PHAROS
THE GREEK AI FACTORY

Scalability results of finetuning: Performance, Efficiency, Convergence and Generalization

Course 3 "Introduction to Large Language Models at Scale"

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Model training experiments

We conducted a series of **training experiments** to *investigate* the impact of hyperparameter choices and computational scaling on the **performance** of large language models (LLMs). Specifically, we trained the meta-llama-3.2-1B and meta-llama-3.2-3B models while varying key hyperparameters, including

- batch size = (4, 8, 16, 32)
- number of training epochs = (10, 30, 50)
- number of GPUs = (1, 2, 3, 4)
- learning rate = 5e-6
- weight decay = 0.01
- warmup ratio = 0.1
- gradient accumulation = 4 steps
- maximum sequence length = 256 tokens

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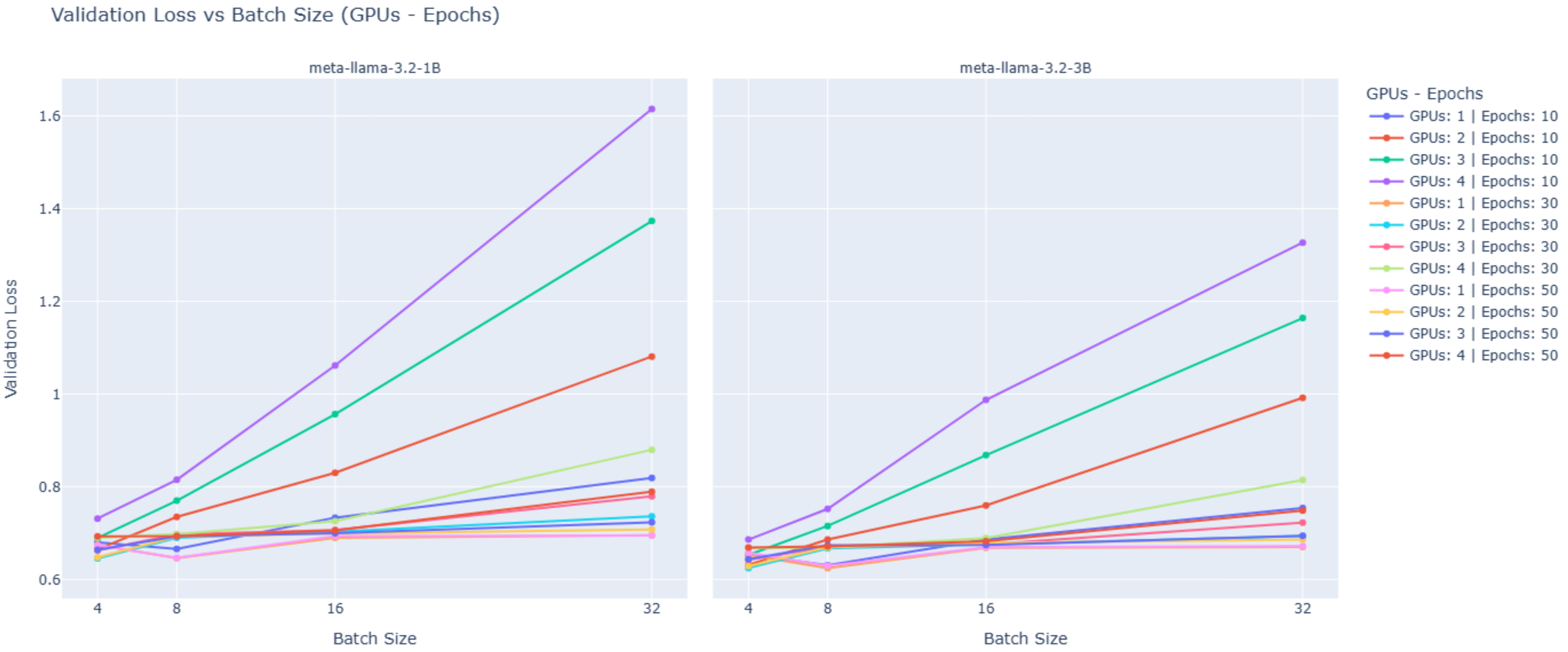
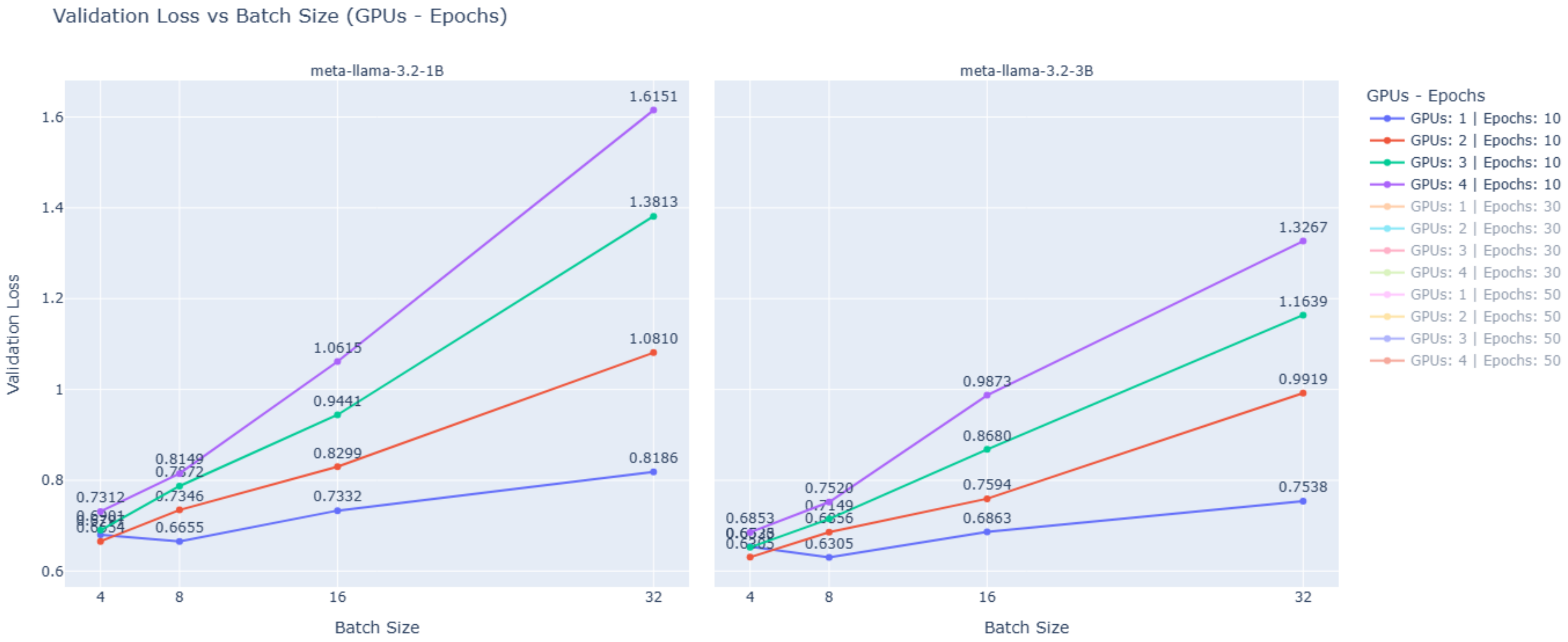
Performance



