A search for $K_L \to \pi^0 \nu\bar{\nu}$ at KEK-PS E391a experiment

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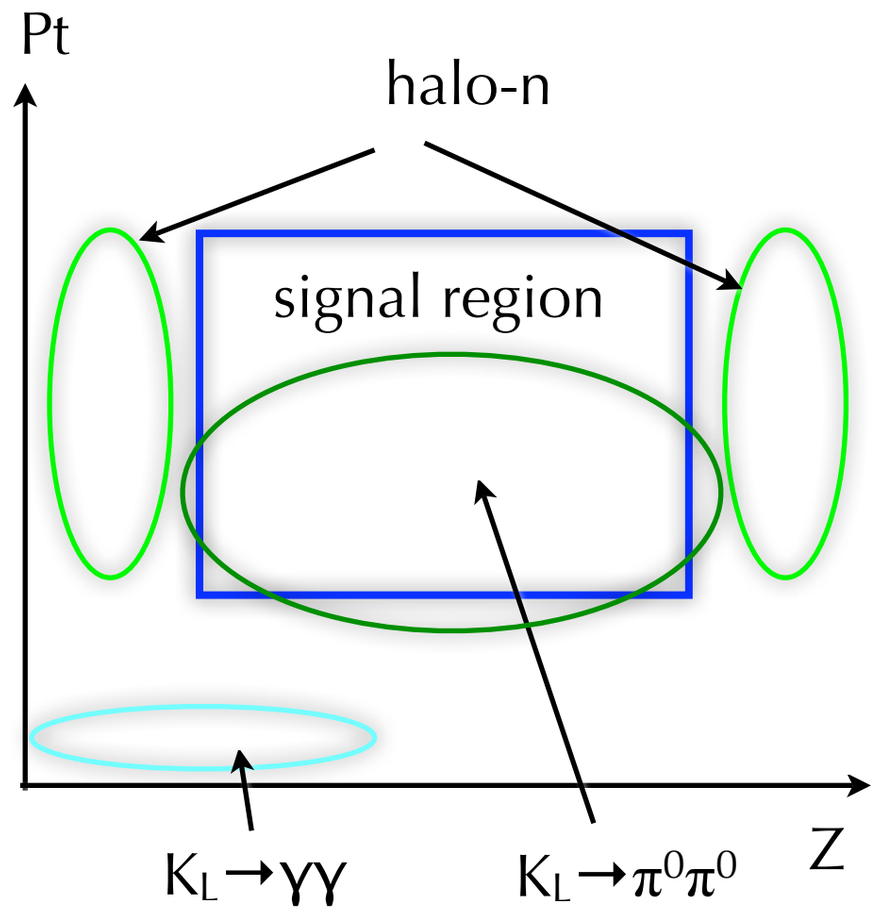
outline

- Background sources for $K_L \to \pi^0 \nu\bar{\nu}$
  - K_L decays
  - Halo neutrons
- Estimation of Backgrounds
  - K_L simulation (cf. previous talk)
  - Halo neutron simulation
  - Special run with π^0 production target
- Summary

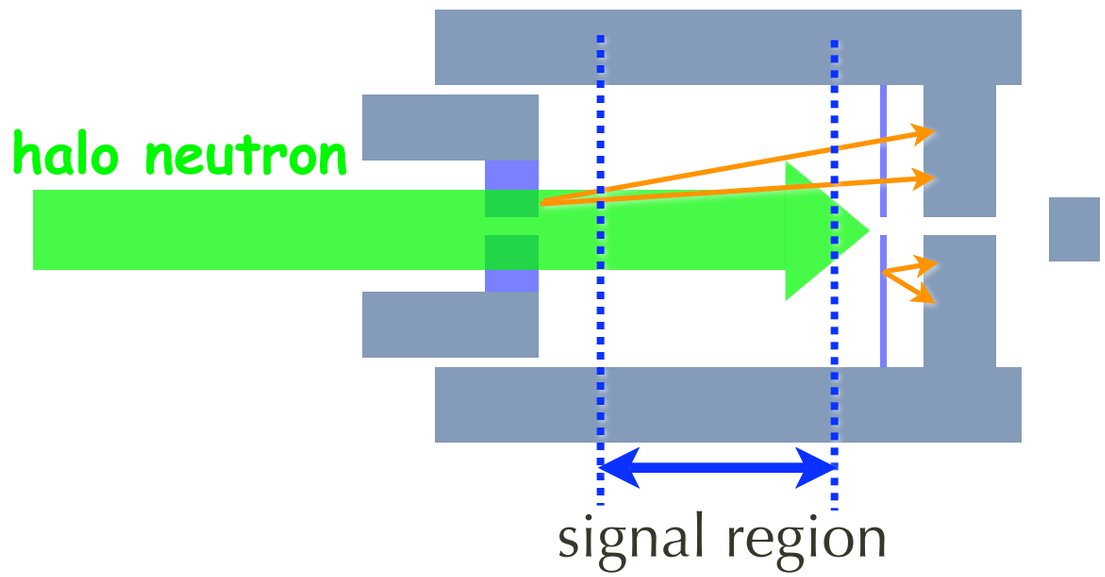
Backgrounds for $K_L \to \pi^0 \nu\bar{\nu}$

- $K_L \to \gamma\gamma$
  - no extra particles
    - cut: Pt, acoplanarity angle
  - negligible

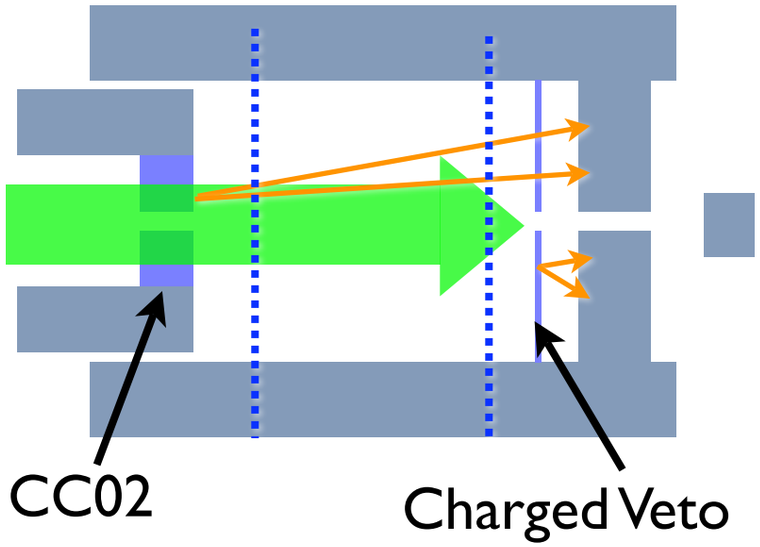
- $K_L \to \pi^0\pi^0 \to 4\gamma$
  - 2 gamma missing
    - cut: veto counters, "fusion" of gammas
  - estimated to be 0.16 events



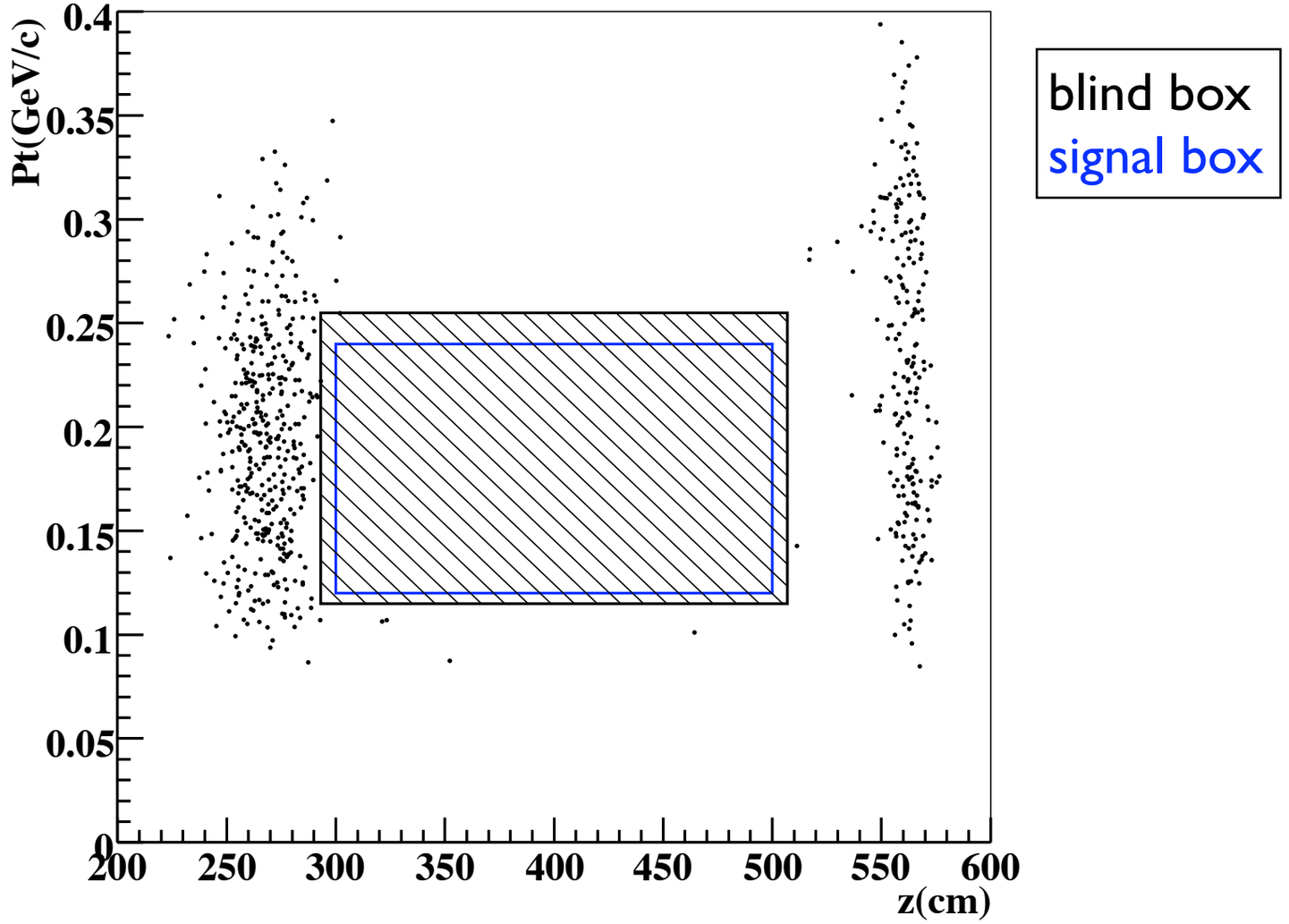
- π^0's from the interaction of "Halo" neutrons
  - neutrons around the beamline
    hit some detectors and produce π^0's
  - cut: reconstructed vertex
    - moved by shower leakage
      and additional energy deposition
  - estimation
    - Halo neutron generation with
      a neutral beamline simulatioin
    - special run



2 gamma plot

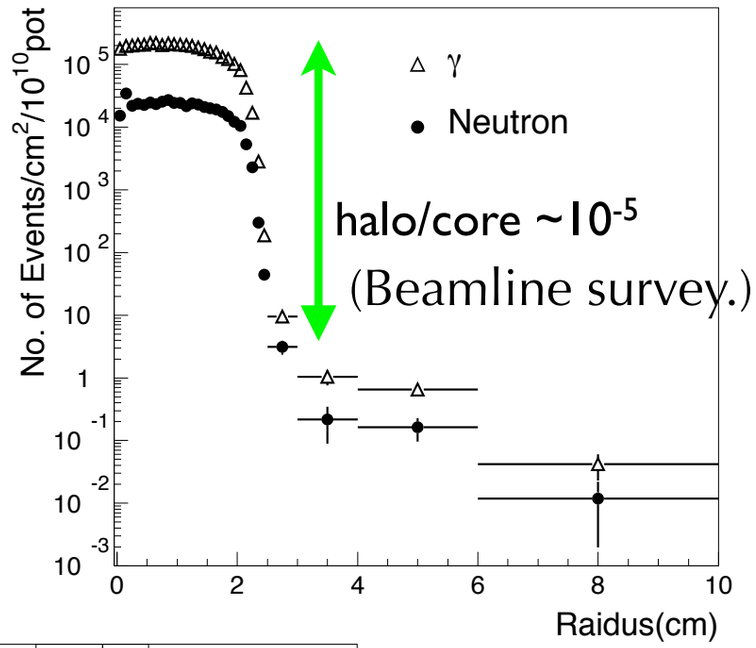


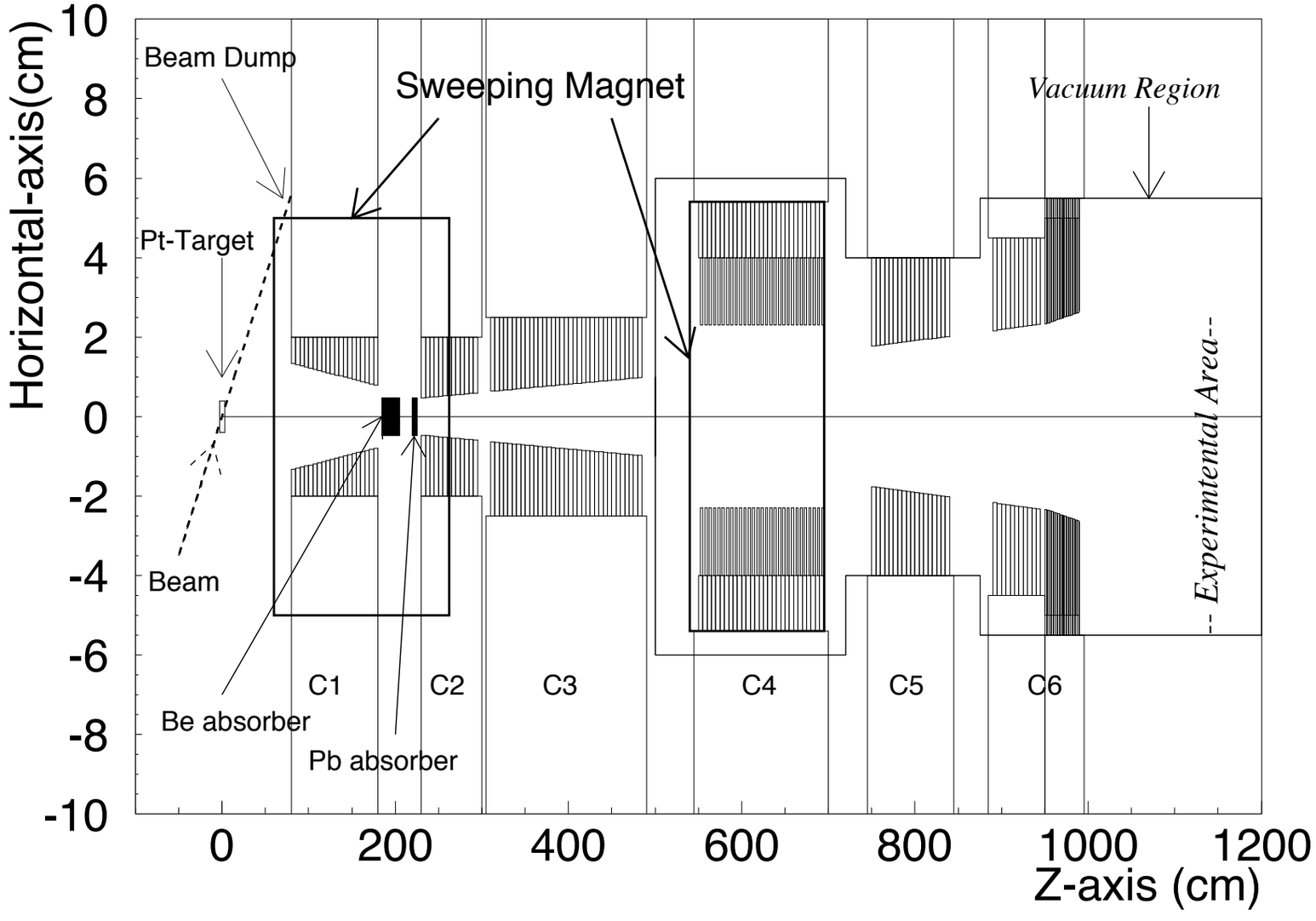
- a tentative plot of single π^0 reconstruction
  - using the full data of the second run in 2005
  - w/ cuts for K_L backgrounds
  - events in the two clusters clearly seen
    - up-stream: "CC02" events
    - down-stream: "CV" events
- "blind" analysis: without looking at the inside the signal box



