# vLLM: Easy, Fast, and Cheap LLM Serving for Everyone

vLLM Team

# vLLM 's Goal

Build the fastest and

easiest-to-use open-source

LLM inference & serving engine

# Why vLLM For Performance?

vLLM implements the key optimizations for **fast inference**

**Inference Optimizations**

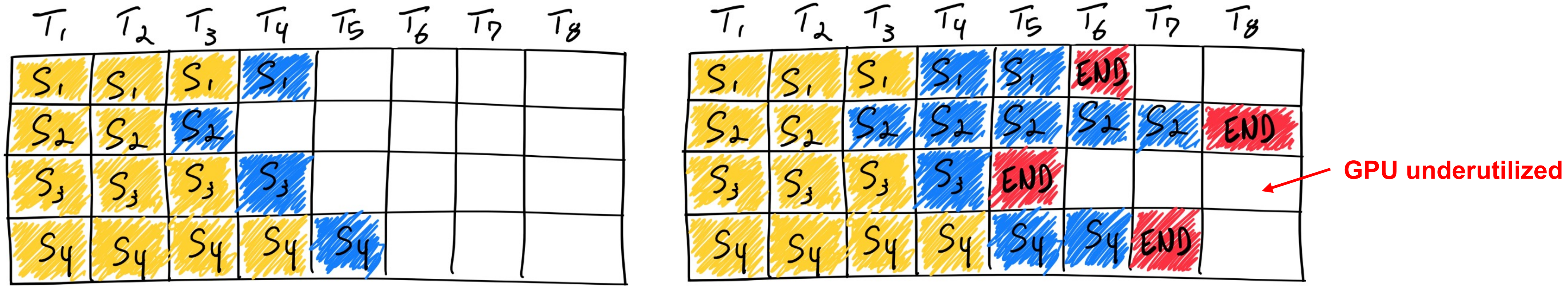
To make your models faster

**Distributed Parallel Inference**

To deploy large models efficiently

# Batching

## ❌Naive batching

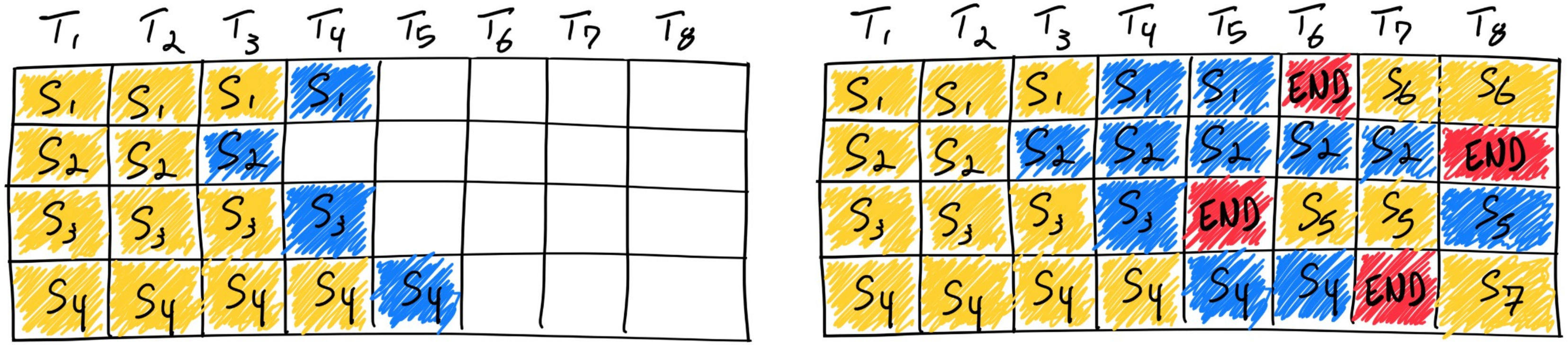


| $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ |
|---|---|---|---|---|---|---|---|
| $S_1$ | $S_1$ | $S_1$ | $S_1$ | | | | |
| $S_2$ | $S_2$ | $S_2$ | | | | | |
| $S_3$ | $S_3$ | $S_3$ | $S_3$ | | | | |
| $S_4$ | $S_4$ | $S_4$ | $S_4$ | $S_4$ | | | |

| $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ |
|---|---|---|---|---|---|---|---|
| $S_1$ | $S_1$ | $S_1$ | $S_1$ | $S_1$ | END | | |
| $S_2$ | $S_2$ | $S_2$ | $S_2$ | $S_2$ | $S_2$ | $S_2$ | END |
| $S_3$ | $S_3$ | $S_3$ | $S_3$ | END | | | |
| $S_4$ | $S_4$ | $S_4$ | $S_4$ | $S_4$ | $S_4$ | END | |

GPU underutilized

## ✅Continuous Batching

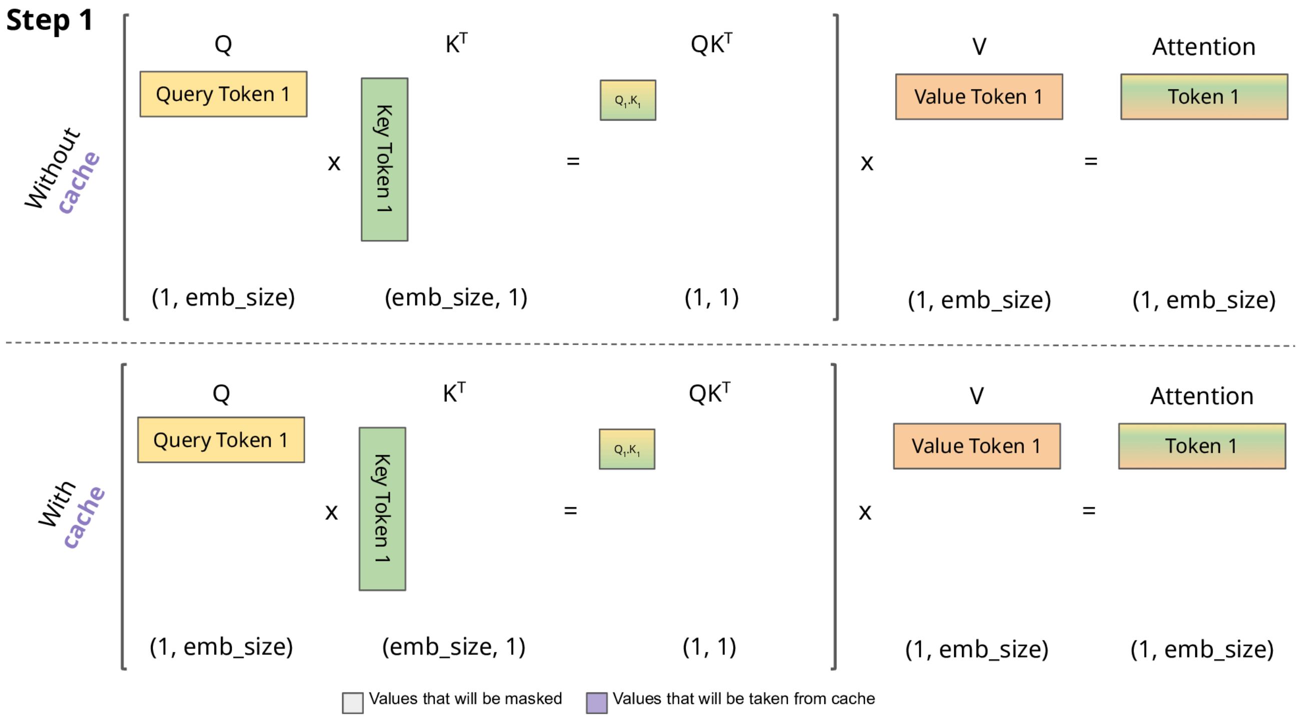


| $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ |
|---|---|---|---|---|---|---|---|
| $S_1$ | $S_1$ | $S_1$ | $S_1$ | | | | |
| $S_2$ | $S_2$ | $S_2$ | | | | | |
| $S_3$ | $S_3$ | $S_3$ | $S_3$ | | | | |
| $S_4$ | $S_4$ | $S_4$ | $S_4$ | $S_4$ | | | |

| $T_1$ | $T_2$ | $T_3$ | $T_4$ | $T_5$ | $T_6$ | $T_7$ | $T_8$ |
|---|---|---|---|---|---|---|---|
| $S_1$ | $S_1$ | $S_1$ | $S_1$ | $S_1$ | END | $S_6$ | $S_6$ |
| $S_2$ | $S_2$ | $S_2$ | $S_2$ | $S_2$ | $S_2$ | $S_2$ | END |
| $S_3$ | $S_3$ | $S_3$ | $S_3$ | END | $S_5$ | $S_5$ | $S_5$ |
| $S_4$ | $S_4$ | $S_4$ | $S_4$ | $S_4$ | $S_4$ | END | $S_7$ |

# KV Cache

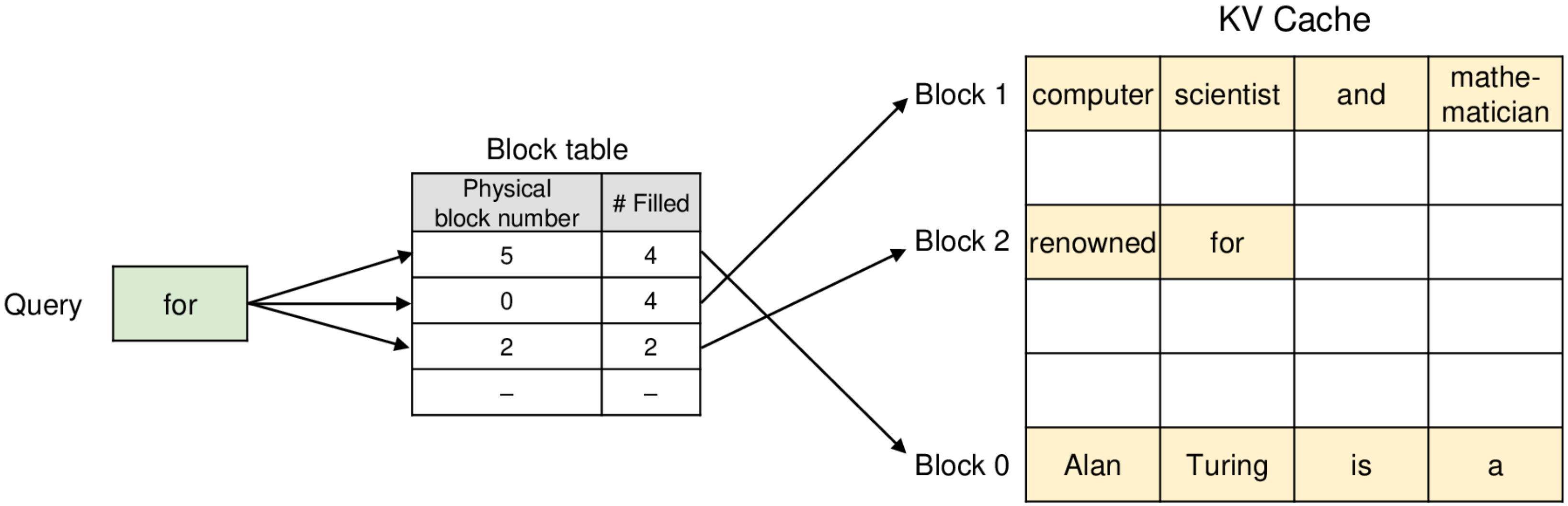
## Caching Key and Value vectors in self-attention saves redundant computation and accelerates decoding



https://medium.com/@joaolages/kv-caching-explained-276520203249

# PagedAttention

An attention algorithm that allows for storing continuous keys and values in non-contiguous memory space.



Block table

| Physical block number | # Filled |
|---|---|
| 5 | 4 |
| 0 | 4 |
| 2 | 2 |
| – | – |

KV Cache

| | | | | |
|---|---|---|---|---|
| Block 1 | computer | scientist | and | mathe-matician |
| | | | | |
| Block 2 | renowned | for | | |
| | | | | |
| | | | | |
| Block 0 | Alan | Turing | is | a |

Woosuk Kwon, etc. Efficient Memory Management for Large Language Model Serving with PagedAttention, SOSP 2023

# vLLM Combines All Optimizations Together

## Without Optimizations

Prompt

<SYSTEM> You are a helpful assistant. ...
Keep your answers precise and concise.
<USER> Generate a description for this item: ...

Output

## vLLM

Prompt

<SYSTEM> You are a helpful assistant. ...
Keep your answers precise and concise.
<USER> Generate a description for this item: ...

