Forward and backward tracking at the EIC using small strip Thin Gap Chamber detector

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Outline:

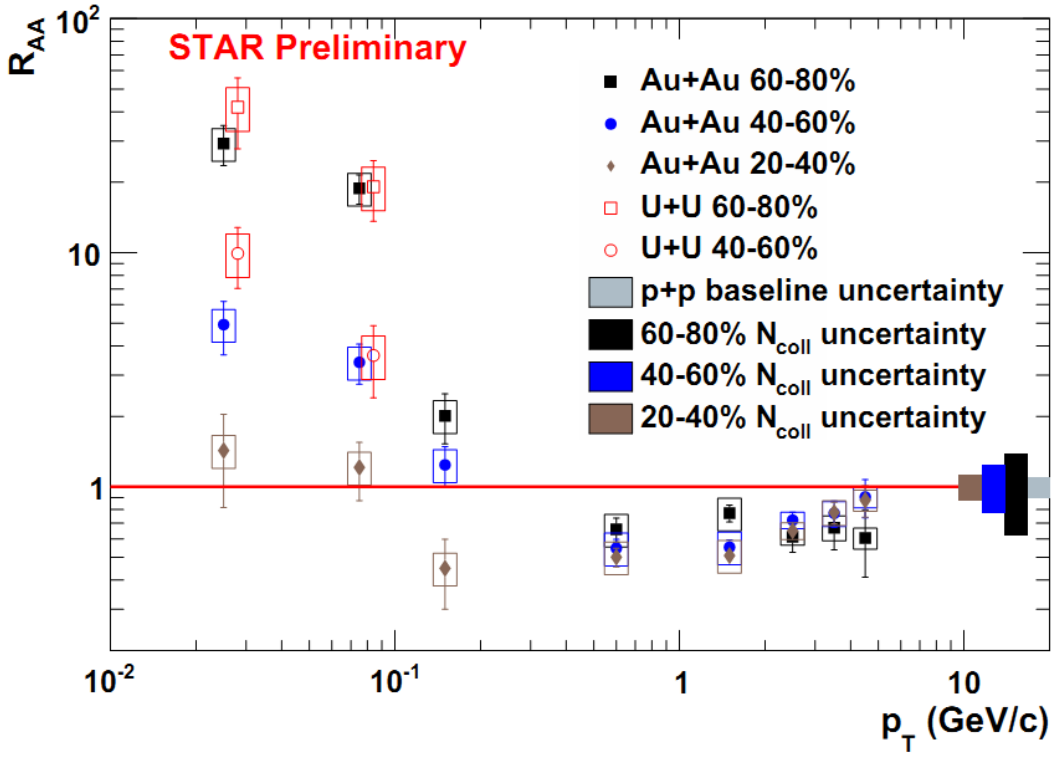
- Physics Motivation
- sTGC detector
- Organization, Schedule, Budget
- Summary

My background

- I am a heavy ion physicist and have expertise in the measurements of identified particles, dileptons, and quarkonia. Played a leading role in the Time of Flight (TOF) Detector and Muon Telescope Detector (MTD) construction and operation at STAR.

- Very recently, my group measured very low p_T J/ψ and dileptons in heavy ion collisions.

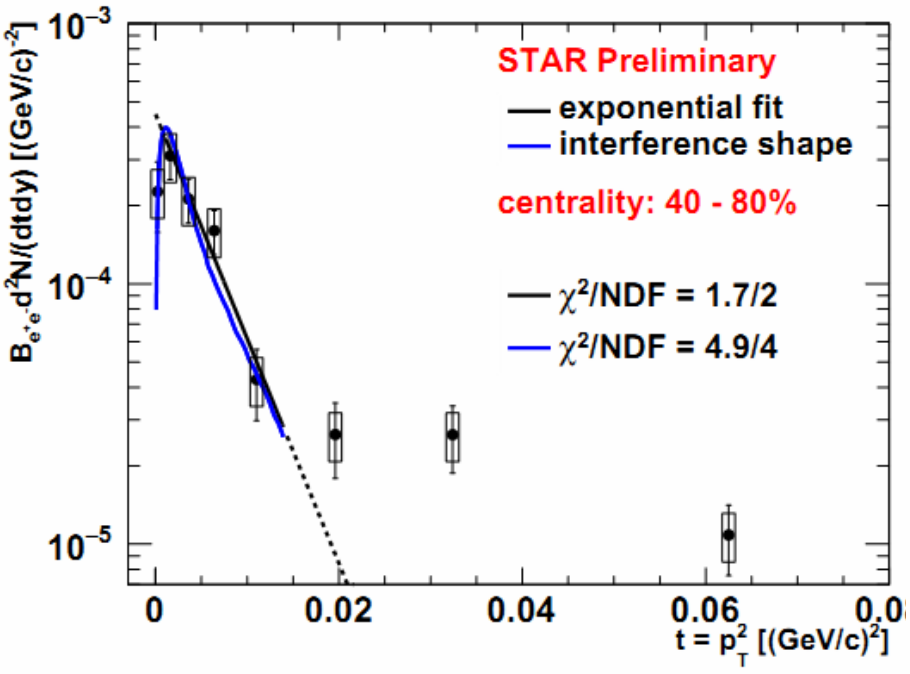
Very low p_T J/ψ in heavy ion collisions

