Performance of Hyperball-J with hadronic beams on target

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for the E13 coraboration

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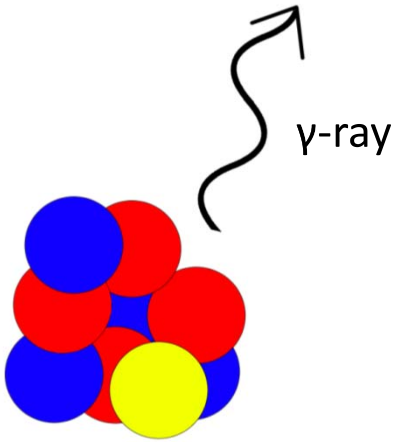
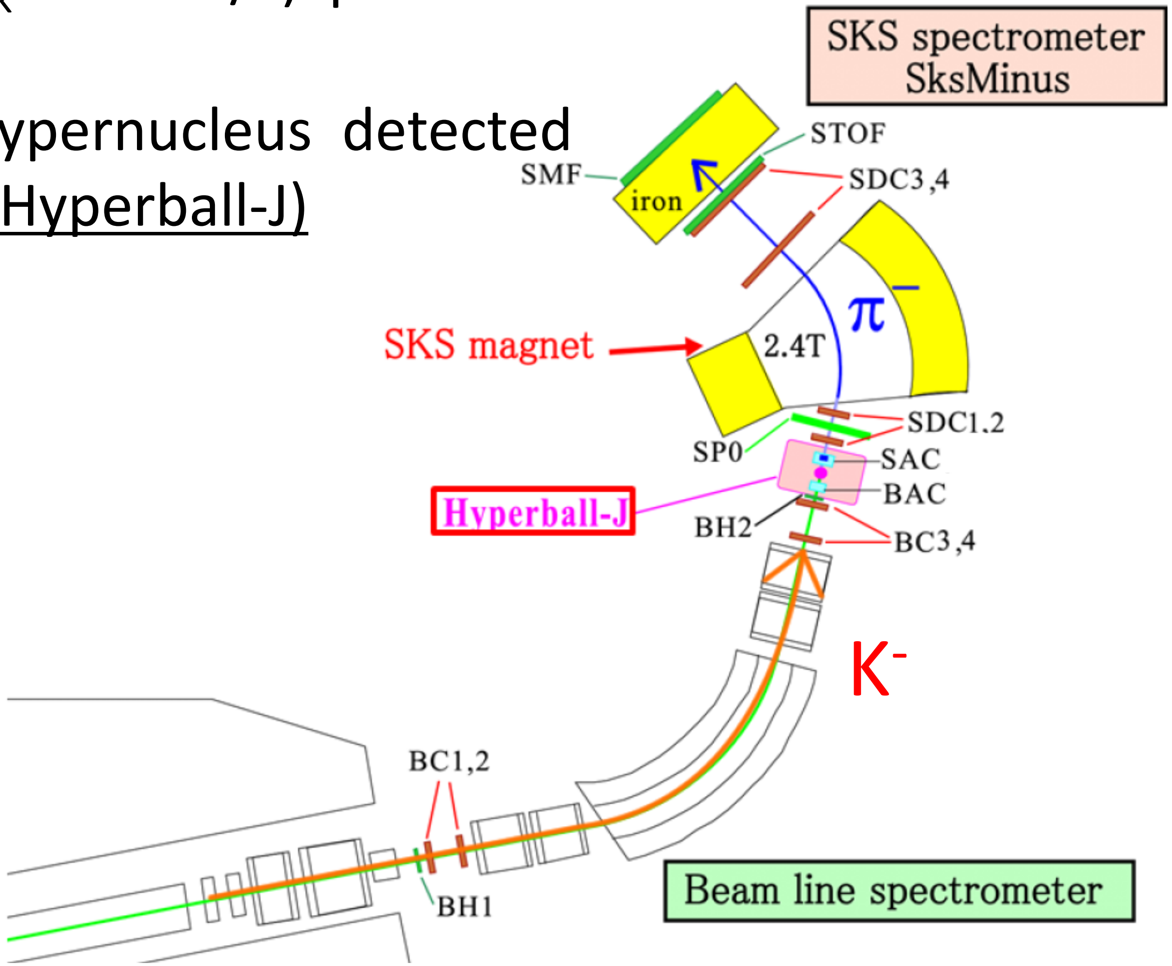
- Overview of the hypernucler gamma-ray spectroscopy experiment (E13)
- In-beam performance of Hyperball-J
  - performance of Ge detectors
  - monitoring by LSO detectors
  - background suppression by PWO detectors
- Summary and plan

Overview of the E13 experiment

Hypernucler gamma-ray spectroscopy（E13 1st）@ J-PARC K1.8

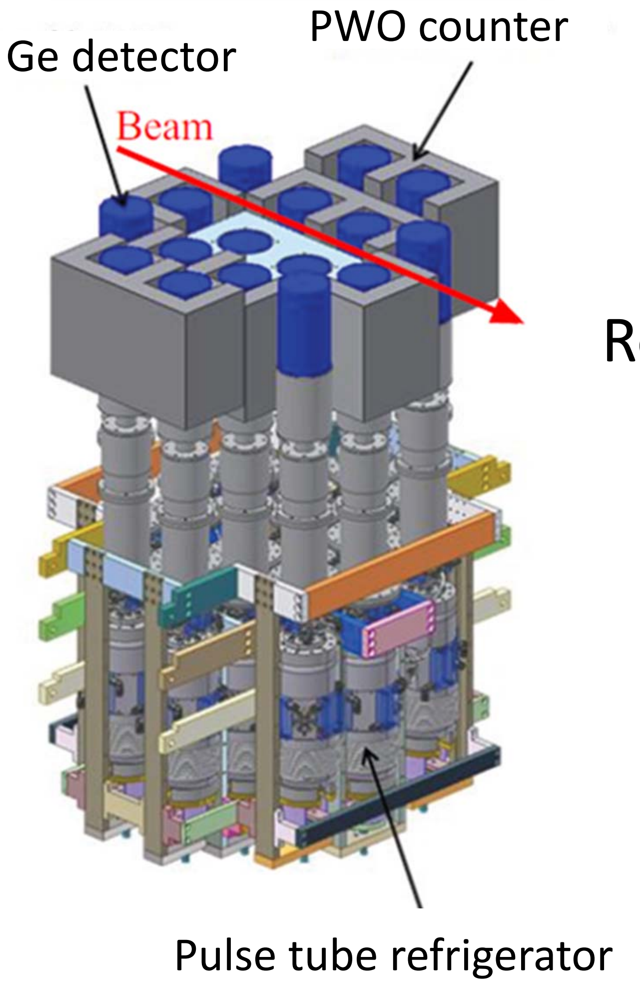
・${}^{4}_{\Lambda}$He(P_k=1.5GeV/c),${}^{19}_{\Lambda}$F(P_k=1.8GeV/c) produced using（K^-,π^-）reaction
・gamma ray from the Λ Hypernucleus detected by the Ge detector array (Hyperball-J)





