# Measurement of CSNS Back-n Neutron Beam Profile with Micromegas Detector

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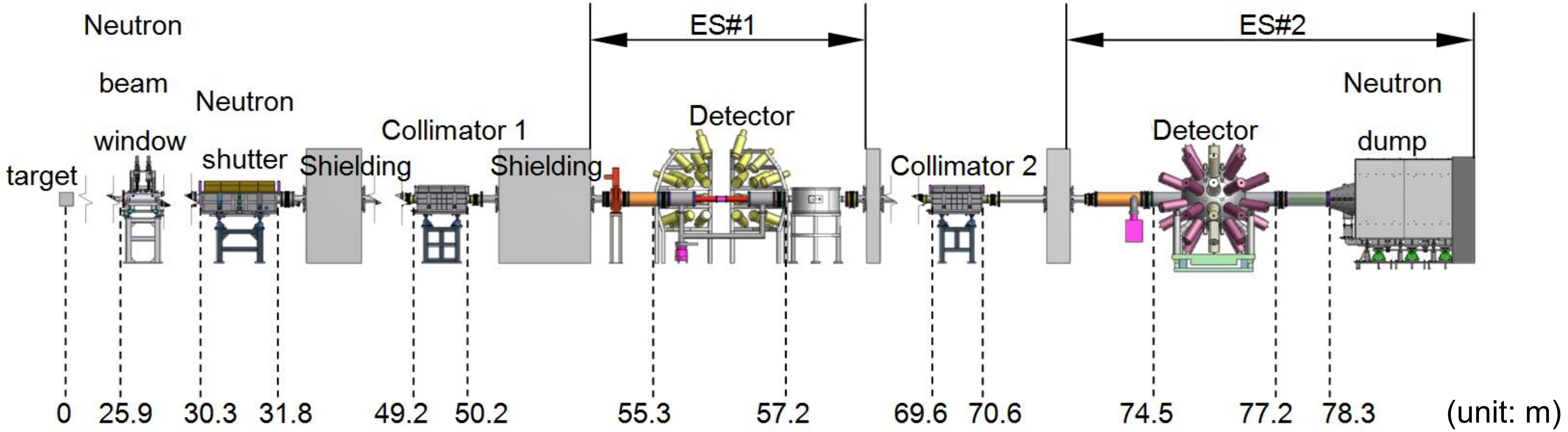
# CSNS Back-n Beamline




**Distance from spallation target**

- Endstation-1: ~55 m; Endstation-2: ~70 m

**Neutron energy**

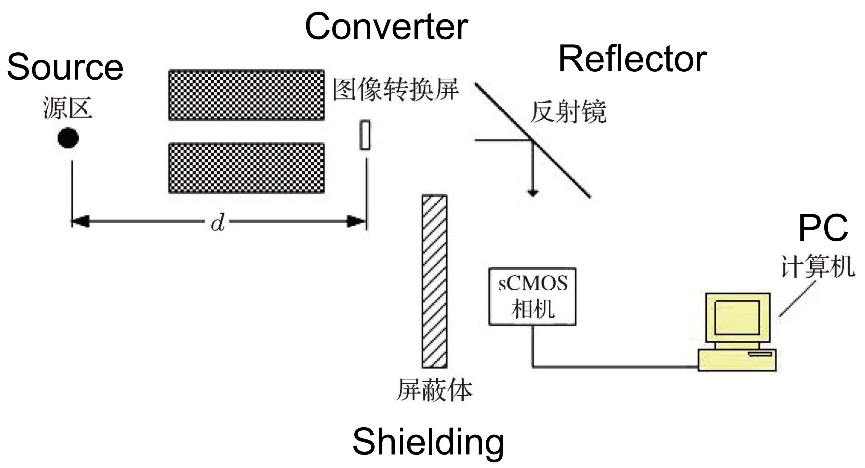
- Thermal to 300 MeV

**Neutron flux**

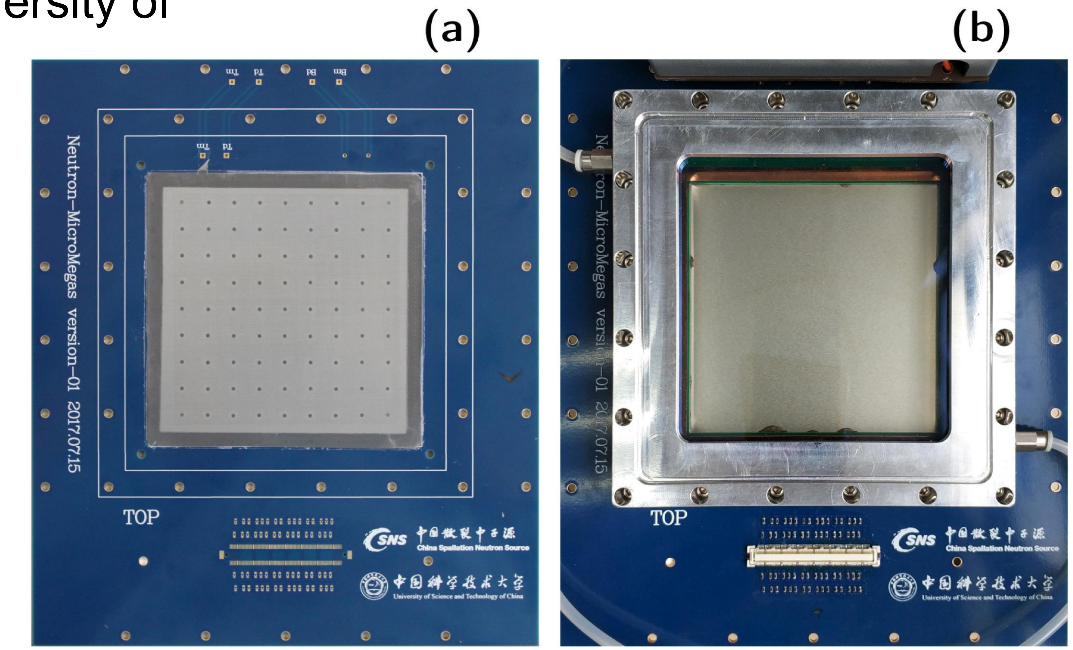
- $10^7$ n/cm$^2$/s @100 kW proton beam power

# Measurement of Back-n Beam Profile

- Neutron beam profile is one of the key properties of Back-n
- Measured when Back-n started commissioning in 2018 ~ 2019, by a scintillator-CMOS detection system [DOI: 10.7498/aps.68.20182191]

