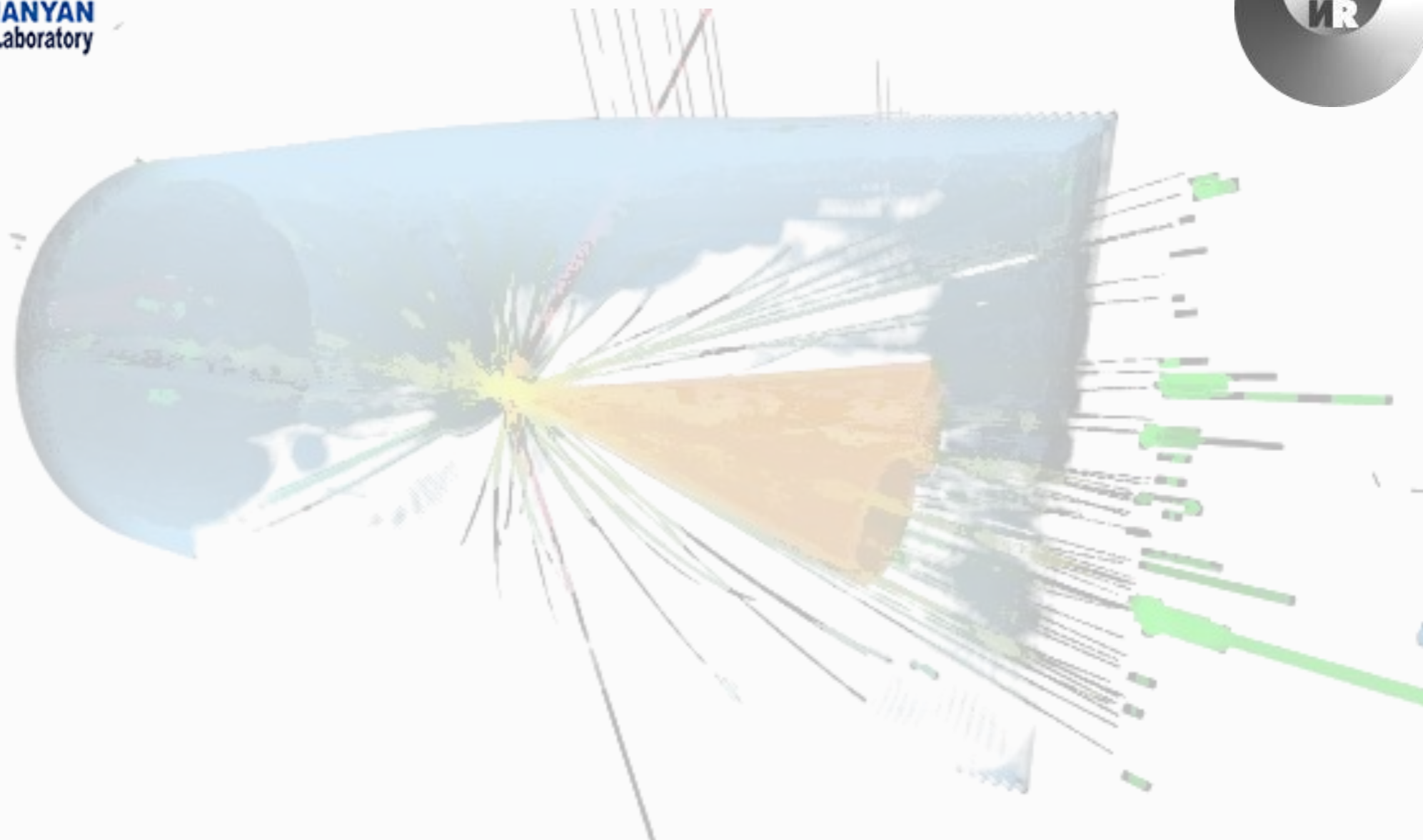


# PARTICLES OF NEW PHYSICS AT NICA



D. Kalashnikov, D. Gorbunov  
INR RAS, MIPT

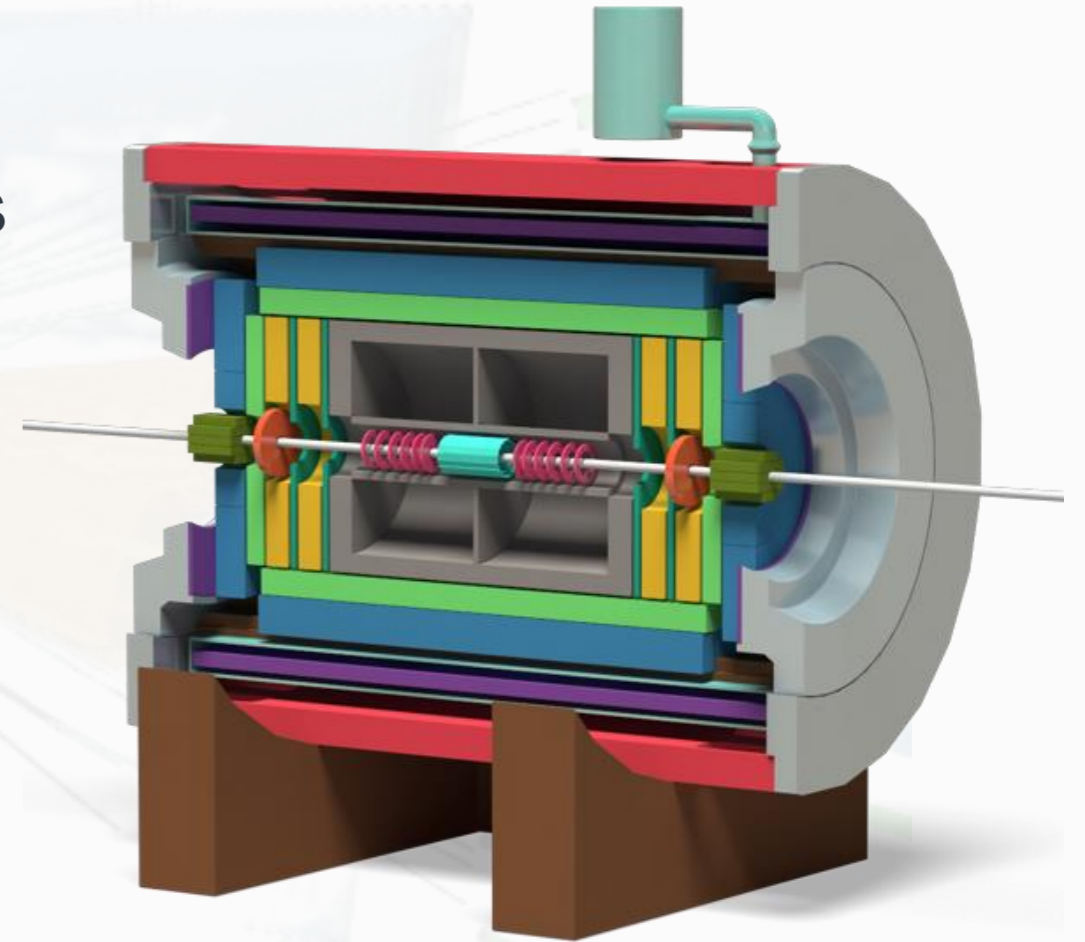
# PARTICLES OF NEW PHYSICS AT NICA

## Experimental Setup

Variety of beam species: from  $p$  to  $Au$  ions

