

Classification of near-threshold structures + Zotero-INSPIRE

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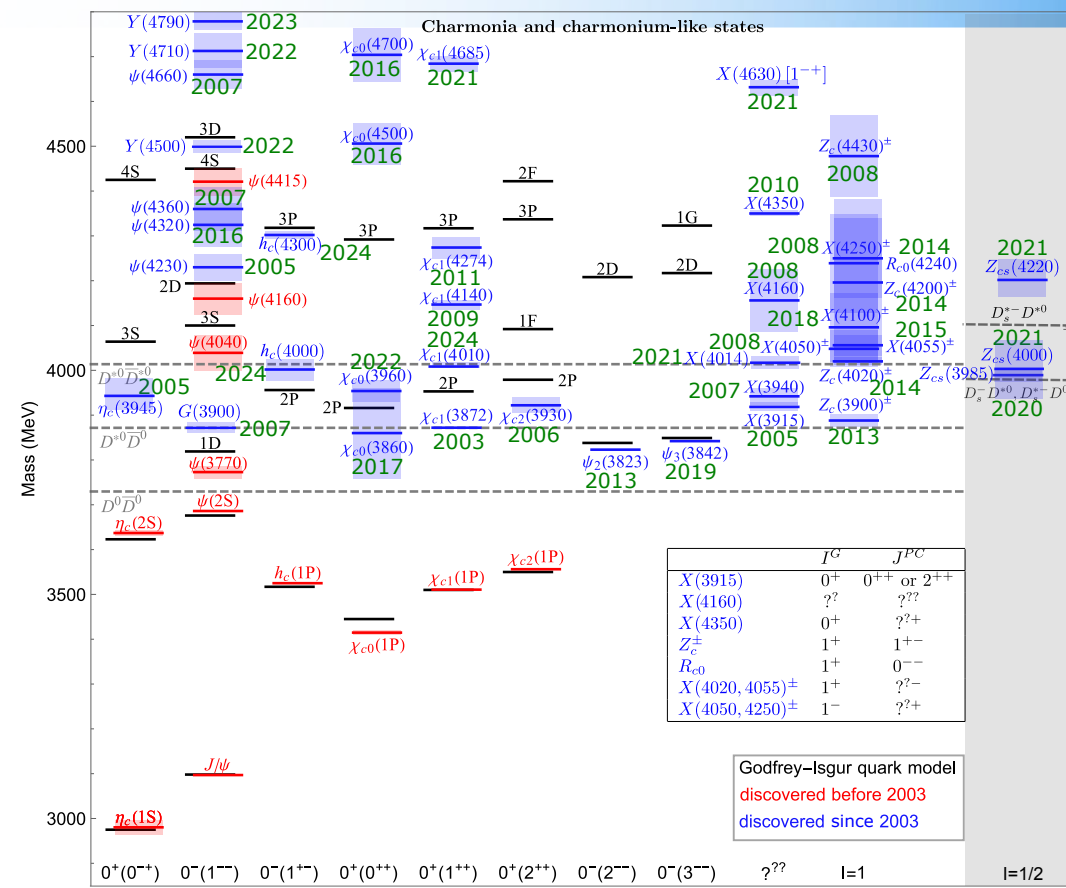
X.-K. Dong, FKG, B.-S. Zou, PRL 126, 152001 (2021)

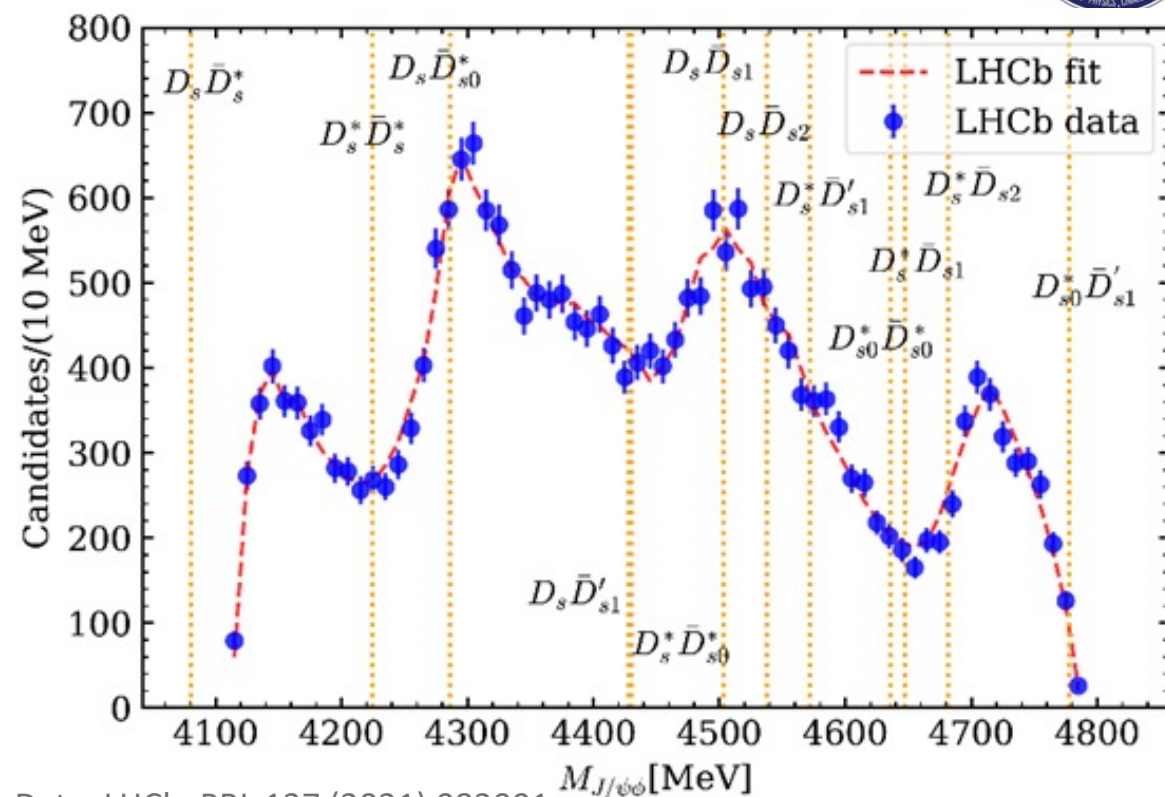
V. Baru, FKG, C. Hanhart, A. Nefediev, PRD 109, L111501 (2024)

Z.-H. Zhang, FKG, PLB 863 (2025) 139387

<https://github.com/fkguo/zotero-inspire/>

Dec. 05, 2025





Plot: X.-K. Dong, FKG, B.-S. Zou, Progr. Phys. 41 (2021) 65 [arXiv:2101.01021]

- Complicates extraction of resonance properties!
Measurements on various final states are important
- Hadronic molecules?

Molecular line shapes at LO

- Scattering length approx.: $p \cot \delta = \frac{1}{a} + \dots$

- Poles: **bound** ($a < 0$) or **virtual** ($a > 0$) state ($\kappa = 1/|a|$)

- Bound and virtual state can hardly be distinguished above threshold ($E > 0$)

$$|T_{\text{NR}}(E)|^2 \propto \left| \frac{1}{\pm \kappa + i\sqrt{2\mu E}} \right|^2 = \frac{1}{\kappa^2 + 2\mu E}$$

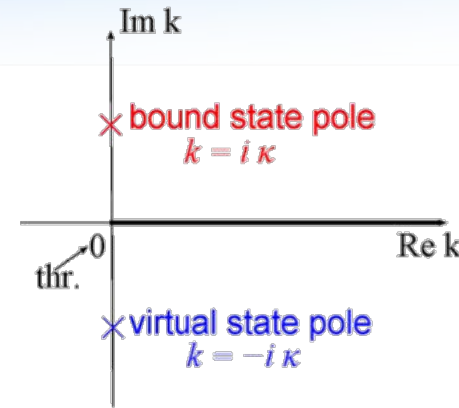
- Different below threshold ($E < 0$)

- bound state: peaked below threshold

$$|T_{\text{NR}}(E)|^2 \propto \frac{1}{(\kappa - \sqrt{-2\mu E})^2}$$

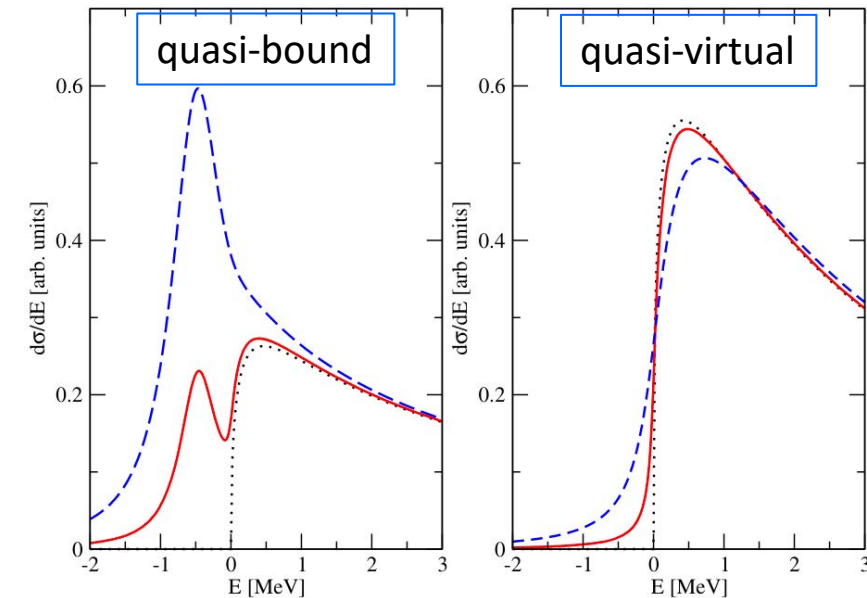
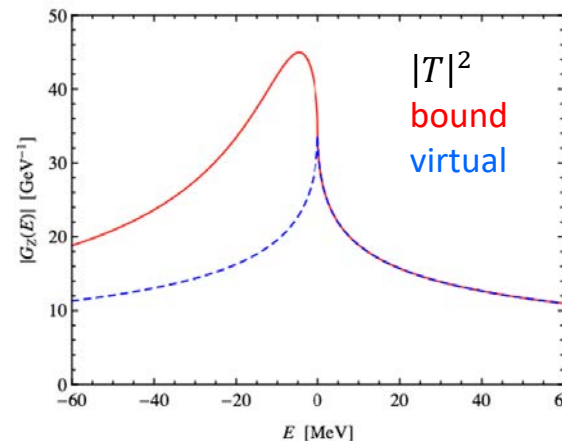
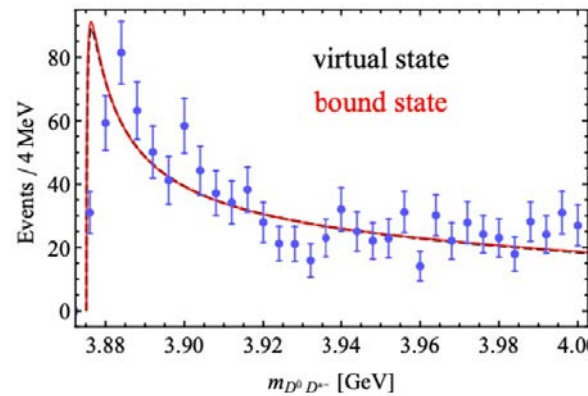
- virtual state: sharp cusp at threshold

$$|T_{\text{NR}}(E)|^2 \propto \frac{1}{(\kappa + \sqrt{-2\mu E})^2}$$



FKG, et al., RMP 90 (2018) 015004;
N. Brambilla et al., Phys.Rept. 873 (2020) 1

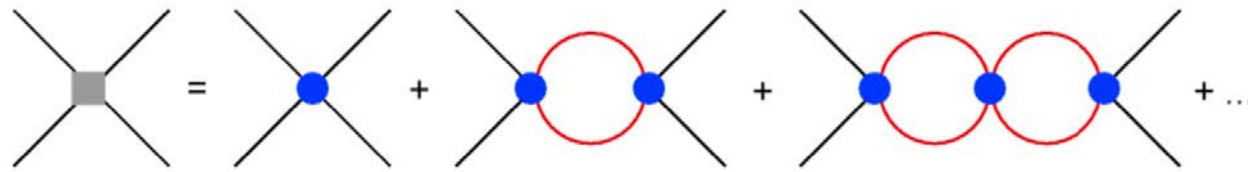
line shapes w/ phase space;
one unstable constituent:



$\Gamma = 0$	0.1 MeV	1 MeV
dotted	dashed	solid

NREFT at LO for coupled channels

- Full threshold structure needs to be **measured in a lower channel (ch-1)** $\Rightarrow$ **coupled channels**
- Consider a two-channel system, construct a “**nonrelativistic**” effective field theory (NREFT)
 - Energy region around the higher threshold (ch-2), Σ_2
 - Expansion in powers of $E = \sqrt{s} - \Sigma_2$
 - Momentum in the lower channel can also be expanded



$$T(E) = 8\pi\Sigma_2 \begin{pmatrix} -\frac{1}{a_{11}} + ik_1 & \frac{1}{a_{12}} \\ \frac{1}{a_{12}} & -\frac{1}{a_{22}} - \sqrt{-2\mu_2 E - i\epsilon} \end{pmatrix}^{-1} = -\frac{8\pi\Sigma_2}{\det} \begin{pmatrix} \frac{1}{a_{22}} + \sqrt{-2\mu_2 E - i\epsilon} & \frac{1}{a_{12}} \\ \frac{1}{a_{12}} & \frac{1}{a_{11}} - ik_1 \end{pmatrix}$$

- a_{22} : single-ch. scattering length of ch-2
- a_{11} : single-ch. interaction strength of ch-1 at Σ_2

$$\det = \left(\frac{1}{a_{11}} - ik_1\right) \left(\frac{1}{a_{22}} + \sqrt{-2\mu_2 E - i\epsilon}\right) - \frac{1}{a_{12}^2}$$

Effective scattering length with open-channel effects becomes **complex**, $\text{Im} \frac{1}{a_{22,\text{eff}}} \leq 0$

$$T_{22}(E) = -\frac{8\pi}{\Sigma_2} \left[\frac{1}{a_{22,\text{eff}}} - i\sqrt{2\mu_2 E} + \mathcal{O}(E) \right]^{-1} \quad \frac{1}{a_{22,\text{eff}}} = \frac{1}{a_{22}} - \frac{a_{11}}{a_{12}^2(1 + a_{11}^2 k_1^2)} - i \frac{a_{11}^2 k_1}{a_{12}^2(1 + a_{11}^2 k_1^2)}.$$

Distinct line shapes of the same pole

X.-K. Dong, FKG, B.-S. Zou, PRL 126 (2021) 152001

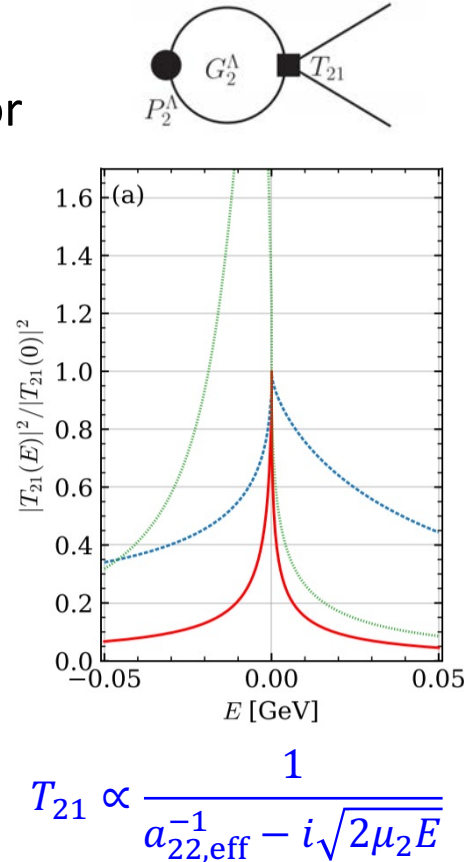
Line shapes of the same pole depend on the production mechanism. Consider production of particles in ch-1

- Dominated by ch-2

- Maximal at threshold for positive $\text{Re}(a_{22,\text{eff}})$ (attraction), $\text{FWHM} \propto 1/\mu$

➤ more pronounced for heavier hadrons and stronger interactions

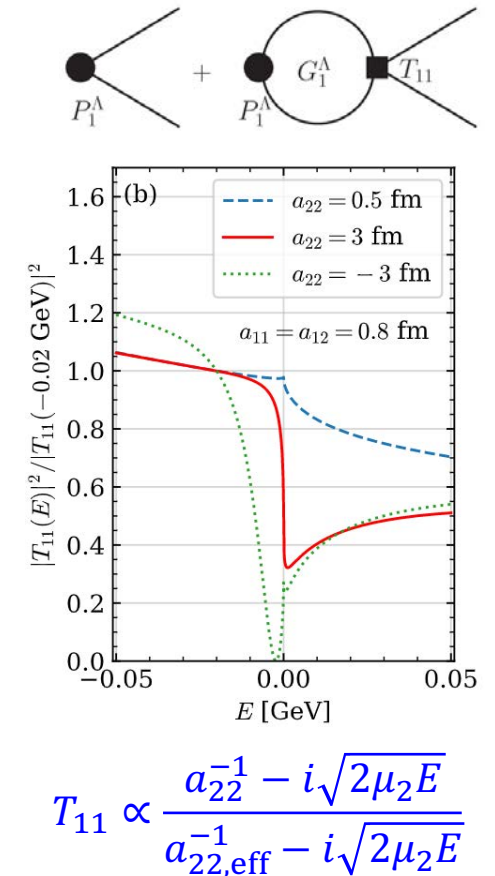
- Peaking at pole for negative $\text{Re}(a_{22,\text{eff}})$



- Dominated by ch-1

- One pole and one zero

- Universality for large scattering length: for large $|a_{22}|$, there must be a dip around threshold (zero close to threshold)



Process-dependent line shapes known since long; see, e.g., J. Taylor, *Scattering Theory*

✓ Classification of near-threshold structures and pole trajectories for two heavy channels: Z.-H. Zhang, FKG, PLB 863 (2025) 139387

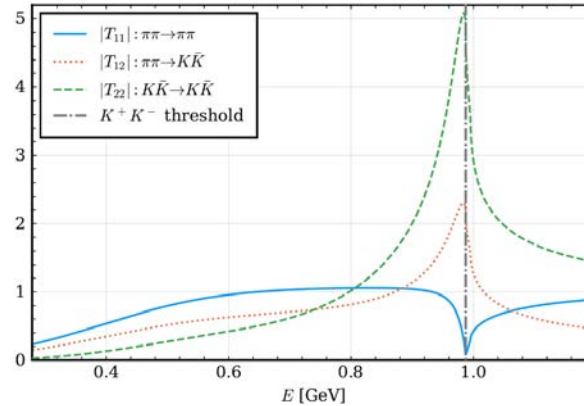
Distinct line shapes of the same pole

● Example-1: $f_0(980)$

□ T -matrix for $\pi\pi$ and $K\bar{K}$

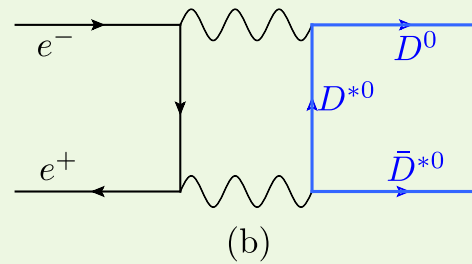
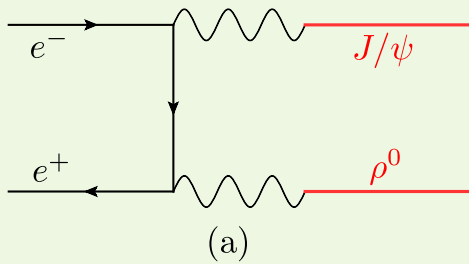
coupled channels

with the T-matrix from
L.-Y. Dai, M. R. Pennington,
PRD 90 (2014) 036004



● Example-2: direct production of $X(3872)$ in e^+e^-

V. Baru, FKG, C. Hanhart, A. Nefediev, PRD 109 (2024) L111501

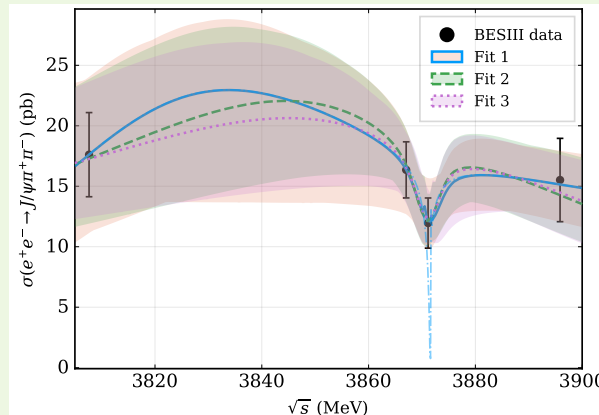


➤ Driving channel:

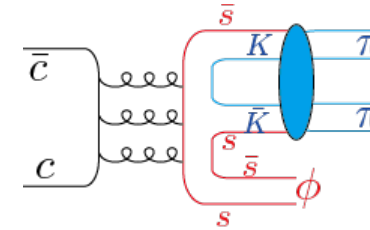
J/ψ + light vector

➤ Prediction: dip around

$D^*\bar{D}^*$ threshold

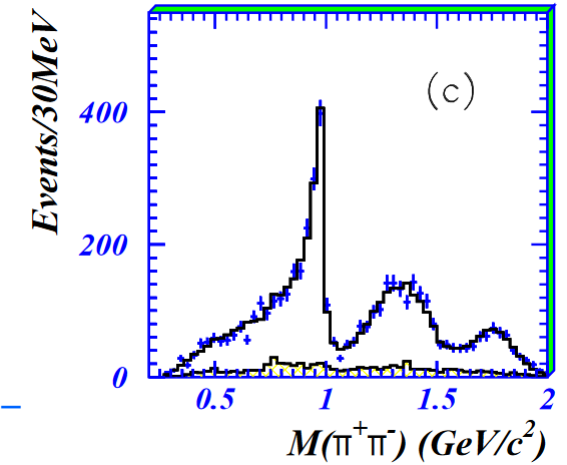


□ $J/\psi \rightarrow \phi \pi^+ \pi^-$



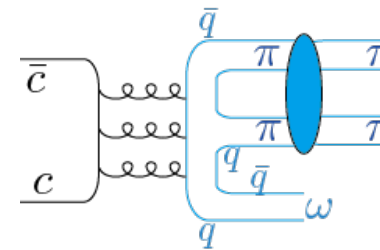
Driving channel: $K\bar{K}$

$J/\psi \rightarrow \phi K\bar{K} \rightarrow \phi \pi^+ \pi^-$



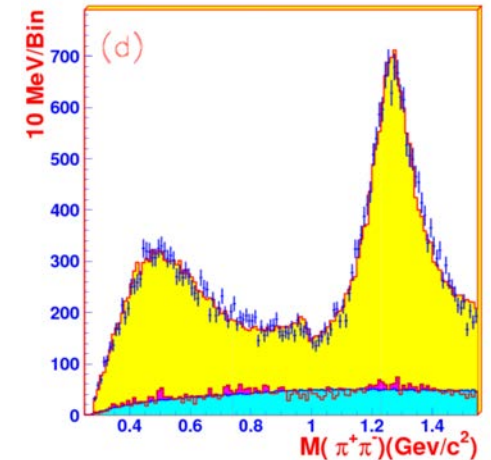
BES, PLB 607 (2005) 243

□ $J/\psi \rightarrow \omega \pi^+ \pi^-$



Driving channel: $\pi\pi$

$J/\psi \rightarrow \omega \pi\pi \rightarrow \omega \pi^+ \pi^-$



BES, PLB 598 (2004) 149

Prediction of an isospin vector partner of $X(3872)$

Z.-H. Zhang, T. Ji, X.-K. Dong, FKG, C. Hanhart, U.-G. Meißner, A. Rusetsky, JHEP 08 (2025) 130

