



DrSai, towards automatic discovery

Tong Liu for the DrSai group

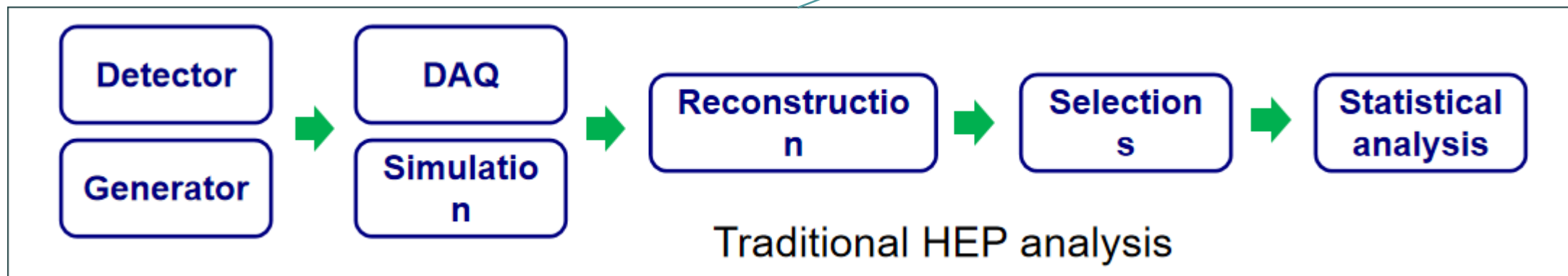
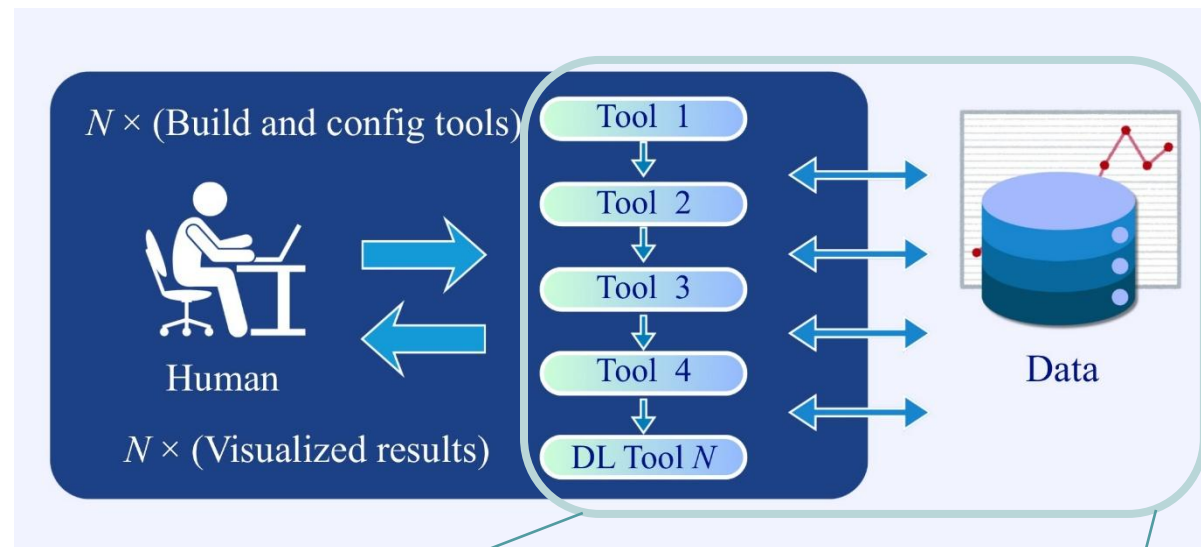
Outline

- Motivation
- DrSai
- Start a new analysis with DrSai
 - A demo: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$
 - The first analysis: exclusive measurement for R@1.9 GeV
 - More analysis with DrSai
- Summary and outlook

Motivation

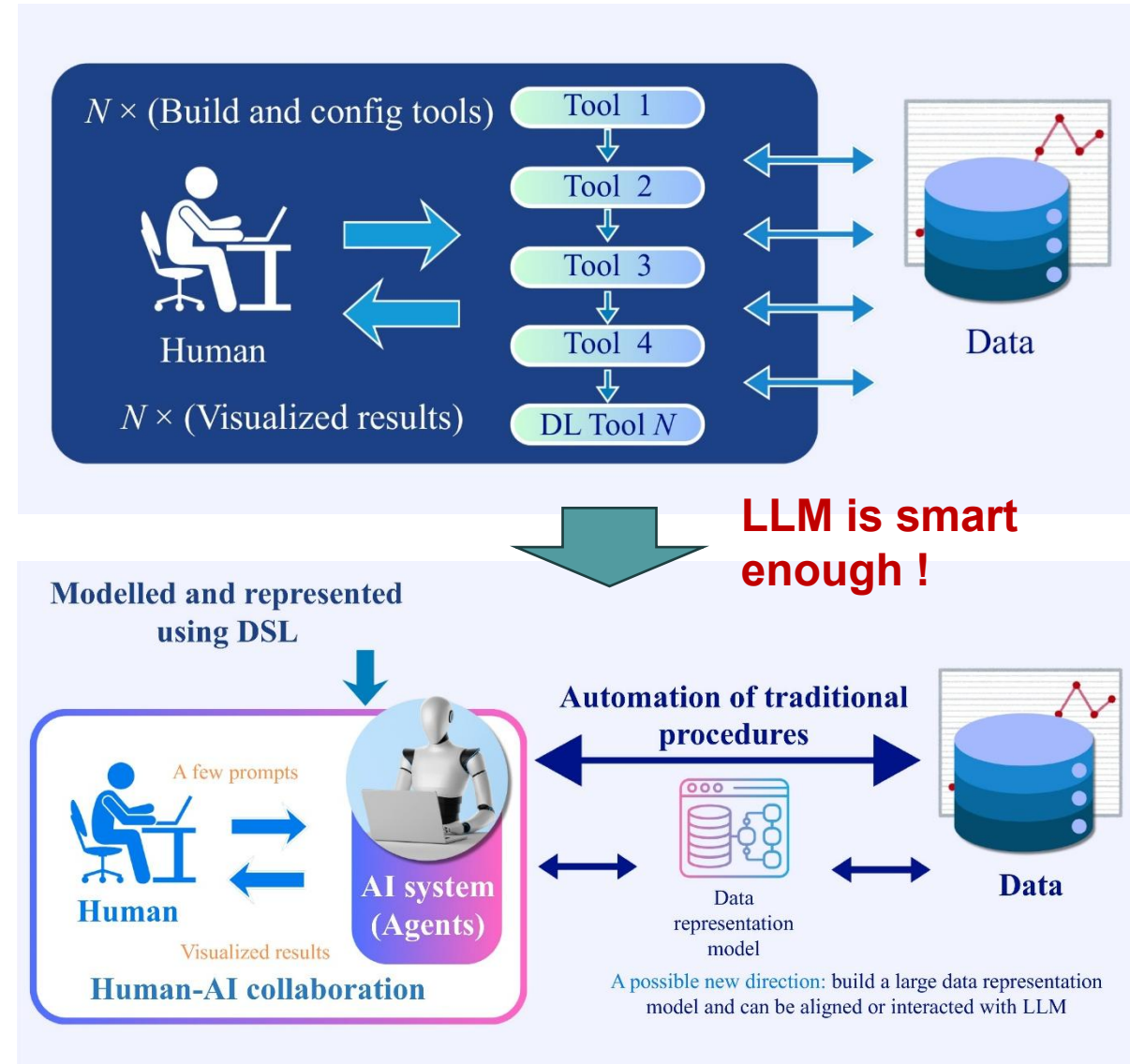
- Traditional HEP analysis: driven by expert

- What is the purpose?
- What are the input/output?
- Setup tools or make a new one
- Monitoring & test
- What is the next step?
- ...
- **Too many complex, empirical knowledge!**



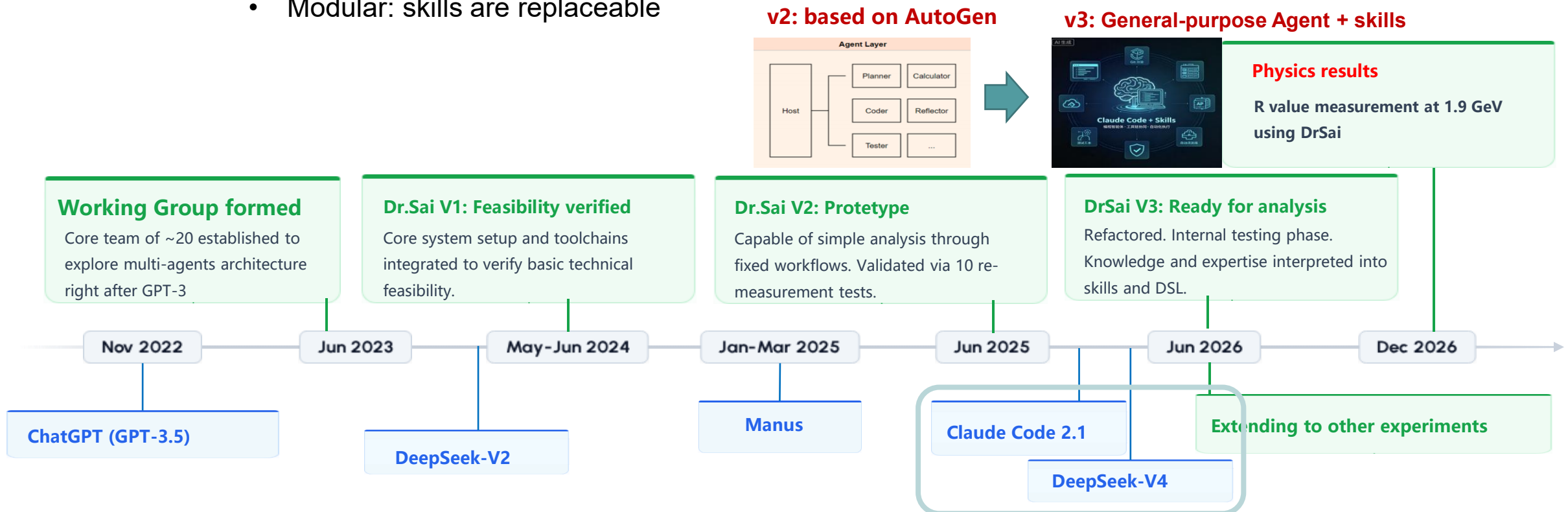
Motivation

- **Is LLM smart enough? YES!**
- AI partner for experts
 - AI holds repetitive work
 - Human holds physics knowledge
 - More efficient analysis !
- DrSai
 - DrSai v1, talked in [ICHEP2024](#)
 - DrSai v2, published in [arXiv:2604.22541](#)
 - DrSai **v3**, current version
 - ...



