Searches with missing energy at BESIII

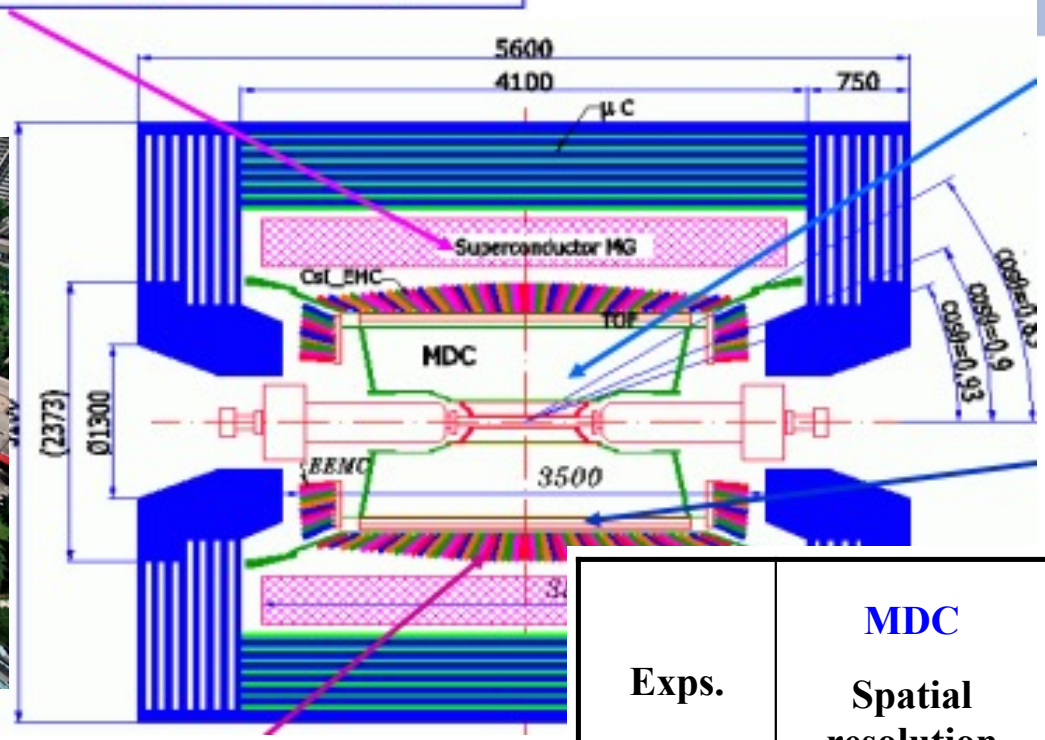
Dayong Wang

Peking University

Belle-II Physics Week

KEK, Oct 7, 2025

BEPCII/BESIII: a τ-c Factory



high lumi, large datasets, hermetic detector with good performance and clean environment

- First collision in 2008, physics run started in 2009
- **Operation c.m. energy: 1.84-4.95GeV**
- BEPCII continues to improve, energy upgrade & top-up reached peak lumi of $1.1\times10^{33}\,cm^{-2}s^{-1}$ @1.89GeV
- Secured the running for another 5+ years, with small(but critical) energy increase and lumi upgrade

Exps.	MDC Spatial resolution	MDC dE/dx resolution	EMC Energy resolution
CLEO-c	110 μm	5%	2.2-2.4 %
BaBar	125 μm	7%	2.67 %
Belle	130 μm	5.6%	2.2 %
BESIII	115 μm	<5% (Bhabha)	2.4%

Data samples by BESIII

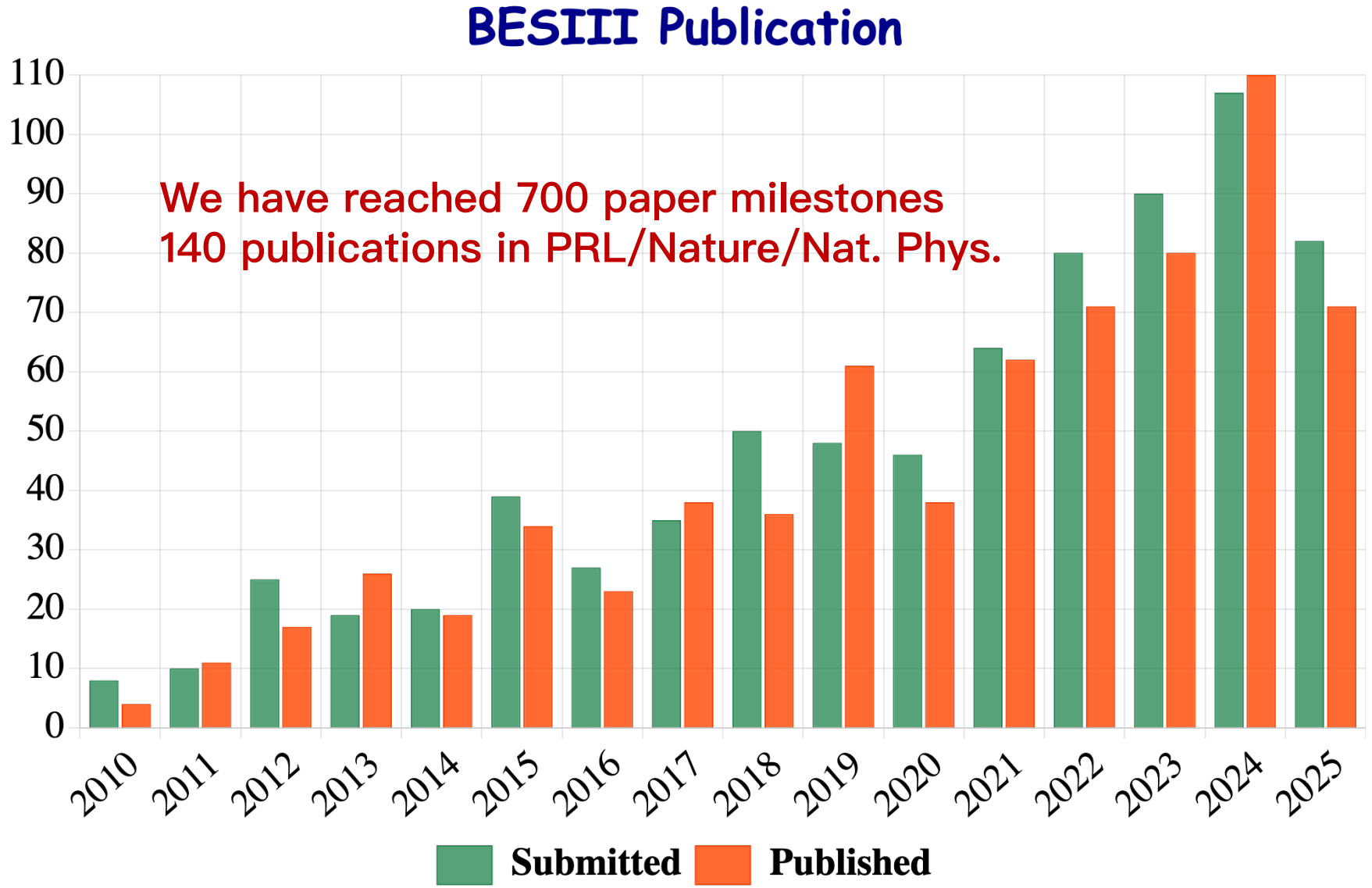
Total: More than 52 fb^{-1}

2009: 106M $\psi(2S)$
225M J/ψ
2010: 0.98 fb^{-1} $\psi(3770)$ (for $D^{0(+)}$)
2011: 2.93 fb^{-1} $\psi(3770)$ (for $D^{0(+)}$, accumulated)
0.48 fb^{-1} @4.01 GeV
2012: 0.45B $\psi(2S)$ (total)
1.30B J/ψ (total)
2013: 1.09 fb^{-1} @4.23 GeV
0.83 fb^{-1} @4.26 GeV
0.54 fb^{-1} @4.36 GeV
10×0.05 fb^{-1} XYZ scan@3.81-4.42 GeV
2014: 1.03 fb^{-1} @4.42 GeV
0.11 fb^{-1} @4.47 GeV
0.11 fb^{-1} @4.53 GeV
0.05 fb^{-1} @4.575 GeV
0.57 fb^{-1} @4.60 GeV (for Λ_c^+)
0.80 fb^{-1} R scan @3.85-4.59 GeV
2015: R-scan 2-3 GeV+2.175 GeV
2016: 3.20 fb^{-1} @4.178 GeV (for D_s^+)
2017: 7×0.50 fb^{-1} XYZ scan@4.19-4.27 GeV
2018: More J/ψ+tuning new RF cavity
2019: 10B J/ψ (total)
8×0.50 fb^{-1} XYZ scan@4.13, 4.16, 4.29-4.44 GeV
2020: 3.8 fb^{-1} @ 4.61-4.7 GeV (XYZ&Λ_c^+)
2021: 2.0 fb^{-1} @ 4.74-4.946 GeV
2021: 2.7B $\psi(2S)$ (total)
2022: 2×0.4 fb^{-1}@3.65, 3.682 GeV,
5.1 fb^{-1} $\psi(3770)$ (for $D^{0(+)}$, total)
2023: ~8 fb^{-1} at $\psi(3770)$
2024: ~5.4 fb^{-1}, 20 fb^{-1} $\psi(3770)$ in total

Dataset	E_{cm} / GeV	$\mathcal{L}_{int}$ / fb^{-1}	days
$\psi(3770)$	3.773	4.2	119
ψ'' scan	3.780	0.41	9
scan	3.800–3.885	0.14 in 14 points	6
ψ'' scan	3.768	0.41	10
χ_{c2}	3.554	0.13	4
< 2 GeV	1.80 – 2.00	0.025 in 13 points	64

BESIII is in good state in all aspects

New lumi and Ecm record
Very stable data-taking
Good detector performance
Aging effects under control
Fruitful publications



Europe (19)

Germany(6): Bochum University, GSI Darmstadt, Helmholtz Institute Mainz, Johannes Gutenberg University of Mainz, Universitaet Giessen, University of Münster

Italy(3): Ferrara University, INFN, University of Turin,

Netherlands(1):KVI/University of Groningen

Russia(3): Budker Institute of Nuclear Physics, Dubna JINR, Lebedev Physical Institute

Sweden(1):Uppsala University

Turkey (1):Turkish Accelerator Center Particle Factory Group

UK(3): University of Manchester, University of Oxford, University of Bristol

Poland(1): National Centre for Nuclear Research

USA(3)

Carnegie Mellon University
Indiana University
University of Hawaii

Mongolia(1)

Institute of Physics and Technology

Pakistan(2)

Institute of Business Administration,
University of the Punjab

Korea(1)

Chung-Ang University

Thailand(1)

Suranaree University of Technology

India(1)

Indian Institute of Technology madras

China (62)

Beihang University, Central China Normal University, Central South University, Chengdu University of Technology, China Center of Advanced Science and Technology, China University of Geosciences, Fudan University, Guangxi Normal University, Guangxi University, Guangxi University of Science and Technology, Hangzhou Normal University, Hebei University, Henan University, Henan Normal University, Henan University of Science and Technology, Henan University of Technology, Hengyang Normal University, Huangshan College, Hunan University, Hunan Normal University, Inner Mongolia University, Institute of High Energy Physics, Institute of Modern Physics, Jiangsu Ocean University, Jilin University, Lanzhou University, Liaoning Normal University, Liaoning University, Longyan University, Nanjing Normal University, Nanjing University, Nankai University, North China Electric Power University,Peking University, Qufu Normal University, Renmin University of China, Shaanxi Normal University, Shanxi University, Shanxi Normal University, Sichuan University, Shandong Management University, Shandong Normal University, Shandong University, handong University of Technology, Shanghai Jiao Tong University, Soochow University,South China Normal University, Southeast University, Southwest University of Science and Technology, Sun Yat-sen University, Tsinghua University, University of Chinese Academy of Sciences, University of Jinan, University of Science and Technology of China, University of Science and Technology Liaoning, University of South China, Wuhan University, Xi'an Jiaotong University, Yantai University , Yunnan University , Zhejiang University, Zhengzhou University

Chile(2)

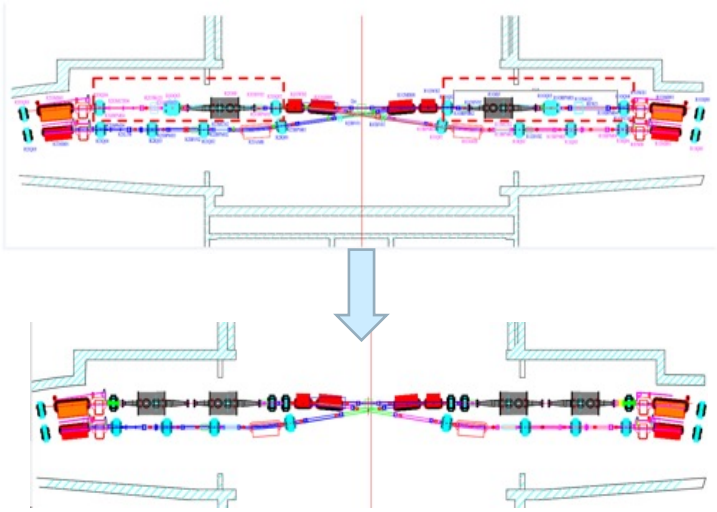
University of Tarapaca,
University of La Serena

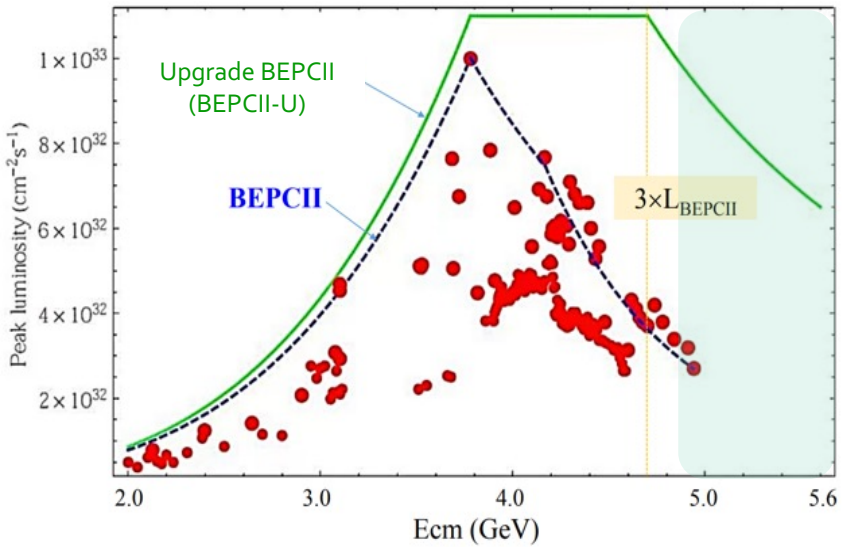
The collaboration size still growing: ~600 members from 92 institutions in 16 countries.

