The low-energy ionization backgrounds in the PandaX-4T experiment

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On behalf of the PandaX Collaboration

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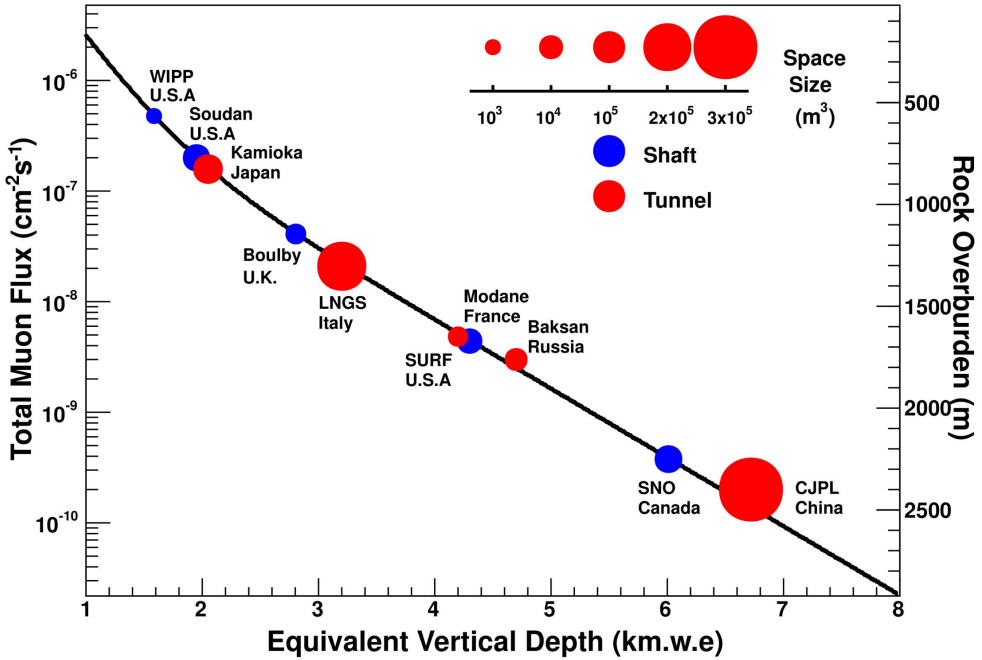
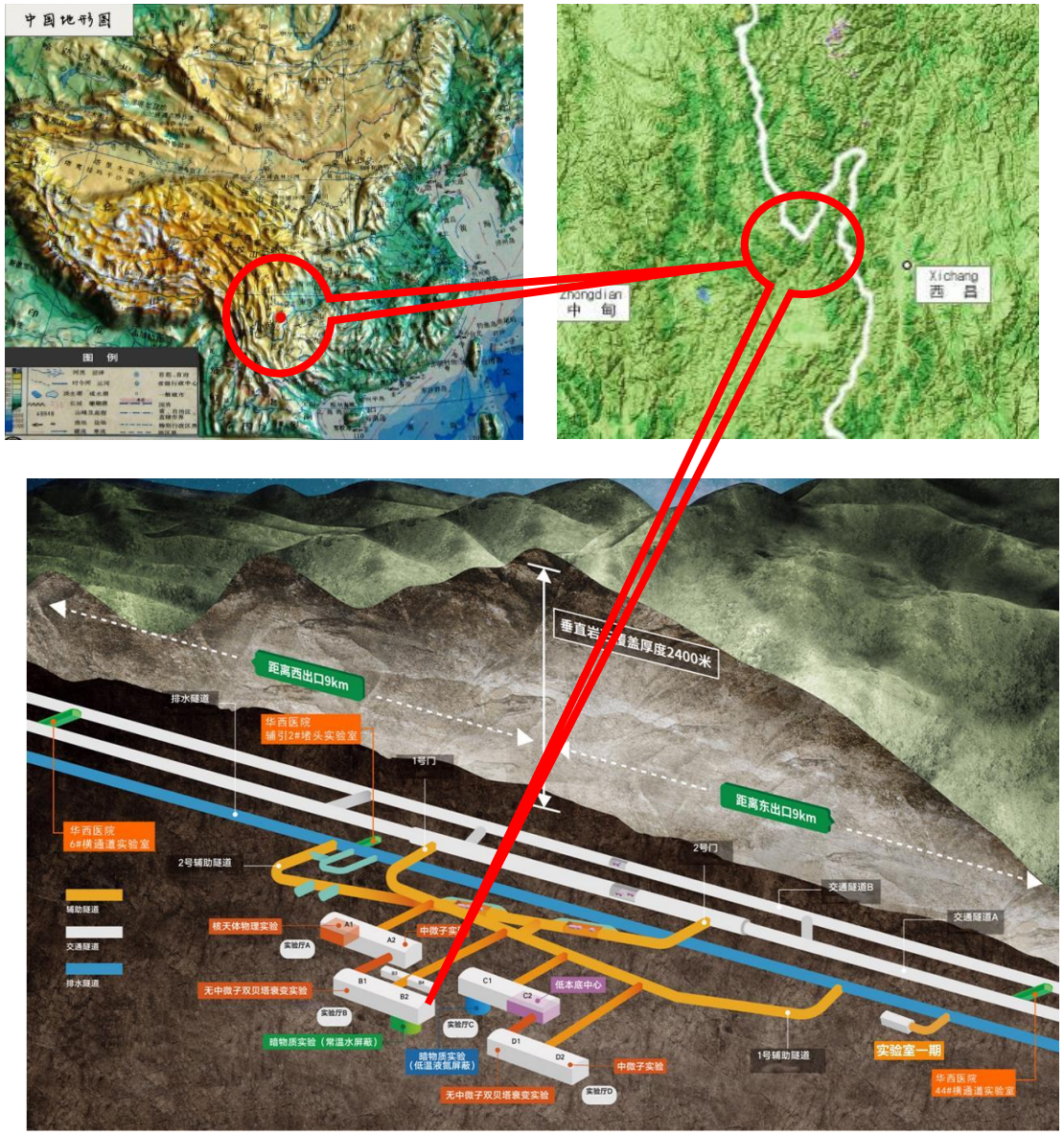
China Jinping underground laboratory-II (CJPL-II)

- the lowest cosmic ray muon flux (0.17/day/m^2)
- the largest experimental space (330000 m^3)
  - 8 main lab halls
- perfect logistics and operation maintenance service
  - provided by YAlONG HYDRO

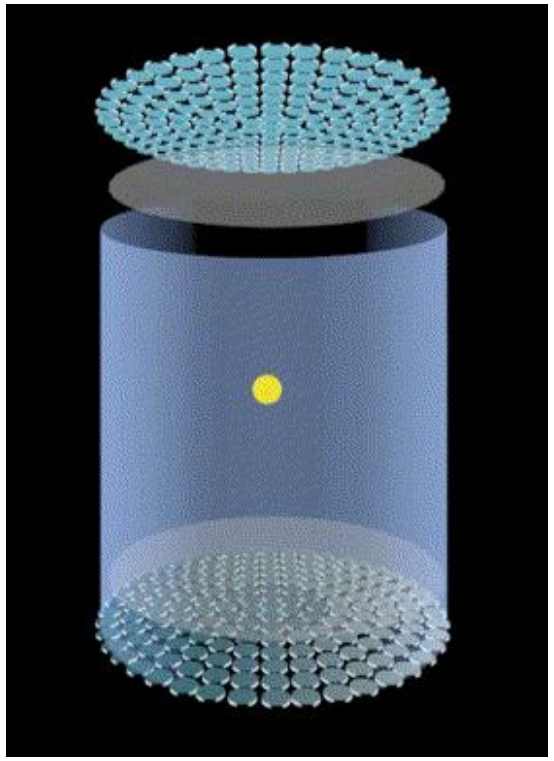
Welcome to join CJPL !

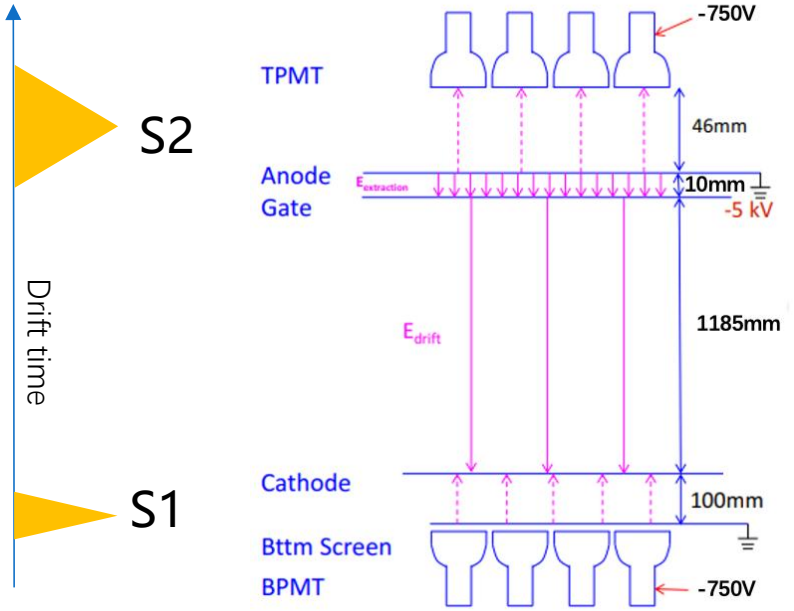


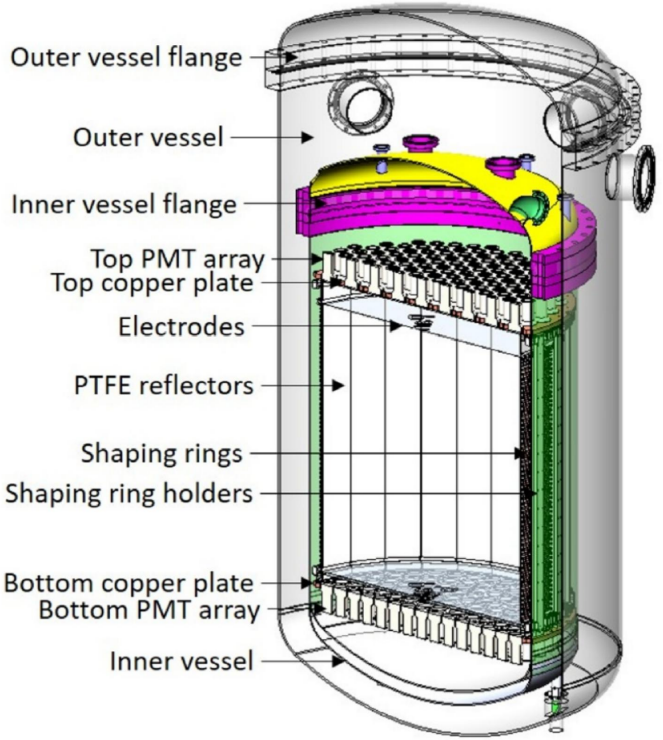


PandaX-4T Time Project Chamber (TPC)

