The Status of KIMS experiment

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For KIMS collaboration

KIMS(Korea Invisible Mass Search) collaboration

清華大學 Tsinghua University

IHEP

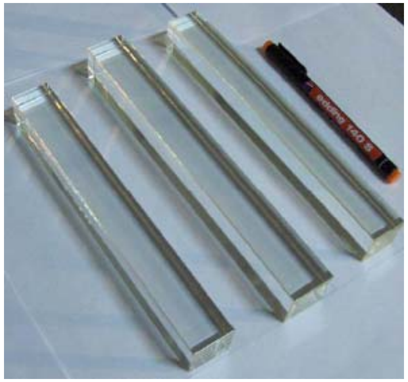
KRISS
Korea Research Institute of Standards and Science

Research Program of KIMS Group

Dark Matter Search

CsI(Tl) crystal detector (with China)

Running



Neutrinoless Double Beta Decay Search

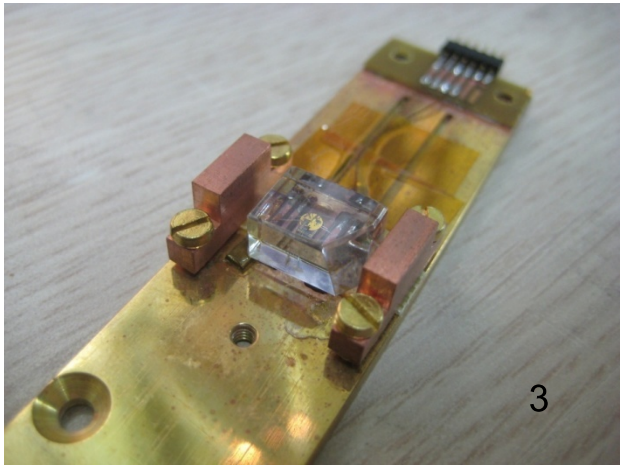
$CaMoO_4$ crystal (with Russia and Ukraine)

R&D effort is on going.

Development of Cryogenic Detector

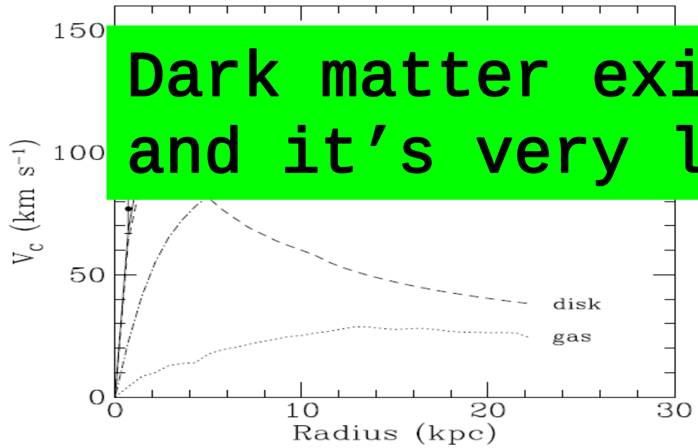
R&D effort is on going

will be reported at LTD09@SLAC

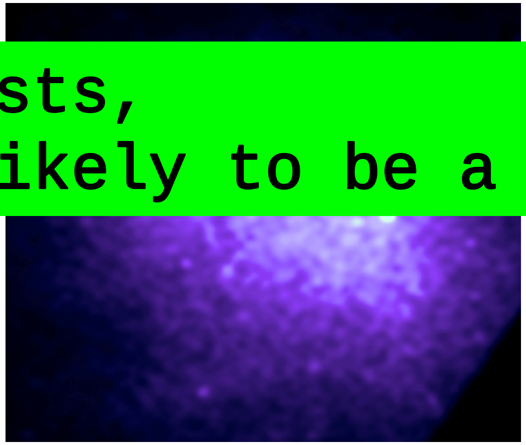


WIMP?

**Dark matter exists,
and it's very likely to be a WIMP.**

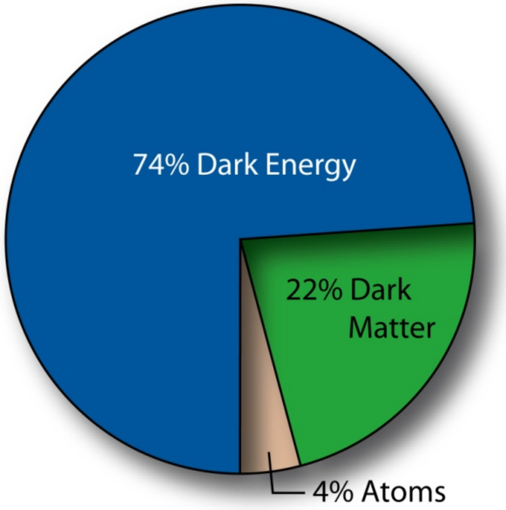


Galaxy rotation curve



X-ray from Hot cluster

Bullet cluster



Non-ordinary, Weakly-interacting,

Stable, Massive (non-relativistic)

Particle required.->WIMP

WIMP candidate?

LSP(lightest supersymmetric particle)

We have plenty of candidates for WIMP from various motivations.

By R parity conservation, lightest supersymmetric particle(LSP) can be the stable, WIMP.
Relic dark matter density for large scale structure can be explained well.

LKP(lightest Kaluza-Klein particle)

Theory with Universal Extra Dimensions introduces lightest KK(Kaluza-Klein) particle.
It becomes stable thanks to Kaluza-Klein parity.

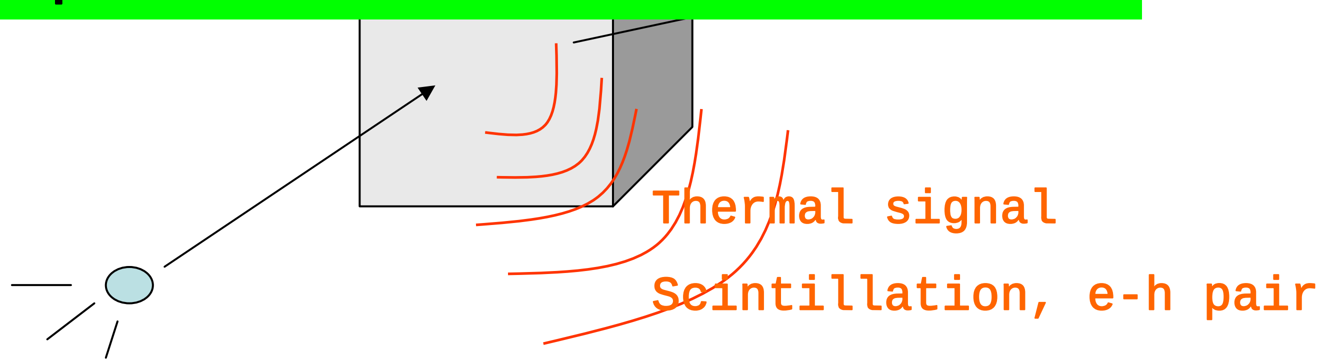
Massive sterile neutrino, axino ...

How to sense WIMP?

WIMP recoils nucleus.

WIMP seems detectible with the state-of-the-art experimental technique.

keV.



Since it interacts rarely,

Background event from radioisotope impurity or cosmic shower must be reduced seriously.

⇒Selection of Radioisotope free material

⇒Location at Underground laboratory

WIMP search of KIMS

WIMP search using CsI(Tl) scintillator

YangYang underground Lab(Y2L)
=>Located in Yangyang pumped storage power plant
=>700m minimum depth, 2000m water-equivalent
=>accessible by car (tunnel~2km)

양양양수발전소

KIMS’ main detector: CsI(Tl) scintillator

CsI crystal?

Easy to get large mass with an affordable cost

High light yield ~60,000/MeV

Easy fabrication and handling

Enabling pulse shape discrimination

-> Statistically, nuclear recoil event rates can be estimated

KIMS’ main detector: CsI(Tl) scintillator

CsI crystal?

Sensitive to both SD and SI WIMP interactions

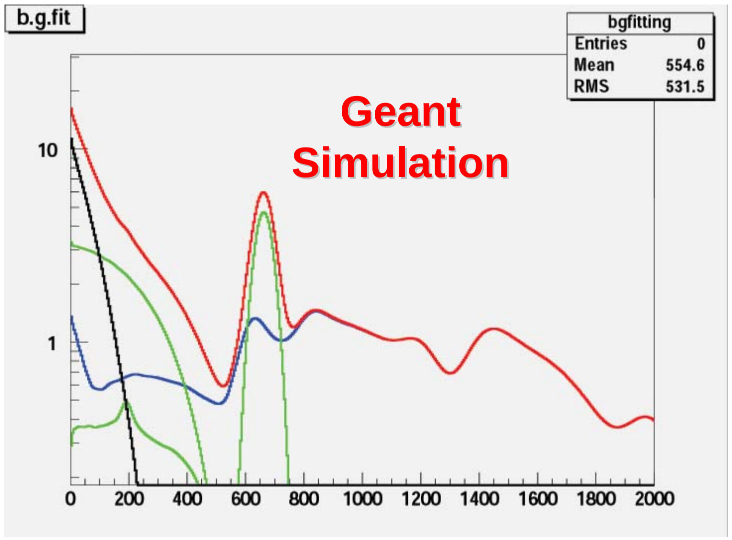
A(Cs) =133, A(I) =127

Isotope	J	Abun	<Sp>	<Sn>
^{133}Cs	7/2	100%	-0.370	0.003
^{127}I	5/2	100%	0.309	0.075
^{73}Ge	9/2	7.8%	0.03	0.38
^{129}Xe	1/2	26%	0.028	0.359
^{131}Xe	3/2	21%	-0.009	-0.227
^{19}F	1/2	100%	0.441	-0.109

KIMS' main detector: CsI(Tl) scintillator

CsI crystal?