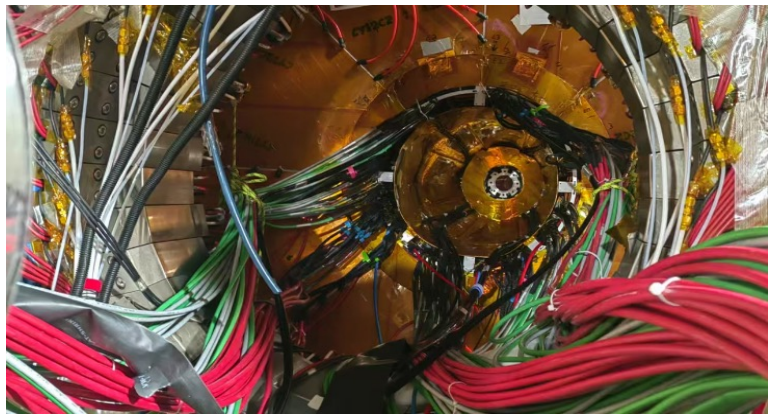
>600 members
From 92 institutions in 16 countries

The upgrade: BEPCII-U

- ✓ An upgrade of BEPCII (BEPCII-U): optimized energy at 2.35 GeV with luminosity 3 times higher than current BEPCII and extend the maximum energy to 5.6 GeV
- ✓ With this critical energy increase and lumi upgrade, the operation is secured for another 5+ years
- ✓ BESIII Detector: inner tracker upgrade (CGEM), installed in Oct 2024, full data taking since May 2025 (>250pb-1 already taken)



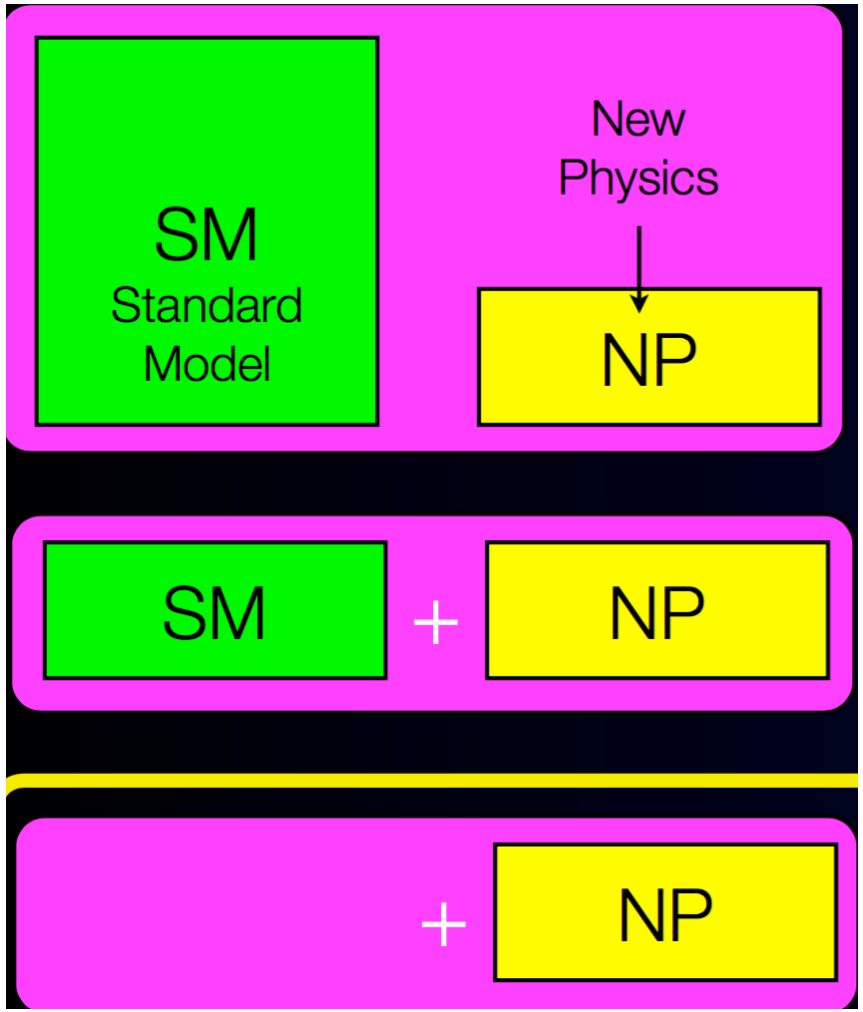




- ✓ Tentative plans
  - ✓ Data taking around beam energy 2.35GeV
  - ✓ Oct. 2026 – Sep. 2028 Data taking within beam energy 2.1-2.5GeV
  - ✓ Sep. 2028 – Jul. 2030 Data taking within beam energy 2.5-2.8GeV

General strategy for New Physics(NP) searches

New physics effects may be very small.



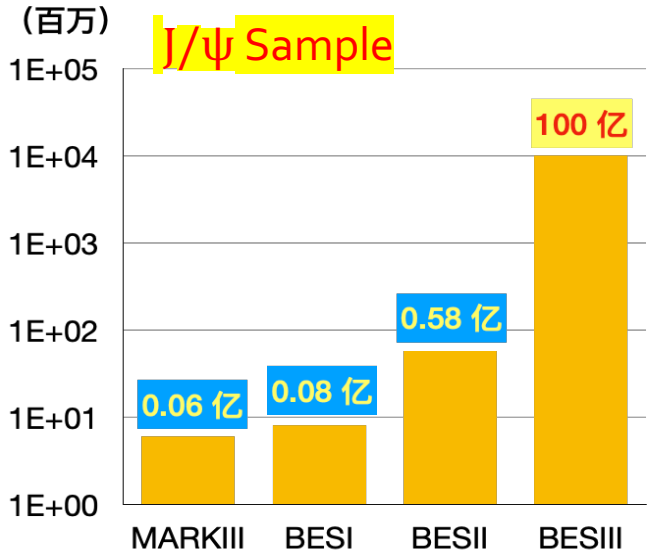
SM contribution is dominant.

SM contribution is highly suppressed.

SM contribution is forbidden.

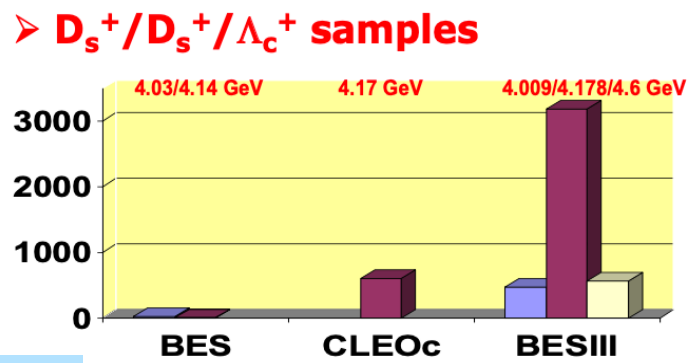
Uniqueness and Strength for NP@BESIII

1. Unique energy region and data samples
2. High statistics, high quality data
3. On-threshold production; correlated tags
4. Close collab of theory and experiment

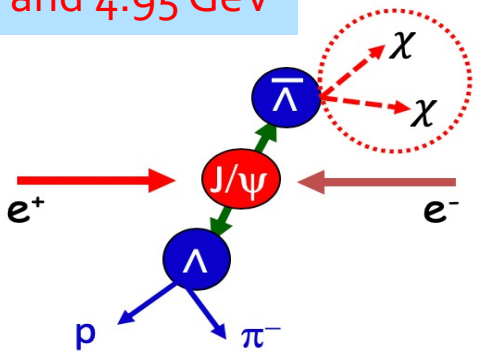


ψ(3686) Sample: 2.7Billion

$D^+(D^0)$ pairs： 20fb^{-1}@3773MeV

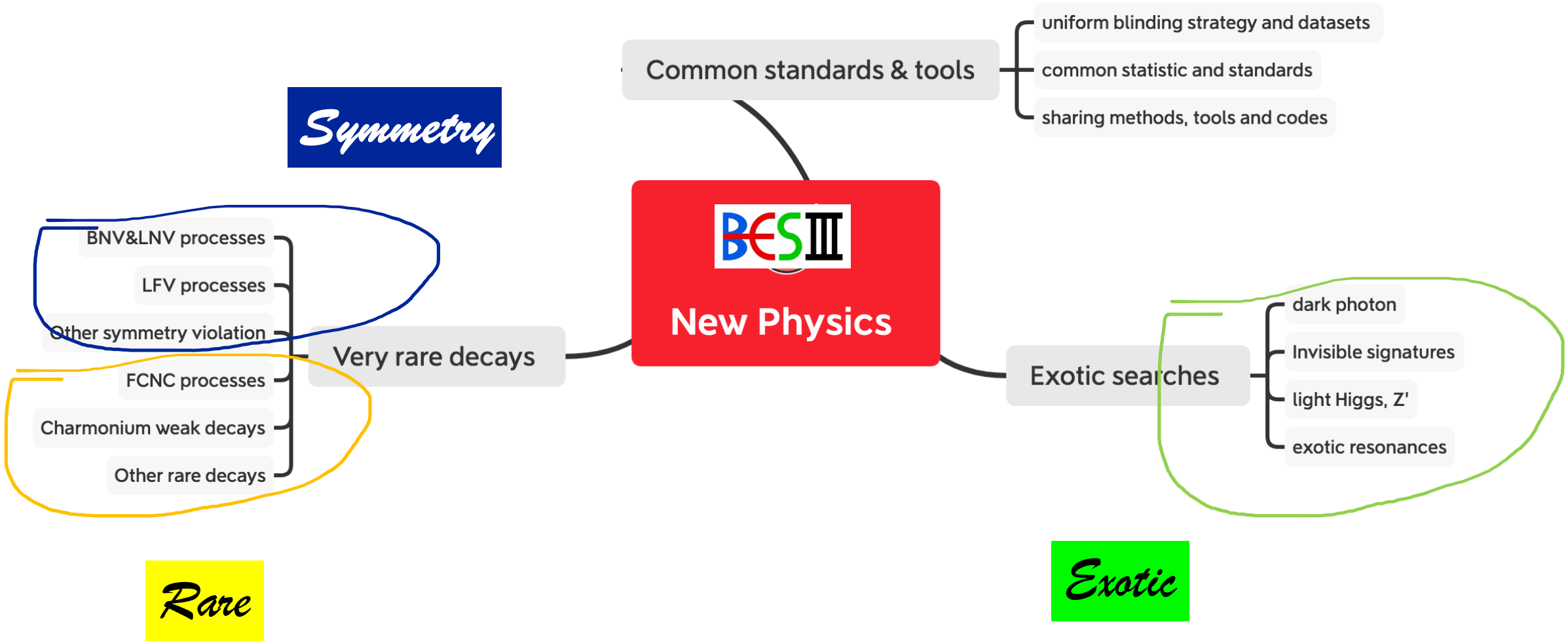


> 52 fb^{-1} of data taken between 1.84 and 4.95 GeV



huge sub-samples, such as $\eta, \eta', \omega, \phi, K_S^0$,hyperons …

BESIII New Physics Program



Selected topics with E_{miss}(invisible) signatures

- Charm decays with missing energy(invisible signatures)
  - Charm meson
  - Charm baryon
- Pure invisible decays
- Strange sectors
  - Hyperons
  - Ks
- Invisible decay of light hadrons/light NP particles
- Other processes with invisible signatures

With world largest J/ψ and $\psi(2S)$ sample, BESIII is also

- ✓ **a (polarized) hyperon factory for both precesion measurement and NP search**

Rept.Prog.Phys. 86 (2023) 1, 016201

- ✓ **Rich source of light hadrons, such as $\eta, \eta', \omega, \phi, K_S^0$ … from huge sub–samples**

- ✓ **Yields of both at level of 10^7**

Features for BESIII searches with missing energy

- Complete kinematic constraints : M^2_{miss}, U_{miss}, M_{recoil}, M_{BC}
- Double tag analysis
- Richness and wide usage of various control samples
  - Validation of analysis
  - Data-driven background estimation
  - Derivation of corrections to various experimental effects
  - Systematic uncertainty evaluation
- EM calo energy and shape variables: E_{EMC}, E_{extra} , moments
- Usage of miscelleneous tools
  - Blind analysis and unblinding strategies
  - mva and machine learning
  - Smooth model description: KDE, Gaussian Process Regression
  - Statistic treatments
  - …