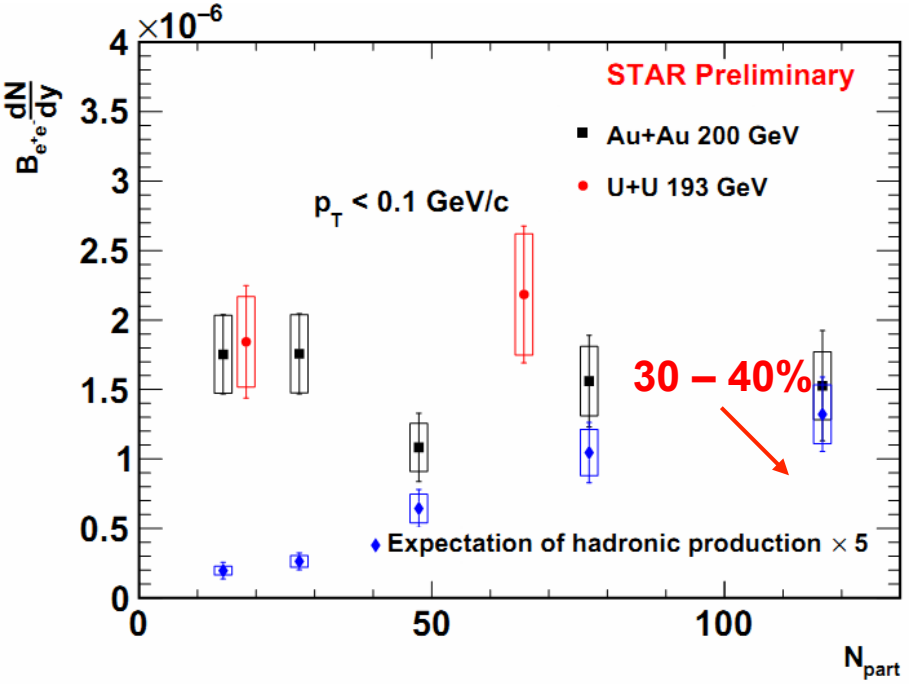


Large enhancement of J/ψ yield observed in peripheral A+A collisions!

Prominent centrality and p_T dependence.

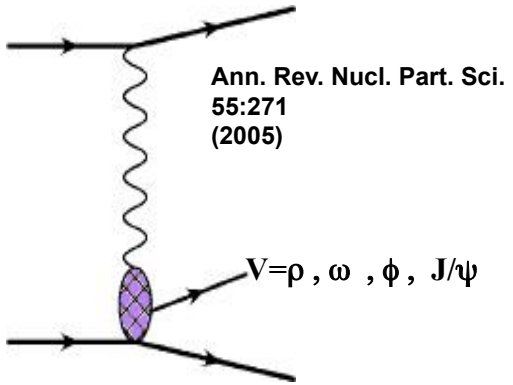
J/ψ yield :$t=p_T^2$ and centrality dependence





Slope parameter consistent with the size of the Au nucleus. Interference structure observed. Coherent photon-nucleus interactions!

No significant centrality dependence of the excess yield! **W. Zha et al., arXiv: 1705.01460**



photonuclear

Physics interest at the EIC

- Semi-inclusive physics measurements (ep/eA $\rightarrow$ e′ + h + X): vector meson (J/ψ, ρ, and ϕ) production to study transverse momentum dependent parton distributions, and fragmentation functions.

- Exclusive physics measurements: diffractive vector-meson production to study parton imagining in transverse position.