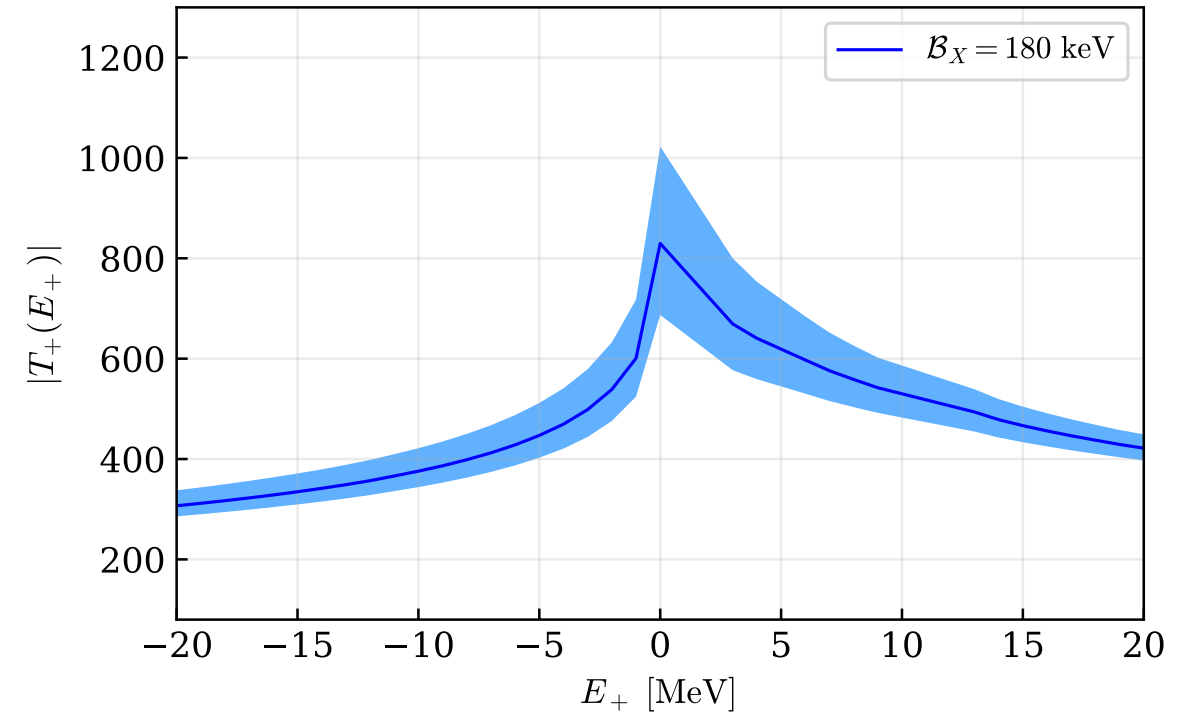
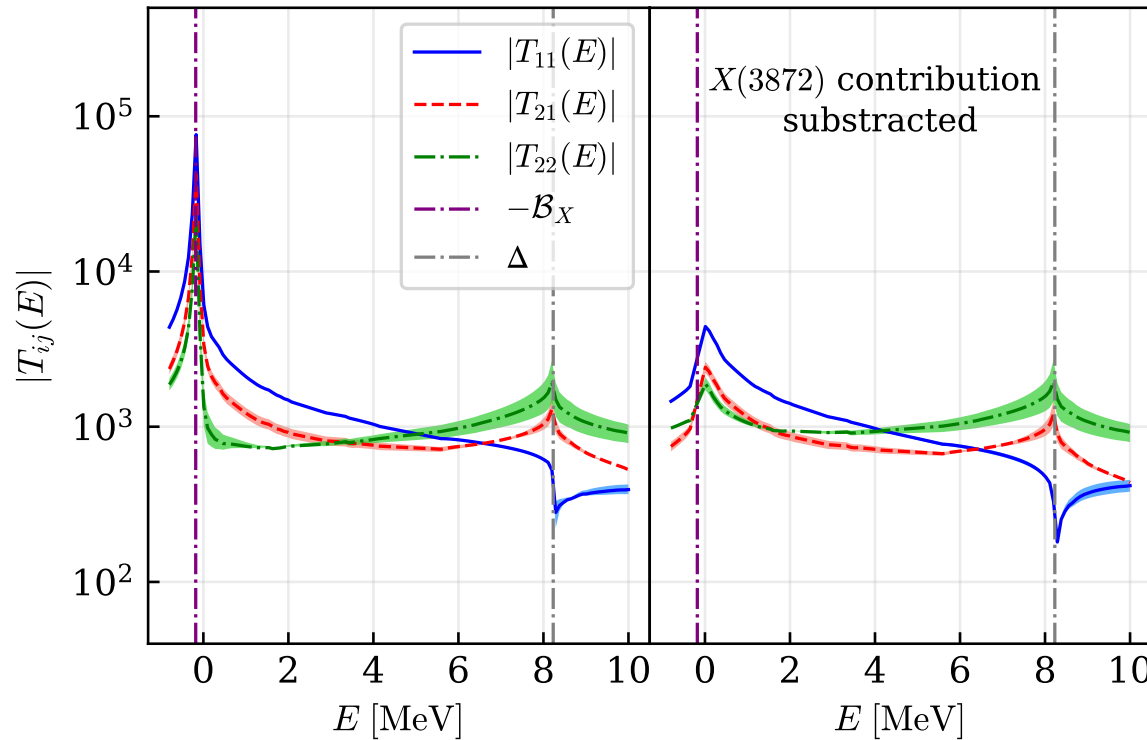
Teng Ji, X.-K. Dong, FKG, C. Hanhart, U.-G. Meißner, arXiv:2502.04458

- There must be an isospin vector partner W_{c1}

□ Virtual state pole in the stable D^* limit $\Rightarrow$ explains why it has not observed so far!

➤ W_{c1}^0 in $D^0 \bar{D}^{*0} - D^+ D^{*-}$ scattering amplitudes

➤ W_{c1}^+ in $D^+ \bar{D}^{*0}$ scattering amplitude



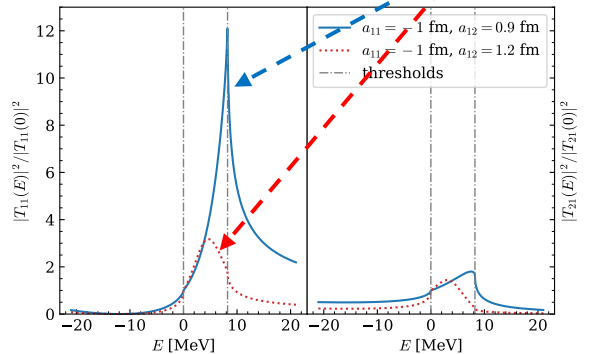
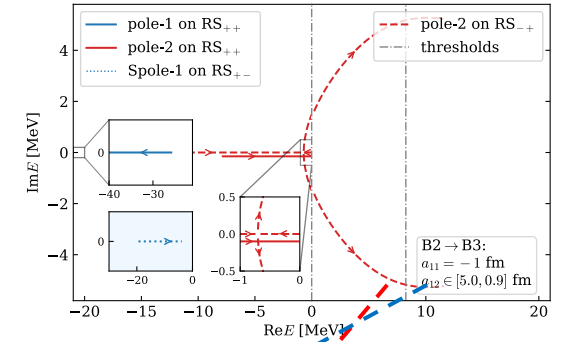
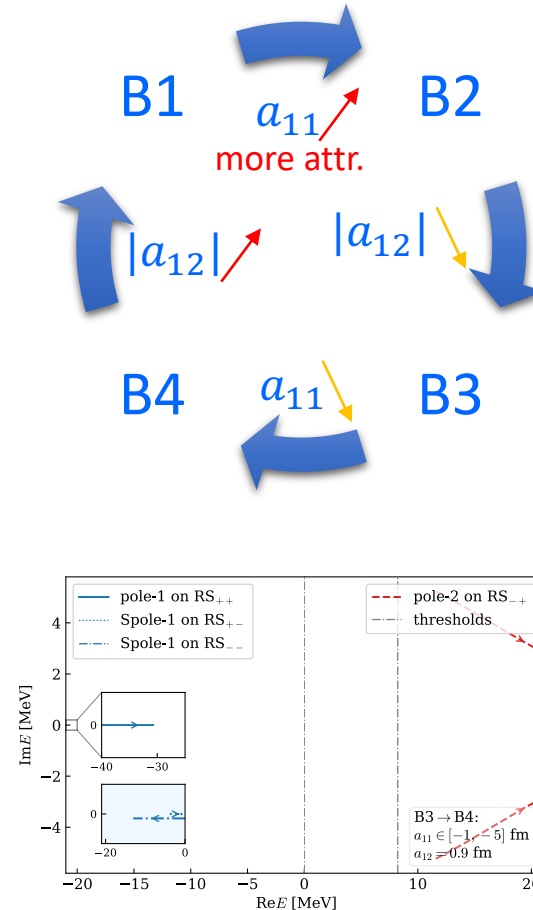
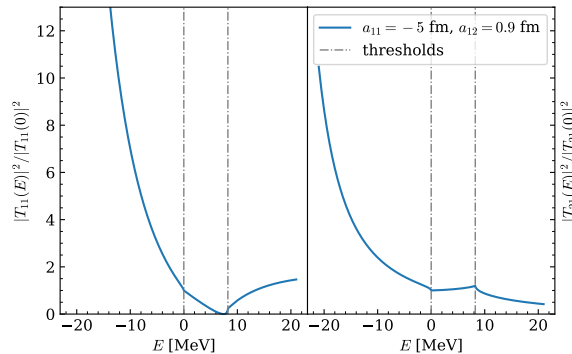
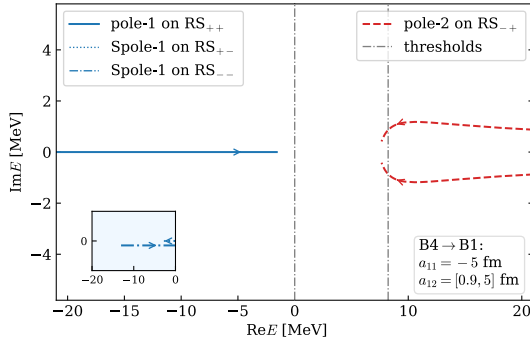
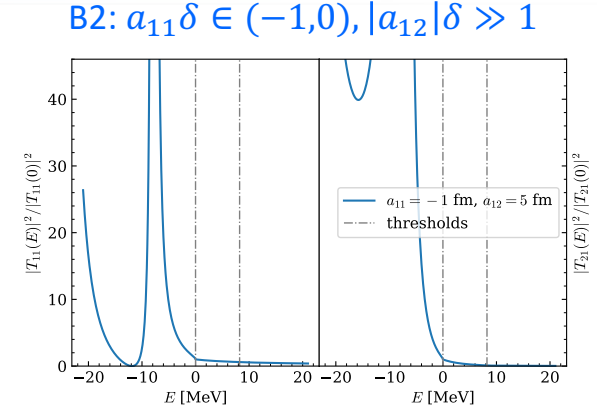
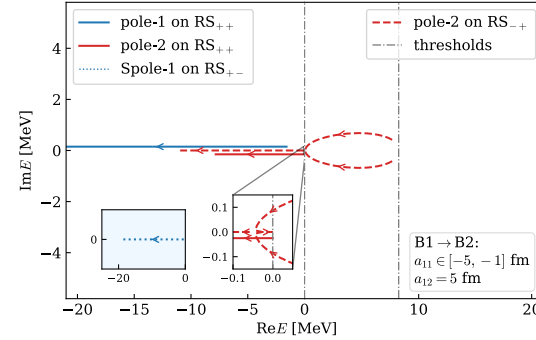
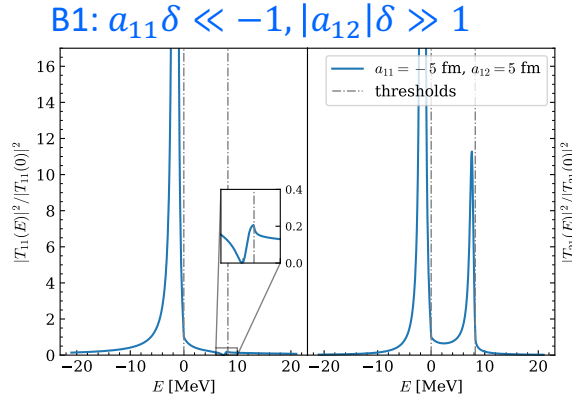
- to be searched for in high-statistic $J/\psi \pi^+ \pi^0$ data
- Compact tetraquark (Maiani et al. (2005)) cannot be virtual state!