Radioisotope in CsI crystal



^{137}Cs :from processing water in manufacturing factory
Using "ultra clean water" reduced to ~1.7mBq/kg

^{134}Cs :produced by neutron capture of ^{133}Cs induced by cosmic ray

^{87}Rb : most dominant background at the low energy
can be reduced by recrystalization technique
=>potential for further background level reduction

Latest crystals are from ~2 cpd level powder

CsI(Tl) crystal detectors

One detector module : one CsI Crystal + 2 PMTs

Crystal size: 8x8x30 cm^3 (8.7 kg)

(Beijing Hamamatsu Photon Techniques Inc.)

PMT : 3″ PMT (9269QA),

Quartz window,

RbCs photo cathode

(green extended)

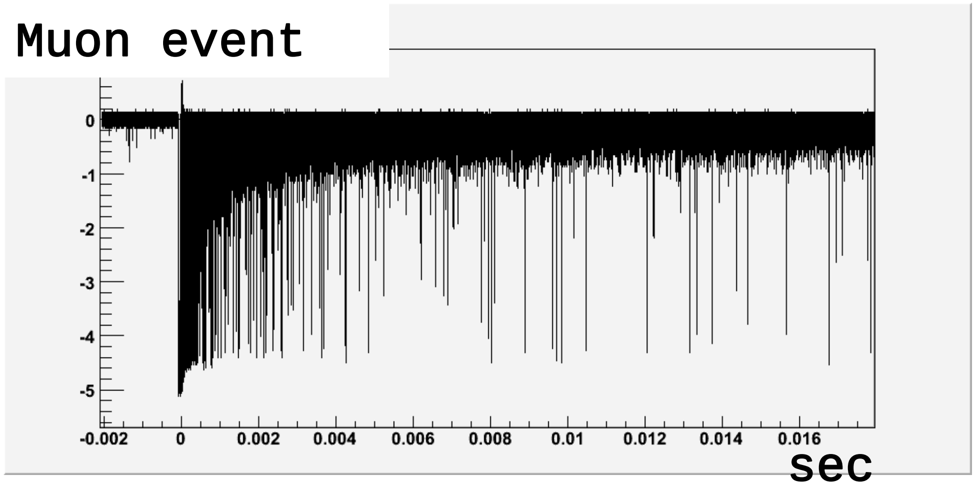
Trigger condition:

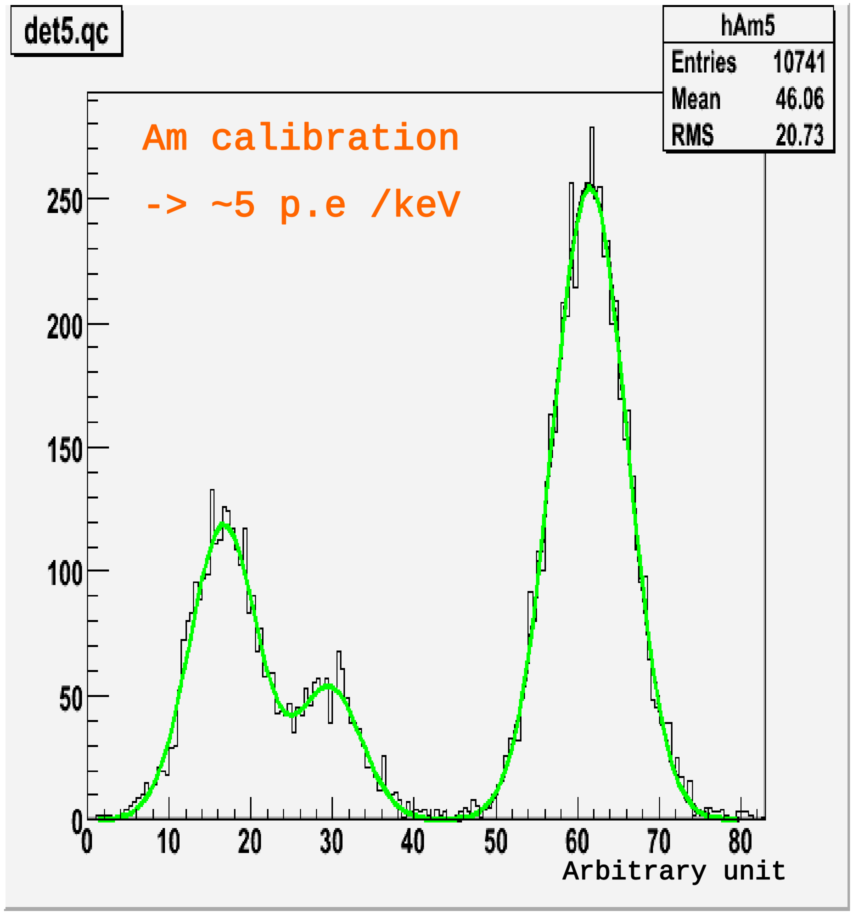
In 2us, 2 more photons in each PMT + high energy event

Event window is 40μs.

Digitized with 400MHz FADC

CsI(Tl) crystal detectors





8ms dead time is applied after high energy event.

->Efficiency > 99%

Muon tail events are rejected

for 30ms after Muon coincidence.

Muon Detector

4π coverage muon detector : 28 channels

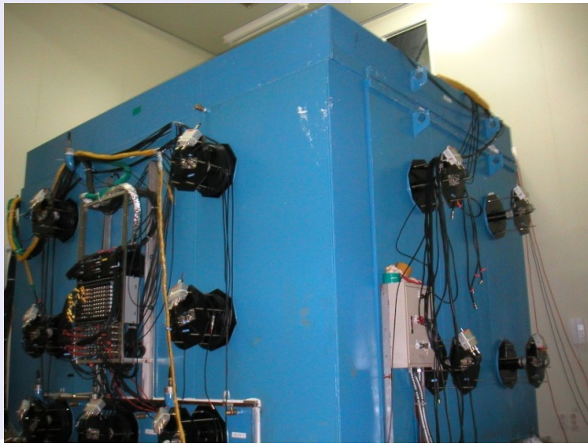
Liquid Scintillator(5%)+Mineral Oil (95%) = 7 ton

Measured Muon flux = 2.7×10^{-7} /cm^2/s

Position resolution : σ_{x}, ~ 8 cm

Reconstructed muon tracks with hit information

Muon veto efficiency ~99.9%



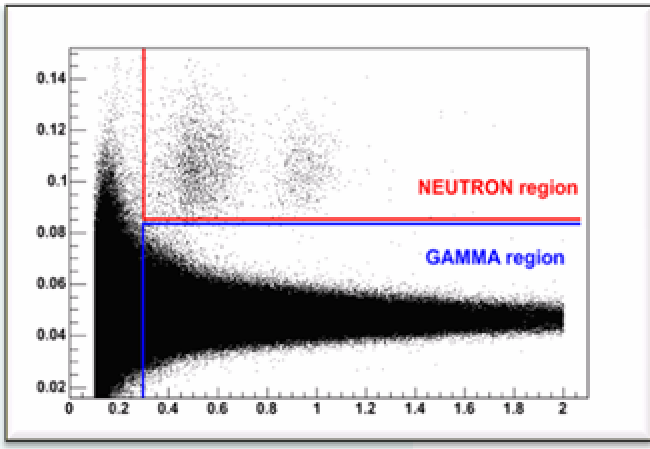
Neutron detector

1 ~ 1.2 liter BC501A liquid scintillator x 3

n/g separation using PSD

E_vis > 300 keV

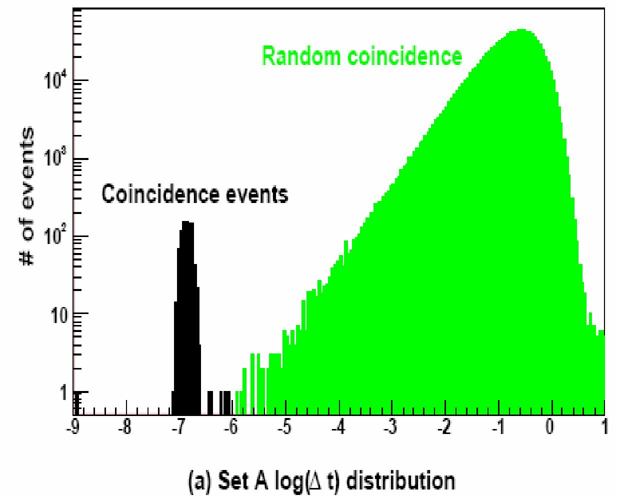
Measured neutron flux (outside shield)
→ 8×10^{-7} /cm^2/s (1.5 < E neutron < 6 MeV)