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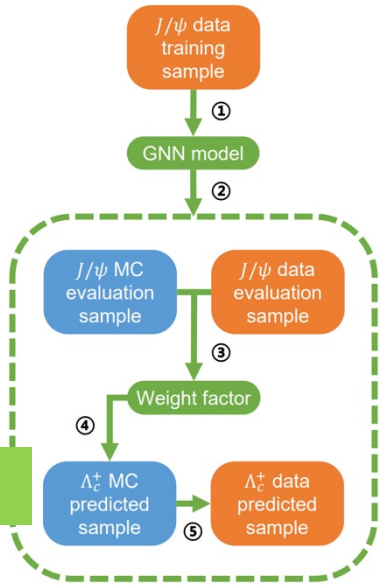
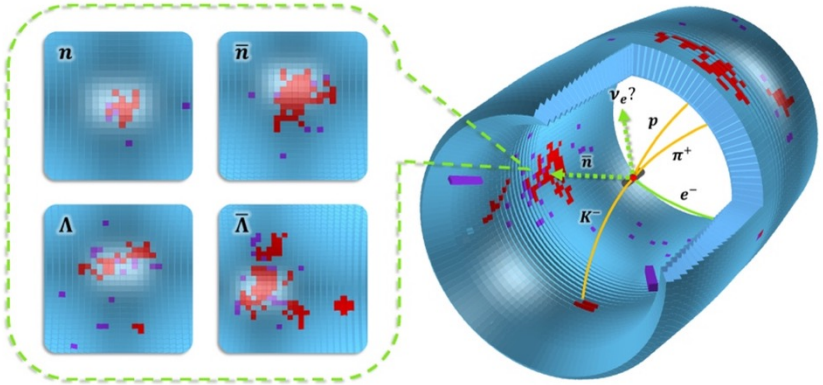


First Observation of $\Lambda^+_c \to ne^+\nu$

NatComm 16, 681 (2025)



More : Chin. Phys. C 49, 083001 (2025), PRD 111, L051101 (2025) …

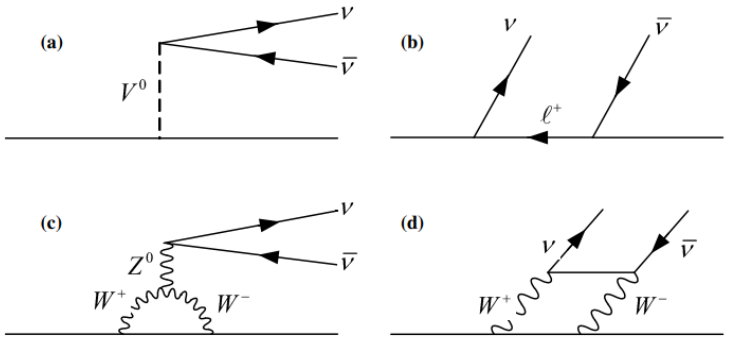
Charm dineutrino decays

- In SM, highly suppressed by GIM mechanism, with a very small BF 10^{-9} ~10^{-15}
- Stronger diagram cancellation than B & K systems
- $\boldsymbol{D^0 \to \pi^0 \nu\bar{\nu}}$ is the most suggested channel as null test

Upper limits $\mathcal{B}^{\max}(h_c \to F\nu\bar{\nu})$ depend on lepton flavor structure (LFV,cLFC,LFU) 2010.02225

From G. Hiller

	$\mathcal{B}^{\max}_{\text{LU}}$ $[10^{-7}]$	$\mathcal{B}^{\max}_{\text{cLFC}}$ $[10^{-6}]$	$\mathcal{B}^{\max}$ $[10^{-6}]$	$N^{\max}_{\text{LU}}/\eta_{\text{eff}}$	$N^{\max}_{\text{cLFC}}/\eta_{\text{eff}}$	$N^{\max}/\eta_{\text{eff}}$
$D^0 \to \pi^0$	6.1	3.5	13	47 k (395 k)	270 k (2.3 M)	980 k (8.3 M)
$D^+ \to \pi^+$	25	14	52	77 k (650 k)	440 k (3.7 M)	1.6 M (14 M)
$D_s^+ \to K^+$	4.6	2.6	9.6	6 k (50 k)	34 k (290 k)	120 k (1.1 M)
$D^0 \to \pi^0\pi^0$	1.5	0.8	3.1	11 k (95 k)	64 k (540 k)	230 k (2.0 M)
$D^0 \to \pi^+\pi^-$	2.8	1.6	5.9	22 k (180 k)	120 k (1.0 M)	450 k (3.8 M)
$D^0 \to K^+K^-$	0.03	0.02	0.06	0.2 k (1.9 k)	1.3 k (11 k)	4.8 k (40 k)
$\Lambda_c^+ \to p^+$	18	11	39	14 k (120 k)	82 k (700 k)	300 k (2.6 M)
$\Xi_c^+ \to \Sigma^+$	36	21	76	28 k (240 k)	160 k (1.4 M)	590 k (5.0 M)



Search for $D^0 \to \pi^0 \nu\bar{\nu}$

PRD 105 L071102 (2022)

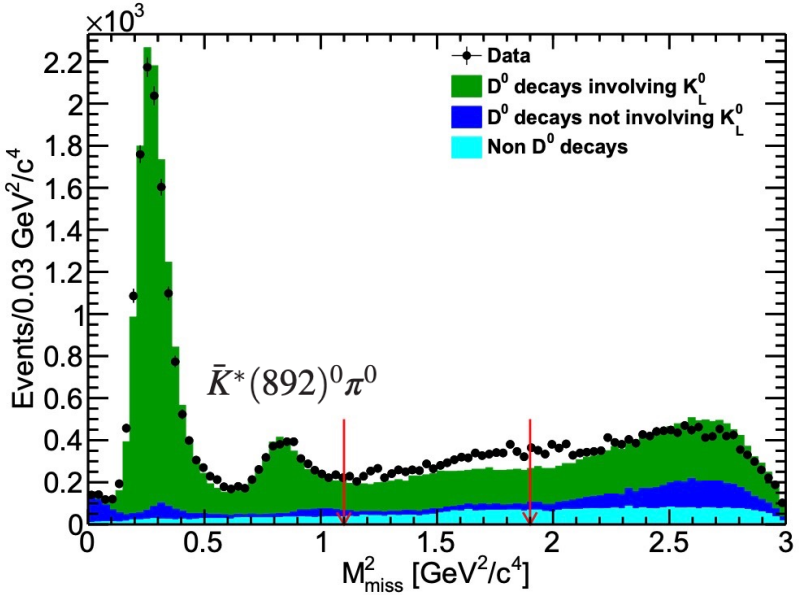
- Analyzing $D^0\bar{D}^0$ pairs from 2.9fb-1 psi(3773) data $\mathcal{B}_{\rm sig} = \frac{N_{\rm sig}}{\mathcal{B}_{\pi^0\to\gamma\gamma}\sum_\alpha N^\alpha_{\rm tag}\epsilon^\alpha_{\rm tag,sig}/\epsilon^\alpha_{\rm tag}}$.
- Double tag
- Data-driven modeling of $D^0 \to \pi^0 K_L X$ shape
  - KL energy control samples: $J/\psi \to \phi K^\pm\pi^\mp K^0_L$ $J/\psi \to K^\pm\pi^\mp K^0_L$
  - X energy control sample: $D^0 \to \pi^0 K^0_S X$
  - The final bkg shape is constructed by sampling $E^{K^0_L}_{\rm EMC}$ and $E^{X}_{\rm EMC}$ w/ reweighting
  - The corrections are derived with control sample $D^0 \to \pi^0 K^0_S X$
  - Some systematics are investigated with $D^0 \to K^-\pi^+\pi^0$

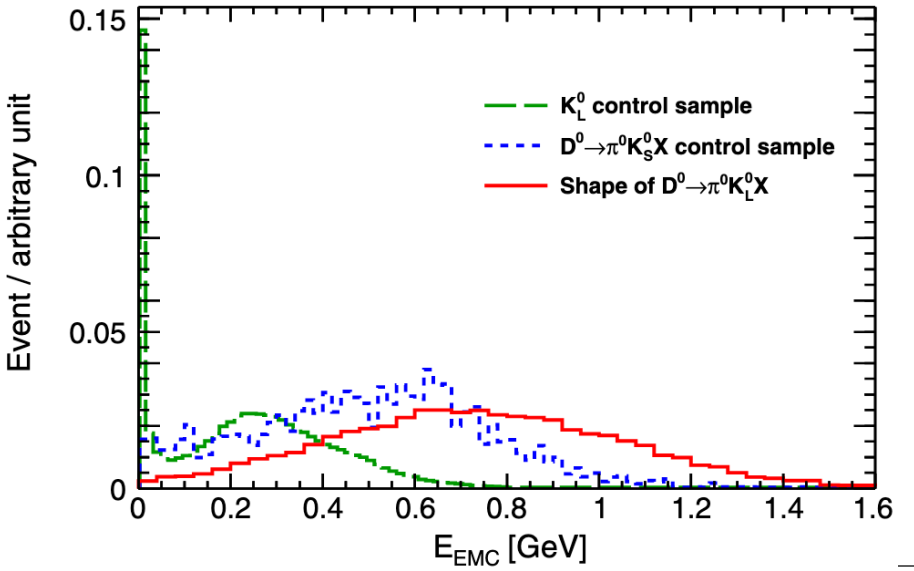
$D^0 \to K^0_L\pi^0$

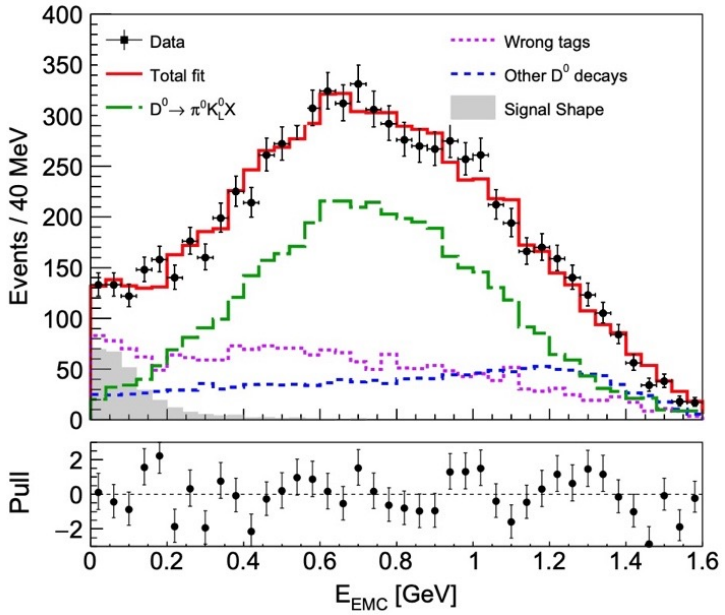
BESIII Result

$\mathcal{B}(D^0 \to \pi^0\nu\bar{\nu}) < 2.1\times10^{-4}$ @ 90% C. L.

The first constraint on charmed hadron to di-neutrinos

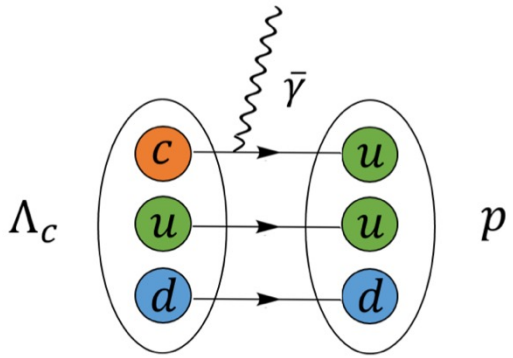




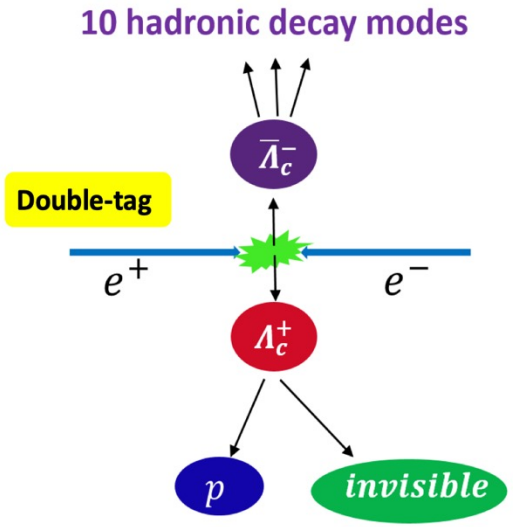


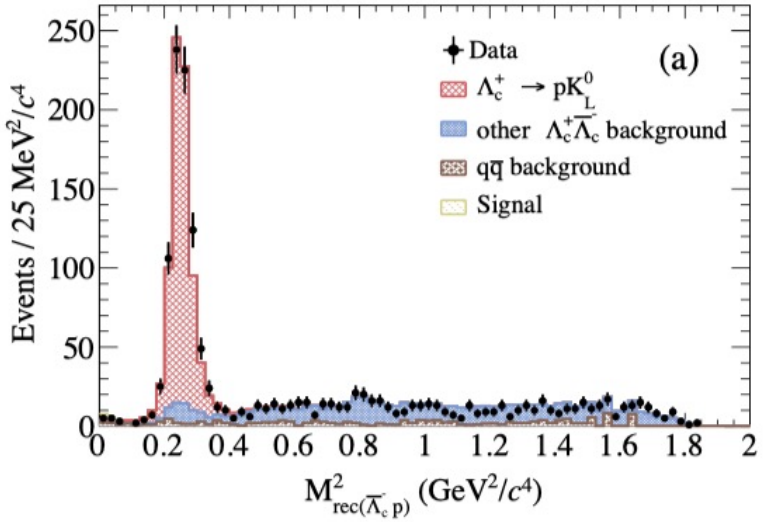
Search for $\Lambda_c \to p\gamma'$ (massless DP)