Kinetic energy up to  $E \approx 10 AGeV$

Multi-Purpose Detector (MPD) capable of detecting charged hadrons, electrons and photons



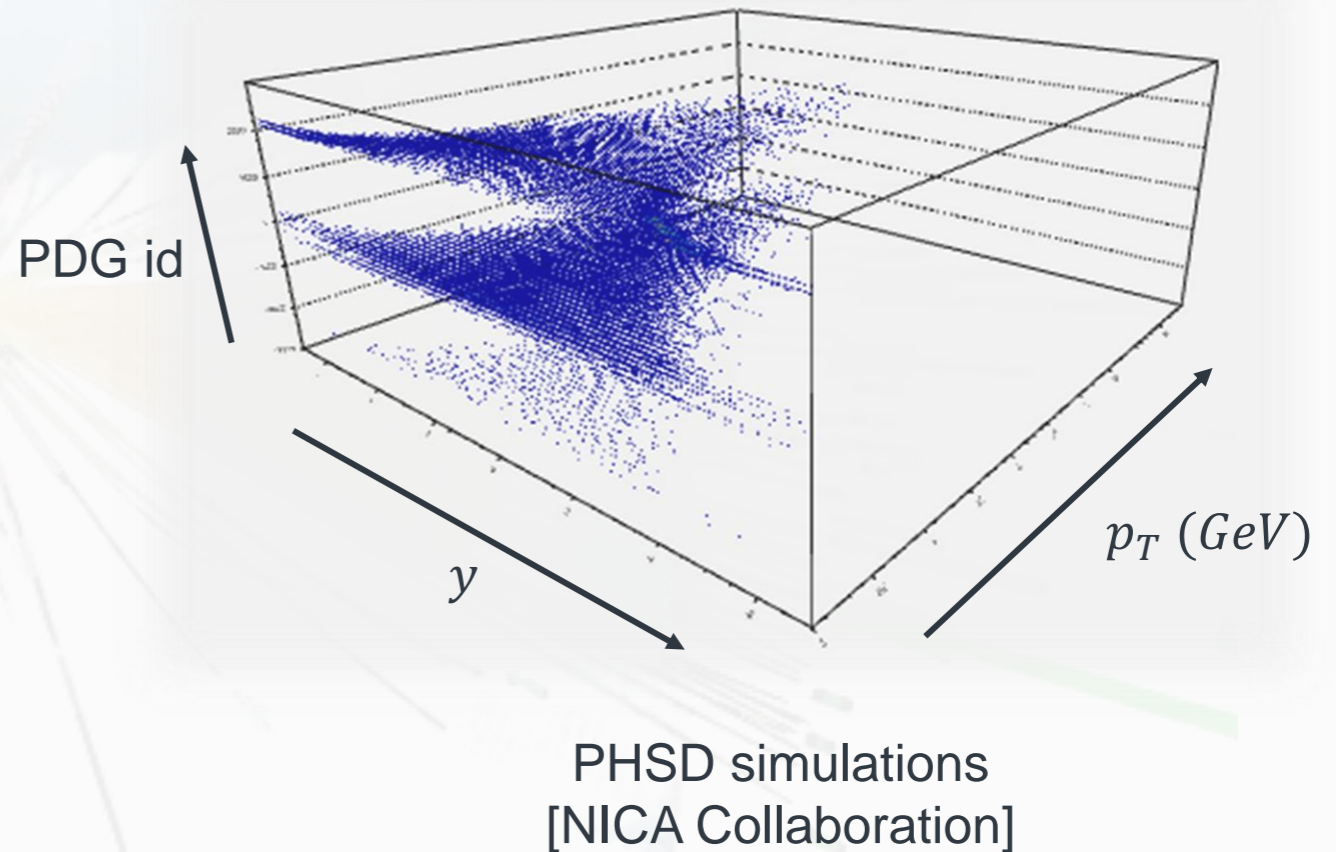
MPD layout  
[[www.nica.jinr.ru](http://www.nica.jinr.ru)]