Halo neutron simulation

- MC scheme: 3 steps
  - target simulation
    - w/ 12GeV proton on the platinum target
  - beamline simulation
    - w/ particles from target sim. into the collimator system
  - detector simulation
    - w/ neutrons hitting the detector





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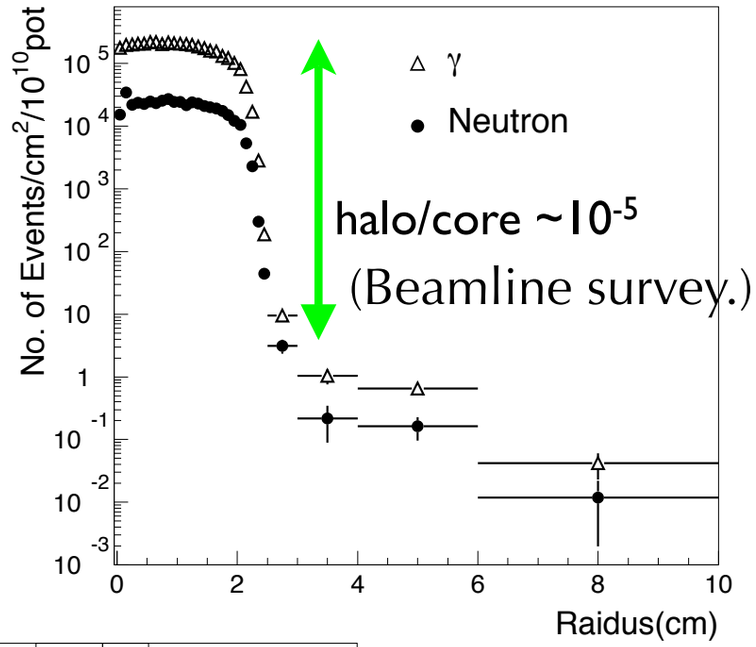

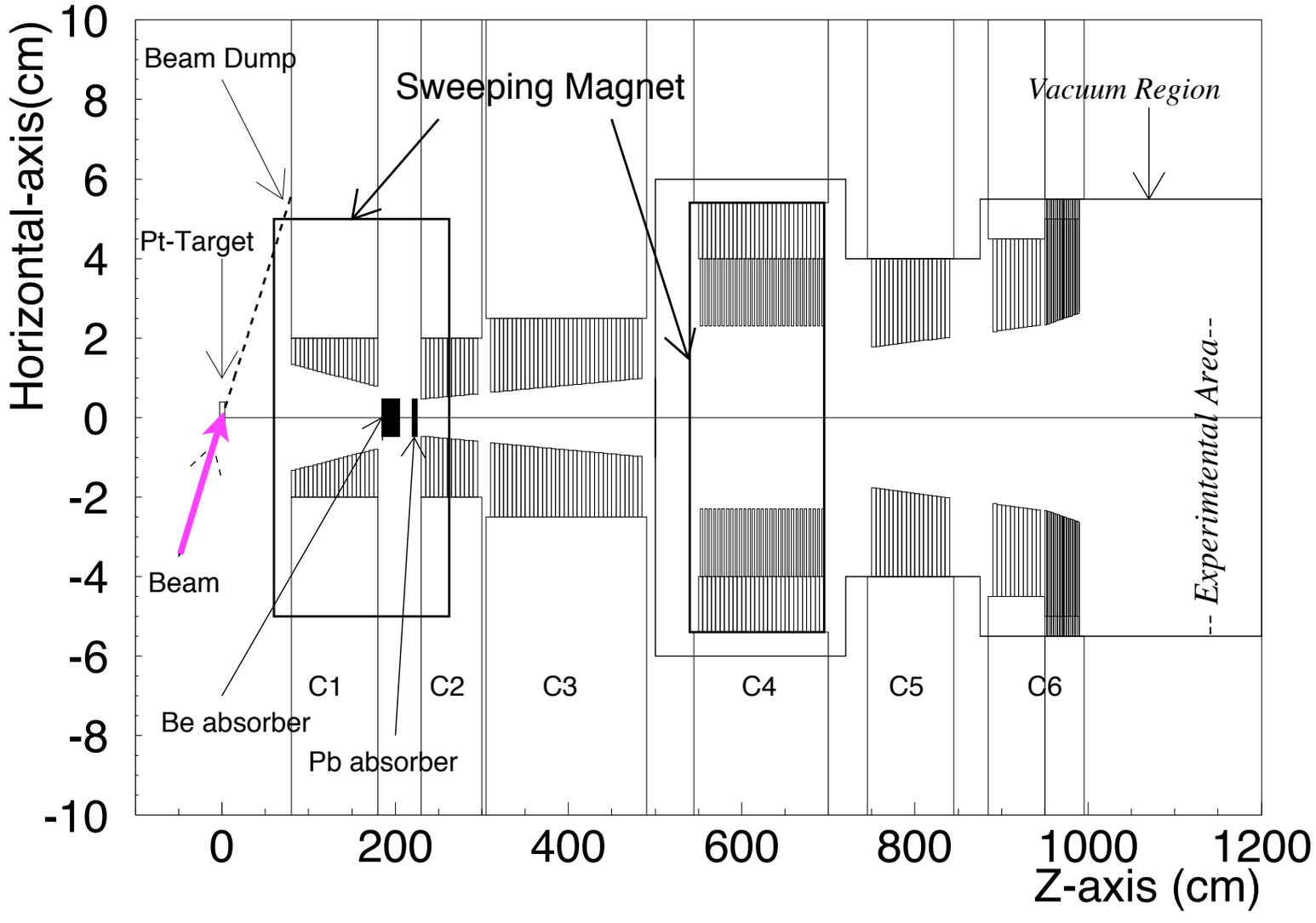

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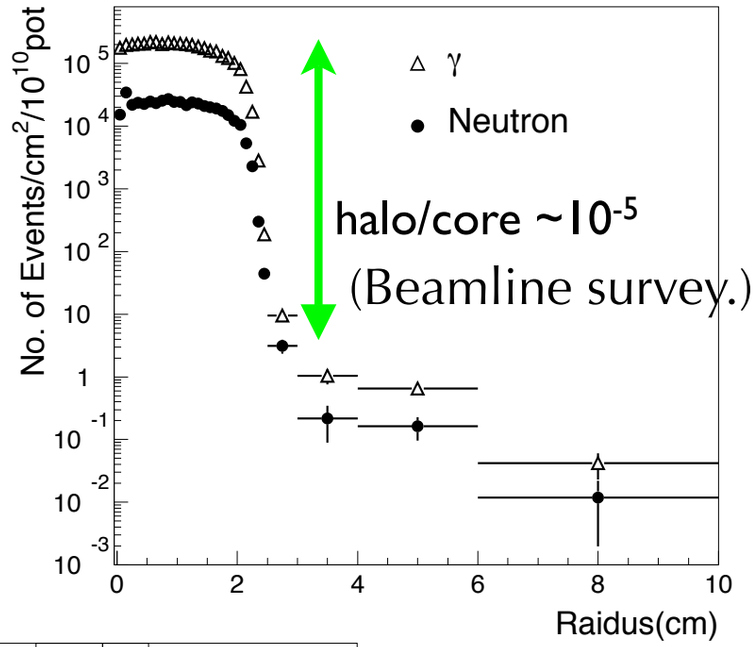

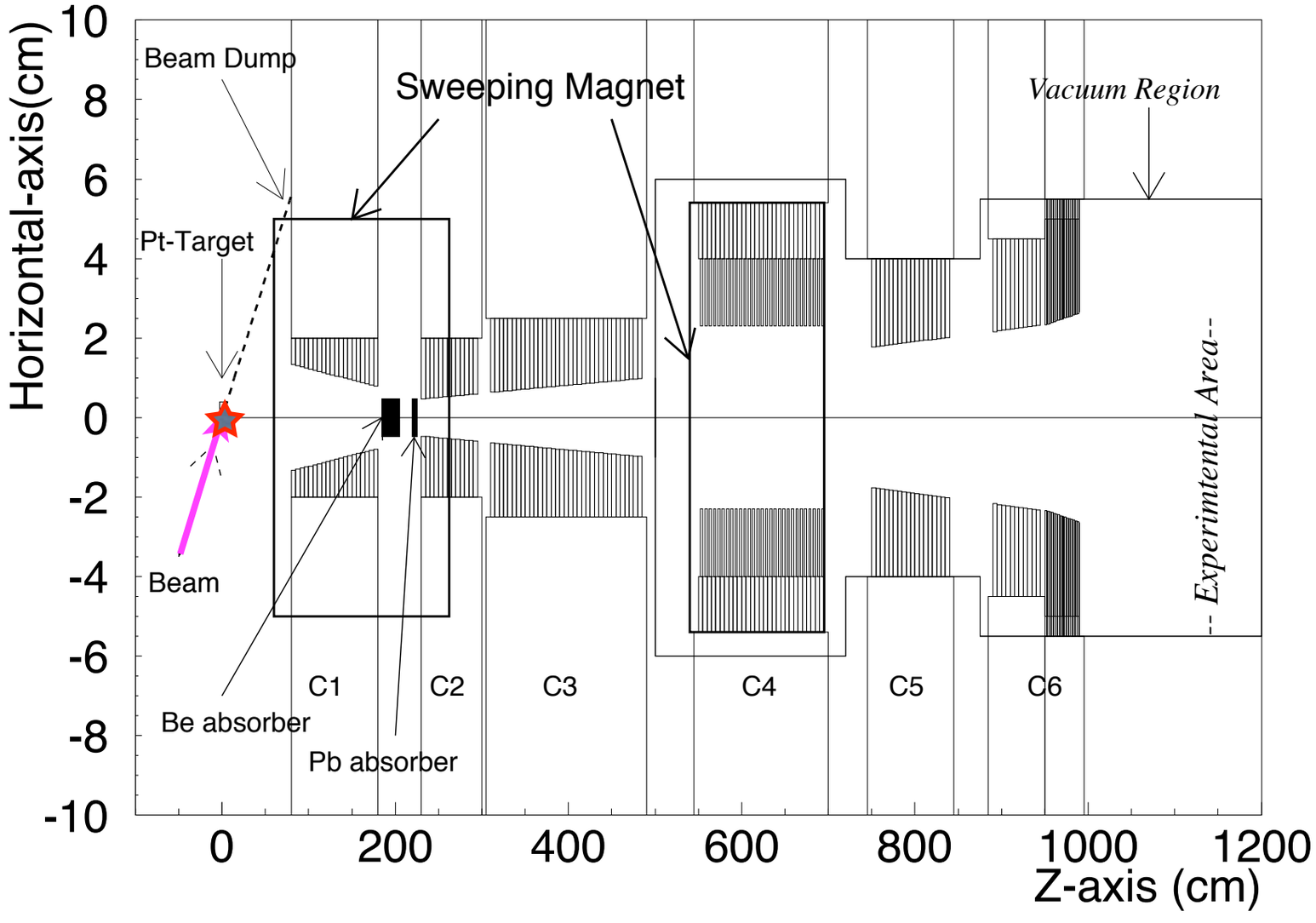

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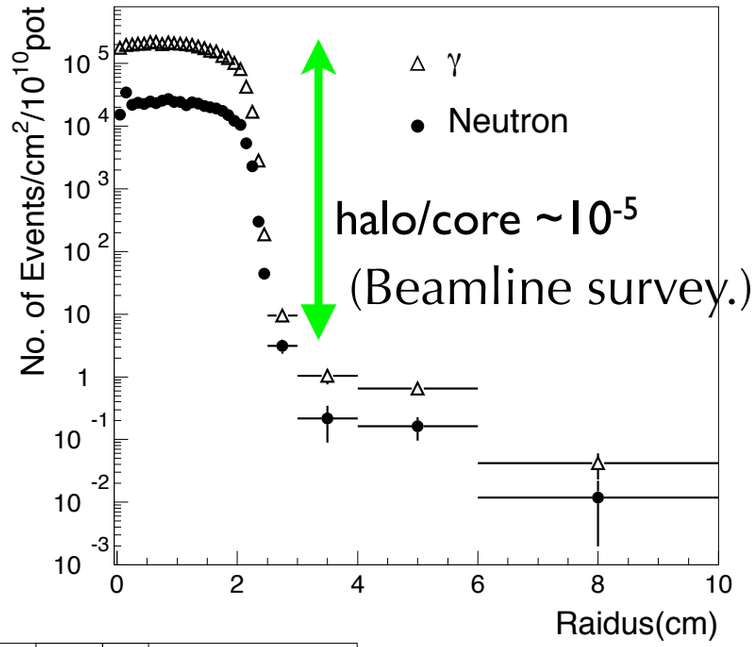

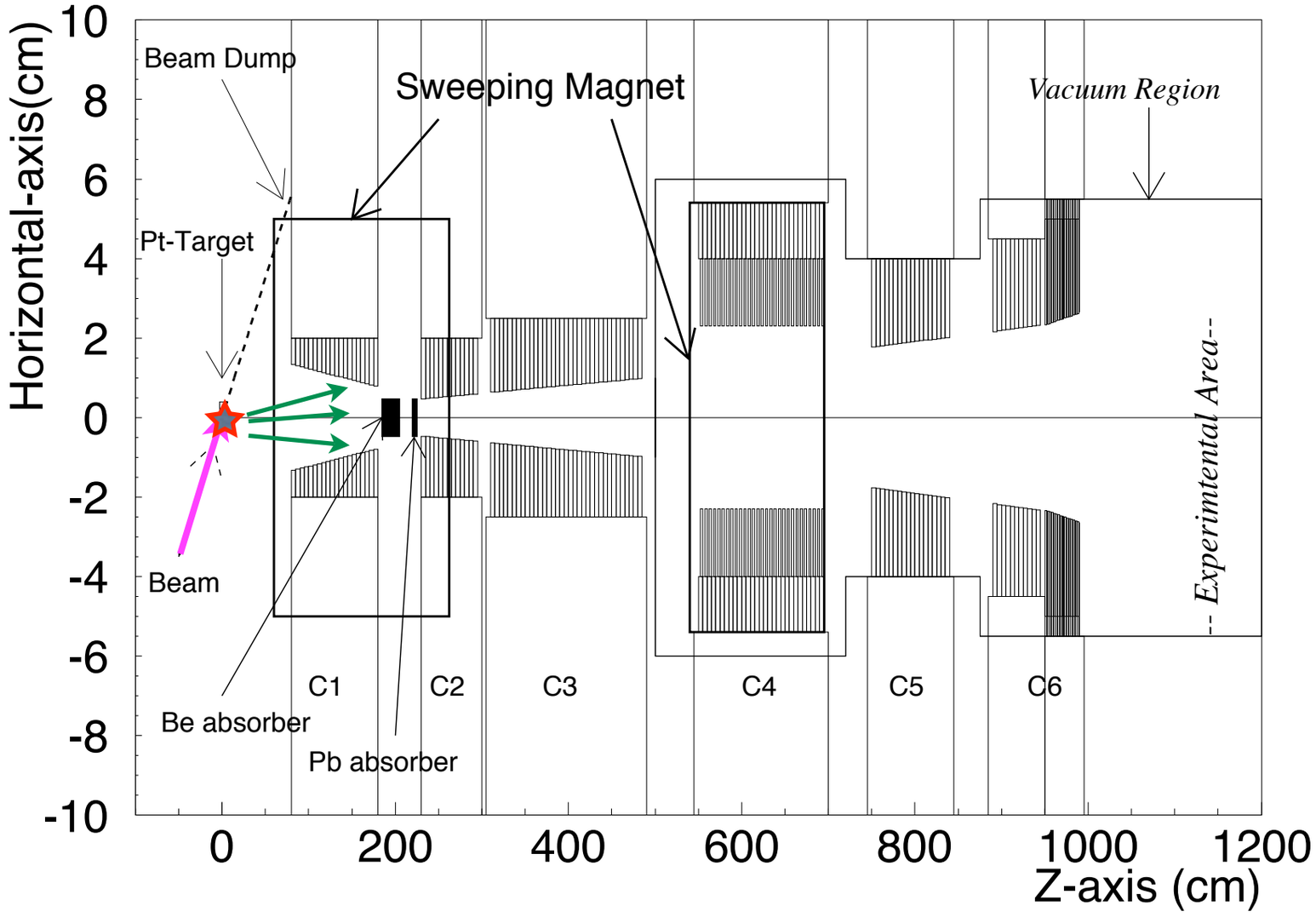

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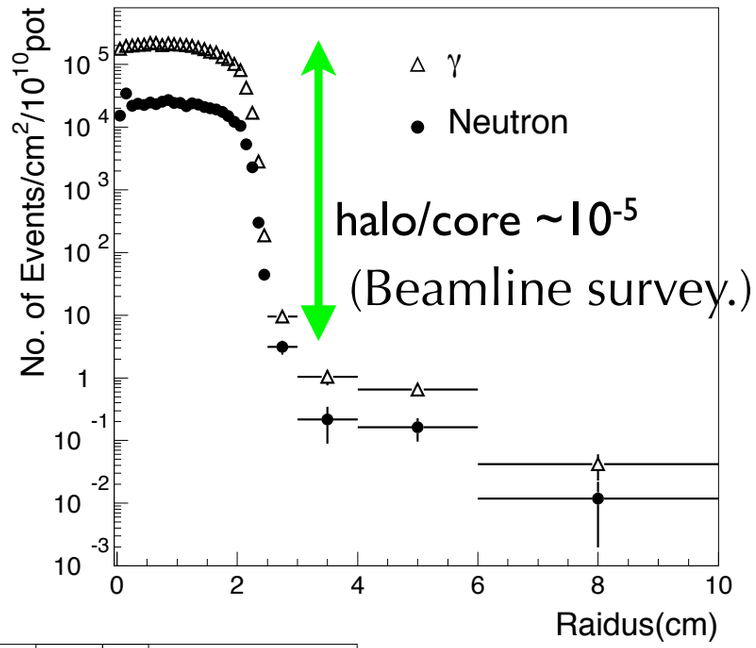