Output

# Forms of Parallelism in vLLM

**Tensor Parallelism (TP)**

**Pipeline Parallelism (PP)**

**Expert Parallelism (EP)**

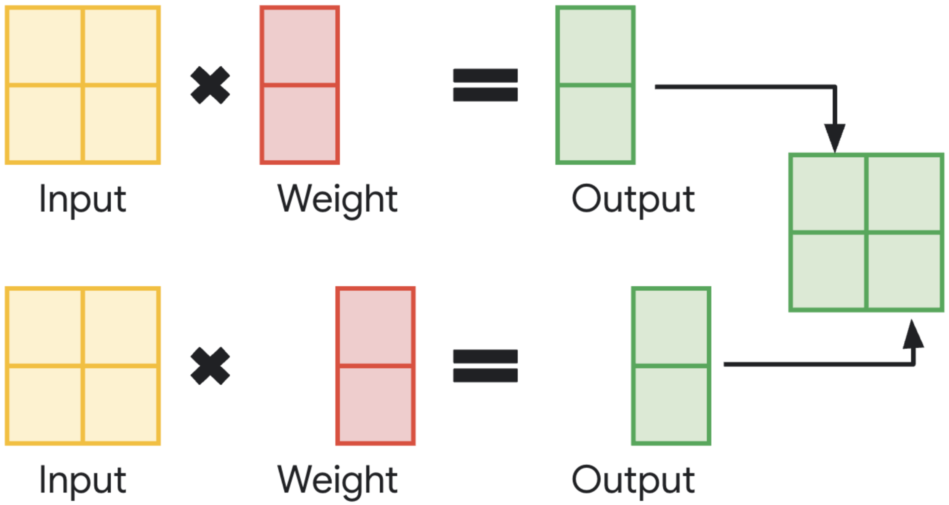
**Data Parallelism (DP)**

**Disaggregated Serving**

# Tensor Parallelism

Partition the model’s hidden dimension → All-reduce to aggregate the outputs

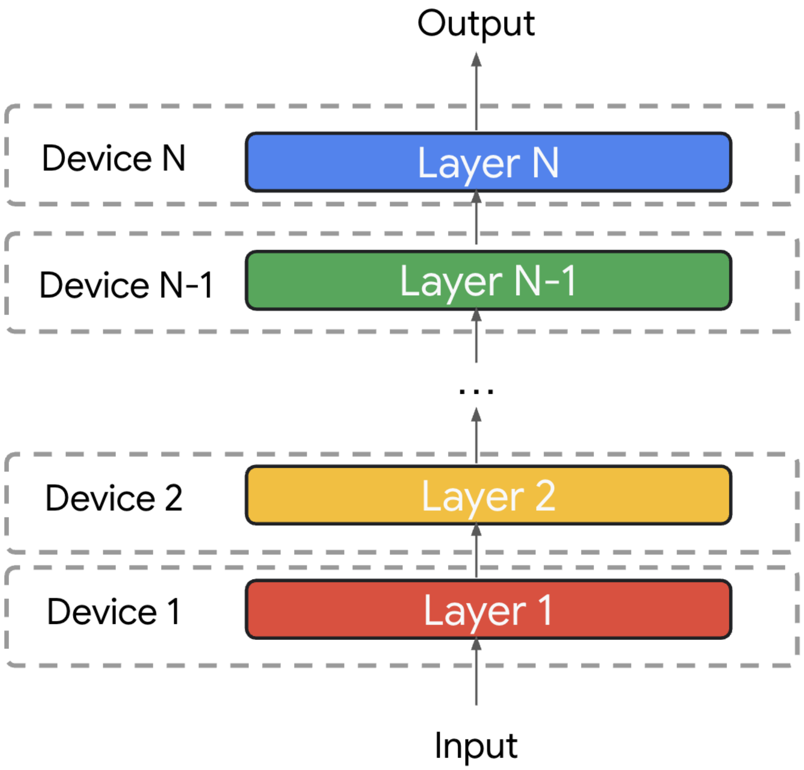
- Works well for ≤ 8 devices
- vLLM provides optimized all-reduce implementation
- Limited scalability
- Communication overhead can be critical for small model



# Pipeline Parallelism

Distribute layers to different devices → execute in a pipelined fashion

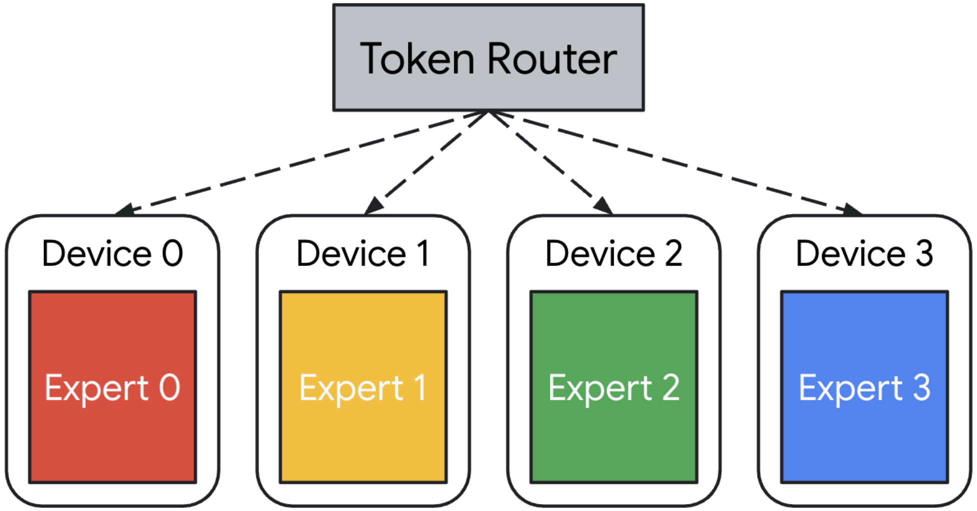
- Point-to-point communication instead of expensive all-reduce
- Load imbalance b/t stages
- Doesn’t reduce latency



# Expert Parallelism

Place experts to different devices
→ All-to-all to exchange tokens

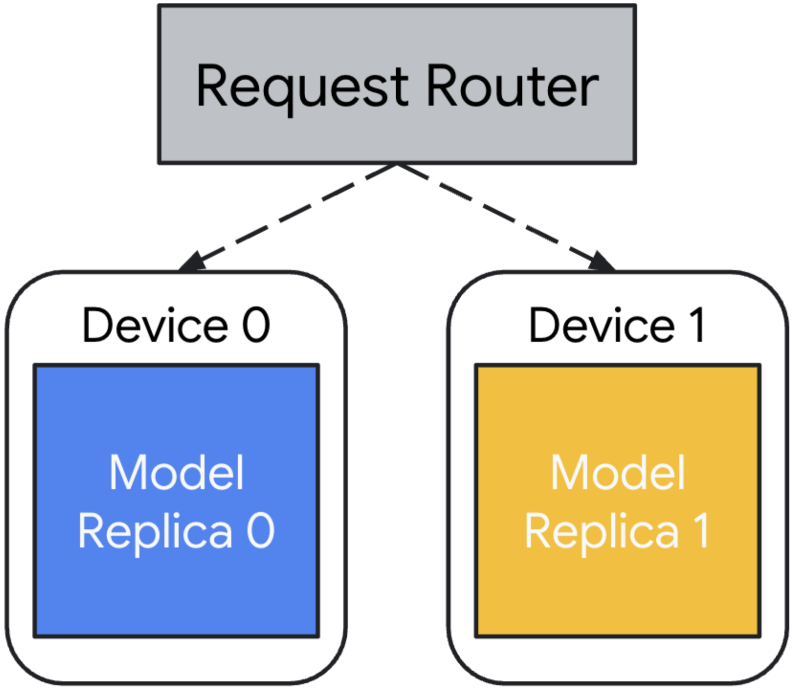
- Lower communication overheads than tensor parallelism
- Load imbalance between experts



# Data Parallelism

Partition the inputs instead of the model → Model weights are replicated

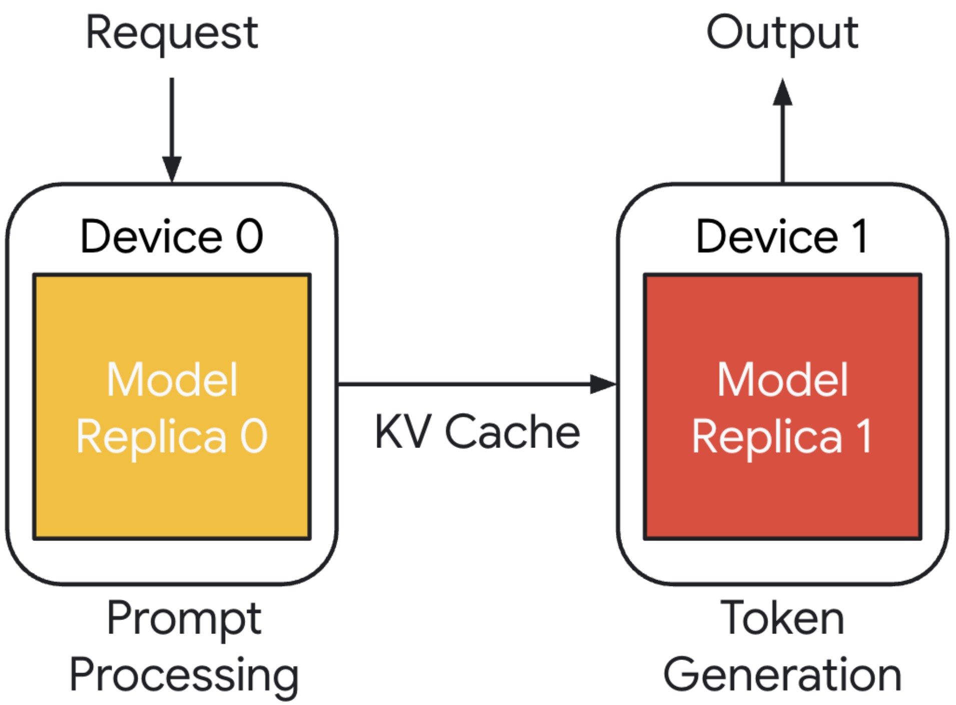
- Lower communication overheads
- Load imbalance between replicas
- Increased memory consumption for model weights



# Disaggregated Serving

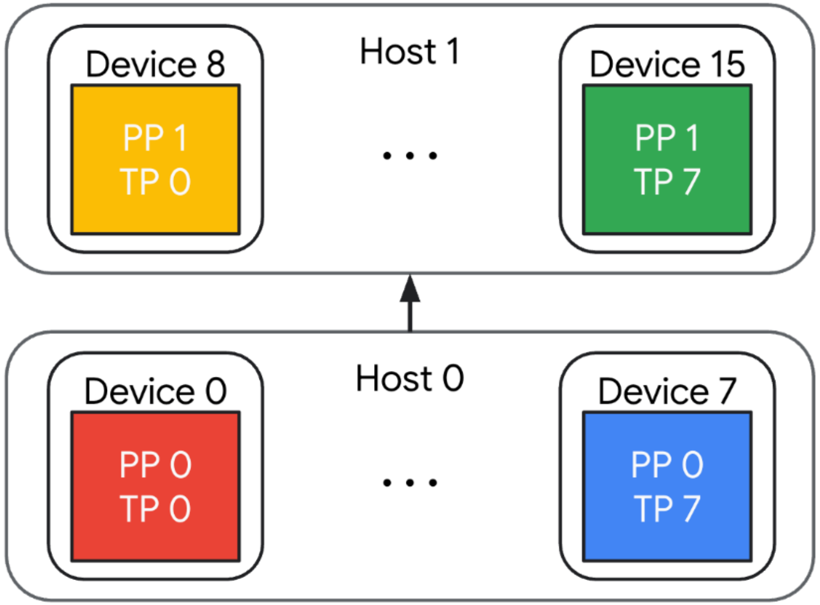
Partition the “time” dimension
→ Separate instances for prompt processing & token generation

- Separation of concern
- Better control over latency
- KV cache transfer overheads
- Lower device utilization



# vLLM Supports Mixed Parallelism

**Tensor + Pipeline Parallelism**
(e.g., Llama 3 405B)



Host 1

Device 8
PP 1
TP 0

. . .

