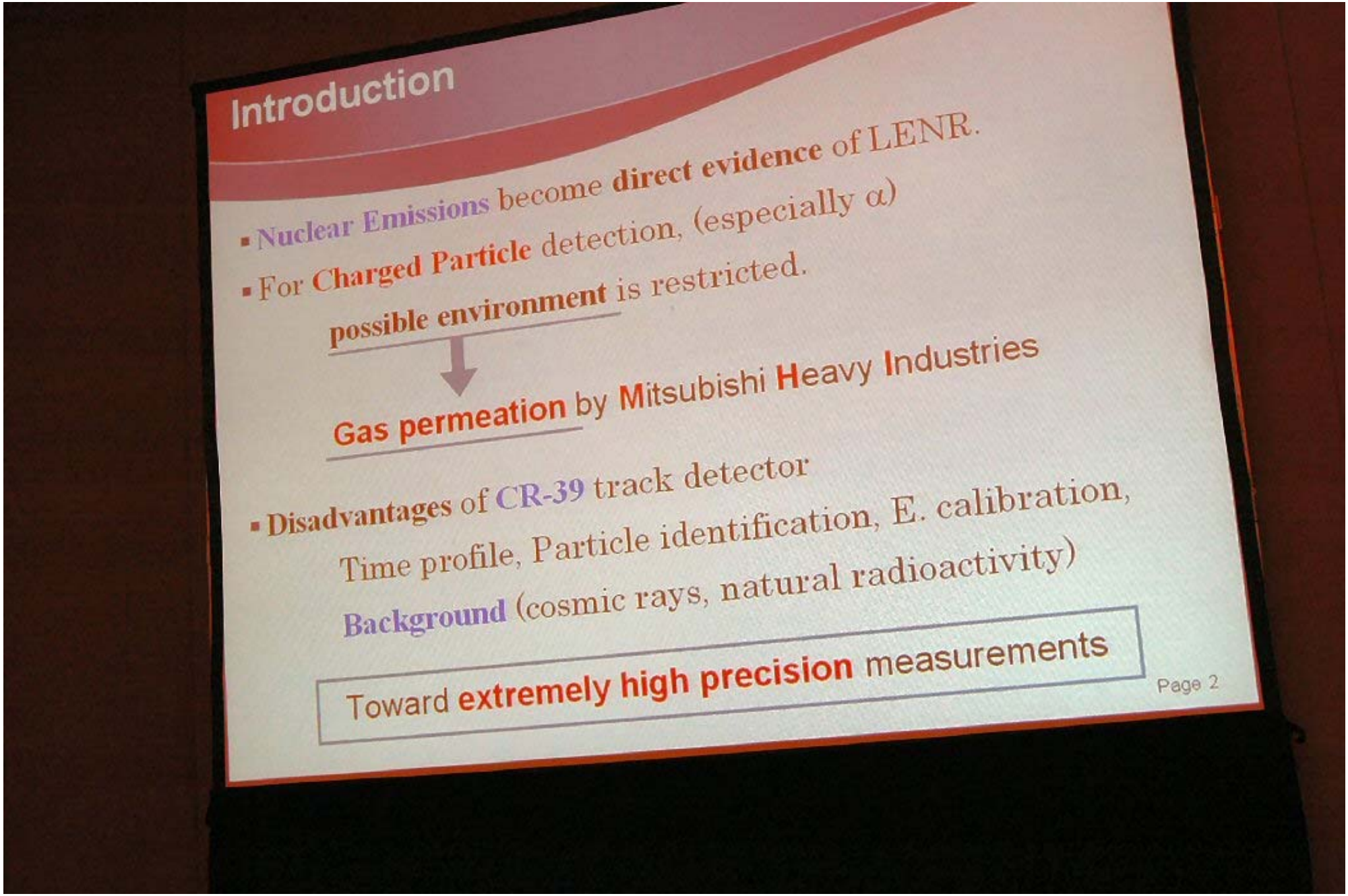

Introduction
▪ Nuclear Emissions become direct evidence of LENR.
▪ For Charged Particle detection, (especially α)
possible environment is restricted.
Gas permeation by Mitsubishi Heavy Industries
▪ Disadvantages of CR-39 track detector
Time profile, Particle identification, E. calibration,
Background (cosmic rays, natural radioactivity)
Toward extremely high precision measurements
Page 2

Charged Particle Detection

- Emissions are too weak in CMNS exp.

1. **Extremely low background** (**cosmic ray**, natural RI)
2. **Particle Identification** (at least cosmic ray or not)
3. High energy resolution
4. Time profile → **Relation** with exp. Condition
5. Large detection area (efficiency)
6. No shielding materials
7. Stable in **high temperature** hydrogen
8. Electrical noise

Ce doped Yttorium Aluminum Perovskite : **YAP(Ce)**

Page 3

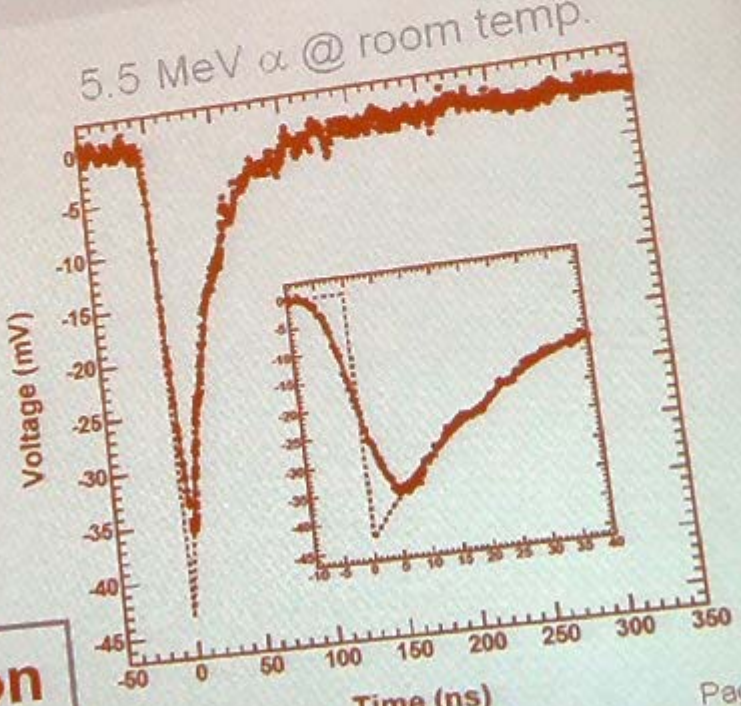
YAP(Ce) Characteristics

- Non-hygroscopic, Small **temp. dependent** (+2, -8 % ~200°C)
- **0.5mm thickness**, 20 mmϕ , optical polish (Crytur, Czech)
- Max. Measuring E. (SRIM2008)

