# Ph.D. research journey

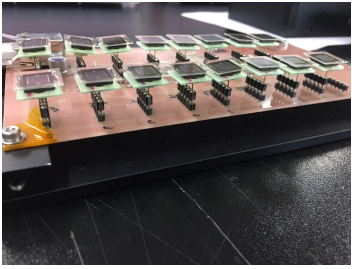
Junlee Kim

August 26, 2023
Heavy-Ion Meeting
Jeonbuk National University & Inha University

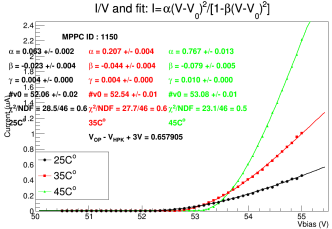

- KOTO experiment at the J-PARC
- Searching for clean and rare kaon decay of $K_L \to \pi^0 \nu\bar{\nu}$
- Contributions to innermost sampling calorimeter

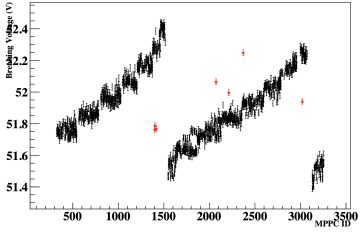

- ALICE experiment at the LHC
- Relativistic Heavy-Ion physics
- A wide range of experiences over PWGLF, PWGCF, PWGMM, PWGJE

# Operating voltages of MPPCs for the KOTO experiment (2018. 06.)

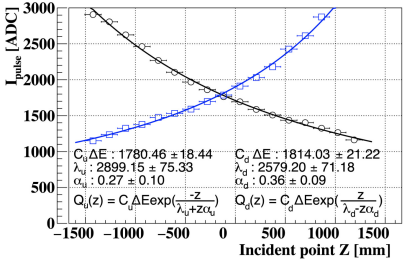



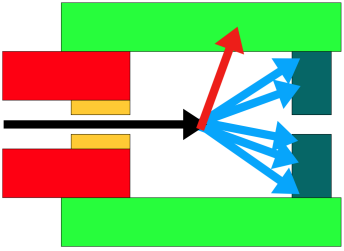
- Measurement of operating voltages for about 3,000 MPPCs
- Test successfully conducted

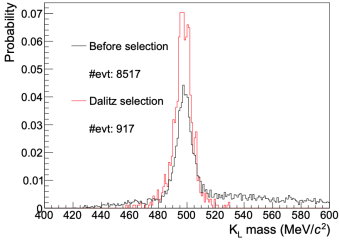


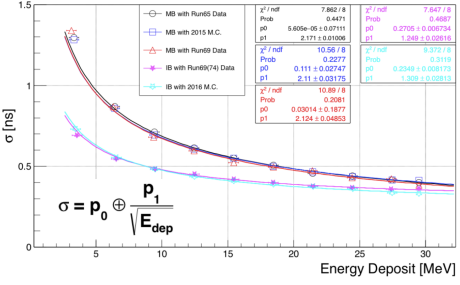
# $K_L \to 5\gamma + \gamma$ reconstruction with the sampling calorimeter (2018. 07.)

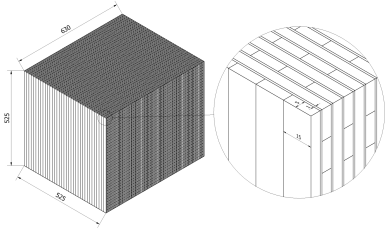


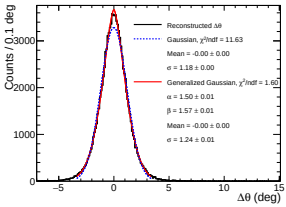



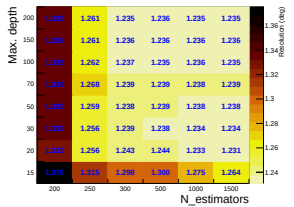



- Attenuation length measurement with cosmic-ray
- $K_L \to 5\gamma$ (CsI) + $\gamma_B$ (Barrel) reconstruction
- Timing resolution using reconstructed $\gamma_B$
- ICHEP 2018 3rd best poster awarded

