KOPIO sensitivity and backgrounds

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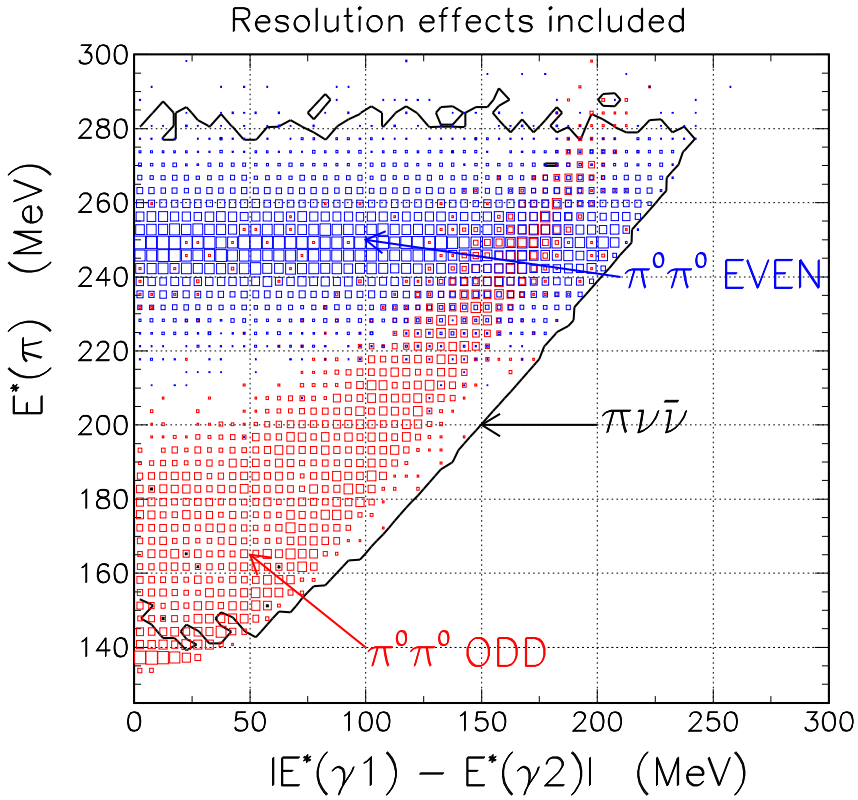
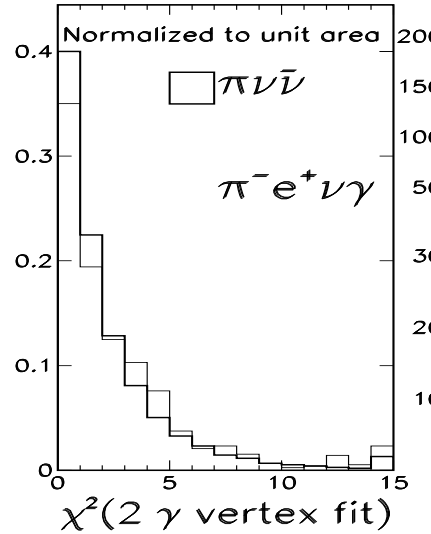
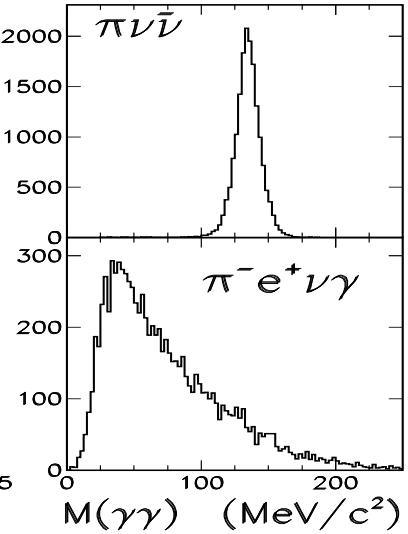
From the TDR:

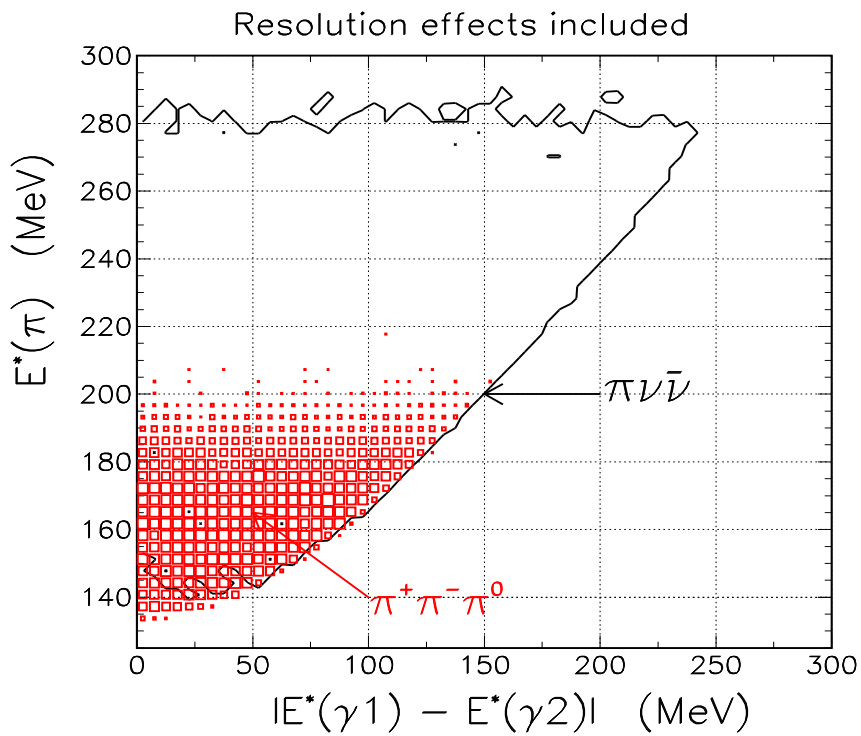
Main process	Related Modes	Events
$K_L^0 \to \pi^0 \nu\bar{\nu}$		41
$K_L^0 \to \pi^0\pi^0$	$\pi^0\gamma\gamma$,$\pi^0\pi^0\pi^0$	12.8
$K_L^0 \to \pi^- e\nu\gamma$	$\pi^\pm\ell^\mp\nu\gamma$,$\pi^\pm\ell^\mp\nu\pi^0$,$\pi^+\pi^-\gamma$	4.4
$\pi^+\pi^-\pi^0$		0.65
$\gamma\gamma$		0.02
$K_L^0 \to \pi^- e\nu$	$\pi^\pm\ell^\mp\nu$,$\pi^+\pi^-$	0.02
$\Lambda \to \pi^0 n$	$\Sigma^+ \to p\pi^0$,$K^\pm \to \pi^\pm\pi^0$	0.01
$nA \to \pi^0 X$	n, γ, K_L^0 Interactions	0.2
Accidentals		0.8
Total		18.9

I will comment on studies since the TDR and conclude with what could be done for the new proposal.









Kinematic background suppression

Some KOPIO performance requirements

Parameter	Minimal Requirement	Expected Performance
E_γ resolution	$3.5\%/\sqrt{E}$	$2.7\%/\sqrt{E}$
θ_γ resolution(250 MeV)	25 to 30 mrad	23 mrad
t_γ resolution	100 ps$/\sqrt{E}$	50 ps$/\sqrt{E}$
x_γ,y_γ resolution(250 MeV)	10 mm	< 1 mm
microbunch width	300 ps	200 ps
microbunch extinction	10^{-3}	$< 10^{-3}$
photon veto inefficiency	$\bar{\epsilon}_{\mathrm{E787}}$	$0.3\bar{\epsilon}_{\mathrm{E787}}$
charged veto ineffiency	$10^{-5}(\pi^+), 10^{-4}(\pi^-)$	$< 10^{-5}(\pi^+), < 10^{-4}(\pi^-)$

Assumptions about backgrounds

Resolutions for preradiator (PR) and calorimeter (CAL) approximated in FastMC

- TN034 and subsequent documents: $\sigma/E = 2.5\%/\sqrt{E(\mathrm{MeV})}$ "ideally" for PR/CAL.
- TN014, TN016, TN066: Simulated and prototype PR with required position, angular resolution.
- Not verified with reconstruction algorithm (see figures), most important for energy and time resolution.