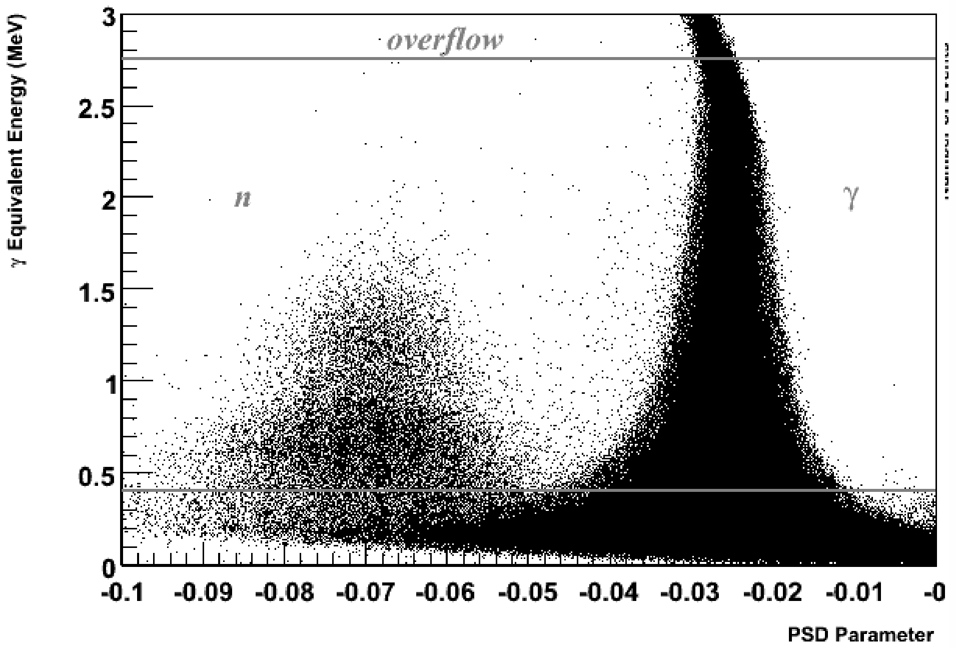


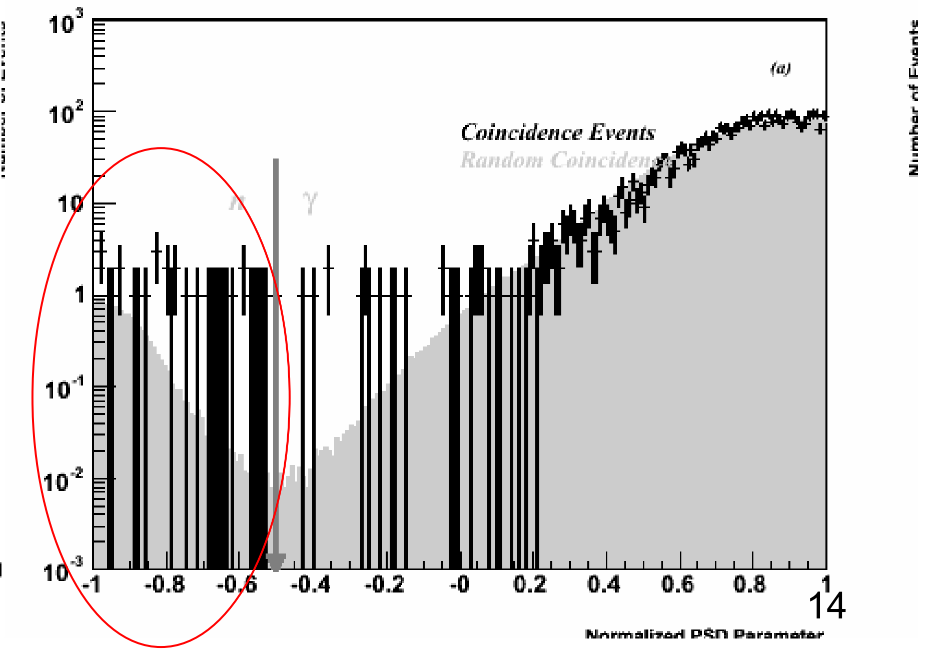
Neutrons induced by muon

Coincidence between Muon and Neutron
n/γ separation using PSD
Neutron energy: 0.4MeV<E<2.75MeV

Measured : $(3.8\pm0.7)\times10^{-2}$ counts/day/liter
GEANT4 : $(2.0\pm0.2)\times10^{-2}$ counts/day/liter







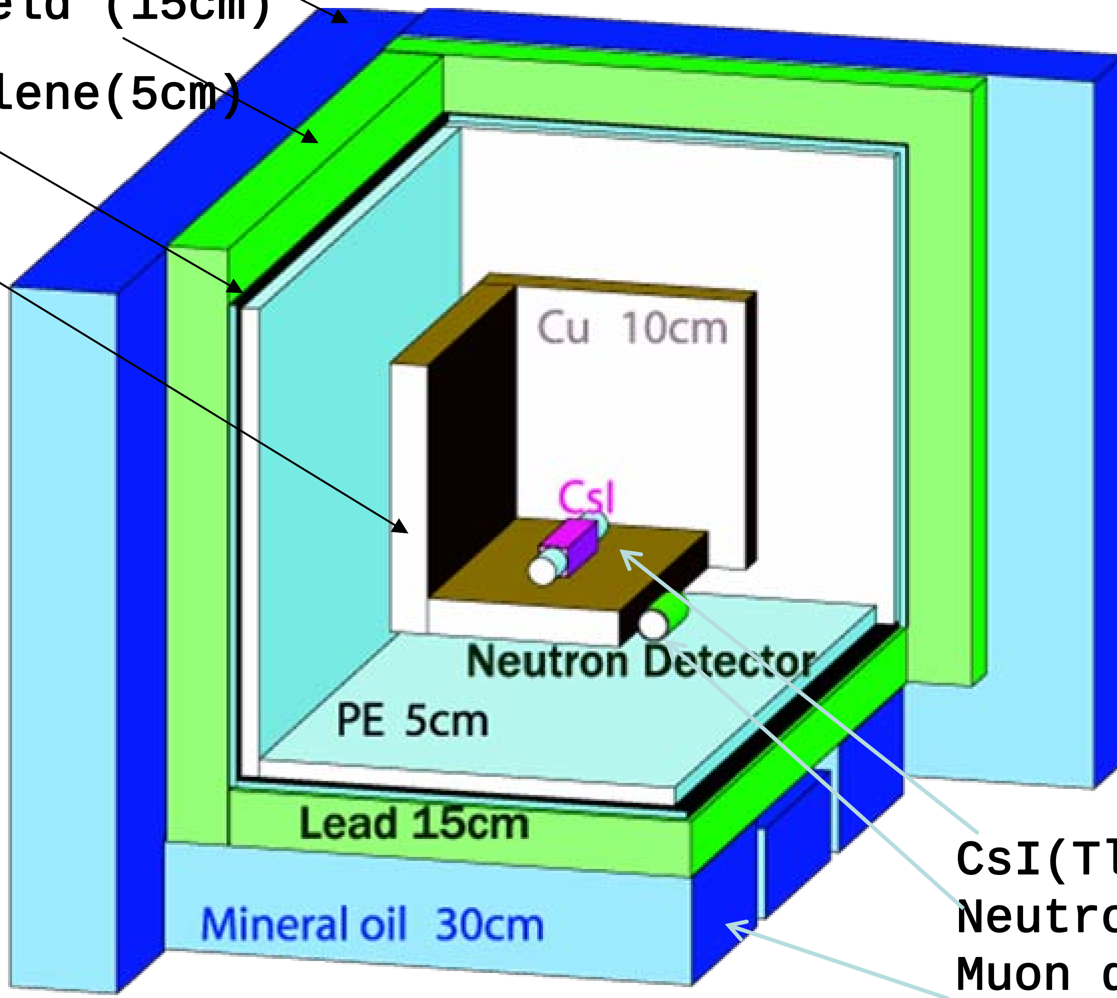
KIMS Detector system

Neutron shield(30cm mineral oil)

Lead shield (15cm)

Polyethylene(5cm)

Copper
(10cm)



CsI(Tl) Scintillator
Neutron detector
Muon detector
(Neutron sheild)

