Ion Feedback Suppressing by Using Graphene Membrane

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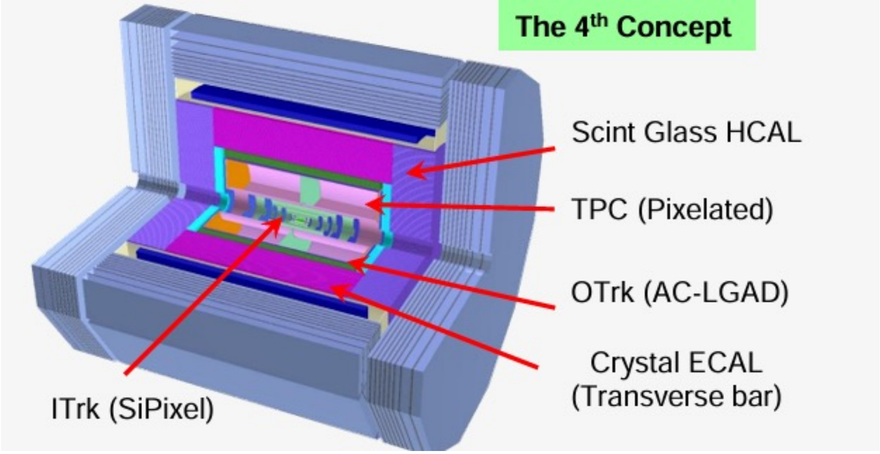
CEPC and TPC tracking detector

◆The CEPC was proposed by the Chinese HEP community in 2012 right after the Higgs discovery.

◆It aims to start operation in 2030s, as a Higgs / Z / W factory in China.

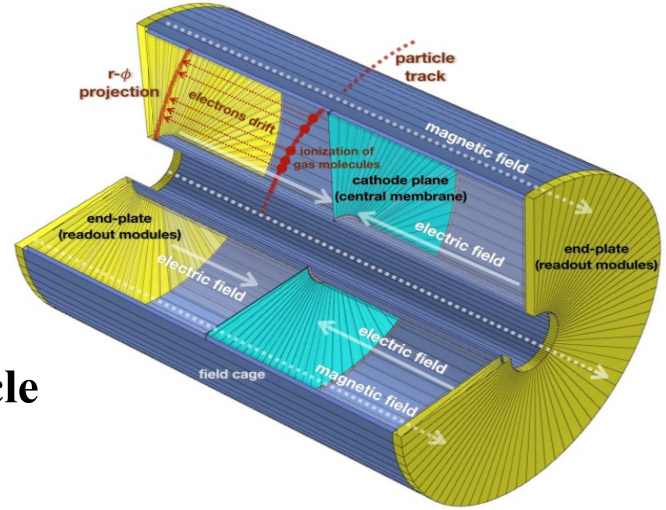
◆High luminosity and low background



The CEPC Conceptual Detector Design

➢Time Projection Chamber (TPC)

- **Track measurement**
  - ◆Measure passing points along trajectory ↪ **Directions of track**
- **Momentum measurement**
  - ◆Measure the bend of tracks in B-Field ↪ **Momentum of charged particle**
- **Particle Identification (PID)**

