

SK-Iにおける過去の超新星からの
flux探索
現状と展望

久野研究室 M2

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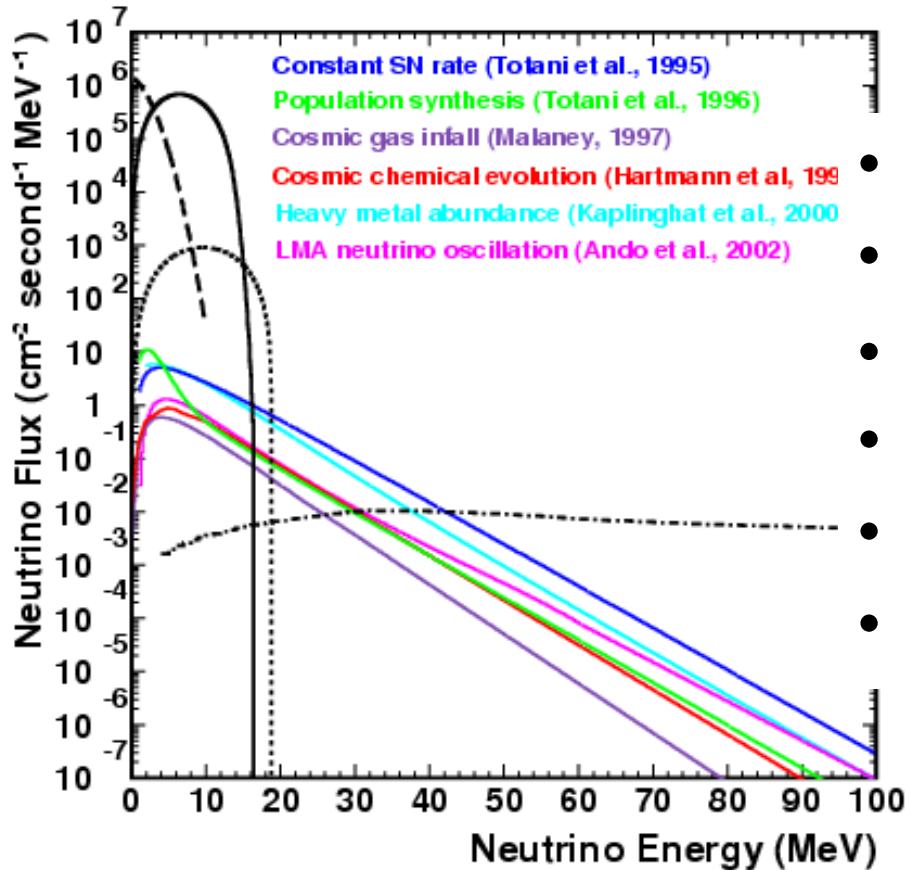
超新星残骸 (Supernova relic neutrino:SRN)とは

- 宇宙初期に爆発した超新星から放出された のことをいう。
- 背景 として等方的・均一に偏在している。
- 宇宙モデルの検証に有力な情報を与える。
- 検出にはbackgroundの除去が不可欠。

Spallation, atmospheric , solar ,...

重力崩壊核から放出される、光分解反応、中性子捕獲反応などによって生まれた $\bar{\nu}_e$ を探索する。

Main background



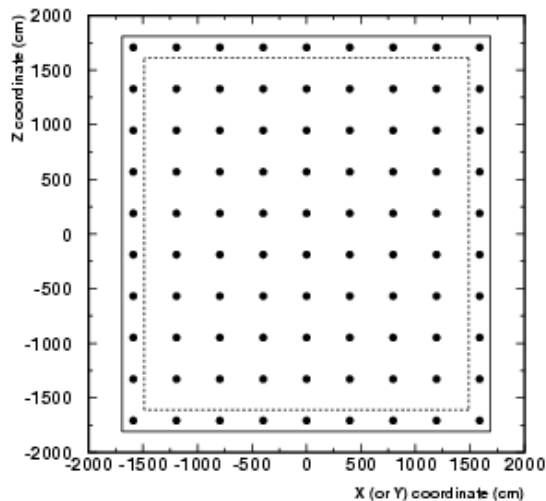
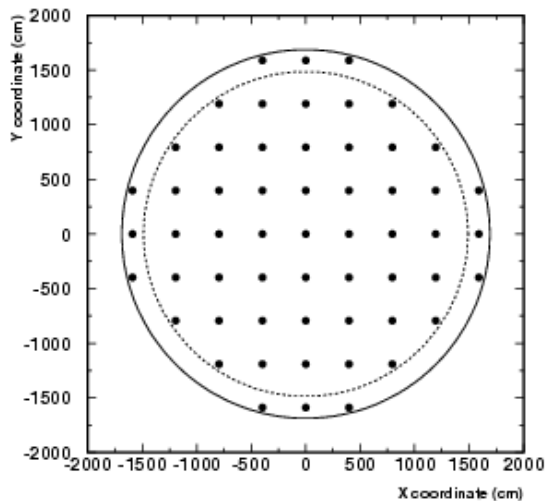
- 大気ニュートリノの <50 MeV領域
- 太陽ニュートリノ (hep, ^8B)
- 核破碎反応
- $\mu \rightarrow e$ decay による e^+ event
- γ - rays
- Reactor $\bar{\nu}_e$