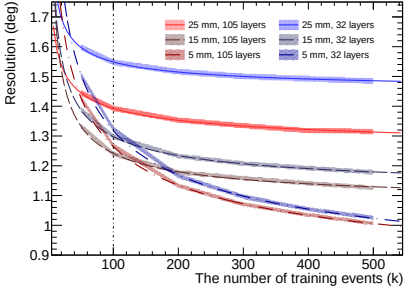




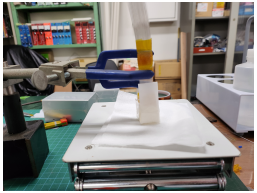



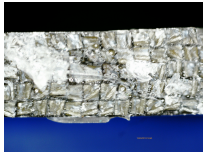

- Measurement of incident photon directions identifies the decay vertex of 2 photons.
- Optimization of XGBoost hyperparameters
- Performance dependence of the number of inputs and training events
- NIM A 1052 (2023) 168261

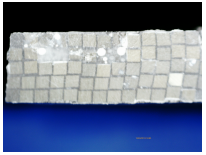


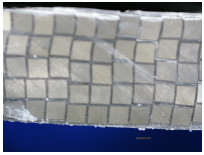
# R&D for the ongoing mass production (ongoing from 2022. 11.)

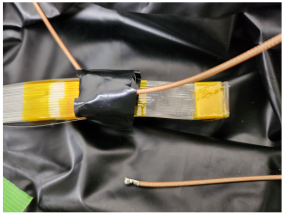


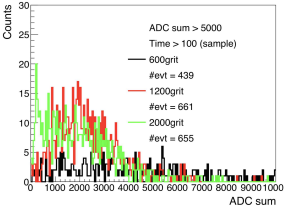
- Initial R&D for bundling 5 × 14 fibers (1 $mm^2$ square) with 5 tungsten plates using optical cement
- Study on polishment effect











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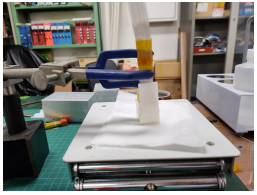
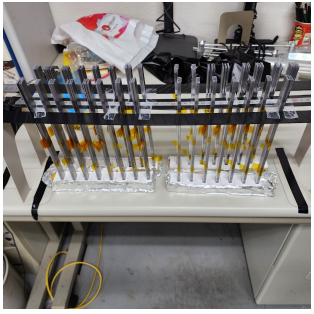
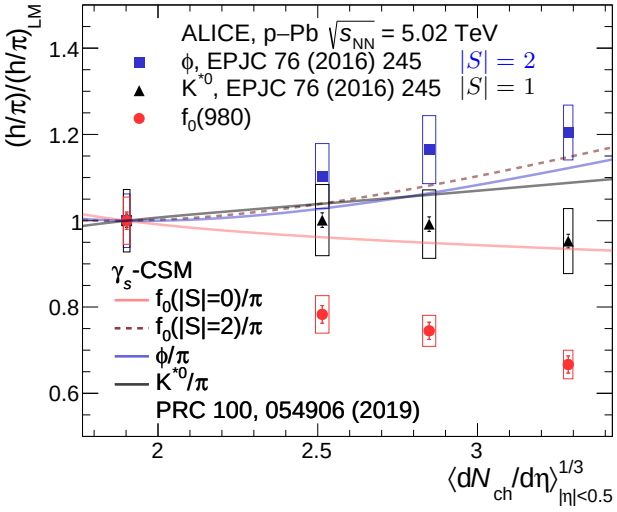


- Mass production ongoing at KEK
- JBNU + PNU + KU contributing to mass production
- Plan for electron beam (500 MeV) test at Tohoku university

