R&D and related Simulation Studies for the sPHENIX Time Projection Chamber

Prakhar Garg, *for the sPHENIX Collaboration*

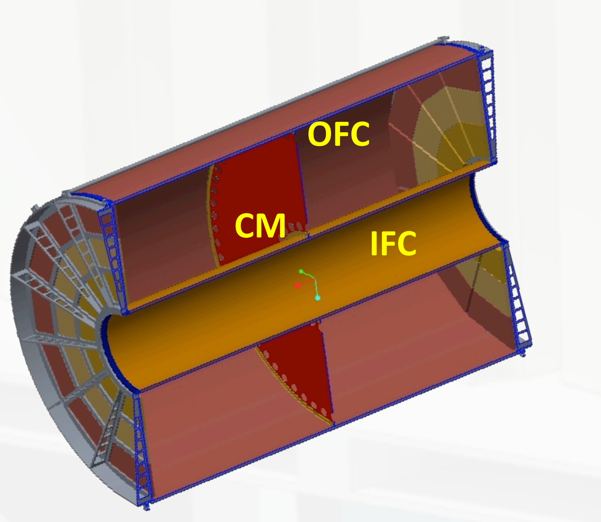
Department of Physics and Astronomy,
Stony Brook University, SUNY, Stony Brook, New York 11794-3800, USA

Abstract

The proposed sPHENIX detector design is focused mainly on a physics program of precise upsilon spectroscopy and jet measurements, which require a high tracking efficiency and excellent momentum resolution. A time projection chamber (TPC) is proposed as the outer tracking detector for sPHENIX, which has a rapidity coverage of |η| < 1.1 and full azimuthal coverage. The sPHENIX TPC design has to be optimized for operation in the high rate, high charged particle multiplicity environment that is anticipated at RHIC in 2022. In this poster, we show the results of R&D, its related simulations and describe the ongoing efforts to optimize the design of the sPHENIX TPC.

sPHENIX Time Projection Chamber

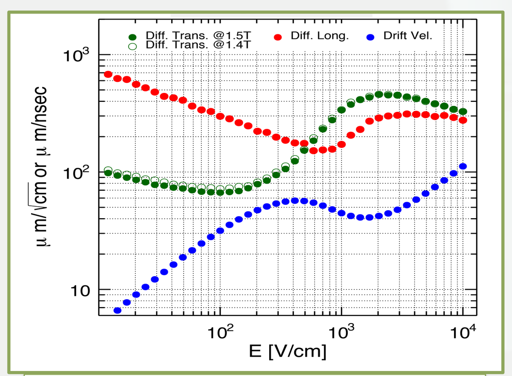
⌘ Coverage
- 20 cm < r < 78 cm
- |η| <1.1 (2.11 meter of full length)
- Full azimuthal coverage



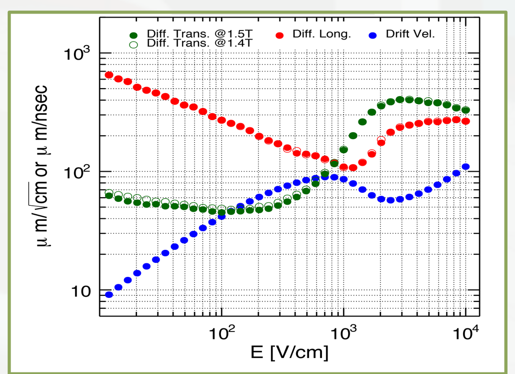
⌘ Ne based Gas mixture

Ne + CF_4 + iC_4H_{10} [95:3:2] & Ne + CF_4 [90:10] are explored

- Dominantly Neon ⇨ Low Space Charge
- Low diffusion ⇨ Better Resolution
- Plateau in v_{drift} ⇨ Stability @ 400 V/cm