# PARTICLES OF NEW PHYSICS AT NICA Simulations

PHSD simulations of BiBi collisions at  $E = 9.2 \text{ GeV}$

Total numbers of mesons were taken from [NICA White paper]

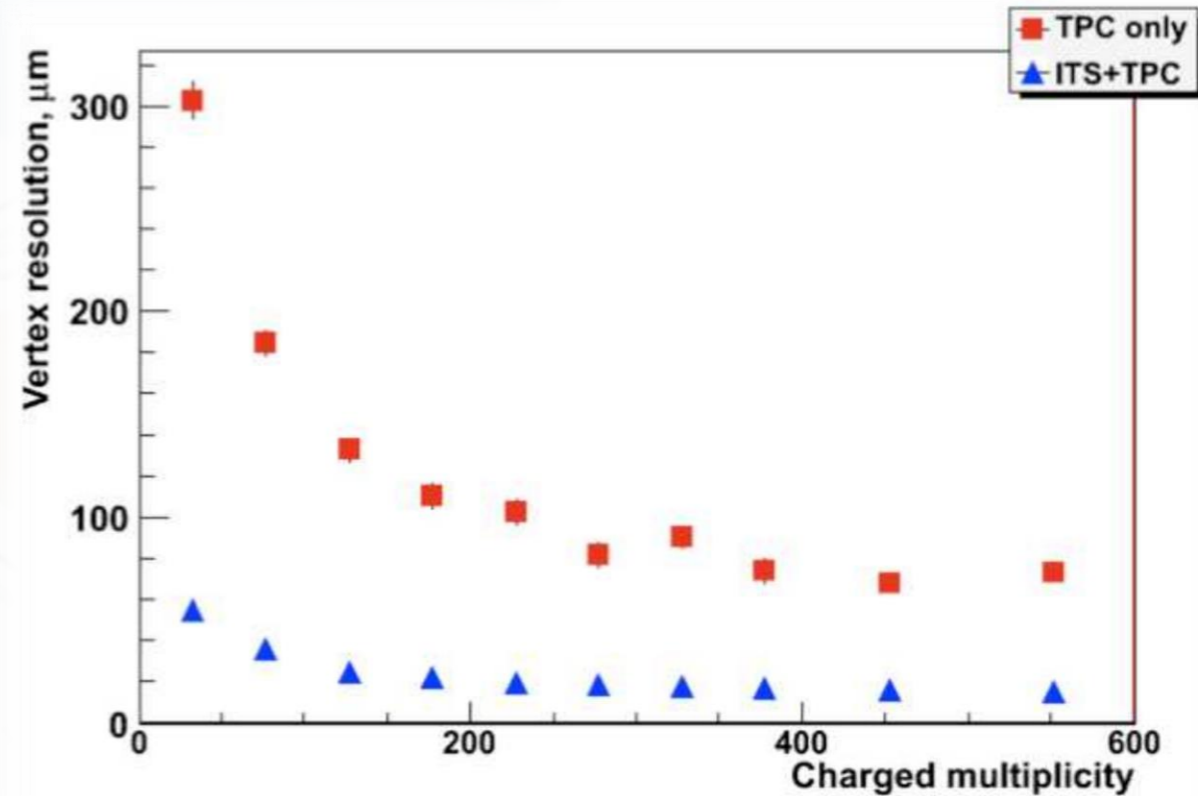
$$N_{\pi} \sim 10^{12}$$



# PARTICLES OF NEW PHYSICS AT NICA

## Displaced Vertex

$$P = \exp\left(-\frac{L_{min}}{d}\right) - \exp\left(-\frac{L_{det}}{d}\right)$$
$$\exp\left(-\frac{L_{det}}{d}\right) \rightarrow 0 \Rightarrow P \approx \exp\left(-\frac{L_{min}}{d}\right)$$
$$L_{min} = \begin{cases} 10 \mu m \\ 100 \mu m \\ 1000 \mu m \end{cases}$$



The resolution of vertex reconstruction.  
[NICA White Paper]

# PARTICLES OF NEW PHYSICS AT NICA

## Models

Dark Photon

$$\mathcal{L} = \mathcal{L}_{SM} - \frac{1}{4} F'^{\mu\nu} F'_{\mu\nu} - \frac{\epsilon'}{2} F'_{\mu\nu} F_Y^{\mu\nu} - \frac{m_X^2}{2} X^\mu X_\mu$$

$$\mathcal{L}_{DP} = \frac{m_{A'}^2}{2} A'^\mu A'_\mu - \epsilon e A'^\mu j_\mu - \epsilon e A^\mu j'_\mu$$

[2203.05090]

