第十七届TeV工作组学术研讨会

2023

会议总结

廖益 2023-12-17

Material partly prepared by 周也铃

第十七届TeV物理工作组学术研讨会合影
2023.12.15–19

19 plenary talks

08:00

Opening speech 【孙立涛副校长】
锦江南京饭店 08:15 - 08:30

ATLAS new physics search highlights *Zhijun Liang*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 08:30 - 09:05

09:00

CMS new physics search highlights *Congqiao Li*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

New physics searches in the LHCb experiment
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

10:00

photo & coffee break
锦江南京饭店

Super Tau Charm Facility: Physics and Challenges
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

11:00

Neutrino phenomenology: recent progress
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

Probing dark matter particles with astronomical observations
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

12:00

暗物质直接探测实验进展 *Fei Gao*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 08:30 - 08:55

09:00

Dark SHINE – a Dark Photon Search Experiment initiative at SHINE facility *Shu Li*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 08:55 - 09:20

The status of light dark matter *Jia Liu*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 09:20 - 09:45

SRF Cavity Searches for Dark Photon Dark Matter: First Scan Results *Jing Shu*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 09:45 - 10:10

10:00

coffee break
锦江南京饭店 10:10 - 10:30

Axion Haloscopes Meet the E Field
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

11:00

Long-lived dark photons at the LHC
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

Quark masses and low energy constants in the continuum from Lattice
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

The Circular Electron Positron Collider - Physics, Status and the Perspe
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店

12:00

14:00

Neutrinoless double beta decay and related searches in PandaX *Ke Han*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 14:00 - 14:30

宇宙相变引力波理论和实验进展 *Huaike Guo*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 14:30 - 15:00

15:00

Cosmological implications of large galaxy surveys *Gongbo Zhao*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 15:00 - 15:30

Non-Gaussianity in the primordial black hole formation *Shi Pi*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 15:30 - 16:00

16:00

coffee break
锦江南京饭店 16:00 - 16:30

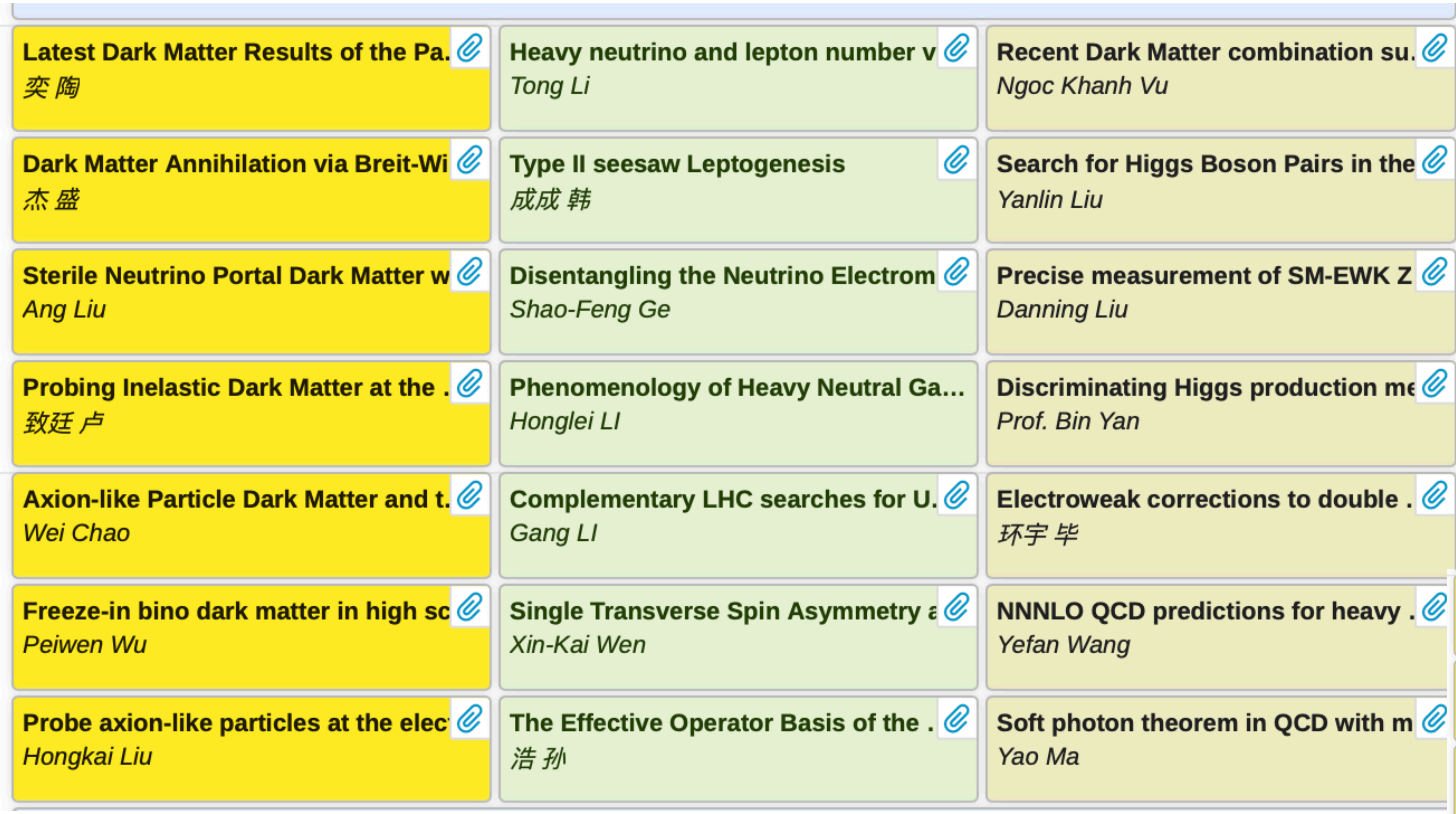
Quantum Computing for High Energy Physics *Yingying Li*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 16:30 - 17:00

17:00

Progress on perturbative QCD at the LHC *HuaXing Zhu*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 17:00 - 17:30

Workshop summary *Yi Liao*
钟山厅 腾讯会议 ID: 682 232 1942, 锦江南京饭店 17:30 - 18:00

48 parallel talks



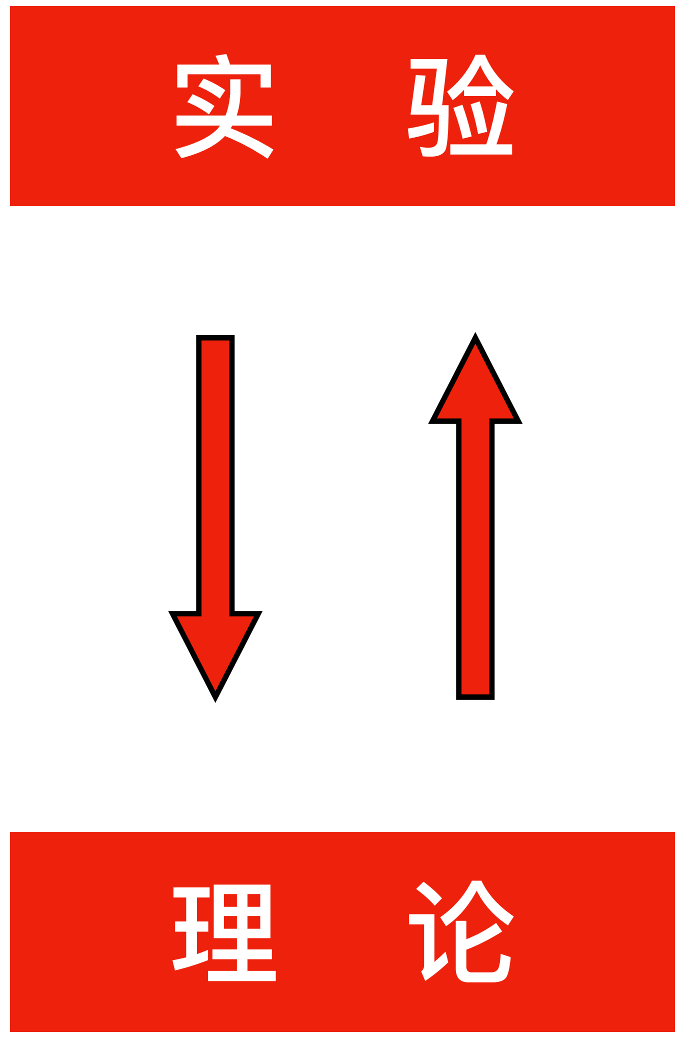
Latest Dark Matter Results of the Pa. *奕 陶*	**Heavy neutrino and lepton number v** *Tong Li*	**Recent Dark Matter combination su.** *Ngoc Khanh Vu*
Dark Matter Annihilation via Breit-Wi *杰 盛*	**Type II seesaw Leptogenesis** *成成 韩*	**Search for Higgs Boson Pairs in the** *Yanlin Liu*
Sterile Neutrino Portal Dark Matter w *Ang Liu*	**Disentangling the Neutrino Electrom** *Shao-Feng Ge*	**Precise measurement of SM-EWK Z** *Danning Liu*
Probing Inelastic Dark Matter at the . *致廷 卢*	**Phenomenology of Heavy Neutral Ga…** *Honglei LI*	**Discriminating Higgs production me** *Prof. Bin Yan*
Axion-like Particle Dark Matter and t. *Wei Chao*	**Complementary LHC searches for U.** *Gang LI*	**Electroweak corrections to double .** *环宇 毕*
Freeze-in bino dark matter in high sc *Peiwen Wu*	**Single Transverse Spin Asymmetry a** *Xin-Kai Wen*	**NNNLO QCD predictions for heavy .** *Yefan Wang*
Probe axion-like particles at the elec *Hongkai Liu*	**The Effective Operator Basis of the .** *浩 孙*	**Soft photon theorem in QCD with m** *Yao Ma*

Detecting Quadratically Coupled Ultr *Mr Yuanlin Gong*	**Probing the four-fermion operators v** *Hao-Lin Wang*	**Search for T-odd mechanisms beyo** *Boxing Gou*
Non-perturbative Effect on DM Electr… *锦汉 梁*	**On-Shell Construction of Effective Fi** *Ming-Lei Xiao*	**Optimizing Fictitious States for Bell** *Kun Cheng*
Feeble Sterile Neutrino Portal Dark M *昂 刘*	**Probing levitodynamics with multi-st** *Wenyu Wang*	**Long-lived Searches of Vector-like L** *Yan Luo*
Z Portal to the Dark Sector Through . *Mr Xuhui Jiang*	**利用LHAASO伽马暴数据限制洛伦兹对.** *玉明 杨*	**Probing quirk signal at the LHC far .** *Jinmian Li*
Broadband Search Strategies throug *Xiaolin Ma*	**Dynamical realization of the small fie** *Hexu Zhang*	**Search for nearly-degenerate higgsi** *航 周*
Dark matter candidates from U(1) hid… *Wan-Zhe Feng*	**Nonanalyticity and On-Shell Factoriz** *哲涵 秦*	**CPV double-aligned 2HDMs at the L** *MICHIHISA TAKE…*
Dark matter from hot big bang black *Ningqiang Song*	**Bootstrapping One-loop Inflation Co** *Hongyu Zhang*	**Global Symmetries and Effective Po** *Dr Changlong Xu*
Neutrino CP Measurement in the Pre *Chui-Fan Kong*	**Gravitational waves produced by do…** *晨 杨*	**Testing Bell inequalities in W boson** *Mr Qi Bi*
用机器学习方法探测对撞机中的重狄拉. *Jie FENG*	**First-order phase transition during in…** *铂烨 苏*	**Alternative Froggatt-Nielsen like me…** *Fei Wang*

TeV… more than TeV …

非常丰富的报告主题

- Colliders
  ATLAS, CMS, STCF, CEPC, LHCb
- Dark matter
  WMIP, light DM, ultralight DM
- Neutrino
  Nu Pheno, 0νββ
- Cosmology
  GW, Non-Gaussianity,
- Computation
  pert. & non-pert. QCD, quantum computing



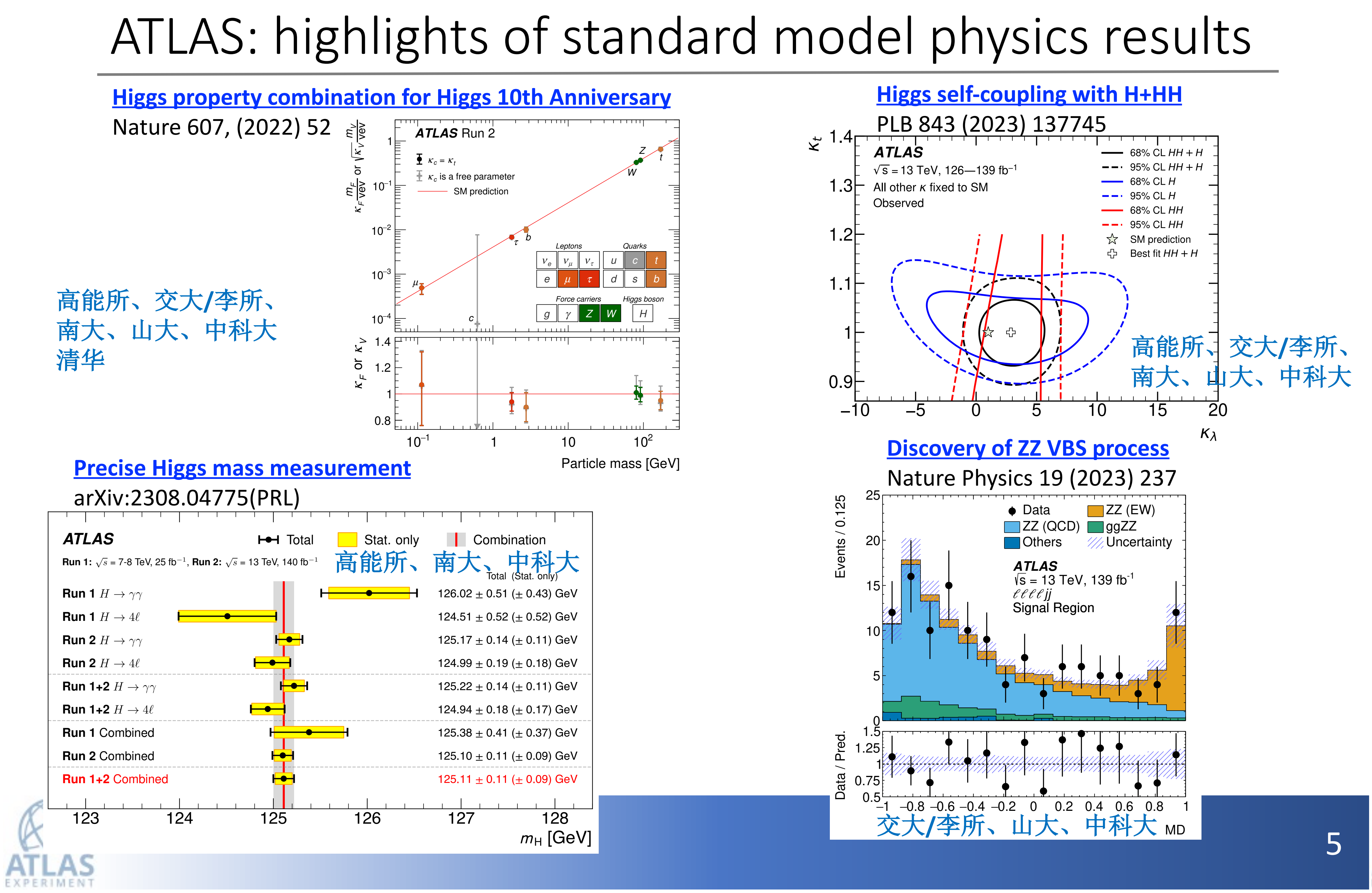
实　验

理　论

ATLAS Highlights

梁志均的报告

- Traditional SM searches
- Observation of entanglement in t-tbar pairs



ATLAS: highlights of standard model physics results

Higgs property combination for Higgs 10th Anniversary

Nature 607, (2022) 52

高能所、交大/李所、南大、山大、中科大清华

Higgs self-coupling with H+HH

PLB 843 (2023) 137745

高能所、交大/李所、南大、山大、中科大

Precise Higgs mass measurement

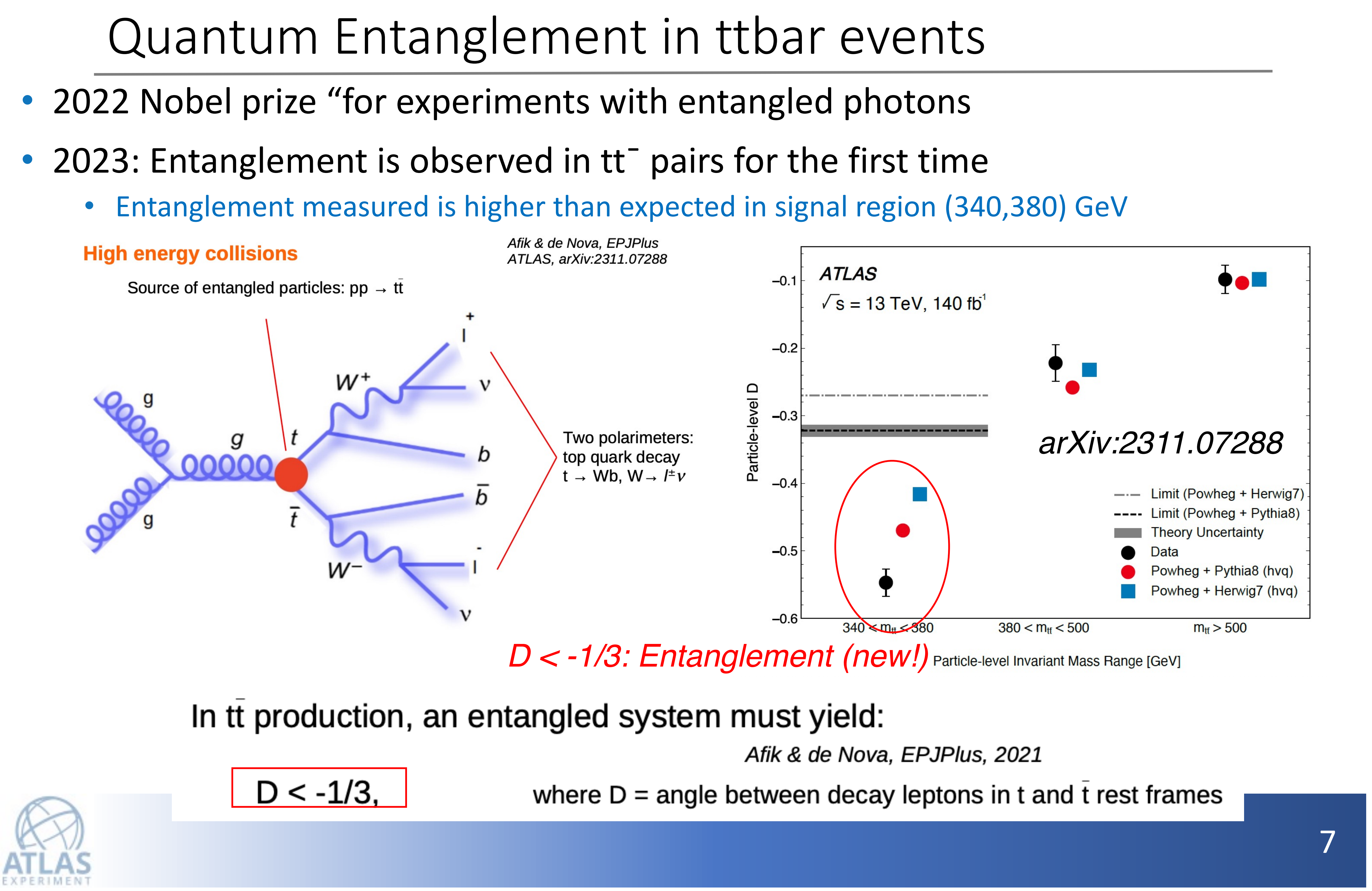
arXiv:2308.04775(PRL)

高能所、南大、中科大

Discovery of ZZ VBS process

Nature Physics 19 (2023) 237

交大/李所、山大、中科大



Quantum Entanglement in ttbar events

- 2022 Nobel prize “for experiments with entangled photons
- 2023: Entanglement is observed in tt¯ pairs for the first time
  - Entanglement measured is higher than expected in signal region (340,380) GeV

Afik & de Nova, EPJPlus
ATLAS, arXiv:2311.07288

arXiv:2311.07288

D < -1/3: Entanglement (new!)

In tt̄ production, an entangled system must yield:

Afik & de Nova, EPJPlus, 2021

D < -1/3,

where D = angle between decay leptons in t and t̄ rest frames

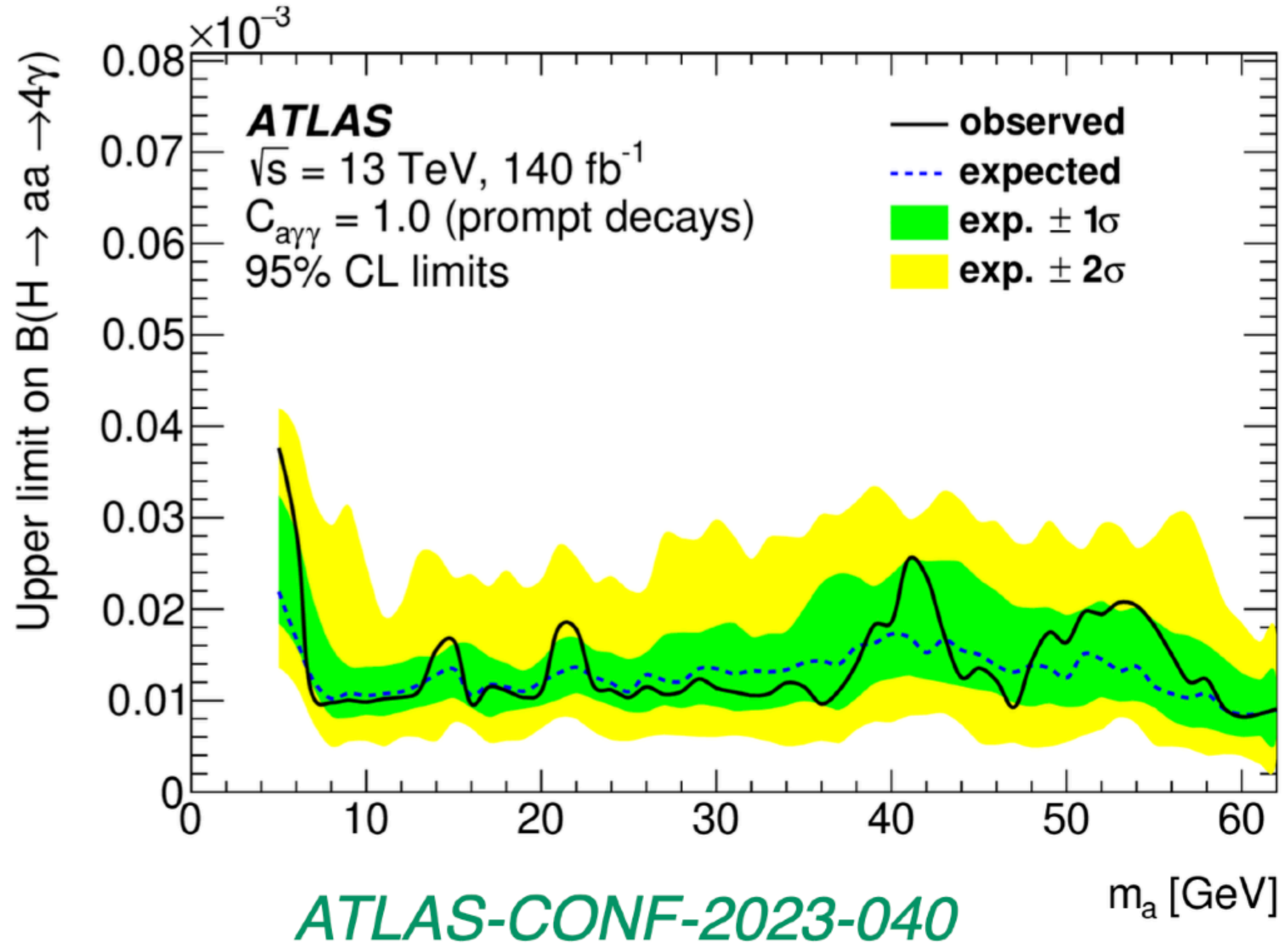
- Improvements on searches of DM, long-lived particle, SUSY, LVF, etc

CMS highlights, more on experimental innovations

李聪乔的报告

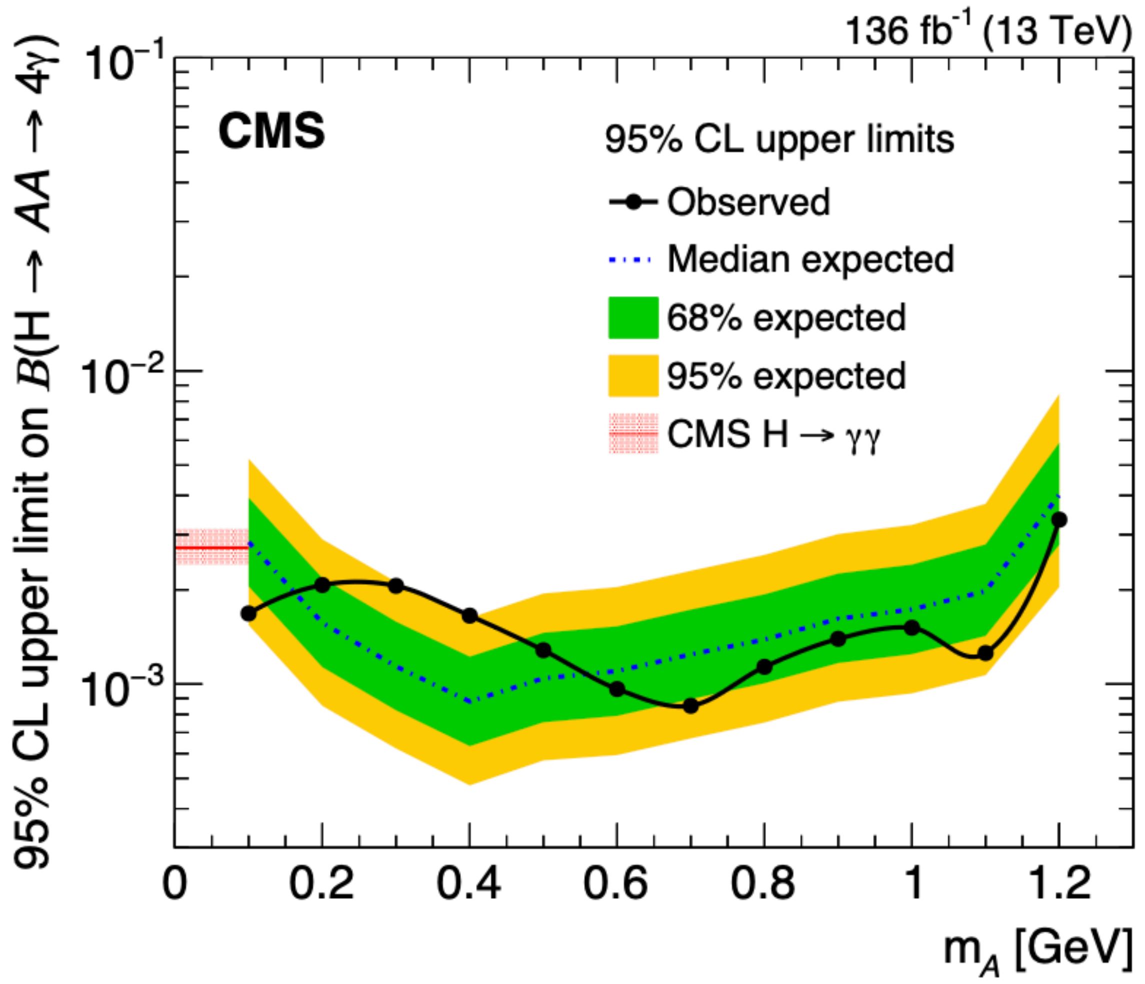
- Advanced jet neural network (ParticleNet) for low-level input

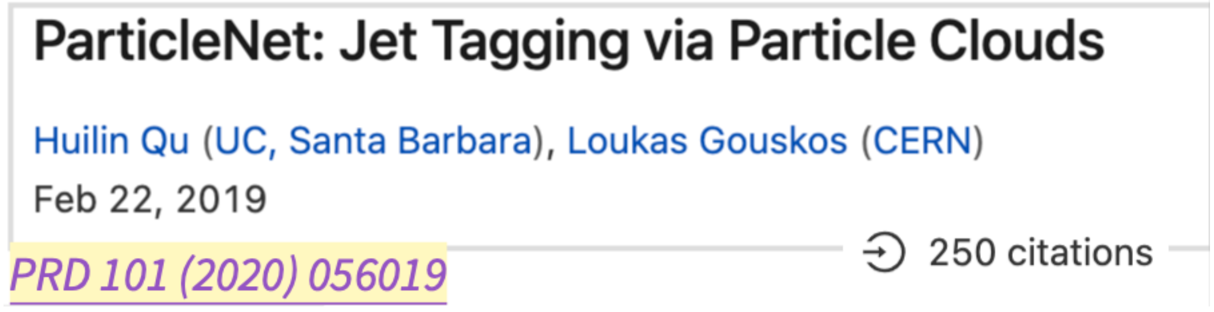
Traditional analysis in ATLAS



ATLAS-CONF-2023-040

ANN in CMS





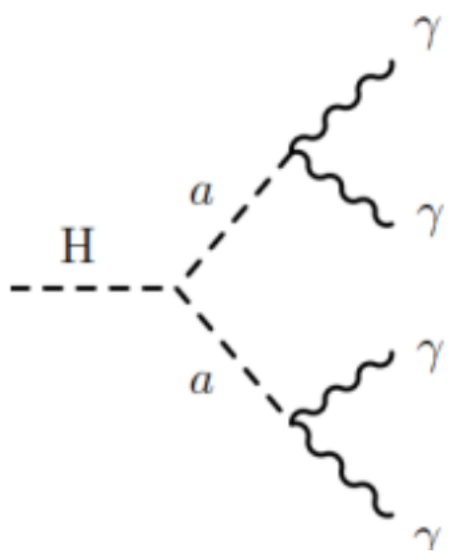
ParticleNet: Jet Tagging via Particle Clouds

Huilin Qu (UC, Santa Barbara), Loukas Gouskos (CERN)