Device 15
PP 1
TP 7

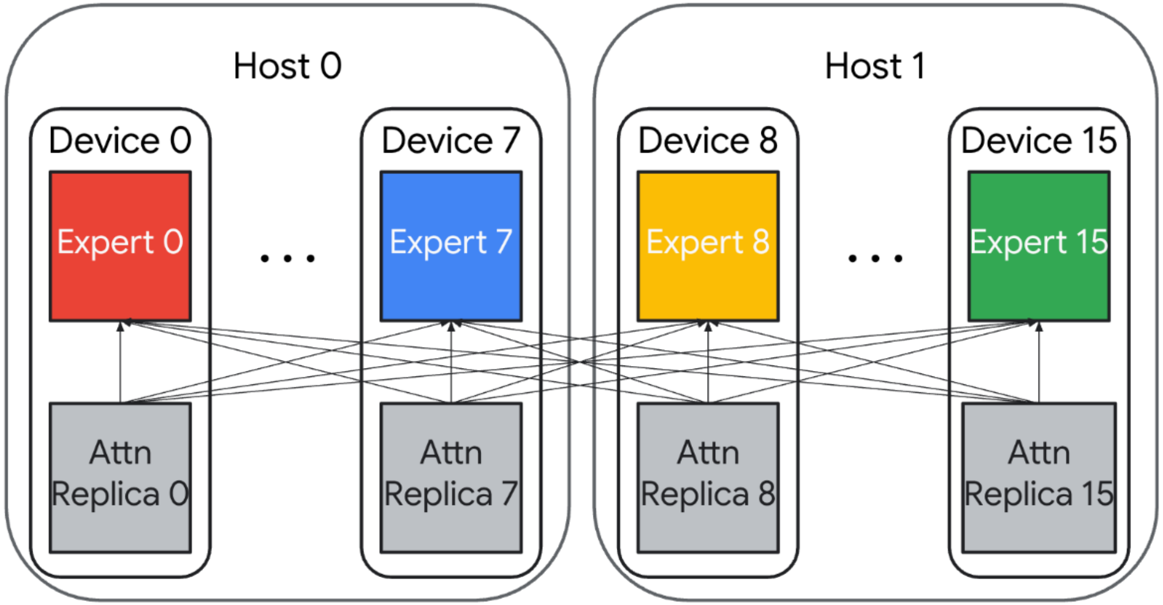
Host 0

Device 0
PP 0
TP 0

. . .

Device 7
PP 0
TP 7

**Data + Expert Parallelism**
(e.g., DeepSeek V3)



Host 0

Device 0
Expert 0
Attn Replica 0

. . .

Device 7
Expert 7
Attn Replica 7

Host 1

Device 8
Expert 8
Attn Replica 8

. . .

Device 15
Expert 15
Attn Replica 15

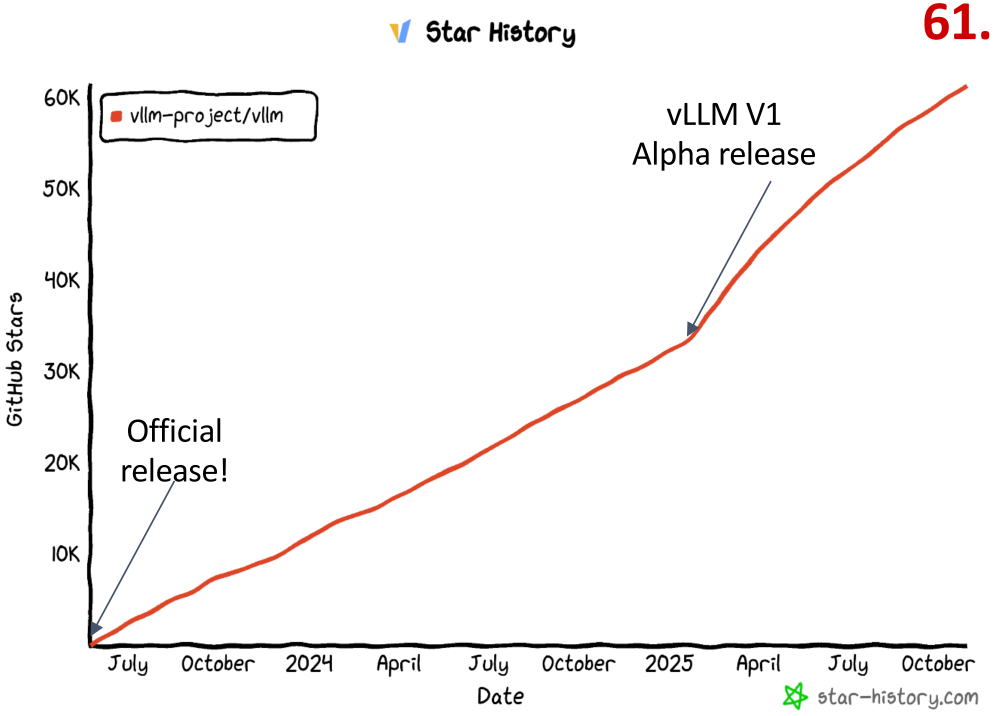
**How do I run model X on hardware Y with task Z?**

See our out-of-box recipes: **https://docs.vllm.ai/projects/recipes/en/latest/index.html**

```
$ pip install vllm
```

vLLM

61.3K Stars



vLLM V1 Alpha release

Official release!

# vLLM Adopters

## Open-Source Projects

LLaMA-Factory

Easy and Efficient LLM Fine-Tuning

LangChain

unsloth

verl

Dify

...

## Companies

### Hardware

NVIDIA

AMD

intel

Apple

...

### Cloud

aws

Microsoft Azure

Google Cloud

Alibaba Cloud

...

### Model Vendor

Qwen

KIMI

deepseek

Mistral AI

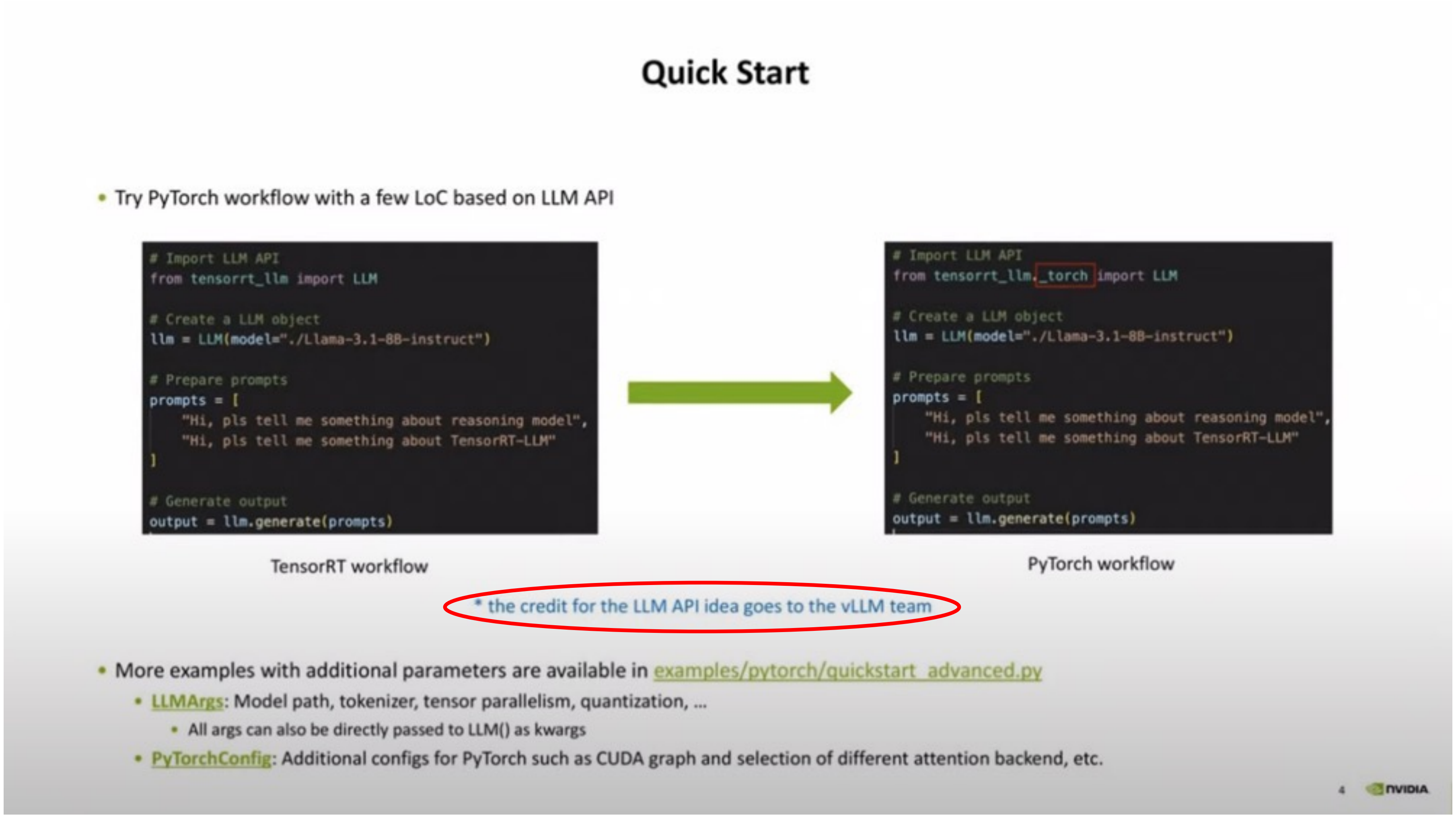
...

# vLLM API (1): LLM class

A Python interface for offline batched inference

```python
from vllm import LLM

# Example prompts.
prompts = ["Hello, my name is", "The capital of France is"]
# Create an LLM with HF model name.
llm = LLM(model="meta-llama/Meta-Llama-3.1-8B")
# Generate texts from the prompts.
outputs = llm.generate(prompts)
```

# vLLM API (1): LLM class



## Quick Start

- Try PyTorch workflow with a few LoC based on LLM API

```
# Import LLM API
from tensorrt_llm import LLM

# Create a LLM object
llm = LLM(model="./Llama-3.1-8B-instruct")

# Prepare prompts
prompts = [
    "Hi, pls tell me something about reasoning model",
    "Hi, pls tell me something about TensorRT-LLM"
]

# Generate output
output = llm.generate(prompts)
```

TensorRT workflow

```
# Import LLM API
from tensorrt_llm._torch import LLM

# Create a LLM object
llm = LLM(model="./Llama-3.1-8B-instruct")

# Prepare prompts
prompts = [
    "Hi, pls tell me something about reasoning model",
    "Hi, pls tell me something about TensorRT-LLM"
]

# Generate output
output = llm.generate(prompts)
```

PyTorch workflow

* the credit for the LLM API idea goes to the vLLM team

- More examples with additional parameters are available in examples/pytorch/quickstart_advanced.py
  - LLMArgs: Model path, tokenizer, tensor parallelism, quantization, …
    - All args can also be directly passed to LLM() as kwargs
  - PyTorchConfig: Additional configs for PyTorch such as CUDA graph and selection of different attention backend, etc.

# vLLM API (2): OpenAI-compatible server

A FastAPI-based server for online serving

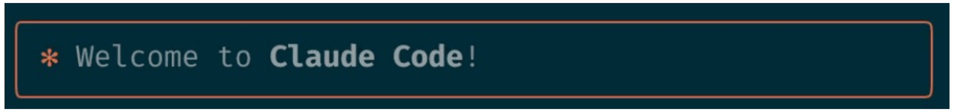
Server

```
$ vllm serve meta-llama/Meta-Llama-3.1-8B
```

Client

```
$ curl http://localhost:8000/v1/completions \
    -H "Content-Type: application/json" \
    -d '{
        "model": "meta-llama/Meta-Llama-3.1-8B",
        "prompt": "San Francisco is a",
        "max_tokens": 7,
        "temperature": 0
    }'
```