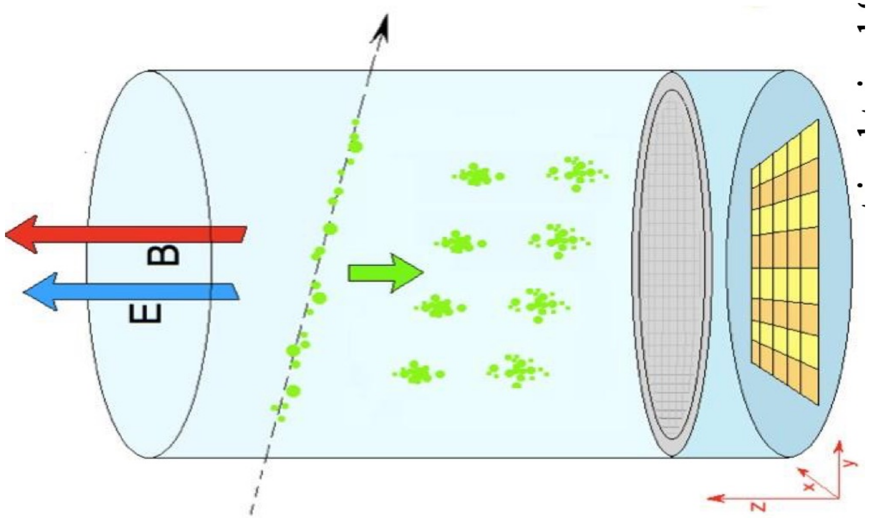


Central tracker of CDR concept

Ion feedback in TPCs

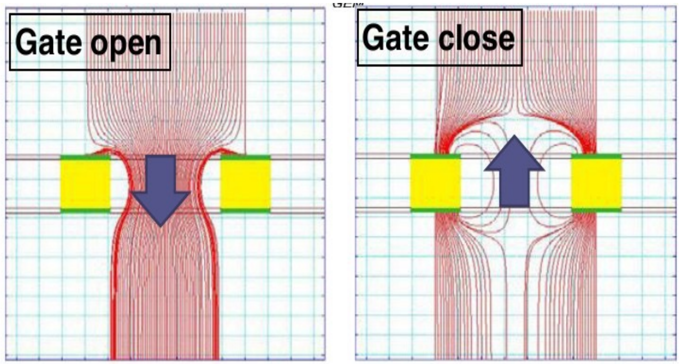
➢Ion feedback in TPCs

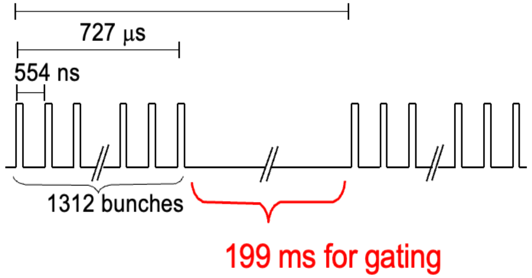
- affects the drift of electrons
- decreased momentum resolution
- introduce distortions in the reconstructed tracks

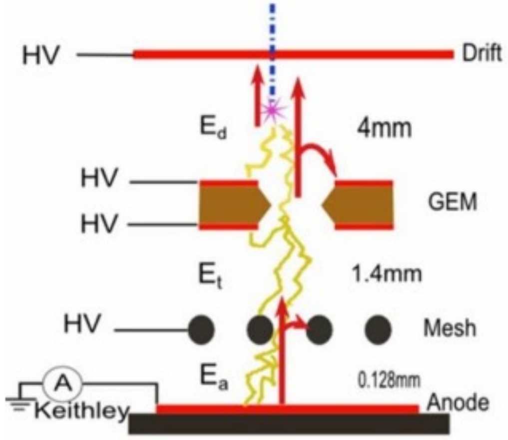


➢Methods to suppress IBF

- **Gating --- Gating GEM**
- **MPGD --- GEM + MicroMegas**







Schematic diagram of the GEM-MM hybrid detector module.

Feasibility of Graphene Membranes

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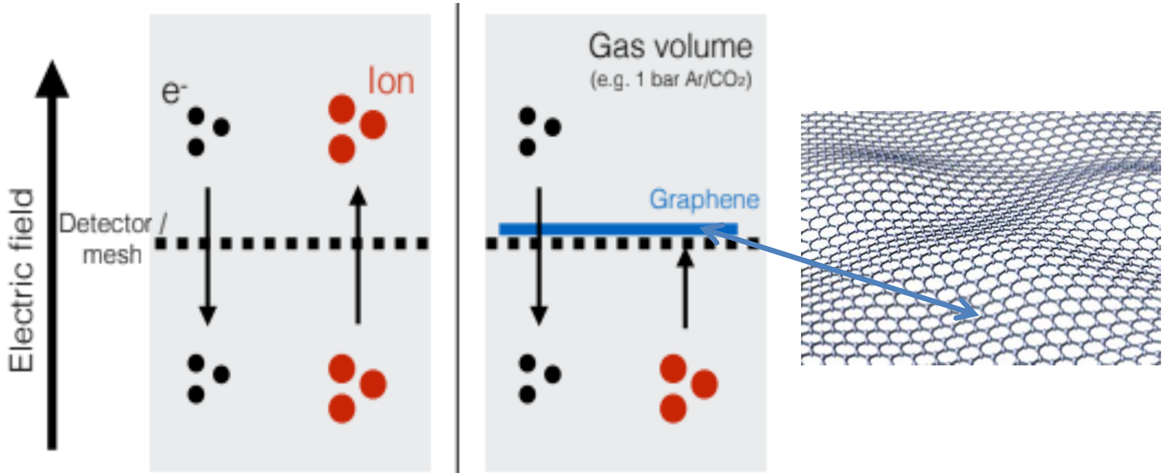
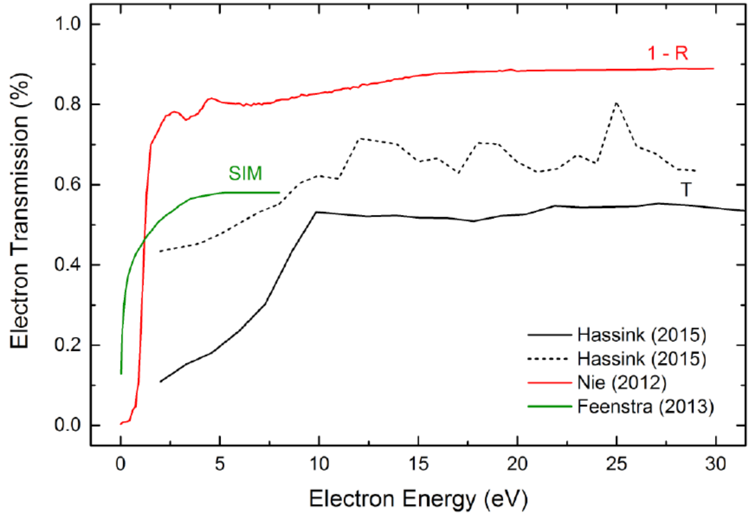
➢Nature of graphene