Ge detector array Hyperball-J

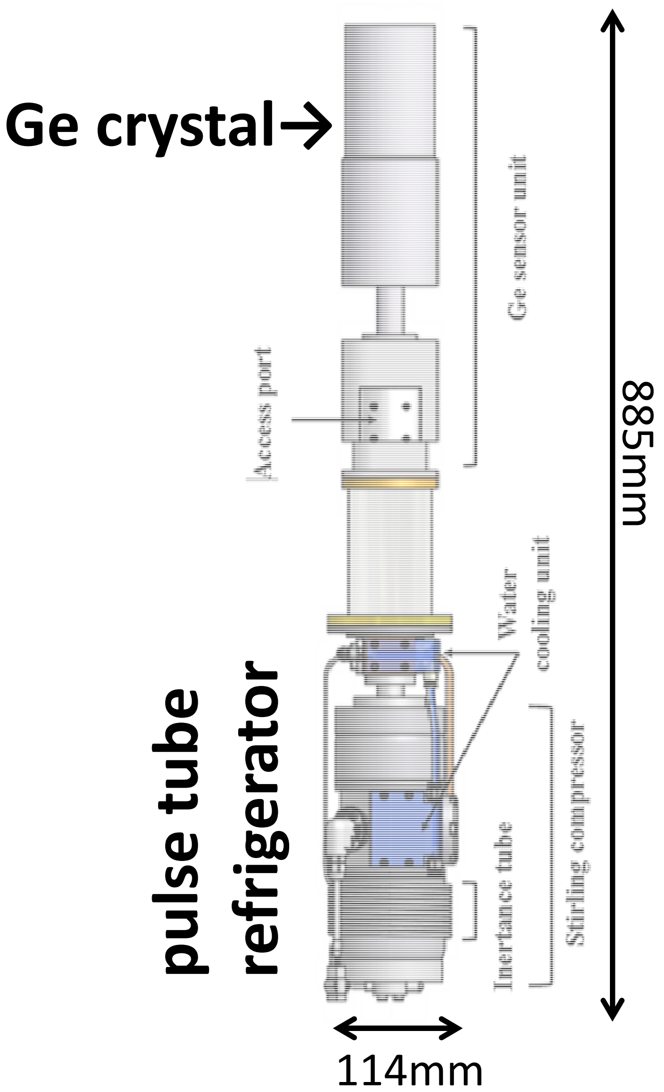
Lower half of Hyperball-J



Features

- 32 Ge detectors in compact geometry
  →total photopeak efficiency 6% @1MeV
- Cooling of Ge crystal by a Pulse Tube Refrigerator(PTR)
  →reduce effects of radiation damages of Ge crystals on resolution
- LSO detector for Ge monitoring
  → placed near the Ge detectors for monitoring such as live time and gain stability between beam ON and OFF
- Fast background suppressor
  → using PWO crystals

Ge detectors with PTR



detector's overview

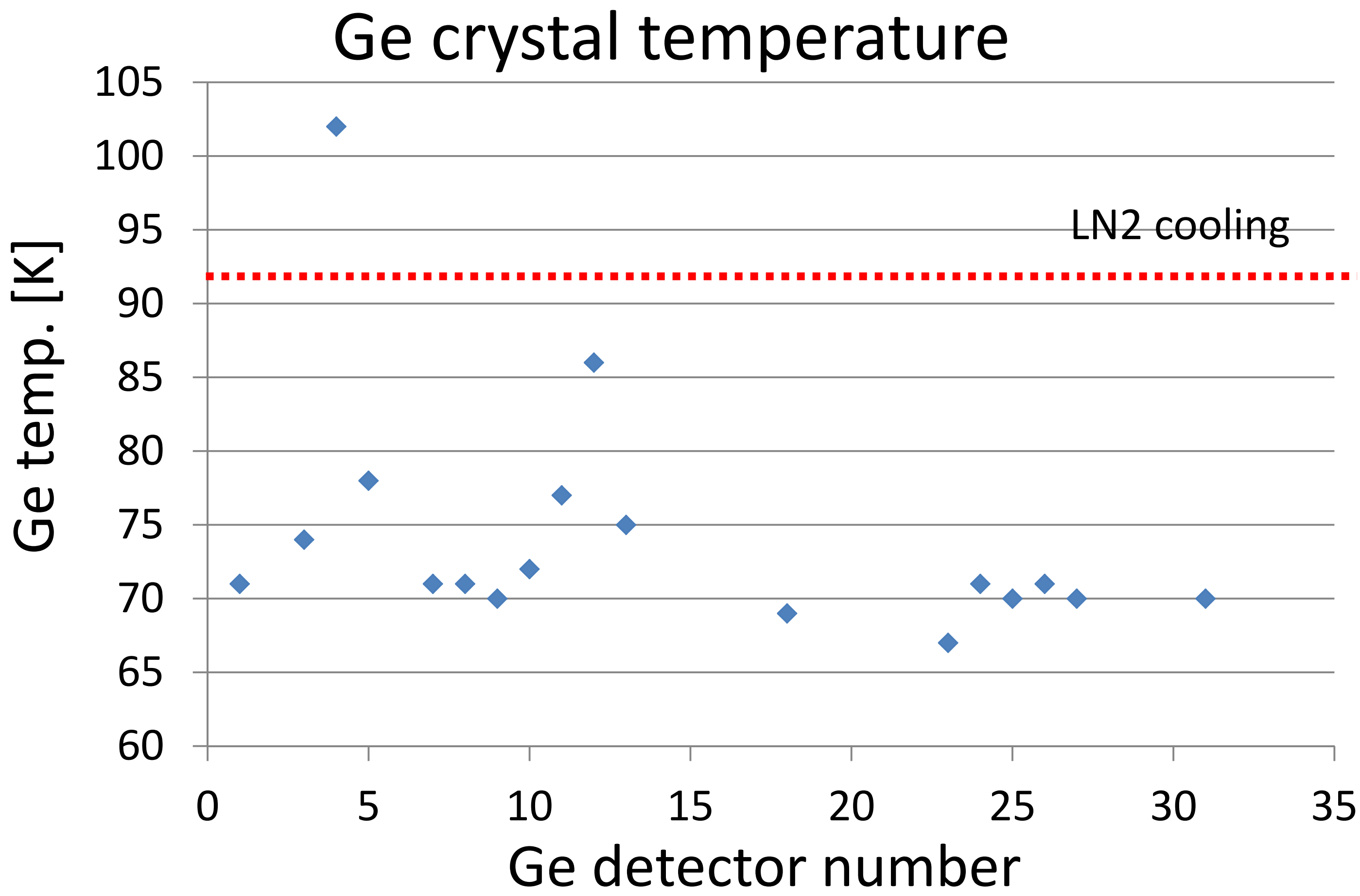
1. Mechanical vibration
   - ➢microphonics noise
2. Power supply + controller of PTR
   - ➢electric noise