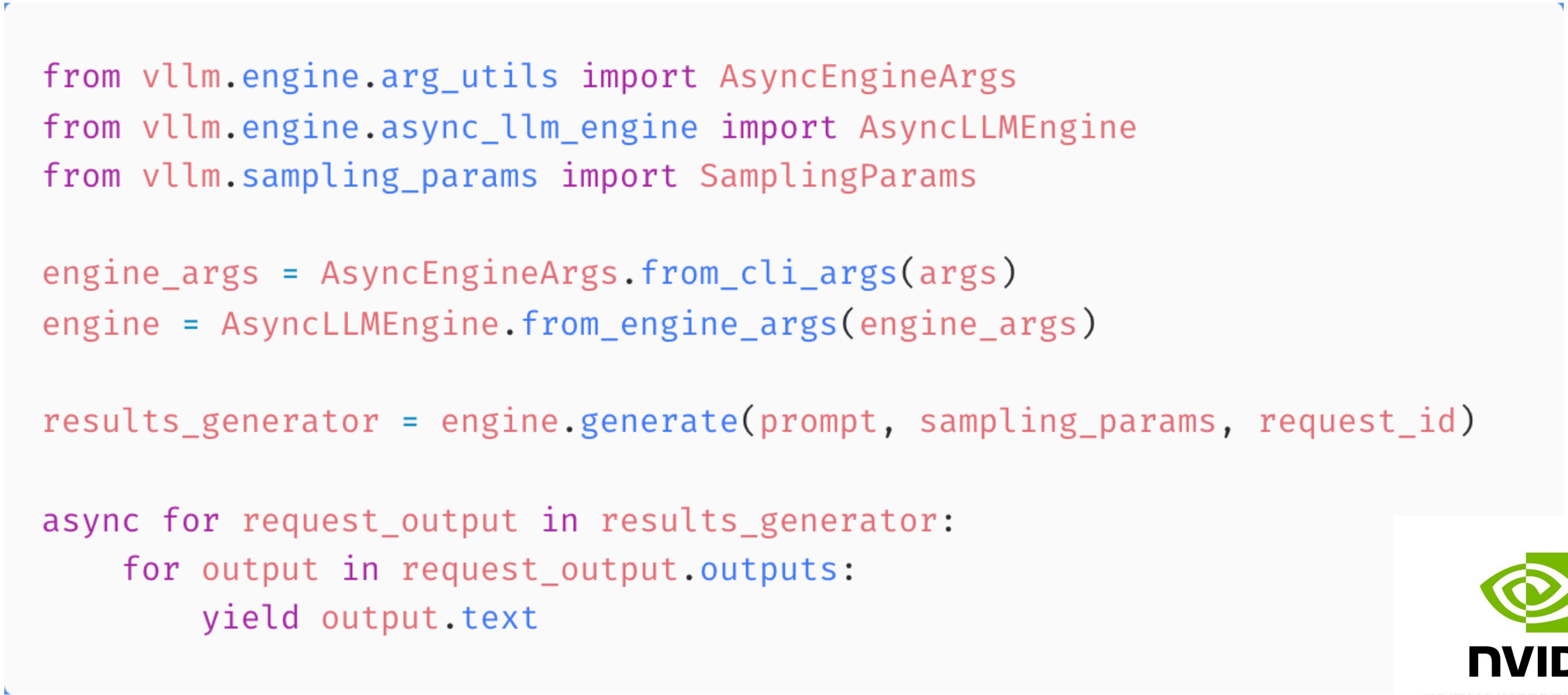
MinerU



```
* Welcome to Claude Code!
```

# vLLM API (3): Embeddable LLMEngine

A Python library with the full power of vLLM in your framework



```
from vllm.engine.arg_utils import AsyncEngineArgs
from vllm.engine.async_llm_engine import AsyncLLMEngine
from vllm.sampling_params import SamplingParams

engine_args = AsyncEngineArgs.from_cli_args(args)
engine = AsyncLLMEngine.from_engine_args(engine_args)

results_generator = engine.generate(prompt, sampling_params, request_id)

async for request_output in results_generator:
    for output in request_output.outputs:
        yield output.text
```

# Broad Model Support

vLLM supports almost all popular **text-generation models**!

StepFun Step-3

KIMI Kimi-K2

Deepseek-3.2

ERNIE

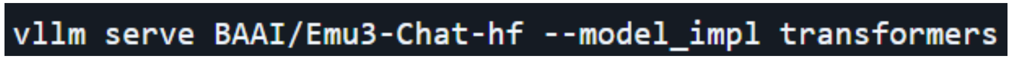
Tencent Hunyuan

GLM-4.6

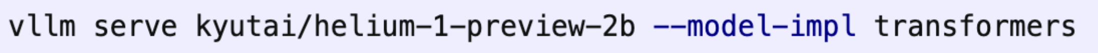
# Transformers backend

## Supports models not in vLLM, but runnable by Transformers

https://blog.vllm.ai/2025/04/11/transformers-backend.html



```
vllm serve BAAI/Emu3-Chat-hf --model_impl transformers
```



```
vllm serve kyutai/helium-1-preview-2b --model-impl transformers
```

- Write model implementation in Transformers
- Leverage vLLM’s kv cache management and continuous batching
- Work for both vision and language models
- Performance on par with pure vLLM implementation

For model vendors who develop new models, it is also recommended to use https://docs.vllm.ai/en/latest/contributing/model/registration.html#out-of-tree-models

# Broad Model Support

## Architecture

- Transformer-like LLMs
  - Llama
- Mixture-of-Expert LLMs
  - DeepSeekV3
- State-Space Models
  - Jamba
- Linear-Attention Models
  - Minimax-M2
- ……

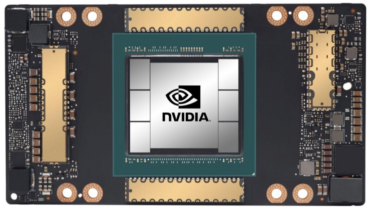
## Modality

- Text-input LLMs
  - Llama
- Image-text input LLMs
  - Deepseek-OCR
- Video-input LLMs
  - Qwen3-VL
- Audio-input LLMs
  - Whisper
- ……

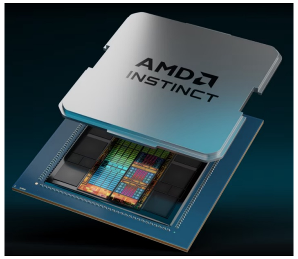
## Task

- Chat/Completion
  - Llama
- Embedding
  - E5-Mistral
- Reward
  - Qwen2.5-Math-RM
- Rerank
  - Qwen3-Reranker
- ……

# Diverse Hardware Support



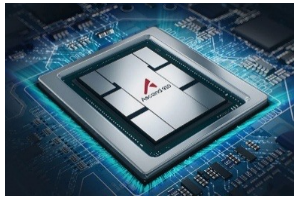
NVIDIA GPU



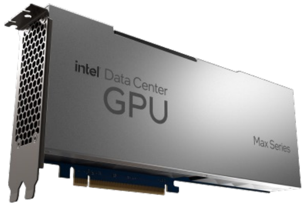
AMD GPU

x86 CPU

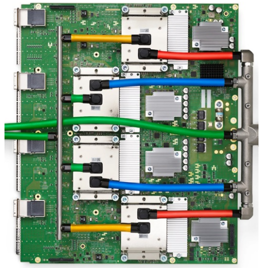
AWS Neuron (WIP)



