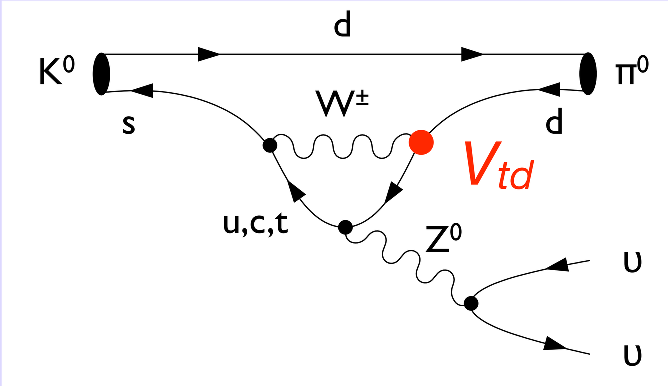
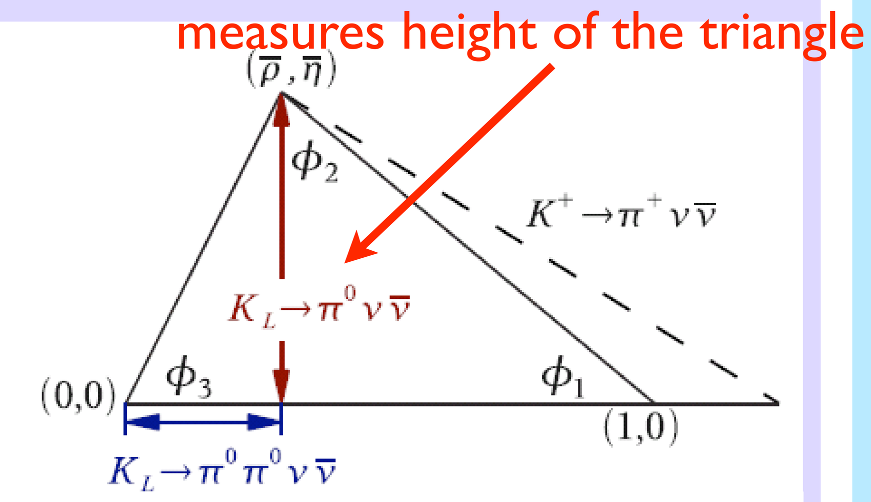
Final Results on the Rare Decay $K_L^0 \to \pi^0 \nu\bar{\nu}$ from the KEK-E391a Experiment

KEK-E391a Collaboration

Physics Motivation

- Features of this decay mode
  - "direct" CP violating process
  - measures η in CKM matrix
    $Br(K_L \to \pi^0 \nu \bar{\nu}) \propto \eta^2$
  - small theoretical uncertainty
    ~ a few % : called as "gold-plated" mode
  - rare decay : 2.5×10^{-11} @SM
- Comparison to the measurement in B-system
  - precise check of SM
  - probe to NP

