



中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

AI for HEP experiment

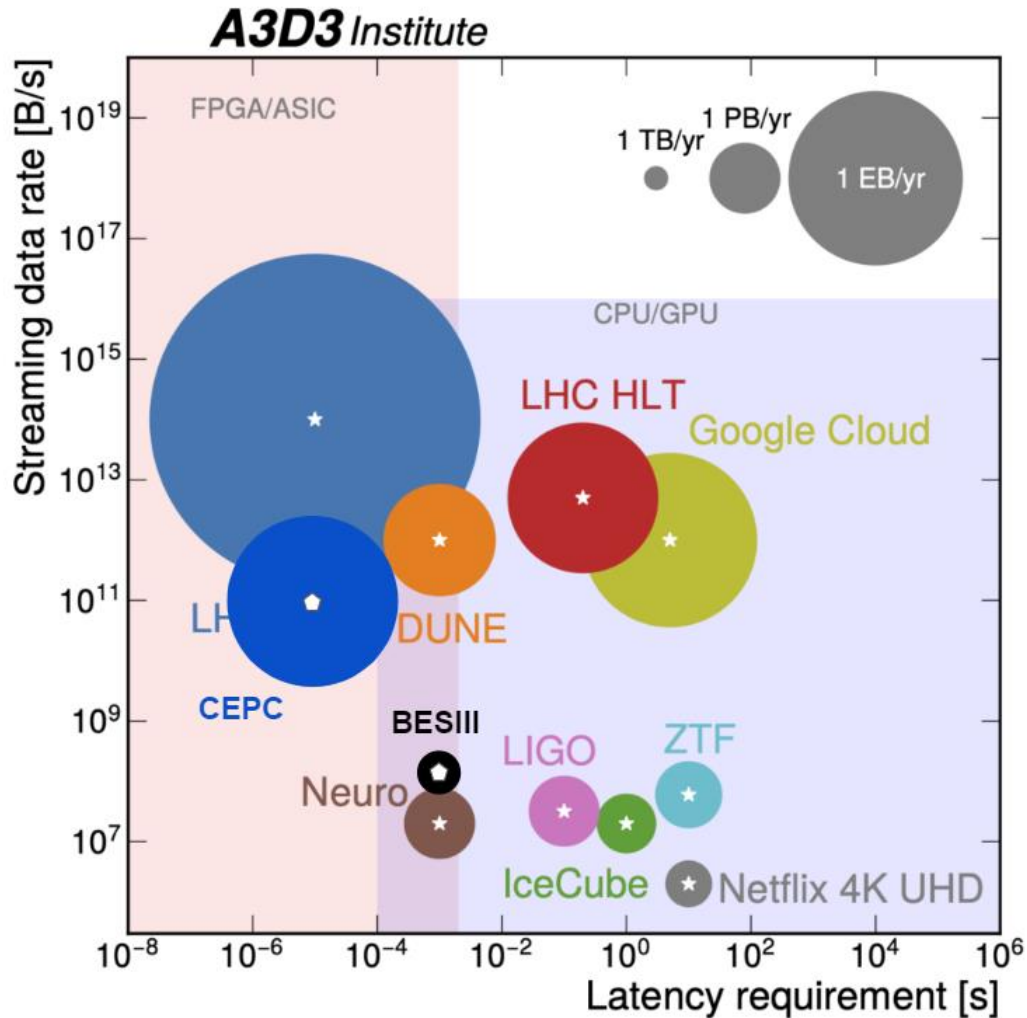
Personal overview

with a focus on LLM

Ke Li (like@ihep.ac.cn)

Institute of High Energy Physics, CAS

HEP experiment \approx Big Data



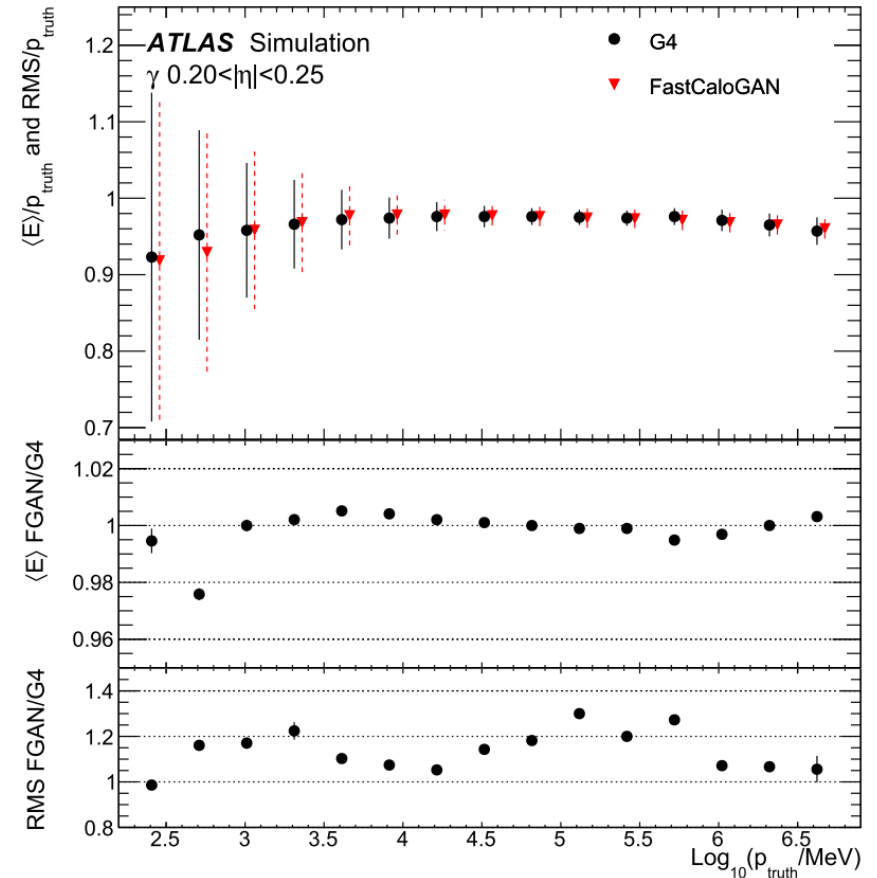
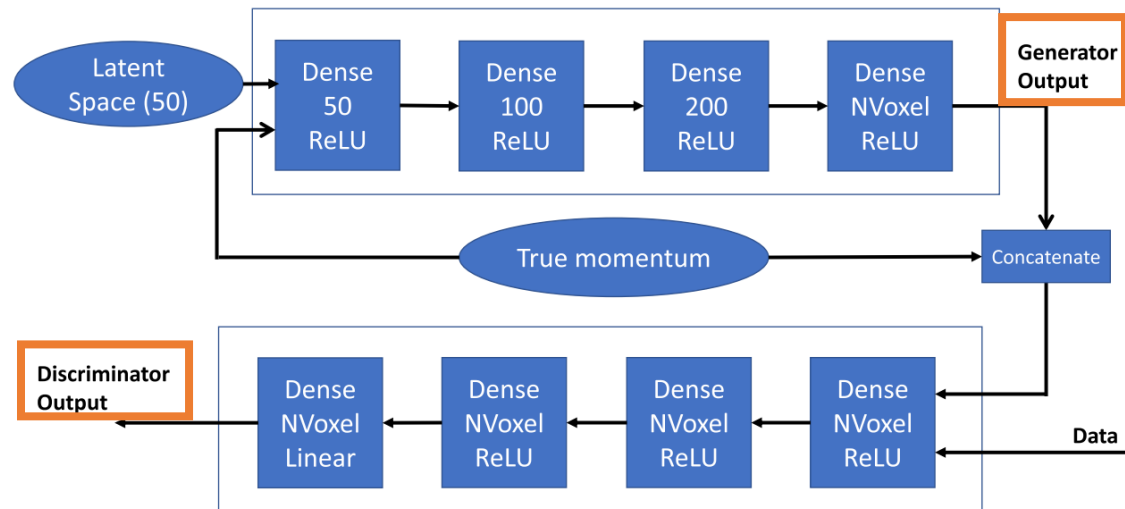
- One of the main challenges
 - How to analyze the data **efficiently** and **accurately** ?
- Most promising solution
 - **AI/ML**

Outline

- State-of-art ML studies for HEP data analysis
 - Simulation
 - Tracking
 - Jet tagging
 - Un-supervised learning
- LLM-based AI assistants
 - Data analysis assistant
 - Online monitoring and shift assistant
 - Academic research support platform
- Summary and prospects

Simulation - CaloGAN

- Generator: generate relative deposit energies in each voxel
- Discriminator: discriminate if the input is generated or real
- A few hundreds time faster



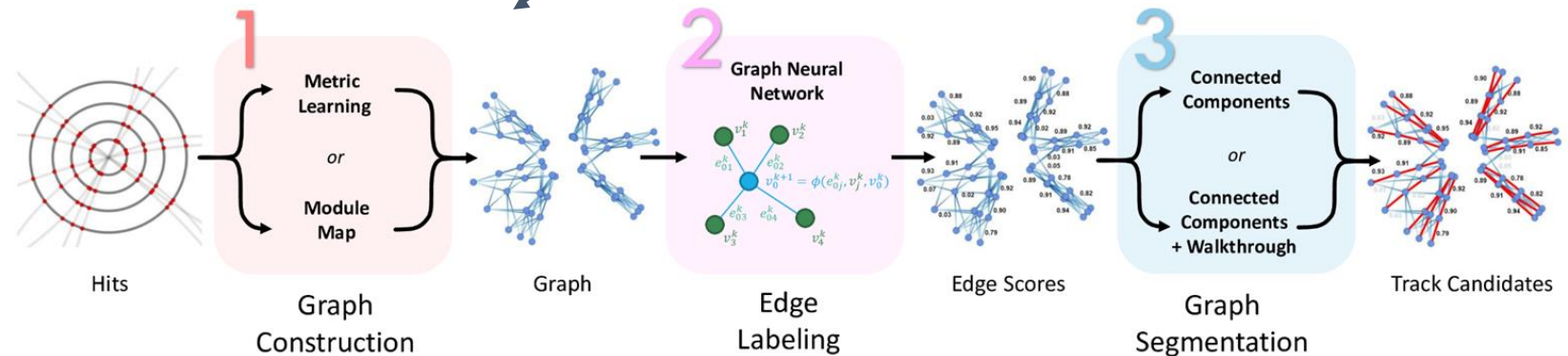
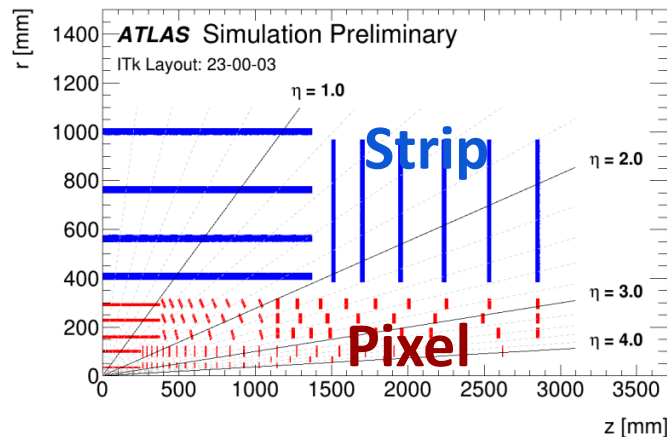
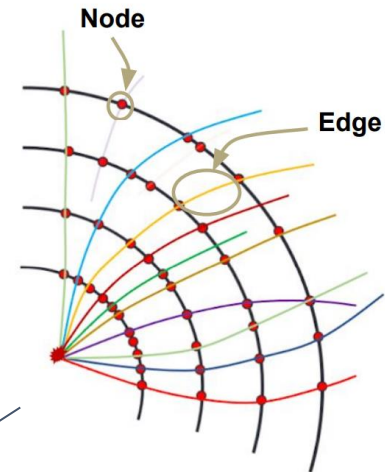
New ideas: diffusion model([arXiv:2405.10106](https://arxiv.org/abs/2405.10106)), sim+reco in one model([arXiv:2406.01620](https://arxiv.org/abs/2406.01620))

GNN track finder in ATLAS

Convert event to graph:

- Represent each hit as a node
- Connect nodes by edges
 - Edge means two hits belong to the same track
- Edge classification
 - Classifies edges as true or false by assigning score to each edge
- Graph: track candidate, a list of nodes based on edges
- Trained on simulated events in InnerTracker (ITk)