Huawei Ascend

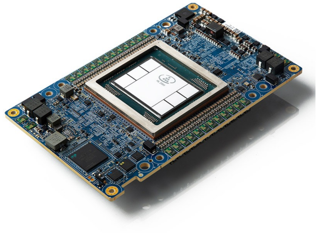


Intel GPU



Google TPU

ARM CPU

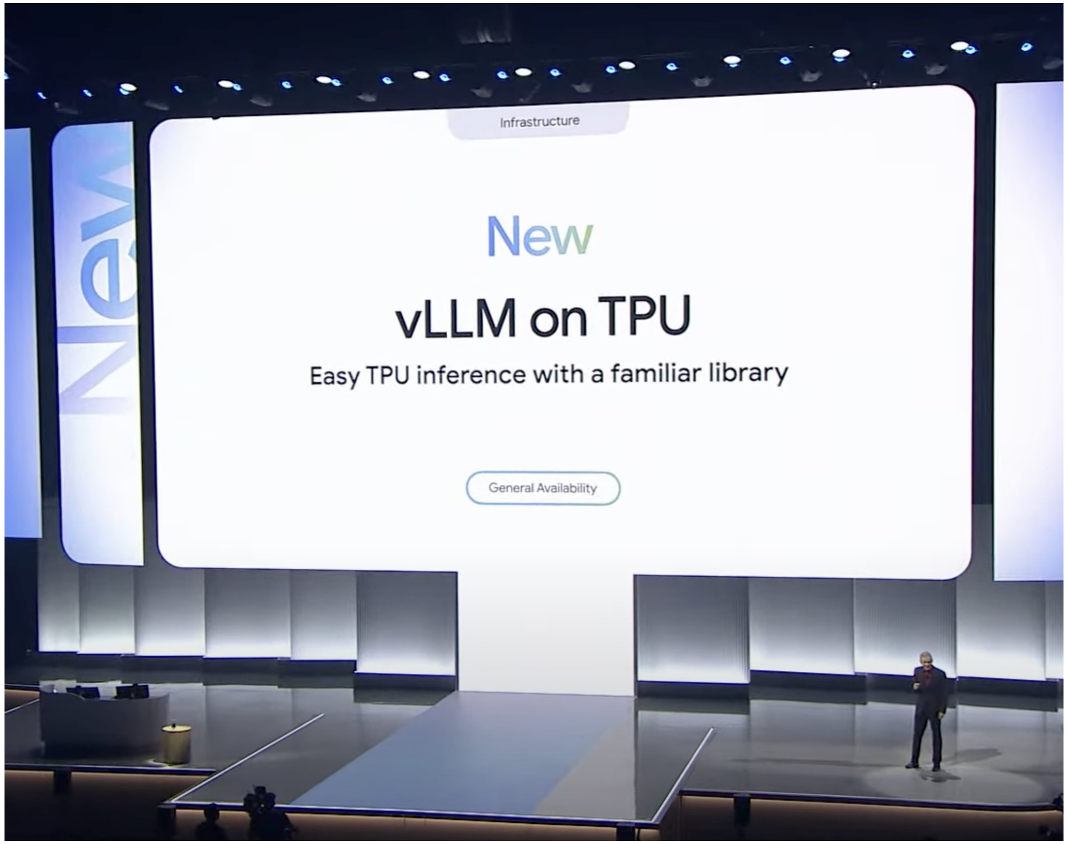


Intel Gaudi

IBM Spyre

support in vllm repo

hardware plugin ⭐



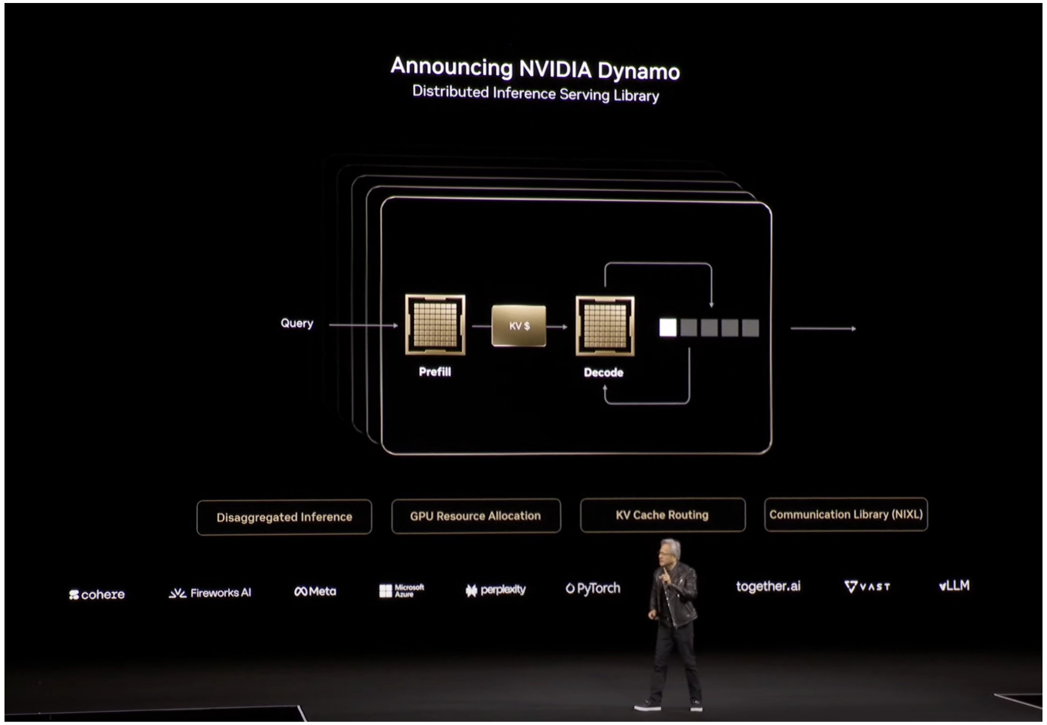
Infrastructure

New

vLLM on TPU

Easy TPU inference with a familiar library

General Availability



Announcing NVIDIA Dynamo

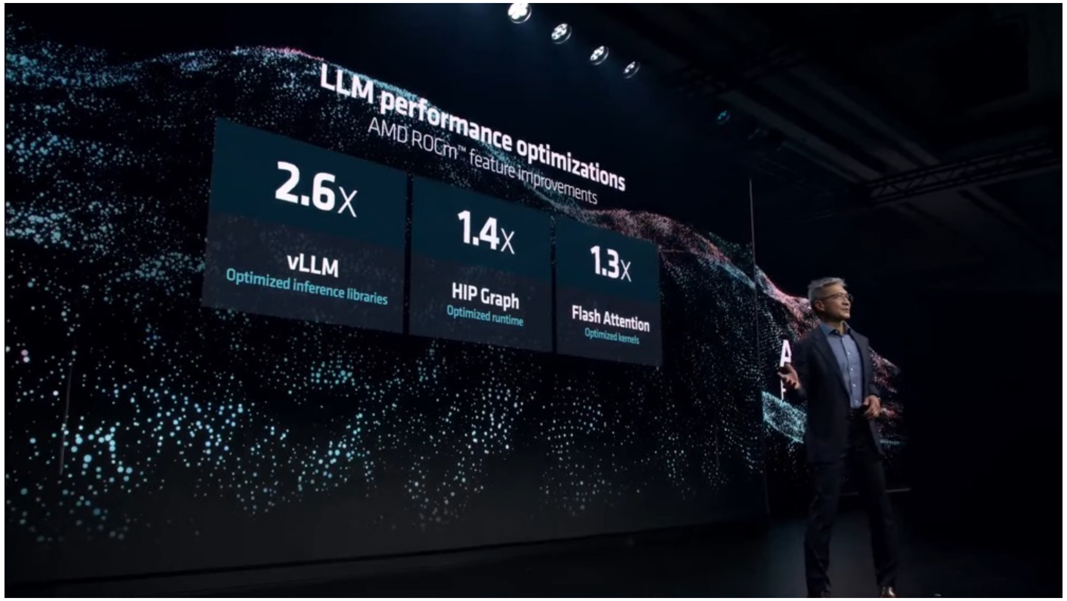
Distributed Inference Serving Library

Disaggregated Inference

GPU Resource Allocation

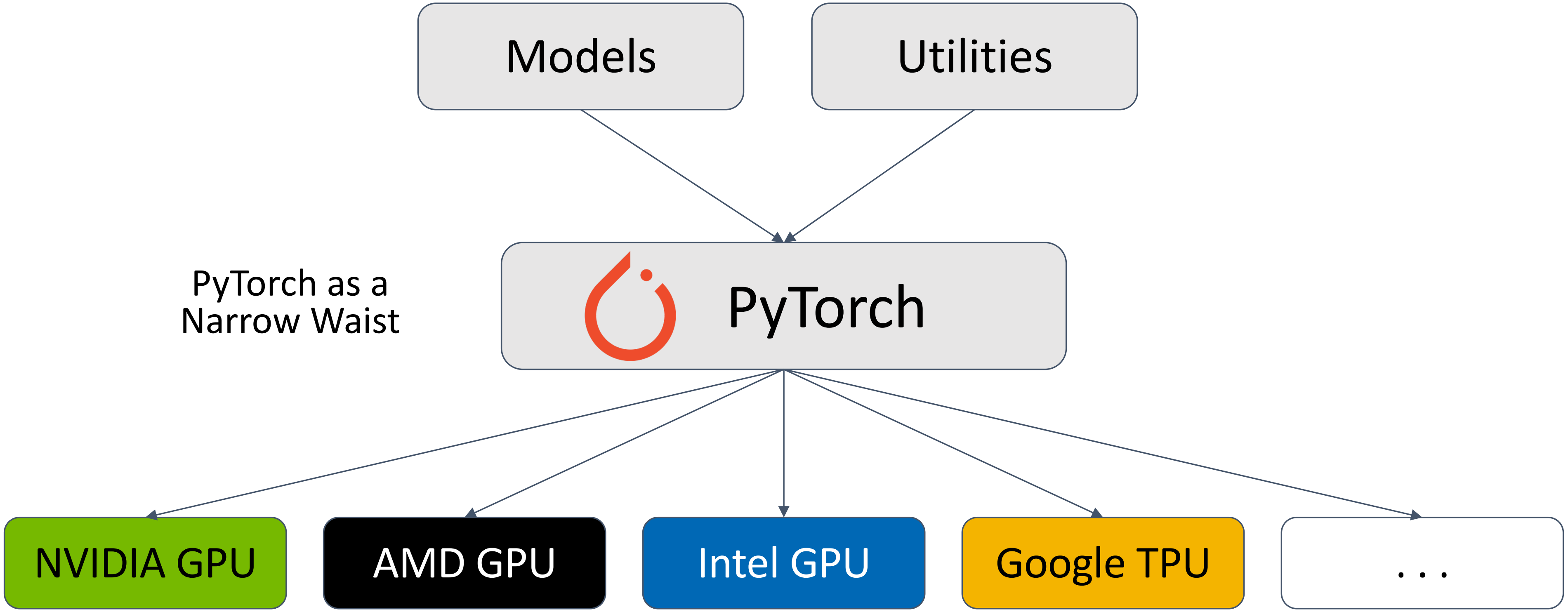
KV Cache Routing

Communication Library (NIXL)


LLM performance optimizations
AMD ROCm™ feature improvements
2.6x
vLLM
Optimized inference libraries
1.4x
HIP Graph
Optimized runtime
1.3x
Flash Attention
Optimized kernels

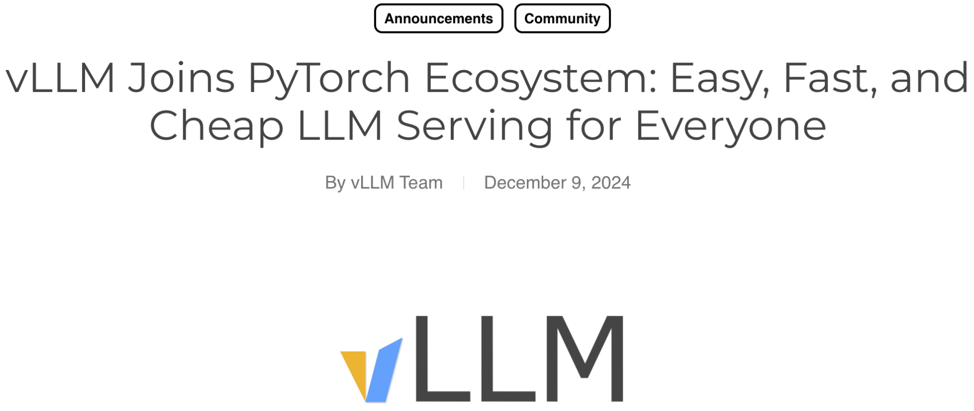
kubernetes
llm-d
vLLM

# Diverse Hardware Support



PyTorch as a
Narrow Waist

# Close Collaboration with PyTorch



Announcements Community

vLLM Joins PyTorch Ecosystem: Easy, Fast, and Cheap LLM Serving for Everyone

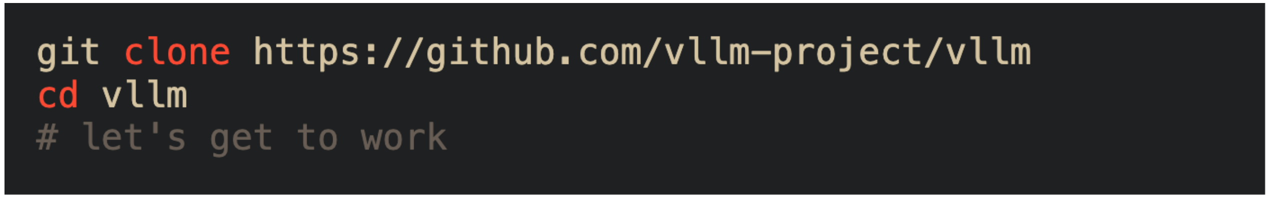
By vLLM Team | December 9, 2024

vLLM has joined PyTorch Foundation!

# vLLM: Building, Testing and Contributing

# So how does I get started with vLLM?

- Source: github.com/vllm-project/vllm



```
git clone https://github.com/vllm-project/vllm
cd vllm
# let's get to work
```

- Docs: docs.vllm.ai/en/latest Yes! Docs are useful!

- Issue tracker is a good source of information vllm-project/vllm/issues

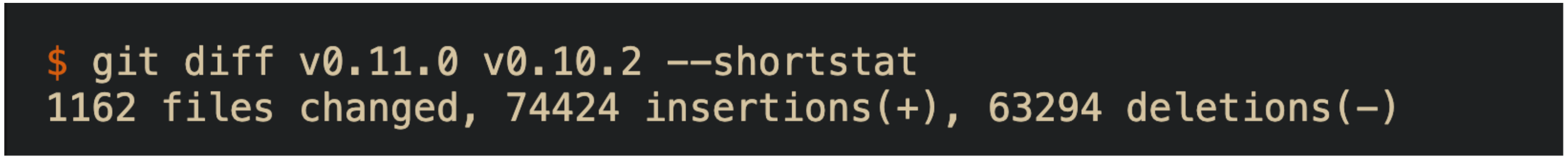
# Some vLLM facts

- Current vllm version v0.11.0 (released Oct 10th), with v0.11.1 brewing (rc1 available)

- One release every three weeks

- 1716 (!) contributors as of today, 207 in the last release (65 new!). This is a 200+ contributor increase from just a couple months ago!

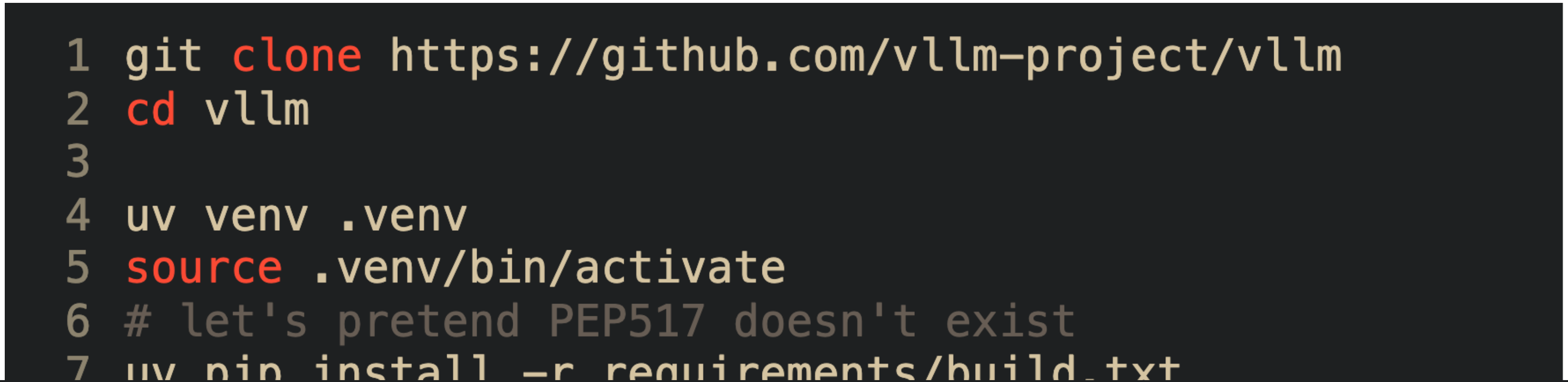
- A lot of code is being pushed out each release. For the last release:



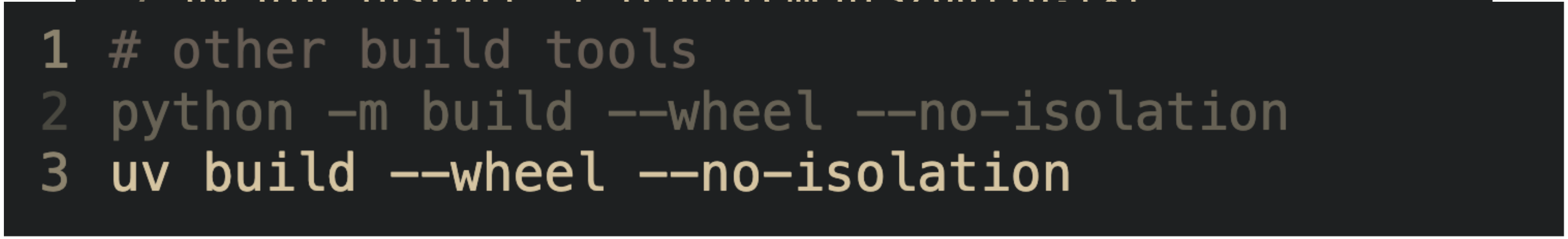
```
$ git diff v0.11.0 v0.10.2 --shortstat
1162 files changed, 74424 insertions(+), 63294 deletions(-)
```