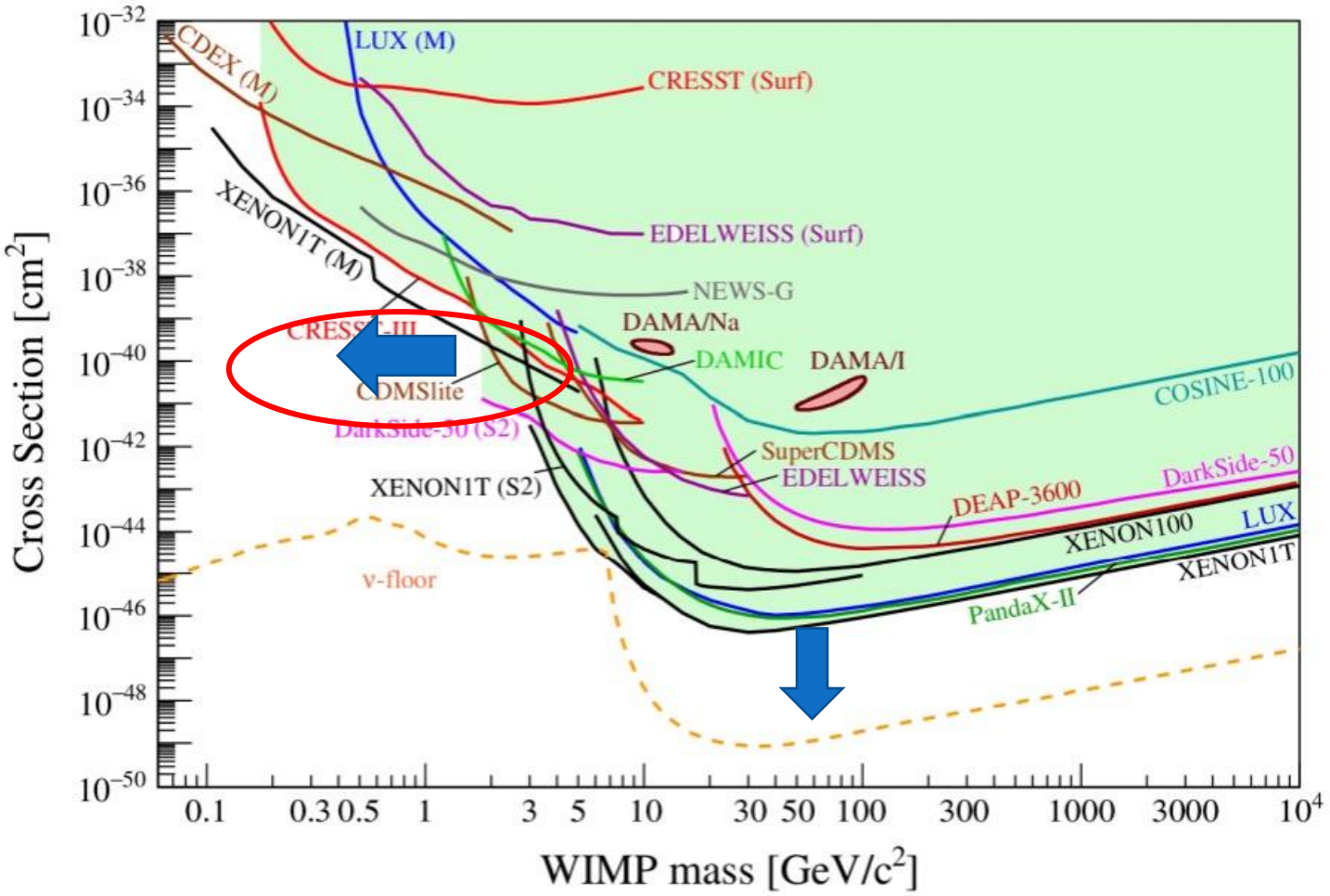
- Physical events produce S1 (scintillation) and **delayed S2 (ionization) signals.**
- **Detection efficiency of S1 << S2**







Dark matter detection

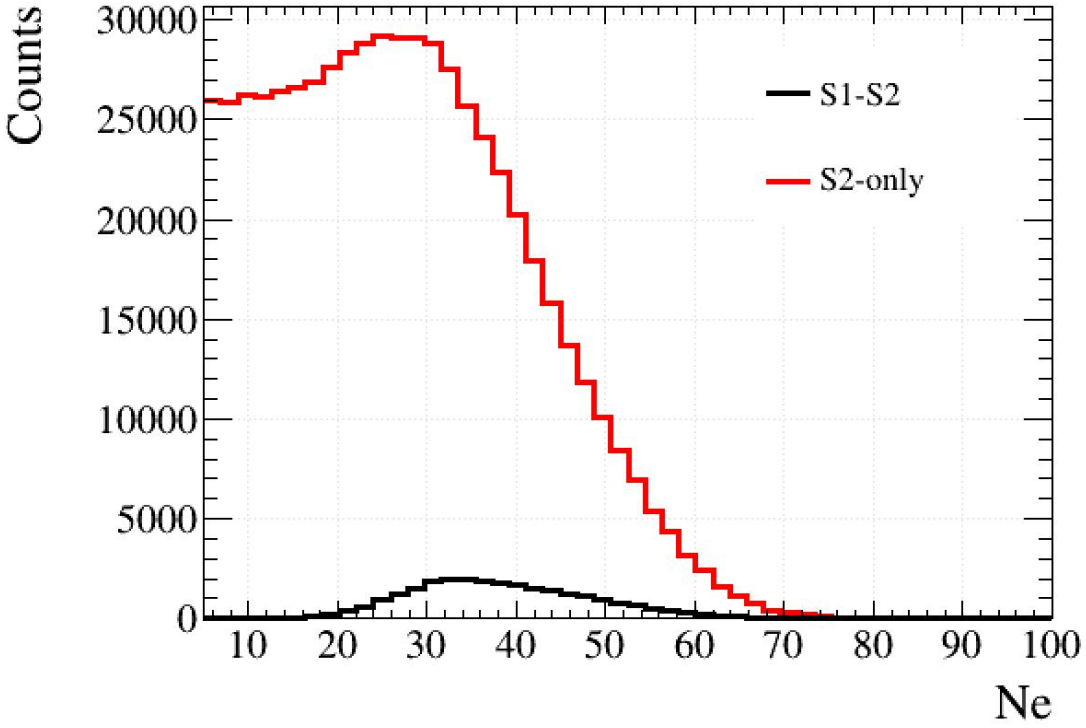


to lower energy, higher sensitivity

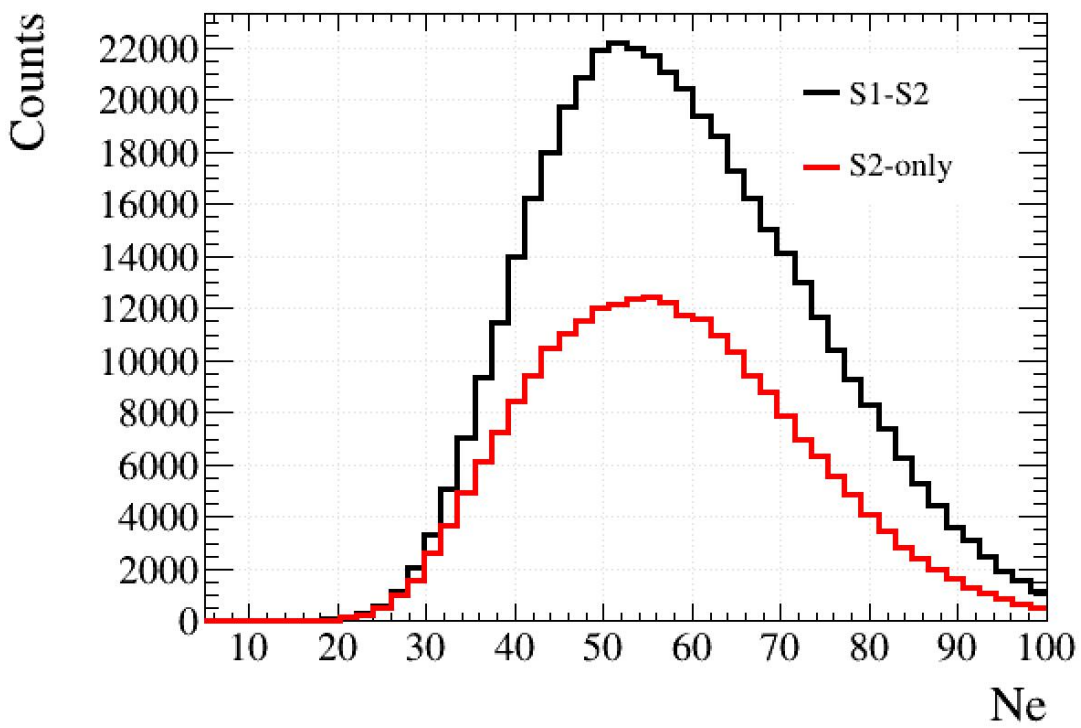
S2-only data has lower energy threshold

- low efficiency of S1 makes the energy threshold to 1 keV for S1-S2 evts
- S2-only evts are dominant below 1 keV

flat ER P4nest simulation (**0-1 keV**)