Performance 10 epochs



Performance 30 epochs

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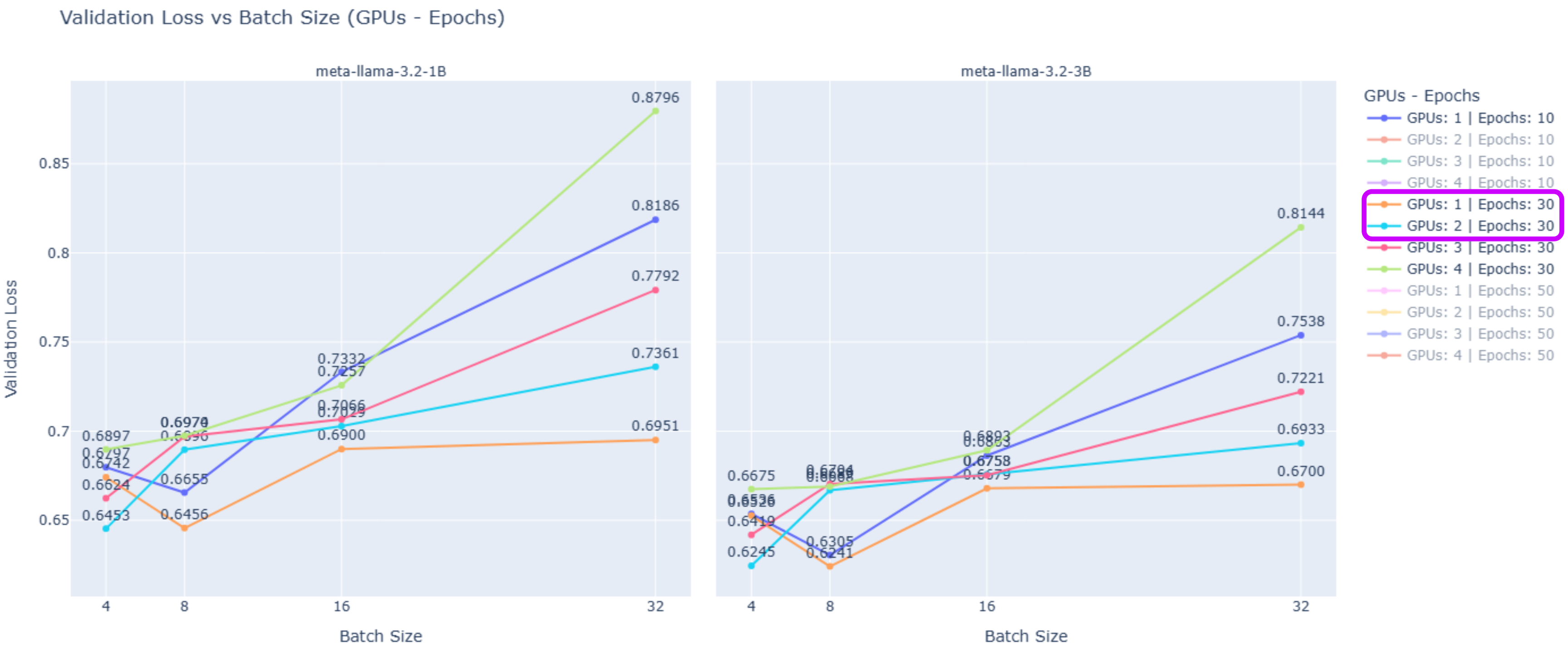
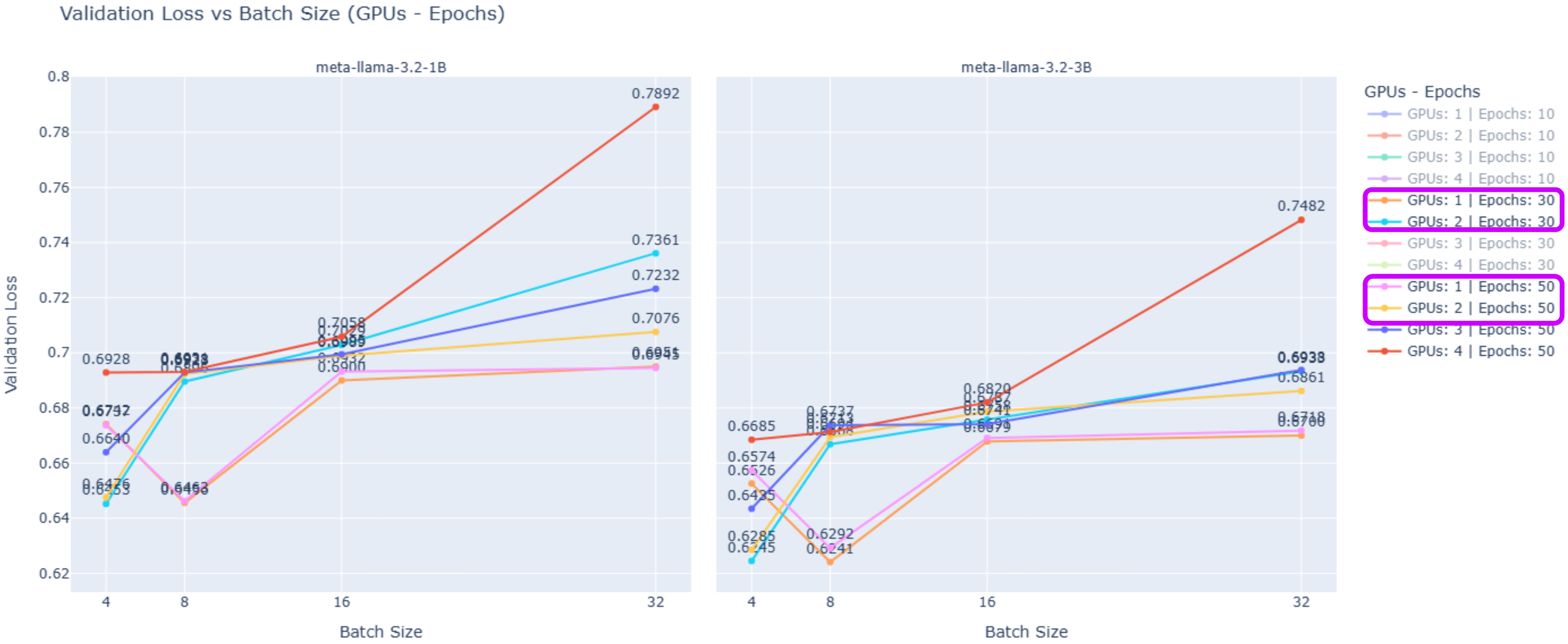


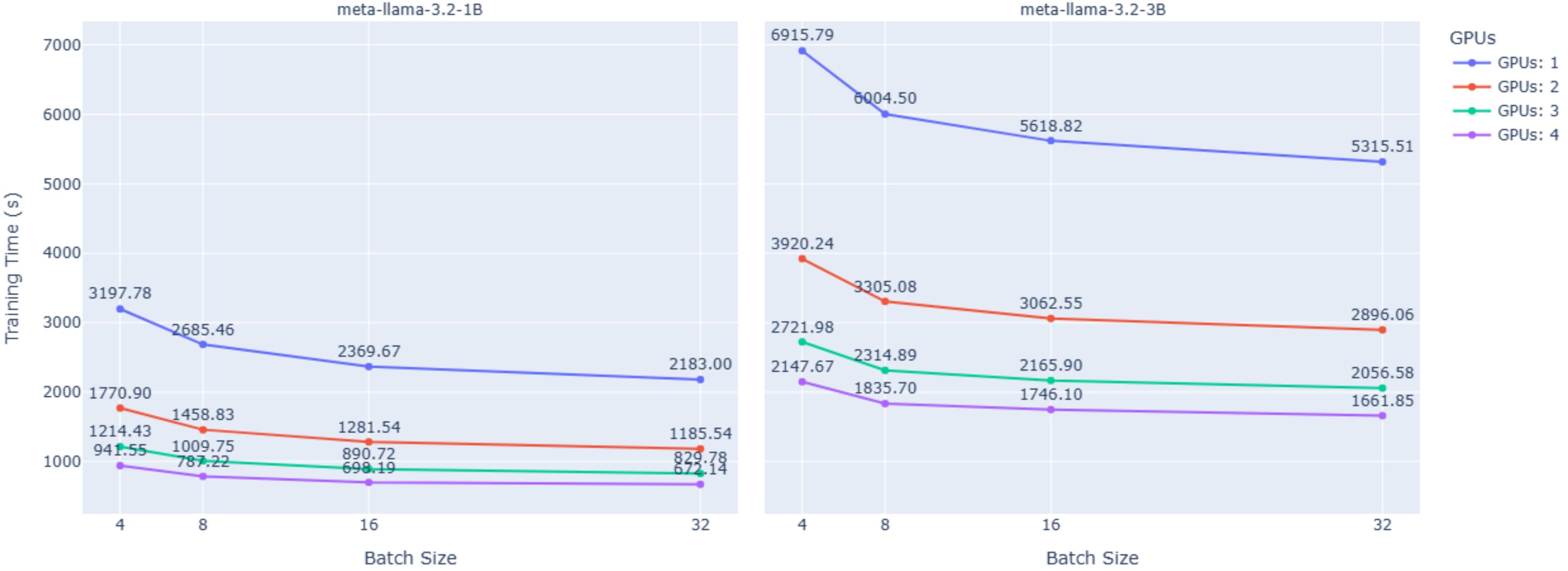
Performance 50 epochs



Validation Loss vs Batch Size (GPUs - Epochs)