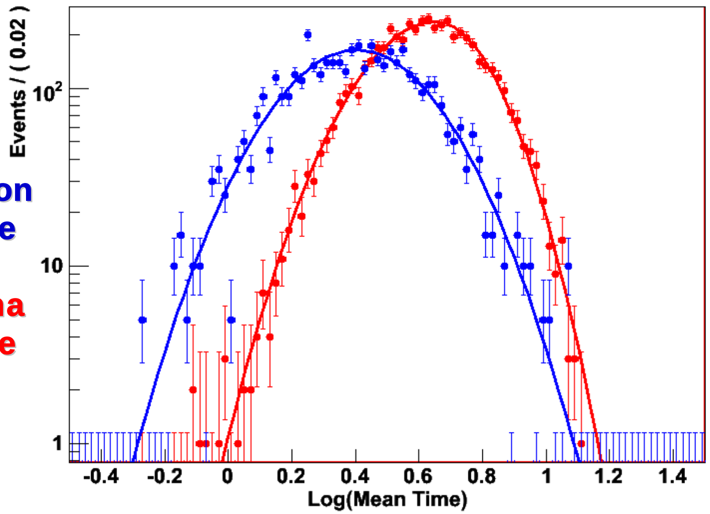
N_2 gas flow inside the Cu shield

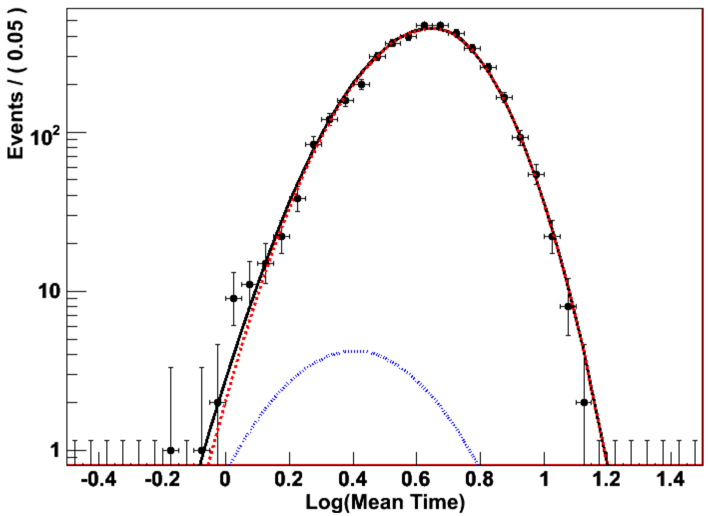
Nuclear Recoil(NR) event rate estimation

Modeling of Calibration data with asymmetric gaussian function

Neutron sample

Gamma sample





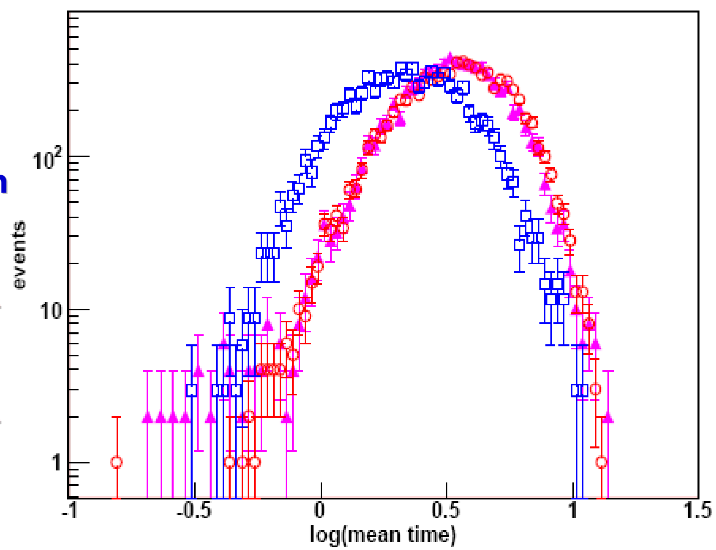
5-7 keV Mean time calibration

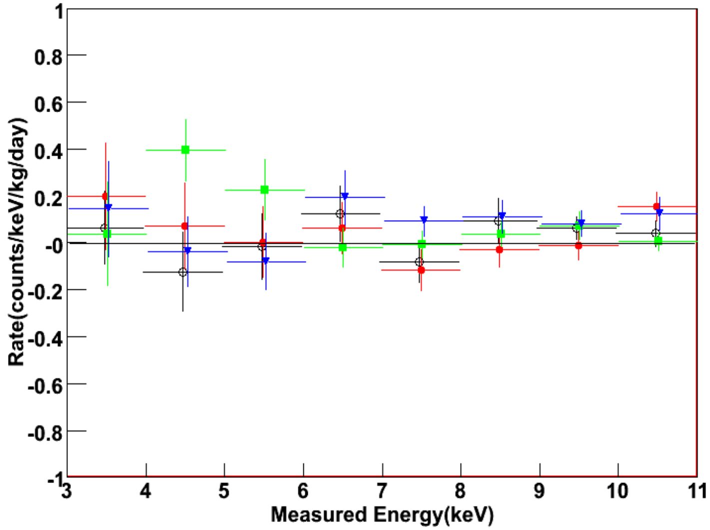
NR estimation

Neutron sample

Gamma (Y2L)

Gamma sample

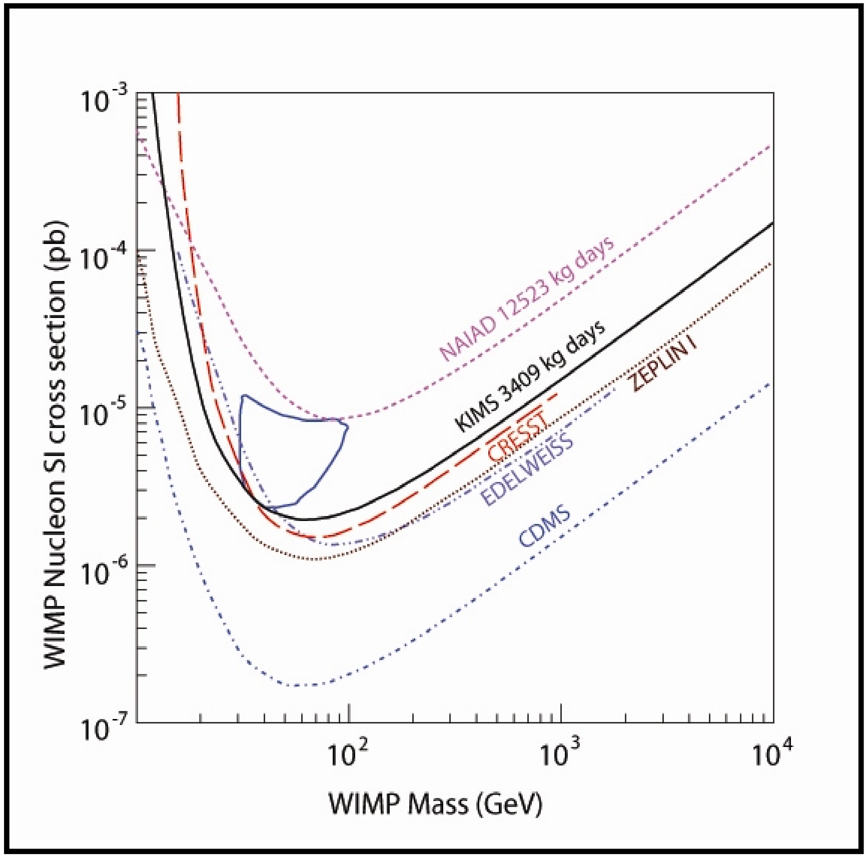


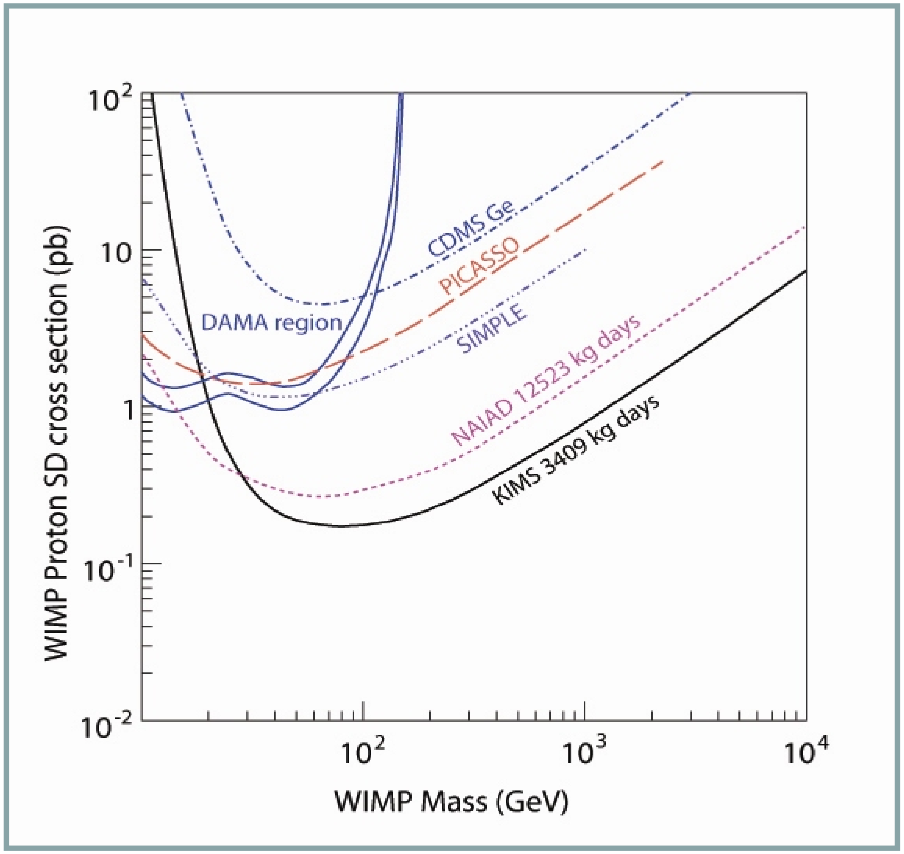


Estimated NR rate

KIMS limits

PRL 99, 091301 (2007)





Nuclear recoil of ^{127}I of DAMA is incompatible with our results => channeling?