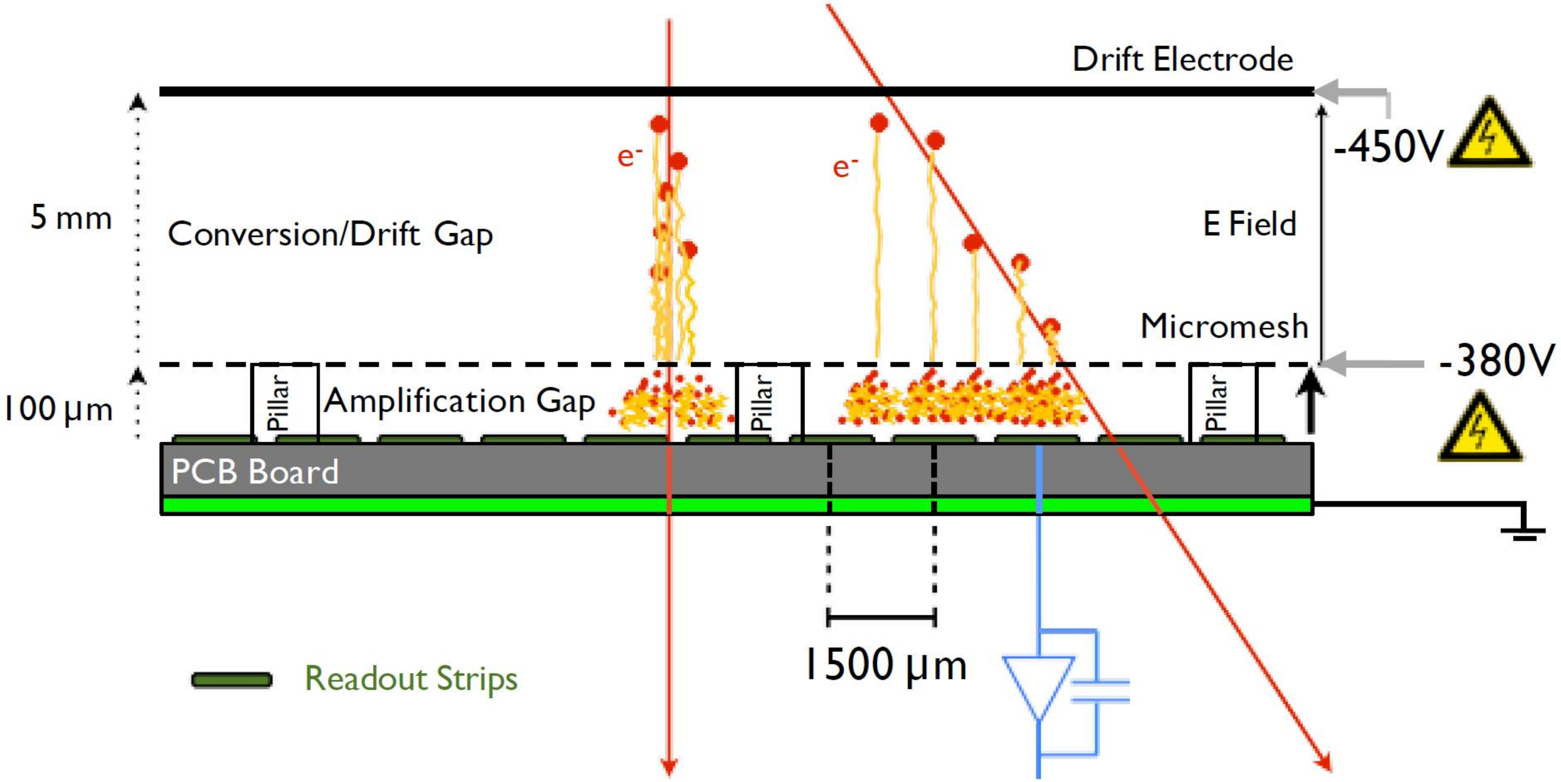



- Meanwhile, a beam profile monitor based on **Micromegas** (micro-mesh gaseous structure) detector was developed by **CSNS** and University of Science and Technology of China (**USTC**)
- **Good 2D spatial resolution**
- **Fast timing capability**



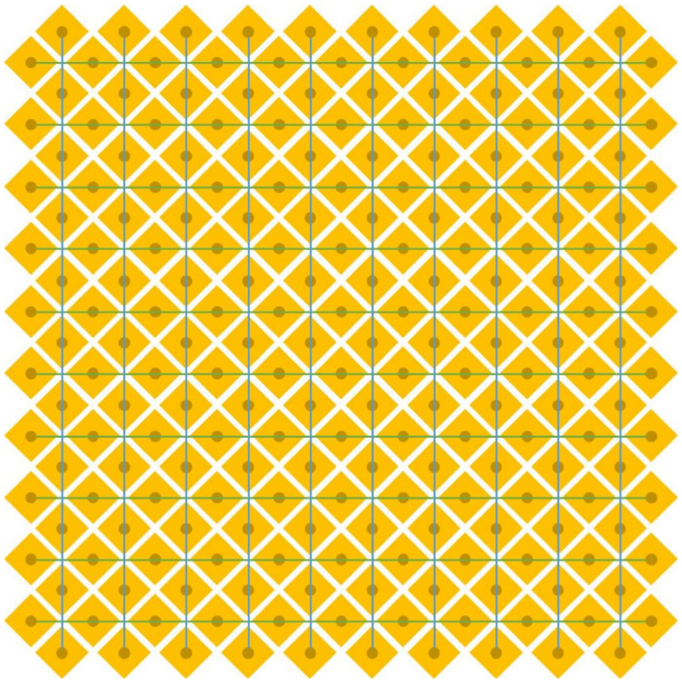
# Micromegas Detector

- To detect neutrons, they must be converted into charged particles via nuclear reactions, e.g. $^{10}B(n, \alpha)^{7}Li$, $^{6}Li(n, t)^{4}He$.
- **Neutron converter** of this work: $B_{nat}$, 1 μm thick, attached to the cathode facing the drift gap
- The mesh-anode amplification gap (where electron avalanches occur) is manufactured with the *thermal bonding method* [https://doi.org/10.1016/j.nima.2020.164958] developed by USTC.