Performance

Training Time vs Batch Size per Model/GPUs - 30 Epochs



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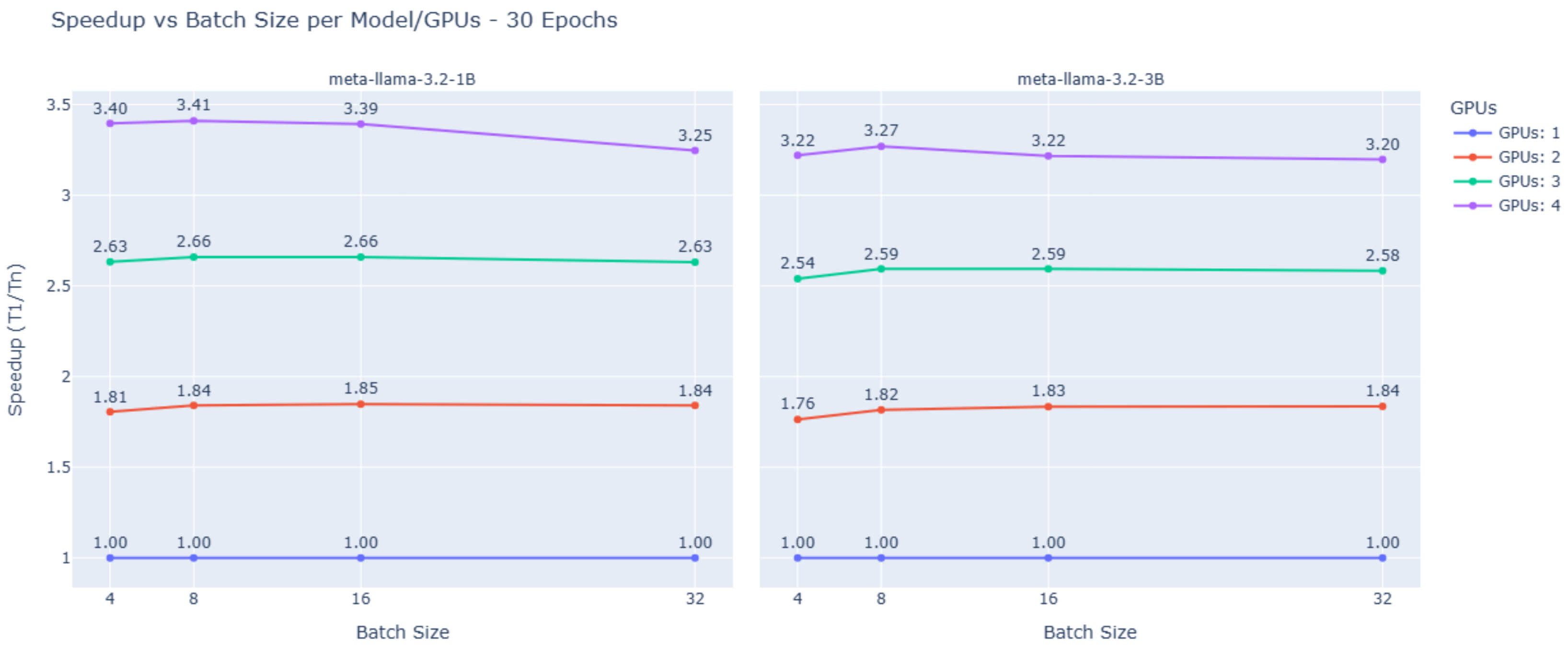
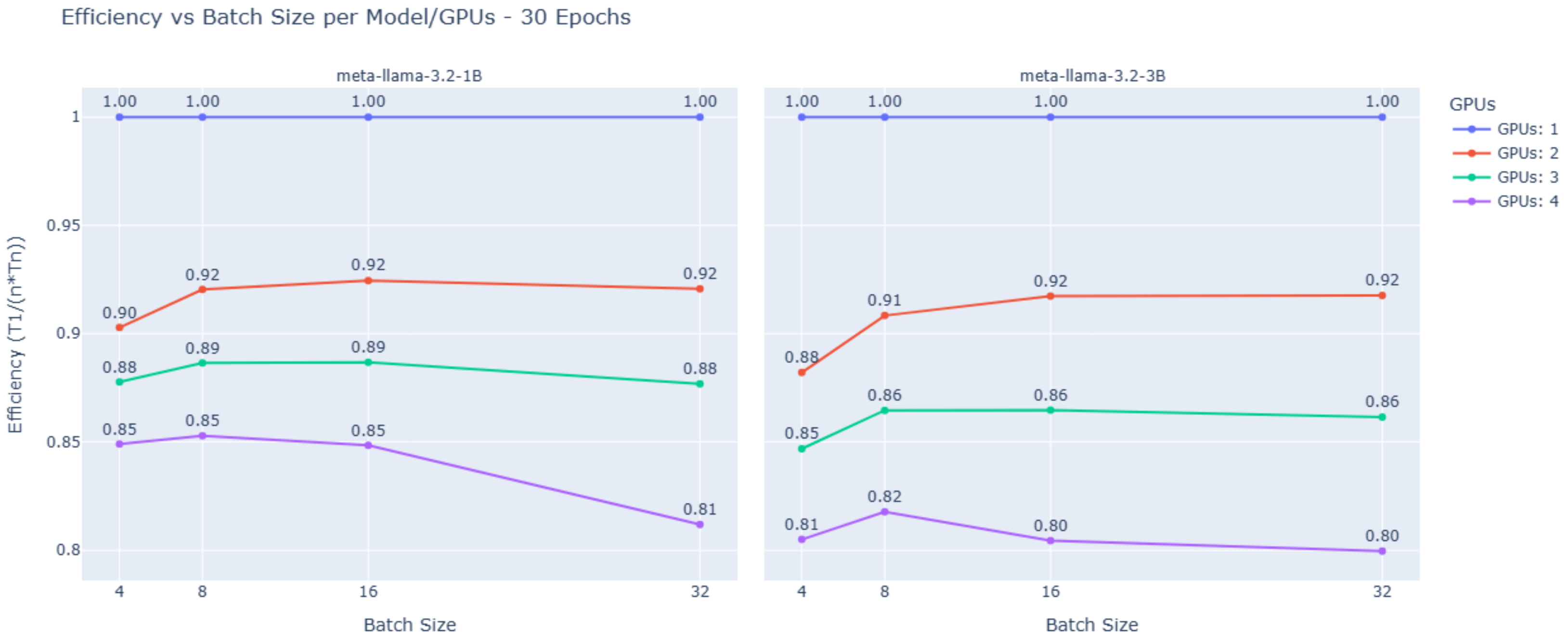

Speedup vs Batch Size per Model/GPUs - 30 Epochs
meta-llama-3.2-1B
meta-llama-3.2-3B
Speedup (T1/Tn)
3.5
3
2.5
2
1.5
1
3.40
3.41
3.39
3.25
2.63
2.66
2.66
2.63
1.81
1.84
1.85
1.84
1.00
1.00
1.00
1.00
4
8
16
32
Batch Size
3.22
3.27
3.22
3.20
2.54
2.59
2.59
2.58
1.76
1.82
1.83
1.84
1.00
1.00
1.00
1.00
4
8
16
32
Batch Size
GPUs
GPUs: 1
GPUs: 2
GPUs: 3
GPUs: 4

Efficiency



Efficiency vs Batch Size per Model/GPUs - 30 Epochs
meta-llama-3.2-1B
meta-llama-3.2-3B
Efficiency (T1/(n*Tn))
1
0.95
0.9
0.85
0.8
Batch Size
4
8
16
32
GPUs
GPUs: 1
GPUs: 2
GPUs: 3
GPUs: 4
1.00
0.90
0.92
0.92
0.92
0.88
0.89
0.89
0.88
0.85
0.85
0.85
0.81
1.00
0.88
0.91
0.92
0.92
0.85
0.86
0.86
0.86
0.81
0.82
0.80
0.80

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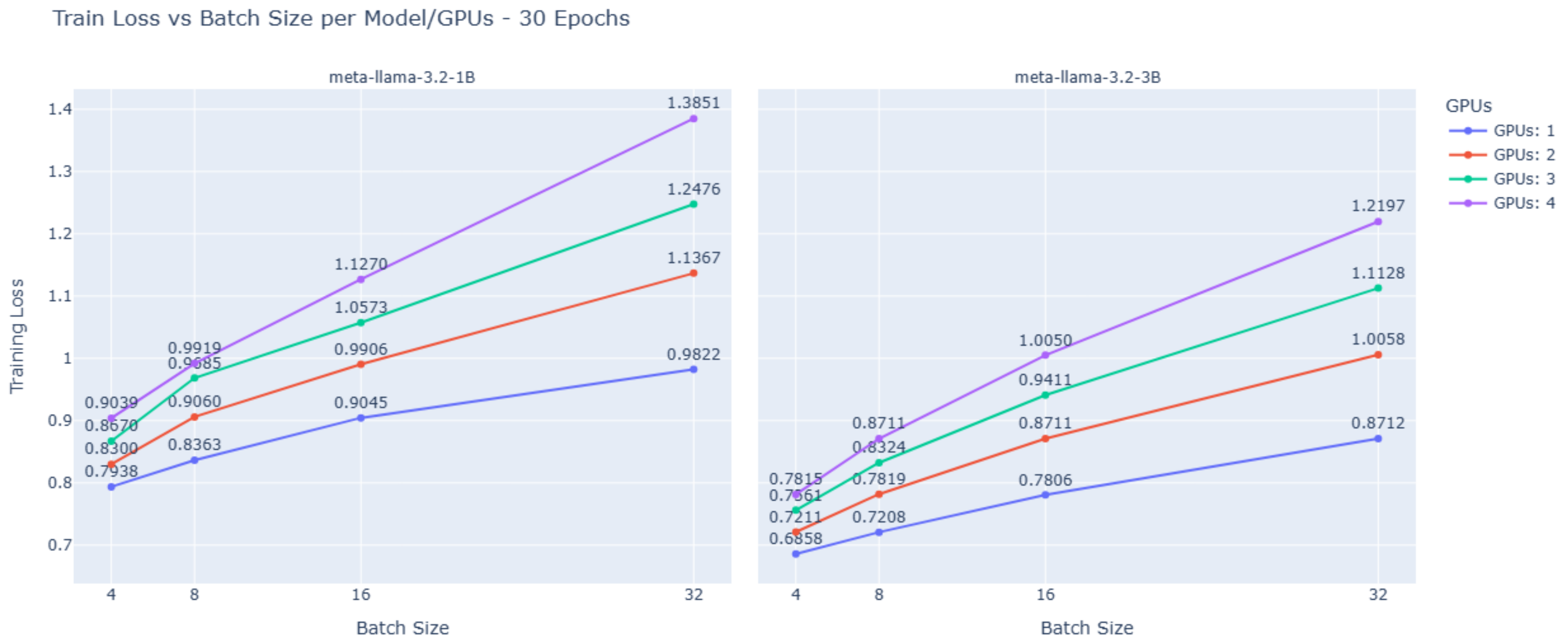
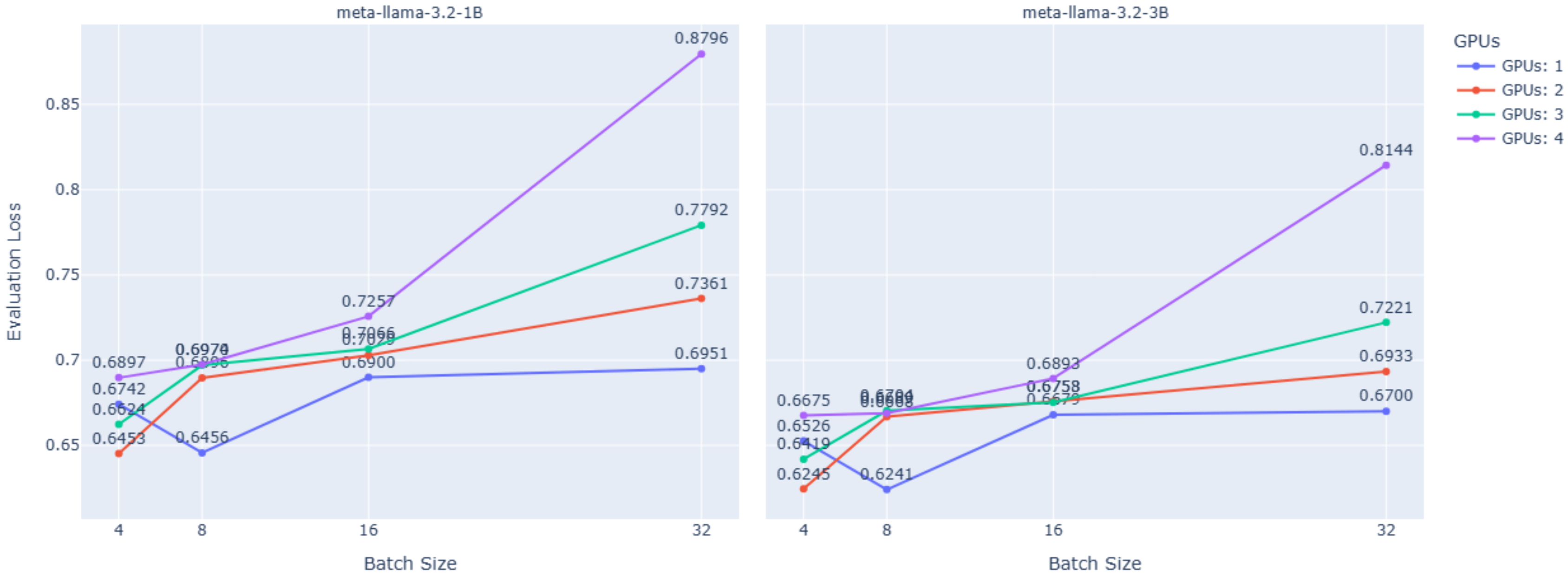