Feb 22, 2019

250 citations

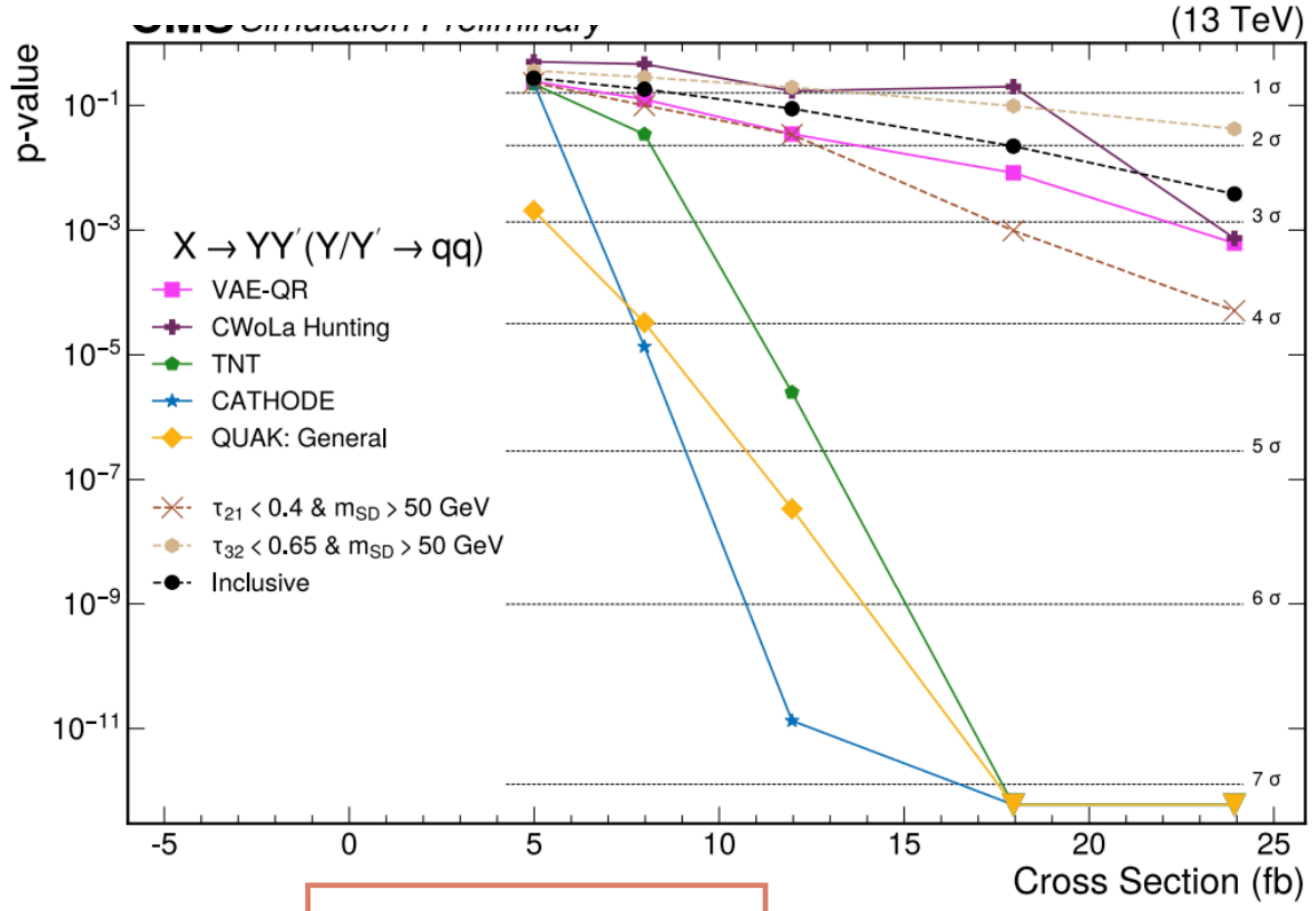
PRD 101 (2020) 056019



- Model-agnostic searches

➔ CMS systematically test all model-agnostic approaches to search for resonance

- ❖ first performed on toy data (from simulation)
- ❖ achieve comparable/better performance than conventional search using jet substructure selection (τ_{21}, τ_{32})



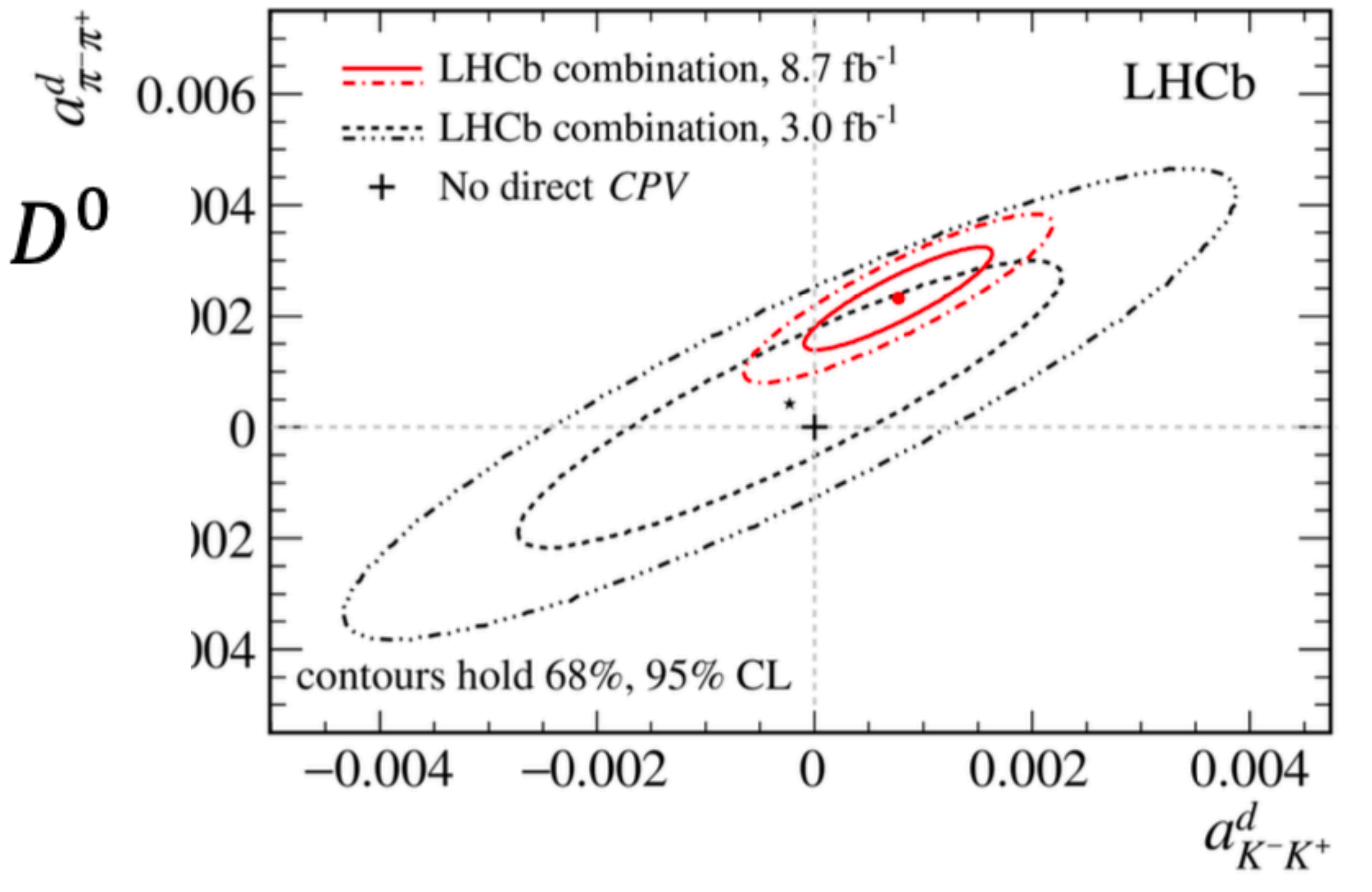
2-prong + 2-prong

New Physics at LHCb

王纪科的报告

CP 破坏的测量

- **1.4σ and 3.8σ derivation** for $D^0 \to K^- K^+$ and $D^0 \to \pi^- \pi^+$
- The **first evidence for direct *CPV*** in a specific D^0 decay

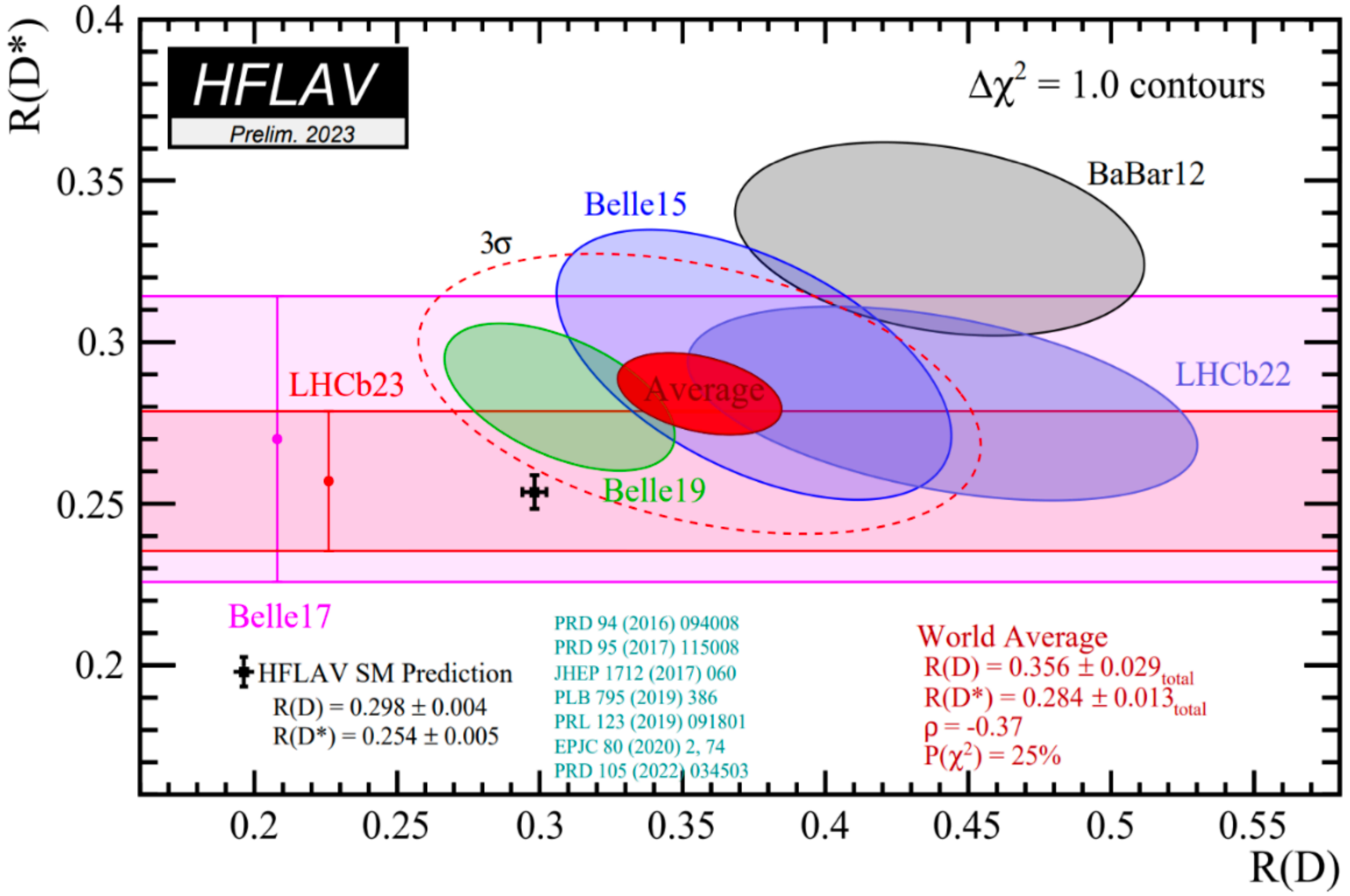


PRL 131 (2023) 091802

Lepton Universality

Deviation from SM for combined R(D) – R(D*) now moves from 3.3σ to 3.2σ

arXiv:2212.13072
arXiv:2301.03214
PRL 131 (2023) 111802



No tension for $b \to sl^+l^-$

稀有衰变（包括LFV）

$\mathcal{B}(D^{*0} \to \mu^+\mu^-) < 2.6\,(3.4) \times 10^{-8}$ at 90 (95)% CL .

$\mathcal{B}(D^0 \to \mu^+\mu^-) < 3.1\,(3.5) \times 10^{-9}$ at 90 (95)% CL .

$\mathcal{B}(B^0 \to \mu^+\mu^-) < 2.6 \times 10^{-10}$

$\mathcal{B}(B^0_s \to \mu^+\mu^-\gamma) < 2.0 \times 10^{-9}$

$$
\begin{aligned}
&\mathcal{B}\left(B^0_s \to \mu^+\mu^-\mu^+\mu^-\right) && < 8.6 \times 10^{-10}, \\
&\mathcal{B}\left(B^0 \to \mu^+\mu^-\mu^+\mu^-\right) && < 1.8 \times 10^{-10}, \\
&\mathcal{B}\left(B^0_s \to a\left(\mu^+\mu^-\right) a\left(\mu^+\mu^-\right)\right) && < 5.8 \times 10^{-10}, \\
&\mathcal{B}\left(B^0 \to a\left(\mu^+\mu^-\right) a\left(\mu^+\mu^-\right)\right) && < 2.3 \times 10^{-10}, \\
&\mathcal{B}\left(B^0_s \to J/\psi\left(\mu^+\mu^-\right) \mu^+\mu^-\right) && < 2.6 \times 10^{-9}, \\
&\mathcal{B}\left(B^0 \to J/\psi\left(\mu^+\mu^-\right) \mu^+\mu^-\right) && < 1.0 \times 10^{-9}.
\end{aligned}
$$

$$
\begin{aligned}
&\mathcal{B}(K^0_{\mathrm{S}} \to \mu^+\mu^-\mu^+\mu^-) < 5.1 \times 10^{-12}, \\
&\mathcal{B}(K^0_{\mathrm{L}} \to \mu^+\mu^-\mu^+\mu^-) < 2.3 \times 10^{-9},
\end{aligned}
$$

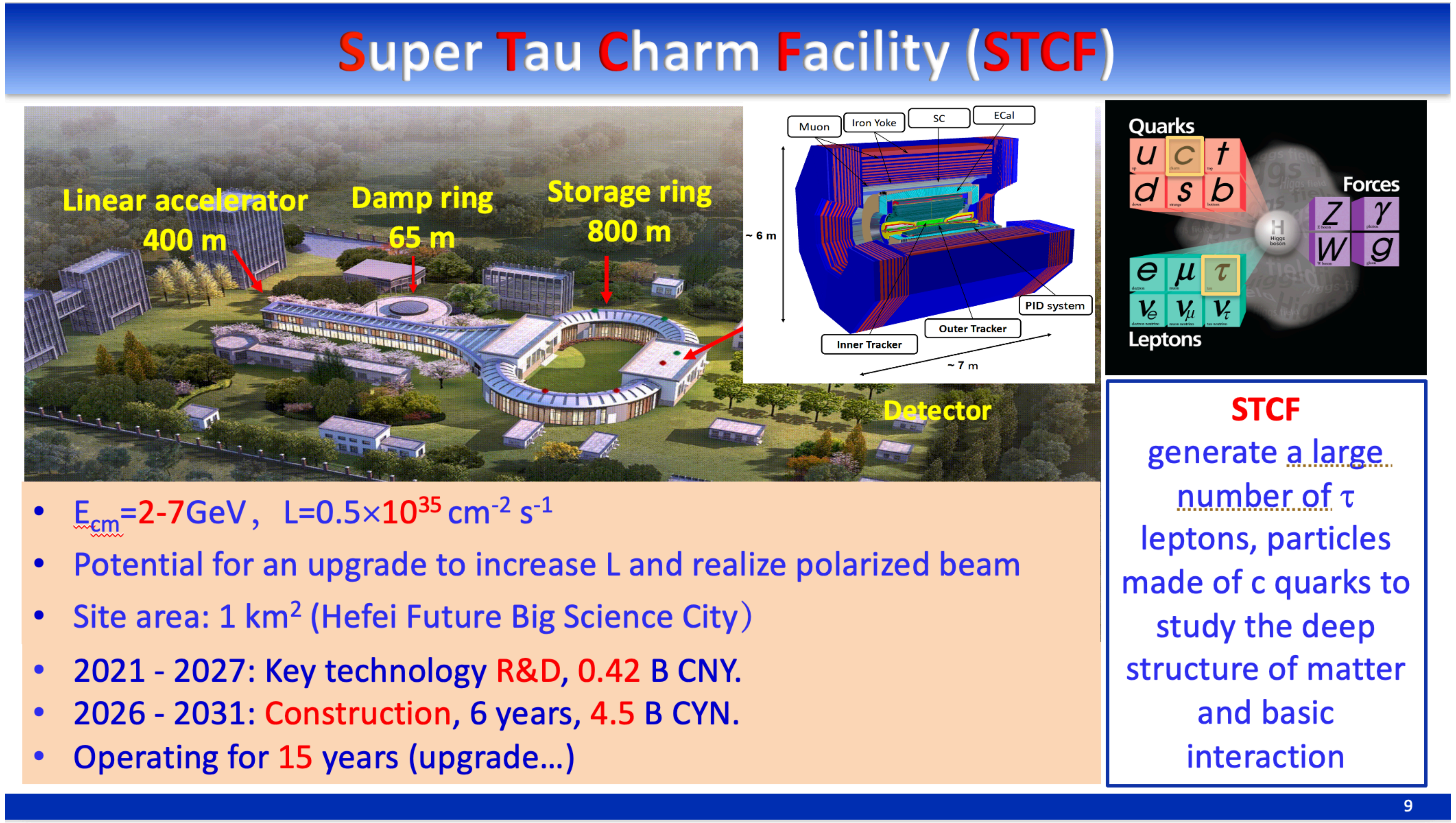
$B^0 \to p\mu^-$	$1.9\ (2.4) \times 10^{-9}$	$2.6\ (3.1) \times 10^{-9}$
$B^0_s \to p\mu^-$	$7.0\ (8.6) \times 10^{-9}$	$12.1\ (14.0) \times 10^{-9}$

$$
\begin{aligned}
&\mathcal{B}(B^0 \to K^{*0}\mu^+e^-) < 5.7 \times 10^{-9}(6.9 \times 10^{-9}), \\
&\mathcal{B}(B^0 \to K^{*0}\mu^-e^+) < 6.8 \times 10^{-9}(7.9 \times 10^{-9}), \\
&\mathcal{B}(B^0 \to K^{*0}\mu^\pm e^\mp) < 10.1 \times 10^{-9}(11.7 \times 10^{-9}), \\
&\mathcal{B}(B^0_s \to \phi\mu^\pm e^\mp) < 16.0 \times 10^{-9}(19.8 \times 10^{-9})
\end{aligned}
$$

$\mathrm{BR}(B^0 \to K^{*0}\mu^-\tau^+) < 1.0(1.2) \times 10^{-5}$,

$\mathrm{BR}(B^0 \to K^{*0}\mu^+\tau^-) < 8.2(9.8) \times 10^{-6}$

Super Tau-Charm Facility (STCF) Physics and Challenges 赵政国的报告

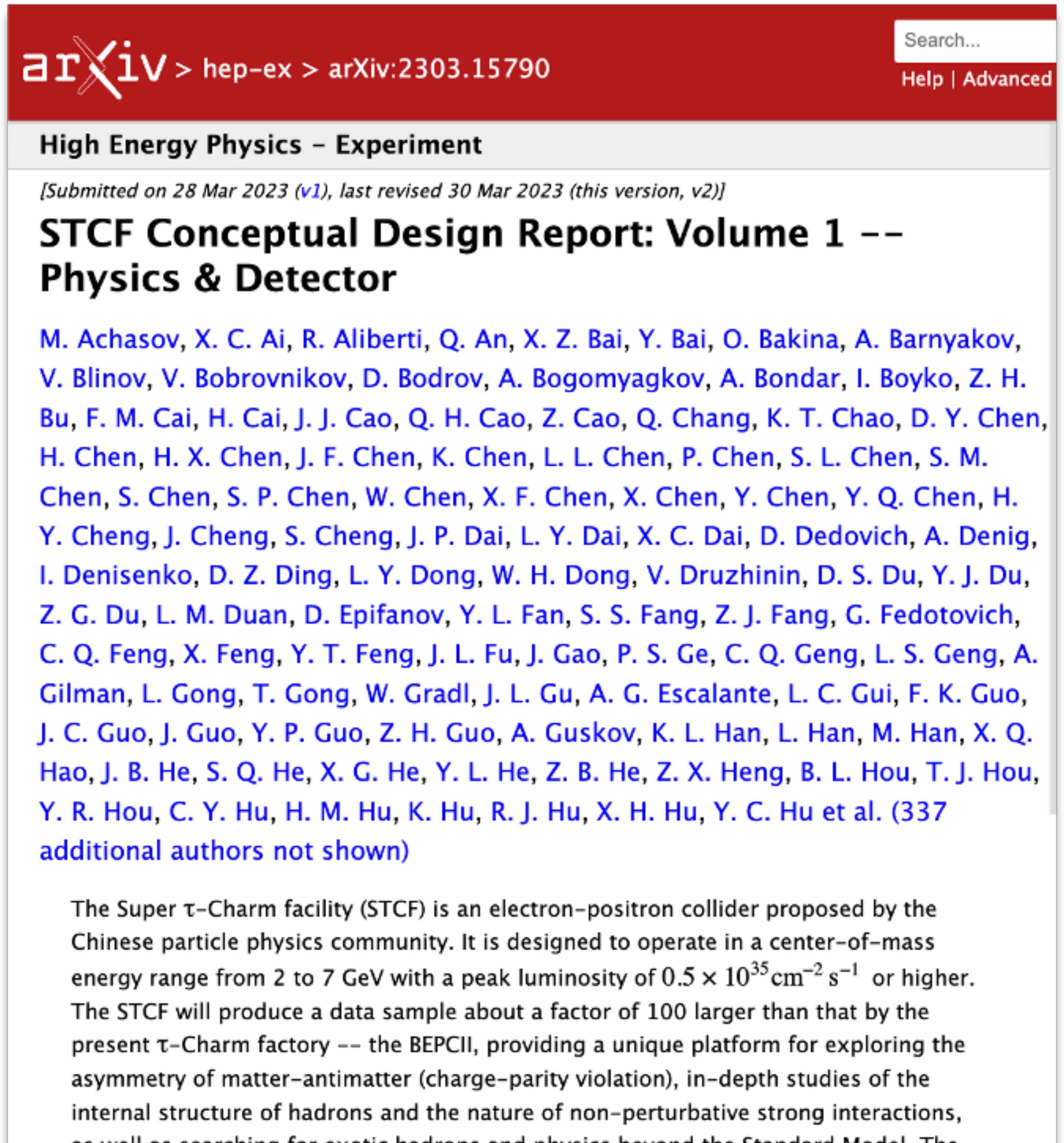


Super Tau Charm Facility (STCF)

- E_{cm}=2-7GeV， L=0.5×10^{35} cm^{-2} s^{-1}
- Potential for an upgrade to increase L and realize polarized beam
- Site area: 1 km^2 (Hefei Future Big Science City）
- 2021 - 2027: Key technology R&D, 0.42 B CNY.
- 2026 - 2031: Construction, 6 years, 4.5 B CYN.
- Operating for 15 years (upgrade…)

STCF

generate a large number of τ leptons, particles made of c quarks to study the deep structure of matter and basic interaction



arXiv > hep-ex > arXiv:2303.15790

Search...

Help | Advanced

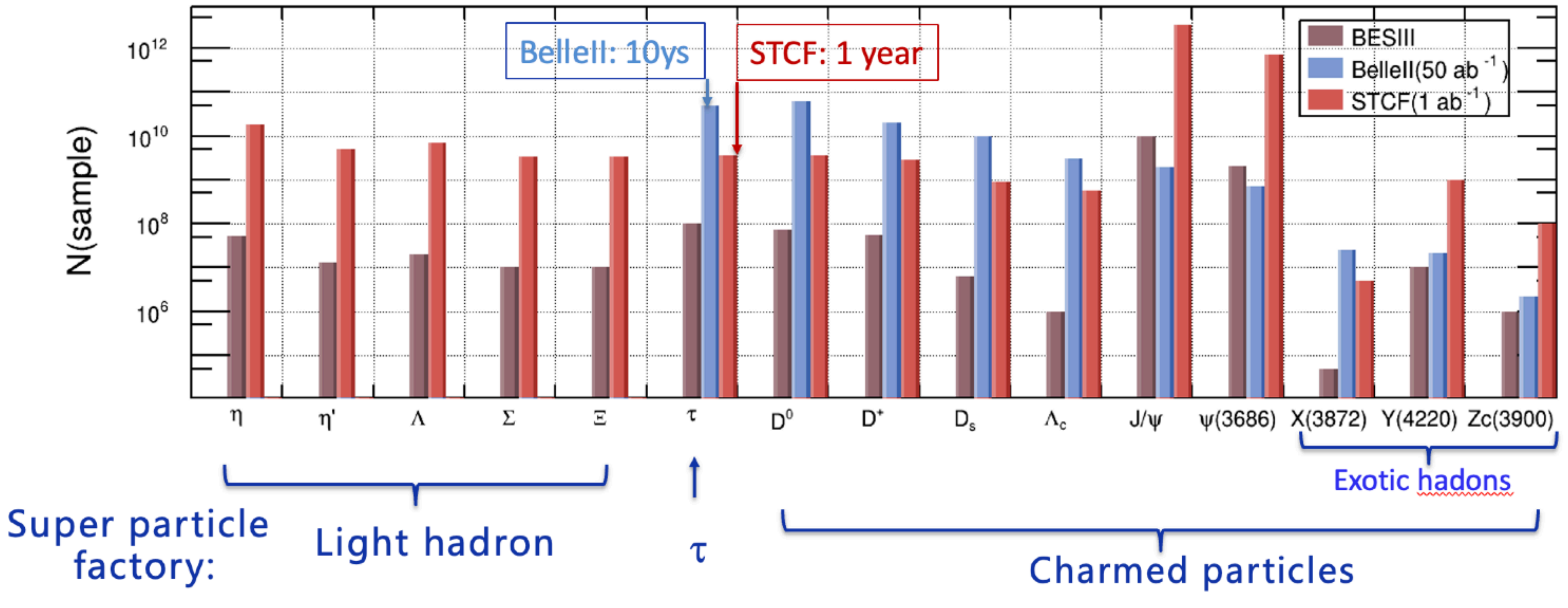
High Energy Physics – Experiment

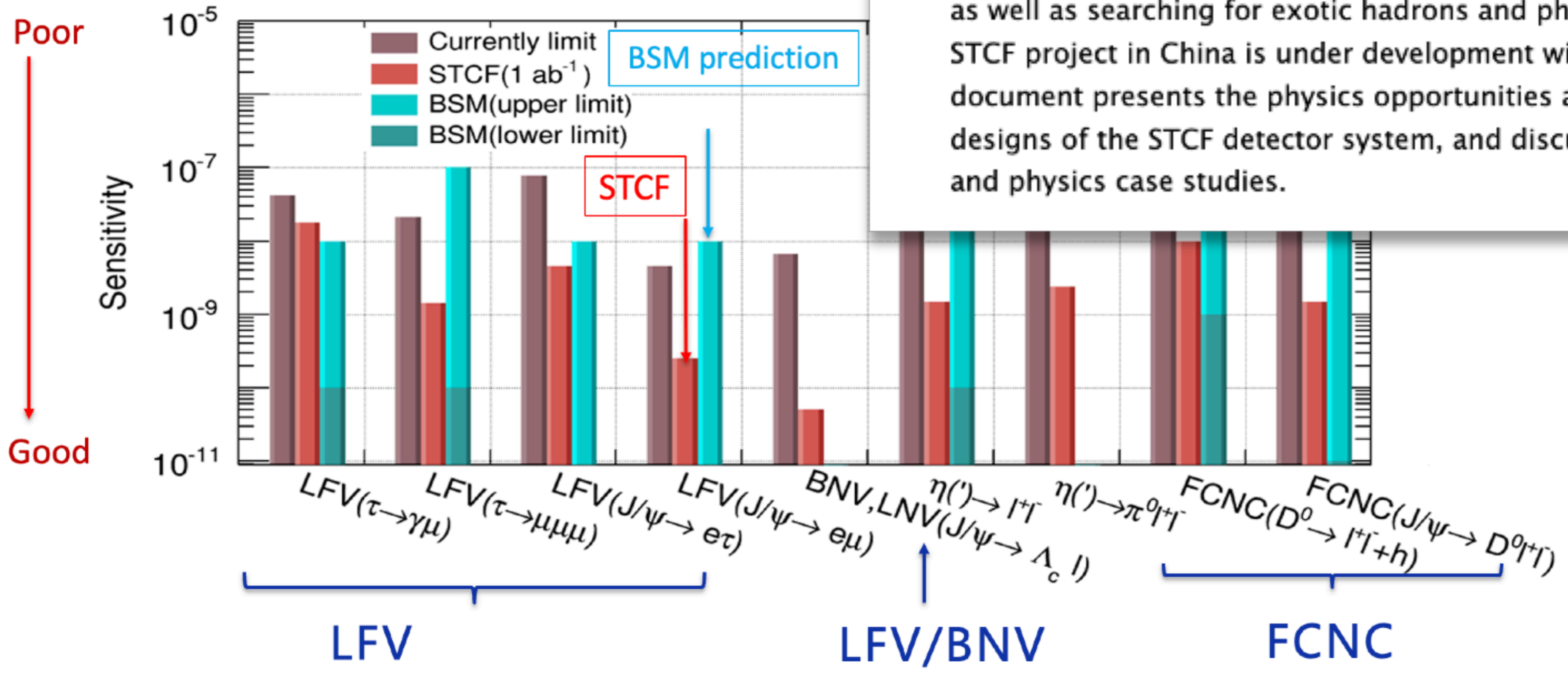
[Submitted on 28 Mar 2023 (v1), last revised 30 Mar 2023 (this version, v2)]

STCF Conceptual Design Report: Volume 1 -- Physics & Detector

M. Achasov, X. C. Ai, R. Aliberti, Q. An, X. Z. Bai, Y. Bai, O. Bakina, A. Barnyakov, V. Blinov, V. Bobrovnikov, D. Bodrov, A. Bogomyagkov, A. Bondar, I. Boyko, Z. H. Bu, F. M. Cai, H. Cai, J. J. Cao, Q. H. Cao, Z. Cao, Q. Chang, K. T. Chao, D. Y. Chen, H. Chen, H. X. Chen, J. F. Chen, K. Chen, L. L. Chen, P. Chen, S. L. Chen, S. M. Chen, S. Chen, S. P. Chen, W. Chen, X. F. Chen, X. Chen, Y. Chen, Y. Q. Chen, H. Y. Cheng, J. Cheng, S. Cheng, J. P. Dai, L. Y. Dai, X. C. Dai, D. Dedovich, A. Denig, I. Denisenko, D. Z. Ding, L. Y. Dong, W. H. Dong, V. Druzhinin, D. S. Du, Y. J. Du, Z. G. Du, L. M. Duan, D. Epifanov, Y. L. Fan, S. S. Fang, Z. J. Fang, G. Fedotovich, C. Q. Feng, X. Feng, Y. T. Feng, J. L. Fu, J. Gao, P. S. Ge, C. Q. Geng, L. S. Geng, A. Gilman, L. Gong, T. Gong, W. Gradl, J. L. Gu, A. G. Escalante, L. C. Gui, F. K. Guo, J. C. Guo, J. Guo, Y. P. Guo, Z. H. Guo, A. Guskov, K. L. Han, L. Han, M. Han, X. Q. Hao, J. B. He, S. Q. He, X. G. He, Y. L. He, Z. B. He, Z. X. Heng, B. L. Hou, T. J. Hou, Y. R. Hou, C. Y. Hu, H. M. Hu, K. Hu, R. J. Hu, X. H. Hu, Y. C. Hu et al. (337 additional authors not shown)

The Super τ-Charm facility (STCF) is an electron-positron collider proposed by the Chinese particle physics community. It is designed to operate in a center-of-mass energy range from 2 to 7 GeV with a peak luminosity of $0.5\times10^{35}\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ or higher. The STCF will produce a data sample about a factor of 100 larger than that by the present τ-Charm factory -- the BEPCII, providing a unique platform for exploring the asymmetry of matter-antimatter (charge-parity violation), in-depth studies of the internal structure of hadrons and the nature of non-perturbative strong interactions, as well as searching for exotic hadrons and physics beyond the Standard Model. The STCF project in China is under development with an extensive R\&D program. This document presents the physics opportunities at the STCF, describes conceptual designs of the STCF detector system, and discusses future plans for detector R\&D and physics case studies.