Classification of coupled-channel near-threshold structures

Starting from RGE fixed point with two zero-energy bound state:

Two-channel cases (**B**):
 $a_{11} < 0$

Here, $\delta \equiv \sqrt{2\mu_2\Delta}$,
 Spole: shadow pole



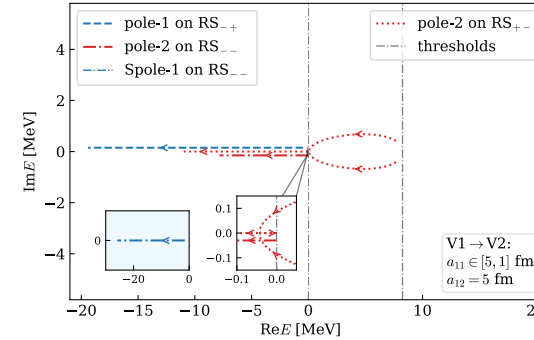
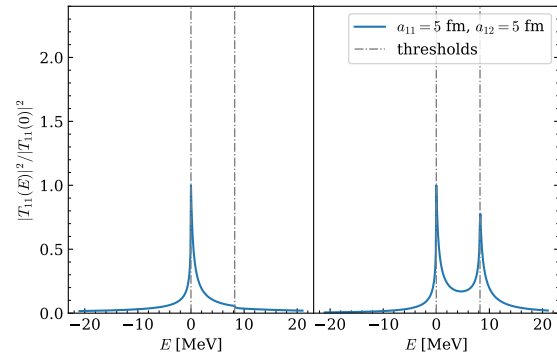
Classification of coupled-channel near-threshold structures

Starting from RGE fixed point with two zero-energy bound state:

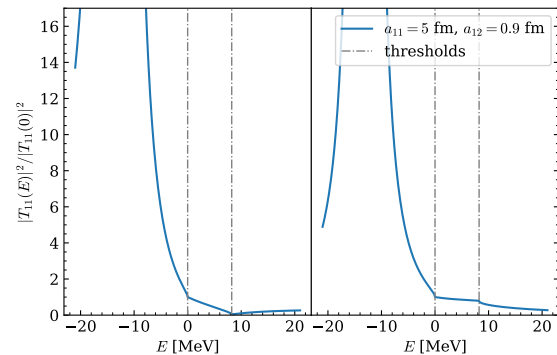
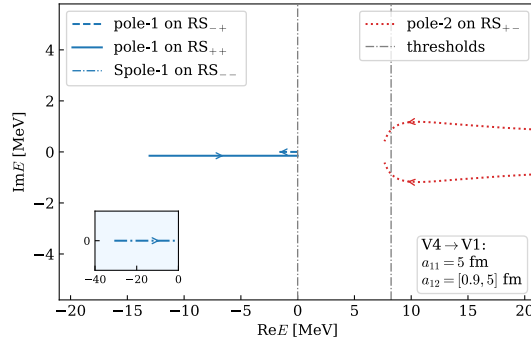
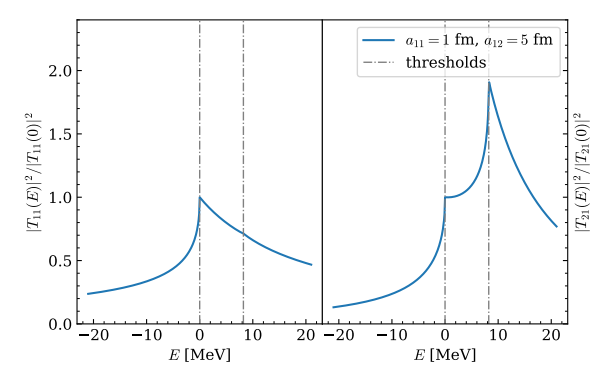
Two-channel cases (V):
 $a_{11} > 0$

Here, $\delta \equiv \sqrt{2\mu_2\Delta}$,
 Spole: shadow pole

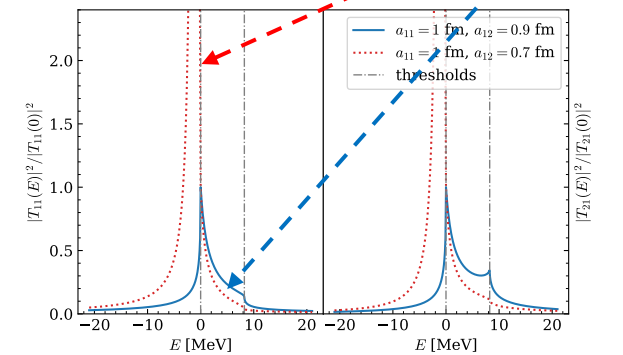
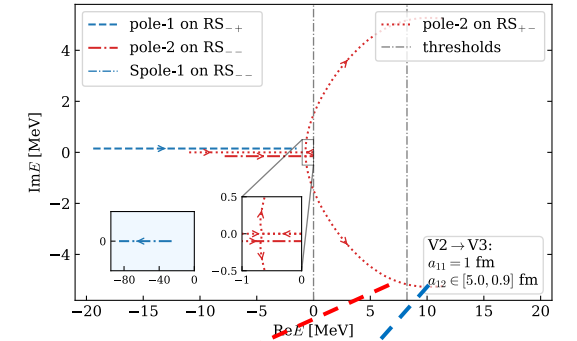
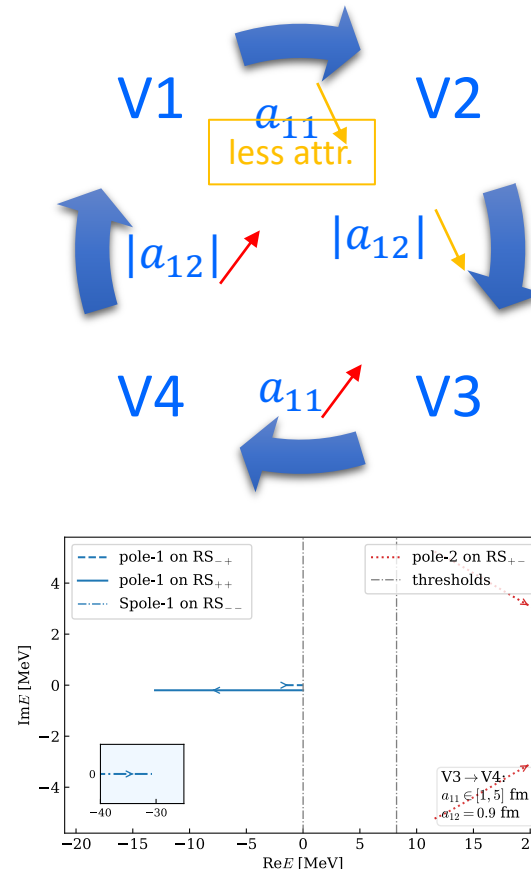
V1: $a_{11}\delta \gg 1, |a_{12}|\delta \gg 1$



V2: $a_{11}\delta \in (0,1), |a_{12}|\delta \gg 1$



V4: $a_{11}\delta \gg 1, |a_{12}|\delta \in (0,1)$



V3: $a_{11}\delta \in (0,1), |a_{12}|\delta \in (0,1)$

- General rules for (near-)threshold structures
 - S-wave attraction, more prominent for heavier particles and stronger attraction
 - Pole behavior: distinct line shapes depending on reaction mechanism
 - Universality: a dip (for large $|a_{22}|$) at the higher channel threshold in T_{11}
- Zotero-INSPIRE: brings INSPIRE into your zotero, and more!

Thank you for your attention!

More interesting stuff



- 开源免费（若用它的官方云端存储超过一定额度，需要付年费）、多系统 (windows, linux, mac, ios, android)
- 标签、多层次 collection（同一个文献可以同时存在于多个 collections）、可设置有关联的文献
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 - 国内 Zotero 社区维护的插件市场: <https://plugins.zotero-chinese.com>
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 - ...
- 可以将某个 collection 的文献信息输出 .bib 文件，并自动更新（后面有对写文章来说更便捷的更新 bib 文件的方式）
- 构建好文献库后，可以结合 vs code (+ vs code 的 LaTeX workshop 插件) 实现边写边引，极大节省精力!

- 稳定版: 7
- Beta 版: 8

Given an infinite-volume t -matrix, eq. (2.3) can be solved to find spectrum, $\{E_{\text{cm}}\}$. However, the reverse is in general an under-constra

12

Zotero 中添加文献

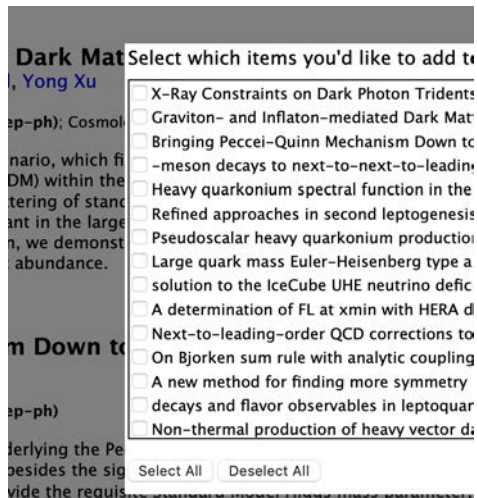
● 多种方式

- ❑ 直接拖拽 pdf 文件到zotero 中
- ❑ 导入 bib 文件
- ❑ 在浏览器中安装 zotero connectors

<https://www.zotero.org/download/connectors>

- 在 arxiv 或 INSPIRE 或各期刊文章页面上直接点击 Zotero connector
 - ✧ 若单篇文章，直接导入
 - ✧ 若多篇文章，可选择

- ❑ Beta 版：直接点 pdf 文件中引用文献的链接



<https://github.com/nutstore/zotero-plugin-nutstore>



- ❑ 安装 Zotero-inspire 插件后，也可以通过 arXiv 号、doi、INSPIRE citekey、INSPIRE recid 将文章信息导入，例如在 extra 项中输入

➢ arXiv:1706.04100

➢ 或 Citation Key: BESIII:2017bua

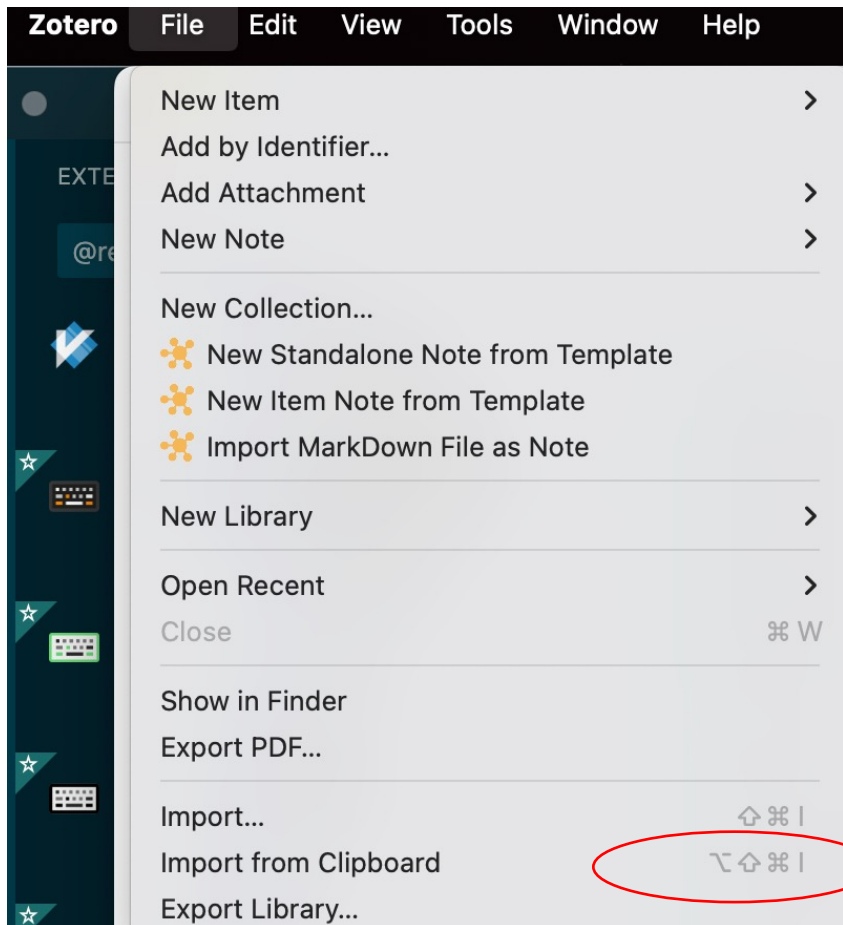
更多小技巧及说明，参见

<https://github.com/fkguo/zotero-inspire/tree/main?tab=readme-ov-file>

Zotero 中添加文献

● 多种方式

- 能处理特殊符号的方式: 从 INSPIRE 中复制文献条目的 bibtex, 用 Import from clipboard 的快捷键导入, 可自动将上下标、希腊字母等从 latex 格式转化成特殊符号的形式