Current status

12 detectors(104.4kg) installed in the shield.

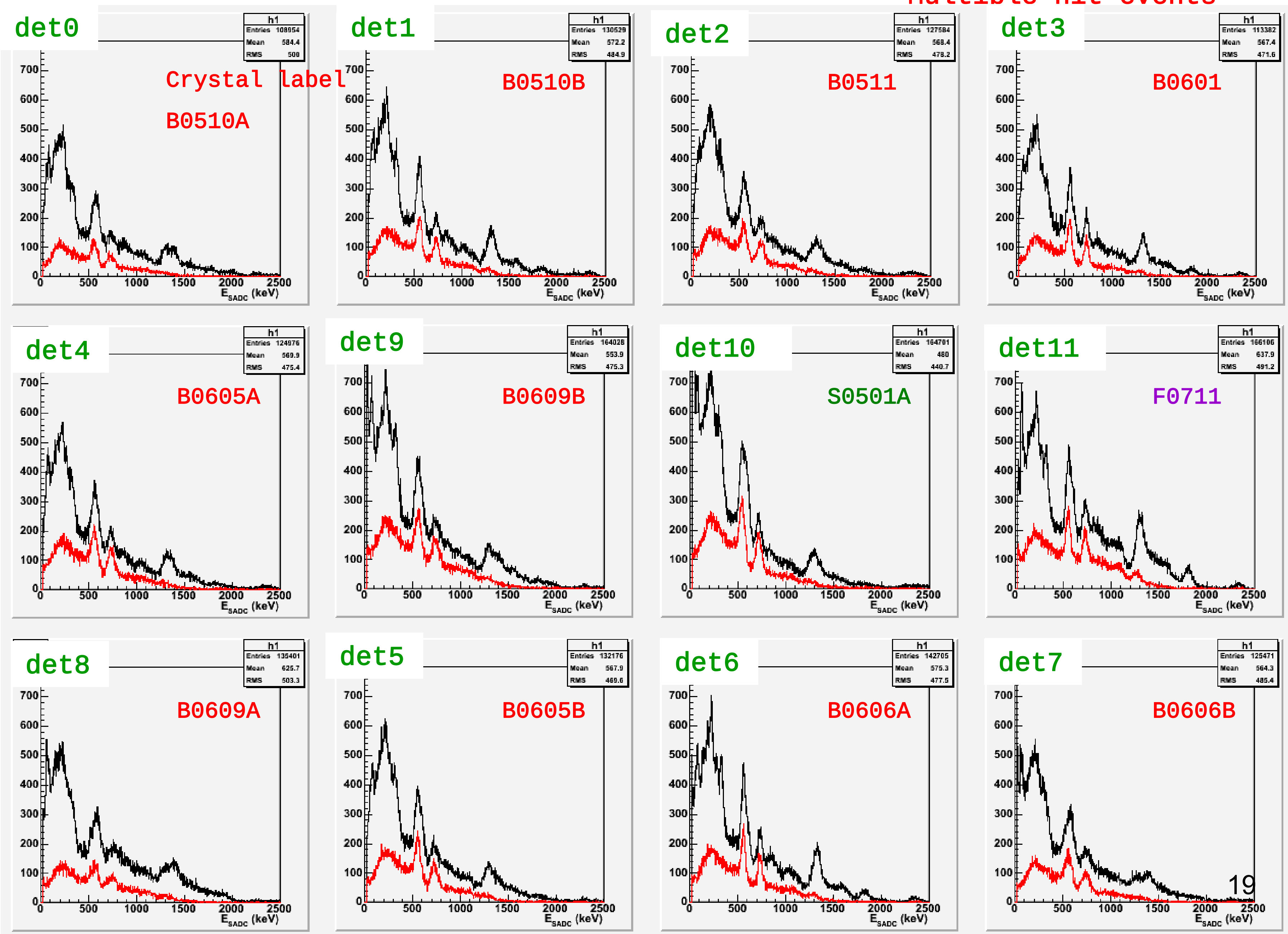
More than 1 year data collected.

various analysis is going on.

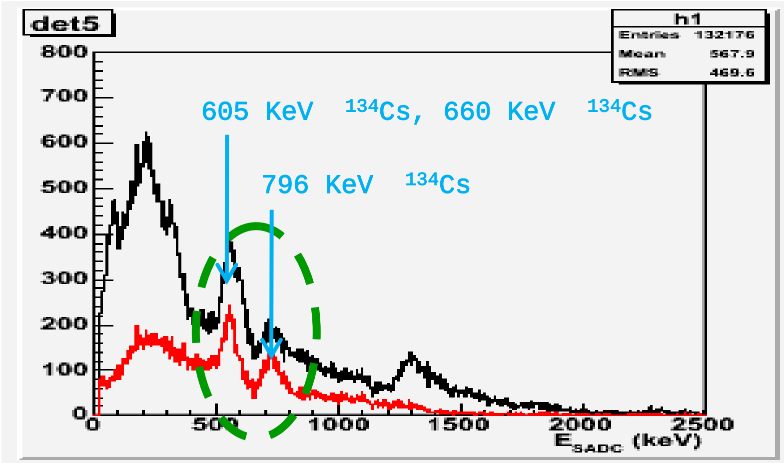
Full range Energy spectrum

— Total events

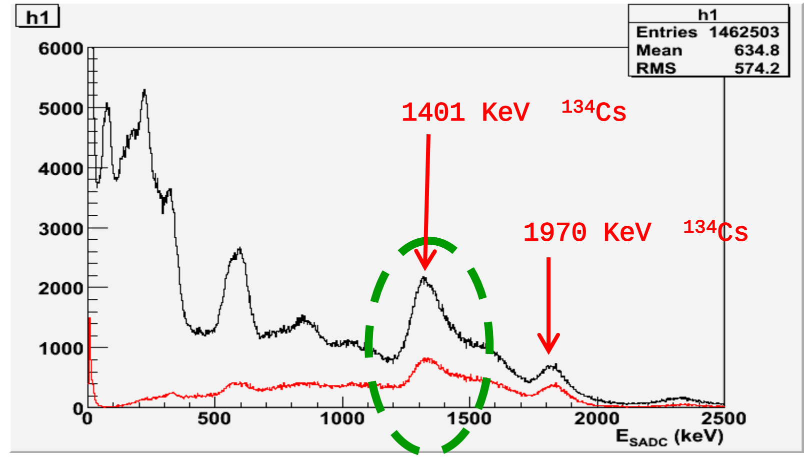
— Multiple hit events



Full range Energy spectrum

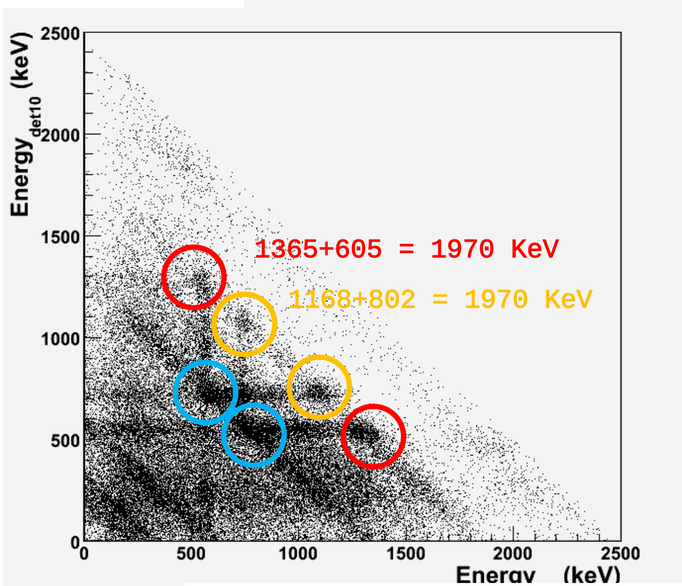


Energy spectrum of one detector



Spectrum of total energy sum of whole detectors

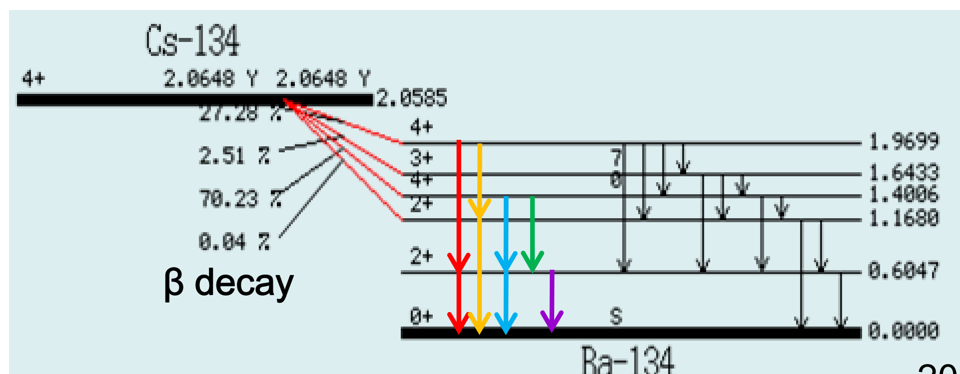
E of det10



Total E except det10

— Total events

— Multiple hit events



PMT noise event rejection

PMT noise limits the sensitivity at the low energy level experiment seriously.

