In-vehicle battery durability for electrified vehicles

PART A: Verification of monitors
Option B

Web meeting

Gian Luca Patrone, Elena Paffumi

26th May 2021

Verifying the method Option B for the battery monitors

- For evaluating the SOCR/SOCE monitors normalised values shall be calculated:

$x_i = \frac{SOC_{read,i}}{SOC_{measured,i}}$ or $x_i = SOC_{read,i} - SOC_{measured,i}$

- Where: $SOC_{read,i}$ is the SOCR/SOCE monitor read from the vehicle i

  $SOC_{measured,i}$ is the measured SOCR/SOCE monitor of the vehicle i

- For the total number of N tests and the normalised values of the tested vehicles, x_1, x_2, … x_N, the **average** X_{tests} and the **standard deviation** s shall be determined:

$$X_{tests} = \frac{(x_1 + x_2 + x_3 + \cdots + x_N)}{N}$$

$$s = \sqrt{\frac{(x_1 - X_{tests})^2 + (x_2 - X_{tests})^2 + \ldots + (x_N - X_{tests})^2}{N - 1}}$$

Summary of the methodology

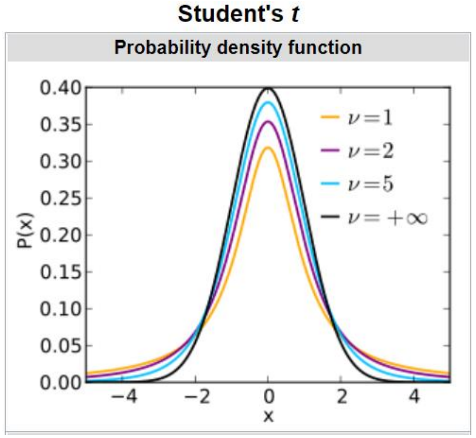
- The proposed testing method follows the same steps of CO_2 CoP testing:
  - Boundaries around a theoretical mean

$$m(i) = A - t_{N-1,cL} * \frac{s(i)}{\sqrt{N}}$$

$$lb(i) = \mathrm{m(i)} - t_{i-1,cL} * \frac{s(i)}{\sqrt{i}} = A - \left(\frac{t_{i-1,Cl(i)}}{\sqrt{i}} + \frac{t_{N-1,Cl(i)}}{\sqrt{N}}\right) * s(i)$$

$$ub(i) = \mathrm{m(i)} + t_{i-1,cL} * \frac{s(i)}{\sqrt{i}} = A + \left(\frac{t_{i-1,Cl(i)}}{\sqrt{i}} - \frac{t_{N-1,Cl(i)}}{\sqrt{N}}\right) * s(i)$$

  - If $Xtests \leq A - (t_{P1,N}+t_{P2,N}) \cdot s$ the family gets a pass
  - If $Xtests > A + (t_{F1,N} - t_{F2,N}) \cdot s$ the family gets a fail
  - Else it is required to measure another vehicle, increase N by 1, recalculate the mean and the standard deviation and repeat until a decision of pass or fail is reached



	PASS		FAIL	
Tests (i)	$t_{P1,i}$	$t_{P2,i}$	$t_{F1,i}$	t_{F2}
3	1.686	0.438	1.686	0.438
4	1.125	0.425	1.177	0.438
5	0.850	0.401	0.953	0.438
6	0.673	0.370	0.823	0.438
7	0.544	0.335	0.734	0.438
8	0.443	0.299	0.670	0.438
9	0.361	0.263	0.620	0.438
10	0.292	0.226	0.580	0.438
11	0.232	0.190	0.546	0.438
12	0.178	0.153	0.518	0.438
13	0.129	0.116	0.494	0.438
14	0.083	0.078	0.473	0.438
15	0.040	0.038	0.455	0.438
16	0.000	0.000	0.438	0.438

- Fail boundary with constant confidence level (same as CO_2 CoP)

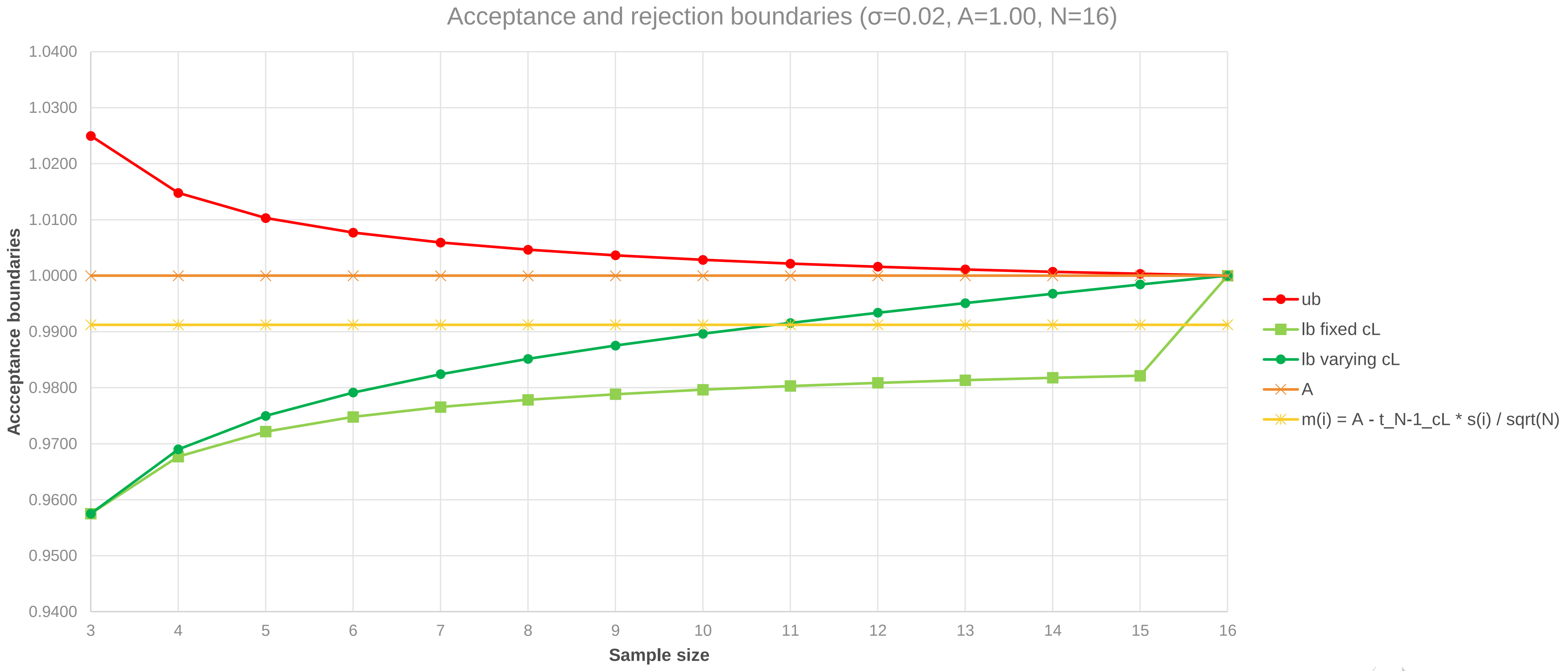
```
cL_up = 0.95;
```

- Pass boundary with decreasing confidence level (same as CO_2 CoP) while i increases

```
cL_lo = [0.95 0.945 0.935 0.92 0.9  0.875 0.845 0.81 0.77 0.725 0.675 0.62 0.56 0.5];
```

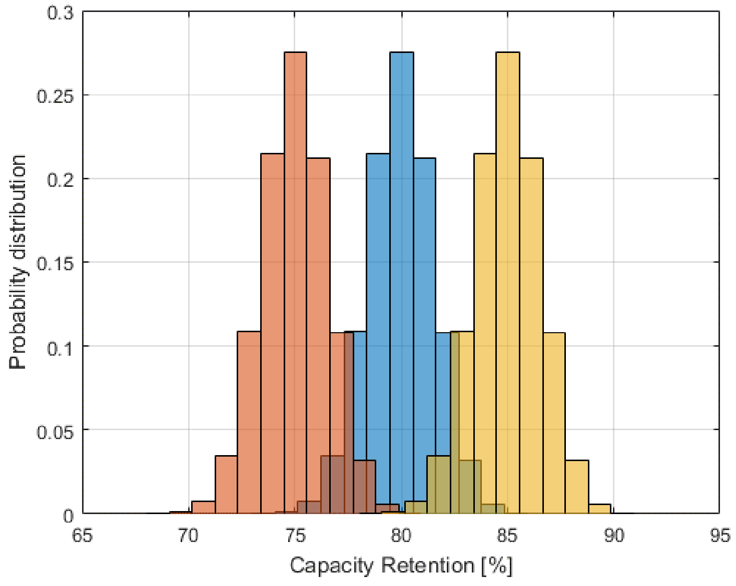
Confidence level decrement increasing proportionally with sample size