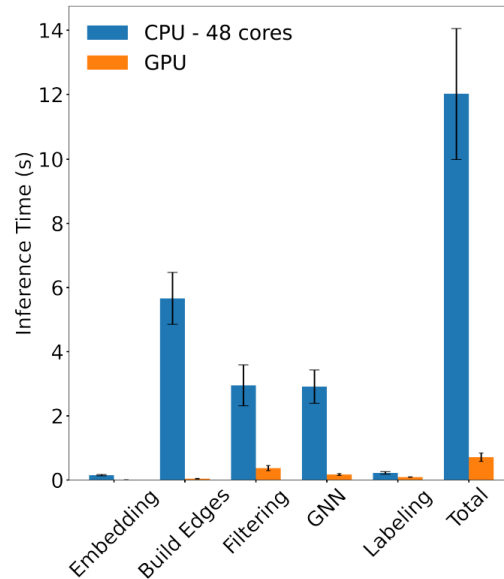
Track finding = connecting the dots



GNN track finder

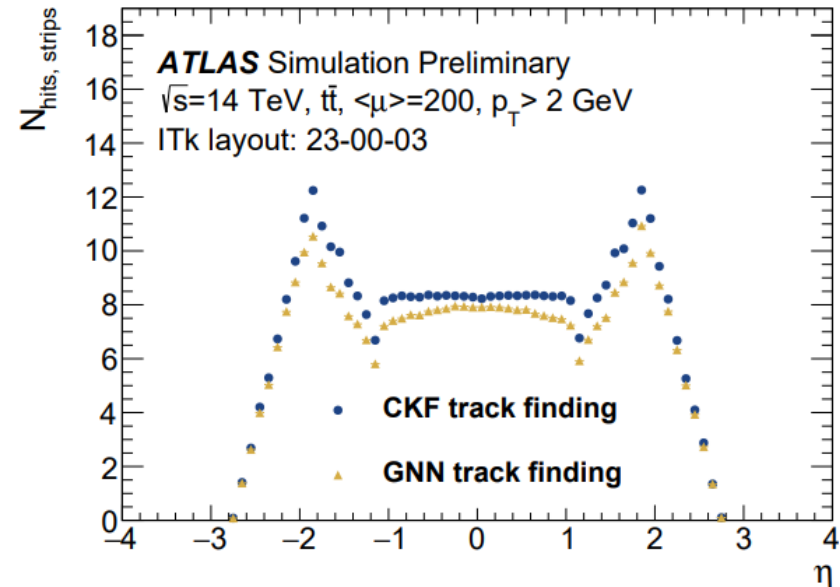
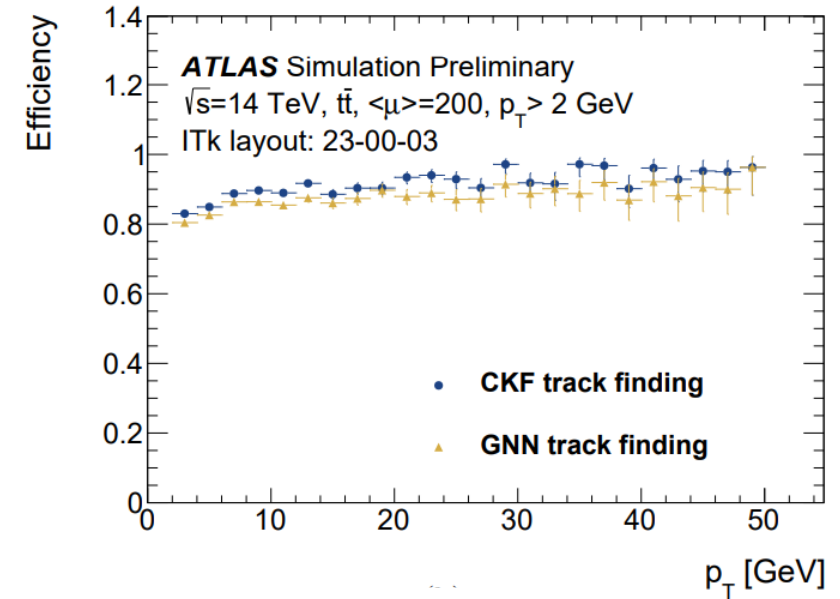
Preliminary comparison to the traditional approach, combinatorial KalmanFilter (CKF)

- Slightly lower efficiency, but at the same level
 - Need further optimization
- Less strip clusters
 - Overlap strip modules are not considered yet
- One advantage:
 - Much faster on GPU

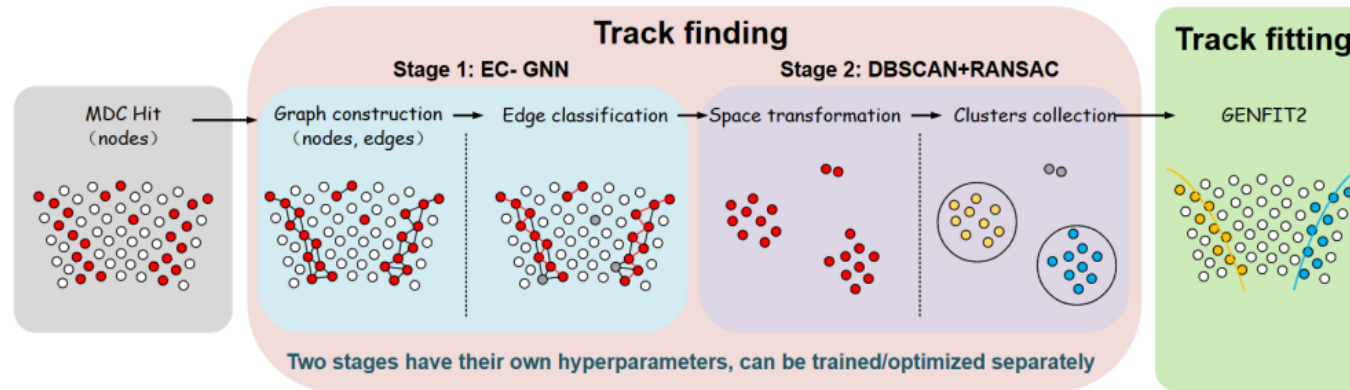


[ExaTrk](#)

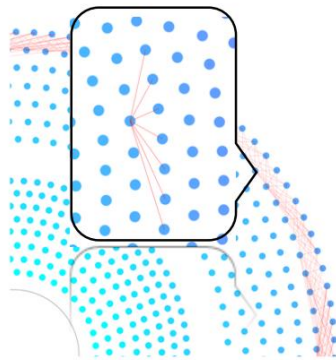
[ATL-SOFT-PROC-2023-047](#)



GNN tracking in BESIII

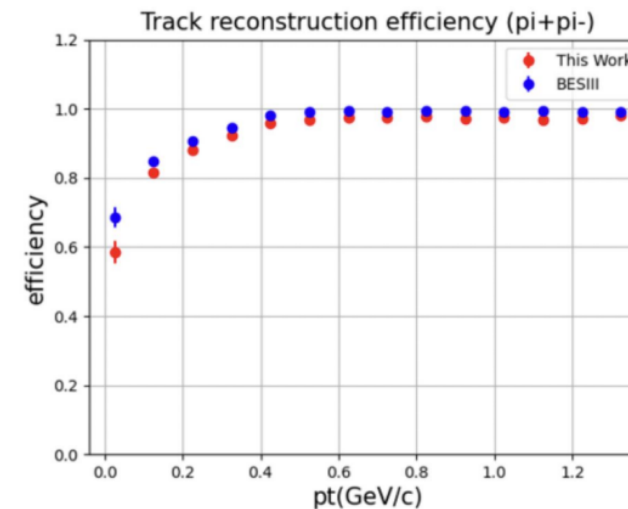


Similar approach, but with **pattern map** to constrain the edge assignment.



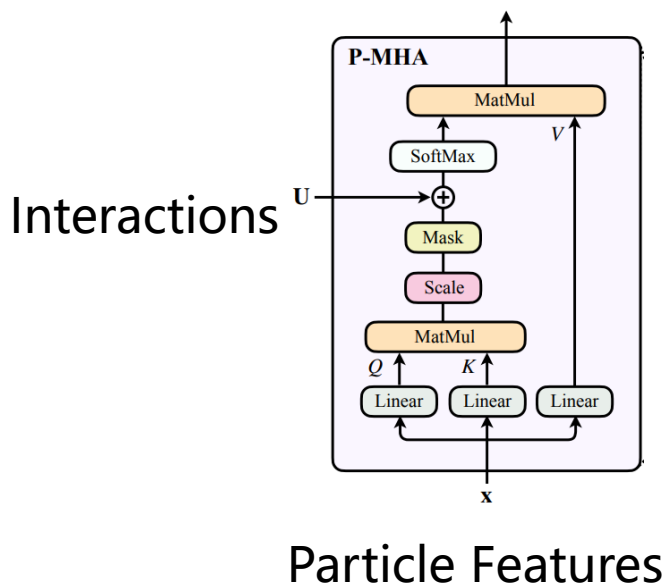
A wire on layer13 and tits neighbors on layer14

Similar performance to start-of-art traditional method.

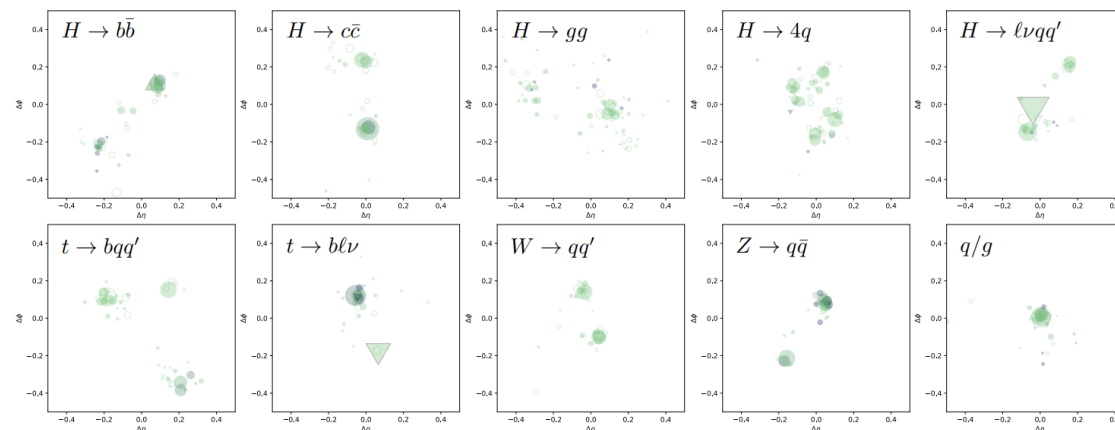


Jet tagging – ParticleTransformer in CMS

Particle Attention Block = Particles exchanging information

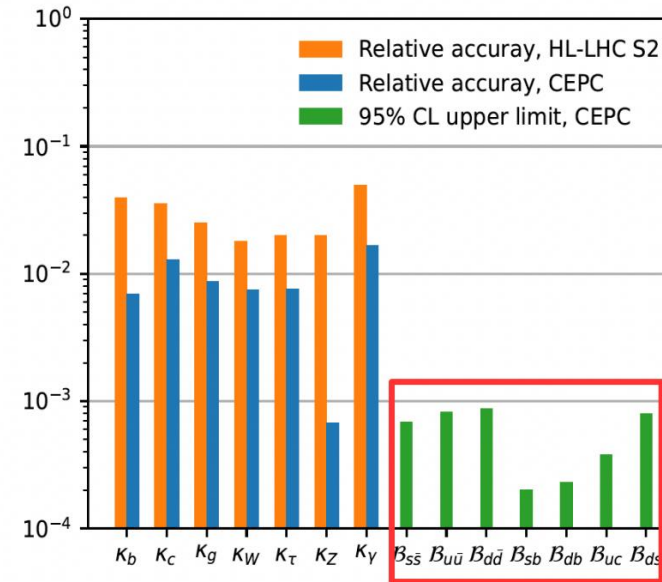
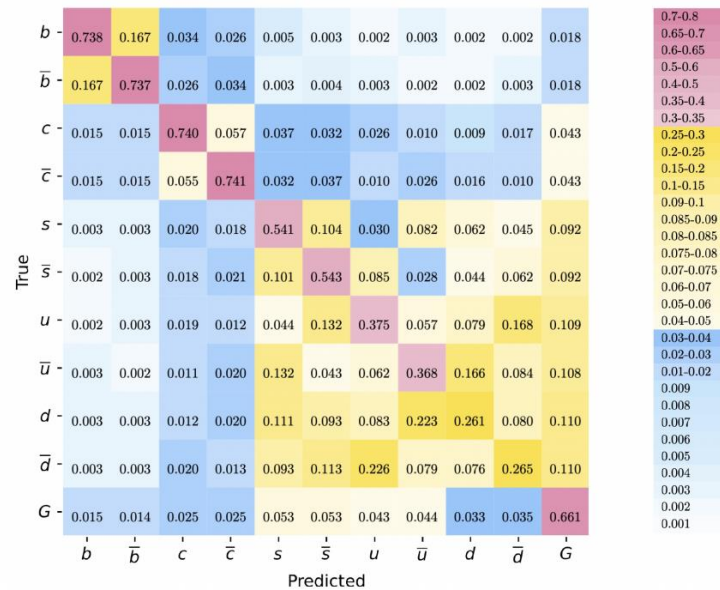


Tagging performance from JetClass dataset



Many talks on JetTagging in this workshop,
For more info, please refer to Congqiao's talk

Jet tagging in CEPC



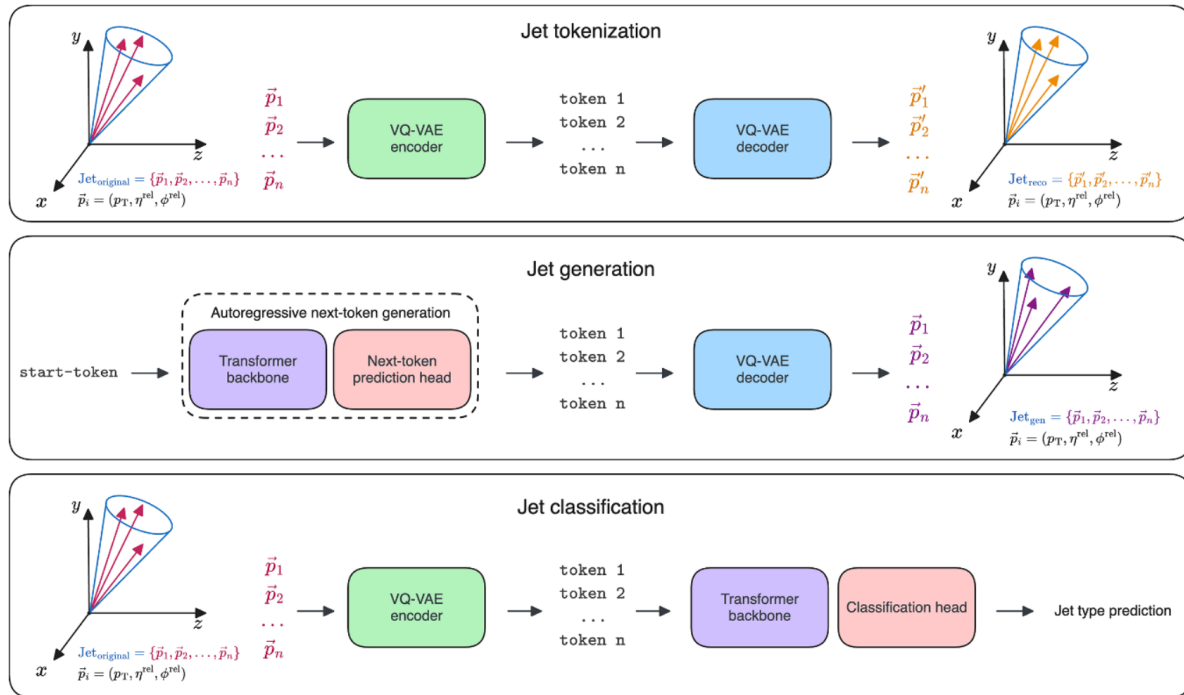
- 11 categories (5 quarks + 5 anti quarks + gluon) identification based on ParticleTransformer, realized at Full Simulated di-jet events
- Improves Higgs rare/exotic hadronic decay measurements **by 3 time – two orders of magnitudes**