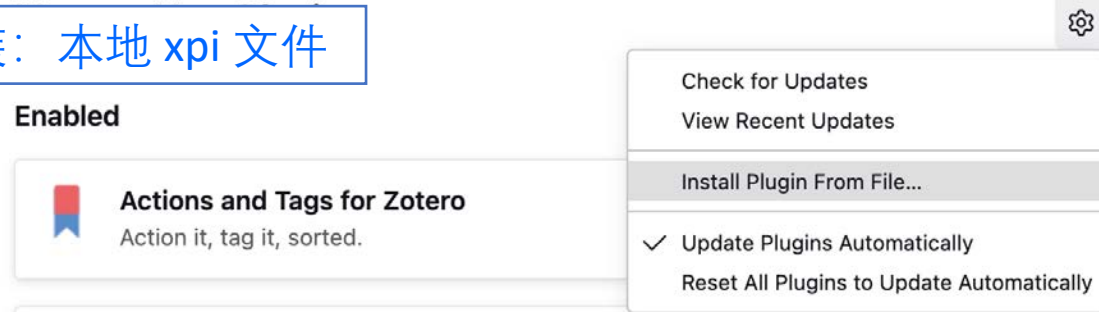
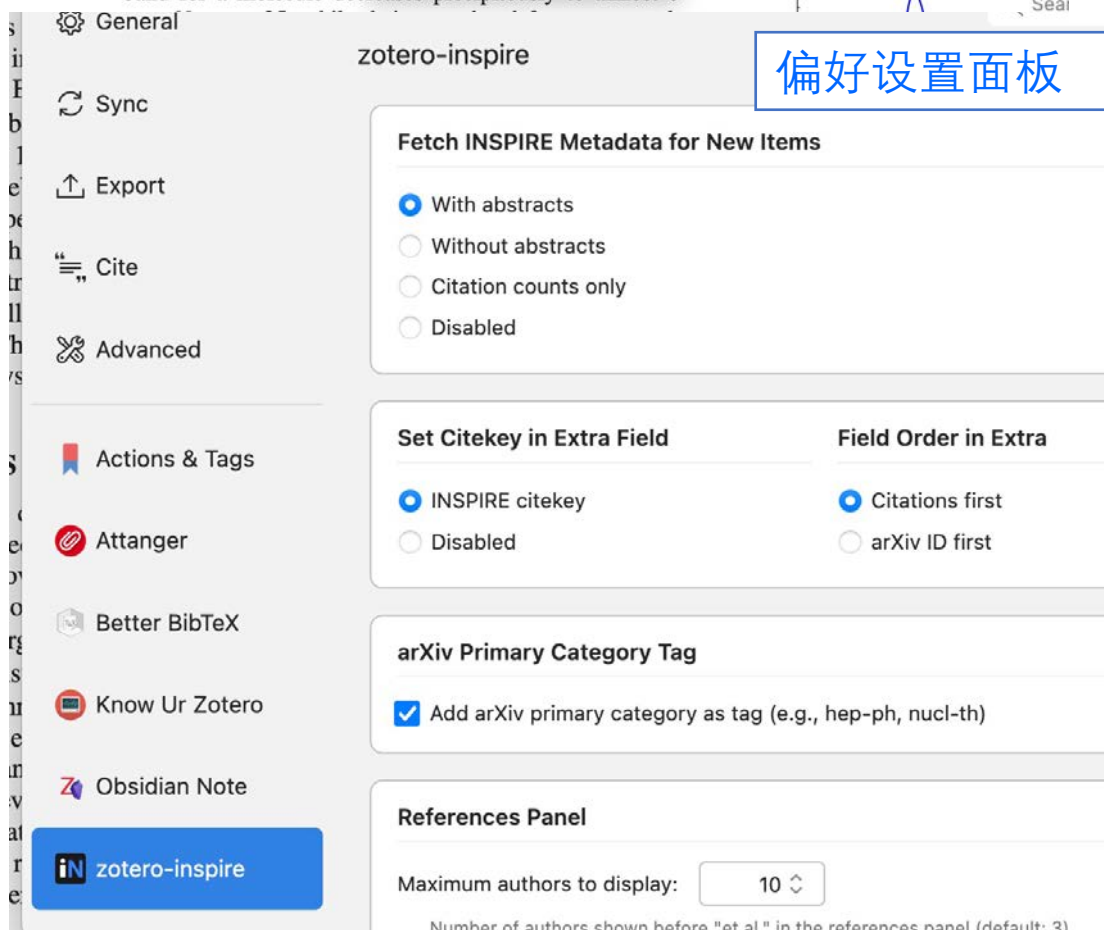
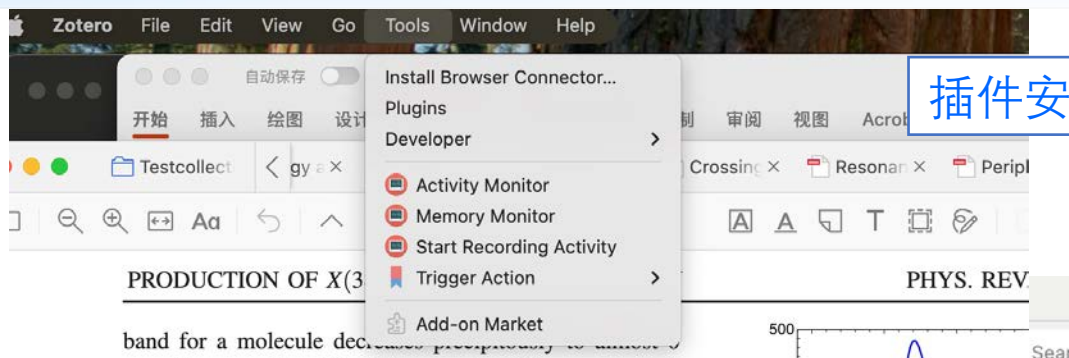


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}
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INSPIRE in Zotero

Zotero-inspire中文说明



References Panel

Maximum authors to display: 10

Number of authors shown before "et al." in the references panel (default: 3)

☒ Enable statistics chart

Show interactive statistics chart (by year/citations) at the top of the panel.

☐ Collapsed by default

Clear Search History

Keep search history for (days):

30

☒ Fuzzy citation detection (experimental)

Enable aggressive pattern matching when PDF text layer is broken (e.g., brackets truncated). May cause false positives.

☒ Parse PDF reference list (fixes multi-citation alignment)

Scans the PDF's References section to determine citation boundaries when INSPIRE labels are missing. Enable this if clicking [21] jumps to [20]'s second paper.



Reader View Navigation

☒ Reopen reader tab when navigating back/forward

When enabled, if the reader tab was closed, it will be reopened automatically when using Back or Forward navigation.

Local Cache

☒ Enable local cache for offline access

Cache references and cited-by data to disk. Speeds up loading and enables offline browsing.

☒ Show cache source indicator in panel

☒ Compress cache files (gzip)

Reduces disk usage by ~80% for large cache files. Recommended for users with many references.

Metadata enrichment

Controls how many INSPIRE records are fetched in parallel when completing reference metadata.

Batch size:

100

Parallel requests:

5

Larger values are faster but may trigger INSPIRE errors (HTTP 502/400). Allowed range: 25–110 entries, 1–5 requests.

Current: 100 entries / 5 requests. Defaults: 100 entries / 4 requests.

偏好设置面板

Batch size:

100

Parallel requests:

5

Larger values are faster but may trigger INSPIRE errors (HTTP 502/400). Allowed range: 25–110 entries, 1–5 requests.

Current: 100 entries / 5 requests. Defaults: 100 entries / 4 requests.

Cache expiry (cited-by data):

24

hours

How long to keep cited-by and author papers data. References are cached permanently.

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/Users/fkg/Nutstore Files/我的坚果云/Zc

Browse...

Reset

Leave empty to use default location (Zotero Data Directory). Custom directory will NOT sync with Zotero.

Clear Cache

513 files, 8.1 MB

INSPIRE Record Not Found

☐ Add tag to items without INSPIRE record

Tag name:

No INSPIRE record found



INSPIRE in Zotero

Zotero-inspire中文说明

INSPIRE

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 - CharmBottomN
 - e+ e- to Jpsi p pbar
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 - IsovectorX
 - PoS Lattice2022
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- 0Grants
 - 2023YFA1606703
- 0MyNotes
- 0MyPapers
- 0MyReferees
- Books
- BSM
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- Axion and strong C
- Astrophysics co
- Detection methods
- EDM
- Other solutions of s...
- Barvon-number violati...

#status/reading ● reviews

Title Creator Date Journal Abbr Date Modified Extra

The Spectrum of Charmonium	Eichten et al.	1975	Phys. Rev. Lett.	12/5/2025, 10:...	1377 ci...
What exactly is a parton density?	Collins	2003	Acta Phys. Pol...	12/5/2025, 10:...	305 cit...
Nonforward parton distributions	Radyushkin	1997	Phys. Rev. D	12/5/2025, 10:...	1383 c...
Scaling limit of deeply virtual Compton scattering	Radyushkin	1996	Phys. Lett. B	12/5/2025, 10:...	874 cit...
Calculation of the Structure Functions for Deep Inelastic Scattering and e+ ...	Dokshitzer	1977	Sov. Phys. JETP	12/5/2025, 10:...	3872 c...
Diffraction leptoproduction of vector mesons in QCD	Brodsky et al.	1994	Phys. Rev. D	12/5/2025, 10:...	757 cit...
Workman a...	2022-08-08	PTEP	12/5/2025, 10:...	5324 c...	
perturbation theory	Gribov and ...	1972	Sov. J. Nucl. P...	12/5/2025, 10:...	5618 c...
ons	Diehl	2003	Phys. Rept.	12/5/2025, 10:...	1640 c...
and gravitational form factors	Xu et al.	2024-02-26	Eur. Phys. J. C	12/5/2025, 10:...	48 cita...
light-cone sum rules at leading order	Anikin	2019-05-17	Phys. Rev. D	12/5/2025, 10:...	52 cita...
s and strong forces inside nucleons and nuclei	Polyakov	2003	Phys. Lett. B	12/5/2025, 10:...	450 cit...
on-Nucleon Scattering and Lepton Pair Anni...	Drell et al.	1970	Phys. Rev. D	12/5/2025, 7:5...	405 cit...
on Nucleon Scattering and Lepton Pair Anni...	Drell et al.	1970	Phys. Rev. D	12/5/2025, 7:5...	328 cit...
on-Nucleon Scattering and Lepton Pair Anni...	Drell et al.	1969	Phys. Rev.	12/4/2025, 9:4...	480 cit...
tructures in the heavy-quark hadron spectr...	Dong et al.	2021-04-13	Phys. Rev. Lett.	12/3/2025, 2:3...	144 cit...
c* molecular state	Poca et al.	2015-11-02	Phys. Rev. D	11/26/2025, 10:...	270 cit...
Heavy Quarks in e+ e- Annihila					11 citat...
The Interplay of Confinement a					298 cit...
Evolution Equations for QCD St					286 cit...
Quarkonium Level Spacings					671 cit...
Quigg and R...	1977	Phys. Lett. B	11/24/2025, 8:...	552 cit...	