18MeV~80MeVの範囲で、最終的に $\chi^2 = \sum_{I=1}^{16} \frac{[(\alpha \cdot A_I) + (\beta \cdot B_I) + (\gamma \cdot C_I) - N_I]^2}{\sigma_{data}^2 + \sigma_{MC}^2 + \sigma_{sys}^2}$

でfitする。A:SRN flux, B:Michael スペクトル, C: 大気 flux

$\bar{\nu}_e p \rightarrow ne^+$ event の検出

(kai fitによるCherenkov光の発生点、向きの割り出し)



SK tankを図のようなグリッドで分割し、各グリッドで最もgoodnessが高いエリアを選ぶ。

$$g_v = \frac{\sum_{i=1}^{N_v} \frac{1}{\sigma_i^2} \exp\left(-\frac{(T_{res,i}(x))}{2\sigma_i^2}\right)}{\sum_{i=1}^{N_v} \frac{1}{\sigma_i^2}}$$

進行方向

$$\log(L(d)) = \sum_{i=1}^{N_{50}} \log\left(f(\cos \theta_{dir,i}(d))\right) \frac{\cos \theta_i}{a(\cos \theta_i)}$$

の最大値を与える向き

Reduction

1st reduction

$<1000\text{p.e}$ (=140MeV)