Can we develop a reconstruction algorithm that can achieve the required resolution on 'data' from the GEANT simulation?

In my opinion, this is the the single most important task in confirming the signal and background predictions of the proposal.

Reconstruct this

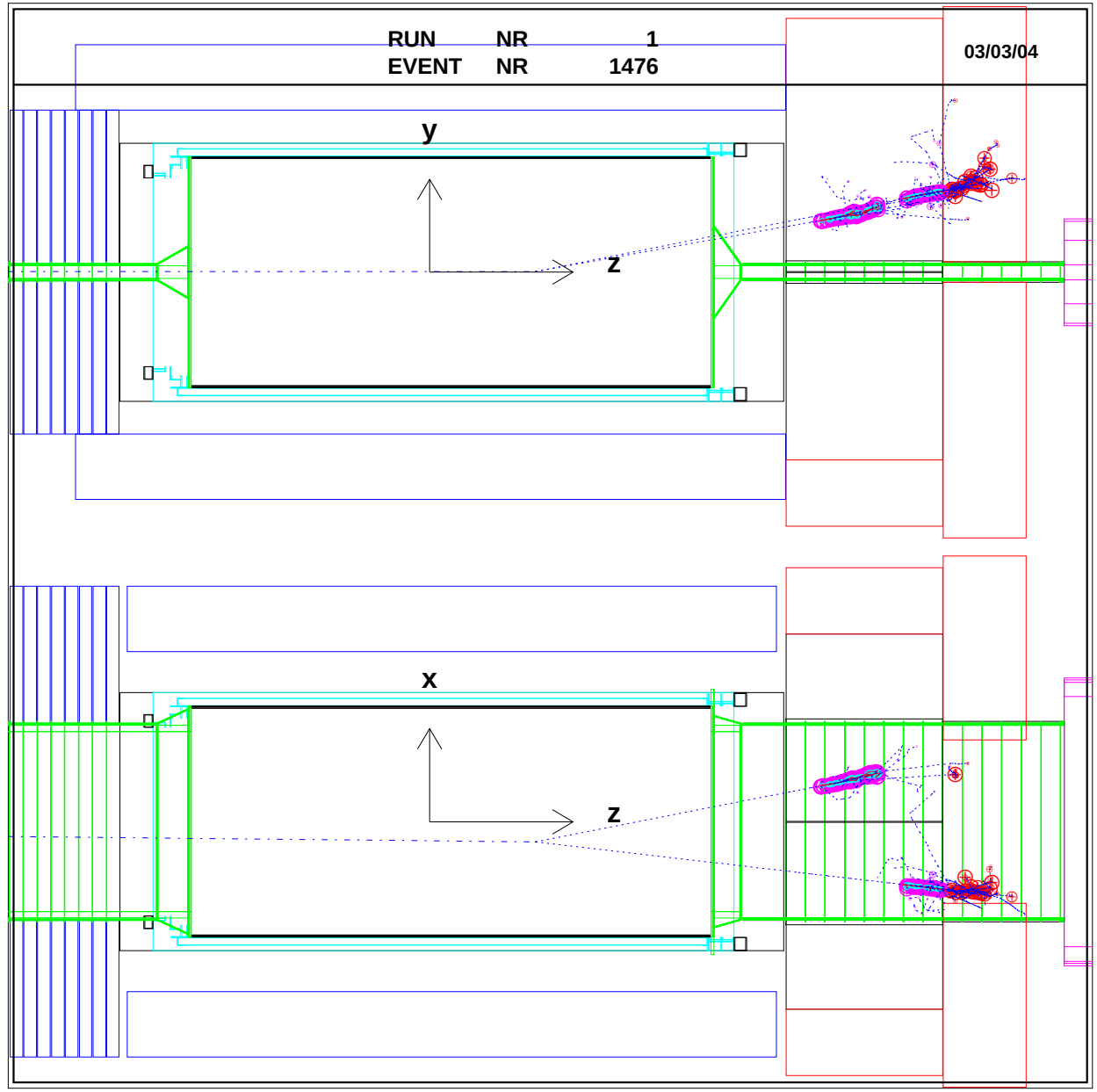
View of decay region and Outer Veto,PR,CAL for $K_L^0 \to \pi^0 \nu\bar{\nu}$ decay in MC.