Ne + CF_4 + iC_4H_{10} [95:3:2] at NTP

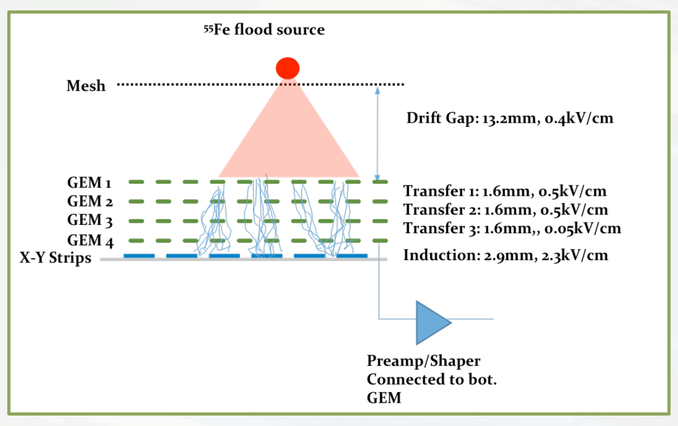


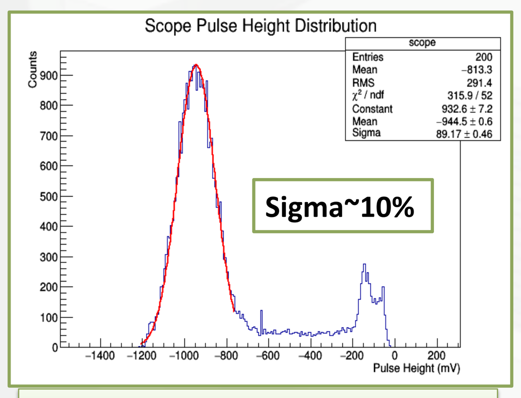
Ne + CF_4 [90:10] at NTP

⌘ Quad GEM Based Readout for Low Ion-back-flow

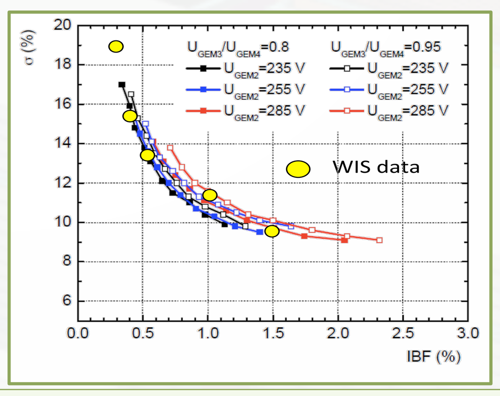
Gas Properties Measurements

Set-Up
- Use Ne2K gas [Ne-CF_4-iC_4H_{10}/95:3:2] Flow = 1.4 slpm @22C/~1atm [high purity]
- 4-GEM stack of CERN Cu 4-way segmented foils [pitch-inner/outer hole : 140-50/70 μm]
- Used ^{55}Fe flood source, no collimation
- Ion backflow measurements reproduced ALICE results
- Energy resolution gets worse at lower IBF => still need to be optimized

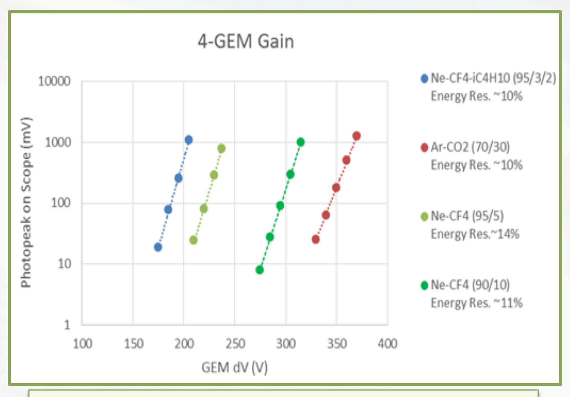




Energy Resolution observed is ~10% (Sigma)



Ion back flow measurements are reproduced for Ne+CO_2+N_2



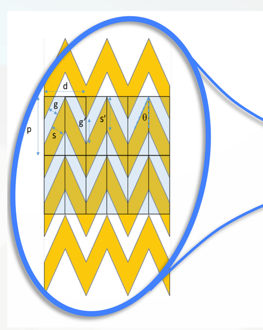
High Gain at lowed GEM Voltages with Ne2K gas

➢ WIS IBF results were done using the ALICE 4-GEM configuration with 140-280-280-140 pitch GEM's

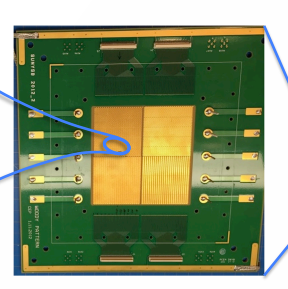
Chevron Pad Readouts

⌘ Optimize resolution:
More sharing – More accuracy
Less sharing – Less occupancy