Spallation cut

cut within 0.15 seconds events after cosmic μ

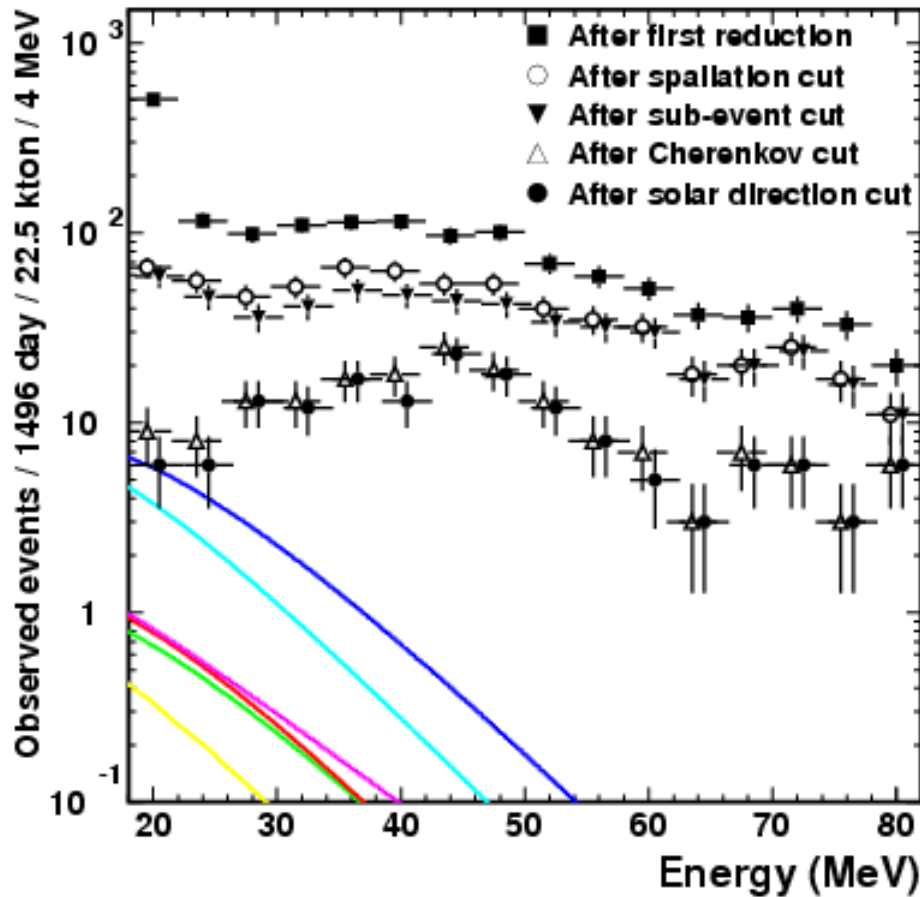
Sub event cut

Cherenkov angle cut

Cut $\cos(\theta_{sun}) < 0.86$

Supernova Relic Neutrino flux の絞込みの現状(2003/12/20)

Candidate flux



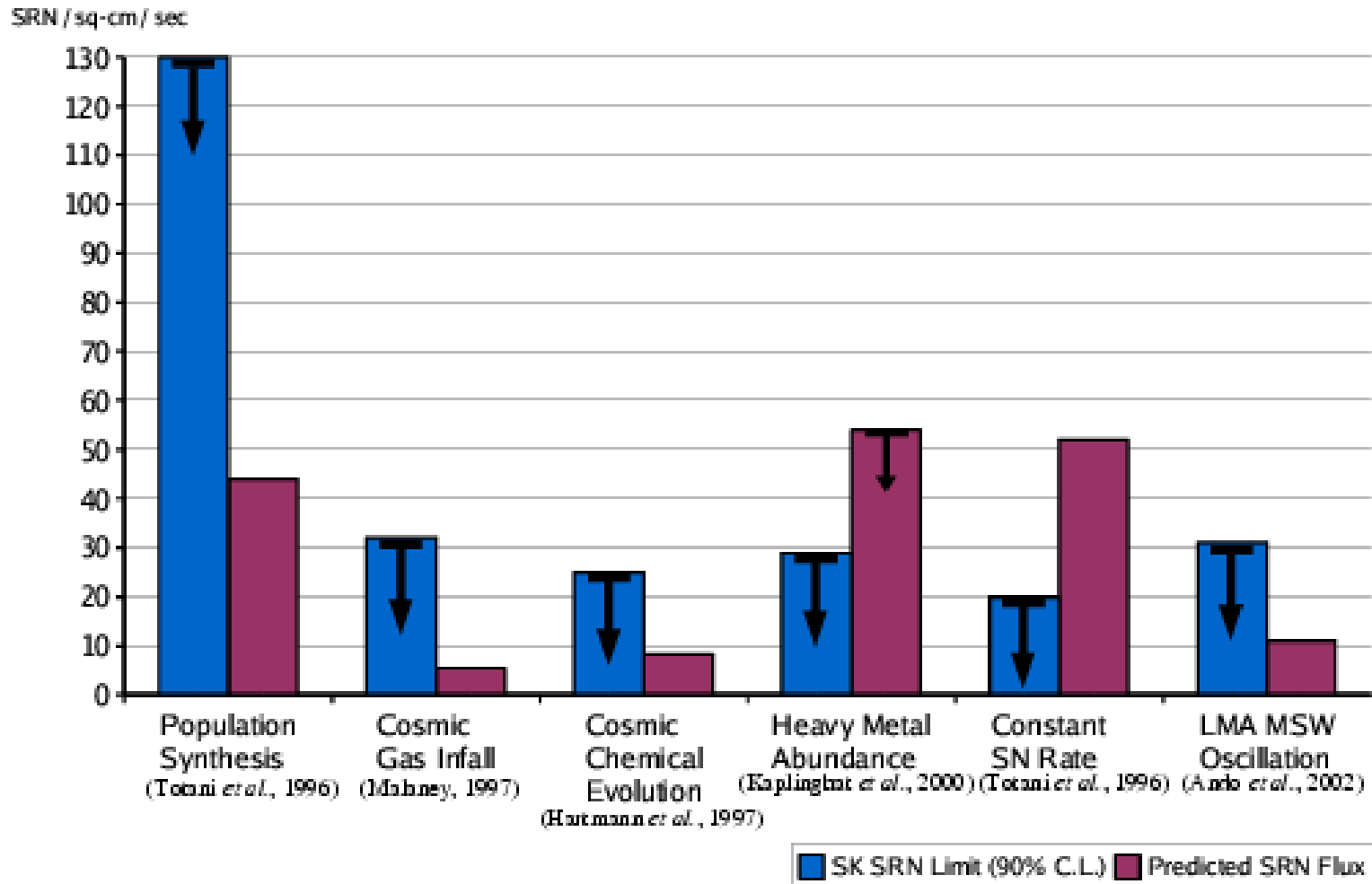
Reduction step	# of events
1st reduction	1602
Spallation cut	992
Sub event cut	828
Cherenkov angle cut	278
Solar-dir cut	271
Candidate	271