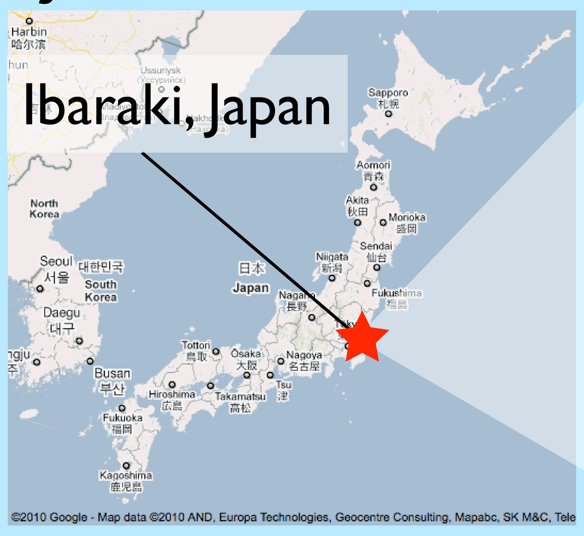


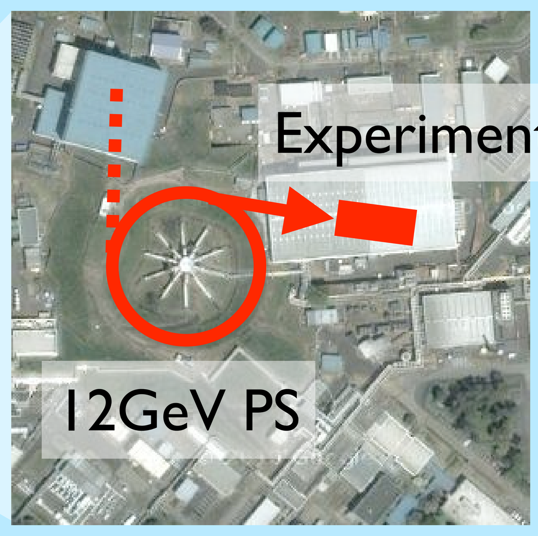


unitarity triangle of CKM matrix

E391a Experiment

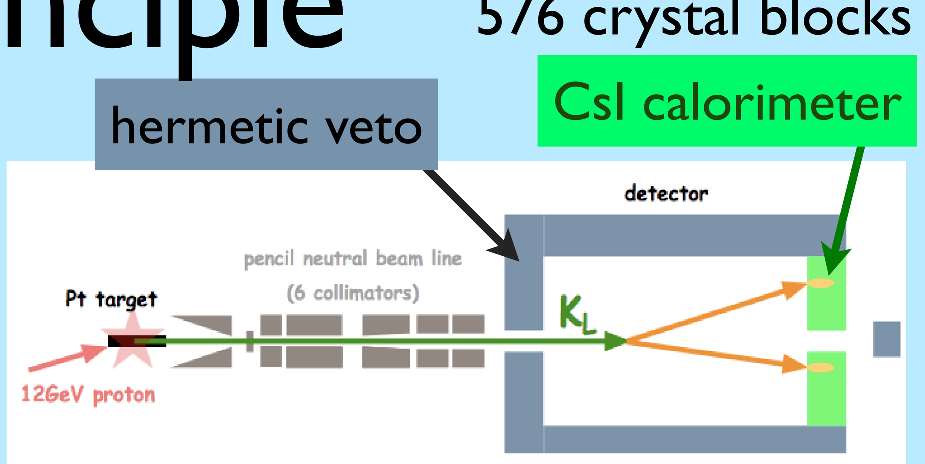
- Measures $K_L \to \pi^0 \nu \bar{\nu}$ @ KEK 12GeV PS (Japan)
  - first dedicated experiment to this decay mode
  - pilot experiment for K^OTO (J-PARC E14)
  - physics runs are taken in 2004-2005

