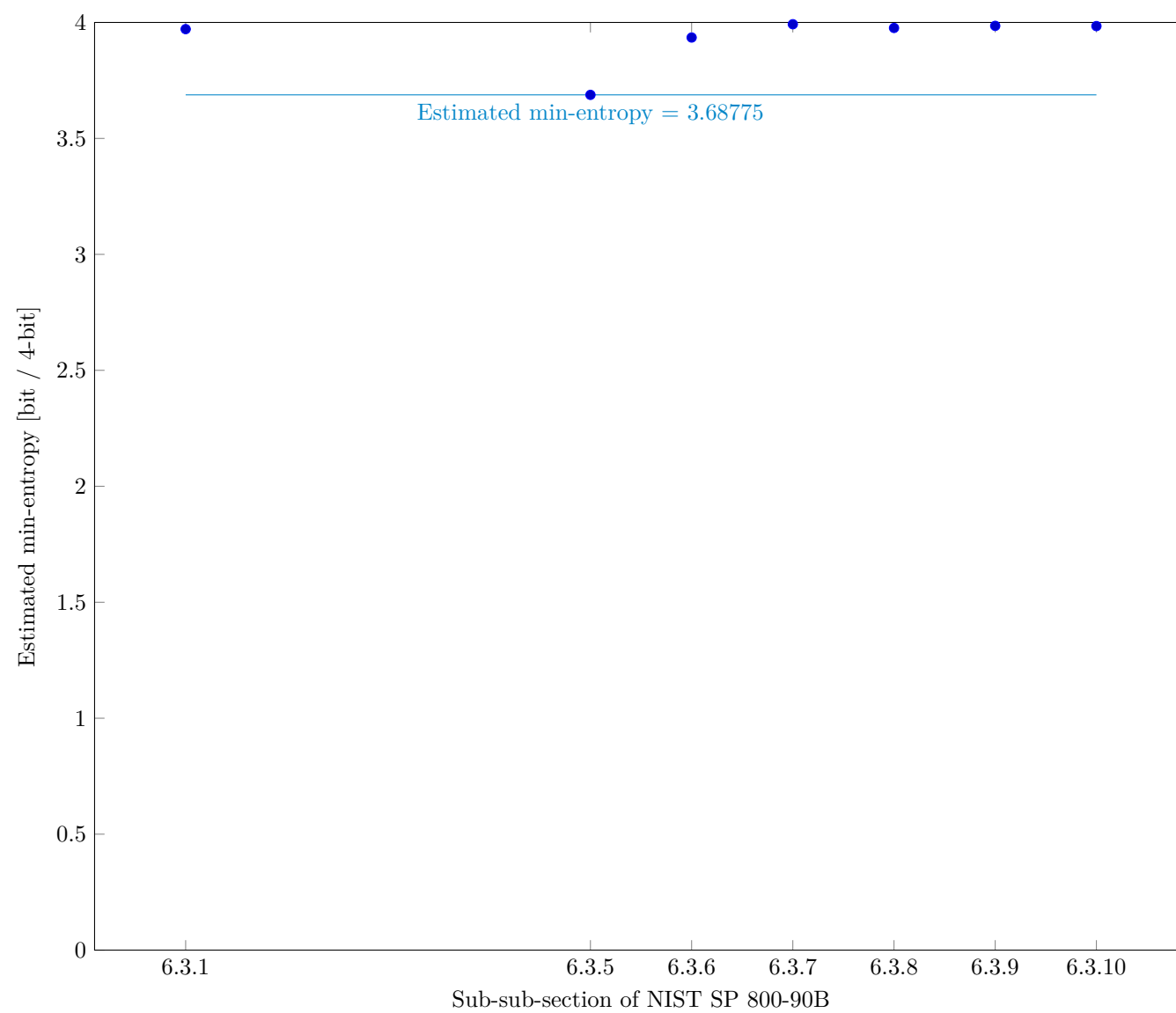


Fig. 1 Estimated Min-Entropy using §6.3 of NIST SP 800-90B

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

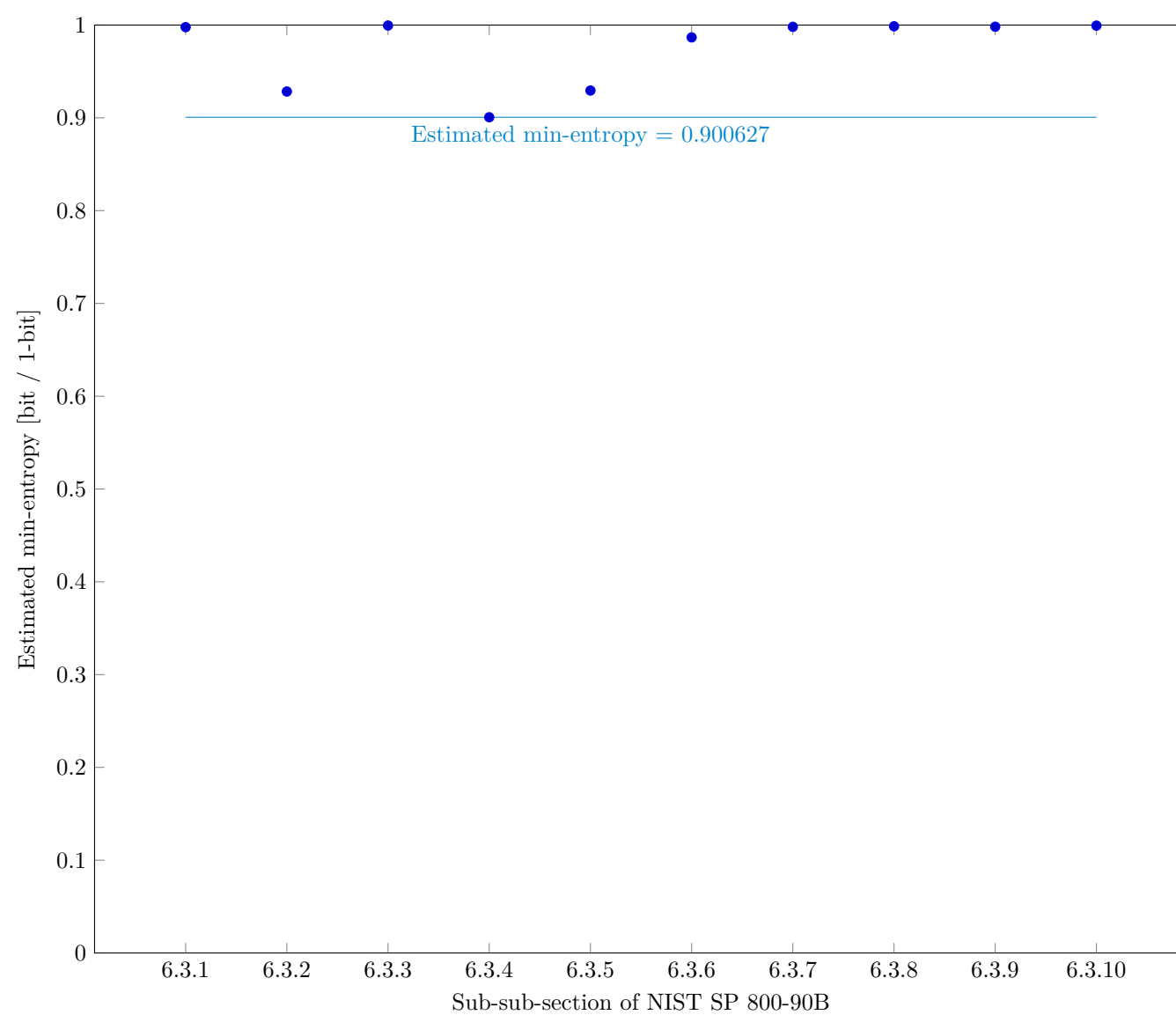


Fig. 2 Estimated Min-Entropy using §6.3 of NIST SP 800-90B

3 Detailed results of analysis from original samples

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

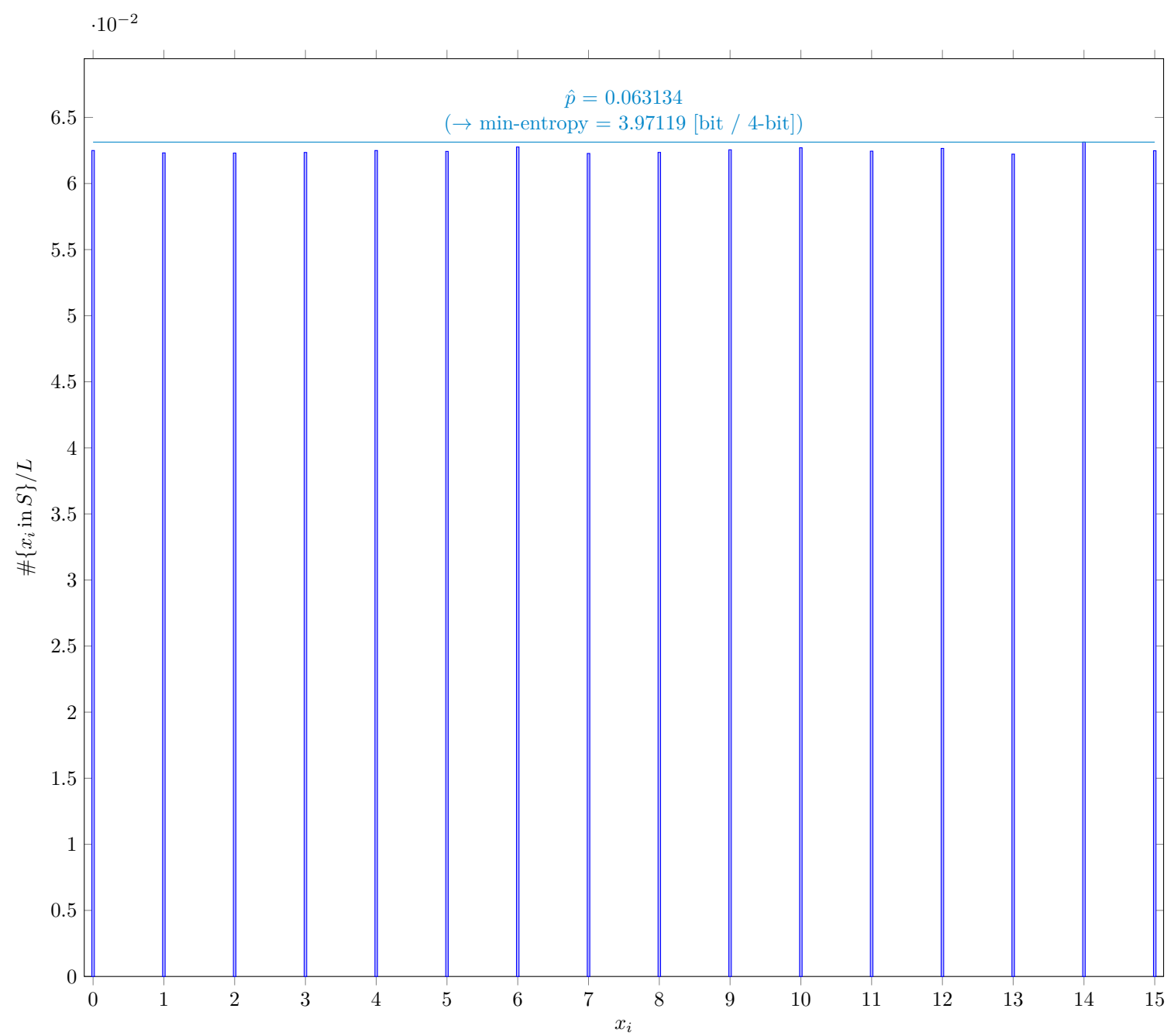


Fig. 3 Distribution of  $x_i$

3.1.1 Supplemental information for traceability

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

Symbol	Value
mode	63134
$\hat{p}$	0.063134
$p_u$	0.0637605

