

# Search for $X(214)$ in $K_L \rightarrow \pi^0 \pi^0 X (X \rightarrow \mu^+ \mu^-)$ using Back-Anti counter at the E391a experiment

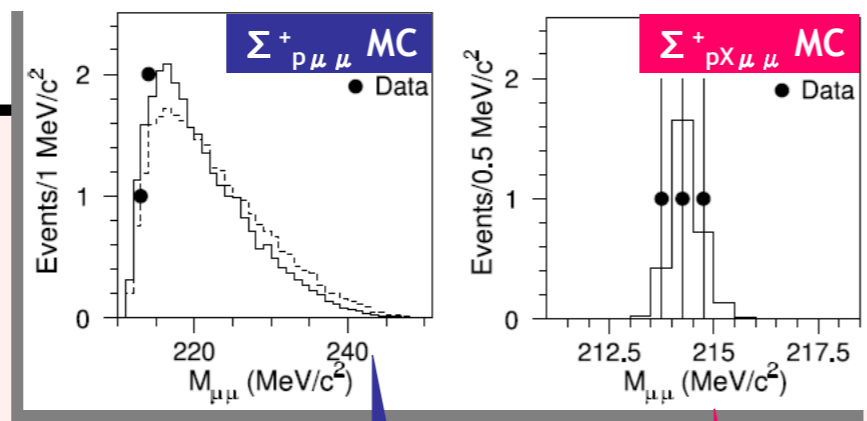


Risa Ogata (Saga Univ.) for the E391a collaboration

## Physics Motivation

### Hyper CP experiment @ Fermilab.

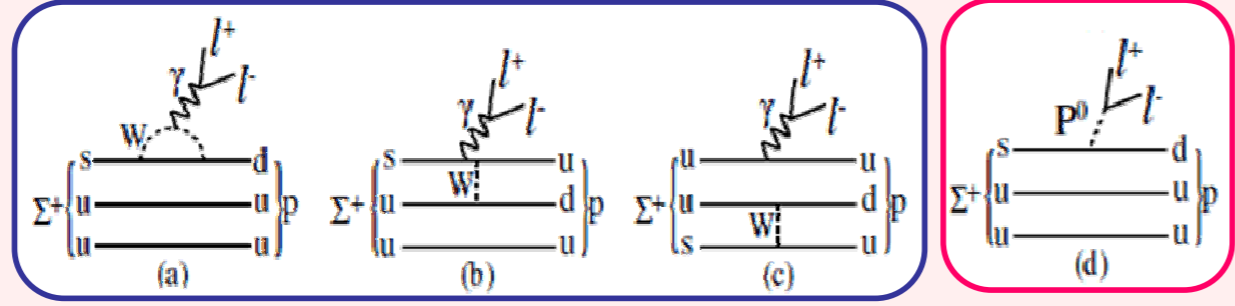
- $\Sigma^+ \rightarrow \rho \mu^+ \mu^-$  decay
- Invariant mass  $M_{\mu^+ \mu^-}$ :  $214.3 \pm 0.5 \text{ MeV}/c^2$
- 3 events found
- Data and phase space M.C. are quite different.



New Particle X is indicated !?

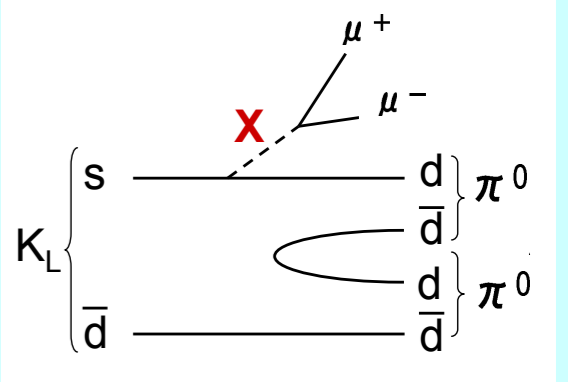
### What is "X" ???

- Invariant mass of X is around  $214 \text{ MeV}/c^2$ .
- might be Sgoldstino (super symmetry particle) ...? [PR D73(2006) 035002]
- Light higgs boson by the NMSSM [Phys.Rev.Lett.98(2007), 081802]
- Pseudoscalar (spinless)



## Search

- Search for  $K_L \rightarrow \pi^0 \pi^0 X$  decay (and  $\pi^0 \pi^0 \mu^+ \mu^-$  decay)
- FCNC process (as well as  $\Sigma^+ \rightarrow \rho \mu^+ \mu^-$  decay)
- Gorbunov and Rubakov suggested that this X particle can be searched in the  $K_L \rightarrow \pi^0 \pi^0 X$  decay process
- X can be decayed  $e^+e^-$ ,  $\mu^+ \mu^-$ ,  $\gamma \gamma$ ,  $\nu \nu$  etc...
- $\text{Br} = 1.2 \times 10^{-8}$  (Gorbunov and Ruvakov predicted. [PR D73(2006) 035002] etc...)