How we built DrSai v3

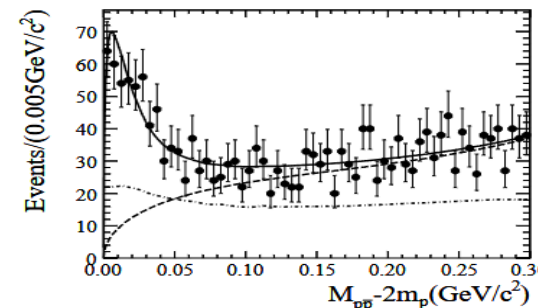
- Drsai_v3: **General-purpose Agent + skills**
 - Skill: turns AI's understanding into actionable, reusable capabilities.
 - Portable: not tied to any framework or base model
 - Maintainable: debug through human-agent interaction
 - Modular: skills are replaceable



How we built DrSai v3

- Drsai_v3: **General-purpose Agent + skills**
- **Skills:** modular and reusable, knowing how to do something, not just knowing about it
- Use **DSLs** to represent the analysis pipeline
 - DSL is a computer programming language of limited expressiveness focused on a particular domain
 - A **DSL-yaml** as work "note", updated as the work proceeds
 - A **DSL-ruby** (HepScript): more stable coding, help users check/confirm code logic [arXiv:2605.01423](https://arxiv.org/abs/2605.01423)
- **GraphRAG:** improve code generation
- **Agentic RAG:** knowledge from previous work → strategy for new work

CPC 34, 421 (2010)

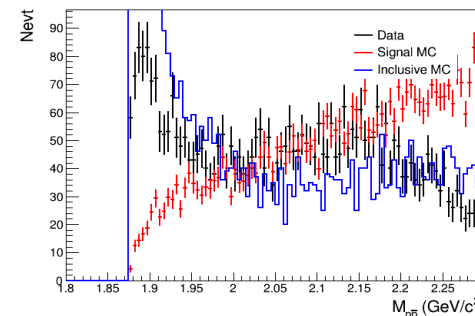


DrSai



```
setDatabase:
  name: ppbar_threshold
  BAK: '000'
  datatype: None
  comment: "Observation of a ppbar mass threshold enhancement in psi' to
selection:
  analysis: "psi' to pi+ pi- 3/psi, 3/psi to gamma p pbar"
analysis:
  dir:
    dir_data: None
    dir_smc: None
    dir_inmc: None
    dir_fit: None
  sample:
    data: None
    incMC: None
    sigMC:
      - num_events: 50000
        process: "psi' to pi+ pi- 3/psi, 3/psi to gamma p pbar"
    otherMC: []
  base_selection:
    comment: "Events require at least one photon and four charged track
rged tracks: 3/psi identified by |M_(pi+pi- recoil) - m_0/psi| < 0.00
tagged_data: None
tag:
  common: gamma pi+ pi- p pbar
  basic_pid:
    - pi "Identified with highest confidence level"
    - pbar: "Identified with highest confidence level"
    - pi: "no PID required"
  kofits:
    var: 4C
    setting: setChisqCut(100,0.005)
```

DSL



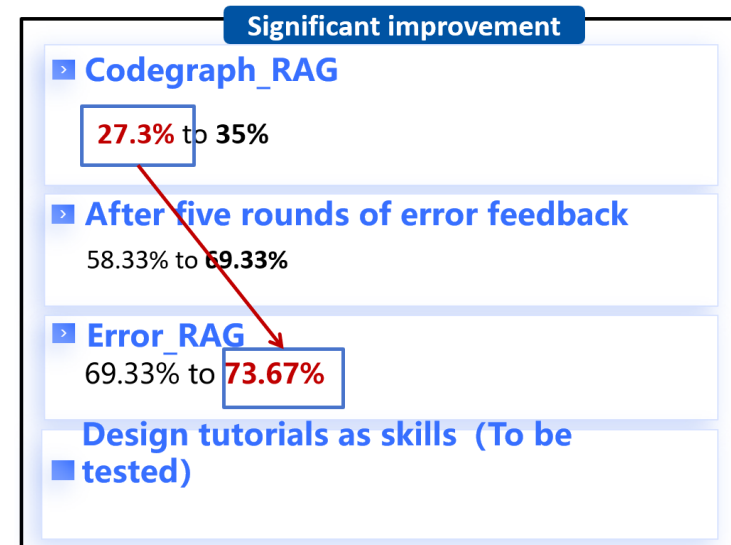
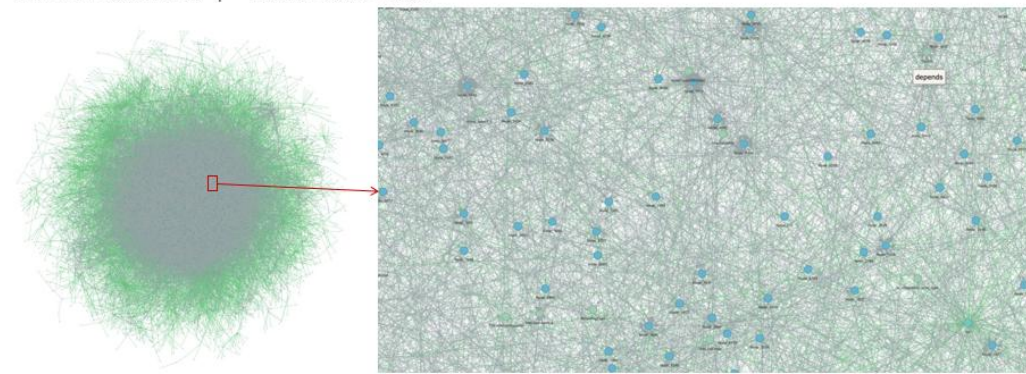
DrSai



How we built DrSai v3

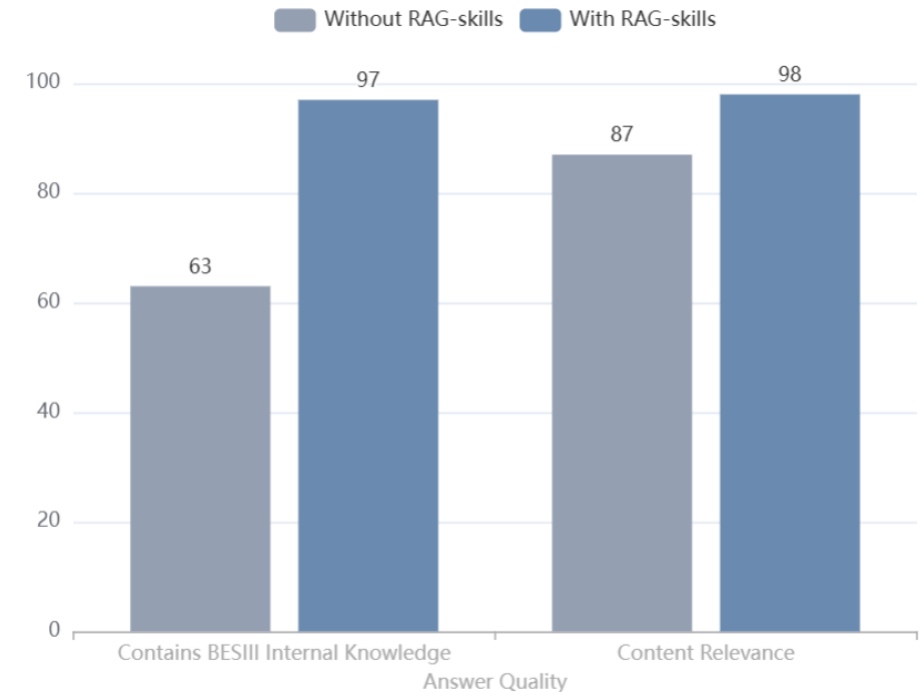
- GraphRAG: improve code generation
 - For complex, un-open-source HEP software
- Currently applied on ROOT
 - Take each class/package as a node
 - Define edges - contains, extends, depends
 - Extract the connections to a large graph
 - Total nodes: 48813
 - Total edges: 170619
 - Obvious improvement
 - Further improved with Error-Aware RAG
- Applied **as a skill** to DrSai

- Total nodes: 47851
 - Total edges: 163795
 - REPO nodes: 1 | - PACKAGE nodes: 2609 | - FILE nodes: 19347
 - TEXTFILE nodes: 5255 | - CLASS nodes: 20639



How we built DrSai v3

- Agentic RAG: knowledge from previous work → strategy for new work
- Previous analyses at BESIII are chunked by physical meaning
 - Selection, optimization, systematic uncertainty, etc.
 - Define metadata for each analysis
 - Different triggers for Grep and RAG
- User can ask the previous analysis details, eg.
 - How to select xxx ?
 - How to deal with xxx systematics ?
 - How to suppress xxx background ?
 - ...
- Applied **as a skill** to DrSai