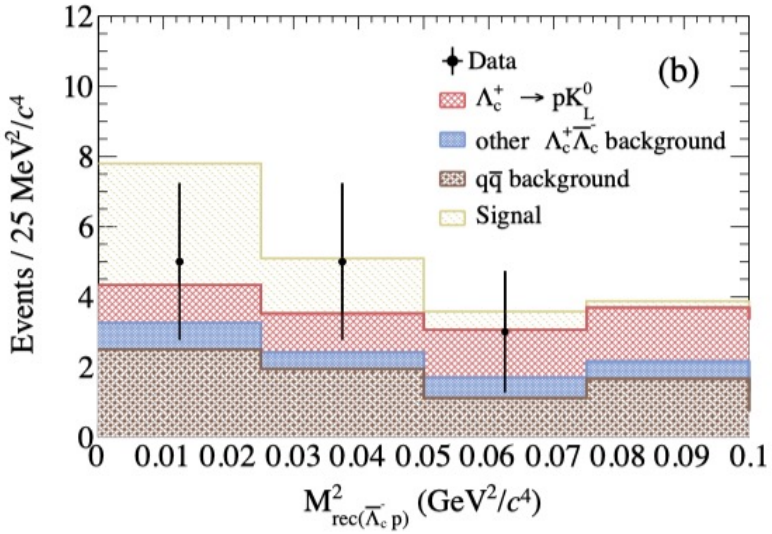
Massless dark photon is predicted
with $U(1)_D$ staying unbroken,
which can induce FCNC transitions



Using 4.5 fb^{-1} data in 4.6 - 4.7GeV





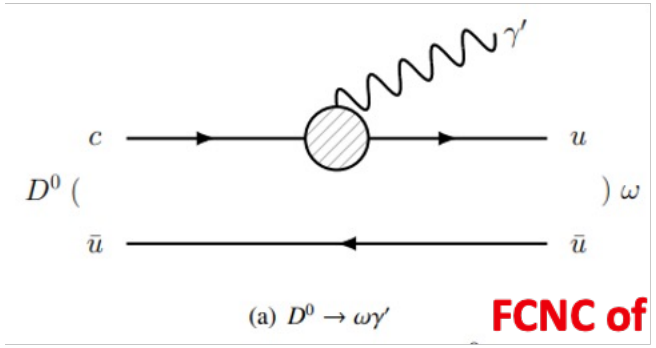


$\mathcal{B}(\Lambda_c \to p\gamma') < 8.0\times10^{-5}$ @ 90% C.L.

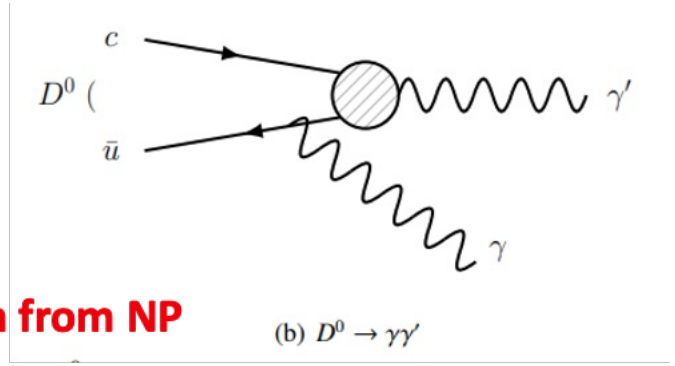
PRD 106, 072008 (2022)

Search for $D^0 \to \omega\gamma'$ and $D^0 \to \gamma\gamma'$

- Double tag: ~ 6×10^6 $D^0(\overline{D^0})$ are tagged with 7.9fb^{-1}data @3.77 GeV
- The massless dark photon is invisible



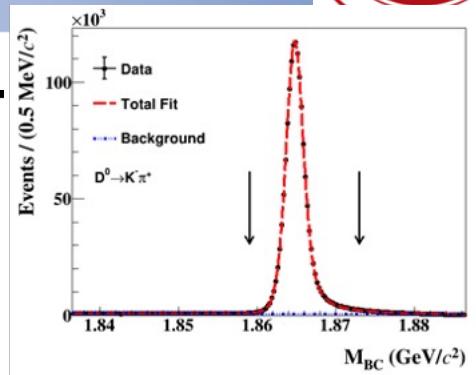
(a) $D^0 \to \omega\gamma'$

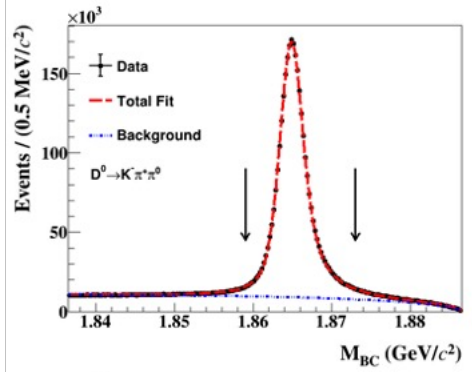


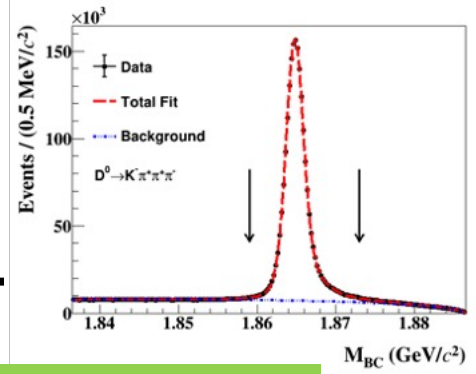
(b) $D^0 \to \gamma\gamma'$

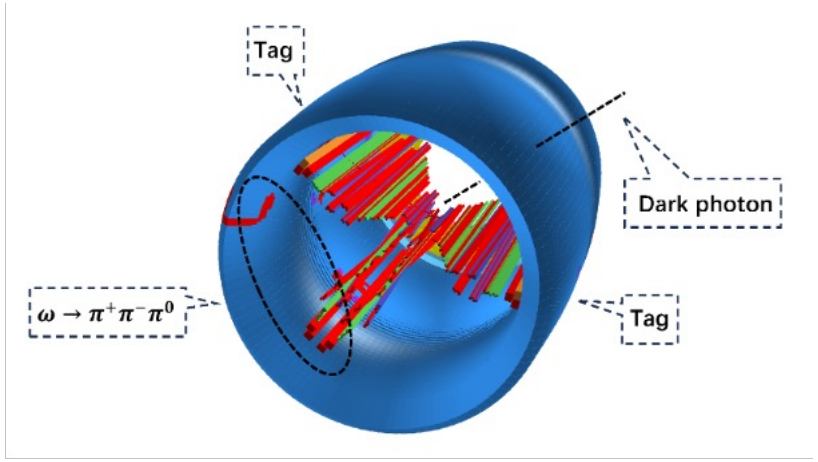
FCNC of charm from NP

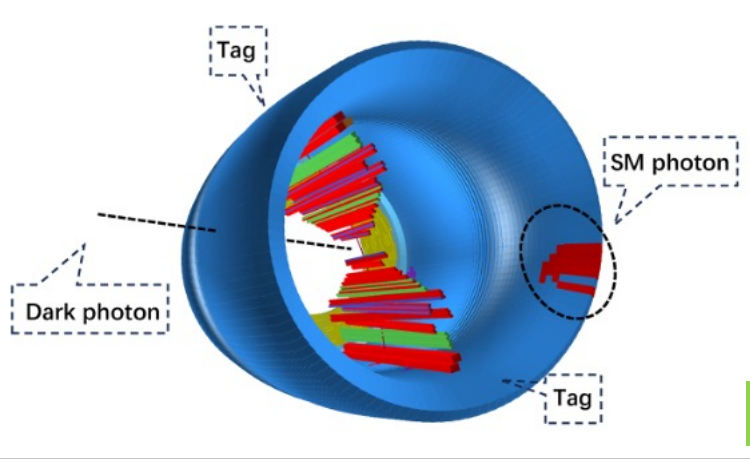
Tag





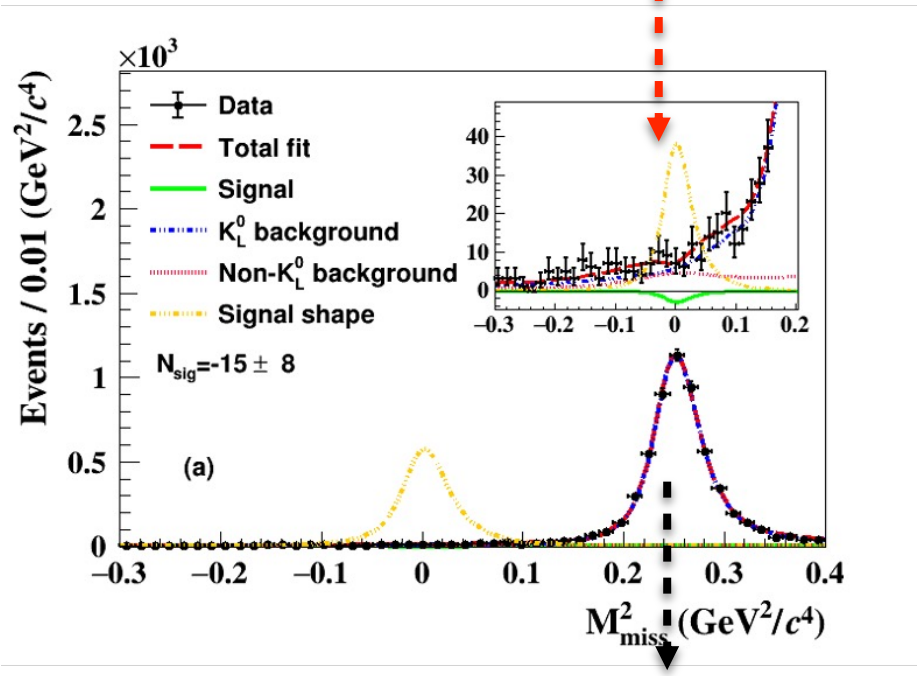






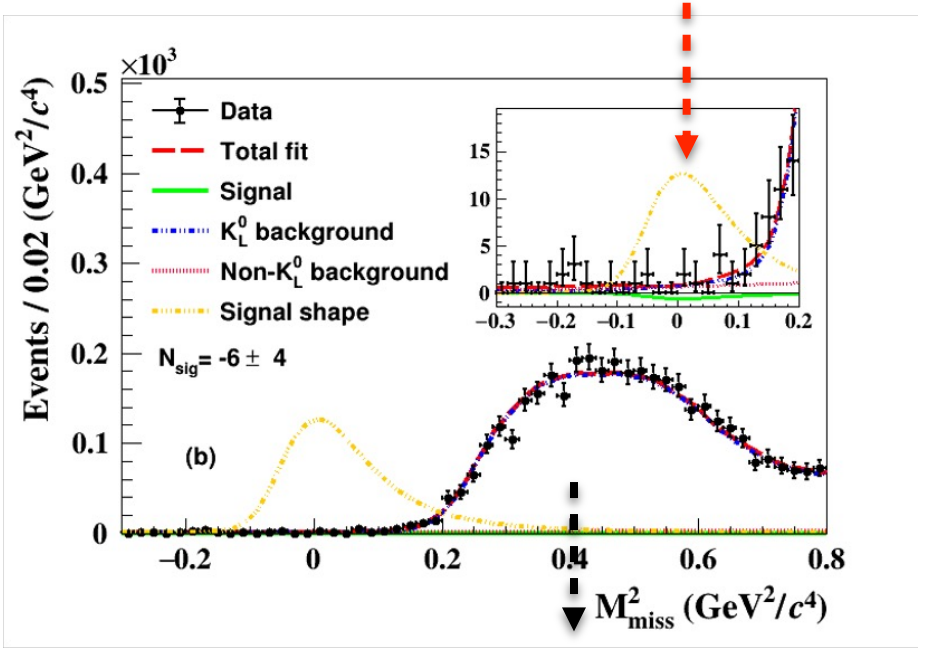
Phys.Rev.D 111 (2025) 1, L011103

Signal peaks around zero



$D^0 \to \omega K_L^0$ background

Signal peaks around zero



$D^0 \to \pi^0 K_L^0$ background

Signal extraction of $D^0 \to \omega\gamma'$

Signal extraction of $D^0 \to \gamma\gamma'$

Phys.Rev.D 111 (2025) 1, L011103

Coupling constraints

This work

$$\mathcal{B}(D \to V\gamma') = \frac{\tau_D f_{DV}^2 (m_D^2 - m_V^2)^3}{2\pi m_D^3}(|\mathbb{C}|^2 + |\mathbb{C}_5|^2)$$

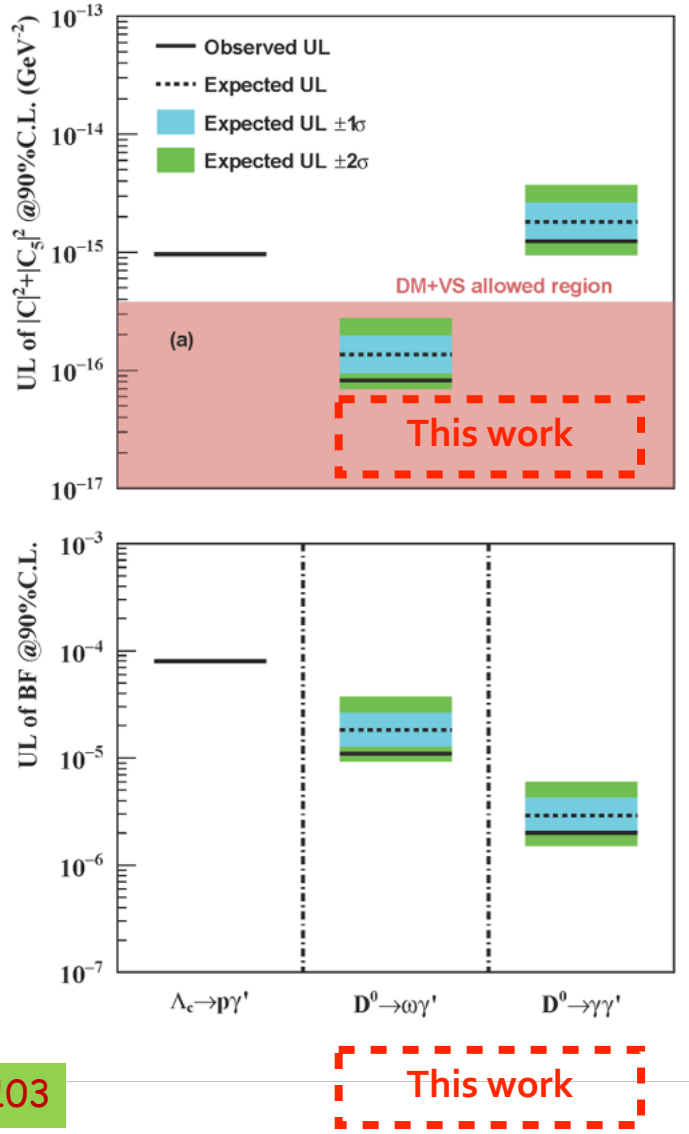
$$\mathcal{B}(D \to \gamma\gamma') = \frac{\alpha_e}{2}\tau_D f_{D\gamma}^2 m_D^3 (|\mathbb{C}|^2 + |\mathbb{C}_5|^2)$$