## Search by E391a exp.

### Hermetic veto system

- Detectors in beam hole.  $\rightarrow$  BHCV, Back Anti(B.A.)
- Small Q-value ( $K_L \rightarrow \pi^0 \pi^0 X(214)$ ,  $X(214) \rightarrow \mu^+ \mu^-$ )
- 2muon go into the beam direction  $\rightarrow$  Can be detected by beam hole counters
- $\pi^0 \pi^0 \rightarrow 4 \gamma$  is detected by Csl calorimeter

### Using RUN III full data

- B.A. was upgraded using the fine segmented  $\text{PbWO}_4$  (PWO) scintillator blocks  $\rightarrow$  Muons can be well identified
- Momentum can't be measured. (No magnet in E391a detector)

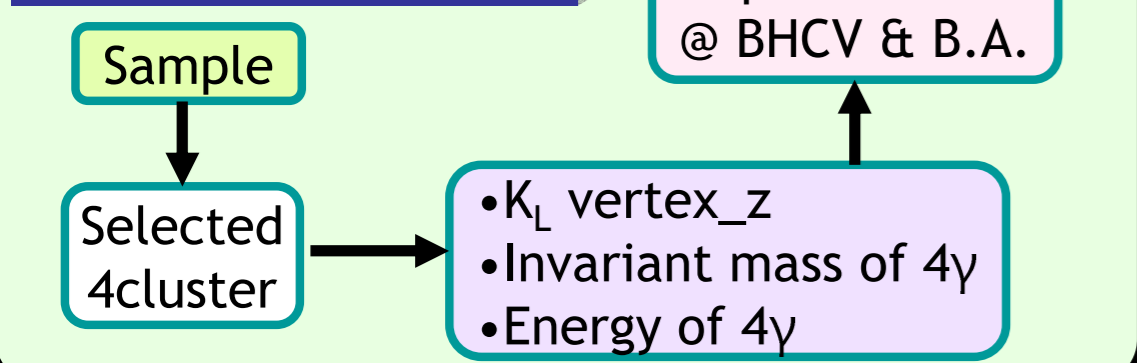


## Event Selection

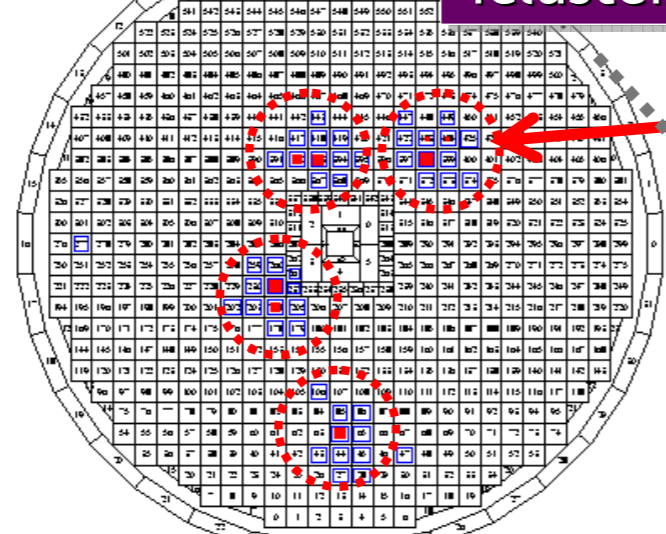
### Required

- 4clusters by Csl calorimeter
- Invariant mass of reconstructed  $4 \gamma$
- Energy of each  $4 \gamma$
- $K_L$  Vertex\_z
- 2muons @B.A. (only PWO info.) & BHCV