How we built DrSai v3

- DSL-yaml as work "note"
 - Use existing work to extract knowledge for preliminary DSL-yaml generation
 - YAML format, parsed by LLM, high readability
 - Interactive work, revisable manually or via LLM
 - Finally obtain a "note" that **contains all the information** of this analysis
 - Write MEMO automatically
 - Repeat the analysis
 - Shift to similar works
 - ...

```

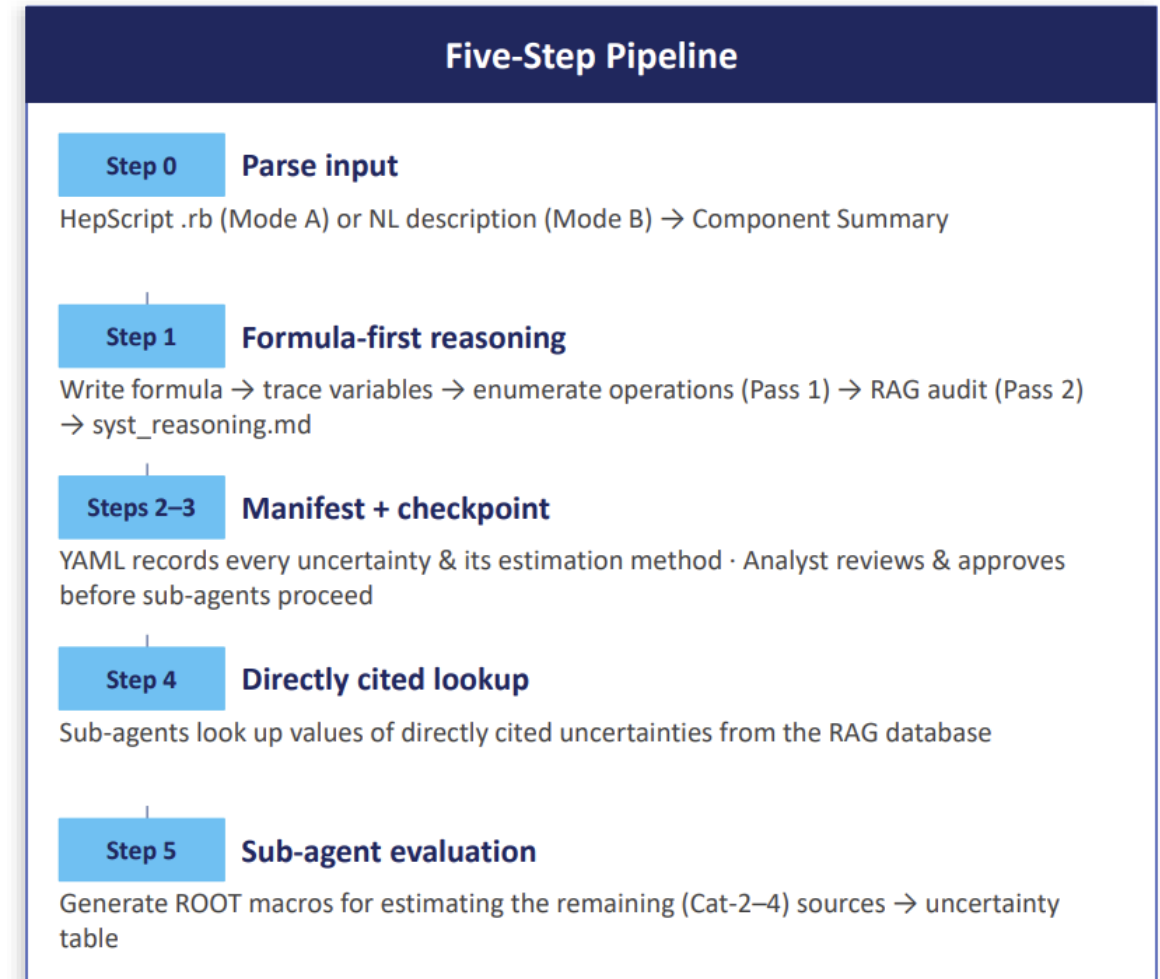
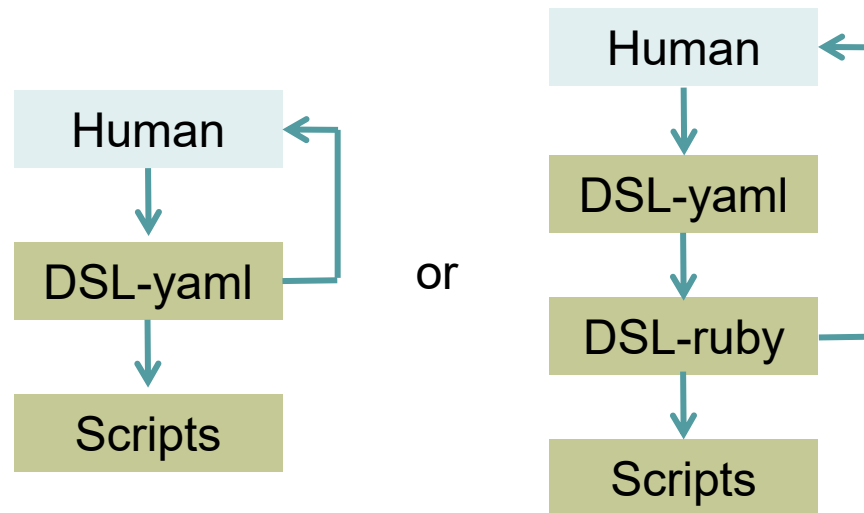
metadata:
  name: pip psi
  BAM: "000"
  dataType: 4260
  comment: "Absolute branching ratio of J/psi to lepton pair via radiative return at 4.26 GeV. The signal yield of e+e- -> pip
  pim J/psi, J/psi -> ep em (mup mum) is determined by fitting the invariant mass distribution of the lepton pair. The signal y
 ields N_signal are determined with the fit to data. The efficiencies are given by signal MC samples."
  selections:
    - analysis_1:
      - "e+e- -> pip pim J/psi"
      - "J/psi -> ep em"
    - analysis_2:
      - "e+e- -> pip pim J/psi"
      - "J/psi -> mup mum"

analysis_1:
  dir: .
  dir_data: None
  dir_sigMC: None
  dir_incMC: None
  dir_draw: None
  sample:
    data: None
    incMC: None
    sigMC:
      - num_events: 50000
      process: e+e- -> pip pim J/psi, J/psi -> ep em
  otherMC:
    base_selection:
      comment:
        tagged_data: "nCharge>3, nCharge<5"
        tag:
          common: pip pim ep em
          other:
            basic_pid:
              - pi: "momentum less than 0.7 GeV/c"
              - e: "momentum larger than 1 GeV/c, EMC deposition 126 x 76 an 0.8 GeV"
              - mu: "momentum larger than 1 GeV/c, EMC deposition less than 0.4 GeV"
            knfit:
              - var: 4C
                setting: setChisqCut(200,0.005)
              - var: 5C (4C, M_jpsi)
                setting: setChisqCut(9999,0.005)
            further_selection:
              chisq:
                - {var: chisq4C, optimize: 1D, strategy: FoM, default: (0,200), Nbin_region: "100, (0,200)"}
              cosTheta:
                - {var: polarAngle_pip, optimize: False, strategy: FoM, default: (-0.8,0.8)}
                - {var: polarAngle_pim, optimize: False, strategy: FoM, default: (-0.8,0.8)}
              theta:
                - {var: openAngle_pip_pim, optimize: False, strategy: FoM, default: (0.2, 3.2)}
              Mass:
                - {var: "Mjpsi: p4_ep + p4_em", optimize: False, strategy: FoM, default: (3.09,3.11), Nbin_region: "100, (3.,3.2)"}
              RM_pi:
                - {var: "maxRMpi: max(RM(pi+), RM(pi-)), ecms=4.25795", optimize: False, strategy: FoM, default: (3.6,4.2), comment: "di
                  agnostic only, NRM=100(3.6,4.2), sideband defined as (3.05,3.08)U(3.12,3.15)"}
            fit:
  analysis_2:
  systematic_uncertainties:
  result:

```

How we built DrSai v3

- HepScript: a ruby-based DSL (DSL-ruby)
 - Closer to executable code: more stable coding, easier logic review
 - A systematic uncertainty workflow based on HepScript



Start a new analysis using DrSai v3

- Say “analysis with DrSai, see config.yaml”
 - A yaml-like configuration
 - Prepare based on the example
 - Or generate via human-AI interaction
- config.yaml contains:
 - Directories
 - Confirmation
 - subAgents-parallel
 - sysErr estimation
 - BOSS package generation
 - Physical processes
 - Samples

```
# ===== Global Fields =====

outdir: ./logR # directory for analysis output.
runBOSS_outdir: ./logR/proj # directory for BOSS job projects. omitted → interaction
workarea: /workfs2/bes/liutong2016/boss713/workarea/Analysis/R # BOSS package workarea. omitted → interaction

confirm_mode: minimal # detailed (ask at every step) | minimal (interact only for required items)
parallel: yes # yes | no. Whether to enable parallel agent execution.

# If both yes, LLM will combine the outputs
sysErr: yes # yes | no. Whether to generate systematic error code via RAG
sysErr-ruby: yes # yes | no. Use the systematic error analysis benchmark developed for HepScript

genBOSSCode: direct # ruby | direct. BOSS code generation method.
# ruby - generate BOSS code via Ruby/HepScript
# direct - generate directly

# ===== entries Mode and Entries =====

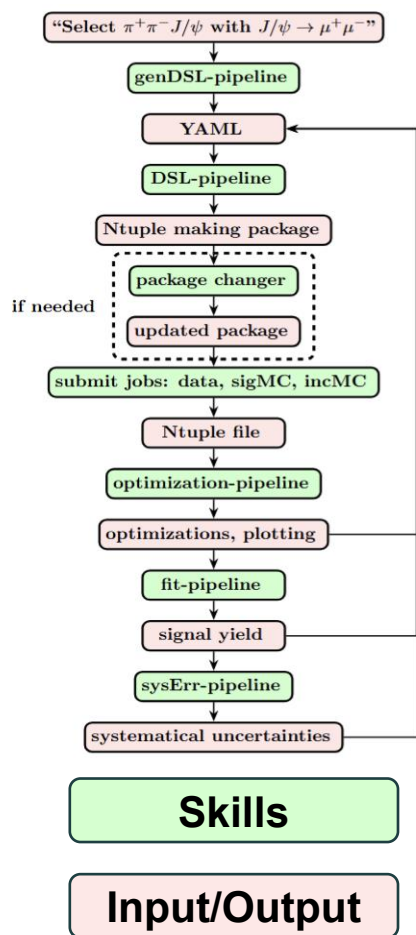
mode: single # single | multi
# single - one analysis
# multi - multiple independent analyses

ww: Rvalue # Optional. Valid only when mode=single and entries≥2
# Ignored in other modes (multi / single+entries=1)

entries:
# Format per line: process threshold_cut=<GeV> description
# - process - channel name & algorithm base name, used for subdirectory and analysis package naming.
# - threshold_cut - energy threshold for KKMC+BesEvtGen (GeV). If missing, full-pipeline will interactively p
rompt at load time (default 3.0).
# - description - brief description of the analysis procedure: final-state particles, etc.
- "bhabha threshold_cut=0.001022 select e+e- at 1.9 GeV"
- "dimu threshold_cut=0.2113 select mu+mu- at 1.9 GeV"
- "pipi threshold_cut=0.280 select pi+pi- at 1.9 GeV"
- "pipipi0 threshold_cut=0.415 select pi+pi-pi0, pi0->gamma gamma at 1.9 GeV"
```

Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

- A demo with DrSai_v3.0.0, Continuously updated



The terminal window shows the execution of a pipeline for the rediscovery of $Z_c(3900)$. The configuration details include:

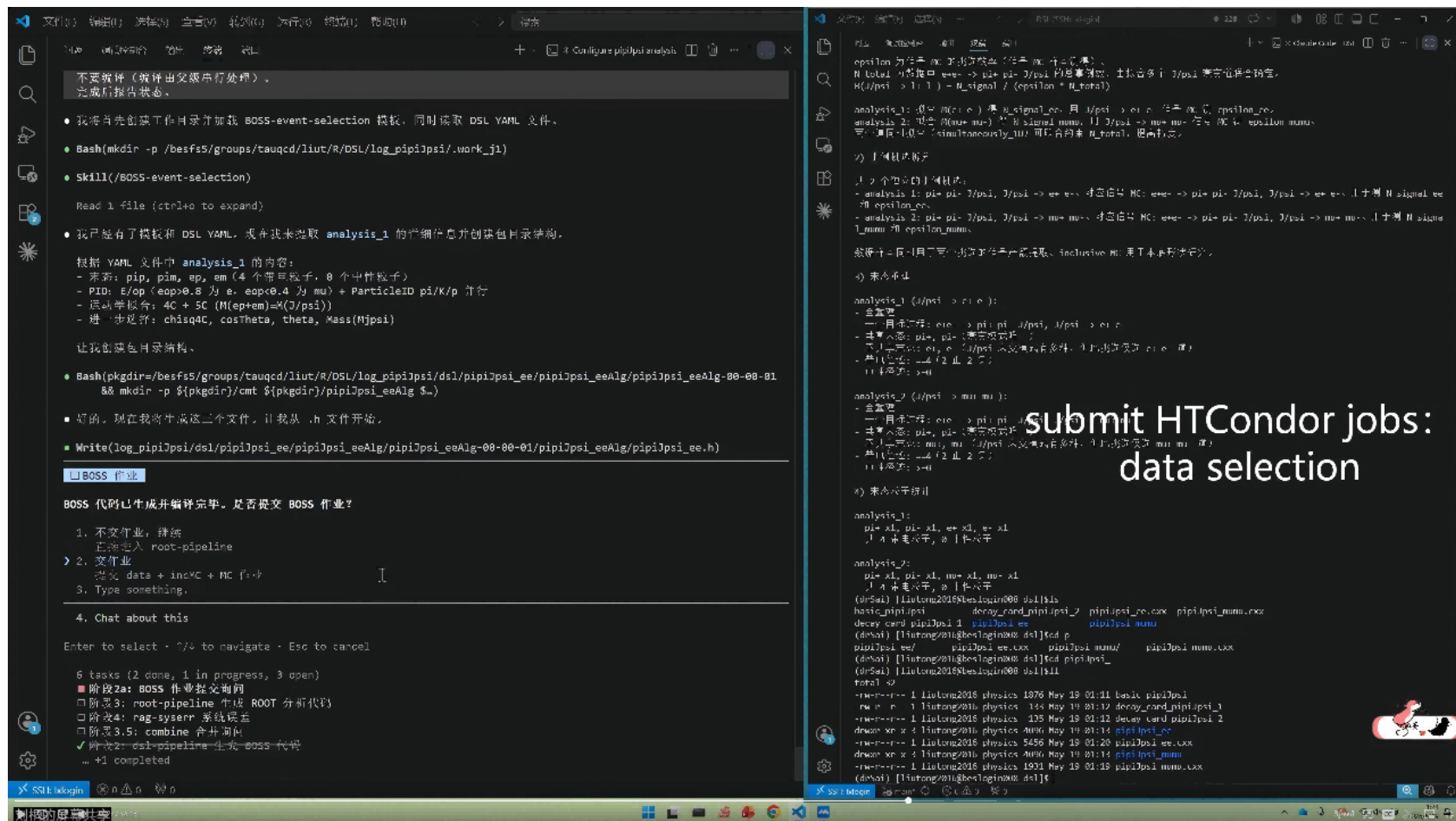
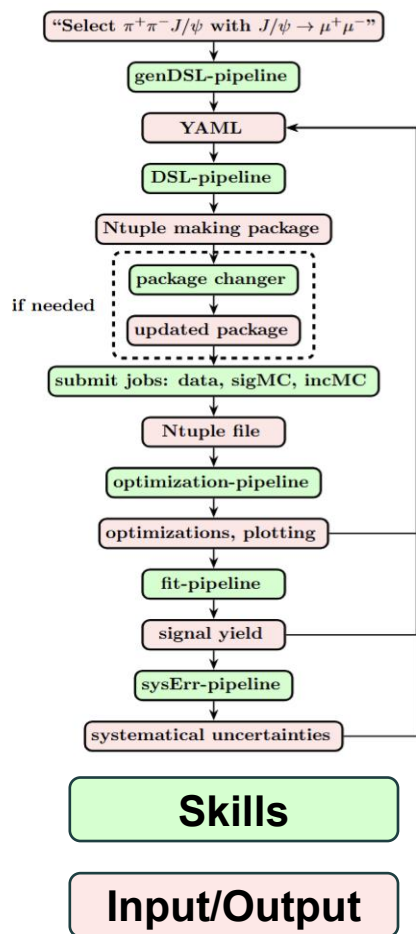
- 1a changeBOSS: genBOSSCode=direct. 跳过
- 1b confirm_mode: config 已设 minimal. 直接采用 [config] confirm_mode=minimal
- 1c parallel: config 已设 yes. 直接采用 [config] parallel=yes

