A brief consideration on μ-bunched beam for $K_L \rightarrow \pi^0 \nu\nu$ experiment

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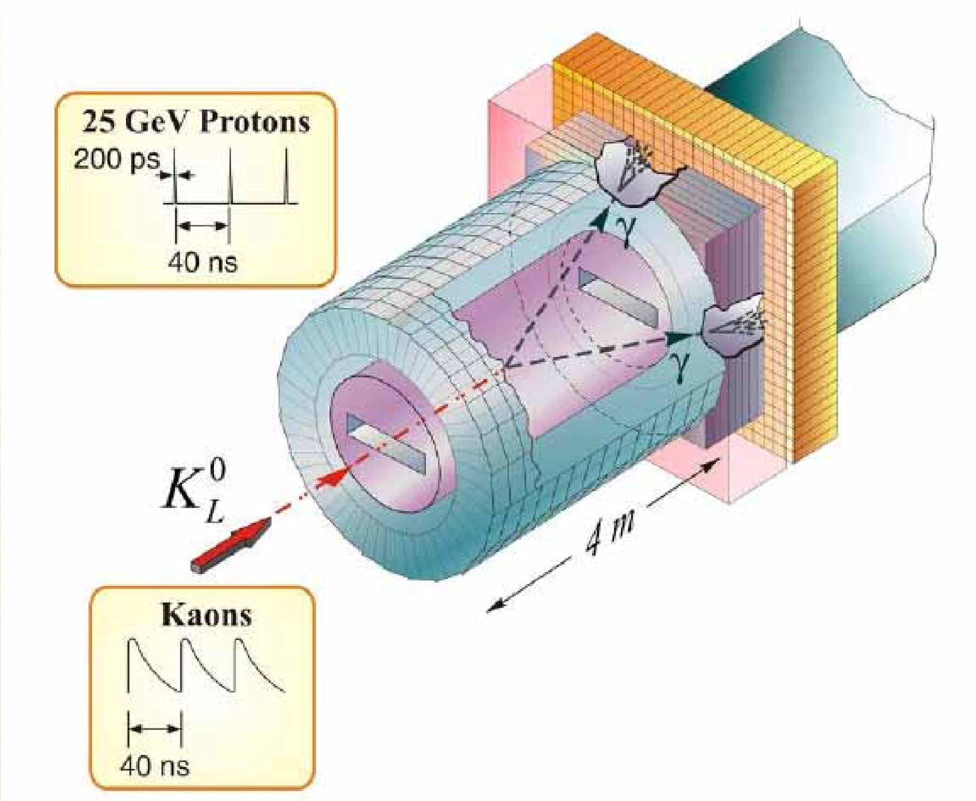
μ-bunched beam - KOPIO case

- Protons packed in narrow bunch
  (a few hundred ps)

→ One can know K_L (and other) generated time



μ-bunched beam - KOPIO case

- TOF measurement
  with low momentum K_L (<1GeV/c)
- Calculate kinematic variables
  in K_L rest frame and
  obtain additional BG rejection
  - For example,
    $E^*(\pi^0)$ of $K_L \rightarrow 2\pi^0$ becomes monochromatic

Application to E14 and toward

- Possible benefits

1. TOF difference between K_L and neutrons
   - To reduce neutron-induced backgrounds

2. TOF difference between K_L decay photon and beam photon and neutron
   - For in-beam photon veto detector

3. K_L momentum (velocity) measurement

Points to be considered

- K_L yield in one bunch
- Arrival time chart of K_L, n, γ
  at the detector
- ~~Required resolution for β measurement~~
  I can't cover it at this time. Sorry.

K_L yield in one μ-bunch

- Multiple K decays in one μ-bunch cause accidental signal loss.
  - Loss = P(n>=2)/P(n>=1) ~ <x>/2

<x>: mean of N(decay) in a bunch

	NK_L/spill	Decay prob	N decay	μ-bunch freq for <x>=0.2
step1	8×10^6	~10% (in 6m)	1MHz	5MHz
step2	4×10^7	~10% (in 15m)	6MHz	30MHz

Spill length is assumed to be 0.7sec.

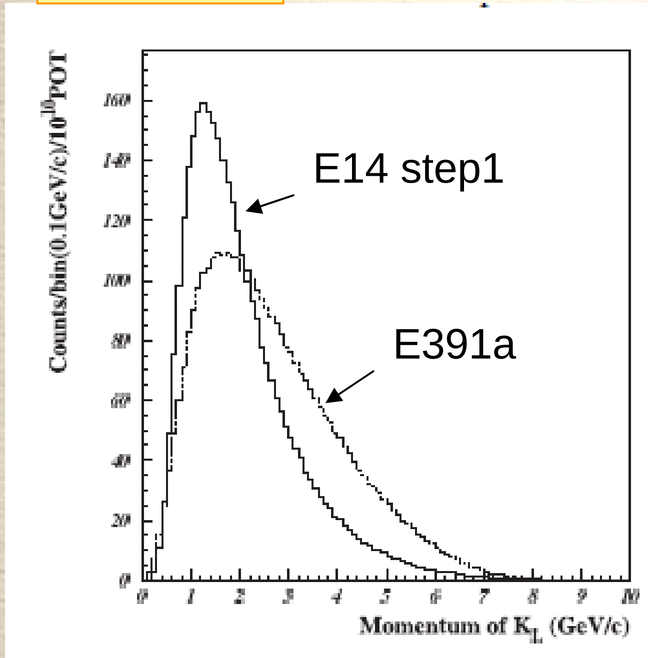
Arrival time chart

- Arrival time of photons at the calorimeter
    - Z(calorimeter)=Z(downstream end) for easiness