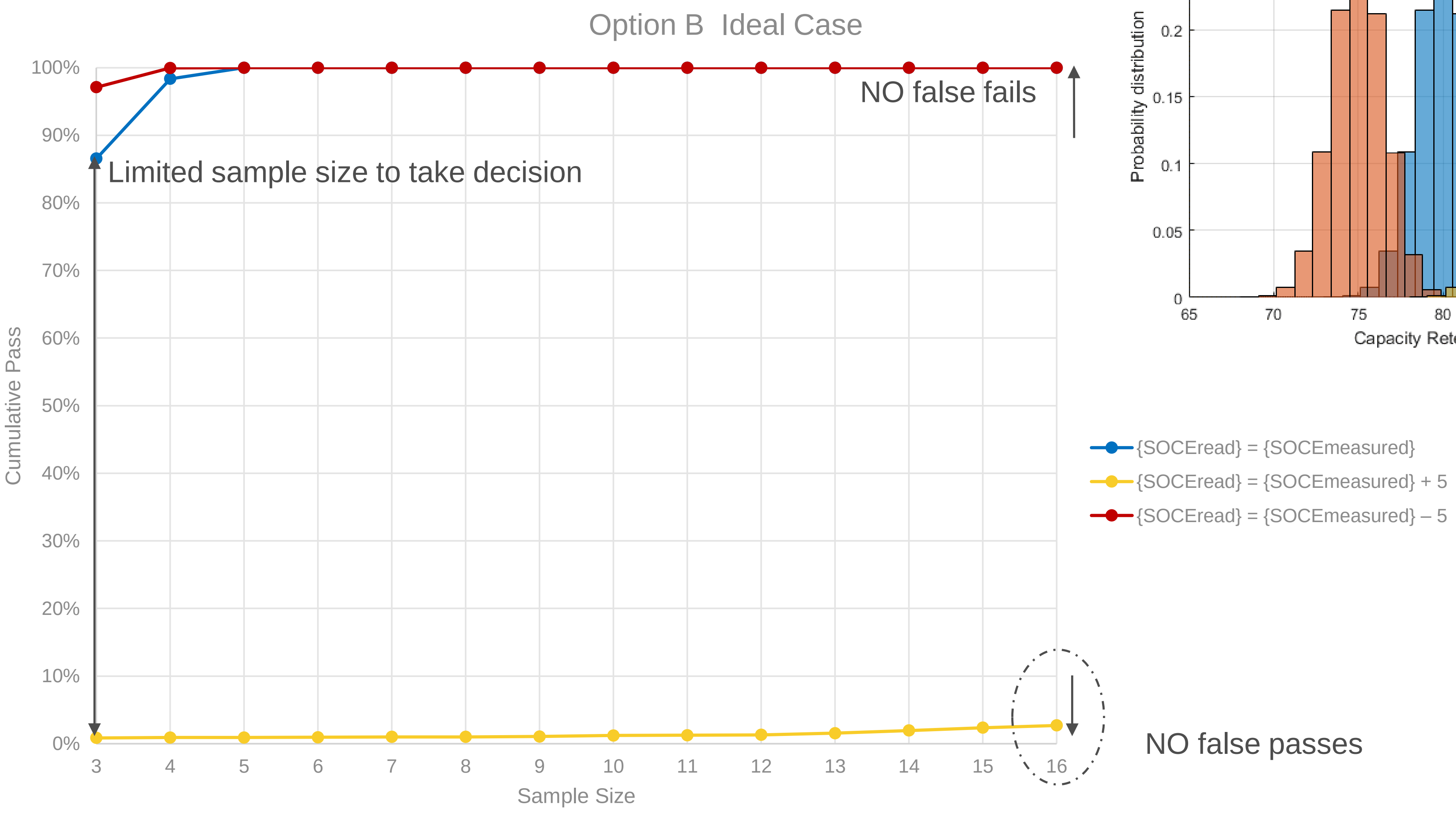
Visualisation of the proposed method



cL_lo = [0.95 0.945 0.935 0.92 0.9 0.875 0.845 0.81 0.77 0.725 0.675 0.62 0.56 0.5];   growing difference for bigger sample sizes

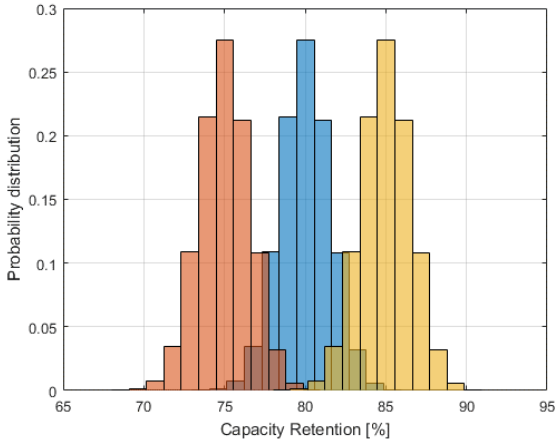
Ideal case


0.3
0.25
0.2
0.15
0.1
0.05
0
Probability distribution
65
70
75
80
85
90
95
Capacity Retention [%]

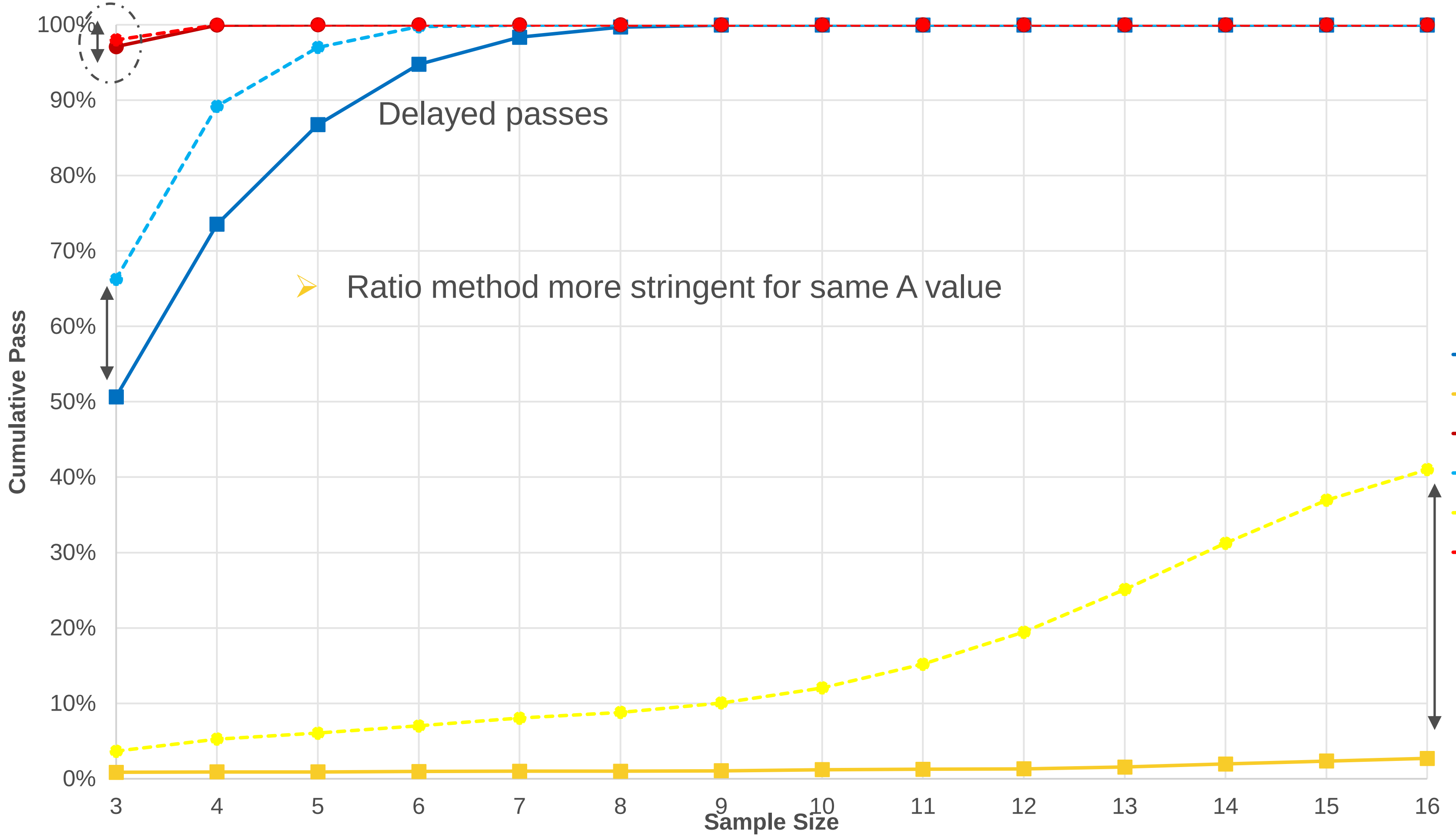

Option B Ideal Case
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative Pass
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Sample Size
NO false fails
Limited sample size to take decision
NO false passes
{SOCEread} = {SOCEmeasured}
{SOCEread} = {SOCEmeasured} + 5
{SOCEread} = {SOCEmeasured} – 5