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

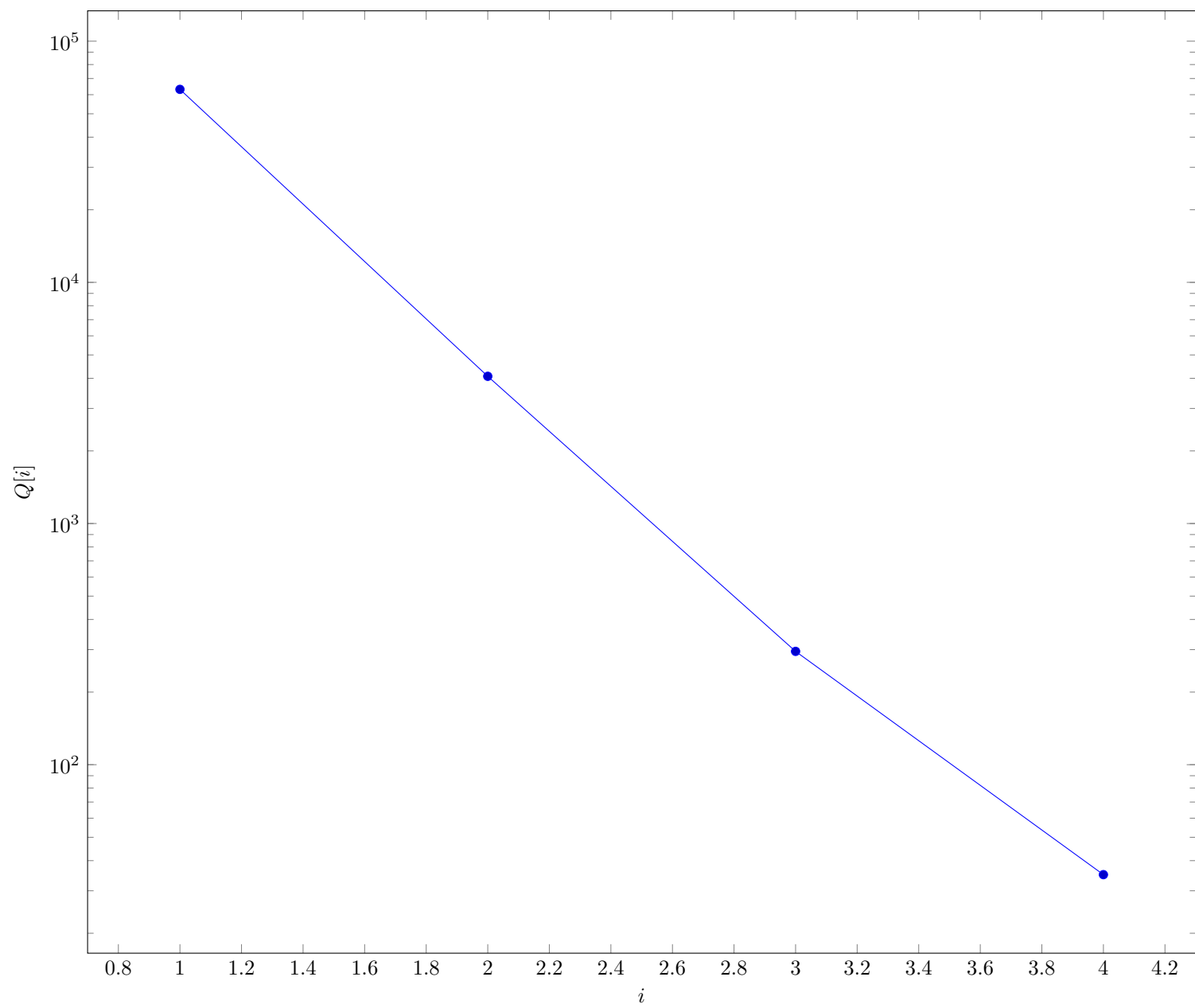


Fig. 4 Intermediate value  $Q[i]$  in §6.3.5 of NIST SP 800-90B

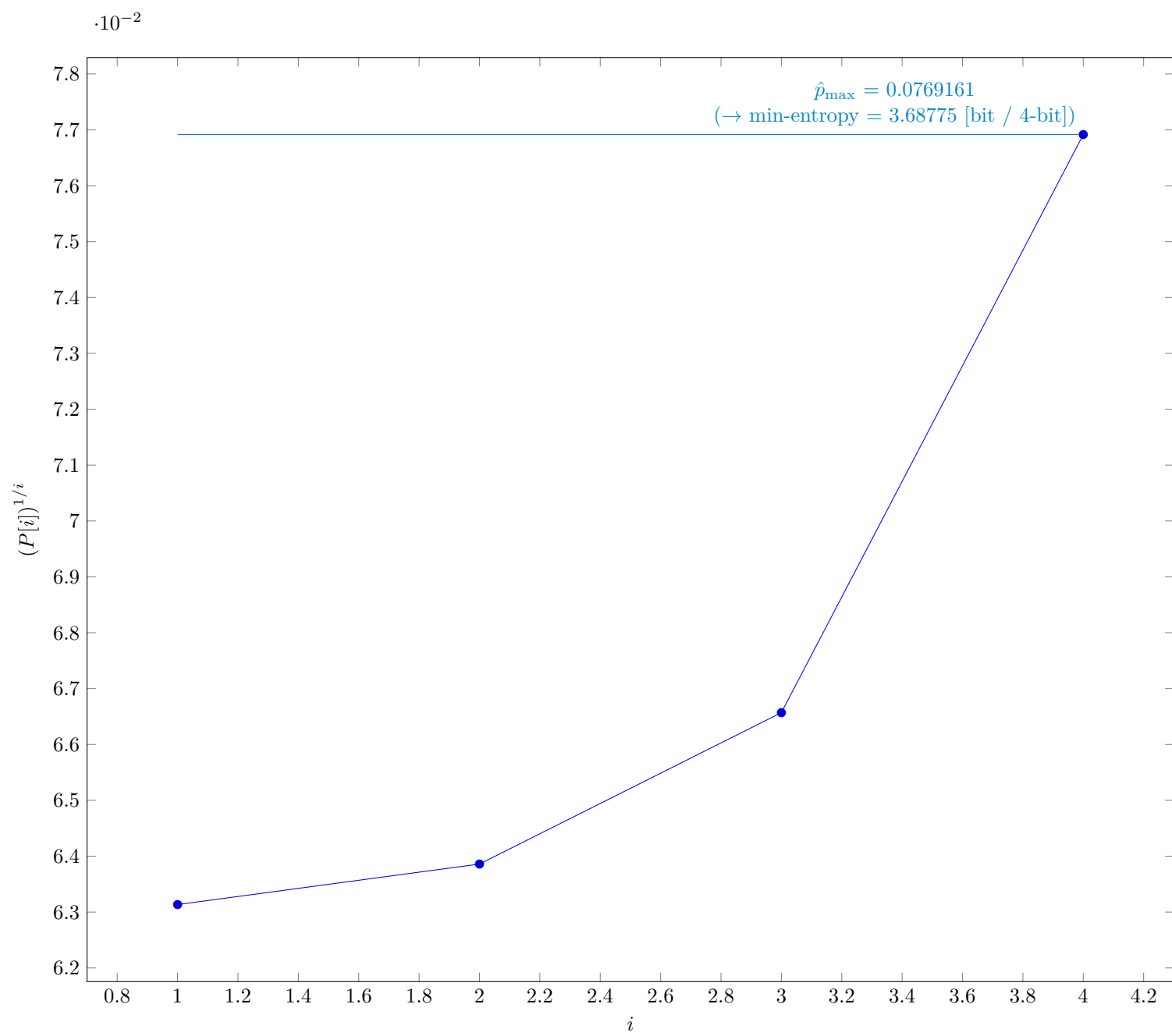


Fig. 5  $P[i]^{1/i}$  in §6.3.5 of NIST SP 800-90B

3.2.1 Supplemental information for traceability

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

Symbol	Value
$t$	4
$\hat{p}_{\max}$	0.0769161
$p_u$	0.0776025

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

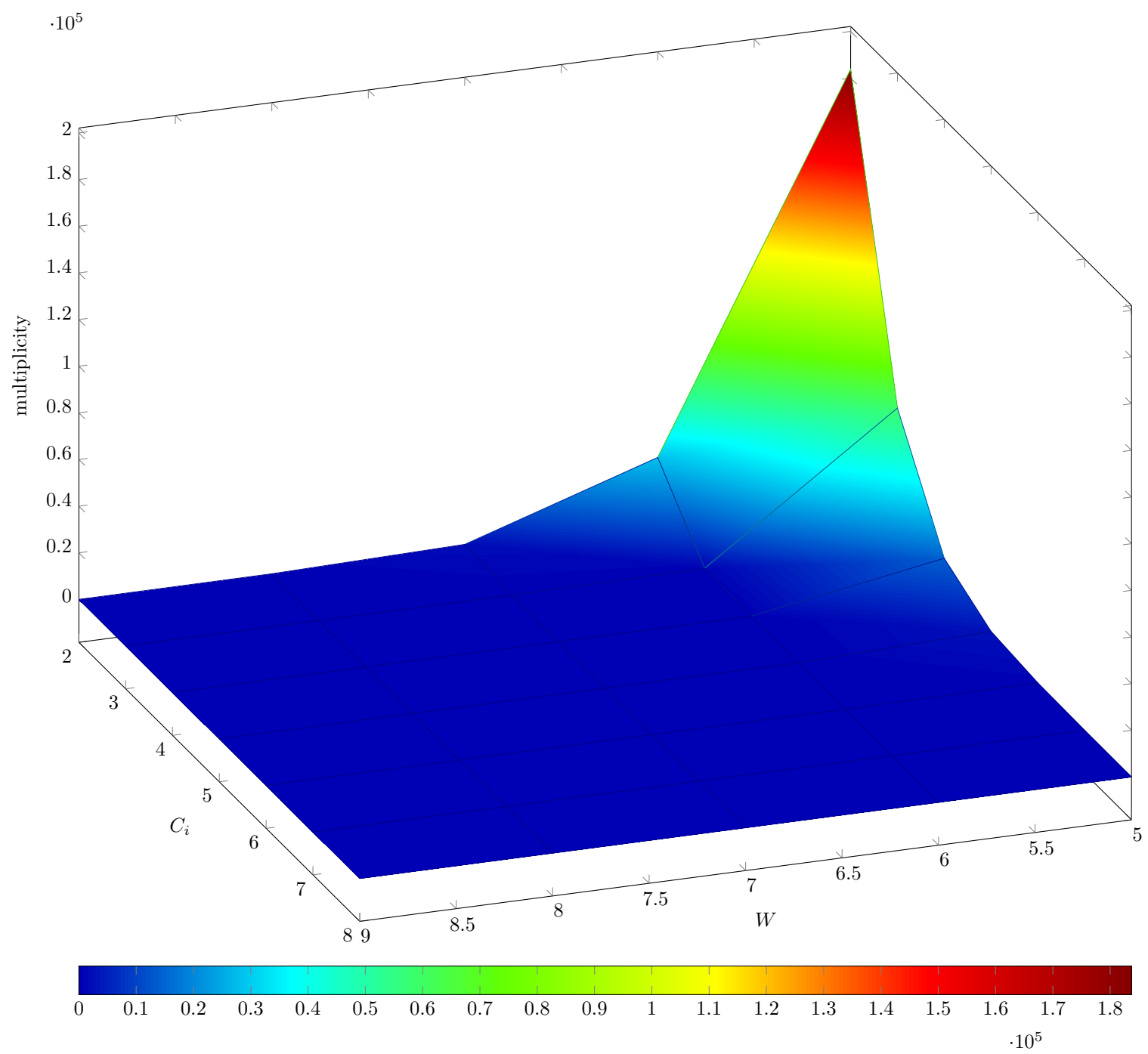


Fig. 6 Estimated  $W$ -tuple collision probability in Step 3 of §6.3.6 of NIST SP 800-90B