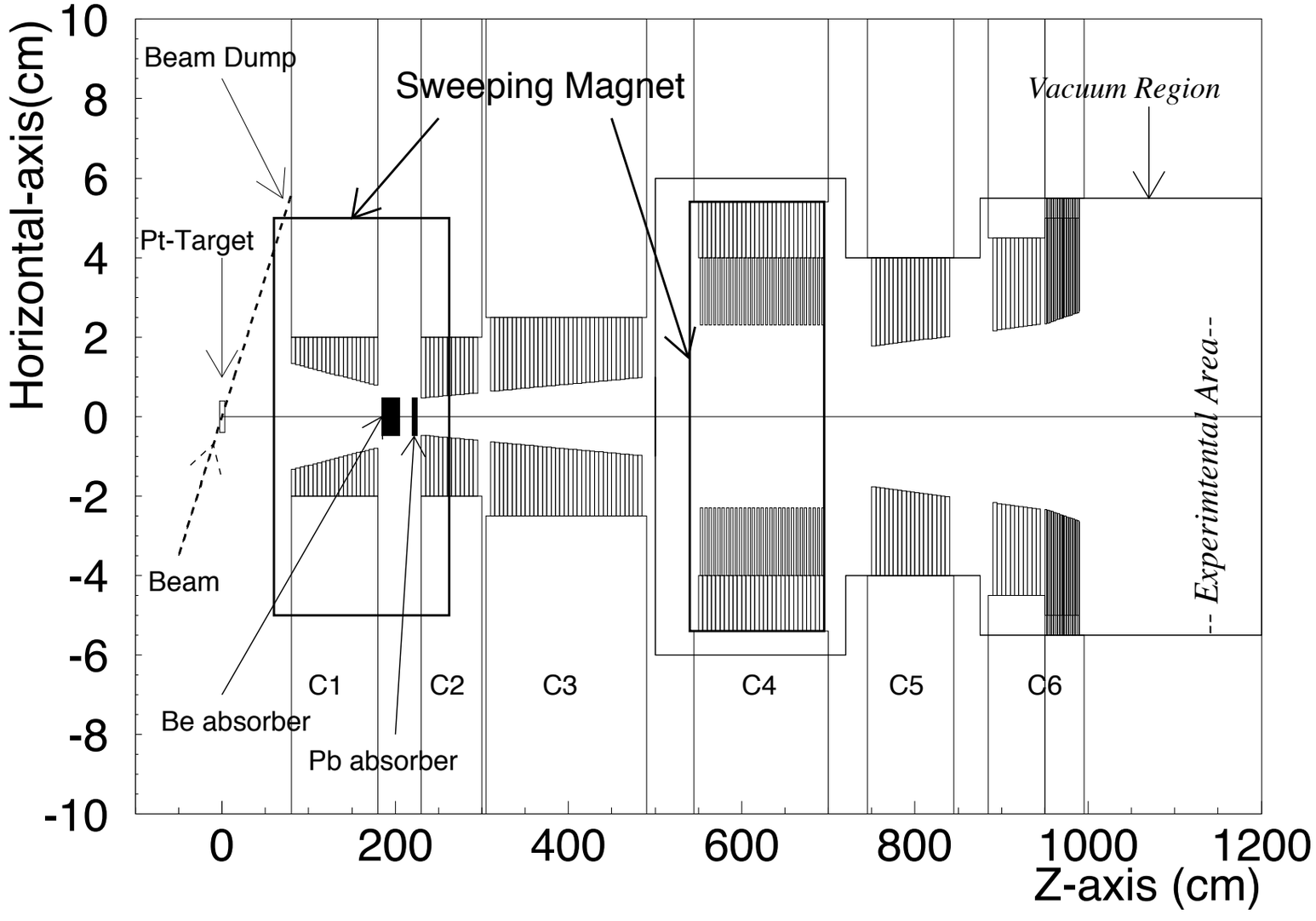

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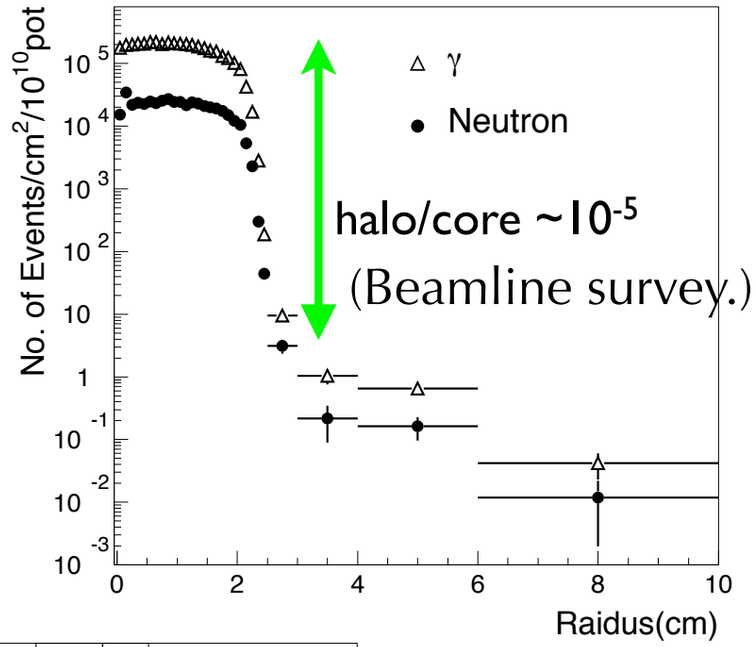

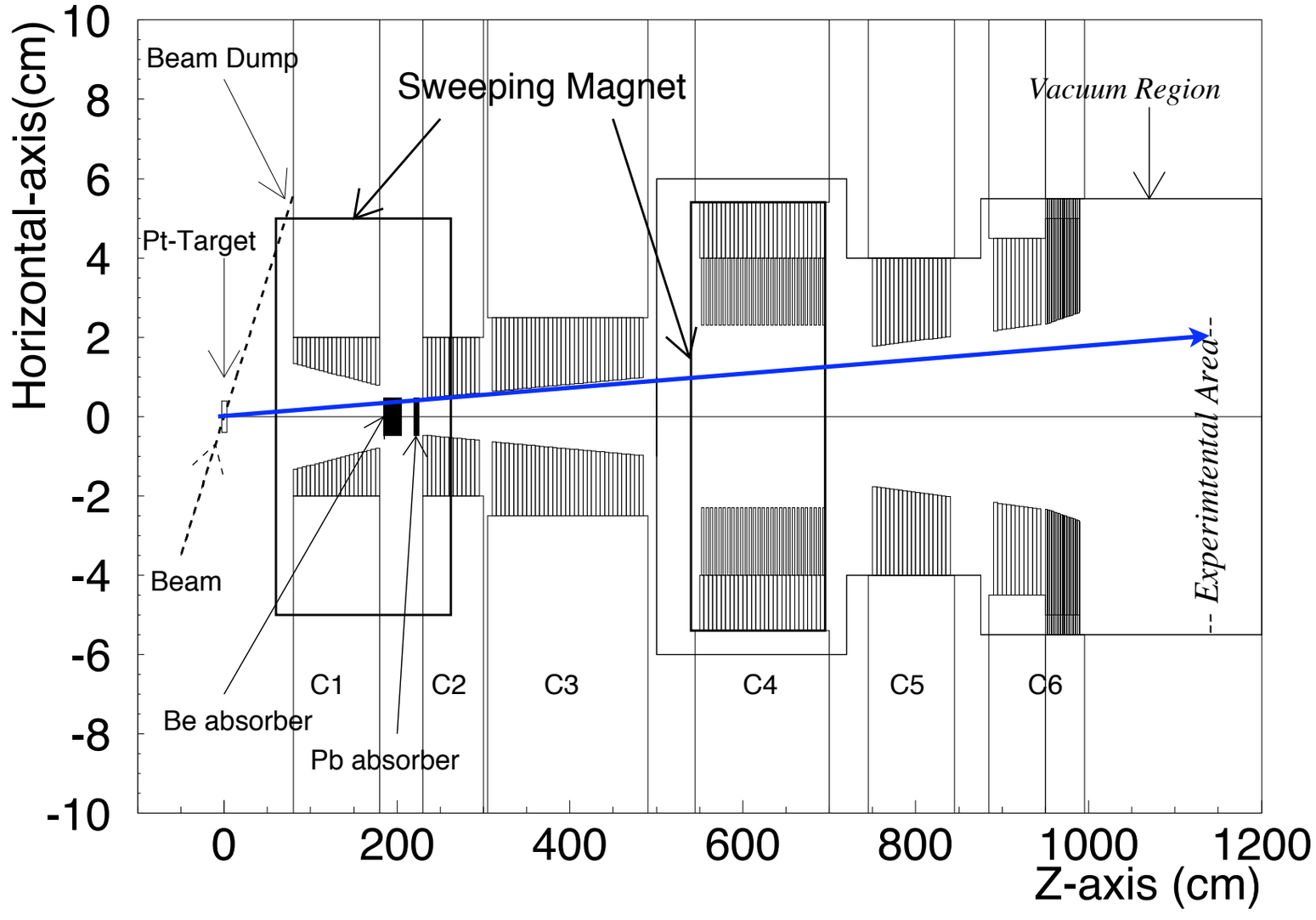

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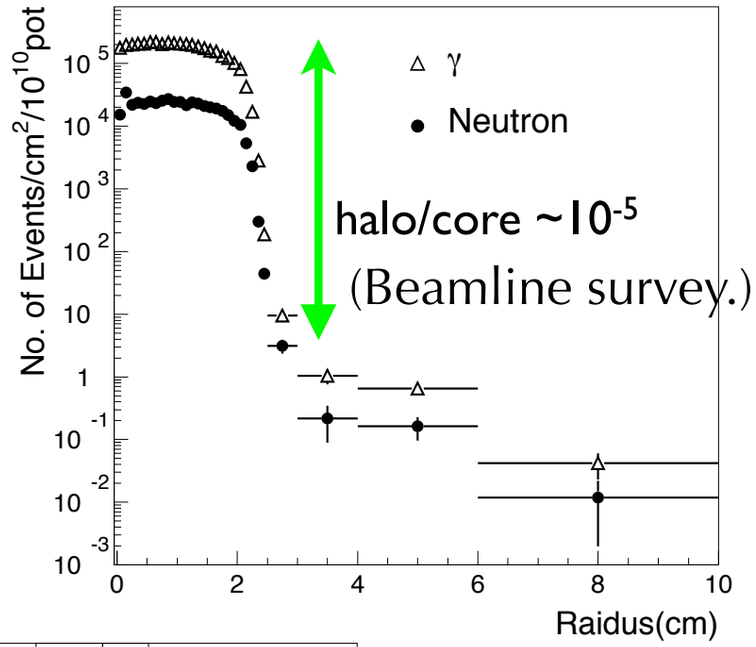

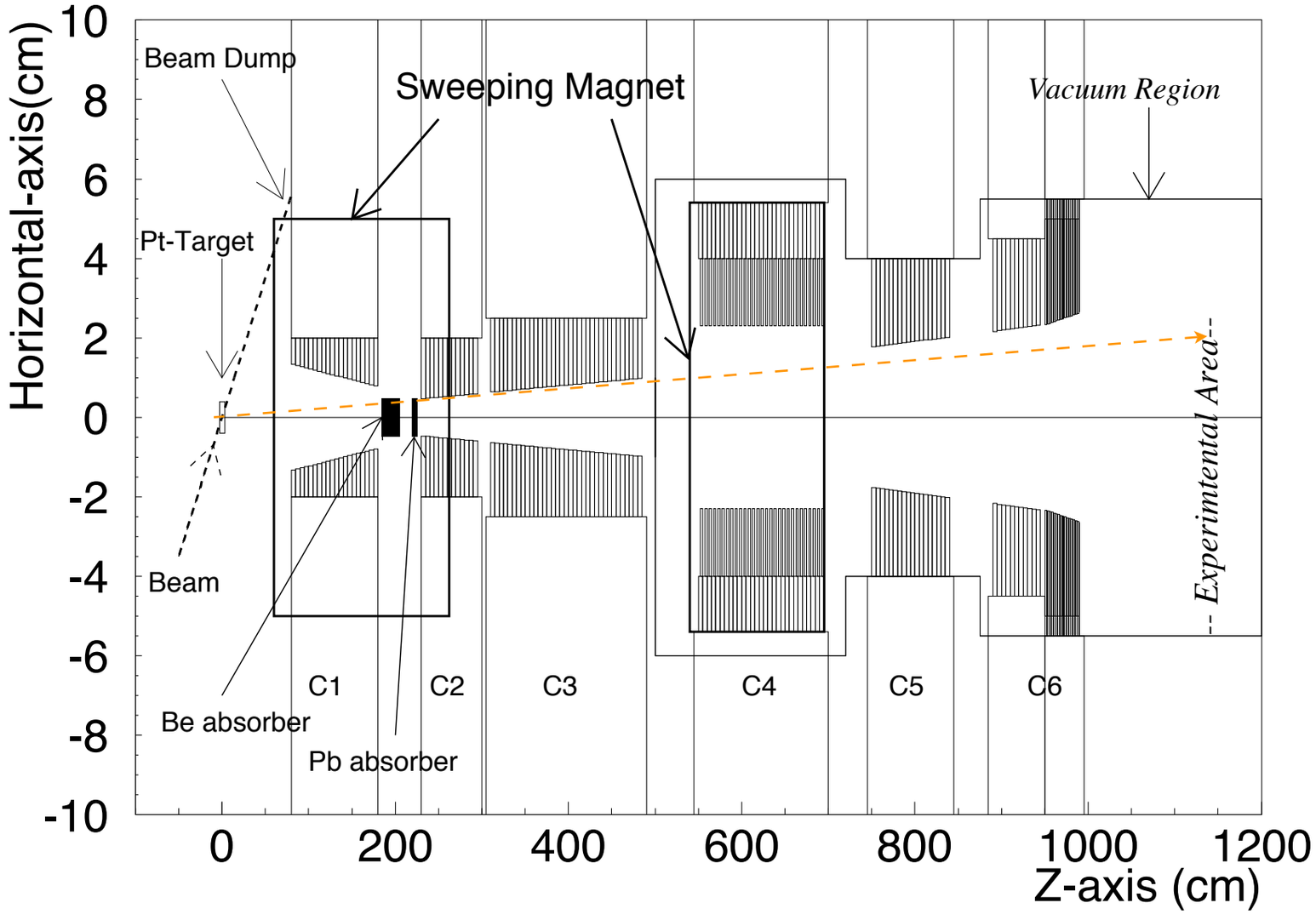

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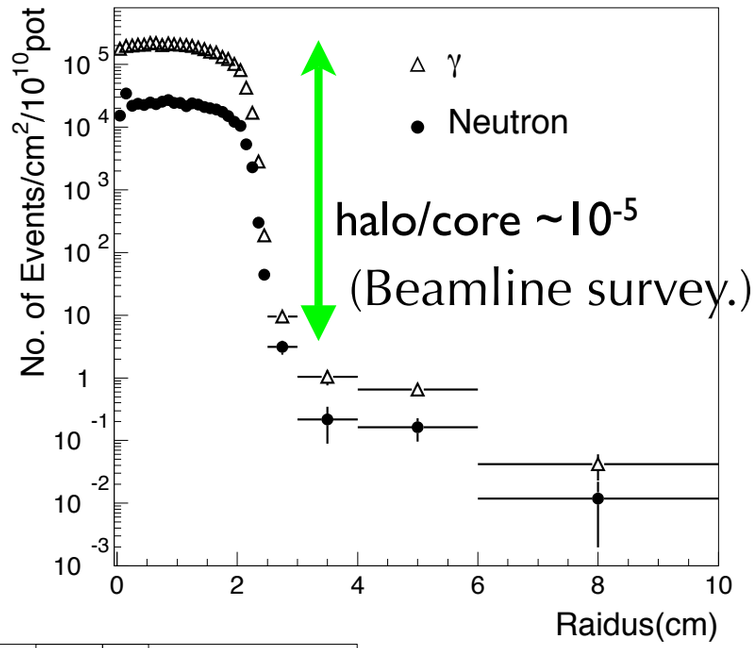