Two interesting ideas

OmniJet-alpha:

First, let the model “understand” jet

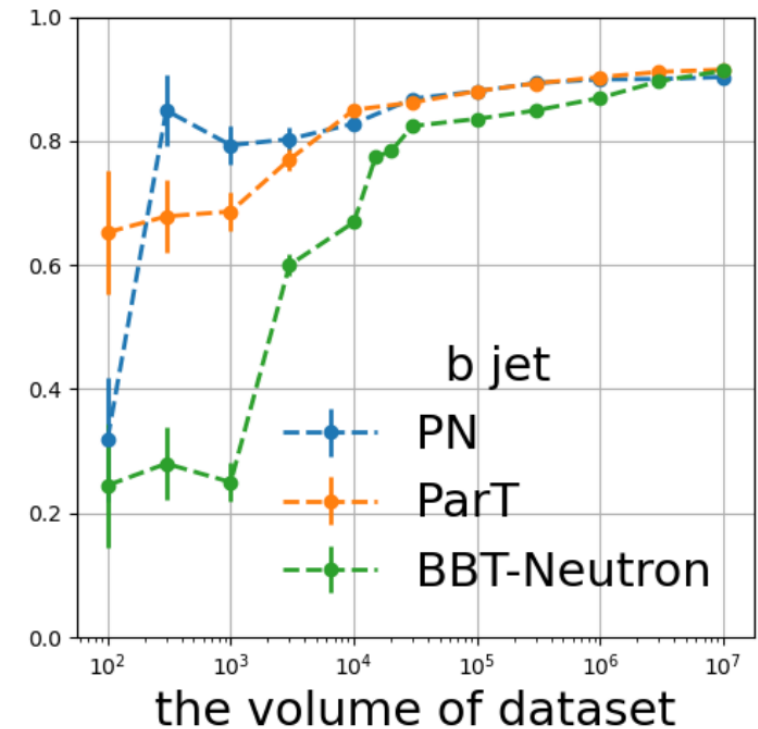
Second, transfer the “knowledge” to specific task



BBT-Neutron:

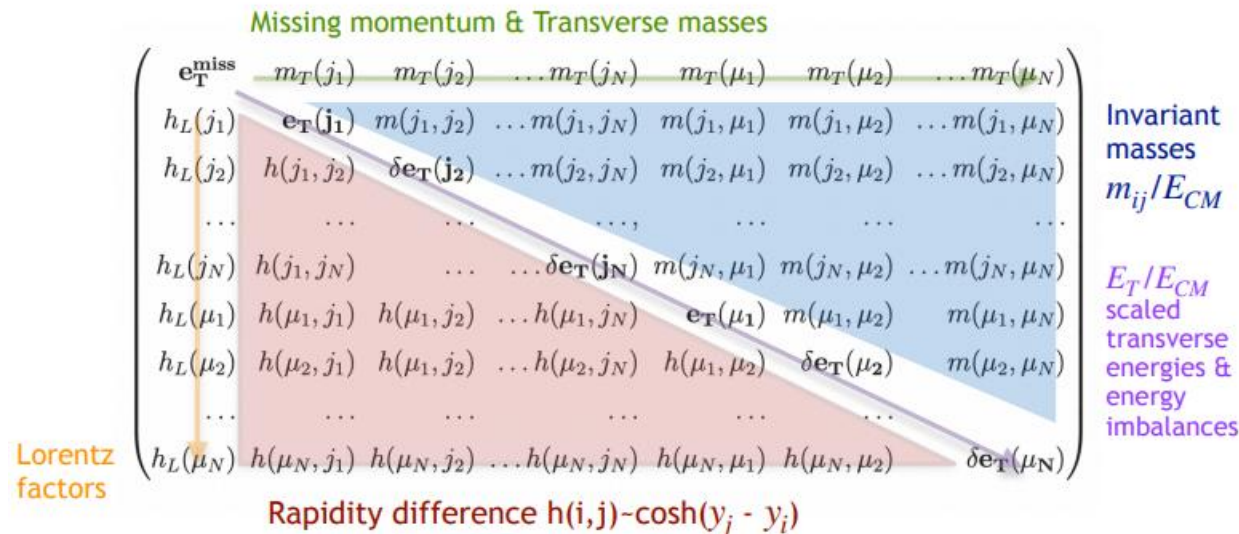
Take jet as “language”

Interesting scaling law



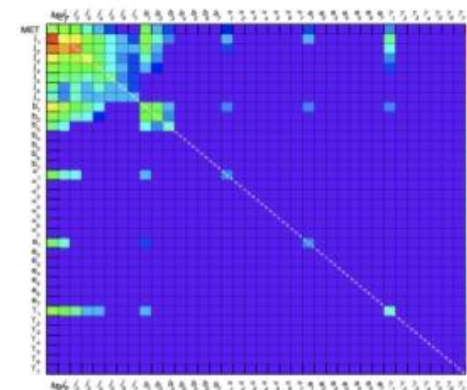
Anomaly detection using unsupervised ML

- Model independent search
- Use ML to define anomaly region
 - Train the NN to learn the SM events from **data**
 - Input features are Rapidity Mass Matrix constructed from final states object kinematics
 - RMM was found to produce more robust AutoEncoder(AE) training
 - Expected to have different characteristics for different processes

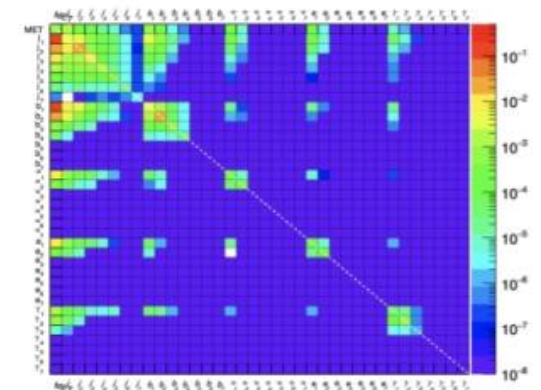


Example

Multi-jet QCD process

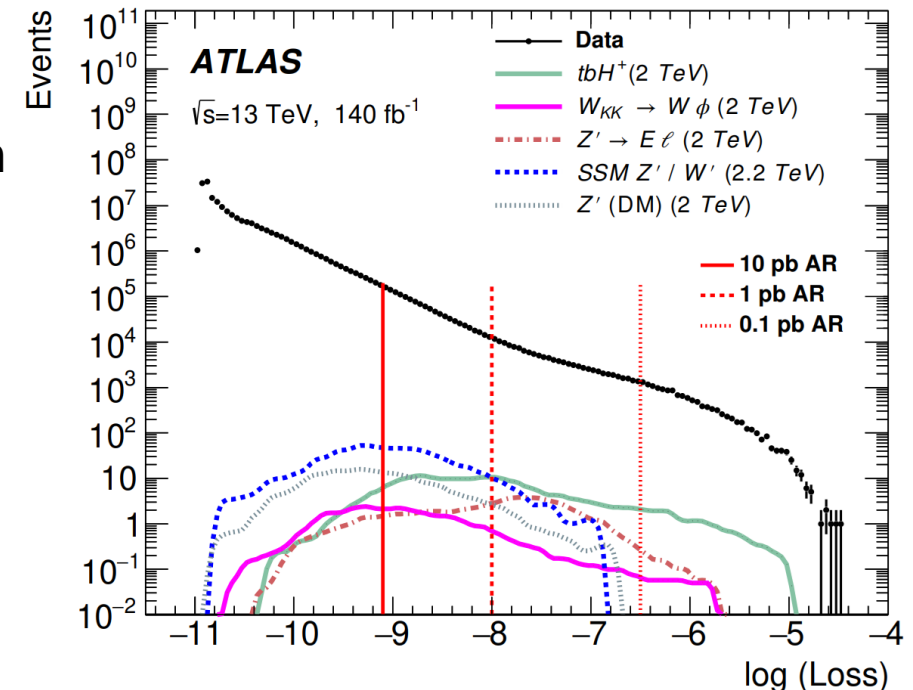
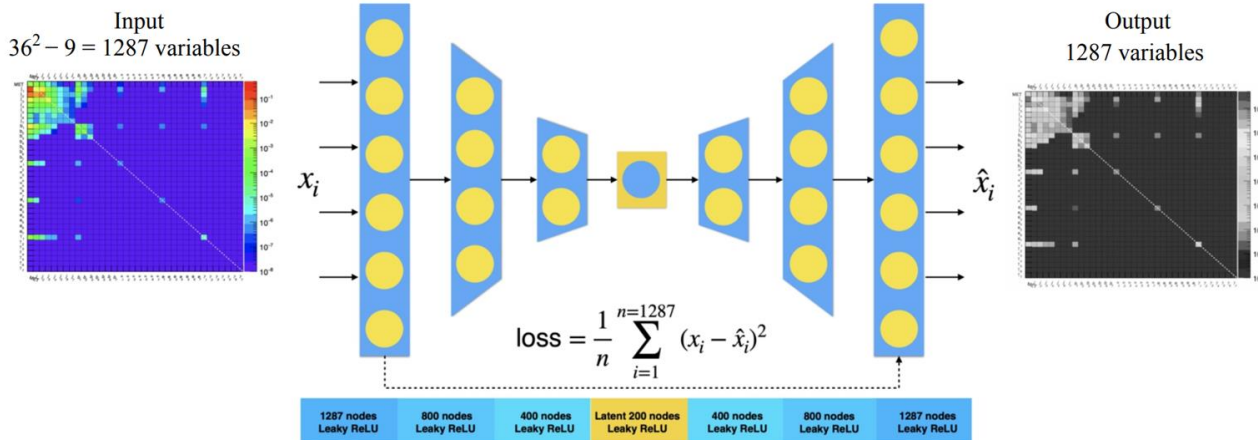


Higgs process



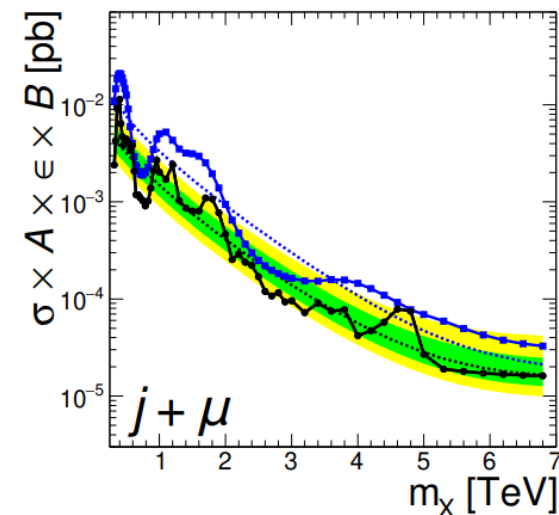
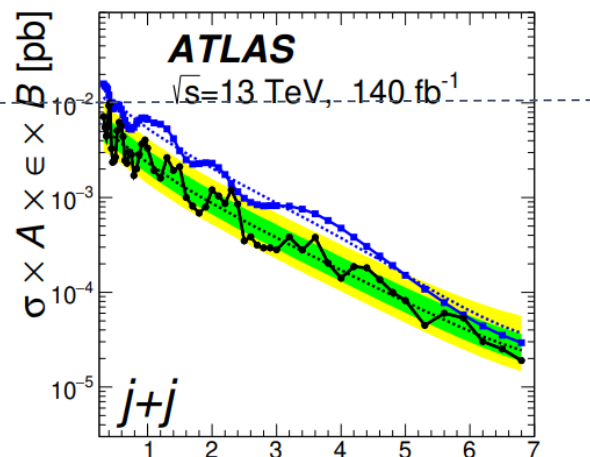
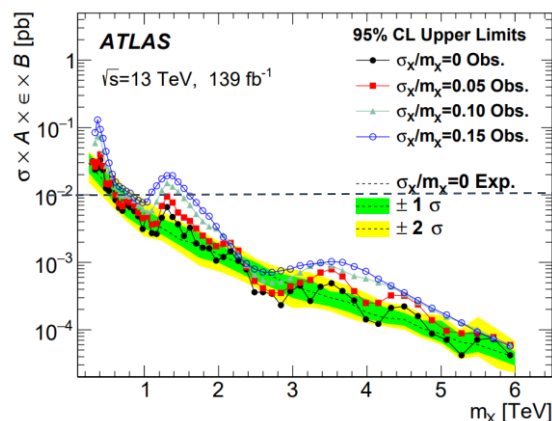
Anomaly detection using unsupervised ML

- Trained with randomly selected 1% events
 - Sufficient statistics to train and well represent the full collision dataset
 - Expected to have no anomaly (signal) events
 - Even if there are, shape of anomaly score is not expected to produce bumps, so search for the enhancements should not be affected significantly
- Define anomaly region
 - Should enhance BSM signal
 - 3 regions for different assumption on cross sections
- Then do bump-hunting on 2 object mass spectrum



Anomaly detection using unsupervised ML

- Searched in 9 invariant masses including $j+j$, $b\text{-jet}+j$, $j+e/\mu$
- Largest deviation reported by BumpHunter is at $m(j+\mu) \sim 4.8$ TeV, local significance 2.9σ
- For $j+j$, the limits are factor 2-3 better than a dedicated search
- Demonstrated the successful application of unsupervised anomaly detection using event level info