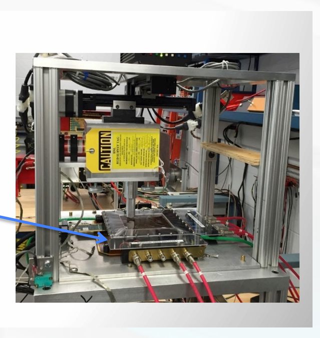
⌘ Goal:
100 μm intrinsic resolution with 2mm pad structure & Linearity across the structure



Chevron patterns guided by simulation

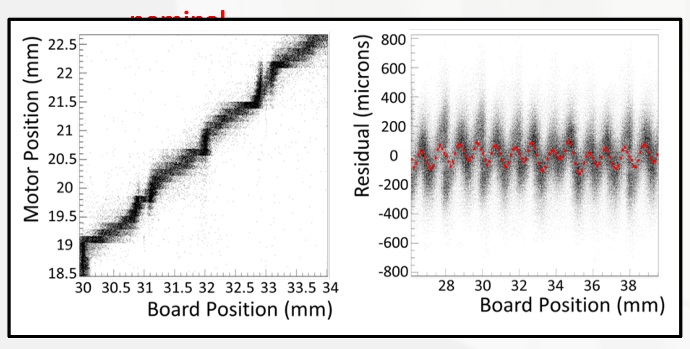


Manufactured for testing in the lab condition

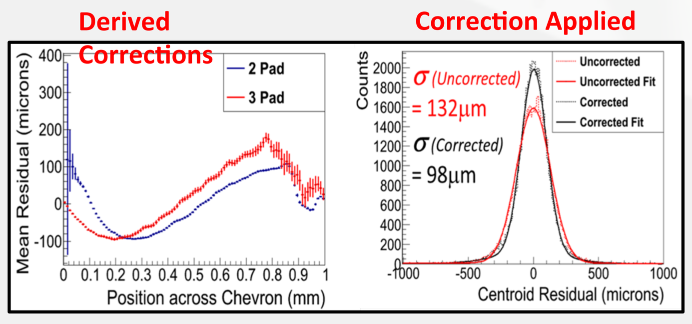


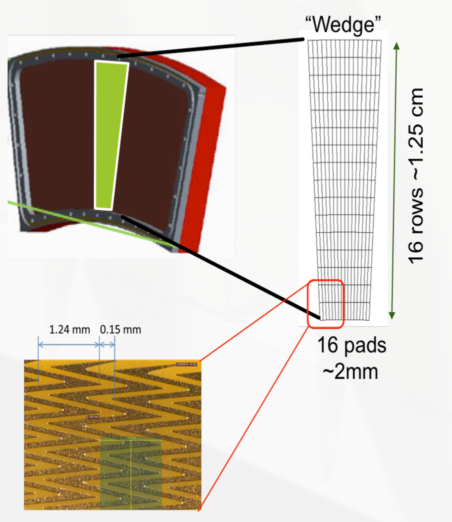
X-Y scan facility with collimated X ray source

Reconstructed vs. nominal | Residual distortion

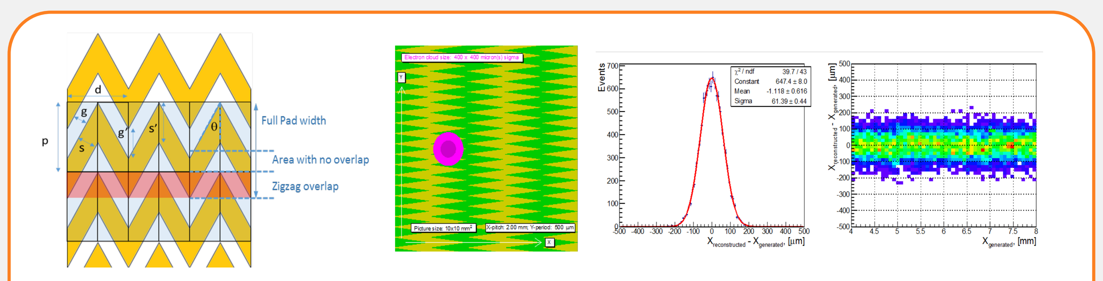


Derived Corrections | Correction Applied





- Module anodes segmented into 16x16 pad "wedges" in terms of FEE cards.
- Pads average 2mmx 1.25 cm in size.
- Individual pads segmented as Chevron.
- Each FEE card supports a single wedge.