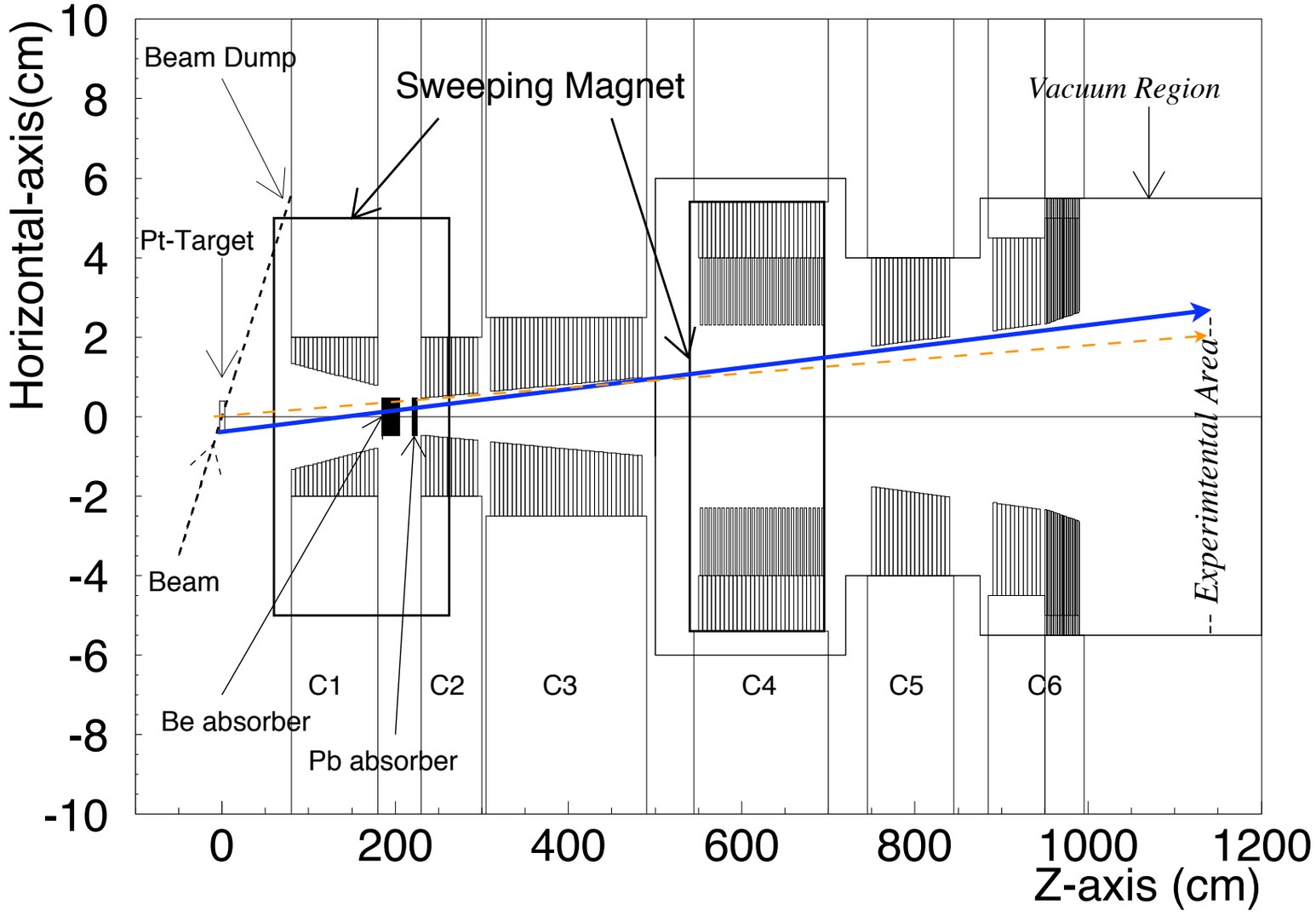

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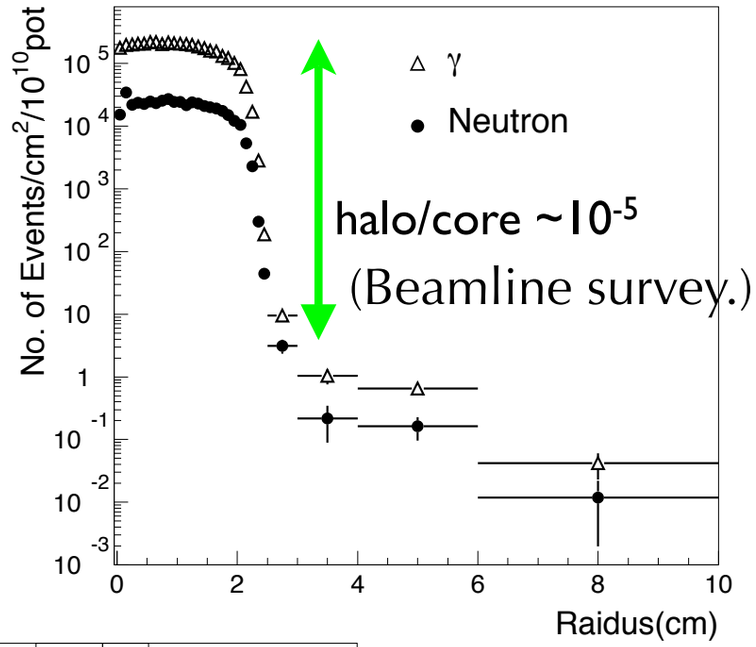

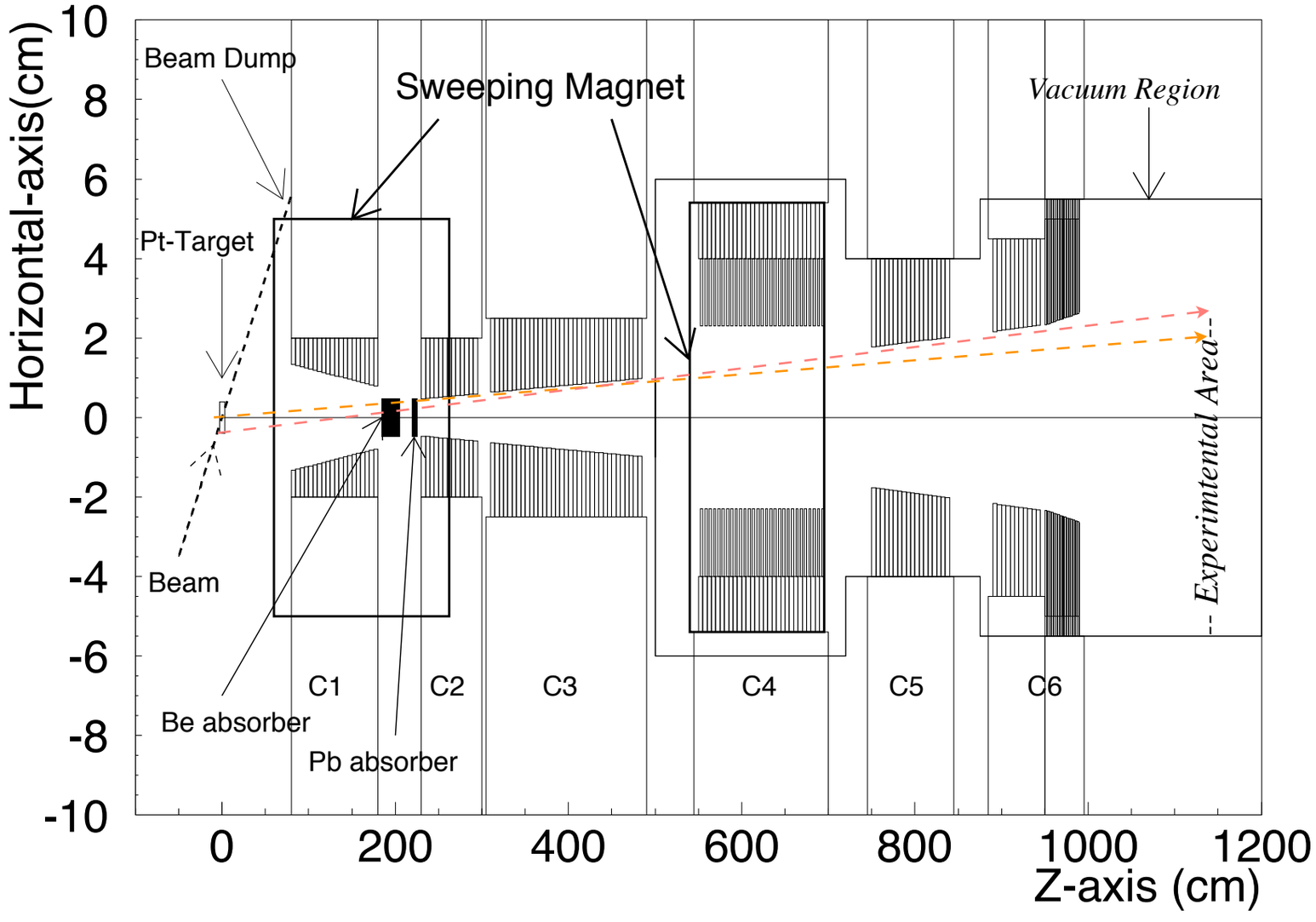

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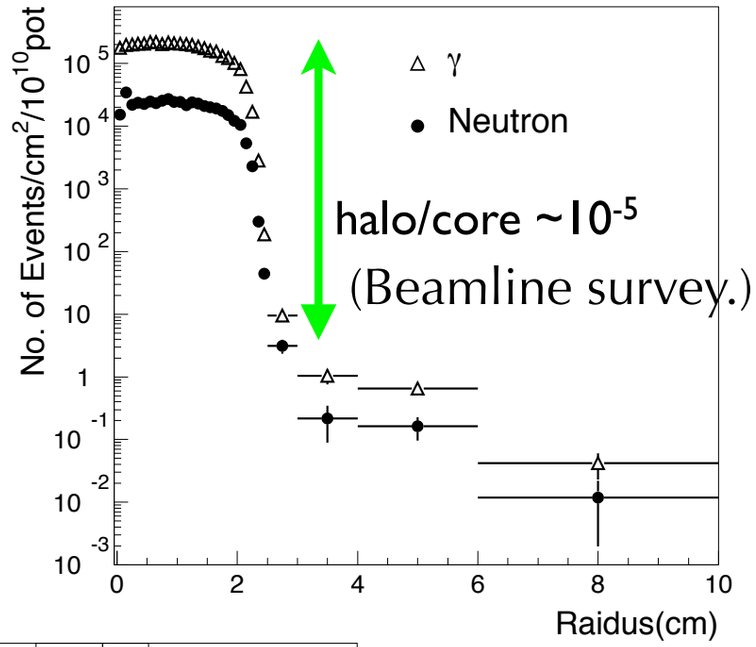
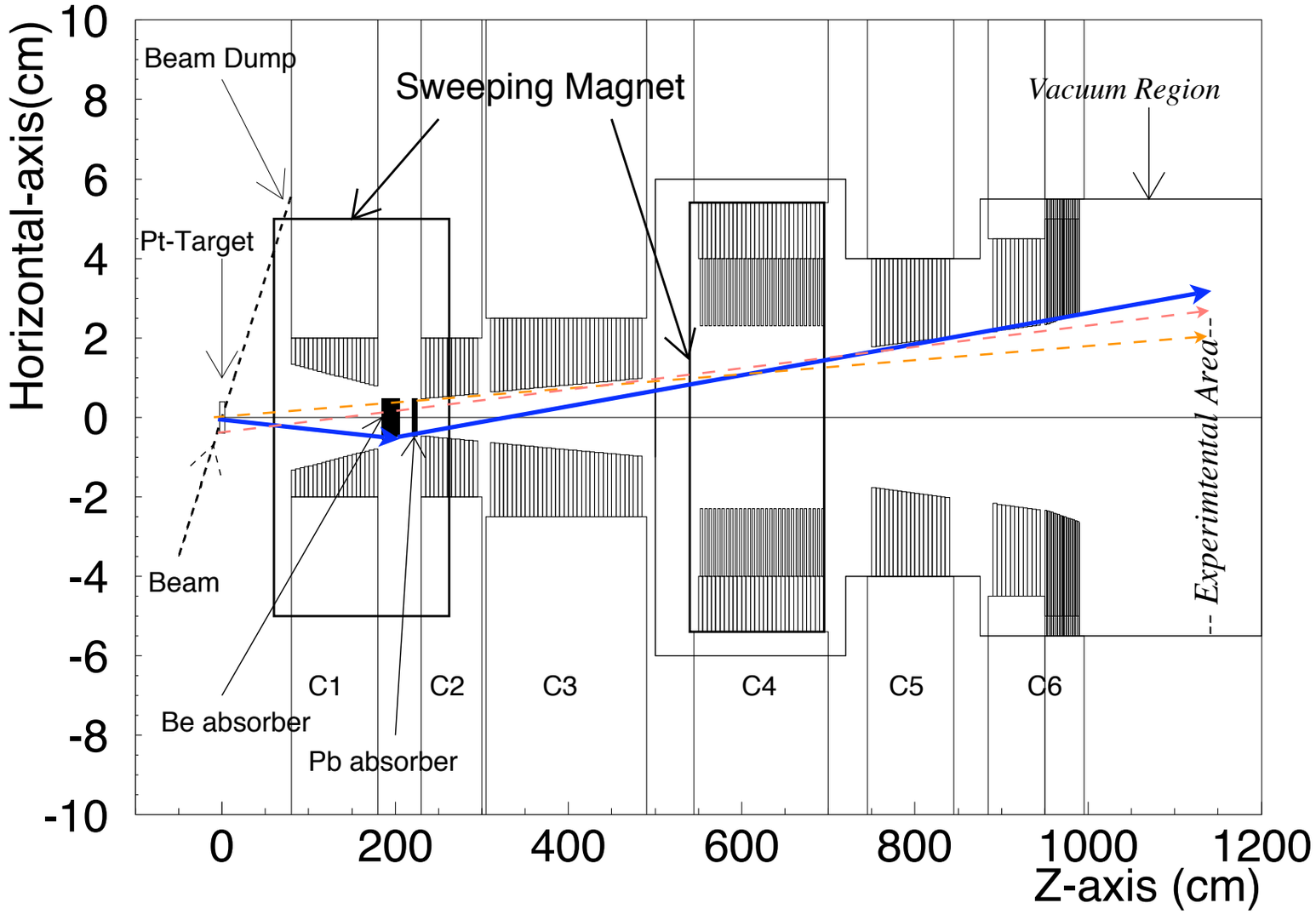