K_L^0 = Dot-dash line,

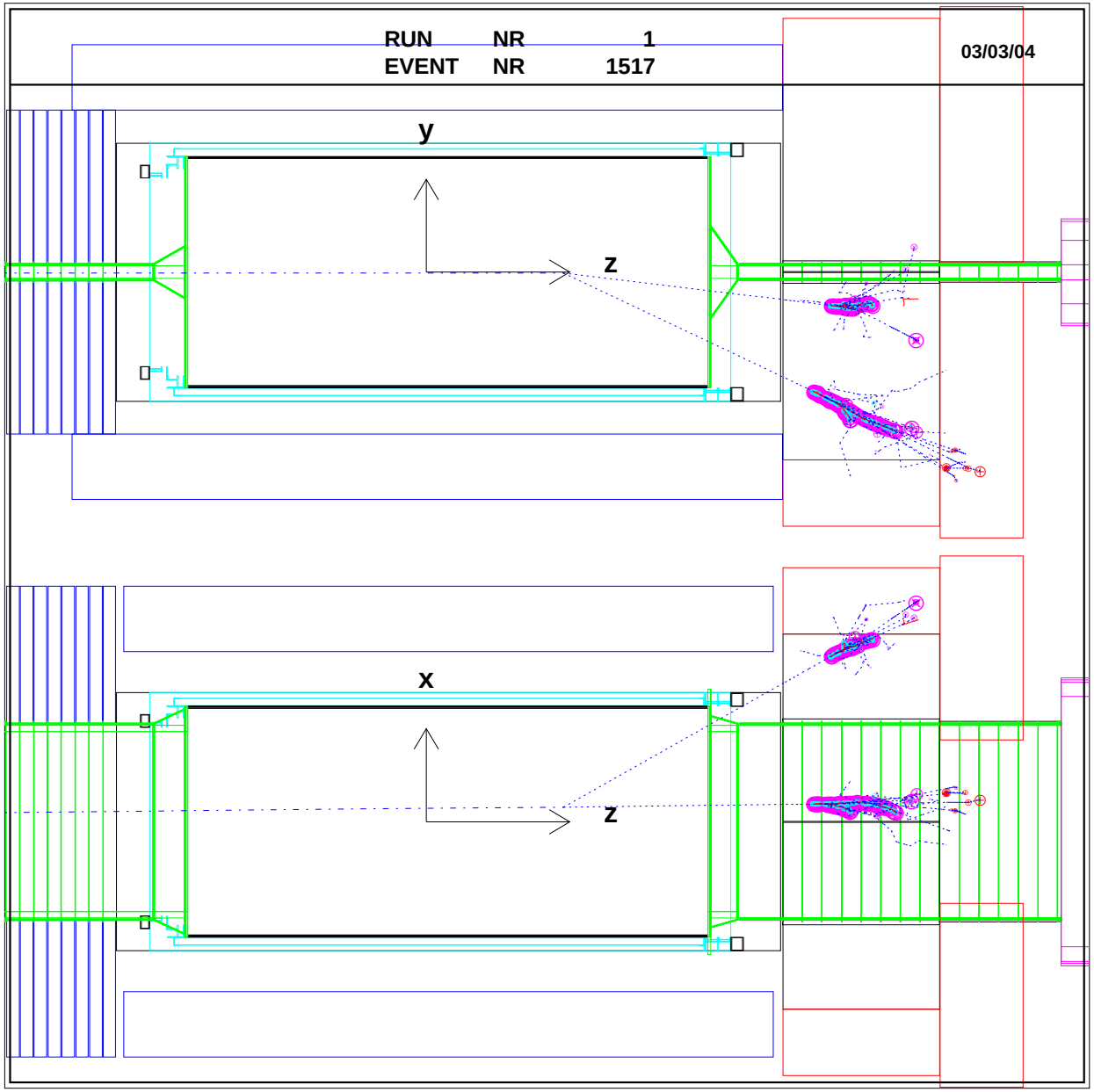
Charged tracks = solid lines,

γ = Dotted lines.