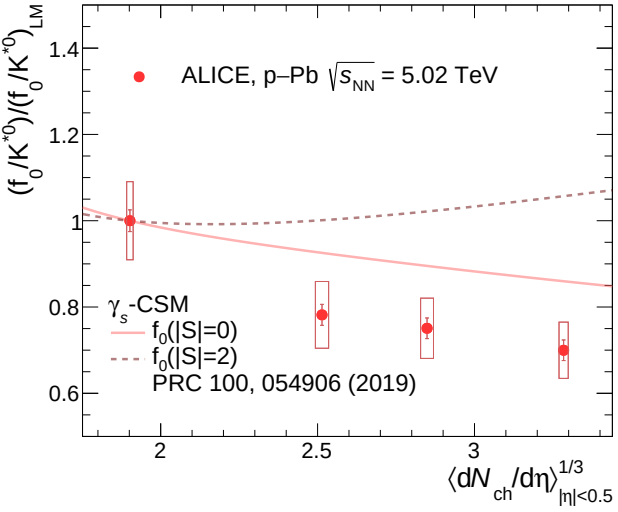


- Decreasing particle yield ratio of $f_0(980)$ to the charged pion with increasing multiplicity.
  - Dominant rescattering effects
- CSM overestimates yield ratio of the $K^{*0}$ to charged pion due to the no consideration of interactions between the hadron gas and the decay products of $K^{*0}$.
- CSM calculations overestimate the ratio of $f_0(980)$ to the charged pion yields because of no rescattering effects.



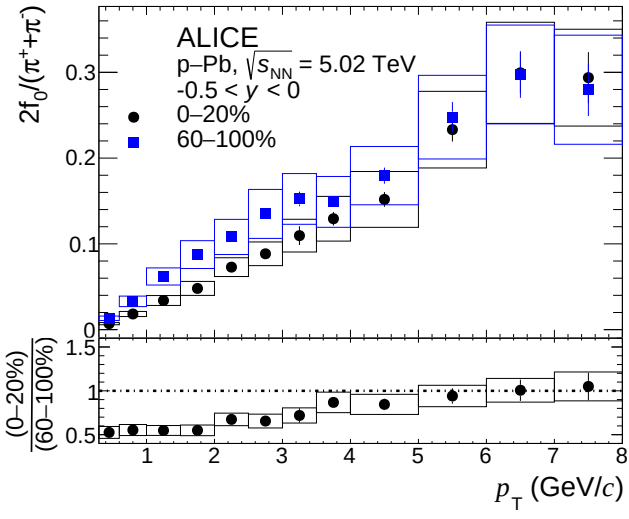
# $p_{\mathrm{T}}$-integrated yield ratio of $f_0(980)$ to $K^{*0}(892)$

- Both particle yields are expected to be largely affected by the rescattering effects.
- Decreasing ratio with increasing multiplicity.
- CSM estimates the ratio to be increasing with the $|S| = 2$ assumption because the strangeness enhancement is more significantly there for $f_0(980)$ than $K^{*0}$.
- The decreasing trend is qualitatively predicted using CSM model with the $|S| = 0$ assumption.
- Absence of strange quarks in $f_0(980)$ is also contradictory with the tetraquark suggestion for the $f_0(980)$ state.



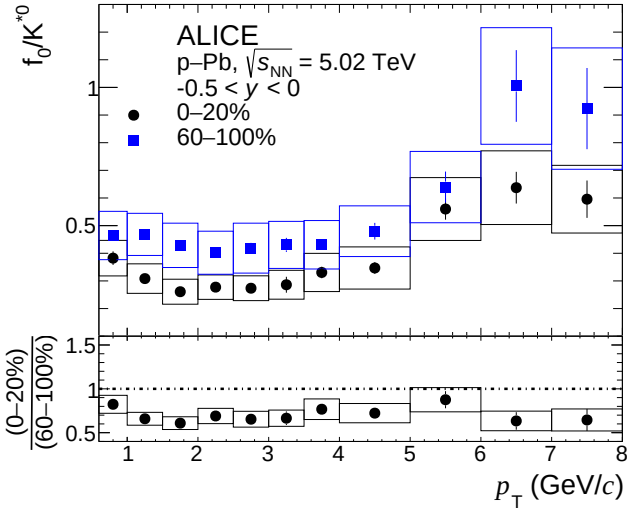
# $p_{\mathrm{T}}$-differential yield ratio of $f_0(980)$ to charged pions

- Suppression of the particle yield ratio at low $p_{\mathrm{T}} < 4$ GeV/$c$ in high-multiplicity events
- No suppression of the particle yield ratio at high $p_{\mathrm{T}} < 4$ GeV/$c$
  $\rightarrow$ rescattering effects