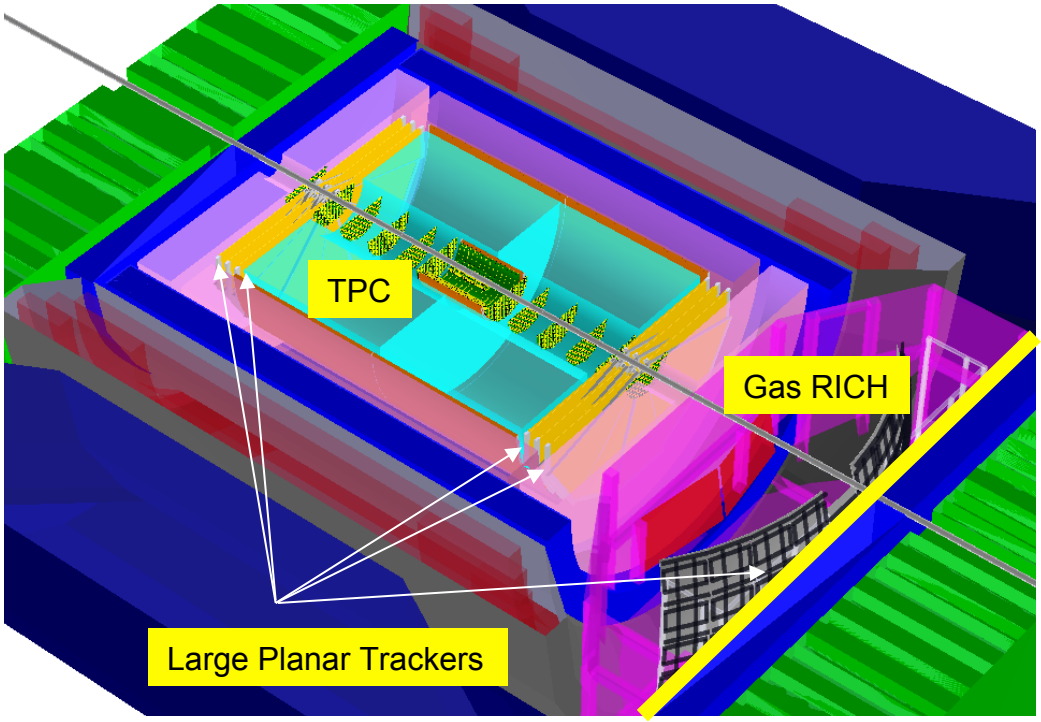
It requires large rapidity coverage and good momentum resolution:

For $1<|\eta|<2.5$, $\sigma_p/p = 0.05\%p+1\%$

For $2.5<|\eta|<3.5$, $\sigma_p/p = 0.1\%p+2\%$.

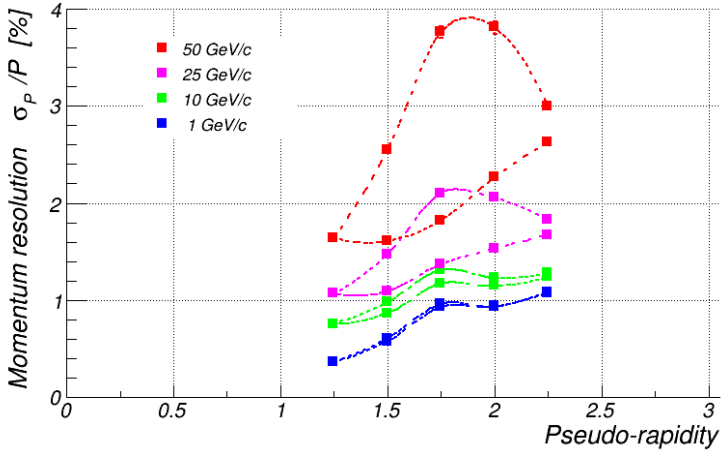
EIC detector design

Use BeAST as an illustration



sTGC tracker applications:

- Supplement TPC with fast (bunch crossing synchronized) hits
- Provide reliable reference track measurement for the forward RICH
- Improve momentum resolution for high momentum hadron tracks (requires spatial resolution down to ~50um or better)