Dedicated search for $j\bar{j}$

LLM-based AI assistants

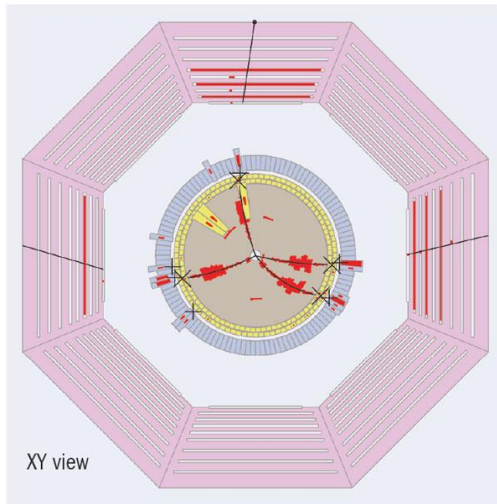
- Many generic LLM models, e.g. GPT/LLaMa/Gemini
 - astonishing capabilities in recognition and **generation of text/code**
- How it can help us
 - Text-related works
 - Coding and debugging
 - Understand heterogeneous sources of knowledge
 - Assistant, could be a teacher
- Many projects on-going
 - Dr. Sai (赛博士)
 - chATLAS
 - TAO online monitoring system
 - HaiAcademic

Why we need LLM

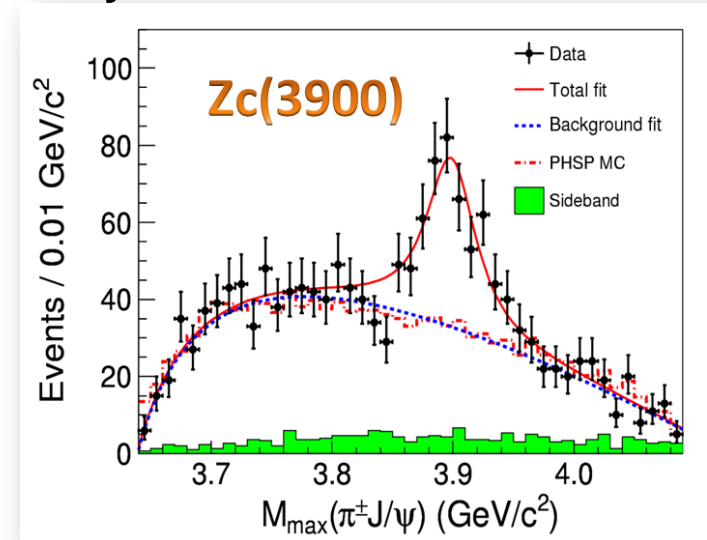
- Major effort in BESIII analysis is spent in writing/testing/updating code/text
 - **LLM is good at code/text generation !**
- Key problems for LLM at HEP
 - How to make sure the outputs are reliable?
 - How to avoid hallucinations ?
 - Current solutions:
 - **More accurate and good quality data for training**
 - **More tests and validations**
 - **More proper architecture**

Data processing and analysis

Collision event



Physics result



DAQ->Hits -> reconstruction -> selections and statistical analysis -> physics results extraction

Can we use AI(LLM) to automate the workflow ?

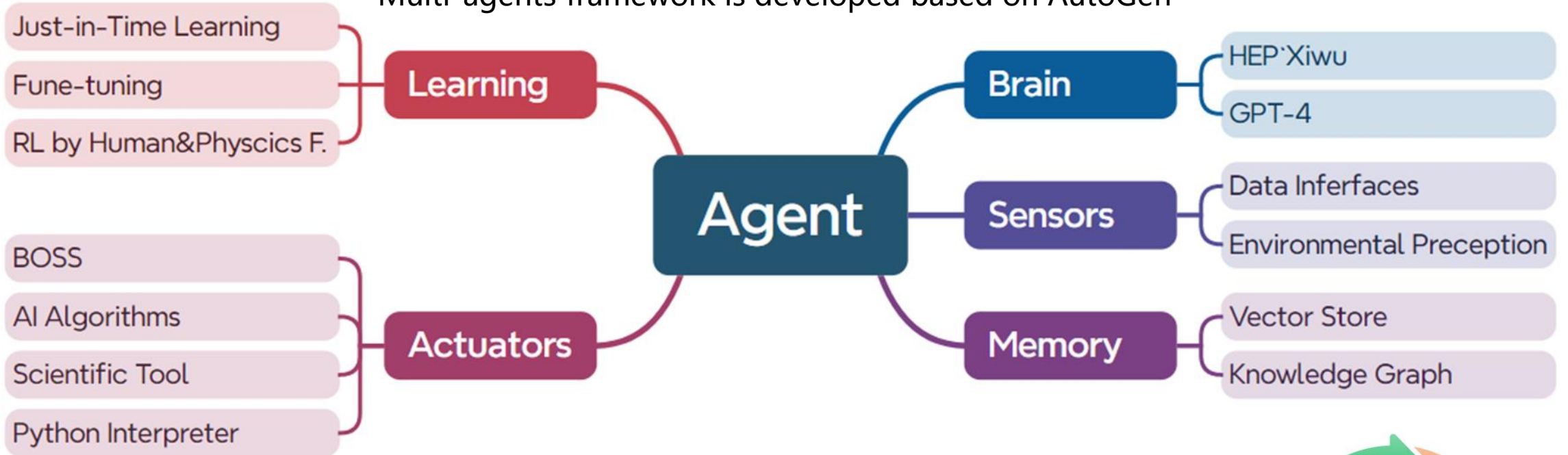
Take BESIII as an example

Dr. Sai (赛博士) project for BESIII/HEP

- AI Agent: AI tools capable of autonomously performing complex tasks
 - LLM = brain -> AI agent = human
- AI agent based on **Xiwu** model (LLM for HEP)
 - based on Llama 2/3, will train with BESIII internal data, e.g. internal docs, BOSS source code, Q-As from internal review
- One milestone: **AI assistant** (<https://drsai.ihep.ac.cn>)
 - chatbot, MC generation, signal extraction, and a navigator inside BESIII
 - Capable of simple task
 - **Ready for BESIII internal test !**
- Final goal: **AI scientist**, it can analyze the collision data automatically and understand the physics behind data
 - Developing new AI models, targeting at ~2026-2027

Dr. Sai

Multi-agents framework is developed based on AutoGen



Key of this project:

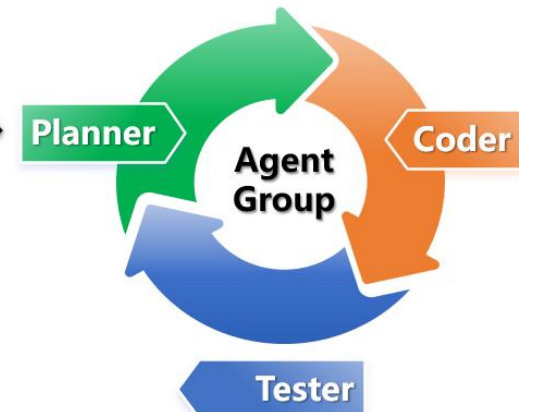
make the results from AI more reliable

- Good quality data
- In-the-fly validation and test
- Multi-agents architecture

Main Agents:

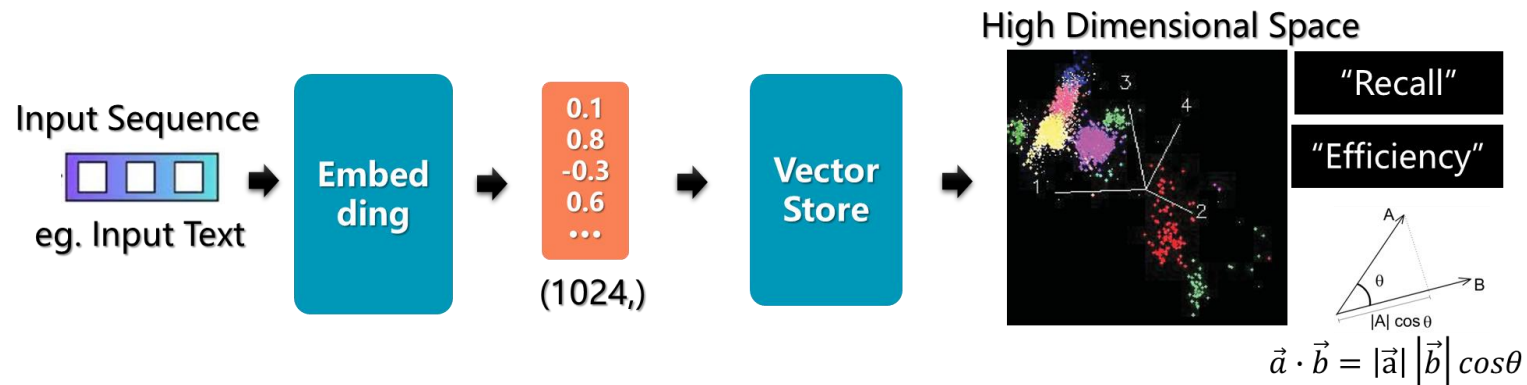
- Planner: Planning and tasks decomposition
- Coder: Write BOSS code
- Tester: Using scientific tools for testing

Scientist ↔



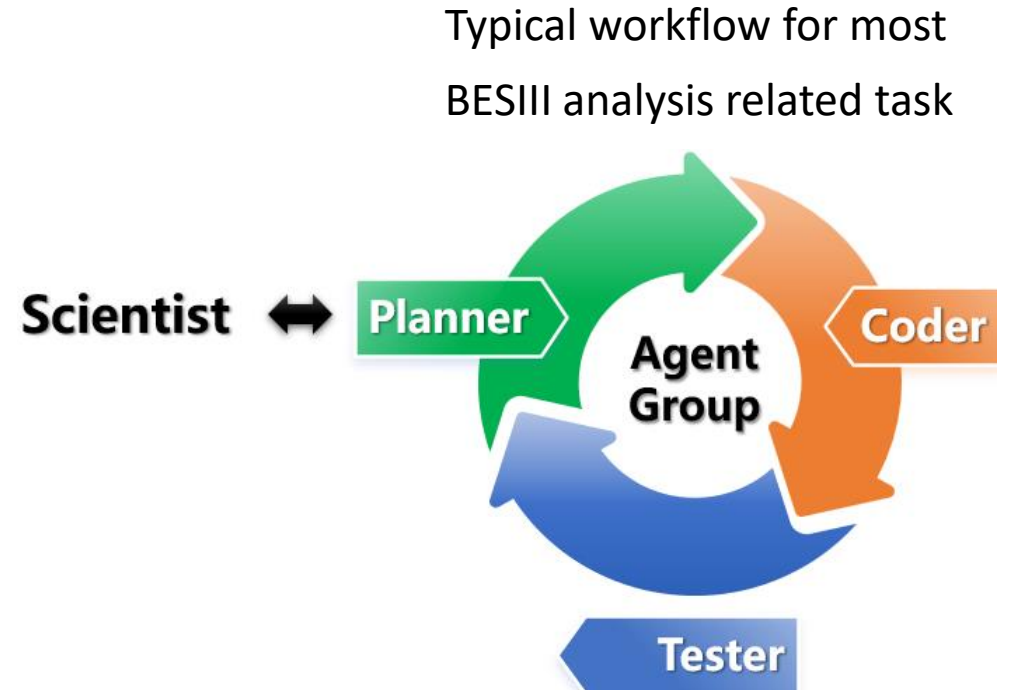
The Memory of Dr. Sai - RAG

- Retrieval-Augmented Generation (RAG)
 - Most promising solution to avoid hallucinations
 - Goal: store private data so no need for retraining
 - Current approach: vector store
 - Embeddings (BGE-M3 or [physBERT](#) model):
 - Convert input data into vectors of a multidimensional space
 - Usage: store BESIII internal data
 - user send BESIII related questions
 - RAG return question + BESIII internal data to LLM



Multi-agents management system

- Developed based on AutoGen framework
- Normally one agent is dedicated for one task, HEP data processing is very complicated, impossible for one agent
- Multi-Agents (foundation model is switchable):
 - **GroupChatManager**
 - **Planner**: Planning and tasks decomposition
 - **Coder**: Write C++/python/BOSS code
 - **Tester**: Using scientific tools for testing/execution
 - **Charm**: BESIII internal assistant
 - Common tools: arXiv navigator, plotting et.al.
- Human can interact via HumanProxy



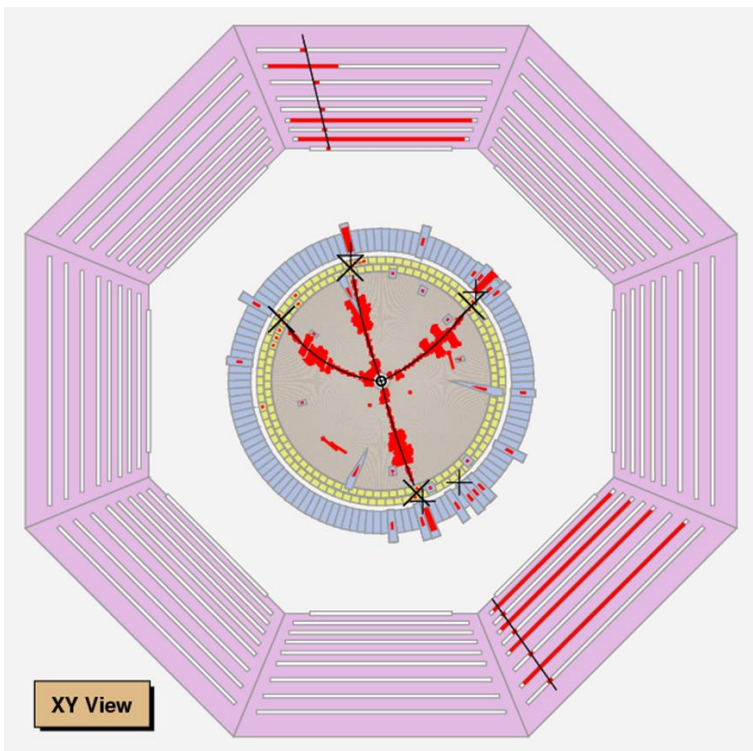
- If test failed, the feedback will be used to improve the prompts at next iteration.
- For each task, we have multi-unittests