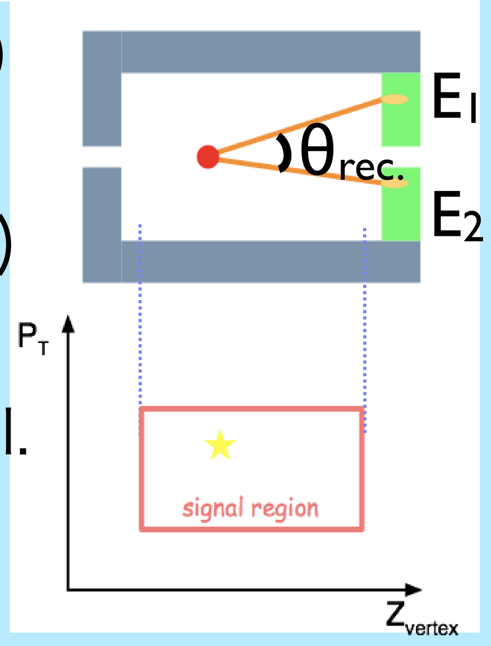




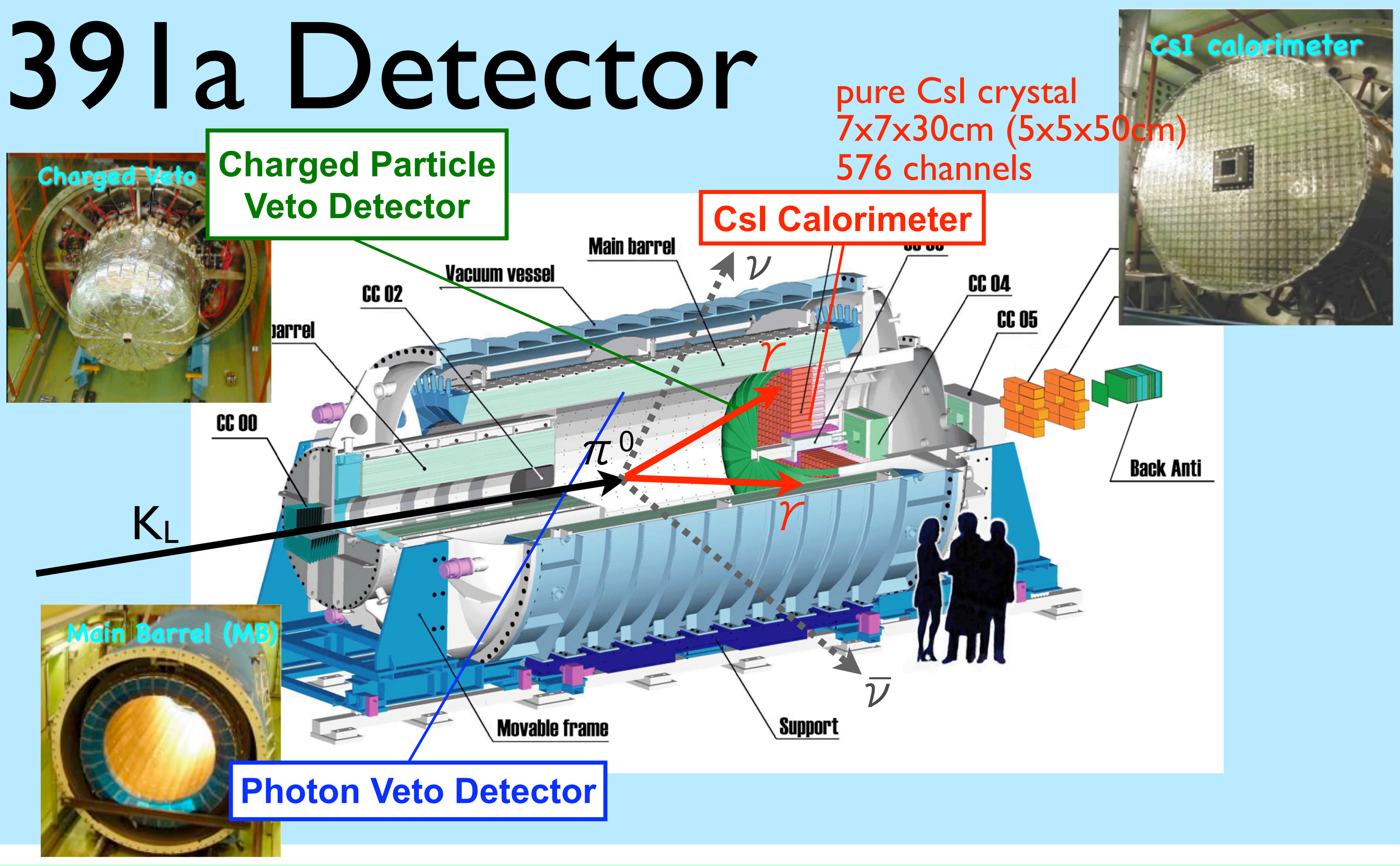
Detection Principle

- To identify
  $K_L \to \pi^0 \nu \nu$ state
  $\to 2\gamma$ → cannot detect
- To say "2γ + nothing"
  - 2γ → CsI calorimeter (energy, position)
  - nothing → hermetic veto detector
- Reconstruct decay vertex with $M(\pi^0)$
  $M(\pi^0)^2 = 2E_1E_2(1-\cos\theta)$
  ← "pencil" beam to improve p_T resol.
- select signal using decay vertex and transverse momentum