Energy resolution at 1332 keV in each conditions (one detector)

	energy resolution (FWHM)
LN2	3.1(1) keV
PTR	3.1(1) keV

achieved the resolution comparable to LN2 cooling

Ge crystal temp. with PTR



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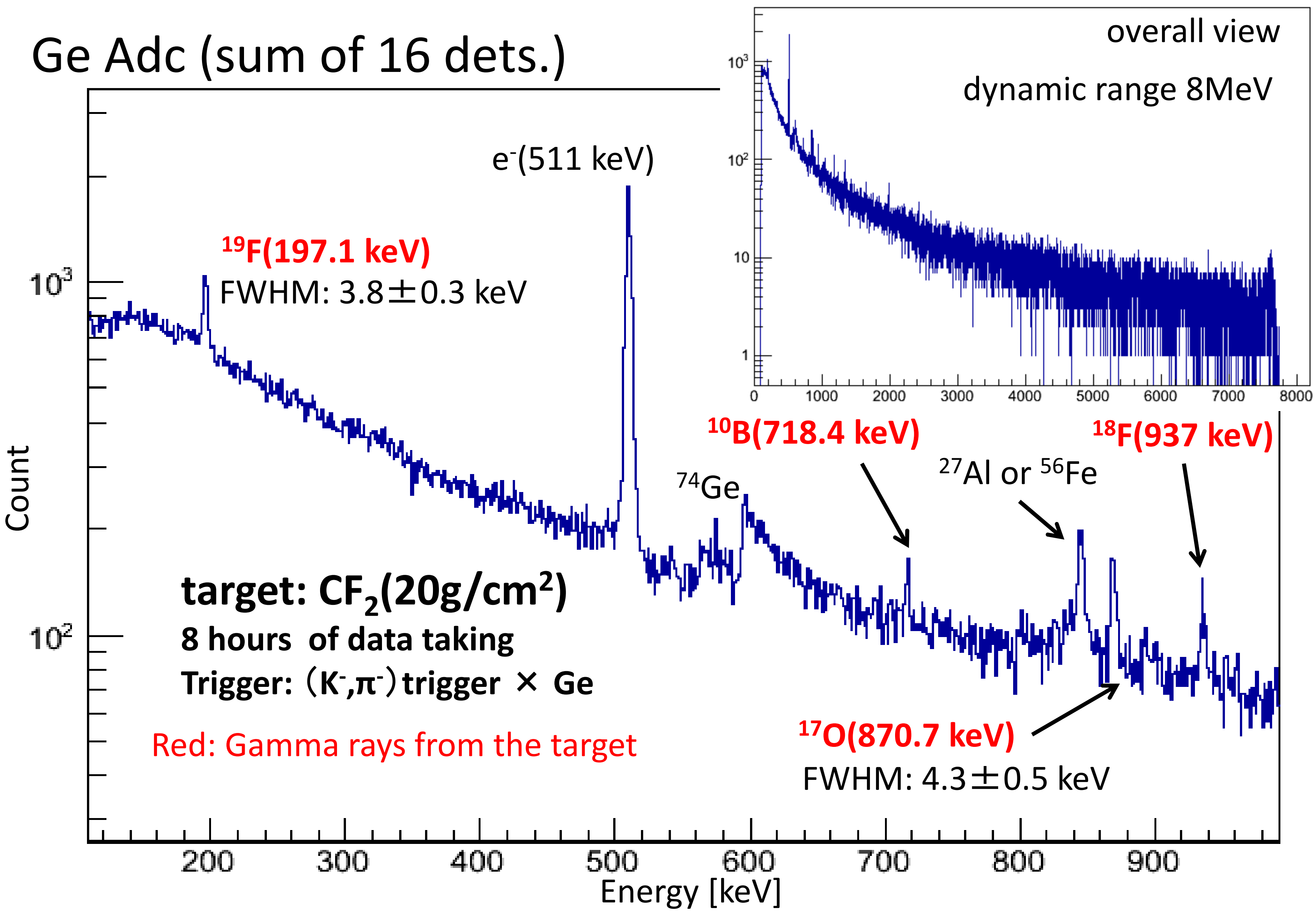
May, 2013 the E13 commissioning beam time

under this condition, we checked in-beam performance of Hyperball-J

- target: CF_2(20g/cm^2)
- Total Beam rate: 400～800k/spill
- Trigger: (K^-,π^-) trigger × Ge
- Ge: 16 detectors

The experimental conditions were almost the same as the physics run

In-beam performance of Hyperball-J



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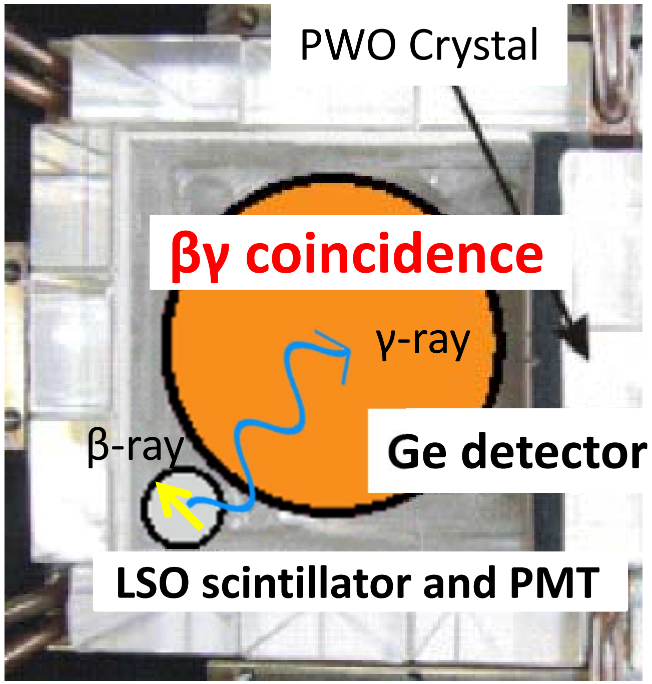
lutetium