The terminal also shows the execution of the pipeline, including the command `runBOSS_outdirs/besfs5/groups/tauqcd/liut/R/DSL/log_pipilpsi/proj_pipilpsi` and the confirmation prompt `是否确认执行? (y/n)`.

On the right side of the terminal, the word **confirm** is displayed, indicating the confirmation step.

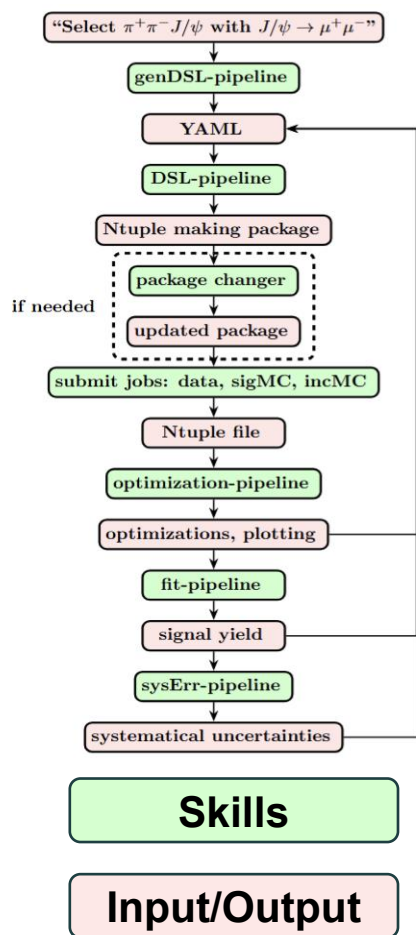
Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

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Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

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Screenshot of the DrSai_v3.0.0 interface showing the configuration for the $\pi^+\pi^-J/\psi$ analysis.

Configuration parameters:

运行阶段	sim+rec+ana
alignname	pipiJpsi_ee
队列类型	普通队列
产生模式	B (KKMC + BesEvtGen)
GeneratePsi flag	GeneratePsi4260
CMSEnergy	4.26 GeV
ThresholdCut	3.376 GeV
Ana InputEcms	4.26 GeV
Decay card 母粒子	psi(4260)
Decay card 路径	/besfs5/groups/tauqcd/liut/R/DSL/log_pipiJpsi/dsl/decay_card_pipiJpsi_1
xs_user.dat	需要复制
RunIdList	-31561,0,-31981
ana 分析模式	普通分析 (dtag_mode=no)

MC jobs: sim-rec-ana

Confirmation dialog:

是否按此参数生成 pipiJpsi_ee MC 作业并提交?

- y. 确认
按此参数生成并提交
- n. 修改
需要修改参数
- 能量能散= 4.25795 0.001329
- Chat about this

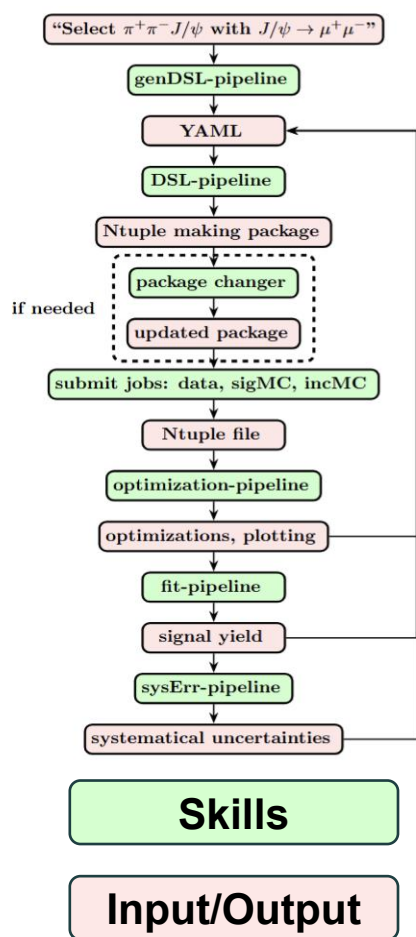
Enter to select · /? to navigate · ctrl+g to edit in Vim · Esc to cancel

6 tasks (2 done, 1 in progress, 3 open)

- 阶段2a: BOSS 作业提交询问
- 阶段3: root-pipeline 生成 ROOT 分析代码
- 阶段4: rag-syserr 系统误差
- 阶段3.5: combine 合并询问
- 阶段2: dsl-pipeline 生成 BOSS 代码
- +1 completed

Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

- A demo with DrSai_v3.0.0, Continuously updated



The screenshot shows a Claude Code v2.1.145 interface. The left sidebar displays a file explorer with a project named 'Continue pipilpsi analysis homework'. The main terminal window shows a series of commands and outputs related to monitoring job status. The output includes a list of directories and a confirmation that the 'auto mode' is on. The right sidebar shows a list of jobs being monitored, with the text 'monitor jobs' status' overlaid.

```

Claude Code v2.1.145
deepseek-v4-pro[1m][1m] · API Usage Billing
/besf5/groups/taucqd/liut/R/DSL

> 继续pipilpsi, 检查作业

Skill(/checkBOSS_jobs)
  Successfully loaded skill

• 请先找到 pipilpsi 的配置, 确定作业类型和日志目录。

Searched for 2 patterns, read 1 file, listed 2 directories (ctrl-o to expand)

• 看到项目有 data, incMC, MC 三种作业类型 (各有 ee 和 mumu 两个通道), 我来检查所有作业状态。

Listing 3 directories.. (ctrl-o to expand)
  $ ls /besf5/groups/taucqd/liut/R/DSL/log_pipilpsi/proj_pipilpsi/MC/txt/ 2>/dev/null | head -30;
  echo "---"; ls /besf5/groups/taucqd/liut/R/DSL/log_pipilpsi/proj_pipilpsi/MC_mumu/txt/
  2>/dev/null | head -30

+Proofing.. (1m 23s · 1.7k tokens · almost done thinking)
  Tip: Use /btw to ask a quick side question without interrupting Claude's current work

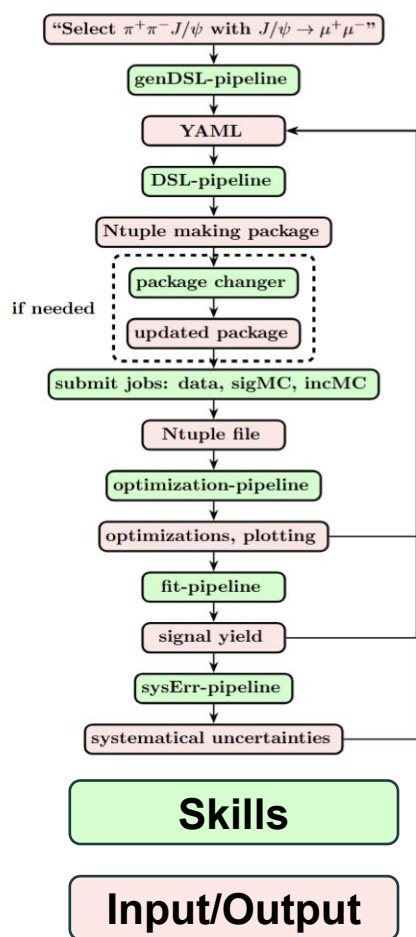
>

>> auto mode on (shift-tab to cycle) · esc to interrupt
  