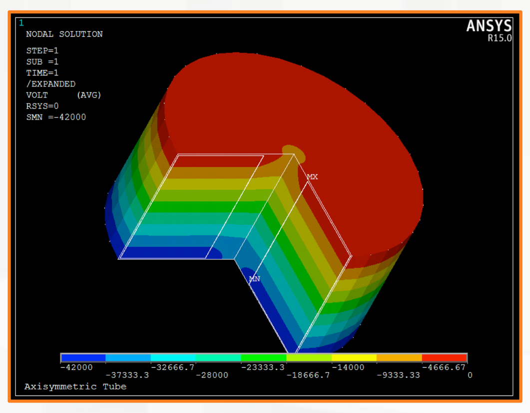
Further optimized 4-parameters for best resolution using simulation

Manufacturing imposes very strong constraints on design

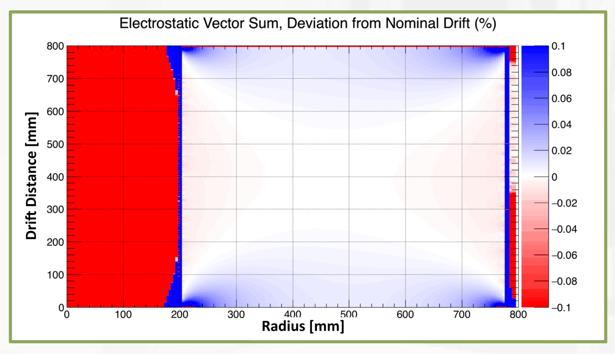
- High intrinsic resolution (σ_0 ~100um) with relatively large pads (2mmx10mm)
- Minimum differential nonlinearity
- Maximize overlap of adjacent pads
- Minimize gap between adjacent pads

Mechanical Tolerance and Electric Field Distortions

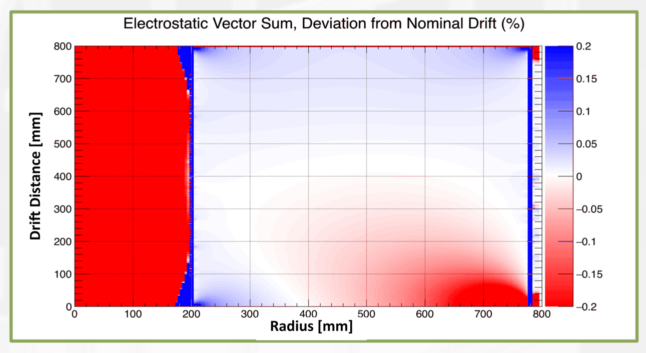
⌘ Unique feature of the field cage is its internal potential defining system designed to provide a highly uniform electric field with small radial distortions.



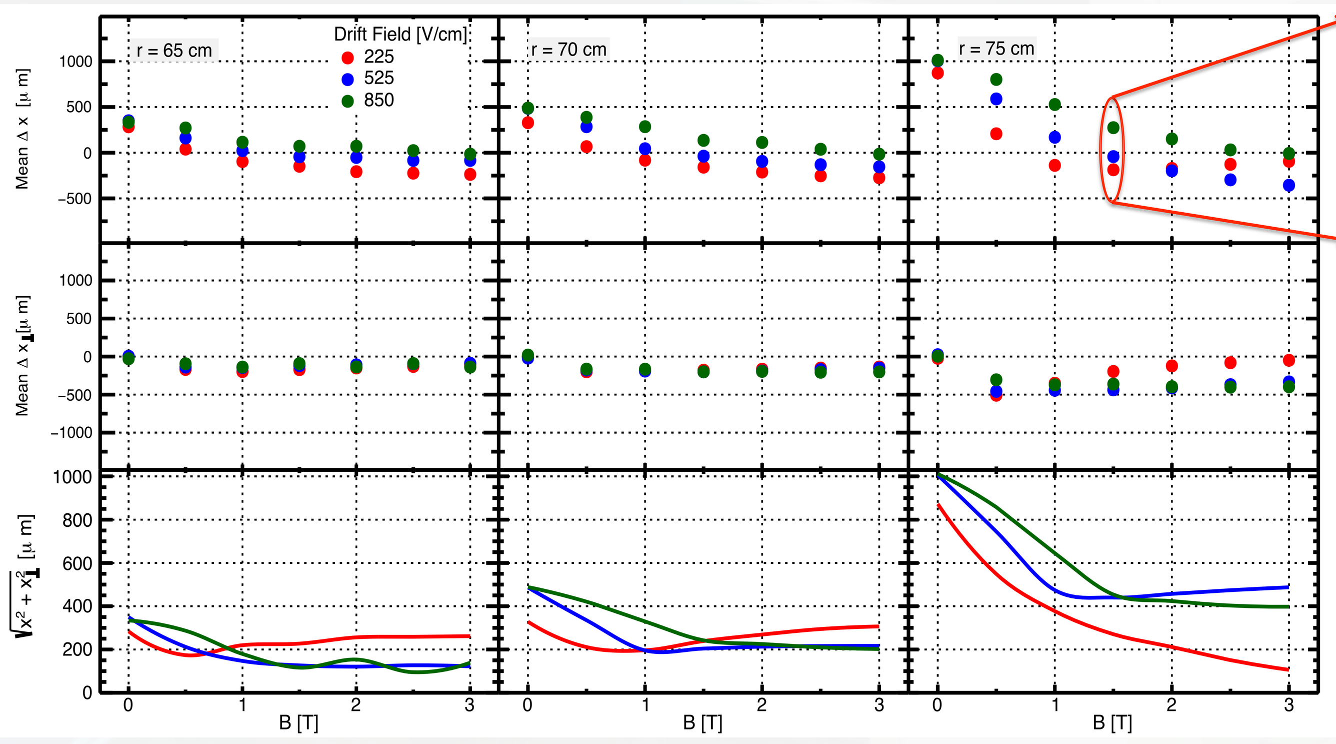
Equipotential Contours in ANSYS solved for sPHENIX TPC Geometry