Recent Progress on Neutrino Phenos

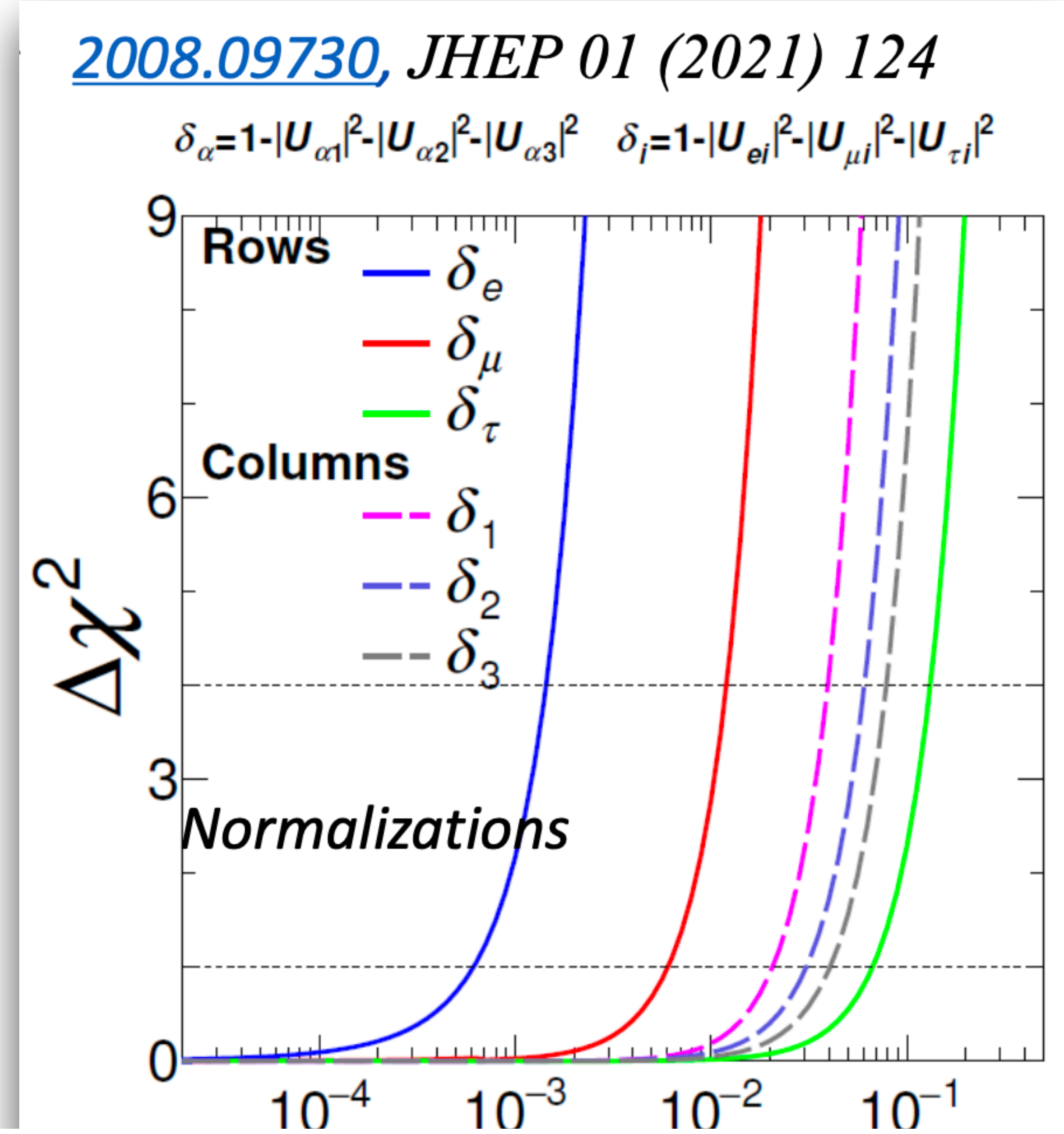
唐健的报告

Lots of neutrino experiments to get a new horizon

More are coming…

2023/12/15 Jian Tang 10

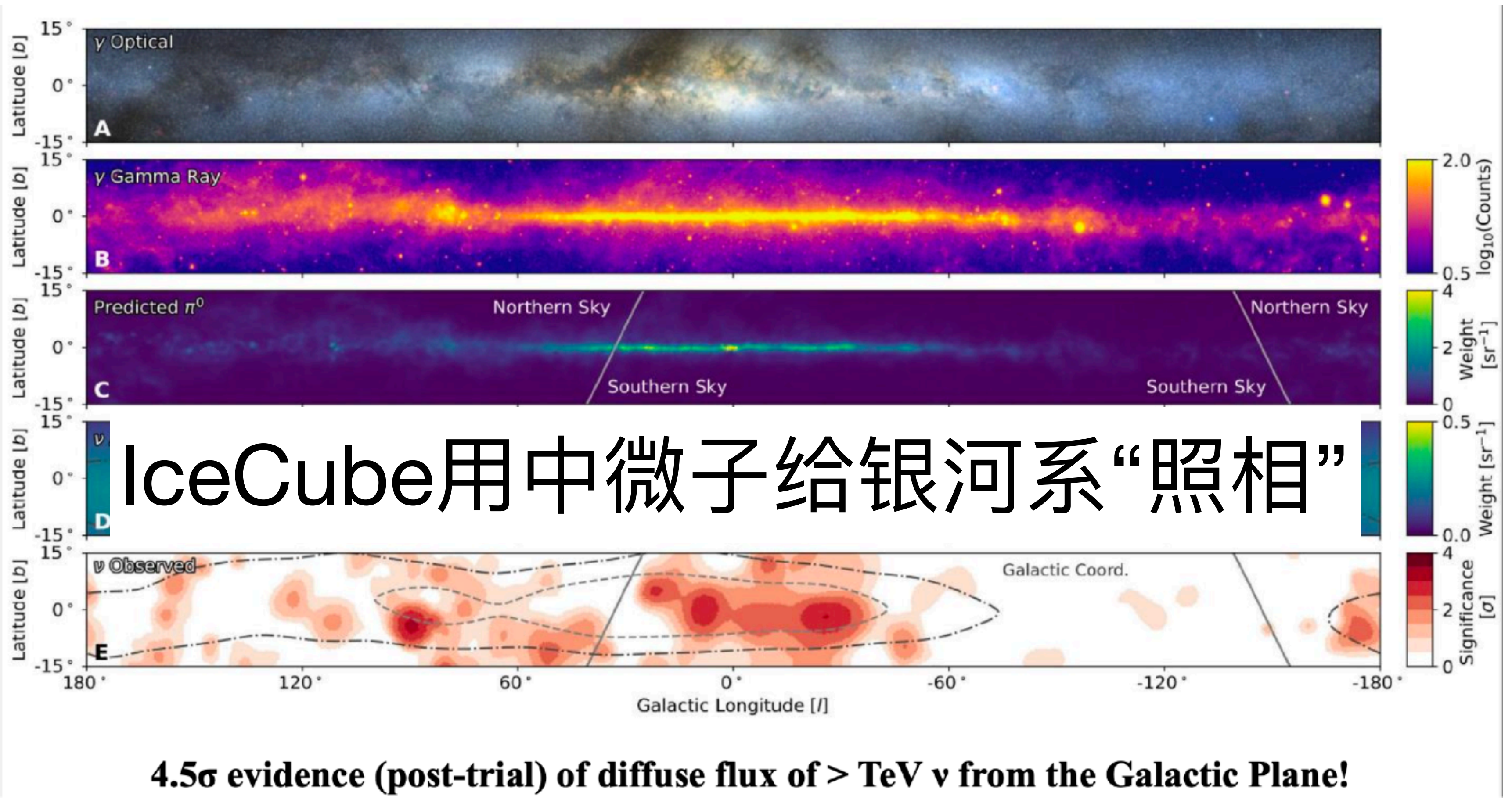
实验 → 唯象



2008.09730, JHEP 01 (2021) 124

$\delta_\alpha=1-|U_{\alpha1}|^2-|U_{\alpha2}|^2-|U_{\alpha3}|^2$ $\delta_i=1-|U_{ei}|^2-|U_{\mu i}|^2-|U_{\tau i}|^2$

非幺正性、
惰性中微子、
中微子散射
……



IceCube用中微子给银河系“照相”

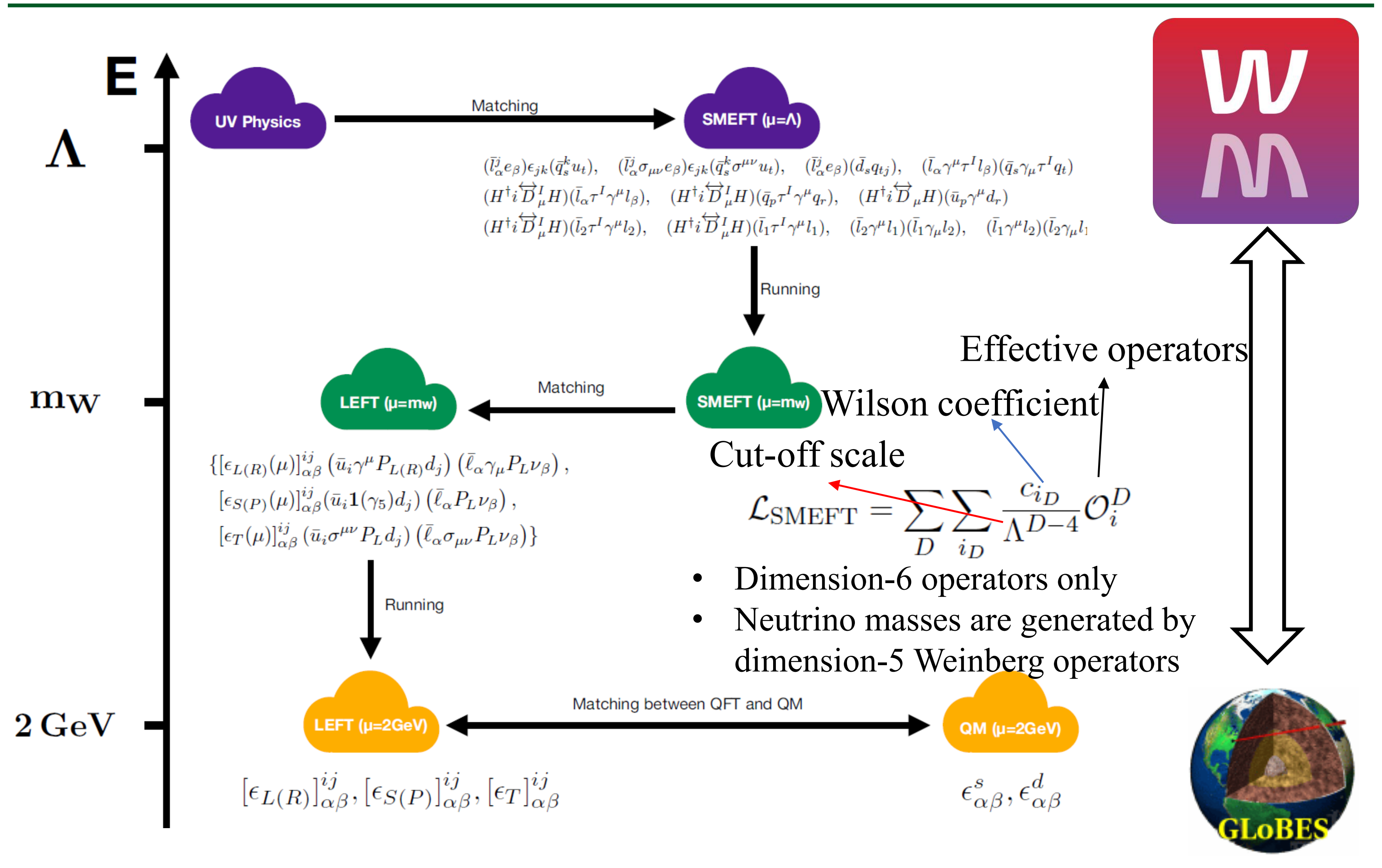
4.5σ evidence (post-trial) of diffuse flux of > TeV ν from the Galactic Plane!

中微子天文学、宇宙学

理论

EFT、
质量起源、
味道起源、
……

EFT: connecting low-energy phenomenon to high-energy scale



$(\bar{l}^j_\alpha e_\beta)\epsilon_{jk}(\bar{q}^k_s u_t)$, $(\bar{l}^j_\alpha\sigma_{\mu\nu}e_\beta)\epsilon_{jk}(\bar{q}^k_s\sigma^{\mu\nu}u_t)$, $(\bar{l}^j_\alpha e_\beta)(\bar{d}_s q_{tj})$, $(\bar{l}_\alpha\gamma^\mu\tau^I l_\beta)(\bar{q}_s\gamma_\mu\tau^I q_t)$
$(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{l}_\alpha\tau^I\gamma^\mu l_\beta)$, $(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{q}_p\tau^I\gamma^\mu q_r)$, $(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{u}_p\gamma^\mu d_r)$
$(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{l}_2\tau^I\gamma^\mu l_2)$, $(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar{l}_1\tau^I\gamma^\mu l_1)$, $(\bar{l}_2\gamma^\mu l_1)(\bar{l}_1\gamma_\mu l_2)$, $(\bar{l}_1\gamma^\mu l_2)(\bar{l}_2\gamma_\mu l_1$

$\{[\epsilon_{L(R)}(\mu)]^{ij}_{\alpha\beta}\,(\bar{u}_i\gamma^\mu P_{L(R)}d_j)\,(\bar{\ell}_\alpha\gamma_\mu P_L\nu_\beta)\,,$
$[\epsilon_{S(P)}(\mu)]^{ij}_{\alpha\beta}(\bar{u}_i\mathbf{1}(\gamma_5)d_j)\,(\bar{\ell}_\alpha P_L\nu_\beta)\,,$
$[\epsilon_T(\mu)]^{ij}_{\alpha\beta}\,(\bar{u}_i\sigma^{\mu\nu}P_L d_j)\,(\bar{\ell}_\alpha\sigma_{\mu\nu}P_L\nu_\beta)\}$

$[\epsilon_{L(R)}]^{ij}_{\alpha\beta}, [\epsilon_{S(P)}]^{ij}_{\alpha\beta}, [\epsilon_T]^{ij}_{\alpha\beta}$

$\epsilon^s_{\alpha\beta}, \epsilon^d_{\alpha\beta}$

Effective operators

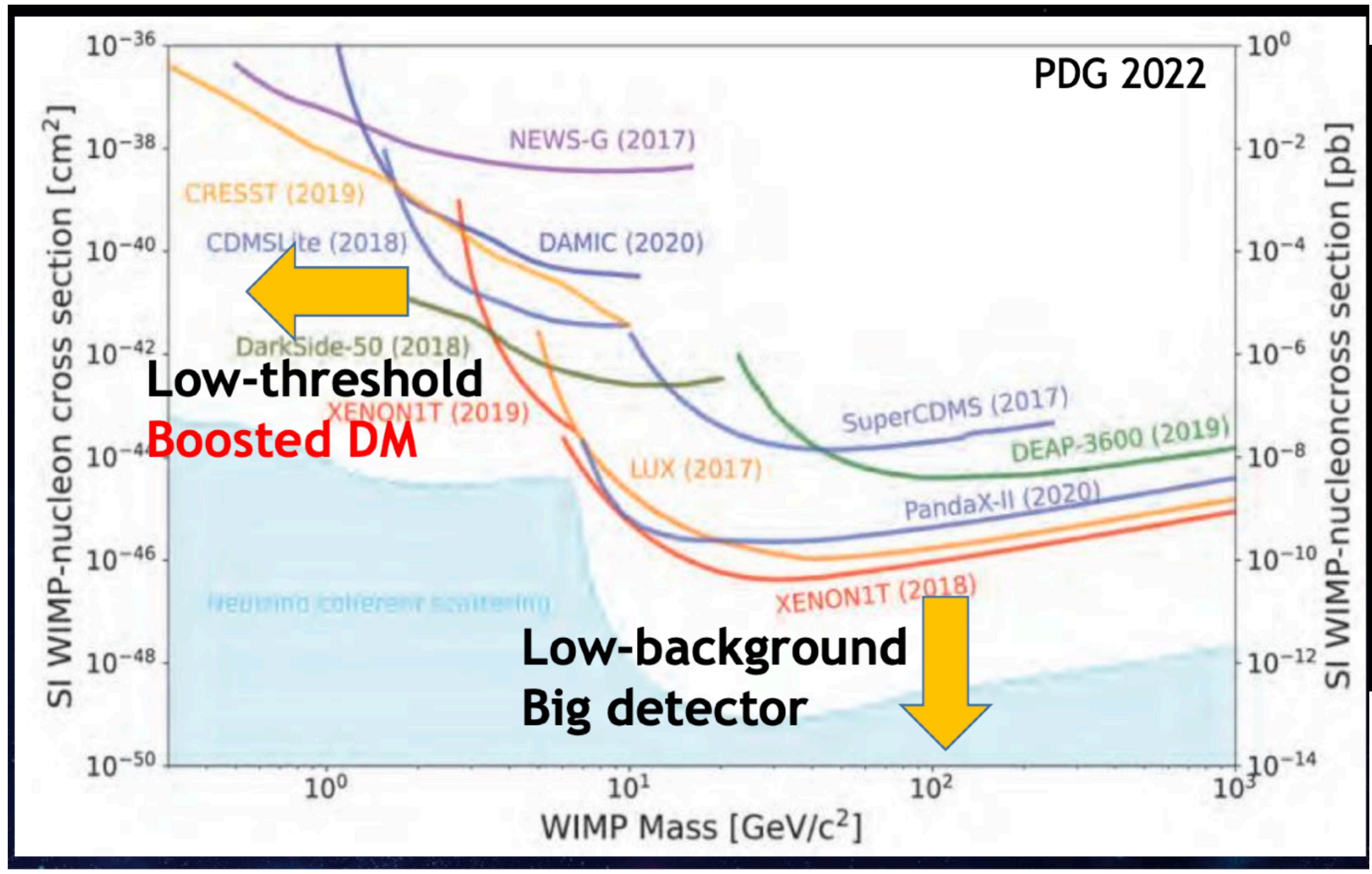
Wilson coefficient

Cut-off scale

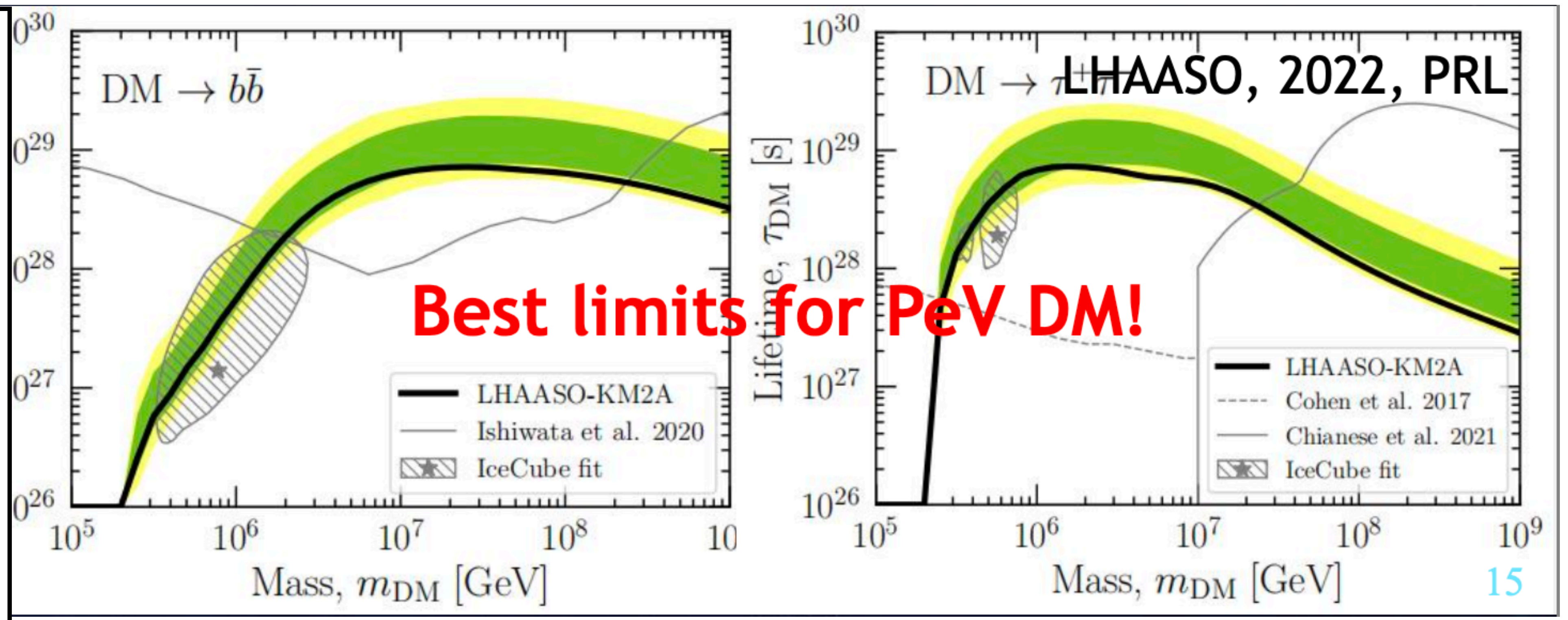
$$\mathcal{L}_{\rm SMEFT}=\sum_D\sum_{i_D}\frac{c_{i_D}}{\Lambda^{D-4}}\mathcal{O}^D_i$$

- Dimension-6 operators only
- Neutrino masses are generated by dimension-5 Weinberg operators

Probing Dark Matter Particles with Astronomical Observations 袁强的报告



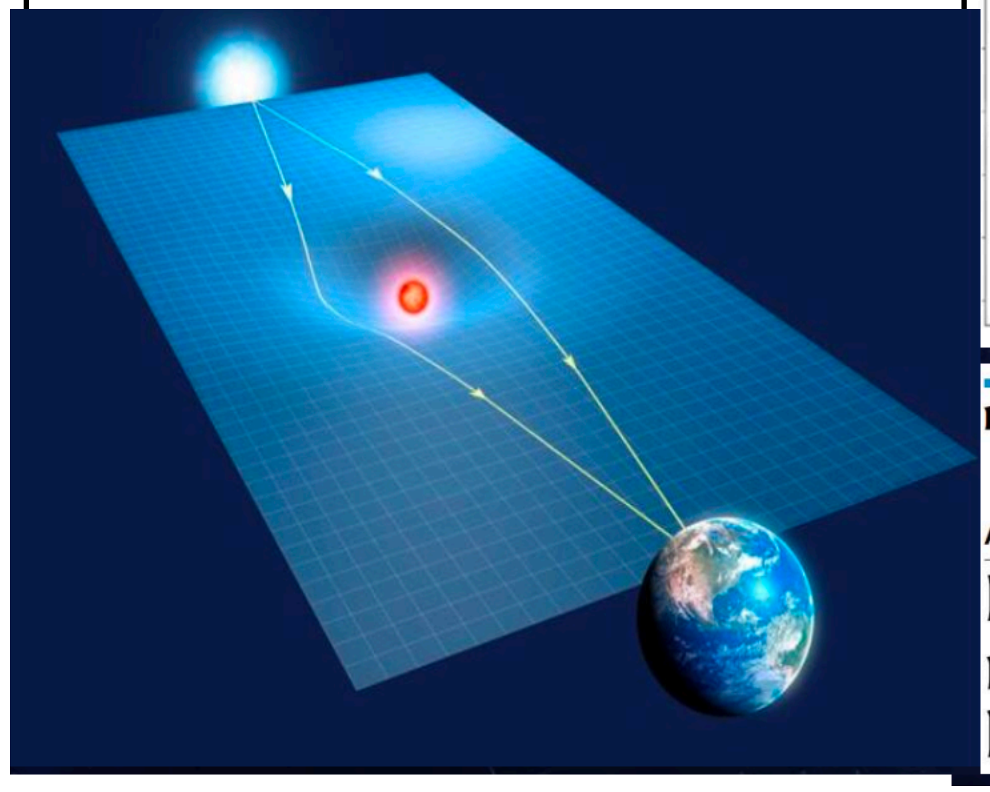
WIMP 存在很强实验限制，如何继续探索：Boosted DM, 更大体量更低本底, 或者更大质量的DM?

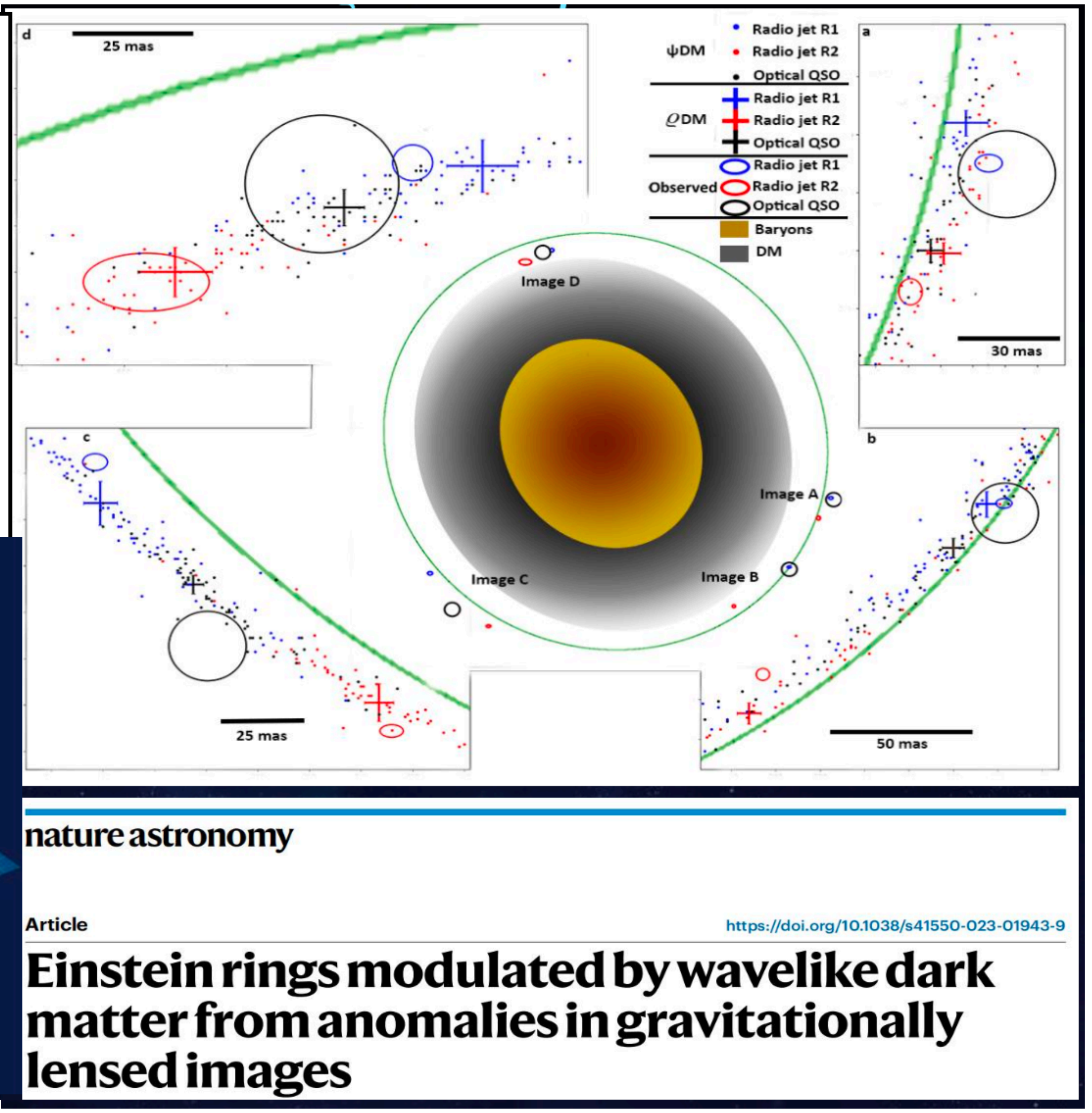


2023, Science Advances, 9, eadj2778

利用Primakoff效应、双折射效应以及引力效应，可以在不同天文环境检验波动型暗物质（比如ALP和Dark photon等）

强引力透镜似乎更支持波动型暗物质，这是真的吗？这是否为未来暗物质理论研究指明一些方向？





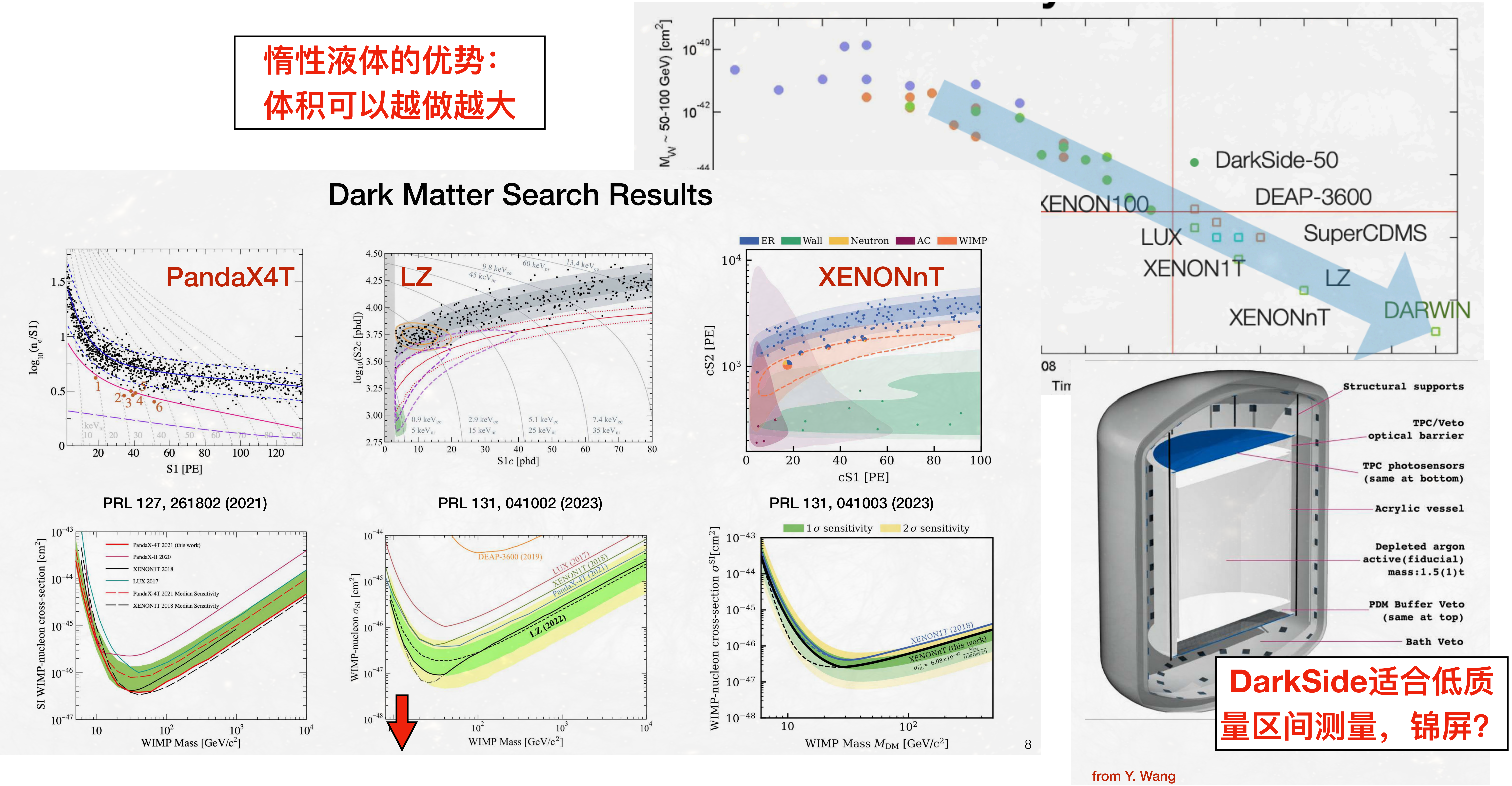
nature astronomy

Article

https://doi.org/10.1038/s41550-023-01943-9

Einstein rings modulated by wavelike dark matter from anomalies in gravitationally lensed images

惰性液体的优势：
体积可以越做越大



Dark Matter Search Results

PRL 127, 261802 (2021)

PRL 131, 041002 (2023)

PRL 131, 041003 (2023)

DarkSide适合低质量区间测量，锦屏?