```

monitor jobs' status

Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

- A demo with DrSai_v3.0.0, Continuously updated

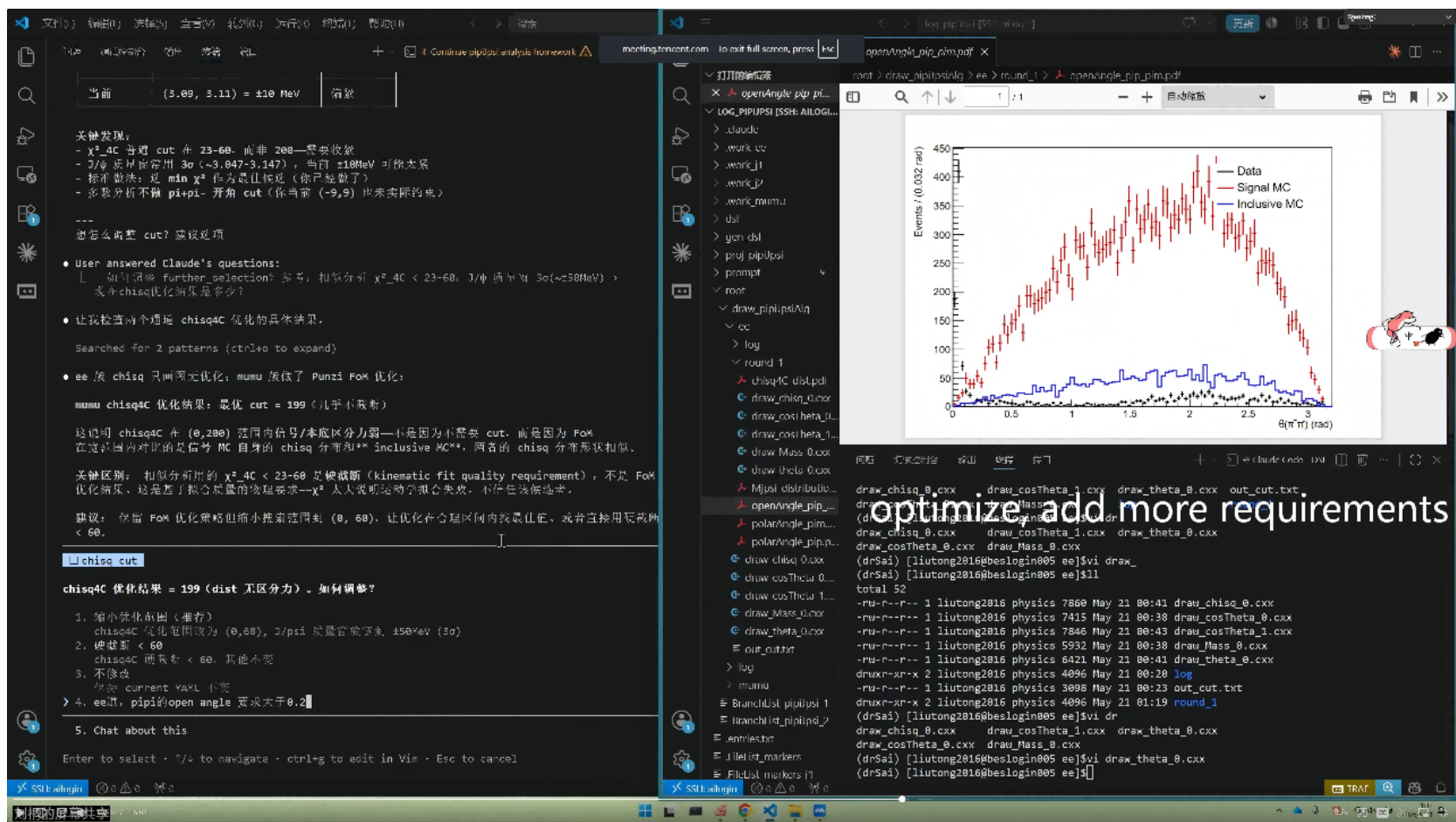
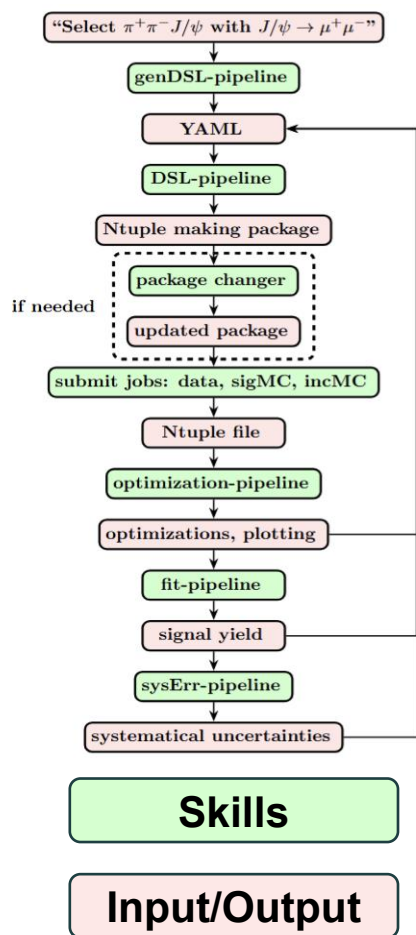


The terminal window shows the execution of a pipeline for the rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$. The pipeline is executed using a series of commands, including the generation of a DSL pipeline, the creation of a package, the submission of jobs, and the execution of the optimization pipeline. The output shows the results of the fit, including the signal yield and systematic uncertainties.

generate plotting/optimizing code

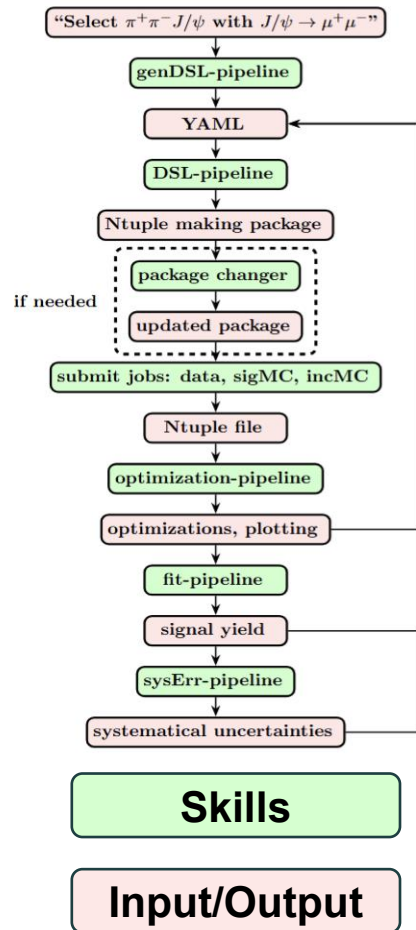
Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

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Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

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Terminal output showing the execution of the pipeline:

```

ee maxRM: sig=3.854, data=3.856, inc=3.849 - 二者吻合 < 7 MeV. 现在 muu
Bash(cat > /besfs5/groups/taugcd/liut/R/DSL/log_pipi3psi/.work_mumu/draw_maxRM.cxx << 'ENDOFSCRIPT'
...)
...+5 lines (ctrl+o to expand)
(timeout 10m)
Allowed by auto mode classifier
Done

Bash(cp /besfs5/groups/taugcd/liut/R/DSL/log_pipi3psi/.work_ee/maxRM_ee_all.pdf
/besfs5/groups/taugcd/liut/R/DSL/log_pipi3psi/root/draw_pipi3psiAlg/ee/round_2/)
Done

Bash(cp /besfs5/groups/taugcd/liut/R/DSL/log_pipi3psi/.work_mumu/maxRM_mumu_all.pdf
/besfs5/groups/taugcd/liut/R/DSL/log_pipi3psi/root/draw_pipi3psiAlg/mumu/round_1/)
Done

max RM(n) = max(RM(n+), RM(n-)). 范围 3.6-4.2 GeV:

```

通道	样本	Candidates	Mean [GeV]
ee	sig MC	11,226	3.854
	data	857	3.856
	inc MC	3,456	3.849
mumu	sig MC	15,681	3.855
	data	1,107	3.848
	inc MC	4,512	3.852

二者高度一致 (mean 差 < 8 MeV). incMC 初始数与 sigMC 的 maxRM 形状匹配良好. PDF 已归档.
进入拟合?

* Crunched for 4m 39s

> 1) 同时画出 jpsi sideband. 2) 把这个图归档到yaml

+ Generating draw_chisq_0.cxx.

auto mode on (shift-tab to cycle) · esc to interrupt · ctrl-t to show tasks

change plotting

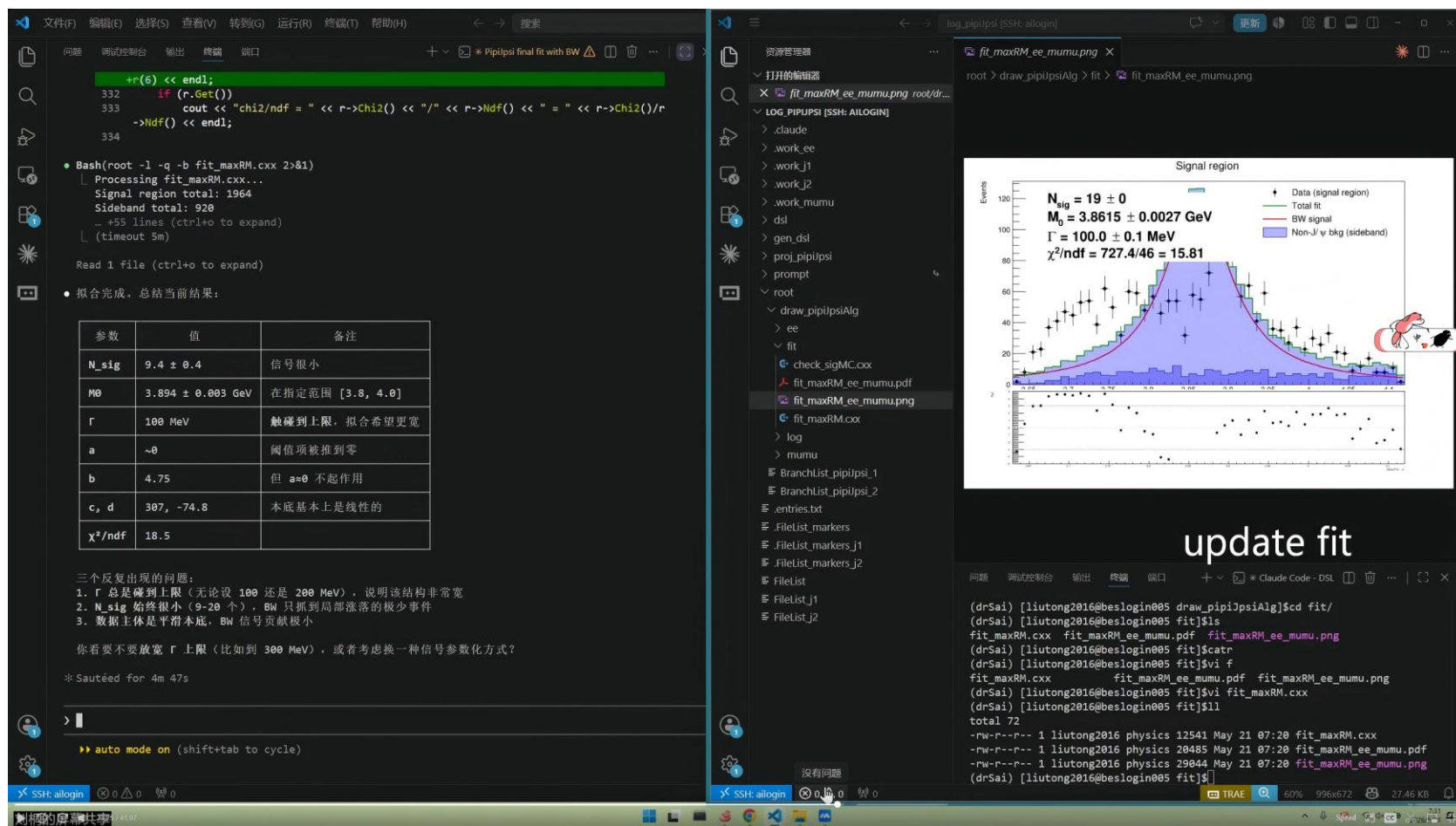
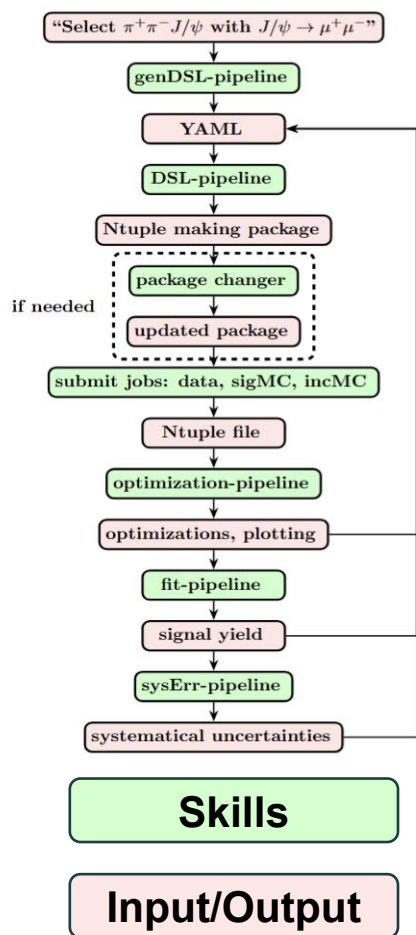
```

draw_chisq_0.cxx draw_cosTheta_1.cxx draw_theta_0.cxx
draw_cosTheta_0.cxx draw_Mass_0.cxx
(drSai) [liutong2816@beslogin005 ee]$vi draw_
(drSai) [liutong2816@beslogin005 ee]$ls
total 52
-rw-r--r-- 1 liutong2816 physics 7860 May 21 00:44 draw_chisq_0.cxx
-rw-r--r-- 1 liutong2816 physics 7415 May 21 00:38 draw_cosTheta_0.cxx
-rw-r--r-- 1 liutong2816 physics 7846 May 21 00:43 draw_cosTheta_1.cxx
-rw-r--r-- 1 liutong2816 physics 5932 May 21 00:38 draw_Mass_0.cxx
-rw-r--r-- 1 liutong2816 physics 6421 May 21 00:41 draw_theta_0.cxx
drwxr-xr-x 2 liutong2816 physics 4096 May 21 00:28 log
-rw-r--r-- 1 liutong2816 physics 3098 May 21 00:23 out_cut.txt
drwxr-xr-x 2 liutong2816 physics 4096 May 21 01:19 round_1
(drSai) [liutong2816@beslogin005 ee]$vi dr
draw_chisq_0.cxx draw_cosTheta_1.cxx draw_theta_0.cxx
draw_cosTheta_0.cxx draw_Mass_0.cxx
(drSai) [liutong2816@beslogin005 ee]$vi draw_theta_0.cxx
(drSai) [liutong2816@beslogin005 ee]$..
(drSai) [liutong2816@beslogin005 ee]$ls
ee log mumu
(drSai) [liutong2816@beslogin005 ee]$cd mumu/
(drSai) [liutong2816@beslogin005 ee]$ls
draw_chisq_0.cxx draw_cosTheta_1.cxx draw_Mass_0.cxx log rou
nd_1
draw_cosTheta_0.cxx draw_Mass_0.cxx draw_theta_0.cxx out_cut.txt
(drSai) [liutong2816@beslogin005 ee]$cd -
(drSai) [liutong2816@beslogin005 ee]$vi dr_