Ratio vs Difference

soc_{read} shifted above or below the mean value by 5%

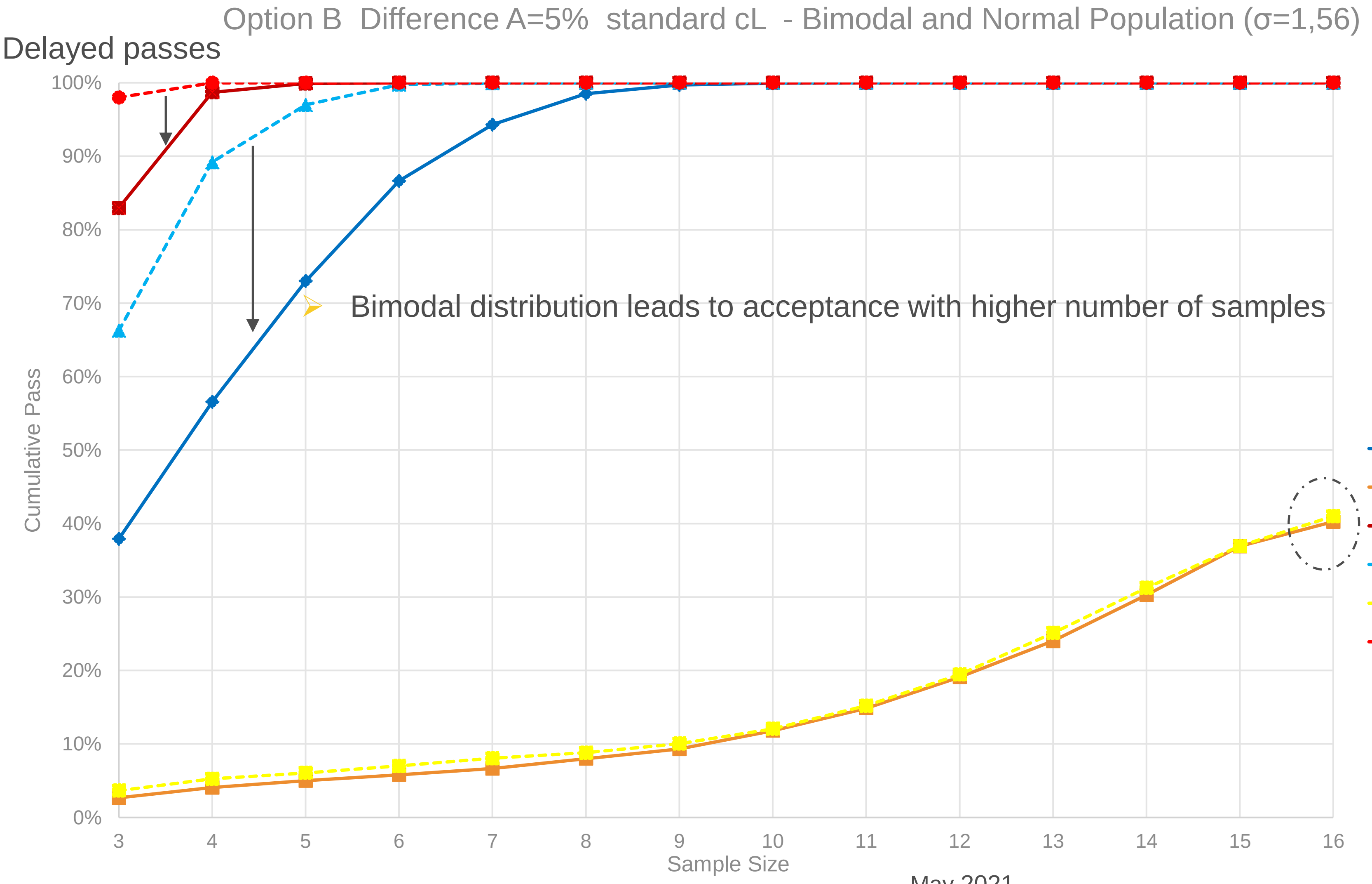


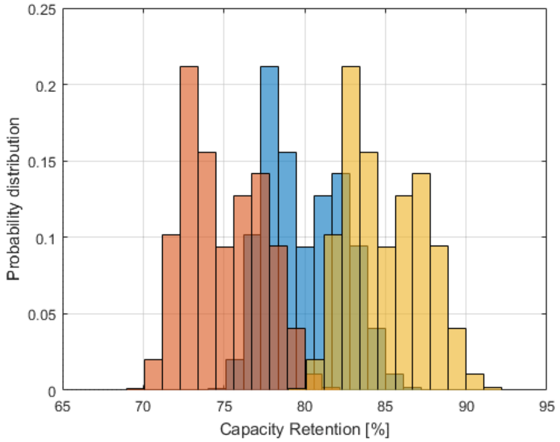
Option B Ratio (A=1.05) and Difference (A=5%) σ=1.56



Bimodal populations

soc_{read} shifted above or below the mean value by 5%

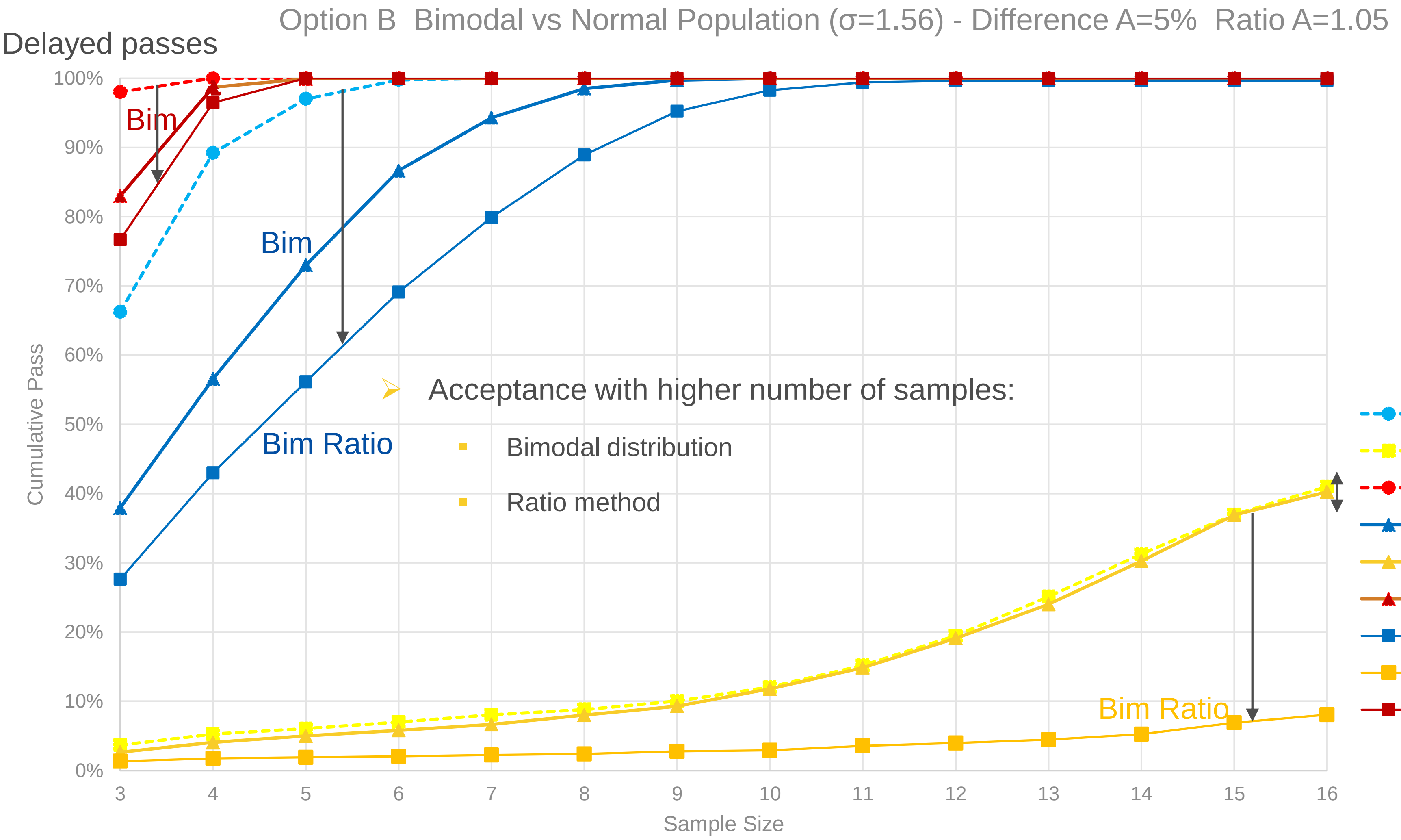




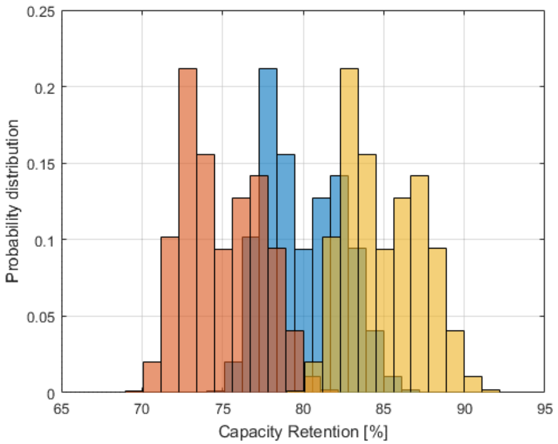
Randomly generated bimodal distribution
(μ=78; σ=1 and μ=82; σ=1,5)