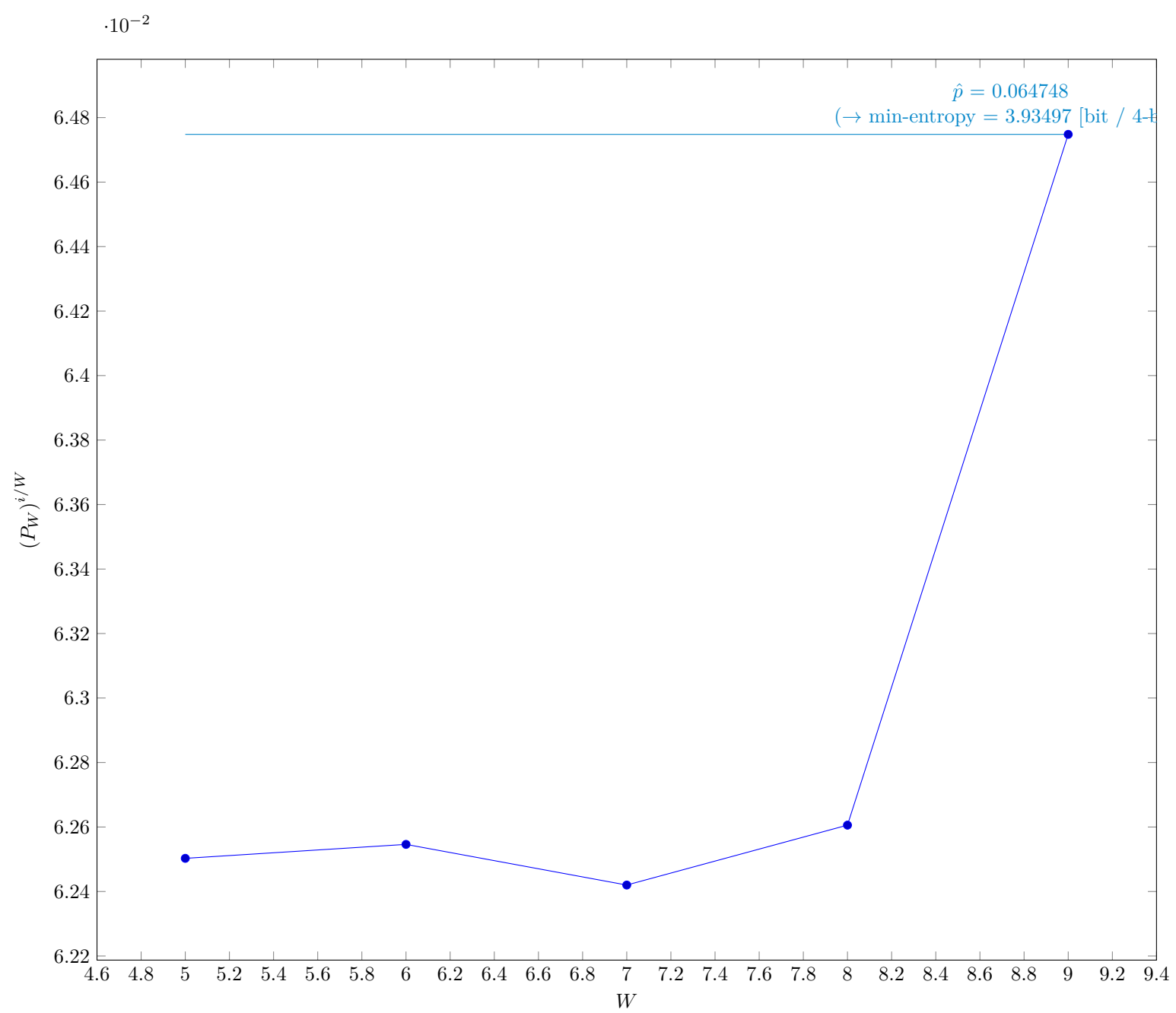


Fig. 7 Estimated average collision probability per string symbol in Step 3 of §6.3.6 of NIST SP 800-90B

3.3.1 Supplemental information for traceability

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

Symbol	Value
$u$	5
$v$	9
$\hat{p}$	0.064748
$p_u$	0.0653819

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

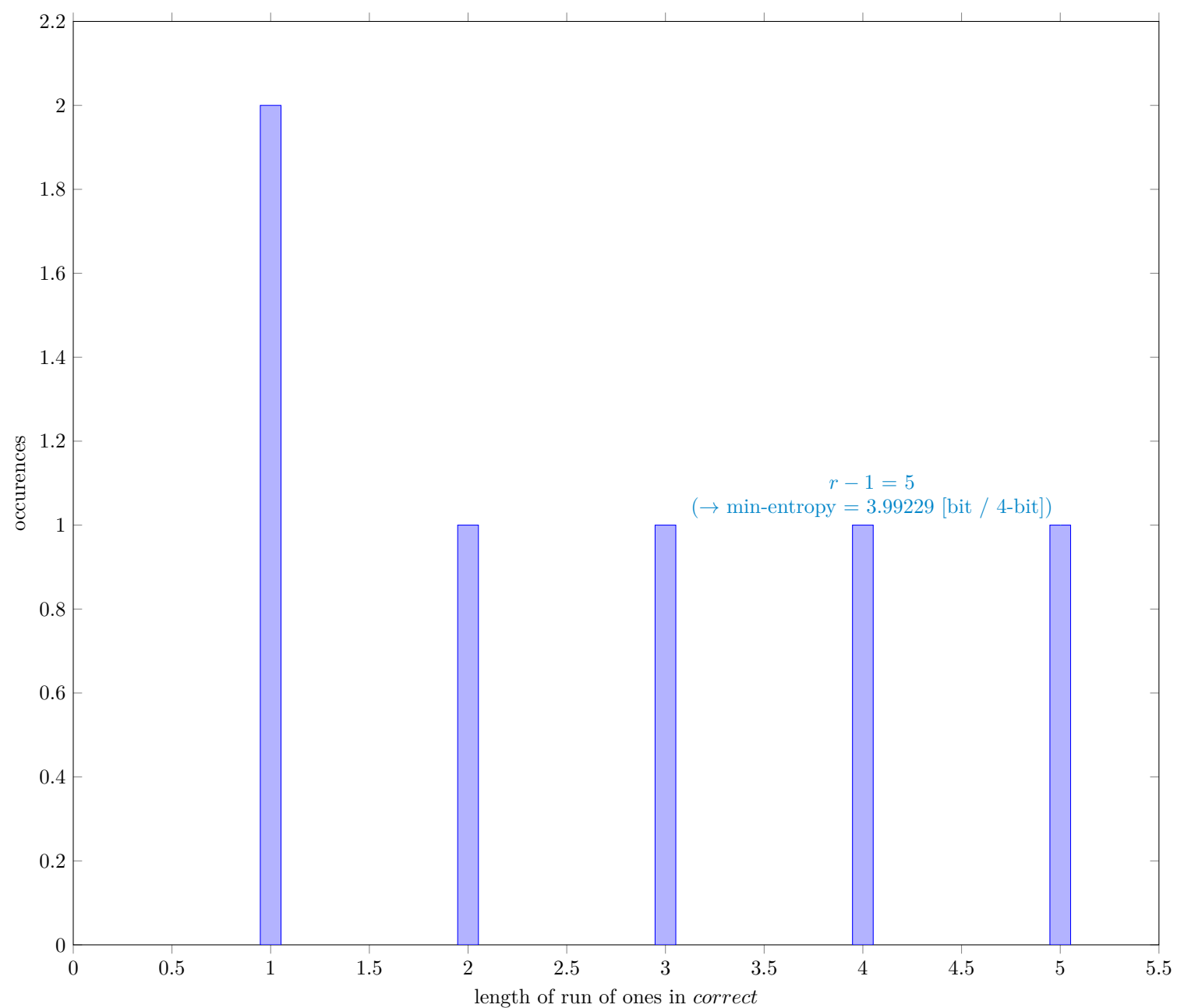


Fig. 8 Distribution of *correct*

#### 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
$C$	62209
$P_{\text{global}}$	0.0622129
$P'_{\text{global}}$	0.0628351
$r$	6
$P_{\text{local}}$	0.0468281

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

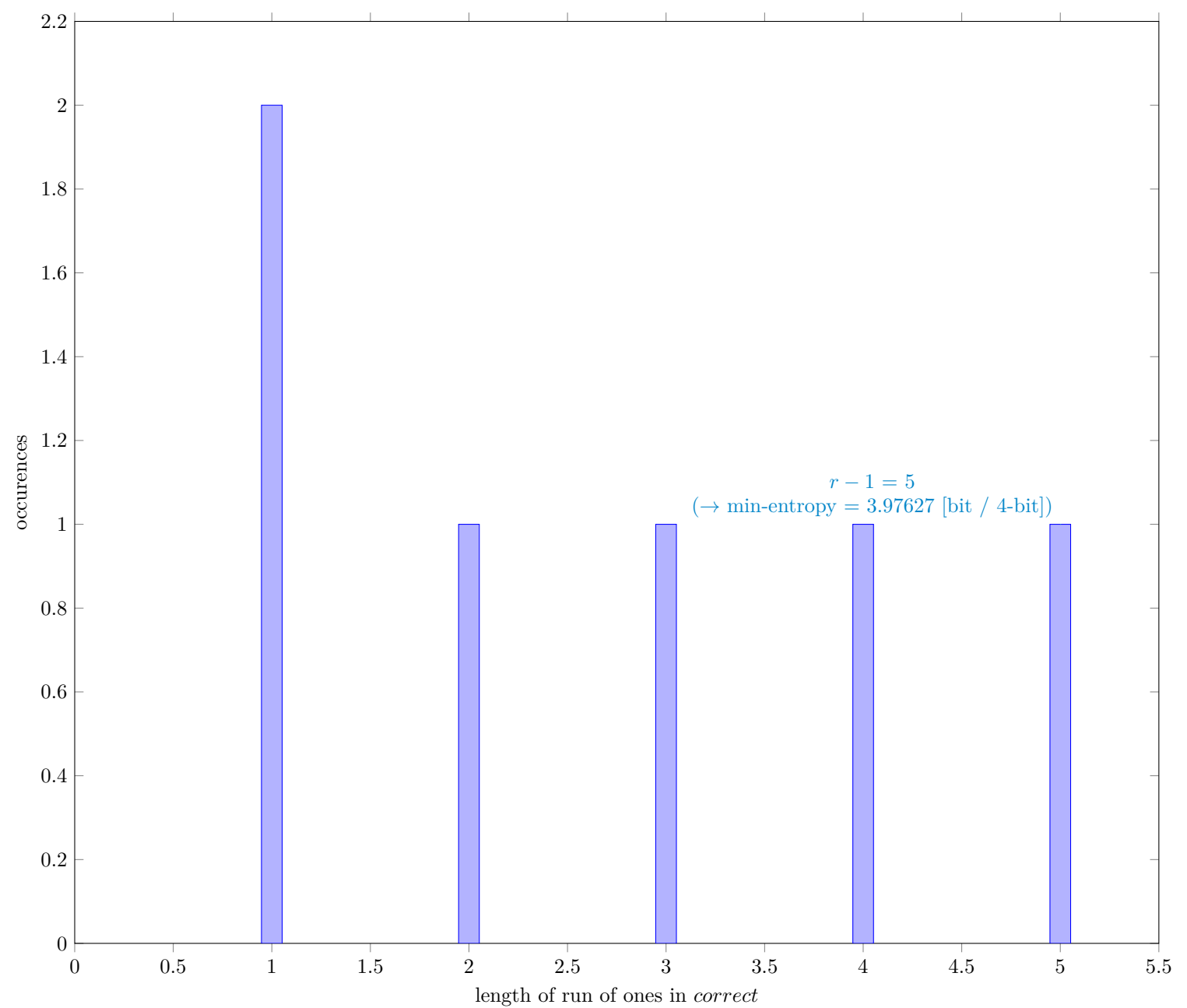


Fig. 9 Distribution of *correct*

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
$C$	62911
$P_{\text{global}}$	0.0629111
$P'_{\text{global}}$	0.0635365
$r$	6
$P_{\text{local}}$	0.0468276