- **Hexagonal atomic structure Effective radius0.6 Å**
- **Allows electron passage, blocks large molecules**
- **Excellent mechanical performance**
  - Capable of withstanding 10^{16} ions/cm^2 @KeV
  - It can be suspended over micrometer-sized holes



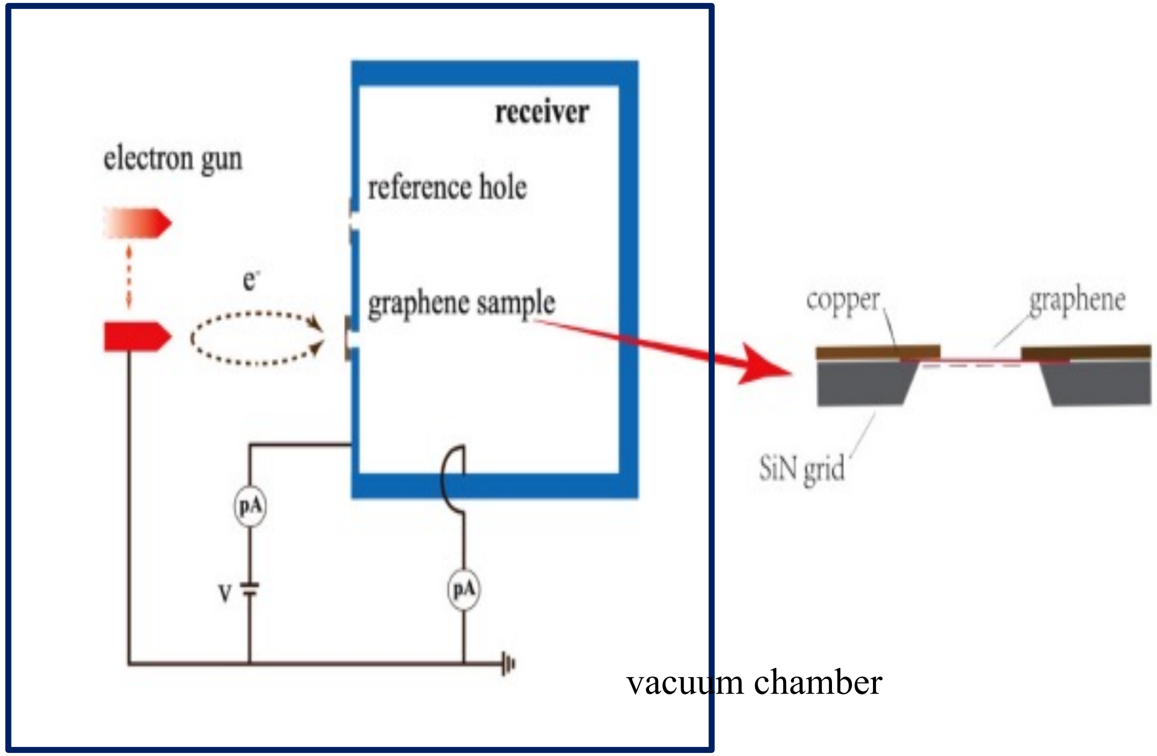
➢Key factor

- **Transmission rate of eV-scale electron**
- **Graphene laying on micromesh structure**
- **Large area preparation of suspended pore graphene structures**