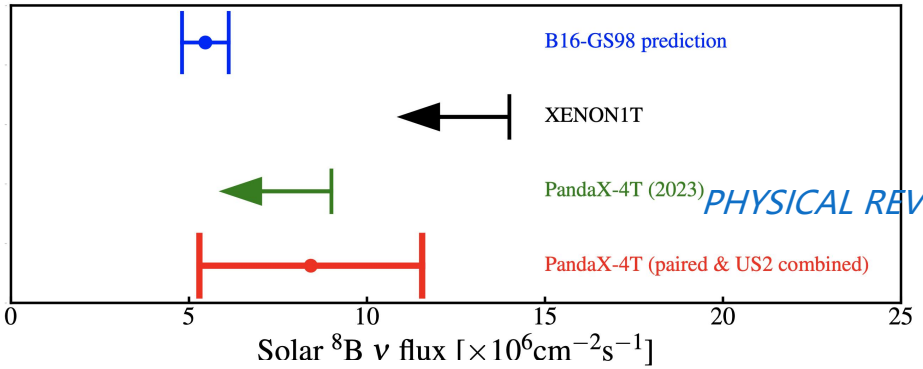


flat ER P4nest simulation (**1-2 keV**)

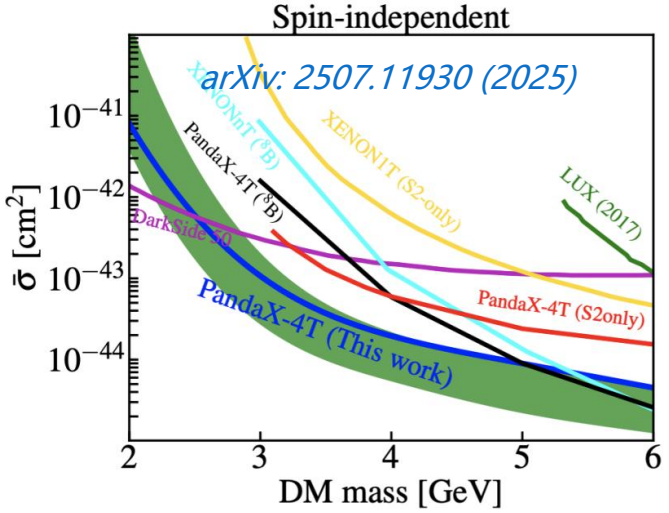


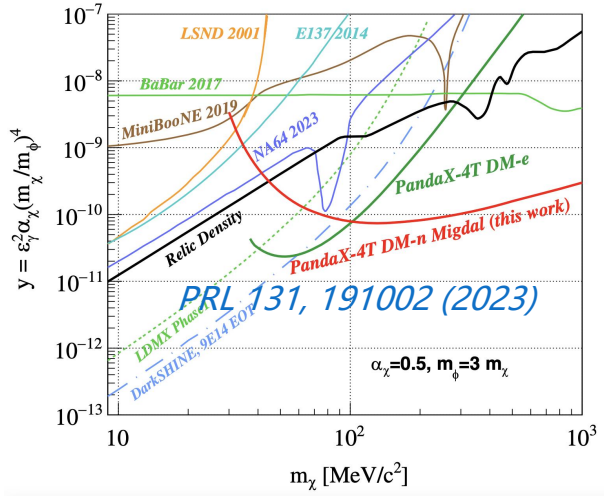
S2-only data

- Abundant physics: solar ν, LDM, migdal effect, dark photon/ALPs...
- Backgrounds: dominant by delayed electrons and cathode events

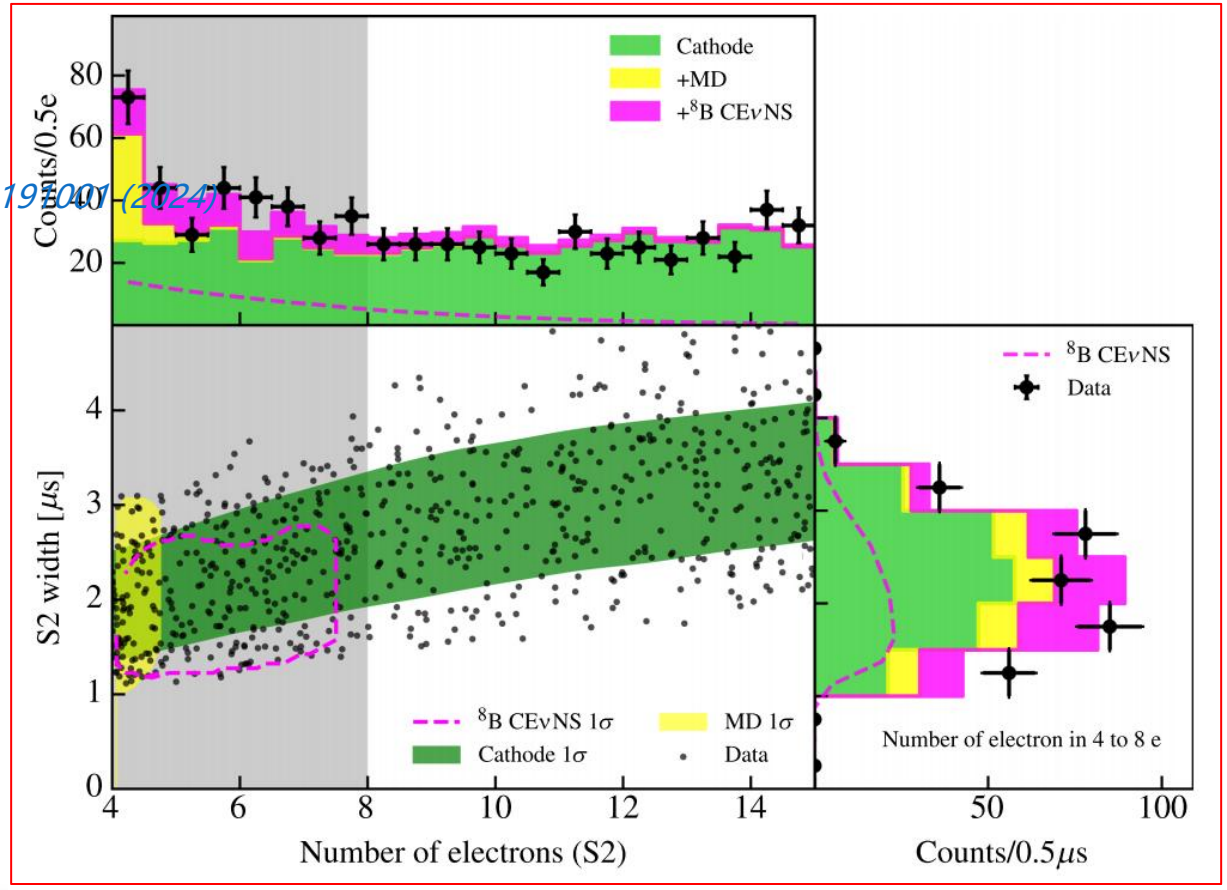


PHYSICAL REVIEW LETTERS 133, 191001 (2024)