Towards Dr. Sai V2

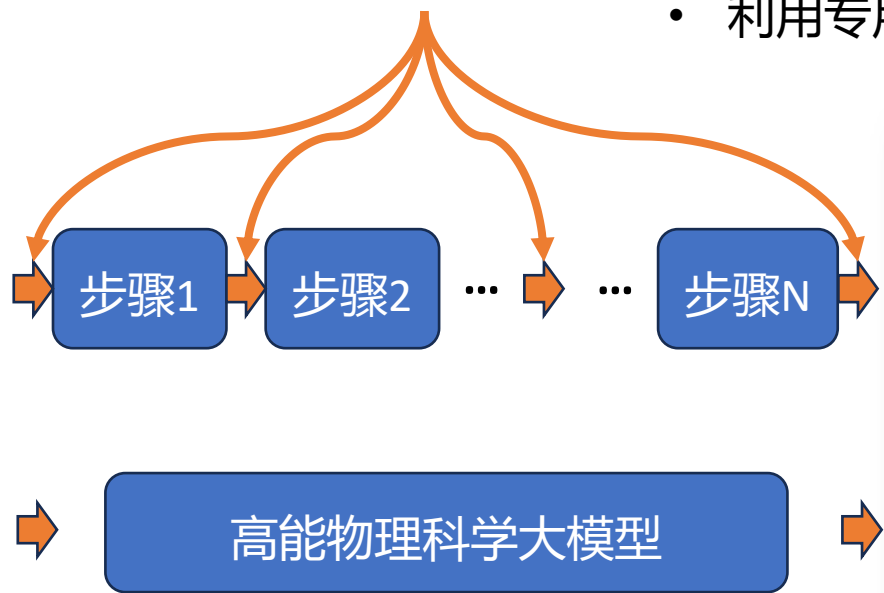
- More proper knowledge representation
 - Vector store -> **knowledge graph**
- Better agents interaction logic
- Better quality data
 - Manually parsed **DSL** (domain specific languages) for HEP analysis
- Comprehensive evaluation system

Lots of on-going activities, stay tune

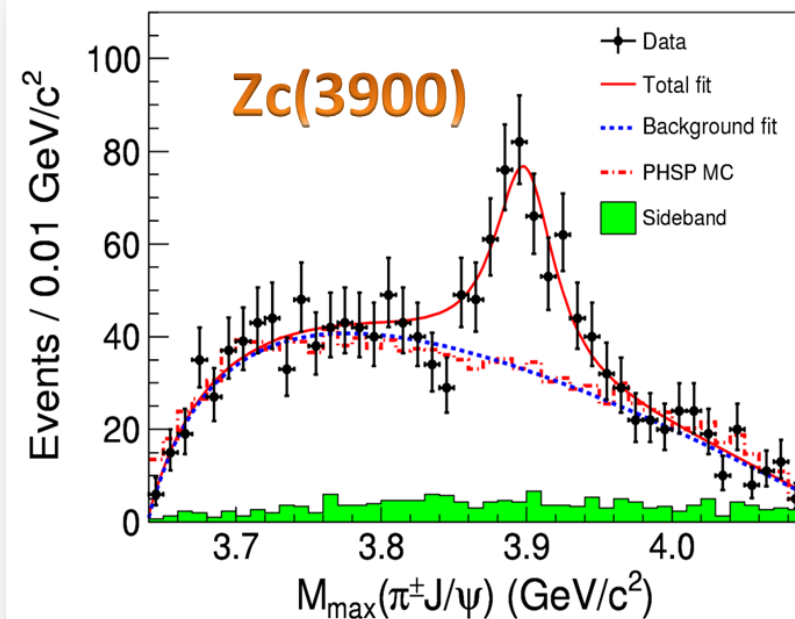
Future plans



Dr. Sai



- 利用专家反馈强化学习持续升级语言模型
- 利用专用模型改善各步骤



- 高能所于2024年10月份成立机器学习合作组，共同推进ML/QC相关工作，欢迎大家加入
- 多个项目支持，亟需人力

AI assistant: chATLAS

- An AI Assistant for the ATLAS Collaboration, chATLAS
- Inspired by the chatGPT
- Motivation:
 - An assistant which understand the internal heterogeneous sources of knowledge, e.g. twiki, indico, cds
 - Provide quick and accurate search result and summary
 - Long-term plan: debugging software
- Use GPT3.5/4 as backend
- PDF files from cds/indico scraping shown with Nougat and Marker
- Status:
 - Prototype finished
 - Preparing more data

ATLAS Twiki

- Start with set of "Starting URLs"
- Recursively visit included links
- Find all headers, and visit content below
- Append metadata of twiki (parent structure, date revised, etc.)

CDS

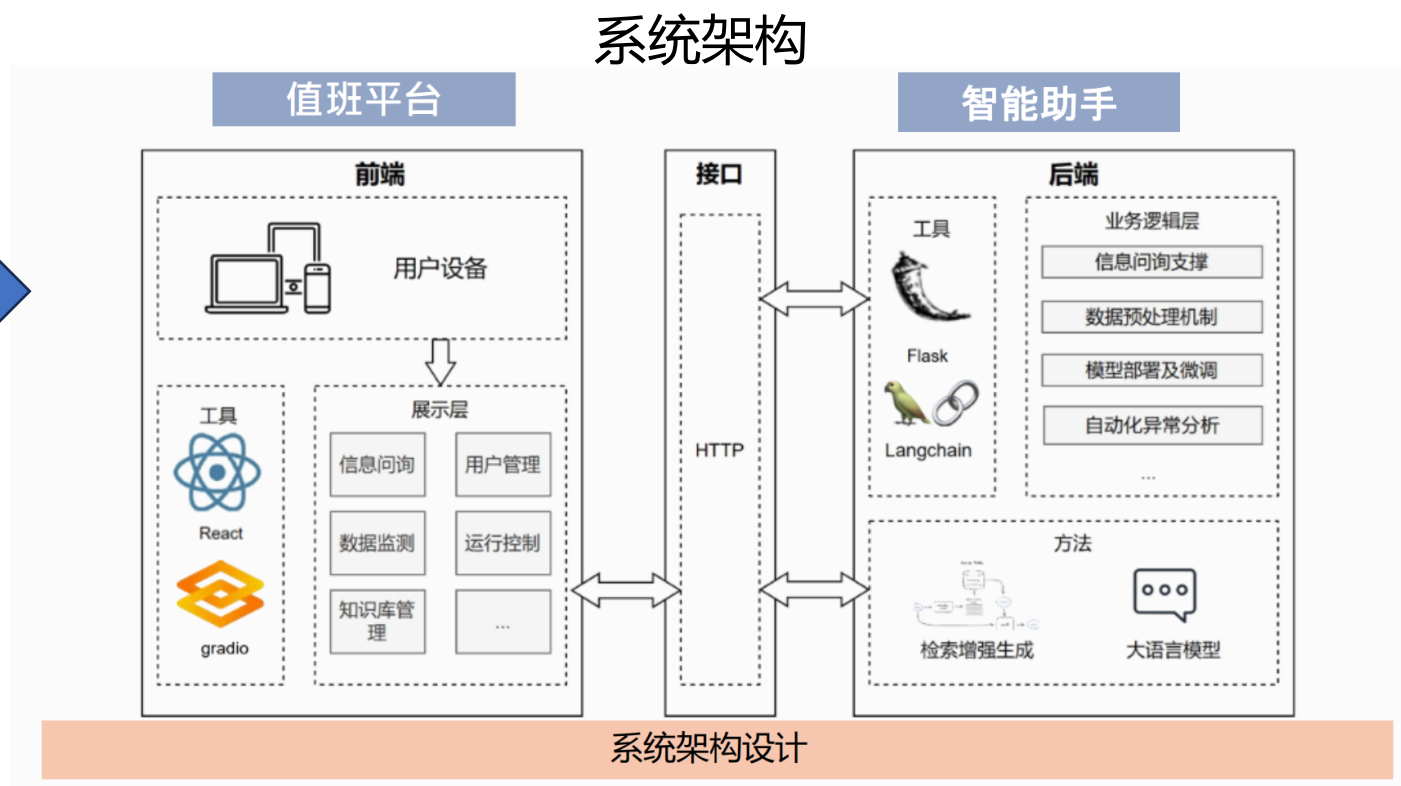
- Discover whether the CDS paper has a Gitlab latex repo
- If latex exists, pull from repo and (planned) convert to markdown
- (Planned) Use **unstructured** library to parse markdown
- If latex *does not* exist, use **nougat** library to read PDF (including equations) into markdown

Indico

- Load event list
- Scrape timetable contents (date, title, speaker, etc.)
- (Planned) Pull PDF slide decks and minutes
- (Planned) Parse in the same way as in CDS

TAO台中微子实验智能值班助手

- 目标：远程稳定的智能化值班助手
- 内容：
 - 远程在线监控实验数据
 - 实验故障及异常自动告警
 - 智能化地分析各类异常
- 现状：
 - 基于Qwen2-7B
 - 知识问答功能
 - 自动化异常分析测试
- 可扩展至其它实验

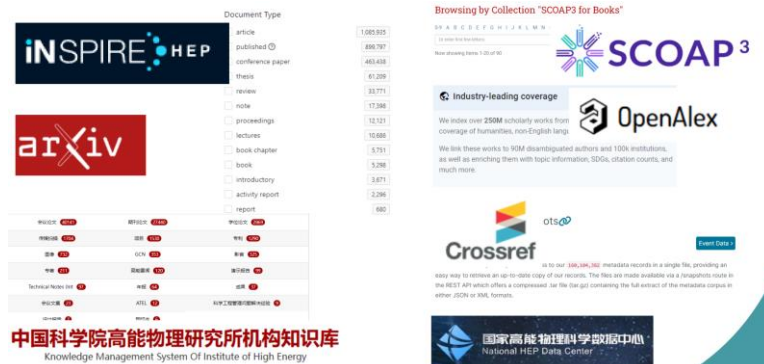


高能物理知识底座&智能科研/文献助手

- 目标：助力科学研究

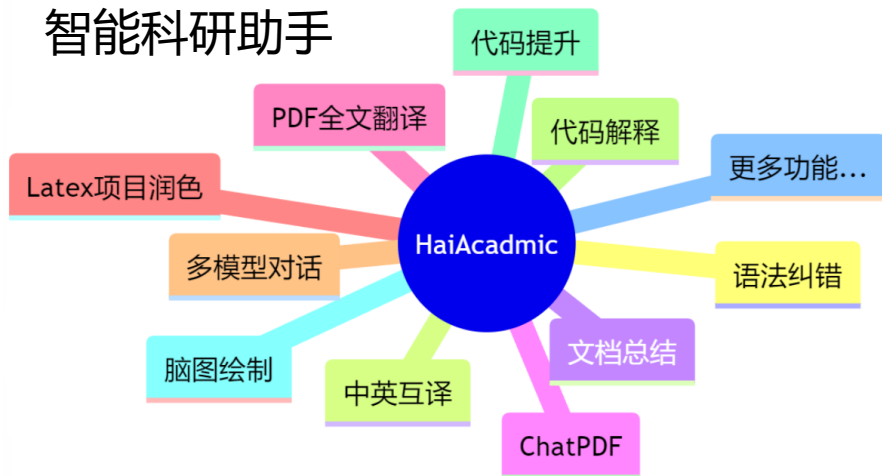
- 内容：

- AI4S知识资源底座
 - 挖掘文献数据
- 智能科研助手HaiAcademic
- 文献情报智能助手
- 欢迎使用：<https://ai.ihep.ac.cn>



- 数据的分级管理
- 数据的大批量使用
- 新功能的加入
- 数据安全
- “以我为主”科学研究的支撑
- 国际合作话语权

智能科研助手



文献情报智能助手



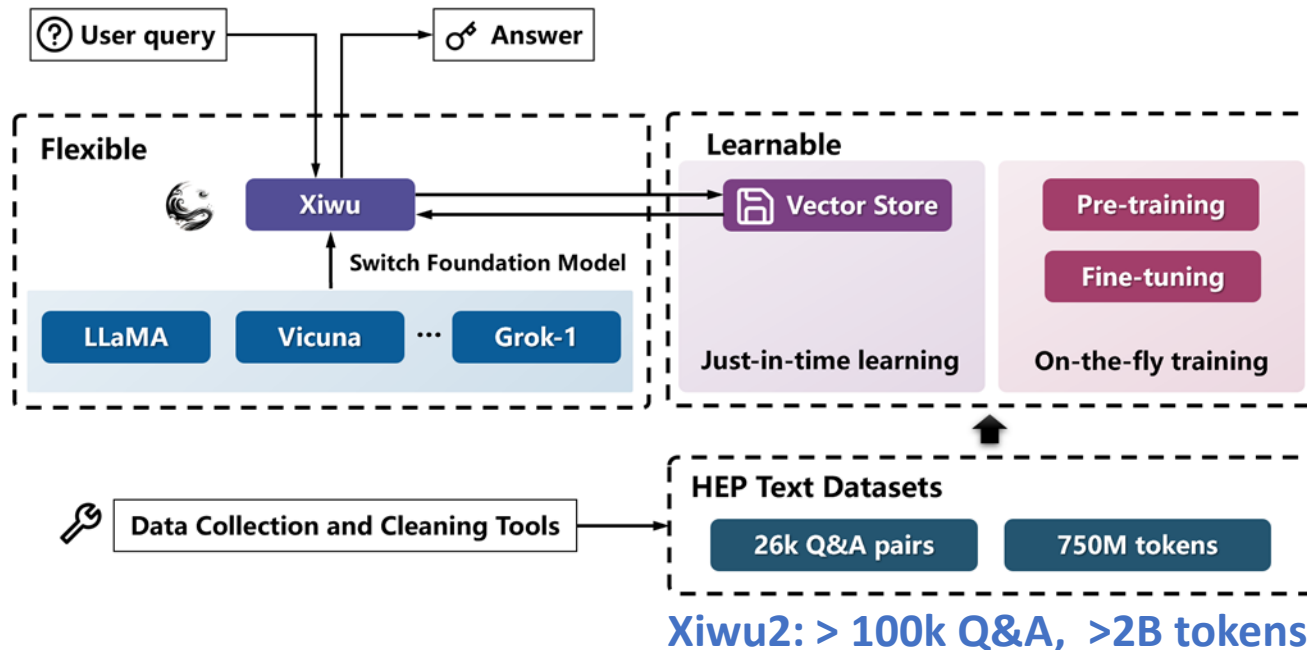
Summary

- **AI era is coming**
 - It will not replace you but will help you to work more efficiently
- We need both LLM and non-LLM
 - LLM can be used to automate the whole workflow
 - Non-LLM can be used to improve each step
- IHEP formed a **ML Collaboration** to work on AI4HEP
 - Lots of on-going activities, more details in the [kick-off meeting](#)
 - Welcome to join the working groups or discussions
 - Contact me (like@ihep.ac.cn) or Execute Board (ml_group_eb@maillist.ihep.ac.cn)
 - We will organize annual ML/QC workshop and winter school

back-up

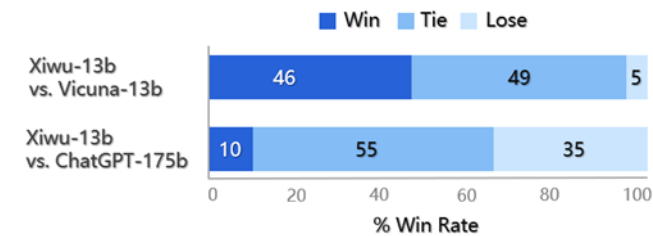
The brain of Dr. Sai - Xiwu (溪悟) model

- Xiwu: a basis flexible and learnable LLM for HEP
- First version release at April (refer to [arXiv:2404.08001](https://arxiv.org/abs/2404.08001) for more details)
 - High level model based on open-source foundational LLM, e.g. LLaMa
 - **First LLM for HEP, version 2 is ready**