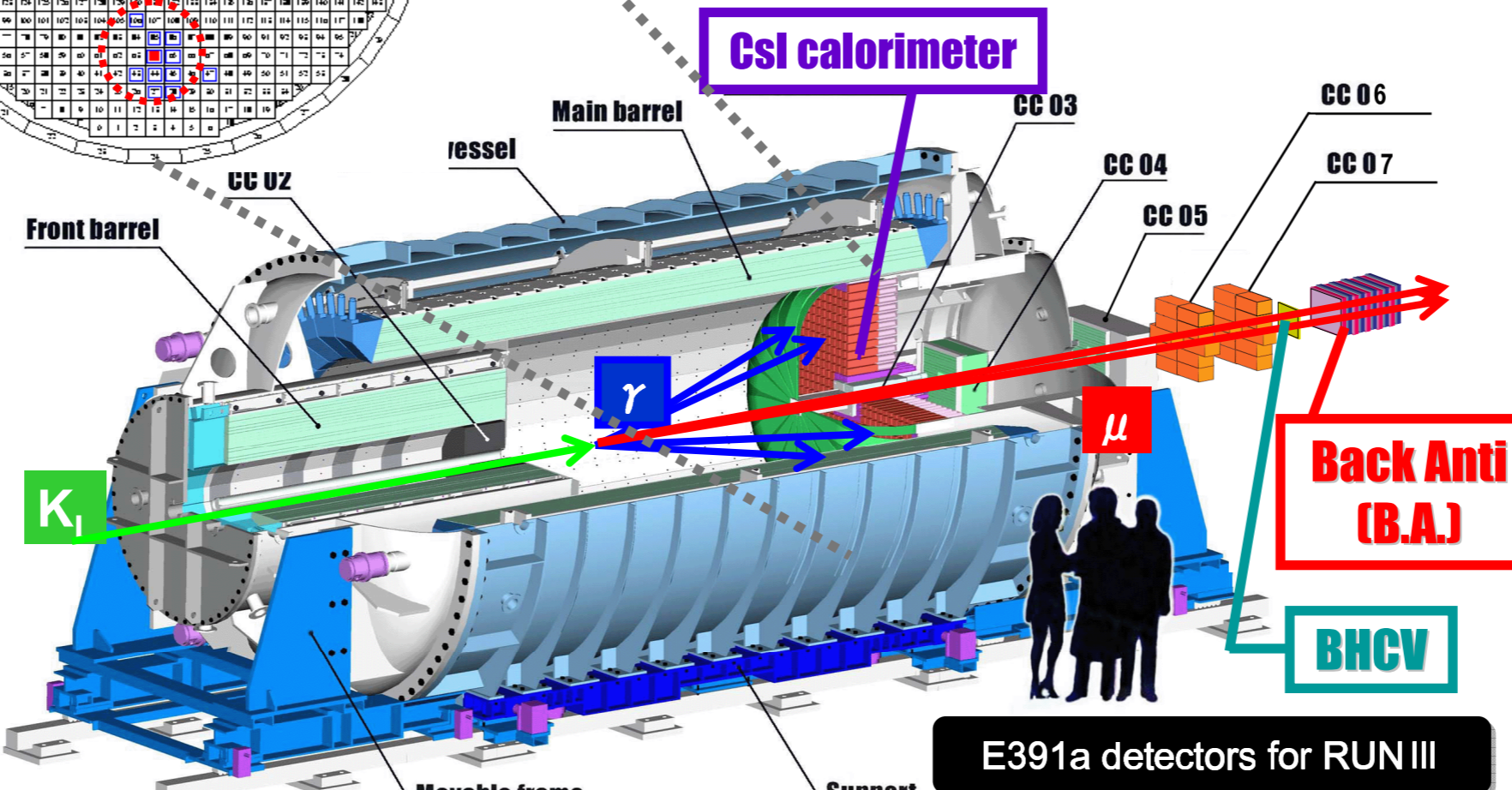
### Process of analysis



### 4clusters @Csl



Cluster defined as a group of neighboring Csl crystal with finite energy deposit



## Analyzed Sample

### $\pi^0 \pi^0 X(X \rightarrow \mu^+ \mu^-)$ & $\pi^0 \pi^0 \mu^+ \mu^-$ M.C.

- # of incident  $K_L$ :  $3 \times 10^8$  events
- Invariant mass of X:  $214.3 \text{ MeV}/c^2$
- $\text{Br}(X \rightarrow \mu^+ \mu^-)$ : 100%
- Decay probability: 2%

### RUNIII full data

- $K_L$  flux:  $3.4 \times 10^9$  events (# of decayed  $K_L$  in decay volume)

### 3 $\pi^0$ M.C.

- # of incident  $K_L$ :  $5 \times 10^9$  events (~20% of RunIII data)