# BUILDING

Here's how easy it is to build vLLM using uv



```
git clone https://github.com/vllm-project/vllm
cd vllm

uv venv .venv
source .venv/bin/activate
# let's pretend PEP517 doesn't exist
uv pip install -r requirements/build.txt
```



```
# other build tools
python -m build --wheel --no-isolation
uv build --wheel --no-isolation
```

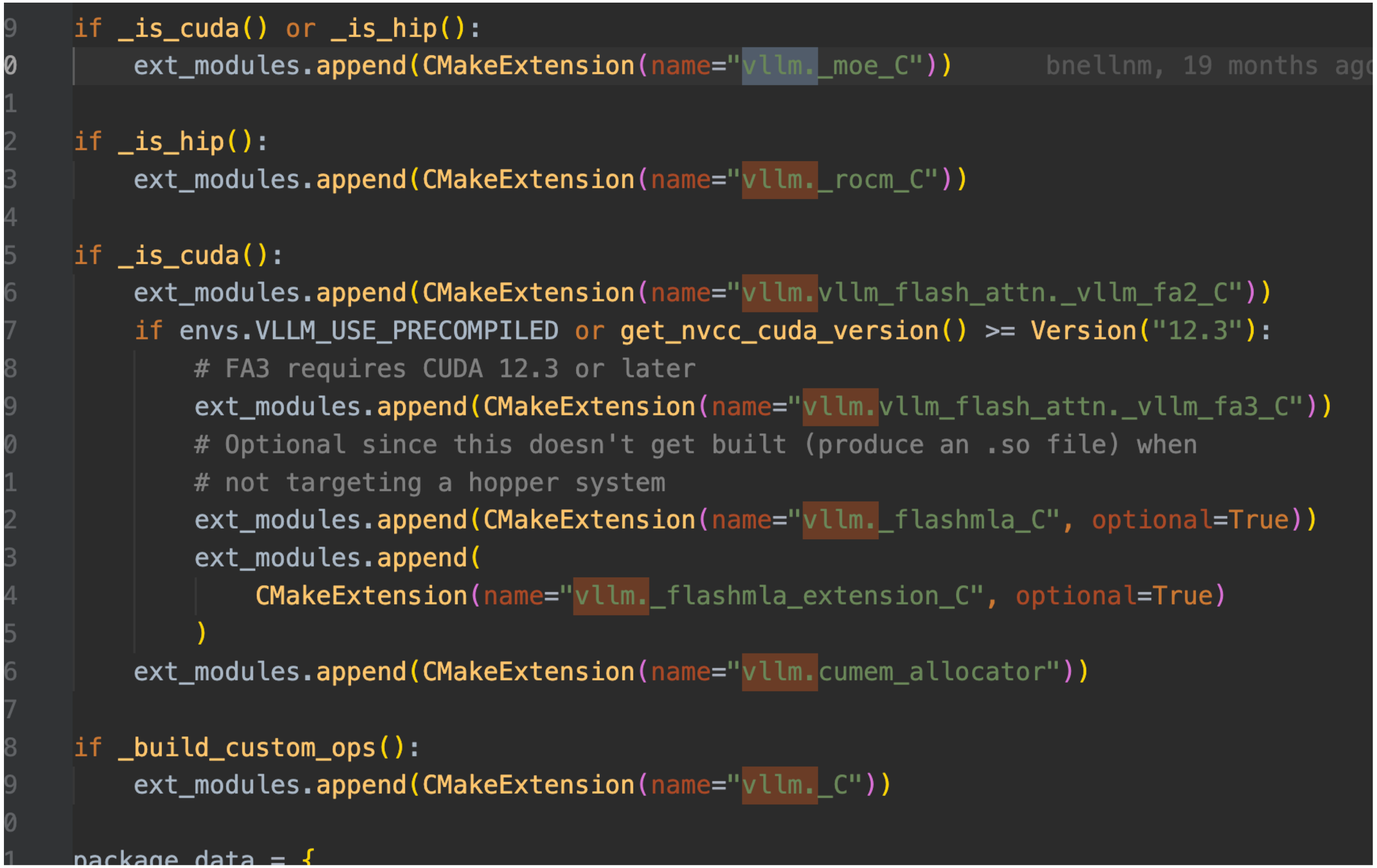
# What's not simple?

- There are several available targets: Nvidia CUDA, AMD ROCm, Google TPU, Intel HPU, CPU, ...

- Different toolchains required, depending on target
- Hardware requirements

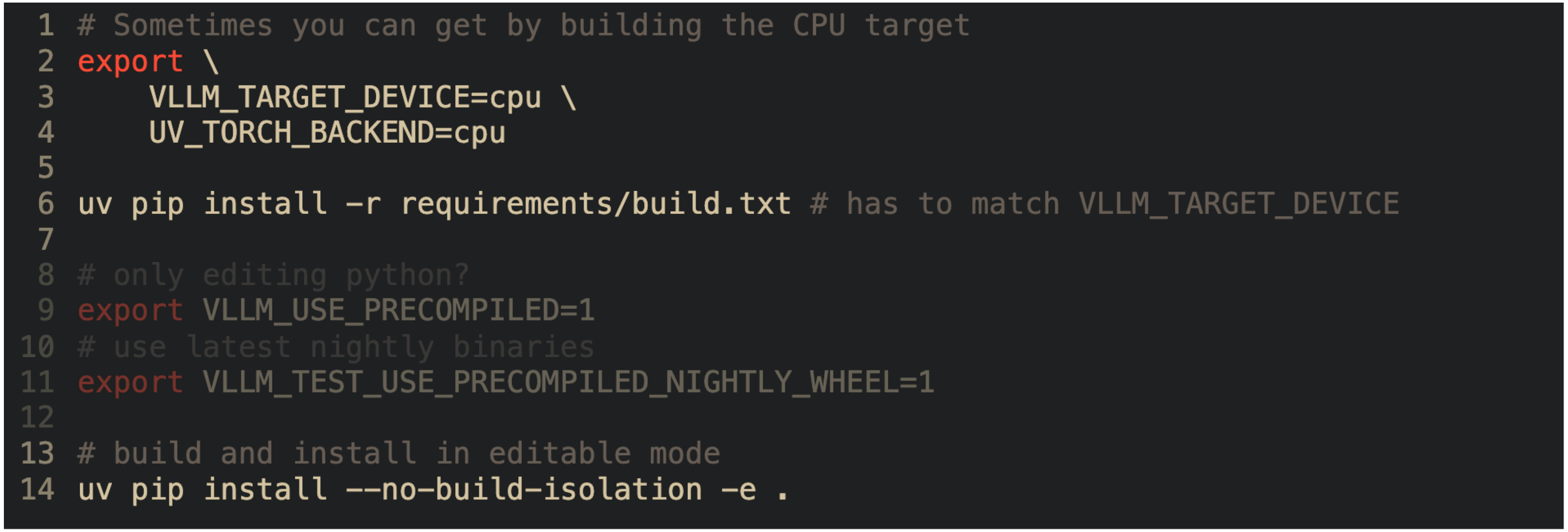
- Build can be very hungry for memory and CPU (several GBs of memory required per process)

# vLLM extensions



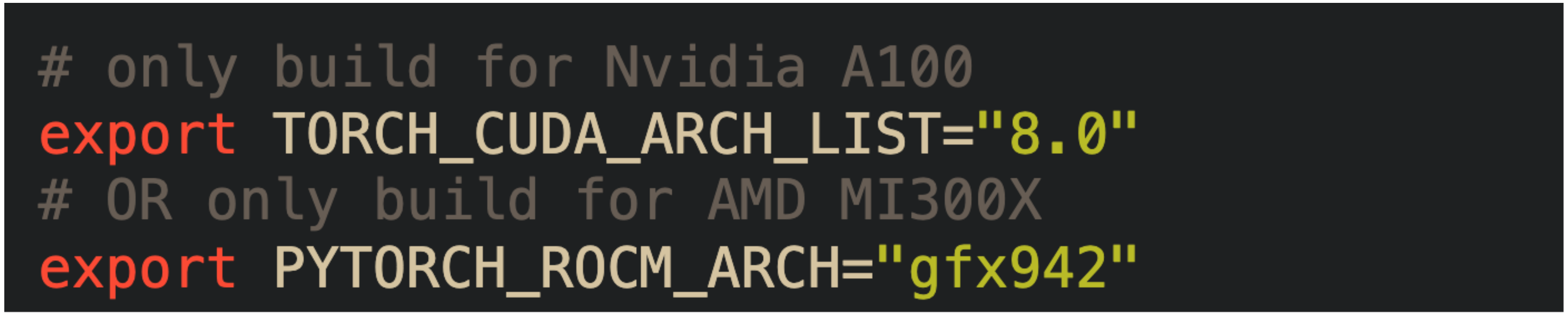
```
if _is_cuda() or _is_hip():
    ext_modules.append(CMakeExtension(name="vllm._moe_C"))      bnellnm, 19 months ago

if _is_hip():
    ext_modules.append(CMakeExtension(name="vllm._rocm_C"))

if _is_cuda():
    ext_modules.append(CMakeExtension(name="vllm.vllm_flash_attn._vllm_fa2_C"))
    if envs.VLLM_USE_PRECOMPILED or get_nvcc_cuda_version() >= Version("12.3"):
        # FA3 requires CUDA 12.3 or later
        ext_modules.append(CMakeExtension(name="vllm.vllm_flash_attn._vllm_fa3_C"))
        # Optional since this doesn't get built (produce an .so file) when
        # not targeting a hopper system
        ext_modules.append(CMakeExtension(name="vllm._flashmla_C", optional=True))
        ext_modules.append(
            CMakeExtension(name="vllm._flashmla_extension_C", optional=True)
        )
    ext_modules.append(CMakeExtension(name="vllm.cumem_allocator"))

if _build_custom_ops():
    ext_modules.append(CMakeExtension(name="vllm._C"))

package_data = {
```

# Local Development

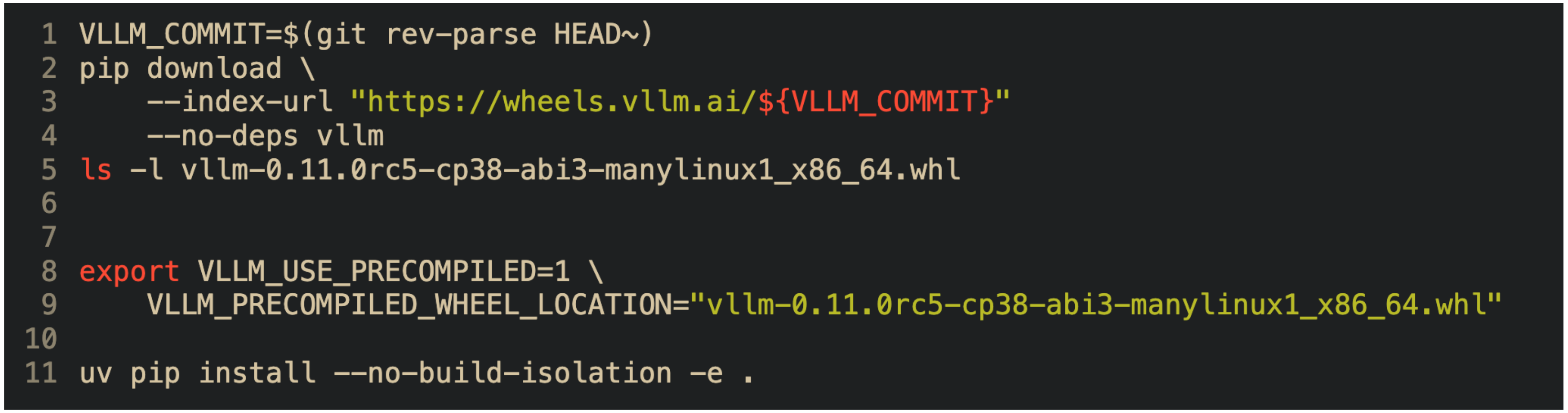


```
# Sometimes you can get by building the CPU target
export \
    VLLM_TARGET_DEVICE=cpu \
    UV_TORCH_BACKEND=cpu

uv pip install -r requirements/build.txt # has to match VLLM_TARGET_DEVICE

# only editing python?
export VLLM_USE_PRECOMPILED=1
# use latest nightly binaries
export VLLM_TEST_USE_PRECOMPILED_NIGHTLY_WHEEL=1

# build and install in editable mode
uv pip install --no-build-isolation -e .
```

Using a precompiled wheel from a specific commit



```
# only build for Nvidia A100
export TORCH_CUDA_ARCH_LIST="8.0"
# OR only build for AMD MI300X
export PYTORCH_ROCM_ARCH="gfx942"
```

