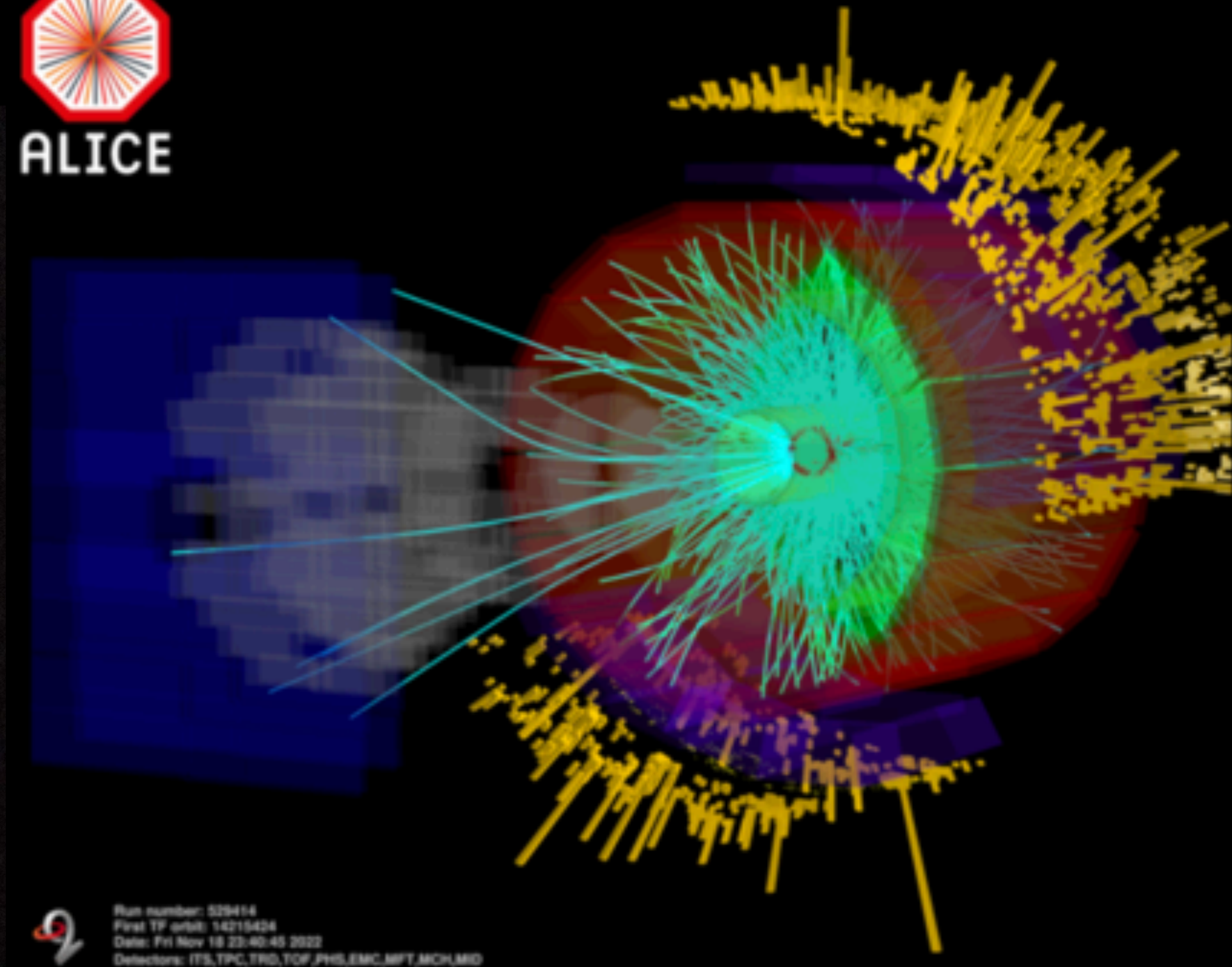
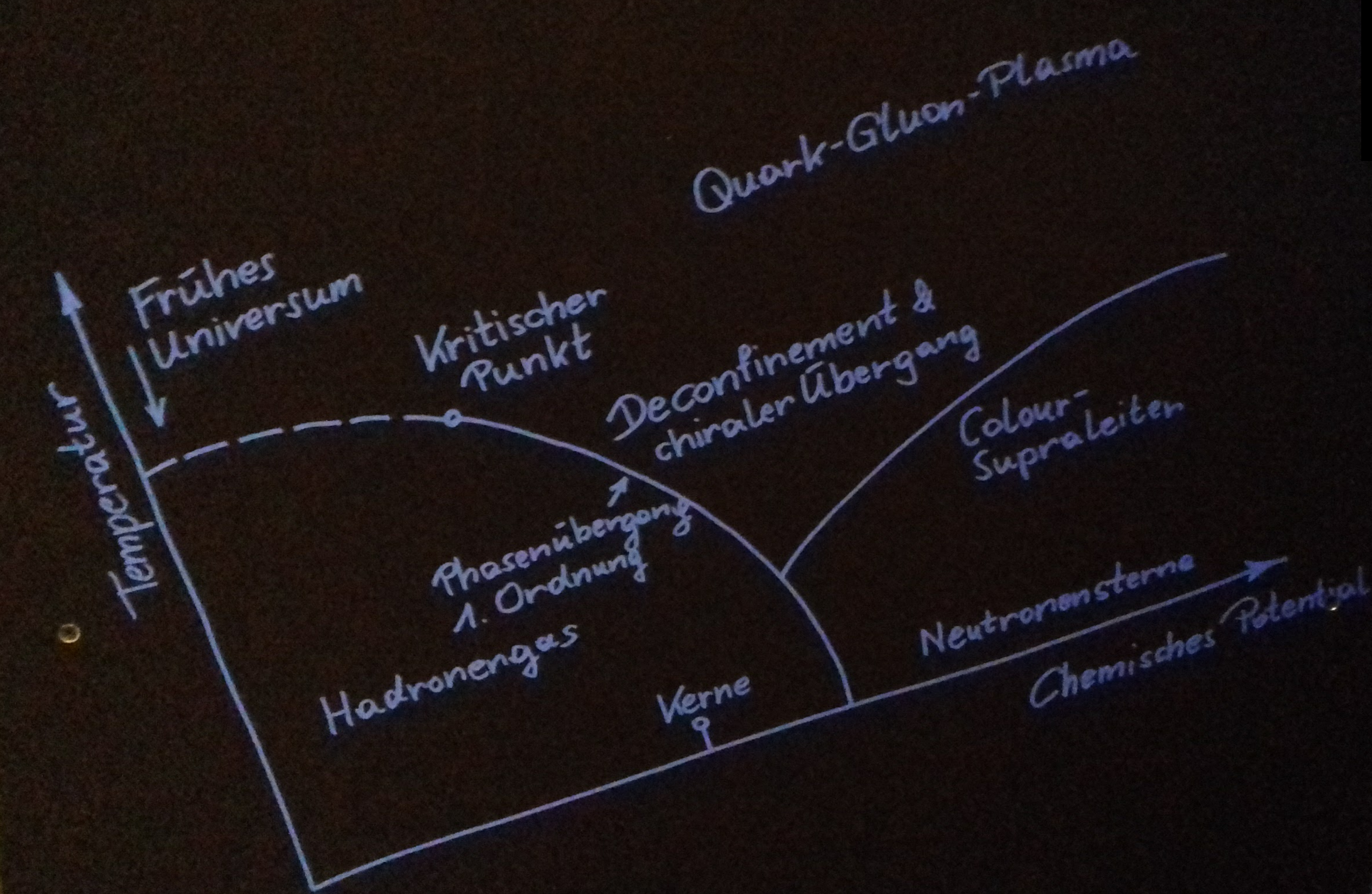


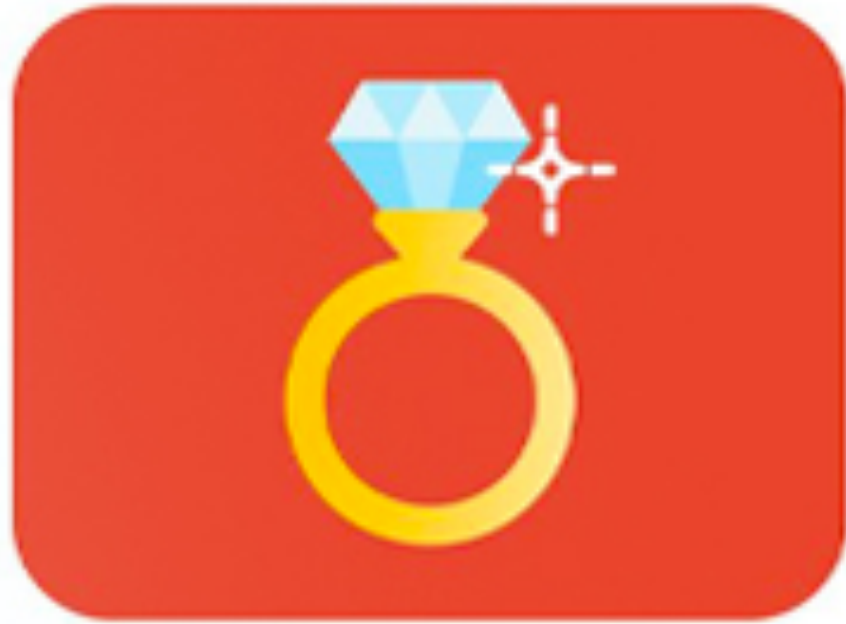


Introduction of ALICE experiment

张晓明 华中师范大学

Physical status

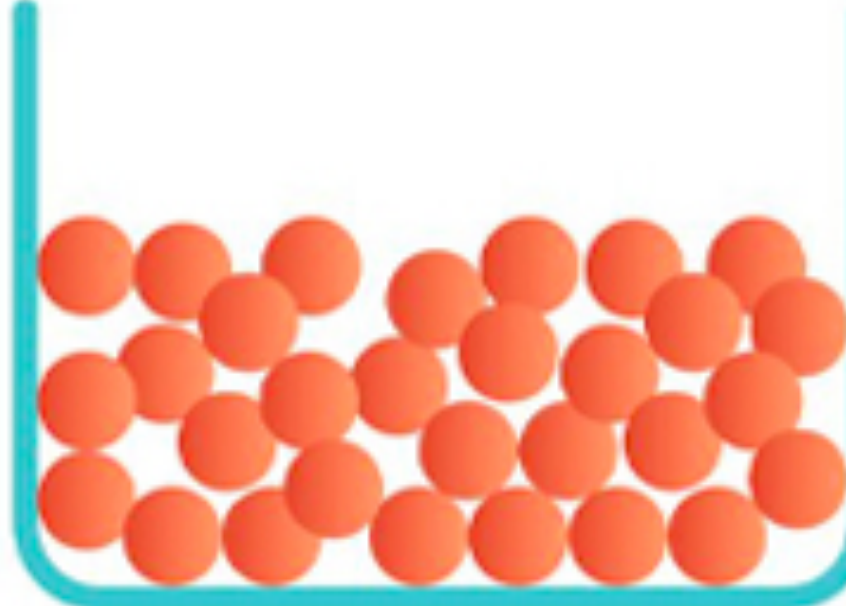
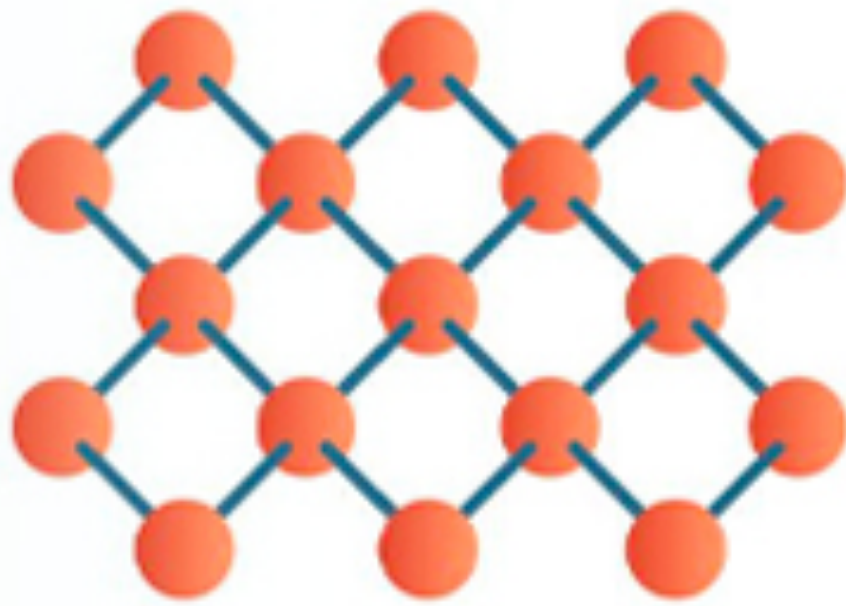
Diamond



Juice



Clouds



SOLID

LIQUID

GAS

Melting



Freezing



Vaporization



Condensation



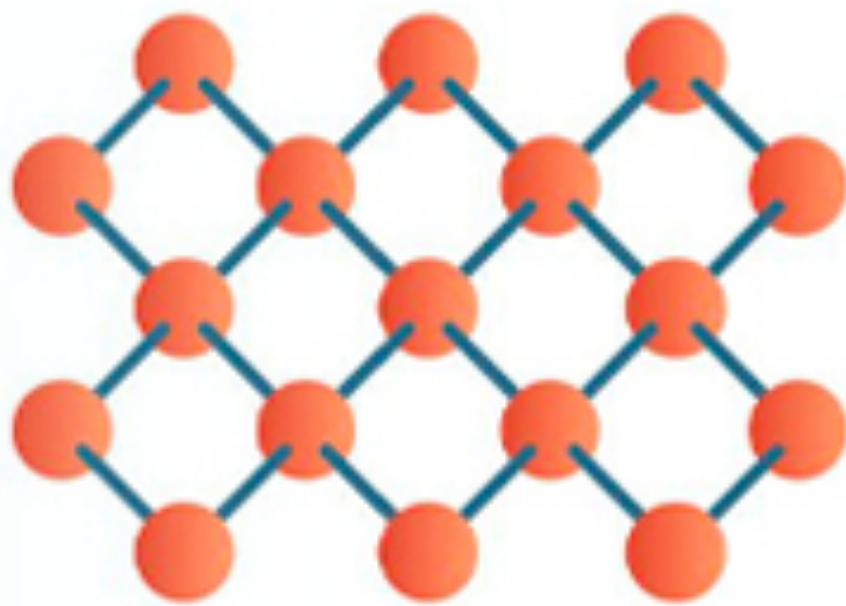
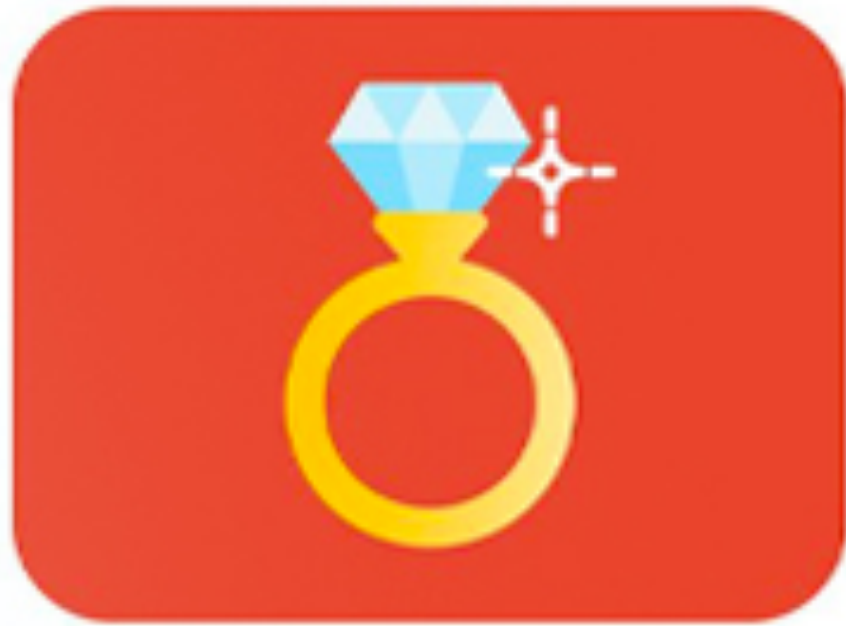
Energy
Temperature

Energy
Temperature

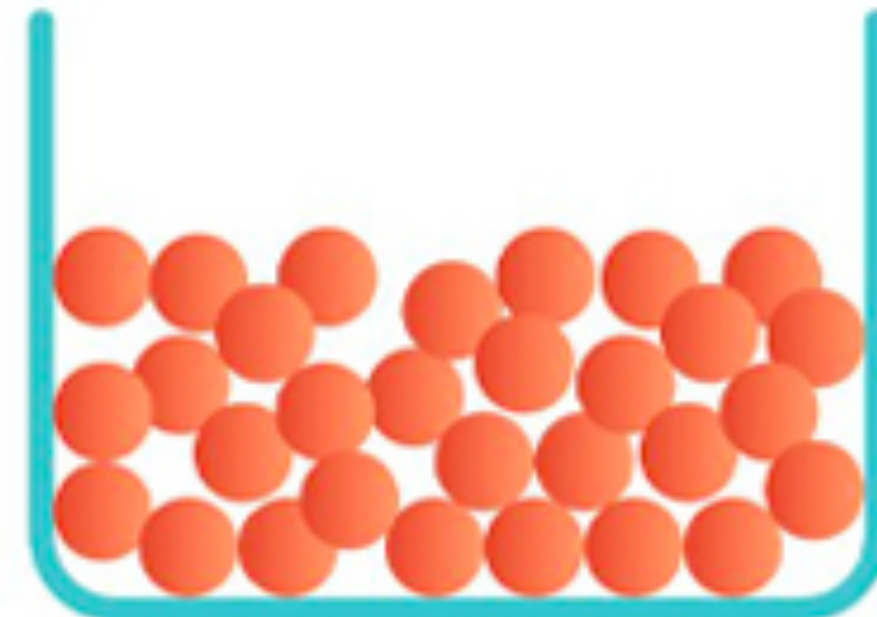
Physical status



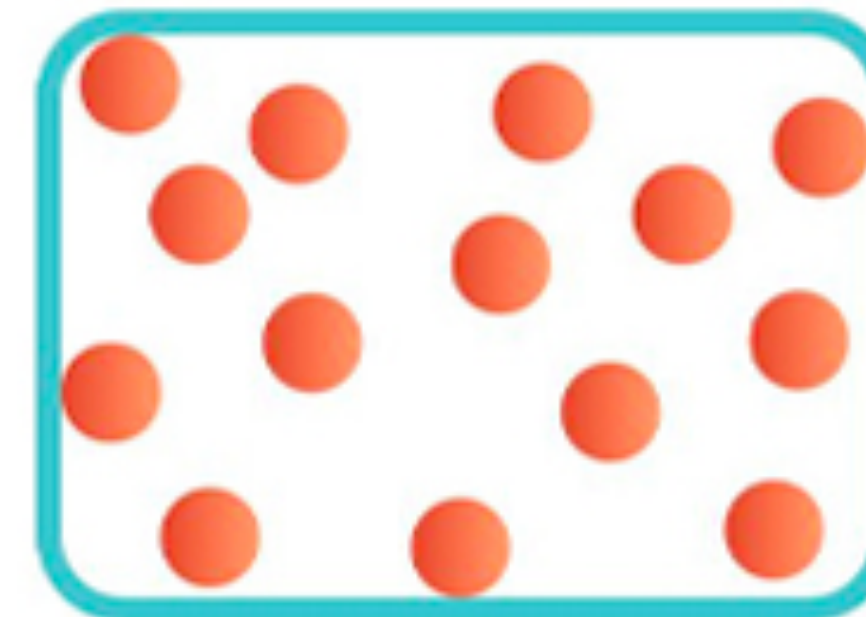
Diamond



Juice



Clouds



Ionized Neon Gas



SOLID

Melting



Freezing



LIQUID

Vaporization



Condensation



GAS

Ionization



Deionization



PLASMA

Energy
Temperature

Energy
Temperature

Energy
Temperature

...And higher temperatures?



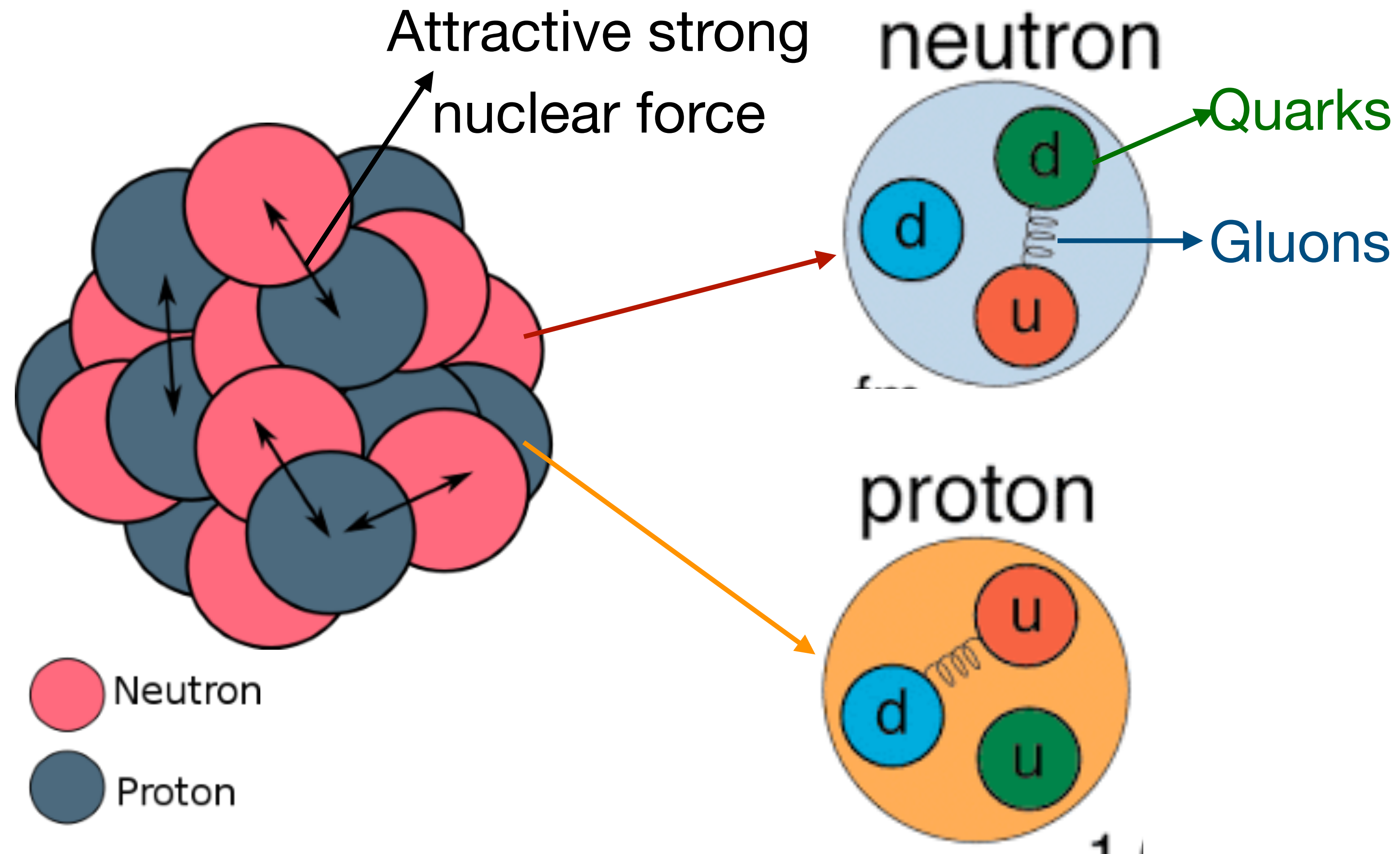
What will happen if
continuing heating
the matter?

Ionized Neon Gas

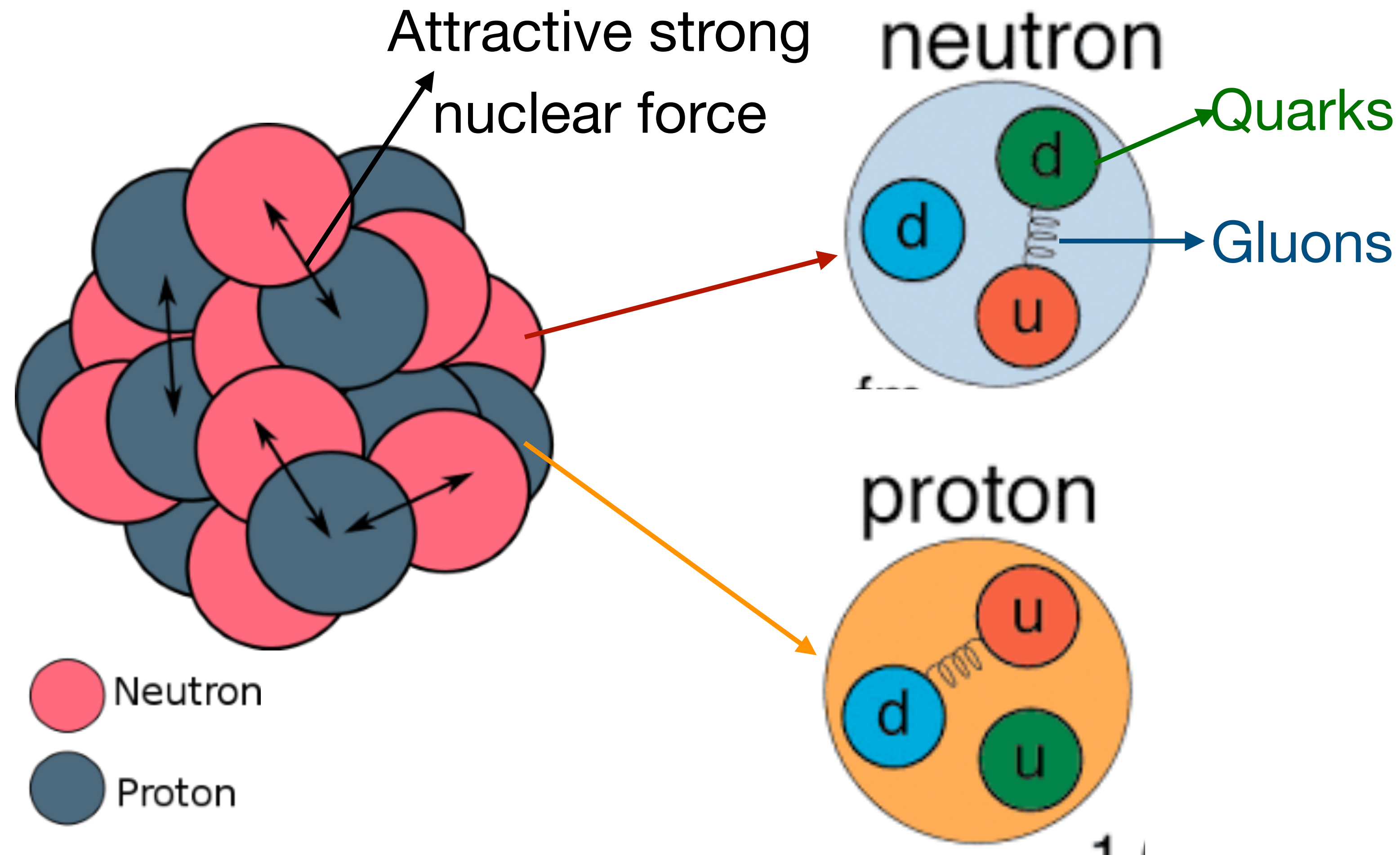


PLASMA

Strong force in nuclear

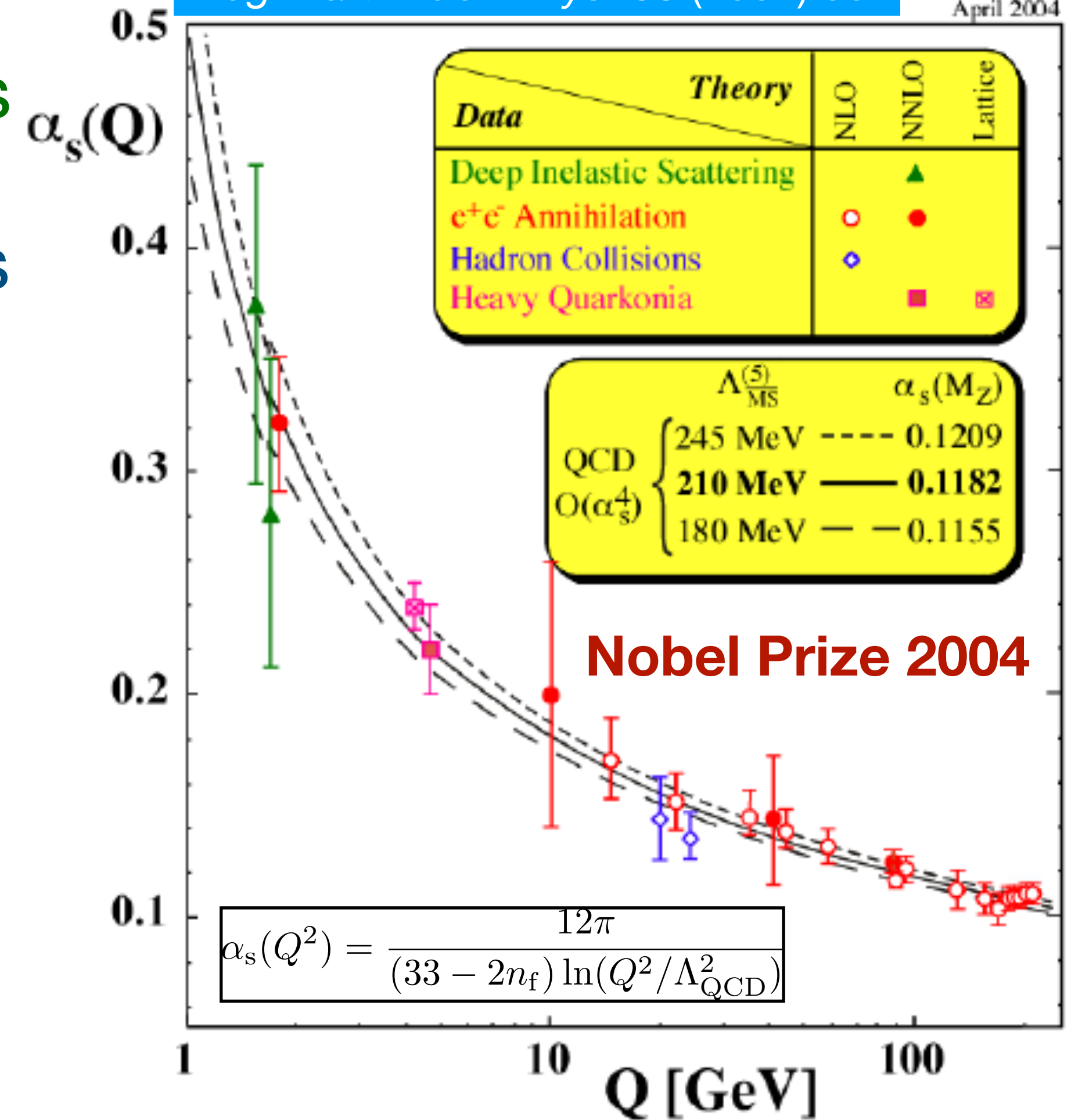


Strong force in nuclear



Prog. Part. Nucl. Phys. 58 (2007) 351

April 2004



Strong force in nuclear



RBRC-664

BROOKHAVEN
NATIONAL LABORATORY

BNL-77850-2007-CP

T. D. Lee: Relativistic Heavy Ion Collisions
and the Riken Brookhaven Center

L. McLerran and N. Samios

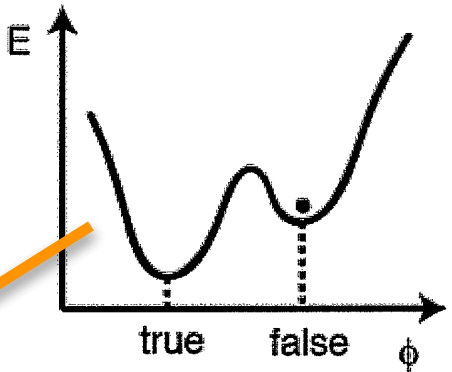
RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY 11973, USA
Physics Department, Brookhaven National Laboratory, Upton, NY 11973, USA