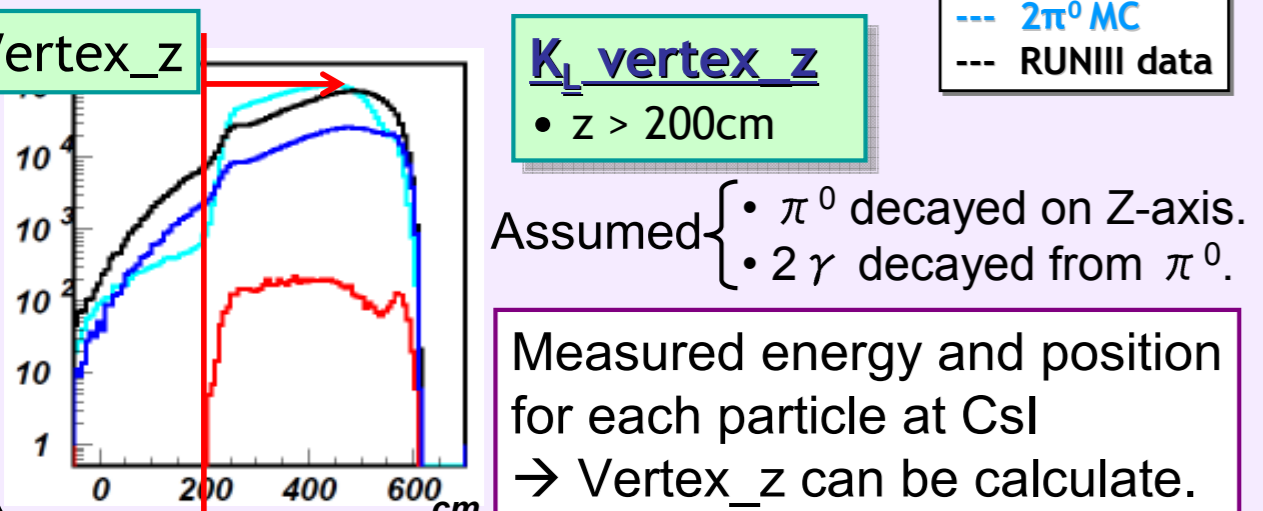
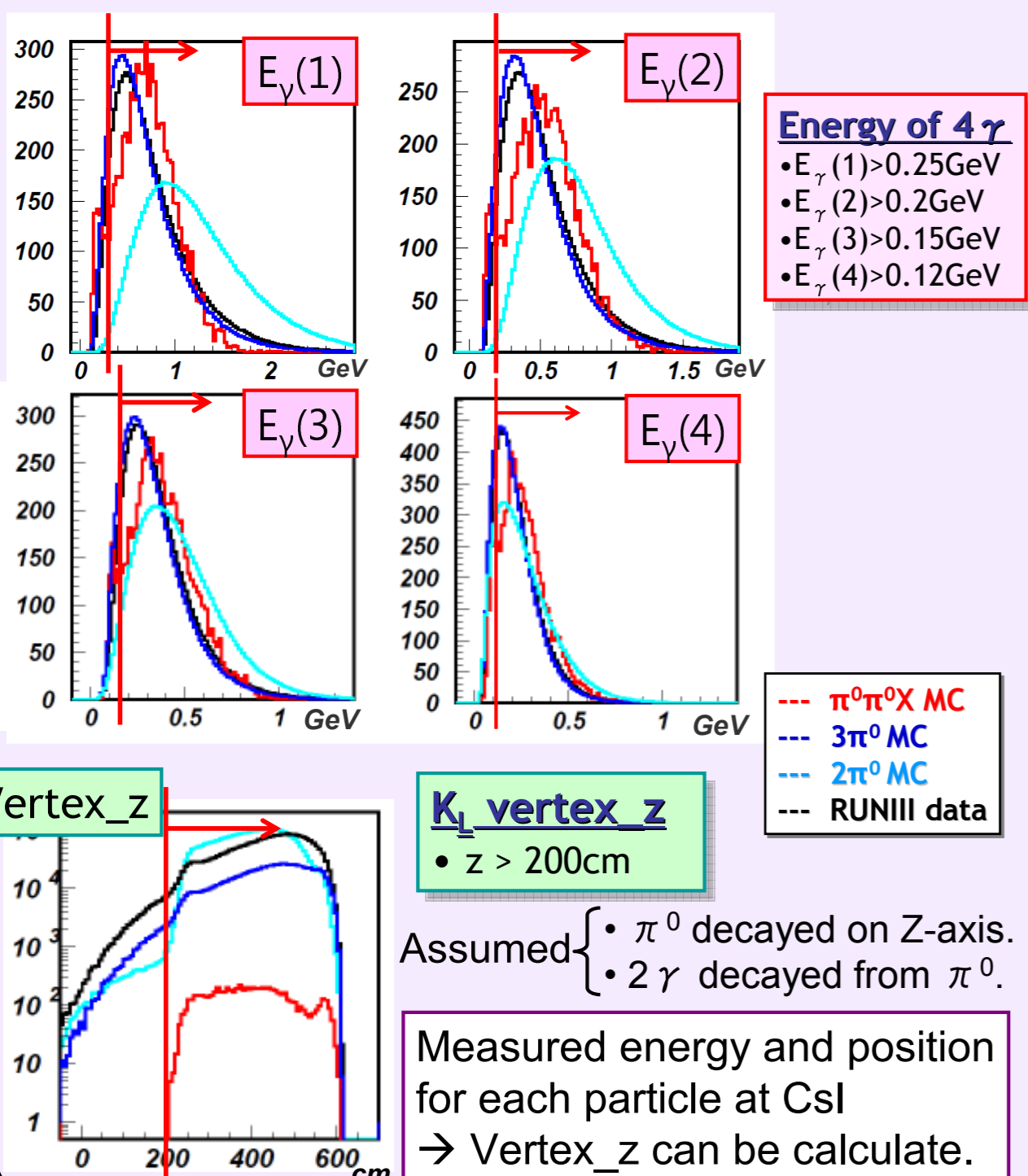
### 2 $\pi^0$ M.C.