Electric Field Distortions [%] for Ideal TPC Geometry



Electric Field Distortions [%] after Tilting the Central Membrane



Zero Crossing for sPHENIX TPC => Forces Balance if

$$\frac{E}{v_d} = B \times \frac{\cos\gamma}{\cos\alpha}$$

Similar Studies are done for:
- Module tilt
- Membrane tilt
- Shifted field cage
- Rotated field cage
- Resistor tolerance

These results seem to RELAX our mechanical design constraints.

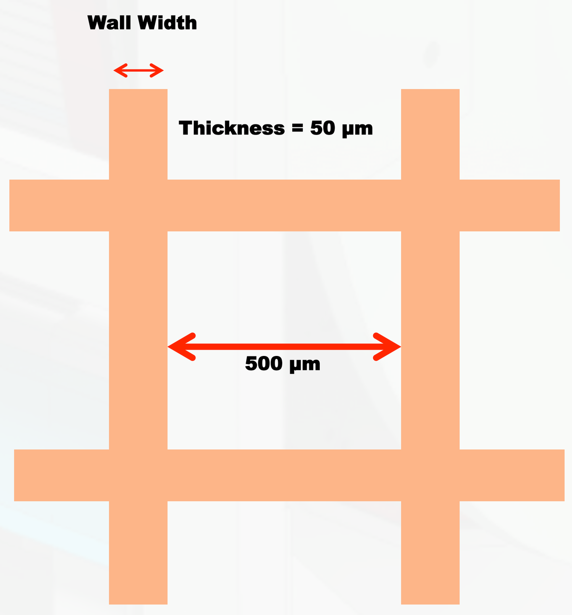
Distorted Field Maps are imported to Garfield++ with the Magnetic Field (1.5 T) after tilting the Central Membrane to study the Errors in Electron's Position in Ne2K Gas near the Outer Field Cage

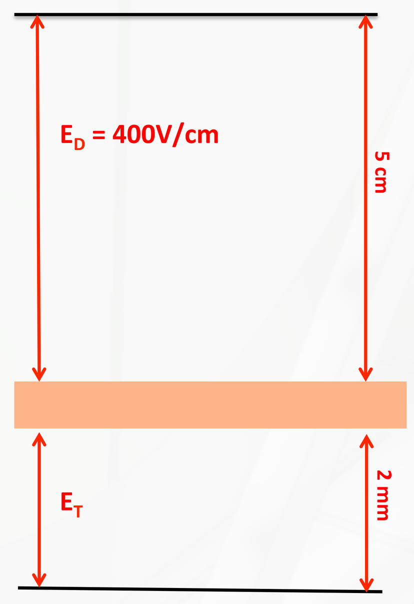
Strong magnetic fields guide the electrons and hide electric field imperfections!