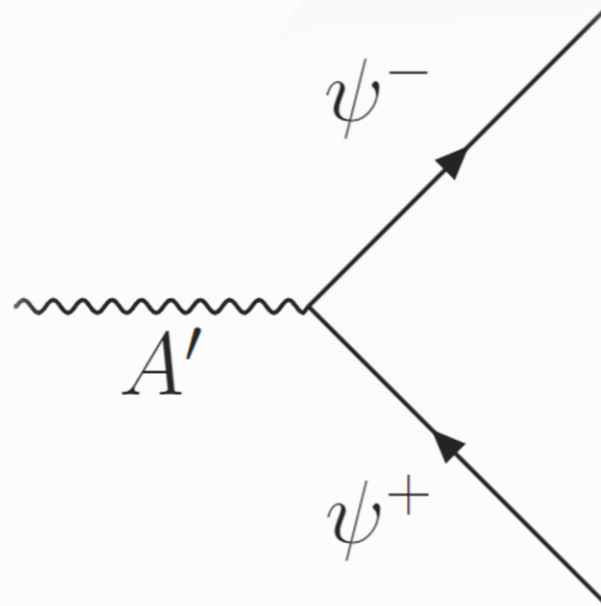
Axion

$$\mathcal{L} = \mathcal{L}_{SM} - \frac{m_a^2}{2} a^2 - \frac{1}{4} g_{a\gamma\gamma} a F^{\mu\nu} \tilde{F}_{\mu\nu} - \sum_f g_{aff} \partial_\mu a \bar{f} \gamma^\mu \gamma^5 f - \sum_F \frac{1}{4} g_{aFF} a F^{\mu\nu} \tilde{F}_{\mu\nu}$$

[2203.05090]

# PARTICLES OF NEW PHYSICS AT NICA

## Dark Photon



$$\mathcal{A}(\eta(\pi) \rightarrow \gamma\gamma) = -\frac{\alpha}{4\pi f} c F_{\mu\nu} \tilde{F}^{\mu\nu}$$

$$\eta(\pi) \rightarrow \gamma A'$$

$$Br(\eta(\pi) \rightarrow \gamma A') \propto \epsilon^2 Br(\eta(\pi) \rightarrow \gamma\gamma)$$

[arXiv:hep-ph/9806303, 2308.01565]

$$\Gamma(A' \rightarrow l^+ l^-) \propto \frac{\epsilon^2 e^2}{12\pi} m_{A'}$$

$$\Gamma(A' \rightarrow \pi\pi) = \Gamma(A' \rightarrow \mu^+ \mu^-) \times \frac{\sigma(e^+ e^- \rightarrow \pi\pi)}{\sigma(e^+ e^- \rightarrow \mu^+ \mu^-)}$$

[2308.01565, pdg]