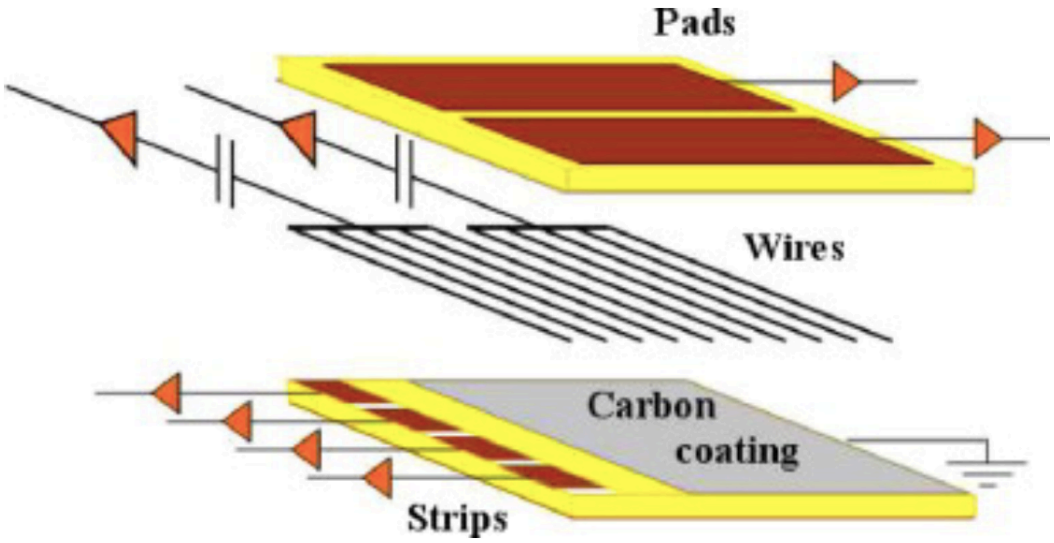


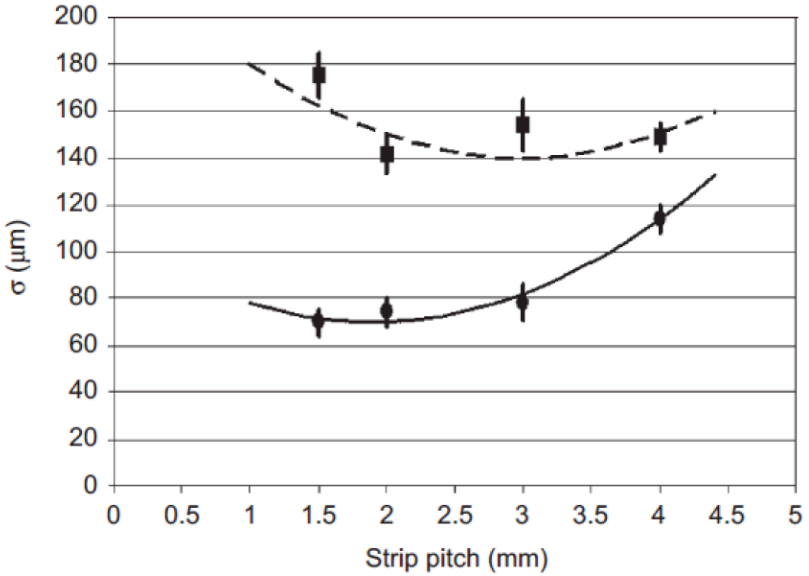
- **The is an apparent need to cover large flat surfaces with *fast reliable high resolution trackers at an affordable cost***

The proposal

We propose to develop a concept for forward and backward tracking detector at pseudo-rapidity $1<|\eta|<3.5$ using the small strip Thin Gap Chamber (sTGC). The sTGC detectors present an attractive option for building a tracking device as they have minimum material budget, are easy to construct, and most-importantly are cost effective. We focus on the detection of all charged hadrons and will study tracking performances such as the tracking efficiency and momentum resolution. As part of our proposal, a prototype sTGC will be designed and constructed. Cosmic ray and beam tests will be carried out to demonstrate the position resolution. A prototype sTGC detector will be installed at the Solenoidal Tracker at RHIC (STAR) experiment, and tested in the 2019 and 2020 runs. Results will be analyzed and compared to those from cosmic ray and beam tests. The conceptual design of sTGC disks will be laid out, including the disk location, detector size, and readout.

The sTGC





- No space charge accumulation up to 100 kHz/cm^2 single hit rate
- Counting rate 20 kHz/cm^2

Material budget:

- 0.5% x_0 per layer.
- May reduce the height of FR4 board

Layout of side view

1.4mm between
wire and graphite electrode

FR4 board 1.5mm

Copper strip: 3.2mm pitch, 2.7mm width
35μm height

Space between strip and FR4 inner face:
200μm

Graphite electrode: 25μm

Copper pad: 35μm "large"
Other parts are same as "upper half"

Wire: Φ50μm Au-plate tungsten wire, 1.8mm pitch
Working gas: 55% n-pentane + 45% CO_2
Honeycomb paper for mechanic support outside of the layer or in between two layers

The organization

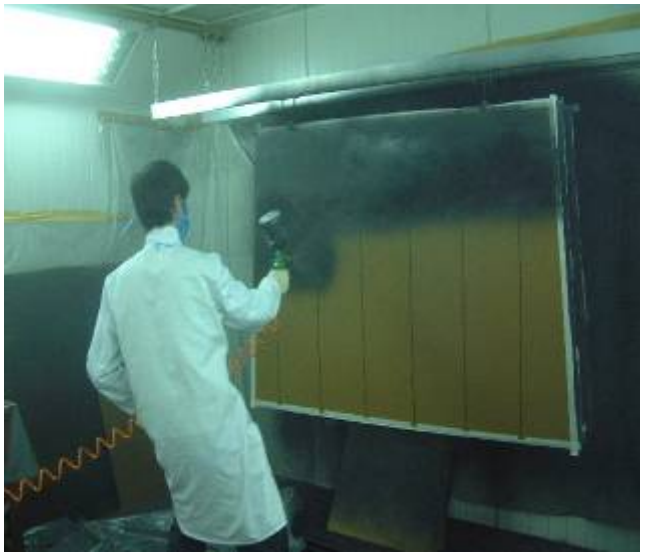
Collaborate with Shandong University (SDU):