```

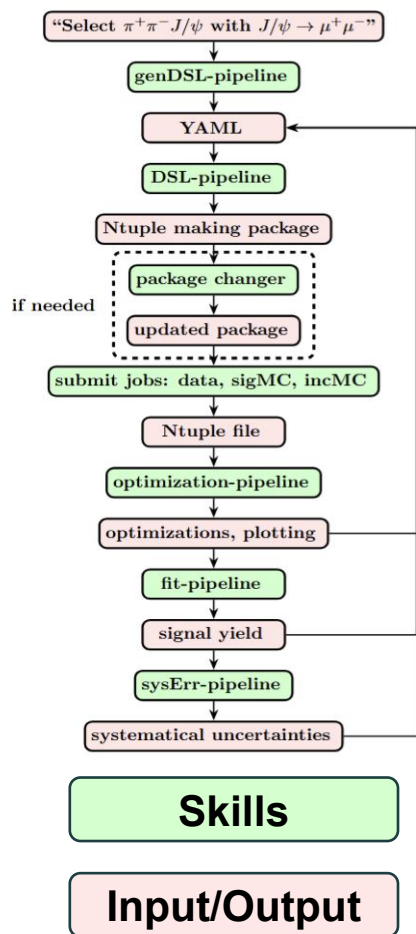
Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

- A demo with DrSai_v3.0.0, Continuously updated



Eg: rediscovery of $Z_c(3900)$ in $e^+e^- \rightarrow \pi^+\pi^-J/\psi$

- A demo with DrSai_v3.0.0, Continuously updated



Screenshot of a terminal window showing the output of the `genDSL` pipeline. The output includes a table of fit results and a list of systematic uncertainties recommended by RAG.

类别	来源	估计值	方法
探测器效率	径迹重建 (4 tracks)	4.0%	1%/track, 参考 BAM-00348
	π PID	2.0%	控制样本, 变化 PID cut
	e PID ($E/p+EMC$)	1.0%	Bhabha 控制样本
	μ PID (MUC)	1.0%	$\mu\mu$ 控制样本
	运动学拟合 (4C)	0.5%	helix 参数修正有无效率差之半
MC	MC 统计 (50k)	0.1%	可忽略
	产生子模型 (VVPIPI vs PHSP)	1.0%	模型效率差
其他	ISR 修正	0.5%	KKMC $\pm$ ISR
	积分亮度	1.0%	Bhabha 标准方法
	分支比 $B(J/\psi \rightarrow \mu^+\mu^-)$	0.5%	PDG 值
选择裁断	chisq4C 变化	-	± 20 变动
	$\cos\theta$ cut (0.8 ± 0.7)	-	BAM-00348 方法
	J/ψ 质量窗变化	-	窗口 ± 10 MeV
拟合系统	信号模型 (BW M0, Γ)	-	参数在拟合误差内变化
	本底形状替代	-	多项式替代 $a/(x-3.6)^b$
	拟合范围变化	-	边界 ± 20 MeV
	Sideband 归一化	-	$\pm 20\%$ 变动

输出文件: log_pipilpsi/gen_dsl/pipilpsi.yaml (YAML 校验通过)

* Worked for 10m 31s

chisq4C 变化, 拟合范围变化 不需要

Symbioting...

auto mode on (shift+tab to cycle) · esc to interrupt

Systematic uncertainties recommended by RAG

```

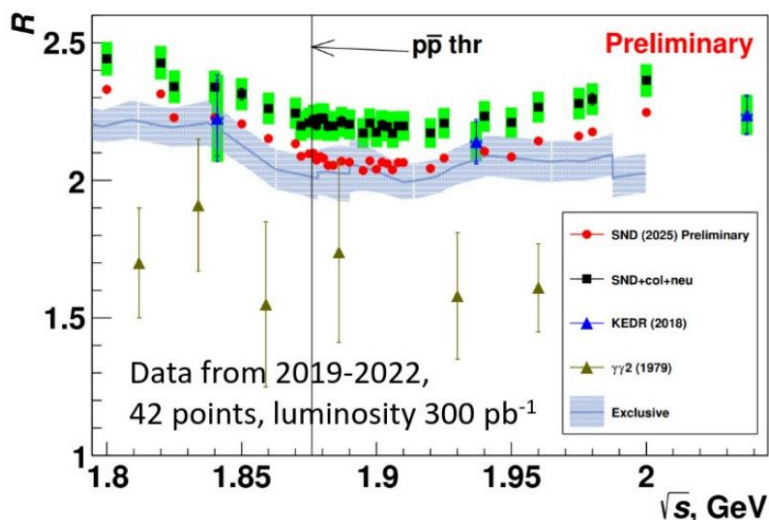
other:
  basic_pid:
    - pi: "momentum less than 0.7 GeV/c"
    - e: "momentum larger than 1 GeV/c, EMC deposition larger than 0.8 GeV"
  V:
    - mu: "momentum larger than 1 GeV/c, EMC deposition less than 0.8 GeV"
  kmfit:
    - var: 4C
      setting: setChisqCut(200,0.005)
    - var: 5C (4C, M_jpsi)
      setting: setChisqCut(9999,0.005)
  further_selection:
    chisq:
      - {var: "chisq4C", optimize: 10, strategy: FoM, default: (0,200), Nbin_r: 100, (0,200)}
    cosTheta:
      - {var: "polarAngle_pip", optimize: False, strategy: oM, default: (-0.8,0.8)}
      - {var: "polarAngle_pim", optimize: False, strategy: FoM, default: (-0.8,0.8)}
    theta:
      - {var: "openAngle_pip_pim", optimize: False, strategy: FoM, default: (-99,99)}
    Mass:
      - {var: "Mjpsi: p4_mup + p4_mum", optimize: False, strategy: FoM, default: (3.09,3.11), Nbin_region: "100, (3.3,2)"}
    RM_pi:
      - {var: "maxRMpi: max(RM(pi+), RM(pi-)), ecms=4.25795", optimize: False, strategy: FoM, default: (3.6,4.2), comment: "diagnostic only, NRM=100(3.6,4.2), sideband defined as (3.05,3.08)U(3.12,3.15)"}
  fit:
    systematic_uncertainties:
      result:
        (drSai) [liutong2016@beslogin005 gen_dsl]$
  
```


The first analysis with DrSai: R@1.9 GeV

22

PRD 97, 114025 (2018)

- Exclusive R value measurements at 1.9 GeV
 - Difference between inclusive and exclusive results



Recent results from the SND experiment

Signature	Final states (preliminary, published)
2 charged	$\pi^+\pi^-, K^+K^-, K_S K_L, p\bar{p}$
2 charged + γ 's	$\pi^+\pi^-\gamma, \pi^+\pi^-\pi^0, \pi^+\pi^-\eta, K^+K^-\pi^0, K^+K^-\eta, K_S K_L \pi^0, K_S K_L \eta, \pi^+\pi^-\pi^0\eta, \pi^+\pi^-\pi^0\pi^0, \pi^+\pi^-\pi^0\pi^0, \pi^+\pi^-\pi^0\pi^0\pi^0$
4 charged	$\pi^+\pi^-\pi^+\pi^-, K^+K^-\pi^+\pi^-, K_S K^\pm \pi^\mp, K_S K_L \pi^+\pi^-, K_S K_S \pi^+\pi^-$
4 charged + γ 's	$\pi^+\pi^-\pi^+\pi^-\pi^0, \pi^+\pi^-\eta, \pi^+\pi^-\omega, \pi^+\pi^-\pi^+\pi^-\pi^0\pi^0, K^+K^-\eta, K^+K^-\omega$
6 charged	$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-, K_S K^\pm \pi^\mp \pi^+\pi^-, K_S K_S \pi^+\pi^-$
6 charged + γ 's	$3(\pi^+\pi^-\pi^0)$
Neutral	$\pi^0\gamma, \eta\gamma, \pi^0\pi^0\gamma, \pi^0\eta\gamma, \pi^0\pi^0\pi^0\gamma, \pi^0\pi^0\eta\gamma$
Other	$n\bar{n}, \pi^0 e^+ e^-, \eta e^+ e^-$
Rare decays	$\eta', D^*(2007)^0, f_1(1285)$