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

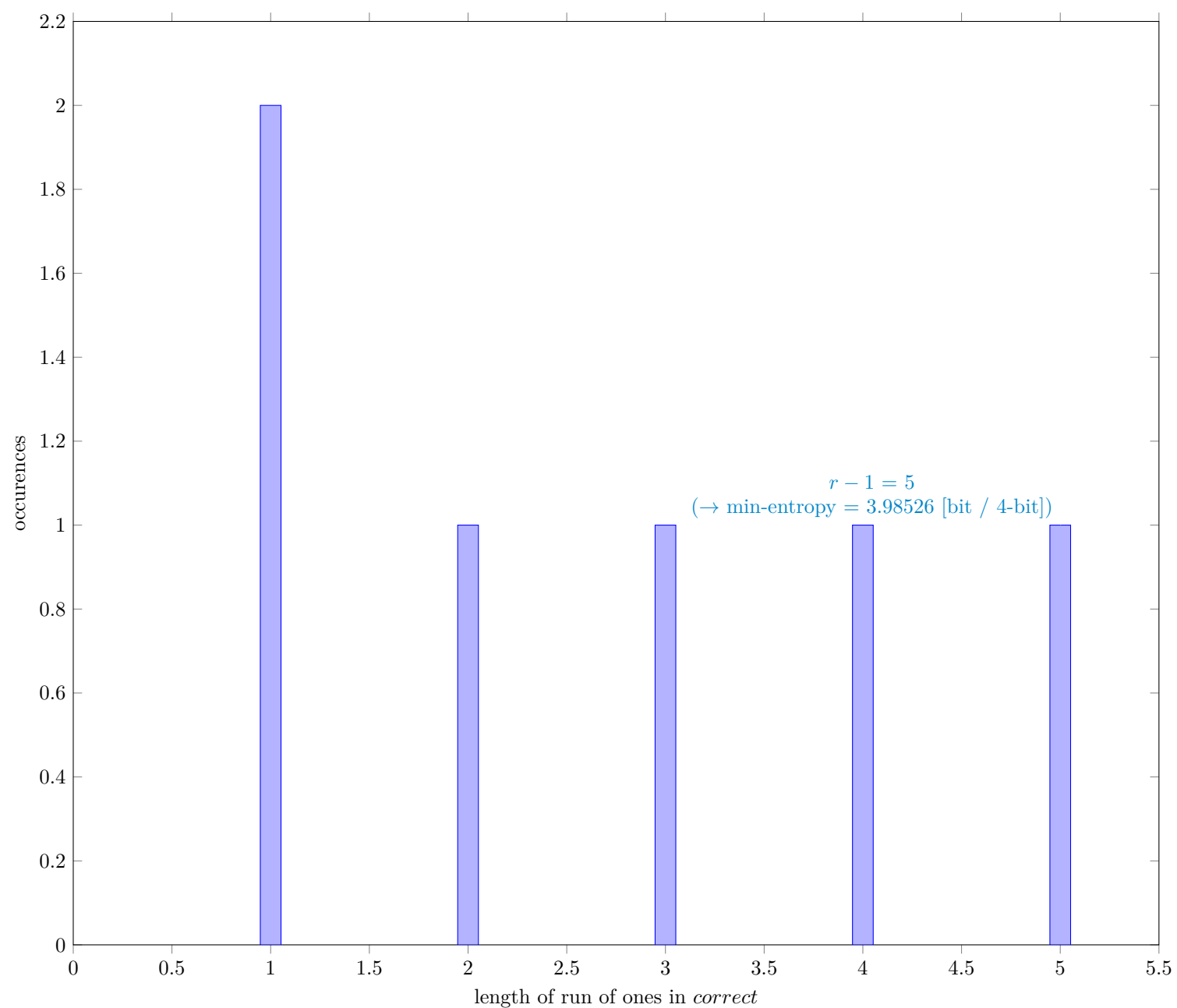


Fig. 10 Distribution of *correct*

#### 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
$C$	62518
$P_{\text{global}}$	0.0625181
$P'_{\text{global}}$	0.0631417
$r$	6
$P_{\text{local}}$	0.0468276

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

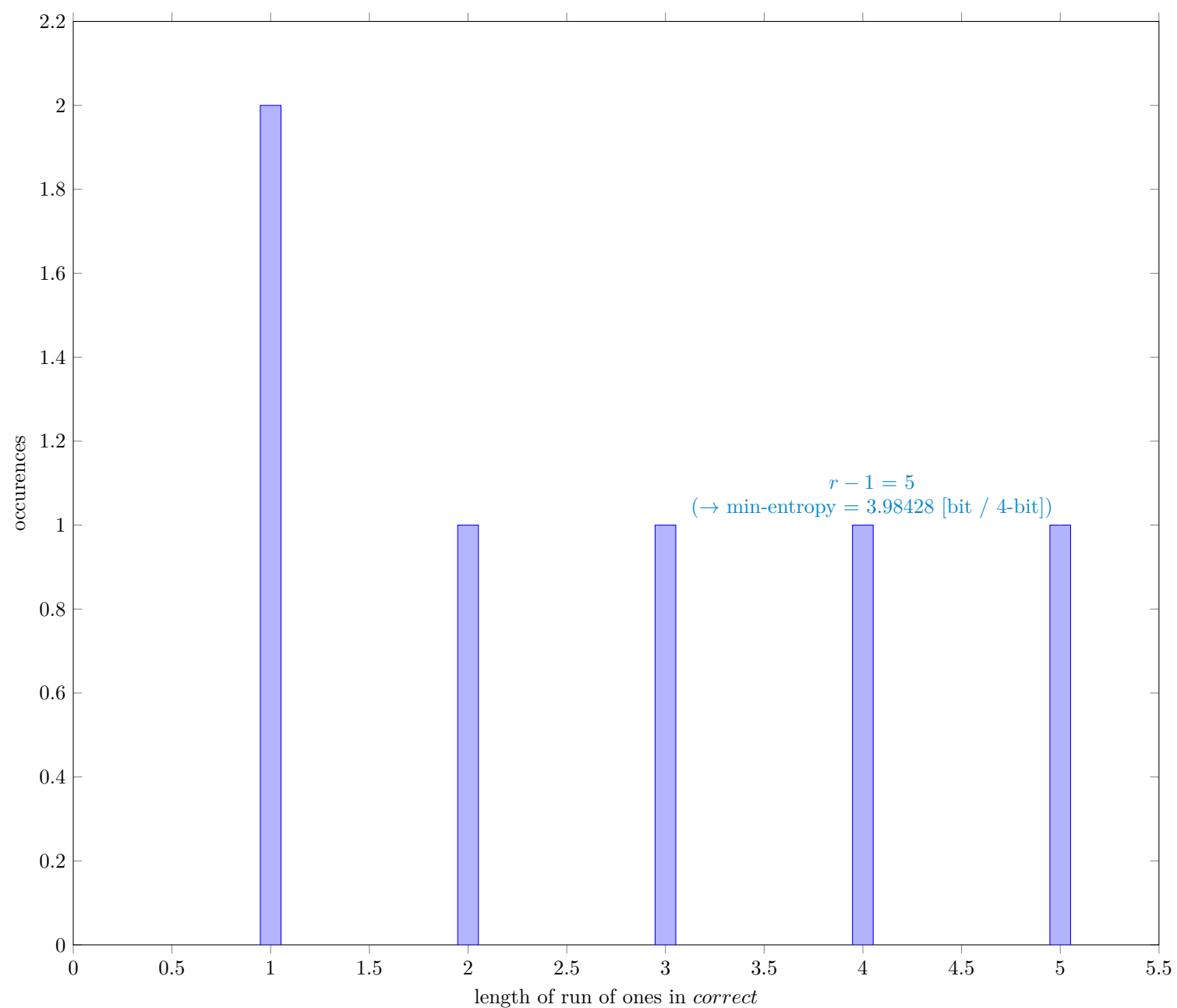


Fig. 11 Distribution of *correct*

#### 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
$C$	62560
$P_{\text{global}}$	0.0625611
$P'_{\text{global}}$	0.0631849
$r$	6
$P_{\text{local}}$	0.0468277

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)