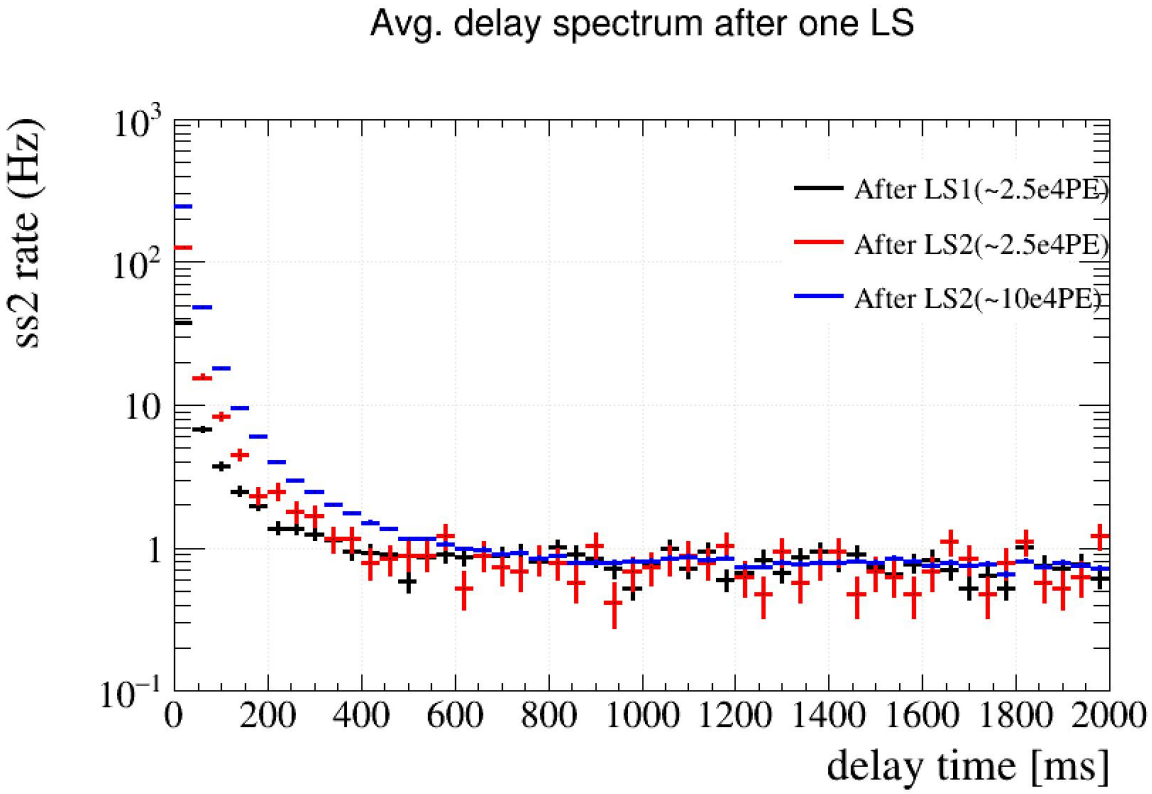


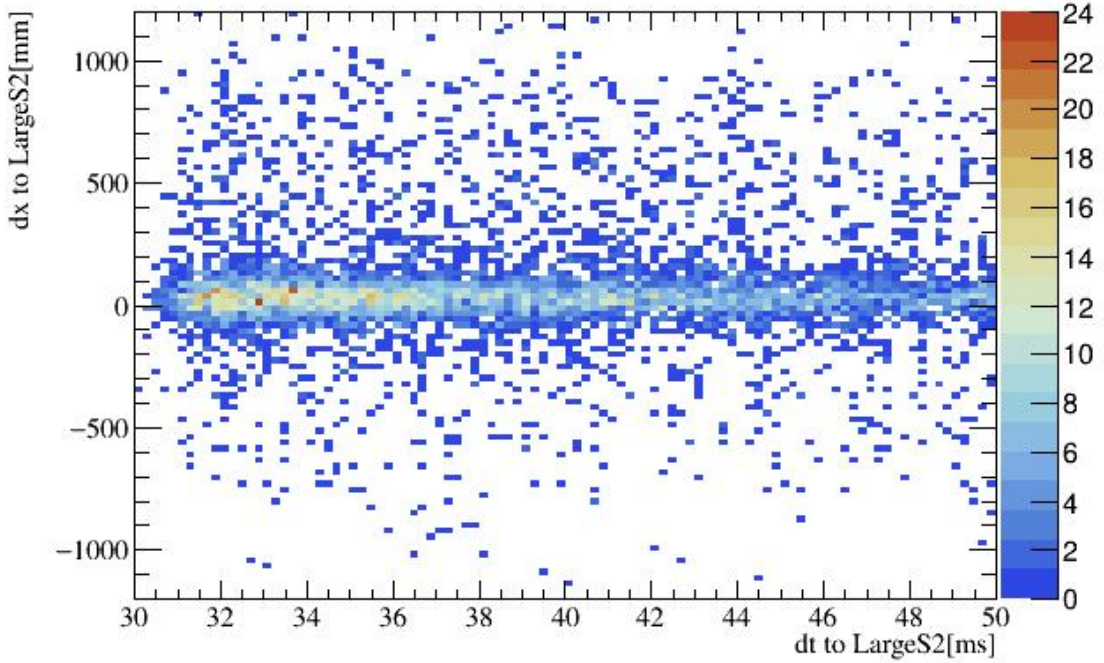
PRL 131, 191002 (2023)



Delayed electrons after large signal

- High delayed electrons rate after large signal
- Both Δx and Δt show high correlation with the large signal

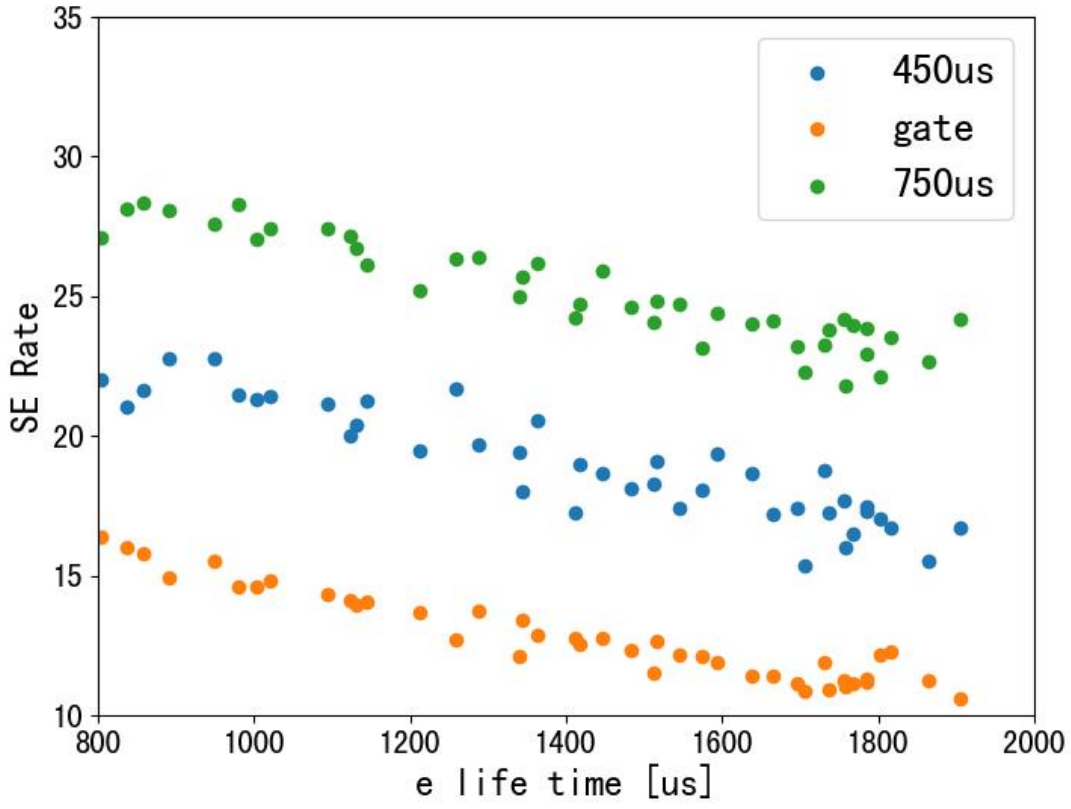


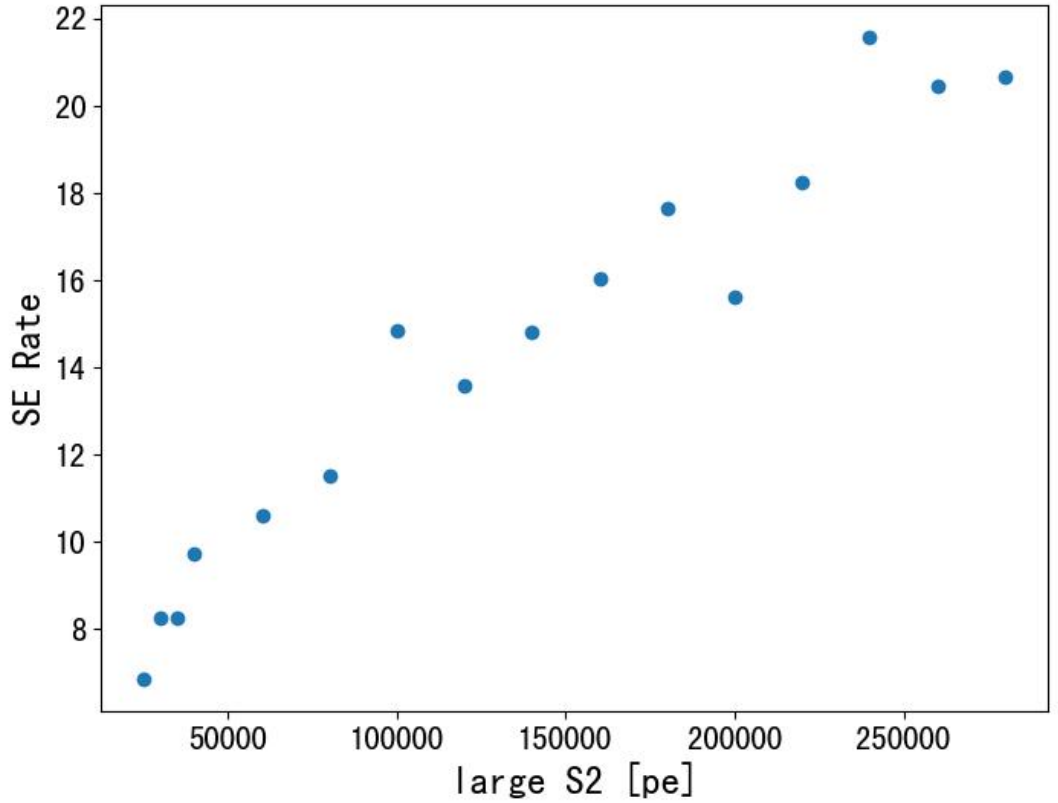


cannot be eliminated completely

Delayed electrons vs. elifetime/drift time/LS2

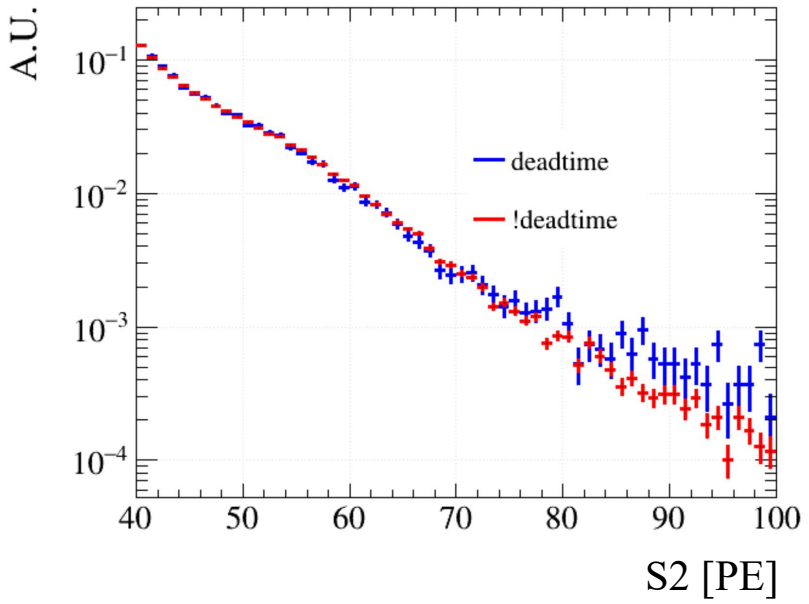
- higher elifetime, higher delayed electrons rate
- longer drift time of large signal, higher delayed electrons rate
- larger S2, higher rate