- # of incident  $K_L$ :  $1.5 \times 10^9$  events ( $\gg$  RunIII data)

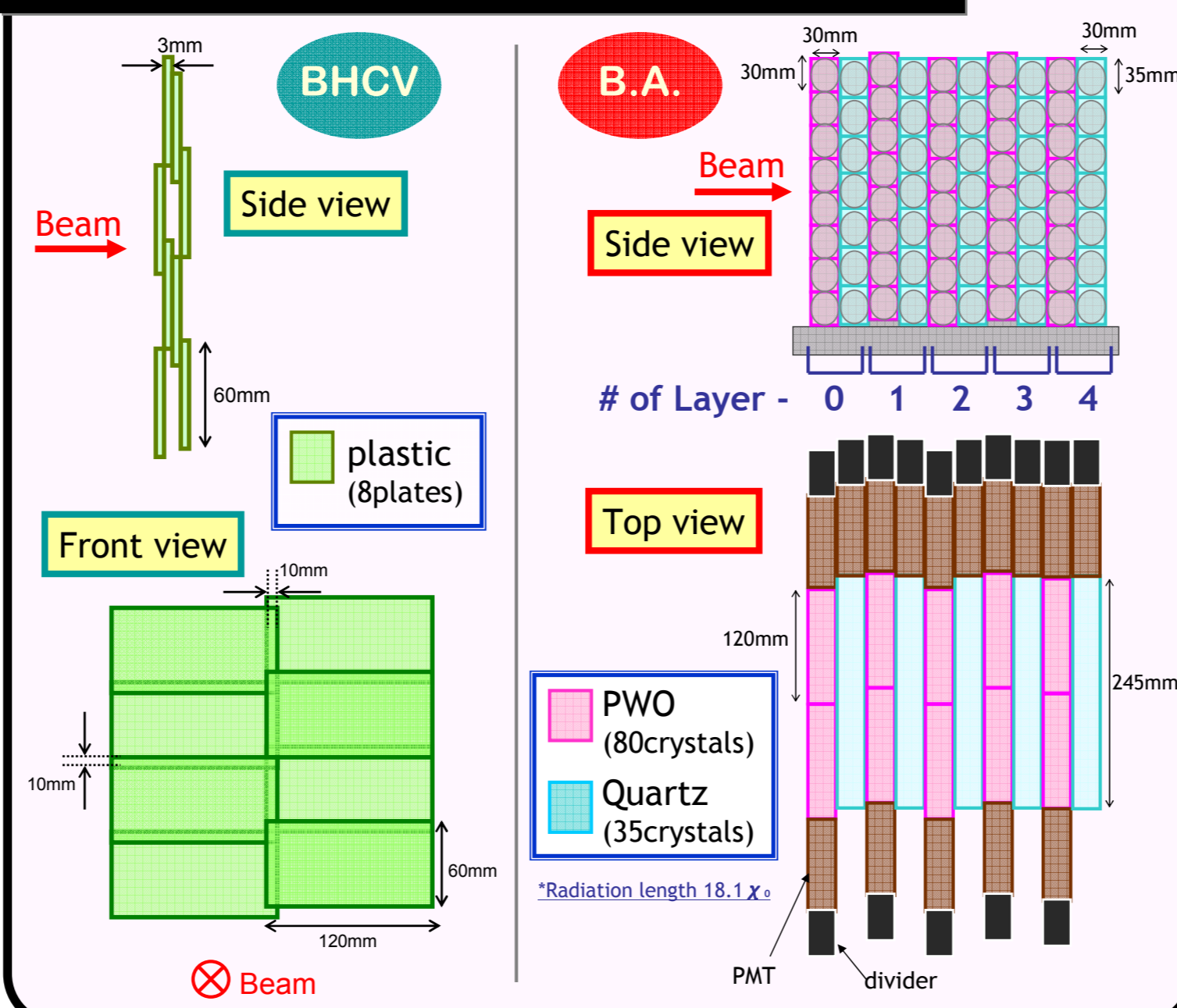
### Feed across from major decay modes

- $K_L \rightarrow \pi^0 \pi^0 +$  accidental hit@beam hole counter(BC)
- $K_L \rightarrow \pi^0 \pi^0 \pi^0$  (1  $\gamma$  missing + 1  $\gamma$  hits BC)
- $K_L \rightarrow \pi^0 \pi^0 \pi^0$  (2  $\gamma$  missing + accidental hit@BC)