Test Results

Size: 13B



Xiwu 2.0 evaluation: result

Model	MMLU_average	BoolQ	Humaneval	Hep_test
Baichuan2-7B-Chat	48.9	5.44	2.44	74.56
chatglm3-6b	51.82	72.6	61.59	71.52
vicuna-7b-v1.5-16k	33.03	45.81	17.07	62.67
Llama3-8b	58.34	83.61	21.34	76.94
Xiwu 1.0	41.66	0.8	12.2	48.06
Xiwu 2.0	58.23	83.55	19.51	78.06

Xiwu 2.0, based on Llama3-8B, has shown

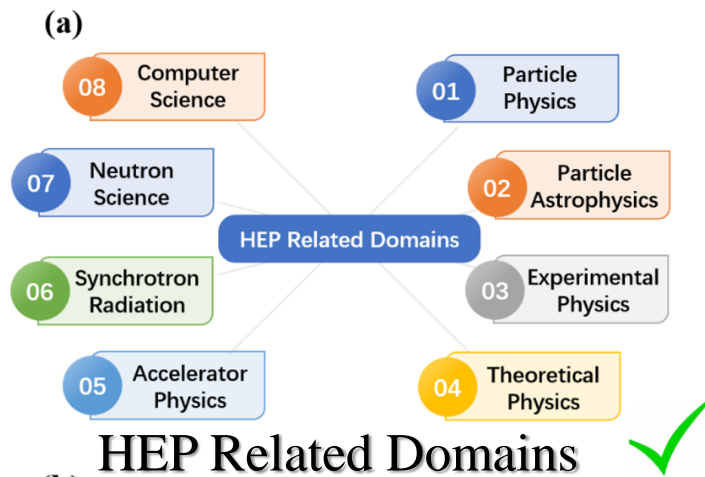
- ① Excellent performance in general ability evaluation;
- ② No disastrous forgetting, compared to its base model;
- ③ Significant progress in HEP domain tasks;
- ④ Additionally, it also possesses stable self-identity awareness.

Training data

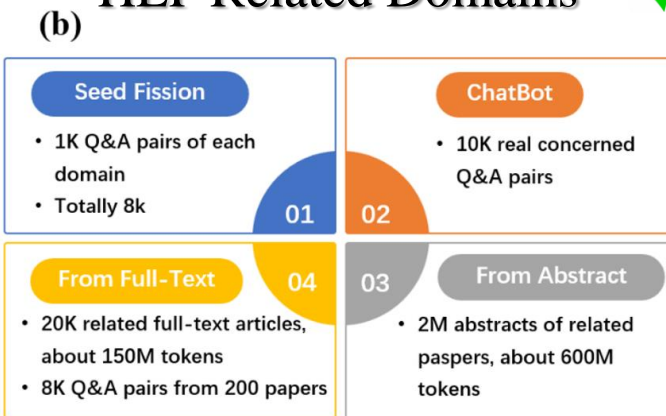
- Recent papers on arXiv
 - PDF files parser: HaiNougat, advanced iteration of the Nougat model
- Good quality chat history from IHEP-AI platform
 - The data is cleaned by human or AI (GPT4)
 - 180k Question-Answer pairs in 3 months
- **BESIII internal data**
 - internal memo, parsered by HaiNougat
 - Question-Answer pairs from hypernews during internal paper review
 - BESIII Offline Software System (BOSS) source code
 - BESIII public webpages and internal webpages (please help to update these webpages !)
 - The data on indico will be used later
- All the BESIII internal data sets are stored in RAG or used in training and fine-tuning

Sensors of Dr. Sai

Data flywheel enables **continuous iterative evolution of models**

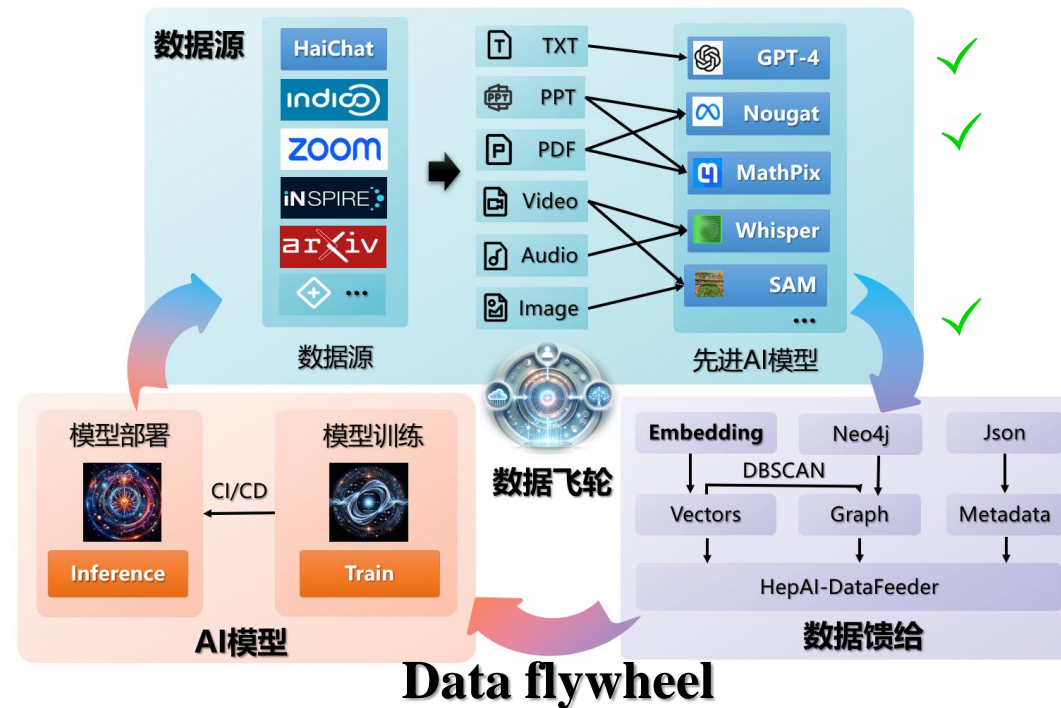


HEP Related Domains



Totally 26k Q&A pairs for fine-tuning, 750M tokens for pre-training.

Four ways to collect data



The "data-driven flywheel effect" improves the algorithm model by constructing a circular data path, attracting more users and generating more data during their use. The new data is then used to improve the algorithm model, forming a positive feedback loop.

Memory of Dr. Sai

- Hepai worker+llama index+qdrant



Collections

Q Search Collection

BESMEMO	DoSai-coder
DELETE	DELETE
DrSai-admin	DrSai-anonymous
DELETE	DELETE
DrSai-charm	DrSai-coder
DELETE	DELETE



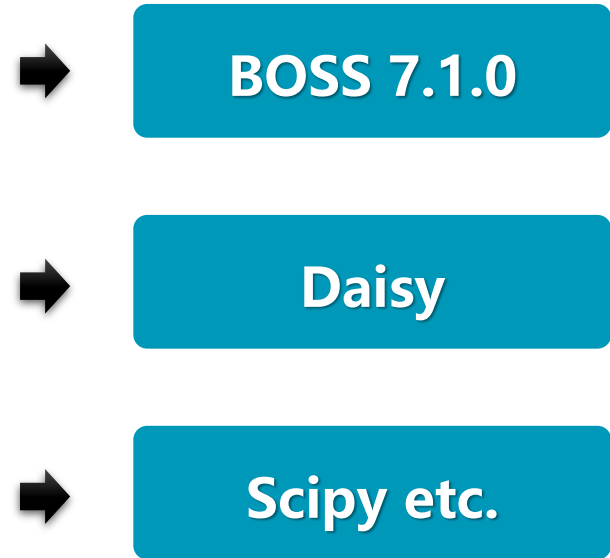
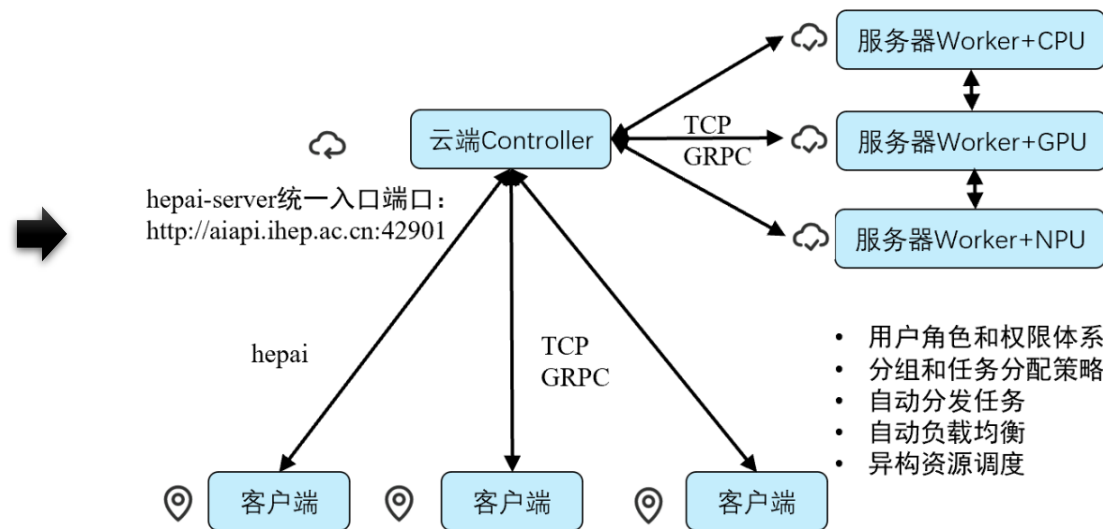
- Precise Electromagnetic Structure of Neutron Measured at BESIII—Beijing Spectrometer(BEIII) Experiment
- Physics Journal Publications—Beijing Spectrometer(BEIII) Experiment
- Ongoing analyses - Light Hadron Group
- New Vector Particles Observed at BESIII—Beijing Spectrometer(BEIII) Experiment
- PDGIDtoName - New Physics Group
- RScan 3960 - Tau and QCD Group
- GangaBOSS Release Notes - Offline Software Group
- The most precise measurements of the Lambda Decay Parameter—Beijing Spectrometer(BEIII) Experiment
- Coll. Meeting in Winter of 2017, Dec.2 -6, 2017, IHEP, Beijing—Beijing Spectrometer(BEIII) Experiment
- RScan 3000 - Tau and QCD Group
- D Tagging Tools - Charm Group
- The BESIII collaboration 2018 Winter Meeting was held at Wuhan University—Beijing Spectrometer(BEIII) Experiment
- BF2016-03OngoingAnalyses - Charmonium Working Group
- PDGIDtoName - Offline Software Group
- Probing CP symmetry with Entangled Double-strange baryons—Beijing Spectrometer(BEIII) Experiment
- All Analyses - Charm Group
- Doxygen Documentations - Offline Software Group
- Special pages - Offline Software Group
- Publication - New Physics Group
- D Decays - Charm Group
- BEAN InstallationOLD - Offline Software Group
- Viewpoints - Offline Software Group
- Miscellaneous - Charm Group
- Help:Contents - Charmonium Working Group
- RScan 3990 - Tau and QCD Group
- D0 Decay Table - Charm Group
- Conference Talks - New Physics Group
- Physics and Software Workshop in Spring 2024, Mar. 18-21, 2024, IHEP—Beijing Spectrometer(BEIII) Experiment
- Become a BESIII site step by step - Offline Software Group
- Software Validation - Offline Software Group
- RScan 4150 - Tau and QCD Group
- Useful-Links - Charm Group
- CEPCDIRAC User Tutorial - Offline Software Group
- D Tagging Modes - Charm Group
- Author Page—Beijing Spectrometer(BEIII) Experiment
- J/psi (round05) Inclusive MC Simulation - Offline Software Group
- How to create a new package in the CVS - Offline Software Group
- How to use MC truth information - Offline Software Group
- Committees—Beijing Spectrometer(BEIII) Experiment
- Become Member—Beijing Spectrometer(BEIII) Experiment
- RScan 4020 - Tau and QCD Group
- Analyses - Tau and QCD Group
- Data Quality/Software Validation related reports - Offline Software Group



Actuators of Dr. Sai

Based on HepAI DDF, it is easy to expand Dr Sai's actuator component.

The Distributed Deployment Framework (HepAI-DDF)



Example: fitting

Prompt:

"I want to do two things:

1. generate a fitting script to fit a Gaussian distribution from the output file 'fake_data.root'. There is a TH1F name 'h_gaus' in the file.
2. use Tester to execute this code."

Example: BESIII assistant

Prompt:

"what is the path of inclusive MC sample produced at center-of-mass energy = 3.773 GeV."

what is the path of inclusive MC sample produced at center-of-mass energy = 3.773 GeV

Attention: auto-selected speaker 'Charm' is ready to handle the current task:
'what is the path of inclusive MC sample produced at center-of-mass energy = 3.773 GeV'.