Train Loss vs Batch Size per Model/GPUs - 30 Epochs

Convergence

Eval Loss vs Batch Size per Model/GPUs - 30 Epochs



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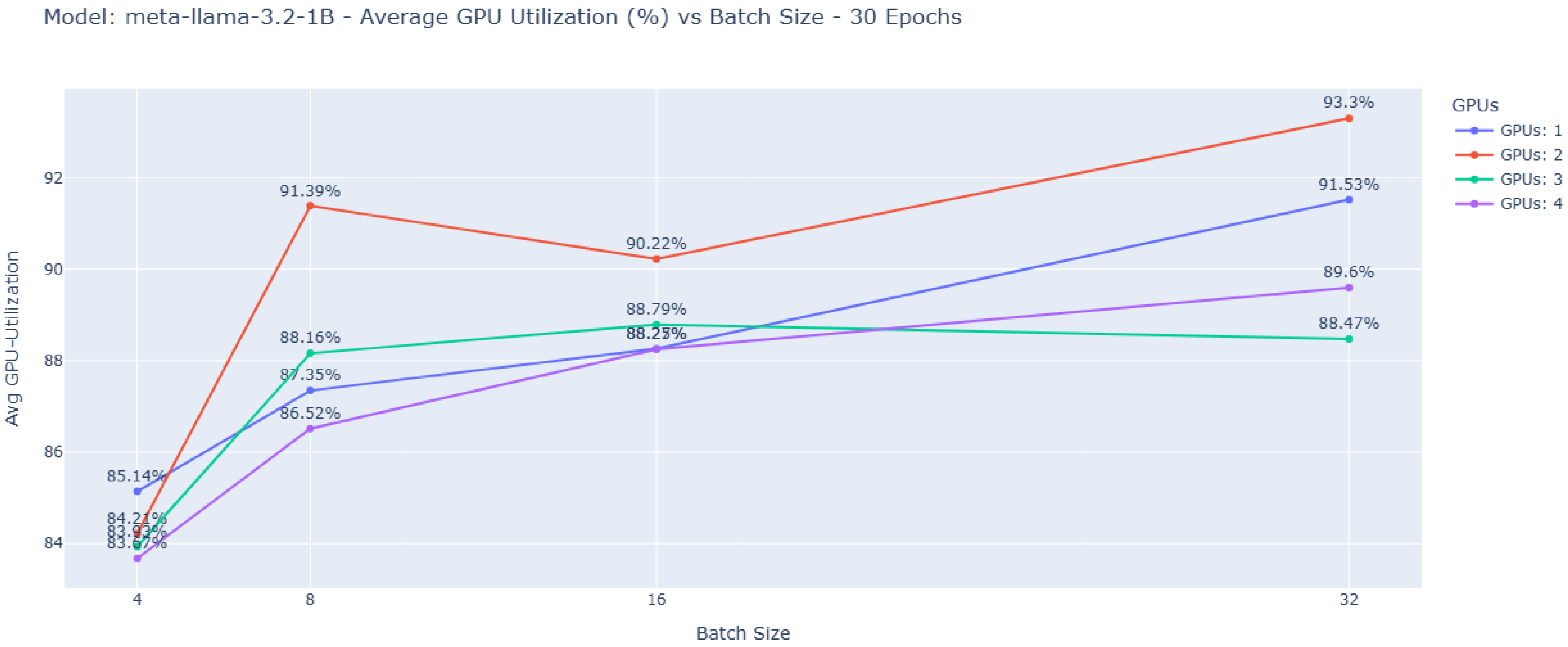
GPU Utilization – nvidia-smi 1B



GPU Utilization – nvidia-smi 3B

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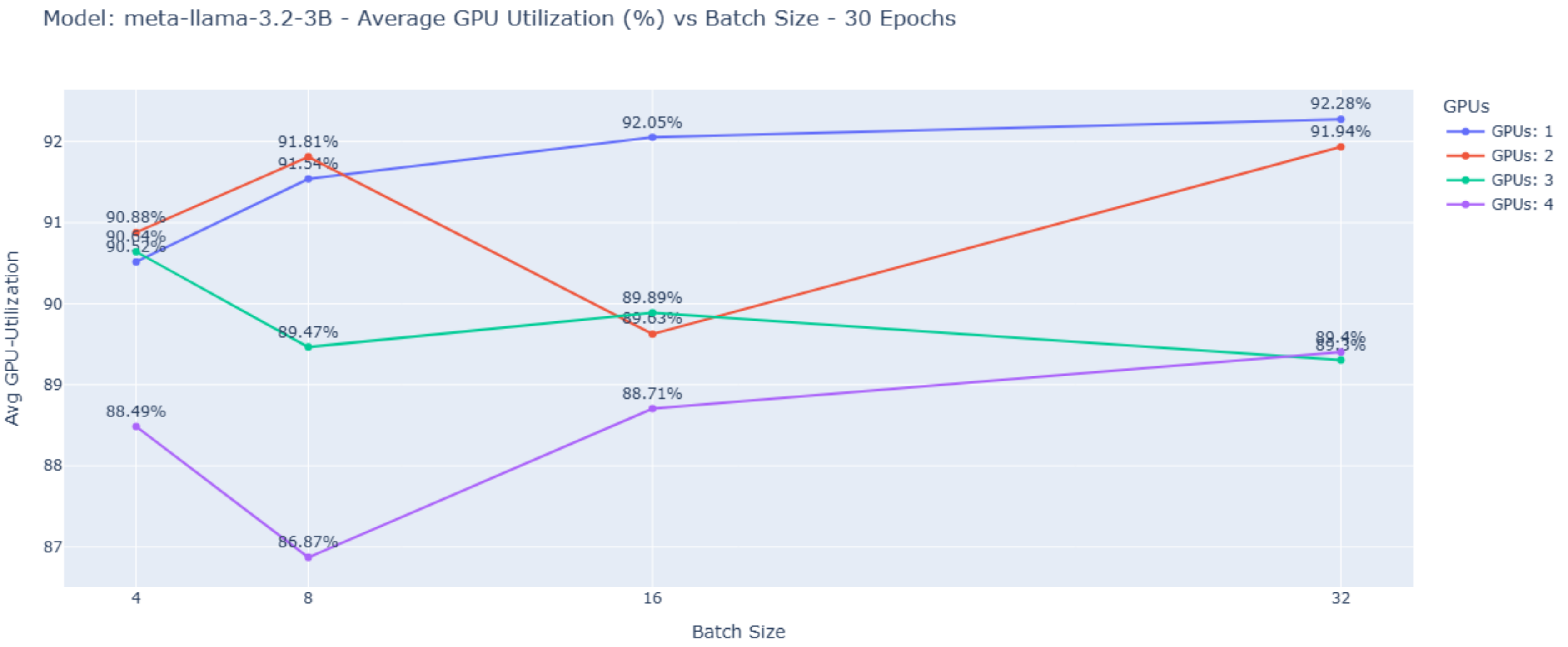
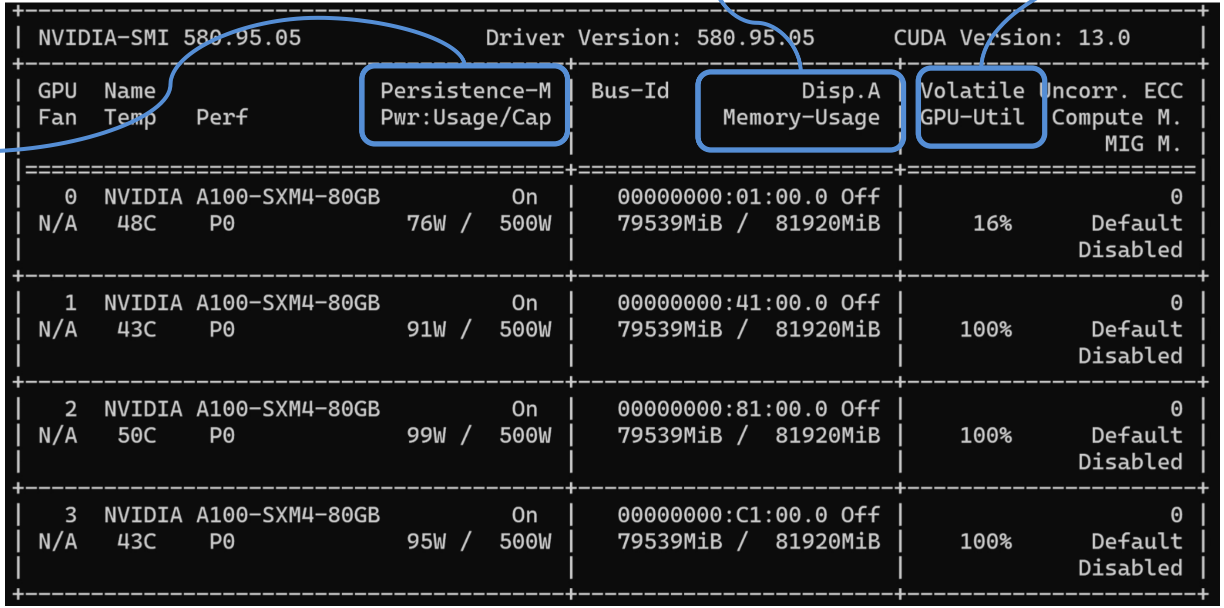