Previous BESIII work

$$\mathcal{B}(\Lambda_c \to p\gamma') = \frac{\tau_{\Lambda_c} f_{\Lambda_c p}^2 (m_{\Lambda_c}^2 - m_p^2)^3}{2\pi m_{\Lambda_c}^3}(|\mathbb{C}|^2 + |\mathbb{C}_5|^2)$$

- $\mathbb{C} = \Lambda_{NP}^{-2}(C_{12}^U + C_{21}^{U*})v/\sqrt{8}$
- $\mathbb{C}_5 = \Lambda_{NP}^{-2}(C_{12}^U - C_{21}^{U*})v/\sqrt{8}$

The constraint from $D^0 \to \omega\gamma'$ goes into the dark matter (DM) and vacuum stability (VS) allowed region for the first time, improved by more than 1 order



Phys.Rev.D 111 (2025) 1, L011103

Invisible decay of K_S^0:motivation

K_S^0

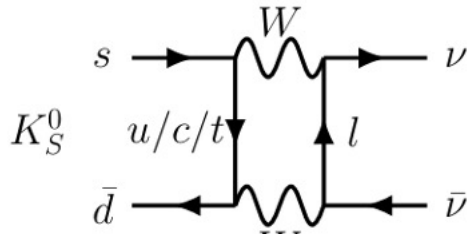
Invisible

SM decay

$K_S^0 \to \nu\bar{\nu}$

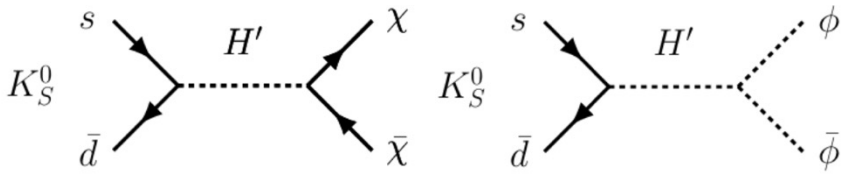
Phys.Rev.D 91 (2015) 1, 015004

FCNC && helicity suppression, BF < 10^{-16}



Decay to DM

$K_S^0 \to \chi\bar{\chi}$



2HDM model
BF~$\mathcal{O}(10^{-6})$

Natural Sci.Rev. 1 (2024) 5

Ordinary-mirror particle oscillations

$K_S^0 \dashrightarrow K_S^{0\prime}$

Mirror matter model
BF~$\mathcal{O}(10^{-6})$

arXiv: 2006.10746

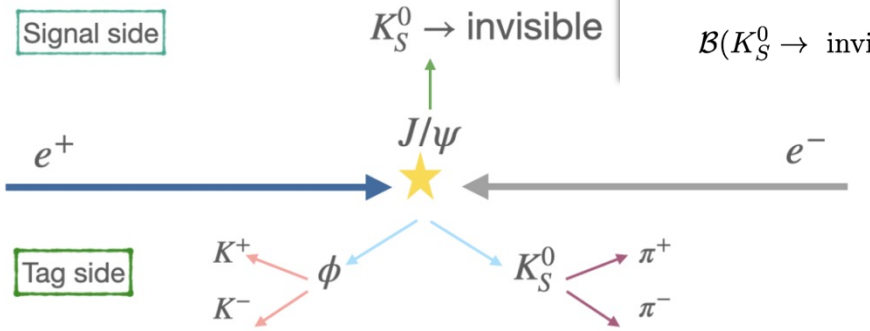
Input for CPT test

Bell-Steinberger relation connects CPTV to the amplitudes of all decay channels of neutral kaons.
BUT currently assumes no invisible modes

Phys.Rev.D 91 (2015) 1, 015004

Analysis strategy

- $J/\psi \to \phi K_S^0(\text{tag}) K_S^0$, $K_S^0(\text{tag}) \to \pi^+\pi^-$ from 10Billion J/ψ events

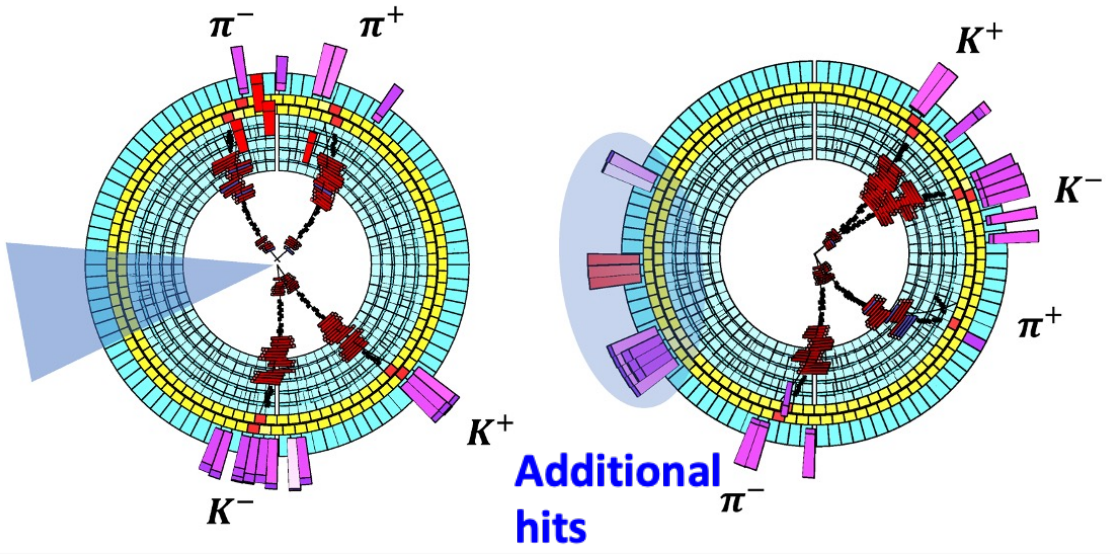


$$\mathcal{B}(K_S^0 \to \text{ invisible}) = \frac{N_{\text{signal}}}{N_{\text{norm.}}\,(\varepsilon_{\text{signal}}/\varepsilon_{\text{norm.}})}\,(1-\mathcal{B}(K_S^0 \to \pi^+\pi^-)).$$

Signal feature

Signal

Background



- $J/\psi \to \phi K_S^0 K_L^0$ is forbidden by C-parity conservation, lower background
- But still have $J/\psi \to K^+K^-K_S^0K_L^0$

$$N_{\text{signal}} = 2 \times N_{J/\psi\to\phi K_S^0 K_S^0} \times \mathcal{B}(\phi \to K^+K^-) \times \mathcal{B}(K_S^0 \to \pi^+\pi^-) \times \mathcal{B}(K_S^0 \to \text{invisible}) \times \varepsilon_{\text{signal}},$$

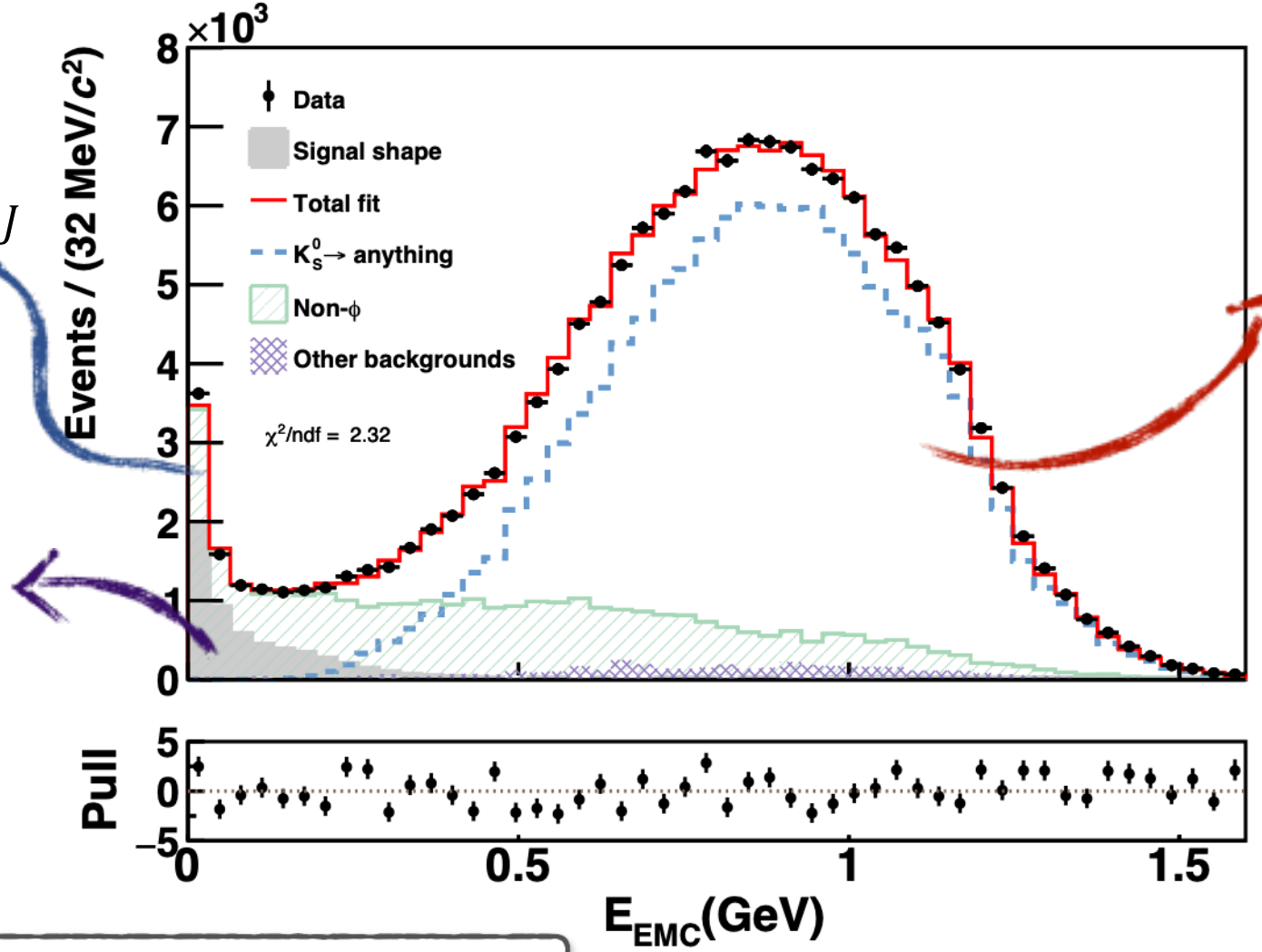
$$N_{\text{norm.}} = 2 \times N_{J/\psi\to\phi K_S^0 K_S^0} \times \mathcal{B}(\phi \to K^+K^-) \times \mathcal{B}(K_S^0 \to \pi^+\pi^-) \times (1-\mathcal{B}(K_S^0 \to \pi^+\pi^-)) \times \varepsilon_{\text{norm.}},$$

Using the deposited energy in EMC(energy calorimeter) to identify the invisible signal

JHEP 05 (2025) 092

Signal extraction

Peaking background from non-ϕ processes, $J/\psi \to K^+K^-K_S^0K_L^0$,
Shape from ϕ sideband



Invisible Signal peaks around zero

Other background modeled with MC simulation, such as $K_S^0 \to \pi^0\pi^0$,validated by control sample $J/\psi \to \phi K_S^0(\pi^0\pi^0)K_S^0\ (\pi^+\pi^-)$

$N_{\text{invisible}} = 56 \pm 201$,

$\mathcal{B}(K_S^0 \to \text{invisible}) < 8.4 \times 10^{-4}$

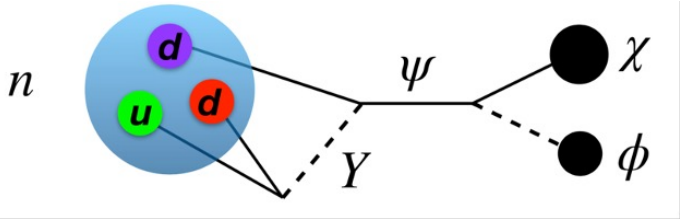
(90% C.L)

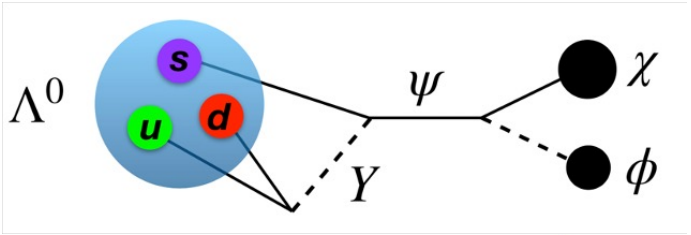
First direct measurement of K_S^0 →invisible!