# PARTICLES OF NEW PHYSICS AT NICA

## Half Hidden

$$A' \rightarrow \psi\bar{\psi}$$

$$A' \rightarrow \varphi\varphi^*$$

$$A' \rightarrow HS$$

$$A' \rightarrow SM^*$$



$Br(A' \rightarrow \text{visible})$

*Decay length*



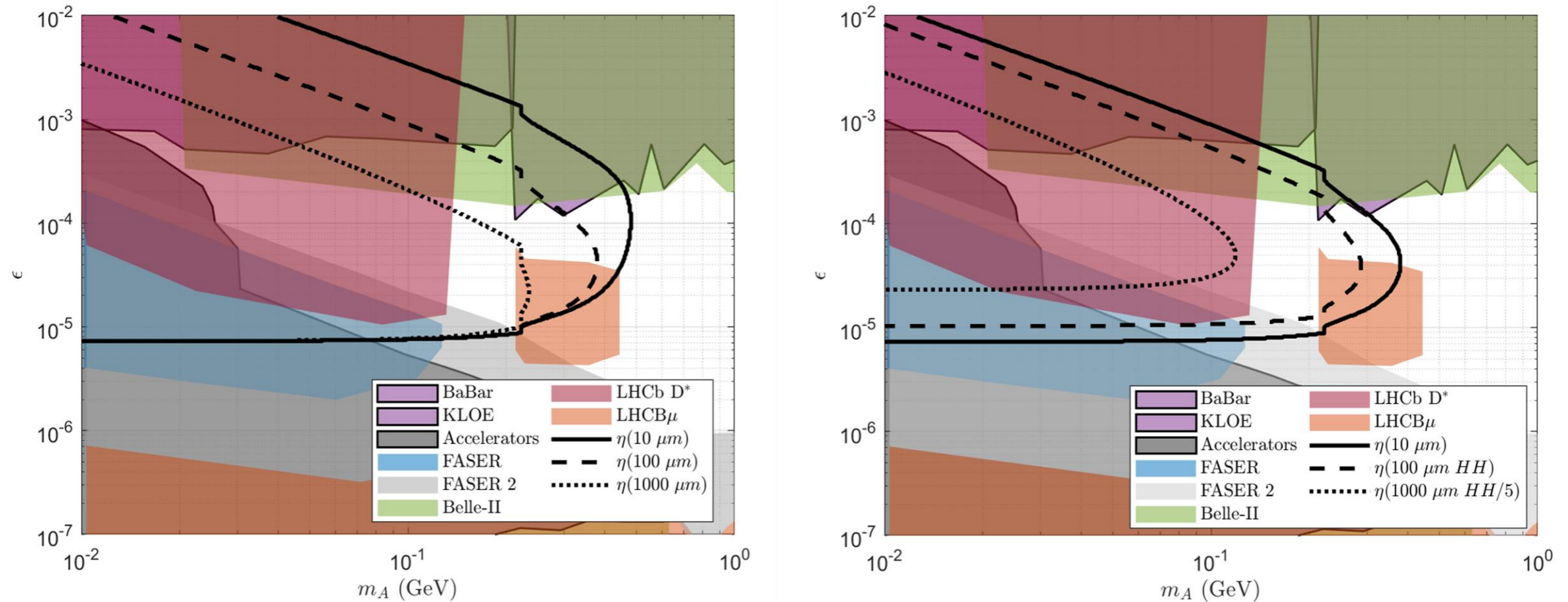
$$SM: \Gamma_{tot} = \Gamma_{SM}$$

$$HH: \Gamma_{tot} = 2\Gamma_{SM}$$

$$HH/5: \Gamma_{tot} = 10\Gamma_{SM}$$

# PARTICLES OF NEW PHYSICS AT NICA

## Dark Photon. $\eta$ decays

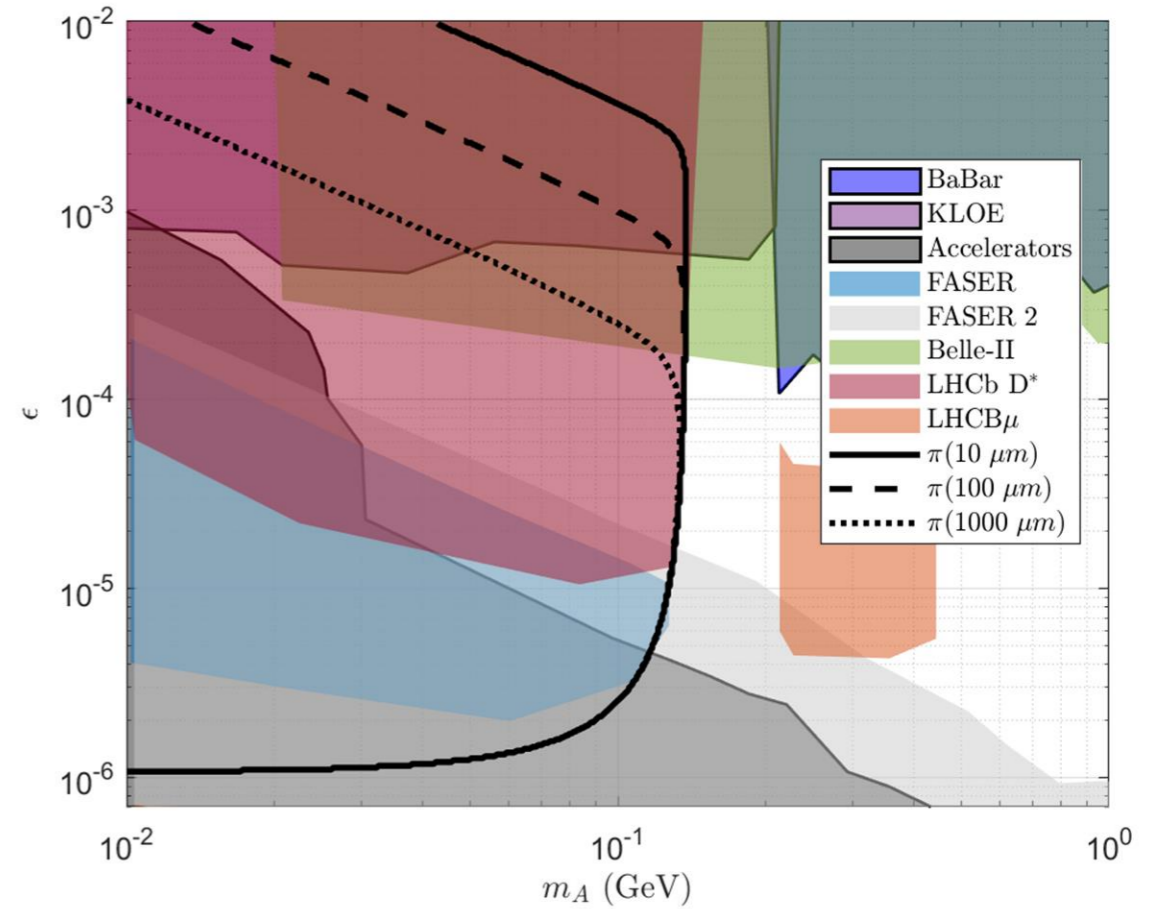
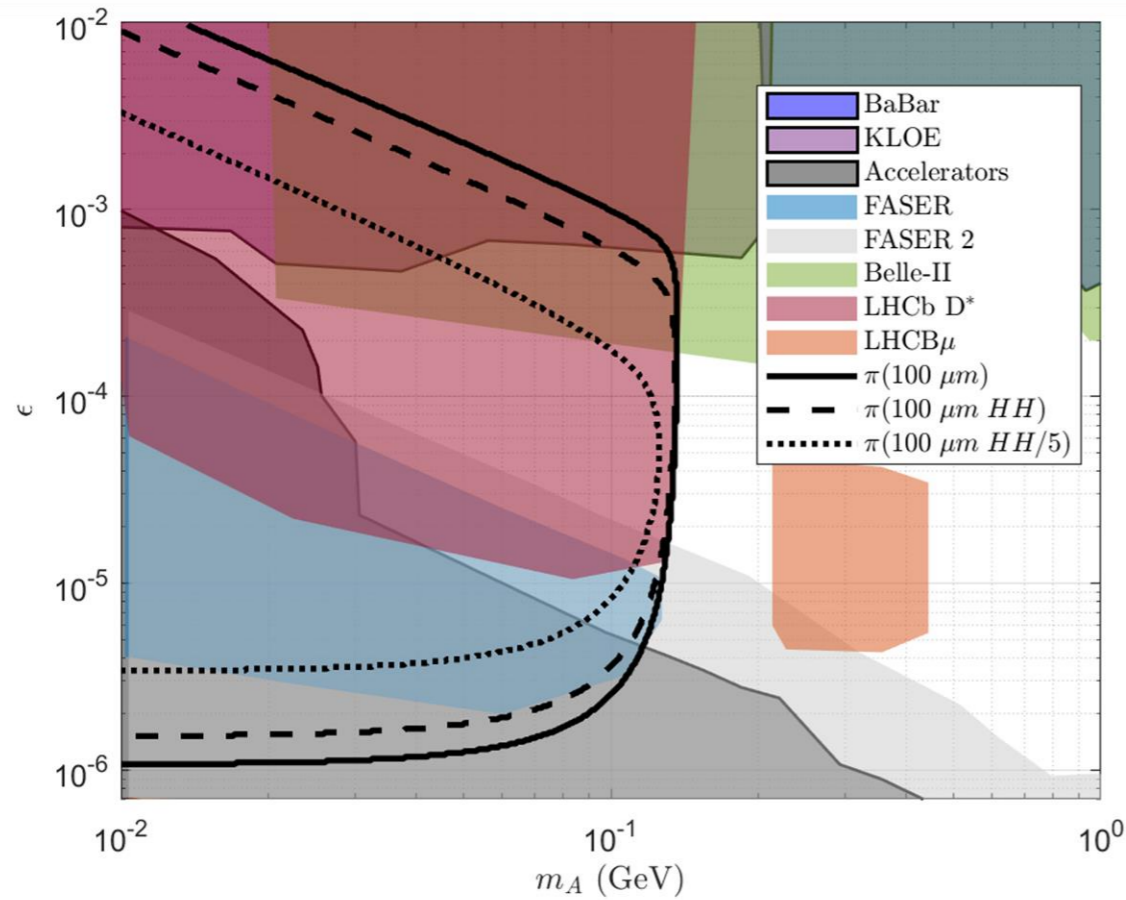