To appear in the
Proceedings of the T. D. Lee
80th Birthday Symposium, Beijing, China
November 24, 2006

March 2007

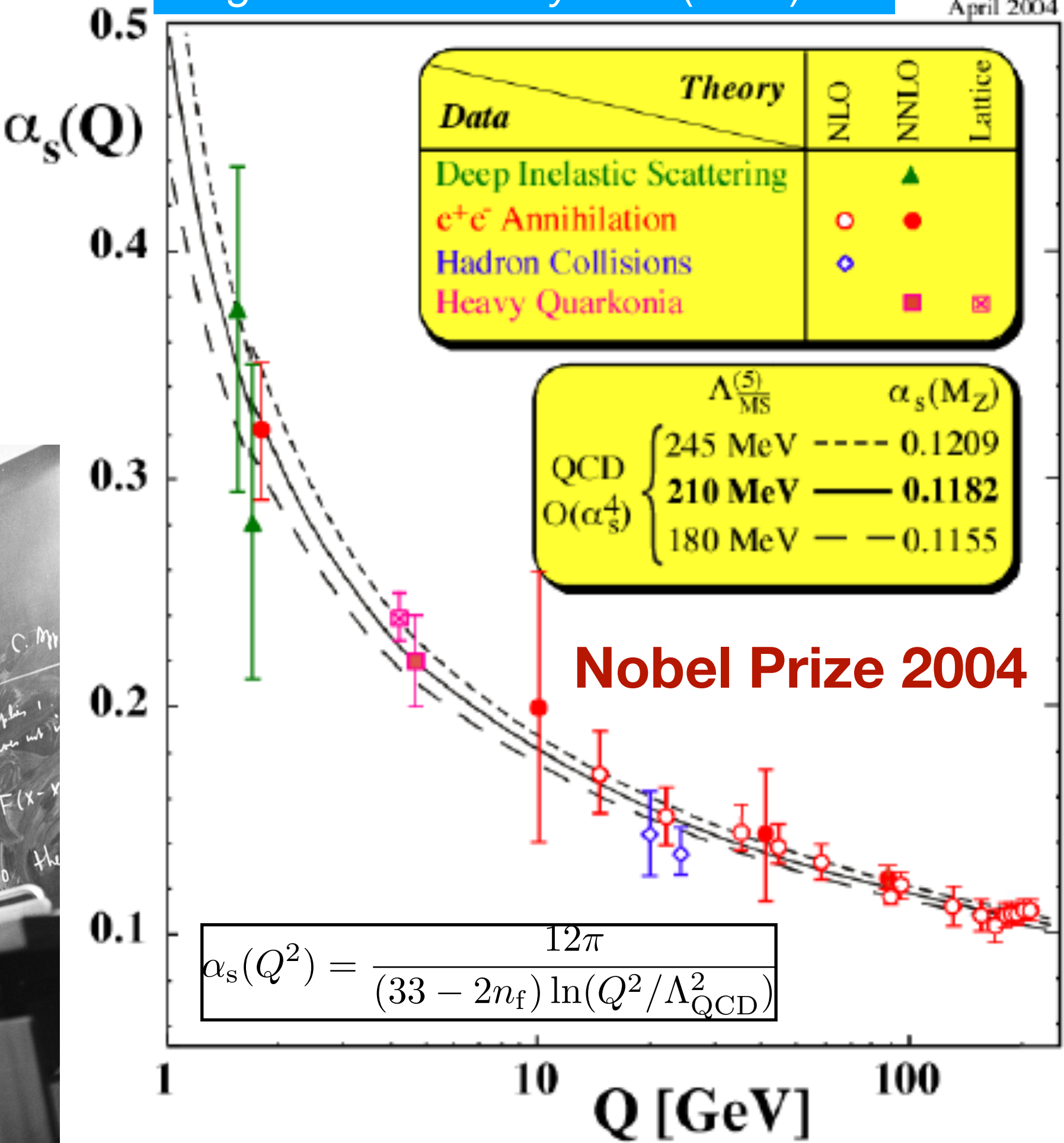
The idea that one could make new forms of matter on size scale large compared to microphysics size scales and that this might probe fundamental properties of matter at energy densities much larger than that of nuclear matter was born at this workshop. Prof. Lee described the possibility that our vacuum might be unstable with respect to another vacuum, characterized by the expectation value of a scalar field, the Lee-Wick matter.[2]. This

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-AC02-98CH10886 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes. This preprint is intended for publication in a journal or proceedings. Since changes may be made before publication, it may not be cited or reproduced without the author's permission.



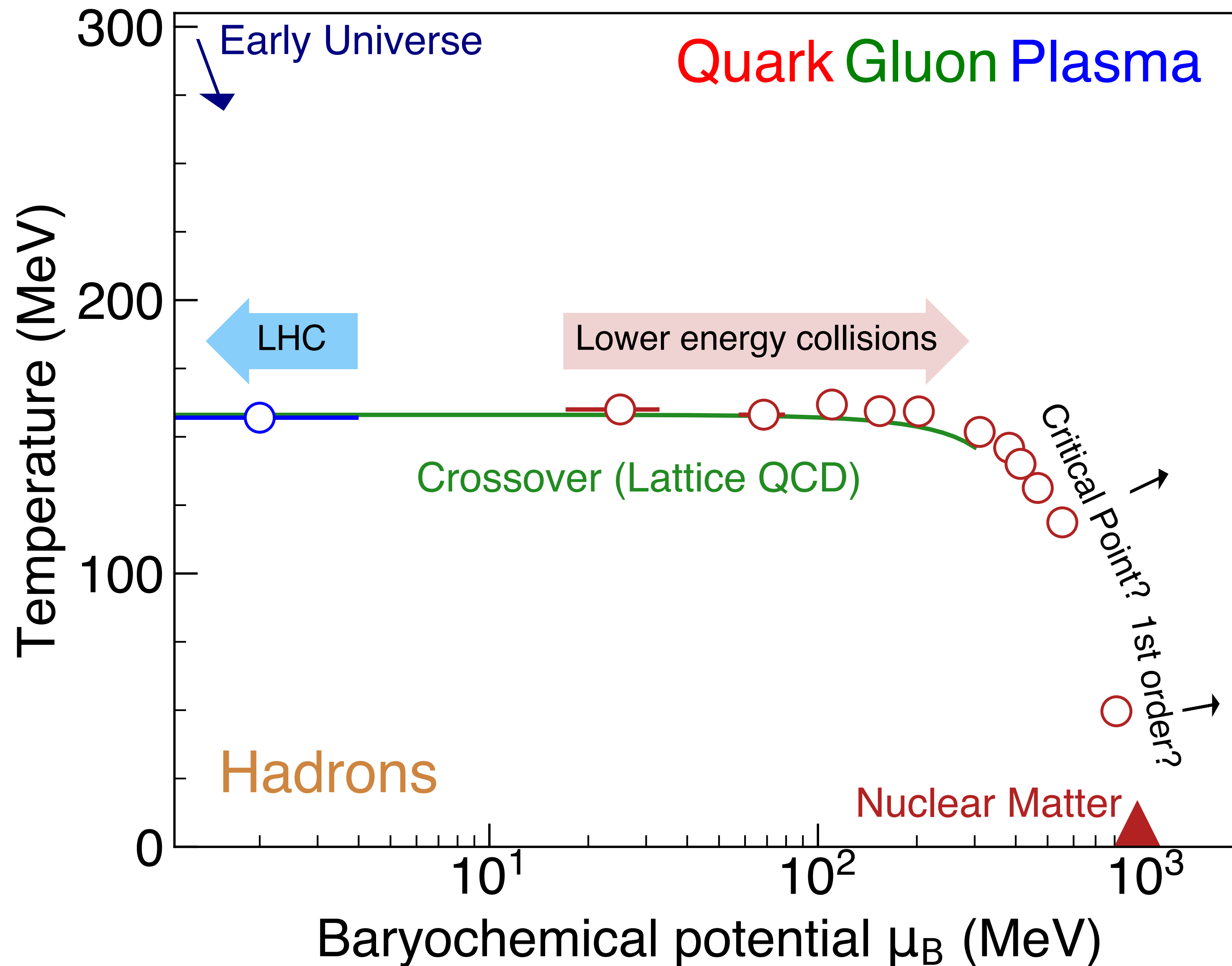
Prog. Part. Nucl. Phys. 58 (2007) 351

April 2004

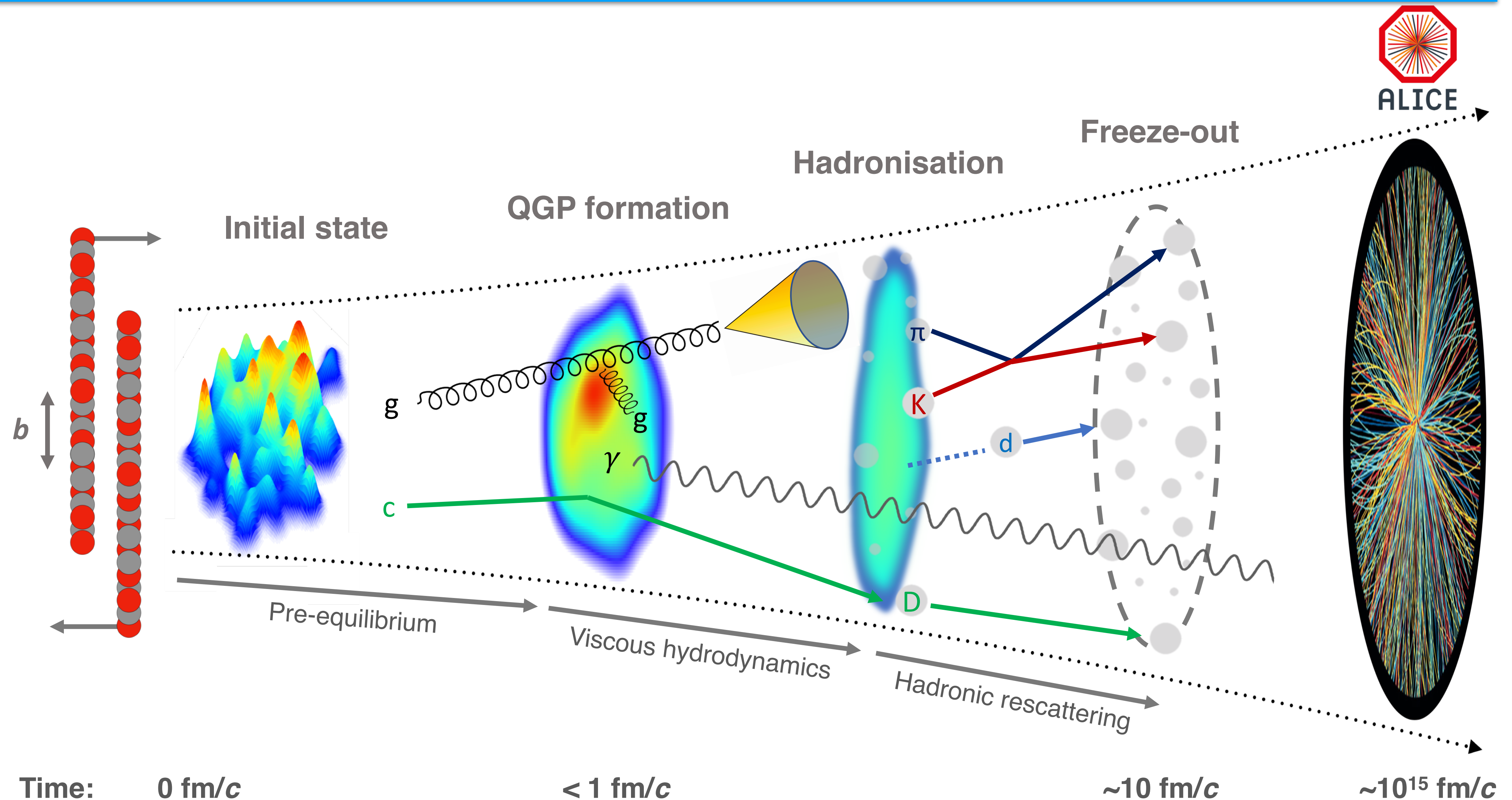


Nobel Prize 2004

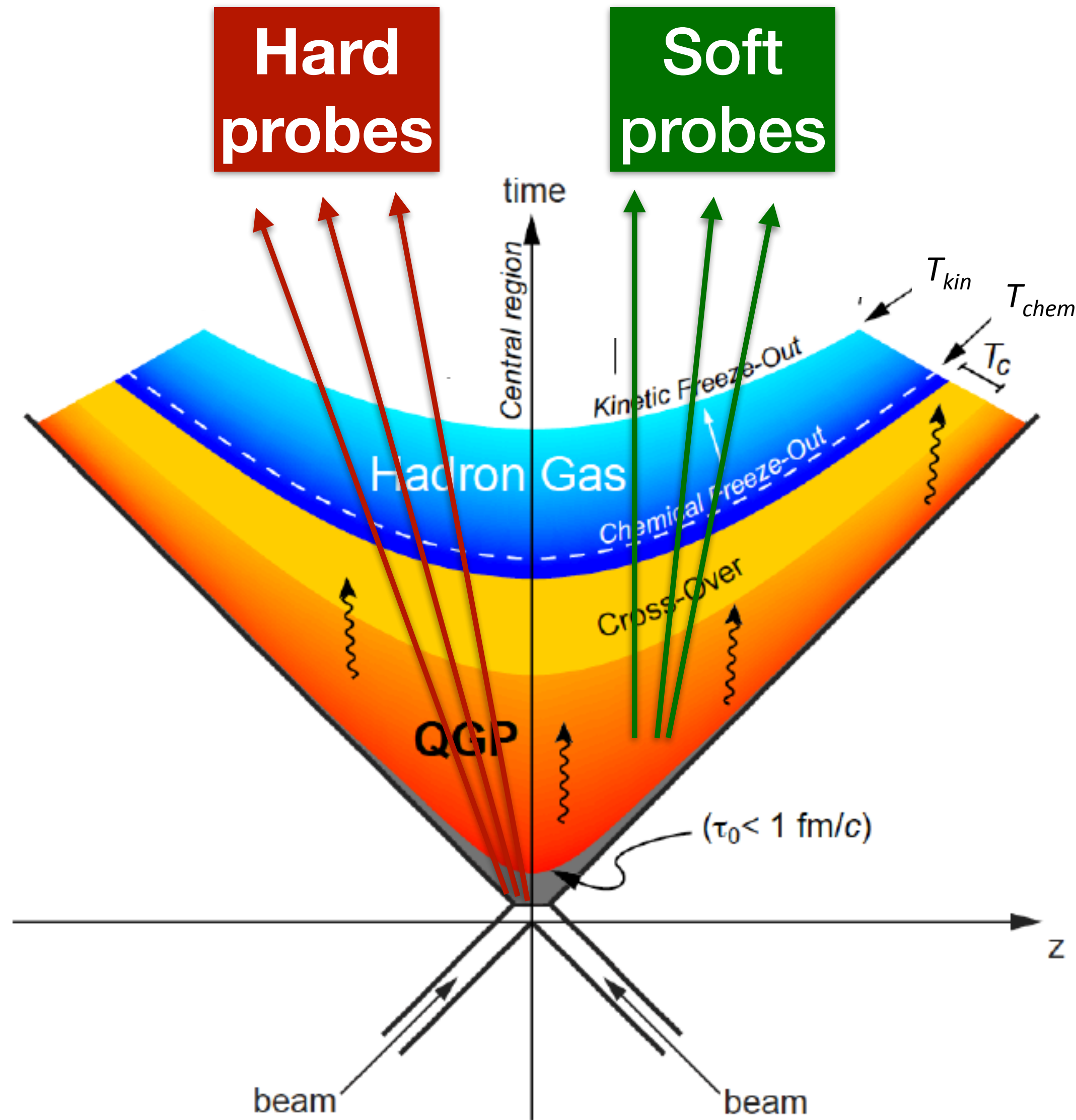
QCD phase diagram



Heavy-ion collisions



Quark–gluon plasma



Heavy-ion collisions probe the strongly-interacting matter — the quark-gluon plasma (QGP) under extreme conditions of high temperature and energy density

Hard probes created at initial stage of the collision

➡ QGP tomography

Soft probes created in the “fireball”

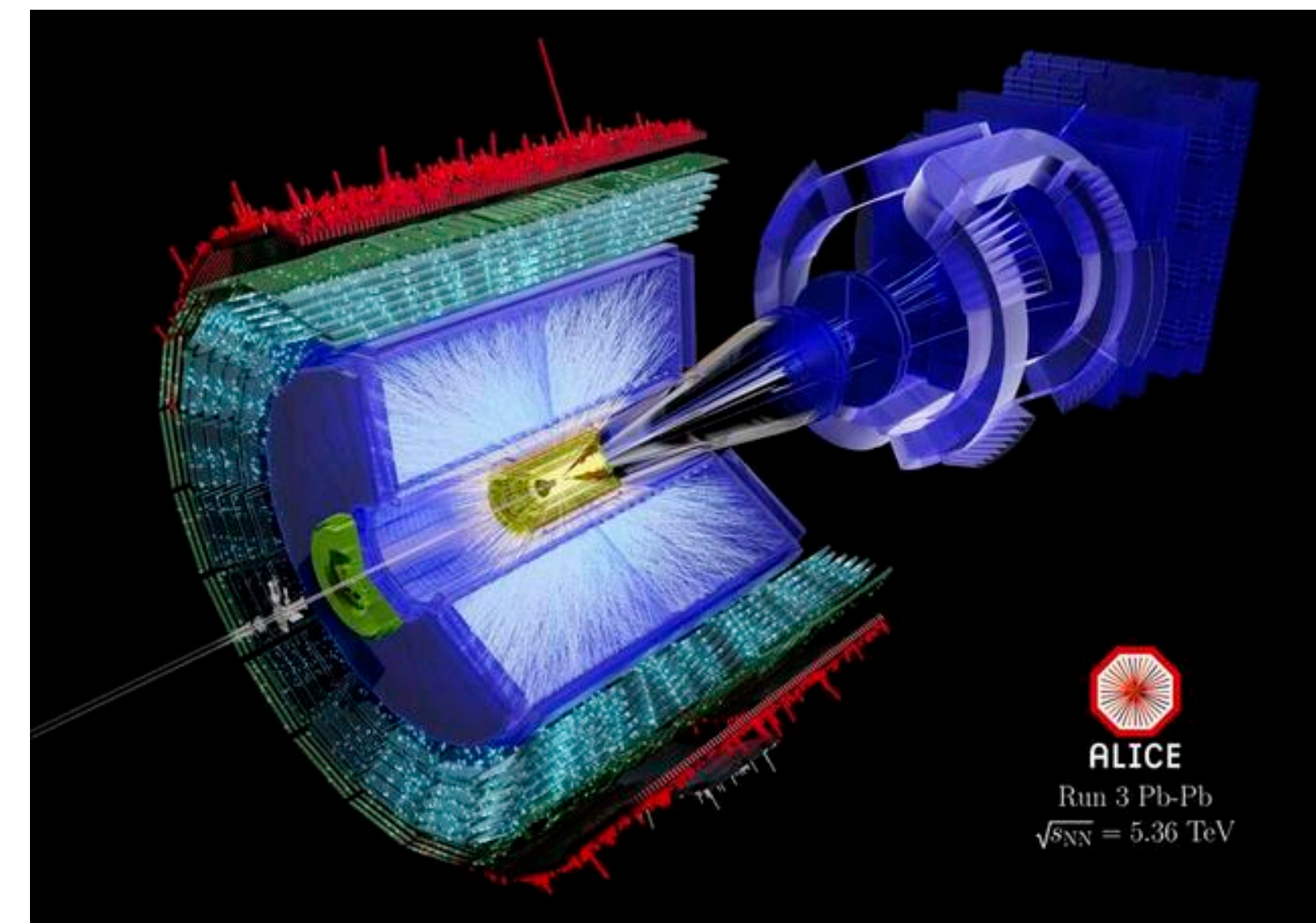
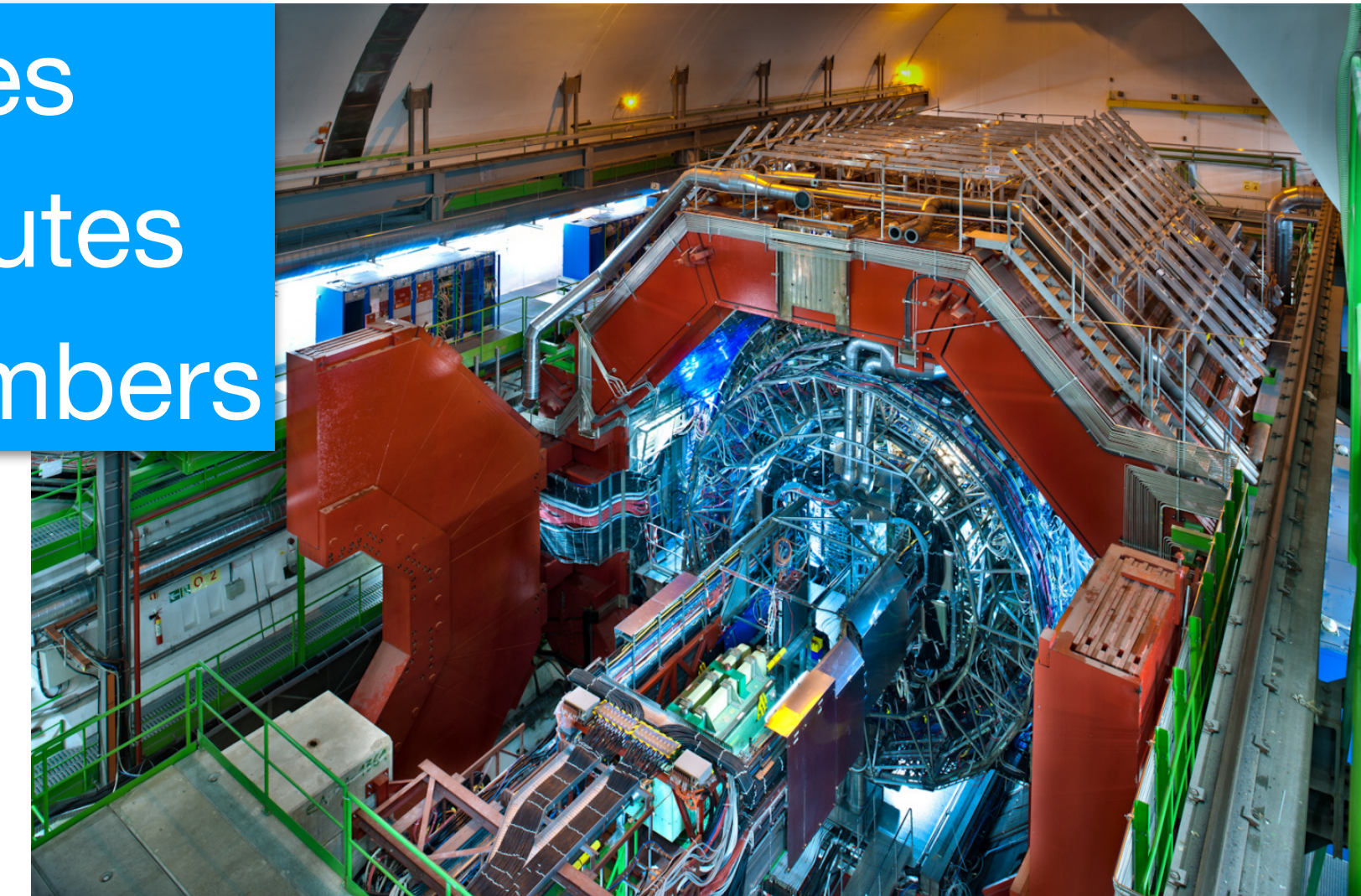
➡ Fingerprint of the QGP evolution