CMD-3 analysis

Channel	This work (KNT18)	HLMNT11 [9]	Difference
Chiral perturbation theory (ChPT) threshold contributions			
$\pi^0\gamma$	0.12 ± 0.01	0.12 ± 0.01	0.00
$\pi^+\pi^-$	0.87 ± 0.02	0.87 ± 0.02	0.00
$\pi^+\pi^-\pi^0$	0.01 ± 0.00	0.01 ± 0.00	0.00
$\eta\gamma$	0.00 ± 0.00	0.00 ± 0.00	0.00
Data based channels ($\sqrt{s} \leq 2$ GeV)			
$\pi^0\gamma$	4.46 ± 0.10	4.54 ± 0.14	-0.08
$\pi^+\pi^-$	502.99 ± 1.97	505.77 ± 3.09	-2.78
$\pi^+\pi^-\pi^0$	47.82 ± 0.89	47.51 ± 0.99	0.31
$\pi^+\pi^-\pi^+\pi^-$	15.17 ± 0.21	14.65 ± 0.47	0.52
$\pi^+\pi^-\pi^0\pi^0$	19.80 ± 0.79	20.37 ± 1.26	-0.57
$(2\pi^+2\pi^-\pi^0)_{\text{no } \eta}$	1.08 ± 0.10	1.20 ± 0.10	-0.12
$3\pi^+3\pi^-$	0.28 ± 0.02	0.28 ± 0.02	0.00
$(2\pi^+2\pi^-\pi^0)_{\text{no } \eta\omega}$	1.60 ± 0.20	1.80 ± 0.24	-0.20
K^+K^-	23.05 ± 0.22	22.15 ± 0.46	0.90
$K_S^0 K_L^0$	13.05 ± 0.19	13.33 ± 0.16	-0.28
$K\bar{K}\pi$	2.80 ± 0.12	2.77 ± 0.15	0.03
$K\bar{K}2\pi$	2.42 ± 0.09	3.31 ± 0.58	-0.89
$\eta\gamma$	0.70 ± 0.02	0.69 ± 0.02	0.01
$\eta\pi^+\pi^-$	1.32 ± 0.06	0.98 ± 0.24	0.34
$(\eta\pi^+\pi^-\pi^0)_{\text{no } \omega}$	0.63 ± 0.15	-	0.63
$\eta 2\pi^+2\pi^-$	0.11 ± 0.02	0.11 ± 0.02	0.00
$\eta\omega$	0.31 ± 0.03	0.42 ± 0.07	-0.11
$\omega(\rightarrow \pi^0\gamma)\pi^0$	0.88 ± 0.02	0.77 ± 0.03	0.11
$\eta\phi$	0.45 ± 0.04	0.46 ± 0.03	-0.01
$\phi \rightarrow \text{unaccounted}$	0.04 ± 0.04	0.04 ± 0.04	0.00
$\eta\omega\pi^0$	0.42 ± 0.10	-	0.42
$\eta(\rightarrow \text{npp})K\bar{K}_{\text{no } \phi \rightarrow K\bar{K}}$	0.01 ± 0.01	-	0.01
$p\bar{p}$	0.07 ± 0.00	0.06 ± 0.00	0.01
$n\bar{n}$	0.06 ± 0.01	0.07 ± 0.02	-0.01
Estimated contributions ($\sqrt{s} \leq 2$ GeV)			
$(\pi^+\pi^-\pi^0)_{\text{no } \eta}$	0.53 ± 0.05	0.60 ± 0.05	-0.07
$(\pi^+\pi^-\pi^0)_{\text{no } \eta}$	0.25 ± 0.25	0.28 ± 0.28	-0.03
$K\bar{K}3\pi$	0.08 ± 0.03	0.08 ± 0.04	0.00
$\omega(\rightarrow \text{npp})2\pi$	0.10 ± 0.02	0.11 ± 0.02	-0.01
$\omega(\rightarrow \text{npp})3\pi$	0.20 ± 0.04	0.22 ± 0.04	-0.02
$\omega(\rightarrow \text{npp})K\bar{K}$	0.01 ± 0.00	0.01 ± 0.00	0.00
$\eta\pi^+\pi^-\pi^0$	0.11 ± 0.05	0.11 ± 0.06	0.00

The first analysis with DrSai: R@1.9 GeV

- Beyond small processes, remain **~40** channels !

- Traditional: **40 PhD * 1 year**
- DrSai: **1 PhD * 1 month !**
- Codes are generated with subAgents simultaneously
- Only human-AI interaction, no manual coding

```

> |
>> auto mode on · 25 local agents · ↓ to manage

• main
  general-purpose BOSS code gen: bhabha (j2=1) 6m 52s · ↓ 69.8k tokens
  general-purpose BOSS code gen: digam (j2=2) 6m 3s · ↓ 73.4k tokens
  general-purpose BOSS code gen: dimu (j2=3) 6m 3s · ↓ 75.8k tokens
  general-purpose BOSS code gen: eeee (j2=4) 6m 3s · ↓ 61.9k tokens
  general-purpose BOSS code gen: eeeta (j2=5) 6m 3s · ↓ 53.4k tokens
  general-purpose BOSS code gen: eeetap (j2=6) 6m 3s · ↓ 50.9k tokens
  general-purpose BOSS code gen: eekk (j2=7) 5m 17s · ↓ 31.8k tokens
  general-purpose BOSS code gen: eepipi (j2=8) 5m 17s · ↓ 51.8k tokens
  general-purpose BOSS code gen: eemumu (j2=9) 5m 17s · ↓ 54.7k tokens
  general-purpose BOSS code gen: pi0 gamma (j2=10) 5m 17s · ↓ 56.5k tokens
  general-purpose BOSS code gen: eta gamma (j2=11) 5m 17s · ↓ 55.8k tokens
  general-purpose BOSS code gen: pi+pi- (j2=12) 5m 17s · ↓ 47.3k tokens
  general-purpose BOSS code gen: pi+pi-pi0 (j2=13) 4m 22s · ↓ 48.4k tokens
  general-purpose BOSS code gen: pi+pi-pi+pi- (j2=14) 4m 22s · ↓ 49.9k tokens
  general-purpose BOSS code gen: pi+pi-pi0pi0 (j2=15) 4m 22s · ↓ 38.5k tokens
  general-purpose BOSS code gen: pi+pi-pi+pi-pi0 (j2=16) 4m 22s · ↓ 39.7k tokens
  general-purpose BOSS code gen: pi+pi-3pi0 (j2=17) 4m 22s · ↓ 35.7k tokens
  general-purpose BOSS code gen: 6pi (j2=18) 4m 22s · ↓ 50.6k tokens
  general-purpose BOSS code gen: 4pi2pi0 (j2=19) 3m 18s · ↓ 11.5k tokens
  general-purpose BOSS code gen: pipi4pi0 (j2=20) 3m 18s · ↓ 30.3k tokens
  general-purpose BOSS code gen: omega eta pi0 (j2=21) 3m 18s · ↓ 38.3k tokens
  general-purpose BOSS code gen: K+K- (j2=22) 3m 18s · ↓ 29.2k tokens
  general-purpose BOSS code gen: K_S0 K_L0 (j2=23) 3m 18s · ↓ 46.8k tokens
  general-purpose BOSS code gen: KKpipi (j2=24) 3m 18s · ↓ 31.5k tokens
  general-purpose BOSS code gen: KKpi (j2=25) 3m 18s · ↓ 49.4k tokens
  
```

nCharge=0	
$\gamma\pi^0$	
$\gamma\eta$	

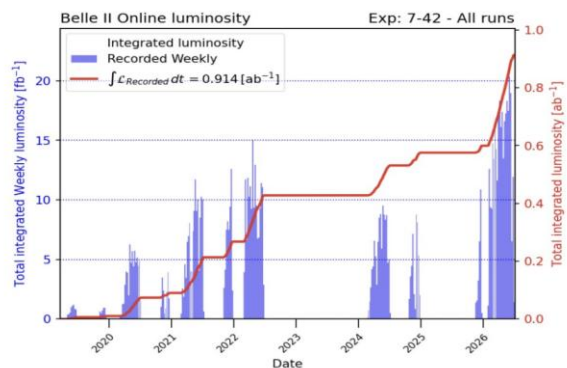
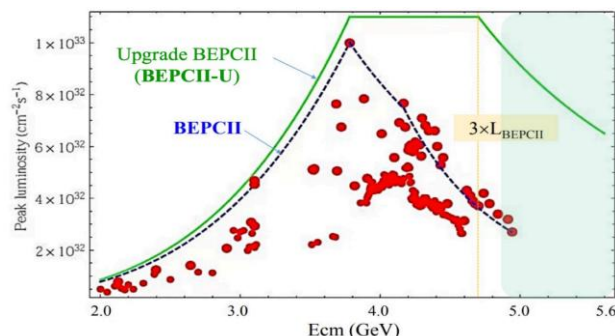
nCharge=2	
$\pi^+\pi^-$	
$\pi^+\pi^-\pi^0$	BAM-546
$\pi^+\pi^-2\pi^0$	
$\pi^+\pi^-3\pi^0$	
$\pi^+\pi^-4\pi^0$	
$\pi^+\pi^-\eta$	
$\omega\eta\pi^0$	BAM-00672
K^+K^-	
$K^+K^-\pi^0$	BAM-376, BAM-655
$K^+K^-\pi^0\pi^0$	BAM-229, BAM-346
$K^+K^-\pi^0\pi^0\pi^0$	KK3 π ~0.08
$K^+K^-\eta$	$\phi\eta$ dom.
$K_S^0 K_L^0$	
$K_S^0 K_L^0 \pi^0$	BAM-376, BAM-655
$K_S^0 K_L^0 \pi^0 \pi^0$	KK3 π ~0.08
$K_S^0 K_L^0 \eta$	

nCharge=4	
$2(\pi^+\pi^-)$	
$2(\pi^+\pi^-)\pi^0$	BAM-416, BAM-596
$2(\pi^+\pi^-)2\pi^0$	
$2(\pi^+\pi^-)3\pi^0$	
$2(\pi^+\pi^-)\eta$	~0.11
$K^+K^-\pi^+\pi^-$	BAM-229, BAM-346
$K^+K^-\pi^+\pi^-\pi^0$	KK3 π ~0.08
$K^+K^-\pi^+\pi^-\pi^0\pi^0$	<3($\pi^+\pi^-$)~0.28
$K^+K^-\pi^+\pi^-\pi^0\pi^0\pi^0$	<3($\pi^+\pi^-$)~0.28
$K^+K^-\pi^+\pi^-\eta$	<0.11 ?
$K_S^0 K^{\pm}\pi^{\mp}$	BAM-376, BAM-655
$K_S^0 K^{\pm}\pi^{\mp}\pi^0$	
$K_S^0 K^{\pm}\pi^{\mp}\pi^0\pi^0$	KK3 π ~0.08
$K_S^0 K^{\pm}\pi^{\mp}\pi^0\pi^0\pi^0$	<3($\pi^+\pi^-$)~0.28
$K_S^0 K^{\pm}\pi^{\mp}\eta$	
$K_S^0 K_L^0 \pi^+\pi^-$	
$K_S^0 K_L^0 \pi^+\pi^-\pi^0$	KK3 π ~0.08
$K_S^0 K_L^0 \pi^+\pi^-\pi^0\pi^0$	<0.08
$K_S^0 K_L^0 \pi^+\pi^-\pi^0\pi^0\pi^0$	<0.08
$K_S^0 K_L^0 \pi^+\pi^-\eta$	<0.11 ?