Source of PMT noise

=>Thermionic Emission

=>Afterpulse:

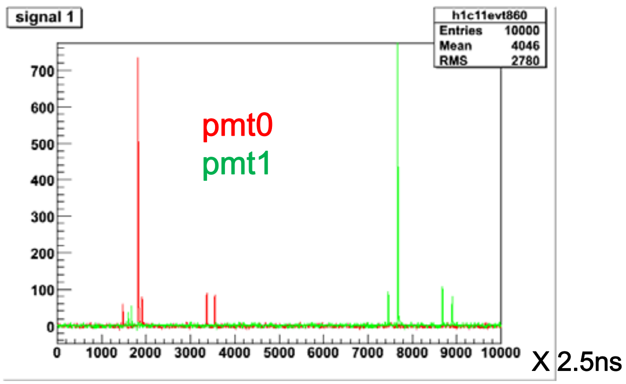
the drift of ionized residual gas in the PMT toward photocathode

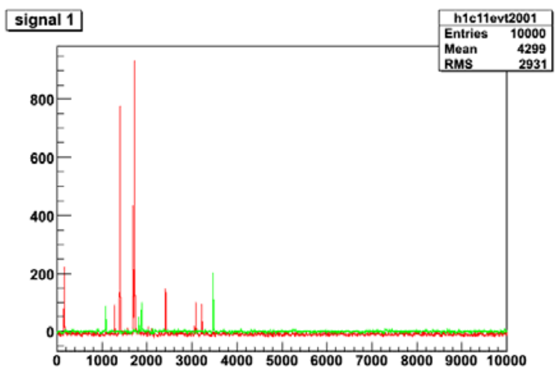
excitation of metastable state of photocathode or glass

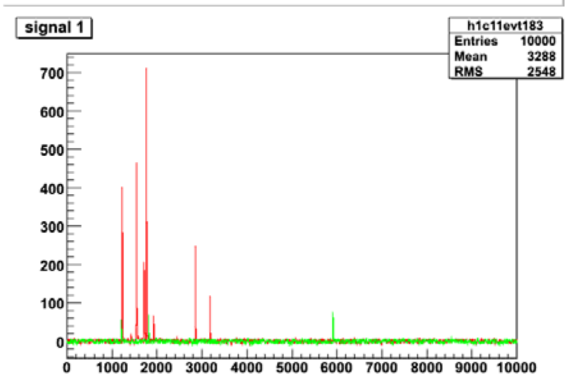
=> Cerenkov radiation from Cosmic ray or background radio-isotope

=> Fluorescence of glass

Characters of PMT noise event







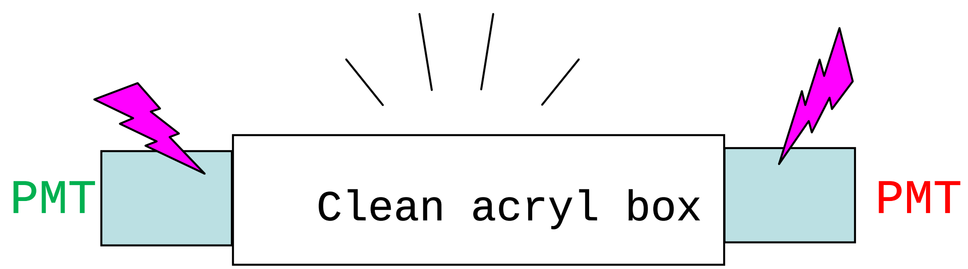
Very big single photo-electron(cluster)

Asymmetric along 2 PMTs in size and time

Decaying very fast

⇒ Data from PMTs + acryl box system

We have 1-2 month data for this.



Event rate: a few to a few hundreds events per day

Afterpulses in PMT-only -detector

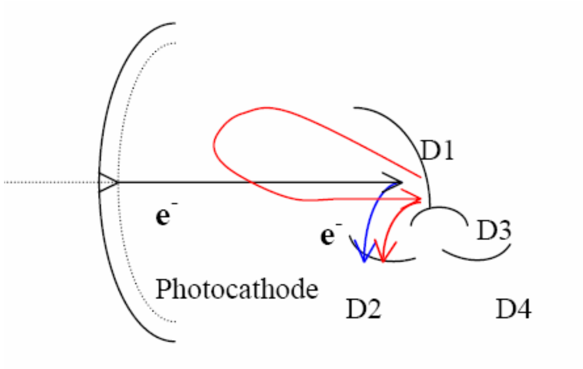


FIGURE 5.2: AFTERPULSE MECHANISM

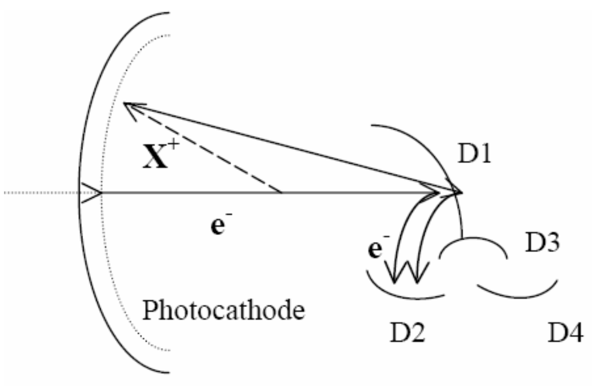
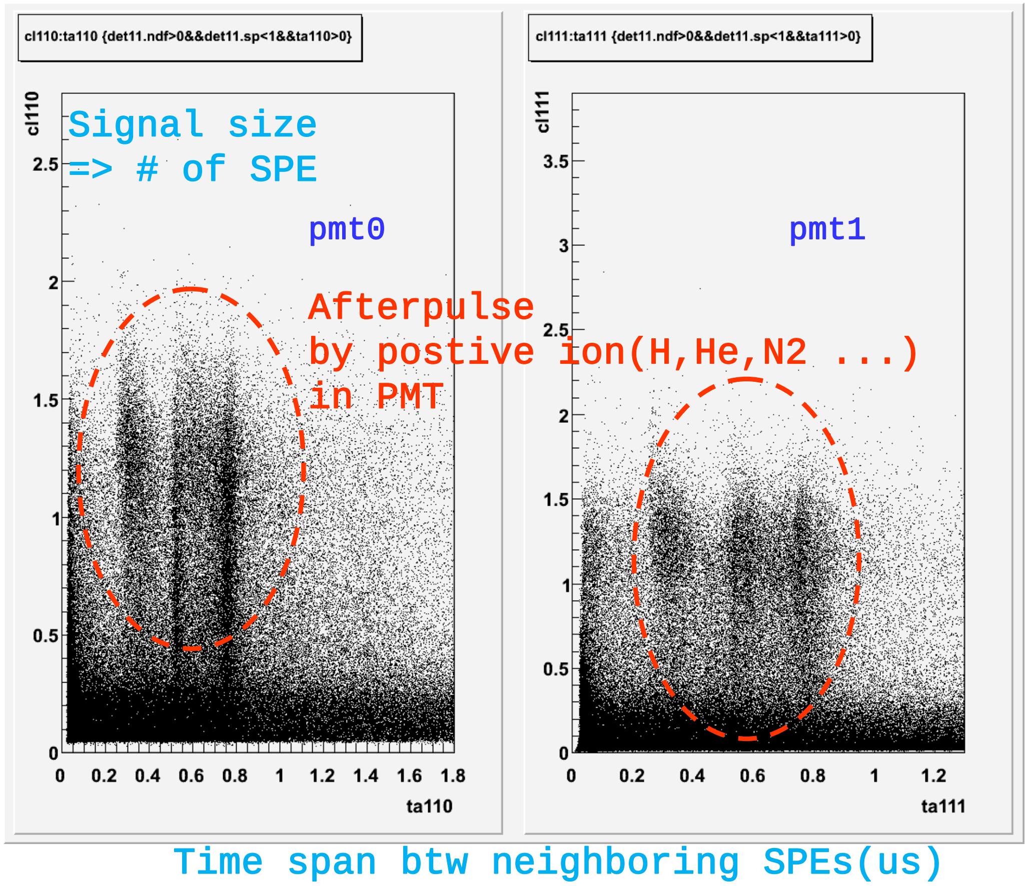
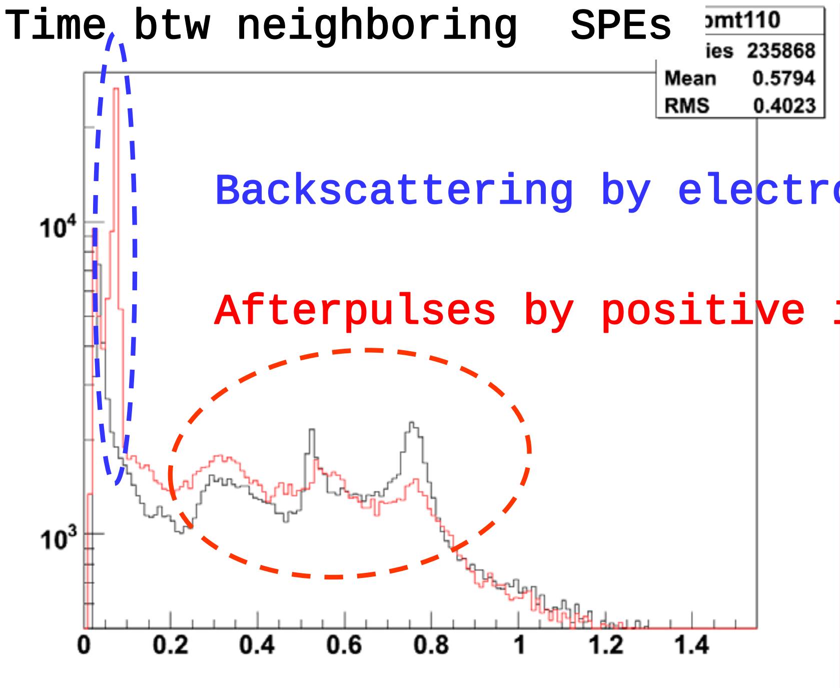
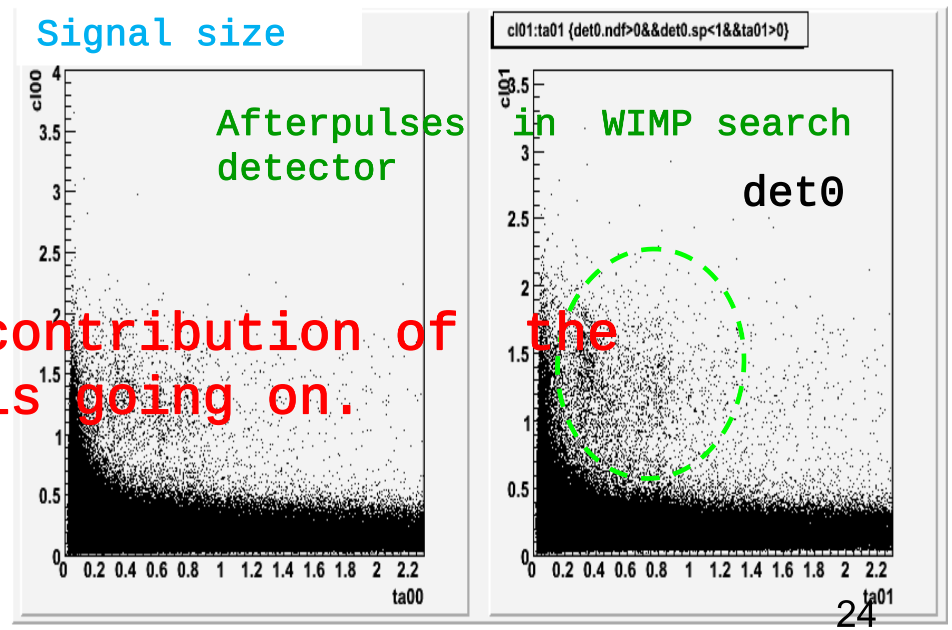