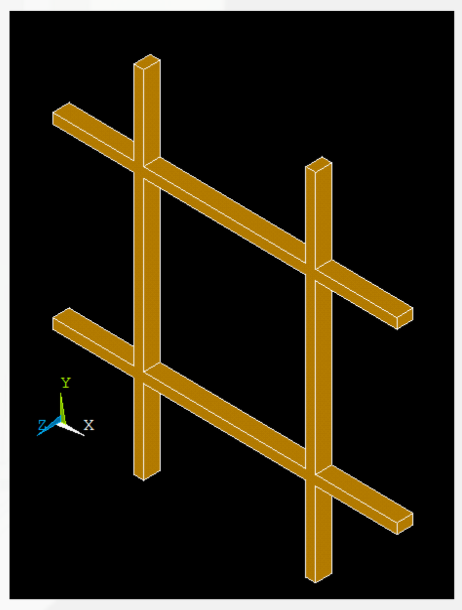
More on Mechanical Design updates : poster by Niveditha Ramasubramanian

Passive Gating Option for TPC

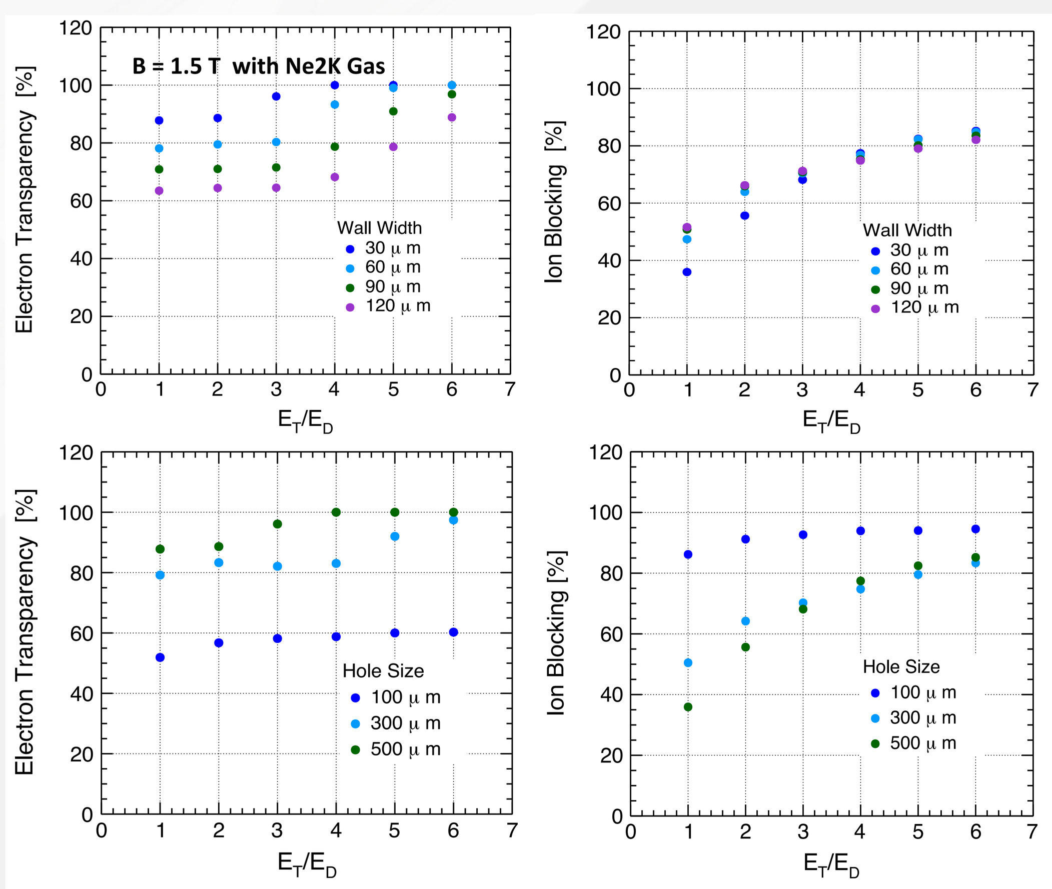
- The feedback of positive ions in drift volume of a time projection chamber (TPC) causes adverse effects on the electric field in the drift region, thereby degrading the spatial resolution of the TPC.
- A gating device located between the drift volume and the gas amplification is used to prevent positive ions from entering the drift region.
- Multiple ANSYS and Garfield++ simulations are performed for square/circular hole grid, wire mesh and Photo-etched mesh to study the electron transparency and ion blocking.







- It is possible to tune the field ratio surrounding the mesh to block most of the positive ions with good electron transparency
- It will also serve as a "termination grid" to ensure uniformity of the field in the drift volume.



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