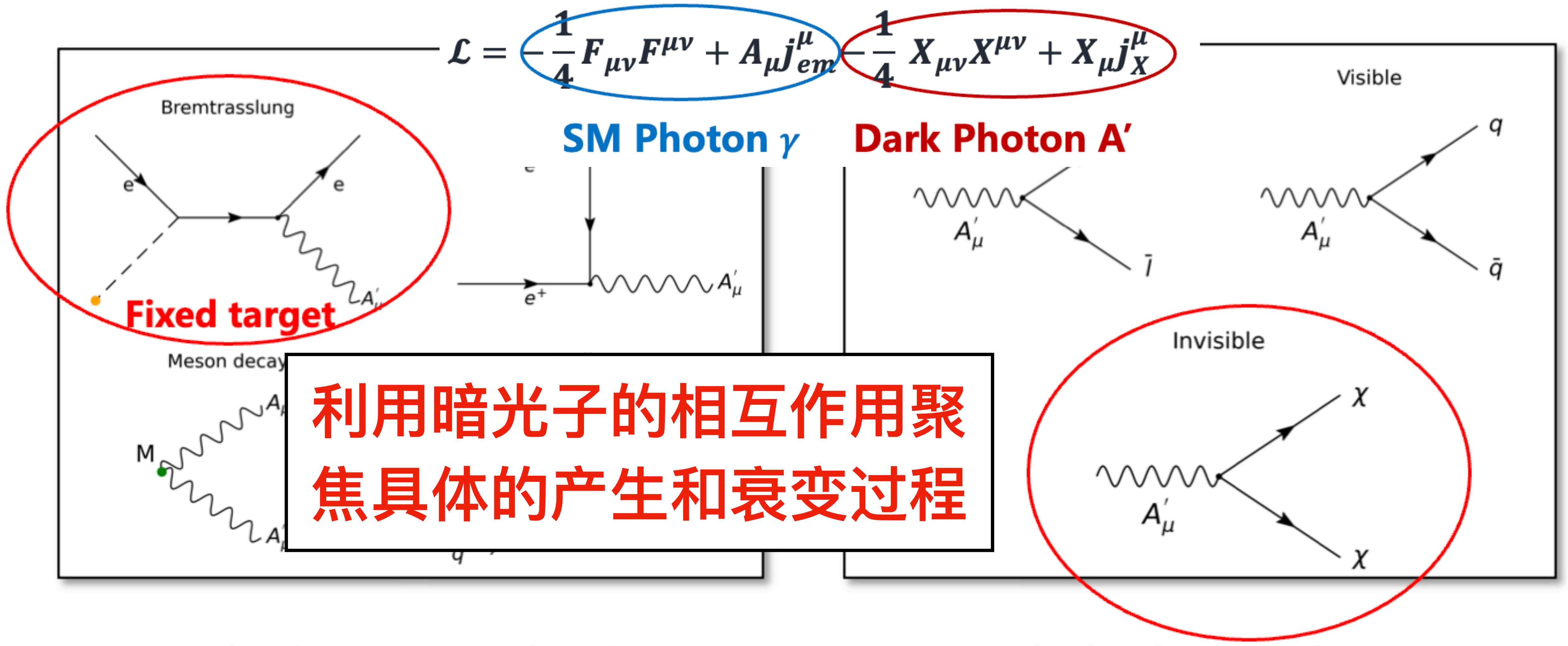
from Y. Wang

更轻的暗物质：新技术，更低的能量阈值

Dark SHINE（暗光计划）

基于上海硬X射线自由电子激光装置的暗光子寻找实验

核心要求：短时间强束流

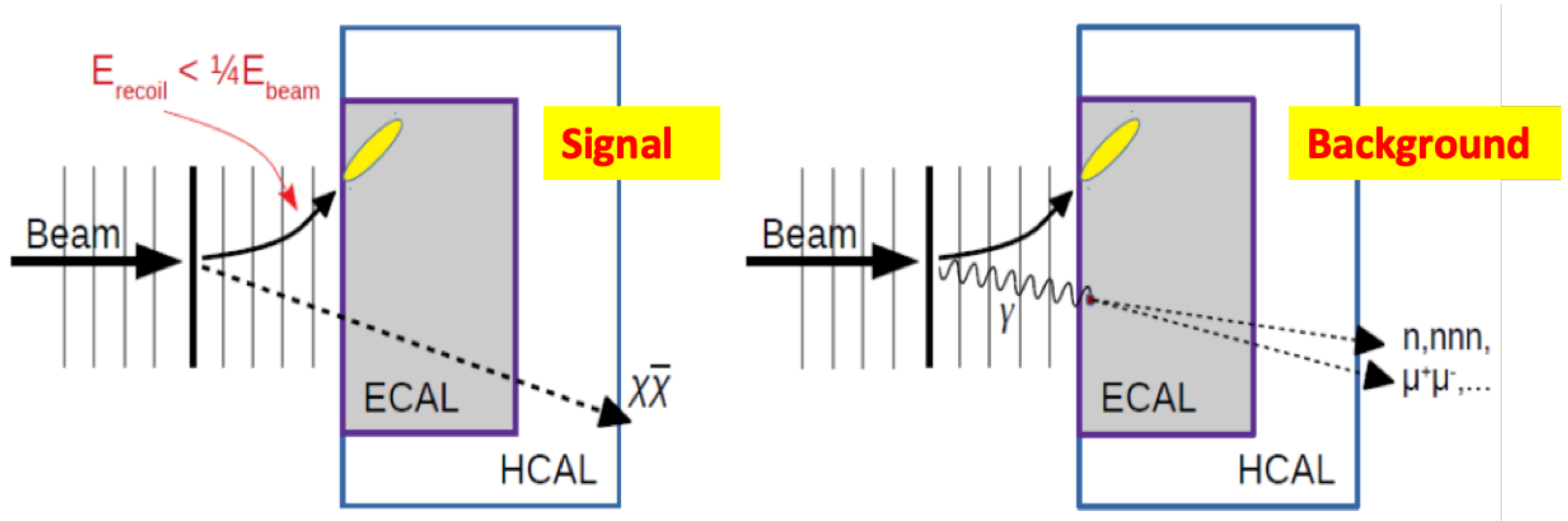


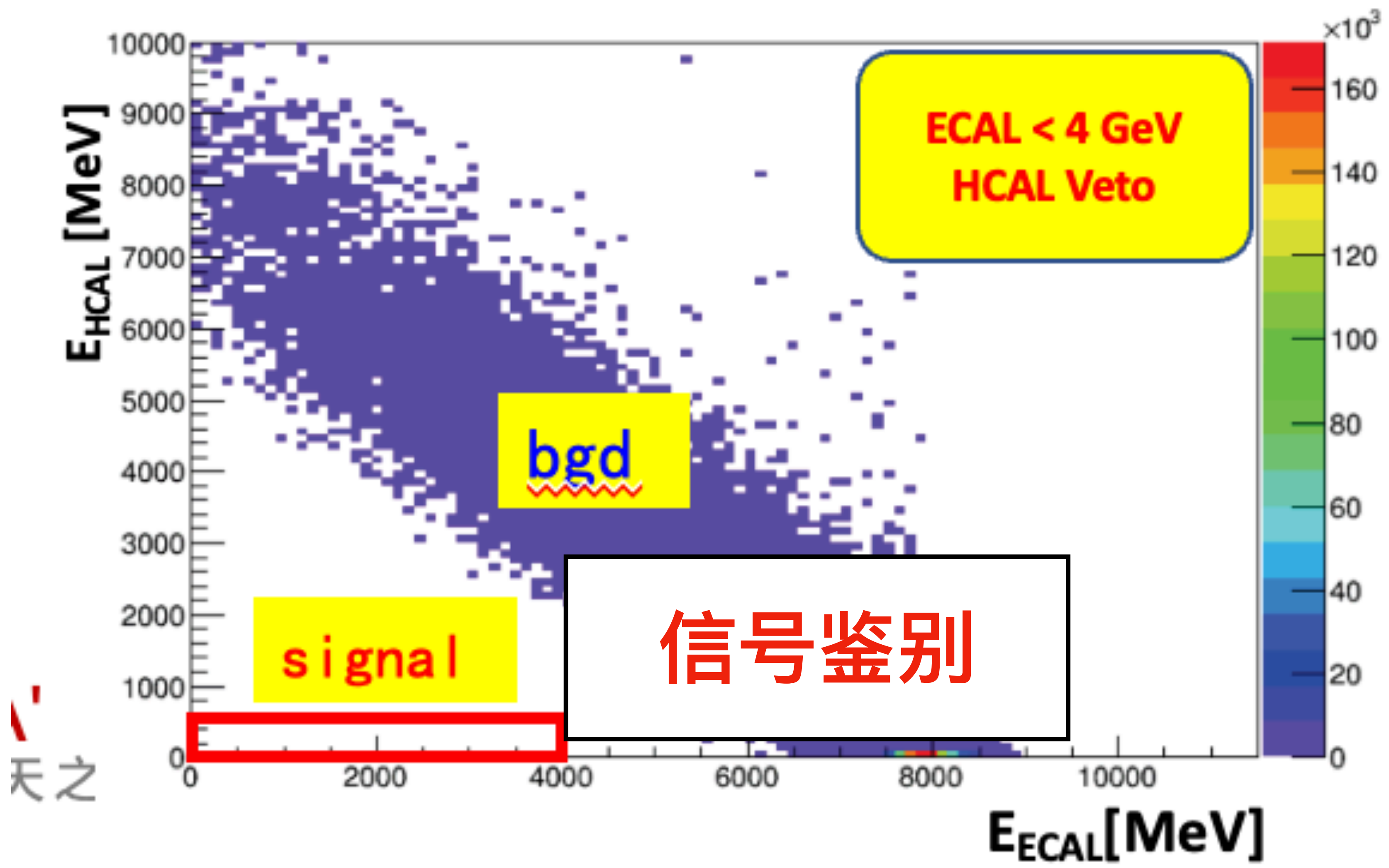
$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + A_\mu j^\mu_{em} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} + X_\mu j^\mu_X$$

利用暗光子的相互作用聚焦具体的产生和衰变过程

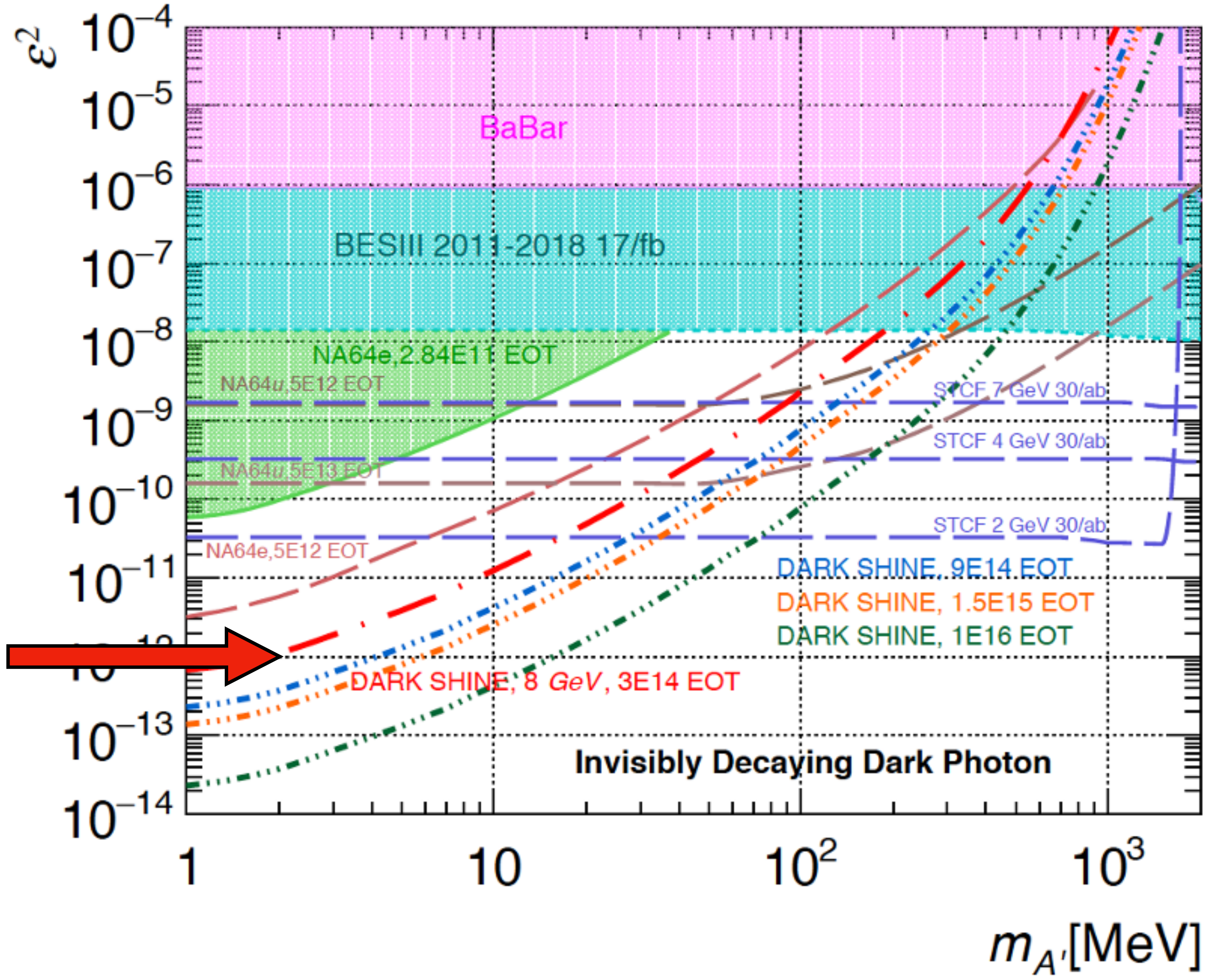
(Dark photon production)

(dark photon decay)





信号鉴别



预期排除线

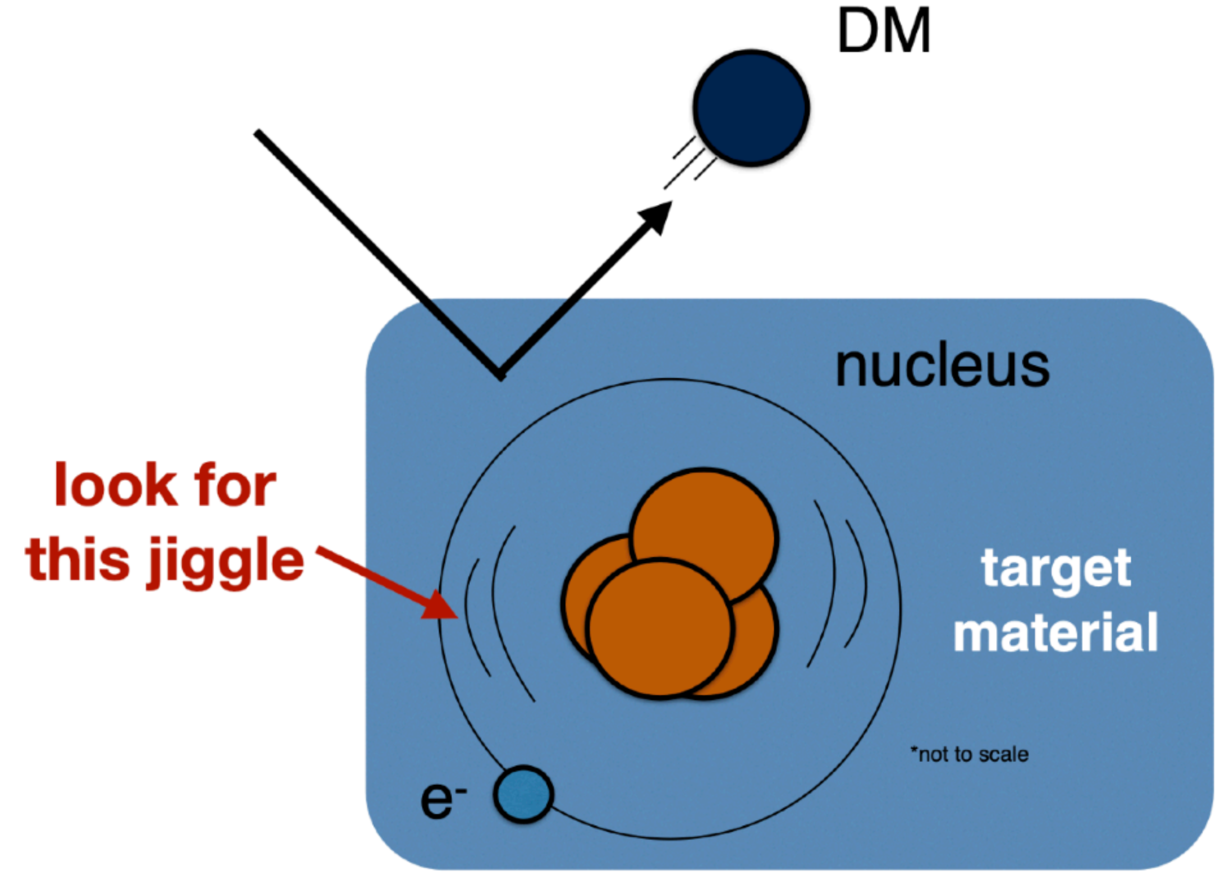
Light dark matter ~ keV-GeV

刘佳的报告

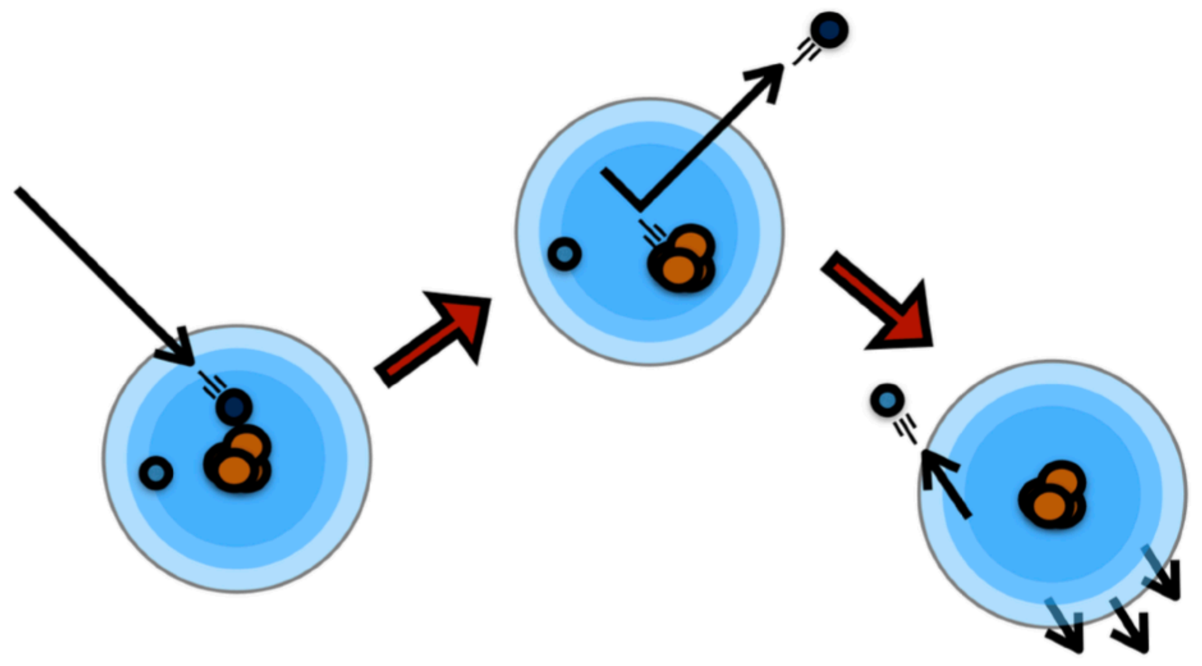
- 模型: dark photon, dark scalar, and dark sector …
  More: asymmetric, freeze-in, SIMP, ELDER, co-annihilation, non-thermal…
  non-minimal misalignment, cosmic strings, inflationary fluctuations

- 探测

Elastic nuclear scattering

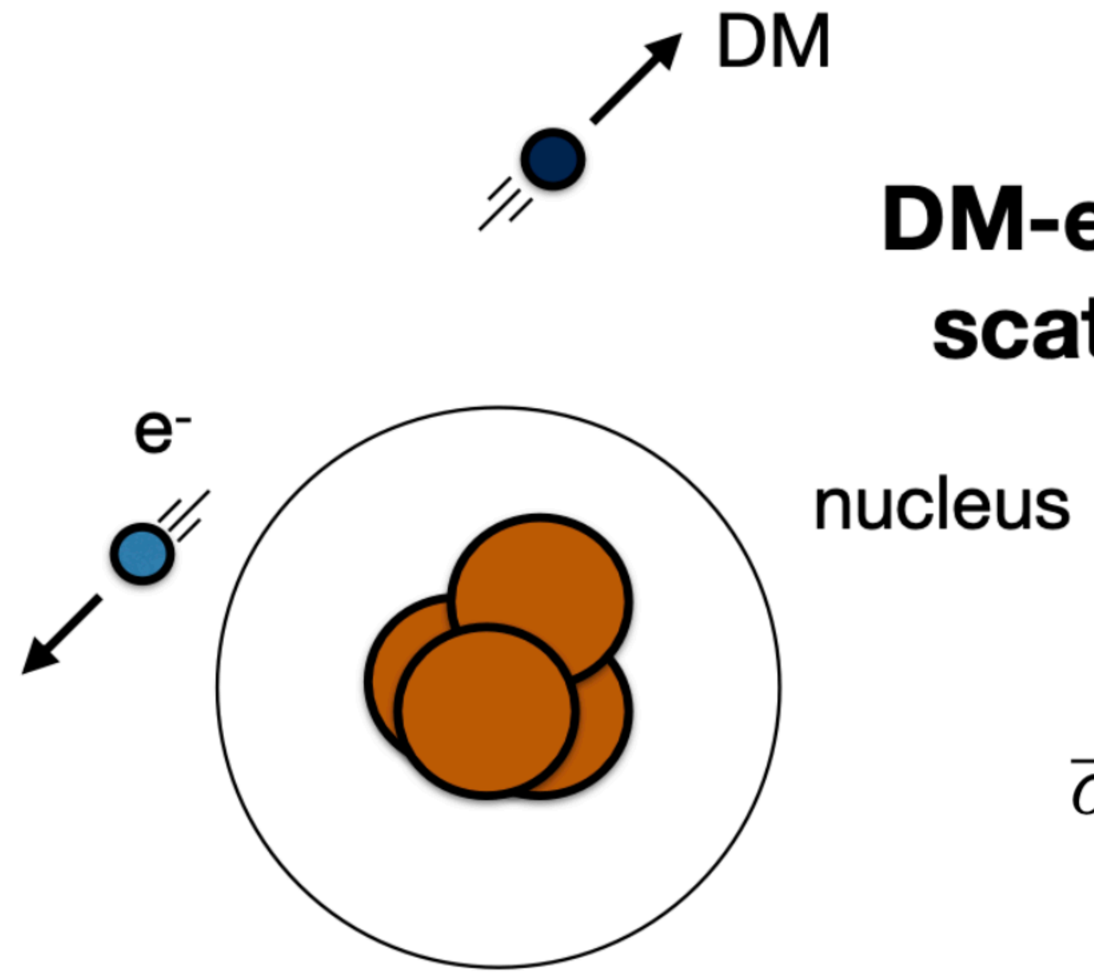


Migdal effect



**Electron scattering:
excitation/ionization**

**CDEX-10
2206.04128 [PRL]**



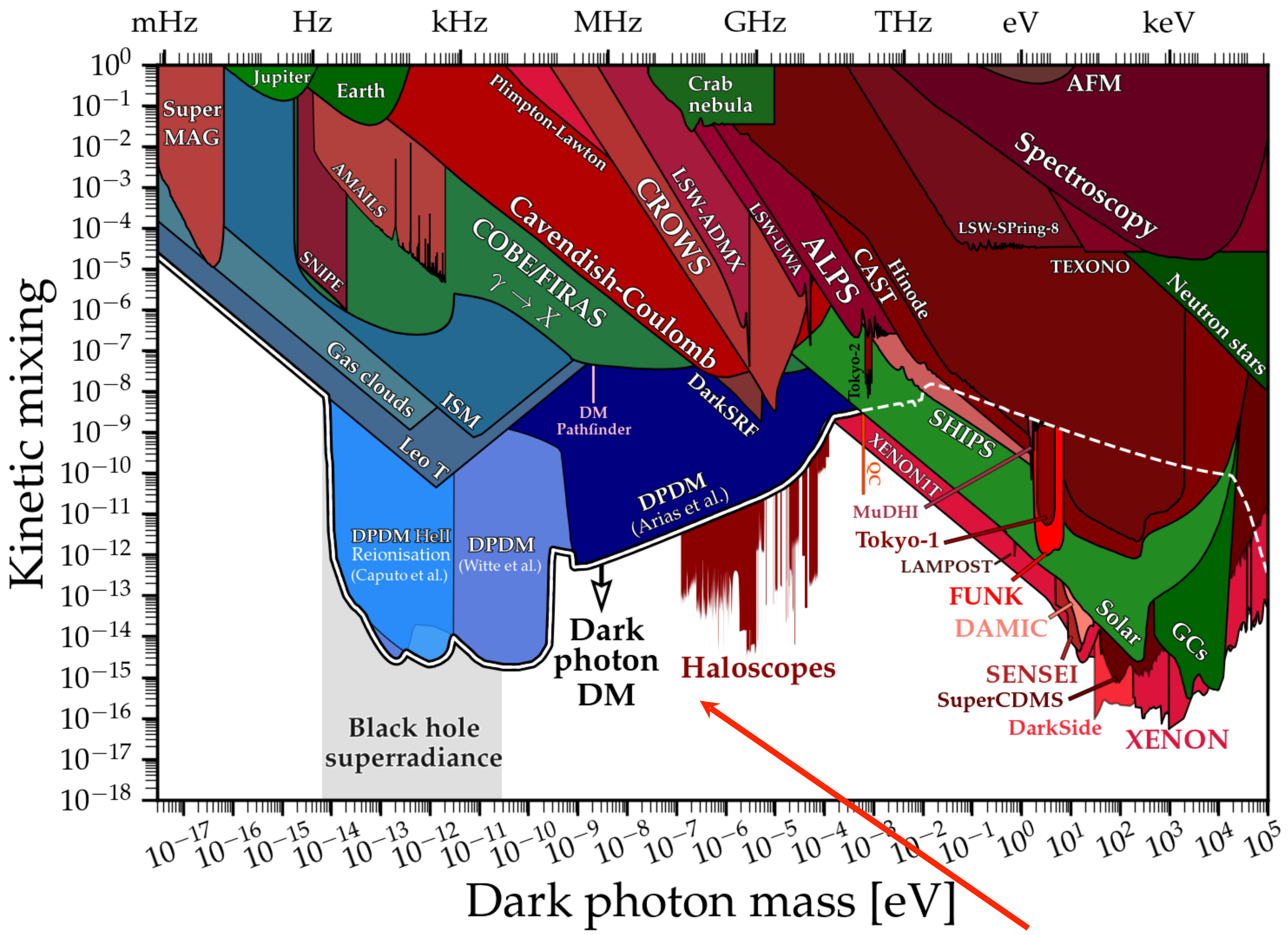
**DM-electron
scattering**

$$\overline{\sigma}_e \sim 4\pi\alpha_D\epsilon^2\alpha\frac{\mu_{\chi,e}^2}{q^4}$$

**DarkSide-50
2207.11968 [PRL]**

Ultra-light dark matter detection in Tunable SRF Cavities 舒菁的报告

Current DPDM search



Haloscope sensitivity largely depends on Q: Superconducting cavity has Q~10^{10}

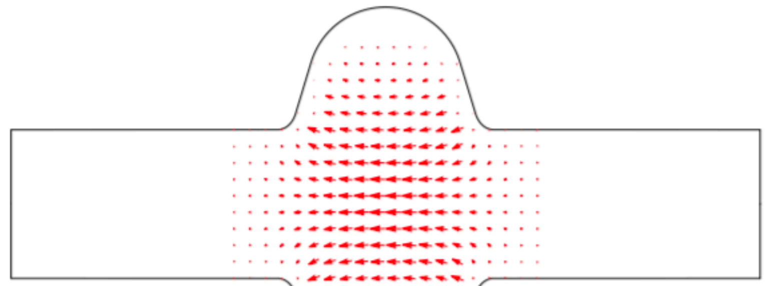
Still a lot of room to detect

how to make use it? 5 orders more than traditional cavity.