FIGURE 6.1: LATEPULSE MECHANISM



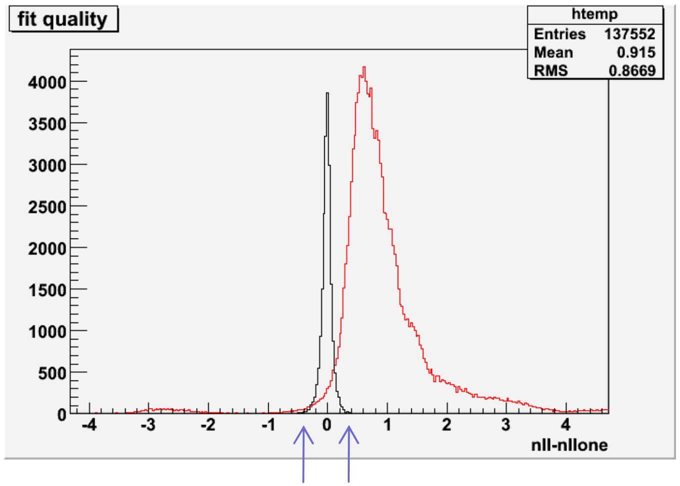
Afterpulses in PMT-only -detector





Still, study about the contribution of the afterpulse to the data is going on.

PMT noise event rejection cut

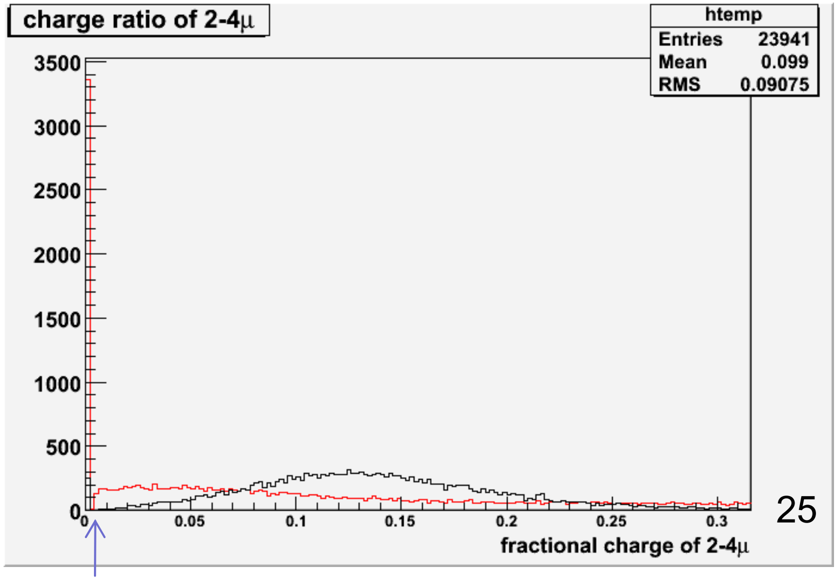


All the events are fitted with one component exponential function and two components, respectively.
We used the fit quality as the event selection criteria.

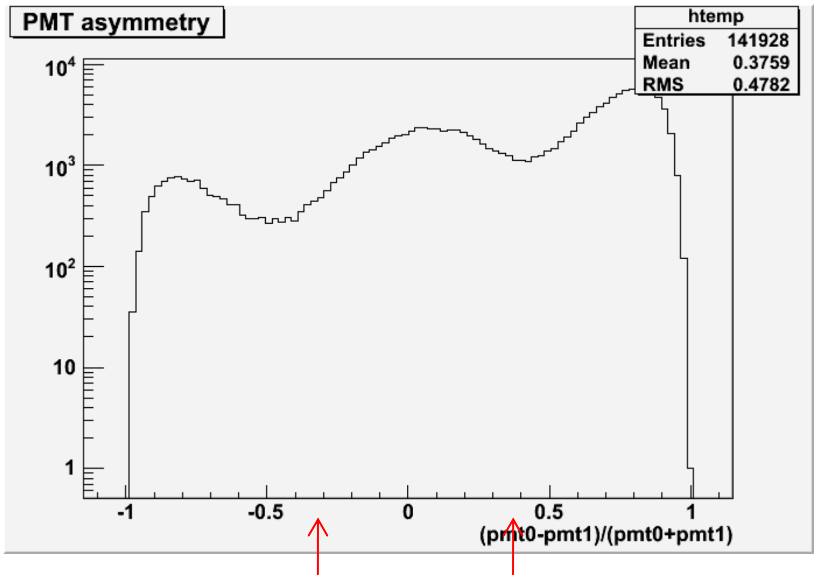
pmt noise
compton scattering events

ratio btw signal area in 2-4μs and total signal area

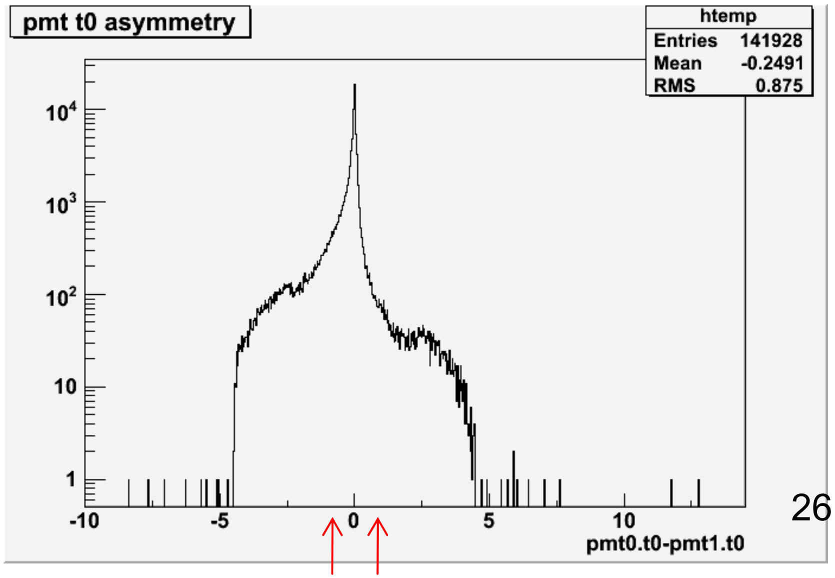
PMT events decays fast.