Boxes, circles are hits.



Next event.



Assumptions about backgrounds: Photon Veto (PV)

$\epsilon_{\rm PV} \approx 3 \times \epsilon_{\rm PV}^{\rm E787}$

- FLUKA study of inefficiency underway. Current FLUKA results do not agree with compilation of PV results in TN071.
- TN034: $\bar{\epsilon} < 2 \times 10^{-5}$ at 100 MeV for PR/CAL
- TN075-77: GEANT studies of hermeticity. Barrel Veto (BV) cracks not a problem.
- Inefficiency due to shower overlap estimated. Need recon. algorithm for rigorous study.

$\epsilon_{\rm PV}(\text{beam}) > 99\%$

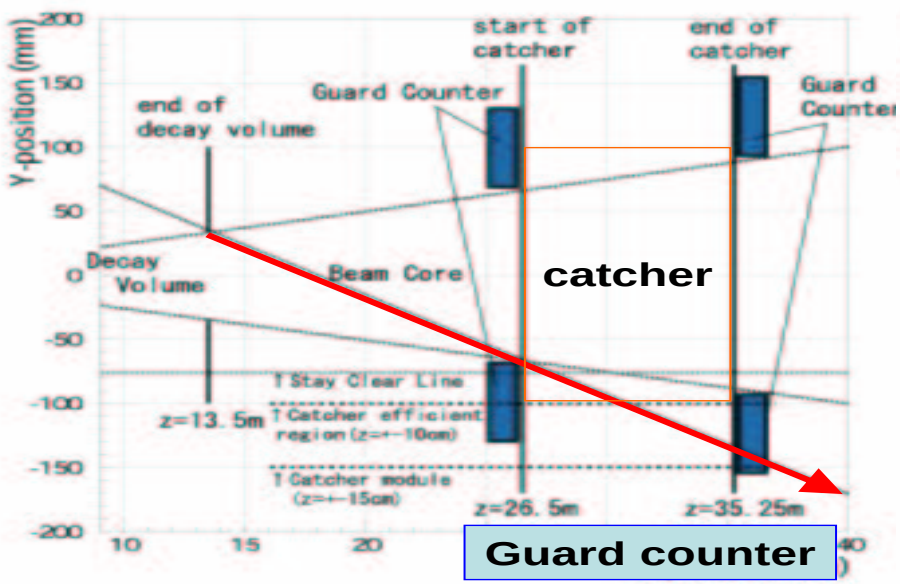
- Hermeticity near beam region is a difficult problem.
- New n=1.05 aerogel increases light yield for catcher (7Nov03)
- 'Double-wide' catcher proposed Feb 2004 meeting.

Further modification

Two options to widen vertical coverage

- ¾ Photons indicated by the red line must be tagged…
- ¾ Even worse than "Stay clear line" problem

Side view (both figs)