  12.5MeV proton, **50MeV α**
- **Resolution** : **22%** in FWHM
- **Decay constant** : $\tau \sim 30$ ns

$$I = I_0 \exp\left(-\frac{t}{\tau}\right)$$

exhibits **particle identification**.



Pulse Shape Discrimination

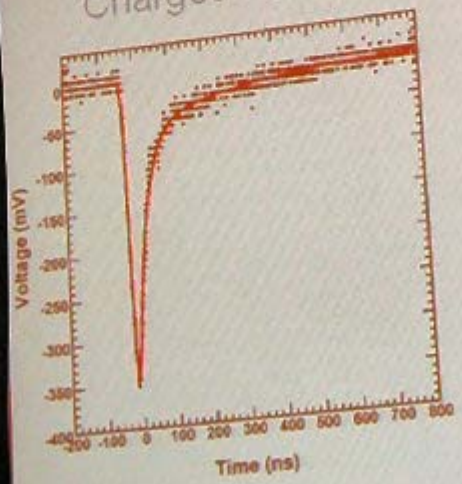
Page 4

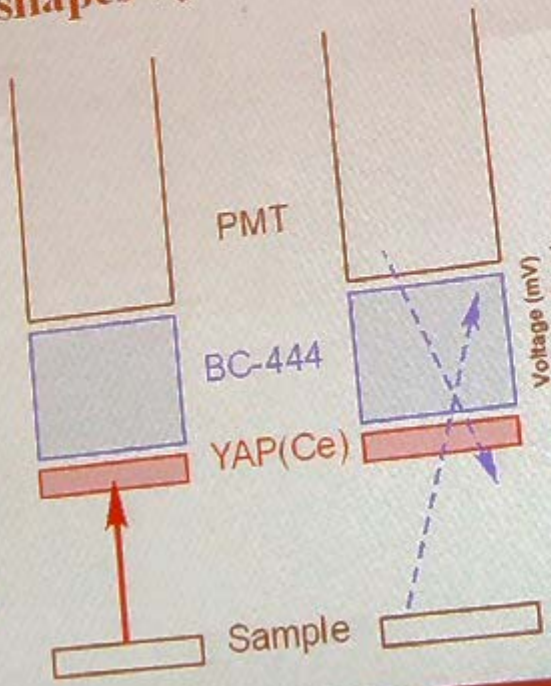
Phoswich Detector

2 Scintillators / 1 PMT

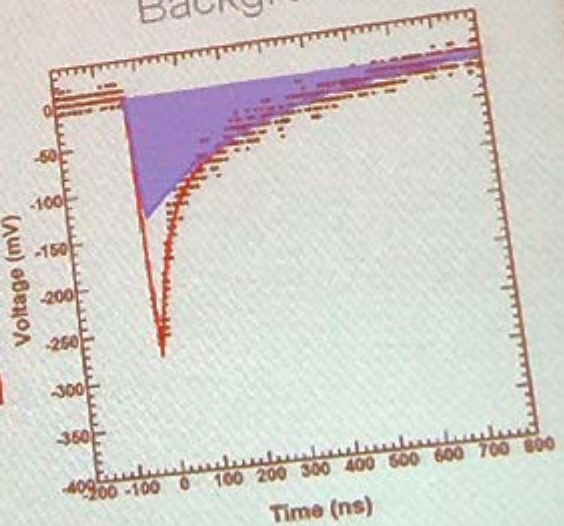
- Front : **YAP(Ce)**, 20mmϕ, 0.5mm, τ_{YAP} ~ **30ns**
- Back : **BC444 Plastic**, 20mmϕ, 5mm, τ_{BC} ~ **300ns**
- We **record all pulse shapes** by digital storage oscilloscope.

Charged Particle





Background



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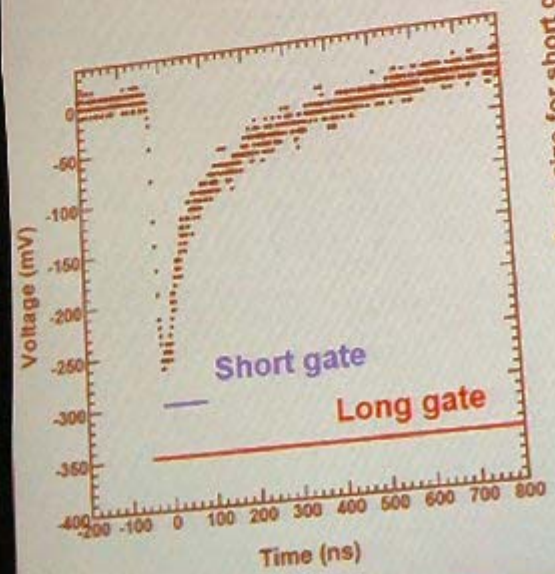
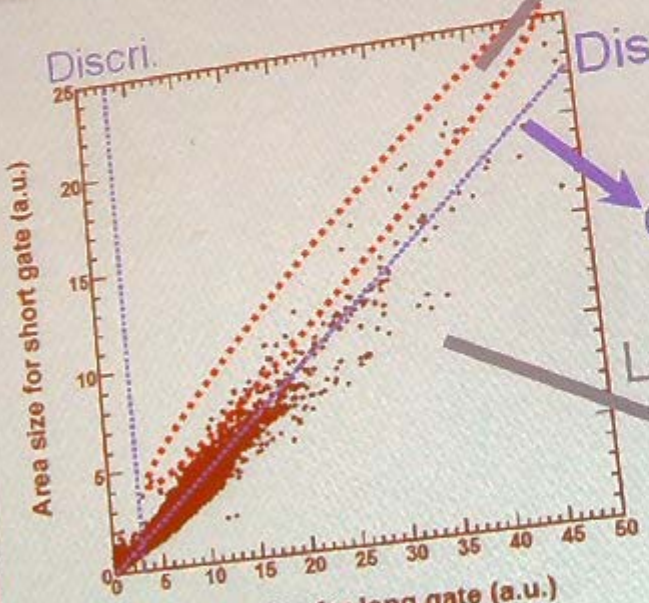
Pulse Shape Discrimination 1