the UL still lies above the NP prediction

Search for invisible decays of the Λ baryon

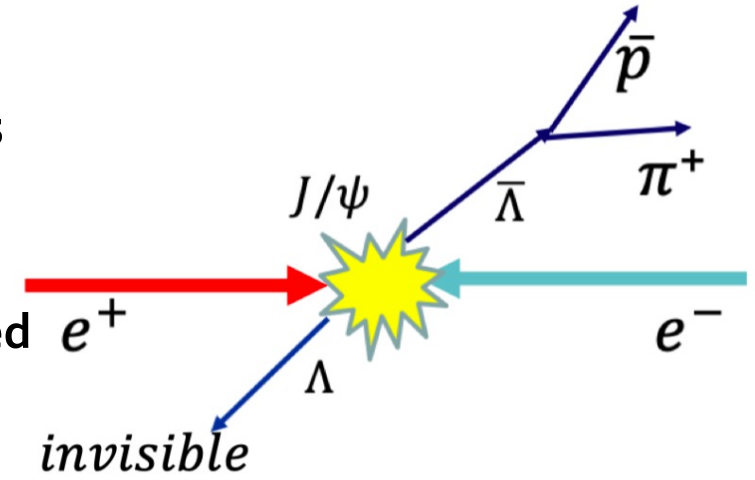
- **Motivation**
  - Dark matter may be represented by baryon matter with invisibles, and many theories suggest a potential correlation between baryon symmetry and dark sector Phys. Rev. D 105, 115005 (2022)
  - Discrepancy of neutron lifetime in beam method and the storage methods → B(n → p + X) ≈ 99% Phys. Rev. D 99, 035031 (2019)

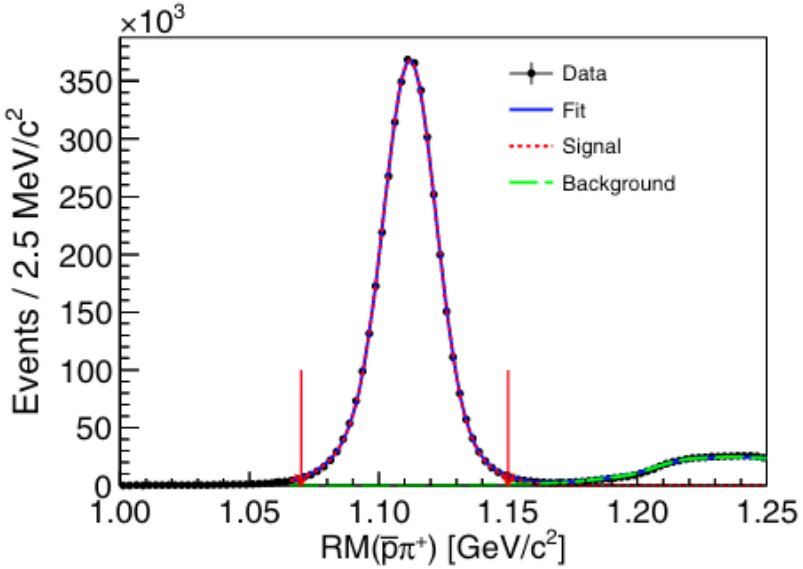




$$\mathcal{B}(\Lambda \to \text{invisible}) = \frac{N_{sig}}{N_{tag} \times (\epsilon_{sig}/\epsilon_{tag})}$$

- **Data samples: 10B J/ψ events**
- **Method: Double tag method**
  - **4 Million tag $\bar{\Lambda}$ events obtained**





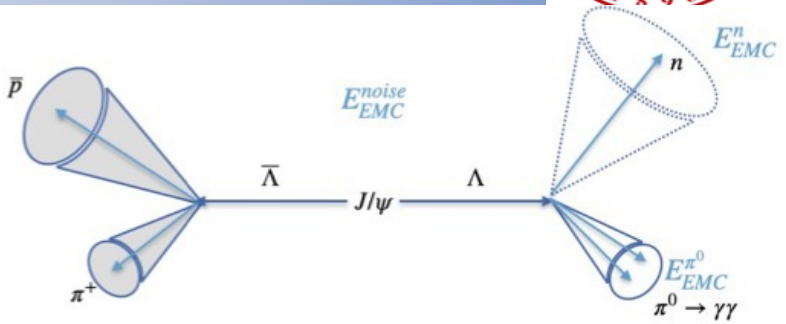
PRD 105, L071101(2022)

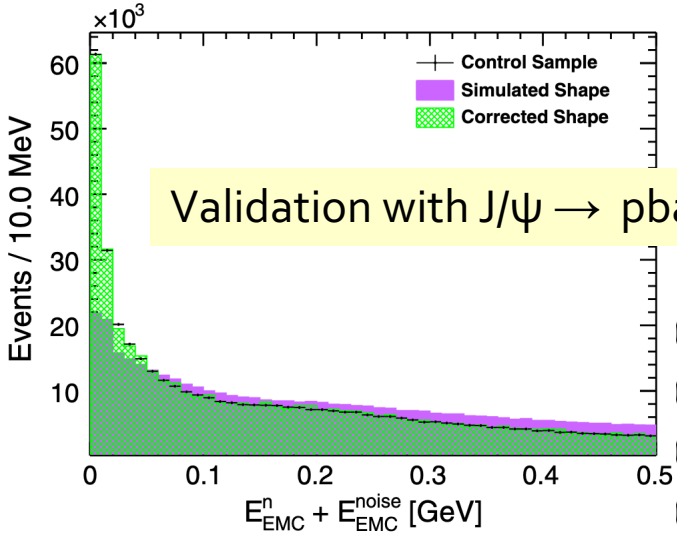
Search for invisible decays of the Λ baryon

- **Signal extraction**
  - Search for signal on total energy deposited E_{EMC};
  - **Dominating background:** $\Lambda \to n\pi^0$
  - E_{EMC} **divided into three parts**
    - $E_{EMC}^{\pi^0}$**: based on the MC simulations**
    - $E_{EMC}^{n} + E_{EMC}^{\text{noise}}$**: based on control sample**

$$E_{\text{EMC}} = E_{\text{EMC}}^{\pi^0} + E_{\text{EMC}}^{n} + E_{\text{EMC}}^{\text{noise}},$$

$$J/\psi \to \Lambda(n\pi^0)\bar{\Lambda}(\bar{p}\pi^+)$$





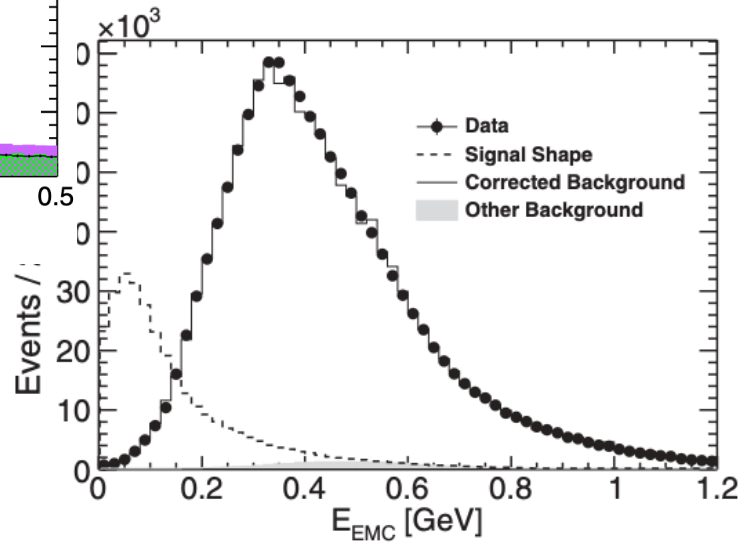
Validation with J/ψ → pbar π n

- **Upper limits**
  - **No obvious signal observed**
    - $\mathcal{B}(\Lambda \to \text{invisible}) < 7.4\times10^{-5}$ **at 90% CL**

arXiv:2006.10746

✓ **Consistent with the prediction of** 4.4×10^{-7} **from the mirror model**

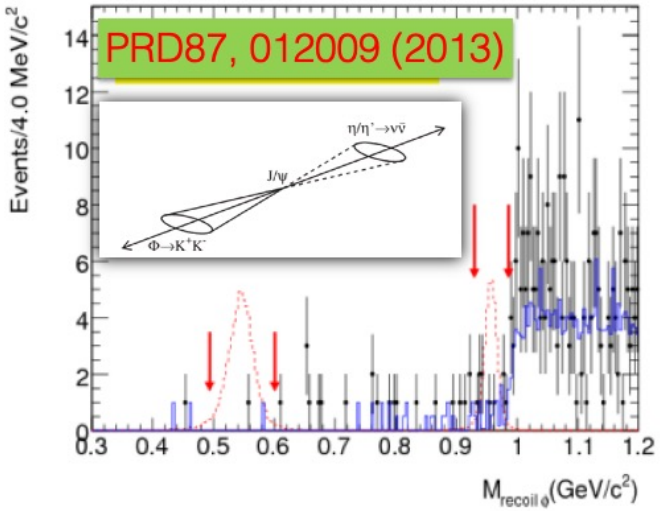
✓ **The first search of invisible decays of baryons**



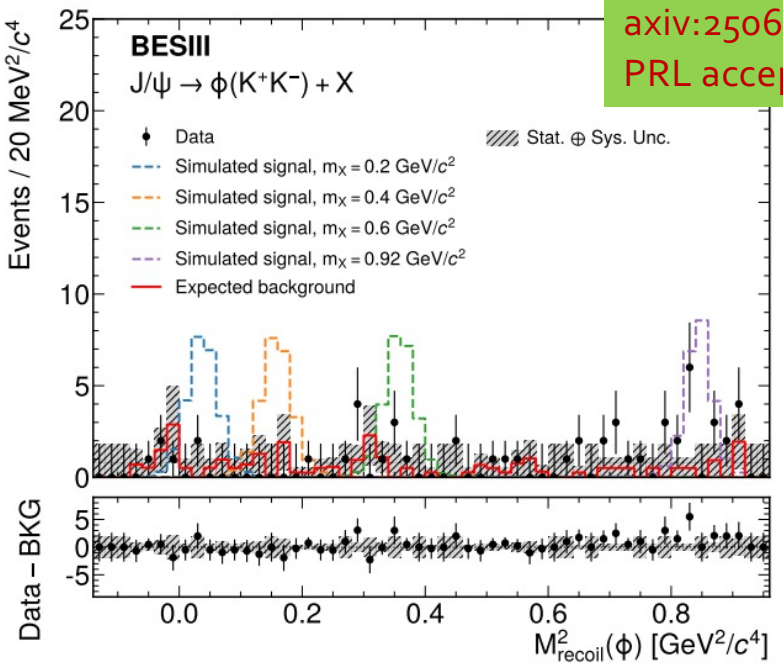
PRD 105, L071101(2022)

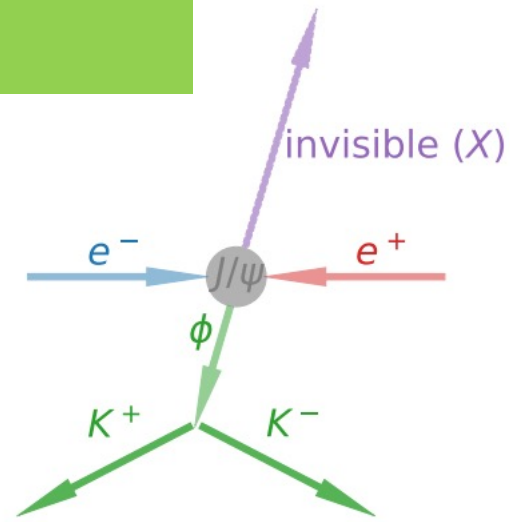
Other fully invisible decays: η /η′/ ω/ϕ/ sub-GeV NP particles

η /η′ invisible decays



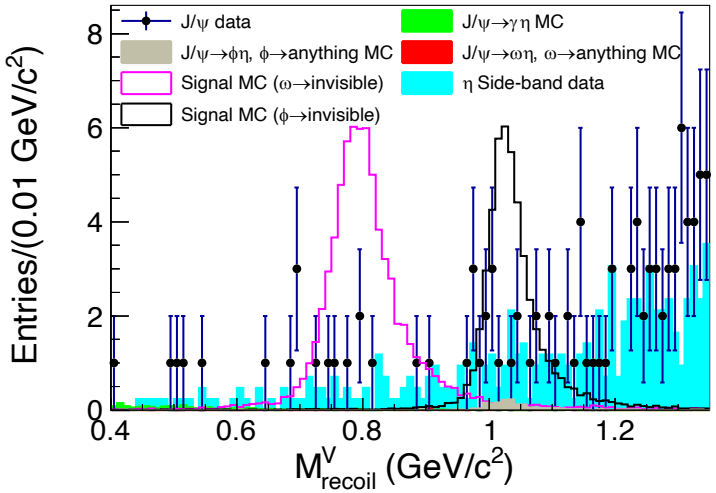
axiv:2506.10316
PRL accepted

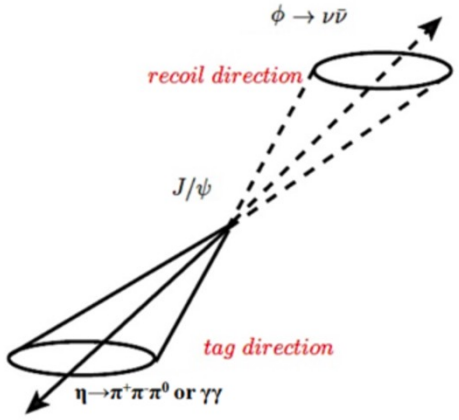


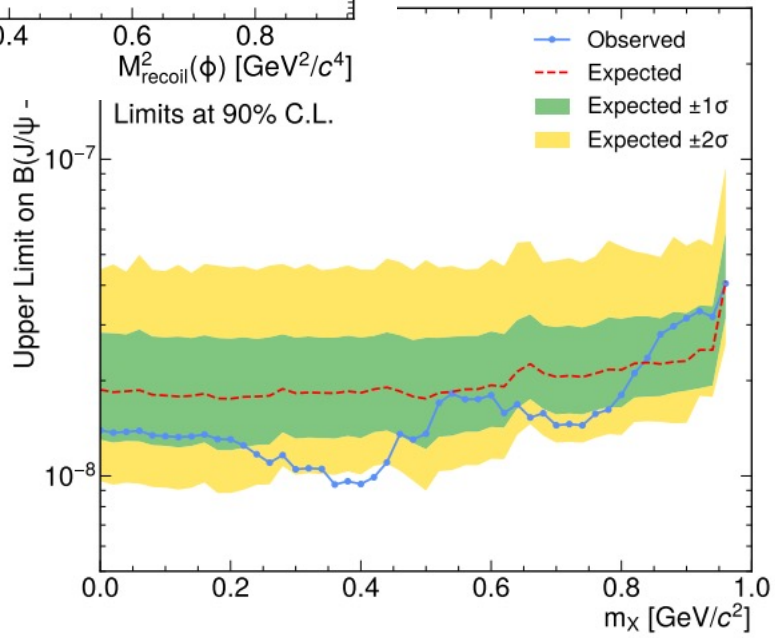


ω/ϕ invisible decays

PRD 98, 032001(2018)