    - Consider arrival time window for K_L decay = momentum window for K_L
    - Consider photons from neutron interactions with materials (a detector) at
        - Upstream end of decay region
        - Downstream end of decay region

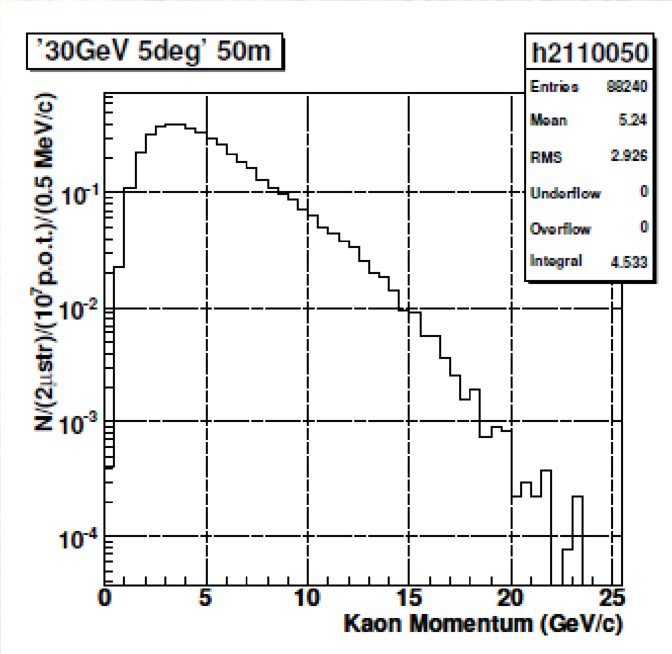
Arrival time window ~ P_K window

P_K Step 1



From E14 proposal

P_K Step 2

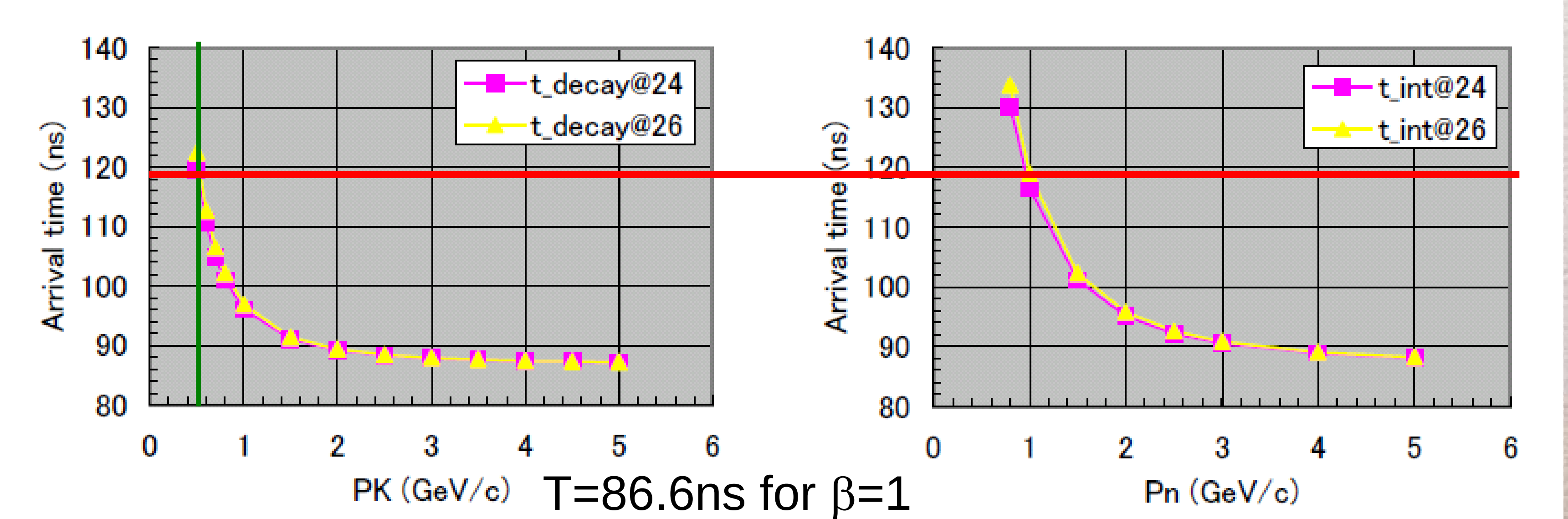


From master thesis by Nakajima (2006, Kyoto U)