- 2 integrations provide **Particle Identification**.
- **Short** gate : 100ns
- **Long** gate : 850ns



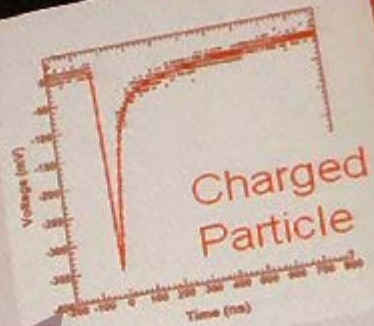


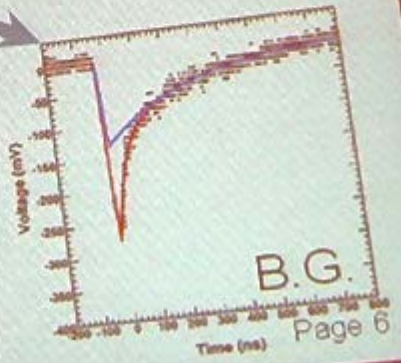
No tail

Discri. Level

Clearly B.G.

Long tail event





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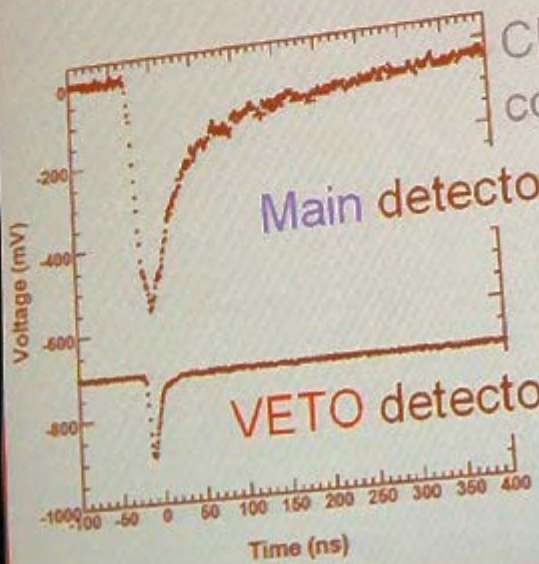
VETO Detectors 1

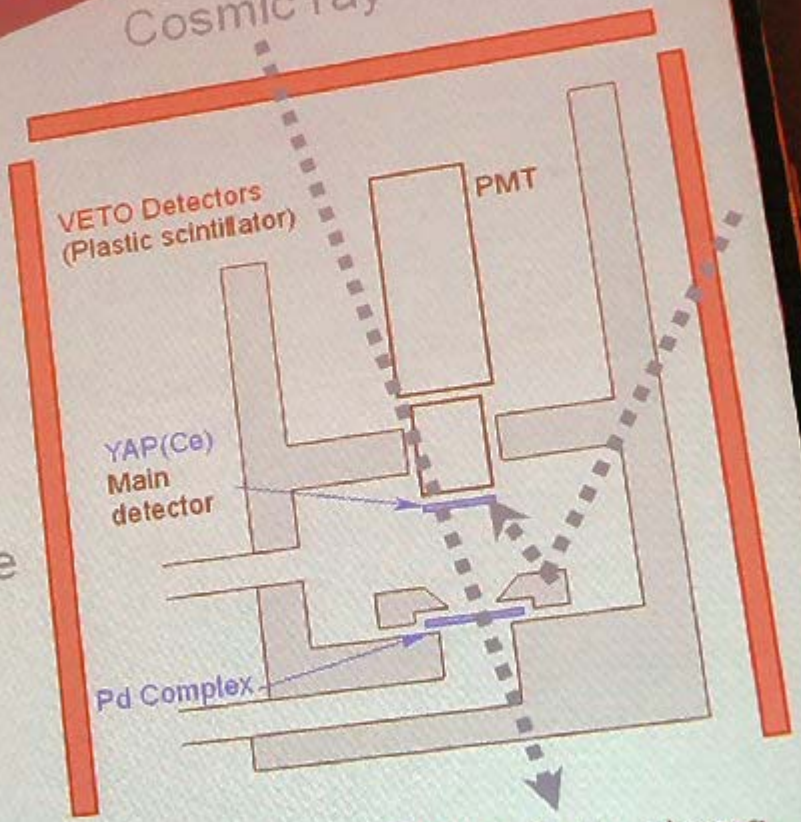
- Reduce cosmic ray events. (include secondary particle)
- **Natural radioactivity** cannot be suppressed.



Check coincidence

Main detector

VETO detector



Main & VETO detectors response at same time.