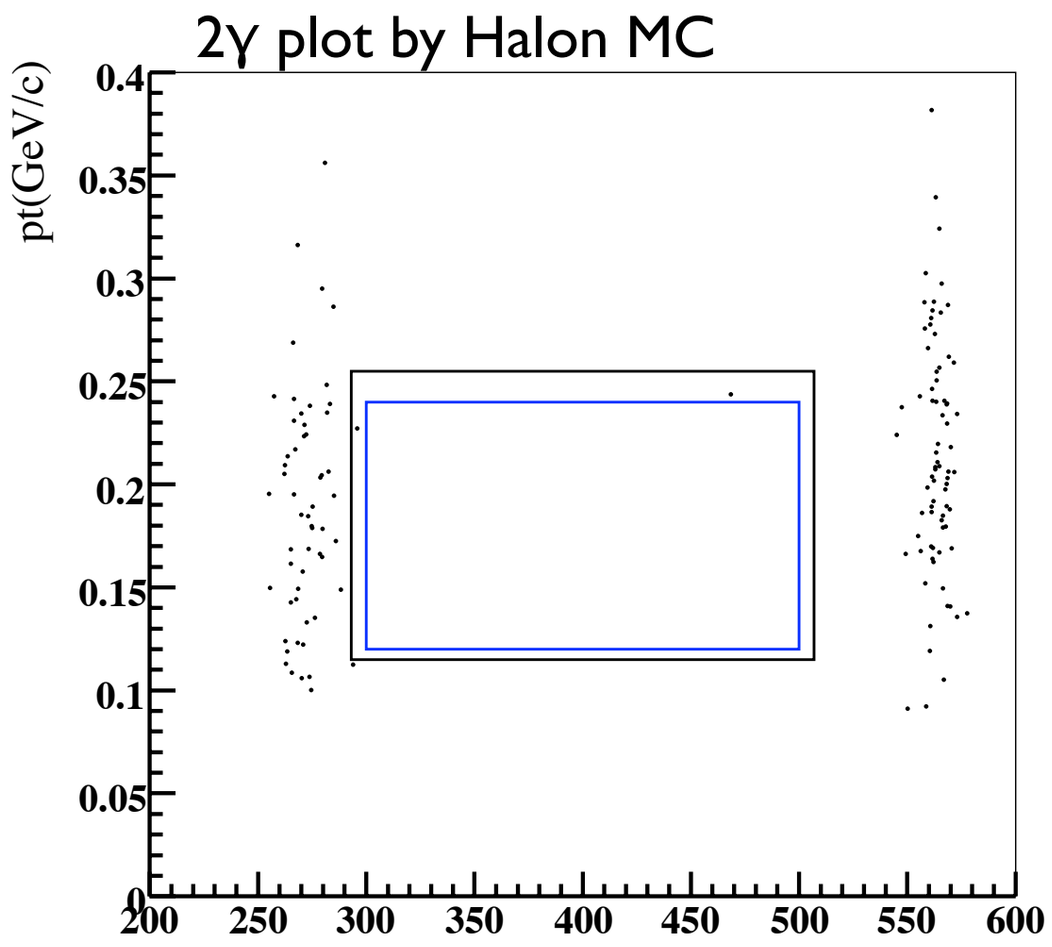


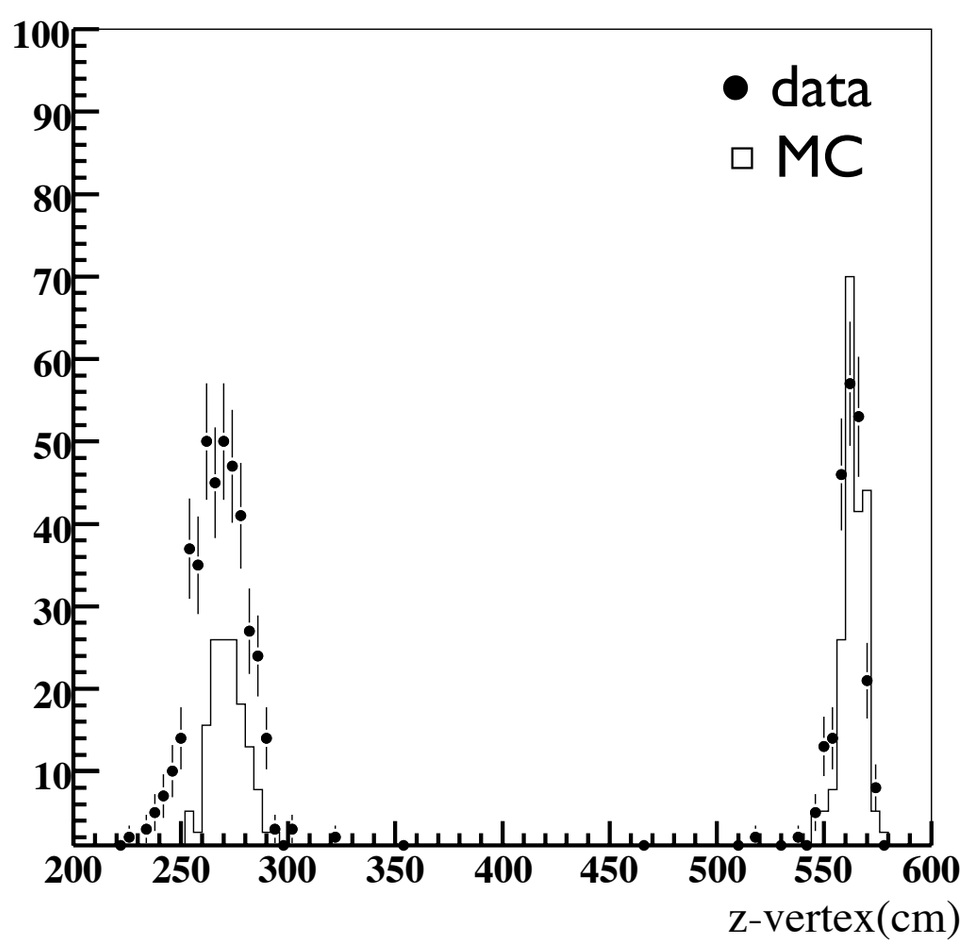
Result

- Statistics
  - 2.8×10^{10} halo neutron incident (1/2.6 of data equivalent)
- downstream events are well-reproduced
  - use this MC to estimate BG

- upstream events are much less than data
  - neutrons w/ large angle might be not correctly reproduced

  → use data of special run for BG estimation



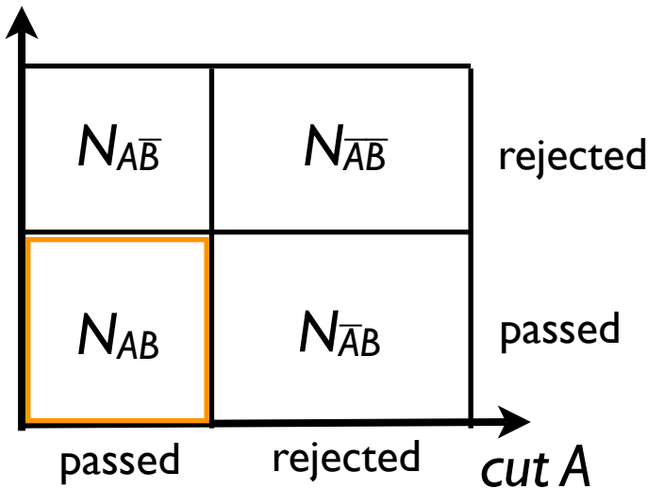


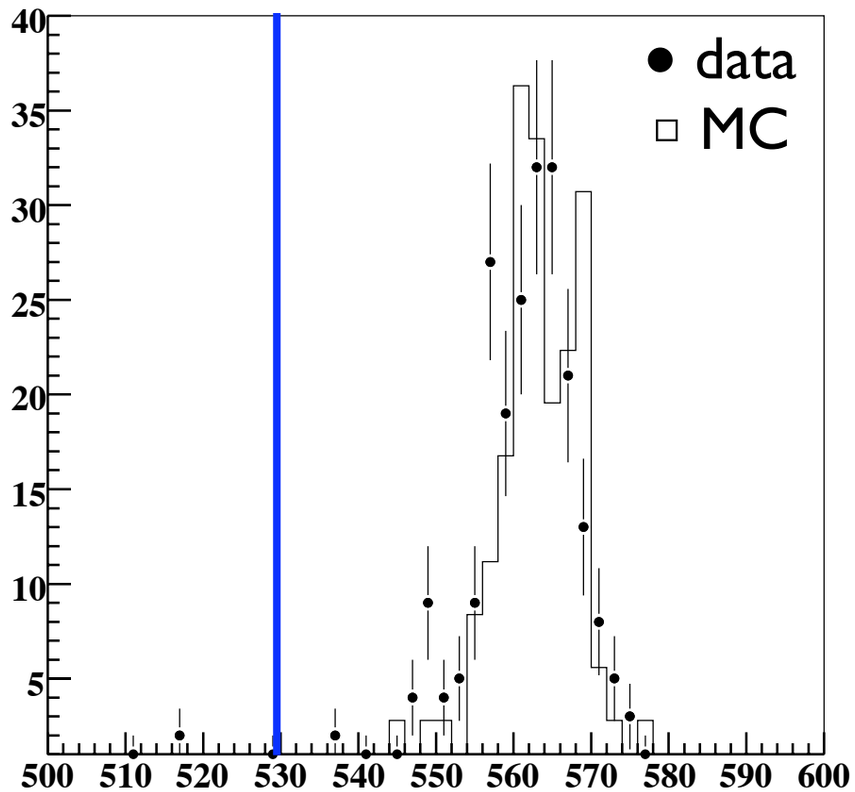
Downstream events

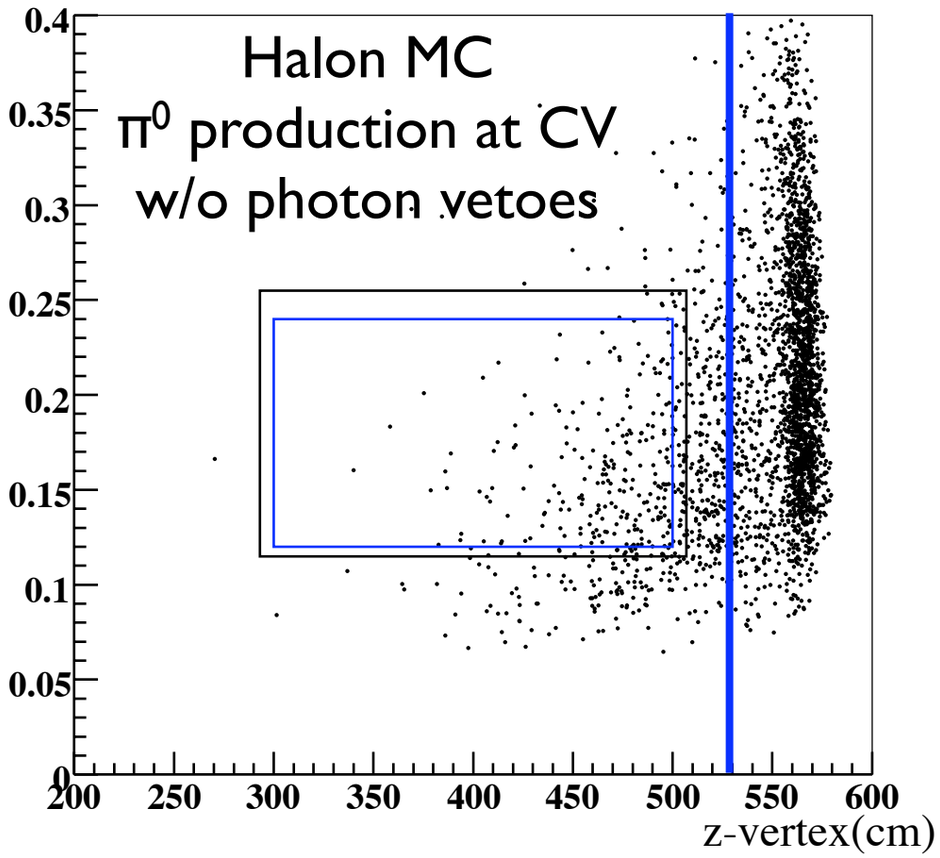
- looking at events with π^0 productions at CV
- data: 226 events, MC: 199±24 events
- BG sources: multi π^0 production, direct hits of neutrons
  - bifurcation method
    - experience in Run-I
      - work at the downstream
      - BG estimation w/ MC

$N_{X\bar{Y}}$: number of events w/ cuts
"$\bar{\ }$" : rejected

$$N_{AB} / N_{A\bar{B}} = N_{\bar{A}B} / N_{\bar{A}\bar{B}}$$
$$\Rightarrow N_{AB} = (N_{\bar{A}B} \times N_{A\bar{B}}) / N_{\bar{A}\bar{B}}$$



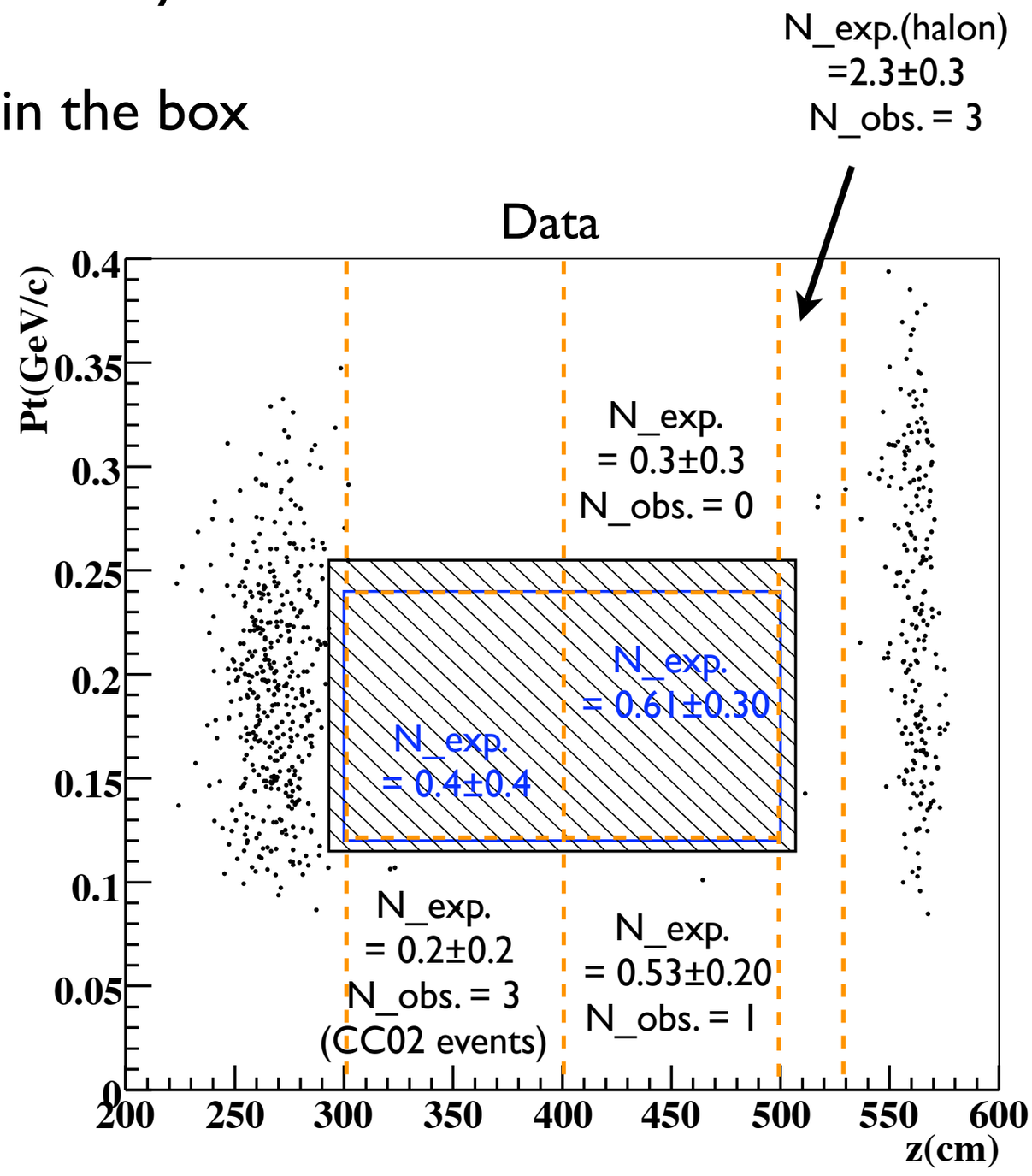




- Cut sets
  - set-up cuts
    - upstream veto detectors, CsI, π^0 kinematics
  - set A
    - downstream veto detectors
  - set B
    - gamma selection

