Co-Operator: An LLM based AI assistant to support the operation of accelerators

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Large-scale accelerator facilities such as GSI/FAIR rely heavily on distributed expertise and fragmented documentation for daily operations, creating persistent challenges in knowledge retention, troubleshooting speed, and workforce continuity. To address these operational bottlenecks, we present an AI assistant designed to deliver context aware, expert level guidance to shift operators. Grounded in large language models (LLM) run locally on the GSI high performance computing infrastructure, the system integrates retrieval augmented generation (RAG) and structured prompt engineering to synthesize domain knowledge from internal wikis, technical manuals, historical logbooks, and online shift data. In addition to the prof of principle status, we present future development plans including incorporation of more knowledge sources, exploration of different LLM models and low-rank adaption and integration with the control system to access accelerator data in real-time.

Idea and Vision

- **Chat-based AI assistant** to support accelerator operation
- Fast, easy and targeted access to **expert domain knowledge**
- Contextual guidance esp. for new/part-time/on-call personnel

Proof of Principle Demo

Co-Operator

Experimental AI for chat based knowledge search and operating support

Max energy for SIS18 uranium beam?

Reasoning

The maximum energy for a uranium beam in SIS18 is limited by the synchrotron's maximum magnetic rigidity of **18 T·m**.

Depending on the ion's charge state, this corresponds to:

- **~1.35 GeV per nucleon** (`GeV/u`) for fully stripped $^{238}U^{92+}$
- **~322 GeV** total kinetic energy

Note on operational beams: In practice, uranium is often extracted from SIS18 with a lower equilibrium charge state (e.g., $^{238}U^{73+}$). Since rigidity limits momentum-per-charge (p/q), a lower charge state yields a proportionally lower kinetic energy per nucleon at the 18 T·m limit. Historically, reaching **1 GeV/u** was the key commissioning milestone for uranium beams at SIS18.

Sources and further information:

- OPE Wiki: Maximale Strahlparameter
- GSI Website: Accelerator Complex & Research Capabilities
- Glossary: SIS18 parameters

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List counters in HHD branch.

Reasoning

Based on the facility nomenclature, there are **no dedicated veto counters** (`DV`) **or radiation safety monitors** (`SM`) installed in the **GHHD** (High Dose Experiment, commonly used as the SIS18 beam dump) branch.

However, the following beam diagnostic devices in the GHHD branch function as particle counters or intensity monitors:

- `GHHDDI2P` : Plastic scintillation counter (Impulsmonitor)
- `GHHDDI2S` : Secondary electron transmission monitor (SEM)
- `GHHDDI2I` : Ionization chamber
- `GHHDDT1C` : Beam transformer (*Strahltrafo*) for fast current/ intensity measurement

Additional beam diagnostics in the branch:

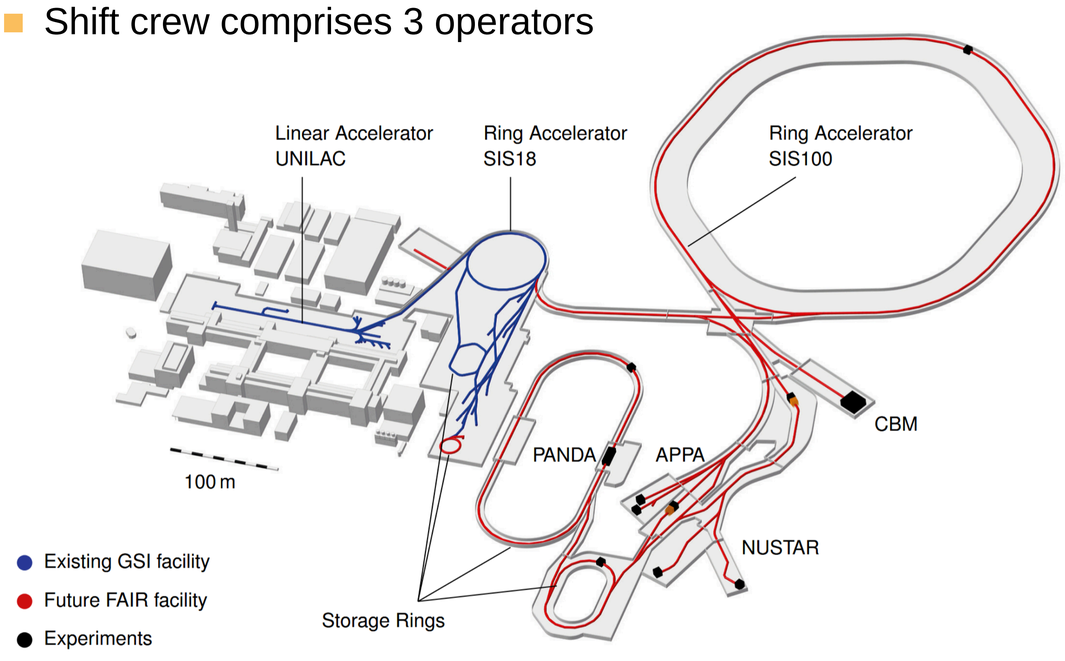
- **Fluorescent screens:** `GHHDDF1` , `GHHDDF2` , `GHHDDF12`
- **Profile grids:** `GHHDDGA` , `GHHDDG2` , `GHHDDG3`
- **Beam position monitor (BPM):** `GHHDDX3`

If you were looking for a specific type of counter (e.g., experimental detectors, radiation dose counters, or devices in an adjacent transfer line), please clarify and I will refine the search.

Agent response to two exemplary prompts

GSI and FAIR accelerators

- Huge facility comprising several linear and ring accelerators, fragment separators, storage rings and decelerators
- Large variety of beam users including fundamental research, industrial, space and medical applications
- Deliver beams from protons to uranium and exotic secondaries
- Shift crew comprises 3 operators



Accelerator facility of GSI and FAIR in Darmstadt

Concept

- **Agentic system**
  - Based on open source LLMs (qwen3.6-27b / gpt-oss-120b)
  - Runs on local cluster infrastructure
  - Engineered system prompt
  - Reasoning loop with extensive tool set
  - Retrieval-augmented generation (RAG) pipeline for domain knowledge search in wikis & internal websites
- **Explain-ability and user trust**
  - Transparent thought & tool calling process
  - Citation of sources & further reading

Let's do a quick search.

Tool call: `gsi_fair_knowledge_base {"query": "SIS18 uranium maximum energy"}`

The search results show that SIS18 has a maximum magnetic rigidity of 18 Tm. From the GSI website: "Ions of all maximum rigidity of the SIS." Also: "GSI provides ion beams of all stable elements up to uranium with energies f Actually, let's calculate the exact energy for Uranium at 18 Tm. Uranium-238, charge state typically around 73+ o

Reasoning excerpt showing though process and tool usage

Tools

- Provide agent with capabilities:
  - Access domain knowledge
  - Perform calculations & verifications
  - Collect information & states

Isotopes
- Periodic table
- Nuclide chart

Knowledge
- RAG pipeline
- Wikis & docs
- Websites

Nomenclature
- Devices
- Areas
- Buildings

Acronyms
- Accelerator
- Technical
- Administrative

Calculator
- Unit conversion
- Ion calculator
- Formulas

Lattice tool
- Ion optics

Verification
- URL check

Logbook
- Operational
- Historical

Monitoring
- Interlocks
- Radiation
- Logging

Machine state
- Beam schedule
- Timing system
- Device status

Implementation

- Agent and pipelines built with haystack by deepset
- Tools built in python
- Deployed as chat completion endpoint using hayhooks
- Demo client (CLI & UI) for test & devlopment