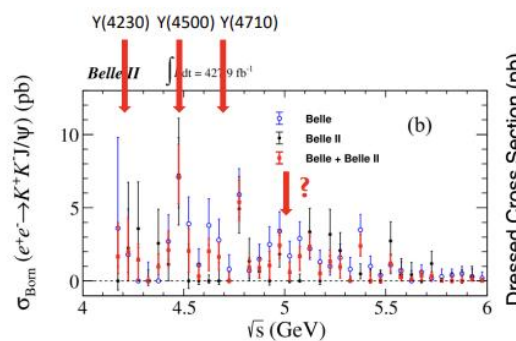
nCharge=6	
$3(\pi^+\pi^-)$	~0.28
$3(\pi^+\pi^-)\pi^0$	
$3(\pi^+\pi^-)\eta$	<<2($\pi^+\pi^-$)~0.11
$K^+K^-2(\pi^+\pi^-)$	<<3($\pi^+\pi^-$)~0.28
$K^+K^-2(\pi^+\pi^-)\pi^0$	<<3($\pi^+\pi^-$)~0.28
$K^+K^-2(\pi^+\pi^-)\eta$	<<2($\pi^+\pi^-$)~0.11
$K_S^0 K^{\pm}\pi^{\mp}\pi^+\pi^-$	KK3 π ~0.08
$K_S^0 K^{\pm}\pi^{\mp}\pi^+\pi^-\pi^0$	<0.08
$K_S^0 K^{\pm}\pi^{\mp}\pi^+\pi^-\eta$	<0.08
$K_S^0 K_L^0 \pi^+\pi^-\pi^+\pi^-$	<<3($\pi^+\pi^-$)~0.28
$K_S^0 K_L^0 \pi^+\pi^-\pi^+\pi^-\pi^0$	<<3($\pi^+\pi^-$)~0.28
$K_S^0 K_L^0 \pi^+\pi^-\pi^+\pi^-\eta$	<<2($\pi^+\pi^-$)~0.11

More analysis with DrSai

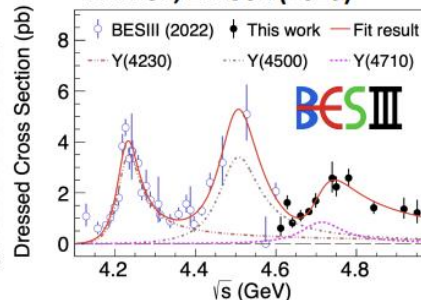
- Automatically repetition for published analysis
 - Traditional: **1 PhD**
 - DrSai: **1 published paper, 0 PhD ?**
 - With BESIII's and BelleII's upcoming statistics ...



PRD 113, 112010 (2026)
 $e^+e^- \rightarrow K^+K^-J/\psi$ via ISR:



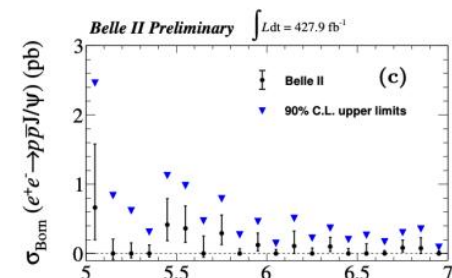
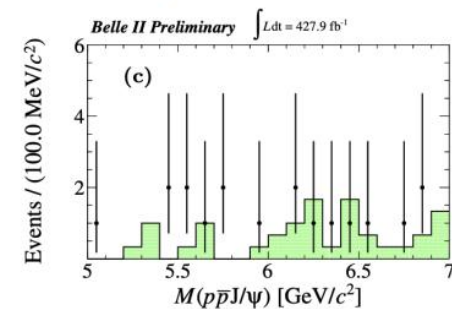
PRL 131, 211902 (2023)



- No clear signals were observed at Belle II.
- More data are needed.

$e^+e^- \rightarrow p\bar{p}J/\psi$ via ISR:

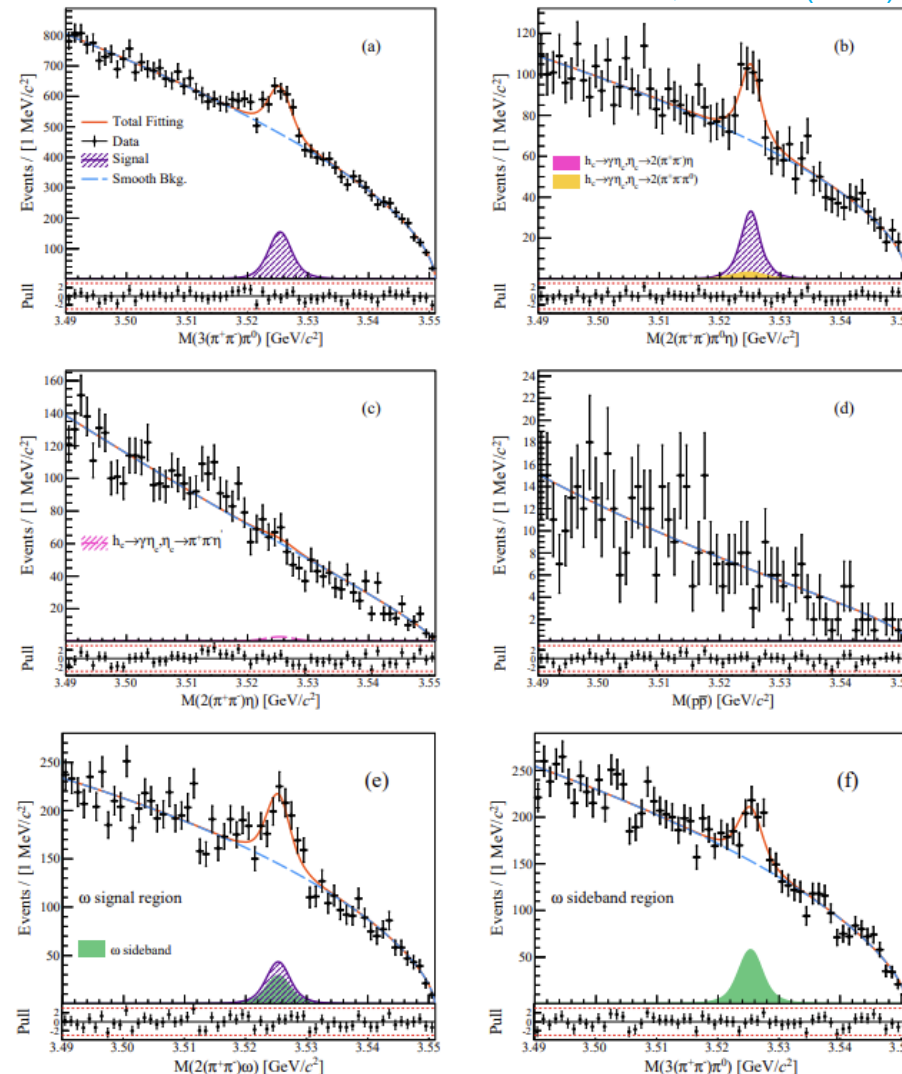
The cross section for $e^+e^- \rightarrow p\bar{p}J/\psi$ is estimated to be $\lesssim \mathcal{O}(0.1 \text{ pb})$ [PLB 872 (2026) 140007].



More analysis with DrSai

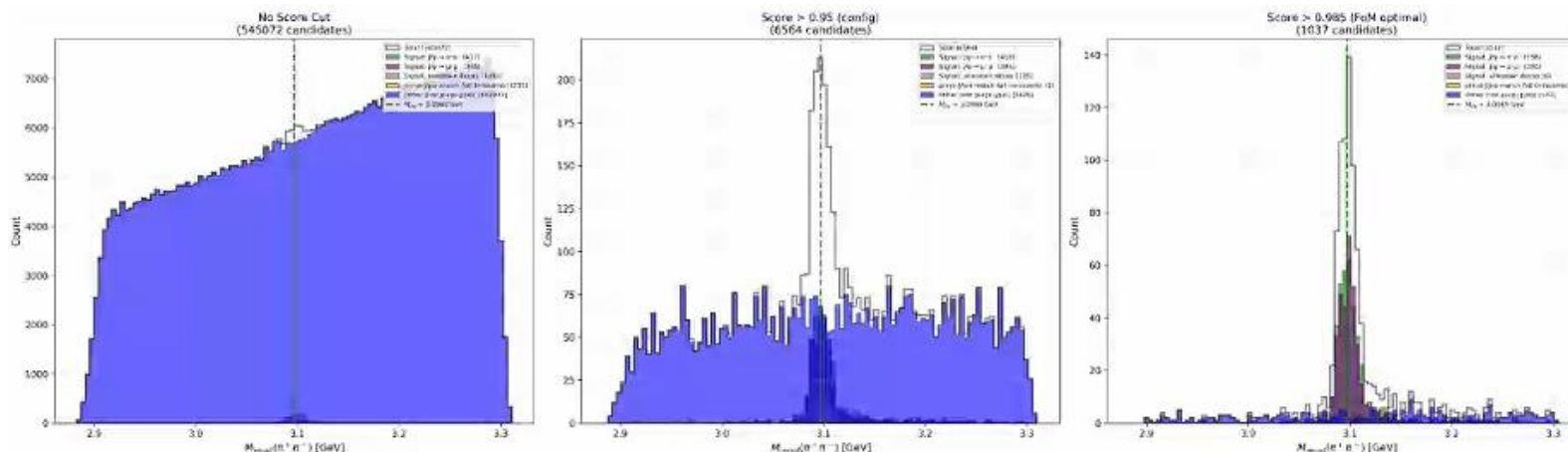
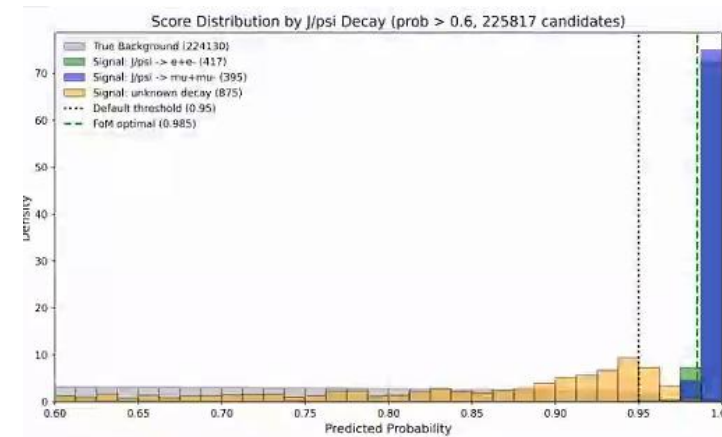
- Similar as R measurement...
- A set of exclusive analyses, to search for unknown decay modes
 - $\text{Br}(h_c \rightarrow \text{light hadrons})$ to be $(8.8 \pm 0.8)\%$ and $(48 \pm 7)\%$ with the perturbative QCD(PQCD) and non-relativistic QCD (NRQCD) [PRD 65, 094024 (2002)]
 - $\text{Br}(h_c \rightarrow \text{ggg}) = 57\%$ based on QCD calculations [PRD 66, 014012 (2002)]

PRD 109, 072018 (2024)



More analysis with DrSai

- More complex jobs:
 - PWA
 - With amplitudes written with AI
 - Based on available PWA packages
 - Build ML-based selection, **no need of the knowledge of ML**
 - Build user-friendly skills
 - To improve efficiencies of $J/\psi, \eta_c \dots$


$$e^+e^- \rightarrow \pi^+\pi^-J/\psi \text{ training}$$

Summary & Outlook

- We release DrSai v3: General-purpose Agent+Skills+DSL+RAG
 - https://code.ihep.ac.cn/liutong2016/DrSai_v3
- AI partner and agent-based analysis is being realized today
 - Only human-AI interaction, no manual coding
 - **Human focus on physics!**
 - **10~30 CNY** per channel (deepseek-v4-pro)

Thank you!

For the Tutorial

- Necessary:
 - Claude code
 - LLM API
 - DrSai: https://code.ihep.ac.cn/liutong2016/DrSai_v3
- Suggested:
 - cernROOT (for plotting)
 - lxlogin account (for RAG dataset)
 - Ruby > 3.4.2
 - BESIII user: BOSS 710 or higher