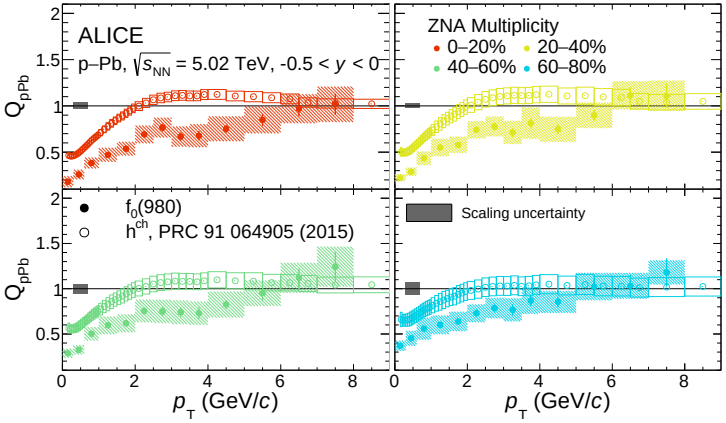
# $p_{\mathrm{T}}$-differential yield ratio of $\mathrm{f}_0(980)$ to $\mathrm{K}^{*0}(892)$

- Suppression at entire $p_{\mathrm{T}}$ in high-multiplicity events
- Different $p_{\mathrm{T}}$ dependence from that of rescattering effects
- Absence of the strangeness enhancement for $\mathrm{f}_0(980)$



# Nuclear modification factor of $f_0(980)$

- Multiplicity dependent stronger suppression only at low $p_T < 4$ GeV/$c$ for $f_0(980)$
  $\rightarrow$ Confirming rescattering effects



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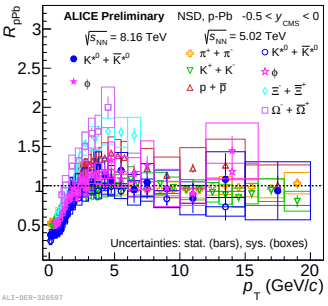
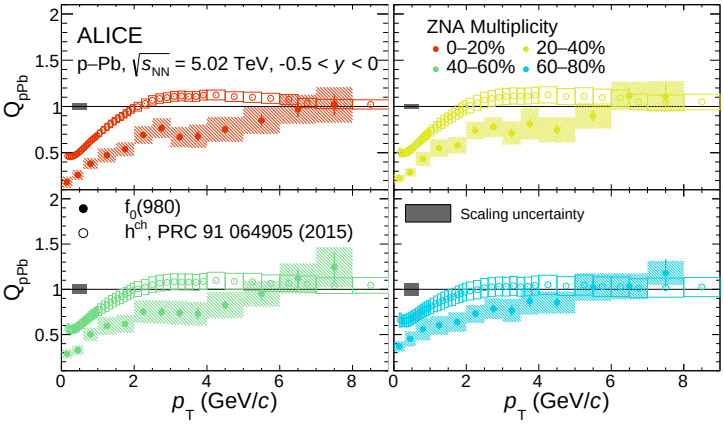
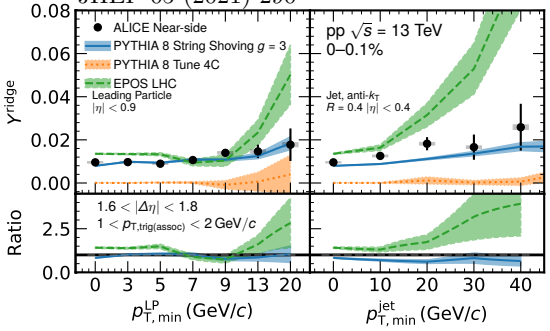



- No Cronin-like enhancement observed for $f_0(980)$
  $\rightarrow$ Conventional meson to be favored as the internal structure of $f_0(980)$