$\Sigma^+ \to p$ +invisible: motivation

Σ^+

p +Invisible

Decay to SM

FCNC && GIM suppression, BF $< 10^{-11}$

$s \to d\nu\bar{\nu}$

ROPP. 86, 016201 (2023)

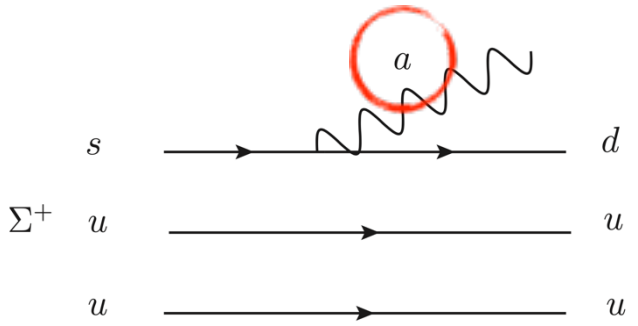
Contributions from BSM can enhance the BF (~ 10^{-4})

JHEP 04, 104 (2019).

Decay to BSM particle

- Massless dark photon γ' && QCD axion, a

$m_a \propto 1/f_a$ 👉 $m_a \ll 1eV$



Phys. Rev. D 102, 015023 (2020).

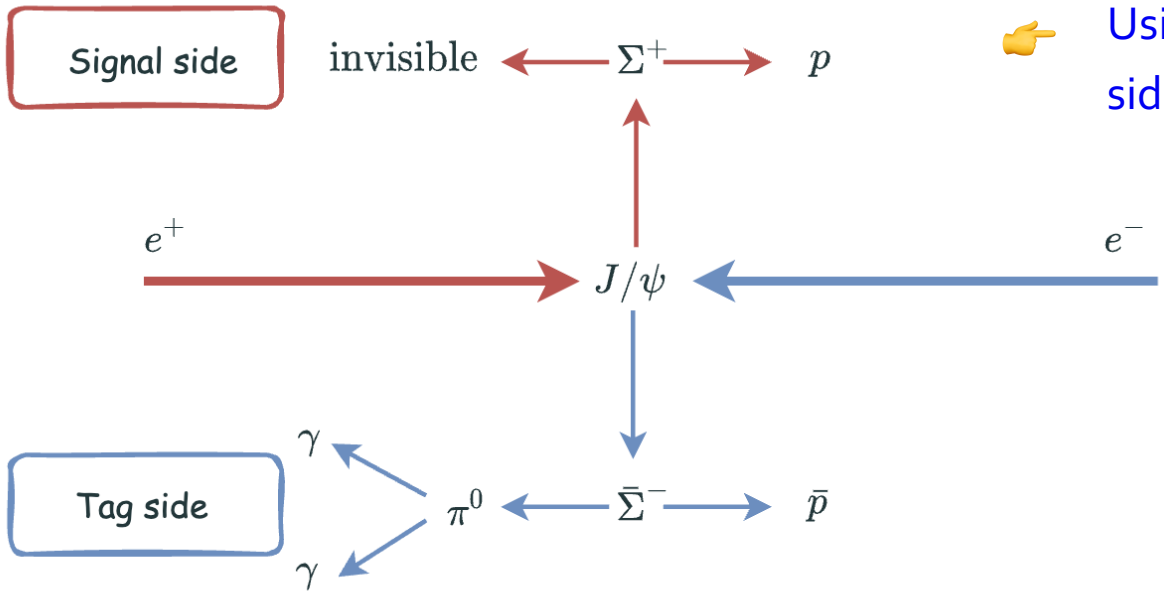
$$\Gamma(\Sigma^+ \to pa) = \frac{M_{\Sigma^+}^3}{16\pi}\left(1-\frac{M_p^2}{M_{\Sigma^+}^2}\right)^3 \left(\frac{(-1)^2}{|F_{sd}^V|^2}+\frac{0.34^2}{|F_{sd}^A|^2}\right)$$

Our measurement can set limits on axion-fermion effective decay constants

Analysis strategy

- 10B J/ψ events, $J/\psi \to \Sigma\bar{\Sigma}$ (~$10^7 \Sigma^+\bar{\Sigma}^-$ pairs), double tag method

Kinematic fit to constraint the invisible axion mass to zero

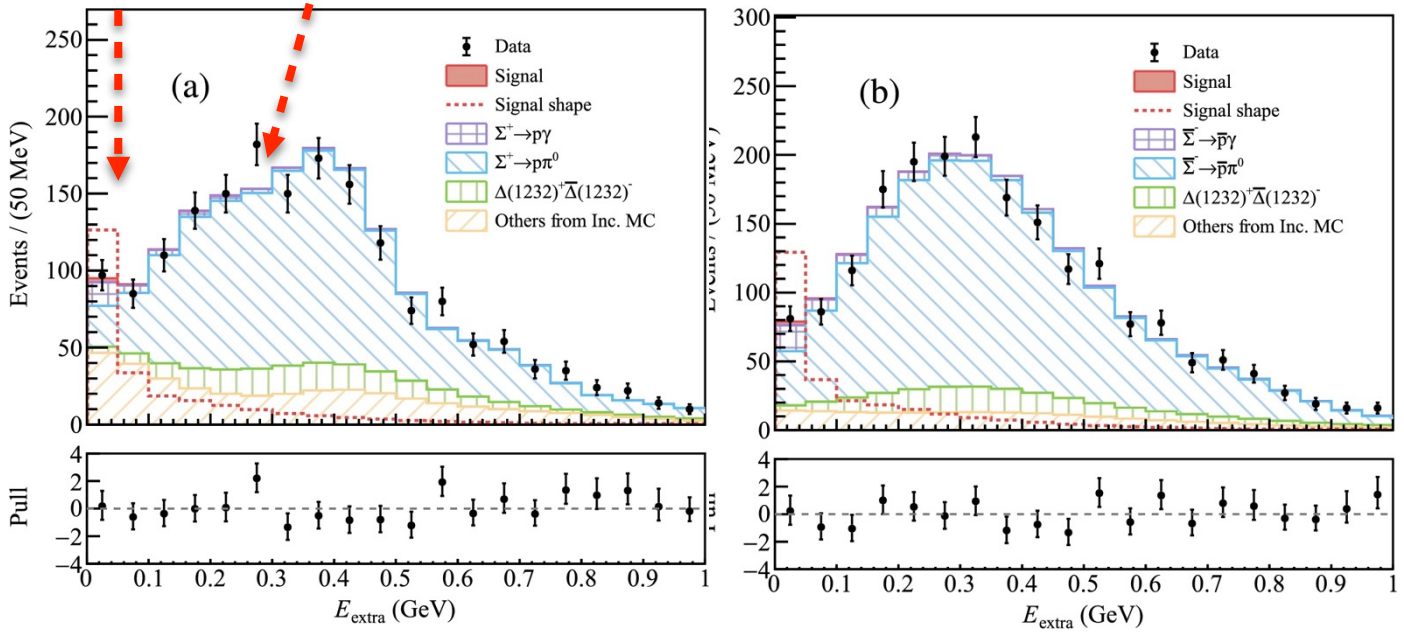


👉 Using the deposited energy except for those from tag side π^0 in EMC to identify the invisible signal

Signal extraction

Background modeled with MC simulation, such as $\Sigma^+ \to p\pi^0$

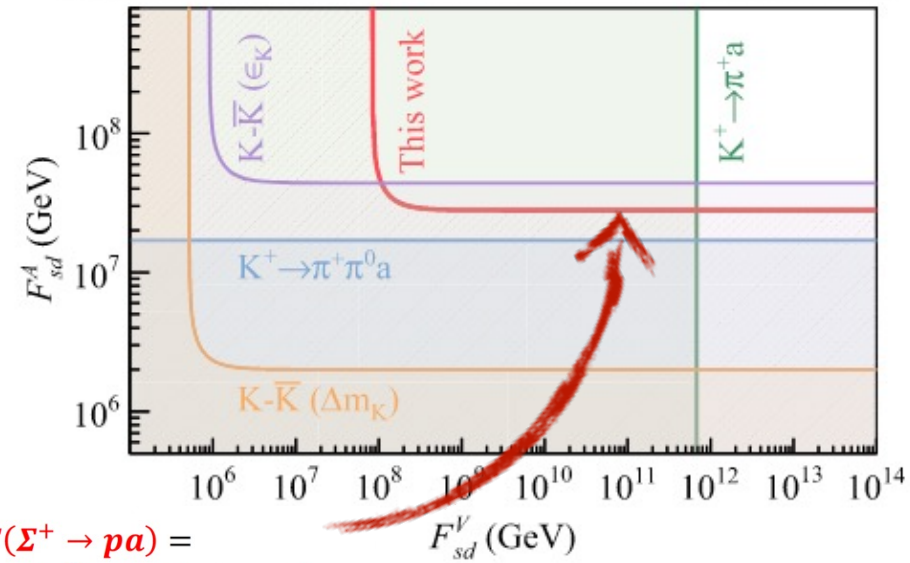
Invisible Signal peaks around zero



BF($\Sigma^+ \to p$ +invisible) < 3.2×10^{-5} @ 90% CL.

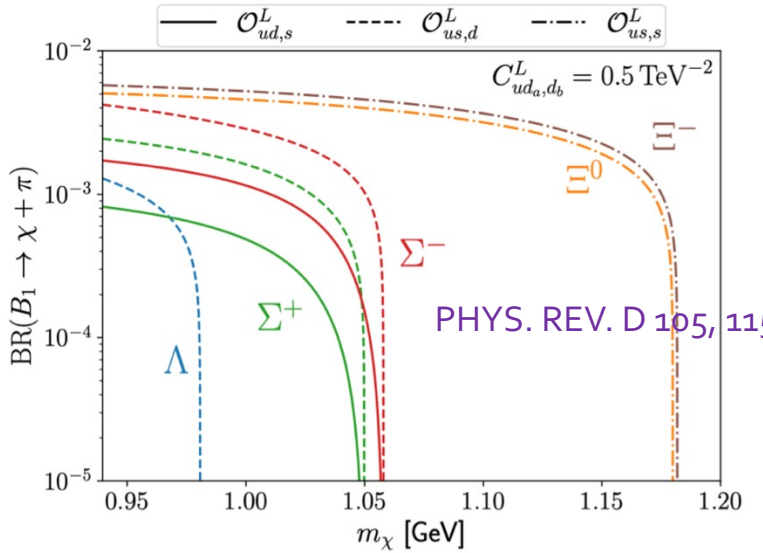
Phys.Lett.B 852 (2024) 138614

- Our result lies below the maximum BF allowed for $\Sigma^+ \to p$+invisible in certain scenarios, under the hypothesis of massless γ'
  $\to 3.8 \times 10^{-5}$ Phys. Rev. D 101, 035044 (2020)
- Competitive limit on the axial-vectorial part of axion-fermion effective decay constant F^A_{sd} :
  $\to F^A_{sd} > 2.8 \times 10^7$ GeV

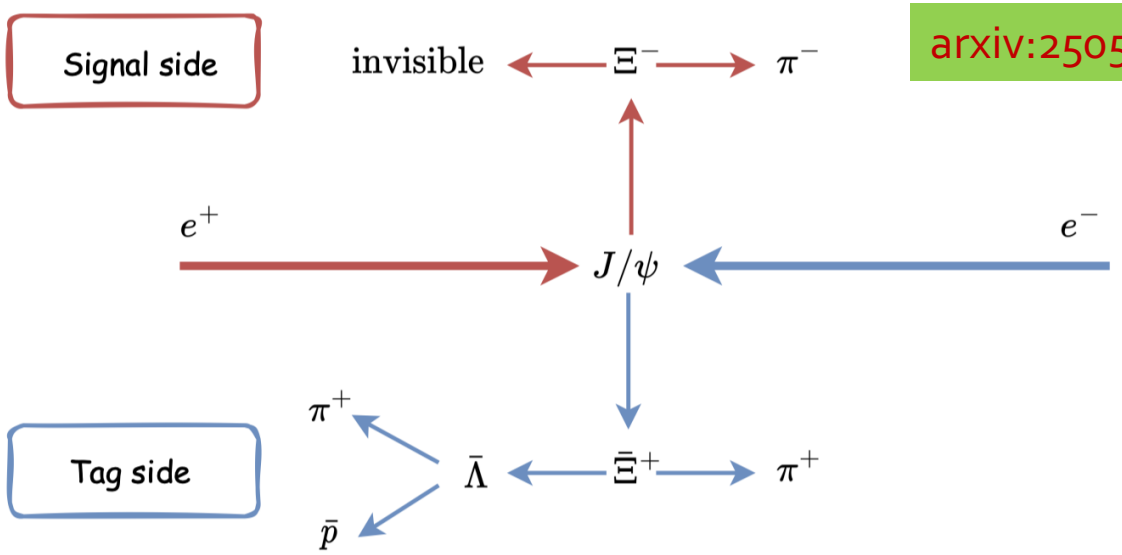


$$\Gamma(\Sigma^+ \to pa) = \frac{M^3_{\Sigma^+}}{16\pi}\left(1-\frac{M_p^2}{M^2_{\Sigma^+}}\right)^3 \left(\frac{(-1)^2}{|F^V_{sd}|^2}+\frac{0.34^2}{|F^A_{sd}|^2}\right)$$