Electron transmittance measurement

- Schematic view of measurement system
  - **Lower-energy electron sources**
    - Kimball elg-2/egps-1022
  - **Graphene sample**
    - Tedpella SiN-grid substrate
  - **Electron receiver**
  - **Pico-ampere meter**
  - **vacuum chamber**
    - Pv $<1e^{-5}Pa$



Schematic view of measurement system

Electron transmittance measurement

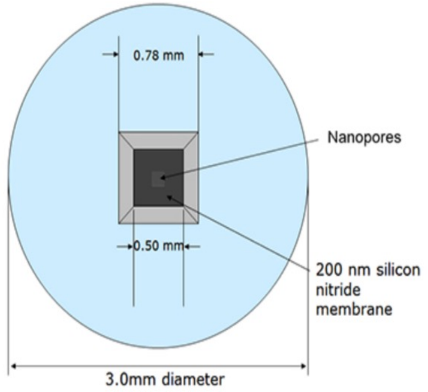
➢ Tedpella finished product：

- **Silicon nitride covered with monolayer of graphene ~ 75% covered region.**

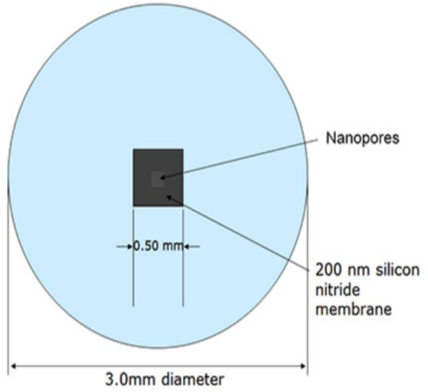
parameter	value
aperture	2.5 μm
pitch of hole	4.5 μm
thickness	200nm
mesh region	0.45*0.45mm

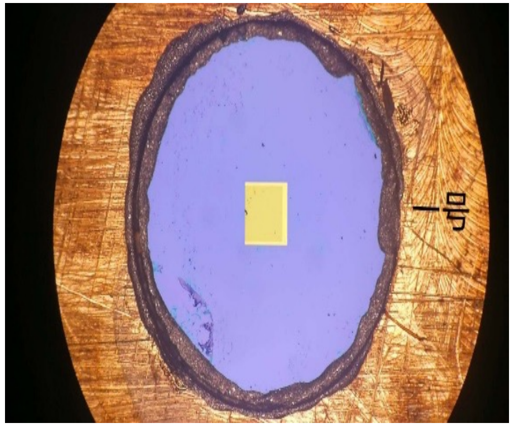
- **Multiple-holes measurements with 360μm diameter region;**
- **Correct the hole proportion.**

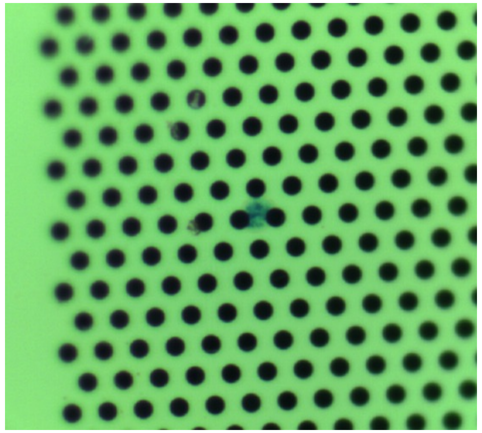
Back Side of a Nanoporous Membrane Disk (enlarged)



Front Side of a Nanoporous Membrane Disk (enlarged)







Electron transmittance measurement

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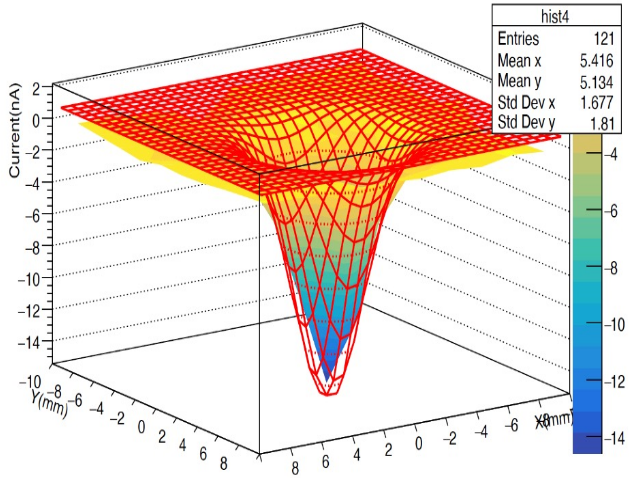
➢ Calibration of measurement system