ALICE Collaboration



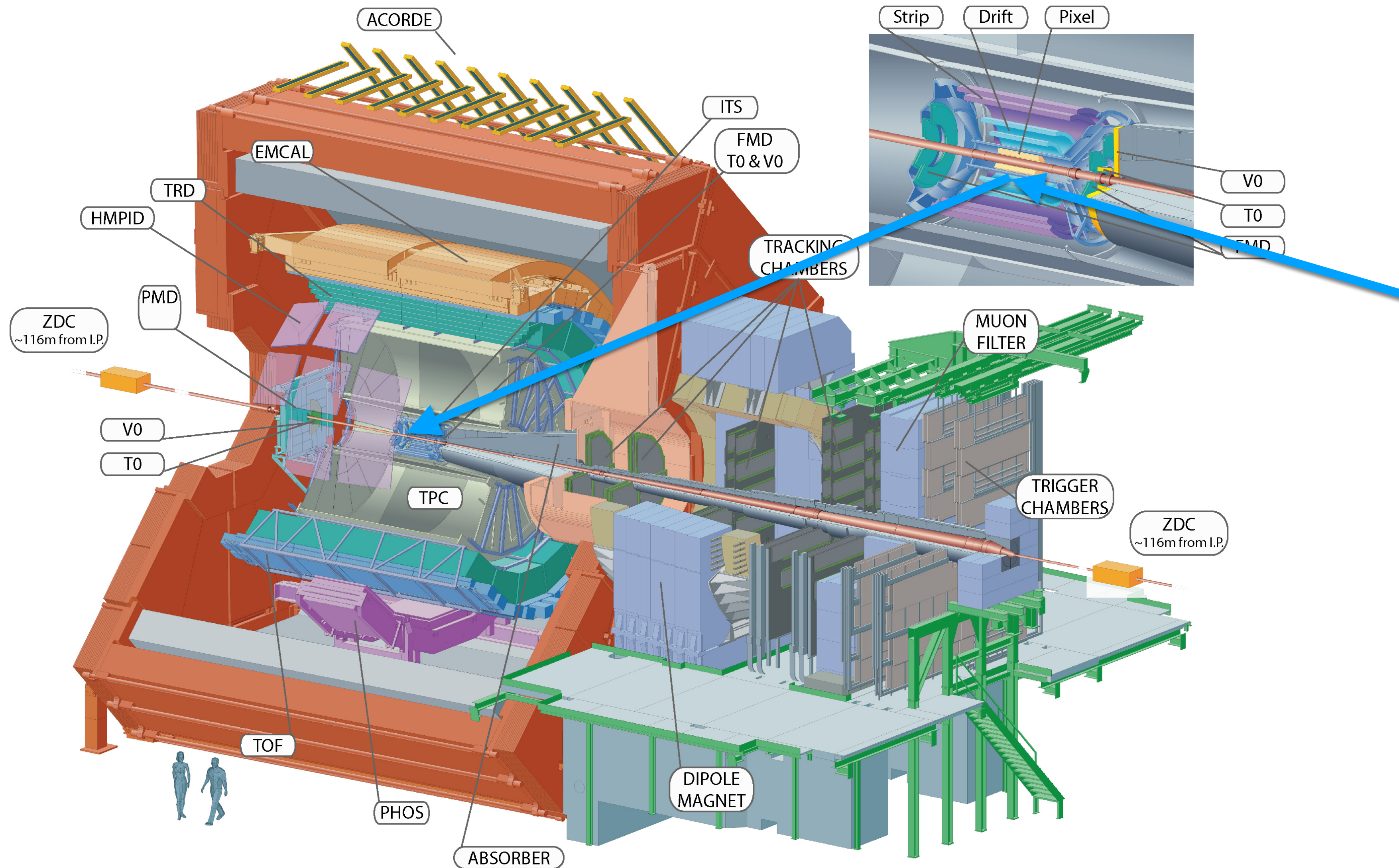
A large ion collider experiment — ALICE

- 39 countries
- 146 institutes
- 1893 members

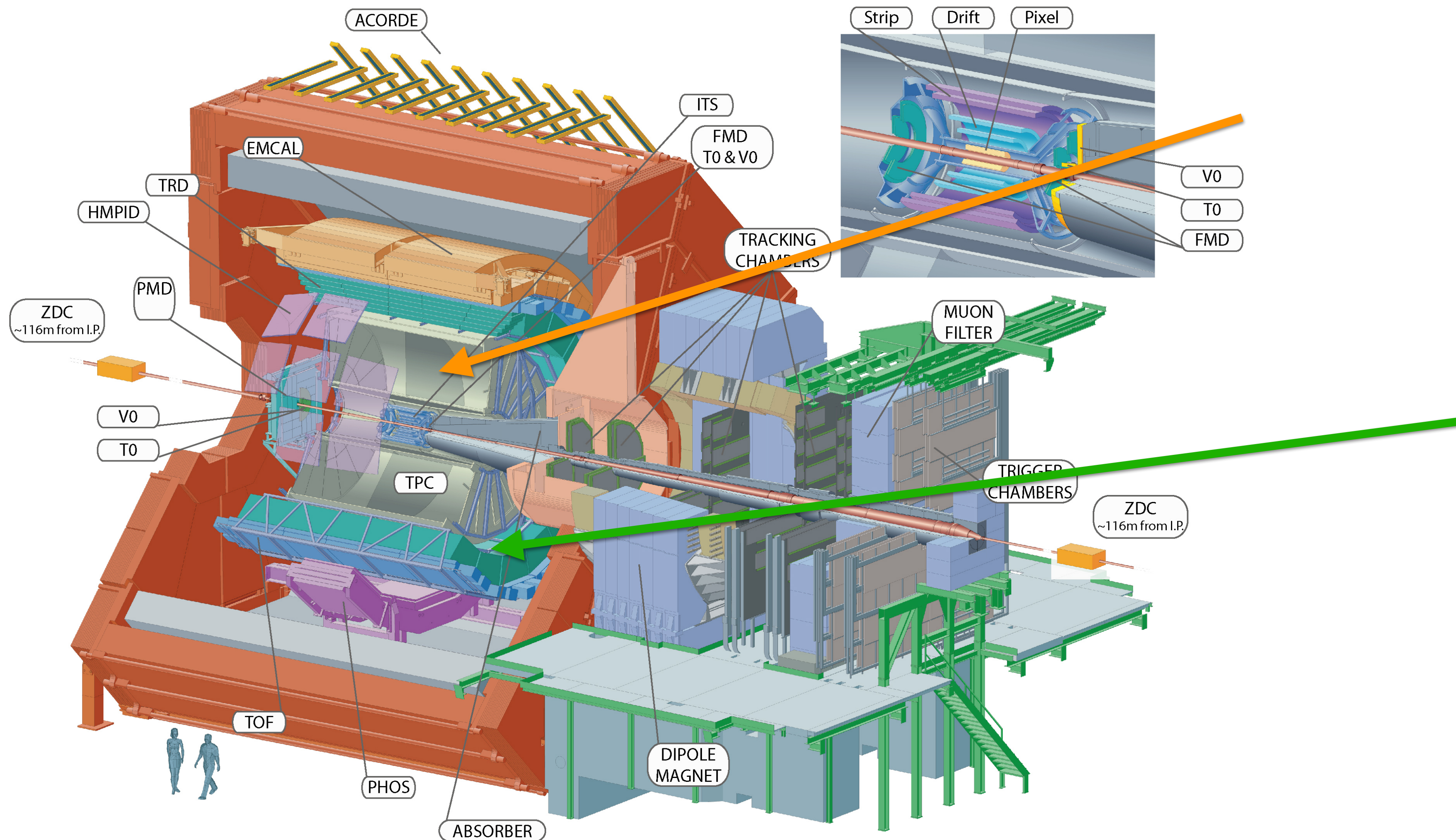


Study the primordial matter existed after the Big Bang via ultra-relativistic heavy-ion collision “little bang”

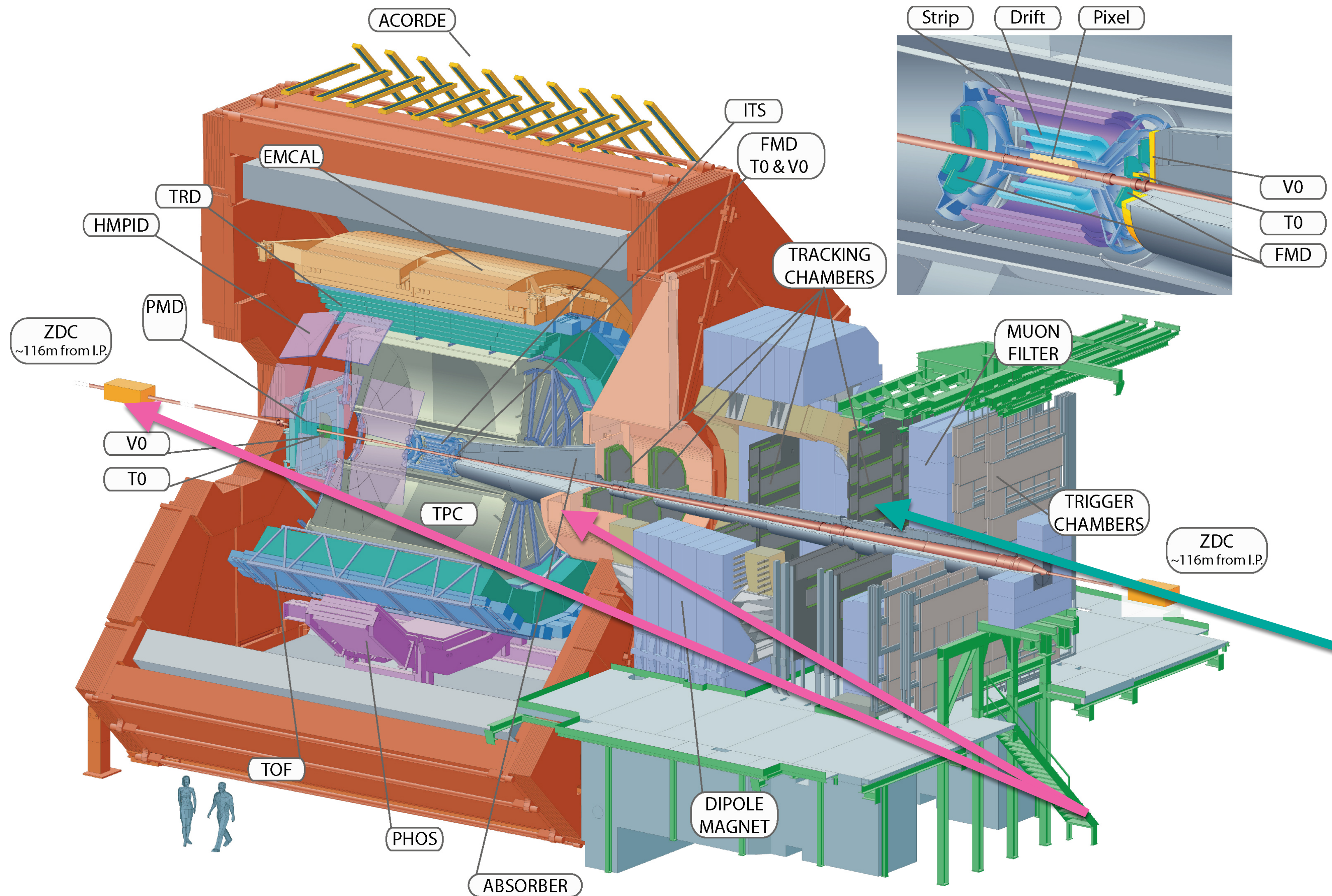
ALICE apparatus



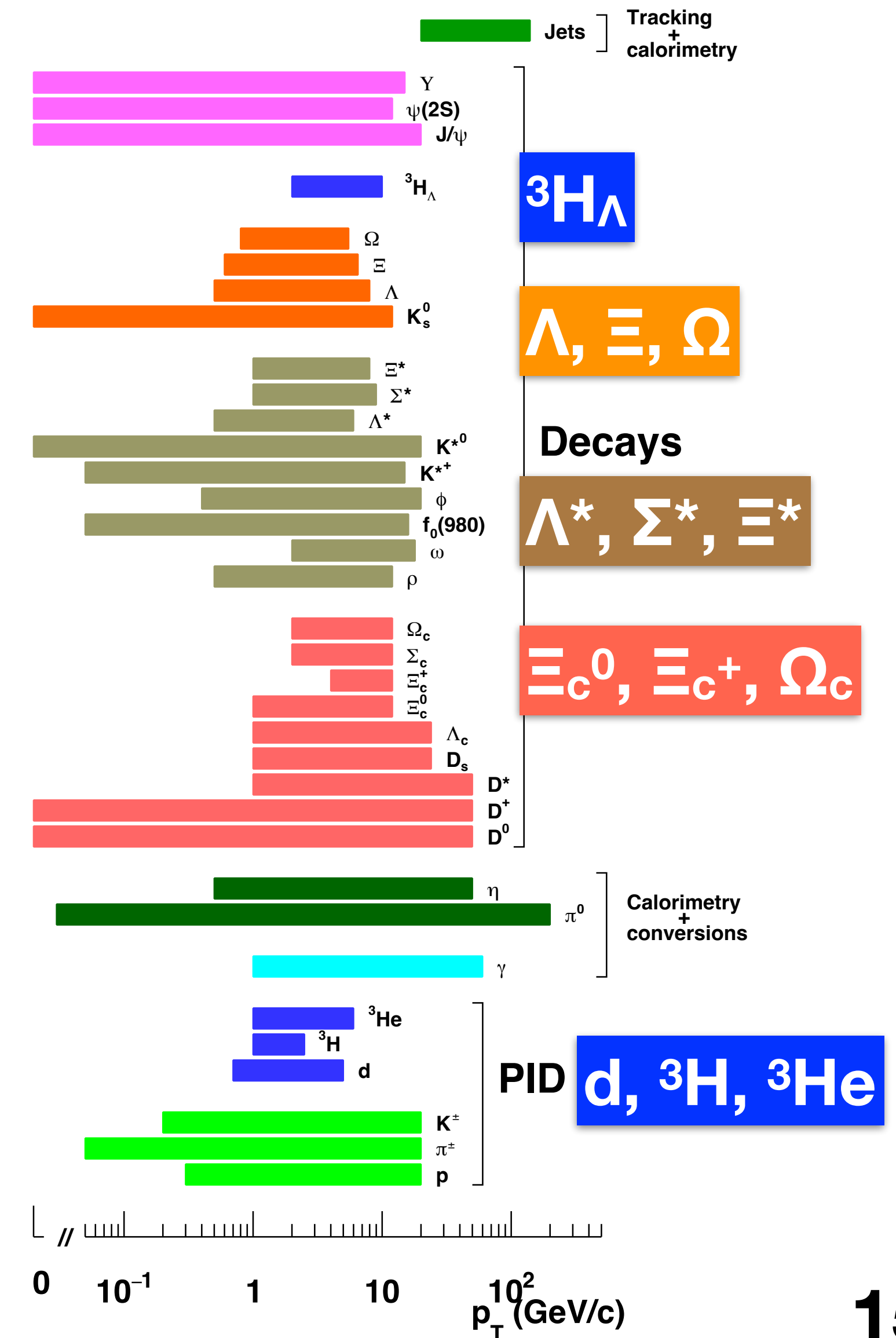
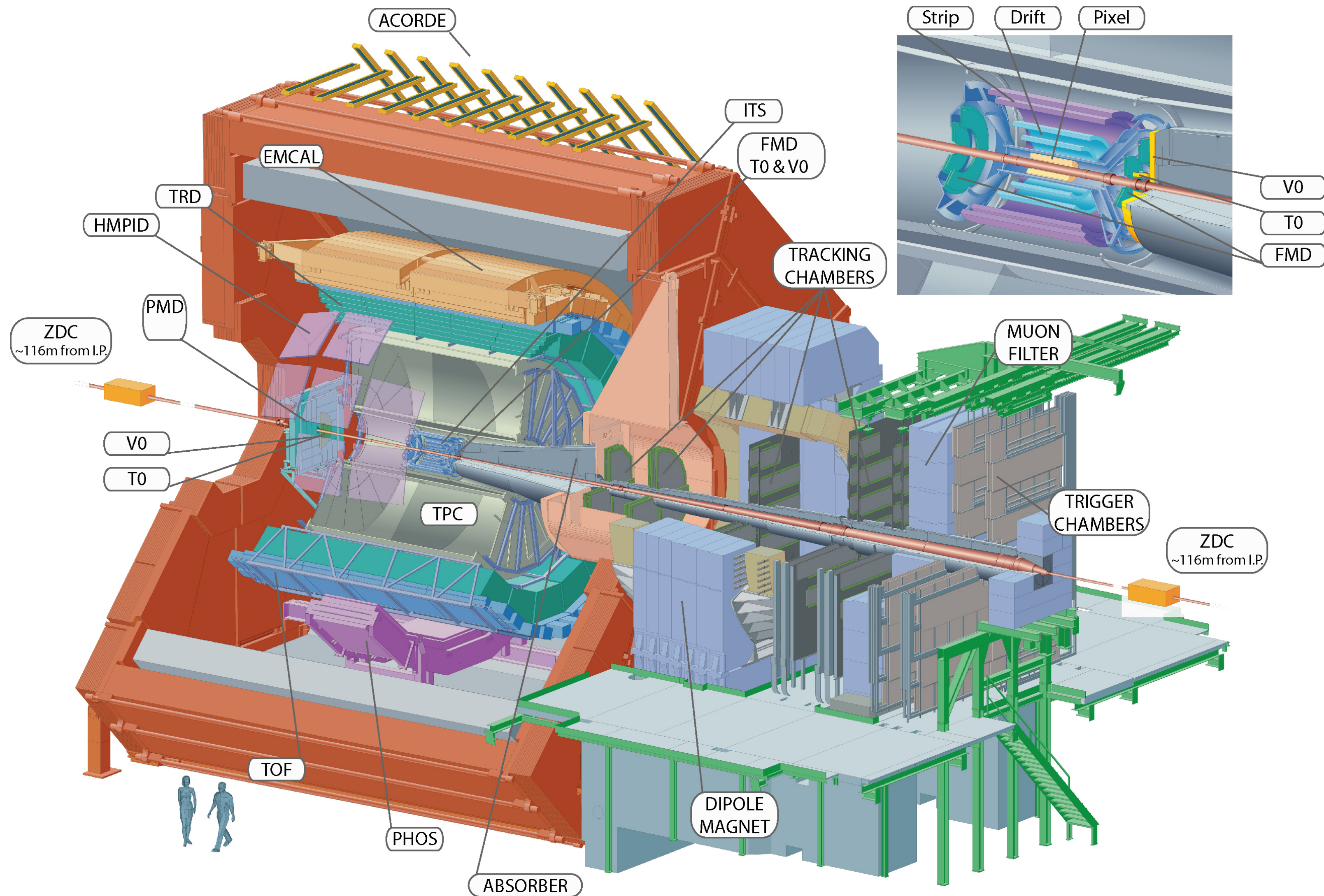
ALICE apparatus



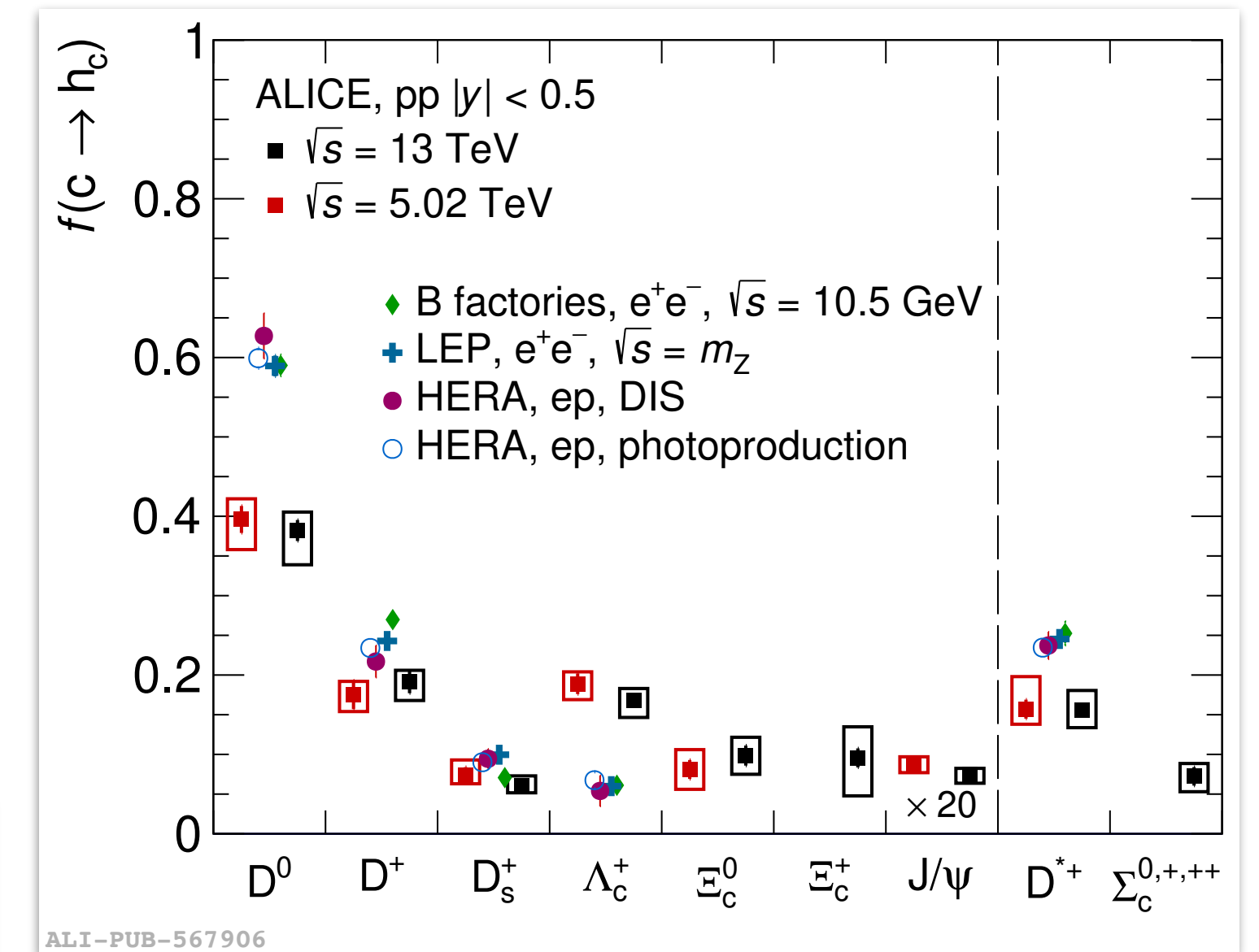
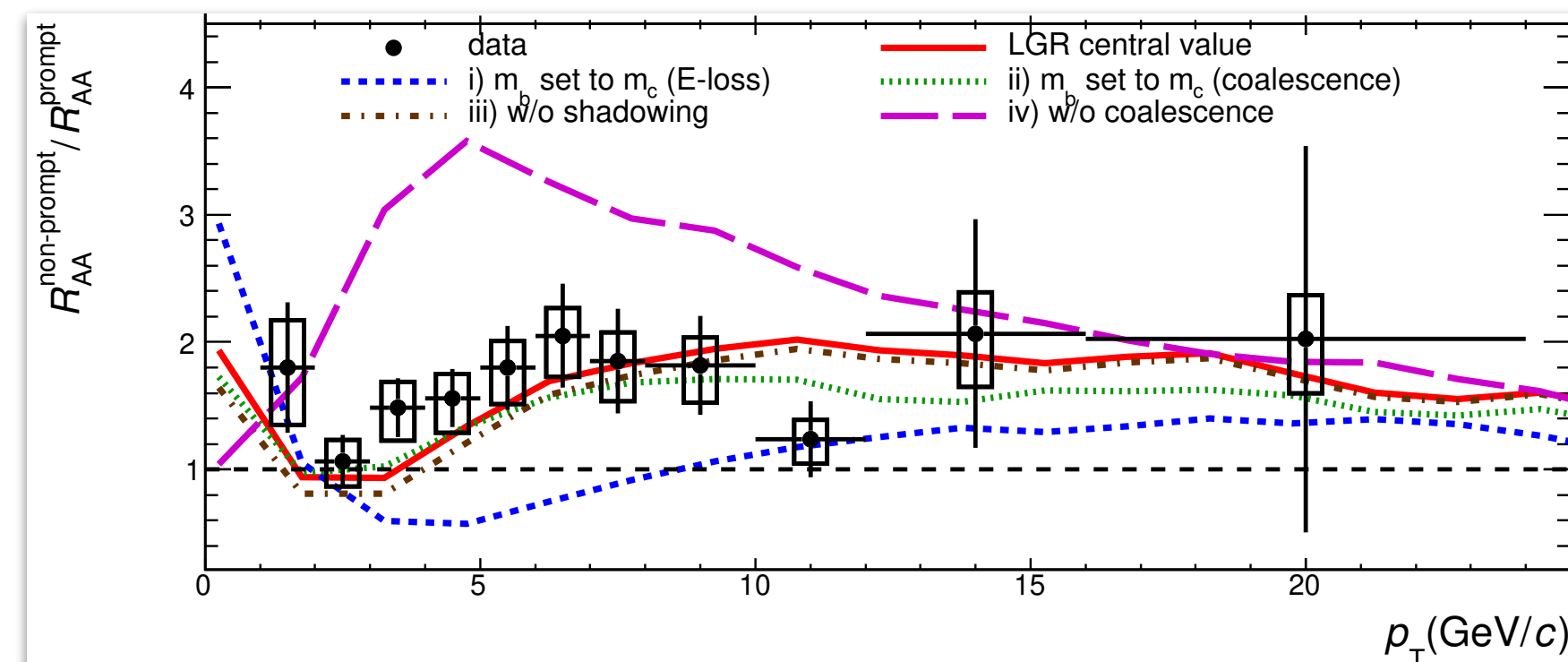
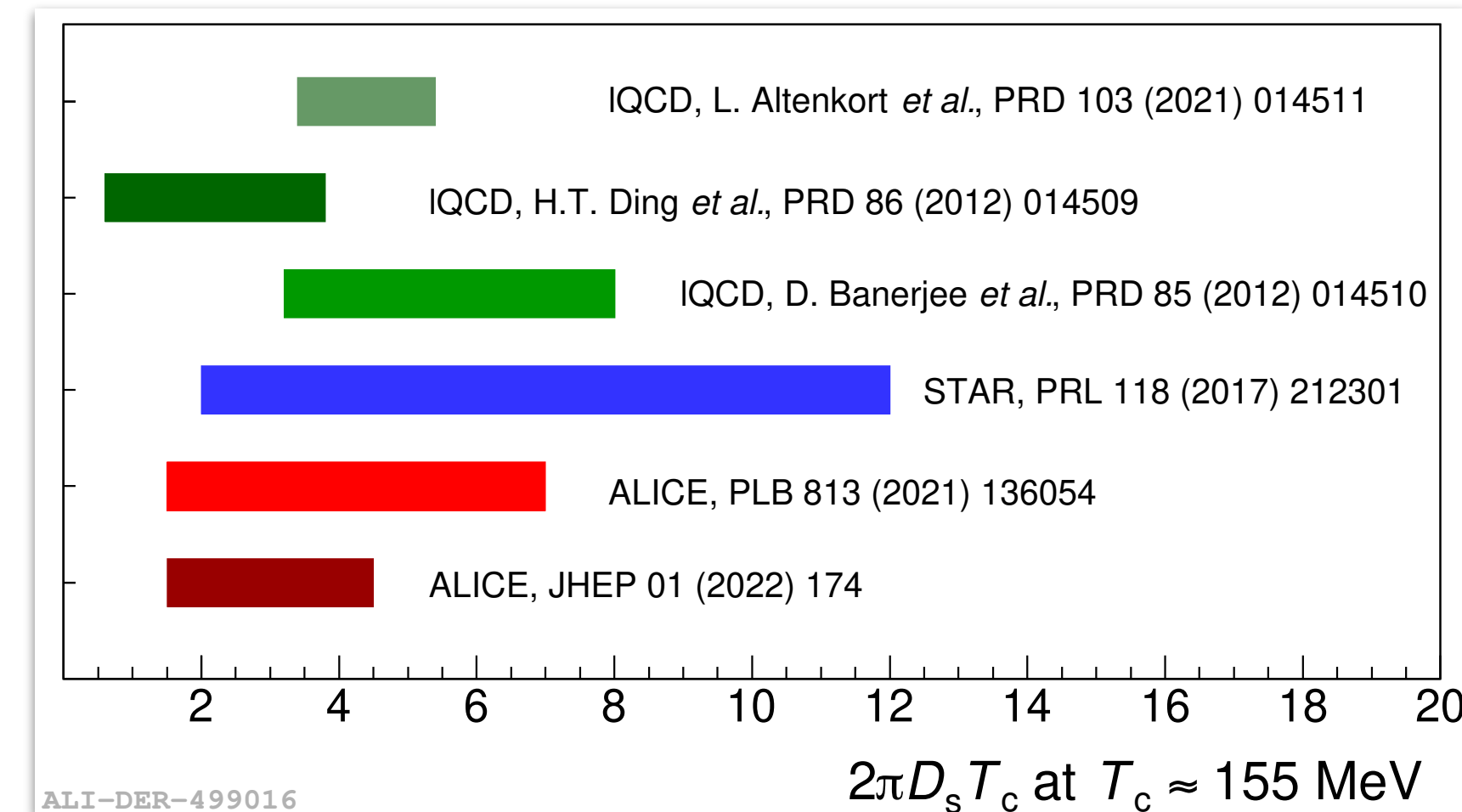
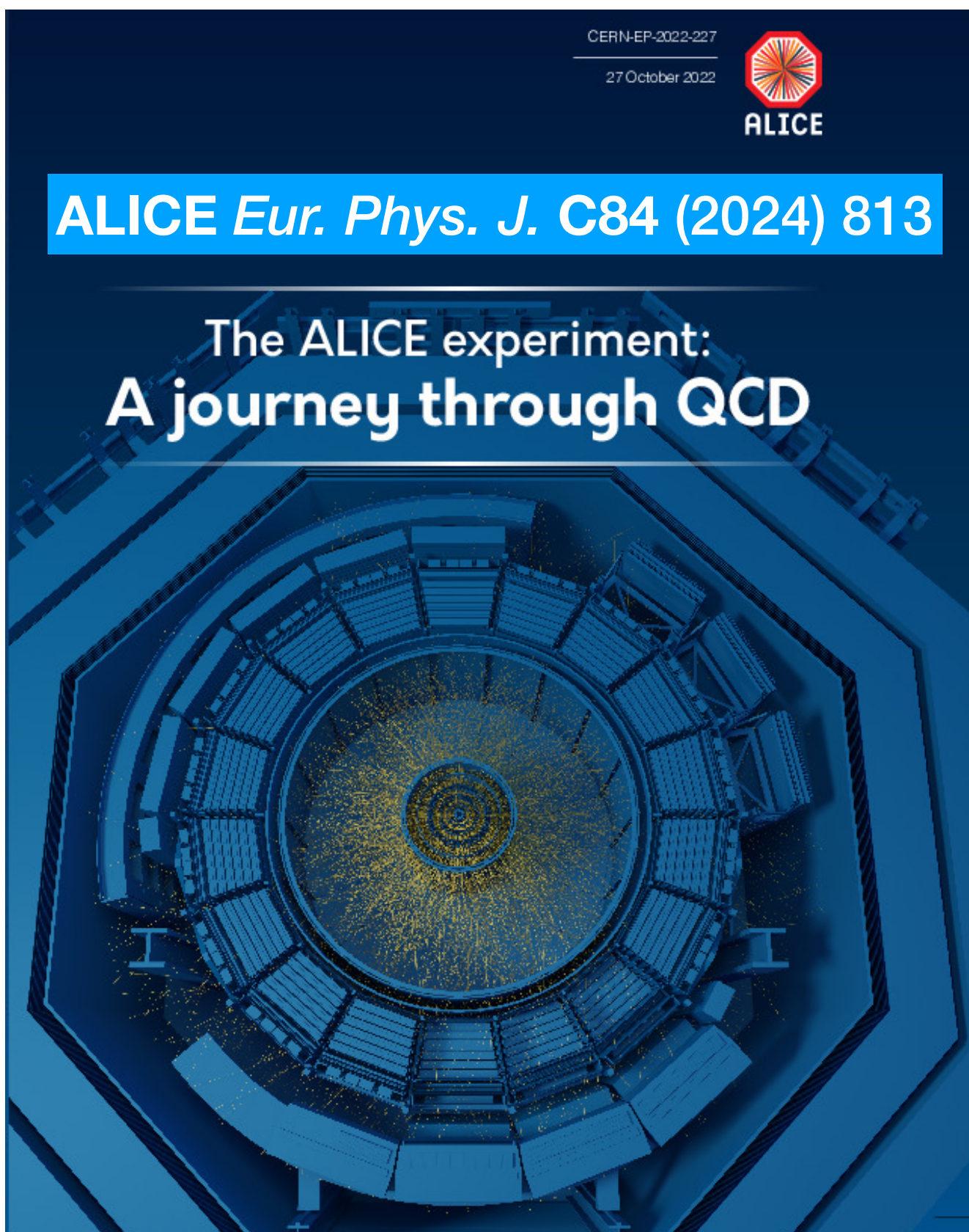
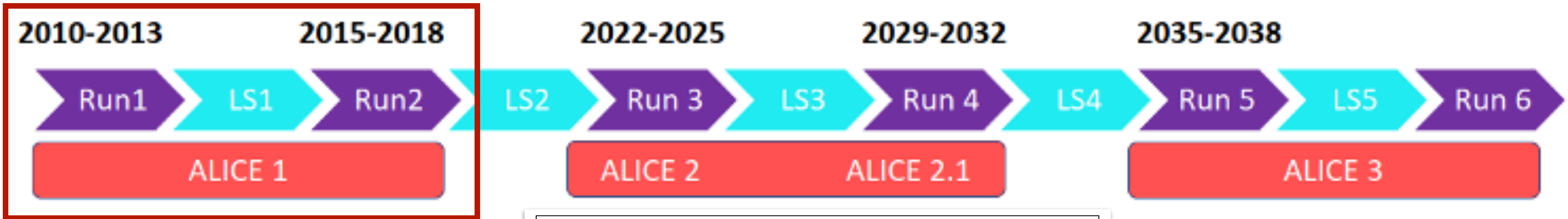
ALICE apparatus