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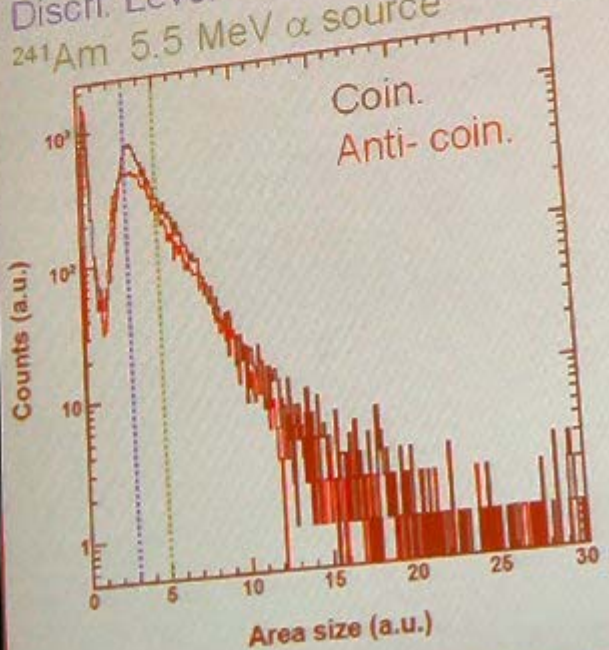
VETO Detectors 2

MHI sample,
D_2 permeation, 333.7 hours,
Discri. Level
^{241}Am 5.5 MeV α source



- **Coincident events**
  100 % cosmic ray events
  (ignore chance event)
- **Anti - coincident events**
  Real events or cosmic rays
  (not cover all area)
- 57 % is rejected.
- ~75 % could be predicted by additional detectors.
- Origin of **high energy** counts are unknown.
  Elastic recoil ? p(μ, μ)p, d(μ, μ)d

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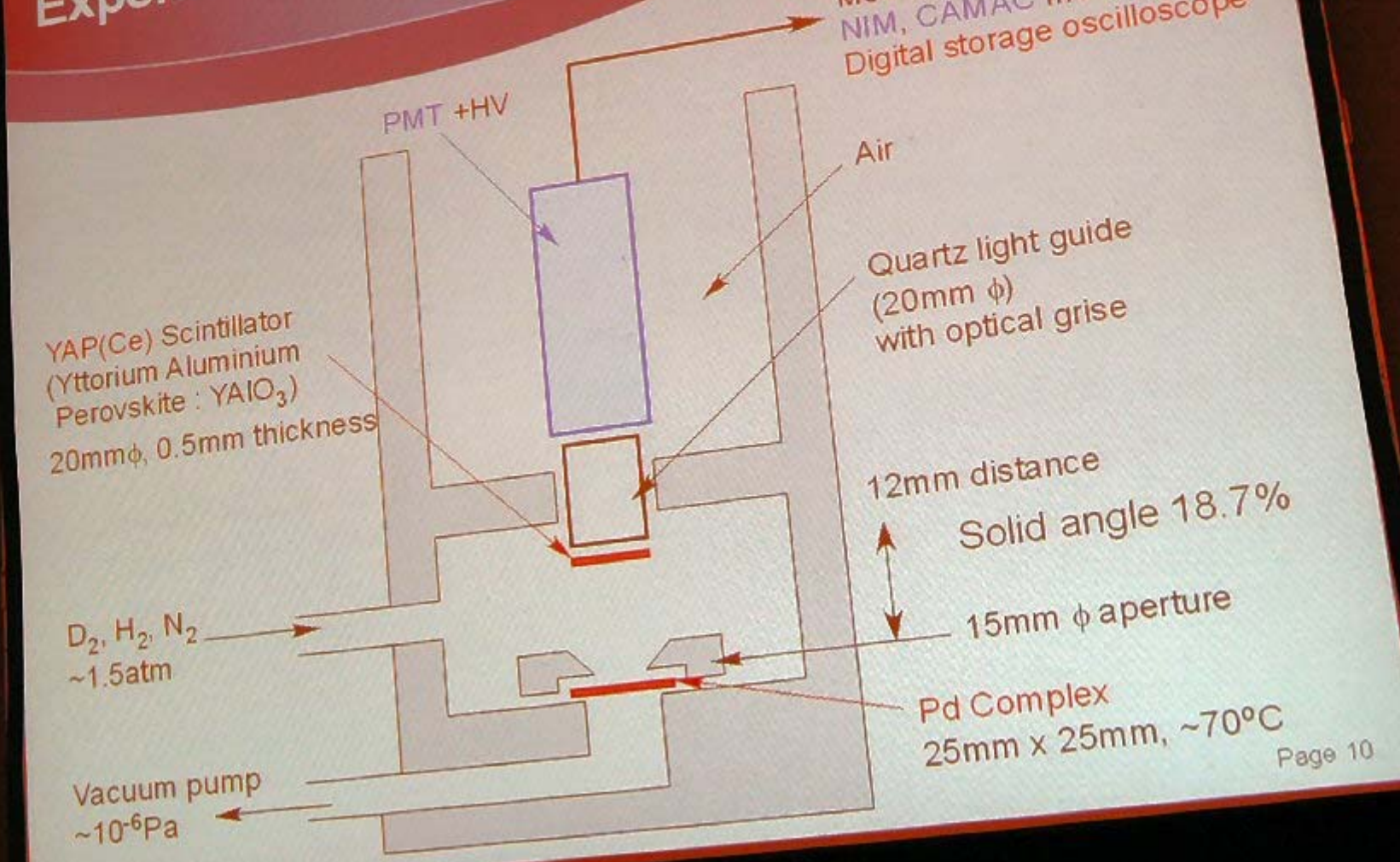
Experimental Set-up