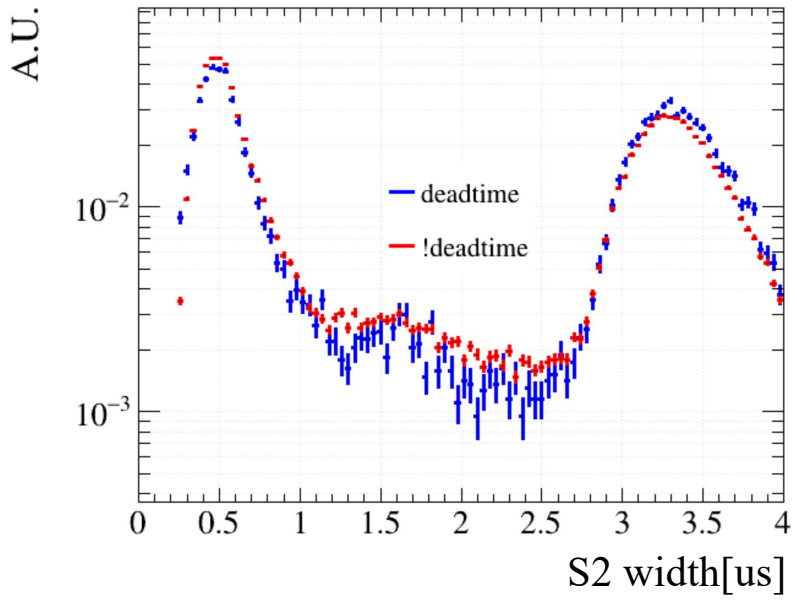


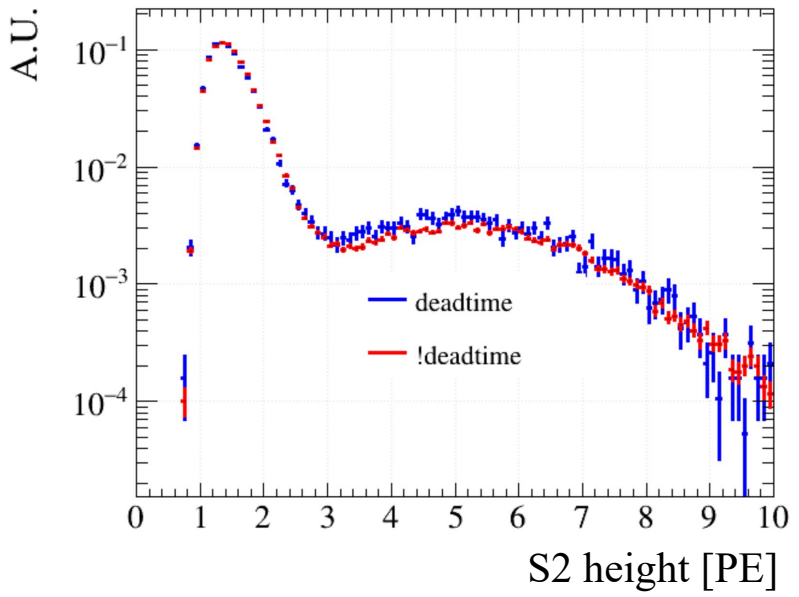


Delayed electrons after large signal

- Deadtime cut was develped to reduce the delayed electrons
- Compare the waveform features of S2-only events with and without deadtime cuts



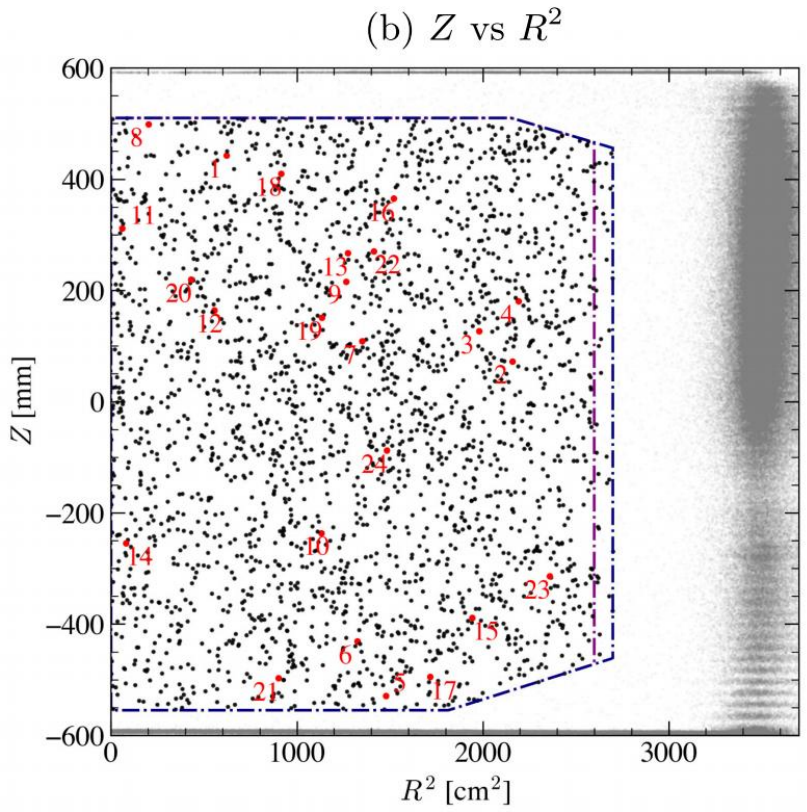


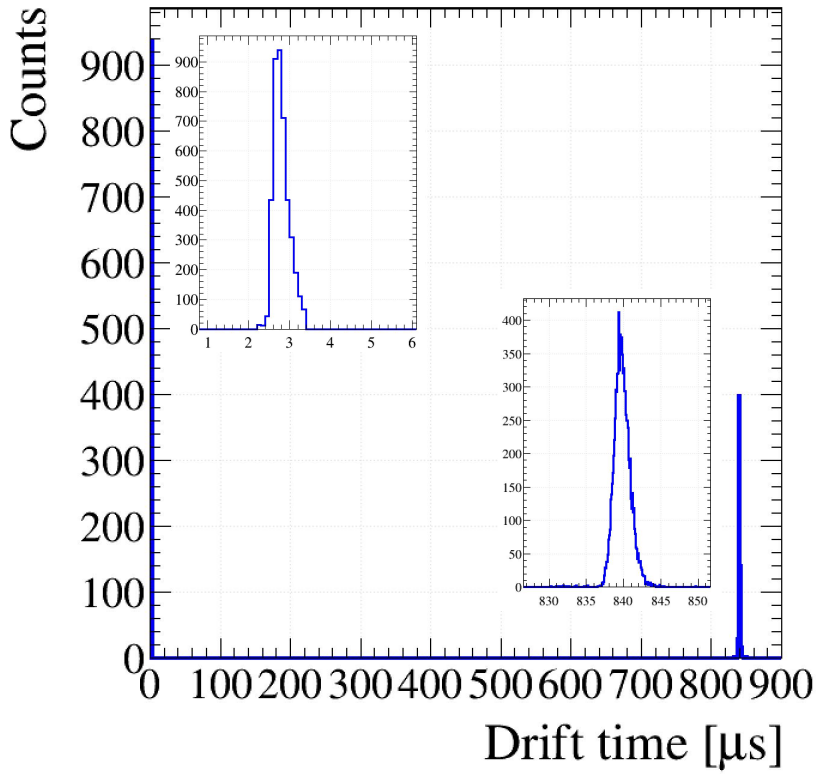


Delayed electrons are still dominant with deadtime cut

Electrode events: cathode and gate electrode

- Delayed electrons in S2-only >5e are negligible
- Electrode events contaminate the S2-only data without information of drift time



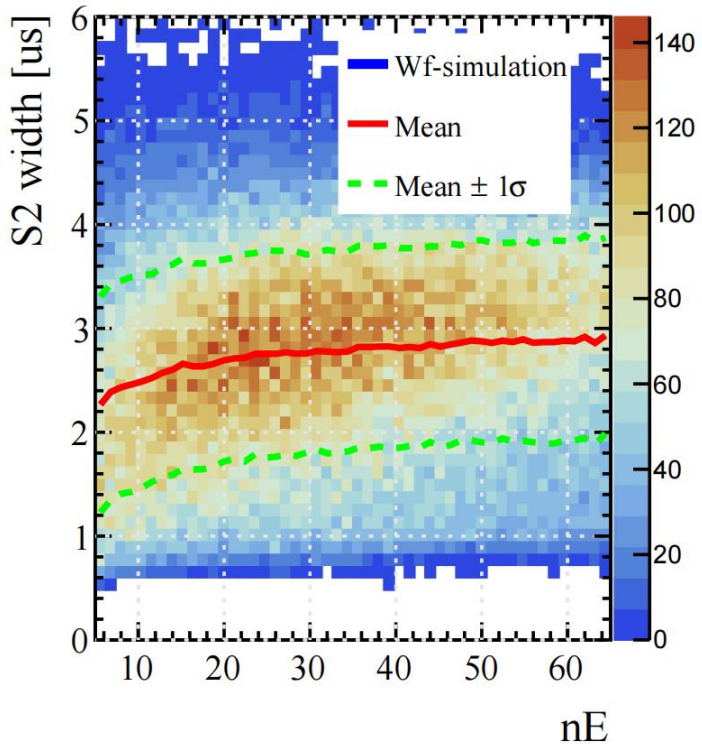


PHYSICAL REVIEW LETTERS 134, 011805 (2025)