Bimodal populations

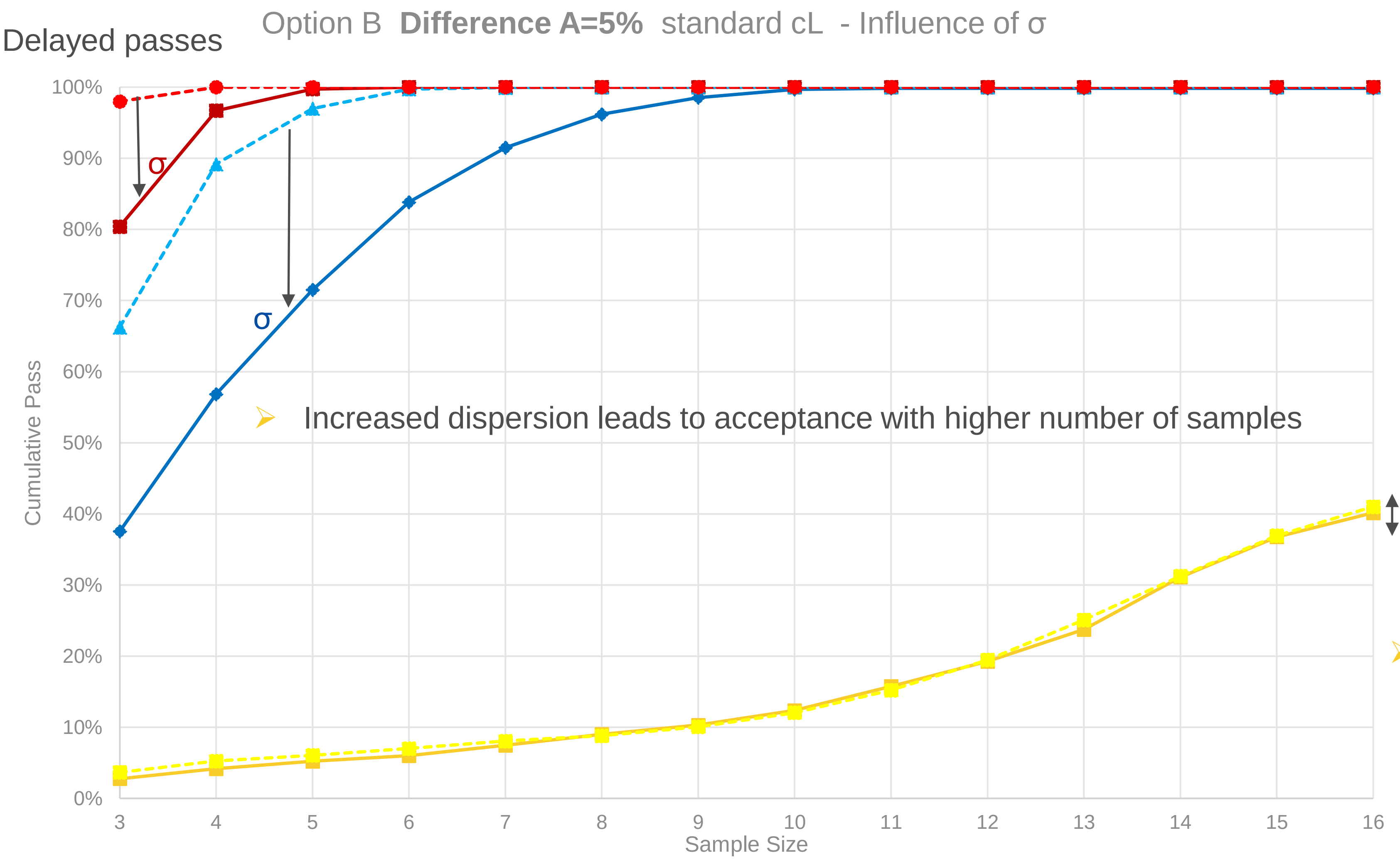
soc_{read} shifted above or below the mean value by 5%



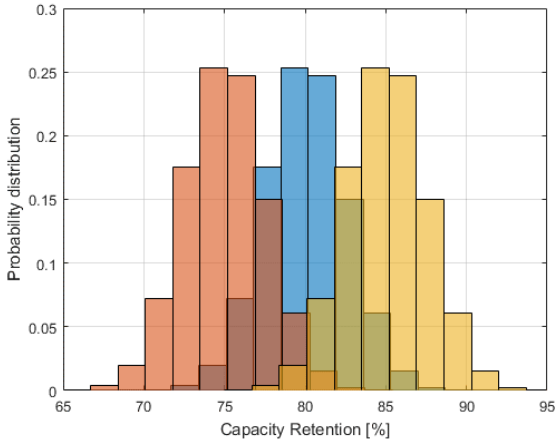
- Acceptance with higher number of samples:
  - Bimodal distribution
  - Ratio method



Increased dispersion of data (higher σ) or lost of accuracy
socread shifted above or below the mean value by 5%



- Increased dispersion leads to acceptance with higher number of samples



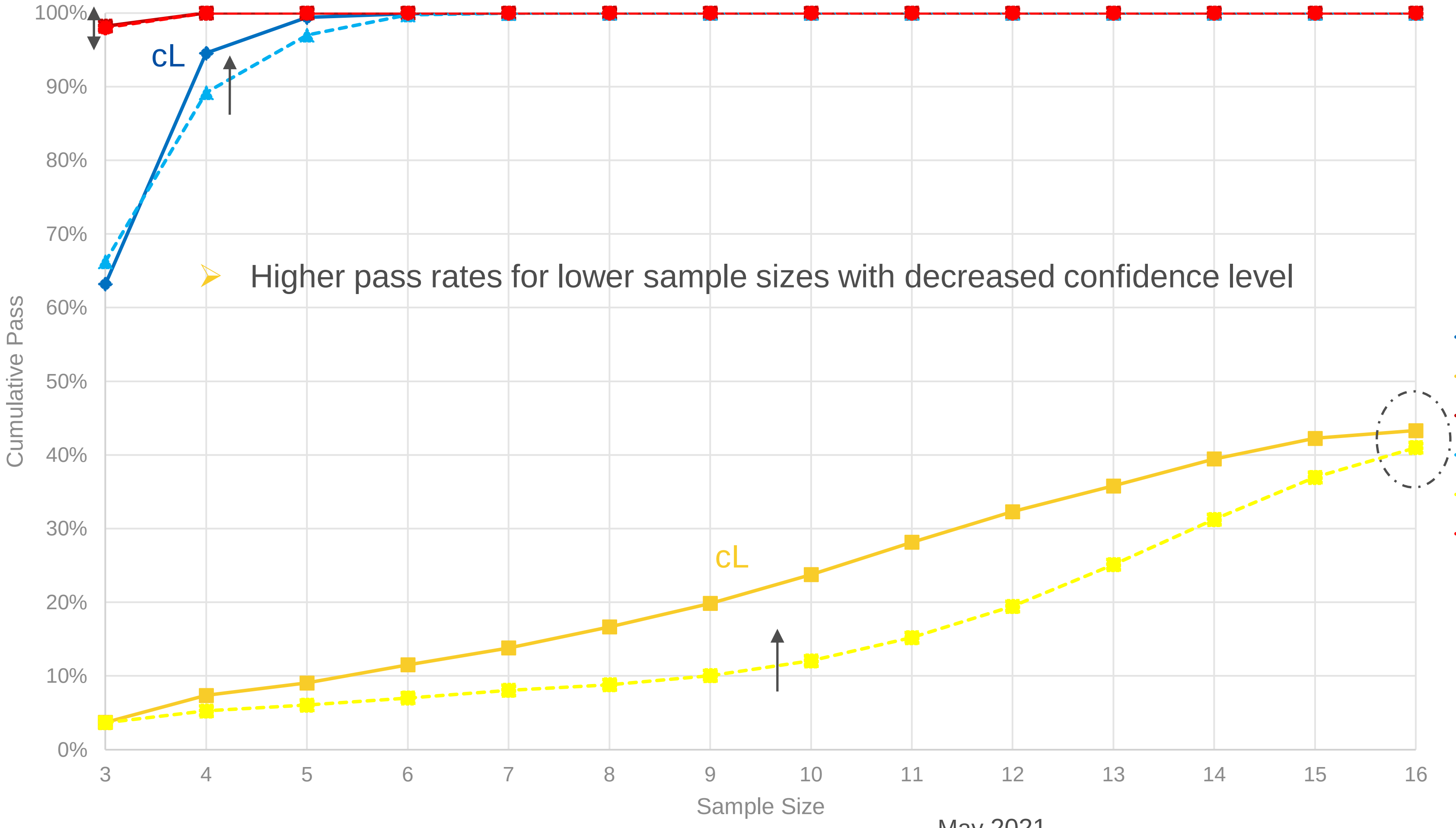
- Possibility to read data as data at 5y and 8y