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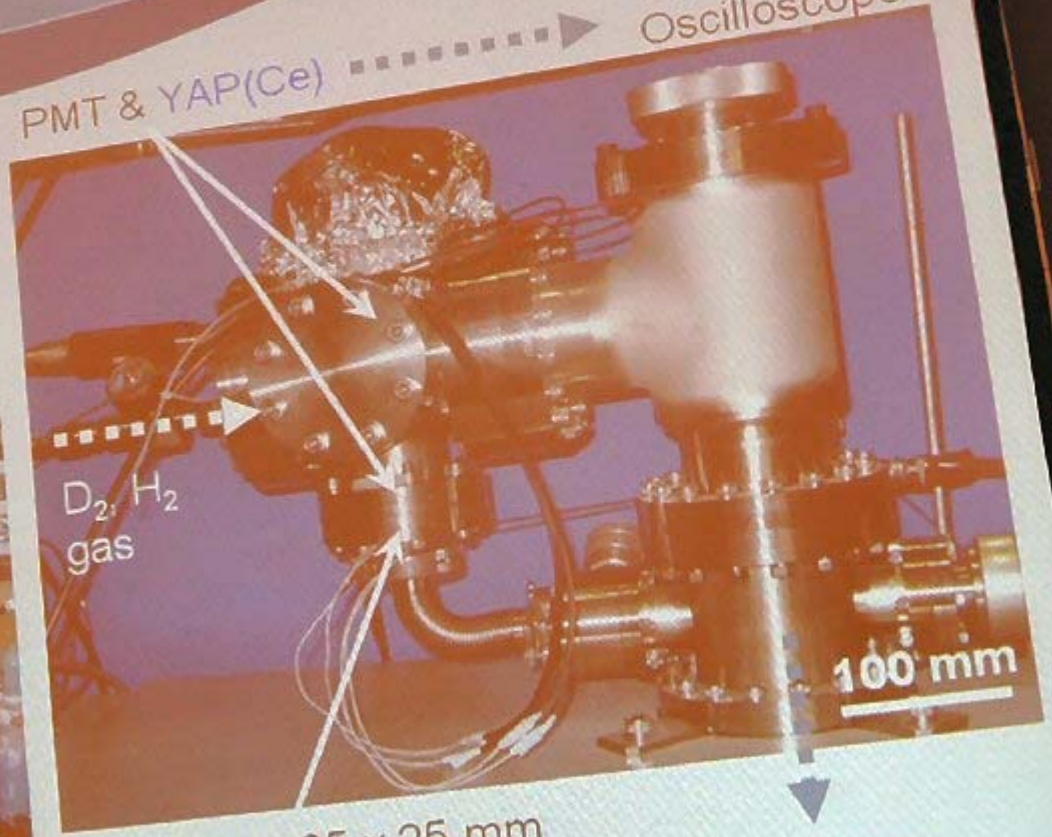
Picture


Chamber
VETO Detector


PMT & YAP(Ce)
NIM, CAMAC
Modules &
Digital Storage
Oscilloscope
D_2, H_2
gas
100 mm
Pd sample, 25 x 25 mm
Heater & T.C.
Vac., TMP

Samples & Permeation

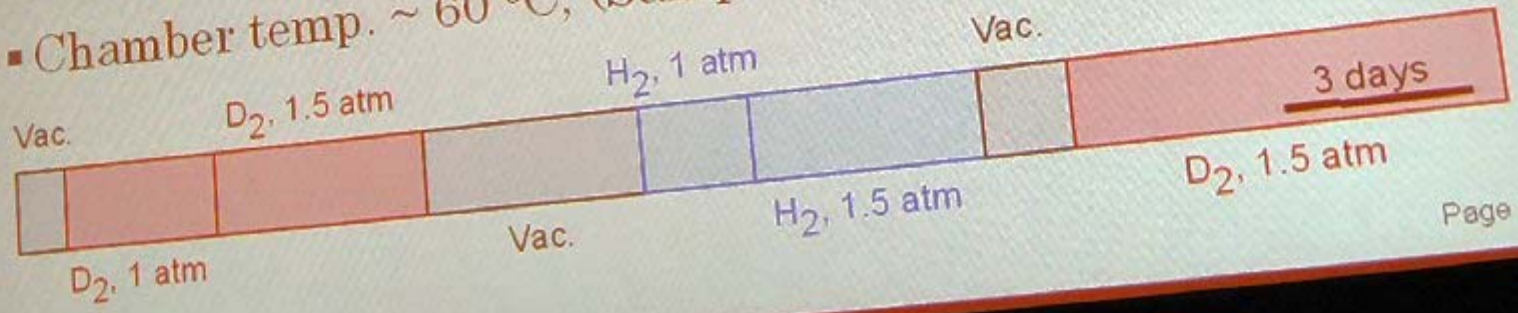
- **Pd Complexes** were supplied by **Iwate Univ.** & **MHI**
- **Pd** (0.1 mm) / **CaO** (2 nm) & **Pd** (18 nm) 5 layers / **Pd** (60 nm)
- **Cs** is electrodeposited. (Iwate sample)

→ **Yamada** *et al.*, *ICCF12*

- **Vac.** B.G. & **1 ~ 2 weeks** D_2 & H_2 permeation (1.0 ~ **1.5 atm**)
- Flow rate ~ **0.5 ccm**(Max.), typically **0.1 ccm**

MHI condition (over 1 ccm) **has never been achieved.**

- Chamber temp. ~ 60 °C, (Sample temp. is higher : **~70 °C**)



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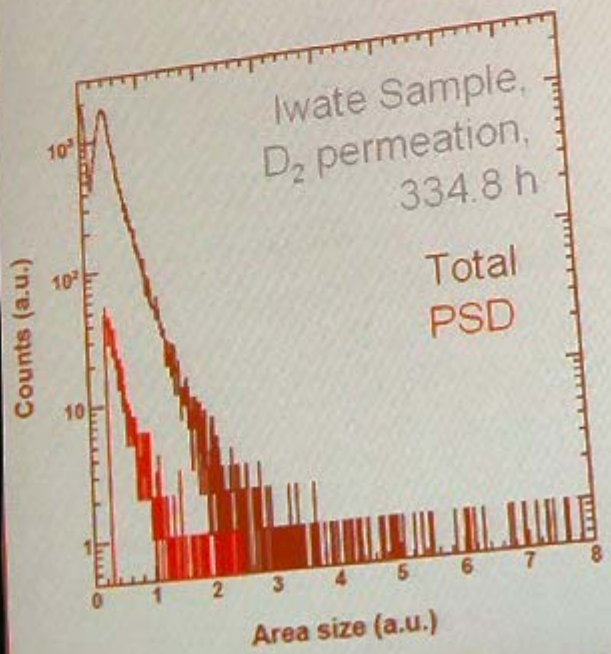
Result 1 : Iwate Sample

- Reduction of B.G.(dark current, long tail event)
- 84684 counts in total → 1150 counts / 334.8 hours

1.4 %

without VETO



- Counting rate : ~ **3 counts / h**
- Bad separation for low energy.
- Dark current & Cosmic rays are included in lower range.