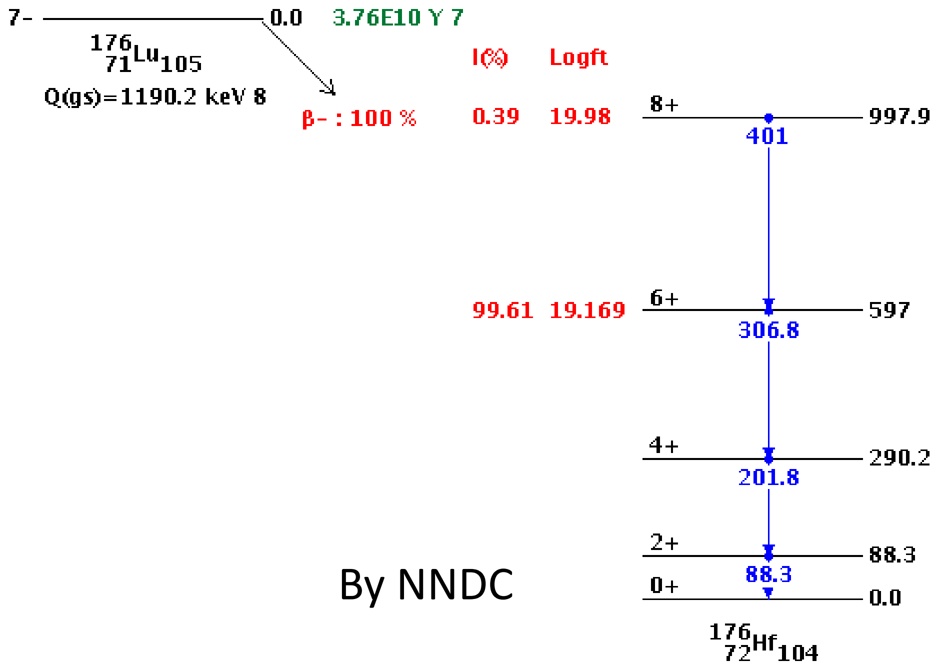
LSO detectors for live Ge monitoring

The function of LSO detector is to monitor Ge detector while beams are on target

LSO(Lu_2SiO_5) Crystal

- ^{176}Lu (Isotopic abundance 2.59%)
- Gamma rays from β decay (201.8 keV , 306.8 keV)
- Φ 1cm, 1mm thickness
- Coincidence rate: 1Hz/photo peak

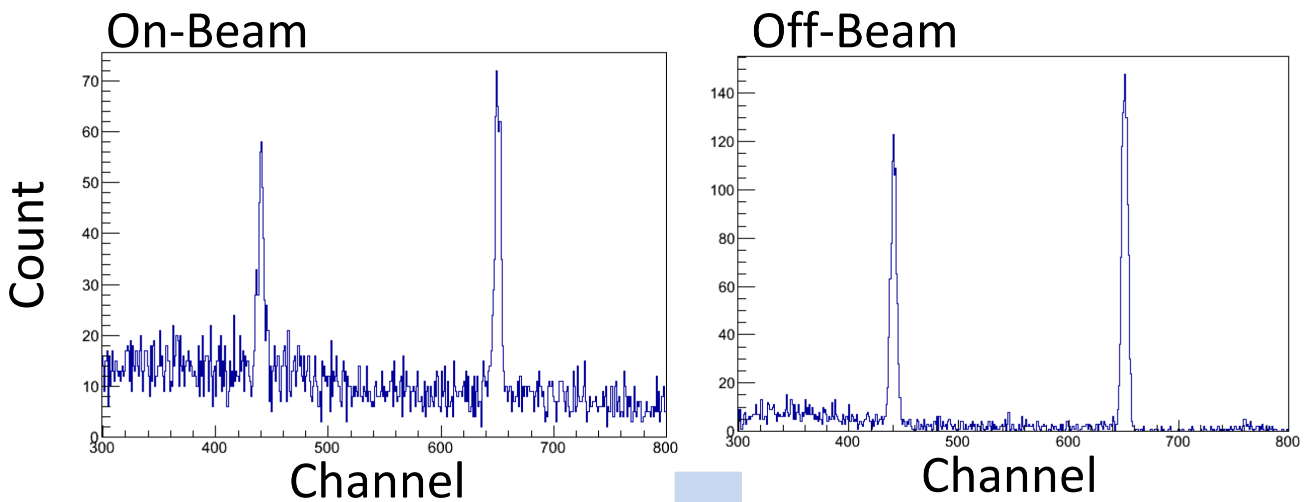




By NNDC

LSO detectors for Ge monitoring

βγ coincidence energy spectrum



On-beam/Off-beam live time ratio: 0.73±0.05
(Beam 400 K/Spill + CF2 20g/cm^2)
Data taking time : 35minits

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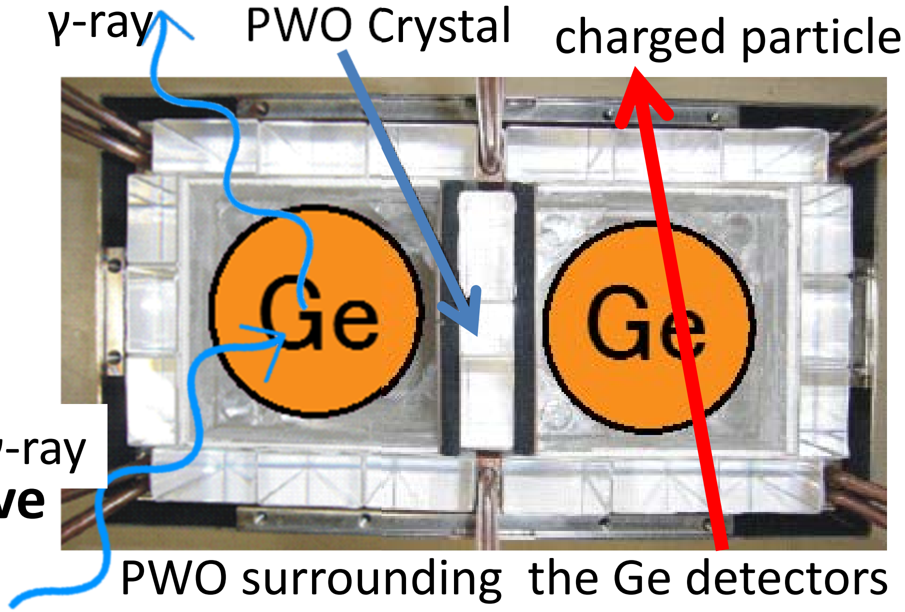
PWO background suppressor