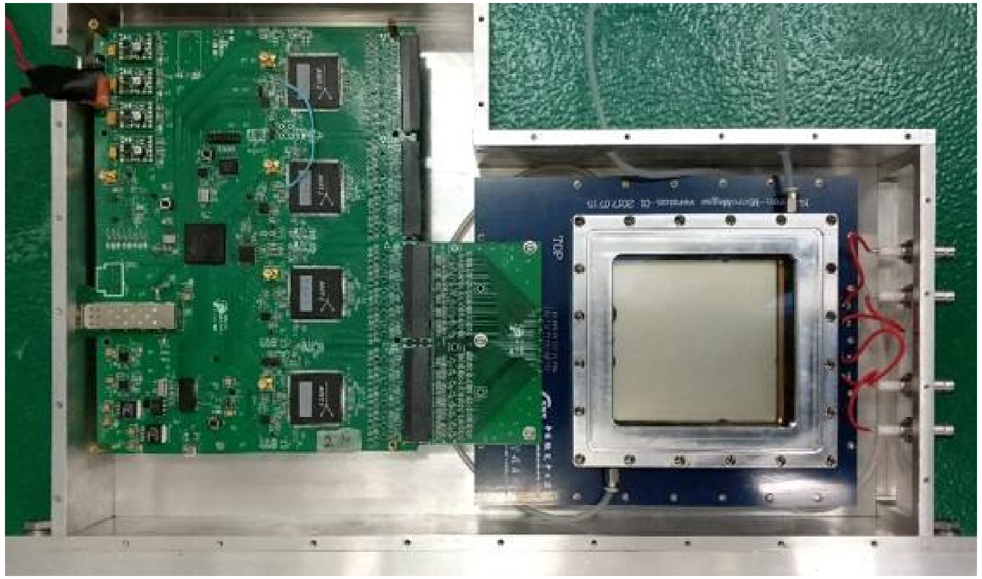



- **Drift gap:** 5 mm
- **Amplification gap:** 100 μm
- **Active area:** 90×90 mm²
- Mesh and anode plane separated by insulating pillars (2 mm in diameter)
- Readout PCB of 2 mm thick

# Micromegas Detector

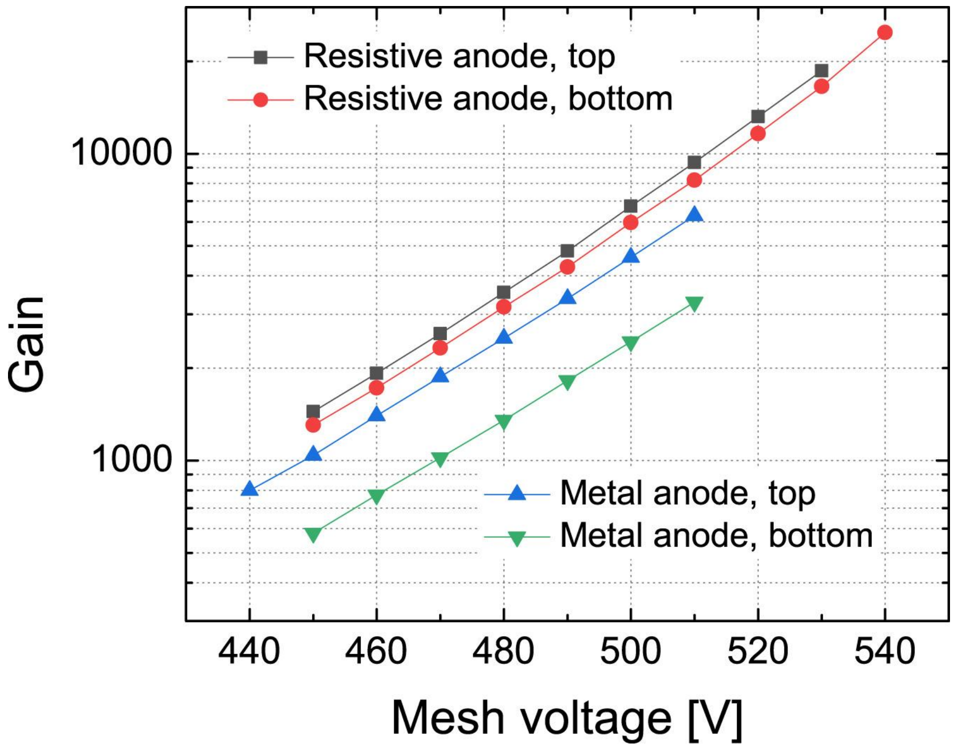


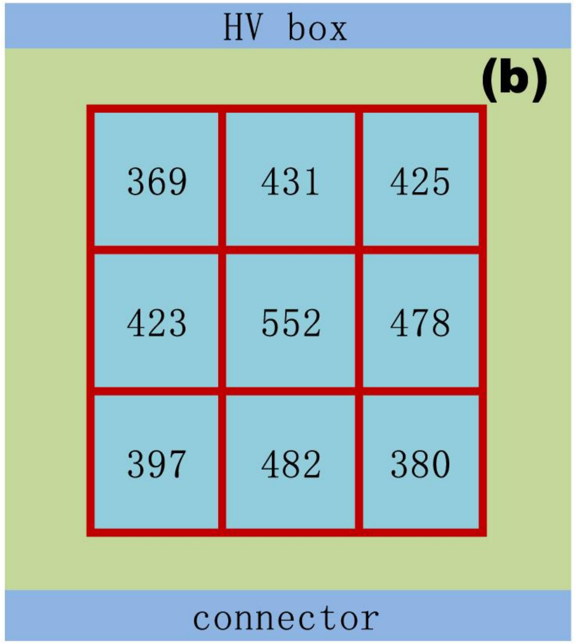
- **2D readout structure** has been designed to reconstruct the 2D position using strip coincidences
- **64 strips** (1.5 mm pitch) in each direction
- Each readout strip capacitively coupled to a charge amplifier, corresponding to one readout channel
- Goals of this 2D readout scheme:
  - **Mitigate the unequal charge sharing** between the two strip layers that occurs in conventional XY detectors
  - **Minimize the material budget** of the detector
- **Front-end readout electronics**
  - Two AGET chips, 128 channels
  - 512 sampling points, sampling frequency 3–100 MHz
  - 12-bit ADC



# Detector Performance Test with X-rays

- Collimated $^{55}Fe$ X-ray source ($E_{K\alpha}$=5.9 keV, $E_{K\beta}$=6.5 keV) was used to test the **detector gain, gain uniformity, and energy resolution.**
- Energy resolution (FWHM) 37% at 5.9 keV
  - Gap between the anode pads is 0.1 mm – comparable to the amplification gap length – the effects of the electric field inhomogeneities near the edges of the pads are nonnegligible.
  - This leads to considerable gain variations and consequently deteriorates the energy resolution.