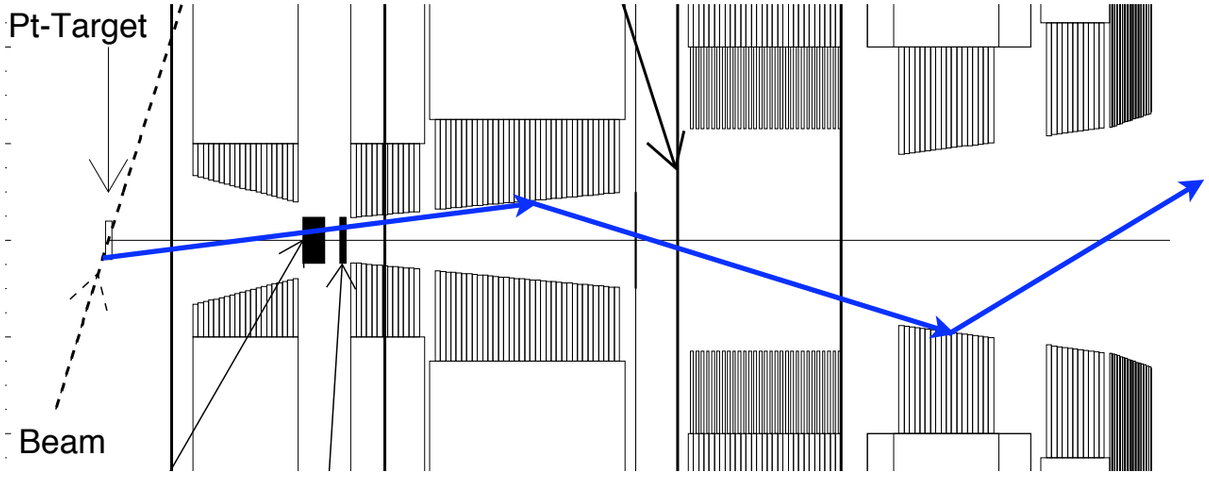
Result of BG estimation

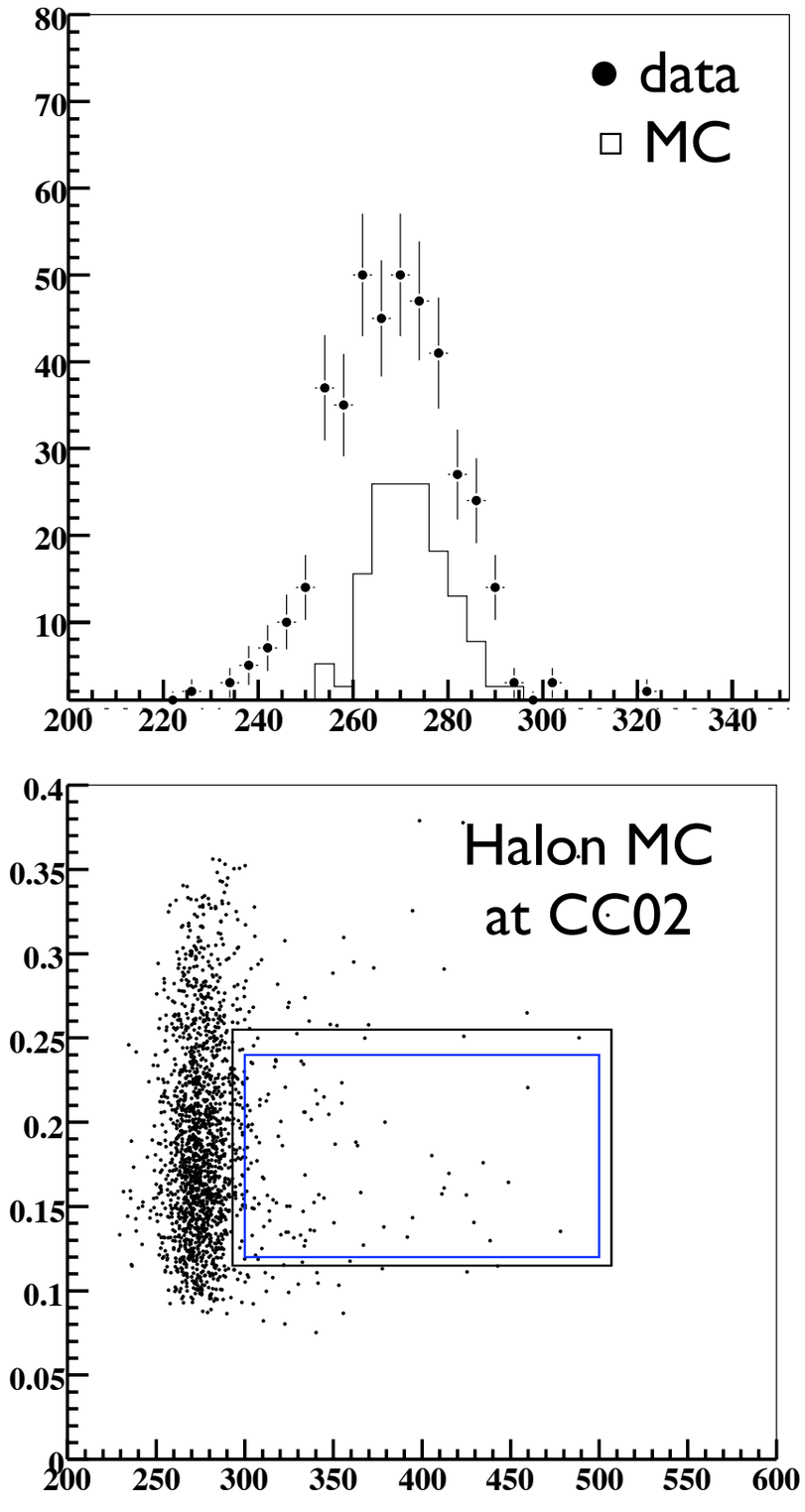
- Statistics: 1/2.6 of data
- downstream events by Halo neutron MC
- BG events
  - ~ 1.0 event in the box



Upstream events

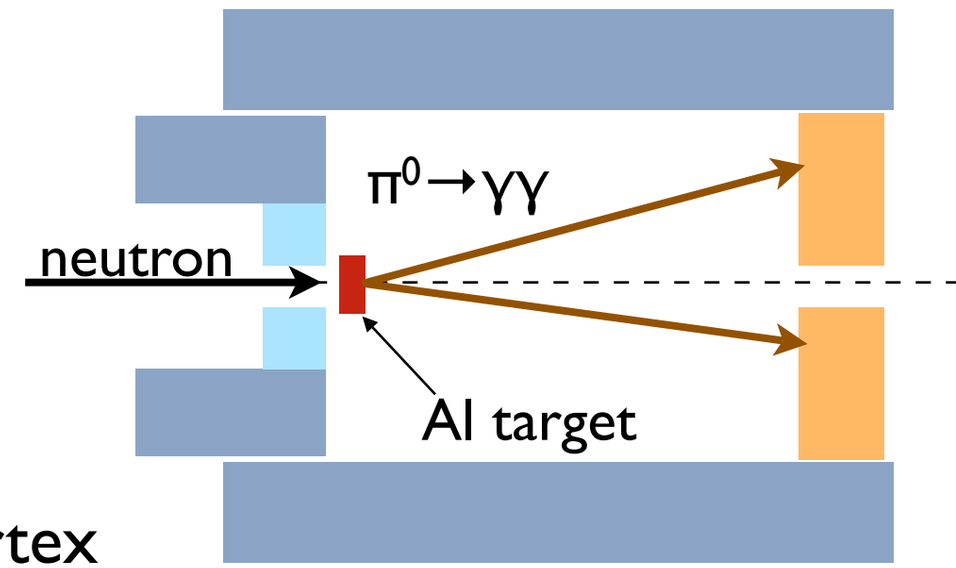
- Big discrepancy between data and MC
  - absolute number of Halo neutrons?
  - efficiency of upstream counters?
- BG source
  - shower leakage in CsI
    - rec. vertex move to downstream
    - estimation
      - π^0 production target run data



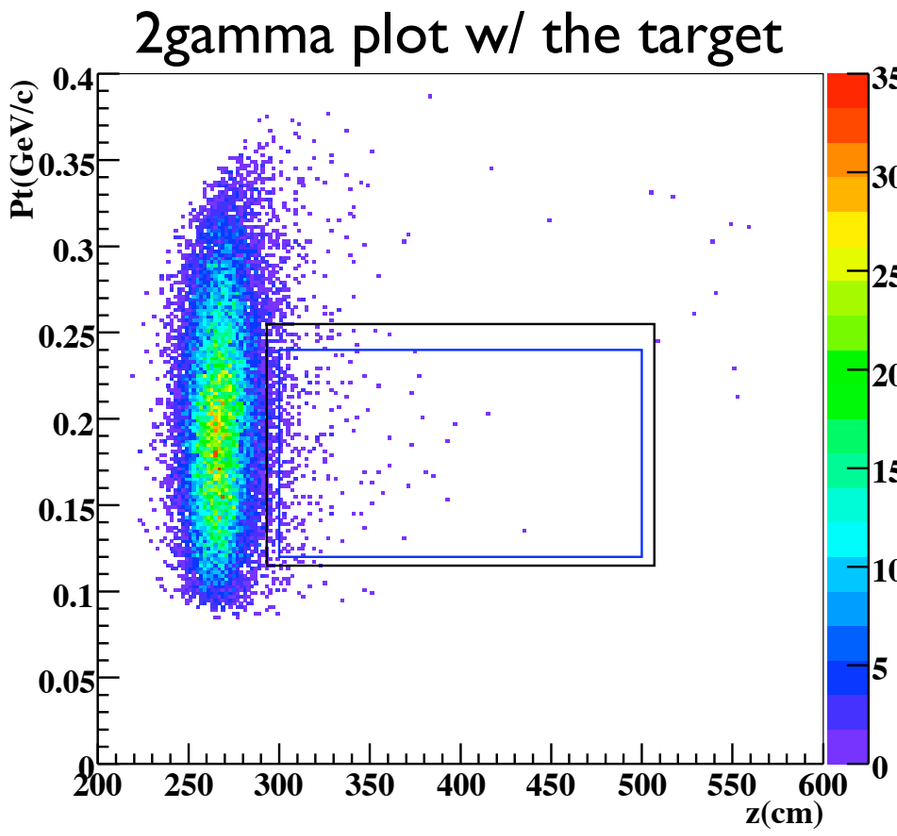


π^0 production target run

- special run with a 5 mm thick aluminum target
  - the Al target at the entrance of decay region
  - "core" neutrons hit it and produce π^0's
  - used for correction of calibration w/ known vertex
  - Half intensity of primary proton



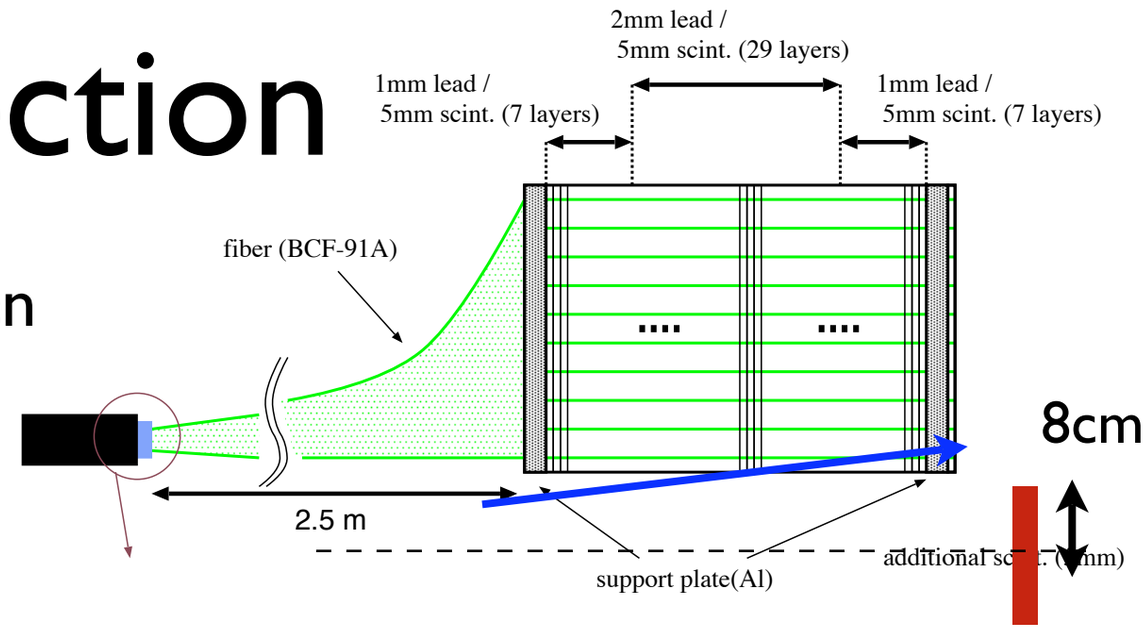
- look at the behavior of the tail by leakage
- same cuts for $\pi^0\nu\bar{\nu}$ analysis
  - ~ 20000 CC02 events (halon MC: ~50 events)