Signal efficiency: 47%

(for $E < 34\text{MeV}$)

理論モデルの検証のためには、さらなるbackgroundの除去が求められる。

SK SRN Flux Limits vs. Theoretical Predictions



2004/2/5 までに...

- $34\text{MeV} < E_e < 80\text{MeV}$ の領域について、
 1. $\bar{\nu}$ から発生する invisible μ e decay、
 2. SLE triggerの後に accidental に入ってくる stop μ e decay
を Background として取り除く。
 3. 残ったcandidateについて、

$$\chi^2 = \sum_{I=1}^{16} \frac{[(\alpha \cdot A_I) + (\beta \cdot B_I) + (\gamma \cdot C_I) - N_I]^2}{\sigma_{data}^2 + \sigma_{MC}^2 + \sigma_{sys}^2}$$

でfittingを行って、

SRNの探索をおこない、もし発見されなければ、残り4つのモデルの検証を行う。

付録

Possibility of detecting 2.2MeV
gamma ray
in SK-I data

Junko Ishii

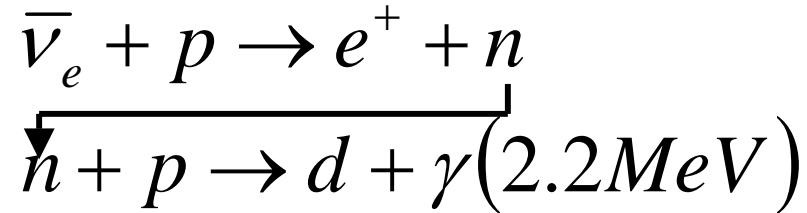
Osaka Univ.

Collaboration meeting

2003.11.21

μ capture を利用して $\bar{\nu}_e$ を同定する試み

Possibility of detecting 2.2MeV γ was studied in order to actively tag $\bar{\nu}_e$ signals by



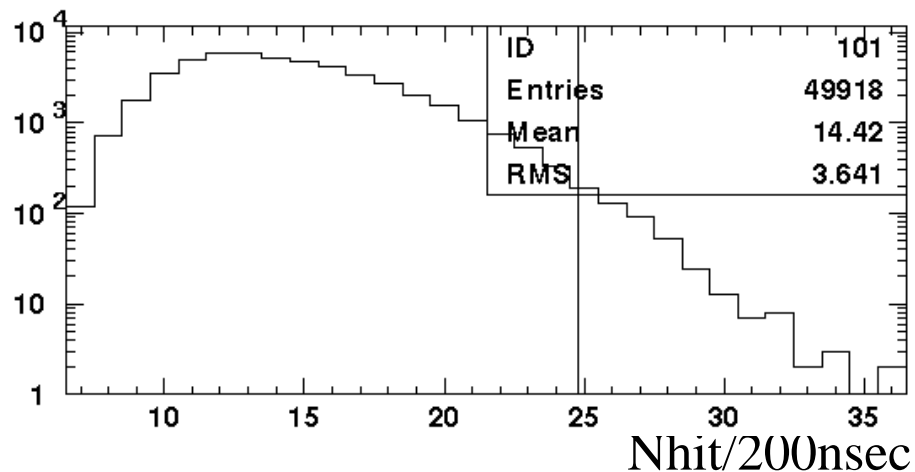
Possible $\bar{\nu}_e$ sources

- Relic neutrino
- Reactor neutrino (few 1000 events in SK-I data)
- Search for solar $\bar{\nu}_e$

Super LowE triggerが2.0MeVに設定された後のSK-Iのデータを使って、2.2MeV gamma反応の検出効率(efficiency)を求める。

M.C simulation

・2.2MeV を50000 event発生させる。



dark noise: 3.55kHz

⇒ 7.9 hit/200nsec

SLE trigger threshold: 186 mV

⇒ 186/11=16.9 hit/200nsec

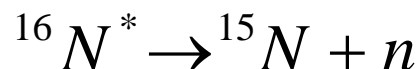
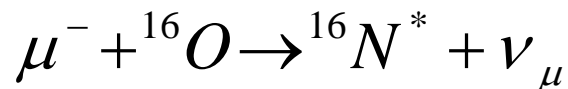
Nhit threshold by SLE trigger

24.8 hit/200nsec

M.C. 2.2MeV efficiency = 524/50000=1.05%

Is this simulation reliable?

