### Results on WIMP search with CsI(Tl) Detector at KIMS

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For the KIMS Collaboration

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## **KIMS** Korea Invisible Mass Search

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## **Research Program of KIMS**

#### WIMP Search

- CsI(Tl) crystal detector

running  $\rightarrow 1^{st}$  result was reported

- Ultra-low energy HPGe detector (with Taiwan & China) R&D setup is running
- Development of cryogenic detector
   R&D effort is on going

Neutrinoless double beta decay Search

- Metal loaded liquid scintillator

pilot experiment is running – a preliminary result

- CaMoO<sub>4</sub> crystal (with Russia and Ukrine)
 R&D effort is on going → poster in this symposium



## **Yangyang Underground Laboratory**

Korea Middleland Power Co. Yangyang Pumped Storage Power Plant

(Power Plant)



Access to the lab by car (~2km)

er Dam)

(Upper Dam)

# CsI(Tl) Crystal

#### Advantage

Easy to get large mass with an affordable cost → Good for AM study High light yield ~60,000/MeV Pulse shape discrimination → Moderate background rejection Easy fabrication and handling



#### Disadvantages

Emission spectra does not match with normal bi-alkali PMT => Effectively reduce light yield  $^{137}Cs(t_{1/2} \sim 30y)$ ,  $^{134}Cs(t_{1/2} \sim 2y)$  may be problematic

	CsI(Tl)	NaI(TI)		<sp></sp>	<sn></sn>
Photons/MeV Density(g/cm3)	~60,000 4.53	~40,000 3.67	Cs-133	-0.2~-0.39	~0
Decay Time(ns)	~1050	~230	I-127	0.309	0.075
Hygroscopicity	slight	415 strong	Na-23	0.248	0.019



Pulse shape discrimination Of gamma background





H. Park et al. | Nuclear Instruments and Methods in Physics Research A 491 (2002) 460-469

# KIMS



#### **Muon Detector**

- $4\pi$  coverage muon detector : 28 channels
- Liquid Scintillator(5%) + Mineral Oil (95%) = 7 ton
- Measured Muon flux =  $2.7 \times 10^{-7} / \text{cm}^2/\text{s}$
- Position resolution :  $\sigma_{x_1} \sim 8 \text{ cm}$
- 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)

→  $8 \times 10^{-7} / \text{cm}^2/\text{s}$  (1.5 < E neutron < 6 MeV)



### Muon induced neutron

#### Log<sub>10</sub>(∆t)



Set-up	Events	Day	Liter
Α	2	67.4	1.2
В	9	203.0	1.0
С	11	203.0	1.2

22 events of Muon induced neutrons  $(4.2\pm0.9)\times10^{-2}$  counts/day/liter





### Radon Monitoring

- Electrostatic alpha spectroscopy : 70 liter stainless container
- Use Si(Li) photodiode : 30 x 30 mm
- Estimate <sup>222</sup>Rn amount with energy spectrum of a from <sup>218</sup>Po & <sup>214</sup>Po.
- Photodiode calibration : <sup>210</sup>Po, <sup>241</sup>Am
- <sup>222</sup>Rn in air = 1 ~ 2 pCi/liter
- Absolute efficiency calibration done with <sup>226</sup>Ra





## Internal background

#### Radioisotopes in the crystal



## Reduction of internal background

#### Cs-137 reduction – use ultra pure water in powder prodcution



### **Detector & DAQ**

CsI(Tl) Crystal 8x8x30 cm<sup>3</sup> (8.7 kg)

3" PMT (9269QA) : Quartz window, RbCs photo cathode

~5 Photo-electron/keV



DAQ : 500MHz Home Made FADC

trigger condition : 5 photo-electrons within 2µsec + high energy trigger

 $32\mu$ sec window

vme to pc connection by usb

DAQ written in ROOT



## Neutron calibration

300 mCi Am/Be source

- $\rightarrow$  neutron rate 7 x 10<sup>5</sup> neutrons /sec
- → a few 100 neutrons/sec hit 3cmX3cm cry stal
- → Quenching factor of Recoil Energy NR mean time distribution



@Energy = 4-5 keV
137 Cs Compton
Neutron Recoil



### Crystals and data taking



## **KIMS First WIMP Limit**

Dark matter density at the solar system

 $\rho_{\rm D}$  = 0.3 GeV c<sup>-2</sup> cm <sup>-3</sup>

#### > Use annual average parameters

 $\mathcal{V}_0 = 220 \text{ km s}^{-1}, \ \mathcal{V}_E = 232 \text{ km s}^{-1}, \ \mathcal{V}_{Esc} = 650 \text{ km s}^{-1}$ 



#### Data used for this analysis

```
S0501A (8.7kg) 1147 kg days
S0501B (8.7kg) 1030 kg days
at T = 0° C
```

### Calibration and control data samples

```
Neutron ~ 500 kg days (at 4~6 keV)
Gamma (using <sup>137</sup>Cs)
~ 1100 kg days (0501A), 1650 kg days(0501B)
PMT only ~190 kg days for each crystal with the PMTS used
for each crystal
```



# Cut list

- Base cut to get rid of junk events
- Coincidence event cut
- Fit quality cut
  - fitted  $\mathbf{T}_{f}$
  - log likelihood value for two exponential fit and one expo nential fit
  - ratio of fitted mean time to the calculated mean time
- Short component rejection
  - ratio of tail (t> 10  $\mu$ s) to the whole amplitude
  - asymmetry cut

#### Coincidence event rejection



#### Decay time fit and fit quality cut





### Efficiency



### NR event rate estimation



• Modeling of Calibration data with asy mmetric gaussian function



- Fit the WIMP search DATA with PDF function from gam ma and neutron calibration da ta
  - $\rightarrow$  extract NR events rate

#### NR recoil event rate





#### Spin dependent limits (only with I)



#### Pure proton case

**Pure neutron case** 

Form factor and spin expectation value for "I" are obtained from "M.T.Ressel and D.J.Dean PRC 56(1997) 535

#### What's next?

Analyze R&D run data carefully

- optimize the running condition (temperature, quartz)

Understand short <t> components (origin & characteristics)

- surface alpha : careful surface treatment
- PMT background : taking data w/o crystal

Install >12 crystals(~100 kg) - upgrade of FADC (8 bit 500 Ms → 10 bit 400 Ms) + 12 bit 64Ms)

- take data for long term with stable condition

Keep R&D on reducing internal background - needs < 1cpd → for larger mass detector

#### Fast events at high energy



## Summary & Prospects

- Pilot run with one crystal of 6.6 kg mass
   Published the first physics result
- Various R&D run was done
  - About 4000 kg day data accumulated
  - With and without quartz block (5cm thick)
  - 0 degree and Room temperature operation
  - Analysis is ongoing
  - **Preliminary result with 2177 kg days**
- Successfully reduced internal backgrounds of CsI(Tl) crystals (latest powder ~ 2cpd)
  - 100 kg full size crystals(8x8x30cm3)
  - Current shielding can accomodate 250 kg
- 100 kg crystals run will start within a few mont hs
  - Annual modulation