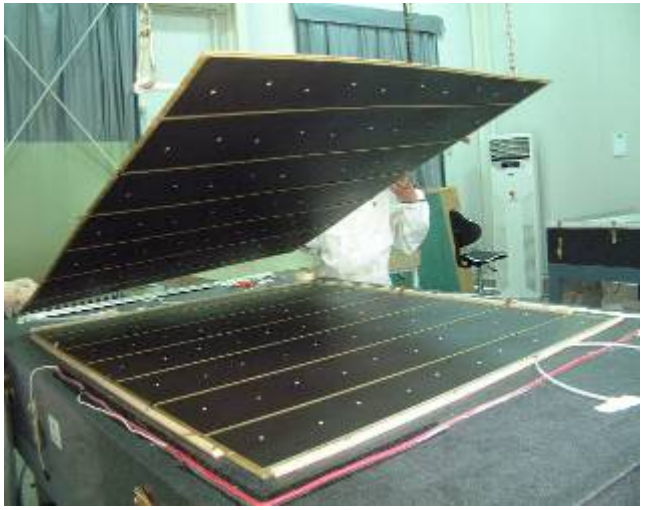
- design, construction, and operation of Thin Gap Chamber detector at the ATLAS.
- constructing the sTGC detectors for the tracking upgrades at ATLAS, beneficial for muon identification.
- constructing the wire chamber for the inner Time Projection Chamber upgrades at STAR

BNL:

- Played a leading role in TOF and MTD construction and operation at STAR
- Extensive expertizes in tracking and software integration with a solid track record of delivering physics with the TPC, Heavy Flavor Tracker and other tracking detectors in STAR. Recently, did the generic forward tracking with the sTGC performance.

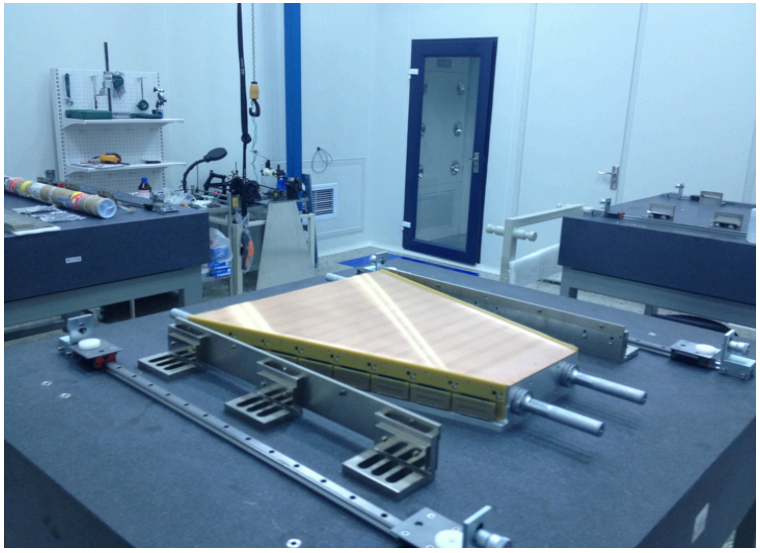
SDU facilities





iTPC laboratory at SDU

- New building in 2000 for ATLAS Thin Gap Chamber (TGC). Produced 400 modules of high quality TGC for ATLAS during 1999-2004.
- The lab is ~400 m^2 , recently refurbished. New clean room built for iTPC project.
- Detector test system for detector testing.



Clean room with granite table

Clean room for wire winding, testing

The schedule

In the first year 10/1/2017-9/30/2018, we propose to do the following two things:

- Build an sTGC prototype with a square shape of 60 cm x 60 cm, with 3.2 mm strip pitch perpendicular to wire direction. We will use the current STAR TPC electronics for the readout. A cosmic ray test will be performed to obtain the spatial resolution. Specifically, we will study the spatial resolution as a function of angle of incidence. Understanding this is necessary for a conceptual design of the sTGC disk for an EIC experiment.

- With the information obtained from the above step, we will carry out a simulation of sTGC in an EIC experiment. As a first step, we will use knowledge acquired in the tracking efforts made in STAR (track finding) into an EIC framework context and further develop a fast simulator in which the spatial resolution obtained from the cosmic ray tests will be used. The next step is to study the tracking performance at $1<|\eta|<3.5$ by combining the sTGC disks and other tracking devices for an EIC experiment.

The schedule

- In the second year 10/1/2018-9/30/2019, we propose to install the sTGC prototype at STAR in Run 2019. We will also analyze data from the heavy ion collisions to obtain its performance at STAR. We will build another module. The specification might be slightly modified depending on the test results from the first year. A beam test will be carried out. Finally, and to address the full response (hence efficiency) of the prototype, we propose to develop a slow simulator for the sTGC in that same year.