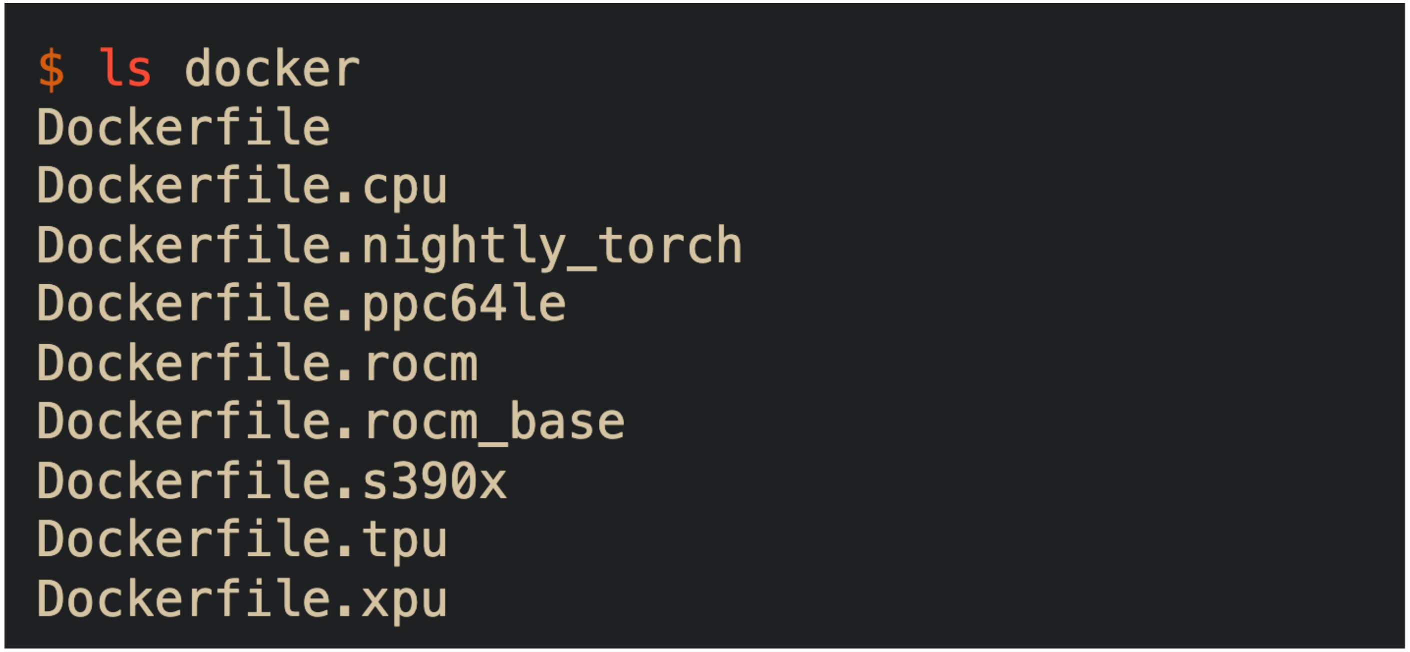


```
VLLM_COMMIT=$(git rev-parse HEAD~)
pip download \
    --index-url "https://wheels.vllm.ai/${VLLM_COMMIT}"
    --no-deps vllm
ls -l vllm-0.11.0rc5-cp38-abi3-manylinux1_x86_64.whl


export VLLM_USE_PRECOMPILED=1 \
    VLLM_PRECOMPILED_WHEEL_LOCATION="vllm-0.11.0rc5-cp38-abi3-manylinux1_x86_64.whl"

uv pip install --no-build-isolation -e .
```

# Docker

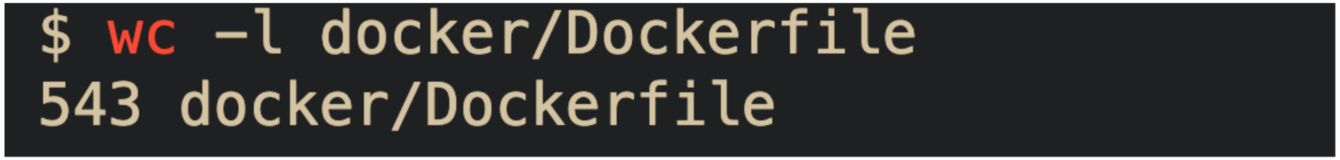
The vLLM wheel is built in a Dockerfile step.

There are different dockerfiles for each target:



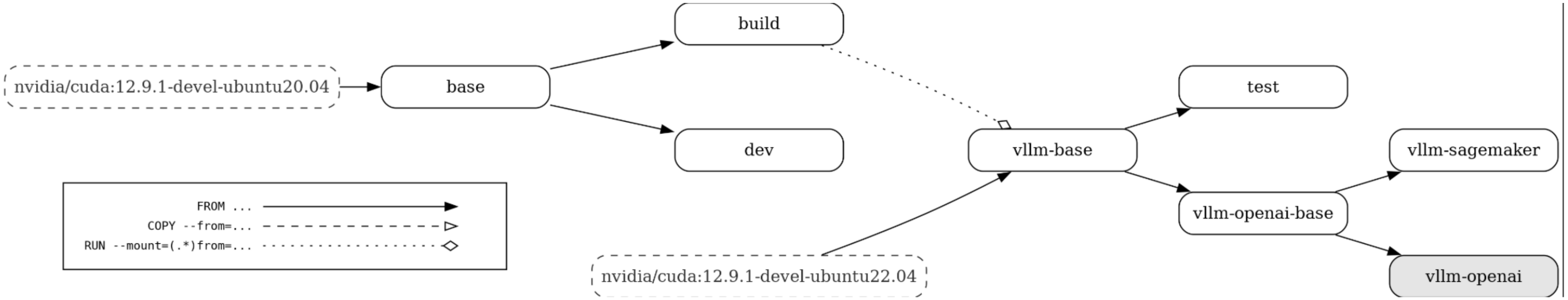
```
$ ls docker
Dockerfile
Dockerfile.cpu
Dockerfile.nightly_torch
Dockerfile.ppc64le
Dockerfile.rocm
Dockerfile.rocm_base
Dockerfile.s390x
Dockerfile.tpu
Dockerfile.xpu
```

## Docker



```
$ wc -l docker/Dockerfile
543 docker/Dockerfile
```

## Dependency graph

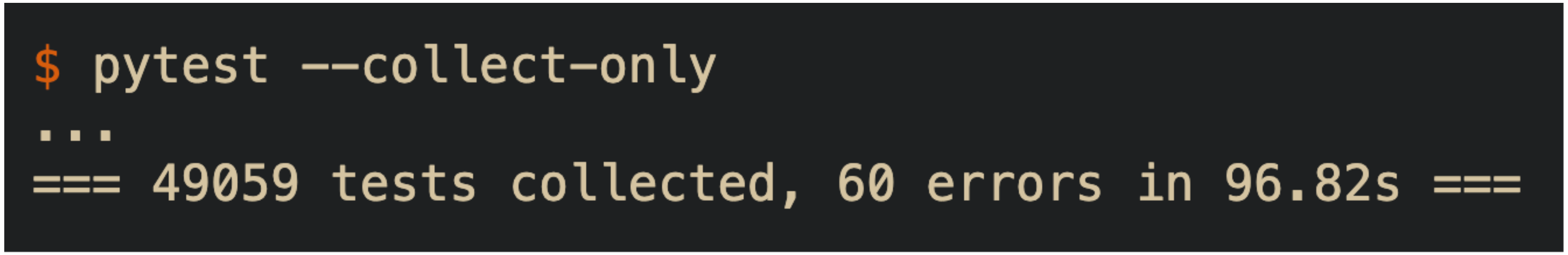


- base: toolchain setup (CUDA, nvcc, ...), python build/runtime deps
- build: vLLM wheel build
- vllm-base: installs vLLM wheel
- vllm-openai*: final stage for REST API (extra deps)
- test: stage used by CI

# Testing

Unit tests: "just" run pytest

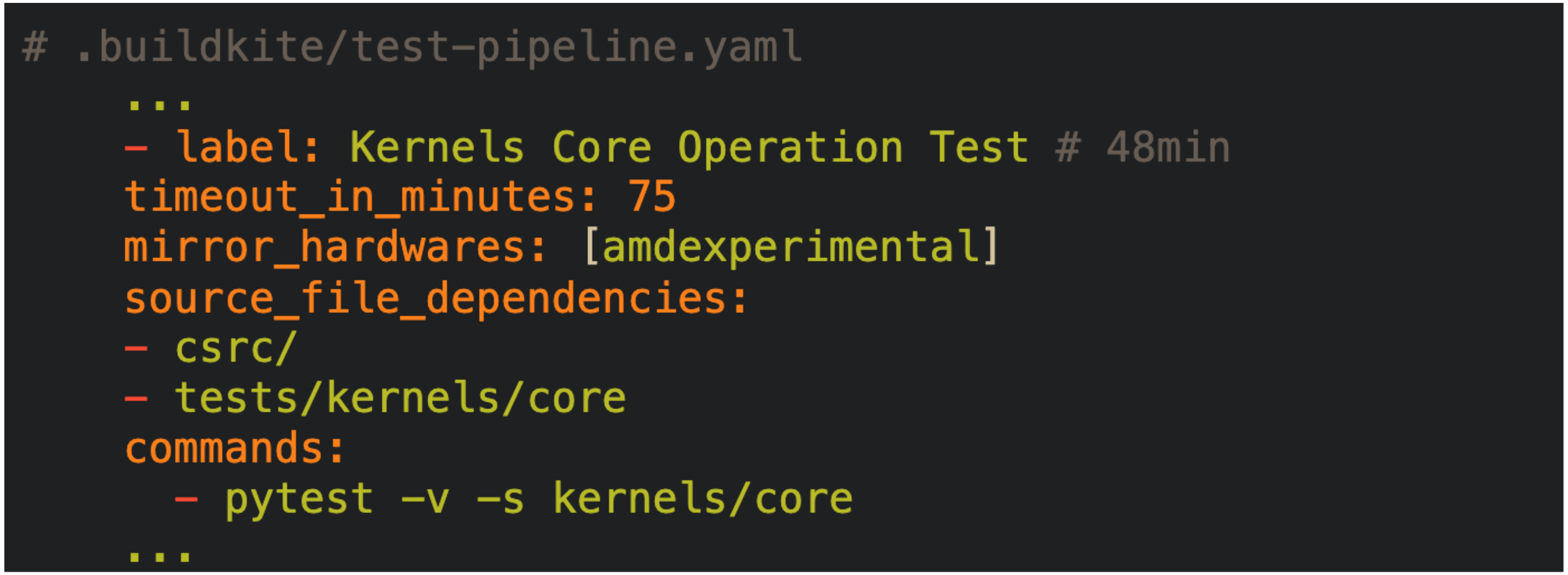
Example:



```
$ pytest --collect-only
...
=== 49059 tests collected, 60 errors in 96.82s ===
```

# **Testing** Tips

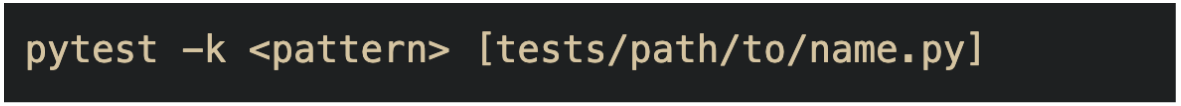
Buildkite (buildkite.com) is used for CI, check the pipeline definition to see which tests are run and how:



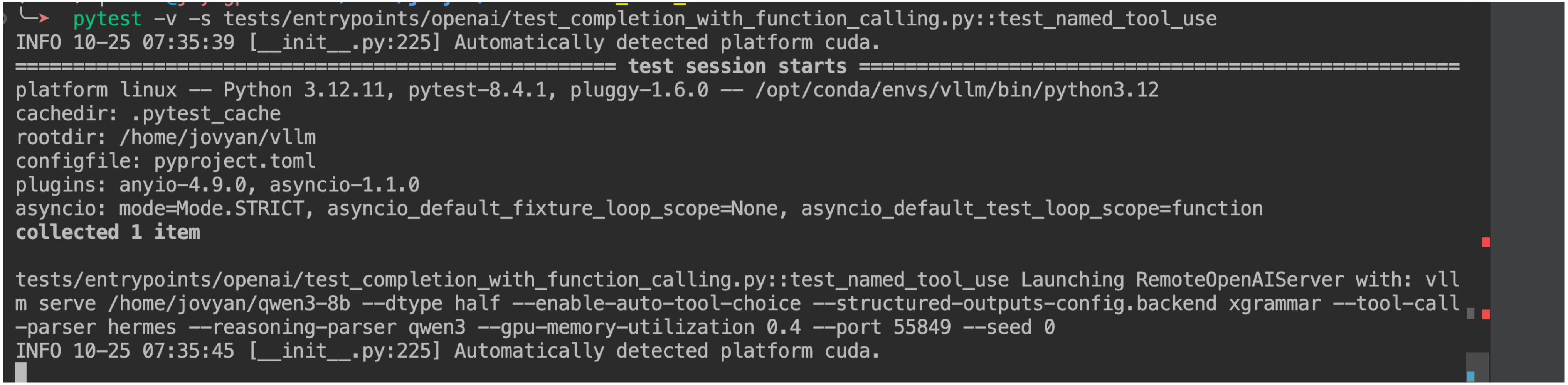
```yaml
# .buildkite/test-pipeline.yaml
    ...
    - label: Kernels Core Operation Test # 48min
    timeout_in_minutes: 75
    mirror_hardwares: [amdexperimental]
    source_file_dependencies:
    - csrc/
    - tests/kernels/core
    commands:
      - pytest -v -s kernels/core
    ...
```

## Testing

Use pytest -k to select tests by name/pattern



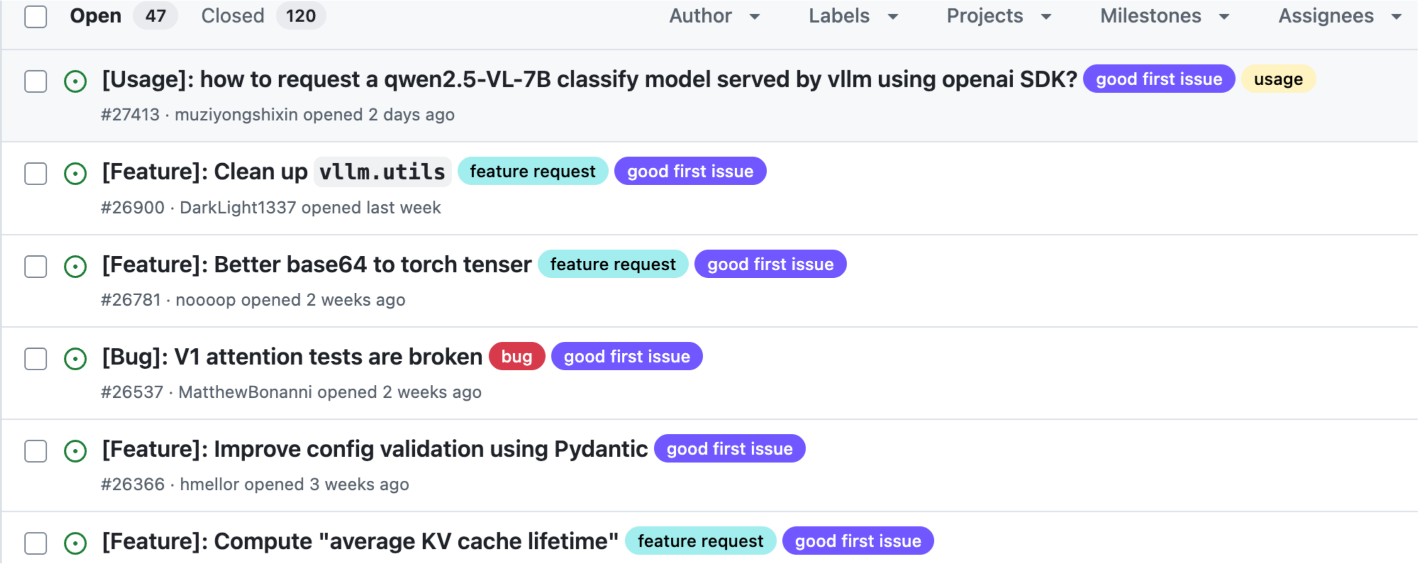
```
pytest -k <pattern> [tests/path/to/name.py]
```



```
└─➤  pytest -v -s tests/entrypoints/openai/test_completion_with_function_calling.py::test_named_tool_use
INFO 10-25 07:35:39 [__init__.py:225] Automatically detected platform cuda.
==================================================== test session starts =====================================================
platform linux -- Python 3.12.11, pytest-8.4.1, pluggy-1.6.0 -- /opt/conda/envs/vllm/bin/python3.12
cachedir: .pytest_cache
rootdir: /home/jovyan/vllm
configfile: pyproject.toml
plugins: anyio-4.9.0, asyncio-1.1.0
asyncio: mode=Mode.STRICT, asyncio_default_fixture_loop_scope=None, asyncio_default_test_loop_scope=function
collected 1 item

tests/entrypoints/openai/test_completion_with_function_calling.py::test_named_tool_use Launching RemoteOpenAIServer with: vll
m serve /home/jovyan/qwen3-8b --dtype half --enable-auto-tool-choice --structured-outputs-config.backend xgrammar --tool-call
-parser hermes --reasoning-parser qwen3 --gpu-memory-utilization 0.4 --port 55849 --seed 0
INFO 10-25 07:35:45 [__init__.py:225] Automatically detected platform cuda.
```

# Contributing

Search for "good first issue" labeled issues



□ **Open** 47   Closed 120   Author ▾   Labels ▾   Projects ▾   Milestones ▾   Assignees ▾

□ ⊙ **[Usage]: how to request a qwen2.5-VL-7B classify model served by vllm using openai SDK?** good first issue usage
#27413 · muziyongshixin opened 2 days ago

□ ⊙ **[Feature]: Clean up `vllm.utils`** feature request good first issue
#26900 · DarkLight1337 opened last week

□ ⊙ **[Feature]: Better base64 to torch tenser** feature request good first issue
#26781 · noooop opened 2 weeks ago

□ ⊙ **[Bug]: V1 attention tests are broken** bug good first issue
#26537 · MatthewBonanni opened 2 weeks ago

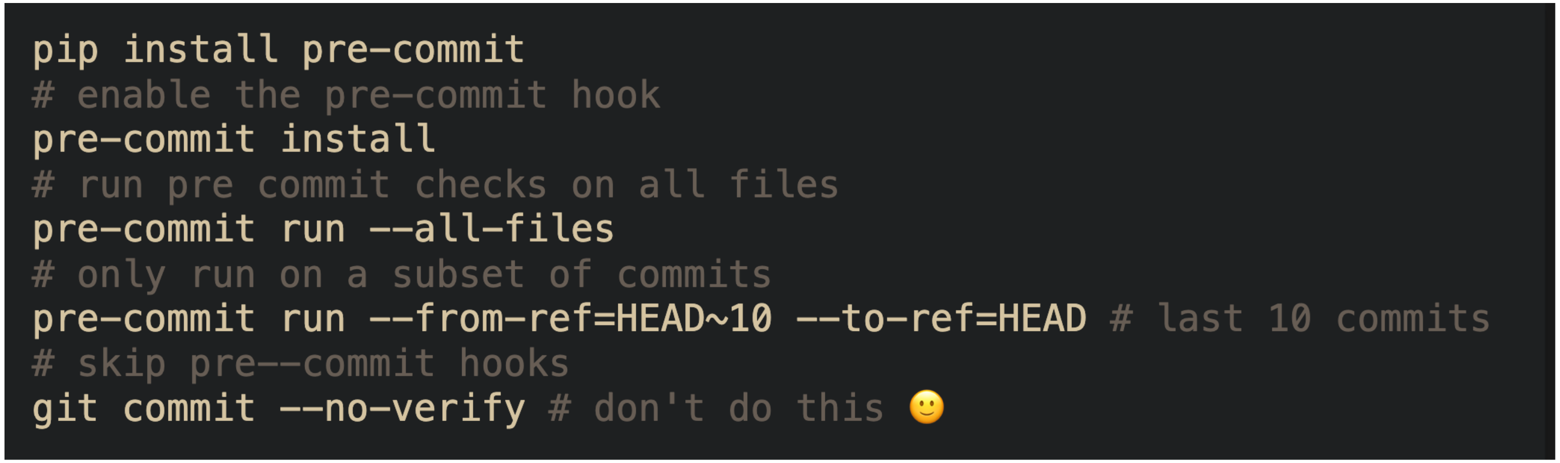
□ ⊙ **[Feature]: Improve config validation using Pydantic** good first issue
#26366 · hmellor opened 3 weeks ago

□ ⊙ **[Feature]: Compute "average KV cache lifetime"** feature request good first issue

# Contributing

- Signoff commits with git commit --signoff since Developer Certificate of Origin signoff is a required check

- Run pre-commit: pre-commit/pre-commit is used to enforce coding standards (formatting, linting)



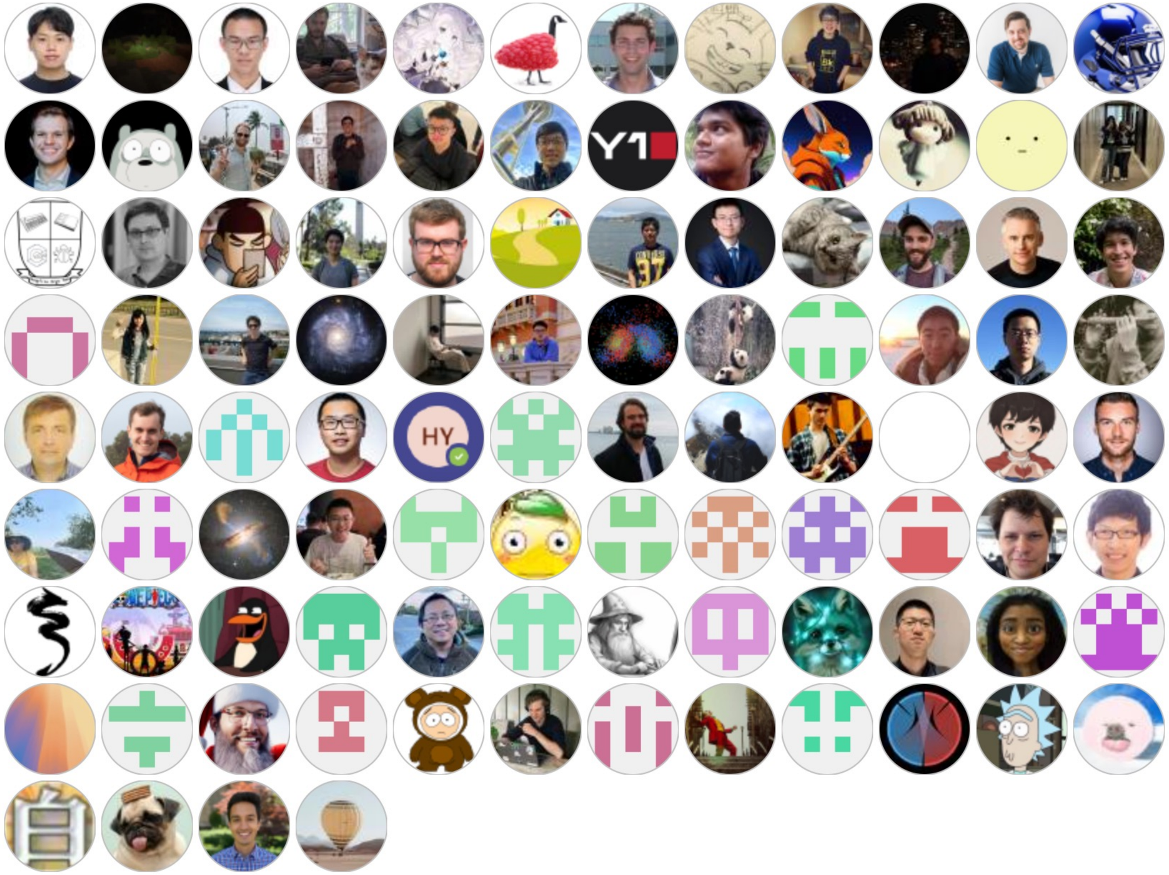
```
pip install pre-commit
# enable the pre-commit hook
pre-commit install
# run pre commit checks on all files
pre-commit run --all-files
# only run on a subset of commits
pre-commit run --from-ref=HEAD~10 --to-ref=HEAD # last 10 commits
# skip pre--commit hooks
git commit --no-verify # don't do this 🙂
```

# Contributing

- Write tests (unit/integration)
- Add documentation to docs/
- Keep changes small/incremental when possible

# Thank you contributors!

Thanks to 1700+ contributors who raised issues, participated in discussions, and submitted PRs!



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Building the fastest and easiest-to-use open-source LLM inference & serving engine!

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✉ vllm-questions@lists.berkeley.edu