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The Spectrum of Charmonium	Eichten et al.	1975	Phys. Rev. Lett.	12/5/2025, 10:...	1377 ci...	
What exactly is a parton density?	Collins	2003	Acta Phys. Pol...	12/5/2025, 10:...	305 cit...	
Nonforward parton dist	Radyushkin	1997	Phys. Rev. D	12/5/2025, 10:...	1383 c...	
Scaling limit of deeply v	Radyushkin	1996	Phys. Lett. B	12/5/2025, 10:...	874 cit...	
Calculation of the Struc	Dokshitzer	1977	Sov. Phys. JETP	12/5/2025, 10:...	3872 c...	
Diffractive leptonprod	Brodsky et al.	1994	Phys. Rev. D	12/5/2025, 10:...	757 cit...	
Review of Particle Ph	Workman a...	2022-08-08	PTEP	12/5/2025, 10:...	5324 c...	
Deep inelastic e p scatt	Gribov and ...	1972	Sov. J. Nucl. P...	12/5/2025, 10:...	5618 c...	
Generalized parton c	Diehl	2003	Phys. Rept.	12/5/2025, 10:...	1640 c...	
Pion and kaon electrom	Xu et al.	2024-02-26	Eur. Phys. J. C	12/5/2025, 10:...	48 cita...	
Gravitational form facto	Anikin	2019-05-17	Phys. Rev. D	12/5/2025, 10:...	52 cita...	
Generalized parton dist	Polyakov	2003	Phys. Lett. B	12/5/2025, 10:...	450 cit...	
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LHCb pentaquark as a	Roca et al.	2015-11-02	Phys. Rev. D	11/26/2025, 10:...	270 cit...	
Positivity restrictions o	De Rujula a...	1973	Annals Phys.	11/24/2025, 9:...	11 citat...	
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The Interplay of Confin		1976	Phys. Rev. Lett.	11/24/2025, 9:1...	286 cit...	
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A Theory of Deep Inelastic Lepton Nucleon Scattering and Lepton Pair Ann	Drell et al.	1970	Phys. Rev. D	2025/12/5 7...	328...
A Theory of Deep Inelastic Lepton-Nucleon Scattering and Lepton Pair Ann	Drell et al.	1969	Phys. Rev.	2025/12/4 2...	480...
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Deep inelastic e p scattering in perturbation theory	Gribov a...	1972	Sov. J. Nucl...	2025/11/25 ...	561...
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Positivity restrictions on nucleon compton amplitudes	De Rujul...	1973	Annals Phys.	2025/11/24 ...	11 c...
What exactly is a parton density?	Collins	2003	Acta Phys. ...	2025/11/24 ...	304...
Heavy Quarks in e+ e- Annihilation	Eichten a...	1977	Phys. Lett. B	2025/11/24 ...	298...
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Scaling limit of deeply virtual Compton scattering	Radyush...	1996	Phys. Lett. B	2025/11/24 ...	871 ...

Review of Particle Physics

11,225 references

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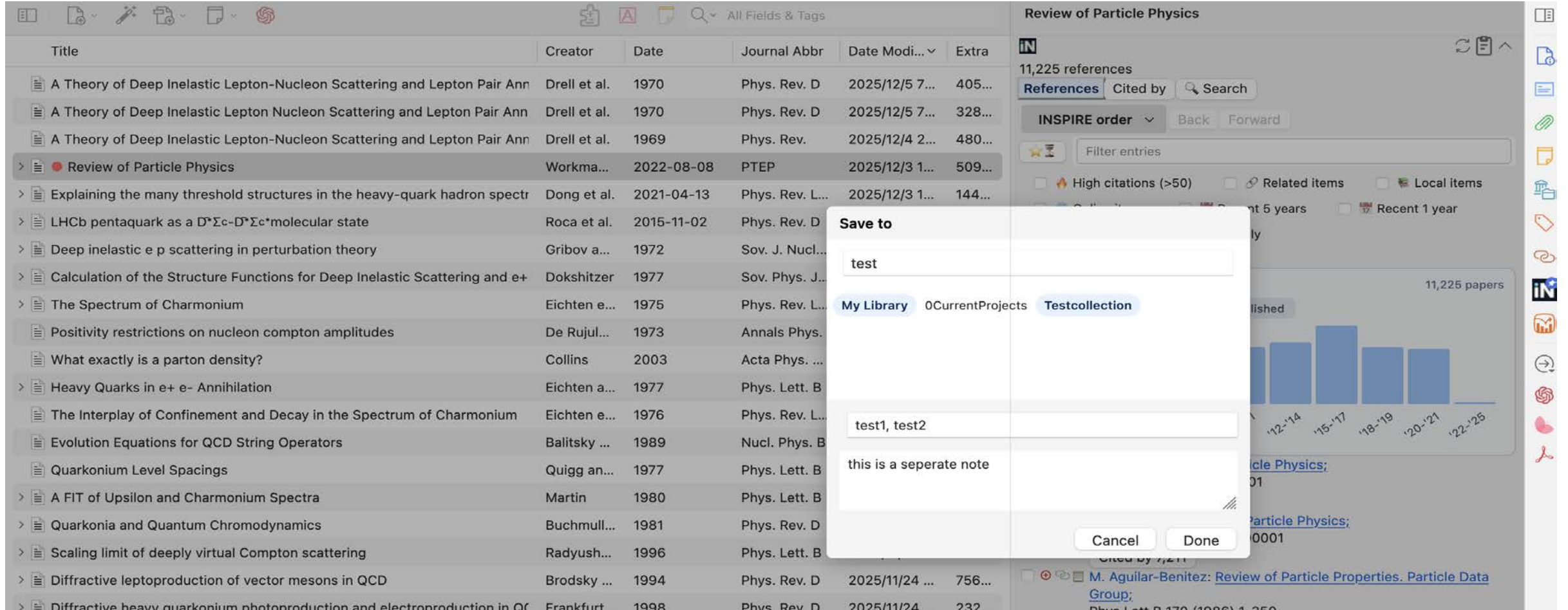
P. A. Zyla: [Review of Particle Physics](#); PTEP 2020 (2020) 083C01
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The screenshot displays the Zotero application interface. On the left, a list of references is shown with columns for Title, Creator, Date, Journal Abbr, Date Modified, and Extra. The reference 'Review of Particle Physics' by Workman et al. (2022-08-08) is highlighted. On the right, the 'Review of Particle Physics' page is open, showing 11,225 references and a bar chart of publication counts over time. A 'Save to' dialog box is open in the center, allowing the user to save the selected reference to a specific collection. The dialog box contains a text input field with 'test', a list of collections including 'My Library', '0CurrentProjects', and 'Testcollection', and a text area with 'test1, test2' and 'this is a separate note'. The 'Done' button is highlighted.

Title	Creator	Date	Journal Abbr	Date Modified	Extra
A Theory of Deep Inelastic Lepton-Nucleon Scattering and Lepton Pair Annihilation	Drell et al.	1970	Phys. Rev. D	2025/12/5 7...	405...
A Theory of Deep Inelastic Lepton Nucleon Scattering and Lepton Pair Annihilation	Drell et al.	1970	Phys. Rev. D	2025/12/5 7...	328...
A Theory of Deep Inelastic Lepton-Nucleon Scattering and Lepton Pair Annihilation	Drell et al.	1969	Phys. Rev.	2025/12/4 2...	480...
Review of Particle Physics	Workman et al.	2022-08-08	PTEP	2025/12/3 1...	509...
Explaining the many threshold structures in the heavy-quark hadron spectrum	Dong et al.	2021-04-13	Phys. Rev. Lett.	2025/12/3 1...	144...
LHCb pentaquark as a $D^*\Sigma_c - D^*\Sigma_c^*$ molecular state	Roca et al.	2015-11-02	Phys. Rev. D		
Deep inelastic $e p$ scattering in perturbation theory	Gribov et al.	1972	Sov. J. Nucl. Phys.		
Calculation of the Structure Functions for Deep Inelastic Scattering and e^+e^- Annihilation	Dokshitzer	1977	Sov. Phys. JETP		
The Spectrum of Charmonium	Eichten et al.	1975	Phys. Rev. Lett.		
Positivity restrictions on nucleon Compton amplitudes	De Rujula et al.	1973	Annals Phys.		
What exactly is a parton density?	Collins	2003	Acta Phys. Hungarica		
Heavy Quarks in e^+e^- Annihilation	Eichten et al.	1977	Phys. Lett. B		
The Interplay of Confinement and Decay in the Spectrum of Charmonium	Eichten et al.	1976	Phys. Rev. Lett.		
Evolution Equations for QCD String Operators	Balitsky et al.	1989	Nucl. Phys. B		
Quarkonium Level Spacings	Quigg and Johnson	1977	Phys. Lett. B		
A FIT of Upsilon and Charmonium Spectra	Martin	1980	Phys. Lett. B		
Quarkonia and Quantum Chromodynamics	Buchmüller et al.	1981	Phys. Rev. D		
Scaling limit of deeply virtual Compton scattering	Radyushkevich et al.	1996	Phys. Lett. B		
Diffractional lepton production of vector mesons in QCD	Brodsky et al.	1994	Phys. Rev. D	2025/11/24 ...	756...
Diffractional heavy quarkonium photoproduction and electron production in QCD	Frankfurt et al.	1998	Phys. Rev. D	2025/11/24 ...	232...



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2.3 ± 0.1, $F_{out,X} = 2.9 ± 0.7$, $\langle v_{\sigma_X} \rangle = 2.6 ± 0.7$ mb, and $N_{X/\psi'}$ = ... ion matrix for these seven para-

0	+0.83	-0.28	+0.35
0.22	-0.45	+0.86	-0.86
0.08	-0.76	0	+0.04
1	0	-0.29	-0.20
	1	-0.40	+0.43
		1	-0.83
			1

(9)

$\langle v_{\sigma_X} \rangle$ is about 1 σ smaller than the fitted value of $\langle v_{\sigma_X} \rangle$ is about 5 σ Ref. [12] if X is a tetraquark. It is an the contribution from $\pi X \rightarrow$ f hadrons with $T = 100$ MeV in of $\langle v_{\sigma_X} \rangle$ is less than 1/4 the total from Ref. [34]. This could be of the three-dimensional Bose-a model for comoving pions. A hat is isotropic in the two trans-longitudinal dimension seems

OUTLOOK

e multiplicity dependence of the in pp collisions is incompatible

compact hadron should be interpreted as a fictitious hadron that does not couple to the charm mesons at the nearby $D^{*0} \bar{D}^0$ threshold. It may be an interesting exercise to rule out such a possibility using experimental data, but it is already excluded by theoretical considerations.

The universal physics of a loosely bound S-wave molecule reveals a dramatic failure of the simplistic model in Refs. [12] and [20] for $\langle v_{\sigma_Q} \rangle$ based on the geometric cross section πr_Q^2 . That model overestimates $\langle v_{\sigma_X} \rangle$ by orders of magnitude. The breakup cross section σ_X is comparable to πr_X^2 , which is close to the th σ_X is determin constituents o

Our fit to the a quantitative energy hadron broken up in comoving pions mesons will e will coalesce calculate the pp collisions Coalescence c nucleus-nucle meson that are of the product Collaboration be much large [36]. Underst nucleus-nucle collisions even at the quantitative level remains a challenging open problem.

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Production of X(3872) at High Multiplicity

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References Cited by Search

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51 papers

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L. M. Abreu: Production of the $X(3872)$ state via the $B^0 \bar{B}^0 \rightarrow K^0 \bar{K}^0 X(3872)$ decay; Phys.Rev.D 112 (2025) 096002 [arXiv:2508.21223]

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J.-H. Chen, J. Chen, F.-K. Guo, Y.-G. Ma, C.-P. Shen, Q.-Y. Shou, Q. Shou, Q. Wang,

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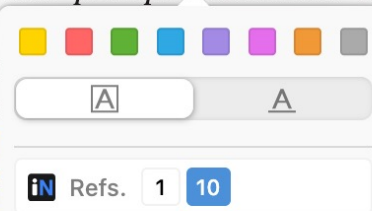
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and with universal properties determined by ε_X [9]. The mean separation of its constituents is $r_X = (8\mu|\varepsilon_X|)^{-1/2}$, where μ is the reduced mass of $D^{*0}\bar{D}^0$. The upper bound $|\varepsilon_X| < 0.22$ MeV implies $r_X > 4.8$ fm. Thus, this amazing hadron has a radius more than an order of magnitude larger than that of ordinary hadrons. More relevant to the other exotic heavy hadrons is what X would have been if not for the fine-tuning of its mass to the $D^{*0}\bar{D}^0$ threshold. The possibilities that have been proposed include the P-wave charmonium state $\chi_{c1}(2P)$, an isospin-0 charm-meson molecule, and an isospin-1 compact tetraquark. In all these cases, the tuning of the mass to the $D^{*0}\bar{D}^0$ threshold produces resonant couplings to $D^{*0}\bar{D}^0$ and $D^0\bar{D}^{*0}$ that transforms X into a loosely bound molecule of neutral charm mesons.