Sensitivity regions for NICA MPD



# PARTICLES OF NEW PHYSICS AT NICA

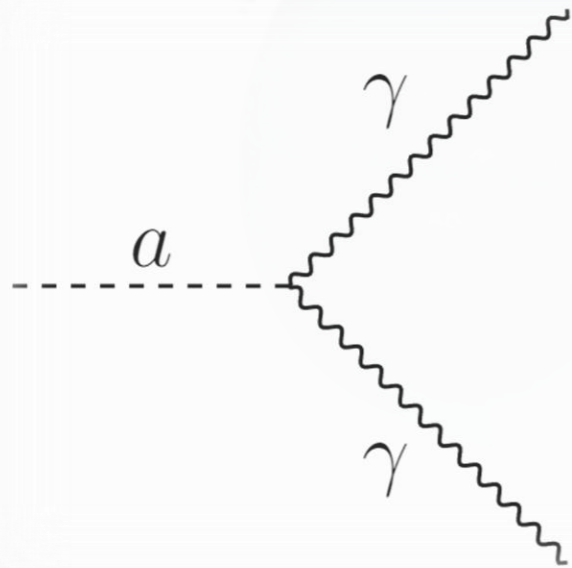
## Dark Photon . $\pi$ decays



Sensitivity regions for NICA MPD

# PARTICLES OF NEW PHYSICS AT NICA

## Axion



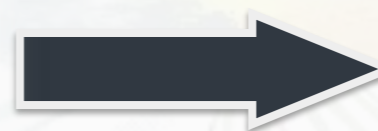
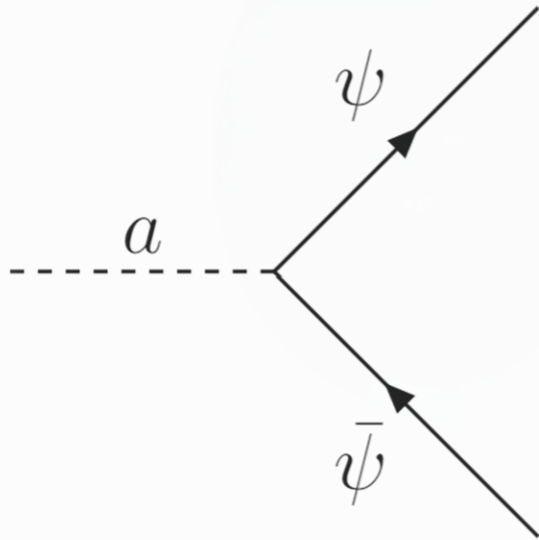
$$\mathcal{A}(\eta \rightarrow \gamma\gamma) = -\frac{\alpha}{4\pi f} c F_{\mu\nu} \tilde{F}^{\mu\nu}$$