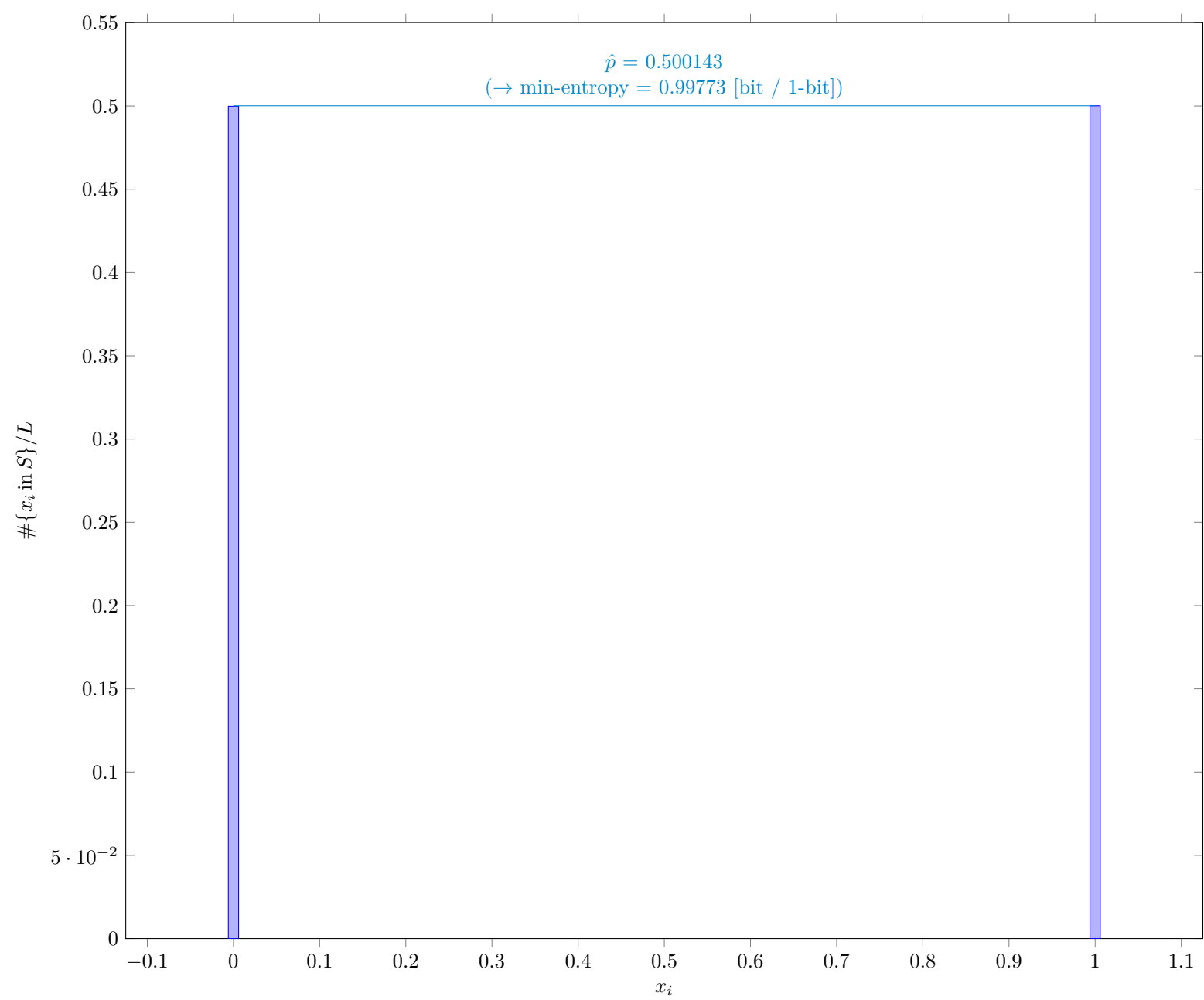


Fig. 12 Distribution of  $x_i$

4.1.1

Supplemental information for traceability

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

Symbol	Value
mode	2000573
$\hat{p}$	0.500143
$p_u$	0.500787

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

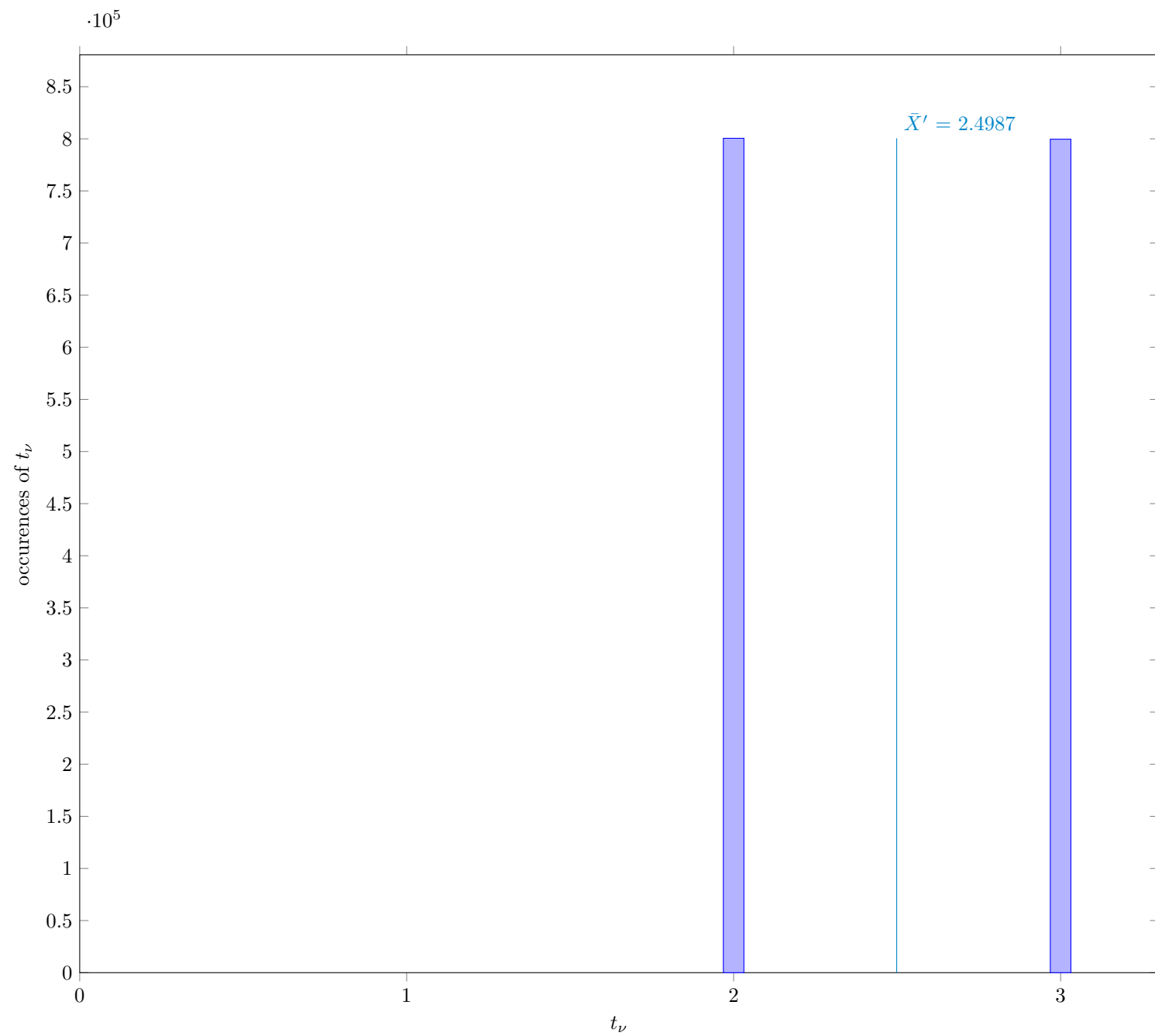


Fig. 13 Distribution of intermediate value  $t_\nu$



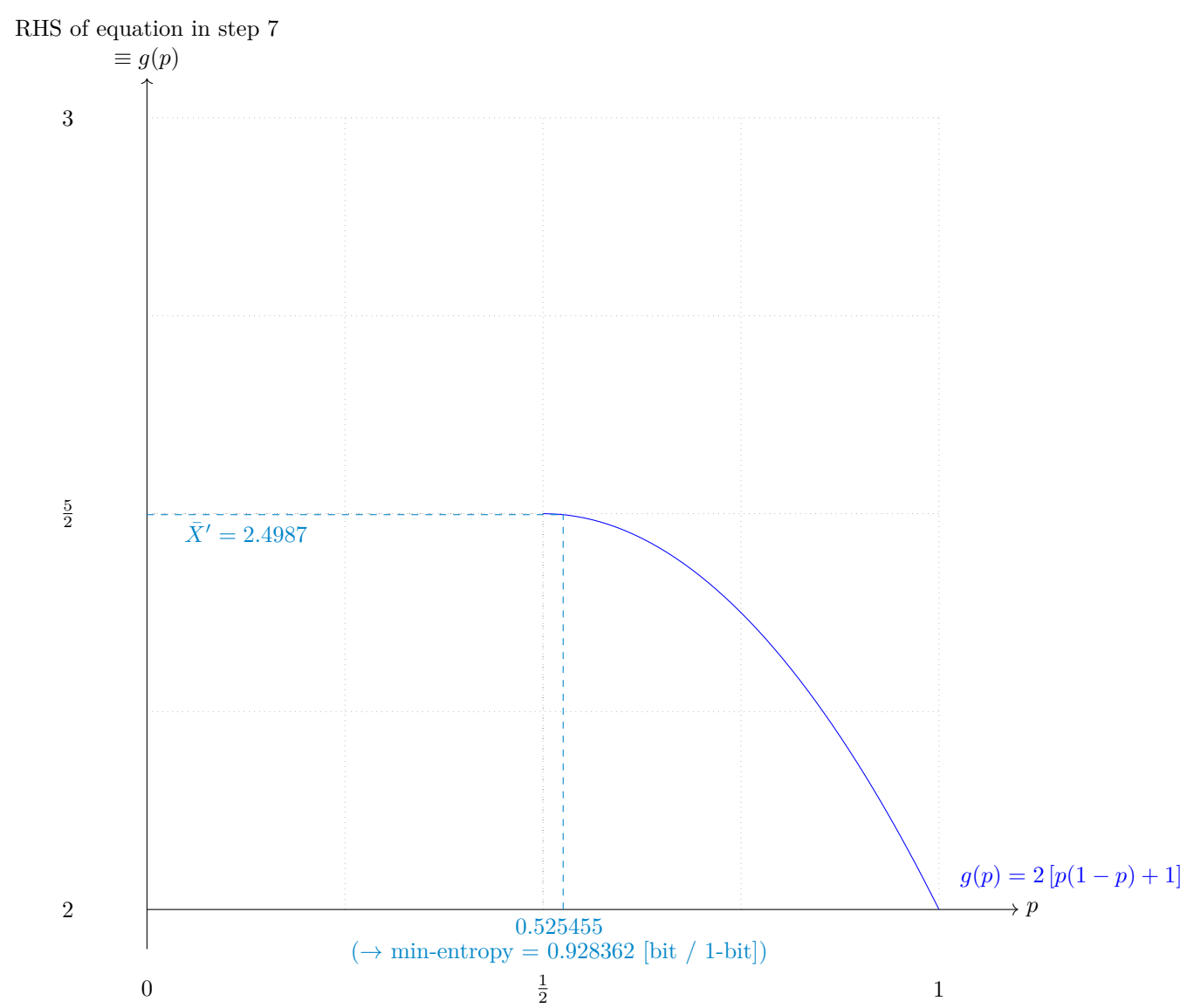


Fig. 14 Solution to the equation in step 7

4.2.1 Supplemental information for traceability

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

Symbol	Value
$p$	0.525455
$\bar{X}$	2.49972
$\bar{X}'$	2.4987