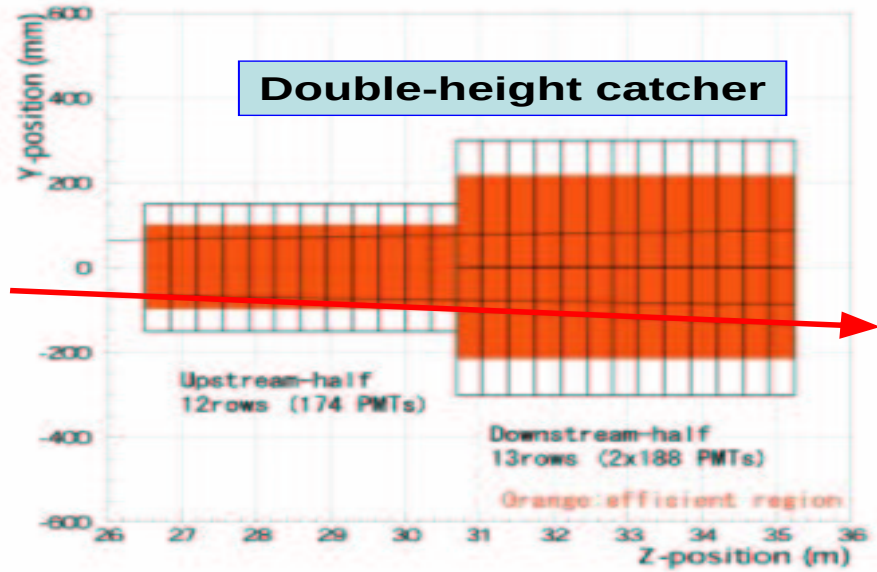
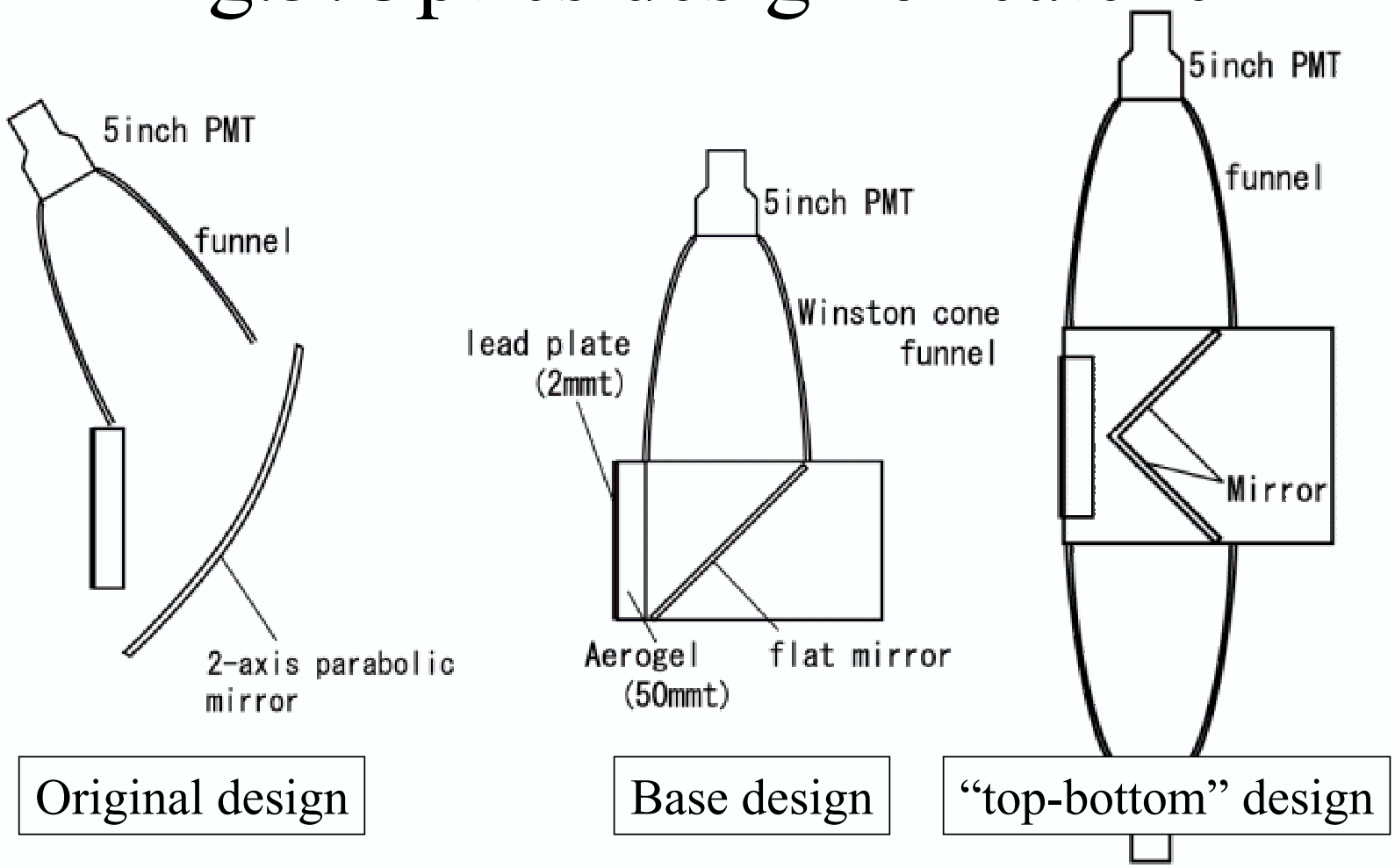


Fig.3:Optics design of catcher



Assumptions about backgrounds: Charged Veto (CV)

$\bar{\epsilon}_{\rm CV}(\pi^+) < 10^{-5}$, $\bar{\epsilon}_{\rm CV}(\pi^-) < 10^{-4}$, $\bar{\epsilon}_{\rm CV}(e^+) = 0.05/E(\rm MeV)$
In the FastMC study for the TDR, we neglected timing of CV.