$$\eta \rightarrow \gamma\gamma a$$

$$\Gamma(a \rightarrow \gamma\gamma) = \frac{g_{a\gamma\gamma}^2 m_a^3}{64\pi}$$

# PARTICLES OF NEW PHYSICS AT NICA

## Axion



$$K \rightarrow \pi a$$

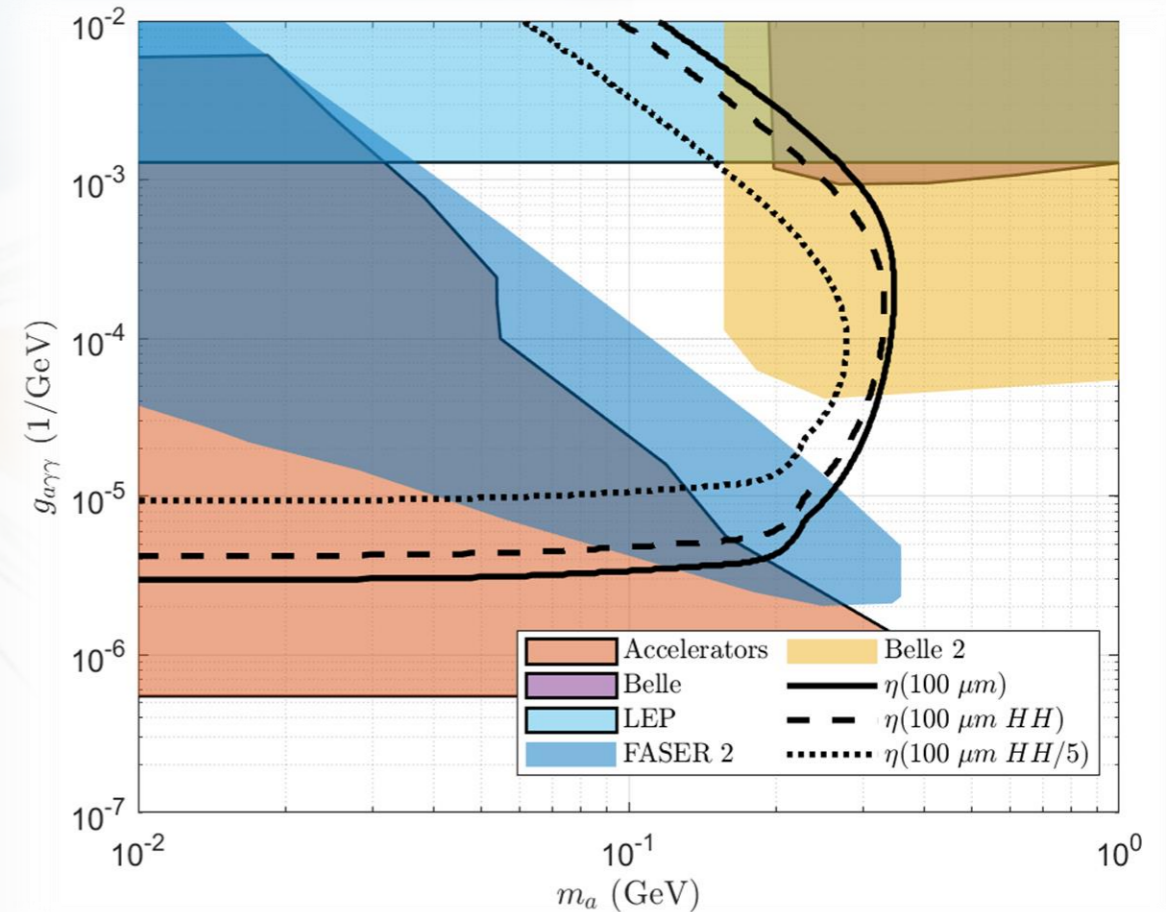
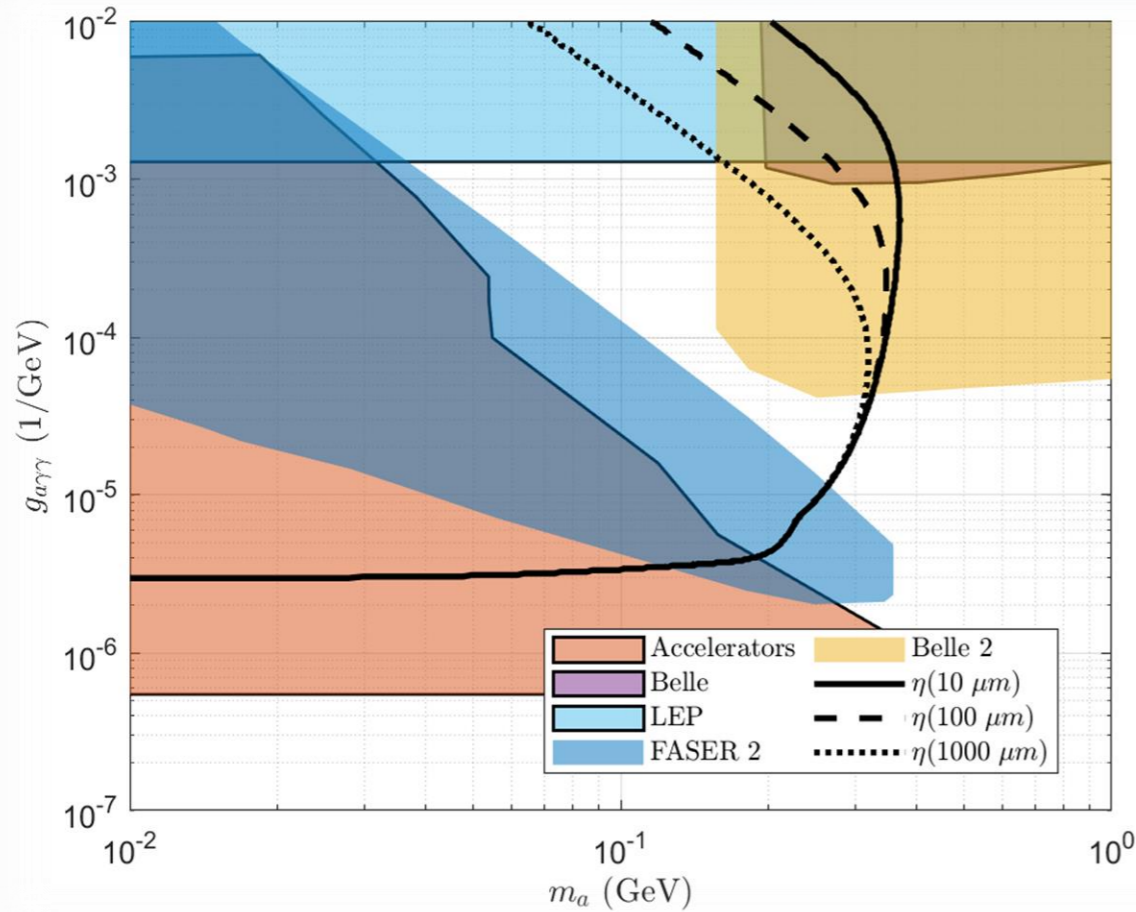
$$a \rightarrow \psi \bar{\psi}$$