$\hat{\sigma}$	0.5

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

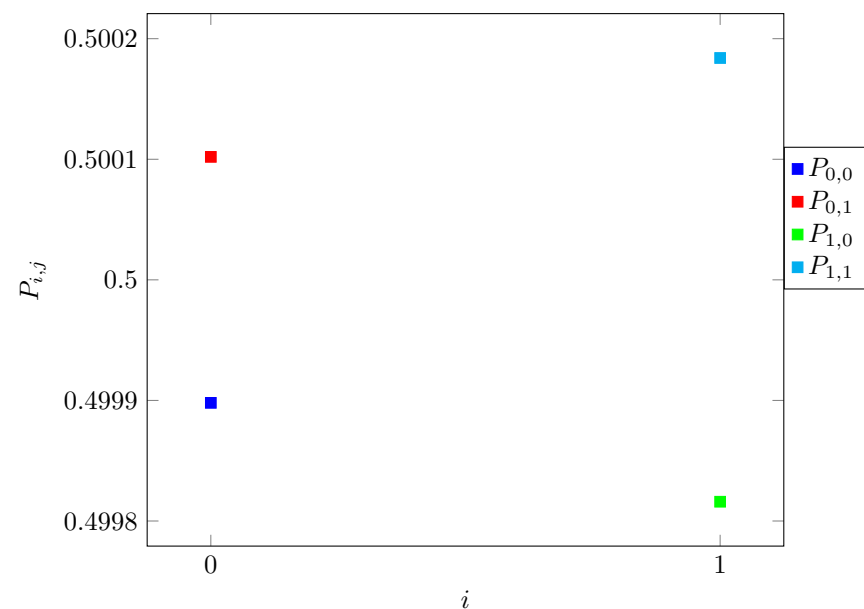


Fig. 15 Transition probability  $P_{i,j}$  of §6.3.3 of NIST SP 800-90B

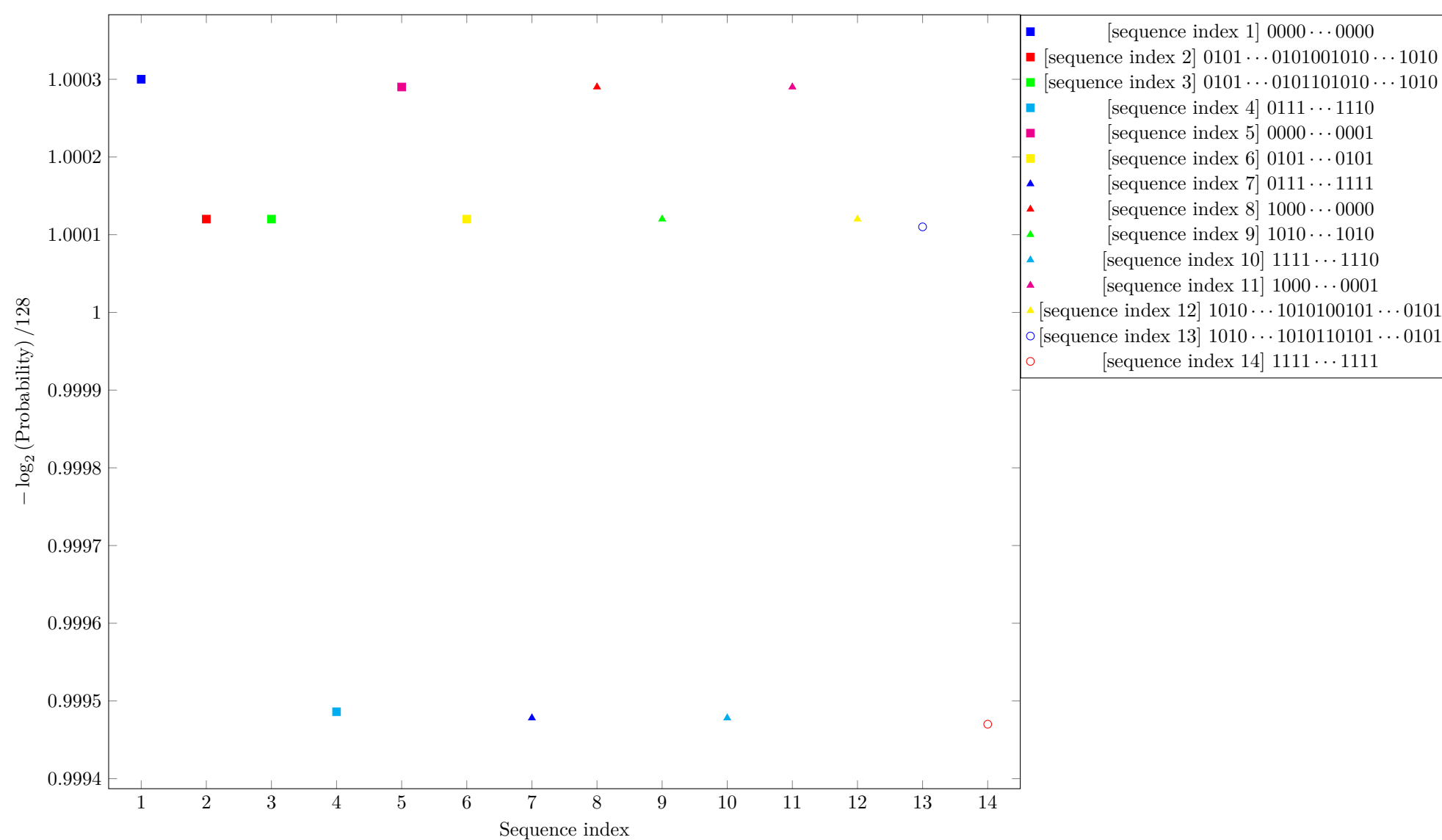


Fig. 16 Estimated Min-Entropy using §6.3.3 of NIST SP 800-90B

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

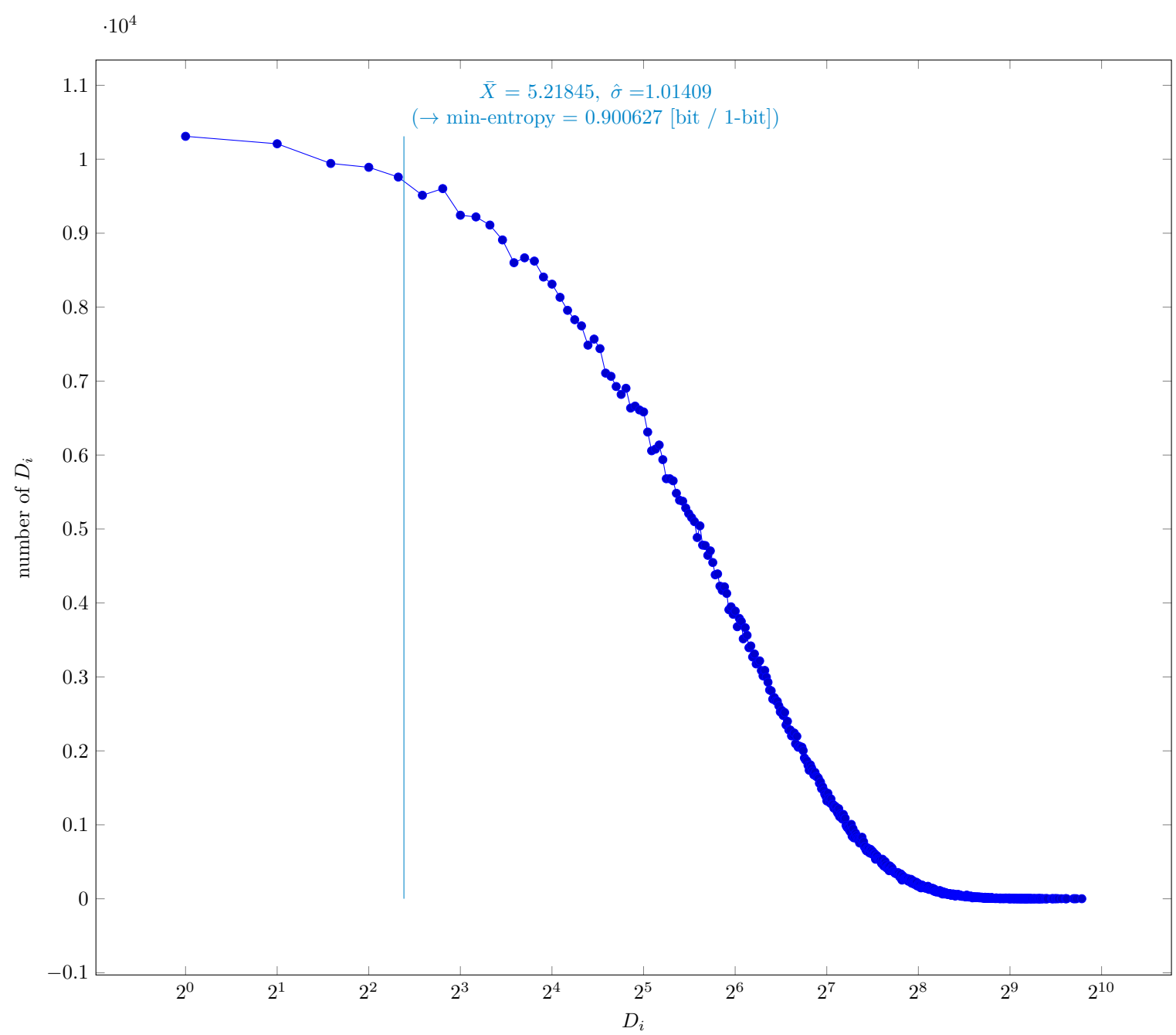


Fig. 17 Distribution of intermediate value  $D_i$

4.4.1 Supplemental information for traceability

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

Symbol	Value
$p$	0.0236214
$\bar{X}$	5.21845
$\hat{\sigma}$	1.01409
$\bar{X}'$	5.21525