- In the third year 10/1/2019-09/30/2020, we would gain experience of running sTGC in the forward rapidity at STAR in its 2019 run. If there were any issues preventing us from obtaining useful data from STAR during Run 2019, we would need to resolve the corresponding issues and take data again with the sTGC prototype in Run 2020. We propose to come up with a conceptual design in using sTGC disks as part of the forward and backward tracking detectors that year.

The funding request

Table 1: The cost information for different years and categories.

Category	Cost (year 1, $)	Cost (year 2, $)	Cost (year 3, $)	Cost (years, $)
Material	25 k	25 k	0	50 k
FTE	31 k	31 k	21 k	83 k
Travel	8 k	12 k	8 k	28 k
Total	64 k	68 k	29 k	161 k

Note that the post-doc will be jointly supported by SDU and BNL. The post-doc will be hired by SDU and stay at BNL. We request the funds to cover the housing (1600 $/month), per diem (1600 $/ month), and medical insurance (100 $/month) for the stay at BNL.

The budget scenarios

- Under the scenario of a nominal budget – 20%, for the first year, it will affect the proposed activity on the simulation. Fast simulation results will not be delivered for the first year and will be delivered for the second year. The slow simulation results will be delivered for the third year. We will not be able to make possible revisions and run a prototype of sTGC at STAR for Run 2020.
- Under the scenario of a nominal budget – 40%, for the first year, it will affect the proposed activity on the simulation. Fast simulation results will not be delivered for the first year and will be delivered for the second year. The slow simulation results will be delivered for the third year. We will not be able to carry out a beam test for the proposed three years. We will not be able to make possible revisions and run a prototype of sTGC at STAR for Run 2020.

Summary

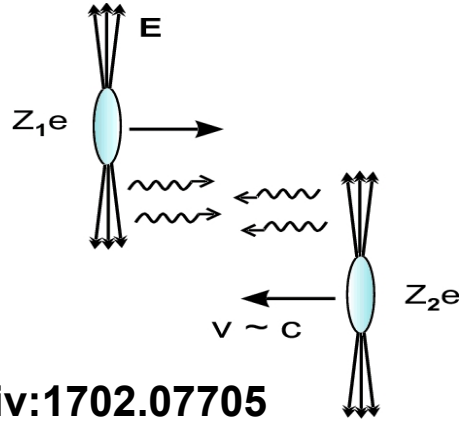
We request funding support to develop a concept for forward and backward tracking detector at pseudo-rapidity $1<|\eta|<3.5$ for charged hadrons and electrons using the small strip Thin Gap Chamber (sTGC) at the EIC:

- build smaller sTGC modules with shorter strips, redesign the PCB boards,
- Study the performance in cosmic ray, beam test, and at STAR.
- Perform full tracking simulations

The expertise makes our group well suited for carrying out the proposed research.

Backup

ρ and J/ψ in ultra-peripheral A+A collisions



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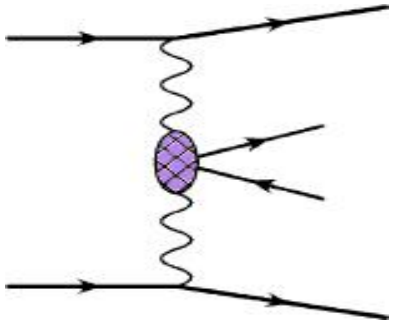

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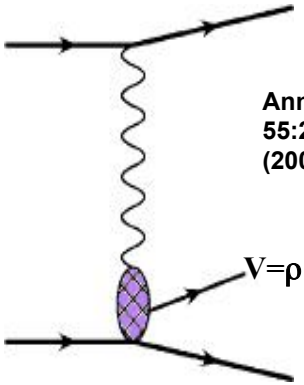
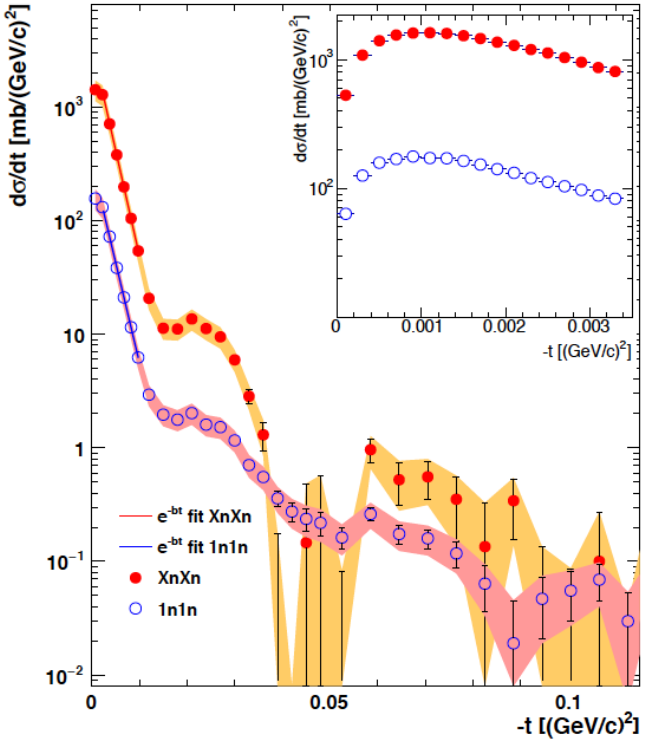