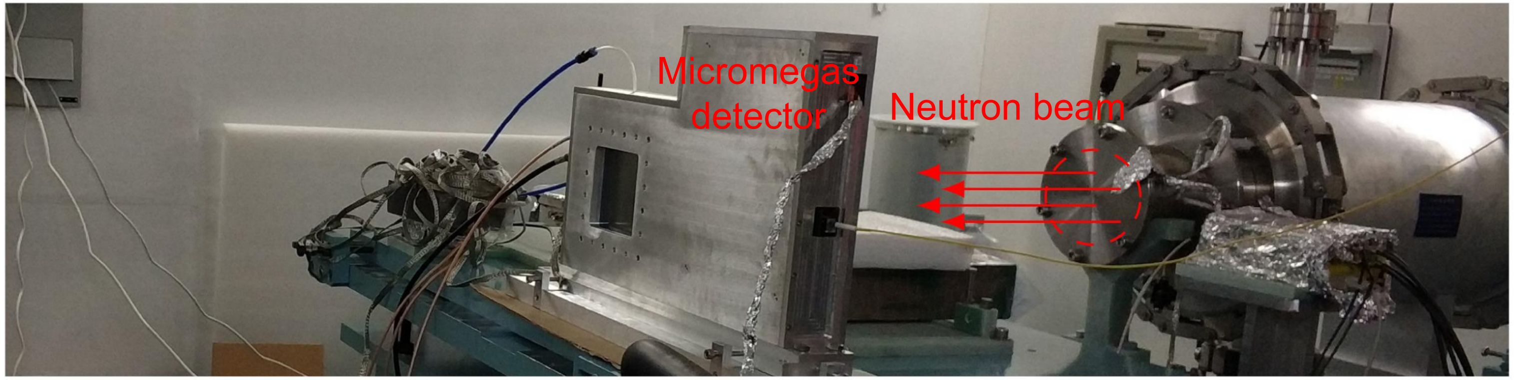




gain uniformity ~ 13%

The number in the cell indicates the position of $^{55}Fe$ dominant peak (in units of ADC)

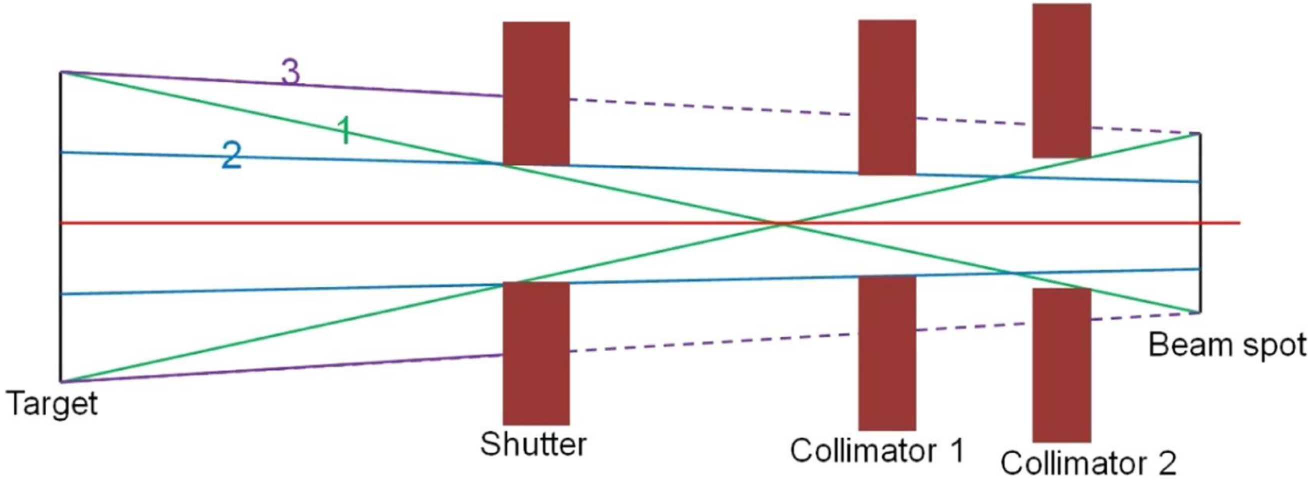
# Measurement of Back-n Beam Profile

- Measured at Back-n ES#1 (56 m)
- 20 kW proton beam power, 25 Hz
- Detector gas:
  - 90% Ar and 10% $CO_2$ at atmospheric pressure




## Configuration of collimation aperture

- ⌀ 50 mm for Shutter, ⌀ 50 mm for Collimator-1
- Beam spot size at ES#1 expected to be about ⌀ 50 mm according to MC simulation




## Data collection time

- Physics data collection time about nine hours
- Dedicated run with neutron shutter being closed to collect data for pedestal correction (230 s)