- Kimball elg-2/egps-1022 e-Gun
  - Focusing ability

    <2 mm@<10 eV
  - Beam energy distribution

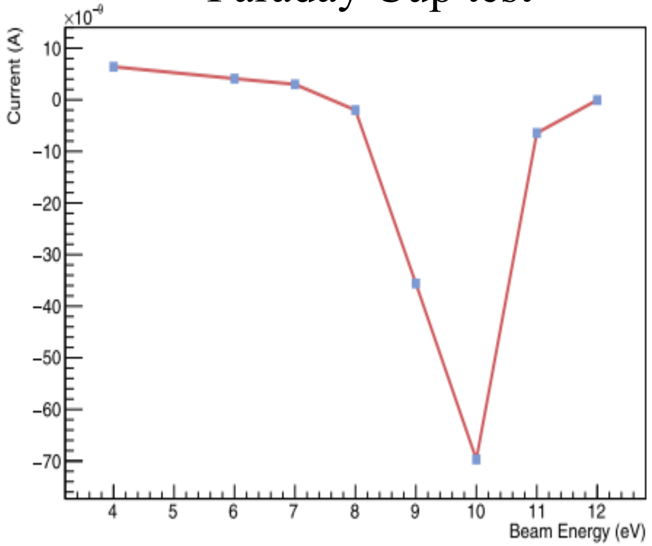
    0.9 eV @ 10 eV
- Global system noise testing

Focusing test



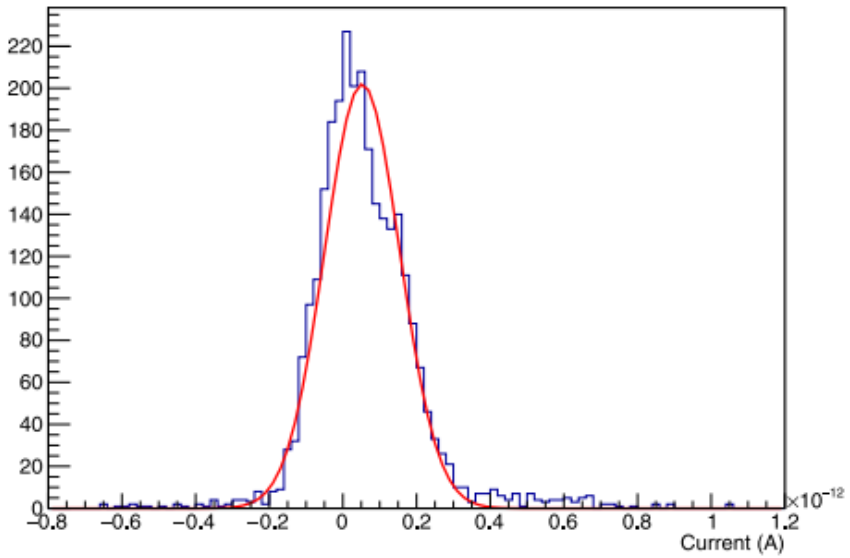
1.87mm@10eV

Faraday Cup test



σ~0.9eV@10eV

No-sources noise test



σ~0.4 pA

Measurement Result

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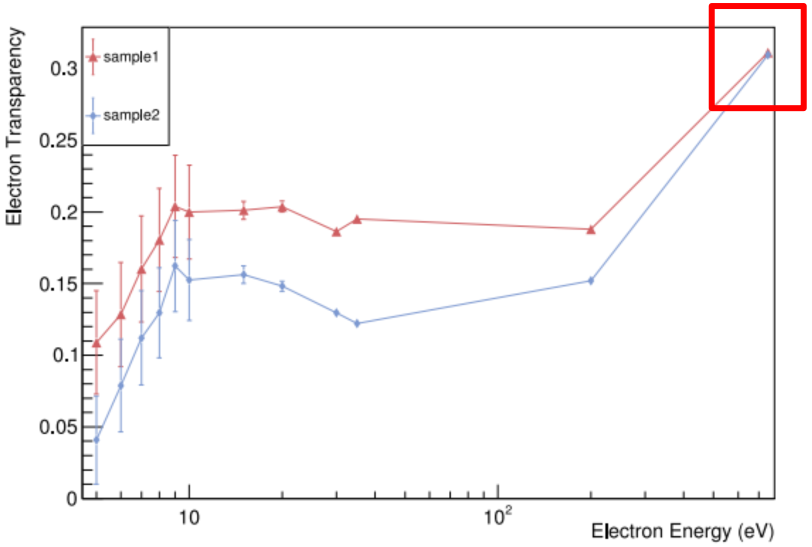
- transmission coefficient:

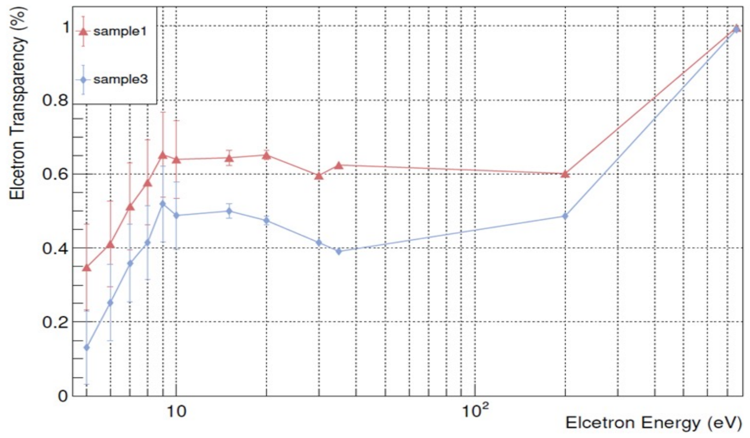
3

$$T = \frac{I_P - I_{ped}}{(I_T - I_{ped}) * M}$$

  - **Same trend with the increase of electron energy.**
  - **The differences due to the different quality of the graphene samples.**

- Effective aperture correction:
  - **charge effect of the edge of SiN hole reduces the effective aperture to 31%.**





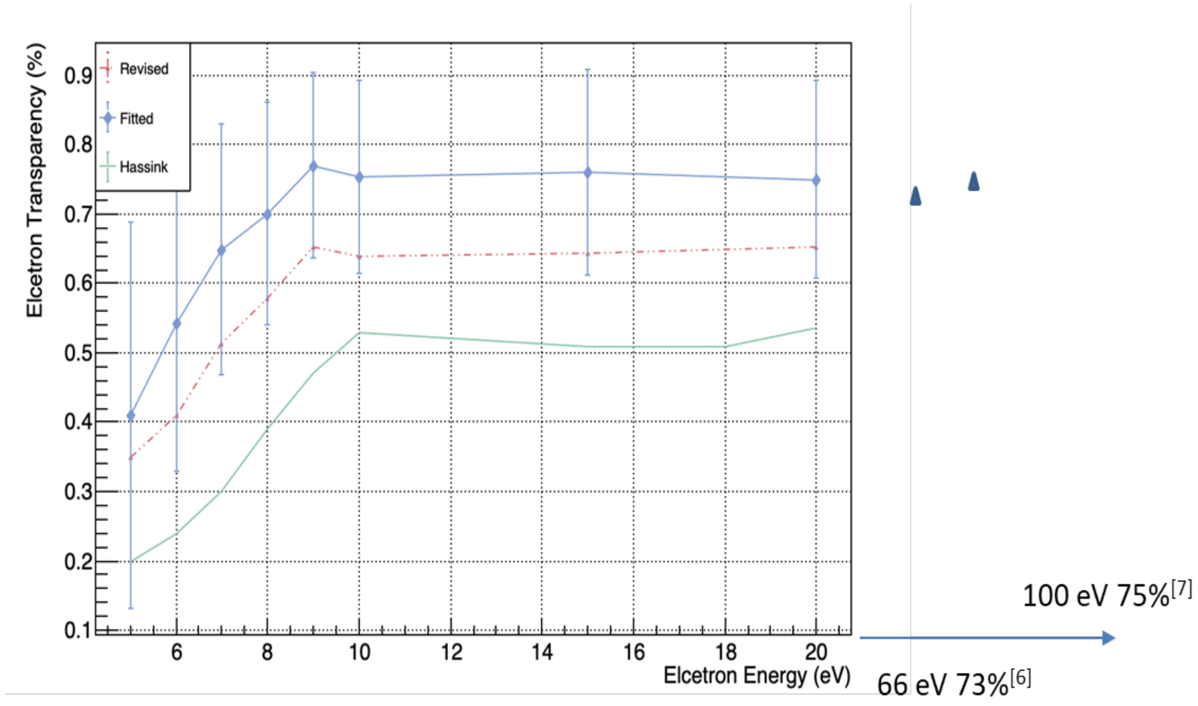
The electron transparency after effective aperture correction

Fitted Result

➢ χ^2-Fit

$$\chi^2 = \sum_{i=1}^{num} \frac{(f_E \times a + f_E^n \times (1-a) - T_E)^2}{\sigma_T^2 + \sigma_h^2}$$