Ann. Rev. Nucl. Part. Sci.
55:271
(2005)

arXiv:1702.07705



Two-photon

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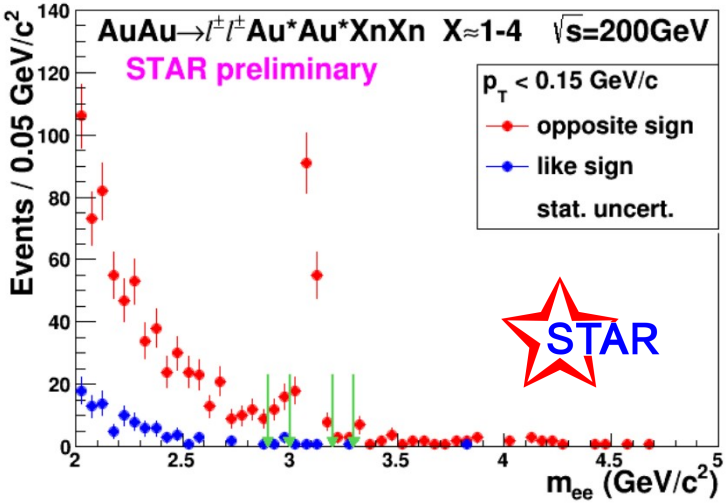
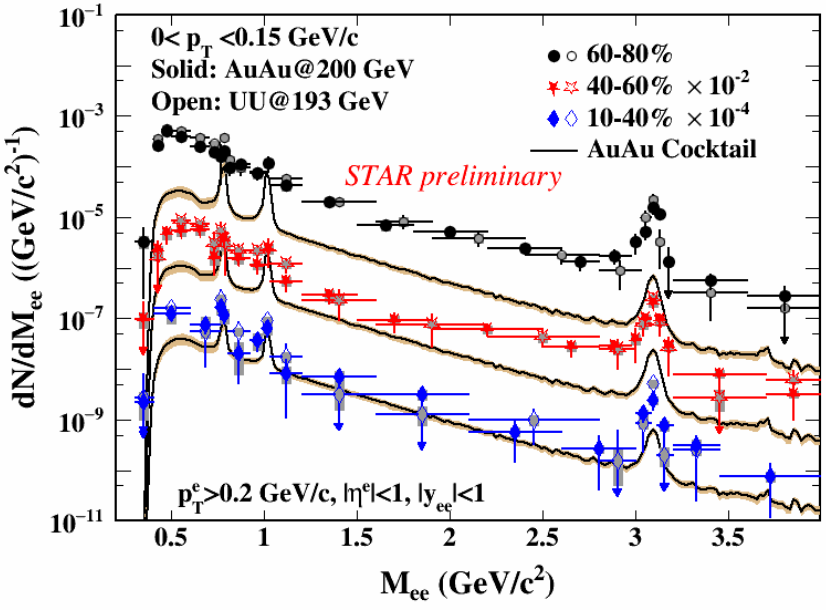
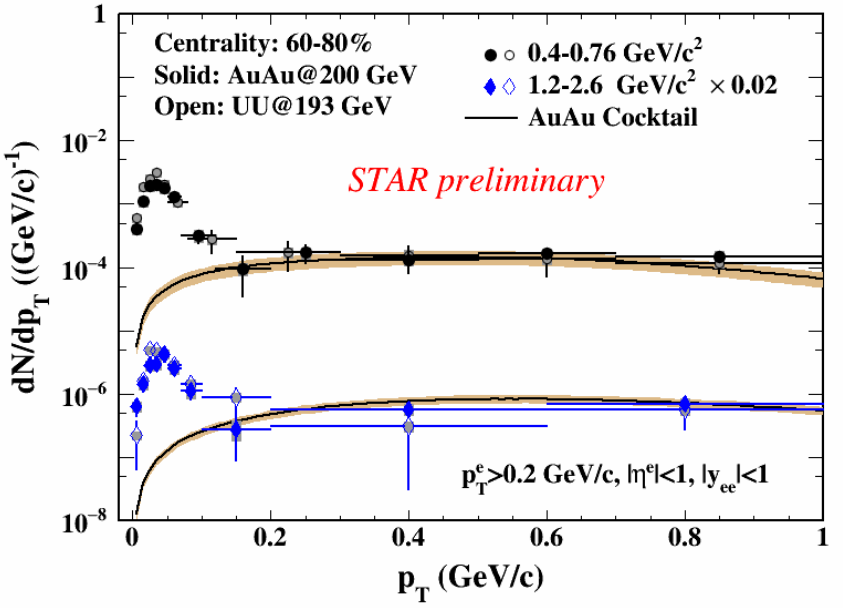