ALICE Capability

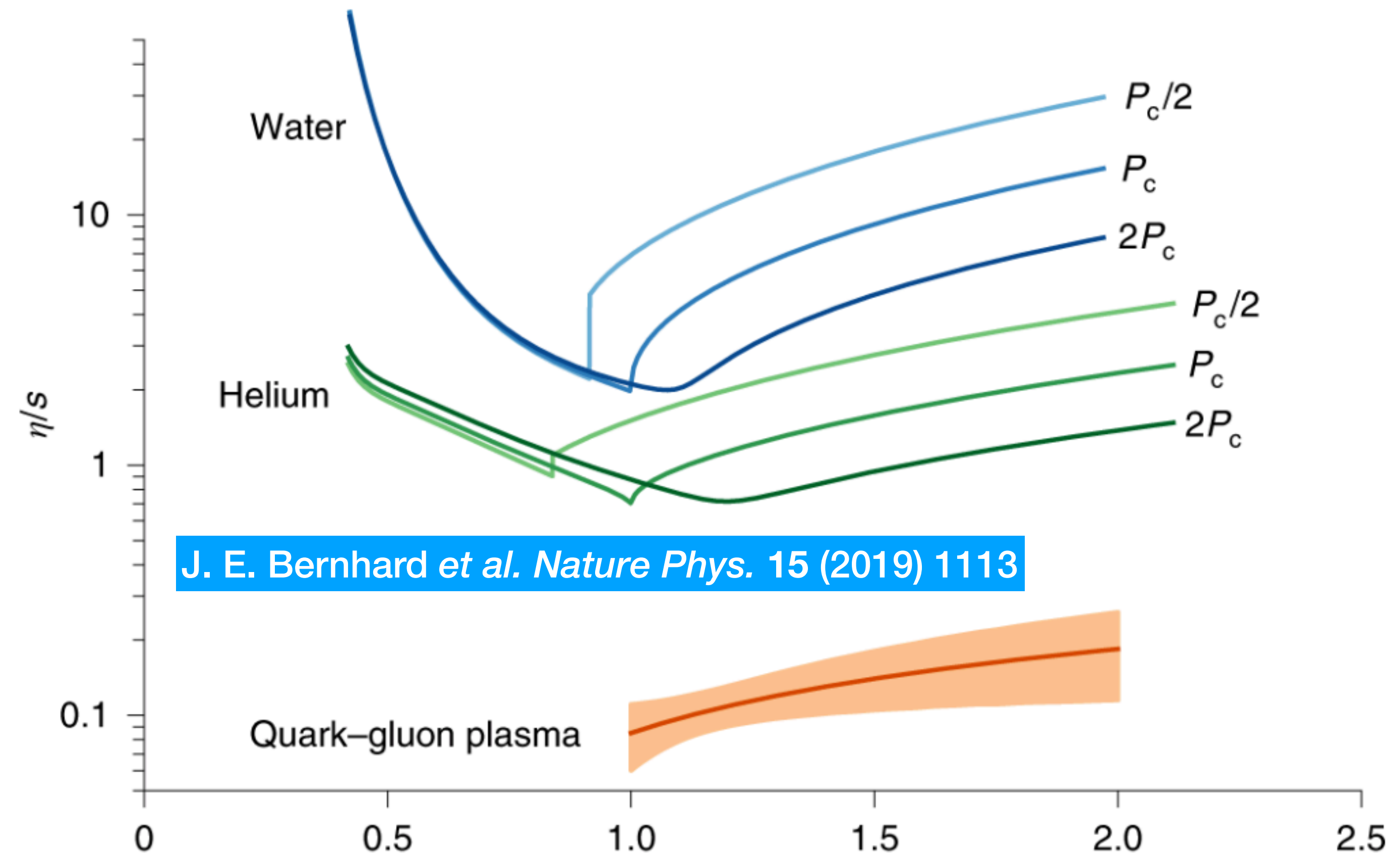
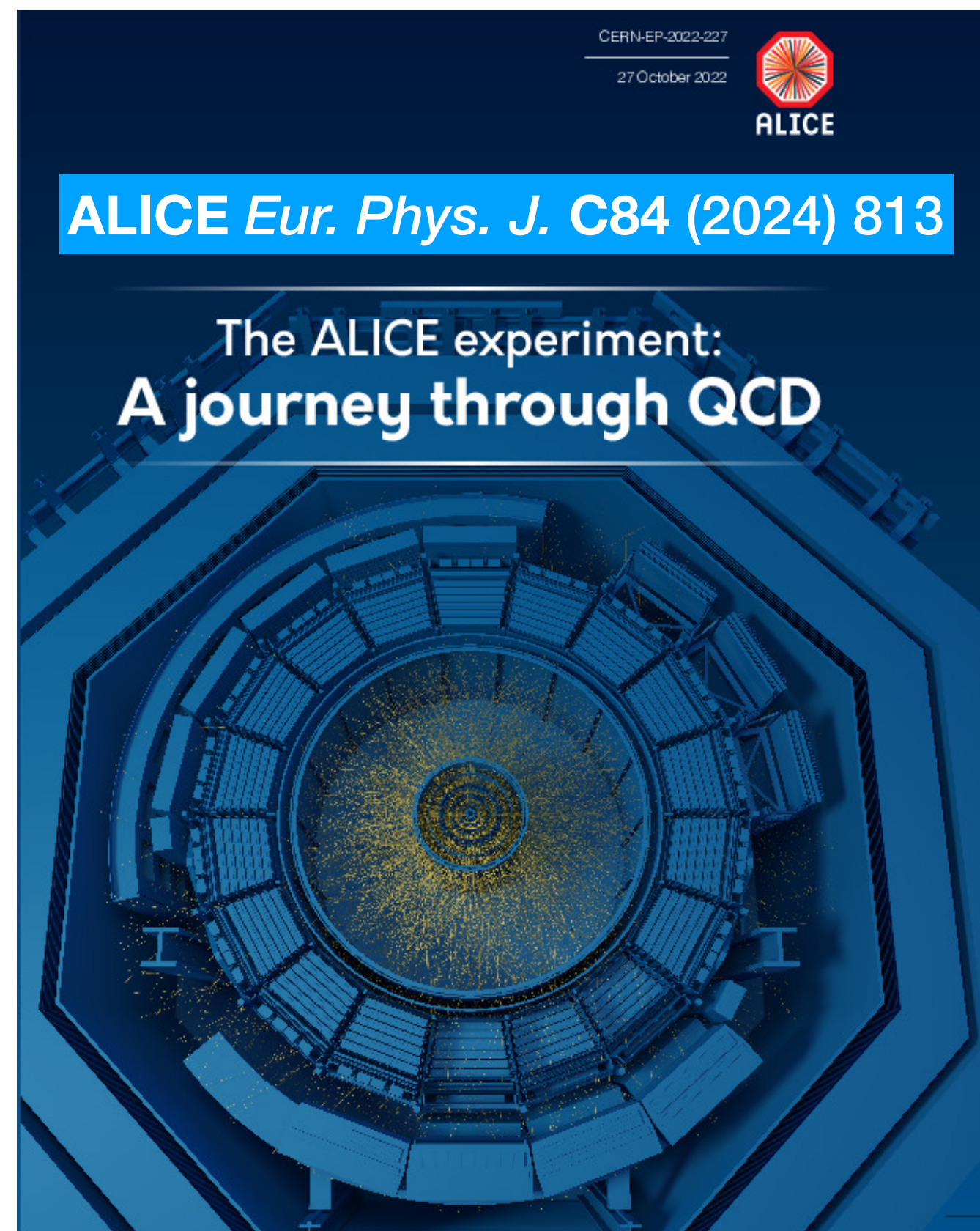
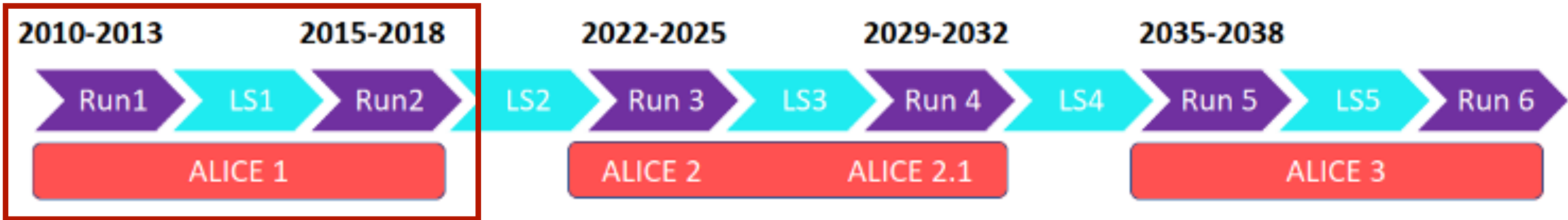


A journey through QCD



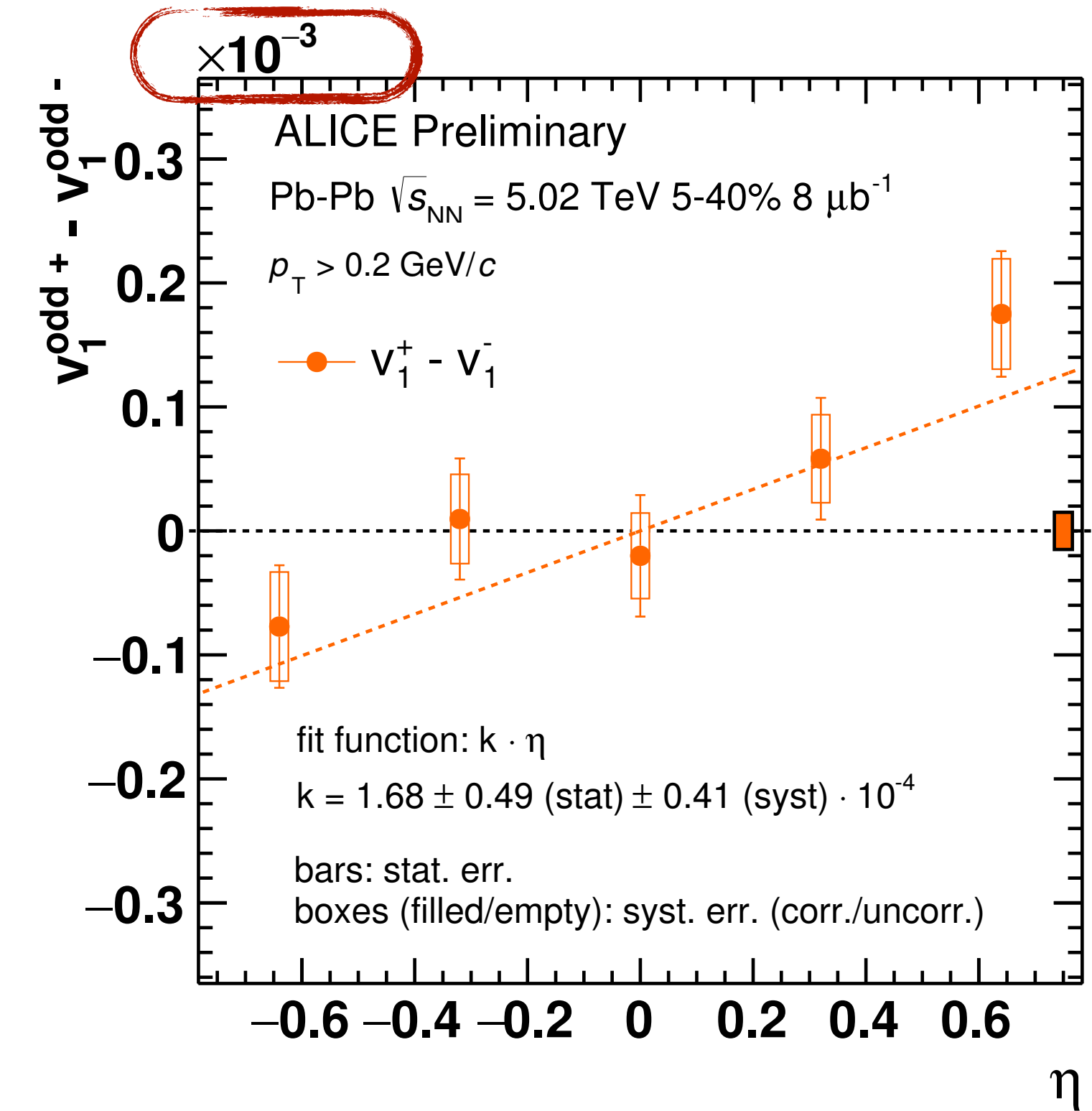
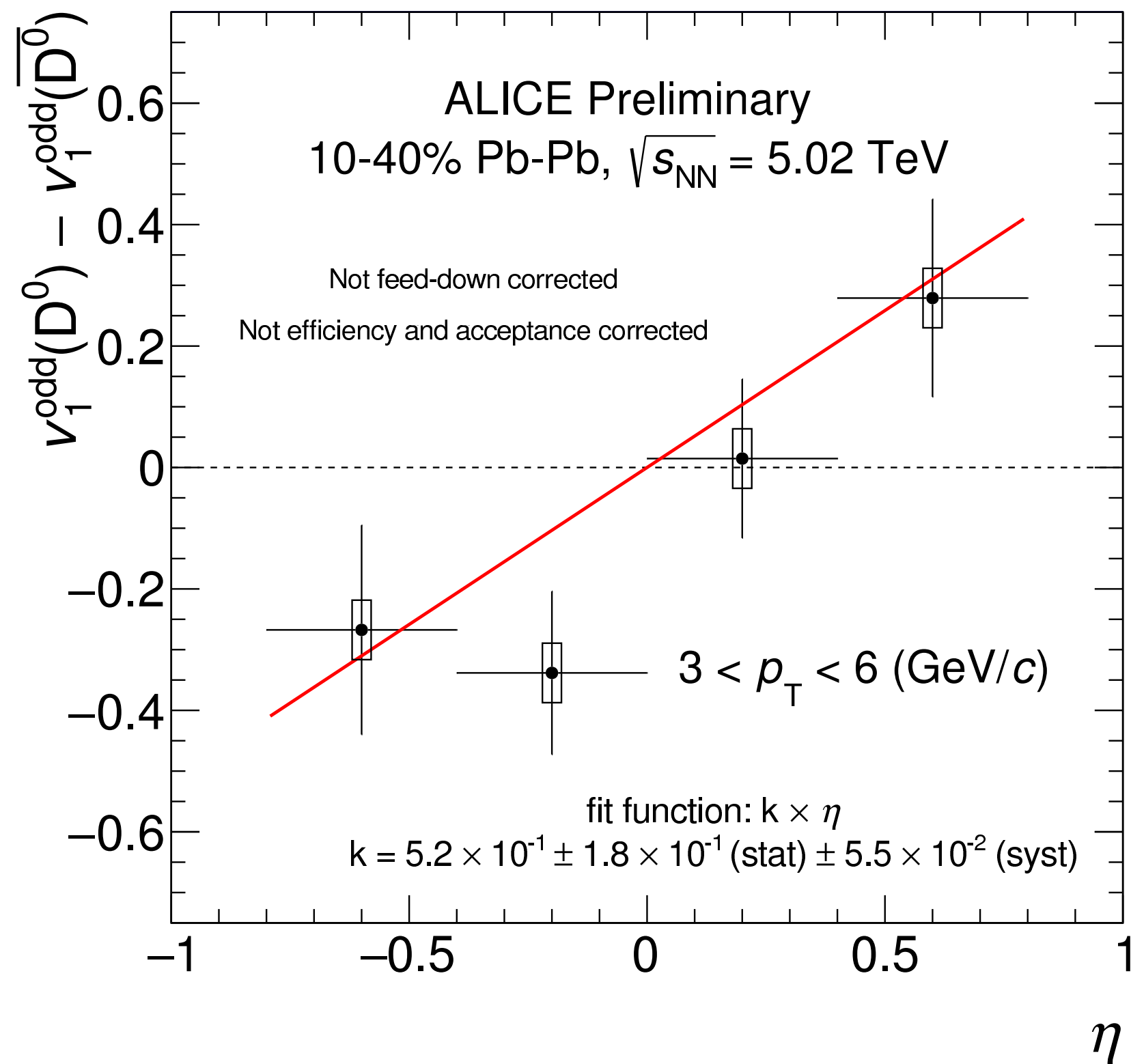
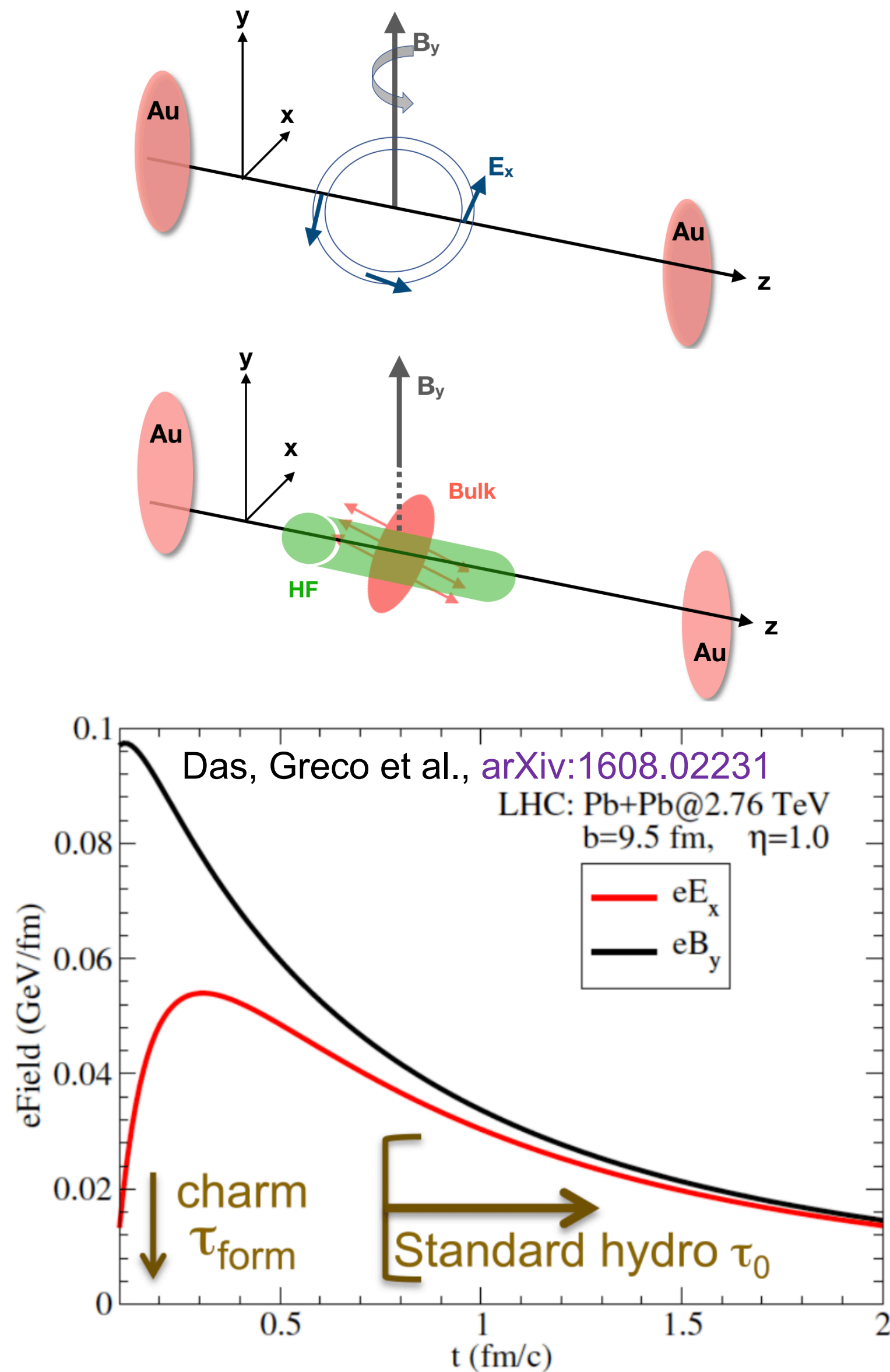
More than a QGP factory

A journey through QCD



J. E. Bernhard *et al.* *Nature Phys.* 15 (2019) 1113

The strongest magnetic field

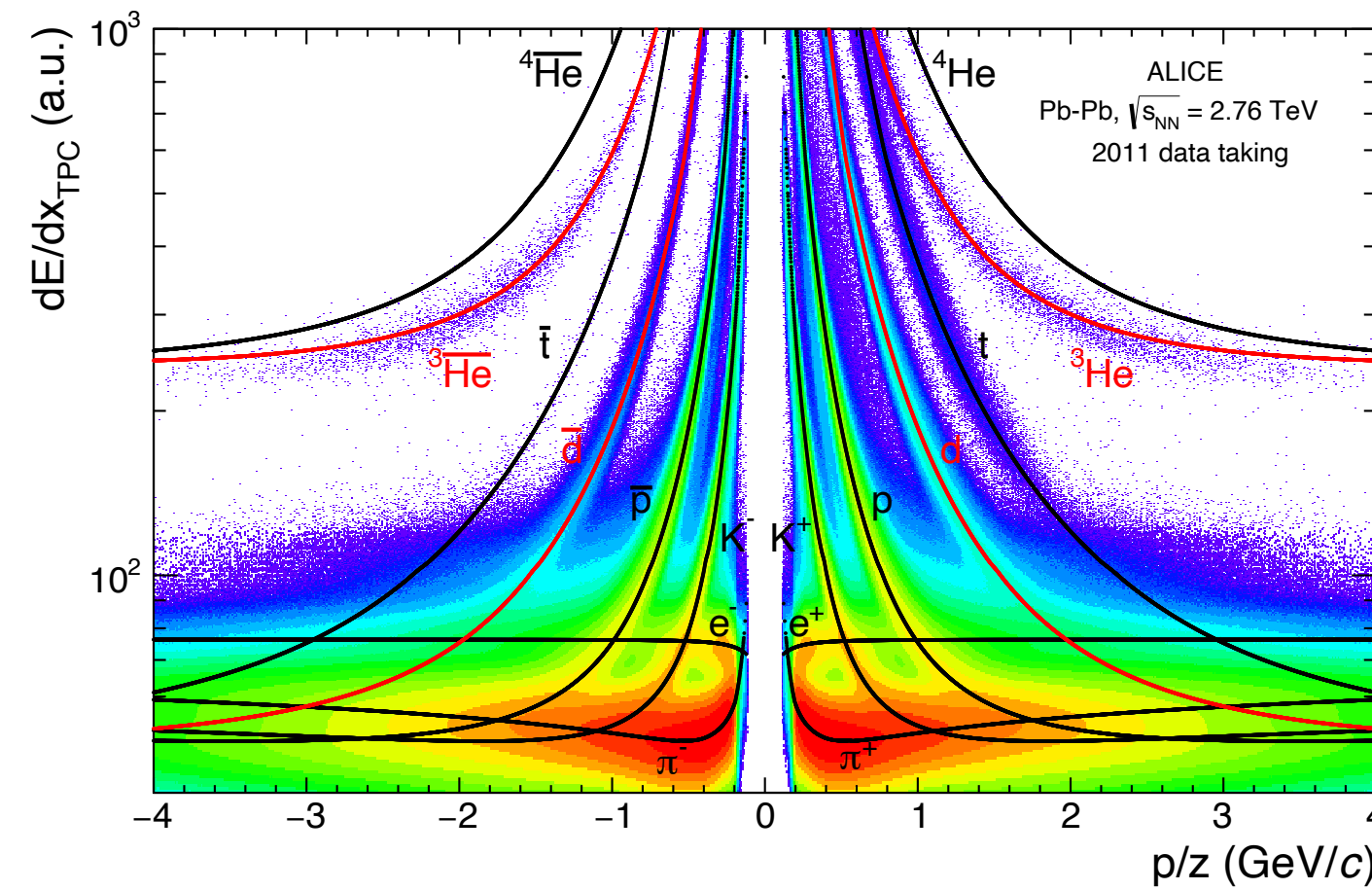


Hint of positive slope with a significance of 2.7σ
Similar trend observed for charged particles, but
different magnitude