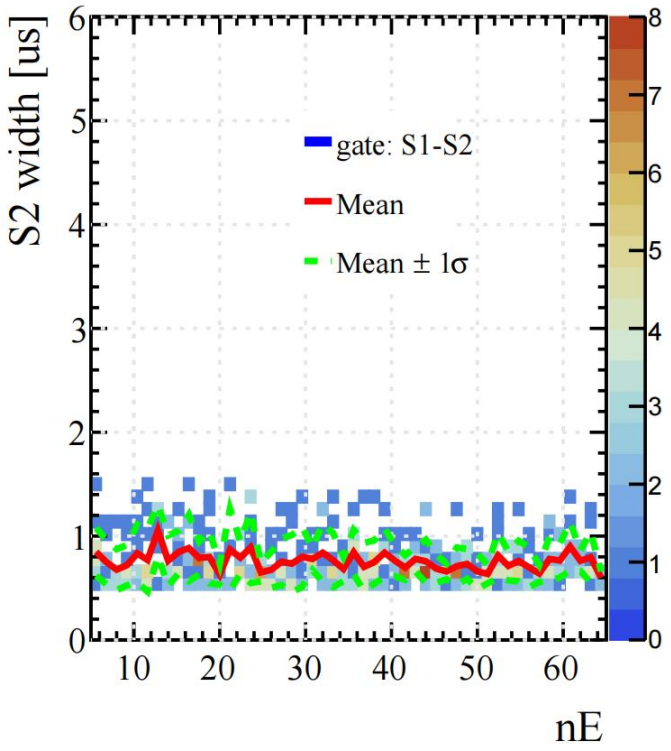
Gate events

- Gate events has short drift time and concentrated waveform width

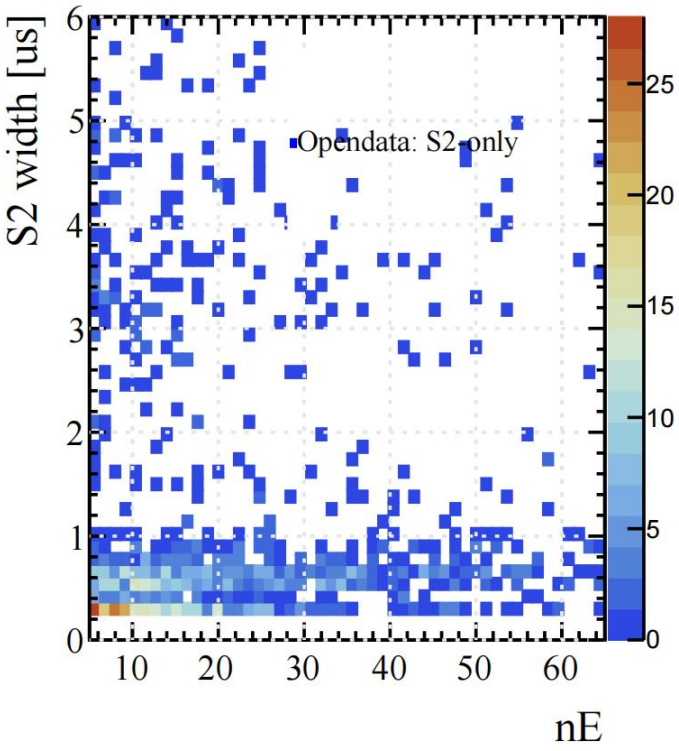
flat ER wf-simulation



paired gate events



S2-only in opendata

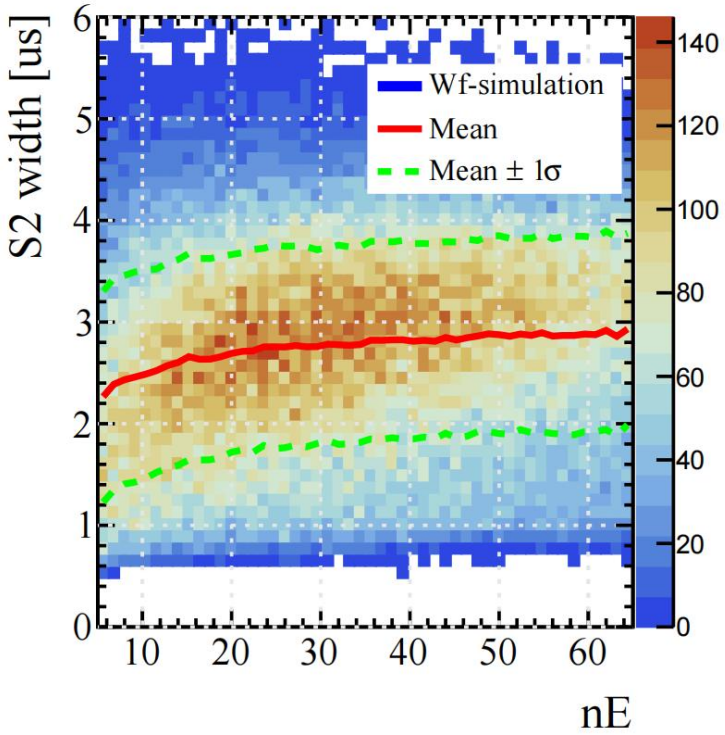


Can be removed by width selections

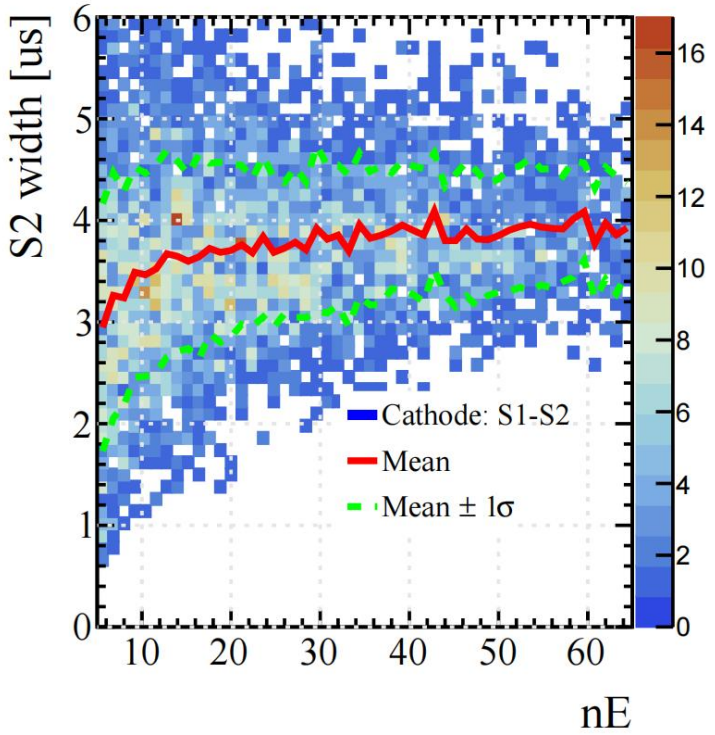
Cathode events

- cathode events has large drift time, large and dispersed waveform width

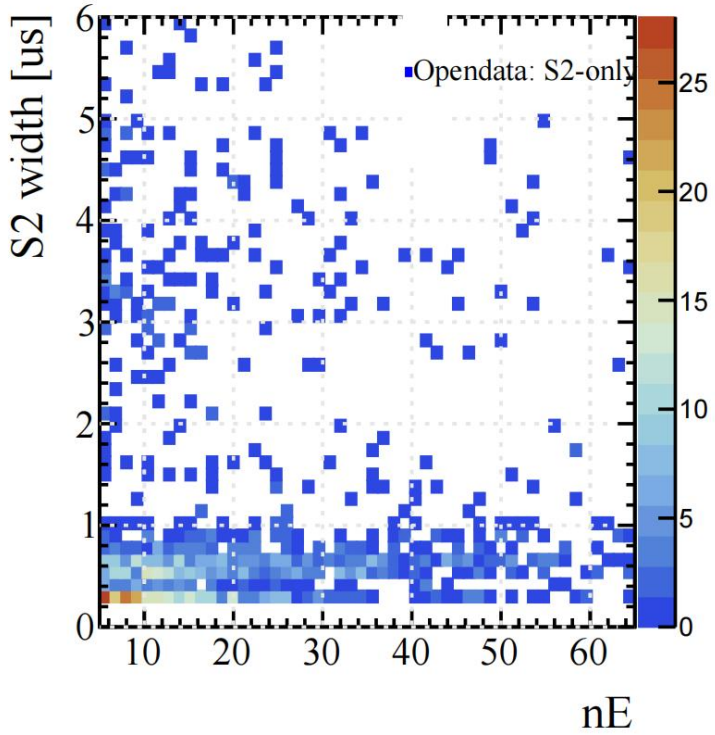
flat ER wf-simulation



paired cathode events



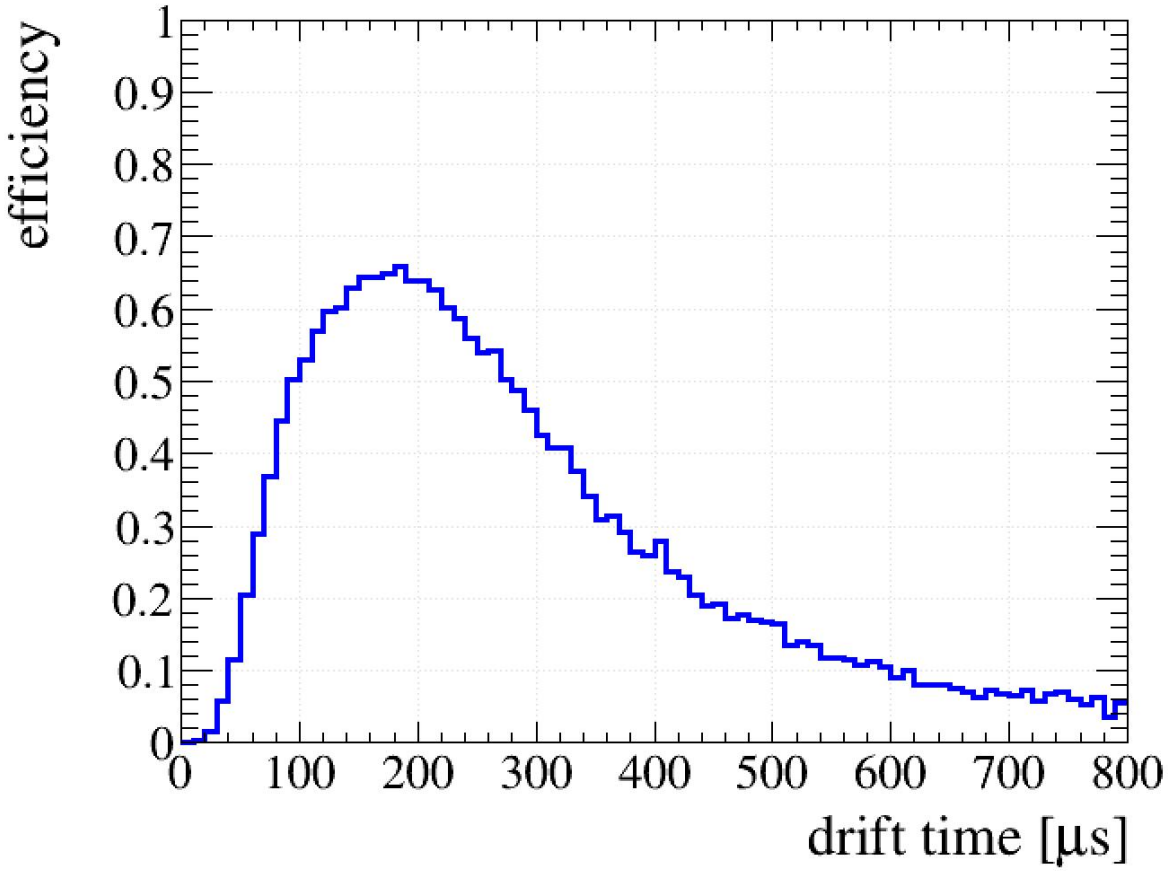
S2-only in opendata



cannot be eliminated completely