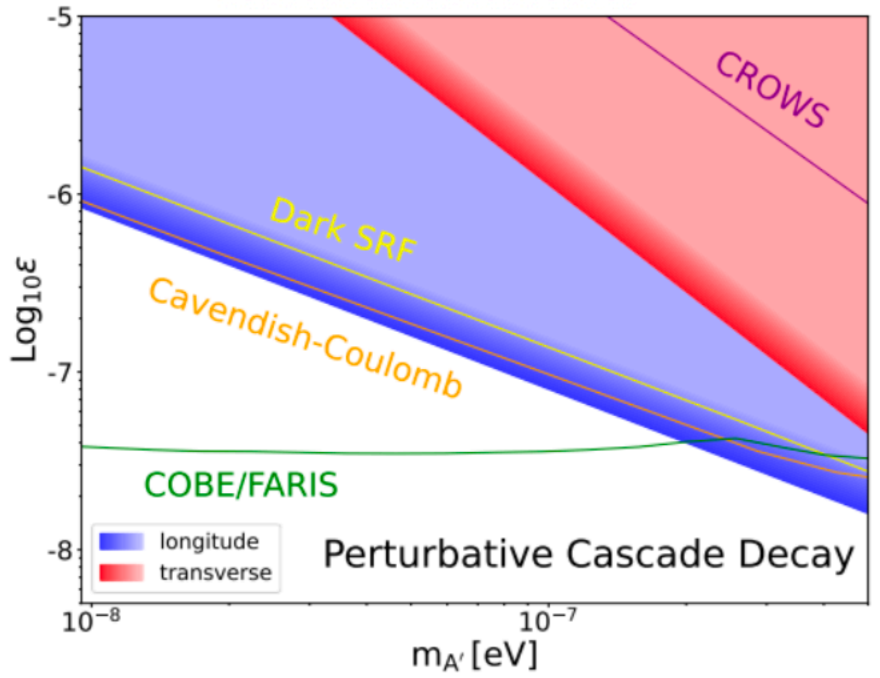
Axion limit webpage: https://github.com/cajohare/AxionLimits/blob/master/docs/dp.md

SRF Cavity

- Significant $Q_0 > 10^{10}$ compared to copper cavity
- Superconducting Radio-Frequency (SRF) Cavities: extremely high $Q_0 \simeq 10^{10}$ $\to$ improve SNR $\propto Q_0^{1/4}$
- 1-cell elliptical niobium cavity with mechanical tuner, immersed in liquid helium at $T \sim 2\,K$
- TM_{010} mode: z-aligned $\vec{E}$, **maximizes the overlap** for dark photon dark matter (DPDM)



- Longitude mode has better sensitivity because of the larger spatial wavefunction



preliminary

polarization-dependent,

Axion Haloscope in Electric Field

共振腔的增益计算：基于量子力学计算高Q值增益

$$R = |\int_0^t \langle 1| H_I |0\rangle e^{i(\omega_k-\omega_a)t} dt|^2$$

$$= (g_{a\gamma\gamma}\frac{\sqrt{2\rho_a}}{m_a}B_0 \int dx^3 \hat{z}\cdot|\langle 1|\vec{E}|0\rangle|)^2 \delta(\omega_k-\omega_a)$$

$$R \approx \frac{\pi}{2}g^2_{a\gamma\gamma}\frac{\rho_a}{m_a^2}B_0^2 V \sum_k C_k \omega_k \delta(\omega_k-\omega_a)$$

$$\int d\omega(\omega/d\omega)\delta(\omega-\omega_a) \approx Q$$

- axion-modified Maxwell equations:

$$\vec{\nabla}\cdot\vec{E} = \rho_e + \underline{g\vec{B}\cdot\nabla a}$$

$$\vec{\nabla}\times\vec{B} - \frac{\partial\vec{E}}{\partial t} = \underline{g\vec{E}\times\vec{\nabla}a} - \underline{g\vec{B}\frac{\partial a}{\partial t}} + \vec{j}_e$$

$$\vec{\nabla}\cdot\vec{B} = 0$$

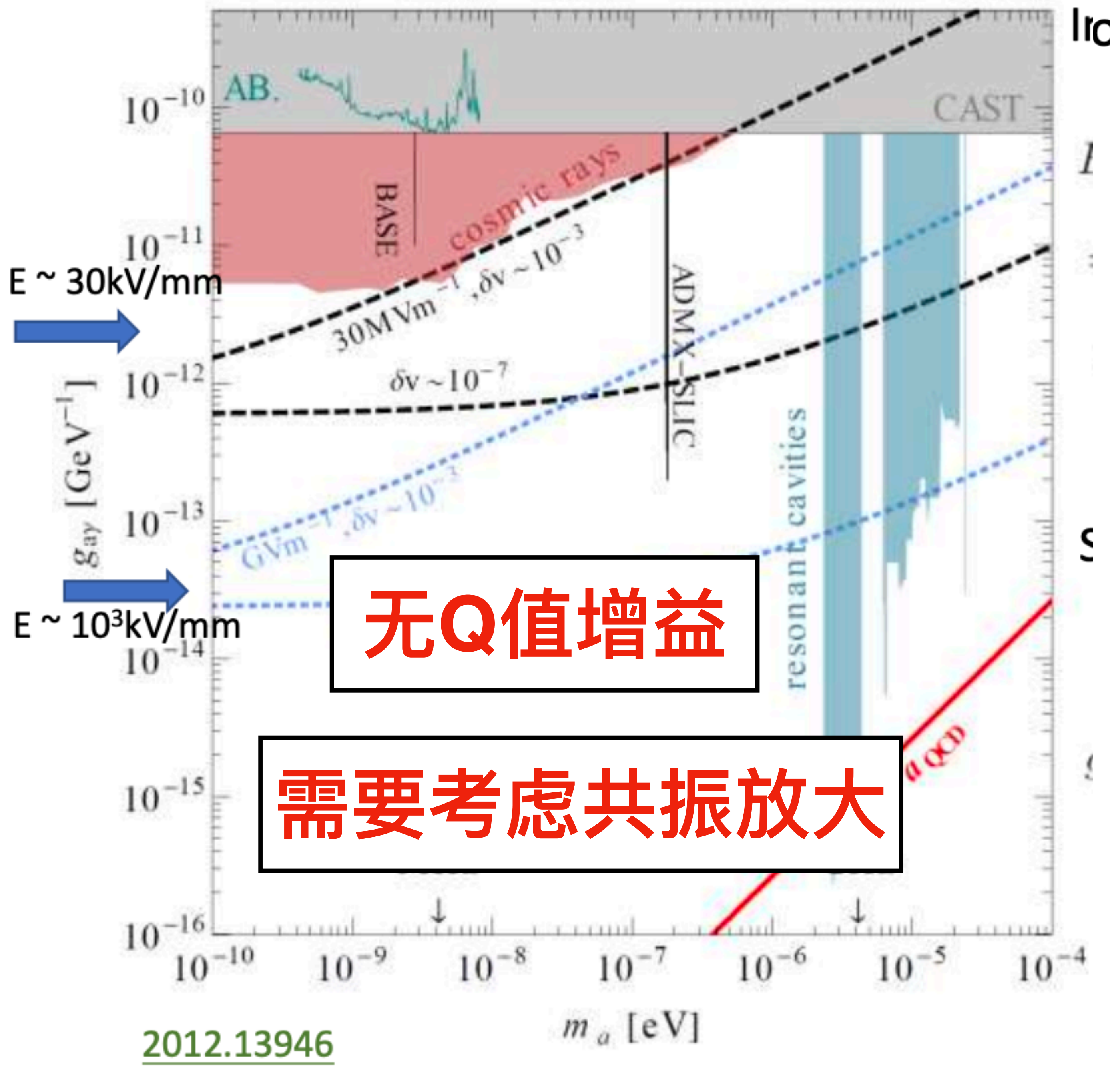
$$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} ,$$

Effective charge: (suppressed as $v_a \ll 1$)
($j^0$of the locally conserved 4-current $\partial_\mu j_a^\mu$=0)

Axio-magnetic current:
ADMX-SLIC(LC), Abracadabra, DM-Radio, etc

Axio-electric current $\vec{j}_a = g\vec{E}\times\vec{\nabla}a$

DM axion flow Induces a magnetic signal
inside E field: see 2012.13946 (broad-band)
& 2204.14033 (narrow-band)

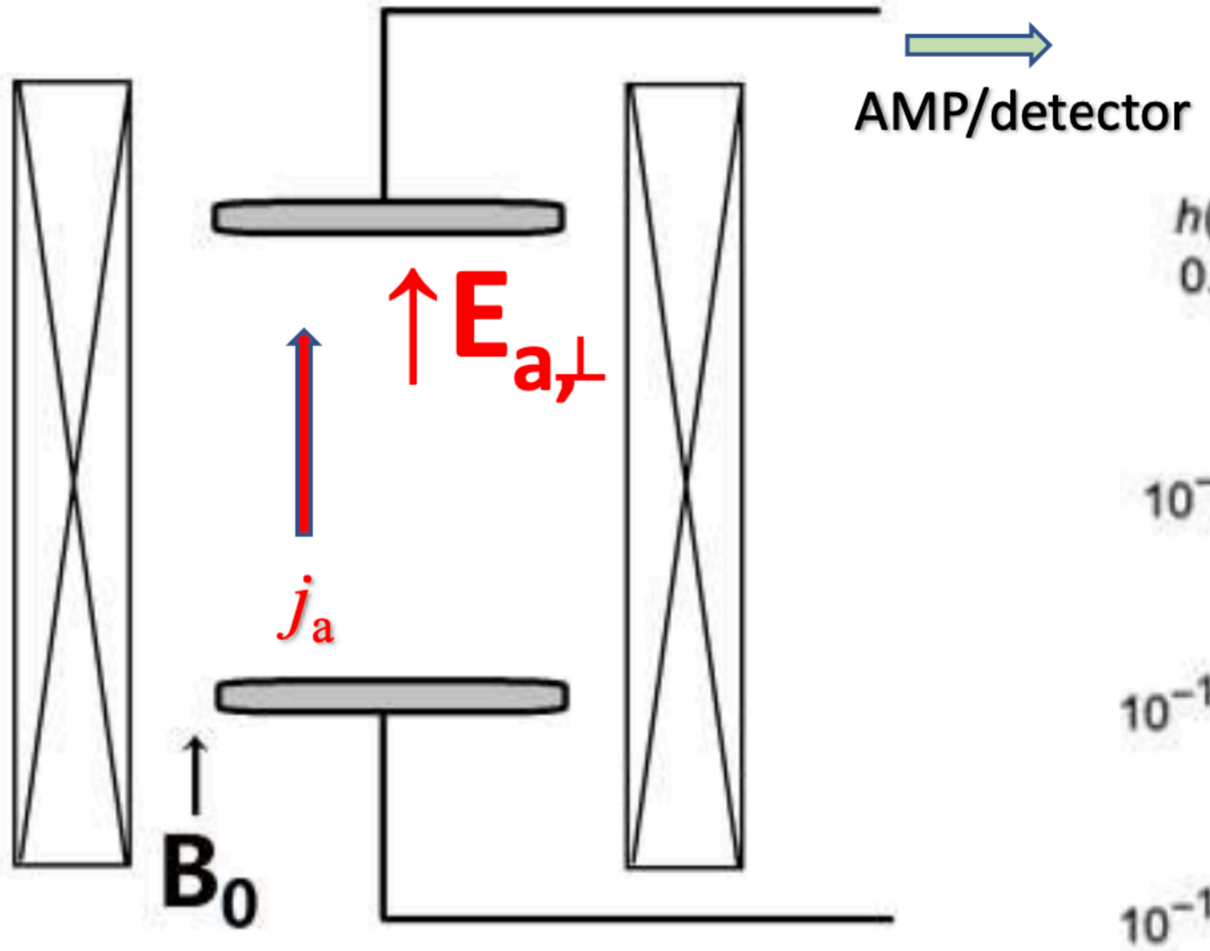


无Q值增益

需要考虑共振放大

2012.13946

See 1803.07755 for a broadband attempt (UWA)

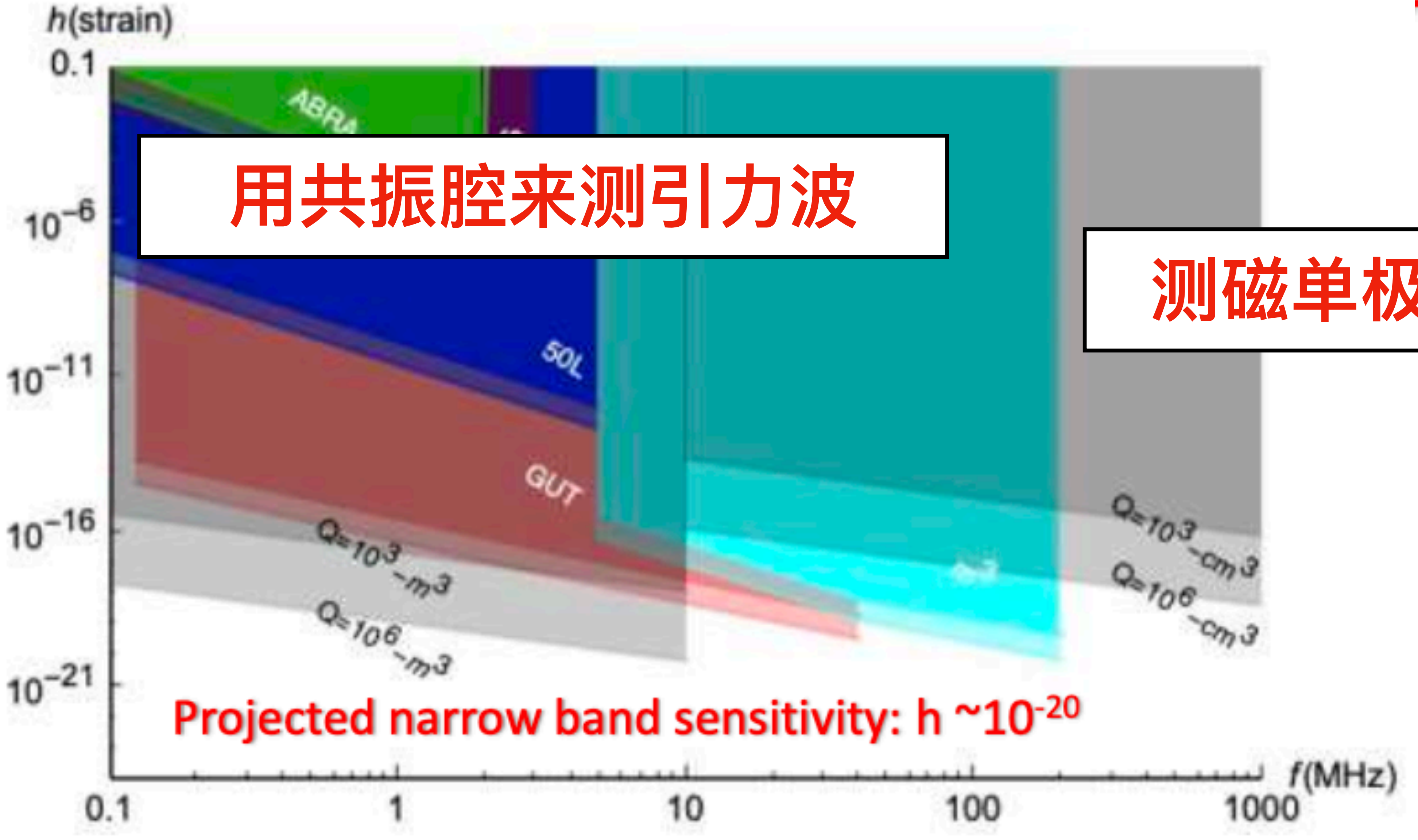


用电场测轴子流

$$P_{sig.} = \frac{\langle q^2\rangle}{C}\omega$$

tive sources:

wing) charge &



用共振腔来测引力波

Projected narrow band sensitivity: h ~10^{-20}

测磁单极...

Long-lived dark photons at LHC

刘佐伟的报告

$SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_X$

[Feldman, ZL, Nath, hep-ph/0702123, 372 cites]

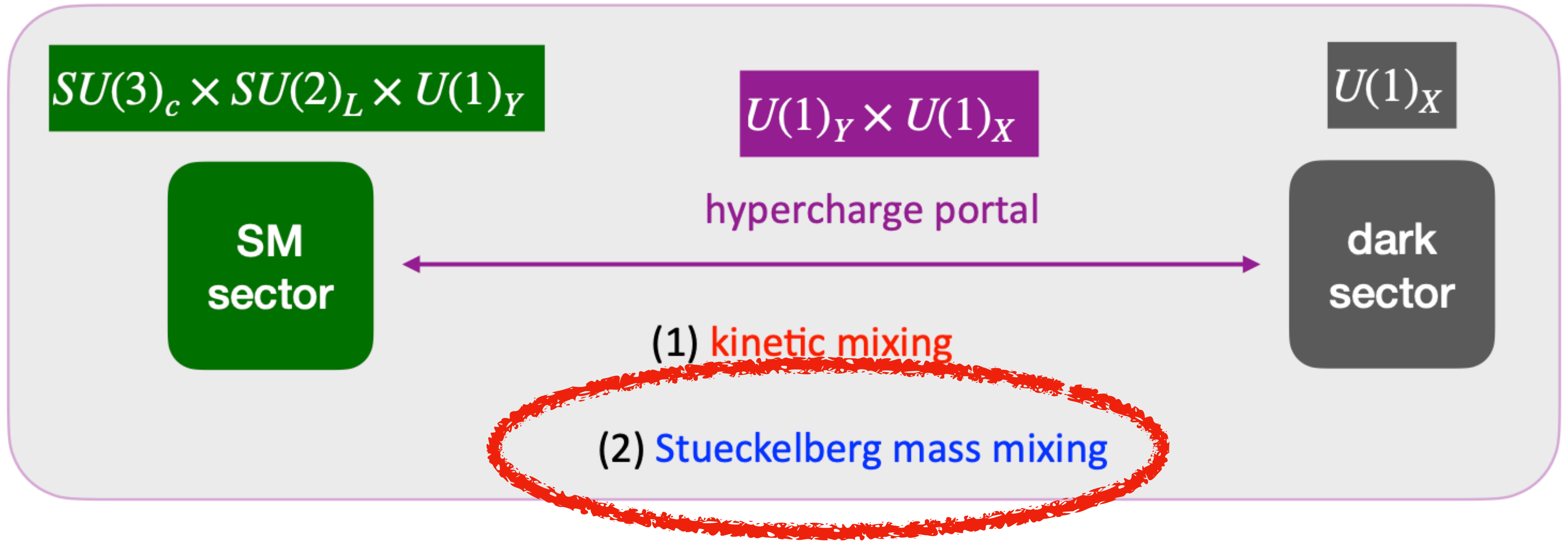
$$\mathcal{L} = -\frac{1}{4}B_{\mu\nu}B^{\mu\nu} - \frac{1}{4}X_{\mu\nu}X^{\mu\nu} + g_D X_\mu \bar{\chi}\gamma^\mu \chi - \frac{\tilde{\delta}}{2} B_{\mu\nu}X^{\mu\nu} - \frac{M_1^2}{2}(\partial_\mu \sigma + X_\mu + \tilde{\epsilon}\, B_\mu)^2$$

kinetic mixing

mass mixing

Minimal DP model

dark photon的模型构建



$SU(3)_c \times SU(2)_L \times U(1)_Y$

$U(1)_Y \times U(1)_X$

$U(1)_X$

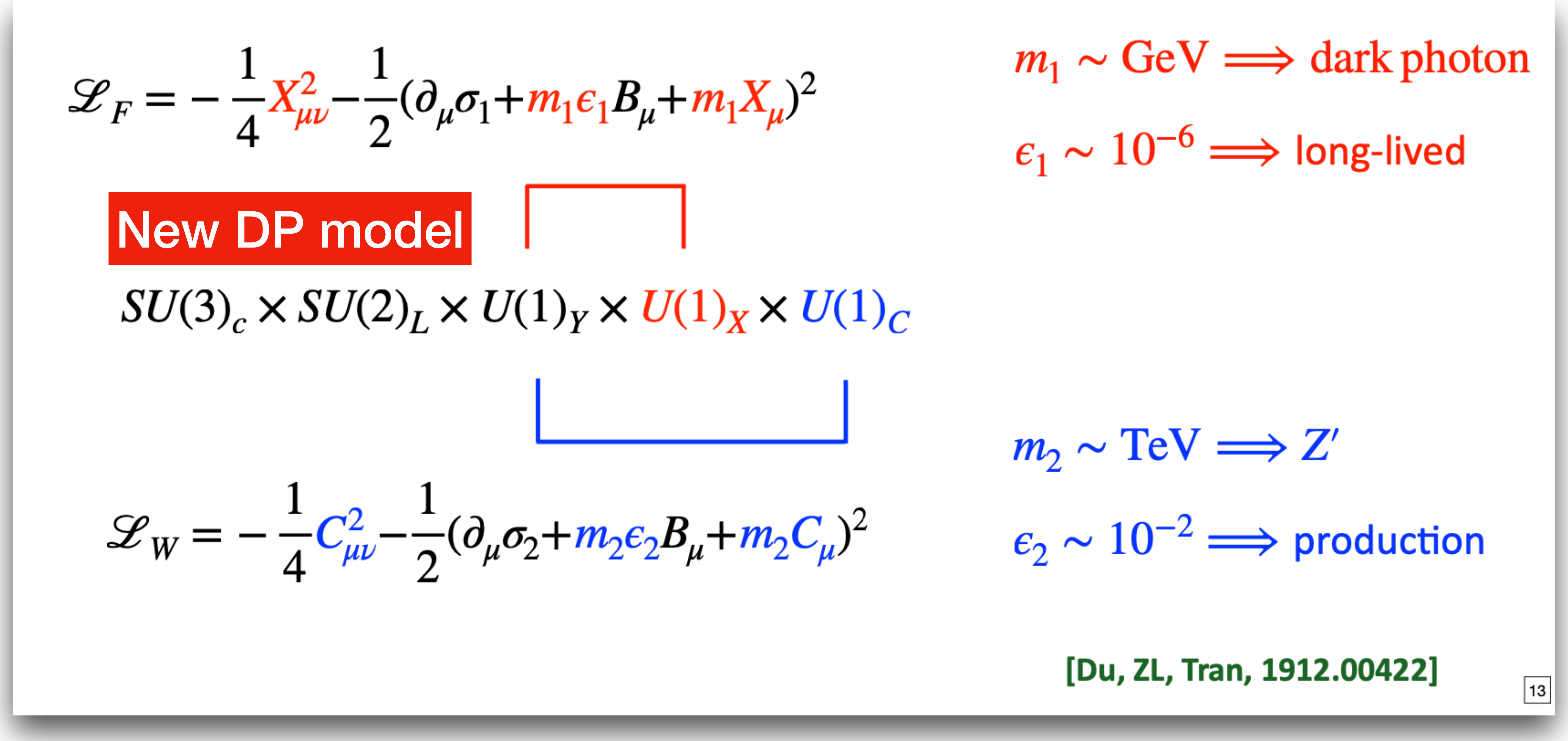
SM sector

hypercharge portal

dark sector

(1) kinetic mixing

(2) Stueckelberg mass mixing



$$\mathcal{L}_F = -\frac{1}{4}X_{\mu\nu}^2 - \frac{1}{2}(\partial_\mu \sigma_1 + m_1 \epsilon_1 B_\mu + m_1 X_\mu)^2$$

$m_1 \sim$ GeV $\Longrightarrow$ dark photon

$\epsilon_1 \sim 10^{-6} \Longrightarrow$ long-lived

New DP model

$SU(3)_c \times SU(2)_L \times U(1)_Y \times U(1)_X \times U(1)_C$

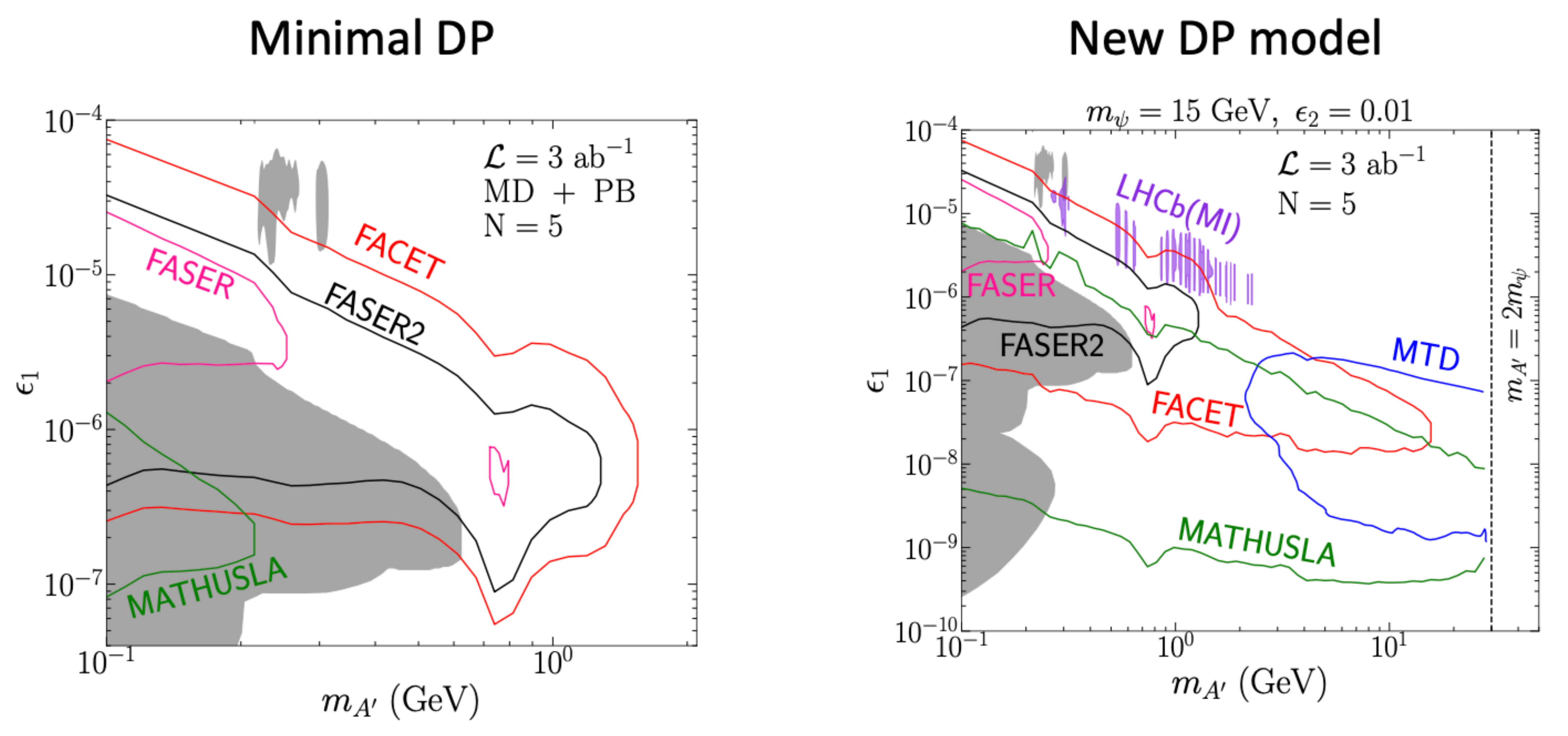
$m_2 \sim$ TeV $\Longrightarrow Z'$

$$\mathcal{L}_W = -\frac{1}{4}C_{\mu\nu}^2 - \frac{1}{2}(\partial_\mu \sigma_2 + m_2 \epsilon_2 B_\mu + m_2 C_\mu)^2$$

$\epsilon_2 \sim 10^{-2} \Longrightarrow$ production

[Du, ZL, Tran, 1912.00422]

13



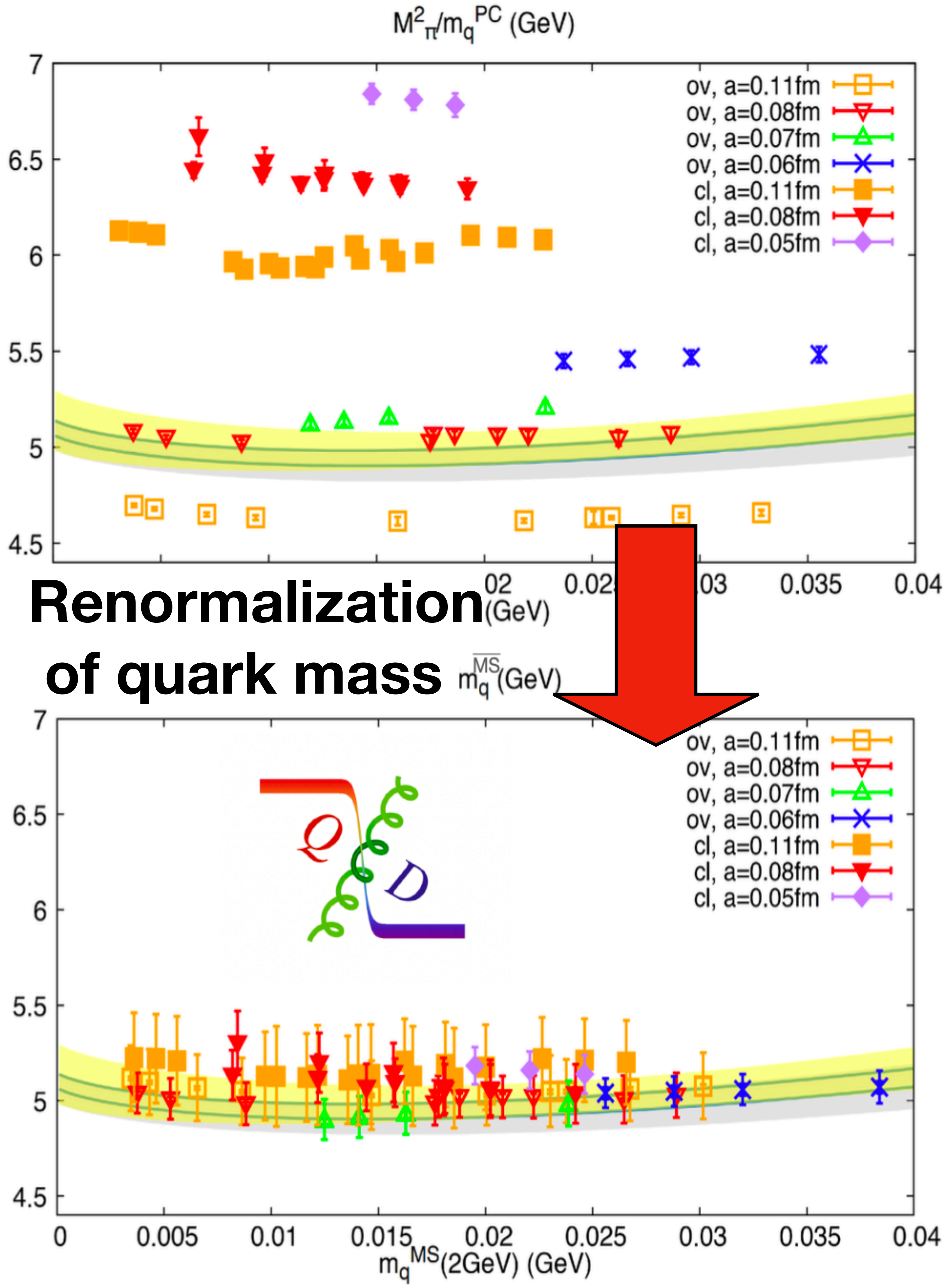
[Du, Fang, ZL, Tran, 2111.15503]

长寿命暗光子模型参数的典型量级

$$L_{A'} = \gamma v \tau \simeq 100 \text{ meter} \left[\frac{10^{-6}}{e\epsilon Q_f}\right]^2 \left[\frac{E_{A'}}{100 \text{ GeV}}\right] \left[\frac{0.1 \text{ GeV}}{M_{A'}}\right]^2$$

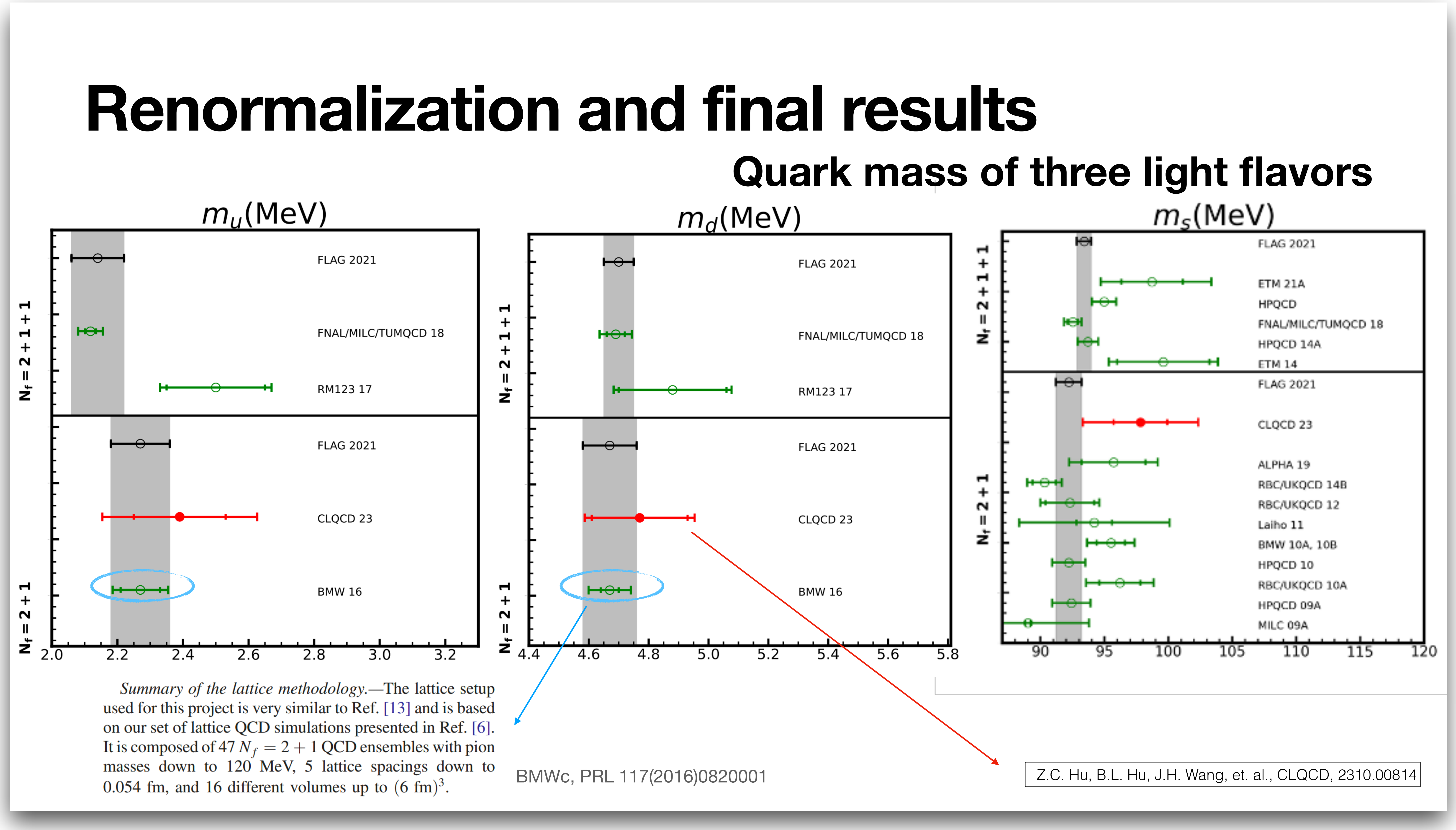
Quark masses and low energy constants in CLQCD