Shortly after the discovery of X in B -meson decays [1], its existence was confirmed in $p\bar{p}$ collisions [10]. The production of X at a hadron collider can be resolved into two contributions: *prompt* production by strong interactions at the primary vertex and *secondary* production by b -decay of a bottom quark containing a secondary vertex. The behavior of the X may provide evidence for the significant difference between the X and the $\psi(3723)$ is the X decay emerges at the primary vertex. Collisions with comoving hadrons



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[4] M. Karliner, J. L. Rosner, T. Skwarnicki: [Multiquark States](#); Ann.Rev.Nucl.Part.Sci. 68 (2018) 17-44 [arXiv:1711.10626]

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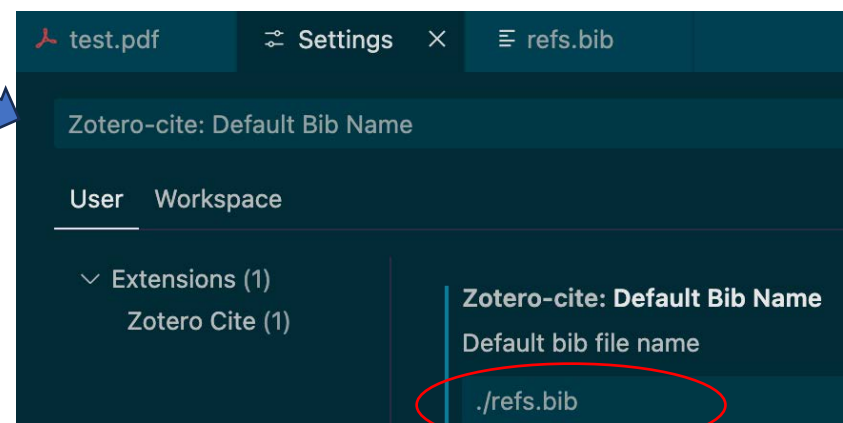
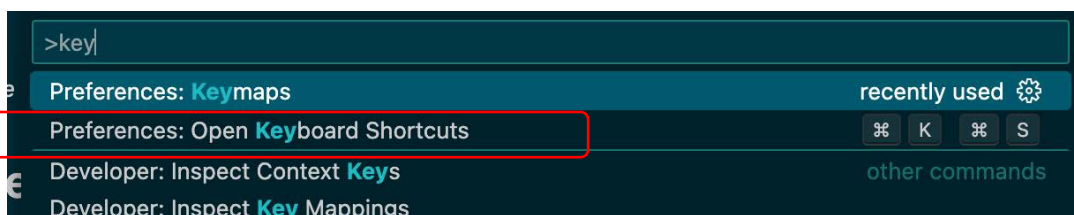
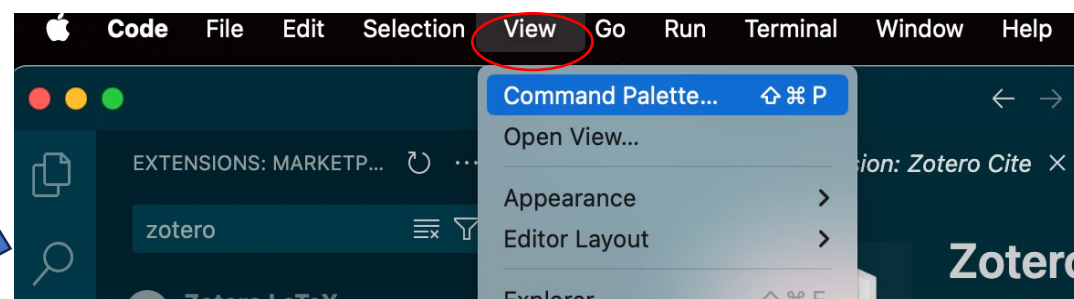
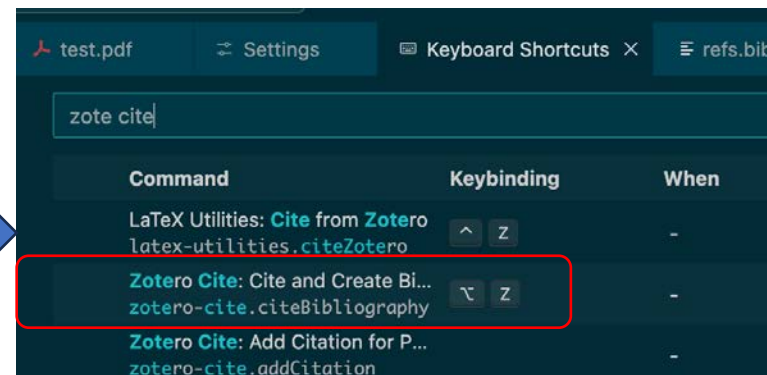
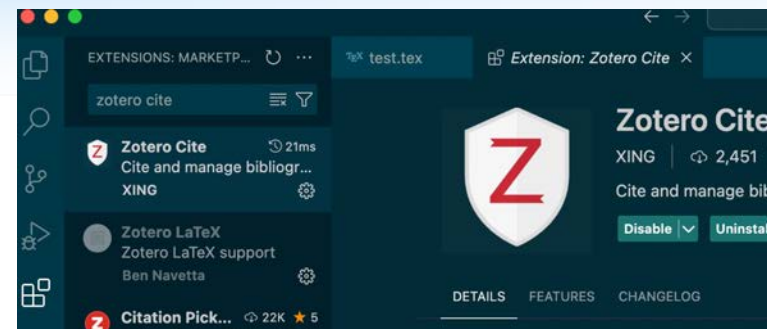
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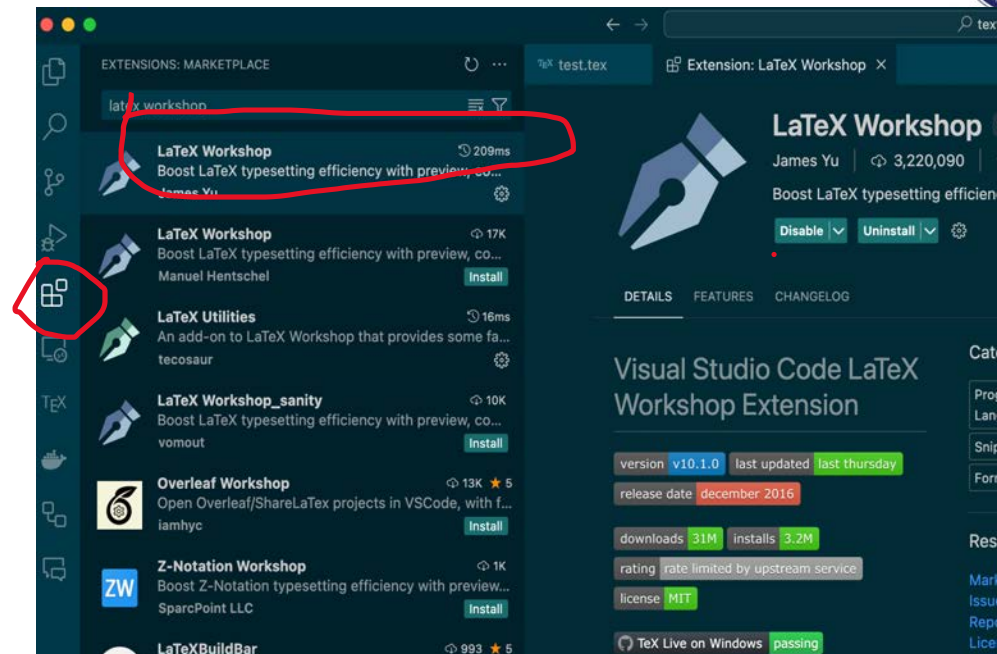
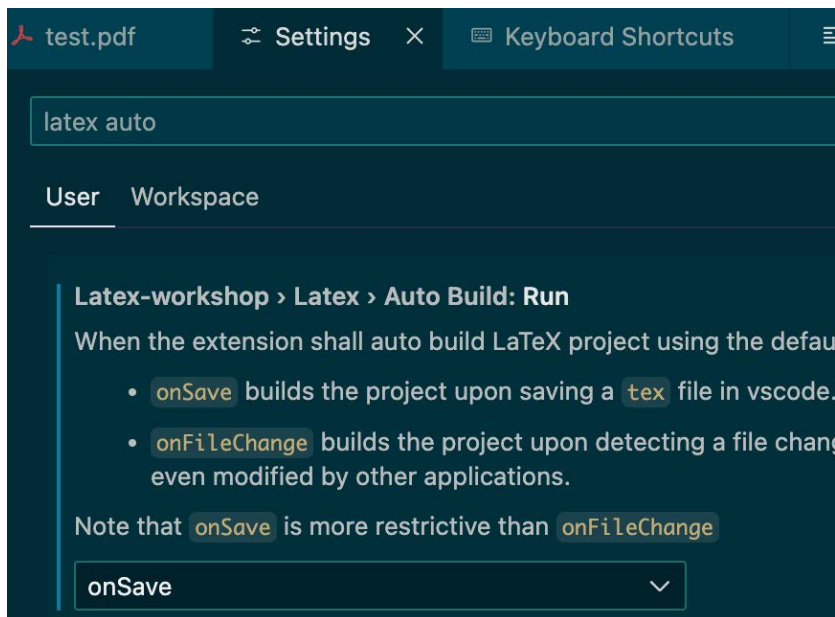
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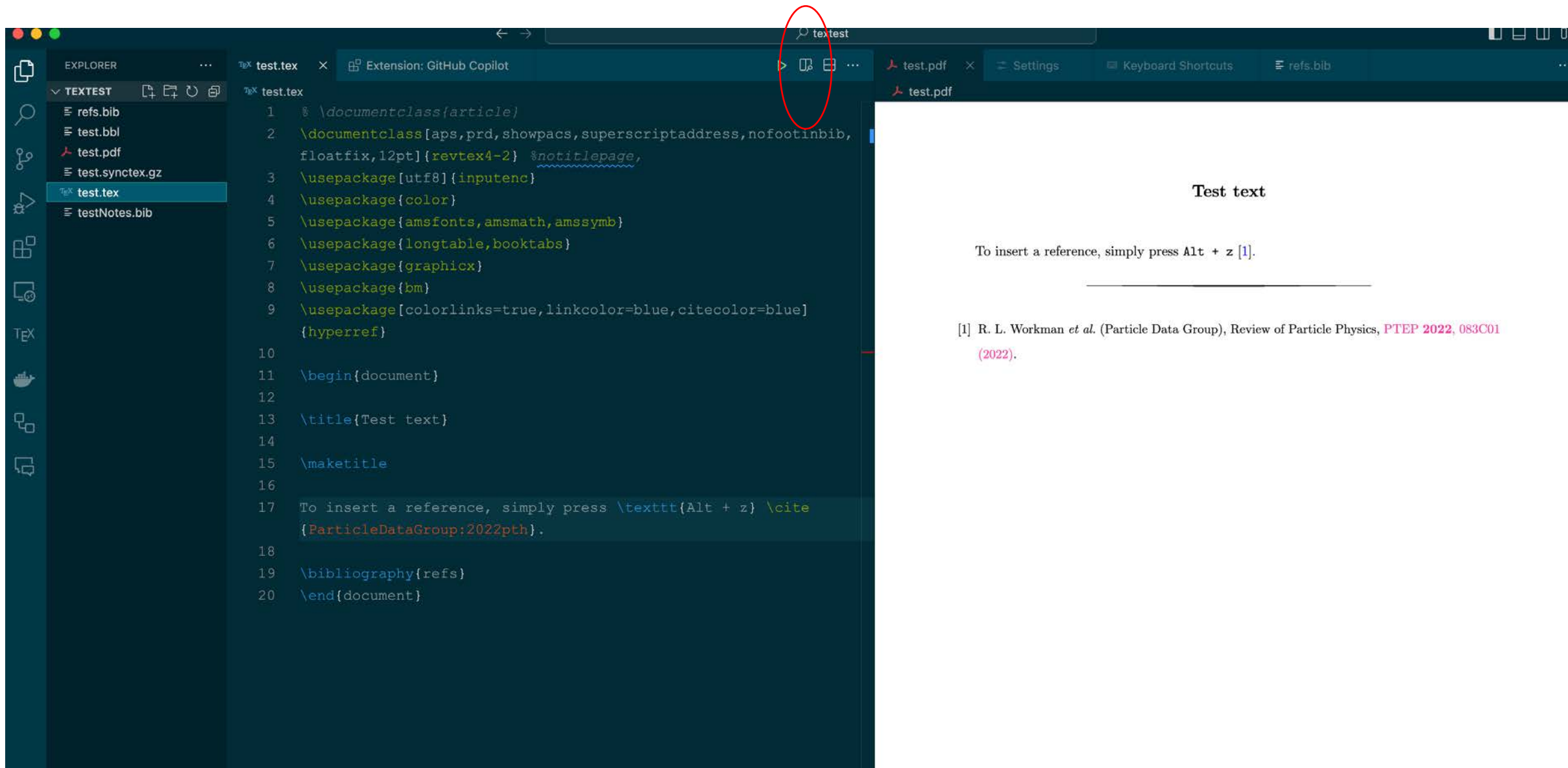