nvidia-smi

The amount of memory currently in use versus the total available memory (in MiB).

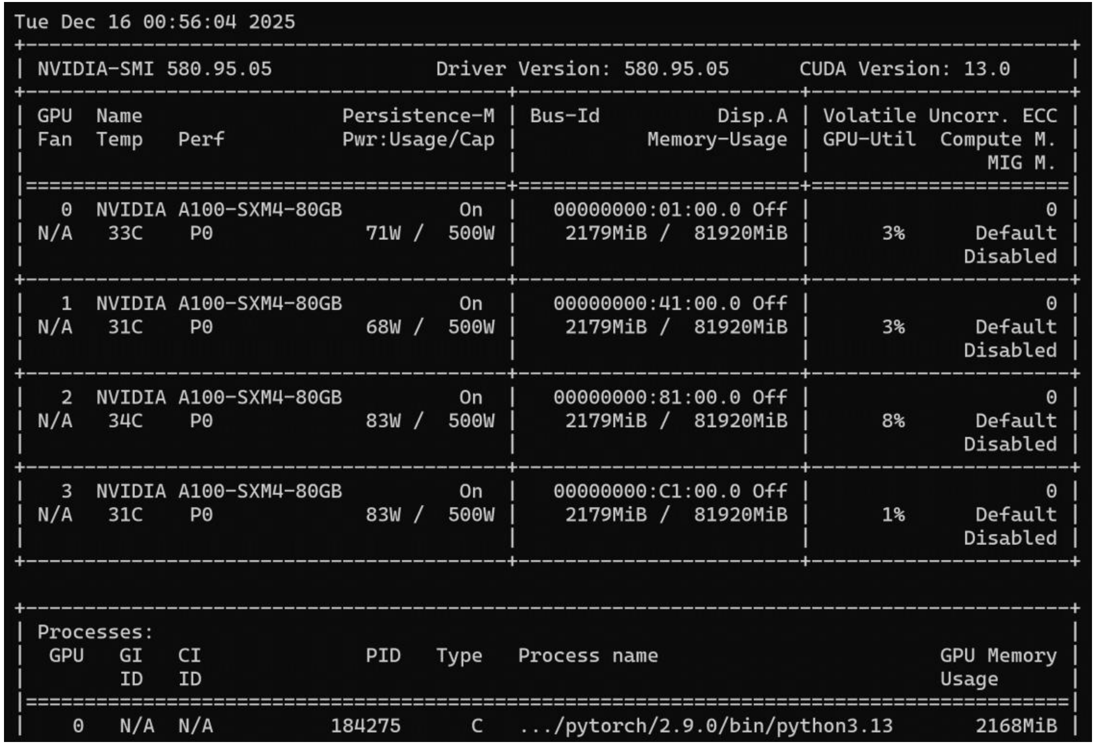
The current power draw versus the maximum power limit (in Watts).



```
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 580.95.05              Driver Version: 580.95.05      CUDA Version: 13.0     |
+-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  NVIDIA A100-SXM4-80GB          On  |   00000000:01:00.0 Off |                    0 |
| N/A   48C    P0             76W /  500W |  79539MiB /  81920MiB  |     16%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   1  NVIDIA A100-SXM4-80GB          On  |   00000000:41:00.0 Off |                    0 |
| N/A   43C    P0             91W /  500W |  79539MiB /  81920MiB  |    100%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   2  NVIDIA A100-SXM4-80GB          On  |   00000000:81:00.0 Off |                    0 |
| N/A   50C    P0             99W /  500W |  79539MiB /  81920MiB  |    100%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   3  NVIDIA A100-SXM4-80GB          On  |   00000000:C1:00.0 Off |                    0 |
| N/A   43C    P0             95W /  500W |  79539MiB /  81920MiB  |    100%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
```

The percentage of the GPU's processing capacity being utilized for computation.

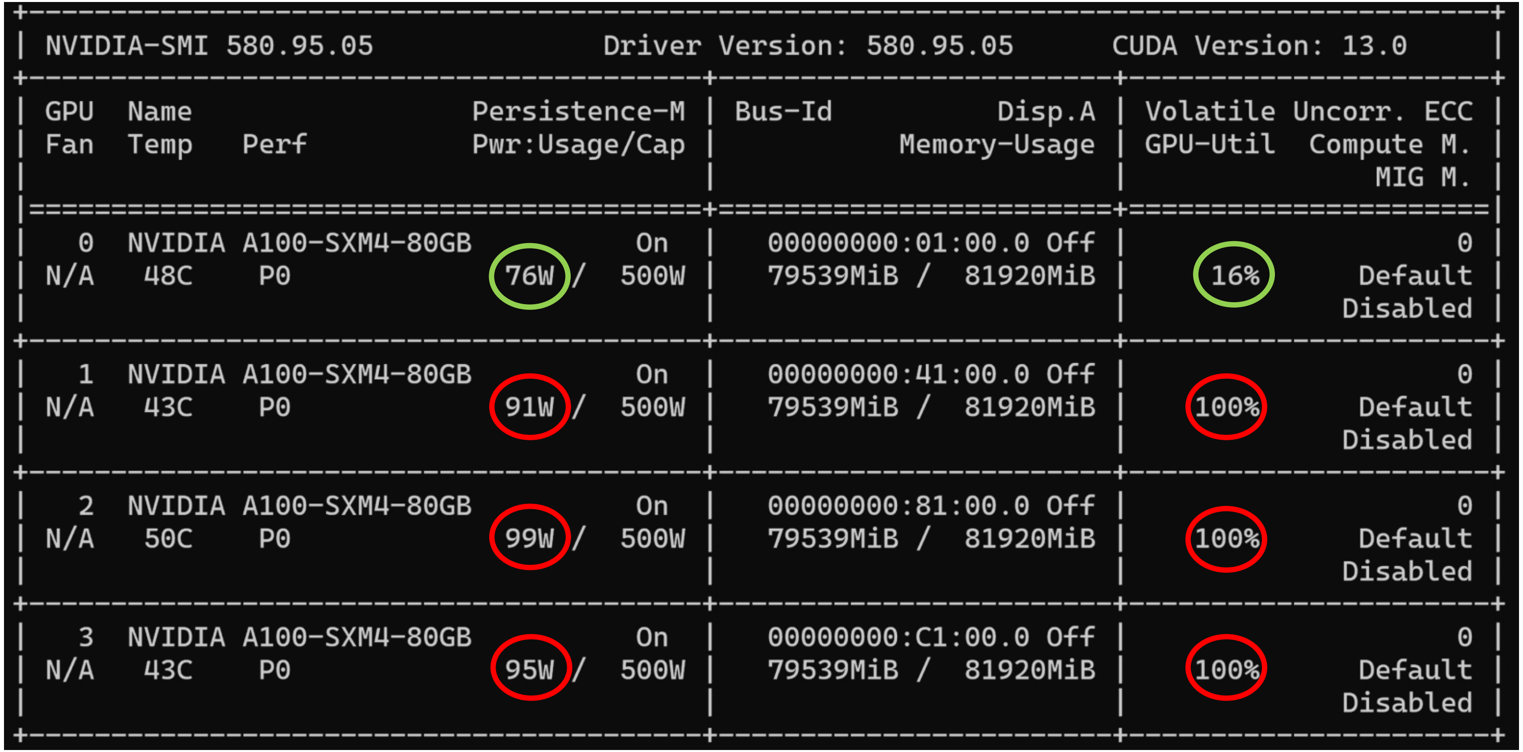
nvidia-smi



```
Tue Dec 16 00:56:04 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 580.95.05              Driver Version: 580.95.05      CUDA Version: 13.0     |
+-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  NVIDIA A100-SXM4-80GB          On  |   00000000:01:00.0 Off |                    0 |
| N/A   33C    P0             71W /  500W |    2179MiB /  81920MiB |      3%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   1  NVIDIA A100-SXM4-80GB          On  |   00000000:41:00.0 Off |                    0 |
| N/A   31C    P0             68W /  500W |    2179MiB /  81920MiB |      3%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   2  NVIDIA A100-SXM4-80GB          On  |   00000000:81:00.0 Off |                    0 |
| N/A   34C    P0             83W /  500W |    2179MiB /  81920MiB |      8%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   3  NVIDIA A100-SXM4-80GB          On  |   00000000:C1:00.0 Off |                    0 |
| N/A   31C    P0             83W /  500W |    2179MiB /  81920MiB |      1%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI              PID   Type   Process name                        GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|    0   N/A  N/A          184275      C   .../pytorch/2.9.0/bin/python3.13      2168MiB |
```