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

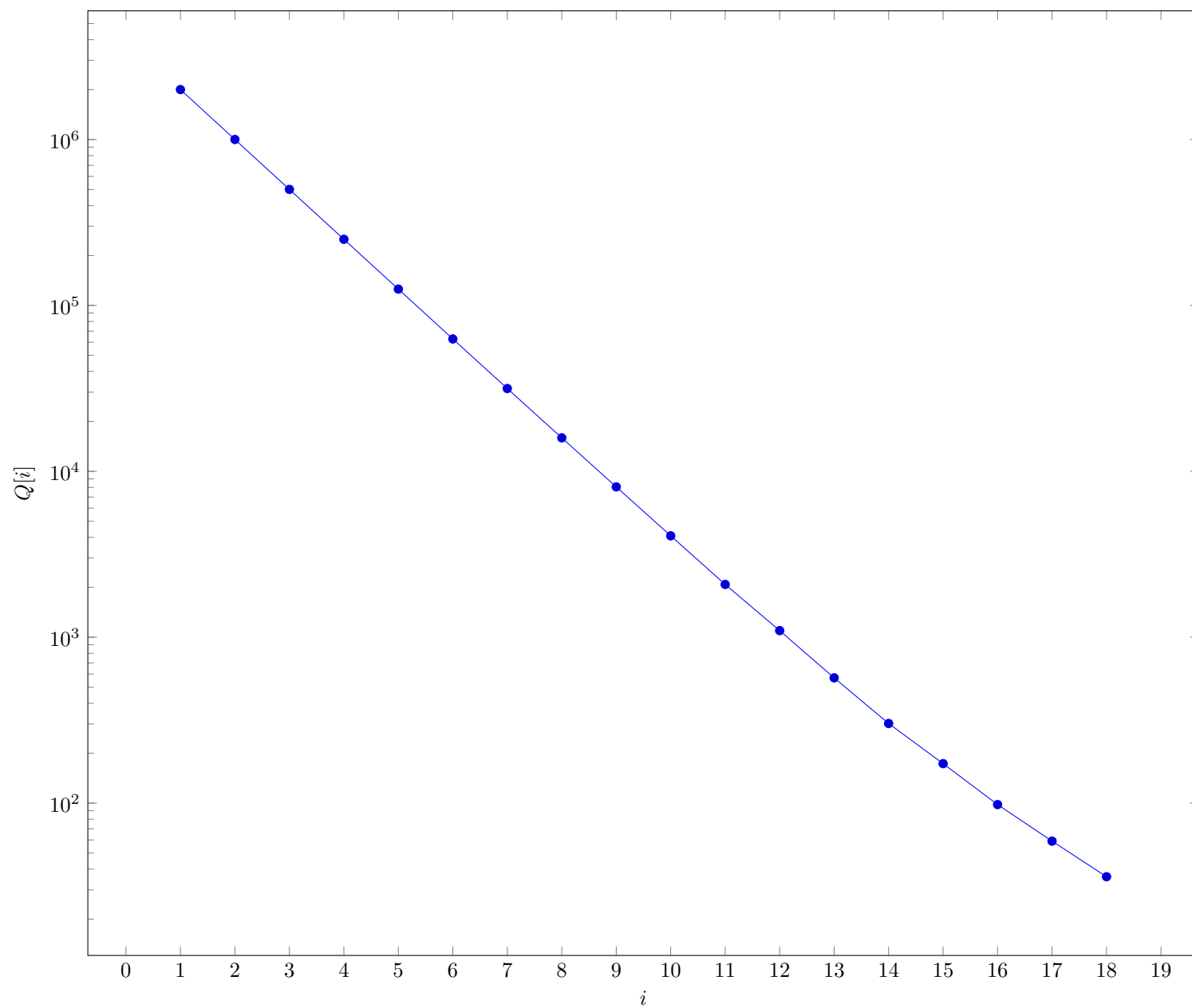


Fig. 18 Intermediate value  $Q[i]$  in §6.3.5 of NIST SP 800-90B

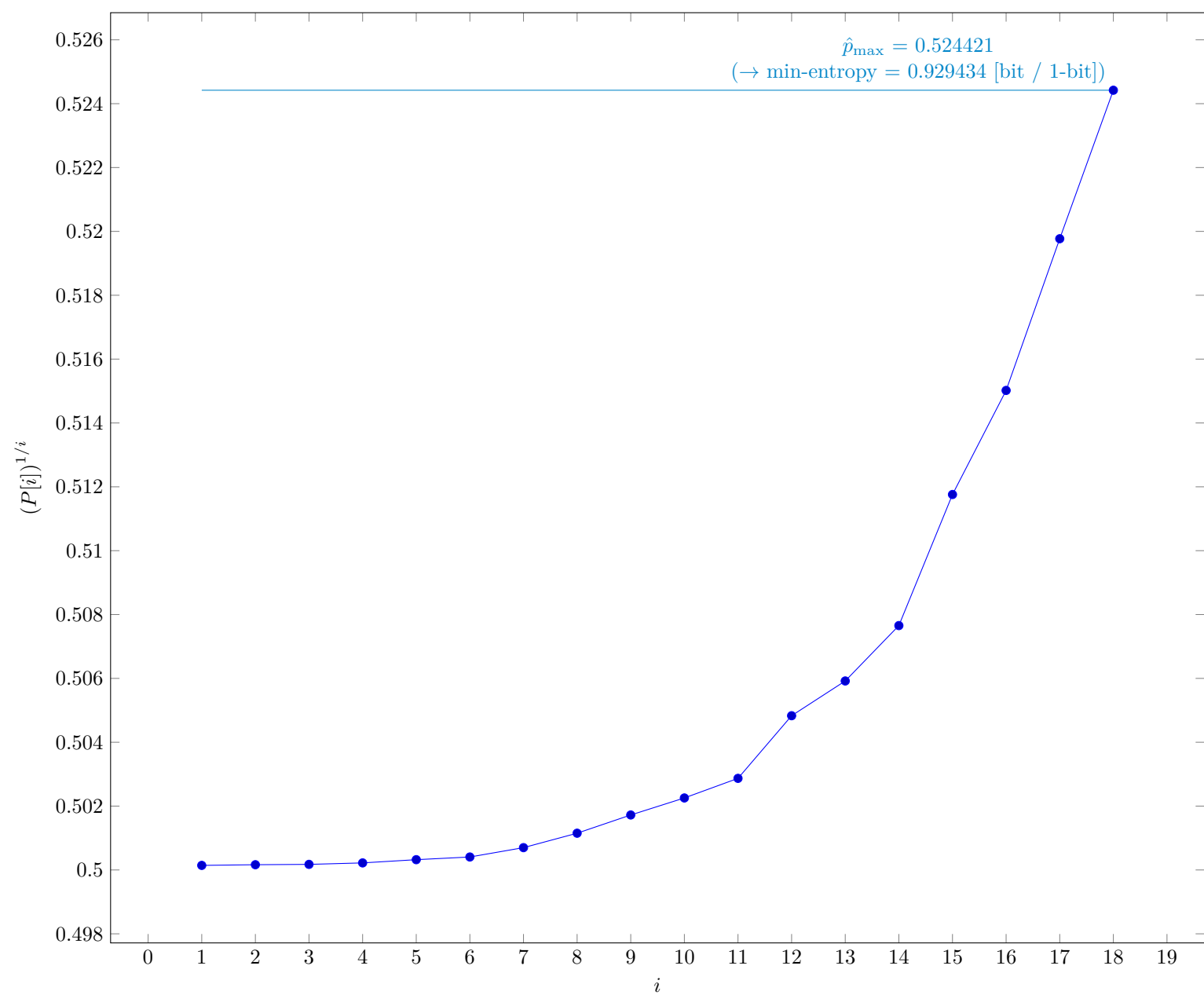


Fig. 19  $P[i]^{1/i}$  in §6.3.5 of NIST SP 800-90B

4.5.1 Supplemental information for traceability

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

Symbol	Value
$t$	18
$\hat{p}_{\max}$	0.524421
$p_u$	0.525064

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

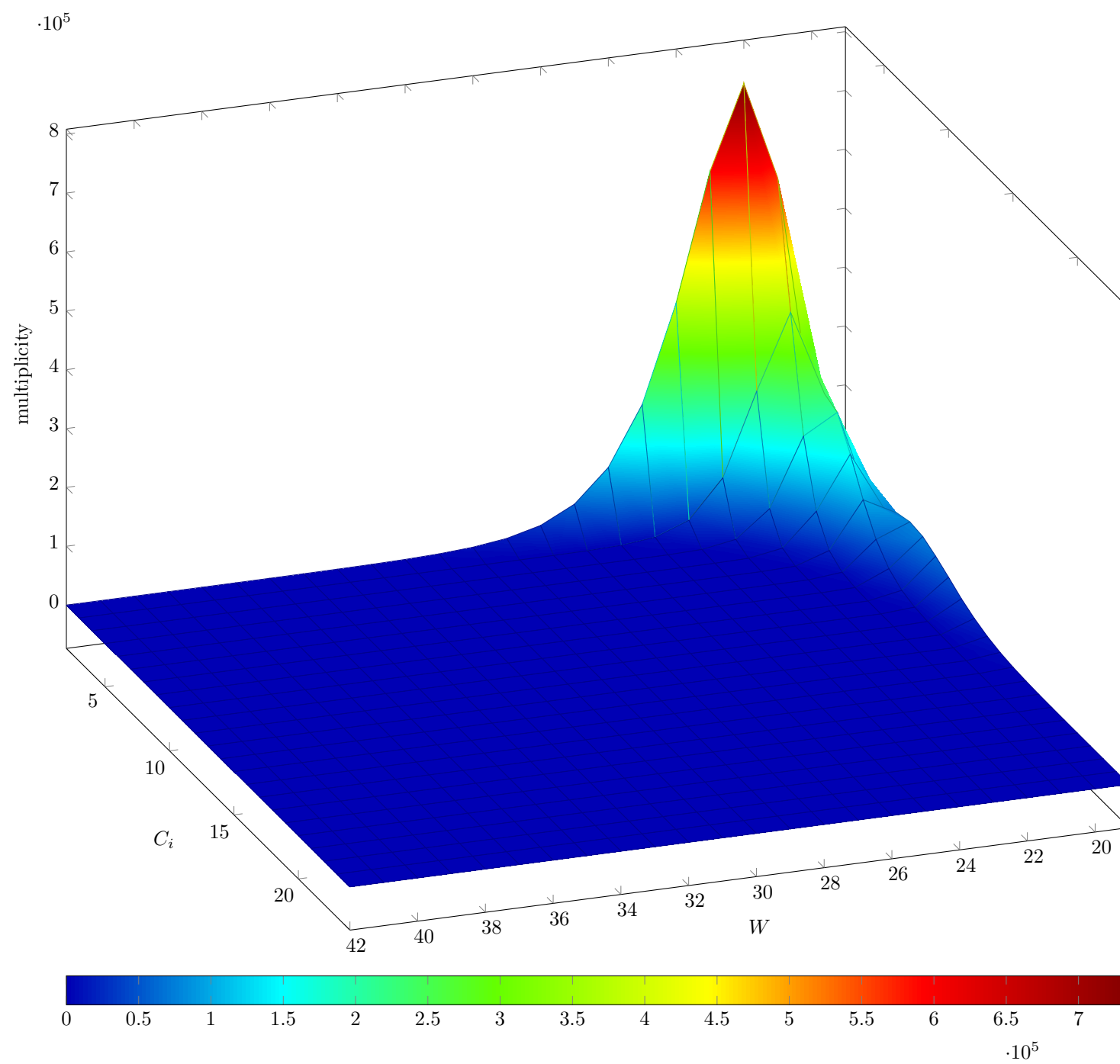


Fig. 20 Estimated  $W$ -tuple collision probability in Step 3 of §6.3.6 of NIST SP 800-90B



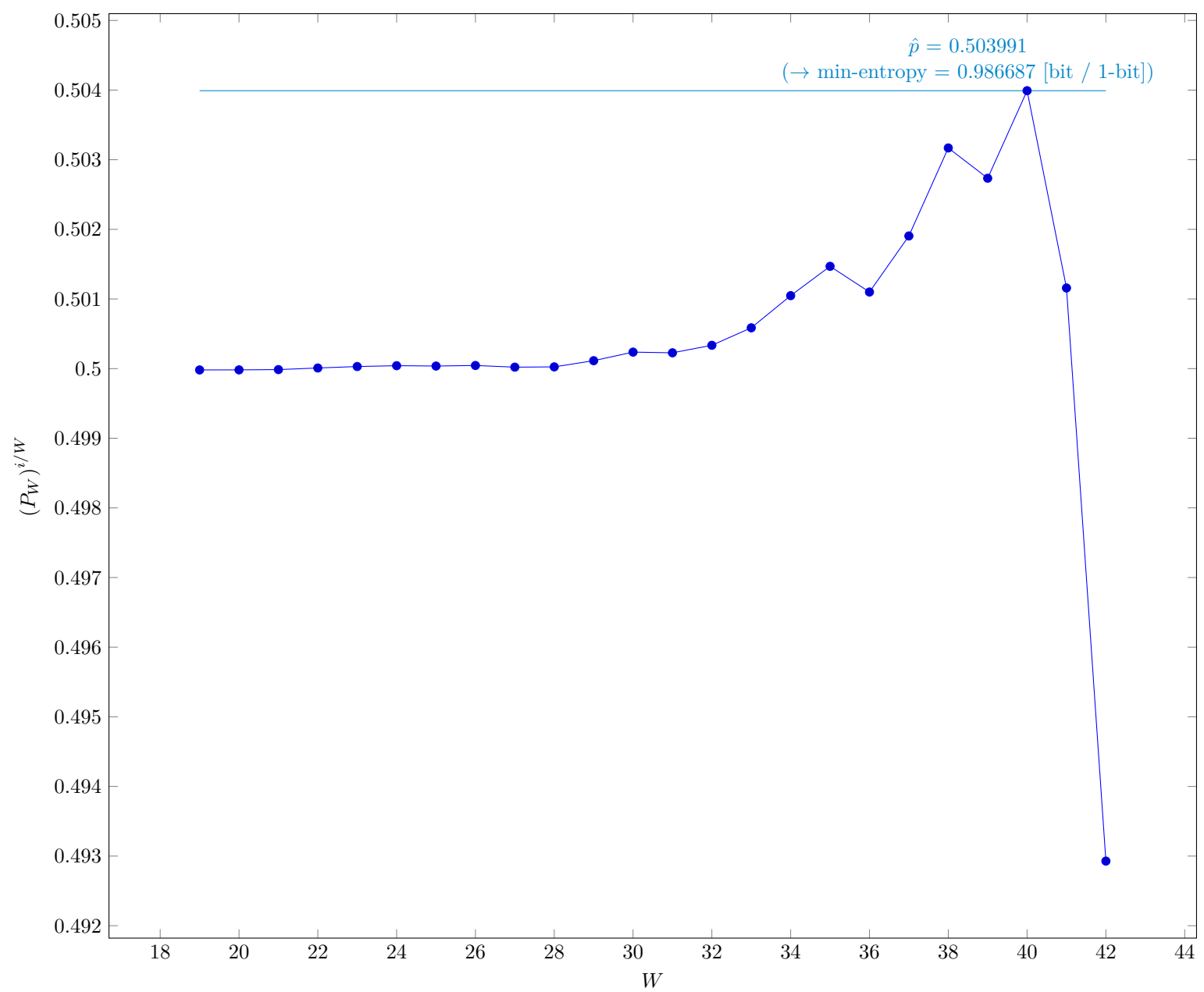


Fig. 21 Estimated average collision probability per string symbol in Step 3 of §6.3.6 of NIST SP 800-90B

4.6.1 Supplemental information for traceability

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

Symbol	Value
$u$	19
$v$	42
$\hat{p}$	0.503991
$p_u$	0.504635

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

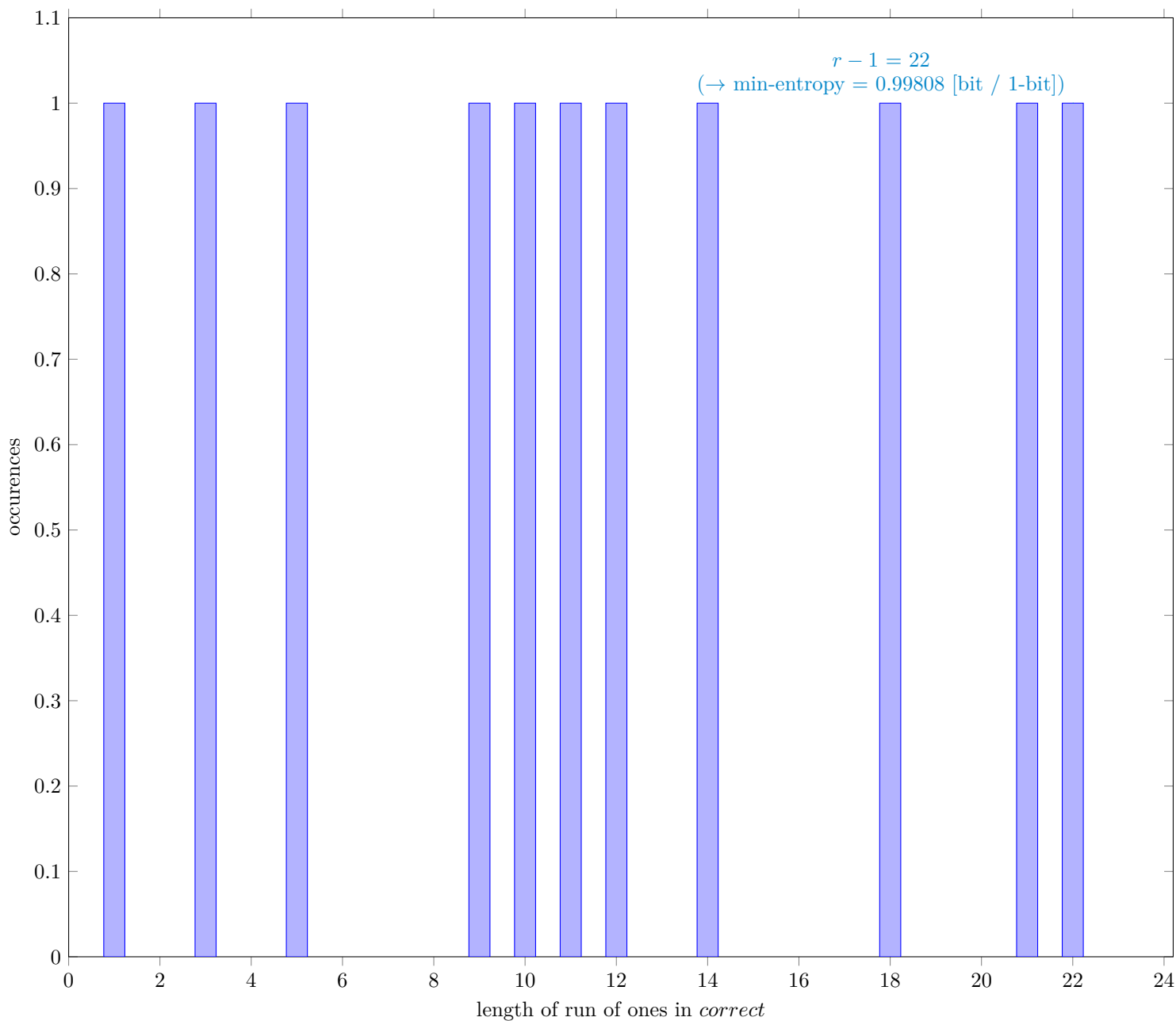


Fig. 22 Distribution of *correct*

4.7.1 Supplemental information for traceability

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

Symbol	Value
$N$	39999937
$C$	2000056
$P_{\text{global}}$	0.500022
$P'_{\text{global}}$	0.500666
$r$	23
$P_{\text{local}}$	0.433329