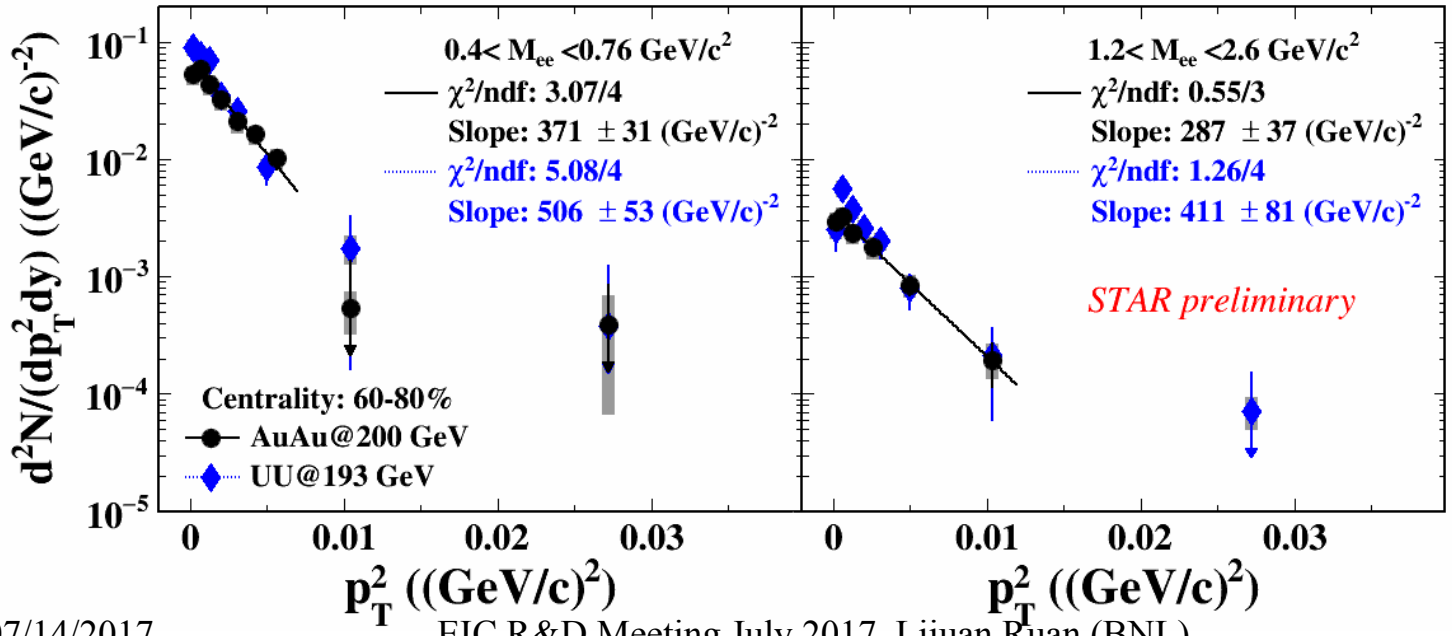
J/ψ signal

ρ: characteristic diffractive dips observed

Very low p_T electron-positron excess







The funding request

First year:

25,000 $ for the materials, assembly, and test of an sTGC prototype at Shandong University

0.5 post-doc FTE: to work on the cosmic ray test of the sTGC at BNL.

0.25 post-doc FTE: to work on simulations by developing a fast simulator.

3 trips to enable post-docs to attend two workshops (2000 $/trip) in US and to visit colleagues at Shandong University (4000 $/trip)

Second year:

25,000 $ for the materials, assembly, and test of another sTGC prototype at Shandong University.

0.5 post-doc FTE: to install and commission the sTGC at STAR and carry out a beam test.

0.25 post-doc FTE: to work on simulations by developing a slow simulator.

4 trips to enable post-docs to attend two workshops (2000 $/trip) in US and one international conference (4000 $/trip), and to carry out a beam test (4000 $/trip)

Third year:

0.25 post-doc FTE: to install and commission the sTGC at STAR.

0.25 post-doc FTE: to work on simulations by developing a conceptual design in using sTGC as part of the tracking detectors at forward rapidity for an EIC experiment.

3 trips to enable post-docs to attend two workshops (2000 $/trip) in US and one international conference (4000$/trip)

The milestones

- The milestone for the first year is to build an sTGC prototype and obtain its position resolution through cosmic ray test.

- For the second year, install the prototype at STAR and carry out a beam test.

- For the third year, obtain the prototype performance at STAR and have a conceptual design in using sTGC disks as part of the forward and backward tracking detectors.