Mass difference of (anti)-nuclei

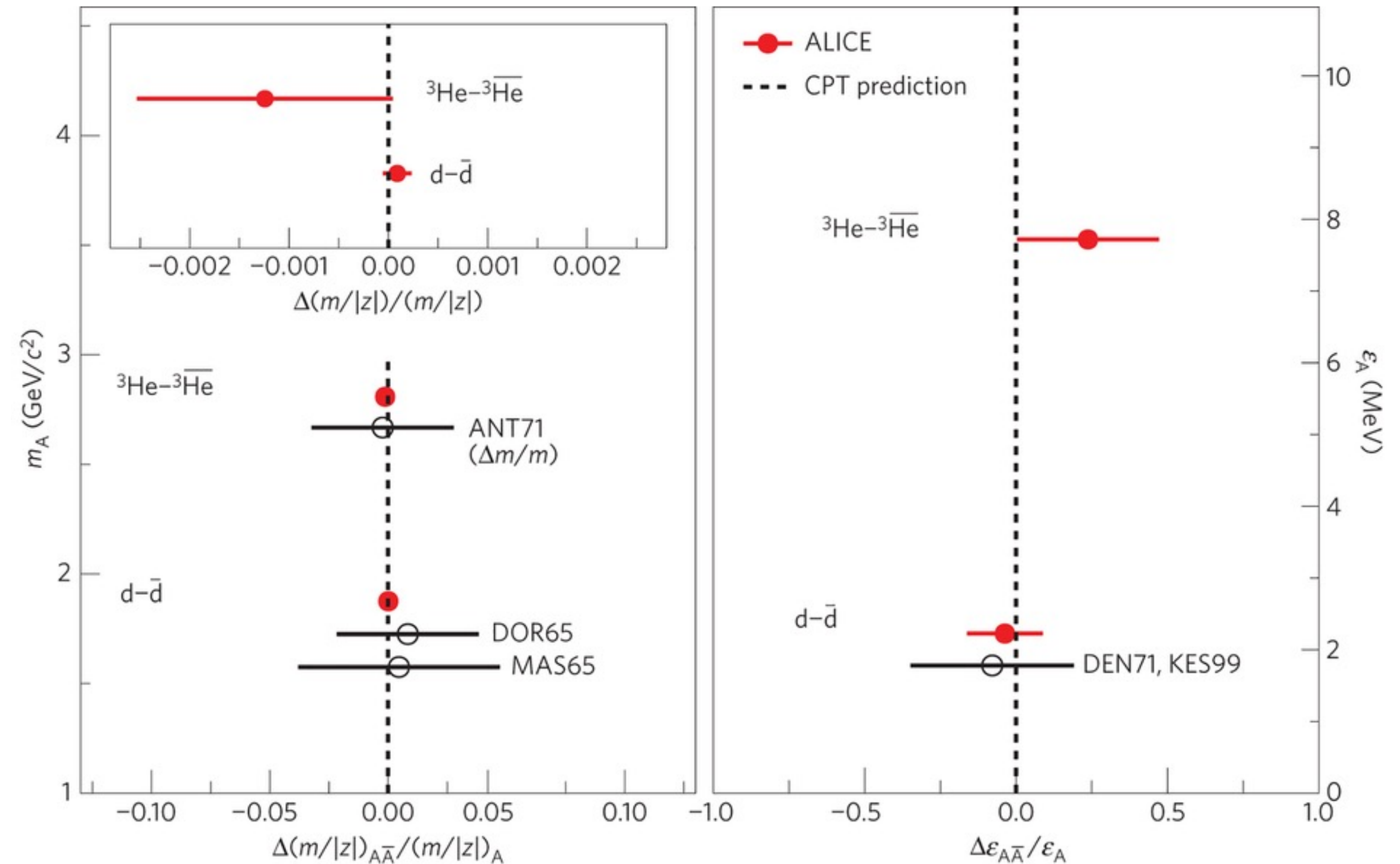


- Test of CPT invariance of residual nuclear force by measuring mass difference in the nuclei sector (${}^3\text{He}$ and deuterons)



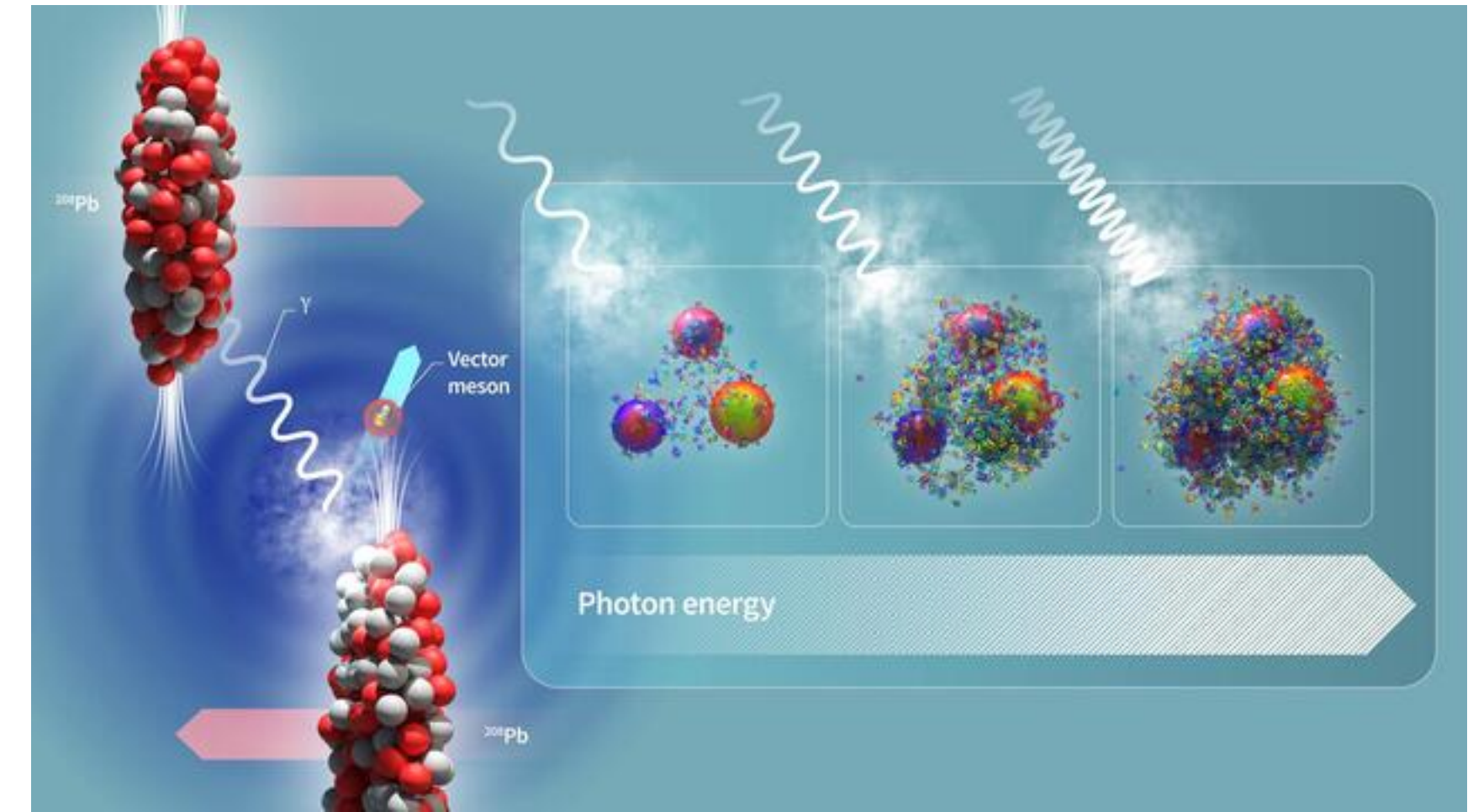
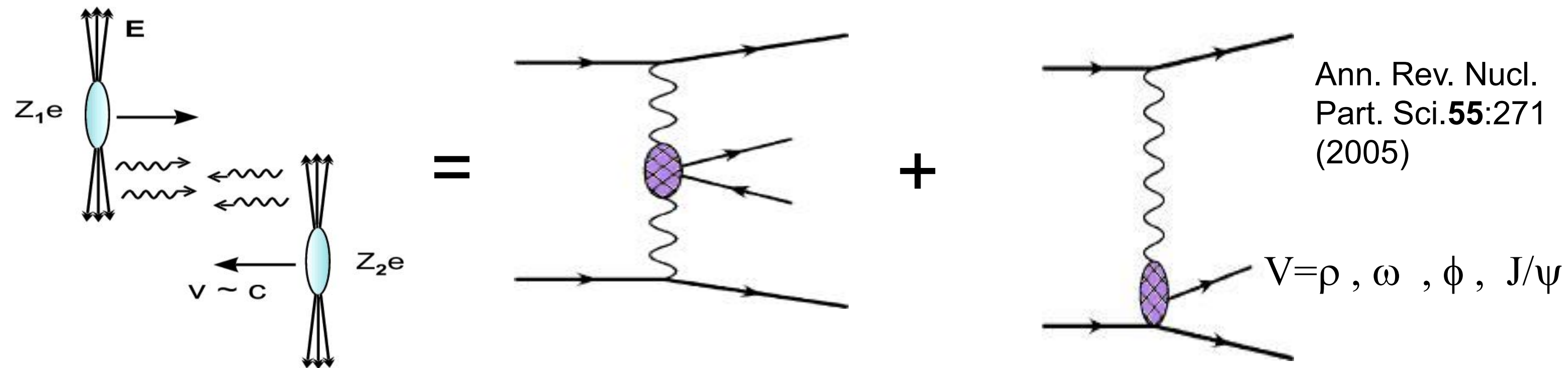
- Improved by one to two orders of magnitude compared to earlier measurements

- First measurement of binding-energy for (anti-) ${}^3\text{He}$
- Confirms CPT invariance for light nuclei

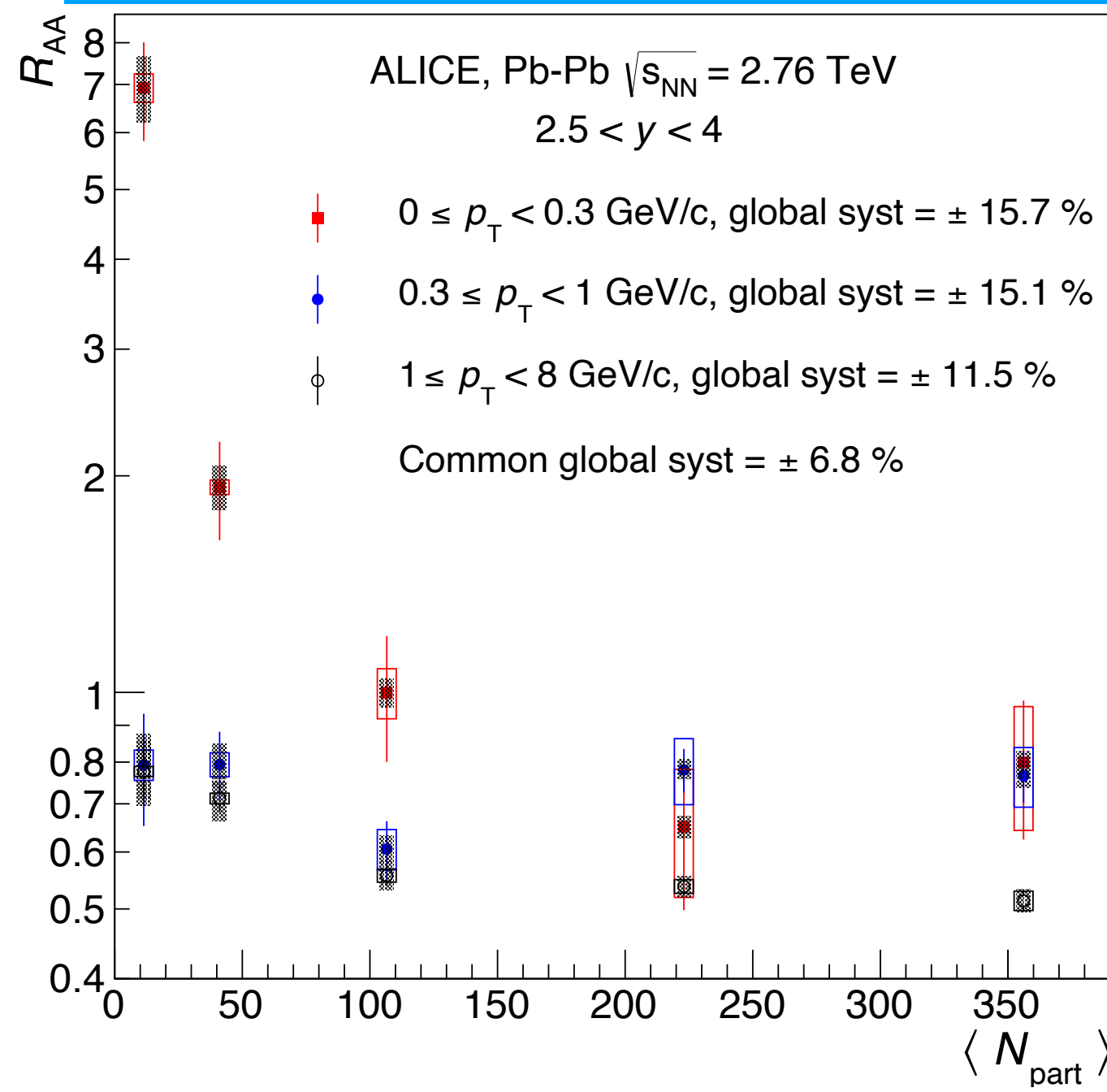


ALICE *Nature Physics* 11 (2017) 811

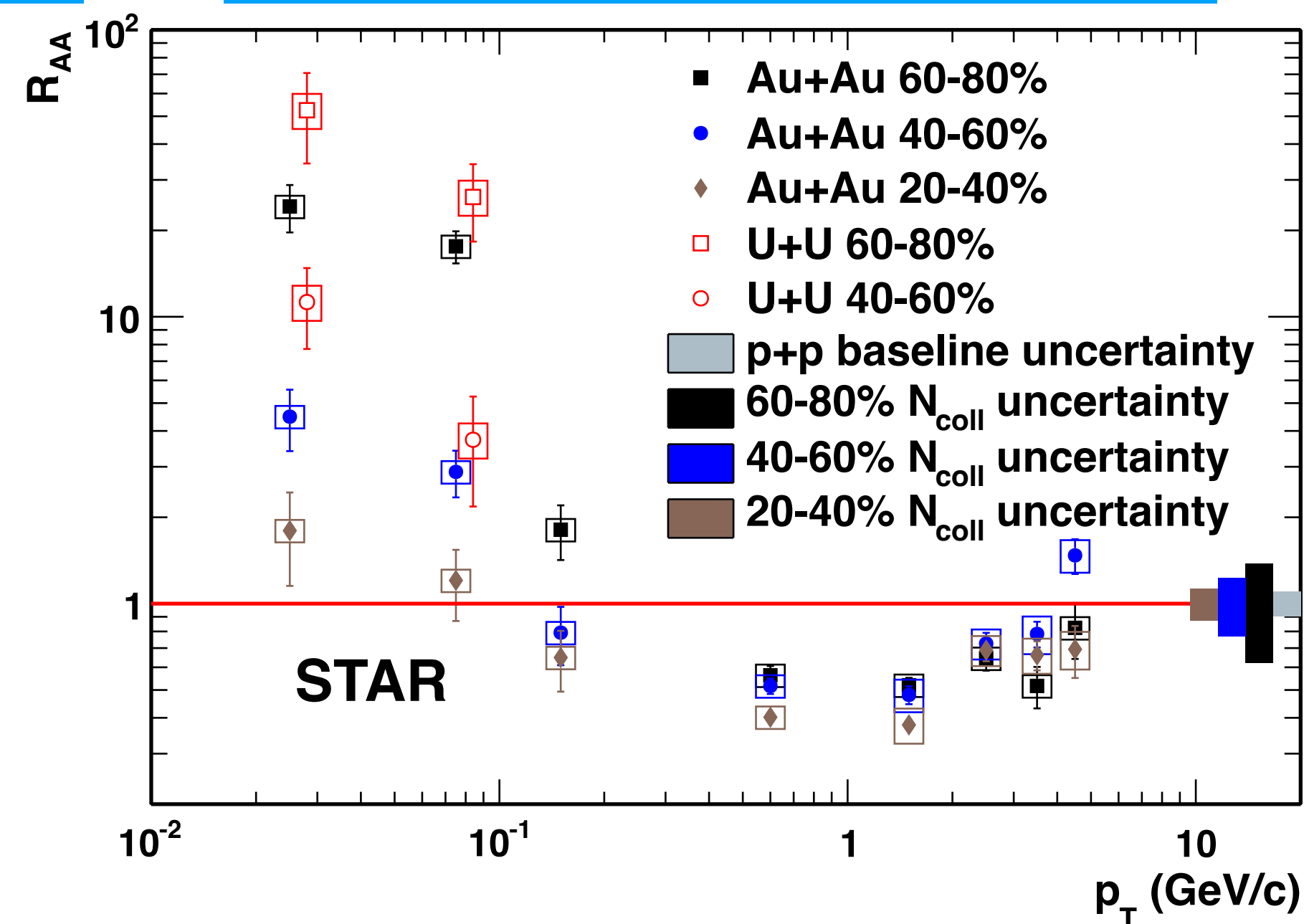
Photon interactions



ALICE Phys. Rev. Lett. **116** (2016) 222301

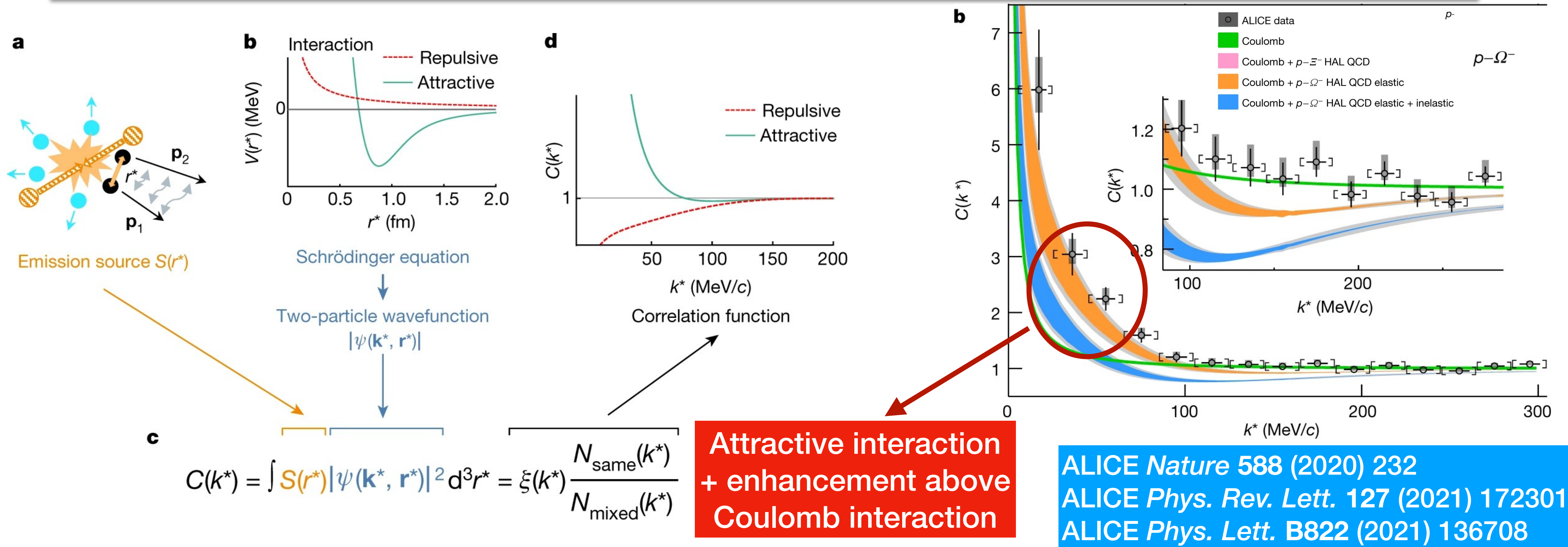


STAR Phys. Rev. Lett. **123** (2019) 132302



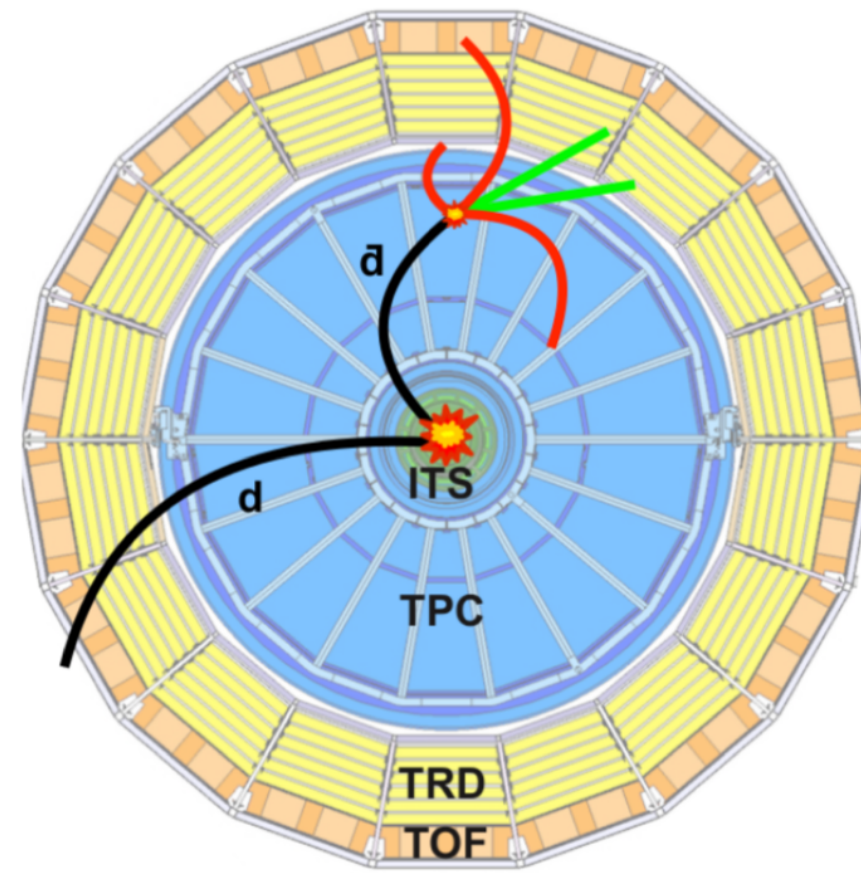
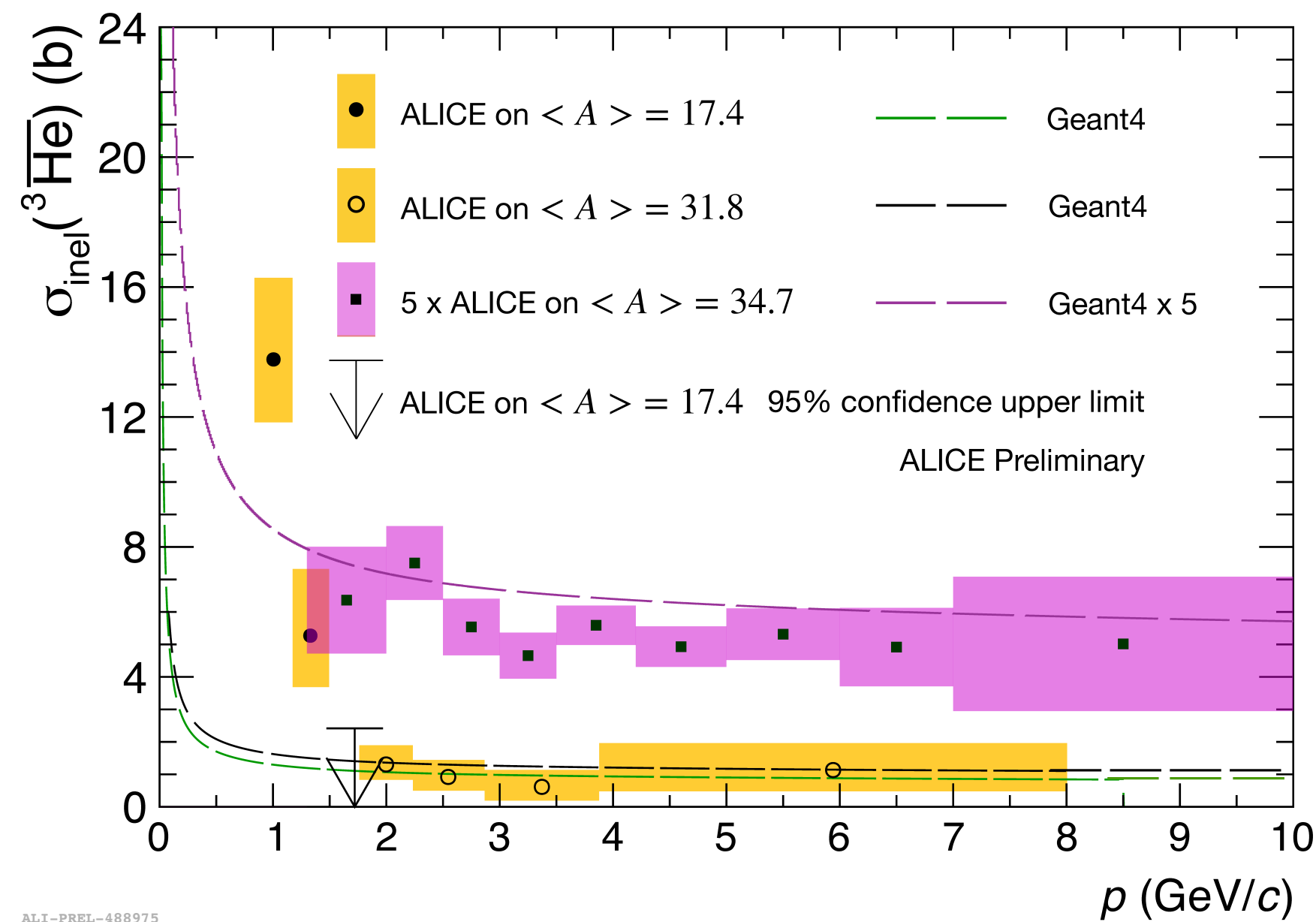
- Exceed J/ψ at low- p_T : coherent photo-production
- Sensitive to gluon distribution function at very low Bjorken- x

Unveiling strong interaction



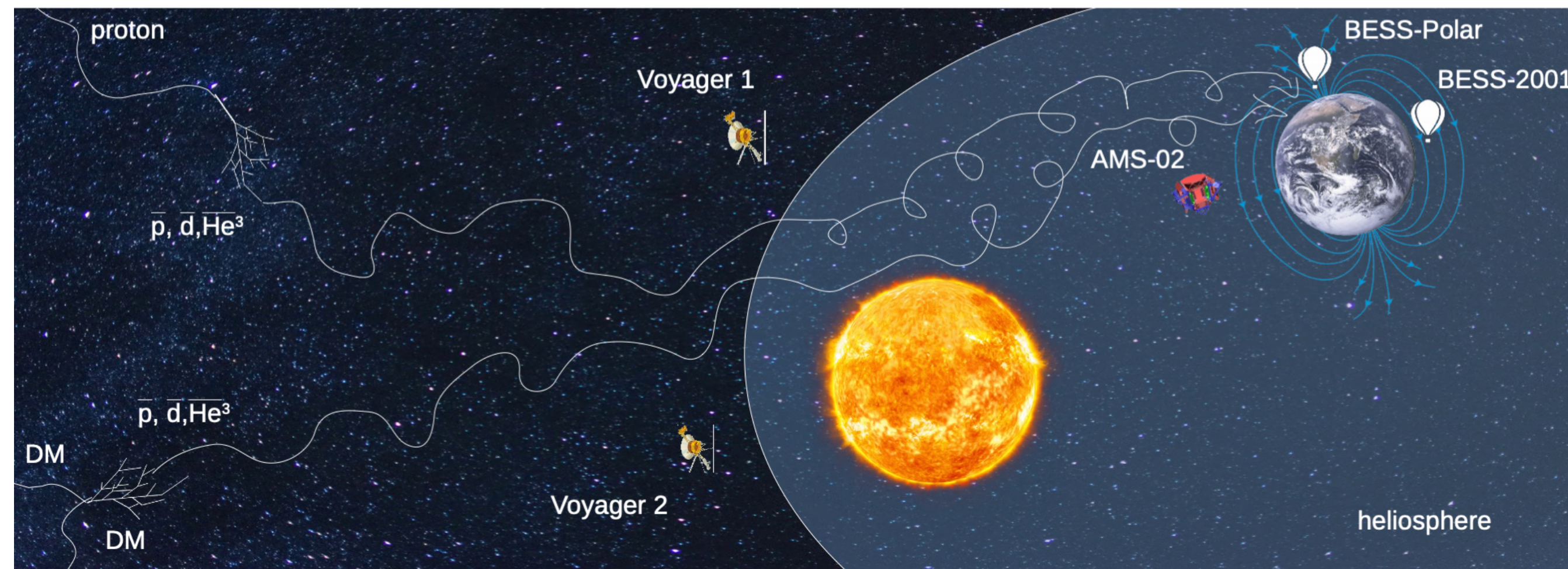
- Unveiling strong-interaction potentials among hadrons via femtoscopy
- Important test for lattice QCD, input for EOS of neutron stars

(Anti-)nuclei factory



- Production not yet fully understood
- Nucleon coalescence, statistical hadronization...
- New tool to study QGP hadronization

