4th EIC Asia Workshop @ Shanghai, China

RBRC exp. group meeting

July 9th, 2024

Yuji Goto (RIKEN)

4th EIC Asia Workshop

- Fudan Univ. Jiangwan Campus, Shanghai, China
  - 复旦大学江湾校区
- July 1st (Mon) – 5th (Fri), 2024
- 55 participants on the participant list
  - From China, Korea, Japan, Taiwan, USA, Italy, Germany

Talks

- EIC/ePIC status
  - EIC status (Aschenauer)
  - ePIC status (Reed) remotely
  - EIC physics (Surrow)
- Theory overview
  - Intrinsic charm (Nocera)
  - Flavor structure (Kim)
  - Hadrons, superconductors, cosmic (Liu)
  - Jets (Kang)
  - TMD (Watanabe)
  - Lattice TMD (Morris)
  - FF (Xing)
- Experimental overview
  - HI collision in China (Zhang)
  - EicC (Zhao)
  - Belle exotics (Li)
  - STCF (Yan)

Talks

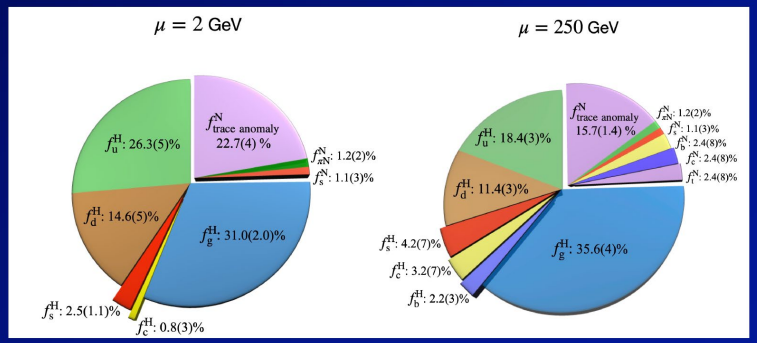
- EIC Asia status
  - China (Wang)
  - Japan (Gunji)
  - Korea (Bok)
  - Taiwan (Yang)
- ePIC detectors
  - AC-LGAD (Yano)
  - MPGD (Yoon)
  - BIC (Bok)
  - FECal (Ma)
- Discussions
  - Roundtable (Xu & Gunji)
    - To be summarized by Gunji-san
  - Intent of interest (Yang & Ma)

Talks

- Other theory talks
  - Energy correlator, 3D nuclei, Lattice PDF, Meson FF, eHIJING, polarized FF, BSM at EIC, nuclei at EIC
- Other experimental talks
  - Pol. 3He, PID detector, X(3872), STAR results, UPC results, Proton radius

Liu's talk

Rest Energy Decomposition from Hamiltonian



$$f_f^H = \langle H_q\rangle/M = \frac{3}{4}\langle x\rangle_f(\mu), \quad f_g^H = \langle H_g\rangle/M = \frac{3}{4}\langle x\rangle_g(\mu),$$

$$f_{\pi N}^N = \frac{1}{4}\frac{\sigma_{\pi N}}{M}, \quad f_s^N = \frac{1}{4}\frac{\sigma_s}{M}, \quad f^N_{\text{trace anomaly}} = \frac{1}{4}\frac{\langle H_{\text{ta}}\rangle}{M}$$

Y.B. Yang et al (χQCD) [arXiv: 1511.15089]

Momentum fractions from CT18 (T.J. Hou et al, PRD, arXiv:1912.10053) at μ = 2 GeV and 250 GeV.

Trace Anomaly and Gluon Condensate

- Equation of state $E_0 = \epsilon\, V + \epsilon_K\, V^{-1/3}$, (cf. MIT Bag Model)

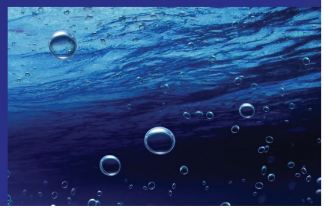
  where $\epsilon = \frac{E_S}{V}, \quad \epsilon_K = E_T\, V^{1/3}$ are constants
- Picture: Nucleon is a bubble in the sea of gluon condensate, where

  $\epsilon = -\epsilon_{\text{vac}}$ N.B. $\langle OG_2\rangle_{\text{correlated}} = \langle OG_2\rangle - \langle O\rangle\langle G_2\rangle$

  $\epsilon_{vac} = \frac{\beta(g)}{2g}\langle 0|F^{\alpha\beta}F_{\alpha\beta}|0\rangle < 0 \qquad V = \frac{E_S}{|\epsilon_{\text{vac}}|}$
- Trace anomaly gives a negative constant pressure ⟹ confinement

  Same as in charmonium $V(r) = |\epsilon_{vac}|\, A\, r = \sigma\, r$

  Bali ('97), Baker ('18)
- Many facets of color confinement
  - Dual superconductor
  - Magnetic monopole
  - Center vortices