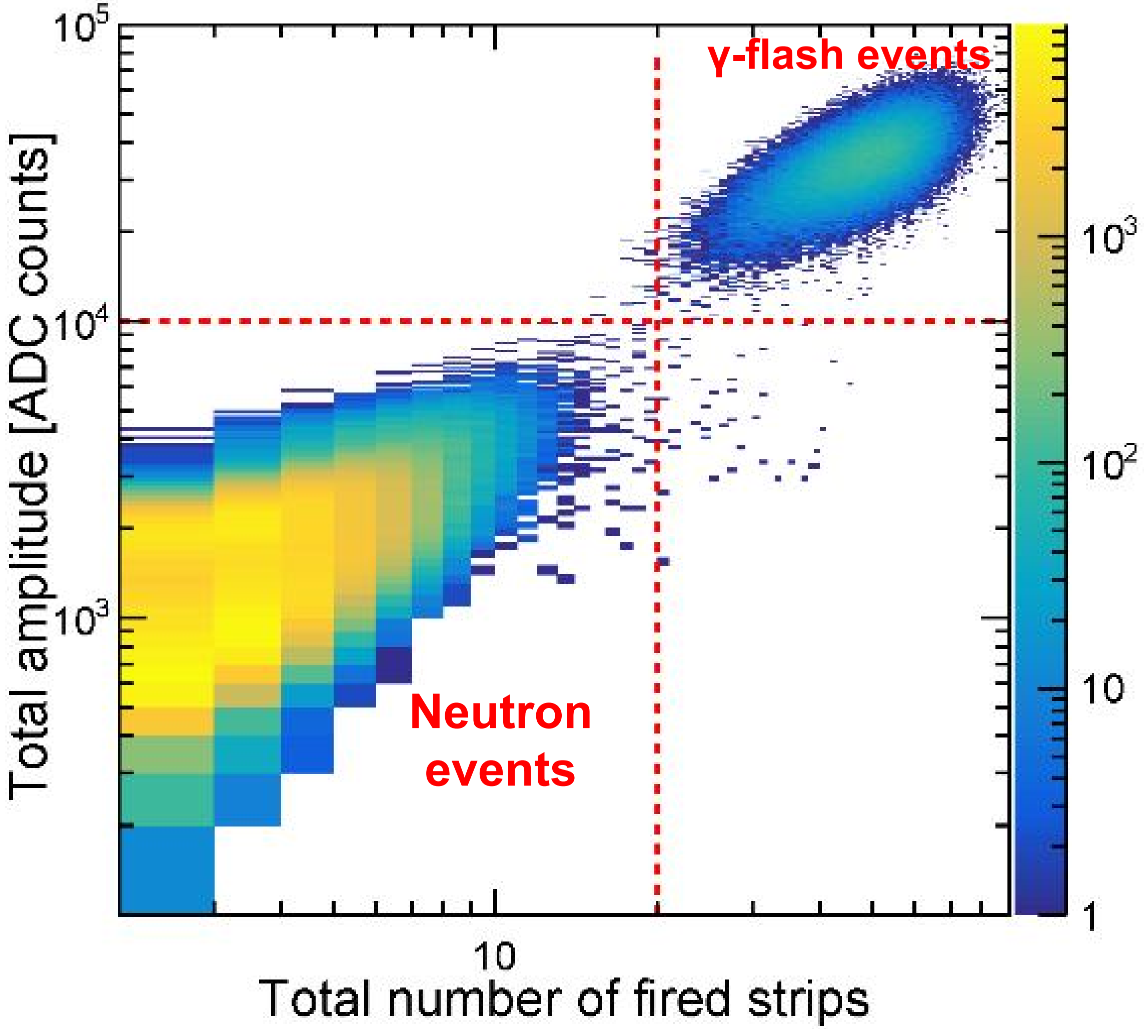
# Data Analysis

## Event selection

- Signal of strip with S/N > 5
- Fired strips should be consecutive, ensuring a continuous ionization of the gas when the charged particle traverses the drift gap

## Background rejection

- Dominant background: γ-flash
- Using **total number of fired strips** and **sum of amplitudes** of all fired strips to discriminate γ-flash from neutron events

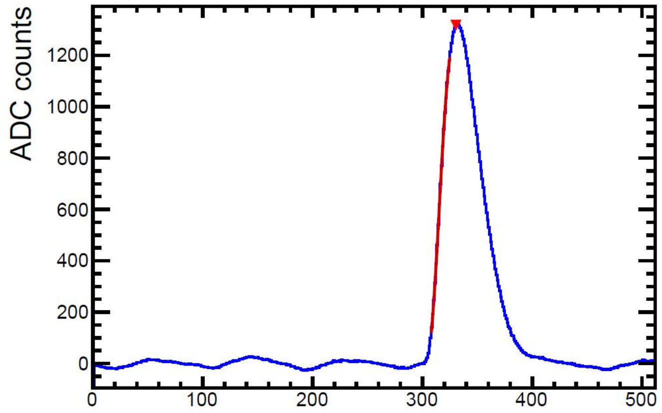


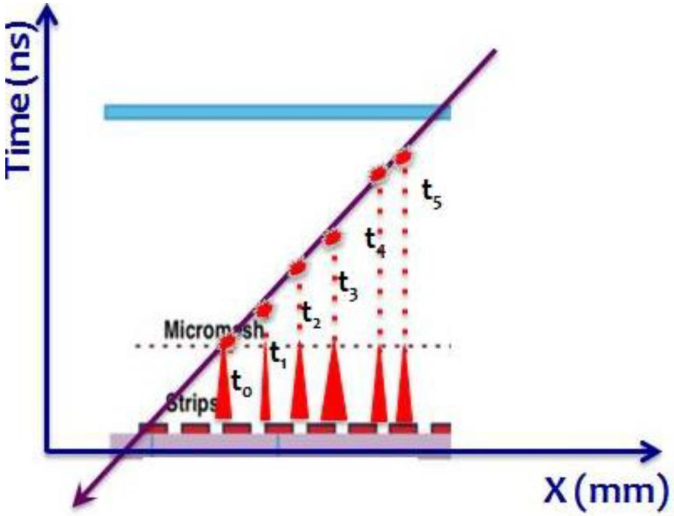
# Beam Profile Reconstruction

- After event selection and background rejection, clean neutron events are obtained for beam profile reconstruction.
- **Reconstruction method**: Micro Time Projection Chamber (μTPC)
  - ① Fit the leading edge of the waveform to obtain relative time information of each fired strip
  - ② Use the positron of the latest strip as an estimation of the neutron interaction position

Fermi–Dirac function

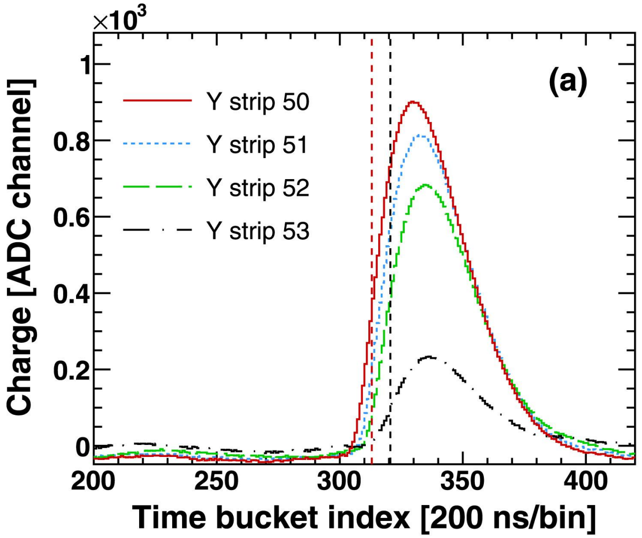
$$F(t) = \frac{K}{1 + \exp\left[-(t - t_{\rm FD})/\sigma\right]} + B$$