- **We can identify 3 counts / day several MeV α particles.**

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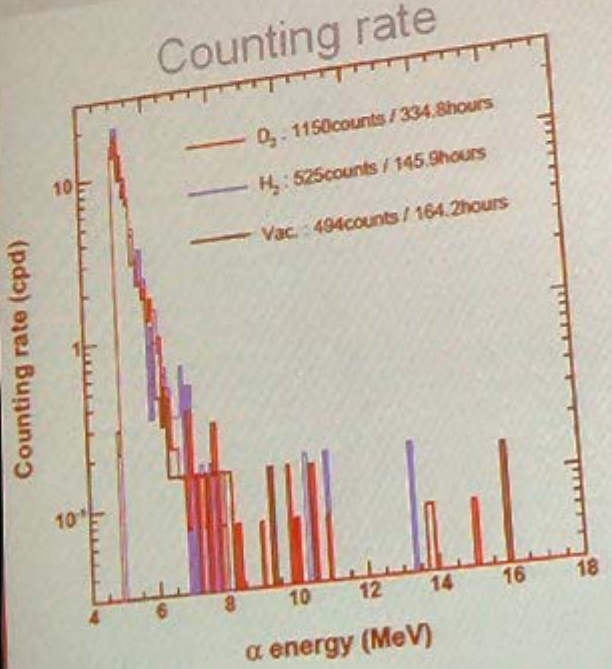
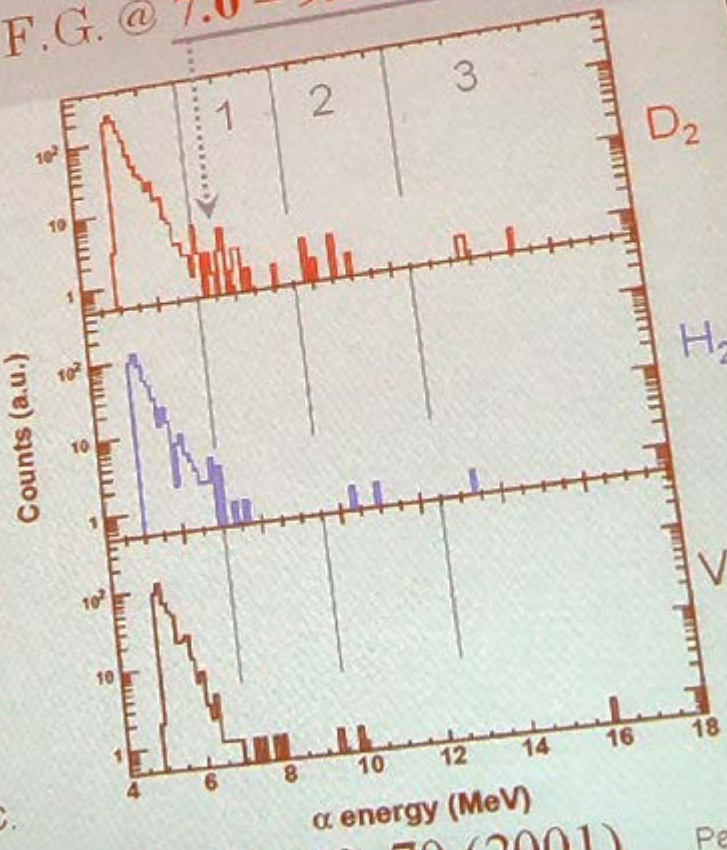
Result 2 : Iwate Sample

- Small **difference**, between B.G. & F.G. @ **7.0 – 9.5 MeV**



Vac.
↓
D_2
↓
Vac.
↓
H_2
↓
Vac.
↓
D_2
↓
Vac.



Energy Calibration : *Nucl. Inst. Meth. A*, **469**, 70 (2001)

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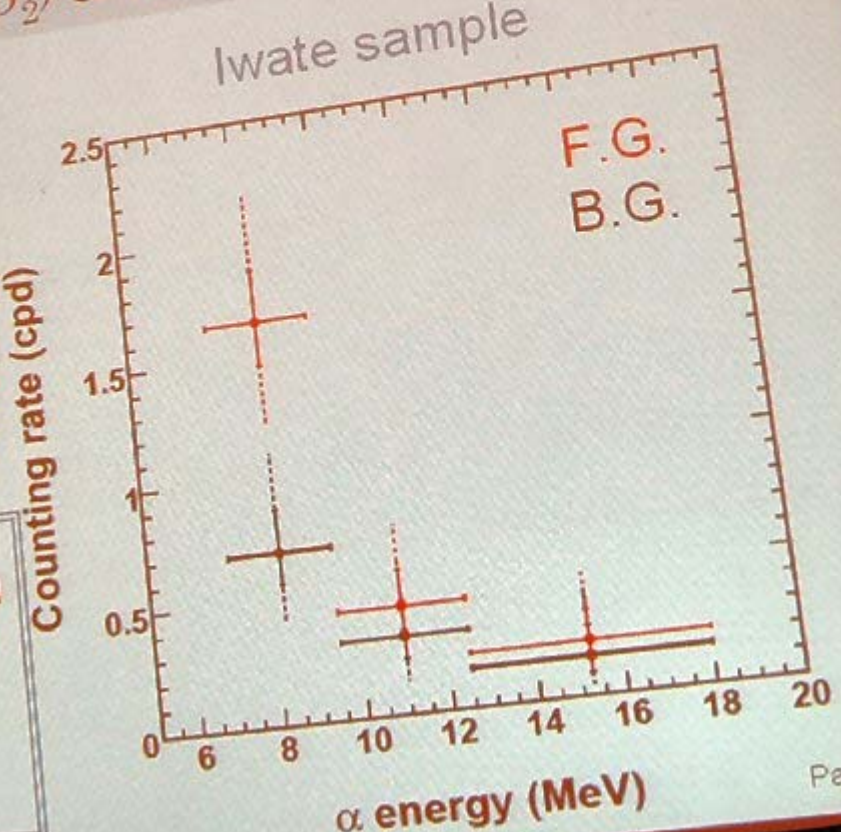
Final Result : Iwate Sample

- Counting rate [cpd] of **F.G.**(D_2) & **B.G.**(H_2 & Vac.)
- Vertical errors are
  - **68.3 %** (solid line)
  - **90.0 %** (dashed line)
  - **confidence level**.
- At **7.0 – 9.5** MeV

Charged Particle Emission is Significant with 99.97 % reliability.