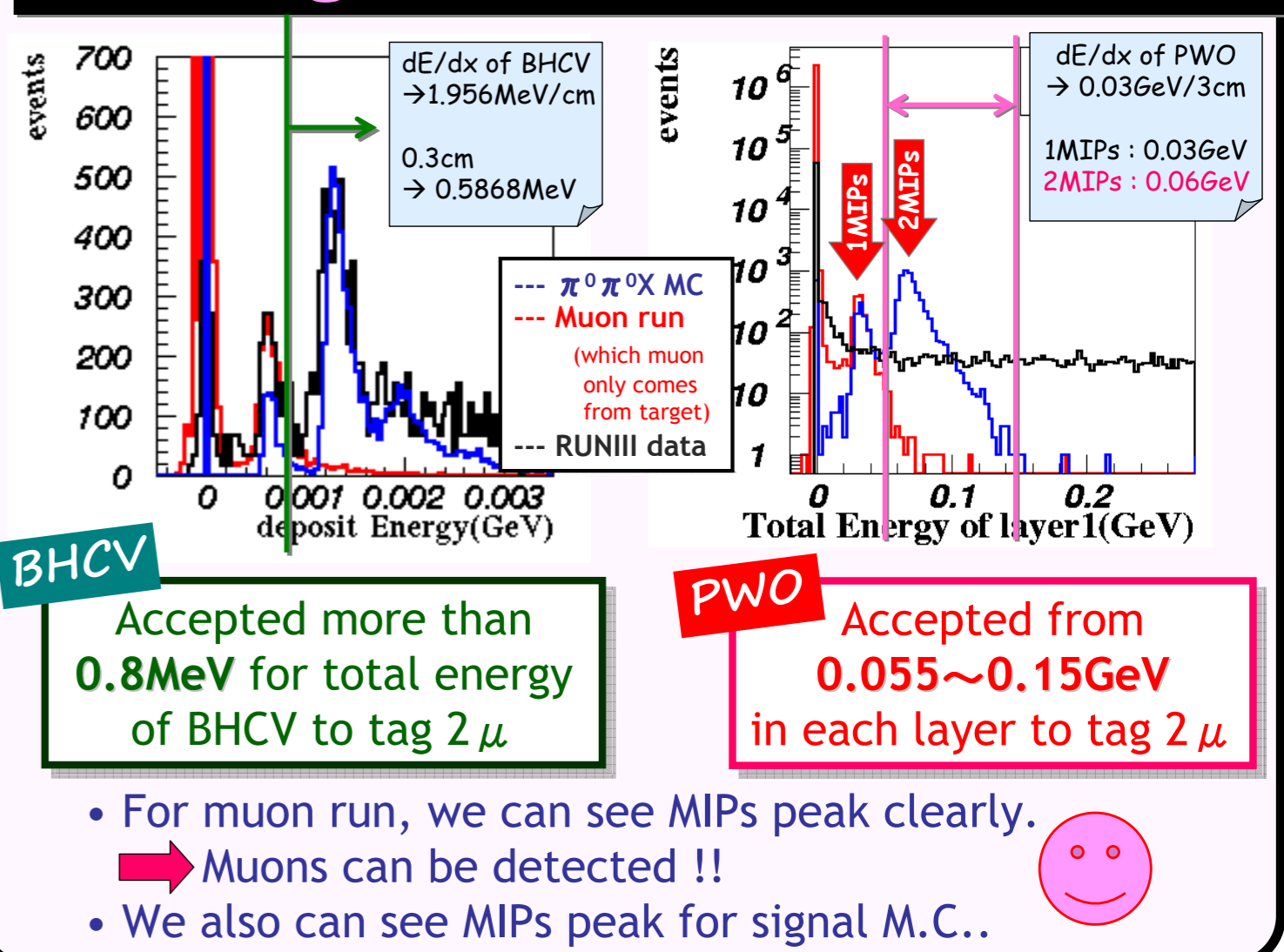
## Selected $\gamma$ from Csl Info.