Arrival time chart : step1

Decay region		K_L momentum		
Begin	End	Min	Av.	Max
(21+3) m	(21+5) m	~0.5	~2	~3

➔Not so effective,
since harmful neutrons
(above π^0 production thres.; ~1GeV/c) can't be rejected



T=86.6ns for β=1

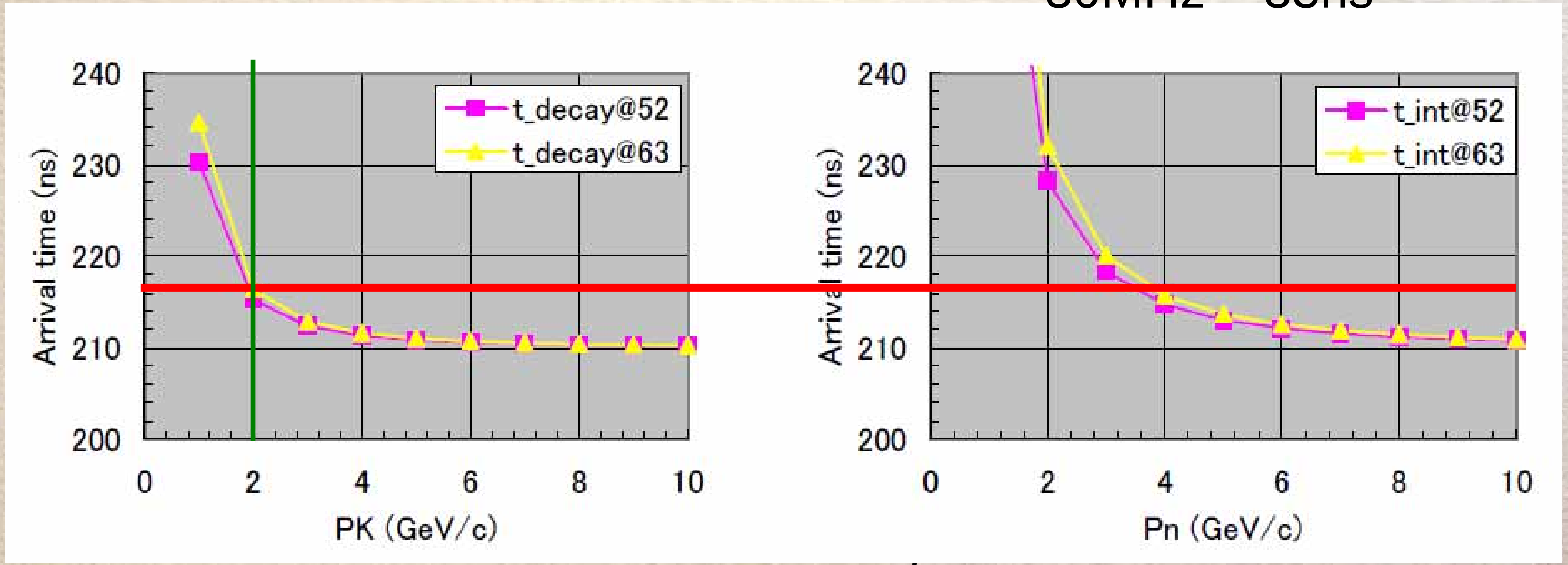
Arrival time chart : step2

Decay region		K_L momentum		
Begin	End	Min	Av.	Max
(50+2) m	(50+13) m	~2	5.2	~8

➔May have a chance to reject halo n BG.

But...,

recall required repetition:
30MHz = 33ns



Arrival time chart at in-beam veto

1. Beam photons come first.
2. K decay photons come next.
3. Beam neutrons come at last.

(2 & 3 depends on momentum)

← We want to detect "2" only

Can we distinguish them by arrival time and avoid performance loss?

➔ Unfortunately, "NO"

Arrival time chart at in-beam veto

- Difference between beam photon and K decay photon
  - Same as arrival time difference at the calorimeter (see previous slides)

  ➔ difficult to distinguish in both step1 and 2
- Difference between neutron and K decay photon

  ➔ May have a chance in step1

  ➔ probably not in step2 due to harder core neutron

Large angle extraction?

- Pros
  - Lower K_L momentum, better TOF resolution
  - Softer neutron, less harmful
- Cons
  - Less K_L yield (N(45deg)/N(5deg) ~ 1/10?)
  - Larger target image, impact on beam-line design
- BG rejection power, not clear

Detailed studies are necessary

Summary

- Back-of-an-envelope consideration
  for μ-bunched beam option
  → So far, I cannot find promising merit
  in case step1 (16deg) and step2 (5deg)
  → But, it depends on various parameters

- Further consideration is needed
  - BG rejection, parameter optimization, etc.