To check the efficiency, We made use of Real Data of μ capture reaction.



Data sample 11 July, 2003 ~ 12 July, 2003

RUN 10361, subrun 000001~000745

Stop mu selection

- sum of Q < 4000p.e (>2m pathlength)
- Individual max Q < 200p.e



3,491 stop mu

× 1/ 2.2 by μ^+ / μ^- ratio: 1.2/1
~1590 stop μ^-

× 18.3% by O^{16} capture rate
291 muon capture

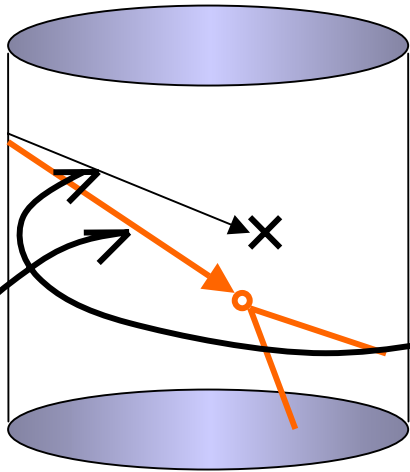
× 0.9 by $^{16}N^* \rightarrow ^{15}N + n$ branching ratio
262 neutron events

If each neutron react to np d at once on the average,

$262 \times 0.0105 = 2.75$ events should be detectable in SK-I data.

Test vertex difference between decay electron and stopmu position

Stop mu events: 3491



- Get muon stop position and its momentum
 - Muon momentum : sprngsep.F
 - Muon entry position : stmentsearch.F

“Muon pathlength 1” = momentum/2.2 MeV

“Muon stop position”

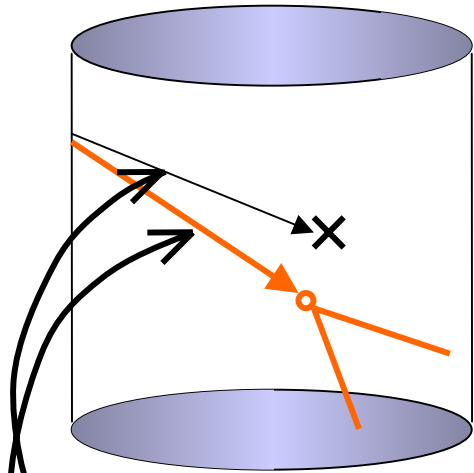
$$= \text{momentum}/2.2 \cdot \text{direction}(x,y,z) + \text{entry position}(x,y,z)$$

- Search 1msec event after stop mu events with the following criteria
 - $1 < T < 20$ micro sec
 - $N50 \leq 20$
 - goodness ≤ 0.4