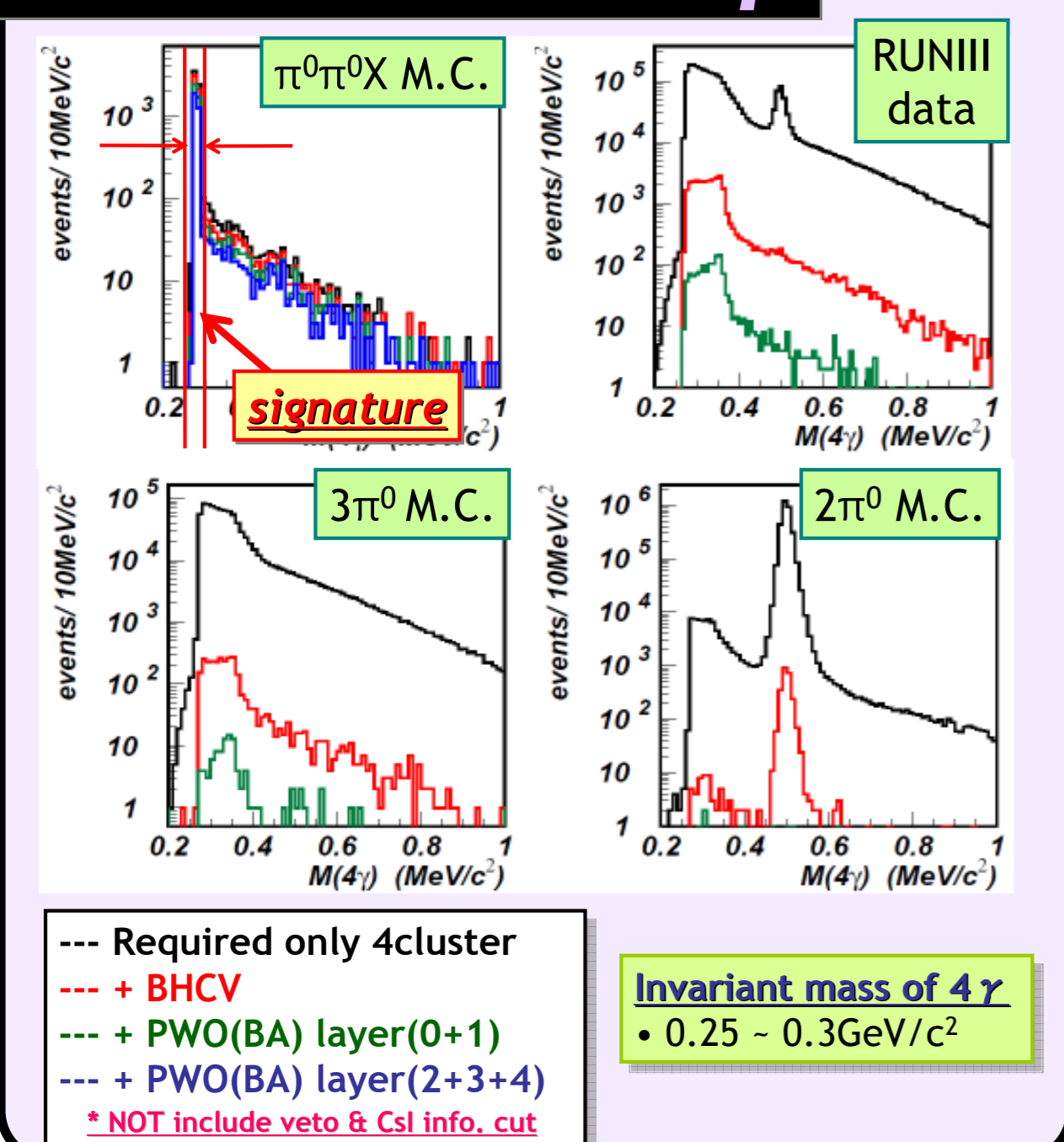
## Construction of BHCV & B.A.