Please give feedback if you have any comments (in 10 seconds).
1.'r' - Revise.
2.'c' or None - Continue.
3.'s' - Stop. ●

[ST]Ask human input for 10s[END]

No user input ●

To determine the path of the inclusive MC sample produced at a center-of-mass energy of 3.773 GeV, we need to identify the relevant information from the provided cases.

From the given cases, Case 3 provides specific information about the inclusive MC samples at 3.773 GeV:

```
Raw code
Sample Type
Sample Type,Ecm (GeV),RUNS,Luminosity(pb^-1) of DATA (not MC)
```

system tools

Please refer to Pan's talk for more details

Sample Type
Sample Type,Ecm (GeV),RUNS,Luminosity(pb^-1) of DATA (not MC)
on-ψ(3770) (2010),3.773,11414-13988,2931.8+-0.2+-13.8 *
on-ψ(3770) (2010),3.773,14395-14604,2931.8+-0.2+-13.8 *
on-ψ(3770) (2011),3.773,20448-23454,2931.8+-0.2+-13.8 *

Additionally, Case 4 provides the location of the dst files for MC samples:

```
Raw code
Location of dst Files
Directories for the MC samples can be found at:
BESIII DOC-228 http://docbes3.ihep.ac.cn/cgi-bin/DocDB/ShowDocument?docid=228
* Scripts were copied from
/panfs/panfs.ihep.ac.cn/home/data/bes3gen/workarea6XX/TestRelease/TestRelease-00-00-XX/psipp/
/ihepbatch/bes/ambrose/workarea-662/workarea/Reconstruction/QCMCFilterAlg/QCMCFilterAlg-00-00-01/share/jobOptions_QCMCFilter_makedst.txt
/besfs/offline/data/661-1/psipp/mc/4040/JobOptions/
```

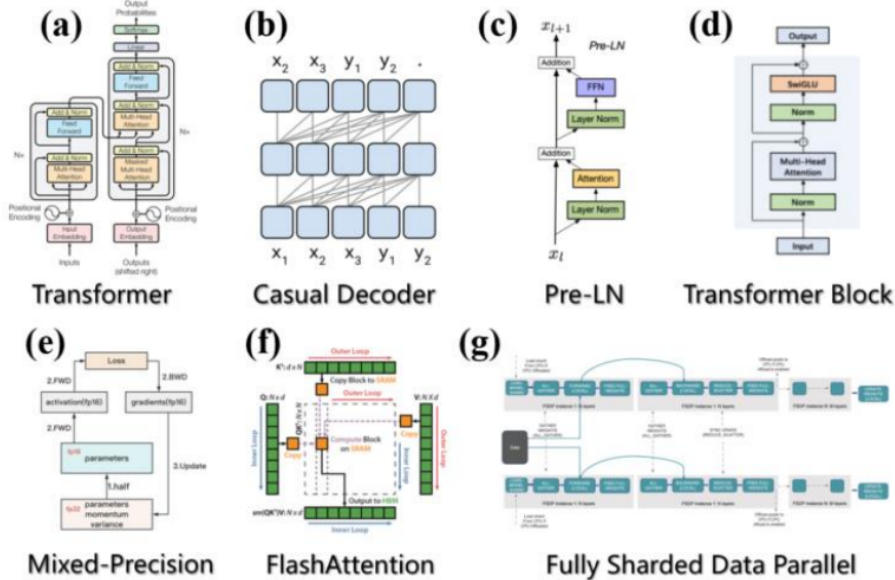
Combining this information, the path for the inclusive MC sample produced at a center-of-mass energy of 3.773 GeV can be inferred as follows:

```
Raw code
/besfs/offline/data/661-1/psipp/mc/3770/JobOptions/
```

This path is derived from the general structure provided in Case 4, adapted for the specific energy level of 3.773 GeV mentioned in Case 3.

Xiwu 2.0: Training techniques

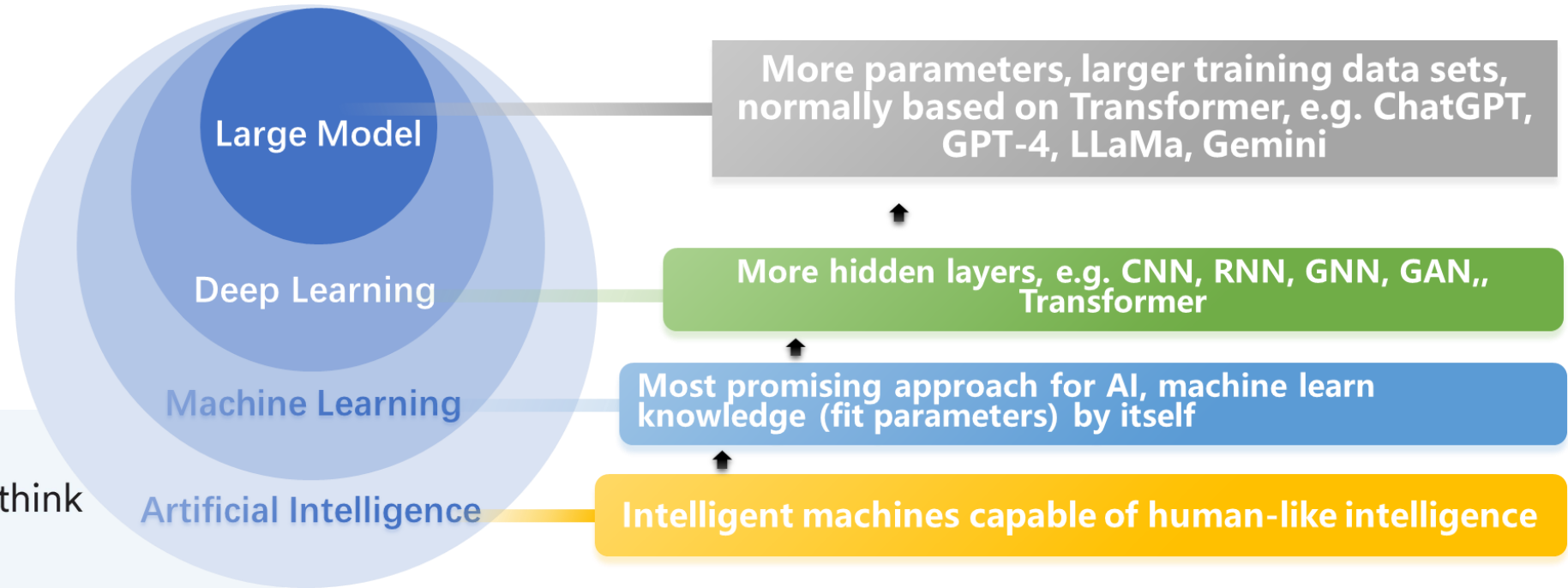
Frequently used techniques in LLM training



Reduce computational cost and training time, while improving model's performance

- **Mixed-precision Training**
reduce memory usage and improve computational throughput without sacrificing model accuracy
- **FlashAttention**
enhance floating-point operations per second (Flops)
- **Fully Sharded Data Parallelism (FSDP)**
parallel training across multiple devices
- **CPU-Offload**
offload certain computations from GPU to the CPU
- **Torchrun Parallelism**
Training on single node with Multi-GPU
- **Bitsandbytes**
vector quantization and mixed-precision decomposition
- **Deepspeed**
utilize mixed precision, gradient checkpointing, and offloading memory to the host CPU
- **ZeRO Series (ZeRO-2, ZeRO-3, ZeRO-offload)**
memory optimization strategies, such as activation checkpointing and optimizer state partitioning
- **Low-Rank Adaptive (LoRA)**
Approximate the weight matrices with low-rank factors while preserving the model's representational capacity

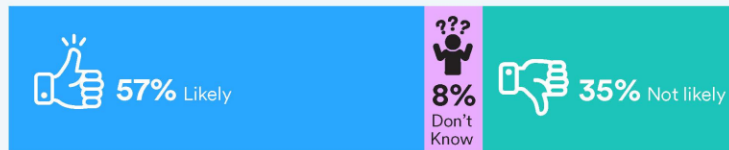
Machine learning and AI



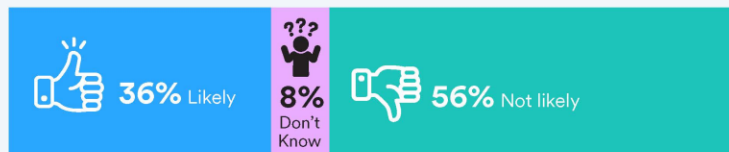
Global opinions: How people think AI will affect jobs, 2023

Source: Ipsos, 2023 | Chart: 2024 AI Index report

AI will change how you do your current job in the next 5 years



AI will replace your current job in the next 5 years

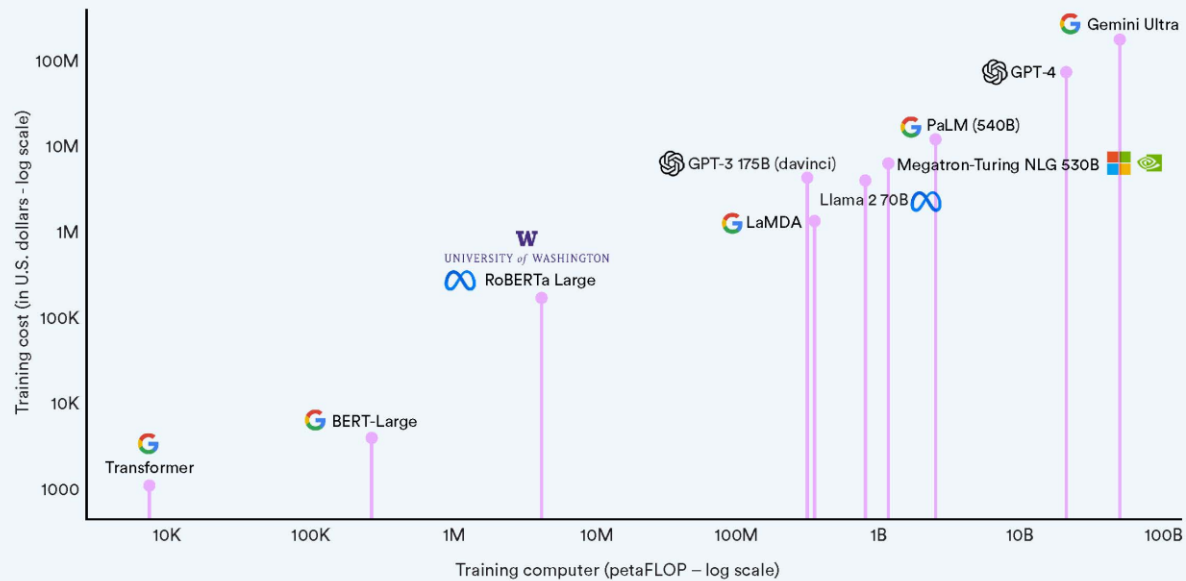


2024 AI index report

the next industrial revolution

Estimated training cost and compute of select AI models

Source: Epoch, 2023 | Chart: 2024 AI Index report



This is a C++ code for a class called `Gam4pikp` which is used to analyze data from the BaBar experiment. The class contains several methods for filtering and sorting data, as well as outputting results.

This is a C++ code for a data analysis algorithm called Gam4pikp. The algorithm is designed to analyze data from high-energy particle collisions and identify specific patterns of particles. The code appears to be a part of a larger program that is used to analyze data from the Large Hadron Collider (LHC) at CERN.

This is the implementation of a ROOT-based algorithm called `Gam4pikp` which is used to analyze particle physics data. The algorithm is designed to identify and reconstruct events containing four-pion (4π) and four-kaon ($4K$) resonances, and to perform various calculations and data analysis tasks.

This is a C++ code for a particle physics analysis tool, specifically a program that analyzes data from the Belle II experiment at the SuperKEKB collider. The code is designed to identify and reconstruct particles produced in high-energy collisions, and to study the properties of these particles.

Simple test: Dr. Sai vs GPT4

As expected, better performance in HEP

Q: 如何使用BOSS处理数据？

Answer from Dr. Sai

Answer from GPT-4

HaiChat Chat with AI Large Language Model v1.3 模型: GPT-4

如何使用BOSS处理数据

BOSS, 也就是Bit Oriented Synchronous Serial, 是一种数据通信协议, 但它并不直接用于数据处理。如果你指的是某种特定的数据处理软件或系统, 例如“BOSS系统”, 那可能需要更具体的信息来提供一个准确的答案。如果你是指一种名为“BOSS”的系统或软件, 一般来说, 使用这类系统处理数据的步骤可能包括以下几个步骤:

1. 数据输入: 首先, 你需要将数据输入到BOSS系统中。这可能涉及到上传文件, 或者通过API将数据导入系统。
2. 数据处理: 在数据被输入到系统之后, 你可以使用BOSS系统提供的工具和功能进行数据处理。这可能包括排序、过滤、聚合等操作。
3. 数据分析: 处理后的数据可以用于生成报告或进行进一步的分析。
4. 数据输出: 最后, 你可以将处理后的数据导出, 或者在BOSS系统中直接查看和分享。

不过, 具体的使用方法会根据BOSS系统的具体功能和你要处理的数据类型而变化。如果你能提供更多关于你正在使用的BOSS系统的信息, 我可能提供更具体的帮助。

```
43 question = "如何使用BOSS处理数据"
44 # question = "给出一个BOSS上进行模拟的例子"
45 db_names = ["particle_physics_basic_concepts"]
46 print(f"Question: {question}")
47 print(f"Answer : ", end="")
48 answer = request_model(prompt=question, db_names=db_names,
49
50
```

问题 输出 终端 2

llm/chat_in_http.py
['hepai/chat', 'hepai/knowledge-DAO', 'openai/gpt-4', 'openai/gpt-3.5-turbo', 'meta/segment_anything_model', 'hepai/be-s-student-001']
Question: 如何使用BOSS处理数据
Answer : 要使用BOSS处理数据, 首先需要安装BOSS软件包并设置环境变量。然后, 按照以下步骤进行数据处理:

1. 模拟: 使用BOSS提供的模拟程序生成模拟数据。输入文件是一个配置文件, 输出文件是一个.rtraw文件。
2. 重建: 使用BOSS提供的重建程序对模拟数据进行重建。输入文件是.rtraw文件, 输出文件是一个.dst文件。
3. 分析: 使用BOSS提供的分析程序对重建数据进行分析。输入文件是.dst文件, 输出文件是一个.root文件。