Electrode backgrounds efficiency

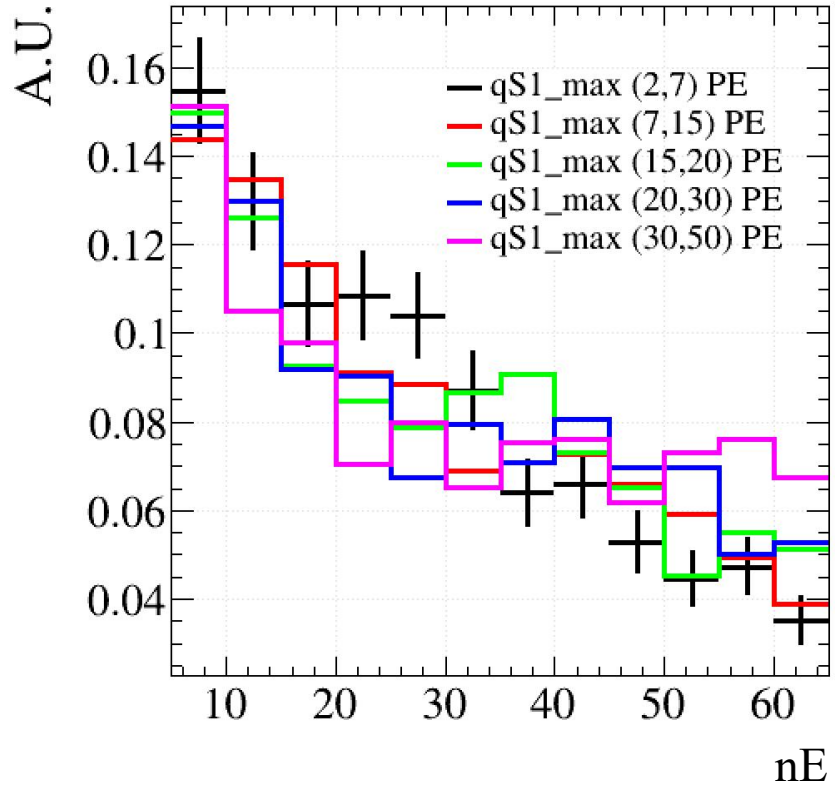
- Use wf-simulation data to check the drift time efficiency
- The efficiency curve shows strong capability to reduce electrode backgrounds (for 5-65 e)

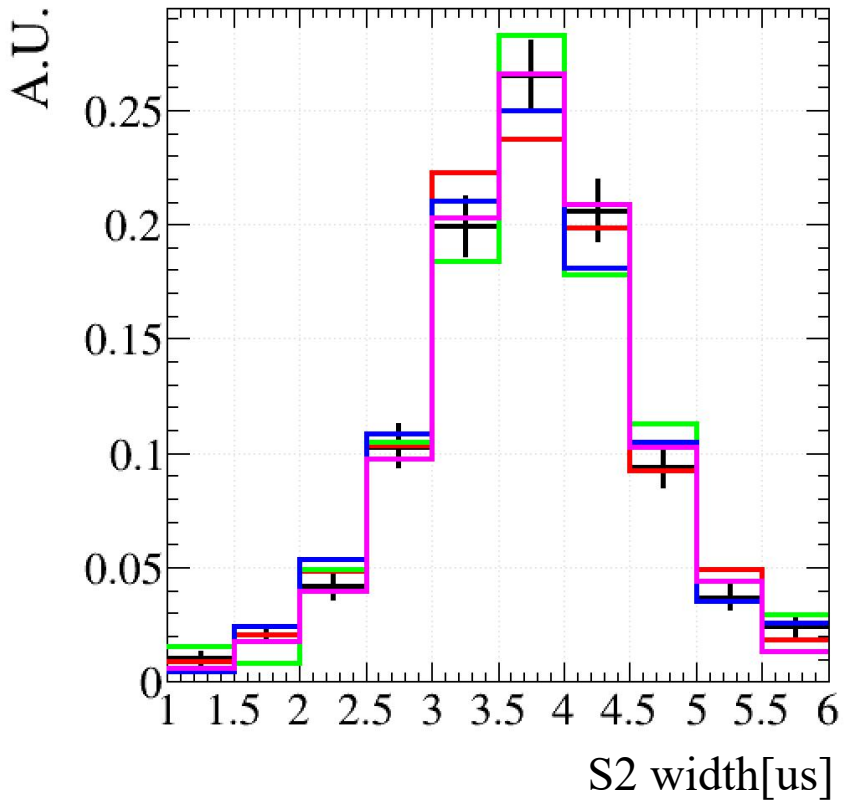


- efficiency=0 in dt<20 us
  - gate events can be removed by selections
- efficiency~5% in dt>800us
  - Strong suppression capability for cathode events

Special cathode feature

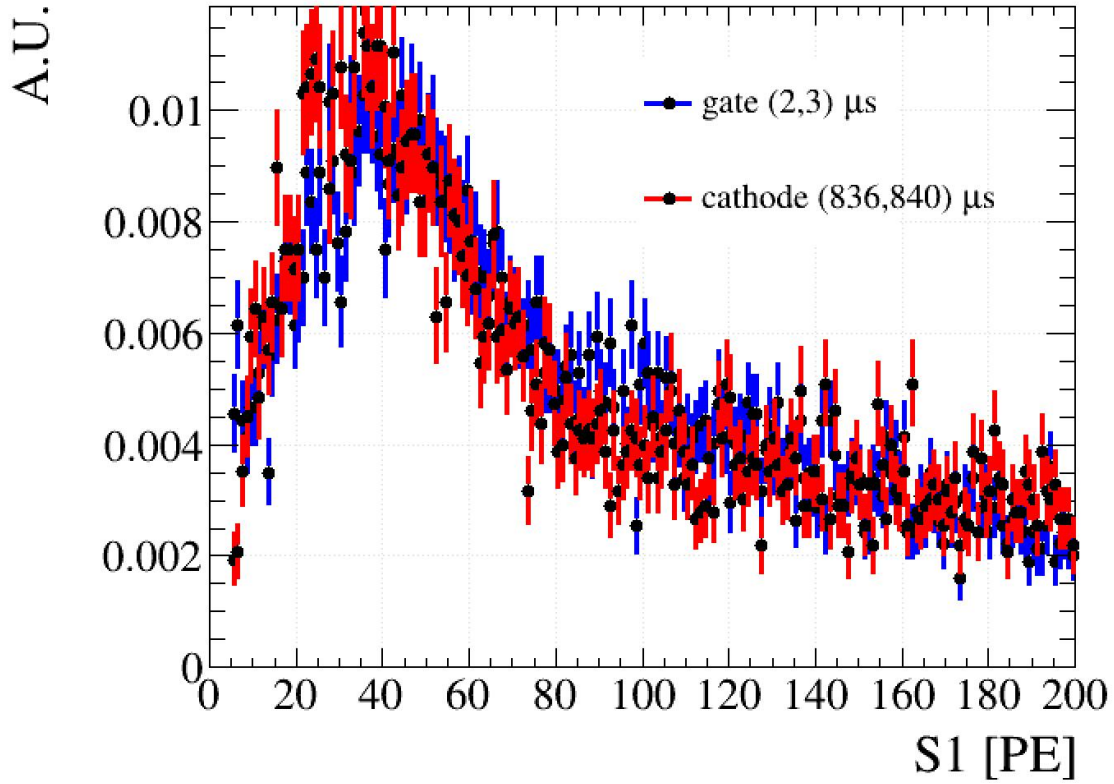
- Paired cathode S2 spectrum is independent with S1
- Then can imagine: S2-only cathode has the similar features with paired cathode