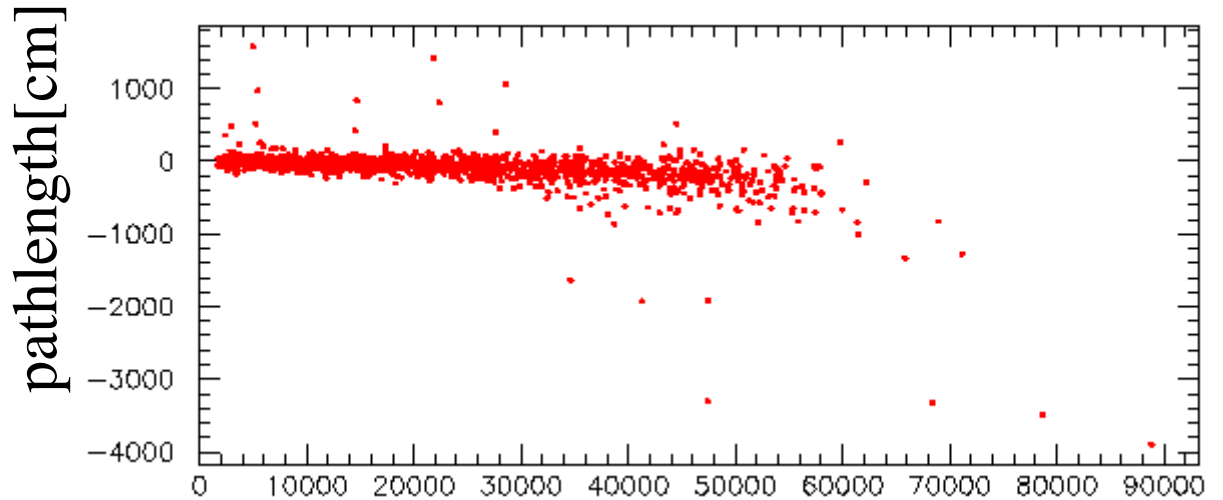
Good kai fit events: 1474

“Muon pathlength 2” = $\sqrt{\{(\text{entry position}) - (\text{kai fit vertex})\}}$

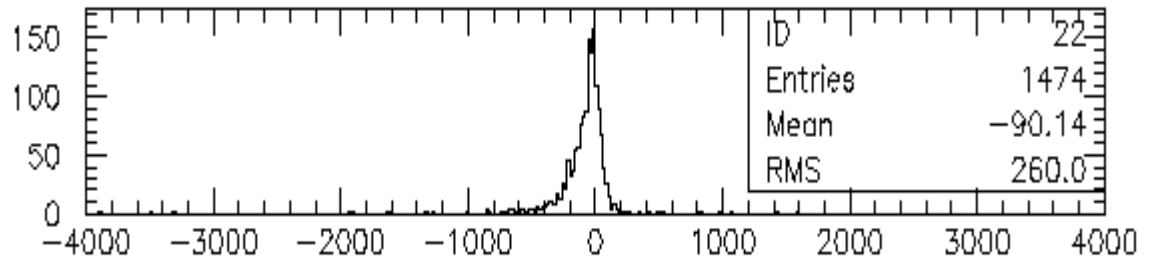
Confirm muon pathlength



pathlength 1
pathlength 2



Muon 1Ring Q [p.e]



pathlength [cm]

$$\text{pathlength} = \text{pathlength 1} - \text{pathlength 2}$$

Estimated “Muon stop position”

$$= \text{momentum}/2.2 \text{ MeV} \cdot \text{direction}(x,y,z) + \text{entry position}(x,y,z)$$

Search for 2.2MeV

Criteria:

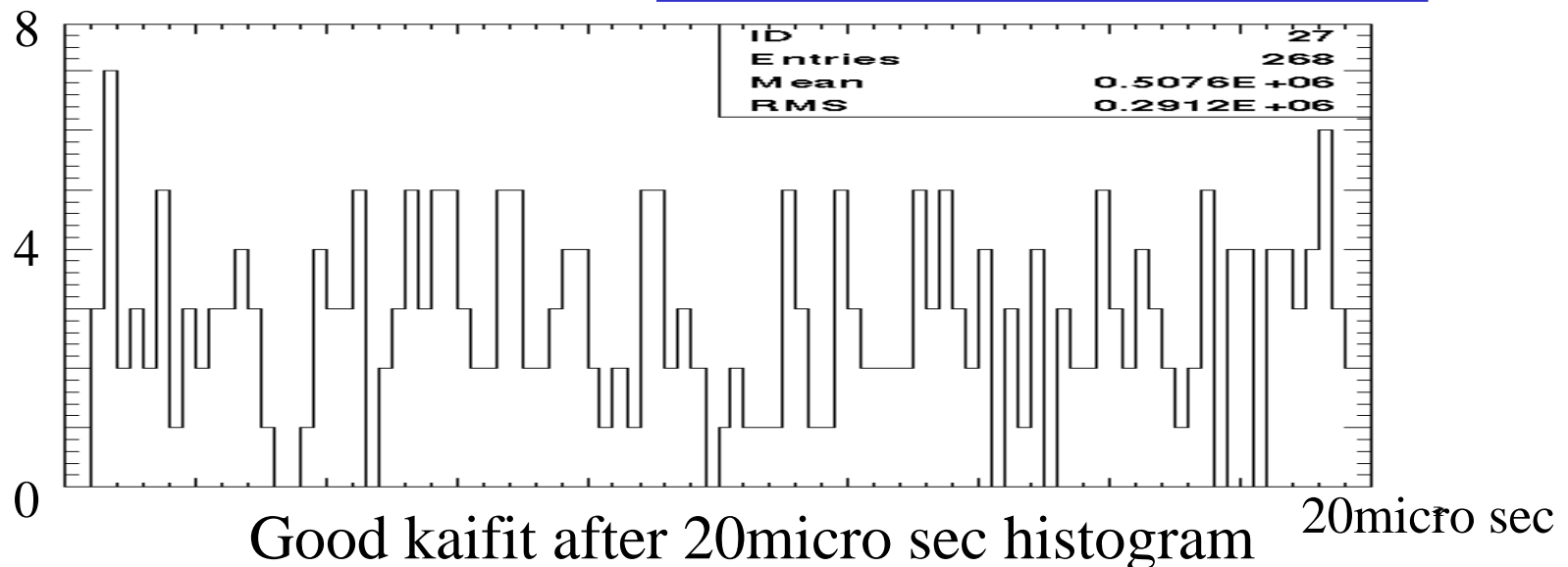
- stop mu without μ e decay signal

$T < 20 \mu \text{ sec}$

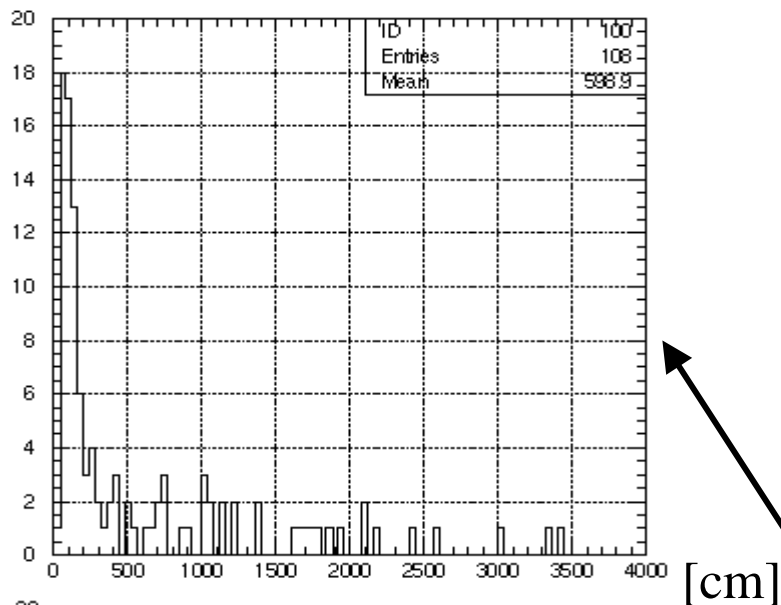
goodness > 0.4

- 20 $\mu \text{ sec}$ 1000 $\mu \text{ s}$ after such stop μ 's

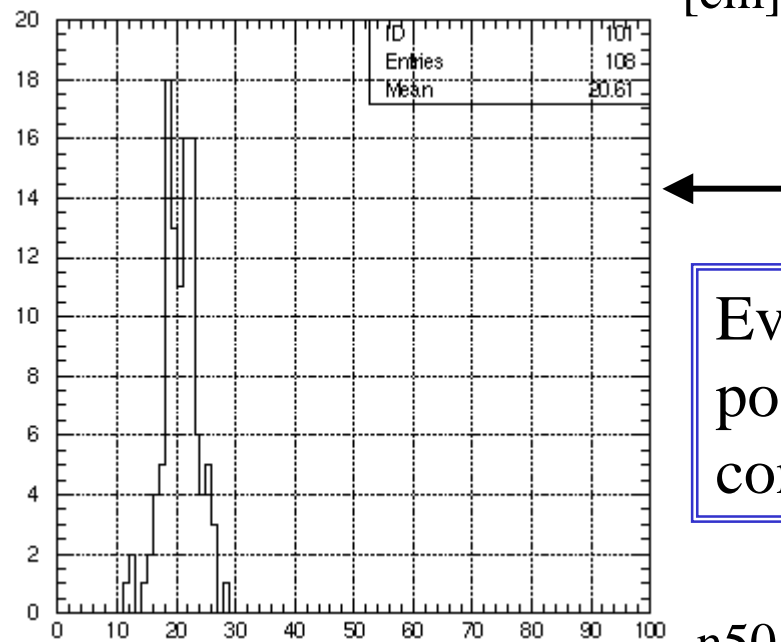
Good kai fit events: 268



2.2MeV events after trigger simulation



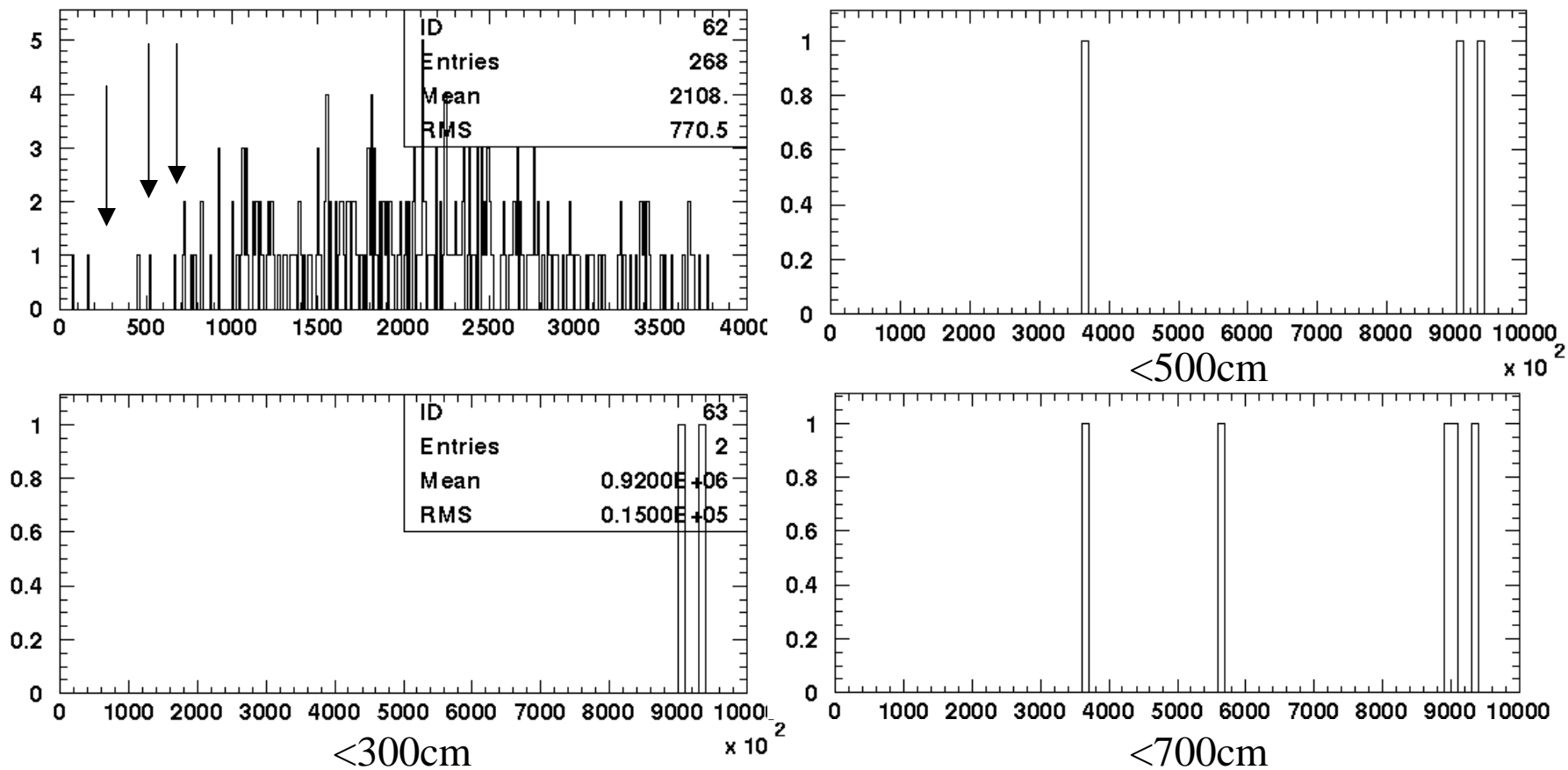
Generate 50000 events
After trigger simulation
111 events
Successful kaifit events
108 events



1. Comparing M.C. vertex
and kai fit vertex
2. N50 distribution

Events which distance from true position are under 500cm mainly contribute to 2.2MeV gamma events

Search 2.2MeV events under 3m,5m,7m distance between kaifit vertex and muon stop position



In the vicinity of 200 μ s after stopmu, No significance signal.

No 2.2MeV gamma events in this calculation.

Conclusion : efficiency of 2.2MeV gamma in SK-I

At 186mV threshold < ~1% (90% C.L.)

Need more statistics to verify Monte Carlo.