European Commission

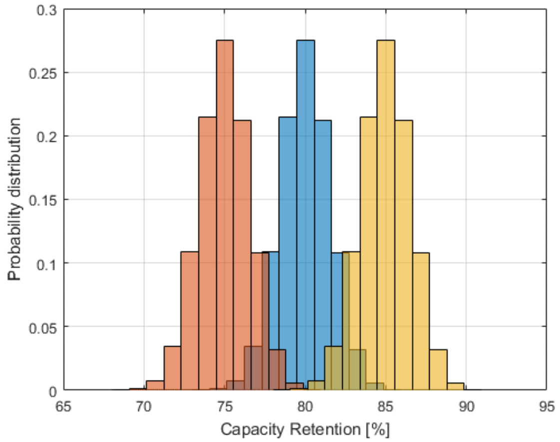
Standard cL and modified cL

soc_{read} shifted above or below the mean value by 5%

Delayed passes   Option B **Difference A=5%** σ=1.56 - Influence Confidence Level

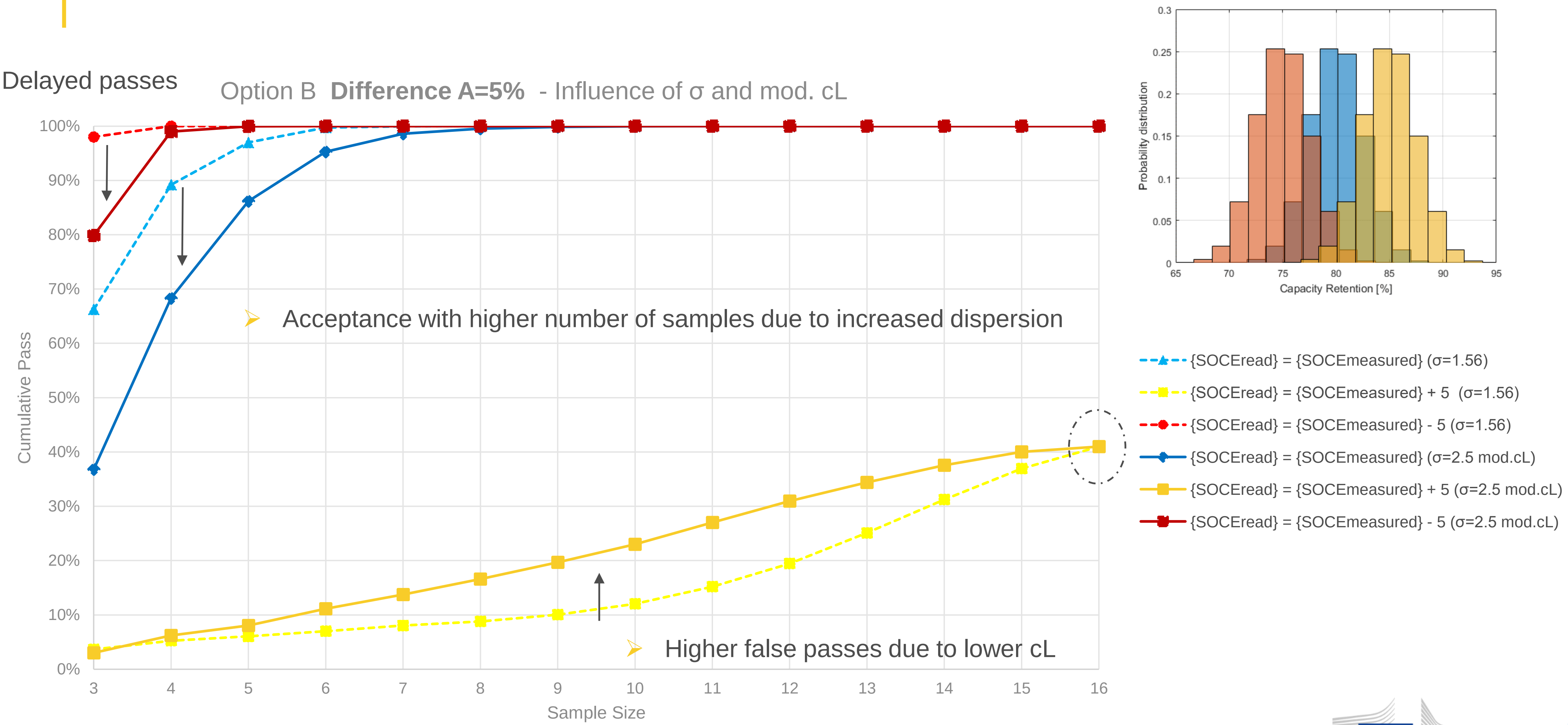


- Higher pass rates for lower sample sizes with decreased confidence level



Combining modified cL and increased σ

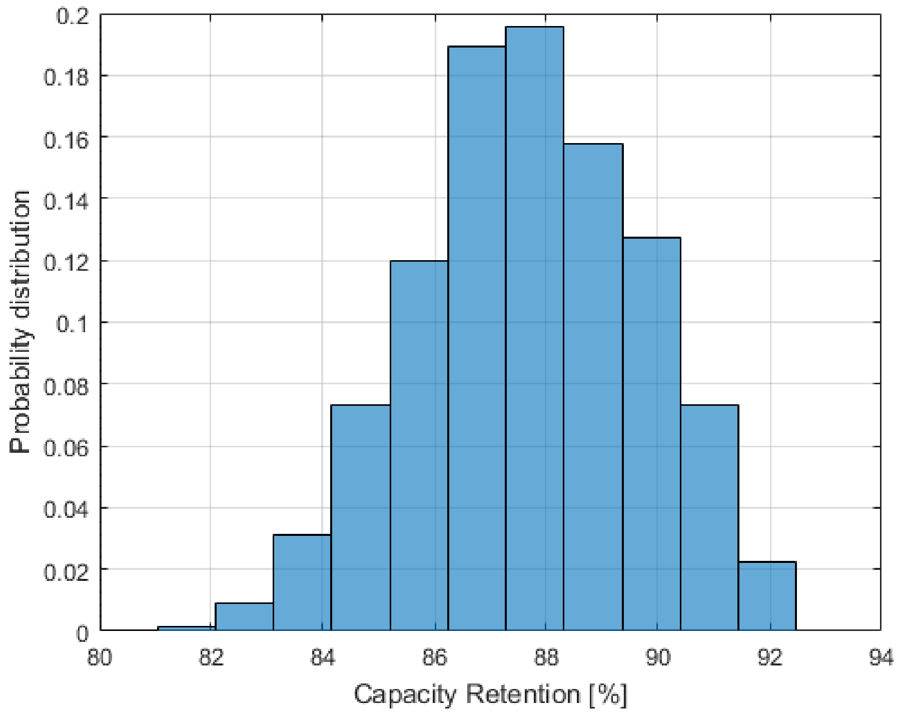
soc_{read} shifted above or below the mean value by 5%



Testing statistics with different distribution shape

- JRC TEMA simulated capacity retention data at 5y and 8y (ref. EVE-41-03e)