- f_E: monolayer transmittance
- a: monolayer proportion
- n: Multilayer quality factor

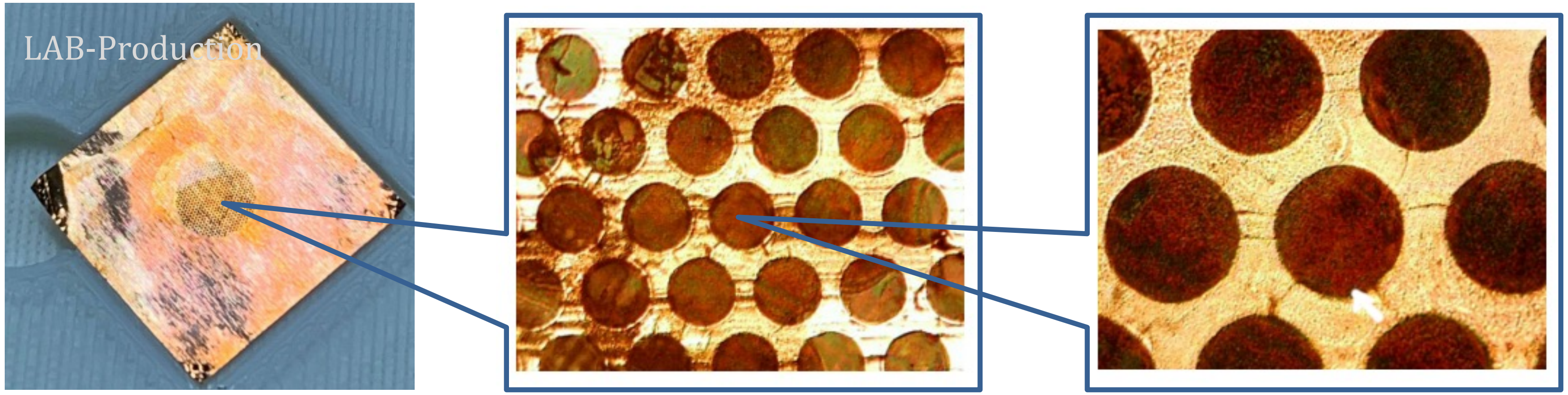


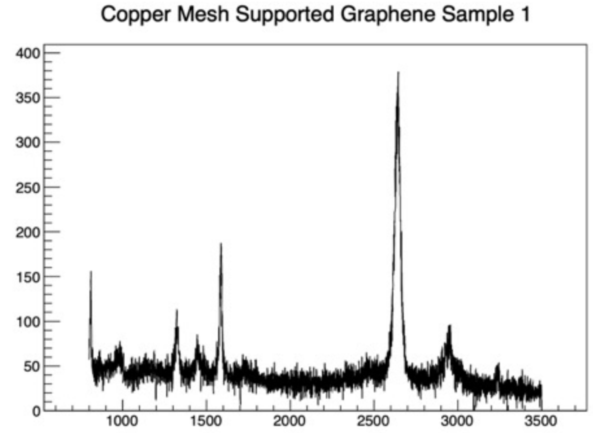
- 1.The transmittance increases with the increase of energy between 5 and 10 eV.
- 2. The transmittance remains stable between 10 and 20 eV.
- 3.Monolayer graphene has a transmittance of about 40% near 5 eV.

Micromesh structure covered with graphene

➢ Graphene laying under microgrid structure

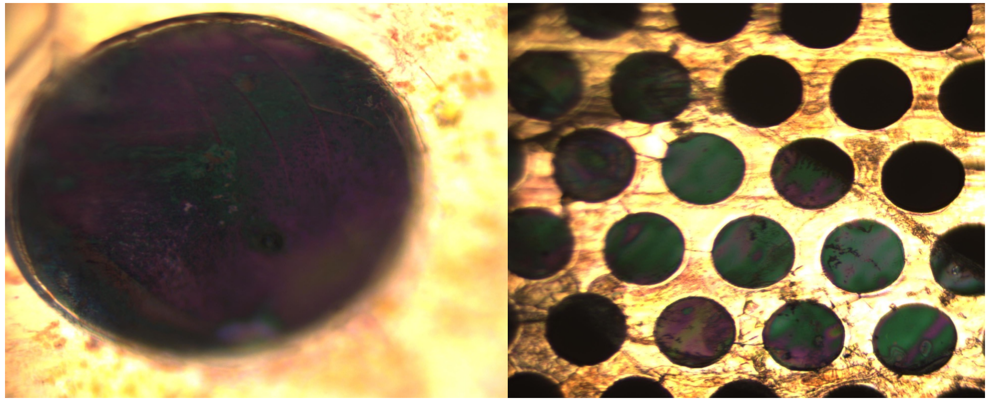
- **Substrate： Copper mesh R:100um d:130um h:10um**
- **Wetting transfer method**