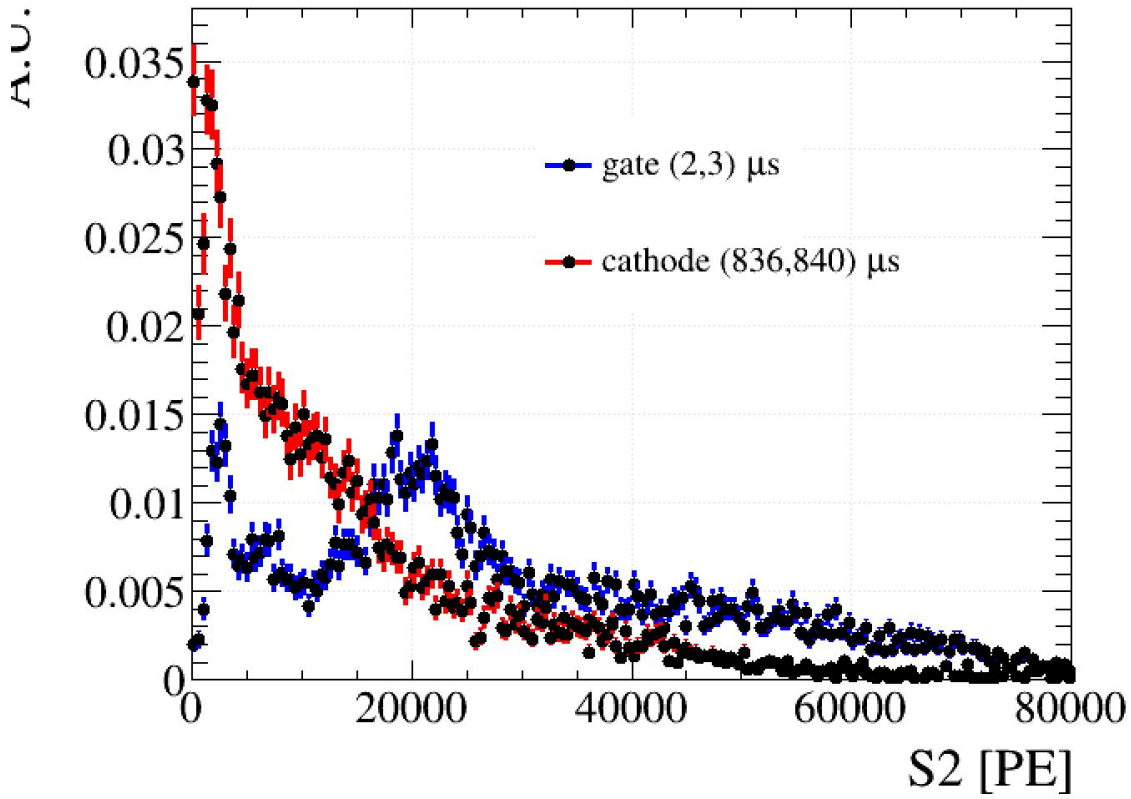




Cathode has smaller S2 than gate

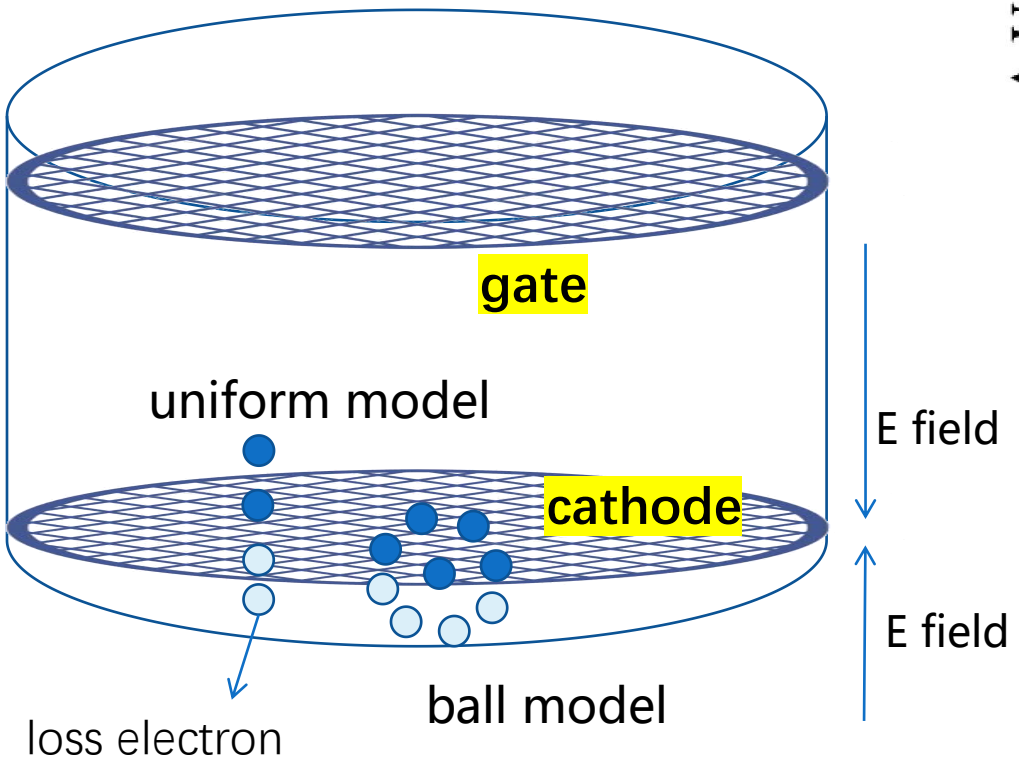
- gate and cathode use the same material
- gate S2 > cathode S2 within similar S1

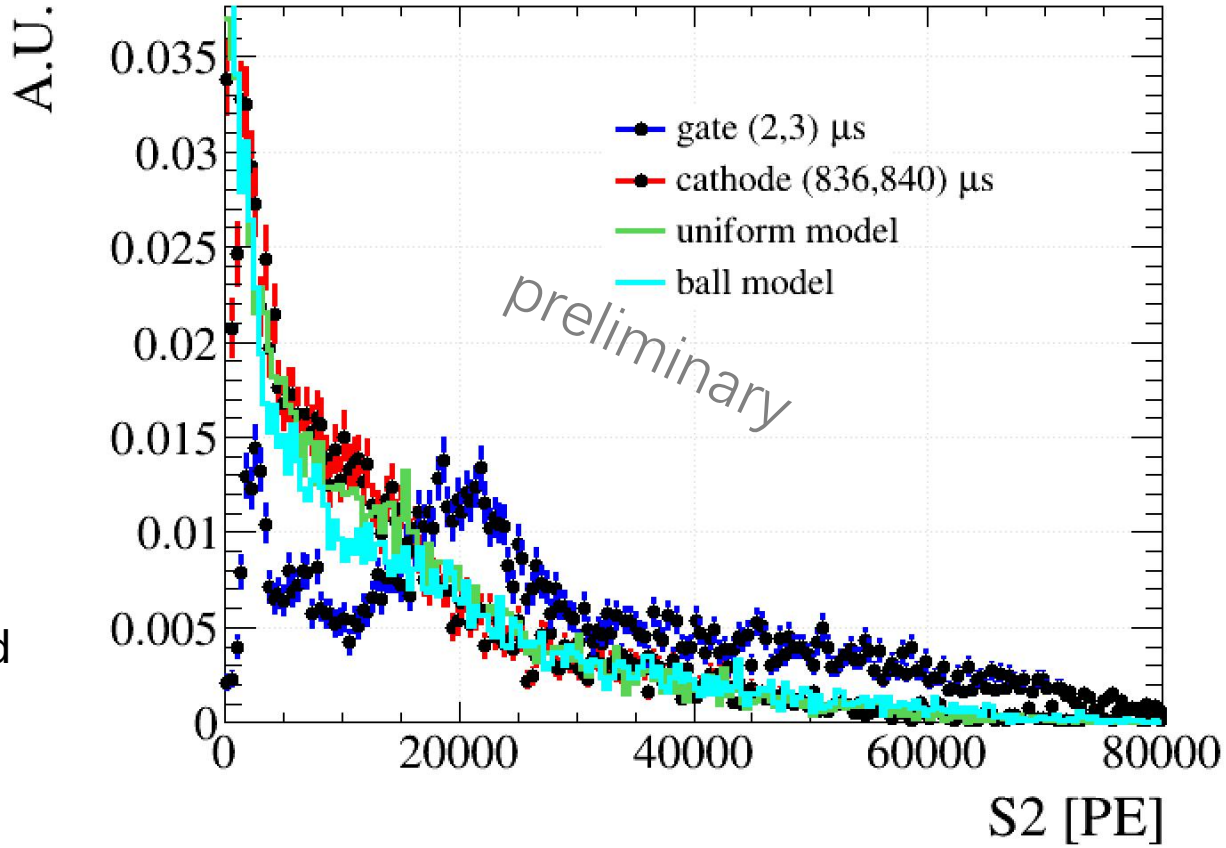




Smaller S2 mechanism

- Electron cluster can be divided by cathode electrode





The electron loss mechanism decreases the correlation between S2 and S1

Summary

- S2-only is an important channel for lower energy physics
- Delayed electrons and cathode events are dominant backgrounds in S2-only events
- Delayed electrons are from the large signal and cathode events are from the radioactivity from cathode electrode

Thanks!