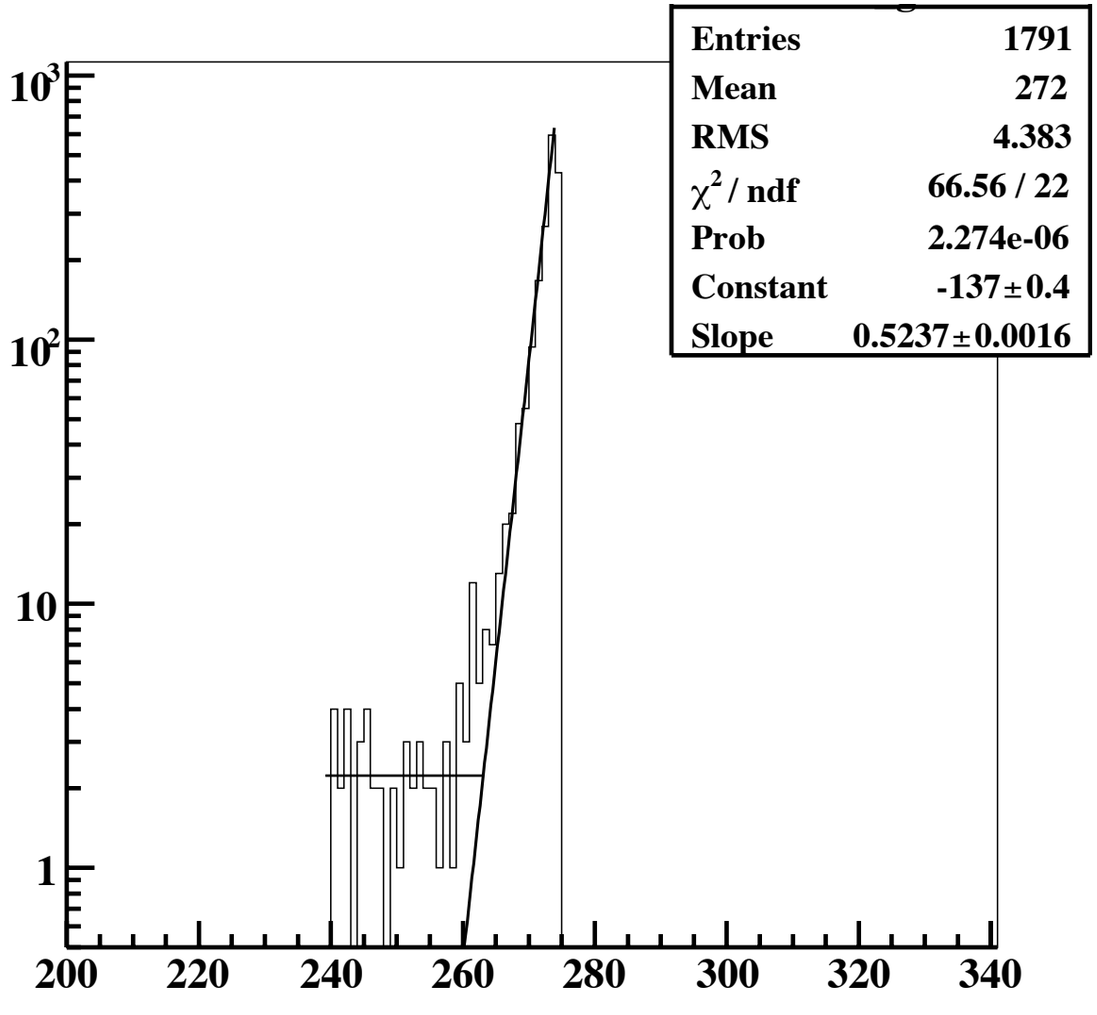


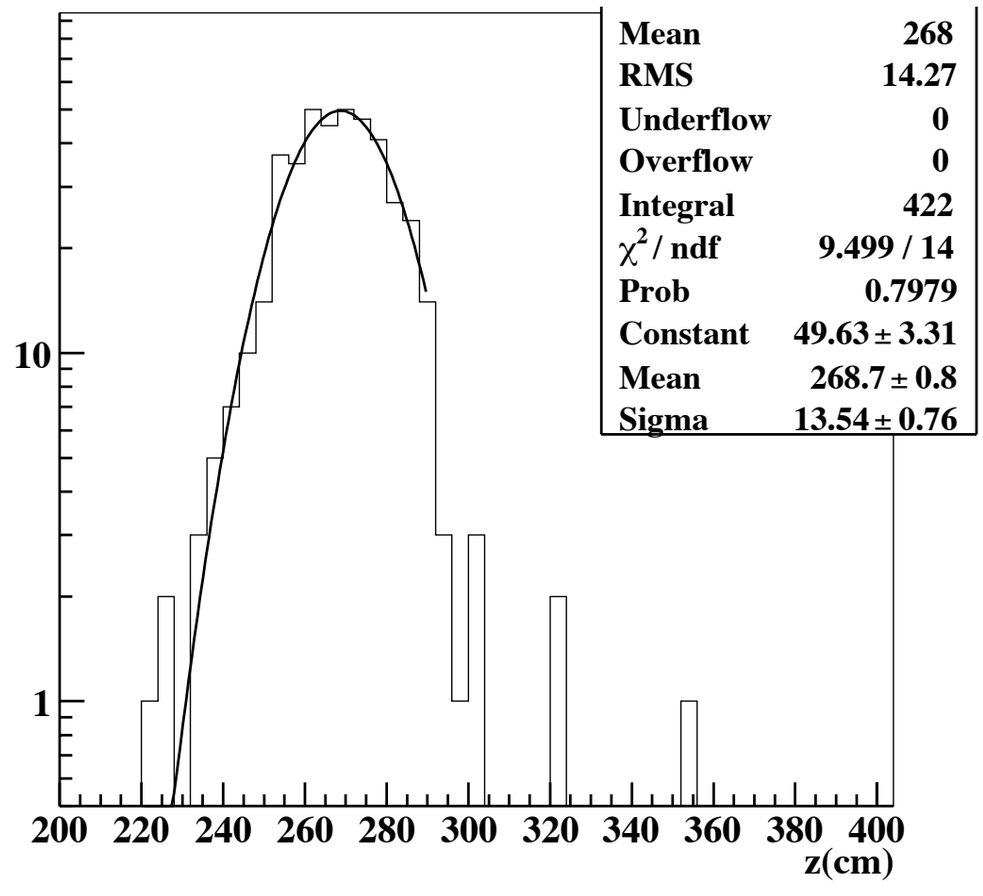
Position correction

- π^0 generation points are different between CC02 and the target
- convolution in π^0 reconstruction
  - R: 8cm
  - z: correction with the target position

    PDF of interaction point : f(exp(-x/λ)) : λ=0.5cm

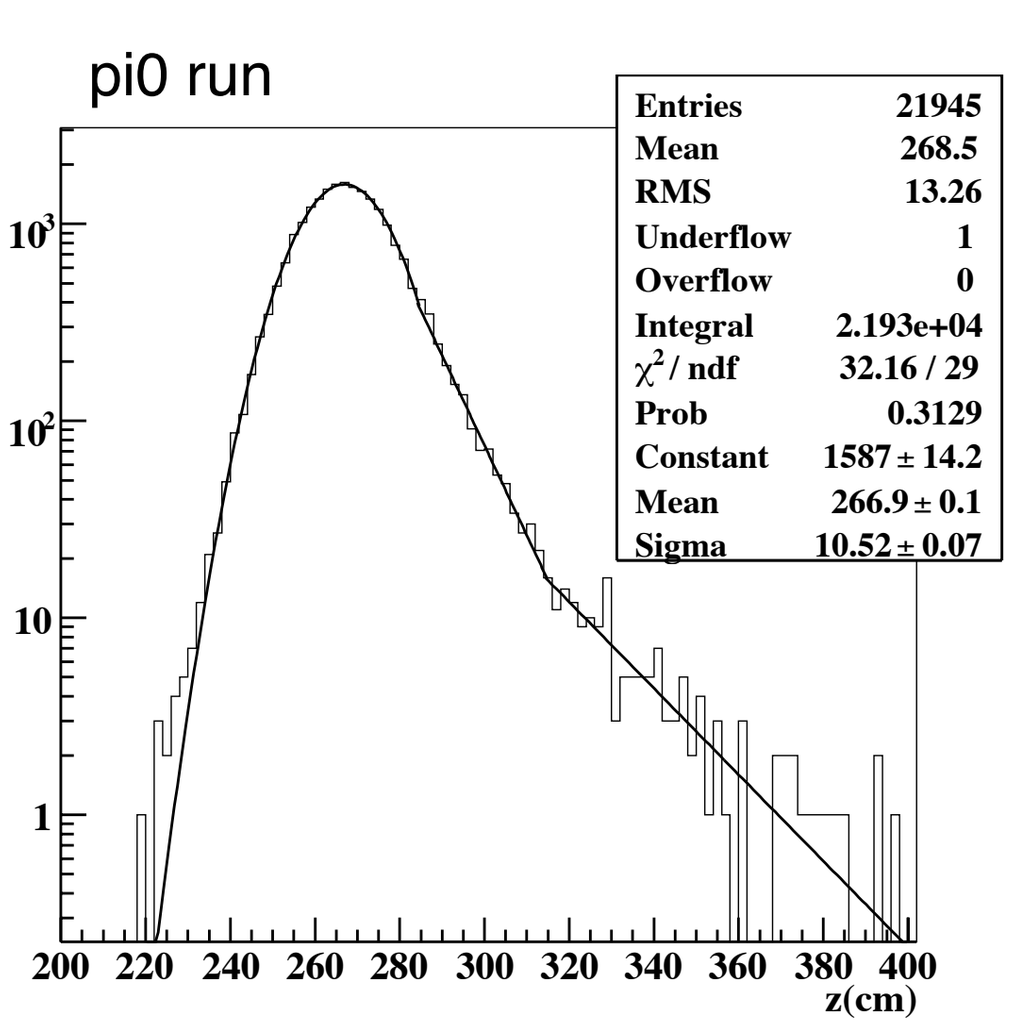


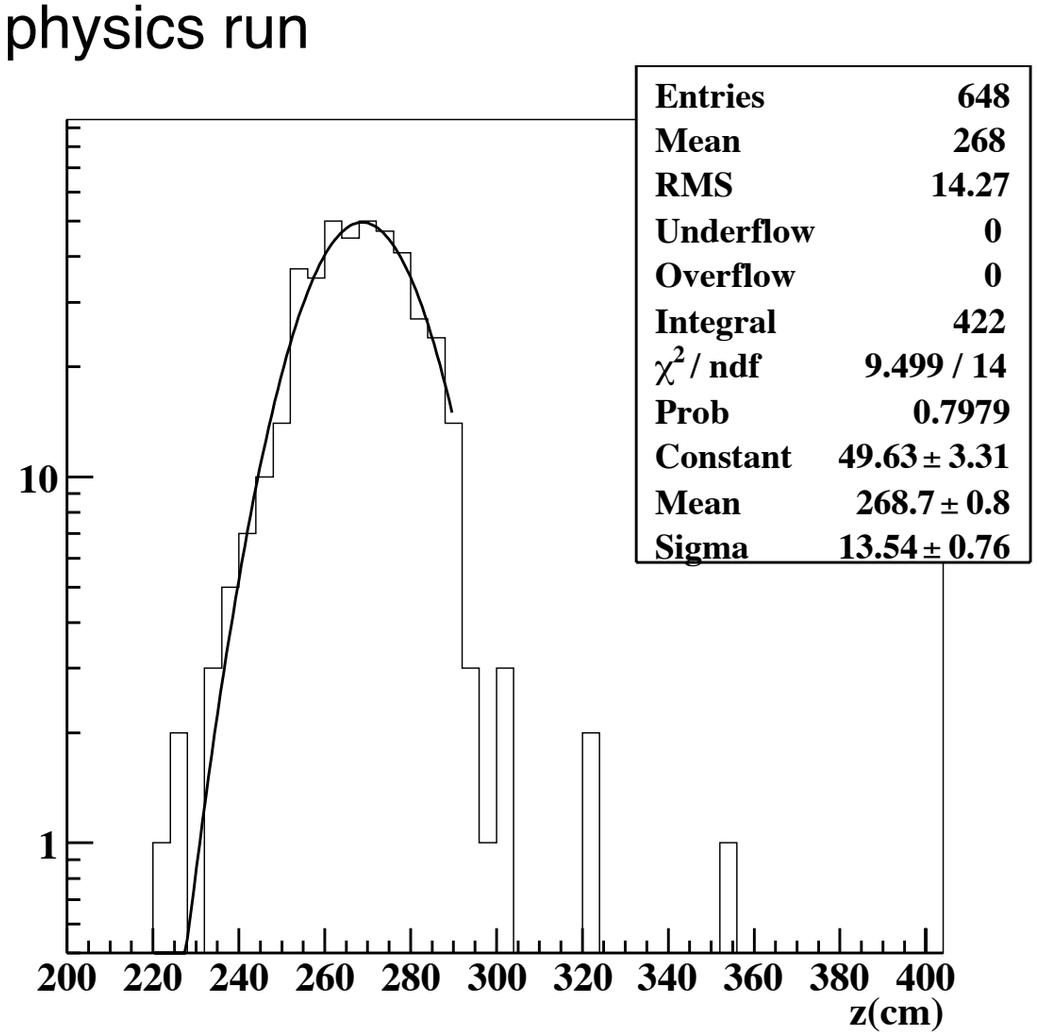




Result of position correction

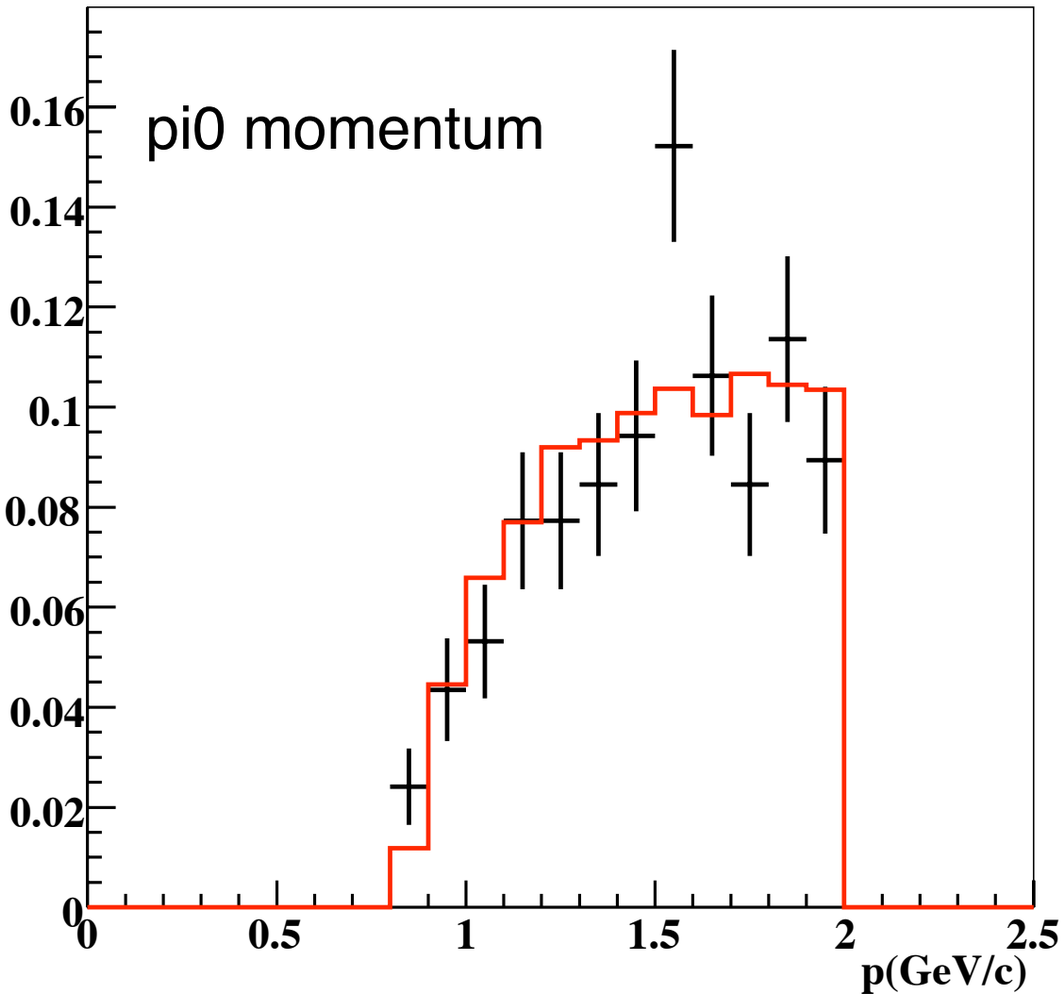
- peak
  - target run: 266.9, physics run: 268.7±0.8
- sigma
  - target run: 10.52, physics run: 13.5±0.8