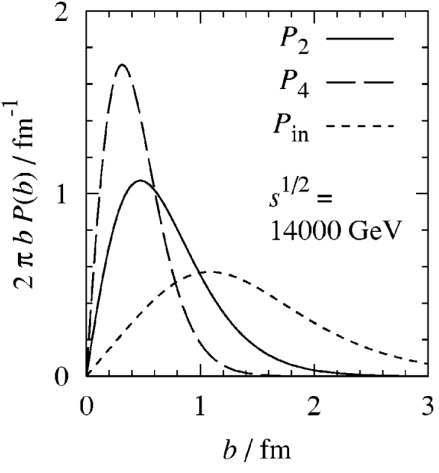


JHEP 05 (2021) 290



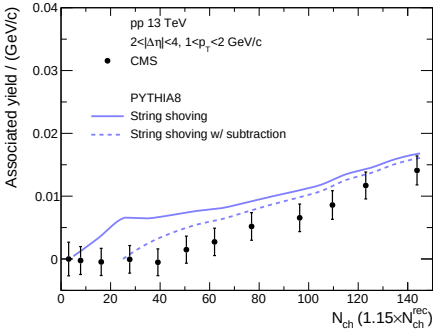

- Constraints on the impact parameter in pp collisions with reconstructed jets to engineer the impact parameter
- No significance so far owing to poor statistical uncertainties
  - Will be improved with Run 3 data

PRD 69 (2004)114010



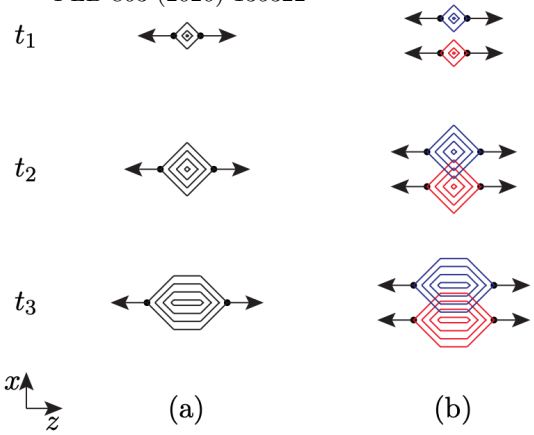
# String shoving model (2021. 08.)

JKPS 79 (2021) 5, 447-454

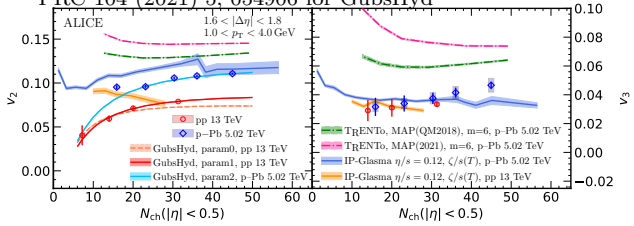



- Alternative approach to explain the origin of the collectivity in small collision systems.
- Expanding strings produce transverse pressure in their overlapping region.
- Qualitative reproduction of experimental data after subtraction