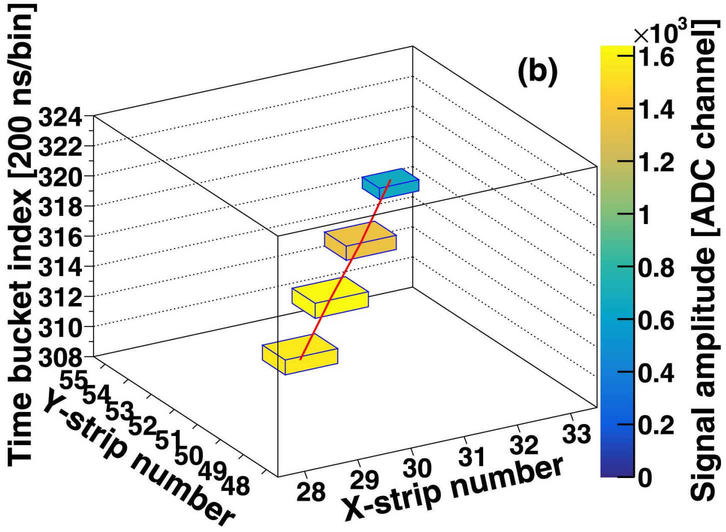



μTPC method

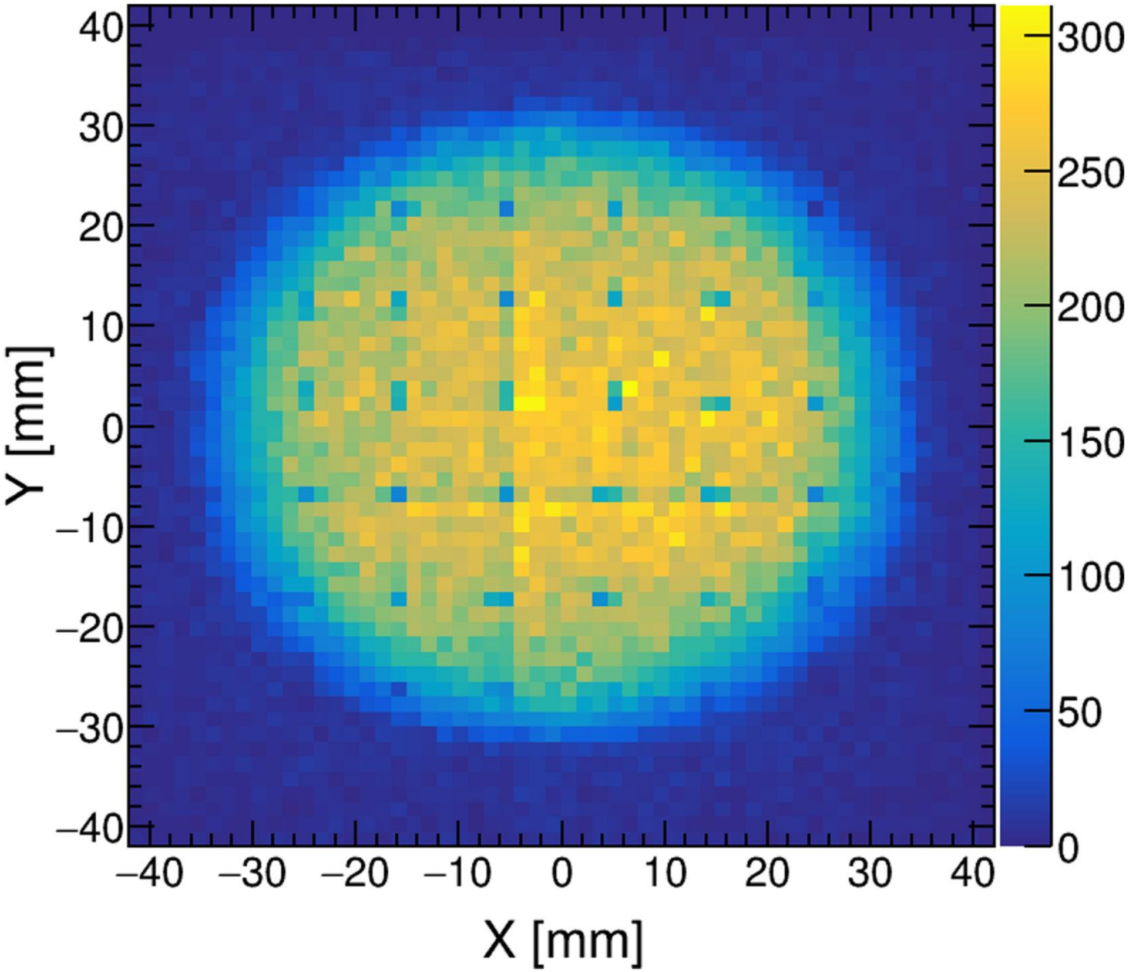
**Experimental data**



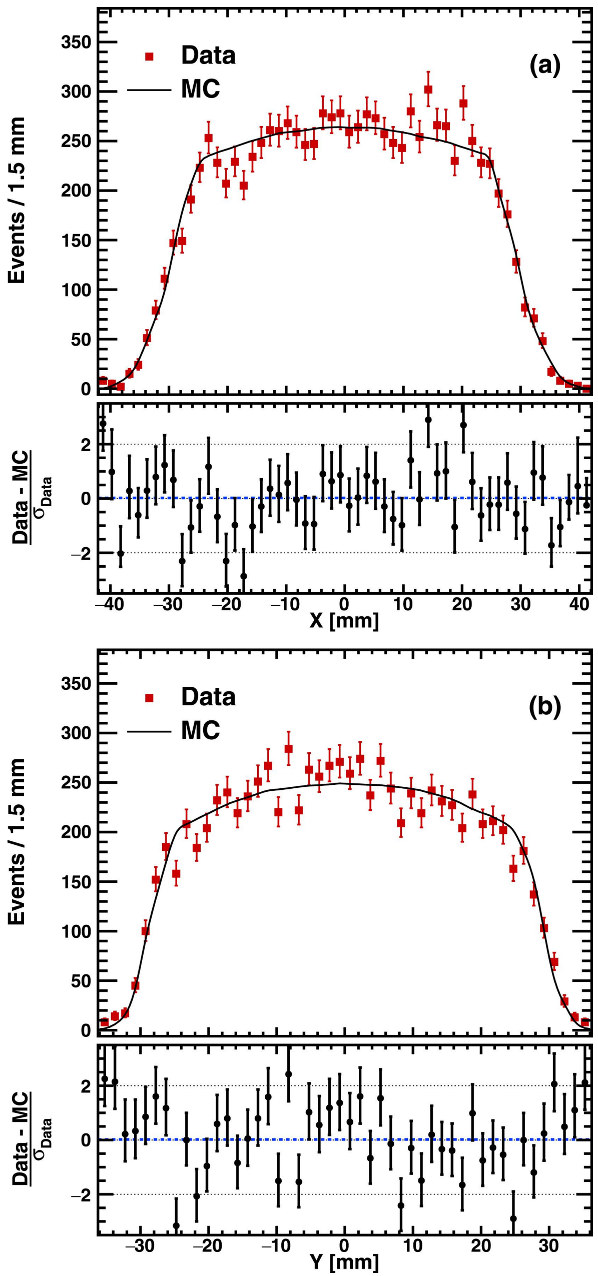
# Result

- 2D profile of Back-n white neutron beam at ES#1 measured by Micromegas detector [https://doi.org/10.1016/j.nima.2020.163407]




- Bin width 1.5 mm
- Shaded dots correspond to the pillars (∅ 2 mm) between the mesh and anode plane