➢ Technical challenges

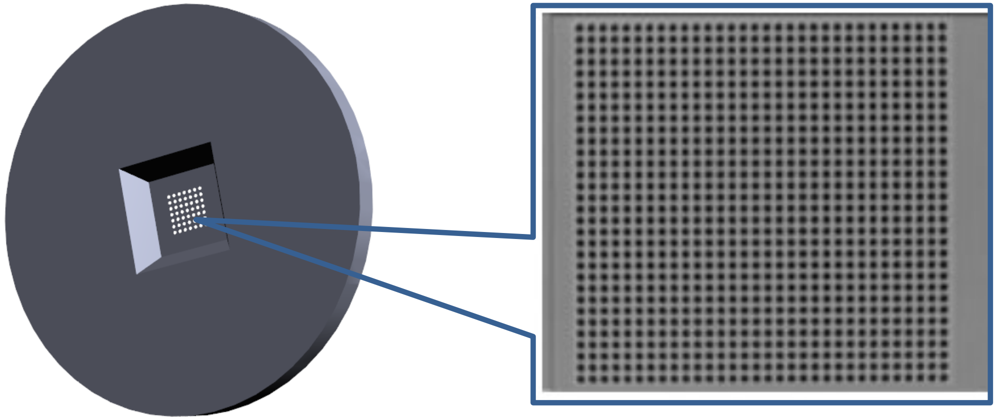
- **Large Area Graphene breakage**
- **PMMA residue**



Substrate optimization scheme

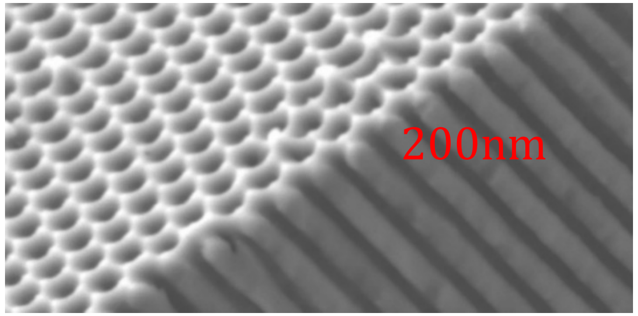
➢Silicon nitride micromesh

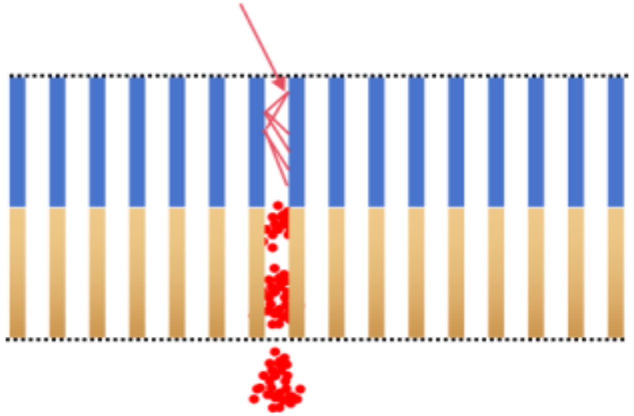
- **R:2.5um d:4.5um h:0.2um**
- **high successful graphene laying**
- **tackle problems in technologies:**
  - ◆ Large area preparation of silicon nitride micromesh
  - ◆It is used to study the electrical properties of particle detectors



➢Micro-nano channel plat

- **R:1<um h:<50um**
- **Mature preparation process**
- **Smaller hole sizes make it easier to lay graphene**





Summary

- Experimentally measured the transmittance of graphene to EV-scale electrons.
  - **The transmission coefficient of 5 eV electrons to monolayer graphene is about 40%~50% , 10 eV and 200 eV, the transmission coefficient remains stable at ~80%.**
  - **It provides the basis for its application of the IBF suppression in the TPC.**
- Studying for graphene laying under micromesh structure.
  - **The preparation of graphene membrane with 100 um copper micromesh structure was studied.**
  - **Two new schemes :**
    - SiN-Substrate and MNCP
    - Current Plan : Investigate MNCP samples and graphene laying
    - Current Plan : Construction of small TPC test system

Thank you for listening