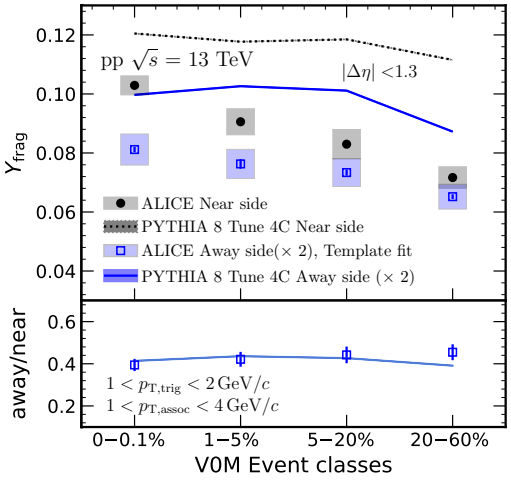
PLB 803 (2020) 135322



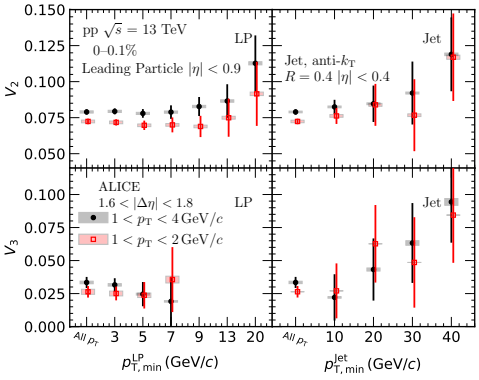
PRC 104 (2021) 5, 054906 for GubsHyd



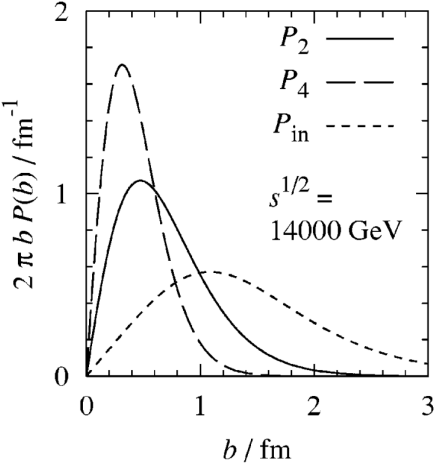

- Flow extraction method proven with the ratio of jet fragmentation yields
- $v_n$ as a function of multiplicity in small systems
  - Decreasing trend in pp collisions can be described by "GubsHyd"
  - "GubsHyd": analytical calculation for freeze-out energy density with $\tau T = \text{cte}$



# Jet-production-dependent flow (Collab. Rev. R2)

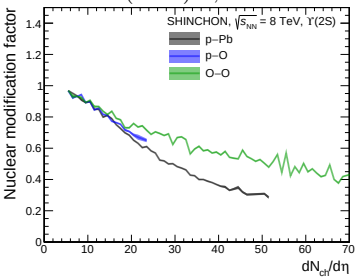


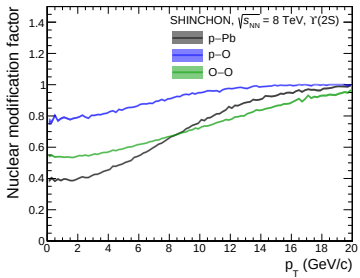

PRD 69 (2004)114010



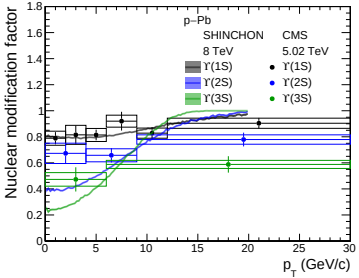

- Constraints on the impact parameter in pp collisions with reconstructed jets to engineer the impact parameter
- No significance so far owing to poor statistical uncertainties
  - Will be improved with Run 3 data

PRC 107 (2023) 5, 054905

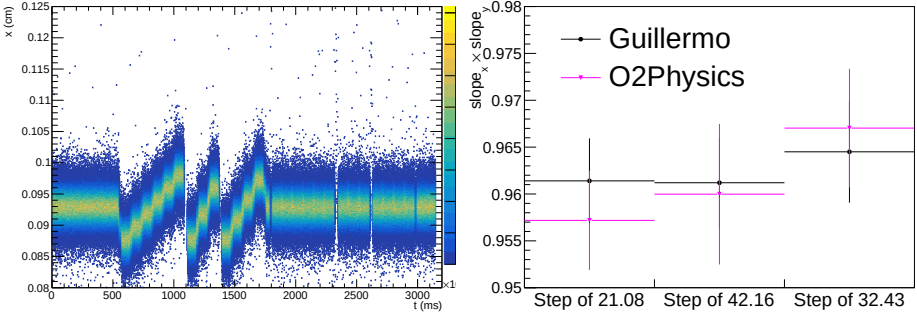



15% larger multiplicity for 8 TeV

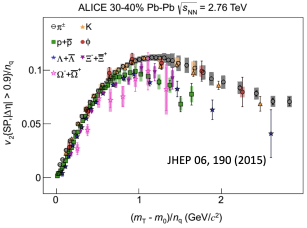


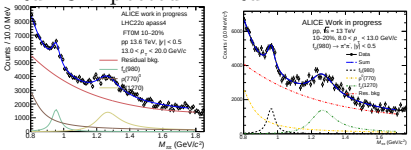

- Energy density (temperature): $R_{\mathrm{pPb}} < R_{\mathrm{OO}}$
- Interplay of formation time and energy density: crossing point of $R_{\mathrm{pPb}}$ and $R_{\mathrm{OO}}$



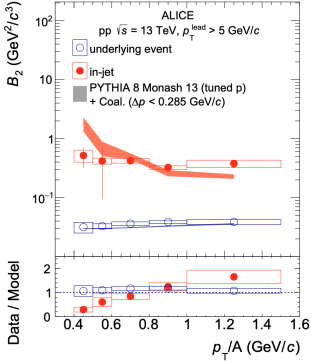

- Length-scale Calibration: comparison of reconstructed vertices and beam separations from LHC.
- One of main corrections