Main backgrounds

・Compton scattering
・high energy gamma ray from π^0decay (～several tens of MeV)
・penetrating charged particles

The background suppressor can remove by Ge and PWO anticoincidence



Compare PWO and BGO crystal properties

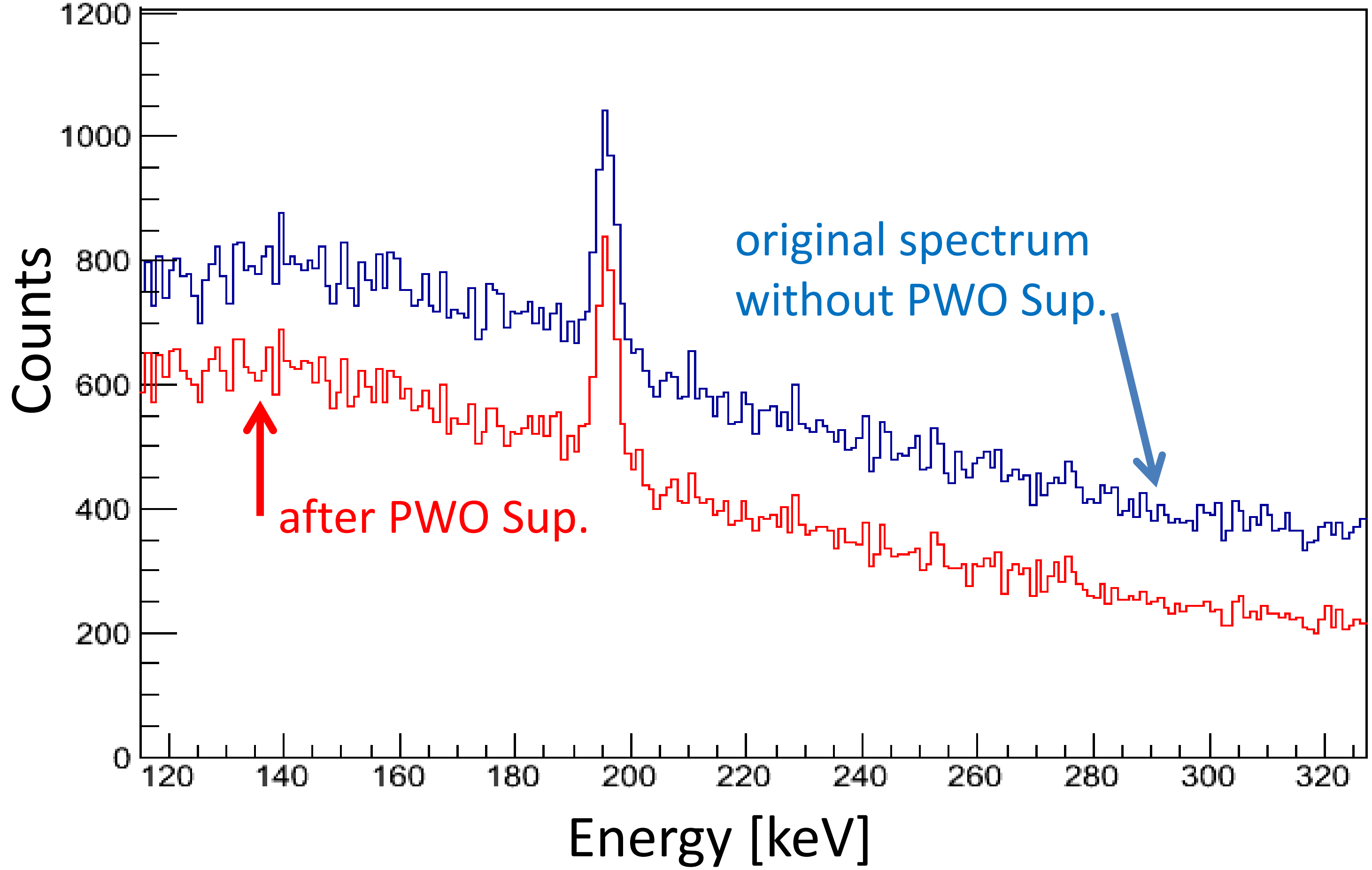
Crystal	PWO($PbWO_4$)	BGO($Bi_4Ge_3O_{12}$)
effective atomic number	76	75
decay constant[ns]	~6	300
Gamma-ray absorption ratio[%]	67	62
quantity of light [NaI(TI)=100]	1	15

clystal:20mm width
1 MeV gamma-ray

shorter decay constant -> **<u>high count rate environment</u>**, but light yield is small

The background suppression performance

Ge spectrum between before and after PWO Sup.