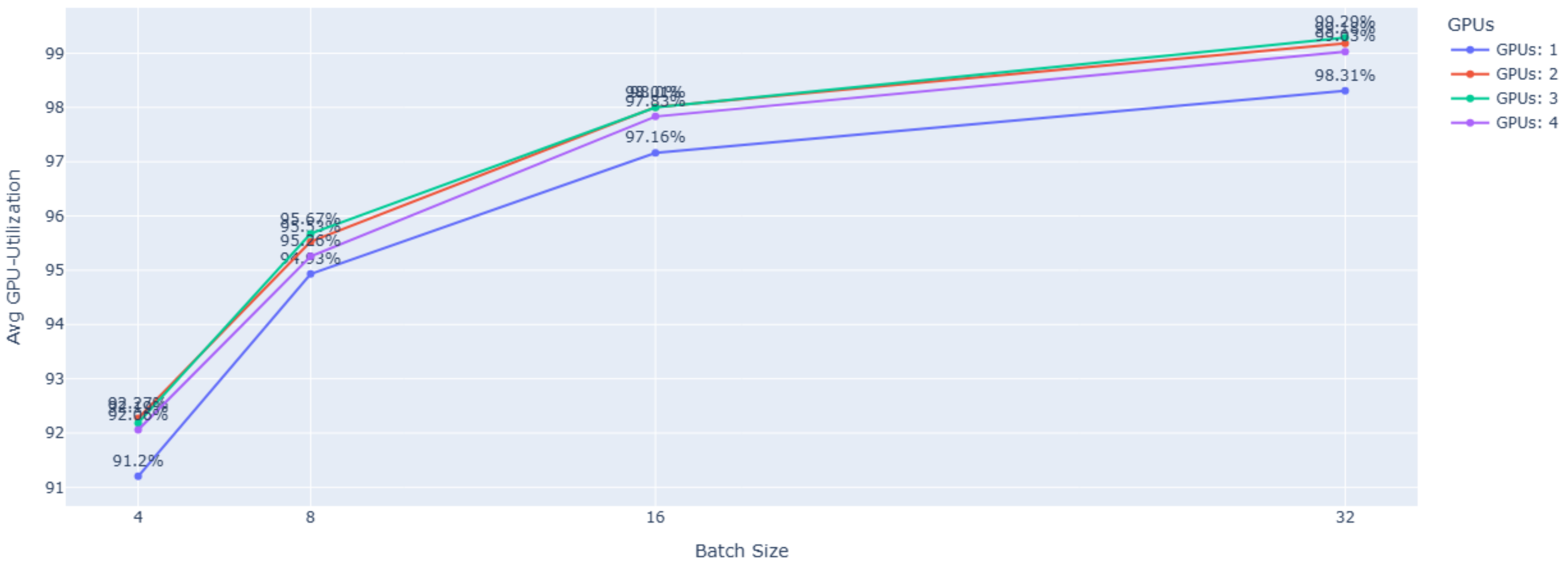
nvidia-smi



```
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 580.95.05              Driver Version: 580.95.05      CUDA Version: 13.0     |
+-----------------------------------------+------------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id          Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |           Memory-Usage | GPU-Util  Compute M. |
|                                         |                        |               MIG M. |
|=========================================+========================+======================|
|   0  NVIDIA A100-SXM4-80GB          On  |   00000000:01:00.0 Off |                    0 |
| N/A   48C    P0             76W /  500W |   79539MiB /  81920MiB |     16%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   1  NVIDIA A100-SXM4-80GB          On  |   00000000:41:00.0 Off |                    0 |
| N/A   43C    P0             91W /  500W |   79539MiB /  81920MiB |    100%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   2  NVIDIA A100-SXM4-80GB          On  |   00000000:81:00.0 Off |                    0 |
| N/A   50C    P0             99W /  500W |   79539MiB /  81920MiB |    100%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
|   3  NVIDIA A100-SXM4-80GB          On  |   00000000:C1:00.0 Off |                    0 |
| N/A   43C    P0             95W /  500W |   79539MiB /  81920MiB |    100%      Default |
|                                         |                        |             Disabled |
+-----------------------------------------+------------------------+----------------------+
```

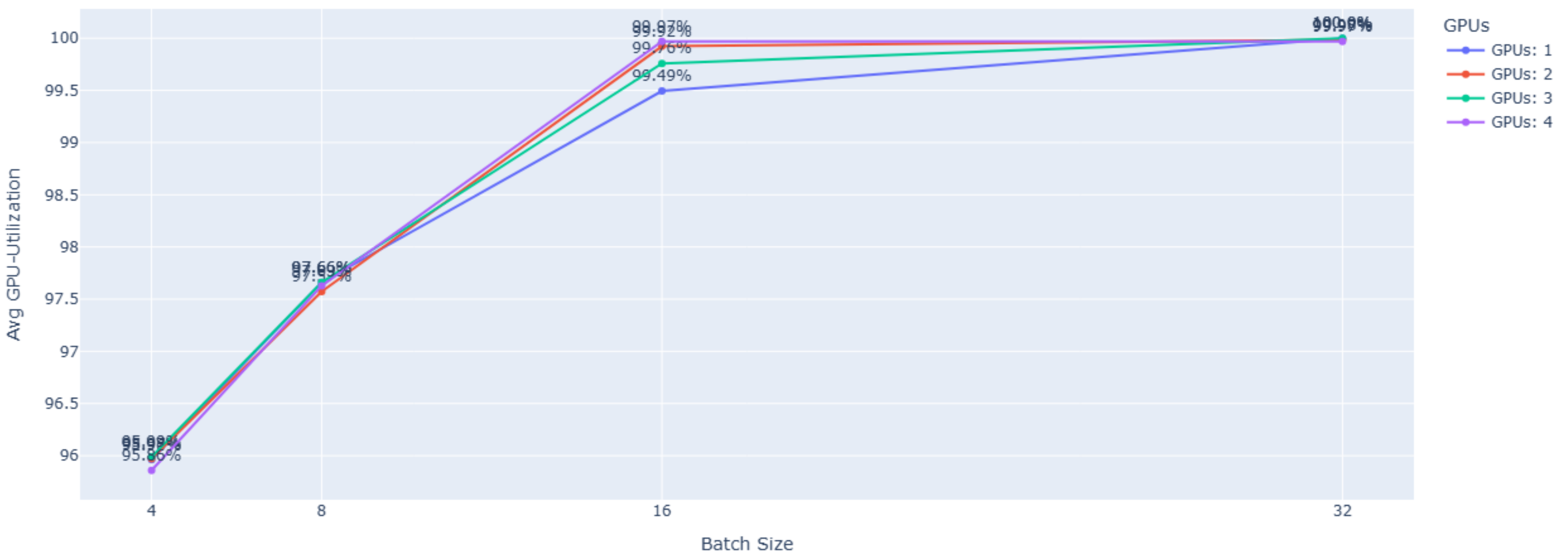
GPU Utilization – pynvml 1B

Model: meta-llama-3.2-1B - Average GPU Utilization (%) vs Batch Size Epochs per Model/GPUs - 30 Epochs



GPU Utilization – pynvml 3B

Model: meta-llama-3.2-3B - Average GPU Utilization (%) vs Batch Size Epochs per Model/GPUs - 30 Epochs