5y aged BEV1 vehicles – strategy 1 and 2

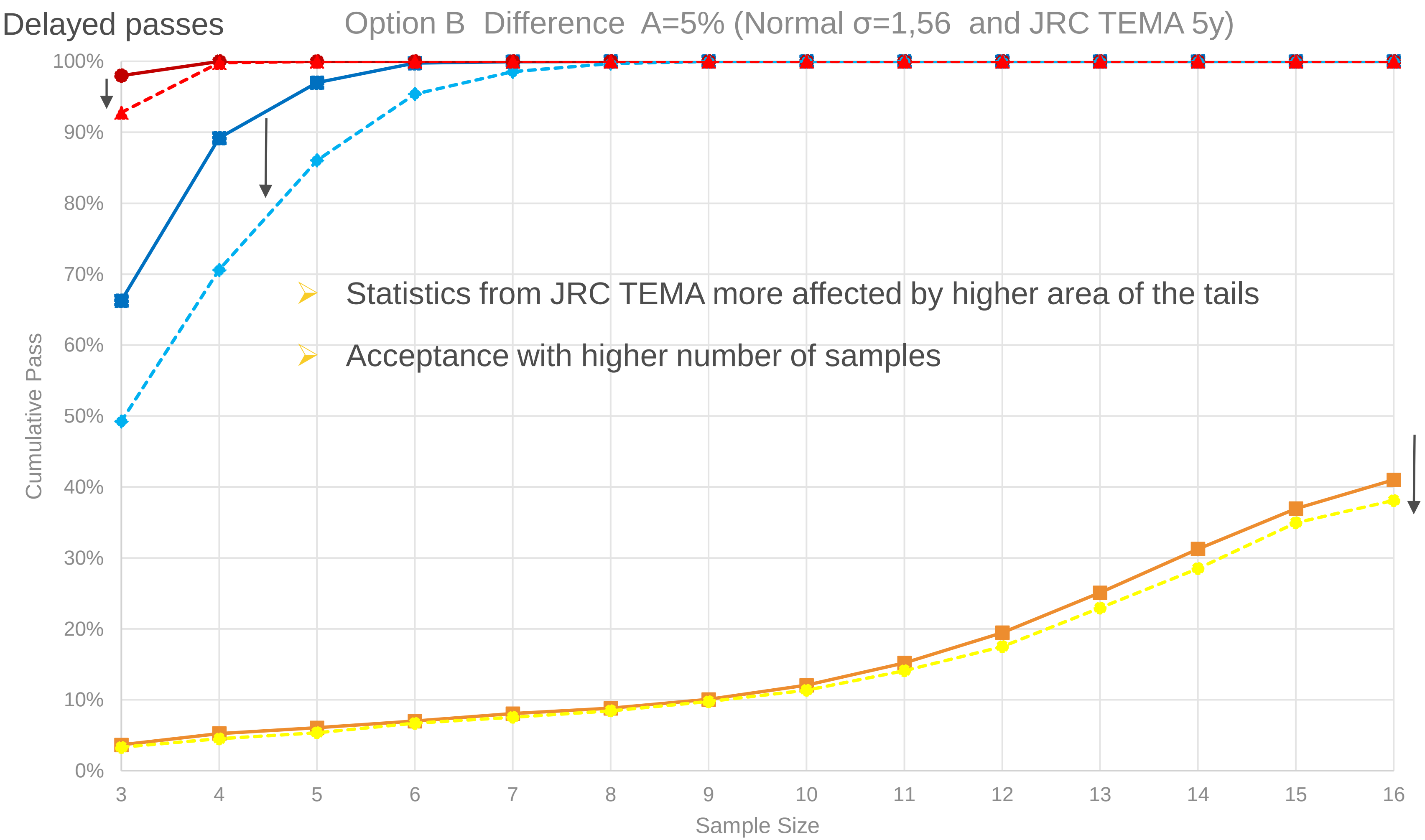


min	1st Qu	median	mean	3rd Qu	max	sd
80.168	86.319	87.675	87.694	89.155	92.437	2.002

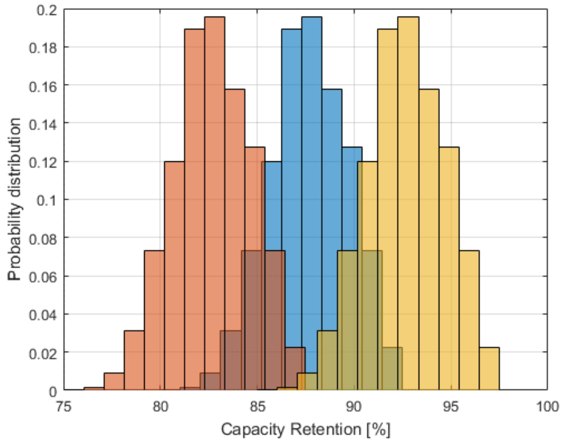
European Commission

Normal vs JRC TEMA

soc_{read} shifted above or below the mean value by 5%



- Statistics from JRC TEMA more affected by higher area of the tails
- Acceptance with higher number of samples