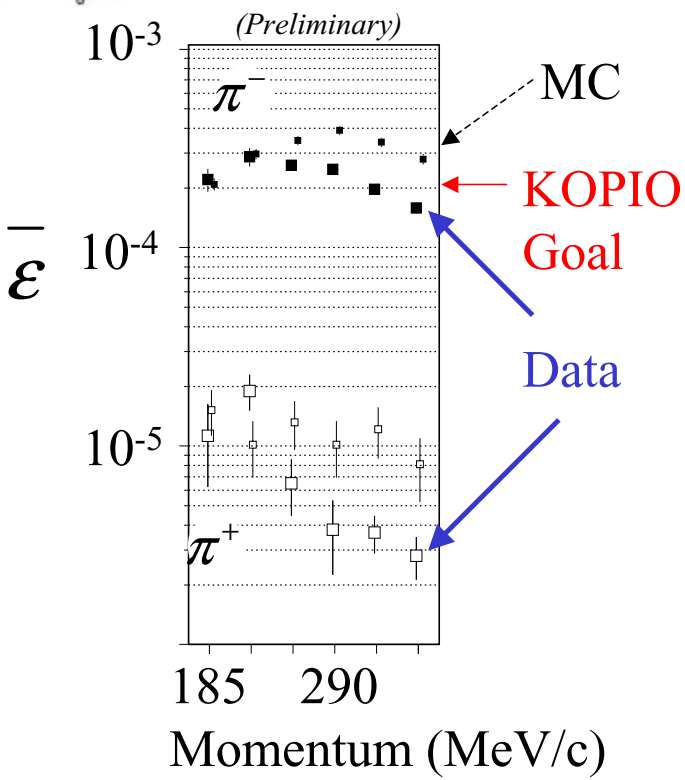
- TN027: Achieveable in decay region. (see figure)
  Requires < 20 mg/cm^2 in front of counter, 75 keV threshold.
  $\sim$10 keV may be possible.
- More difficult in DS regions. TN072: Novel Chamber CV proposed.
- Some FastMC studies of CV timing and loss rates. More rigorous estimates needed.

Charged Particle Vetoing

Example Background: $\mathbf{K}_L^0 \rightarrow \pi^- e^+ \nu \gamma$

Plastic Scintillator

PSI Measurement



KEK: 1 GeV/c

Particle	$\bar{\varepsilon}$
e^+	$(3.2 \pm 0.9)\ x\ 10^{-4}$
π^+	$< 1.6 x 10^{-5}$
e^-	$< 1.3 x 10^{-4}$
π^-	$(6.0 \pm 0.6)\ x\ 10^{-4}$

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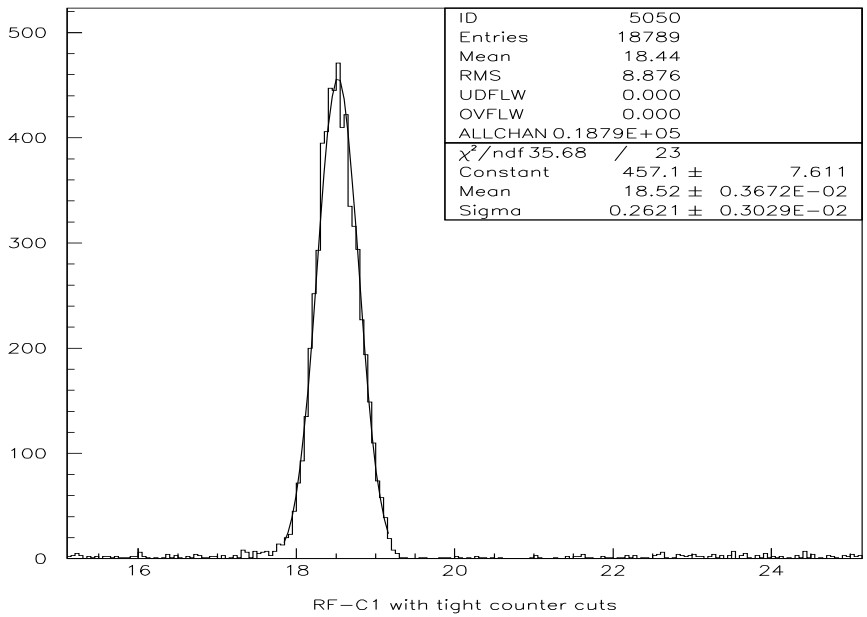
Assumptions about backgrounds: beam and vacuum