# Research interests - $f_0(980)$ production



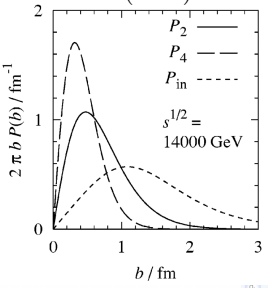

arXiv:2211.15204

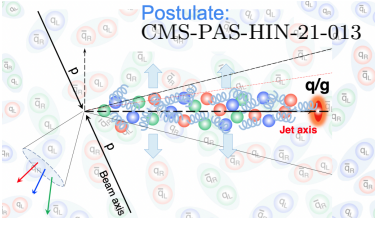



- Event plane dependent $f_0(980)$ production in Pb–Pb
  - NCQ-scaling can provide the number of constituent quarks of $f_0(980)$
  - Access to high kinetic energy region thanks to Run 3 statistics
  - Participating in the event plane reconstruction task
- $f_0(980)$ production inside jets
  - Enhanced deuteron coalescence inside jets due to smaller average phase-space distance.
  - Measurement of coalescence probability for $f_0(980)$ from KK to further explore the internal structure of $f_0(980)$

- Improvement of the measurement for the event-scale dependent flow with better statistics in high-multiplicity pp collisions
- Recent observation of enhanced long-range elliptic anisotropies inside high-multiplicity jets in pp collisions.
  - Single jet forming QGP-like state?
  - Measurement with identified particles?

PRD 69 (2004)114010



# Summary

## Publications

- **J. Kim,** *et al.* **"Model study on $\Upsilon(nS)$ modification in small collision systems", Phys. Rev. C 107 (2023) 5, 054905**
- **J. Kim,** *et al.* **"Simulation of angular resolution of a new electromagnetic sampling calorimeter", Nucl. Instrum. Meth. A 1052 (2023) 168261**
- **J. Kim,** *et al.* **"Exploring the string shoving model in Pythia8 for collective behaviors in pp collisions", J. Korean Phys. Soc. 79 no. 5, (2021) 447-454**
- **ALICE Collaboration, "Long- and short-range correlations and their event-scale dependence in high-multiplicity pp collisions at $\sqrt{s} = 13$ TeV", JHEP 05 (2021) 290**

## Ongoing projects

- Two manuscripts in internal reviews
- $f_0(980)$ production in Run 2 and Run 3
- Event plane reconstruction in Run 3
- Jet fragmentation shape in pp collisions
- Beam test preparation

## Conferences

- **Third J-PARC HEF-ex WS**, Simulation of angular resolution of a new electromagnetic sampling calorimeter for the KOTO2 experiment, Parallel talk
- **ExHIC 2022**, Understanding the nature of light scalar meson with ALICE, Parallel talk
- **INPC 2022**, Understanding the nature of $f_0(980)$ with ALICE at the LHC, Parallel talk
- **Confinement 2022**, Understanding the nature of $f_0(980)$ with ALICE at the LHC, Parallel talk
- **SQM 2022**, Understanding the nature of $f_0(980)$ with ALICE at the LHC, Parallel talk
- **ATHIC 2021**, Two-particle long-range correlations in small systems with ALICE, Parallel talk
- **Initial Stage 2021**, Characterizing system dynamics with short- and long-range correlations in pp, p–Pb, and Pb–Pb collisions at ALICE, Parallel talk
- **Hard Probes 2020**, $f_0(980)$ resonance production in small collision systems with ALICE, Poster
- **EPS-HEP 2019**, Measurement of long-range correlations in pp collisions at 13 TeV with ALICE at the LHC, Parallel talk
- **Initial Stage 2019**, Measurement of long-range correlations in pp collisions at 13 TeV with ALICE at the LHC, Poster
- **SQM 2019**, Multiplicity dependence of f0(980) resonance production in pp collisions at 13 TeV with ALICE at the LHC, Poster
- **ICHEP 2018**, Performance of the KOTO Sampling Calorimeter, Poster

# BACKUP