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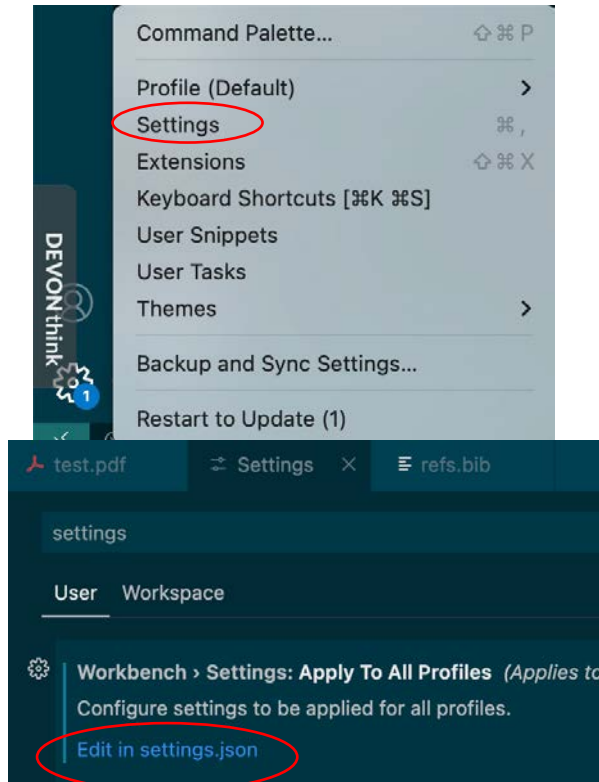
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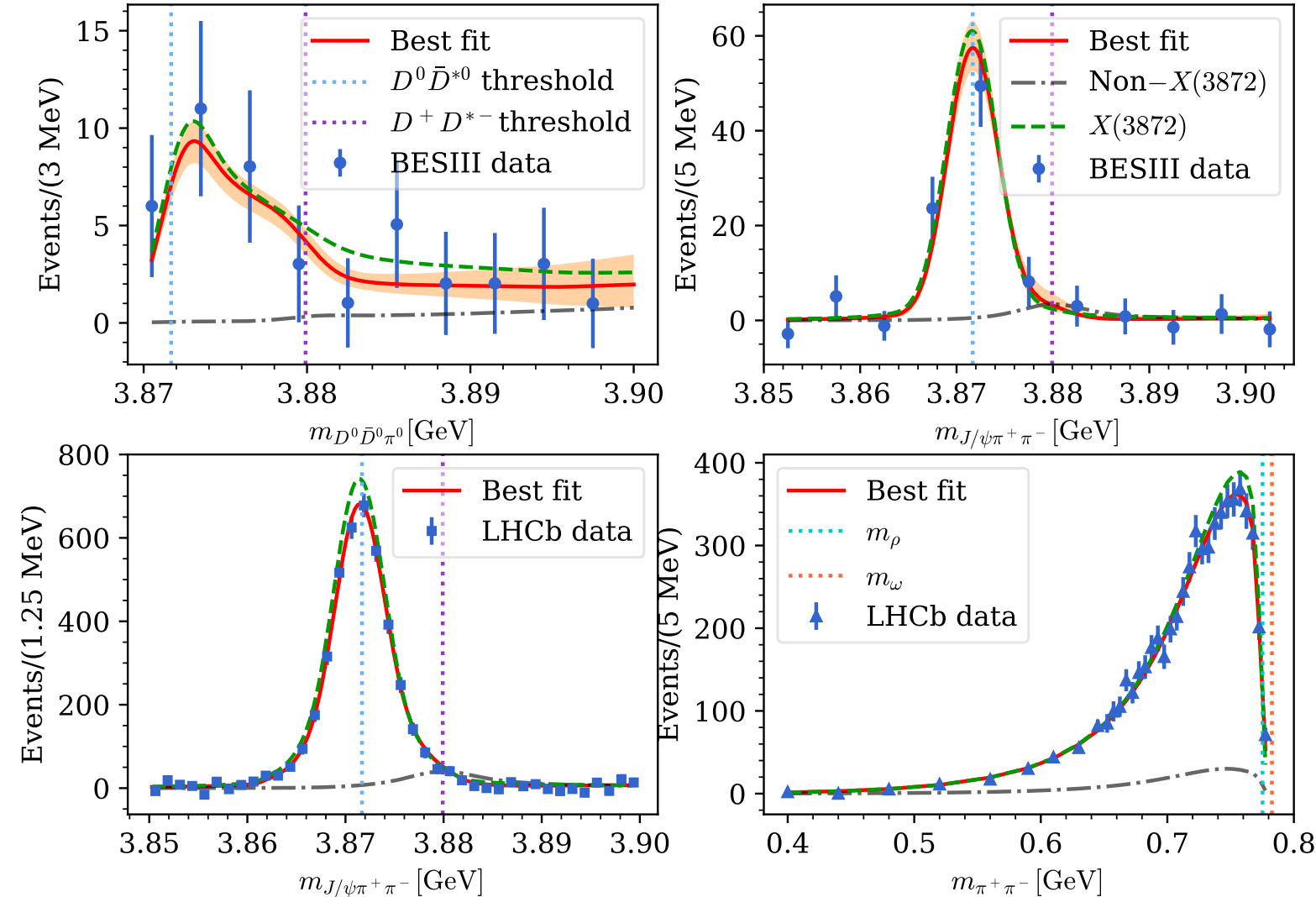


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Combined analysis of BESIII and LHCb data for $X(3872)$



Best fit: $\chi^2/\text{dof} = 57/(96 - 10) = 0.66$

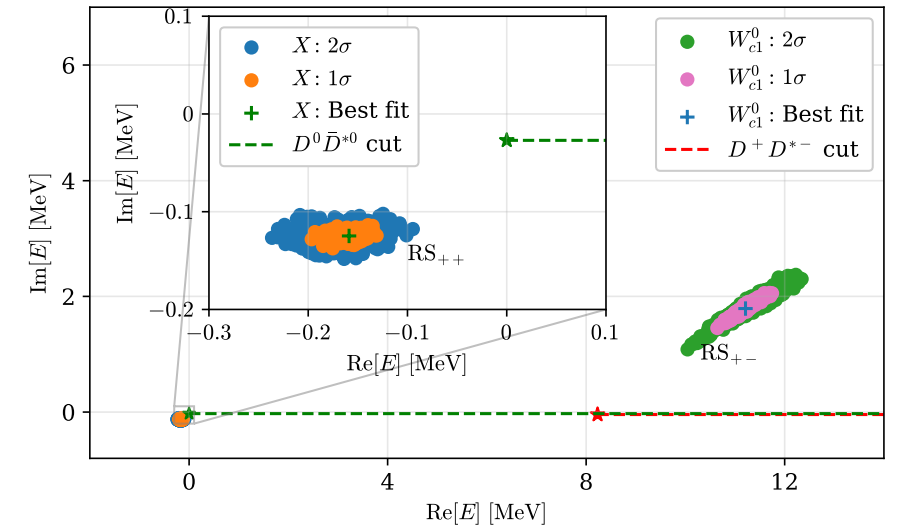
● Poles

□ $X(3872)$ as a bound state below $D^0 \bar{D}^{*0}$ threshold (2.8σ)

$$E_X = (-160^{+43+38}_{-47-57} - 125^{+18+15}_{-25-28}i) \text{ keV}$$

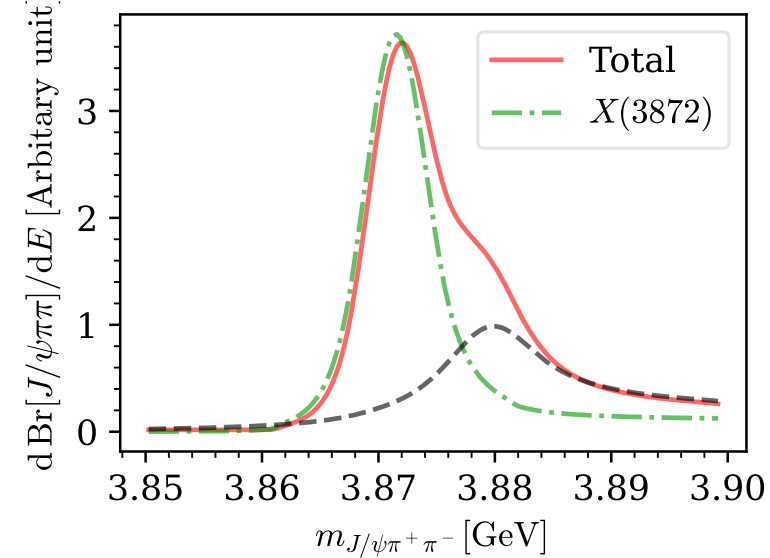
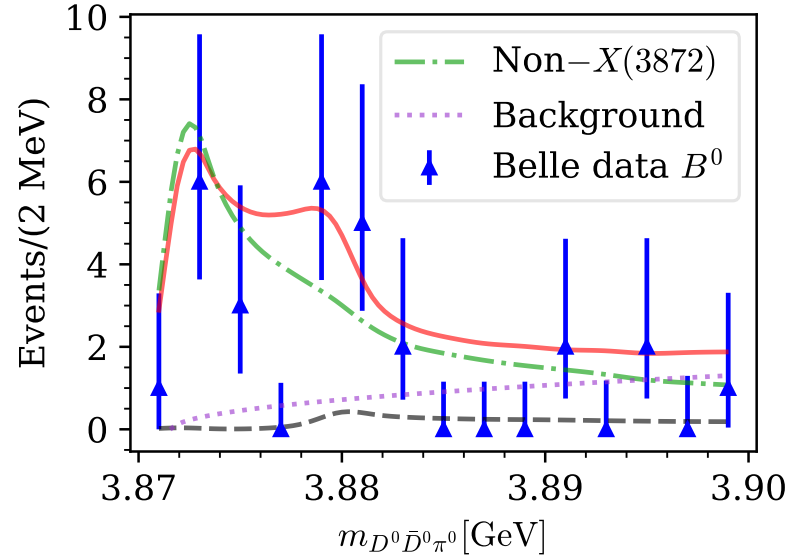
□ $W_{c1}(3880)^0$ pole on RS_{+-} , relative to the $D^+ D^{*-}$ threshold:

$$E_W = (3.1 \pm 0.7 + 1.3^{+1.9}_{-0.6}i) \text{ MeV}$$



Implications of the existence of $W_{c1}(3880)$

- $W_{c1}(3880)^0$ signal should be stronger in $B^0 \rightarrow K^0[D^0\bar{D}^0\pi^0, J/\psi\pi^+\pi^-]$ decays, to be checked @ LHCb, Belle II



- Cusp at $D^+\bar{D}^{*0}/D^{*+}\bar{D}^0$ threshold in $J/\psi\pi^\pm\pi^0$