杨一波的报告



Renormalization of quark mass

Clover fermion + Symanzik gauge actions 框架



Renormalization and final results

Quark mass of three light flavors

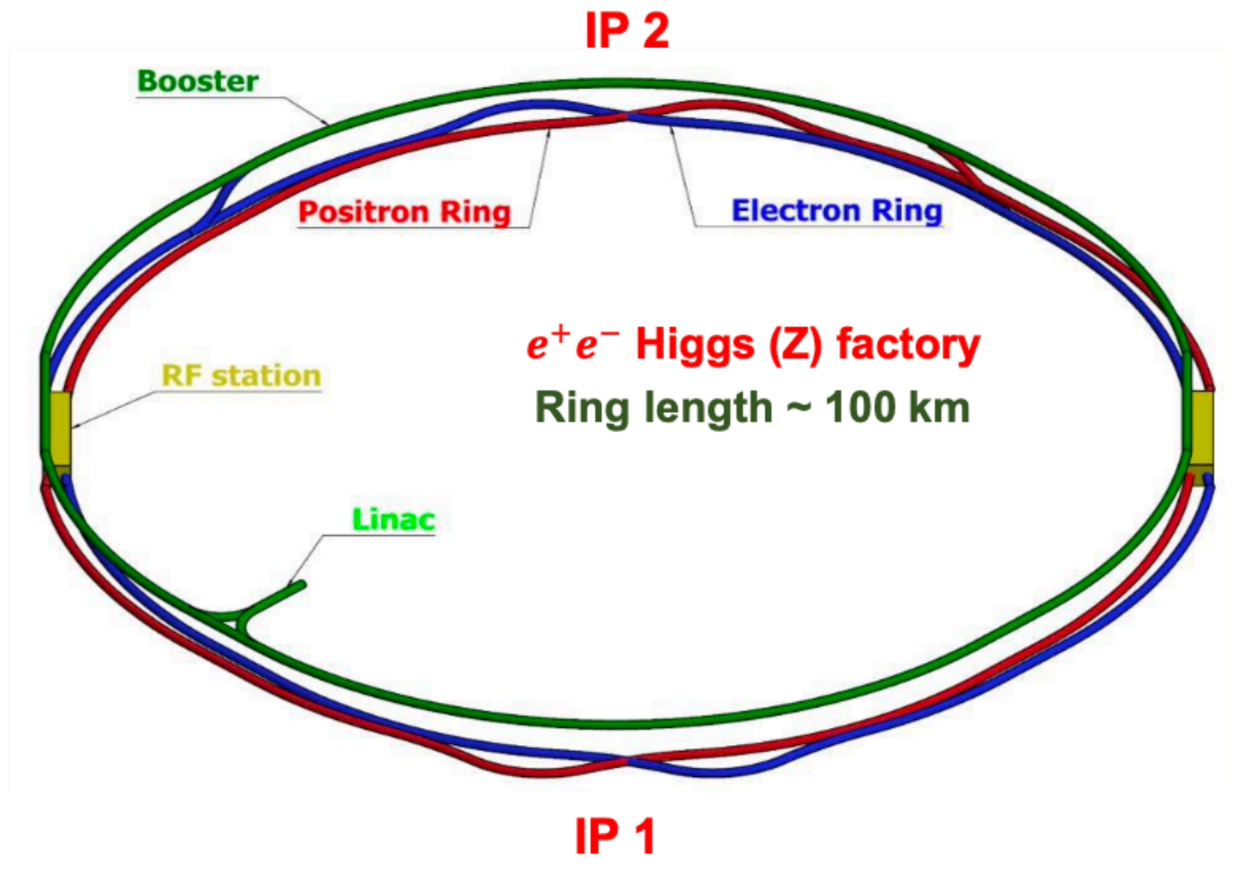
Summary of the lattice methodology.—The lattice setup used for this project is very similar to Ref. [13] and is based on our set of lattice QCD simulations presented in Ref. [6]. It is composed of 47 $N_f = 2 + 1$ QCD ensembles with pion masses down to 120 MeV, 5 lattice spacings down to 0.054 fm, and 16 different volumes up to $(6\ \text{fm})^3$.

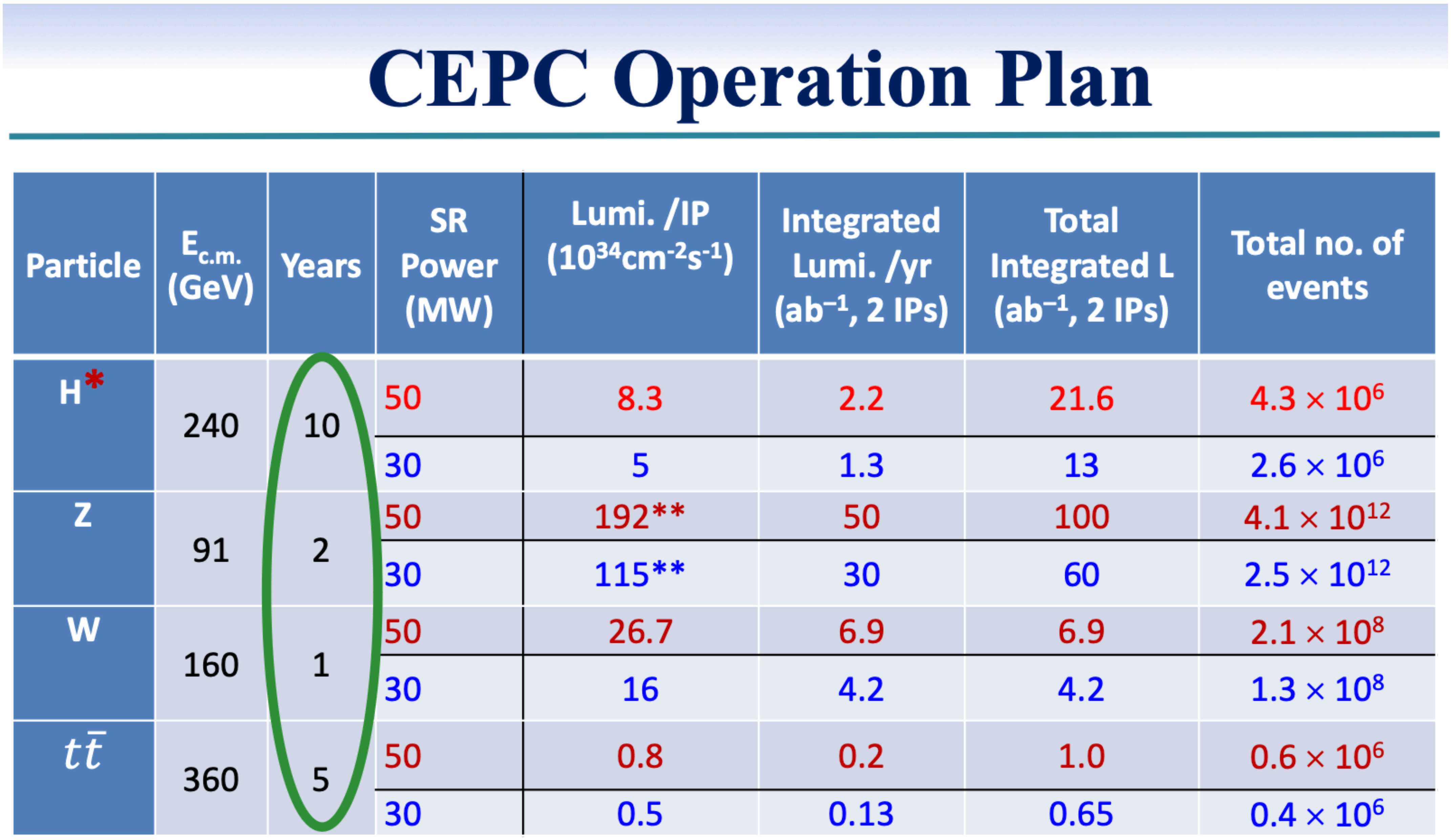
BMWc, PRL 117(2016)0820001

Z.C. Hu, B.L. Hu, J.H. Wang, et. al., CLQCD, 2310.00814

更重的夸克？正在向前……

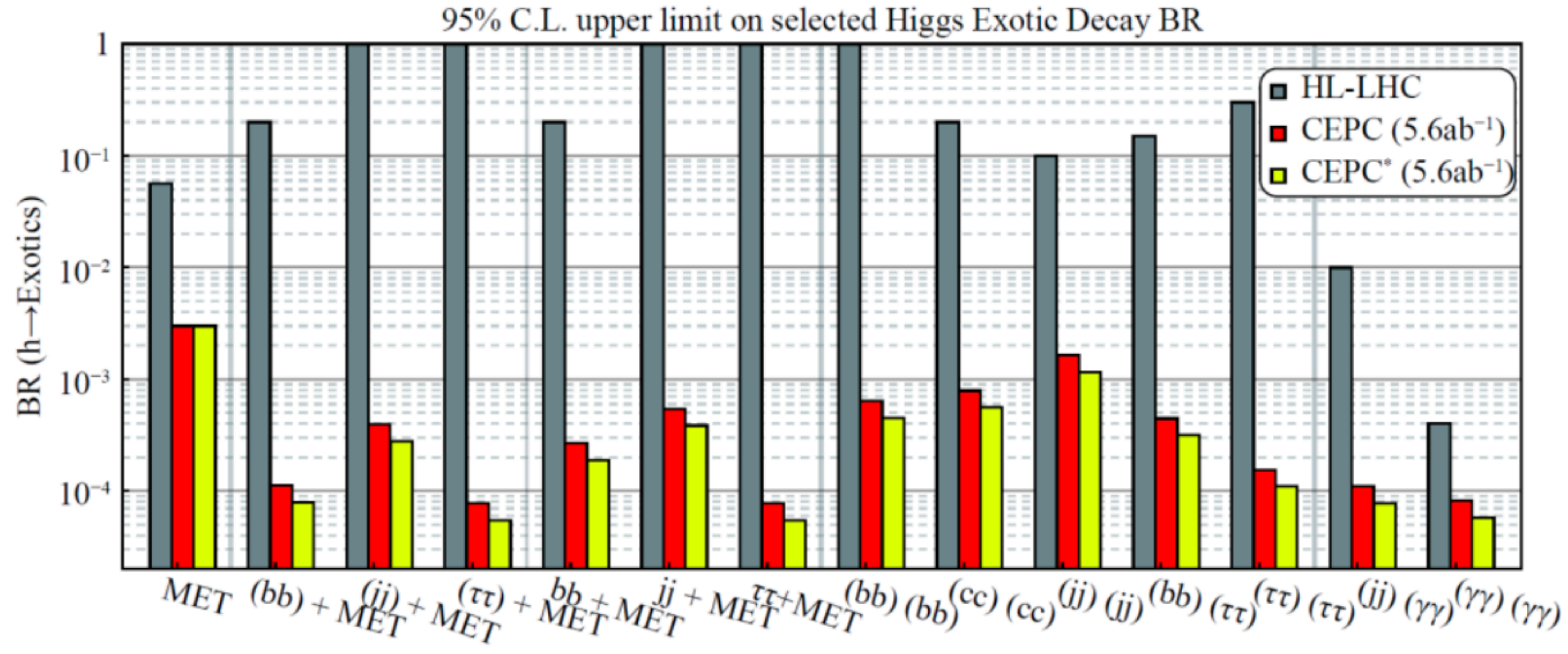
CEPC

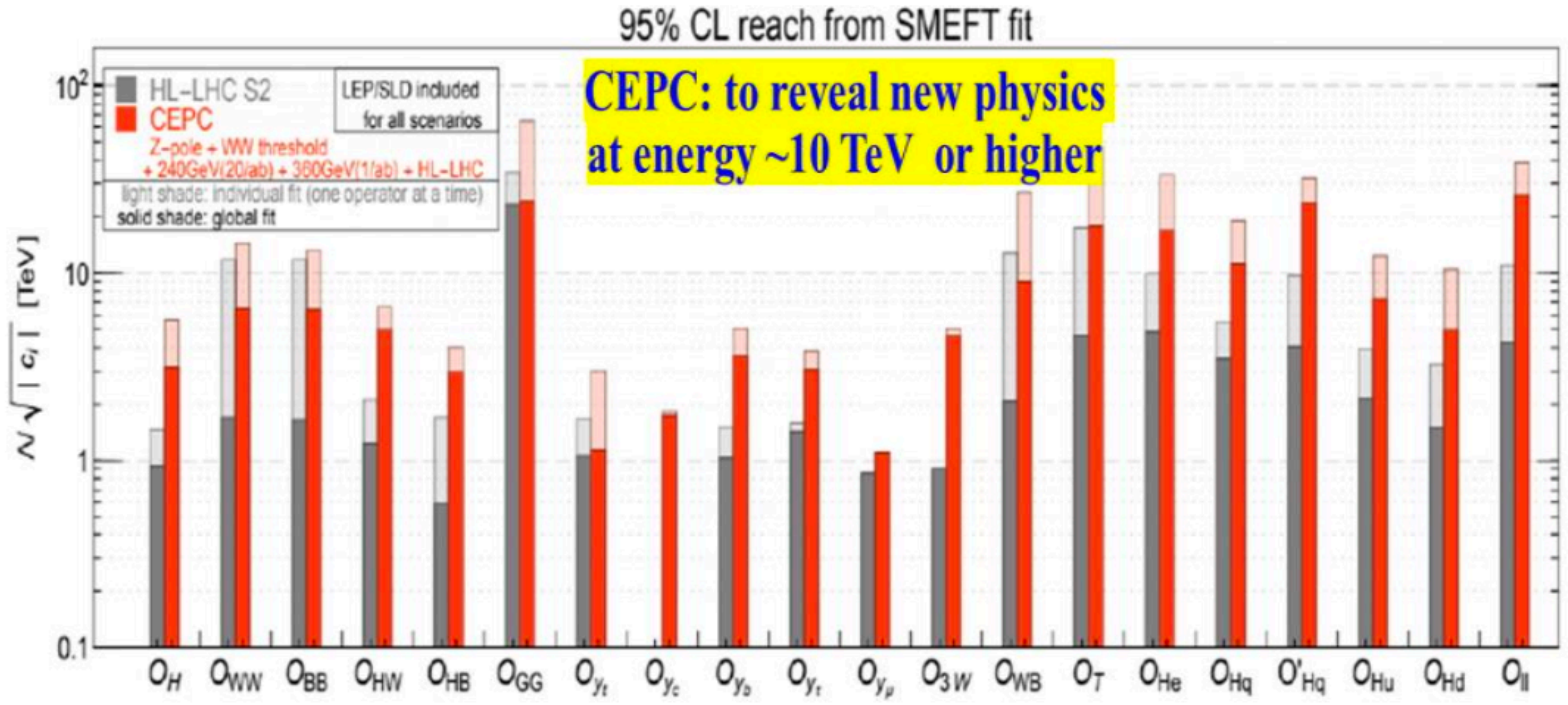




CEPC Operation Plan

Particle	$E_{c.m.}$ (GeV)	Years	SR Power (MW)	Lumi. /IP ($10^{34}cm^{-2}s^{-1}$)	Integrated Lumi. /yr (ab^{-1}, 2 IPs)	Total Integrated L (ab^{-1}, 2 IPs)	Total no. of events
H*	240	10	50	8.3	2.2	21.6	4.3×10^6
			30	5	1.3	13	2.6×10^6
Z	91	2	50	192**	50	100	4.1×10^{12}
			30	115**	30	60	2.5×10^{12}
W	160	1	50	26.7	6.9	6.9	2.1×10^8
			30	16	4.2	4.2	1.3×10^8
$t\bar{t}$	360	5	50	0.8	0.2	1.0	0.6×10^6
			30	0.5	0.13	0.65	0.4×10^6

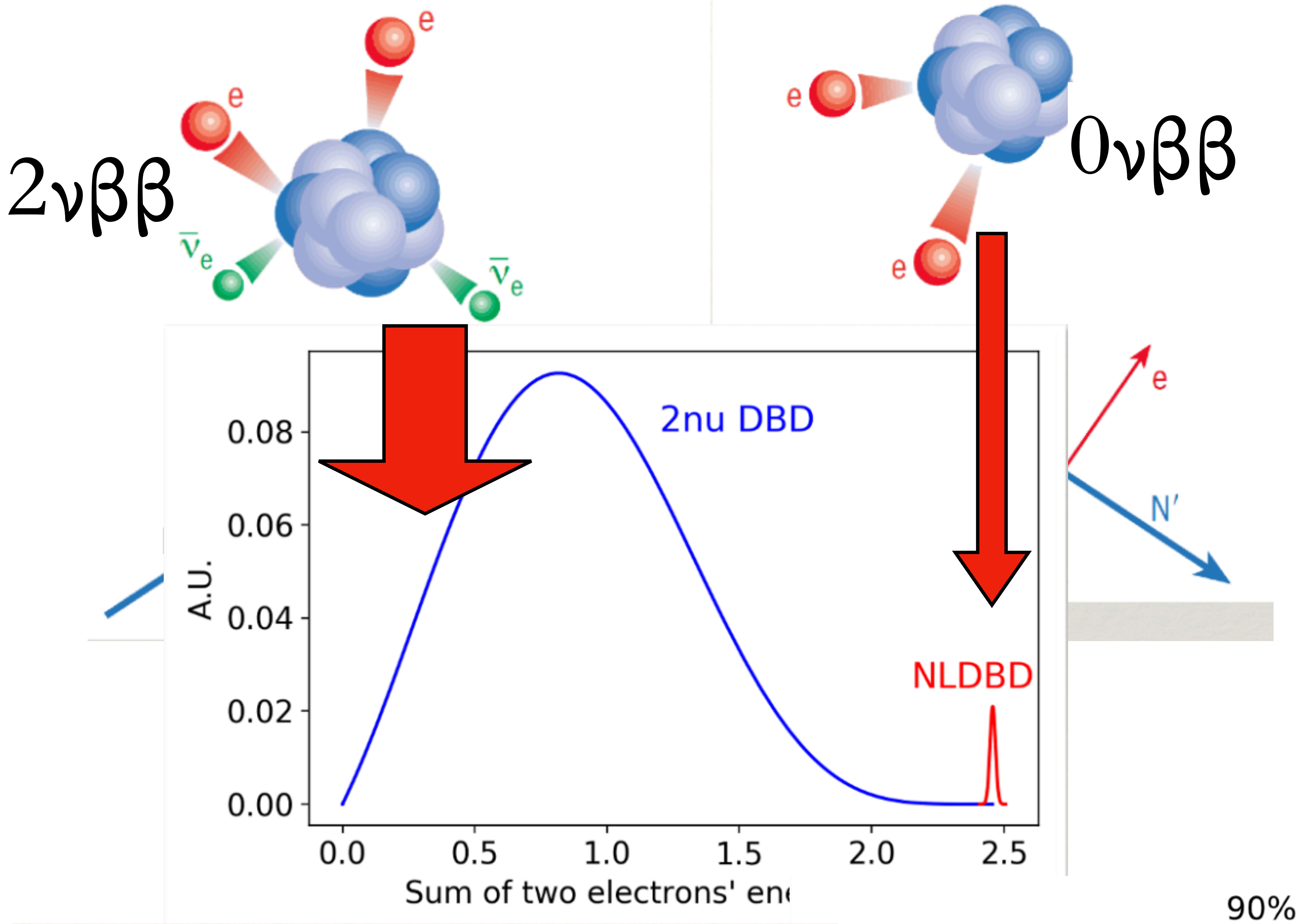




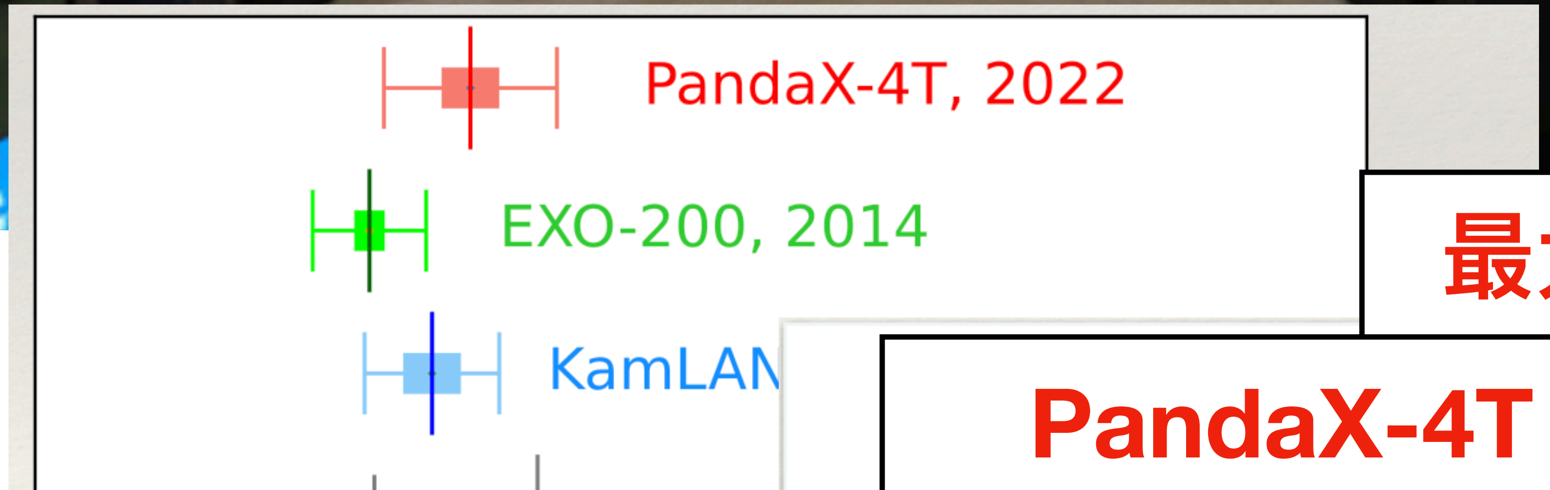
CEPC: to reveal new physics at energy ~10 TeV or higher

无中微子双贝塔衰变（0νββ）

韩柯的报告

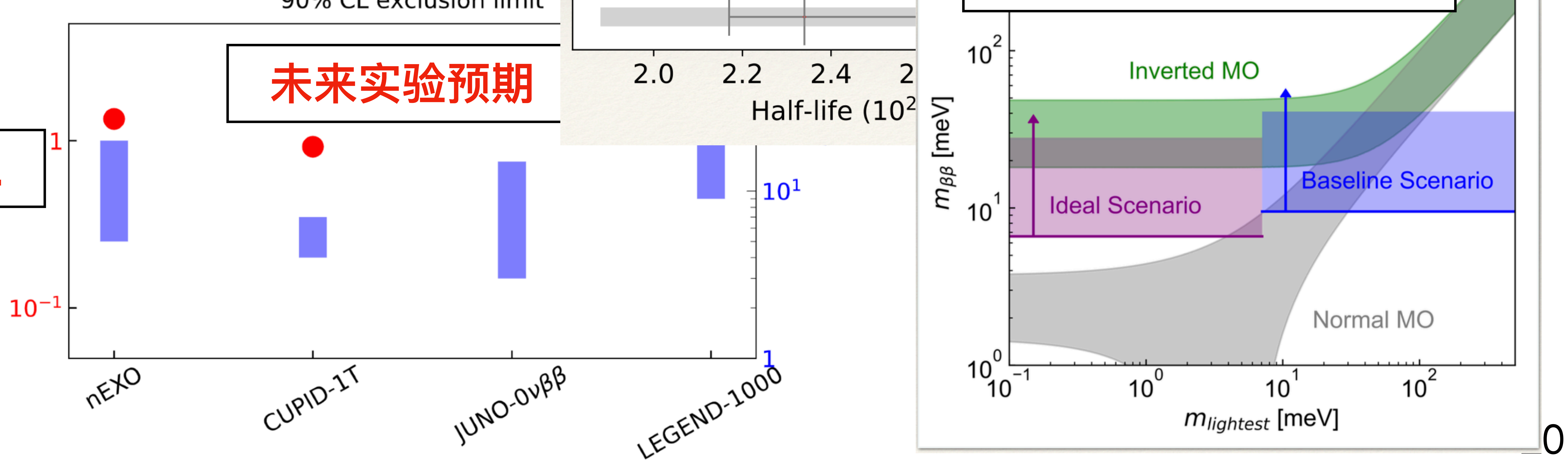


10个实验组正式入驻锦屏实验室！

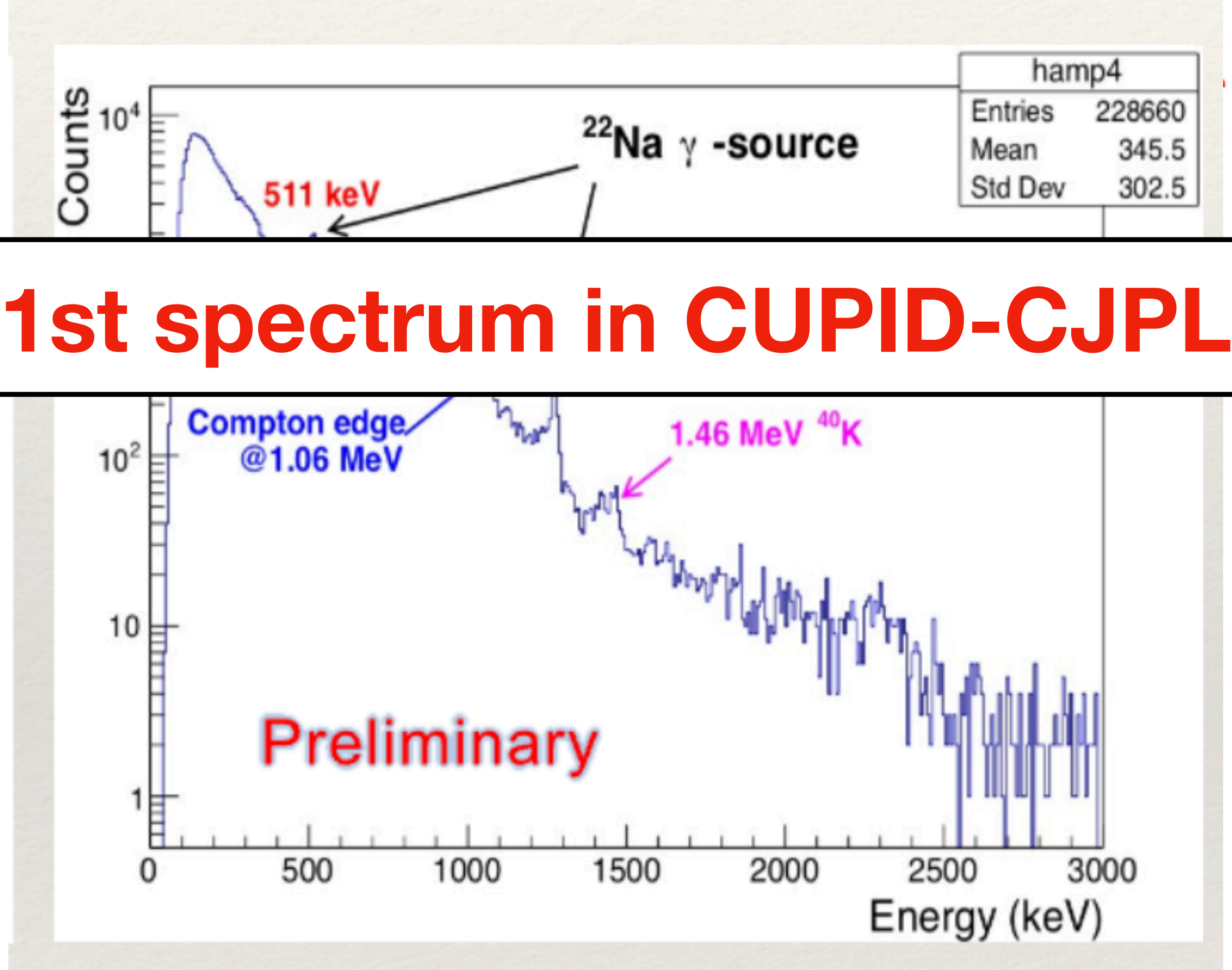


最大的DBD实验之一

PandaX-4T & -xT



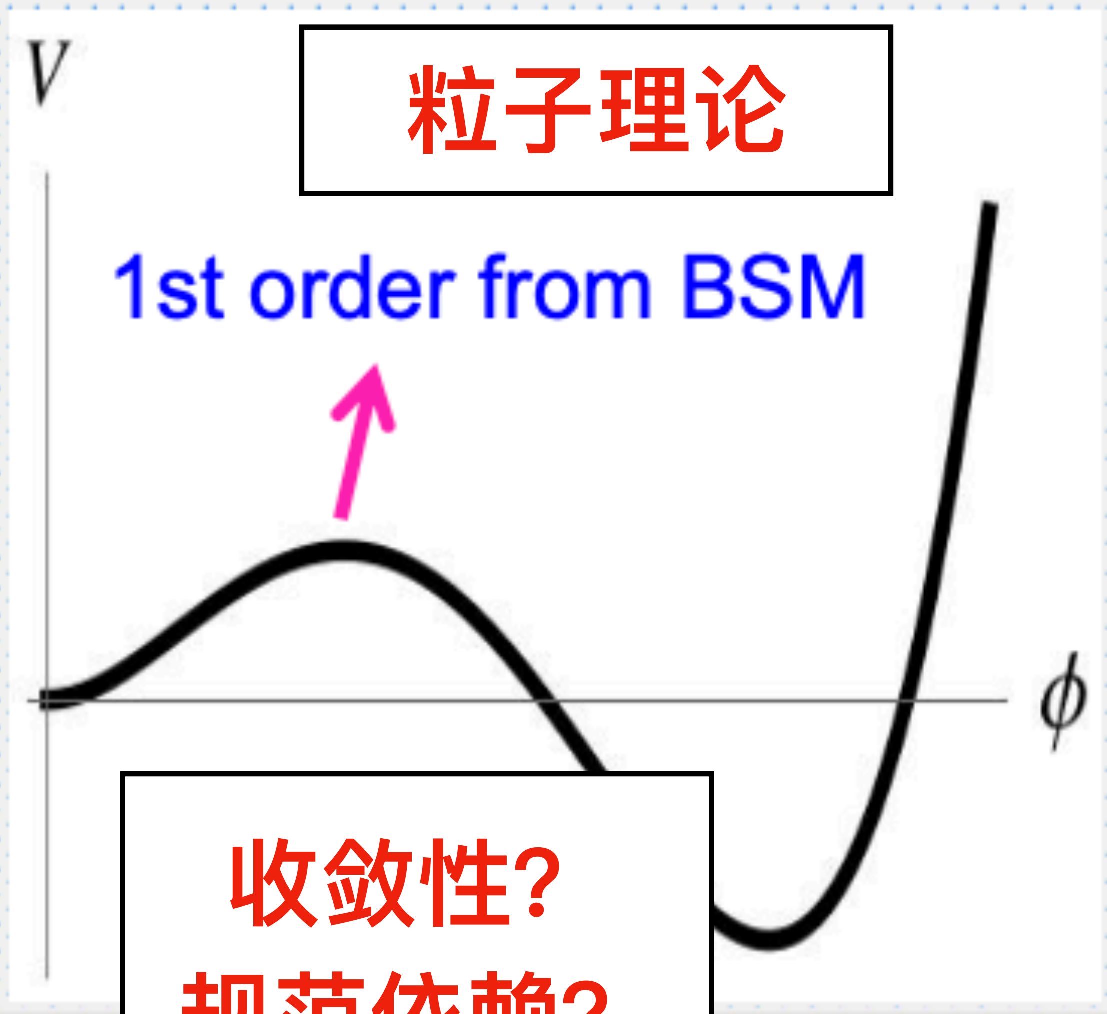
未来实验预期



1st spectrum in CUPID-CJPL

相变引力波理论与实验进展

郭怀珂的报告



粒子理论

收敛性?
规范依赖?
成核率计算?