ALICE *Phys. Rev. Lett.* **127** (2021) 172301
Nature Phys. **19** (2023) 61



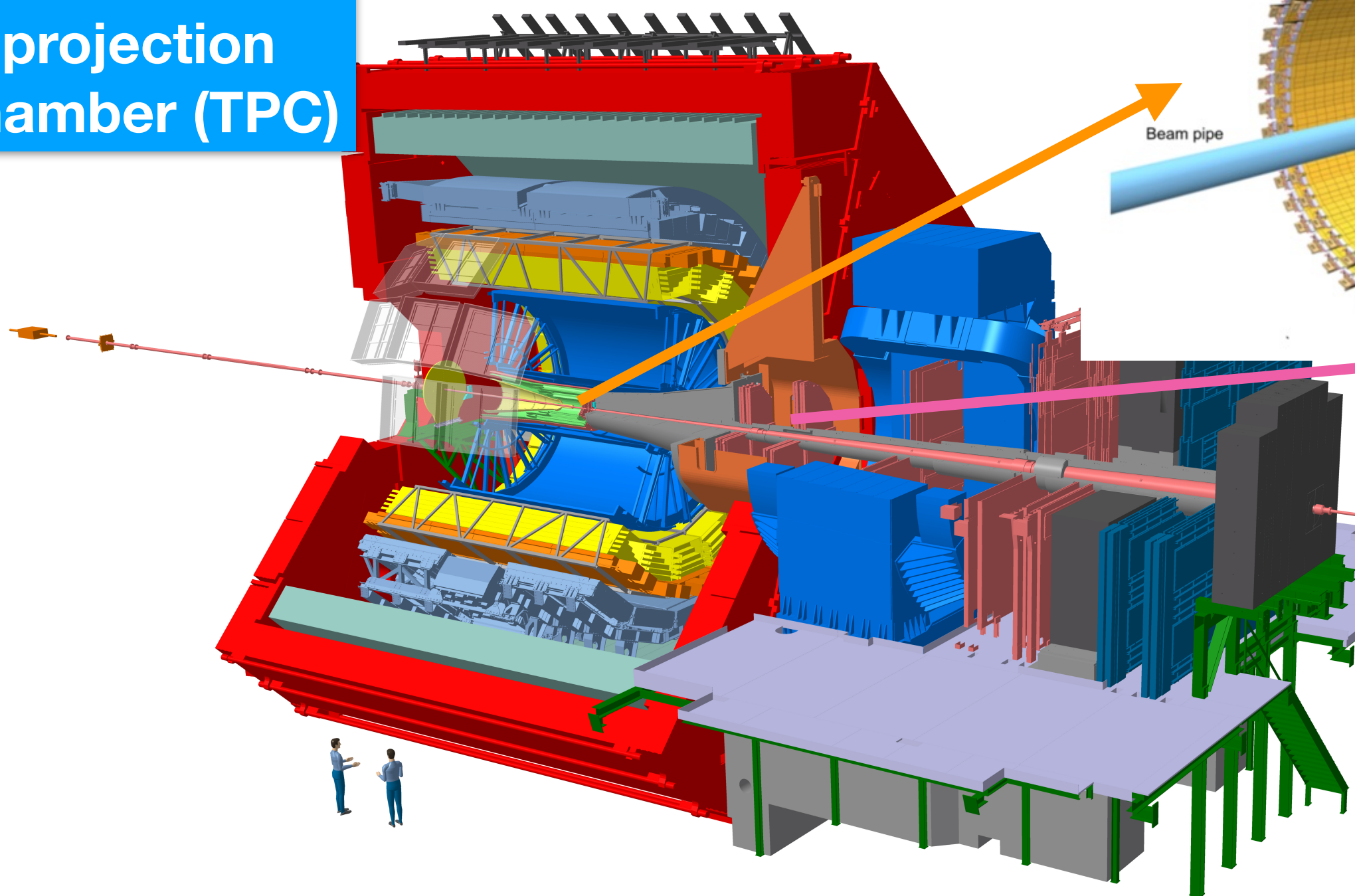
- Strong impact on Dark Matter searches, e.g.

$$\chi_0 \chi_0 \rightarrow \bar{d}, \overline{{}^3\text{He}} + X$$

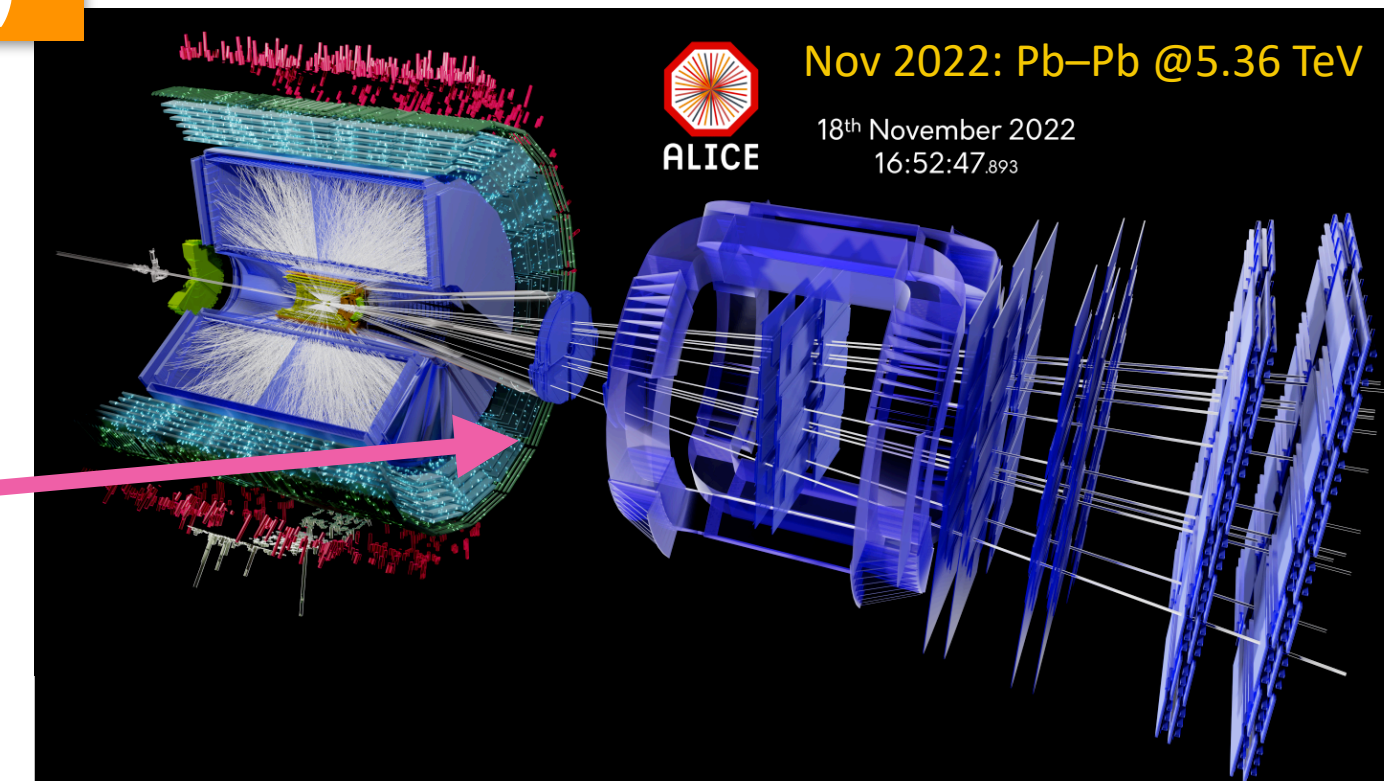
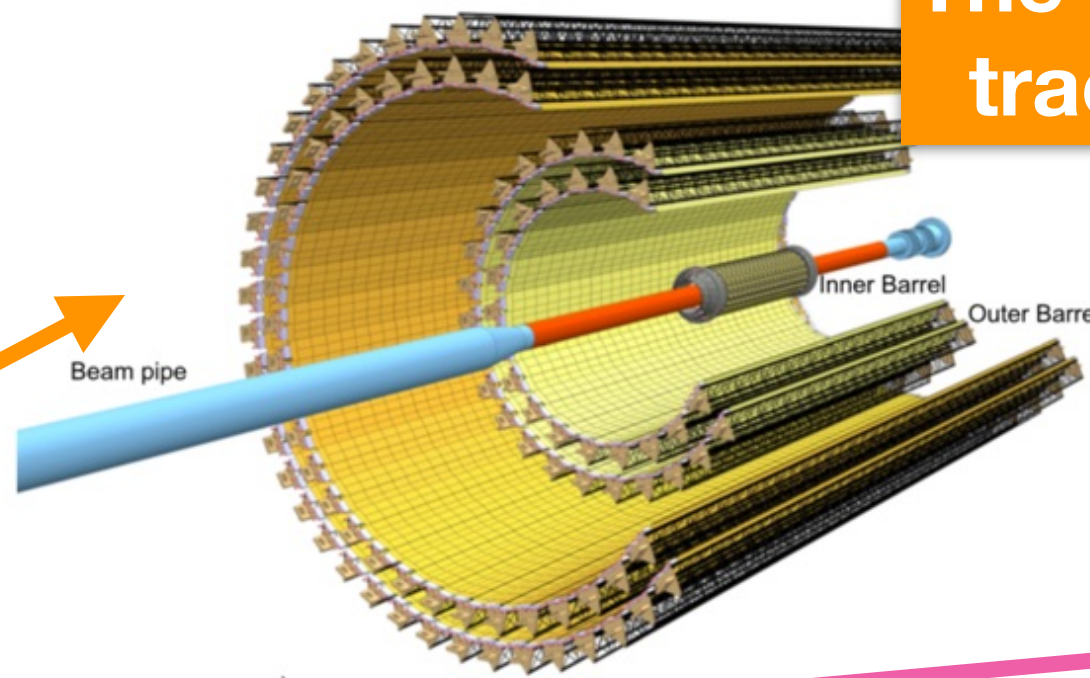
ALICE at the LHC Run 3



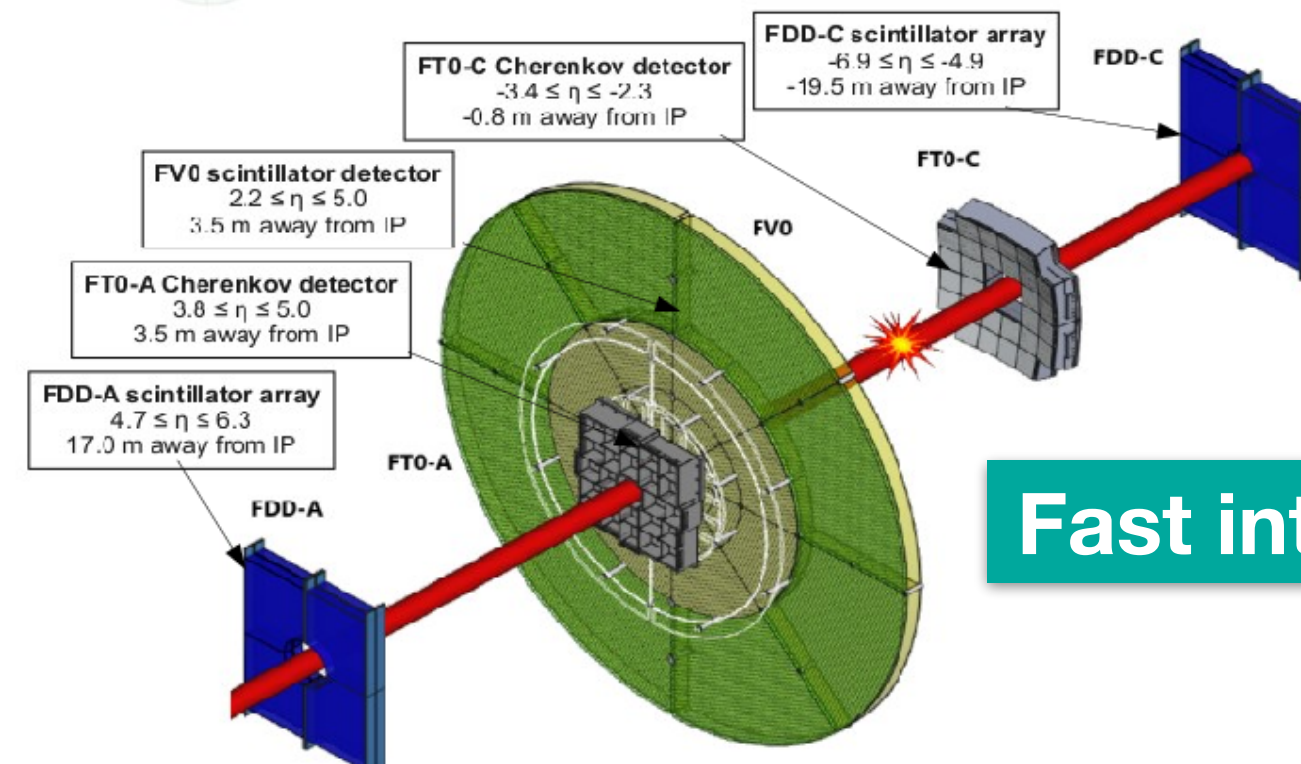
Upgraded readout of time projection chamber (TPC)



The 2nd generation inner tracking system (ITS2)

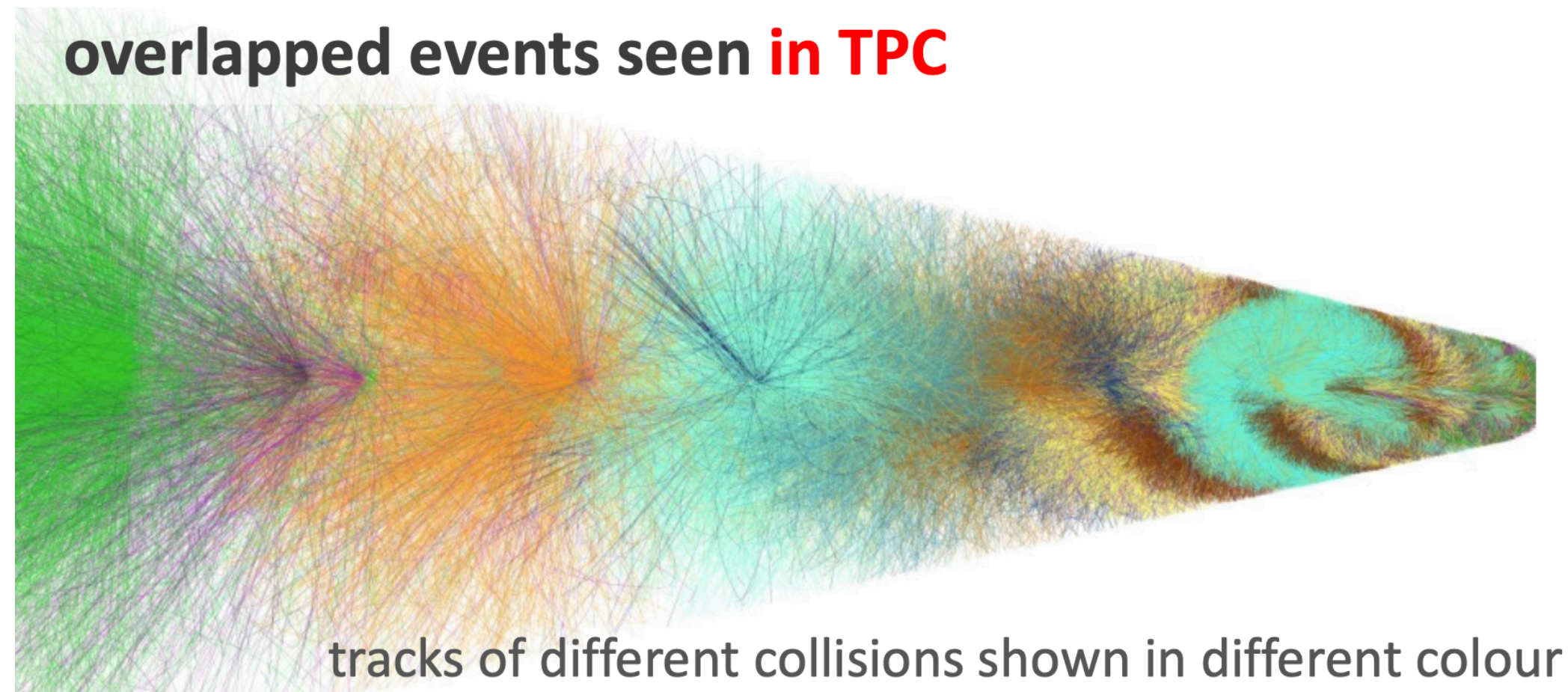


Muon forward tracker (MFT)



Fast integrated trigger (FIT)

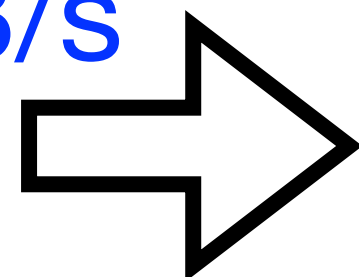
GEM-based TPC



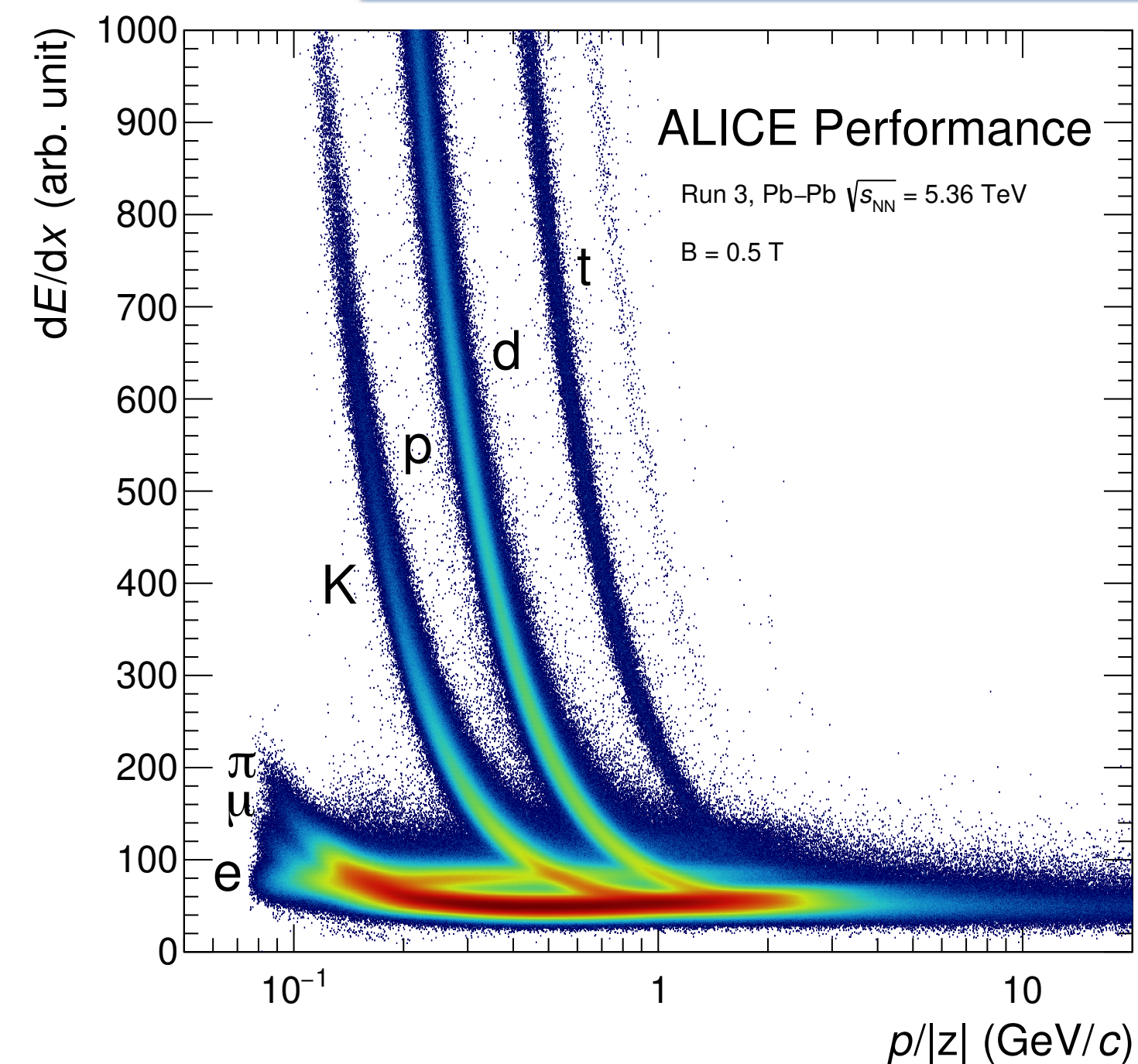
GEM-based TPC

➡ 50 kHz Pb–Pb, continuous readout

From detector ~ 3.6 TB/s
 ➡ Run 2: ~ 450 GB/s



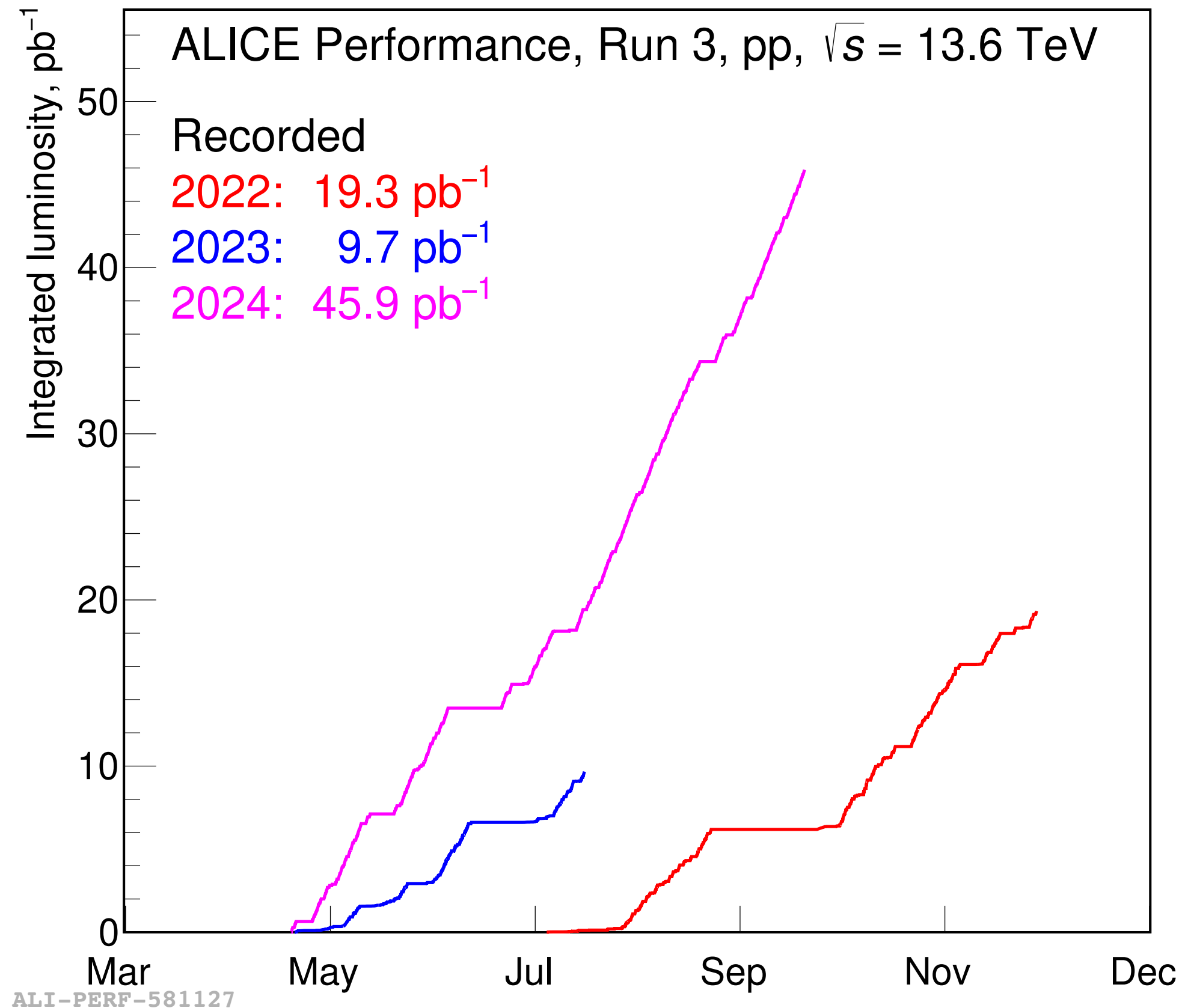
Storage: 130 PB
 ➡ Run 2: 1 PB



ALI-PERF-529714

Excellent TPC PID ➡ Directly “see”
 light nuclei (d, t, ^3He , ^4He)

ALICE data taking in Run 3



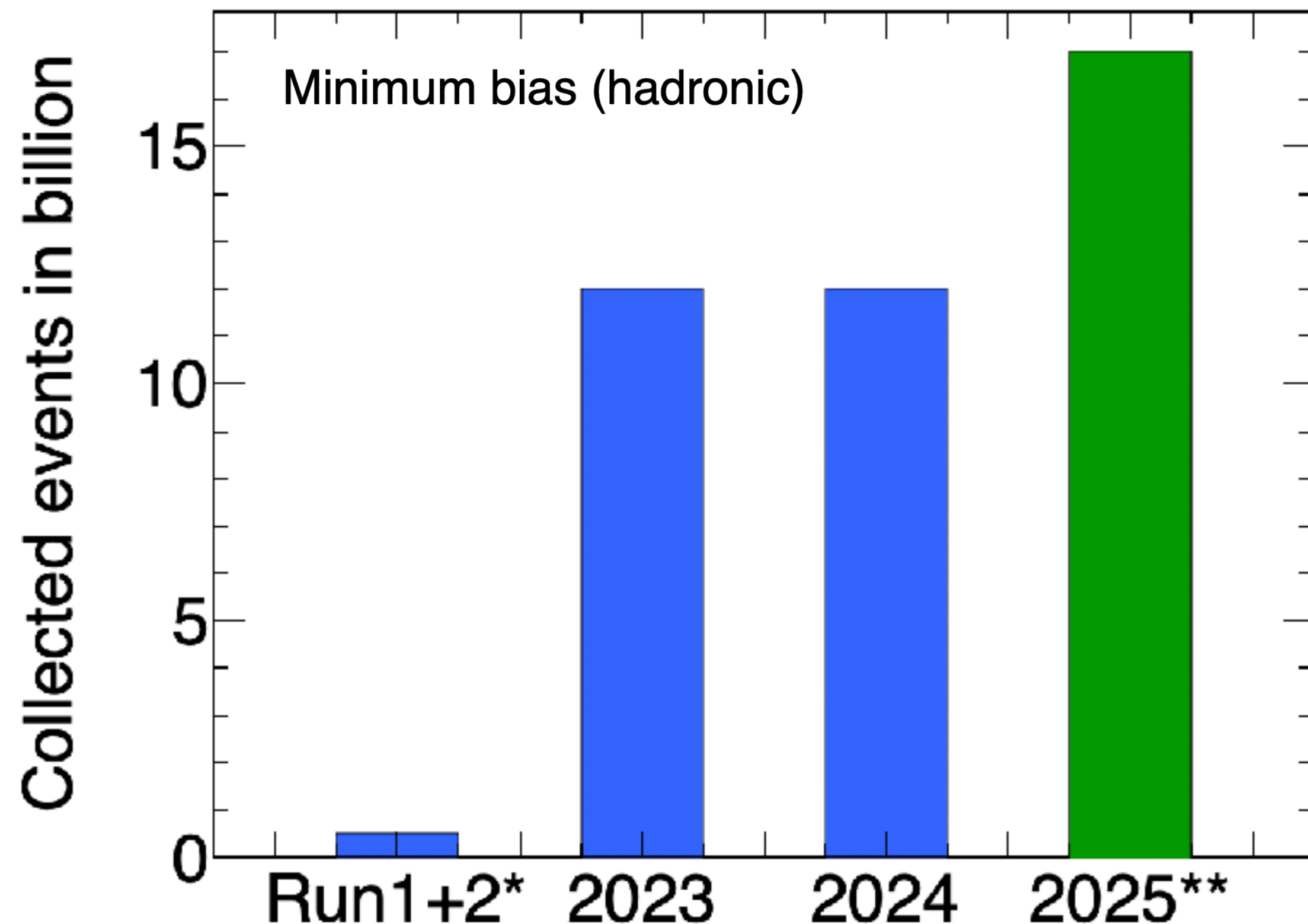
pp data taking

- Nominal interaction rate: 500–1000 kHz
- 2022–2024: 5.7×10^{12} minimum-bias (MB) events
 - ➔ ALICE LHC Run 1 & 2: 2×10^9 MB events
 - ➔ Event count increase: $\sim 3000 \times$