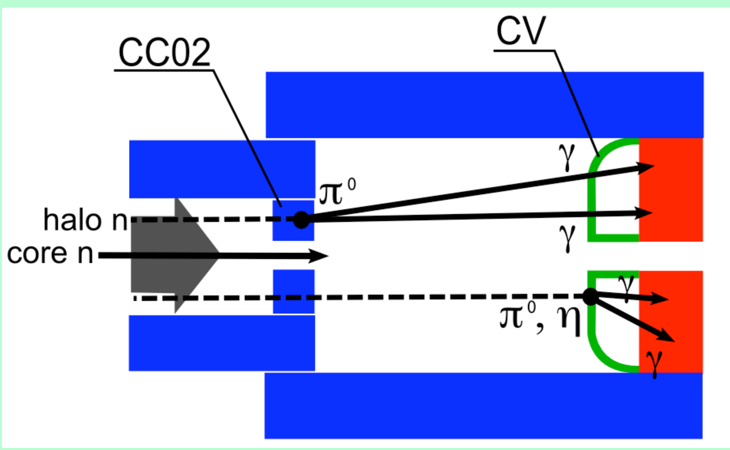


E391a Detector

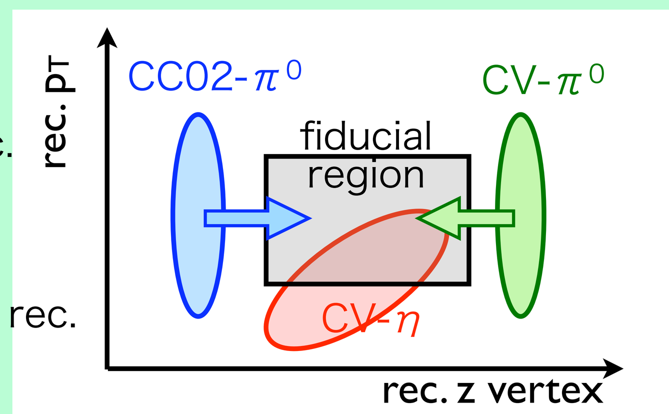


What makes background?

- Halo neutron BG : the dominant BG
  - neutron flux surrounding beam core hits detector around beam →creates π^0 or η ($\to 2\gamma$)

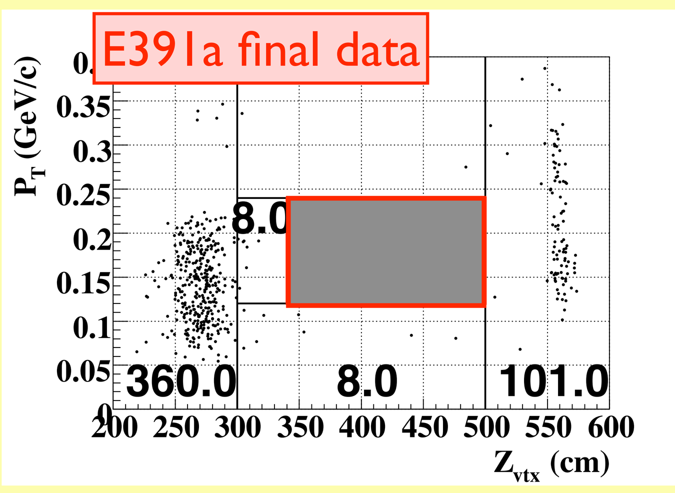


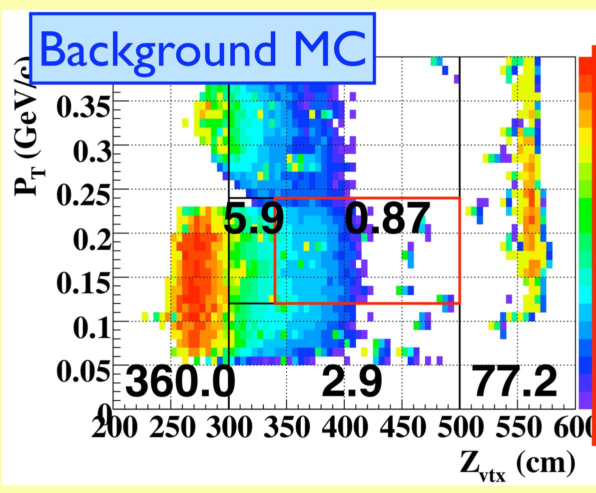
- Three types of halo-n BG :
  - Collar Counter (CC02) π^0 BG
    miss-meas. E_γ lower → larger $\theta_{rec.}$
  - CV π^0 BG
    miss-meas. E_γ higher → smaller $\theta_{rec.}$
  - CV η BG
    $M(\pi^0) \neq M(\eta)$ → smaller $\theta_{rec.}$



Background Estimation

- Halo neutron BG was estimated by FLUKA simulation
  - π^0 & η production rate was confirmed by a dedicated run