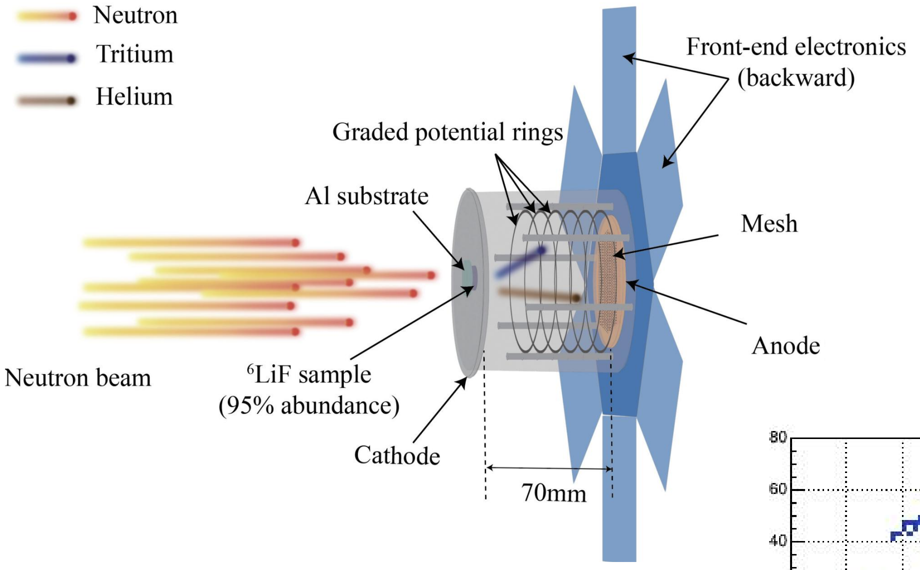
**Data/MC comparison**

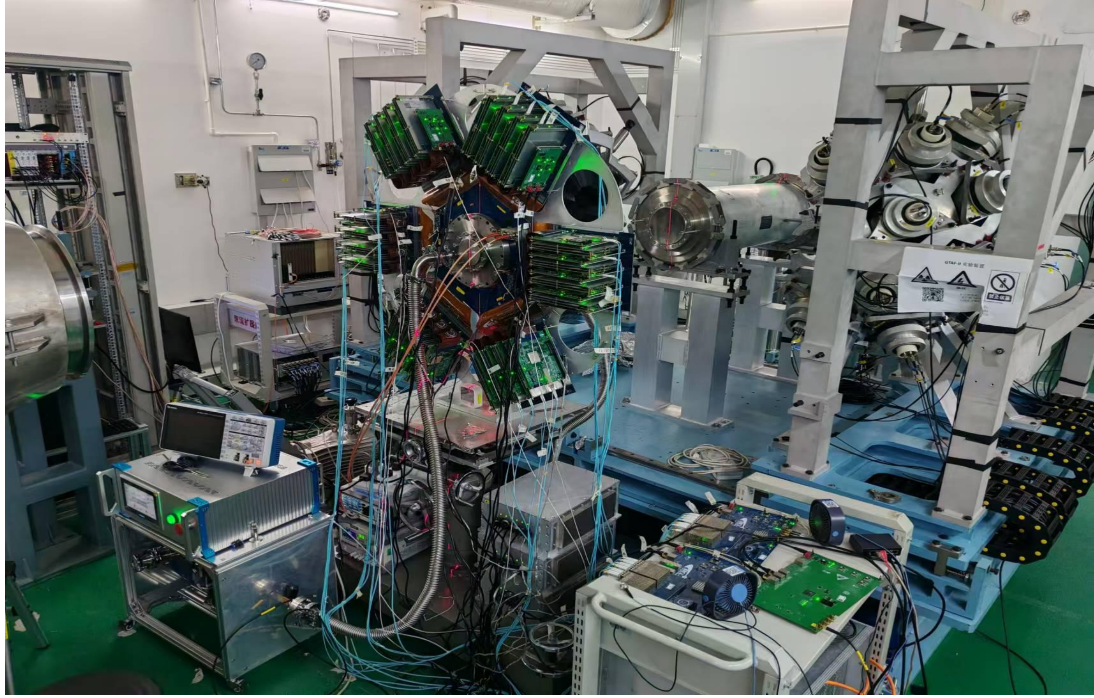


# Other Beam Profilers at Back-n

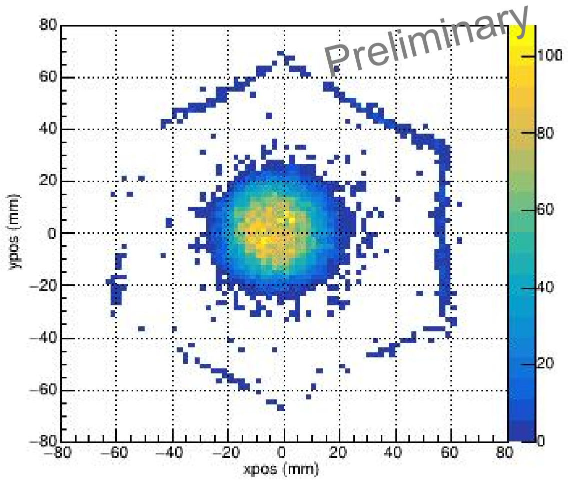
## Multi-purpose Time Projection Chamber (MTPC)

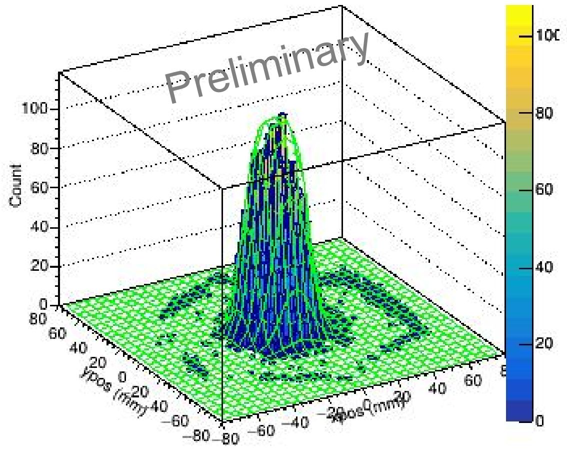
- Developed for cross section measurement of neutron-induced light-charged particle emission and fission reactions