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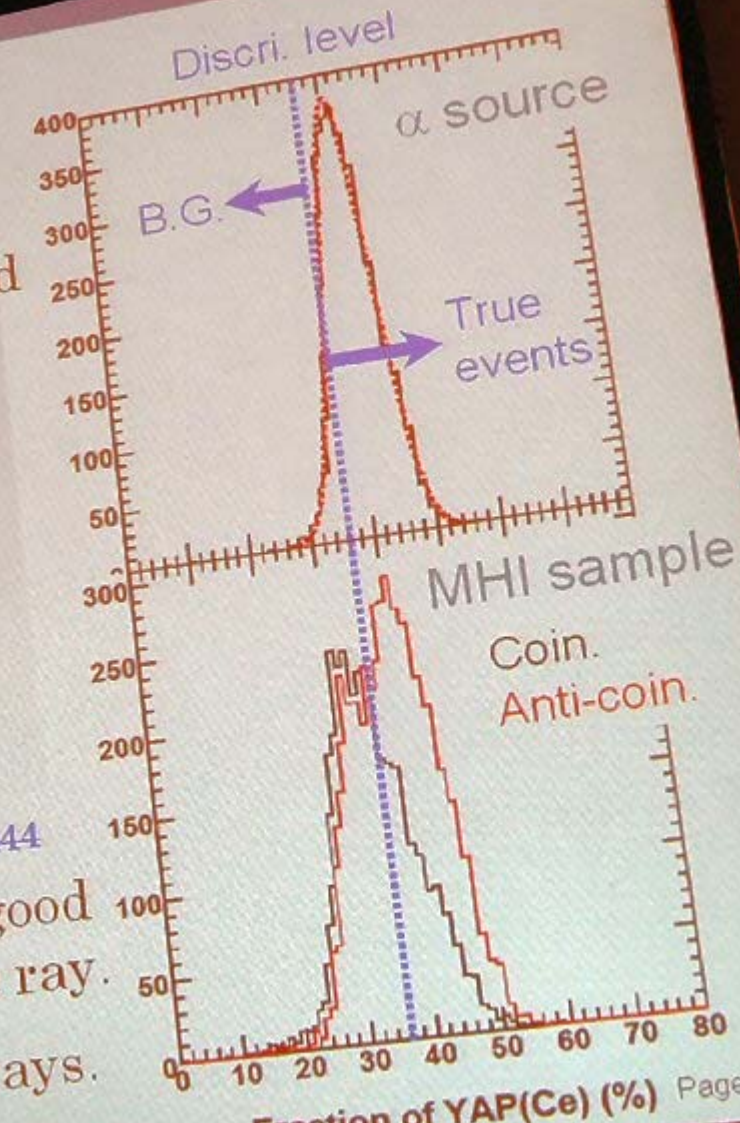
Result 3 : MHI Sample

- τ_{YAP} , τ_{BC444} & **Fraction** were derived by 2 component fitting.
- **Coin.** with VETO : All cosmic rays
- **Anti-coin.** : True events & **B.G.** (limited efficiency of VETO)
- **Discri.** : ^{241}Am source 1σ
- No significant difference for τ_{YAP} & τ_{BC444}
- **Fraction (Light yield ratio)** gives good separation, Cosmic / Not-cosmic ray.
- **PSD** can reduce almost cosmic rays.



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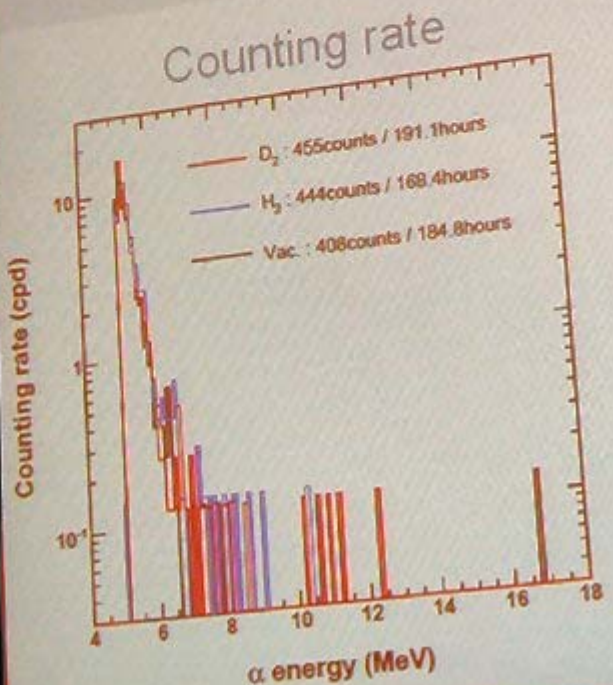
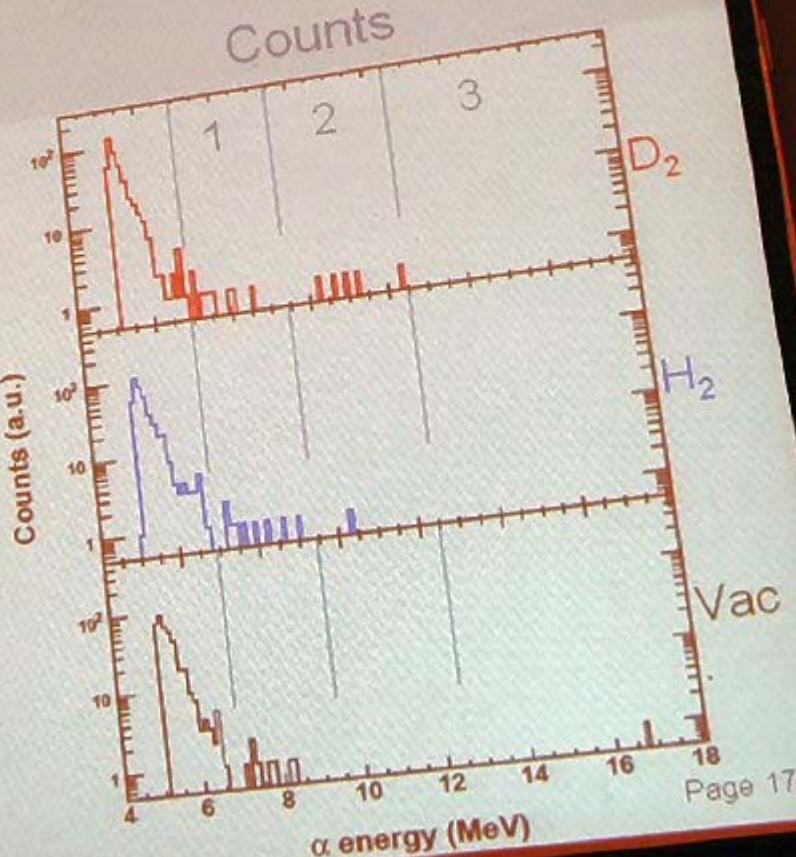
Result 4 : MHI Sample