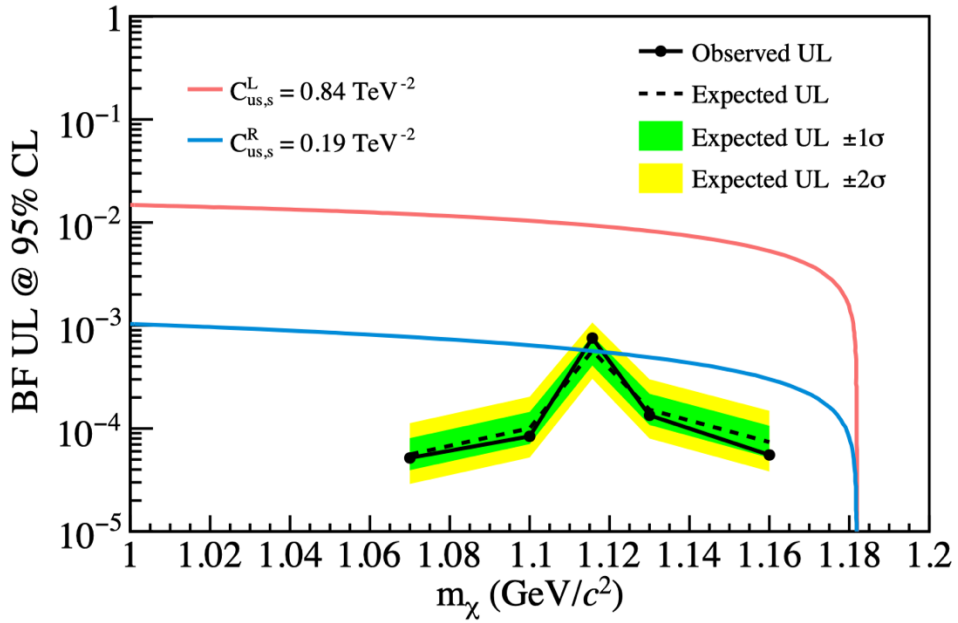
Search for $\Xi^- \to \pi^- +$ invisible

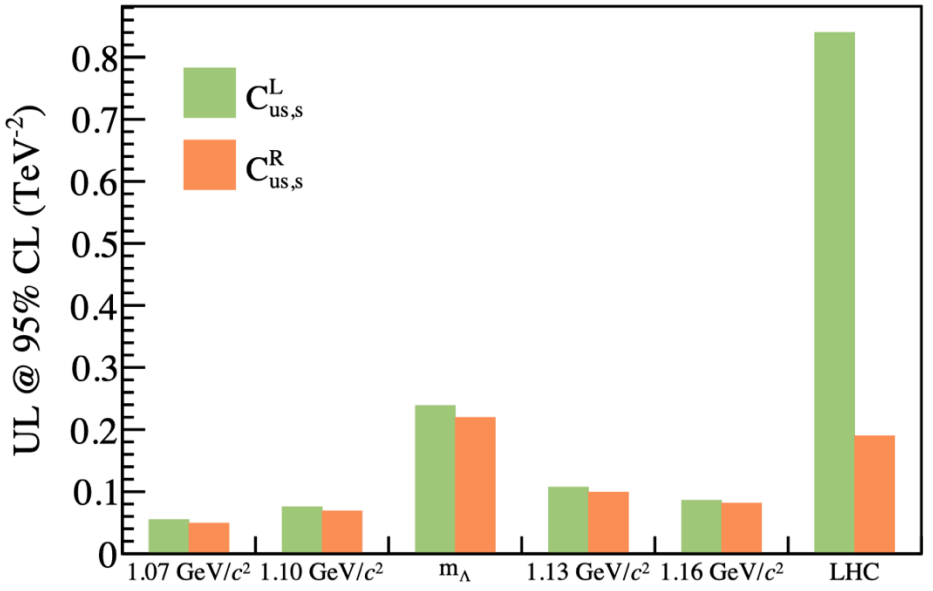


PHYS. REV. D 105, 115005 (2022)



arxiv:2505.22140



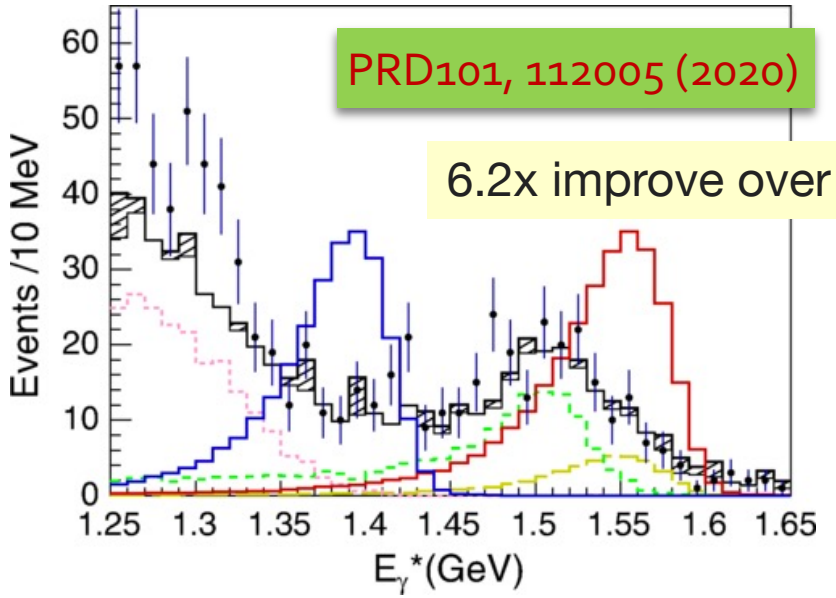


Other searches with invisible signatures

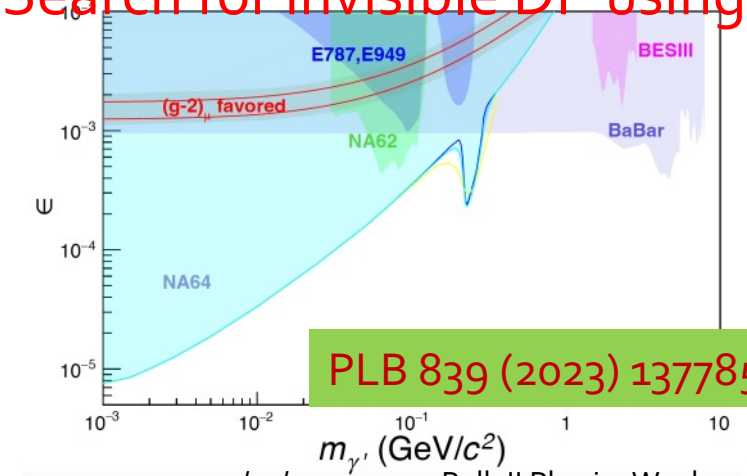
$J/\psi \to \gamma$+invisible via $\psi(3686) \to \pi^+\pi^- J/\psi$

PRD101, 112005 (2020)

6.2x improve over CLEO



Search for invisible DP using ISR

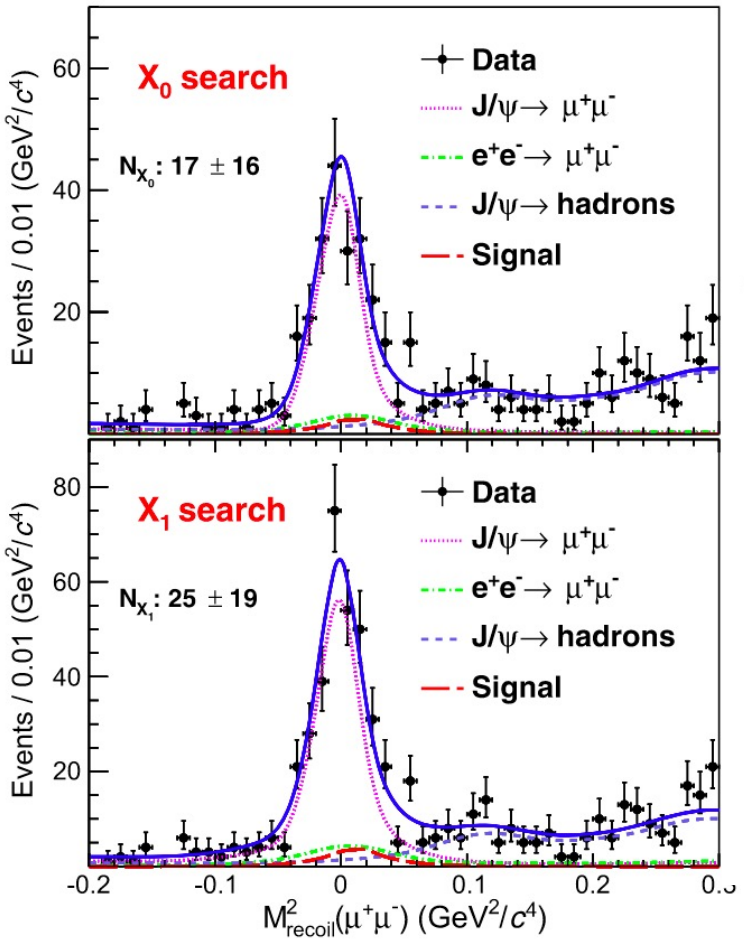


PLB 839 (2023) 137785

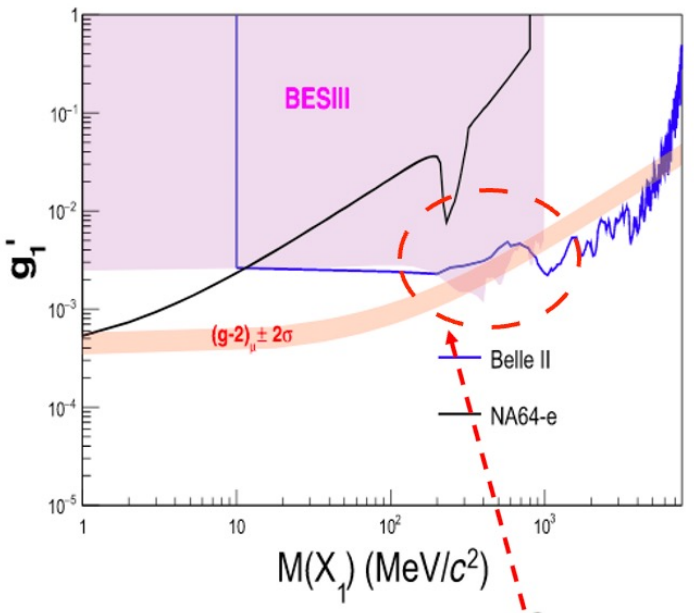
Search for $J/\psi \to \mu^+\mu^- X_{0,1}$

Phys.Rev.D 109 (2024) 3, L031102

- **Low mass region**, with $M(X_{0,1}) = 120\ \mathrm{MeV}/c^2$



"invisible" $L_\mu - L_\tau$ model



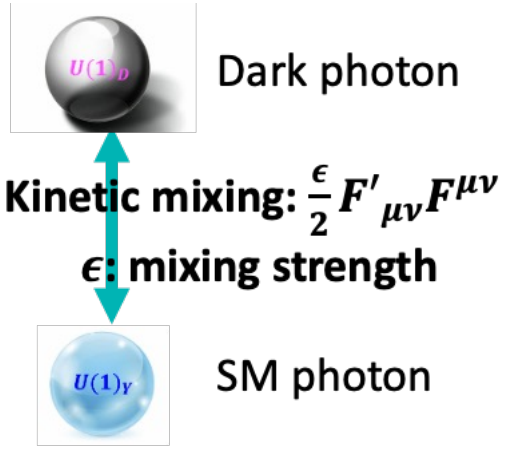
Better sensitivity in the range 200–860 MeV/c^2 is obtained

Summary

- BESIII with good performance after 16 years
  - large unique data samples in 1.84~4.95 GeV
- Wide range of searches with missing energy are performed
  - Great strength from unique datasets and techniques
  - many first searches or competitive constraints
- Operation for another 5+ years foreseen
  - BEPCII-U upgrade going on well
  - Plenty of opportunities ahead
  - Synergy with theorists, BELLE-II and other experiments

Appendix: Massless Dark photon

- A minimal extension to SM, $U(1)_D$, causing the associated spin-one boson, the dark photon



- Massive γ', if the symmetry is spontaneously broken
- Massless γ', if the symmetry is unbroken

👉 Only couple to SM particles through operators of higher dimension

PRL 94, 151802 (2005)

Dimension-six operator

$$\mathcal{L}_{NP} = \frac{1}{\Lambda_{NP}^2}(C_{jk}^{U}\bar{q}_j\sigma^{\mu\nu}u_k\tilde{H} + C_{jk}^{D}\bar{q}_j\sigma^{\mu\nu}d_kH + C_{jk}^{L}\bar{l}_j\sigma^{\mu\nu}e_kH + h.c.)\bar{F}_{\mu\nu}$$

Up type quarks coupling	Down type quarks coupling	Charged leptons coupling	Massless dark photon