早期宇宙作为热力学系统的演化

流体力学的复杂性

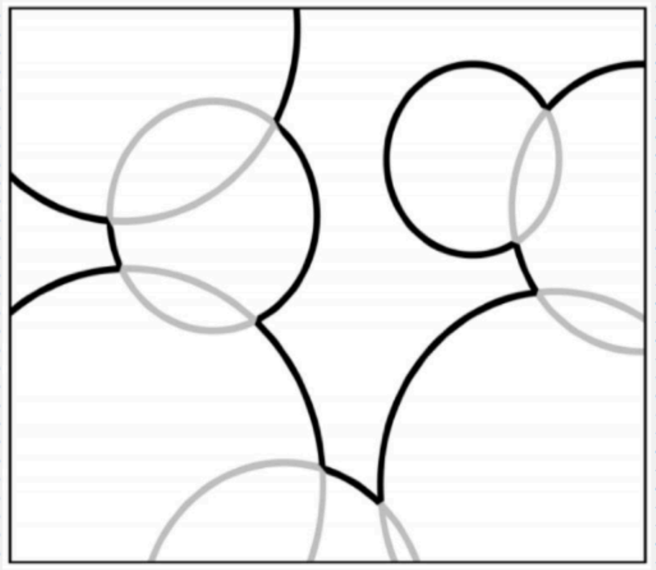
Bubble wall 速度的计算很重要

Hindmarsh, et al, 2015

$$\Box\bar{h}_{\mu\nu} = -\frac{16\pi G}{c^4} T_{\mu\nu}$$

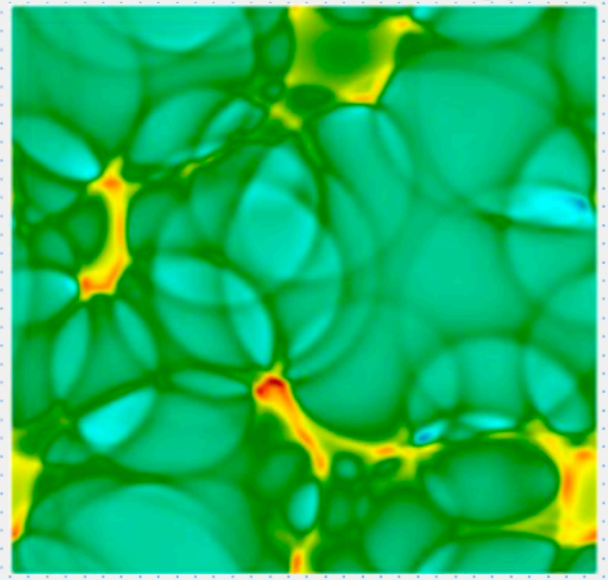
GW的组成

energy near the wall



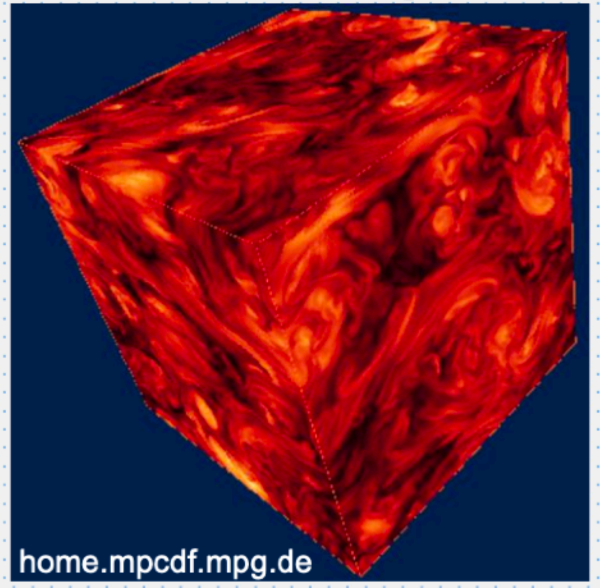
Bubble Collisions

fluid kinetic energy



Sound Waves

turbulent fluid + magnetic field

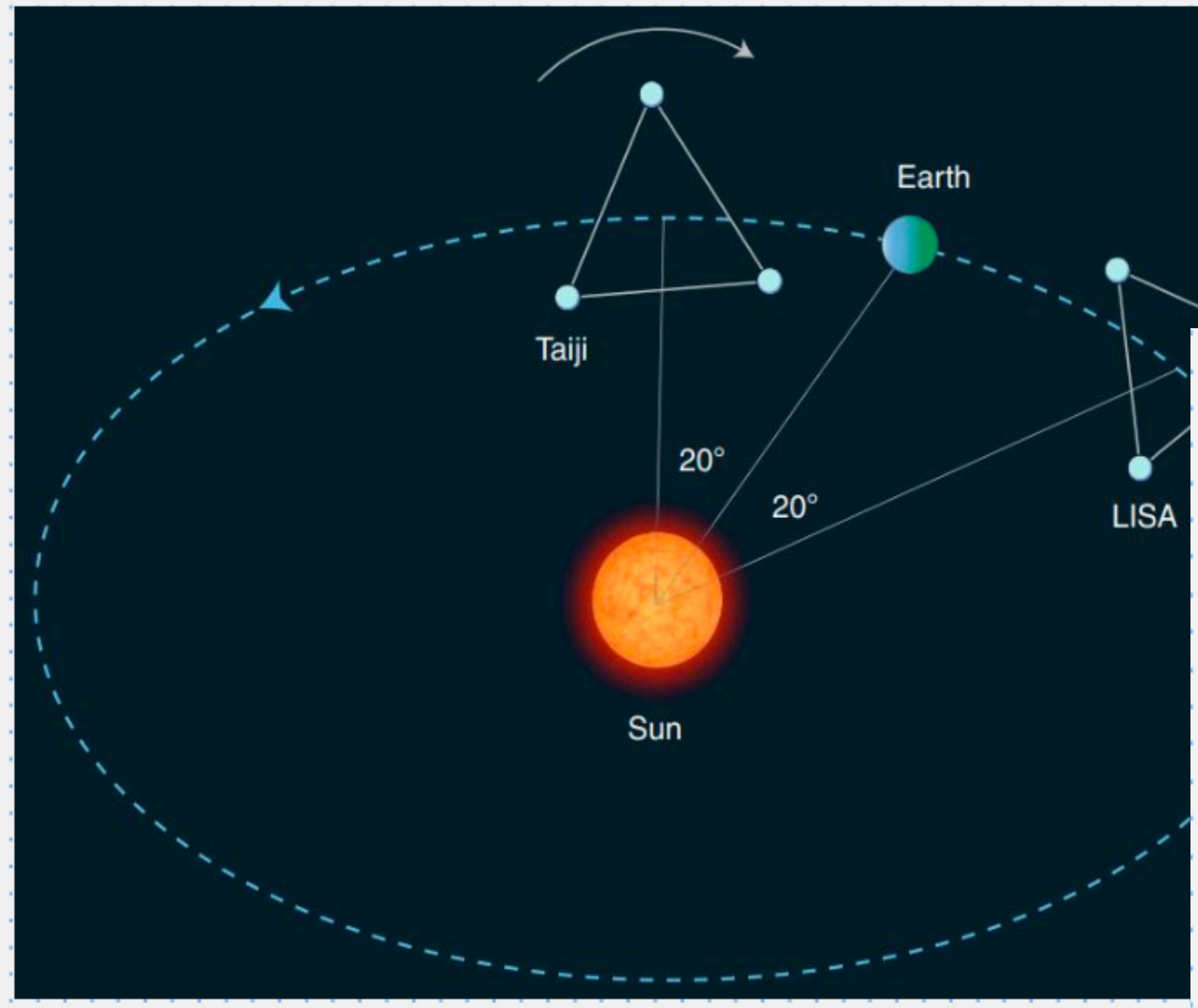


Magnetohydrodynamic Turbulence

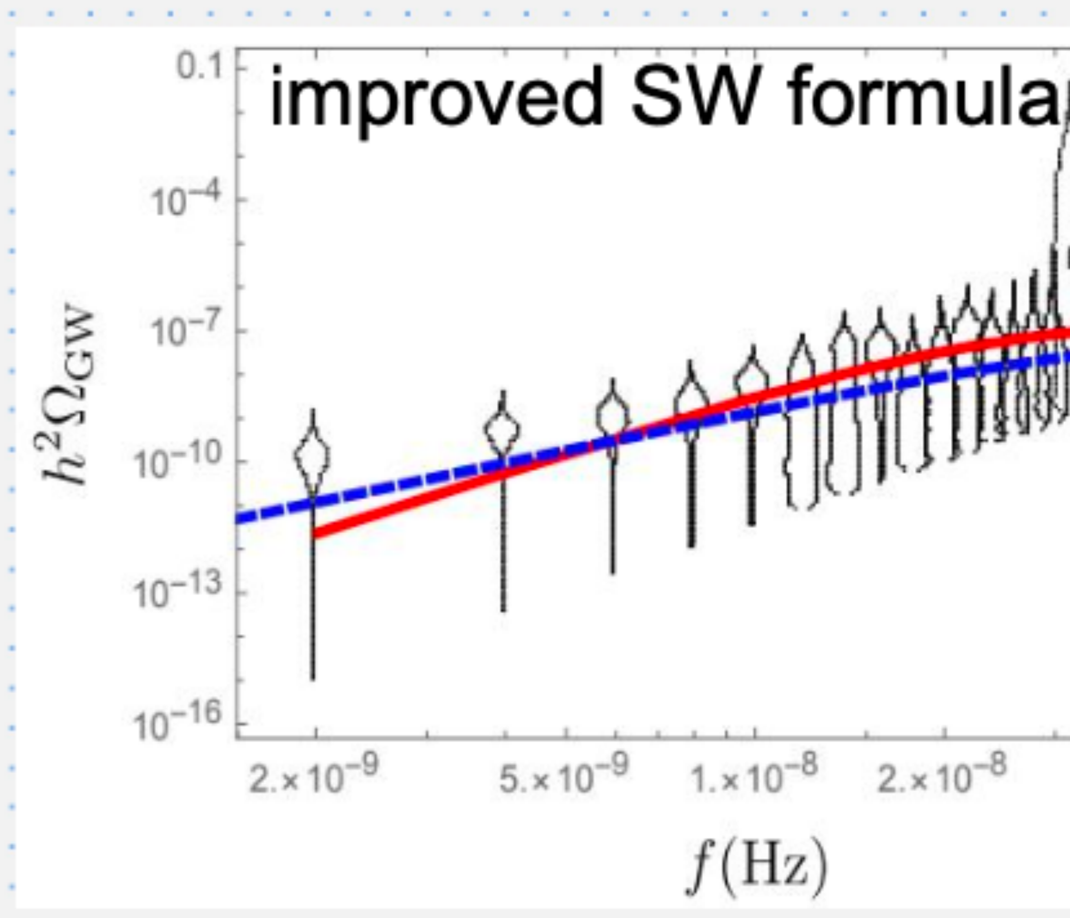
$$h^2\Omega_{\rm sw}(f) = 2.65\times10^{-6}\left(\frac{100}{g_*}\right)^{\frac{1}{3}}\left(\frac{H_*}{\beta}\right)\left(\frac{\kappa_{\rm sw}\alpha}{1+\alpha}\right)^2 v_w S_{\rm sw}(f)\Upsilon(\tau_{\rm sw})$$

HG, Sinha, Vagie, Wh
JCAP [2007.08537]

The LISA–Taiji network

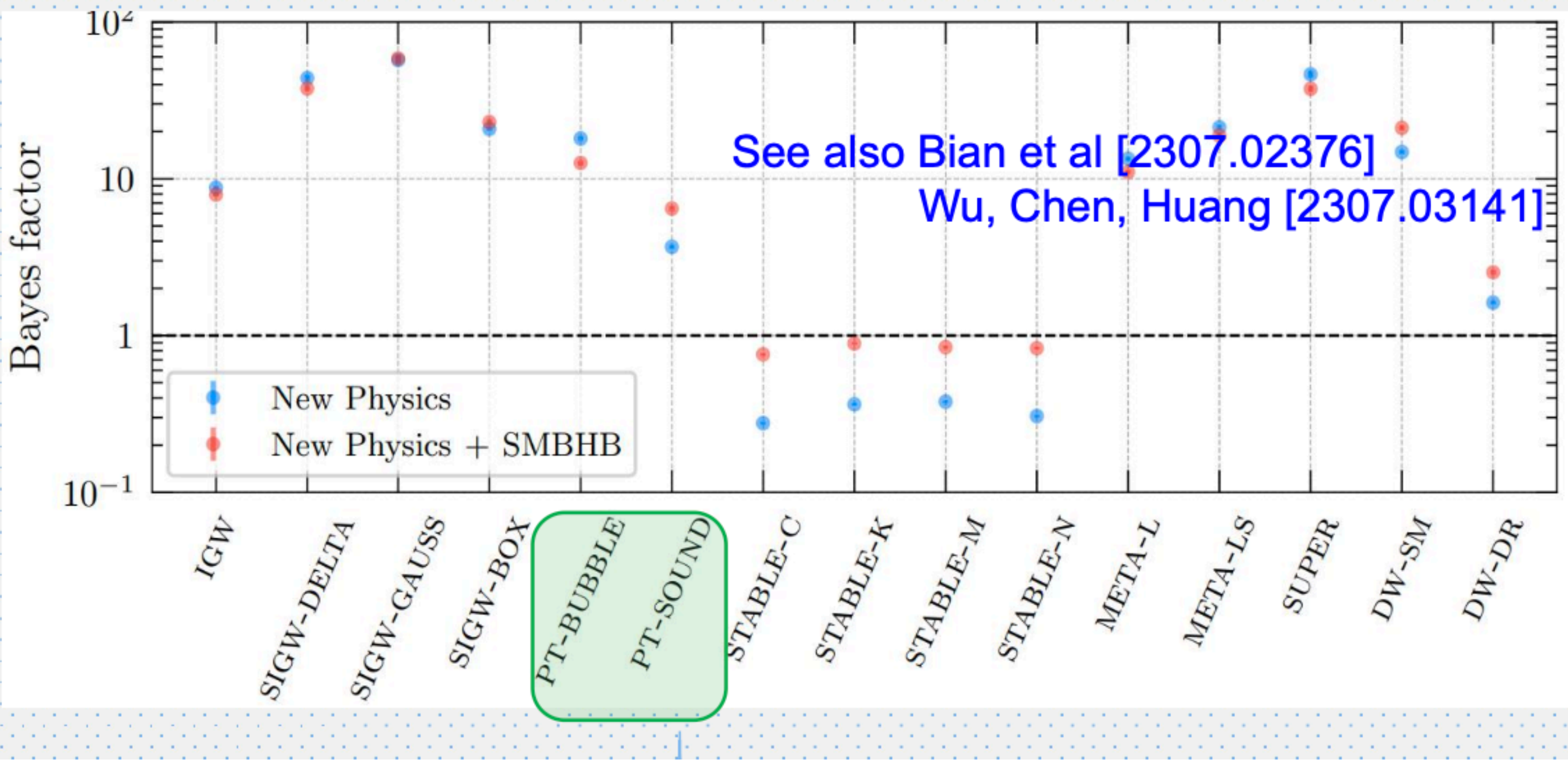


Ruan, Liu, Guo, Wu, Cai, Nature Astron [2002
Cai et al [2305.04551]



al, HG ..[2307.02

NANOGrav-15等PTA数据如何解释?



See also Bian et al [2307.02376]
Wu, Chen, Huang [2307.03141]

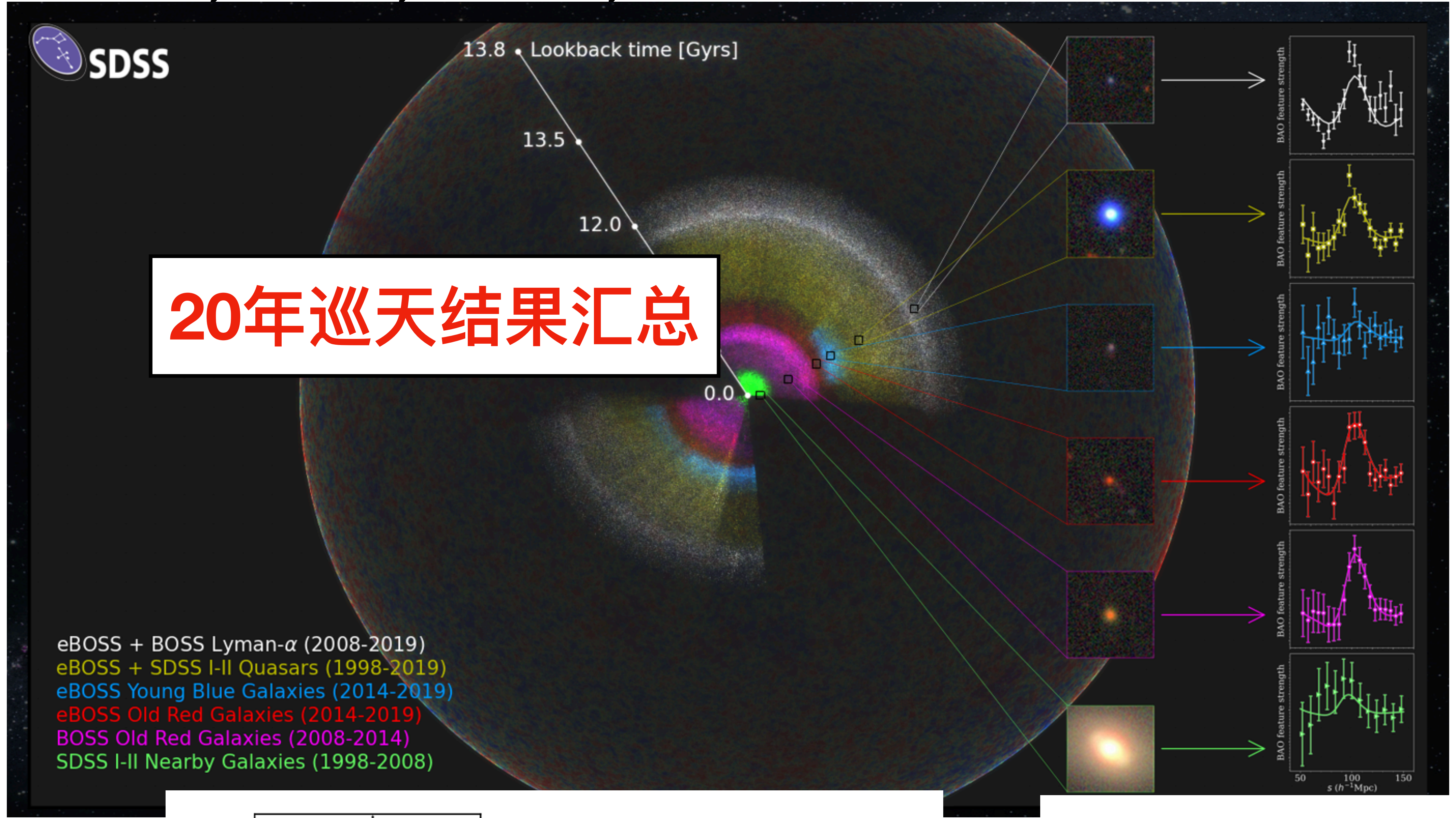
直接用理论能谱拟合数据

Cosmological implications of large galaxy surveys

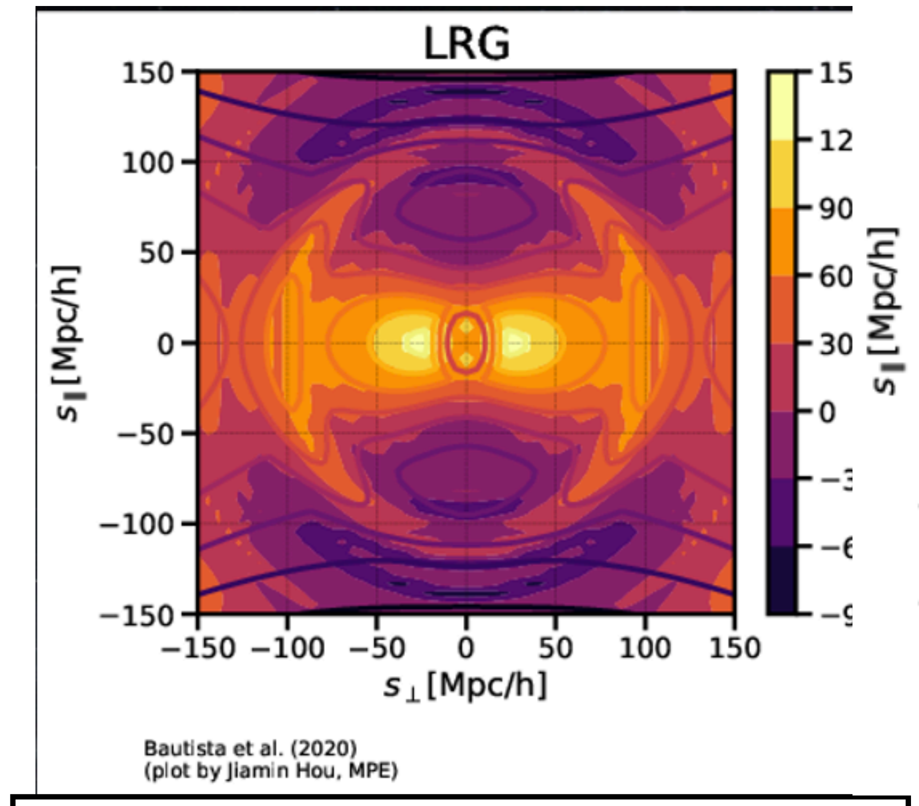
Multiple cosmological probes:
CMB, SNe, GWs, **LSS**

galaxy surveys →

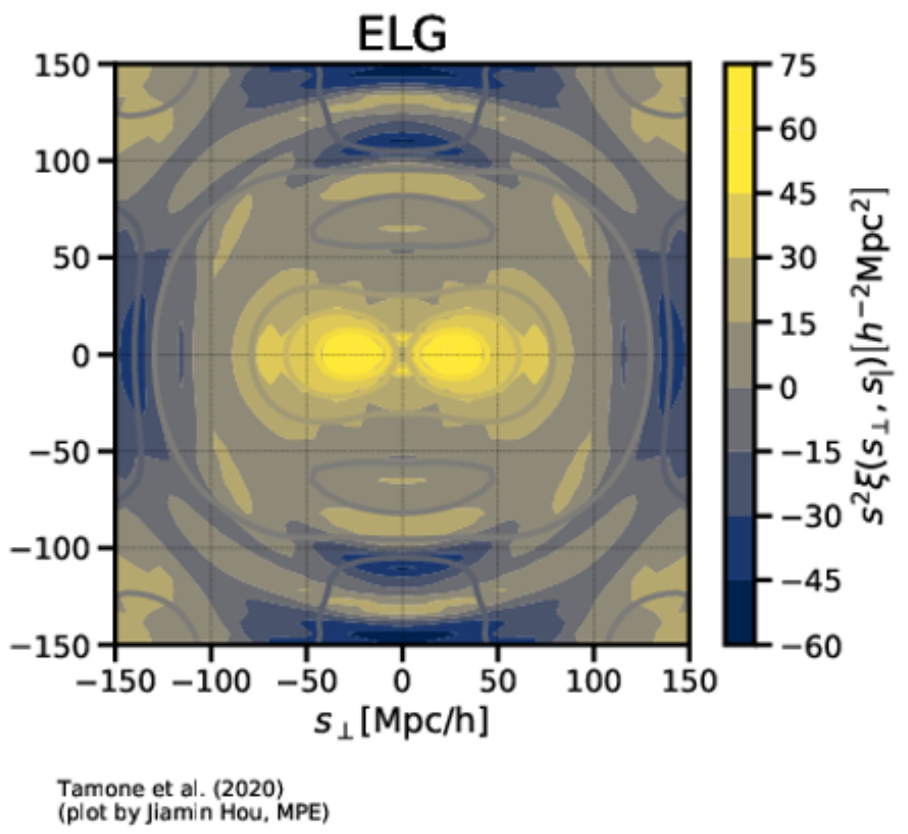
Break degeneracy between
Dark Energy and Modified Gravity



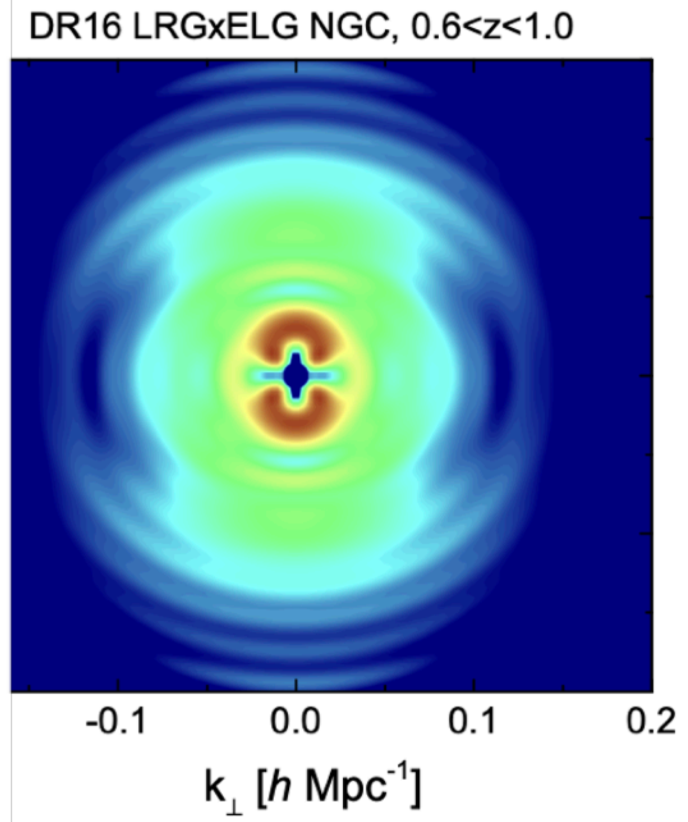
20年巡天结果汇总



Bautista et al. (2020)
(plot by Jiamin Hou, MPE)

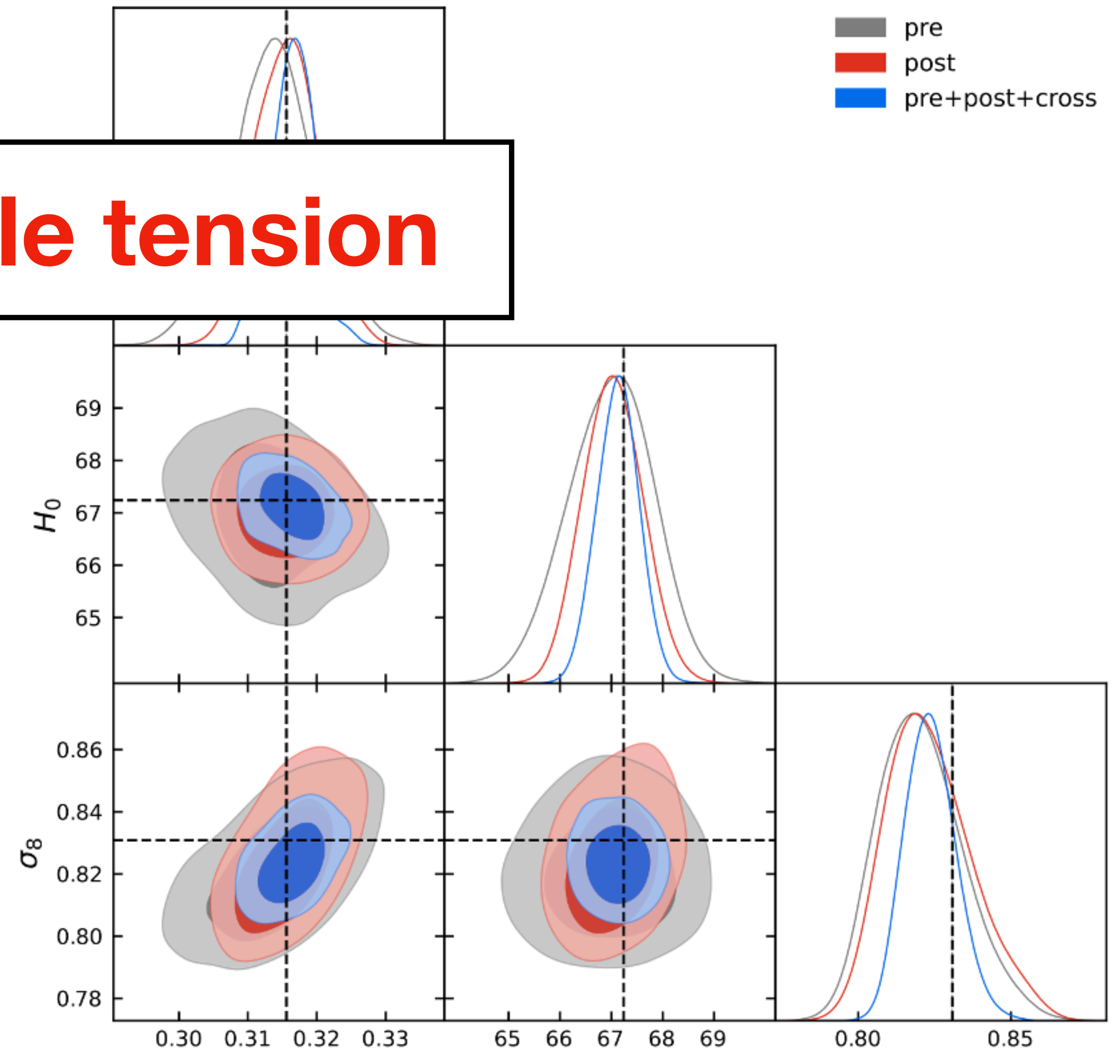


Tamone et al. (2020)
(plot by Jiamin Hou, MPE)