每一步的输出文件格式如下:

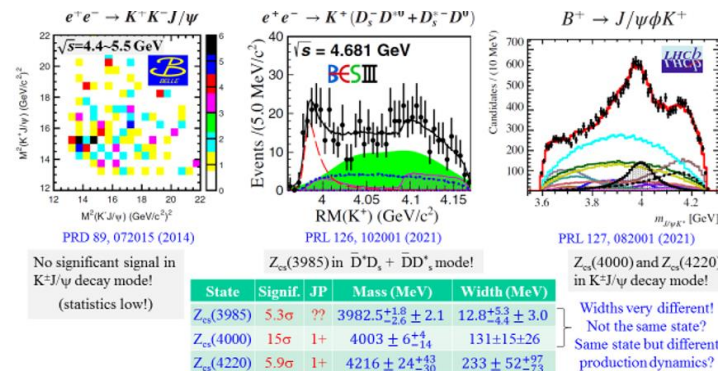
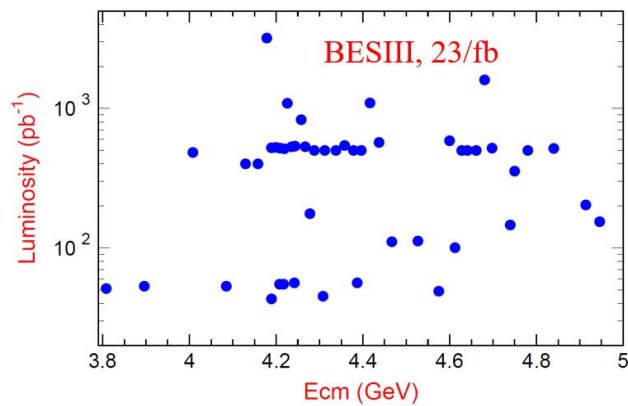
- 模拟: .rtraw文件是模拟数据的原始二进制文件。
- 重建: .dst文件是重建数据的二进制文件, 包含了事件的重建信息。
- 分析: .root文件是ROOT格式的文件, 其中包含了重建数据的分析结果, 可以使用ROOT软件包进行进一步的分析和可视化。

请注意, 以上是一般的BOSS数据处理流程和输出文件格式, 具体的流程和文件格式可能会根据实际需求和使用的BOSS版本而有所不同。建议参考BOSS的官方文档和示例程序以获取更详细的信息和指导。

(langchain) → Re:Zc3900 git:(dev) X

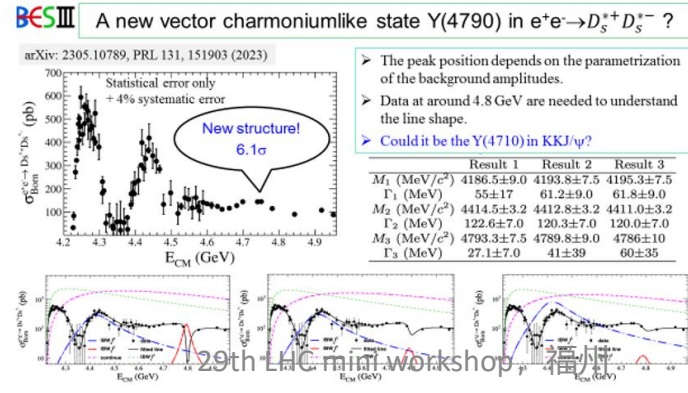
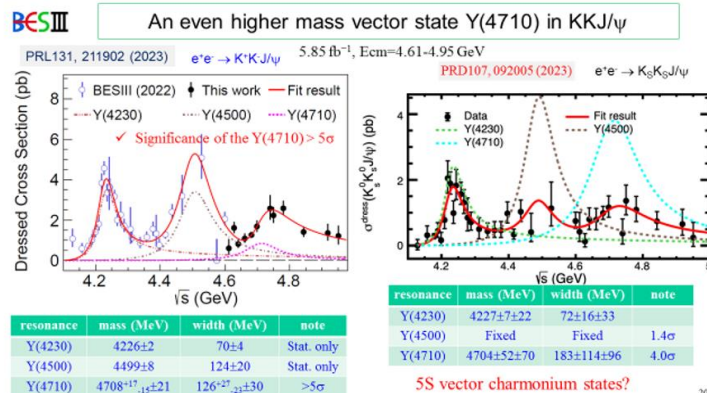
Status and prospects for Dr. Sai

- XYZ studies at BESIII:
 - Many (intermediate) resonants, many decay channels -> interferences
 - Difficult to retrieve useful information correctly



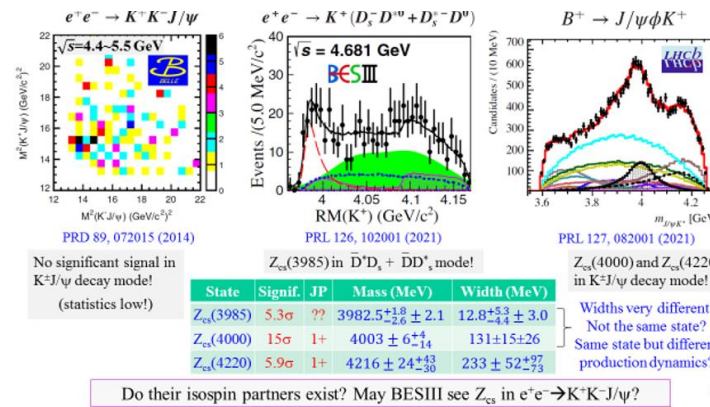
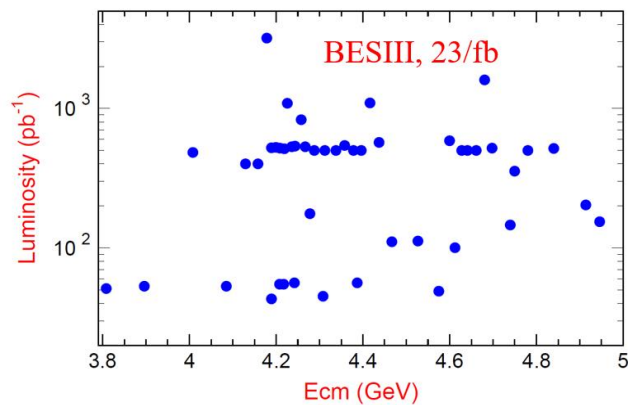
How to understand them? what is the physics behind them ?

Do their isospin partners exist? May BESIII see Z_{cs} in e⁺e⁻→K⁺K⁻J/ψ?



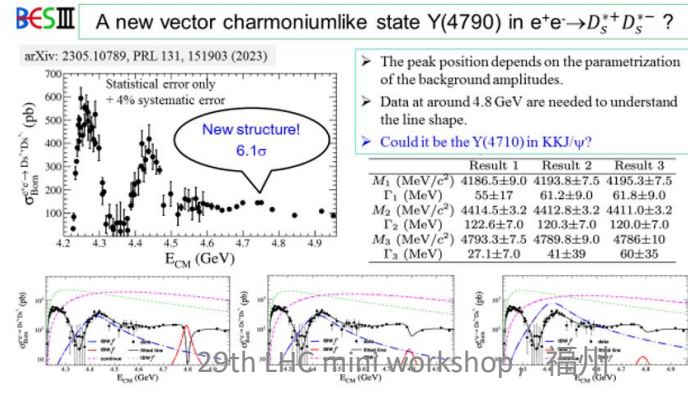
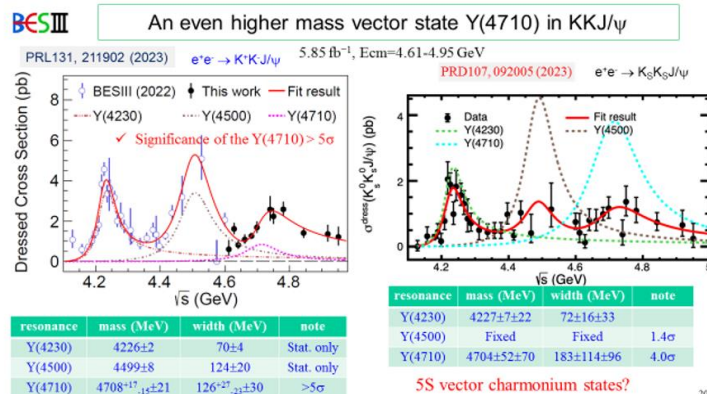
Status and prospects for Dr. Sai

- XYZ studies at BESIII:
 - Many (intermediate) resonants, many decay channels -> interferences
 - Difficult to retrieve useful information correctly



How to understand them? what is the physics behind them ?

As a experimental people, I don't know.



But the cross section measurements of ALL channels should be one necessary condition.

how many papers published from BESIII



The number of papers published by the BESIII collaboration can vary over time as new research is conducted and published. As of my knowledge cutoff date in October 2023, I don't have the exact count of papers published by BESIII.

To get the most up-to-date and accurate information, you can:

1. **Visit the BESIII Collaboration Website:** The official website of the BESIII collaboration may have a list of their publications or a link to their recent papers.
2. **Check Scientific Databases:** Use databases like the INSPIRE HEP (High Energy Physics) database, the arXiv preprint service, or journal publishers' websites to search for papers published by the BESIII collaboration.
3. **Contact the Collaboration Directly:** You can reach out to the BESIII collaboration or one of its representatives for detailed information on their publications.

These methods should provide the latest count and specifics of the academic papers published by the BESIII collaboration.

tion has published over 1,200 papers in peer-reviewed journals. This number is constantly growing as new data is

iment at the Beijing Electron Positron Collider (BEPC) in studying the properties of exotic hadrons and other aspects. The collaboration is one of the largest in the world, with over 1,000 institutions in 20 countries.

cover a wide range of topics, including the properties of quark states, the search for new physics beyond the Standard Model, and b-c reactions and processes.

Summary:

- **Production Channel:**

- e^+e^- collisions with ISR: $(e^+ e^- \rightarrow \gamma \pi^\pm X(3872))$

- **Decay Channels:**

- Predominantly hadronic decays like $(X^\pm(3872) \rightarrow \pi^\pm J/\psi)$
- Radiative decays like $(X^\pm(3872) \rightarrow \gamma \pi^\pm J/\psi)$
- Multi-body decays where the final state includes charmonium.

By focusing on these channels, you can efficiently search for the charged partner of $X(3872)$ at BESIII.

Data preparation: HaiNougat

- During the data clean for Xiwu LLM system, we found it is hard to obtain correct information from PDF, especially for Math equations and Tables
- For HEP-related papers, 20% more formulas per pages and 27% longer formulas than typical academic documents (computer science, chemics ...)
- Develop a model for HEP (HaiNougat) from the Visual Transformer model Nougat. Also an important part for dataset preparation from Xiwu LLM system!
- A demo accessible via <https://ai.ihep.ac.cn/m/hai-nougat>
- More details in <https://github.com/ai4hep/hai-nougat>

Data preparation: HaiNougat

HaiNougat

HaiNougat, the advanced iteration of the Nougat model, specializes in transforming PDFs into Mathpix Markdown, facilitating the extraction of complex information from high-energy physics documents. On this platform, you can experience HaiNougat's capabilities, upload PDFs, obtain Mathpix Markdown versions, visualize the results in an editor and preview area, and download the processed output.

You can drop a PDF here:

Choose a PDF

10.pdf

Upload to HaiNougat

File processed successfully

Download

```

as

\[\eta = \frac{1}{2} M_D^{\dagger} M^{\dagger} M^{-1} M^{-1} M_D \tag{33}\]
\[\eta = \frac{1}{2} m_D^{\dagger} M_{\Sigma}^{\dagger} M_{\Sigma}^{-1} M_{\Sigma}^{-1} M_{\Sigma}^{-1} m_D\]
\[\eta \approx \frac{1}{2} m_D^{\dagger} M_{\Sigma}^{\dagger} M_{\Sigma}^{-1} m_D\]

\[\Gamma(Z \to \ell^+ \ell^-) = \frac{m_Z^3}{12\pi v^2} \left[ |g_{\ell Z}^V|^2 + |g_{\ell Z}^A|^2 \right] \tag{34}\]
\[\Gamma(h \to \ell^+ \ell^-) = \frac{m_h}{8\pi} \left[ |g_{\ell h}^L|^2 + |g_{\ell h}^R|^2 \right] \tag{35}\]
        
```

as

$$\eta = \frac{1}{2} M_D^{\dagger} (M^{\dagger})^{-1} M^{-1} M_D \tag{33}$$

$$= \frac{1}{2} m_D^{\dagger} (M_{\Sigma}^{\dagger})^{-1} \left[\mathbb{1}_3 + \mu^{\dagger} (M_{\Sigma}^{\dagger})^{-1} (M_{\Sigma}^{\dagger})^{-1} \mu \right] M_{\Sigma}^{-1} m_D$$

$$\approx \frac{1}{2} m_D^{\dagger} (M_{\Sigma}^{\dagger})^{-1} M_{\Sigma}^{-1} m_D$$

$$\Gamma(Z \rightarrow \ell^+ \ell^-) = \frac{m_Z^3}{12\pi v^2} \left[|(g_{\ell Z}^V)_{\alpha}|^2 + |(g_{\ell Z}^A)_{\alpha}|^2 \right], \tag{34}$$

$$\Gamma(h \rightarrow \ell^+ \ell^-) = \frac{m_h}{8\pi} \left[|(g_{\ell h}^L)_{\alpha}|^2 + |(g_{\ell h}^R)_{\alpha}|^2 \right], \tag{35}$$

BESIII Data cleaning

BESIII Official Website:

- Physics working groups

- ...

Code examples: Decay channels:

- $J/\psi \rightarrow \rho\pi$

- $\psi(3686) \rightarrow \pi^+\pi^-J/\psi$

-

$e^+e^- \rightarrow Z_c(3900)\pi^\pm, Z_c(3900) \rightarrow J/\psi\pi^\pm$

Hyper-news: Question and answer pairs in memo review

DocDB: Latest version memos (Published)

Memory of Dr.Sai