- Interbunch protons $< 10^{-3}$, σ_t(bunch) < 300 ps

– Measurement $\sim 10^{-2}$. See M. Sivertz talk.



measured σ_t(bunch) $= 262 \pm 3$ ps

- In beam vacuum 10^{-7} Torr and $n, \mathrm{K}^0_\mathrm{L}, \gamma$ scattered into detector $\sim$1, 0.1, 0.01 MHz, resp.

– Careful beam collimation design and many studies have shown that neutron rates acceptable with 10^{-7} Torr. Low energy neutrons and vetos?

Assumptions about acceptance

- Decay region 950 - 1350 cm
  - Collimation moves decay region to 1015 - 1415 cm
- Reject microbunches with > 1 K_L^0 decay in decay region
  - Prob(1 K_L^0) + Prob(2 K_L^0)$\times\mathcal{B}(K_L^0 \to \pi^{\pm}\ell^{\mp}\nu) = 0.65 + 0.28 \times 0.66 = 0.83$
- single PR conversions accepted (adds 19% more acceptance)
  - see C.Scarlett talk on 1 BV γ + 1 PR/CAL γ.
  - What gain from 1 PR/OV γ + 1 PR/CAL γ?
- 8% accidental veto loss
  - Requires reconstruction algorithm and full analysis program
- $\sim$100% trigger and reconstruction efficiency assumed
  - TN025: estimated 20% self-veto loss but S/B unchanged
  - TN057 & addendum: self-veto rate $\geq$ 12%
- Losses to due vacuum tank and beam pipe walls neglected.
  - TN024: 5% loss for 10% R.L. tank. Recoverable? M.Blecher studies.

Assumptions about flux

TDR assumed

- 70×10^{12}p/2.4s spill with 2.3s interspill,
  2.6×10^{-7} K_L^0 decays/spill and
  9.2×10^6 pulses in 12000 hours ($\sim$ **4 years**)
- Now 100×10^{12}p/2.7s spill but only 80 hours/week realistic.

$$\frac{80}{168} \times \frac{100}{5.0} \Big/ \frac{70}{4.7} = 0.48 \times 1.34 = 0.64$$

- 4 years/0.64 = **6.3 years**

Updating the proposal

Cannot have reconstruction algorithm and full analysis of GEANT data by May.

Possible solution: Improve FastMC with more realistic assumptions and/or input from GEANT MC

1. Position-dependent ϵ_{PV} from GEANT MC
2. Angular dependence of $\mathrm{K}_{\mathrm{L}}^{0}$ beam
3. Extended target
4. Move decay region from (950,1350) to (1015,1415) cm
5. Larger downstream beam hole
6. etc.

Will need to re-optimize cuts.

Updating the proposal

With improved FastMC we could investigate

1. > 1 K_L^0 decay in decay region per microbunch
2. Interbunch backgrounds
3. Using 1 BV γ + 1 PR/CAL γ
4. Using 1 PR/OV γ + 1 PR/CAL γ
5. etc.

Updating the proposal

Need GEANT MC to have more robust (or any) estimates of

1. Reconstruction efficiency and resolutions
2. Trigger efficiency
3. Self-veto losses
4. Losses due to material between K_L^0 decay point and PR
5. Neutron background rates
6. Losses due to accidentals
7. Losses due to un-instrumented regions
8. CV timing and loss rates
9. PV inefficiency due to shower overlap
10. etc.