ALICE data taking in Run 3



Pb-Pb



Pb-Pb data taking

- 2022–2024: 2.4×10^{10} MB events
 - 2025 scheduled: 1.7×10^{10} MB events
- ➡ Event count increase: $\sim 70\times$

Expected later in 2025/2026

p-Pb: $\sim 150 \text{ nb}^{-1}$

p-O: $\sim 2.5 \text{ nb}^{-1}$

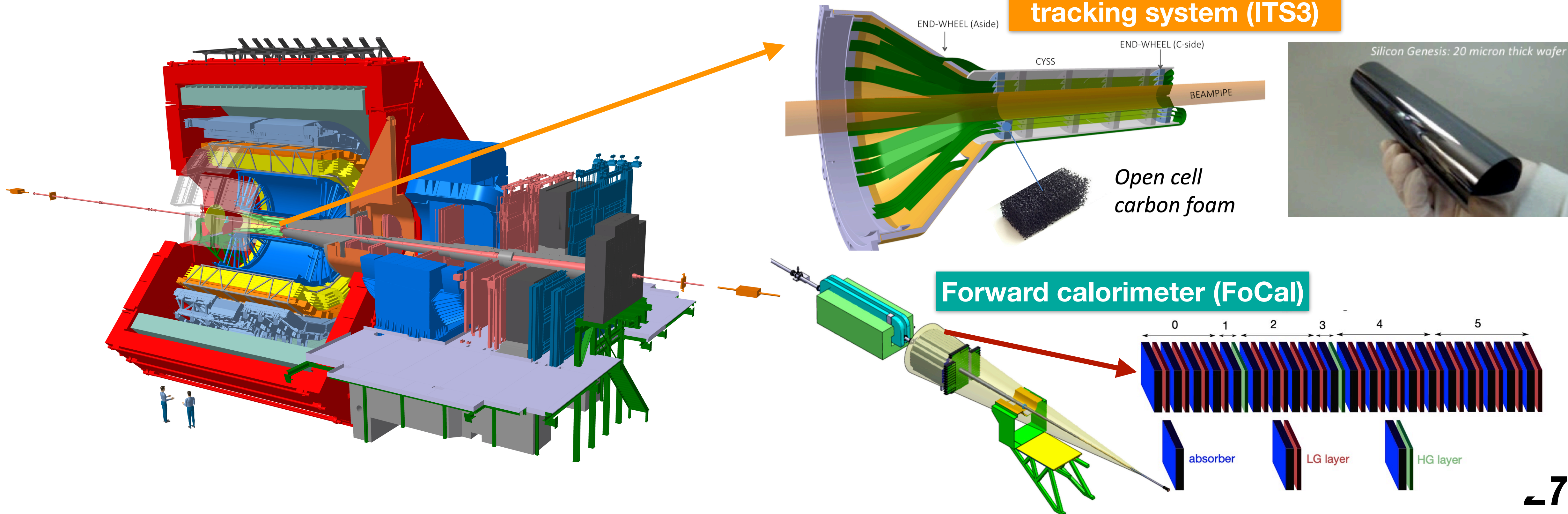
Ne-Ne: 0.1 nb^{-1}

O-O: 0.5 nb^{-1}

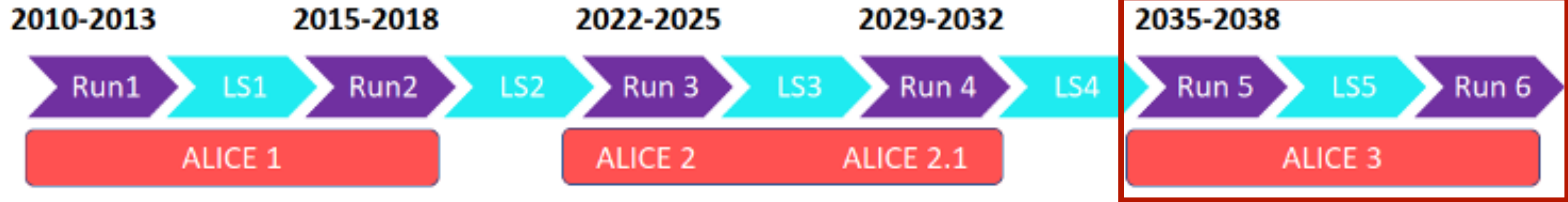
ALICE data taking in Run 4



The 3rd generation inner tracking system (ITS3)



Next-generation experiment



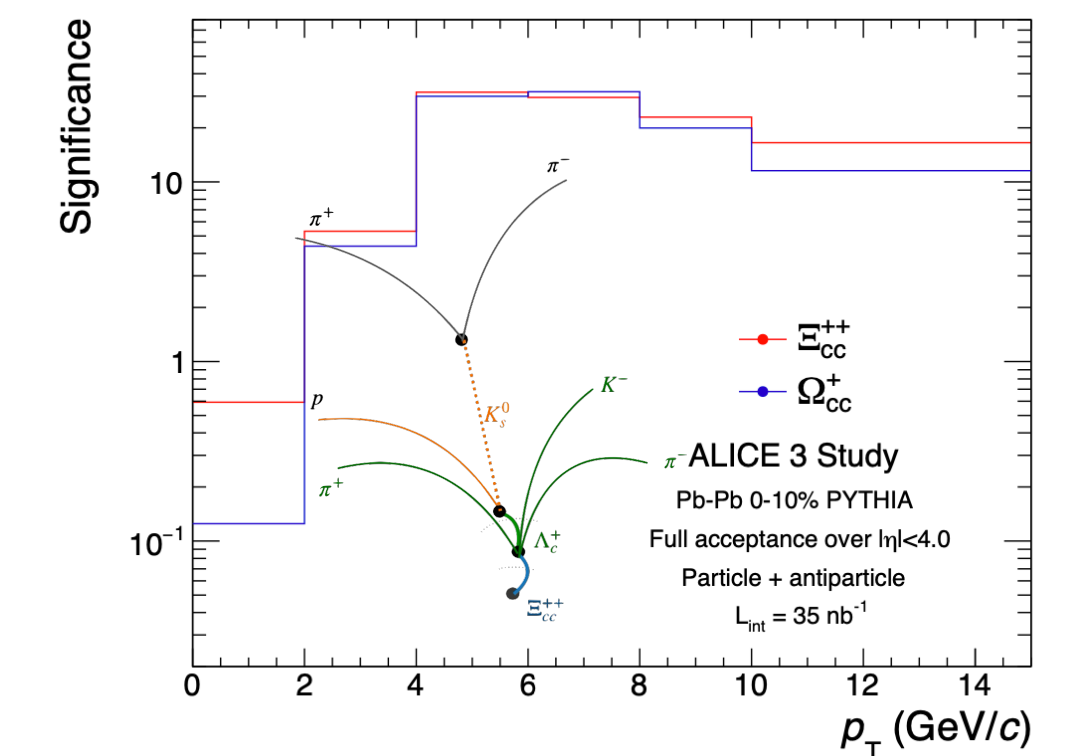
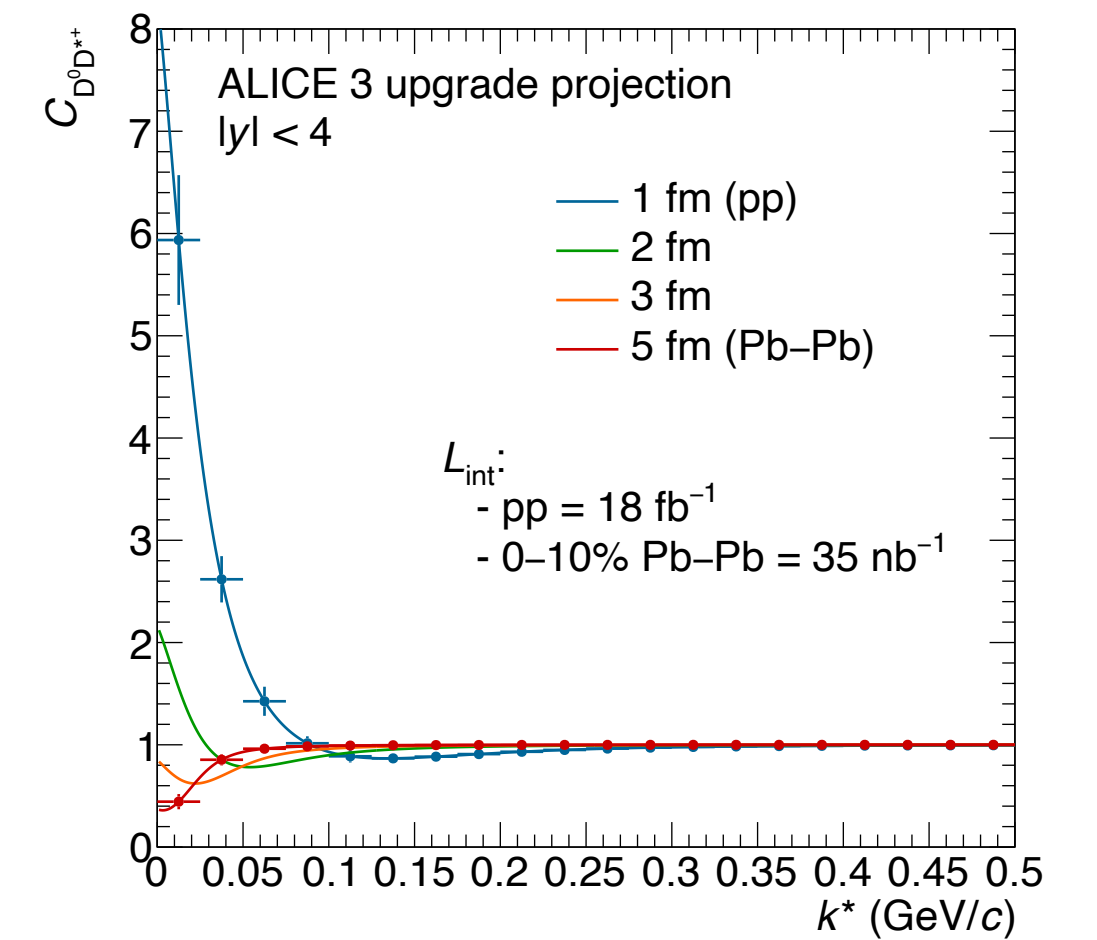
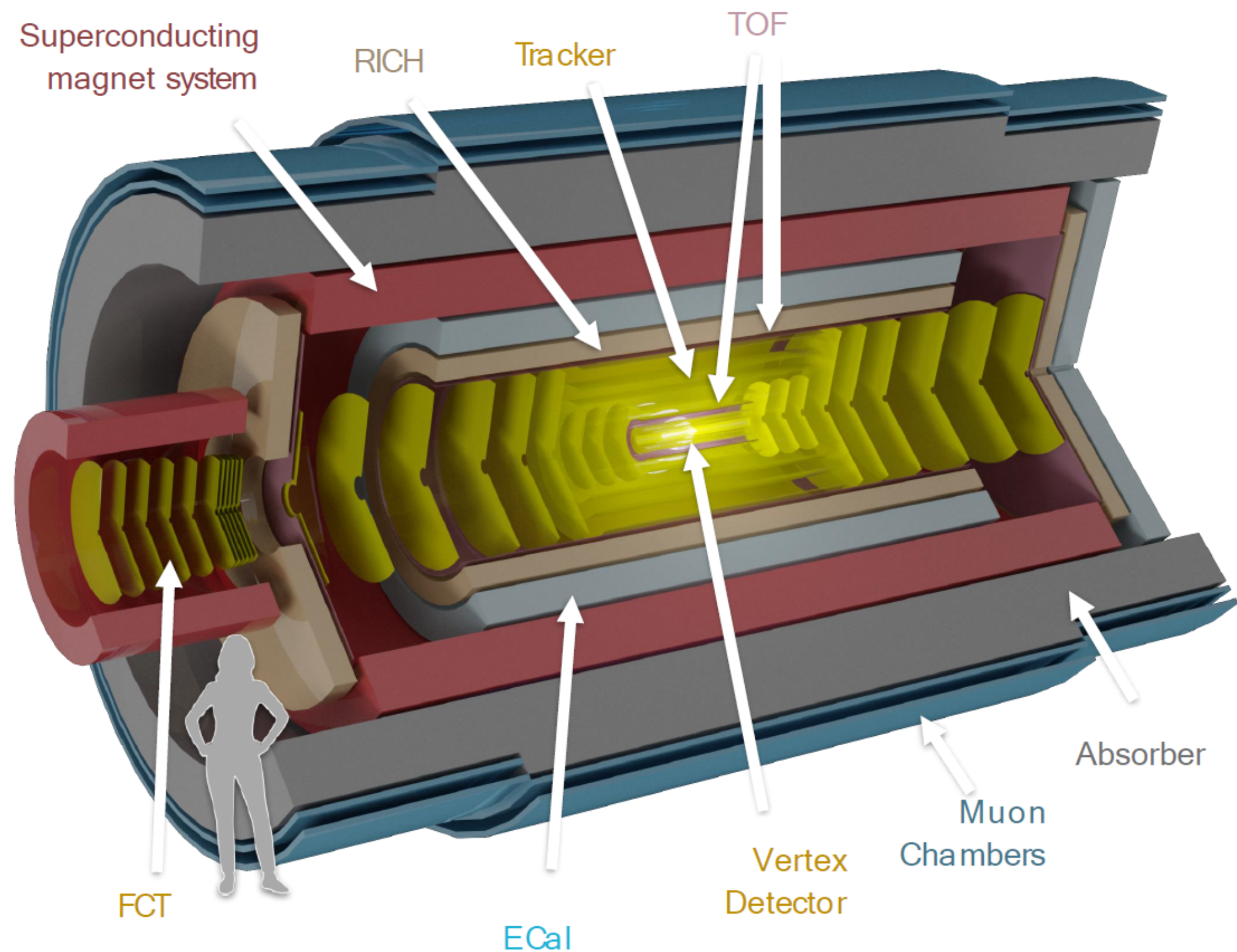
ALICE 3
Letter of intent

CERN-LHCC-2022-009
(LHCC-4-038)
4 November 2022

ALICE arXiv:2211.02491

A next-generation heavy-ion experiment at the LHC

VERSION 2



ALICE-China team



中方负责人：

殷中宝

中方主要参与单位

- 华中师范大学
- 复旦大学
- 中国原子能科学研究院
- 中国科学技术大学
- 中国地质大学（武汉）

负责人

张晓明

马余刚

李笑梅

唐泽波

彭忻烨

准成员单位（2025年获批）

- 中国科学院大学
- 中国科学院近代物理研究所
- 山东大学



M&OA人员：15人（占比3%）

参加人员：99人（占比：5%）

自然科学

科学家

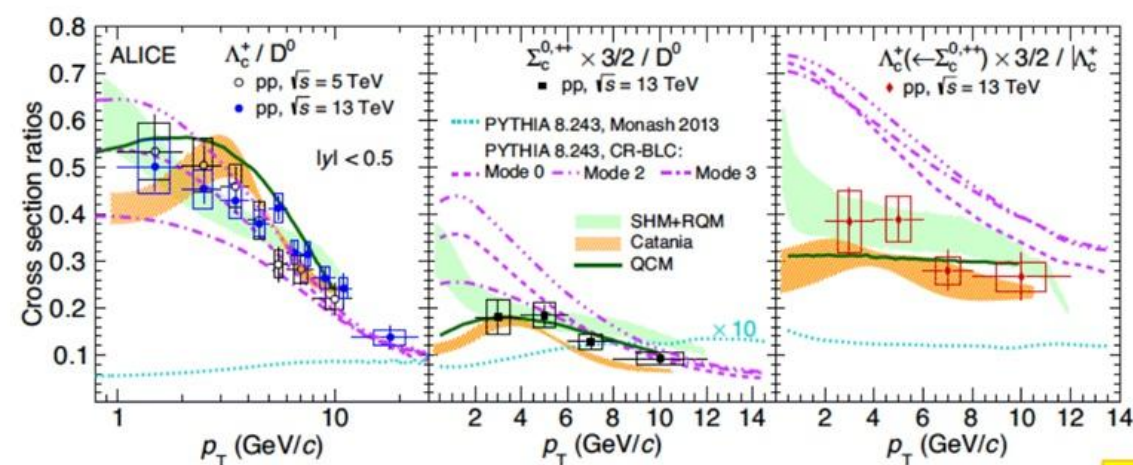
科学

科学学

基础科学

最近五十年内，中国科学家在基础科学领域都有哪些世界级的贡献？ 任何应用技术不在此讨论之内？

粲夸克强子化- $\Sigma_c, \Xi_c, \Omega_c$



PRL128, 012001 (2022)

SHM+RQM:

M. He, R. Rapp,
PRL124, 042301 (2020)

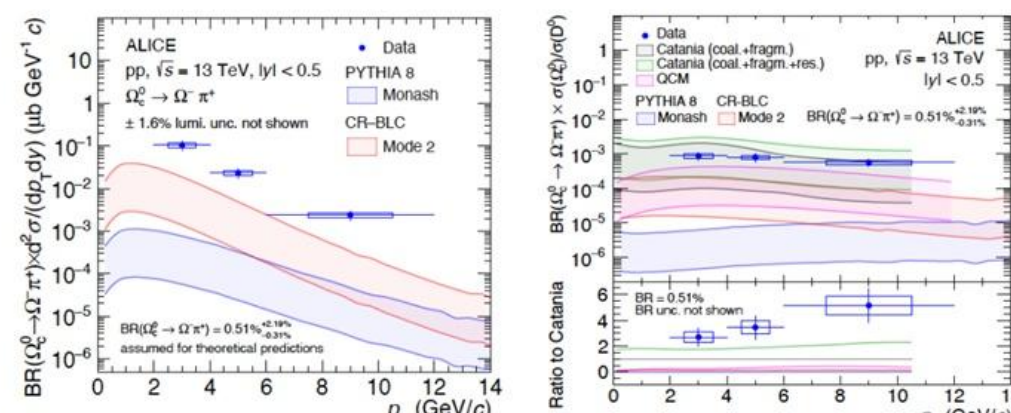
QCM:

J. Song, H. Li and F. Shao,
EPJC78, 344 (2018)

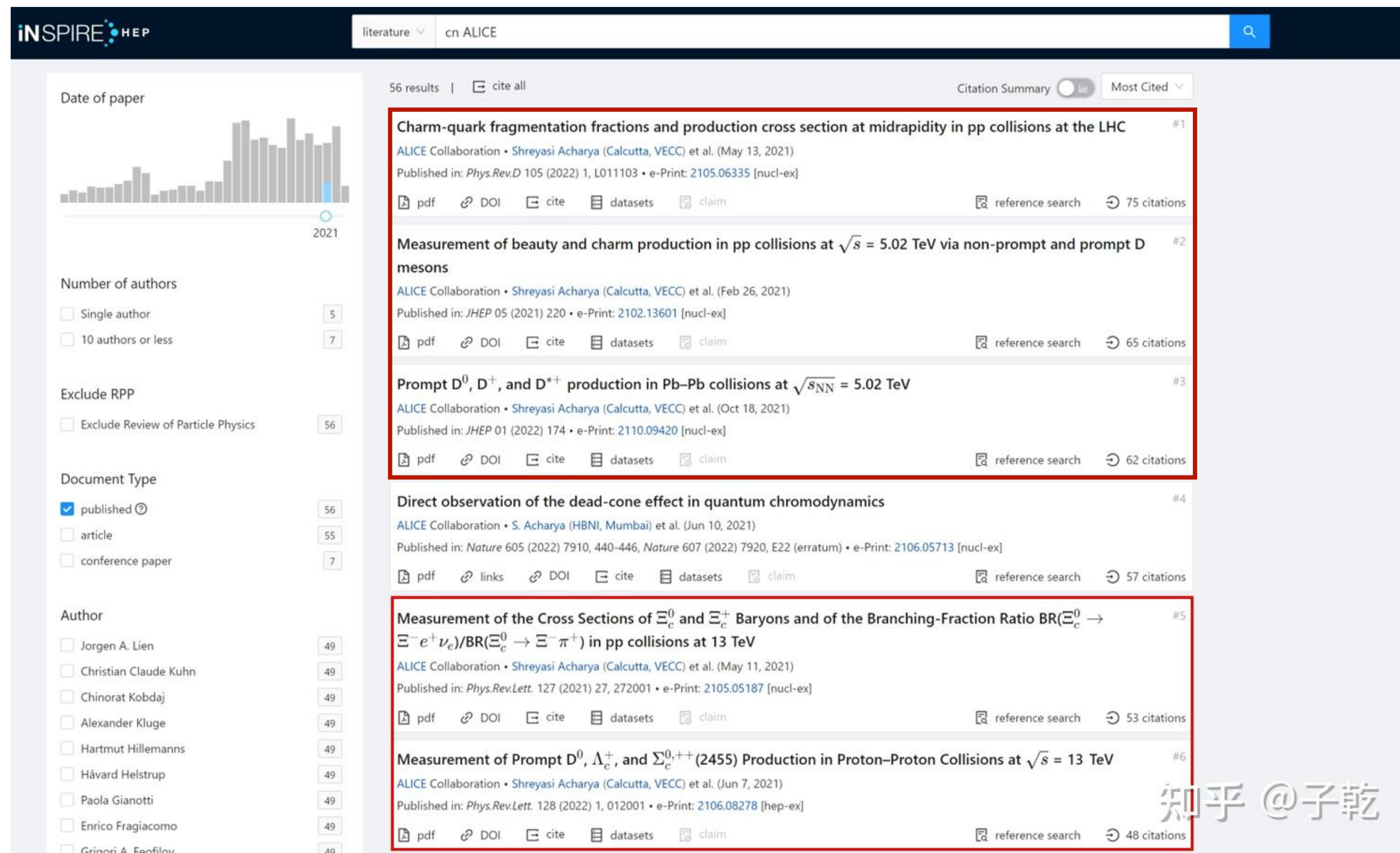
PRL127 (2021) 272001

- 系统测量了含粲夸克和奇异夸克的重子 $\Sigma_c^{0,++}, \Xi_c^0, \Xi_c^+$
- 与多种理论计算进行对比

arXiv: 2205.13993 。 sub to PLB



进一步系统测量了含粲夸克和奇异夸克的重子 $\Sigma_c^{0,++}, \Xi_c^0, \Xi_c^+$ ，并与多种理论计算进行对比，有些描述较好，有些还有较大差别，为理论模型提供了实验证据。中国理论家何江、邵凤兰等的相关工作也非常重要。本工作华师有重要贡献。





广阔天地 大有作为

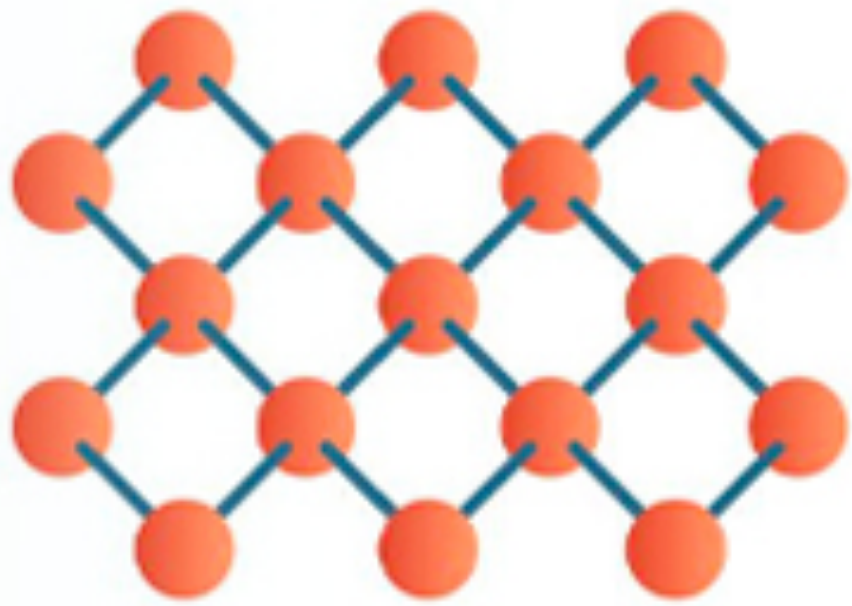
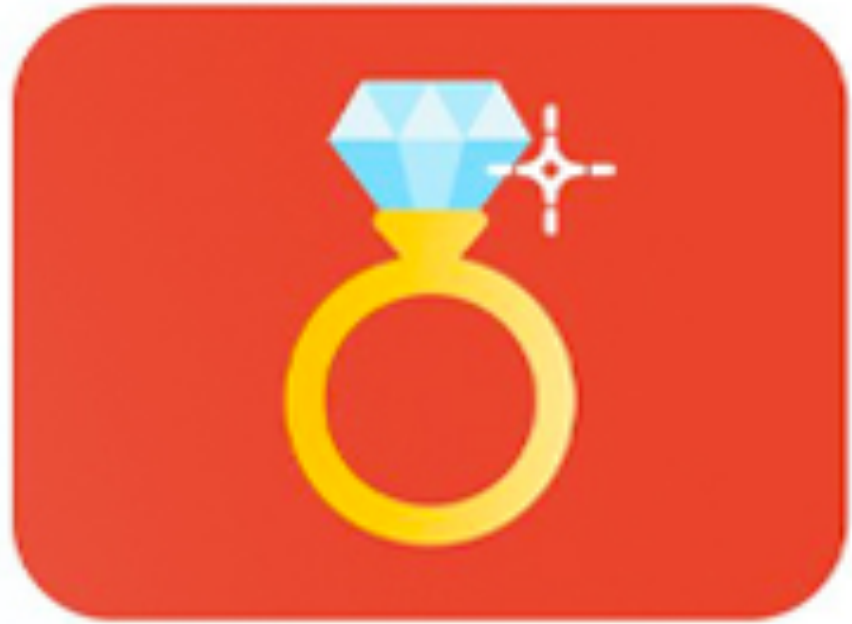
Backup



Physical status



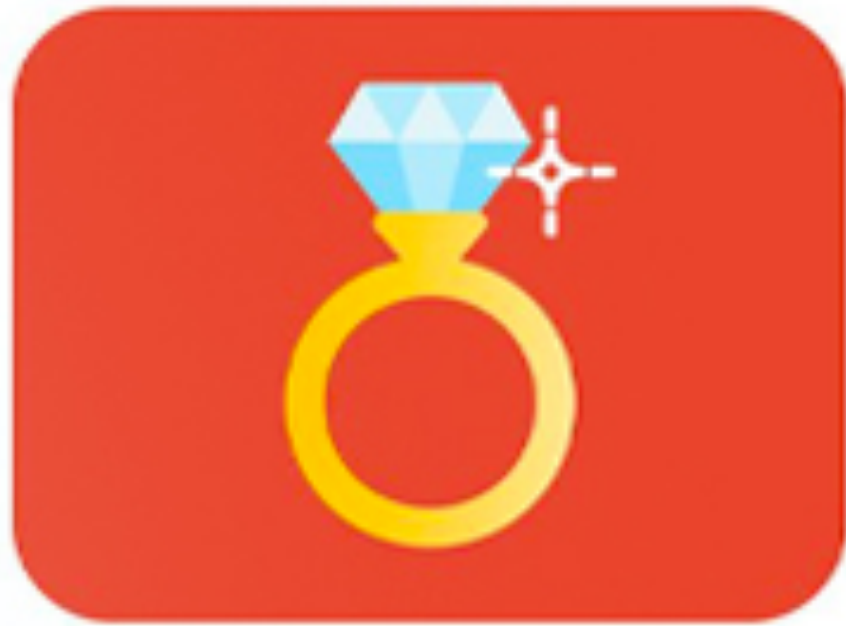
Diamond



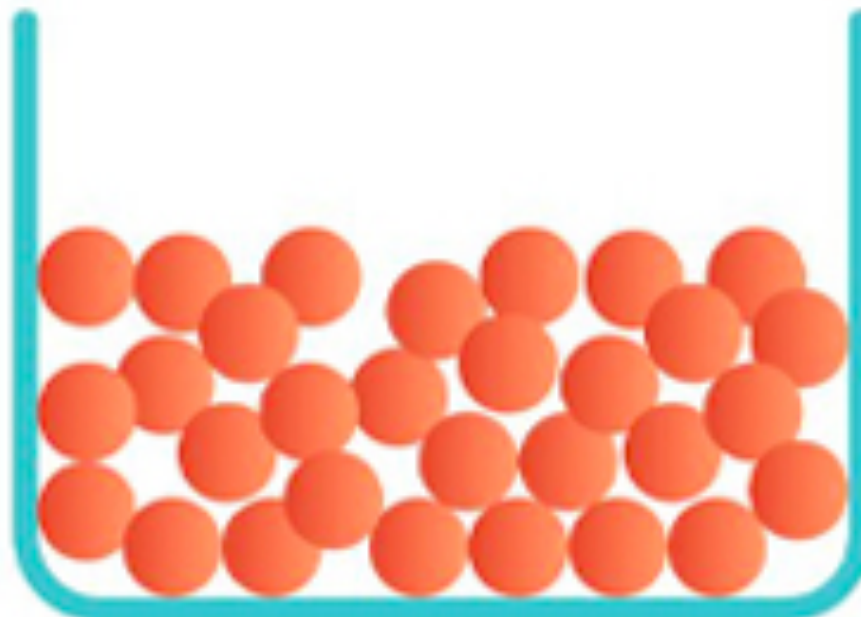
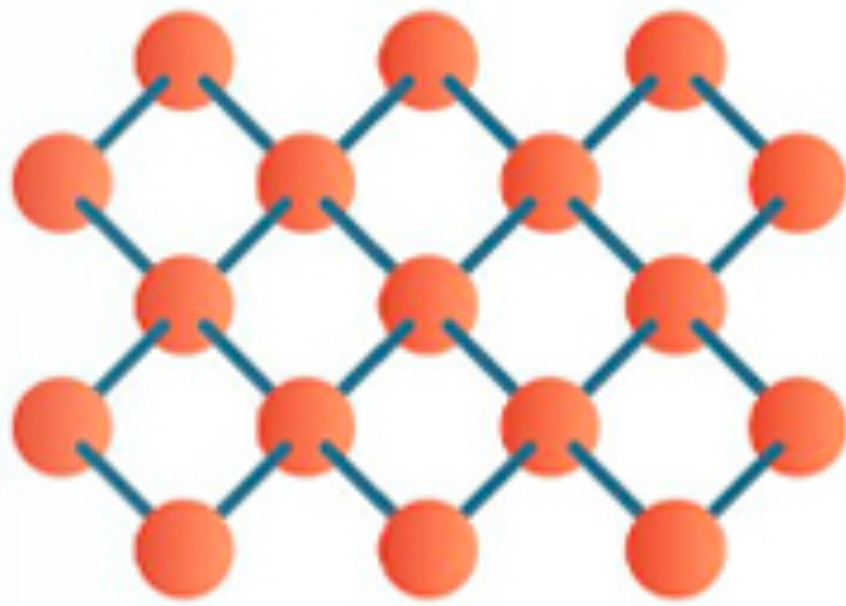
SOLID