Superconductor Vortex

- F_S – Cost of compensation energy
- F_B -- Magnetic field energy
- F_{SC} -- Supercurrent energy
- Total Electron mass $m_e\langle\bar\psi\psi\rangle \sim m_e\langle\psi^\dagger\psi\rangle$
- Negative constant pressure from F_S
- Confinement due to the superconducting condensate

Hadron

- H_{ta} -- Trace anomaly
- H_g -- Glue field energy (E^2+B^2)
- H_q -- Quark energy
- H_σ -- Sigma terms
- Negative constant pressure from trace anomaly
- Confinement due to the glue condensate

Trace Anomaly and Cosmological Constant

- Note the energy density-pressure relation of both hadrons and superconductor vortices satisfy $P = -\epsilon\,(\omega = -1)$ -- a unique feature arising from a vacuum condensate with constant energy density, much like the Archimedes principle. $P = -dE/dV = -d(\epsilon V)/dV = -\epsilon$
- Rewrite Einstein's equation -- the cosmological constant is an extra term in the energy-momentum tensor $\omega = -1.00 \pm 0.04$

$$R_{\mu\nu} + \frac{1}{2}R\, g_{\mu\nu} = 8\pi G\, T_{\mu\nu} + \Lambda\, g_{\mu\nu}$$

$$T^{\mu\nu} = \overline{T}^{\mu\nu} + \frac{1}{4}g^{\mu\nu}(T^\rho_\rho)$$

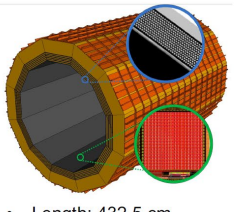
- This suggests that, by analogy, the cosmological constant is a quantum trace anomaly which arises from gravitational conformal symmetry breaking like in QCD.

$$\Lambda = \frac{1}{4}\langle T^\mu_\mu\rangle_U/8\pi G$$

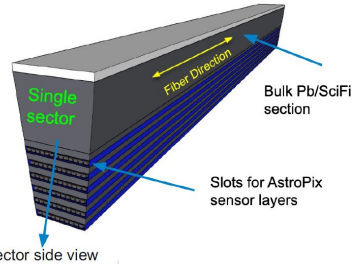
Bok's talk

- Barrel Imaging Calorimeter in Korea

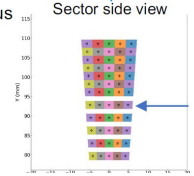
Detector Structure: Imaging Layer



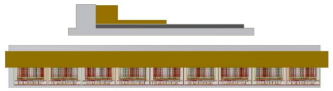
- Length: 432.5 cm
- Radius: ~ 80 cm radius
- Structure: 48 sectors
- $-1.71 < \eta < 1.31$



Sector side view

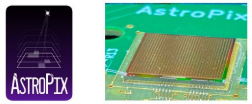


- Pb/SciFi Layer - 12 layers per sector
- Structure: 5 readout cells (one light-guide per readout cell)



Imaging Layer (Silicon Pixel)

- Module – Several AstroPix chips daisy-chained together on Flex PCB
- Length ~16 cm, Width ~2 cm
- Gaps < 200 µm
- Structure: ~ 8 chips/module



- AstroPix tracking layers to capture 3D image of shower development

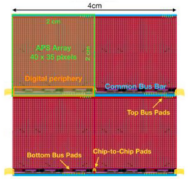
Imaging Layer: AstroPix

- Imaging layers based on AstroPix sensors
  - Developed for AMEGO-X NASA mission
  - CMOS sensor based on ATLASpix3 (arXiv:2109.13409)
- Key features:
  - Very low power dissipation
  - 500 μm pixel size
  - Time resolution ~3.25 ns

AstroPix chip R&D:

- v1 (4.5×4.5 mm2, 200 μm pixel)
  - Early prototype
- v2 (1×1 cm^2, 250 μm pixel)
  - Tested with γ, β sources, and 120 GeV proton beam
- v3 (2×2 cm^2, 500 μm pixel, quad chip)
  - Ongoing bench and beam test
  - Main prototyping with this chip version
- v4 (1×1 cm^2, 500 μm pixel)
  - better noise/threshold performance
- v5 (1.87x1.96 cm^2, 500 μm pixel)
  - Final production version for BIC

Quad chip v3



v3 carrier board

arXiv:2208.04990 **[astro-ph.IM]**

Targeted AstroPix performance goals

Pixel size	$500\,\mu m \times 500\,\mu m$
Power usage	< 1 mW/cm^2
Energy resolution	10% @ 60 keV (based on the noise floor of 5 keV)
Dynamic range	~ 700 keV
Passive material	$< 5\%$ on the active area of Si
Time resolution	25 ns
Si Thickness	$500\,\mu m$

Total number of 2x2 cm^2 chips: 249,600 **~100 m^2**

Discussions

- ASIC support limitation
  - How to readout ZDC crystal?
  - AstroPIX detector
- Cooperation with China
  - Involving China colleagues in EIC-Asia group meeting & eic-asia-l ML
  - Detector cooperation incl. EicC
  - Crystal from China

Photos