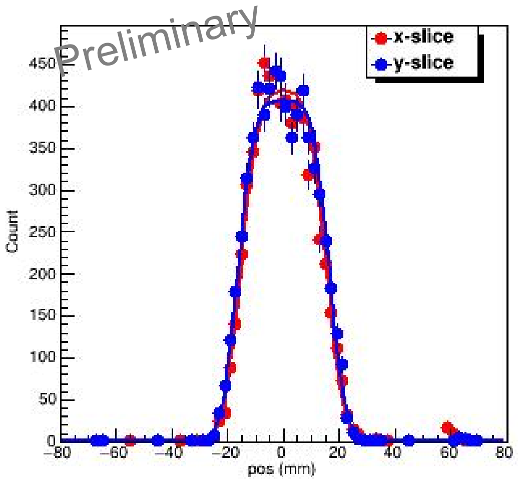


Ø 30 mm beam profile at ES#2



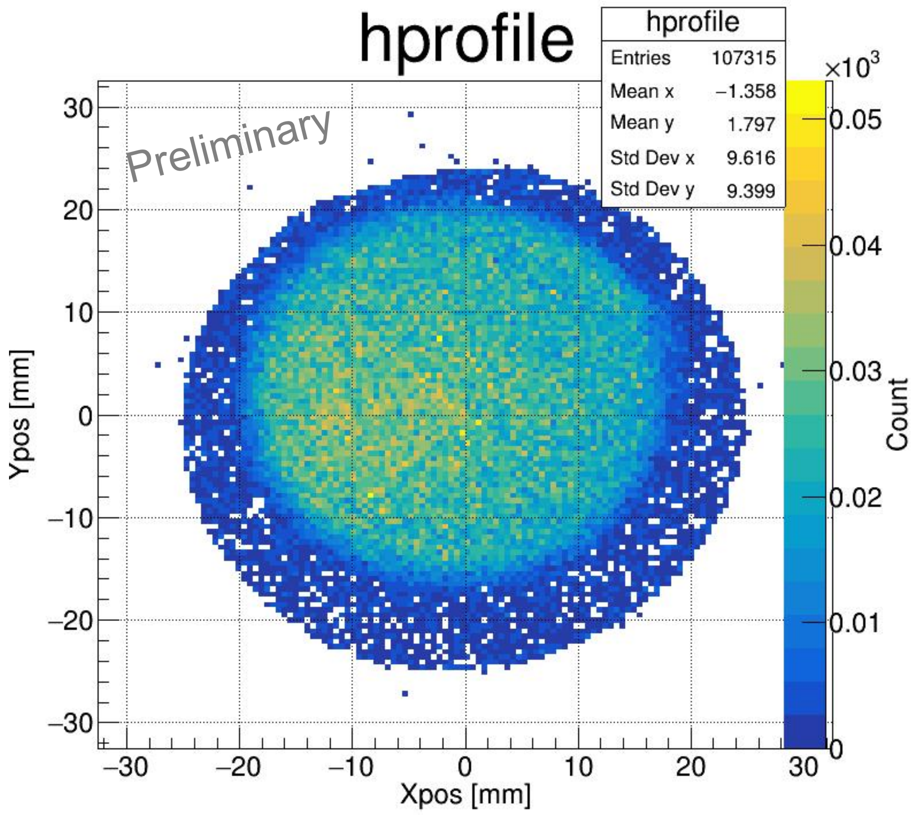

*Courtesy: Dr. Han Yi from CSNS*

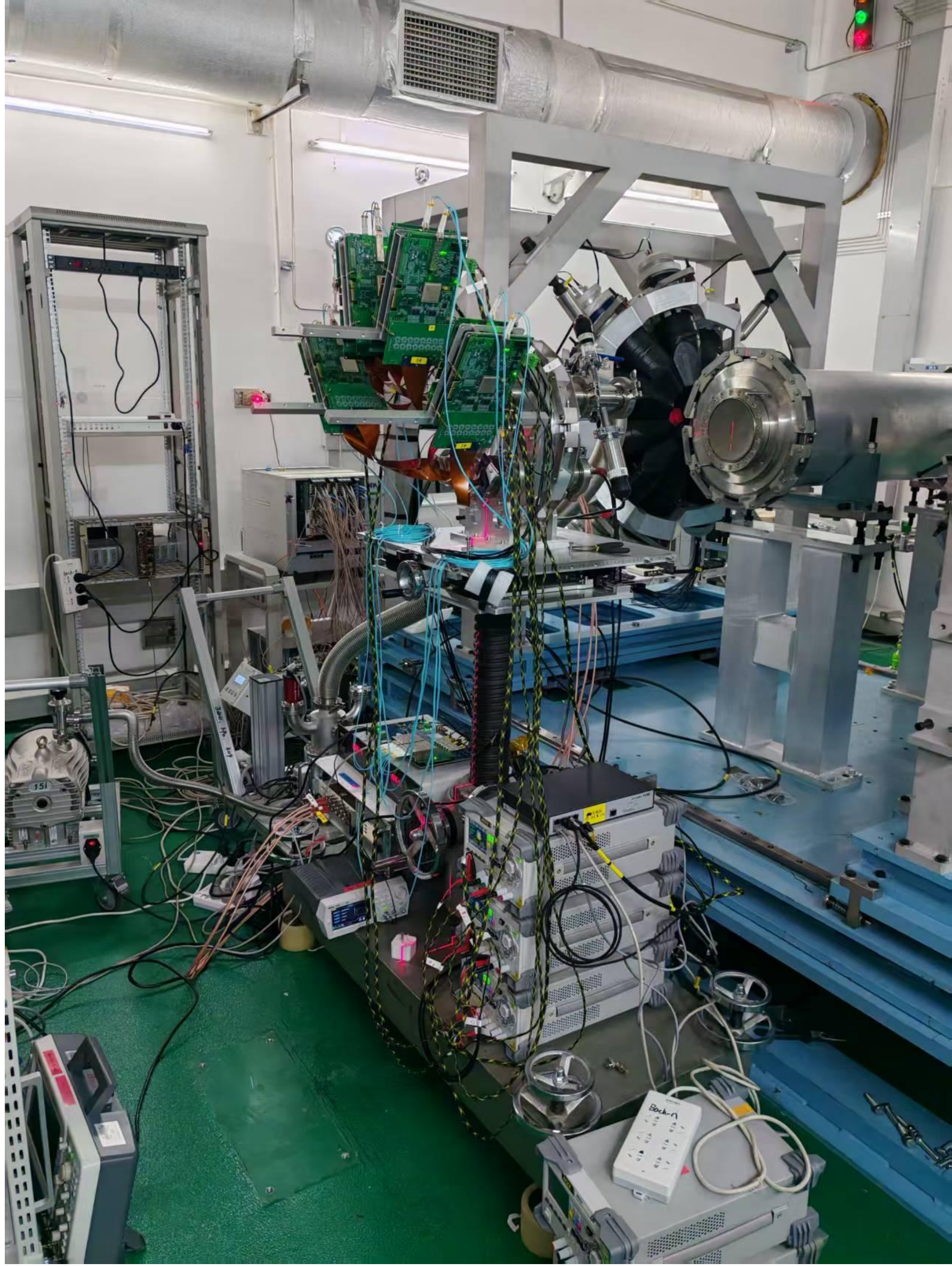
# Other Beam Profilers at Back-n

**$^{10}$B-doped Micro-Channel Plate detector (B-MCP)**

- Developed for neutron resonance imaging

∅ 30 mm beam profile at ES#2



*Courtesy: Dr. Han Yi from CSNS*

# Summary

- Developed a Micromegas-based neutron detector for 2D beam profile measurement of CSNS Back-n beamline
- Utilized μTPC method for accurate neutron beam profile reconstruction
- Achieved good agreement between data and simulation
- Other advanced detectors at Back-n, such as MTPC and B-MCP, which are designed for dedicated physics experiments, exhibit the capability to measure (neutron-energy-dependent) beam profiles