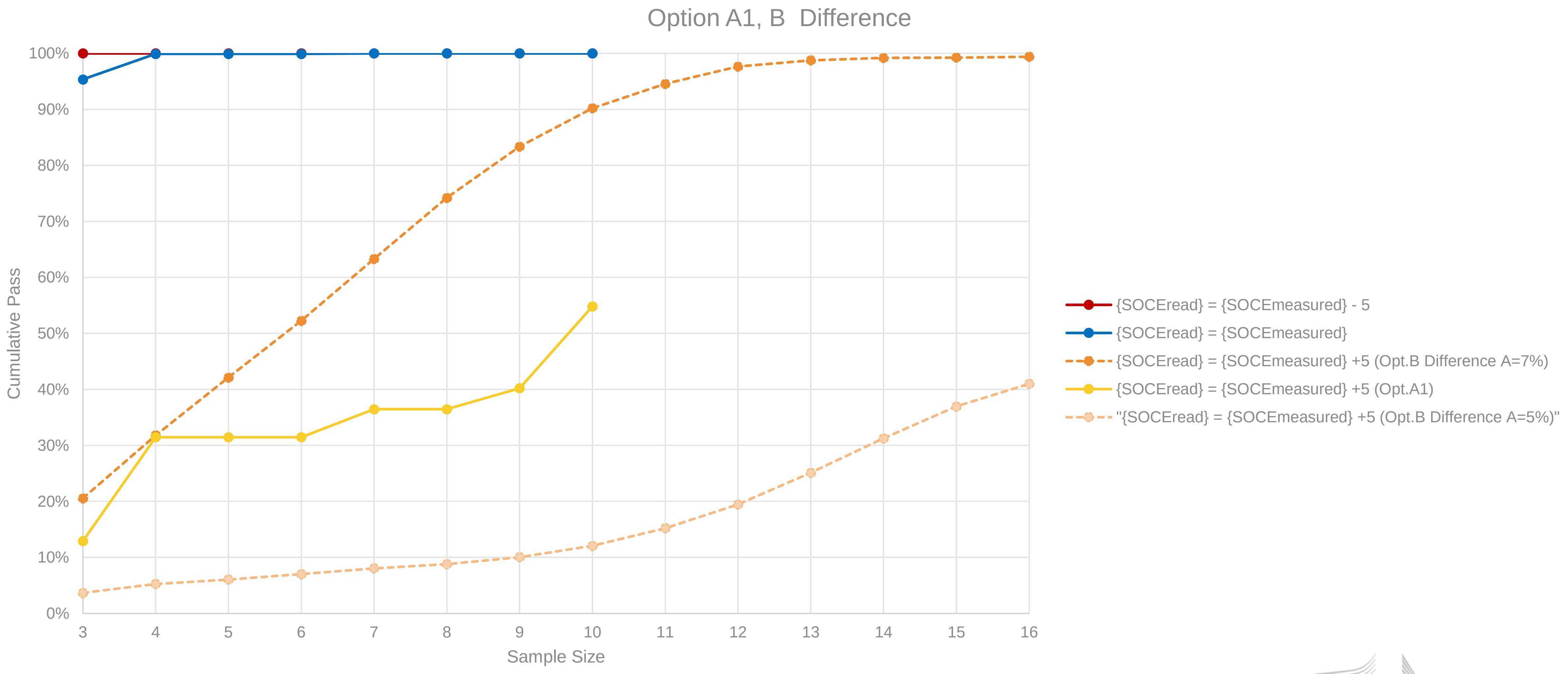
Thank you

Q&A

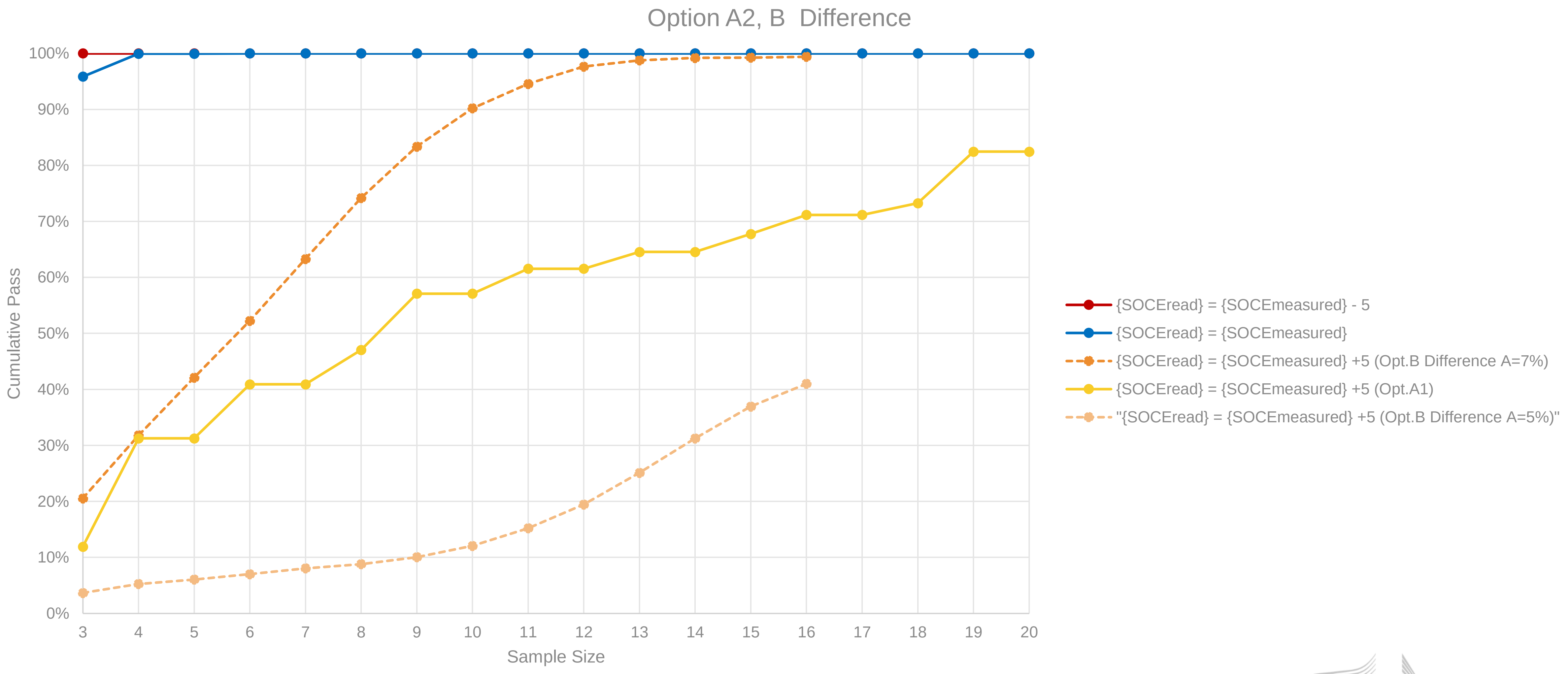
Contacts Info:
EC DG JRC DIR-C Energy, Transport and Climate, Sustainable Transport Unit
gian-luca.patrone@ec.europa.eu elena.paffumi@ec.europa.eu

European Commission

Comparing Options A1and B

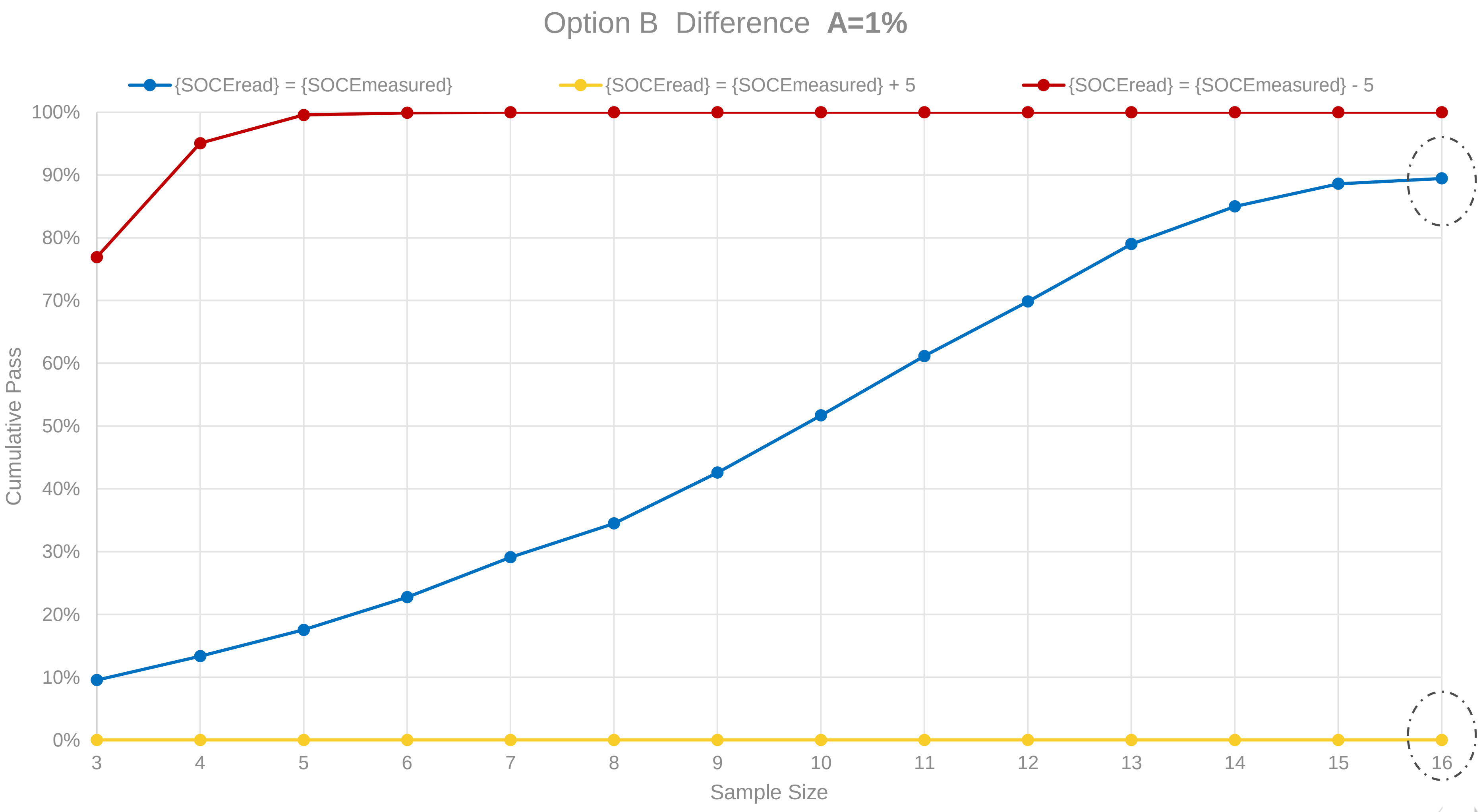


Comparing Options A2 and B



Option B Difference A=1%

soc_{read} shifted above or below the mean value by 5%



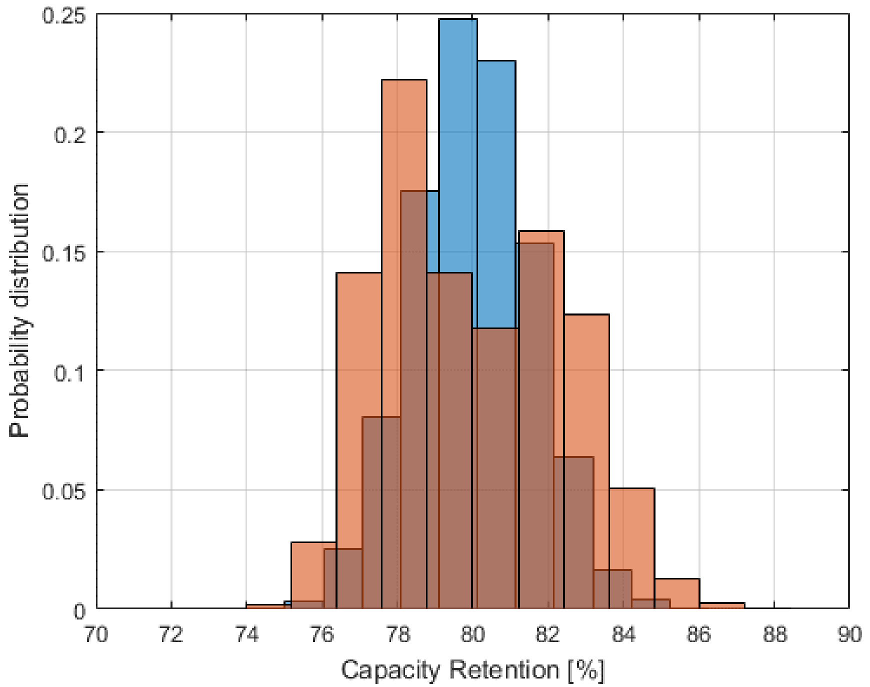
Dataset

- Randomly generated bimodal distribution 10’000 values as combination of two normal distributions

  (μ=78; σ=1 and μ=82; σ=1,5)