Physical status

Diamond



Juice



SOLID

Melting



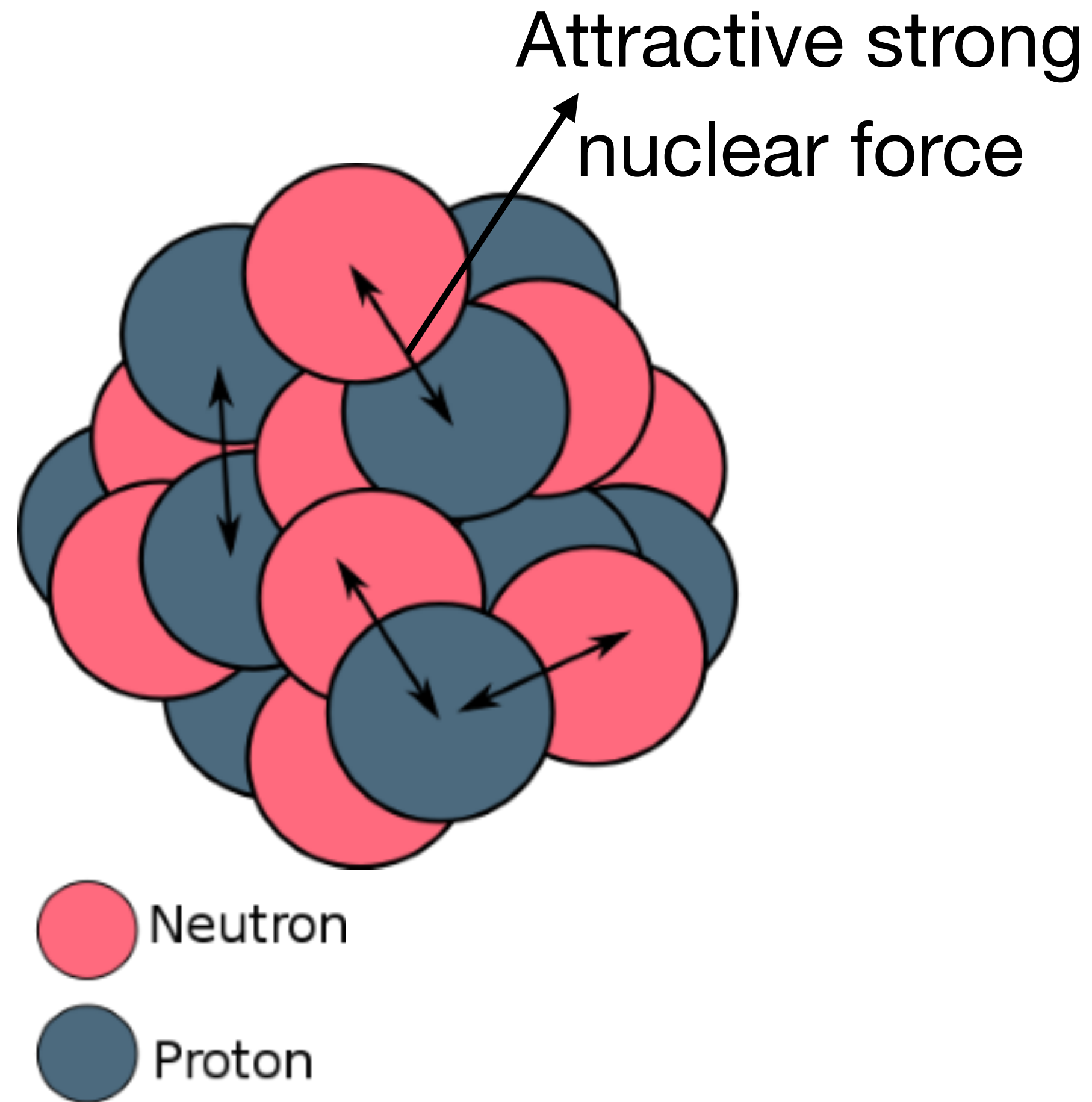
Freezing



LIQUID

Energy
Temperature

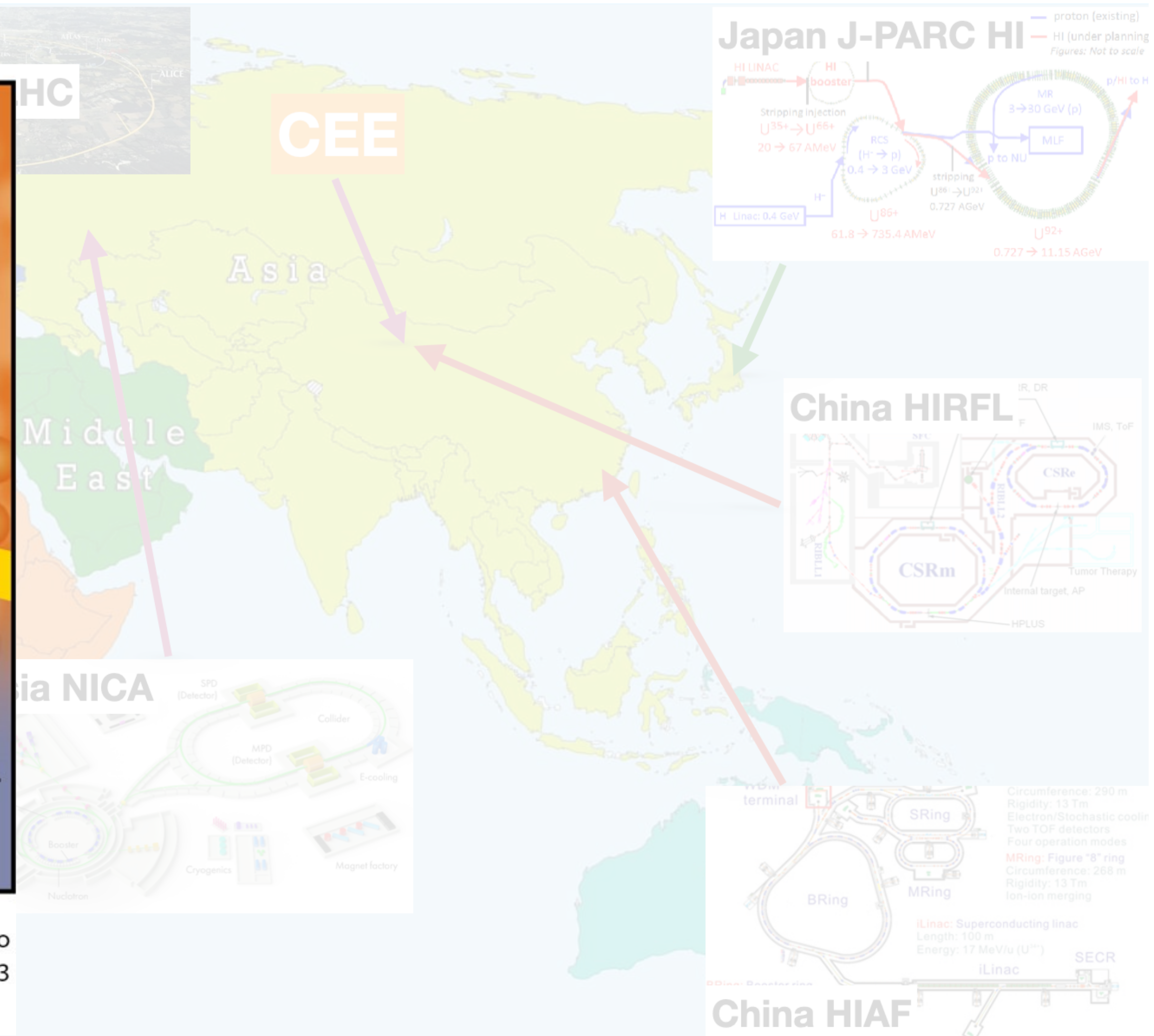
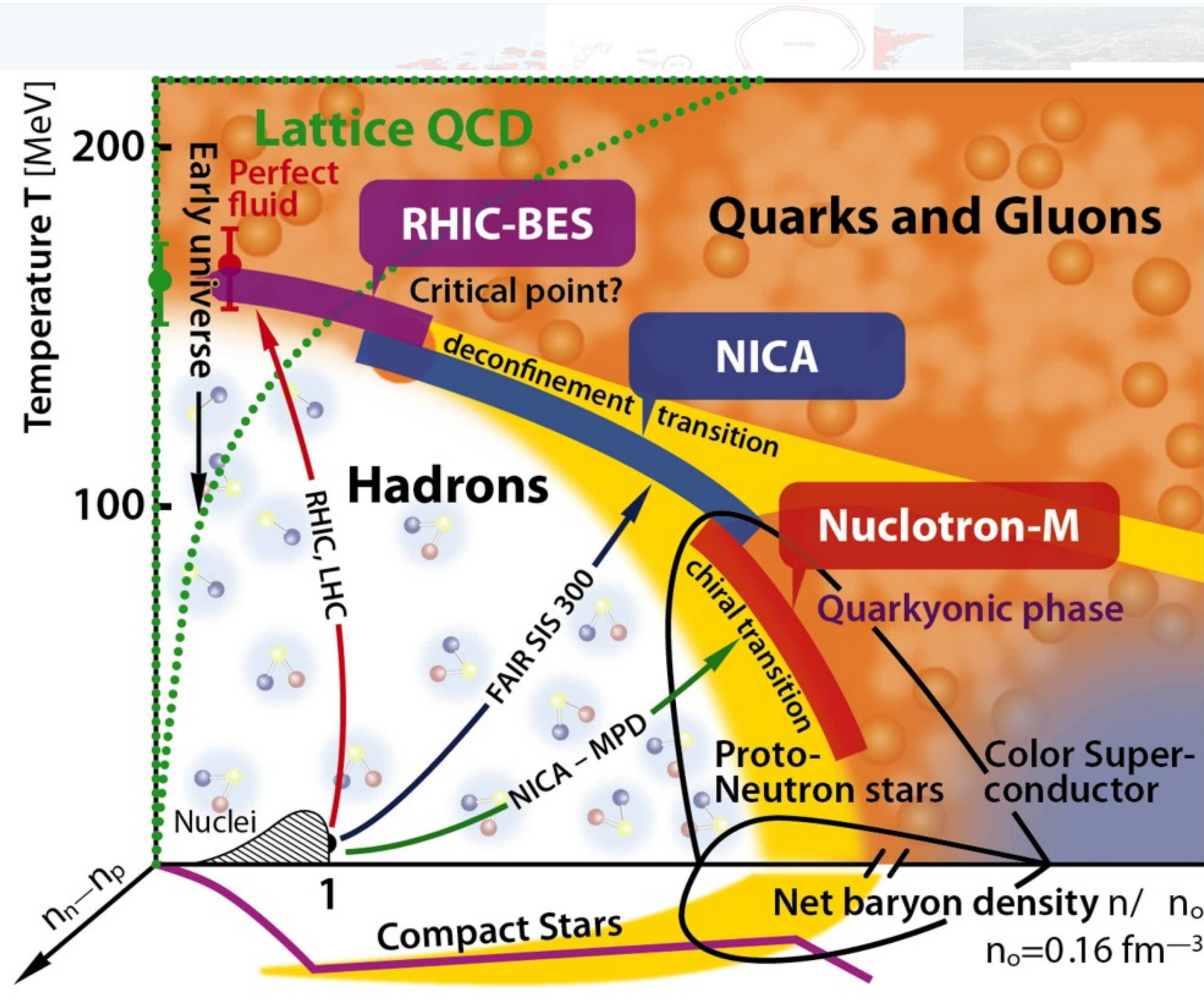
Strong force in nuclear



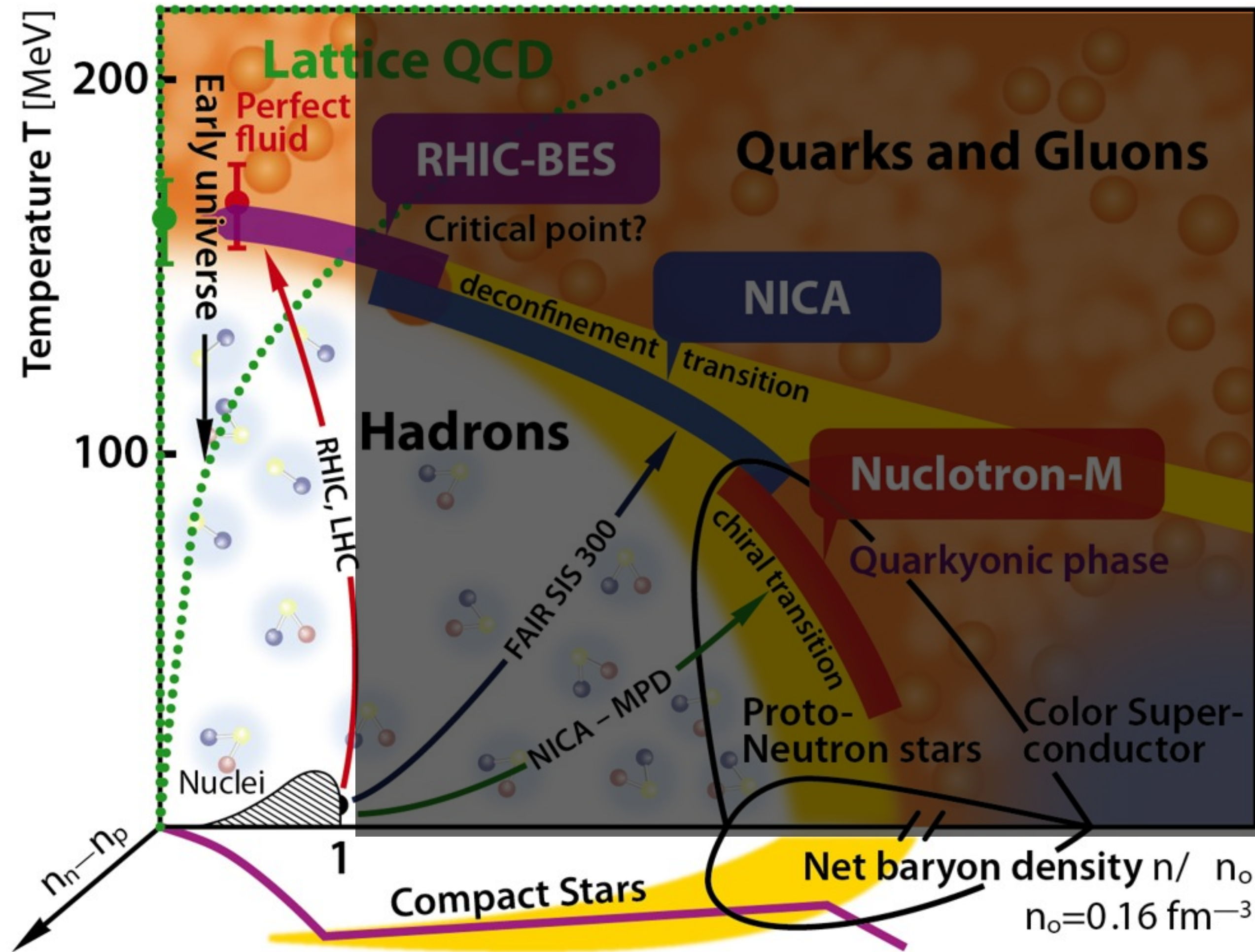
Heavy-ion program



Heavy-ion program



Heavy-ion program



High temperature and low μ_B : LHC, RHIC

- Global properties (T , $\eta/s...$) and collectivity
- Hard probes (jets, heavy quarks...)

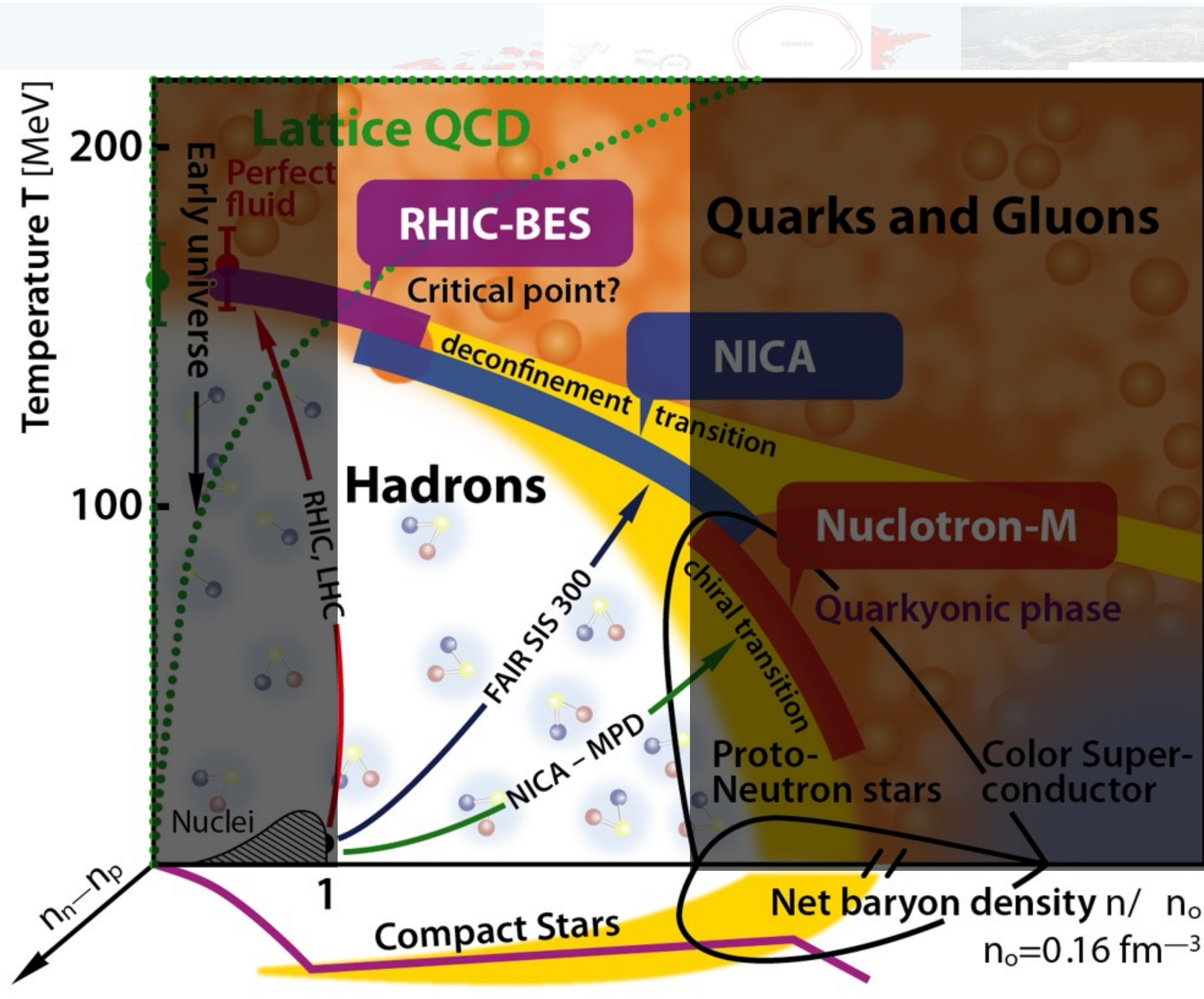
Finite temperature and μ_B : RHIC-BES, NICA

- Critical point search
- Correlations, di-lepton production...

Low temperature and large μ_B : NICA, FAIR

- Search rich structure of phase diagram
- EOS at large μ_B , chiral symmetry...

Heavy-ion program



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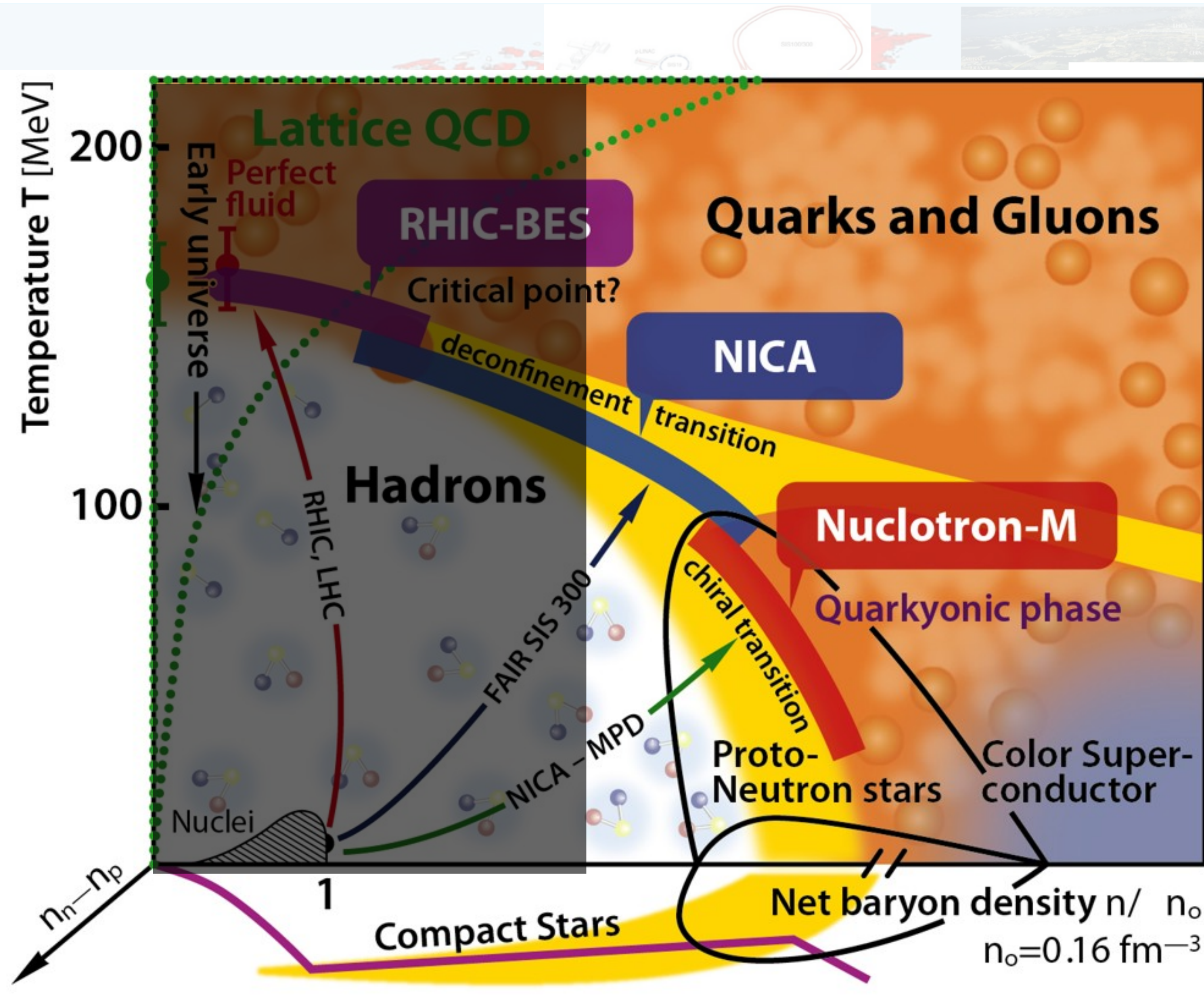
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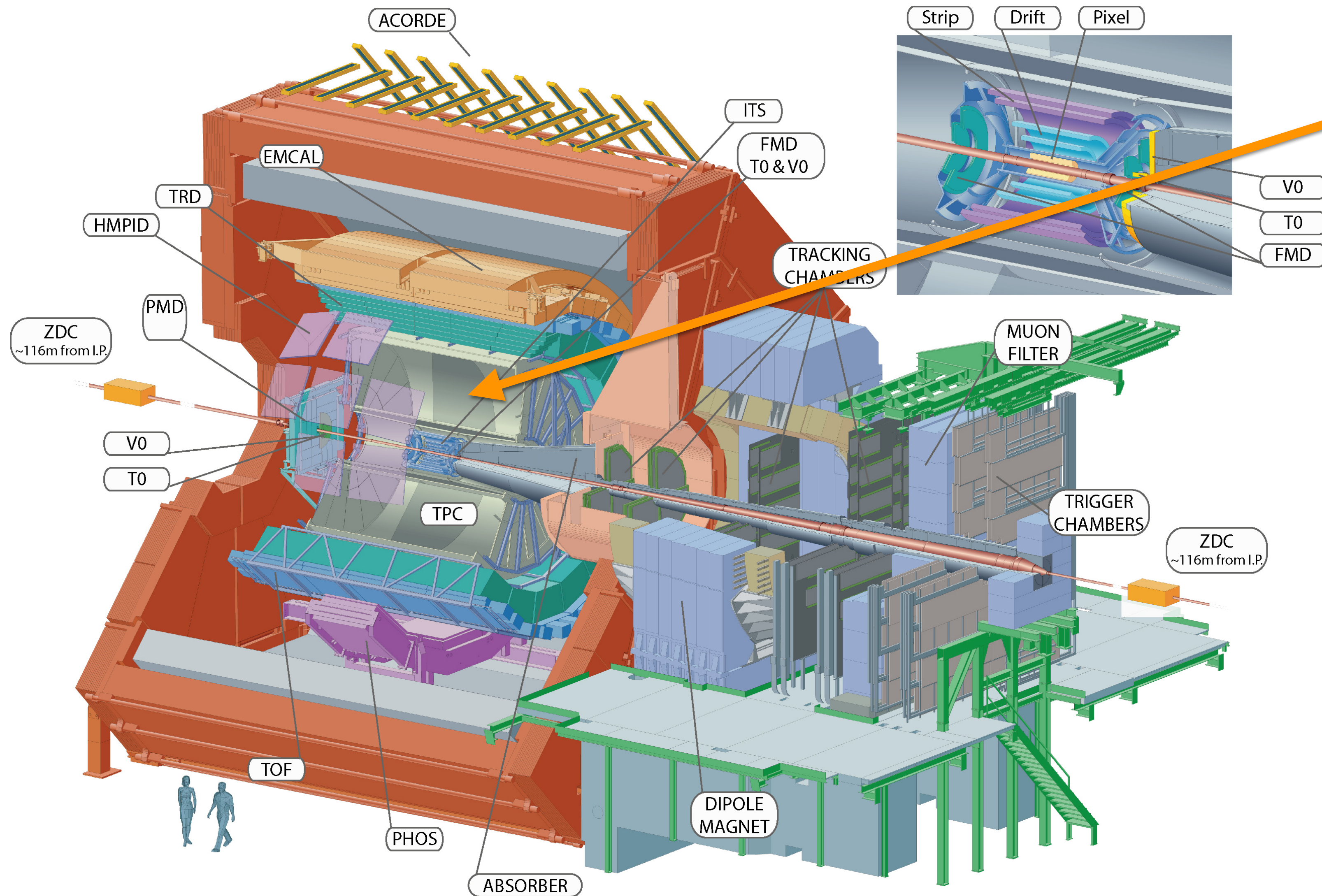
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ALICE apparatus



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