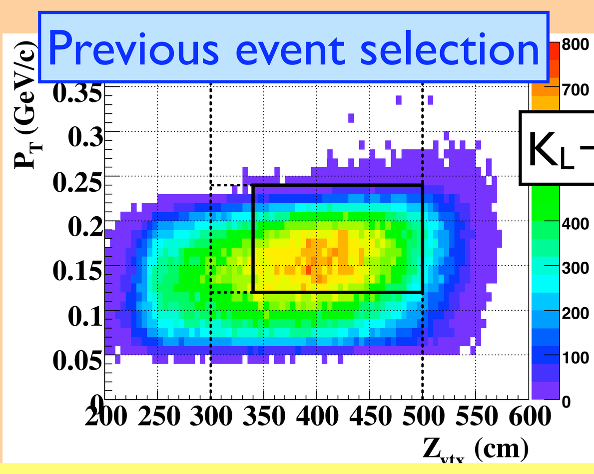


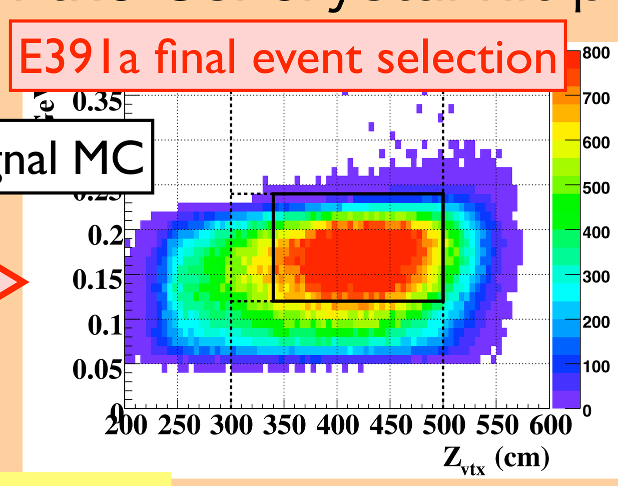


estimated # of BG	
CC02	0.66±0.39
CV-π^0	0.0 (<0.36)
CV-η	0.19±0.13
$K_L \to 2\pi^0$	0.02±0.02

Optimized Event Selection

- Event selection was optimized from our previous analysis
  - Introduced new selections on the CsI crystal hit pattern

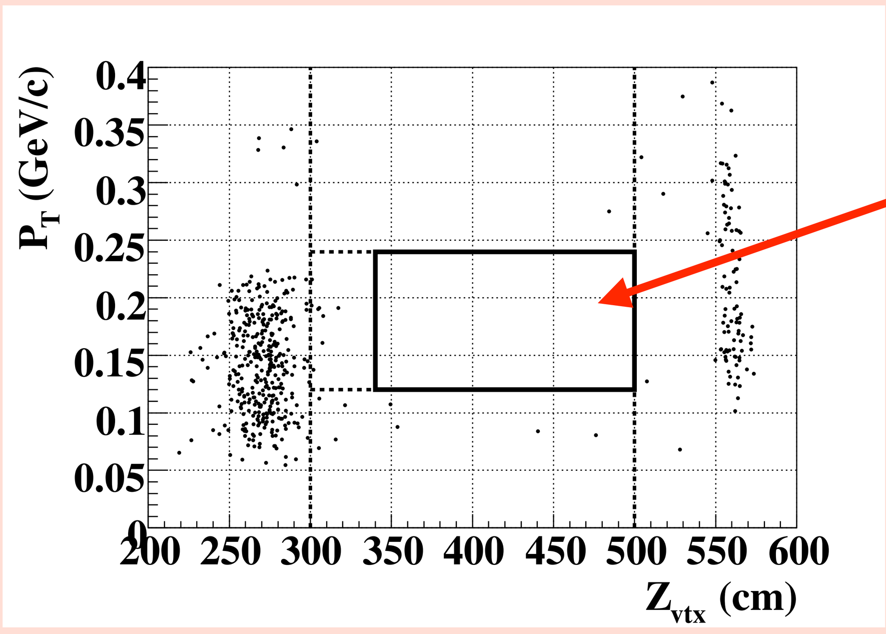




Acceptance : 0.67% → 1.04% (+50%) with keeping the S/N as same level

Results & Summary

- Opening the signal box for the final data sample



NO event observed in the signal box!

- Statistics
  - $(8.70 \pm 0.61) \times 10^9$ K_L decays
  - estimated by $K_L \to 2\pi^0$ event sample

E391a Final Upper Limit
$BR(K_L \to \pi^0 \nu\bar{\nu}) < 2.6 \times 10^{-8}$ @ 90% C.L.

- Improvements
  - ×20 from previous experiment (kTeV)
  - ×2.6 from our previous result