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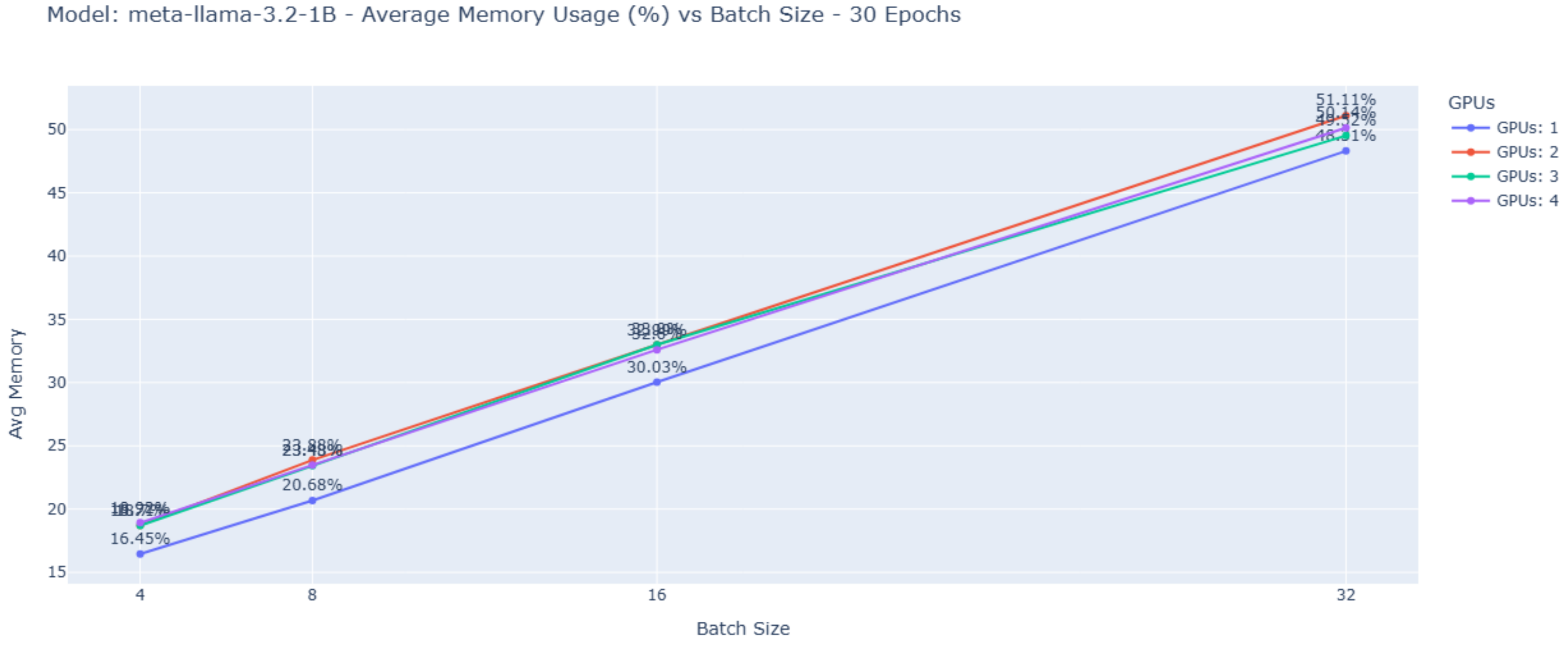
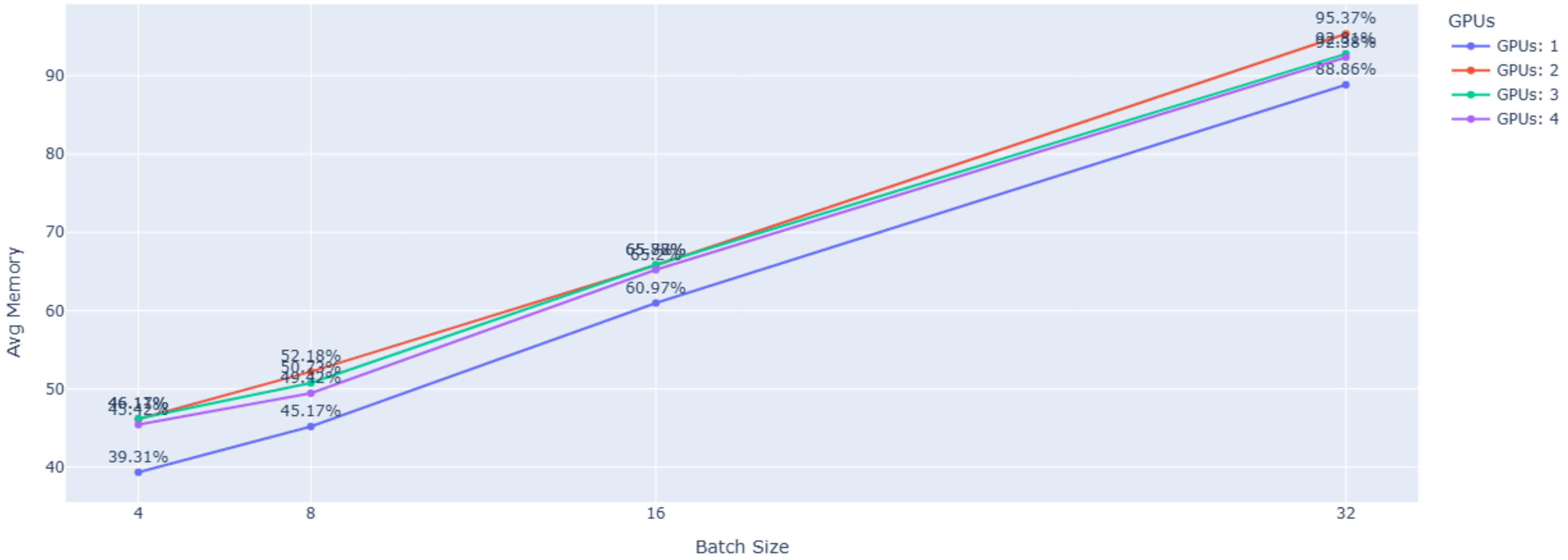


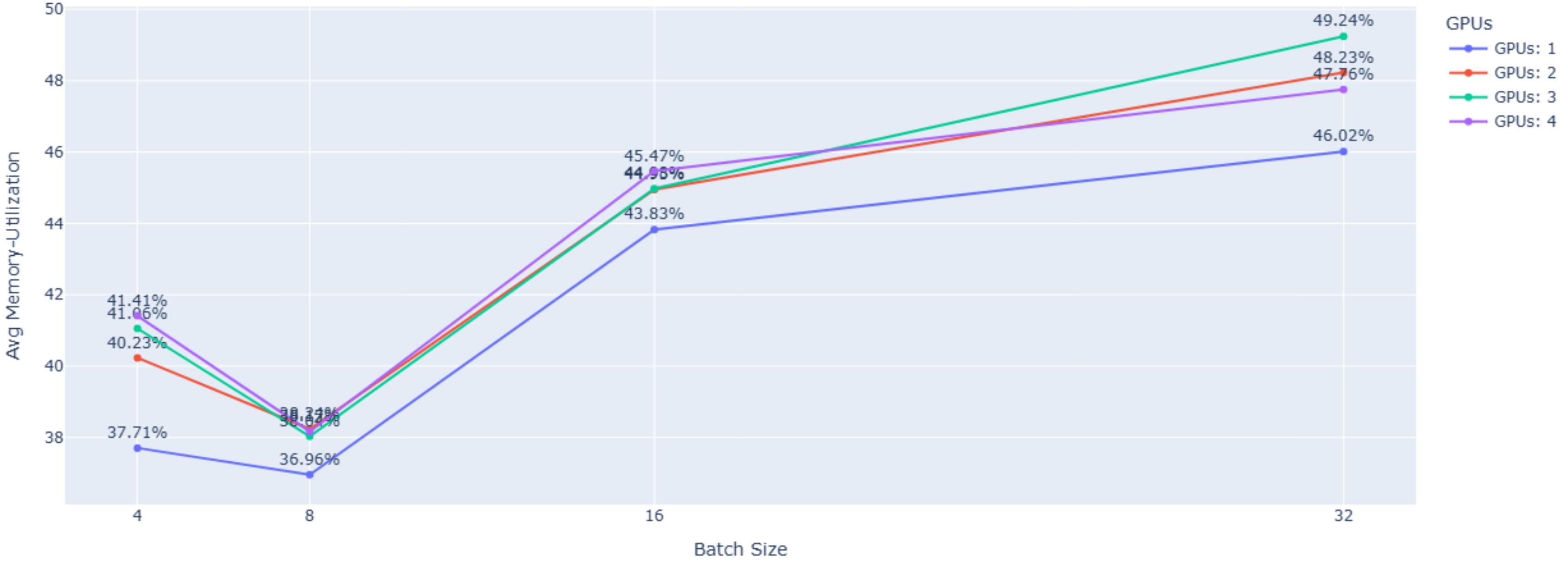
Memory Usage – nvidia-smi 3B

Model: meta-llama-3.2-3B - Average Memory Usage (%) vs Batch Size - 30 Epochs

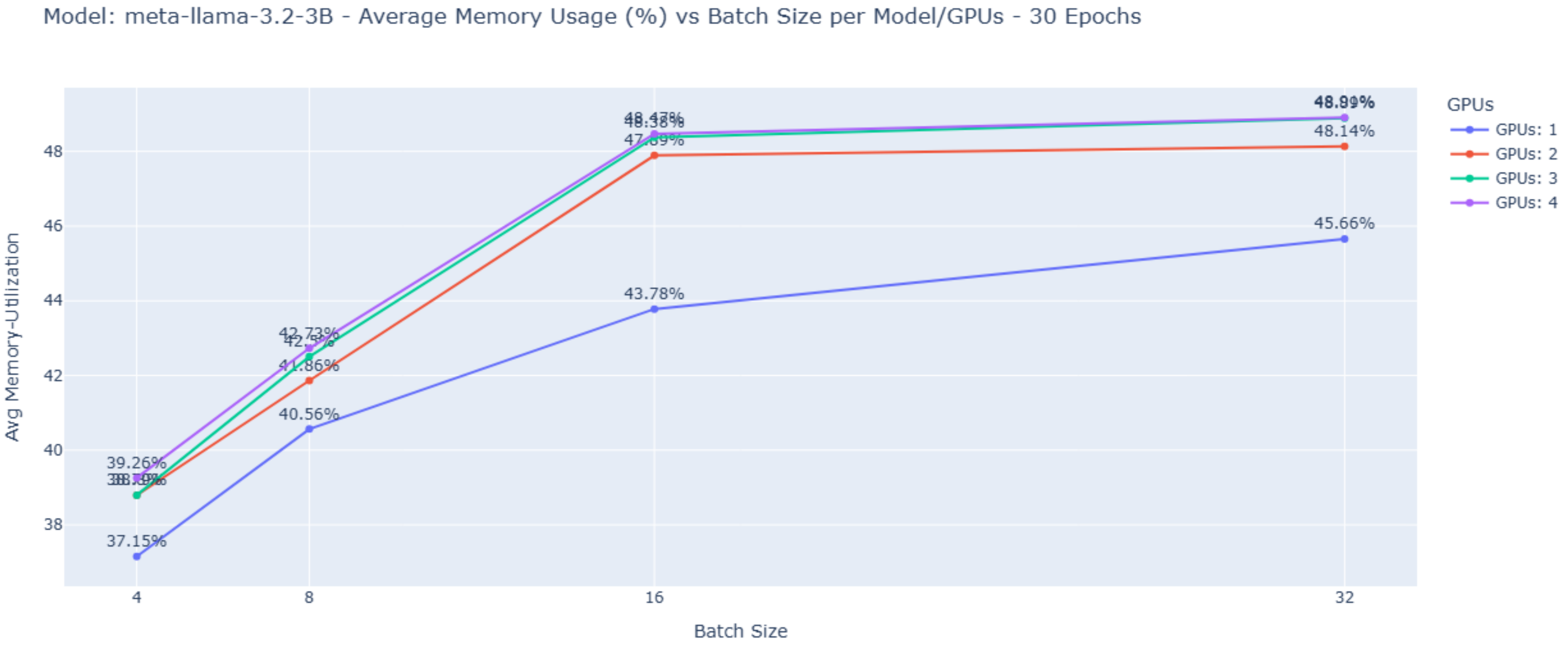


Memory Utilization – pynvml 1B

Model: meta-llama-3.2-1B - Average Memory Usage (%) vs Batch Size per Model/GPUs - 30 Epochs