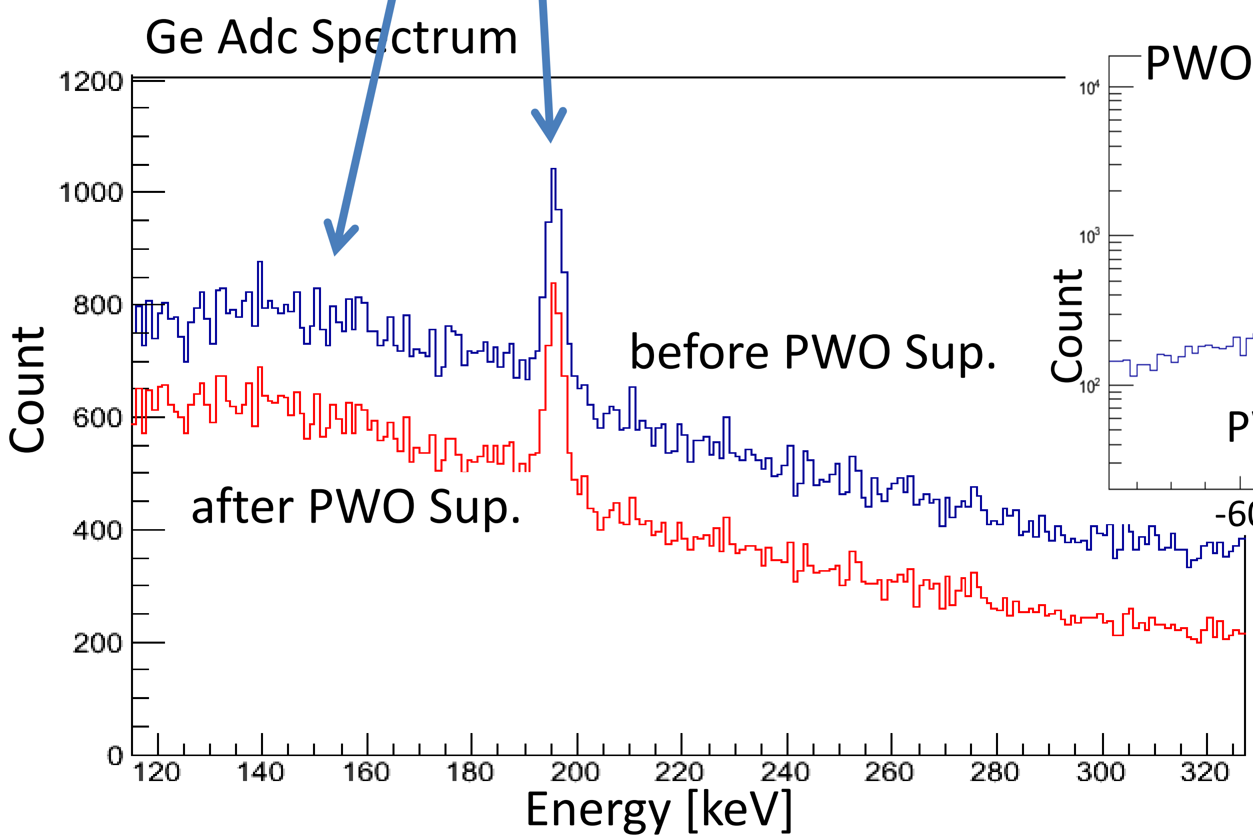
<u>PWO background suppression works</u>

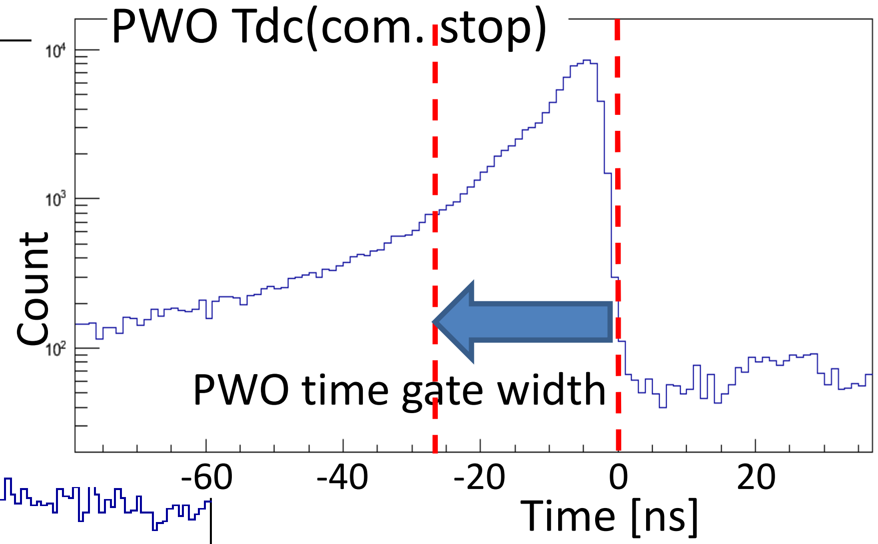
The background suppression performance

■ **Suppression factor** $= \dfrac{background\ counts\ before\ PWO\ Sup.}{background\ counts\ after\ PWO\ Sup.}$

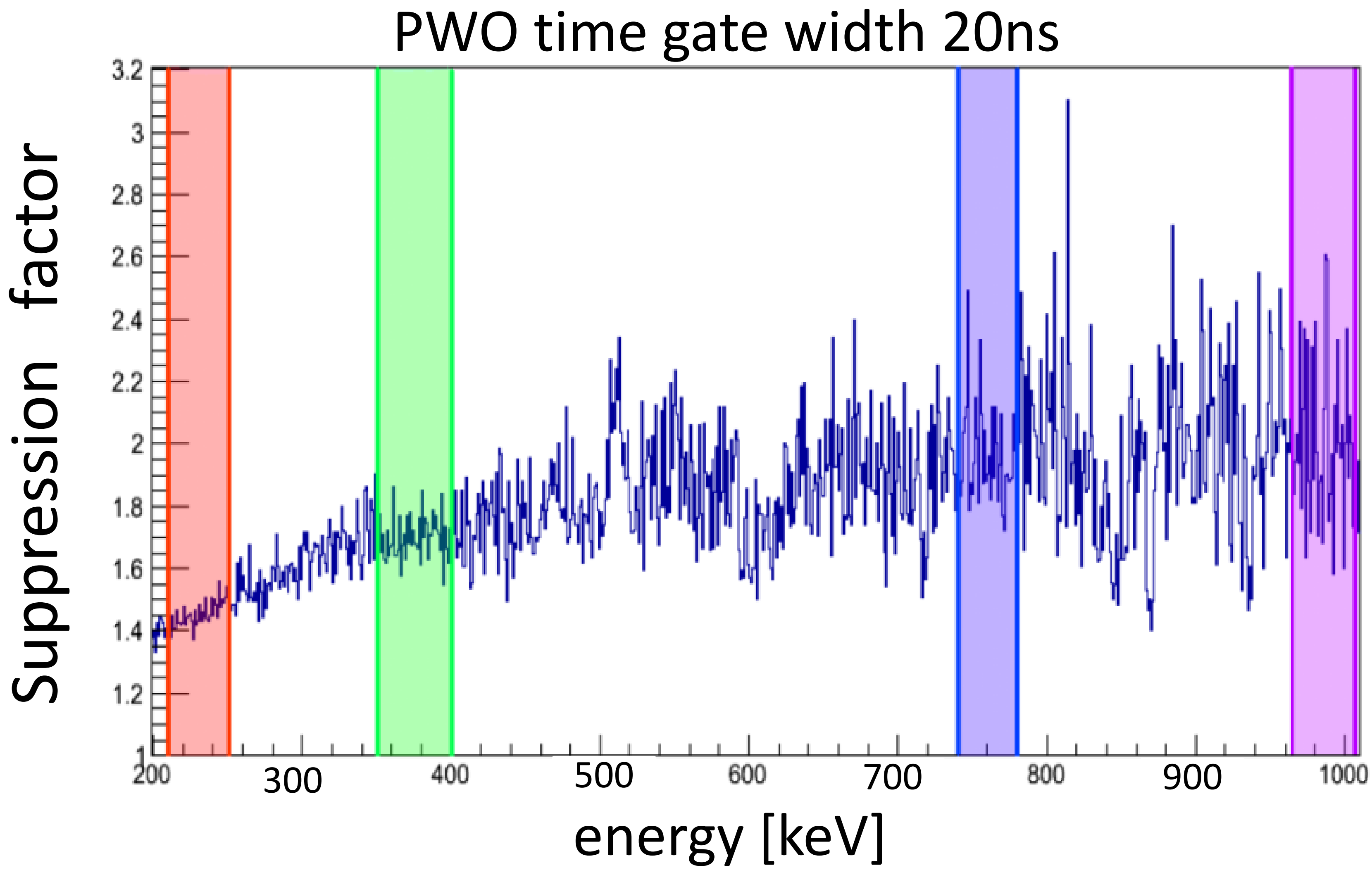
■ **Over suppression ratio** $= \dfrac{peak\ counts\ after\ PWO\ Sup.}{peak\ counts\ before\ PWO\ Sup.}$