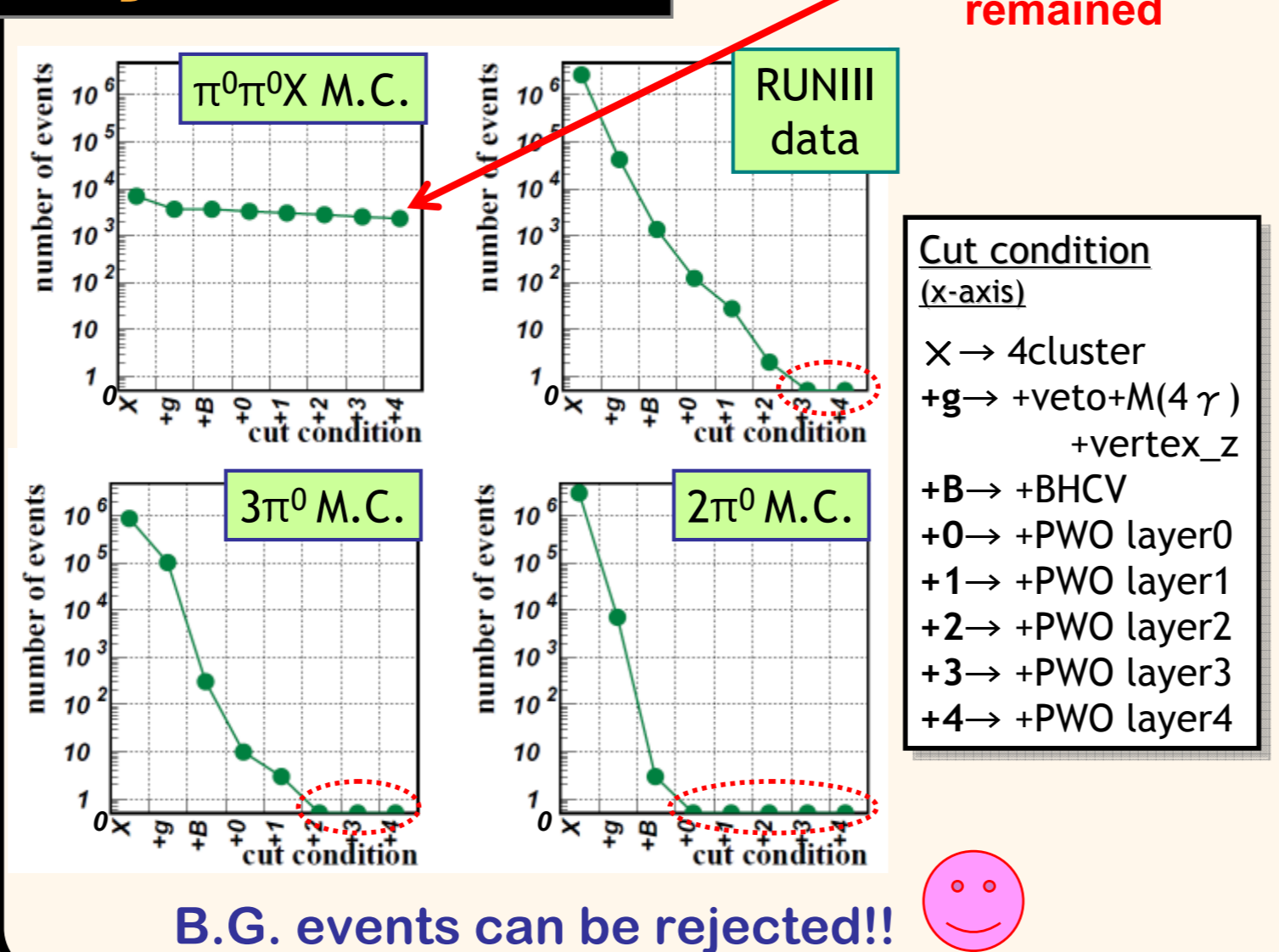
## MIPs signal for BHCV & PWO(B.A.)



## Invariant Mass of 4 gamma



## Rejection Power



## Acceptance & Single Event Sensitivity

$\star K_L$ :  $3 \times 10^8$  generated, decay prob.: 2%,  $N_{KL}$ :  $3.4 \times 10^9$

Acceptance =  $\frac{\text{remaining events}}{\text{gen. KL} \times \text{decay prob.}} = \frac{2344}{3 \times 10^8 \times 0.02} = 3.9 \times 10^{-4}$

S.E.S. =  $\frac{1}{N_{KL} \times \text{Acceptance}} = \frac{1}{3.4 \times 10^9 \times 3.9 \times 10^{-4}} = 7.5 \times 10^{-7}$

Decay mode	Cut condition	remaining events	acceptance	S.E.S.
$\pi^0 \pi^0 X$	$M(4 \gamma) + \text{PWO} + \text{vertex}_z$	2344	$3.9 \times 10^{-4}$	$7.5 \times 10^{-7}$
$\pi^0 \pi^0 \mu^+ \mu^-$	$\text{PWO} + \text{BHCV}$	4174	$6.9 \times 10^{-4}$	$4.3 \times 10^{-7}$

## Summary

- We searched for  $X(214)$  in  $K_L \rightarrow \pi^0 \pi^0 X (X \rightarrow \mu^+ \mu^-)$  decay.
- Noise reduction  $\rightarrow$  B.G. events can be rejected.
- Signal event "X(214)" is empty.
- Upper limit (@90% CL)
  - $\text{Br}(K_L \rightarrow \pi^0 \pi^0 X(X \rightarrow \mu^+ \mu^-)) < 1.7 \times 10^{-6}$
  - $\text{Br}(K_L \rightarrow \pi^0 \pi^0 \mu^+ \mu^-) < 9.9 \times 10^{-7}$