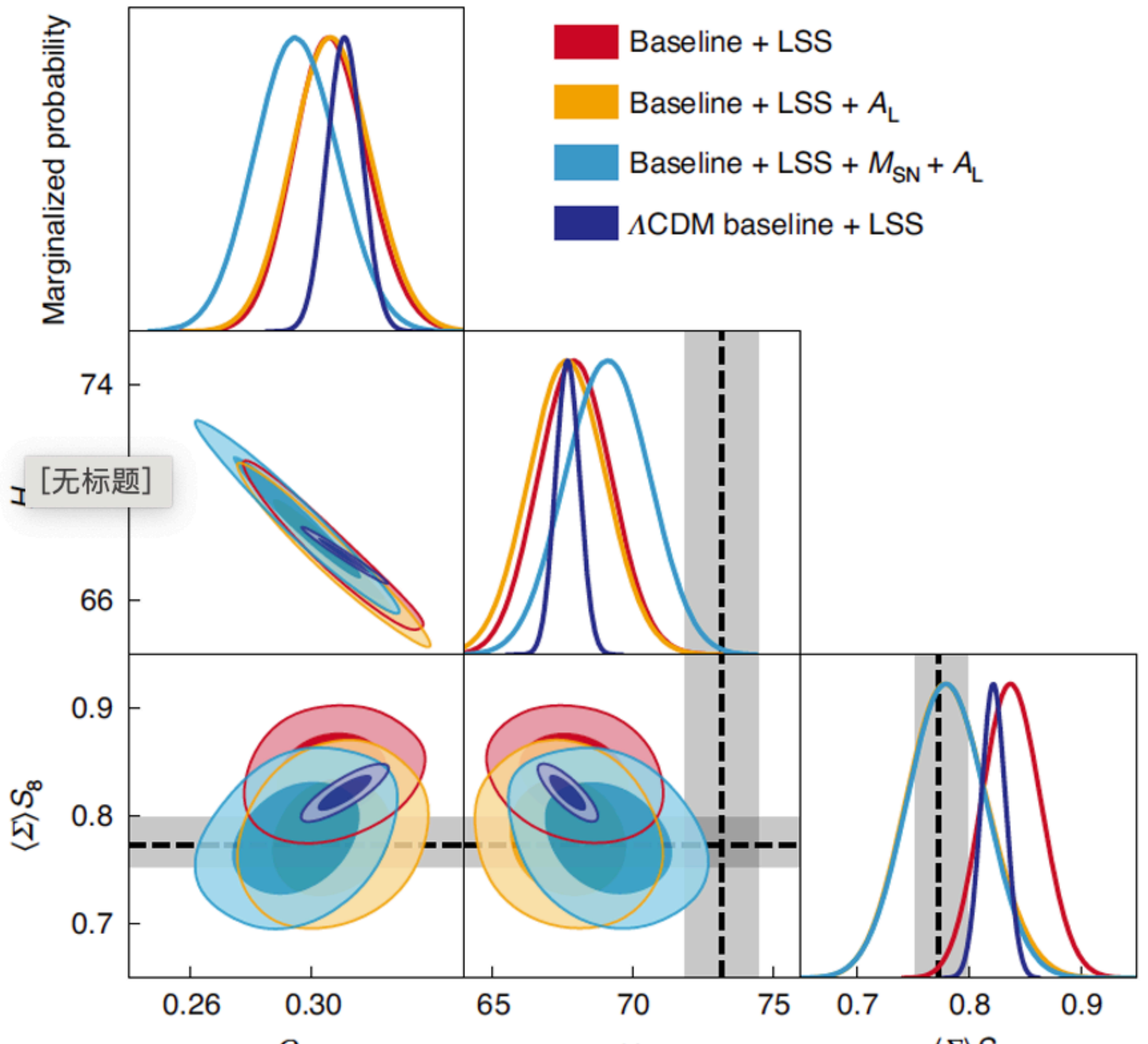


Luminous Red Galaxies (LRGs)
$0.6 < z < 1.0$, $z_{\rm eff} = 0.77$

Emission line Galaxies (ELGs)
$0.6 < z < 1.1$, $z_{\rm eff} = 0.845$



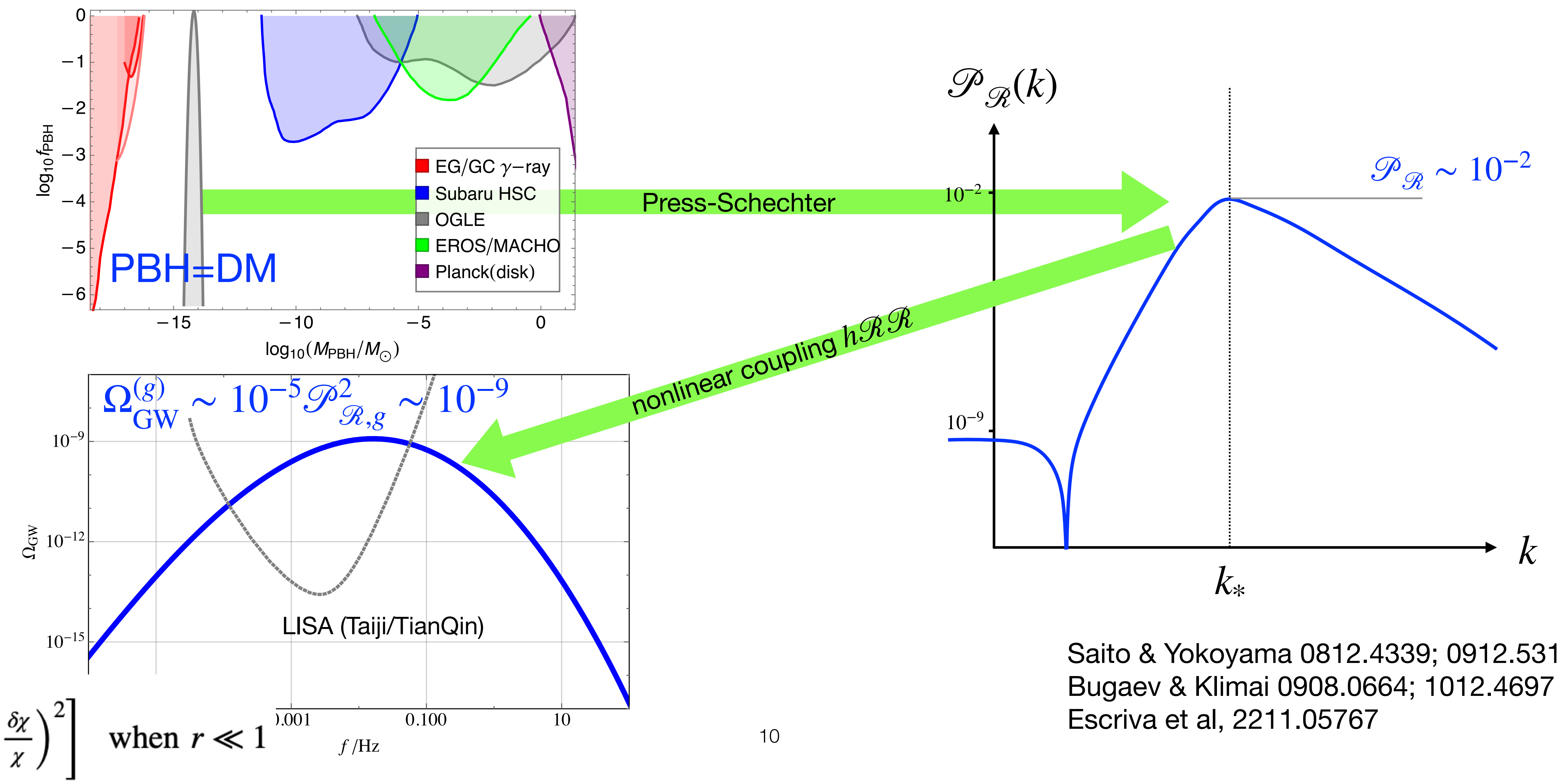
Hubble tension



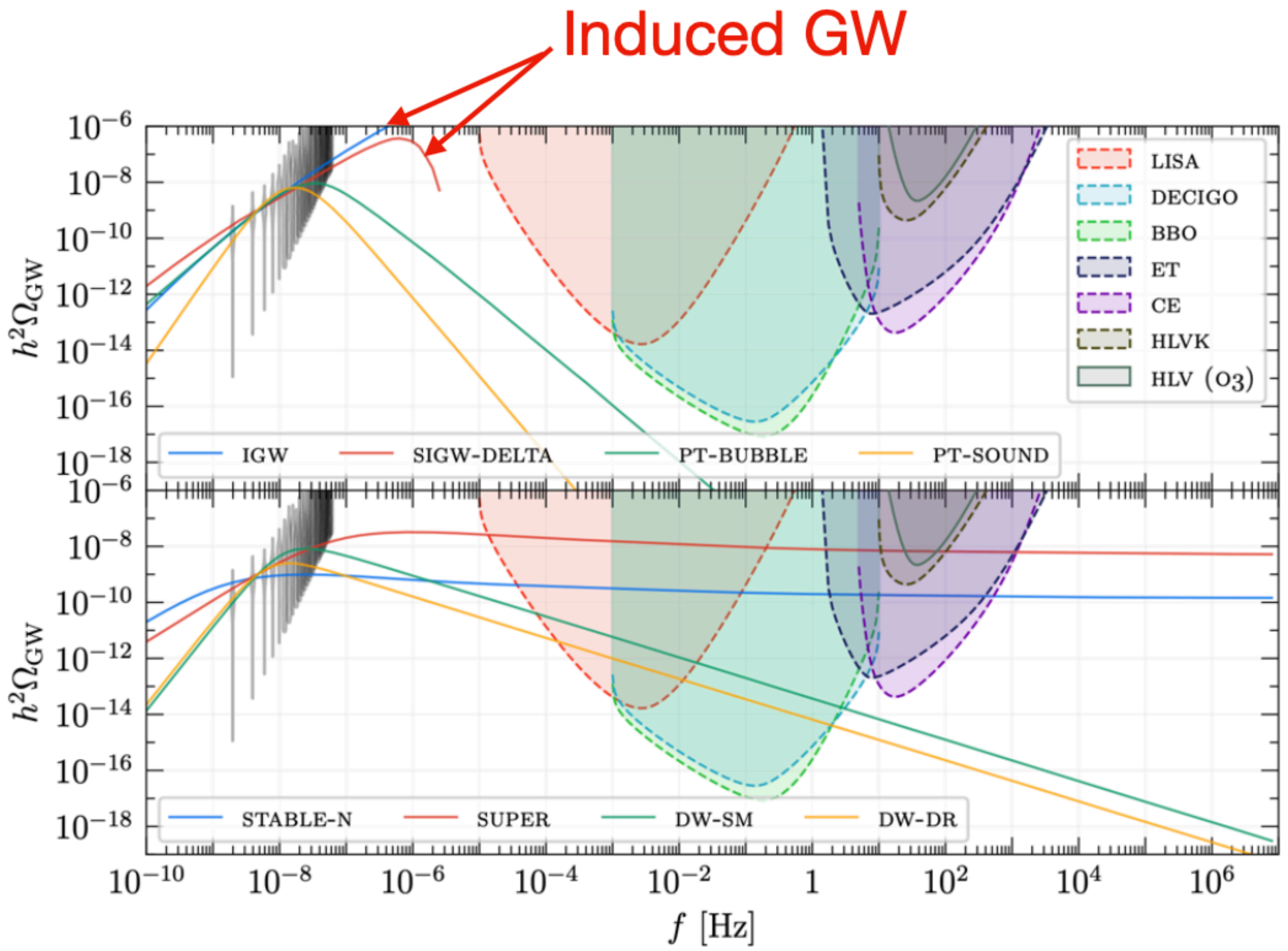
A multi-tracer analysis was performed for LRGs and ELGs, and a RSD signal is detected at 4 sigma in the cross-power spectrum;

Non-Gaussianity in the primordial black hole formation

PBH-IGW crosscheck



Saito & Yokoyama 0812.4339; 0912.5317
Bugaev & Klimai 0908.0664; 1012.4697
Escriva et al, 2211.05767

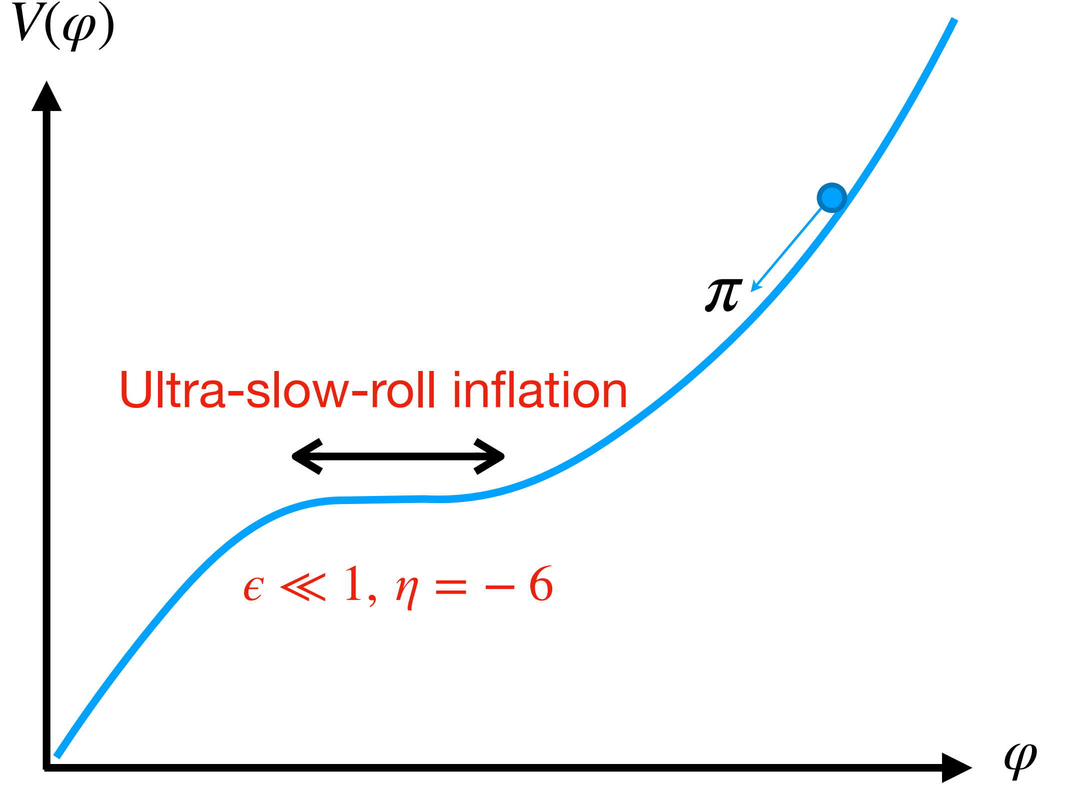


$$\zeta = \zeta(\delta\chi/\chi) \longrightarrow \begin{cases} \frac{r}{3}\left[2\frac{\delta\chi}{\chi} + \left(\frac{\delta\chi}{\chi}\right)^2\right] & \text{when } r \ll 1 \\ \frac{2}{3}\ln\left|1+\frac{\delta\chi}{\chi}\right| & \text{when } r \sim 1 \end{cases}$$

大曲率导致非高斯

超慢滚inflation模型中的非高斯性

$, \eta) \sim \mathcal{O}(1)$



$$\mathscr{R} = \delta N = N_{,\varphi}\delta\varphi + \frac{1}{2}\boxed{N_{,\varphi\varphi}}\delta\varphi^2 + \cdots$$

$$+N_{,\pi}\delta\pi + \frac{1}{2}N_{,\pi\pi}\delta\pi^2 + \cdots$$

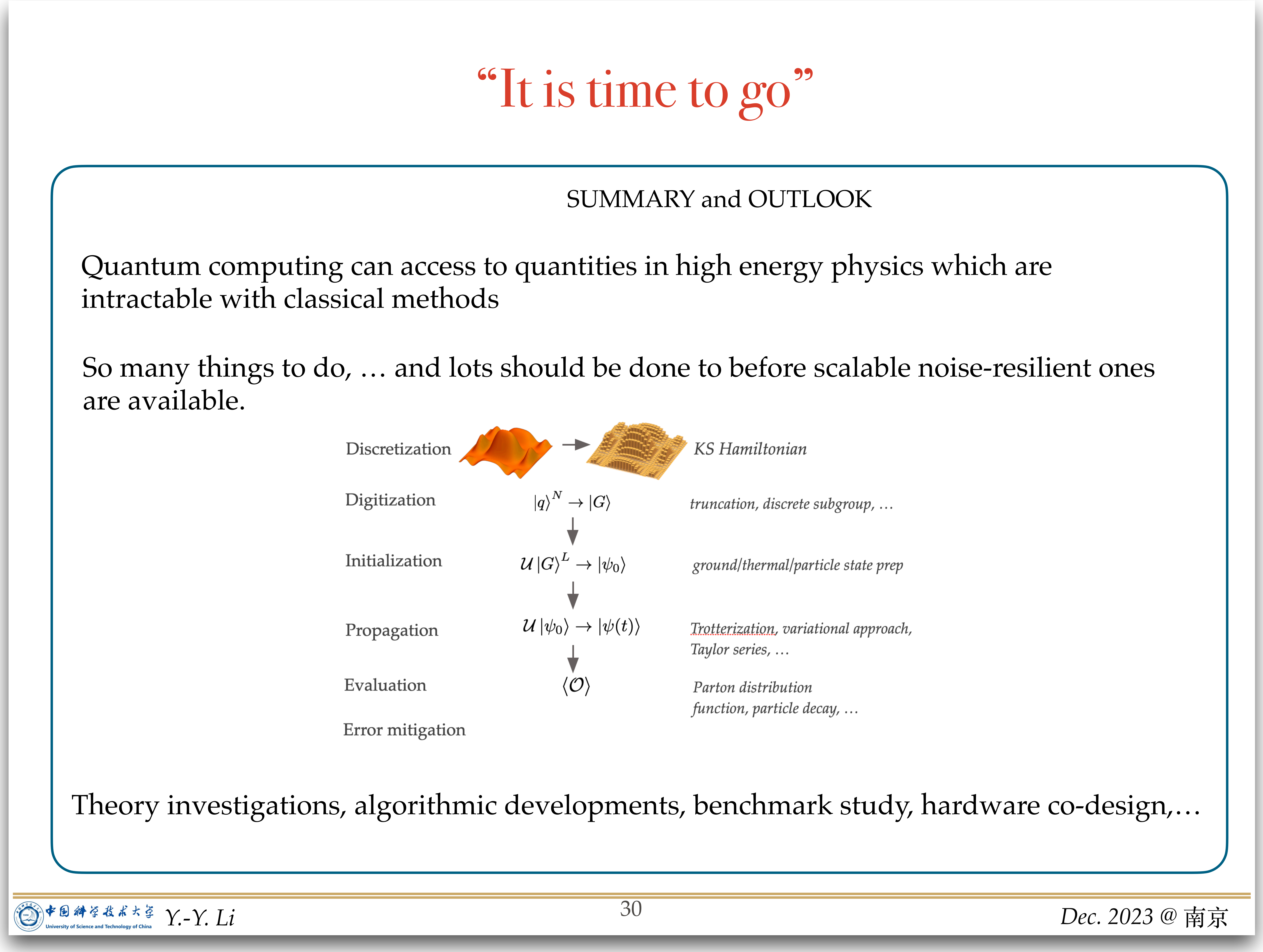
(For USR) $= -\frac{1}{3}\ln\left(1+\frac{3\delta\varphi}{\pi_*}\right).$

$$\left(f_{\rm NL} = \frac{5}{2}, \quad g_{\rm NL} = -\frac{25}{3}, \quad \cdots\right)$$

Namjoo, Firouzjahi, Sasaki, 1210.3692
Chen, Firouzjahi, Komatsu, Namjoo, Sasaki, 1308.5341
Cai, Chen, Namjoo, Sasaki, Wang, Wang, 1712.09998
Biagetti, Franciolini, Kehagias, Riotto, 1804.07124

Quantum Computing for High Energy Physics

李英英的报告



“It is time to go”

SUMMARY and OUTLOOK

Quantum computing can access to quantities in high energy physics which are intractable with classical methods

So many things to do, … and lots should be done to before scalable noise-resilient ones are available.

Discretization → *KS Hamiltonian*

Digitization $|q\rangle^N \rightarrow |G\rangle$ *truncation, discrete subgroup, …*

Initialization $\mathcal{U}\,|G\rangle^L \rightarrow |\psi_0\rangle$ *ground/thermal/particle state prep*

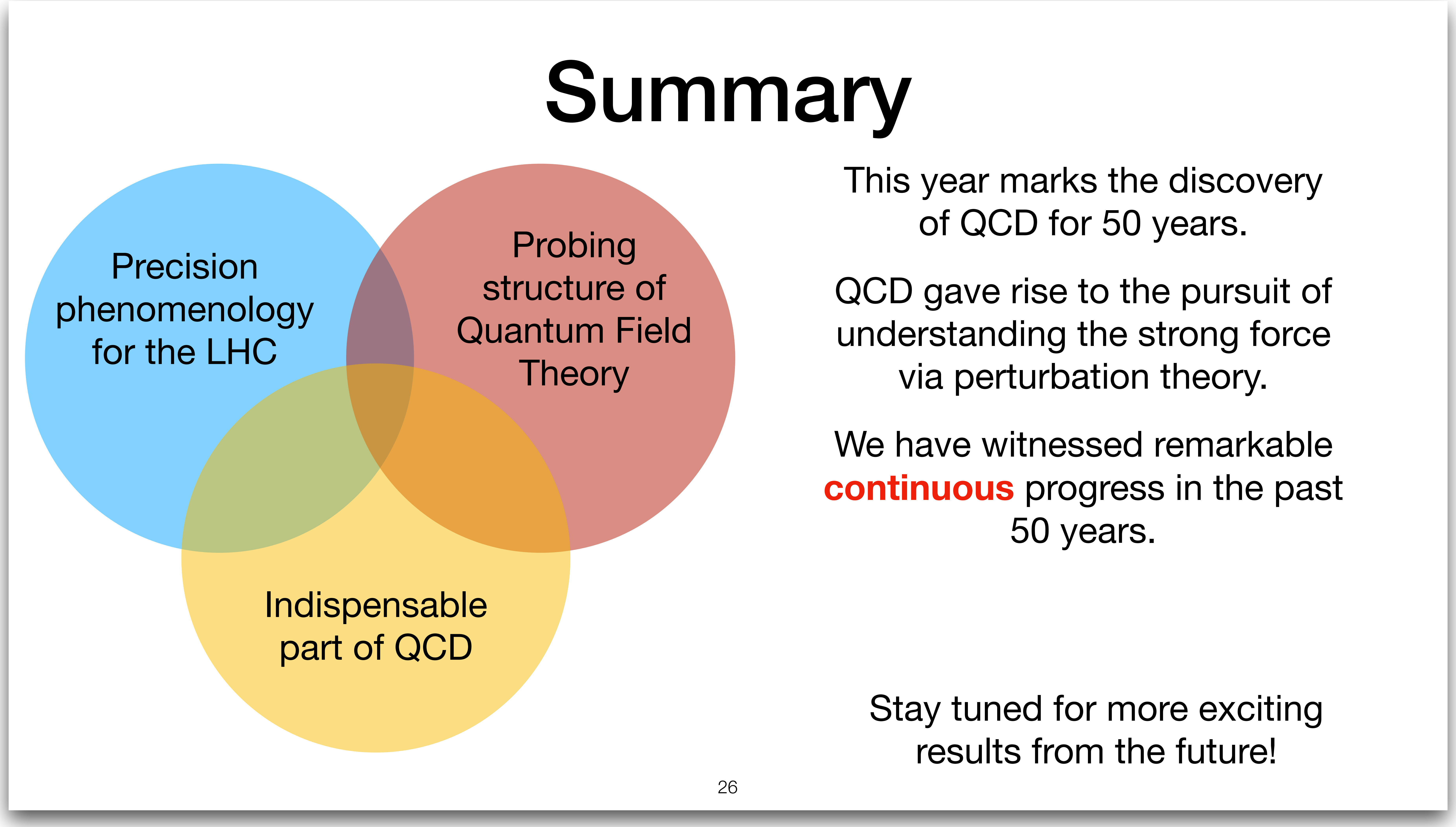
Propagation $\mathcal{U}\,|\psi_0\rangle \rightarrow |\psi(t)\rangle$ *Trotterization, variational approach, Taylor series, …*

Evaluation $\langle\mathcal{O}\rangle$ *Parton distribution function, particle decay, …*

Error mitigation

Theory investigations, algorithmic developments, benchmark study, hardware co-design,…

中国科学技术大学 University of Science and Technology of China *Y.-Y. Li* 30 *Dec. 2023* @ 南京



Summary

Precision phenomenology for the LHC

Probing structure of Quantum Field Theory

Indispensable part of QCD

This year marks the discovery of QCD for 50 years.

QCD gave rise to the pursuit of understanding the strong force via perturbation theory.

We have witnessed remarkable **continuous** progress in the past 50 years.

Stay tuned for more exciting results from the future!

48 parallel talks

Latest Dark Matter Results of the Pa. 奕 陶	Heavy neutrino and lepton number v Tong Li	Recent Dark Matter combination su. Ngoc Khanh Vu
Dark Matter Annihilation via Breit-Wi 杰 盛	Type II seesaw Leptogenesis 成[illegible]韩	Search for Higgs Boson Pairs in the Yanlin Liu
Sterile Neutrino Portal Dark Matter w Ang Liu	Disentangling the Neutrino Electrom Shao-Feng Ge	Precise mea[illegible] of SM EWK Z Danning Liu
Probing Inelastic Dark Matter at the . 致廷 卢	Phenomenology of Heavy Neutral Ga… Honglei LI	Discriminating Higgs production me Prof. Bin Yan
Axion-like Particle Dark Matter and t. Wei Chao	Complementary LHC searches for U. Gang LI	Electroweak corrections to double . 环宇 毕
Freeze-in bino dark matter in high sc Peiwen Wu	Single Transverse Spin Asymmetry a Xin-Kai Wen	NNNLO QCD predictions for heavy . Yefan Wang
Probe axion-like particles at the elec Hongkai Liu	The Effective Operator Basis of the . 浩 孙	Soft photon [illegible] in QCD with m Yao Ma

Detecting Quadratically Coupled Ultr Mr Yuanlin Gong	Probing the four-fermion operators v Hao-Lin Wang	Search for T-odd mechanisms beyo Boxing Gou
Non-perturbative Effect on DM Electr… 锦汉 梁	On-Shell C[illegible] Fi Ming-Lei Xi[illegible]	Optimizing Fictitious States for Bell Kun Cheng
Feeble Sterile Neutrino Portal Dark M 昂 刘	Probing levitodynamics with multi-st Wenyu Wang	Long-lived Se[illegible]r-like L Yan Luo
Z Portal to the Dark Sector Through . Mr Xuhui Jiang	利用LHAASO伽马暴数据限制洛伦兹对. 玉明 杨	Probing quirk signal at the LHC far . Jinmian Li
Broadband Search Strategies throug Xiaolin Ma	Dynamical realization of the small fie Hexu Zhang	Search for nearly-degenerate higgsi 航 周
Dark ma[illegible] from U(1) hid… Wan-Zh[illegible]	Nonanalyticity and On-Shell Factoriz 哲涵 秦	CPV double-aligned 2HDMs at the L MICHIHISA TAKE…
Dark matter from hot big bang black Ningqiang Song	Bootstrapping One-loop Inflation Co Hongyu Zhang	Global Symmetries and Effective Po Dr Changlong Xu
Neutrino CP Measurement in the Pre Chui-Fan Kong	Gravitational w[illegible] do… 晨 杨	Testing Bell inequalities in W boson Mr Qi Bi
用机器学习方法探测对撞机中的重狄拉. Jie FENG	First-order phase transition during in… 铂烨 苏	Alternative Froggatt-Nielsen like me… Fei Wang

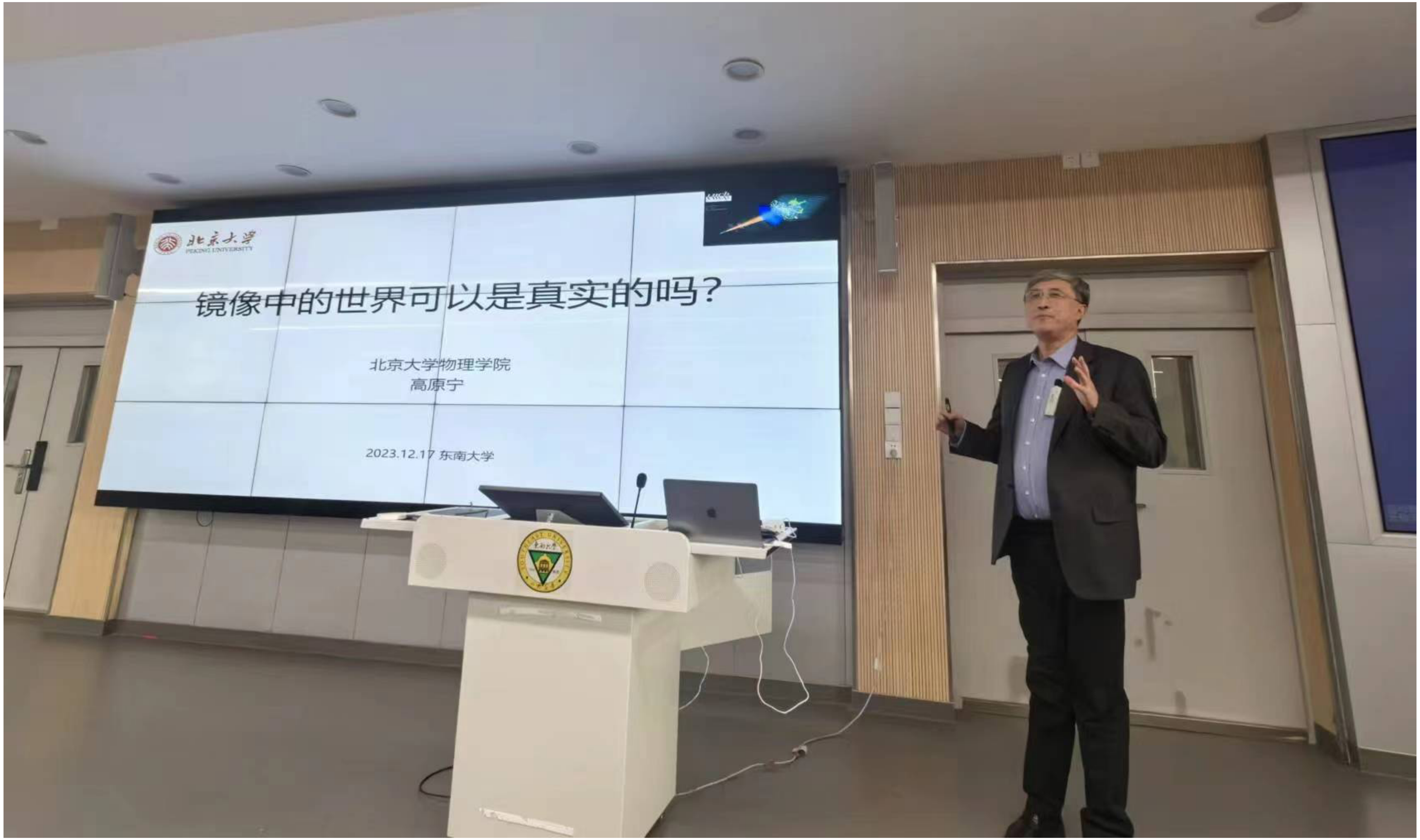
分会场报告

- 陶奕，PlandaX-4T, 暗物质电磁性质的测量，e-DM散射最强限制
- 晁伟，Majoron DM and leptogensis in global U(1)_L,
- 宋宁强，纯引力DM，但是对Inflation能标要求很高；额外维可以显著降低能标
- 冯万哲，hidden U(1)里的暗物质，Hidden sector全自由度的Boltzmann演化
- 葛韶锋，中微子电磁性质诱导的原子到中微子对的辐射
- 文新锴，Spin Asymm. vs SMEFT Dipole Operators
- 王雯宇，Levitodynamics in optical levitation experiment
- 李刚，0vββ EFT & UV completion
- 孙浩，Basis in Higgs EFT
- 岩斌，通过Jet charge区分Higgs产生机制
- 李金勉, quirk particle @ FASER
- Kun Cheng, t-tbar中的量子纠缠
- 毕琪, W-W pair中的量子纠缠

还有很多精彩的报告……

很抱歉，由于研究背景所限，不能做很好的总结

Public lecture



精彩瞬间


Bell inequality
• Quantum Theory or Realistic Local Theory ?
➡ Bell inequality
1964: John Bell at CERN sharpened the formulation of the Einstein Podolsky Rosen experiment in terms of Bell inequalities
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生日快乐
HAPPY
EVERYDAY

感谢大家的参与！

下次再见！