Used peaks ^{19}F: 197 keV ^{10}B: 718 keV ^{17}O: 871 keV



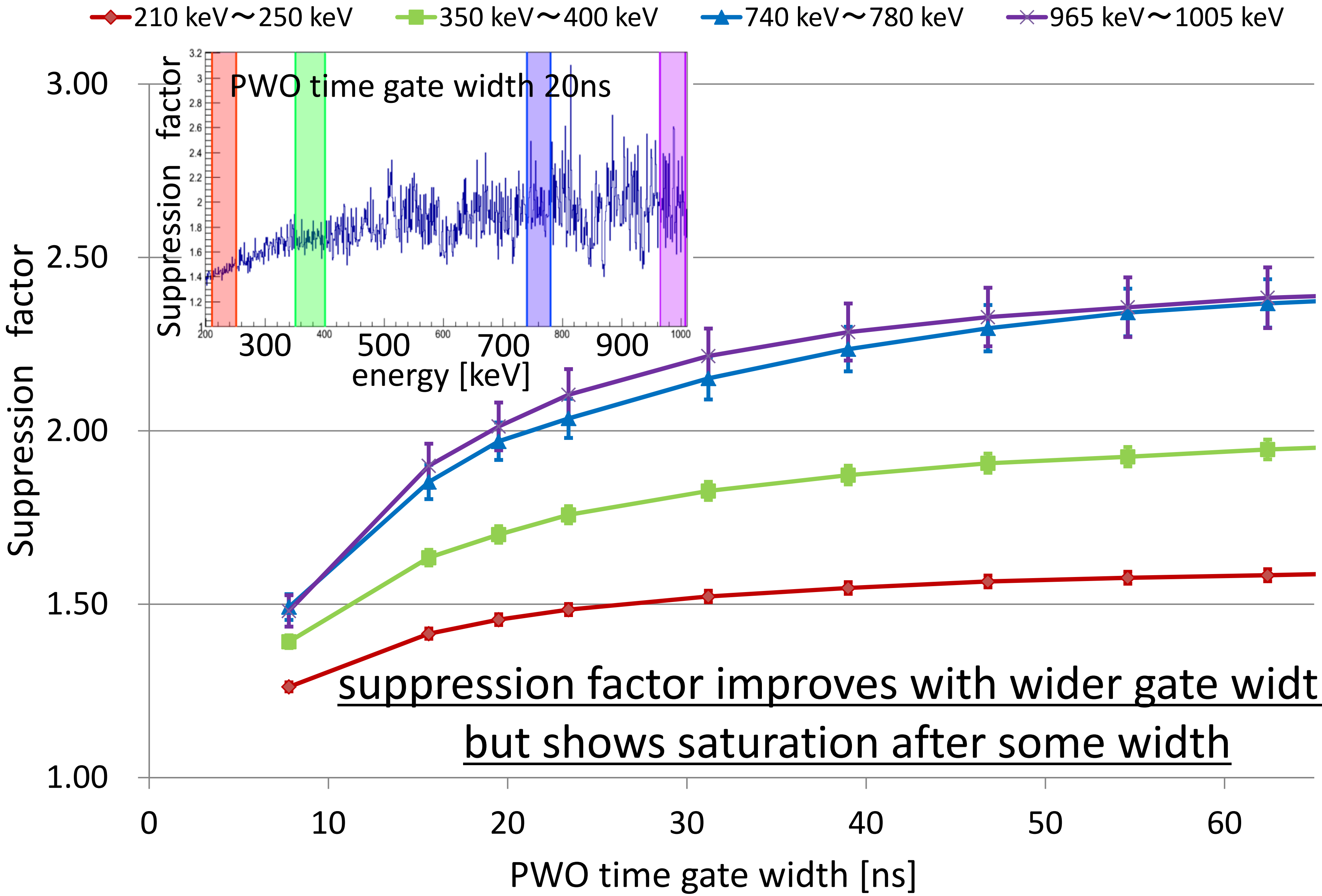


Suppression factor



<u>Suppression factor depends on energy region</u>

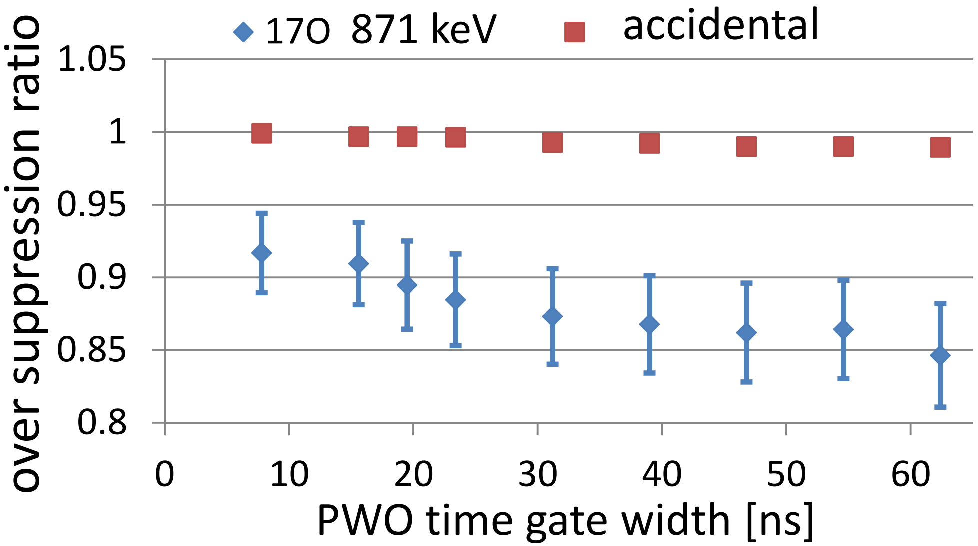
Suppression factor



suppression factor improves with wider gate width, but shows saturation after some width