$$\frac{Br(a \rightarrow \gamma\gamma)}{Br(a \rightarrow e^+e^-)} \approx \frac{g_{a\gamma\gamma}^2 m_a^2}{2g_{aee}^2 (2m_e)^2} \ll 1$$

[2304.05435]

# PARTICLES OF NEW PHYSICS AT NICA

## Axion. $\eta$ decays



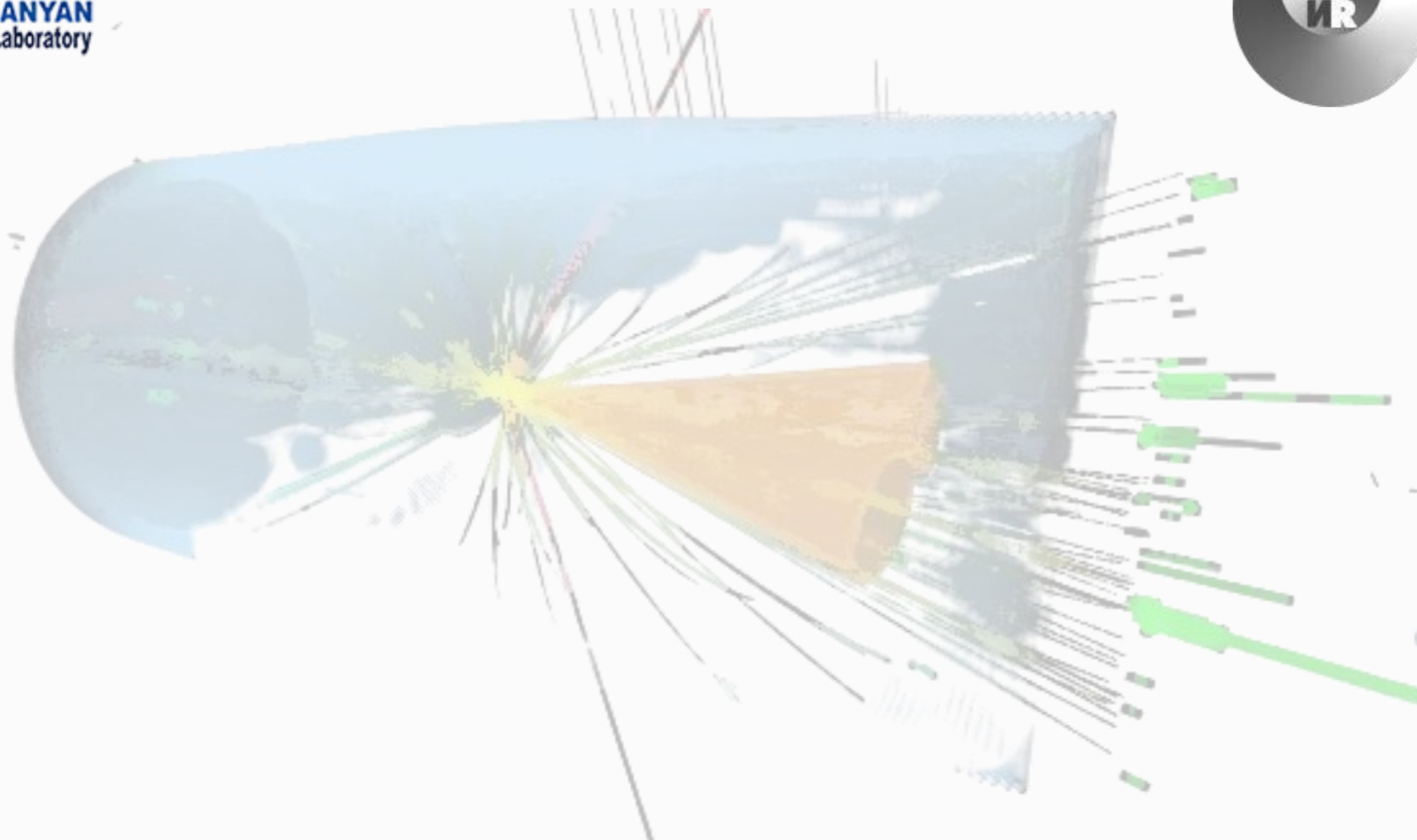
Sensitivity regions for NICA MPD

# PARTICLES OF NEW PHYSICS AT NICA

## Summary

- Promising results complementary to other experiments
- An upgrade including installation of ITS with high resolution will greatly increase sensitivity of NICA in case of NP searches

# PARTICLES OF NEW PHYSICS AT NICA



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