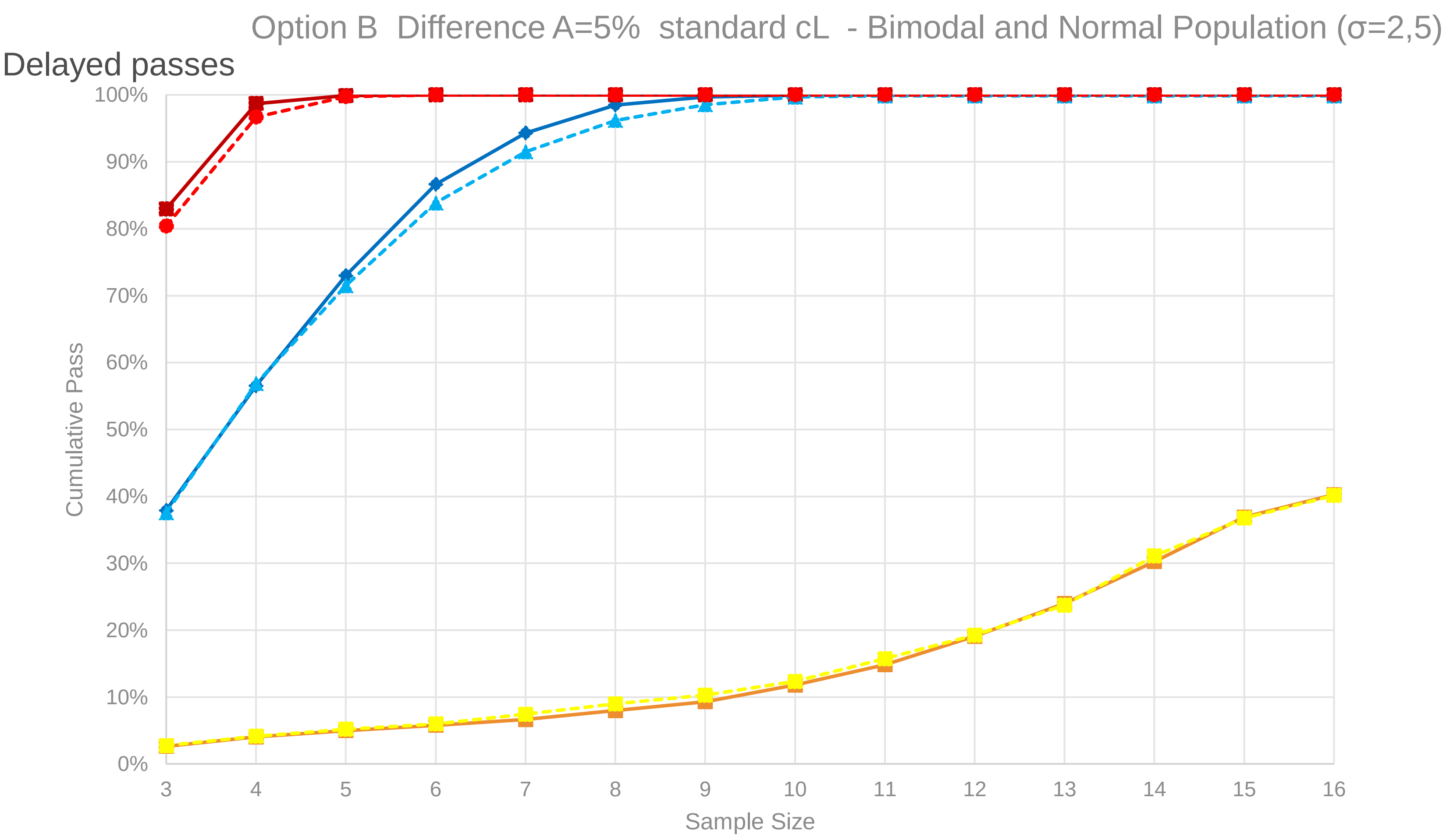
```
Data = [normrnd(78,1,[5000,1]) ; normrnd(82,1.5,[5000,1])];
```

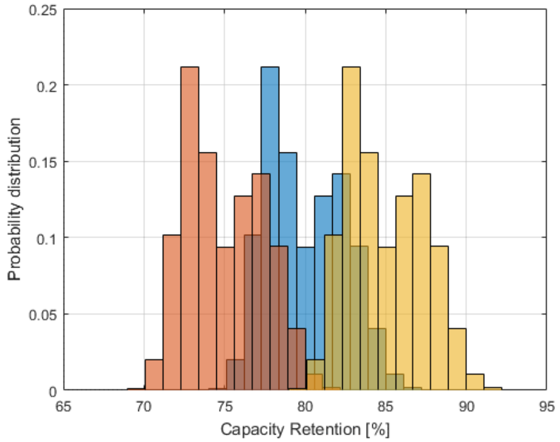
Example of randomly generated bimodal distribution



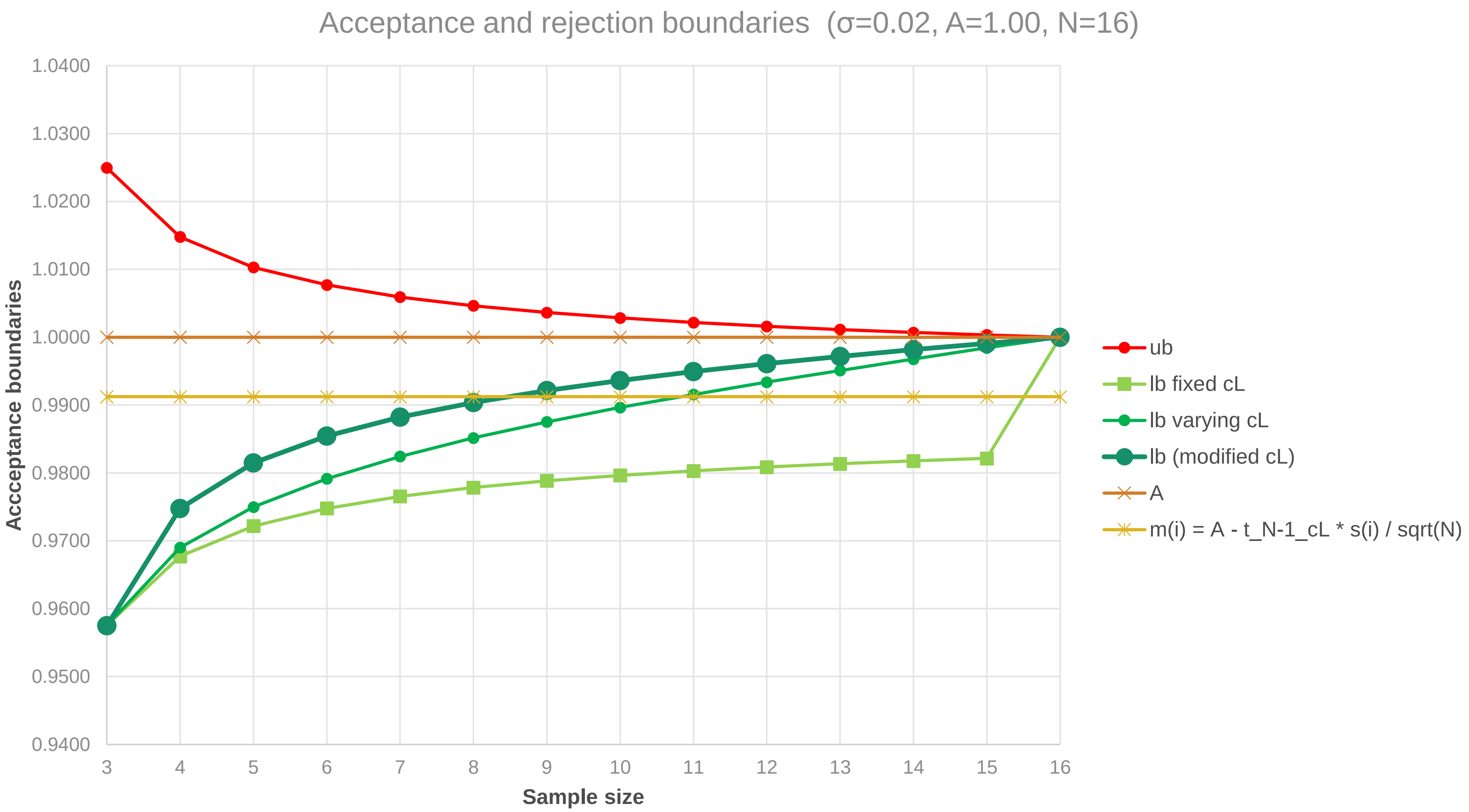
min	1st Qu	median	mean	3rd Qu	max	sd
74.492	78.016	79.599	79.989	81.950	87.295	2.350

Bimodal population same results as more dispersed distribution soc_{read} shifted above or below the mean value by 5%





Changing Confidence Level




```
cL_lo = [0.95 0.945 0.935 0.92 0.9  0.875 0.845 0.81 0.77 0.725 0.675 0.62 0.56 0.5];
cL_lo = [0.950 0.915 0.881 0.846 0.812 0.777 0.742 0.708 0.673 0.638 0.604 0.569 0.535 0.500];
```

growing difference for bigger sample sizes

constant difference

European Commission

Ratio A=1.05 Increased σ
soc_{read} shifted above or below the mean value by 5%