PMT noise event rejection cut

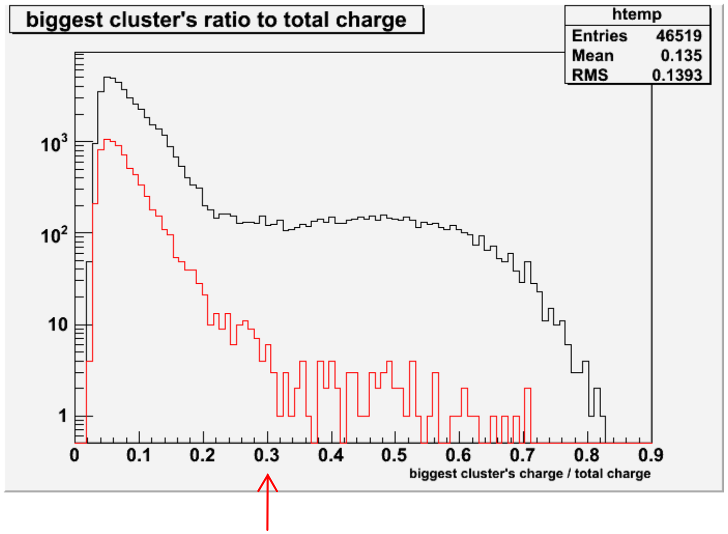


Signal size asymmetry



Difference of the start time of 2 PMT

PMT noise event rejection cut



Rejecting abnormal big cluster(SPE) events

total events
compton scattering events

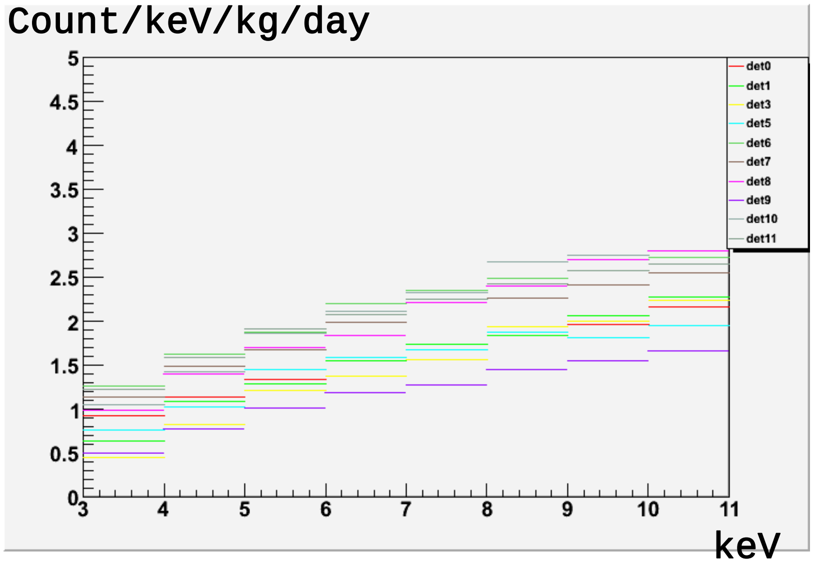
And with other cuts (multiple hit veto …)

For 25days pmt-only-detector data,

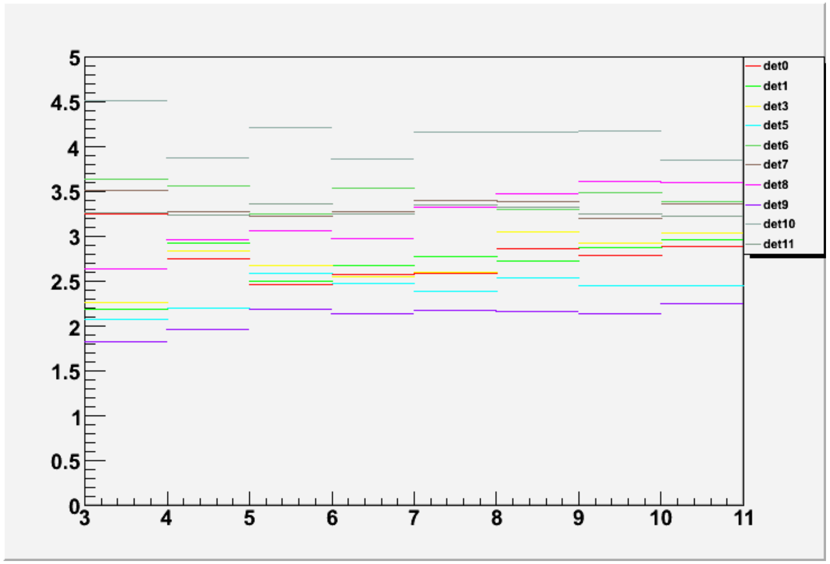
After applying the cut developed above,

Less than 10 events survived for almost detectors => < 0.05 count/kg/day

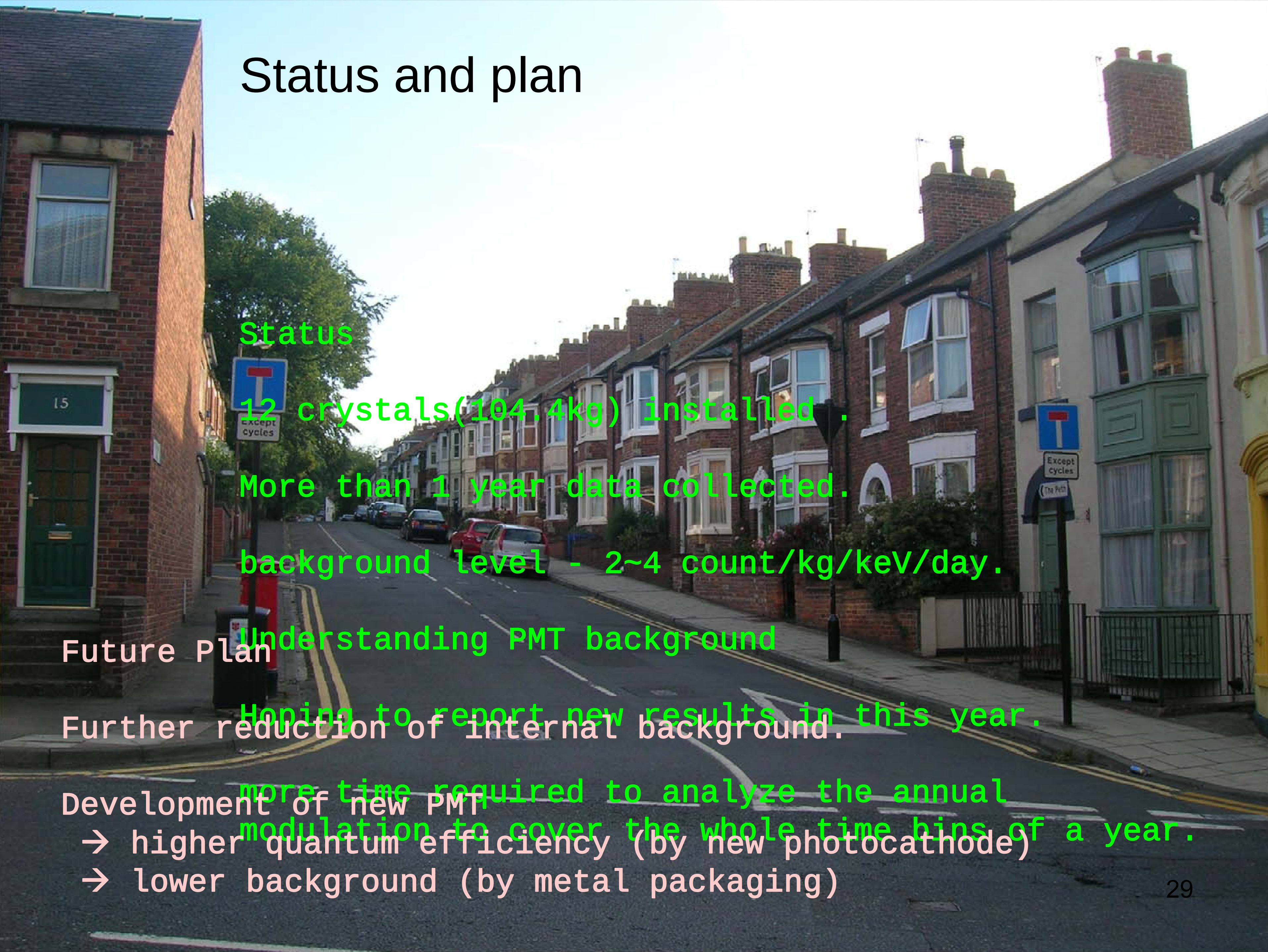
Preliminary background level
after applying cut rejecting pmt noise events



After applying cut



After efficiency correction



Status and plan

Status

12 crystals(104.4kg) installed .

More than 1 year data collected.

background level - 2~4 count/kg/keV/day.

Understanding PMT background

Hoping to report new results in this year.

more time required to analyze the annual modulation to cover the whole time bins of a year.

Future Plan

Further reduction of internal background.

Development of new PMT
→ higher quantum efficiency (by new photocathode)
→ lower background (by metal packaging)