Memory Utilization – pynvml 3B



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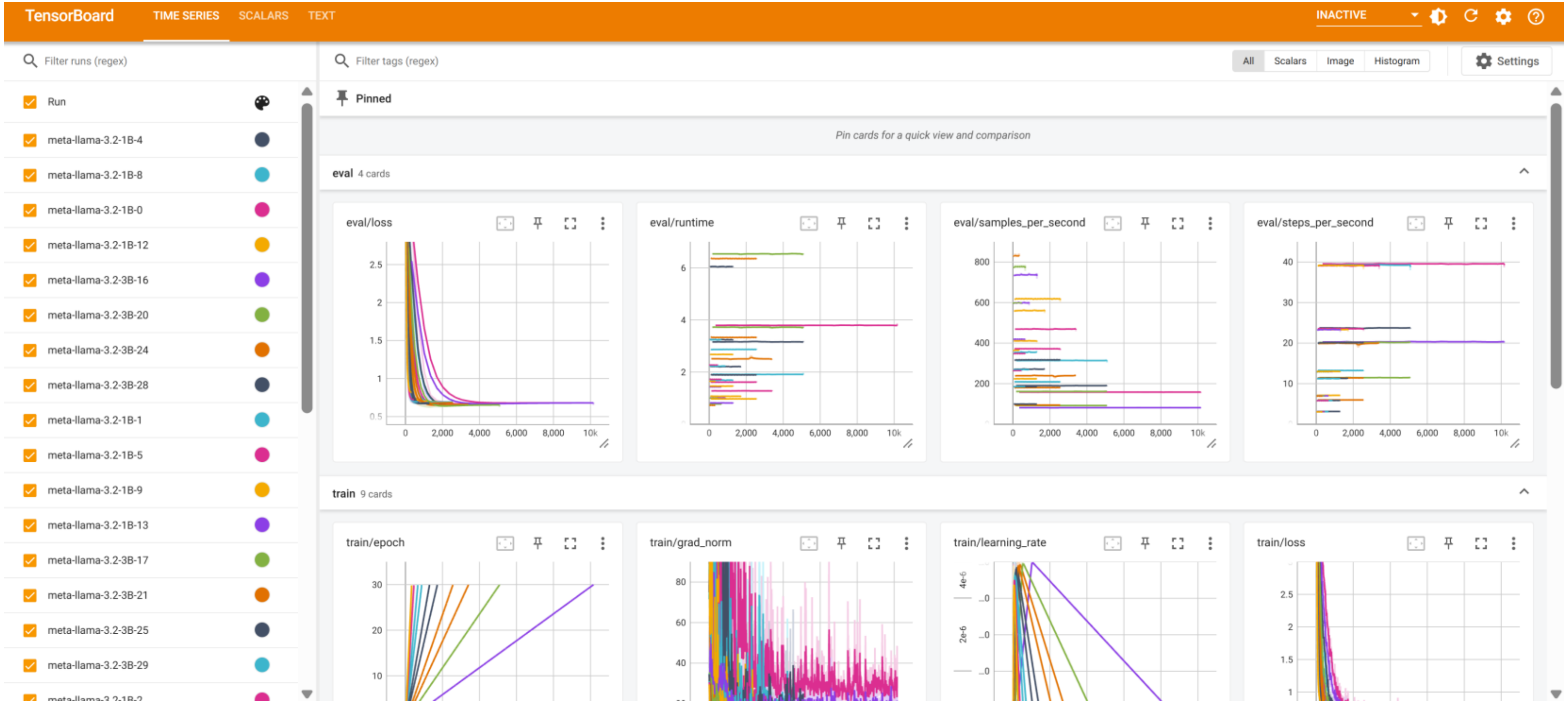


- ☑ Run
- ☑ meta-llama-3.2-1B-4
- ☑ meta-llama-3.2-1B-8
- ☑ meta-llama-3.2-1B-0
- ☑ meta-llama-3.2-1B-12
- ☑ meta-llama-3.2-3B-16
- ☑ meta-llama-3.2-3B-20
- ☑ meta-llama-3.2-3B-24
- ☑ meta-llama-3.2-3B-28
- ☑ meta-llama-3.2-1B-1
- ☑ meta-llama-3.2-1B-5
- ☑ meta-llama-3.2-1B-9
- ☑ meta-llama-3.2-1B-13
- ☑ meta-llama-3.2-3B-17
- ☑ meta-llama-3.2-3B-21
- ☑ meta-llama-3.2-3B-25
- ☑ meta-llama-3.2-3B-29
- ☑ meta-llama-3.2-1B-2

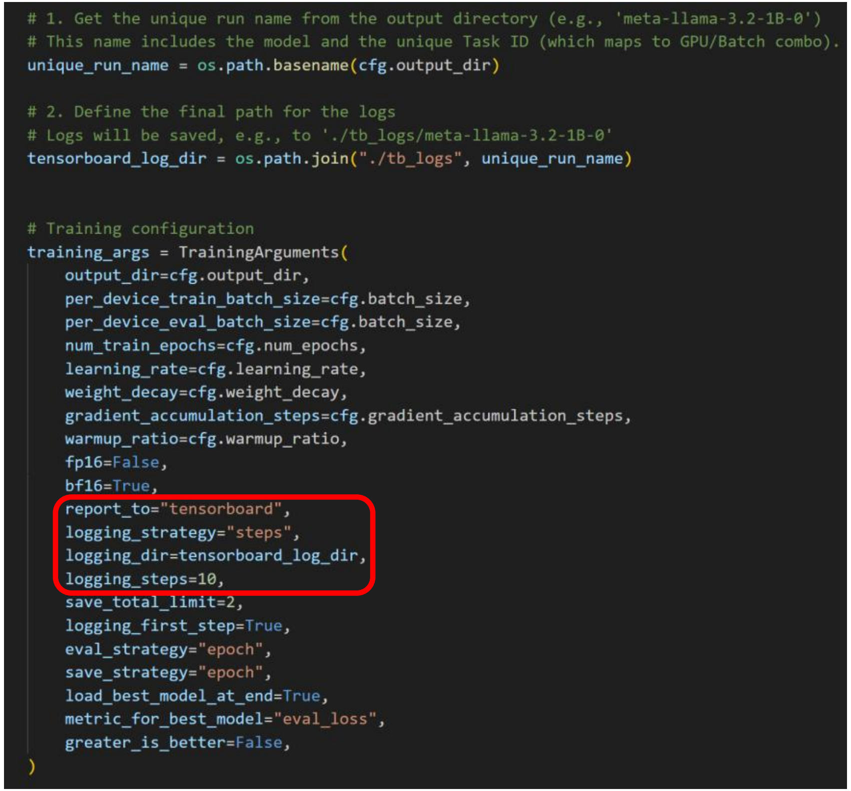
Tensorboard - Parameters

`report_to="tensorboard"` By setting the value to "tensorboard", you instruct the training system to send all gathered metrics (like loss, accuracy, runtime, etc.) to TensorBoard. The system then generates the necessary **event files** that the TensorBoard application reads and visualizes.

`logging_strategy="steps"` With the value set to "steps", the system records the metrics **after a certain number of training steps** are completed. **Note:** This is usually accompanied by another parameter (e.g., logging_steps=X) `logging_steps=10,`

`logging_dir=tensorboard_log_dir` Specifies the local directory where the log files are stored.

`logging_first_step=True` Ensures that metrics are logged **immediately** after the very **first training step** is completed.



```python
# 1. Get the unique run name from the output directory (e.g., 'meta-llama-3.2-1B-0')
# This name includes the model and the unique Task ID (which maps to GPU/Batch combo).
unique_run_name = os.path.basename(cfg.output_dir)

# 2. Define the final path for the logs
# Logs will be saved, e.g., to './tb_logs/meta-llama-3.2-1B-0'
tensorboard_log_dir = os.path.join("./tb_logs", unique_run_name)


# Training configuration
training_args = TrainingArguments(
    output_dir=cfg.output_dir,
    per_device_train_batch_size=cfg.batch_size,
    per_device_eval_batch_size=cfg.batch_size,
    num_train_epochs=cfg.num_epochs,
    learning_rate=cfg.learning_rate,
    weight_decay=cfg.weight_decay,
    gradient_accumulation_steps=cfg.gradient_accumulation_steps,
    warmup_ratio=cfg.warmup_ratio,
    fp16=False,
    bf16=True,
    report_to="tensorboard",
    logging_strategy="steps",
    logging_dir=tensorboard_log_dir,
    logging_steps=10,
    save_total_limit=2,
    logging_first_step=True,
    eval_strategy="epoch",
    save_strategy="epoch",
    load_best_model_at_end=True,
    metric_for_best_model="eval_loss",
    greater_is_better=False,
)
```

Thank you for your attention.

Questions?

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