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

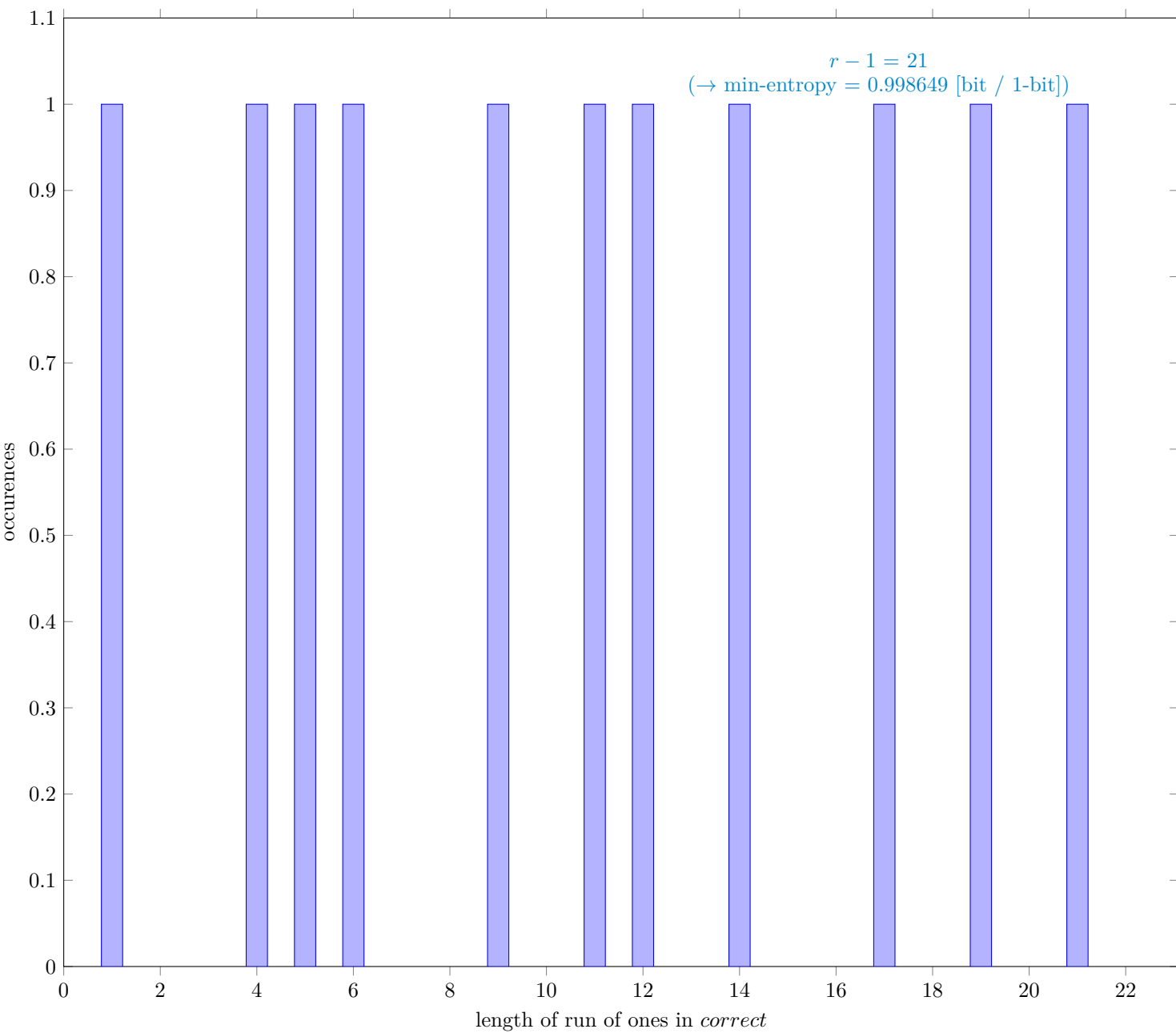


Fig. 23 Distribution of *correct*

4.8.1 Supplemental information for traceability

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

Symbol	Value
$N$	3999999
$C$	1999298
$P_{\text{global}}$	0.499825
$P'_{\text{global}}$	0.500469
$r$	22
$P_{\text{local}}$	0.416615

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

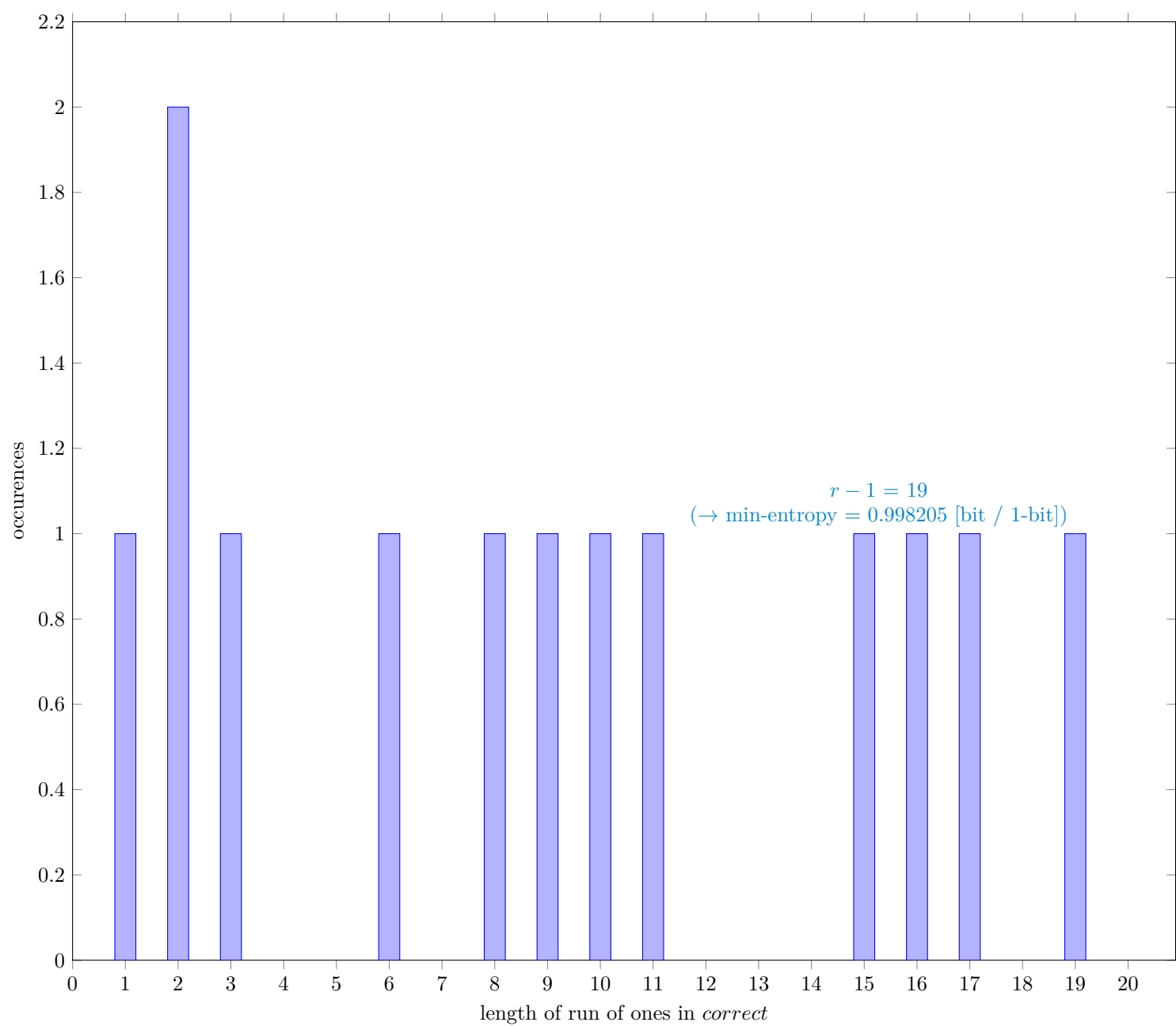


Fig. 24 Distribution of *correct*

4.9.1 Supplemental information for traceability

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

Symbol	Value
$N$	3999998
$C$	1999913
$P_{\text{global}}$	0.499978
$P'_{\text{global}}$	0.500622
$r$	20
$P_{\text{local}}$	0.380545

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

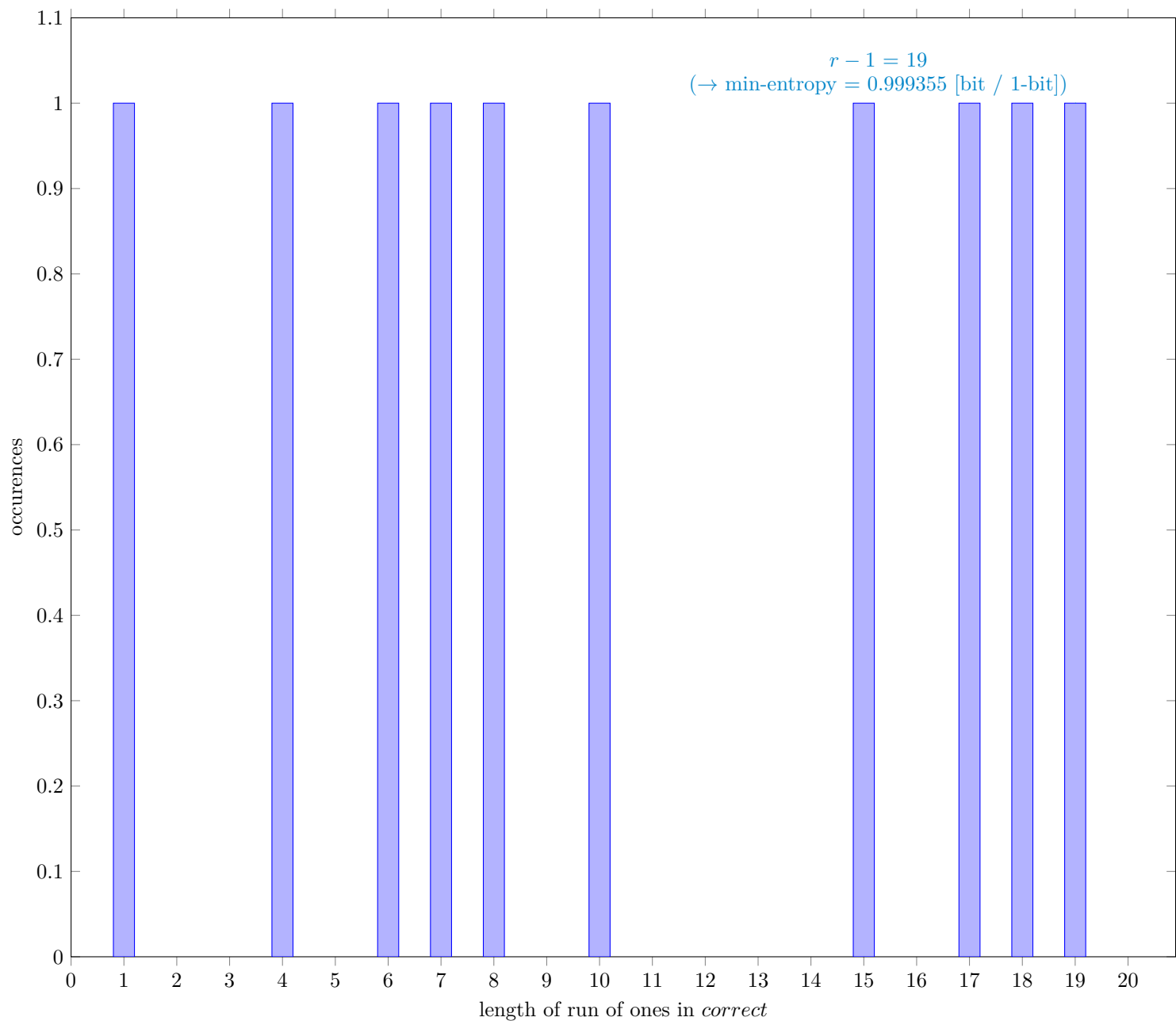


Fig. 25 Distribution of *correct*

4.10.1 Supplemental information for traceability

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

Symbol	Value
$N$	3999983
$C$	1998310
$P_{\text{global}}$	0.49958
$P'_{\text{global}}$	0.500224
$r$	20
$P_{\text{local}}$	0.380545

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](https://github.com/g-g-sakura/AnotherEntropyEstimationTool/blob/main/documentation/ProposedListOfCorrections_SP800-90B.pdf)