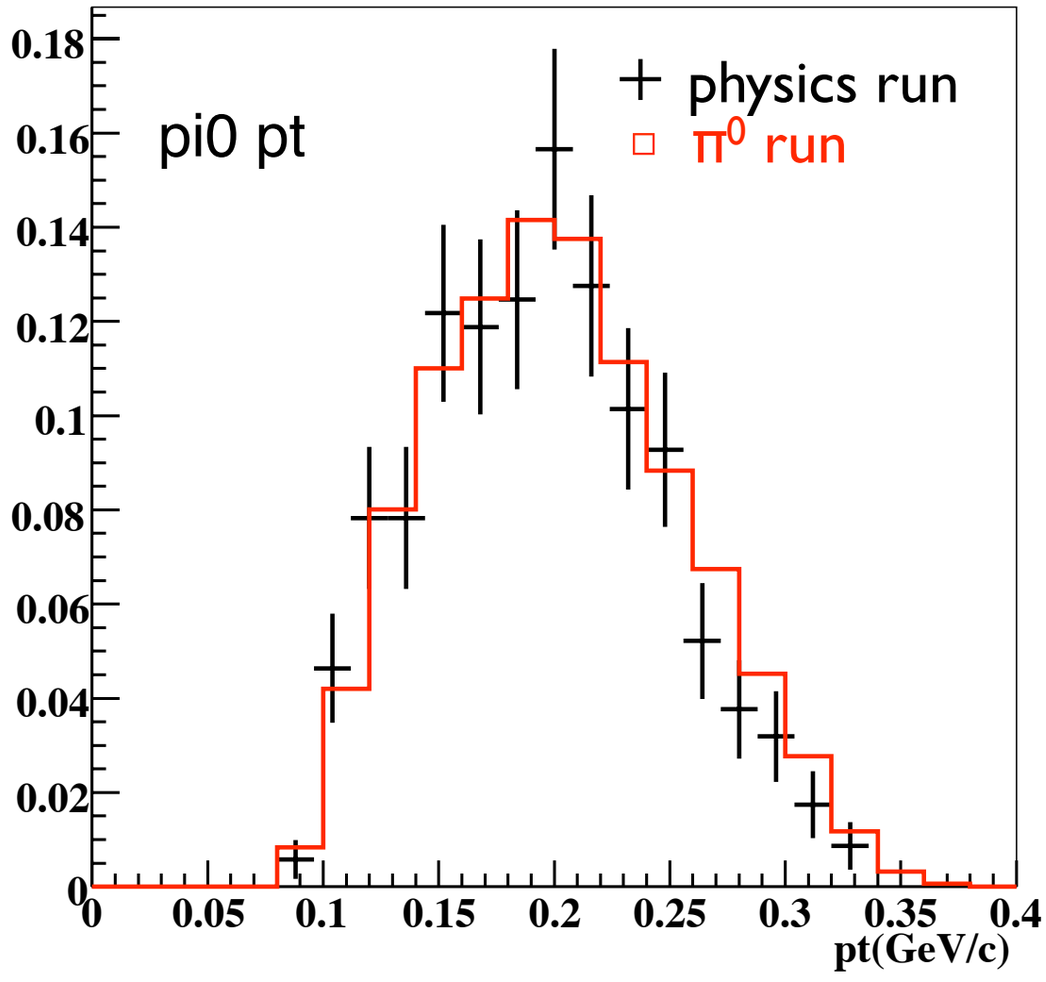




distributions of π^0's

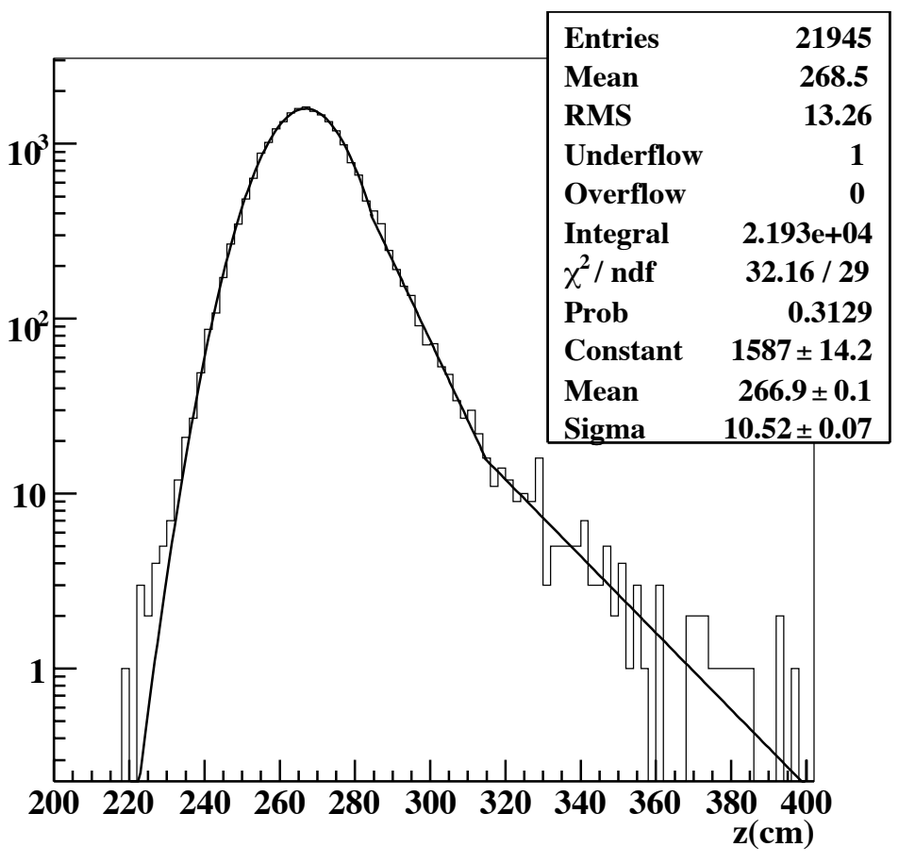
- momentum and pt of π0
  - limited by the geometrical acceptance
  - distributions from pi0 target run and physics run show good agreement
    ⇒ estimate shower leakage probability

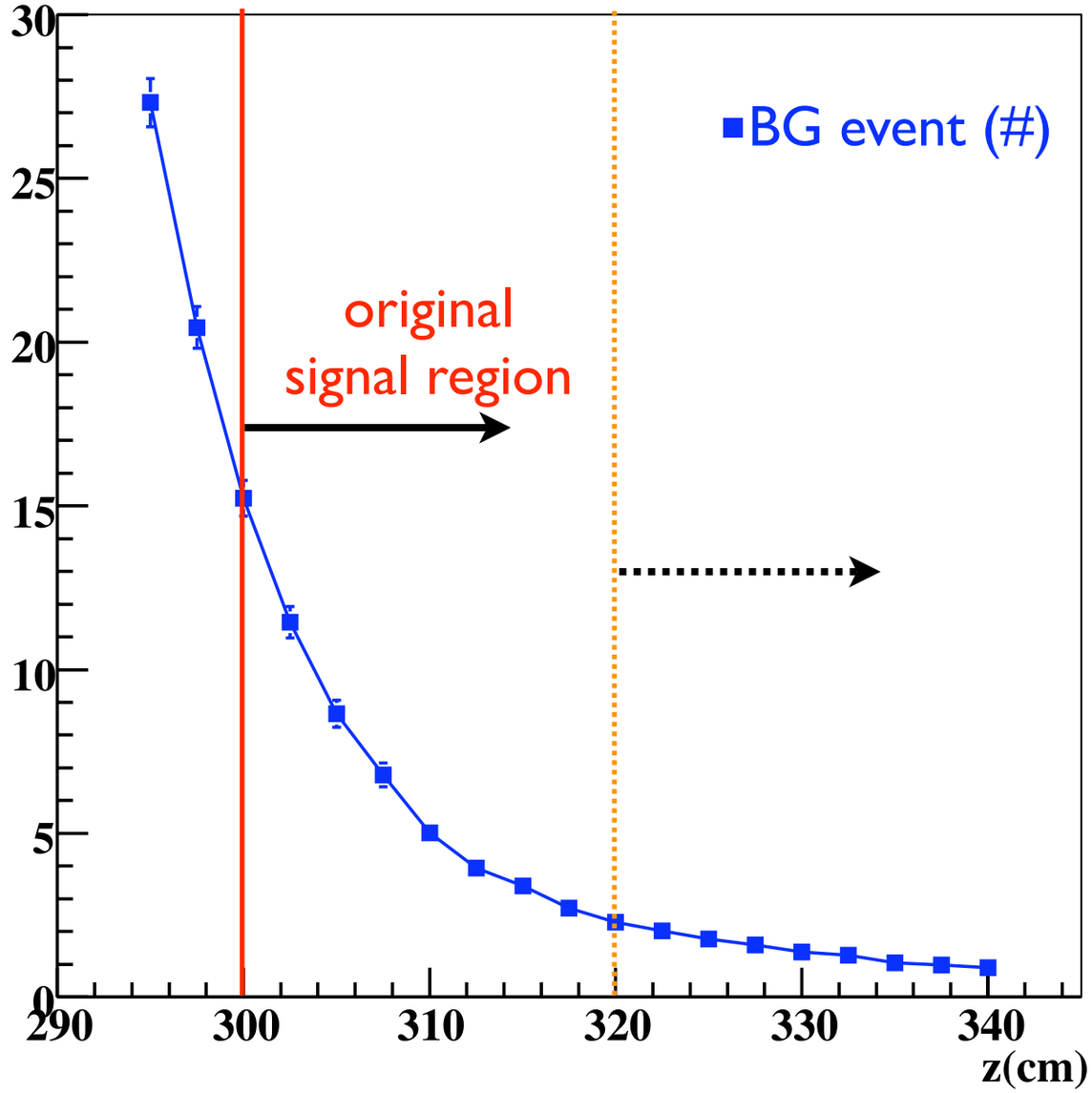




Result

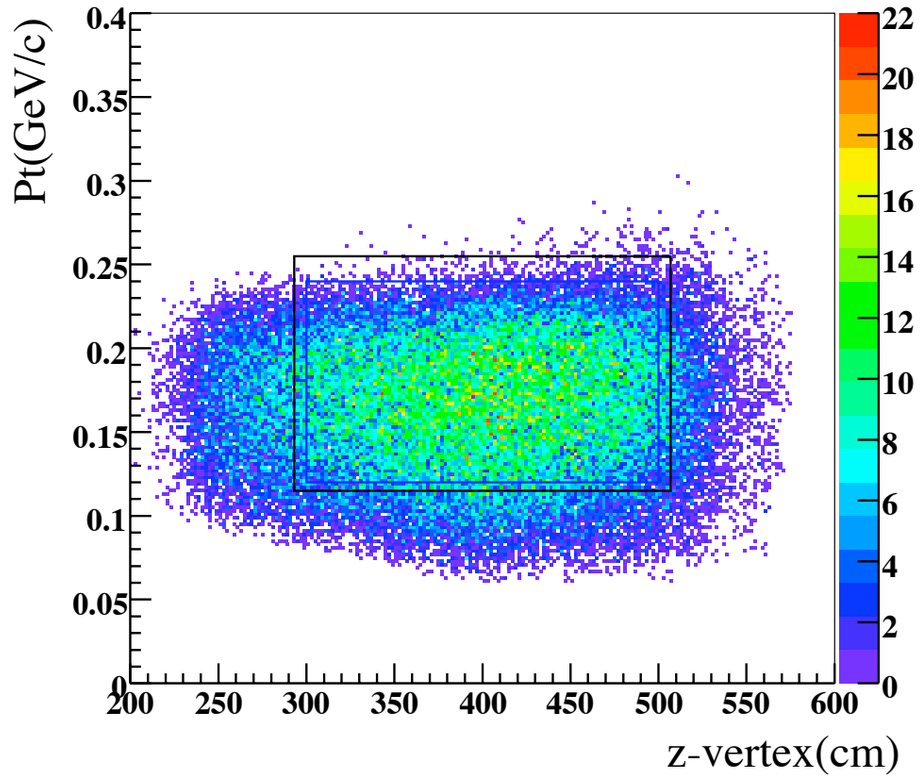
- counting the number of events in the box
  - fit functions not used
- BG events in upstream
  - z=300-320: 13.0 ± 0.6 events
  - z>320 : 2.3 ± 0.3 events

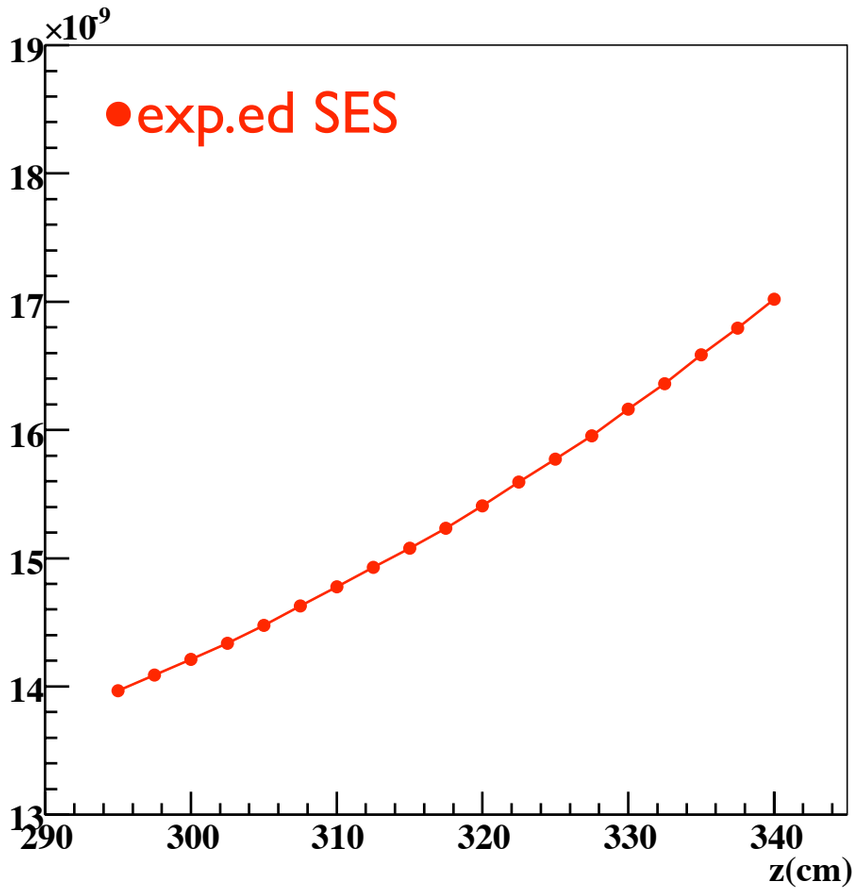


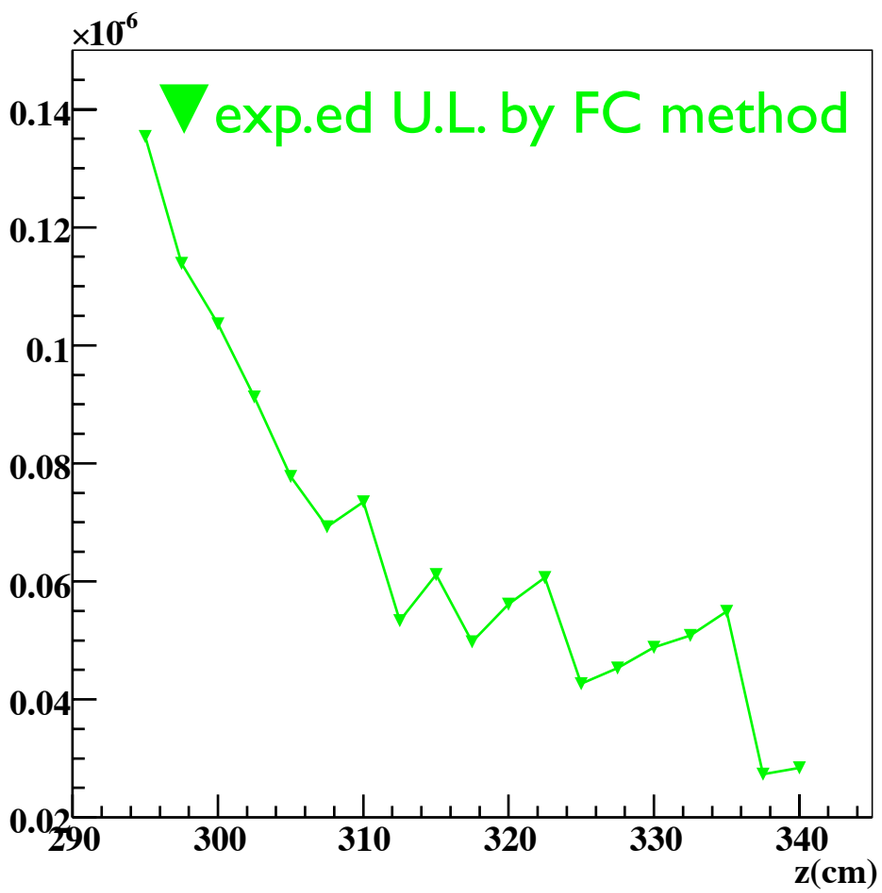


Sensitivity

- pi0nn MC
  - 10^8 KL
    - ex.) 40654 events in 320-500cm
  - Acceptance
    = 40654 / 10^8 / 0.0283 (decay prob.)
    * 0.8445 (acci. loss)
    = 1.21×10^{-2}
- NKL = $(5.35 \pm 0.74) \times 10^9$
- SES = $1 / (1.21 \times 10^{-2} * 5.35 \times 10^9)$
  = 1.54×10^{-8}







Summary

- we understand the behavior of backgrounds for $K_L \to \pi^0 \nu\bar{\nu}$
  - KL decays
    - well-reproduced by MC
    - almost negligible
  - Halo neutron background
    - two kinds of events
      - downstream
        - reproduced by the combination of MC's
      - upstream
        - estimated of the tail events by π^0 production at Al target
    - Result
      - still more than 3.0 event
        - developing further cuts

- Future
  - optimize upstream halo neutron events
  - examine other small background sources

⇒ open the BOX!!