Over suppression ratio

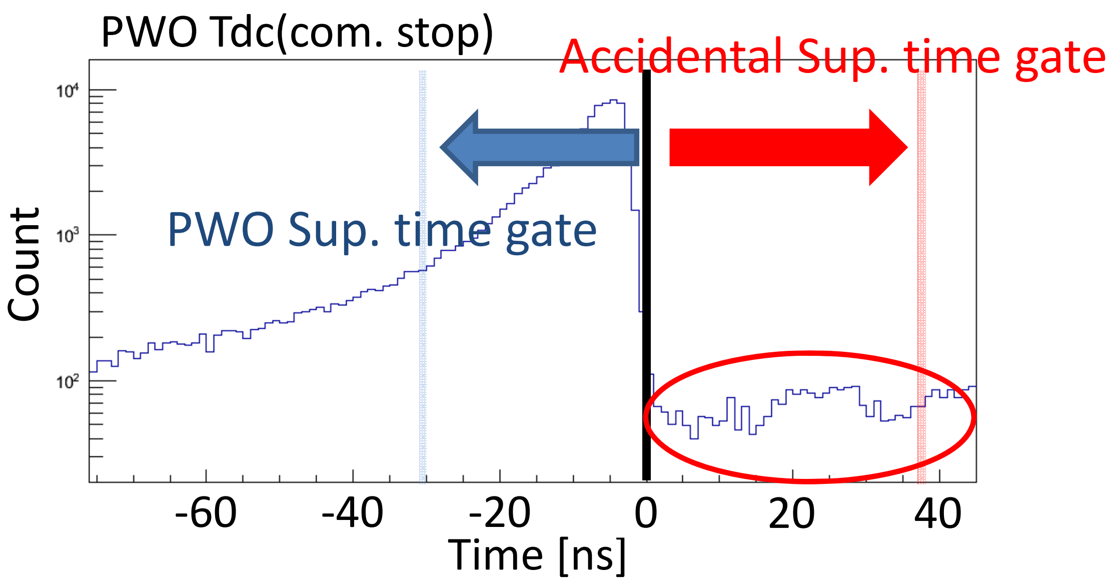
^{17}O 871 keV (other peaks follow the same trend)



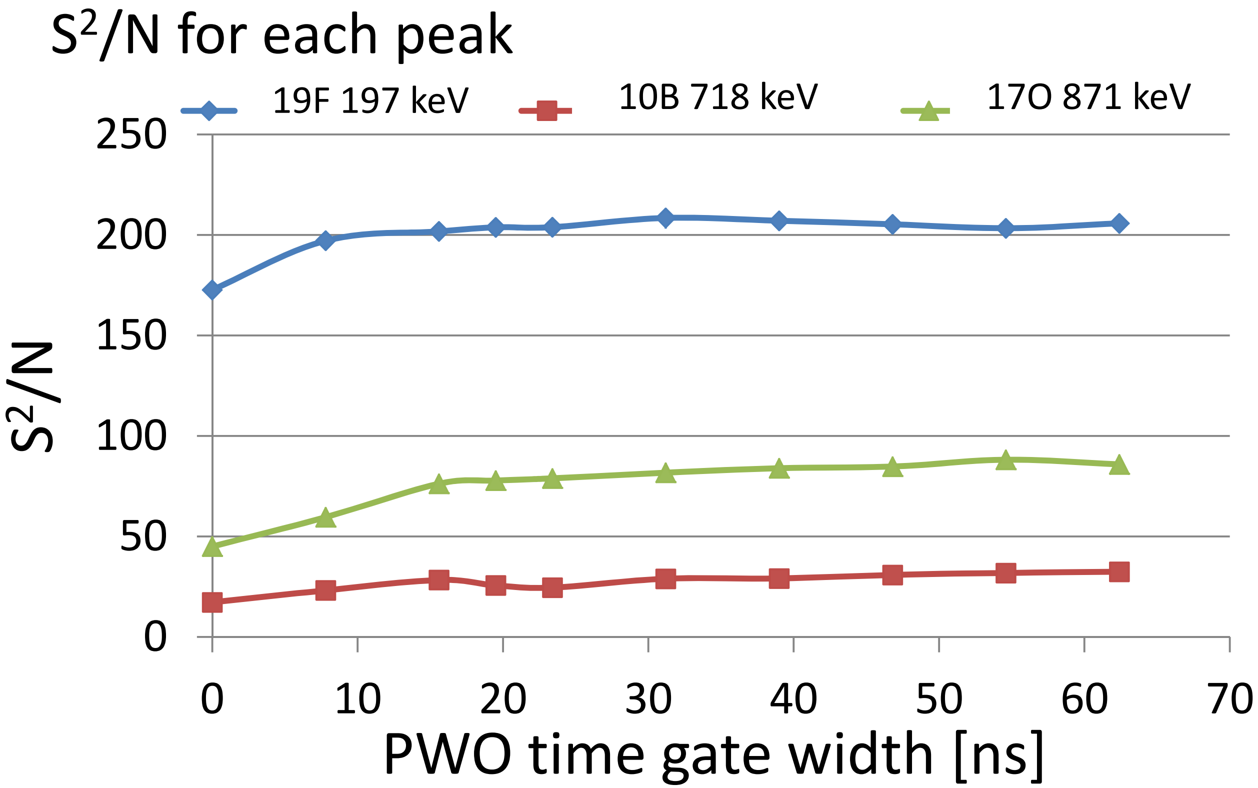
gating on the background region

gating around the prompt peak

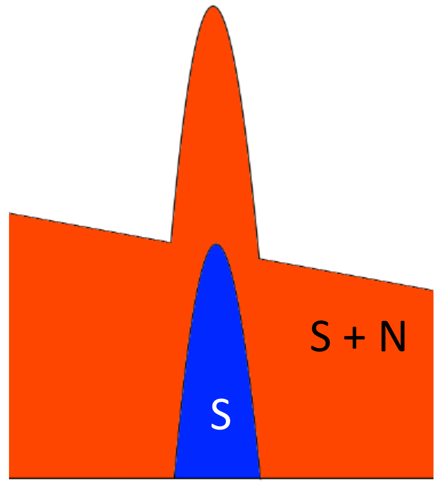
<u>blue points are lower than purely accidental red points</u>



S^2/N of gamma-ray peak



S=peak count
N=background count



spectrum conception

A typical BGO gate width : BGO～100ns

Summary

- In-beam data taken with Hyperball-J in coincidence with (K^-,π^-) trigger (J-PARC K1.8 beam line, May, 2013)
  - the same condition as the E13 1st stage experiment
- Overall Hyperball-J operation confirmed
  - Stable Ge crystal temperature with PTR during the beam time
  - Reference energy spectrum by β-γ coincidence using LSO detector obtained for beam ON and OFF period.
  - Improved S/N with 5 times smaller time gate of PWO than BGO
  - 197 keV gamma-ray from CF_2 ; 3.8 keV (FWHM)

We were and will be Ready!