- Lower counts are similar to Iwate's.
- **Difference @ 9.5 - 12.5 MeV region.**



Vac.
↓
D_2
↓
Vac.
↓
H_2
↓
Vac.



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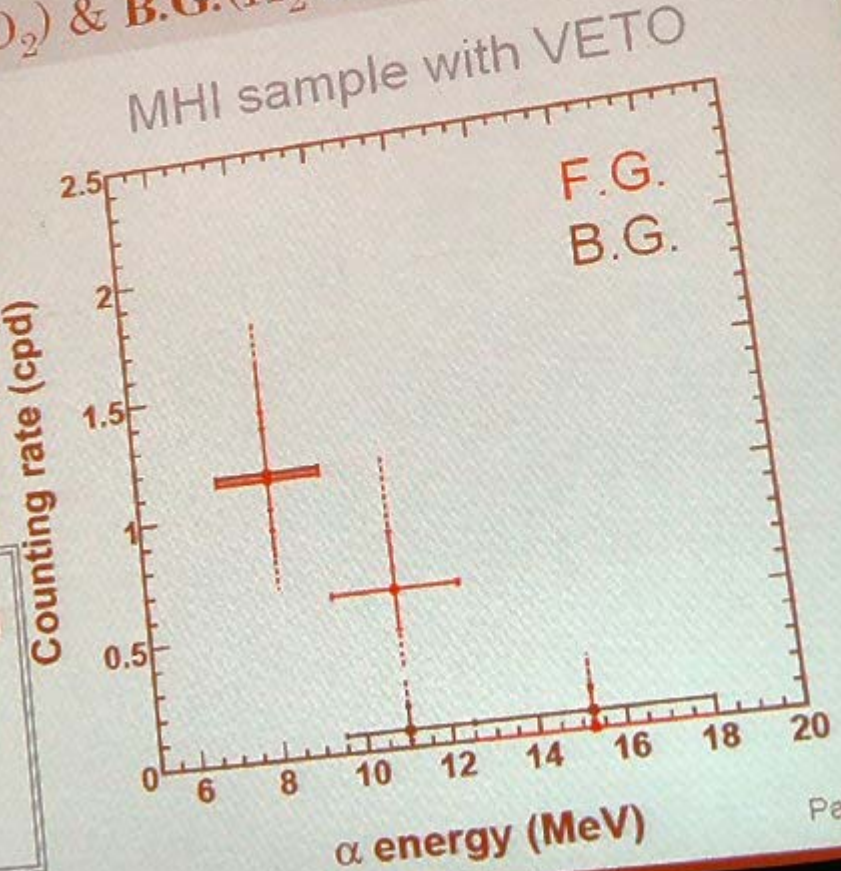
Final Result : MHI Sample

- Counting rate [cpd] of **F.G.**(D_2) & **B.G.**(H_2 & Vac.)
- Vertical errors are
  - **68.3 %** (solid line)
  - **90.0 %** (dashed line)
  - **confidence level.**
- At **9.5 – 12.5** MeV

Charged Particle Emission is Significant with 99.63 % reliability.



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Charged Particle Detections

High energy counts during D_2 gas permeation

Phoswich & PSD

- **Iwate (Cs)**
  99.97 % reliability @ 7.0 - 9.5 MeV
  Reaction rate : R ~ **6.8 x 10^{-3}** [f/s/cc], σ ~ **10^{-29}** [barn]
- **Iwate (no Cs)**
  No significant event

Phoswich & PSD & VETO

- **MHI (Cs)**
  99.63 % reliability @ 9.5 – 12.5 MeV
  R ~ **4.4 x 10^{-3}** [f/s/cc], σ ~ **10^{-29}** [barn]
- **MHI (Cs)**
  No significant event
  but too **Bad Permeation** rate (almost 0)

- Significant Detection : **2 / 4** samples

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Conclusion : Detector System

We developed a new detector system with **PSD** analysis, **Phoswich** & VETO detectors.

- **YAP(Ce)** performs good temp. dependence and **stability**.
- This system reduces B.G. down to ~ **1 %**.
- B.G. rate : **0.012** [counts / MeV / day]
  ~ $\mathbf{10^{-2}}$ [counts / MeV / day] (over 7.0 MeV)
- Not good PSD separation @ low energy (small pulse).
- **High energy charged particle background induced by cosmic rays** cannot be ignored.

Border for **Clear Evidence** : **3 counts / day** F.G.

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Conclusion : Gas Permeation

Charged Particle Measurements were carried out in **Gas Permeation Exp.** with **Pd Complexes**.

- **High Energy** & **Large Energy Loss** particles were detected in D_2 runs **Only**.

  99.97 % Reliability @ 7.0 – 9.5 MeV, **Iwate** sample
  99.63 % Reliability @ 9.5 – 12.5 MeV, **MHI** sample

- Few counts caused by cosmic ray in H_2 & **Vac**. runs.

Detected particles are most likely to be …

α Particles

Acknowledgements

- **Pd complexes** were provided by

  Prof. **Yamada**, **Iwate Univ.**
  Dr. **Iwamura** & Dr. **Itoh**, **MHI**

- Authors would like to thank the collaborators.
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